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Supersonic Gas Jets
Detection Techniques
Data Acquisition Systems
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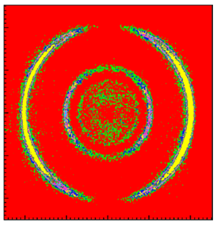
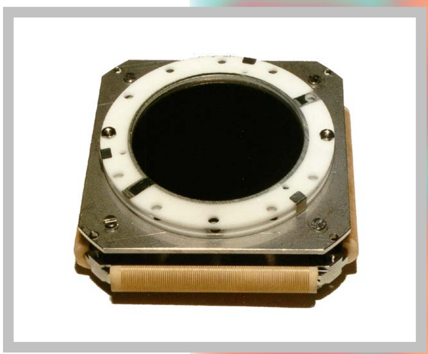


MCP Delay Line Detector Manual

(Version 11.0.2402.1)



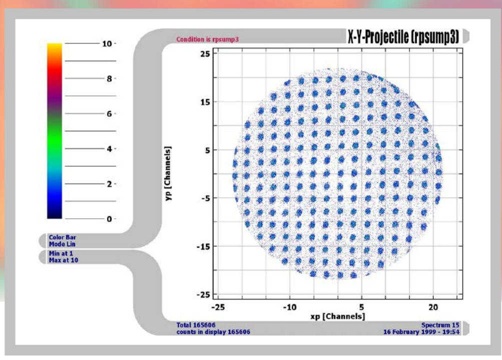


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Table of Contents

Detector System - Components

This manual describes all major components of the **RoentDek DLD** and **Hexanode** delay-line detector system. For the **DET** and **RS** version of **RoentDek** MCP detectors (e.g. with air-side readout anodes) separate manuals exist and refer to parts of this manual, too. Even if you have not purchased the complete detector system you will find valuable information in the chapters describing the different components necessary for detector operation. However, you may have received only the relevant parts of this manual for the purchased system components.

The complete manual is available on the **RoentDek** website where it is updated regularly. The manual is not complete in the sense that some detail information on components may be given in another component-specific manual for download from the website. For custom-made systems/components you may have extra documentation.

The manual is sub-divided into the following parts:

1. **DLD** or **HEX** microchannel plate detector with delay-line anode
2. **FT12(16)TP(/xxx)** 12-pin CF35 (and fourfold MHV or SHV) UHV-feedthrough flange(s) with signal decouplers and (optional) flange mounting gear on DNxxxCF flange with CF35 ports (xxx = 100 – 300)
3. **FEE** (**F**ront-**E**nd **E**lectronics) for delay-line read-out with **FAMP**, **CFD** and/or **ATR19** fast (differential) amplifier/ constant-fraction-discriminator units
4. **TDC8HP** or other time to digital converter and CoboldPC read-out software
   (fADC4/8 fast ADC units for download)
5. **HV2/4, BIASET3** or similar high voltage supply assembly and **BA3/HVT/HVZ** auxiliary bias units.

Please follow the link *http://www.roentdek.com/manuals* for device-specific manuals.

If you have received special detector components, i.e. a detector of different size or type, or other electronic modules you will find a separate manual commenting on peculiarities of your special system. In this case the information given here is mostly relevant for your system but you might need extra information. Please also refer to the FAQ document on the website.

Please always check our website for updates after you have received our products or contact **RoentDek**.

1 The Microchannel Plate Detector with delay-line anode

The **M**icro-**C**hannel **P**late (MCP) detector with delay-line anode is a device for single particle/photon counting, giving information on the position of each particle/photon and its impact time with high precision. It uses an electronic read-out scheme employing fast timing amplifiers, timing discriminators and digitizers. It operates under ultra-high vacuum and requires high voltage supplies.

This detector system is modular and com in different sizes and versions.

Typical performance:

position resolution	< 0.1 mm
overall linearity	0.3 mm
temporal resolution	< 0.2 ns
rate capability	1 MHz
multi-hit dead time	10-20 ns

Typical characteristics of MCPs (for **DLD40EP**, **DLD75** and **HEX75** see below)

# of MCPs in stack	2
Outer Diameter:	50/86.6/127 mm
Active Diameter:	45/80/120 mm
Aspect Ratio L/D	60:1
Thickness	1.5 mm
Pore size	25 μm
Center-to-center spacing:	32 μm
Bias Angle:	8° ± 1°
Open Area Ratio:	>50 %

for **DLD40EP**:	40 mm OD (> 40 mm active), L/D 80:1; 1 mm thickness, 12 μm pore size, bias angle: 20°, OAR > 70 %
for **DLD75/HEX75**:	87 mm OD (75 mm active), L/D 80:1; 1 mm thickness, 12 μm pore size, bias angle: 20°, OAR > 70 %

Most detectors can also be supplied with triple stack (**...Z**).

Typical characteristics of the detector assembly

Height above a mounting Flange:	about 100 mm (adjustable)
Mounting Diameter:	94/144/196/246 mm
Operating Temperature Range:	-50 to 70 °C
Operating Pressure:	$< 2*10^{-6}$ mbar
Baking Temperature:	150 °C Maximum
Electron Gain @ 2400 Volts: (for 80:1 MCP @ 2500 Volts)	10^7 Minimum

If you have chosen a detector set with central hole, its size in the MCP is usually 6.4 mm and the minimum active diameter 9 mm.

If you have chosen a different custom detector type please refer to the separate instructions.

1.1 General Description

The **RoentDek** MCP detector with delay-line anode is a high-resolution 2D-imaging and timing device for charged particle or photon detection at high rates with limited multi-hit capability. The linear active diameter is at least 40 mm for the detectors with the **DL40** anode (e.g. **DLD40** and **DLD40EP**), 75 mm for the **DL80** anode (e.g. **DLD80** and **DLD75**), and about 120 mm for the **DLD120**. The **RoentDek Hexanode** has a third delay-line layer that gives redundant detection opportunities either to improve the multi-hit performance, linearity or to allow the use of a MCP setup with central hole and minimized blind detection area. In its usual version, commonly referred to as **HEX80** (although the MCP choice restrict is to be a **HEX75**), it has about 75 mm redundant detection area. This triple area inner diameter is 100 mm for the **HEX100** (sometimes referred to as **HEX120** due to MCP choice and 40 mm in case of the **HEX40**[*]. For detectors with central hole (e.g. **HEX80/o** and **HEX120/o**) the descriptions in this manual are also relevant unless otherwise stated. A **DLD150** version is available on demand

[*] In the following we will refer to those detectors using the same anode only by nominating one detector version, e.g. for **DLD40** and **DLD40EP** as **DLD40** unless otherwise noted. Additional remarks, if any, will refer to the different MCP types.

with 150 mm active detection diameter. The **DL40** anode can also be equipped with smaller MCP stack, e.g. turning it into a **DLD25**.

The detector consists of a pair of selected MCPs in chevron configuration or of a triple stack (Z-stack) and a helical wire delay-line anode for two-dimensional position readout. The MCPs are supported partially metalized ceramic rings or metal rings. Ceramic rings (1.5/2 mm thick, 65/105 mm outer diameter) are typically used for **DLD40**/**DLD80** and **HEX80**. These ceramic rings are suitable for soldering, clamping or spot welding). The MCP stack can also be mounted between a metal front ring and a (sometimes square-shaped) rear side carrier plate. This is the standard method for the **DLD120**, **HEX100** and **DLD40SL** or custom MCP stack designs.

Operation requires two DC voltages for a (resistance matched) MCP stack on front and back contacts and three voltages for the anode's support plate ("Holder") and the anode wire array. All voltages can be supplied by separate HV-supplies or voltage dividers. The baking limit is specified as 150 °C for the detectors and for optionally provided in-vacuum cables and feedthroughs.

The wire array consists of two or three helical wire propagation double (delay) lines. For each dimension a differential wire pair is formed by a collection (***signal***) wire and a ***reference*** wire. A potential difference of 20 V to 50 V between *signal* and *reference* wires ensures that the electron cloud emerging from the MCPs is mostly collected on the signal wires, shared between the wire layers for different position encoding directions. The anode's Holder is in some assemblies conductively connected to an intermediate MCP stack carrier plate and must be biased with an intermediate potential with respect to the anode wires and the MCP back potential to ensure proper charge cloud propagation and spatial broadening in the drift zone between MCPs and anode wires. The optimal voltage depends on the distance between the MCP carrier plate and the anode wires.
Typically, the wires should have about 250 V more positive potential than MCP back side and the carrier about +50 V with respect to the MCP back potential.

Avoid penetration of strong external electrical and magnetic fields into the electron cloud drift region (between MCPs and wire anode). Electrical fringing fields can produce image distortion, magnetic fields (> 50 Gauss) disturb the proper charge cloud broadening and will lead to malfunction of the anode.

1.1.1 Position Encoding

The position of the detected particle/photon is encoded by the signal arrival time difference at both ends of each parallel-pair delay-line, for each layer independently. While the signal speed along the delay line is close to speed of light, one can define a perpendicular signal speed $v_\perp$ given by the pitch of one wire loop (typically 1 mm) and the time, which a signal needs to propagate though this loop. This defines the single pitch propagation time per 1 mm which is equal to $1/v_\perp$ (in units mm/ns).

The corresponding ends of the delay-lines for each dimension are located on the opposite corners of the wire array terminals on the rear side. The electrical resistance of each wire is between 5 and 100 Ω end-to-end, depending on the size of the delay-line and the wire type used. Corresponding ends of wires can thus be identified. The four (or six) terminal pairs have to be connected to vacuum feedthroughs by a twisted-pair cable configuration (both cables of a pair must have equal lengths, within 5 mm). From the feedthroughs the signals must be transmitted (after DC-decoupling) to a differential amplifier or signal transformer with equally adequate transmission cables.

The difference between the signal arrival times at the adjacent ends of each delay-line is proportional to the position on the MCP in the respective dimension. The sum of these arrival times is fairly constant with few ns for each event (see below). The time sequence of the signals can be measured via time-to-amplitude converters (TAC) or an n-fold time-to-digital converter (TDC), n is at least 4 or up to 7 (**Hexanode** with separate timing channel). As reference time the signal on the MCP back or front side can be used for correlating each particle to others or to an external trigger (TOF-measurement).

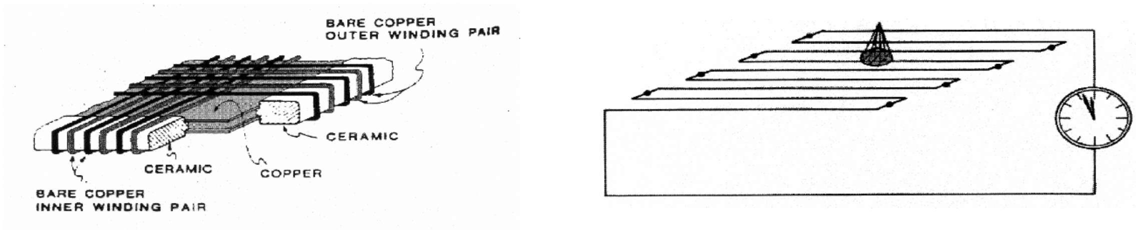
For the **DLD** detectors, the digital encoding for obtaining a 2d digital image (X/Y) is

$$X = x1 - x2 + O_x \quad \text{and} \quad Y = y1 - y2 + O_y \qquad \textbf{Equation 1.1}$$

with x1, x2, y1 and y2 denominating the time for each signal, O_x and O_y are arbitrary offsets.

The fast timing signal picked up from an MCP contact or, in the case of a pulsed particle/photon source, a "machine trigger" signal can serve as time reference. The single pitch propagation time (for 1 mm) on the delay line is about 0.75 ns for **DLD40**, 1 ns for **DLD80** and 1.24 ns for **DLD120**. Thus, the correspondence between 1 mm position distance and relative time delay in the 2d image is twice this value: about 1.5 ns, 2 ns or 2.5 ns, respectively. Note that these numbers are only accurate within 5 % and are slightly different for each dimension. In order to calculate the position in mm from the digital X and Y values you have to take into account the bin width of your TDC and the single pitch propagation time for the respective layer.

Figure 1.1: Operation principle of the delay-line-anode,



left picture from: Sobottka and Williams IEEE TS-35 (1988) 348

The **Hexanode** has an additional layer and gives over-determined (redundant) position information: It is possible calculating the two-dimensional particle position of signals from of any two of the tree layers. The signals from the third layer serve as a redundant source of information for cases when signals are "lost" due to electronic dead-time (multiple hit events), non-continuous winding schemes (anode with central holes) or non-perfect electronic threshold conditions/damping on special very large delay-line anodes. With the **Hexanode** it is also possible to control their delay-lines' intrinsic resolution and linearity, improving the overall imaging performance. The **Hexanode**'s coordinate frame u, v, w can be transformed into a Cartesian coordinate system by the following equations using only two of the hexagonal coordinates respectively, if the connection scheme in the next section is chosen:

$$X_{uv} = u + Ox$$

$$Y_{uv} = \frac{1}{\sqrt{3}}(u-2v)+O_y$$

$$X_{uw} = X_{uv}$$

$$Y_{uw} = \frac{1}{\sqrt{3}}(2w-u)+O_y \qquad \textbf{Equation 1.2}$$

$$X_{vw} = w+v+O_x$$

$$Y_{vw} = \frac{1}{\sqrt{3}}(w-v)+O_y$$

O_x and O_y are arbitrary offsets. The position in a hexagonal coordinate frame is coded by the arriving time differences from signals in opposite corners of the anode as in case of the **DLD**.

$$u = (x1 - x2) * d1$$

$$v = (y1 - y2) * d2 \qquad \textbf{Equation 1.3}$$

$$w = (z1 - z2) * d3 + o$$

If $1/v_i$ is the single pitch propagation time for a delay line layer i (v_i is slightly different for each layer) then d_i is given by

$$d_i = \tfrac{1}{2} v_i * \Delta t \qquad \textbf{Equation 1.4}$$

d_i must be precisely known to make the images obtained via different layer combination coherent. o is an offset value that shall unify the "time difference zero" of all three layers, i.e. it must be chosen so that geometrically the position lines for calculated u, v, w have a common crossing point, e.g. w must be zero when u and v are zero. The X and Y positions can be calculated from any combination of the Equation 1.2. If for a given event more signals than from the minimum of two layers are available, it is recommended to choose signals from those two layers where the positions are most distant from the respective delay line ends (or gaps).

For the **HEX80** the single pitch delay is about 1.4 ns. The exact values u, v, w, o differs from anode to anode. There relative values must be precisely determined which can be done by a self-calibration routine (for details please contact **RoentDek**). o is also a function of connection cable lengths and cable lengths all the way to the TDC/TAC inputs (and internal offsets therein) and must therefore be recalibrated whenever these parameters have changed. The single pitch delay for the **HEX100** is about 1.75 ns which corresponds to a pitch of 1 mm or 1.5 mm, depending on the anode version which you have received (default: 1.5 mm).

The linearity deviations in each delay-line layer should be calibrated to achieve optimal results. For detectors with central hole, the gaps in the wiring have to be taken into account. Please contact **RoentDek** for special program codes appropriate for your detector including auto-linearization routine and advanced position codes.

1.1.2 Timing information:

In order to determine the time difference between an outer time marker and the particle impact, the signal at the MCP contact can be used. But it is also possible to deduce the particle impact time from the delay-line signals:
If the MCP signal is used as the time-zero, the "time sum" values

sumx = x1 + x2
sumy = y1 + y2
sumz = z1 + z2 (only for Hexanodes) **Equation 1.5**

are constant within the time resolution (less than one ns) but have a slight "position walk" which can be determined by plotting sum vs. difference (i.e. position). Via the time sums it is possible to deduce the particle impact time, independently from the MCP signal. But verifying proper time sum spectra is generally mandatory to verify proper detector function. "Satellite peaks" or background besides distinct time sum peaks for each delay-line layer indicate poor detector function or less than-optimal electronic threshold settings (see Figure 3.9).

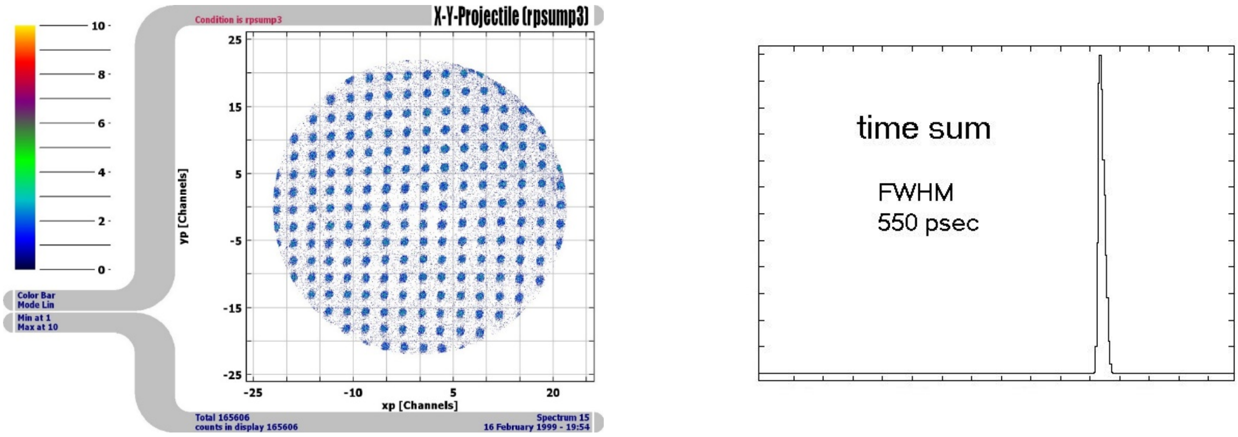


Figure 1.2: Typical imaging/timing performance of a DLD40 detector. The detector (shaded by a mask) was irradiated with α-particles. Similar or better results can be achieved with adequate read-out electronics. Temporal resolution is significantly better than the local time sum width (see right picture) which indicates an upper limit.

1.2 Assembly of the MCP Detector

The assembly should take place under clean and dry conditions. It is recommended to wear powder-free clean area approved gloves. Normal high vacuum cleanliness procedures and practices must always be observed.

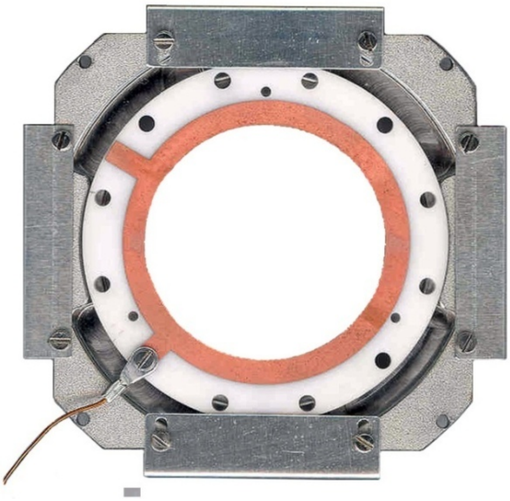
1.2.1 List of Detector Assembly Parts

- ceramic rings, partially metal coated (for **DLD40**, **DLD80** and **HEX80/HEX75**) or metal rings/plates
- two or three micro-channel plates, usually matched in resistance
- metal spring clamps (for **DLD40**, **DLD80** and **HEX80/HEX75**)
- M2, M2.5 or M3 screws/nuts or rods, some used only during assembly of the MCP stack)
- assorted PEEK screws/nuts for **DLD120/HEX100** and other assemblies with metal MCP mounting rings
- delay-line anode
- assorted small parts for cable connections (optional)

For delay-line detectors with central hole please refer to Chapter 1.2.3.5 before continuing.

*If you have purchased the detector with the "**readily mounted**" option (only available with* **FT12(16)TP/xxx** *flange mounting) you need to remove the detector case (and may return it to* **RoentDek** *for receiving a refund). All connections to the anode should already be in place but the MCPs must be mounted according to the directions below. You will also have to verify all anode connections and check for absence of shorts which may have occurred during transport. Therefore, please review the following instructions even if you have received a "readily mounted" anode.*

For **DLD40**, **DLD80** and **HEX80** typically MCP mounting assemblies based on ceramic rings are provided. The carrier plate with or without rear ceramic ring may already be placed on the delay-line anode, it is fixed by the retractable "shields" in a position that should be resumed after assembly of the MCP stack. If the rear ceramic ring is not pre-mounted (i.e. for transport safety reasons) please test-mount it now and observe the relative angle of the metallization structure. You will in any case have to remove it for assembling the MCP stack (see below). After this assembly, the rear ceramic ring has to be in about the same orientation as shown in Figure 1.3.



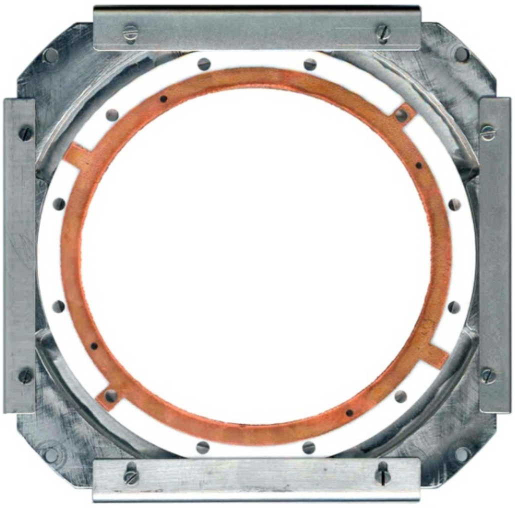


Figure 1.3: Orientation of the rear ceramic ring on the Delay-line assembly (DLD40, DLD80). For HEX80/HEX75 the orientation is similar, but there is only one pair of flat "shields".

All parts, especially the MCPs and the wire anode structure should be handled with great care. The wire array is very delicate. The ceramic rings should not be exposed to exceeding mechanical or thermal stresses. The MCP surfaces are very sensitive and should never be touched or scratched. Some "optical defects" may be seen on the MCPs surfaces after removing them from the transport packing. Unless the MCP are broken (transport damage) this will not affect performance within specifications. Please read the whole assembly section before starting the mounting, see also Appendix for MCP handling.

1.2.2 Preparation

1. Verify with an Ω meter that no dust particles have electrically shortened the anode wires. The anode contains one pair of wires for each special direction. Neither the two wires of one pair nor the wires of the different layers should be in contact (>10 MΩ). Also verify that there is no electrical connection between the wires and the Holder plate which is the metal anode body. Dust particles can be removed by gentle blow with dry air or a soft brush. Check the resistance of each of the 4 wires. From one end to the other it should be around 5Ω for the **DLD40**, 12 Ω for the **DLD80**, 17 Ω for the **HEX80/HEX75**, 25 Ω for **DLD120** and about 40 Ω for the **HEX100**. These are the values for the standard **RoentDek** anodes. If you have ordered and received a special type, the resistance might be different. Note, that even after testing for the absence of a short between wires, at any time, after assembly, installation, baking or after biasing the detector, a metallic dust particle from the environment can short signal and reference wires. If such a problem persists, contact **RoentDek** for advice.

   Humidity from ambient air can temporarily cause a semi-conducting film on the ceramic rods supporting the wire arrays. This may yield a non-infinite resistance between reference and signal wires of a few MΩ. This shams a problem on the anode although the resistance will drop to near-infinity once the detector is exposed to vacuum.

2. For assemblies with ceramic ring supports of the MCP stack read side (only for **DLD40**, **DLD80** and **HEX80**) remove the ceramic ring from the assembly (if pre-mounted). Two of the shields can be retracted to liberate the stack after the M2 screws are loosened. Note, that the shields must not touch any contacts on the ceramic rings and that the spring clamps that hold the stack together are mounted with about 45° angle with respect to the delay line so that they are not touching any metal part. This orientation has to be resumed when re-assembling the detector.

3. Optionally: a mesh can be glued, soldered or spot-welded directly onto the front side of a *front* side ceramic ring such being at a position of 1.5/2 mm in front of the MCP surface. However, it is recommend using one of the **RoentDek** detector meshes of type **(w)Mesh 40/80/120** which can be mounted to any front ring with screws. Please refer to the descriptions in the corresponding Mesh Manual.

4. Prepare the connection cables for the MCPs and the delay-line anode. If you have ordered a **FT12(16)TP** you should have received these connection cables. For the MCP and Holder connection 3 (single) cables are used. For the anode 4 or 6 (Hex) cable pairs with proper impedance (ideally 100-150 Ω) are needed. Unless you have received special cable pairs or twisted pairs with adequate lengths you must form twisted cable pairs: The two cables of a pair must have equal lengths within a few mm. The pair must be twisted at least 3 turns per 10 cm to form a well-transmitting twisted pair cable line.

For connecting these cables to the delay-line terminals special 2 mm connector pins are provided. The three other single cables are needed for "MCP front", "MCP back" and "Holder" (see also next section). A fourth single cable can be used for connecting a mesh.

5. For **DLD40**, **DLD80** and **HEX80** assemblies with ceramic rings: The cables for the MCP connections can be soldered or spot-welded directly onto the metallization of the ceramic rings or clamped to the ring with special recessed M2 nuts (with very thin collar) and screws (obtainable from **RoentDek**). Special 3 mm and/or 2 mm lugs for crimping a cable may have been supplied. If soldering is preferred use the metallization strips which are *not* located at a hole position on the ceramic rings. Do that *before* mounting the MCP. Alternatively, (and only for 3 mm total MCP stack thickness) special spring clamp with 1 mm contact pin can be placed between the rings at the position of a metallization around a hole on MCP back ring for its contacting after MCP assembly. Connect one side of each ring with a cable to bias "MCP back" and "MCP front" respectively. **DLD40**, **DLD80** or **HEX80** assemblies with metal rings use a slightly different cable connection scheme as described later in Chapter 1.2.3.3. If you have received the detector with **readily mounted** option the connection cables to MCP front and back have intermediate connection junction that are differently coded (only for **DLD**, see Figure 1.5). **Make sure to connect the right cable to the respective ceramic ring**. Once the MCPs are mounted the cables must be connected to the corresponding cable ends from the feedthroughs

   For **DLD120**, **HEX100** or **DLD40SL**: The cable for the "MCP back" connection can be fixed by a M2 screw to the rear MCP plate. The cable for the "MCP front" connection is either clamped to the front ring with one of the M3 polyimide screws or for newer systems alternatively via an M2 screw that can be fixed to the front ring (or plate), see also Chapter 2.

   A cable for the anode body "Holder" can be connected anywhere on one of the metal M2 rods in the anode, or any part electrically connected to that, see Figure 1.6. Note that **DLD40**, **HEX100** or **DLD40SL** have no intermediate plate between anode and the MCP stack's rear supporting plate which is referred to as MCP back carrier plate. It is insulated from the M2 rods that pass through the anode Holder by collared ceramic eyelets.

You may clean all parts ***except the MCPs*** in an ultrasonic bath for a few minutes with a mild alcoholic solvent like isopropanol. However, since the delay-line could come into resonance with the ultrasonic bath it is not recommended to do that. Please seek advice from **RoentDek** for other options. MCPs should only be exposed to a cleaning procedure if they have serious surface contamination that cannot be removed by spraying with dry air or using a fine soft (!) brush. Please contact **RoentDek** for further advice. It is to note that MCPs sometimes come with "optical artifacts" like stains or even white dots near the rim. These do not affect the performance.

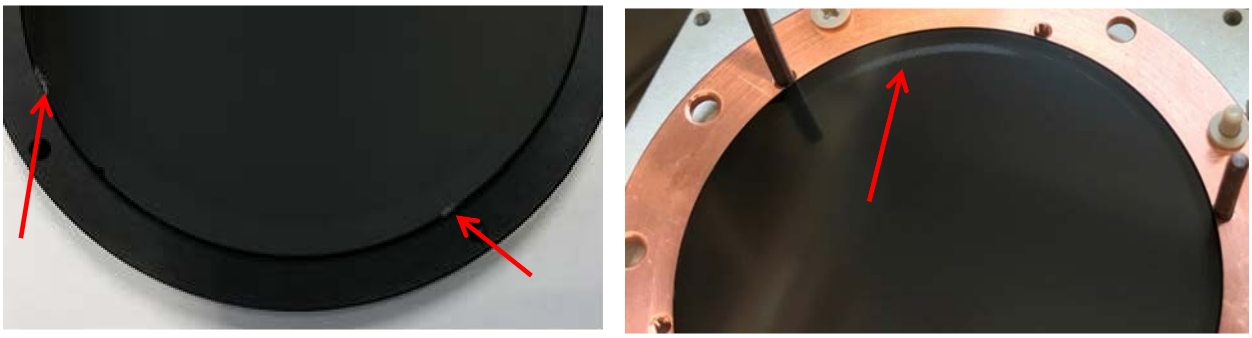
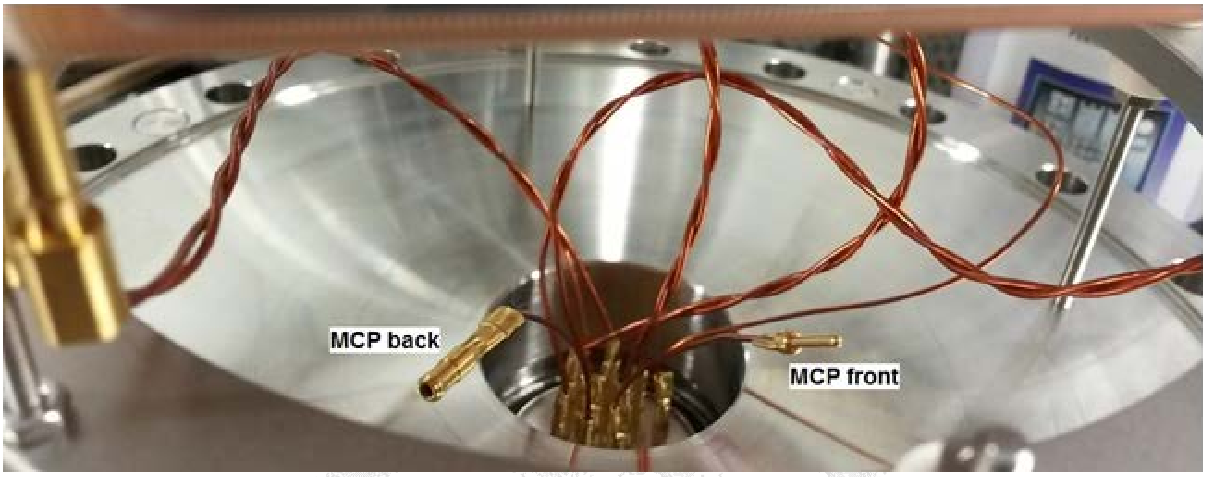


Figure 1.4: examples for optical artefacts that do not image, nor affect dark count rate or efficiency.

For MCP general handling see also instructions on the manufacturer's web sites and in an Appendix of this manual. Touch MCPs only with care along the rim, preferably with gloves. If the MCPs need replacement mount a set with matching electrical resistance unless you operate the MCP stack with a special intermediate shim ring containing a bias contact (available from fro certain MCP stacks and mountings) and specific bias options (please contact **RoentDek** for advice).
Now the detector can be finally assembled, preferably under clean room conditions

Figure 1.5: MCP connection cables for DLD with readily mounted option contain an intermediate connection coded male/female so that they can't be swapped (see above). It is important that the connection junctions don't get too close to each other (> 3 mm distance) or to any other metal part after connections are in place and that they don't get close (see below). Extra insulation may be added.



1.2.3 Connecting the Wires to the Delay-line Anode

A proper design and use of connection cables is essential for a decent detector performance. Therefore, we strongly recommend using the feedthroughs of type **FT12** for the delay-line connections (**DLD** and **HEX**). For the **DLD** the **FT12** can also accommodate the bias for the other detector parts, while for the **HEX** an additional feedthrough set is required to connect Holder, MCP front and MCP back (and an optional mesh), for example the **FT4 (FT4** plus **FT12** from the **FT16** feedthrough set product for **HEX** detectors). Please refer to Chapter 2 of the manual even if you have not purchased this option because important features for proper cabling and signal decoupling circuits are described there*.

You need a set of 4 (Hexanode: 6) twisted pair cables to connect the anode wires. In the four (six) corners of the anode's rear side each pair must be connected to the wire terminals formed as M2 stubs, preferably with the connector pins provided. Mounting the cable in a different way (i.e. by M2 nuts) is possible but not recommended, see also Chapter 2. Note that the M2 stubs are not secured against torque. If you have purchased the **FT12(16)** feedthroughs adequate cables with adequate connector pins/lugs for both ends are provided with it. Use only so much force that the cables are safely connected and are not moving when gently wiggling on them. Also connect the anode holder with a cable, wherever suitable (see also below). This cable has to supply the anode holder potential.

Figure 1.6: Cables for Holder and wires on DLD40, DLD80 and HEX80. The four M2 rods and the MCP holder plate are on the same Holder potential as the delay-line anode body. The cable can be connected anywhere on these parts.

Please note again that this is NOT the case for the DLD120, HEX100 and DLD40SL assemblies where the MCP carrier plate is insulated from the Holder and carries the MCP back potential.

Before connecting the cables to a feedthrough it is important to distinguish the cables that lead to ends of the same single delay line wire. Both ends must receive the same voltage (U_{ref} or U_{signal}, see Chapter 2.2).

* If you have purchased the detector with **SRM** option, the cable connections for the delay-line anode are already in place.

In order to later obtain an image on the PC monitor according to a phosphor screen (rear) view, the following connection scheme in the corners is recommended for the **DLD** and **HEX** detectors.

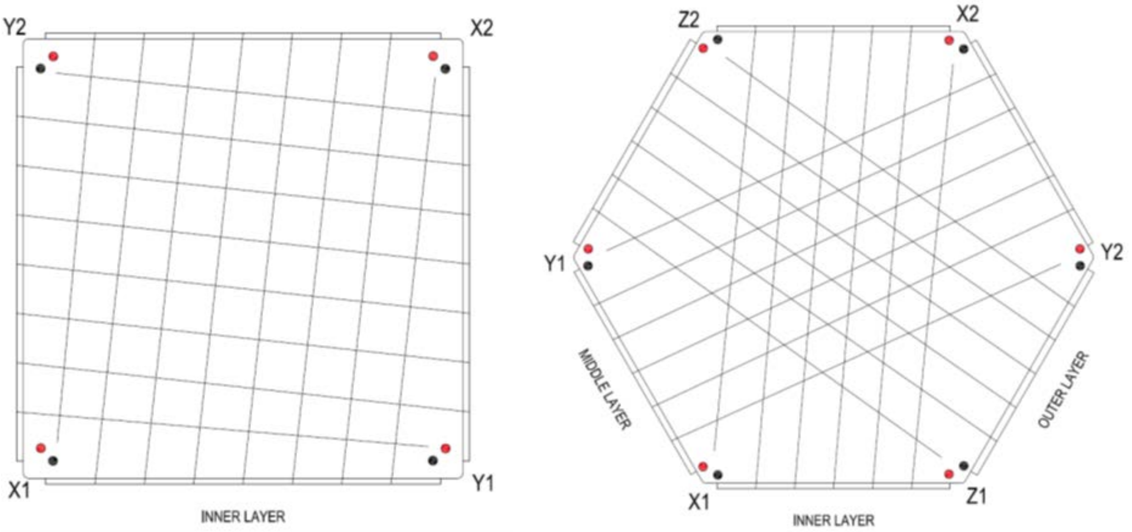


Figure 1.7: Orientation of x and y (and z) wire pair terminals on anode corners viewed from rear side. For DLD the sliding shields should be placed up and down on the (inner) X-layer side. For the Hexanode, the wiring scheme as shown is mandatory to comply with the position computations in Equation 1.2. If the Hexanode has a central hole and auxiliary support rods for cable guidance (see Chapter 1.3) the rods for the inner layer should be on the low side of the inner layer. Colorization on the terminal pairs in each corner here indicate an example scheme which terminals shall receive signal (red) or reference (blue) potential. Other connection schemes are possible as long as both ends of the same wire receive the same potential.

MCP stacks for **RoentDek** delay-line detectors are usually of circular shape and there is freedom to mount those in any azimuthal orientation. However, it should be noted that even round MCPs do not have a perfect rotational symmetry due to the (polar) tilt angle of channels, its direction being indicated as a mark near each MCP's rim (input side only). Due to this tilt the electron avalanche is emitted from an MCP pore at an angle with respect to the direction towards the anode and the charge cloud follows a parabolic path. This results in a slight side shift (<1 mm) of the charge cloud's center when it reaches the anode, thus shifting measured position likewise. The shift is uniform across the MCP and can usually be neglected in terms of imaging performance. However, due a slight dependence of this shift on charge cloud intensity (the signal pulse height) a so-called "detector walk" as function of pulse heights is introduced that will affect the spatial resolution on a level below 100 μm resolution: the spatial resolution is slightly inferior along the direction where the rear MCP angle marker points to. The detector walk effect, if remarked at all, can be corrected by recording pulse heights with more advanced timing electronics like the **RoentDek fADC** or **CFDx** units. For control and correction of detector walk one should keep record of the azimuthal position of the rear MCP tilt marker with respect to the anode orientation (e.g. the "X-direction") or even to align the tilt angle direction to the anode coordinate system, thus determining the direction where detector walk may affect data.

RoentDek uses different mounting options for the MCPs depending on MCP type, anode shape and customer demand. Circular MCPs with 40 and 80 mm can be clamped between special ceramic rings. Other assemblies nowadays mostly use metal rings, metal plates or a combination of ceramic and metal mounting parts, see Chapter 1.2.3.2 and 1.2.3.3). For assemblies using metal rings for MCP framing a specific *short manual* is provided with the detector. A tutorial cartoon about the assembly of the standard MCP stacks with ceramic rings can be found on our website in the ***MOVIES*** section. There you can also find cartoons showing the mounting of the MCP stack to the anode.

Handle MCPs only with care along the rim, preferably with gloves. Unless otherwise noted, any of the supplied MCPs can be selected for the position in the stack.

1.2.3.1 Assembly of the MCP stack for the DLD40, DLD80 and HEX80 using ceramic rings

(If you have received a **XHV** detector assembly with MCP mounting via ceramic rings please refer to Chapter 2.6 first.)
First you have to decide if you prefer soldering the cables for the MCP contacts directly to the contact pads on the ceramic rings or if screw contacts are preferable. Note, that even for UHV environment small amounts of lead-free solder/flux are usually tolerable. All parts should be cleaned again after the soldering.

If you prefer not to solder the cables to the ring, fix a cable with the optionally provided sets of countersunk M2 screw with special recessed nut on the ceramic rings now. The cable can either be crimped to a contact lug and fixed with a M2 screw or wound around this screw without using the lug.

If you have received (or prepared your own) connecting lugs screw set fix a cable to the front ceramic ring now. The cable to the feedthrough must first be crimped (or soldered) to the contact lug with 3 mm eye-let and fixed with a special recessed M2 nut and a countersunk M2 screw (4 mm long for **DLD80/HEX80** or 3 mm long for **DLD40**), see Figure 1.8. In some cases, (e.g. **SRM** option), you have received the rings with pre-mounted cables.

If you have purchased a mesh from **RoentDek** you may mount it now to the front side of the front ceramic ring with same type or other M2 screws (and recessed nuts) at a desired distance from the front ring. Please refer to the descriptions in the corresponding Mesh Manual. It should be fixed on at least two (for zero distance) or more positions and must be connected with a bias cable to a feedthrough. If you have purchased any of the **FT12(16)TP** products you may connect this bias cable to the "X" line on pin1 of the **FT12TP** or in case of **HEX**, to the vacant MHV/SHV feedthrough on the **FT16TP** feedthrough assembly. It is then recommended also using a **HFST** for biasing the mesh, see Chapter 2, or to connect it via a blocking resistor (see Chapter 2.3) placed close to the contact.

Figure 1.8: Connections to a ceramic ring. Left: cable clamped to a "front" ring. Middle/right: cable clamped to a back ring with 3 mm lug, countersunk M2 screw and special M2 nut.

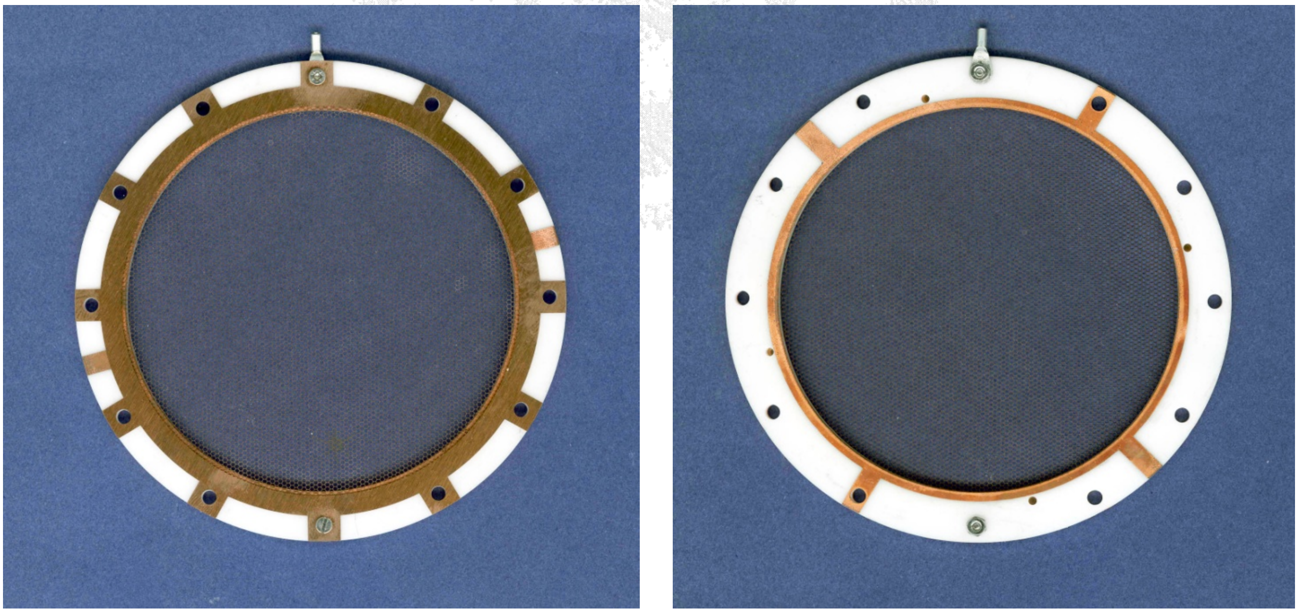


Figure 1.9: Free-standing mesh mounted to the MCP front ring (left: front side, right: rear side of the front ring). Unused lugs of the mesh can be cut away with a scissor to avoid conflicts with the MCP front contact.

Depending on the connecting scheme of the MCP contact there may be mechanical conflicts to consider during mesh mounting. It may especially be required that the MCP front contact lug is placed on the MCP side of the ceramic ring. Make sure that the mesh is not touching any other biased part of the detector assembly (and none of the spring clamps) and that there is sufficient distance between detector parts biased at different potentials (> 500 V) relative to the mesh potential. Allow at least 1 mm distance per 1 kV potential difference (more in case of sharp edges). Use extra insulation (e.g. with Kapton sheet) when distances are too small in this respect. The maximum rating between mesh and MCP front potential is 2 kV if mounted right on the ceramic ring.

RoentDek also provides calibration masks that are mounted in a similar way as the mesh type shown in Figure 1.9 and also woven meshes of type **wMesh40, wMesh80** and **wMesh120**. For mounting of those please refer to the separate description sheet on the **RoentDek** website.

The MCP back contact on the rear ceramic ring can be made in the same way as on the front ring.

It is very important

- that no part of the screw/nut protrudes more than 0.8 mm towards the carrier plate (a screw tip must end in a recessed nut or just on the nut edge). Use only countersunk M2 screws for fixing things on the ceramic rings.
- to rotate the ring on the carrier plate such that the screw is located at or near the holes along the diagonal (see Figure 1.8). Any other contact or mounting screw (i.e. for a mesh) cannot be on the same azimuthal position later.

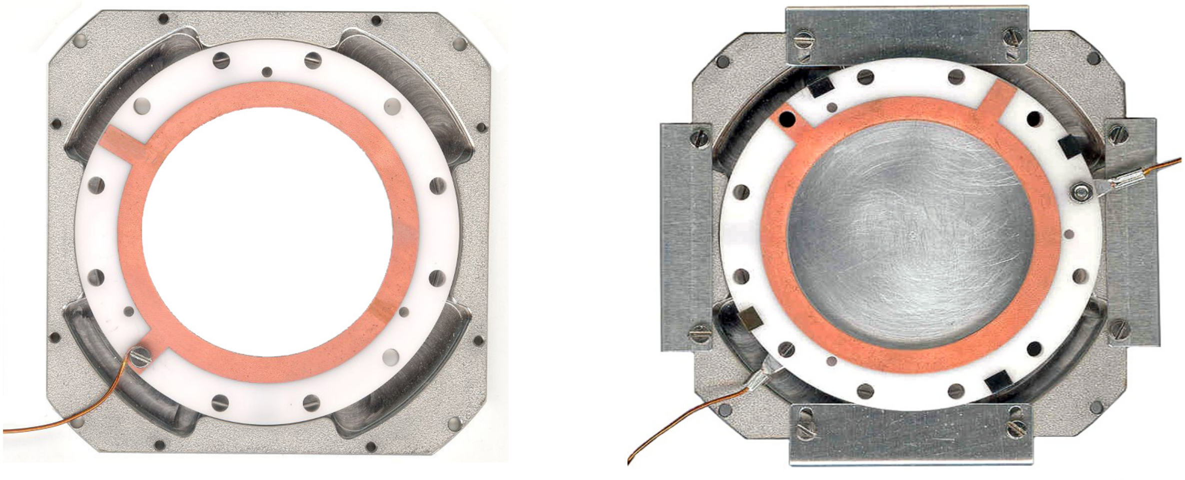


Figure 1.10: Recommended ring orientations on a DLD40 assembly (DLD80 & HEX80 similar). Left picture: cable connection of this type without lug. Cable connection pads must rest in the recessed parts of the carrier plate near the diagonal. Right picture: the assembled MCP stack with recommended orientation. Here, lugs with crimped wires crimped are used. Please follow the next figures/directions to achieve such a detector mounting

After having safely fixed the contact cables on the ceramic rings (in the following assembly drawings, cables are omitted).

1. Place the front ceramic ring (metallization on both sides), with the contact for MCP front side pointing upward, with inserted mounting screws (at least three, four in case of center-hole MCP) from below on a flat table (for center-hole MCP the mounting must take place on the MCP stack carrier plate, please refer to Chapter 1.2.3.5 before continuing). For total MCP stack thickness < 2.5 mm the rods may be secured by nuts during the assembly (recommended for mounting center-hole MCP).

Figure 1.11: Assembly of MCP stack - Stage 1 (DLD40, DLD80 & HEX80)

2. Remove one MCP (for first stage of the stack) carefully from its transport package and place it centered onto the ceramic ring. After the stack is piled you have to check if it is well centered, adjustments can be done by carefully shifting individual MCPs sideways. Unless otherwise noted any of the delivered MCPs can be used for this and will have a mark on the outer rim defining the input (front) side, indicating the MCP pores' tilt angle in the azimuthal plane. This side has to face down and will be in contact with the front ceramic ring. Remember the position of the mark.

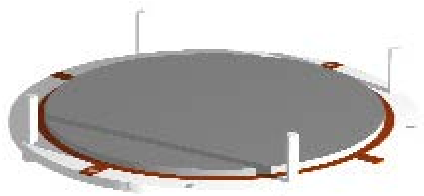


Figure 1.12: Assembly of MCP stack - Stage 2a (DLD40, DLD80 & HEX80)

The second (and possibly a third) MCP will be placed with its mark also facing down and should be rotated by about 180 azimuthal degrees with respect to the mark position on the MCP under it. In a side view cross section of the stack, the pores of the MCP would resemble a (broad) "v" shape (or chevron), or a "z" shape for triple stacking. Such an angle orientation is very important for proper stack performance, however, any relative azimuthal angle between 150° and 210° will serve as well as having exactly 180° between marks. This gives options to aim the MCP's tilt angle marker such that the pore tilt direction is parallel to an edge of the carrier plate once the stack is mounted onto it. This helps controlling detector walk.

A shim ring may be placed between the MCP stages of the stack. Usually, the delivered MCPs will be matched in resistance within 10 % for direct stacking. If not, a shim ring *with contact lug* <u>must</u> be used with cable connection to a feedthrough for bias via a high voltage supply. Please contact **RoentDek** in such a case.

- **DLD40**, **DLD80**, **HEX75Z** with 60:1/40:1 MCP: there is no intermediate contact ring recommended, the second (and possibly third) MCP can be placed in direct contact with each other.
- **HEX80** with 60:1 MCP: a shim ring can optionally be supplied to reduce the active MCPs diameter to 75 mm. This is beneficial for some multi-hit applications.
- **DLD40EP/DLD75**, **HEX75** with 80:1 MCP: a shim ring may be used for reducing ion feedback and increased gain at lower bias (but may affect temporal resolution adversely).

Figure 1.13: Assembly of MCP stack - Stage 2b (DLD40, DLD80 & HEX80/HEX75)

After possibly placing a shim ring on the first MCP the second (and optionally third) MCP can be stacked on top of the first one, observing the position of marks (see above). Dust particles that may have settled on MCPs surfaces can usually be blown away by dry air over the surface or may be removed with the help of a soft (!) brush. ***It is especially important to avoid that dust particles settle between the MCPs during assembly.*** After the stack is piled up you may check if it is well centered, adjustments can be done by carefully moving the MCPs on the ring, ideally with plastic tools (e.g. tweezers).

3. Place the second ceramic ring (with the MCP back contact facing down) carefully on the MCP stack. The rods will guide the alignment.

Figure 1.14: Assembly of MCP stack - Stage 3-1 (DLD40, DLD80 & HEX80)

Note, that the contact positions on the two ceramic rings must not oppose each other.

Now fix the stack with the plastic nuts gently and very carefully. Use only so much force ("hand-tight") that rings and MCPs cannot move any more.

Figure 1.15: Assembly of MCP stack - Stage 3-2 (DLD40, DLD80 & HEX80)

The MCP holding stack can now be finally fixed with 4 spring clamps. Make sure that one of the rings is close to the cable contact of the back ring and the other three at about 90° relative angle to that (see Figure 1.10). No clamp should be right at the position of a contact pad on any side of the rings.

Figure 1.16: Assembly of MCP stack - Stage 3-3 (DLD40, DLD80 & HEX80)

Now remove the plastic nuts and screws again. The MCP holding stack can be used as an independent unit.

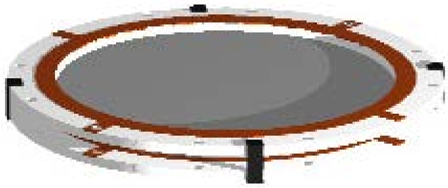


Figure 1.17: Assembly of MCP stack - Stage 3-4 (DLD40, DLD80 & HEX80)

4. Now the MCP stack can be mounted to the anode by inserting it into the butterfly-shaped indent of the carrier plate and fixing it with the movable shields (the ceramic ring side without metallization faces towards the anode). For detectors with central hole please refer to Chapter 1.2.3.5 first. Only uncoated parts of the ceramic ring shall rest on the carrier plate, i.e. the spring clamps and protruding contacts from the back ring must be located along the diagonal of the plate, not touching it.

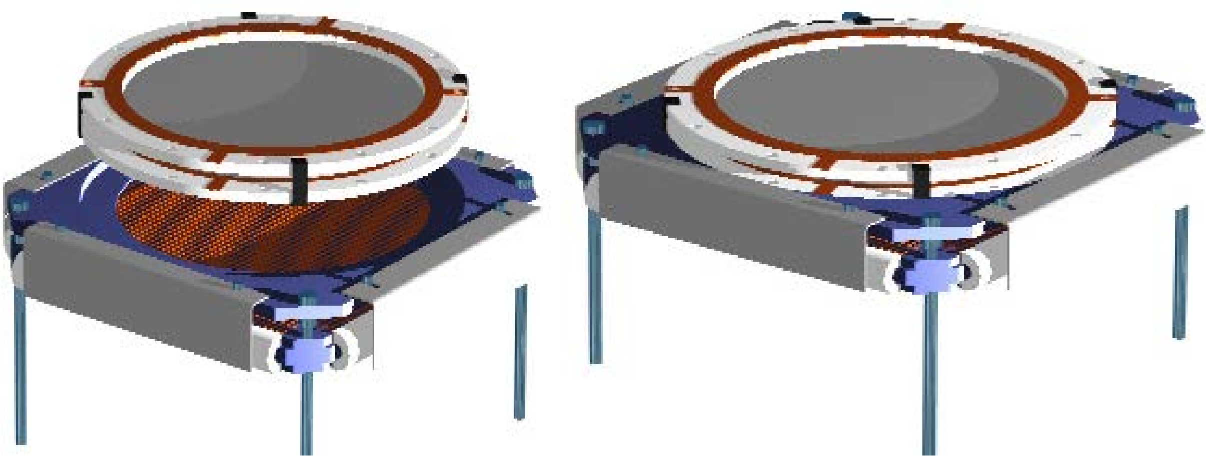


Figure 1.18: Assembly of MCP stack - Stage 4 (DLD40 & DLD80)

Check with an Ω meter that there is no electric contact between "MCP back", "MCP front" and "Holder". There should be a resistance in the 10-100 MΩ regime between "MCP back" and "MCP front". In the presence of humidity, the MCP stack resistance may be less than the default value. Once the stack is fixed on the carrier plate **verify that the distance between the**

MCP front contact lug and carrier plate is > 2 mm at any position. This can be achieved by a slight upward bending of the lug.

For the **HEX80**, the same butterfly-shaped MCP carrier plate as for the **DLD80** is used. Additionally, a hexagonally-shaped intermediate plate links the standard **DLD80** carrier plate to the **Hexanode**. The shields are replaced by a pair of metal sheets that hold the MCP stack in position. The recommended distance between the MCP back plate and the anode body plate is about 7-10 mm.

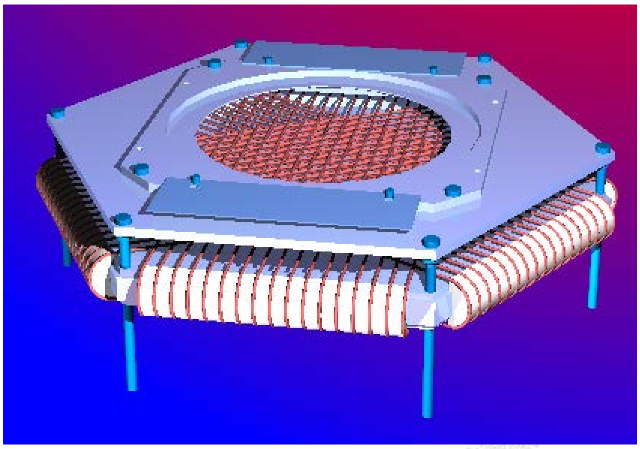


Figure 1.19: Hexanode with carrier plate

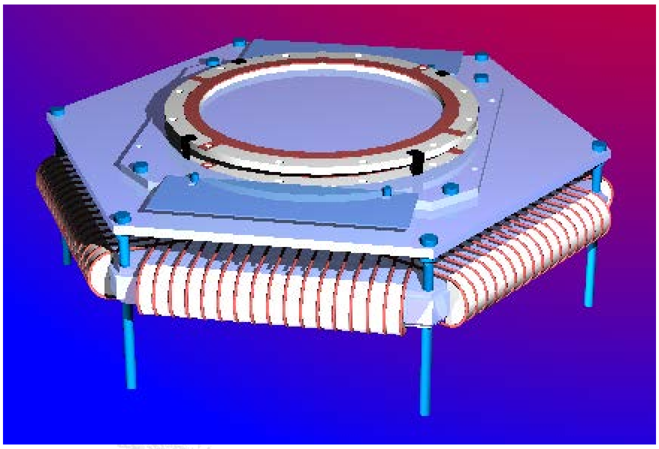


Figure 1.20: Hexanode with mounted MCP stack

For disassembly reverse all steps

If an MCP stack shall be mounted to an over-sized anode e.g. in case of **DLD40L**, where a 40 mm MCP stack is placed on a **DLD80** anode), intermediate adapter plates are provided.

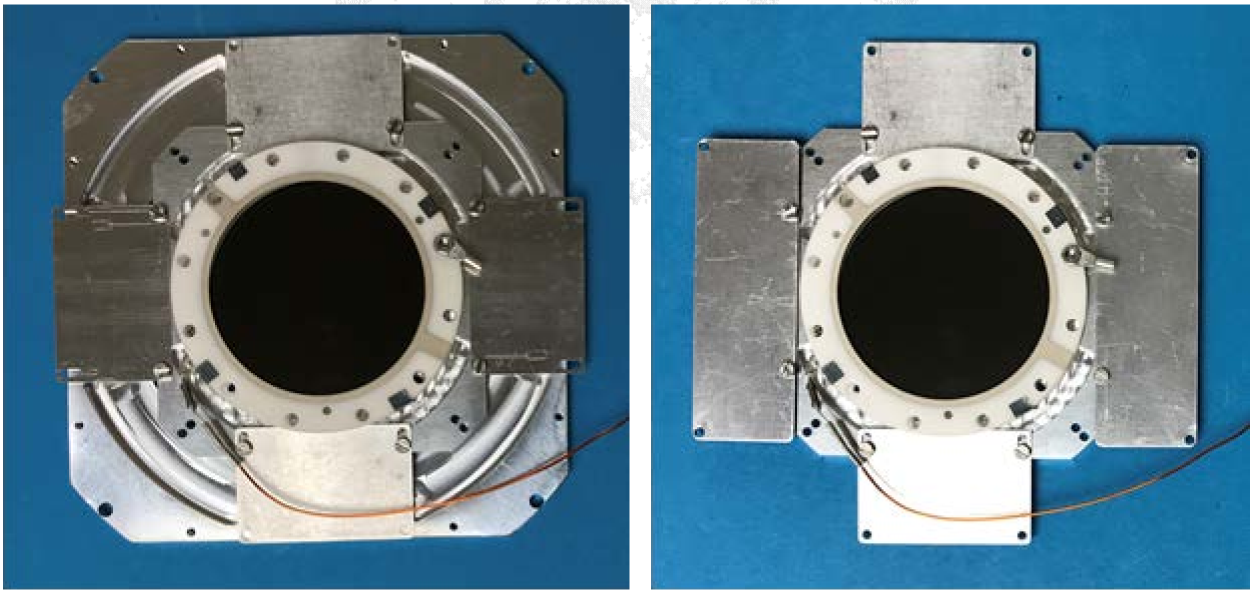


Figure 1.21: 40 mm MCP assembly with adapter plates to a larger anode. Left: for DLD40L, right for Hex40s.

1.2.3.2 Assembly of the MCP stack for the DLD120, DLD105 (and HEX100*)

For the 120 mm or 105 mm MCP size the mounting is different than for the standard 40 mm or 80 mm mountings with MCP clamped between ceramic rings. Instead, the MCPs are fitted between a metal square-shaped rear support plate which mates to the delay-anode and a metal front ring. The rear support plate and the front ring have an indention for the MCP on one side. The mounting plate for **DLD105** may additionally have permanent M2 bolts in place to ease in MCP stack alignment. The

* For **HEX100** equipped with 105 mm MCP you may have received different MCP clamping gear (without square MCP back mounting plate). In this case please refer to the separate MCP mounting instructions as provided with the detector delivery.

MCP stack is fixed by 6 special M3 screws make from PEEK which is an insulating UHV-compatible polyimide material. For detectors with central hole please refer to Chapter 1.2.3.5 first.

Place the rear support plate (which may be pre-mounted on the anode) with the indention for the MCP pointing upward according to the sketch below. You may leave the MCP back plate mounted on the delay-line anode if you have received it pre-mounted in this way. Screw the three M3 guide rods symmetrically into three of the six M3 tapped holes (only one side of the rods may have a useful thread). Remove the MCPs carefully from their transport package and insert the first one (the designated rear MCP in the stack) centered into the indention, with the bias angle marker (triangle on the outer rim on one side or according to separately supplied description sheet) pointing upwards. Make note of the azimuthal orientation relative to the anode to control possible detector walk effects.

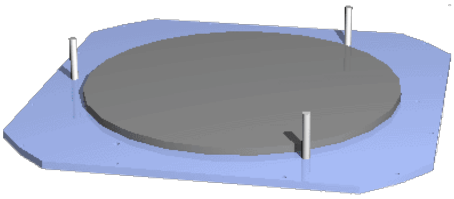


Figure 1.22: Assembly of MCP stack – Stage 1 (DLD120, DLD105 and HEX100)

Now the second (and possibly a third) MCP will be placed with its mark also pointing upwards and should be rotated by about 180 azimuthal degrees with respect to the mark position on the MCP under it. ***It is especially important to avoid that dust particles settle between the MCPs during assembly***. Dust particles that may have settled can usually be blown away be spraying dry air across the MCPs surface or may be removed with the help of a soft (!) brush. In a side view cross section of the stack, the pores of the MCPs would resemble a (broad) "v" shape (or chevron), or a "z" shape for triple stacking. Such an angle orientation is very important for proper stack performance, however, any relative azimuthal angle between 150° and 210° will serve as well as having exactly 180° between marks. Optionally, shim rings can be supplied for being placed between MCPs which may improve overall gain and homogeneity and/or to reduce the active MCP diameter to the active anode size. Usually, the delivered MCPs will be matched in resistance within 10 % for direct stacking. If not, a shim ring *with contact lug* <u>must</u> be used with cable connection to a feedthrough for bias via a high voltage supply. Please contact **RoentDek** in such a case. After the stack is piled up you may check if it is well centered, adjustments can be done by carefully moving the MCPs on the ring, ideally with plastic tools (e.g. tweezers).

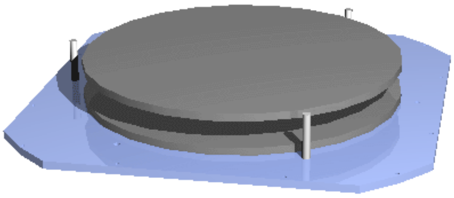


Figure 1.23: Assembly of MCP stack – stage 2 (DLD120, DLD105 and HEX100)

If the MCPs need replacement, mount a set with matching electrical resistance only or employ a shim ring with contact lug for intermediate bias (see above).

Place the front metal ring with the indented side facing downward on the MCP. The guide pins will help in the alignment.

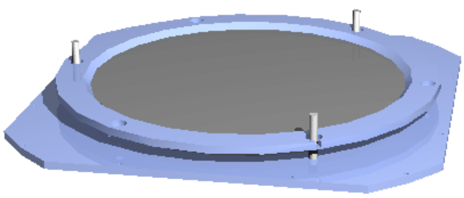


Figure 1.24: Assembly of MCP stack – Stage 3-1 (DLD120, DLD105 and HEX100)

It is very important that the MCP stack is well centered and will fit into the indention of the front ring. Now fix the front ring onto the stack with three plastic screws very carefully and only lightly. Due to the indentions in the rear support plate and the front ring, the MCP stack will not slip out even if the screws are not entirely tightly fixed. Remove the guide pins (for storage, they may be needed again) and add the other three screws. Once all screws are in place fix them again slightly without excessive force.

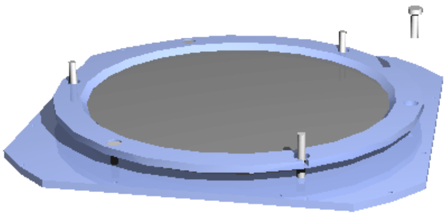


Figure 1.25: Assembly of MCP stack – Stage 3-2 (DLD120, DLD105 and HEX100)

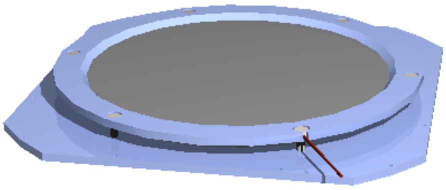
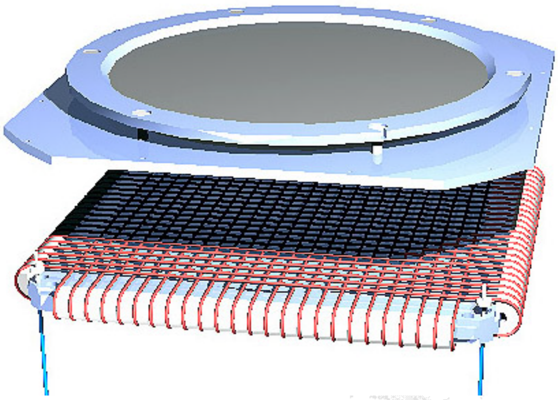


Figure 1.26: Assembly of MCP stack – Stage 3-3 (DLD120, DLD105 and HEX100)

Now the MCP back contact cable can be fixed to the rear MCP support plate on any of the M2 threads along the edges and likewise the MCP front contact cable to the front ring. **The screw must not protrude towards the rear metal plate**. Optionally, the MCP front cable can be mounted sunken on the recessed hole position as shown in Figure 1.26. For this remove the respective M3 screw, insert the MCP front contact cable (e.g. on a 3 mm eyelet lug) and re-fix the screw as tight as the others.



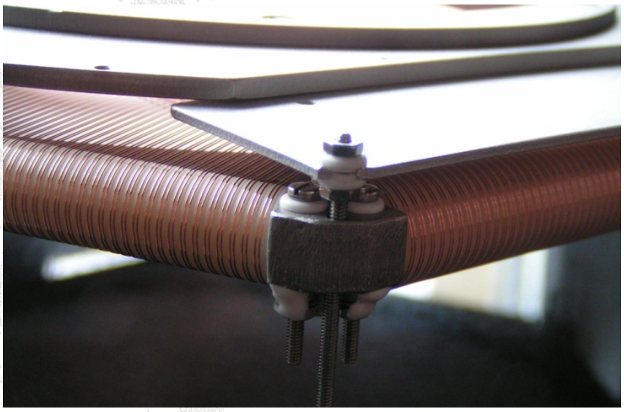


Figure 1.27: Assembly of MCP stack – Stage 4 (DLD120, DLD105 and HEX100)

Finally, the mounted MCP stack can fixed to the anode with nuts on the M2 rods (in case of **HEX100** via wing rails as shown in Figure 1.27 right, collared ceramic eyelet care for insulation. The recommended distance between the MCP back plate and the anode body plate is about 7-10 mm.

A woven potential mesh **wMesh120,** a free-standing mesh (similar to the one in Figure 1.9) or calibration mask can be supplied for being placed on the MCP front side. Please contact **RoentDek** for this option.

1.2.3.3 Assembly of DLD25/40(SL)80 and HEX40/80 (HEX100) with metal rings for MCP

The alternative MCP assembly option for **DLD25/40/80**, **HEX40/80** and **HEX100** with 105 mm MCP using metal rings enables the installation of thin MCPs (e.g. 0.72 mm) and simplifies the use of shim rings for intermediate stack bias. The latter is important whenever MCPs are not matched in resistance or the individual MCPs shall be operated with variable potentials. The metal ring assembly is specified for total MCP stack thickness of > 1.5 mm (incl. shim ring). If you want to use an MCP stack with smaller total thickness, please contact **RoentDek**. Only the assembly frame for 25 mm MCPs on a **DL40** anode (**DLD25)** is readily prepared for thinner MCP.

PEEK screws (countersunk type) are used to clamp the MCP between the metal rings. The PCD of these M2 screws is chosen such that they also safely center the MCPs on the ring. Length of screws must match to the total thickness of the MCP stack used. For stack thickness between 1 and 2.5 mm screws with 6 mm lengths shall be used, 8 mm long screws are needed for stack thickness between > 2.5 mm up to 4.5 mm. The same standard MCP stack carrier plate as used for the mounting with ceramic rings is employed*. Only the Holder plate is flipped so that the indented side points towards the anode, see Figure 1.28.

* only novel carrier plates with holes at PCD 60 mm (for **DLD40**) or 98 mm, respectively (**DLD80/Hex80**) can be used.

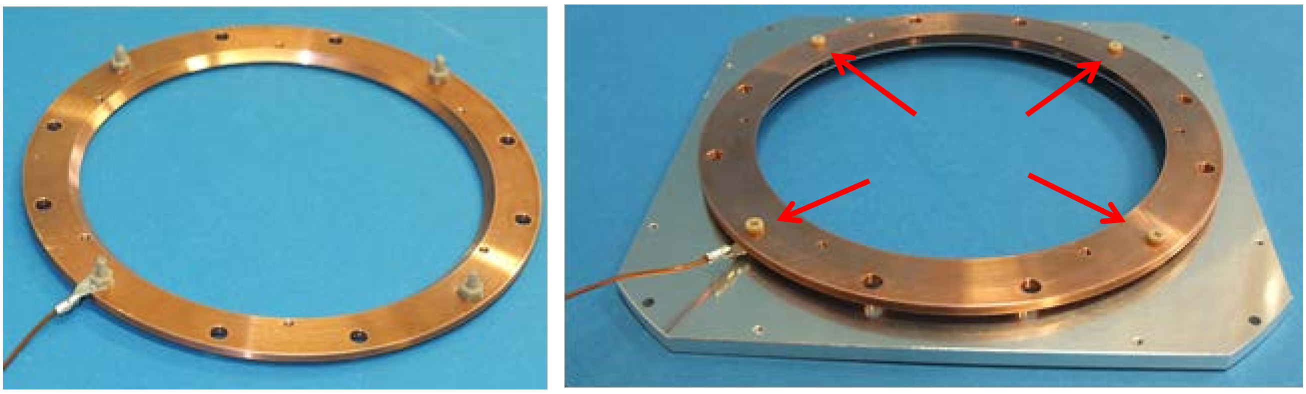


Figure 1.28: Rear MCP ring (here: for DLD80) made from Cu with cable contact (left), mounted on a standard carrier plate (right picture, plate flipped over compared to operation with ceramic MCP mounting rings. Similar carrier plates are used for HEX75. For MCP stacks of thickness < 1.5 mm countersunk PEEK screws in 3.2 mm holes must be used for fixing the rear ring onto the carrier plate. For the red arrows see caption of Figure 1.29.

Usually, the metal MCP back ring will be found pre-mounted to the carrier plate with cable connection for MCP back in place. Please make sure that the connector lug is bent such that safe insulation distance to the carrier plate is insured (> 1 mm). At this time the cable connection for MCP front should be prepared, too, although the standard connection scheme as shown in Figure 1.29 left can also be set after the MCP assembly. **It is important to choose a screw length so that the screw does not protrude towards the rear metal ring**.

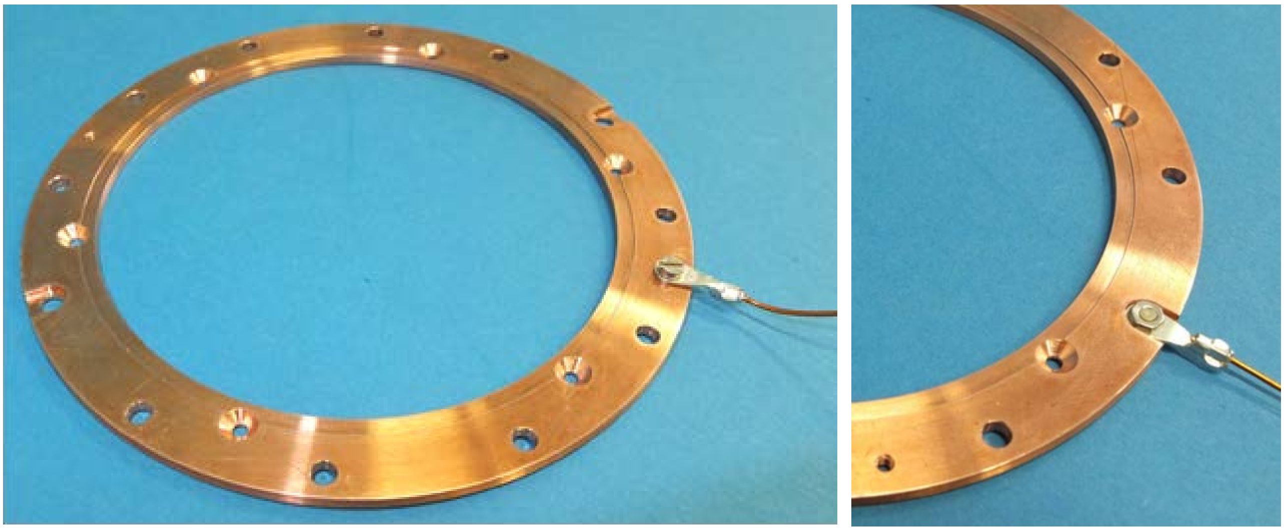


Figure 1.29: Front MCP ring (here: for DLD80) with cable contact options to MCP front side. Note, that for DLD25/40/80 and HEX40/80 indented ring side is <u>not</u> pointing towards the MCP in the typical mounting assembly (using metal rings on both sides). For Hex100 both mounting rings are identical and the MCP faces are placed in the indentions. A special recessed cable connection scheme can be supplied on demand (right picture). If this cable connection scheme is used (possible only for MCP stacks with > 1.7 mm thickness) the contact hole cannot be located at the fixing positions of the rear MCP ring (see red arrows in Figure 1.28), once assembled.

Mounting of **RoentDek** potential meshes near the MCP front surface is accomplished by use of the outer 3 mm holes in the ring. A mesh must usually be mounted <u>before</u> stack assembly. Please refer to the descriptions in the corresponding Mesh Manual.

Once cable connections are settled, the MCP stack can be mounted. Place the rear metal plate (which may be pre-mounted on the anode) with cable connection installed according to Figure 1.30. Screw the three M2 guide rods symmetrically into three of the six M2 tapped holes (only one side of the rods may have a useful thread). Remove the MCPs carefully from their transport package and insert the first one (the designated rear MCP in the stack) centered between the guide pins, with the bias angle marker (triangle or other mark on the outer rim on one side) facing upward (should the MCPs diameter be too large to fit in contact **RoentDek**). Observe the azimuthal orientation of the mark relative to the anode to control possible detector walk effects. Handle MCPs only with care along the rim, preferably with gloves. Unless otherwise noted, any of the supplied MCPs can be selected for this position in the stack.

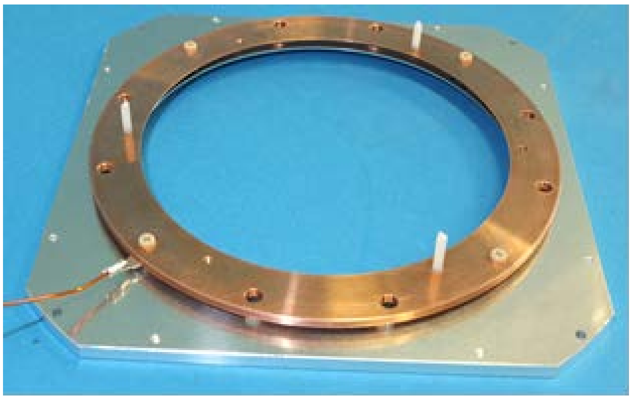
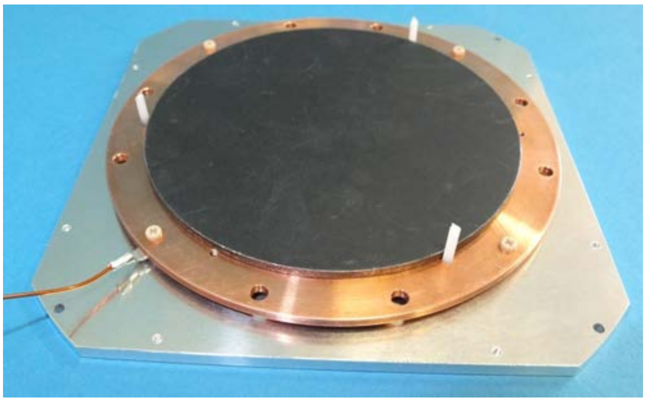



Figure 1.30: Rear MCP ring with guide pins inserted and MCP in place (right).

Then the second (and possibly a third) MCP can be placed with its mark also facing upwards and should be rotated by about 180 azimuthal degrees with respect to the mark position on the MCP under it (a shim ring may be placed between MCPs, see below). ***It is especially important to avoid that dust particles settle between the MCPs during assembly***. Dust particles that may have settled can usually be blown away be spraying dry air across the MCPs surface or may be removed with the help of a soft (!) brush. In a side view cross section of the stack, the pores of the MCPs would resemble a (broad) “v” shape (or chevron), or a “z” shape for triple stacking. Such an angle orientation is very important for proper stack performance, however, any relative azimuthal angle between 150° and 210° will serve as well as having exactly 180° between marks. Optionally, shim rings can be supplied for being placed between MCPs, which may improve overall gain and to allow an intermediate MCP bias. Usually, the delivered MCPs will be matched in resistance within 10 % for direct stacking. If not, a shim ring *with contact lug* must be used with cable connection to a feedthrough for bias via a high voltage supply, see Figure 1.34. If the MCPs need replacement mount a set with matching electrical resistance only or employ a shim ring with contact lug for intermediate bias (see above).

Now place the front metal ring onto the MCP stack with the indented side facing upward*. The guide pins will help proper alignment. The azimuthal position of the MCP front contact lug must not be located in the diagonals of the holder plate, to avoid spatial interference with the M2 screws underneath (i.e. those fixing the back ring to the holder plate).

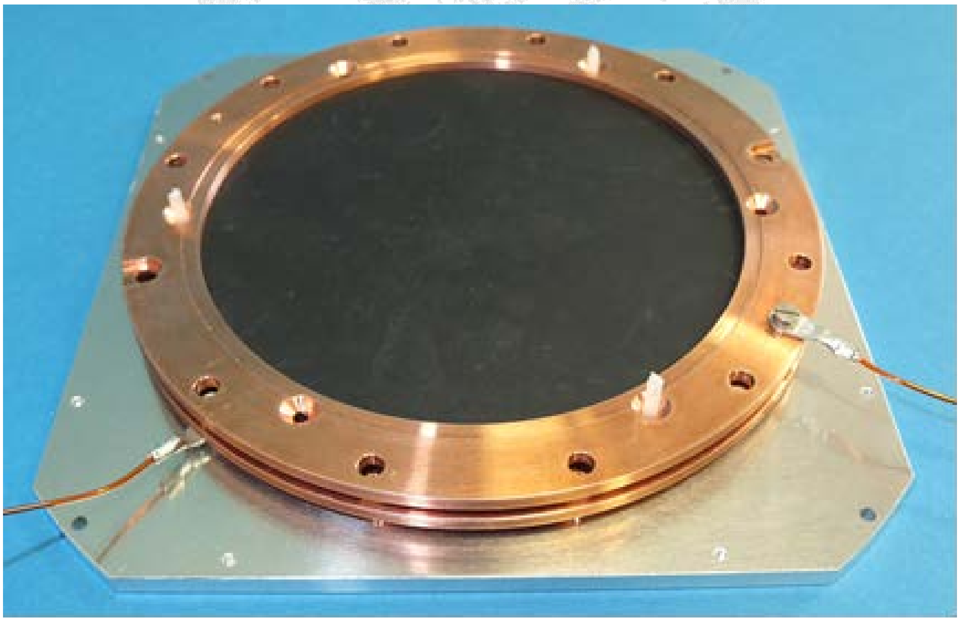


Figure 1.31: The front MCP ring (here with cable connection already installed) is placed on the MCP stack. Note, that the MCP front contact must not be located along the diagonals of the holder plate, to avoid spatial interference with M2 screws underneath.

* Only for custom mountings via screws in the outer 3 mm holes the indented side shall be used to center the MCP stack.

Fix the front ring on the stack with three plastic screws very carefully and only lightly. Remove the guide pins (for storage, they may be needed again for dis-/reassembly) and add the other three screws (for mounting 25 mm MCPs via the respective rings this is not necessary because just three screws are sufficient). Once all screws are in place, tighten them carefully without excessive force. For disassembly reverse all steps.

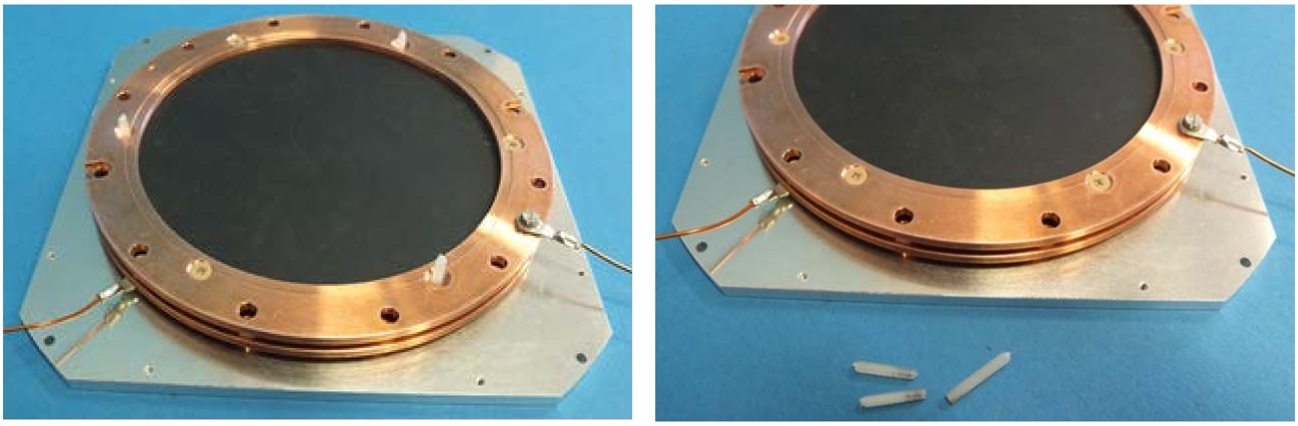


Figure 1.32: Assembly of MCP stack with front ring secured.

If not already in place, the MCP front contact cable can be fixed to the front MCP ring on any of the M2 threads now. ***It is important to choose a screw length so that the screw does not protrude towards the rear metal ring***.

Finally, the carrier plate with MCP stack has to be mounted onto the anode with M2 nuts. Special ceramic spacers are provided to ensure an ideal distance between anode and MCP, see Figure 1.33).

Figure 1.33: Special ceramic spacers (left picture) are placed on the rods protruding from the anode before the carrier plate is fixed to the anode holder with M2 nuts (right picture, here for DLD80).

1.2.3.4 Intermediate MCP stack connection

RoentDek can provide for any MCP assembly special shim rings for placement between MCPs to supply an intermediate MCP stack bias. This is mandatory if MCPs without resistance matching are used or if the relative MCP bias voltages shall be individually addressable. These shim rings have a lug for the optional cable connection, see Figure 1.34. The cable can either be soldered to the lug or connected via hole(s) in the lug.

Especially when using a metal ring it is very important that the lug is not bent considerably so that neither the lug, the cable nor the connecting eyelet/screw get too close to any part on very different potential, e.g. the bias of the MCP stack's back or front side. ***Otherwise discharge may occur, affecting the detector function or even damage the MCP stack and/or read-out electronic circuits***. Therefore, the lug position must be stabilized/supported, for example by PEEK screw/spacers (not necessary for **DLD40S**).

For certain standardized products with unmatched MCP, for example **DLD40_f**, **DLD75_f** and **HEX75_f**, **RoentDek** provides height-adjusted connection posts which may already be fixed to a shim ring for intermediate bias contact, see Figure 1.34.

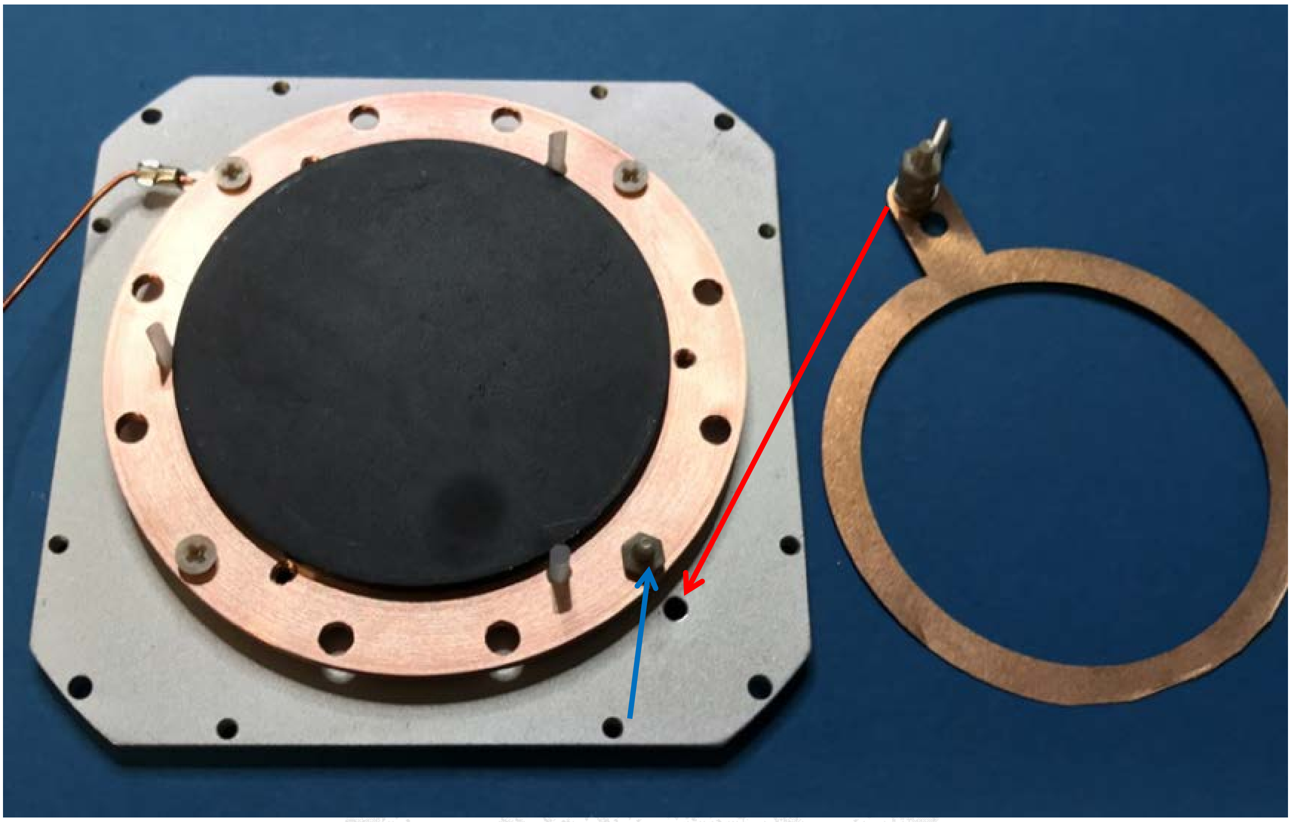


Figure 1.34: If a non-matched MCP set (here for DLD40_f) is supplied the MCP carrier is usually equipped with an adequate supporting rod (blue arrow) for a shim ring with biasing post that can be fixed on the carrier (red arrow).

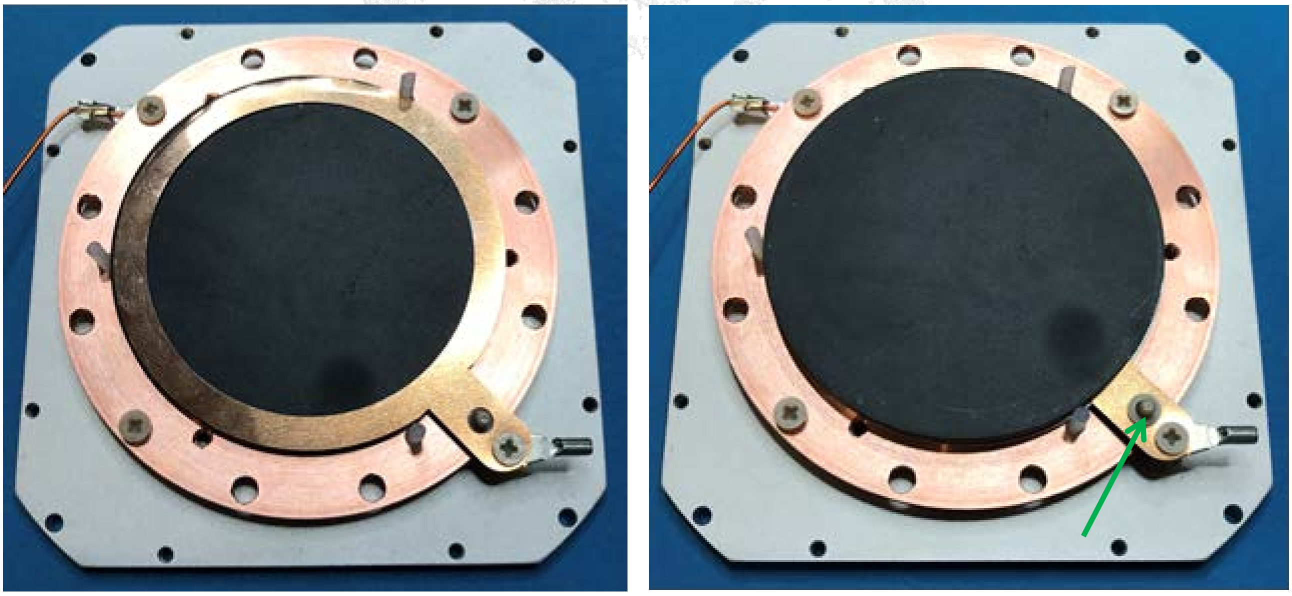


Figure 1.35: Spacers ensure safe positioning of the connection lug between the metal rings. The picture up left shows the shim ring resting on the back MCP. After the front MCP is mounted (picture up right) a washer may be placed as spacer on the support rod (see green arrow). Its thickness must be slightly smaller than of the front MCP.

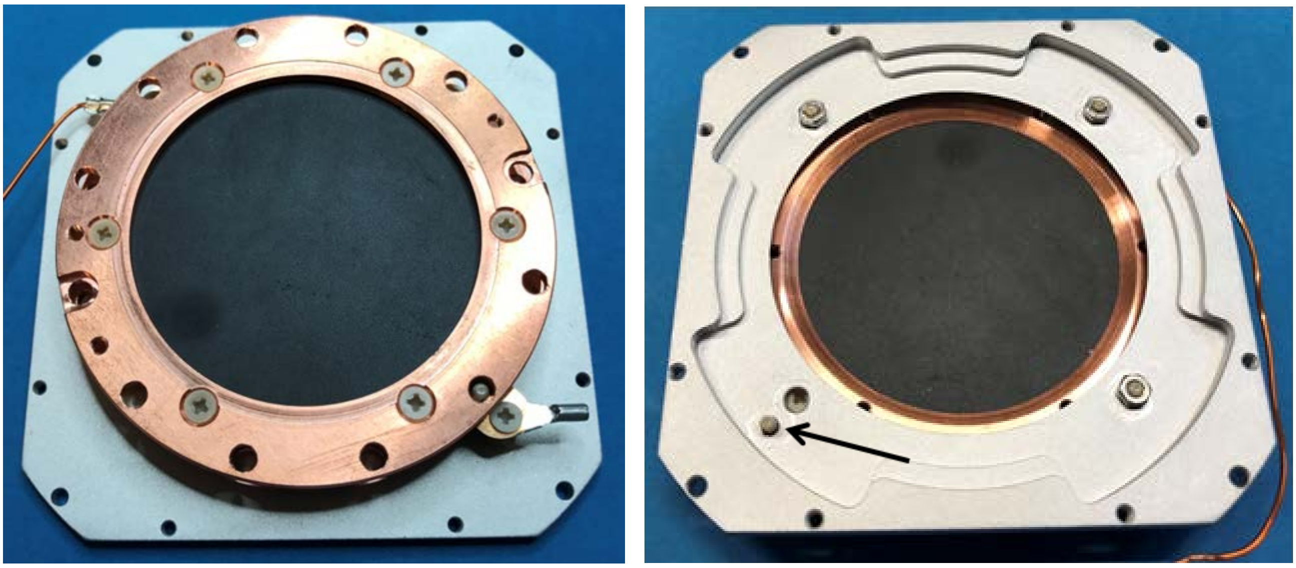


Figure 1.36: Once the front ceramic ring is in place and secured (left picture) the connection post for the shim ring (see right picture, black arrow) may be secured by another M2 nut (not shown) on the reverse side. (only if it sticks out far enough). Before disassembly of the MCP stack (reverse all steps) remove this nut first.

If non-matched MCP are used special requirements are necessary for detector operation, please refer to Chapter 2.5.1.

1.2.3.5 Assembly of the DLD40SL

The **DLD40SL** is a rectangular-shaped version of the standard **DLD40**, optimized to overcome certain space restrictions in specific instrumentation environments. Its basic design is also used for assemblies where only one-dimensional imaging is predominately required. Elongated versions are used for rectangular MCP stack sets with up to 200 mm length.

To account for different spatial constraints the layout of cable connection scheme is kept flexible and the here-shown assemblies are only a variation of options. Figure 1.37 shows a version that can be operated in a tube on a moveable mounting rod with fixed cabling to an intermediate PCB connector. The **DLD40SL** can be equipped with a Kapton jacket for insulation from nearby surfaces in especially tight environment. If spatial restriction in a certain application allow, the anode is constructed to allow connection cables emerging sideways, or to the rear.

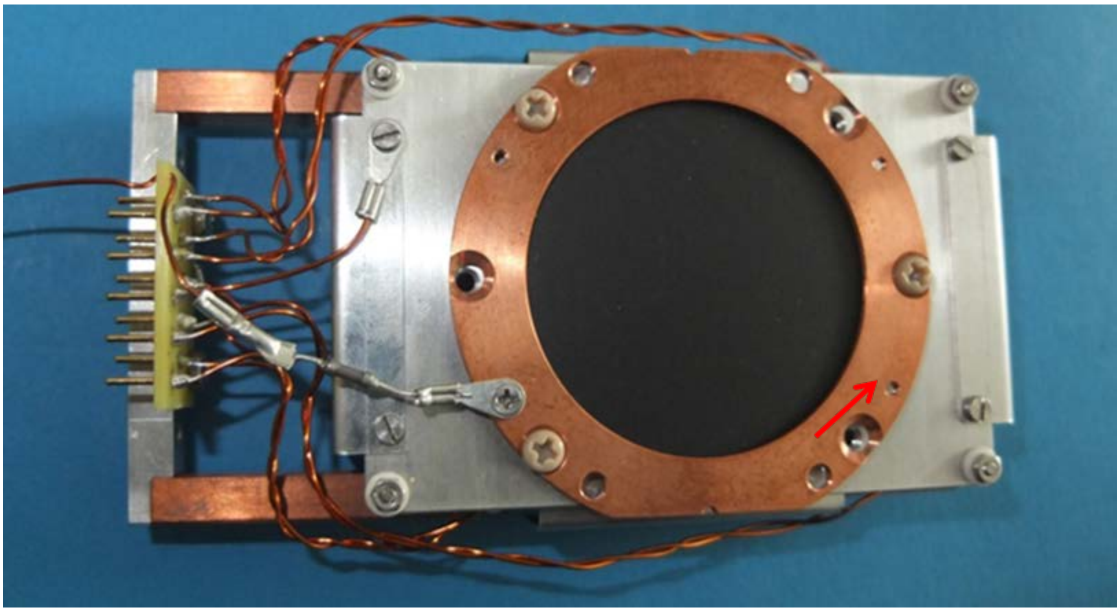


Figure 1.37: DLD40SL with fixed cabling to an intermediate PCB connector, for further cabling to the signal feedthrough. The MCP carrier plate is in contact with the MCP stack (as for DLD120/HEX100) and must be insulated from the mounting posts (protruding from the Holder) via pairs of collared ceramic eyelets (see red arrow) in each corner.

Unless you have received the **DLD40SL** readily mounted, the MCP carrier plate has to be fixed on the threaded M2 rods, insulated from those via collared ceramic eyelets, see Figure 1.37 and Figure 1.38. This may happen after the MCP stack is assembled.

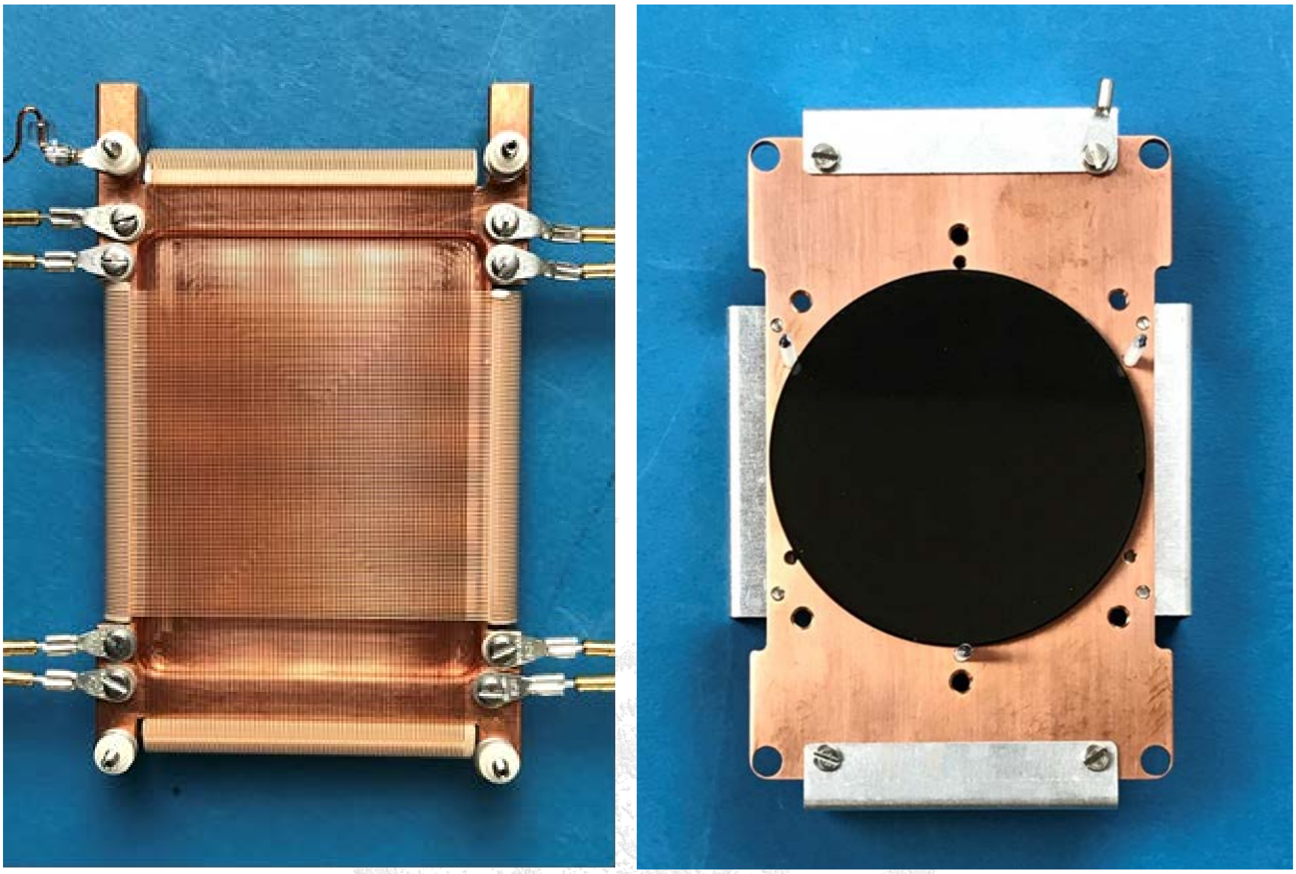


Figure 1.38: DL40SL anode with mounting post and lower set of insulating eyelets (left). The Holder connection can by fixed on a post via a lug (if there are no external space restrictions preventing this). In the design shown here connection ports on the delay-line terminals point sideways. For this connection scheme it is advisable not to remove/reconnect pre-mounted cables from the wire terminals (avoiding mechanical stress). Other assemblies for environments with sufficient rear space may have the anode wire terminals sticking out towards the rear anode side as the standard DLDs. Right picture: carrier plate with guide pins inserted, ready for placing the MCP stack.

The MCP mounting is mostly identical to the scheme as used for the DLD40 with Cu rings and can take place before or after the carrier plate is fixed to the anode. As mentioned earlier it is advisable to protocol the positions of the markers on the MCP rims with respect to the MCP carrier plate orientation. Here, it is recommended to rotate the MCP such that the markers point toward the long sides of the MCP carrier plate (up/down in Figure 1.37). Only in case there is demand for an improved resolution along the up/down dimension (for this detector orientation), markers should rather point towards the short edges.

If an intermediate shim ring with bias lug is used this shall point towards a long edge (see Figure 1.39). This relieves from the need of securing the lug position. Still, care should be taken so that stress from the detection cable does not bend the lug.

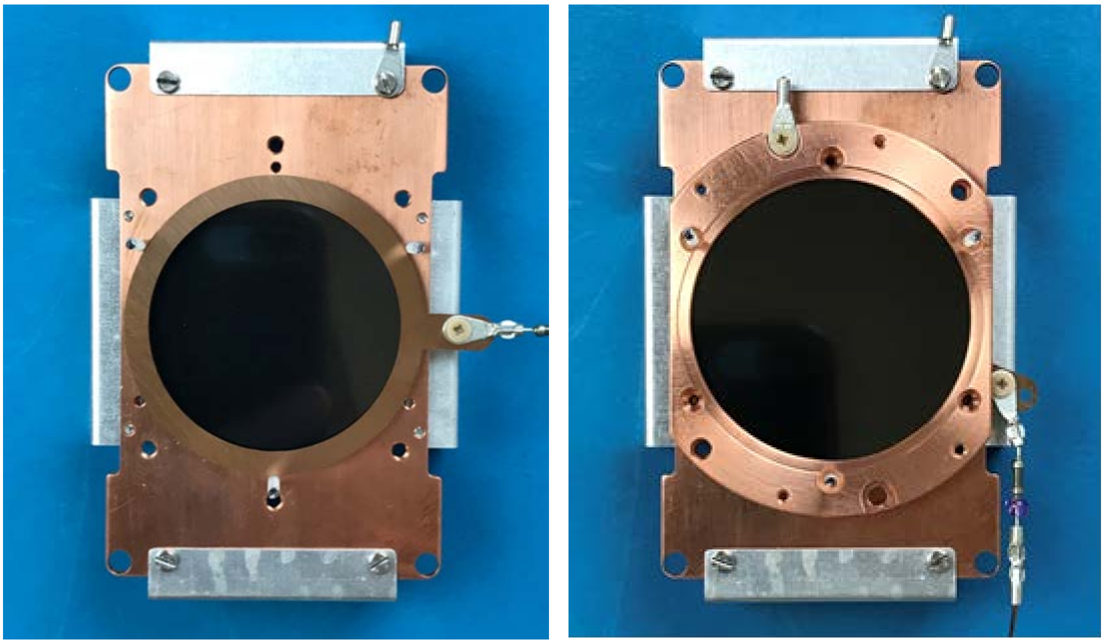


Figure 1.39: MCP mounting with intermediate lug. Depending on spatial restrictions its connection cable may be guided out sideways or alongside.

If the connection scheme is chosen as in Figure 1.40 the single pitch delay in X-direction (here: left to right) is about 0.57 ns/mm and 0.77 ns/mm in Y-direction.

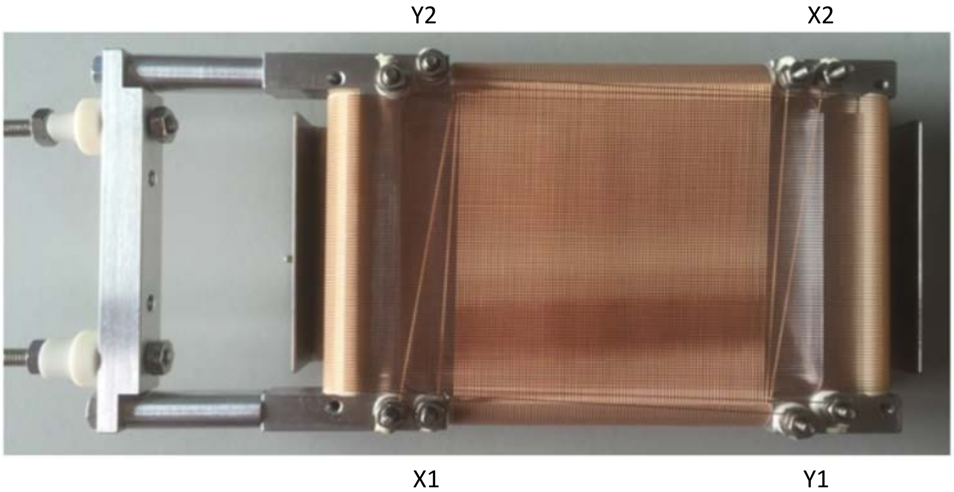


Figure 1.40: DLD40SL views with default assignments of the delay-line coordinates. The default mounting method is via M3 rods emerging from the frame on the left which carries "Holder" potential. Insulating collared ceramic eyelets for mounting purposes can be provided on request.

1.3 Delay-line detector with central hole

For specific experimental situations it is mandatory to allow for a charged particle or gas beam to pass through a central hole in the detector. This requires the use of special MCPs with a central hole (typical hole size is 6.4 mm) and likewise an anode with a hole. It introduces a gap in each delay-line layer where a particle position coordinate cannot be detected on the respective layer. If a **Hexanode** is used the gap in one delay-line layer is mostly covered by the other two, allowing a fairly homogenous imaging outside a certain distance from the central hole. To reduce the effects of fringing fields (resulting from the hole geometry) on the anode imaging properties, the hole in the anode should contain a tube that extends close towards the MCP (see Figure 1.34) and an inner tube that passes through the MCP stack. For most detector biasing schemes this ***inner tube is mandatory for safe MCP operation***. Biasing an MCP stack without a properly designed inner tube may cause charge feedback effects that can ultimately destroy the MCPs and connected electronics. The inner tubes must carry an ***outer insulation layer specified up to at least 3 kV*** voltage and should have a separate bias contact. Usually, an inner tube is part of the detector delivery (see Figure 1.35) and may already be inserted.

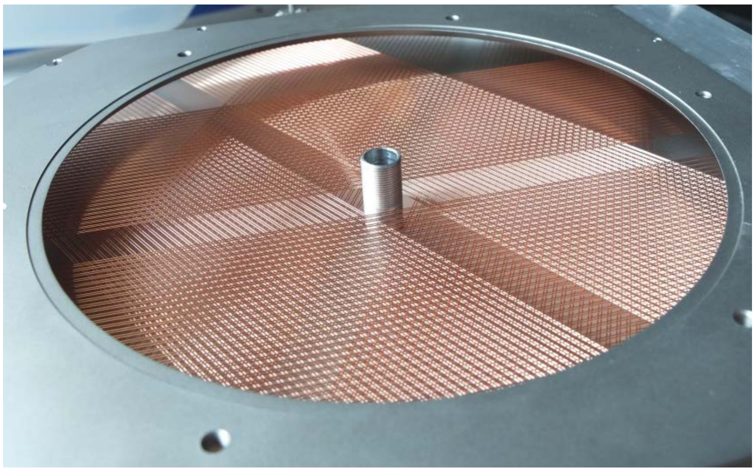
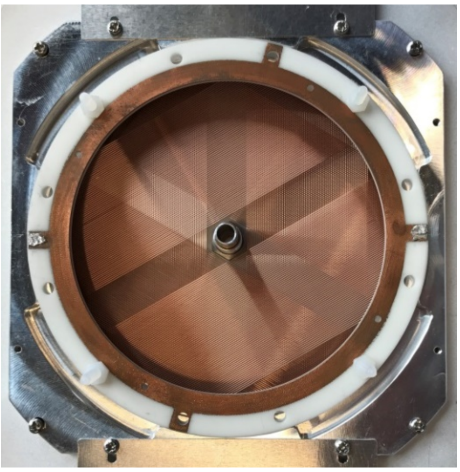



Figure 1.41: Hexagonal delay-line anodes with central hole. Left picture: view of Hex120/o (only with outer tube) and MCP back support plate. Right picture: Hex80/o with inner tube and ceramic ring (with temporary plastic screws secured in position by nuts), placed in the indentions of the carrier plate, ready for MCP stack assembly.

The so-called "outer tube" is physically attached to the anode body and is thus on the same "Holder" potential. Usually the MCP stack carrier plate (or MCP back carrier plate) will be mounted on the anode when the detector is dispatched. To reduce the effect of fringing fields on anode performance, the distance between the (outer) tube and the MCP stack should be not more than 1 mm. ***This distance*** was carefully adjusted prior to shipping but ***must be verified and possibly re-adjusted*** because during transport and unpacking procedures it might have changed. While a larger distance may merely lead to inferior imaging properties a too-close distance with the ***outer tube protruding over the position where the MCPs will come to rest may cause major damage*** to the MCPs as soon as it is placed on the support/carrier.

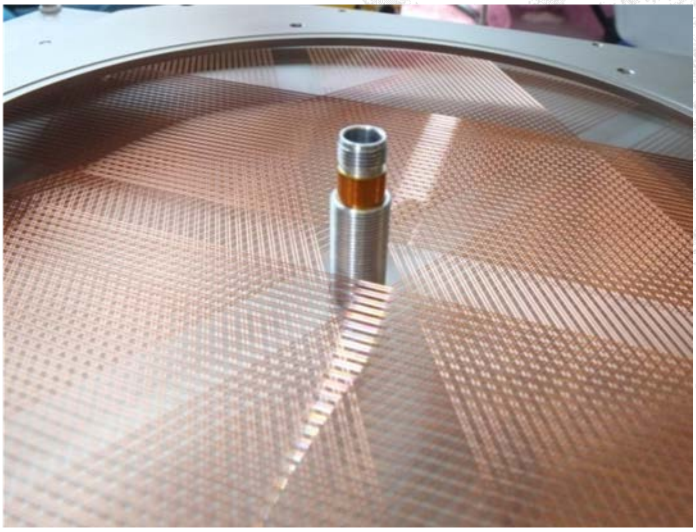
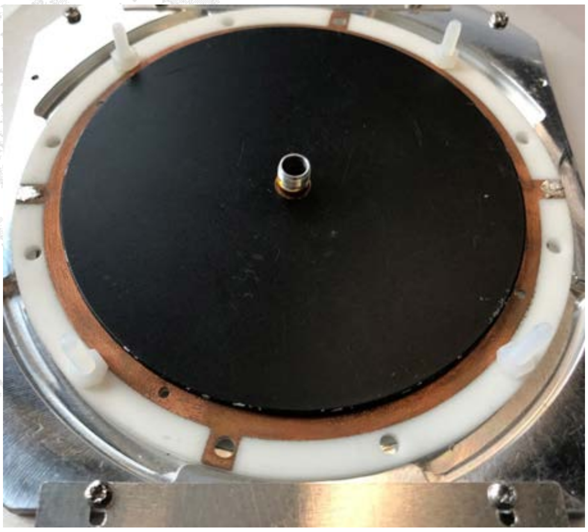



Figure 1.42: Photo of Hex/o tube assemblies with removed front cap. Left: Hex120/o, ready to pass a MCP stack with adequate central hole diameter over the inner tube. Right: MCP stack with central hole placed on the ceramic back side ring (as in Figure 1.12). After stage 3-2 of the MCP clamping the stack must be temporarily lifted from the MCP carrier for fixing the spring clamps and removing the plastic screws.

Therefore, verify this distance, e.g. by simply placing a ruler or a flat bar across the support/holder plate and ensure a safe distance between the support's top surface (where the MCPs will rest on) and the tube. If you find that the height of the holder plate needs adjustment change this height after loosening the M2 screws on the threaded rods in the corners of the anode and re-fix them after height adjustment. The plate and the anode body must be aligned in parallel. At this time, the detector shall be placed on its mounting gear or a provisional rear support so that the carrier plate is oriented horizontally.

The MCP stack has to be well-centred on the MCP back carrier plate. Therefore, the inner tube must be inserted <u>before</u> the MCP stack assembly and shall protrude towards the detector front side by about 10 mm beyond the MCP carrier plate, with the front cap removed. The MCP must be placed onto the carrier one by one with the inner tube passing through the holes in the MCPs, which requires careful alignment.

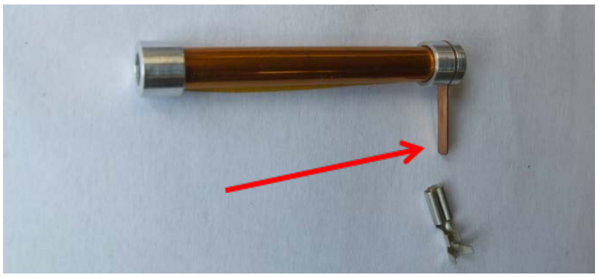
For **Hex80/o** and **Hex40/o** detectors with MCP clamping via ceramic rings the MCP stack mounting as described in Chapter 1.2.3.1 must take place on the carrier plate readily mounted to the anode, the plastic screws resting near the carrier plate's holes along the diagonals (see Figure 1.41). This insures proper alignment of the MCPs on the ceramic rings so that the stack can be removed later (e.g. for setting the clamps and removing the plastic screws). When re-placing the stack over the inner tube for finally fixing the MCP stack on the carrier plate via the retractable shields, great care has to be taken again.

The inner tube as supplied by **RoentDek** is biased via a contact lug in the rear. Screwed-on caps on both ends fix the insulating Kapton sheet cover. The inner tube's diameter is 4.5 mm for MCPs with 6.4 mm hole and the outside diameter (without caps) is 6 mm so that it can pass through this standard MCP stack's central hole size.

After that, continue with the detector mounting as described in Chapter 1.2. Great care should be taken when placing the MCPs above the inner tube (see Figure 1.42).

The inner tube can be biased to any potential between +4 kV and -4 kV but must have a voltage < 3 kV with respect to any other potential on the detector. However, biasing the inner tube to a potential very different from MCP front bias will divert trajectories of slow charged particles before detection. Ideally, the inner tube potential shall be similar to the MCP front potential.

After having fixed the MCP stack with the front MCP ring the front cap can be screwed onto the inner tube again for securing the insulating Kapton sheet. During this procedure the inner tube may have to be pushed further forward so that the cap never gets into contact with the MCP surface.



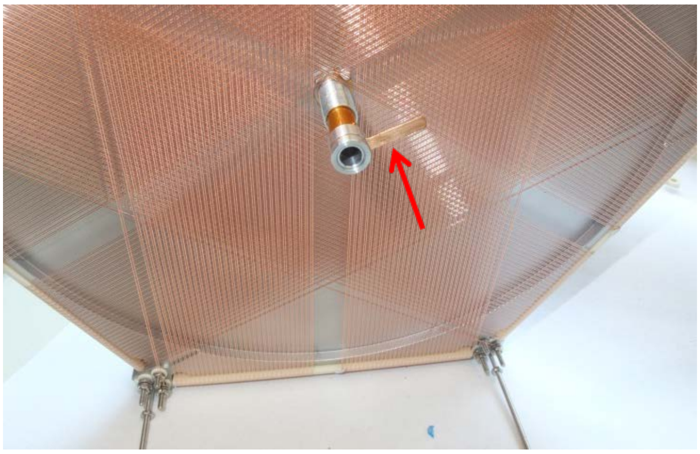


Figure 1.43: Photos of the tube assembly and of the inner tube bias contact on the rear side of a Hexanode

If necessary, the position of the inner tube can now be finally adjusted: The distance between front cap and MCP stack must be sufficient to allow for operating a safe potential difference between tube and MCP front, as defined by the application. The friction from the Kapton insulation between inner and outer tube help to keep the inner tube at a chosen lateral position during adjustment. This position will be maintained once the detector is mounted, ***but it is necessary to secure the position against vibration by using some fairly rigid (form-stable) connection cable (i.e. as supplied by RoentDek on the inner tube's rear-end contact pin***.

An example biasing scheme for an electron scattering experiment looks as follows: An electron beam passes through the tube and re-scattered electrons with low to medium energy shall be detected. The inner tube should then be biased at MCP front potential (ideal) or (if that distorts the beam) at ground potential while MCP front is at about +200 V (the latter may cause trajectory distortions of detected electrons). For operation the delay-line detector will (finally) be biased in "electron mode" (see Table 2.3). However, during the initial start-up procedure (see Chapter 2.5.1) it is recommended to use always the same potential for the inner tube and for MCP front, ***ideally drawn from the same high voltage supply channel***. This reduces the risk for operational mistakes. The inner tube can be biased through a vacant lead (i.e. "X") of the **FT12/16TP** feedthrough assembly.

If you need advice on appropriate distances/biasing schemes for certain applications, please contact **RoentDek**, also if you need help to simulate fringing field effects on particle trajectories.

For technical reasons, the gap of the delay-lines may have a slight offset with respect to the hole in the anode. You have received a specs sheet that defines possible shifts. Final position calibration is achieved by software.

2 Mounting of the Detector and cable connections via vacuum feedthrough

RoentDek provides the **FT12** and **FT16** products (with or without mounting option) to allow a proper cable feeding through the vacuum wall. The **FT16** is a combination of an **FT12** feedthrough and an **FT4** feedthrough (the latter also used for the **DET40/75** timing detectors). These products can be completed by airside decoupling circuits forming the **FT12TP** and **FT16TP** products (not for operation with older **DLATR6/8** units). The maximum voltage rating of the **FT12** and the standard **FT4** feedthroughs is 4 kV (5 kV or higher only if explicitly specified so), likewise, the flange mounting is also specified up to this rating. The detector can either be custom-mounted to an experimental setup or to a special mounting flange. **RoentDek** provides a product option for each detector type for mounting it onto a flange of "Conflat" norm. The minimum (and default) size of the flange is given by the detector dimension. However, mounting on larger flanges are possible and often beneficial, even mandatory for operation at very high voltages (**XHV** mounting). In case you have purchased a **readily mounted** or **XHV** detector assembly option the following chapters are only partially relevant. However, you may read through all sections and verify a proper state of the delivered assembly according to the specifications below because in spite of all care for safe packing some cable connections may have been affected during transport and may be in need for re-fixing.

If you do not want to or cannot mount the detector in such a way, it is strongly recommended to still use the **RoentDek** **FT12TP** or **FT16TP** cable feedthrough(s) and signal decoupling plugs. For a custom mount to an existing experimental setup we recommend using the outermost threaded holes (in the "Holder") to fix the detector to your experimental setup, e.g. employing the supplied threaded rods in the shipping mount. Please note that the holder plate/the threaded rods will usually be biased during operation at a different potential than the mating part of your experimental setup. A proper insulation is needed. One (or two for **FT16TP**) DN40CF port(s) must be in the vicinity of the detectors (distance <50 cm).

Notice: It is important to have at least 2 mm distance between any part of the detector and any other metal part of a setup, unless the voltage difference is small during operation.

As a thumb-rule, at least 1 mm distance for every 1 kV of voltage difference should be allowed, assuming also absence of sharp edges or tips.

If this is not fulfilled, discharge can occur during operation with the consequence of possible damage of the detector or the electronics.

One can use sheets of Kapton for security if distances appear too small for safe operation. Please contact **RoentDek** for options.

The vacuum port where the detector is mounted must have at least 100 mm open diameter for* DLD40*, 150 mm for* DLD80*, 200 mm for* HEX80/HEX75 *and* DLD120 *and 250 mm for* HEX100 and DLD150*. If the detector shall come to rest within the port/tubing of this minimum diameter it may be required to care for extra insulation.

2.1 Mounting of the Detector on a Vacuum-Flange

If you have purchased the flange mounting option (e.g. **FT12TP/100**, the red number denominating the ID of the mounting flange in mm) fix the stainless steel support ring via the outer threaded M2 rods to the delay-line anode. You may use one of these threaded bolts to supply the anode Holder voltage with an appropriate cable. Allow at least 30 mm distance between support ring and delay-line anode.

Then mount the support ring with 8 ceramic insulators and 8 nuts using the M3 threaded bolts onto the flange. The threaded bolts are grinded at one end. This end must be on the flange side to avoid air pockets in the tapped holes of the flange. The **HEX80** and **DLD150**, **HEX100** or any other detector's mounting on a DN250CF or DN300CF flange, special M6-to-M3 adapter rods are provided. For these large flanges, an alternative mounting option via long rods ("COLTRIMS mounting") is available. Please refer to the separate description if you have received this option. Rod elongations for the standard flange size are also available and separately described. For more information on flange mounting options please refer to the description sheet on the **RoentDek** website.

Please note that the ceramic insulators will not tolerate excessive force when fixing the nuts.

Adjust everything parallel to the flange and fix the nuts. The height above flange of the detector can be varied by choosing specific distances for fixing the nuts on the M2 and M3 rods. Make sure to allow sufficient distance for slipping the wire contact pins for the delay-line-terminals on and off. In case you need to further reduce distance to the flange it is possible to alternatively contact the cable pairs by 2 mm lugs and nuts on the wire terminal. Please see advice from **RoentDek** before choosing this option.

Additional cartoons and drawings about the mounting of the **DLD** and **HEX** detector to a mounting flange can be found on the *MOVIES* section on our website.

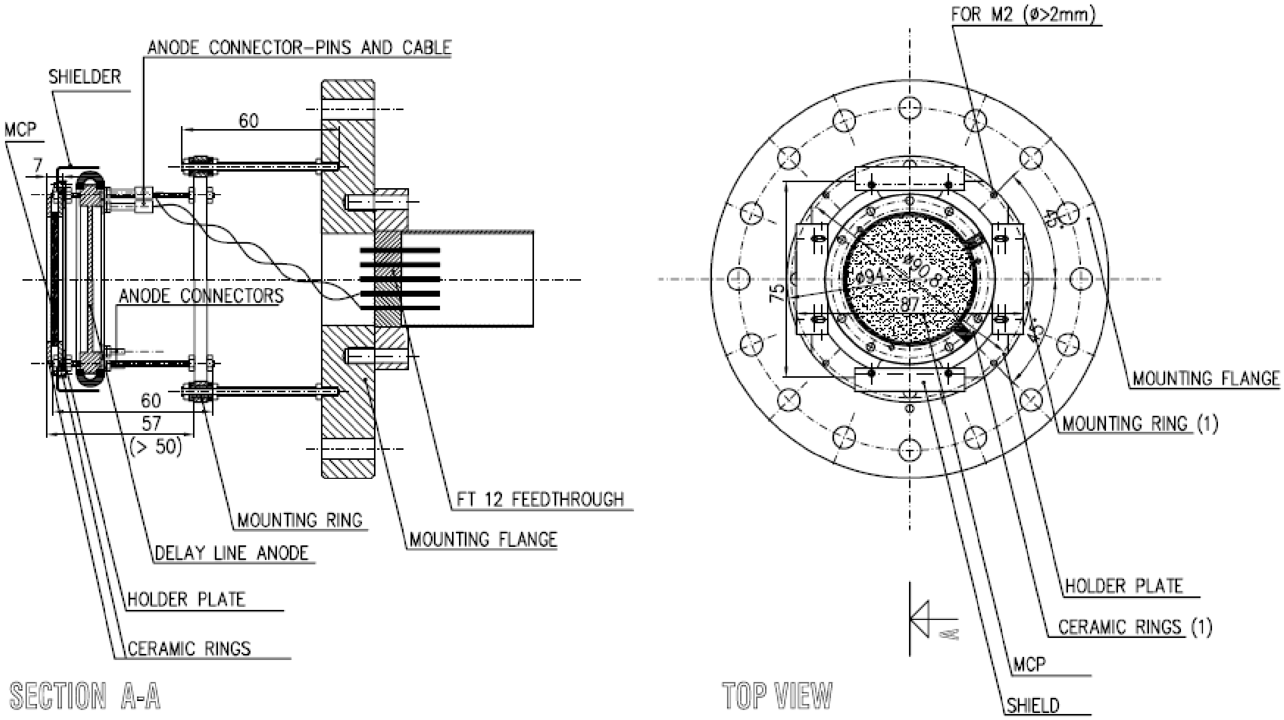


Figure 2.1: Sketch of the detector with mounting flange (only flange mounting option, here: FT12TP/100). For connecting a Hexanode, the same 12-pin feedthrough is used and an additional set of at least 3 MHV or SHV feedthroughs (e.g. the FT4) is needed for connecting the MCP front, MCP back, Holder (and optionally a mesh). Some of the mounting flanges have a groove for a Viton ring gasket.

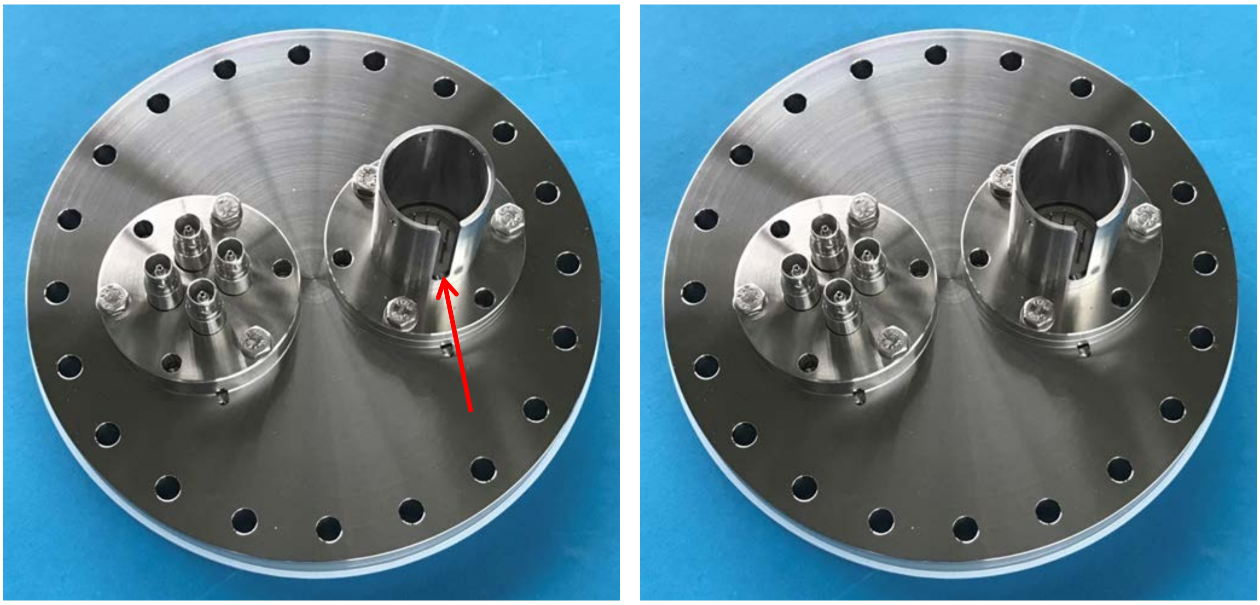
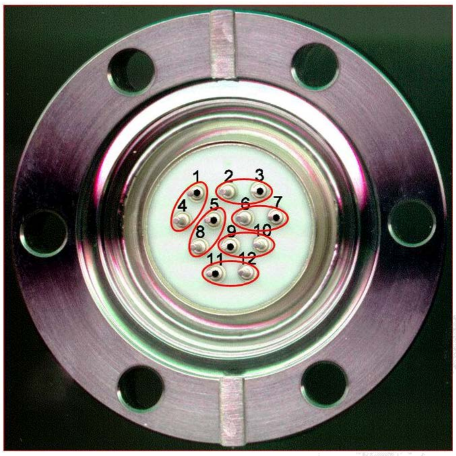


Figure 2.2: The groove in the 12-pin feedthrough (see arrow in left picture) must be set to a specific position of about 90º to the direction of a closely located FT4 feedthrough port to avoid spatial conflicts of signal decouplers.

2.2 Connecting the Signal Cables to a Feedthrough Flange

In the following the connection scheme to the **FT12** feedthrough flange is described. This flange is used for airside coupling to the **FT12TP(hex)** signal decoupling plugs. The following connection schemes are also compatible with earlier read-out concepts (**FT12/16** with **DLATR6/8**). For the **DLD** detectors the **FT12** offers also feedthrough leads for the remaining detector contacts (e.g. for the MCP and Holder), while **HEX** detectors require additional feedthroughs like in the **FT16** product assembly which contains 4 additional MHV (or SHV) feedthroughs on a separate flange. These can also be used for providing some or all contacts for MCP/Holder/Mesh for a **DLD**, e.g. as required for the optional **DLD** operation with increased MCP front rating up to -6 kV. For cable connections for even higher operation voltages with **XHV**-mounting assemblies please refer to Chapter 2.6. Unless you have purchased the flange mounting option you will usually receive a spool of Kapton isolated cables (for **DLD**) which can be used in UHV. You need to produce single and twisted-pair cables of sufficient lengths as described before in this section. The cables should only be as long as necessary. Especially the quality (amount of "ringing") of the MCP signal is usually better if the connection cable is very short. If you have purchased a Hexanode without flange mounting option, you have received a set of cables with two parallel wires (about 0.5 m long) for connecting the Hexanode delay-line. For the **DLD** connect all 8 cables from the delay-line and the other 3 (or 4) high voltage cables (MCP front, MCP back, anode holder plate and optional Mesh) from the vacuum side of the feedthrough flange. Figure 2.3 shows the **FT12** flange from the vacuum side.



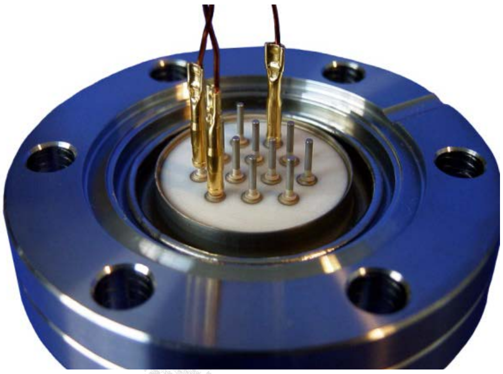


Figure 2.3: Pin numbers at the FT12 flange (the air-side guiding groove points upwards) and cable connections. The red ovals mark the pins for twisted cable pairs (1/4 and 3/2 only for Hexanode).

Unless you have purchased the flange mounted option with pre-manufactured cable connections (or even pre-connected with **SRM** option) you will usually receive a spool of Kapton-shielded cables which can be used in UHV. You may need to produce single and twisted-pair cables of sufficient lengths as described before. The cables should only be as long as necessary. Especially the MCP signal quality (amount of "ringing") is usually improved if the connection cables are kept as short as possible. For the **DLD** connect all 8 cables from the delay-line and the other 3 (or 4) in vacuum cables for MCP front, MCP back, anode holder plate and optional mesh from the vacuum side of the 12-pin feedthrough flange according to Table 2.1.

Pin number **FT12** flange	Function	**FT12TP** channel	**FAMP8** channel	**CFD8 (7x)** channel	**ATR19** channel	**HM1/TDC4HM or TDC8HP/HQ** channel
No. 1	X (e.g. Mesh)					
No. 2	MCP front	MCP	No. 7 or No. 8 (or **FAMP1+**)	No. 1 (or **CFD1**)	(No. 1 or 2)	"start" or 8
No. 3	MCP back					
No. 4	Anode Holder					
No. 5	x_1-reference	x1	any other (for other **FAMP** units refer to separate manual or instructions)	any other (for other **CFD** units refer to separate manual or instructions)	any other	x1 / 1
No. 6	x_2-signal	(No. 4)				
No. 7	x_2-reference	x2				x2 / 2
No. 8	x_1-signal	(No. 3)				
No. 9	y_1-reference	y1				y1/ 3
No. 10	y_1-signal	(No. 5)				
No. 11	y_2-reference	y2				y2 / 4
No. 12	y_2-signal	(No. 6)				

Table 2.1: FT12TP pin description for DLD detectors. For > 4 kV operation, MCP front is not connected here.

In case of a Hexanode detector, the 12-pin feedthrough is only used for the anode terminals (according to Table 2.2). Other detector contacts are connected via separate feedthroughs, e.g. the **FT4** (part of the **FT16**) or via individual coaxial SHV or MHV feedthroughs. Please give special attention to the assignment of neighboring pins 5 and 6 which are NOT attributed to cable pairs from the same anode terminal, likewise for pins 1 and 2 in case of the Hexanode.

Pin number **FT12** flange	Function	**FT12TP**hex channel	**FAMP8** channel	**CFD8c (7x)**	**ATR19** channel	**TDC8HP** channel
No. 1	z_1-reference	z1	any from no. 1 to 6 (for other **FAMP** units refer to separate manual or instructions)	any from no. 2 and higher (for other **CFD** units refer to separate manual or instructions)	any other (for **ATR19-8** only from no. 3 and higher)	5
No. 2	z_2-signal	(No. 2)				
No. 3	z_2-reference	z2				6
No. 4	z_1-signal	(No. 1)				
No. 5	x_1-reference	x1				1
No. 6	x_2-signal	(No. 4)				
No. 7	x_2-reference	x2				2
No. 8	x_1-signal	(No. 3)				
No. 9	y_1-reference	y1				3
No. 10	y_1-signal	(No. 5)				
No. 11	y_2-reference	y2				4
No. 12	y_2-signal	(No. 6)				

Table 2.2: FT12(TP) pin description for HEX detectors

Verify proper anode cabling with an Ω meter. Check for

- proper resistance between the ends of all wires (e.g. between pin 5 and pin 7)
- absence of "shorts" between any single wire to others and to other detector parts or ground
- absence of shorts between any of the other detector parts and ground

A "short" in this respect is any resistance < 10 MΩ (except for the resistance between MCP back and front, which may be smaller, see next section).

If you perform these checks from the air side of the feedthrough make sure to identify the pin numbers correctly (mirror-inverted compared to Figure 2.3). **RoentDek** can supply a test plug to ease this verification task. Some of the tests can be done more efficiently via the **RoentDek** signal decoupler plug (see next section). A cabling error which cannot be detected by verifying the cables with an Ωmeter from the feedthrough air-side alone (e.g. when the parts in vacuum are not accessible any more) is for example a swap between pin 6 and 8. If a connector pin is too close to the chamber wall or a neighboring pin, this may result in a discharge during detector operation, with consequences to the electronics and detector (see above). In case of **DLD** please give extra attention to pins 1 and 2, which can have especially high potential relative to the others.

The in-vacuum connection cables for **DLD** and **HEX** detector can be marked by colored glass beads. For the anode contacts only one cable of a pair carries a glass bead. When connecting opposing terminals of a delay-line which belong to the same layer (e.g. y1 and y2), make sure that cables with glass bead are connected to both ends of the same physical wire (see also Figure 1.7).

When the far ends of these cable pairs are connected to the 12pin feedthrough the cable with glass beads must be connected to the corresponding pins (i.e. with number code 9 to 12 for the y-layer) in such a way that cables carrying glass beads go to the even numbers (i.e. 10 for y1 and 12 for y2) of the feedthrough. These cables will then receive the "signal" potential when the **FT12TP** plug is biased, the unmarked cables are the "reference" wires.

The color code of the delay-line cables corresponds to the standard color code of lemo cables for connecting the electronics modules (if these cables were delivered), the MCP signal is connected via a brown-collared lemo cable.

Figure 2.4: In-vacuum cable color code

Once all cables are properly connected and verified the chamber can be evacuated. Before, additional checks may be performed by connecting the **FT12TP** plug (see next chapter, Figure 2.7). Always evacuate the vacuum chamber slowly (≤50 mbar/s) and vent the chamber as carefully. This is to prevent turbulence near the detector as this can cause spurious dust particles settling on MCPs or the anode, with very adverse effects. The maximum recommended operating pressure for the detector is $2*10^{-6}$ mbar). Remember that the gauge pressure may not always reflect the vacuum conditions at the position of the detector.

2.3 The FT12TP (hex) – Signal Decoupler

The **FT12TP** feedthrough and signal decoupling option allows using any adequate amplifier and timing discriminator or recording electronics to operate a **RoentDek DLD** (or **HEX**, see also **FT16TP** in the next section). Examples for adequate amplifier/CFD are the **RoentDek ATR19** units or the **FAMP1/3/6/8** (amplifier only, with output to CFD or fast-ADC follow-up electronics).

The **FT12TP** for **DLD** contains the standard 12 pin feedthrough **FT12** for the in-vacuum cables as described above and an air-side connector plug. The plug provides adequate RC decoupling circuits and special transformer circuits to turn the differential delay-line signals into single-line signals with 50 Ω line impedance output connectors. The detector voltages are supplied via SHV input cables sockets:

$U_{Reference}$	Reference wires' bias
U_{Signal}	Signal wires' bias
U_{Holder}	Anode-plate (Holder) bias, not in hex-version
$U_{MCP\ front}$	MCP front bias, not in hex-version
$U_{MCP\ back}$	MCP back bias, not in hex-version
U_X	optional "X" potential, can be used for a mesh or intermediate MCP bias, not in hex-version

"Raw" (unamplified) signals from the MCP and delay-line contacts are delivered to LEMO 00 series type connectors.

The **FT12TP** plug may contain additional circuits such as an integrated **HVZ** voltage divider unit (see Chapter 5.5 and 5.6 of the **RoentDek** Power Supply Manual). Both front- and back-side MCP signals are delivered via LEMO sockets. To optimize the signal shape, it is recommended to "close" one of the MCP outputs with a 50 **Ω** terminator and to adjust the in-line potentiometer (0-200 Ω). Such in-line "potis" are also available for the "Holder" and "X"-lines.

Figure 2.5: FT12TP plug for DLD with rectangular case and 50 Ω terminator, here placed on MCP front output (MCP back output can thus be used for MCP signal pickup)

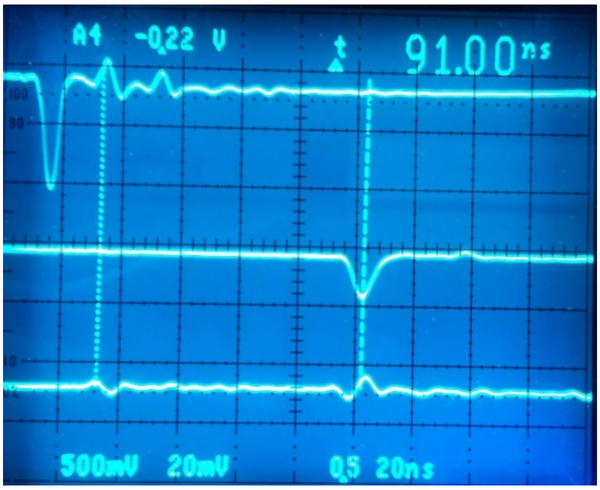
The so-called **FT12TPhex** plug for the **Hexanode** is very similar to the **FT12TP** for **DLD** but has 6 LEMO outputs for the delay-line anode signals and two SHV bias inputs for U_{ref} and U_{sig}. It serves as connector/decoupling unit only for the Hexanode while the bias and signal pickup to the remaining parts of the detector is routed via different feedthroughs and decoupling/terminating circuits. The **FT12TP(hex)** plug is supplied since 2013 with the rectangular-shaped case which contains a flexible circuits architecture, i.e. one can use an alternate biasing scheme for special detector setups and it allows a differential signal transmission to special amplifiers (e.g. the **RoentDek DFAMP6**) via CAT6 cables, see Figure 2.6.

When the **FT12TP(hex)** plug is connected to the delay-line it is possible verifying the absence of shorts between signal and reference wires or some of the possible cabling errors on the vacuum side of the feedthrough: The resistance between U_{ref} and U_{sig} SHV inputs should exceed 10MΩ. A resistance value between 100 kΩ and 2 MΩ indicates a cabling error or a short on the delay line. Please note that some other possible misconnections on the feedthrough may not be found by this test.

Figure 2.6: FT12TPhex plug with rectangular case, here with differential signal output via CAT6 cables

Likewise, the presence of shorts between other parts of the detector or from parts to ground will be revealed by a <10 MΩ "short" if measured through the SHV inputs of the decoupler circuits (assuming that all connections are in place). Exception: between properly connected MCP front and MCP back input one can measure a resistance on the order of the expected MCP stack resistance which may be <10 MΩ in some cases, especially when the detector is still exposed to ambient air. In case of the **FT12TPhex** please also refer to the next section for this test.

With the help of a fast signal pulse generator (e.g. the **RoentDek APG1**) one can send a signal via an (output) LEMO connector (e.g. x1) of the **FT12TP(hex)** through a delay-line layer and verify the (delayed and slightly damped/distorted) response signal from the (x2) output with an oscilloscope (see Figure 2.7, the same check can be done for the other layers). Most wiring errors will be revealed by a strongly distorted signal response (Figure 2.7, right picture).



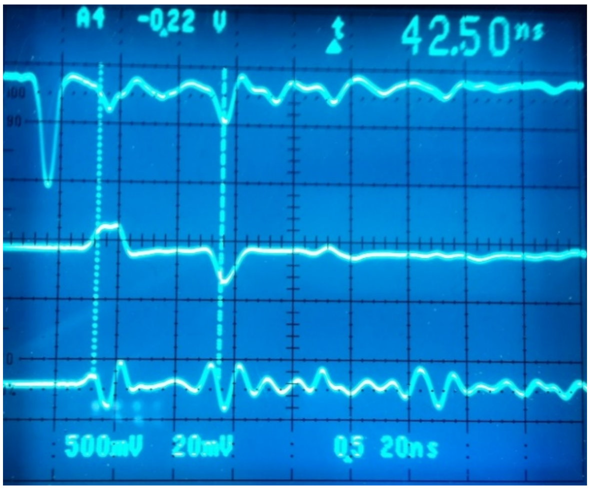


Figure 2.7: Response of a delay-line to a signal passing through a FT12TP(hex) plug. Upper trace: input signal (here: to x1 LEMO socket), middle trace: output signal from the opposing terminal of the same layer (here: from x2), lower trace: output from a terminal of another layer (25x enlarged), here y1. The left marker defines the input signal's time reference. The left picture shows the signals on a correctly connected DLD80, e.g. on middle trace a signal damped and delayed according to the delay-line transmission time (path delay about 90 ns plus offset from connection cables). The cross talk to the other layer (lower trace) is small. The right image shows the same outputs for a DLD40 (path delay about 40 ns) where the connections to pin 6 and 8 have been erroneously swapped so that signals from opposing terminals become mixed.

Blocking resistors:

An integral part of most signal decoupling circuits is a serial resistor in the connection line between the MCP stack and the bias input, e.g. from the high voltage supply. The resistor forms a chain with the MCP stack resistance (and more resistors in the line, e.g. a serial resistor on the other MCP stack side) and alters the effective potential present on the MCP surface: it is shifted by a value ΔU towards the potential on the other MCP side, compared to the set potential coming from the high voltage supply. These serial resistors are usually small compared to the MCP resistance but the effect cannot always be neglected.

$$dU_{MCP\ front} = \Delta U_{MCP} \times \frac{R_{Df}}{R_{MCP} + (R_{Db} + R_{Df})} \qquad dU_{MCP\ back} = \Delta U_{MCP} \times \frac{R_{Db}}{R_{MCP} + (R_{Db} + R_{Df})}$$ **Equation 2.1**

dU_{MCP} front/back are the potential shifts between set and effective potential on the MCP stack ends, R_{MCP} is the MCP stack resistance and R_{Df}/R_{Db} the serial resistors' values in the respective decoupling circuits and ΔU_{MCP} is the set voltage difference across the MCP ($\Delta U_{MCP} = U_{MCP\ back} - U_{MCP\ front}$). Usually, the term ($R_{Df} + R_{Db}$) can be neglected in the denominator of the equations.

Example: R_{MCP} = 60 MΩ, R_{Df} = 10 kΩ, R_{Db} = 1 MΩ, $U_{MCP\ front}$ = -600 V, $U_{MCP\ back}$ = +1800 V
→ $U_{MCP\ front\ effective}$= -599.6 V, $U_{MCP\ back\ effective}$ = +1760 V, $\Delta U_{MCP\ effective}$ = 2360 V

In the round **FT12TP** decoupler R_{Df} and R_{Db} are 10 kΩ and 1 MΩ, respectively (older **FT12TP** plugs may have 1 MΩ as default value everywhere). 1 MΩ blocking resistors are also placed in series for biasing the "X" and "Holder" connections the rectangular-shaped **FT12TP** usually have 10 kΩ on "X", special biasing schemes may apply (see Chapter 5 or the Power Supply Manual). It is possible to verify the actual resistance values with an Ω meter between the high voltage input socket and the pin that connects to the respective feedthrough. The sum ($R_{MCP} + R_{Df} + R_{Db}$) can also be measured through the decoupler's high voltage inputs for U_{back} and U_{front} if all connections to the MCP are made. Note that the measured value R_{MCP} can differ compared to operation conditions if the stack is at atmospheric pressure. R_{MCP} is also temperature dependent.

Attention: Although the outputs of the **FT4TP** *and* **FT12TP** *are delivered with DC-coupling to ground potential, a discharge on a detector can damage the electronics which is used to analyze or amplify the signals.*

Before vacuum-baking of the experimental setup all air-side connections on the **FT12** *and* **FT4** *feedthroughs must be removed. The* **FT12TP** *plugs and* **HFSD/T** *connectors are not rated for typical bake-out temperatures.*

2.4 The FT4(TP) for FT16(TP) and DET40/75

For the **RoentDek HEX** detector and the timing detectors of type **DET** the **FT4**, a four-fold MHV feedthrough set (optionally SHV) on **DN40CF** flange is used to supply cable contacts to MCP front, MCP back, Holder (or the timing anode, respectively) and an optional mesh. It is important that the feedthrough is placed as close as possible to the detector. The cables between detector and feedthrough should be shorter than 50 cm, 20 cm in case of **DET** (the shorter the better for the MCP signal quality). If this cannot be fulfilled please contact **RoentDek** for advice). For signal pickup or termination, individual ***HF-signal-decoupler plugs*** (**HFSD/HFST**, see Figure 2.8) for each detector contact can be provided to complete the product set **FT4TP**. This combines with **FT12TPhex** to the **FT16TP**. The *HF-signal-de-coupler plug* for the Hexanode "Holder" is of type **HFST** and has a signal terminating potentiometer ("poti"). The same type is used on one of the MCP contacts, while the other MCP contact (and the timing anode contact, respectively) is supplied via a **HFSD** signal decoupler with a LEMO output socket for the signal to further process it to an amplifier and timing circuit. An *Adjustable LEMO Terminator* (**AST)** can be optionally supplied to turn a **HFSD** into a double-use unit (as **HFSD** or **HFST**). The latest version of the **HFSD** has a poti in the signal line (see red arrow in Figure 2.8) which can also be used to improve the signal quality in combination with the other potis (like with the **FT12TP** connector plug and **DLD**). Optionally, the **HFSD** and **HFST** can be supplied with (or switched to) a 10 kΩ serial resistor in the line to the high voltage power supply (default is 1 MΩ)*. Before opening a **HFSD** or **HFST** make sure that no high voltage is applied. If a detector bias shall not be supplied via a **HFSD** or **HFST**, it is necessary to place an in-vacuum resistor very near the respective detector contact (see Figure 2.10). In some cases, this is even recommended, e.g. when the bias exceeds the **HFSD/HFST** max. voltage rating of 4 kV (5 kV for **DET** assemblies).

The **HFSD** and **HFST** are built <u>for direct connection onto the 4 fold MHV or SHV feedthrough</u>. Spatial restrictions require mounting the **HFSD/HFST** in a specific 90° pattern (see Figure 2.2). Optimal signal quality is only achieved if no cable is placed between a **HFSD/HFST** and the feedthrough.

* If setting/knowing the exact MCP front bias should be a critical parameter it is recommended to switch the serial resistor to 10 kΩ in the signal decoupler (or terminator) connected to MCP front.

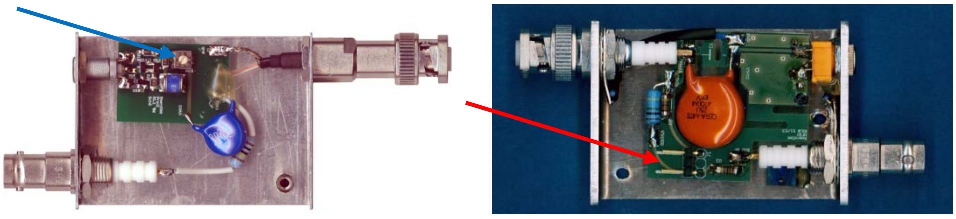


Figure 2.8: Left: Single HF-signal-decoupler plug (HFSD) with LEMO output and in-line poti (blue arrow). Newer versions may have the in-line poti located at the housing and/or allow to switch the serial (blocking) resistor value between 1 MΩ (internal jumper <u>not</u> set, default) and 10 kΩ (internal jumper set) as shown in the right picture of an HFST (jumper position marked by red arrow)

The ***HF-signal-decoupler plugs*** can also contain an additional resistor to ground which provides the **HVT** function (see **RoentDek** power supply manual which may be appended to this document). Furthermore, they may be used in series with separate blocking resistor plugs or boxes to allow for specific biasing schemes (see Chapter 5 or the Power Supply Manual).

Attention: when verifying connections via the **FT4** feedthrough by an Ω meter never poke the probe into the air-side MHV socket pin because it may be bent and cause connections failures when connecting an MHV cable or signal decoupler. Perform such test with the **HFSD** or **HFST** connected to the feedthrough (presence of in-line resistors must be considered).

2.5 Operation of the MCP detector with delay-line (or timing) anode

This introduction to the MCP detector operation shall only give general info on the detector startup and basic function verification. For fine-tuning please refer to the specific sections describing the front end electronics (amplifier and timing circuits), digital read-out and high voltage supply with accessory passive voltage dividing units, e.g. as optionally available from **RoentDek**. If you have purchased a detector for operation at very high voltages (with **XHV** pre-mounting and special high voltage feedthroughs and signal decoupling, see Chapter 2.6) please refer first to additional preparation steps as described in there.

After you have installed fresh MCP you must follow an initial startup procedure. The voltage across the MCP must be raised very slowly to the operation voltage which can take over an hour. This procedure is also recommended when the MCP of a detector have been exposed to ambient air for a long time (several days).

2.5.1 Initial Startup Procedure

After installation of the detector and verification of all connections it is advisable to verify the absence of electronic noise on the detector parts, i.e. on the MCP front/back and anode contacts. Continuous noise should be <1 mV peak-to-peak. Noise should be checked by connecting an amplifier (band width about 100 MHz or higher) to the outputs of the signal decouplers (high voltage supplies turned off) and verifying the amplified output on an oscilloscope (taking into account the amplification factor to judge the noise amplitude). If you should find a too-high noise level (or no noise at all) this may indicate erroneous cable connections. External sources for noise may be found in the lab equipment and can be traced by turning off lab equipment sequentially, or outside the lab/building (power stations, heavy machinery operating, radio stations …). This test can already be done before starting the vacuum pump. Those, however, may also contribute to the noise level when in operation.

When evacuating the vacuum vessel with the detector inside or connected to make sure that the pressure is reduced slowly, <u>never exceeding 10 mbar/s of pressure change</u>. This is also necessary during venting: use a slow valve.

For supplying the MCP operation voltages it is strongly recommended to use low-ripple power supplies with current limitation and “fast” shutdown for protection (as available from **RoentDek**). The maximum ramp speed should be limited to about 500 V/s. High voltage supplies that can (at least partially) only be regulated step-wise (e.g. via a 500 V or higher step selector switch) and do not having a “slow” ramp are not adequate.

If you are using a **XHV** biasing scheme with a **RoentDek HVZ10** (see Chapter 5.7 of this manual or refer to the **RoentDek** Power Supply Manual) please install now the adequate PCB.

Before applying any voltage to the detector, it should be verified that:

- the detector is in appropriate vacuum conditions (< 10^{-6} Torr) for at least 24 h, see also the Appendix to this manual
- all connections inside the vacuum are complete and have been carefully verified, also for absence of shorts
- safe distances are kept or adequate insulation is installed between all biased parts of the detector (including attached cables) and the chamber wall and or other metal parts on ground or other potentials (i.e. mounting gear)
- safe distances are kept between the MCP front (and optional mesh) contacts and exposed cable parts to any other part of the detector (double-check also exposed cable/connector parts on the vacuum feedthrough)
- all feedthroughs, decoupling circuits and high voltage cables are rated for the targeted maximum detector voltage,
- potential EM noise sources are turned off
- UV sources, high power laser sources, charged particle sources (also ion gauges or ion pumps, discharge gaps) in the detector's vacuum recipient are turned off.

If you have received a non-matched MCP set (i.e. MCPs with different strip current) or plan to use non-matched MCPs it is **mandatory to place an intermediate contact ring (shim ring) with connection to a vacant feedthrough between the MCP, and:**

a. If you use a separate high voltage supply for the intermediate MCP bias make sure that the power supply can operate adequately under this condition (refer to Chapter 5 of this manual or to the **RoentDek** Power Supply Manual).

b. Alternatively, you can "force-match" the MCP stack by placing a parallel resistor to the MCPs with higher resistance. Please refer to Chapter 5 of this manual or to the **RoentDek** Power Supply Manual. For choosing a proper matching resistor R_M it is necessary to determine resistances between MCP front contact and the intermediate contact rings and between MCP back contact and the intermediate contact ring. Resistance values taken from MCPs specs sheet may turn out not to be precise enough. Resistance values measured under ambient air conditions are not reliable. Therefore, it is mandatory to determine resistances accurately once the MCP stack is under vacuum. Adequate ways of determining resistances are either the use of a precise Ohmmeter between the respective contact pins on the feedthroughs' air sides or to measure current as function of applied voltage with a power supply such as the **RoentDek HV2/4**. The latter will usually require to mount **FT4/12/16TP** decoupling connectors first. Please refer to the Appendix: *MEASURING MCPs RESISTANCE IN VACUUM WITH HIGH VOLTAGE SUPPLIES HAVING CURRENT READINGS THROUGH FT4/12/16TP DECOUPLING CONNECTORS.*

   If you have doubts whether you can bias an unmatched MCP safely please contact RoentDek before continuing. Erroneous biasing may damage the MCP or connected electronic circuits.

New MCPs or MCPs that have been exposed to atmospheric pressure for a long time must be biased very slowly in steps of 100 V every few minutes. During this, the current should be monitored for possible deviations from linear current-to-voltage characteristics (indicating a problem). As the operation voltage is approached, the amount of "dark counts" (MCP signals in absence of any particle/photon source) should be monitored. This requires a low noise level (see above). To monitor the noise and the presence of signals, an amplifier should be used for verifying signals from the MCP front or MCP back contact with an oscilloscope. A low dark count rate (typically <100 counts/s, randomly distributed) will at some point already indicate that the MCP is operating normally, especially when the mean pulse height increases/decreases according to the MCP bias setting.

A spontaneous discharge or a significantly higher dark count rate indicates a problem such as a glow discharge or the presence of charged particles/photons triggering the MCP. If this rate is excessive, the MCPs can be damaged. In such an event turn off the high voltage and verify your setup again. Note that it may occur that an excessive load of particles on the MCP detector is not detected by verifying the MCP signal because the MCP stack reaches current saturation before producing individual pulses of detectable signal height (i.e. above noise level). Such MCP saturation can usually be recognized from non-linear bias/current characteristics. Therefore, we recommend using high voltage supplies with current reading, as available from **RoentDek**. Note, that some high voltage supplies may also increase the noise level, especially at high bias.

For **DLD/HEX** detectors it is recommended to initially operate the detector in the so-called "ion mode" as used for detecting slow (and light) positive ions or fast (neutral) particles and photons, e.g. with MCP front potential at negative potential, MCP back near zero voltage to ground with the anode bias on few hundred Volts positive potentials (This safety precaution is not necessary for **DET** detectors). In this biasing scheme, discharge events on the "rear part" of the detector are virtually excluded. Only the MCP front side is at high negative potential and the risk for discharge (malfunction) from preparation mistakes is lowest. Remaining hazards are too-close metal parts in front of the MCP front face or at the cable contacts: nearby cable contacts should either be at least 3 mm away or biased with the same potential for avoiding "sparks" (spontaneous discharges) and glow discharges which can occur from pointy parts already at relative potential well below the critical limit for spontaneous discharge.

Typical potential settings (for Chevron sets of 60:1 MCP, other MCP stacks may require higher or lower voltage) are

	Ion or Photon Detection	Electron Detection
MCP front	–2400 V	+300 V
MCP back	0 V	+2700 V
Delay-line anode Holder	0 V to 250 V*	+2700 V to +2950 V
Reference wires (*respectively timing anode*)	+250 V	+2950 V
Collecting (Signal) wires	+300 V	+3000 V

Table 2.3: Typical detector voltage settings. For photon detection it may be beneficial in terms of background particle suppression to operate detector front bias at about -800 V (with all other potentials then shifted by +1600 V)

It is to note that some high voltage power supplies (including those supplied by **RoentDek**) require a pull-up preventing circuit (e.g. the **RoentDek HVT**) in the connection line to MCP front for electron detection (i.e. when MCP front is at positive potential). However, such a voltage-limiting circuit must be removed/disconnected in ion detection mode.

For same reason the high voltage supplies for MCP back and holder/anode elements must be switched to opposite (positive) polarity before gradually increasing MCP front bias (negative) for “ion mode”, in steps of 100 V every few minutes. If you use a high voltage supply from **RoentDek** turn on the “kill” option so that the voltage is turned off in case of unexpected current peaking (i.e. a discharge, see also the respective manual). It is also recommended to reduce the maximum current limit towards a low setting, just above the expected default current, usually <0.3 mA (other high voltage supplies may have similar safety features which should be engaged). It is recommended disconnecting the signal cables leading to amplifiers or other sensitive equipment (like the oscilloscope) until you have reached about 70 %- 80 % of the recommended default MCP bias for normal operation. Otherwise there is a risk of damaging follow-up electronics in case of an unexpected discharge event.

While increasing MCP front bias in ion mode with negative polarity the MCP current should be recorded. As MCP front voltage is increased MCP stack resistance can be calculated from the current reading for each voltage step. If you use a **RoentDek HVZ** module at this point there will apparently be a strong non-linear response below 300 V MCP front bias: current will stay zero until the nominal voltages of internal Z-diodes are reached (please refer to the respective manual or Chapter 5). **Beyond, MCP stack resistance should stay constant as the voltage is increased ($\Delta I \sim \Delta U$)**.

Typical MCP stack resistance values are between 10 MΩ and several 100 MΩ. You may have received info on the default MCP resistance to compare it with your reading, however deviations within a factor 2 from the nominal numbers are not uncommon. Deviation from strict MCP resistance constancy can arise from temperature effects: For a 1 K increase in temperature the resistance drops by about 1 %. Note, that the MCP stack can be heated up from the strip current, i.e. the resistance at high current (voltage) may be lower than at low current (voltage). In-line decoupling resistors or an (undetected) minor “voltage pull-up” of the high voltage supply for MCP back may also lead to small deviations between measured and real MCP resistance.

Once you have reached about 80 % of the default MCP stack bias you can start observing dark counts (and potentially counts from particles) with low pulse height (10 mV, positive polarity, few ns width). From now on the signal from MCP back should be verified on an oscilloscope. **Unless your decoupling circuit's signal output is internally DC-terminated** (the **RoentDek** decouplers are) you must turn down the voltage before connecting a cable for signal verification. **Otherwise a discharge may occur and potentially damage the detector and/or the follow-up electronics**.
(If you had to turn down the voltage you can steadily increase the voltage again with a ramp speed of up to 1 kV per second to the value which was reached before).

One should never connect an oscilloscope directly to the signal output of a decoupler because a discharge may damage it. Instead, one should route the signal through an amplifier. The amplifier input may also be destroyed by a discharge but it is usually easier to repair. **RoentDek** decoupling circuits and amplifier inputs contain several safety circuits (and are more robust than most other circuits). However, those may be damaged in some cases, too.

* Ideal Holder potential setting (minimizing radial image distortion) depends on the detector geometry and is usually close to the MCP back potential.

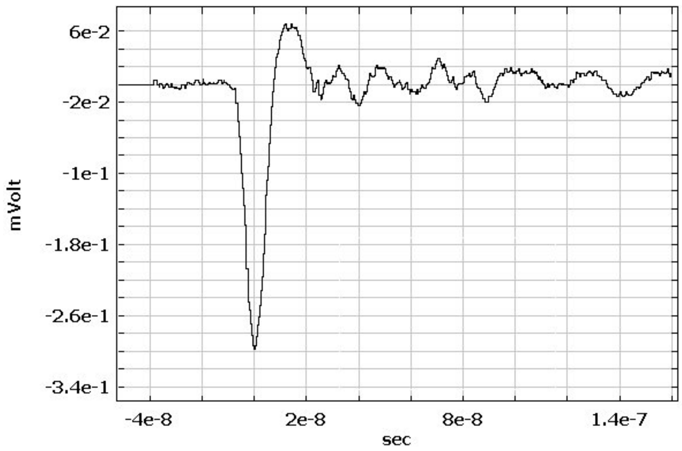


Figure 2.9: Typical amplified pulse shape from the MCP after processing with an inverting amplifier (here: analog monitor output from a RoentDek ATR19 module).

If you will observe dark counts at a decent rate you may further increase the voltage in steps and watch their growing pulse height with each step until you reach the default voltage. Generally, MCP stacks can be operated with a relative bias voltage up to about 1300 V for each MCP in the stack for MCP with L/D 60:1 or 80:1 (only 1 kV per MCP with L/D of 40:1, for 80:1 even higher bias up to 1500 V per MCP may be required). Applying lower bias on the MCP often yields sufficient performance and can increase the lifetime of the MCP stack. Higher voltages are not recommended and will only improve the performance if the amplifiers still have sufficient dynamics.

At this point one should also connect the delay-line anode (or timing anode) signal output(s) to amplifiers (see safety consideration above before that) and verify all signals on the oscilloscope. Signals from the delay-line or timing anode look similar like MCP signals but have negative polarity. If anode signals should be “missing” or noisy please verify their connections. You may be required to vent the vacuum chamber and open it for that. However, most wiring errors can be found by verifying connections with an Ω meter or passing a test pulse from an external source (e.g. the **RoentDek APG1**) through the delay-line layers.

Always make sure to turn high voltage off before venting the chamber.

Even if you have vented the chamber only for a short time you should allow at least 8 hours of pumping at sufficient pressure level. You may raise the voltage on the MCP up to the level that was reached once before in much shorter time (100 V/s), however, be aware of the risk for discharge events after the detector or the cables have been touched or moved. Verify all signals until the detector operates normally.

2.5.2 General Operation

Depending on the particle species to be detected you will have to shift all detector voltages with respect to ground, maintaining the relative detector potentials at about the same levels.

The optimal potential of the MCP front side with respect to ground depends on the particles to be detected. Ions should be pre-accelerated onto the detector with a potential of -2 kV or higher. For most ion species it is suitable to operate the MCP back side on or near ground potential, thus the front side is in the range of –2 kV to –3 kV (ion mode). Electrons should be accelerated to at least 300 eV to ensure high detection efficiency. Thus, the MCP front should be around +300 V or higher with respect to the electron source for low energetic electrons (electron mode). For UV photon detection or fast particles with >10 keV/u the MCP front side potential is arbitrary.

If you want to operate the detector at different bias than the now verified “ion mode” you may simply change your voltage settings accordingly. It is important to never exceed relative voltages of 100 V between the reference and signal wire and of 500 V between Holder and signal wires or Holder (respectively the timing anode) and MCP back. Otherwise discharges can occur and damage the detector and electronics.

Before applying different voltage settings for the first time or after manipulating on the detector hardware / in-vacuum cables in some way you have to make sure that these voltages (e.g. high potential with respect to ground on MCP back and the anode contacts) can be safely set without discharge occurring. You should slowly increase the voltage towards the target values and observe MCP back/front signal and the MCP resistance carefully during this procedure, as in described for the initial startup procedure. It is advisable that all voltages for the anode and MCP back are drawn from only one (or as few as possible) high voltage supply channels by using a voltage dividing scheme (e.g. with the **RoentDek HVZ** and/or **BA3**).

Again, you must verify that set voltages on high voltage supplies for MCP back and MCP front are maintained which is sometimes not the case, especially when biased with the same polarity, see above. A **HVT** circuit may have to be introduced.

For achieving optimal results, it is now necessary optimizing MCP gain and amplifier gain for the follow-up timing electronics. You should refer to the specific manuals. Generally, it is advisable to operate at a high MCP gain because only this ensures optimal signal-to-noise ratio. Although it is also possible to increase the signal height by increasing the amplifier gain, it will also increase the noise level. Therefore, it is better to operate at a moderately high MCP gain, i.e. where the MCP stack can still produce a decent pulse height distribution and no excessive after-pulses (ion-feedback). However, there are reasons to operate at lower MCP gain (and compromise on position and time resolution) if the highest MCP signals in the distribution saturate the amplifier (at its lowest gain setting), if ion feedback must be reduced (e.g. for multi-hit applications) or if MCPs life-time is an issue (i.e. for very high particle flux).

If you have removed the MCP stack, replaced the MCP stack for a new one or have left the detector exposed to ambient air for a few days' period it is necessary to follow the routines of the startup procedure again. **It is especially important to raise the voltage on the MCP stepwise (as described) and only after the MCP stack was in high vacuum for 24 h at least**. Please also refer to the Appendix: MCP's

2.6 The XHV mounting and other biasing options

The operational limits for the "floating" potential of a **RoentDek** detector with respect to ground is determined by the signal feedthrough and decoupling capacitor ratings and by the high voltage tolerance of the employed mounting gear. The standard elements provided only allow operation with MCP front bias in the range from about +1 kV to -4 kV, expandable to -6 kV if a SHV feedthrough is used that supplies MCP front bias via an in-vacuum blocking resistor (see Figure 2.12). The MCP timing signal can then only be picked up from the MCP back contact. In case of a detector with **Hexanode** the standard **FT4** feedthrough with MHV sockets must be replaced by the SHV-version, and the **HFSD** and **HFST** must be replaced by the corresponding **…shv** types for increasing the MCP front bias rating to -6 kV. For **DLD** and extra SHV feedthrough is required.

By modifying the mounting scheme (fortifying the insulation capacity by ceramic standoffs) and employing different feedthroughs and signal decoupling components, any **RoentDek** detector can be operated at a higher floating potential. Circuits/mounting schemes for this so-called **XHV** operation have been specified to date for operation of MCP front bias between +5 kV and -10 kV. **RoentDek** can supply all components for a complete **XHV** detection system or parts of that.

If you have ordered a complete flange-mounted system, there may be a specific add-on manual provided. If a partial system was delivered, you are obliged to ensure a high voltage safe detector mounting scheme. You may contact. **RoentDek** for advice.

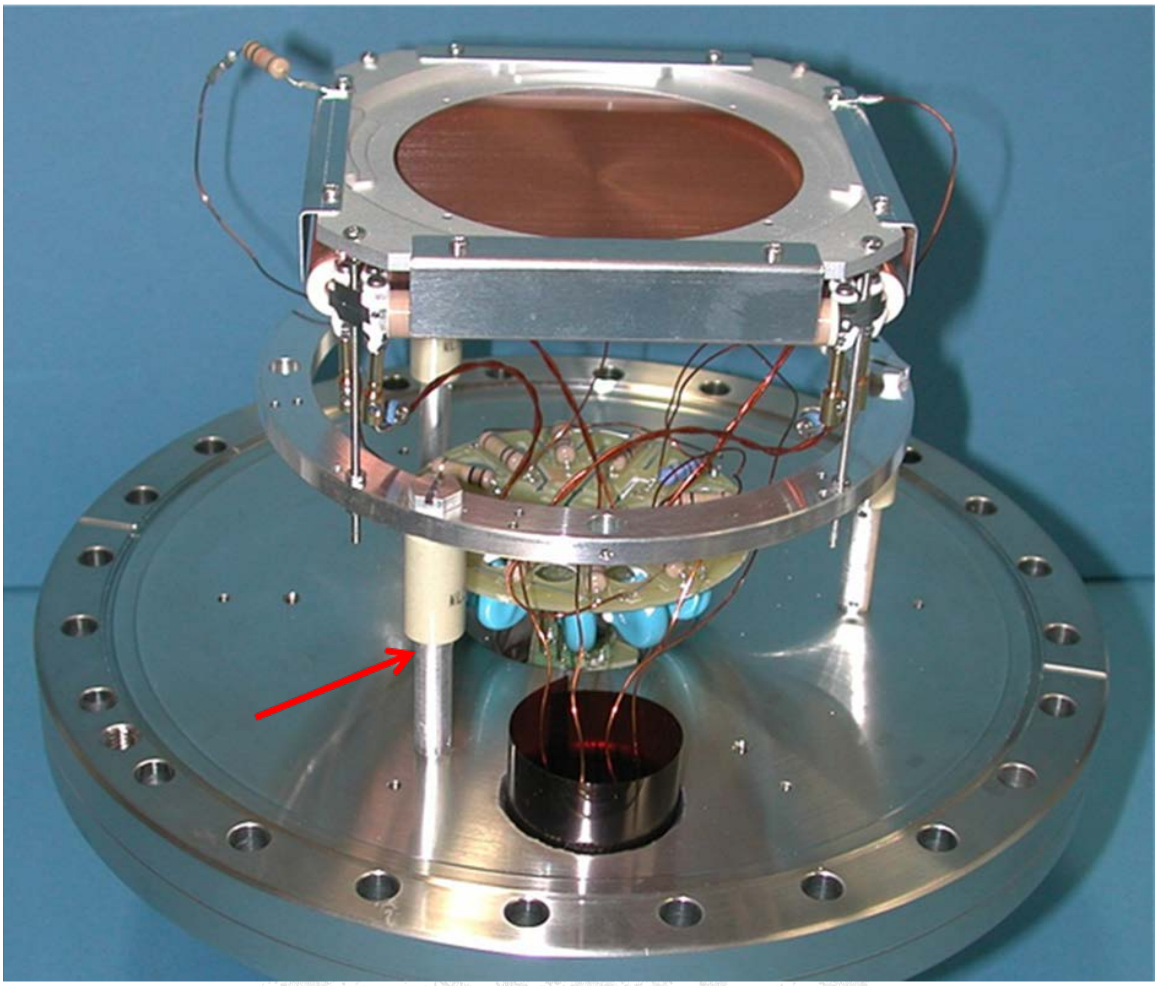


Figure 2.10: Typical mounting and cable scheme for a DLD80 detector (MCP stack removed here) on DN200CF flange specified for XHV operation (MCP front between -10kV and +5kV). Special ceramic standoffs (see red arrow), sufficient clearing/Kapton insulation to the walls and in-vacuum capacitors with increased high voltage rating for signal decoupling already in vacuum (see below) allow a safe operation at high detector potential. The "Holder" is connected via in-vacuum resistor (see in left upper corner of the image), therefore, no HFST is needed for signal termination here.

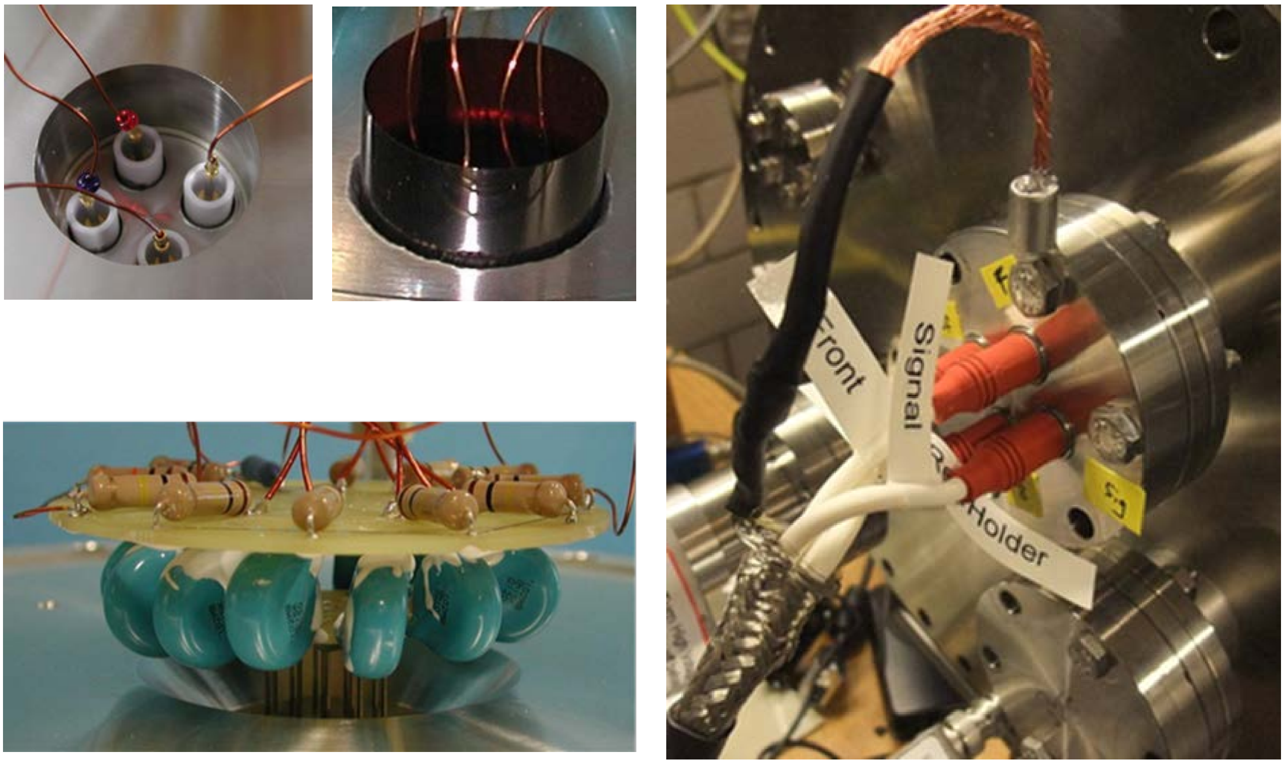


Figure 2.11: A fourfold XHV feedthrough on DN40CF is shown on the upper and right pictures. A Kapton shielding insures that the connection cables don't touch the flange. Left picture below: the signal decoupling PCB is supported by the pins of the FT12 feedthrough and routes the decoupled detector signals to the signal transformers and connectors of the air-side plug.

The **XHV** voltage connection to the detector requires an additional DN40CF feedthrough on a separate port because the standard **FT12** feedthrough cannot tolerate the high voltages. Therefore, high voltages for detector bias must be routed through a special "**XHV**-feedthrough" (rated for >10 kV) with four leads (see Figure 2.11). The signal decoupling takes place on an in-vacuum UHV-compatible printed circuit board (PCB) which is connected to the standard **FT12** feedthrough (see Figure 2.11 and Figure 2.13). For positive MCP front bias up to +4 kV (or +5 kV with special **HFSD**, likewise labeled) this voltage can be supplied via a separate MHV or SHV feedthrough and the MCP signal is picked up there. The other four detector voltages for the rear end are supplied via the XHV feedthrough.

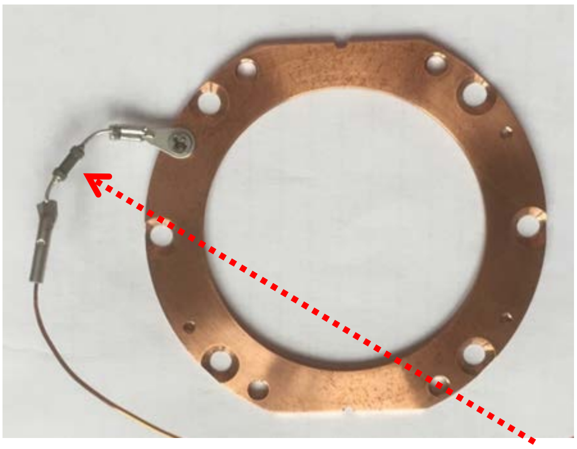


Figure 2.12: MCP front ring with cable connection and blocking resistor.

For highly negative MCP front potential (-5 kV to -10 kV) MCP back and Holder potentials must be set to the same value which can give rise to minor radial image distortion only for those MCP mountings using ceramic rings (correctable by software). This is because only four high voltage bias connections can be routed to the detector through the **XHV**-feedthrough. If the Holder potential (and other potentials, e.g. for a mesh) shall rather be supplied independently, a second **XHV**-type feedthrough can be installed at another port. The cable from the MCP front contact is guided directly to the corresponding lead on the **XHV** feedthrough flange, equipped with a blocking resistor near the contact on the MCP front ring/plate (see Figure 2.12). All other high-voltage in-vacuum cables (U_{sig}, U_{ref} and U_{back}) from the **XHV** feedthrough are connected to the PCB which distributes those voltages to the detector via specified junctions nearby (see Figure 2.13). The cables from the detector must be soldered to these. Detector signals are decoupled from the high voltage load and routed through the **FT12** feedthrough to the air-side plug (Figure 2.13, right) which contains further signal transforming circuits. In this scheme the MCP timing signal can only be picked up from MCP back*.

The in-vacuum PCB contains a connection cable to ground which must be fixed somewhere on ground potential. **If this cable is not connected to ground it can be dangerous to unplug the FT12TP connector on air-side. When reconnecting it a discharge may happen that can damage the detector and the read-out electronics**. If a **RoentDek** flange mounting is used the 3 mm lug can be grounded on a M3 hole of the flange, e.g. where a mounting rod is fixed. The same safety consideration is also relevant whenever signals are routed through a separate feedthrough (e.g. for Hexanode use). Please contact **RoentDek** for operational advice in such case.

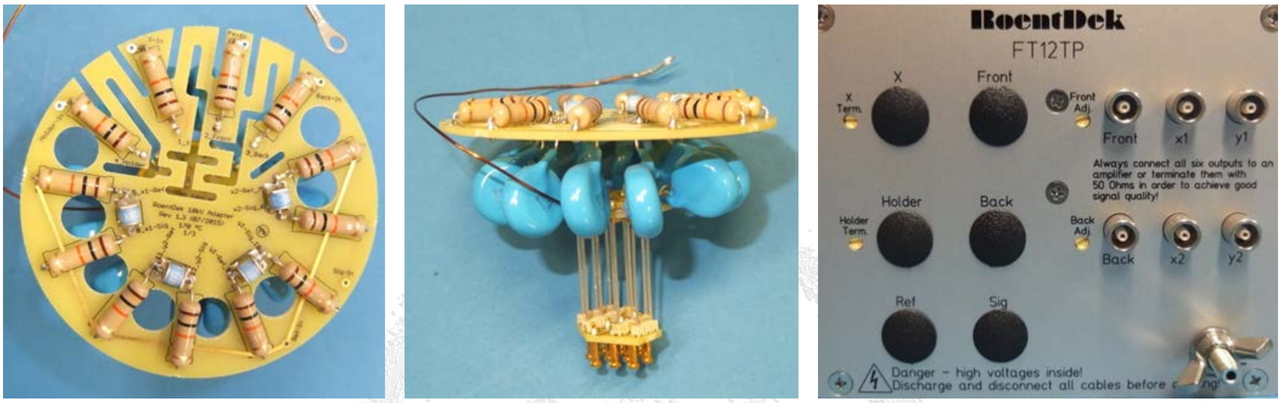


Figure 2.13: Signal decoupling elements of the XHV mounting scheme (here for DLD, similar to the circuits used in a FT12TP plug). The PCB has connection junctions for the high voltages and the detector cables. It can be directly connected to the FT12 feedthrough or via extension cables. Usually, MCP front is not connected through this PCB. The ground cable must always be connected. The airside plug (right picture) has the same outputs and functions as in the standard FT12TP assembly and may have no SHV inputs.

* For a **Hexanode** this PCB supplies high voltage only to the anode wires (U_{ref} and U_{sig}) and decouples signals only from those. The voltage to Holder/MCP back is supplied via the cable from the **XHV** feedthrough directly to the respective contacts on the detector, usually through blocking resistors. The MCP signal is picked up via a capacitor on the MCP back contact and routed to an additional BNC feedthrough. This signal line must be connected to ground via a kΩ resistor at all times.

3 The FEE front-end electronics for delay-line detector readout

The read-out of delay-line and timing/counting anodes requires analogue electronics that shapes the raw output signals so that the selected follow-up digital read-out electronics (see Chapter 4 of this manual or the *electronics description sheets*) can effectively retrieve and store the time. Thus, TOF and position information coded in the individual signals' arriving sequence can be determined with high precision and throughput. Since the pulse heights of signals from MCP and delay-line (or timing) anode are fairly small, adequate amplifying circuits are required before digitization and data acquisition. **Proper selection of bandwidth and impedance are crucial for optimal performance**. **RoentDek** offers several versions of amplifiers optimized for various read-out anodes. The basic version is the **FAMP1+**, which is employed for the MCP timing channel of delay-line anodes and with DET detectors. Several other multi-channel versions exist and are described in the manual The FAMP Amplifier Modules. All **FAMP** modules have linear response up to 1.5 V output voltage.

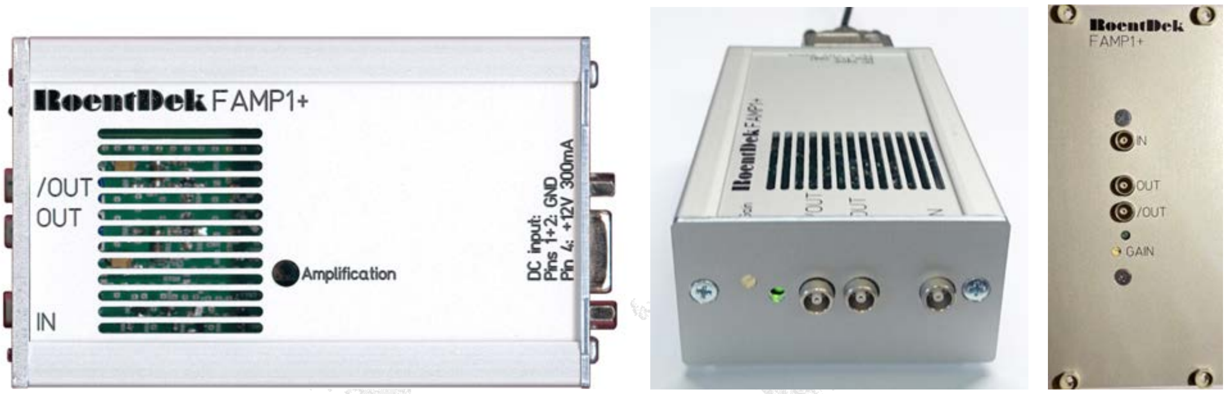


Figure 3.1: FAMP1+ timing amplifier for fast signals off the MCP contact or timing anode. Newer versions (right pictures) have the gain potentiometer on the front panel and can be supplied with alternative front panels.

For detector read-out with fast **ADC** units such as the **RoentDek fADC4/8** modules **FAMP** modules already provide sufficient signal shaping so that the timing information coded in the signal sequence can be retrieved with great precision by software after digitizing the analogue signal shape. After reviewing the FAMP manual please refer to Chapter 4 and the **fADC** manual.

For detector read-out with **TDC** modules (see Chapter 4 of this manual or the *electronics description sheets*) additional signal processing and discrimination circuits are needed. Since the width of detector signals (typically > 1 ns) is beyond the required timing precision so-called *Constant Fraction Discriminator* (**CFD**) circuits are necessary for further signal processing. Such circuits produce "digital" signals, e.g. NIM signals, from the amplified signals which retrieve the timing information on the signal with sub-ns precision which are suitable for digitization with TDCs and similar data acquisition modules.

Figure 3.2: Single-channel constant fraction discriminator CFD1c for retrieving the time information of fast signals off an MCP detector or similar devices.

RoentDek provides several types of **CFD** units with up to eight channels for operation in combination with adequate amplifiers. Detailed description is provided in the manual The **CFD** timing discriminator Modules.

Figure 3.3: with 19" 3HU crate hosting six amplifier channels (FAM6L or two FAMP3) and 4+1 CFD channels (four CFD1c plus one CFD1x). The CFD1x has additional circuits to transform pulse height information into a time delay for recording by a TDC channel. Below: version FEE5 with CFD4L (replacing four CFD1c) and standard CFD1c (can also be upgraded to FEE5x). For cabling please refer to the FEE5 connection scheme.

For use with NIM crate (not included) the **FEE5(x)** can be provided with a **FAMP6** and **CFD4c** (as NIM cassettes), and an adapter frame for convenient placement of remaining **CFD1c(1x)** in the crate.

Alternatively, for **DLD** detectors **RoentDek** provides also the **FEE2** and **FEE2x** product assembly with so-called **DLATR** circuits inside the **ATR19** units, containing both an amplifying stage and **CFD** stage for delay-anode read-out on a single circuit board. The **FEE2(x)** product combination uses the latest version of the two-channel model **ATR19-2b** in combination with **FAMP1+** and **CFD1c** or **x** (for MCP timing readout). Each **ATR19-2b** host s a dual channel **DLATR2** board for read-out of one delay-line layer of a **DLD**. For cabling please refer to the **FEE2** connection scheme.

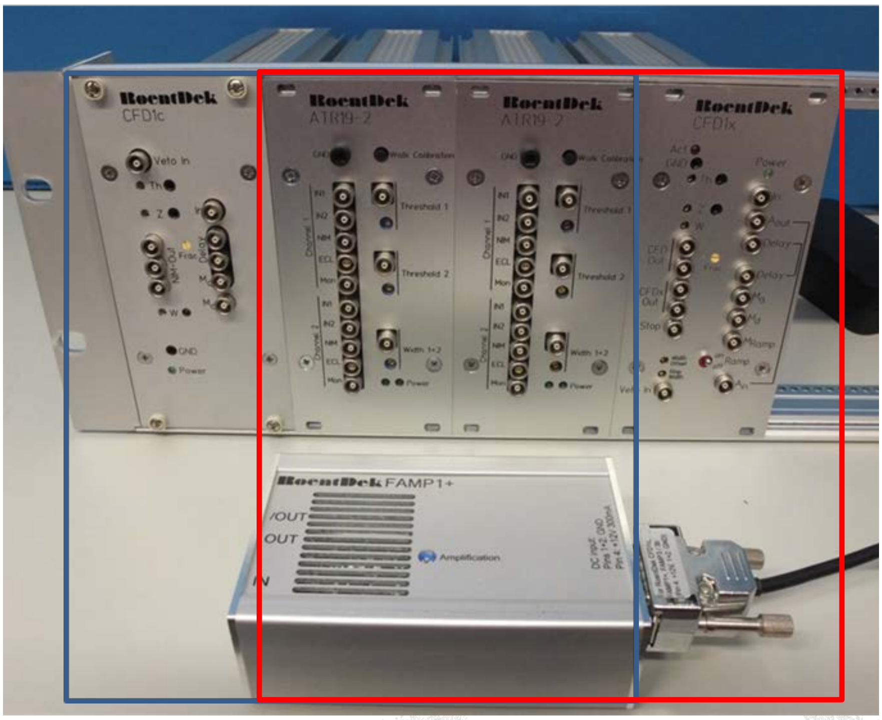


Figure 3.4: left picture: front side of FEE2 product assembly mounted in a 19" 3HU frame, three modules plus FAMP1+. The blue rectangle shows the items of the standard version with CFD1c, which can be replaced by a CFD1x (version FEE2x, in red rectangle). Upper picture: rear side view with loop through cable connections. The FAMP1+ module is also available as 3HU unit for rack mounting.

Figure 3.5: ATR19-2b module (left: older version with gain potentiometer on the side panel and walk button on front panel which is out of function for DLATR2 boards).

3.1 The ATR19-2b module

The **ATR19-2b** module is a two-channel amp&CFD unit for use with **DLD** anodes. The **FEE2(x)** product combination consists of two **ATR19-2b** units with **FAMP1+** and **CFD1c** (or **x**), the recommended modules for achieving optimal timing performance for the MCP signal. The **ATR19-2b** is operated with the standard **RoentDek** 12 V mains adapter which can power several daisy-chained units via rear panel connectors.*

The **ATR19** units have been specifically designed for read-out of **RoentDek** delay-line anodes. The amplifying stage on the internal **DLATR** board is not bipolar like the **FAMP** circuits because the internal CFD stage requires negative signal polarity

* older **ATR19-2** versions, require ±6 V DC (600 mA) operation voltages, e.g. from an **SPS1(b)**, mains adapter. Please refer to the manual The ATR19 Amplifier & CFD Module

for further processing (like most CFD modules). Depending on input signal polarity either the "IN1" socket has to be used (for negative signals) or the "IN2" socket in case of positive input signals (inverting line). Input/output impedance is 50 Ω to ground. Differential input signals (supplied to both sockets) can also be used (100 Ω relative impedance) but proper input polarity resulting in negative output signals has to be ensured. The output signals (entering the CFD stage of the circuit) can be monitored on the "Mon" output for each channel.

The general function a CFD circuit for determining signal timing with great precision is illustrated in the The CFD timing discriminator Modules manual. The **DLATR** circuit which is described in detail in the The ATR19 Amplifier & CFD Module manual requires less adjustments since it is designed and optimized for signals from helical-wire delay-line anodes. It is only necessary to set a proper threshold for discriminating signals against noise. This threshold can be set either using the front panel potentionmeters, independently for each channel (default) or by supplying 0-1 V DC-voltages, e.g. from a **RoentDek USB-IO2** module. This is explained in below and with more detail in The ATR19 Amplifier & CFD Module manual. If a signal exceeds the threshold a NIM (or ECL) timing signal for the TDC is delivered. Controls to set/measure the threshold and timing signal width are found on the front panel.

The **ATR19** units have been carefully adjusted prior to delivery. Changing settings on the internal **DLATR2** board is not recommended. Please contact **RoentDek** if an **ATR19-2b** requires service. To open the module, remove the screws on the front and rear panel which fix the right side panel (the one with holes). Now you can remove the side panel and have access to the **DLATR2** board inside. For complete disassembly and full access to all components remove also the remaining screws on front and rear panel.

3.2 ATR19-2b adjustment for detector operation

If the voltages to the detector are supplied in the recommended way, the signals from the delay-line anode contacts (negative output polarity) via a standard **FT12TP** have to be connected to the "IN1" socket ch1 or ch2. The analogue signal height on the monitor outputs linearly corresponds to the charge of the electron cloud delivered from the detector output. The outputs from the delay line should have similar mean signal heights. If not, the amplification factors should be adjusted as long as the output pulse height is smaller than 1 V (negative polarity) the shape of the pulses resembles the input signals that enter the constant fraction stage. For normal noise levels below 20 mV sufficient imaging results are obtained if the pulse heights distribution has a mean value of 300 mV at least. The lowest pulse heights should still be higher than the noise level. To increase the pulse height one can increase the MCP bias (not exceeding the maximum recommended value!) or the amplifier gain. If you increase the amplifier gain, please be aware that the noise level will increases proportionally to the amplification factor. The signal-to-noise ratio, limiting detector performance, can only be improved be increasing MCP gain (which may require reducing amp gain for avoiding saturation effects and non-linear amplification).

If the analogue outputs are satisfactorily, one can check the corresponding timing (CFD) outputs on the sockets "NIM" or "ECL". If your module is set to NIM-output levels you can directly verify the signals on an oscilloscope (coax input, 50 Ω terminated). For the ECL output setting the presence of signals can be probed likewise on the NIM output with an oscilloscope (but with at least 1 MΩ input impedance). Note that this may disturb the signal from the ECL output). Now the thresholds on all channels can be adjusted, ideally so that even the smallest pulse heights from particle/photon triggered MCP charge cloud are above the threshold but noise is still fully discriminated (typical threshold level 1.5x - 2x higher than the continuous noise level). Figure 3.6 shows such a typical case. It should be noted that it may be beneficial to allow occasional noise triggers in order to safely detect also the smallest real signals and not to "lose" counts. This will not lead to false data because if they do not appear on all signal chains or if such random counts can be dismissed in coincidence-triggered measurements. Such signals will either not be processed by the data acquisition or can easily be sorted out later during data analysis (see below).

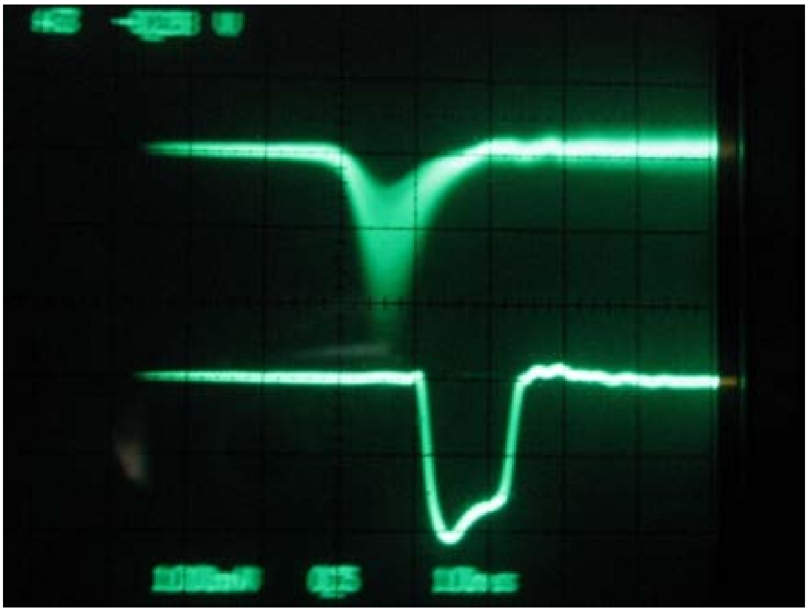


Figure 3.6: Typical (analogue) oscilloscope screen output showing ATR19 response to delay-line signals routed through an FT12TP decoupling circuit: analogue signals (monitor output) on upper trace and the correlated CFD outputs (NIM) on the lower trace. Both traces are triggered by the NIM signal. The pulse height distribution of the analogue signals can be seen and also the effect of the threshold setting on the registered events (cut-off of smaller signals not being registered).

However, one should avoid a too-low threshold setting which may cause a so-called "pre-trigger" operation mode of the CFD circuit. In this mode the CFD threshold will not block off signals that have been slightly distorted by noise in a way that the CFD circuit cannot function normally, see Figure 3.7. A source of pre-triggers may also be direct electronic cross talk of the MCP signal to the anode (see *The CFD timing discriminator Modules* manual). If the pre-trigger signal is registered, false time will be measured. For delay-line signals this can be recognized in a false time sum for this detected particle / photon on the respective layer and the event can be dismissed by software. However, this may lead to non-linear imaging and timing response on the detector.

If thresholds are set to a very low value it can be of advantage to mix the delay-line outputs between channels so that signals from the same delay-line layer (i.e. from x1 and x2 outputs) are not processed on the same internal board, i.e. on those neighbouring channels that share a width potentiometer. Otherwise inter-channel cross talk is more likely to happen.

If a RoentDek delay-line detector is used the presence of such events can be clearly observed in the time sum spectrum during data acquisition, see Figure 3.9. Ideally, the time sum on each layer consists only of one narrow peak with few ns width (lower pictures left side). Pre-trigger events contribute a more or less continuous "background" of falsely timed signals (lower pictures right side). It should be noted, however, that also a too high threshold level on the CFDs for the delay-line leads to a "non-perfect" time sum spectrum.

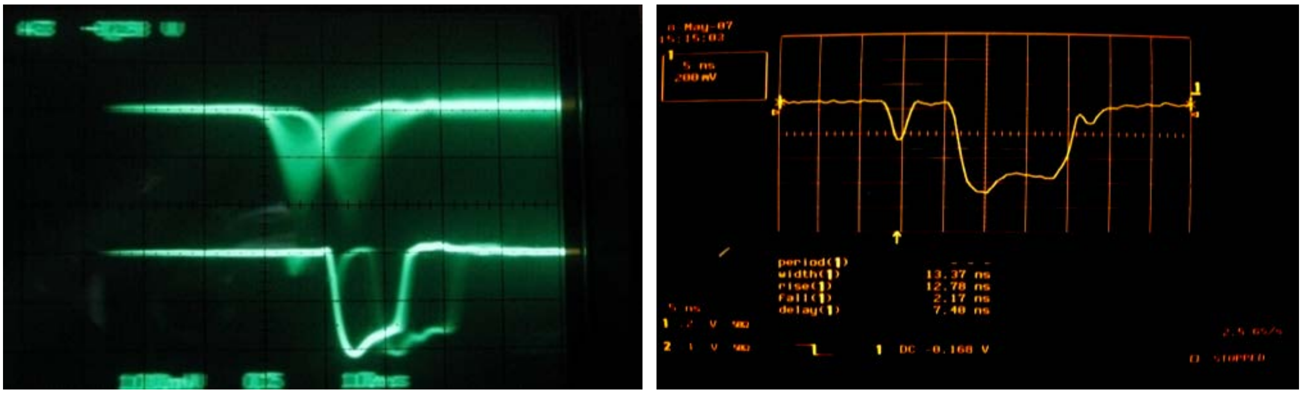


Figure 3.7: Signal traces as in Figure 3.6, but with low threshold setting very close to the noise level (left). Pre-triggered signals are present. The right picture shows the CFD output of an erroneous pre-triggered event.

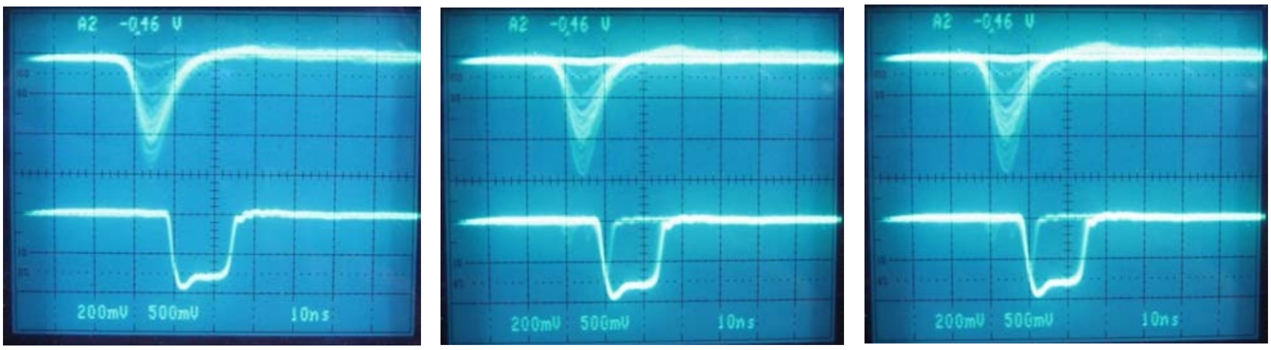


Figure 3.8: Overview of ATR19 signal outputs for low threshold settings, triggered on the CFD signal.

Figure 3.8 shows signals at low threshold values. Ideally, the threshold should be set so low that all valid input signals produce a NIM-output from the CFD stage (left image) but high enough to exclude noise triggers (as in the middle image) and pre-triggers (as in the right image). The spurious per-trigger events can be identified by a small signal appearing occasionally just before the "main" NIM signal on the CFD output line.

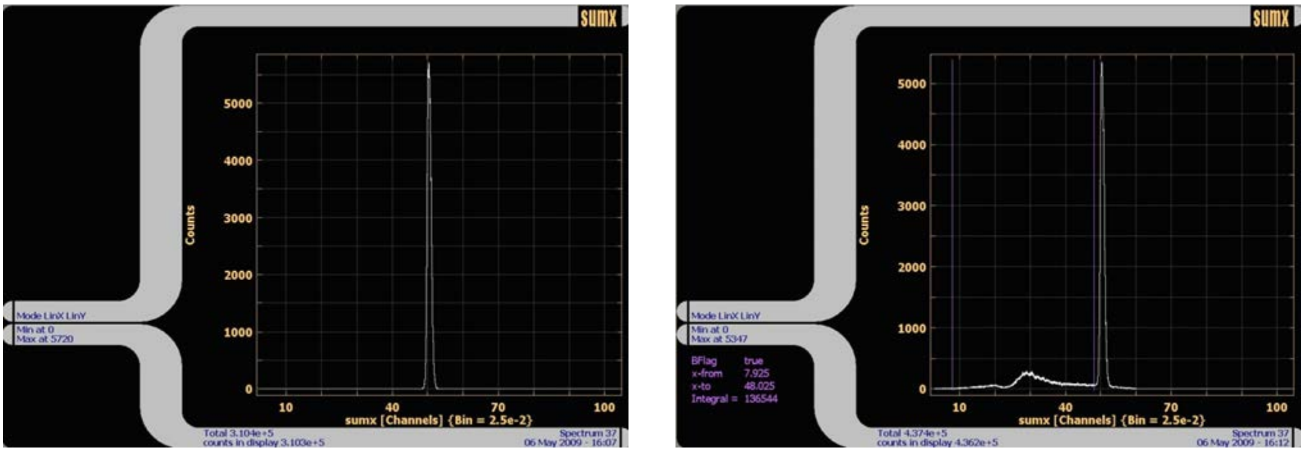


Figure 3.9: Time sum spectra from a delay-line anode for different threshold setting. Left: clean spectrum, right: contribution of noise and pre-trigger signals can be seen.

It is not recommended to simply ignore pre-trigger events by setting a narrow software window in the time sum spectra because these pre-trigger events are not uniformly distributed across the active area of a delay line detector, see Figure 3.10.

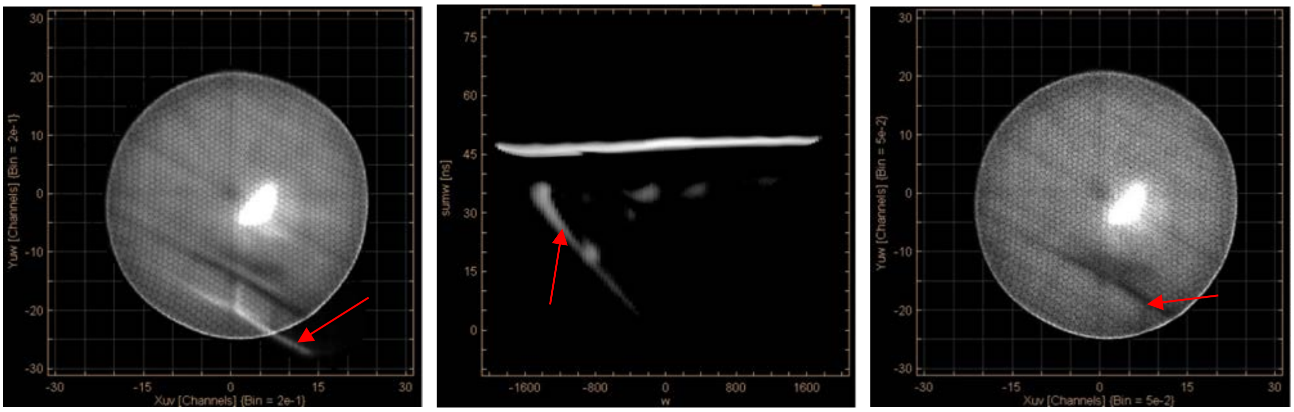


Figure 3.10: Typical image artefact caused by pre-trigger events (left picture). These events may appear only on certain parts of the detector (see red arrow). Here, thresholds of the channels for the w-layer were set too low, causing image artefacts. If the time sum is plotted as function of position (middle picture) the localized contribution of pre-trigger events is revealed. Setting a narrow time sum gate can remove the pre-trigger events but the image artefact (missing data) remains, see right picture.

4 Data acquisition Hard- and Software

RoentDek has developed data acquisition concepts for PCs, especially suited for correlated multi-parameter read-out. It consists of the software package **CoboldPC** with plug-ins for certain hardware applications. Currently Windows XP, Windows Vista and Windows 7 operating systems (OS) are supported. x64 (64 bit) OS systems are not supported for all hardware. Windows 8 is partially supported but not yet for hardware read-out.
For the data acquisition with **RoentDek** delay-line detectors we have developed three types of TDCs. The **TDC8HP**, **HM1(B)**, and the **TDC8** (for ISA and PCI bus). The **fADC** units are not yet documented in this manual. If you have purchased **fADC** units, please contact **RoentDek**. For all data acquisition hardware modules there are separate more detailed manuals available. Please see **http://roentdek.com/manuals/**.

4.1 The Time-to-Digital-Converters (TDC) for PC

RoentDek currently supports different TDC modules for PC, the **TDC8HP**, **HM1** and the **TDC8**, all suitable as stand-alone units controlled by PC (**CoboldPC** software): The **TDC8HP** is available as a PCI board. The **HM1** can be delivered with an ISA or PCI I/O card that needs to be inserted into the PC. The **TDC8** exists as an ISA-PC plug-in board and in a PCI version (this product line discontinued).

4.1.1 TDC8HP

The **TDC8HP** system is based on the CERN HPTDC chip. The **TDC8HP** system consist of the **HPTDC8** board and the **CoboldPC** software. This card is in function very similar to the older **TDC8PCI2** board.

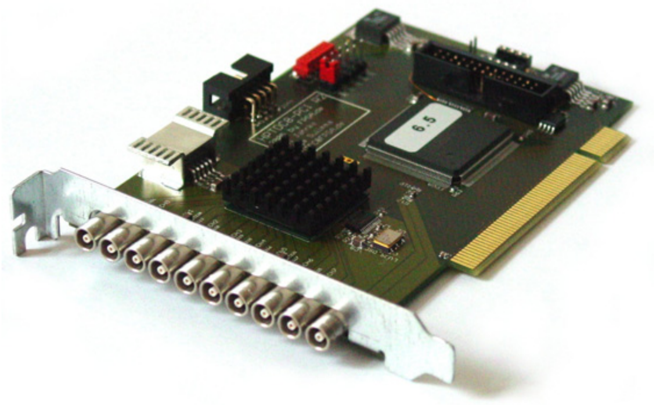


Figure 4.1: HPTDC8 PCI Card

The **TDC8HP** continuously record the digital waveform (high/low) on its inputs similar to a logic analyzer.

TDC8HP features are:

- 8 NIM compatible inputs on LEMO 00/250 connectors with 25 ps LSB* (high resolution)
- 1 NIM compatible LEMO input with 12.8 ns LSB††† (low resolution, e.g. for event stamping or rate meter function)
- Additional 12 TTL inputs with 12.8 ns LSB, accessible via optional connector board
- typical deadtime between multiple hits on one channel 5 ns
- unlimited number of hits per trigger
- no dead time due to readout, new data is acquired during readout
- 4 MHits/s maximum readout rate, with **CoboldPC** the read out rate is about up to 1.3 MEvents/s
- 419 µs range w. trigger logic enabled
- 2 h range without trigger logic, can be extended by software (with **CoboldPC 2011**)
- adjustable trigger window (size, position of trigger)
- easy to use driver for windows operating systems
- on board storage for calibration data
- support for up to three event-synchronized boards via a clock card
- 5 V, 32 bit, 33 MHz PCI target device

* On most recent modules the exact value is 25.117 ps, the low resolution channels' LSB matches 512 high resolution bins.

Typical applications for a **TDC8HP** include atomic physics experiments (e.g. momentum imaging, time-of-flight spectroscopy), mass spectroscopy.

A **PCI2PCIe** adapter is available which allows the read-out of **TDC8HP** modules via PCIe bus and via further adapters to laptop computers.

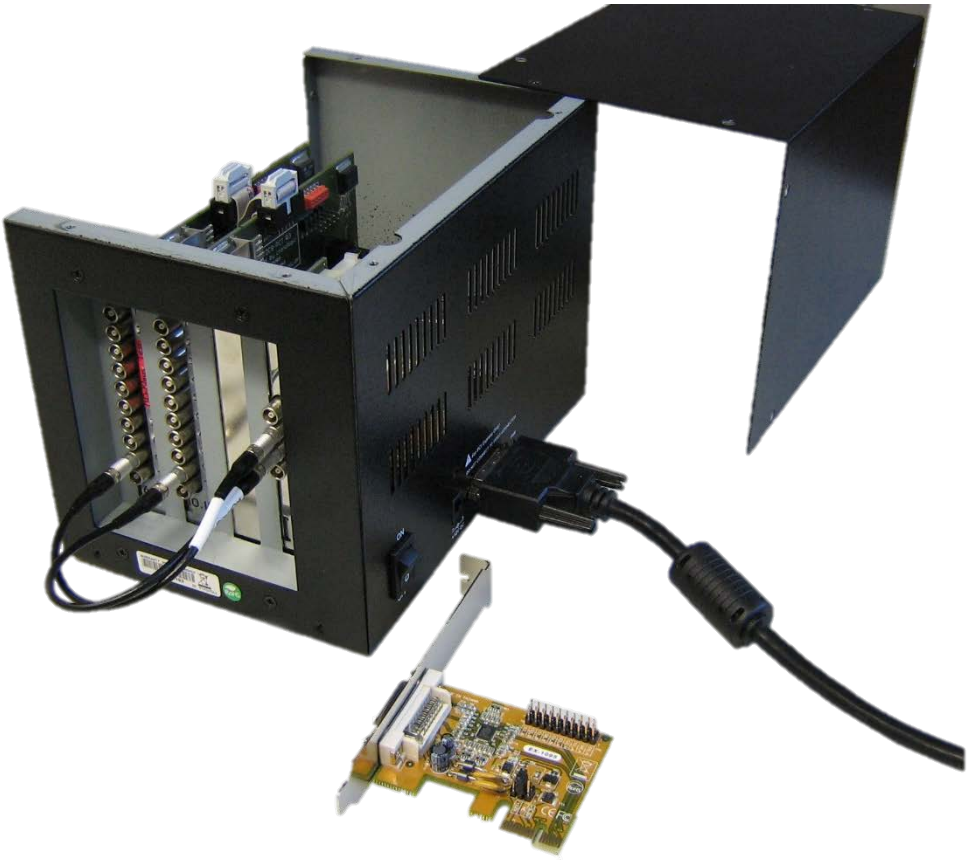


Figure 4.2: PCI2PCIe adapter crate with PCIe card for the PC. Here two TDC8HP and a clock card are inserted

The **PCI2PCIe** adapter requires a mains cord with IEC-60320-C7 norm (only the EURO version of this cord can be supplied by **RoentDek**.

4.1.2 TDC4HM

The **TDC4HM** is a common-start time-to-digital converter. The timestamps of leading or trailing edges of digital pulses are recorded. The **TDC4HM** produces a stream of output packets, each containing data from a single start event, i.e. the relative timestamps of all stop pulses that occur within the user defined range.

Figure 4.3: TDC4HM PCIe Card

TDC4HM features are:

- 4 channel common start TDC with 13 ps resolution
- Standard Range: 218 µs (24 bit timestamp)
- Extended Range: 13,975 µs
- Bin size: approx. 13 ps
- Double pulse resolution: 5 ns
- Dead time between groups: none
- Maximum start rate: 4 MHz
- PCIe 1.1 x1 with 200 MB/s throughput

At the beginning of the CCF-file, please make sure that the line
LoadDAqModule DAq_TDC4HM.dll,Applicationpath
Is active instead of the usual line
LoadDAqModule DAq_TDC8HP.dll,Applicationpath

4.1.3 The HM1 / HM1-B

The **HM1** is based on the GP1-chip of ACAM. It has a common-start input and 4 channels of stop inputs, all differential ECL. The resolution is 133 ps or better (adjustable) the range is 14 bit or up to 30 bit in a special long-range mode (resolution and pulse-pair separation ability reduced). It can be operated in three modes:

a) In the standard mode, *"transparent mode"*, it can detect up to 3 or 4 hits per channel with a pulse pair resolution of about 15 ns. The data acquisition (DAq) in this operation mode is managed by the PC. The DAq speed is limited to about 18 kHz, divided by the number of hits to be detected per channel. The data are stored in list-mode on the PC- hard disc. Two **HM1** modules can be combined to a double module featuring effectively an 8-channel version (with half read-out speed), e.g. for coincident read-out two **DLD** detectors (ISA version only).

b) The *burst mode* is a pre-calculated transparent mode (only available in the **HM1-B** module). The values for x1,x2,y1 and y2 are calculated inside the **HM1-B** Module to x, y and z. x, y and z is then coded into a single 32 bit value. The number of bit for x, y and z can be programmed. This 32 bit value is store in a small FIFO. Only 1 hit can be detected in this mode. This mode is mostly controlled by the **HM1-B** itself, therefore the DAq speed is about 150 kHz.

c) In the so called *histogram mode* (optional, not for **HM1/T**) the DAq speed is significantly enhanced (more than 1 MHz). The data (only single hits per channel are registered) are stored on the TDC board in a 2D histogram (X and Y position, 11 bit) or 3D histogram (X, Y and Z=TOF) memory. After a measuring cycle the content of the histogram can be transferred to the PC in a block for further data treatment. A dual memory bank on the board allows continuous data taking even during data transfer to the PC. The range of the TDC is limited by the histogram partitioning.

Figure 4.4: HM1-B/T and HM1-B front panel

Figure 4.5: PCI interface card

The **HM1-B** is fully compatible to the **HM1** as well as the **HM1/T** model. Additionally, to the **HM1** this module has the *burst mode* ability.

Details of the HM1(-B) operation is given in a separate manual. **HM1** modules cannot be operated with x64 OS.

4.1.4 The TDC8

(This product line is discontinued!)
The **TDC8** is based on the LeCroy MTD133B-chip (production discontinued). It has an input for common start or common stop operation and 8 channels. It operates only in "transparent mode" (list mode) and can collect up to 16 hits per channel. The resolution is 500 ps and the range is 16 bit. The input level is NIM. Up to three **TDC8** can be combined. Especially, two of the **TDC8** can be coupled to an effective 15 (ISA) or 16 (PCI) channel single start/stop TDC.

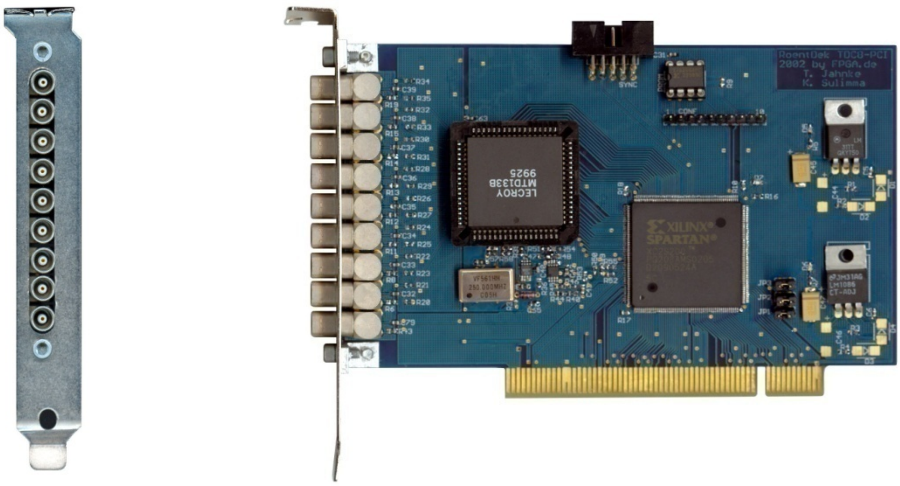


Figure 4.6: TDC8PCI2 board

For details of the TDC8 module versions please refer to the separate manual.

4.2 Hard- and Software Installation

4.2.1 TDC8HP

- Shut down your computer
- For your devices safety, turn off the power to your computer and all peripheral devices.
- Drain static electricity from your body by touching the metal chassis (the unpainted metal at the back of your computer)
- For your personal safety, remove the power cord from your computer
- Remove the cover of the computer as described in your computer's manual.

- Locate a free PCI slot in your computer, and firmly insert the card into the selected slot. To avoid damaging your hardware, insert the card only into a slot with the same bus type as the card. Inserting the card into any other type of slot can damage your card, your computer, or both.
- If available insert your 2nd **TDC8HP** card into another free PCI slot.
- Connect both **TDC8HP** cards with a 16 pin flat ribbon cable (like the grey cable on top of the TDCs, seen in Figure 4.2).
- If using two **TDC8HP** cards, you have to insert also a **Clock** card. To apply power to the **Clock** card.
- Firmly secure the adapter(s) with a screw(s) (or clip), to ensure that the adapter is properly grounded to the computer's chassis.
- Replace the cover of the computer as described in your computer's manual.

For a detailed description and how to install **TDC8HP** drivers please refer to the **TDC8HP** manual

4.2.2 TDC8HP with PCI2PCIe adapter

- Shut down your computer.
- For your devices safety, turn off the power to your computer and all peripheral devices.
- Drain static electricity from your body by touching the metal chassis (the unpainted metal at the back of your computer)
- For your personal safety, remove the power cord from your computer
- Remove power cord from the **PCI2PCIe** crate.
- Remove the cover of the computer as described in your computer's manual.
- Locate a free PCIe slot in your computer, and firmly insert the PCIe IO card into the selected slot. To avoid damaging your hardware, insert the card only into a slot with the same bus type as the card. Inserting the card into any other type of slot can damage your card, your computer, or both.
- Firmly secure the adapter(s) with a screw(s) (or clip), to ensure that the adapter is properly grounded to the computer's chassis.
- Replace the cover of the computer as described in your computer's manual.
- Open the PCI2PCIe adapter crate and locate a free PCI slot.
- Firmly insert your **TDC8HP** card into the selected slot.
- If available insert your 2nd **TDC8HP** card into another free PCI slot.
- Connect both **TDC8HP** cards with a 16 pin flat ribbon cable (like the grey cable on top of the TDCs, seen in Figure 4.2).
- If using two **TDC8HP** cards, you have to insert also a **Clock** card. To apply power to the **Clock** card, connect the 26 pin flat ribbon cable (only 2 lines on connector crimped) to the either TDCs 26 pin connector (there is only one) and the other side to the **Clock** card.
- Close the **PCI2PCIe** adapter crate.
- Connect the **PCI2PCIe** adapter crate with the PCIe card in your computer.
- Apply power to your adapter crate first then to your computer. If you have to power down the crate, you have to reboot after power up the crate again.

For a detailed description and how to install **TDC8HP** drivers please refer to the **TDC8HP** manual

4.2.3 TDC4HM

- Shut down your computer
- For your devices safety, turn off the power to your computer and all peripheral devices.
- Drain static electricity from your body by touching the metal chassis (the unpainted metal at the back of your computer)
- For your personal safety, remove the power cord from your computer
- Remove the cover of the computer as described in your computer's manual.
- Locate a free PCIe x1 slot (or higher amount of lanes) in your computer, and firmly insert the card into the selected slot. To avoid damaging your hardware, insert the card only into a slot with the same bus type as the card. Inserting the card into any other type of slot can damage your card, your computer, or both.
- Firmly secure the adapter with a screw (or clip), to ensure that the adapter is properly grounded to the computer's chassis.
- Replace the cover of the computer as described in your computer's manual.

4.2.4 HM1 / HM1-B

- Shut down your computer.
- For your devices safety, turn off the power to your computer and all peripheral devices.
- Drain static electricity from your body by touching the metal chassis (the unpainted metal at the back of your computer).
- For your personal safety, remove the power cord from your computer.
- Remove the cover of the computer as described in your computer's manual.
- If necessary, adjust the I/O address setting on the I/O card to a free I/O address (ISA-I/O card version only). Do not forget to adjust *parameter 1* in your .ccf file to this I/O address or set the value of this parameter to 0 to automatically determine the I/O address.
- Locate a free ISA/PCI slot in your computer, and firmly insert the card into the selected slot. To avoid damaging our hardware, insert the card only into a slot with the same bus type as the card. Inserting the card into any other type of slot can damage your card, your computer, or both.
- Firmly secure the adapter with a screw (or clip), to ensure that the adapter is properly grounded to the computer's chassis.
- Replace the cover of the computer as described in your computer's manual.
- Connect the HM1 module with the I/O card using the connection cable. The three green LED on the HM1 module should be on now.

Note that the I/O card is not using SCSI signaling standard, although it has a SCSI socket and cable.

Major damage to your hardware will occur if you connect a SCSI device to the HM1 interface card or the HM1 to an SCSI controller.

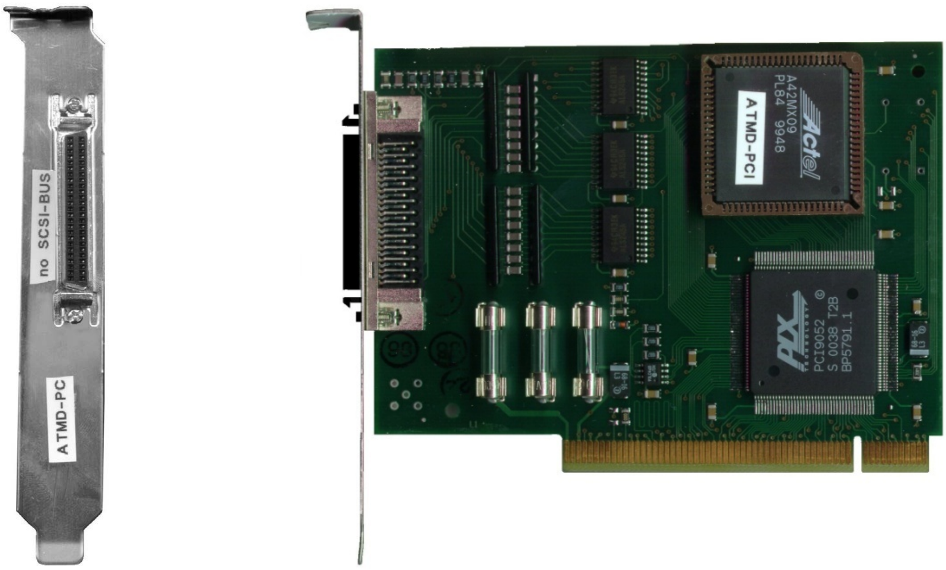


Figure 4.7: Side and input panel view of the HM1 - I/O-board (PCI)

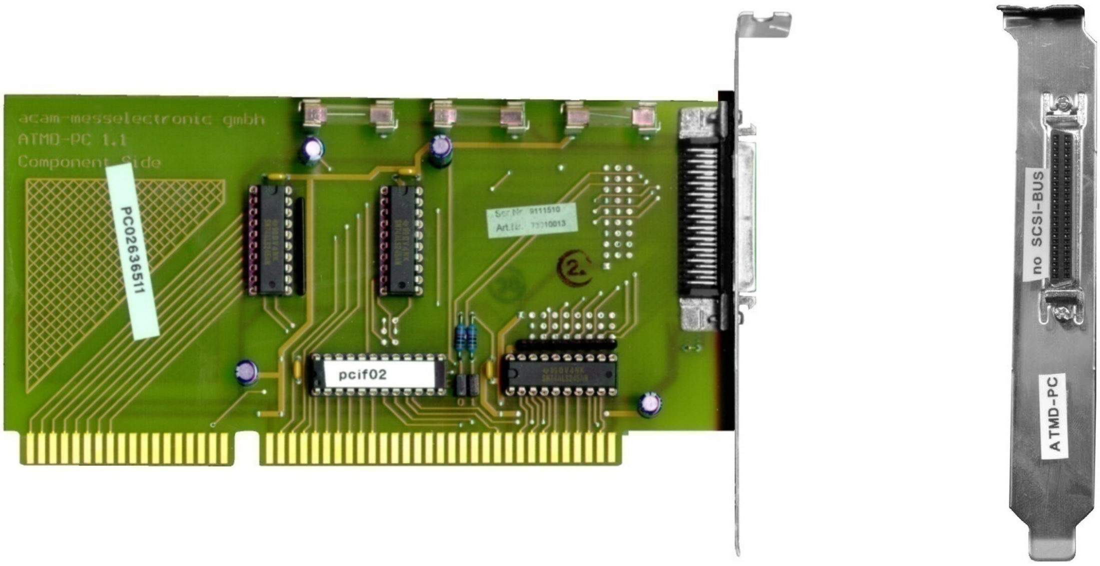


Figure 4.8: Side and input panel view of the HM1 - I/O-board (ISA)

For a detailed description please refer to the HM1-B Module manual

4.2.5 TDC8

(This product line is discontinued!)

- Shut down your computer
- For your devices safety, turn off the power to your computer and all peripheral devices.
- Drain static electricity from your body by touching the metal chassis (the unpainted metal at the back of your computer)
- For your personal safety, remove the power cord from your computer
- Remove the cover of the computer as described in your computer's manual.
- Adjust the I/O address setting on the card to a free I/O address.
  Do not forget to adjust parameter 1 in your .ccf file to this I/O address. For the PCI-Version set this parameter to 0.
- Locate a free ISA or PCI slot in your computer, and firmly insert the card into the selected slot. To avoid damaging your hardware, insert the card only into a slot with the same bus type as the card. Inserting the card into any other type of slot can damage your card, your computer, or both.
  The **TDC8PCI** needs two PCI slots even though it connects only to one PCI slot connector.
  The **TDC8PCI2** needs only one PCI slot!
- Secure the adapter with a screw (or clip), to ensure that the adapter is properly grounded to the computer's chassis.
- Replace the cover of the computer as described in your computer's manual.

Note for TDC8PCI(2) board!
Normally the PCI support in the BIOS is set to "Plug and Play" for operating systems that can handle plug and play components like Windows 2000 or Windows XP. In very rare occasions, the TDC is not working in this mode. In this special case the TDC card is detected but no data taking can be initiated. A DAq Software like **CoboldPC** will therefore give no warning that the TDC could not be detected but the event rate will always be zero.
In this case try to switch the PCI support in BIOS from "Plug and Play" to "None Plug and Play" and try again.

For a detailed description please refer to the **TDC8** manual

4.3 Connecting the ATR19 or CFD with the TDC

Before you finally connect the TDC with the **ATR19** or CFD units you should have verified that the detector and the **ATR19** or **CFD** unit are operating properly.

4.3.1 TDC8HP (or TDC8)

(You should have installed the TDC *card already in the PC)*

Connect via the short LEMO coax cable the **TDC8HP** channel 8 (in case of **TDC8** input "C") with the timing (CFD) output (NIM signal only) used for the MCP signal. Likewise connect the outputs of the delay line anode timing signals to the channels 1 to 4(6) according to Chapter 2 of the manual.
*For **TDC8** only: If you have received cables of different lengths use the four or six long cables for that. For coincidence experiments it is often of advantage to operate in "common stop" mode and supply a delayed trigger signal to the common input (to arrive after the last significant signal in channels TDC1-8. Such a signal can be a coincidence trigger, to collect only selected events.*
Note that this is only the standard connection scheme, for other connecting schemes the software must be adapted. Additional channels can be used for other signals to be correlated (i.e. from a second detector or a TOF trigger).
Operating two or more **TDC** modules:
If you operate two **TDC8HP** modules only channel 8 of the first **TDC8HP** board (lowest TDC ID) have to receive the trigger signal. Additionally, connect the "External Clock" Module with each **TDC8HP** channel "C". Also apply the flat ribbon cable to the two **TDC8HP**s (on top of the card). The two **TDC8HP** board will now operate as a virtual "**TDC16HP**" board with doubled input channels. The TDC with the lowest TDC ID provides channels 1-9 (1-8 and T on the board) and the other board the channels 10-17 (1-8 on the board). A third **TDC8HP** can also be linked in the same way.
*For operation of two **TDC8** modules: both common inputs must receive the same (trigger) signal. Additionally, one TDC channel in each module must receive the same signal to ensure correlation between the modules (by software).*
*Note, that the **TDC8** needs a minimum time difference of about 10 ns between start and stop signals in case of "common start" operation. It is then advisable to use cable sets so that the common input cable is at least 3 m shorter than the other input cables.*

4.3.2 TDC4HM

Connect the TDC start via the short LEMO cable with the timing (CFD) output used for the MCP signal. Use the four long cables to connect the (stop) channels x1, x2, y1 and y2 for the delay-line CFD timing output channels 3, 4, 5 and 6 according to Chapter 2 of the manual. Note that this is only the standard connection scheme, for other connecting schemes, the software must be adapted. Additional channels can be used for other signals to be correlated (i.e. from a second detector or a TOF trigger).

4.3.3 HM1 / HM1-B

Connect the TDC start via the short two-pin cable with the timing (CFD) output (ECL signal only) used for the MCP signal. Use the four long cables to connect the (stop) channels x1, x2, y1 and y2 for the delay-line CFD timing output channels 3, 4, 5 and 6 according to Chapter 2 of the manual. If a **NIM2ECL** converter is used, it is placed between the CFD NIM output sockets and the **HM1** inputs.
If you operate two **HM1 / HM1-B** as a double unit, the "start" needs to be supplied to both modules (ISA version only).

4.4 Starting the CoboldPC 2011 Software:

Once the software is successfully installed you are ready to run a **CoboldPC** session from a pre-acquired list-mode file to make you acquainted with the software, found on the **RoentDek** web-site or on the supplied CD in folder *CoboldPC20NNSampleFiles* (NN referring to the latest version). For this it is not necessary to install or operate any hardware but you have to have all drivers installed. We have provided you with a sample file (list-mode file) that was acquired with the hardware that you have received (or similar hardware) on the CD. From now on you may also refer to the **CoboldPC** help file (this has replaced the **CoboldPC** manual) as this small section can give only a very brief overview how to get started.

Tutorials for the **CoboldPC** software are available on our web-site: *http://roentdek.com/info/movies*

There is also a "zero-level" operation mode for **CoboldPC 2011** (and higher) versions, allowing to address the **CoboldPC** commands by a "remote-controlling" scripting language. Please contact **RoentDek** if you are interested in controlling **CoboldPC** session from an external program. It is strongly recommended to use the program directly for first operation.

CoboldPC loads the DAq (Data Acquisition module) and DAn (Data Analysis module) dynamically. After starting the program, the first time you have to specify the right DAq and DAn modules. This can be accomplished in either the About-Box or in the File-Menu. DAq modules are normally named like DAq_*.dll and DAn modules as DAn_*.dll. 64-Bit modules contains "x64" in the filename. For the DAq module please select the one with the appropriate hardware that you have purchased that will support the readout of your hardware. These files can be found in the main **CoboldPC** installation directory. If you have purchased the **HM1** with histogramming option, please refer also to the **HM1**-TDC manual. The following procedure is mainly describing the start-up in the standard (transparent mode), which is recommended for first use of the detector system. The **HM1** will only operate on 32 bit operation systems.

After starting the **CoboldPC** program and selecting the appropriate DAq and DAn modules (there is a flag to load the last selected DAq and DAn modules at start time) the program has linked the proper program parts and waits for input from the command line (type the command text and "enter") or the tool bar buttons. With the command "exeute filename.ccf" or from the drop down menu you can start a so called "batch-file", i.e. a series of commands as written in the file (new line = next command). For example, any "Startup.ccf" file (see below) defines a set of *parameters*, *coordinates*, *conditions*, and *spectra* necessary for a **CoboldPC** session. A dialogue box will ask you to define the type of session, hardware acquisition or re-sorting of a previously acquired listmode-file.

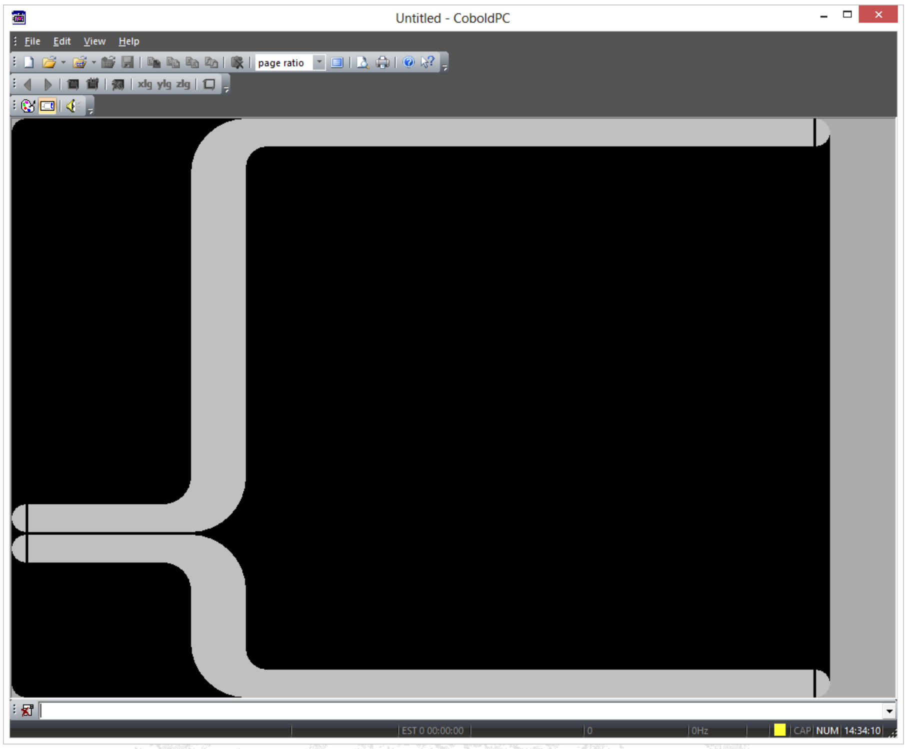


Figure 4.9: Screen after starting the CoboldPC program

You will recognize corresponding files easily from the similarities in the filenames. Browse for a "filename.lmf" and select it. If you have selected an adequate listmode file, the program will resume and sort the file. Now you can look at the *spectra* (one- or two-dimensional histograms) with the `view` command. First you may check with the `show spectra` command which *spectra* are defined and can be displayed. If you have not yet referred to the **CoboldPC** help file so far, it is time for that now in order to proceed. Some frequently-used standard commands are listed below:

`exe`	calls a command file
`new hardware`	prepares for starting hardware acquisition
`start`	starts the acquisition
`pause`	pauses the acquisition (for starting again use the start command)
`stop`	stops the acquisition (for starting again use the new hardware and the start commands)
`clear all`	clears the contents of all spectra (instead of all, a certain spectrum number is also possible to clear only one spectrum)
`restart`	deletes all coordinates, parameters, conditions and spectra for a total reset
`coordinate`	defines a coordinate
`parameter`	defines a parameter
`condition`	defines a condition
`define1`	defines a 1-dimensional spectrum
`define2`	defines a 2-dimensional spectrum
`view 1`	shows spectrum 1
`show status`	shows the status report window
`wait`	next command will not be executed before a certain time(parameter) has passed or a measurement/listmode file read is stopped

`help` shows the help file (or press *F1*)

We have prepared a startup command file "Startup.ccf" which contains all commands for reading one (or two) TDCs **TDC8HP**, **HM1** or **TDC8PCI2**. It provides already most of the desired definitions, i.e. 2d position spectra and time-of-flight *spectra* in various *coordinate* representations which will allow you verifying the detector functions. It may in some cases also be sufficient for your task. After you are acquainted with the program and have produced first data files using this startup command file you may contact **RoentDek** for receiving advice if you should use another more advanced startup routine*. Depending on the hardware used there are additional read-out options, e.g. an independent rate-meter function of the **TDC8HP** or a histogramming mode for **HM1** modules.

The program calls a sub-script for defining hardware-specific *parameters* which must be chosen (default: **TDC8HP**). You may replace this execute command by directly copy & pasting the commands in the called sub-script for your hardware option at this position in the startup file. Due to this modular construction it is possible to use almost the same data analysis sequences for different hardware, i.e. TDC types. The parameters from 0 up to 999 are reserved for DAq-parameters.
Module names (*.dll) will be automatically corrected for x64 or x86 mode modules.
If you use other hardware than the **TDC8HP** you are requested to modify one command:

For **TDC4HM**: remove the ";" in front of the command lines

```
;execute TDC4HM-DAq-Parameters.ccf
```

and

```
;LoadDAQModule DAq_TDC4HM.dll,Applicationpath
```

For **HM1**: remove the ";" in front of the command lines:

```
;execute HM1-DAq-Parameters.ccf
```

and

```
;LoadDAQModule DAq_HM1.dll,Applicationpath
```

For **TDC8PCI2**: remove the ";" in front of the command lines

```
;execute TDC8PCI2-DAq-Parameters.ccf
```

and

```
;LoadDAQModule DAq_TDC8PCI2.dll,Applicationpath
```

Generally, everything from ";" (including) in a command line will be ignored as input, i.e. it is considered as a comment.
For this reason, ***spectrum* titles, *condition* titles, axis titles, etc. that are part of a command line (or a comment in the "new" command) CANNOT contain semicolons**. Likewise, **commas CANNOT be used in above titles, etc**. because commas are interpreted as parameter separators in command lines. For non-integer numbers within a command line **the decimal point "." must be used to separate integer and decimal space.**
If you need to use "," or ";" as input use a leading and ending " character.
For example: `setspectrumtitle 5,"Testing , and ; character"`

The "Startup.ccf" begins with the following commands/parameter settings common to all different hardware components, followed by hardware-specific commands, data analysis specific commands and finally commands to define spectra and begin the data acquisition (see sub-sections):

`Restart`	reset of any earlier commands and definitions
`setpath APPLICATIONPATH`	sets the file paths to the directory containing the Cobold.exe
`LoadDAqModule DAq_TDC8HP.dll,Applicationpath`	loads the hardware DAq module. For **HM1** or **TDC8PCI2** replace **TDC8HP**
`LoadDAnModule DAn_Standard.dll,Applicationpath`	loads the DAn module

Internally used *parameters* are marked in a gray color.
Some *parameters* are auto-set by hardware-specific program codes (such as *parameter 20*: TDC resolution), some others may be overwritten when a collected list-mode data file is re-analyzed off-line. Specific *parameters* such as parameter 32 (number of channels) or *Parameter 33* (number of hits per channels) will be overwritten by the values corresponding to the data-file. Unless you change the list of hardware *coordinates* on purposes, automated definition commands (such as `SetDAQCoordinates,Ch??n,Ch??S??`) adjust the hardware *coordinate* set accordingly. However, some *spectra* definitions may miss *coordinates* and lead to error messages. Therefore, *spectrum* definition commands can be replaced by the `try define1` or `try define2` commands which will ignore the definition command without comment if a *coordinate* or some *parameter* is missing or undefined. In such case you will find less *coordinates* and *spectra* defined than you expect. With the `show` command you can always control what was defined.

* In case of **Hexanode** this is mandatory for final calibration.

`Parameter 2`	*Time stamp* for an event as obtained from the CPU (or TDC in case of the **TDC8HP**). Setting this parameter to 1 or 2 will record the time stamp with each event as 32bit or 64bit value (0 = acquisition start). Please note that the accuracy of the recorded time is not guaranteed. In case of the **HM1** and **TDC8PCI2** the CPU time is written with an accuracy of a several microseconds. In case of the **TDC8HP** the internal TDC clock is with an accuracy of 25ps. 0 = no Timestamp, 1 = 32Bit Timestamp (Low.Low, Low.High) 2 = 64Bit Timestamp (Low.Low, Low.High, High.Low, High.High)
`Parameter 5`	*Time scaling* (internal parameter). Used to calibrate the time stamp.
`Parameter 6`	DAq-version number (internal parameter)
`Parameter 7`	Start time of list mode file (internal parameter)
`Parameter 8`	DAq-ID (internal parameter)

DAQ_ID_RAW	0x000000	for RAW (no Data)
DAQ_ID_HM1	0x000001	for HM1 (single)
DAQ_ID_TDC8	0x000002	for TDC8/ISA/PCI
DAQ_ID_CAMAC	0x000003	for CAMAC
DAQ_ID_2HM1	0x000004	for 2 HM1
DAQ_ID_2TDC8	0x000005	for 2 TDC8
DAQ_ID_HM1_ABM	0x000006	for HM1 ABM Mode
DAQ_ID_HM1_LR	0x000007	for HM1 LR Mode
DAQ_ID_HPTDC	0x000008	for TDC8HP
DAQ_ID_HPTDCRAW	0x000010	for HPTDC writing RAW data
DAQ_ID_FADC8	0x000011	for FADC8
DAQ_ID_FADC4	0x000012	for FADC4

`Parameter 9`	LMF-version number (internal parameter)
`Parameter 20`	TDC resolution in ns. (internal parameter. Do not set)
`Parameter 21`	TDC data type information (internally set) 0 = Not defined 1 = Channel information 2 = Time information (in ns)
`Parameter 32`	number of channels (from 1) to be read out (only up to 18 recommended)
`Parameter 33`	number of hits per channel to be read out (should be only 1 or 2 recommended)
`Parameter 40`	DataFormat (Internally set)
`Parameter 50`	unique ID-number checking compatibility of CCF with DAq

4.4.1 Hardware-specific commands: DAq-parameters and coordinates

`execute TDC8HP-DAq-Parameters.ccf` executes the commands in the specific file, here for **TDC8HP**, if you use different hardware please enable a different sub-script execution (see above).

The following commands are part of the standard.ccf file. For details please refer to the **TDC8HP** manual. For the commands in the other parameter files for **HM1** and **TDC8PCI2** please also refer to the specific manuals. Sub-scripts as HM1-DAq-Parameters.ccf and TDC8PCI2-DAq-Parameters.ccf contains their specific hardware parameter set. In the startup.ccf there are two lines like ;execute. Just remove the appropriate ; according to your TDC.

```
Parameter 50,201311200000 ; check-ID (tests compatibility of CCF/DAq)
Parameter 53,1            ; display/process only every (n)th event but write all events to hard drive
                          ; (for high rate measurements)

Parameter 60,0            ; 0 = don't read driver config file (default 0)
Parameter 61,0x000000000  ; RisingEnable, 0 = none (register trailing edge of NIM signal: transition from -0.8 V to 0 V
;Parameter 61,0x000000080 ; RisingEnable on channel 8)*
;Parameter 62,0x1ff1ff1ff ; FallingEnable, Channel 1-9 on first TDC (#1 to #9), second TDC (#10 to #18) and
                          ; third TDC(#19 to #27), register leading edge of NIM signal: transition from 0 V to -0.8 V
Parameter 62,0x0001ff1ff  ; default for one or two TDC: register leading edges in channels define via Parameter 32
Parameter 63,0            ; TriggerEdge, 0 = falling, i.e. leading edge of NIM signal
```

* Setting *parameter* 61 to 0x00080 allows pulse height measurement via the ***CFDx*** output on channel 8 with some **RoentDek** CFD units. Parameter 33 must be set to 2 or higher.

```
Parameter 64,8              ; TiggerChannel, channel 8 for trigger
Parameter 65,0              ; OutputLevel, 0 = false
Parameter 66,1              ; GroupingEnable,    1 = true = 25ps binsize and max. +-200µs range
                            ;                    0 = false = 16ps binsize and max. +-32ms range
Parameter 67,0              ; AllowOverlap, 0 = false (0 = default)
Parameter 68,310            ; TriggerDeadTime, time in ns (recommended value: 10ns more than parameter 70)
Parameter 69,-300           ; GroupRangeStart, time in ns
Parameter 70,300            ; GroupRangeEnd, time in ns
Parameter 71,0              ; External Clock, 0 = false (0 = default, should be 1 if two TDCs are synched)
Parameter 72,1              ; OutputRollovers, 1 = true (1 = default)
Parameter 78,1              ; VHR (TDC8HP only: 0 = 100ps LSB, 1 = 25ps LSB)
Parameter 79,0.2            ; Group Timeout in seconds (default 0.2s, do not adjust)
Parameter 80,0              ; INL, 0 = false = do not read file (default)
Parameter 81,0              ; DNL, 0 = false = do not read file (default)
Parameter 86,1              ; MMXEnable (never set to 0, always 1)
Parameter 87,1              ; DMAEnable (never set to 0, always 1)
Parameter 88,0              ; time zero channel, set all times (parameter 64) relative to last hit in this channel
                            ; please set to 0 if not used. "Grouping" must be disabled (parameter 66)
Parameter 89,0x00000000     ; Trigger channel mask (active only when parameter 66 is set to 0)
```

From these DAq parameters the following are of special interest and are therefore explained in more detail here:

`Parameter 53` NumberOfDAQLoops (normally 1)
The maximum data read-out speed from the hardware may not be reached if all events are processed through on-line analysis and spectra sorting routines. Therefore it may be necessary to increase this *parameter* value for example to n = 10. In this example, only every 10[th] event will be sent to the DAN for on-line analysis and sorted into spectra, while <u>all</u> events are stored in the listmode file for later off-line analysis

`Parameter 61`
`Parameter 62`
`Parameter 63` These parameters determine whether the leading (falling) edge of a signal on a certain input channel and/or the trailing (rising) edge of the signal shall be registered as a "hit", i.e. if a certain TDC channel is "switched on" to register a certain transition of type falling and/or rising. The nine digits following *0x* code three hex numbers (grouped in triples for up to three TDC cards) with possible values *000* to *1ff* for each triple (the right triple codes the "first" TDC having the lowest serial number, thus defining channels #1 to #9). Likewise, the second TDC (if any) is coded in the middle three digits and defines channels #10 to #18. Each triple codes in binary values *000000000* to *111111111*. These 9 digits denominate the 9 channels of the respective TDC card (the ninth channel is the one with low resolution, labled *T*). Value 1 in a digit enables the respective TDC channel for registering a certain NIM transition (falling/leading, respectively) Example: binary 10000000 corresponds to 0x80 and only channel #8 would register a certain transition, while *1ff* would enable all 9 channels of a TDC. If for a certain channel both the leading and the trailing edge are enabled, the trailing edge will be registered as second hit in this channel.

`Parameter 64` TriggerChannel: Determines the trigger input channel (1-9)

`Parameter 68` TriggerDeadTime: Defines the time range in ns before a next signal in the trigger channel will be considered as the trigger for the next event. Recommended value: 10ns more than parameter 70.

`Parameter 69` GroupRangeStart: from this time (in ns, minimum -2E5) relative to the trigger signal all signals in the other channels are registered as belonging to the same event until

`Parameter 70` sets the GroupRangeEnd as time in ns (maximum 2E5) after the trigger for this event.

`Parameter 78` VHR-flag: Enables the **TDC8HP**'s very high resolution mode with an LSB of 25ps (set to 1). Per default this parameter is set 1 (25ps LSB). For measurements in which more than 4 particles are expected within a time range of 400 ns or in measurements with signal rates exceeding 2 MHz it is recommend to set this parameter to 0.

`new` This command is defining the type of session but also validates/checks many parameter commands on consistency. It has to be given before the coordinate definitions

`SetDAQCoordinates,Ch??n,Ch??S??` defines coordinates for number of hits per channels and values for each hit according to parameters 32 and 33. This command (for parameter 32 = 10 and parameter 33 = 2) is the equivalent to the following "manual" coordinate definition block:

`;Coordinate Ch01n,Ch01S01,Ch01S02;` note that it is possible to define several coordinates in one

`;Coordinate Ch02n,Ch02S01,Ch02S02;`	command line separated by “,”.
`;Coordinate Ch03n,Ch03S01,Ch03S02;`	Example: Ch02n is the coordinate for the number of hits
`;Coordinate Ch04n,Ch04S01,Ch04S02;`	in TDC channel 2
`;Coordinate Ch05n,Ch05S01,Ch05S02;`	Ch03S01 is the coordinate for the value of hit 1in
`;Coordinate Ch06n,Ch06S01,Ch06S02;`	TDC channel 3
`;Coordinate Ch07n,Ch07S01,Ch07S02;`	Ch04S02 is the coordinate for the value of hit 2in
`;Coordinate Ch08n,Ch08S01,Ch08S02;`	TDC channel 4
`;Coordinate Ch09n,Ch09S01,Ch09S02;`	TDC channel T (low resolution)
`;Coordinate Ch10n,Ch10S01,Ch10S02;`	first TDC channel of the second card (if installed)
`Coordinate LevelInfo;`	do not change or move this line

It is mandatory that the number and order of these so-called DAq *coordinates* are in accordance with the algorithms in the DAq dll module and the DAn dll module and also with the settings of *parameters* 32 and 33. The hardware *coordinates* and the *time stamp coordinate* (optionally) are stored in the list mode file if this function is enabled before the data acquisition starts (see `new` command).
The previous *parameters* of the DAq part have the function to define and organize the hardware (and are mandatory), the set of so-called DAn *parameters* is used in the data analysis part. During offline analysis of an earlier acquired list mode file some of these *parameters* are automatically set from the *parameter* information (settings during data acquisition) that is stored in the header of the list mode file.
For further computations with the obtained raw data (DAq *coordinates*), the DAn dll as a data analysis subprogram uses these DAq *coordinates* and creates computed *coordinates* (DAn coordinates), such as the position or time sum (TOF) derived from the raw data. It also comprises some correction, shifting and rotation computations and coordinate system transformations, so that the basic computations for experiments with a position and time sensitive detector are already available without changing the DAn dll as it was supplied with the **CoboldPC** program.
The DAn-*coordinates* are internally treated as independent *coordinates* and are internally listed by numbers, following the last DAq *coordinate*. However, the DAn *coordinates* will not be appended in the list mode file.
The DAn dll may be altered using the Microsoft-C++ compiler of Visual Studio 2010 or higher (see **CoboldPC** help file) and the list of *coordinates* may be changed (with any text editor), creating additional *coordinates* (and *parameters*) for further computation, unused DAn *coordinates* may be removed. Any newly defined *coordinate* is available for further computations. Note that the program will only operate normally, if all definitions are in accordance with the DAq dll and DAn dll modules used. After the `new` and `start` commands the program makes a consistency check and may give an error message if the number of *coordinates* and *parameters* defined are not sufficient, however, it may not detect all possible discrepancies.

4.4.2 Analysis specific commands: DAn parameters and coordinates

The *parameters* from 1000 onwards are reserved for DAn parameters. Note that some parameters (for DAq and DAn) are set automatically or values may be overwritten when reading a previously recorded list mode file.
The following DAn *parameters* used in the DAn part can have the function of variables for computations, of pointers or of flags. Some are mandatory, some are optional. The standard DAn will use the *parameter* range 1000-1999.

`Parameter 1050` check-ID (tests compatibility of CCF/DAn), for **CoboldPC 2011 R4** the value is `201102080000`

`Parameter 1000` internal DAN calibration parameter, do not change

`Parameter 1002` Hexanode calculation flag
- 0 = no Hexanode
- 1 = Hexanode (special version information displayed)
- 2 = Hexanode (no special version information displayed)

If a Hexanode is used additional calculations are required to retrieve the position information. For these parameters and coordinates please refer to the add-on manual.

`Parameter 1003` R-Phi coordinates conversion
- 0 = RAD [-π..π]
- 1 = RAD [0..2π]
- 2 = DEG [-180..180]
- 3 = DEG [0..360]

This parameter defines the angular range and unit for the *phi* coordinate in the R-Phi representation of the 2d-image.

`Parameter 1004` DNL correction (GP1/HM1 only)
- 0 = no DNL correction
- 1 = Correction value (typically 0.31)

`Parameter 1005` Start of DAq Data for DAn (Start Coordinate)

`Parameter 1006` Start of DAn Data (Start Coordinate)

	This pointer value defines the position in the coordinate list where the DAn coordinates begin, i.e. it should equal the number of hardware coordinates. If you want to analyze the data from the first hit you can set this value also to -1 and the program will automatically enter the right number.
`Parameter 1007`	Hit number to be analyzed. Usually the position coordinates are calculated from the first hit in the TDC channels (default value: 1). If you instead want to get position and time sum coordinates calculated for a different hit number you have to enter the hit value here. Note that it can happen that the values from different channels do not necessarily correspond to the desired particle hit number if reflections on the raw amplifier signals or missed signals produce "false" hits in a certain TDC channel.
`Parameter 1010`	Time to Position calibration factor for *PosX* coordinate ($v_\perp$ in mm/ns) DLD40: 1.32, DLD80: 1.02, DLD120: 0.77 For Hexanode (u): HEX80: 0.737, HEX100: 0.857 (for standard 2/3 wiring)
`Parameter 1011`	Time to Position calibration factor for *PosX* coordinate ($v_\perp$ in mm/ns) DLD40: 1.43, DLD80: 1.13, DLD120: 0.85 (for standard 2/3 wiring) For Hexanode (v): HEX80: 0.706, HEX100: 0.567 These two parameters define the value of position to time calibration, the effective signal propagation speed across the delay-line. It depends on the size and geometry of the delay-line used. The suggested values are only accurate within few percent for a given delay-line. If a higher precision is needed one needs to make a position calibration with a test mask in front of the detector. If the detector image boundary has an oval shape, exchange the values for X and Y (only for DLD) and try again sorting the data (may be the physical dimensions of the anode have been exchanged during mounting).
`Parameter 1012`	Time to Position calibration factor for the w-layer (Hexanode only): HEX80: 0.684 HEX100: 0.81

Please note that it is required to calibrate the numbers for parameters 1010-1012 for a Hexanode anode more accurately. Additional software can be provided for **Hexanode** calibration. Please contact **RoentDek**.

`SetDAnResolutionParameters;` This command pre-sets *parameters 1013* to *1019*

Parameters 1013 to 1019 can be used for defining bin sizes of spectra. These are defined here via a `UserFCall` command which yields the same bin size values as from computations via the `parsemathcommand` function *parameters* in the lines below as stated in SetDAnResolulutionParameters.ccf. `Parsemathcommand` and `UserFCall` are newly introduced command classes explained in Chapter 4.4.

`parsemathcommand reset;`	resets early *parsemathcommands*
`parsemathcommand p1013 = p1010*0.5*p20;`	high resolution binning
`parsemathcommand p1014 = p1011*0.5*p20;`	high resolution binning
`parsemathcommand p1015 = p1010*2.0*p20;`	normal resolution binning
`parsemathcommand p1016 = p1011*2.0*p20;`	normal resolution binning
`parsemathcommand p1017 = p1012*2.0*p20;`	normal resolution binning
`parsemathcommand p1018 = p1010*8.0*p20;`	coarse resolution binning
`parsemathcommand p1019 = p1011*8.0*p20;`	coarse resolution binning
`parsemathcommand execute;`	the above lines are executed only once

The pre-defined values for *parameters 1013* to *1019* can be modified simply by overwriting the `parameter` commands, either with by enabling the `parsemathcommand` lines (and changing the computation formulas) or by setting the *parameter* with standard commands as below

```
;Parameter 1018,1;
;Parameter 1019,1;
```

`Parameter 1020`	Rotation offset center for coordinate *PosX*
`Parameter 1021`	Rotation offset center for coordinate *PosY* These parameters define the center point for an online detector image rotation and also the center point in the X/Y plane for a coordinate transformation into R/Phi representation. Note that R/Phi transformation will only give good results if the position unit is mm (see parameter 1000).
`Parameter 1022`	Rotation angle in mathematical direction (counter clock wise) for an online detector image rotation (value to be supplied in RAD or DEG depending on parameter 1003)
`Parameter 1023`	X-value of center for r/phi coordinate computation
`Parameter 1024`	Y-value of center for r/phi coordinate computation

`Parameter 1025`	MCP channel number. If the trigger signal is NOT the MCP signal the parameter 1025 shall contain the channel number of the MCP signal to achieve sum spectra with the time reference set to the MCP signal.

Parameters 1026 to 1032 can be used to change the assignment of the "raw" DAq coordinates from TDC channels to the calculated (DAn) *coordinates x1, x2, ...*

`Parameter 1026`	channel number for *x1*
`Parameter 1027`	channel number for *x2*
`Parameter 1028`	channel number for *y1*
`Parameter 1029`	channel number for *y2*
`Parameter 1030`	channel number for *z1* (ignored if parameter 1002 = 0)
`Parameter 1031`	channel number for *z2* (ignored if parameter 1002 = 0)
`Parameter 1032`	channel number for *TOF* (0 if not used)
`Parameter 1035`	Offset for *PosX*
`Parameter 1036`	Offset for *PosY* These two parameters are offset (additive) constants for shifting the detector image in the X/Y plane. Note, that in case of the Hexanode these values define the offsets for the calculated x and y and not for the raw u and v values.
`Parameter 1037`	Offset for third anode layer (added to w, only for Hexanode)
`Parameter 1038`	Offset for *Sum/Diff* coordinate calculations. This offset value is an additive constant to all time *Sum/Diff* coordinates
`Parameter 1039`	Anti-Moire (0 = no, 1 = yes)
`Parameter 1040`	Reset EventCounter (1: reset after "new" command, 0: no reset)
`Parameter 1041`	Integration time in seconds for *RealTriggerRate* coordinate
`Parameter 1060`	Condition flag: value will appear as value in coordinate *Condition1*

The following DAn *coordinates* are by definition only the additional *coordinates* that are computed from the (raw) DAq *coordinates* retrieved from the hardware or from a previously accumulated event file (not part of a list mode file). Here, only one set of delay-line read-out relevant *coordinates* for one of the hits (default: first hit, see *parameter 1005*) is selected and position and time coordinates are calculated. If you have changed *parameter 2*, *32* or *33* from their default value (first hit only) or if you sort a listmode file acquired with non-default *parameter* settings you need to adjust the (pointer) *parameters 1005* and *1006*. It is such possible to apply the position and time calculations to the next hits if such are (or have been) acquired. The DAn module will read the values of the status registers and the value in the 4 (Hexanode: 6) raw position *coordinates* (and optional *TOF*) defined by *parameter 1005* (default: first hits) and calculate the desired position and time information. Note that even for the use of a DLD (4 delay-line signals only), the *coordinates* for two additional delay-line signals (as from a Hexanode) are defined but set to zero. A set of DAn *coordinates* is created by using the defined set of DAq *coordinates*:

`Coordinate AbsoluteEventTime`	defines the absolute event time and
`Coordinate DeltaEventTime`	the time between one event and the next
`Coordinate EventCounter`	event number since start or last event number reset
`Coordinate True`	internal coordinate
`Coordinate False`	internal coordinate
`Coordinate ConsistencyIndicator`	The value of this coordinate is: $\sum u \cdot 2^{i-1}$, i is the TDC channel, u =1, if at least one hit in the TDC channel i was registered, otherwise 0. If each TDC-channel for the selected hit number has received at least one hit of the value is 15 for a DLD and 63 for a Hexanode. This assumes that the first TDC channels are used for the delay-line signals.
`Coordinate PLLStatusLocked`	internal coordinate for HM1 (see manual), must always be defined
`Coordinate RealTriggerRate`	calculates the trigger (count) rate (please see parameter 1041)
`Coordinate Condition1`	the value of this coordinate is set by a condition command
`Coordinate n1,n2,n3,n4,n5,n6,n7,n8`	number of hits in the TDC channels 1-8 (not higher than parameter 33)
`Coordinate x1,x2`	Values in the TDC channels 1-6, "position calibrated" in mm. For Hexanode: x = u, y = v, z = w (not used for DLD)
`Coordinate y1,y2`	If parameter 1010 to 1012 are set to 1 these values correspond to time calibrated
`Coordinate z1,z2`	values (in ns).

`Coordinate TOF`	Values in the TOF-TDC time calibrated in ns (see parameter 1032)
`Coordinate raw_x,raw_y,raw_w`	difference of TDC channel values 1&2, 3&4, 5&6 (uncalibrated)
`Coordinate raw_sumx,raw_sumy,raw_sumw`	sum of TDC channel values 1&2, 3&4, 5&6 (uncalibrated)
`Coordinate raw_sumxyw`	sum of TDC channel values 1 to 6 (DLD 1 to 4 only)
`Coordinate raw_diffxy`	sum of TDC channel values 1&2 minus sum of 3&4 (not useful for Hexanode)
`Coordinate sumx,sumy,sumw,sumxyw`	same as *raw_sum…* but calibrated in ns and shifted (parameter values) example: *sumx* = *x1* +*x2* + pOSum
`Coordinate diffxy`	same as *raw_diffxy* but calibrated in ns and shifted (parameter values)
`Coordinate PosX,PosY`	calibrated position coordinates after shift/rotation (parameter values) example: *PosX* = *x1* - *x2* + pOPx, and possibly rotated (for Hexanode: *Xuv* + pOPx and *Yvw* + pOPy)*
`Coordinate r,phi`	calibrated position coordinates in R/Phi coordinate system
`Coordinate Xuv,Yuv,Xuw,Yuw,Xvw,Yvw`	only for Hexanode: calibrated position coordinates retrieved from respective two layers, *Xuv*/*Xuw* use only the u layer
`Coordinate dX,dY`	control coordinates: difference between *Xuv*/*Xvw* and *Yuv*/*Yvw*
`Coordinate reflection_in_MCP`	control coordinate: time between second and first hit in TDC channel 8 (MCP) in ns. Can also be used to measure the signal width on channel 8 (see below)

`Coordinate reflection_in_x1,reflection_in_x2`
`Coordinate reflection_in_y1,reflection_in_y2`
`Coordinate reflection_in_z1,reflection_in_z2`
	control coordinates: time between hit on one delay-line contact and second hit on the other contact of the same delay-line, for all layers and all ends (z only for Hexanode)

`SetHitMatrixCoordinatesAndSpectrum,Const??,Ch??n,n_matrix_x,n_matrix_y;`	Defines HitMatrix Coordinates (ConstXX, n_matrix_x, n_matrix_y) and HitMatrix Spectrum according to parameter 32 and 33

This special command defines the so-called "Hit Matrix" which displays the number of hits per TDC channels in form of a two-dimensional map: a spectrum (see Chapter 4.4.3). For this a set of internal coordinates is defined:
Const01,…, ConstXX, n_matrix_x, n_matrix_y (XX is the number of channels according to the value of parameter 32)

4.4.3 Spectra and condition definition commands

The final purpose of the data acquisition is to display and analyze the acquired data. For this purpose it is possible to define *spectra* for observing the value range and frequency of the defined *coordinates*. A spectrum is a histogram over a predefined range and fix bin width (thus defining the number of bins), either as a one- or two dimensional array of these bins. For a one-dimensional *spectrum* this resembles a graph, the bins forming a row of columns along the ordinate (X-axis), the frequency of certain values determine the respective columns' heights (along the Y-axis of this graph). As data are acquired (or read from a list-mode file), the value of the *coordinate* for each event will be attributed to the closest bin and the histogram content (the column height) in this bin will be incremented by one unit. Such a histogram (*spectrum*) could for example show the distribution of time of flight values for a number of acquired events, or computed values from raw data as is displayed in Figure 4.10.

* In order to get an optimal image from a Hexanode it is important to calibrate the layers accurately using add-on software

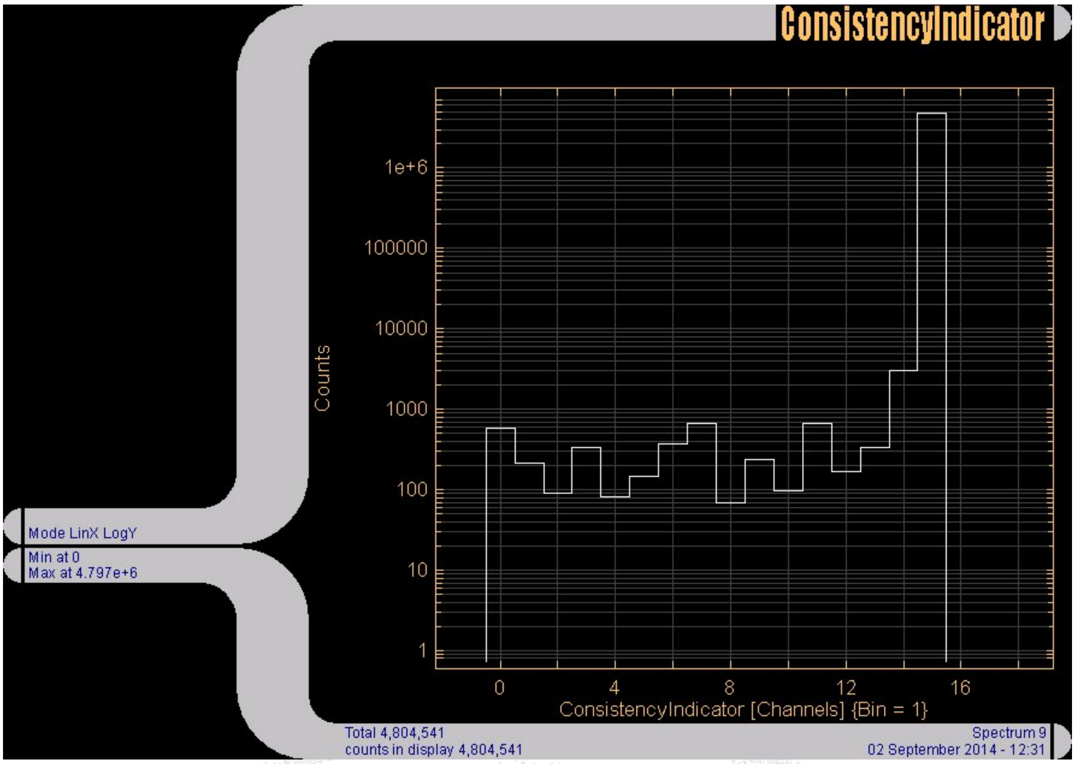


Figure 4.10: Typical one-dimensional spectrum (here: showing the value distribution of the coordinate `ConsistencyIndicator` for a DLD) in logarithmic scale. The `ConsistencyIndicator` (CI) spectrum gives an overview whether all signals from the delay-line anodes are always present or which one(s) are occasionally missing. CI is calculated from the number of hit values > 0 in those four TDC channels (or six, in case of Hexanode) that are attributed to delay-line anode signals: CI = $\sum k \cdot 2^c$, with c = number of channel (1 to 4 or 6) and k = 0 with no hit present in TDC channel c or k = 1 if the hit number in this TDC channel is > 1. If all channels have registered at least one hit, CI equals 15 for DLD and 63 for Hexanode

Likewise it is possible to display two-dimensional *spectra*, i.e. the simultaneous occurrence of values pairs in two different *coordinates* within the corresponding bin widths in form of a map (for example the 2d position distribution of detected particles). To visualize such a histogram the two *coordinates* span a plane (X/Y) like a checkerboard, each bin corresponds to a field on this checkerboard which identified by specific values of the respective X- and Y-*coordinates*. The frequency (Z) for occurrence of value pairs in each bin is displayed as gray or color scale (see Figure 4.11), also contour lines or scatter plots can be used for display. The range of the displayed *spectra* in X, Y (and Z), the bin size(s) and the "unit" of incrementing ("weighparameter") can be defined for optimal visualization and manipulation.

To analyze multi-fold *coordinate* correlations in the data it is possible to "gate" the *spectrum* incrementing process by defining a *condition* for sorting data into a *spectrum*. Such a condition can be a "gate" (or window, region of interest, value range) on the occurrence of values for another *coordinate* (not displayed) within a certain range. For example, one can generate different 2d spatial *spectra* (i.e. maps) of particle position distributions as function of their time-of-flight (TOF). For this one needs to define several conditions (gates) on the TOF *coordinate* and attribute the position *spectra* to the different *conditions*. It is also possible to couple different *conditions* (e.g. by an "AND") to allow the analysis of even higher-dimensional *coordinate* correlations.

For details about the definition of *spectra* and *conditions*, for *spectrum* manipulation options and data I/O to other programs please refer to the **CoboldPC** manual. Examples will also other be given below. All *spectra* and *conditions* must be defined by the user before the acquiring re-sorting data, e.g. via executing the Startup.ccf file or other.

The only internally defined *spectrum* is the `HitMatrix` *spectrum*, leading the list of defined *spectra* as number zero. It is defined with a specific command (see above).

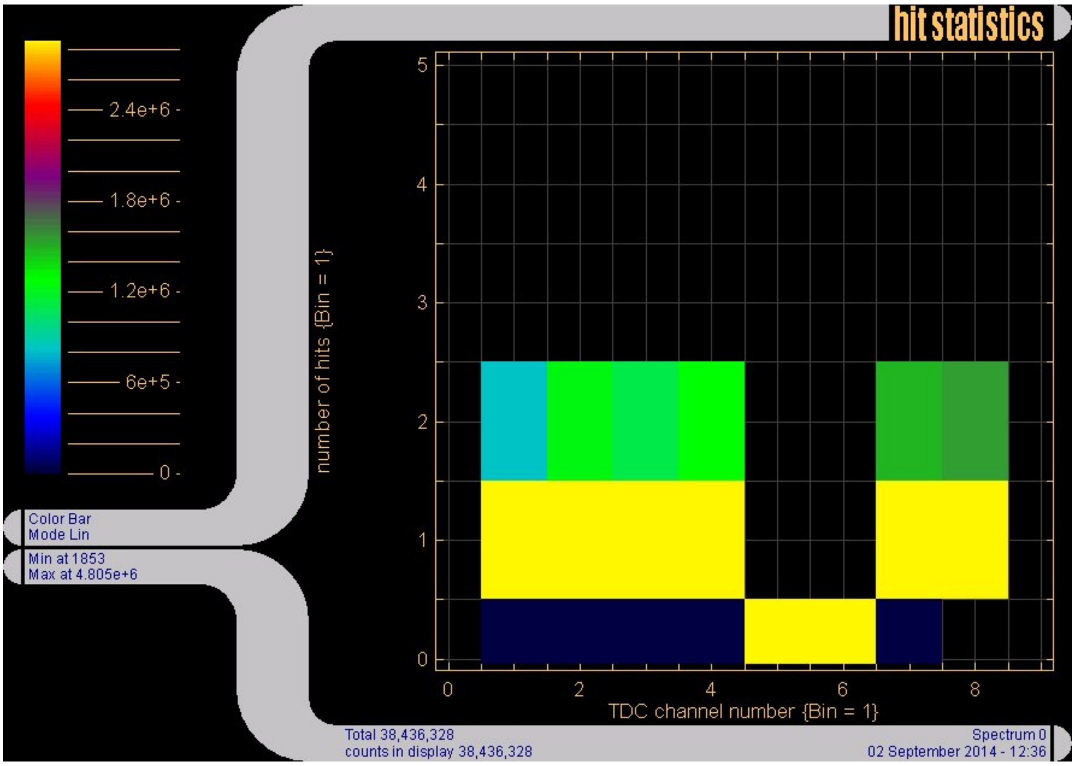


Figure 4.11: Two-dimensional Hit matrix spectrum showing the distributions of hit numbers (Y-axis) for the different TDC channels (X-axis). The respective abundances (Z) are color-coded here and correspond to the height of columns in a 3-dimensional representation. Note, that only up to two hits are displayed here because this was set as number of hits to be recorded (*parameter* 33) independent from the actual number of hits during the `GroupRange` (defined by *parameters* 69 and 70). The *spectrum* definition is automatically done as function of *parameters* 32 and 33 as was set for data acquisition.

In the following you find some pre-defined *conditions* (as examples) and *spectra* as part of the "startup.ccf" that will allow you to view the most important *coordinates*. For example, you will immediately be able to see a position *spectrum*. You may later edit the "startup.ccf" and all sub-scripts to adjust them to your needs, e.g. setting the right *condition* gates on the time sum peak(s), omitting *spectra* that you do not need, adjust *parameters* (for shifting or rotating the *spectra*, calibrating position and time), changing or appending *spectrum* definitions. For the Hexanode an extra software package is available to optimize its function. Please contact RoentDek on the availability of specific software packages for your application.
The following *condition* and *spectra* definition commands are recommended for first time users. Those definitions disabled by the ";" may also be of use and can be activated by removing the ";" in front of each command line:

`condition ConsistencyIndicator,14.5,15.5,clean_hit;`	true if x1,x2,y1 and y2 signals were registered (DLD)
`;condition ConsistencyIndicator,62.5,63.5,clean_hit;`	true if x1,x2,y1,y2,z1,z2 signals were registered (Hexanode)

`condition sumx,1,1000,sumx`	condition on time sum regions(here:x-layer)
`condition sumy,1,1000,sumy`	to be narrowed to actual peak widths
`;condition sumx,and,sumy,sum;`	combination between time sum gates
`;condition sumw,1,1000,sumw;`	
`condition sumxyw,1,1000,sum;`	

This defines a more specific filtering for "clean" events. The boundary parameters for sumx and sumy *conditions* should be narrowed according to the actual time peak widths/positions.

Examples for empty *spectra* definition (for spectra computations or projections) are

```
;define1 -100,100,1,none,,none,always,Empty 1D
;define2 -100,100,1,none,,-100,100,1,none,,none,always,Empty 2D
```

The following *spectra* display the number of hits per TDC channels in various representations (only those spectra will be defined where the *coordinates* exists), and the rate of the trigger signals.

```
try define1 0,32,1,Ch01n,,none,always,Ch01n
try define1 0,32,1,Ch02n,,none,always,Ch02n
try define1 0,32,1,Ch03n,,none,always,Ch03n
try define1 0,32,1,Ch04n,,none,always,Ch04n
try define1 0,32,1,Ch05n,,none,always,Ch05n
try define1 0,32,1,Ch06n,,none,always,Ch06n
try define1 0,32,1,Ch07n,,none,always,Ch07n
try define1 0,32,1,Ch08n,,none,always,Ch08n
define1 -2,66,1,ConsistencyIndicator,,none,always,ConsistencyIndicator
define1 0,100000,10,RealTriggerRate,,none,always,RealTriggerRate,true

try define1 0,32,1,Ch09n,,none,always,Ch09n (low res 1st TDC)
try define1 0,32,1,Ch10n,,none,always,Ch10n
try define1 0,32,1,Ch11n,,none,always,Ch11n
try define1 0,32,1,Ch12n,,none,always,Ch12n
try define1 0,32,1,Ch13n,,none,always,Ch13n
try define1 0,32,1,Ch14n,,none,always,Ch14n
try define1 0,32,1,Ch15n,,none,always,Ch15n
try define1 0,32,1,Ch16n,,none,always,Ch16n
try define1 0,32,1,Ch17n,,none,always,Ch17n
try define1 0,32,1,Ch18n,,none,always,Ch18n (low res 2nd TDC)
```

The following `spectra` show the "raw" (uncalibrated) values of the first hits in the TDC channels.

```
try define1 -12000,12000,1,Ch01S01,Ch01S01 (x1 raw),none,always,Ch01S01,,true
try define1 -12000,12000,1,Ch02S01,Ch02S01 (x2 raw),none,always,Ch02S01,,true
try define1 -12000,12000,1,Ch03S01,Ch03S01 (y1 raw),none,always,Ch03S01,,true
try define1 -12000,12000,1,Ch04S01,Ch04S01 (y2 raw),none,always,Ch04S01,,true
try define1 -12000,12000,1,Ch05S01,Ch05S01 (z1 raw),none,always,Ch05S01,,true
try define1 -12000,12000,1,Ch06S01,Ch06S01 (z2 raw),none,always,Ch06S01,,true
try define1 -12000,12000,1,Ch07S01,Ch07S01 (TOF raw),none,always,Ch07S01,,true
try define1 -12000,12000,1,Ch08S01,Ch08S01 (Trigger),none,always,Ch08S01,,true
;define1 0,10000000,1000,EventCounter,,none,always,EventCounter,,true
;define1 0,10000,1,AbsoluteEventTime,AbsoluteEventTime [s],none,always,Time since Start,,true
define2 0,10000,10,AbsoluteEventTime,Time [s],0,10000,10,RealTriggerRate,Rate,none,always,Rate(time)
;define2 0,10000,10,AbsoluteEventTime,Time [s],0,1000000,1000,RealTriggerRate,Rate,none,always,Rate(time)
define1 0,0.005,0.00001,DeltaEventTime,DeltaEventTime [s],none,always,Time between Events,,true

try define1 -12000,12000,512,Ch09S01,Ch09S01 (low res_1),none,always,Ch09S01 (low res 1st TDC),,true
try define1 -12000,12000,1,Ch10S01,Ch10S01 (x1_2 raw),none,always,Ch10S01,,true
try define1 -12000,12000,1,Ch11S01,Ch11S01 (x2_2 raw),none,always,Ch11S01,,true
try define1 -12000,12000,1,Ch12S01,Ch12S01 (y1_2 raw),none,always,Ch12S01,,true
try define1 -12000,12000,1,Ch13S01,Ch13S01 (y2_2 raw),none,always,Ch13S01,,true
try define1 -12000,12000,1,Ch14S01,Ch14S01 (z1_2 raw),none,always,Ch14S01,,true
try define1 -12000,12000,1,Ch15S01,Ch15S01 (z2_2 raw),none,always,Ch15S01,,true
try define1 -12000,12000,1,Ch16S01,Ch16S01 (TOF_2 raw),none,always,Ch16S01,,true
try define1 -12000,12000,1,Ch17S01,Ch17S01 (Trigger_2),none,always,Ch17S01,,true
try define1 -12000,12000,512,Ch18S01,Ch18S01 (low res_2),none,always,Ch18S01 (low res 2nd TDC),,true
```

The following *spectra* give information on computed (raw) time sum and position *coordinates*

```
;define1 -5000,5000,4,raw_x,,none,always,raw_x (channels),,true
;define1 -5000,5000,4,raw_y,,none,always,raw_y (channels),,true
;define1 -5000,5000,4,raw_w,,none,always,raw_w (channels),,true
;define1 -1000,9000,4,raw_sumx,,none,always,raw_sumx (channels),,true
;define1 -1000,9000,4,raw_sumy,,none,always,raw_sumy (channels),,true
;define1 -1000,9000,4,raw_sumw,,none,always,raw_sumw (channels),,true
;define1 -3000,27000,4,raw_sumxyw,,none,always,raw_sumxyw (channels),,true
;define1 -5000,5000,4,raw_diffxy,,none,always,raw_diffxy (channels),,true
;define2 -5000,5000,10,raw_x,x1-x2 raw,-5000,5000,10,raw_y,y1-y2 raw,none,always,X/Y (u/v) raw,,true
;define2 -5000,5000,10,raw_x,u1-u2 raw,-5000,5000,10,raw_w,w1-w2 raw,none,always,u/w raw,,true
;define2 -5000,5000,10,raw_y,v1-v2 raw,-5000,5000,10,raw_w,w1-w2 raw,none,always,v/w raw,,true
```

If *parameters 1010-1012* = 1 the following time *spectra* for *x1*,…,*y2* (and also *z1*, *z2* with **Hexanode**) are calibrated in ns:

```
;define1 -300,300,p20,x1,ch1 Time,none,always,ch1,,true
;define1 -300,300,p20,x2,ch2 Time,none,always,ch2,,true
;define1 -300,300,p20,y1,ch3 Time,none,always,ch3,,true
;define1 -300,300,p20,y2,ch4 Time,none,always,ch4,,true
;define1 -300,300,p20,z1,ch5 Time,none,always,ch5,,true
;define1 -300,300,p20,z2,ch6 Time,none,always,ch6,,true

define1 -300,300,p20,TOF,TOF [ns],none,always,TOF;                 usually on ch7
```

if a ***CFDx*** circuit is used the TOF *coordinate* may be used to display pulse height distribution:

`;define1 -10,90,0.1,TOF,PHD [ns],none,always,PHD;`	if the CFDx "stop" out is on ch7 and MCP signal is trigger
`;define1 -10,90,0.1,TOF,PHD [ns],none,clean_hit,PHD;`	... and only the PHD for "clean" events shall be displayed
`;define1 -10,50,0.1,reflection_in_MCP,PHD [ns],none,always,PHD;`	if "CFDx" is on ch8 with trailing edge enabled (*Parameter* 61)
`;define1 -10,50,0.1,reflection_in_MCP,PHD [ns],none,clean_hit,PHD;`	... and only the PHD for "clean" events shall be displayed

Calculated and calibrated *spectra* definitions:

```
define1 1,400,p20,sumx,sumx Time [ns],none,always,sumx (ns)
;define1 1,400,0.1,sumx,sumx Time [ns],none,always,sumx (ns)
define1 1,400,p20,sumy,sumy Time [ns],none,always,sumy (ns)
;define1 1,400,0.1,sumy,sumy Time [ns],none,always,sumy (ns)
define1 1,400,p20,sumw,sumw Time [ns],none,always,sumw (ns)
;define1 1,400,0.1,sumw,sumw Time [ns],none,always,sumw (ns)
define1 1,900,p20,sumxyw,sumxyw Time [ns],none,always,sumxyw (ns),,true
;define1 1,900,0.1,sumxyw,sumxyw Time [ns],none,always,sumxyw (ns),,true
define1 -300,300,p20,diffxy,diffxy Time [ns],none,always,diffxy (ns),,true
;define1 -300,300,0.1,diffxy,diffxy Time [ns],none,always,diffxy (ns),,true
define1 -100,100,p1015,PosX,PosX [mm],none,always,PosX (mm),,true
define1 -100,100,p1016,PosY,PosY [mm],none,always,PosY (mm),,true
```

Position spectra definitions:

```
define2 -100,100,p1018,PosX,PosX [mm],-100,100,p1019,PosY,PosY [mm],none,clean_hit,PosX/PosY coarse (mm),true
```

If the *parameters 1010* to *1012* are set properly for the delay-line in use the spectra with *PosX* and *PosY* as *coordinates* show position values in mm. Specific *conditions* remove incompletely registered events and produce "clean" images. The *condition clean hit* may be replaced by a more refined *condition* (i.e. on the time sums).

```
definemulti Overview,hit statistics,PosX/PosY coarse (mm),sumxyw (ns),TOF;          overview
;definemulti Overview,hit statistics,PosX/PosY coarse (mm),sumxyw (ns),PHD;
```

gives an overview of several *spectra* of interest (up to four) in a multi-spectrum view

The user defined section is used to add your own *condition* and *spectrum* definitions here, for example position spectra with different resolution (bin size) or with different software gates.

```
;define2 -50,50,p1015,PosX,PosX [mm],-50,50,p1016,PosY,PosY [mm],none,clean_hit,PosX/PosY clean (mm)
;define2 -50,50,p1015,PosX,PosX [mm],-50,50,p1016,PosY,PosY [mm],none,sum,PosX/PosY sum (mm)
```

Control *spectra* as the following may be found useful for trouble-shooting:

```
;condition PosX,-10,10,dX1
;condition PosY,-10,10,dY1
;condition dX1,and,clean_hit,dX1clean
;condition dY1,and,clean_hit,dY1clean
;condition dX1clean,and,dY1clean,spot
```
These *conditions* define a local spot on the detector.

```
;define2 0,100000,100,AbsoluteEventTime,Time[s],50,150,0.1,sumxyw,sum [ns],none,spot,time walk
```
This *spectrum* can reveal fluctuations of the electronic timing due to temperature drift or else. The parameters in this *spectrum* definition must be fine-adjusted first.

```
;define2 -5000,5000,40,raw_x,x(u),-10,200,1,sumx,sumx [ns],none,clean_hit,x/sumx (clean_hit),true
;define2 -5000,5000,40,raw_y,y(v),-10,200,1,sumy,sumy [ns],none,clean_hit,y/sumy (clean_hit),true
;define2 -5000,5000,40,raw_w,w,-10,200,1,sumw,sumw [ns],none,clean_hit,w/sumw (clean_hit);true
```

These *spectra* show the time sum walk for the different delay-line layers.

```
;define2 0,150,p1015,x1,,0,150,p1015,x2,,none,clean_hit,x1/x2,true
;define2 0,150,p1016,y1,,0,150,p1016,y2,,none,clean_hit,y1/y2,true
;define2 0,150,p1017,z1,,0,150,p1017,z2,,none,clean_hit,z1/z2,true
```
These *spectra* show whether delay-line layer pickups give consistent data from both ends.

```
;define2 1,201,p1018,x1,PosX1[mm],-100,100,p1019,PosY,PosY[mm],none,always,X1/PosY (mm),true
```

This *spectrum* uses only data from one x-layer end for displaying the 2d detector image.

```
;define1 -10,1000,1,reflection_in_MCP,dt [ns],none,always,reflection in MCP signal (ns)
```

This *spectrum* shows the difference between the second and the first hit in ch8. If the second hit is produced by the trailing edge of each signal it shows the signals' width distribution. This is useful for operating the **RoentDek** *CFDx* units. The *spectra* below show the time difference distribution between a delay-line signal from a specific output (e.g. x1) and the signal portion that may have been reflected on the terminal and travels to the opposite end (e.g. x2, respectively) where it gets recorded as a "false" second hit. By plotting this *coordinate* which corresponds to T1Ch02S01 - T1Ch01S01 in this example gives information about the amount of reflection for channel x1. It is assumed here that the delay-line outputs are connected to the TDC channels in default order.

```
;define1 -10,400,1,reflection_in_x1,dt [ns],none,always,delay-line reflection in x1 (ns)
;define1 -10,400,1,reflection_in_x2,dt [ns],none,always,delay-line reflection in x2 (ns)
;define1 -10,400,1,reflection_in_y1,dt [ns],none,always,delay-line reflection in y1 (ns)
;define1 -10,400,1,reflection_in_y2,dt [ns],none,always,delay-line reflection in y2 (ns)
;define1 -10,400,1,reflection_in_z1,dt [ns],none,always,delay-line reflection in z1 (ns)
;define1 -10,400,1,reflection_in_z2,dt [ns],none,always,delay-line reflection in z2 (ns)
```

For Hexanode read-out, the following *spectra* show the differences between position calculations from different layers:

```
;define2 -100,100,p1018,PosX,PosX [mm],-5,5,p1015,dX,dX [mm],none,clean_hit,PosX dev (mm),true
;define2 -100,100,p1019,PosY,PosY [mm],-5,5,p1016,dY,dY [mm],none,clean_hit,PosY dev (mm),true
```

Now the data acquisition can be started:

```
start
sleep 2s;                this command delays the execution of the next commands so that data
;sleep 5s;               statistics can be acquired (larger delays may be needed when re-sorting larger lmf files
show status
view hit statistics
;update 2s
```

Note that the command definitions here shall only allow a "quick start" for the use of our delay-line detectors. You will then modify the lines for preparing a set of spectra with conditions suited for your detector operation task. Note that the order of commands is important because (for example) a newly defined *spectrum* containing a *condition* requires that this *condition* was defined earlier.

More advanced data treatments like defining new (computed) coordinates to the analysis can be done via the *Parsemathcommands* (see below) and by additionally modifying the DAn dll module using a MS C++ compiler of Visual Studio 2011 or above. Please refer to the **CoboldPC** manual for details.

4.4.4 Advanced command classes: `UserFCall` *and* `Parsemathcommand`

The `UserFCall,command` defines a new class of commands beyond the standard commands in **CoboldPC**. The list of these commands is continuously amended by responding to requests of users. Due to the special nature of some of these commands it cannot be guaranteed that a given command from this class works or gives useful results for your specific application or **CoboldPC** compilation.

An example of such a command is

```
UserFCall,fitg
```

which can be used to conform Gauss fit on a region of interest in a spectrum where the standard `fit gauss` command does not produce useful results.

Due to the fact that UserFCall is included into the standard search for commands (except for UserFCall,help), the above command can also be submitted as

```
Fitg
```

Internally it will converted and transferred to **CoboldPC** command execution as

```
Call UserFCall,fitg
```

Command execution processing in **CoboldPC** tries the following order until success

1. Direct **CoboldPC** command
2. Use Execute command
3. Use *CallMyFunction* command
4. Use *CallMyFunction UserFCall,…* command
5. Display Error Information!

For a list of predefined *UserFCall* commands and how to use them, type

```
UserFCall,help
```

The command class `Parsemathcommand` allows performing mathematical operations from within a CCF-file. One can for example create new custom-defined *coordinates* which contain values from mathematical operations with other *coordinates* or *parameters*. This relieves the user of doing the same by compiling a modified DAn.dll by C++ programming.*

It is very important to note that a `Parsemathcommand` is not immediately executed like standard commands in a ccf-file or `UserFCall` commands. The `Parsemathcommand` are internally stored at first in a list of "to-be-executed" commands. Only when the command

```
Parsemathcommand execute
```

is given all early command lines in the ccf will be executed <u>once</u> in listed order.

With the command

```
Parsemathcommand reset
```

a list of `Parsemathcommand` lines given earlier in the ccf-file list is cleared and will not be executed. This is useful to avoid unwanted commands that may still be internally stored for execution due to inadvertent prior commands. This command is comparable in application and function of the standard **CoboldPC** `restart` command). It is recommended to group all `Parsemathcommand` lines that shall be executed only once in a group and those to be executed for each event loop in another group, beginning each group with `Parsemathcommand reset`.

Example:

`;parsemathcommand reset;`	resets early *parsemathcommands*
`parsemathcommand p1013 = p1010*0.5*p20;`	high resolution binning
`parsemathcommand p1014 = p1011*0.5*p20;`	high resolution binning
`parsemathcommand p1015 = p1010*2*p20;`	normal resolution binning
`parsemathcommand p1016 = p1011*2*p20;`	normal resolution binning
`parsemathcommand p1017 = p1012*2*p20;`	normal resolution binning
`parsemathcommand p1018 = p1010*8*p20;`	coarse resolution binning
`parsemathcommand p1019 = p1011*8*p20;`	coarse resolution binning
`parsemathcommand execute;`	the above lines are executed only once

This sequence defines *parameters* which are computed from the value in *parameter 20*.

If no `parsemathcommand execute` command is given before data acquisition or a file-read is initiated by the `start` command, all `parsemathcommand` lines (since the last `parsemathcommand execute` or `parsemathcommand reset` command) will be executed <u>for each event</u> while data are read from a data file or from the hardware. These commands are used to compute/fill newly defined *coordinates* and/or *spectra* with values (according to the desired computation codes) like the standard DAn *coordinates* are computed according to predefined codes in the DAn.dll.

Example: A 2d position histogram (2d *spectrum*) from a DLD detector without using the *x1* coordinate is desired. For this a new coordinate *neg_x2* shall be defined with inverted values: *neg_x2* = - *x2* to be calculated for each event. Reason: If *neg_x2* is used as *coordinate* in a newly defined *spectrum* the resulting "position image" is not mirrored compared to the standard *spectrum* definition using *PosX* and *PosY* as *coordinates*. A newly defined *spectrum* can use this new *coordinate*.

To enable this the following command lines shall be pasted in the startup.ccf just before the `start` command:

* It is to note, however, that the data analysis runs faster when all those calculations that are done for each event are embedded in the DAn.dll

```
Coordinate neg_x2;                                  definition of the new coordinate
;parsemathcommand reset;
parsemathcommand execute;
define1 -1000,1000,p1018,neg_x2,PosX2[mm],none,always,PosX from neg_x2 (mm),,true
define2 -201,-1,p1018,neg_x2,PosX2[mm],-100,100,p1019,PosY,PosY[mm],none,always,neg_x2/PosY (mm),true
parsemathcommand neg_x2 = - x2
```

While the `parsemathcommand` defining the *parameter* will be executed only once, the last `parsemathcommand` will be executed for each event (as soon as the `start` command has initiated the data-read loop). With similar codes more advanced recalibrations of coordinate values can be done, e.g. non-linearity corrections.

It is also possible to directly fill a predefined *spectrum* with values.

Example:

```
define2 -60,60,p1018,none,X [mm],-60,60,p1019,none,Y [mm],none,always,parse_PHD1;
define2 -60,60,p1018,none,X [mm],-60,60,p1019,none,Y [mm],none,always,parse_counter1;
define2 -60,60,p1018,none,X [mm],-60,60,p1019,none,Y [mm],none,always,parse_PHD1_div;   PHD mean map
define1 -100,1000,1,none,Pulse height,none,clean_hit,PHD_hist;                         PHD spectrum

parameter 4000,0.;              increase parameter definition range
parameter 2107,400;             zero pulse height (here at 400) must be correctly set
parameter 2108,500;             calibration pulse height in Volts to time delay in TDC
;                               channels (should be correctly set)
Coordinate phd;                 pulse height coordinate (offset corrected)

parsemathcommand reset;
parsemathcommand phd=(T1Ch07S01-p2107)*p2108;
parsemathcommand if (phd > -0.1 && phd < 2 && sumxyw > 1);      condition set
parsemathcommand      fill_hist_1d(PHD_cal,phd);                fills spectrum PHD_cal with
                                                                actual values from coordinate phd
parsemathcommand      fill_hist_2d(parse_PHD1,PosX,PosY,phd);   fills 2d spectrum
parsemathcommand      fill_hist_2d(parse_counter1,PosX,PosY,1.);  fills 2d spectrum for normalization
parsemathcommand endif;
```

This command sequence is used to generate *spectra* (= histograms) of calculated values from a *coordinate* (here: pulse-height values of signals) under *conditions* that also can be set via a `parsemathcommand`.

Every standard **CoboldPC** command (e.g. `xyz`) can be executed via a `parsemathcommand`:

```
Parsemathcommand cobold_command(xyz);
```

Example:

```
Parsemathcommand cobold_command(update all);            update all spectra
```

The following `Parsemathcommands` are supported (in the following only the suffix after `Parsemathcommand`:is named here):

if ()
endif

the if-condition can contain several statements, e.g.: if (p0<0 && x==7)
These bool-operations are recognized: > , < , >= , <= , == , != , && , ||

Lxxx:

Sets a marker in a command sequence

goto Lxxx

The goto-statement jumps to the marker Lxxx. The marker must exist and its last character must be a ":".

sqrt(),exp(),sin(),cos(),atan2(x,y),tan(),abs(),mod(),x^y

Mathematical standard expressions

fill_hist_1d(h,x) or fill_hist_1d(h,x,w)
fill_hist_2d(h,x,y) or fill_hist_1d(h,x,y,w)

Spectrum fill commands:
h is either a *coordinate*, *parameter*, integer number (which defines the *spectrum* number) or a *spectrum* title of an existing *spectrum*. (if a h value is non-integer the closest integer number will be used):
x (and y) are the position(s) in the histogram and must be numbers, for example from an actual *coordinate* value or value pair (the closest bin in the *spectrum* will be filled)..
w is the number which will be added to the prior value in this bin. It may be a fix number, a *parameter* or *coordinate* value. If w is not defined then w=1 is used.

More examples of `parsemathcommand` sequences (independent from data acquisition):

These codes will plot a sinus curve into histogram number 0. Each fill-operation will use a weight factor of p0*2:

```
define2 0,180,1,none,x,-60,60,0.5,none,y,none,always,sinus_curve;
parameter 0,0;
parameter 1,0;
;Parsemathcommand reset
Parsemathcommand p0 = 0
Parsemathcommand p1 = 0
Parsemathcommand L100:;
Parsemathcommand p0+=1;
Parsemathcommand p1=50*sin(2.*p0*3.14/180)
Parsemathcommand fill_hist_2d(0, p0, p1, p0*2)
Parsemathcommand if (p0<180)
Parsemathcommand goto L100
Parsemathcommand endif
Parsemathcommand cobold_command(view 0)
Parsemathcommand execute
```

The following example will create an image of the Mandelbrot-set:

```
restart
define2 -2,1,0.01,none,x,-1.5,1.5,0.01,none,y,none,always,Mandelbrot
parameter 5,0
;Parsemathcommand reset
Parsemathcommand p0 = -2;
Parsemathcommand L100:;
Parsemathcommand p0+=0.01;
Parsemathcommand if (p0>1)
Parsemathcommand      goto L666
Parsemathcommand endif
Parsemathcommand p1 = -1.5;
Parsemathcommand L200:;
Parsemathcommand p1+=0.01;
Parsemathcommand if (p1>1.5);
Parsemathcommand      goto L100;
Parsemathcommand endif;
Parsemathcommand p2=0;
Parsemathcommand p3=0;
Parsemathcommand p4=0;
Parsemathcommand L300:
Parsemathcommand p2+=1
Parsemathcommand p5=p3
Parsemathcommand p3=p5*p5-p4*p4+p0
Parsemathcommand p4=2*p5*p4+p1
Parsemathcommand if (p3*p3+p4*p4 <= 4 && p2 < 100)
Parsemathcommand      goto L300;
Parsemathcommand endif
Parsemathcommand if (p2<100)
Parsemathcommand      fill_hist_2d(Mandelbrot,p0,p1,p2)
Parsemathcommand endif
Parsemathcommand goto L200
Parsemathcommand L666:
Parsemathcommand execute
```

```
update all
view 0
```

These examples shall show how the program can also be used for advanced data simulation purposes. One can create random data as may be produced by a real experiment and simulate the analysis.

4.4.5 Navigating inside spectra

4.4.5.1 The view command

The *view* command is used to display spectra. Beside the spectrum number it is possible to specify directly the boundaries for x, y and (for 2 dimensional spectra) z axis.

For example

View 5,0,100,-100,200

Displays the spectrum 5 and sets xmin to 0, xmax to 100, ymin to -100 and ymax to 200.
It is possible to skip entries for the boundary definition. In that case the value will not be changed. Only if there was now previous setting of that value, the value is recalculated due to the actual data.

View 5,0,100,,200

So here spectrum 5 will be displayed with xmin set to 0, xmax to 100 and ymax to 200. ymin is not changed

It is also possible to specify which axis needs a rescale.

View 5,y

Shows spectrum 5 after a rescale of the y axis

View 6,x,y,z

Shows spectrum 6 (here a 2 dinensional spectrum) rescaling al axis. This is equivalent to

View 6,r

Which shows spectrum 6 after rescaling all axes.

The command

View last

Show the last spectrum in the spectrum list. To display the first spectrum simply use *view 0*.

To modify directly one of the boundaries you may use the following commands:

xmin value
xmax value
ymin value
ymax value
zmin value
zmax value

To display the next or previous spectrum simply use *next* or *previous* command.

4.4.5.2 Special keyboard commands

The following keys are available

Number pad + or PAGE DOWN	displaying next spectrum
Number pad – or PAGE UP	displaying previous spectrum
ALT+Cursor right	shift spectrum by 80% to the right (increasing x axis)
ALT+Cursor left	shift spectrum by 80% to the right (decreasing x axis)

In 2 dimensional spectra

ALT+Cursor up	shift spectrum by 80% to the up (increasing y axis).
ALT+Cursor down	shift spectrum by 80% to the down (decreasing y axis).

To move only 10% in the specified direction add the CTRL key.

F5 rescales the last axis (in 1D it's y and 2D it'z) and updates the display.

4.4.5.3 Mouse commands

In CoboldPC 2011 R5 there will be mouse commands available.

When the cursor is over the spectrum area the cursor changes from arrow to cross mode. If the cross is displayed the following functions are available.

expand	click when cross is active for 1st corner, 2nd click for 2nd corner
zoom	use the mouse wheel. zoom center is the mouse cross center (not available in 1D xLog mode and 2D contour plots)
shift by drag	press the mouse button until mouse hand shows up or move the mouse while left mouse button is pressed (not available in 1D xLog mode and 2D contour plots)
right button click	opens the context menu for cut/paste/clipboard functions

5 The RoentDek High Voltage Supplies

Safe and high-performance operation of RoentDek detectors requires adequate high voltage supplies and auxiliary passive bias units. In the following the standard units are described. If you have received a different model, please refer to the respective manual.

5.1 The HV2/4 (/6 /8 /10) dual High Voltage supply module

The RoentDek 2×4kV High Voltage power supply is especially designed for biasing multi-channel-plate detectors, featuring low ripple and regulated current limitation and protection. It is usually powered by a NIM crate or via the RoentDek **SPS2(mini)** mains adapter (through the 9-pin socket on the rear side panel). Special versions of this module for up to 6, 8 and 10 kV (**HV2/6**, **HV2/8**, …) are available, also for "pseudo-floating" operation mode (see Chapter 5.2).

The switches on the side panel will set the respective channels A and B to negative or positive output polarity (not for **HV2/10**, which has factory-fixed polarities). The polarity is indicated by an LED on the front panel. **Only change polarity when mains power is off**.

If a channel of the power supply is switched on (indicated by an LED), and the "DAC" switch is set to the upward position, the 10-turn potentiometers on the front panel can be used for manual setting of the output potential U_o, 10 turns corresponding to U_{max} (e.g. 4 kV in case of the **HV2/4**) with linear progression. The voltages can also be set externally via an analog voltage input to the LEMO-sockets on the rear panel (0-10 V positive input corresponds to 0-4 kV voltage output for **HV2/4** (1:400) or 1 kV progression for every 1 V analog input for **HV2/6**, **HV2/8** and **HB2/10** (1:1000) with linear progression). For this the "DAC" switch must be set to "DAC". Please contact RoentDek for adequate DC level remote controls (e.g. the **USB-IO1, see Chapter 5.10**).

The A/B switch will allocate the display to channel A or B, the V/I switch will enable voltage or current reading of the respective channel. The accuracy of the reading is within a few volts and a few µA (typically 1 µA), respectively.

If a channel is turned on, the "Inhibit" input can be used for enabling / disabling the voltage output with a TTL level. Specified operation modes are:

a) Input open (resistance to ground > 10 kΩ) or level > +2.5 V: high voltage output is enabled
b) Input shorted (resistance to ground < 1 kΩ) or level < +1 V: high voltage output is disabled

Do not use input voltages outside of the range from 0 V to +6 V.

The "Inhibit" input can be used for remote safe-guarding or actively enabling/disabling the voltage output by applying a TTL level as described above. Notice: if the "Enable" switch is on "Kill" position, high voltage output must be resumed manually.

The maximum current I_{max} delivered is 3 mA for the **HV2/4** (1 mA for **HV2/6** and **/8**, and 0.5 mA for **HV2/10**). Both I_{max} and U_{max} can be restricted in 10 % steps (e.g. from 0.3 mA/400 V to 3 mA/4 kV for the **HV2/4**, the latter corresponding to 100 %). Usually the current limiter should set to 10 %, i.e. 0.3 mA when using it with a RoentDek MCP detector (exception: biasing via an **HVT** device).

If a pre-set limit is exceeded (e.g. too high current) a red "Error" LED on the front flashes once and the high voltage "trips": it turns off when the "Enable" switch on the front table is in the "Kill" position (see Figure 5.1, on channel B). Re-engagement must be manually prompted by turning the channel off and on again via the red main switch.

If the "Enable" switch is **not** in "Kill" position (see Figure 5.1, on channel A) the unit will automatically try to resume the set value. **The latter is NOT a favorable operation condition if the tripping is caused by detector sparks and may cause damage if prolonged. We strongly advise to operate the power supply only in "Kill Enable" mode**. In case of an "Error", turn off the voltage to 0 Volts and switch the module off. Do not turn it on again before a proper state for safe operation has been verified.

Figure 5.1: 2x4kV Power Supply (front panel)

Important: The safest operation mode for MCPs is the "Enable Kill" position. If the current limitation is set low and the switch is on this position it can happen that an error is indicated when starting to increase the voltage on a certain detector part, although no problem of the hardware actually exists. This is due to the loading current of capacitors in the power supply itself or in the signal decoupling circuits. In that case set the switch to the other direction when starting to increase voltage. You may switch to the "Enable Kill" position later after the voltage setting is finished.

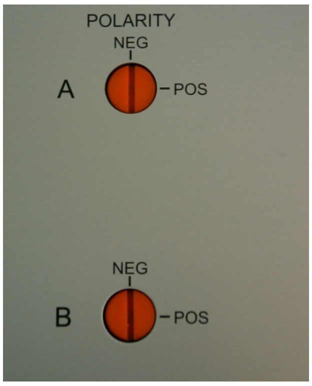
The hardware ramp speed is 500 V/s. (power switch or inhibit turned on/off.)

For standard modules the 9-pin socket located on the rear panel can be used to alternatively receive power via a **SPS2(mini)** mains adapter (in absence of a NIM crate. Pin assignments are

Pin1/2: ground
Pin6: -24 V, Pin7 +24 V for N24 modules (see Figure 5.9) and
Pin5: -6 V, Pin8: +6 V additionally for 6 V modules (not with N24 label)*

Further specifications:

Operation/storing temperature:	0 ... +50 °C / -20 ... +60 °C
Ripple (peak-to-peak)	< 50 mV_{pp} for all frequencies (**HV2/4** and **/6**)
	HV2/8 and **/10**: for < 1 kHz up to 200 mV_{pp}
Display reading precision	±0.1% plus 1 digit
Stability	$\Delta U_o < 2 \times 10^{-4}$ of U_{max} or 5×10^{-5} of ΔU_o
Temperature coefficient	$< 1 \times 10^{-4}$/°C



Changing the Polarity:
To change the polarity of either channel A or B, locate the corresponding "red knobs" on the left side-panel (see Figure 5.2, here: negative polarity is selected for both channels). **Only if the mains power is off** adjust the slit of the "red knob" to the desired polarity using either an adequate screwdriver or a coin. **Do not press on the knob! Do not use force!** The channel is adjusted if you hear and feel the lock click into place.

Figure 5.2 (left side): 2x4kV Power Supply

Warning: the HV output of this power supply can be hazardous if not properly operated. Never operate the module with open housing. **RoentDek** *denies any responsibility for accidents with their products and is protected by German laws. If you need special instructions how to handle high voltage power supplies please contact* **RoentDek**.

Notice: **HV2/4** and similar units may need an adequate pull-up preventer circuit like the **RoentDek HVT** when operating two channels at the same polarity supplying resistive-coupled contacts such as the two sides of an MCP stack (see Chapter 5.5).

For optimal stability of the set values it is recommended to operate the **RoentDek** high voltage power supplies mainly between 2% and 100% of U_{max}, e.g. between 80 V and 4000 V for the **HV2/4**. Lower voltage settings are possible but specs are not guaranteed below 1% of U_{max}. If you want to achieve stable voltage outputs well below 100 V with a **HV2/4**, **RoentDek** can provide a voltage divider based on the **RoentDek HVT+** passive voltage dividing unit (see Chapter 5.9).

Figure 5.3: 2x4kV Power Supply (rear-panel)

* Modules with 6 V operation (as displayed in Figure 5.3) can be used for routing voltages from a NIM bin to the 9-pin socket which acts then as a DC-output for ±6 V, ±24 V, +12 V (pin4) and -12 V (pin9) in order to bias other modules like the **DLATR6** and **ATR19-2**. Please observe the label next to the socket.

Module versions with the "KIB" label (see Figure 5.4) have an internal jumper switch that allows linking the "*Enable Kill*" function of both channels: If one of the channels experiences a current drain at the I_{max} set value (a "trip"), both channels will be turned off (but only if both channels are set to "*Enable Kill*"). The "kill both" (KIB) setting is of advantage when tripping of one channel alone will result in a problematic bias situation while the other channel maintains its set potential*. This is especially relevant for high voltage units with higher than 4 kV output.

Unless otherwise indicated the factory setting of the jumper position does NOT support the "kill both" functionality (see in Figure 5.5). The jumper for enabling the "kill both" functionality can be accessed after opening the side panel with the polarity switches (**before opening the case switch off both channels, wait for one minute and then remove all cable connections to the module, otherwise there is risk of electro-hazard. Only touch the inside at the jumper position!**). To enable the "kill both" functionality set the jumper to the position as shown in Figure 5.5, lower picture).

Figure 5.4: Label on the side panel indicating availability of the "kill both" functionality:

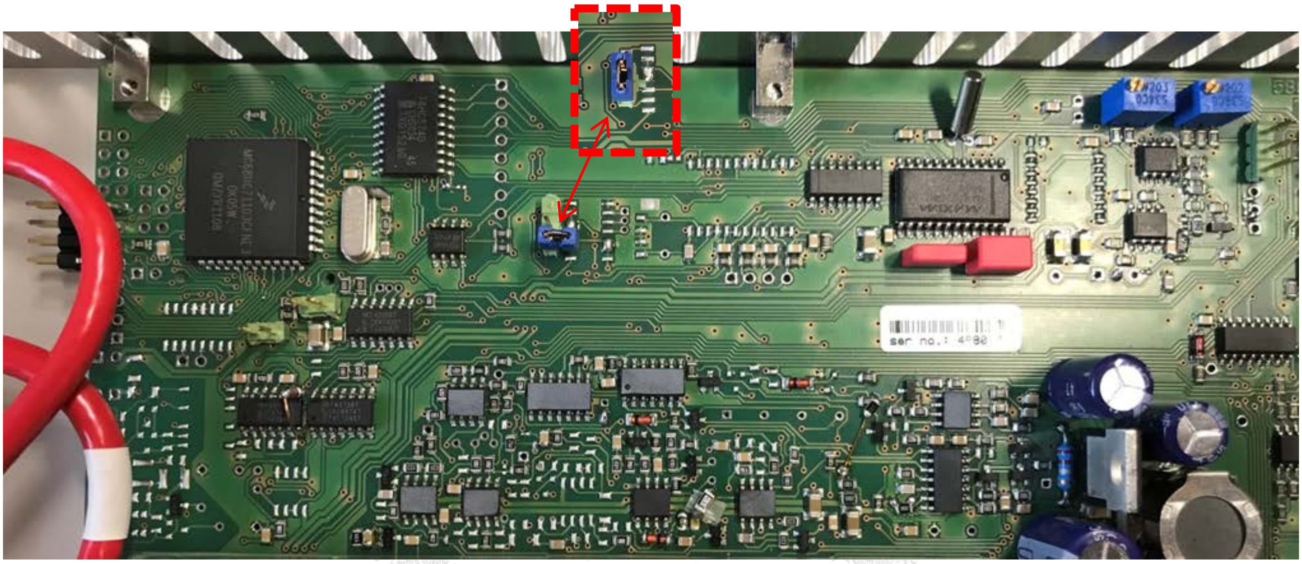


Figure 5.5: Photos of the internal circuit board (after opening the side panel).
In big picture: standard jumper position for not enabling the "kill both" function (blue jumper not set, only "parked on one of the pins).
Insert picture: Jumpers is set, bridging the pins for enabling "kill both" function.

* Such a potentially damaging bias scheme can for example occur when both channels bias an MCP stack on same polarities. Tripping of only one channel can then result in a situation that the other channel in function produces an excessive voltage across the MCP stack or between an intermediate MCP stack contact and front/back side.

5.2 The Pseudo-Floating power supply options PF+ and PF-

For some applications it is beneficial to operate a high voltage supply for detector bias in the so-called "Pseudo-Floating" mode. While the function of channel A corresponds to the standard high voltage supply version, channel B output is determined not only by the setting of channel B (via the corresponding dial or remote control) but also by the setting of channel A:

$$\mathbf{B'} = \mathbf{B} + \mathbf{A} \qquad \text{and} \qquad \mathbf{A'} = \mathbf{A} \qquad \text{(for PF+, same polarity)}$$

A' and **B'** are the actual output potentials U_o from the corresponding SHV sockets on rear panel, **A** and **B** are the set values, controlled by the dials or remote control inputs. If both channels are set to same polarity, **A** defines the "float potential" while the **B** setting defines the potential difference between the outputs (**A'** and **B'**). For detector operation, the **A'** output is used for MCP front or the anode bias while **B'** biases the opposing detector end. **B** then determines voltage across the detector while **A** defines the "float" potential of the respective detector part relative to ground: Changing **A** setting only will not affect the detector function, e.g. in terms of gain.

It is to note, however, that **B'** can never exceed the maximum rating U_{max} of the specific high voltage supply (4, 6, 8 or 10 kV), e.g. **B'** is always < 4 kV for **HV2/4PF+** even if (B + A) would mathematically yield a higher value.

It is also possible to operate the two channels of a PF+ high voltage power supply at alternating polarities. In this case, however, the voltage difference **B' = B +A** between the SHV output does not stay constant when **A** is varied due to the sign change.

For this reason a the HV2/4 version can be supplied as **PF**- version, internally set to

$$\mathbf{B'} = \mathbf{B} - \mathbf{A} \qquad \text{and} \qquad \mathbf{A'} = \mathbf{A} \quad \text{with} \quad \mathbf{B} > \mathbf{A} \qquad \text{(for PF-, different polarities)}$$

correspondences between set values and outputs. This allows for an equivalent pseudo-floating operation scheme when the potentials at the detector ends have different sign.

For the **PF**- version the minimum value of **B'** is 0, i.e. the polarity of the output cannot change if (**B - A**) would mathematically yield a negative value. The versions **PF**- or **PF**+ are factory-fixed and cannot be changed

It is to note that the high voltage outputs of the **PF** high voltage supply versions are <u>not</u> physically floating, only the function of a floating power supply channel as simulated by special voltage control circuits inside the units. Therefore, it is not possible to reverse the output polarity of **B'** by changing set values from A < B to A > B.

The following table shows some examples. Channel B is set to the MCP voltage (here: 2700 Volts), while channel A can be varied.

Examples for **HV2/4PF+/-**	pol. **B**	**B** set (diff.)	pol. **A**	**A** set range and output	output on lower SHV socket **B' = B + A (PF+)**
electron mode	+	2700 V	+	0 V to 1300 V (front)	+2700 V to +4000 V (back)
pos. ion mode	-	2700 V	-	1300 V to 0 V (back)	- 4000 V to -2700 V (front)
					B' = B - A (PF-)
alternate mode	+	2700 V	-	2700 V to 0 V (front)	0 V to +2700 V (back)

Figure 5.6: HV2/4PF+ Power Supply

Note that also the operation the pseudo-floating **HV2/4** and similar units may need an adequate pull-up preventer circuit like the **RoentDek HVT** when operating two channels at the same polarity supplying resistive-coupled contacts such as the two sides of an MCP stack (see Chapter 5.5).

5.3 The BIASET3 with SPS2(mini)

The **BIASET3** consists of the 90-250 V_{AC} main power supply **SPS2 or SPS2mini** and 1 to 4 units of **HV2/4** (or **HV2/6**, **HV2/8** and **HV2/10**) modules (see Chapter 5.1) as a standalone power supply solution without the need for a NIM bin. It can also incorporate single channel high voltage (HV) modules like the **HV1/4** or any of the **EHQ 1xxx** series earlier **BIASET2** product. The **BIASET3** includes a stand for up to 4 HV modules. The HV modules and the **SPS2mini** are interconnected via 9-pin sub-D cables (included) on the rear panels*.

Figure 5.7: BIASET3 with SPS2 and one HV2/4 module (corresponds to BIASET3-2). Alternative mountings include adapter frames for placing several HV2/4 units in 6HU 19" rack or sideways in 3HU racks.

The **SPS2** mains adapter provides power via standard 9-pin sub-D cables for up to two HV modules or via twin-9-pin sub-D cables for up to four HV modules. It measures about 130×130 mm with a depth of approximately 250 mm (extra 100 mm free depth are needed for the cables on the rear panel).

The **SPS2** can be mounted to a 3-HU 19" rack (occupies 24 width units) or can be used as a table-top unit. The unit requires sufficient airflow and an ambient temperature < 40 °C. A spare main fuse (250 V 4 A, slow) is supplied within the AC-input socket. Separate fuses inside the housing (0.63 A "slow") secure the 6 V DC output lines. Lit LEDS on the rear panel indicate normal operation.

Always turn off the unit when connecting/disconnecting the mains power cable or the cables to the HV modules. Always turn off the unit AND remove the power cable when opening the case or changing fuses.

* The output from the **SPS2mini** cannot supply operation voltages for the **(N)DLATR** or **FAMP/CFD** modules.

Figure 5.8: SPS2 front and rear panel with connection cable to HV2/4 module (not shown).

High voltage modules of the type "N24" and **EHQ 1xxx** (e.g. **HV1/4**) can alternatively be supplied via the **SPS2mini** mains adapter which delivers only ±24 V. If you want to purchase a mains adapter for an existing **HV2/4** module, verify of which type it is. The "N24" units can be recognized by the respective label on the front panel or equivalent side-panel labelling:

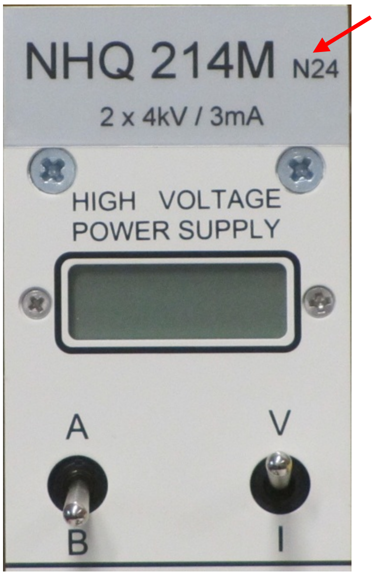


Figure 5.9: SPS2mini mains adapter (left) and the specific label (red arrow) on the front side of a "N24"- type HV2/4 module which can be powered by it (those units with side panel labels will show the N24 indication there). The N24-type HV modules can also be operated with old-type NIM-crates that does not supply the ±6 V.

The **SPS2mini** comes with an external mains adapter, to be connected to the "*DC input*" socket. **Remove the mains power plug from the AC socket when connecting/disconnecting cables on DC input or output sockets of the SPS2mini**.

5.4 BA3 battery unit

The **BA3** battery unit is one of several specific "passive" units for biasing **RoentDek** detectors as an add-on device to a **HV2/4** or similar high voltage supply unit. Its typical application is to simplify helical wire delay-line anode bias but it can also be used whenever a floating battery device is needed for certain biasing schemes. Several **BA3** units can be cascaded and combined with other devices.

Usually it is sufficient to operate a helical wire delay-line anode with voltage difference of 20 to 50 V between the "reference" and the "signal" wires (for details please refer to the RoentDek Delay-line manual. To supply this constant voltage offset between the wires a battery can be used. The **RoentDek** BA3 battery pack provides this offset with values between 35 and 40 V (nominally 36 V, without load 38-39 V).

For using the **BA3** to supply wire potentials you need to connect the SHV output "*HV +36 V*" to the U_{sig} input of the **FT12/16-TP** plug and the other SHV output "*HV*" to the U_{ref} input. The desired potential for the reference wire (U_{ref}) must be supplied to the SHV input. "*HV input*" of the **BA3**'s opposite side. The maximum potential for $\mathbf{U_{ref}}$ is specified as 4 kV, on demand units with up to 6 kV rating can be provided.

Please note that the battery is not discharged during normal operation as no current is flowing between U_{ref} and U_{in}. Even in the presence of a short on the delay-line anode, there is still a 10 kΩ resistance between the poles of the internal battery pack (this is only valid for **BA3** bought in or after 2014). The lifetime of the battery pack is therefore very long (several years). The individual batteries are standard 12 V cells which can be found for example in camera shops. If you need help in replacing the battery, please contact **RoentDek**. Before opening the case, make sure to turn off, discharge and disconnect the high voltage. Only open the side where the "*HV Input"* socket is located. The **BA3** circuits is also used as part of the **HVZ10** voltage dividing unit, see Chapter 5.4.

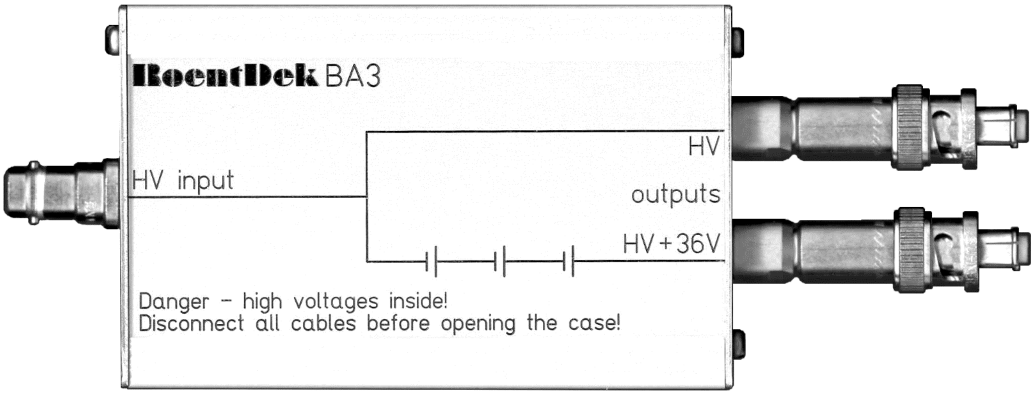


Figure 5.10: RoentDek BA3 battery box. The voltage input is on the left side, the output connectors (here as reserve SHV) on the right side. The input voltage is routed to the upper voltage output (for U_{ref})) and produces with the internal battery pack the signal voltage $U_{sig} = U_{ref} + 36$ V (nominally) on the lower output connector. Newer versions of the BA3 have SHV sockets as outputs (instead of plugs shown here) and in-line 10 kΩ resistors.

5.5 HVT and HVT4(+) High Voltage Terminators

If a micro-channel plate stack or similar semi-conducting devices with resistance in the MΩ to few GΩ range shall be biased with same polarity on both sides (e.g. positive, for electron detection), standard high voltage power supplies' control circuits cannot stabilize the lower bias setting below a certain minimum voltage $\mathbf{U_L}$. The reason is that any biased device with non-infinite resistance (such as an MCP stack) must be described as a "load resistance" $\mathbf{R_L}$ for a high voltage supply which forms a resistor chain to ground with the internal resistance $\mathbf{R_{HV}}$ inside the high voltage supply: While the far end of $\mathbf{R_L}$ is biased to a certain higher voltage $\mathbf{U_H}$ by another power supply channel (with same polarity *) the other end of $\mathbf{R_L}$ will be pulled up to a certain potential $\mathbf{U_L}$, even if the dial setting of the their-connected high voltage supply channel is set to zero or to a lower output potential, see Figure 5.11. This effect prevails even if this channel is connected indirectly via a resistor/diode chain (e.g. through an **HVZ**, see Chapter 5.5.1). As a consequence, only higher voltages than $\mathbf{U_L}$ can be actively selected by the dial setting of the power supply channel in this case.

----------**R_L**----------(-----**R_{HV}**-----**ground**) inside HV supply

(MCP)

U_H **U_L** (> ΔU)

$$\mathbf{U_L/U_H = R_{HV} / (R_{HV} + R_L)}$$

Figure 5.11: Scheme of effective biasing circuit when both ends of a resistor load (e.g. an MCP stack) shall be set to same-polarity potentials $U_L < U_H$ in absolute numbers. U_B is pulled to minimum potential ΔU determined by the resistor ratio R_{HV}/R_L.

* If the ends of R_L are biased at different polarity there is no such effect as described here.

For the RoentDek high voltage supplies R_{HV} is on the order of 100 MΩ. To prevent pull-up when biasing devices having R_L of same order a smaller "terminating" resistor R_{HVT} must be placed to ground, i.e. parallel to R_{HV}, thus reducing U_L. This can for example be achieved by a passive *pull-up preventer circuit*, the RoentDek *High Voltage Terminator* box (**HVT**). On the RoentDek **HV2/4** and similar units U_L can directly be observed on the voltage display (when the respective set voltage is zero or low enough).

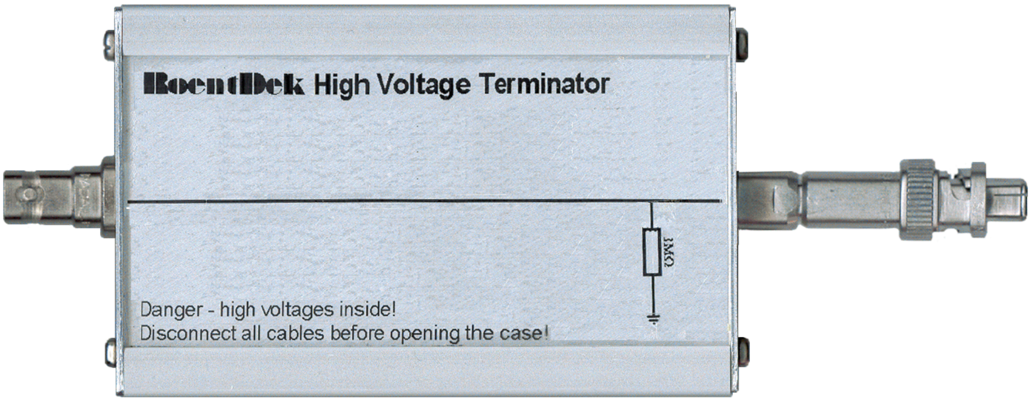


Figure 5.12: High Voltage Terminator, with 1MΩ resistor to ground and reverse SHV connector on one side. A special version (HVT+) is designed as voltage divider enlarging the output range of HV2/4 units (see Chapter 5.9).

The standard **HVT** contains a 1 MΩ resistor to "ground" and is optimized for electron detection purposes with MCP front potential near +200 V or higher. For typical MCP stack resistances (> 20 MΩ), i.e R_L in Figure 5.11. MCP front voltage (U_L) due to the "pull-away" effect will be < 200 V and can actively be raised up to for example 1000 V with a high voltage supply (1400 V maximum rating). If the chievable U_L is still too high even in presence of an **HVT**, a parallel resistor can be placed inside the unit to reduce the effective R_{HVT}.

Note, that the current drawn from the low-voltage power supply channel is then determined by R_{HVT} and may limit the maximum voltage that can be reached in presence of an **HVT** (especially if current limiter settings are engaged). In this case R_{HVT} must be increased, e.g. by adding an in-line resistor inside the **HVT** or replacing it (see **HVT4**, below). Only use resistors with sufficient voltage and power rating. Contact RoentDek if you need extra instruction how to change R_{HVT} and for supply of adequate resistors.

The minimum achievable lowest voltage **UL** in presence of a **HVT** is defined by the following formula:

$$U_L = U_H \cdot R_{HVT} / (R_{HVT} + R_L) \qquad \text{with } R_L = R_{MCP} \text{ in this application.}$$

Note again, that these considerations are only valid when U_L and U_H have same polarity.

It is also possible to change the internal resistor to a customized value so that the desired voltage on MCP front (or back) is generated only by applying the bias on the other MCP side (passive **HVT** use). A special **HVT** version is available that eases the task of adjusting resistor sets. If you need help in determining R_{HVT} for passive **HVT** use or finding adequate resistors, please contact RoentDek. As an alternative the **HVZ-G** circuit can be used (see Chapter 5.6) which sets MCP front potential to a default (positive) value once MCP back potential to a higher positive potential.

It is important to note that the effective MCP front potential may still differ from the set voltage in case of a non-negligible in line resistor value (R_{Df}) in the biasing chain. Please refer to the RoentDek Delay-line manual for determining this effect.

The latest **FT12TP(z)** decoupling plugs can be equipped with an internal on-board **HVT** circuit, please refer to Chapter 5.8.

The **HVT4** version of the **High Voltage Terminator** contains a 10 MΩ resistor rated for up to 4 kV. It is typically used for applications with MCP front at a high negative potential up to -6 kV via an SHV feedthrough and MCP back side thus being at a negative potential well beyond -1 kV (exceeding the standard **HVT** rating). In this case the MCP back side voltage may be pulled away unless connected through **High Voltage Terminator** (see Figure 5.13).

Electron detection (0 V < $U_{MCP\ front}$ < +1000 V)

MCP front ← **HVT** ← HV supply (+)

MCP back ← HV supply (++)

<u>**heavy**</u> **positive ion detection** ($U_{MCP\ back}$ with negative bias)

MCP front ← HV supply (- -)

MCP back ← **HVT4** ← HV supply (-) or via **HVZ**

MCP back ← **HVT4** (for operation with **FT12TPz**)

Figure 5.13: Typical voltage settings requiring an in-line HVT or HVT4 for pull-up prevention. When detecting negative ions (if having low kinetic energy) the MCP front potential must be increased to at least +2000V and an HVT4 is to be used in the left diagram. In this operation mode the necessary MCP back/anode voltages are beyond the rating of the standard feedthroughs typically used for delay-line detectors (see Chapter 5.7).

For applications with demands for slow heavy ion or negative ion detection please contact **RoentDek** for special detector mounting, signal decoupling and high voltage supplies rated up to 10 kV.

The **RoentDek HV3** module can already contain an internal **HVT** circuit.

5.5.1 The HVT4+ matched mode

For MCP stacks with intermediate connection via a shim ring placed in between two MCPs **RoentDek** offers a modified **HVT4+** unit. It alternatively (or additionally) contains an in-line matching resistor (R_M) inserted for forcing a matched MCP stack operation (R_{HVT} is usually removed when the **HVT4+** is used in matching mode).

In this "matching mode" the resistor value R_M is selected so that it reduces the effective resistance on one side of the stack by placing R_M in parallel to the MCP with higher resistance. The **HVT4+** unit in combination with an **SHV-T** plug (also available from **RoentDek**) completes the necessary biasing scheme. The **HVT4+** unit connects between the corresponding high voltage inputs for the intermediate connection, e.g. "**X**" in case of an **FT12TP** plug, or any other SHV/MHV feedthrough connected to the shim ring (as in case of **FT4TP/FT16TP**) and either the MCP front SHV input or the MCP back SHV input (usually via **FT12TP** or **HFSD/HFST**), see Figure 5.15.

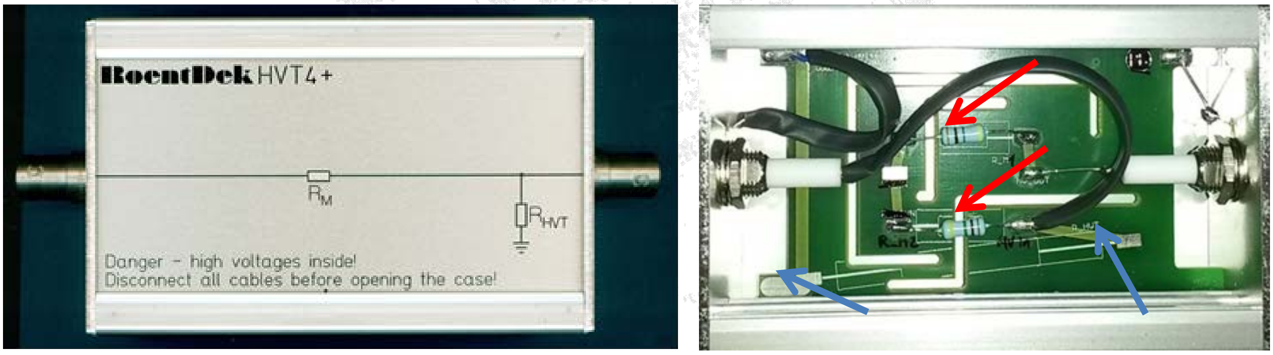
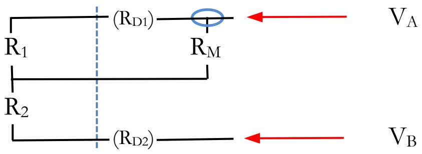


Figure 5.14: HVT4+ showing the circuit with resistors R_M (and optionally R_{HVT}), R_M internally formed by two serial resistors (red arrows), their sum equalling the value of R_M. A specific block digram on the top panel of each unit indicates the installed circuits on delivery. R_{HVT} can also be added later, to be soldered between the pads indicated by blue arrows (right picture). R_M must always be connected parallel to the MCP with higher resistance.

For an MCP stack containing individual MCP with resistances R_1 and R_2 the ratio between the voltages U_1 and U_2 across the respective MCP follow Kirchhoff's law as $U_1/U_2 = R_1/R_2$, with a total voltage across the MCP stack of $U = U_1 + U_2$. Blocking resistors in the signal decouplers can slightly change the effective potential on the MCPs so that V_A-V_B is not exactly equal to U. For a matched chevron MCP set R_1/R_2 is selected to be near unity and the individual MCPs the same voltage. If MCPs have different resistances a matching resistor R_M can be placed in parallel to the MCP with higher resistance (<u>assumed to be R_1</u> in the following considerations).



$$\frac{U_1}{U_2} = \frac{R_M}{R_1+R_M}\,\frac{R_1}{R_2} \qquad \textbf{Equation 5.1}$$

$R_1 > R_2$

$$\frac{U_1}{U_2} = 1: \quad R_M = \frac{R_1 R_2}{R_1-R_2}\left(\frac{R_1+R_{D1}}{R_1}\right) \qquad \textbf{Equation 5.2}$$

Figure 5.15: Connection scheme for the HVT4+ operated in matching mode and equations for determining R_M. The dashed vertical line indicates the vacuum wall with feedthroughs. The MCPs, separated by a shim ring with contact lug, have resistances of R_1 and R_2, respectively, with $R_1 > R_2$. If the resistance of the front MCP is larger than of the rear MCP (which is then R_2 in above equations), V_A denominates the front MCP stack bias (and V_B the rear bias). If the resistance of the front MCP is smaller than of the rear MCP (which is then R_1) V_A denominates the rear bias (and V_B the front bias). R_{D1} and R_{D2} denominate blocking resistors in the signal decouplers/terminators (inside HFSD, HFST or FT12TP) which can usually be neglected (term in parentheses) when determining R_M.

The same considerations hold for triple stack assemblies in which case the sum-resistance of the two unseparated MCPs enter Equation 5.1 as R_1 or R_2. Note, that in this (and in selected other) cases the targeted value of U_1/U_2 may differ from 1 so that the equation to determine R_M must be modified accordingly. In case you need help to find the ideal value of R_M and/or physically a resistor with desired properties please contact **RoentDek**. **It is mandatory to choose resistors with sufficient voltage and power ratings**.

For connecting the **HVT4+** in the biasing scheme for matching mode an additional **SHV-T** plug is required at the position of the blue oval in Figure 5.15. Note again that the **HVT4+** is always placed in parallel to the MCP stack stage that needs resistance reduction*. Typical connection schemes, also in combination with other passive voltage dividing boxes such as the **HVZ** (see Chapter 5.6) can be found on the **RoentDek** web site.

If you have received a non-matched MCP set and **HVT4+** from **RoentDek,** the **HVT4+** will usually be equipped with a resistor set that produces an effective R_M close to the desired value. The choice of the resistor set was then based on estimations about the MCP resistances from specifications values obtained from the manufacturer(s).

However, this does NOT guarantee sufficient matching since the real resistance values can significantly deviate from the specified numbers. Therefore, it is mandatory to verify MCPs resistances (e.g. by a method described in an Appendix of the detector manual) and then modify the resistance in the **HVT4+** accordingly.

An **HVT4+** unit operated in matching mode can only simultaneously be used as bias pull-up preventer on the MCP side with the larger resistance, otherwise R_{HVT} must be located in a separate **HVT** connected to the other MCP bias input. Please contact **RoentDek** for advice in case you are unsure about the proper connection scheme for combining both R_{HVT} and R_M for a certain MCP stack. If an **HVT4+** shall be operated only in the standard **HVT** terminating mode (with R_{HVT} in place), R_M must be set to zero, i.e. short-circuited with a bypass cable.

If you need help in modifying the **HVT4+** to improve matching conditions (i.e. by adding/exchanging resistors) please contact **RoentDek**.

The **HVT4+** unit can alternatively be used to place R_M as "backup resistor" parallel to the whole MCP stack. This can increase operation safety in application with biasing schemes beyond 4 kV detector potential and stabilize MCP bias when a resistor chain is applied for supplying detector voltages. Two **SHV-T** plugs are required for this biasing scheme.

5.6 HVZ voltage divider unit

The **RoentDek HVZ** is a passive voltage distributing box generating intermediate potentials in steps of 28 V or 56 V (±10 %) for all delay-line anode contacts and MCP back side of **RoentDek** delay-line detectors (and a **BA3**-equivalent voltage between the reference and signal wire). This is achieved by a chain of special diodes which are serially placed between the contact junctions to the respective detector parts.

The **HVZ** has one high voltage input socket (SHV) labeled "*HV In*" and four SHV output sockets for providing bias to the MCP back side ($U_{MCP\ back}$), "*Holder*" (U_H) and the delay-line anode wires (U_{ref}/U_{sig}). Thus, only two potentials are to be provided from high voltage supplies for biasing all detector contacts: U_{sig} (via the "*HV In*" socket) and $U_{MCP\ front}$, i.e. the MCP front

* When using a **FT12TP** plug with internal **HVZ** voltage divider circuit (see Chapter 5.8) the plastic stopper on the MCPback SHV needs to be removed if the rear MCP is the one with higher resistance.

potential. The latter may be produced by "terminating" MCP front via a **RoentDek HVT** (see Chapter 5.5). Other detectors like the **RoentDek DET40/75** can also be biased in this way using the **HVZ-T**.

The maximum potential for "*HV In*" is specified as 4 kV, units with up to 6 kV rating can be provided on demand. For operation of detectors at even higher voltage ("**XHV**") a special **HVZ10** can be provided (see Chapter 5.7).

Using the **HVZ** for detector bias distribution is equivalent to applying a resistor divider chain for this purpose. The **HVZ** using Z-diodes has the advantage that the relative voltages set between MCP back, Holder and delay-line wires do not depend on the absolute detector bias with respect to ground (i.e. are independent from the choice of MCP front potential). This ensures the proper voltage difference between the MCP back side and the anode (wires) and provides near-optimal voltage setting for the **DLD**'s or **Hex**' "*Holder*" bias: The voltage drop is generated as soon as a minimum current of few µA is flowing in the proper direction. The intermediate potential of the Holder can be selected in steps of about 28 V or 56 V (for older versions) by jumper settings. A battery box is not needed when using the **HVZ**, however, optional jumper positions also allow bias settings for the wires through a separate **BA3** or other floating battery units. The **BA3** can also be used in combination with the **HVZ** for further increasing the voltage difference between anode wires and MCP back.

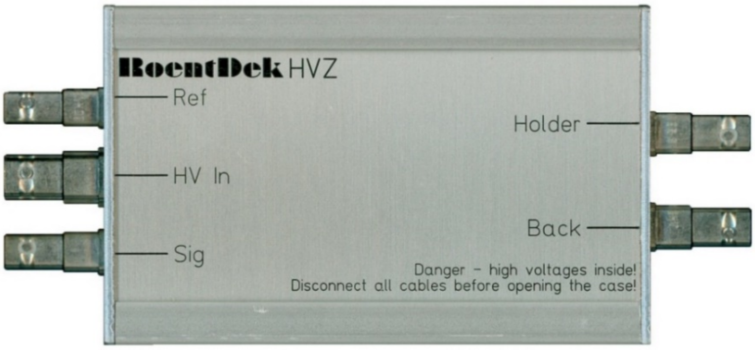


Figure 5.16: HVZ with the SHV connector sockets.

Inside the **HVZ** a total voltage drop of up to a maximum set value (nominally about 260 V) is generated as soon as appropriate electrical current flows through the unit from the input SHV socket labeled "*HV In*" to the "*Back*" socket. This current can only flow if there is an according potential difference maintained between the sockets and if the current is drained by a resistor load connected to the "*Back*" socket. During detector operation this resistor is formed by the microchannel plate stack. For this the **HVZ**' "*Back*" socket must be physically connected to the MCP stack's rear side input and must always be at the same or more positive ptotential than the MCP stack's front side, which is connected to the MCP front high voltage supply. Please insure that $U_{MCP\ front}$ < "*HV In*" at all times, i.e. during increases of the voltages toward normal detector operation and also when voltages are turn down from termination detector operation. **If the potential on the MCP back socket should become more positive than the potential on "*HV In*" the HVZ may be damaged!**

Never supply a separate potential to any other HVZ socket than the "*HV In*" socket. Never directly ground any socket in order to force this potential to zero. This may cause irrecoverable damage to the HVZ circuit.

It is important to note that the relation between the current through the MCP stack and the voltage between "*HV In*" and MCP front potentials is not linear as long as it is lower than the **HVZ'** set value. For calculating the nominal MCP back potential (i.e. on the voltage input of a signal decoupler on MCP back contact) the set voltage needs to be subtracted from the nominal "*HV In*" bias. This is important to note when considering the effective voltage across the MCP stack and when calculating the MCP resistance from the current flowing through the stack.

It is important to ensure that the voltage across the **HVZ** is never inversed and that "*HV In*" > "*Back*" > MCP front bias according to normal detector operation. The use of the **HVZ** requires the "*Back*" output always being connected to the MCP back side when applying voltage.

For operation in the standard configuration (as shipped) with all outputs sockets "*Ref*", "*Sig*", "*Holder*" and "*Back*" connected to the detector (e.g. via the **RoentDek FT12TP** or **FT16TP** decoupling circuits) the bias applied to "*HV In*" is directly connected with the "*Sig*" output socket, i.e. supplying the signal wire potential (U_{sig}). "*Ref*" output provides a 39 V more negative U_{ref} potential (i.e. with the same potential difference as obtained by a **RoentDek BA3** unit).

As described above the "*Back*" output provides the bias for $U_{MCP\ back}$ which is nominally 260 V more negative than "*HV In*". However, the effective bias on MCP back side may be lower (more negative) due to the voltage drop across the blocking resistor in the signal decoupling circuit (typically 1 MΩ, please refer to the delay-line detector manual for determining this additional bias shift).

The bias pickup from the **HVZ** for the Holder potential (U_H) can be adjusted between U_{ref} and $U_{MCP\ back}$ in steps of 56 V or 28 V by selecting a jumper position (default: $U_H = U_{MCP\ back}$ +56 V).* Before opening the **HVZ**, make sure to reduce all voltages to zero and then disconnect all cables from the **HVZ**. When removing the cables while still on high potential, there might still be hazardous voltages stored within the **HVZ**'s capacitors.

There are two different versions of the **HVZ**: the older version (with printed circuit board showing 'Rev. 1.0', 'Rev. 1.1' or 'Rev 1.2' labels) and the newer version ('Rev. 1.3' or higher). Their basic functionality is the same – the new versions just offers additional jumper settings (e.g. with 28 V steps) which might be helpful for special requirements. Please verify which version you own and follow the corresponding setting instructions below:

The latest **FT12TP** decoupling plugs can be equipped with an internal on-board **HVZ** circuit, please refer to Chapter 5.8.

For **DET** detectors a special **HVZ-T** version is available which also contains a separate **HVT(4)** circuit (see in the respective detector manual).

Additionally, a simpler **HVZ-G** version is available for **DET** applications when the anode potential can be fixed to ground.

Figure 5.17 HVZ-G plug, here the version for negative bias of MCP back potential.

The **HVZ-G** is then connected to the MCP back SHV socket. MCP back will be drawn to a fix negative potential of typically - 250 V (default) once MCP front potential is raised to a more negative potential.

The factory set potential may differ slightly from the default value due to chip tolerances. However, the real value, noted on the case (see Figure 5.17), will be close enough to the default value, allowing for proper functionality.

The default value of a specific **HVZ-G** can be factory-set to a variety of voltages depending on the choice of the internal diodes. The **HVZ-G** is specified for up to 500 V potential difference to ground.

The same unit with reverse polarity (positive) can be used to bias MCP front side of **DLD** or **DET** allowing for electron detection. In this case, a positive potential on the rear part of the detector will likewise draw MCP front potential close to the favourable value, e.g. + 250 V in this case.

The **HVZ-G** is also available in a stand-alone case with SHV cable connection, e.g. for **HEX** detectors.

* Note that the detector's Holder potential is not necessarily to be supplied through the **HVZ**. It can also be drawn from an independent high voltage supply if linearity near the MCP edge needs further optimization.

5.6.1 HVZ Revisions 1.3 and newer

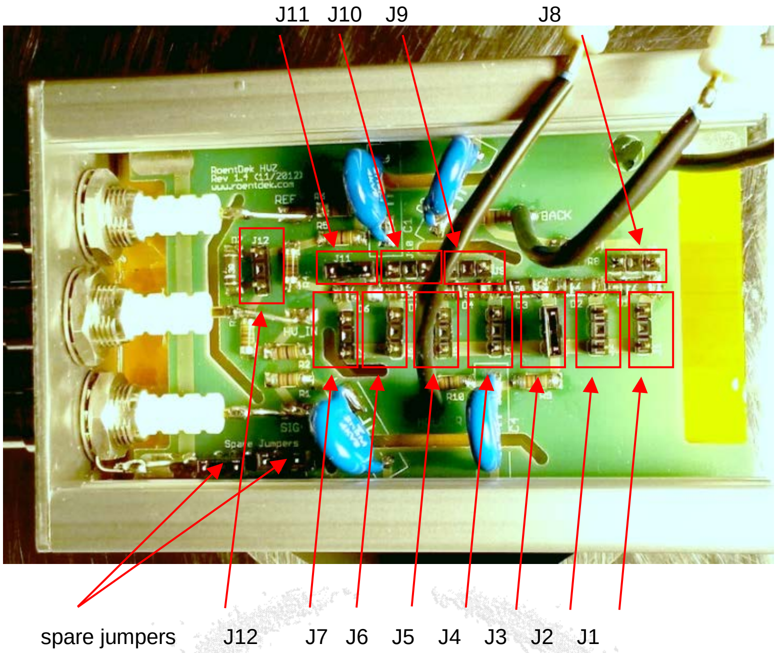


Figure 5.18: HVZ Revisions 1.3 and newer with jumper options.

The standard setting (as shown in Figure 5.18) sets $\mathbf{U_{ref} = U_{MCP\,back} + 224\,V}$ and $\mathbf{U_H = U_{MCP\,back} + 56\,V}$. For this, jumpers are set on positions J3 and J11. You may change U_H (without modifying U_{ref}) as following:

J1 to J7: jumper positions determining "*Holder*" potential. Only one jumper shall be set on J1 to J7.

jumper at J1:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\,back}$
jumper at J2:		$U_H = U_{MCP\,back} + 28\,V$
jumper at J3:	default	$U_H = U_{MCP\,back} + 56\,V$
jumper at J4:		$U_H = U_{MCP\,back} + 112\,V$
jumper at J5:		$U_H = U_{MCP\,back} + 168\,V$
jumper at J6:		$U_H = U_{MCP\,back} + 224\,V$ (= U_{ref})
jumper at J7:		$U_H = U_{MCP\,back} + 224\,V$ (= U_{ref})

Changing this jumper position from the default setting can be beneficial for modified detector geometry (MCP holding plate at a non-standard position) or if the effective MCP back potential is significantly shifted (use J1 position). There are a numerous different settings possible, listed by the value of U_{ref}:

$\mathbf{U_{ref} = U_{MCP\,back} + 280\,V}$ - remove J11 and then follow this table instead of the one above:
J1 to J7: jumper positions determining "*Holder*" potential. Only one jumper shall be set on J1 to J7.

jumper at J1:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\,back}$
jumper at J2:		$U_H = U_{MCP\,back} + 28\,V$
jumper at J3:	default	$U_H = U_{MCP\,back} + 56\,V$
jumper at J4:		$U_H = U_{MCP\,back} + 112\,V$
jumper at J5:		$U_H = U_{MCP\,back} + 168\,V$
jumper at J6:		$U_H = U_{MCP\,back} + 224\,V$
jumper at J7:		$U_H = U_{MCP\,back} + 280\,V$ (= U_{ref})

$\mathbf{U_{ref} = U_{MCP\,back} + 252\,V}$ - remove J11 and set J8. Then follow this table instead of the one above:
J1 to J7: jumper positions determining "*Holder*" potential. Only one jumper shall be set on J1 to J7.

jumper at J1:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\,back}$
jumper at J2:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\,back}$
jumper at J3:	default	$U_H = U_{MCP\,back} + 28\,V$
jumper at J4:		$U_H = U_{MCP\,back} + 84\,V$
jumper at J5:		$U_H = U_{MCP\,back} + 140\,V$
jumper at J6:		$U_H = U_{MCP\,back} + 196\,V$
jumper at J7:		$U_H = U_{MCP\,back} + 252\,V$ (= U_{ref})

$U_{ref} = U_{MCP\ back} + 196$ V - set J11, J10 and J8. Then follow this table instead of the one above:

J1 to J7: jumper positions determining "*Holder*" potential. Only one jumper shall be set on J1 to J7.

jumper at J1:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\ back}$
jumper at J2:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\ back}$
jumper at J3:	default	$U_H = U_{MCP\ back} + 28$ V
jumper at J4:		$U_H = U_{MCP\ back} + 84$ V
jumper at J5:		$U_H = U_{MCP\ back} + 140$ V
jumper at J6:		$U_H = U_{MCP\ back} + 196$ V ($= U_{ref}$)
jumper at J7:		$U_H = U_{MCP\ back} + 196$ V ($= U_{ref}$)

$U_{ref} = U_{MCP\ back} + 168$ V - set J11 and J10. Then follow this table instead of the one above:

J1 to J7: jumper positions determining "*Holder*" potential. Only one jumper shall be set on J1 to J7.

jumper at J1:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\ back}$
jumper at J2:		$U_H = U_{MCP\ back} + 28$ V
jumper at J3:	default	$U_H = U_{MCP\ back} + 56$ V
jumper at J4:		$U_H = U_{MCP\ back} + 112$ V
jumper at J5:		$U_H = U_{MCP\ back} + 168$ V ($= U_{ref}$)
jumper at J6:		$U_H = U_{MCP\ back} + 168$ V ($= U_{ref}$)
jumper at J7:		$U_H = U_{MCP\ back} + 168$ V ($= U_{ref}$)

$U_{ref} = U_{MCP\ back} + 140$ V - set J11, J10 and J9. Then follow this table instead of the one above:

J1 to J7: jumper positions determining "*Holder*" potential. Only one jumper shall be set on J1 to J7.

jumper at J1:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\ back}$
jumper at J2:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\ back}$
jumper at J3:	default	$U_H = U_{MCP\ back} + 28$ V
jumper at J4:		$U_H = U_{MCP\ back} + 84$ V
jumper at J5:		$U_H = U_{MCP\ back} + 140$ V ($= U_{ref}$)
jumper at J6:		$U_H = U_{MCP\ back} + 140$ V ($= U_{ref}$)
jumper at J7:		$U_H = U_{MCP\ back} + 140$ V ($= U_{ref}$)

$U_{ref} = U_{MCP\ back} + 112$ V - set J11, J10, J9 and J8. Then follow this table instead of the one above:

J1 to J7: jumper positions determining "*Holder*" potential. Only one jumper shall be set on J1 to J7.

jumper at J1:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\ back}$
jumper at J2:		$U_H = U_{MCP\ back} + 28$ V
jumper at J3:	default	$U_H = U_{MCP\ back} + 56$ V
jumper at J4:		$U_H = U_{MCP\ back} + 112$ V ($= U_{ref}$)
jumper at J5:		$U_H = U_{MCP\ back} + 112$ V ($= U_{ref}$)
jumper at J6:		$U_H = U_{MCP\ back} + 112$ V ($= U_{ref}$)
jumper at J7:		$U_H = U_{MCP\ back} + 112$ V ($= U_{ref}$)

These options can be beneficial if the effective MCP back potential is strongly shifted, or a lower anode voltage shall be used for some reason (i.e. different anode type). If a larger voltage drop (beyond 280 V between U_{ref} and $U_{MCP\ back}$) is required it is possible placing two **HVZ** units in series or combining a **HVZ** with a **BA3**.

For all HVZ revisions and settings above the following is valid:

J12:	no jumper:	$U_{sig} = U_{ref} + 36$ V (default)
	if a jumper is set on J6:	both Ref and Sig outputs provide the same potential as "*HV in*".

This option allows using a **BA3** or other floating battery device for producing the voltage difference between "*Ref*" and "*Sig*" for a delay-line anode.

If you use an **HVZ** with an older board (revision 1.2 or earlier) please contact **RoentDek** for information on jumper settings/functions).

5.7 HVZ10 voltage divider unit for XHV operation

For the **XHV** option (i.e. **RoentDek** delay-line detectors that can operate beyond the standard high voltage ratings) the **HVZ10** unit is available. It contains a flexible high voltage dividing circuitry in a box with (typically) four output lines rated to 10 kV and up to two input voltages.

Figure 5.20: Left picture: HVZ10 box with four-fold high voltage output cable which will be connected to an XHV feedthrough. Right picture: high voltage inputs on rear panel. Here, two SHV10 socket are provided for supplying two independent voltages. Other versions are available which operate with just one input voltage (MCP front or U_{ref}) and/or use other input socket standards

In the following, the basic **HVZ10** version is described. You may have received a separate add-on manual if your unit differs remarkably from the standard version. You will in any case receive specific information about the circuitry and tables for output voltages as function of input voltage(s) and MCP resistance. The **HVZ10** must be operated in combination with **RoentDek** -approved high voltage supplies and feedthroughs. It is important to verify whether the high voltage supply can deliver sufficient current for the **HVZ10** circuit as it is laid out.

Before using, please verify for which maximum input/output voltages and polarity your HVZ10 version is rated and never exceed this voltage or invert the polarity.

The **HVZ10** contains an exchangeable upper board to allow for different operational modes, e.g. the detector's initial startup procedure at low voltages and the final operation at high voltages. The boards can simply be interchanged after opening the case. Resistor values on the boards may have to be adjusted when the MCPs need replacement. **RoentDek** provides specific information, voltage tables (and adequate resistors, if needed) for this procedure or can completely service a board.

Only apply high voltage to the HVZ10 when the case is closed. Before opening the case, make sure to fully discharge your high voltage power supply and then disconnect it or disable it and secure it against being switched on again.

Once you have received the detector system it is recommended to first install the MCP dummy disc made from insulating material in place of the MCP stack for verifying the high voltage soundness of the whole assembly at first. For this test, the board for normal high-voltage operation should be installed in the **HVZ10**, as it is the case when you receive the setup. Although no MCP stack is installed the voltage should be increased very slowly to the design values (the vacuum within the chamber should be better than 10^{-5} mbar). Minor arcing incidents are not uncommon during this procedure. Once the setup sustains operation at the design potential without discharge, the MCP stack can be installed to the detector. At this point, the top-side board should be exchanged for the PCB designated for the initial startup procedure of the detector. The startup procedure itself is defined in the manual (see Chapter 2).

The PCB for the initial startup procedure will set one detector potential (MCP front or U_{ref}, depending on the polarity of the high voltage supply) to ground potential or near that, while the detector function is verified by raising the MCP bias to operational values as described in the initial startup procedure. General detector performance can thus be fully verified.

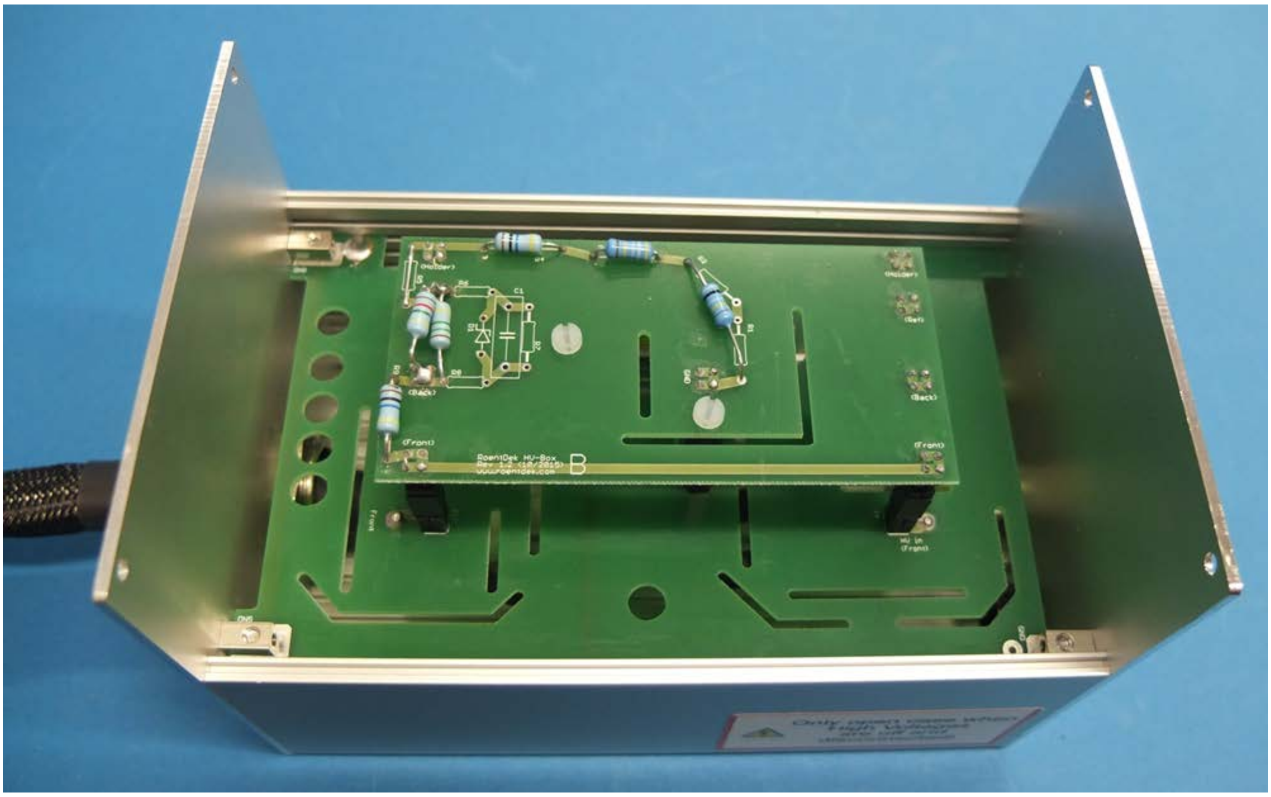


Figure 5.21: Open HVZ10 case with exposed top-side voltage divider PCB which can be reconfigured to allow for different biasing schemes. A BA3 circuit (not visible) is placed on the intermediate PCB plane and produces the differential delay-line wire potentials from U_{ref}. The values of the resistors within the chain are specifically selected for detector operation near the targeted MCP front voltage (here: -10 kV, operated with only one high voltage supply channel) and for the given MCP resistance. PCBs for operation at positive MCP potentials look very similar.

After that, the PCB for high voltage operation may be re-installed and voltage can be raised to the design potential. As a general safety precaution, raising voltages very slowly should be standard practice.

For replacing the PCB **turn off and fully discharge the high voltage** and open the case. Then remove the plastic screws that secure the board onto the back plane PCB. Retract the top-sided PCB and replace it by the desired one. Make sure that all connection posts are well met and then secure the board with plastic screws. **Close the case before applying high voltage**.

The safest operation mode for a detector biased to **XHV** voltages employs only one high voltage channel, which is either connected to “MCP Front” input (positive ion detection, negative polarity) or with positive polarity to the “*Ref*” input (i.e. the anode), for negative ion or electron detection on the positively biased MCP.

In case of operational problems (power failure, vacuum breakdown, etc.) a controlled voltage shut down may be maintained and guarantee safe relative detector voltages at all times, preventing damage from erroneous settings. In this biasing scheme, the counter-side of the detector must be bridged to ground potential via a “terminating resistor” of adequate resistance that may be formed as a chain of resistors (R1 to R4, see Figure 5.22, right picture).

The disadvantage of this scheme is that an optimal MCP bias cannot be set independently from the floating potential value: The terminating resistor bridge and the MCP stack resistance with its parallel resistor (R9) form a voltage dividing chain. The bias across the MCP stack and thus the gain will depend both on the resistor ratio and the floating voltage on MCP front.

Thus, the ideal bias voltage for the MCP stack must be determined before, e.g. during the startup procedure. Bias adjustment for the MCP stack requires changing of resistors R1 to R4 so that the chain yields the right resistance ratio to the parallel array of R9 and the MCP stack resistance. Operation at a different floating voltage will again require adjustments if the ideal MCP bias shall be maintained. Likewise, MCP replacement may also require resistor adjustments.

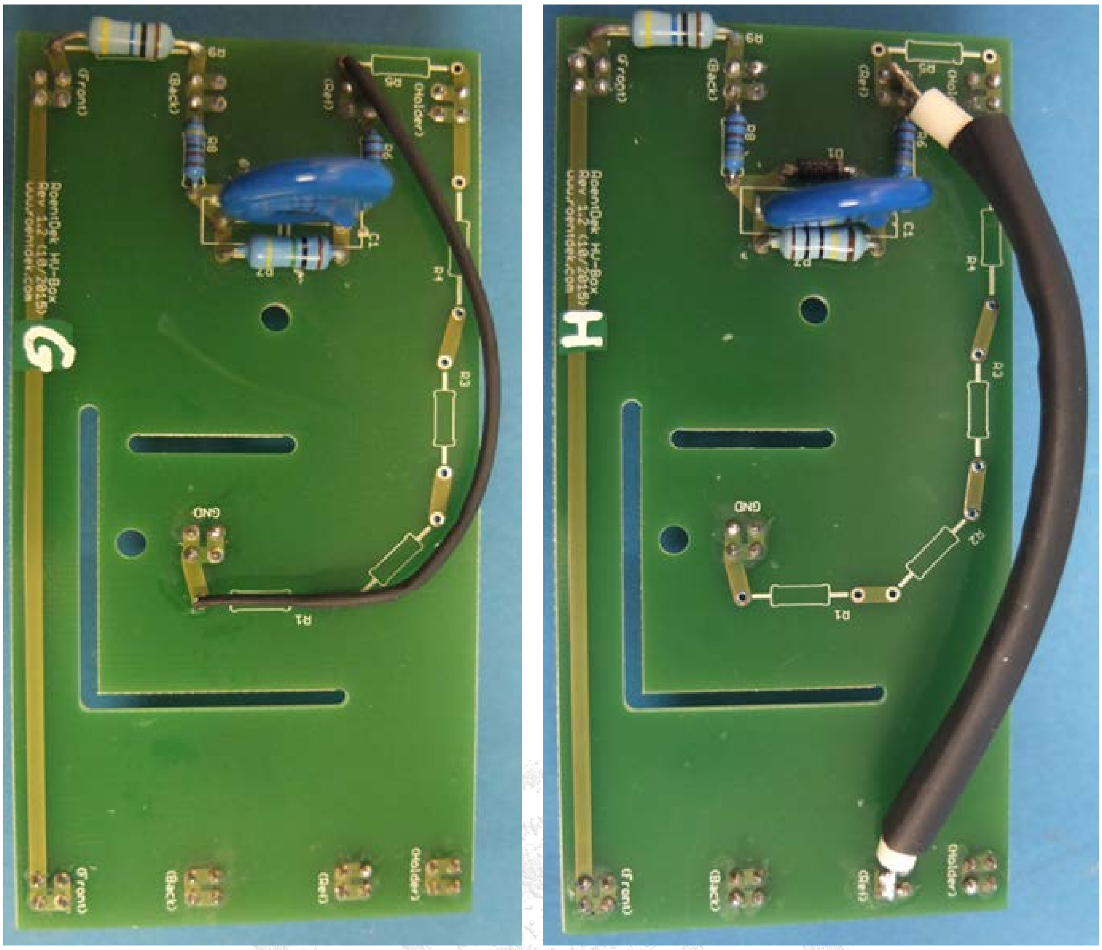


Figure 5.22: PCB for initial start-up procedure (left) for operation with negative polarity on "MCP front" input via HVZ10. U_{ref} potential is set to ground. As the voltage is raised to about -2500 V the detector operates in (positive) ion detection mode. Right picture: PCB for operation at high negative MCP potential using one high voltage power supply which provides U_{ref} plus a floating high voltage power supply that generates the voltage across the MCP stack. In both cases a Z-diode maintains a voltage drop of nominally 230 Volts between U_{ref} and U_{back}.

If two independent high voltage supplies are used, floating voltage and MCP bias can be independently adjusted. However, it is **strongly recommended to ensure that** during voltage increase/decrease and also in case of voltage tripping **both high voltage channels are always ramped in a coordinated and synchronized way** so that no **excessive potential differences** can occur **across the detector** which **will lead to uncontrolled discharge and damage**.

RoentDek can provide approved high voltage power supplies for all operation modes, such as the **HV2/10PF+** and **HV2/8PF+** units

It must also be noted that there are different types of high voltage supplies. Floating power supplies usually do not impose any problems. But when using two fully independent high voltage supplies it must be checked whether they are based on a diode cascade voltage multiplier. If this is the case, an additional resistor from the lower potential to ground must be implemented in order to prevent that the power supplies influence each other. When you plan to replace your power supplies by different ones, please contact **RoentDek** for advice

5.8 HVZ voltage divider circuit and internal HVT inside the FT12TPz

The latest version of the **FT12TP** plug for **DLD** can be upgraded to internally contain **HVZ** and/or **HVT** circuits by replacing PCBs inside the housing. If an **FT12TPz** is ordered, the according PCB set is included and may already be factory-mounted (then noted on a label found on the top lid of the housing).

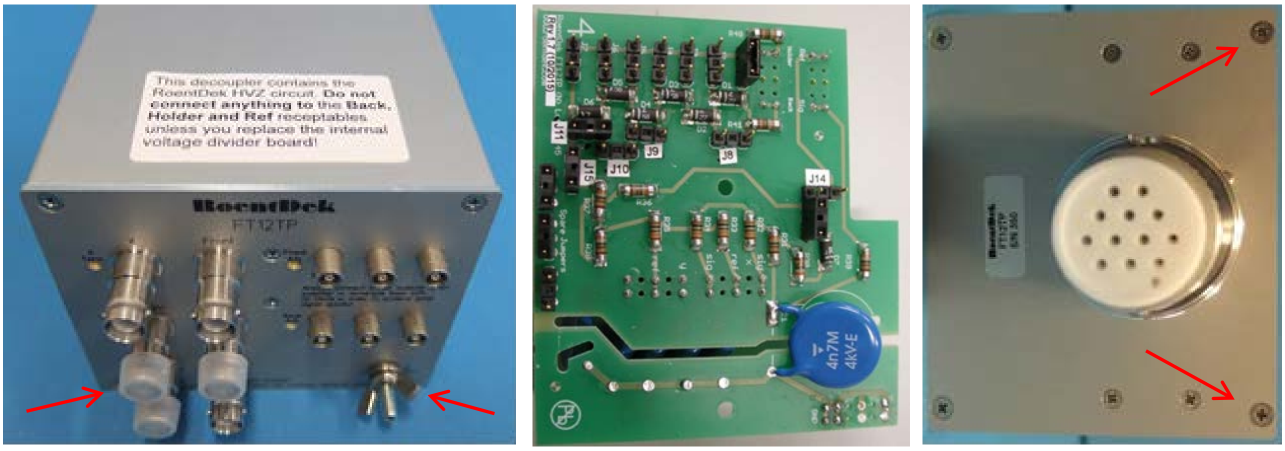


Figure 5.23: FT12TPz with internal HVZ board (#4) which is accessible after removing the bottom side of the case (loosen the four screws indicated by the red arrows). <u>The rear detector potential is applied only via the U_{sig} input</u>.

Before opening the **FT12TP**, make sure to <u>first</u> reduce applied voltages to zero and only then disconnect all **SHV** cables. When removing the cables while still on high potential, there might still be hazardous voltages stored within the **FT12TP's** capacitors.

If an internal **HVZ** board is in place only the (MCP) "*Front*" and the "*Sig*" (and optionally the "X") SHV sockets are used to provide voltage to the detector. Here, the "*Sig*" socket input corresponds to the "*HV in*" socket in the standard **HVZ** box, see Chapter 5.6 and also refer to the operation and safety instructions given there. The white plastic stoppers on the SHV sockets "*Back*", "*Holder*" and "*Ref*" prevent some common mistakes when connecting the high voltage cables. These plastic stoppers may be <u>temporarily</u> removed for connection testing purposes with an Ω-meter, or when a **HVT4(+)** unit is connected on "Back". While in the HVZ operation mode (actively biasing all detector contacts) only via "*HV in*" and "*Front*" sockets). **Neither of "*Back*", "*Holder*" and "*Ref*" sockets should be independently biased or grounded*. MCP front bias must always be more negative than the signal bias. Otherwise the internal HVZ circuits can be damaged.** Note generally that **MCP front bias must always be more negative than the signal bias**.

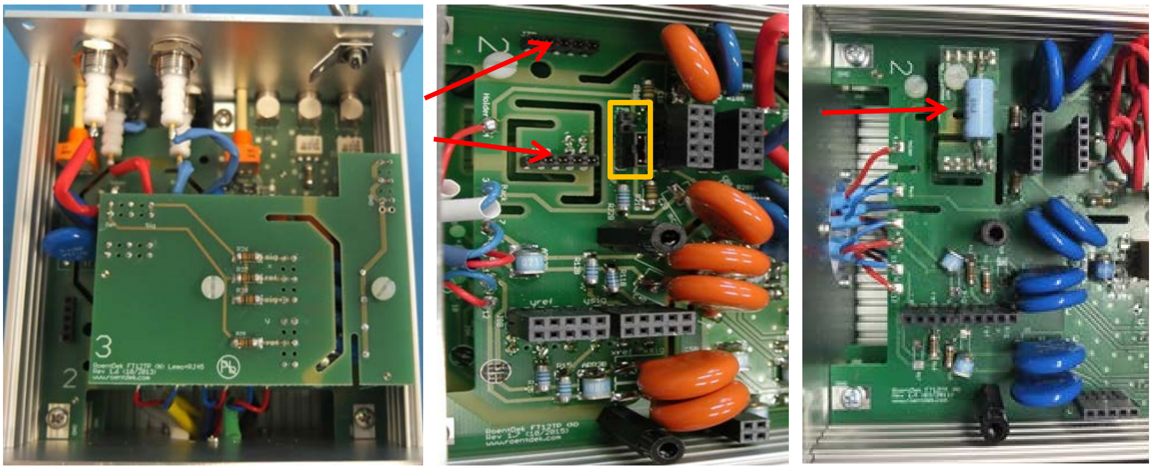


Figure 5.24: Inside view of a FT12TP plug with installed standard board #3 (no HVZ function, left picture) and with exposed base board (#2) when the upper board (#3, #4, or custom board) is removed (for that loosen the two plastic screws and retract the board). The red arrows in the middle picture indicate a bank pair where the optional HVT resistor board *HVTmini* can be placed, see in the right picture on a similar #2 board (description in Chapter 5.8.1). Also described there is the function of the J2B jumper bank (indicated by the yellow rectangle).

In case you achieved an upgrade from a standard **FT12TP** to an **FT12TPz** by exchanging the PCB board #3 to #4 by yourself you should add the supplied label and insert the white stoppers to the SHV sockets for preventing common mistakes when connecting the high voltage cables. Likewise, if you place the internal **HVT** you should add the corresponding sticker supplied with it. The presence of an **HVT** bridge inside the plug can be verified by measuring the resistance between pin 2 and any screw on the plug's case: If 1 MΩ is measured the **HVT** is installed, otherwise there is infinite resistance (>10 MΩ).

* Only MCP back socket may be terminated via an appropriate R_{HVT} (inside an **HVT4** box, one of its SHV sockets then remains unconnected), or connected to an intermediate MCP contact via an **HVT4+** box, see Figure 5.13 and Chapter 5.5.1.

The optional combinations of jumper settings for J1-J11 on the (internal) **HVZ** board as shown in Figure 5.24 (version 1.7 and newer)* result in exactly the same bias output functionalities as described for the (external) HVZ box boards (for version 1.3 as described in Chapter 5.6.1). The factory-set jumper positions are noted on the case of the **FT12TPz**. It is advisable to keep track of any modification at any time.

Since the internal **HVZ** board of the **FT12TPz** is directly supplying the voltages to its decoupling circuits, J12 on the external **HVZ** unit had to be replaced by a combination of jumpers J13-J15 (default: J13 and J15 are set) in order to maintain flexibility for alternative biasing schemes, e.g. during trouble shooting or verification procedures.

These (non-standard) options are summarized as followed:

J14 jumper is set <u>instead</u> of J13:

U_{ref} is separately biased through the "*Ref*" SHV socket.

<u>None</u> of jumpers J1-J7 being set:

Holder bias (U_H) is separately biased via the "*Holder*" SHV socket.

Jumpers from J1-J7, J13 <u>and</u> J15, are all removed (only J14 jumper must be set):

<u>All</u> voltages are supplied through the SHV sockets.

Thus, the **HVZ** function of the internal board can be stepwise reduced to the "standard" **FT12TP** plug (e.g. equipped with internal board #3) bias input scheme through the separate SHV sockets. Obviously, for this the white stoppers on the SHV sockets must be at least partially removed, only temporarily, i.e. as long as these non-standard settings are operated. Please put the stoppers back in place as soon as you reactivate the corresponding **HVZ** functions.

Further biasing options are enabled by changes on the base board (#2):

5.8.1 Internal HVT board and additional bias options of the latest FT12TP plugs for DLD

In the course of ongoing **FT12TP** upgrades further options have been implemented on the base board (#2) to allow for additional biasing functions after internal modifications by the user. These settings are independent from the piggy-back board selection #3 (standard bias through the SHV sockets), #4 (**HVZ**) or else. **FT12TP(z)** units with serial numbers of 360 and higher allow the following options:

Internal HVT functions: A special bridge circuit which can be obtained from **RoentDek** (see Figure 5.24) contains a R_{HVT} resistor and terminates MCP front input to ground via a 1 MΩ, exactly like the external **HVT** box as described in Chapter 5.5. However, there are no options defined of changing this resistor value or of connecting the internal R_{HVT} to any other bias contact.

If you are not sure (while the **FT12TP** plug case is closed) whether an *HVT* resistor bridge is placed on the internal base board (#2) or not you can verify its presence/absence with an Ω meter by checking the resistance to ground (i.e. the **FT12TP** case) of the "*Front*" SHV socket. This should take place while the **FT12TP** plug is removed from the feedthrough. Then you should either measure the 1 MΩ *HVT* resistance (i.e.: bridge in place) or find a near-infinity resistance (no bridge connected).

Internally connecting MCP back to Holder potential: by changing the jumper position J2B from its default position "down" (as shown in Figure 5.24, middle picture) to its upper position, the bias input to MCP back from the corresponding SHV socket (or **HVZ** circuit) is suspended. The "*Holder*" bias input (coming either through the corresponding SHV socket or the **HVZ** circuit) is then routed both to MCP back and "*Holder*", being on nearly the same potential. **For this setting it is important that the "*Back*" SHV socket connected to a high voltage supply or grounded**.

Setting MCP back and Holder on a detector to the same potential cannot always be achieved simply by biasing the corresponding SHV sockets with the same nominal potential (i.e. by short-connecting the sockets "*Holder*" and "*Back*" via a **SHV-T** or by placing a jumper at J1 in case of operation with a **HVZ** circuit):

As soon as the MCP front side is set to a more negative bias during operation, the presence of the blocking resistor R_{Db} (usually 1 MΩ, see Chapter 5.5) in the MCP back connection line will change the effective MCP back bias on the detector. This can only be avoided if the jumper J2B in Figure 5.25 is changed to the "up" position.

* If you have received an earlier board version, please refer to the descriptions obtained with the unit.

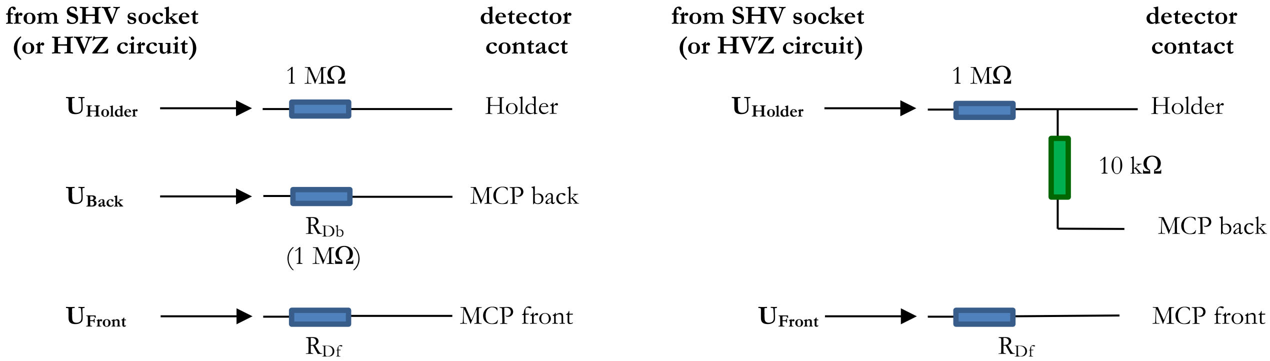


Figure 5.25: Connection circuits for the two J2B jumper settings, left scheme: the standard "down" setting (as in Figure 5.24), right scheme for the alternative "up" setting. The 10 kΩ resistance separating "*Holder*" and MCP back is low enough to not impose a remarkable voltage shift of MCP back compared to "*Holder*" even when MCP front is set to operational values. Note, that there is the 1 MΩ blocking resistor in the line to the MCP back (and "*Holder*") causing a corresponding (common) bias shift, as described earlier.

For detector assemblies without intermediate MCP carrier plate (e.g. **DLD120**, **HEX100** and **DLD40SL**) the Holder bias setting is not affecting the imaging properties on the outer diameter. For these detectors the factory-setting for the Holder potential (i.e. near MCP back potential) can be kept.

5.9 HVT+ and custom-designed voltage dividing circuit boxes

Based on the **HVT** **RoentDek** provides the passive voltage divider **HVT+** for increasing the operation range of the **RoentDek** high voltage supplies (e.g. the **HV2/4**) to voltages well below 100 V. Depending on the internal jumper position the output voltage is nominally reduced by a factor of 10 (jumper at J1 position, see Figure 5.27) or by a factor of 100 (jumper at J2 position). These scaling factors are only accurate within a few % due to resistor tolerances. The presence of an external resistor load (e.g. formed by a series of resistor-coupled spectrometer plates to ground) will alter the scaling factor systematically, see below. With maximum specified input voltage of 1000 V this allows to set stable output voltages between 1 V and 100 V with a **HV2/4**, e.g. for biasing spectrometers, meshes or lens elements.

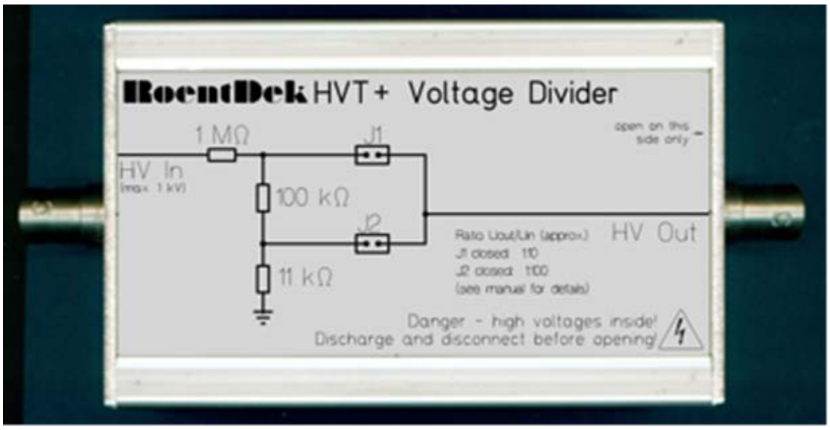


Figure 5.26: HVT+ with 100:10:1 resistor chain. Depending on the jumper the nominal scaling factor between output and input voltage is 1:10 (J1 set) or 1:100 (J2 set). The maximum input voltage is 1000 V. On demand the HVT+ can also come as a version equipped with a third jumper position J3 which enables the standard HVT functionality (see Chapter 5.5) with R_{HVT} having a nominal value of 1111kΩ.

Precision voltage setting via **HVT+** requires measuring the actual output voltage with an adequate instrument (while the output is connected to the resistor load R_L, if any). However, as long as R_L > 10 MΩ, the voltage reading on the **HV2/4** gives a fairly precise indication of the output voltage, taking into account the nominal scaling factor (depending on jumper setting). For smaller R_L the scaling factor deviates from the nominal values. It can be approximated for R_L > 100 kΩ by:

$U_o/U_{eff} = 10 + 1M\Omega/R_L$ (J1 set) or $U_o/U_{eff} = 100 + 1.1\ M\Omega/R_L$ (J2 set)

It is to note that the current drawn from the high voltage supply will be dominated by the "blind" current through the internal resistors to ground inside the **HVT+**. The effect of an external resistor load on this current can hardly be measured via the current display of the **HV2/4**.

For special biasing schemes of detectors RoentDek can provide custom-designed voltage dividing boxes. The following figures show a (not-complete) selection of circuits that have been provided to customers.

Figure 5.27: Set of voltage divider boxes for DET operated at high negative bias (MCP front up to -4800 V) with a mesh biased 200 V more negative than MCP front (lower box) and a resistor divider chain for biasing MCP back and Anode at adequate potential for single particle counting (upper box). The voltage drop between MCP back and Anode is 1/6 of the MCP back potential, here (can be altered by changing the 2 MΩ resistor, see Kirchhoff's laws).

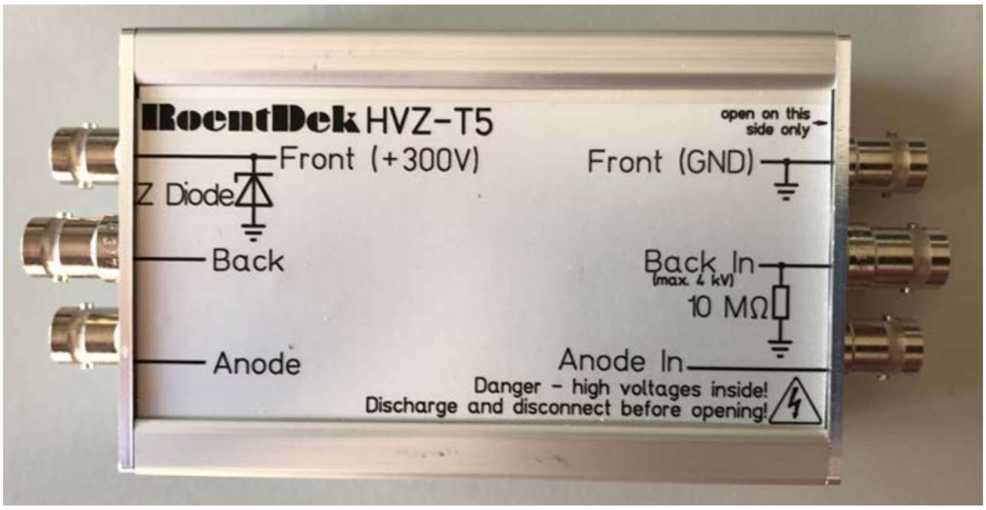


Figure 5.28: Voltage divider for DET operation with MCP front at +300 V (or ground), with MCP back and Anode at any set potentials between MCP front and +5 kV.

5.10 Remote Control of the RoentDek HV supply via USB-IO1

The voltage setting of the **HV2/4 (6/8/10)** units can be operated via the RoentDek **USB-IO1** DA/AD controller. If the control switches on a **HV2/4 (6/8/10)** unit is set to "DAC" (as upper channel in Figure 5.1), its high voltage output is proportional to the voltage input (0 -4 V or 0 -10 V) on the corresponding input socket on the rear panel. A **USB-IO1** can provide two individual voltage outputs up to 10 V for this purpose, controlled by software via USB, see Figure 5.29.

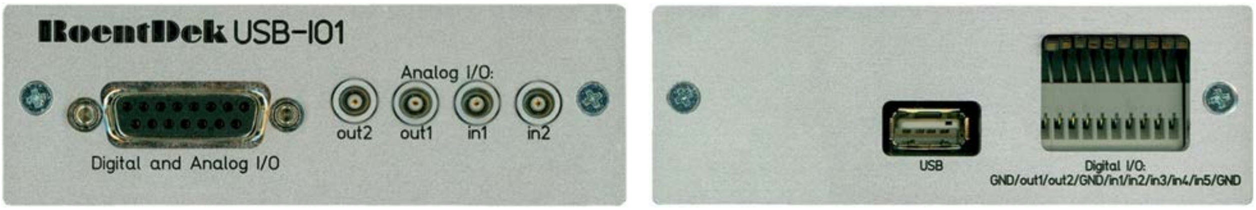


Figure 5.29: Front and rear panels of the USB-IO1 device with USB-port for the PC-connection and the two LEMO analogue out2 and out1 output sockets, suitable for remote-controlling the HV2/4 (6/8/10) units.

Control of the USB outputs is provided by *LabView*, **CoboldPC** and the *Iseg_control_USB_IO1.exe* GUI-program. Please contact **RoentDek** for details of advanced operation with LabView or **CoboldPC**.

For simple tasks of remote voltage setting the GUI program (see Figure 5.30) is usually sufficient, its operation self-explaining for most applications (otherwise please contact **RoentDek**).

The program interface has two sections for two independent output channels. Setting options for channel 2 (output from *out2* socket) are kept minimal while channel 1 (output from *out1* socket) control provides options to ramp the voltage automatically with selectable speed (in 10 V steps) or to change voltage settings after selectable delays (2 steps). Do not enter any set voltage above the maximum range of the connected high voltage supply.

It is very important to first enter the correct conversion factor which is independently selectable for the two channels. This value will determine the correspondence between set voltage and output voltage and depends on the used high voltage unit. For **HV2/4** the conversion is 4000 for **HV2/6 (8/10)** it has to be set to 10000.

False conversion factor setting will result in false output voltages which can cause damage to connected devices.

It is therefore recommended to verify proper output response on the **HV2/4 (6/8/10)** display before connecting any SHV socket.

Minor deviation between set voltage and real output voltage is possible and may be corrected by "fine-tuning" of the conversion factor, e.g. setting it to 3997 instead of 4000 for **HV2/4**.

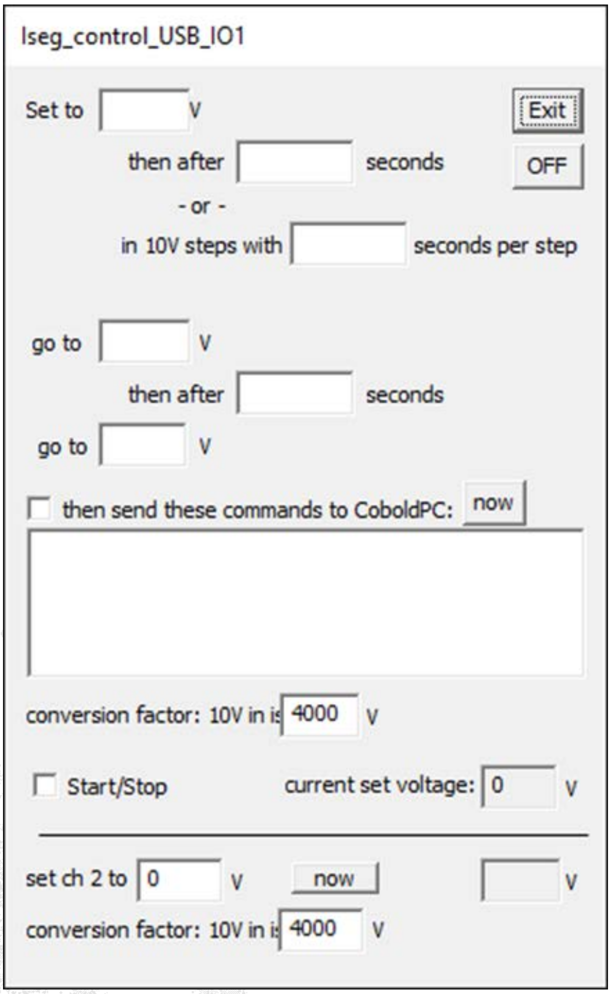


Figure 5.30: Input options of the GUI-program

Appendix: MCP's

STORAGE, HANDLING and OPERATION of MICROCHANNEL PLATES

from Galileo Corp.

STORAGE

Because of their structure and the nature of the materials used in manufacture, care must be taken when handling or operating MCPs. The following precautions are strongly recommended: Containers in which microchannel plates are shipped are *not suitable* for storage periods exceeding the delivery time. Upon delivery to the customer's facility, microchannel plates must be transferred to a suitable long term storage medium.

- Desiccator type cabinets which utilize silica gel or other solid desiccants to remove moisture have been proven *unacceptable*.
- The most effective long-term storage environment for an MCP is an oil free vacuum.
- A dry box which utilizes an inert gas, such as argon or nitrogen, is also suitable.

HANDLING

- Shipping containers should be opened only under class 100 Laminar flow clean-room conditions.
- Personnel should always wear clean, talc-free, class 100 clean-room compatible, vinyl gloves when handling MCPs. No physical object should come in contact with the active area of the wafer. The MCP should be handled by its solid glass border using clean, degreased tools fabricated from stainless steel, Teflon™ or other ultra-high vacuum-compatible materials. Handling MCPs with triceps should be limited to trained, experienced personnel.
- MCPs without solid glass border should be handled *very* carefully with great care taken to contact the outer edges of the plate ***only***.
- All ion barrier MCPs should be placed in their containers with the ion barrier facing down.
- The MCP should be protected from exposure to particle contamination. Particles which become affixed to the plate can be removed by using a single-hair brush and an ionized dry nitrogen gun.
- The MCP should be mounted only in fixtures designed for this purpose. Careful note should be taken of electrical potentials involved.
- ***CAUTION:*** Voltages must not be applied to the device while at atmospheric pressure. Pressure should be 1×10^{-5}bar or lower at the microchannel plate before applying voltage. Otherwise, damaging ion feedback or electrical breakdown will occur.

OPERATION

- A dry-pumped or well-trapped/diffusion-pumped operating environment is desirable. A poor vacuum environment will most likely shorten MCP life or change MCP operating characteristics.
- A pressure of 1×10^{-6} bar or better is preferred. Higher pressure can result in high background noise due to ion feedback.
- MCPs may be vacuum baked to a temperature of 480 °C (***no voltage applied***) and operated at a maximum temperature of 350 °C.

When a satisfactory vacuum has been achieved, voltages may be applied. It is recommended that this should be done slowly and carefully. Current measuring devices in series with power supplies aid in monitoring MCP behavior. Voltage drop across the Ω meter should be taken into consideration when calculating the applied voltage.

- Voltage should be applied to the MCP in 100 V steps. If current is being monitored, no erratic fluctuations should appear. If fluctuations do appear, damage or contamination should be suspected and the voltage should be turned off. The assembly should then be inspected before proceeding.
- Voltage across single thickness MCPs (i.e. with L/D 40:1) should not exceed 1 kV. Higher potentials may result in irreversible damage.

Appendix: MEASURING MCP RESISTANCE IN VACUUM WITH HIGH VOLTAGE SUPPLIES HAVING CURRENT READINGS THROUGH FT4/12/16TP DECOUPLING CONNECTORS

High voltage supplies with precise-enough current monitors (e.g. **RoentDek HV2/4**) can be used to determine MCP resistance. Unless the feedthrough socket and the high voltage cables are compatible it is necessary to connect the high voltage cables through the decoupling connectors of type **HFSD/HFSD** (for **DET** and **HEX** detectors) or **FT12TP** (for **DLD**). Blocking resistors in the decouplers/connection lines add to the measured resistances. These must be known (or determined) and later subtracted for obtaining the exact net resistance values of the MCP. The presence of blocking resistors of 100 kΩ and smaller can usually be neglected. During the measurements, all sockets leading to the anode (U_{ref}/U_{sig} and Holder) shall be kept floating (i.e. open). For **FT12TPz** see below in red.

If one side of an MCP or MCP stack is grounded or terminated via a known resistor, a voltage of U up to 500 V across may be applied to another contact and significant current I will be drawn from the high voltage supply that allows determining MCP resistance R directly via Ohm's law. R = U/I, except if an **FT12TPz** plug with internal **HVZ** circuit is used (see below in red for necessary corrections in this case).

The recommended procedure (after insuring good vacuum condition, with all potential charge/UV emitters turned off) is:

1. ground/terminate MCP front bias (e.g. by connecting a **RoentDek SHV-G** terminating plug (0 Ω), a simple cable bridge or (if available) an **HVT** box (other **HVT** socket floating).* Then slowly raise potential on the intermediate MCP contact socket (usually connected to the "X" line) with a high voltage power supply channel up to 500 V while all other connections (anode/holder/MCP back) are kept floating (sockets open). The current reading on the high voltage supply allows to determine the resistance of the front MCP. If an **HVT** is used during this measurement the value of R_{HVT} (usually 1 MΩ) must be subtracted afterwards and also blocking resistor values, if relevant.
   If an **FT12TPz** plug with internally mounted **HVT** bridge is used, do not terminate MCP front socket, because the internal **HVT** circuit already cares for MCP front termination via 1 MΩ.
   Then turn down voltage.
2. now connect the active high voltage supply to the MCP back contact socket (MCP interminate contact floating) or in case of **FT12TPz** to the HV_{in} socket, the polarity of the high voltage supply must be positive. MCP front termination remains as in step one. Raise potential up to 800 V (slowly). The measured current value now allows to determine the sum resistance of the MCP, with the earlier measurement one can calculate the back MCP resistance.
   In case of **FT12TPz** the voltage of MCP back will be between 200 and 300 V (260 V with default setting) smaller than the voltage supplied to the HV_{in} socket. This has to be taken into account when calculating the resistance: $R = (U - U_{HVZ})/I$. To increase precision one can measure at two values U1, U2 > 300 V and determine $R = \Delta U/\Delta I$.
   After that, turn off high voltage. For crosscheck and increasing the precision, it is recommended to
3. finally place a ground connection / termination to the intermediate connection socket and raise voltage on MCP back socket slowly up to 500 V (800 V). After that turn off high voltage. Now the back MCP resistance can be determined independently, which should be consistent with the earlier calculated value.

Knowing the MCP resistances, it is possible to determine an adequate resistor for an **HVT4+** passive matching box to be connected between the intermediate connection socket and MCP front or back input socket, see Chapter 5.5 of this manual or refer to the **RoentDek** Power Supply Manual.

Once a force-matching **HVT4+** with properly selected resistor R_M is installed, the above procedure may be repeated in order to confirm that the effective resistance measured between the high voltage input front/back sockets and the intermediate contact (through the **HVT4+**) are matched. If you have received a non-matched MCP set and **HVT4+** from **RoentDek** the **HVT4+** may be pre-equipped with a resistor set that produces an effective R_M close to the desired value. The choice of the resistor set was then based on estimations about the MCP resistances from specifications values obtained from the manufacturer(s). However, this does NOT guarantee a sufficient matching since the real resistance values can significantly deviate from the specified numbers. Therefore, it is mandatory to verify MCP resistance with the described method and then modify the resistance in the **HVT4+** accordingly. If you need help in modifying the **HVT4+** to improve matching conditions (i.e. by adding/exchanging resistors) please contact **RoentDek**.

* In absence of all of this, a turned-down high voltage power supply channel may serve for setting zero voltage to MCP front. However, it is important to verify that its voltage is not pulled-up when voltage on the other MCP end is increased. In case of high voltage units supplied by **RoentDek** (e.g. **HV2/4**) it is necessary to switch the two channels used to different polarity (e.g. negative polarity for the ground terminating channel and positive potential for the other).

Appendix: The RoentDek HFSD/T signal decoupler-operational safety

The RoentDek HFSD signal decoupler is a passive device to pick up high frequency signals from a biased contact cable, e.g. off a detector device. The contact line to the detector is routed through the **HFSD** via SHV or MHV connectors. Only the AC content on the line is routed to a "signal" output socket.

A typical application of the **HFSD** is signal pickup or termination from single-particle/photon detectors such as micro-channel plate stacks, photomultipliers or secondary electron multipliers in general.

High voltage may only be applied through the **HFSD/T** if the case is closed and both high voltage sockets are connected via properly rated and specific high voltage coax cables or to a coax feedthrough with shield on ground potential.

Before removing a high voltage cable from a socket or removing the **HFSD/T** from a feedthrough connector the external voltage must be set to zero.

Before opening the case, first the external voltage must be set to 0 and then all connection cables must be disconnected.

For extra safety the case can be connected to ground at all times through a separate cable (not included).

Special spark protection circuits reduce the risk of damage to follow up electronics from excessive signals on the line, e.g. caused by operation failures of the connected detector device. The spark protection circuit also connects the low-voltage side of the internal decoupling capacitor to ground via a resistance of about 400 Ω for additional operational safety in case of erroneous handling of connection cables.

Older versions of **HFSD** have a fixed 1 MΩ series resistor (0.4 W load) between high voltage input and output, newer versions can be switched from default 1 MΩ to 10 kΩ (0.4 W load) via an internal jumper.

The **HFST** version of this device has the same safety features and operation restrictions as the **HFSD**.

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