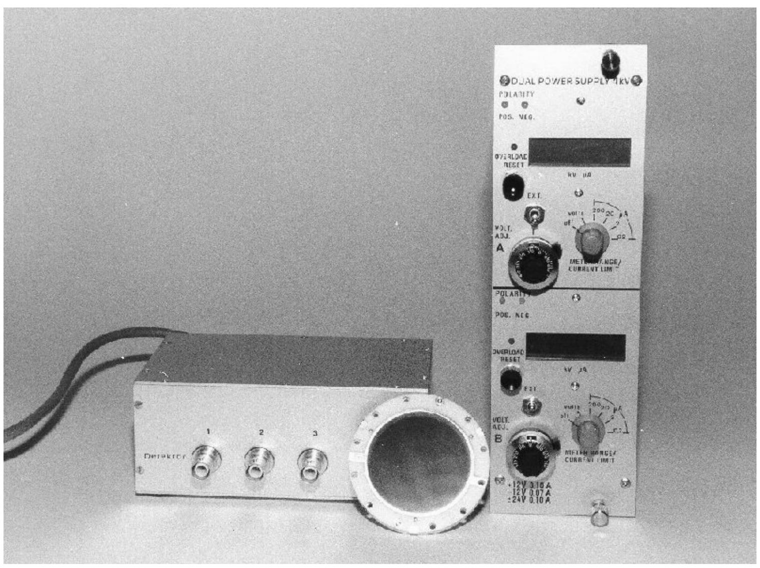
RoentDek Handels GmbH

UHV-Detectors
Supersonic Gas Jets
Multifragment Imaging Systems

3-dimensional resolving Wedge-and-Strip-Detector with image charge coupling

Manual for ceramic Wedge-and-strip detector



Position and Time Sensitive Microchannel Plate Detector with patented image charge Wedge-and Strip Readout (WSD 40), charge sensitive preamplifier (CATSA3) and high voltage bias supply.

Optional Detector-Components

1. MCP-detector with wedge-and-strip-anode
2. 2×4kV high voltage bias supply (**HV2/4**)
3. 4-pin CF35 UHV-feedthrough-flanges and CF100-CF35-adapter-flange with connection cable from the feedthrough-flange to the preamplifier and the high voltage supply (**FT4²**)
4. 3-channel low noise charge sensitive preamplifier (**Catsa**).
5. Timing amplifier (e.g.**FAMP1**)

1 The Microchannel Plate Detector

rate capability	1 MHz (MCP detector alone)
rate capability	20 kHz (MCP detector with charge sensitive anode)
position resolution	50 μm
overall linearity	0.5 mm (after capacitive correction)

1.1 Characteristics

1.1.1 Physical Characteristics of Detector — Specification

Mounting Diameter:	66 mm
Mounting height	9 mm
Baking Temperature:	150°C Maximum

1.1.2 Physical Characteristics of MCPs

# of MCPs in Chevron	2
Diameter:	50 mm *
Active Diameter:	47 mm *
Quality Diameter:	45 mm *
Pore diameter:	25 μm *
Bias Angle:	7° ± 2° *
Open Area Ratio:	>50 %
Operating Temperature Range:	-50 to 70°C
Operating Pressure:	$< 2 \times 10^{-6}$ mbar

1.1.3 Electrical Characteristics of Detector

Electron Gain @ 2400 Volts:	1×10^{7} Minimum *
Operating Voltage:	2500 Volts Maximum *

*** for Photonis MCP:**

Diameter:	46 mm
Active Diameter:	43 mm
Quality Diameter:	41 mm
Pore diameter:	12 μm
Bias Angle:	13° ± 2°
Electron Gain @ 2700 Volts:	1×10^{7} Minimum
Operating Voltage:	3000 Volts Maximum

1.2 General description

The RoentDek Microchannel plate (MCP) detector with Germanium-Wedge-and-Strip-anode (patented) is a high resolution 3D-imaging device for charged particle or photon detection.

It consists of a pair (Chevron) of selected rimless 50 mm diameter MCPs, each 1.5 mm thick, supported by a pair of partially metallized ceramic rings (1.5 mm thick, 65 mm outer diameter) and a position sensitive Wedge-and-strip-anode with germanium layer on a 1.2 mm thick ceramic substrate. Due to the matched resistance the MCPs can be operated as a single stack.

The detector size is 66 mm diameter and 9 mm height. The anode and the MCPs are fixed by spring clamps, the MCP holder is mounted independently so that the MCP detector can be used alone without anode, or with other anode types (e.g. fast delay-line-anodes, also available from RoentDek).

The whole detector is bakeable up to 150°C (UHV-compatible), the metal contacts on the ceramic rings/substrate are suitable for soldering.

The operation requires three DC voltages for MCP front and back contacts and the Germanium layer. It is advisable to bias the three Wedge-and-Strip electrodes with the same voltage as the Germanium layer.

The position of the detected particle/photon is encoded by charge sensitive amplifiers which must be connected to the "wedge"-, "strip"- and "meander"- contacts of the anode and a simple algorithm. A fast timing signal can be picked up from the MCP front or back side by a RC coupler.

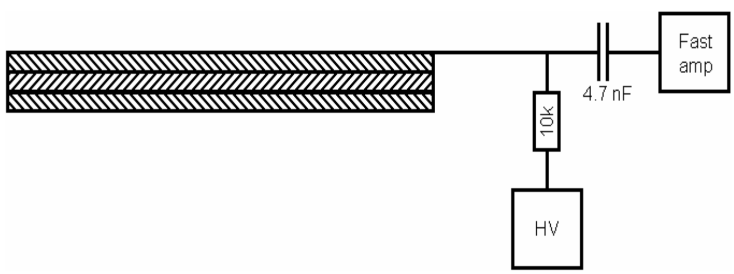


Figure 1.1: RC-coupler for getting a fast timing signal from the MCP

1.3 List of assembly parts

- 2 ceramic rings, partially metal coated
- wedge-and-strip anode with Ge-layer on a ceramic substrate
- 2 micro-channel plates, matched in resistance
- 4 (spring) washers
- M3 plastic screws with nuts (for pre-assembly of the MCP stack)
- M2 screws and special nuts (UHV assembly only)

1.4 Detector assembly

All parts, especially the MCP and the wedge-and-strip structure should be handled with great care since the surfaces are very sensitive and should never be touched or scratched.

The ceramic rings should not be exposed to exceeding mechanical and thermal stresses and the assembly should take place under clean and dry conditions.

1.4.1 Preparation:

- Verify with an Ohm-meter that no dust particles have shortened the superficial W&S structure. The resistance between the "W"-, "S"- and "M"- contacts must exceed 20 MΩ. The resistance between the two M-contacts should be between 100 and 300 Ohm. Dust particles can be removed by spraying with dry air.
- A mesh can be glued or soldered directly onto the front side of the front ceramic ring. Make sure that the mesh is under tension. Undulations in the surface of the mesh act as lenses and will decrease the position/timing resolution of the detector.
- Prepare the connection cables for the MCP detector and the wedge-and-strip anode. You need 6 cables for the MCP front, MCP back, germanium layer and the 3 anode segments. (a 7th if a mesh is used). The cables can be soldered directly onto the metallization of the ceramic rings and the anode. If so, use preferably the metallization strips which are not located on a hole in the ceramic substrate. Please take care that no solder or flux is sprayed over the germanium layer or the anode structures or the MCPs.
- Otherwise the cables on the anodes can be fixed by screws at the metallization rings located at holes in the ceramic parts. Before mounting be aware which holes should be used for that purpose. For the Germanium layer and the 3 anode segments the screws which are used for fixing the anode might also be used. RoentDek provides special contact clamps for the MCP (UHV assembly only).
- Clean all parts **except the MCPs and the Wedge-and-strip-anode** in an ultrasonic bath.

Warning:

Although it is possible to clean also the anode or the MCP in an ultrasonic bath (iso-propanol) for very short time, there is a considerable risk for damage. If cleaning is necessary contact a RoentDek agent before.

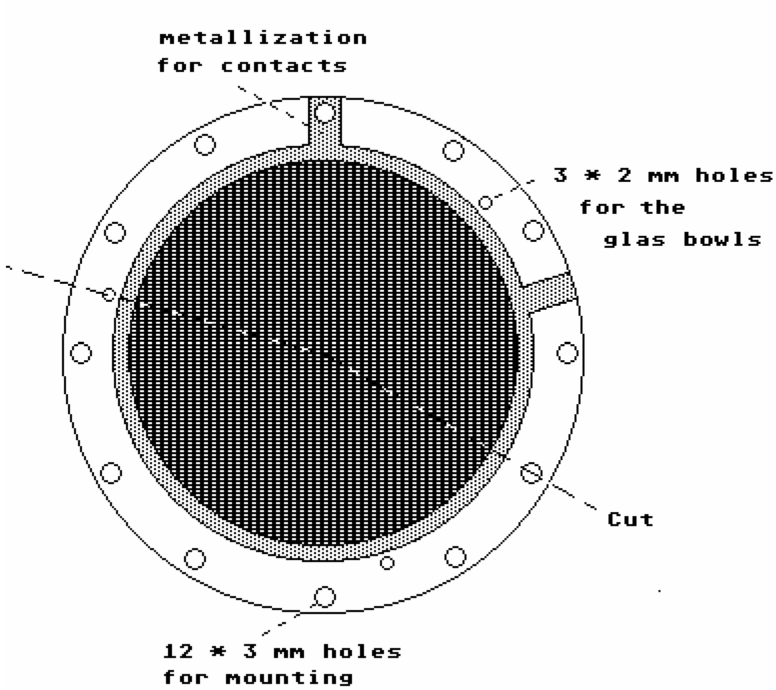


Figure 1.2: front view of the ceramic holder rina

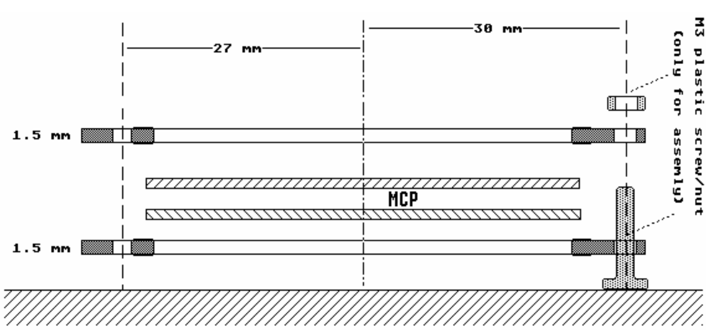


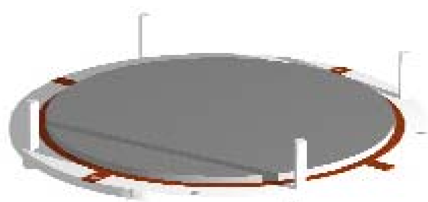
Figure 1.3: side view assembly step 1-3. Example is for chevron configuration

1.4.2 Now the detector can be assembled

(If possible under clean room conditions).

1. Place the rear ceramic ring (metallization on one side), with the contact for MCP back side upward, with inserted plastic screws, on a flat table according figure 1.3 and the sketch below.

2. Remove the MCP carefully from their transport package and place them centered onto the metal contact of the ceramic ring. The delivered MCPs are matched in resistance within 10% for direct stacking.



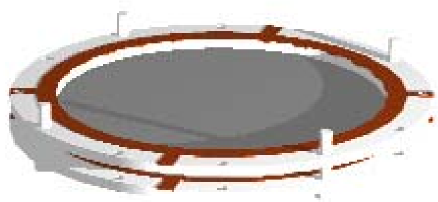
   a. <u>For Burle MCP:</u> there is no intermediate contact ring needed, the MCPs are placed in direct contact. The marks on the MCPs (triangles on the outer rim on one side) should be turned by 180° for consecutive MCPs (the triangles indicate the tilt angle direction of the MCP pores). Note that the marks are only on one side of the MCP.
   b. <u>For Photonis MCP:</u> the thin shim ring must be placed between the MCPs. There is no need for a special tilt angle orientation.

It is especially important to avoid that dust particles settle between the MCP during assembly. Dust particles can usually be blown away be spraying dry air on the MCP.

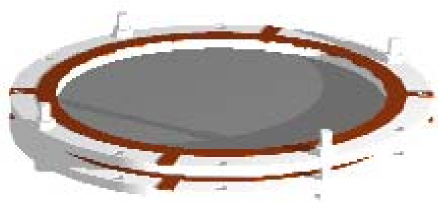
For MCP general handling see also instructions on the manufacturer's web sites or in the Appendix of this manual. Touch MCPs only with care along the rim, preferably with gloves. After the stack is piled you may check if it is well centered, adjustments can be done by carefully moving the MCPs on the ring.

If the MCPs need replacement mount a set with matching electrical resistance only.

3. Place the second ceramic ring (with the MCP contact facing down) carefully on the MCP-stack. The plastic rods will guide the alignment. Note that the wire contacts on the ceramic rings should not be directly opposing each other when the stack is mounted.



Now fix the stack with the plastic nuts gently and very carefully.



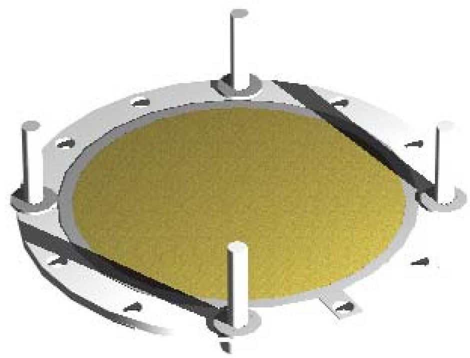
The MCP holder stack can now be finally fixed with 4 spring clamps.

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

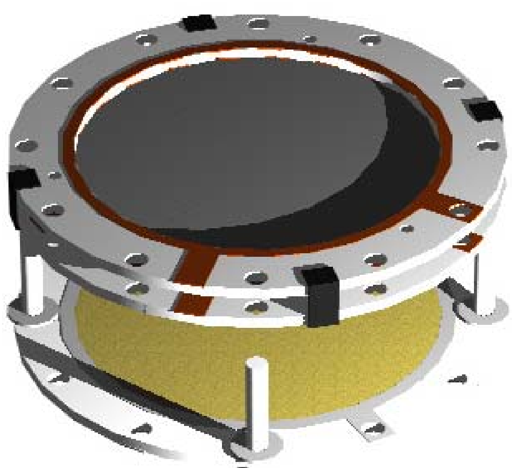
For use under vacuum conditions above 1E-8 mbar and baking below 120°C the plastic screws can also be used for the final mounting. Use the spring clamps as spacers between anode and MCP stack. Using plastic screws and soldering the cables eases assembly and operation very much so that the following mounting is recommended. For UHV assembly please continue with 1.4.2.2.

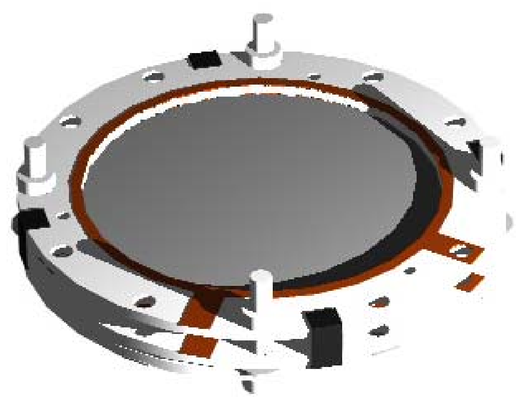
1.4.2.1 Mounting of the anode (non-UHV)

4. Place the anode with the Germanium coating facing upward (towards the MCP stack), with inserted plastic screws, on a flat table and put the spring washers over the screws. Make sure that you have found the desired orientation of the screws with respect to contact pads.



5. Now mount the MCP stack in the desired orientation to the anode and fix it with the nuts.





Of course you can also use these screws to mount the detector directly to your setup

1.4.2.2 Mounting of the anode (UHV)

For the UHV mounting a set of special M2 nuts and screws is provided. The mounting is mostly analog to step 4 in the previous chapter. The MCP stack is fixed with special nuts that must be placed between the ceramic rings in 3 mm holes of the rear ring. These can also provide the contact to the Wedge-and-Strip and the Ge-structures.

Similar screws/nuts or a special clamps are used to connect the MCP contacts.

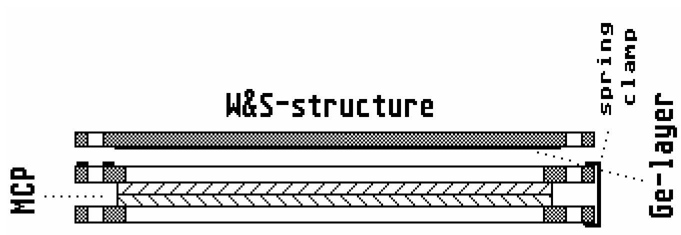


Figure 1.4: side view of the assembly after step 1-4 (chevron configuration)

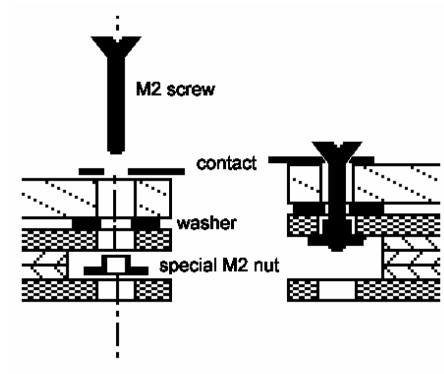


Figure 1.5: detail view of anode mounting

Now the assembly of the Germanium-Wedge-and-Strip-MCP detector is complete.

For disassembly reverse all steps.

Before the installation of the detector it is useful to check all contacts with an Ohm-meter again.

1.4.2.3 Connecting the MCP stack (UHV):

If the cables can not be soldered to the contacts due to serious UHV-demands, MCP front and back side can be connected by clamping a cable with the supplied screw/special nut as shown in figure 1.6.

Figure 1.6: cable connection on MCP ring

1.4.3 Operation

The MCP can be operated with a voltage of 1250 V per plate, i.e. 2500 V for a chevron configuration. However, sufficient gain can be obtained at lower voltage already.*

It is very important to follow the instructions of the MCP manufacturer when you apply voltage to the MCP stack for the first time.

It is advisable to use power supplies with current limitation and extremely fast voltage shutdown for protection of the MCPs (also available from **RoentDek**). During operation the vacuum should never exceed 1E-5 mbar, vacuum conditions below 1E-6 mbar are recommended. The potential of the MCPs front is arbitrary (depending on the particles to be detected). The Ge-layer has to be on a slightly more positive (50 V - 200 V) potential than the back side of the MCPs. The anode segments are decoupled from the other potentials thus the anode and also the preamps can always be operated on ground potential even if the back side of the MCP and the germanium layer are on high voltage. But the anode potentials should be close to the Ge-Layer potential if that is possible. All anode segments must to be on the same potential in any case. If the voltage between the germanium layer and the anode should differ by more than 1kV you must check for voltage stability **before** connecting the preamplifiers.

Example for voltage supply for ion/photon detection (chevron-configuration)

MCP front	- 2300 V
MCP back	ground
Ge-layer	+200 V
Anode segments	ground

1.4.4 Position encoding:

The position of each detected particle is calculated from the charge ratios between the different anode segments Wedge (A), Meander (B) and Strip (C). The simple equations are:
$X = A/(A+B+C)$ and $Y = B/(A+B+C)$

The position resolution is directly proportional to the achieved signal-to-noise ratios. With the **RoentDek** amplifiers a position resolutions of 1/1000 or better can be obtained with this detector. Other charge sensitive preamplifiers in combination with main amplifiers can be used.

Start with minimizing the DC offsets of all amplifiers and other components if necessary. The linearity of the imaging is determined by the amplifier calibration and the cross talk between the anode segments, which also depends on the RC input of the preamplifiers. By calculating the position with the above formula the detector image might be egg shaped.
A mostly linear image can simply be obtained be adjusting the 3 amplification factors, optimizing the image by try and error. A more analytical method is described in the following subparagraph.

* For Photonis MCP up to 3000V total voltage across the MCP stack can be applied.

1.4.4.1 Position encoding with cross talk correction

Calibrate the amplification factors of the amplifiers carefully using a pulser coupled to the Germanium layer. Then check the detector image with real signals, usually it is still egg shaped due to the cross talk. Now use the following algorithm to calculate the position using linear cross talk correction. The following codes describe a Fortran 90 subroutine (be careful with word wrap) for a comfortable position decoding and round and linear image:

```
SUBROUTINE wedge_and_strip(switch,meander,wedge,strip,amp_m,amp_w,amp_s,off_m,
off_w,off_s,mw,ms,ws,x0,y0,cal_x,cal_y,exc_xy,inv_x,inv_y,rotate,
sum,x,y)

implicit none
real*8 switch,cal_x,cal_y,x0,y0,exc_xy,inv_x,inv_y
real*8 amp_m,amp_w,amp_s,off_m,off_w,off_s,mw,ms,ws
real*8 meander,wedge,strip,truemeander,truewedge,truestrip,sum
real*8 x,y,tempx,tempy,a,b,determinante,xnorm,rotate
real*8 irange
!-----------------------------------------------------------------
!     start
!-----------------------------------------------------------------
      irange      = 2048.0                            !Full ADC range
!-----------------------
!     checks
!-----------------------
      if (switch.eq.0.) then                    !All corrections off
            amp_m = 1.
            amp_w = 1.
            amp_s = 1.
            off_m = 0.
            off_w = 0.
            off_s = 0.
            mw          = 0.
            ms          = 0.
            ws          = 0.
            x0          = 0.
            y0          = 0.
            cal_x = 1.
            cal_y = 1.
            inv_x = 0.
            inv_y = 0.
            exc_xy      = 0.
      else
            if (amp_m.eq.0.) amp_m = 1.
            if (amp_w.eq.0.) amp_w = 1.
            if (amp_s.eq.0.) amp_s = 1.
            if (cal_x.eq.0.) cal_x = 1.
            if (cal_y.eq.0.) cal_y = 1.
      endif
!-----------------------
!     offset subtraction and amplification
!-----------------------
      meander     = (meander - off_m) * amp_m
      wedge       = (wedge   - off_w) * amp_w
      strip       = (strip   - off_s) * amp_s
!-----------------------
!     capacitive linear crosstalk
!-----------------------
      if(mw.eq.0.and.ms.eq.0.and.ws.eq.0)then
```

```
            truemeander = meander
            truewedge   = wedge
            truestrip   = strip
      else
            a = mw + ms + ws
            b = (mw*ms) + (mw*ws) + (ms*ws)
            determinante=1.-(2.*a)+(3.*b)
            if(determinante.ne.0)xnorm=1./determinante
      truemeander=xnorm*(meander*(1.-ws-a+b)+wedge*(b-mw)+strip*(b-ms))
      truewedge =xnorm*(wedge *(1.-ms-a+b)+strip*(b-ws)+meander*(b-mw))
      truestrip =xnorm*(strip*(1.-mw-a+b)+meander*(b-ms)+wedge *(b-ws))
      endif
!-----------------------
!     sum and x,y
      sum = truemeander + truewedge + truestrip

      if (sum.ne.0.) then
            x     = cal_x * (truewedge / sum * irange - x0)
            y     = cal_y * (truestrip / sum * irange - y0)
      else
            x     = 0.0
            y     = 0.0
      endif
      sum = sum / 3.0
!-----------------------
!     Exchange
      if (exc_xy.eq.1.) then
            tempx = x
            x = y
            y = tempx
      endif
!-----------------------
!     Invert
      if (inv_x.eq.1.) x = irange/2.0 - x
      if (inv_y.eq.1.) y = irange/2.0 - y
!-----------------------
!     rotating
      if (rotate .ne. 0.0) then
       if (x0.eq.0..and.y0.eq.0.) then
        tempx=x - irange/4.0
        tempy=y - irange/4.0
        x = tempx*cosd(rotate) - tempy*sind(rotate) + irange/4.0
        y = tempx*sind(rotate) + tempy*cosd(rotate) + irange/4.0
       else
        tempx=x
        tempy=y
        x = tempx*cosd(rotate) - tempy*sind(rotate)
        y = tempx*sind(rotate) + tempy*cosd(rotate)
       endif
      endif
return
end
```

Reasonable values for the cross talk strengths ws, mw, ms are:

```
ws = 0.00-0.05
mw = 0.05-0.12
ms = 0.05-0.12
```

1.5 Performance

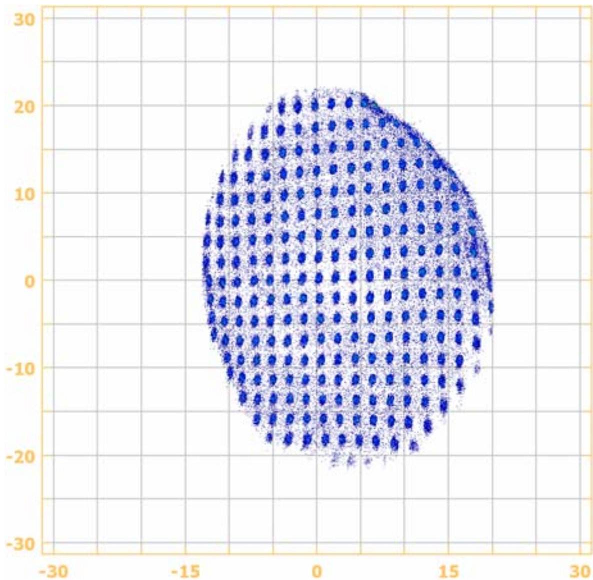


Fig.1.6: Image of a shadow mask without cross talk correction illuminated by an alpha-source

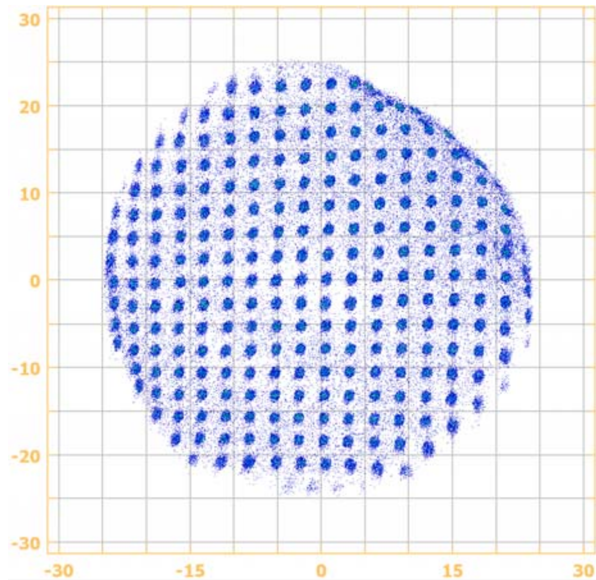


Fig.1.7: same as fig.1.6 but with cross talk correction (mw=0.13, ms=0.08, ws=0.01)

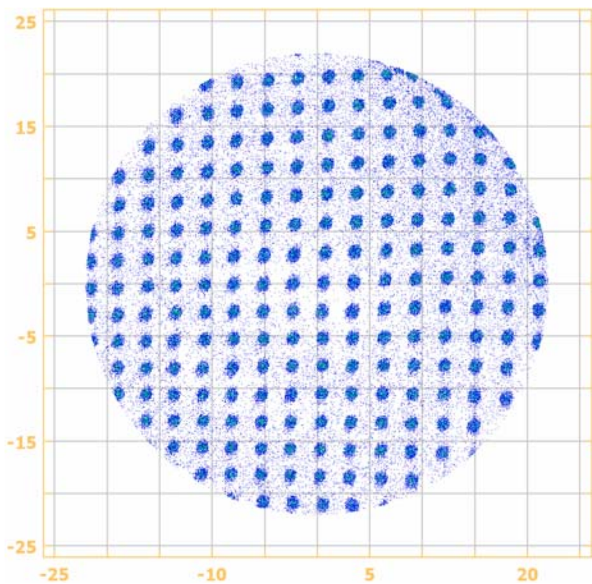


Fig.1.8: same as fig.1.7 with a cut at r=22mm

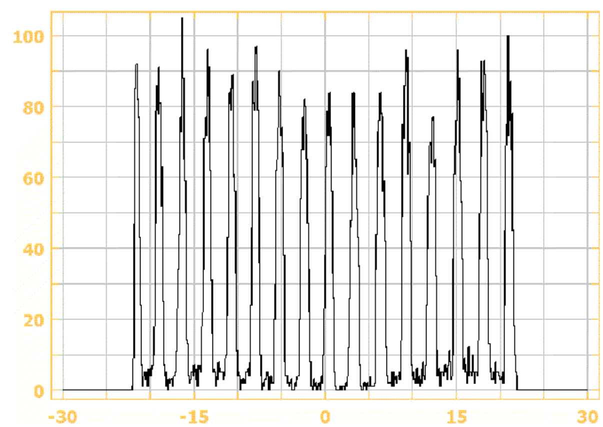


Fig.1.9: projection of one row of fig.1.7 onto the x-axis

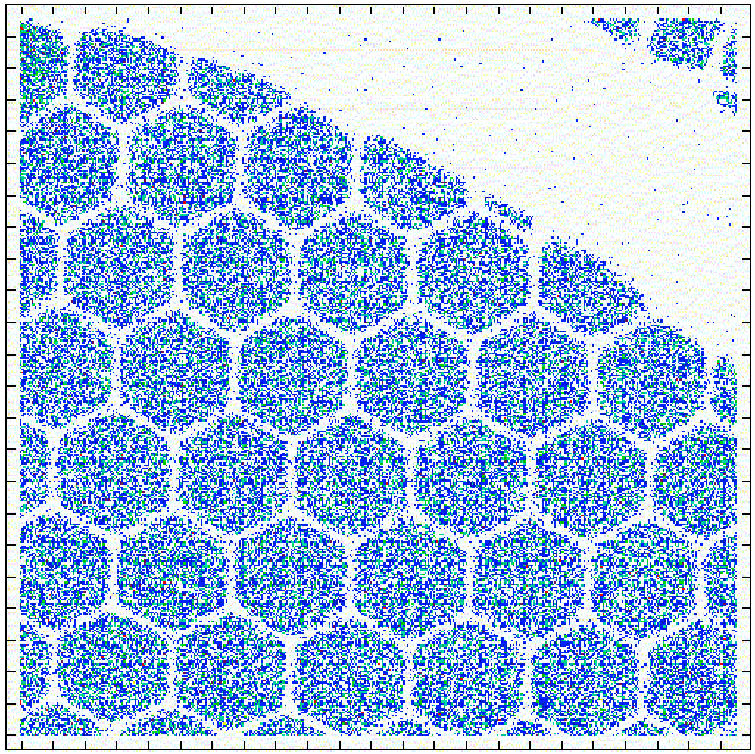


Fig.1.10: Image of a shadow mask created with alpha-particles. The obstacle width is 200μm and the size of hexagonal arrays is 3mm. A position resolution of 47μm is achieved.

2 The RoentDek Charge Sensitive Preamplifier (CATSA)

The RoentDek CATSA box contains 3 preamplifier slots inside which can be used independently. To insert the preamplifier chips open the upper side of the box and insert the chips in the sockets in the direction so that the electronic parts are opposite to the ground plate (see figure 2.3.). When delivered the preamplifier chips are already inserted.

The CATSA has 3 inputs which should be connected to the 3 segments of the Wedge-and-Strip anode (or any other charge integrating anode). The inputs are SHV sockets. They are labeled *Detektor* and numbered from 1 to 3.
On the opposite side of the CATSA is the high voltage input for the anode labeled *HV in, max 3kV*. The voltage applied to this SHV socket will be biased to the 3 detector inputs, i.e. the anode by 3 RC-couplers in the box. This is necessary if the anode should be biased with a certain potential. Whenever possible operate the anode on ground potential (especially possible when the RoentDek Germanium-Wedge-and-Strip-anode is used, since the germanium layer can be put on high voltage and the anode is decoupled to be run on ground). If the anode is put on ground the chance of surviving a high voltage spark at the MCP is much higher than with the anode on high voltage.

The CATSA has a charge integrating energy (*E out*) output and a fast timing output (*t out*) for each channel, labeled from 1 to 3. All outputs are standard Lemo sockets. Use the *E* outputs for the position decoding. The *t* outputs can be used for a fast trigger signal for the data acquisition or a time-of-flight measurement. It is useful to connect all 3 *t* outputs together to get a timing signal which is independent from the detected particle position on the detector. However for advanced users it is also possible to use a standard RC-coupler to take a fast timing signal for a coincidence like a time-of-flight measurement. The timing resolution especially by using a proper RC-coupler and constant-fraction-discriminator is typically in the range of 500-800 ps (see figure 1.1). But also using the CATSA *t* outputs a timing resolution of about 1 ns is achievable.

A test input (*test in*) can be used to couple in a pulser signal (about 1 V) to check if the preamplifiers are working properly. The preamplifier chips also have an error LED which is on when the preamplifier chip is broken.

2.1 How to repair a Catsa

The CATSA preamplifier chip is a very low noise charge amplifier. Due to its sensitivity it is affected by too high charge load, e.g. induced by the tripping of a high voltage bias supply.
Such an event is usually indicated by a LED, however, the Catsa can be „dead“ (no output signals) even without the LED glowing. It can be repaired many times by exchanging the burned elements.

We have supplied you with a special manual for those who want to try a self-repair.

Figure 2.1: inputs

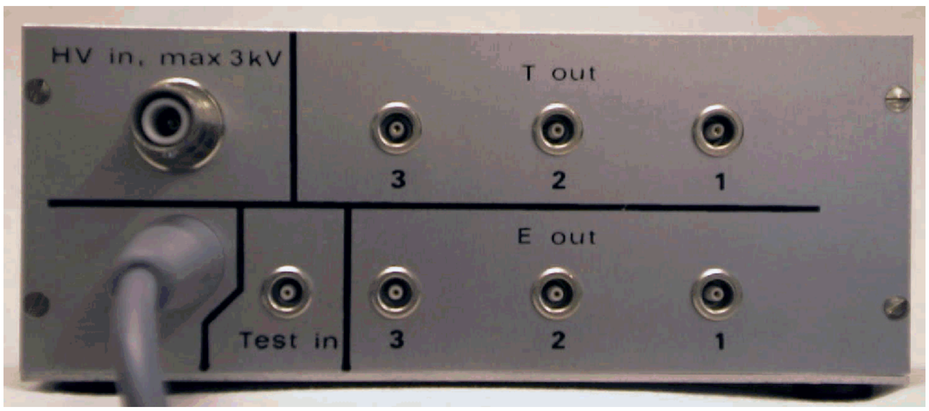
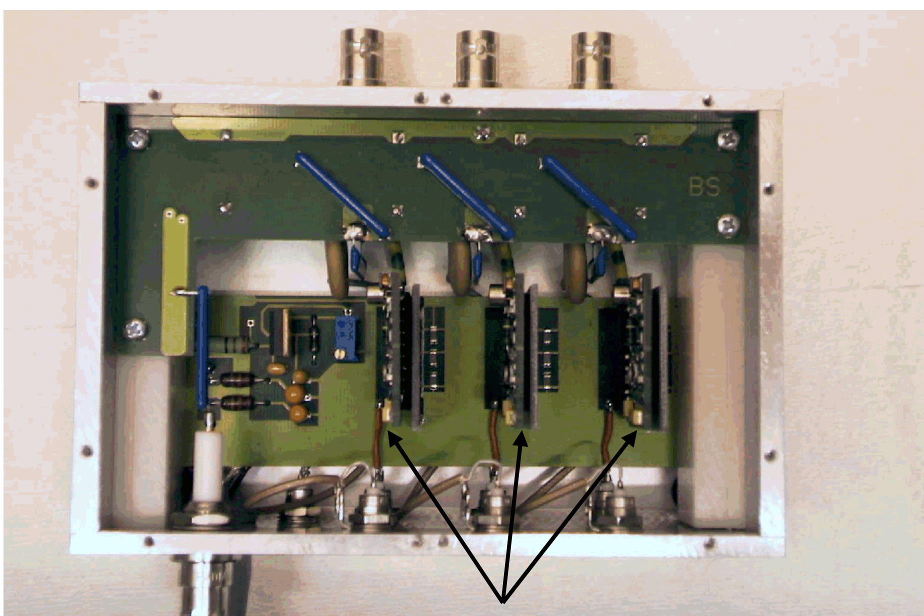


Figure 2.2: outputs



Preamplifier chips

Figure 2.3: inside view

We hope you will be satisfied with your new **RoentDek** detector setup.

Additional information is available for

- MCP-detectors with UHV-compatible Delay-Line-anodes.
- MCP-detectors with UHV-compatible time-of-Flight-anodes.
- MCP-detectors with UHV-compatible one-dimensional resistive anodes and one-dimensional delay-lines
- Residual gas beam profile monitor for UHV based on one- and two-dimensional MCP-detectors.
- Specially adapted electronic modules for position sensitive detectors.
- 2D-position sensitive proportional counters for X-rays and neutrons
- Supersonic gas jet targets
- Multi fragment imaging systems (Cold Target Recoil Ion Momentum Spectroscopy COLTRIMS).

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Appendix (MPCs):

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.

- Dessicator type cabinets which utilize silica gel or other solid dessicants 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} 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} 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 be done slowly and carefully. Current measuring devices in series with power supplies aid in monitoring MCP behaviour. Voltage drop across the meter should be taken into consideration when calculating the applied voltage.

- Voltage should be applied to the MCP in 100 volt 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.