Micromegas-based Central Tracker prototype for the SPD experiment

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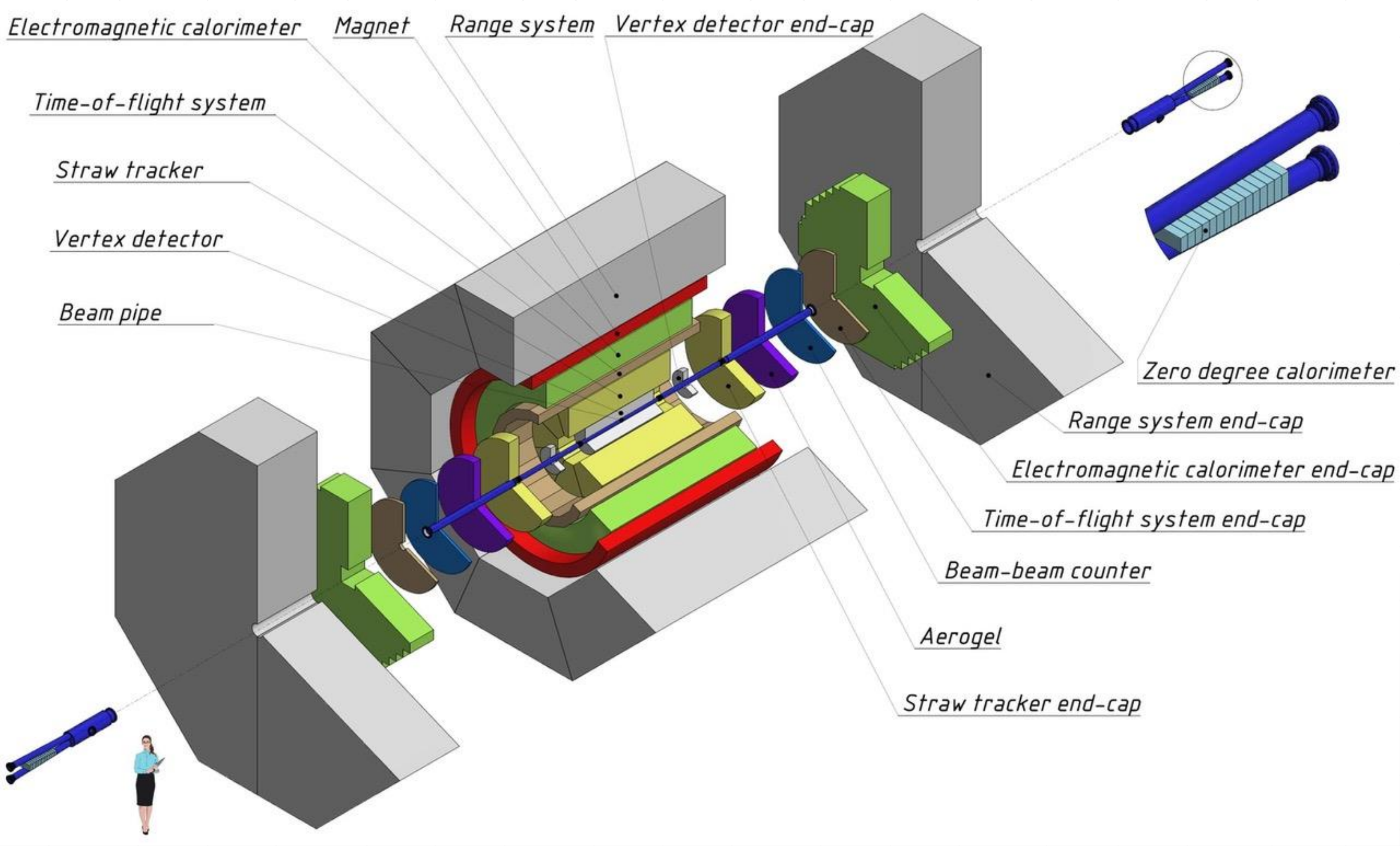
Experimental setup of Spin Physics Detector

The SPD experiment will take place at the NICA accelerator complex in Dubna and will come into operation after the main program of the MPD experiment is completed.

The SPD setup is designed as a universal 4π detector, including tracking systems, a calorimeter, a muon system and particle identification and all this is placed in a superconducting magnet.

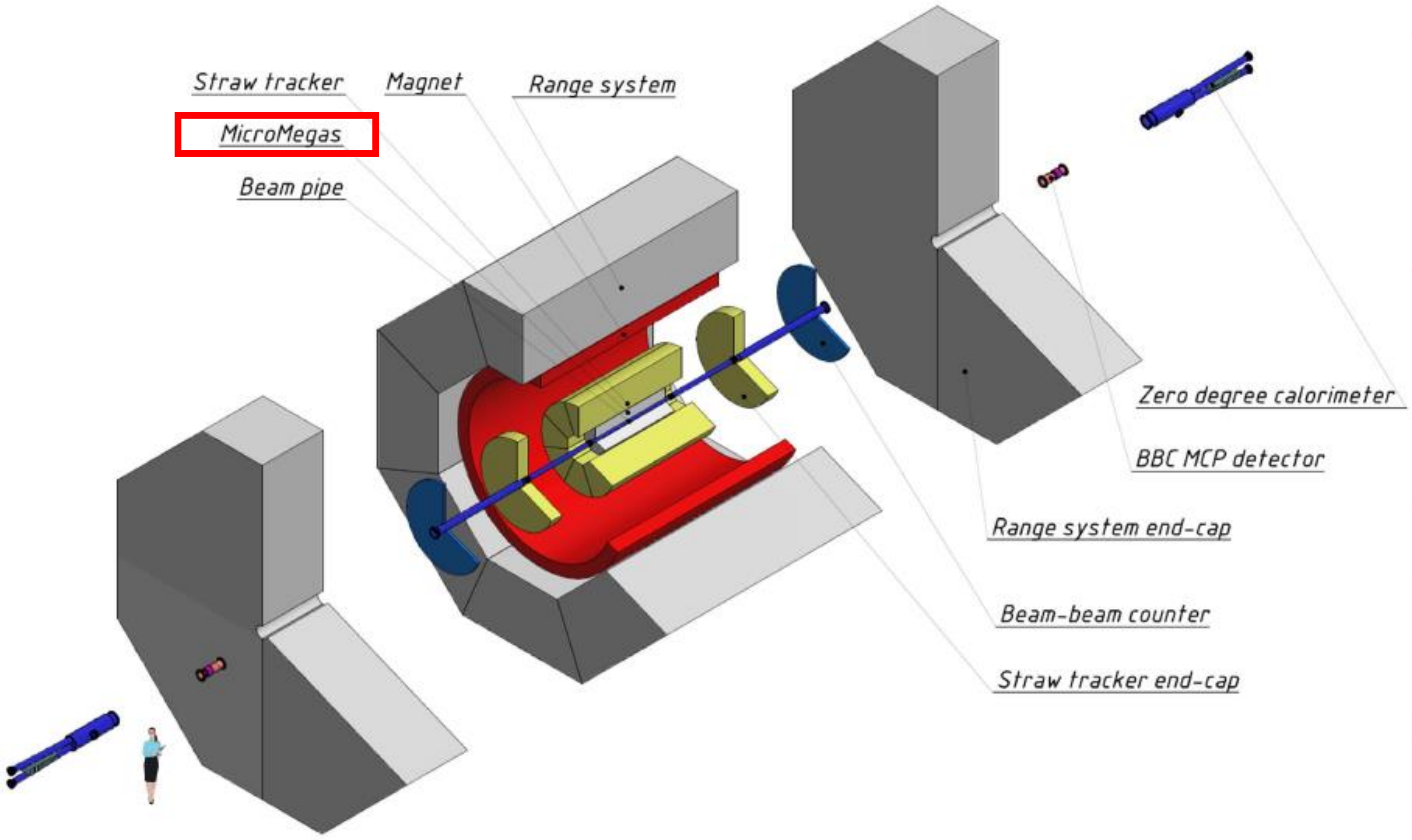


Experimental setup of SPD: Phase 1

It is planned that the SPD will be put into operation in stages and at the first stage there will be no silicon detector (Vertex detector). In fact, the inside of the detector will remain empty.

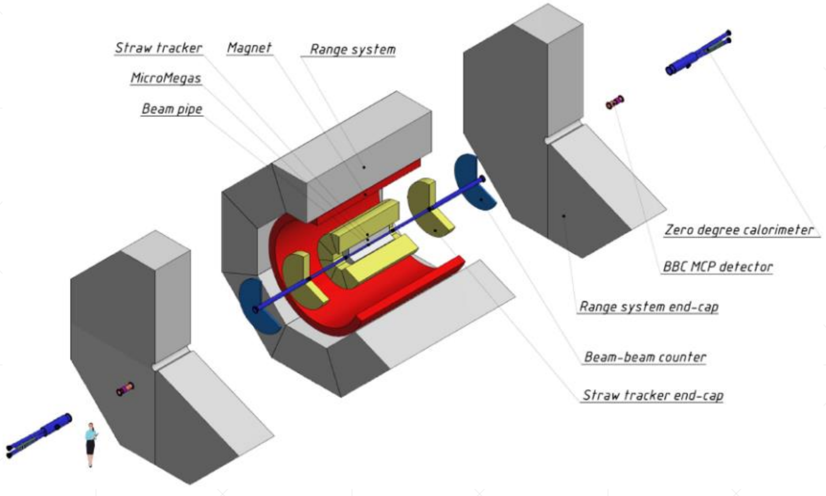
Therefore, a proposal was made to install a relatively cheap (10% of the price of a Silicon detector), simple and easy to implement central tracker based on Micromegas.

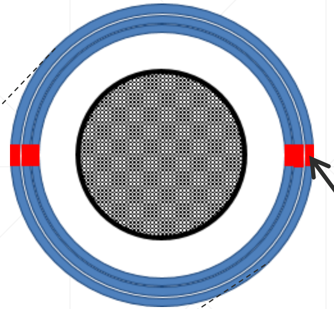
This solution will improve pulse resolution and track search efficiency in the early years of SPD operation.



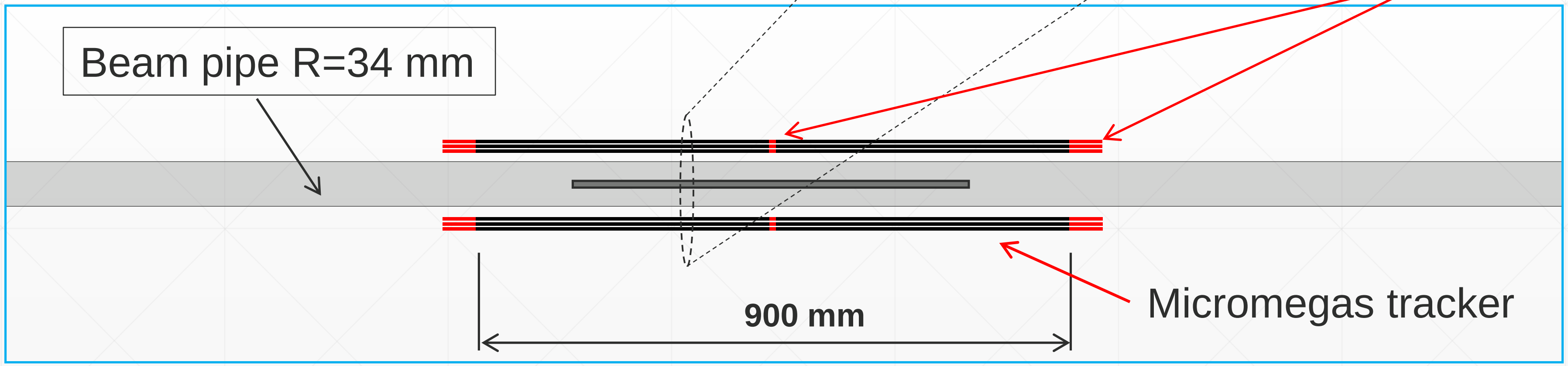
Micromegas Central Tracker (MCT). General view

Micromegas tracker: 3 Layers R=50-61 mm
12 half-cylindrical micromegas chambers





Dead region



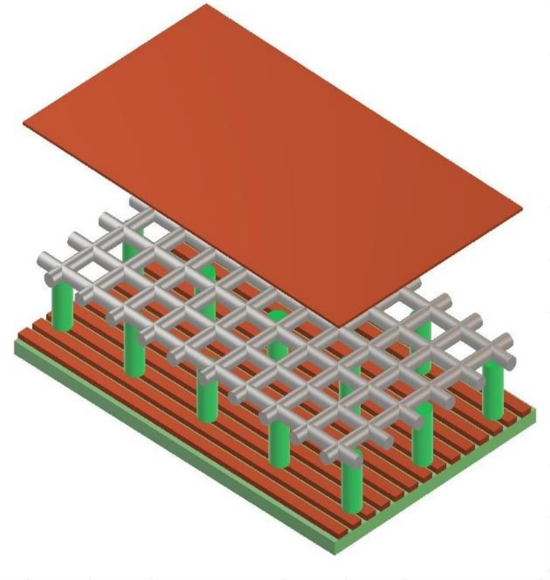
Beam pipe R=34 mm

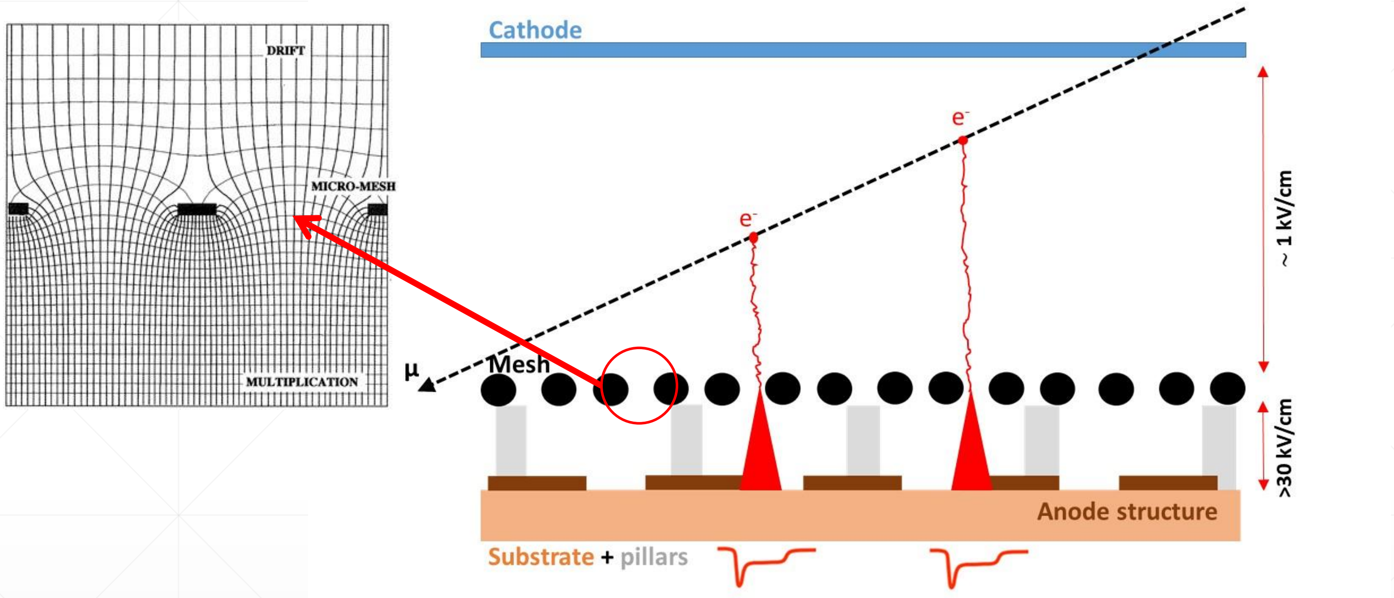
900 mm

Micromegas tracker

Micro Mesh Gaseous Structure

Micromegas is a flat counter with dedicated ionization and amplification gaps separated by a thin mesh. The detector consists of a cathode, mesh and anode. The anode is usually segmented.

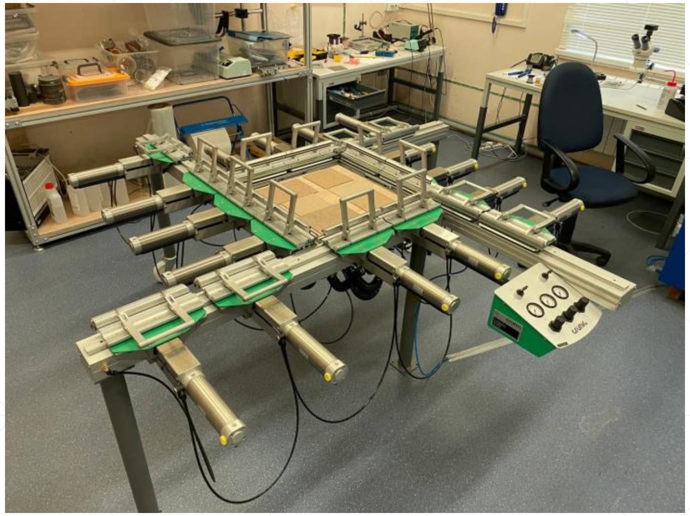




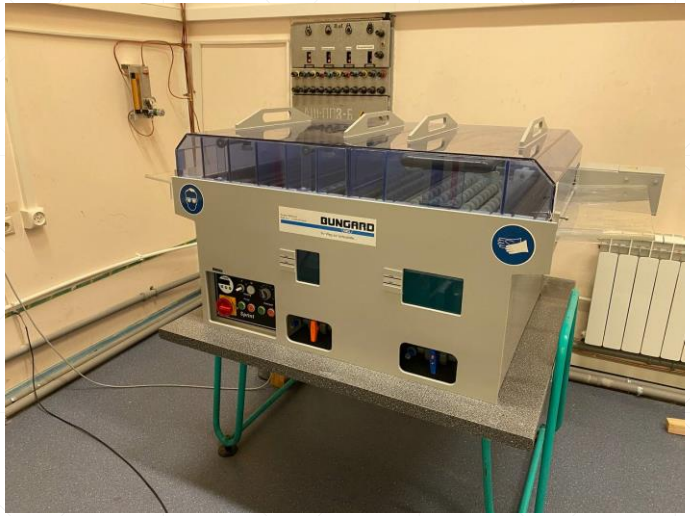
The principle of operation is based on the ionization of gas by charged particles:

1. Charged particles passing through the drift gap ionize the gas, releasing electron-ion pairs.
2. Ionization electrons drift for 100 ns into the region of strong field gain, while ions drift toward the cathode. (mesh transparency ~ 100%)
3. Electrons avalanche-like multiply and are released on the anode strips, where they are recorded.
4. Ions formed in the gain region are quickly removed to the mesh.

Micromegas production complex


Stretching table

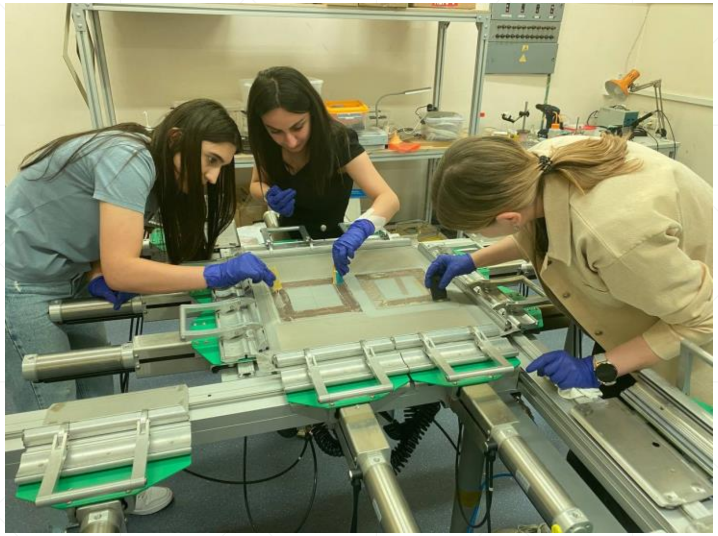

UV Insolator

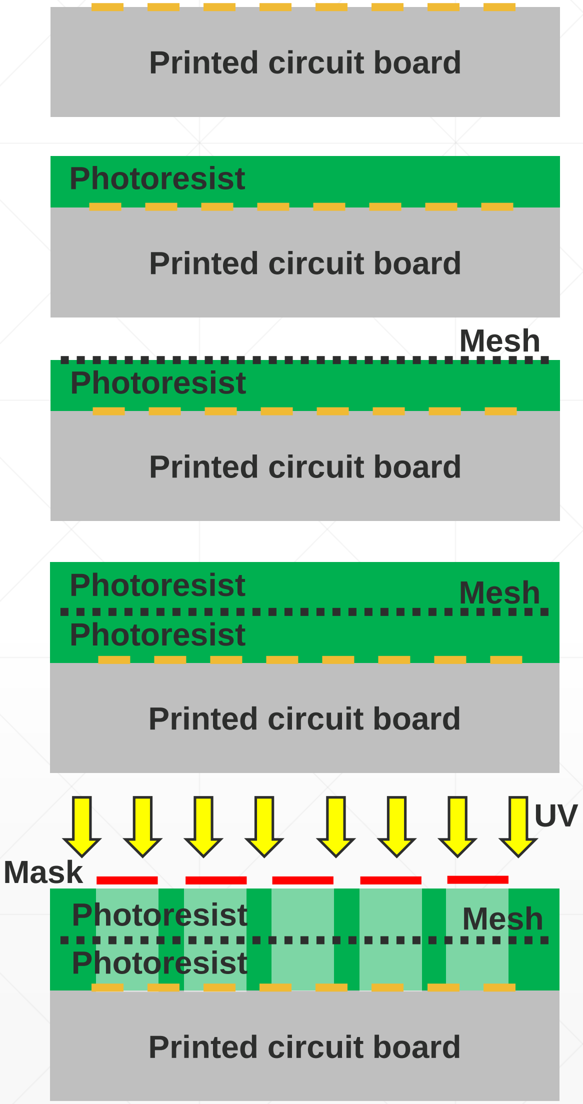

Etching machine

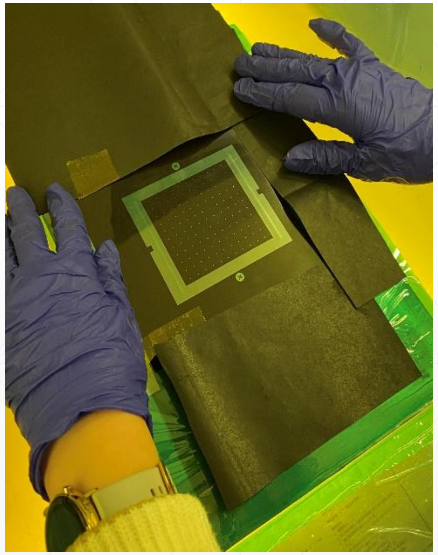

Laminator


Oven

Manufacturing of MM detectors





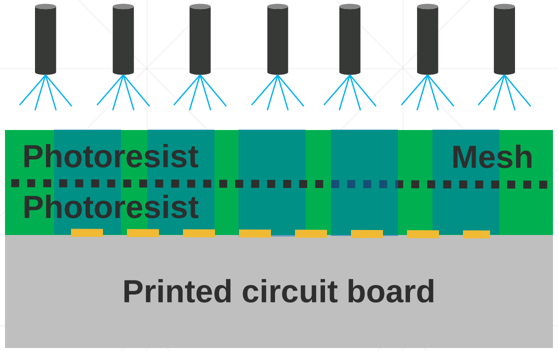


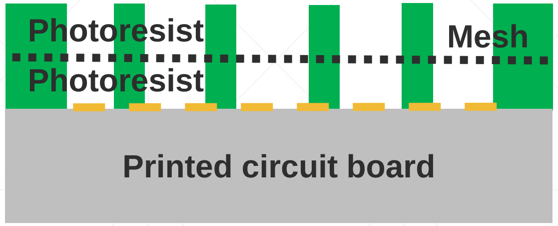
The required number of layers of photoresistive film (DYNAMASK 40 or 75µm) is applied to the PCB.

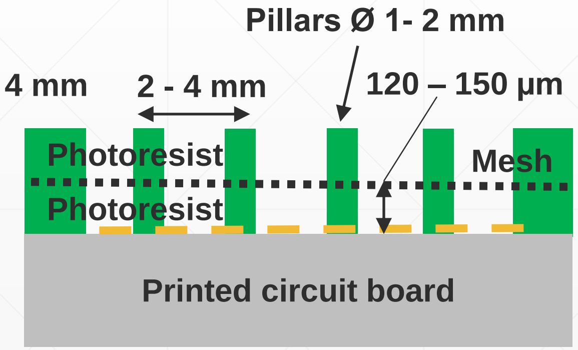
The mesh, pre-stretched on the frame, is fixed with a layer of photoresist

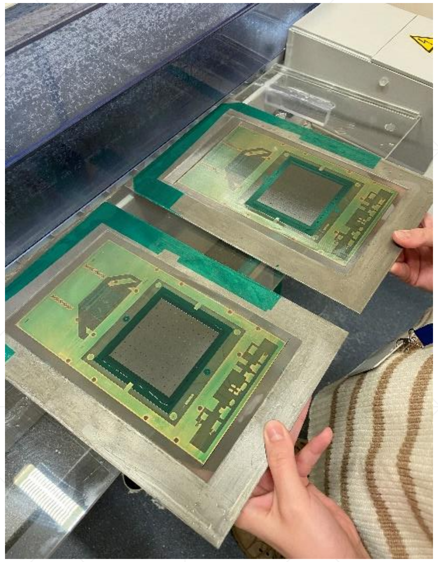
Using a photolithography mask, we illuminate the prototype with ultraviolet light

Manufacturing of MM detectors

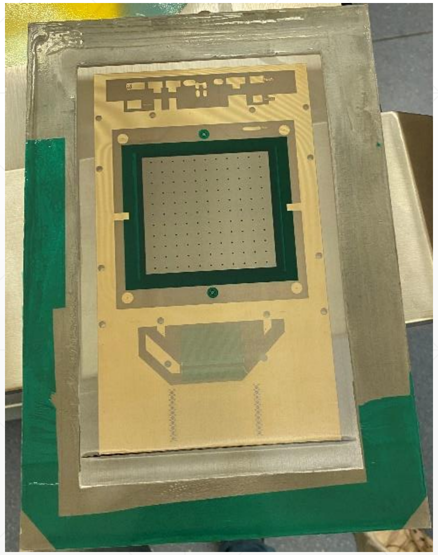






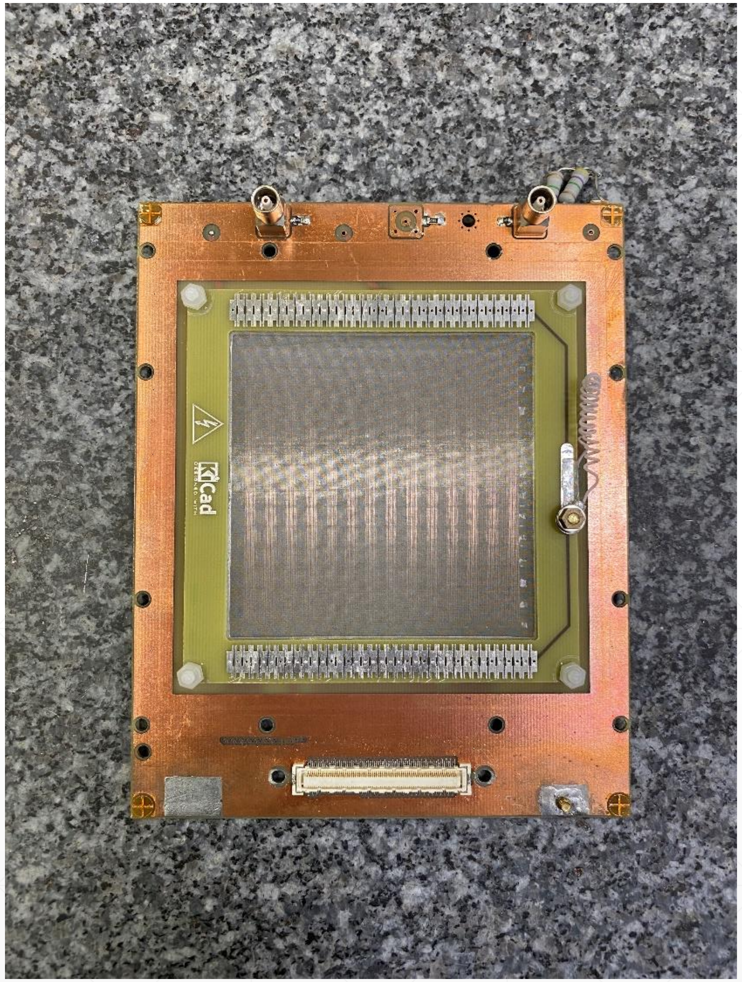


Etching with 1% solution of soda ash Na_2CO_3

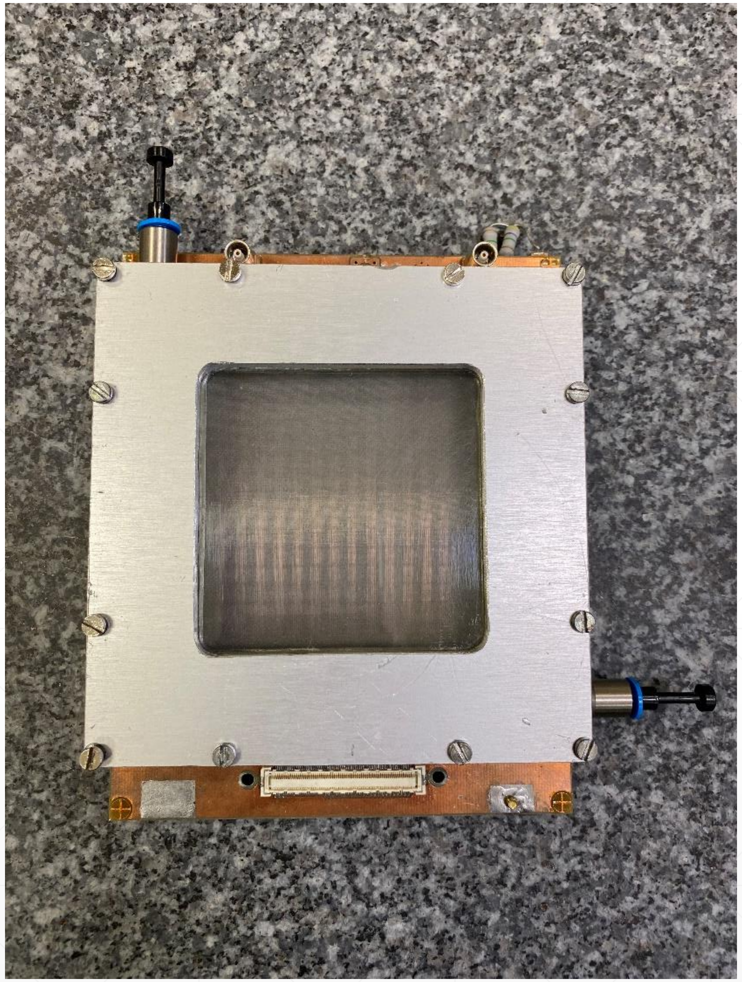


Wash in deionized water and dry in oven at 145^0 for 1 hour to fix photoresist

Manufacturing of MM detectors



Setting the drift gap



Detector assembly

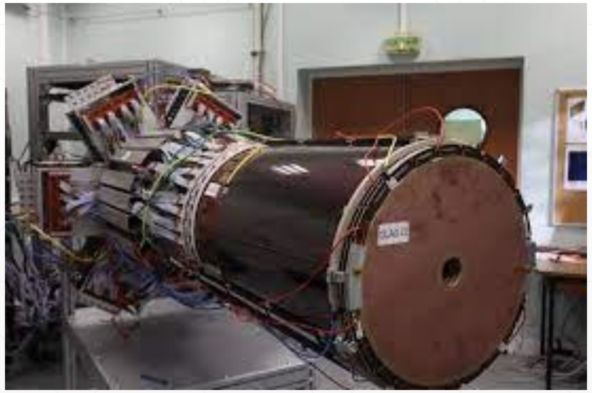
Manufacturing of a cylindrical MM detector

In many ways, we use the experience of our colleagues from CEA Saclay (France), who developed a cylindrical detector based on Micromegas for the CLAS12 experiment.
The difference: theirs radius of curvature is 20 cm, our radius is 5 cm.

Making a flat sample

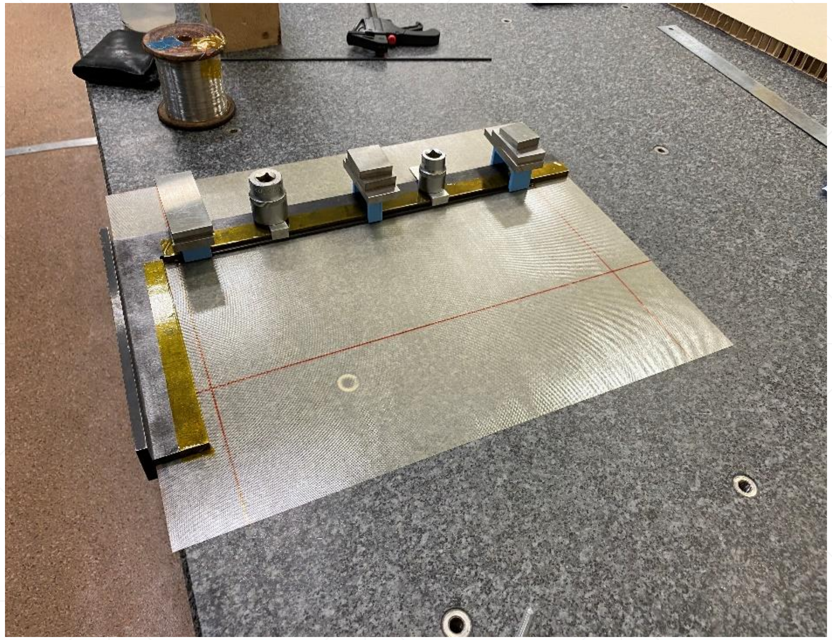
Bend it on a template

Fixing the shape



Development of the MM detector within the CLAS12 experiment

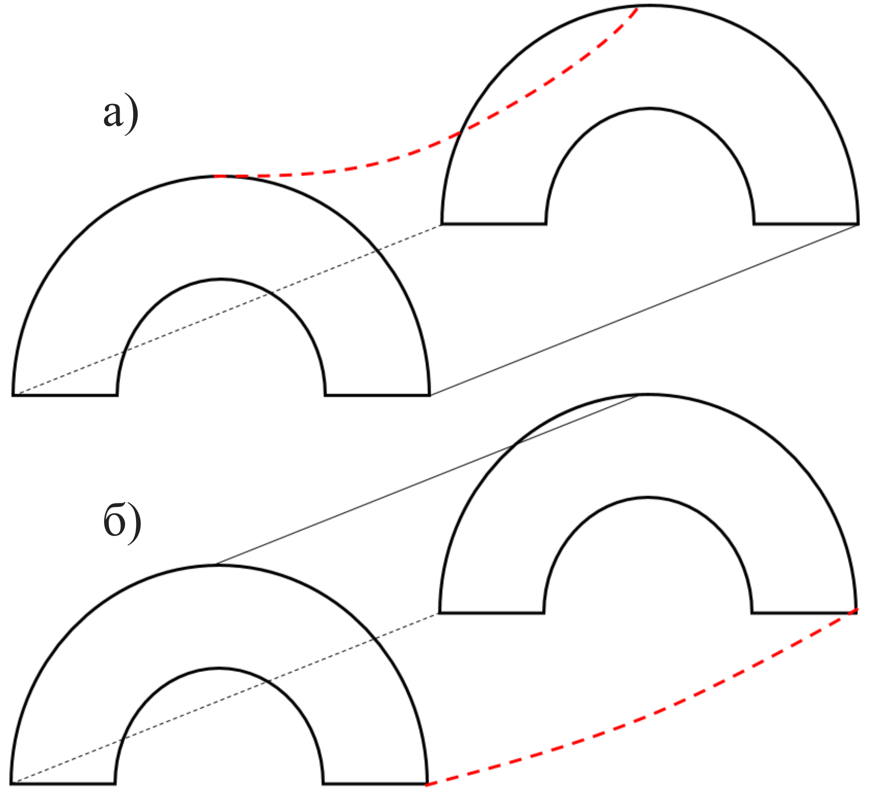
Manufacturing of mechanical half-cylindrical MM



Material: FR4 (thickness = 300 microns). As a power frame: plastic arches, graphite rods
Sample length – 40 cm, Drift gap – 3 mm.
Bending radius – 5 cm.
Epoxy resin Araldite 2011

Mechanical prototype MM

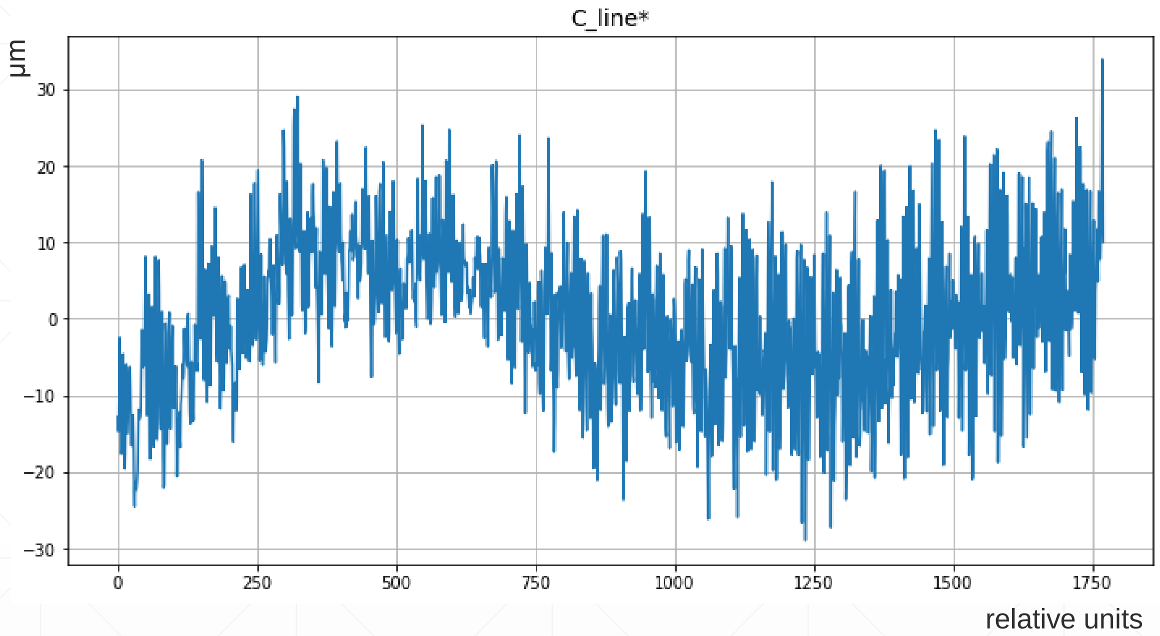
Second less rigid mechanical prototype.
Material: Kapton (thickness = 200 microns)



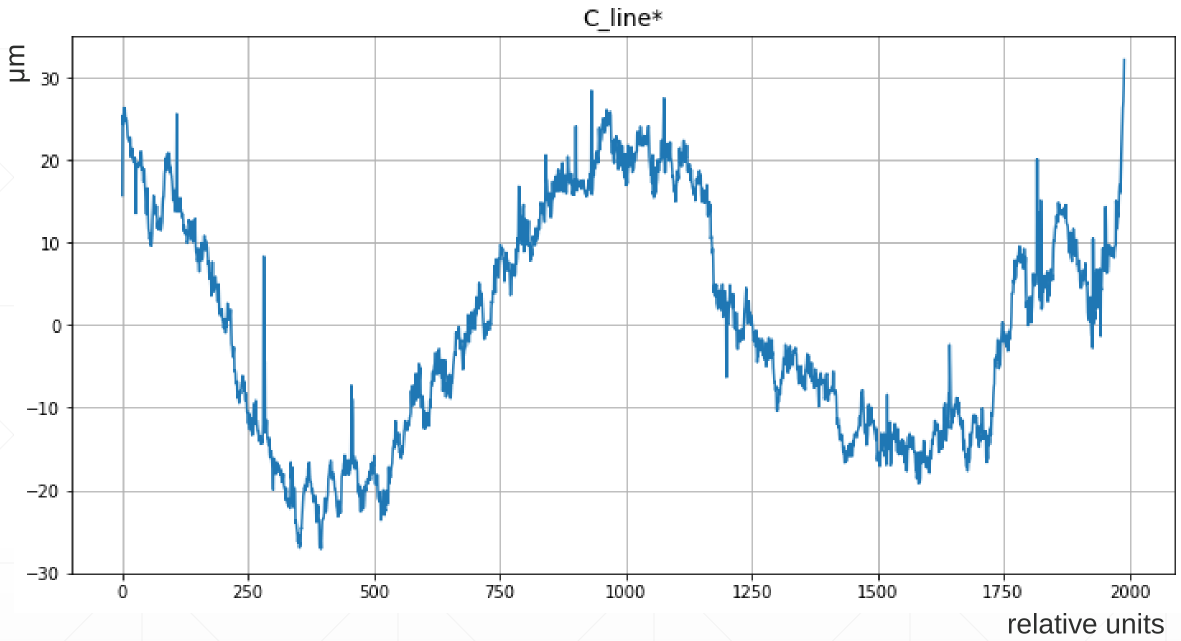
Expected types of deformation:
a) saddle-shaped b) barrel-shaped

Prototype Geometry. Barrel Deformation

Mechanical prototype made of kapton



Measurements of the geometry of the barrel-shaped deformation of **the inner layer** of the prototype using a CNC (computer numerical control) machine.

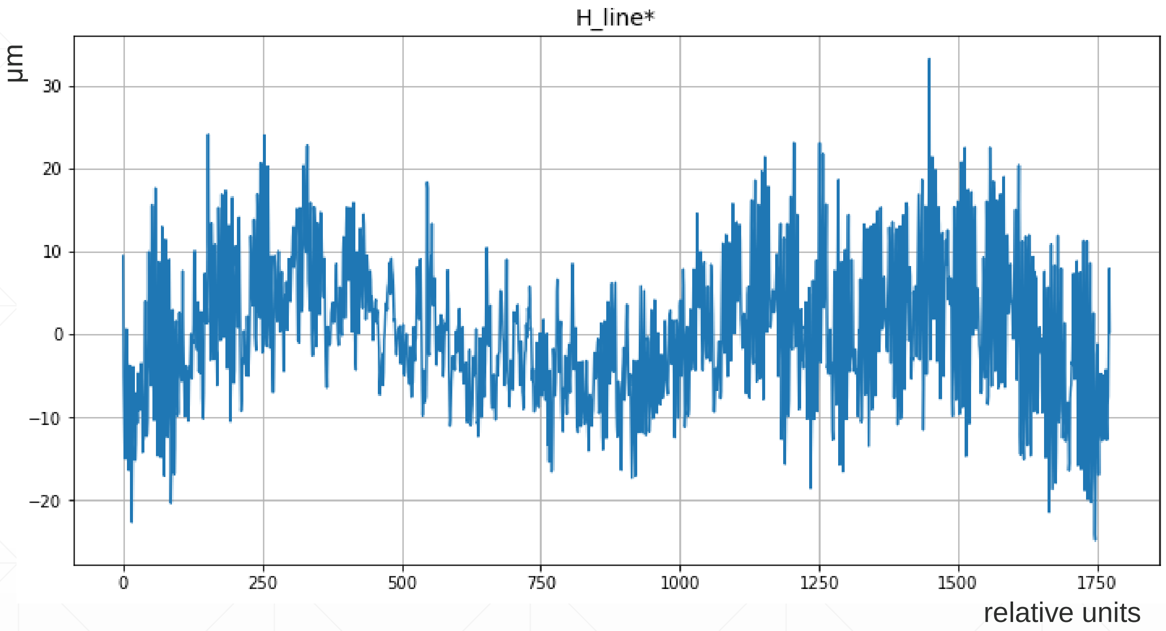


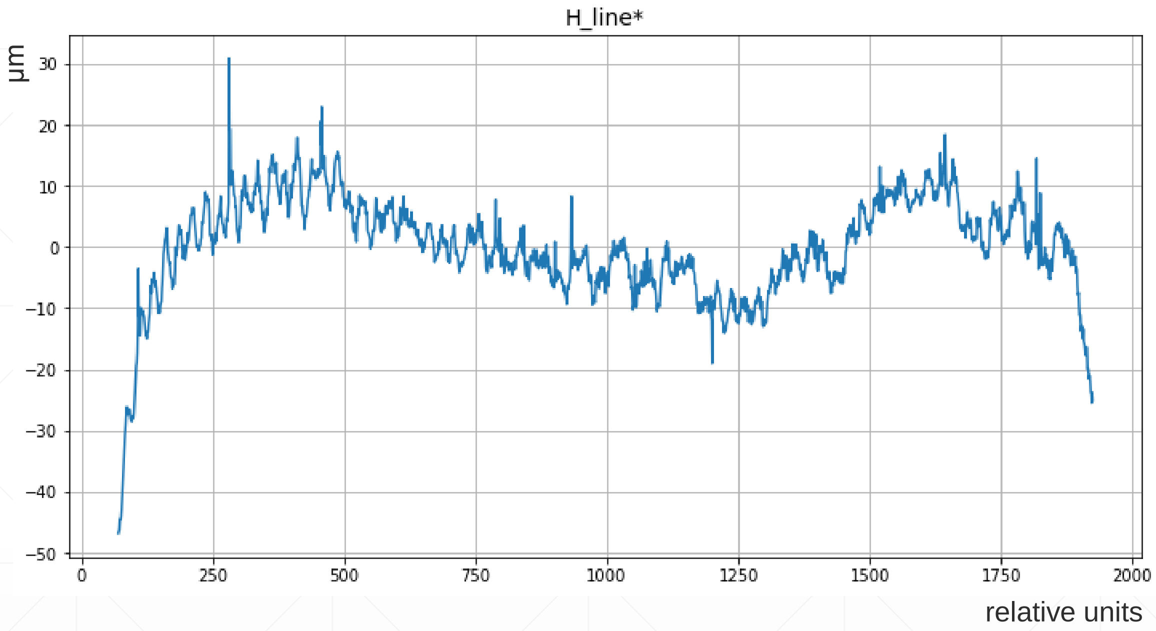
Measurements of the barrel deformation geometry of **the outer layer** of the prototype using a CNC machine.

The spread did not exceed 50 microns

Prototype Geometry. Saddle Deformation

Mechanical prototype made of kapton



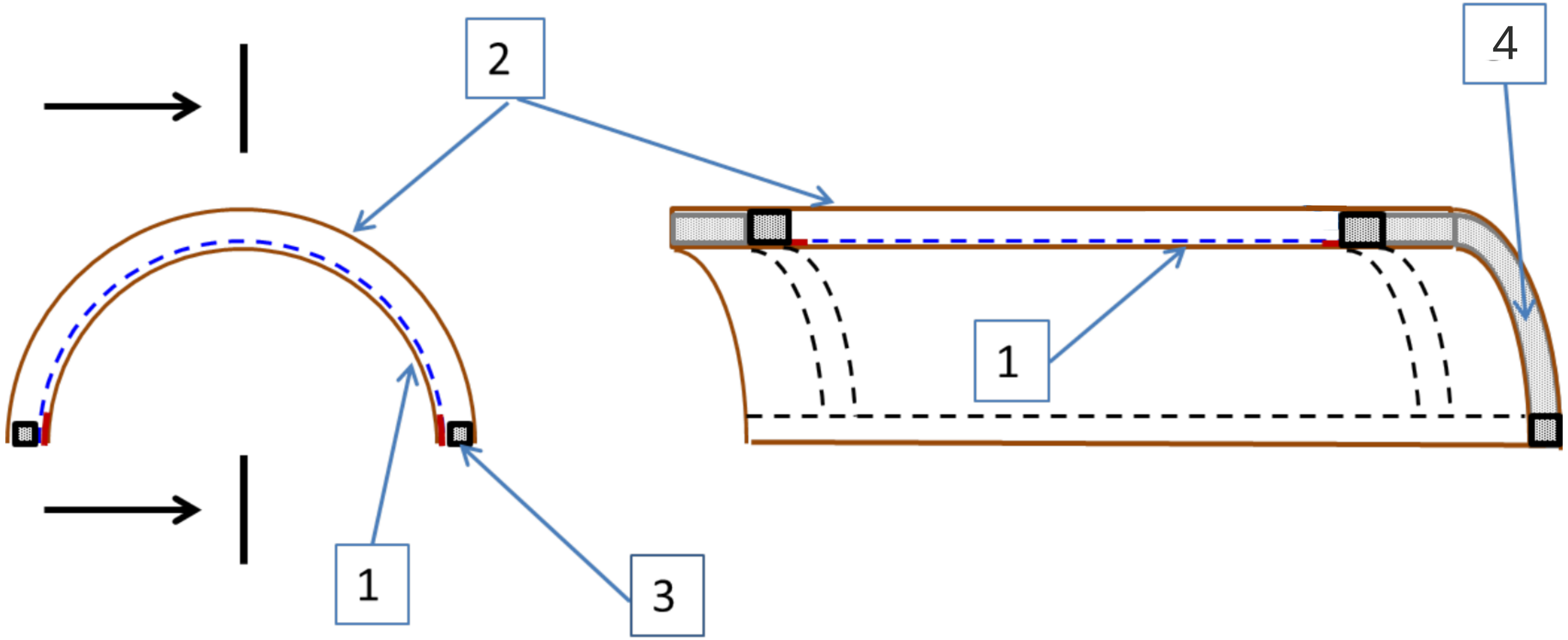


Measurements of the geometry of the saddle deformation of **the inner layer** of the prototype using a CNC (computer numerical control) machine.

Measurements of the geometry of the saddle deformation of **the outer layer** of the prototype using a CNC (computer numerical control) machine.

The saddle deformation of the cathode plane did not exceed 100 μm at the central point

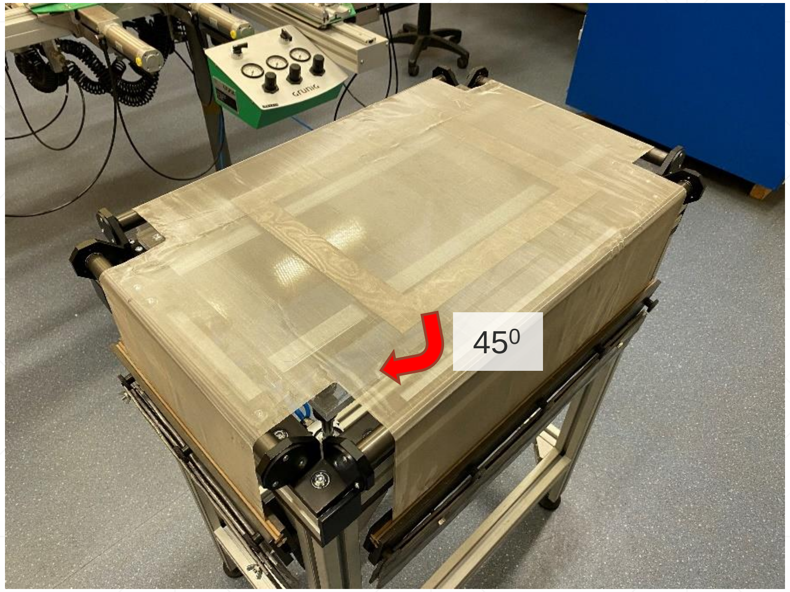
Simplified sketch of a working half-cylindrical prototype



Left: perpendicular section. Right: longitudinal section.
1 - readout board with mesh and amplifying gap;
2 - cathode board; 3 - carbon fiber strips; 4 - plastic power arcs.
Passivated areas are shown in red.

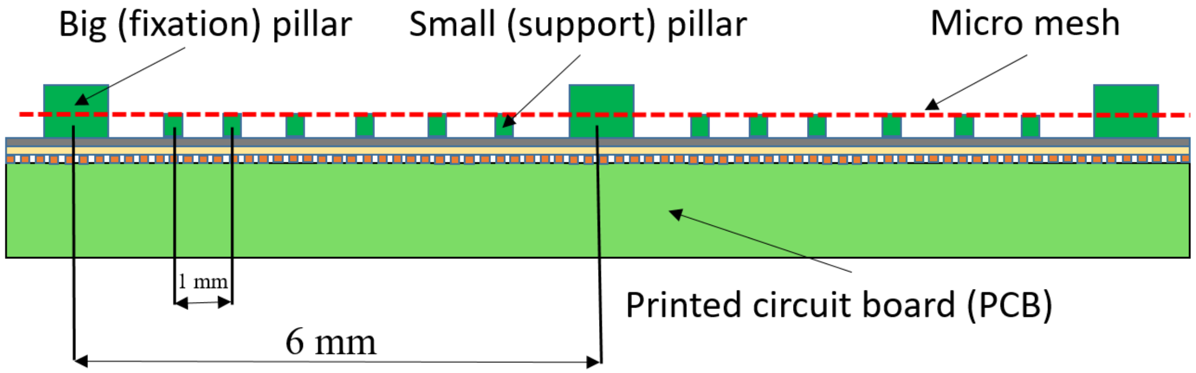
Problems in the manufacture a cylindrical prototype

- When the flat prototype is bent, the mesh tension increases significantly.



- ❖ Our mesh tensioning table can provide a minimum tension of 7 N cm $^{-1}$. This is quite a lot, so we made a new table that reduced the tension to 1 N cm $^{-1}$.
- ❖ Turning the mesh relative to the working surface by 45^0 allowed to distribute the load evenly in all directions of the thread, as well as to reduce the mesh tension by 1.4 times.

- The stretched mesh has a flat shape between the pillars, due to which the distance from the mesh to the cylindrical surface of the anode varies significantly.



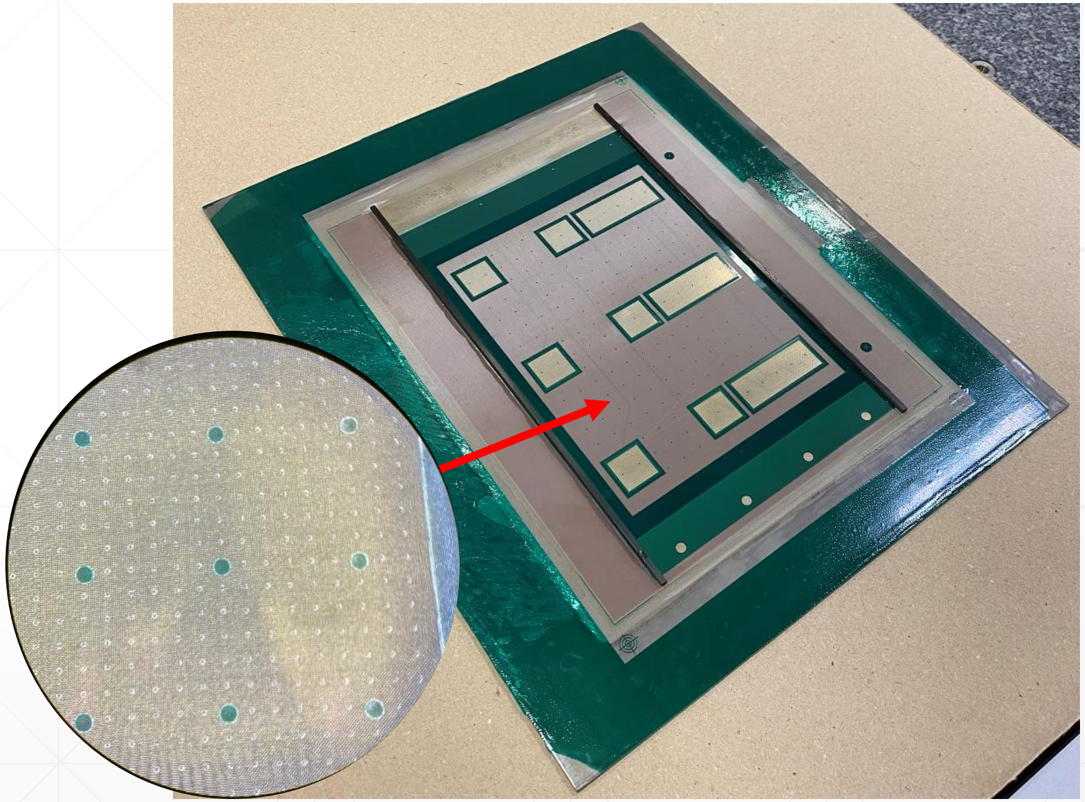
Therefore, a special geometry of the pillars has been developed. At a distance of 1 mm there are small pillars with a diameter of 0.2 mm, which do not fix the mesh, but only support it.

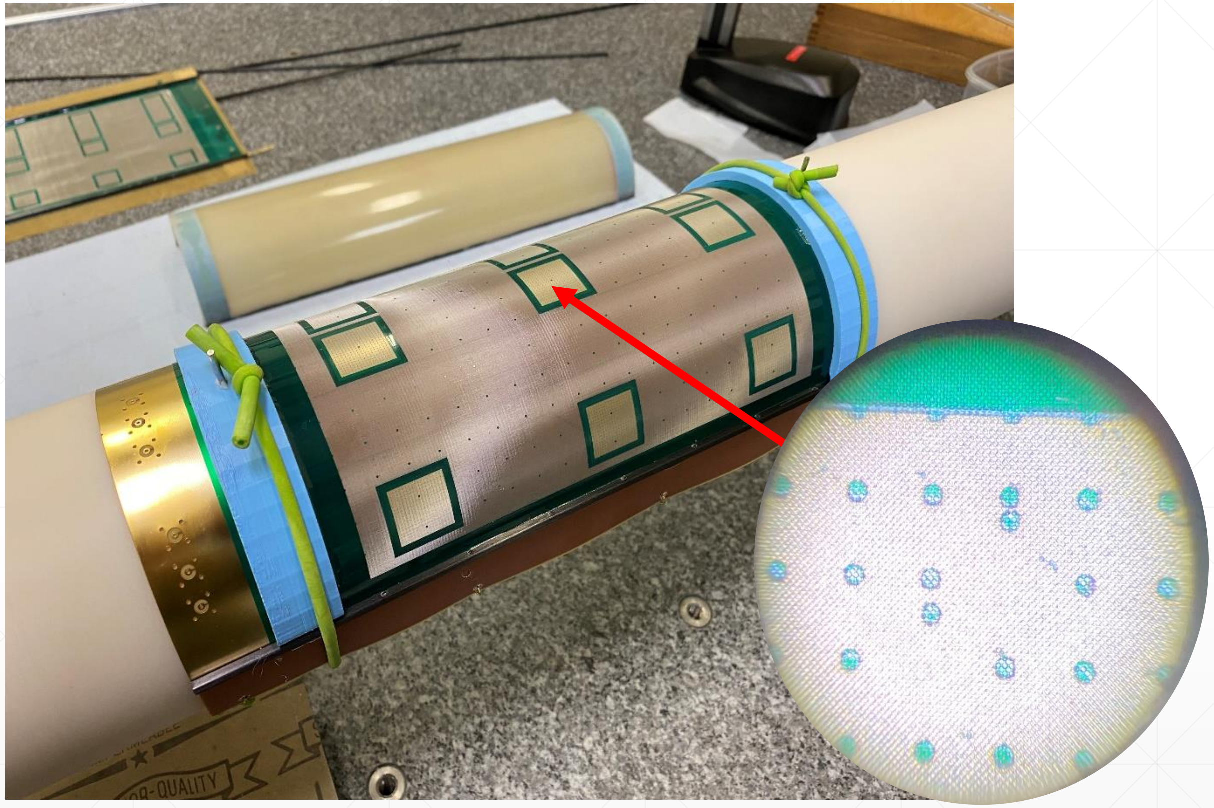
Big fixation pillars with a diameter of 0.75 mm have a pitch of 6 mm.

<u>The total area occupied by the pillars is less than 4%.</u>

Manufacturing a half-cylindrical prototype

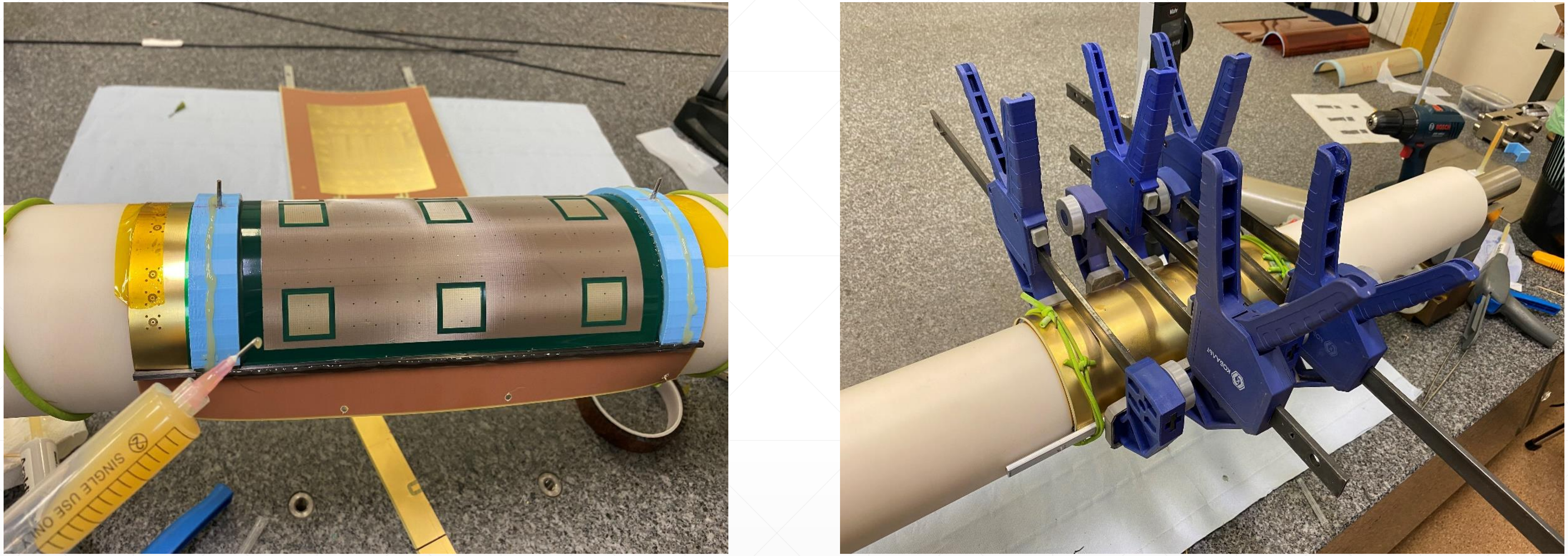
The most important parameter we wanted to control for the first prototype was the stability of the gain gap size and hence the gas gain over the detector area.





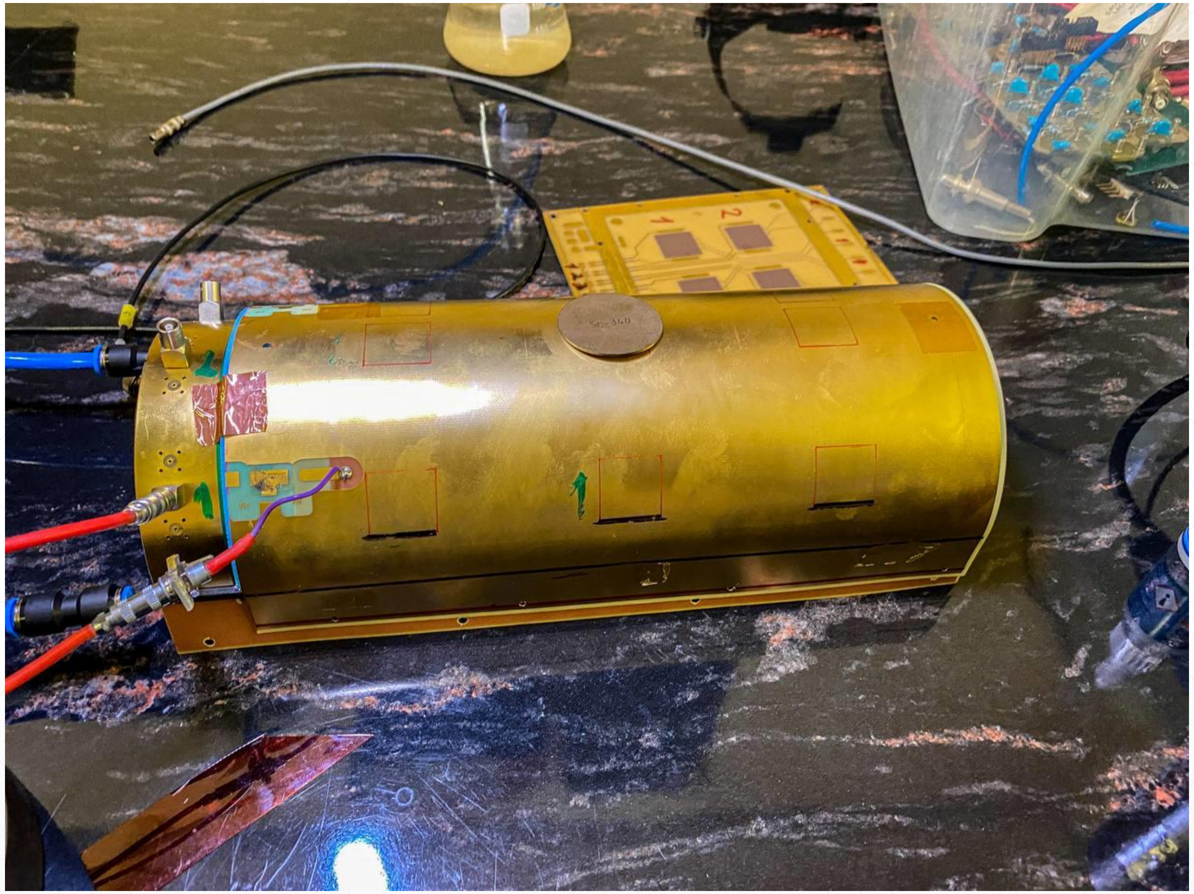
For convenience, the signal electrodes are made in the form of pad measuring 1.5 × 1.5 cm^2 and 1.5 × 4.5 cm^2.
To study possible defects in the detector characteristics during manufacturing, two pillars were shifted on one platform (#6).

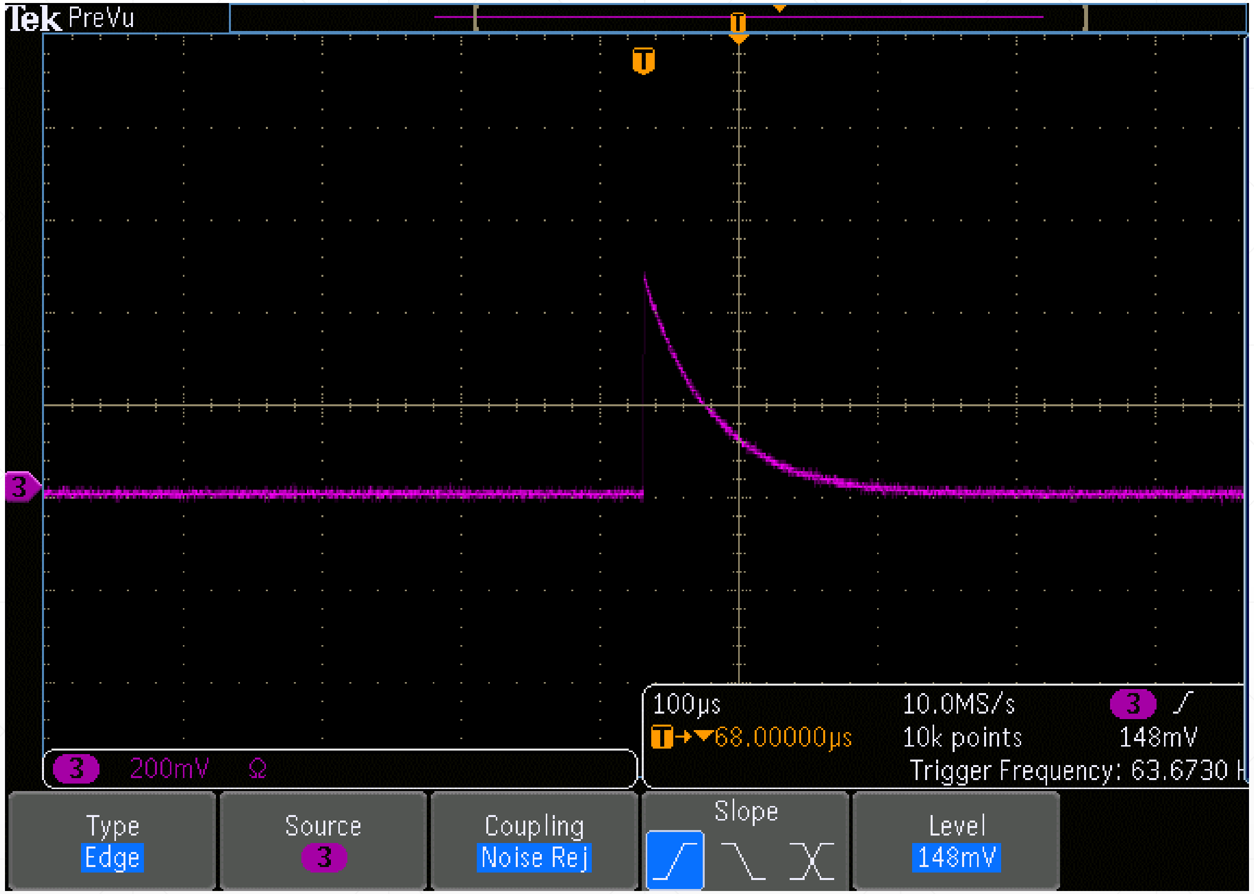
Manufacturing a half-cylindrical prototype



The procedure for applying epoxy resin and gluing the cathode and the power frame

The assembled detector and its first test





3 200mV Ω

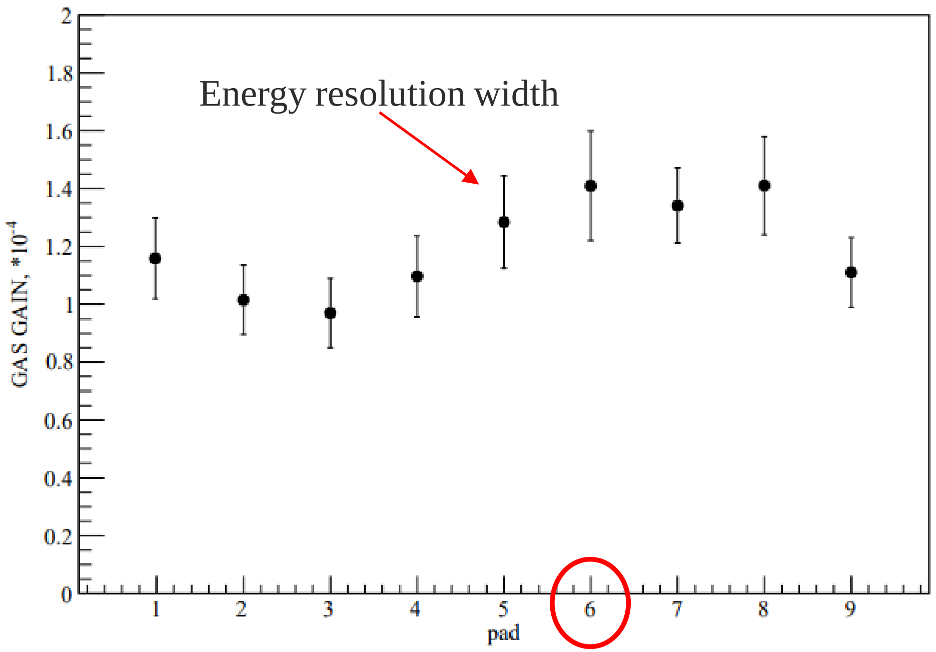
100µs 10.0MS/s 3 ⁄
T→▼68.00000µs 10k points 148mV
Trigger Frequency: 63.6730

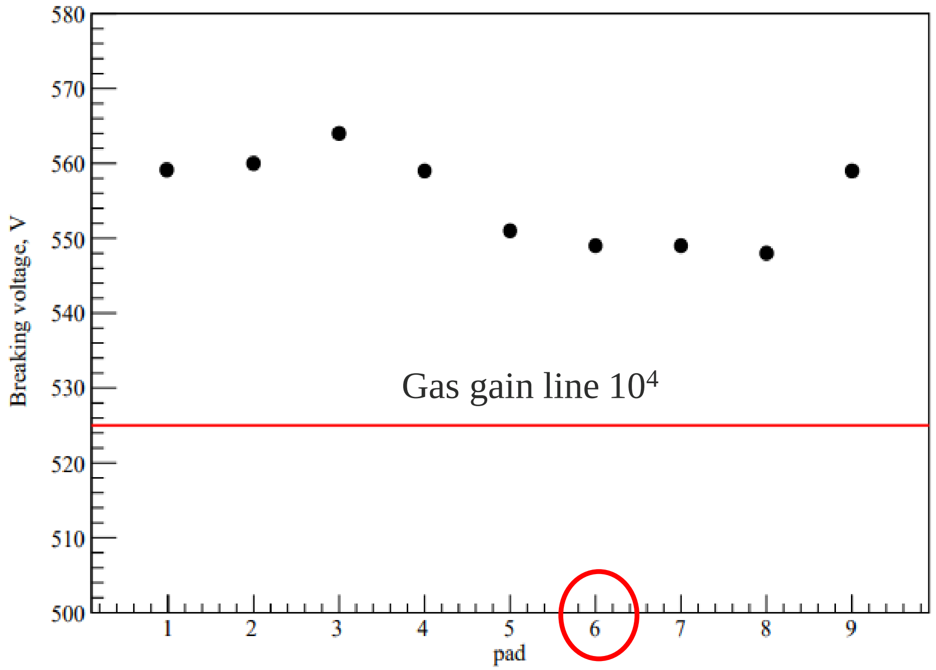
Type Edge
Source 3
Coupling Noise Rej
Slope
Level 148mV

Signal on the oscilloscope. Amplitude – 450 mV, Signal time – 150 µs

Tests of the first cylindrical prototype

The main task is to practice the assembly method and the absence of damage to the mesh and pillars





Left: dependence of the gas gain for each pad at a fixed gain voltage Ugain = 525 V, which corresponded to a gas gain of 10^4. The error bars represent the energy resolution (rms) measured with a Fe_{55} source.

Right: breakdown voltage measured for all pads. The red line represents the working voltage for a gas gain of about 10^4. For all of them we have a voltage margin of 25V.

Conclusion and future plans

During the development of the MCT/SPD project

- The main stages of Micromegas detector production technology were worked out.
- The first cylindrical prototype has been manufactured and tested.

❖ Creation of a fully functional prototype with strips and resistive layer.

Thank you for your attention!