New developments on the Double Micro-Mesh gaseous structure

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Outline

- Motivation
- Double Micro-Mesh gaseous structure
  - Thermal bonding method
  - Schematic and performances of DMM
- New developments on DMM
  - Further attempts to lower the IBF ratio
  - To enlarge the area
  - Fast timing scheme
- Potential applications
- Conclusions and plans

Motivation

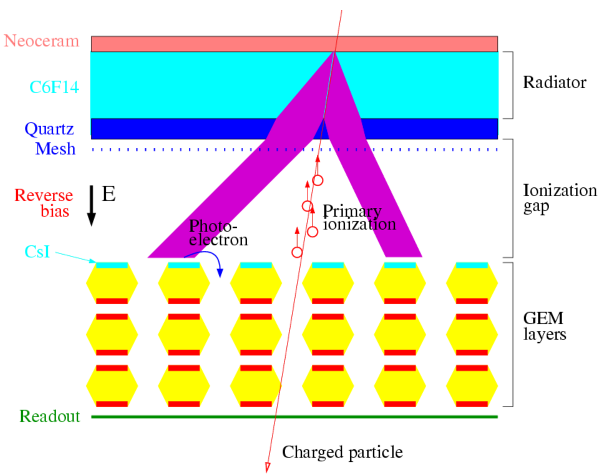
Many advantages of MPGD detectors:

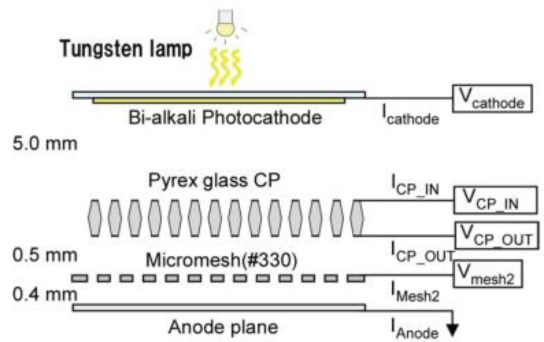
- large effective area
- high spatial and timing resolution
- magnetic field resistant
- Radiation hardness

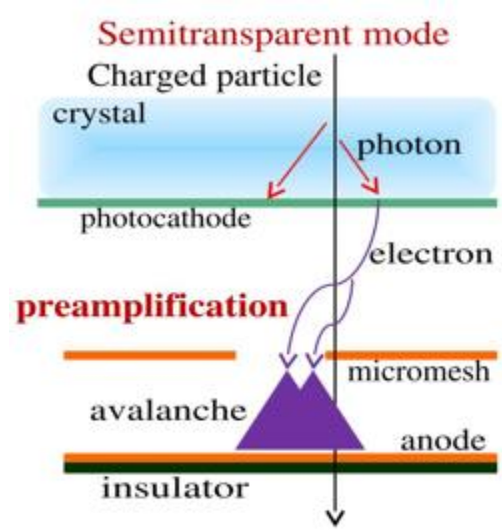
Some attractive applications:

- Photon detector for RICH, gas-PMT, fast timing (PICO-SEC) ⋯
- Electron multiplier for TPC (especially high rate)
- Others like medical imaging, muon tomography, etc.

Where, high gain and low IBF are strongly expected.



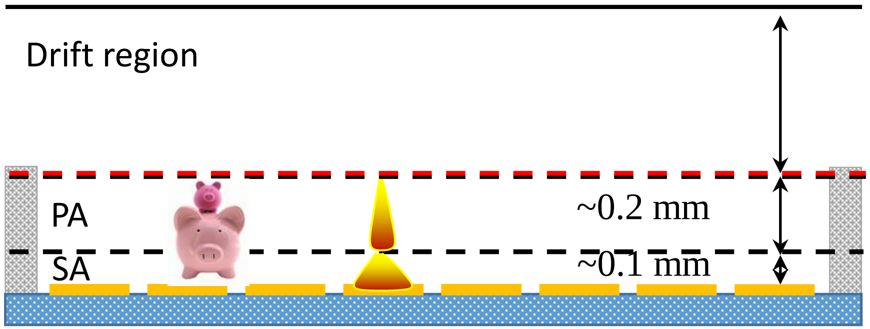




Double Micro-Mesh gaseous structure

Schematic of the DMM

- Hole-style ➔mesh-style to reduce the IBF
- Double or multi-avalanche for high gain



- Stacked two meshes
- Gap between the stacked meshes: 200-300um, serving as pre-amplification (PA)
- Gap between the bottom mesh and anode: 50-100um for secondary amplification (SA)
- This structure allows to achieve very high gain, and yet significantly reduce ion back-flow.

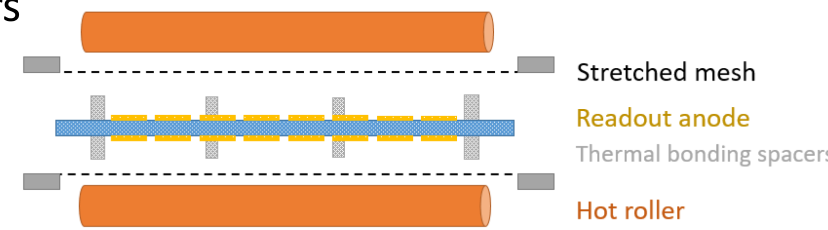
Double Micro-Mesh gaseous structure

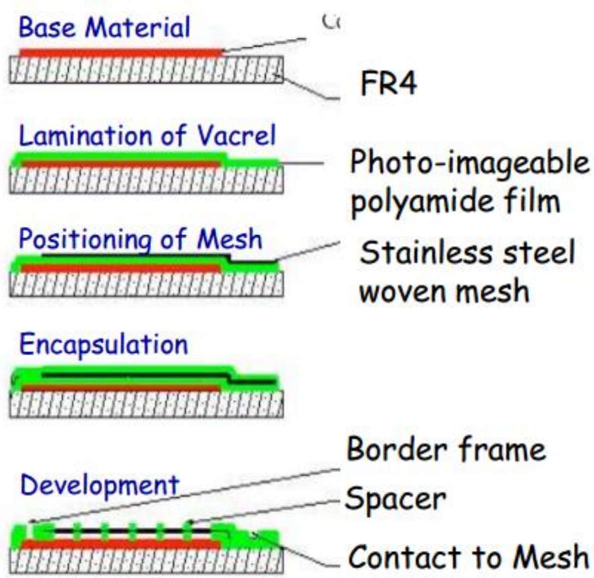
Thermal bonding method

More details, see Jianbei's talk, on 26 Sep, 2017.
https://indico.cern.ch/event/667256/contributions/2730906/attachments/1529745/2393724/Thermal_Bonding_MM_USTC_RD51.pdf

Micromegas in a Bulk:

- Well developed in the past twenty years
- Each to be achieve a uniformity gap
- Low dead area
- Φ0.2mm- Φ0.4mm pillars, ~2mm pitch



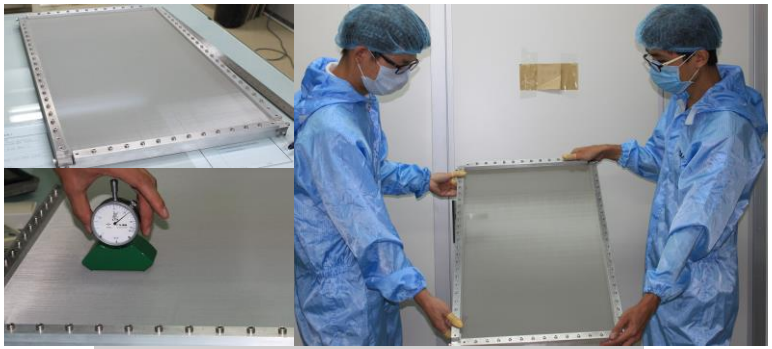


Thermal bonding Micromegas:

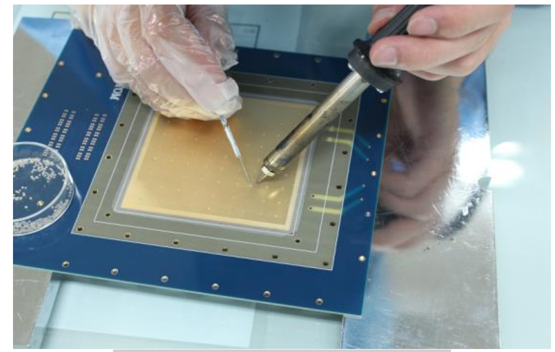
- Good energy resolution
- No etching, no pollution
- Easy to handle at lab
- Easy to make new structures
- Cheap
- Φ1mm- Φ2mm spacers, ~10mm pitch
  ➔easy to clean, especially for large area
- But uniformity to be improved

Double Micro-Mesh gaseous structure

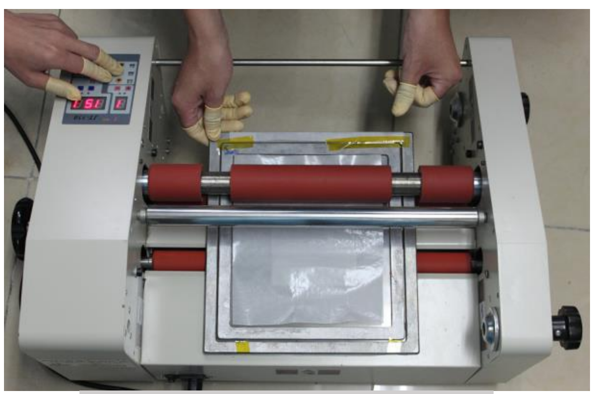
Thermal bonding processing



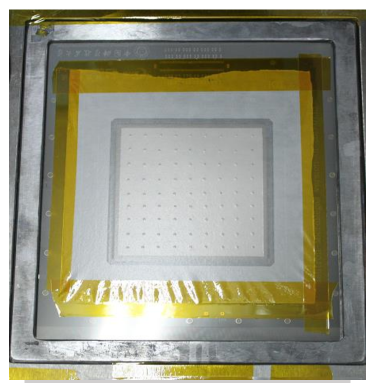
Mesh stretching ~20N/cm



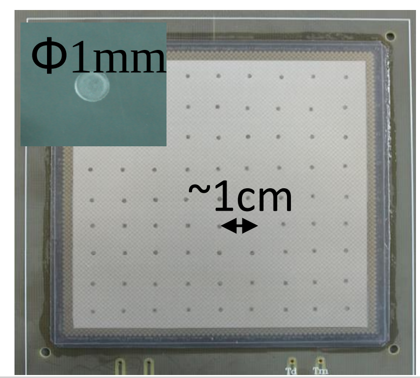
Setting spacers



Thermal bonding



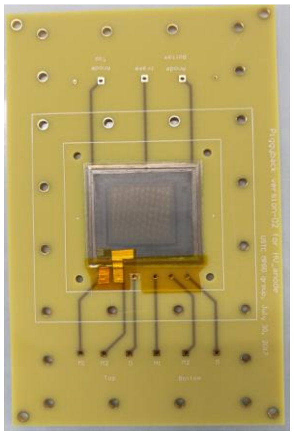
Finished view

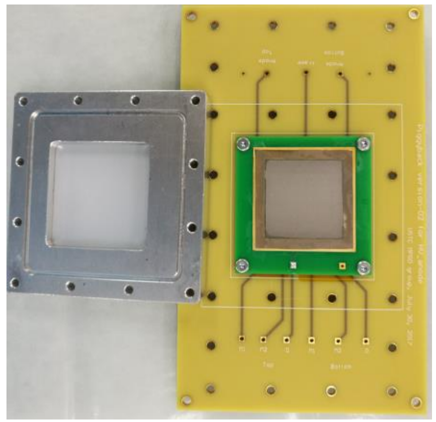


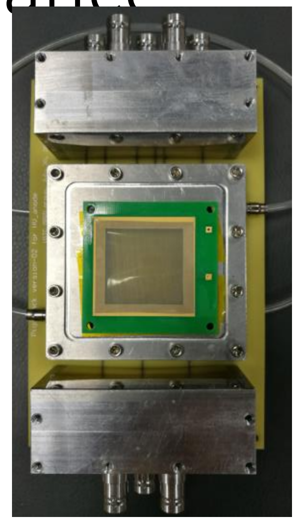
Cutting the meshes

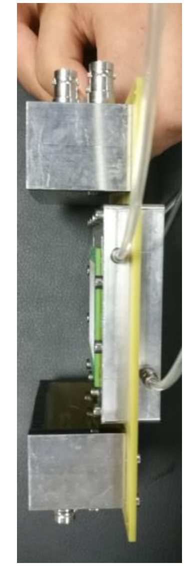
Double Micro-Mesh gaseous structure

A small prototype and performance



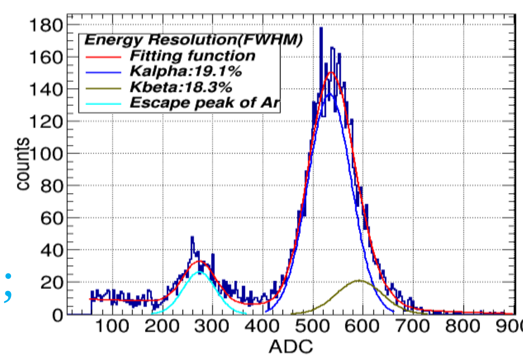




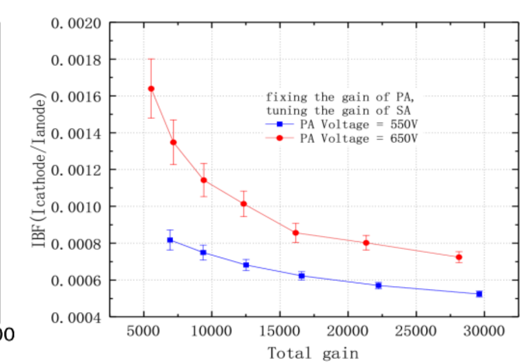


- Design diagram for the fabrication of prototype；
- Fabricated with a thermal bonding technique.
- Small active area of 2 x 2 cm^2;
- Test with a 55Fe source;

A 5.9keV x-ray spectrum



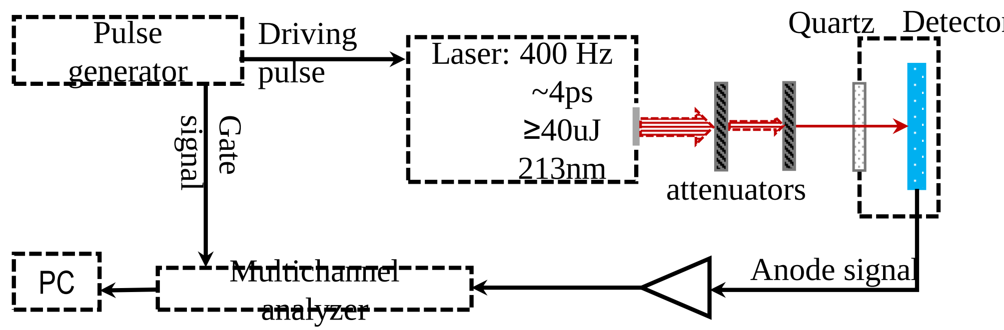
~0.0005 IBF ratio

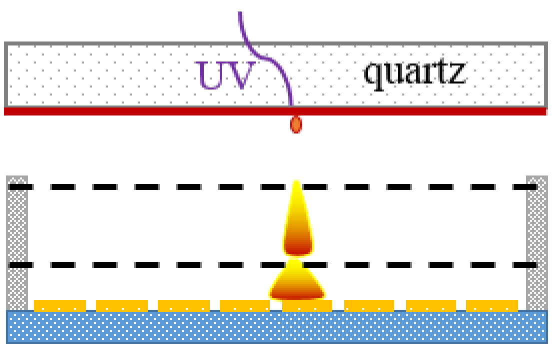


Double Micro-Mesh gaseous structure

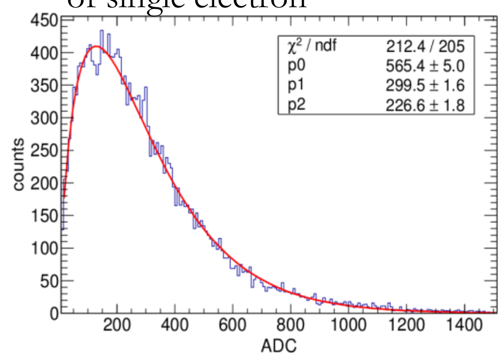
A small prototype and performance

- Test with a laser;
- The lights were attenuated to obtain a single electron response;
- The distribution was fitted with a Polya function;

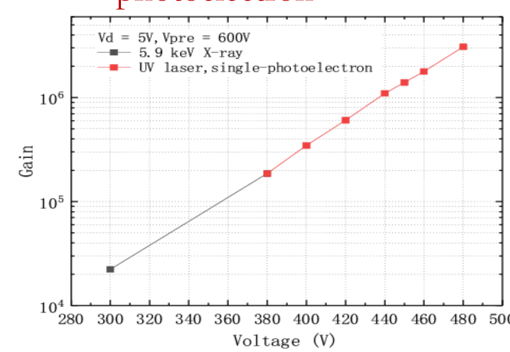




Typical pulse height spectrum of single electron



3 ×10[6] high gain for single photoelectron



Published on NIM-A: A high-gain, low ion-backflow double micro-mesh gaseous structure for single electron detection, 889 (2018) 78 – 82.

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- New developments on DMM
  - Further attempts to lower the IBF ratio
  - Fast timing scheme
  - To enlarge the area
- Potential applications
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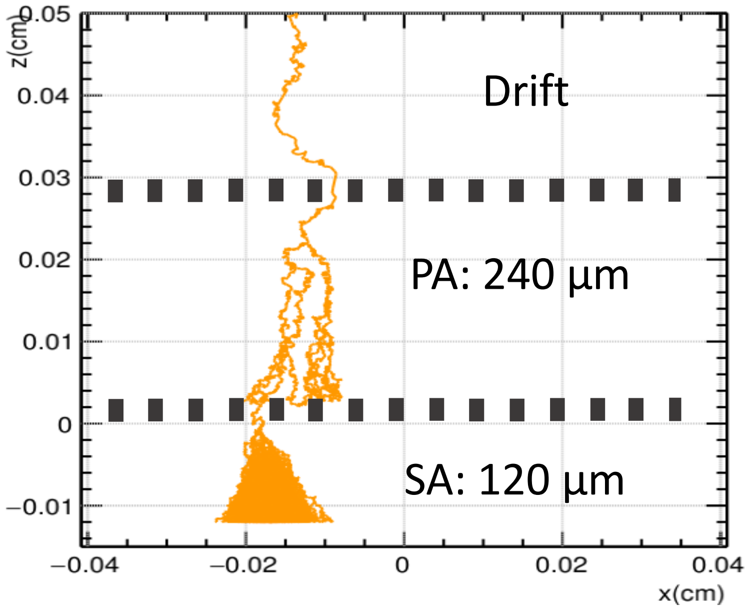
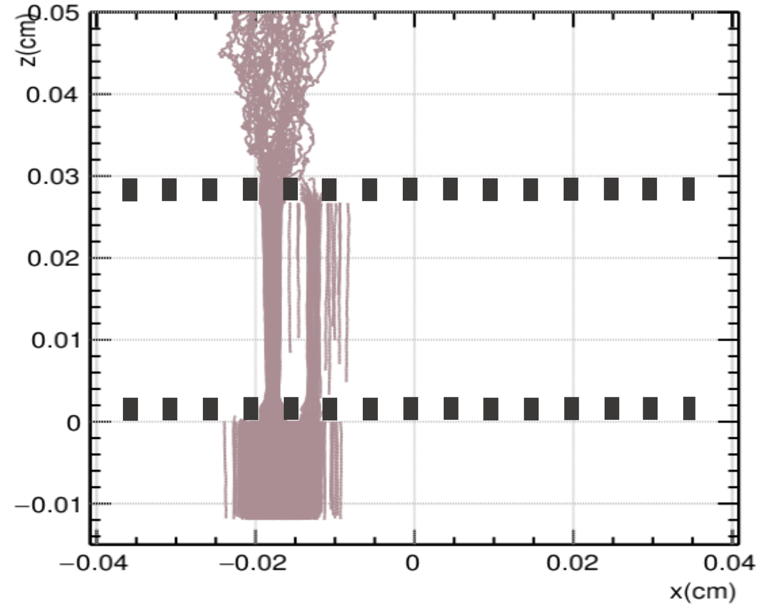
New developments on DMM

Further suppression on IBF of DMM

The IBF of DMM is also seriously depend on the geometric alignment of the double mesh;
The tracks of electron (left) and ions (right) are plotted:
This is the case of that the mesh holes was strictly aligned.

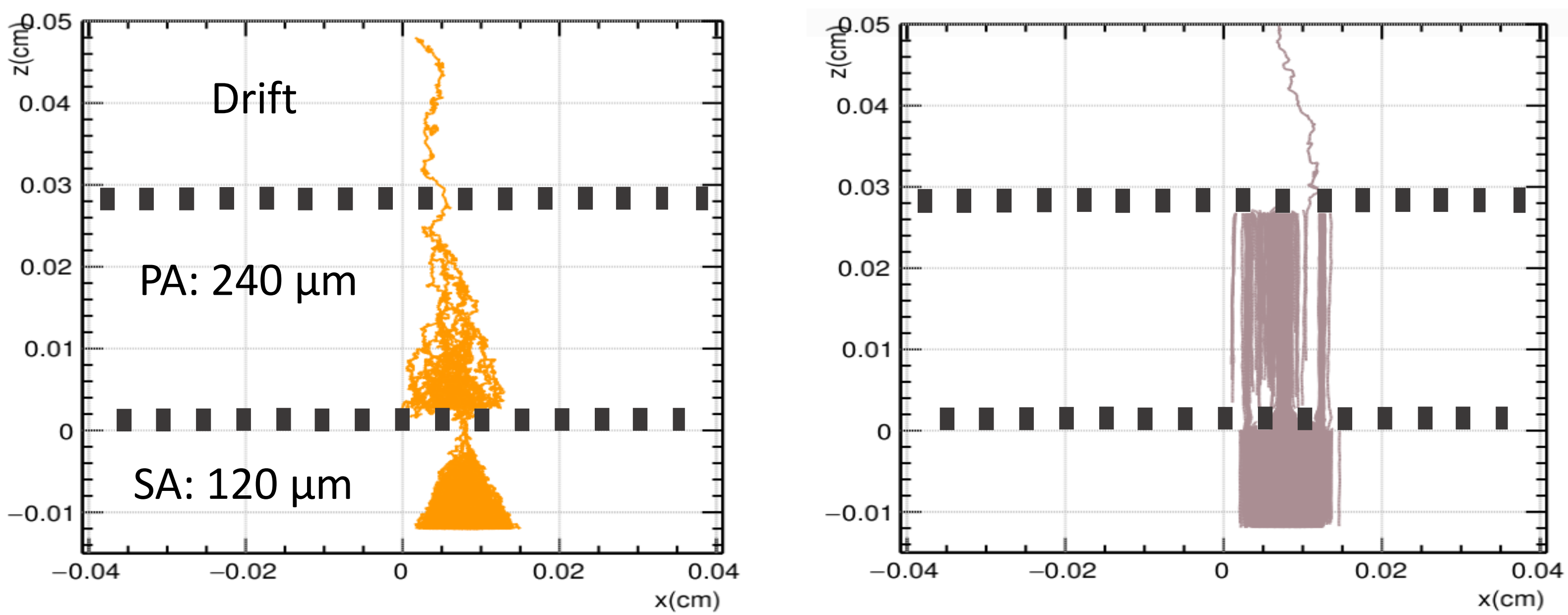




New developments on DMM

Further suppression on IBF of DMM

The case of that the mesh holes was interlaced
➔the ion back-flow from SA are significantly suppressed by the up-mesh!



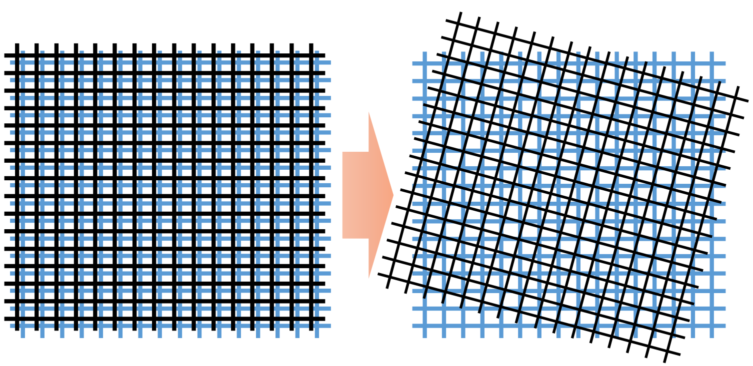
New developments on DMM

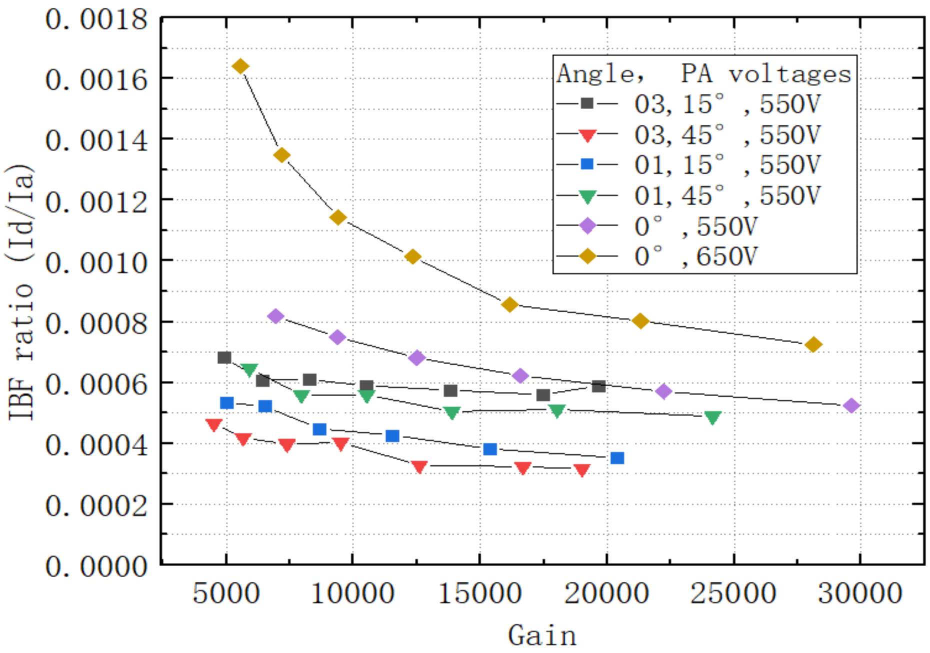
Further suppression on IBF of DMM

According to the simulation, the IBF of the DMM is depend on:

- The geometric alignment of the double mesh;
- Gas mixtures, Mesh types, thickness of the gaps, etc.

A simple attempt is to keep an angle between the mesh lines:





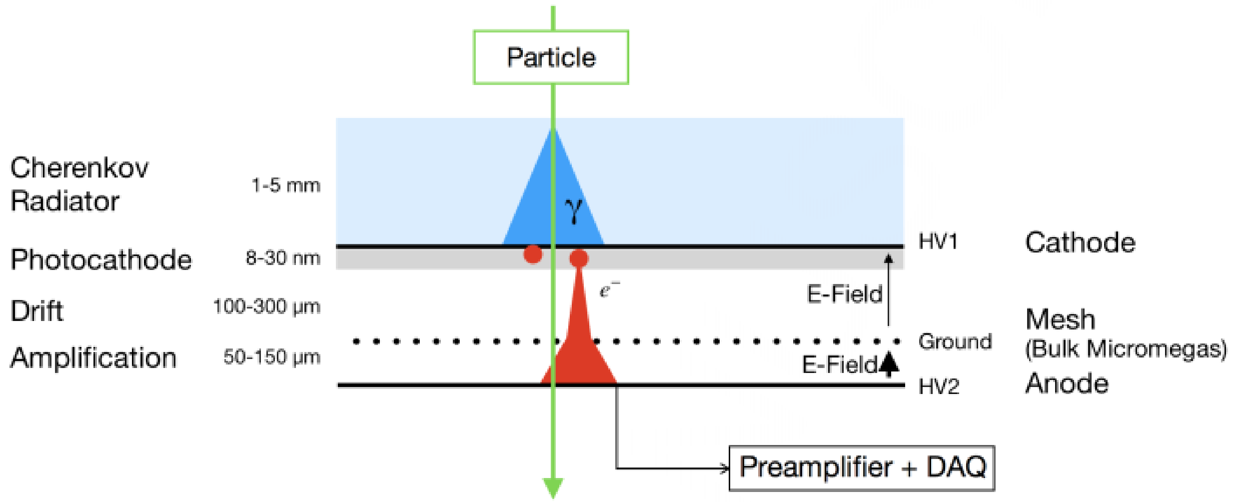
New developments on DMM

Fast timing with DMM, this work is performed in our **PICOSEC collaboration:**

- **CEA Saclay (France):** D. Desforge, I. Giomataris, T. Gustavsson, C. Guyot, F.J. Iguaz, M. Kebbiri, P. Legou, O. Maillard, T. Papaevangelou, M. Pomorski, P. Schwemling, L. Sohl.
- **CERN:** J. Bortfeldt, F. Brunbauer, C. David, J. Frachi, M. Lupberger, H. Müller, E. Oliveri, F. Resnati, L. Ropelewski, T. Schneider, P. Thuiner, M. van Stenis, P. Thuiner, R. Veenhof[1], S. White[2].
- **USTC (China):** J. Liu, B. Qi, X. Wang, Z. Zhang, Y. Zhou.
- **AUTH (Greece):** I. Manthos, V. Niaouris, K. Paraschou, D. Sampsonidis, S.E. Tzamarias.
- **NCSR (Greece):** G. Fanourakis.
- **NTUA (Greece):** Y. Tsipolitis.
- **LIP (Portugal):** M. Gallinaro.
- **HIP (Finland):** F. García.
- **IGFAE (Spain)**: D. González-Díaz.

[1] Also MEPhI & Uludag University.
[2] Also University of Virginia.

PICO-SEC Micromegas concept



Conventional Micromegas with **primary ionization:**

- Uncertain of the collision position
- Spread and low velocity of electrons in drift region

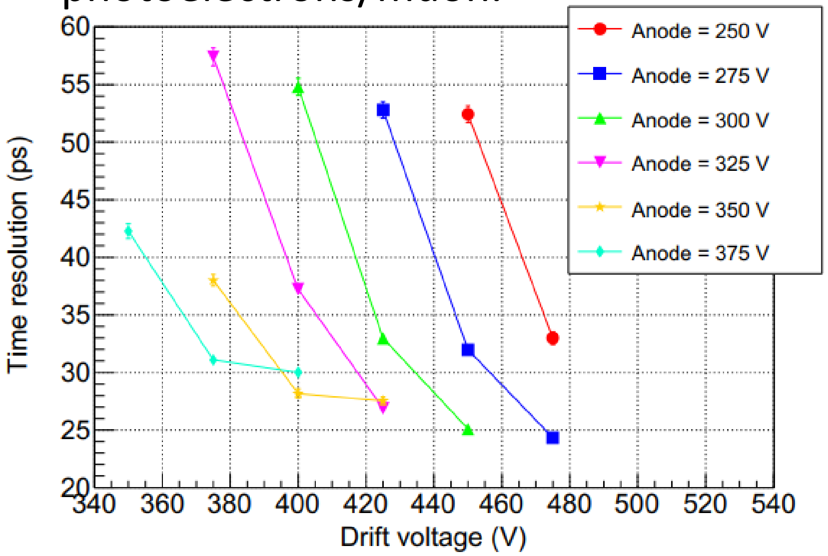
PICOSEC detectors based on **photon detect of** Cerenkov Radiation:

- Smaller drift gap
- Higher electric field

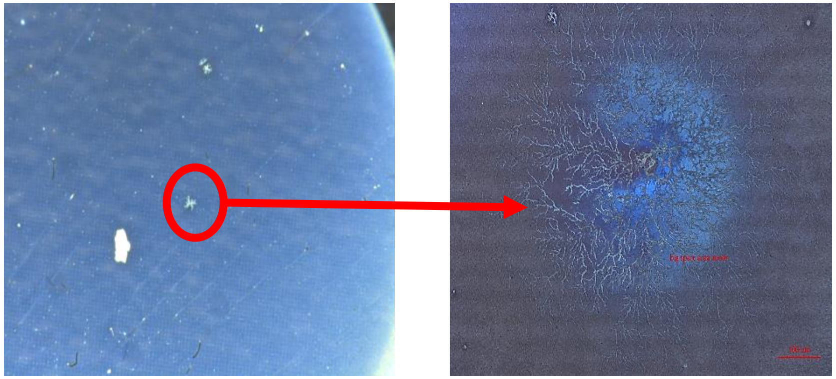
More details see Lukas's talk in WG2 and publication of PICOSEC: Charged particle timing at sub-25 picosecond precision with a Micromegas based detector.

Timing performance and challenge

Test with 150GeV muon, 10.4±0.4 photoelectrons/muon.



Microphotograph of photocathode



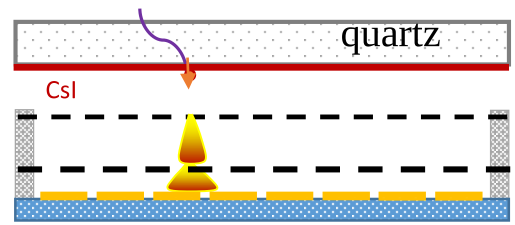
Photocathode: 5nm Cr + 18nm CsI
Sparks, ion Feedback

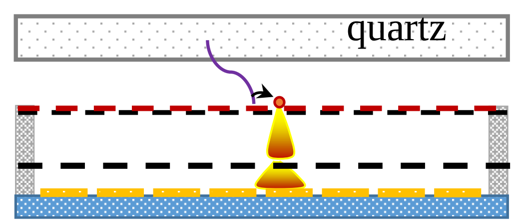
IBF ratio tested with not the same but a very similar PICOSEC detector in the Lab with a laser.

Drift Voltage(V)	Anode Voltage(V)	IBF
-500	300	**46.5%**
-475	300	**42.7%**
-450	300	**38.5%**
-425	350	**42.9%**
-525	250	**52%**

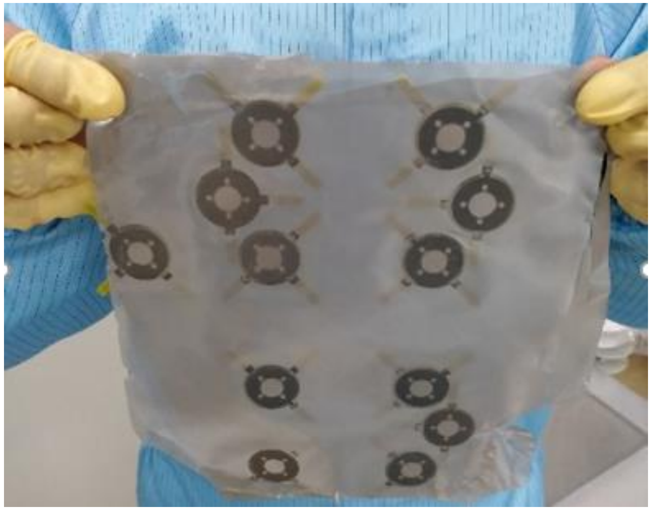
To deal with the irradiation damage

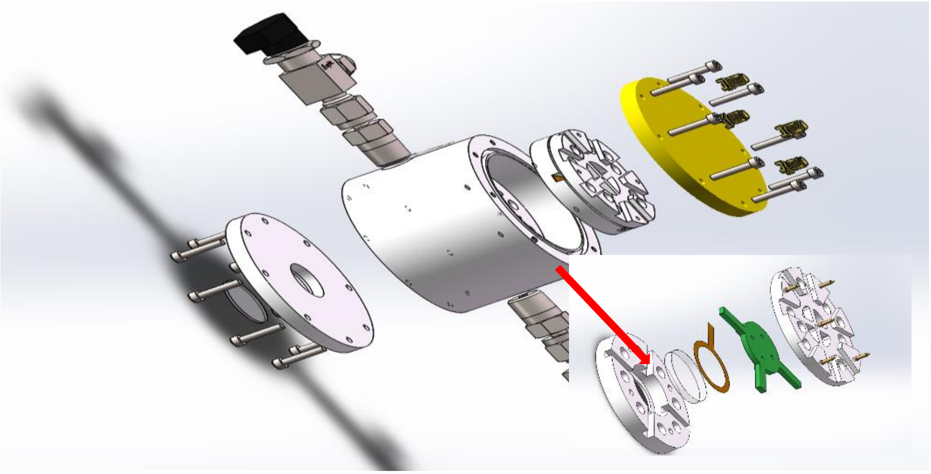
- Double mesh to suppress the IBF to protect the CsI
  - Transmission type with 3.3 nm Cr + 18nm CsI
  - ✓ Low IBF mode with low drift E-field
  - Reflection type with 450 nm CsI coated in the up-mesh
  - ✓ photon signals were observed, CsI layer came off afterwards.
  - ✓ A substrate layer like Cr is likely needed.
- Alternative photocathode, such as Diamond-like Carbon (see Jianbei’s and Lukas’s talks)

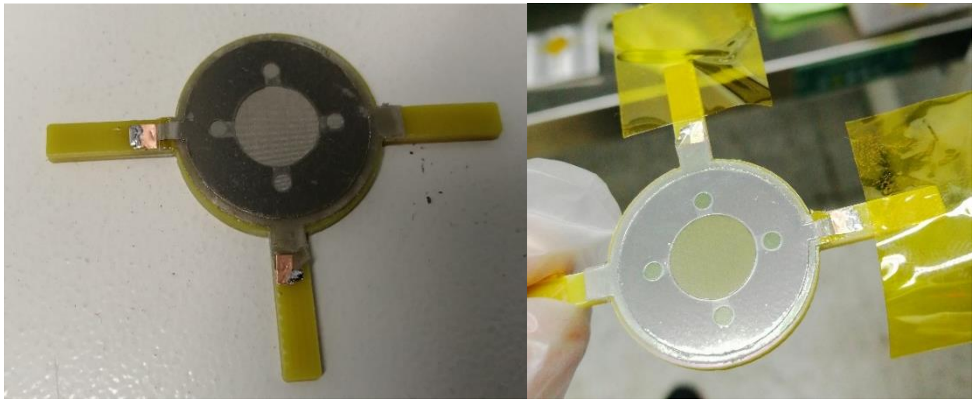




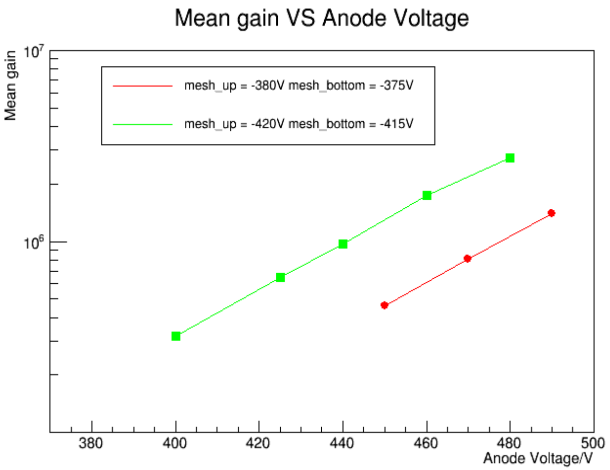
Fabrication of the DMM







The DMM detector for Transmission type on and reflection type one.

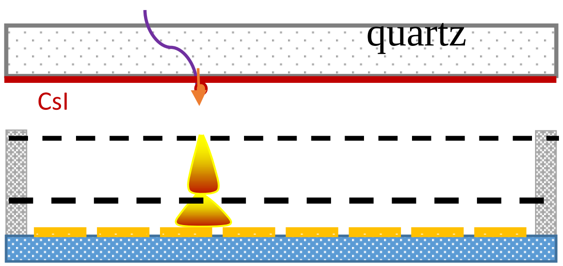


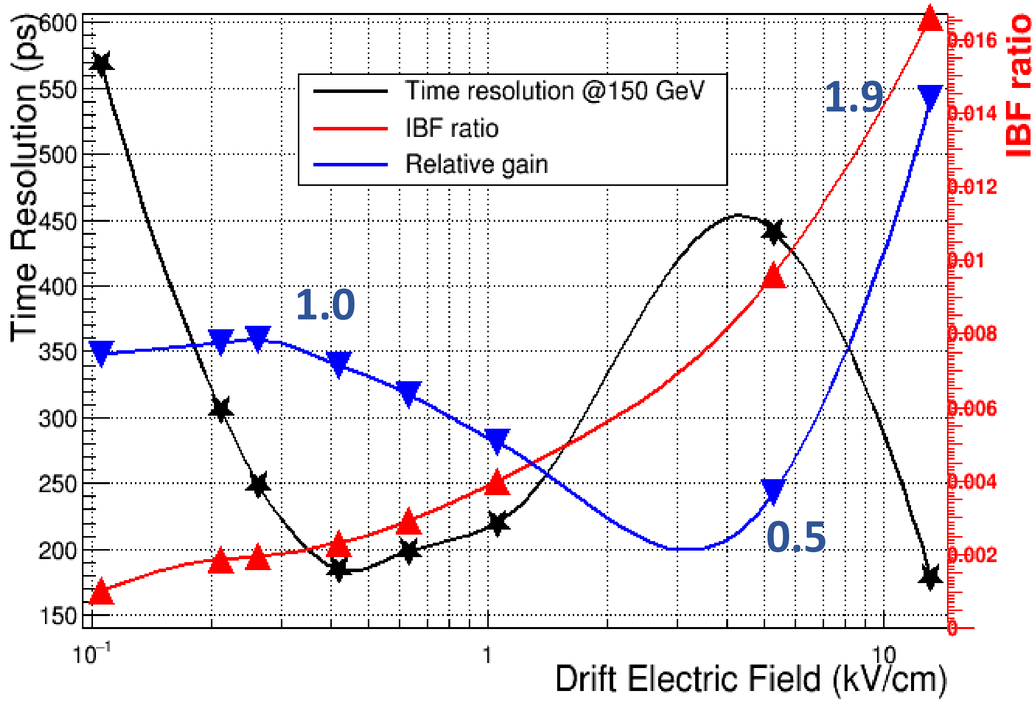
The gas gain test with a laser

New developments on DMM

Performance of the transmission type DMM

- Structure: 190μm (drift)-120μm (pre-amp) -120μm (sec-amp)
- Voltages of PA and SA were fixed to 425V and 360V

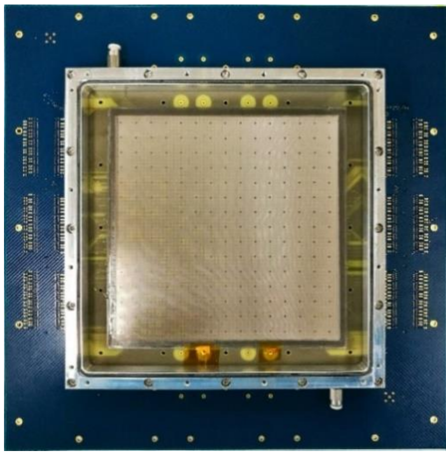


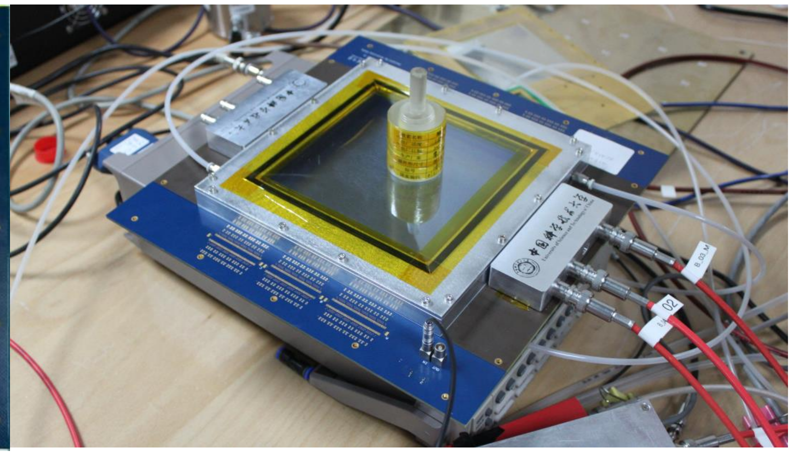


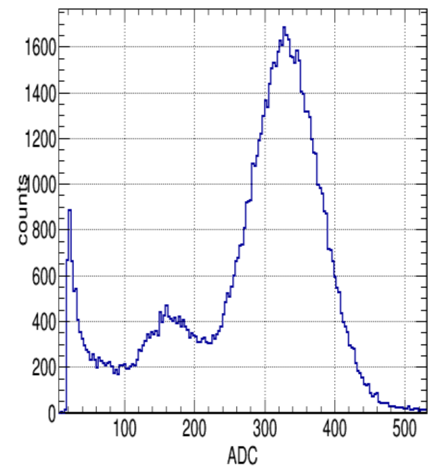
- Time resolution reached 180 ps (can be improved by narrowing the drift gap) at a IBF ratio of 0.2%, that is 40%-50% for standard ones.
- The best time resolution reached ~80 ps at fast timing mode.

New developments on DMM

To enlarge the active area





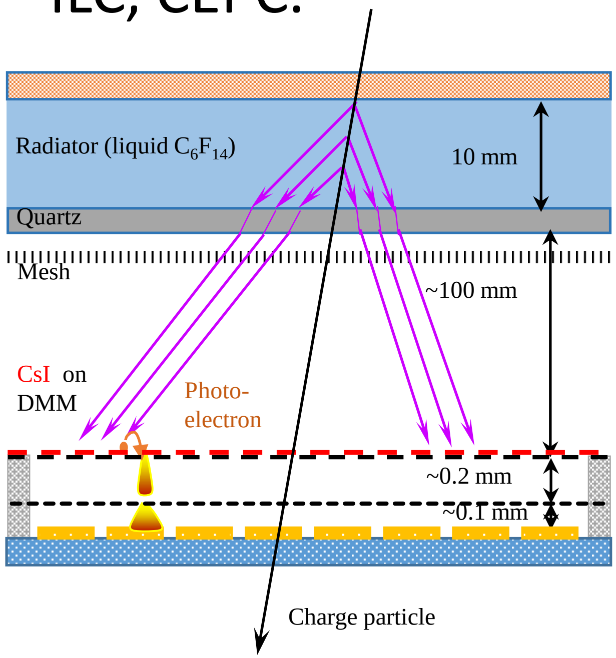


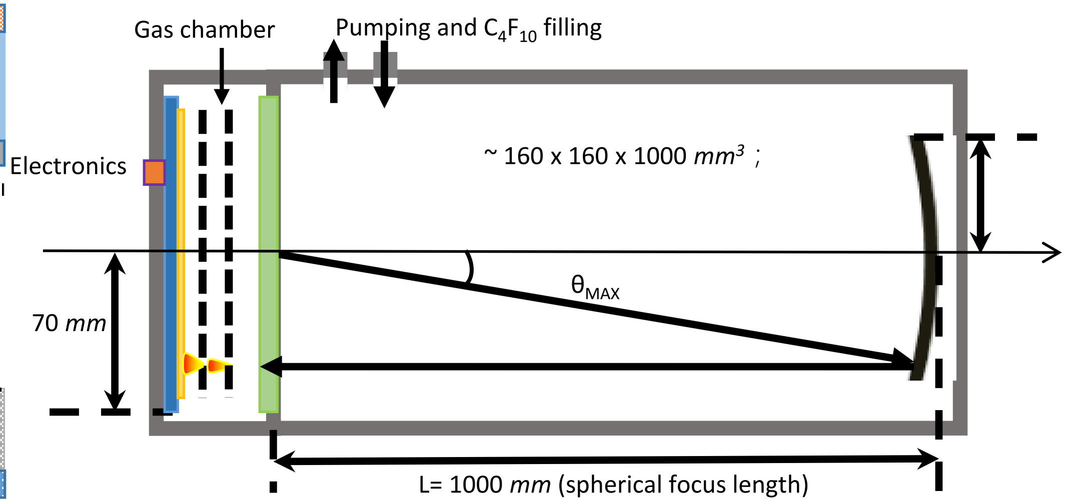
Photographs a 150×150 mm^2 DMM, sensitive structure (left), test in lab with x-rays after assembly (middle);

The preliminary test shows that higher 10^4 gain can be easy achieved, more details are ongoing, the results will come soon.

Potential applications in future

- The high gain, low IBF will fulfill the requirements of a gas-PMT.
- DMM based RICH detectors are under R&D for the Chinese Supper Tau-Charm factory (STCF, left) and Circular Electron Positron Collider (CEPC, right).
- It is also possible used as the readout of high rate TPC, such as ILC, CEPC.





Conclusions

- A DMM detector with high gain ($>10^6$) and low ion feedback ($<$ 0.04%) is developed for single photoelectron detection;
- Simulation studies show strong potential to lower the IBF ratio.
- A 150×150 mm^2 DMM assembled and preliminarily test with x-rays of ^{55}Fe source.
- Many R&D works using DMM for future experiments are ongoing.

Plans

- More attempts to further suppress the IBF ratio.
  - Mesh type, gas, gap size etc.
- Fully studying on the $150 \times 150mm^2$ prototypes
  - including gain, uniformity, spatial resolution etc. especially for single electron;
  - Towards to larger area.
- Optimizing the timing performance:
  - Transmission type, narrow the drift range, resistive anode
  - Reflection type, more efforts will be devoted in.
  - New photocathodes, like DLC are under studying.

Plans

Thanks for your attention!

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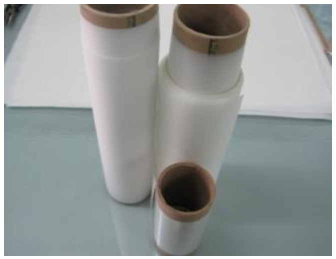
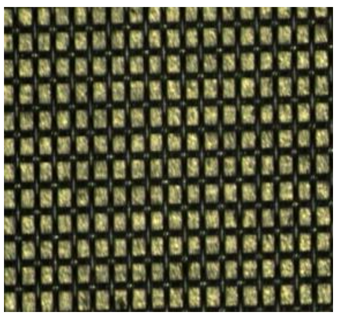
Backup slides

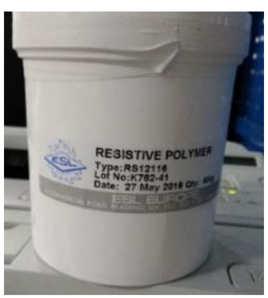
Materials and Specifics

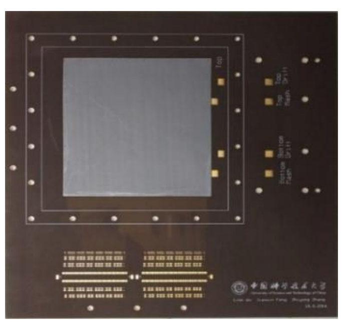


Thermo-bond films with a dry (hot-melt type) adhesive on both sides. A variety of specifications to choose.



Stainless steel woven mesh:
Many types can be chose from;
Thickness: can be thinner than 20 um;
Opening rate: 30%-60%

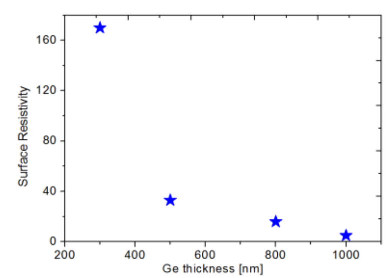




Resistive anode:

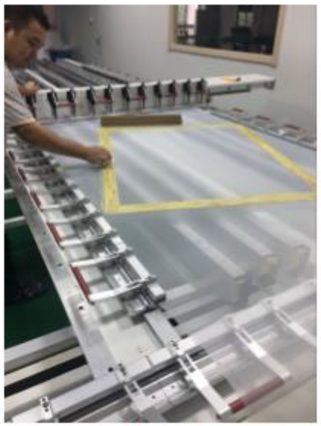
- Carbon paste printing: kΩ/☐ - 100MΩ/☐
- High purity Germanium coating: MΩ/☐ - 100MΩ/☐

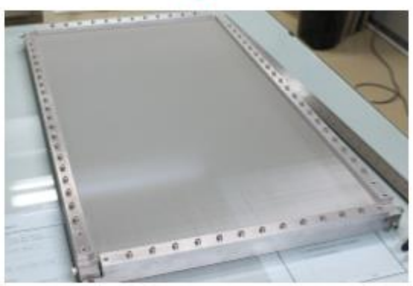
Resistivity versus Ge thickness (FR4 base)



Toward to mass production

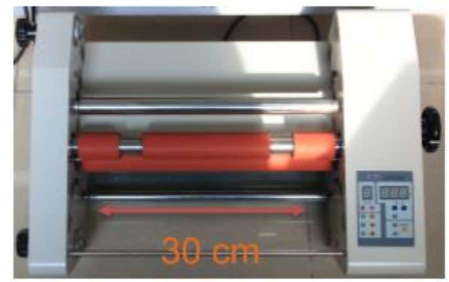
Large Mechanical Stretcher

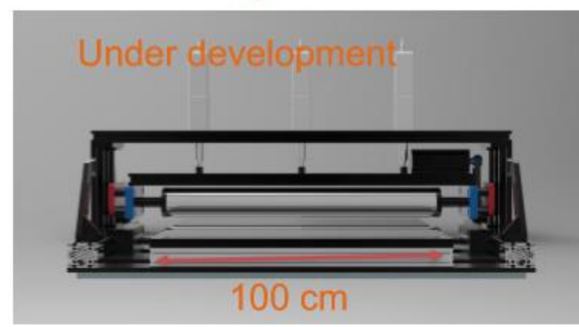




screen printing to make resistive anodes

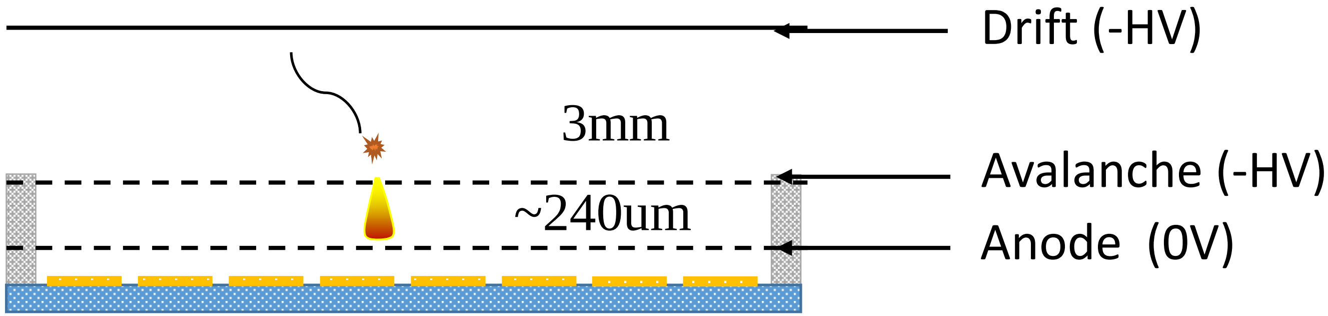
Thermal Roller for Bonding



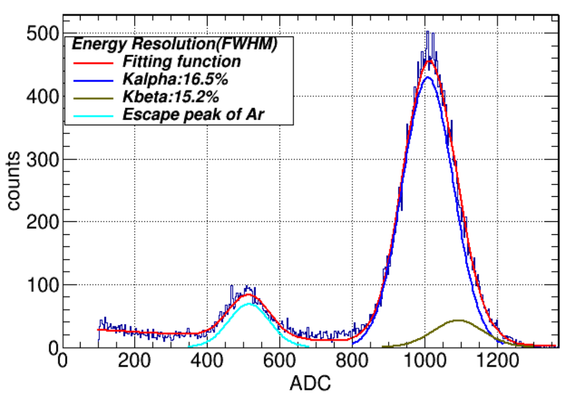


Pre-amplification (PA)

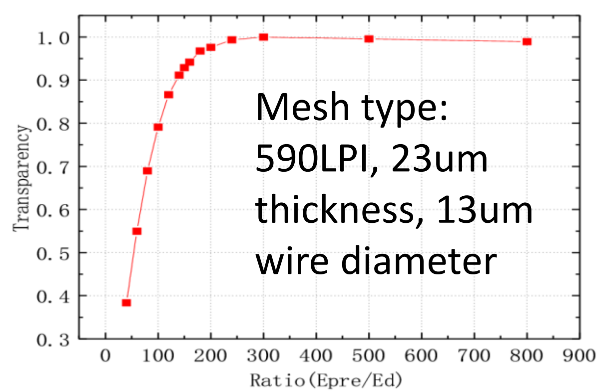
Operating as a typical Micromeags detector individually for PA and SA regions.



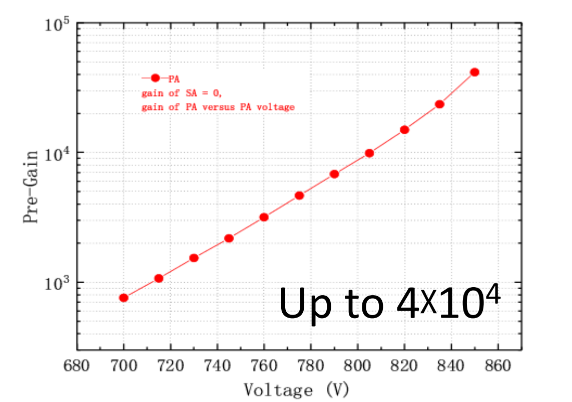
Energy spectrum of ^{55}Fe x-rays



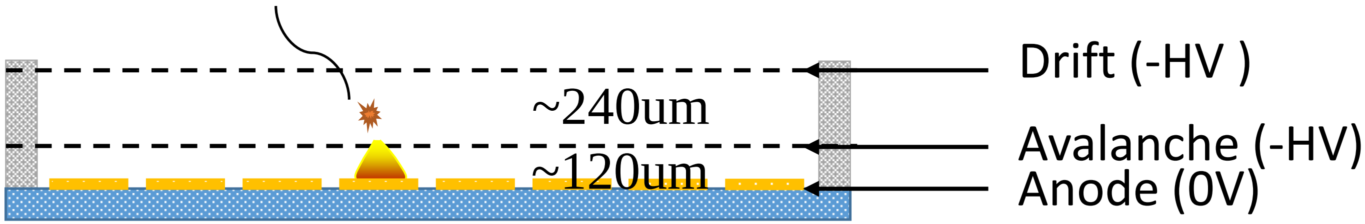
Transparency versus Eratio



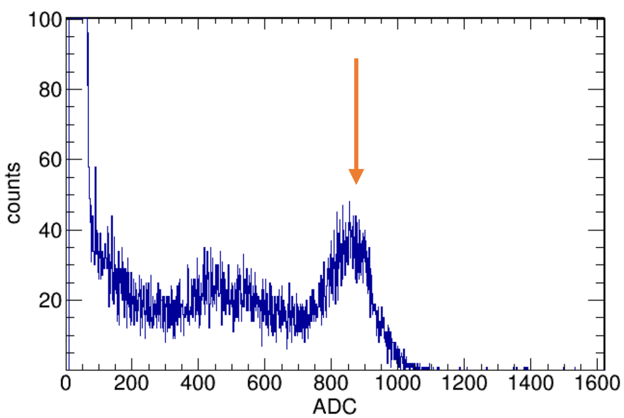
Gain VS avalanche voltages



Sec-amplification (SA)

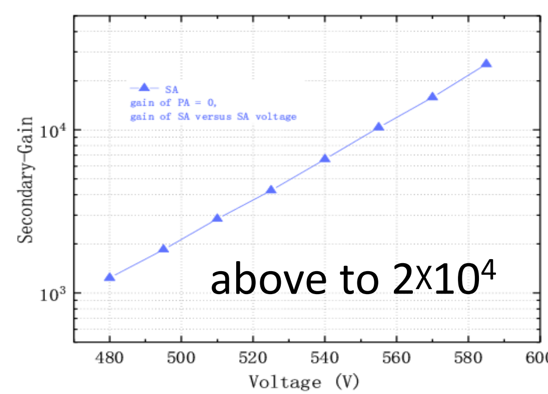


Full energy peak due to the lateral angle
photoelectrons and Auger electrons



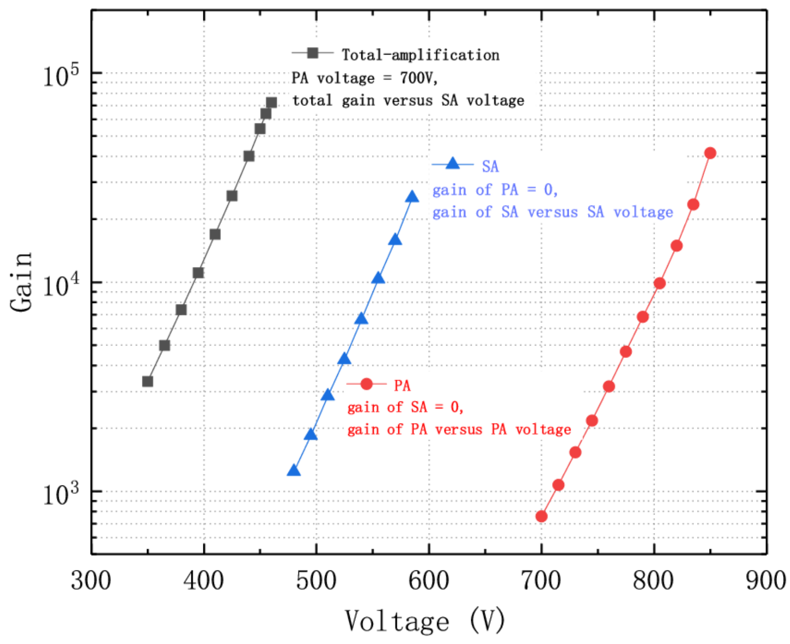
The transparency should be similar to PA's, since their have the same mesh type.

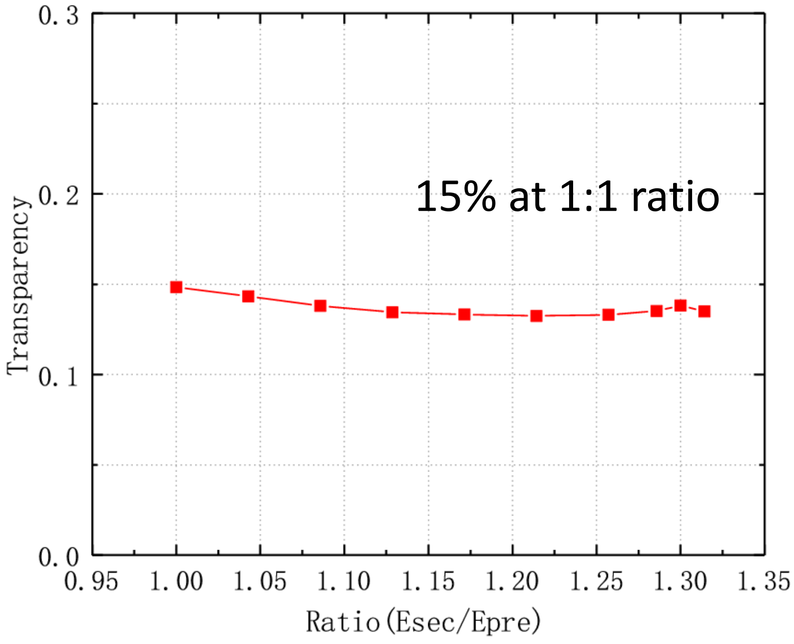
Gain VS avalanche voltages



Electron transparency from PA to SA

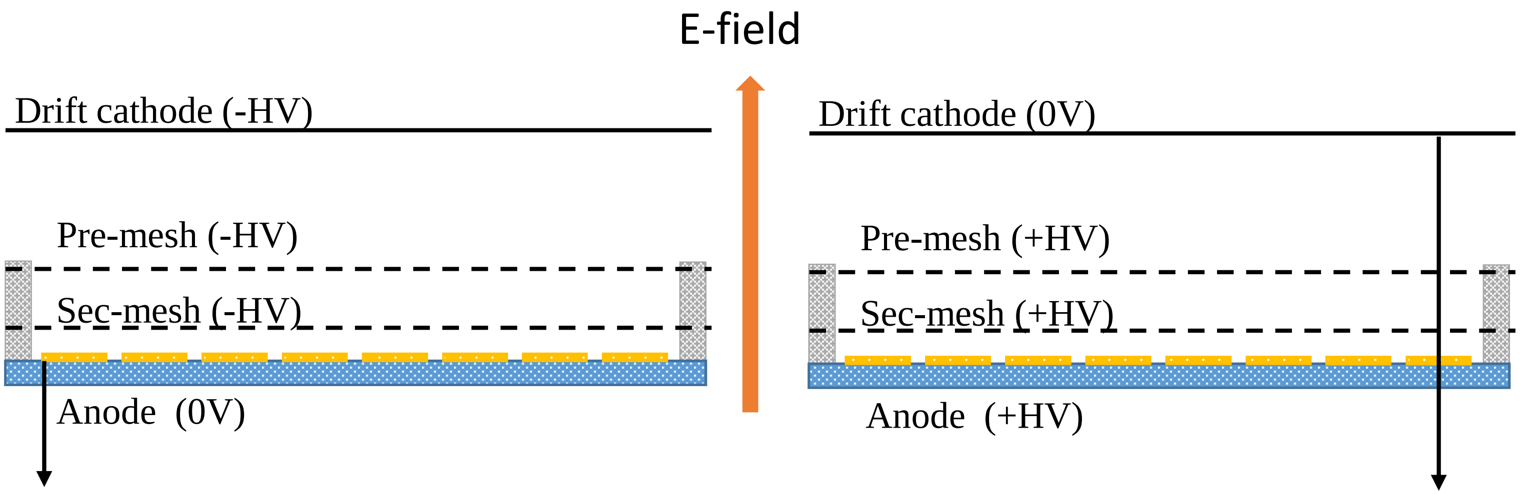
Simply estimate by: Total gain = PA gain*Trans*SA gain





IBF test strategy

IBF ratio = (Idrift-Iprimary)/Ianode ≈ Idrift/Ianode



-1 to -3 nA level

1 pA level

Picoammeter, with a resolution of ~10 fA at ±20 nA