中国科学技术大学
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Recent progress of DMM detector with a double micro-mesh gaseous structure

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Outline

1. Motivation
2. Design and Fabrication of DMM
3. Performance characterization of DMM
4. Applications of DMM
5. Summary

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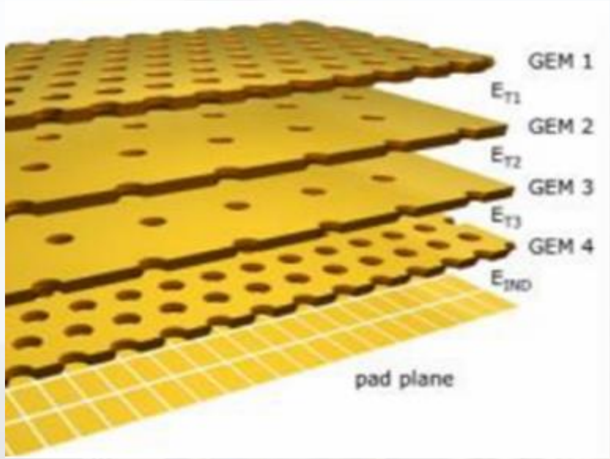
Motivation：TPC

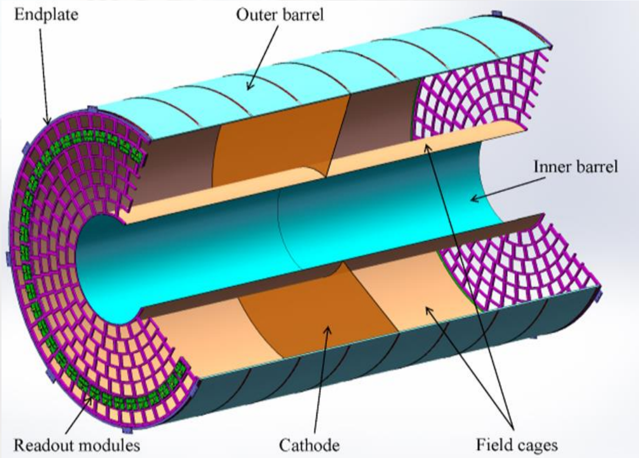
Application of TPC in high-rate environments: ALICE upgrade, CEPC, ILD …

- Low IBF requirement: to minimize drift field distortion caused by ion space charge
- Continuous readout to keep up with high event rate

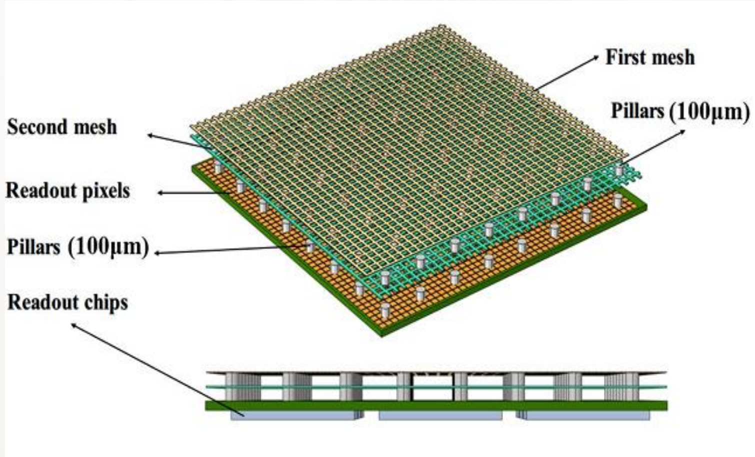
ALICE TPC
quadruple GEM



CEPC TPC



Double Micromegas



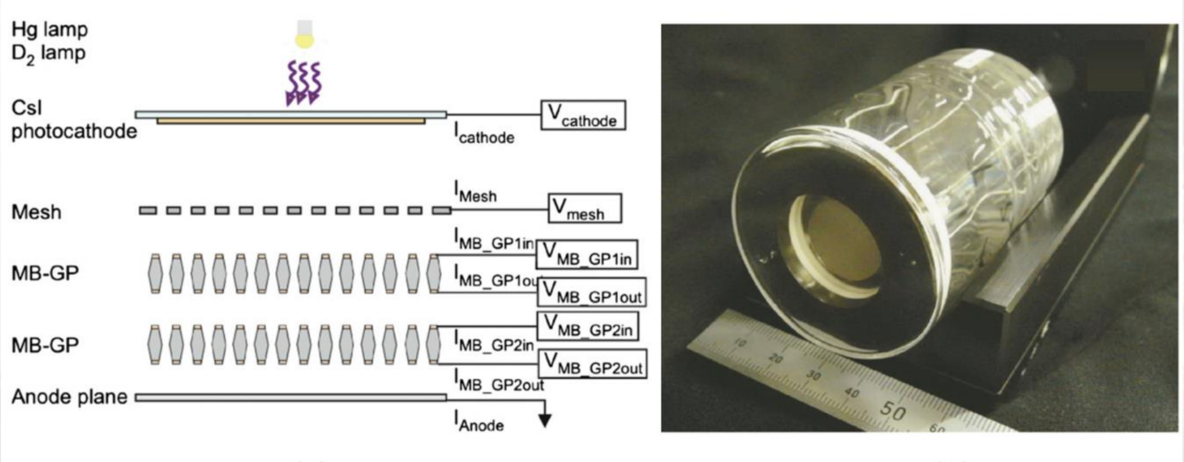
MPGD is the only solution so far. Novel MPGDs with very low IBF are needed to be developed

Motivation：GPD

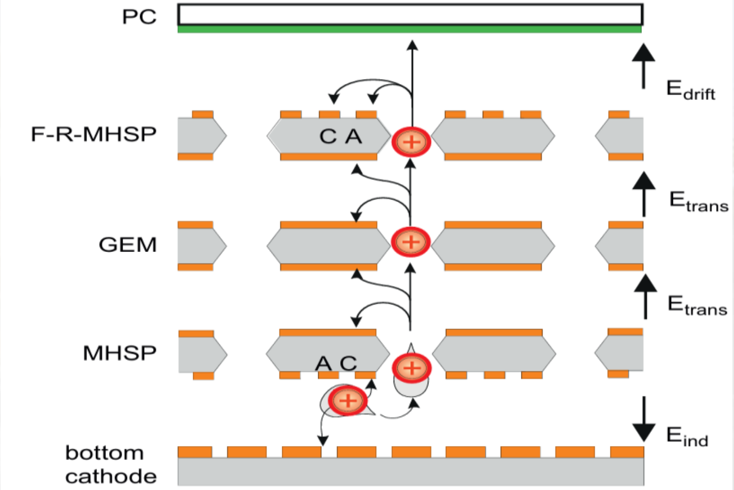
Gaseous photon detector with MPGDs
- Multi layer THGEM-like structure
- Mesh + THGEM -like

→ Large area, high spatial resolution, good time resolution, resistant to magnetic field, IBF suppression, low cost …

Challenges
- High gas gain: to be sensitive to single photons
- Low IBF: to protect photocathode (CsI, Bi-alkali)



(a) (b)



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Detector concept of DMM

DMM：Double Micro-Mesh gaseous structure

Two avalanche gaps:

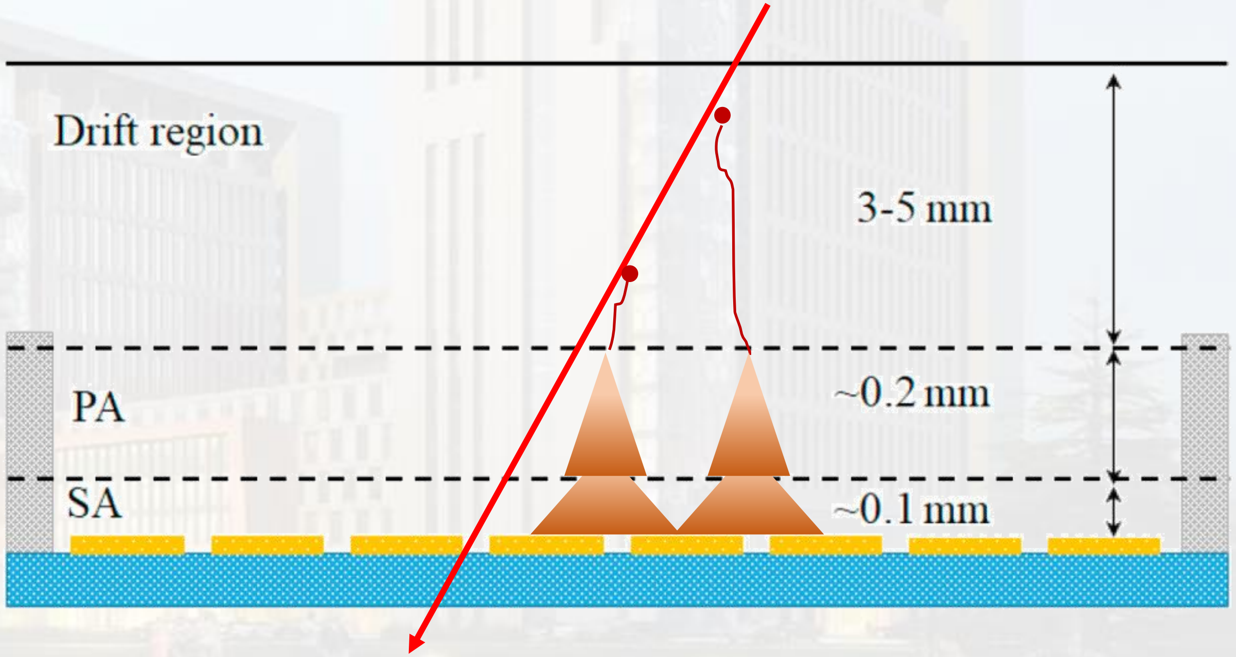
- Gap between the stacked meshes: serving as pre-amplification (PA gap), 200-700 μm
- Gap between the bottom mesh and anode: serving as secondary amplification (SA gap), 100~500 μm

Characteristics：

- Additional Mesh: significantly reduce IBF
- Two-stage avalanche: high gas gain
- Flexible gap control: meet different demands

Fabrication method:

- Typical thermal bonding method
- Optimized thermal bonding method

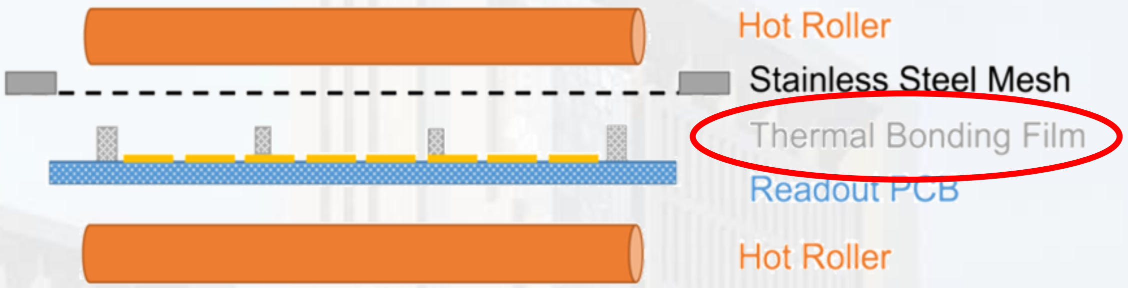


Fabrication methods

DMM is fabricated with **thermal bonding method** that have been developed at USTC

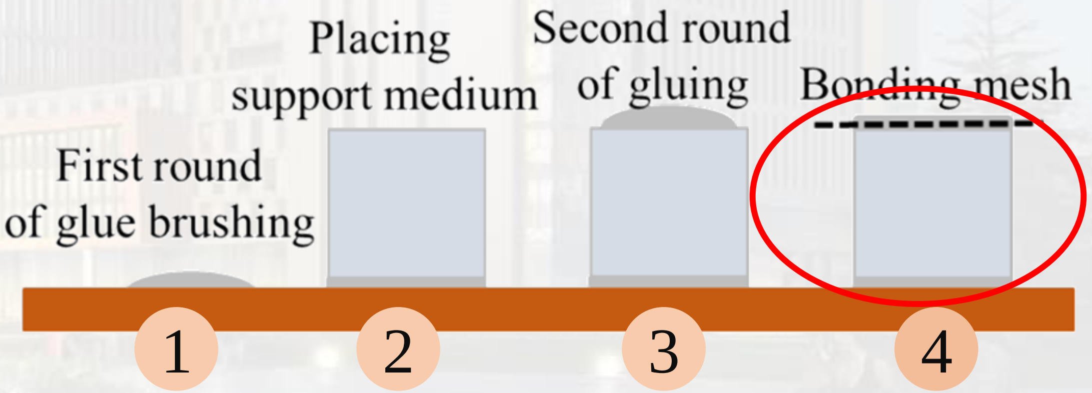
Typical thermal bonding method

- Commercial thermal bonding film
  (specific model, limited options)
- Hot roller (~135℃, less than 1 hour)



Optimized thermal bonding method

- Separate insulating layer and glue layer
  (more options)
- Plate press (~60℃, several hours)



Fabrication

Machines for fabrication of DMM

Hot roller press

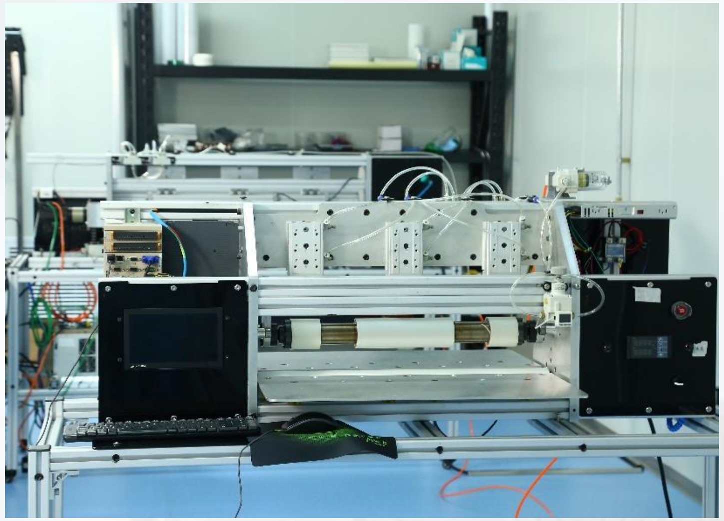
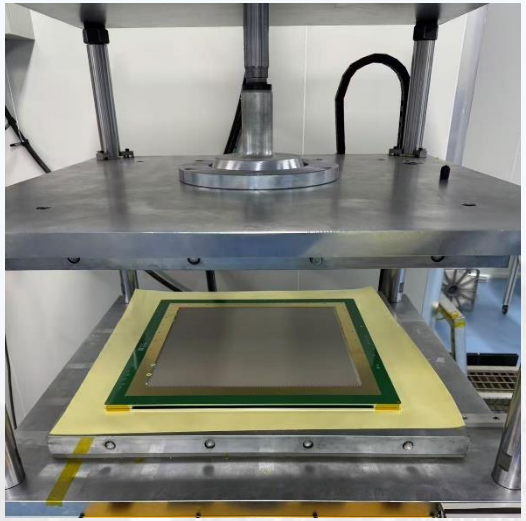


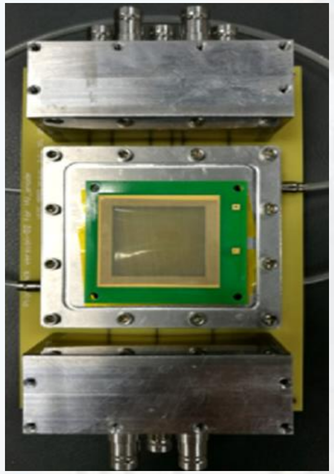
Plate press



- These machines were developed at USTC
- Large area capability: up to 60cm × 60cm (larger machine is under research)
- Easy, reliable, low costs for different size and structures

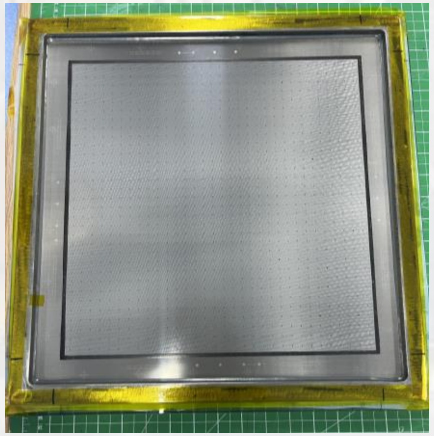
DMM prototypes

25mm × 25mm

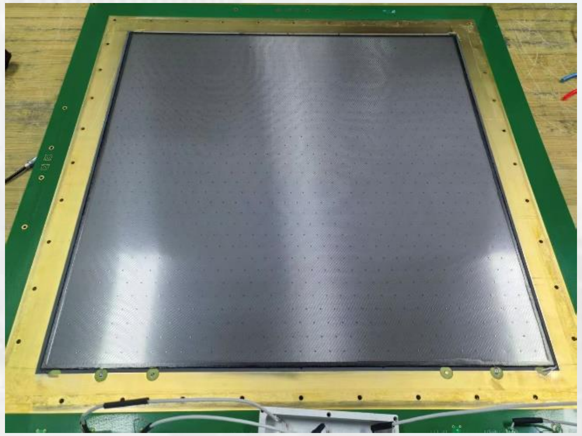


130mm × 230mm

320mm × 320mm



400mm × 400mm



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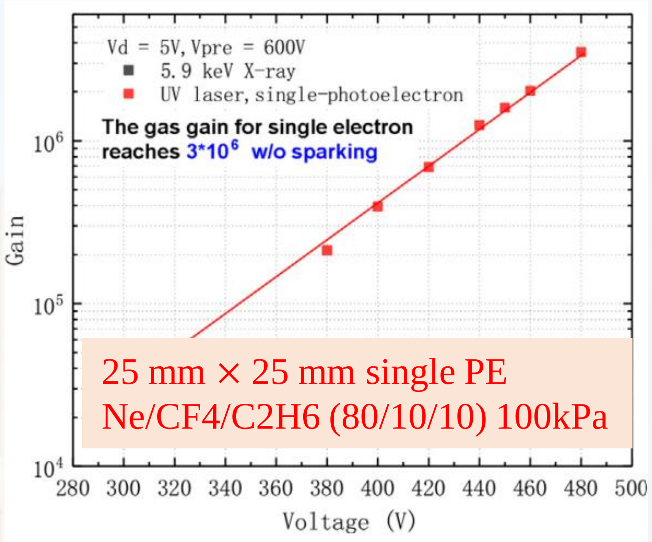
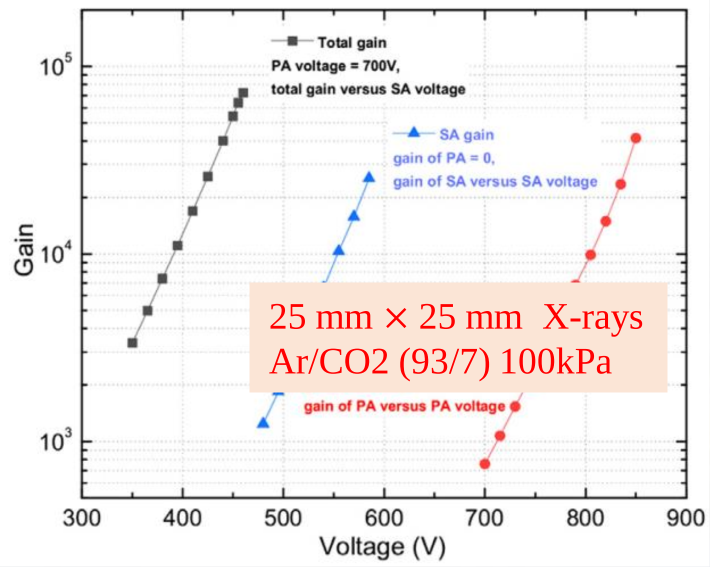
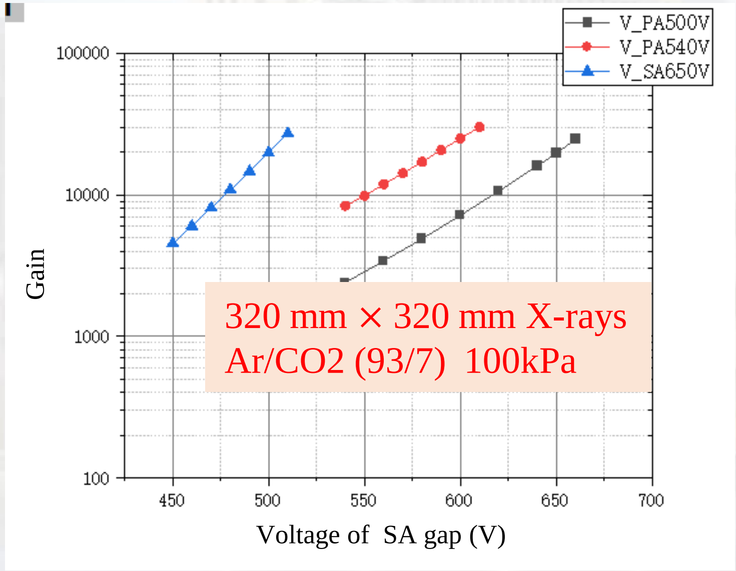
High gas gain of DMM

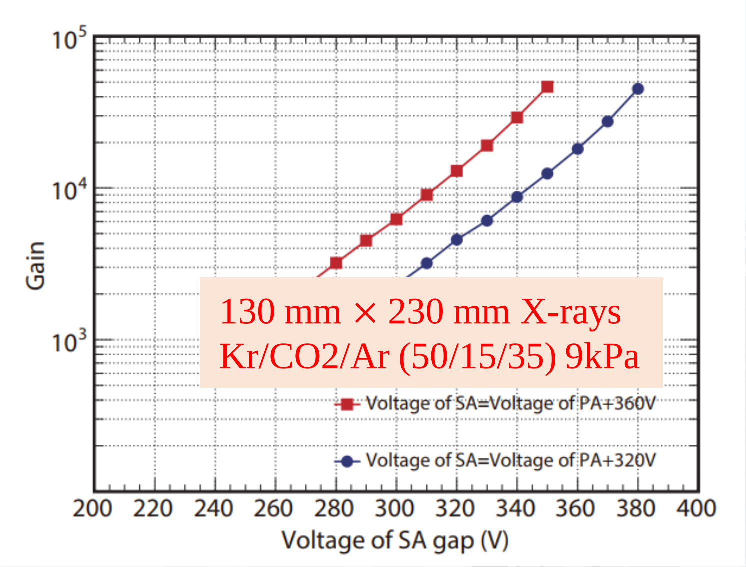
- High gas gain performance has been validated with **different sizes, working gases, and gas pressures**

- Combined gain can reach up
  - 7×10^4 for 5.9keV X-rays
  - 3×10^6 for single photoelectron









Improvement of gain Uniformity

- Manufacture process, design, material are studied to improve the gain uniformity
- RMS/Mean reaches ~5% @320 mm × 320 mm

RMS/Mean ~14%

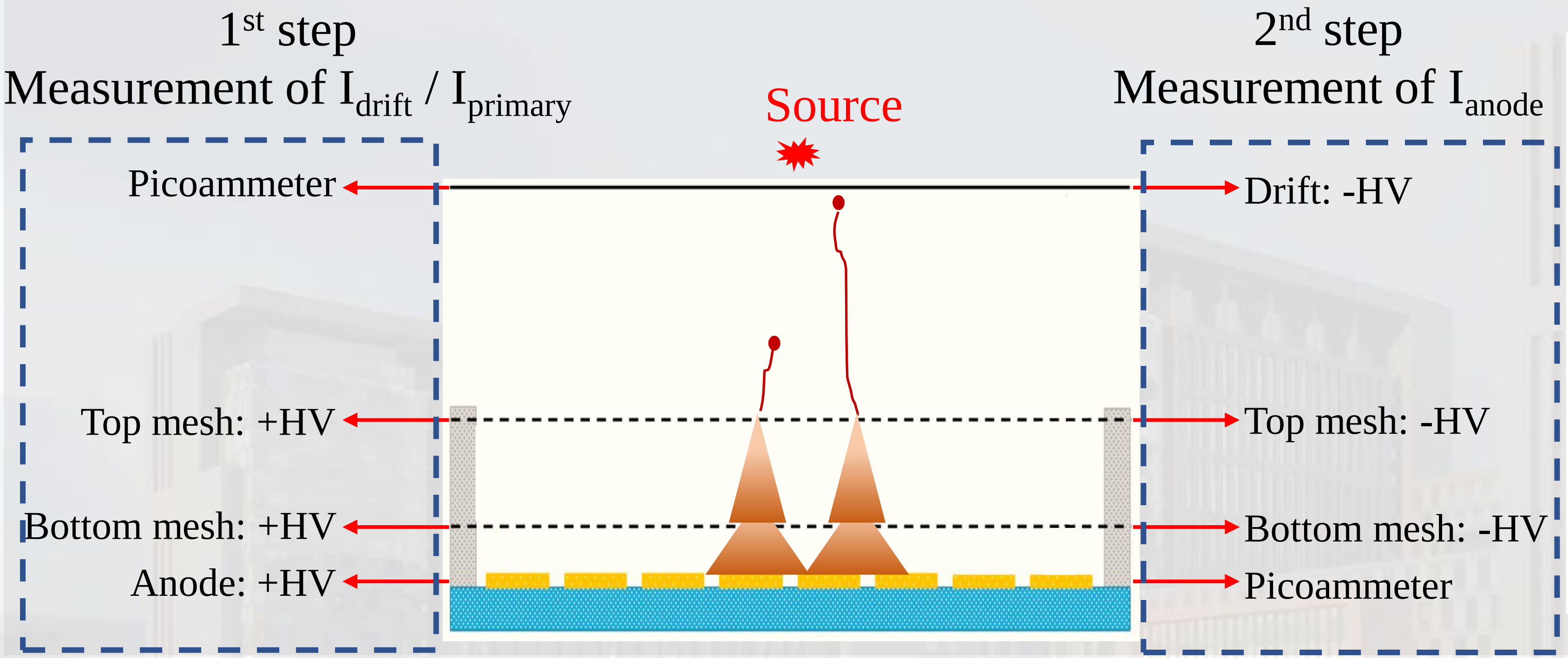
320	283	308	319	322	333	347	343
309	346	329	368	371	363	373	360
264	350	347	374	397	419	390	376
266	321	342	392	422	414	390	396
276	353	352	381	421	431	428	430
223	343	361	387	400	430	466	455
248	333	354	369	377	420	463	412
314	318	322	325	355	386	385	362

RMS/Mean ~5%

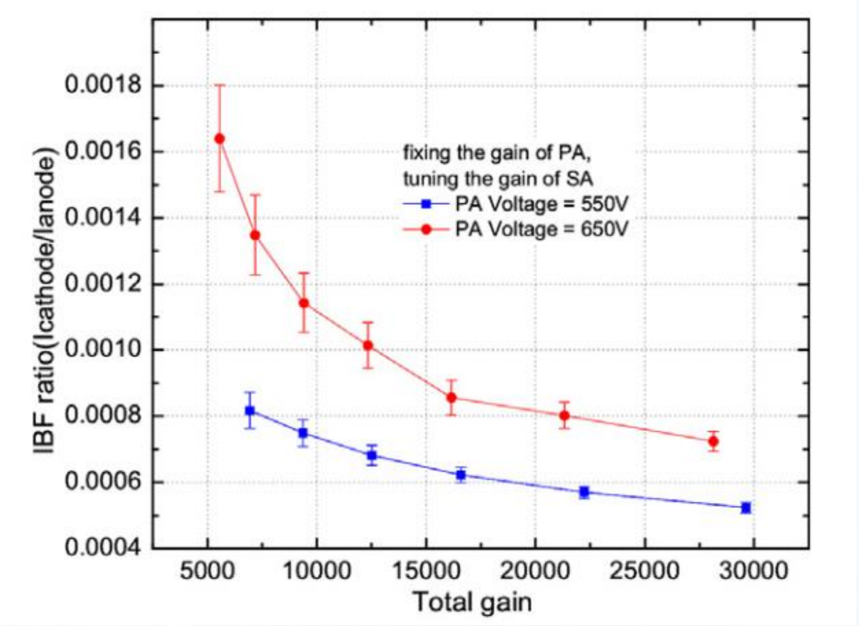
652	679	664	647	649	656	641	626
659	695	680	653	652	654	656	647
540	617	651	658	663	656	650	649
562	588	621	655	662	641	636	641
629	610	617	635	646	645	627	639
668	640	612	619	625	632	638	642
708	698	625	602	612	646	664	654
738	725	616	600	621	647	665	639

Ion Back-Flow (IBF) Measurement

$$\mathbf{IBF = (I_{drift} - I_{primary})/I_{anode}}$$



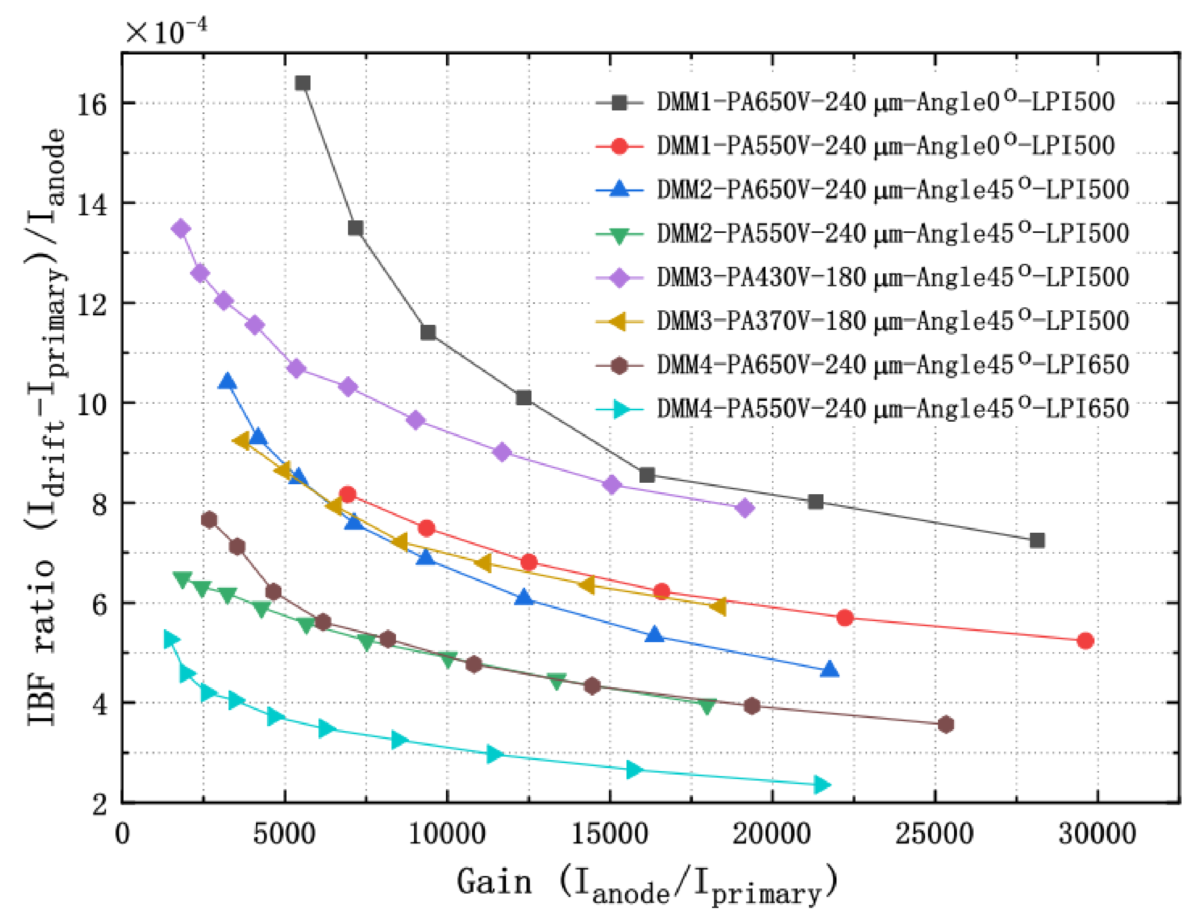
IBF results

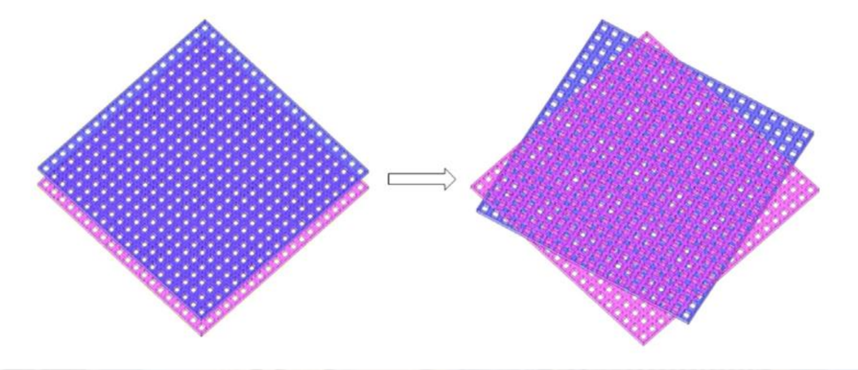


- The current from drift and anode are measured separately using Picoammeter (Keithley6482)
- A high E-field ratio of SA/PA is desirable for IBF reduction
- The IBF reaches lower than 0.05%

Optimization of IBF

Optimization of IBF: mesh LPI, thickness of PA gap, crossing angle of two meshes





To obtain lower IBF:

1. Low electric field of PA gap
2. Large PA gap
3. High mesh density (large LPI)
4. Misalignment of meshes (crossing mesh)

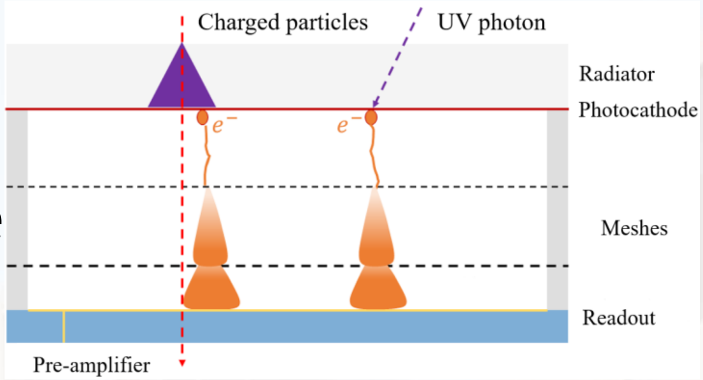
✓ IBF~0.025% was obtained

Fast timing of DMM

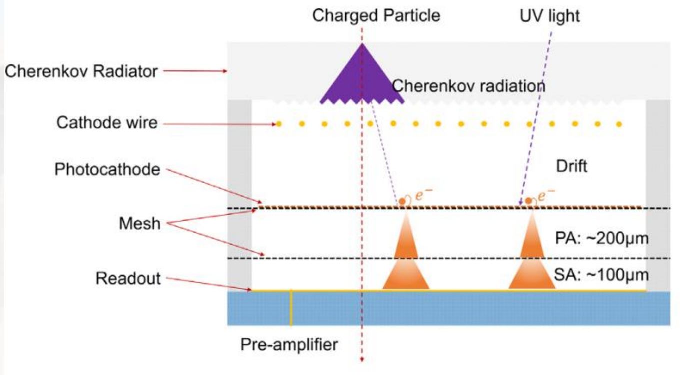
- Compact structure, high electric field are desirable for improved time resolution

- Novel fast timing detector based on DMM
  - Transmission mode (180 ps @MIPs)
  - Reflective mode (160 ps @single PEs)

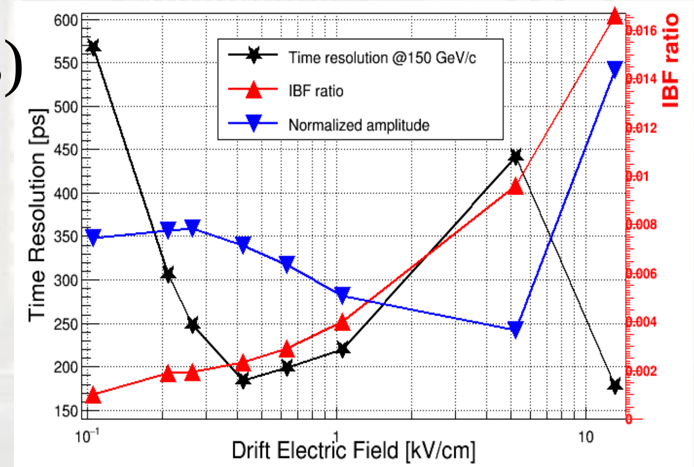
Transmission mode



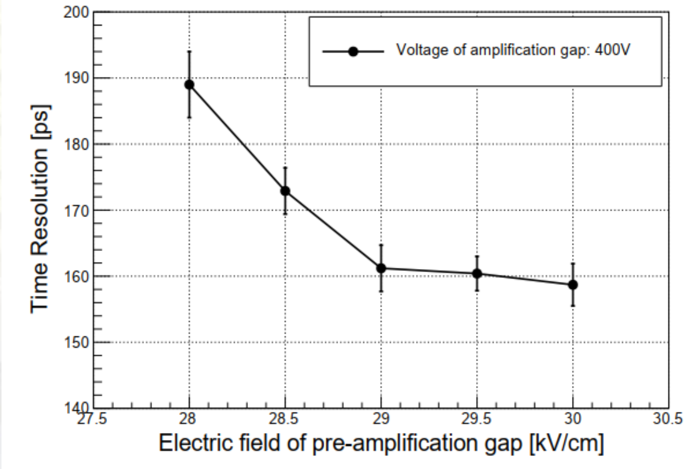
Reflective mode



IBF, time resolution @150 GeV muon



Time resolution @single photoelectron



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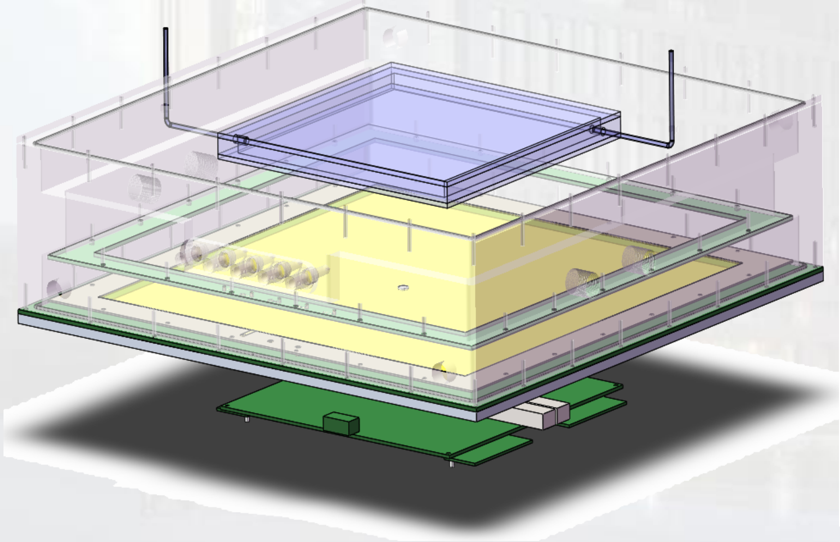
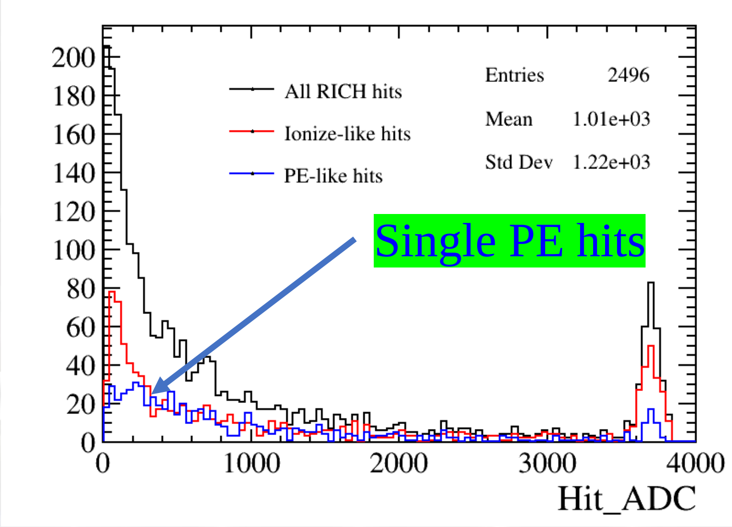
PID-RICH detector based on DMM

- Advantages of DMM as a RICH detector: **high gas gain, protection of CsI photocathode, large area**… …
- Active area: 320mm × 320mm, Gap: 300μm (PA) and 300μm (SA), Gain: >10^5
- Prototypes have been tested under cosmic rays, muon beams and hardon beams

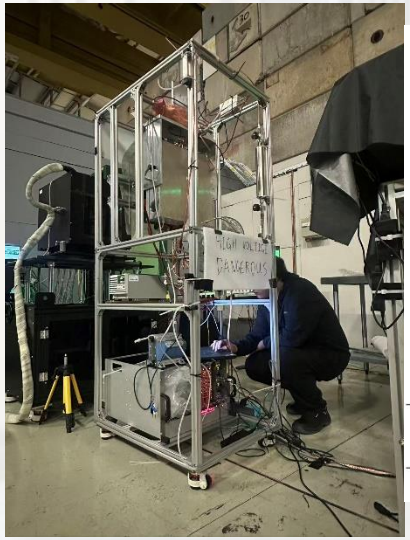
Design of RICH based on DMM

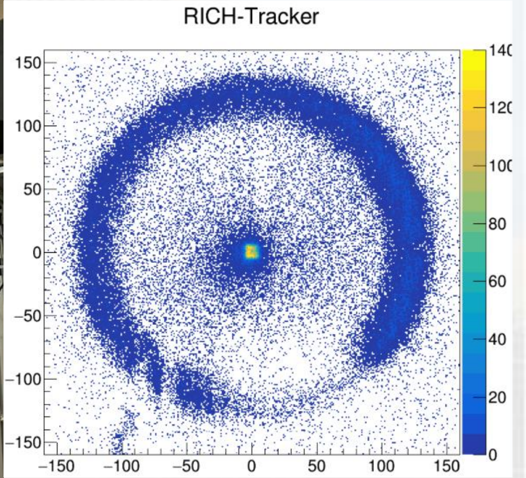


ADC distribution of signals



Beam test of RICH

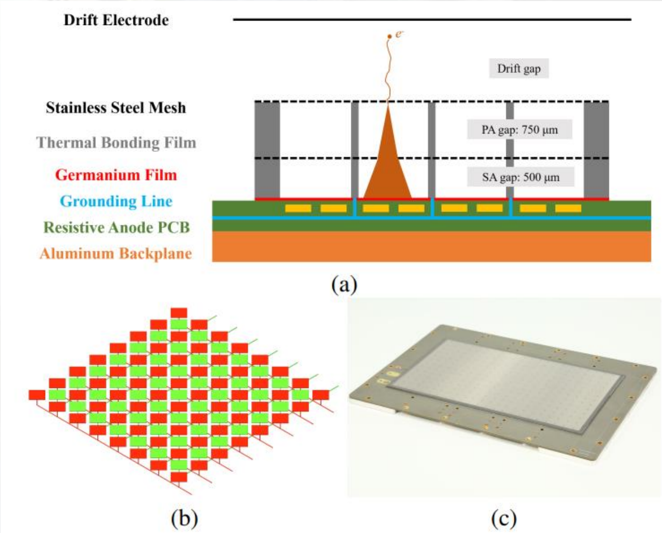




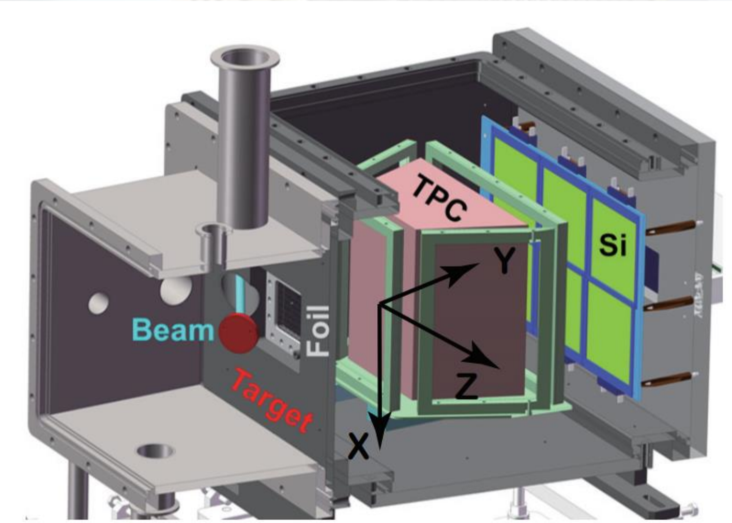
TPC based on DMM

- $^{12}C+^{12}C$ **fusion experiment:** precise carbon fusion rates are fundamental to the study of stellar and cosmic evolution
- **A DMM-based TPC (low gas pressure)** was used to precise three-dimensional reconstruction of α and protons
- Active area: 130mm × 230mm, Gap: 750μm (PA) and 500μm (SA)
- High gas gain, long term stability, low IBF has been validated in the real experiment

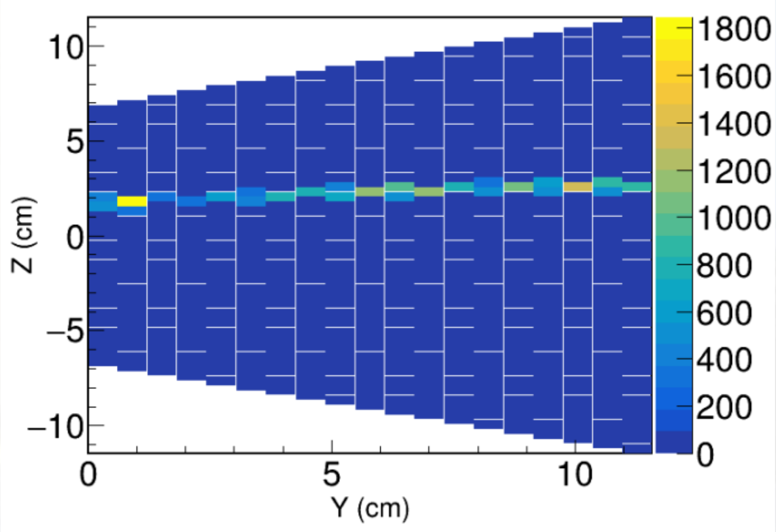
Schematic view



Experiment setup

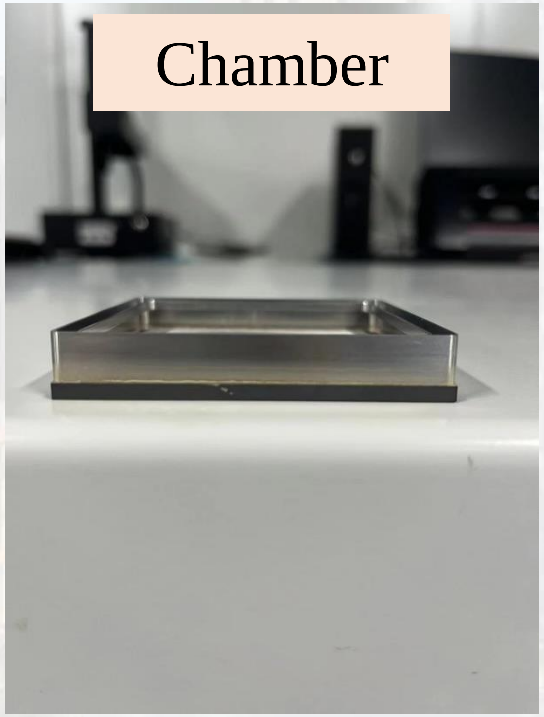


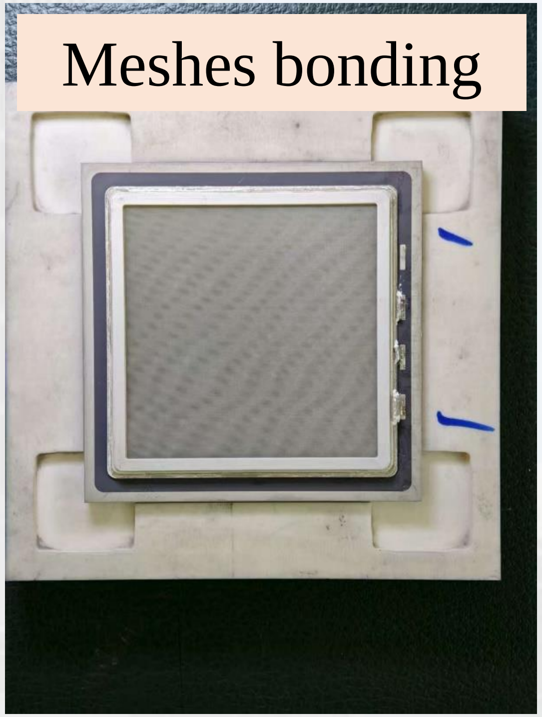
Projected track of a single α event



Gaseous-PMT based on DMM

- Requirements: high gain, low IBF, low gas leak, less gas-outing…
- **Hard solder and other technologies** are chosen to fabricate GPMT based on DMM:
  - Bonding meshes on ceramic PCB (hard solder)
  - Chamber sealing (hard solder, laser welding)
  - Window (hard solder, Melting with glass powder)
- A GPMT based on DMM has been made.





Summary

- The DMM detector with double micro-mesh structure has been developed, featuring high gas gain, low IBF, good uniformity and good time resolution
- Demonstrated the performance of DMM with different prototypes:
  - Gain: 7×10^4 for 5.9keV X-rays (small size), $>4\times10^4$ for 5.9keV X-rays (large size), 3×10^6 for single photoelectron
  - IBF: 0.025% level
  - Uniformity: better than 10%
  - Time resolution: 160 ps for single photoelectron
- Applications:
  - RICH detector, TPC, fast timing detector, GPD…

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Thanks for your listening!