TMM: Triple MicroMegas with ultra-low ion backflow for gaseous photon detectors sensitive to visible light

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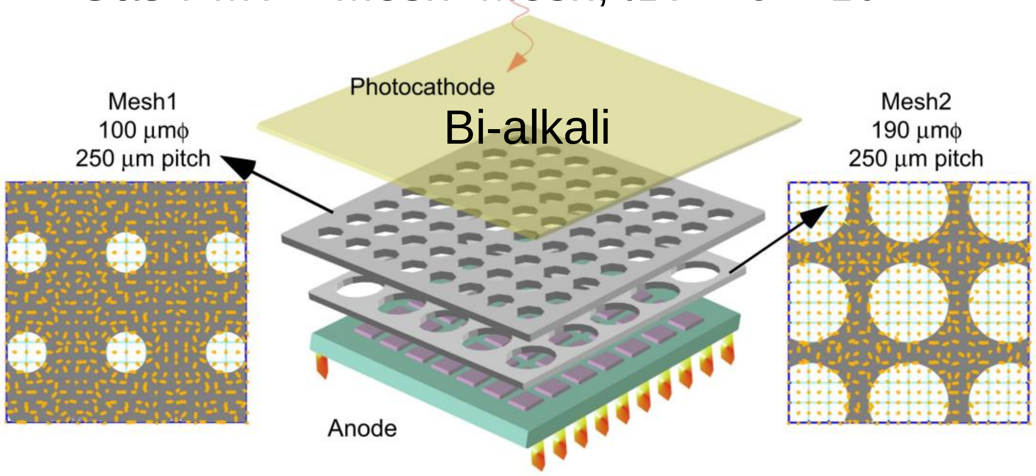
Outline

- Motivation
- Design and Fabrication
- Performance Characterization
  - Gas Gain and IBF Ratio
  - Optimization for Electron Collection
  - Laser Test
- Summary

Motivation: GPD

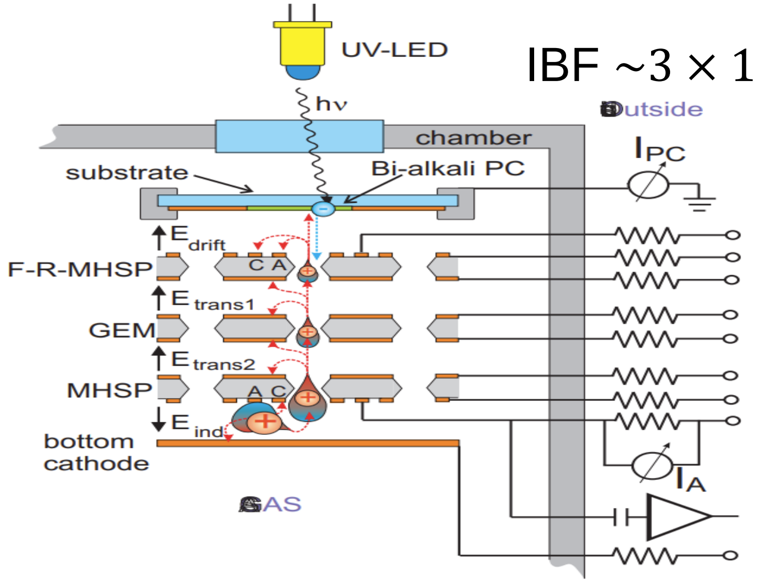
- Gaseous Photon Detector(GPD) based on MPGD
  - large area, low cost, resistance to magnetic field, high spatial and time resolution, **IBF suppression**…
- GPD sensitive to **UV-light** have been successfully applied
  - **Visible-sensitive** GPD is challenging yet promising

Gas-PMT Mesh+Mesh, IBF $\sim 6 \times 10^{-4}$



F. Tokanai et al. , NIM A 766 (2014) 176-179

IBF $\sim 3 \times 10^{-4}$



A V Lyashenko *et al* 2009 *JINST* **4** P07005

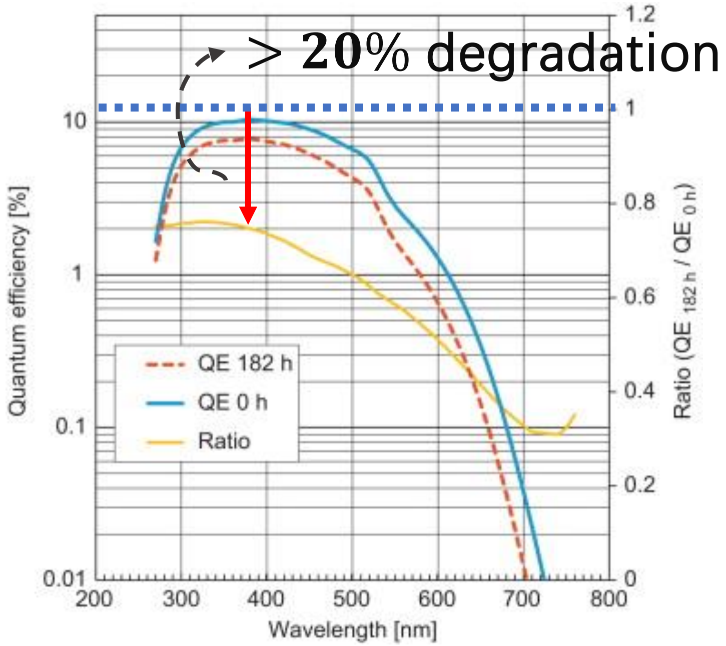
Motivation: Challenges

- Challenges of visible-sensitive GPD
  - ➢ High gain: single photon detection
  - ➢ **Ultra-low IBF: bi-alkali, $\sim \mathbf{\mu C/cm^2}$**

- DMM: Double MicroMegas
  - ➢ IBF ratio: down to $\sim \mathbf{3 \times 10^{-4}}$
  - ➢ Gain for single photon detection: $\sim \mathbf{10^5}$
  - ➢ backflow ions mainly come from the **secondary** amplification gap

IBF × Gain ~ 10^1

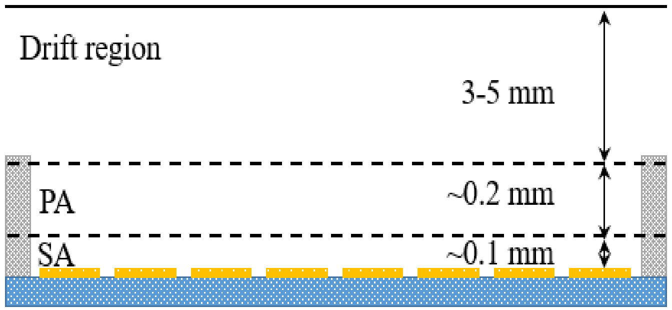
✓IBF Could be further suppressed by **adding an amplification gap**



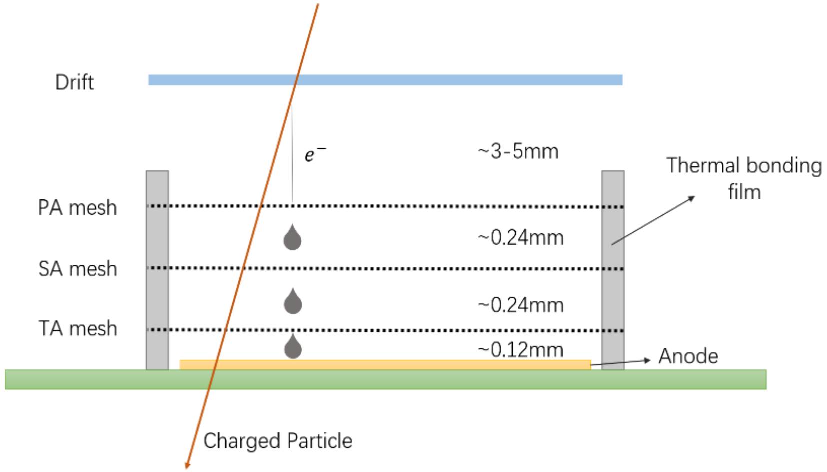
QE of bi-alkali photocathode before and after aging(0.4 $\mu C/cm^2$)

T. Moriya et al. , NIM A 732(2013) 269-272

TMM Design



Double MicroMegas

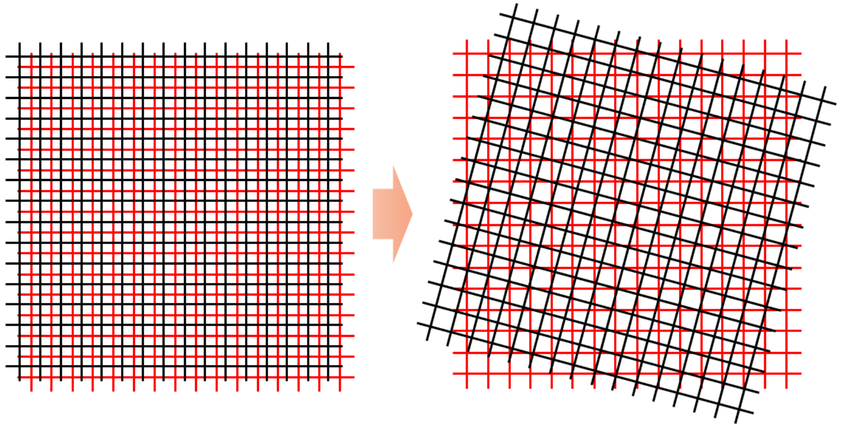


Triple MicroMegas

PA: PreAmplification
SA: Secondary Amplification
TA: Tertiary Amplification

- To suppress IBF:
  - ✓ Large PA gap(~240μm)
  - ✓ High mesh density(LPI650)
  - ✓ Crossing mesh setting
  - ✓ Ions from the **tertiary** amplification could be blocked much easier

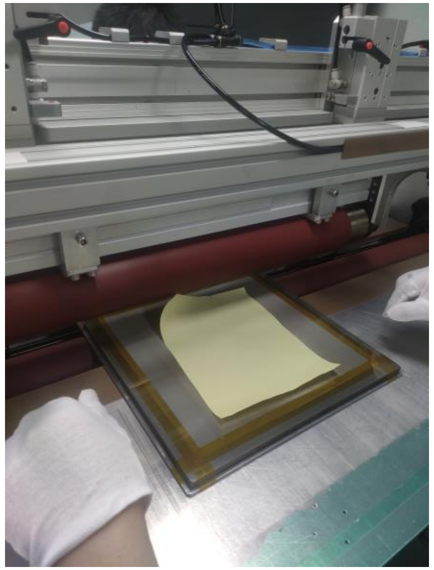
} from study of DMM



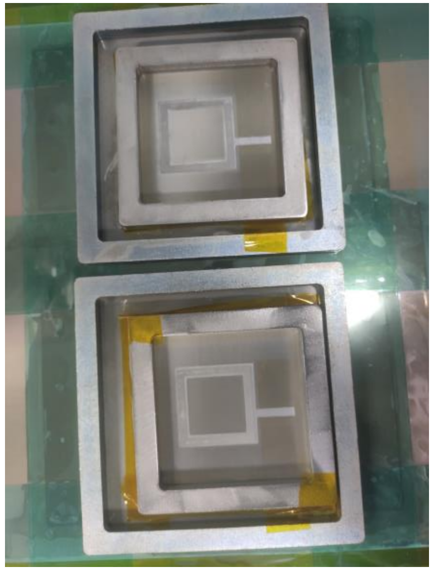
setting adjacent meshes with a crossing angle

TMM Fabrication

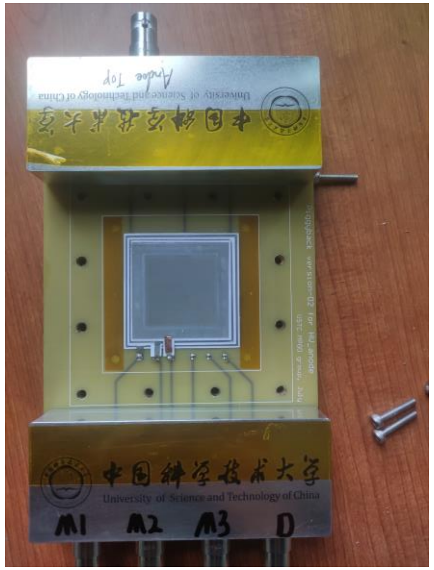
- TMM is Fabricated with the thermal bonding technique developed at USTC
- Thermal bonding films were used to fix the mesh and keep appropriate avalanche gap



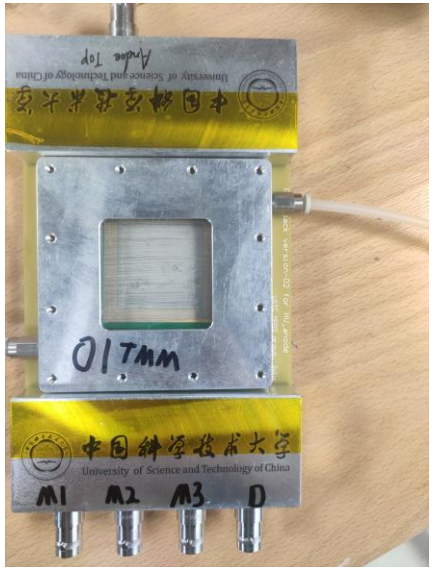
Thermal bonding



After bonding



Mesh cut



TMM prototype

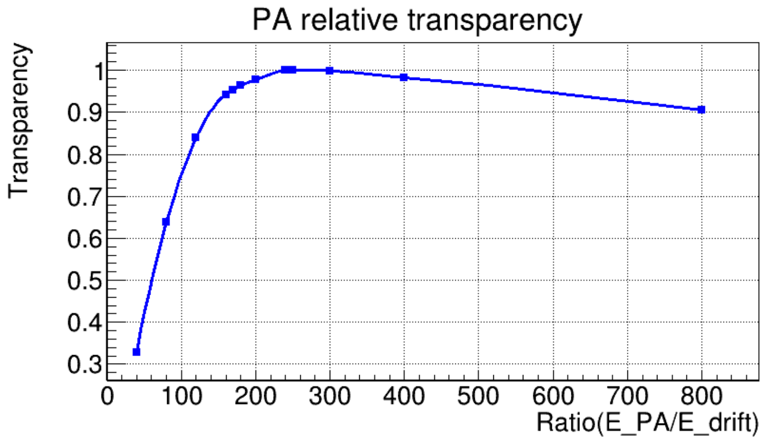
Gas Gain

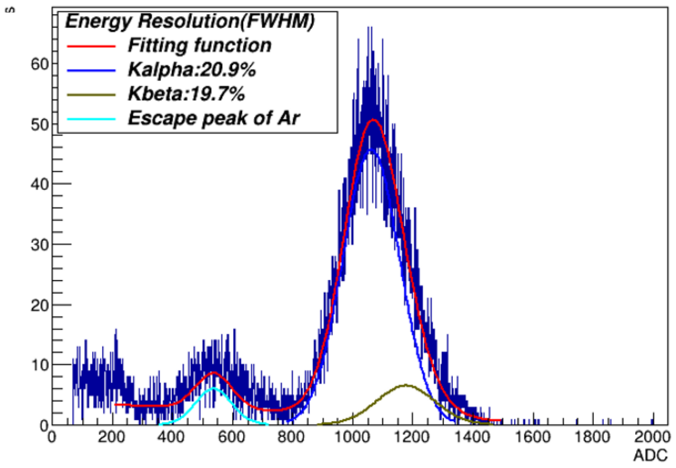
- Tested in $\mathbf{Ar(93\%) + CO_2(7\%)}$, with $^{55}\mathbf{Fe}$ (5.9keV X−ray)
- Ratio=$\frac{E_{PA}}{E_{drift}}$ $= \mathbf{240}$ to maximize electron transparency
- Combined gain: $\mathbf{7 \times 10^4}$
- Typical energy resolution: $\mathbf{\sim 21\%}$

Parameters of meshes

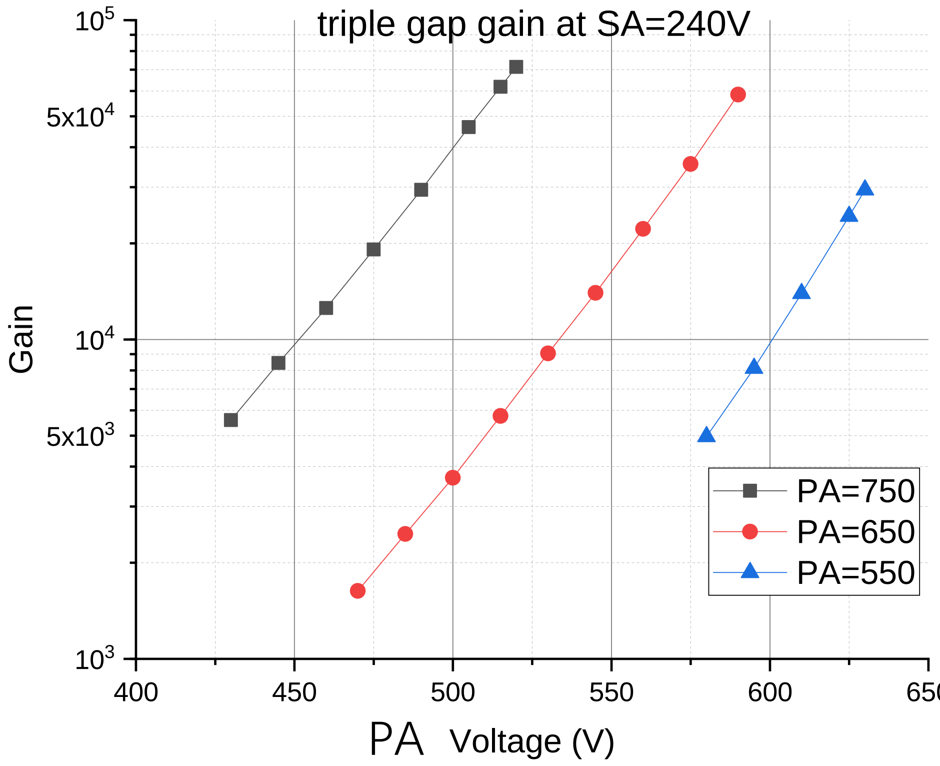
Detector	PA mesh	SA mesh	TA mesh
TMM1	650(40%)*	650(40%)	500(40%)

*: Line Per Inch(Opening Rate) → LPI(OR)



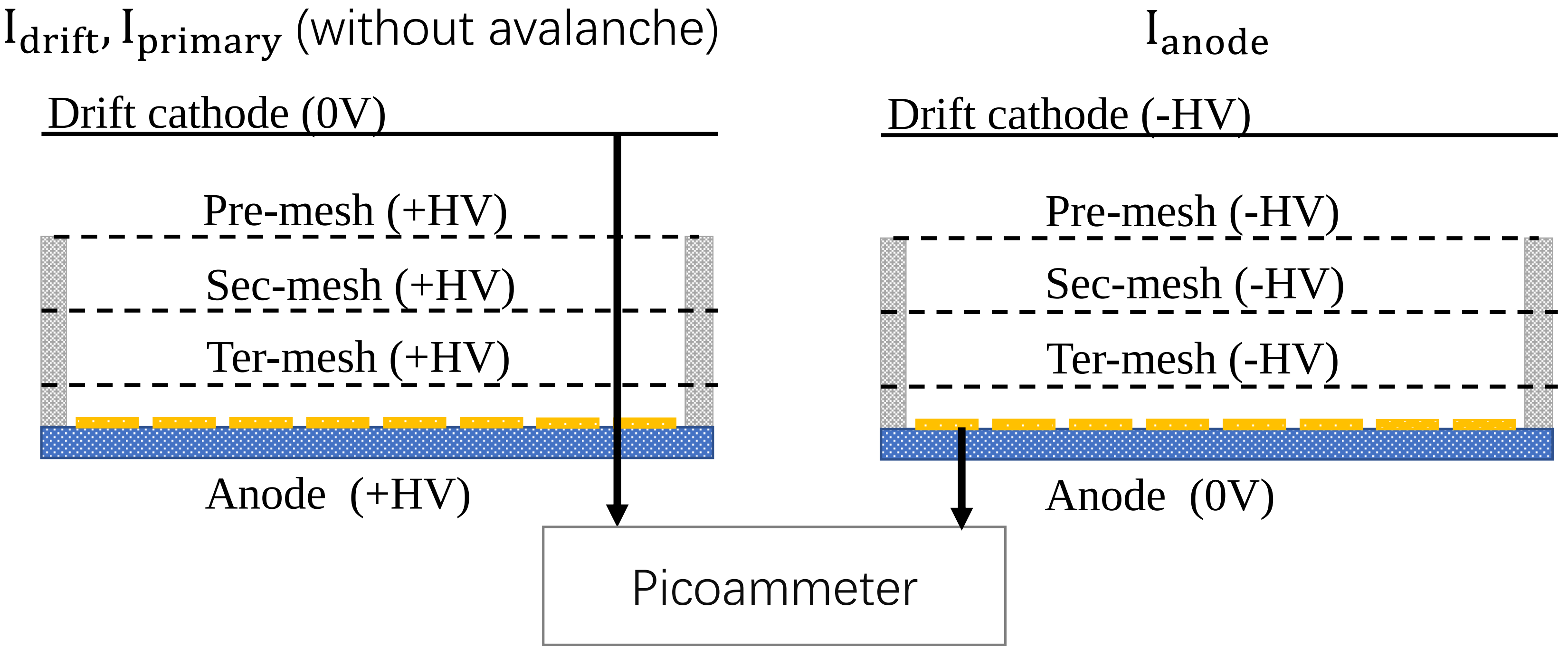


A typical ^{55}Fe energy spectrum



IBF measurement

✓ IBF ratio $= \frac{I_{drift} - I_{primary}}{I_{anode}}$

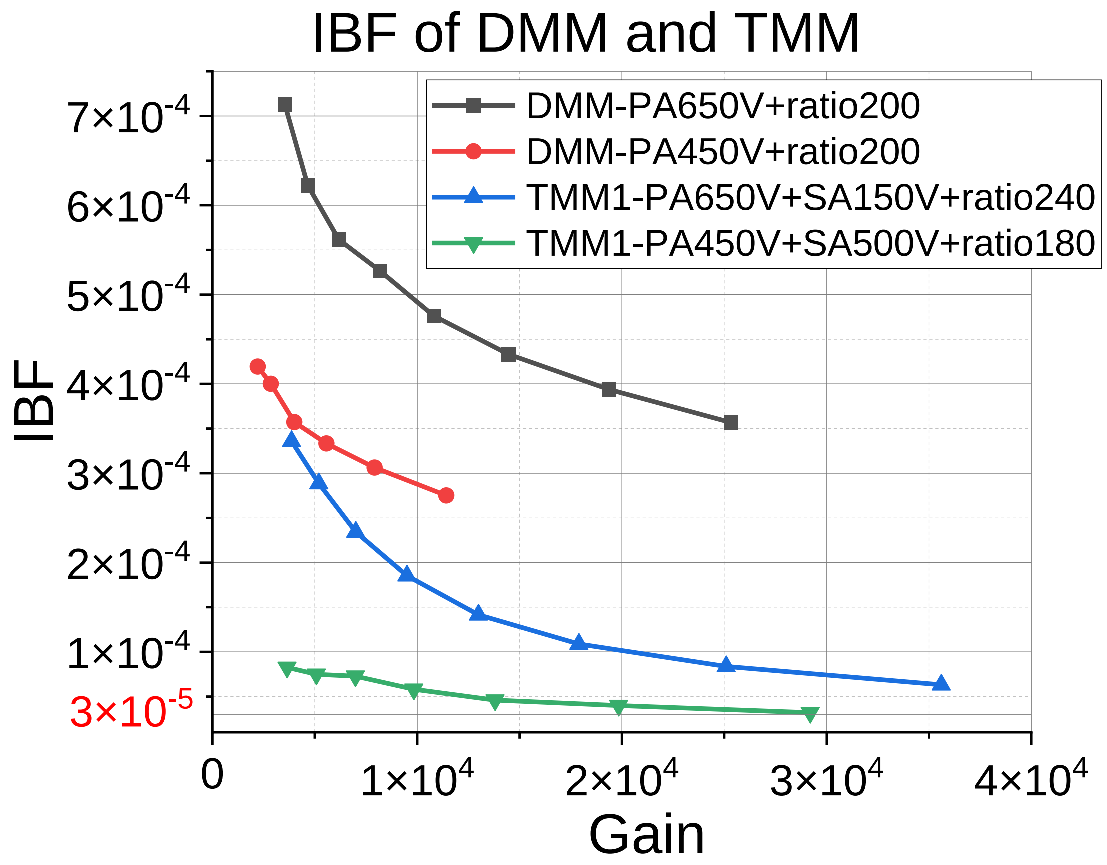


- $I_{primary}$: ~pA, I_{drift}: 10~100 pA, I_{anode}: $-10 \sim -300$ nA
- Keithley(6482) Picoammeter with ~10fA resolution in a range of ±20nA

IBF Ratio

- IBF ratio down to $\mathbf{\sim 3 \times 10^{-5}}$ at a PA voltage of 450V

✓~One order of magnitude better than that of DMM



Optimization for Electron Collection

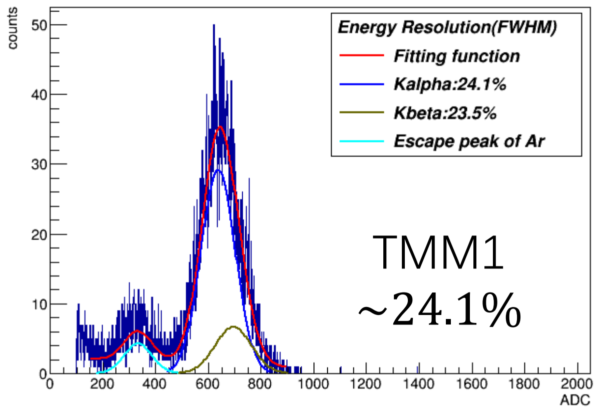
Detector	PA mesh	SA mesh	TA mesh
TMM1	650(40%)*	650(40%)	500(40%)
TMM2	500(50%)	650(40%)	500(40%)
TMM3	500(50%)	650(40%)	500(40%)

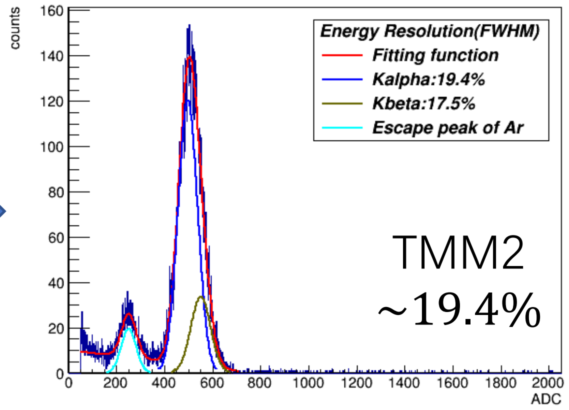
*: Line Per Inch(Opening Rate)

- Low PA voltage would degrade electron collection efficiency

- Two TMM prototype with PA mesh of higher Opening rate and lower LPI were fabricated

- Energy resolution was improved
  - ✓ Implies better electron collection





Combined energy resolution at PA550V+SA650V

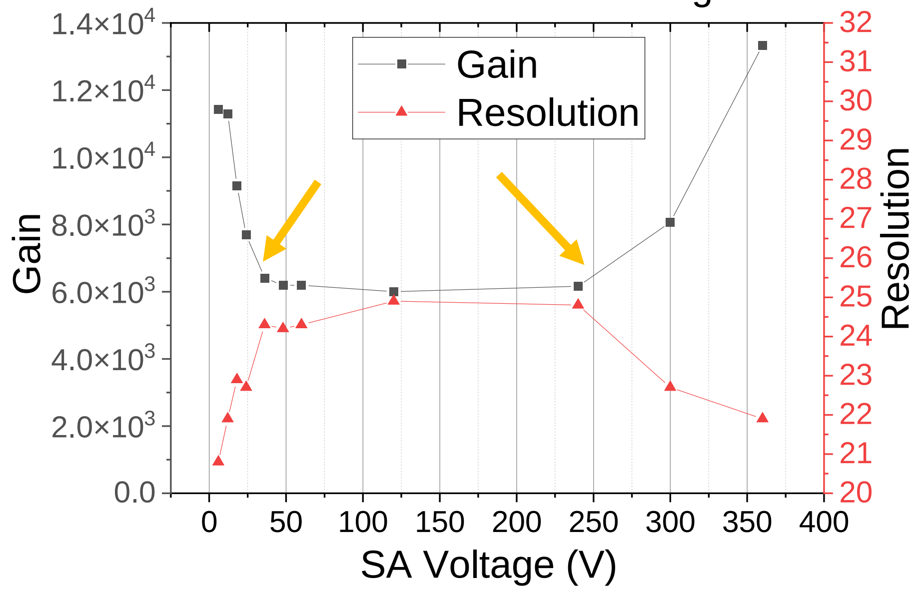
Various SA Voltage

- TMM1, PA fixed to 650V, TA fixed to 500V

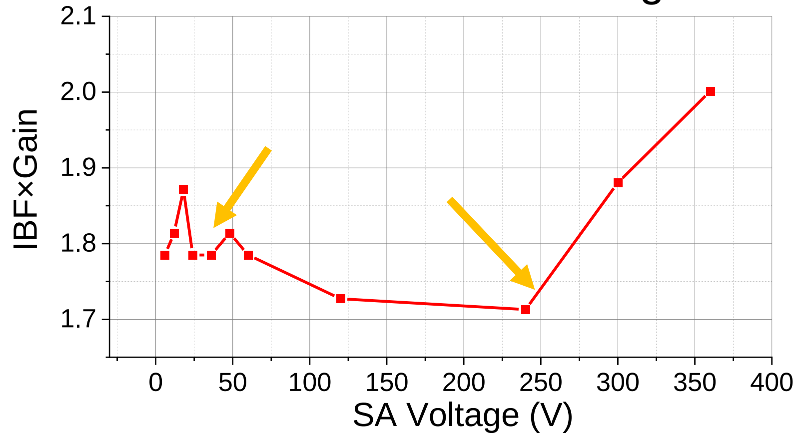
- Two turning points
  - The left one indicates the changing of combined transparency.
  - The right one indicates the begin of electron avalanche ($E \sim 10^4$ V/cm).

✓ Low SA voltage could improve resolution while keeping low IBF

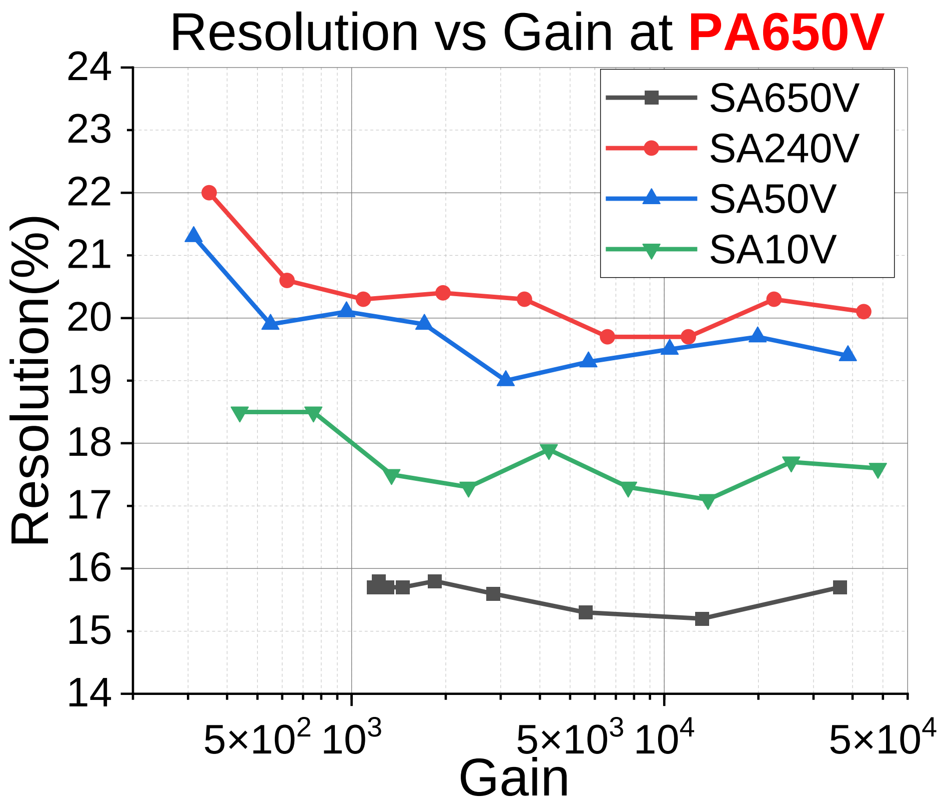
Gain & Resolution vs SA Voltage

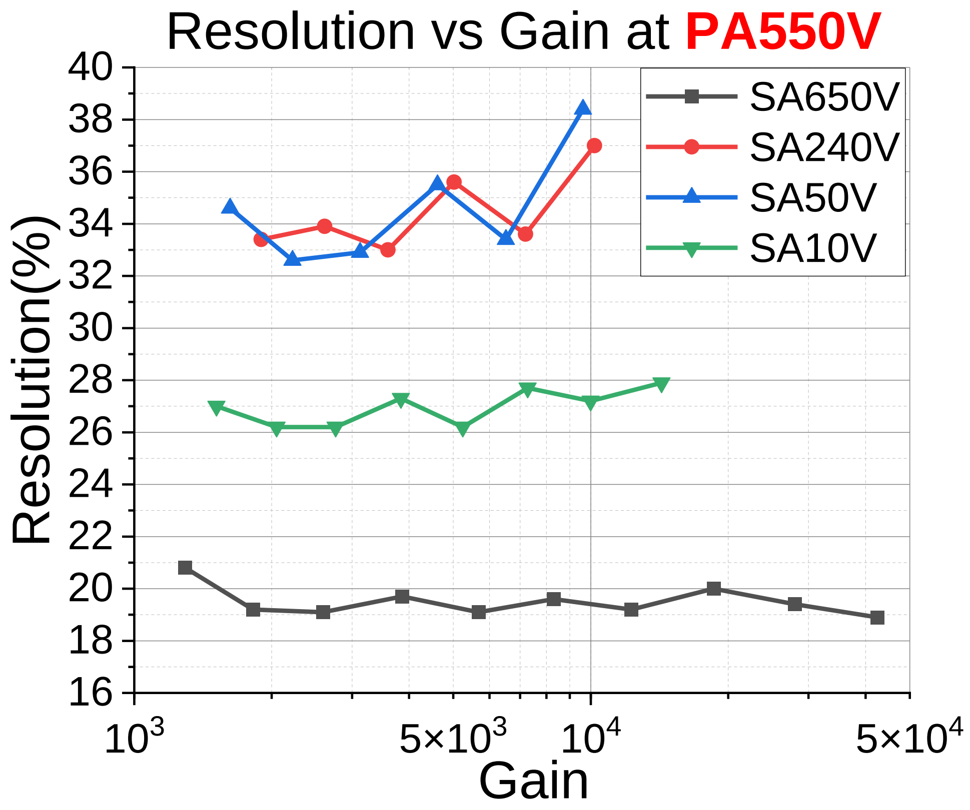


IBF×Gain vs SA Voltage



Energy resolution of TMM2





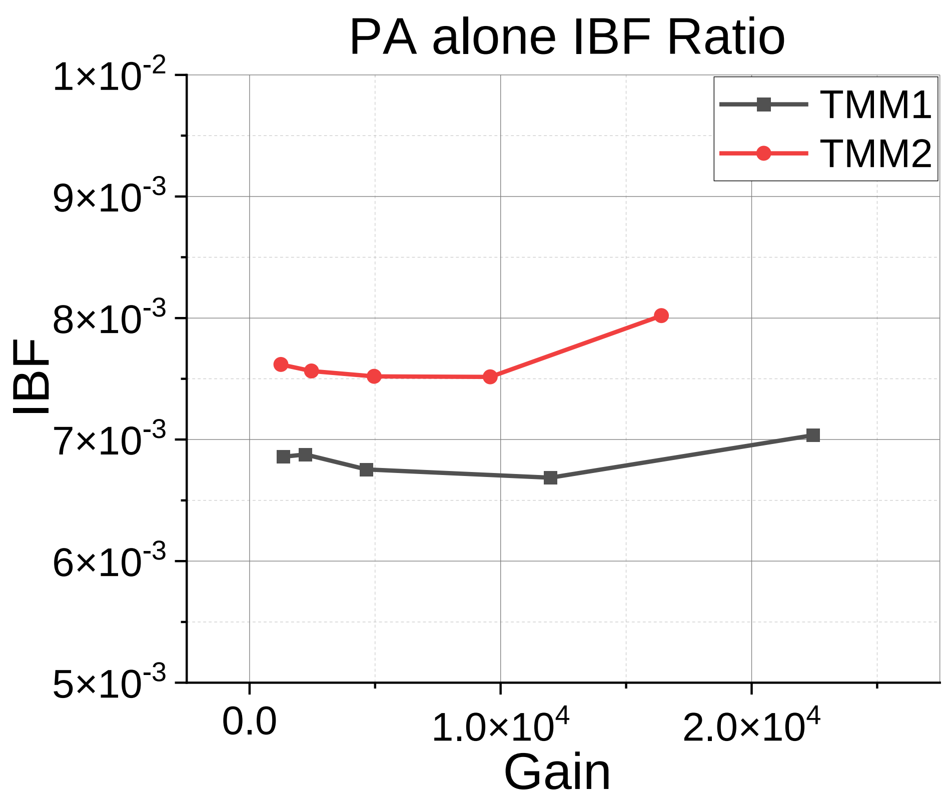
Good energy resolution can be obtained with appropriate voltage

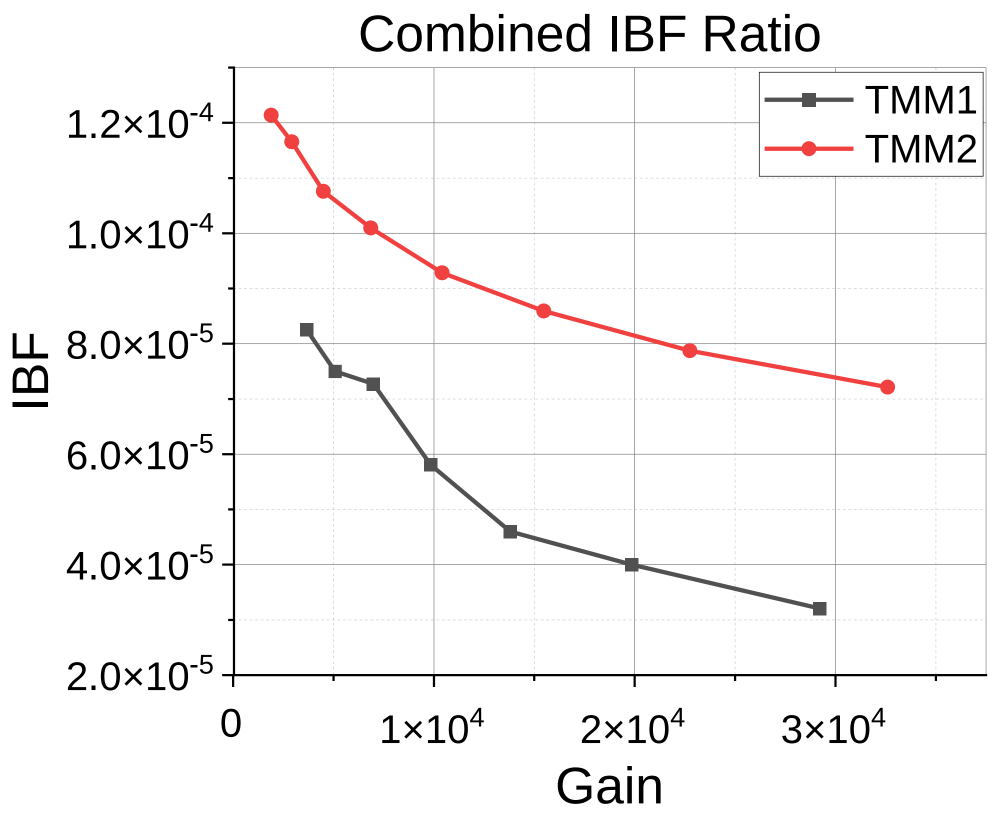
- Higher PA voltage
- High or very low SA voltage

Effect on IBF

- PA mesh of different LPI and OR may affect the IBF ratio
  - ➢ LPI of TMM2 PA mesh is lower
- ✓ Higher LPI and higher OR are preferred

Detector	PA mesh
TMM1	650(40%)
TMM2	500(50%)

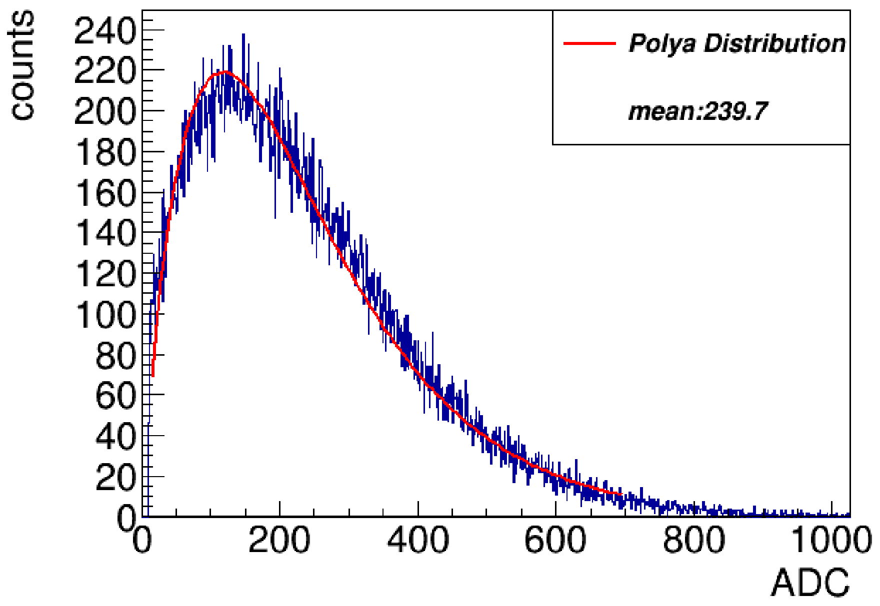




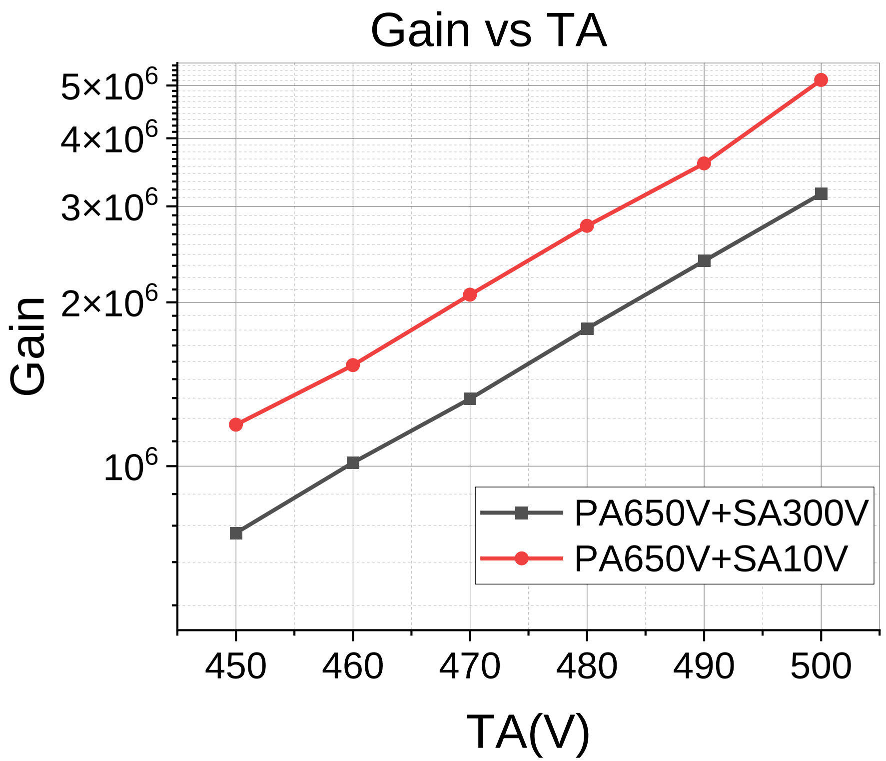
Single Photon-Electron Response

- TMM3, Quartz coated with aluminum layer as photocathode
- Tested in COMPASS gas: Ne (80%), CF_4 (10%) and C_2H_6 (10%)
- Gas gain can reach up to 5×10^6 for single electron

Detector	PA mesh
TMM1	650(40%)
TMM3	500(50%)



Avalanche charge distribution
for single photon-electron



Summary

- Developed a TMM detector featuring ultra-low IBF based on DMM
- Demonstrated the performance of TMM protype
  - Gain: 7×10^4 for 5.9 keV X-ray and 5×10^6 for single photon-electron
  - IBF ratio: down to 3×10^{-5}
- Optimized for electron collection
  - ✓ Higher LPI and Higher Opening Rate mesh are preferred
- Promising for gaseous photon detectors sensitive to visible light
  - Gas-PMT based on TMM now under developing!

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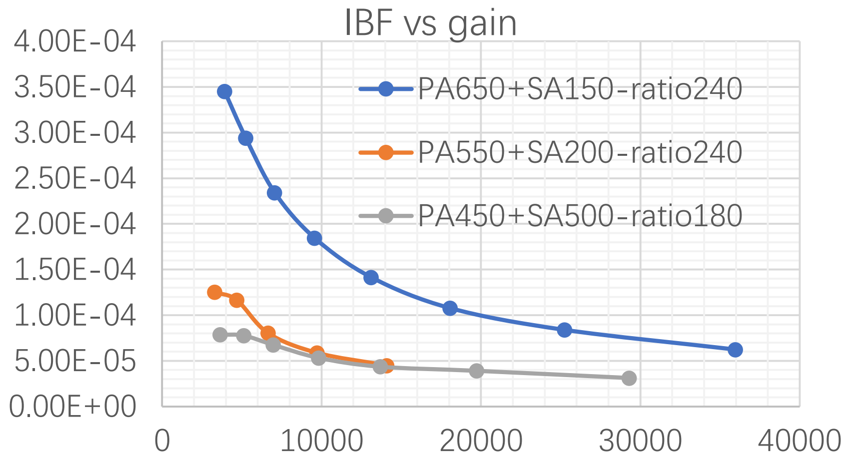
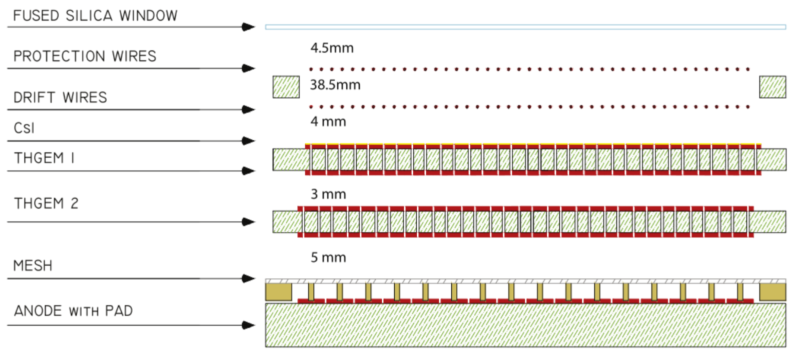
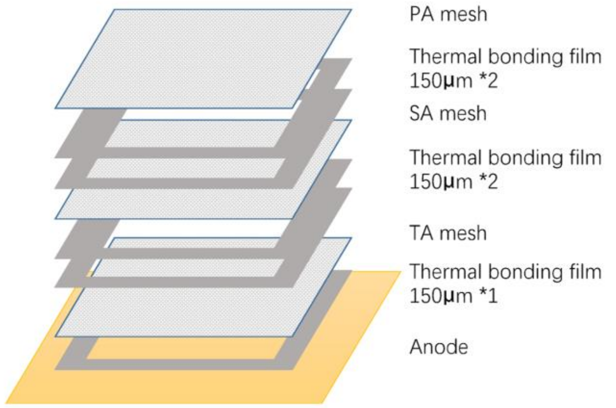
Thanks for Listening!

backup

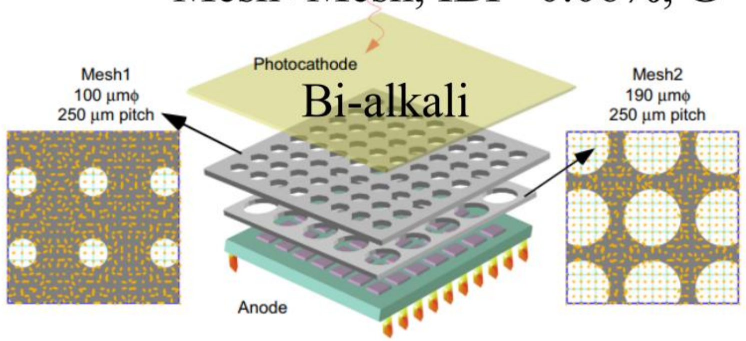




GPD on COMPASS RICH-1



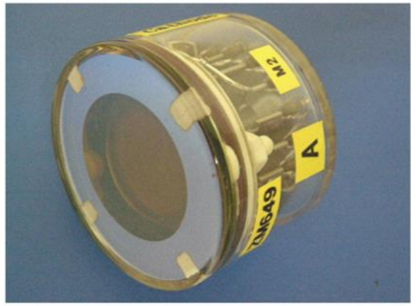
Gas-PMT THGEM-like+MM, IBF~1%
Mesh+Mesh, IBF~0.06%, G~10^4



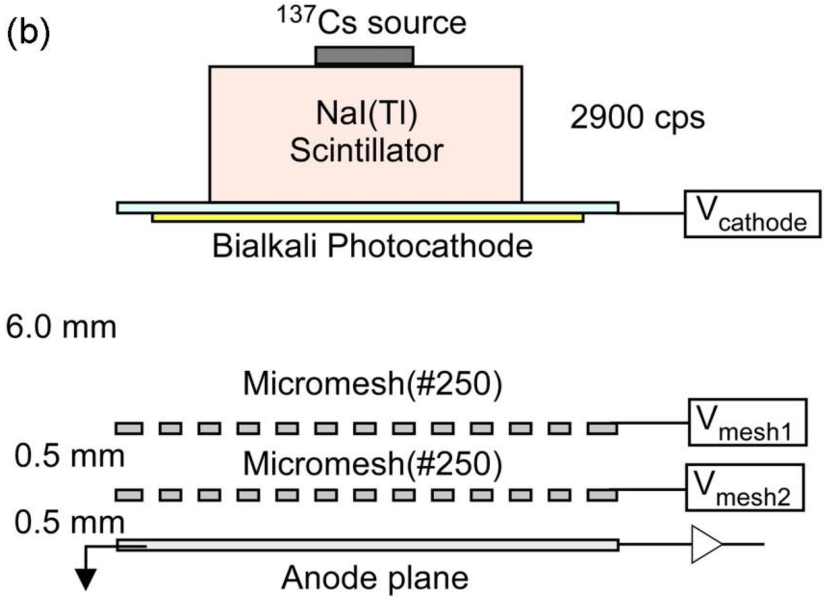
F. Tokanai et al. , NIM A 766 (2014) 176–179

Backup

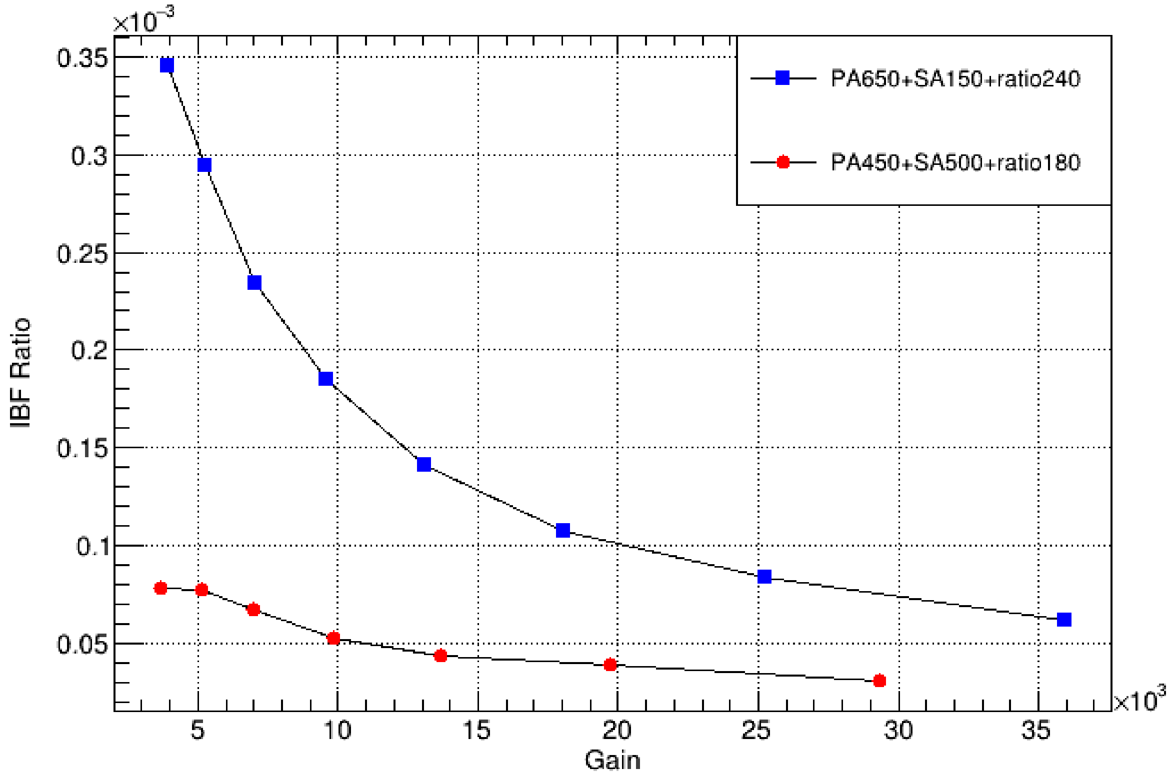
(a)



(b)



^{137}Cs source
NaI(Tl) Scintillator
2900 cps
V cathode
Bialkali Photocathode
6.0 mm
Micromesh(#250)
V mesh1
0.5 mm
Micromesh(#250)
V mesh2
0.5 mm
Anode plane



×10^{-3}
0.35
0.3
0.25
0.2
0.15
0.1
0.05
IBF Ratio
PA650+SA150+ratio240
PA450+SA500+ratio180
5
10
15
20
25
30
35
×10^{3}
Gain

IBF Measurement with Laser

Laser： Max 400Hz 213nm → attenuators → TMM → Picoammeter

$$\mathrm{Gain} = \frac{\mathrm{I_{anode}}}{\mathrm{I_{primary}}}, \qquad \mathrm{IBF} = \frac{\mathrm{I_{drift}} - \mathrm{I_{primary}}}{\mathrm{I_{anode}}}$$

- $\mathrm{I_{primary}}$(~pA): cathode current induced by photon-electrons without avalanche
- Higher IBF($\sim 1.5 \times 10^{-4}$) was measured in the COMPASS gas
  - ➢ Smaller horizontal diffusion of Ne may explain

✓ Working gas of g-PMT needs further research