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A high-gain, low ion-backflow double micro-mesh gaseous structure for single electron detection

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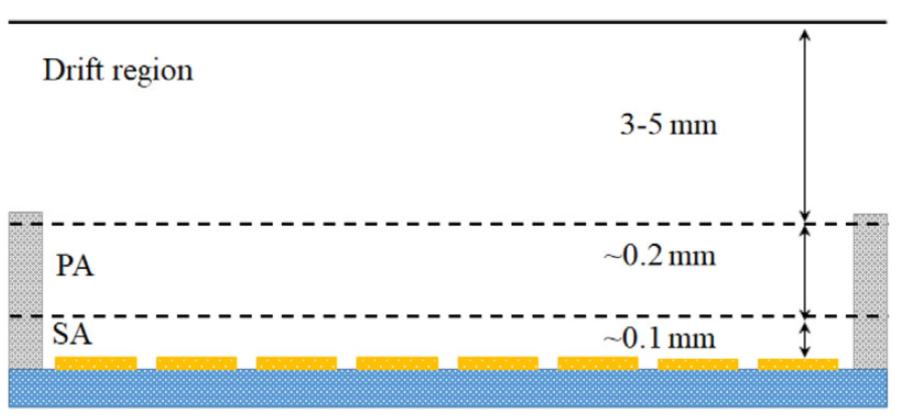
Introduction

Gaseous photon detectors provide the most cost-effective solution to large-area and position-sensitive photon detection. They have enabled application of the Ring Imaging CHerenkov detector (RICH) technology to large-scale experiments. The emergence and rapid development of micro-pattern gaseous detectors (MPGD) has been boosting the development of gaseous photon detectors. The advantages of photon detectors based on MPGDs include low cost, low ion-backflow (IBF), high spatial and time resolution, and great tolerance of magnetic field. However, the typical gain of gaseous photon detectors is ~10^4, two orders of magnitude lower than regular vacuum photomultiplier tubes. And IBF remains a big challenge for application of gaseous photon detectors at high-rate experiments. Exploring a high-gain MPGD structure with low IBF has therefore become an important area of MPGD R&D.

We present a study of a **double micro-mesh structure (DMM)** which has the potential to fulfill both the high-gain and low IBF requirements to be an excellent gaseous detector option in photon detection.

The DMM gaseous structure

DMM is a mesh-type MPGD in which another mesh is added on top of a typical Micromegas structure.



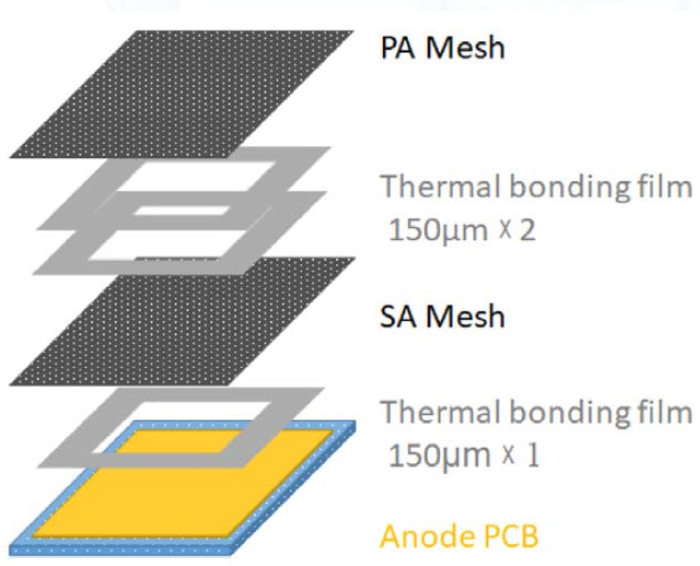
Cascading avalanche amplification in two regions

- PA: pre-amplification
- SA: secondary amplification

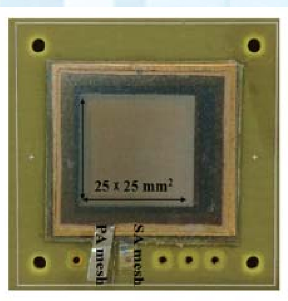
→ Double cascading avalanche gaps ensure a very high gain for a single electron and, with the proper configuration of electric field, a low IBF ratio. Advantages from the typical Micromegas in terms of high rate capability, good time resolution, and excellent spatial resolution are all inherited.

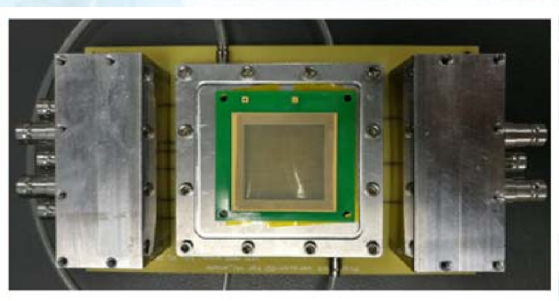
Design and fabrication of a DMM prototype

A DMM prototype was designed for fabrication with a thermal bonding technique, a very lab friendly method to fabricate Micromegas-like structures.



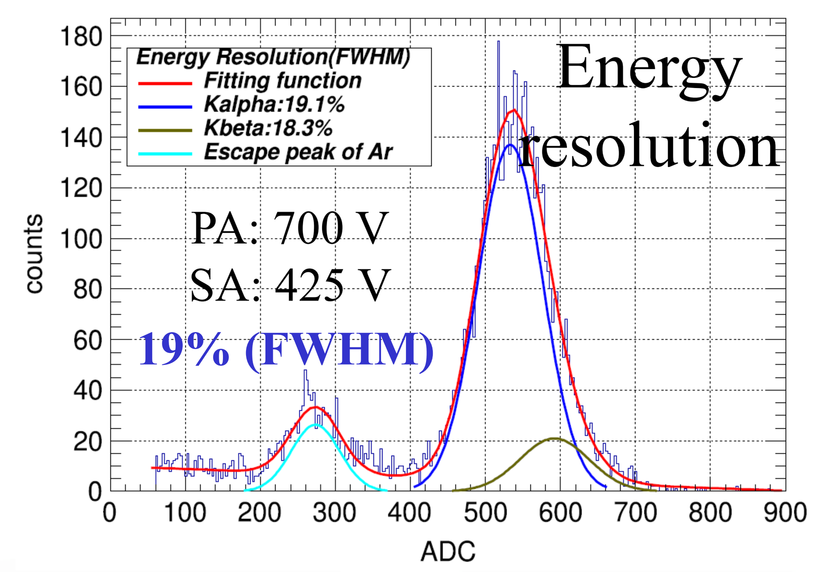
- SA and PA gas gaps were defined by one and two layers of thermal bonding films (120 μm thick each), respectively.
- Stainless steel mesh (500 LPI , 27 um thick, 40% opening rate) was used and stretched at ~20 N/cm.
- Active area: 25 mm × 25 mm

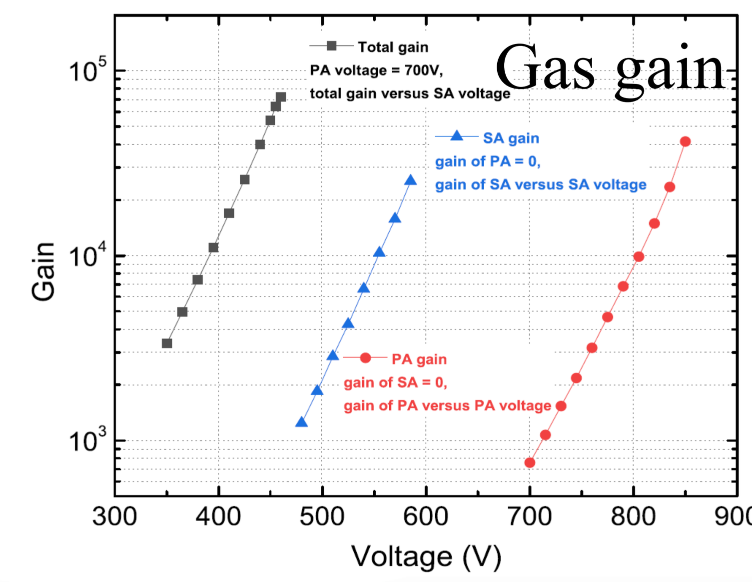


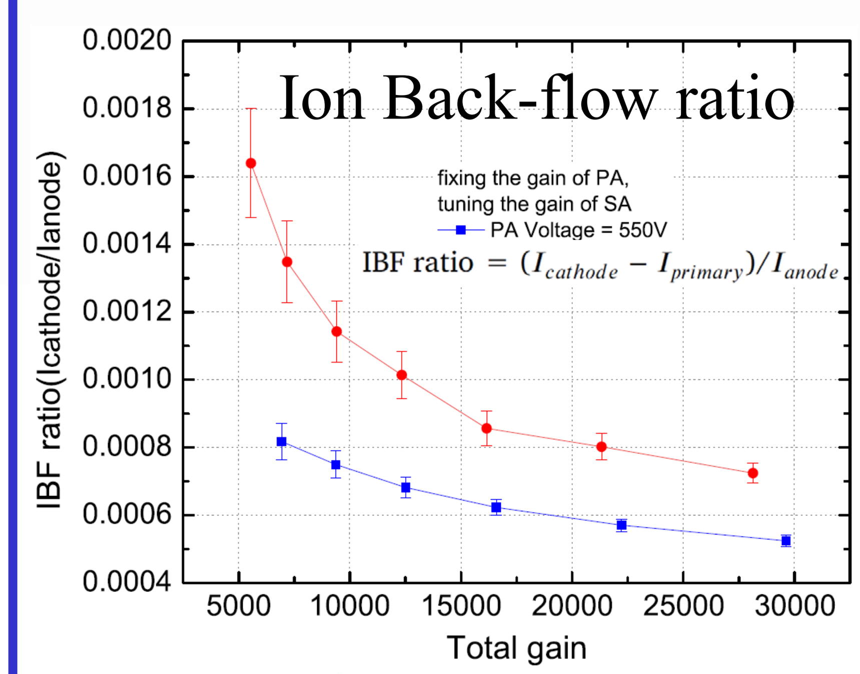


Characterization and Performance of DMM

Test with Fe^{55}, Ar(93%)+CO_2(7%), 5.9 KeV X-rays

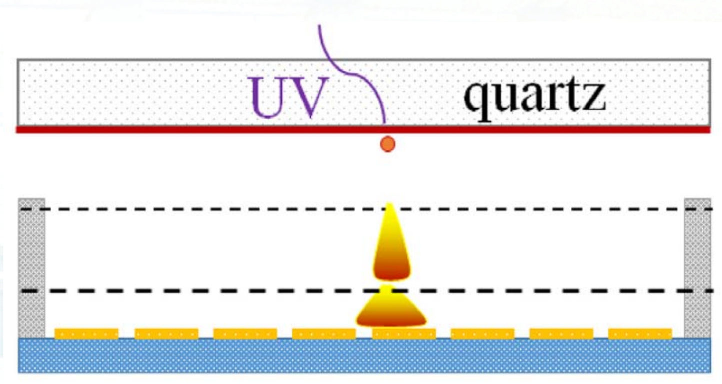




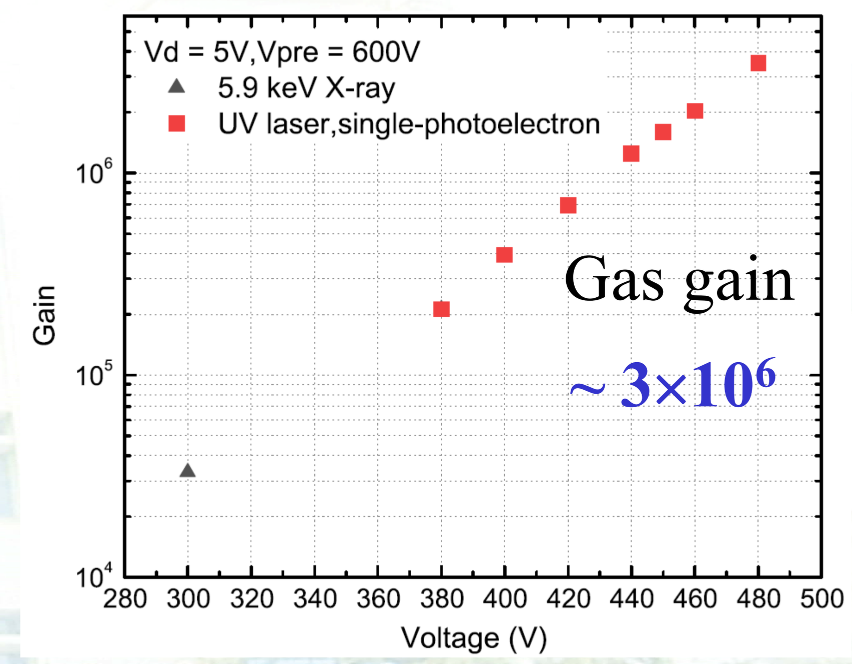


- PA and SA gains can both reach > 10^4 individually. Total gain can reach up to 7×10^4 .
- **IBF ratio ~ 0.0005** at PA of 550V and total gain of ~3 ×10^4
- A lower PA/SA E field ratio leads to a lower IBF at the same total gain.

Single electron response, Ne(80%)+CF_4(10%)+C_2H_6(10%)



Detector configuration for single electron response test with UV laser light. Quartz window coated with Al serving as photo-cathode.



Gas gain for single electrons was scanned by varying SA voltage while fixing PA voltage. Total gain can be maintained at up to 3× 10^6

Conclusions: The features of **high gain of >10^6** and **low IBF ratio of ~0.0005** revealed for the DMM structure present its great potential for photon detection as well as other applications requiring low IBF ratio, for instance, the readout of time projection chambers for future collider experiments. The IBF ratio of the DMM could be further lowered by fine tuning its operation parameters.

Reference: Nuclear Instrument and Methods in Physics Research, A 889 (2018) 78–82

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