STUDY ON THE DOUBLE MICRO-MESHES (DMM) GASEOUS STRUCTURE AS A PHOTON DETECTOR

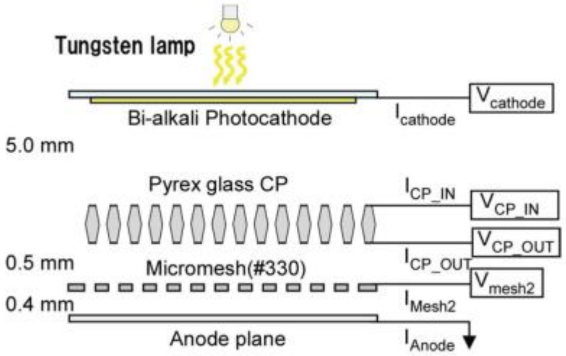
Ming SHAO
On behalf of the USTC MPGD group
State Key Laboratory of Particle Detection and Electronics, China
University of Science and Technology of China, Hefei 230026, China

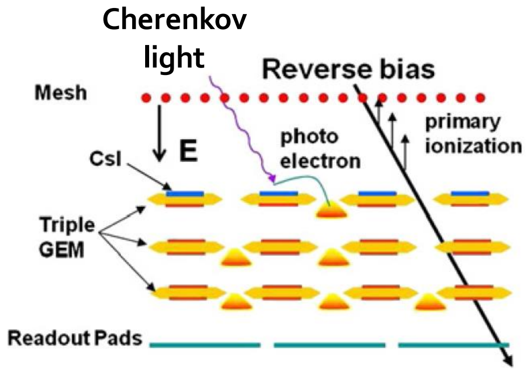
Outline

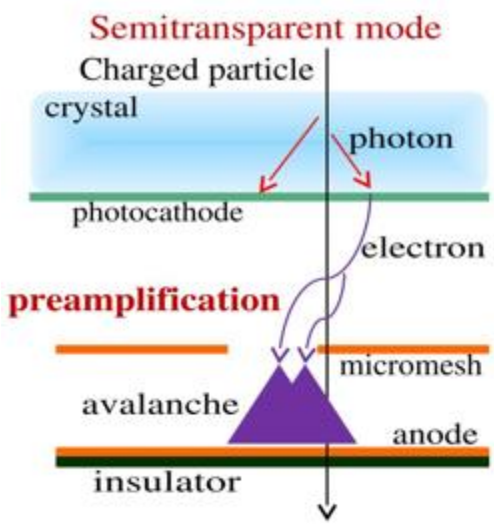
- Motivation
- Design and fabrication
- Performance study
  - Gain etc.
  - IBF
- Summary and Outlook

Motivation

Gaseous photomultiplier (GPM) using micro-pattern gas detectors (MPGDs) sensitive to visible to UV light are widely studied due to its potential advantages, such as large effective area, high spatial and timing resolution, high magnetic field resistant capability etc.



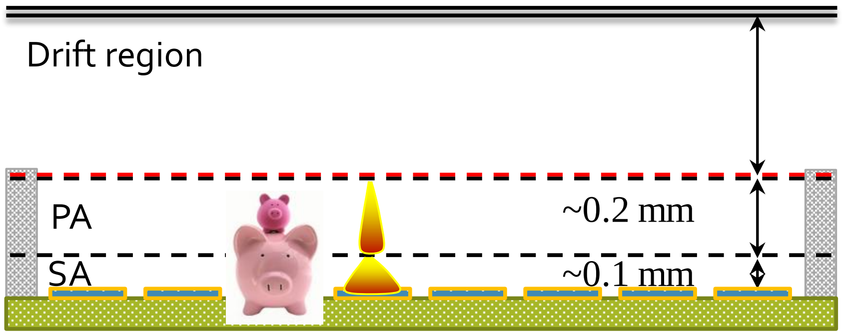




Our aim:

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

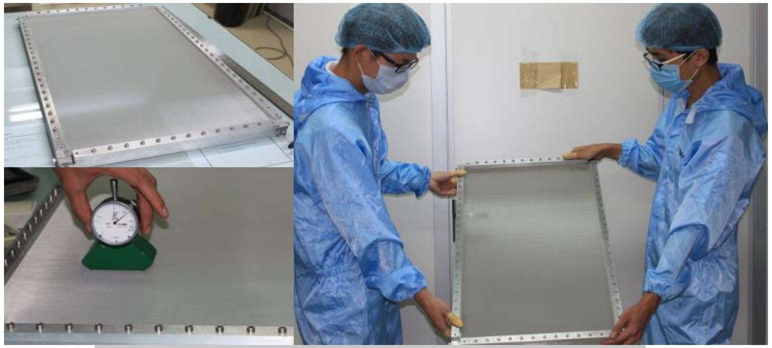
Design of the DMM



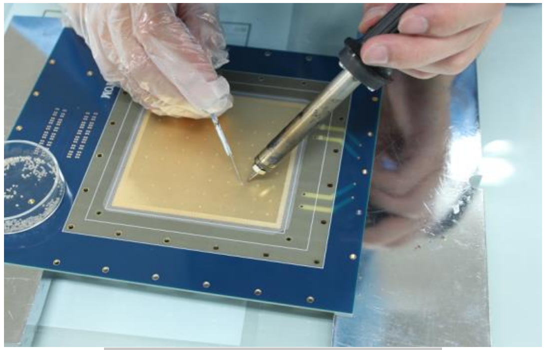
"Piggyback" structure

- Stacked two micro-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.

Thermal bonding processing for DMM

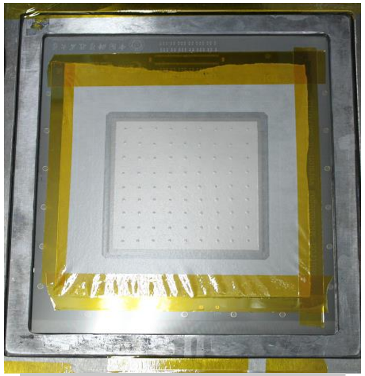


Mesh stretching ~20N/cm

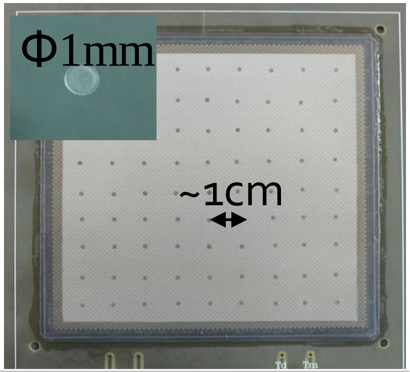


Setting spacers

Thermal bonding



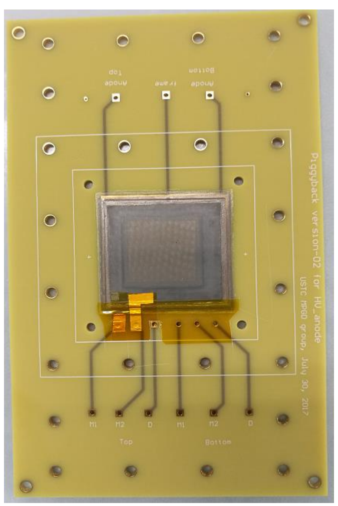
Finished view

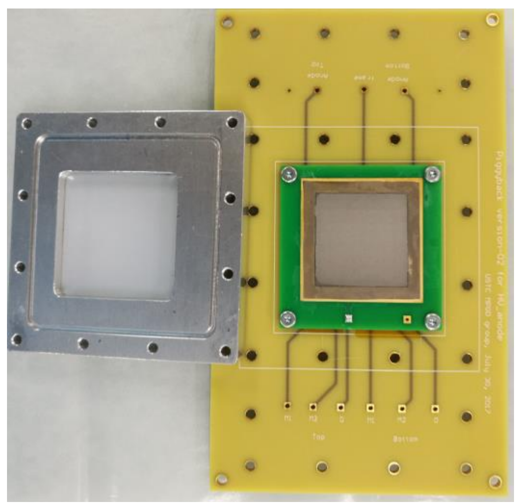


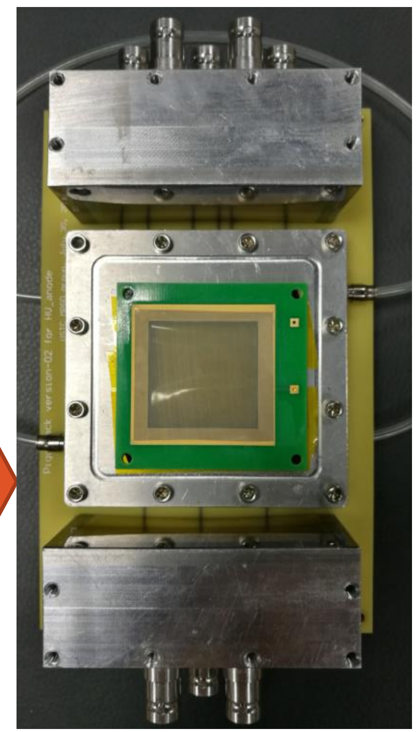
Cutting the meshes

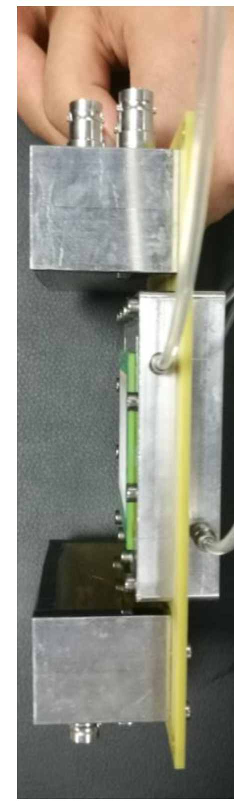
Prototype for this study

- 2 cm x 2 cm active area
- Distance of two meshes: ~240um
- Mesh to anode: ~120um
- 3mm drift region









Performance study

- Test with x-rays (^{55}Fe source)

➔electron transparency versus electric field, energy resolution, gas gain;

➔Ion back-flow (IBF) fraction;

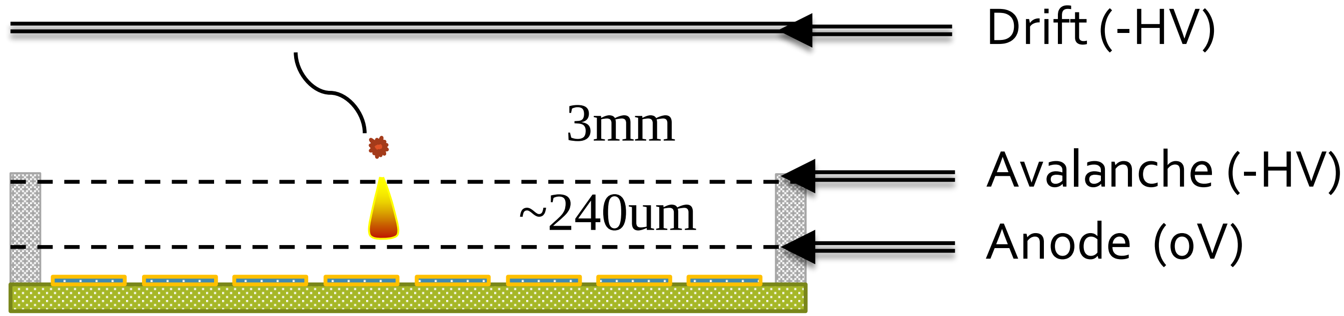
- Laser test

➔single photoelectron response

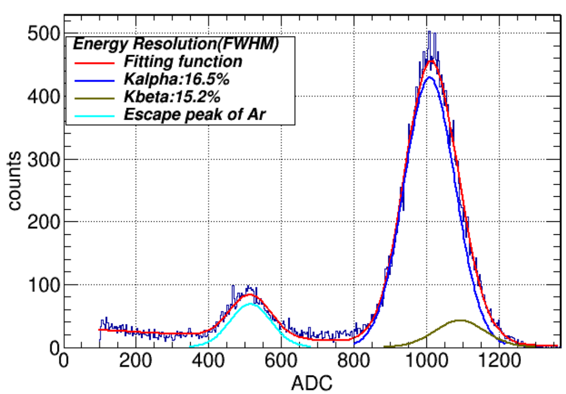
➔high gain for single p.e.

Pre-amplification (PA)

Operating as a typical MM individually for PA and SA regions

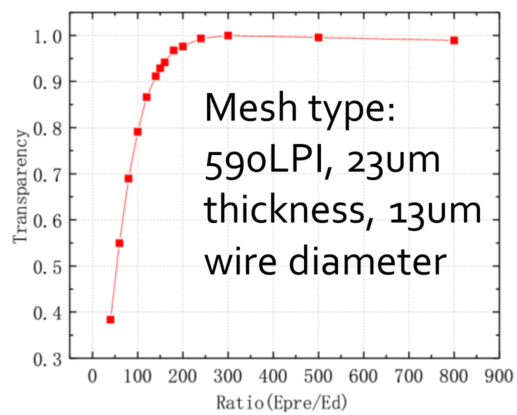


Energy spectrum of ^{55}Fe x-rays

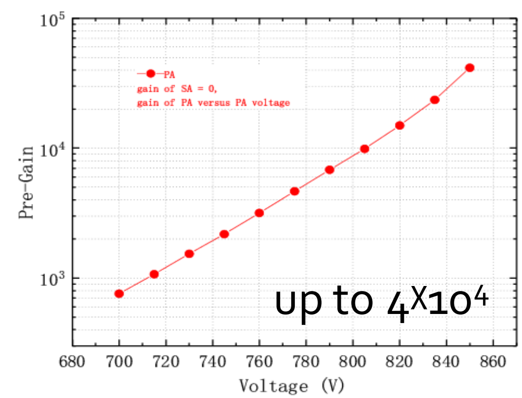


Gas mixture Ar(93):Co_2(7)

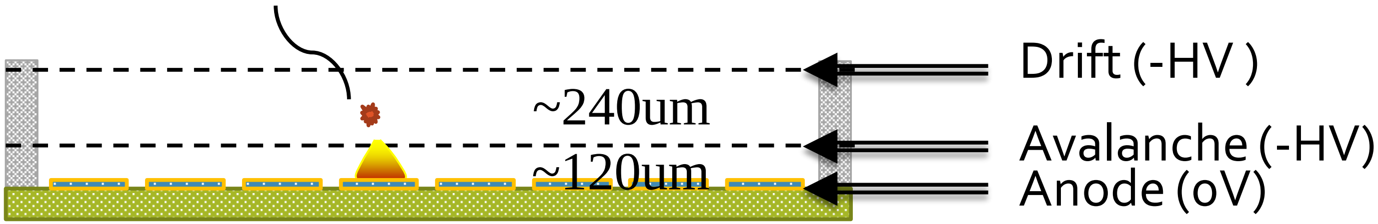
Transparency versus E_{PA}/E_D



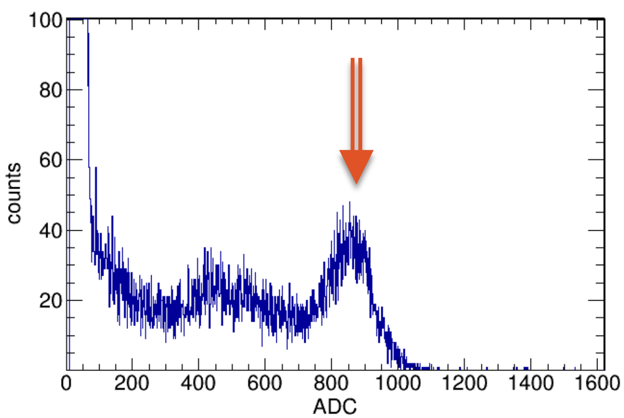
Gain VS avalanche voltages



Sec-amplification (SA)



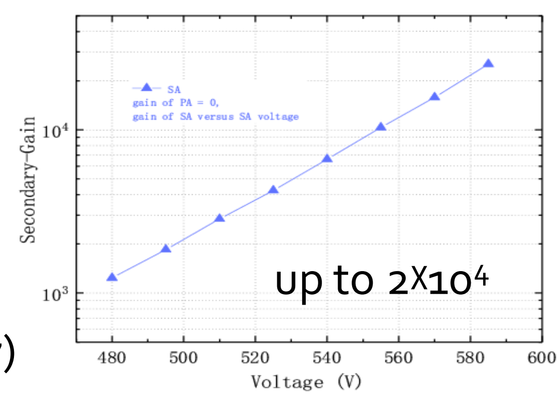
Full energy peak due to the lateral angle
photoelectrons and Auger electrons



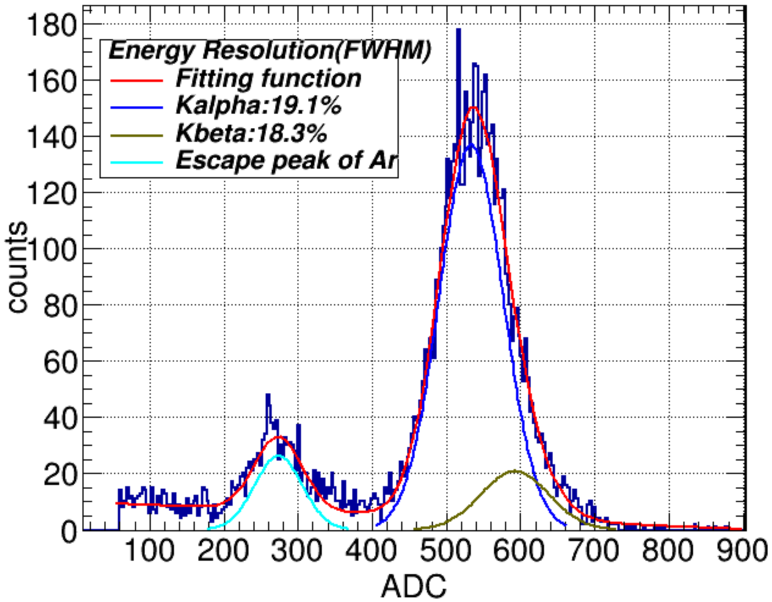
The transparency should be similar to PA's, since their have the same mesh type.

Gas mixture Ar(93):Co_2(7)

Gain VS avalanche voltages

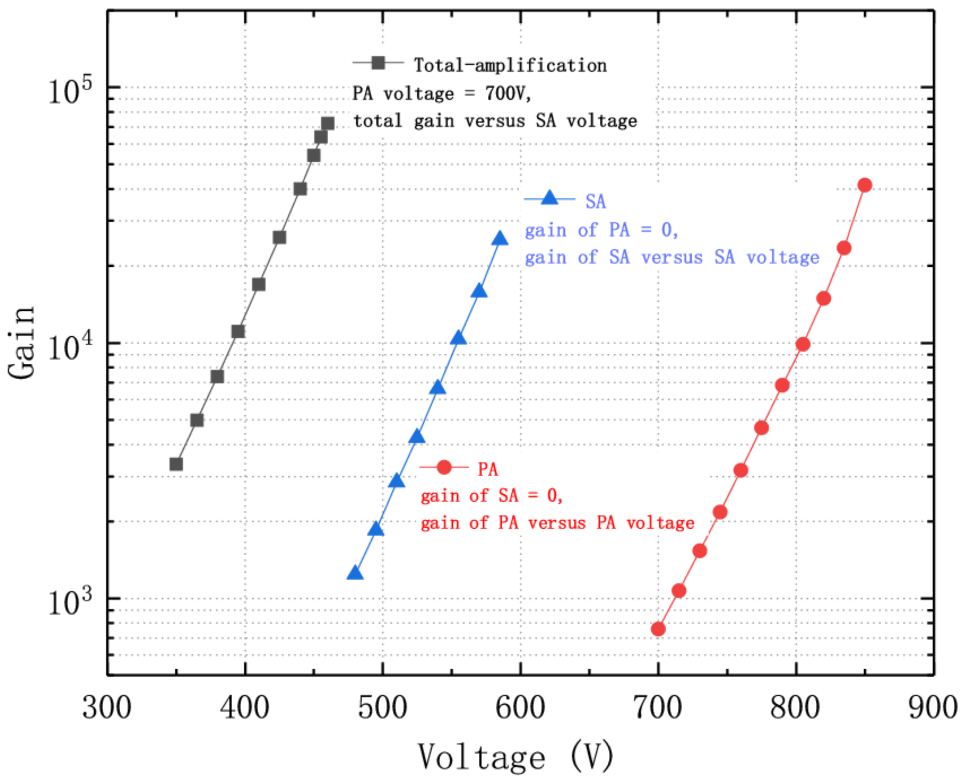


PA+SA test



energy spectrum of ^{55}Fe x-rays at ~30000 gas gain

Gas mixture Ar(93):Co_2(7)

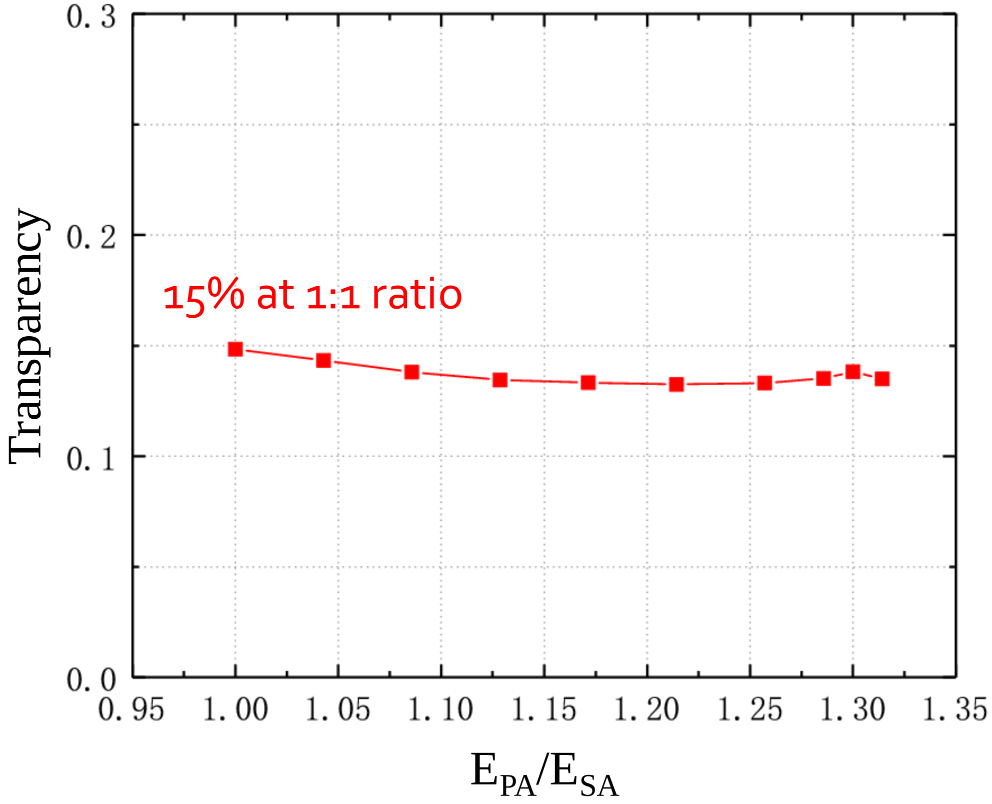


Gas gain up to ~7x10^4

↳ ~10^7 electrons in the SA region

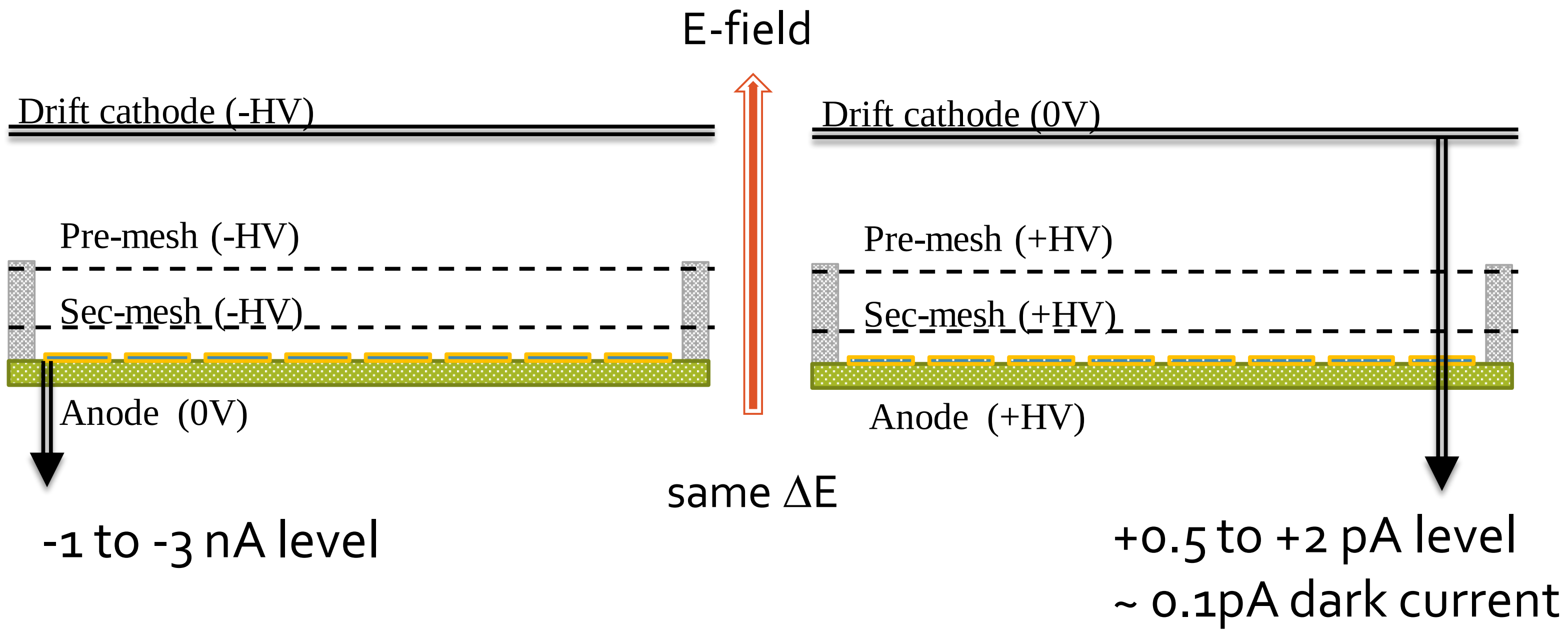
Electron transparency: PA→SA

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



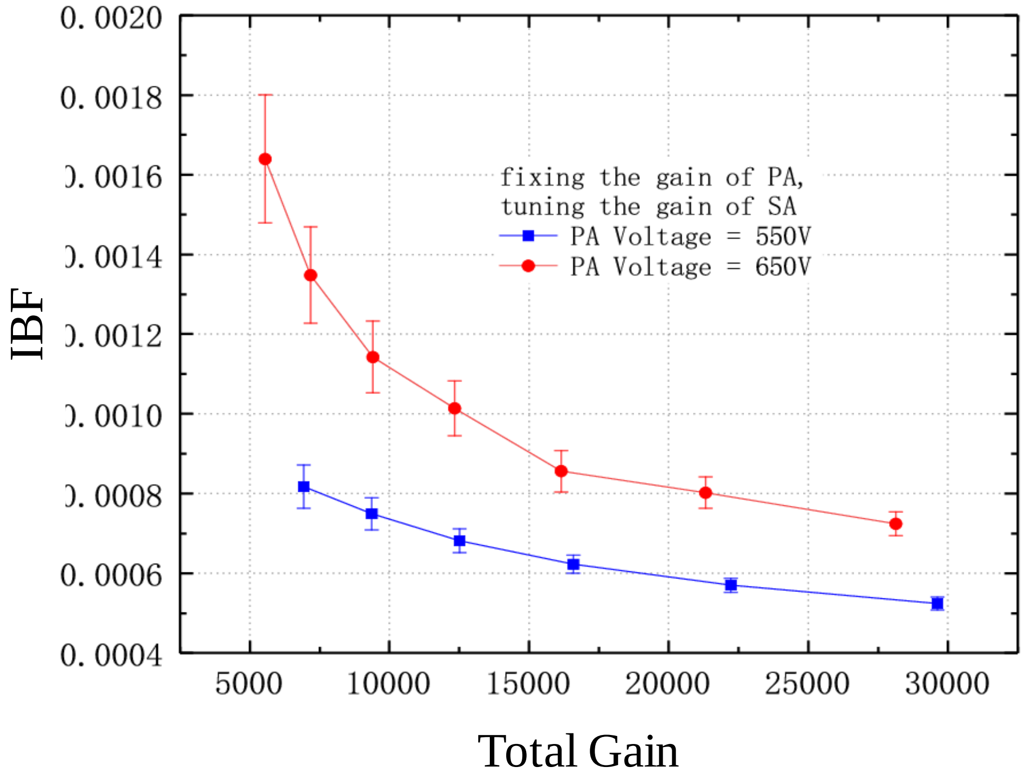
IBF test strategy

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



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

IBF test results

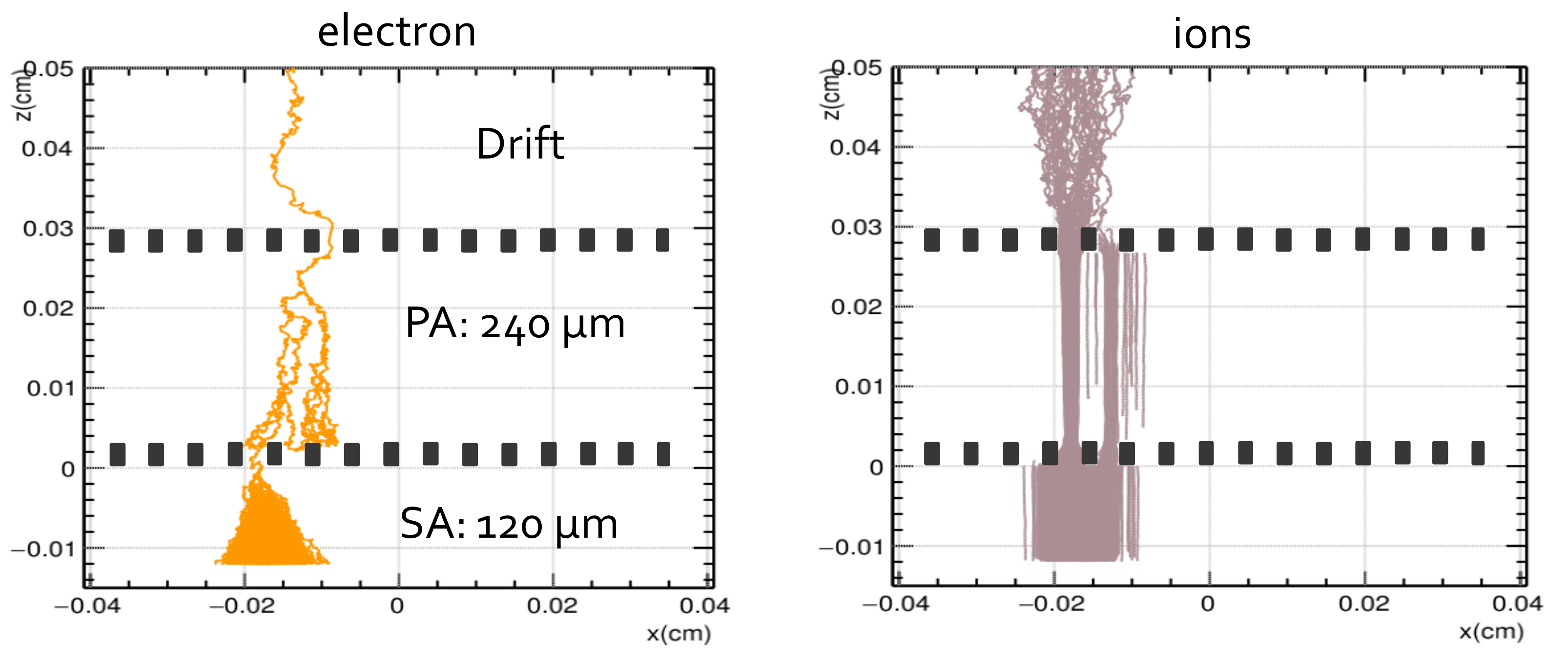


lower E_{PA}/E_{SA} ratio → lower IBF (same total gain)
Practically E_{PA} is not so low: $I_{cathode}$>1 pA , a magnitude higher than the ~ 0.1pA pedestal current

Further suppression of IBF

The IBF of DMM seriously depends on the geometric alignment of the double mesh

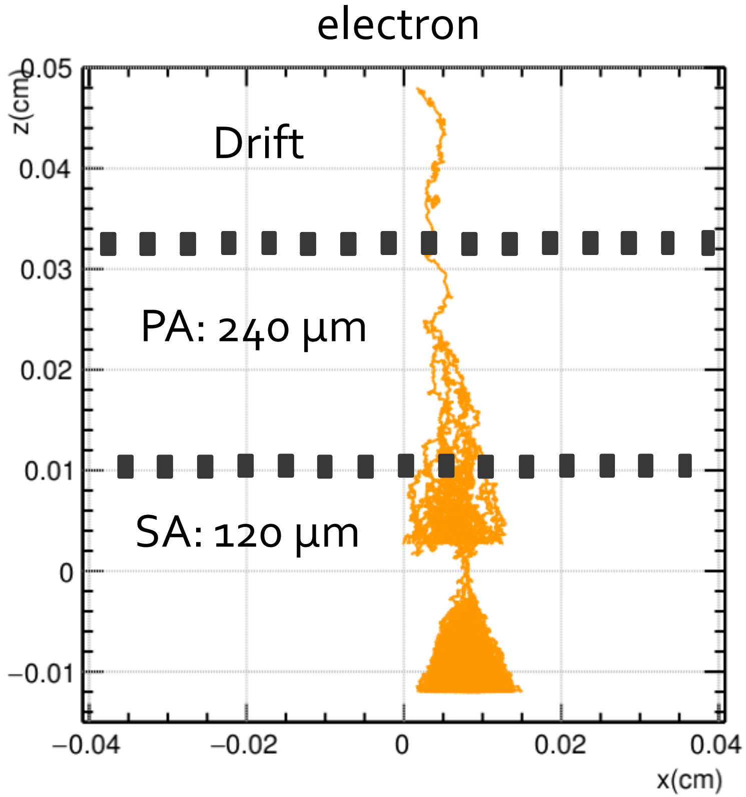
Garfield++ simulation

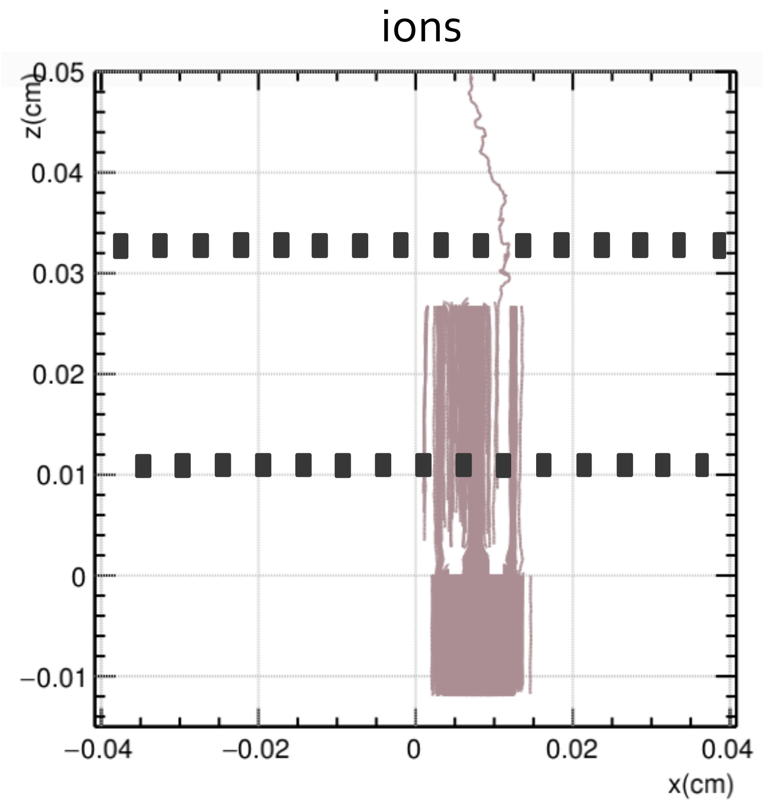


mesh holes strictly aligned

Further suppression on IBF - II

Mesh holes interlaced (stagger aligned)
➔IBF from SA significantly suppressed by the up-mesh





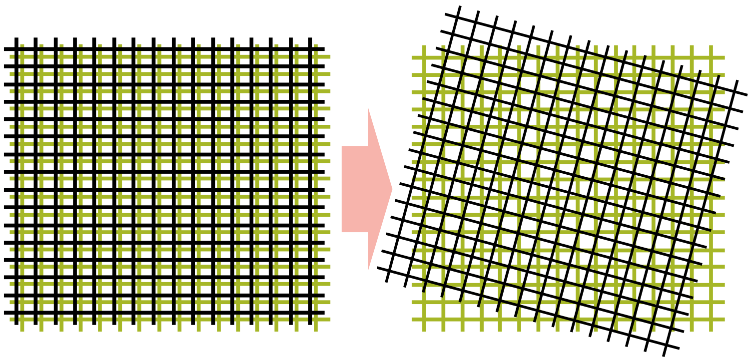
Garfield++ simulation

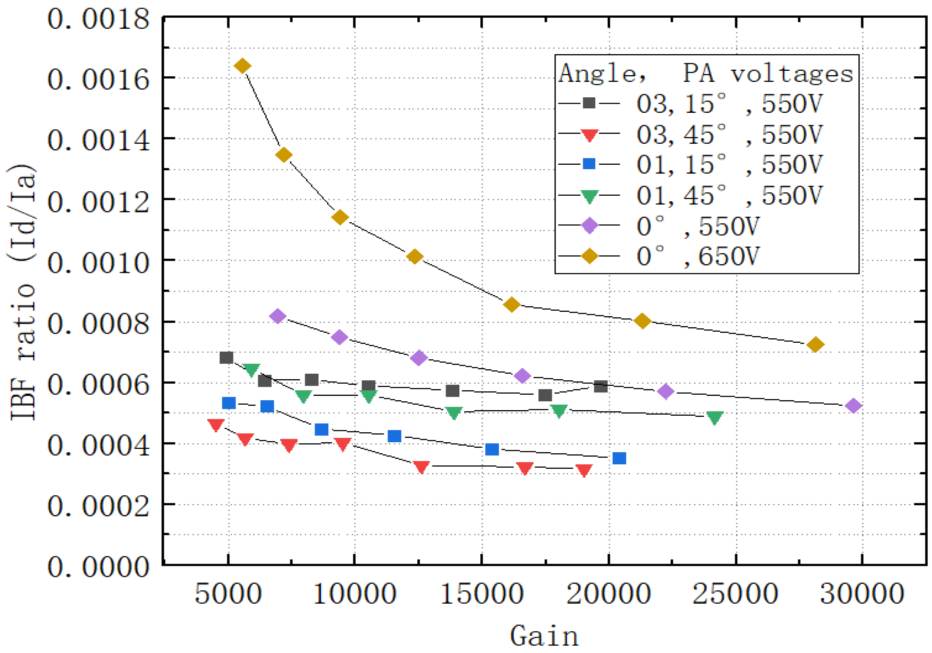
Further suppression on IBF - test

According to MC, the IBF of the DMM depends on:

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

A simple attempt is to tilt an angle between the meshes

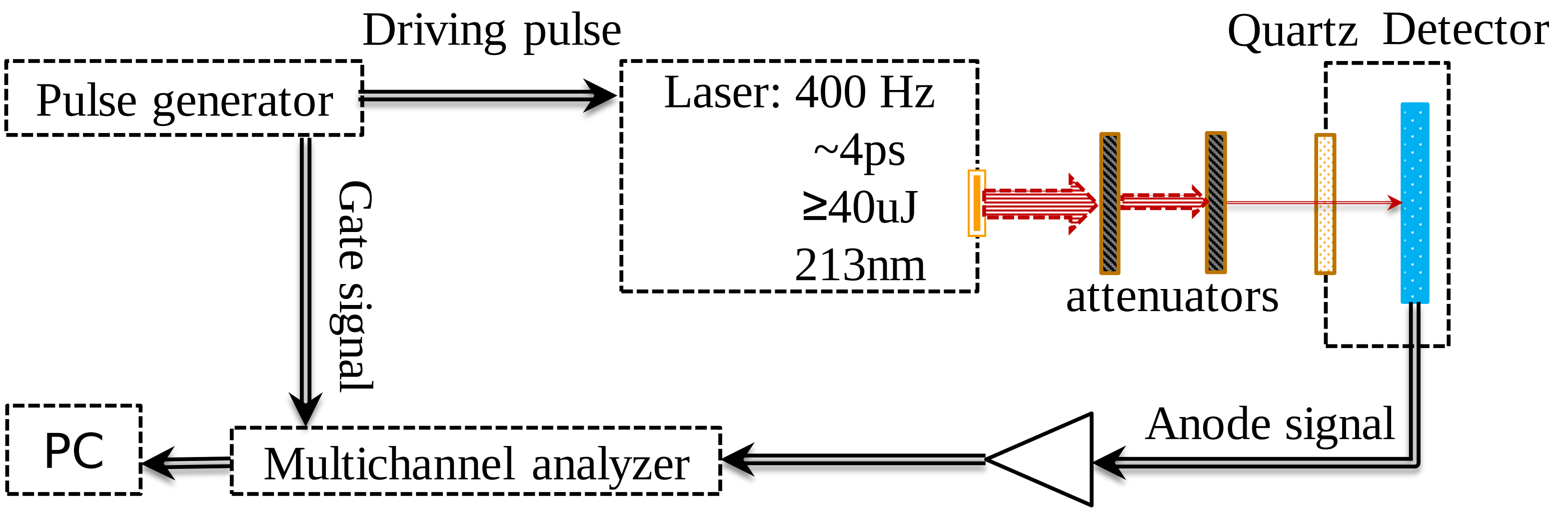




Further study ongoing

Laser test

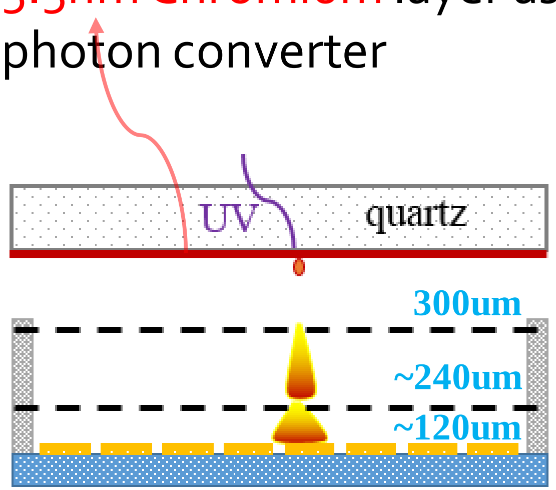
Schematic drawing of the laser test setup



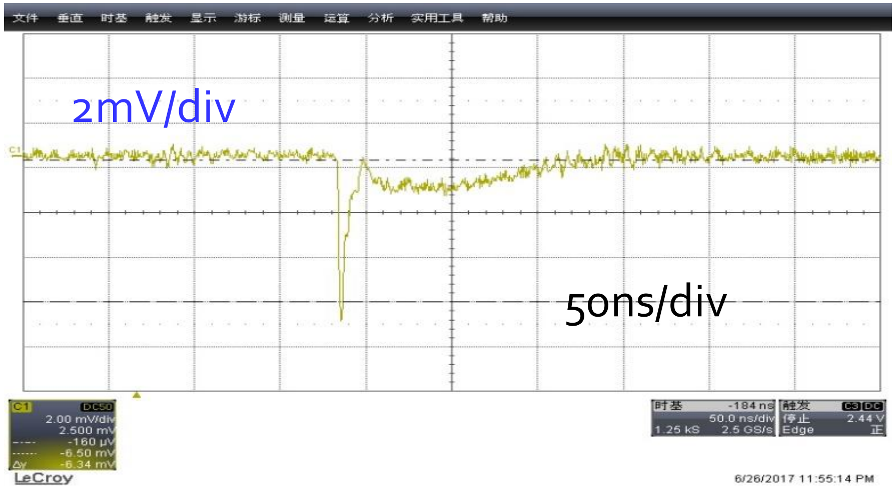
Detector setup and signals

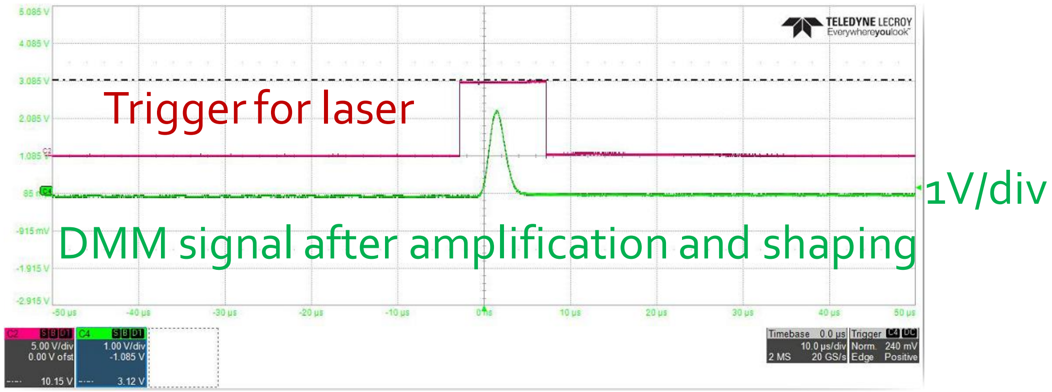
Gas mixture
Ar(80):CF_4(10):C_2H_6(10)

5.5nm Chromium layer as photon converter



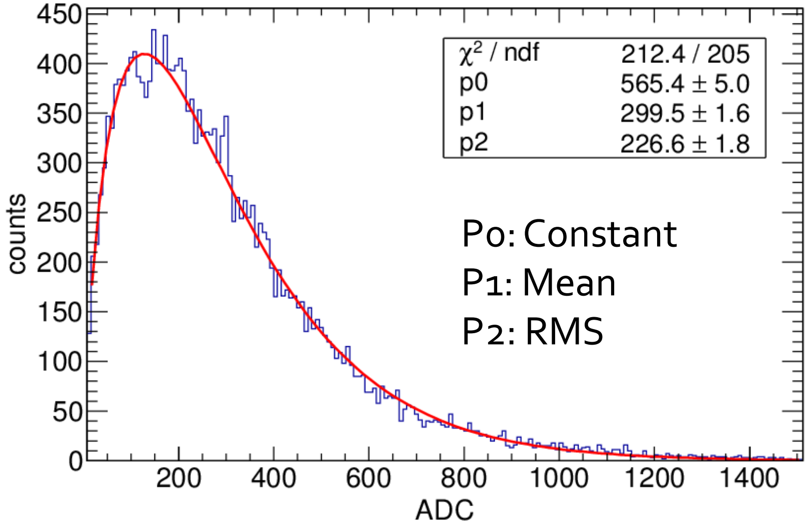
A typical anode signal, w/o amplifier, 50Ω





To extract single electron

A single electron spectrum fitted with a "Polya" distribution

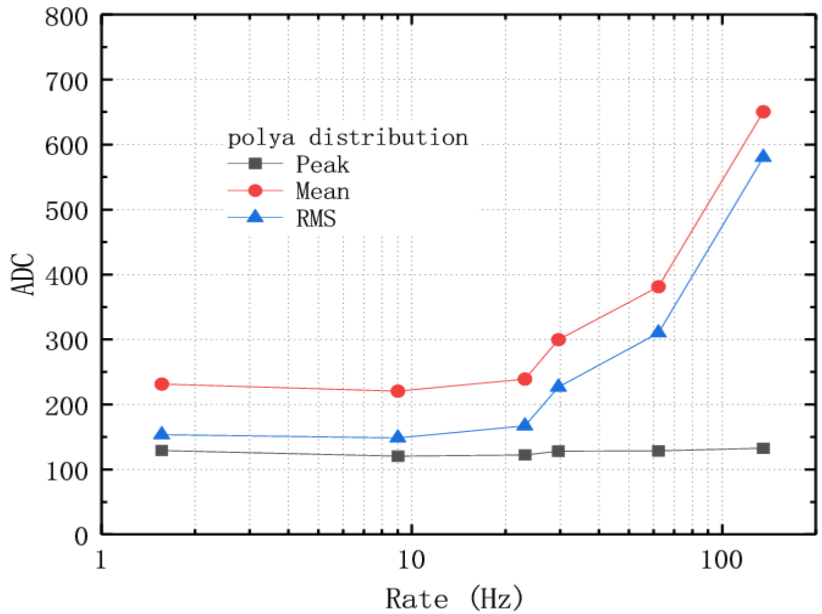


P0: Constant

P1: Mean

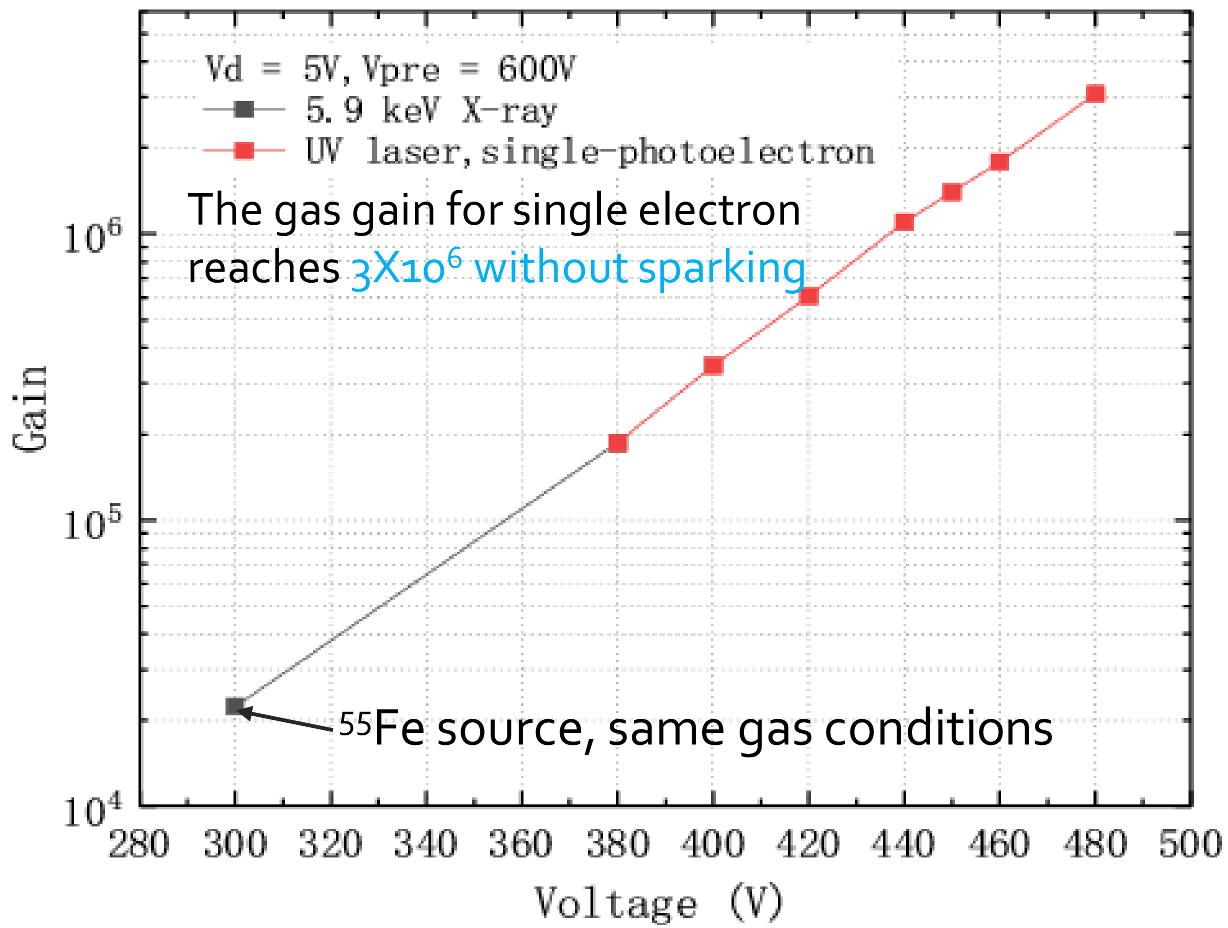
P2: RMS

Gas gain ~1.2X10^6



Laser operated at 400 Hz

Gas gain for single electron

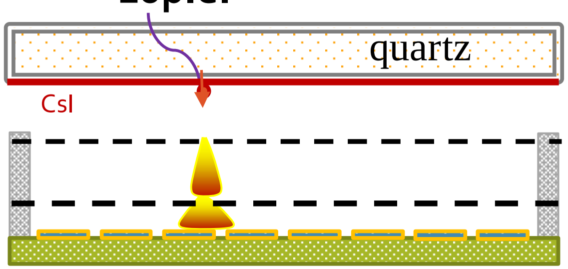


At beam test

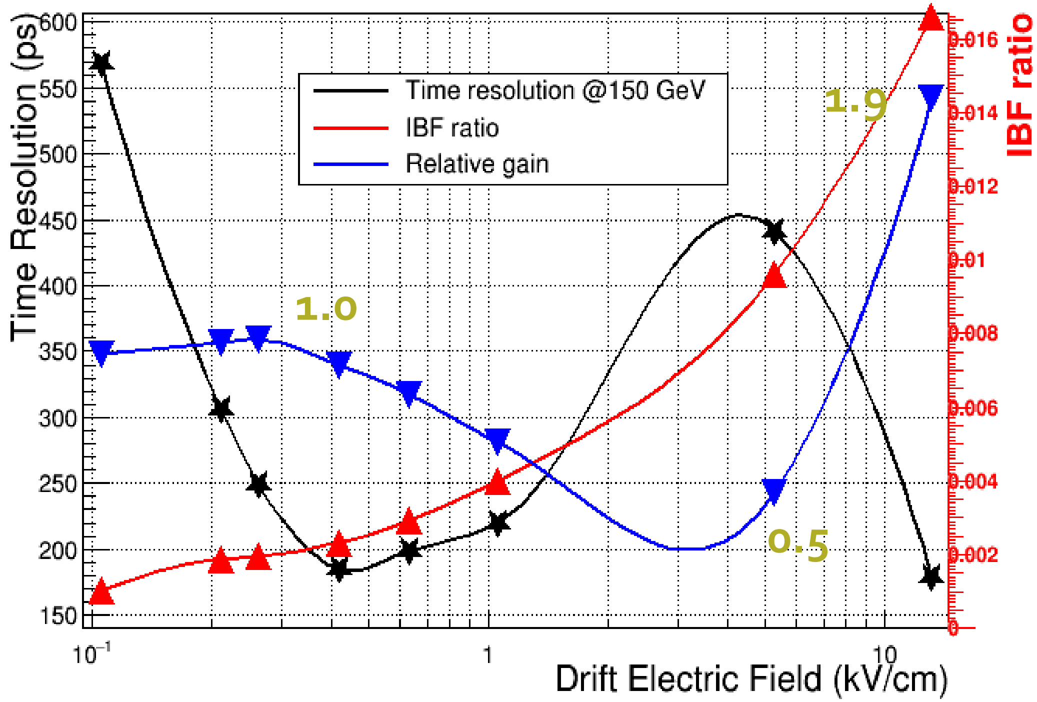
- Structure: 190μm (drift)-120μm (PA) -120μm (SA)
- Voltages of PA and SA were fixed to 425V and 360V

Test at CERN, 150GeV/c muon beam

Cherenkov light
~10p.e.



with the PICOSEC collaboration



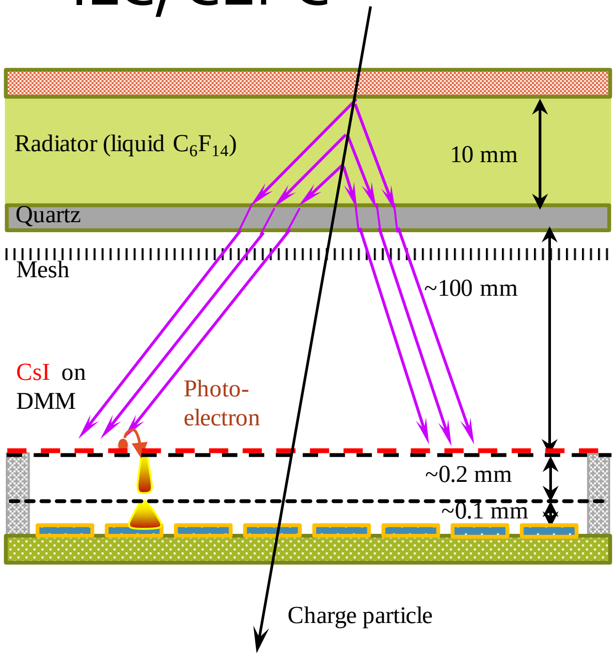
- Time resolution reaches 180 ps (can be further improved by narrowing the drift gap) at a IBF fraction of 0.2%

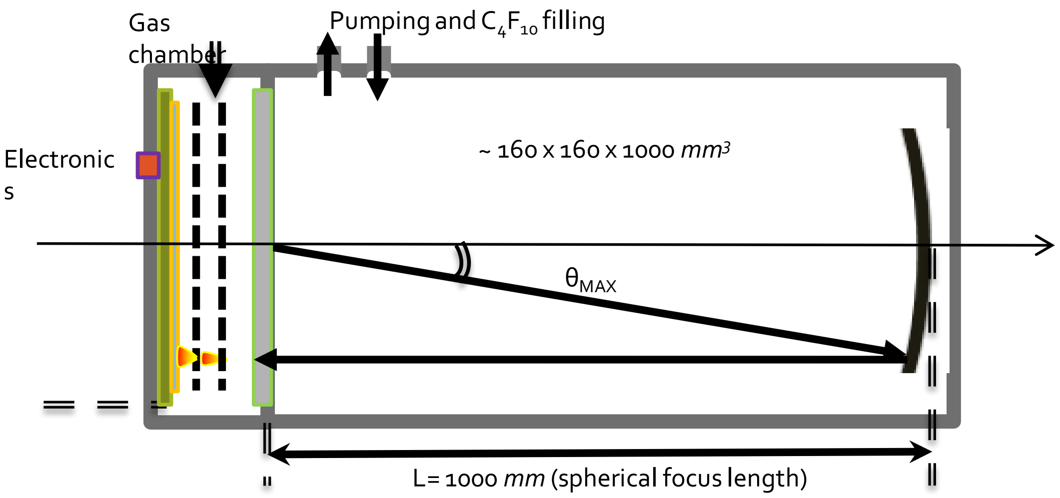
Summary

- A new DMM detector was designed and fabricated, the good performances indicate its potential power for Gas-PM application
- Very low Ion-backflow ratio ~ 0.0004 was obtained at a low pre-amp & high sec-amp mode: high E_{SA}/E_{PA} ratio is helpful to suppress the IBF
- Achieved high gain above 10^6 for single electron, comparable with the normal vacuum PMTs
- Further improvements are being studied

Outlook

- DMM based RICH detectors are under R&D for the the Super 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





Thank you for your attention!