R&D for Fast Timing Detector based on Micromegas

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on behalf of Picosec-MM Collaboration

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Picosec Collaboration

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- **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, S. White[2].
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Outline

- **Motivation**
- **Picosec-MM Based on Single Mesh**
  - Detector Concept & Prototypes
  - Timing measurement
- **R&D on Robust Photocathode**
  - Photocathode Protection
  - New Photocathode
- **Conclusion & Future Work**

Motivation

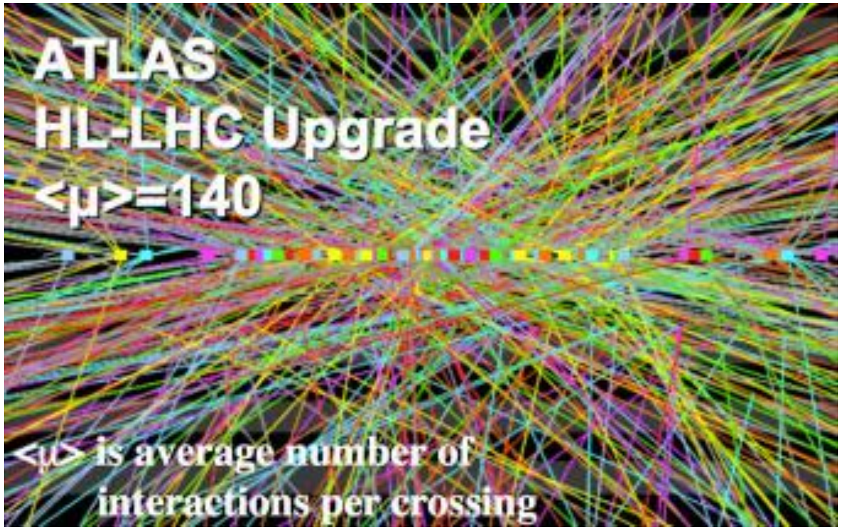
High Luminosity Large Hardon Collider

- Typically 140 collisions per crossing
- High pile-up effect
- tens ps timing & Tracking information

Detectors' performance requirement

- Good time resolution (a few tens ps)
- Hige rate & High Radiation
- High granularity

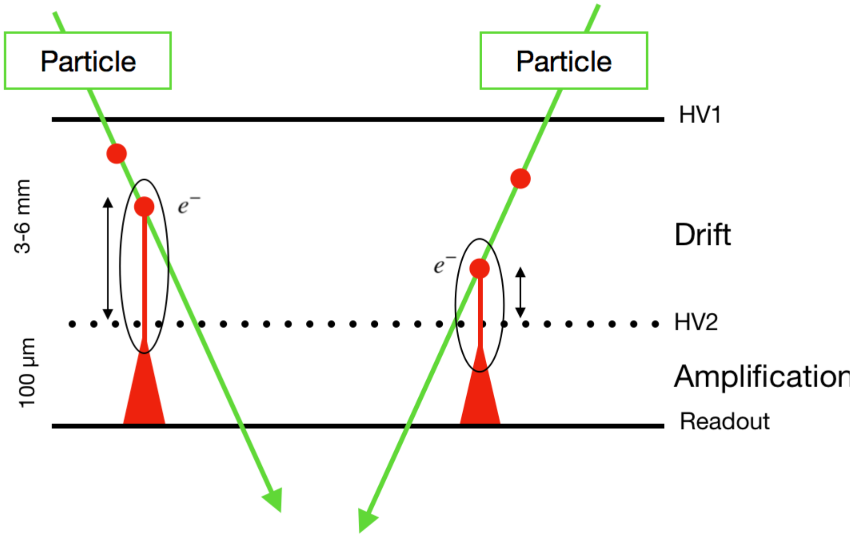
ATLAS simulation



PID techniques: Alternatives to RICH methods, J. Va'vra, NIMA 876 (2017) 185-193.

Detector Concept

Typical MicroMegas detector

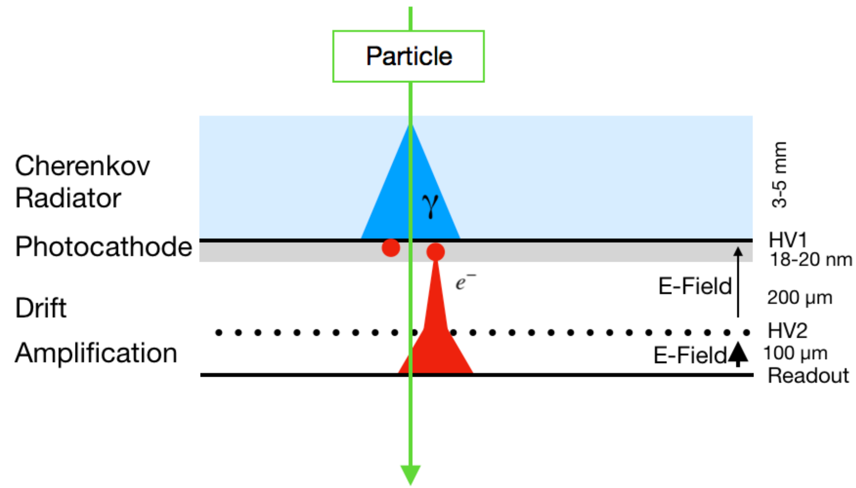


Timing resolution restriction ：

Primary ionization

- Uncertain of the collision position
- Small velocity of electrons
- Spread of electrons during the drifting progress

Picosec-Micromegas (ps-MM) detector



Novel fast time Micromegas detectors:

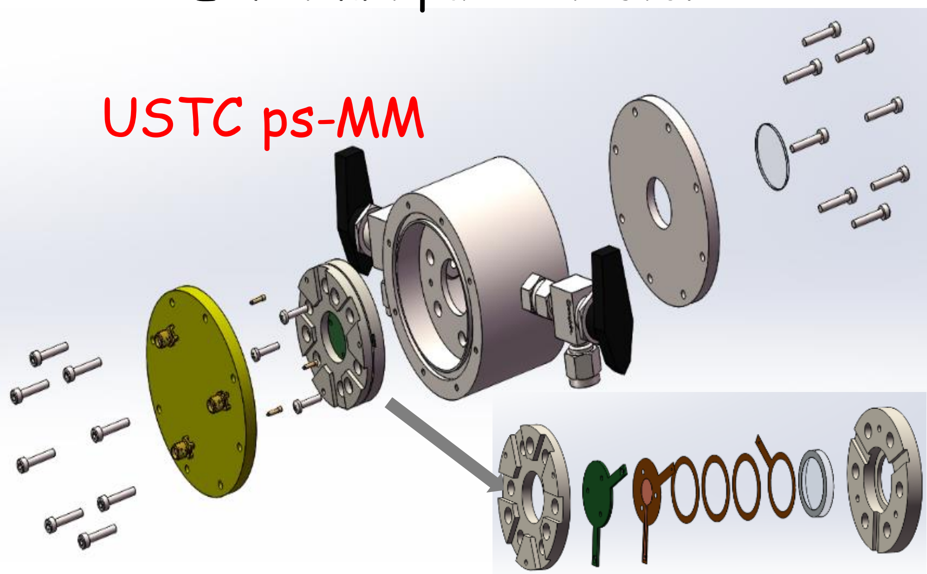
Photon detect

- Cerenkov Radiator & Photocathode
- Smaller drift gap
- Higher electric field (drift)

Prototypes of ps-MM

- Saclay ps-MM
- USTC ps-MM
- CERN Resistive Micromegas
- CERN Multipad detector

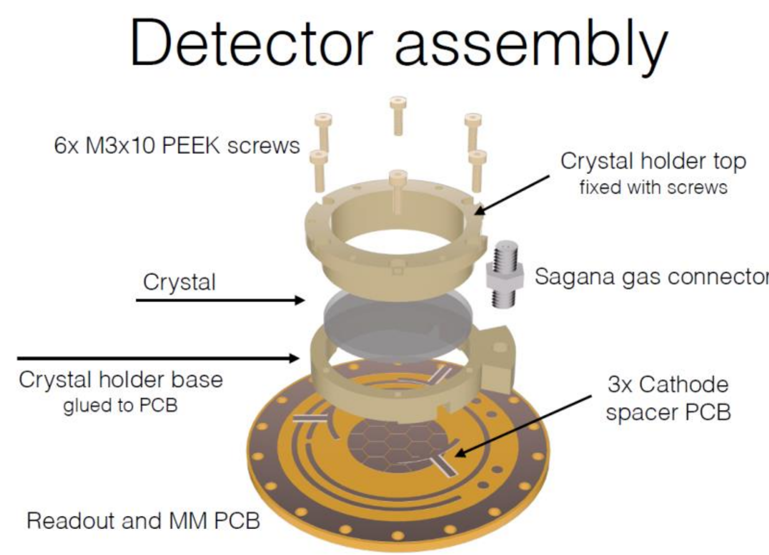
USTC ps-MM



1 cm diameter
128 μm amplitude gap
160 μm drift gap

CEA Sacaly
Bulk Micromegas

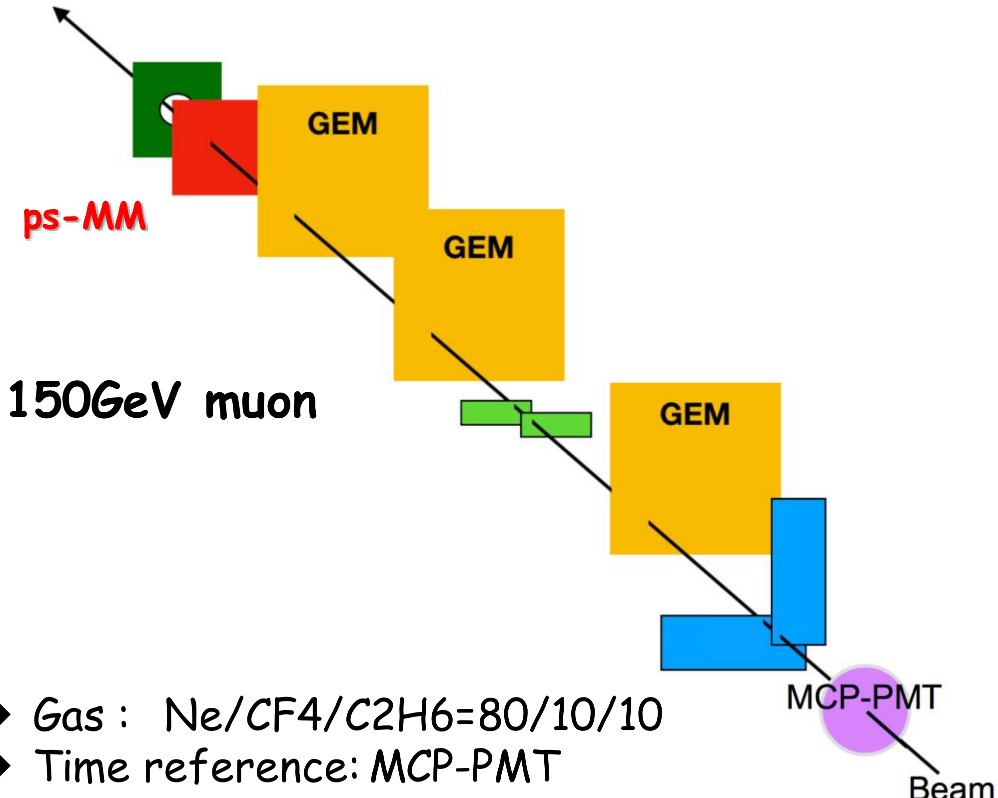
Multipad detector



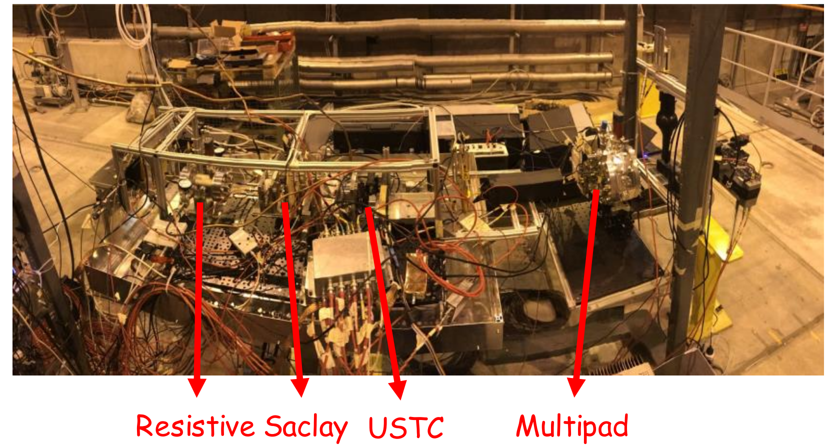
diameter of active area ~ 35mm
19 pads (7 full size)

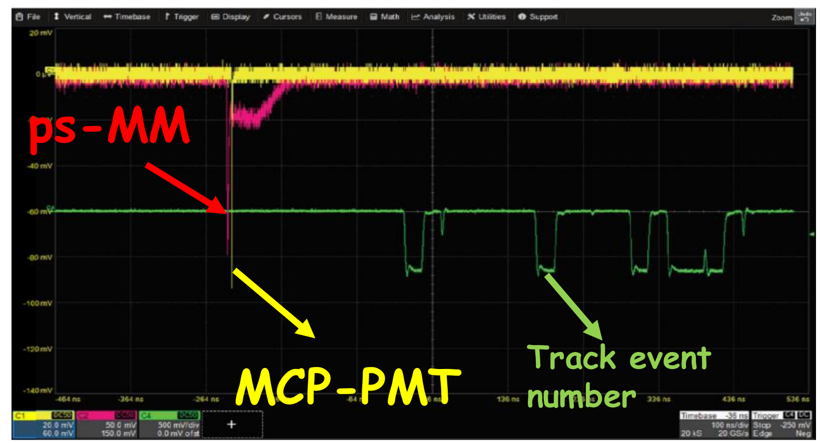
Beam Test Setup

H4 North Area SPS Extraction Line



- Gas： Ne/CF4/C2H6=80/10/10
- Time reference: MCP-PMT
- Trace: Three GEM detectors
- Trigger: Scintillators
- Measurement: Oscilloscope

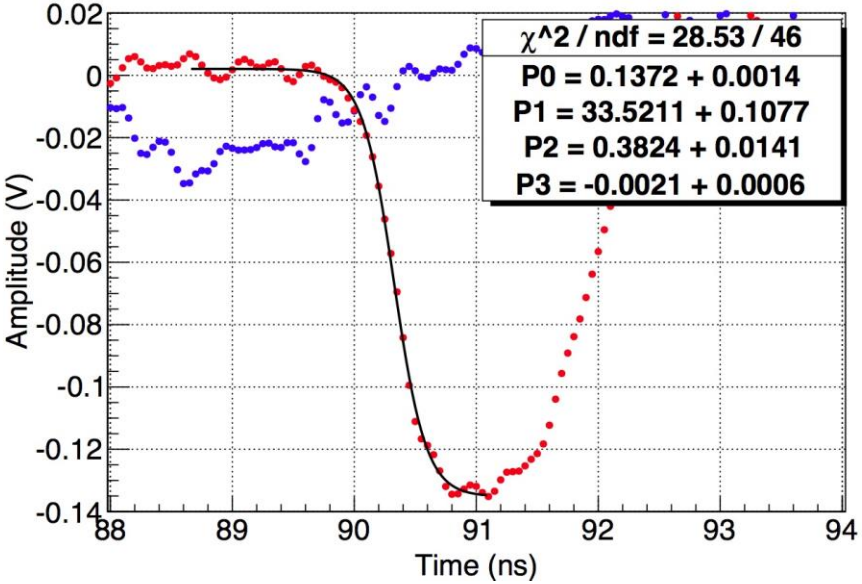


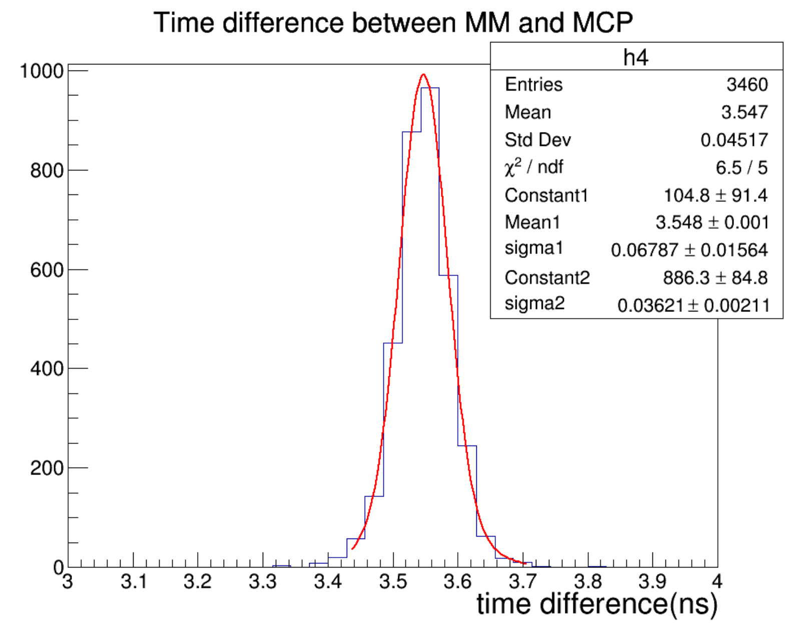


Waveform Sampling

Data Analysis

ps-MM singal





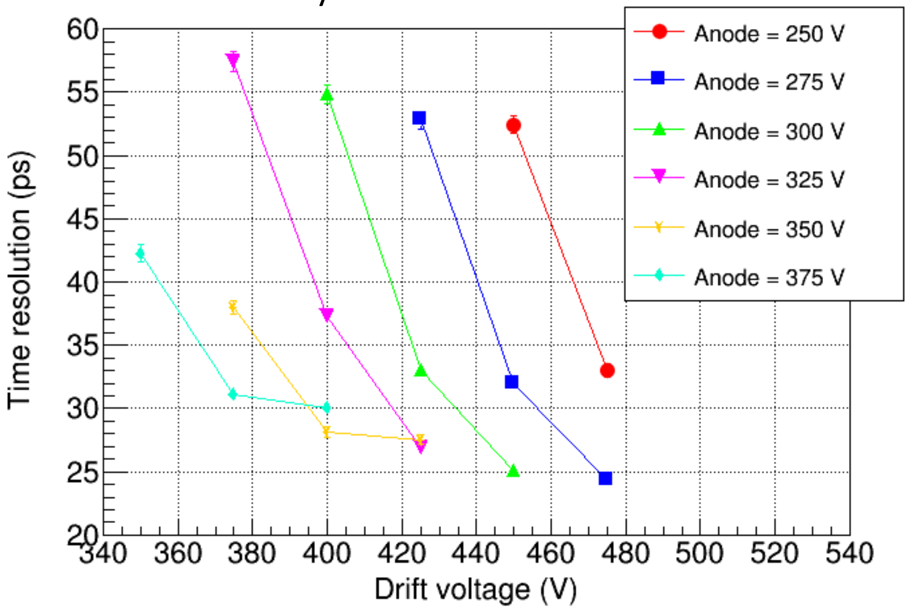
- Fitting the whole leading edge to a functional form- eg "sigmoid" and then calculating the CFD(20%) time

- Fitting the time difference with double-Guass function.
- $Time\ resolution = \sqrt{\frac{C_1}{C_1+C_2} * {\sigma_1}^2 + \frac{C_2}{C_1+C_2} * {\sigma_2}^2}$

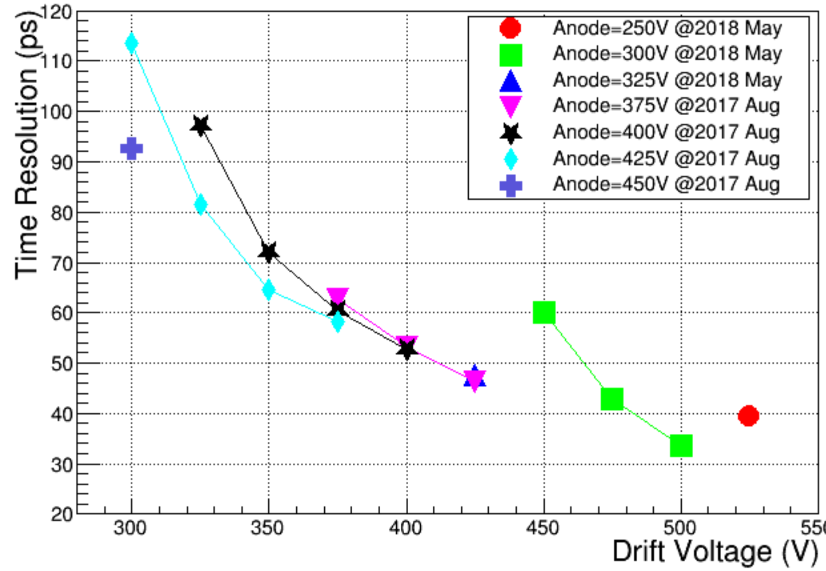
Beam Test Results

Npe: Mean number of photoelectrons per muon

Sacaly bulk MM + 5nm Cr & 18nm CsI



USTC bulk MM + 5nm Cr & 18nm CsI

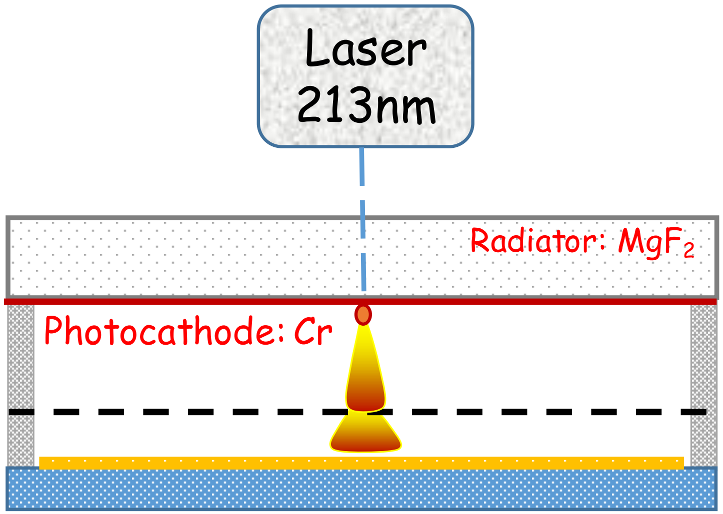


- Sacaly ps-MM: 24 ps @150GeV muon, Npe = 10.4
- USTC ps-MM: 33.7 ps @150GeV muon, Npe = 7.8

More details in:
PICOSEC: Charged particle timing to 24 picosecond precision with a Micromegas based detector, https://arxiv.org/abs/1710.08258

IBF Measurement—High IBF

$$IBF = \frac{Current_{drift}}{Current_{anode}}$$



	First Step ($Current_{drift}$)	Second Step ($Current_{anode}$)
	GND	-HV2
	HV1	HV1-HV2
	HV2	GND

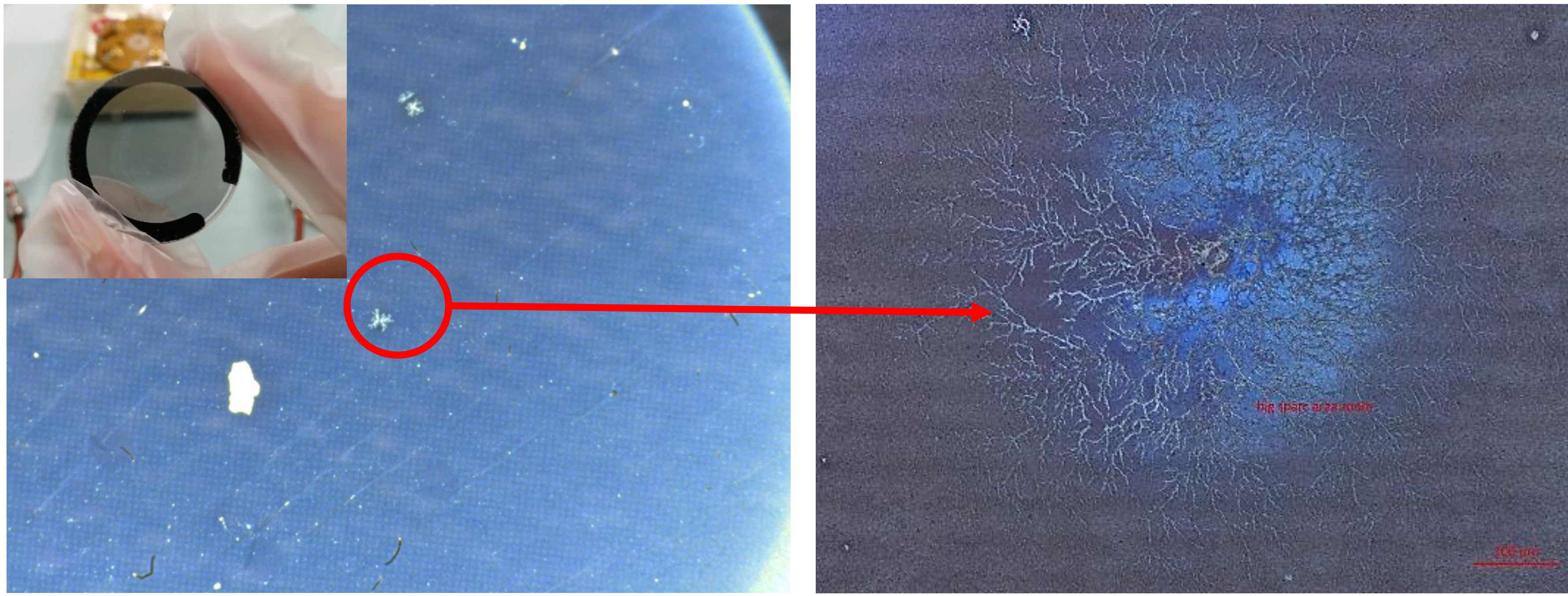
Drift Voltage(V)	Anode Voltage(V)	time resolution（ps）	IBF
-500	300	33.7	46.5%
-475	300	42.8	42.7%
-450	300	60.2	38.5%
-425	350	47.7	42.9%
-525	250	39.4	52%

- At typical ps-MM operation point, the IBF is very big

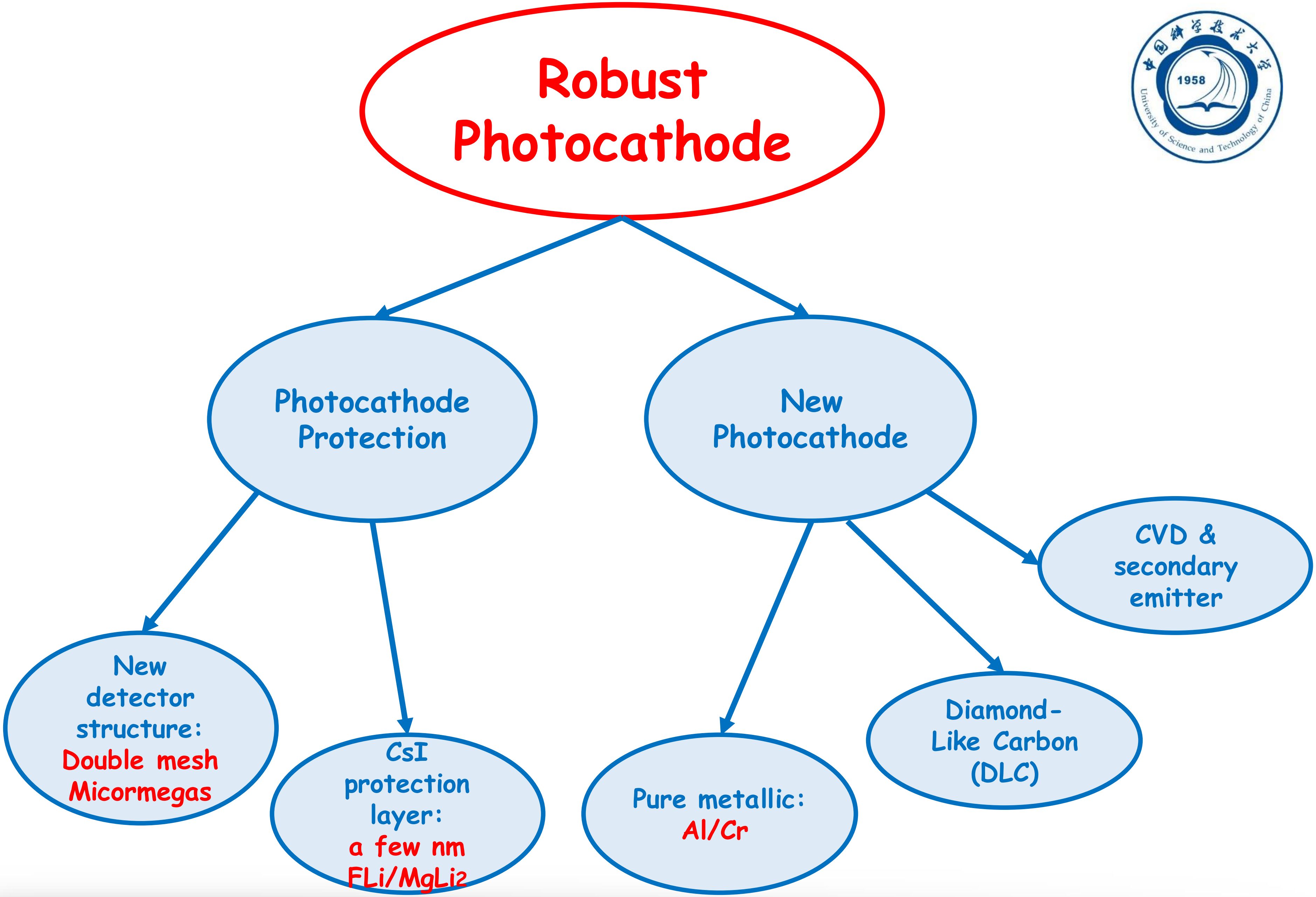
CsI Aging Problem

Photocathode: 5nm Cr + 18nm CsI

Microphotograph of photocathode

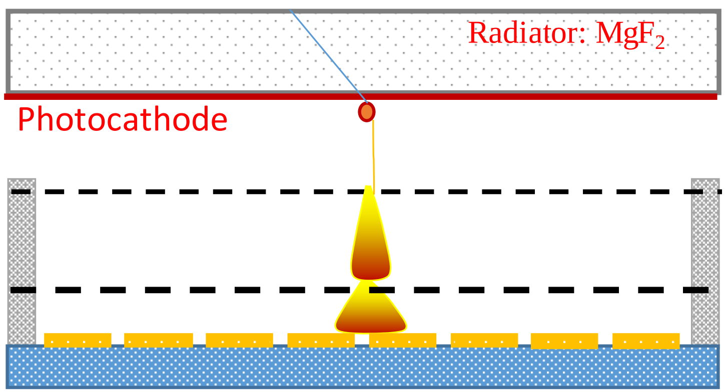


Sparks, ion Feedback

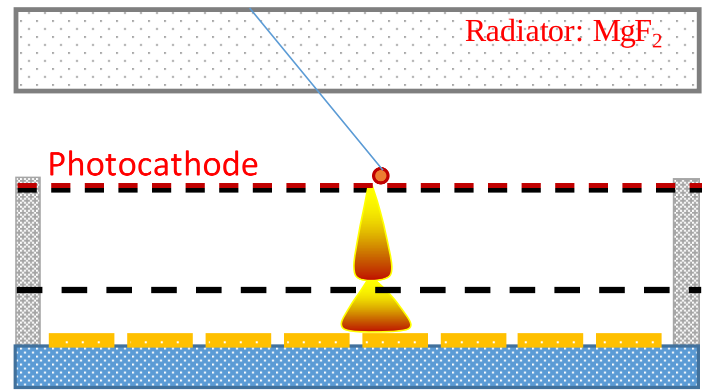

Robust Photocathode
Photocathode Protection
New Photocathode
New detector structure: Double mesh Micormegas
CsI protection layer: a few nm FLi/MgLi2
Pure metallic: Al/Cr
Diamond-Like Carbon (DLC)
CVD & secondary emitter

New Detector Structure

Two types of Double mesh Micromegas (DMM) detector



Transmission Type



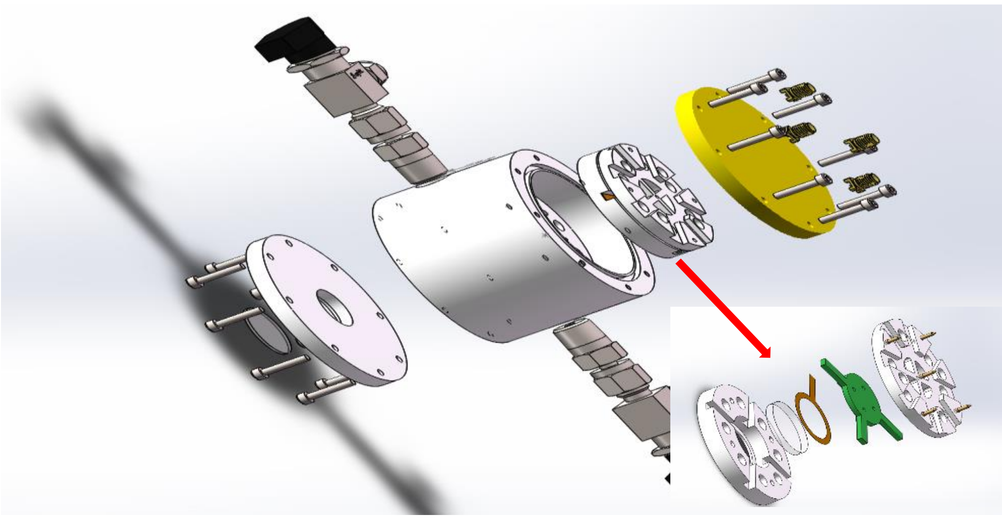
Reflection Type

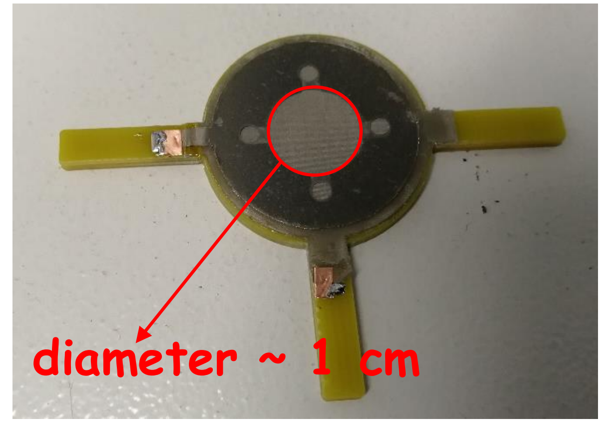
- Triple cascading avalanche
- Low IBF
- Higher gain, more stable

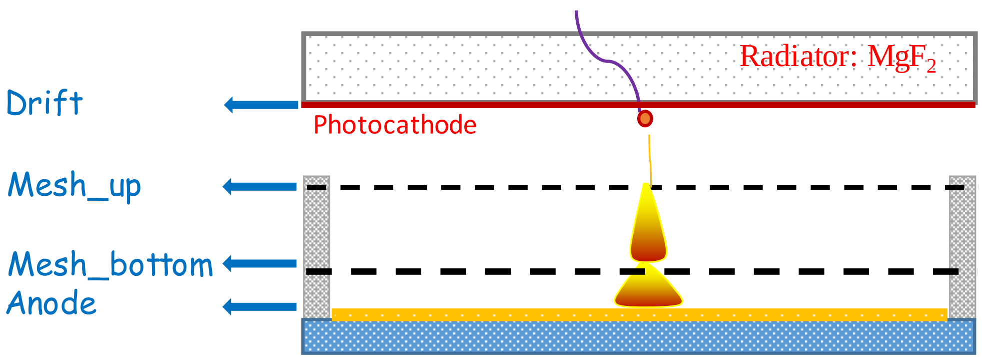
- Higher QE
- Better time resolution
- Photocathode blind to IBF

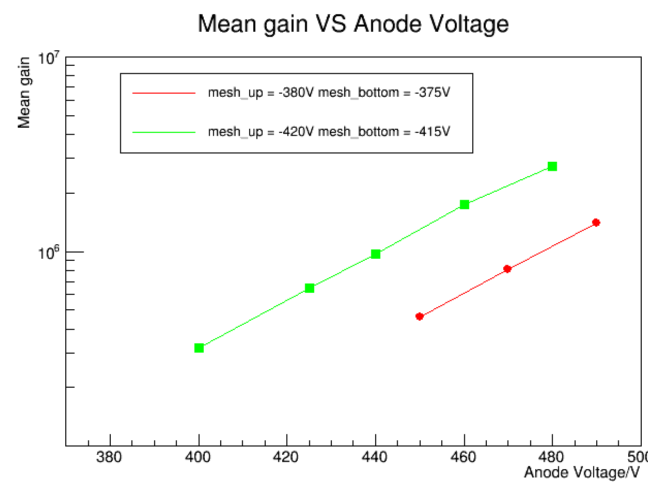
- We already have the transmission type prototype, test it with laser (213nm) and muon beam.

Transmission DMM Detector



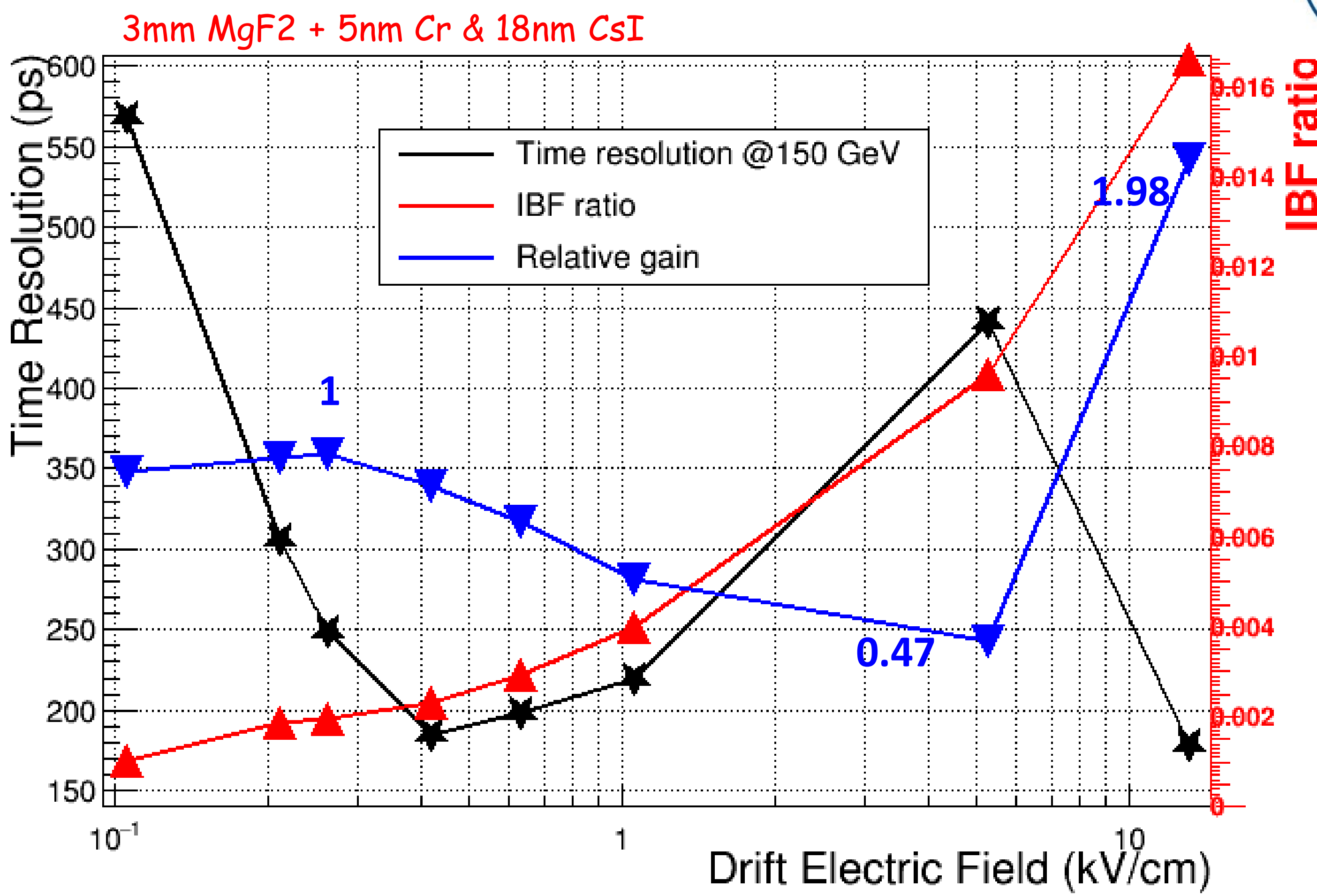






- Structure: 190μm-100μm-100μm
- The gain reached > 10^6, worked stable

DMM detector Test Results



- Fixed: mesh_up: -425 V, mesh_bottom: GND, Anode: +360 V
- Time resolution reached **180 ps** & IBF **2.5‰** at: -433V, -425V, 0, +360V
- The best time resolution reached **~80 ps** at different voltage

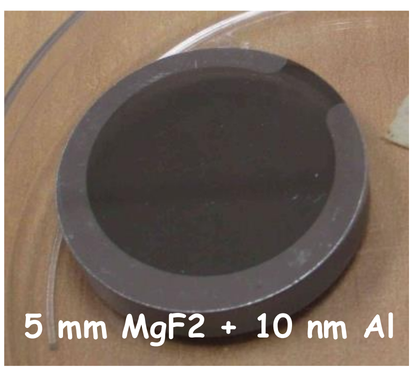
Optional Photocathode

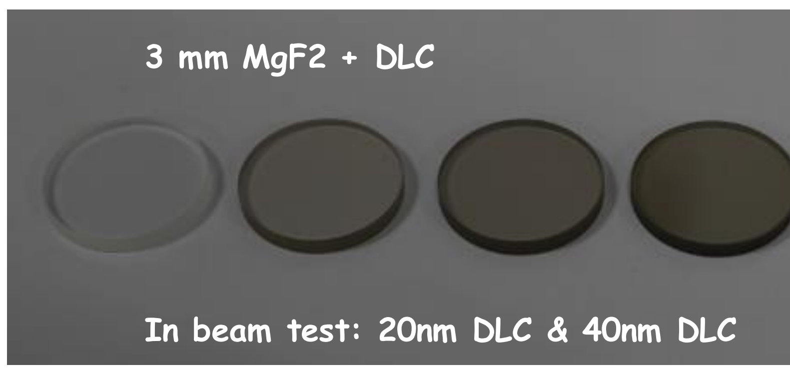
Explored options:

- Pure metallic (Cr/Al)
- Diamond-Like Carbon (DLC)
- CsI protection layers
- CVD or secondary emitter

Magnetron sputtering deposition of DLC

State Key Laboratory of Solid Lubrication, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences

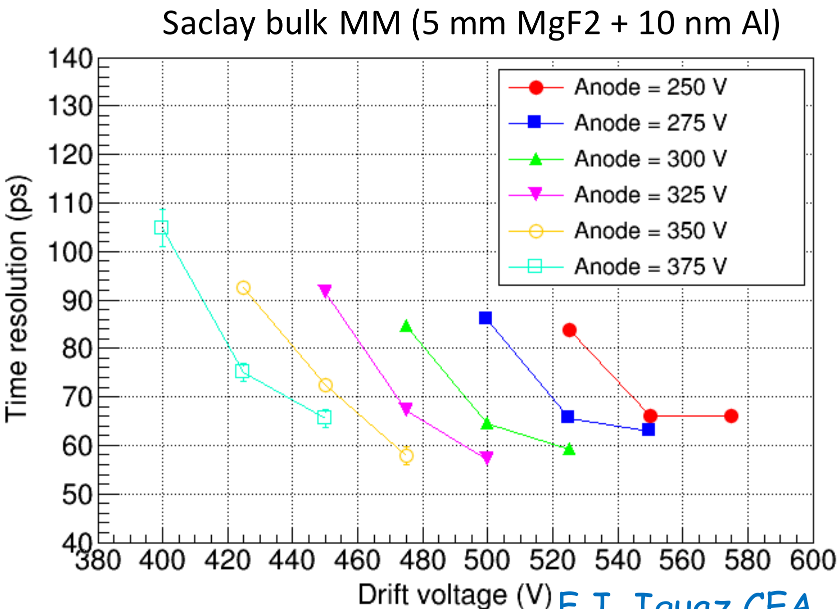




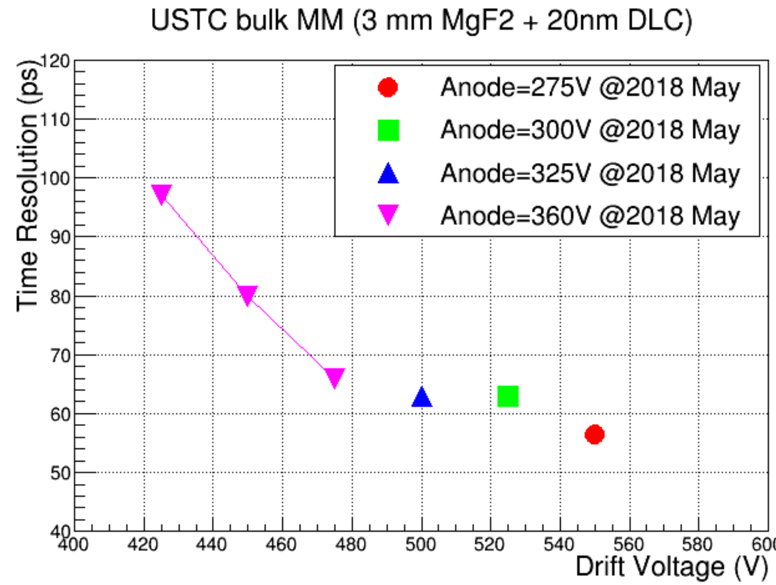
M. Kebbiri (CEA)   Yi Zhou (USTC)

Prelimiary Results

150Gev muon beam test, May 2018



F.J. Iguaz CEA



- Al photocathode (5 mm MgF_2 + 10 nm Al): 58 ps & 2.2 phe/muon
- DLC photocathode (3 mm MgF_2 + 20 nm DLC): 57 ps & 2.4 phe/muon
- DLC detection efficiency: 80%

Conclusion & Future Work

Single mesh ps-MM Timing performance

- 150 GeV muons: 24 ps & 10.4 phe/muon
- Single photo-electrons: 78 ps

R&D on Robust Photocathode

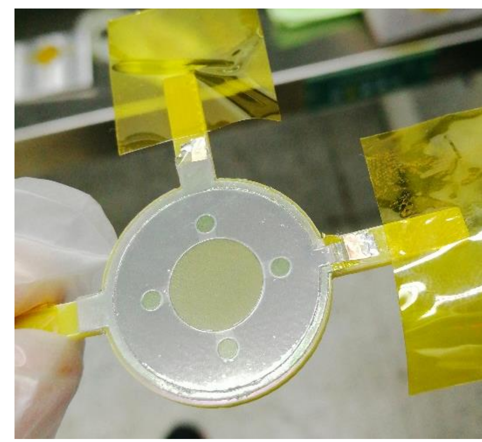
- Double mesh structure ps-MM (DMM): 180 ps at low IBF (2.5‰)
- DMM's time resolution can reach ~80 ps or lower
- New Photocathode:

  3mm MgF_2+DLC (57ps & 2.4 phe/muon)

  5mm MgF_2+Metallic (58 ps & 2.2 phe/muon)

Next Work

- Optimize the DLC photocathode
- Optimize the transmission type DMM
- Reflection type DMM



plating ~450nm CsI on mesh