R&D Progress of Picosec-Micromegas Detectors in 2017

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on behalf of Picosec Collaboration

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[1] Also University of Virginia

Outline

- Introduction
  - Motivation
  - Detector Concept
- New Detector Prototype
- Beam Test
  - Setup of Testing System
  - Topics Studied
  - Preliminary Performance Results
- Conclusion and Future Work

Motivation

Solid state detectors

- Avalanche PhotoDiodes: (σ_t ~ 30 ps)
- Low Gain Avalanche Diodes: (σ_t ~ 30 ps)

→ *High radiation environment?*

Gaseous detectors

- MRPC: (σ_t ~ 30 ps)

→ *Hige rate environmrnt?*

- MPGDs: (σ_t ~ a few ns)

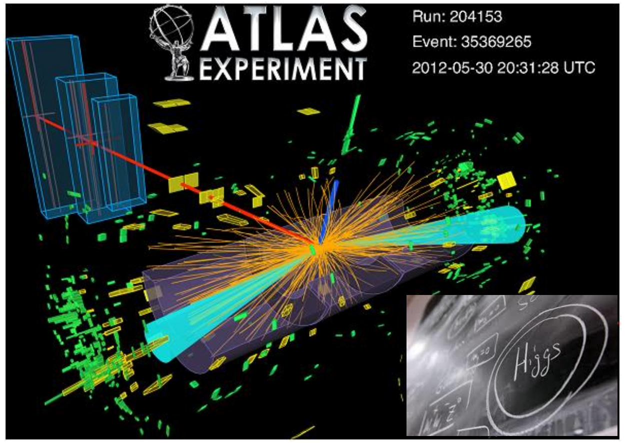
Can a MicroPattern Gaseous Detector reach a timing resolution of the order of few tens of picoseconds?

Motivation

Ⅰ: In Particle Physics

- After the Higgs particle was found, CERN proposed to upgrade the LHC to the High Luminosity Large Hadron Collider(HL-LHC) by 2025.
- The HL-LHC will operate with typically 140 collisions per proton bunch crossing, which will cause greatly pile-up effect. A time resolution of a few tens of ps will be needed to obtain a fake jet rejection rate that is acceptable for physics analysis

Vertex Reconstruction in HL-LHC



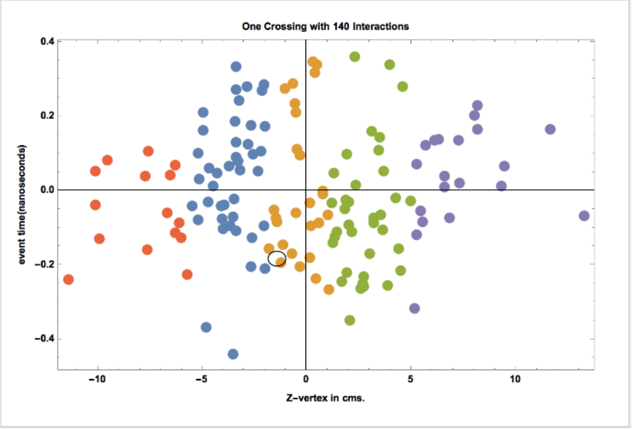
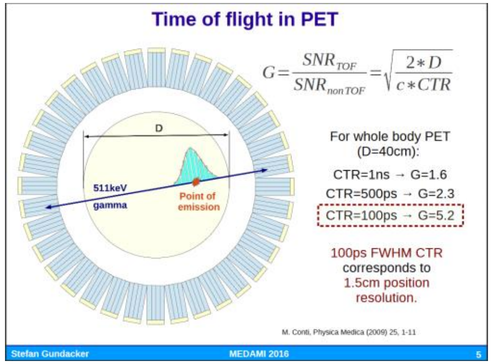
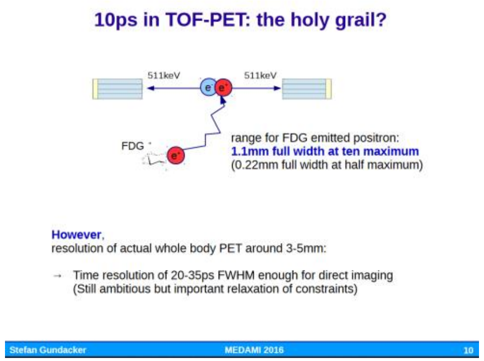


Fig. 1. Simulation of the space(z-vertex) and time distribution of interactions within a single bunch crossing in CMS at a pileup of 140 events- using LHC design book for crossing angle, emittance, etc. Typically events are distributed with an rms-in time- of 170 picoseconds, independent of vertex position.

Ⅱ: In Other Aspects: nuclear medicine...





https://indico.cern.ch/event/446975/contributions/1111046/attachments/1270322/1882084/Gundacker_Medami2016_VF.pdf

- Positron Emission Computed Tomography(PET) is the most advanced clinical medical imaging technique in nuclear medicine.
- Detectors measure the flight time of 511keV gamma photons. A high time resolution is needed, 20~35ps FWHM is enough for direct imaging.

History

Started as an RD51 common fund project:

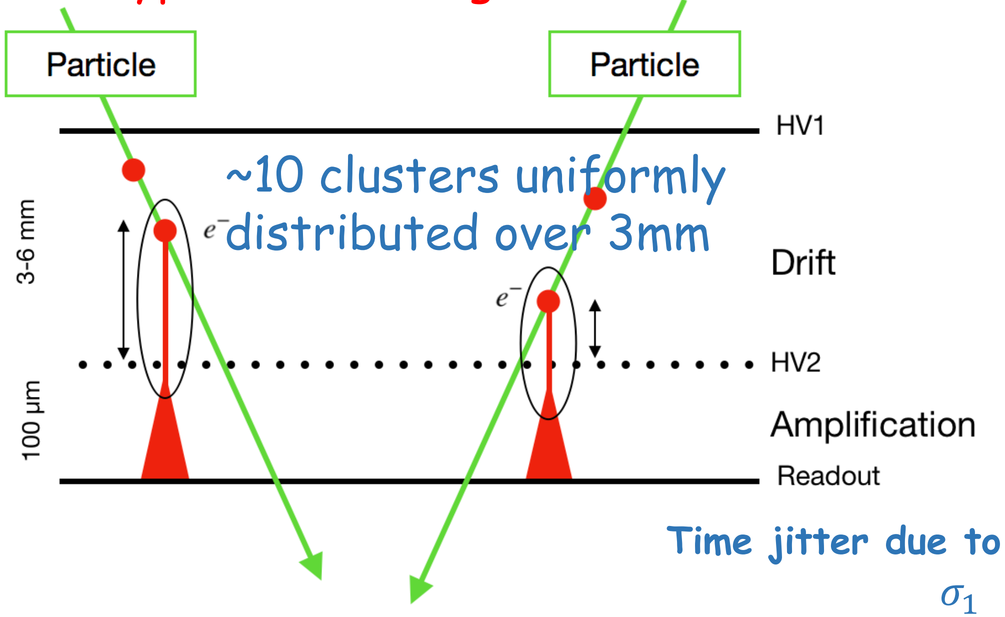
Fast Timing for High-Rate Environment: A Micormegas Solution

Awarded 3/2015

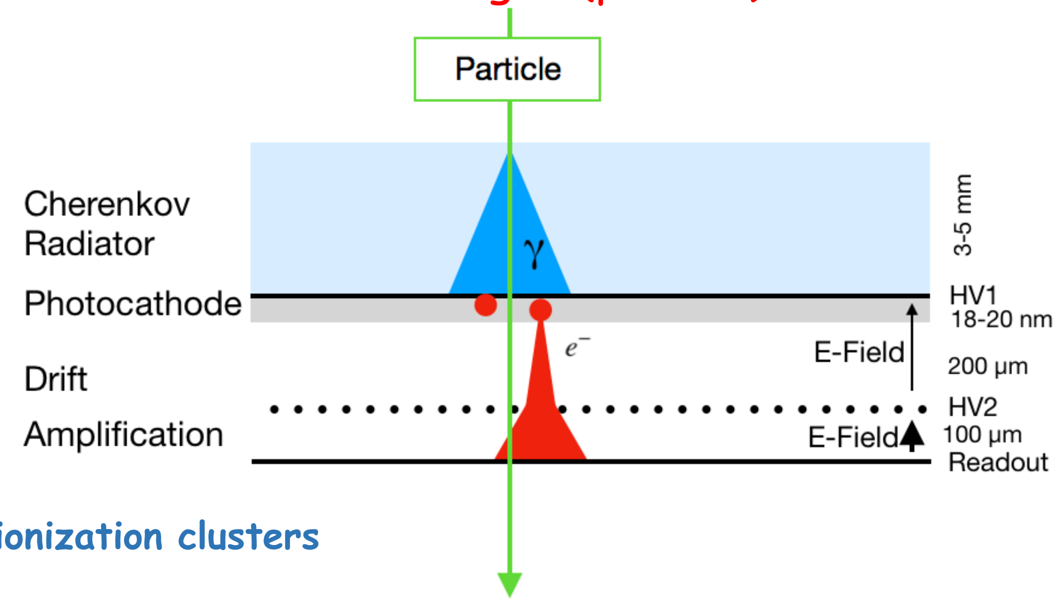
2014	2015	2016	2017
Proposal Submission	First Prototype and laser test	New Prototypes, laser tests and measurements with charged particles (test beam campaign)	Resistive micromegas prototypes, Multi-channel anode and larger area, photocathodes (CsI protection, Diamond,..), New electronics

Detector Concept

Typical MicroMegas detector



Picosec-Micromegas (ps-MM) detector



Time jitter due to multiple ionization clusters

$$\sigma_t = \frac{\sigma_1}{v_e} \sim \frac{300\mu m}{50\frac{mm}{\mu s}} = 6ns$$

The time resolution is mainly limited to the direct initial ionization in the drifting zone:

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

Novel fast time Micromegas detectors:

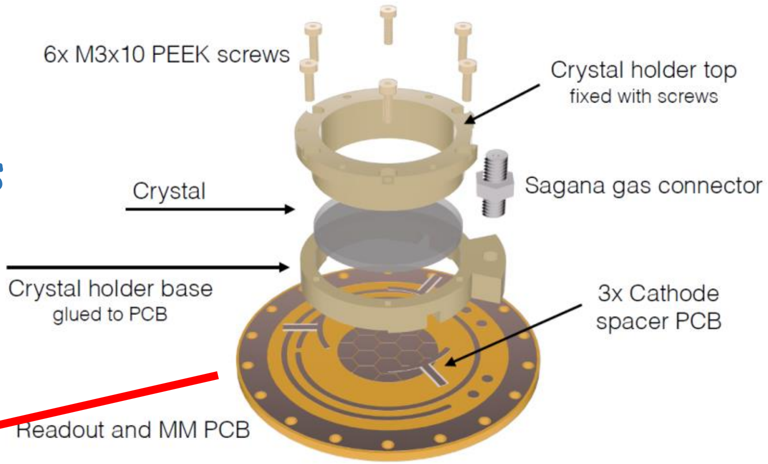
- Reducing the directly initial ionization by reducing the length of drifting zone
- Increasing the electric field
- Cerenkov Radiator and Photocathode produce photoelectrons, small longitudinal diffusion

New Prototype of Detectors

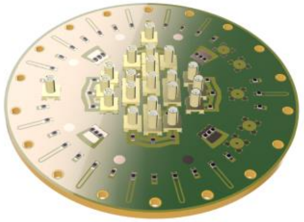
Detectors

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

Multipad detector

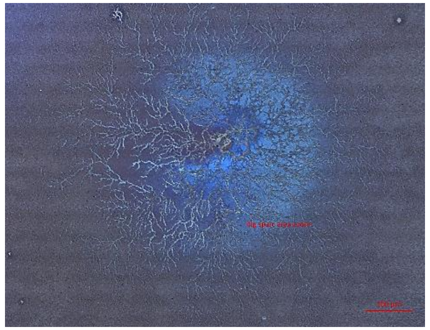


PCB



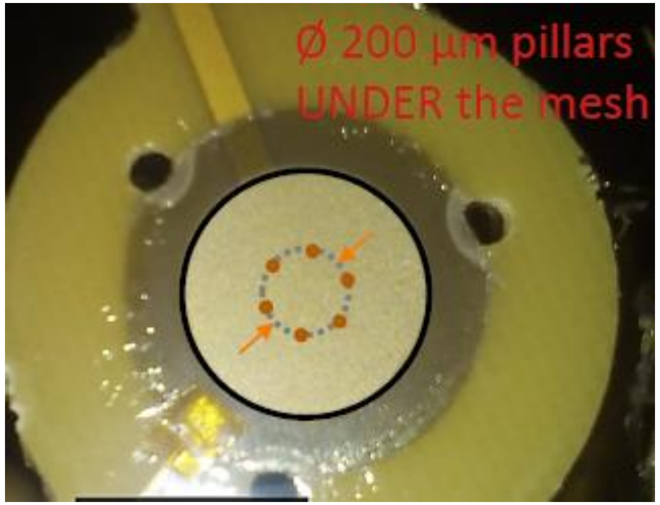
108mm diameter 4-layer PCB with solder mask and solder paste on Top side

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



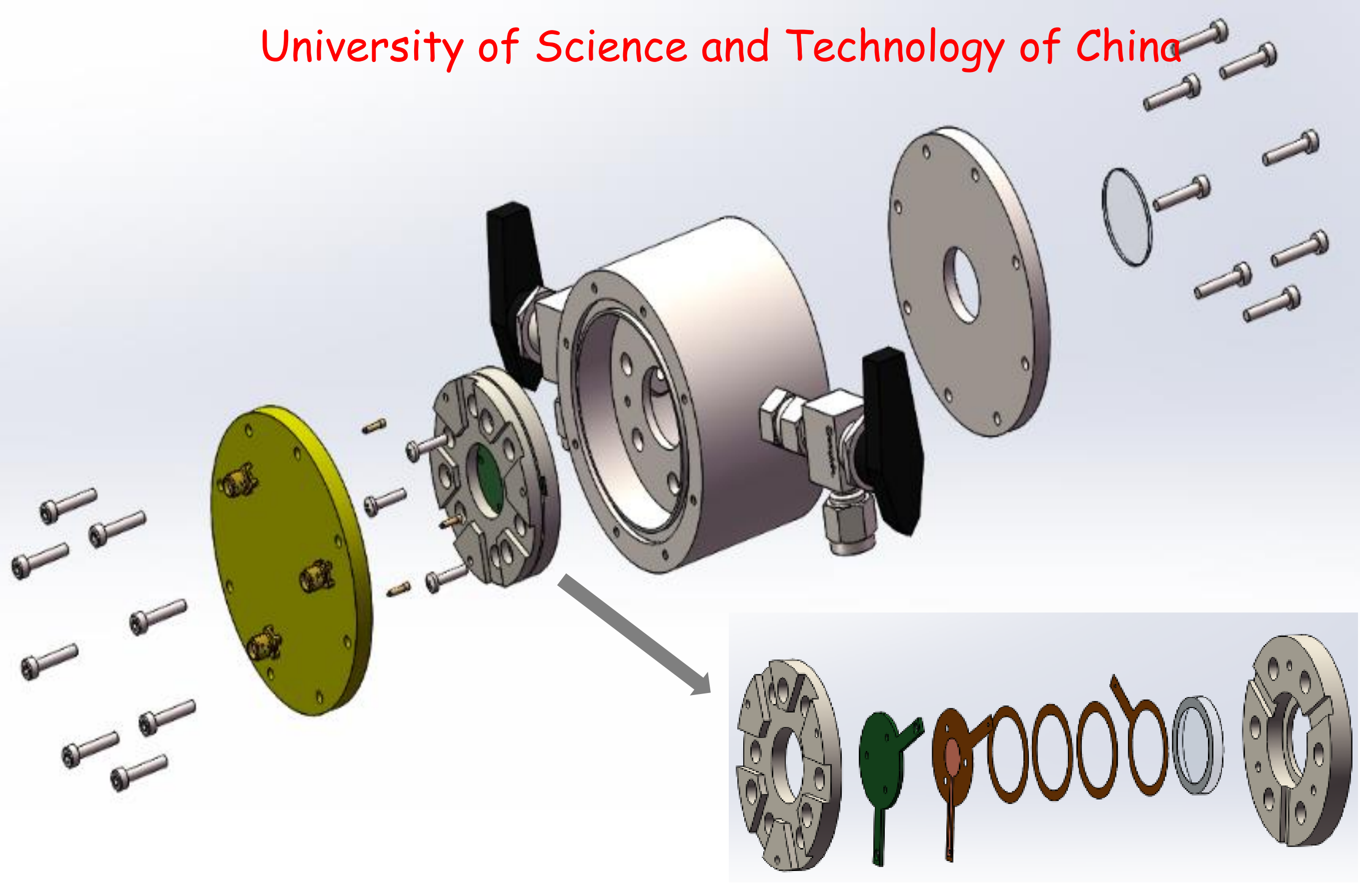
Pictures of Photocathode:
Sparks can be harmful for our detectors

Resistive detector

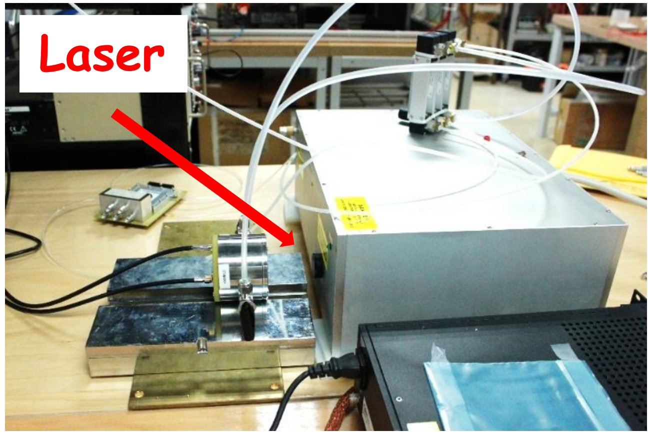


Resisitive Micromegas can reduce sparks and work stablely in high intensity pion beam

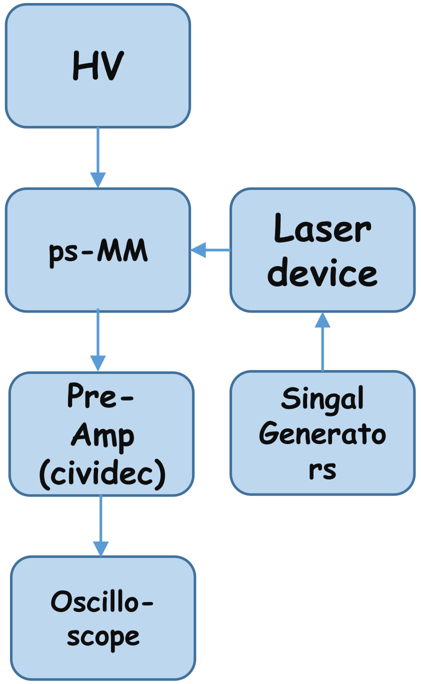
Prototype of USTC Picosec-MM



Active area: ~1cm^2 Drift gap: 120μm Amp gap: 120μm



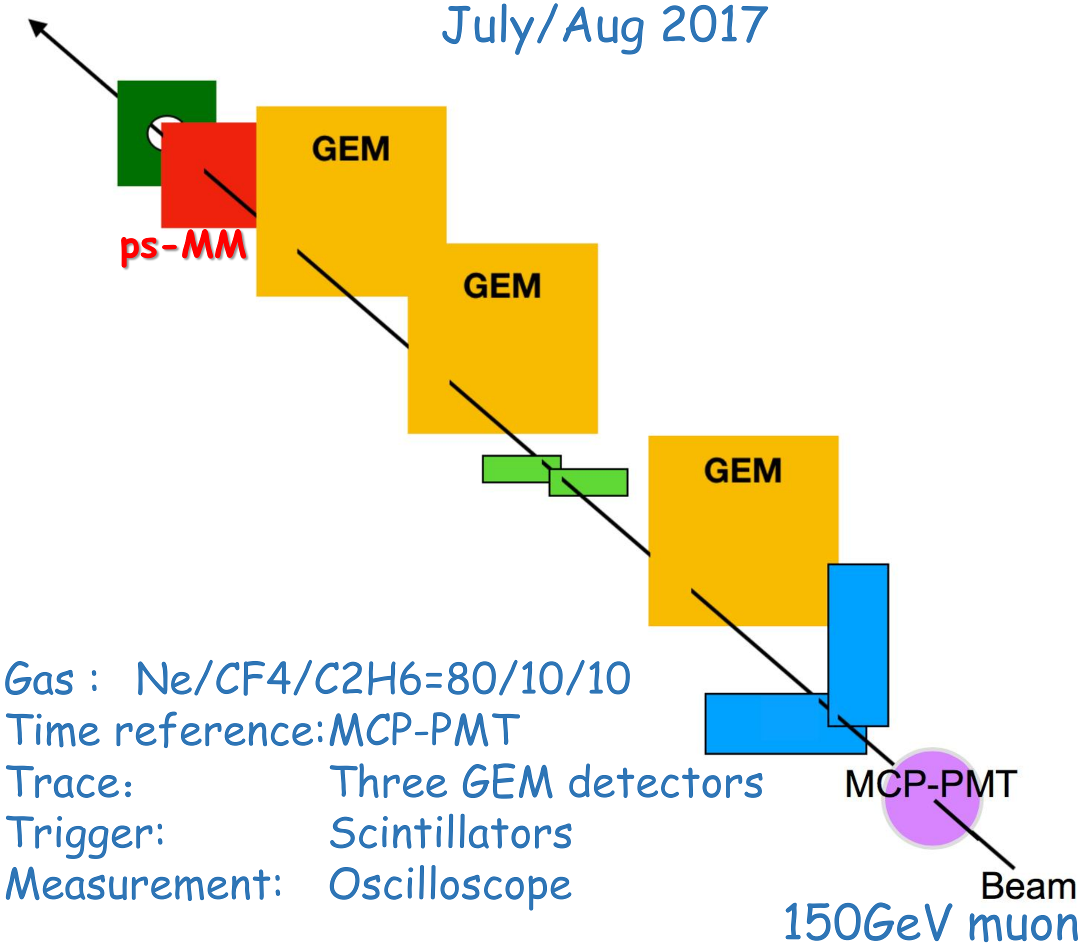
Photocathode: 5.5nm Cr



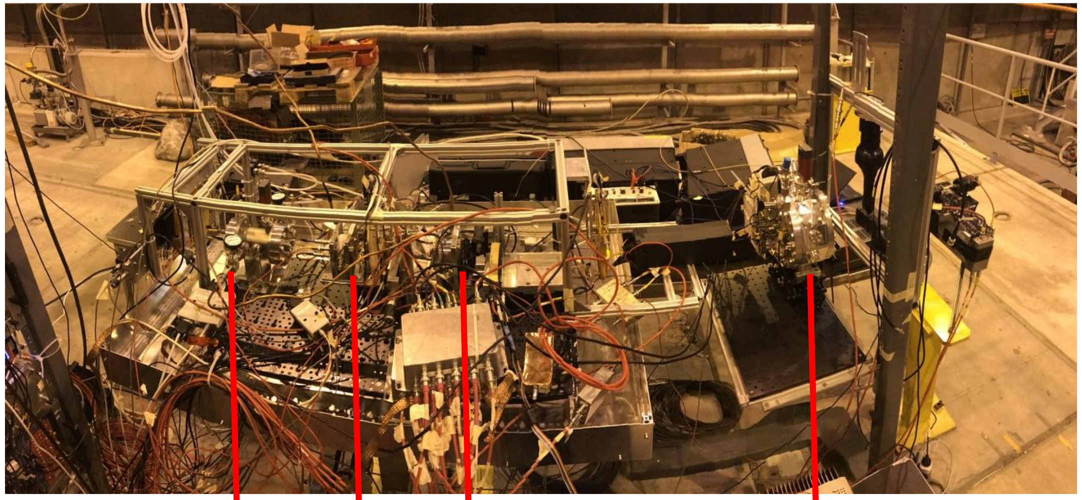
Drift ：Negtive HV
Mesh ：GND
Anode：Positive HV（signal）

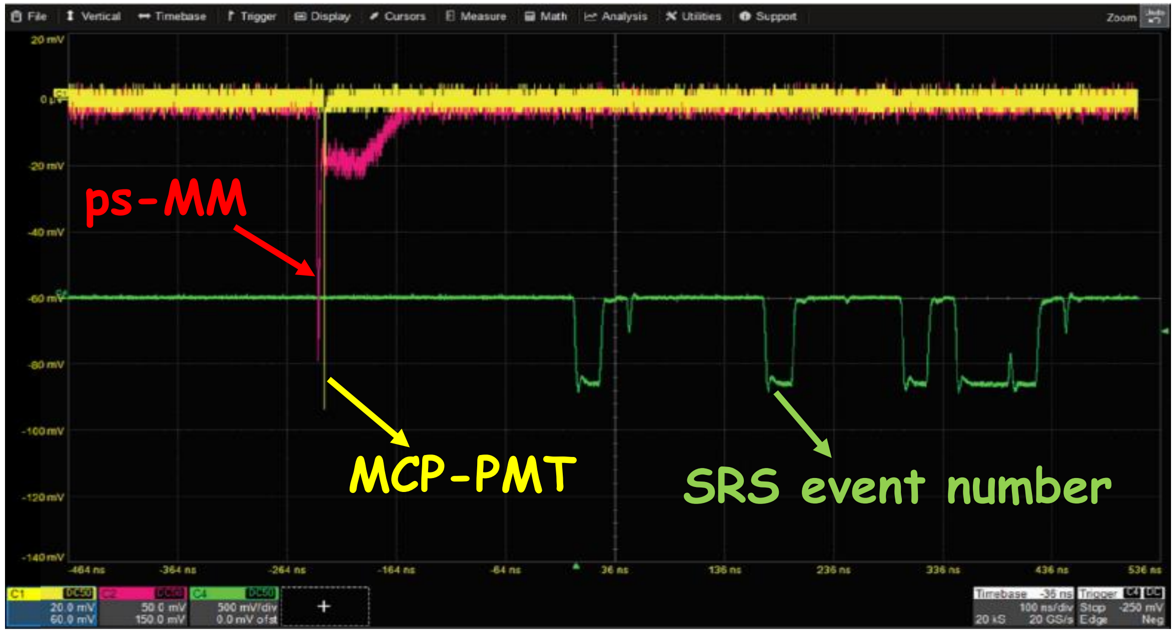
Beam Test Setup

H4 North Area SPS Extraction Line
July/Aug 2017



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





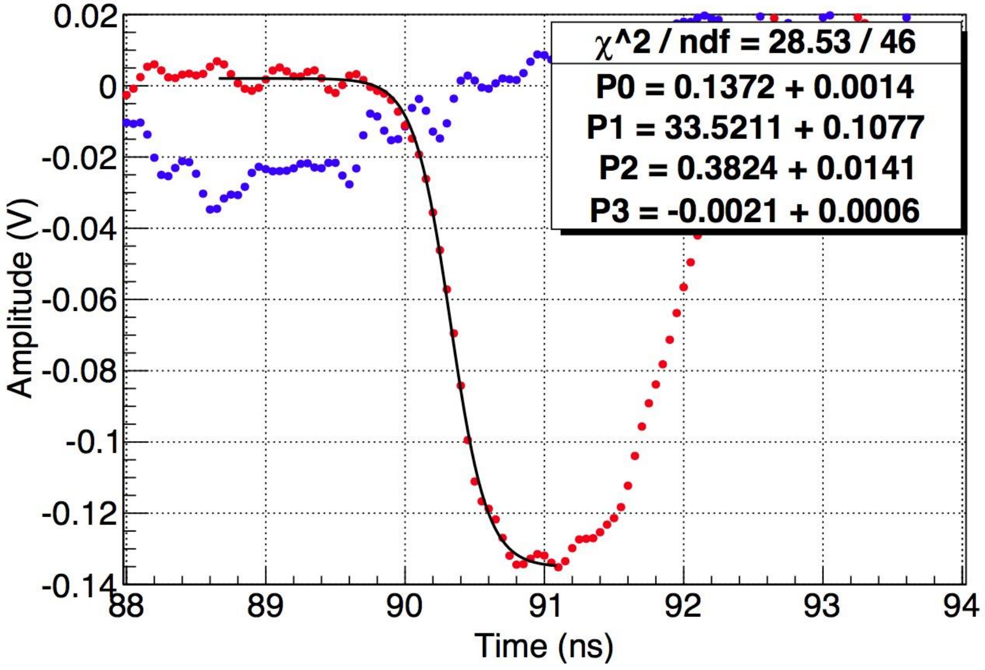
Topics we studied

- Photocathode
  - ➢ Different material
    - 5.7 nm Cr + 20 nm CsI
    - 5.5 nm Cr + 18 nm CsI
    - 20 nm Cr
    - 9.5 nm Al
    - 5.7 nm Cr + 20 nm CsI+2nm LiF/AlF3 (CsI protection)
  - ➢ Photocathode aging
    - Long time testing

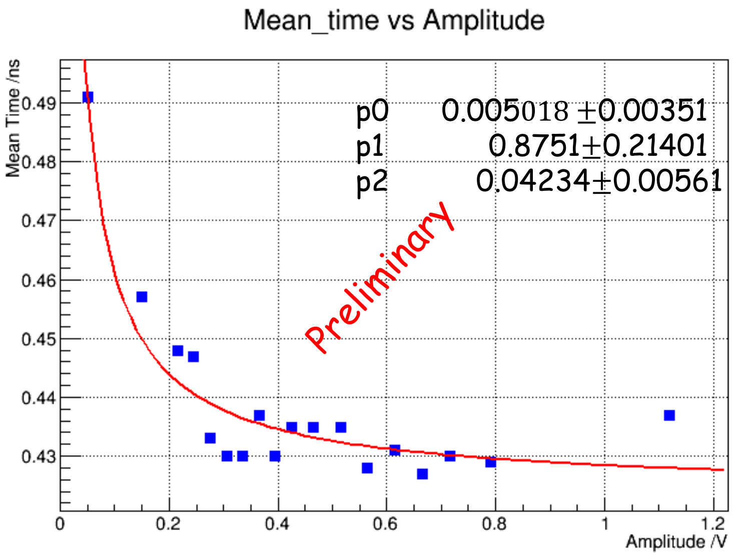
- Sparks
- Ion Backflow

- High Voltage Scan
  - Find the appropriate state
- Functional Test
  - Resistive detector in pion/muon beam
  - Multipad detector
  - USTC's detector
  - Saclay's detector

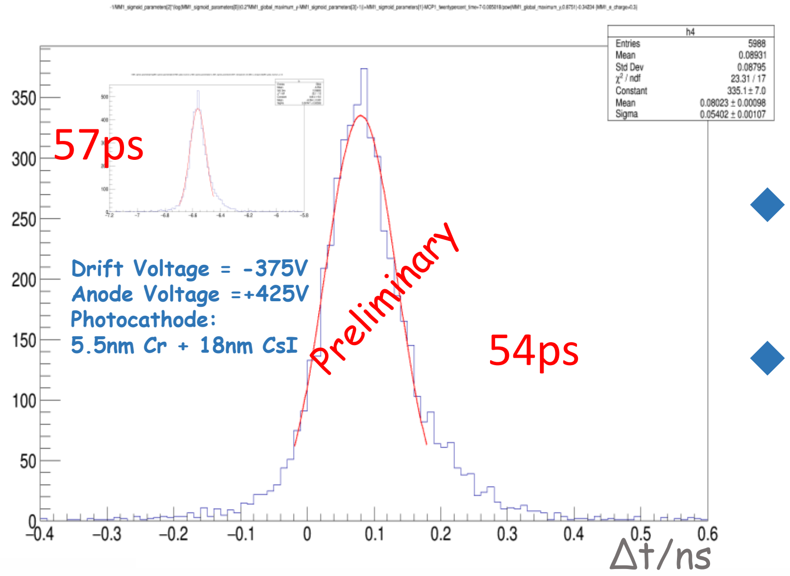
CFD & T-A correction



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



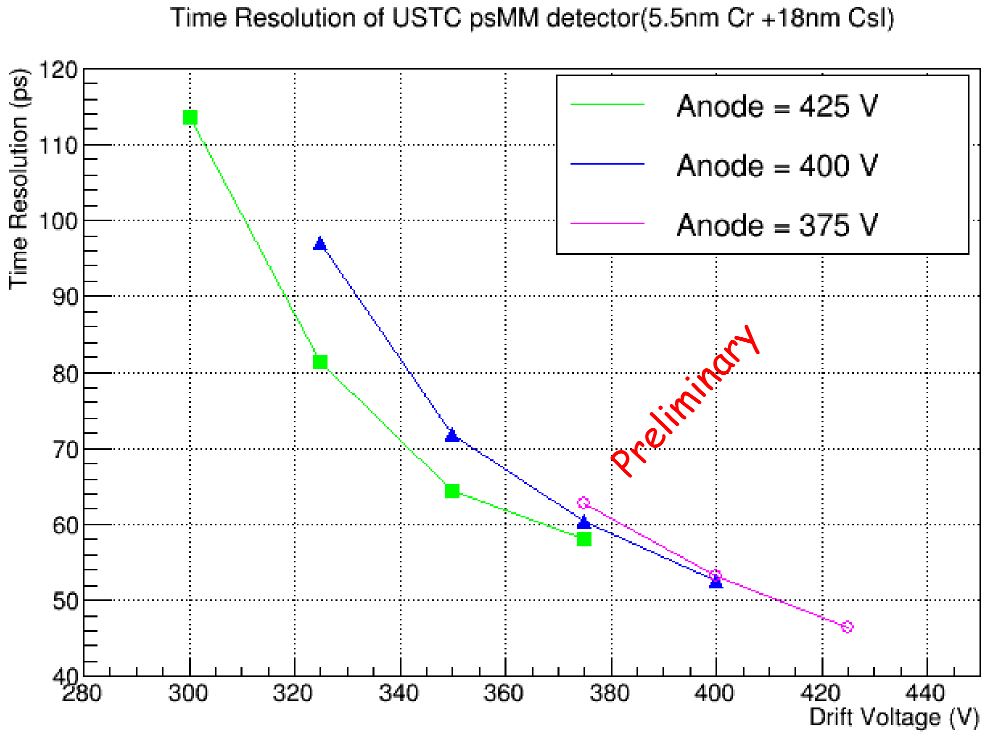
- Fitting function: p0/(x^p1)+p2;
- Mean Time(ps-MM time minus to the MCP)as a function of the e-peak Amplitude.



- Δt: time difference between reference MCP-PMT and ps-MM
- After T-A correction, the sigma become better, and it still need more work.

HV scan of USTC ps-MM

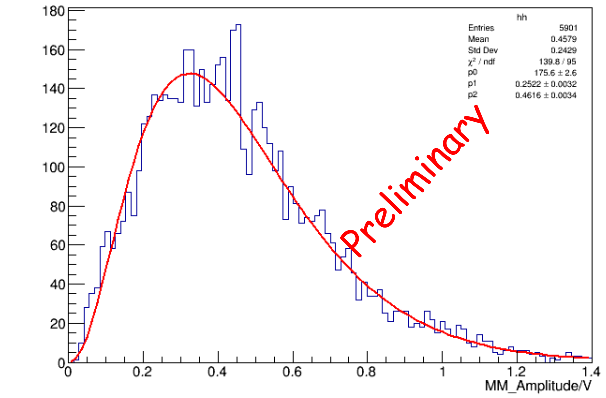
High Voltage Scan in muon beam



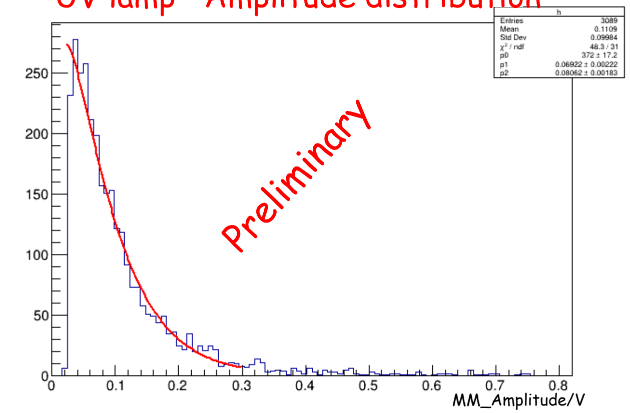
- Detectors worked well during the whole beam
- We tested some different photocathode and finished HV scan
- Time resolution can reach < 50 ps, and can be better when the Drift electric field is higher.

Calculation of Npe(mean number of photoelectrons per muon)

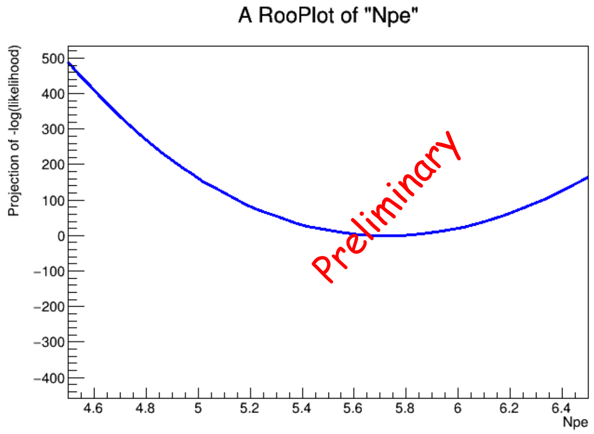
Muon—Amplitude distribution



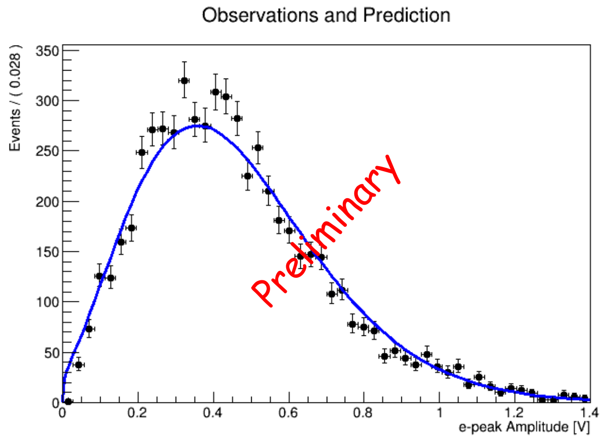
UV lamp—Amplitude distribution



- Fit the e-peak amplitude distribution with polya distribution
- $y = P_0 e^{\left[\frac{{P_2}^2}{{P_1}^2}\ln\frac{{P_2}^2}{{P_1}^2} + \left(\frac{{P_2}^2}{{P_1}^2}-1\right)\ln\frac{x}{P_2} - \frac{{P_2}^2}{{P_1}^2}\frac{x}{P_2} - \ln\Gamma\frac{{P_2}^2}{{P_1}^2}\right]}$
- $P_0: constant, P_1: absolute\ variance, P_2$:mean

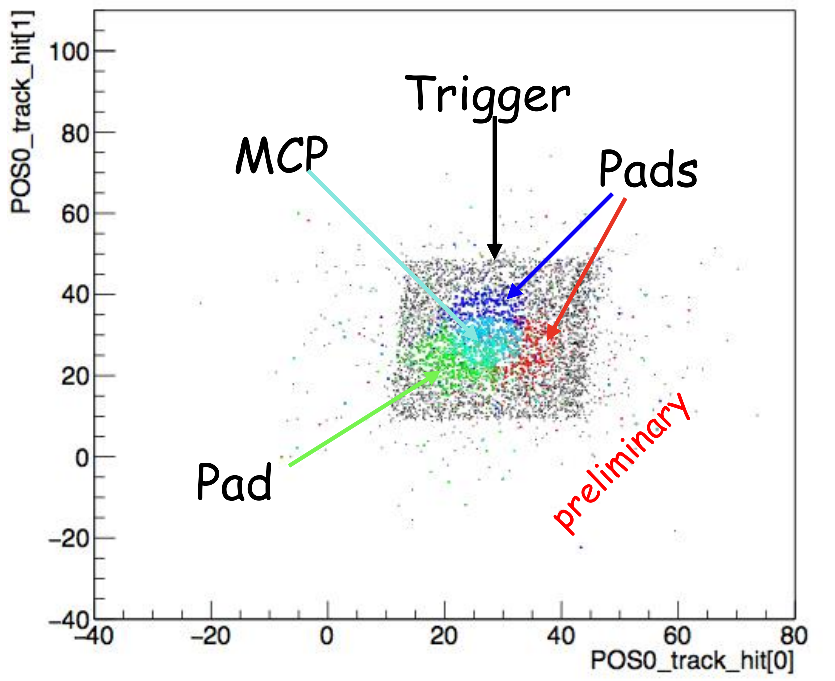


- Left: The negative log likelihood of the data, for several Values of Npe (mean number of pes per muon). The minimum corresponds to **5.75 pes/muon**.
- Right: The data e-peak amplitude distribution(points) in comparison with the statistical prediction with Parameters estimated by the fit.



Performance of Multipad ps-MM

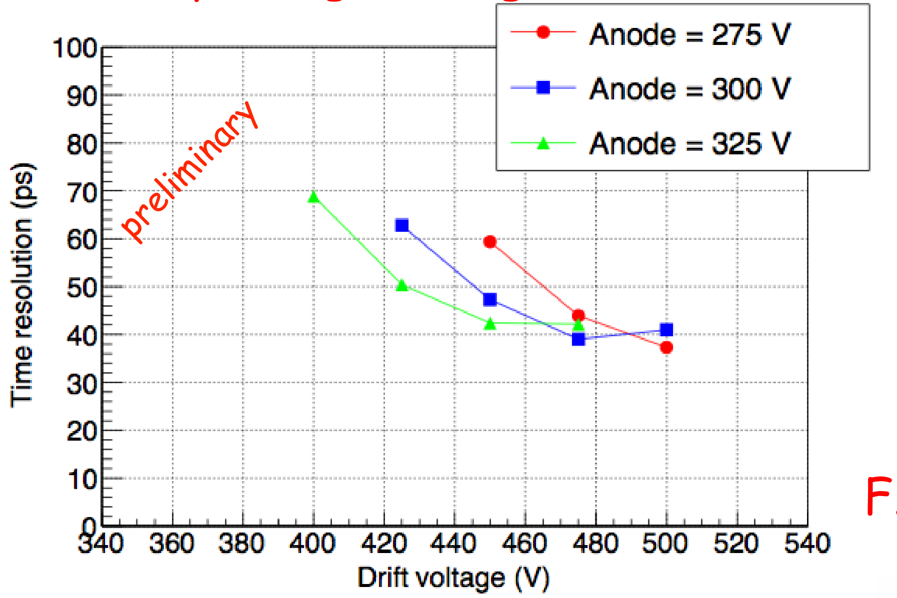
Alignment for charge sharing study



L. Sohl

- High voltage scan of one centered pad
- Time resolution similar to small Picosec with same drift gap size
- Long study (over 1,000,000 events) of charge sharing between three pads

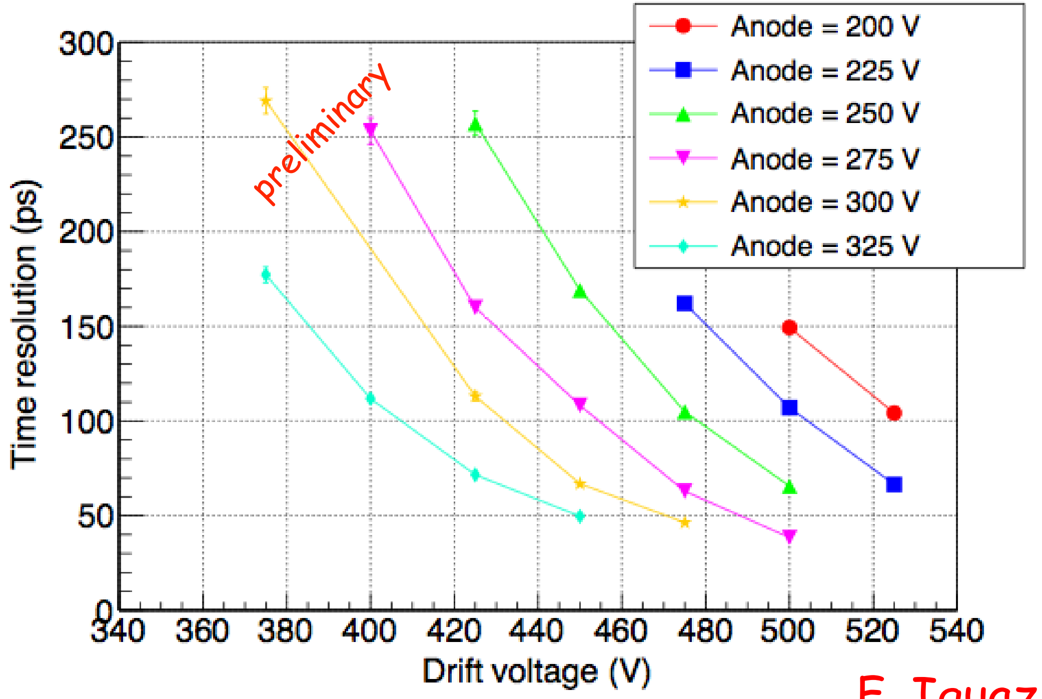
Multipad high voltage scan



F. Iguaz

Performance of Resistive ps-MM

HV scan under muons beam



F. Iguaz

- Measurements with a discrete resistive detectors (R=25 MΩ)
- High voltage scan with muon and high intense pion beam
- Operated full night with pion beam
- Ion backflow of 30% at stable conditions

Conclusion and Future work

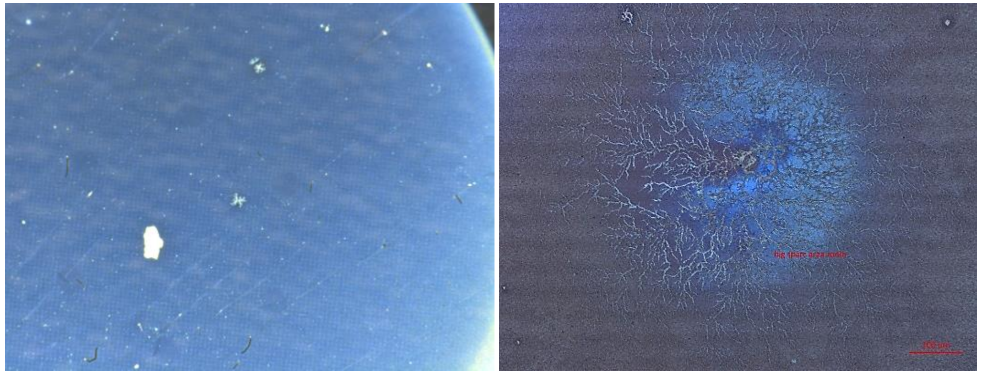
Conclusion:

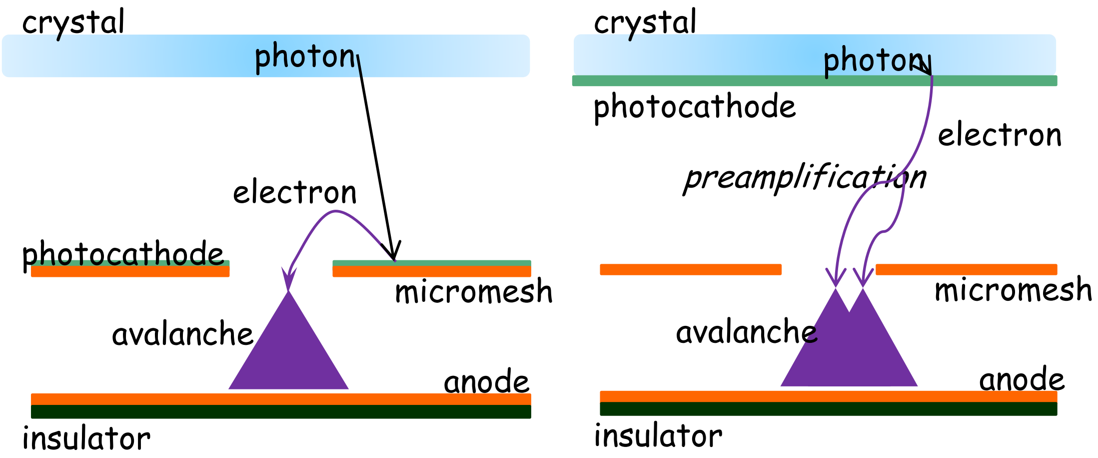
- Detectors worked well，time resolution can reach ＜ **50ps**
- High Voltage scan was finished, some topics were studied
- Some problems still exist

Future Work:

- More data analysis: tracking information …
- Study of photocathode: DLC …
- Study of radiator material
- Reflective mode ps-MM

Photocathode Aging (spark)





Reflective mode　　Semitransparent mode