中国科学院近代物理研究所
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Development of a Time Projection Chamber with GEM technology in IMP

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Gas detector group

Outline

- Introduction
- TPC prototype based on GEM
- performance test based cosmic ray
- Beam test
- Summary

Gas detector group @ IMP

- The gas detector group was founded in 2003.
- **functional positioning**: research and development of gas detectors for physical experiments

- Members

  Professor:1

  Associate professor: 3

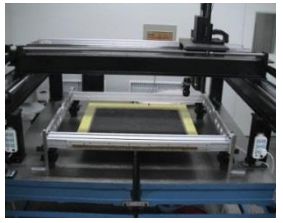
  Research Associate: 5

Gas detector group @ IMP

- **Facilities**

40 m^2 clean room

Automatic winding machine

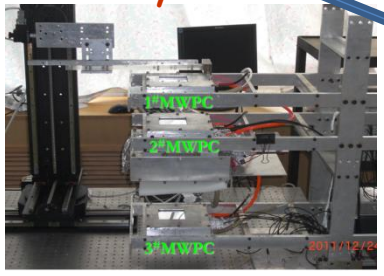


2-dimensional measurement platform

Multi-component gas mixed system

Front-end electronics and data acquisition system

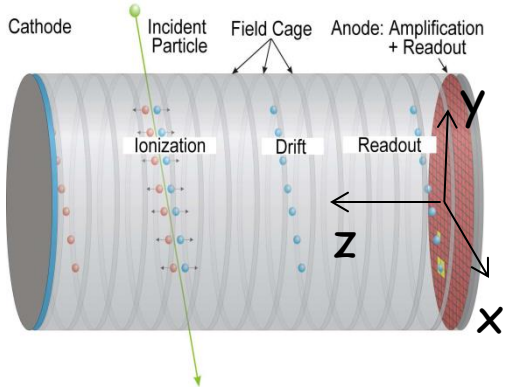
Cosmic ray calibration system



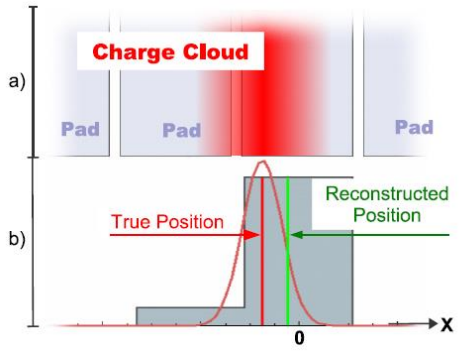
TPC - Time Projection Chamber

Operation Principle of a TPC

- Large gas filled volume.
- The cathode provides a negative potential, resulting in the field of the order of 100 V/cm in the sensitive area.
- Electrons drift towards the endcaps.
- Signal is amplified at endcaps.
- The x(Y)-coordinate is determined by a simple algorithm calculating the center-of-gravity of the hit charge.
- The drift time of electrons which read out by anode pad provide spatial information of z-coordinate.



Sketch of a TPC



Application of TPCs

- Three major fields of application:

1.) TPCs in High Energy Physics (ALEPH, Delphi, ILD)

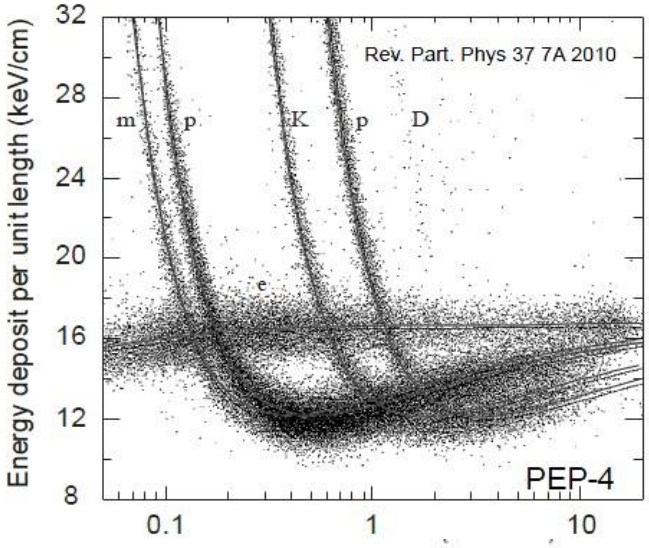
2.) TPCs in Heavy Ion Physics (STAR, ALICE)

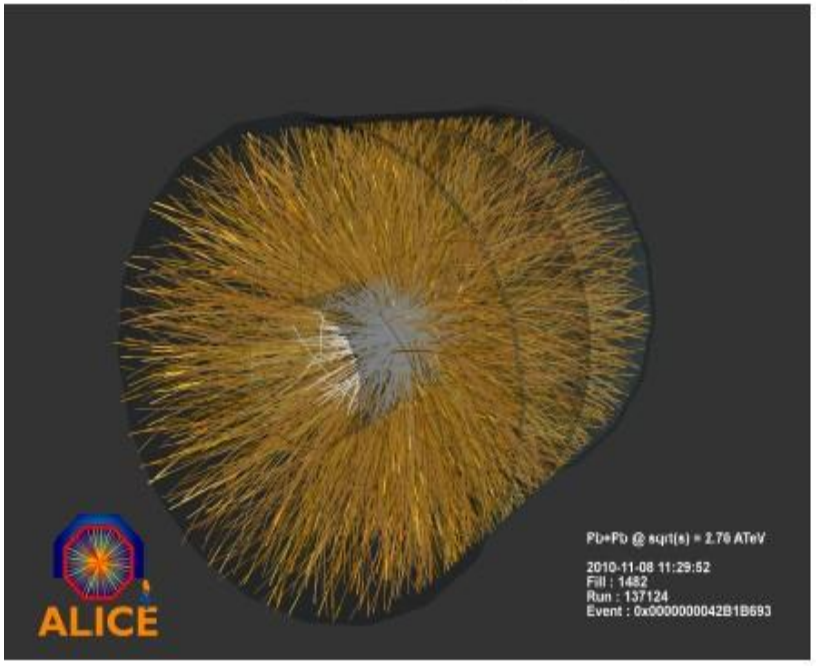
3.) TPCs in rare event searches (T2K, XENON, NEXT)

…….

Advantages of a TPC

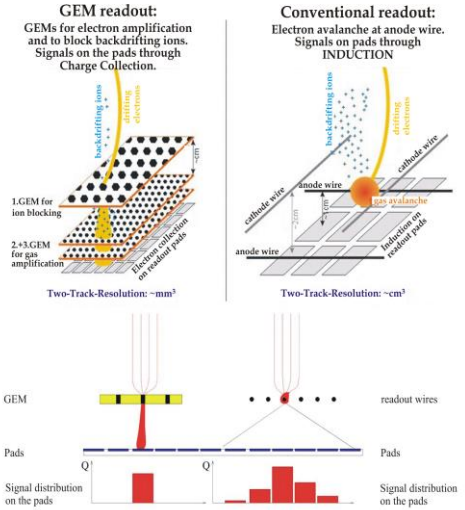
- Good spatial resolution
- Good energy resolution with de/dx
- Large number of measure
- Truly 3-dimensional detector
- Robust tracking in high multiplicity environment
- Very homogeneous (only gas)
- Comparably cheap





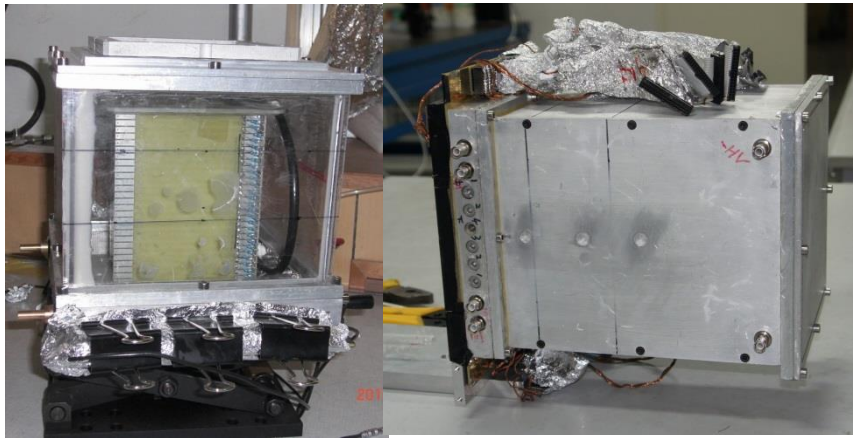
Advantages of MPGDs readout

- ion backflow can be reduced significantly
  => continuous readout might be possible
- small pitch of gas amplification regions (i.e. holes)
  => strong reduction of E × B-effects
- no preference in direction (as with wires)
  => all 2 dim. readout geometries can be used
- no ion tail => very fast signal (O(10 ns))
  => good timing and double track resolution
- no induced signal, but direct e--collection
  => small transverse width
  => good double track resolution

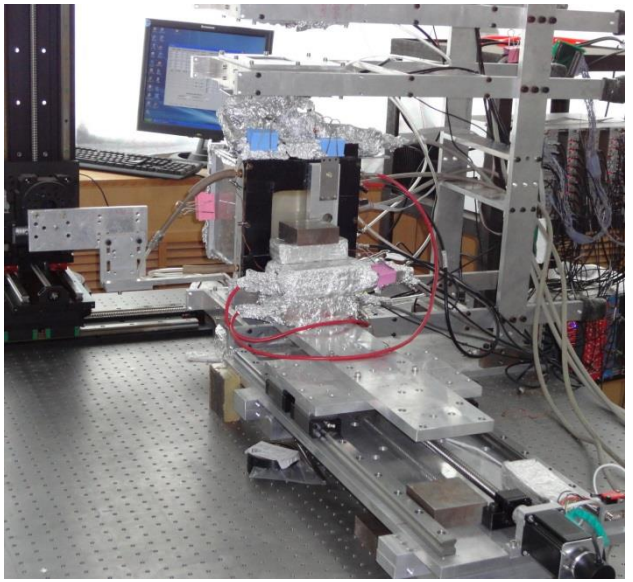


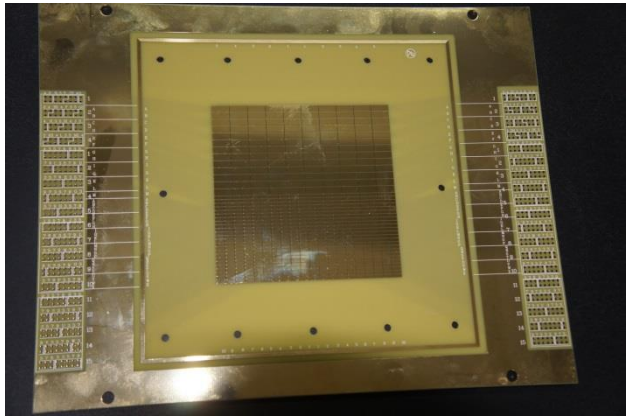
performance test based cosmic ray

data-acquisition system :SFE16+HPTDC



TPC: 100×100 sensitive area， 150mm drift length





Pad size: 2×5mm^2， 4×10mm^2

The cosmic ray calibration system was employed for the test.

The cosmic ray was measured by 3 MWPCs.

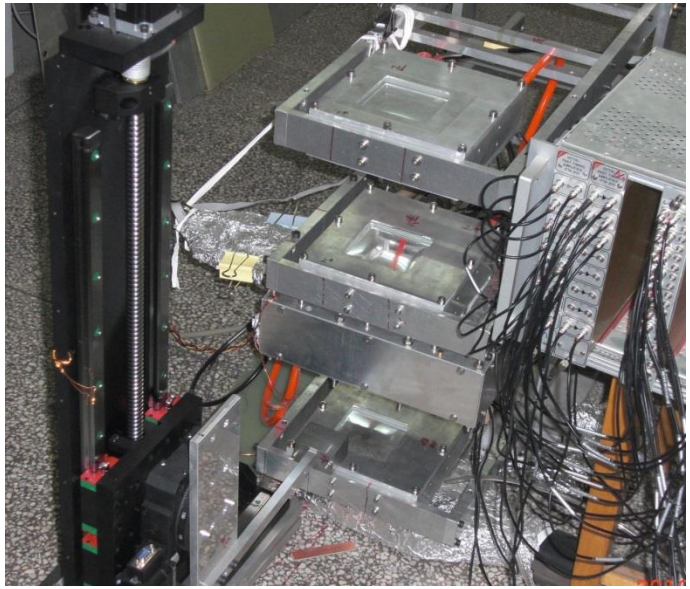
Start signal of cosmic ray was given by a plastic scintillator detector with 150mm*150mm area placed under 3rd MWPC.

electronics

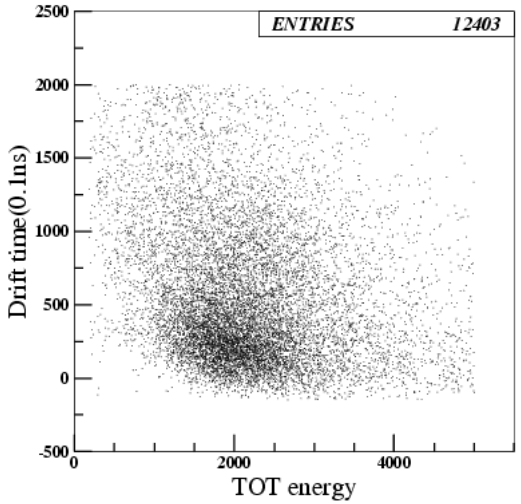
FEE
- SFE16 chip (TOT)
- 16 channels
- Amplification-shaping-discrimination
- Intermediate shaping time range

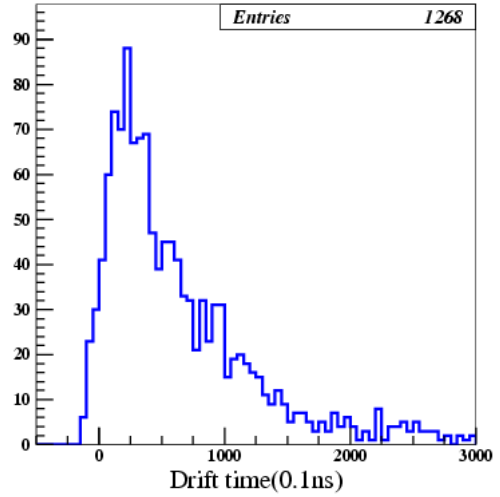
TDC card
- Based on HPTDC
- 128 channels
- PXI plug-un board
- 100ps precision

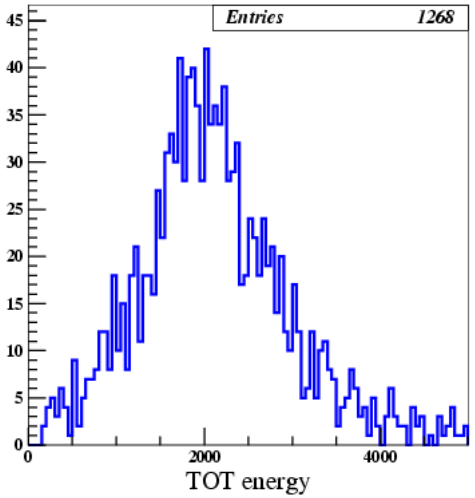
calibration system of the MWPC

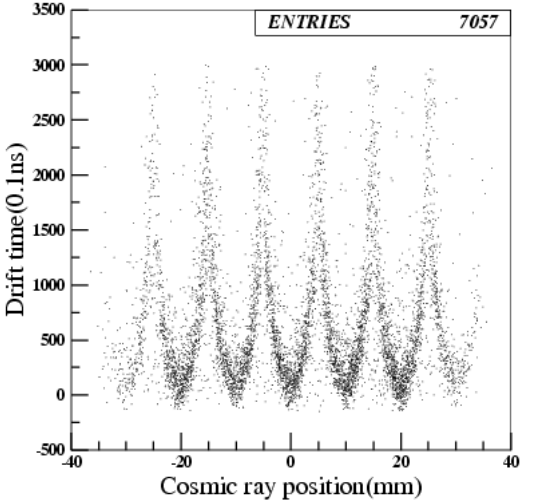


Cosmic ray was measured by 3 MWPC. The MWPC's sensitive area is 80mm*80mm, and position resolution σ_x and σ_y are about 250μm. Start signal of cosmic ray was given by a plastic scintillator detector with 150mm*150mm area placed under 3rd MWPC

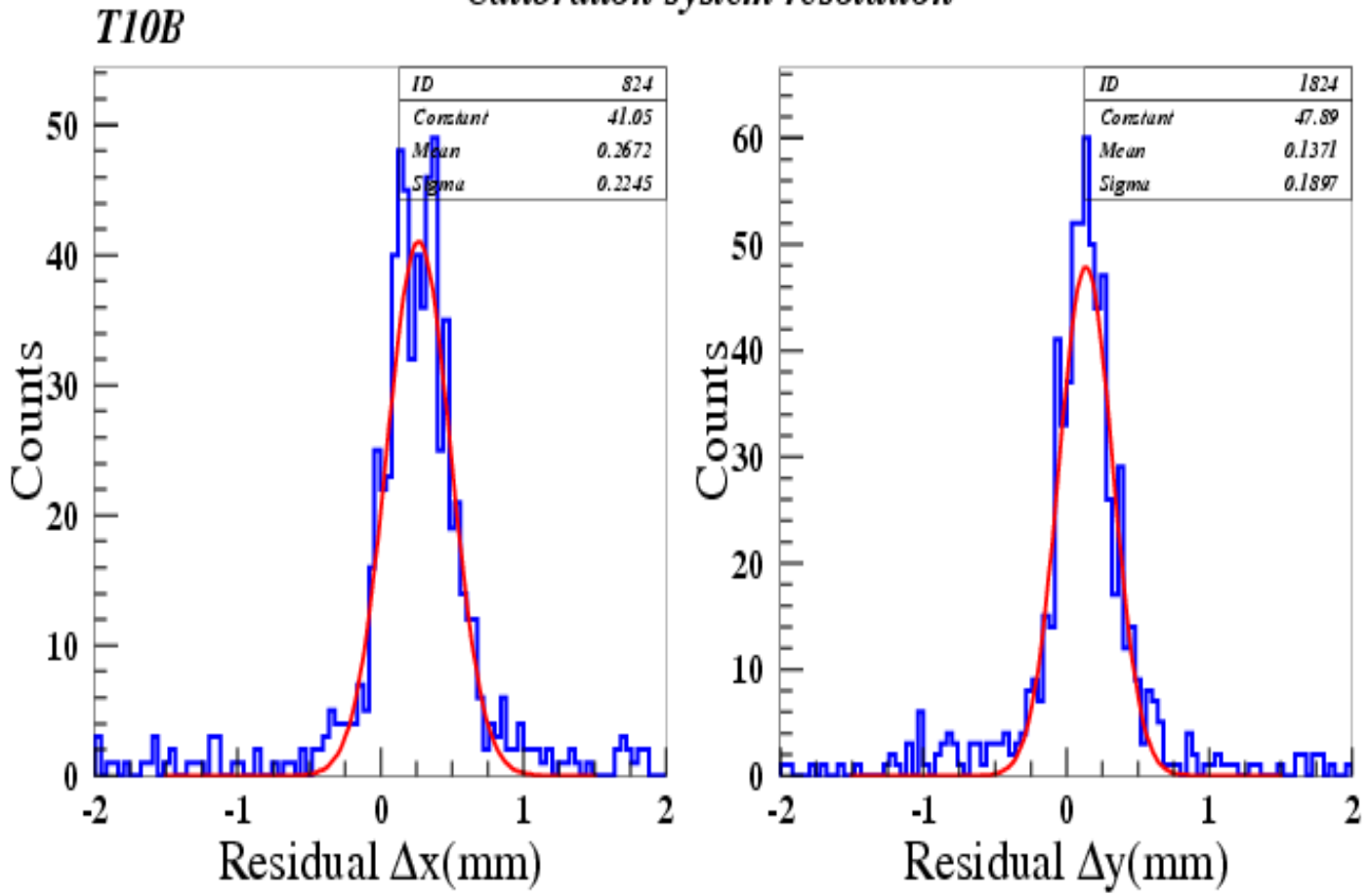




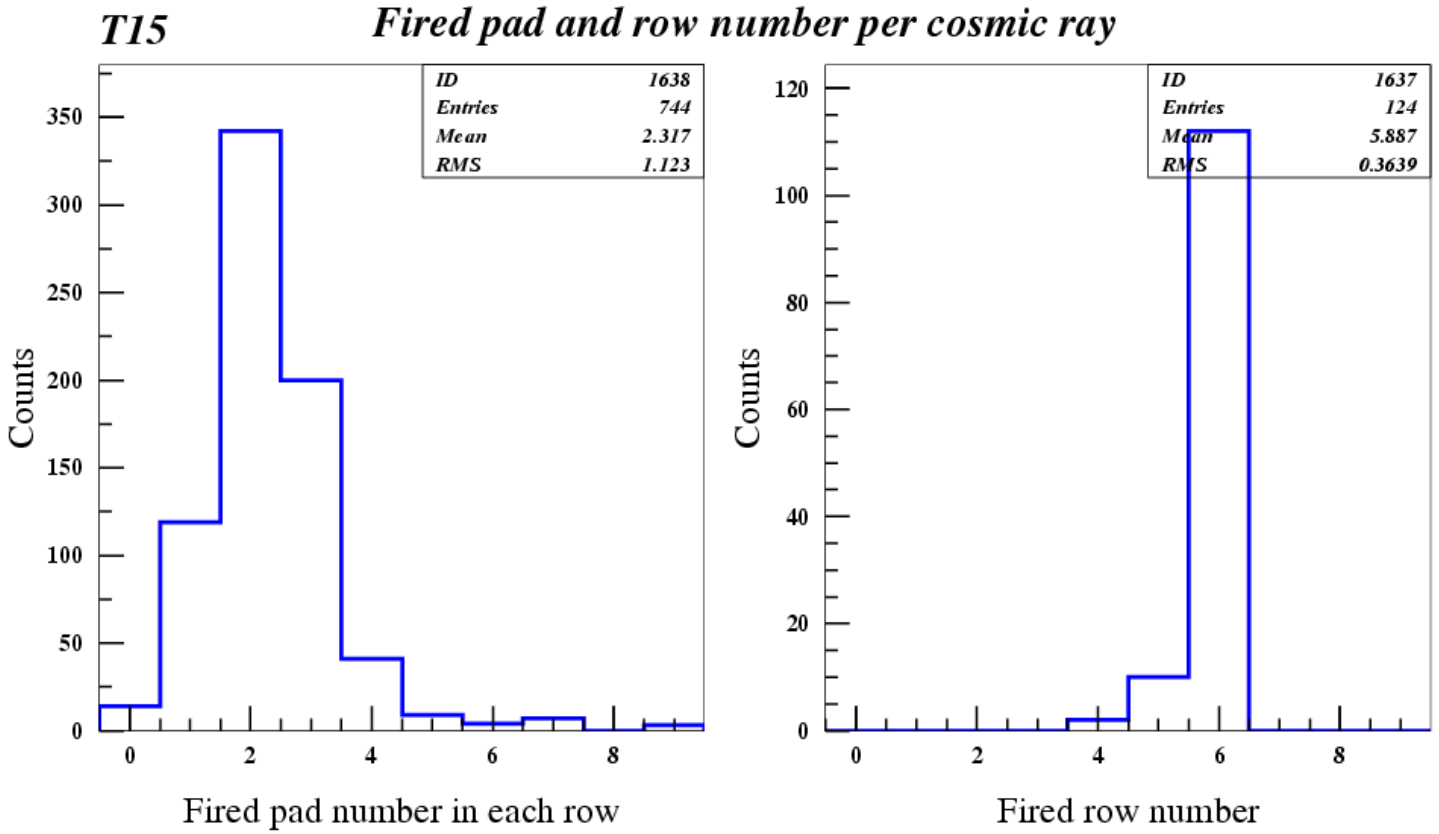




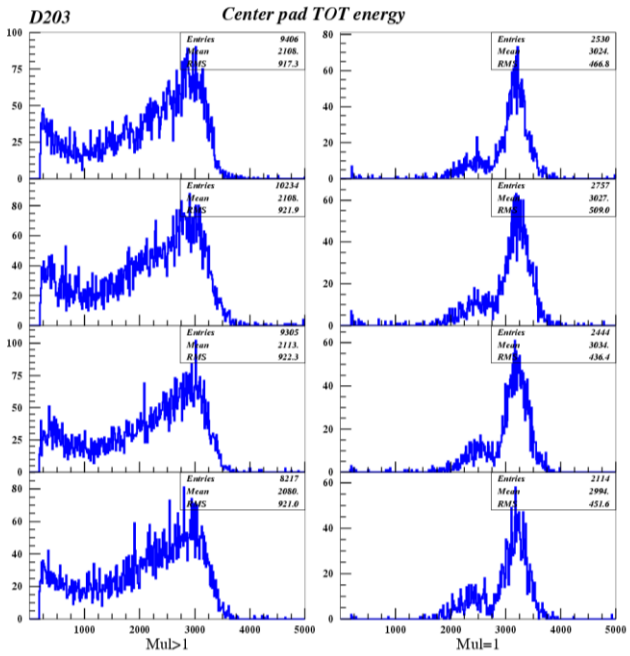
Calibration system resolution



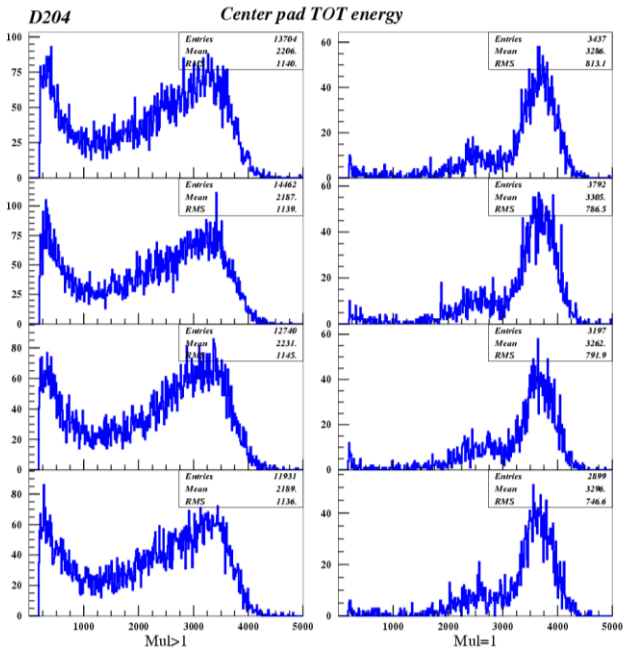
TPC result and analysis



5.9keV X-ray TOT energy spectra



Drift length=50mm

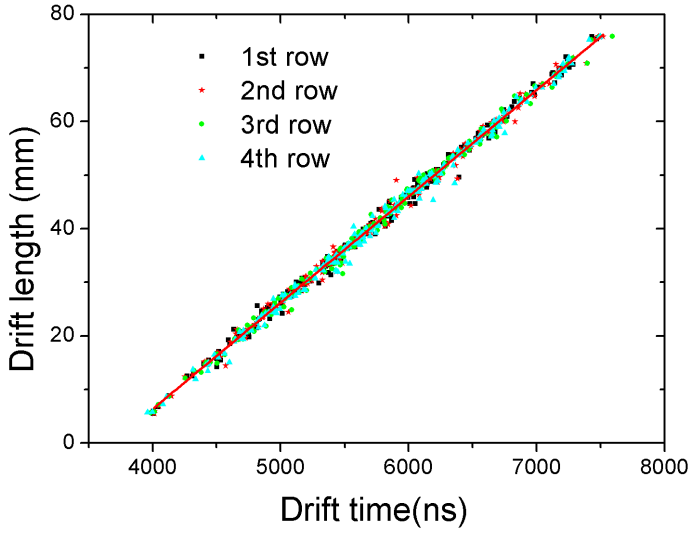


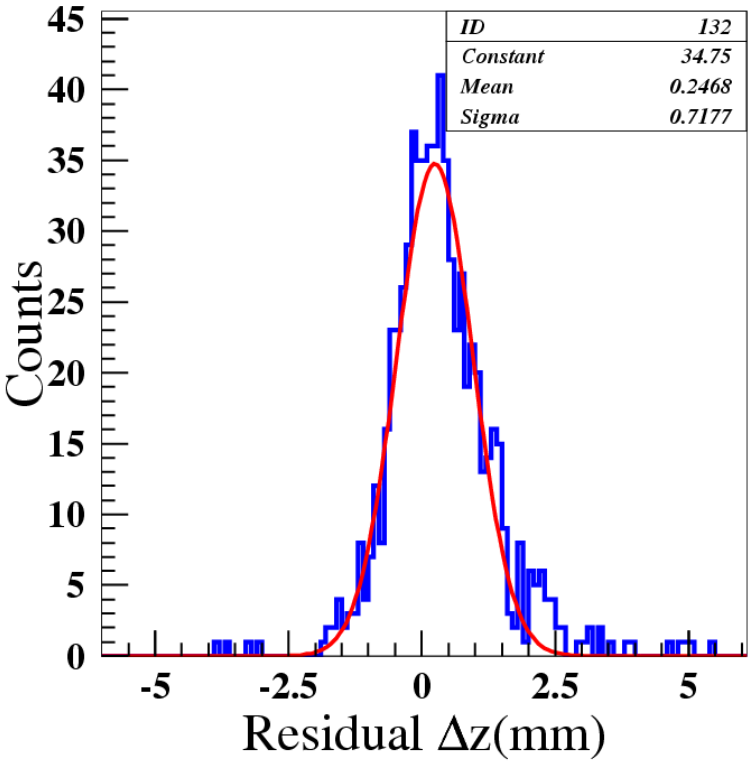
Drift length=100mm

5.9keV X-ray TOT energy spectra.

Left: fired pad>0; right: fired pad=1

E=83.5v/cm, HV=1370V, pad size 4×10mm^2, Gas: Ar+10%iC_4H_{10}; Pressure: 0.85bar





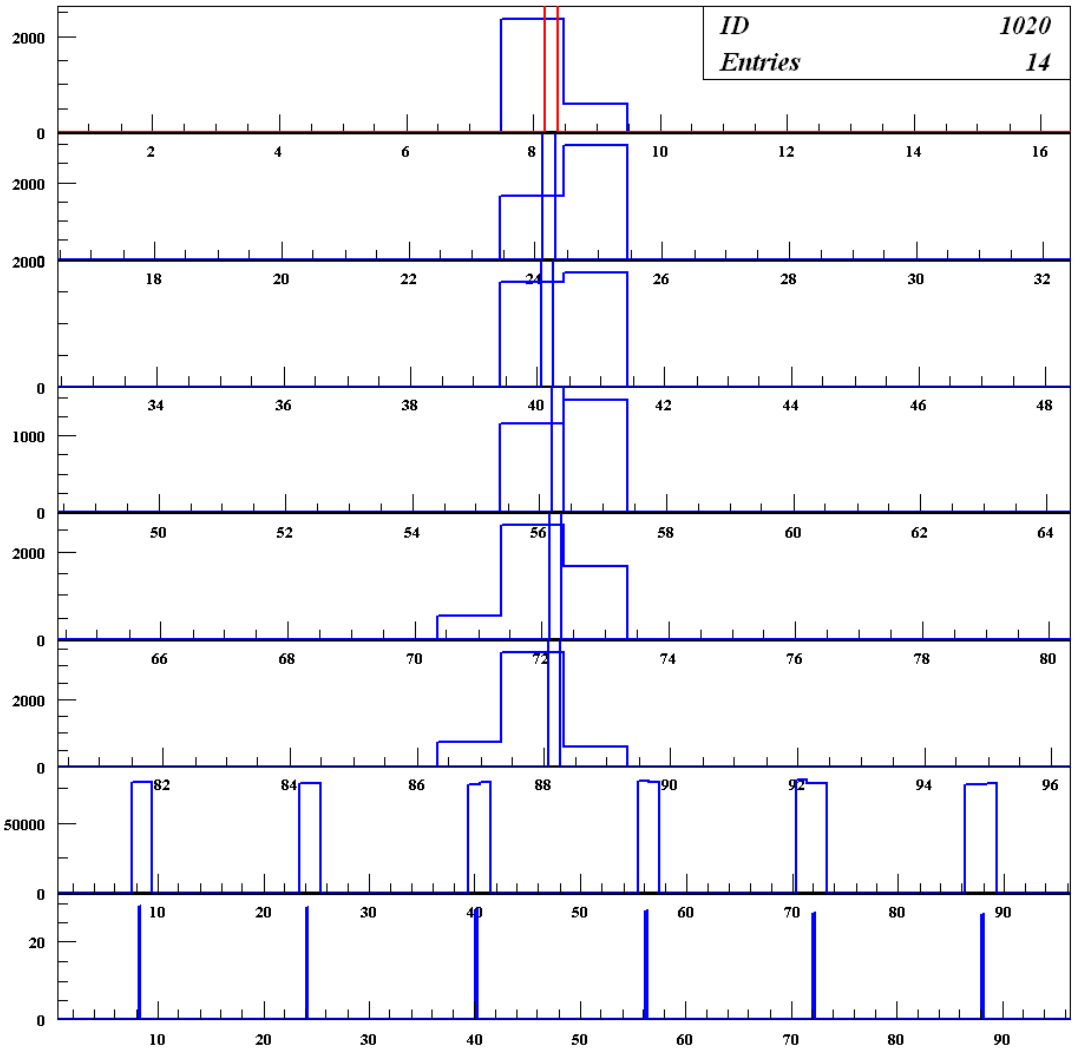
Drift length was given by MWPC ,and Drift-time was given by TPC pad.

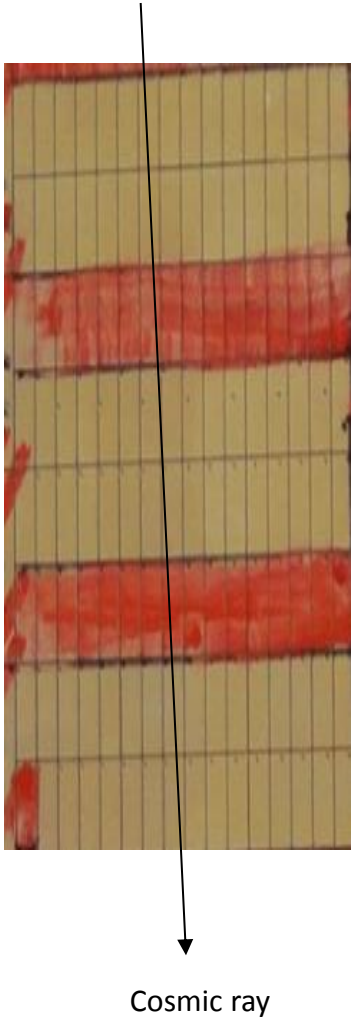
pad size 2×5mm^2, E=130V/cm, HV=1570

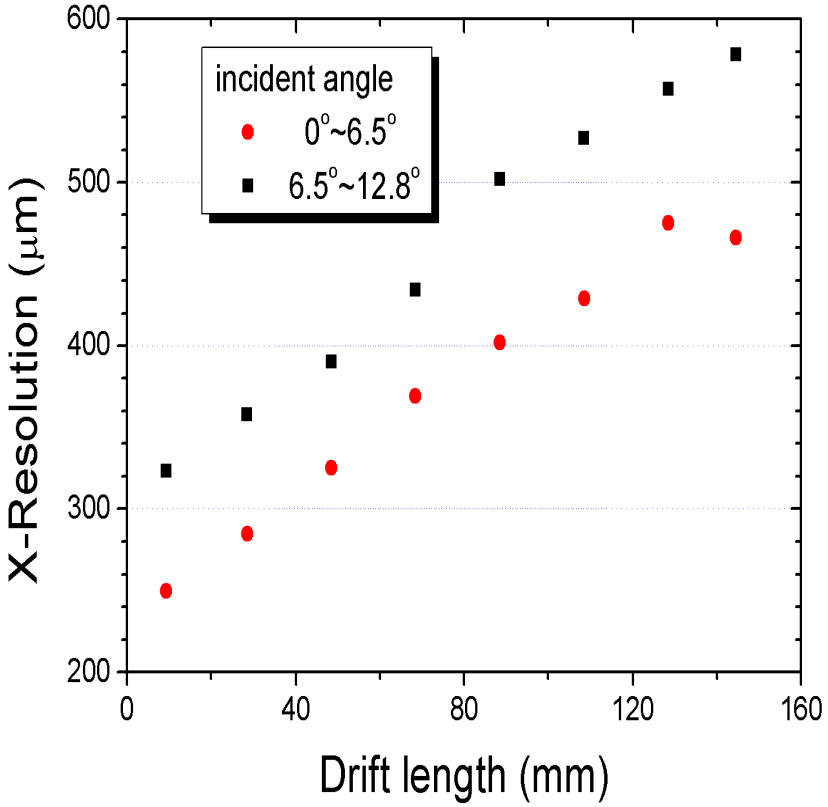
One cosmic ray: histogram is for TPC; the thin one is for mwpc.

drift time is from the tpc，starting time given by PMT

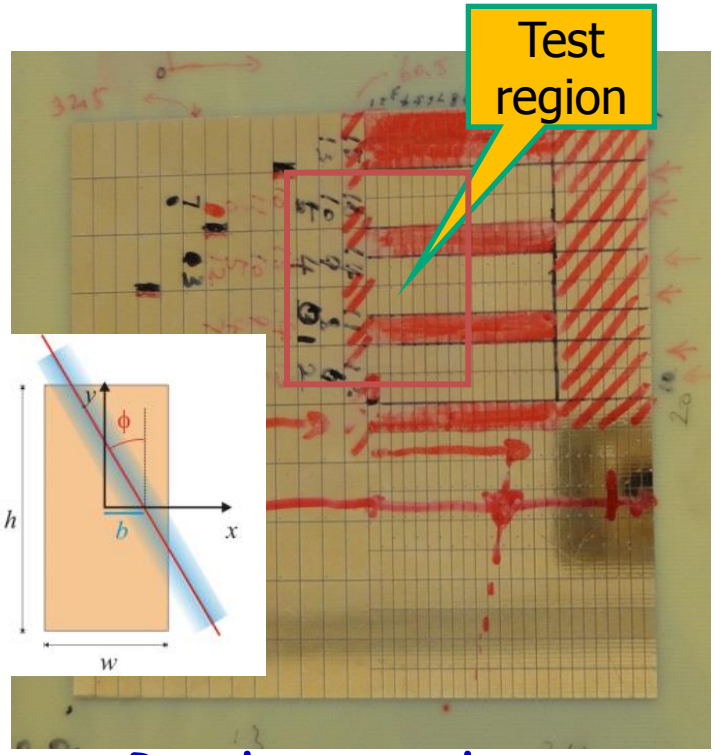
Drift distance is from the mwpc







Drift length was calculated from drift time

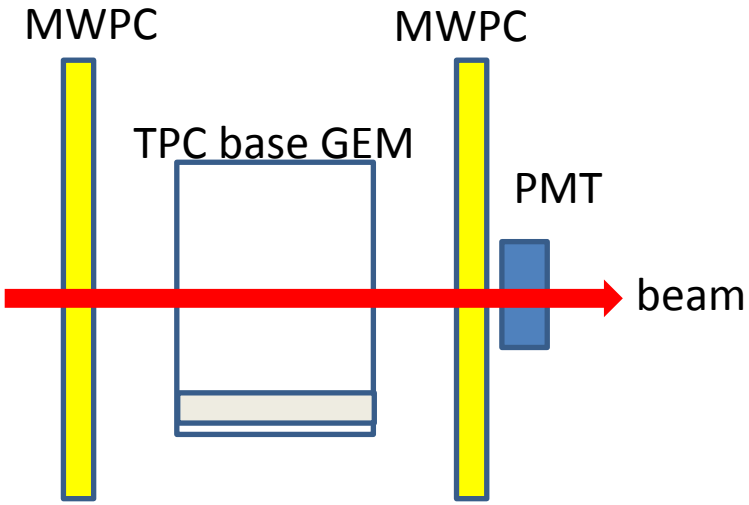


Readout anode

Test region: 6 rows,
each row including 16 pads

Pad size: 2×5mm^2,E=130V/cm, HV=1570

Beam Experimental setup

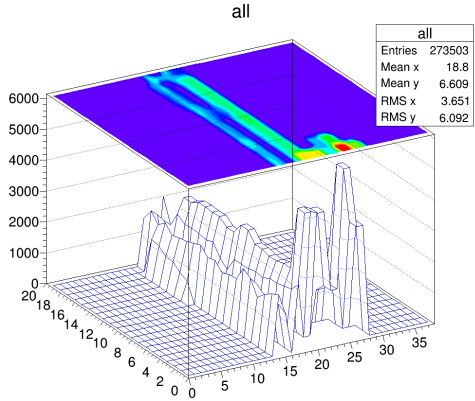


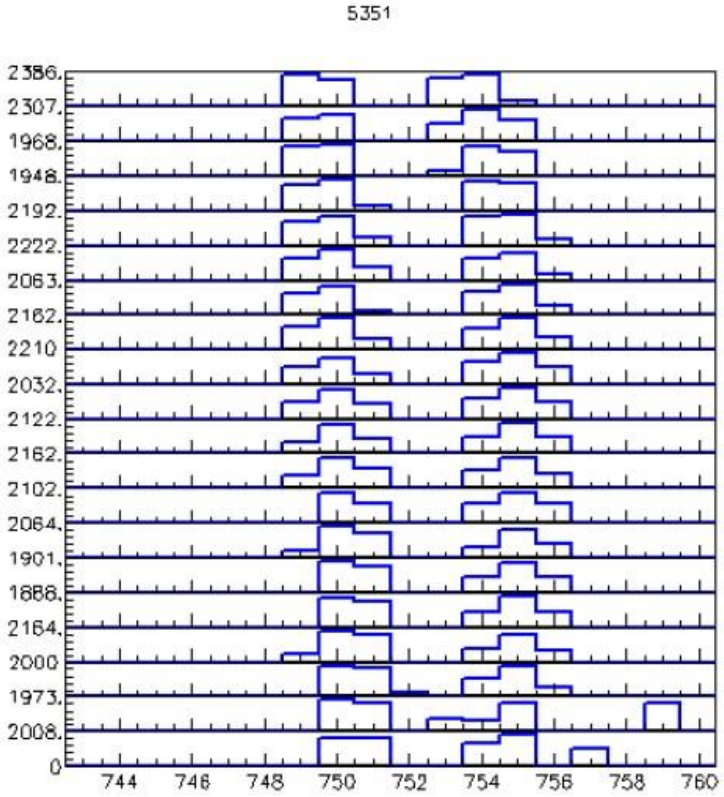
data-acquisition system :SFE16+HPTDC

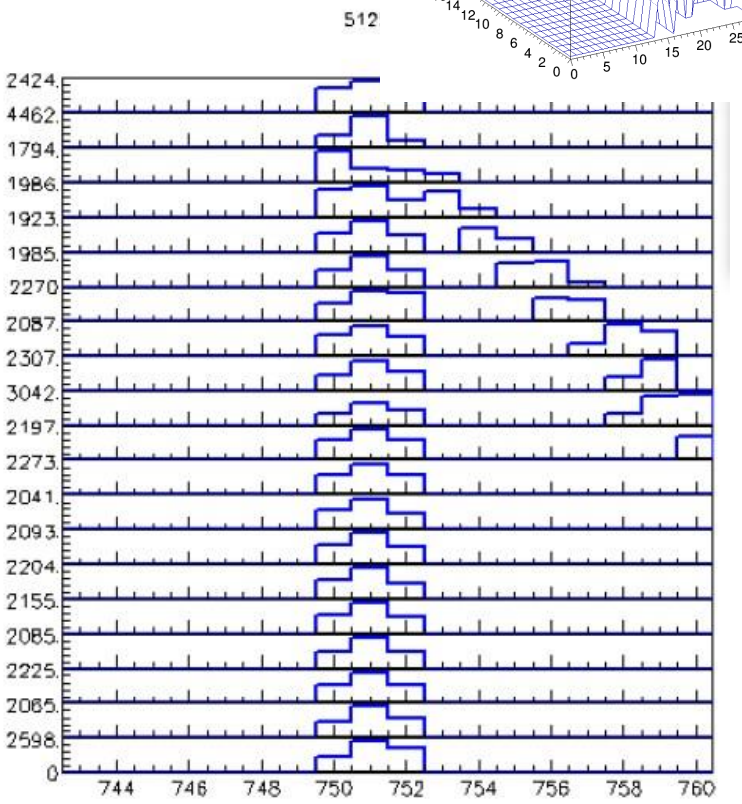
Prototype : TPC

- Sensitive volume: 10.0 x 10.0 x 15 cm3
- Triple-GEM amplification structure
- pad planes:448
  (size: 2.0 x 5.0 mm2 and 4.0 x 10.0 mm2)
- No Magnetic field

Double track events



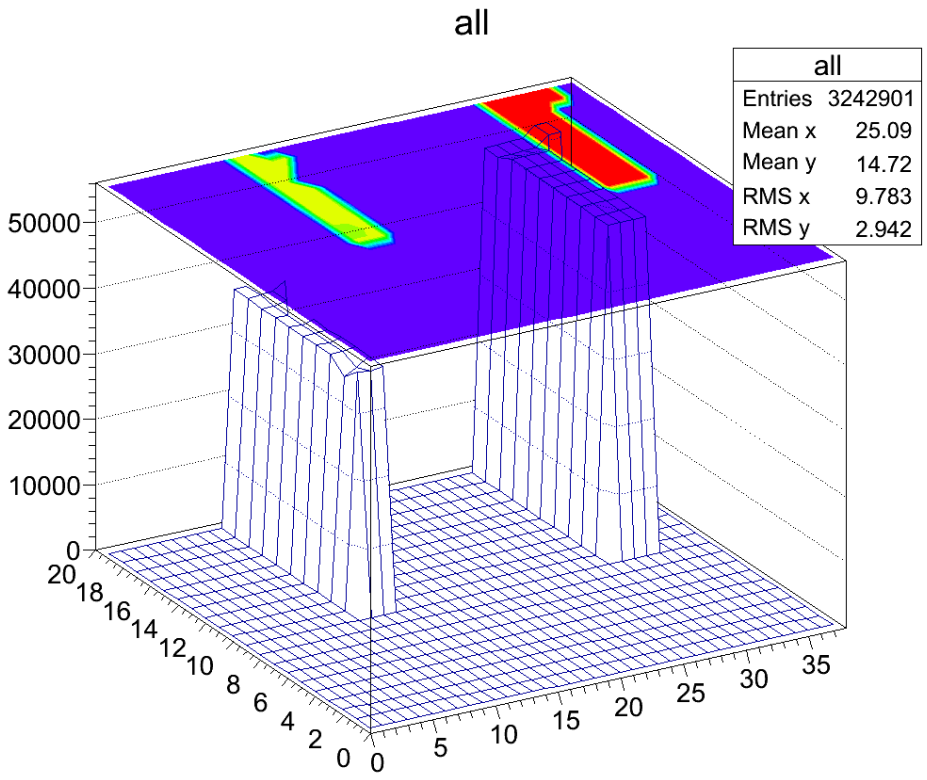




TPC 测量到的 2 个双径迹事件。

drift time

- drift velocity :~3cm/μm for Ar+iC_4H_{10}(20%)
- Z position： ~6cm



Summary

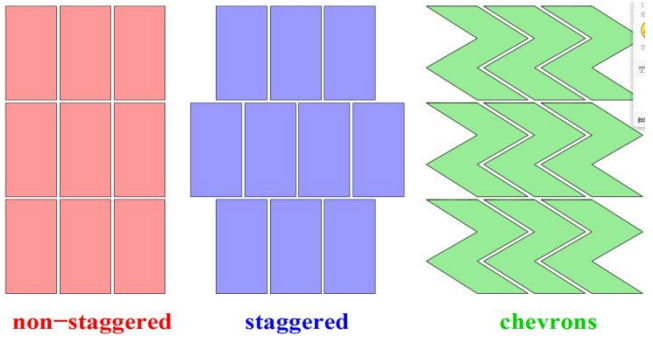
- Time Projections Chambers have been invented 27 years ago
- Wire-based TPC are still widely used – for example in heavy ion physics
- MPGDs give a new boost to the TPC R&D: Improved spatial resolutions, intrinsic ion back flow suppression are only two of many advantages.
- performance test used cosmic ray and beam for TPC based GEM
- **New measurement runs**

  add Magnetic field

  change pad size or style

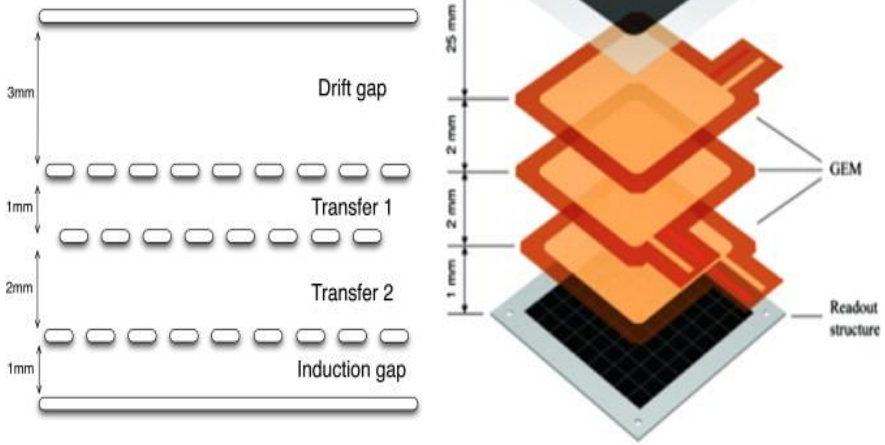
  big Sensitive volume

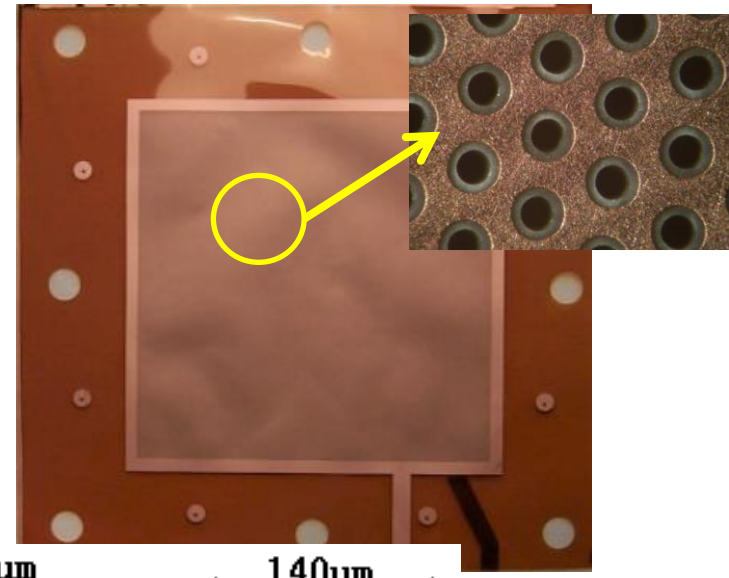
  …….

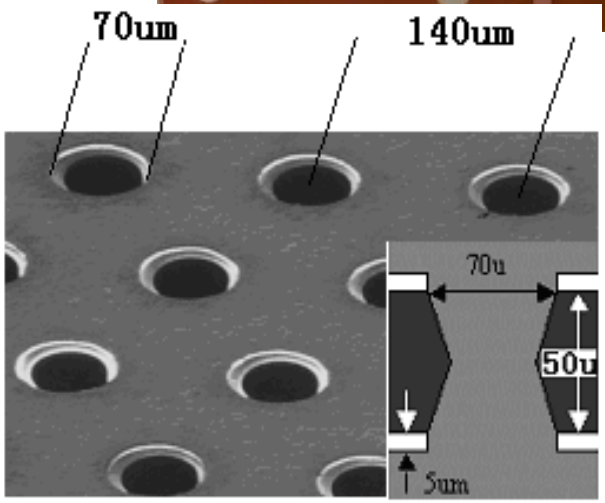


Thanks!

GEM结构图示





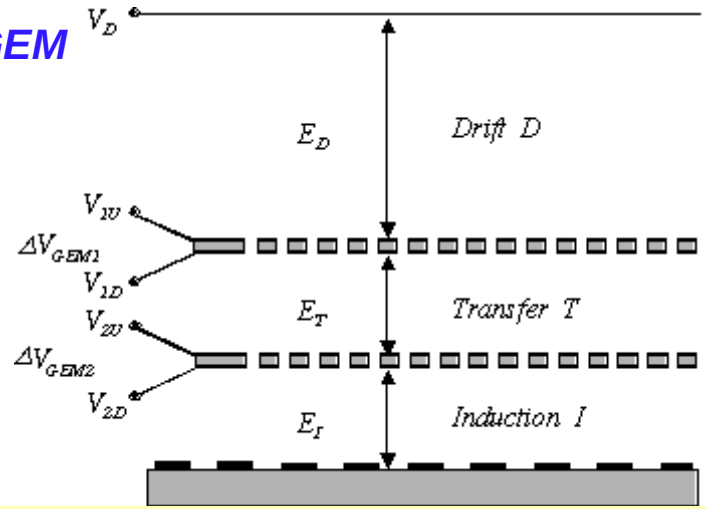


Typical geometry:
5 µm Cu on 50 µm Kapton
70 µm holes at 140 mm pitch

F. Sauli, Nucl. Instrum. Methods A386(1997)531

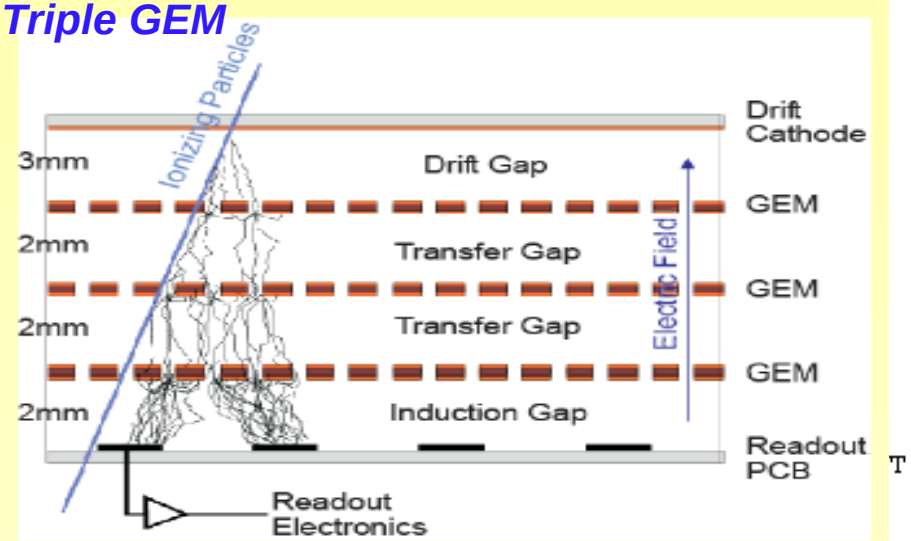
GEM结构图示

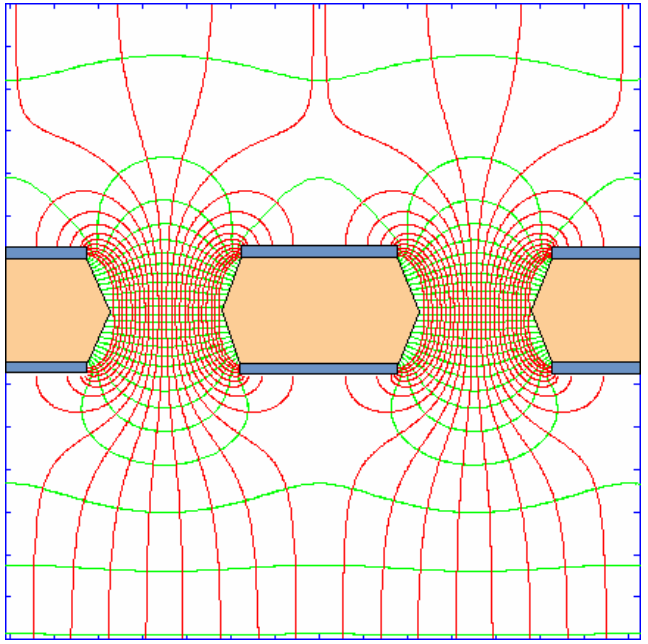
Double GEM



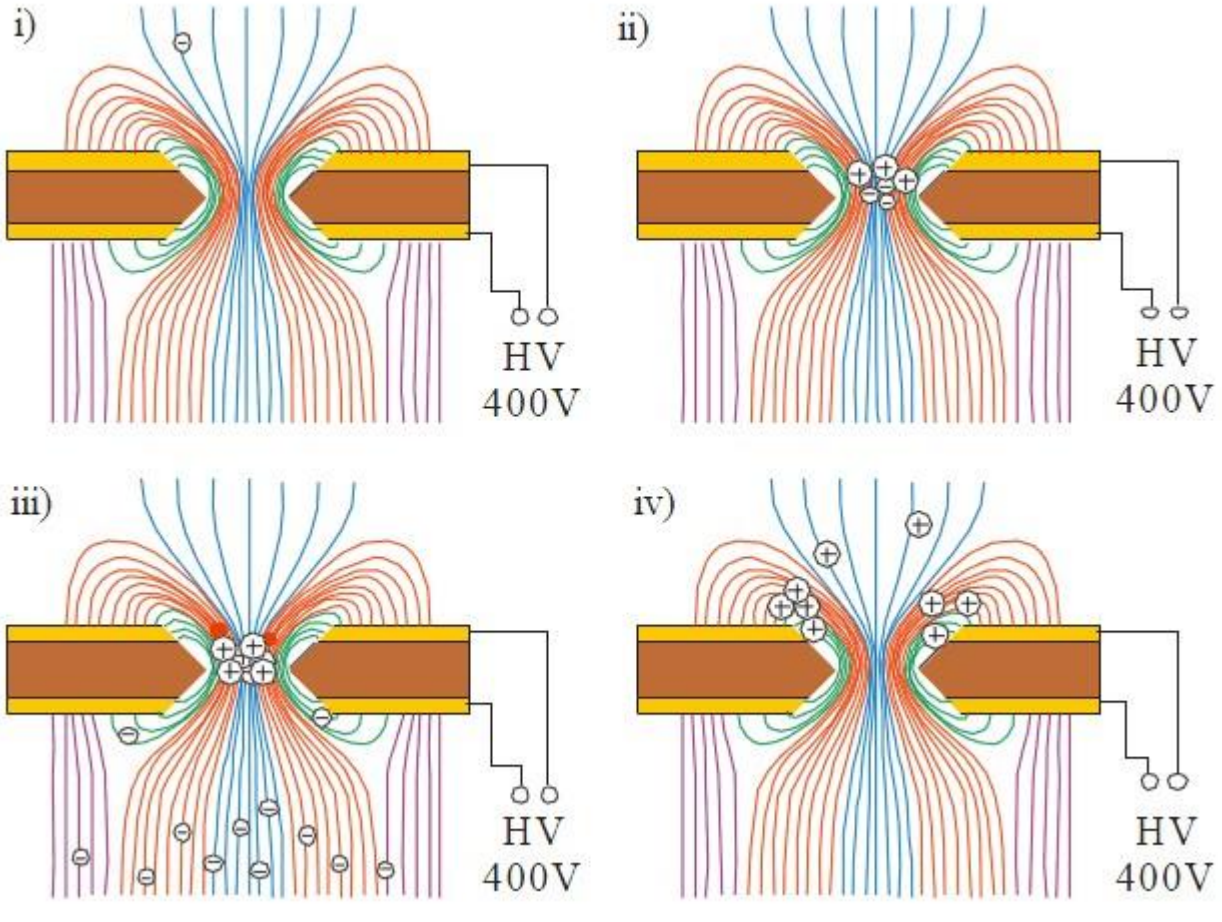
- higher gain at lower GEM voltages
  [S. Bachmann, B. Ketzer et al., NIM A479, 294 (2001)]
- discharge prevention
  [B. Ketzer et al., IEEE Trans. Nucl. Sci. 48, 1065 (2001)]
- no aging up to 7 mC/mm^2
  [C. Altunbas, B. Ketzer et al., NIM A515, 249 (2003)]

Triple GEM





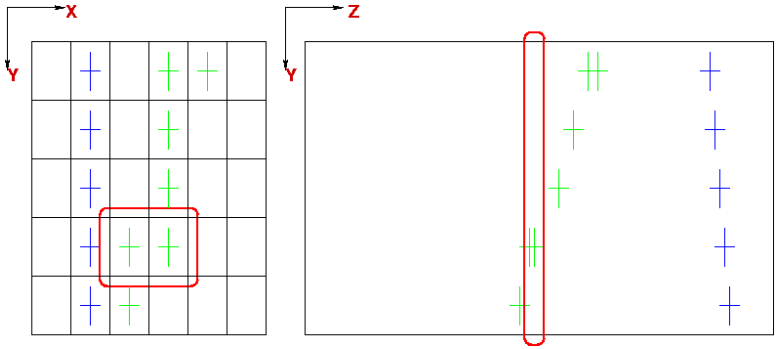
C. Buttner et al, Nucl. Instr. and Meth. A 409(1998)79
S. Bachmann et al, Nucl. Instr. and Meth. A 443(1999)464



A)0 clean room.
C loes, masks ...)

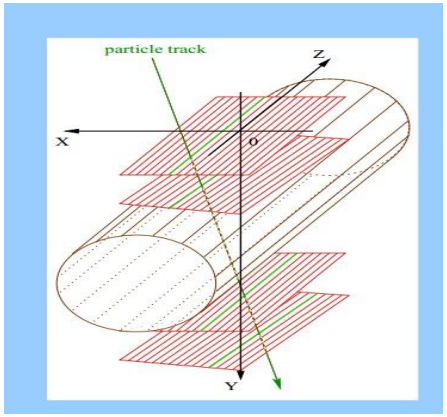
calculate hit coordinates

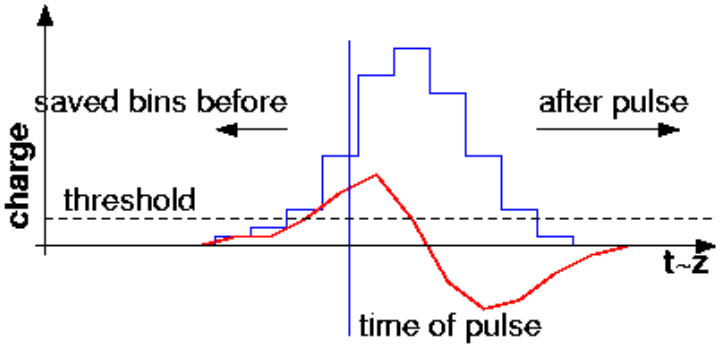
- x: center of gravity (charge)
- y: center of the row
- z: error weighted mean of time of pulses



Find pulses in raw data:

- detect pulses by threshold
- time: inflexion point of rising slope





Standard MWPC readout: potential limitations

- Planar construction

– Planarity must be insured between amplification and collection

- Width of PRF

– Limits resolving power / track density and/or event rate

- Pad/wire angular effects

– Limits usefulness for largeangle tracks

- Ion backflow in the drift region

– Limits track density / event rate

- S/N, calibrations, gain fluctuations,...