Micro Pixel Chamber Operation with Gas Electron Multiplier

Kyoto University dept. of physics
Cosmic-ray group
K. Hattori

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Advanced Compton Camera
based on Micro Pixel Chamber (µ-PIC)

sub MeV ~ MeV gamma-ray
Compton scattering is dominant

micro-TPC
energy and track of a recoil electron

scintillator (surrounding micro-TPC)
energy and position of a scattered gamma-ray

1 photon : reconstruct completely energy & direction

low background images
Improvement of micro-TPC

Position Sensitive Detectors
μ–PIC (Micro Pixel Chamber) & micro-TPC

2-dimensional imaging gaseous detector
(pitch 400μm, size 10cm × 10cm)
larger one: Takada’s poster

Max gas gain \( \sim 15000 \)

Stable operation
\( @ \text{gas gain} \sim 6000 \)

position resolution
\(~ 120\mu m\)

Electric field

micro-TPC
Time Projection Chamber based on μ-PIC

Position Sensitive Detector
For MIP (Minimum Ionizing Particle) detection...

Compton camera · · · · detection of recoil electron by micro-TPC

Recoil electron $dE/dx \sim 2 \sim 3 \times \text{MIP}$

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<th>µ-PIC</th>
<th>stable operation</th>
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<td>@ gas gain 6,000</td>
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Stable gas gain $> 2 \times 10^4$

(We haven’t achieved because of discharge)

Sub amplification device

GEM (Gas Electron Multiplier) F. Sauli (1997)

Operated @ low gas gain (< 50)

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GEM + μ-PIC system

-HV

10MΩ

5MΩ

-drift plane

electron cloud

7.5mm 0.5kV/cm polyimide (50μm)

5mm 2kV/cm GEM

GEM installed just above μ-PIC

Standard GEM design

Mask developed by Hamagaki Lab. @ CNS Univ. of Tokyo

Plasma etching method @Fuchigami Micro Co., Ltd.

Holes with cylindrical shape
**gas gain**

**spectrum**

- Total Gain
- GEM Gain

**requirement**

**Ar** 90% C$_2$H$_6$ 10% with gas flowing

**Energy [keV]**

- 20% (FWHM) @ 5.9 keV
- gain $1.3 \times 10^4$ (1.6 cm$^2$)

**Total Max Gain** $\sim 10^5$

**GEM Max Gain** $\sim 300$

- $\mu$-PIC gain fixed $2.6 \times 10^3$

- enough to detect tracks of MIPs!
Positive ion feedback

Fractional ion current $I_D/I_A$

$I_D$ : the ion current on the drift plane

$I_A$ : the electron current on anodes of µ-PIC

the dependence of the fractional ion current on the gain of the GEM

Ion feedback less than 10%

@ gas gain > 10

without GEM 30%

µ-PIC 30% × GEM 30% → total 10%

GEM suppresses the positive ion feedback in a drift region

Potential of µ-PIC + GEM system for high-rate condition operation
A GEM + $\mu$-PIC TPC -muon track-

$\mu$-PIC Ar 90%
C$_2$H$_6$ 10%
e- drift plane
e- coincidence for muon trigger
at total gas gain of $2 \times 10^4$

GEM 2.5kV/cm 0.2cm 8cm 0.4kV/cm
Cosmic $\mu$

track efficiency
(hit point $> 3$) / (trigger) 97%

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Position resolution

Difference between hit points and tracks obtained from fitting

2-dimensional Gauss distribution
(the position resolution in the direction of a track is unknown)

\[
\frac{\sqrt{2\pi}}{\sigma} r \exp\left(-\frac{r^2}{2\sigma^2}\right)dr
\]

\[\sigma \sim 370\mu m\]

transverse diffusion 460\mu m
Z-pitch (DAQ clock) \sim 400\mu m
reasonable

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Summary & Future Works

µ-PIC + GEM

- stable gas gain of $2 \times 10^4$, ion feedback < 10%

µ-PIC + GEM TPC

- Fine tracks of MIPs were obtained.
  - track efficiency 97%
  - position resolution 370µm

Future Works

µ-PIC & GEM with a larger detection area
about 30cm × 30cm (takada’s poster)

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Performance of \( \mu \)-PIC (Micro Pixel Chamber)

2-dimensional imaging
gaseous detector

anode 256 × cathode 256
\(~ 65000\) pixels

Max gas gain \(~ 15000\)

Stable operation for 1000h
(gas gain \(~ 6000\))

Energy Resolution
30\% (FWHM)@5.9keV(100cm\(^2\))

Position resolution
\(~ 120\mu m\)

\( \mu \)-PIC is on Position Sensitive Detectors
Performance of $\mu$–PIC
- uniformity -

$\sigma \sim 7\%$
μ-TPC
(Time Projection Chamber based on μ-PIC)

Electron cloud  Electric field  10cm × 10cm μ-PIC
2-D hit position (Analog & digital)

Electric field  100MHz encoder  3-D tracking

Applications
Compton camera (recoil electron)
Dark Matter search

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• DAQ system

μ-TPC → ASD → Encoder

512ch digital

summed analog (8ch)

VME Memory Board

VME FADC 100MHz 8ch

memory Detectors
Mask by Hamagaki Lab.
@ CNS Univ. of Tokyo

Plasma etching method
@Fuchigami Micro Co., Ltd.

Holes with cylindrical shape

CERN:
holes with a double-conical shape

CNS-GEM

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Setup

How to glue a GEM

G10 frame

Glued with epoxy (Araldite)

weight

-HV

10MΩ
drift plane

7.5mm 0.5kV/cm

GEM

5MΩ

5mm 2kV/cm

μ-PIC

aging

In dry nitrogen gas

\[ \Delta V_{\text{GEM}} \sim 500\text{V} \]
Dependence of total gain on induction field

$\Delta V_{\text{GEM}} = 250\text{V (gain 10)}$

$E_D = 0.5\text{kV/cm}$

plateau wasn’t observed

the system unstable @ gas gain of $\sim 10^5$

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Long-term gas gain stability

μ-PIC 6% for 70h

The gain increased 50% for 120h
Performance of micro-TPC
- uniformity -
Performance of Hybrid micro-TPC
- gamma – ray –

micro-TPC energy
13%\textasciitilde20\text{keV}(\text{FWHM})

μTPC number of sampling
Points for one electron track

X-ray from Cu electrode in μPIC