Micro Pixel Chamber Operation with Gas Electron Multiplier

Kyoto University dept. of physics

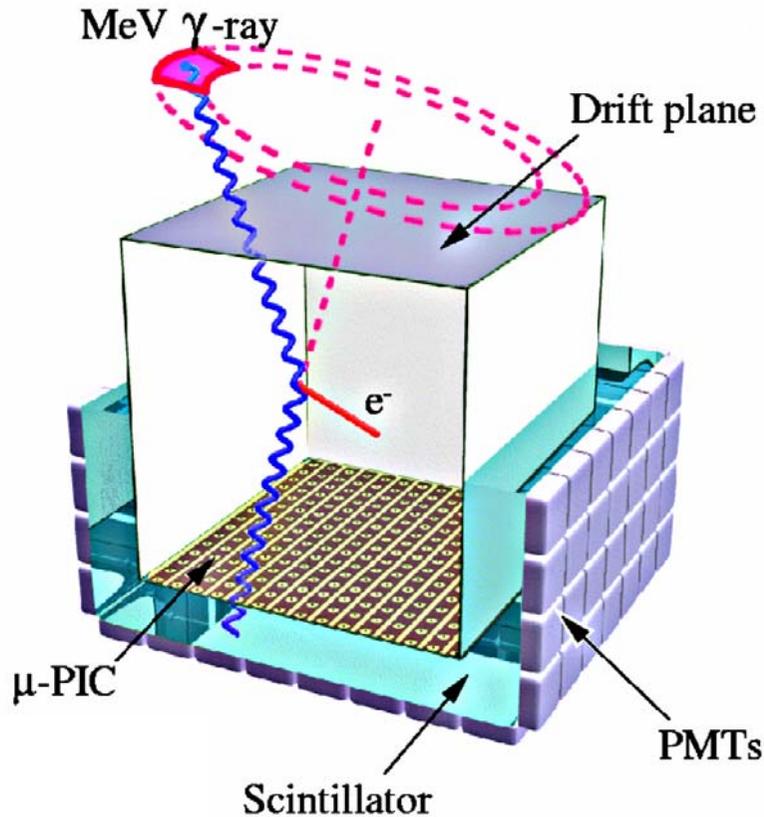**Cosmic-ray group**

K. Hattori

Contents

1. μ -PIC (Micro Pixel Chamber),

    micro-TPC (Time Projection Chamber based on μ -PIC)

2. For detection of MIPs

    μ -PIC + GEM (gas electron multiplier)

3. Performance of GEM + μ -PIC TPC

4. Summary

7th International Conference on Position Sensitive Detectors

γ-ray Detecter
μ-PIC
MPGC TECHNIQUE

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

1photon : reconstruct completely
              energy & direction

low background images
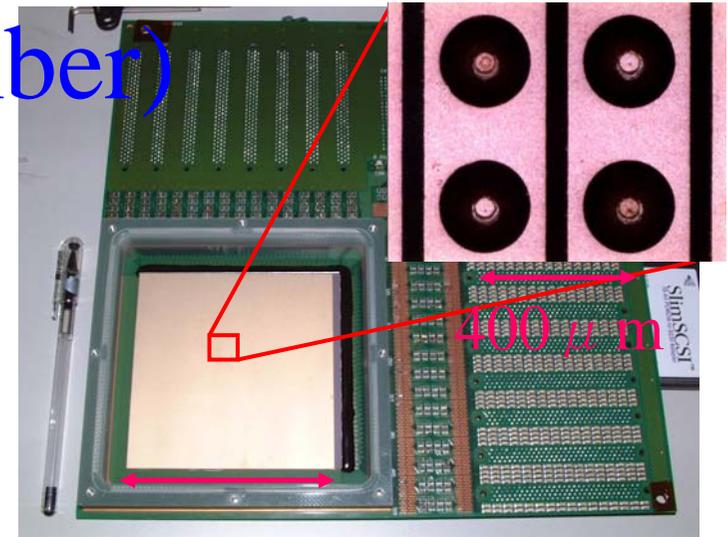Improvement of micro-TPC

Position Sensitive Detectors

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

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

Max gas gain ～ 15000

10cm

400 μ m

Stable operation
@gas gain ~ 6000

position resolution
~ 120 μ m
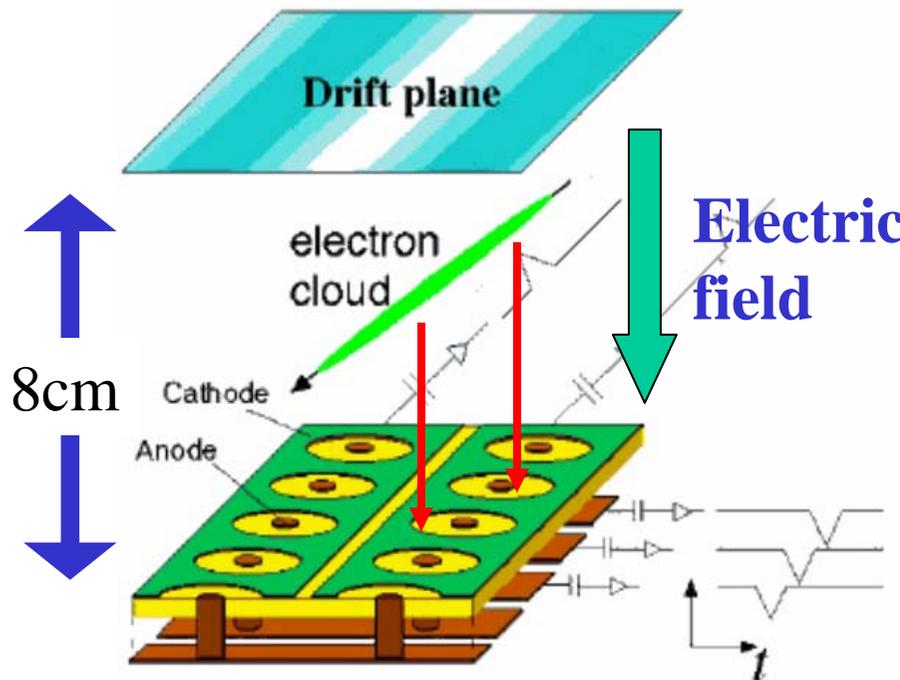
Drift plane

electron cloud

Electric field

8cm

Cathode

Anode

t

micro -TPC
Time Projection Chamber based on μ -PIC

Position Sensitive Detec

drift [cm]

anode [cm]

cathode [cm]
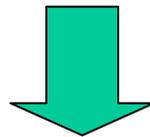
electron

proton
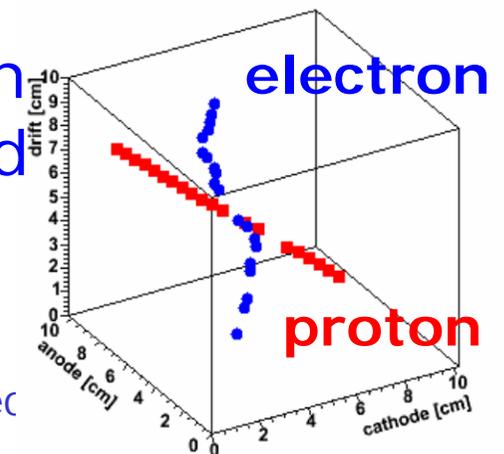
For MIP(Minimum Ionizing Particle) detection…

Compton camera ····· detection of **recoil electron**

by micro-TPC

Recoil electron dE/dx $\sim$ $2 \sim 3 \times$ MIP
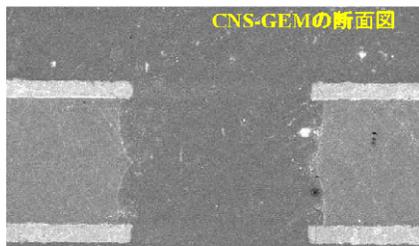
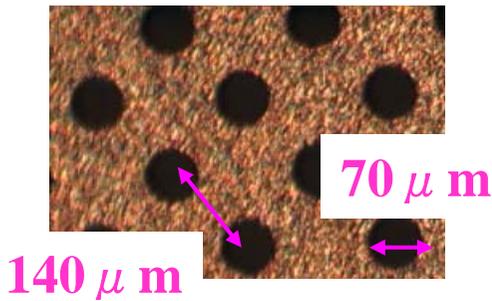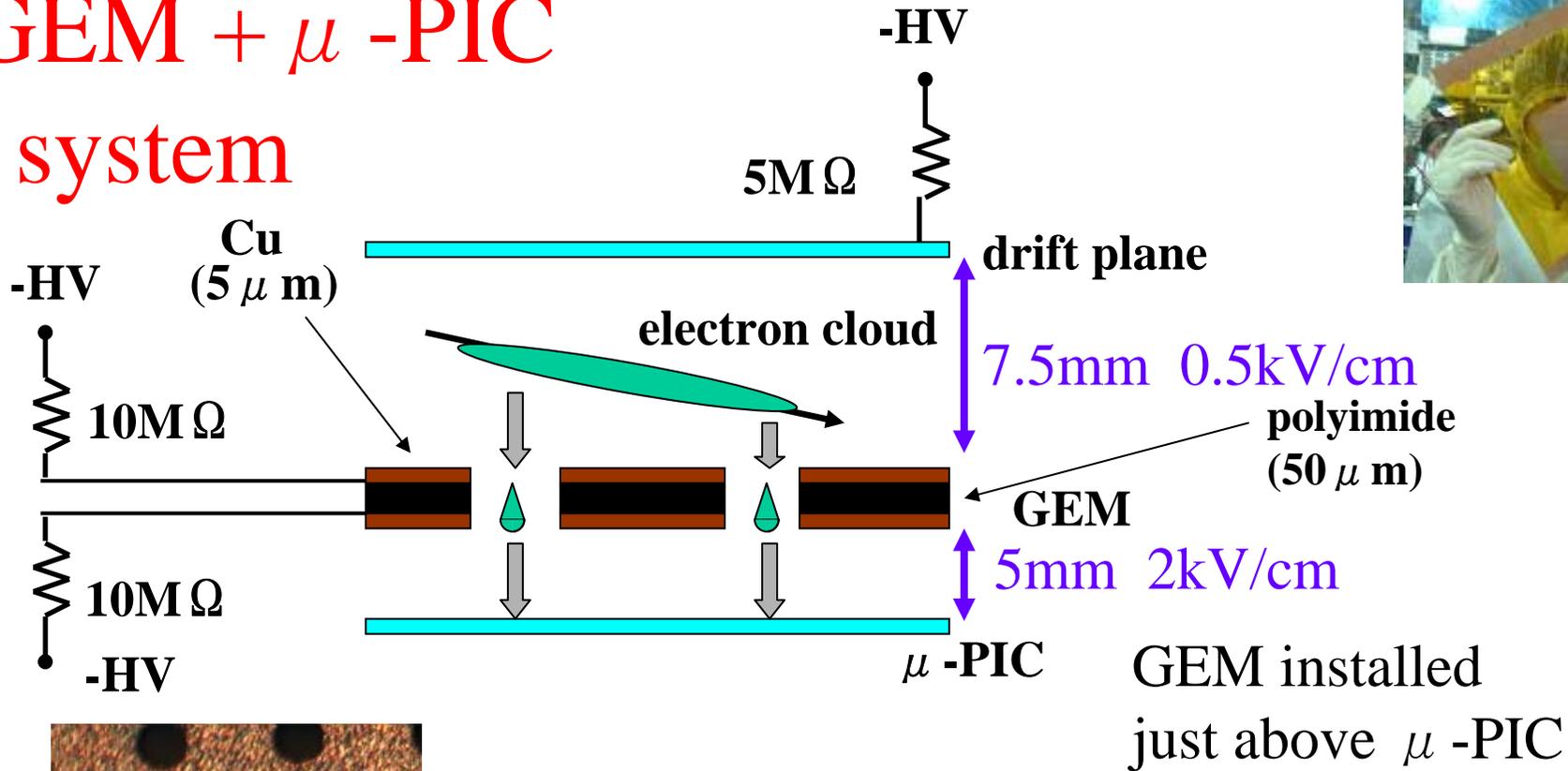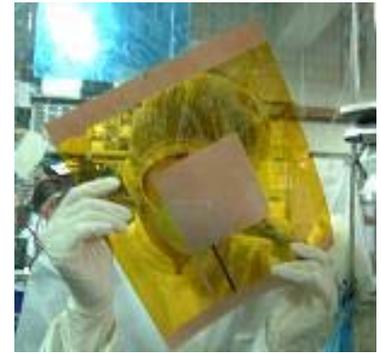**μ-PIC** $\Rightarrow$ **stable operation**

@ gas gain 6,000

Stable gas gain $> 2 \times 10^4$

(We haven't achieved because of discharge)

$\Rightarrow$ **pre- amplification device**

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

Operated @ low gas gain(< 50)

γ-ray Detecter
μ-PIC
MPGC TECHNIQUE

GEM + μ -PIC system

-HV

5M Ω

Cu (5 μ m)

-HV

10M Ω

10M Ω

-HV

drift plane

electron cloud

7.5mm 0.5kV/cm

polyimide (50 μ m)

GEM

5mm 2kV/cm

μ -PIC

GEM installed just above μ -PIC

70 μ m

140 μ m

CNS-GEMの断面図

CNS University of Tokyo

Standard GEM design

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

Plasma etching method

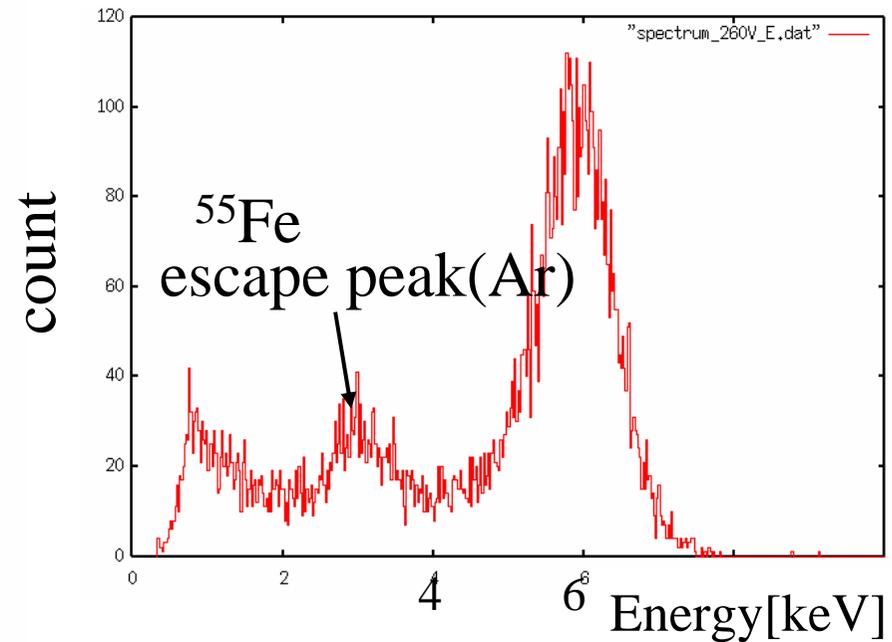@Fuchigami Micro Co., Ltd.

Holes with cylindrical shape

γ-ray Detecter
μ-**PIC**
MPGC TECHNIQUE

gas gain

spectrum

Total Gain
GEM Gain

gas gain

GEM Voltage[V]

requirement

Ar 90% C_2H_6 10%
with gas flowing
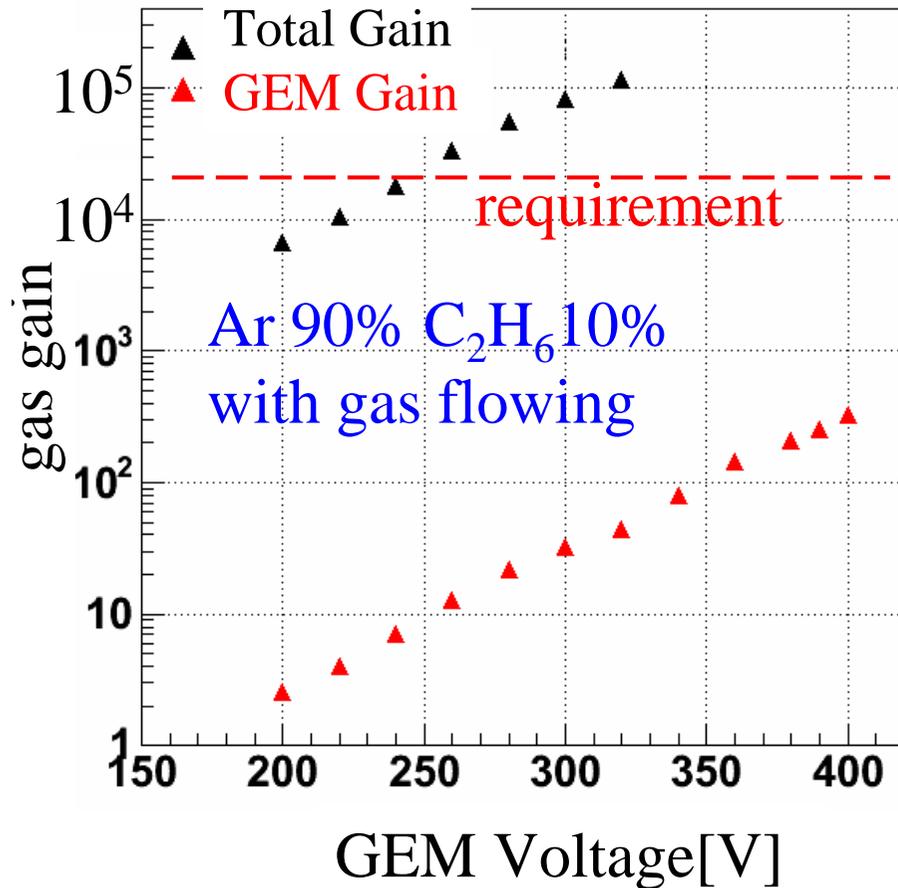
μ -PIC gain fixed 2.6×10^3

Total Max Gain $\sim 10^5$

GEM Max Gain ~ 300

enough to detect tracks of MIPs ！

^{55}Fe
escape peak(Ar)

Energy[keV]

20%(FWHM) @ 5.9keV
gain 1.3×10^4 (1.6cm^2)

ensitive Detectors

γ-ray
Detecter
μ-PIC
MPGC
TECHNIQUE

Positive ion feedback
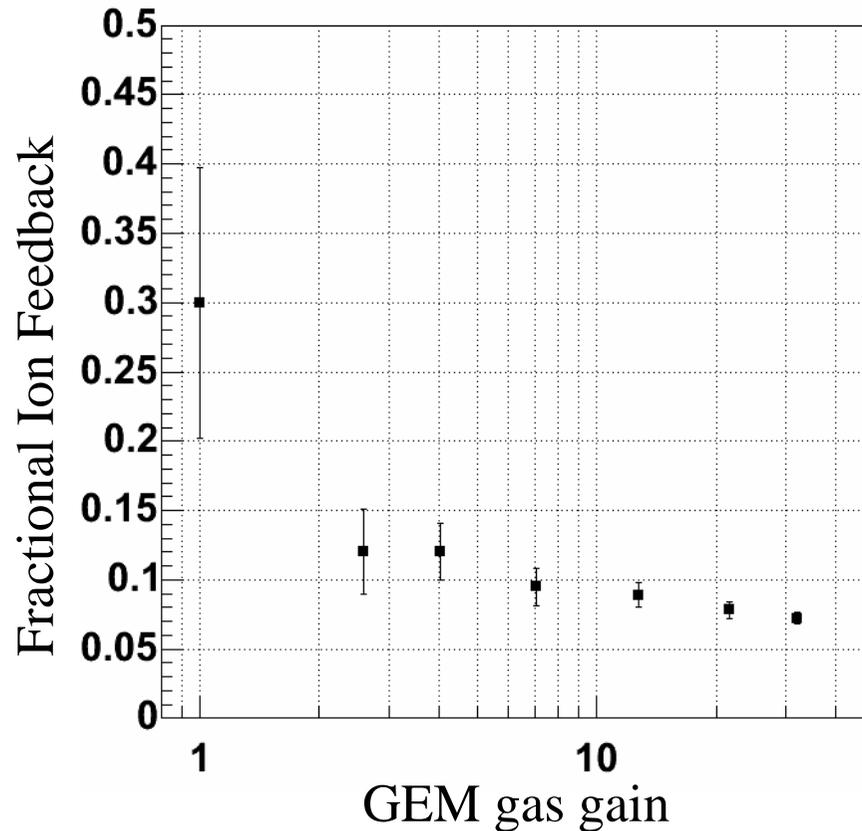
Fractional ion current I_D/I_A

I_D : the ion current
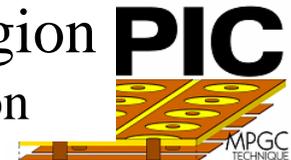on the drift plane

I_A : the electron current
on anodes of μ-PIC

the dependence of the fractional ion
current on the gain of the GEM
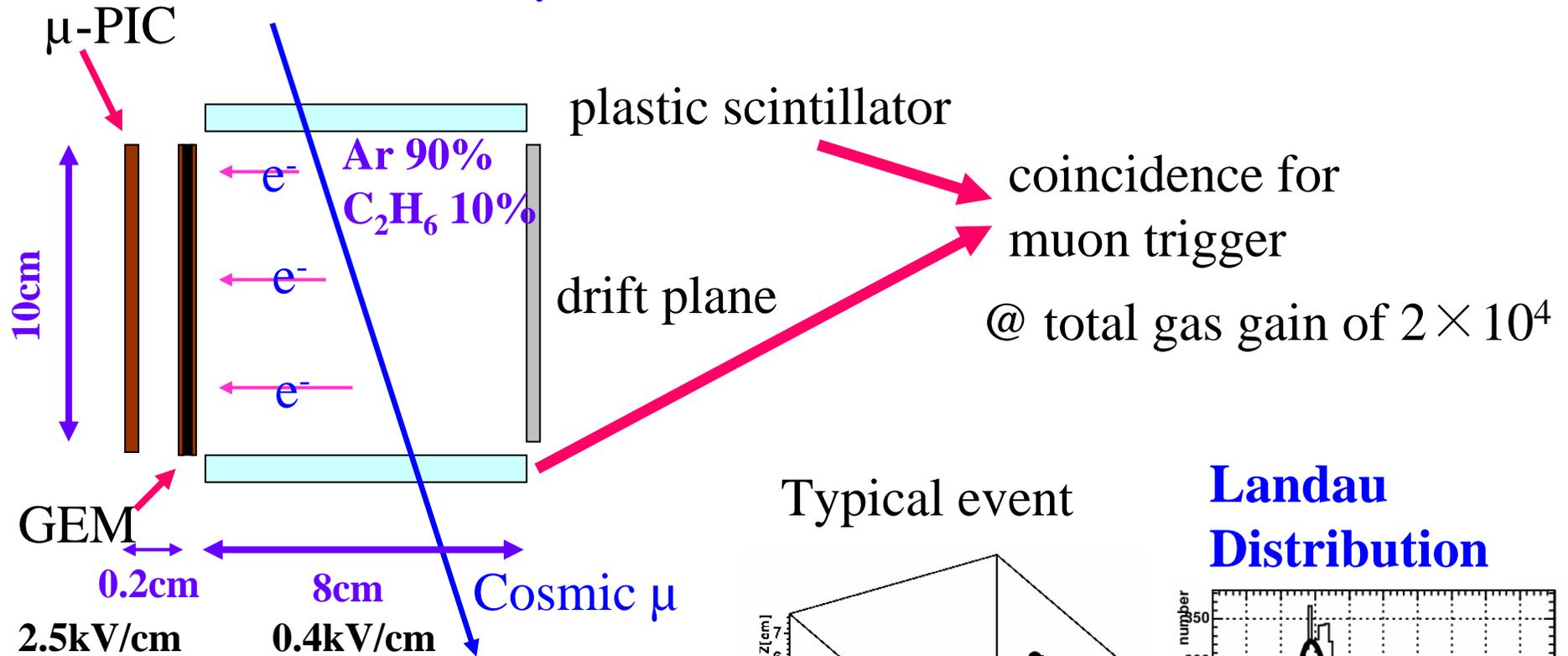
**Ion feedback less than 10%
@ gas gain > 10**

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 + μ-PIC TPC -muon track-
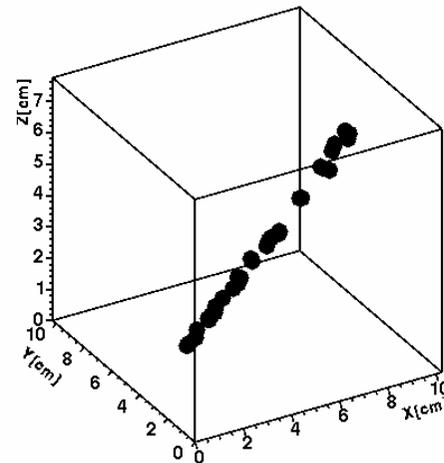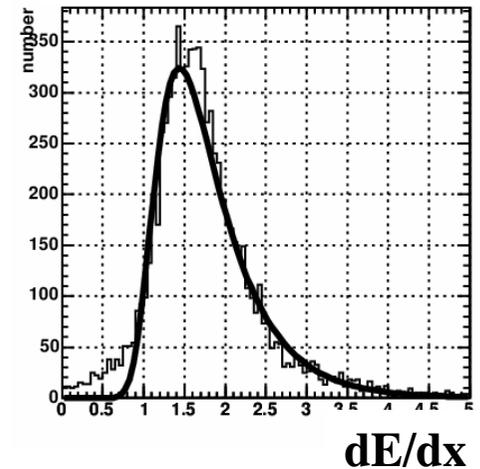
μ-PIC

plastic scintillator

Ar 90%
C_2H_6 10%

e⁻

e⁻

e⁻

coincidence for
muon trigger

@ total gas gain of 2×10^4

drift plane

10cm

GEM

0.2cm   8cm

2.5kV/cm   0.4kV/cm

Cosmic μ

Typical event

**Landau
Distribution**

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

Z[cm]

Y[cm]

X[cm]

number

dE/dx

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)

$$\frac{\sqrt{2\pi}}{\sigma} r \exp\left(-\frac{r^2}{2\sigma^2}\right) dr$$
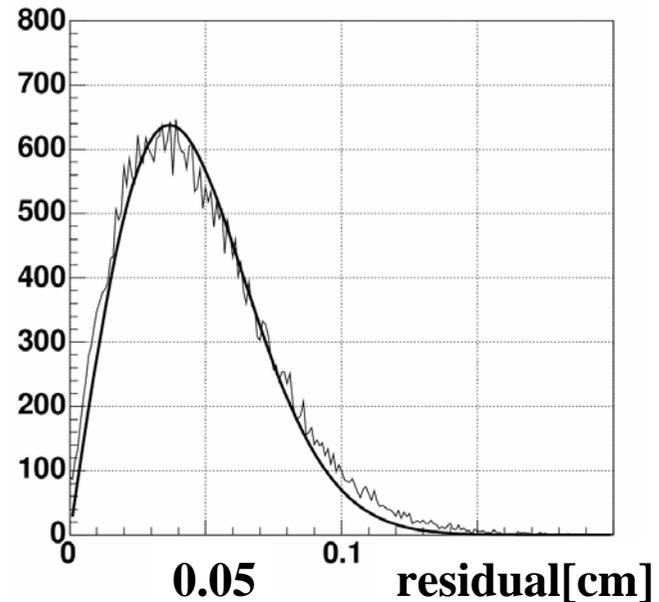
$\sigma \sim 370\mu m$

transverse diffusion 460μm
Z-pitch (DAQ clock) ~ 400μm

reasonable

Summary & Future Works

μ-PIC + GEM

➡ **stable gas gain of 2×10^4, ion feedback < 10%**

μ-PIC + GEM TPC

➡ **Fine tracks of MIPs were obtained.**

track efficiency 97%

➡ **position resolution 370μm**

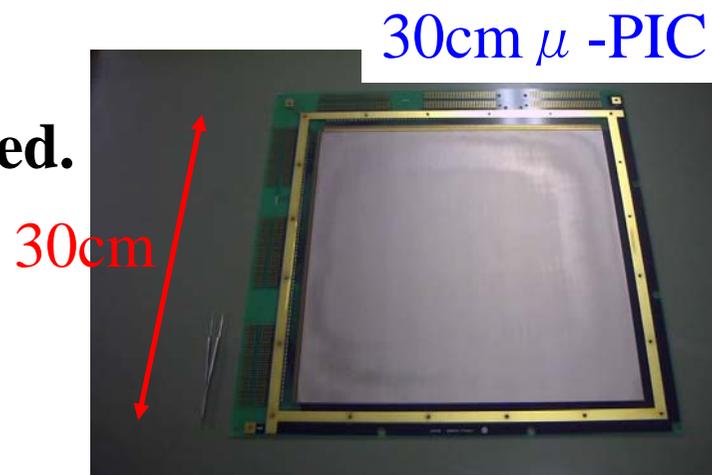## Future Works

30cm μ -PIC

30cm

μ-PIC & GEM with a larger detection area

about $30\text{cm} \times 30\text{cm}$(takada's poster)

30cmGEM

$\phi\, 70\, \mu\, \text{m}$
pitch $140\, \mu\, \text{m}$
standard
design

28cm

23cm
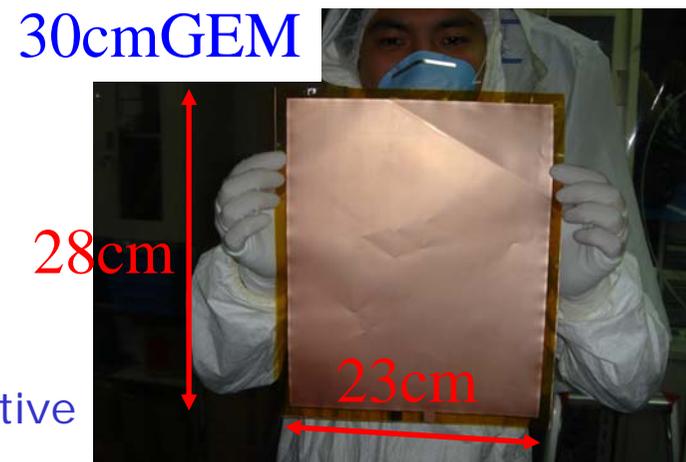
Performance of μ –PIC
(Micro Pixel Chamber)

2-dimensional imaging gaseous detector

anode 256 × cathode 256
 ~ 65000pixels

Max gas gain ～ 15000

400 μ m
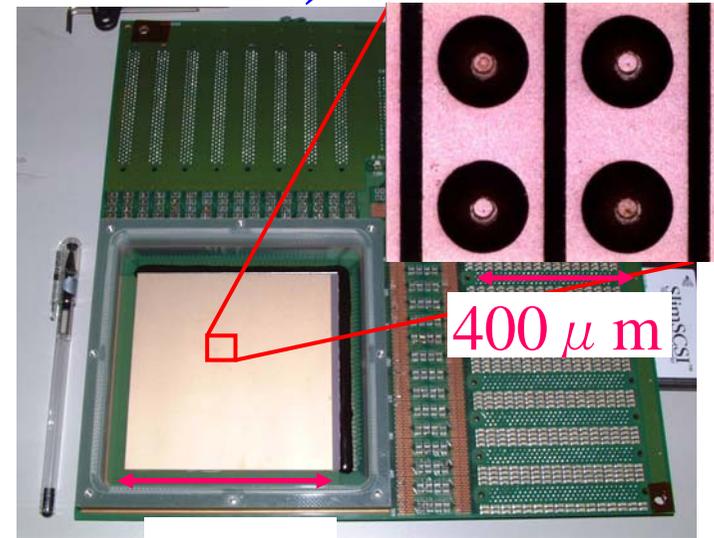
10cm
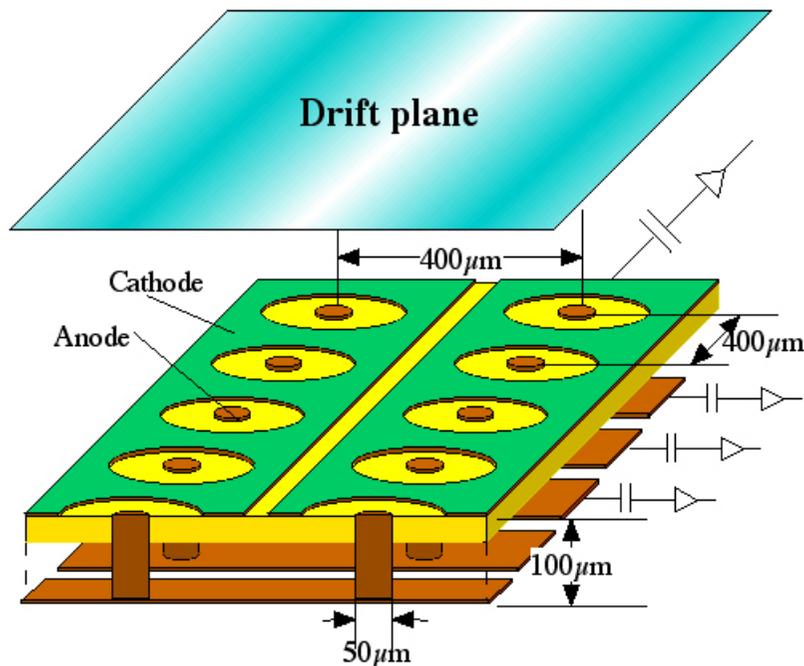
**Stable operation for 1000h
(gas gain ~ 6000)**

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

position resolution

~ 120 μ m

Drift plane

Cathode

Anode

400μm

400μm

100μm

50μm

e on Position Sensitive Detectors

γ-ray Detecter
μ-PIC

MPGC TECHNIQUE

Performance of μ –PIC
- uniformity -
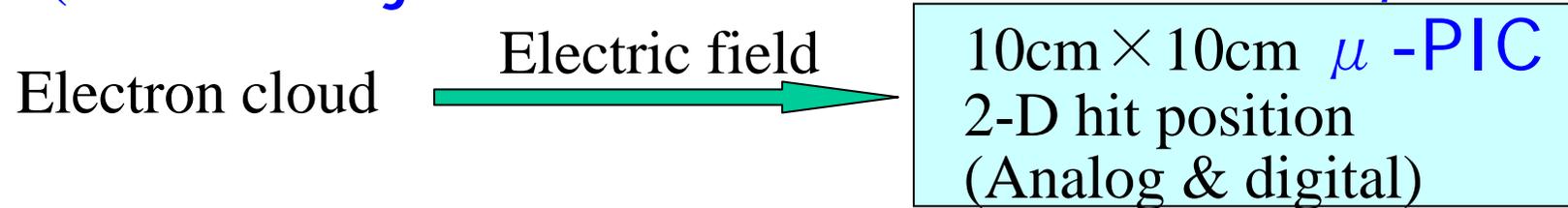
$\sigma \sim 7\%$

μ-TPC

(Time Projection Chamber based on μ -PIC)

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

time → drift distance → 100MHz encoder → 3-D tracking

Drift plane

electron cloud

Electric field

8cm

Cathode

Anode

t

electron

proton
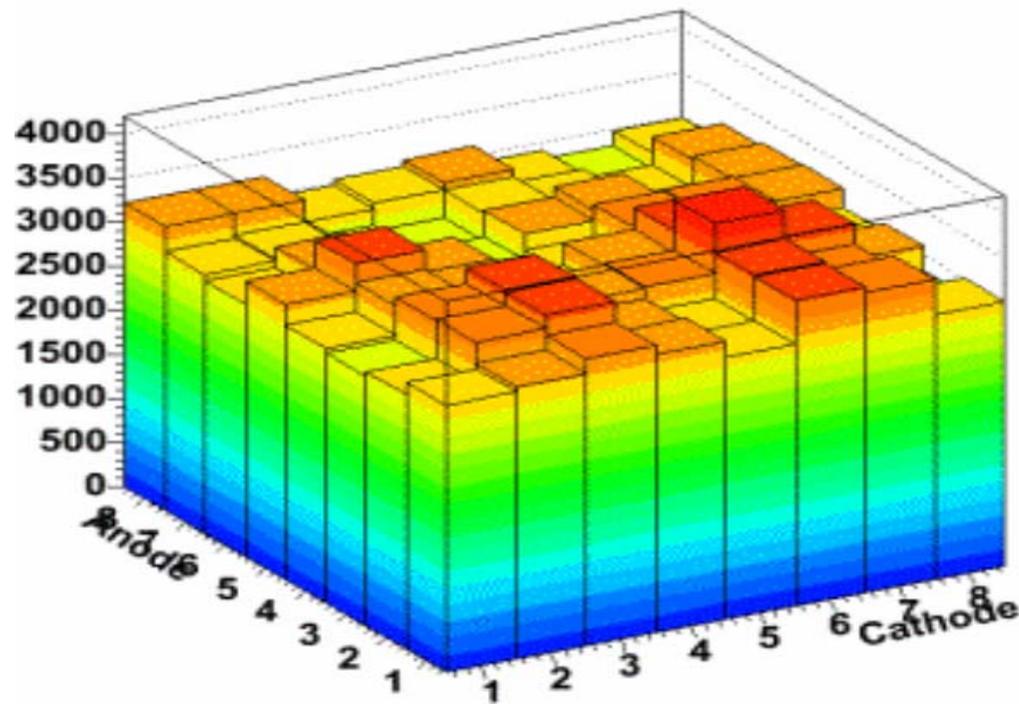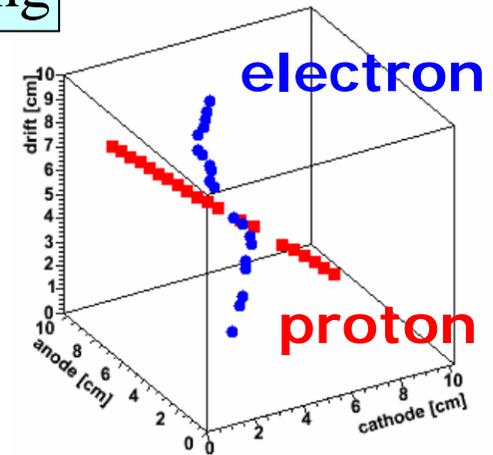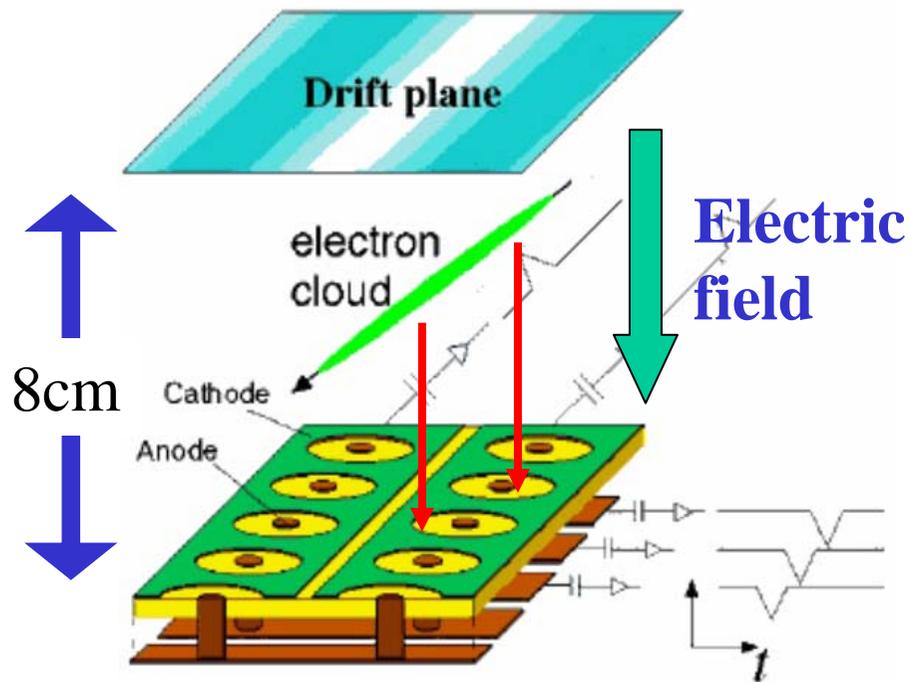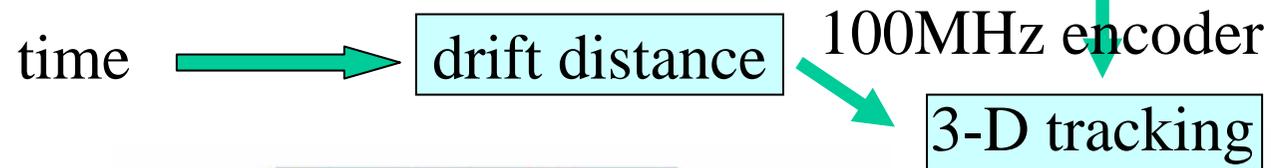
Applications
Compton camera
(recoil electron)
Dark Matter search

μ-PIC

MPGC
TECHNIQUE

· DAQ system

μ-TPC

ASD

Encoder

512ch
digital

512ch

16cm

16cm
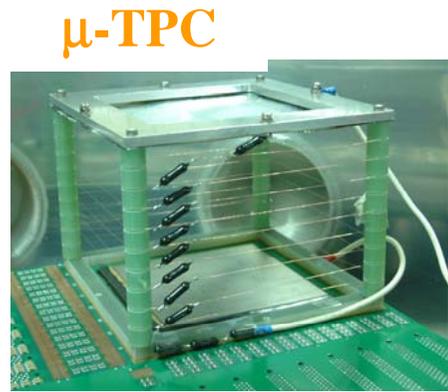
summed analog
(8ch)

32bit

VME
Memory Board

VME FADC
100MHz 8ch

ASD

Position
Encoder

μ-TPC

Anode

A1

A2

A3

A4

C1 C2 C3 C4 . . .

Cathode

Memory
Board

ve Detectors

γ-ray
Detecter
μ-PIC

MPGC
TECHNIQUE
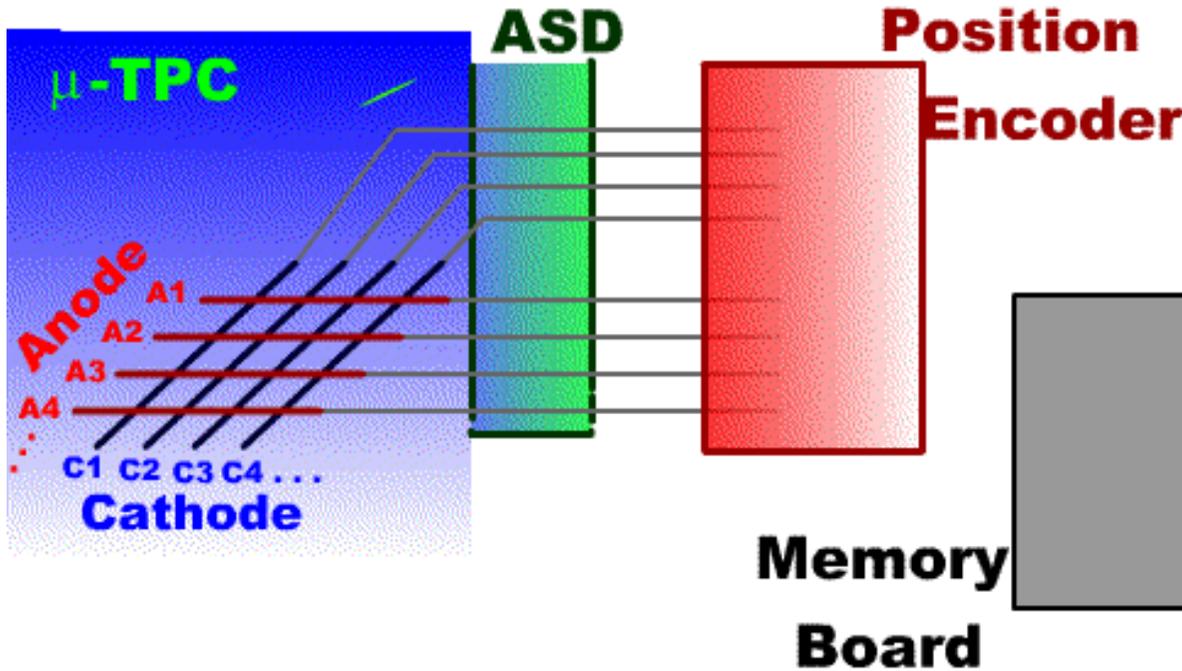
GEM

Mask by Hamagaki Lab.
@ CNS Univ. of Tokyo

Plasma etching method
 @Fuchigami Micro Co., Ltd.

Holes with cylindrical shape
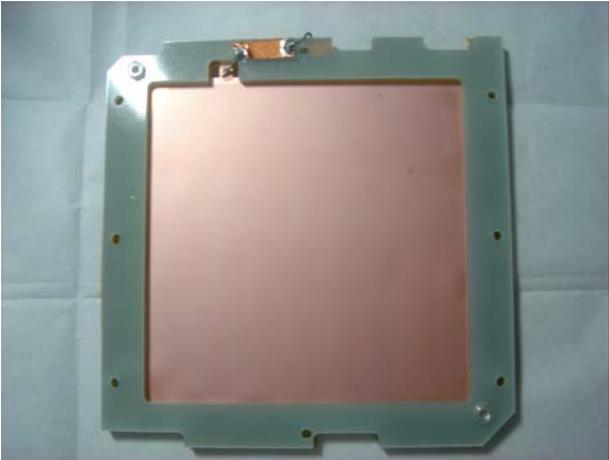
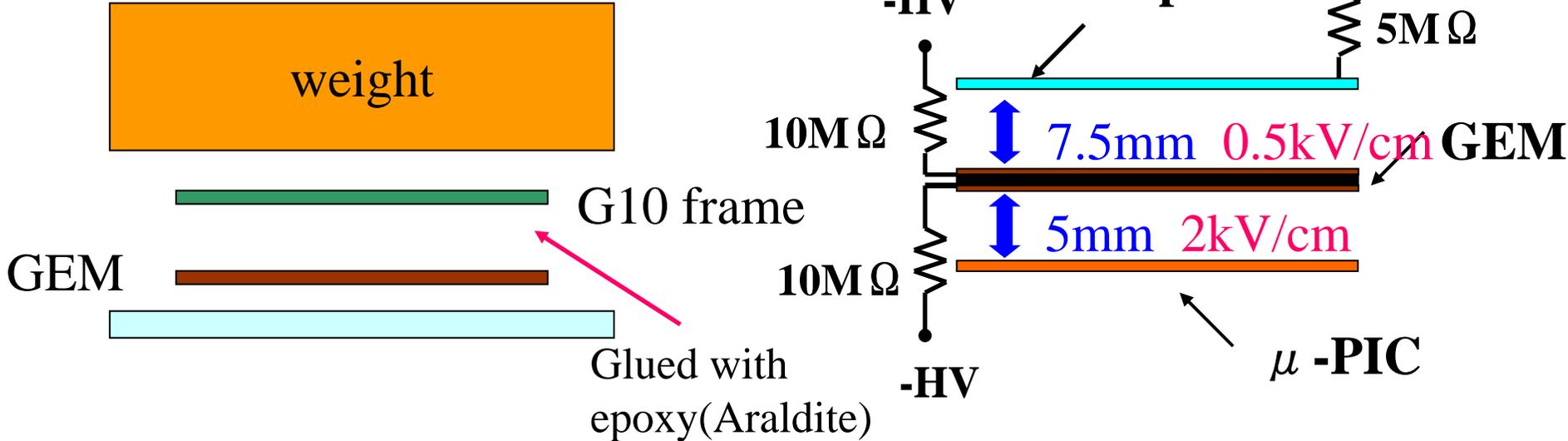CERN :
holes with a double-conical shape

CNS-GEM
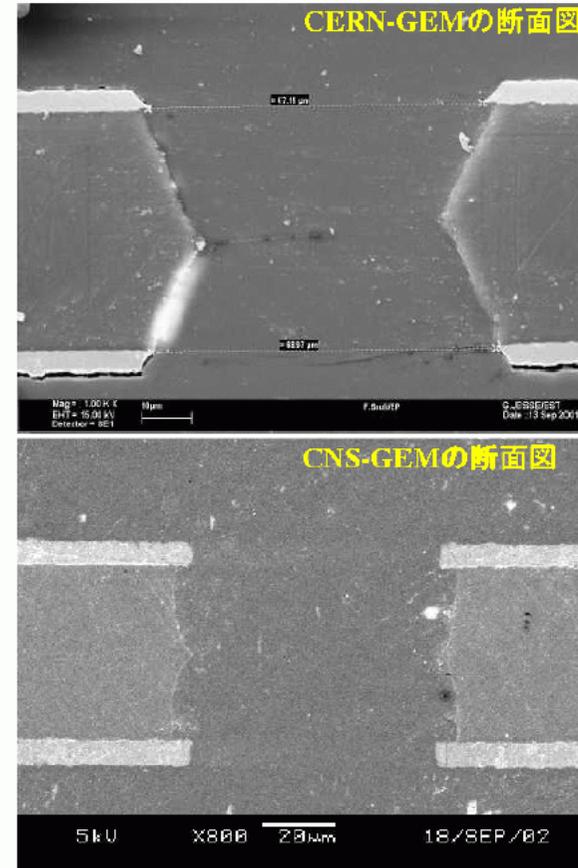
Setup

How to glue a GEM

weight

G10 frame

GEM

Glued with
epoxy(Araldite)

-HV

drift plane

-HV   5MΩ

10MΩ   7.5mm 0.5kV/cm **GEM**

5mm 2kV/cm

10MΩ

-HV μ **-PIC**

aging

In dry nitrogen gas
$\Delta V_{GEM} \sim 500V$

γ-ray
Detecter
μ-PIC
MPGC
TECHNIQUE

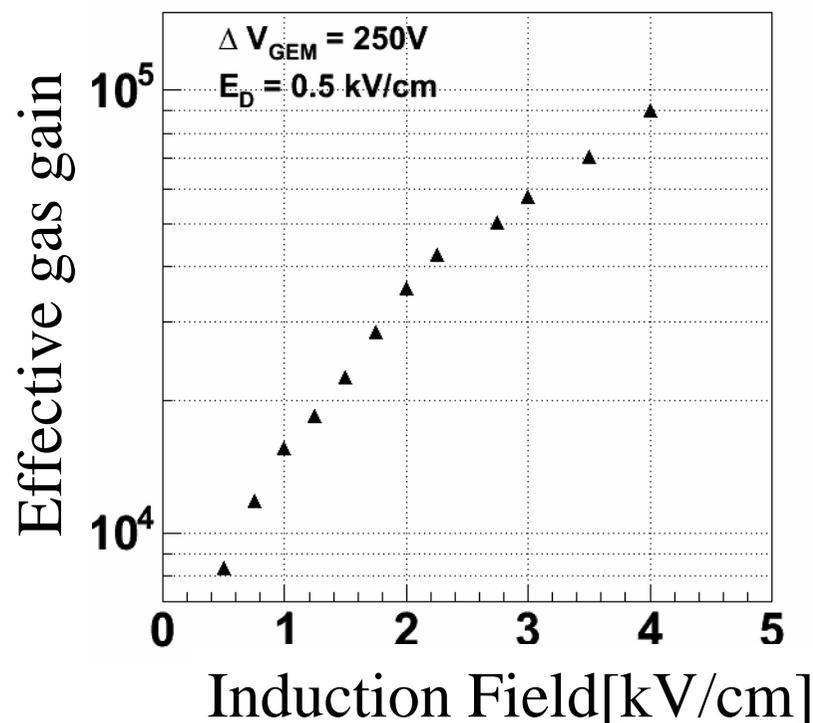# Dependence of total gain on induction field

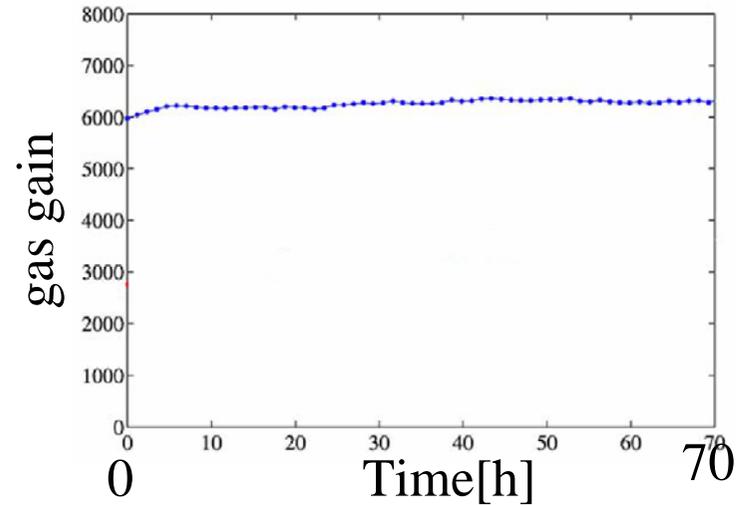$\Delta V_{GEM} = 250V(\text{gain } 10)$
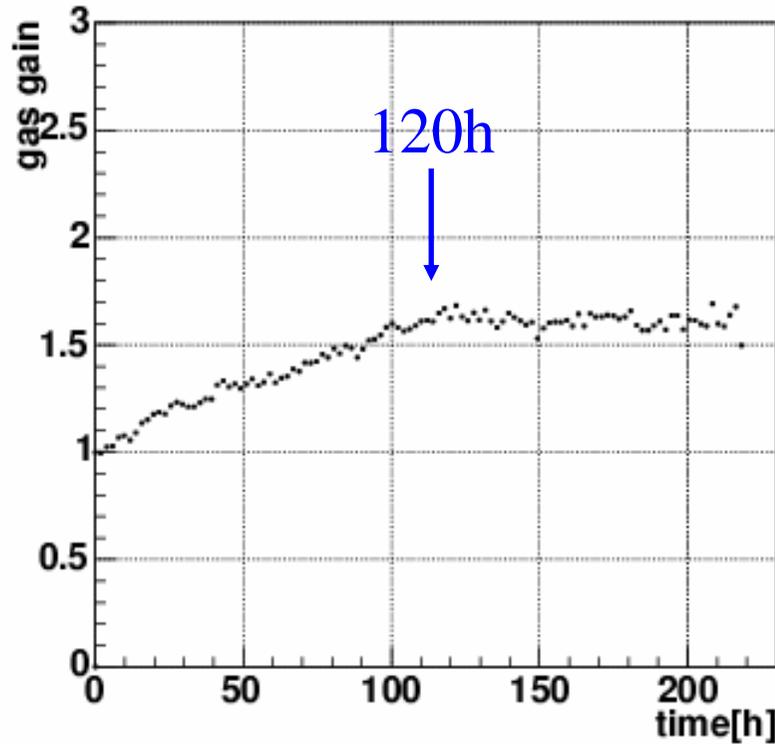$E_D = 0.5kV/cm$

plateau wasn't observed

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

Long-term gas gain stability
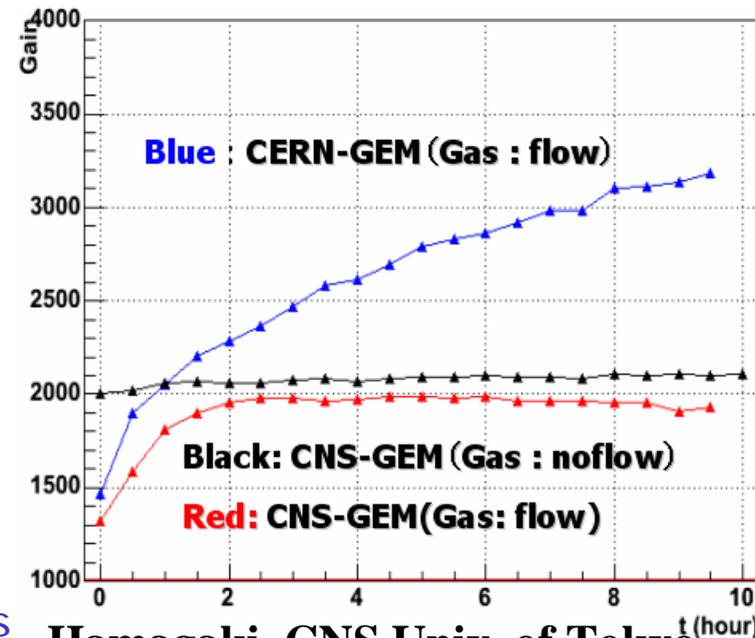
μ-PIC **6%** for **70h**

120h

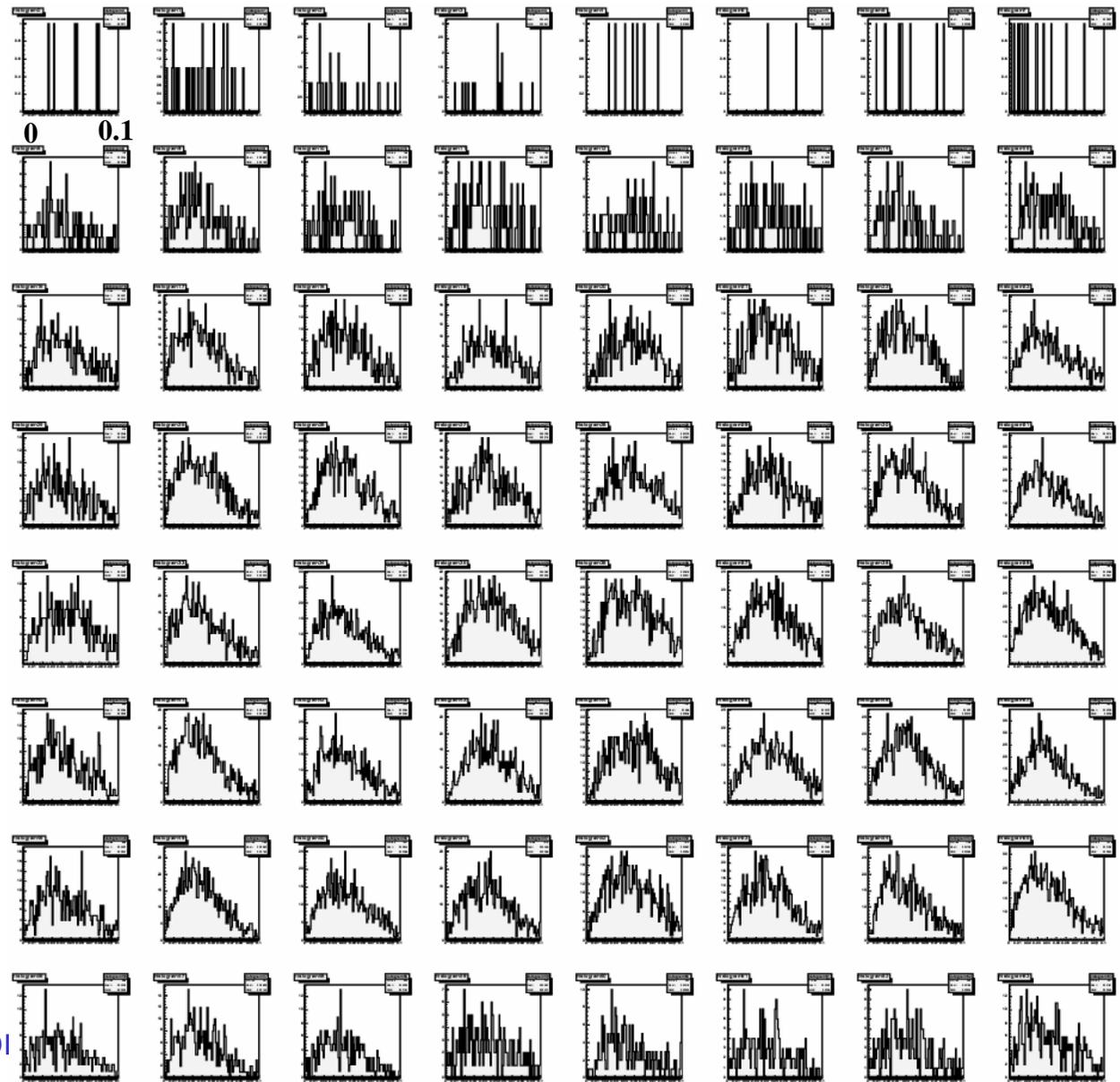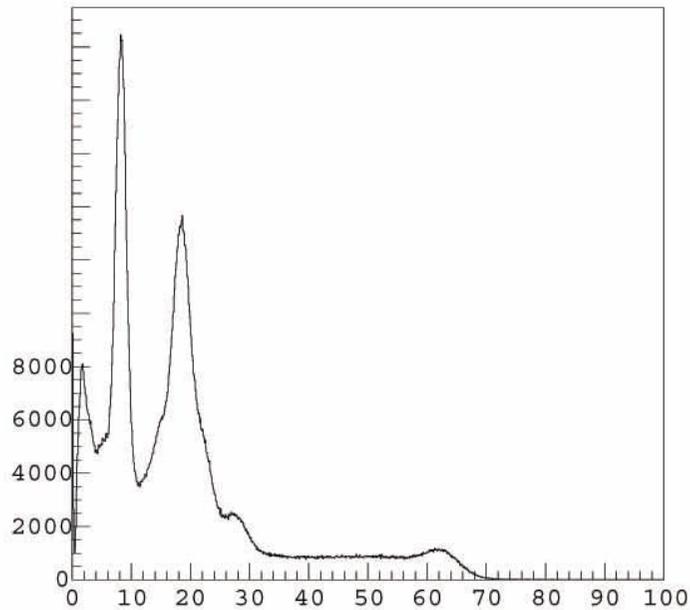The gain increased **50%** for **120h**

Blue : CERN-GEM (Gas : flow)

Black: CNS-GEM (Gas : noflow)

Red: CNS-GEM(Gas: flow)

Hamagaki, CNS Univ. of Tokyo

Performance of micro-TPC
- uniformity -

0   **0.1**

Performance of Hybrid micro-TPC
- gamma – ray -

micro -TPC energy
13%`20keV(FWHM)

μ **TPC   mumber of sampling**
Points for one electron track

X-ray from Cu
electrode in μPIC