Development of μ-PIC and its imaging properties

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   and application of μ-PIC
2. X-ray imaging properties
3. Charged particle tracking
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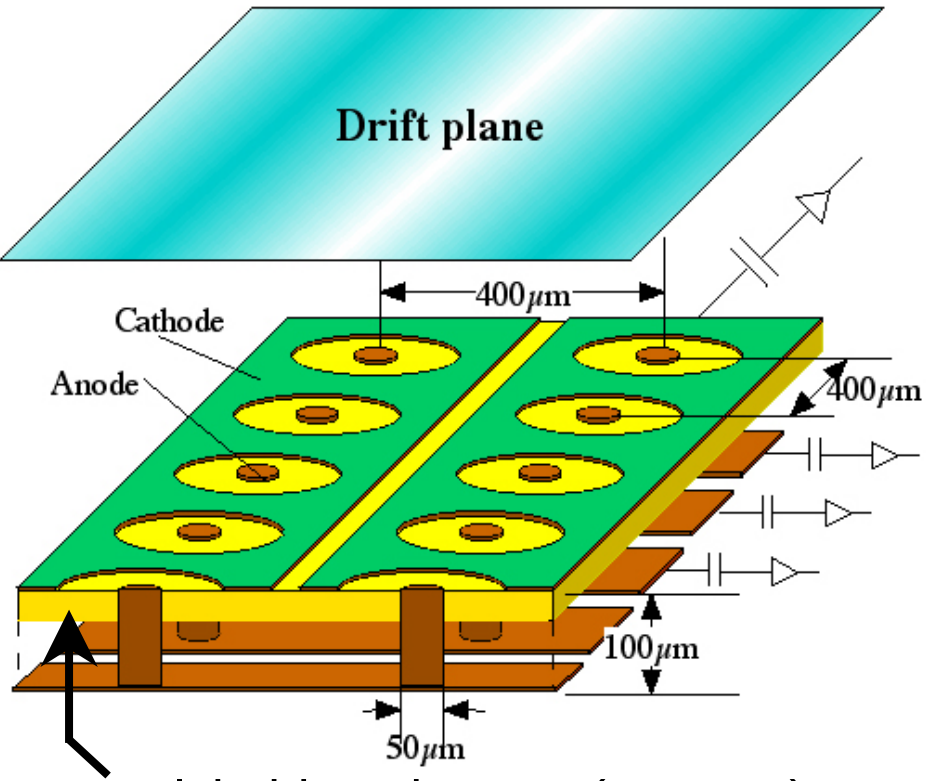
Micro Pixel Chamber (μ-PIC)

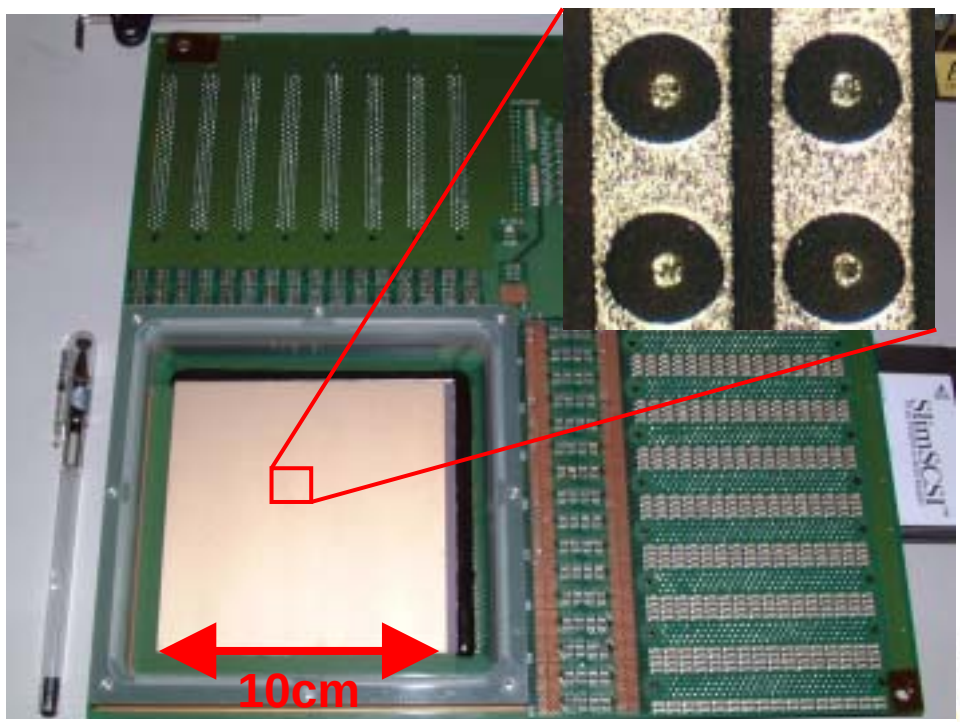


polyimide substrate (prepreg)

- 400μm pitch electrodes
- 256 anodes and
  256 cathodes

Printed Circuit Board (PCB) technology

- Large area
- Low cost



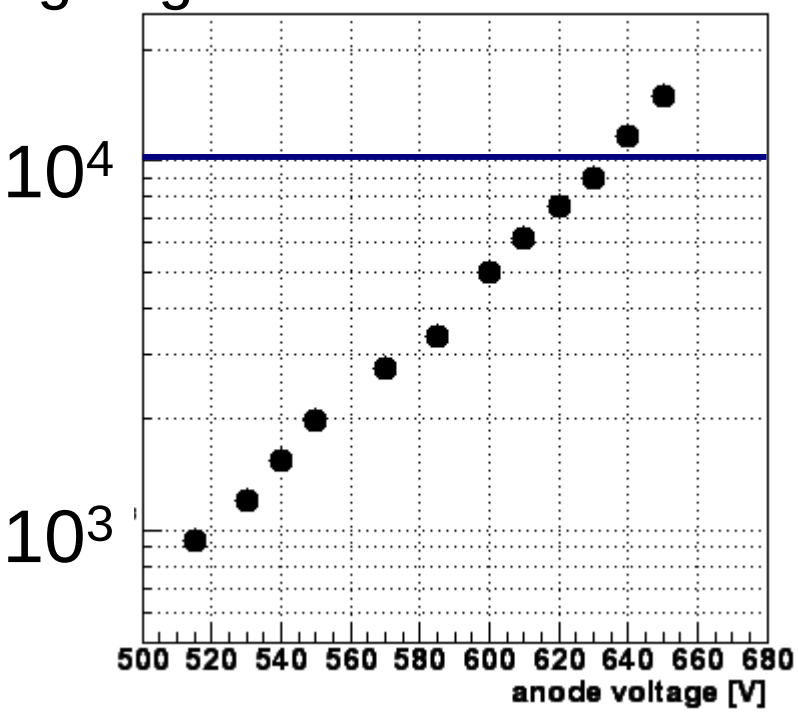
Detection area = 100cm^2

Performances

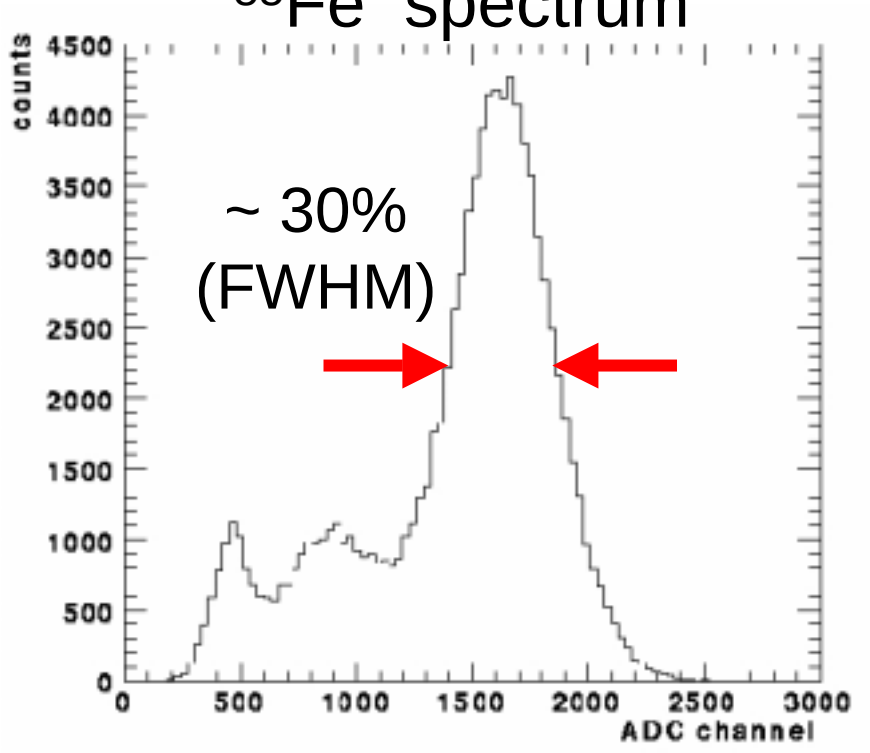
Gas: Ar/C_2H_6 (80/20)

Source: ^{55}Fe (5.9keV)

gas gain



^{55}Fe spectrum



- Gas gain ~ 15,000 (max)
- Stable operation (>1000h)
  @ gas gain ~ 5000
- Energy resolution ~30%

Application of μ-PIC

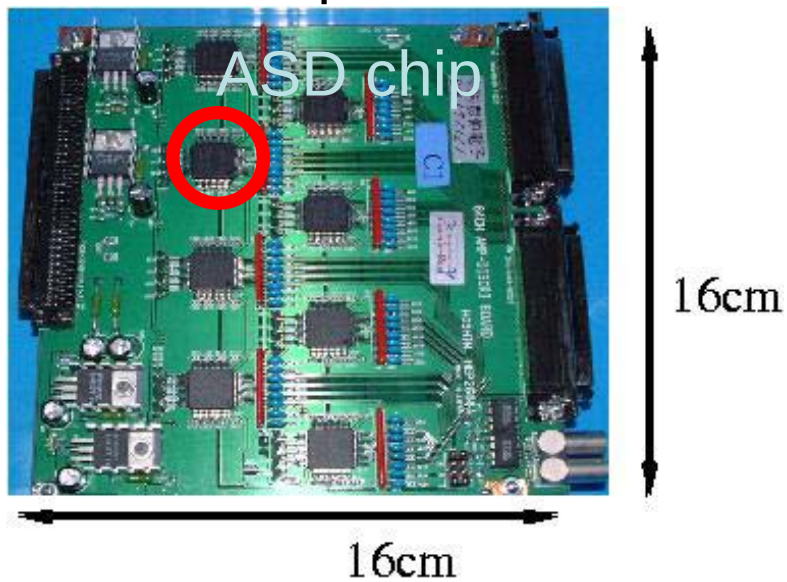
- X-ray imaging → astrophysics, crystal analysis, …
  - X-ray imaging and polarimetry
    → *Next presentation (by Ueno)*
- Time Projection Chamber
  - Charged particle tracking
  - Gamma-ray imaging detector
    → *June 27th (by Orito)*
  - Neutron imaging detector

DAQ system

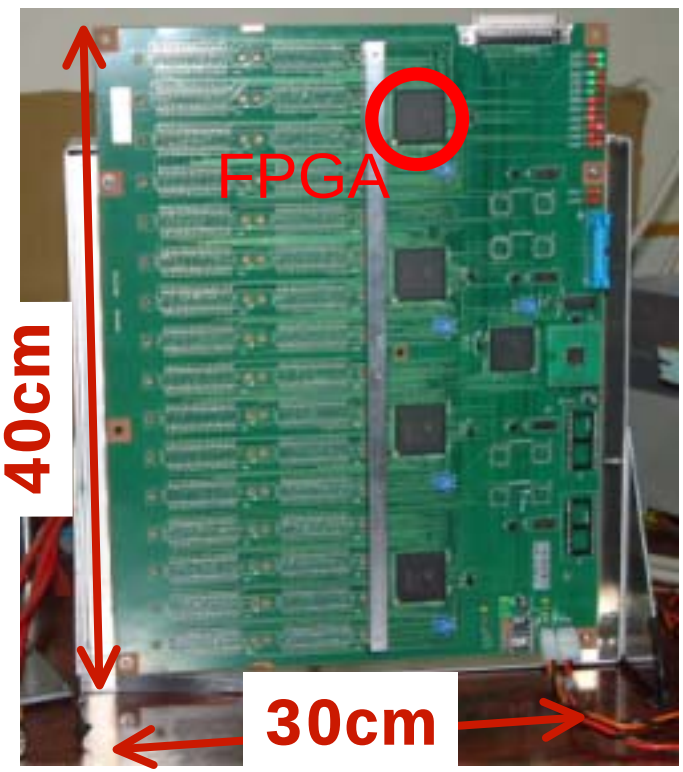
Preamplifier

ATLAS amplifier shaper discriminator (ASD) chip (64ch/card)

Preamplifier

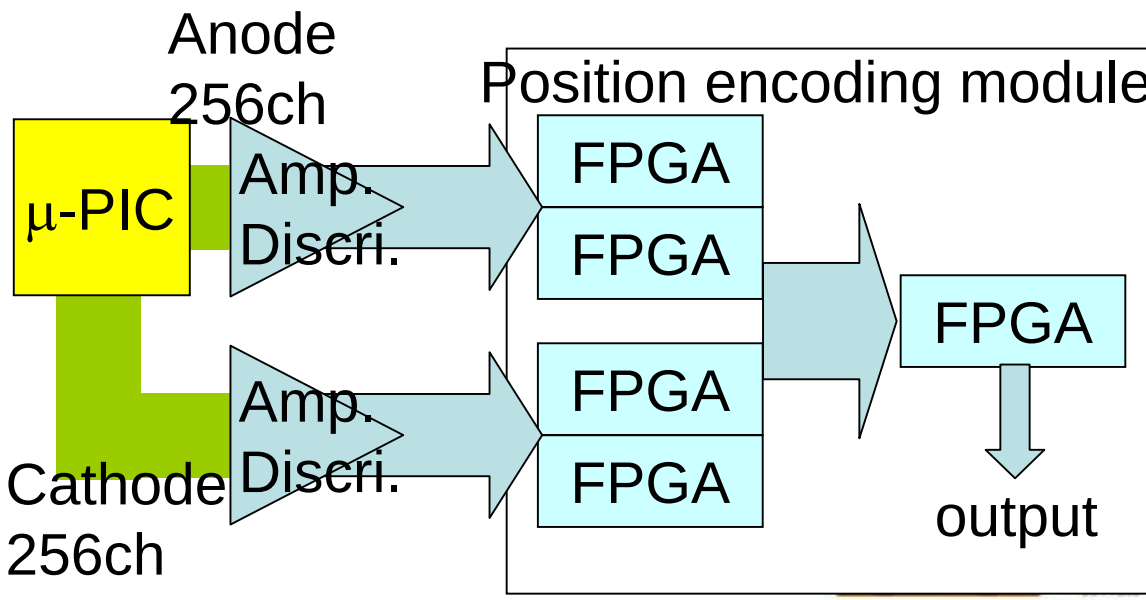


Position encoding module



Position encoding module

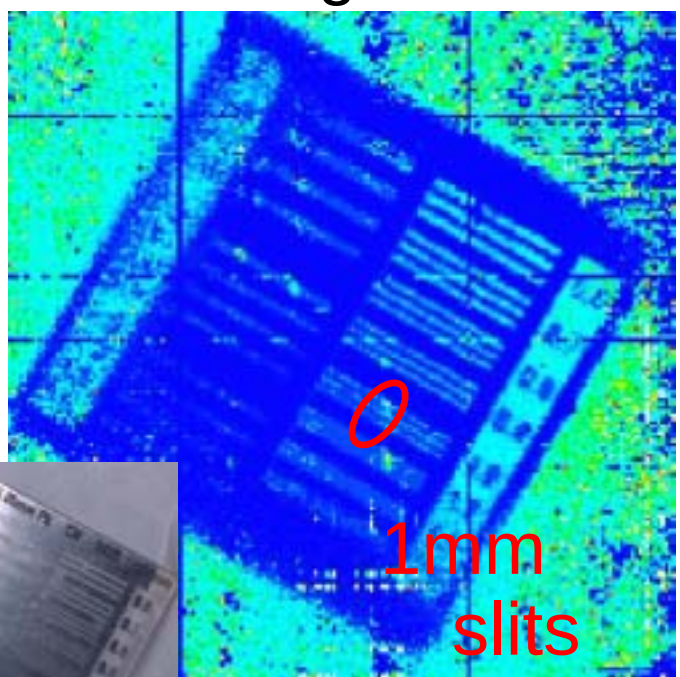
5 FPGAs (clock 20MHz)



X-ray imaging ~ Position resolution ~

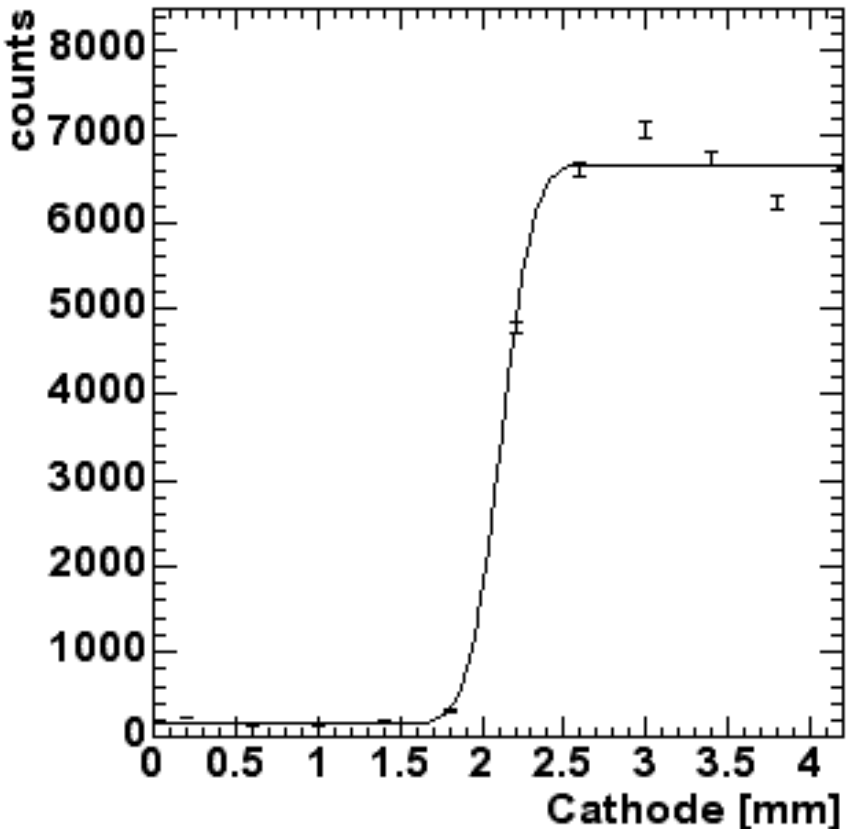
- Gas: Xe/C_2H_6 (70/30)
- Drift: 3mm (500V/cm)

Test chart image



Miuchi et al. 2002

Knife edge test

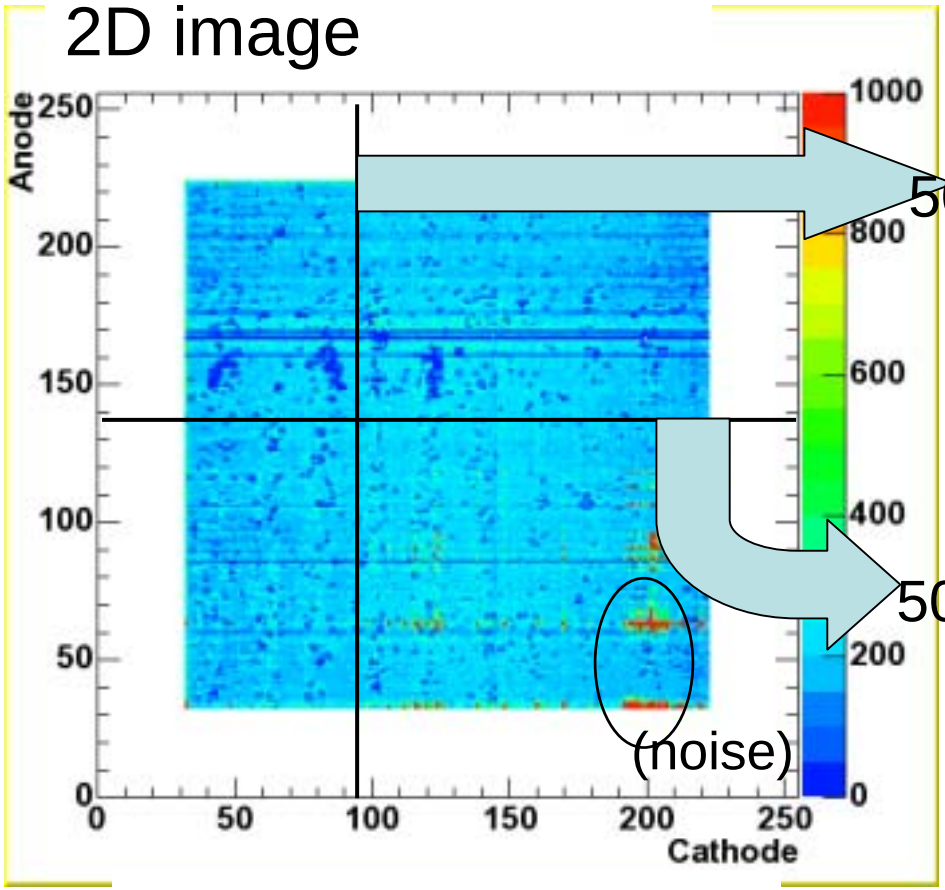


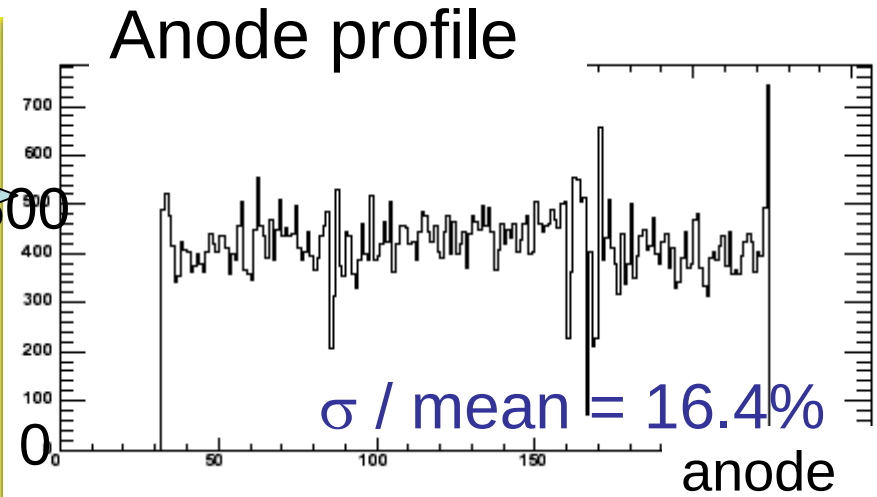
Position resolution

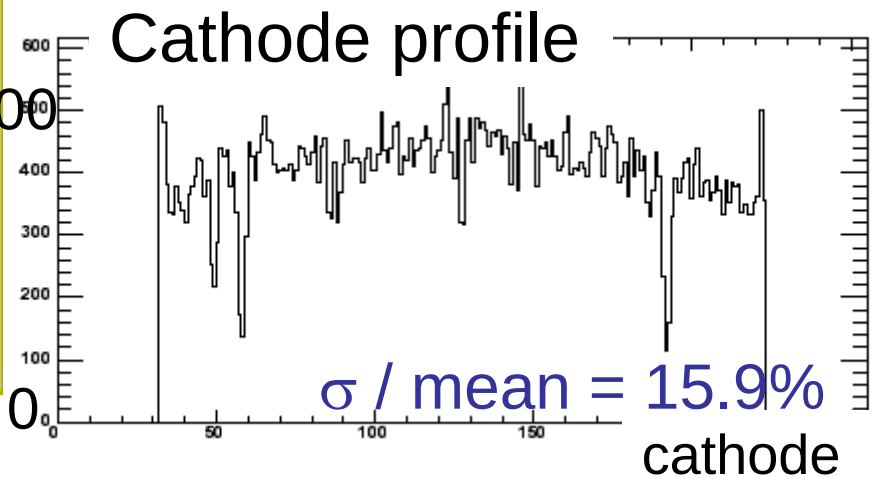
$\sigma \sim 160\ \mu m$

(Theory … $\sigma = 115\mu m$)

X-ray imaging ~ image uniformity ~



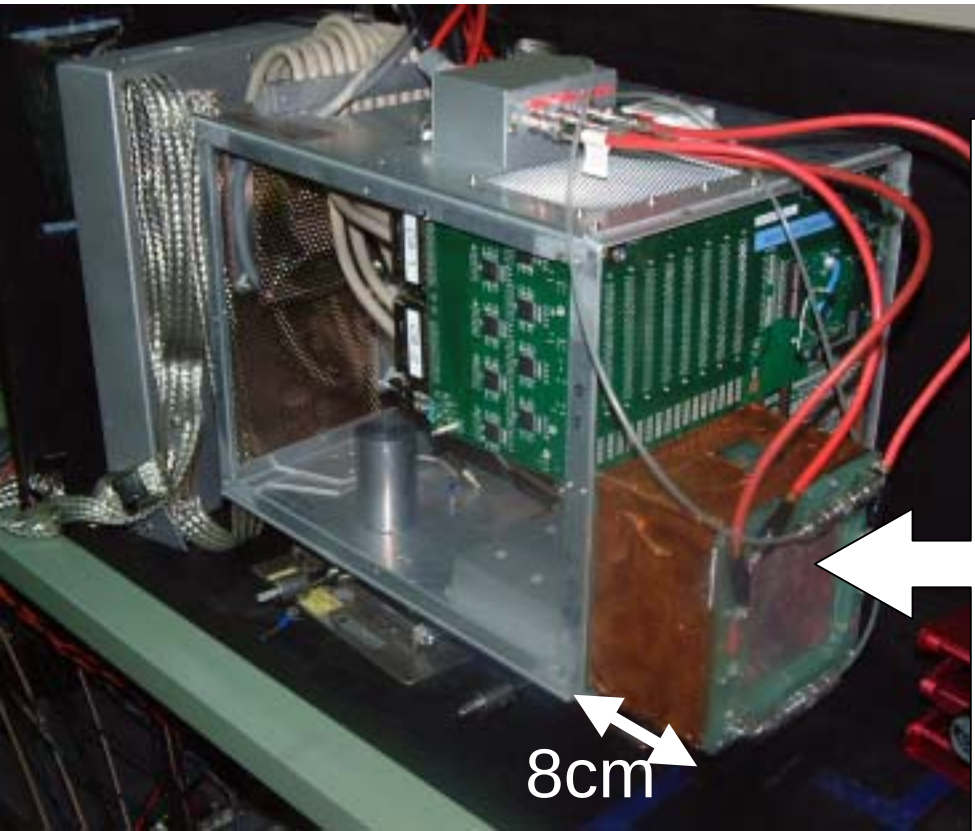




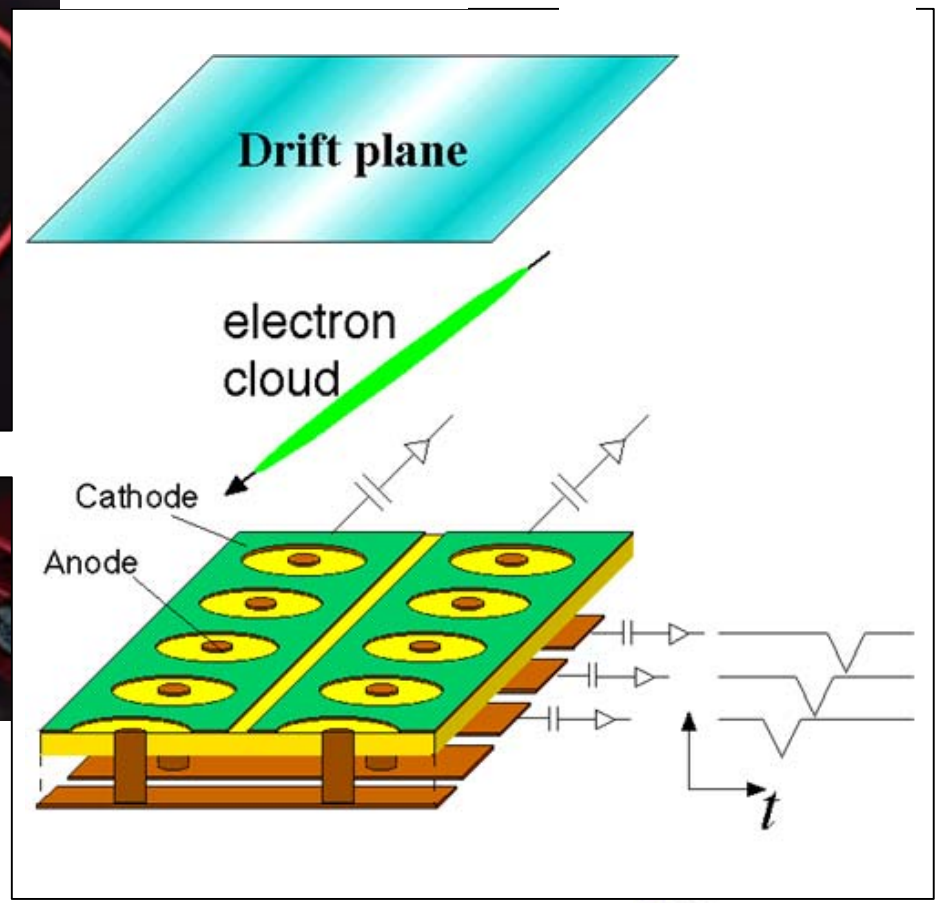
- Continuous X-ray (E < 20keV)
- Uniformly irradiated

Almost uniform image!

Charged particle imaging



2D + timing → 3D track

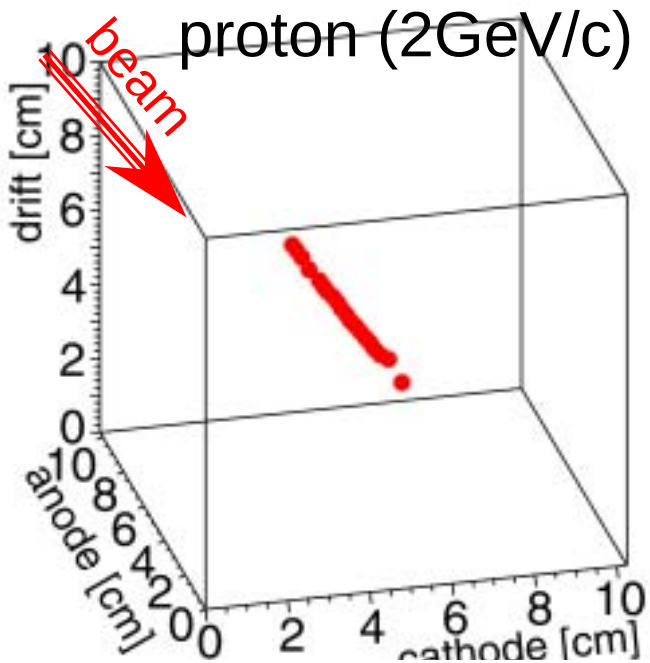


Micro-TPC based on μ-PIC

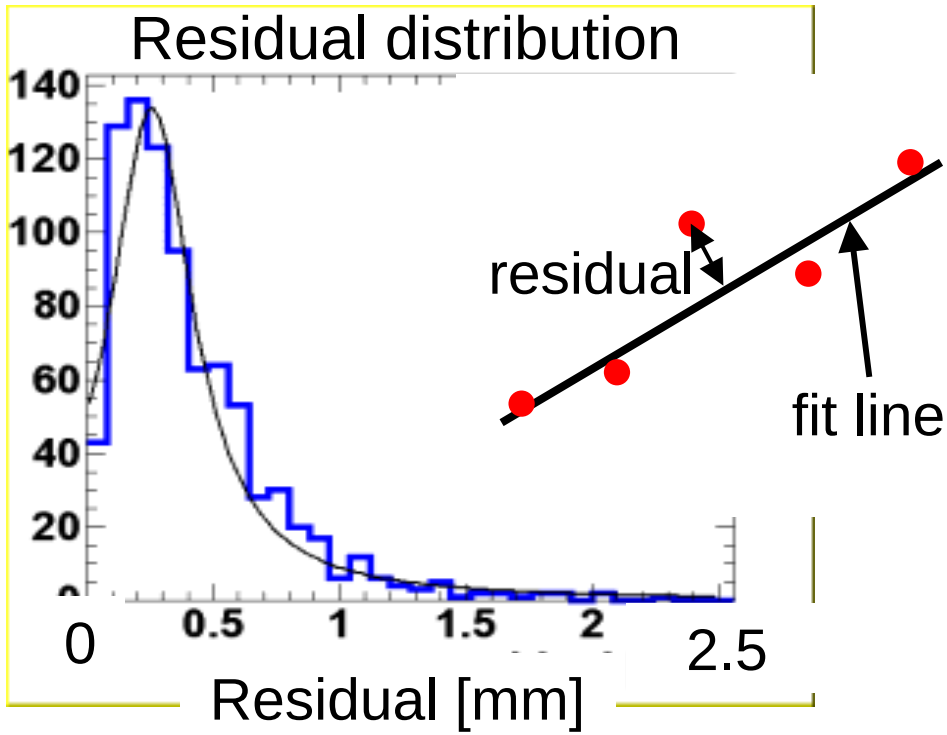
γ-ray Detecter μ-PIC

Charged particle tracking

(Gas: Ar and C_2H_6 mixture)



3D track ➡ Linear fit

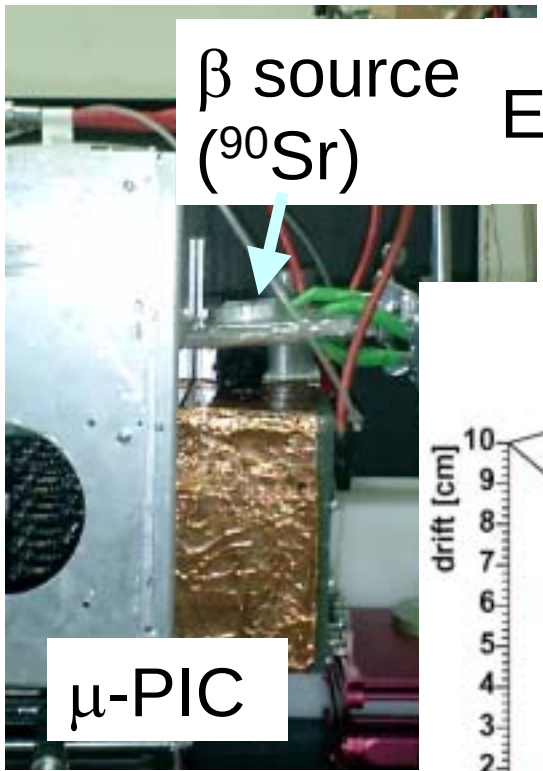


Ar/C_2H_6 ratio	Position resolution (RMS) 2D	3D	Drift velocity
80:20	250 μm	320 μm	(4.7cm/μsec)
90:10	200 μm	260 μm	(3.6cm/μsec)

Limited by DAQ clock (20MHz)

Charged particle tracking

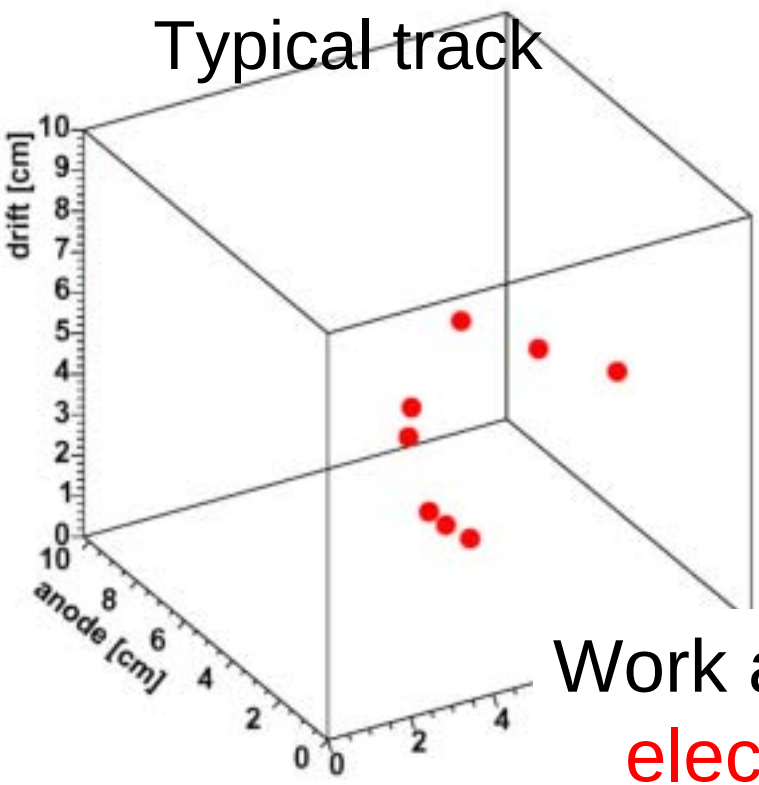
~ Electron tracking ~



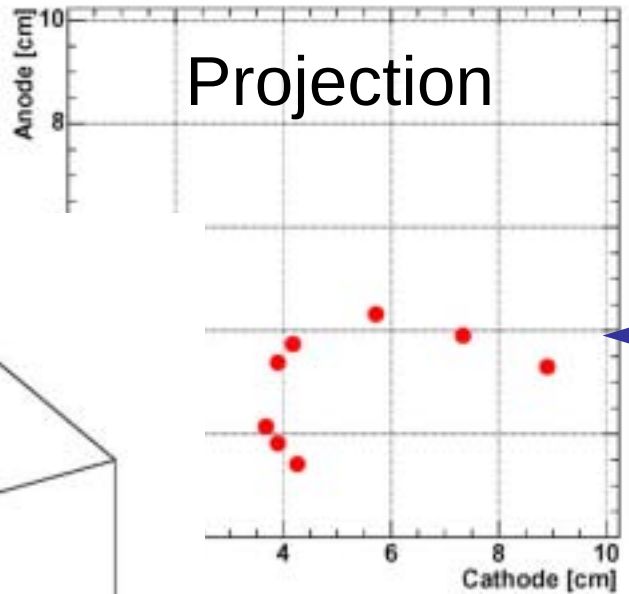
E < 2.3MeV

Set-up

Typical track



Projection



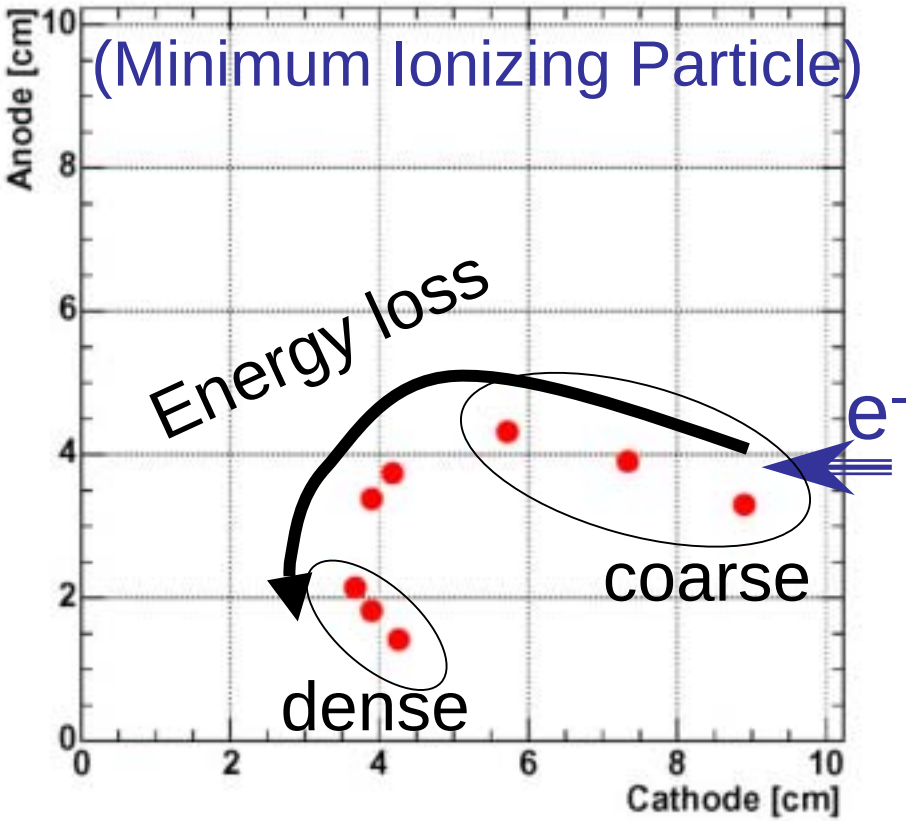
Work as an

electric cloud chamber!

Problem of μ-PIC

Electron track (E ~ 1MeV)

(Minimum Ionizing Particle)



(Gas gain ~ 2000)

small $\frac{dE}{dx}$ → Coarse plot

Gas gain is not enough.

Required gain > 10^4

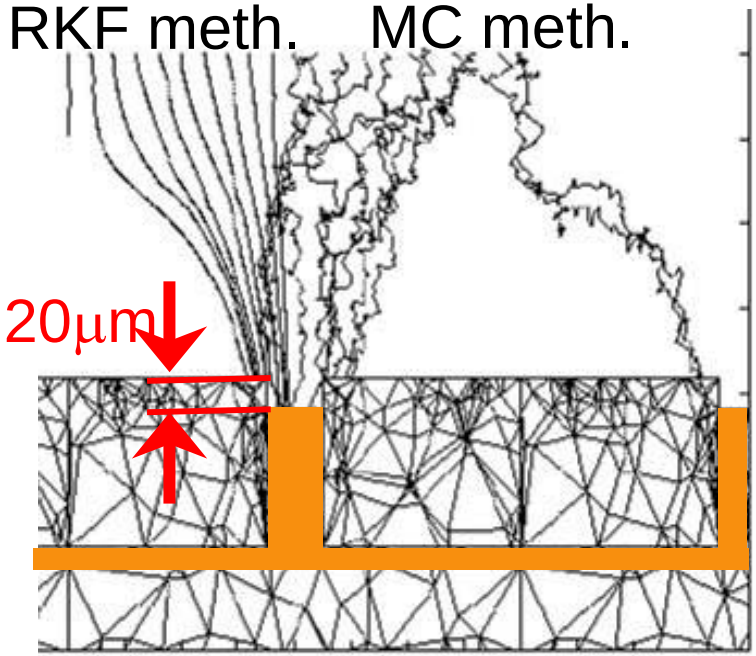
and

Stable operation

Drift simulation *~ For the best electrode ~*

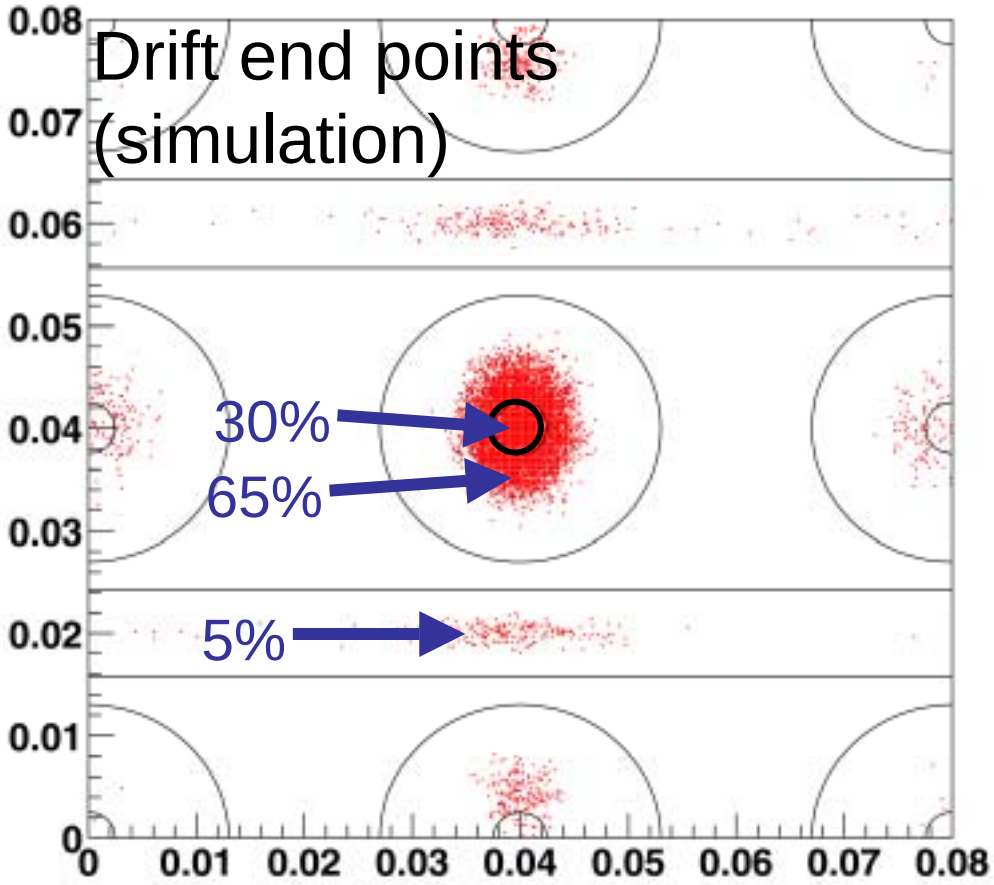
3D simulation
(Maxwell + Garfield)

RKF meth. MC meth.



Drift paths of electrons

Top of anode electrodes are below substrate.



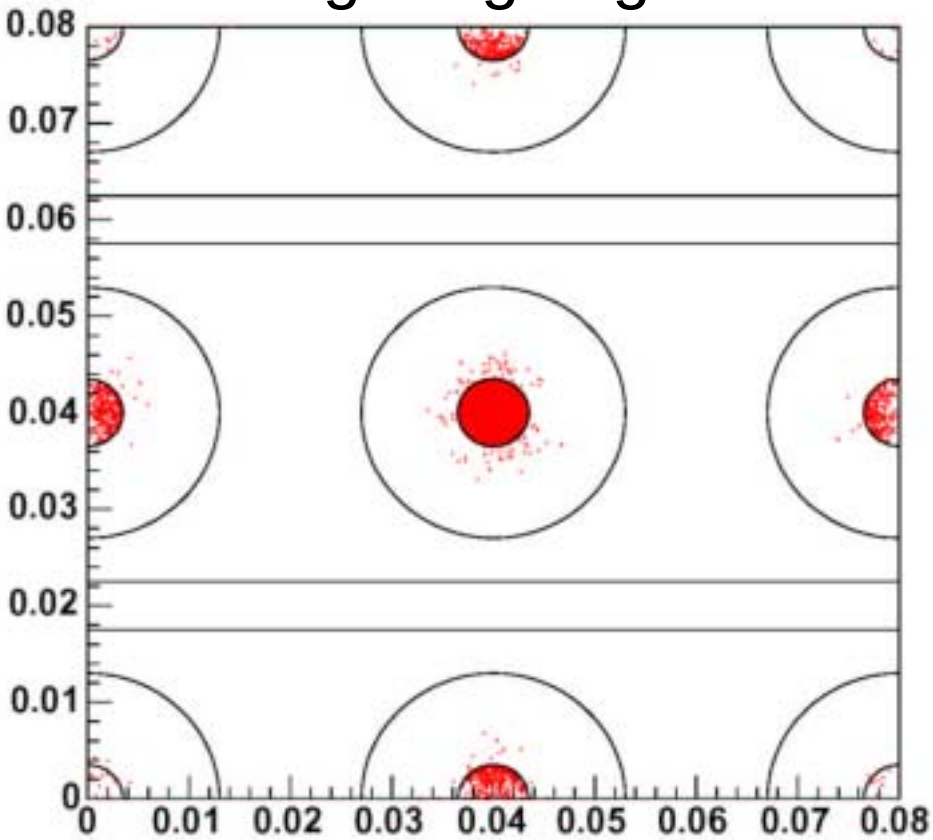
- Collection efficiency ~ 30%
- Low gas gain

Drift simulation *~ The best electrode? ~*

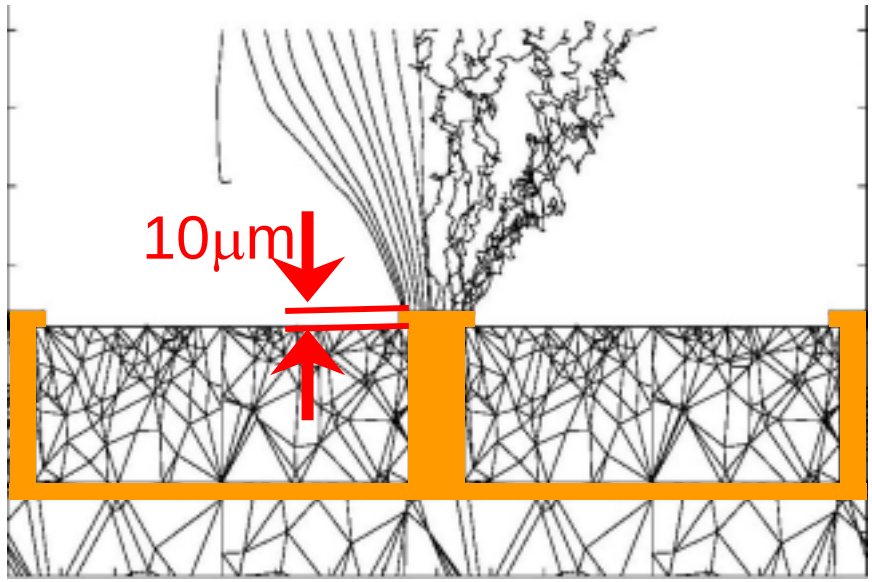
Higher anode

→ Higher efficiency

Higher gas gain



Drift end points (simulation)



Collection efficiency ~ 97%

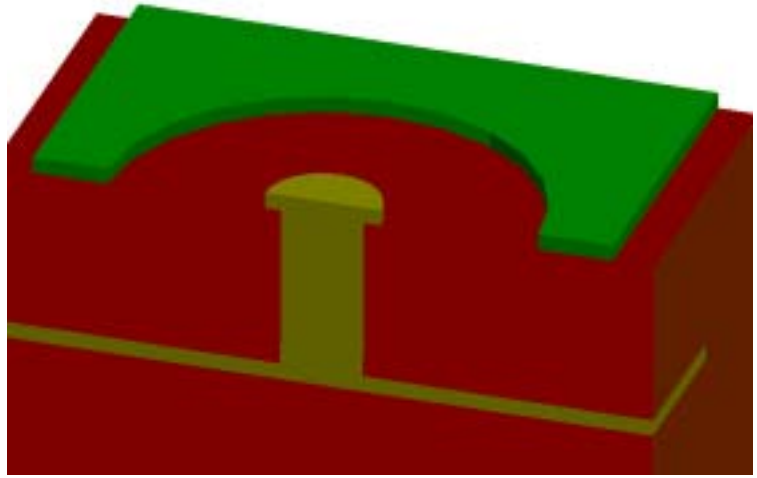
→ Gas gain: **×3**

Other improvement:

Gas selection, etc.

New manufacture technique is required.

Future development



“Cap anode” μ-PIC

electrode formation process

- Current type … normal plating (bottom-up)
- Cap anode … plating and etching (top-down)

➡ Uniform electrodes will be made.

1. Electroless plating

2. Via-fill plating

3. Surface etching

Coming soon!!

Detection area

30cm × 30cm

4. Electrode etching

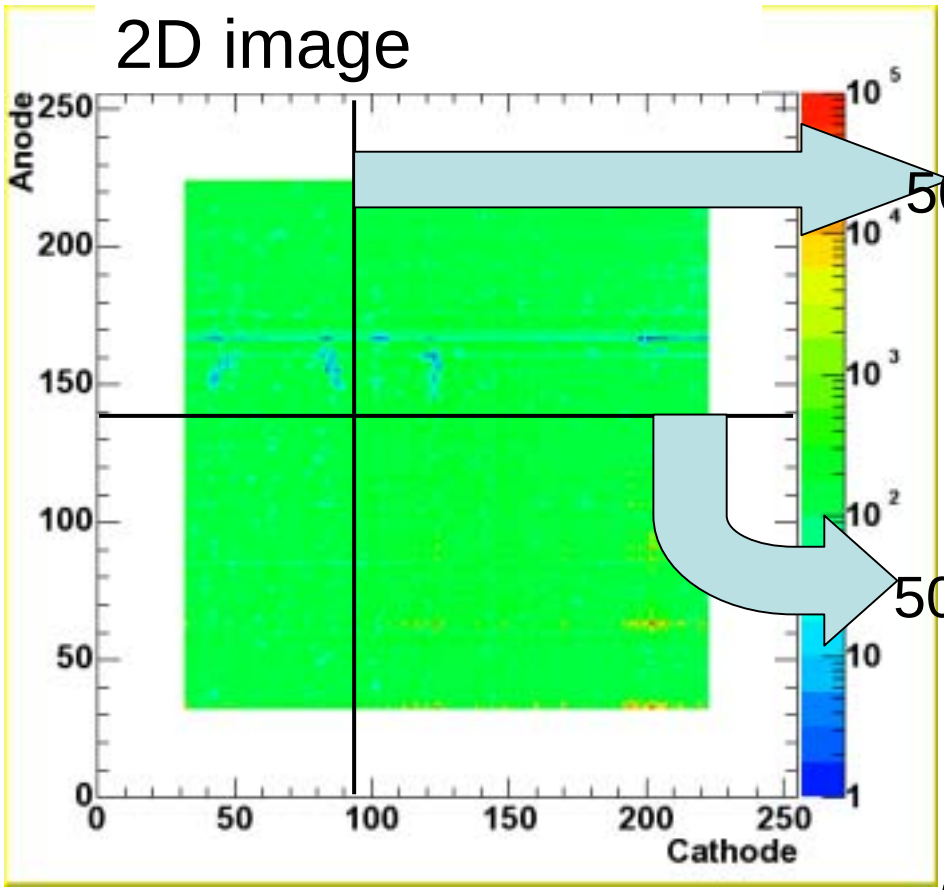
Summary

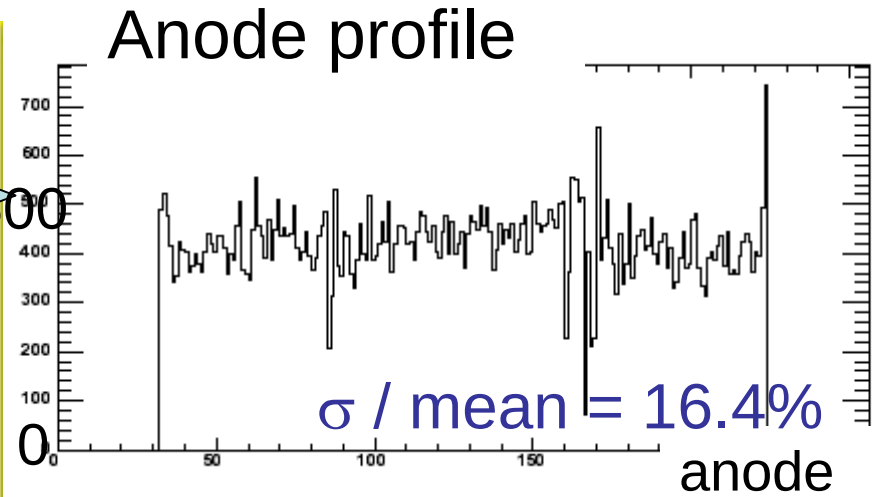
- X-ray imaging property
  - Position resolution ~160μm
  - Uniform image was obtained
- Charged particle imaging (Micro-TPC)
  - 3D tracking ➡ position resolution ~260μm
  - Electron tracks were detected.
- New electrode structure
  - Cap anode μ-PIC

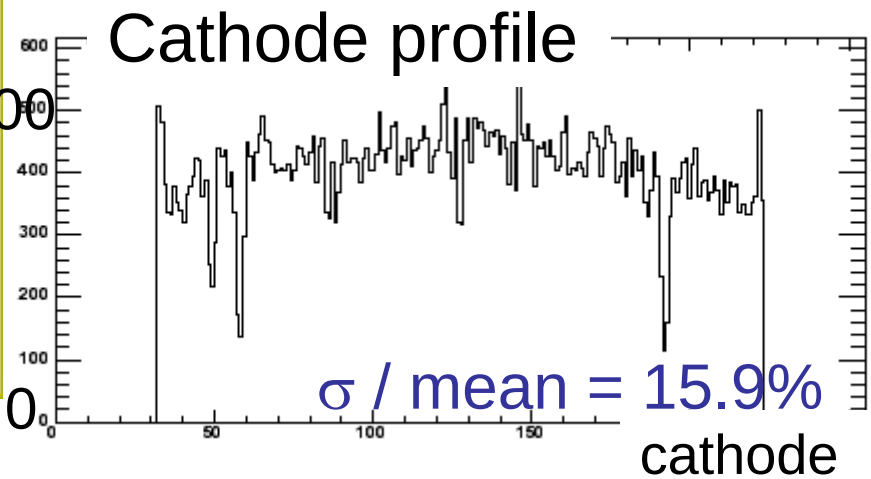
➡ High collection efficiency, Uniform image } are expected.

μ-PIC web site
http://www-cr.scphys.kyoto-u.ac.jp/research/mu-PIC/index.html

X-ray imaging ~ image uniformity ~





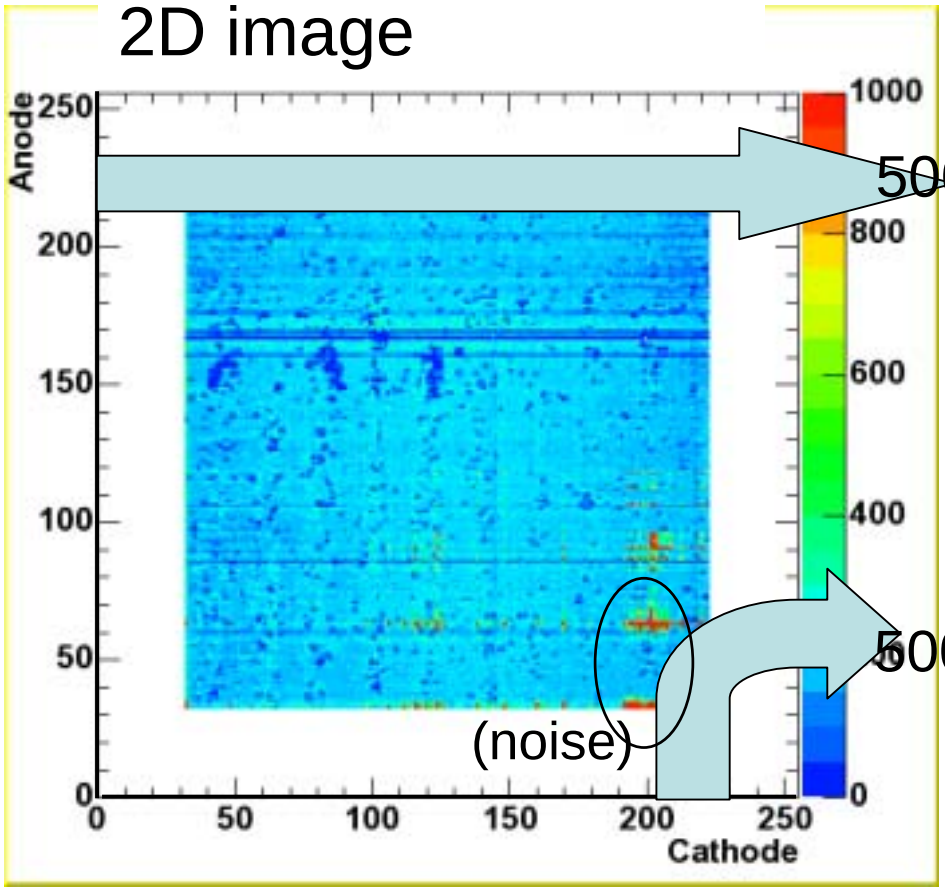


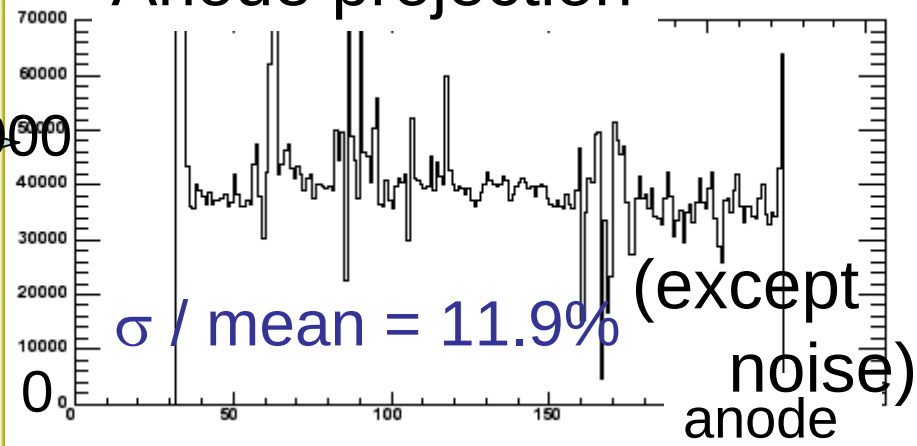
Continuous X-ray
(E < 20keV)

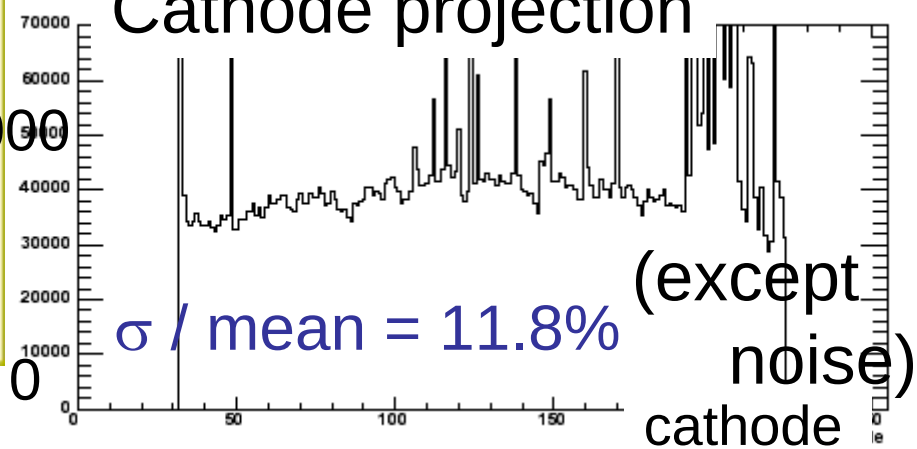
Almost uniform
image was obtained.

γ-ray Detecter μ-PIC MPGC

X-ray imaging ~ image uniformity ~



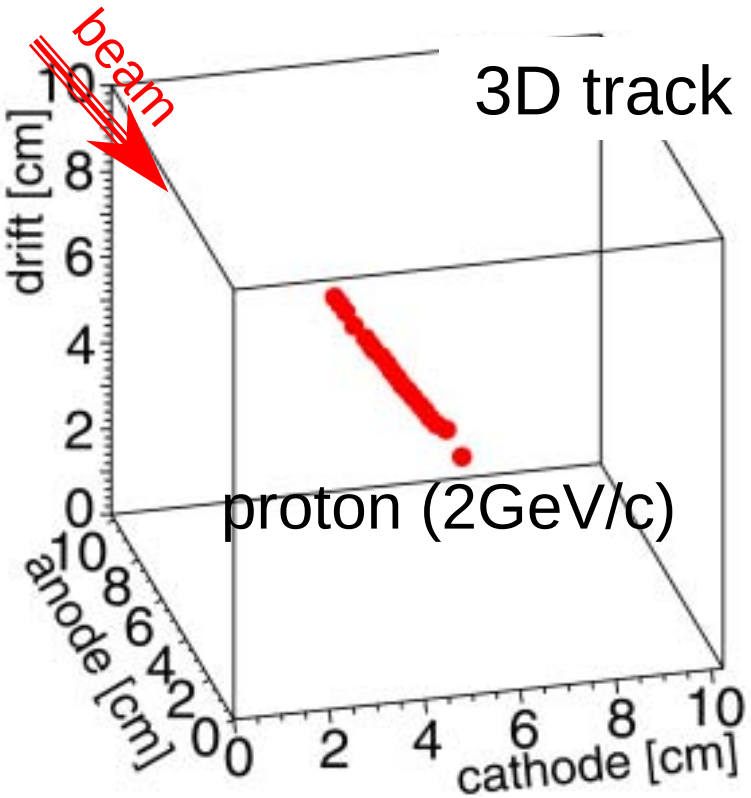




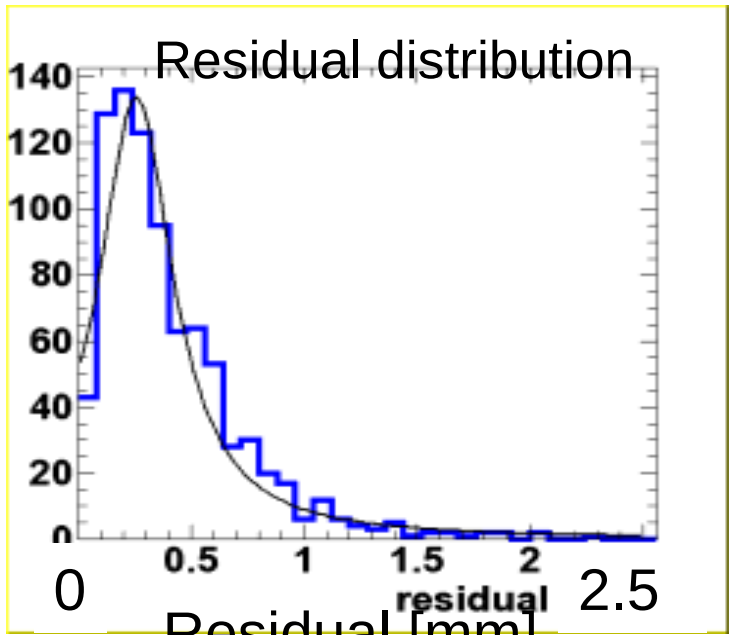
Continuous X-ray
(E < 20keV)

Almost uniform
image was obtained.

Charged particle tracking



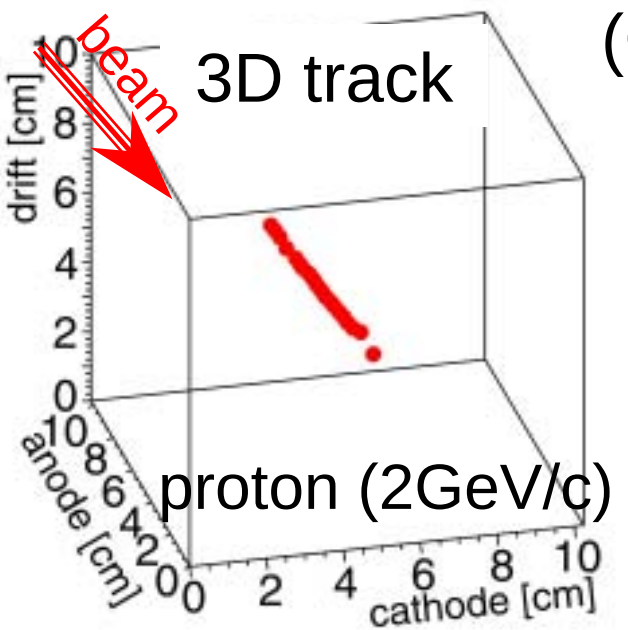
3D track → Linear fit → Residual distribution



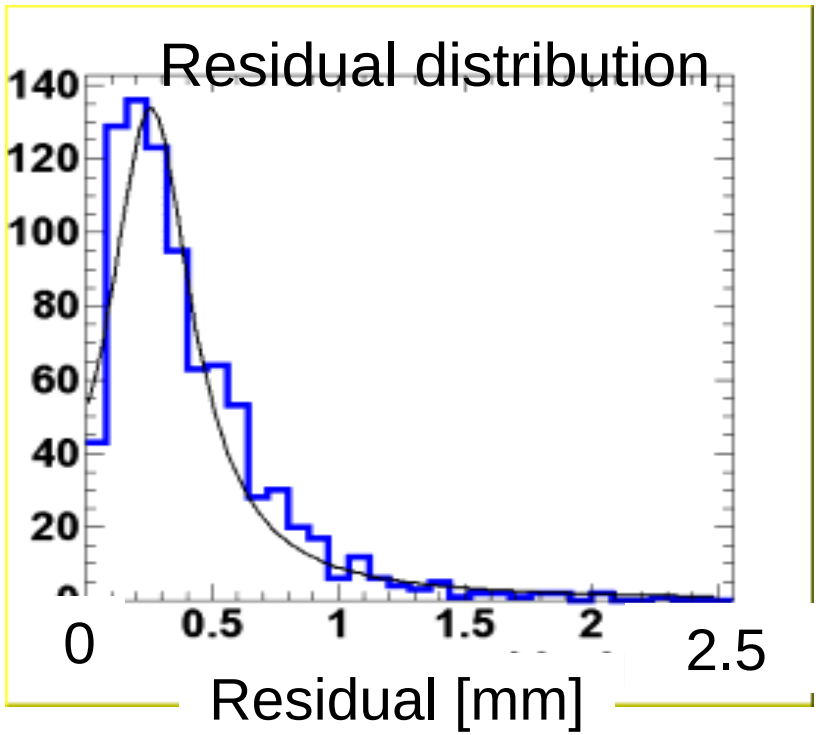
Position resolution (RMS)

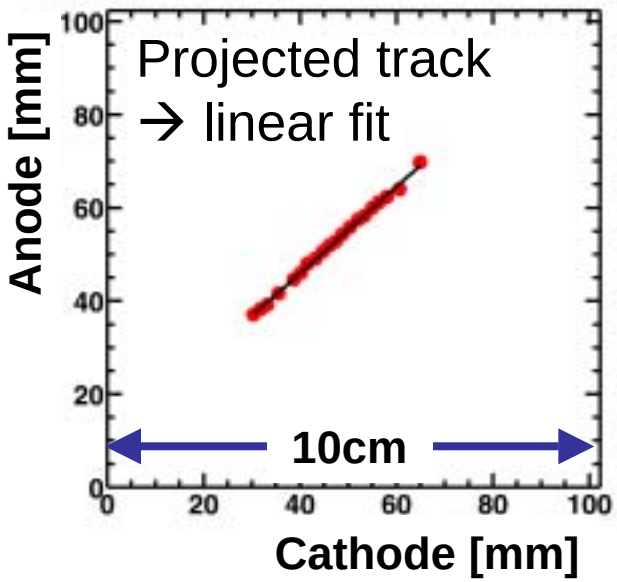
- Ar/C_2H_6 80/20 → 320 μm
- Ar/C_2H_6 90/10 → 260 μm

Charged particle tracking



(Gas: Ar and C_2H_6 mixture)





Position resolution (RMS)

Ratio	2D	3D	Drift velocity
80:20	250 μm	320 μm	(4.7cm/μsec)
90:10	200 μm	260 μm	(3.6cm/μsec)

X-ray imaging ~ image uniformity (1) ~

Fluctuation of anode depth

→ Associated with image uniformity

Distribution of anode depth

Anode R/O

Cathode R/O

	A1	A2	A3	A4	A5
C1	20	15	14	14	19
C2	19	20	20	19	20
C3	16	20	13	14	10
C4	8	6	12	9	12
C5	13	13	16	15	10

Detector #1

depth 14.7μm

σ 4.2μm

Anode R/O

Cathode R/O

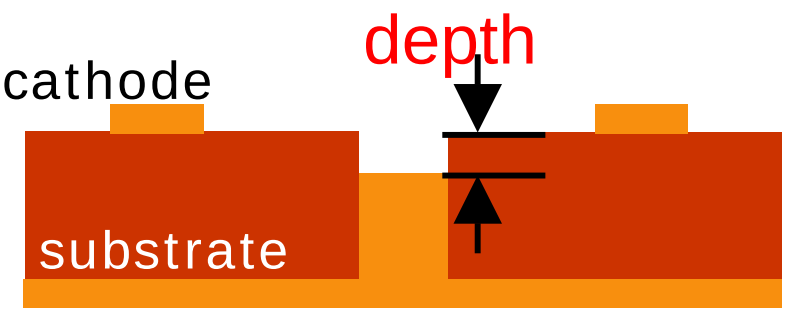
	A1	A2	A3	A4	A5
C1	18	19	20	19	19
C2	23	22	23	22	22
C3	15	22	21	20	19
C4	18	18	17	17	17
C5	21	22	23	22	20

Detector #2

depth 20.0μm

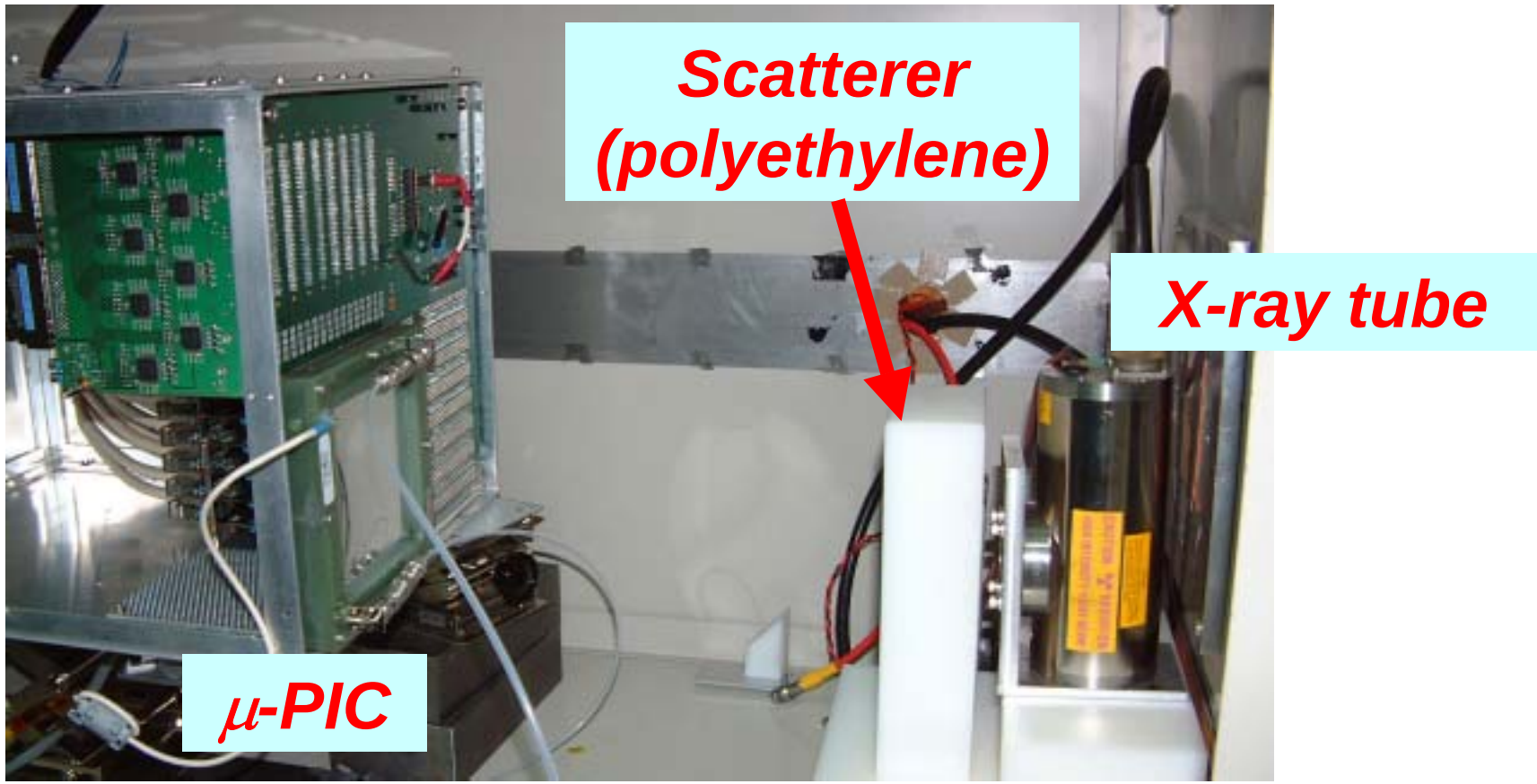
σ 2.2μm

depth	color
10~15μm	
15~25μm	
20~25μm	



(Cross section of μ-PIC)

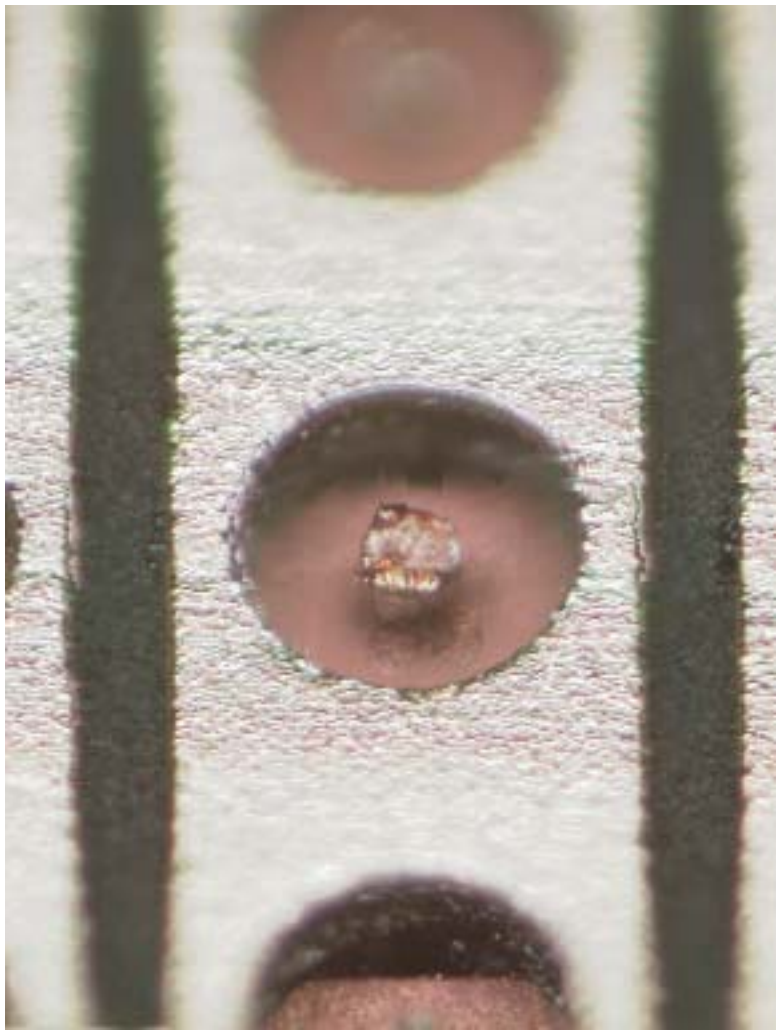
X-ray imaging ~ image uniformity (2) ~



- Source: X-ray tube (20kV)
- Gas: Ar/C_2H_6 (80/20)
- Uniformly irradiated

Resent development

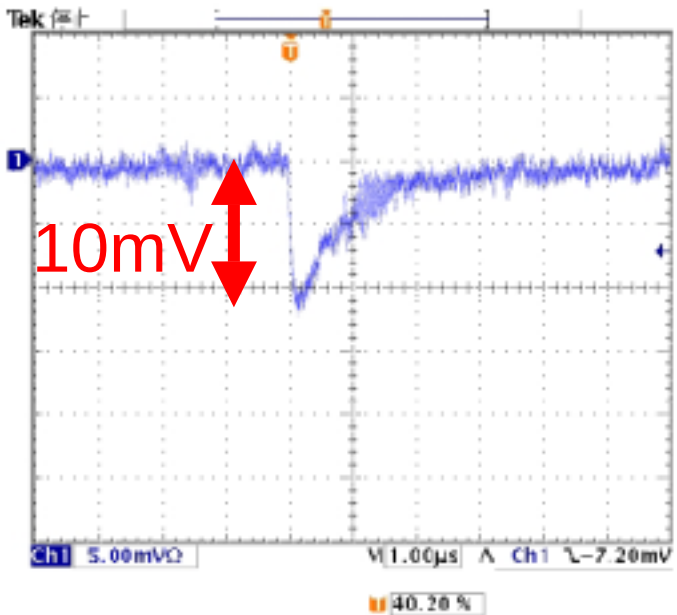
"Well type" μ-PIC



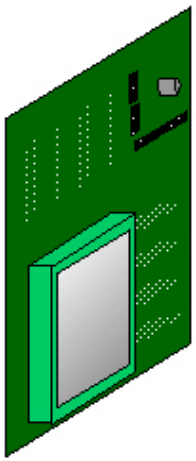
Laser ablation

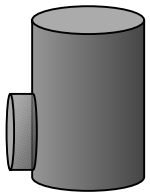
Collection efficiency ↗

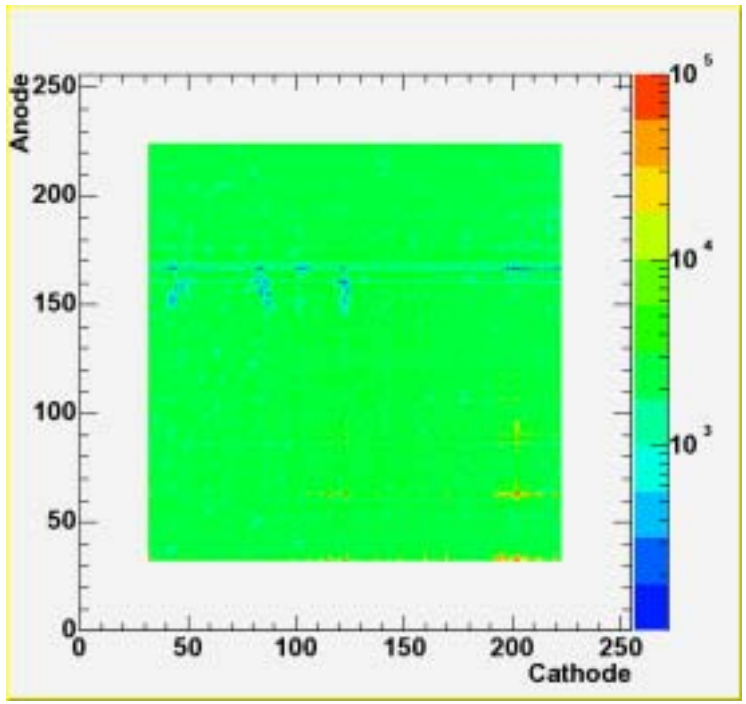
Preliminary result



X-ray imaging property







- Source: X-ray tube (20kV)
- Gas: Ar/C_2H_6 (80/20)
- Uniformly irradiated

γ-ray Detecter μ-PIC MPGC

Application of μ-PIC

- X-ray Imaging
  - X-ray astronomy
  - Crystal structure analysis
- X-ray polarization
  - ➡ *Next presentation (by Ueno)*
- Gamma-ray imaging
  - ➡ *27th, June (by Orito)*
- Charged particle tracking