Development of μ-PIC at Kyoto

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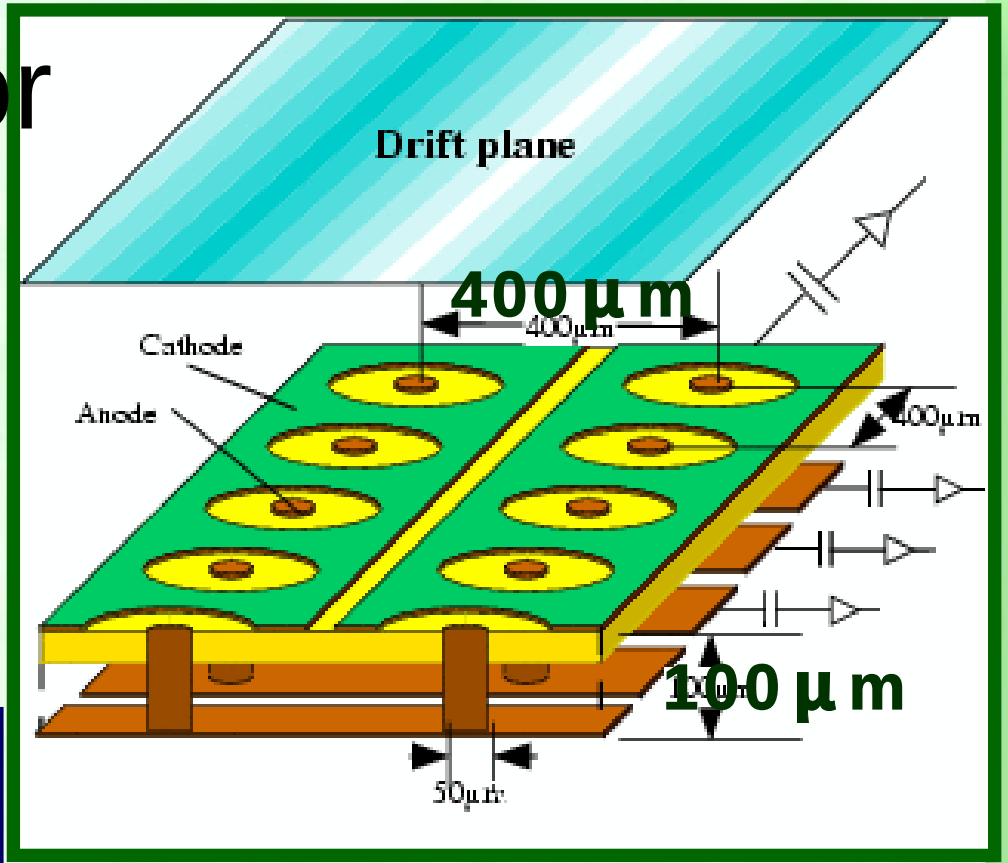
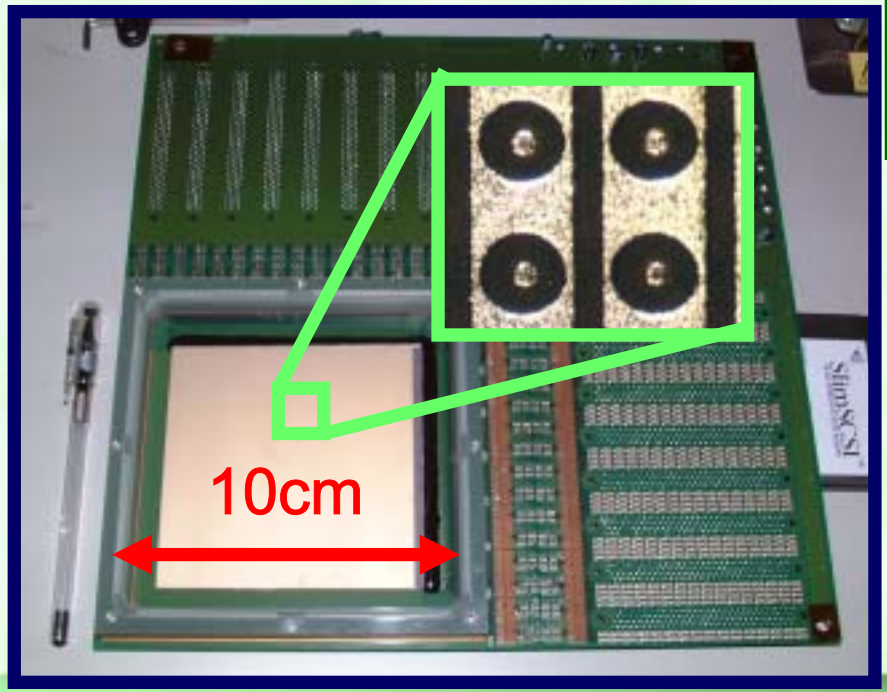
1. μ-PIC Detector

- Micro Pixel Chamber
- 2-D imaging detector for charged particles
- manufactured by the PCB technology





- 10cm×10cm μ-PIC
  256anode + 256 cathode strips
- Fine position resolution
- High gain
- Discharge damage: small

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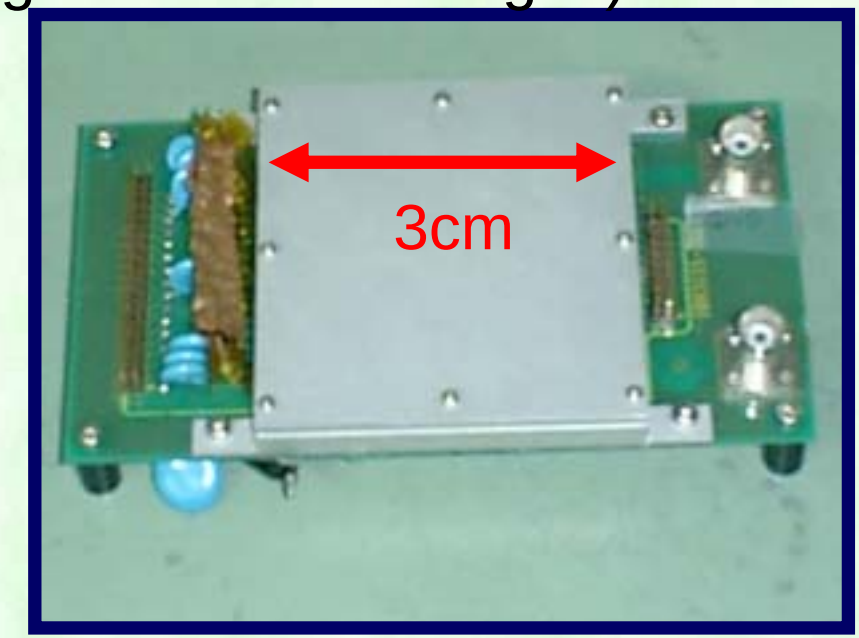
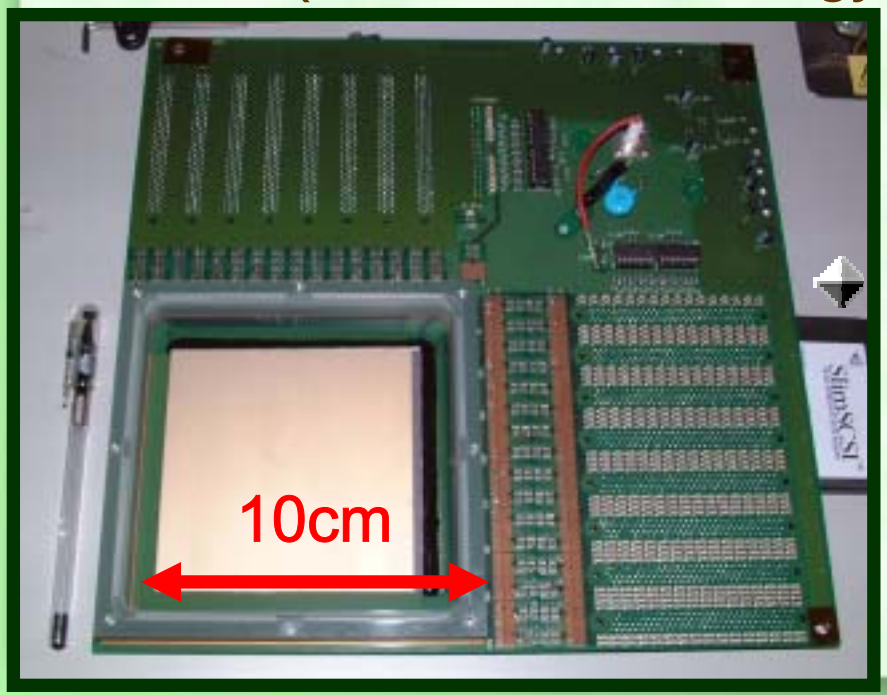
2. Development History

(History of the fight against the discharges)

- Test Piece ($3 \times 3cm^2$)
  - several pieces up to now
  - ~$5,000 /pc
  - for “trials”
    (material, technology, …)



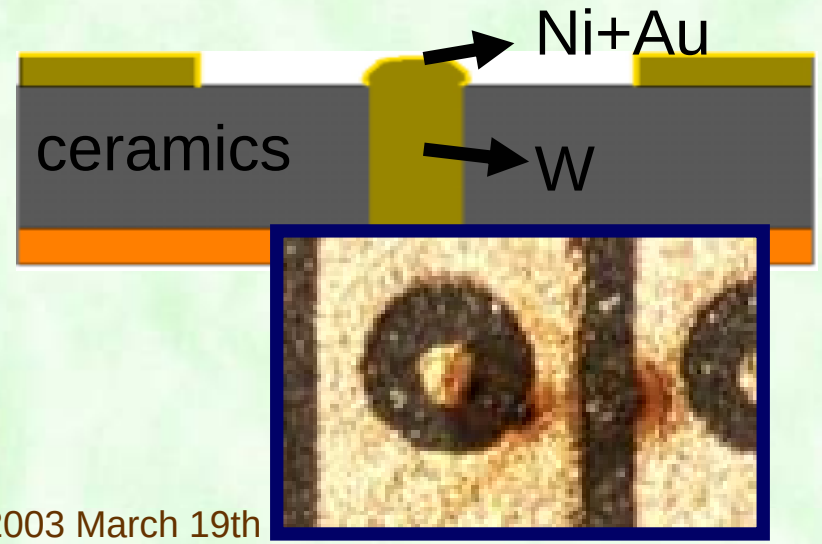


- Full size detector ($10 \times 10cm^2$)
  - 5 detectors up to now
  - ~$30,000/pc
    (including the motherboard.)

Development of the Full size detectors

- started in 2000
- Made by Toshiba

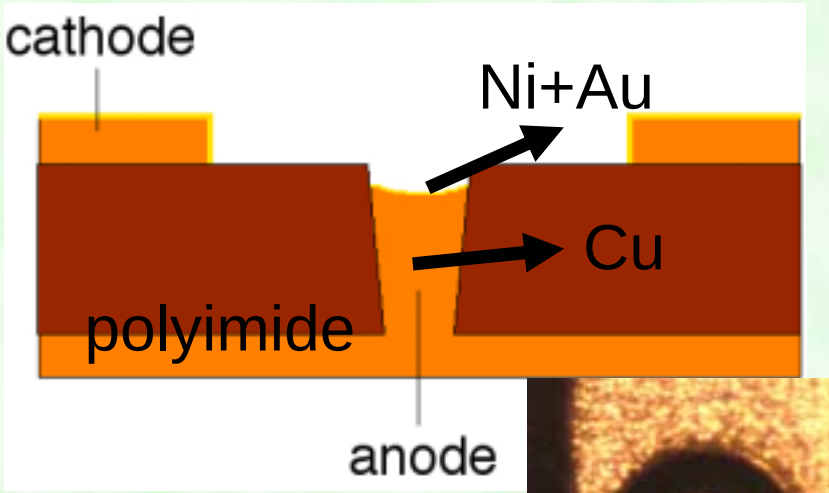
Detector	Substrate	Electrode	Anode height
μ-PIC 1	ceramics	W, Ni, Au	+10 μm
μ-PIC 2	polyimide	Cu, Ni, Au	-25 μm
μ-PIC 3	polyimide	Cu, Ni, Au	-15 μm
μ-PIC 4,5	polyimide	Cu, Ni	-20 μm



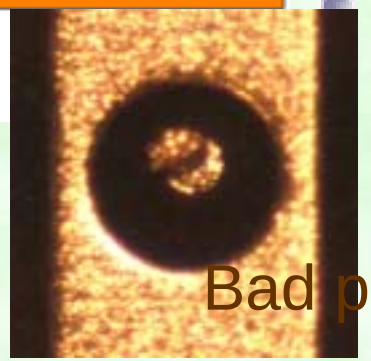
- Manufacturing: easy (uniform anode electrodes)
- Ceramics: Catalytic discharge → conductive
- not for practical use

Development of the Full size detectors

Detector	Substrate	Electrode	Anode height
μ-PIC 1	ceramics	W, Ni, Au	+10 μm
μ-PIC 2	polyimide	Cu, Ni, Au	-40 μm
μ-PIC 3	polyimide	Cu, Ni, Au	-15 μm
μ-PIC 4,5	polyimide	Cu, Ni	-20 μm



- Polyimide base: better
- μ-PIC 2: low gain (<3000)
- μ-PIC 3: higher gain (~7000)
- Gold plating: scatters around discharge → conductive

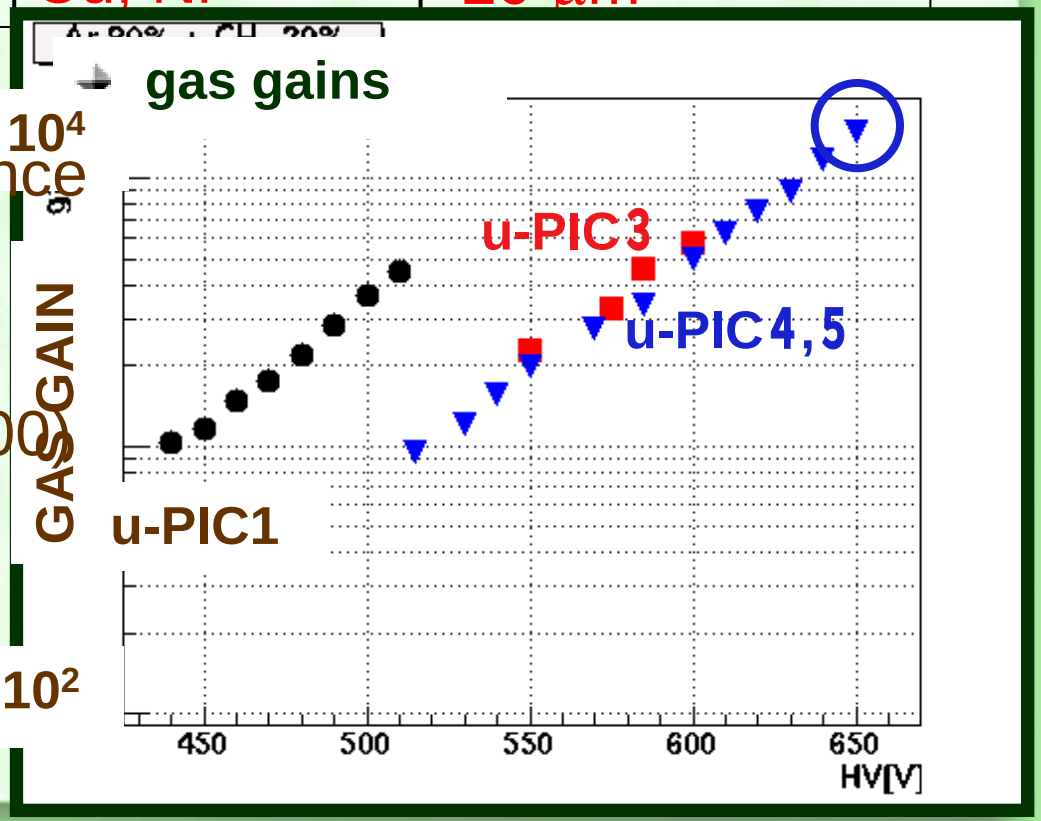


Bad pixel found in μ-PIC 3

Development of the Full size detectors

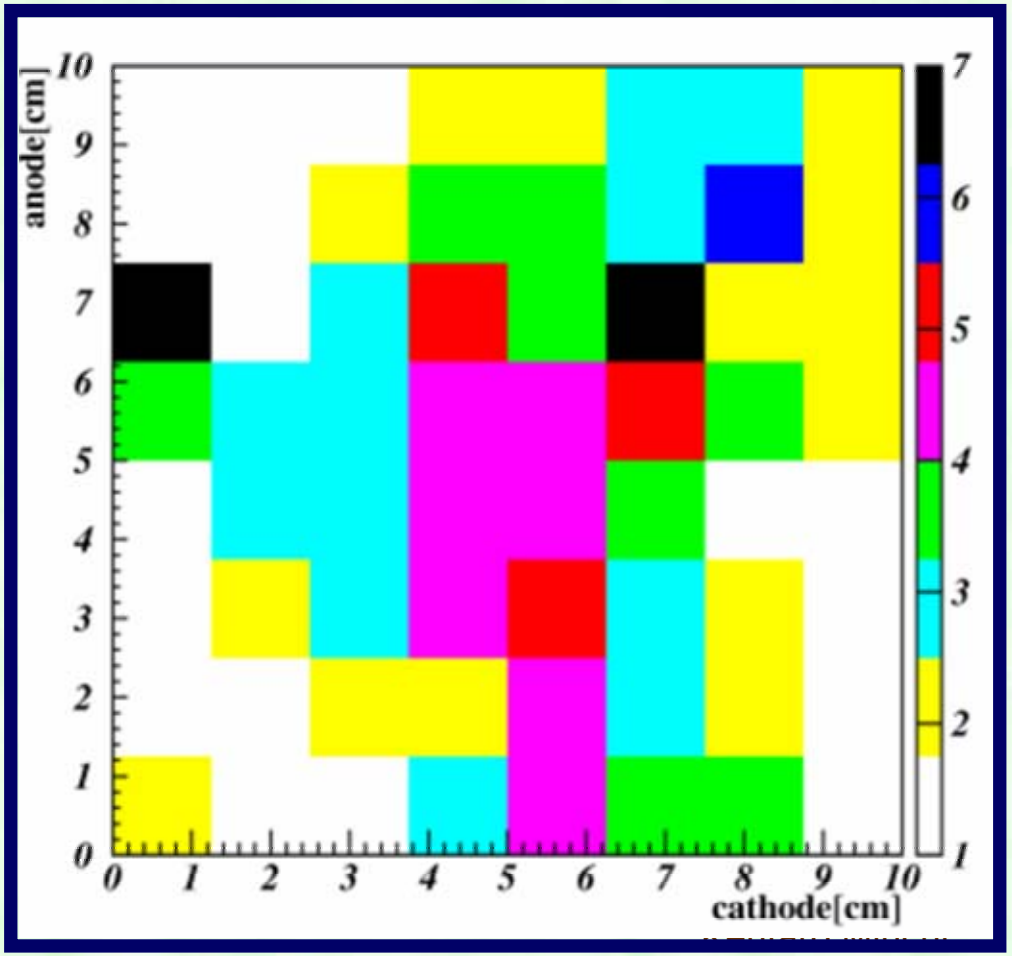
Detector	Substrate	Electrode	Anode height
μ-PIC 1	ceramics	W, Ni, Au	+10 μm
μ-PIC 2	polyimide	Cu, Ni, Au	-40 μm
μ-PIC 3	polyimide	Cu, Ni, Au	-15 μm
μ-PIC 4,5	polyimide	Cu, Ni	-20 μm

- μ-PIC 4,5: good performance
- high gain (~15000)
- stable operation
  (1000 hours with gain 3000)



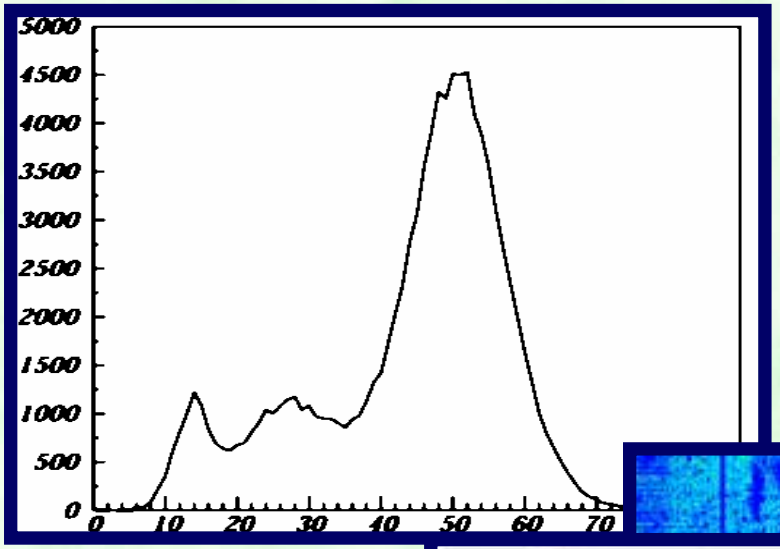
Development of the Full size detectors

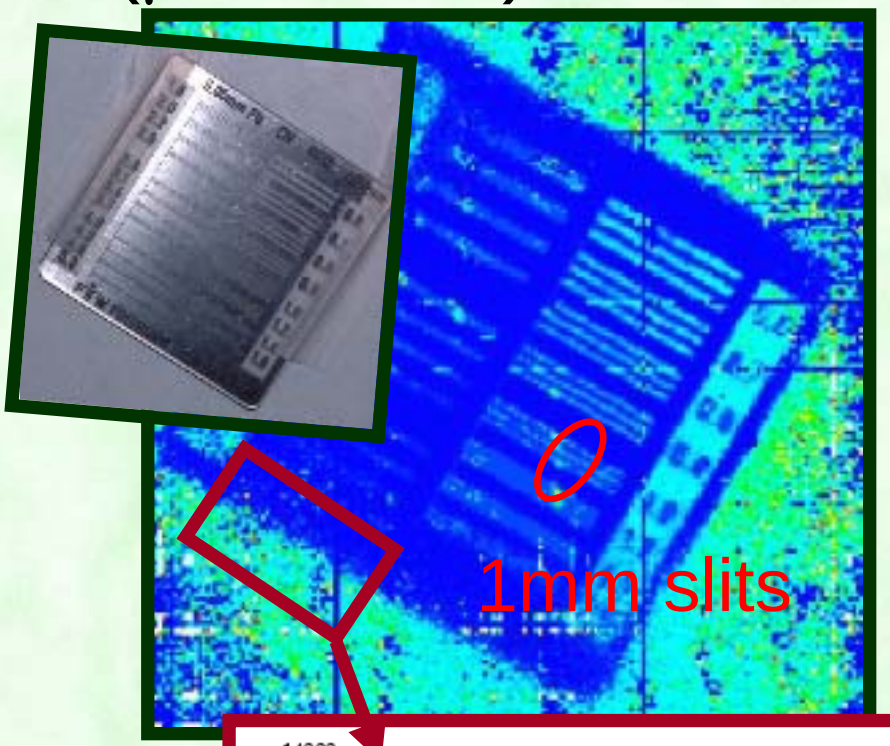
- μ-PIC 4,5: problems to be solved
  anode electrodes heights are not uniform
- large vessel for the plating was prepared
- μ-PIC 6 will be shipped
  at the end of March

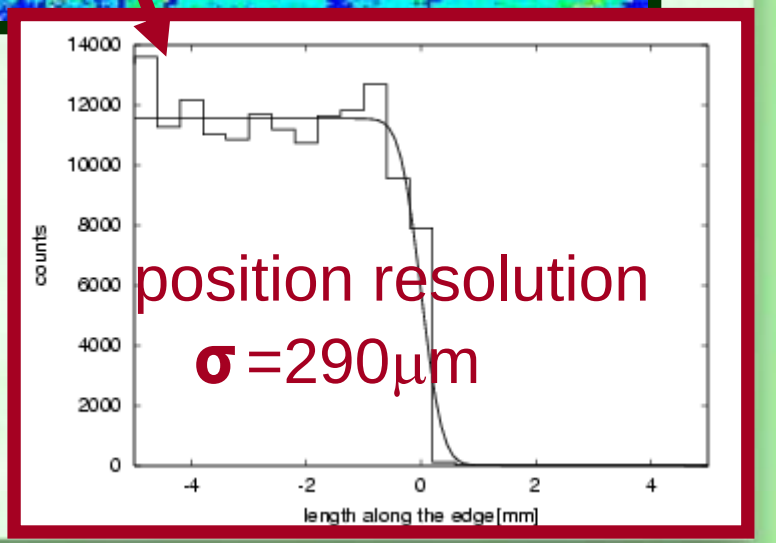


3. Current Status (μ-PIC 4,5)

- Imaging
- Spectrometry
  - energy resolution FWHM30%@5.9keV

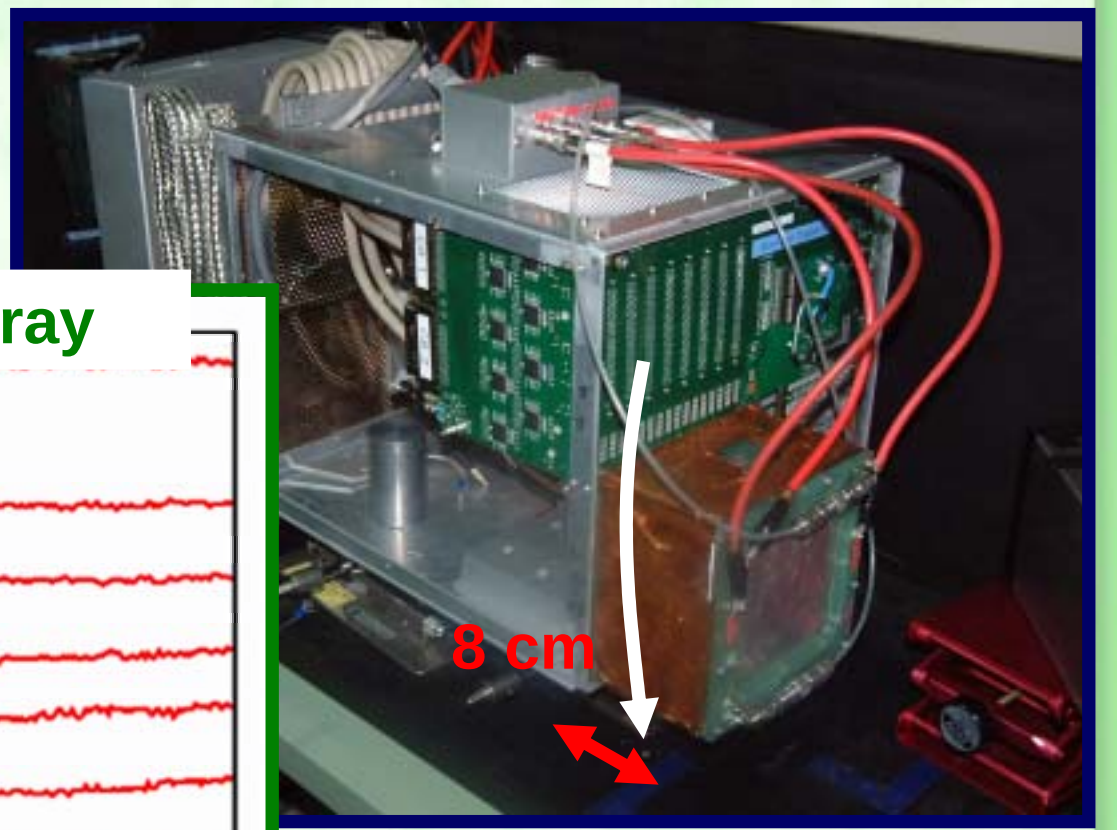


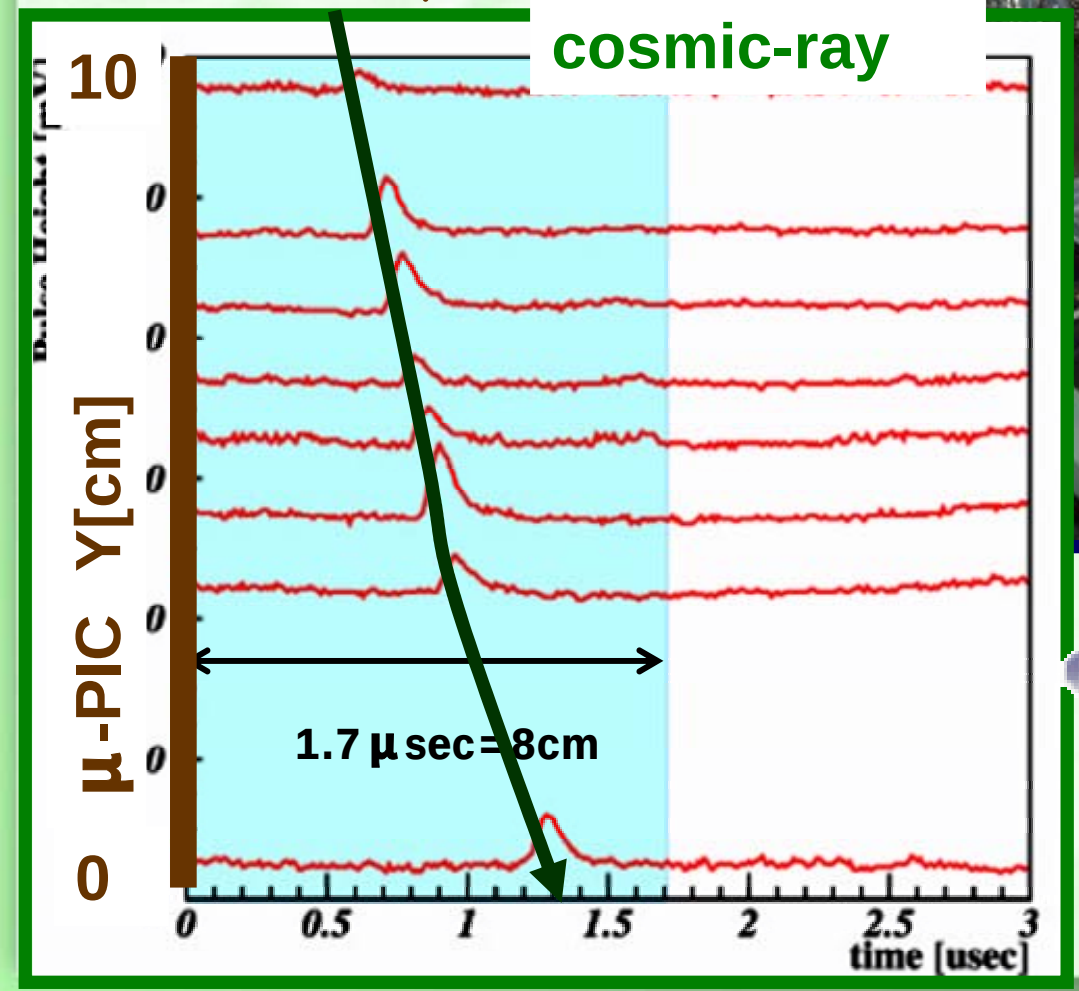




μ-PIC for Micro-TPC

- drift enclosure
  8cm drift length
  4.7cm/μs drift V

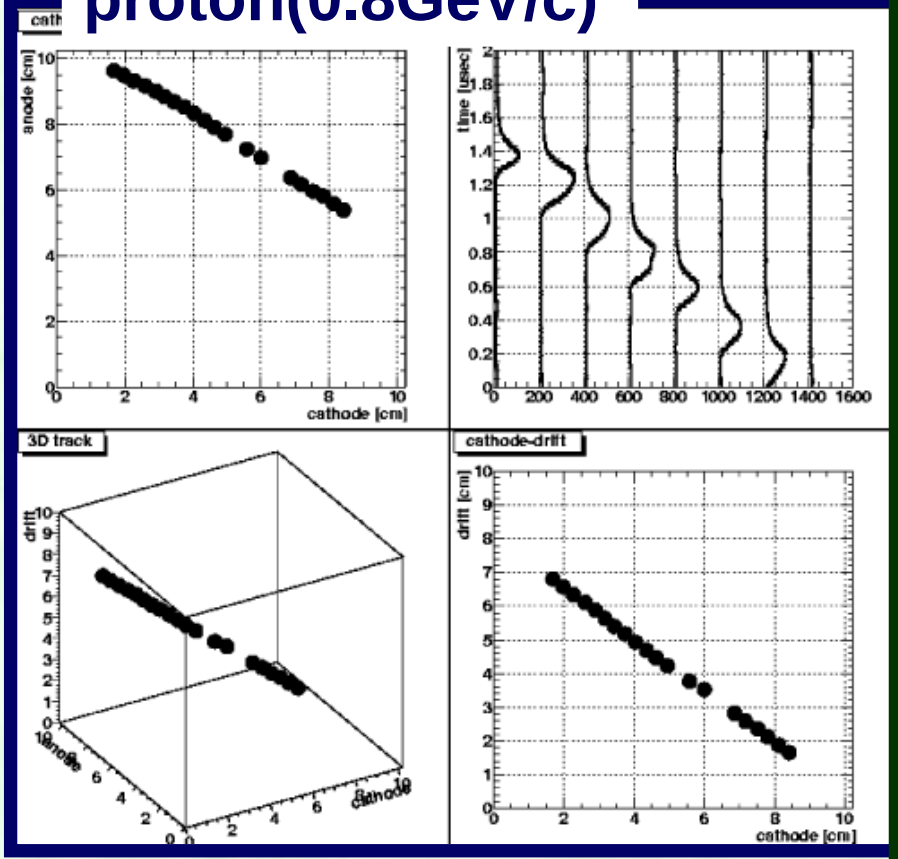




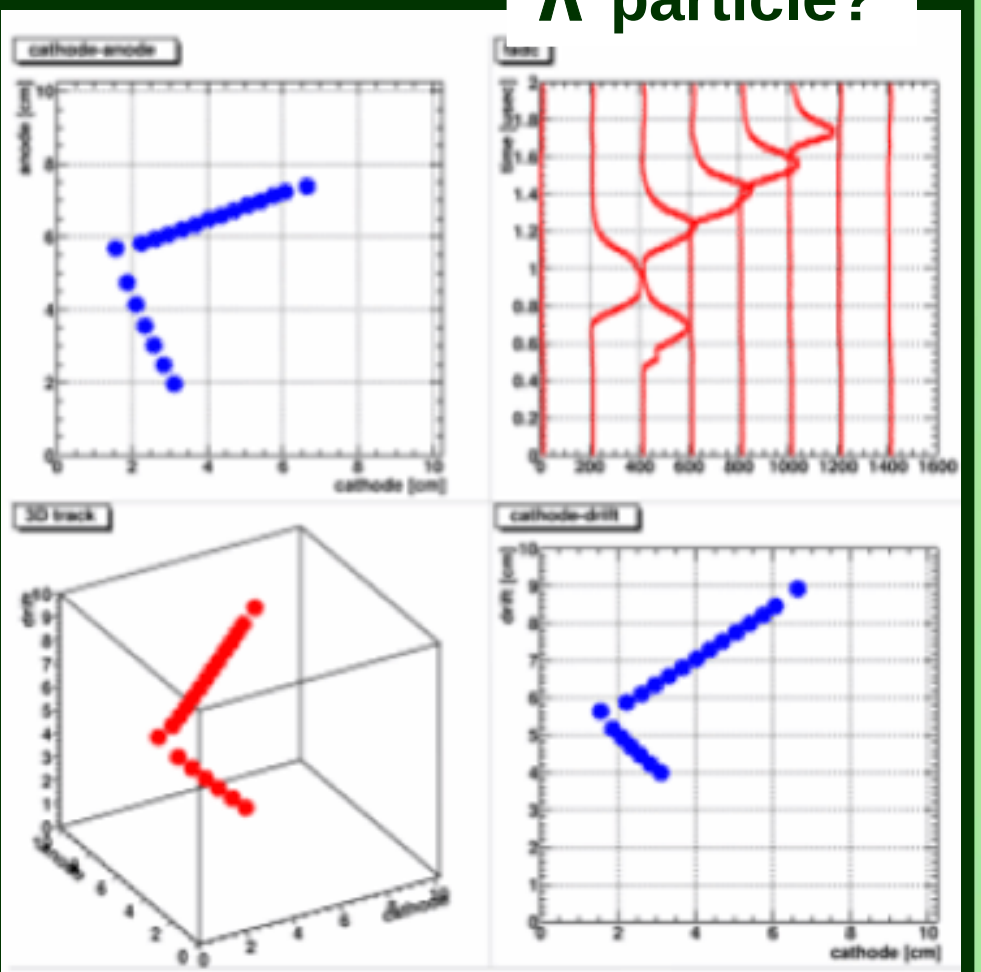
- micro-TPC
  X,Y information : μ-PIC
  Z information: timing

- tracking the charged particles
  @proton synchrotron(gain~3000)

proton(0.8GeV/c)

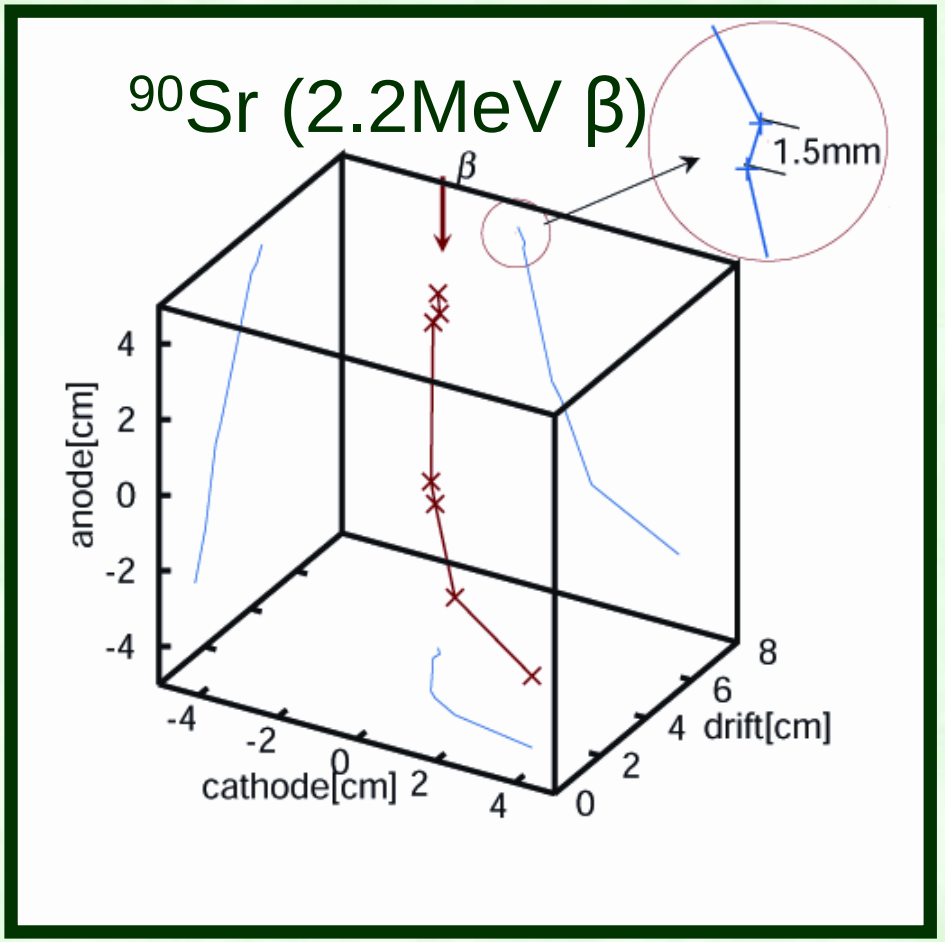


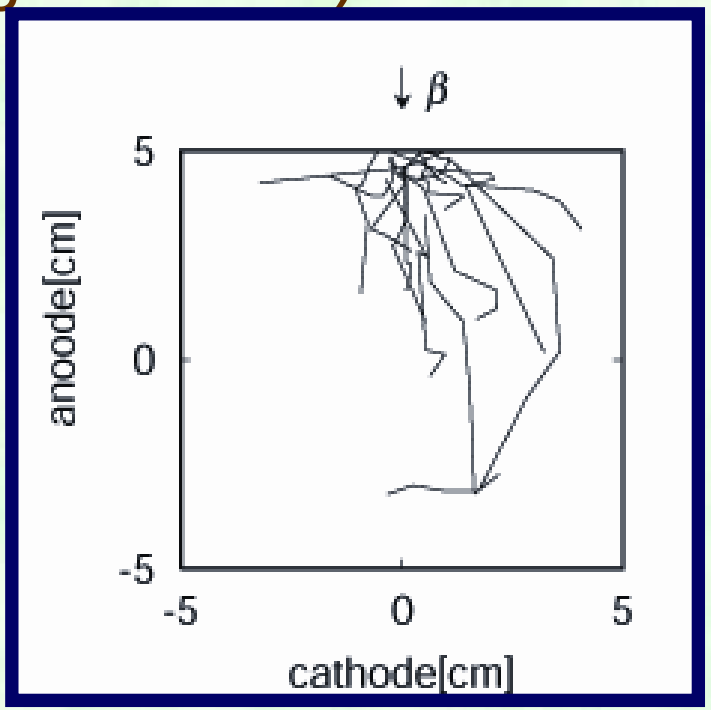
Λ particle?



good tracking ability
for large dE/dx particles

- tracking the charged particles
  @laboratory (gain~7000)



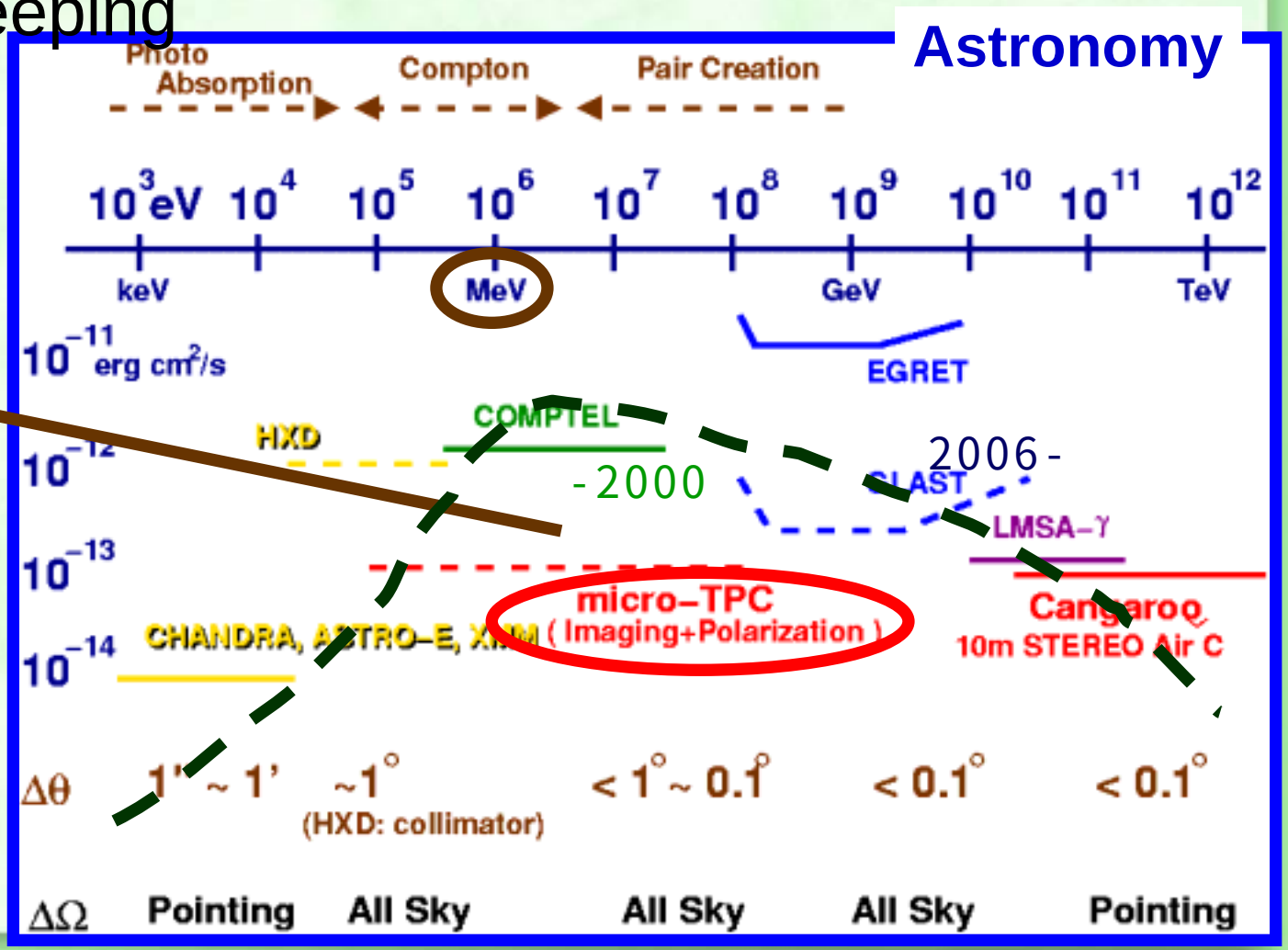


not enough…

more gain

MeV gamma-ray imaging

- Astronomy
- Medical use
- Safety keeping

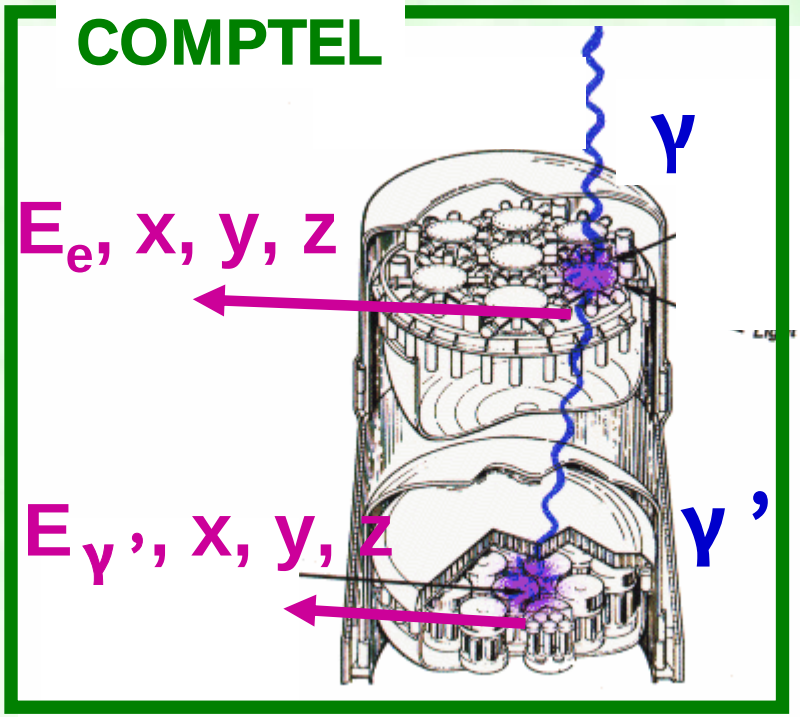


sensitivity gap

Compton γ-ray Imaging

- Double Compton Method

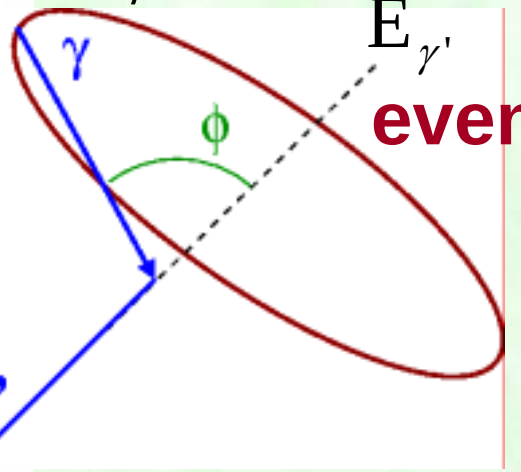
COMPTEL



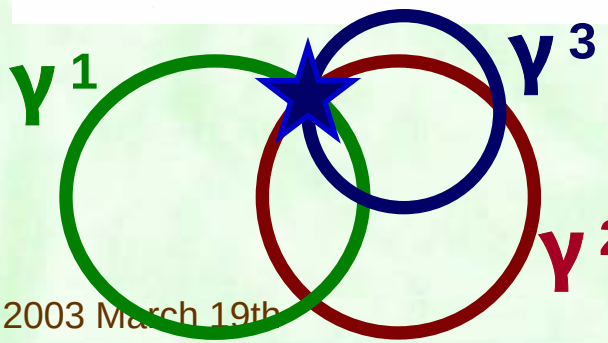
RECONSTRUCTION

$$E_\gamma = E_{\gamma'} + E_e$$

$$\cos\phi = 1 - \frac{m_e c^2}{E_{\gamma'}} + \frac{m_e c^2}{E_\gamma}$$



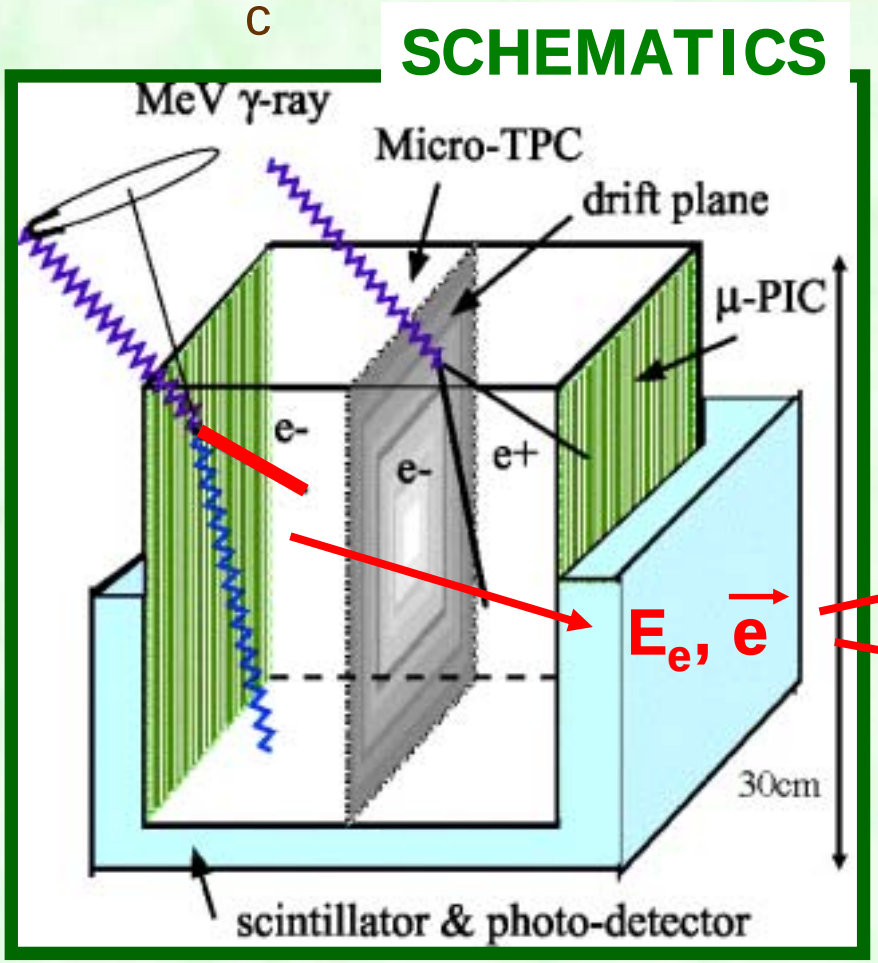
event cone

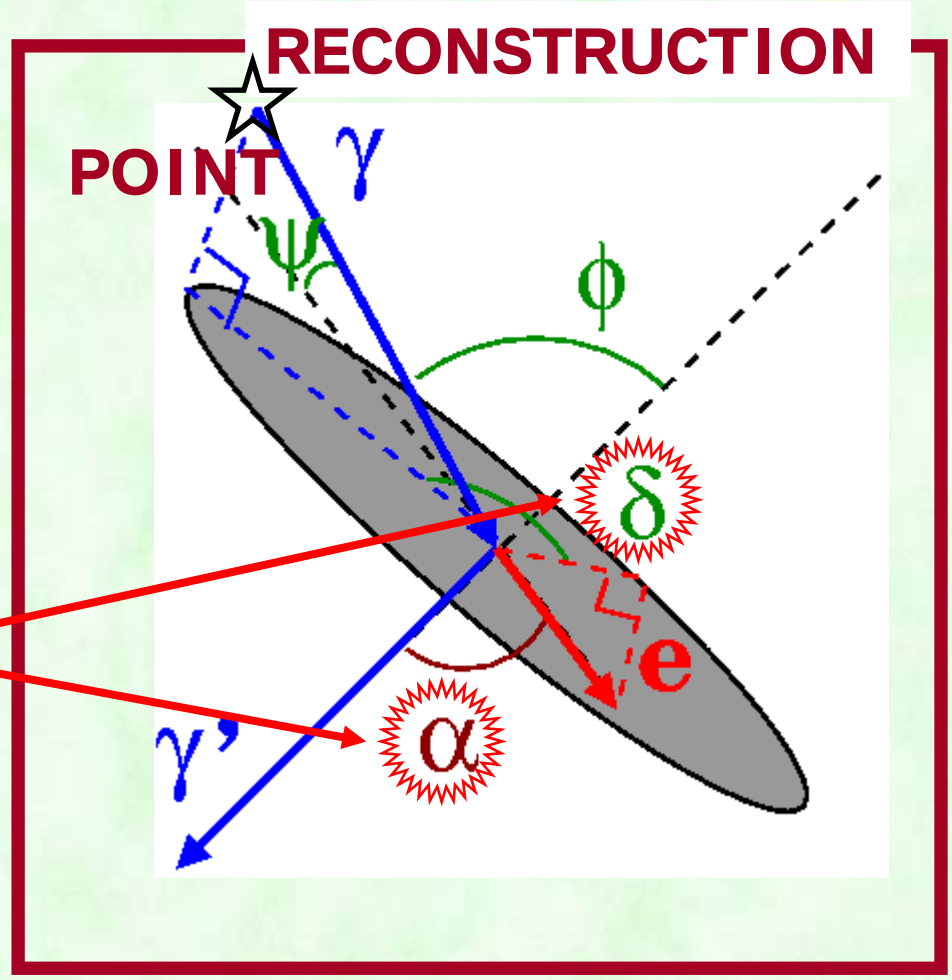


- ✓ **3 γ ⇒ 1 direction**
- ✓ **No background rejection**
- ✓ **needs TOF to know UP or DOWN**

Our method Method

c





α⇒BG rejection

γ-ray imaging with micro-TPC

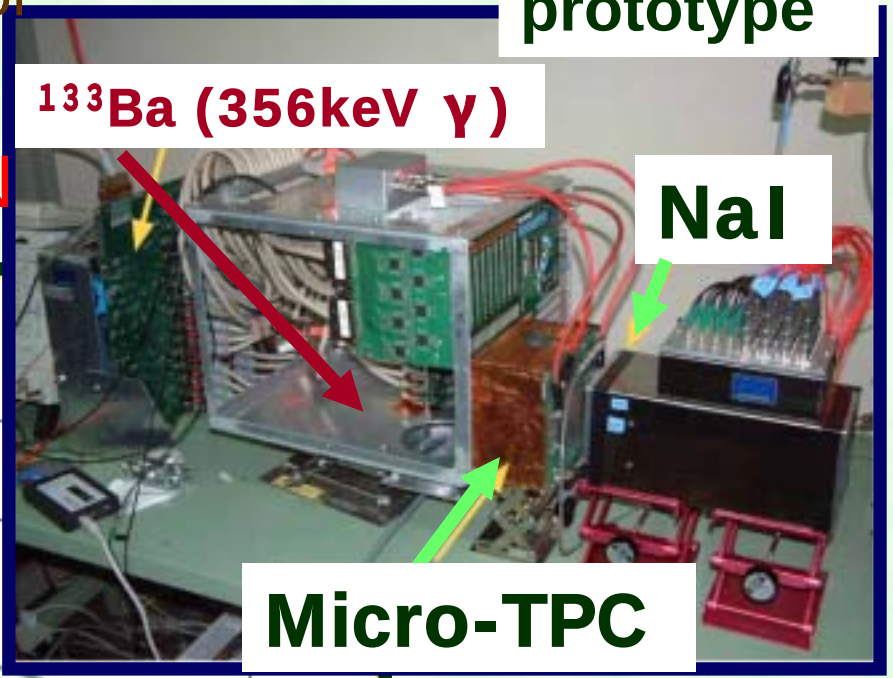
electron track: micro-TPC

+

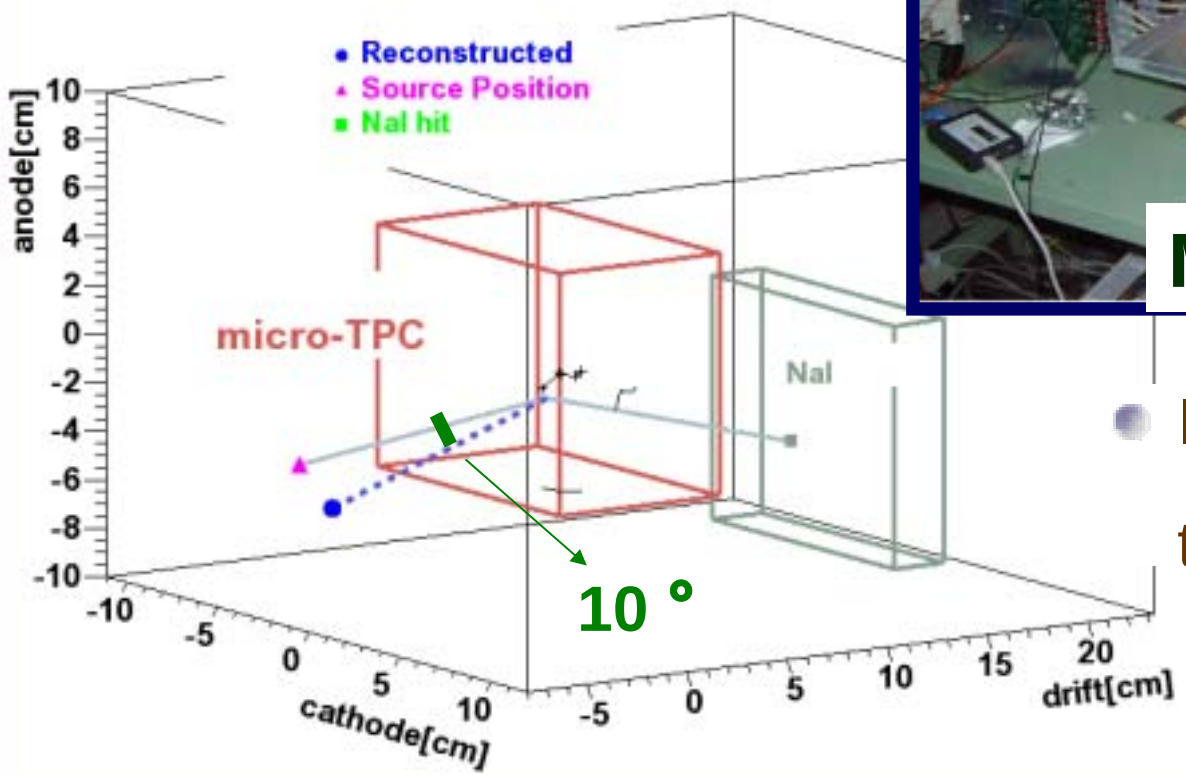
scattered γ : NaI(Tl) scintillator

FULL RECONSTRUCTION

prototype



typical event



- IT WORKS!!
  (for the first time in the world)

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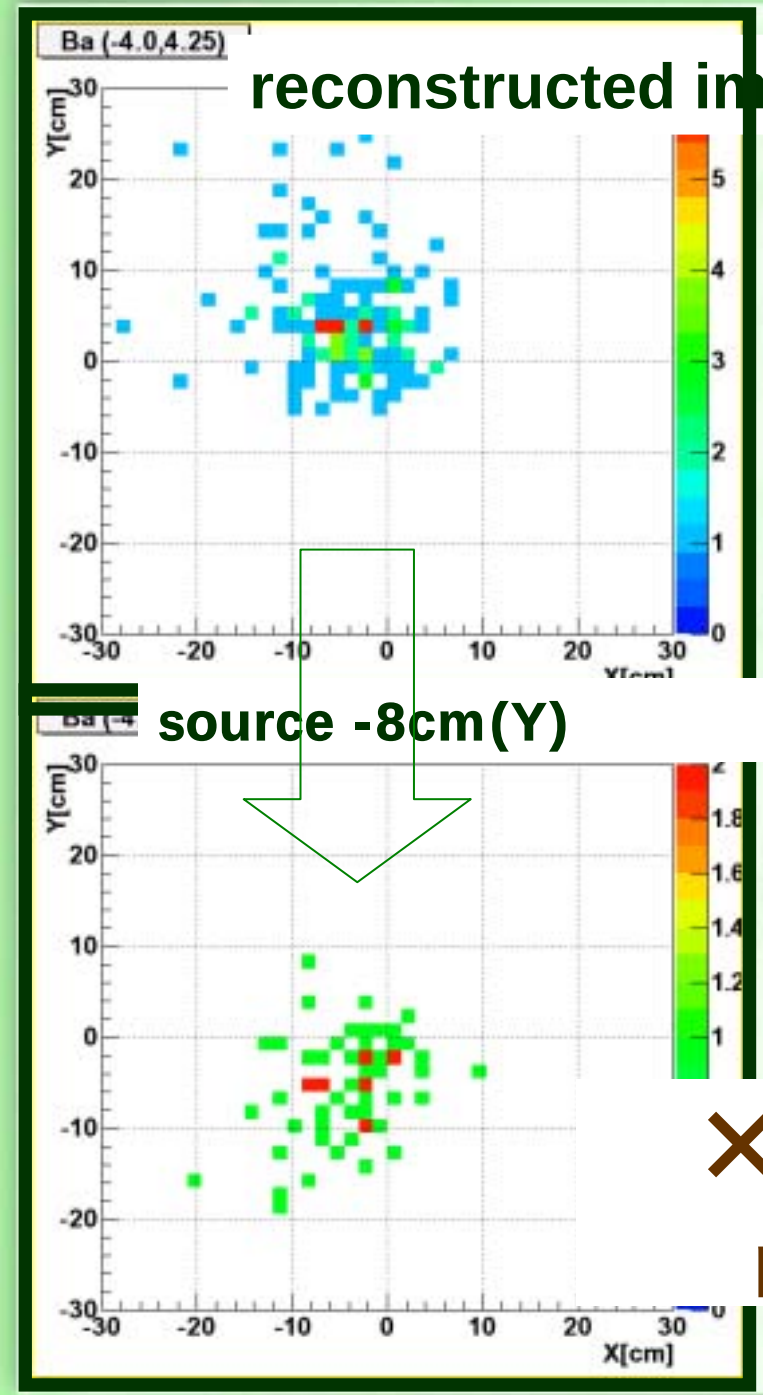


- performance
  angular resolution ～40 °

  not enough…

  more gain

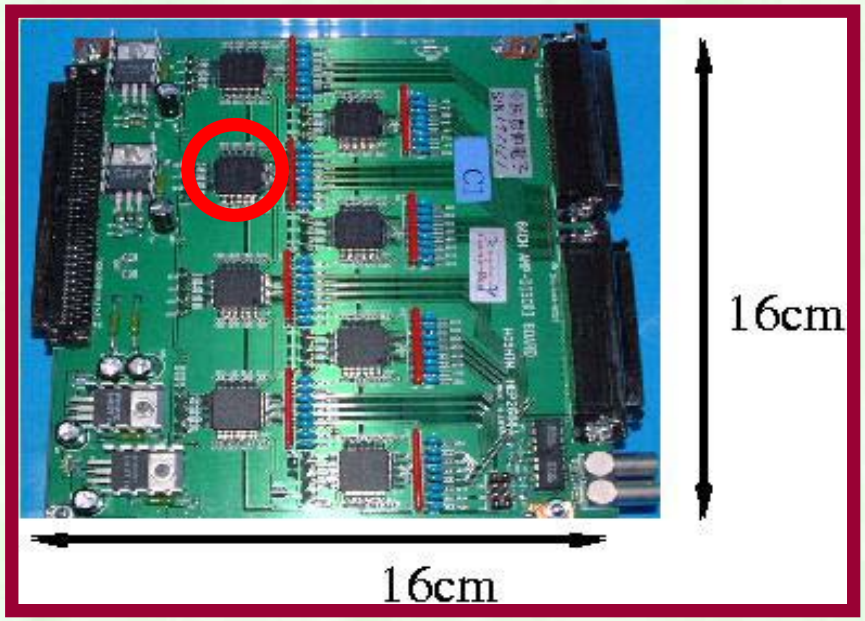
- Current status of μ-PIC
  - X-ray: OK
  - micro-TPC
  - γ-ray imaging

  } not enough

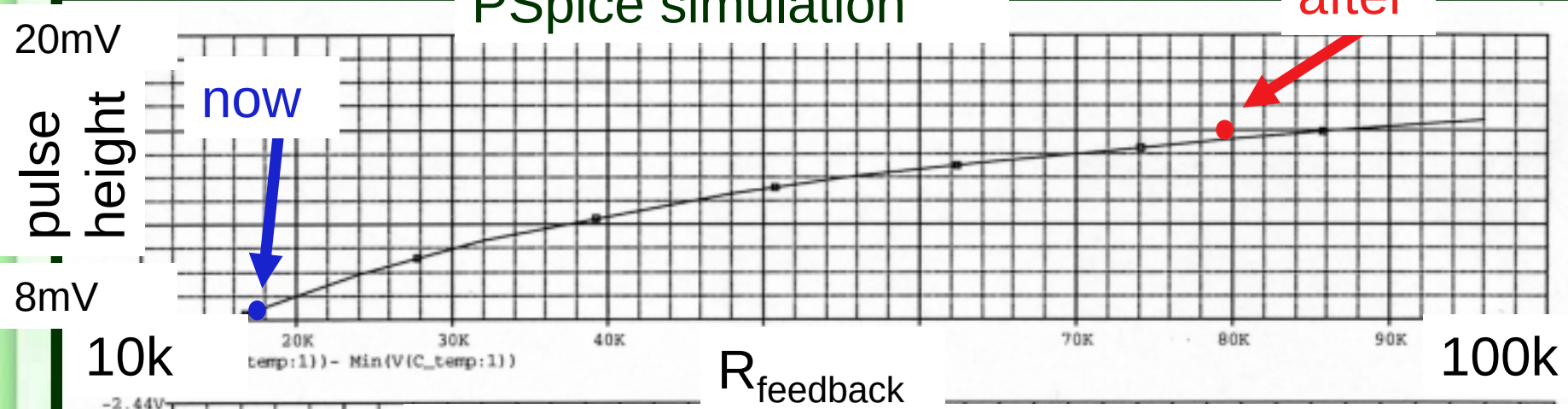
×10 improvement for minimum ionizing particles

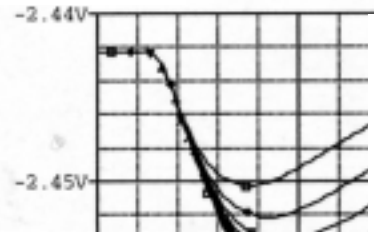
4. Future Works

- Amplifier modifications
  - SONY semi-custom IC
  - ASD (amplifier-shaper -discriminator) chip
  - shaping time 16ns->80ns



PSpice simulation

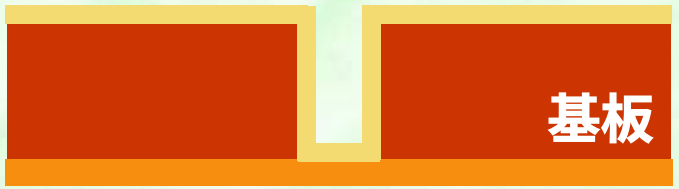




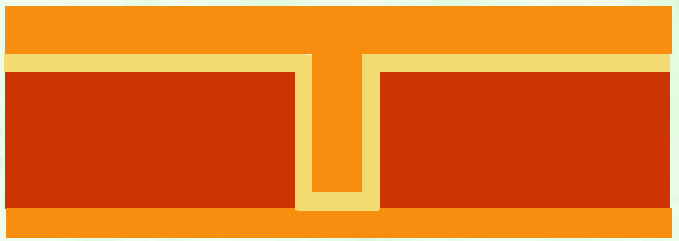
- test chip is shipped in March 20th
- pulse height ✕ 2 expected

New plating technology (for μ-PIC 7+, hopefully)

1. Electroless plating



2. Via-fill plating



3. Surface etching

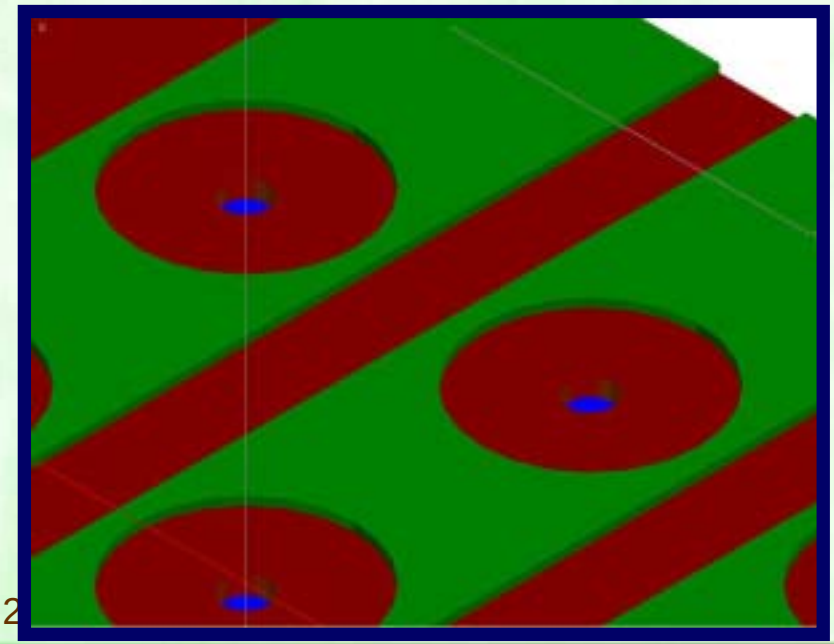
4. Electrode etching

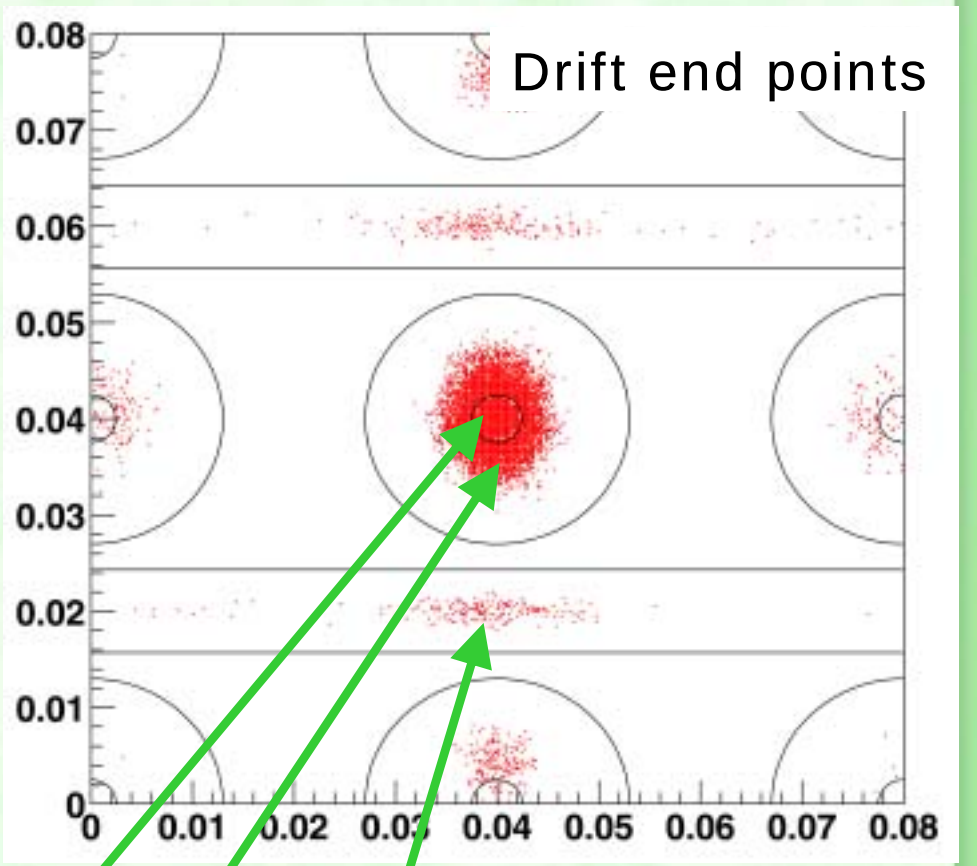
High and uniform anode electrodes will be made.

Geometry studies

- Simulation work at Kyoto (Maxwell + Garfield)
- μ-PIC4,5

  Cathode width: 314μm
  Cathode diameter: 260μm
  Anode height: -20μm
  Anode diameter: 50μm





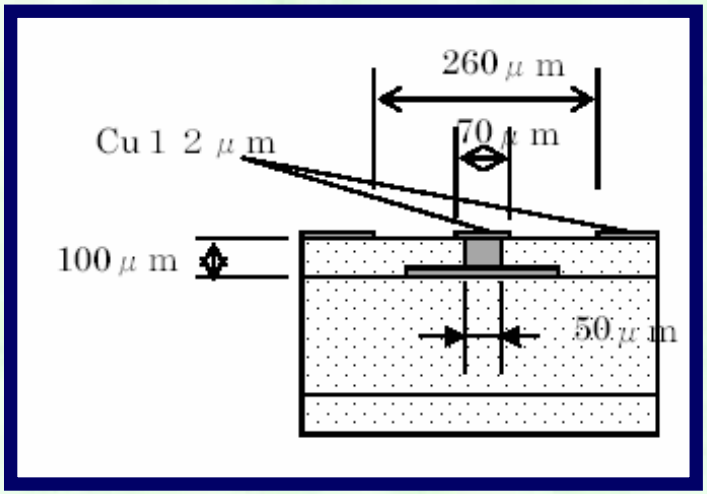
Collection efficiency ··· 30%

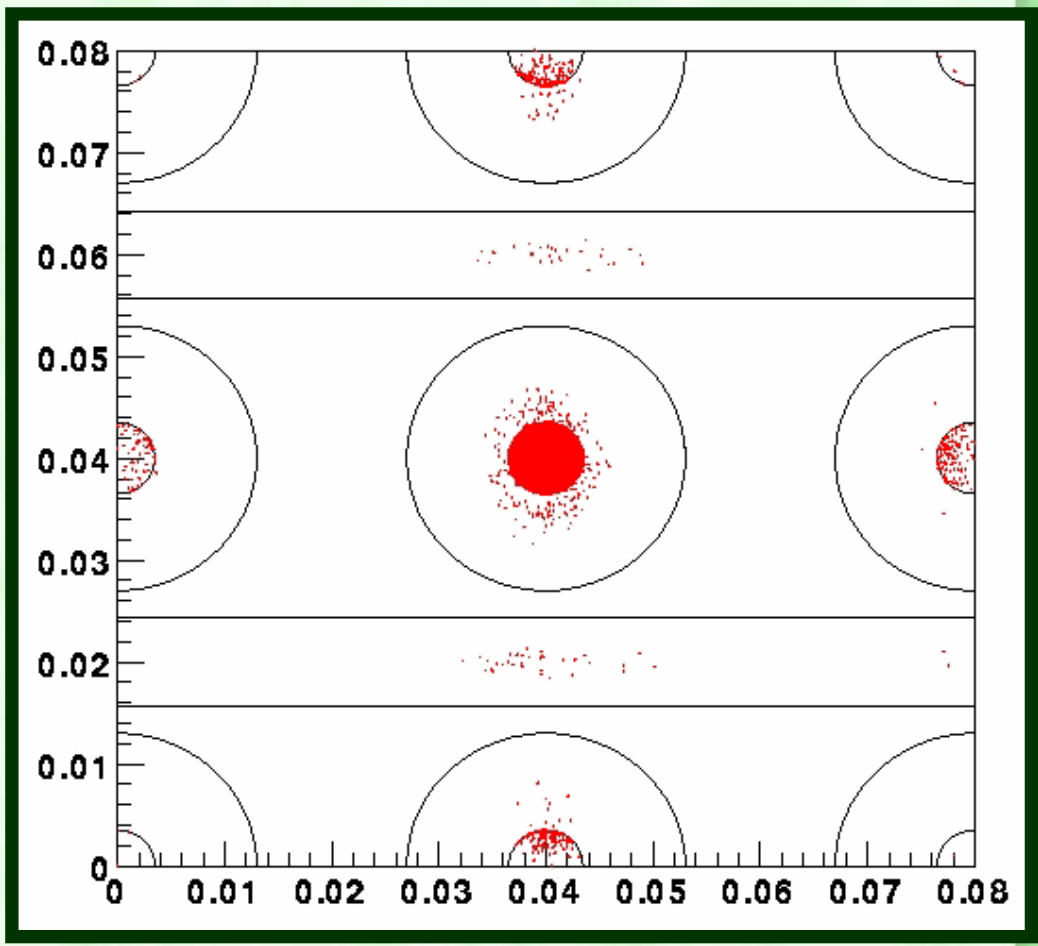
Near pin ··· 65%

Cathode gap ··· 4%

μ-PIC7 (with new plating technology)

- Cathode width: 314μm
  Hole diameter: 260μm
  Anode height: 10μm
  Anode diameter: 70μm





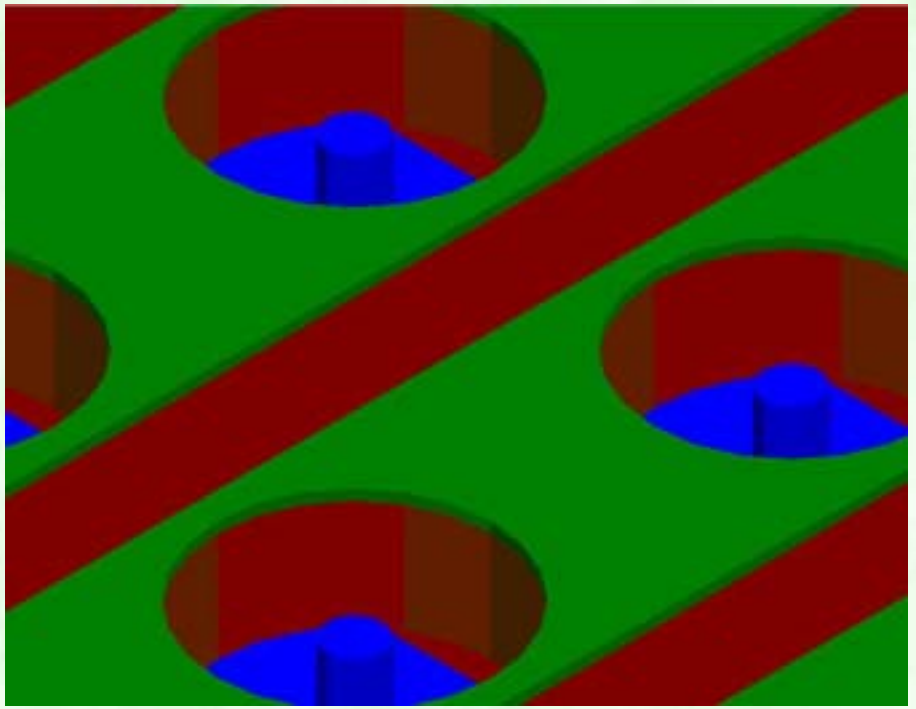
Collection ··· 97%

Near pin ··· 2%

Gap ··· <1%

High efficiency
is expected!!

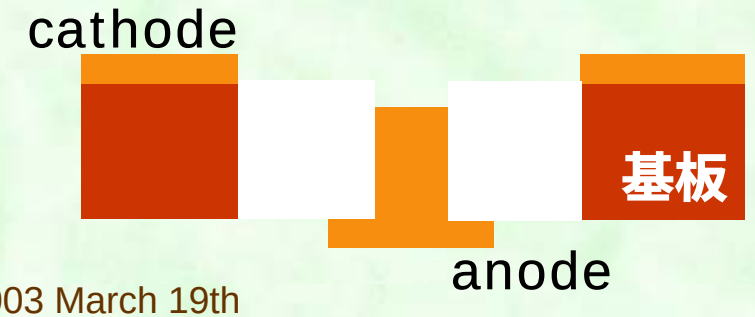
Well type μ-PIC



- Advantages
  - No near pin electrons
  - No discharge?

3cm test piece with laser machining
-->discharge problem

Manufacturing process



- Technology breakthrough is expected (RIE process?)
- Energy resolutions?

5. Summary

- Development History
  - five full-size μ-PIC
  - Polyimide base + no gold plating
- Current Status
  - X-ray 2-D imaging detector
  - Micro-TPC
  - Gamma-ray imaging
- Future Works
  - new plating technology
  - well type μ-PIC