Response of Micro Pixel Chamber to heavy ions with the energy of several hundreds of MeV/n

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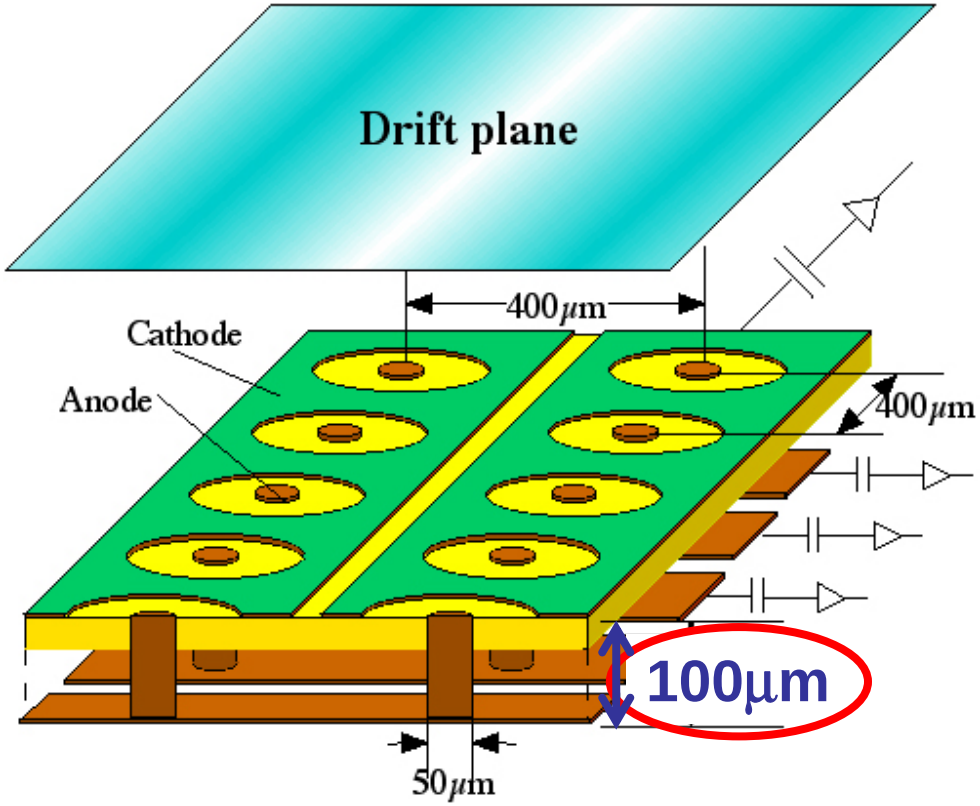
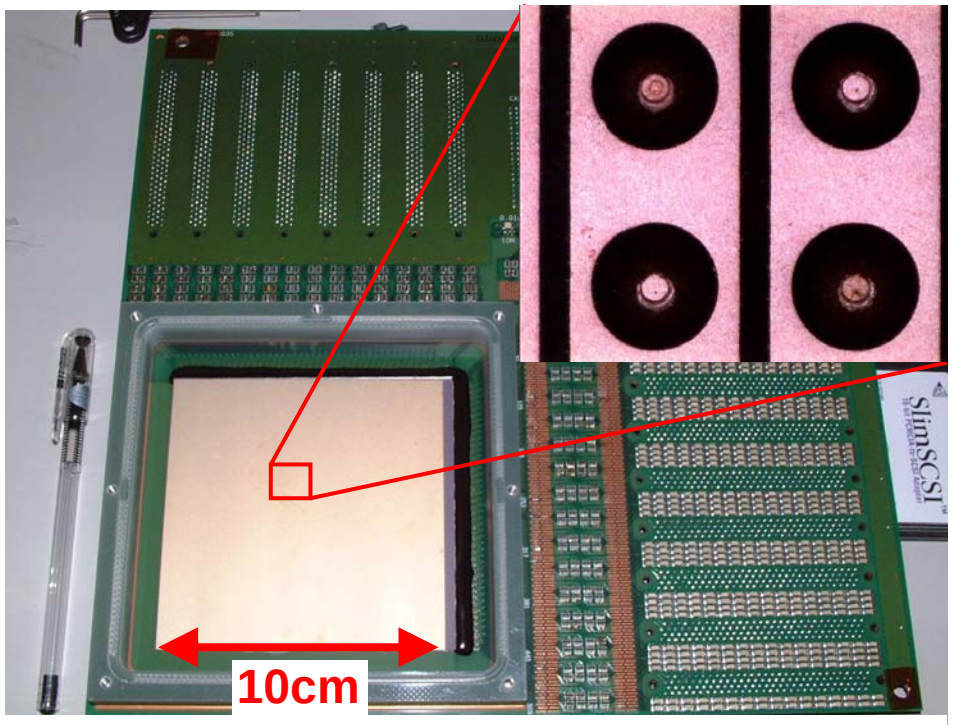
- Imaging properties and application
- Heavy ion irradiation to μ-PIC
- Irradiation test at HIMAC
- Space dosimeter based on μ-PIC
- Summary

Micro Pixel Chamber (μ-PIC)



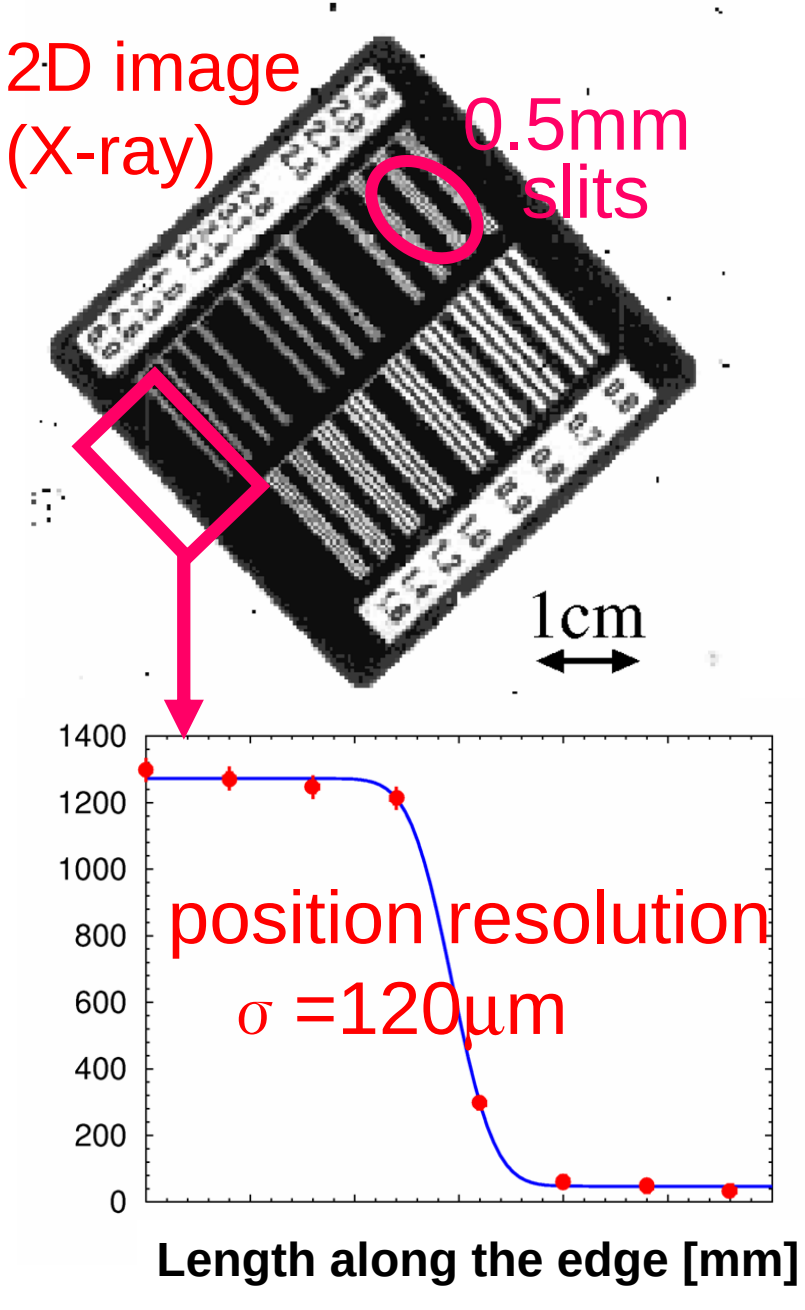
- PCB technology
- Pixel electrode
- 2D readout



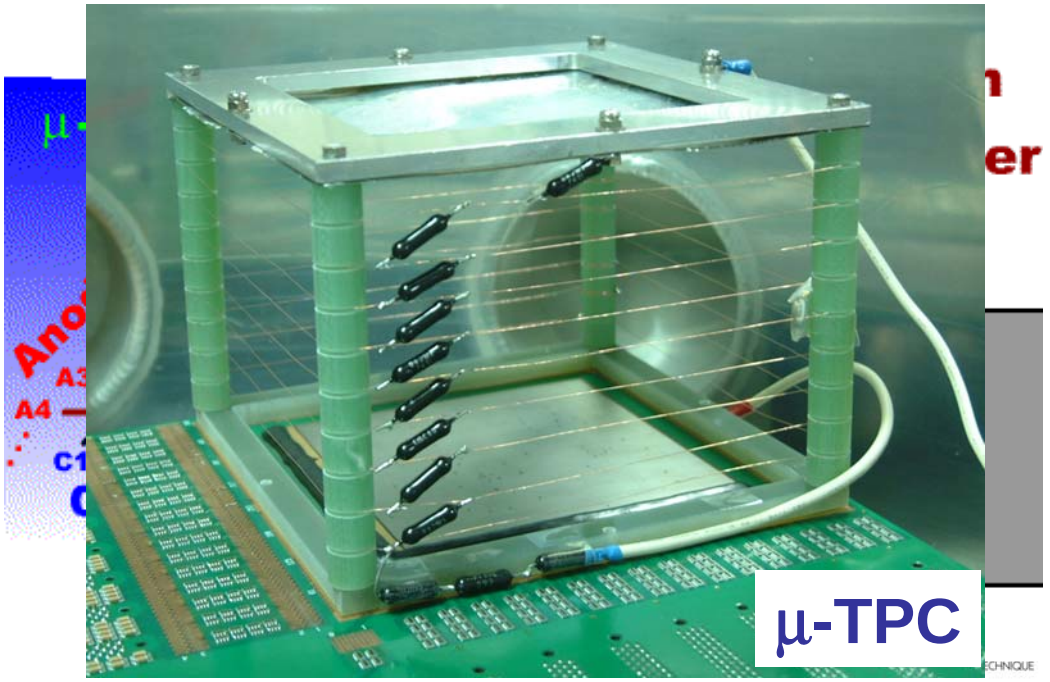
- 400μm pitch electrodes
- Gas gain (max) > 10^4
  Uniformity (σ) ~ 4%

Detection area = $100cm^2$

Imaging

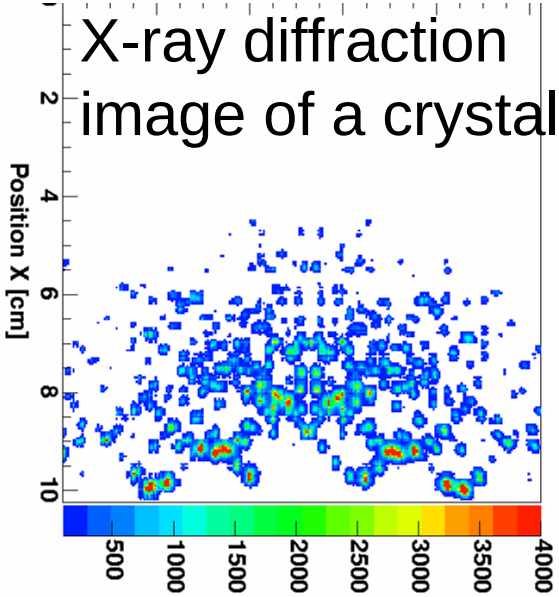


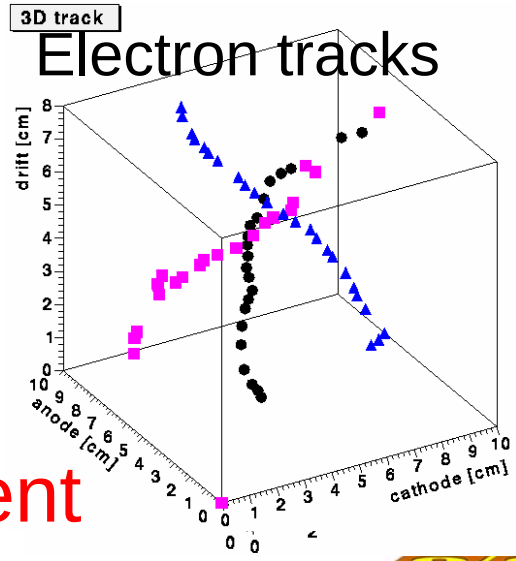
- Time Projection Chamber (TPC) of μ-PIC read-out
- 2D image + Timing
  → 3D track of particles
- Track + Energy
  → dE/dX (LET)
  (for event by event)



Application of μ-PIC & μ-TPC

- 2D X-ray imaging detector
  - X-ray crystal analysis
  - X-ray polarimetry
- 3D tracking detector (μ-TPC)
  - MeV γ-ray imaging (Compton electron tracking)
  - Neutron imaging
  - Dark matter search (“NEWAGE”)
  - Cosmic-ray dosimetry

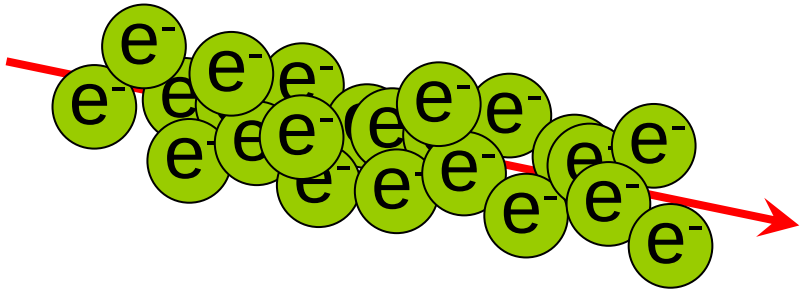




Major use: Satellite-borne equipment

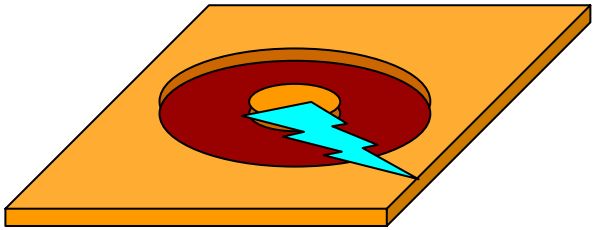
μ-PIC in space environment

- Cosmic-ray : high energy protons or heavy ions
  (100 - 1000 MeV/n)
- Heavy ion irradiation : inevitable for satellite experiment
  (ex. Cosmic X-ray or γ-ray observation)



Heavy ions create enormous number of electrons

→ Discharge breakdown?



(ex.)

dE/dX = 1MeV/cm

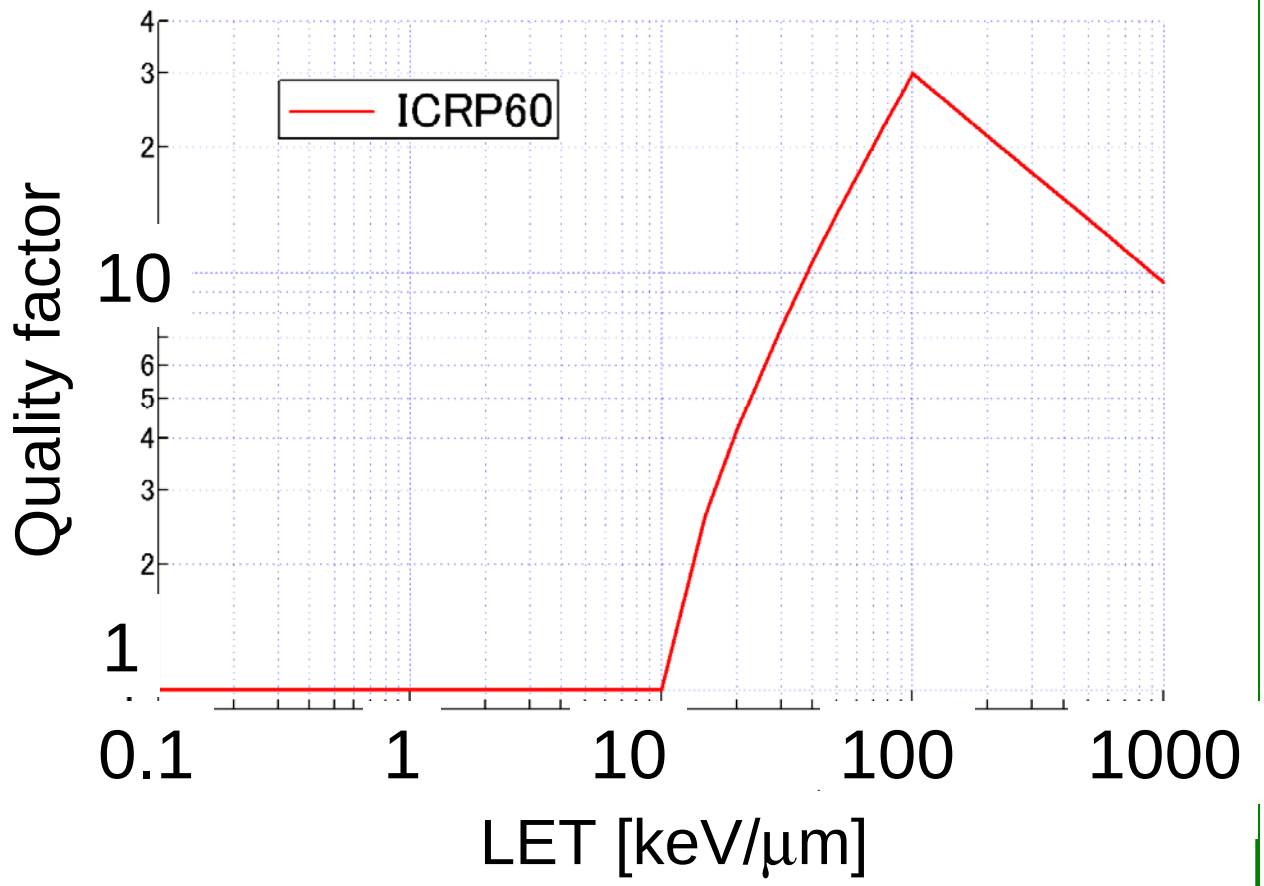
→ 2 x 10^6 electrons/electrode

400mm pitch electrode,
gas gain = 10^3

Cosmic-ray

Manned Space c

- Exposed to cosm
- Dose: ~1mSv/day
- For health manag
  precise measurer



Dose equivaler
= Quality factor (QF) x Absorbed Dose [Gy]

QF: function of LET (Linear Energy Transfer)

Cosmic-ray has various LET → Precise measurement is needed.

γ-ray Detector μ-PIC MPGC TECHNIQUE

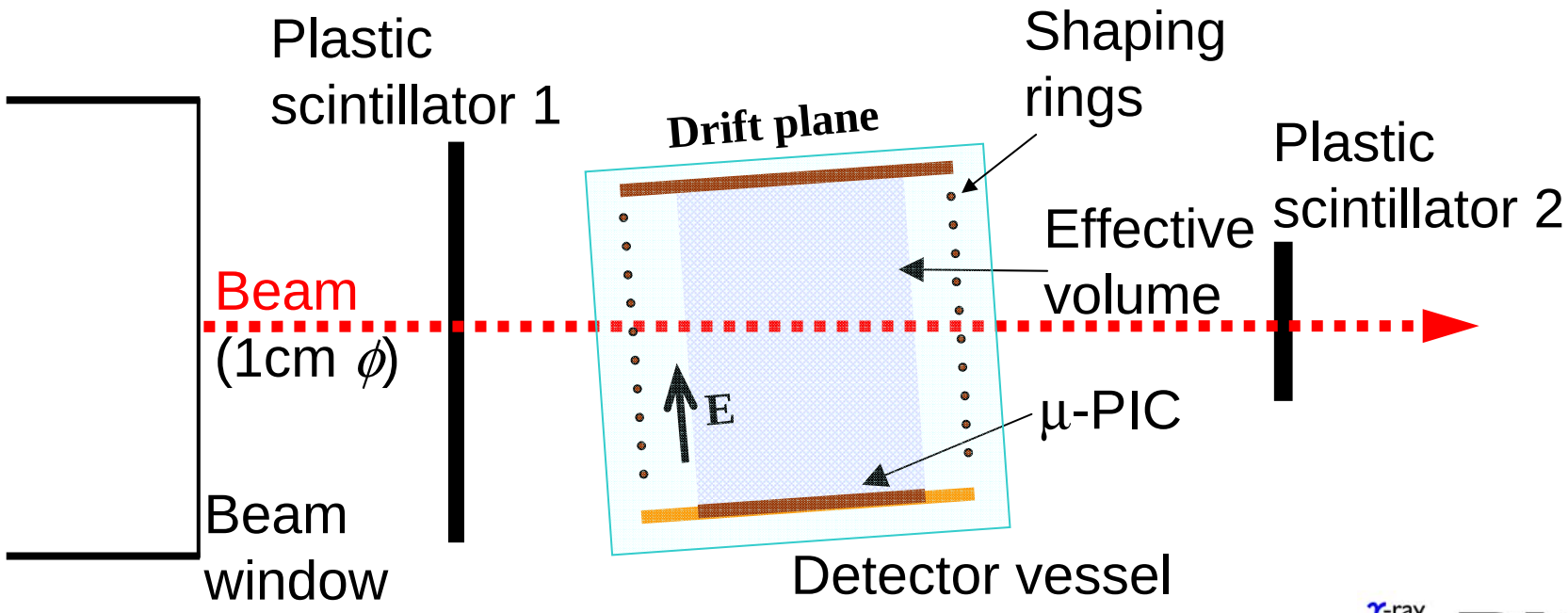
Heavy ion irradiation for μ-PIC

- For all use in space environment …
  - Heavy ions might cause discharges
  - Gamma-ray observation … high gas gain (>10^4) is needed
    →Discharges are more important
- For cosmic-ray dosimeter using μ-PIC
  - Heavy ions are the main target
  - The goal … direct measurement of LET

Heavy ion irradiation should be studied

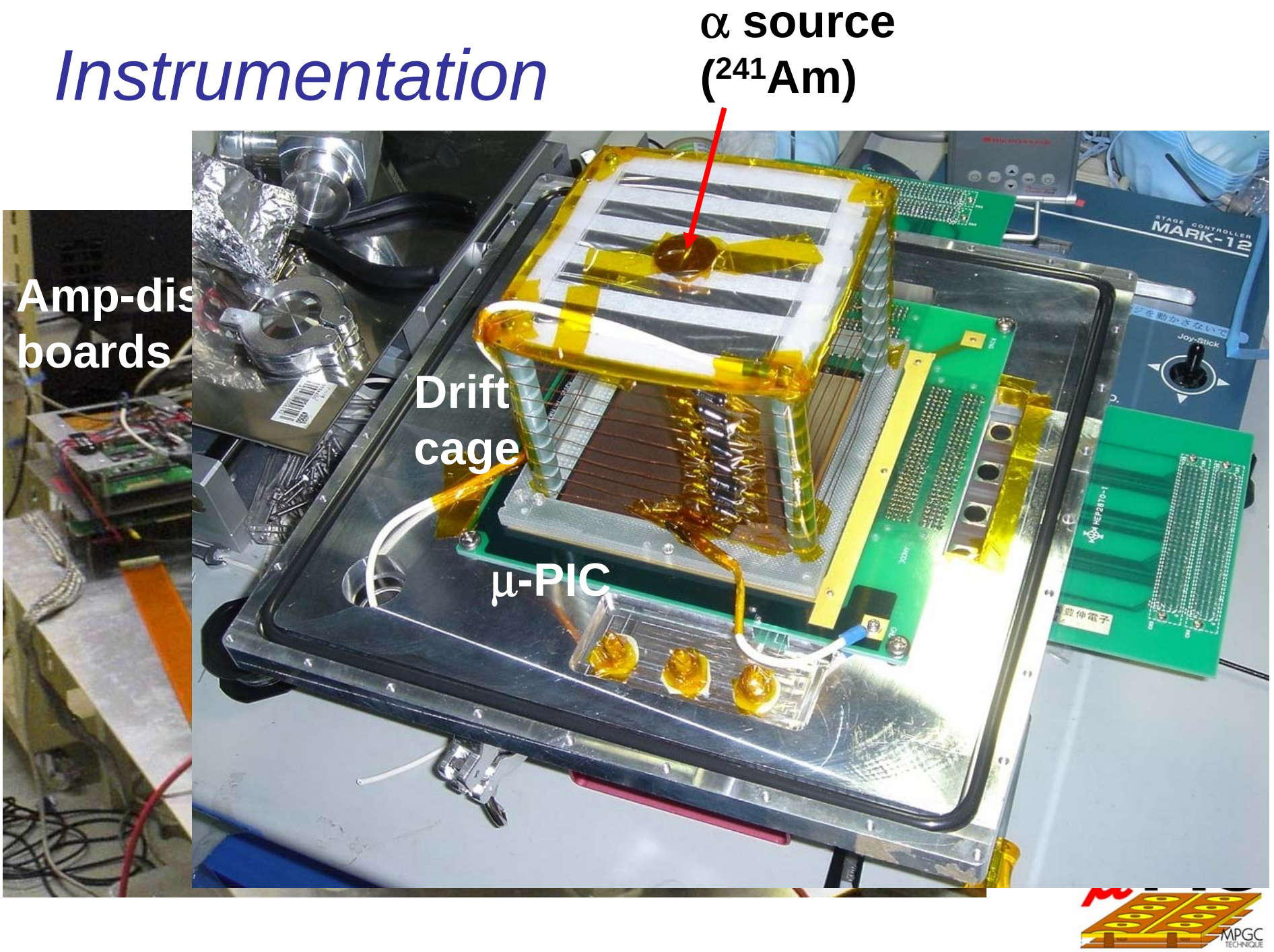
Heavy ion irradiation at HIMAC

- Cosmic-ray = protons and heavy ions
  - Response of μ-PIC for heavy ion irradiation
  - Direct measurement of LET (dE/dX)
- Heavy ion beam-line at HIMAC in NIRS, Japan



DAQ system is triggered by coincidence of scintillators

Instrumentation



Overview of the experiment

- Beam
  - C ion (400MeV/n)
  - Si ion (800MeV/n)
  - Fe ion (500MeV/n)
  - ^{241}Am α source for calibration (5.49MeV)
- Gas (sealed)
  - Ar/C_2H_6 (90/10) 1atm
    - W = 26eV,
  - Drift field = 0.2kV/cm
    - drift velocity = 4.5cm/μsec
  - Gas gain ~10^2
    - Enough for heavy ion detection

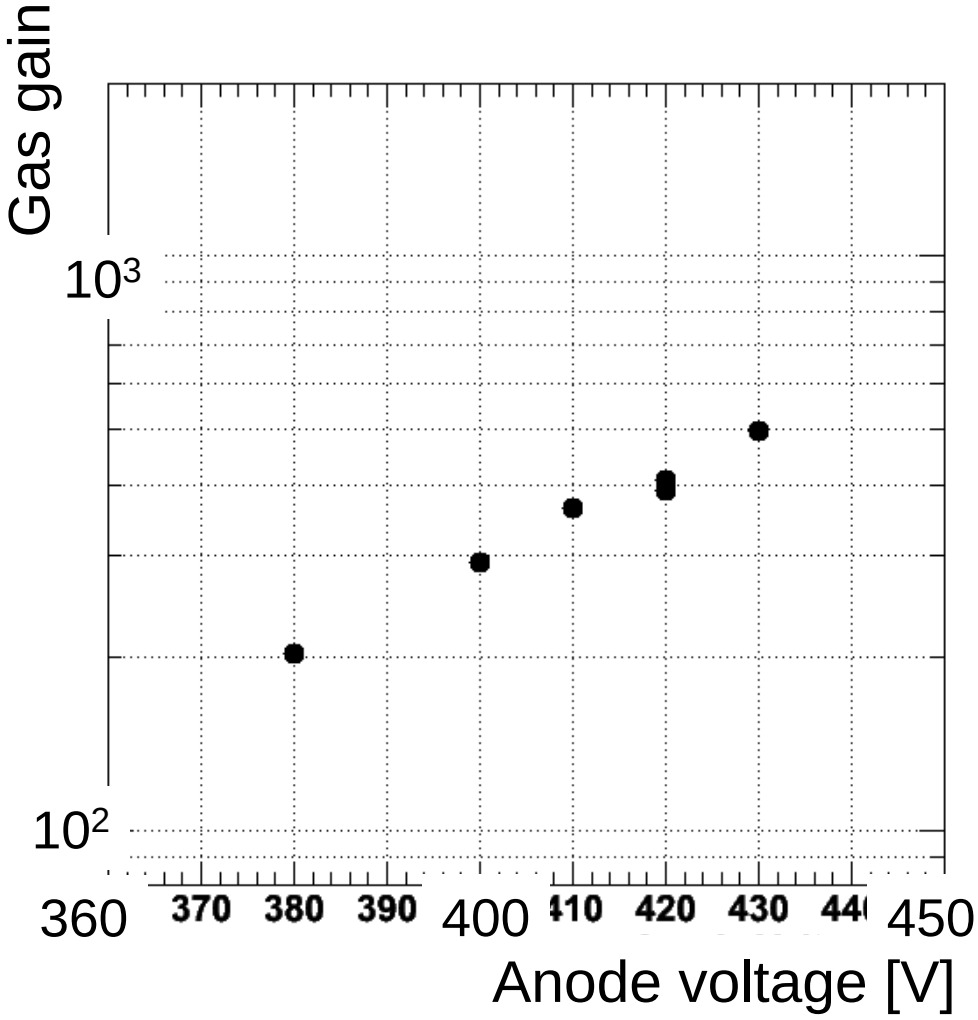
Gas gain

- No discharges
- Gas gain : ~ 500

Electrons due to an α

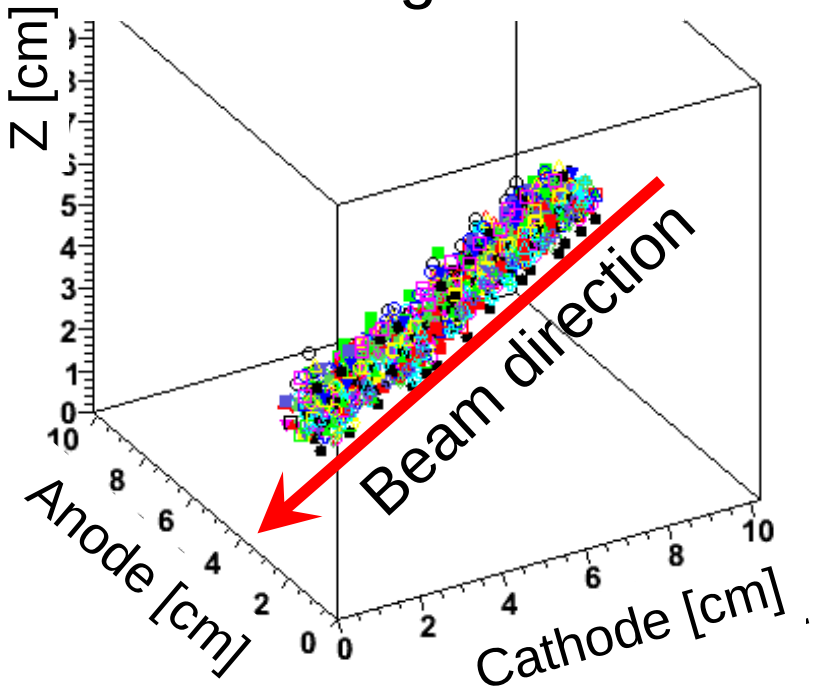
~ 10^6 electrons / electrode
(@gas gain = 500)

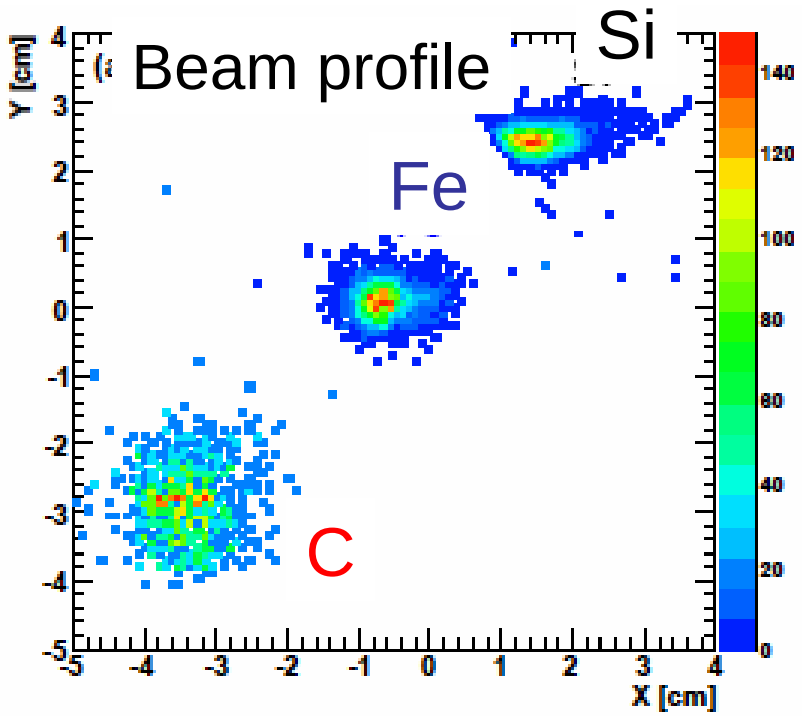
No discharges in
high electron density



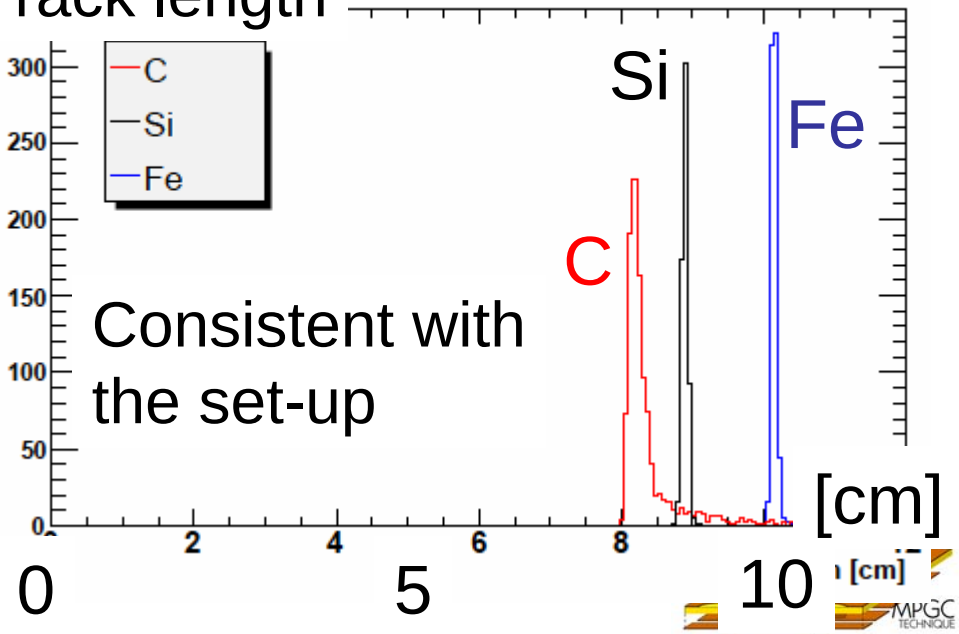
3D imaging

Si beam (100 tracks)
in Ar-based gas





Track length



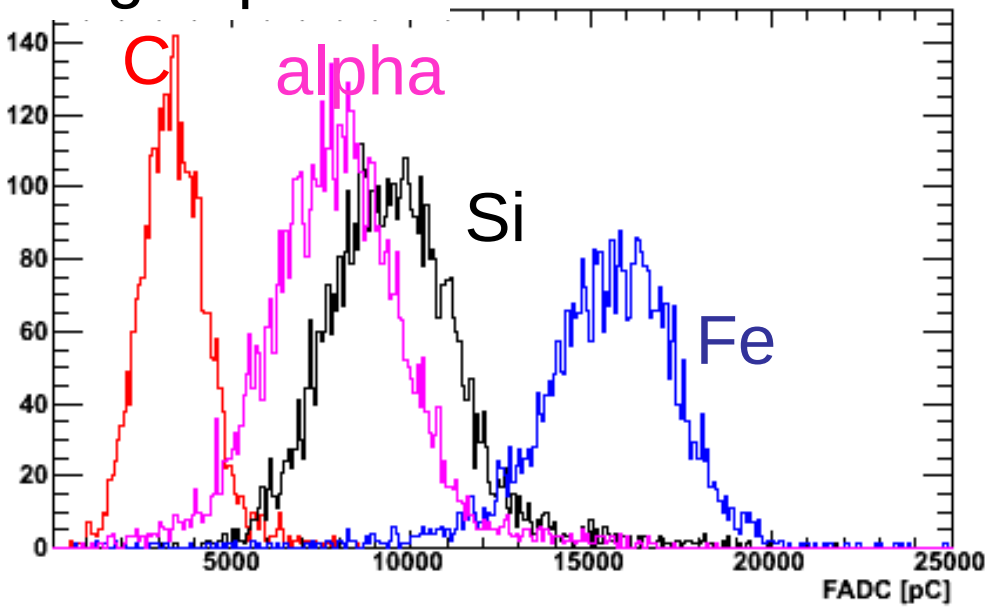
Each rack is fitted as
3D linear function

→ Penetrating length
→ Track length

Energy deposit

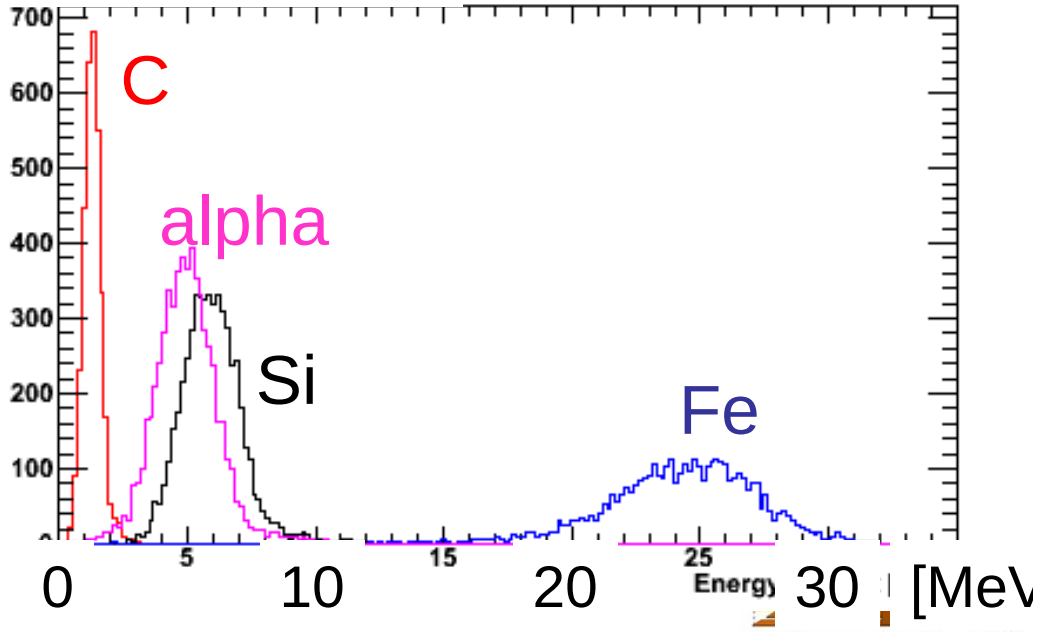
Ionization loss of each ion in the TPC volume

Charge spectra



Calculate energy deposit using gas gains

Energy deposit



Applied voltage

- C: V_A=420V
- Si: V_A=380V
- Fe: V_A=320V
- alpha: V_A=380V

Gas gain ~ 10^2

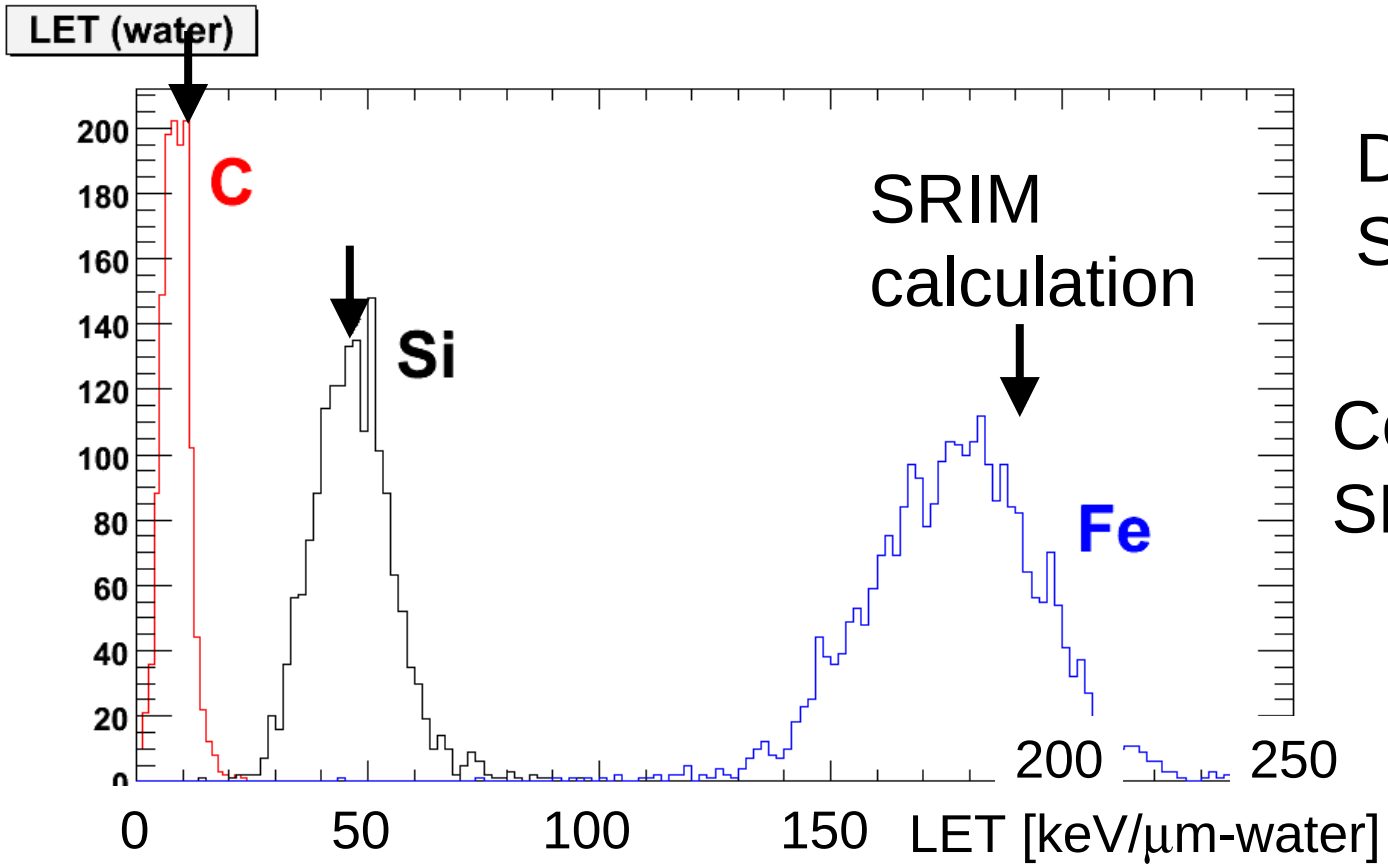
LET distribution

Ratio of mass stopping power of water and Ar/ethane

- For dosimetry, LET in water is important

$$\mathrm{LET}_{\mathrm{water}}[\mathrm{keV}/\mu\mathrm{m}-\mathrm{water}] = \mathrm{LET}_{\mathrm{Ar/ethane}} \times 1.28 \times 1.00/(1.62\times10^{-3})$$

$$\mathrm{LET}_{\mathrm{Ar/ethane}} = (\mathrm{energy\ deposit})/(\mathrm{track\ length})[\mathrm{keV}/\mu\mathrm{m}]$$

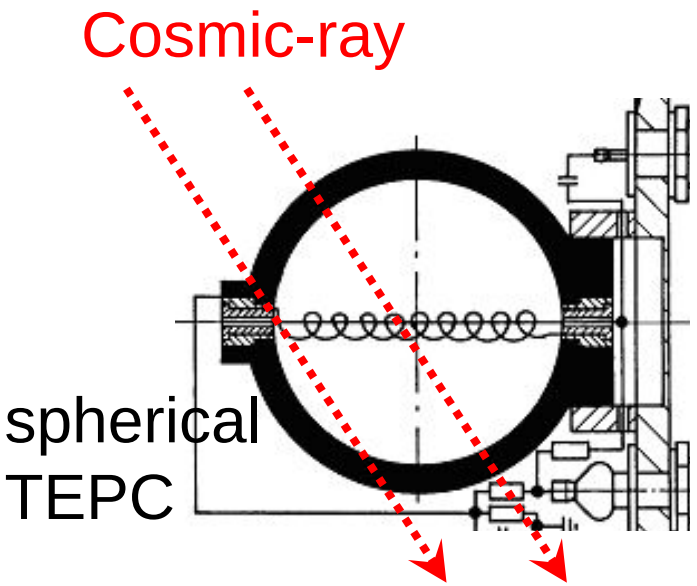


Difference from SRIM = 5 - 10%

Consistent with SRIM calculation

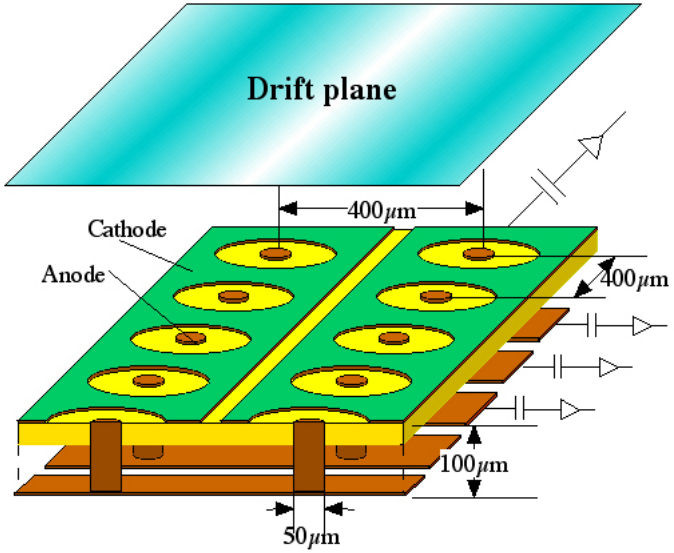
μ-PIC for cosmic dosimetry

- Former dosimeter :Tissue Equivalent Proportional Counter (TEPC)
- No position sensitivity
- Different length between events
- Can not get LET!



Advantage of μ-PIC

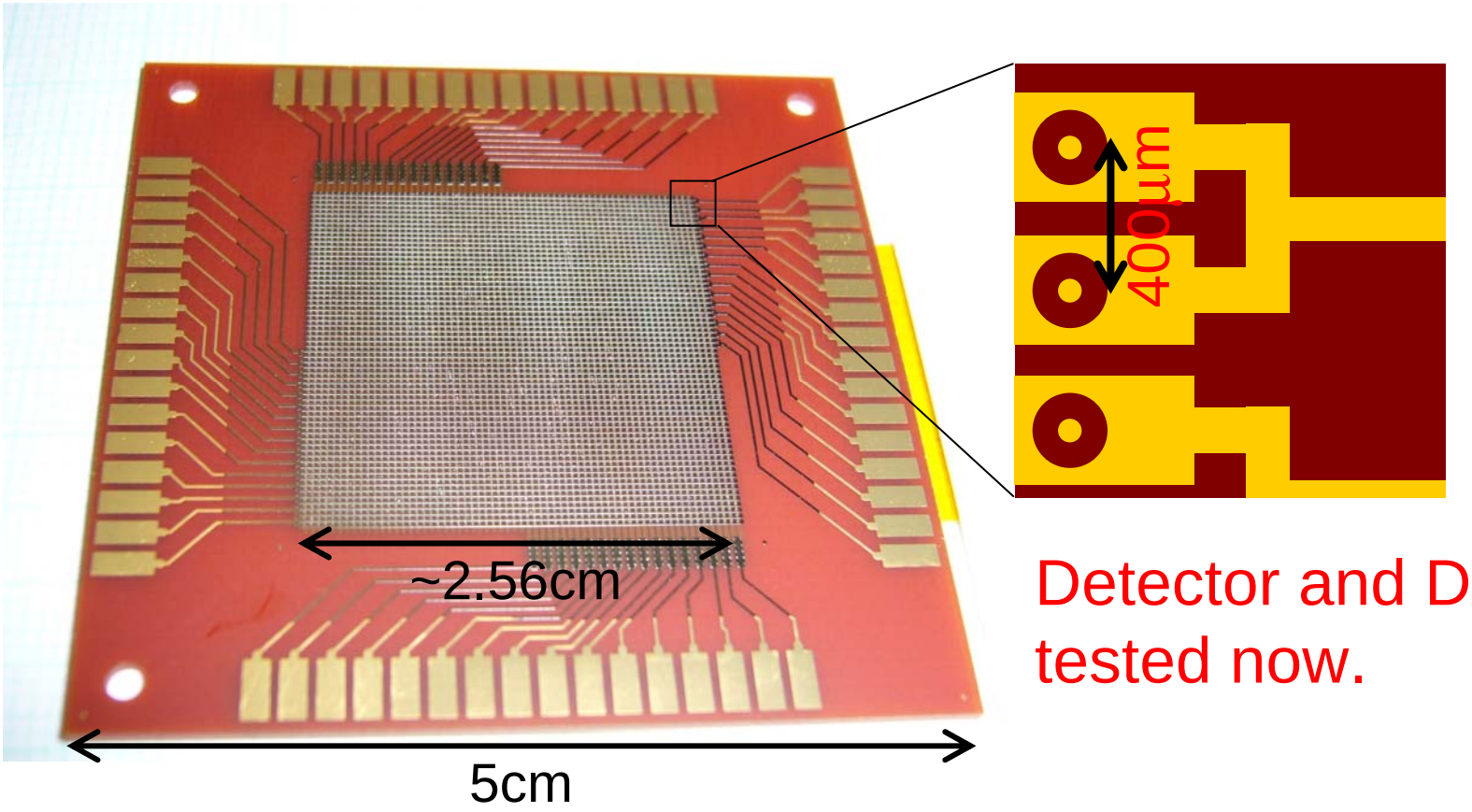
- Position sensitivity
- Event-by-event measurement of LET
- Robustness



Use a μ-PIC as a Position Sensitive TEPC (PS-TEPC)

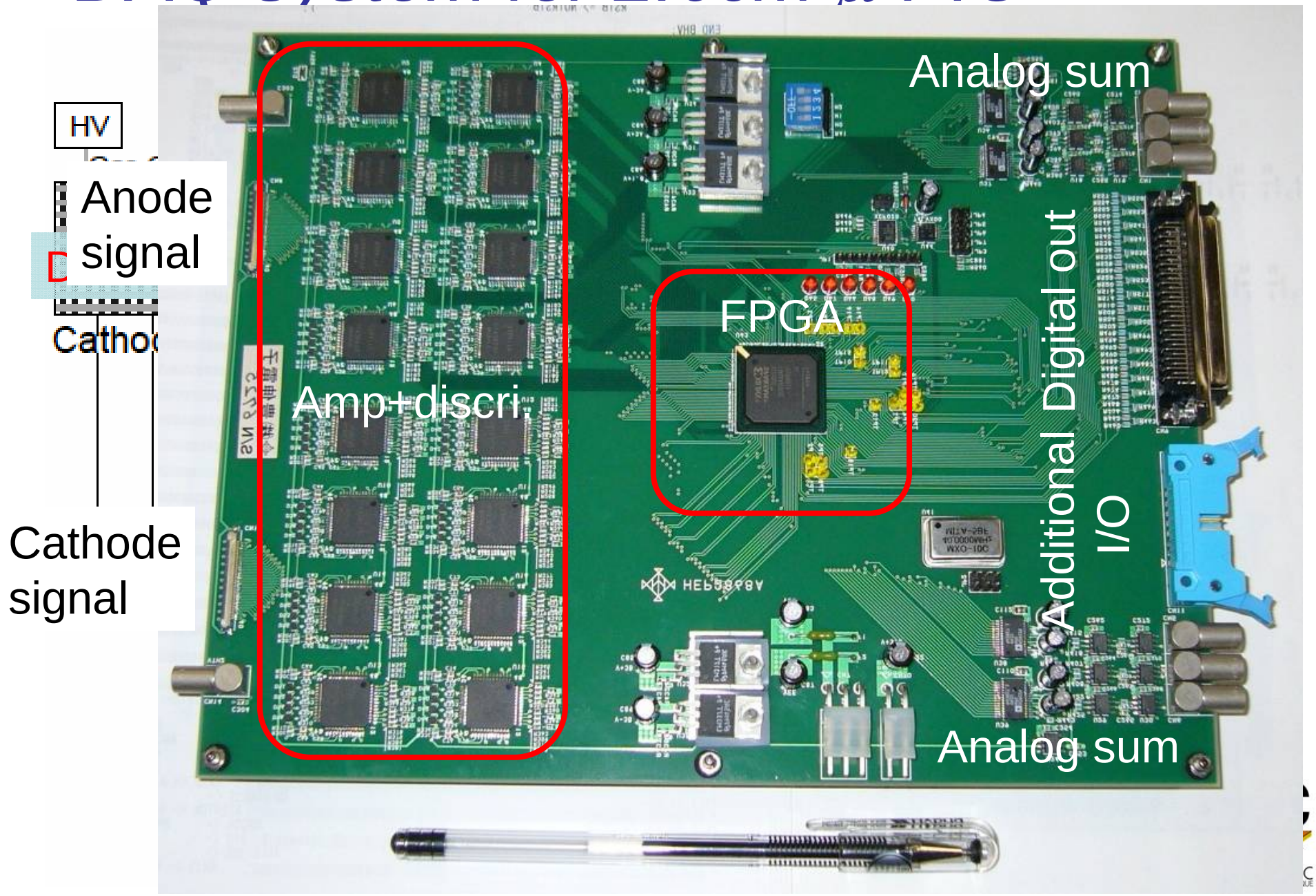
μ-PIC for PS-TEPC

- Small area μ-PIC
- 2.6 x 2.6 cm^2 (~ normal TEPC)
- 2 adjacent electrodes are connected
- Total 32 x 32 channels



Detector and DAQ is tested now.

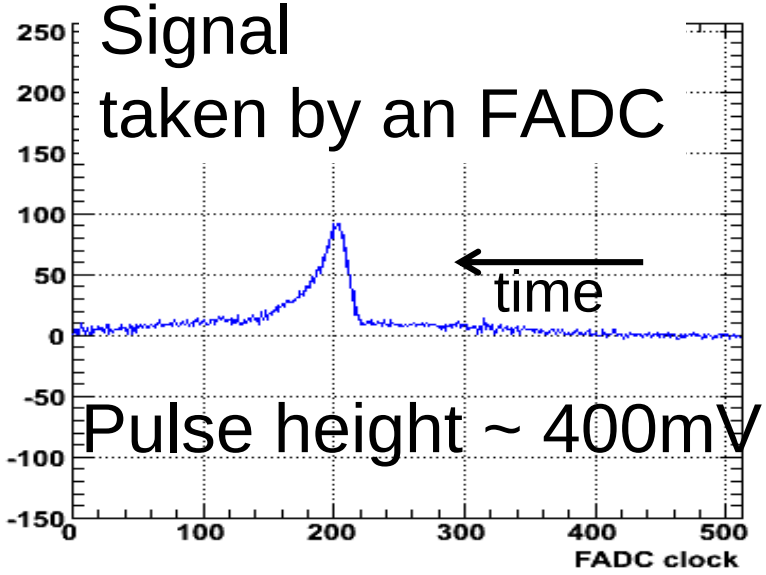
DAQ system for 2.6cm μ-PIC



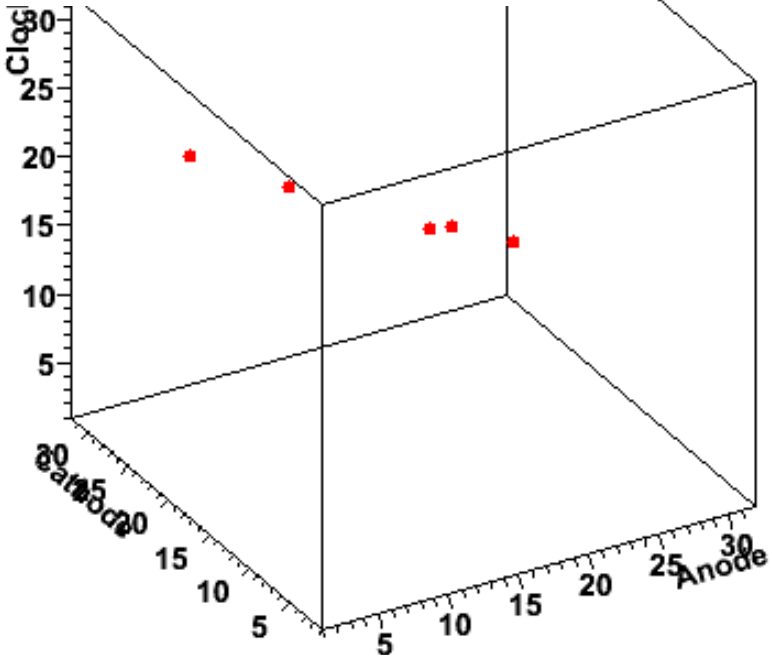
Preliminary results

Irradiation tests were performed at HIMAC in last week!!

Signal taken by an FADC

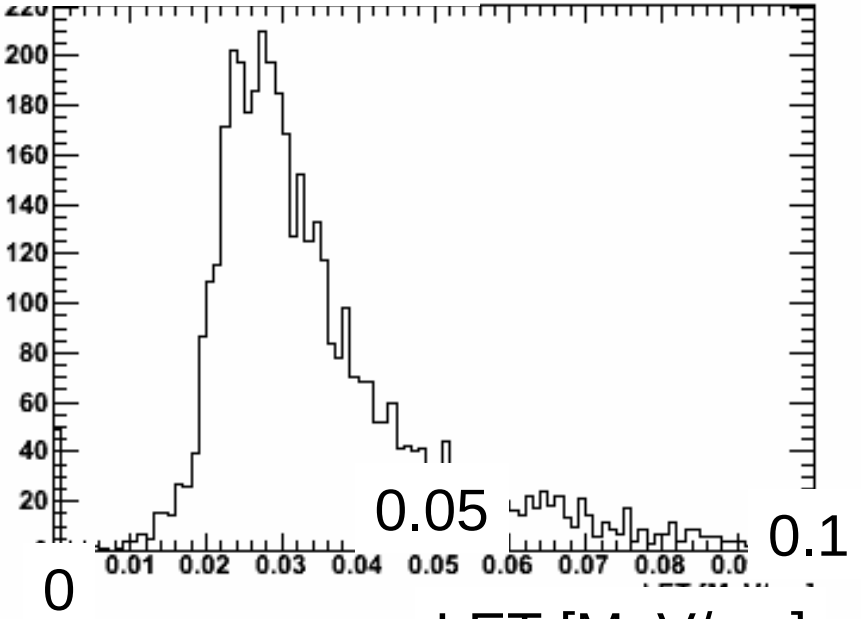


He ion in Ar/C_2H_6 (90/10)



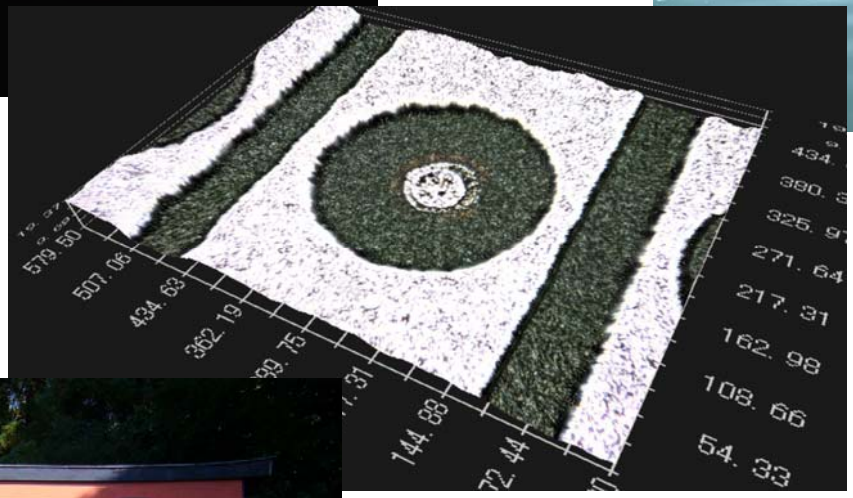
Gas gain ~ 2000

LET distribution



Summary

- The μ-PIC … recently developed MPGD
- 3D imaging using μ-TPC with μ-PIC read-out
- Heavy ion irradiation
  - Cause discharge to the μ-PIC
  - Cause damage to astronauts
- Irradiation test at HIMAC
  - Event-by-event measurement of tracks and energy
  - LET in water was consistent with SRIM
    error < 10%
- Space dosimeter "PS-TEPC"
- A 2.6 x 2.6cm^2 μ-PIC is manufactured



Thank you!!

γ-ray Detector μ-PIC MPGC TECHNIQUE

γ-ray
Detector
μ-PIC
MPGC
TECHNIQUE

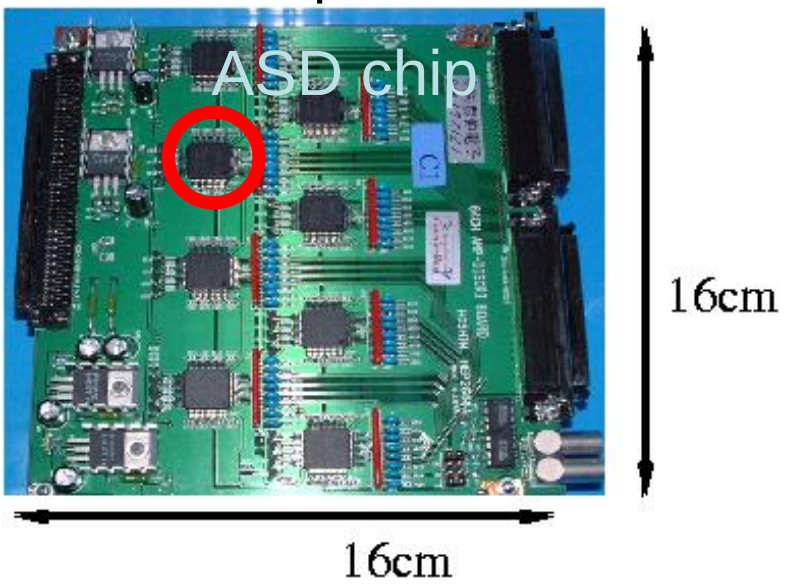
Additional pages

DAQ system

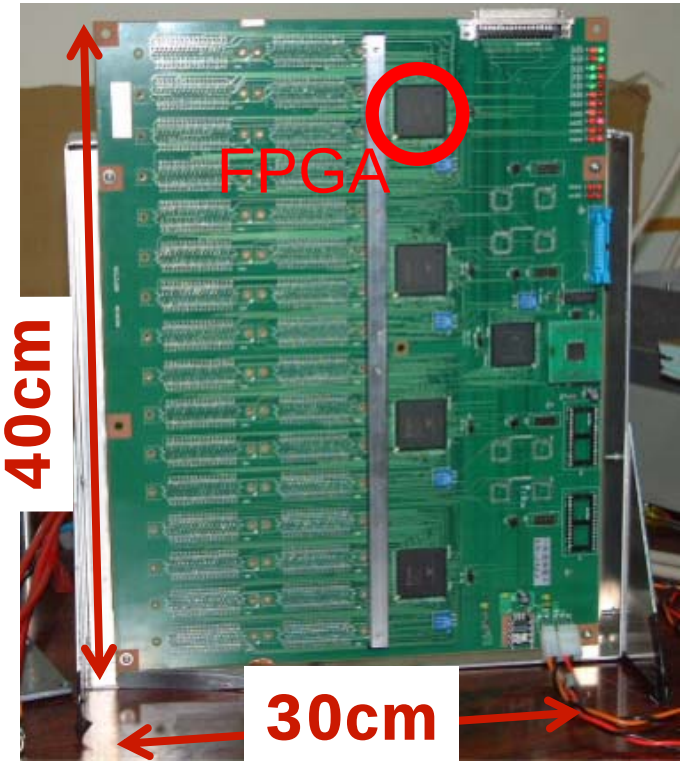
Preamplifier

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

Preamplifier

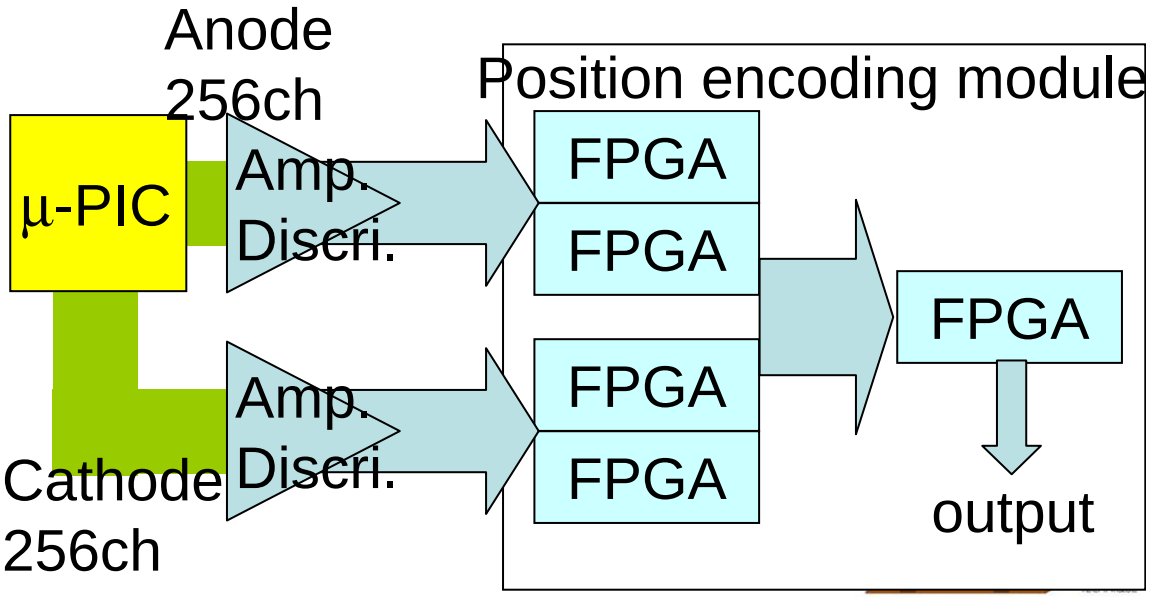


Position encoding module

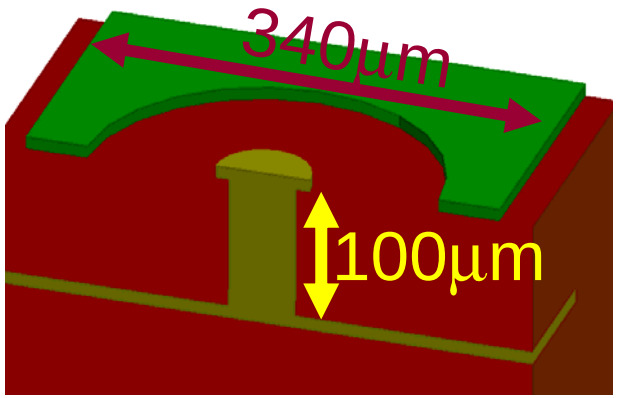


Position encoding module

5 FPGAs (clock 20MHz)



Improved μ-PIC



Electrode formation process

- Former type … normal plating (“*bottom-up*”)
- New type … plating and etching (“*top-down*”)

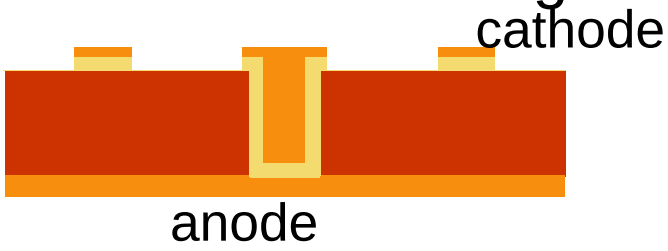
→ Uniform electrodes will be made.

1. Electroless plating

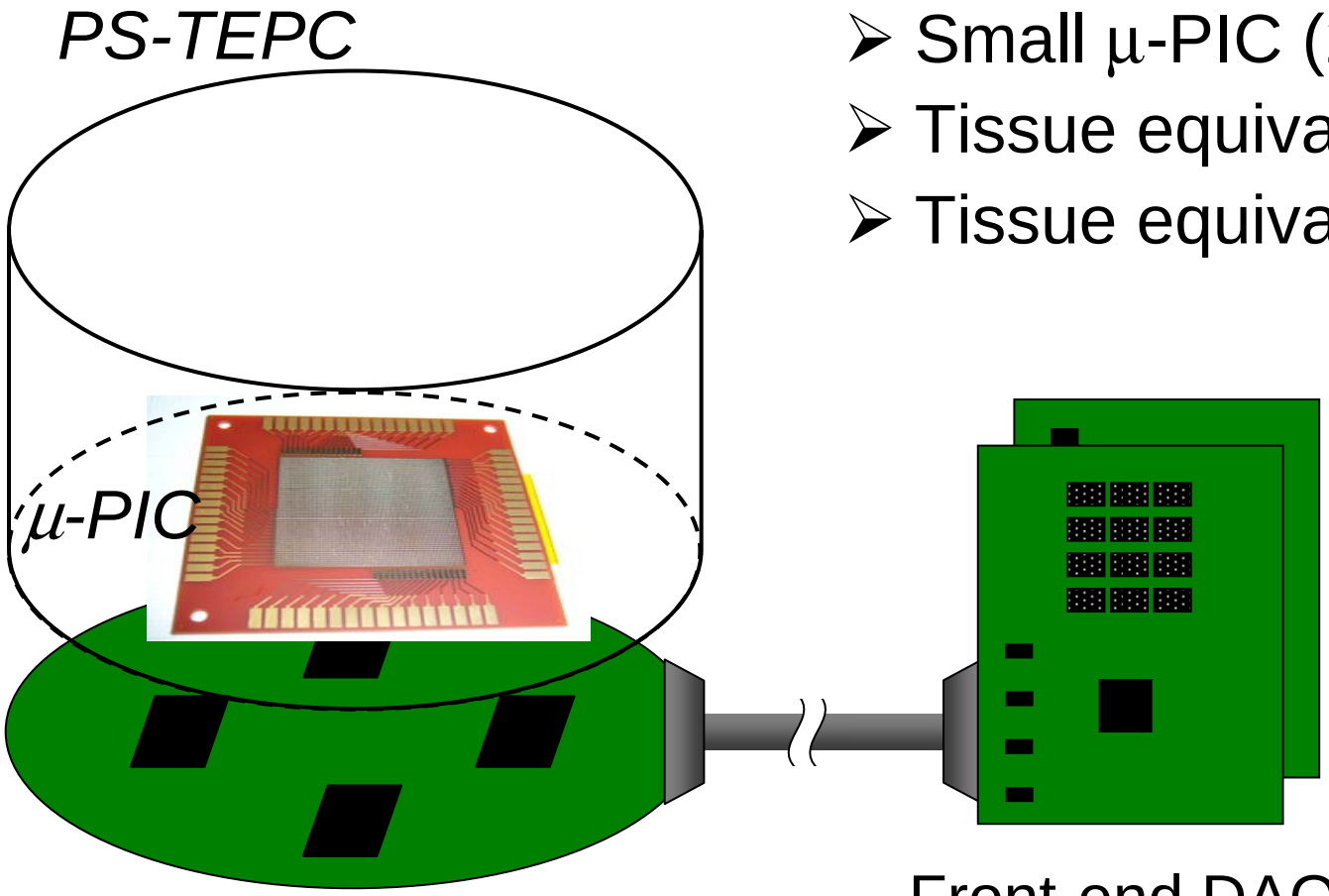
2. Via-fill plating

3. Surface etching

4. Electrode etching



Future PS-TEPC

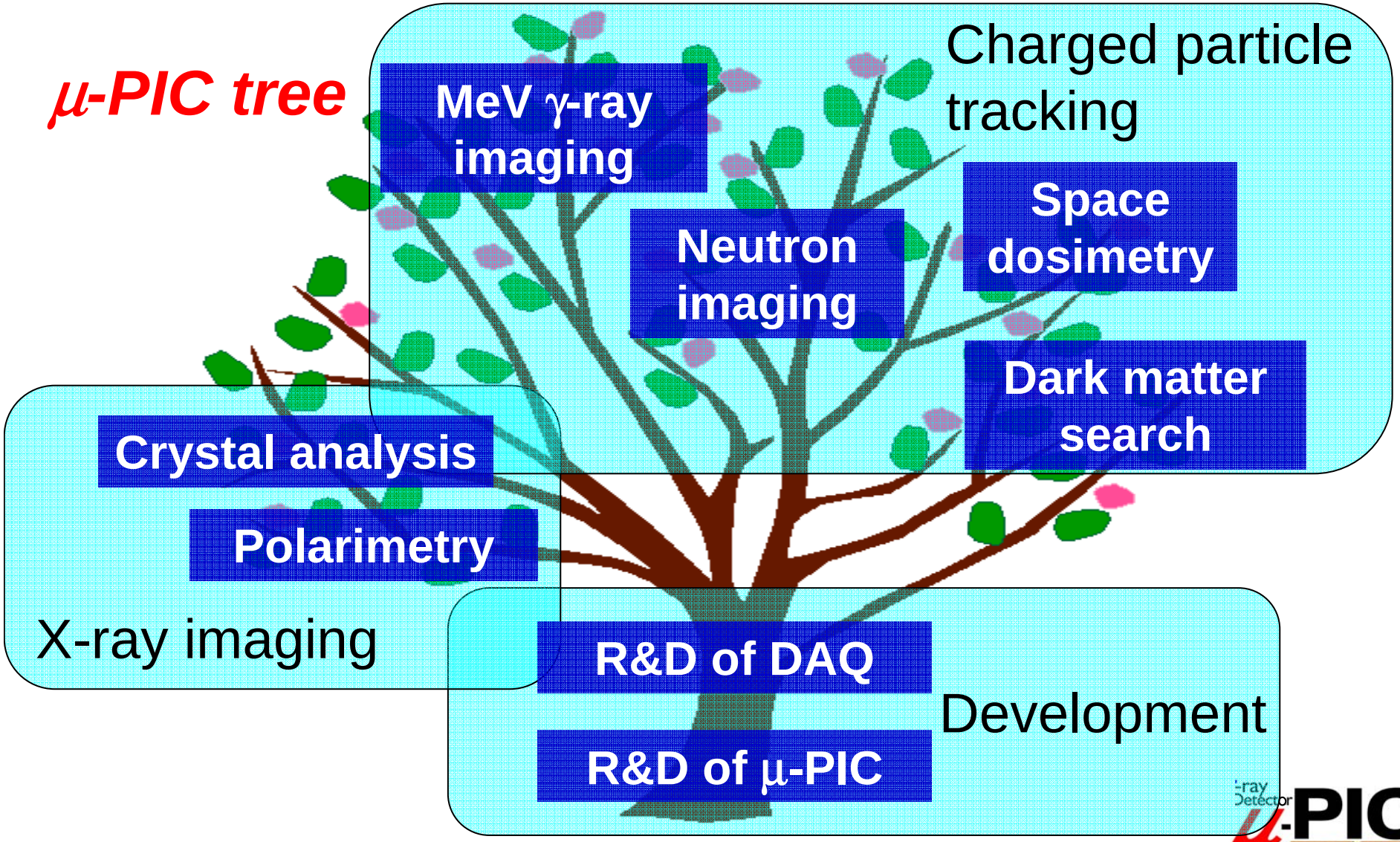


- Small μ-PIC (2.6 X 2.6cm^2)
- Tissue equivalent vessel
- Tissue equivalent gas

Front-end DAQ system

Feed-through, HV division,
pre-amplifier

Application of μ-PIC



Former dosimeter

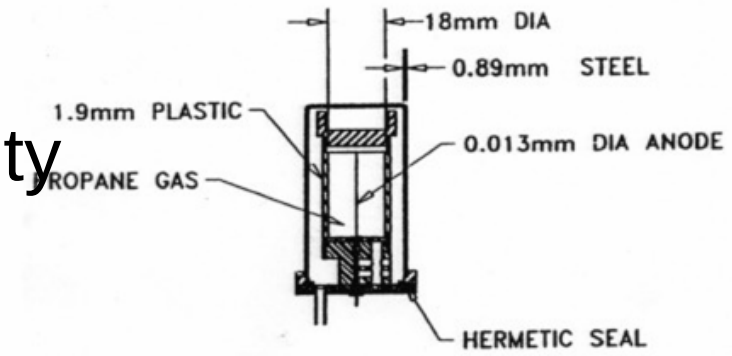
TEPC (Tissue Equivalent Proportional Counter)

- Use tissue equivalent gas
  (CH_4 64.4%,
  CO_2 32.4%,
  N_2 3.2%)
- No position sensitivity
  →can not get LET

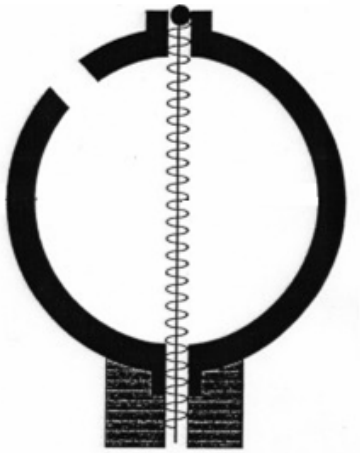
Error (σ) =
51% (Cylindrical)
35% (Spherical)

Position Sensitivity is needed!!

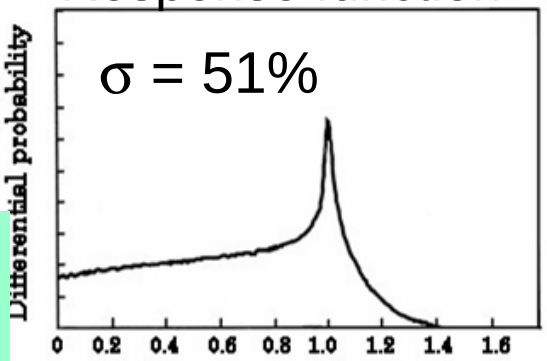
Cylindrical TEPC



Spherical TEPC

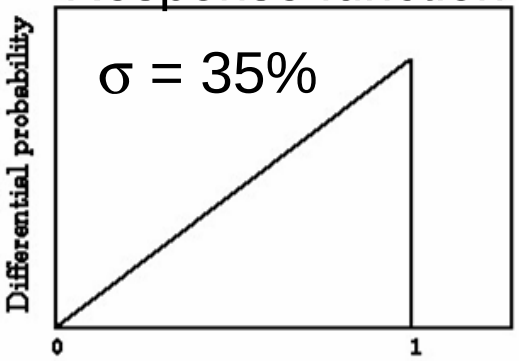


Response function



Chord length

Response function



Chord length