Data acquisition for a Time Projection Chamber based on a μ-PIC

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We report on an improvement on data acquisition for a Time Projection Chamber (TPC) based on a micro-Pixel Chamber (μ-PIC). The μ-PIC is a pixel-type two-dimensional imaging detector with a pixel pitch of 400 μm. The TPC is a component of a Compton camera and a gamma-ray Compton-scattered there is observed. To achieve sensitivity 10 times as high as that of COMPTEL, fine Compton recoil electron tracking in the TPC is crucial. The strip structure of the μ-PIC delivers the simple system while it is difficult to obtain the correct positions of the signals. We improved data acquisition system, solved data loss, and then obtained finer electron tracks. The charge per strip that allows one to refine the position resolution and Compton-scattering points was also measured. The detector was irradiated with 8 keV X-rays and the centroid of charges are calculated. The resultant position resolution was σ = 93. 6 μm.

Electron tracking Compton camera

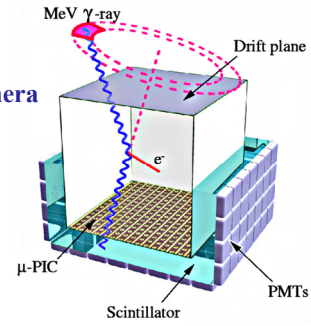
Our Goal

sensitivity 10 times as high as that of COMPTEL [1]

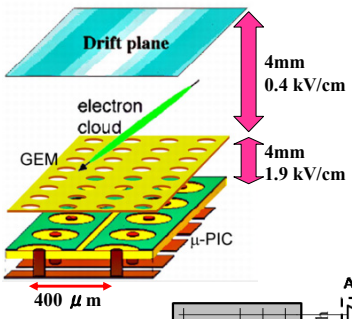
Principle of electron tracking Compton camera

- **TPC (gaseous detector)**
  energy and track of a recoil electron
- **Pixel scintillators (GSO, $LaBr_3$(Ce))**
  energy and position of a scattered gamma-ray

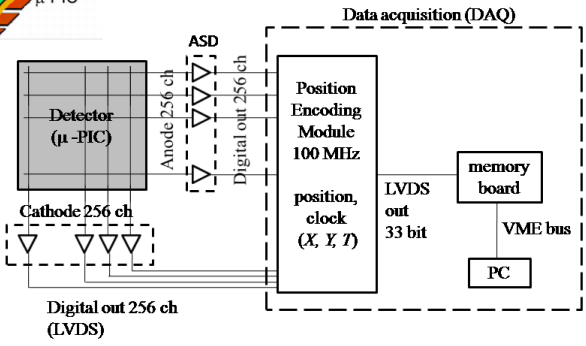
→Complete set of kinematic and geometry information [2]
Reconstruct photons one by one (energy and direction)
Strong background rejection



TPC based on a μ-PIC



μ-PIC
Electrode pitch : 400 μm
Max gas gain : 15,000
Stable gas gain : 6,000
Preamplifier : Gas Electron Multiplier (GEM) [3]
operated at a gas gain of ～10
Operated at a total gas gain of about 30, 000
(μ-PIC 3,000, GEM 10)
Contained in a sealed vessel
Gas : Ar 90% C_2H_6 10 %, 1 atm
Detection volume : 10 cm×10 cm×15 cm



✓The output charges of the 256+256 channels are parallel pre-amplified, shaped, and discriminated in parallel by the ASD chips.
✓All discriminated digital signals are sent to the position encoding module consisting of FPGAs with an internal clock of 100 MHz, allowing the recording of the anode and cathode coincident position = (X, Y) and the time (T) to the memory module [4].

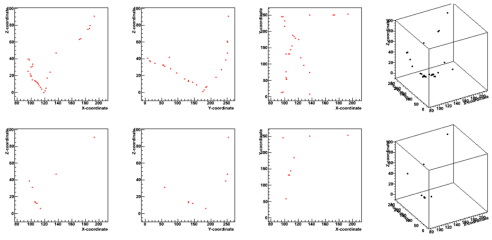
Improvement of position encoding module ①

Count loss

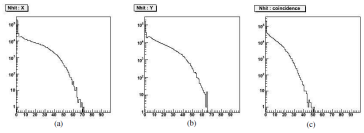
Track of recoil electron

①All hits

②Coincident hits



①All hits are plotted.
②Hits from the anodes and cathodes only when they coincide in a clock interval are used. Many hits are lost because of the failure of coincidence.
The recording of the anode and cathode coincident signals rejects electronic noise but causes the count loss due to timewalk of the ASDs.
All hits must be considered even when they do not coincide in a clock interval.

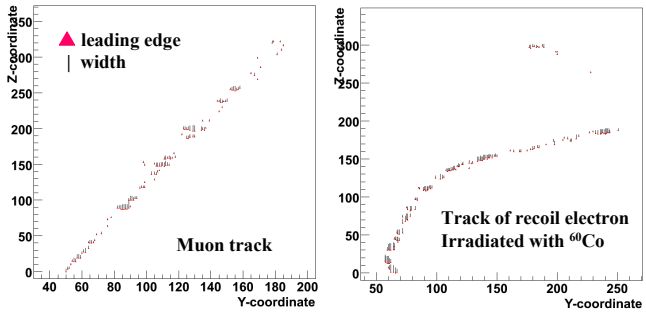


Number of hits per recoil electron track The detector was irradiated with ^{137}Cs. (a)Hits from the cathodes. (b)Hits from the anodes. (c)Hits from the anodes and cathodes which coincided in one clock interval.
70% signals from the anodes and cathodes do not coincide in one clock interval.

Improvement of position encoding module ②

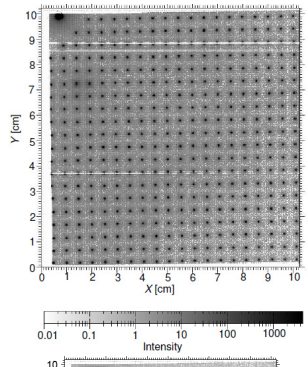
Measure charge without ADCs

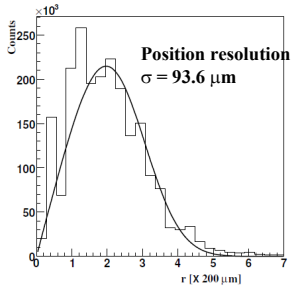
The refined system records both leading and falling edges of the digital signals generated by the ASDs, and thus their widths can be measured. The pulse heights can be roughly determined by the widths. Since this system provide d*E*/d*x*, it allows one to determine Compton-scattering points using d*E*/d*x*.



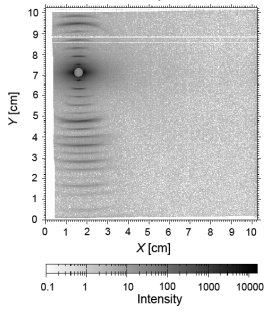
Position resolution

The μ-PIC functions as a two-dimensional X-ray imaging detector [5]. We examined the position resolution at Spring-8 BL45XU using a grid mask where 500 μm-diameter holes were drilled. The detector was irradiated with 8 keV X-rays.





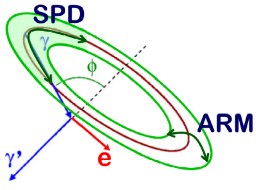
Counts distribution as a function of the distance from the center of the holes.



Operated at a total gas gain of about 5, 000
(μ-PIC 1.5×10³, GEM 3)
Contained in a sealed vessel
Gas : Xe 70% C_2H_6 30 %, 1 atm
Detection volume : 10 cm×10 cm×0.4 cm

←Diffraction from collagen

Future Works



Current status:
ARM (Angular Resolution Measure) < 10°
SPD (Scatter Plane Deviation) > 100°
SPD is not as good as it could be due to the failure to find Compton-scattering points and determine momentum vectors of recoil electrons.
The new criterion using d*E*/d*x* will improve the precision of the Compton-scattering points and then SPD.

[1]V. Schoenfelder et al., *Astroph. J. Suppl. Series.* **86** (1993) 657.
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T. Tanimori et al., *New Astron. Rev.* **517** (2004) 241.
[3] F. *Sauli Nucl. Instr. and Meth. A* **386** (1997) 531.
[4] H. Kubo et al., *IEEE Nuclear Science Symposium Conference Record*, (2005) 371
[5] K. Hattori et al., *J. of Synch. Rad.*, **16** (2009) 231.

URL http://www-cr.scphys.kyoto-u.ac.jp/index-e.html
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