An Electron-Tracking Compton Imaging Camera Based on a Gaseous TPC and a Scintillation Camera

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Electron Tracking Compton Camera (ETCC)

Sub MeV ~ MeV gamma-ray imaging for...

- Astronomy (balloon experiment, SMILE)
- Application → Medical Imaging

See S. Kabuki’s poster (M18-110)

◆ gaseous TPC
  (Time projection chamber based on μ-PIC as readout system)
  → Track and energy of recoil electron

◆ Scintillation camera
  (Multi Anode PMT + Pixelated Scintillator Array)
  → position and energy of scattered gamma-ray

Reconstruct incident gamma-ray event by event

- 1 photon ⇒ direction + energy
- Large FOV (~3str)
- Kinematical background rejection
Gaseous TPC for recoil electron

2D readout (µPIC 400m pitch) + Drift time (100MHz)

>3D tracking and energy

- Volume: 10cm x 10cm x 15cm (prototype)
- Position resolution: 400 µm
- Stable gas gain: ~ 35000 (µPIC ~ 3500, GEM ~ 10)

Using as pre-amplifier to obtain stable high gain

Example of 3D-track

T. Tanimori (MP4-1)
Scintillation Camera
for scattered gamma ray

Scintillation camera (Multi Anode PMT + Pixel Scintillator Array)

Scintillator: GSO(Ce)
Photon sensor: H8500 (HPK)
Position resolution: 6mm (prototype)
Energy resolution: ~11% (FWHM) @ 662keV

Readout system
4 channels readout with resistive chain to 192 pixels (3 PMTs) (H. Sekiya et al., NIM, 2006)
SMILE Sub-MeV gamma-ray Imaging
Loaded-on-balloon Experiment

SMILE-1 (10cm)^3 ETCC (prototype)@ Sanriku, Japan
1st September 2006 launch
Gaseous TPC
33 Scintillation cameras

• Operation test of our Compton Camera @ 35km
• Diffuse cosmic and atmospheric gamma-ray measurement

SMILE-1 has been successful!
See A. Takada’s talk (N59-8)

Next step SMILE-2
• Observation of bright Object (Crab or Cyg X-1)
(10cm)^3 ETCC ➔ Detection efficiency is not good.
We need the larger ETCC, and have developed that!

1st step : 30 x 30 x 15cm^3 TPC with 6 x 6 scintillation camera
2nd step : (30 cm)^3 TPC with 6 x 6 + 6 x 3 x 4 scinti. camera
1st step: $30 \times 30 \times 15 \text{cm}^3$ ETCC

We have developed larger ETCC based on $30\text{cm} \times 30\text{cm} \times 15\text{cm}$ TPC and $6 \times 6$ scintillation cameras which consists of $3\text{mm}$ pitch $256$ pixels.

**gaseous TPC**

- **volume**: $30 \times 30 \times 15 \text{cm}^3$
- **gas**: $\text{Ar} \ 90\% + \text{C}_2\text{H}_6 \ 10\% \ \ 1\text{atm}$
- **drift velocity**: $3.8 \text{ cm}/\mu\text{sec}$
- **gain**: $\sim 30000$
- **energy resolution**: $50\% @ 32\text{keV}$
- **position resolution**: $400 \mu\text{m}$

**scintillation camera**

- **number of pixels**: $9216$
- **pixel size**: $3 \times 3 \times 13 \text{mm}^3$
- **energy resolution**: $10.7\% (@662\text{keV, FWHM})$
- **position resolution**: $3\text{mm}$
- **not using the outer circumferencial pixels**

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![30 cm x 30 cm μPIC](image1)

![30 cm x 30 cm μPIC](image2)

![GEM](image3)
**1st step:** $30 \times 30 \times 15 \text{cm}^3$ ETCC

We have developed larger ETCC based on $30\text{cm} \times 30\text{cm} \times 15\text{cm}$ TPC and $6 \times 6$ scintillation cameras which consists of 3mm pitch 256 pixels.

<table>
<thead>
<tr>
<th>gaseous TPC</th>
<th>scintillation camera</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>volume</strong></td>
<td>$30 \times 30 \times 15 \text{ cm}^3$</td>
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<td><strong>gas</strong></td>
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| **number of pixels** | 9216 |
| **pixel size**       | $3 \times 3 \times 13 \text{ mm}^3$ |
| **energy resolution** | 10.7% (@662keV, FWHM) |
| **position resolution** | 3mm |
| **not using the outer circumferencial pixels** | |

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*Images of TPC and scintillation camera.*
30 × 30 × 15 cm³ ETCC

Front view

Side view

30 × 30 × 15 cm³ ETCC

Size (Camera)
120 × 70 × 150 cm³

Scintillation Camera
TPC

Experimental setup

Source

30 cm

Y

X

Z

Gamma ray

30 cm TPC
Scintillation camera
Point Source Images
Source position : (x,y,z) = (0,0,37cm), 1MBq
2 point sources
356keV(5,8,38) & 662keV(-5,-8,38)

All data
300-400keV
600-750keV

Preliminary!
Furthermore …

For example, using prototype \((10\text{cm})^3\) camera, we can obtain following images.

**Shape of “W”**

$I\-131\ 365\text{ keV}\ 1.\text{MBq}\ 70\text{h}\ (0,0,-20\text{cm})$

**Thyroid phantom**

$I\-131\ 365\text{ keV}\ 1.\text{MBq}\ 40\text{h}\ (0,0,-20\text{cm})$

Now, we are improving the larger ETCC to obtain images like these.
Energy Resolution

Angular Resolution

First performance! Under improvement!

SPD: Scatter Plane Deviation
ARM: Angular Resolution Measure

ARM : 6.1[degree](HWHM)
SPD : 64.5[degree](HWHM)
Energy resolution : 18.0%(FWHM)

@662keV

Prototype(10cm)
2nd step: \((30\text{cm})^3\) ETCC

We are developing \((30\text{cm})^3\) ETCC in parallel!

Scintillation Camera

30cm

Gaseous TPC

30cm

Tracks of cosmic muon

Scattered \(\gamma\) ray

Recoil electron

\(\gamma\) ray

(30cm)3 ETCC
Summary

- **Sub MeV gamma-ray imaging detector, ETCC**
  - We have developed the MeV gamma-ray imaging detector with using Compton scattering, ETCC, for the balloon experiment, SMILE.
  - SMILE-1 has been successful.
  - For SMILE-2, we need the larger ETCC in order to improve efficiency.

- **ETCC based on 30cm X 30cm X 15cm TPC and 6 X 6 GSO Scintillation camera**
  - We have developed larger ETCC. At the 1st step, we made 30 x 30 x 15 cm$^3$ ETCC and tested that.
  - ARM: 6.1[deg](HWHM), SPD:64.5[deg](HWHM), Energy resolution:18.0%(FWHM) @662keV

- **ETCC based on 30cm X 30cm X 30cm TPC and 6 X 6 + 6X 3X4 scintillation Camera**
  - At the 2nd step, we started to develop 30x30x30cm$^3$ ETCC in parallel.
Future work

- Tune up the 30cm X 30cm X 15cm ETCC
- Set the 30cm X 30cm X 30cm ETCC up
- Construct the ETCC with high efficiency and good performances
Thank you!