Development of the Tracking Compton/Pair-Creation Camera based on a Gaseous TPC and a Scintillation Camera


### Abstract
We have developed a tracking Compton/pair-creation gamma-ray camera using a gaseous micro time projection chamber (micro-TPC) and a scintillation camera. Several prototypes of the camera with a detection volume of 10cm\(^3\) x 10cm x 10cm were developed and their performance in Compton mode were studied. Because the micro-TPC can detect large number of hits from charged particles, has a good position resolution of about 0.2mm, and is based on gas, the influence of multiple scattering is small and pair events can be clearly identified. We began development of the camera with the size of 10cm\(^3\) x 10cm x 15cm for pair-mode operation. Using this camera, we performed a proof-of-principle experiment with laser inverse Compton gamma rays at National Institute of Advanced Industrial Science and Technology (AIST) and succeeded in tracking electrons and positrons and reconstructing of gamma rays. In this poster, we report the fundamental performance of the gamma-ray camera with pair-creation mode.

#### 1. MeV Gamma-ray Astronomy

![Gamma-ray Camera](image1)

- **Gamma-ray Camera**
  - MeV Gamma-ray Camera
    - 0.1 – ~10MeV: Use Compton Scattering (Compton mode)
      - Gamma TPC: Time projection chamber with u-PIC
      - Pair-creation Camera: track of electron-positron pair
    - Compton Camera: absorption point and energy of scattered gamma ray
    - Pair-creation Camera: energy of electron-positron pair
    - Stable gas gain: ~30000
    - Position resolution: ~3mm
    - Energy resolution: 28% (FWHM) @31keV
    - Gas: Ar 90% + C\(_2\)H\(_6\) 10% 1atm (sealed)

- **Beam Experiment at Advanced Industrial Science and Technology (AIST)**
  - 1.8mm\(\phi\) 5cm cube prototype camera
  - Position encoding
  - Typical Events
  - E-MeV gamma rays.
  - Angular resolution: 3% of gamma-ray direction

#### 2. Gamma-ray Camera

- **Gamma-ray Camera**
  - MeV Gamma-ray Camera
  - 0.1 – ~10MeV: Use Compton Scattering (Compton mode)
    - Gamma TPC: Time projection chamber with u-PIC
      - Compton mode: track and energy of recoil electron
      - Pair-creation mode: track of electron-positron pair
    - Scintillation Camera: position encoding
    - Compton mode: absorption point and energy of scattered gamma ray
    - Pair-creation mode: energy of electron-positron pair
  - Typical Events
    - 20 MeV gamma rays.
    - Angular resolution: 3% of gamma-ray direction

#### 3. SMILE project

- **Roadmap of the SMILE**
  - 10cm cube camera with Compton mode
    - 0.1~3MeV: E-Gamma, Japan-Dehorn
    - Operation test: balloon altitude
    - Observation of diffuse cosmic atmospheric gamma rays
  - 30cm cube camera with Compton mode
    - 0.1~5MeV: E-Gamma, Japan-Dehorn
    - Observation of Crab (Crabs)

- **SMILE-1**
  - 10cm cube camera with Compton/Pair mode
    - 0.1~10MeV
    - MEOS (Si strip)
    - 8 scintillation camera
    - LAT (Fermi/4) 3 strip
    - Position: 3mm
    - Energy: 10MeV, 20MeV
    - Beam: Laser Inverse Compton
  - Typical Events
    - E-MeV gamma rays.
    - Distribution of the angular resolution between the measured and real origin of 20MeV gamma rays.

- **SMILE-2**
  - 10cm cube camera and readout system (left) and our balloon (right)
  - B100 (100,000m3)
  - 8 scintillation camera
  - Typical Events
    - E-MeV gamma rays.
    - Distribution of the angular resolution between the measured and real origin of 20MeV gamma rays.

#### 4. Proof-of-Principle Experiment for Pair-Creation Mode

- **Gamma-ray Camera with Pair-creation mode**
  - Volume:10cm\(^3\) x 10cm x 15cm
  - Gas: Ar 90% + C\(_2\)H\(_6\) 10% 1atm (sealed)
  - Position resolution: 200\(\mu\)m
  - Energy resolution: 28% (FWHM) @31keV
  - Stable gas gain: ~36000 (µ-PIC) ~36000 (µ-TGC)
  - Scintillation Camera
    - EGRET (CGRO)
    - IBIS, SPI (INTEGRAL)
  - Coded Aperture Imaging
  - High energy (> 100 MeV)
  - E-GRET (CGRO)/Spark Chamber

- **Beam Experiment at Advanced Industrial Science and Technology (AIST)**
  - 1.8mm\(\phi\) 5cm cube prototype camera
  - Position encoding
  - Typical Events
  - 20 MeV gamma rays.
  - Angular resolution: 3% of gamma-ray direction

#### 5. Summary & Future Work

We have succeeded in imaging of gamma rays using Pair-creation mode. We obtained angular resolutions of 9.4 and 7.7 degrees (68% containment) at 10 and 20 MeV, respectively. These resolutions are better by factor of about 1.4 than those of the silicon strip detector. This result is the best in the camera which use pair creation at present.

In the future, we will tune the gamma-ray camera and improve the analysis method in order to achieve close to the resolution of the simulation.

### References

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