Precise Low-Energy Electron Tracking Using a Gaseous Time Projection Chamber for the Balloon-Borne Gamma Ray Compton Telescope

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Contents

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Motivation (sub-MeV/MeV gamma-ray astronomy)

Nucleosynthesis

SNR : Radio-isotopes
Galactic plane : ^{26}Al・^{60}Fe
Annihilation

Acceleration

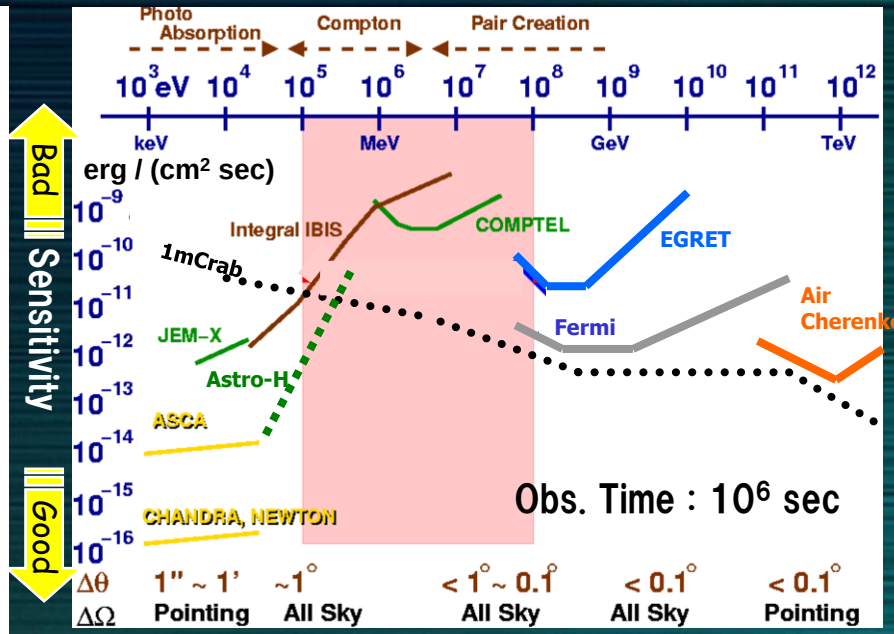
GRB, Jet (AGN) : Synchrotron
+ Inverse Compton

Strong Gravitational Potential

Black Hole : accretion disk, π^0

Etc.

Gamma-ray Pulsar, solar flare



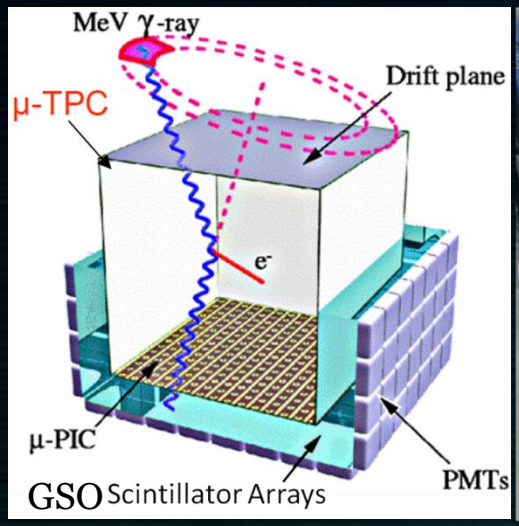
Sensitivity

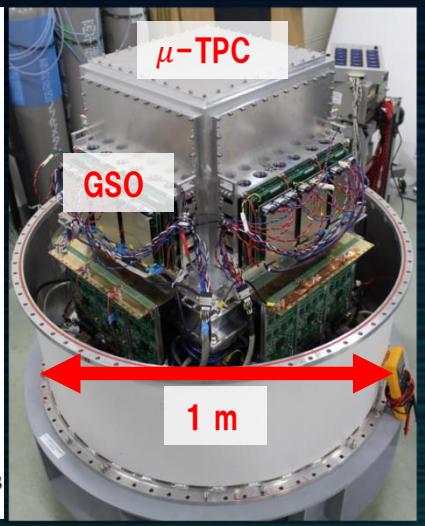
- The observation of continuum component is important.
- Where are MeV gamma-ray objects?
- There are many background events which obstruct the observations.

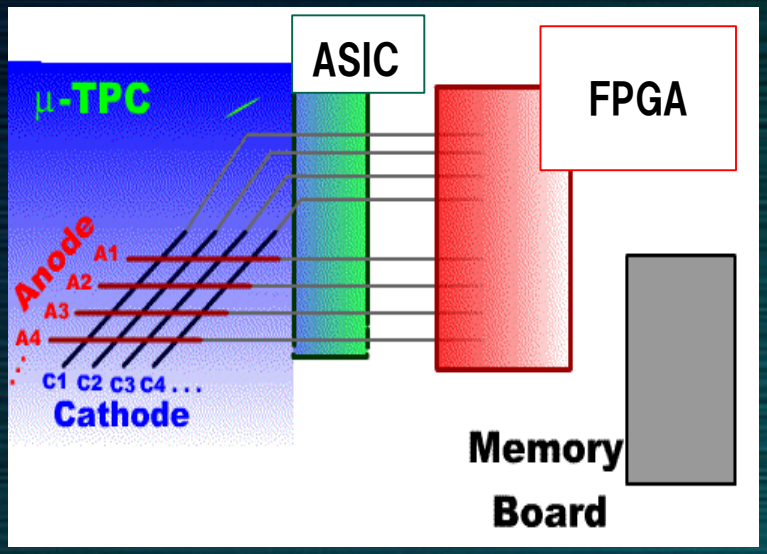
Requirements for
the next-generation detectors are …

- Wide-band detection
- Large Field of View
- Background rejection

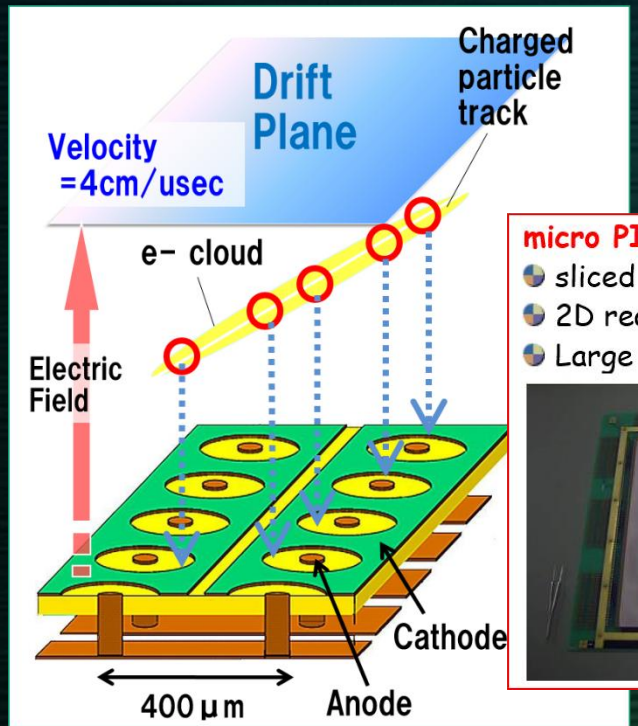
Electron Tracking Compton Camera (ETCC) for SMILE



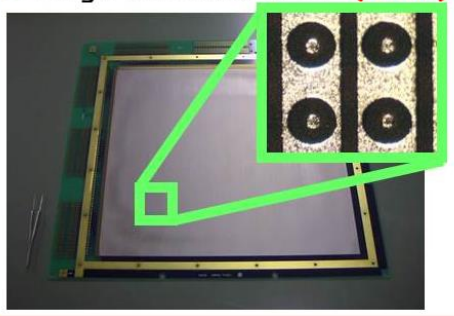




Schematic of ETCC (left) and photograph of flight model ETCC for SMILE-II experiment (right)



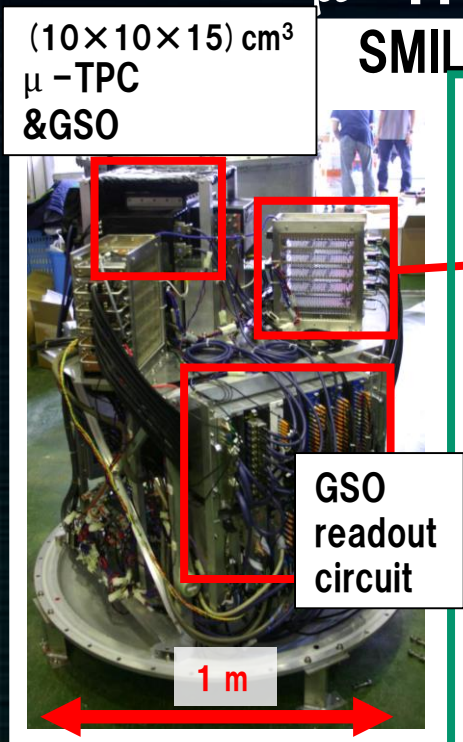
micro PIxel Chamber(μ-PIC)
- sliced proportional chambers
- 2D readout (400 μm pitch)
- Large detection area : $(30cm)^2$



SMILE experiment

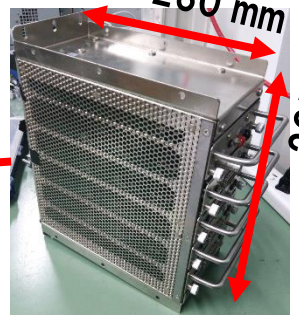
		SMILE-I (2006)	SMILE-II
μ-TPC	Size	(10×10×15) cm^3	(30×30×30) cm^3
	Readout Number	256 strips /10 cm	384 strips /30 cm
	Readout Pitch	400 μm	800 μm
GSO	pixel number	2112 pixels	6912 pixels

μ-TPC readout for SMILE-I and SMILE-II

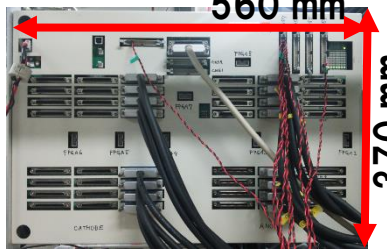


SMILE-I FM ETCC

SMILE-I ETCC

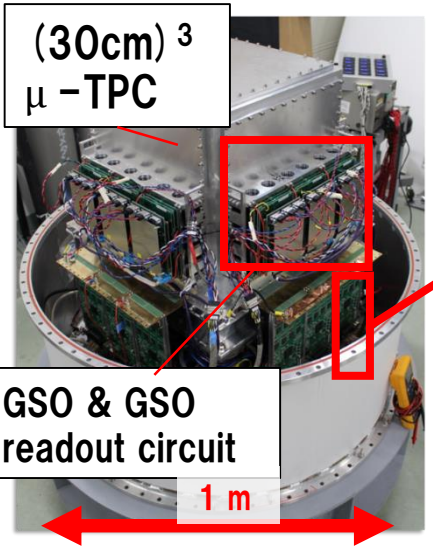


ASD (256ch/10cm)
4.5 kg

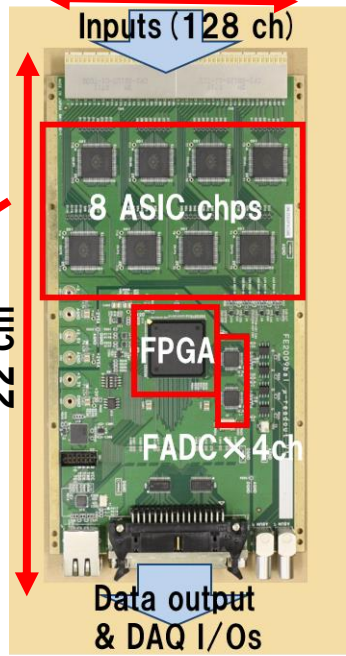


encoder (1 board/1ETCC)
7.8 kg

SMILE-II ETCC



SMILE-II FM ETCC



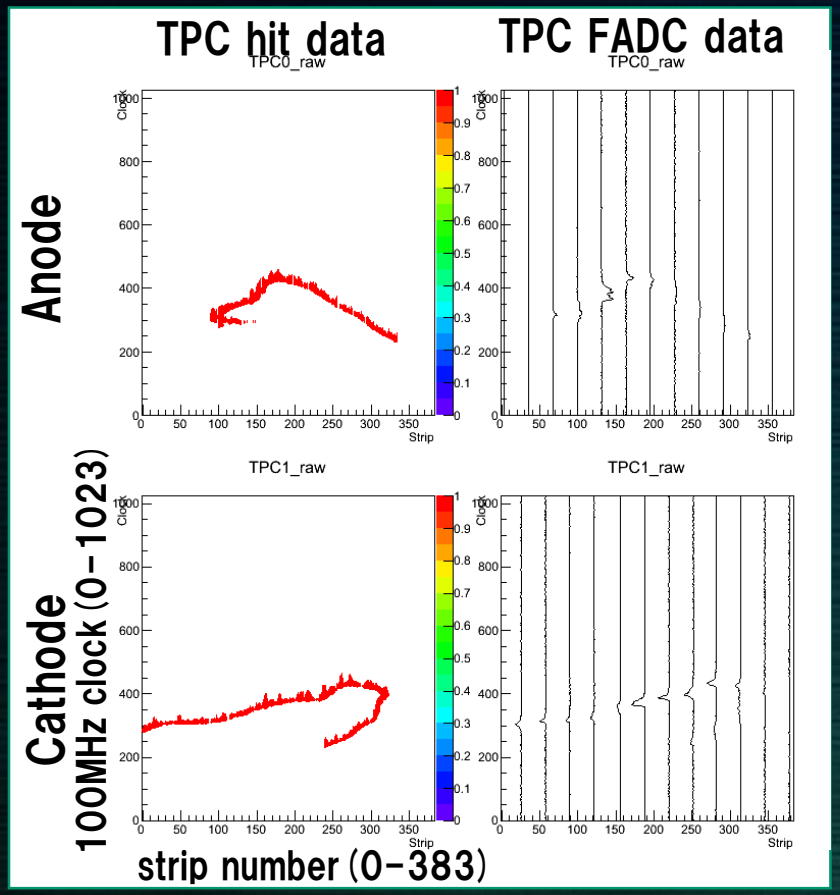
new readout board
(128 strips/10 cm)

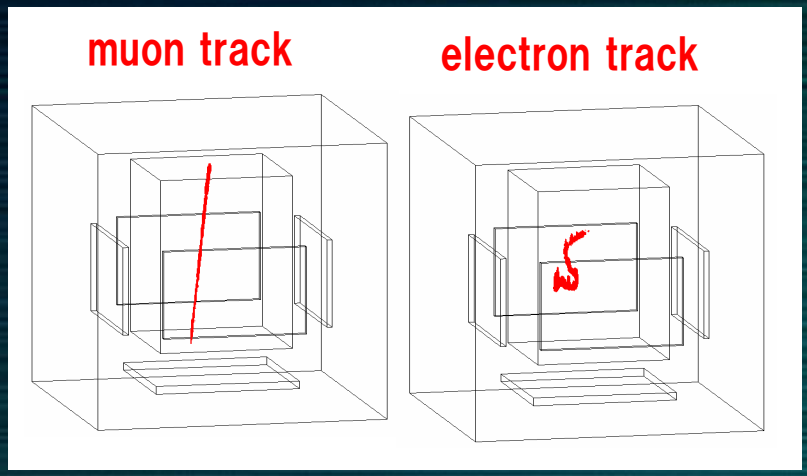
conventional readout circuit ...
- massive
- takes up a lot of space
- high electric power consumption

->developed new readout circuit

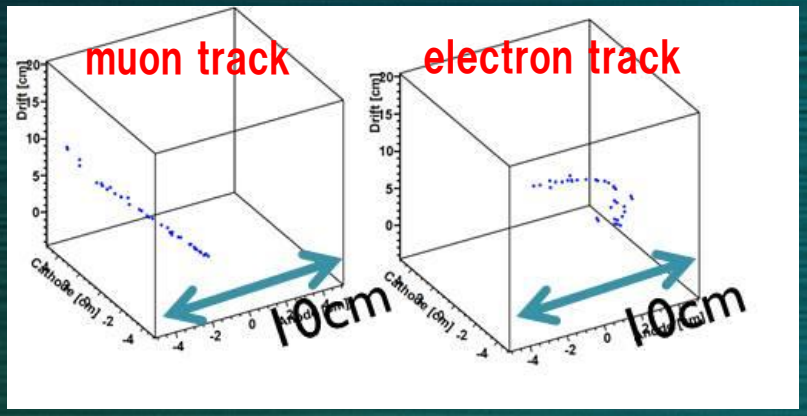
	ASD system (for SMILE-I)	new readout board (for SMILE-II)
ASIC chip transistor type	bipolar transistor	CMOS transistor
strip number per 1 ASIC chip	4	16
power consumption	0.24 W/strip	0.17W/strip

Example TPC data of SMILE-II ETCC with new readout board

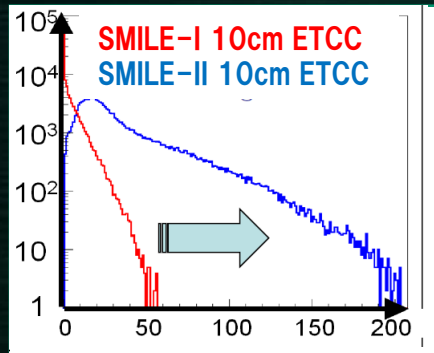




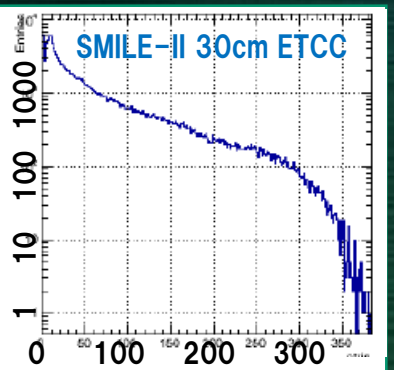
TPC 3D reconstructed track
(SMILE-II ETCC)



TPC 3D reconstructed hit data
(SMILE-I ETCC)

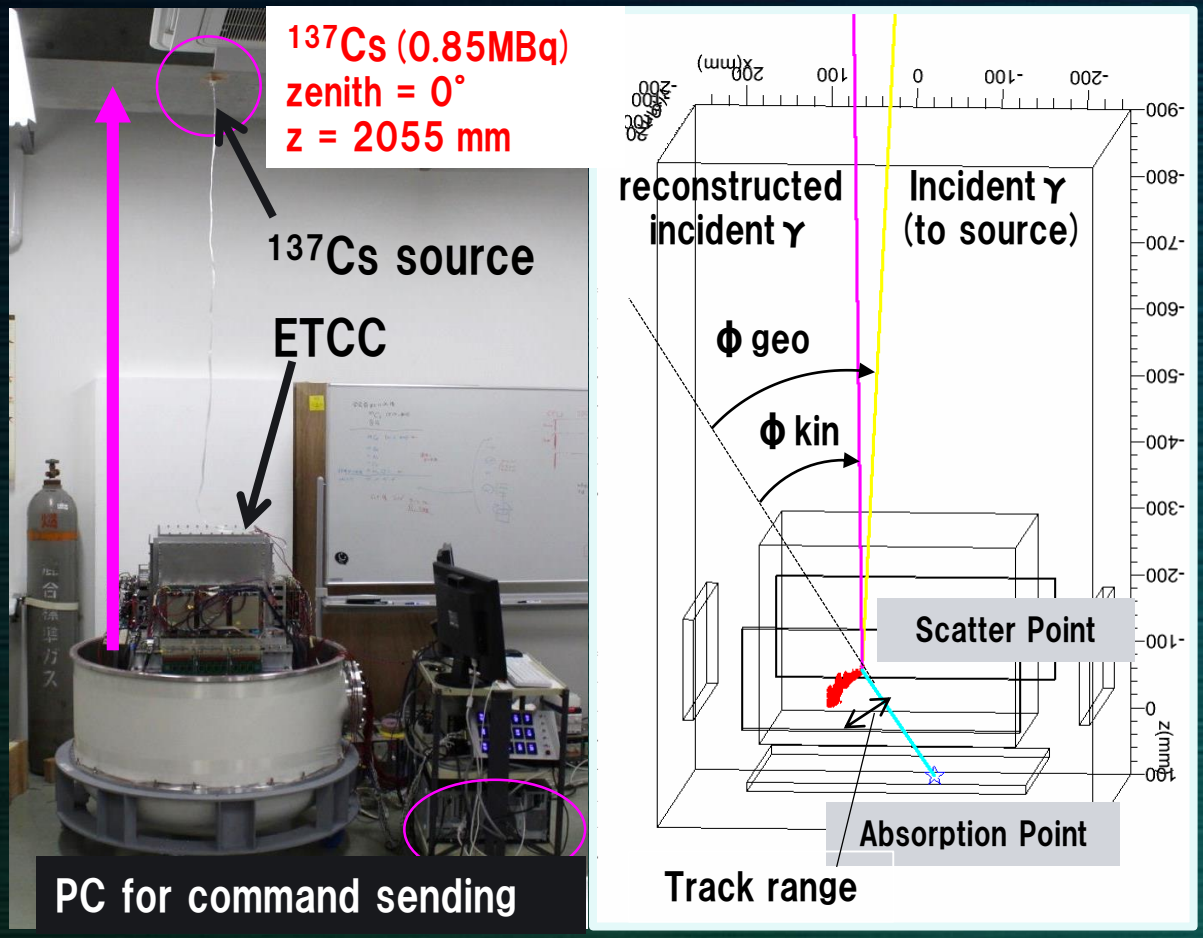


Number of hit pixel strips



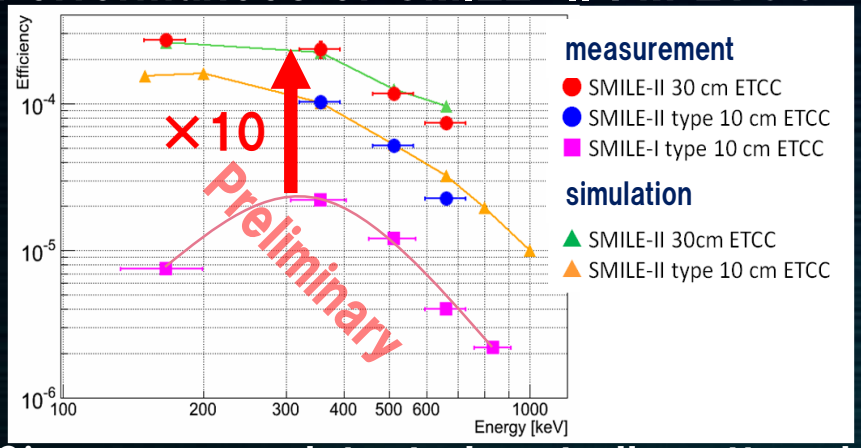
Changed saving method of TPC hit data
→particle tracks are clearer than ever
We can detect recoil electrons perfectly

Example data of SMILE-II ETCC with new DAQ system

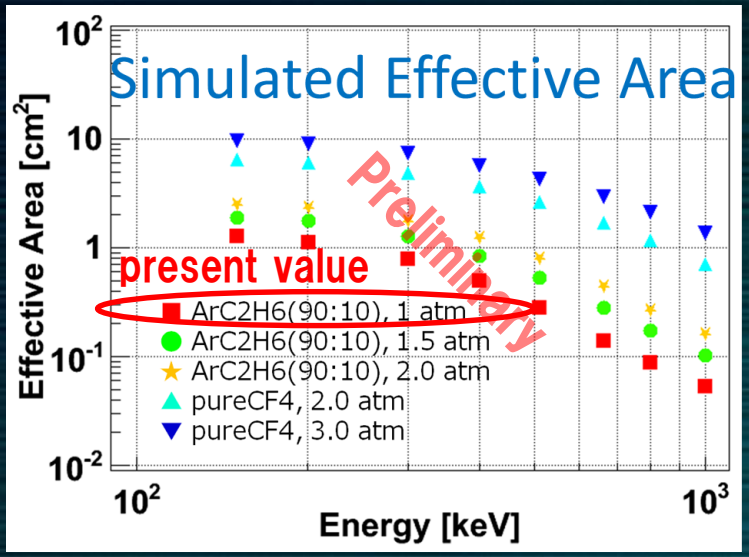


We can reconstruct the incident gamma rays by using the scattering point, direction and gamma ray energy, recoil direction and electron energy event by event.

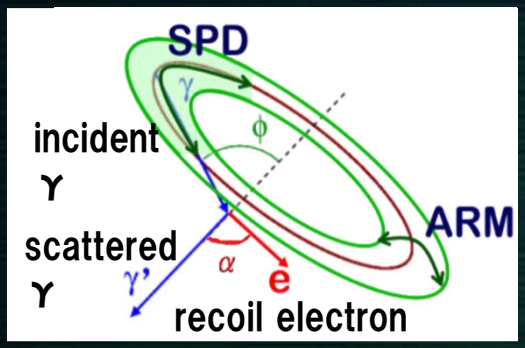
Performances of SMILE-II FM ETCC



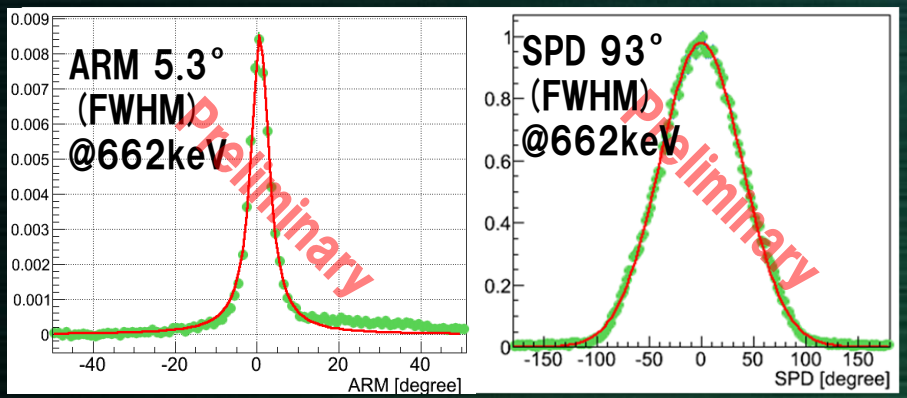
Since we can detect almost all scattered electrons, the measured efficiency is similar to the simulated one.



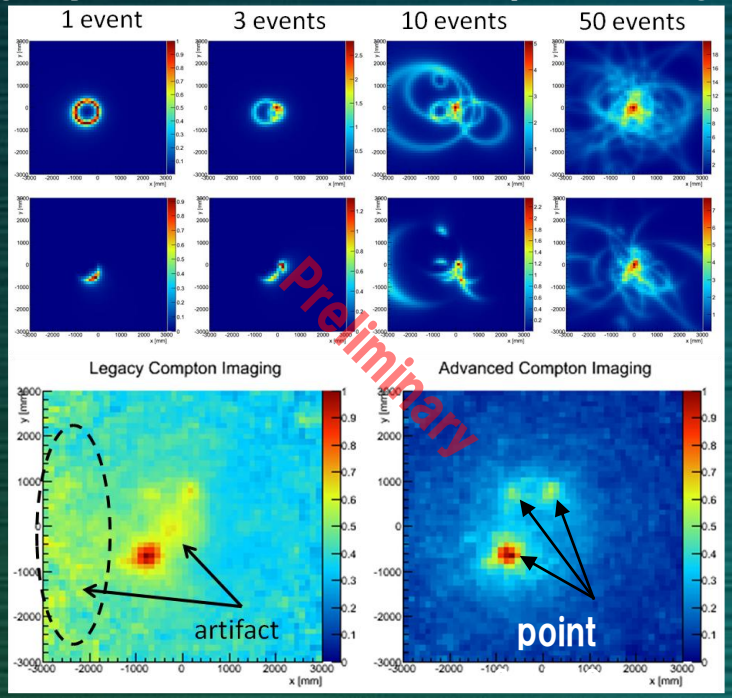
effective area 10cm²
-> reach the efficiency of COMPTEL



ARM : accuracy of the scattering angle
SPD : accuracy of the scattering plane

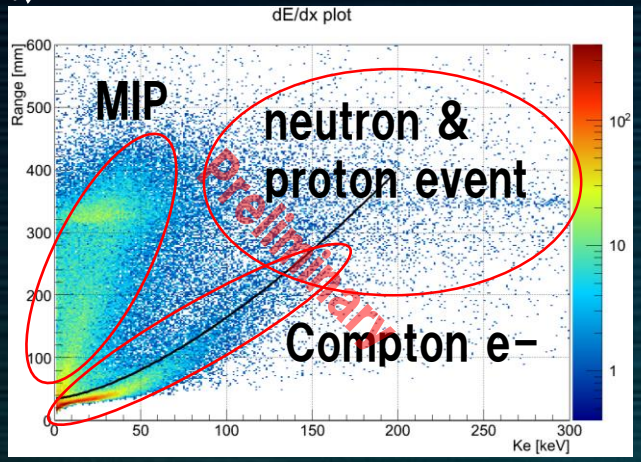


Legacy and Advanced Compton Imaging

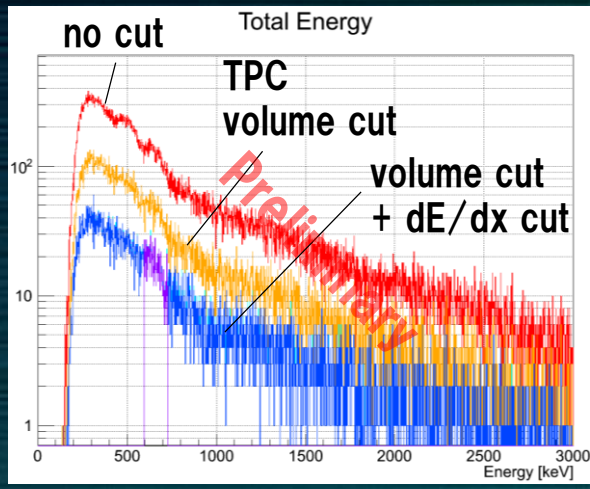


Measurement in the environment of high background level (@RCNP Osaka Univ.)

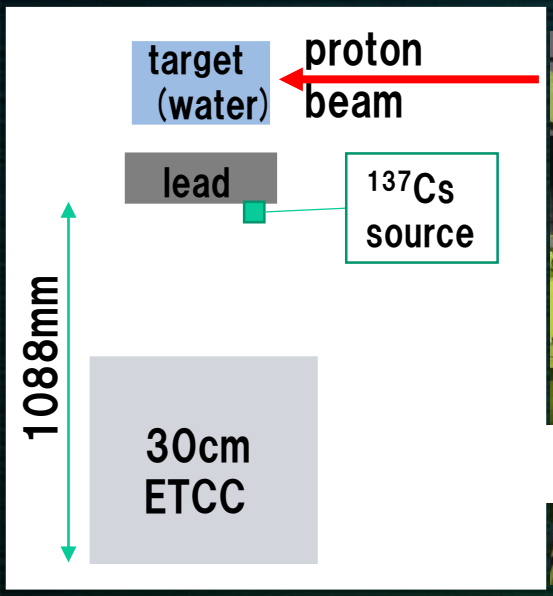
Date 2013/10/17
trigger rate
: 16.2 kHz
data saving event rate
: 394 Hz
Dead Time : 59.6%
^{137}Cs: 0.84 MBq

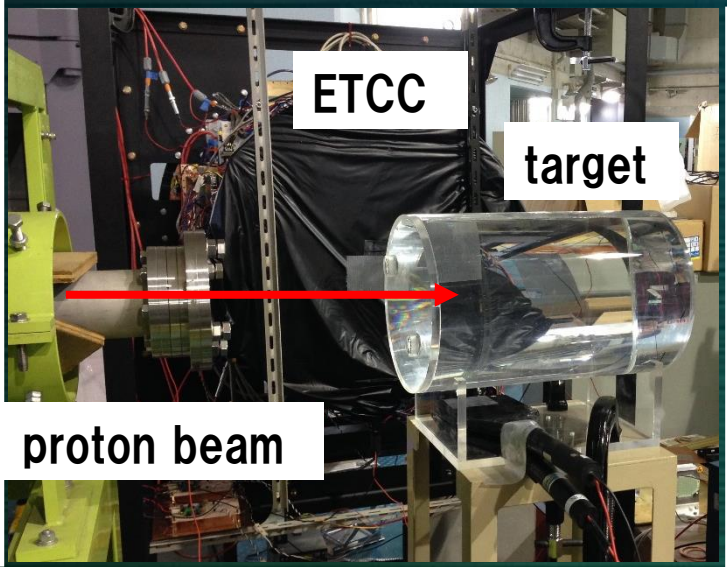


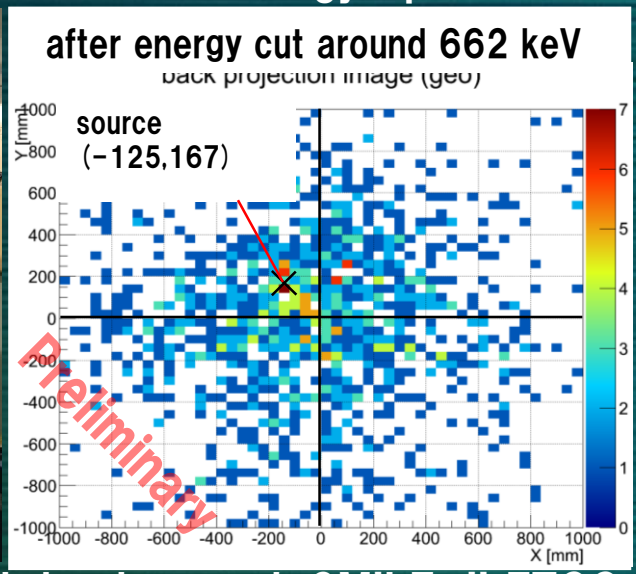
Track range vs energy (dE/dx)



Energy Spectra







In the environment of high background, SMILE-II ETCC system operates correctly and shows powerful imaging ability. Further analysis of the data will be done.

Conclusion

- We have been developing the flight model $(30\ cm)^3$ ETCC for SMILE-II experiment.
- Since we changed the algorithm for taking track hit data of μ-TPC, hit number per event is increased, and almost all recoil electron can be taken.
- From the result of the simulation, we can achieve the efficiency 10 times higher than the present one by changing the gas species and pressure of the TPC.
- For SMILE-II ETCC, we confirmed the detector operates correctly in the high background rate.

Fin

My colleagues

- S. Komura, NPO2-122, Performance Improvement of an Electron-Tracking Compton Camera by a New Track Reconstruction
- S. Sonoda, M12-10, The Performance Evaluation of the Electron Tracking Compton Camera
- D. Tomono, N28-2, First Application to Environmental Gamma-Ray Imaging with an Electron Tracking Compton Camera