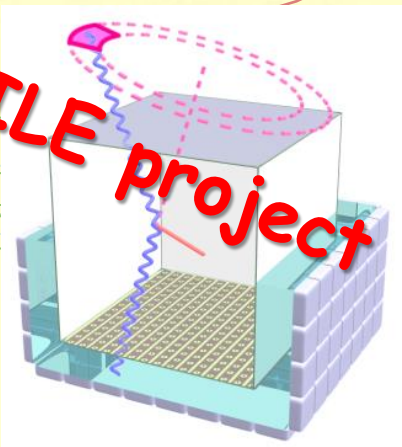
IEEE NSS/MIC 2014 @ Seattle

Effectiveness and Performance of a Full Ray-Tracing Sub-MeV Compton Imager

Yoshitaka Mizumura
(Kyoto Univ.)



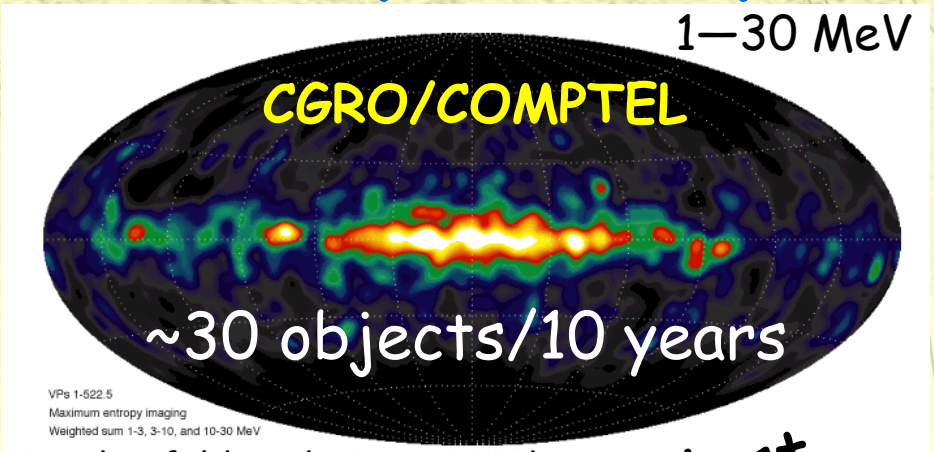
A. Takada, S. Iwaki, S. Komura, H. Kubo, Y. Matsuoka,
K. Miuchi, T. Mizumoto, K. Nakamura, S. Nakamura, M. Oda,
J. D. Parker, S. Sonoda, T. Sawano, T. Tanimori, D. Tomono

Sub-MeV/MeV gamma-ray astronomy

Treasure box of Interesting Science

- Nucleosynthesis
  SNR, Galactic plane
- Particle acceleration
  Relativistic Space Jet
- Strong gravitational potential
  Blackhole, accretion disk
- Evolution of the Universe
  Most-distant GRB
- Others
  Solar flare, Gamma-ray pulsar

All-sky MeV map



V. Schönfelder+ (A&AS, 2000)

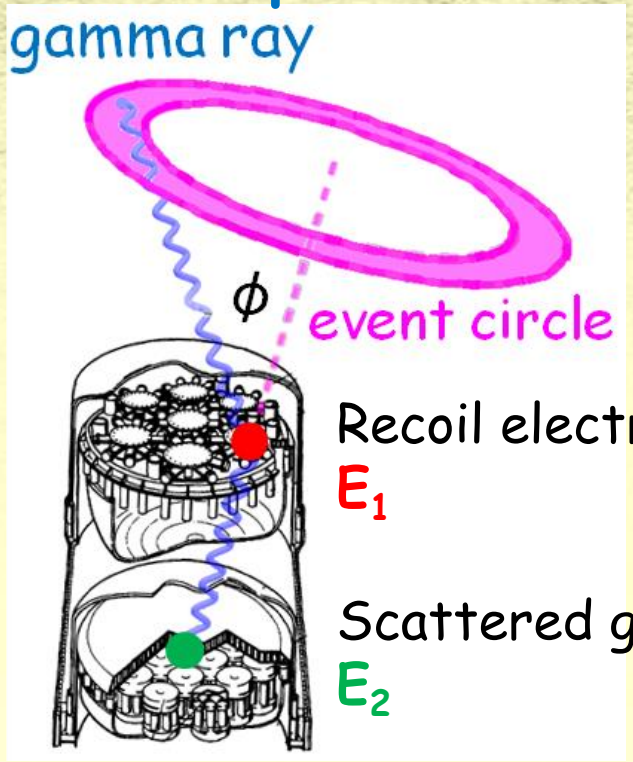
Unrevealed last wide window for Astronomy

Requirements for the next generation telescopes

- Large Field of View
- High quality image
- Wide-band detection

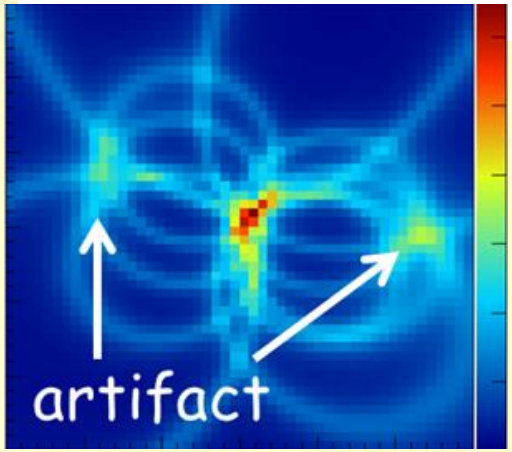
Difficulty of MeV gamma-ray imaging

Compton scattering dominates in MeV cross section



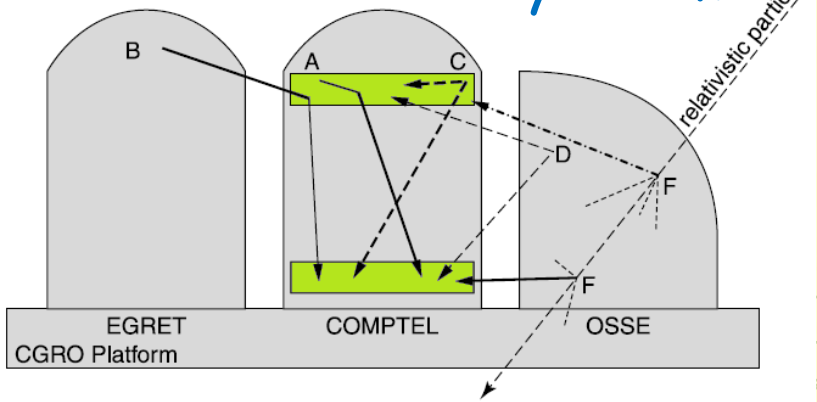
Principle of Compton Imager

$$\cos\phi = 1 - m_e c^2 \left(\frac{1}{E_2} - \frac{1}{E_1 + E_2} \right)$$



Unclearness
&
Artifacts

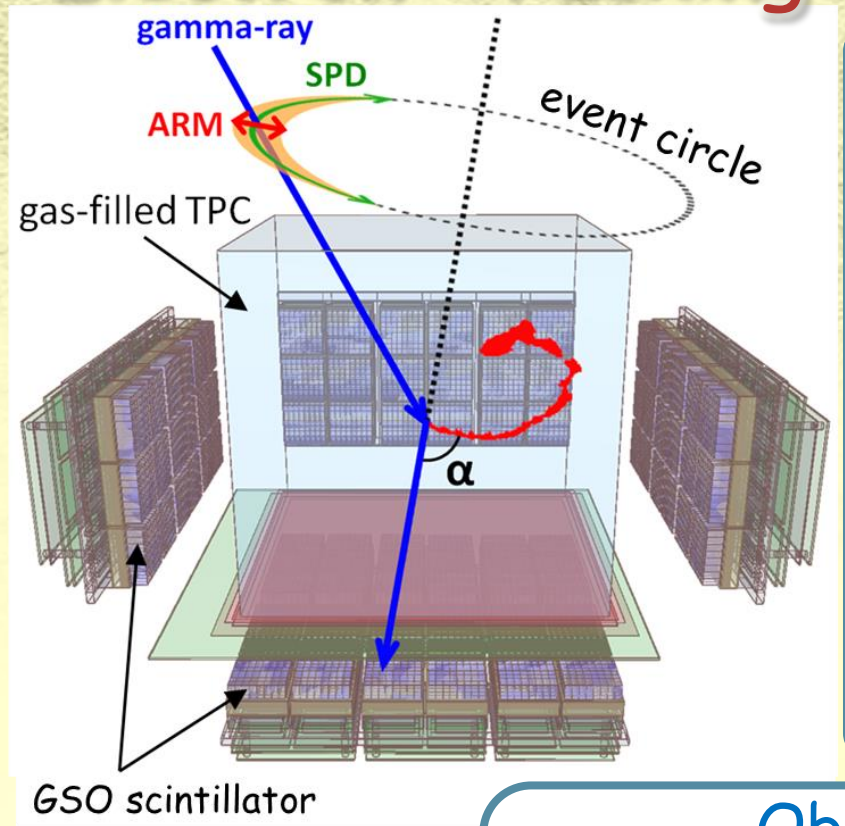
Radioactivation by cosmic-rays -> Huge background in space

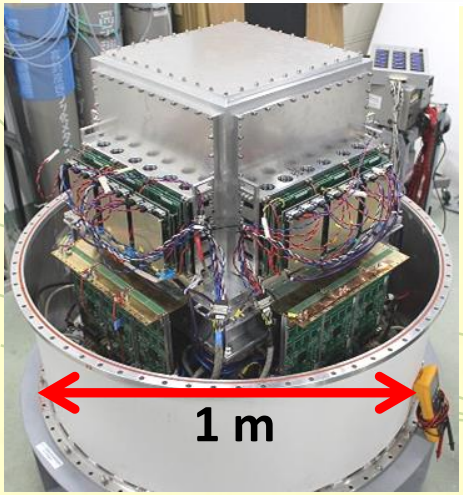


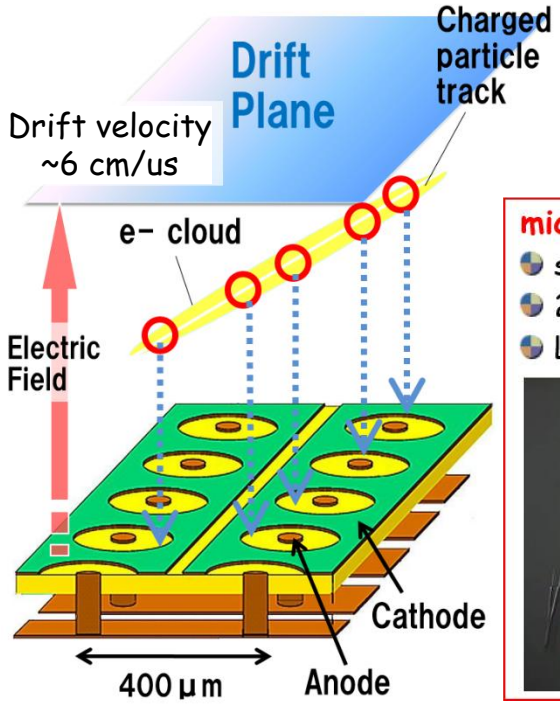
- Improvement of imaging
- Background suppression

are two big tasks in MeV

Electron-Tracking Compton Camera (ETCC)

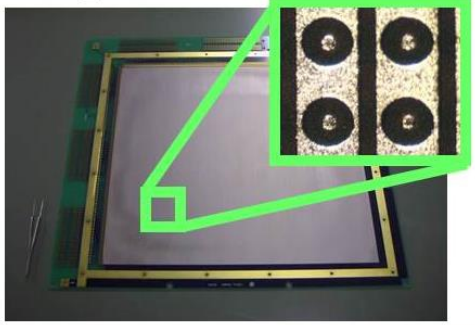




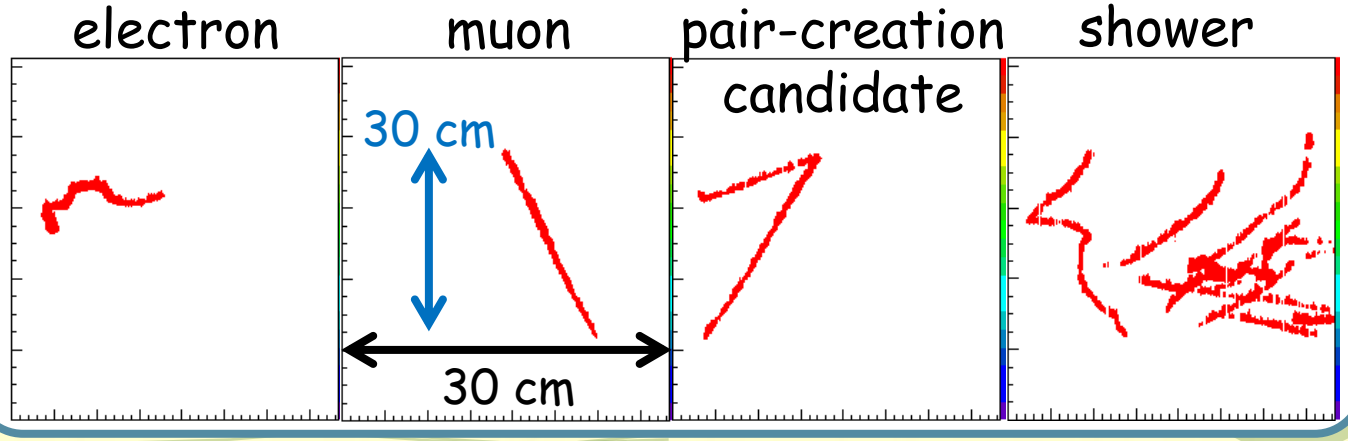


Ray-Tracer (Gas TPC)

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



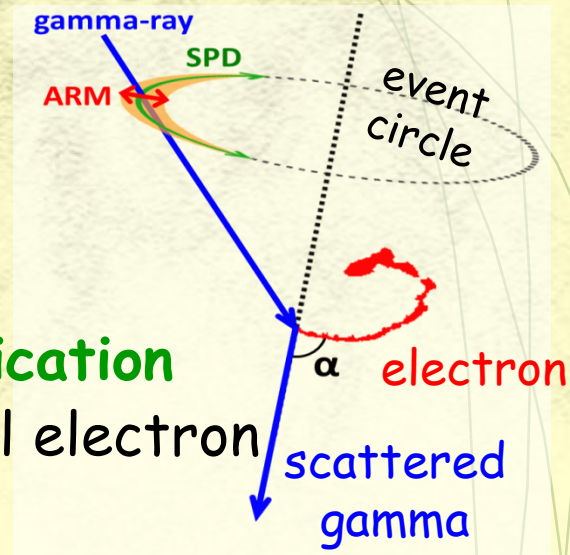
Observed Ray track samples



Effectiveness of Ray-Tracing information

Three additional parameters

1. **SPD**, Direction of scattering plane
   - -> Event by event arrival direction
2. **dE/dx**, Energy deposit rate of particle
   - -> Background rejection by particle identification
3. **α**, Angle between scattered gamma and recoil electron
   - -> Background rejection by kinematics test



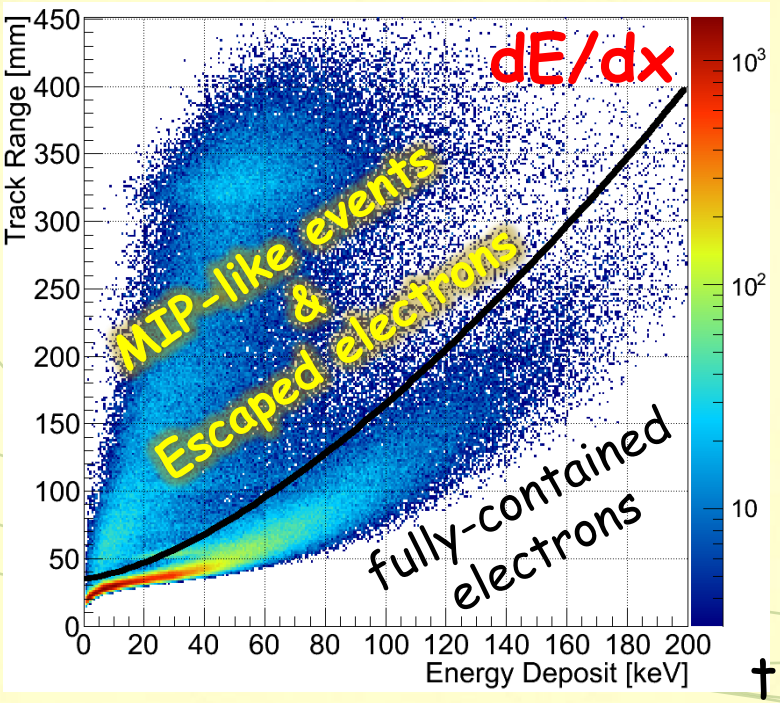
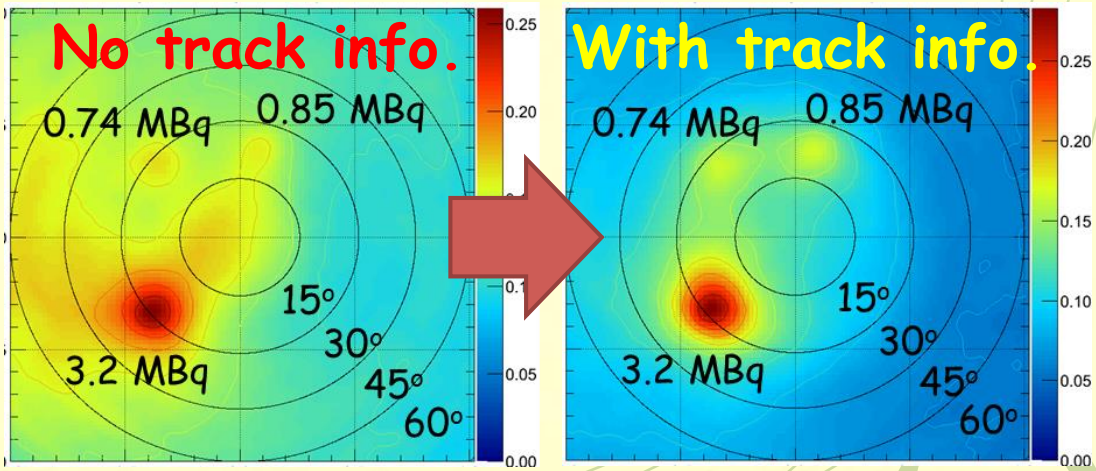


Image of three ^{137}Cs (662 keV) sources with/without ray tracing info.



Ray-Tracing info. enables us to detect the sources by **factor ~3 in significance**

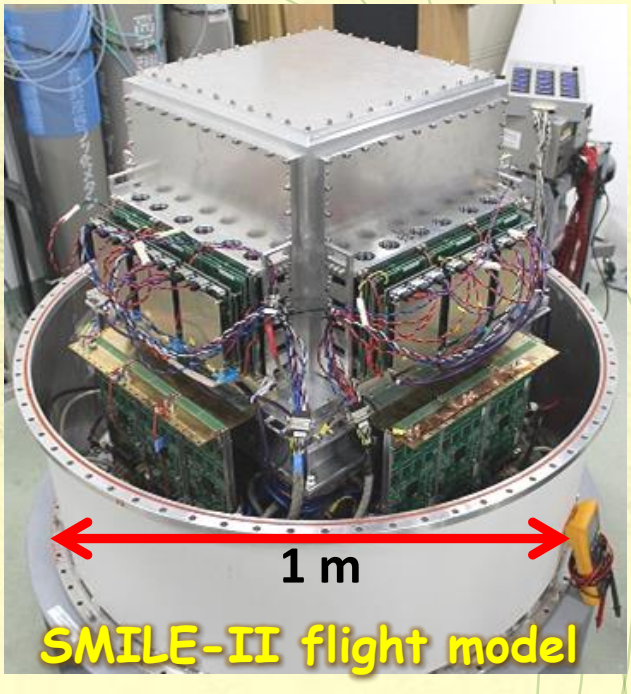
ETCC for 2nd balloon exp. (SMILE-II)

Sub-**M**eV gamma-ray **I**maging
Loaded-on-balloon **E**xperiment

Aim: **Confirmation as a sub-MeV telescope**

-> Imaging of Crab/Cyg X-1

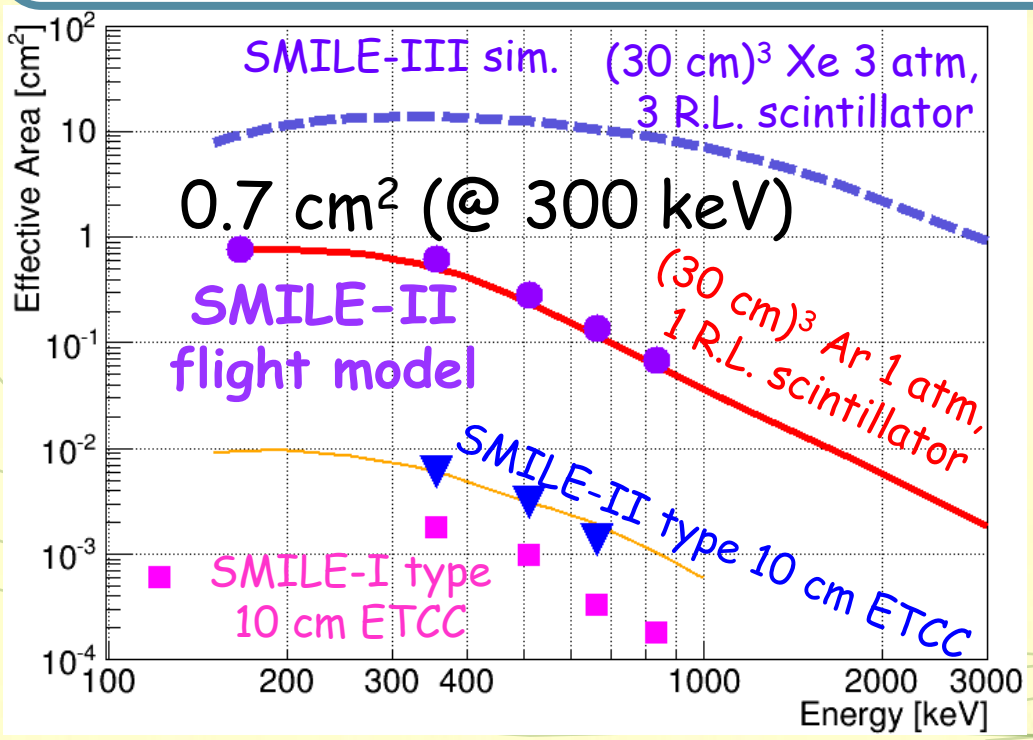
(>3σ detection, ~40 km, one-day flight)

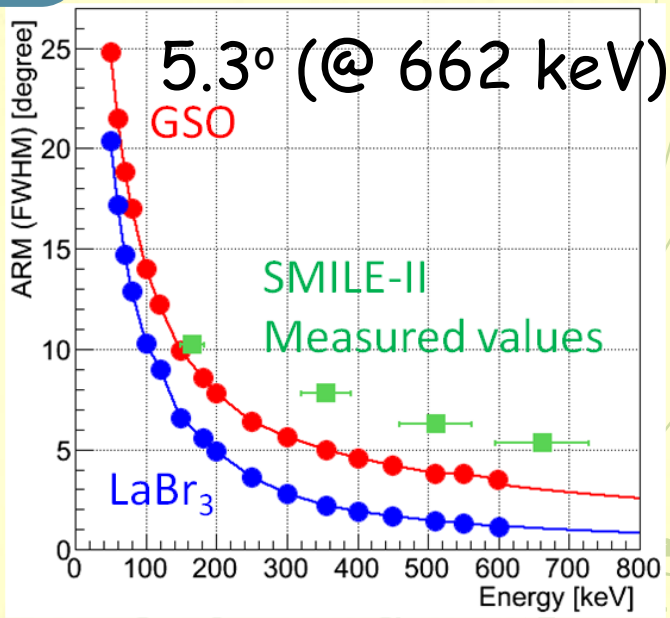


Required Performances

Effective area: >0.5 cm² (@300 keV)

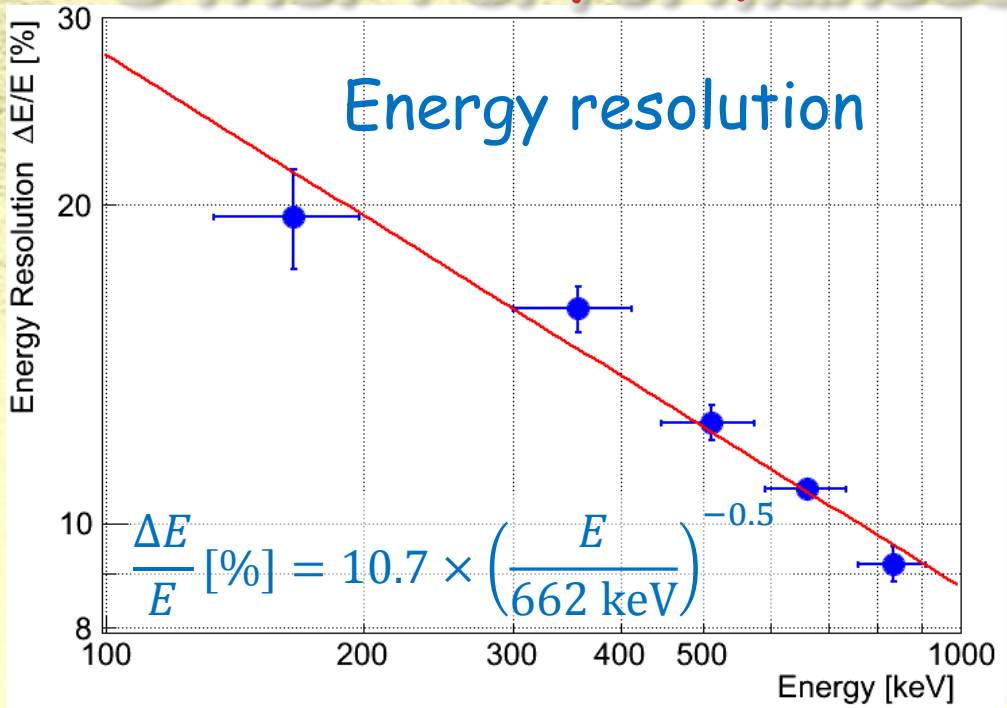
Angular resolution: <10° (@600 keV)

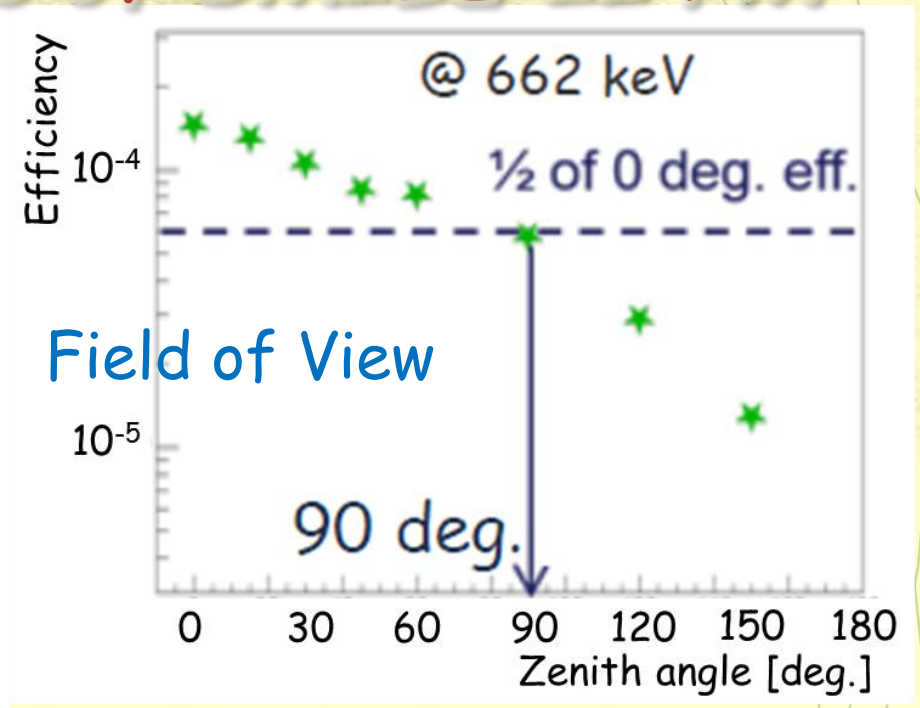




Clear the requirements!!

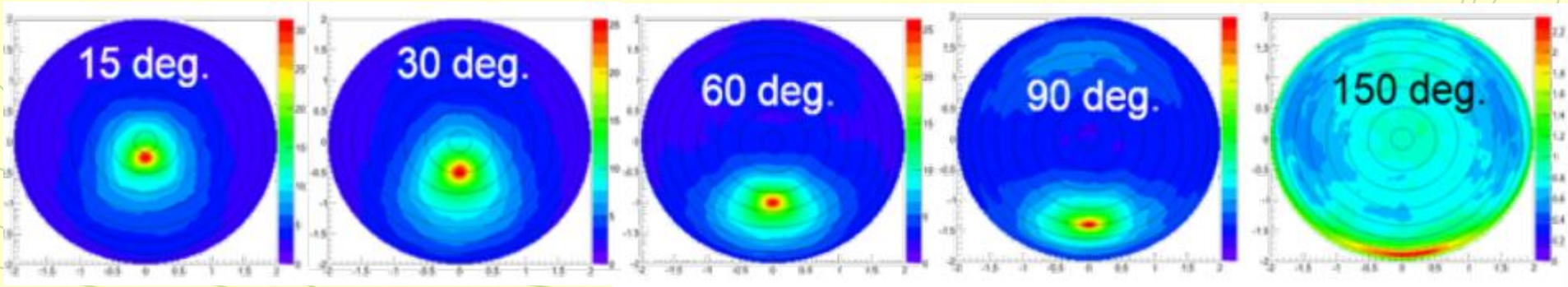
Other Performances of SMILE-II FM





Imaging check for large zenith angles

^{137}Cs (662 keV, 0.7 MBq) at 2 m distance from ETCC

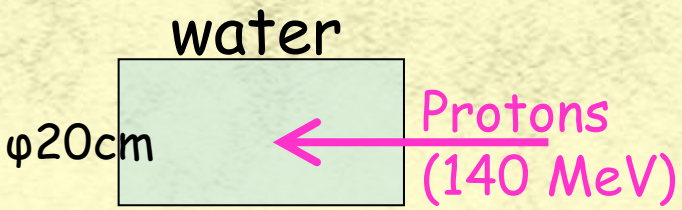


SMILE-II flight model ETCC has large FoV ~2π str

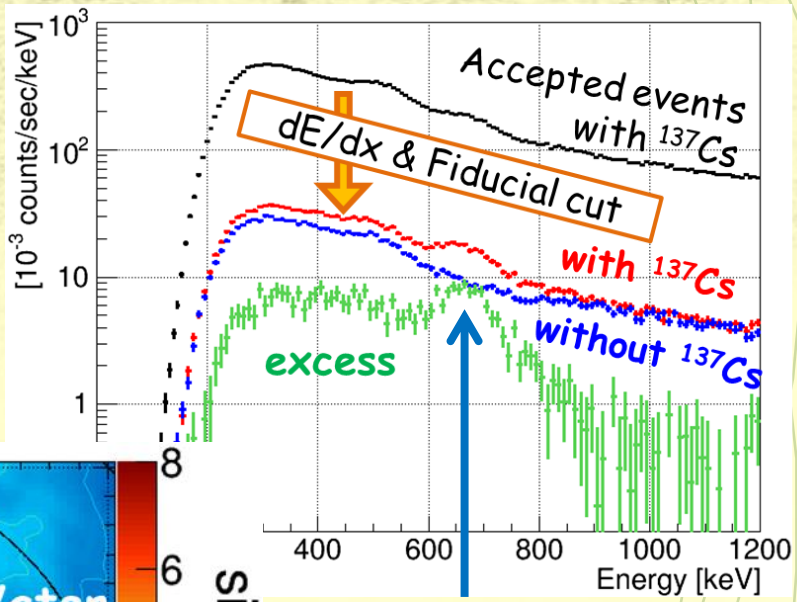
ETCC in intense radiation field

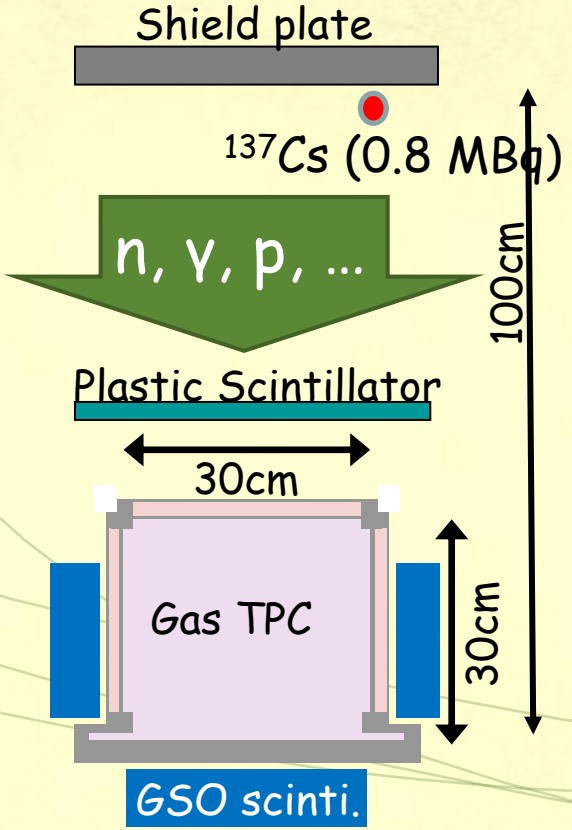
Balloon/Satellite altitude has intense background radiation

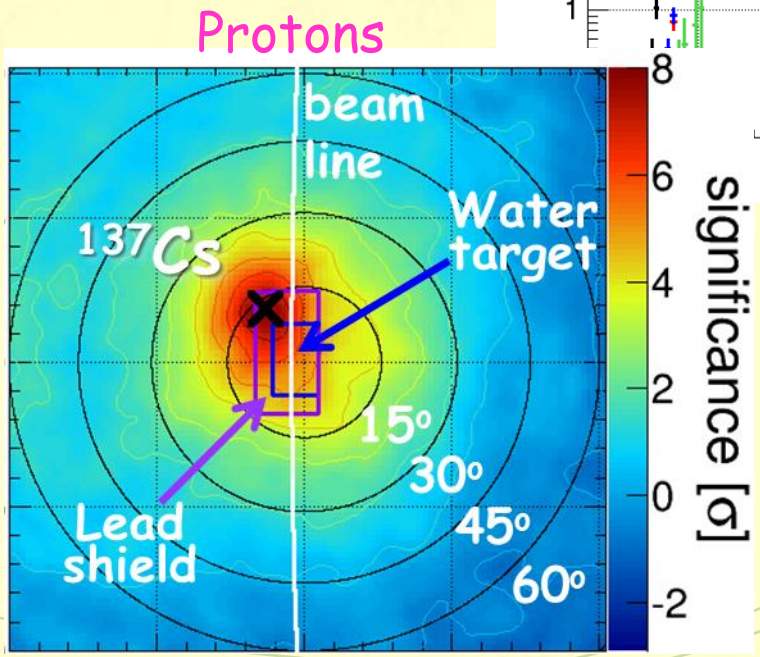
-> Can ETCC image a gamma-ray source in such field?



We generate factor ~5 more intense field than expected BG



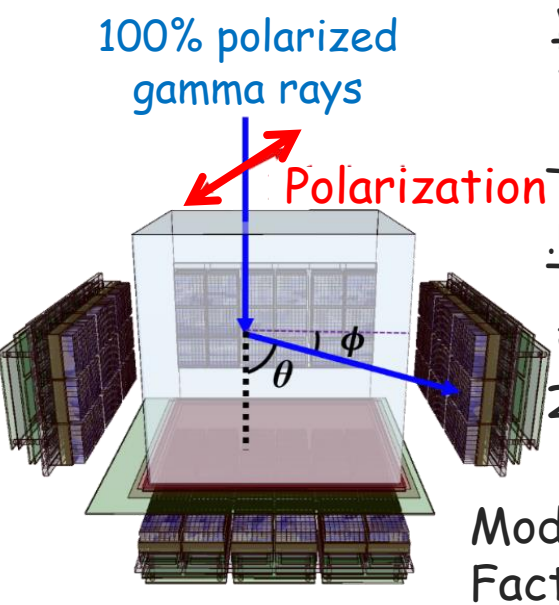


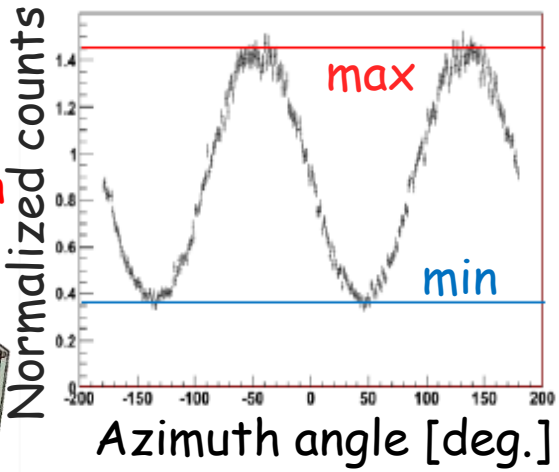


ETCC has imaging capability in intense BG

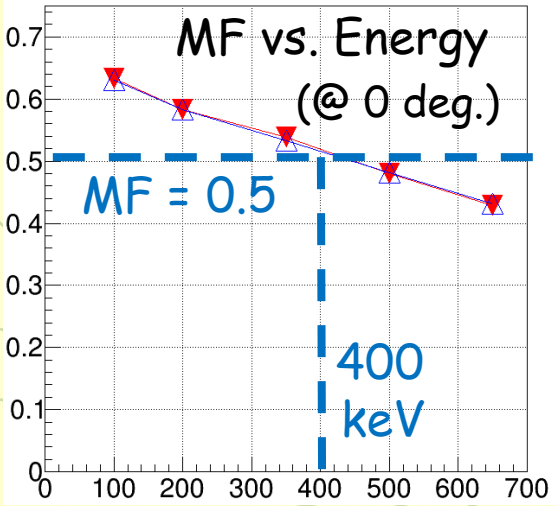
ETCC as a gamma-ray polarimeter

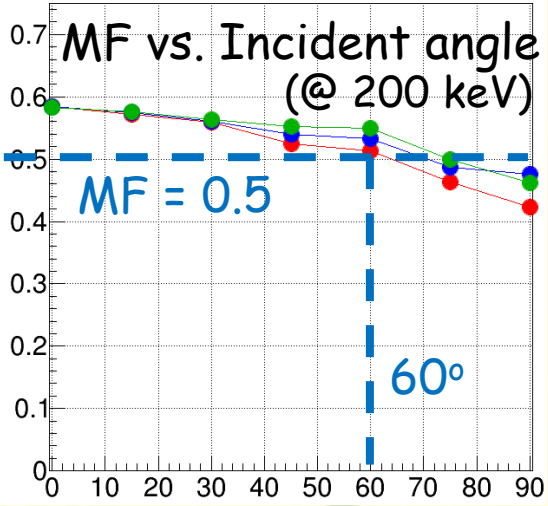
Simulation



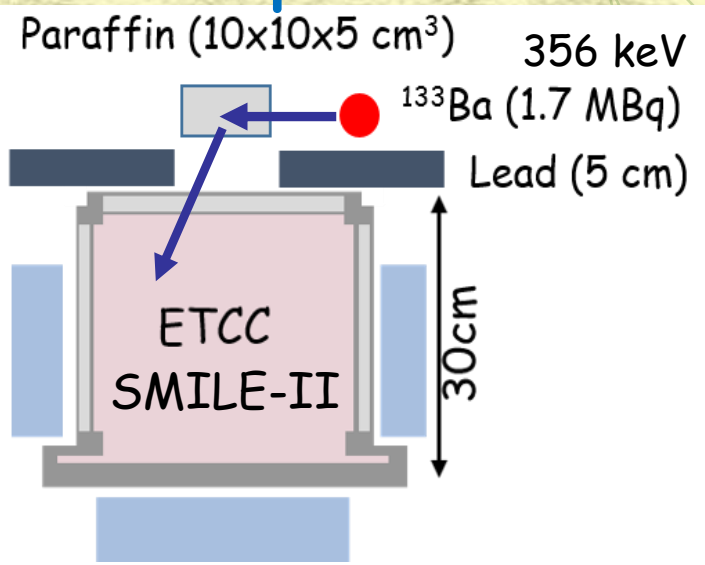


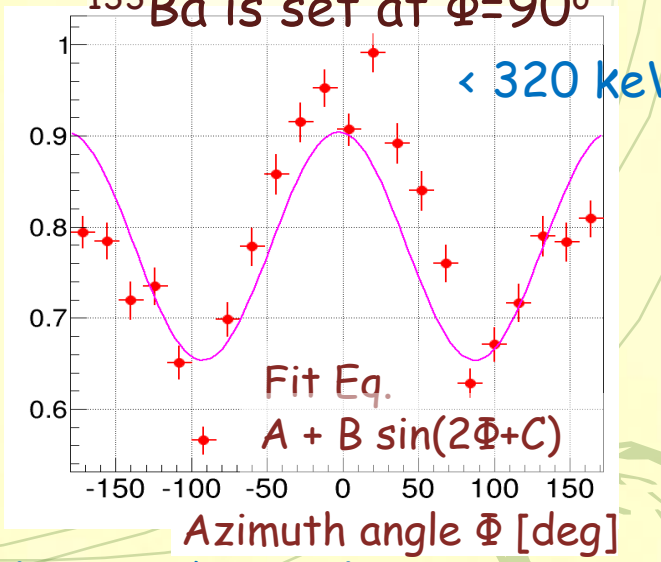
$$\text{Modulation Factor (MF)} = \frac{max - min}{max + min}$$





Experiment





ETCC has large MF which can detect low S/N polarization

Summary

- Ray-Tracing info. brings big benefits for Compton imager
  - High quality/contrast imaging (**SPD**)
  - Efficient background rejection (**dE/dx**, **α**)
- SMILE-II ETCC fulfills the requirement performances
  - Effective area: **0.7 cm^2** (@ 300 keV)
  - Angular resolution: **5.3 deg.** (@ 662 keV)
  - Energy resolution: **10.7% x (E/662 keV)$^{-0.5}$**
  - Wide Field of View: **~2π str** (@662 keV)
- Imaging capability in intense radiation field
- As a background-suppressed imaging polarimeter
  - Modulation Factor: **>0.5** (E < 400 keV, Zenith angle < 60°)

SMILE-II ETCC can detect Crab (>3σ, several hours)

Negotiation with NASA/GSFC for balloon flight(s) @ fort sumner is ongoing

Thank you for your attention!!

Please visit to the SMILE project web page

http://www-cr.scphys.kyoto-u.ac.jp/research/MeV-gamma/index_e.html