Experiment of the 30 cm-cube ETCC under the Intense Radiations with Proton Beam

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Contents

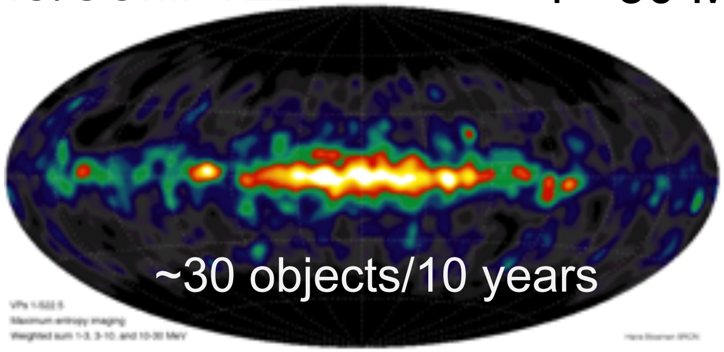
- Compton Camera for MeV gamma-ray
- ETCC (Electron-Tracking Compton Camera) and SMILE project
- Performances of 30 cm-cube ETCC
- Experiment under the intense radiations

PSD10 8 Sep., 2014

MeV gamma-ray astronomy

MeV region

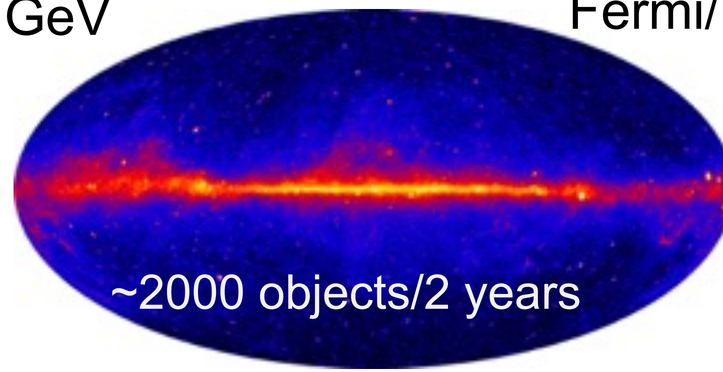
CGRO/COMPTEL 1 - 30 MeV



V. Schönfelder+ (A&AS, 2000)

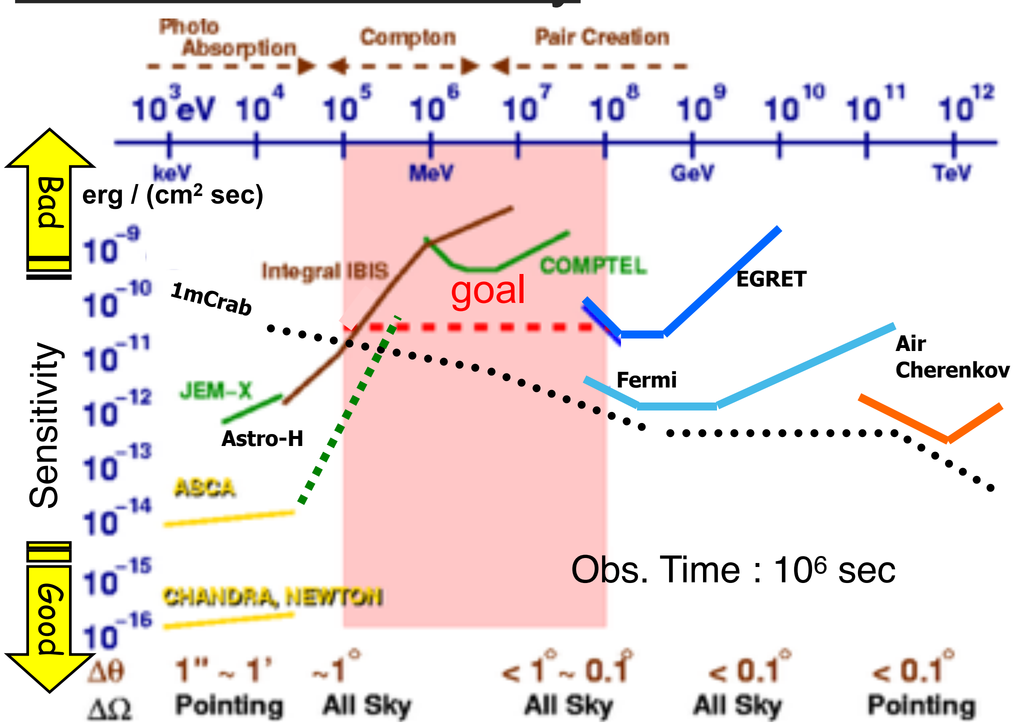
GeV region

> 1 GeV Fermi/LAT



P. L. Nolan+ (ApJS, 2012)

Detection sensitivity



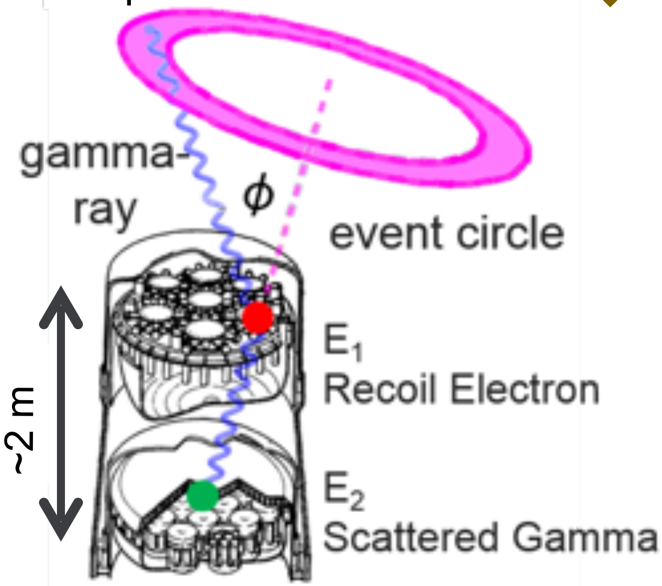
In the MeV region

- **Unclearness of image**
- **Wide sensitivity gap**

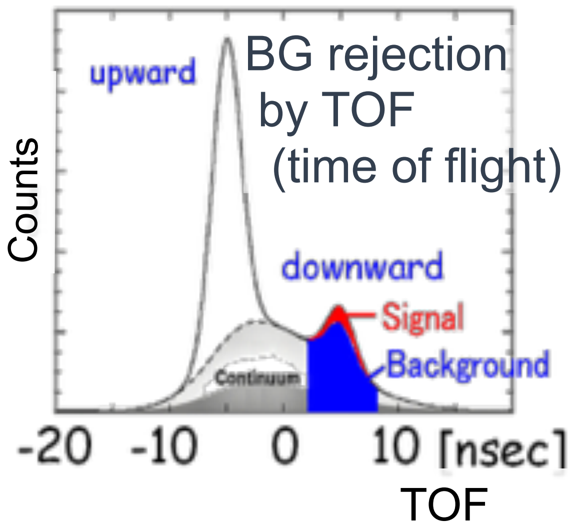
What is the main reason of these problems?

Difficulty of MeV gamma-ray

Principle of COMPTEL



V. Schönfelder+ (ApJS, 1993)



G. Weidenspointner+ (A&A, 2001)

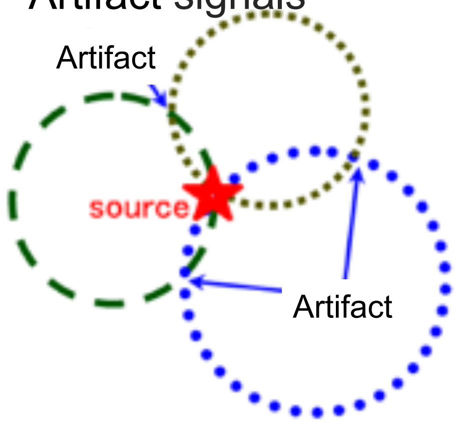
◆ Incomplete Compton reconstruction

Usual Compton Cameras can't measure direction of the recoil electron.

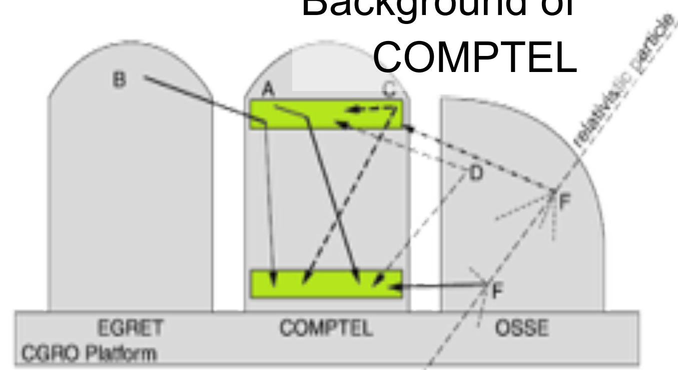
⇨ Imaging by superposition of event circles

New Imaging method is needed.

Artifact signals



Background of COMPTEL



R. van Dijk (Ph.D thesis, 1996)

◆ Huge Background in space

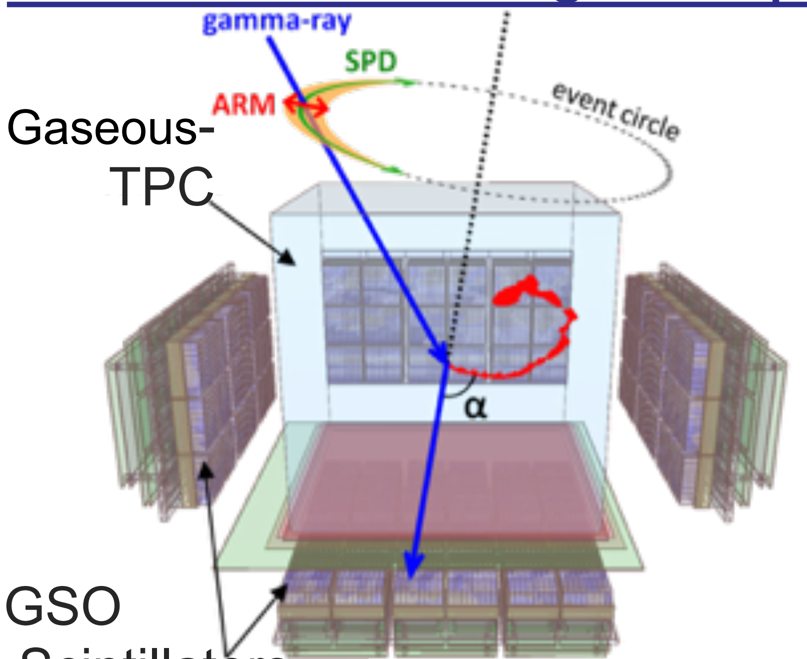
produced by cosmic-ray interactions with detector

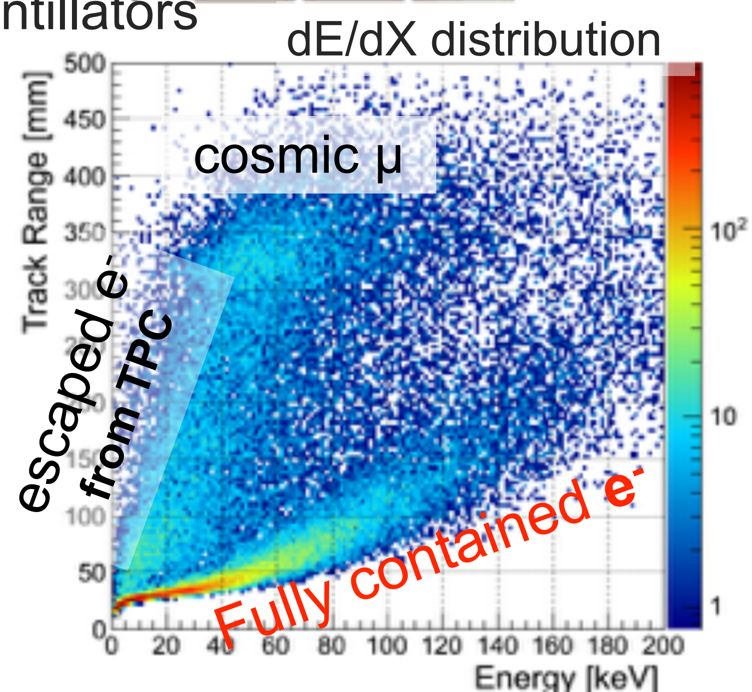
BG rejection in COMPTEL was not sufficient.

⇨ ~ 1/10 of the expected sensitivity

Powerful BG rejection is most important.

Electron-Tracking Compton Camera (ETCC)



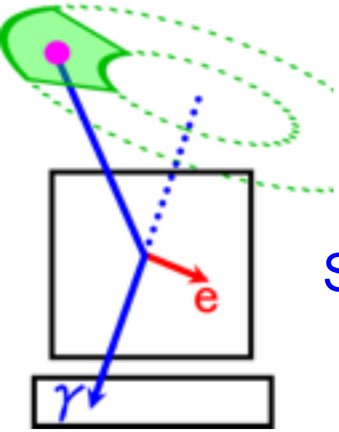


- Gaseous TPC : Tracker
  track and energy
  of a recoil electron
- Scintillator : Absorber
  position and energy
  of a scattered gamma-ray

- Complete Reconstruction event by event
  - 1 photon ⇨ direction + energy
- Particle identification with dE/dX
- Imaging method with direction of the electron

Comparison with the usual Compton method

Electron-Tracking Compton



Using the electron tracks

complete direction within sector form error region

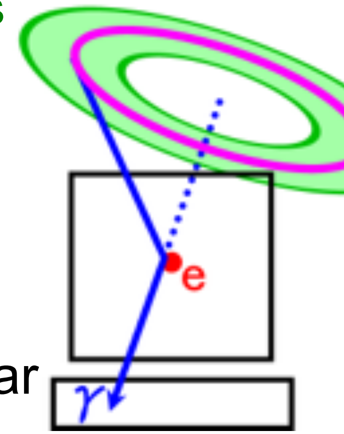
Simply overlay
- High S/N
- No Artifacts

Usual Compton Imaging

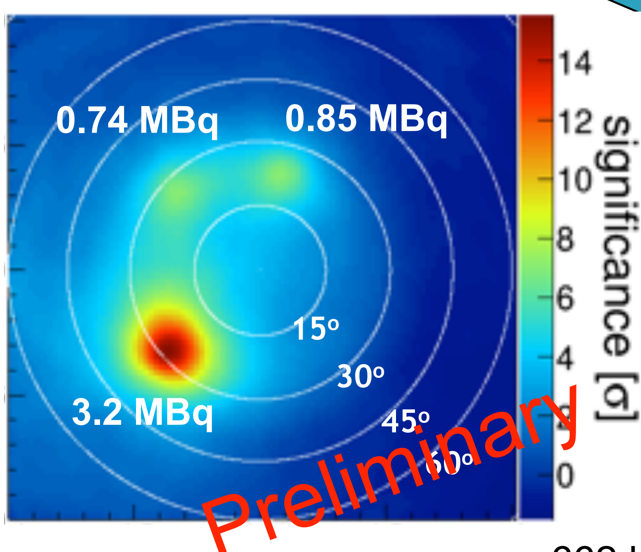
Not using the electron tracks

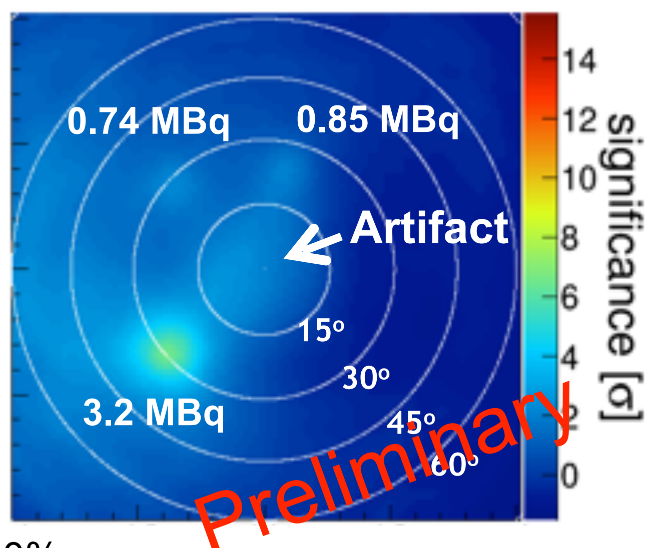
only event circle within ring form error region

Simply overlay
- Low S/N
- Artifacts appear



Images of $^{137}Cs \times 3$ @ 2 m





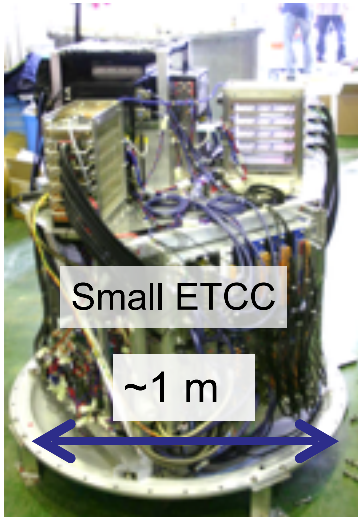
662 keV ± 10%

Electron tracks provide 4 times better S/N than usual Compton imaging !

Balloon Experiment with ETCC (SMILE)

Sub-MeV gamma-ray Imaging Loaded-on-balloon Experiment

SMILE-I @ Japan (2006) 10 x 10 x 15 cm^3 ETCC



Measure diffuse cosmic & atmospheric gamma-ray
0.1 – 1 MeV, @ 35 km, 3 hours

Measured : 420 events
Simulation : ~400 events

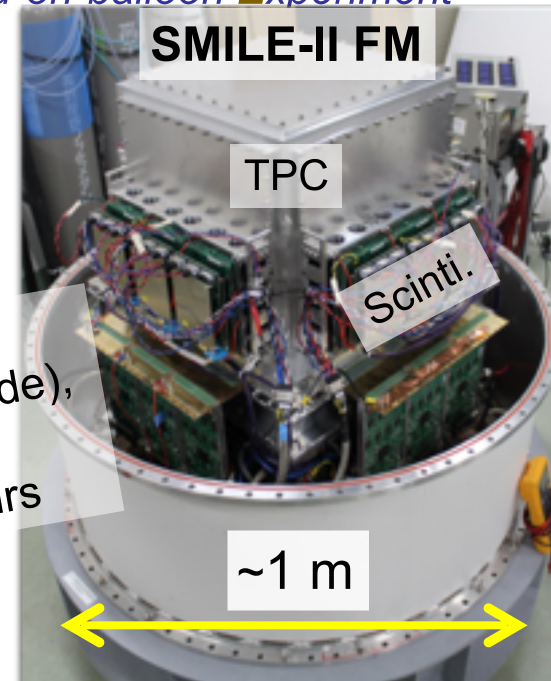
Succeed!!

A. Takada+ (ApJ,2011)

SMILE-II (Next)

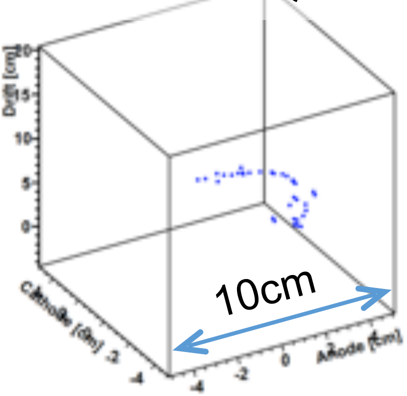
- Gamma-ray Imaging test
- Observation of Crab > 5 σ

Fort Sumner (middle latitude), @ 40 km, several hours



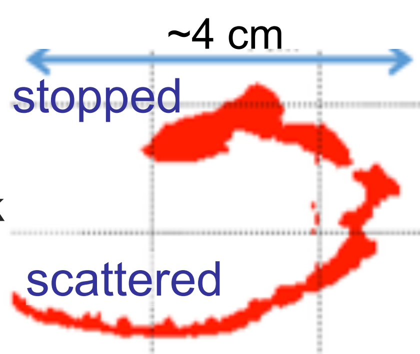
	Requirements	SMILE-I
Effective area @ 300 keV	> 0.5 cm^2	0.01 cm^2
Angular res. @ 662 keV	< 10°	20°

old DAQ



Ex: Electron track

new DAQ



Improvements

✓ Increasing the size of ETCC
- 10 x 10 x 15 cm^3 ⇨ (30 cm)^3

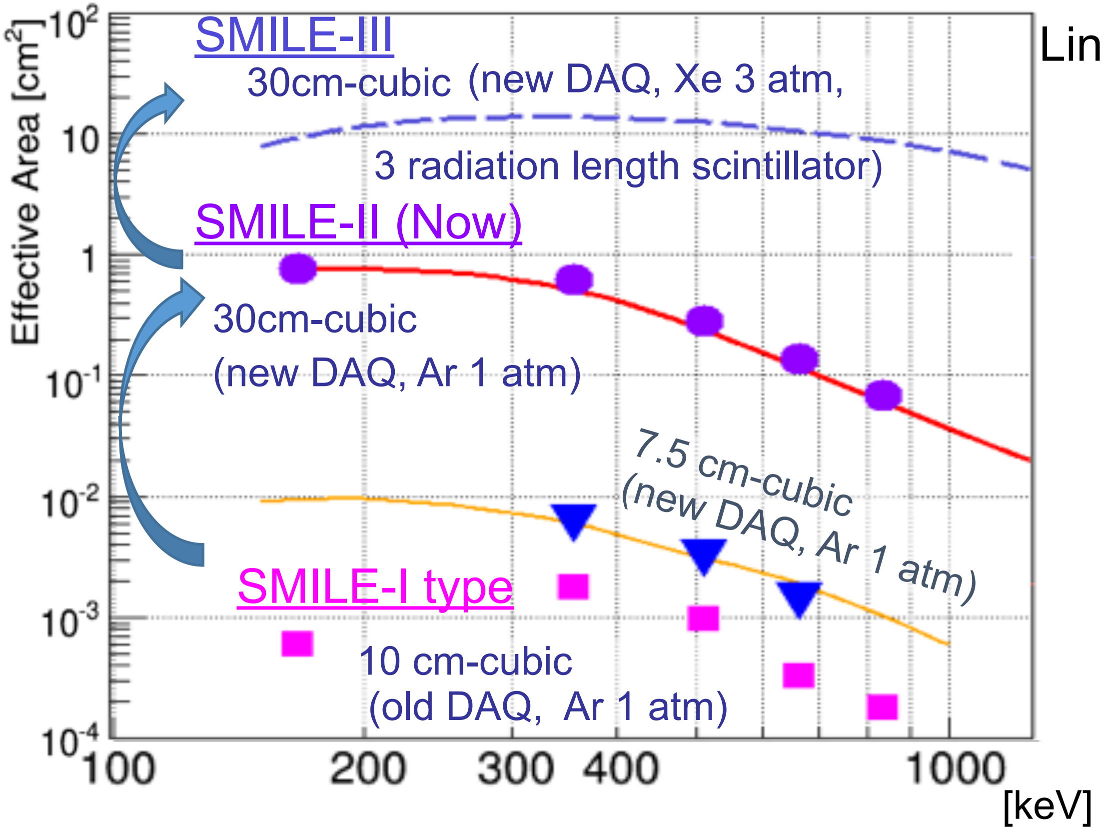
✓ DAQ optimizing for ETCC
- Tracking eff. : ~10% ⇨ ~100%

Performance (Effective area, Angular res.)

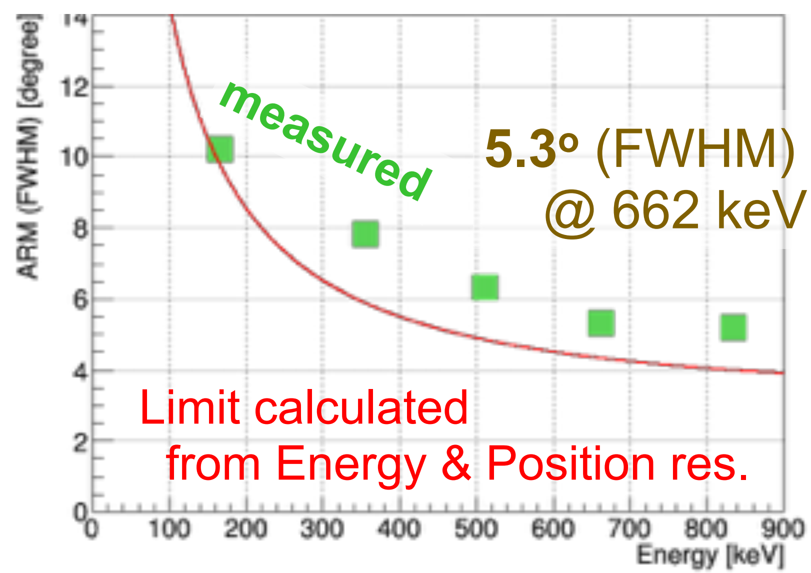
Points: measured
(^{139}Ce, ^{133}Ba, ^{22}Na, ^{137}Cs, ^{54}Mn; 1 MBq @ 2 m)

Lines: simulated
(not including detector response)

◆ Effective area



◆ Angular resolution

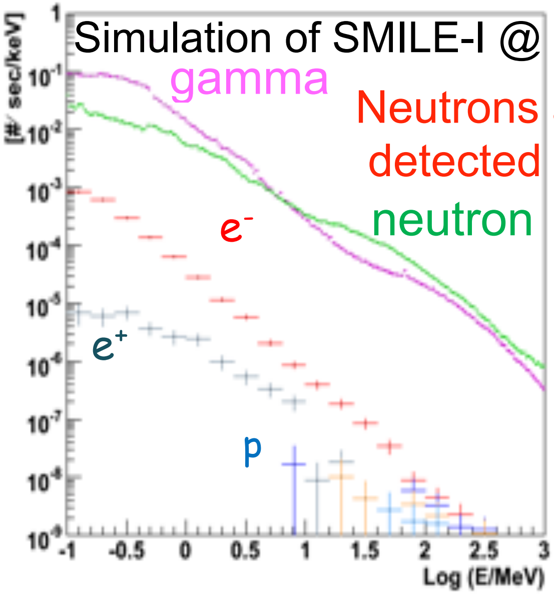


- ✓ SMILE-II ~1 cm^2 @ 300 keV
- ✓ Experiment ≈ Simulation
  => ETCC obtains ~100 % of Compton events.
- ✓ We will upgrade to SMILE-III ~10 cm^2

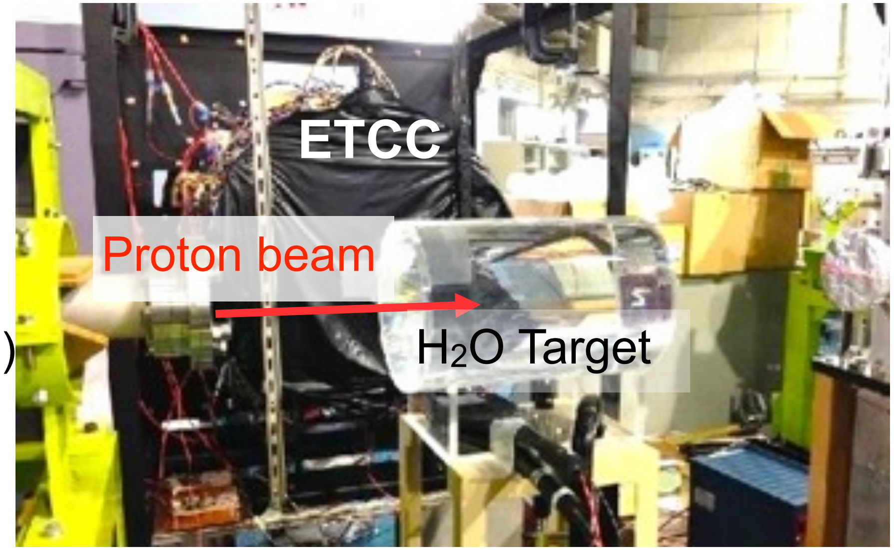
Satisfied the requirements for Crab detection.

Experiment with proton beam @RCNP

Research Center for Nuclear Physics, Osaka Univ.



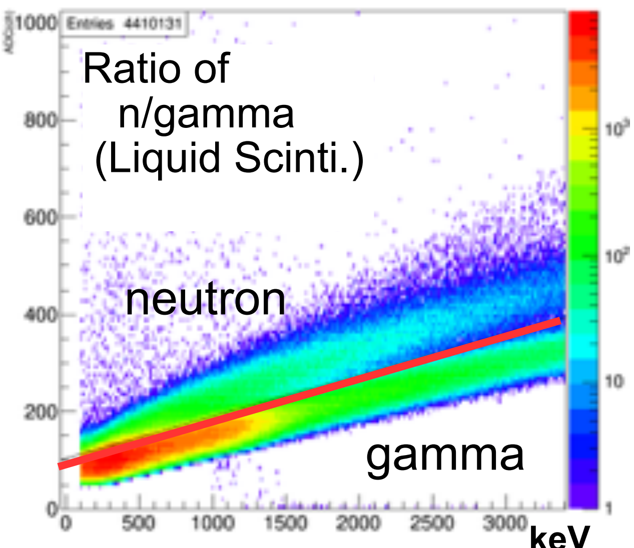
Neutrons are detected similar to Compton-γ

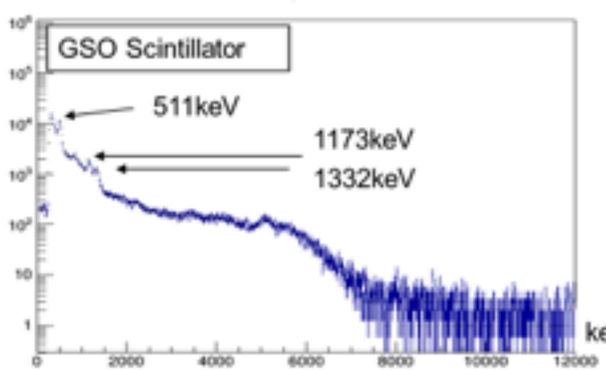


DAQ Rate

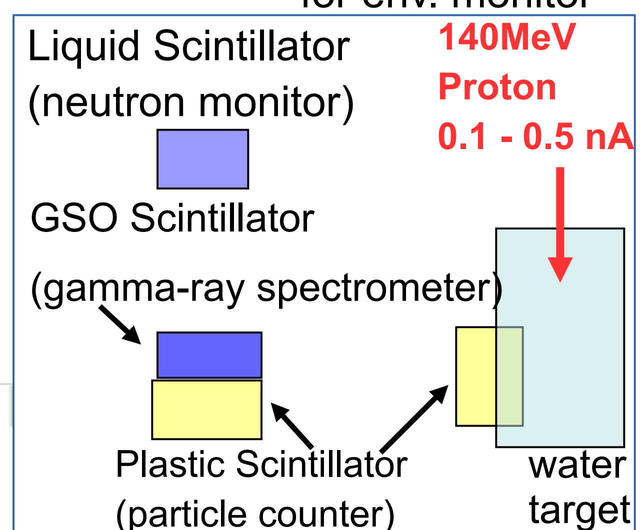
✓ SMILE-II (expected)
100 - 400 Hz

✓ @RCNP
300 - 1000 Hz





Extra detectors for env. monitor

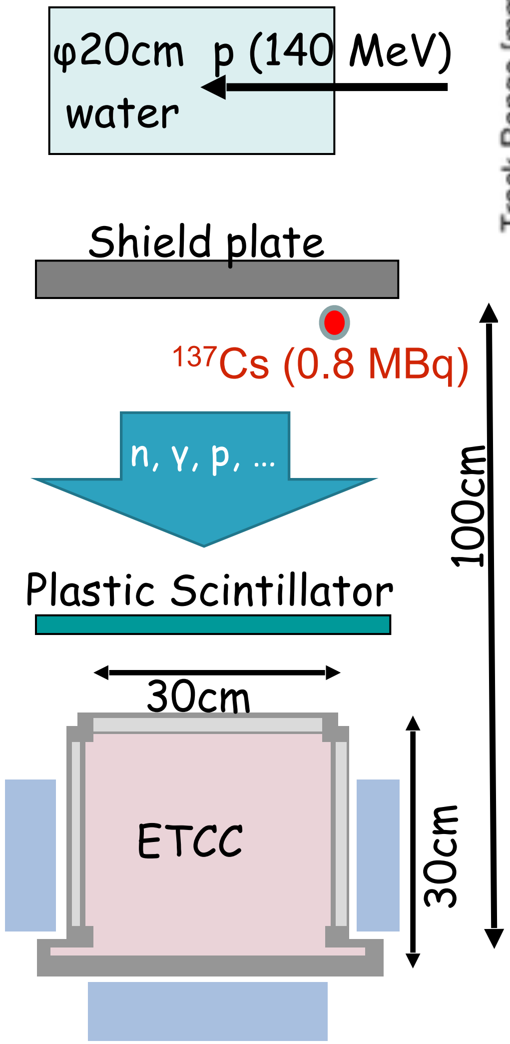


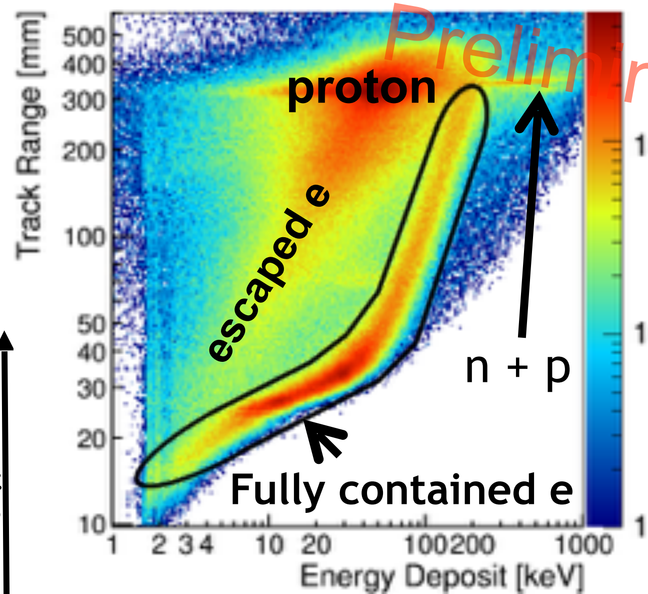
⇨ n/γ ~ 1/3 @ETCC

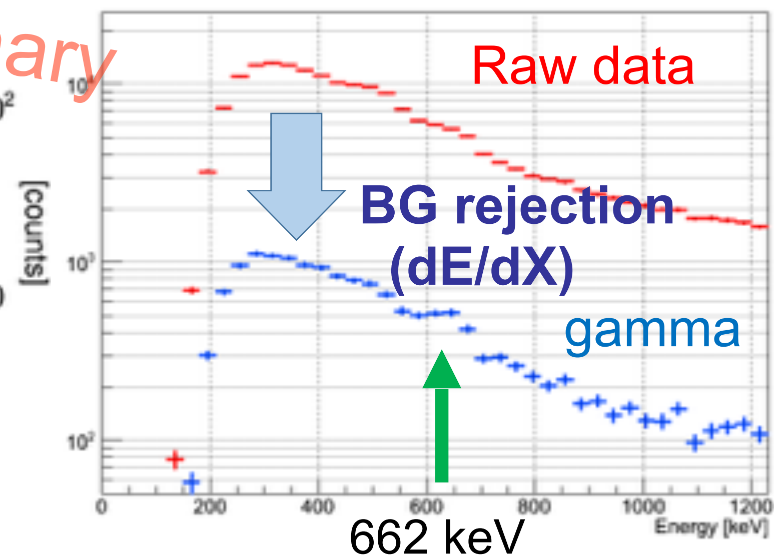
- Similar to background at balloon altitude
- Intensity ~ 5 x balloon altitude

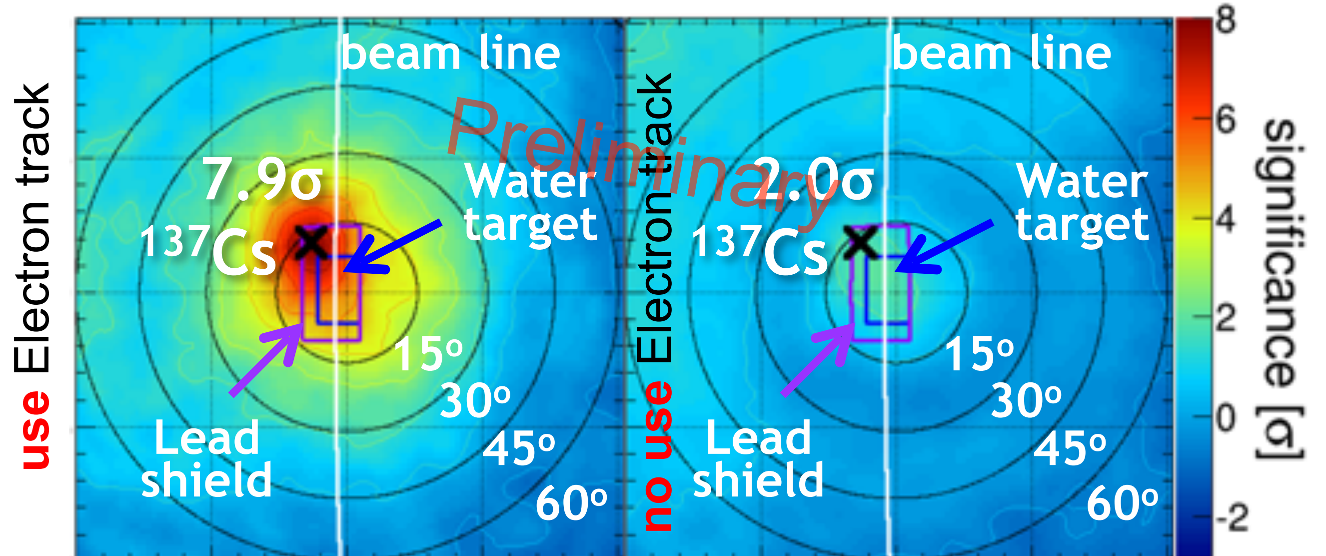
Confirmation of background rejection power

- Imaging of ^{137}Cs(662 keV)





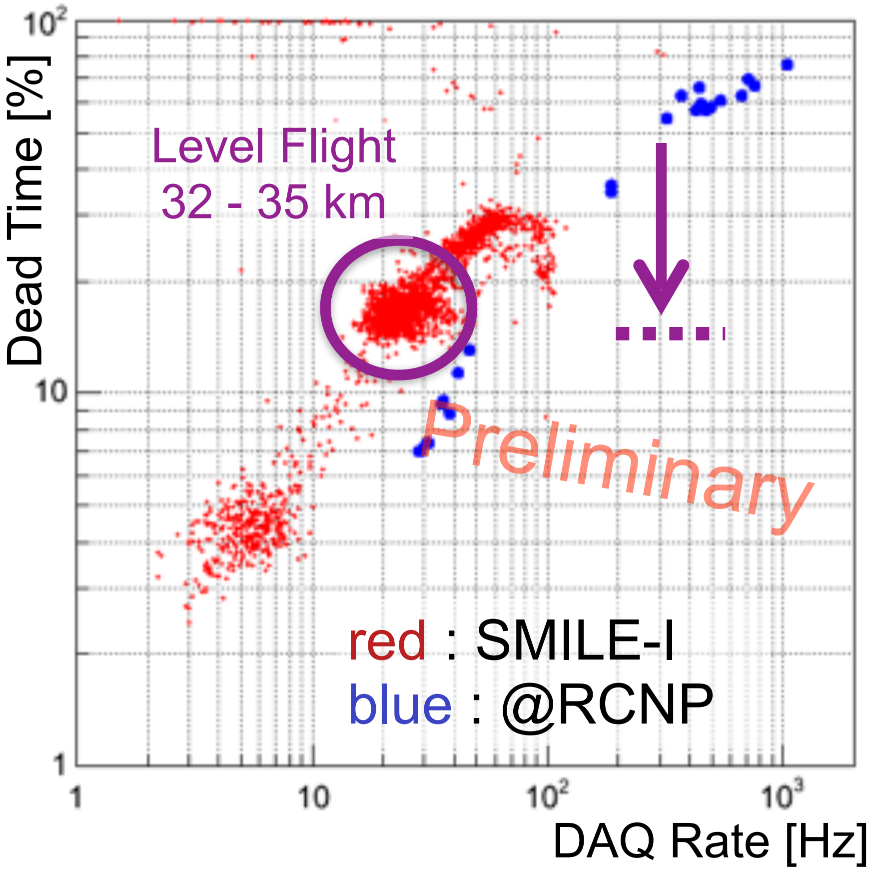




DAQ rate ~ 400 Hz

With dE/dX selection, BG events are rejected.

DAQ (Data acquisition) rate



◆ DAQ Rate

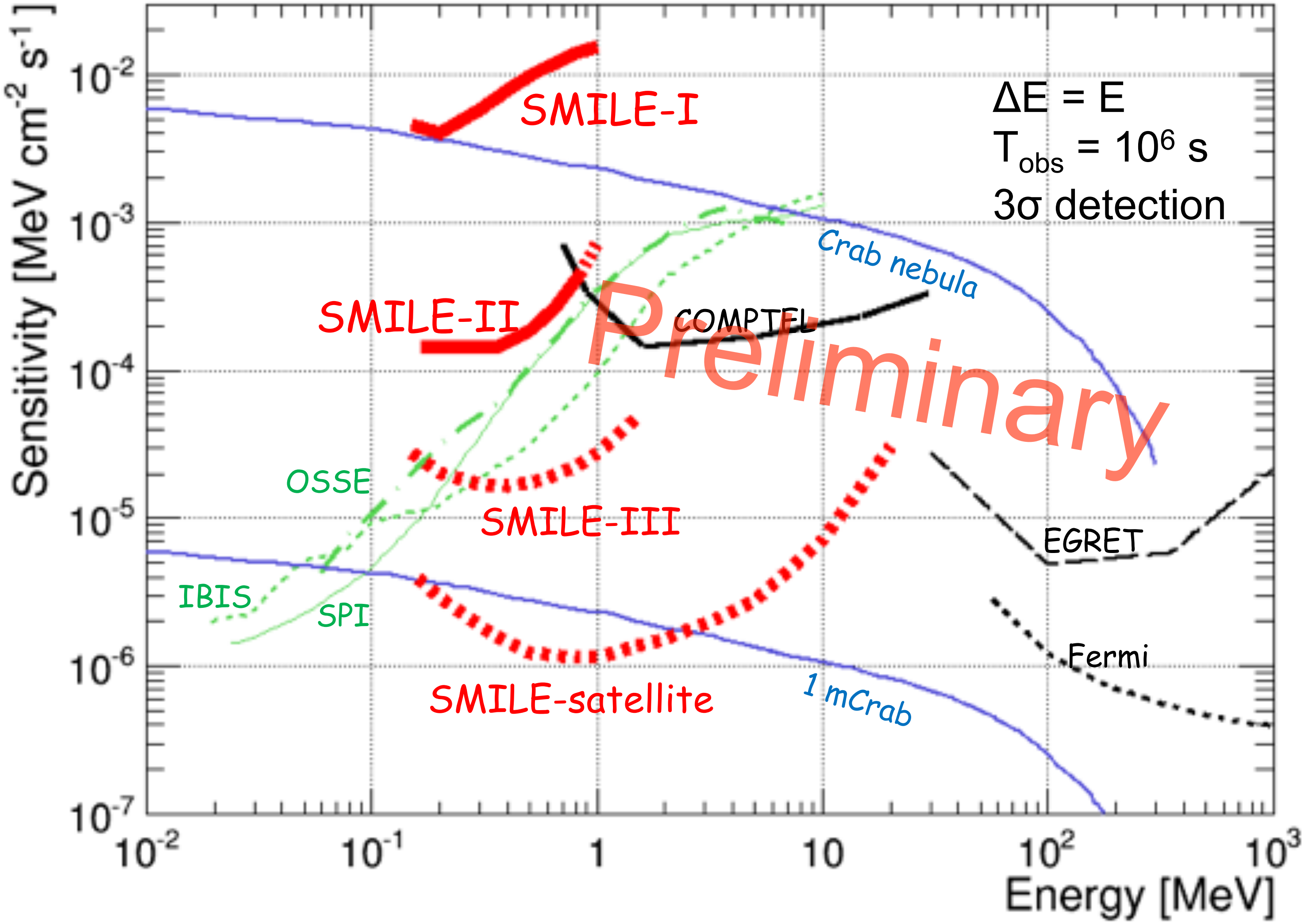
SMILE-I (32-35 km)	*10 - 40 Hz*
SMILE-II (expected)	*100 - 400 Hz*
@RCNP	*300 - 1000 Hz*
Data Trans. Limit	*< 1000 Hz*

DAQ Improvements

- ✓ Speed up the Data transfer rate
  - DAQ CPU upgrade x 2
- ✓ Reduction of the Data
  - Selection and compression x 2 - 3

Dead-Time can be reduced to < 20 % @ ~ 400 Hz

Detection sensitivity



SMILE-II : detectable Crab nebula with several hours at 40 km

SMILE-III : Xe, 3 atm and 2-3 Radiation length GSO -> 10 times better sensitivity

Satellite : (50 cm-cube, Xe 3 atm, 10 Rad. Len. $LaBr_3$)×4 -> reach to 1 mCrab

Summary

- ETCC has
  - High contrast imaging
  - Powerful background rejection with electron-track and dE/dX selection

- SMILE-II ETCC has

  Effective Area ~ 1 cm^2 @ 300 keV

  Angular Resolution 5.3° @ 662 keV

  ✓ satisfied the requirements for Crab detection

  (Fort Sumner @ middle latitude, several hours at 40 km)

- Experiment with Proton Beam

  Intense radiations are available (5 times than balloon altitude)

  ETCC can clearly separate Compton-electron from neutrons

  ✓ ETCC maintains its sensitivity in high background

Thank you for your attention!