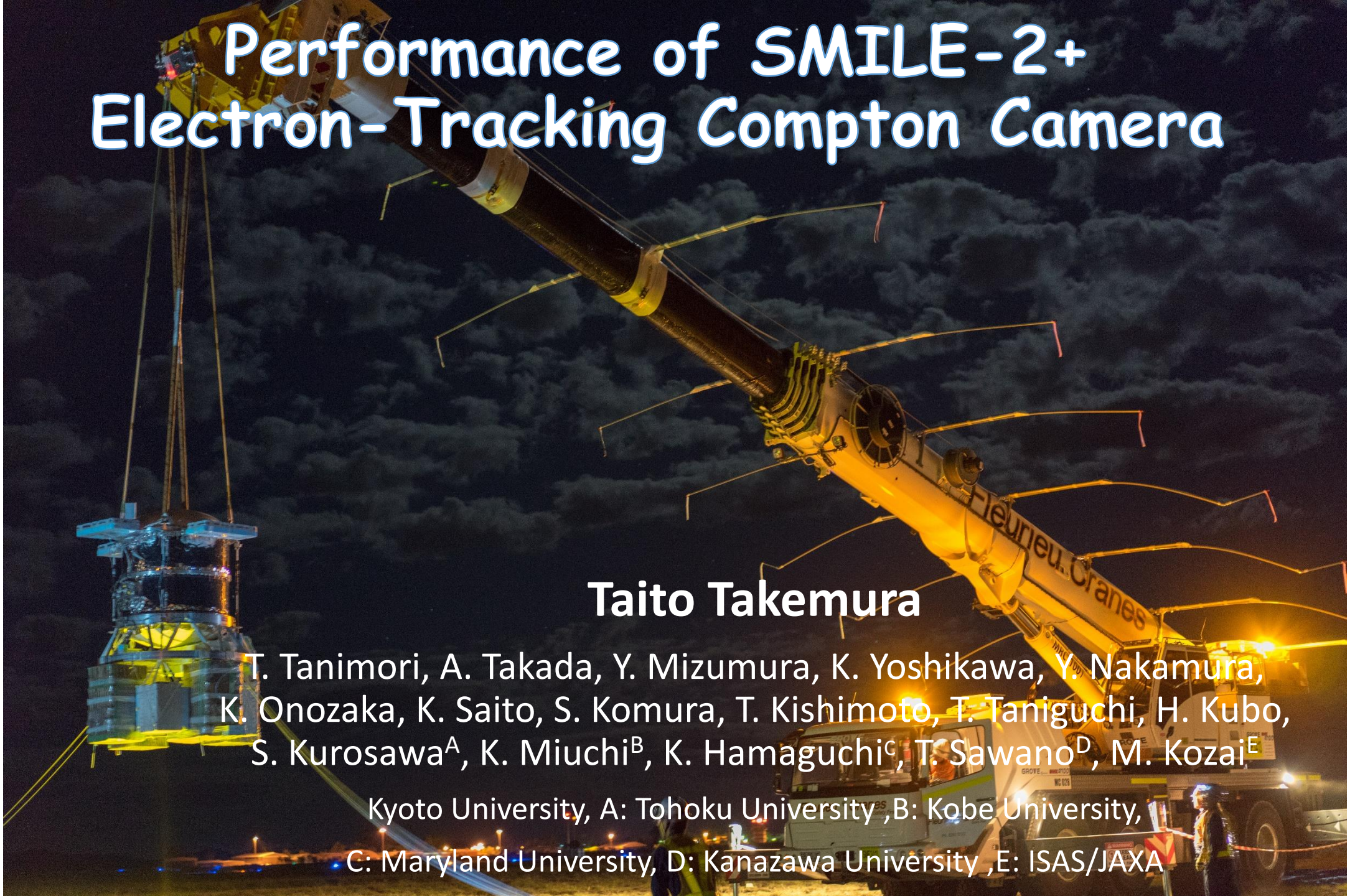
Performance of SMILE-2+ Electron-Tracking Compton Camera



Taito Takemura

T. Tanimori, A. Takada, Y. Mizumura, K. Yoshikawa, Y. Nakamura, K. Onozaka, K. Saito, S. Komura, T. Kishimoto, T. Taniguchi, H. Kubo, S. Kurosawa[A], K. Miuchi[B], K. Hamaguchi[C], T. Sawano[D], M. Kozai[E]

Kyoto University, A: Tohoku University ,B: Kobe University,

C: Maryland University, D: Kanazawa University ,E: ISAS/JAXA

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MeV gamma-ray Astronomy

Nucleosynthesis

SNR (Radio-isotopes)

Galactic Plane (^{26}Al, ^{60}Fe, and annihilation)

Particle Acceleration

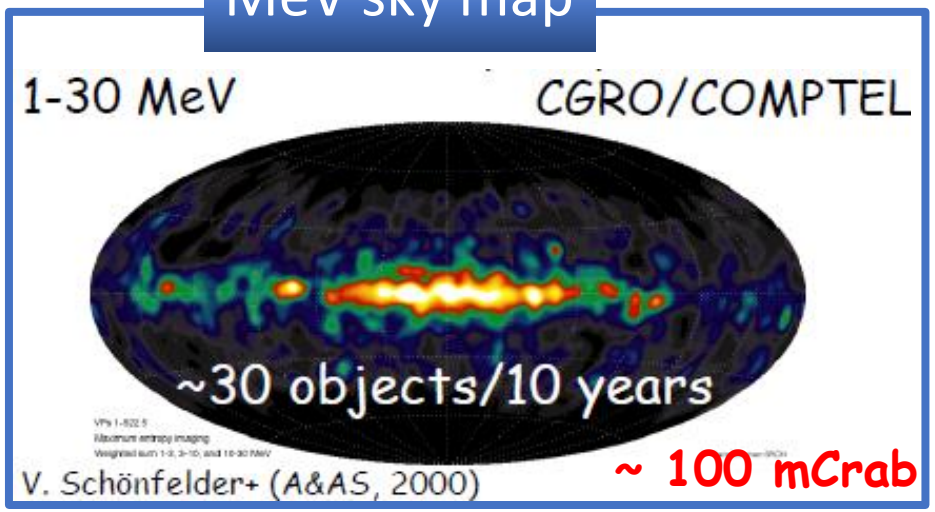
Jets in AGN, GRB (Synchrotron radiation and Inverse Compton)

SNR (π^0-decay and Inverse Compton)

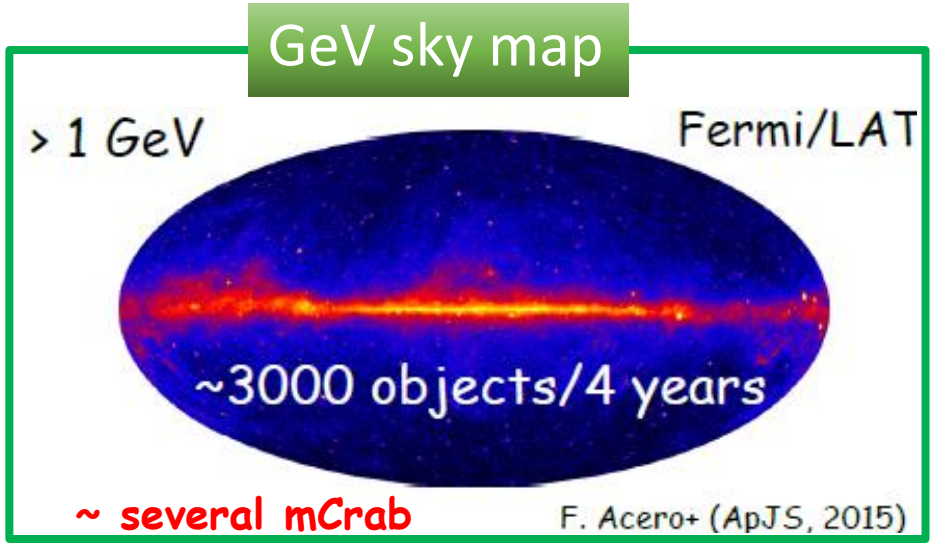
Early universe

GRB of first stars

MeV sky map



GeV sky map



Requirements for the next-generation observation are

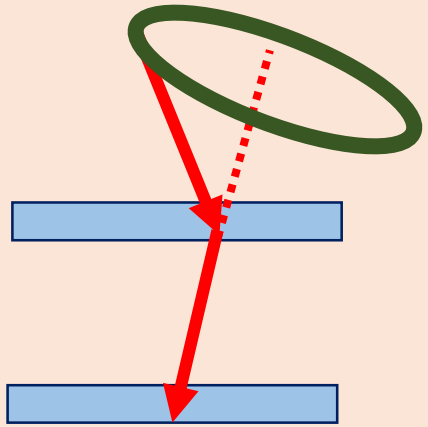
- Wide-band detection
- Large Field of View
- High quality image

Problem and Answer of difficulties

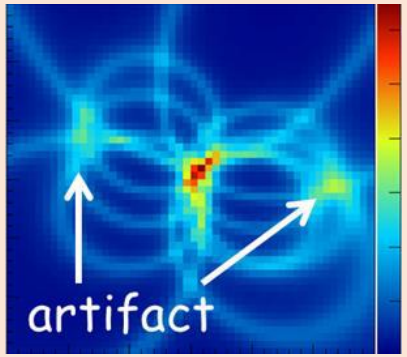
◆Incomplete Reconstruction

Compton Camera loses electron track

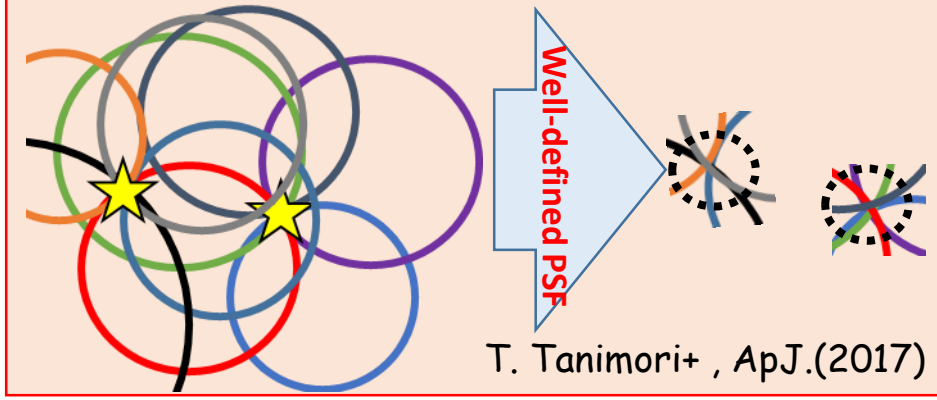
event circle



Imaging by superposition of event circles



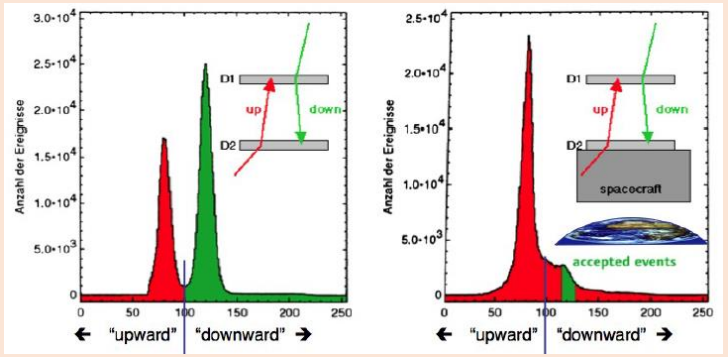
Answer: measure electron track



T. Tanimori+ , ApJ.(2017)

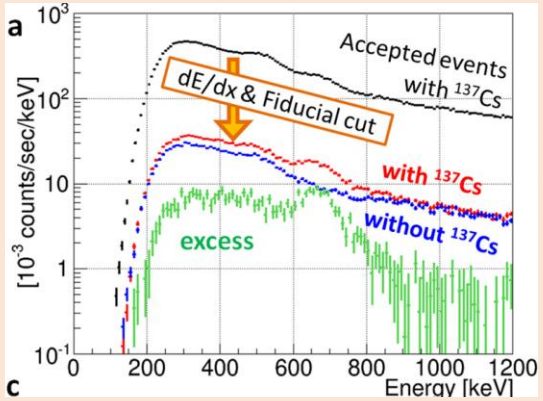
◆Huge Background

The TOF distribution of **COMPTEL** (left) on the ground (right) in low earth orbit



Peter von Ballmons+ (2014)

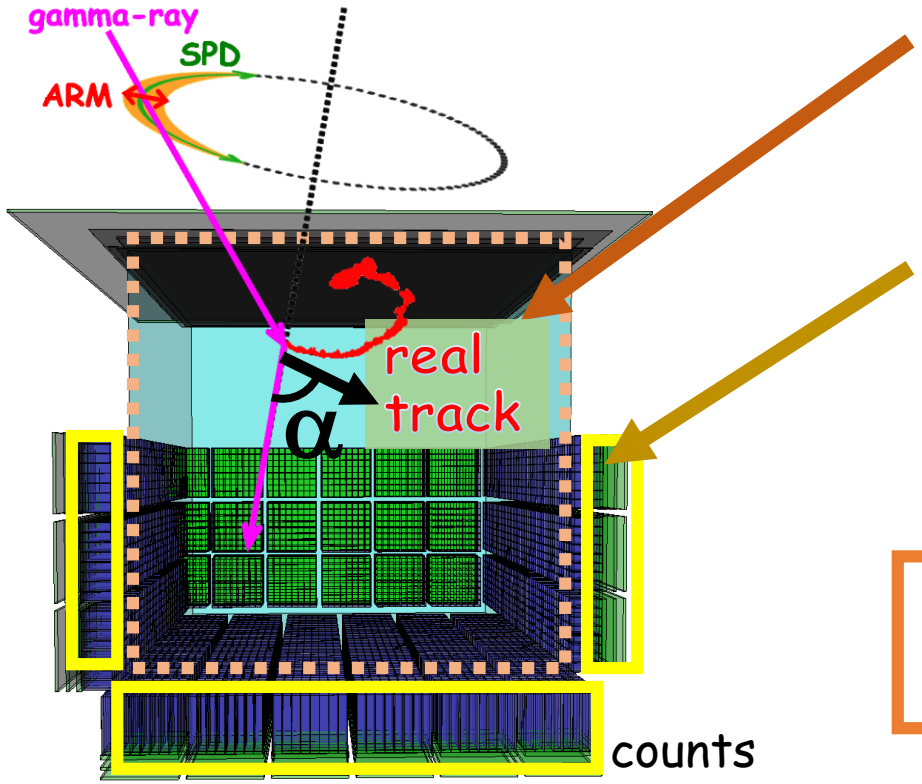
Answer: particle identification

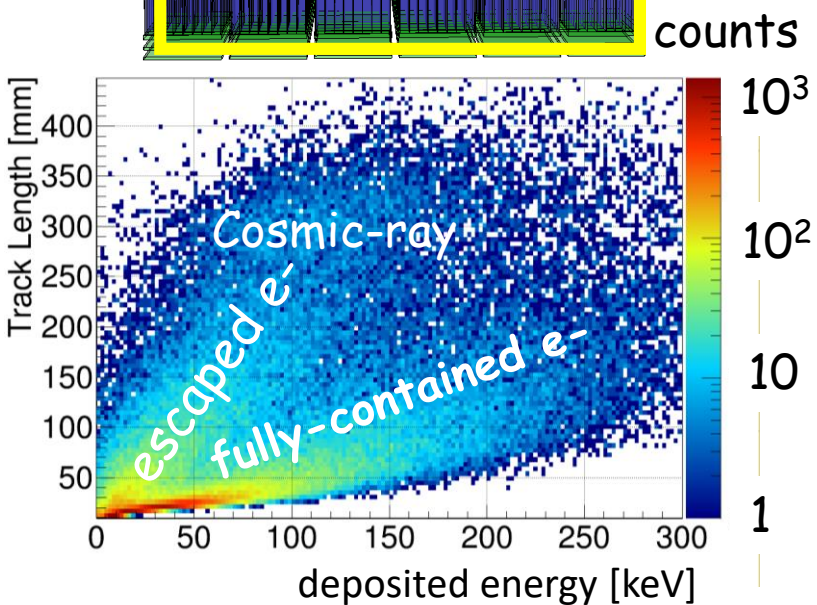


T. Tanimori+ , ApJ.(2015)

Well-defined Point Spread Function (PSF) and Low BG are necessary for MeV gamma-ray telescope

Electron-Tracking Compton Camera (ETCC)





- **Gaseous Time Projection Chamber**

  Tracker: 3-D track and energy of electrons

  2D imaging (x,y) + Drift Time (z) =>3D

- **Pixel Scintillator Arrays**

  Absorber: absorption position and energy of scattered gamma-ray

Reconstruct Compton scattering event by event completely

- Back ground rejection
  - Two-Dimensional PSF
  - Particle identify with $dE/dX = \frac{\text{deposited energy}}{\text{track length}}$
  - Compton Kinematical test with α
- Without heavy VETO
- Large FOV (~ 3 str)

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

SMILE-I @ Sanriku (Sep. 1st 2006)

- We obtained diffuse cosmic/atmospheric gamma-ray spectra
- Success in rejection with dE/dX — A. Takada+. ApJ,2011

SMILE-2: Only ground test — T. Tanimori+. ApJ,2015

SMILE-2+ 1-day flight @ Alice Springs (Apr. 7th 2018)

- Certification of imaging spectroscopy in MeV Astrophysics
- observation of bright objects (Crab & Galactic Center)

NOW!!

Requirement (detect 5σ)

Effective area: a few cm^2

PSF (50% included) radius: ~ 10 deg @ 662 keV

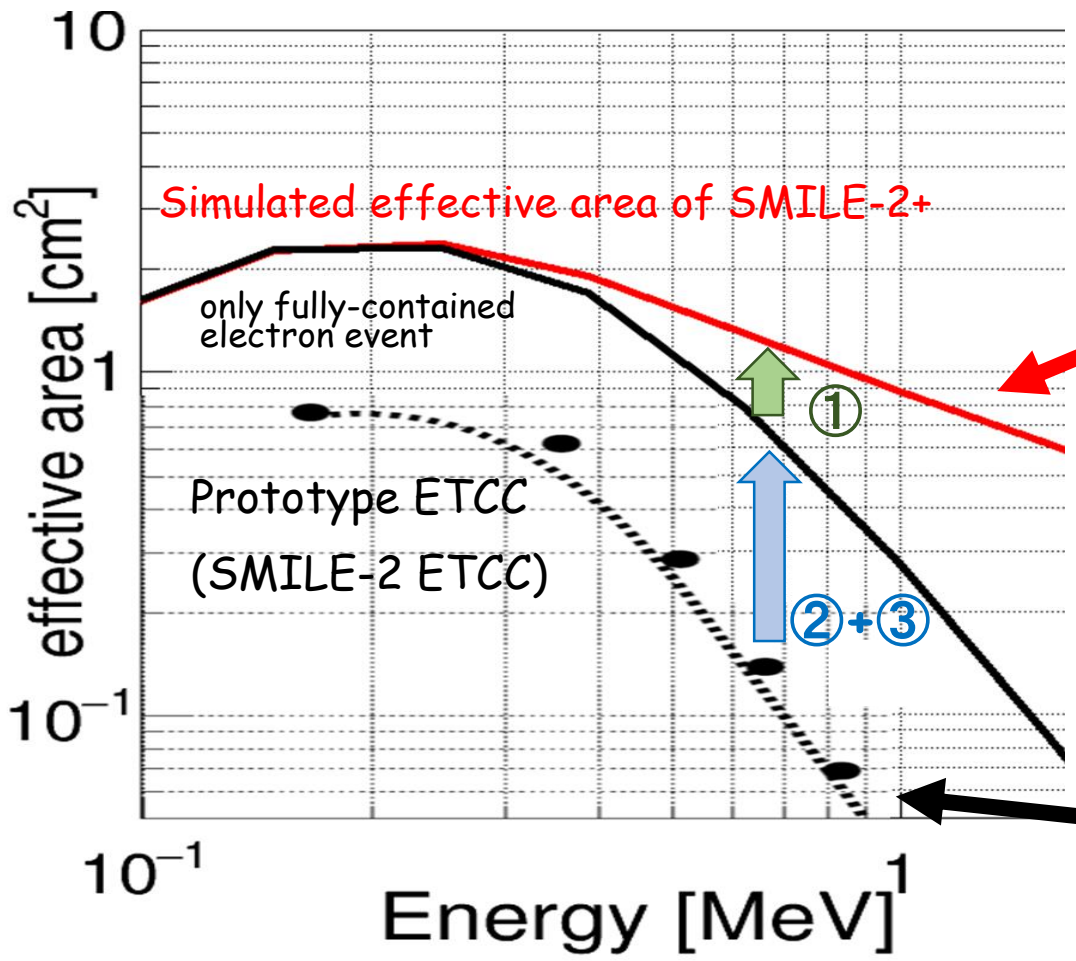
SMILE-3

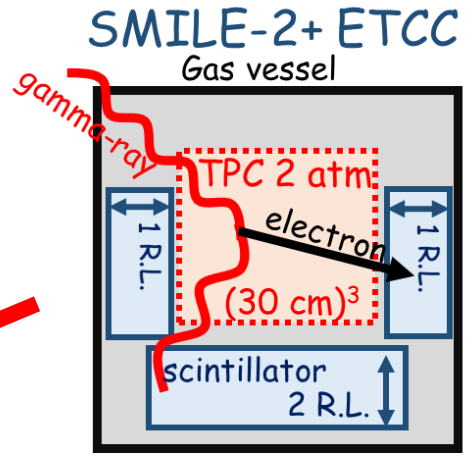
- Scientific observation loaded on a long duration balloon several time with better sensitivities of COMPTEL

All sky survey with an ETCC loaded on a satellite

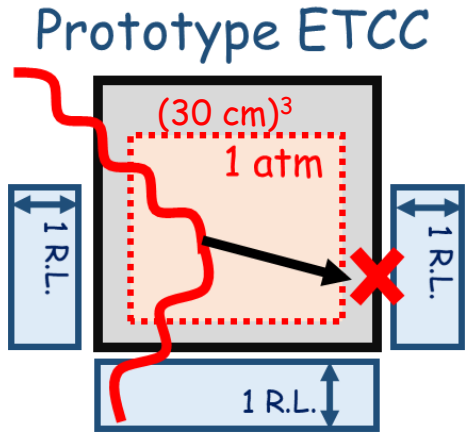
~ sub-mCrab sensitivity

To improve effective area of SMILE-2+





SMILE-2+ ETCC and prototype ETCC are the same at the points of the size of TPC and the number of scintillators



T. Tanimori+ , ApJ.(2015)

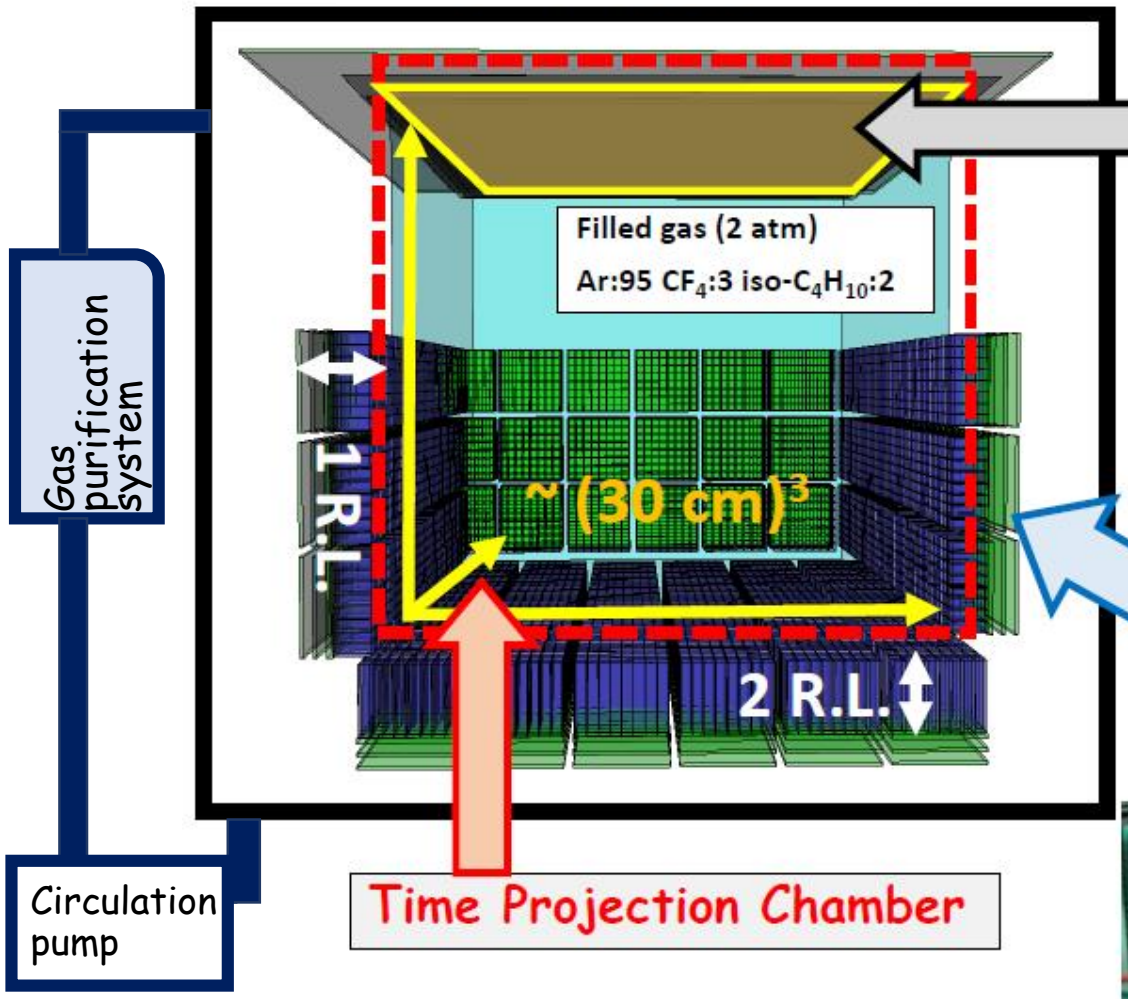
① Positioning scintillators inside the gas vessel to measure high energy electron escaping from TPC

② Addition of scintillator length (Bottom 1 R.L.=> 2 R.L.)

③ Addition of gas pressure (Ar 1 atm => Ar 2atm)

SMILE-2+ ETCC

sealed gas vessel

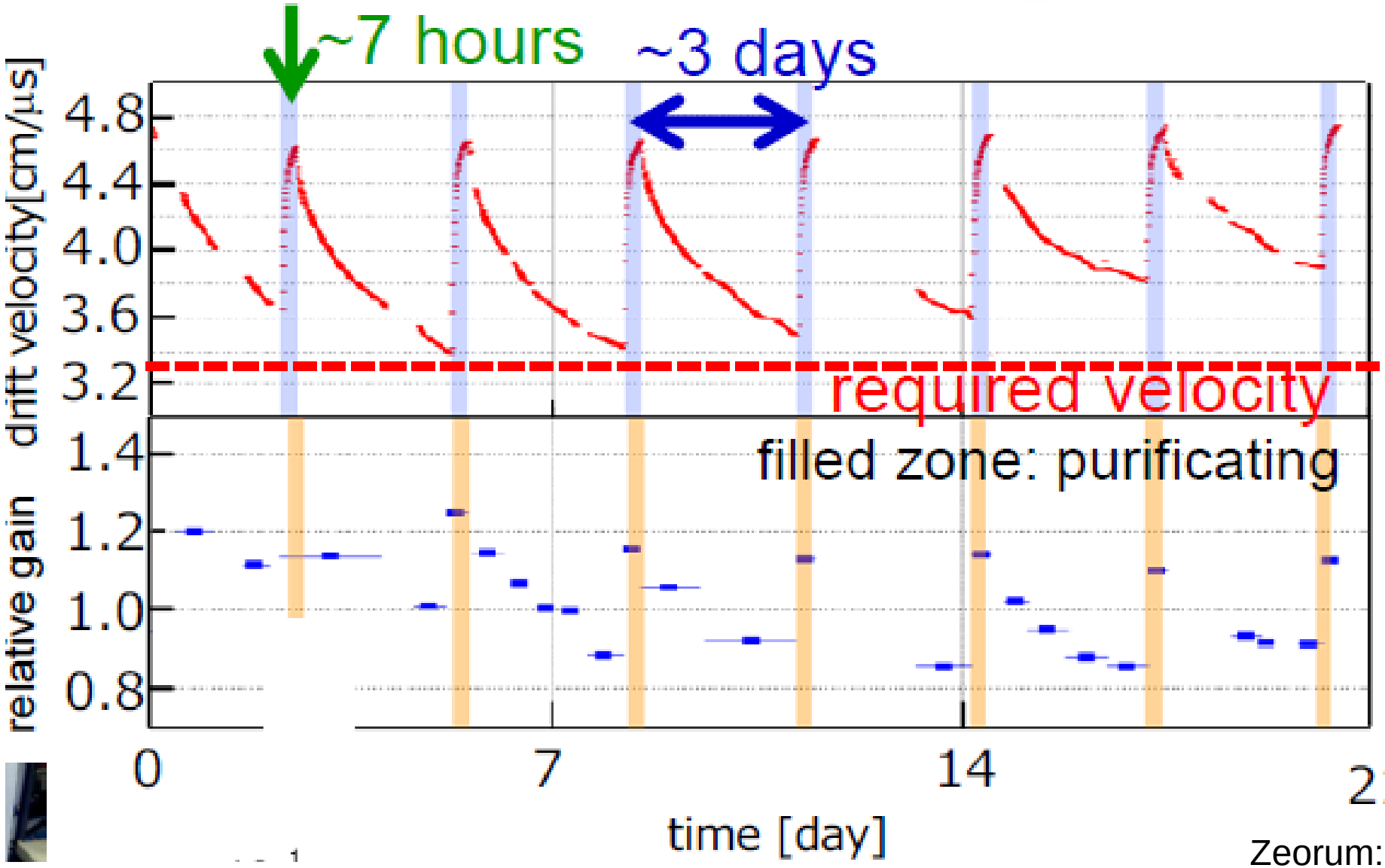


Many materials such as scintillator is in gas vessel

outgas is a serious problem

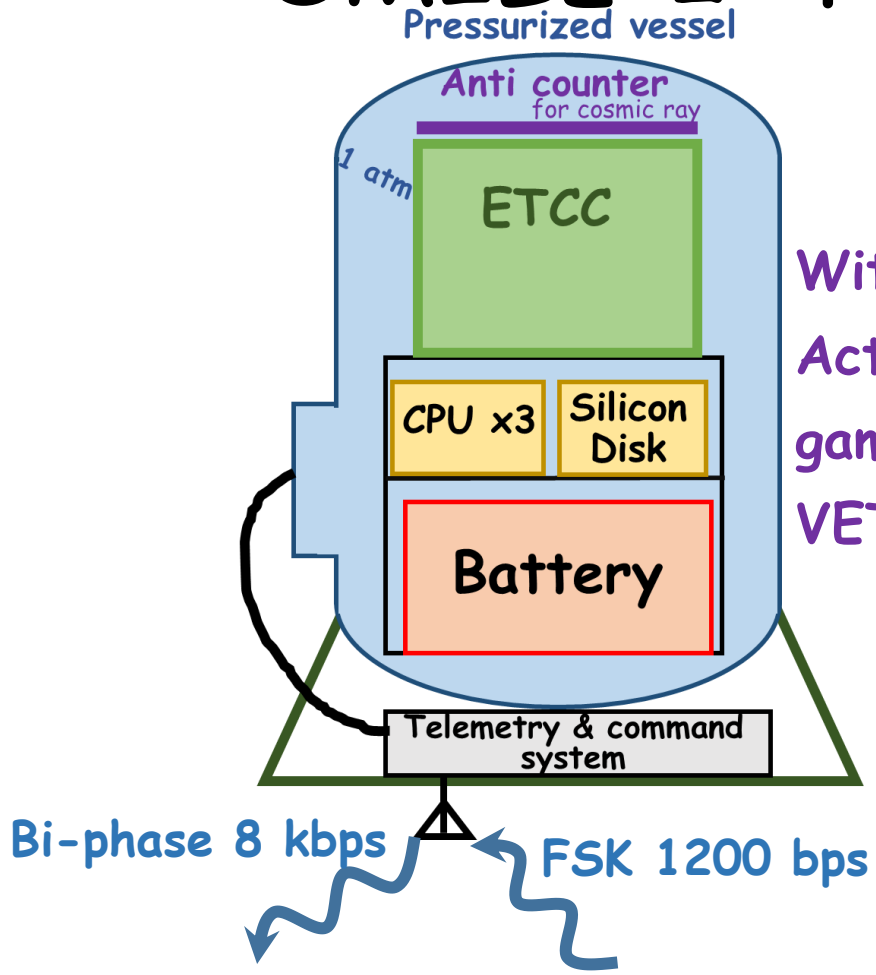
SMILE-2+ ETCC equipped with gas purification system

Gas purification system

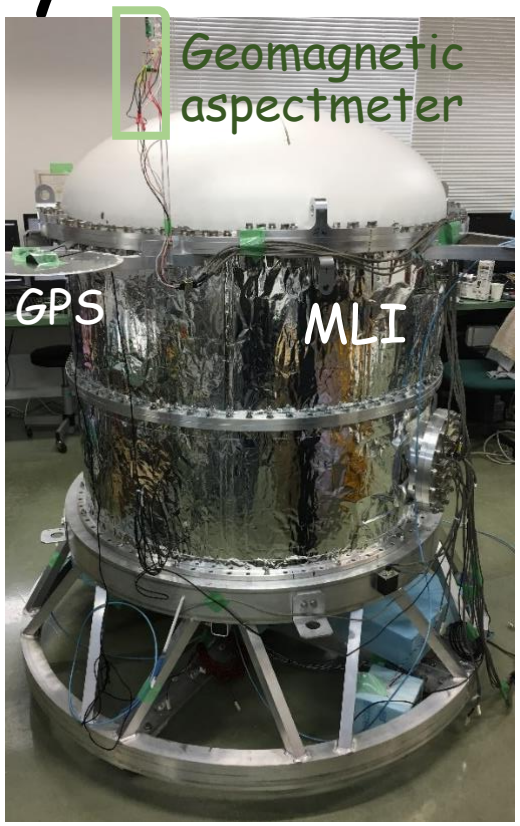


Zeorum: $(AlO_2)_x \cdot (SiO_2)_y$
used as a molecular sieve

SMILE-2+ Flight System



Without Active gamma-ray VETO



➢Battery

Power: ~490 Ah

Power consumption:~214 W

The capabilities of operation ~32 h

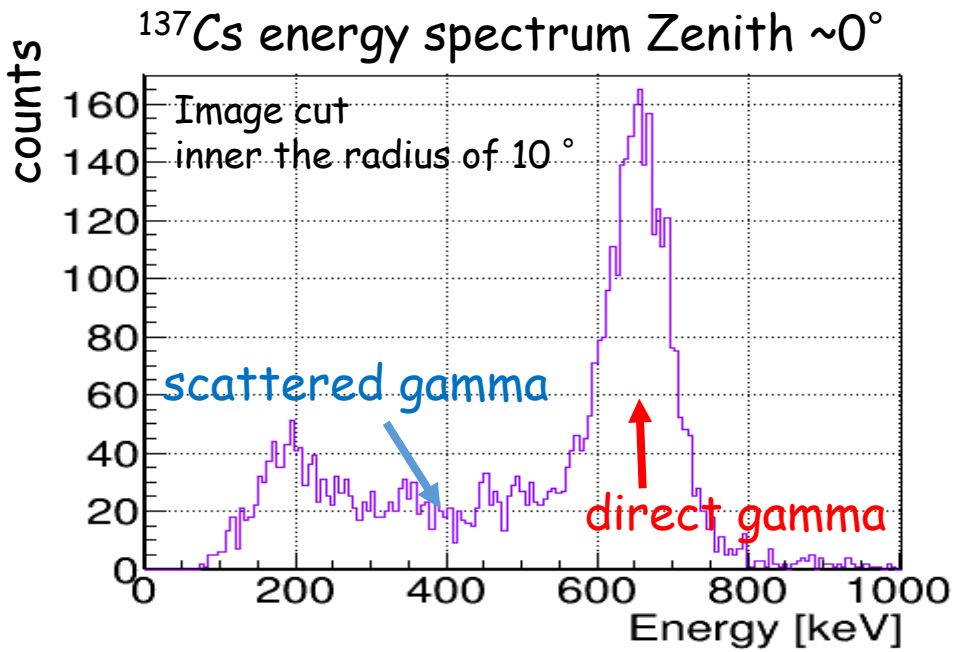
➢Attitude sensor

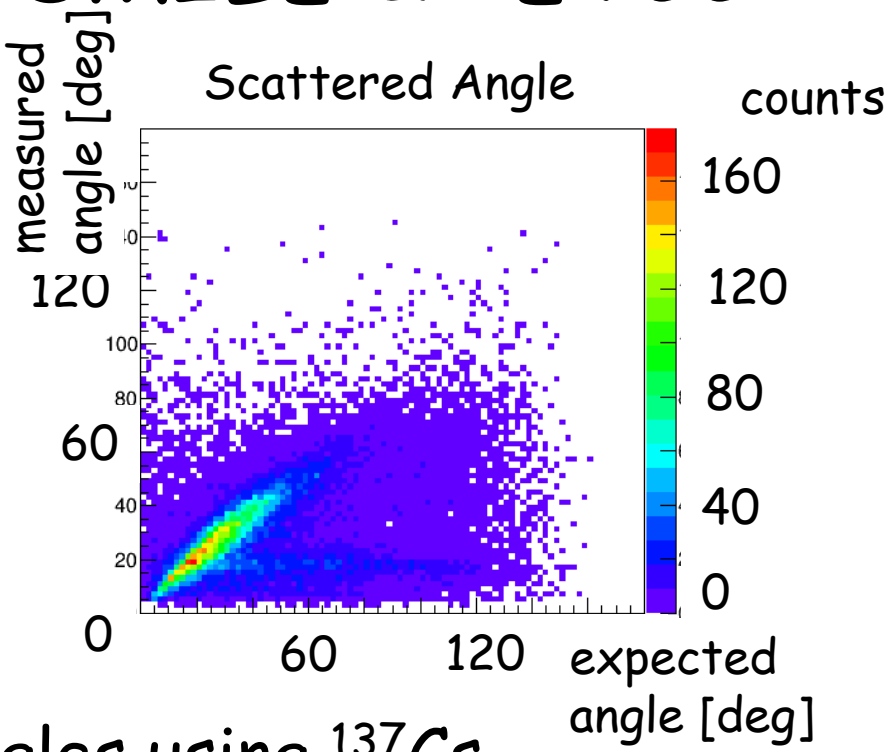
GPS: position and time

Clinometer x2: zenith angle

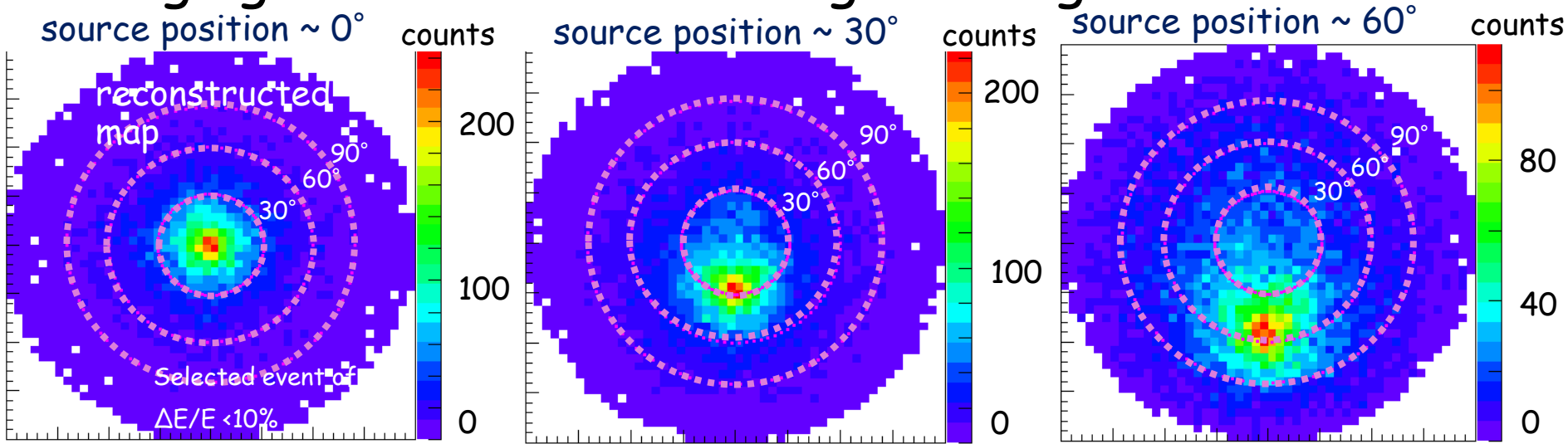
Geomagnetic aspectmeter x3 : azimuth & zenith angle

Ground Calibration of SMILE-2+ ETCC

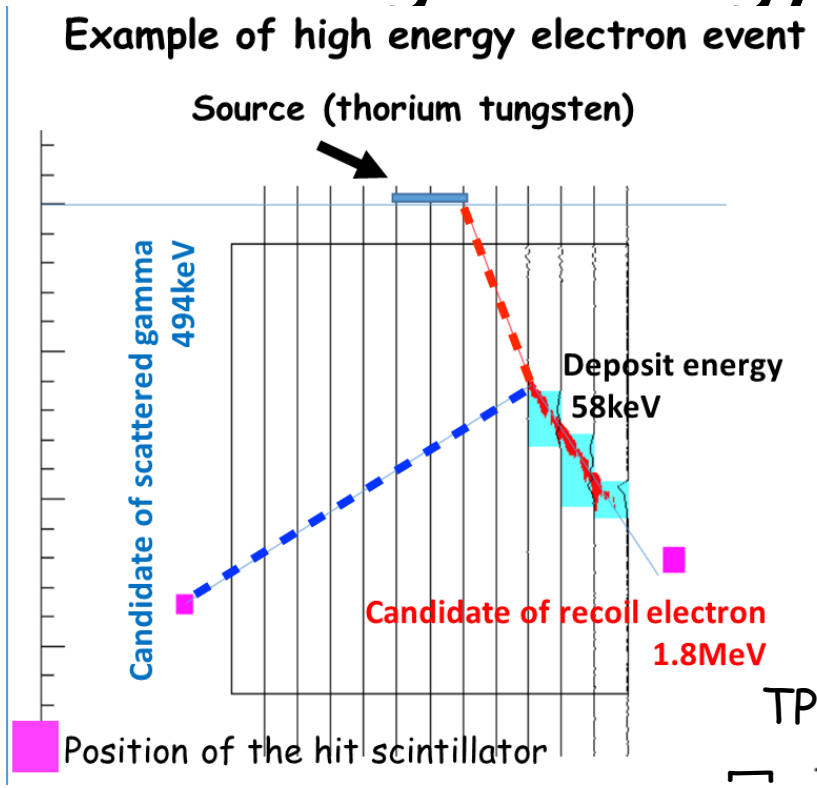




Imaging check for various angles using ^{137}Cs



High Energy Electron Event



Example of the event of electron absorbed by scintillator

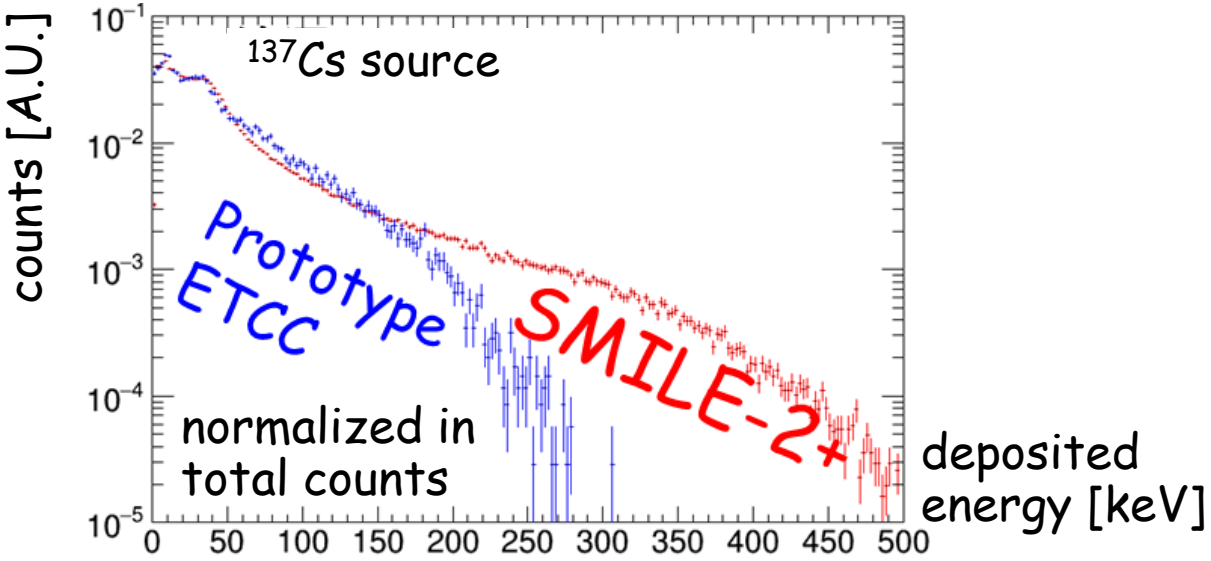
- Reconstructed position agreed with source position
- α value (angle between scattered gamma-ray & recoil electron)

Compton kinematics α_{kin}

geometry α_{geo}

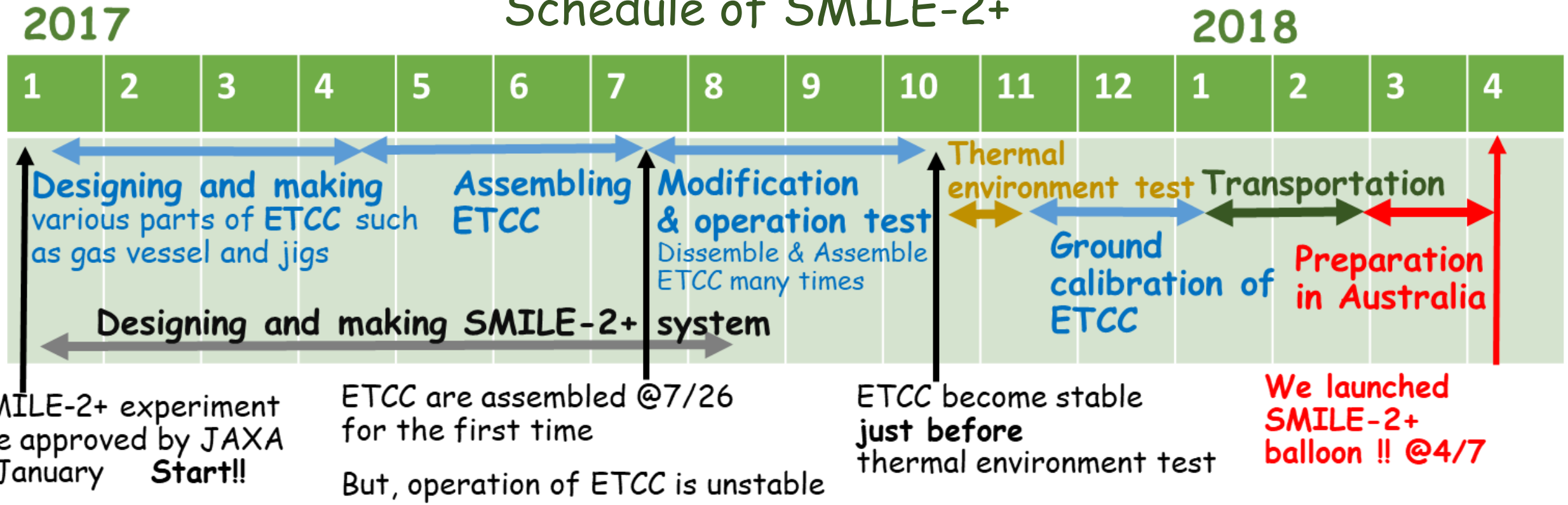
$\triangle\alpha = 0.9°$ good consistency

TPC spectrum of electrons fully contained



Summary

Schedule of SMILE-2+



- Next generation require BG rejection & Well defined PSF
- We are developing ETCC to meet the requirements
- We developed SMILE-2+ as hard as possible

to make shift with launching balloon

Now we are doing best to analyze the data of ground test and flight data

Summ

This schedule was very busy
we were doing our best for one year !!

- Next generation require BG rejection & Well defined PSF
- We are developing ETCC to meet the requirements
- We developed SMILE-2+ as hard as possible

to make shift with launching balloon

Now we are doing best to analyze the data of ground test and flight data