



Observation of Diffuse Gamma-Ray with Electron-Tracking Compton Imaging Camera Loaded on Balloon

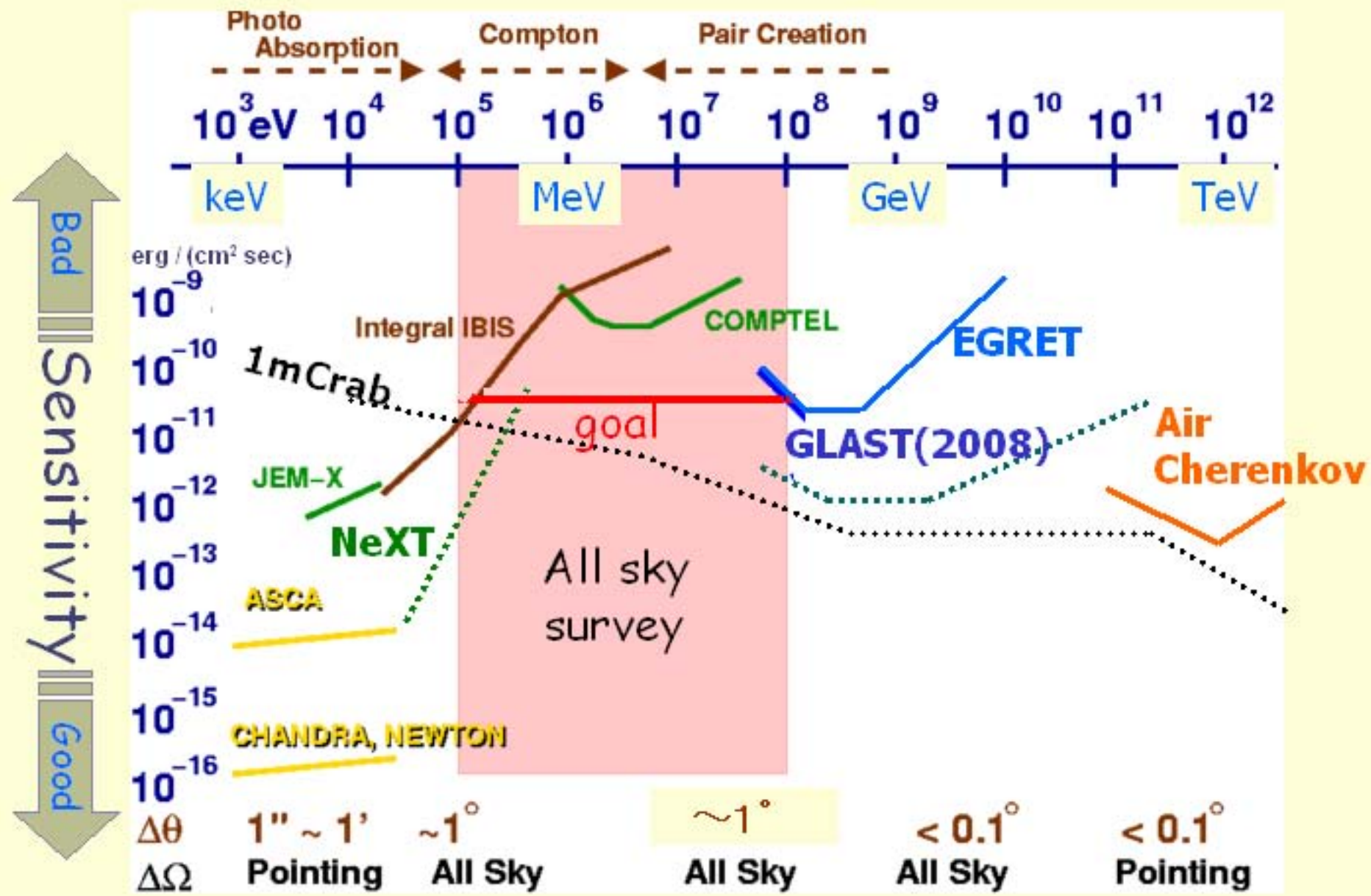
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- Electron-Tracking Compton Camera
- Flight Model Detector
- Balloon Experiment & Results
- Summary

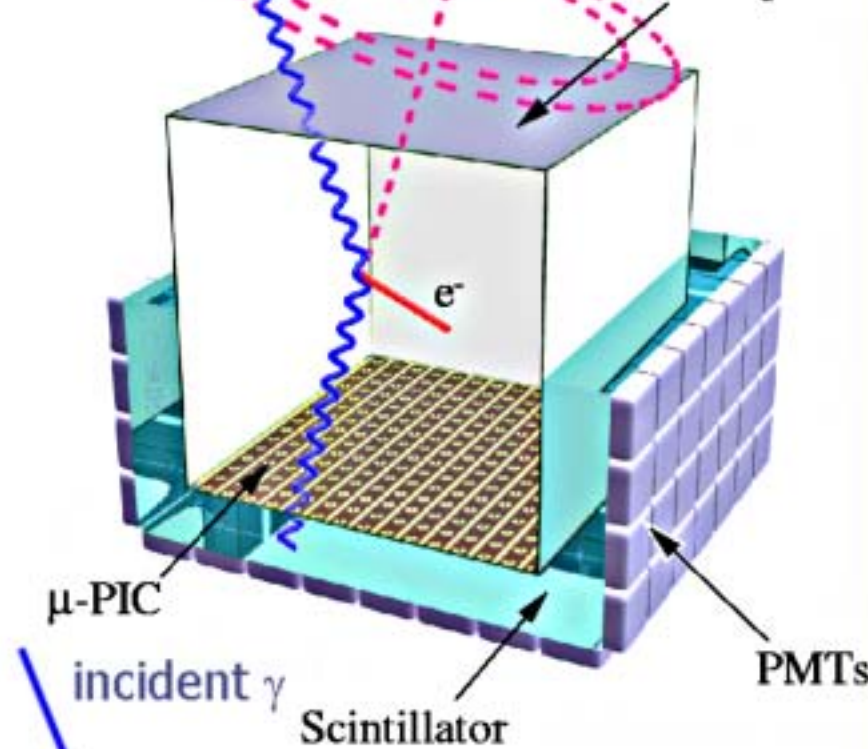


Sensitivity of X/Gamma-ray observations



Electron-Tracking Compton Imaging

MeV γ -ray
Drift plane

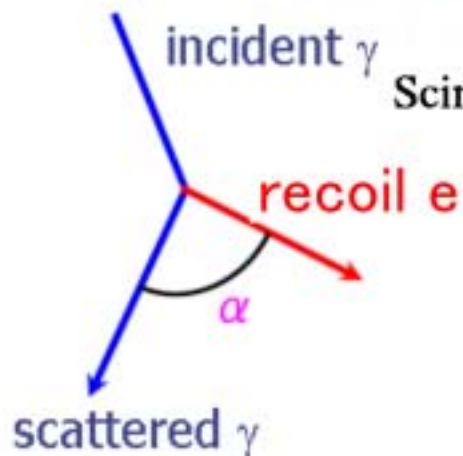


- **gaseous TPC** : Tracker
track and energy
of recoil electron
- **Scintillator** : Absorber
position and energy
of scattered gamma

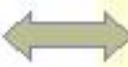


Reconstruct Compton scattering
event by event

- 1 photon \Rightarrow direction + energy
- Large FOV ($\sim 3\text{str}$)
- **Kinematical background rejection**



$$\cos \alpha_{\text{geo}} = \vec{g} \cdot \vec{e}$$



$$\cos \alpha_{\text{kin}} = \left(1 - \frac{m_e c^2}{E_\gamma}\right) \sqrt{\frac{K_e}{K_e + 2m_e c^2}}$$

The performance of the prototype was reported by H. Kubo in 2004 IEEE NSS.

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

10cm cube camera @ Sanriku (Sep. 1st 2006)

- Operation test @ balloon altitude
- Observation of
diffuse cosmic/atmospheric gamma
~200 photons during 3 hours
(100 keV~1MeV)

30cm cube camera

- Observation of Crab/Cyg X-1

40cm cube camera

- Long duration observation
with super pressure balloon

50cm cube camera

- All sky survey (load on a satellite)

SMILE-I gondola

Plastic scinti.

TPC

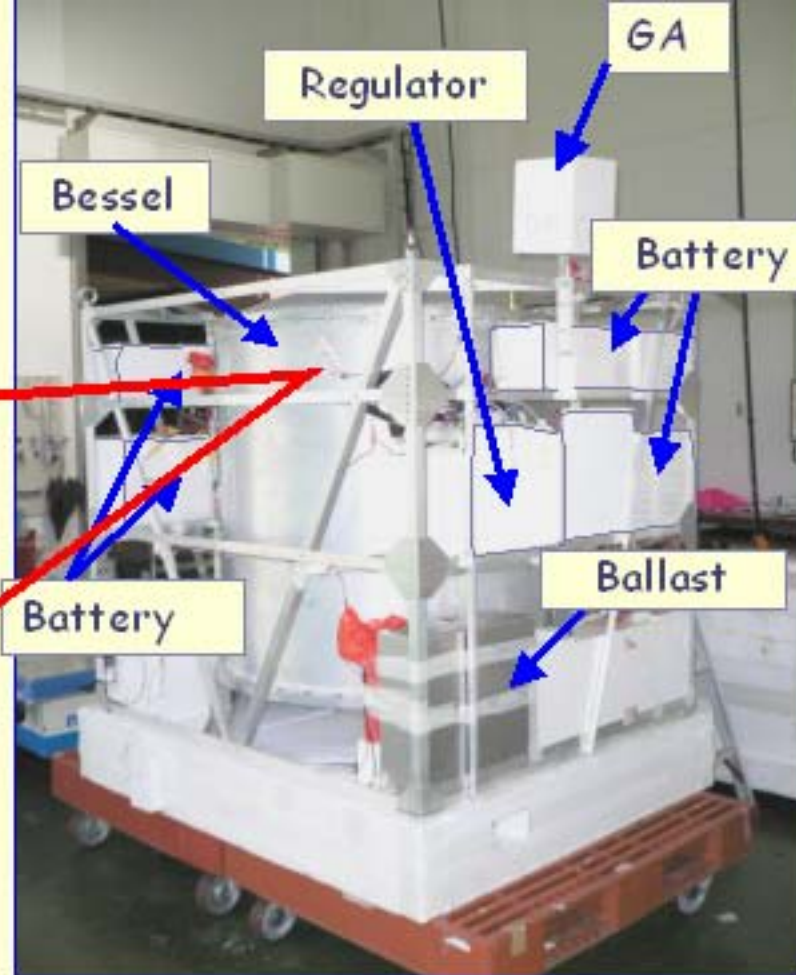
GSO
scinti.

preamplifier

NIM module
• Shaper
• DAC

FPGA encoding
board

VME module
• CPU
• ADC
• telemetry
• scaler



Size : $1.45 \times 1.2 \times 1.55 \text{m}^3$

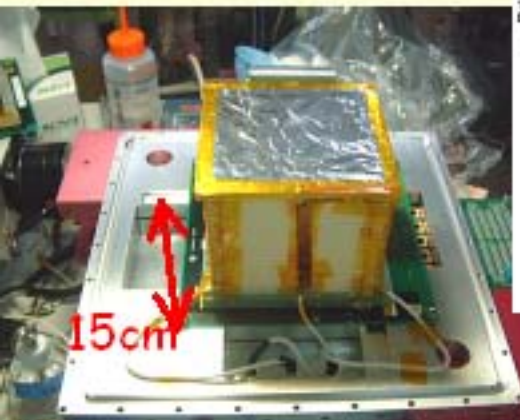
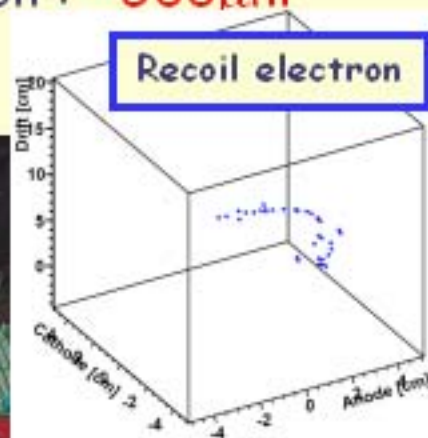
Weight : 397 kg

Power : ~350 W

No posture control !!

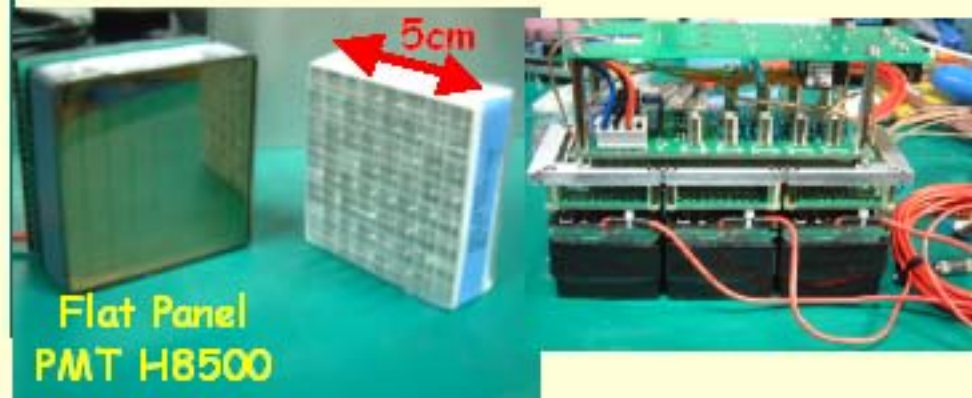
Tracker

- Gas : **Xe 80% + Ar 18% + C₂H₆ 2%**
1atm, sealed
- Gain : **~35000**
- Drift velocity ($V_d=400V/cm$) :
measured **2.5cm/ μ sec**
simulation **2.48cm/ μ sec**
- Volume : **10 \times 10 \times 14 cm³**
- Energy resolution :
~45% (22.2keV, FWHM)
- Position resolution : **~500 μ m**



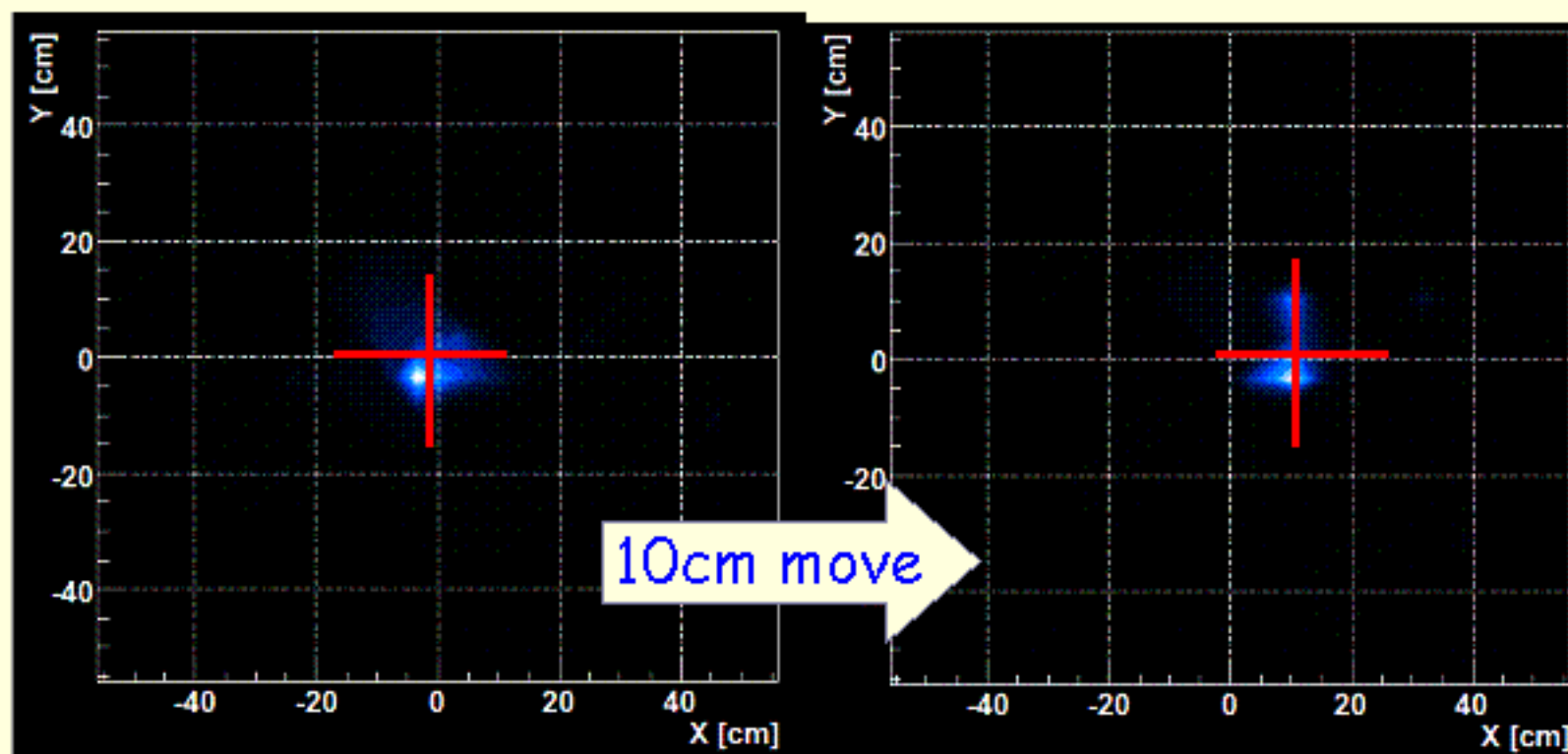
Absorber

- Scintillator : **GSO(Ce)**
- Pixel size : **6 \times 6 \times 13 mm³**
- Photo readout : H8500 (HPK)
- DC/HV : EMCO Q12N-5
- A unit consists of 192 pixels, 3 PMTs, 3 DC/HV and 4 preamplifier
- 4 channels readout with resistive chain (H. Sekiya et al., NIM, 2006)
- Bottom : 3 \times 3 PMTs
- Side : 3 \times 2 PMTs \times 4 } **2112 pixels**
- Energy resolution :
~11% (662keV, FWHM)



MeV gamma-ray imaging

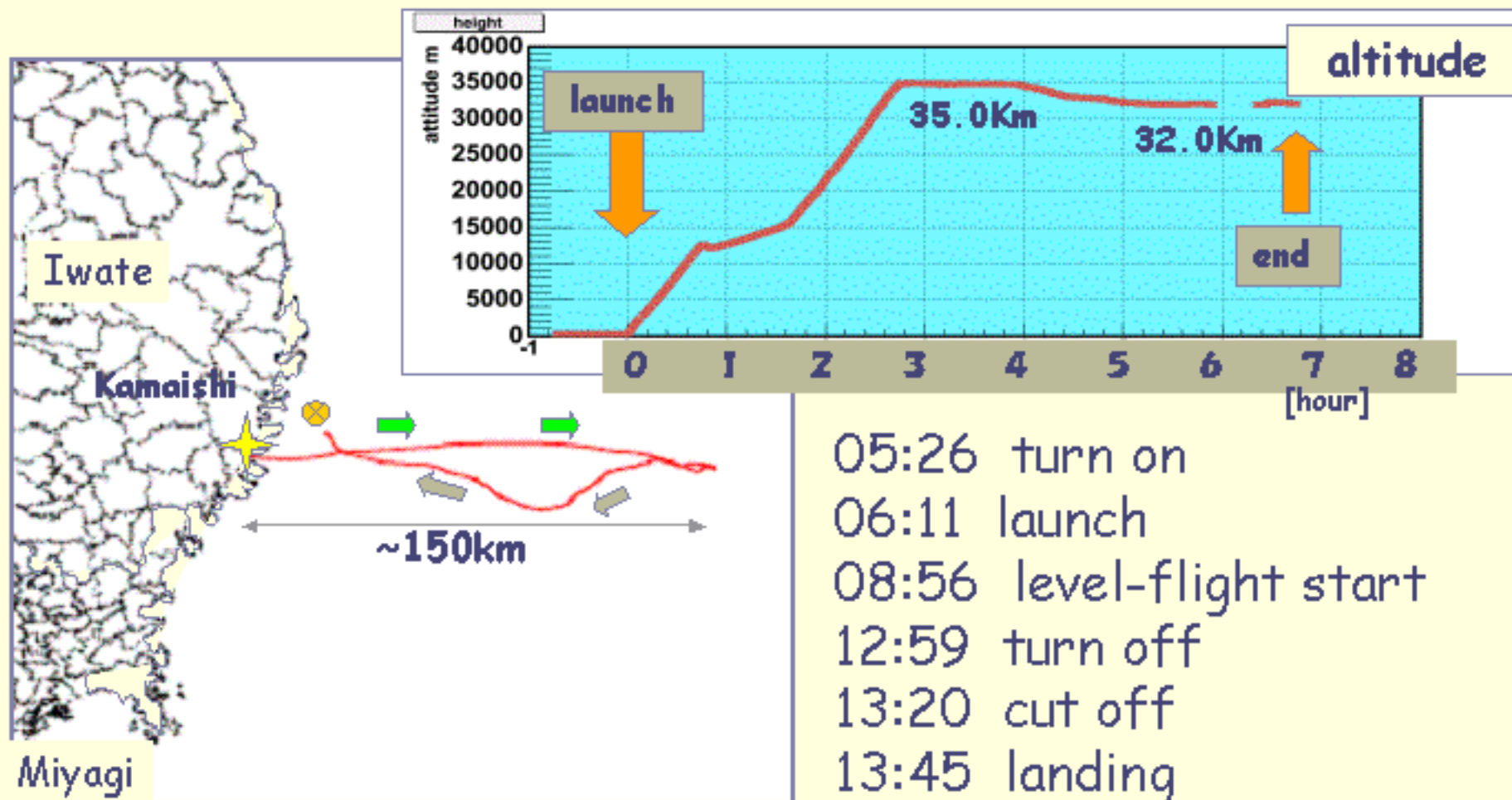
^{137}Cs (662keV) $\sim 50\text{cm}$ from window, 600 - 724keV



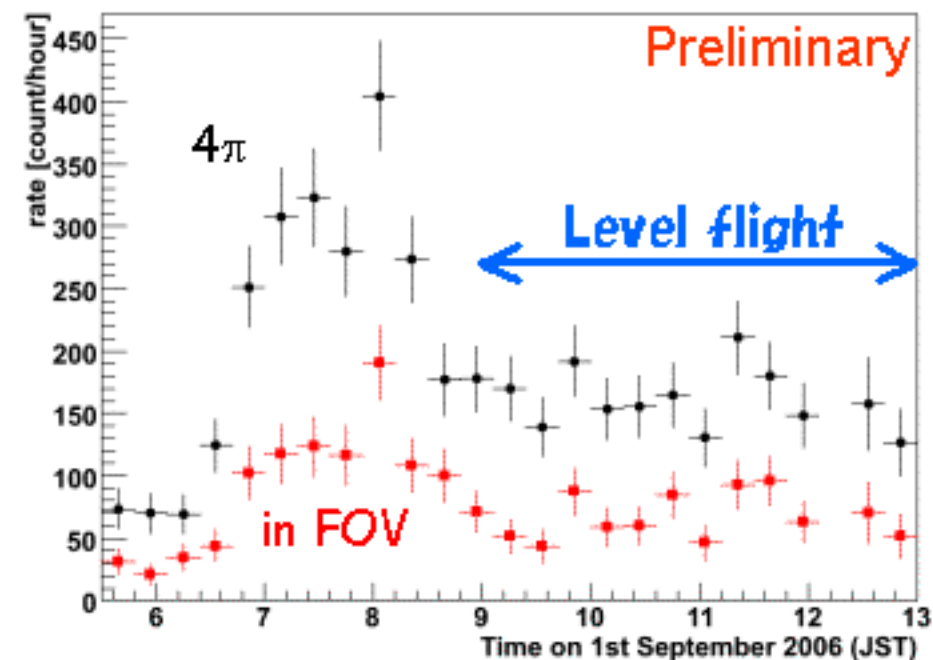
- Energy resolution : $\sim 12\%$ (662 keV, FWHM)
- Detection efficiency : 2.5×10^{-4} (356 keV)
 5.0×10^{-5} (662keV)

Flight

- Sanriku Balloon Center (JAXA)
- Launch at Sep. 1st 2006



Gamma-ray rate & spectrum



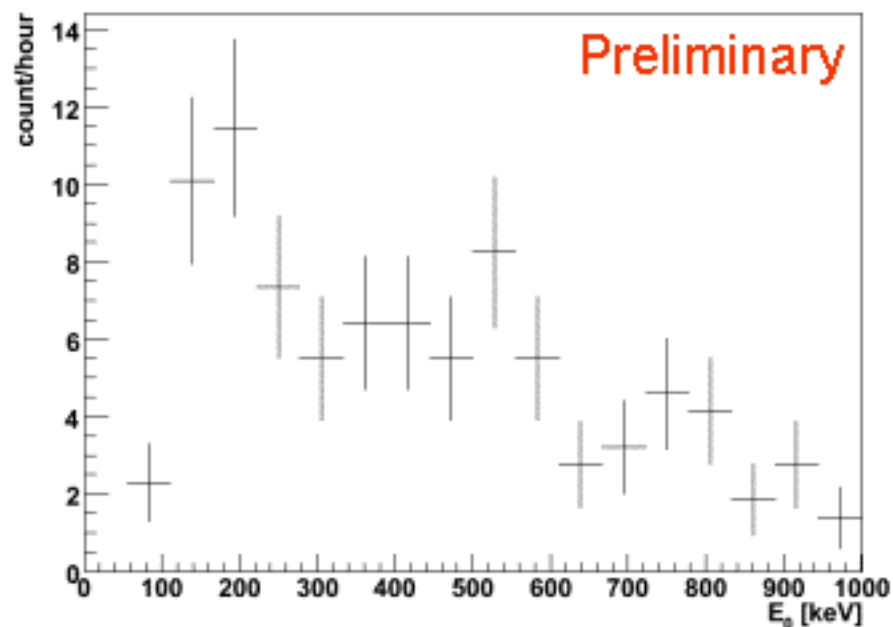
Rate of Gamma-ray event

- 100~900 keV
- All direction ~1000
- in FOV (3 str) ~450

Energy Spectrum

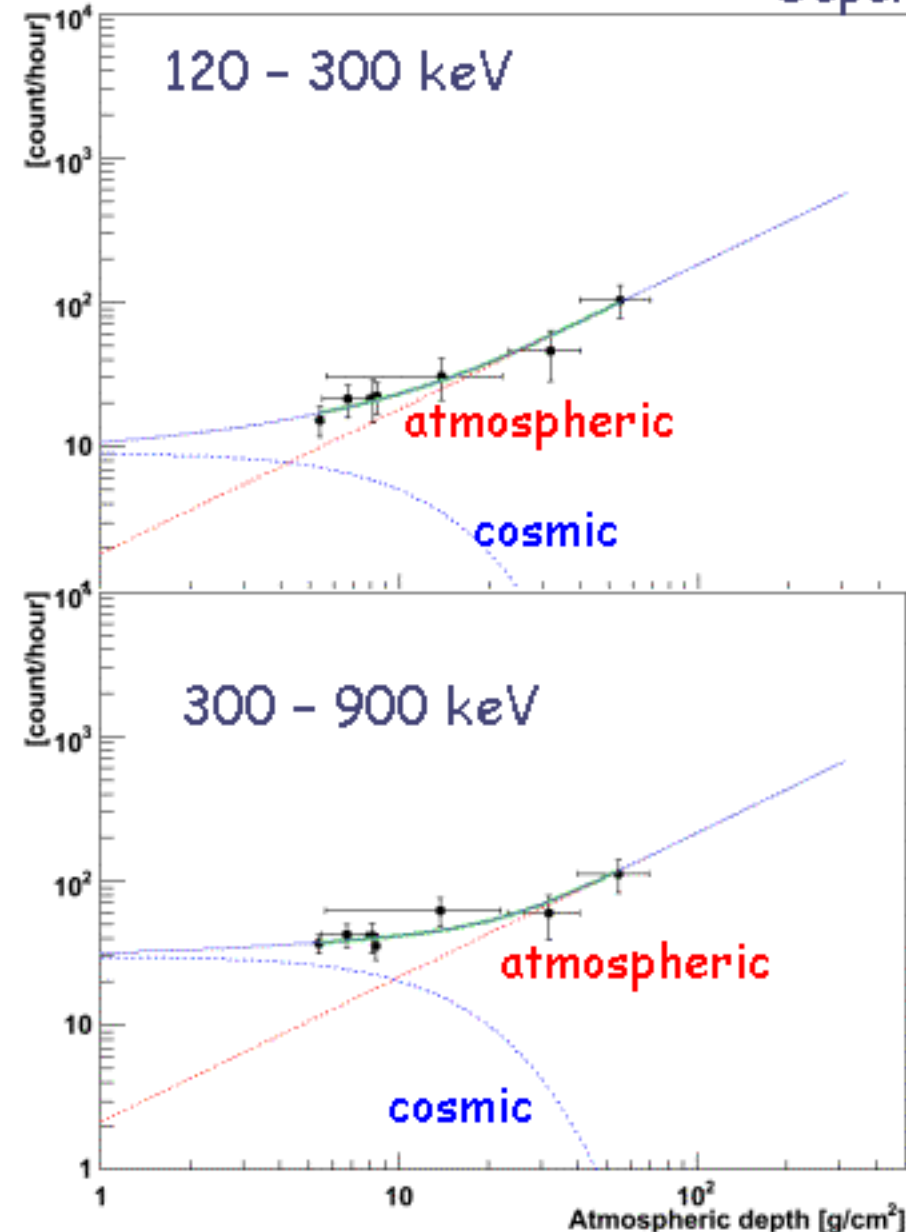
- 32~35 km level flight
- 3.5 hours (live ~3h)
- in FOV event
~200 events

GEANT4 \Rightarrow ~200events



Growth curve

Dependence of Count rate on Atmospheric depth



- **Cosmic** : $\phi_c = \phi_d + \phi_s$
 - **directory incoming component**
 - : Gamma-rays are attenuated by atmosphere
 - **scattered component**
 - : Gamma-rays are scattered in atmosphere before reaching the detector

$$\phi_d = A \times \exp(-z/\tau_{\text{tot}})$$

$$\phi_s = p(E, z) \times \phi_d$$

- **Atmospheric** : ϕ_A
 - The component of the interaction of charged particle and atmosphere

$$\phi_A = B \times z$$

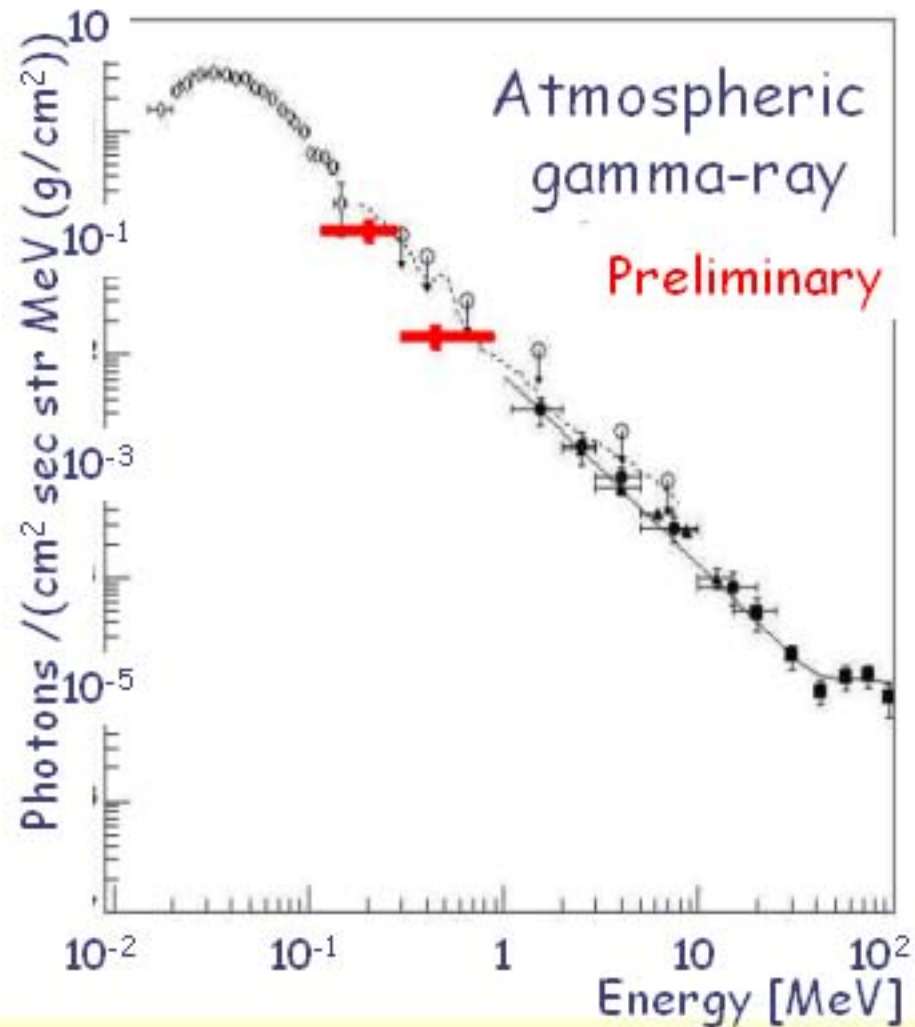
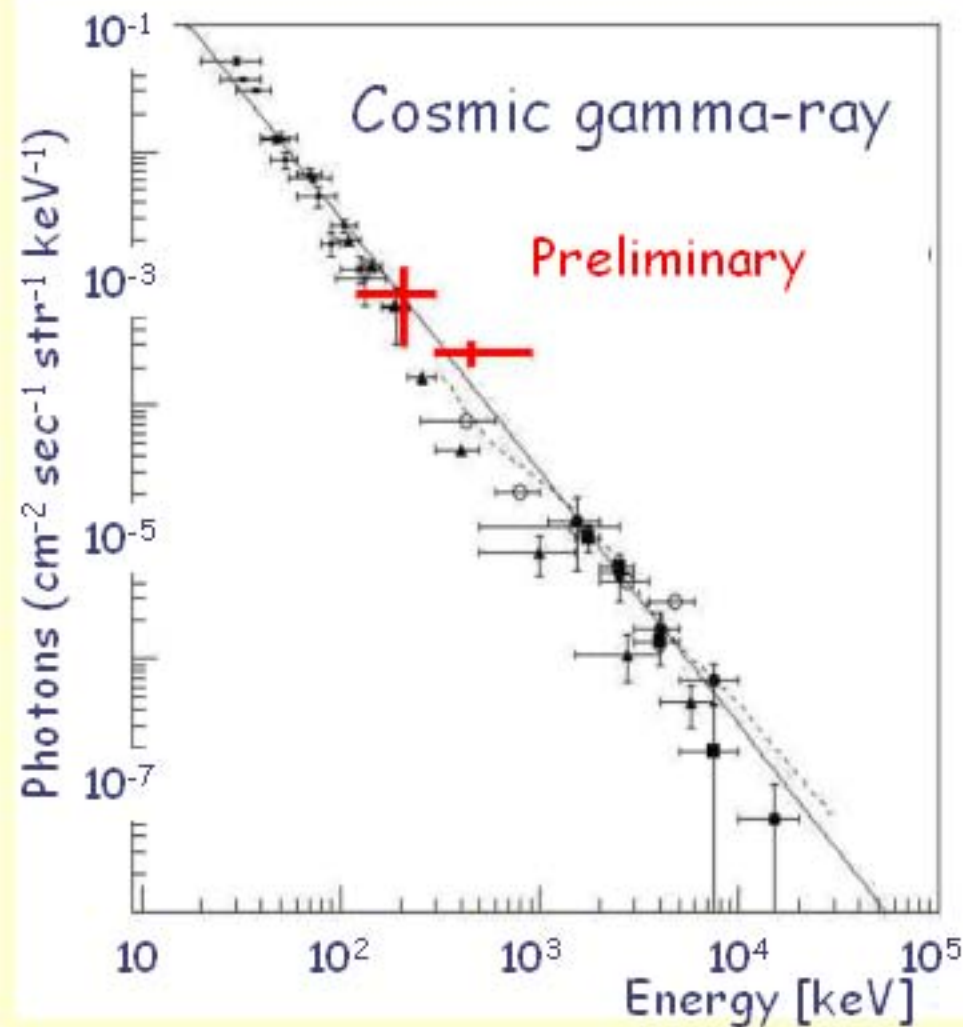
z : atomospheric depth

τ_{tot} : mean free path

$p(E, z)$: correction factor

A, B : free parameter

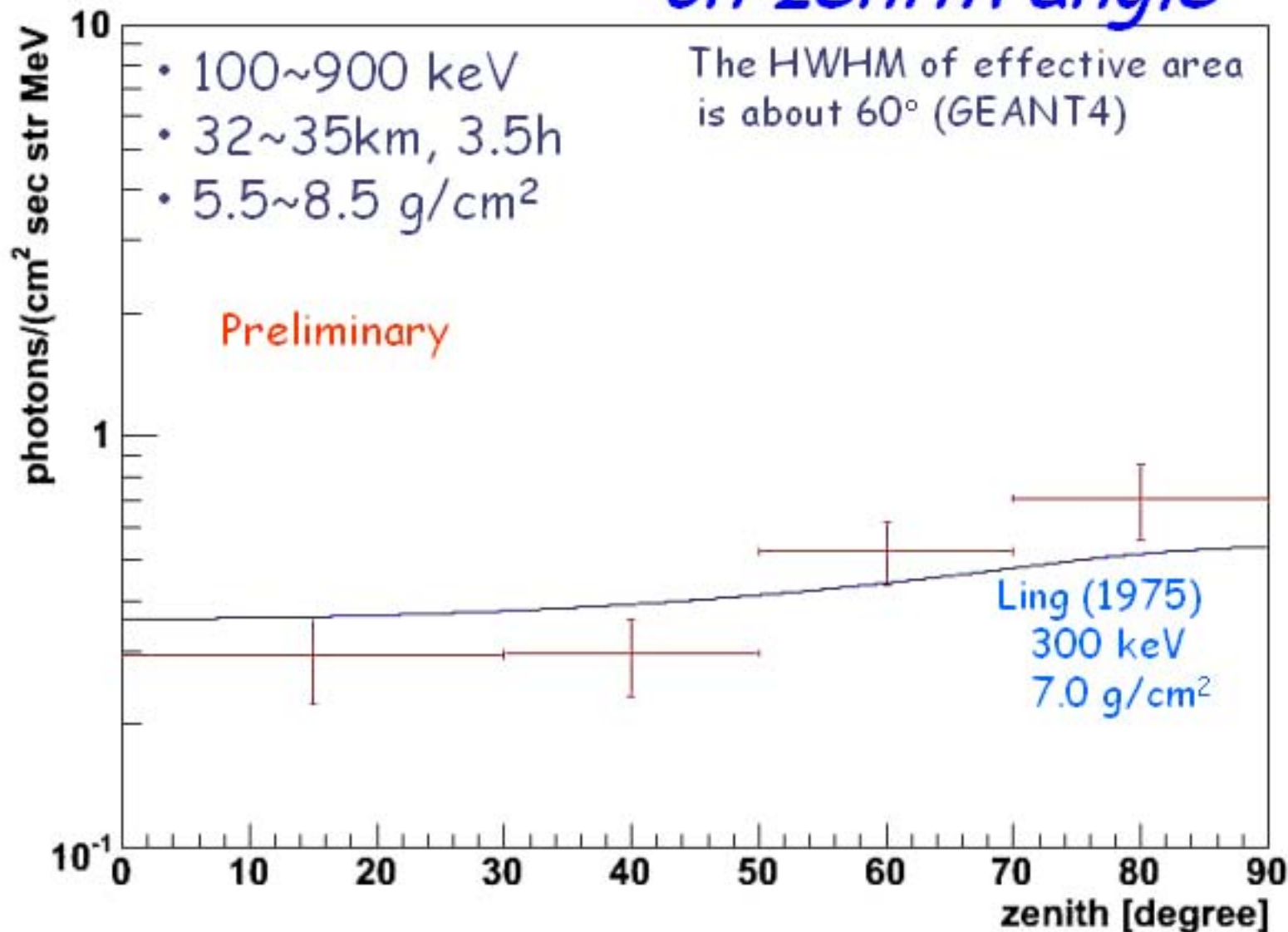
Fluxes of cosmic/atmospheric gamma-ray



We confirmed the results of past observations!!

Dependence of total flux

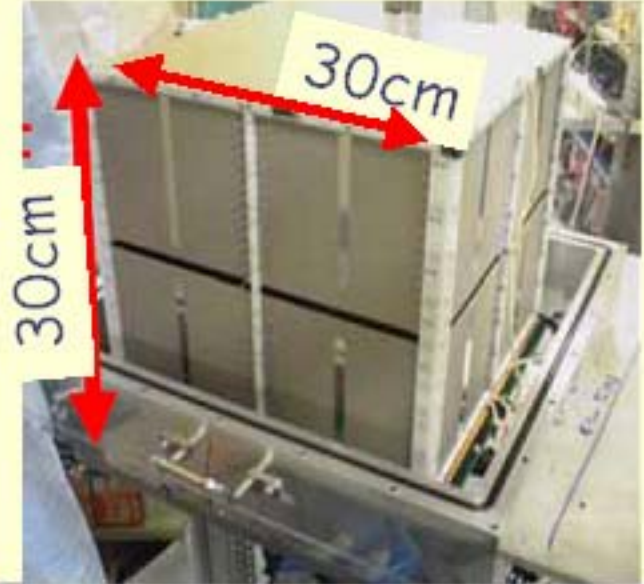
on zenith angle



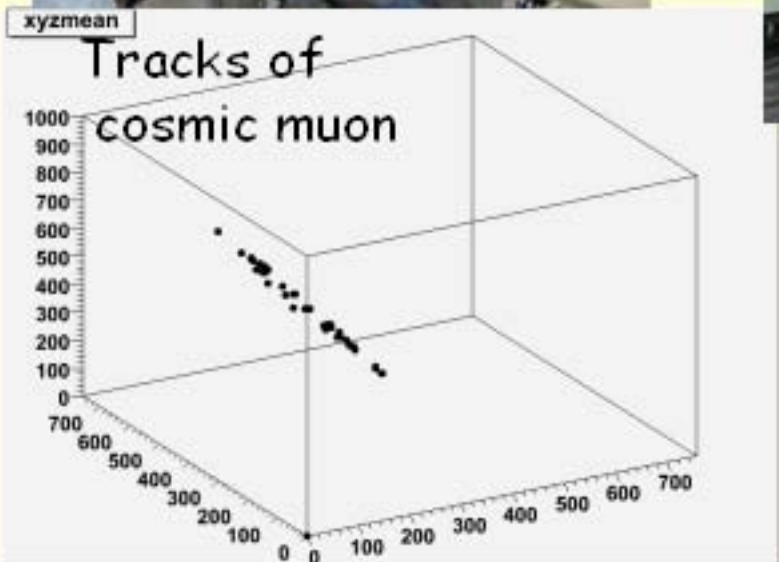
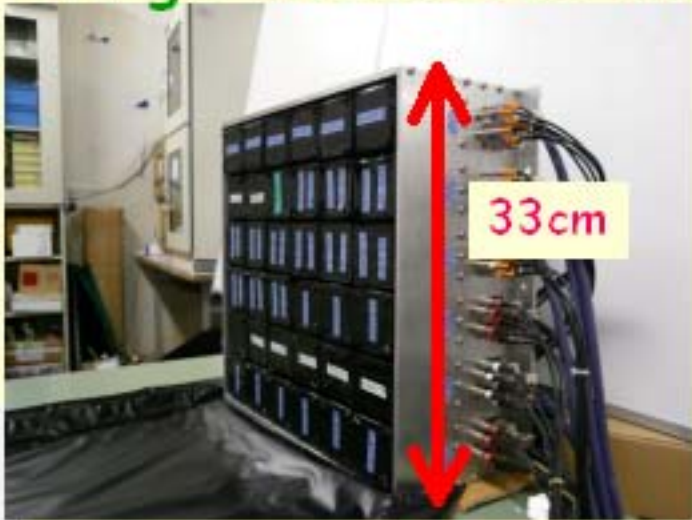
For Next Balloon Experiment

30cm cube TPC

K. Ueno's talk (N33-5)



Large area GSO array



The Development is going on !!

Summary

- We develop an Electron-Tracking Compton Camera.
- The flight model detector for SMILE-I
 - Energy resolution : $\sim 12\%$ for 662keV @ FWHM
 - Detection efficiency : $\sim 2 \times 10^{-4}$ for 356 keV
 - Field Of View : $\sim 3\text{str}$
- The first balloon was launched on September 1st, 2006 from Sanriku-Balloon-Center (ISAS/JAXA).
- The balloon flight lasted 7 hours, and the level flight continued during 4 hours at the altitude of 32-35 km.
- Our detector was stable at the balloon altitude.
- **The experiment is the first observation using ETCC at the balloon altitude.**
- There were ~ 1000 gamma-ray events in this flight, and ~ 200 gamma-ray events in FOV during the level flight.
- **We confirmed the past observations of the fluxes of diffuse cosmic and atmospheric gamma-rays.**
- Our detector realized a large FOV and a high S/N at the balloon altitude.



Thank you!

