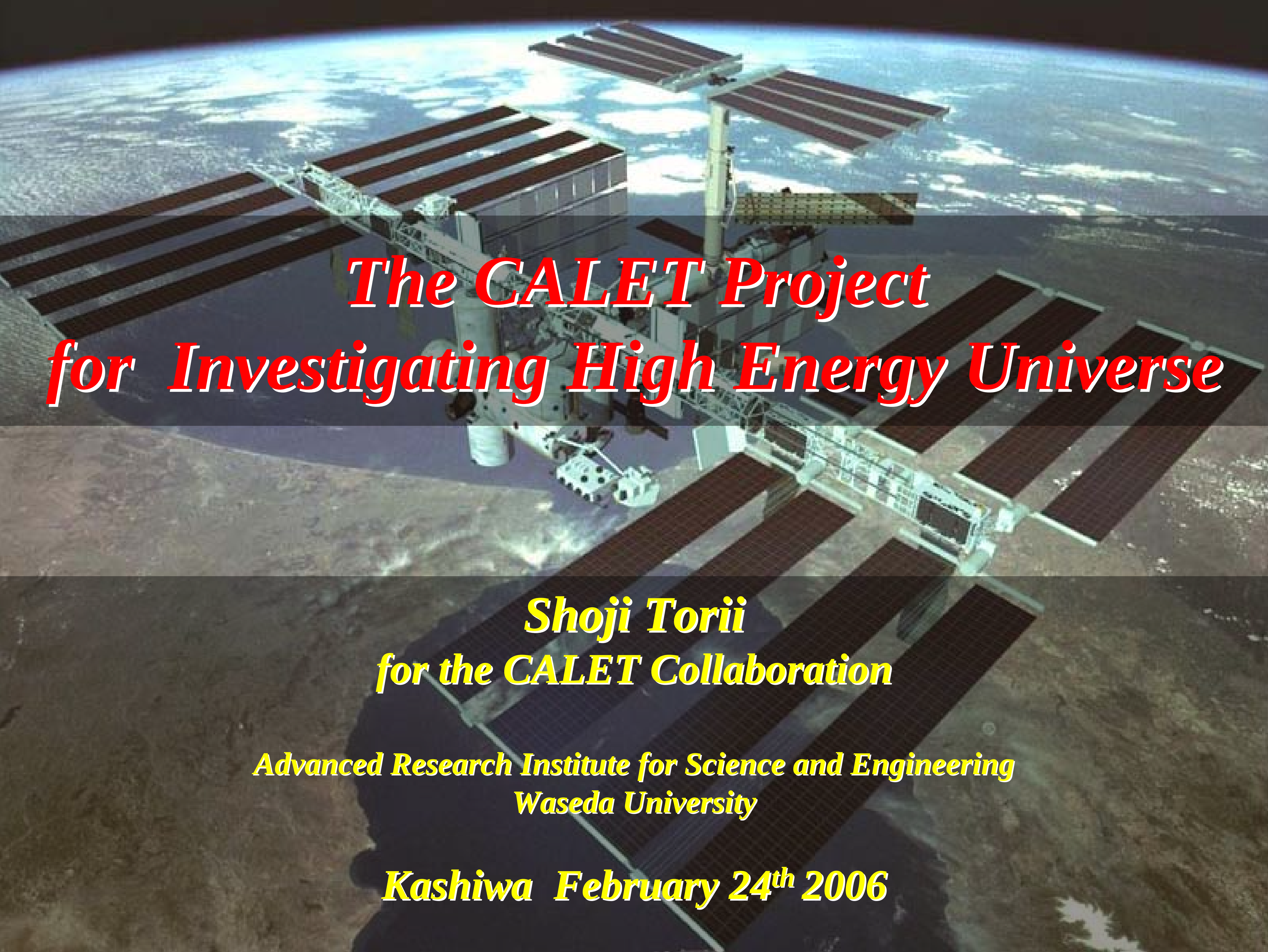


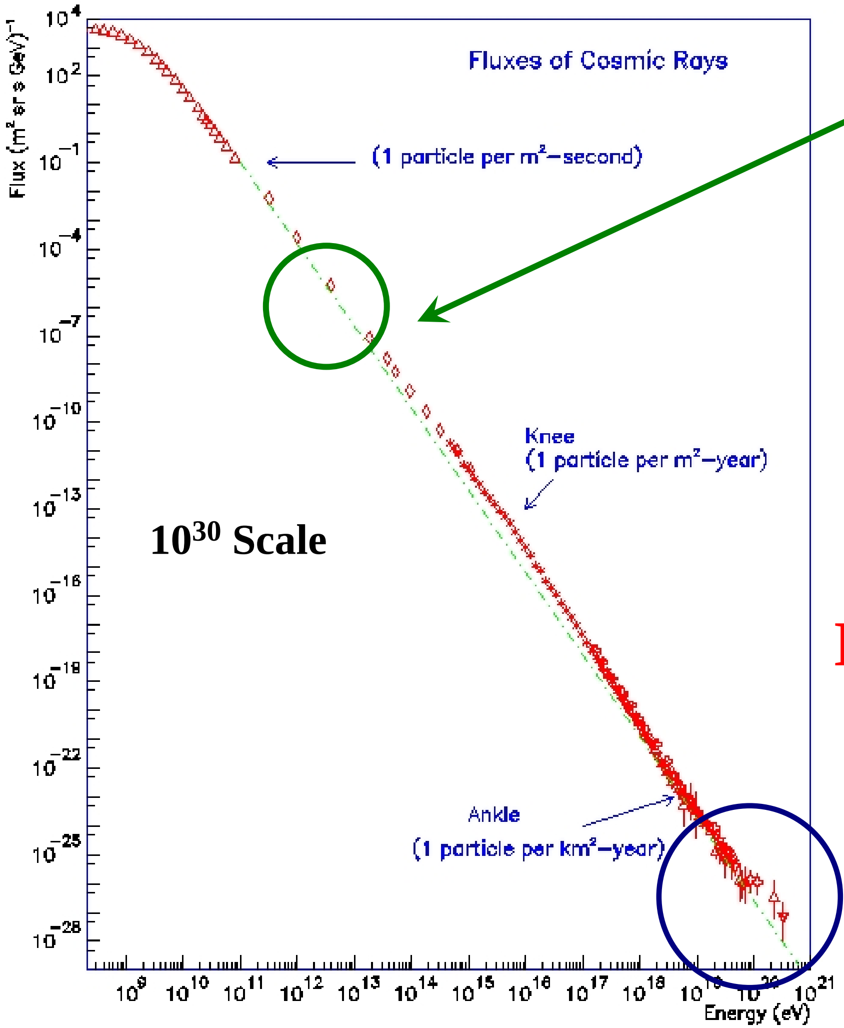
The CALET Project for Investigating High Energy Universe

Shoji Torii
for the CALET Collaboration

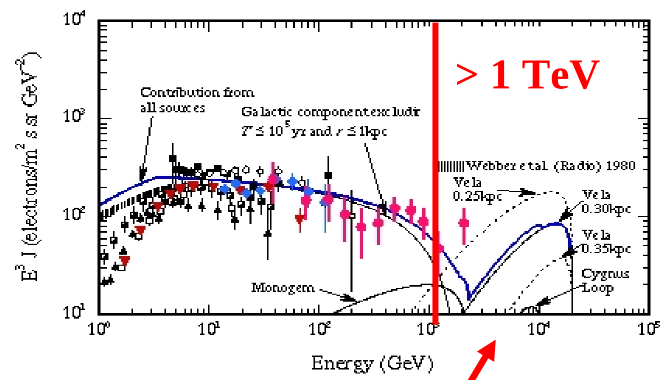
Advanced Research Institute for Science and Engineering
Waseda University

Kashiwa February 24th 2006

Cosmic Ray Energy Spectrum at the Highest Energy for Electrons and Protons



Electron
IC, Synchrotron Cut-off



Nearby (or Unknown) Sources

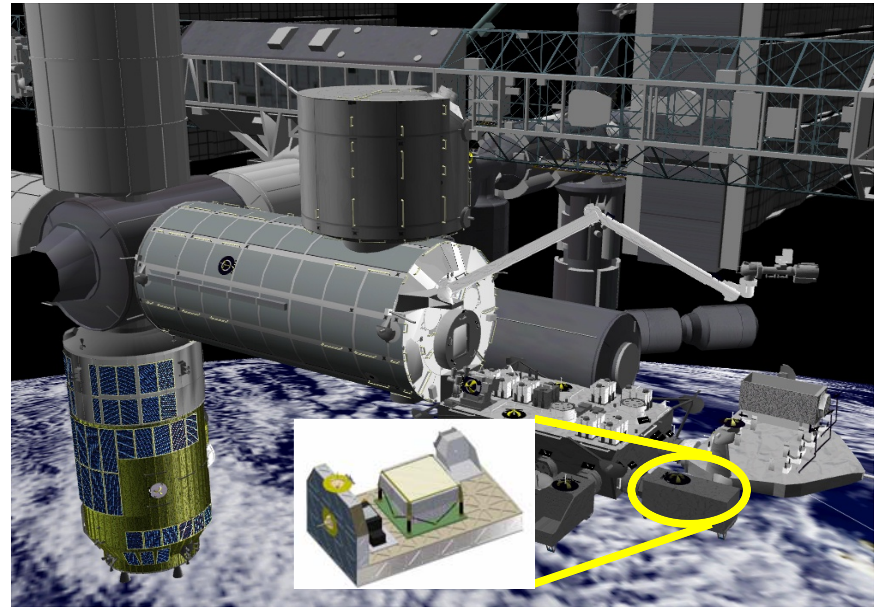
Distance < 1 kpc
Age < 10^5 year

Hadron
GZK Cut -off

CALET: CALorimetric Electron Telescope

CALET Mission Concept

- **Instrument:**
  High Energy Electron and Gamma-Ray Telescope Consisted of
  - Imaging Calorimeter (IMC)
  - Total Absorption Calorimeter (TASC)
- **Launch:**
  HTV: H-IIA Transfer Vehicle
- **Attach Point on the ISS:**
  Exposed Facility of Japanese Experiment Module (JEM-EF)
- **Nominal Orbit:**
  407 km, 51.6º inclination
- **Life Time:**
  3 years (minimum)
- **Mission Status**
  Mission Concept Study
  Launch around 2012 in Plan

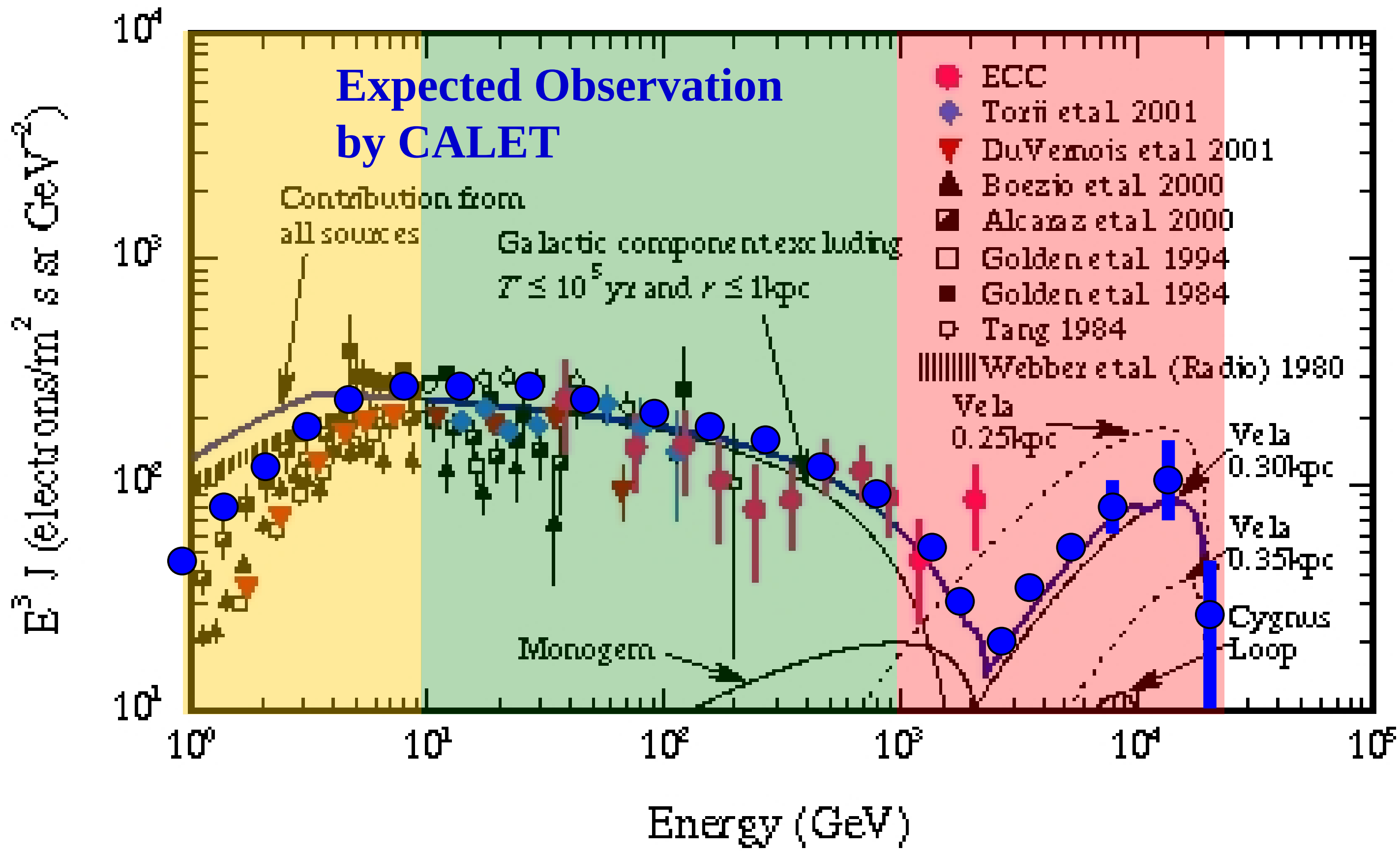


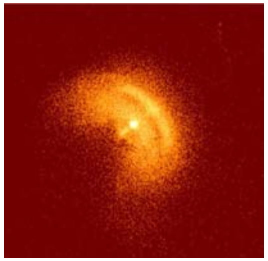
CALET Payload:

- 1GeV ~ 10 TeV for electrons
- 20 MeV ~ TeV for gamma-rays
- several 10 GeV ~ 1000 TeV for p~Fe
- Weight: 2500 kg
- Geometrical Factor: 1 m^2sr
- Power Consumption: 600 W
- Data Rate: 600 kbps

Origin and Propagation of Electrons

- *Detection of Nearby Sources*
- *Electron Propagation in Our Galaxy*
- *Acceleration by Supernova Shock Wave*
- *Solar Modulation*

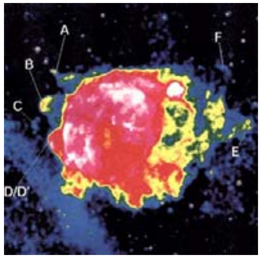


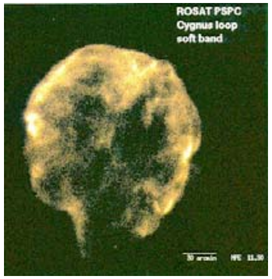


Vela
10,000 years
820 ly

Chandra

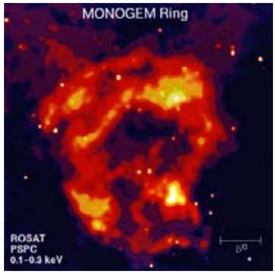
ROSAT





Cygnus Loop
20,000 years
2,500 ly

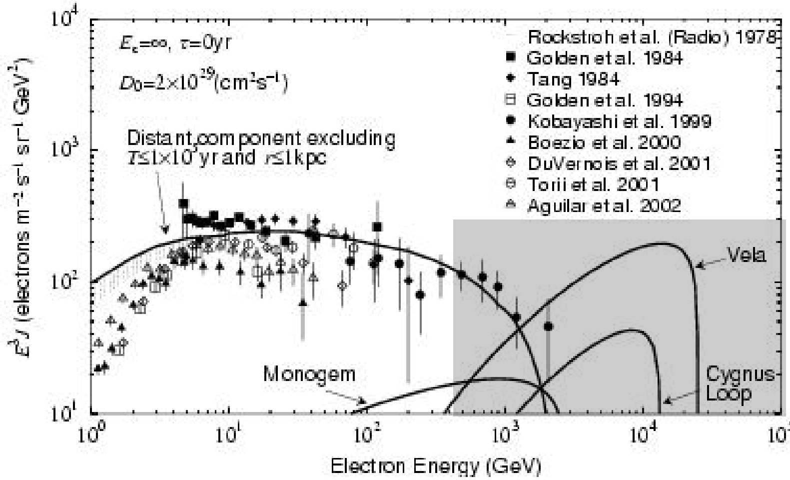
Monogem
86,000 years
1,000 ly



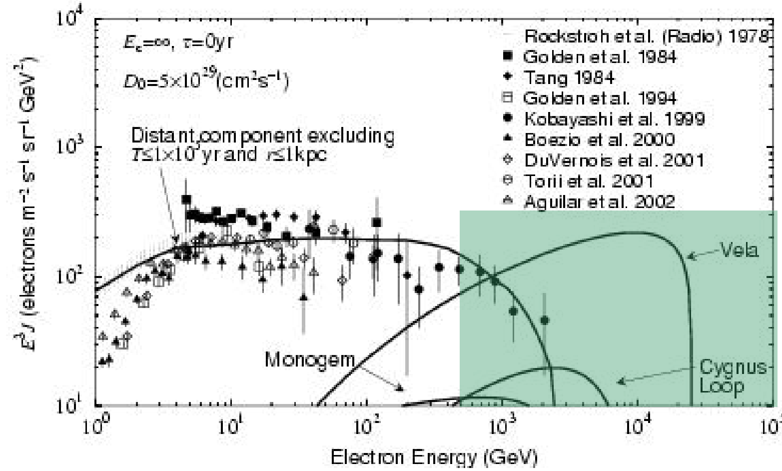
Model Dependence of Nearby Source Effect

Kobayashi et al.

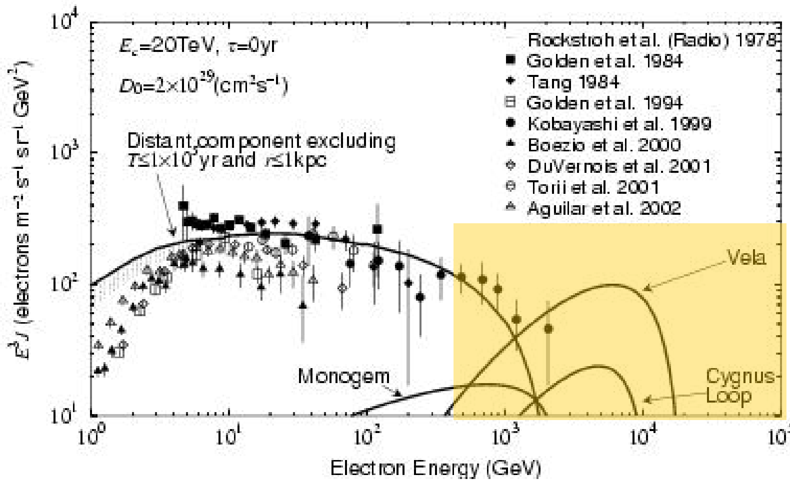
Ec=∞、ΔT=0 yr, Do=2x10^{29} cm^2/s



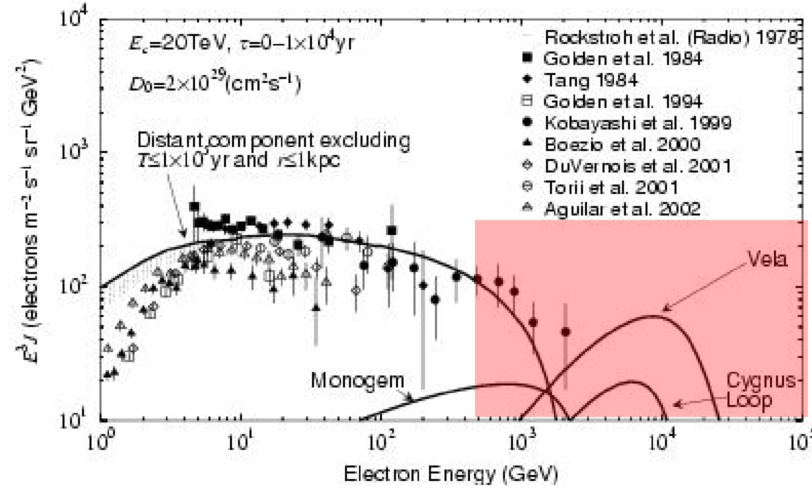
Do=5 x 10^{29} cm^2/s



Ec= 20 TeV



Ec=20 TeV、ΔT=1-10^4 yr



Gamma-Ray Observation in 20 MeV~10 TeV

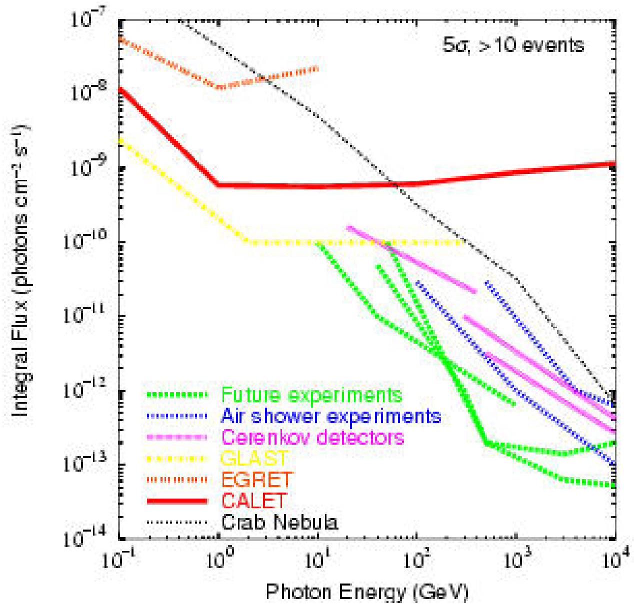
CALET on the ISS orbit without attitude control of the instrument:

Wide FOV (~45°) and Large Effective Area (~0.5 m^2) in 20 MeV- 10 GeV

⇒
- Sky coverage of 70 % for one day
- All sky coverage in 20 days
- Typical exposure factor of ~50 days for point source

Good Energy Resolution (< a few %) over 100 GeV

⇒
- Measurement of change of power-law spectral index
- Possible detection of gamma-ray lines from Neutralino annihilation

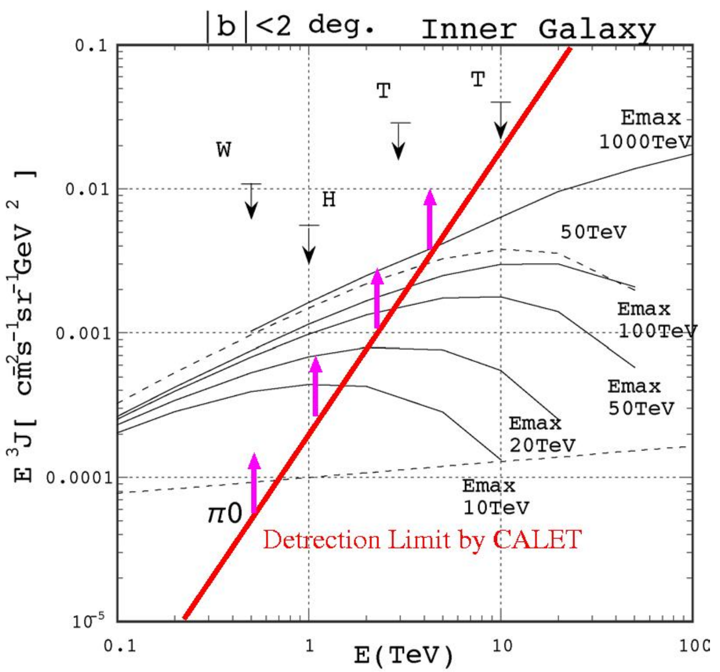


Point Source Sensitivity in One-Year Observation

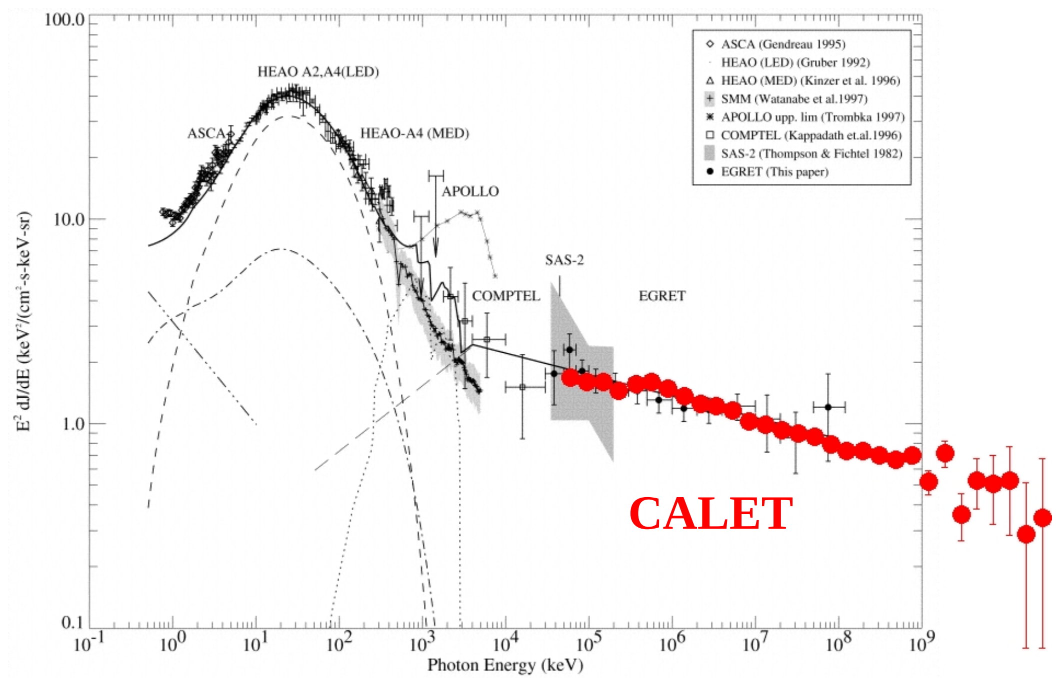
Nature of Cosmic Gamma-Ray Sources (1)

- *Diffuse Components*
  Electron or Proton Origin in the Galectic Plane?
  Origins in the Extra-Galactic Space ?

Galactic Diffuse Component



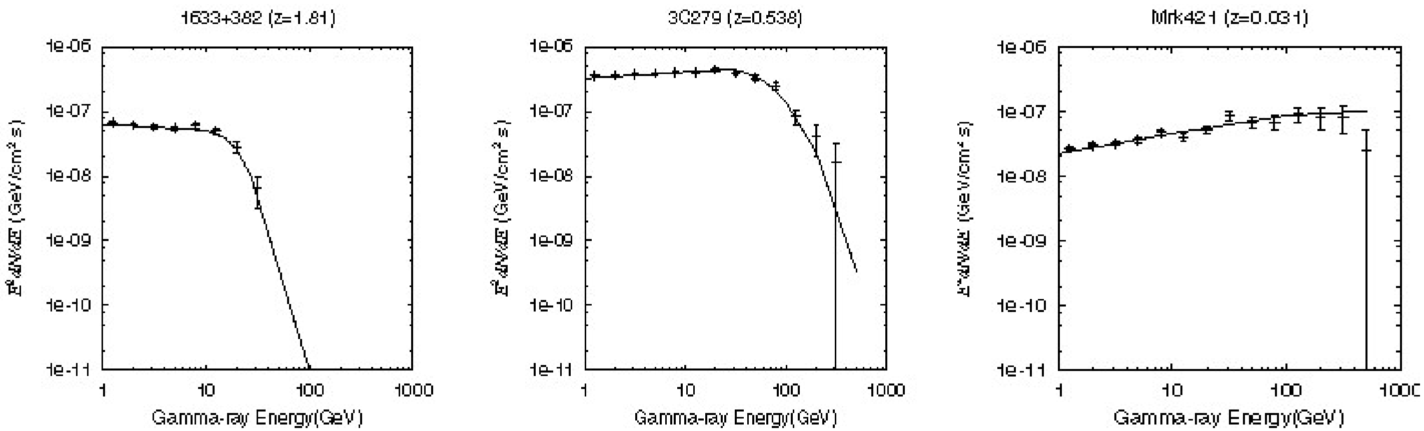
Extra-Galactic Diffuse Component



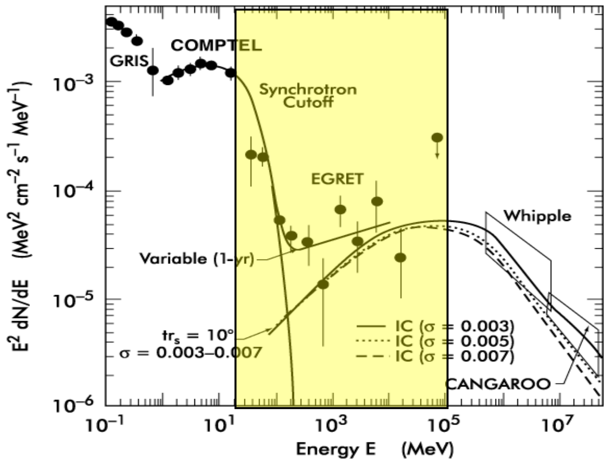
Nature of Cosmic Gamma-Ray Sources (2)

- AGN sources and absorption by IR background

Expected AGN spectra after absorption by IR background



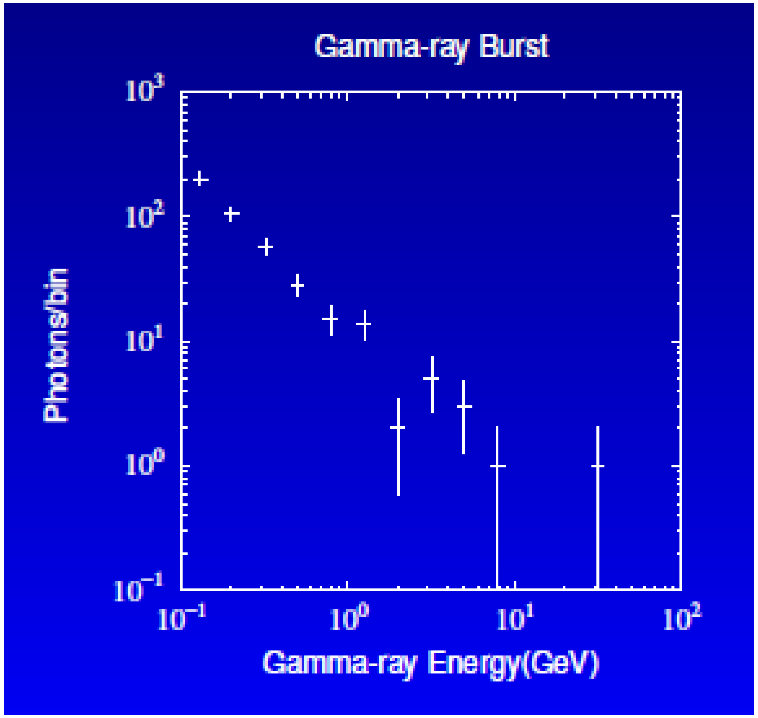
- Supernova Remnants and Pulsar



Predicted CALET measurement region of Crab unpulsed spectrum in the overlap region with ground-based Cherenkov telescopes.

Nature of Cosmic Gamma-Ray Sources(3)

- High Energy Gamma-Ray Bursts



- $> 10^{-5}$ erg/cm^2 Gamma-ray burst $\Rightarrow$ $\sim$10/yr
- $> 10^{-5}$ erg/cm^2 Gamma-ray burst $\Rightarrow$ up to $\sim$10GeV

An expected gamma-ray burst spectrum, assuming a power-law

Origin and Propagation of Proton and Nucleus (1)

- Supernova Shock Acceleration

Change of power spectrum index depending on Z ?

Measurements of proton and heavy ion flux in the energy region exceeding 1 TeV, in which magnet spectrometer is not capable.

For proton measurement:

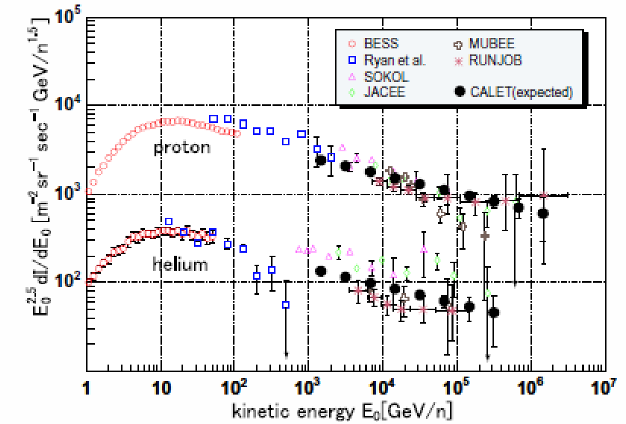
$S_{eff} \sim 0.5\ m^2 \times 1/3\ (\text{for p}) \sim 0.17\ m^2$

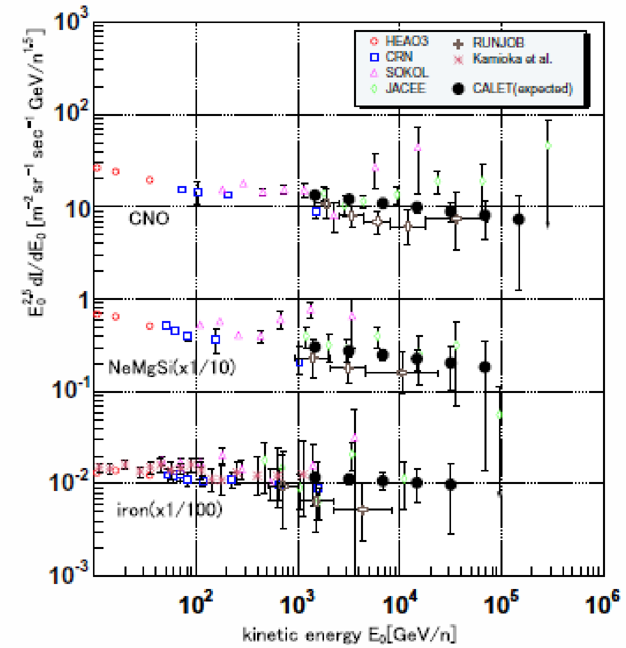
Exposure factor for 1000 days:

$170\ m^2\ sr\ day \sim 1.5 \times 10^7\ m^2\ s\ sr$

Expected numbers of protons:

Energy (TeV)	Number
1	$\sim 10^6$
10	1.8×10^4
100	3.2×10^2
1000	6

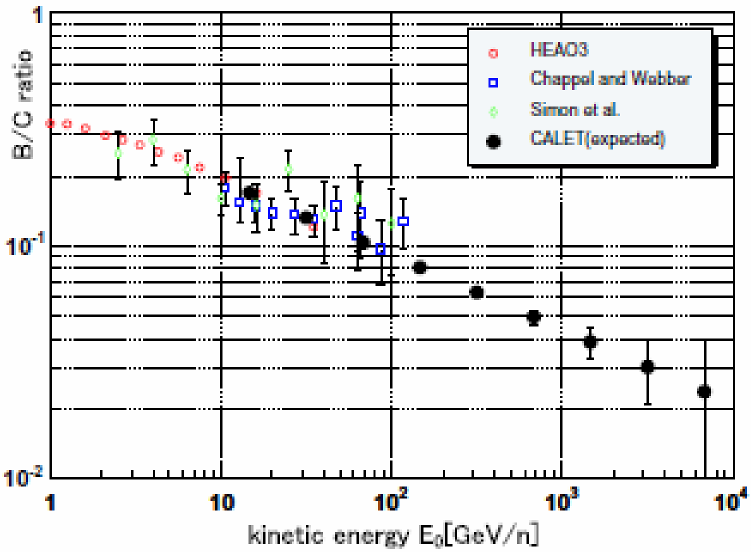




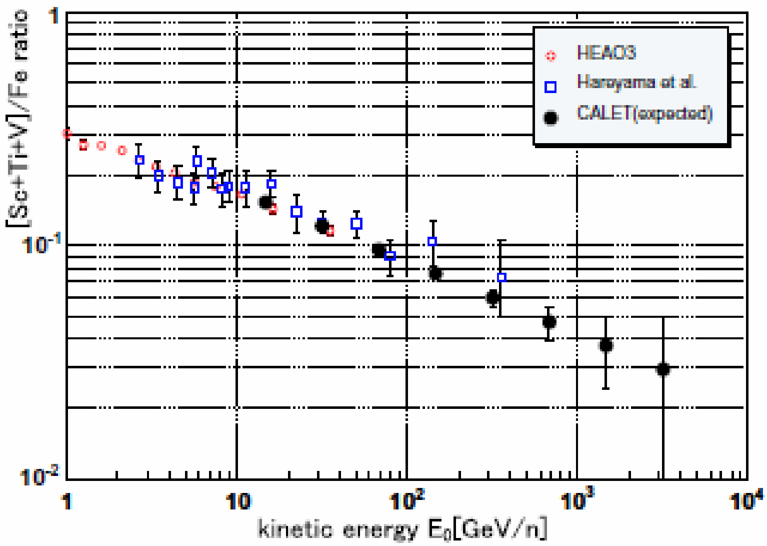
Origin and Propagation of Proton and Nucleus (2)

- Propagation in Our Galaxy : Structure of the Galaxy
Leaky box model is still valid in the Knee region ?

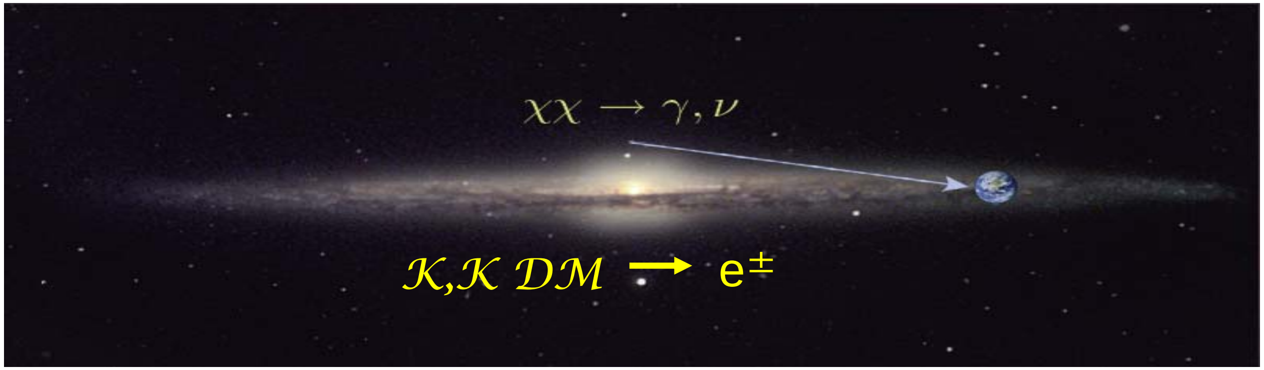
B / C Ratio



Sub Fe / Fe



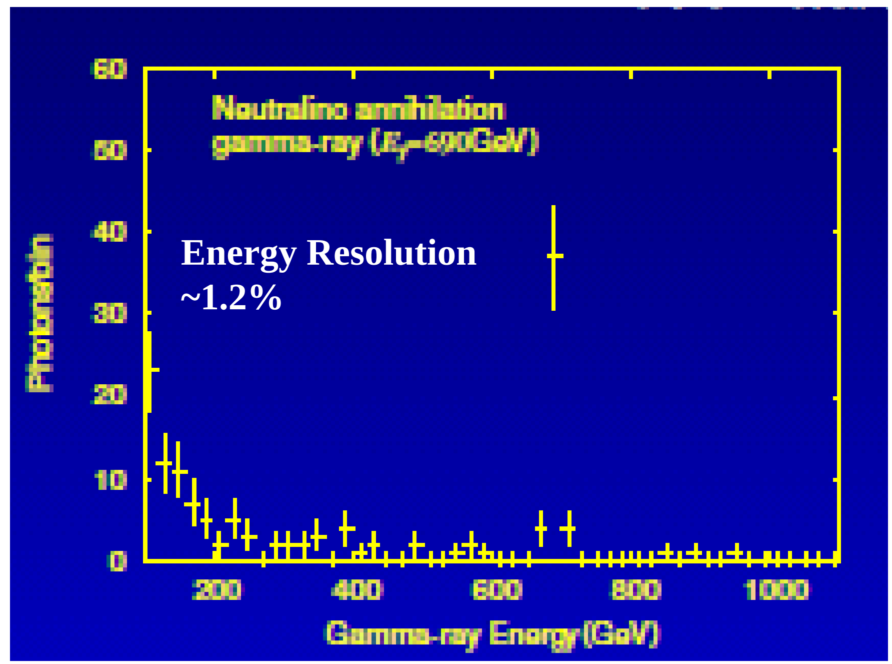
SUSY Dark Matter Search by Gamma-Ray Line



- **690 GeV neutralino annihilating to $\gamma\ \gamma$**
- **Clumpy halo as realized in N-body simulation by Moore et al. (ApJL 1999)**
- **Simulated Signal in CALET for 3 years**

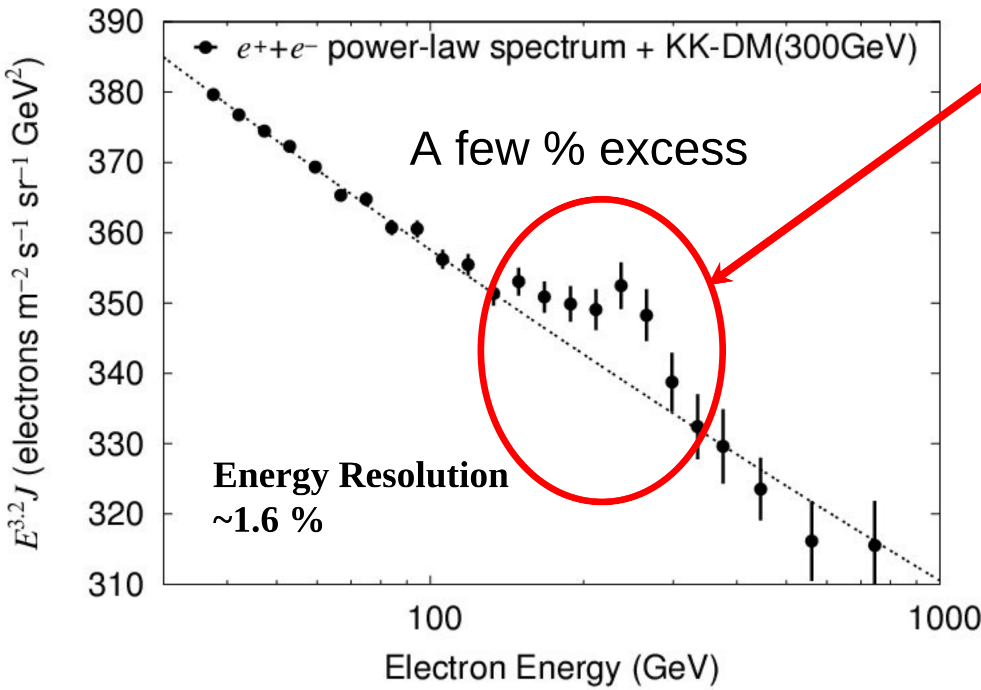
$$\Phi_\gamma = \frac{N_\gamma \sigma v}{m_\chi^2} \frac{1}{4\pi} \int\int_{line\ of\ sight} \rho^2(\ell) d\ell d\Omega$$

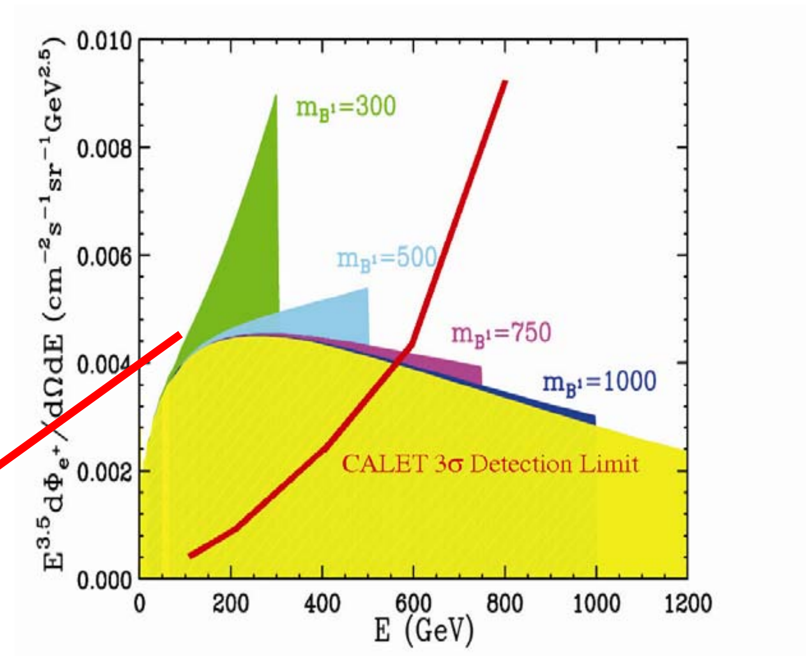
- $m_\chi = 690\text{GeV}$
- $N_\gamma \sigma v = 1.5 \times 10^{-28} \text{cm}^3 \text{s}^{-1}$



Dark Matter Search by Positrons (& Electrons)

Positron will be measured by
- **PAMELA flying soon**
- **AMS to be launched in 2008 on ISS**
- **CALET on ISS (can not separate e+ and e-)**
  Simulation for 300 GeV KK DM





H.C. Cheng et al., PRL 2002.

Conceptual Structure of CALET

Requirements:

- Large Acceptance: 1 m^2 sr
- Imaging Capability: < 1mm
- Hadron Rejection Power: ~10^6
- Energy Measurement:
  20 MeV~10 TeV for e, γ
  1 ~ 1000 TeV for hadrons (Optional)

SciFi/Lead Imaging Calorimeter (IMC):

- Area: ~1 m^2
- SciFi Belt: 1mm square x ~1 m length
  17 layers(x &y)
- Lead Thickness: 4 r.l , 0.13 m.f.p

Total Absorption Calorimeter (TASC):

- Area: ~0.5 m^2
- BGO Log: 25 x 25 x 350 mm
  7 layers (x &y)
- Thickness: 32 r.l , 1.6 m.f.p

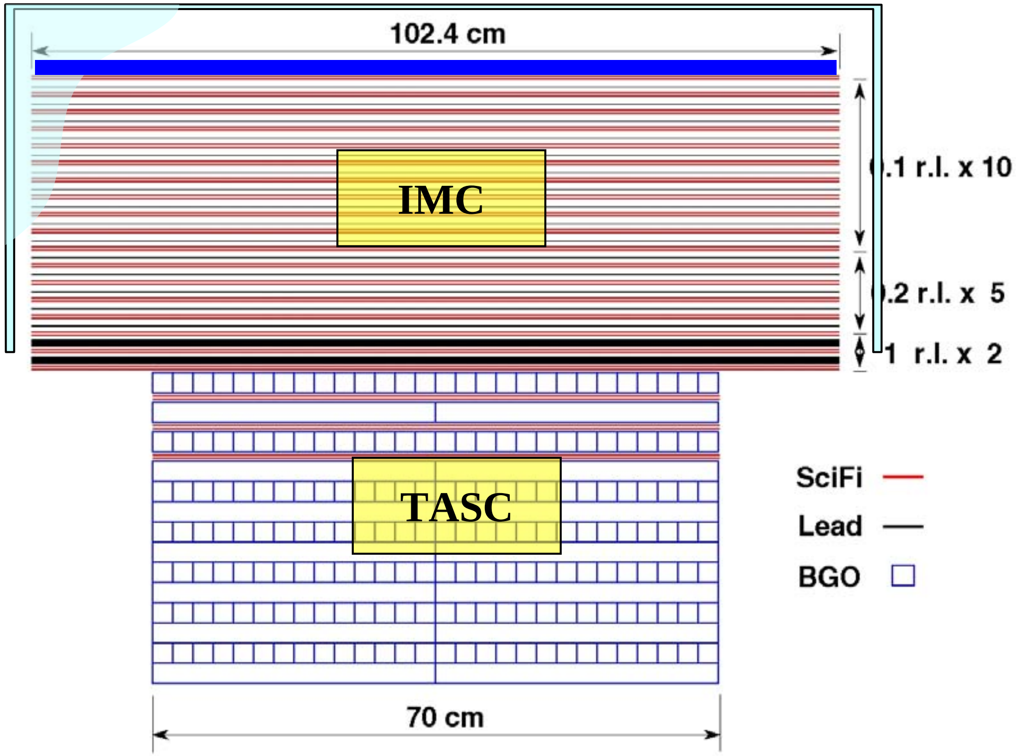
Schematic Side View of CALET

・Anti-Coincidence System for Low E. γ

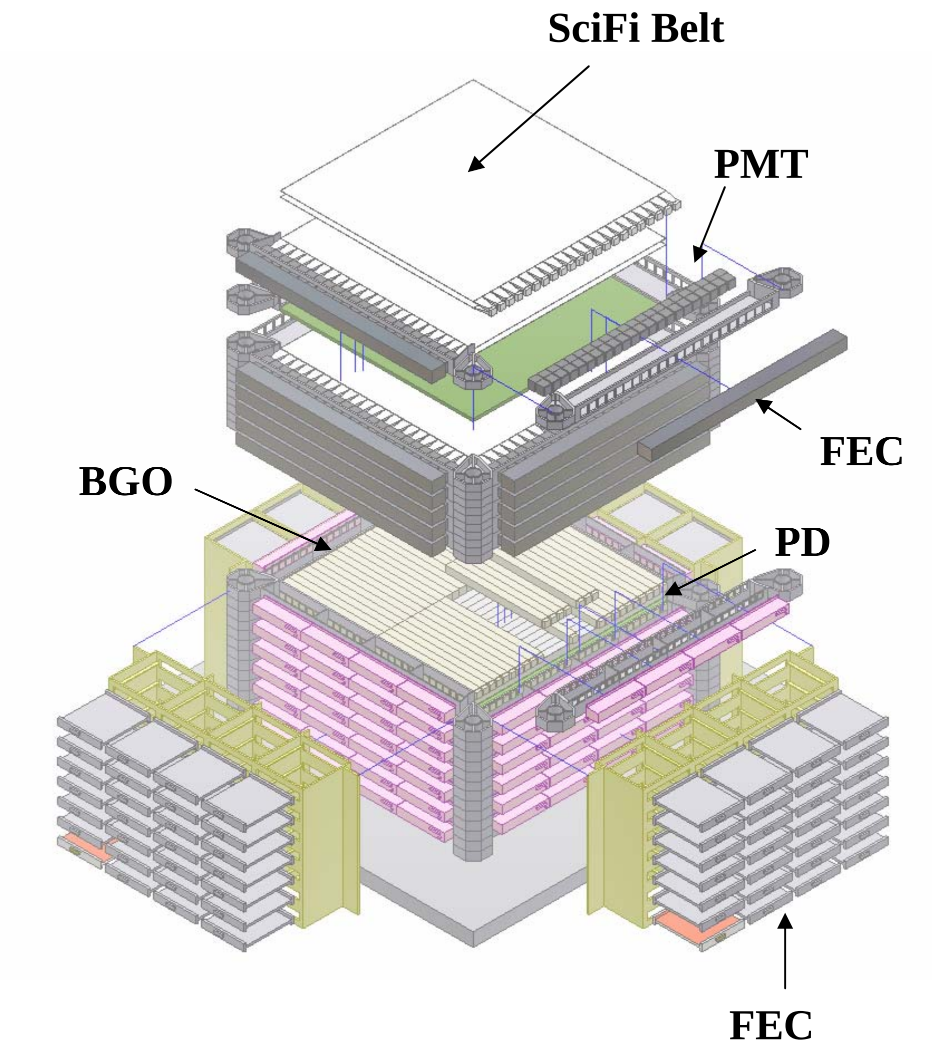
・Silicon Detector for High Z and Particle ID

Detector Weight: 1760 kg

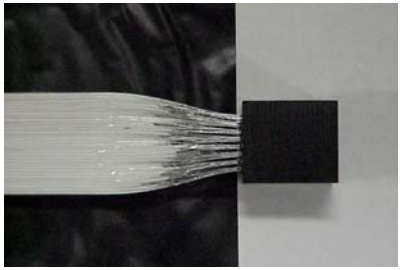
Total Absorber Thickness: 36 r.l, ~1.7m.f.p



Detector Components

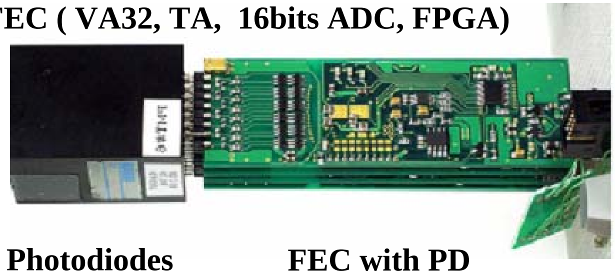


SciFi Belt (32 x 2 layers)

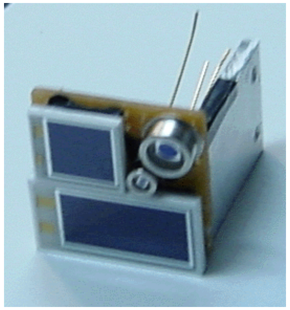


64-anode PMT

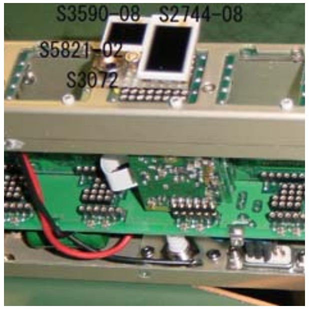
FEC (VA32, TA, 16bits ADC, FPGA)



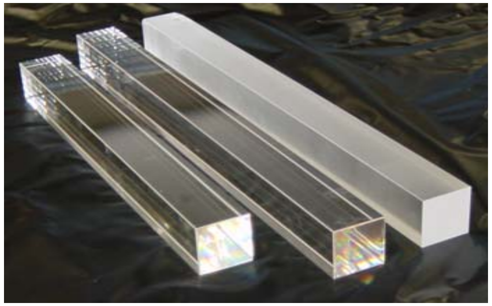
Si PIN Photodiodes



FEC with PD

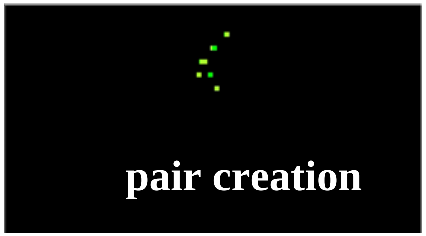


BGO or $PbWO_4$

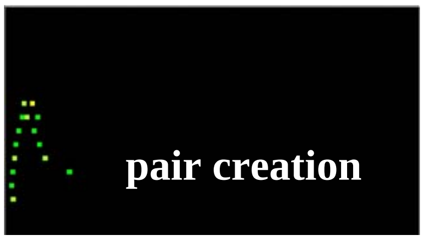


Examples of Shower Profile by Simulation

Gamma-ray 20 MeV

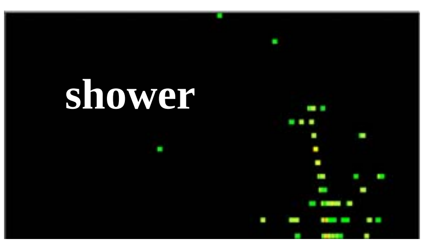


Gamma-ray 100MeV

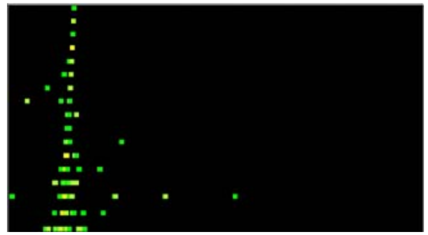


Gamma-ray 1GeV

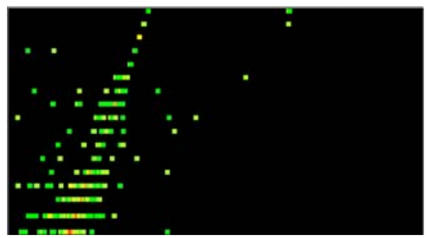
Gamma-ray 10GeV



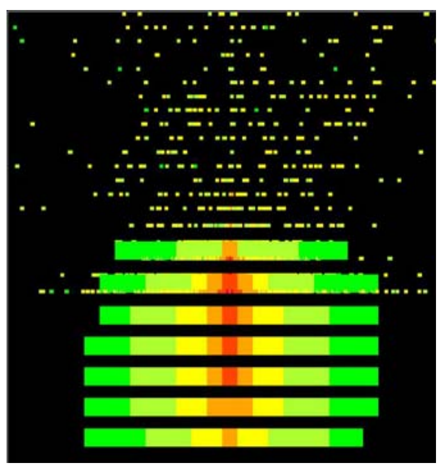
Electron 10 GeV



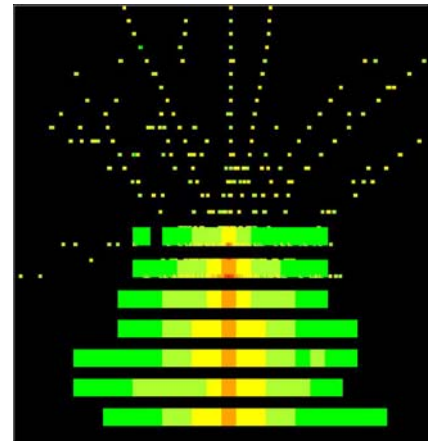
Electron 100 GeV



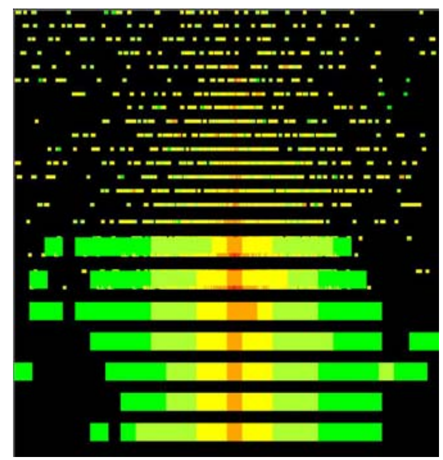
Electron 10 TeV



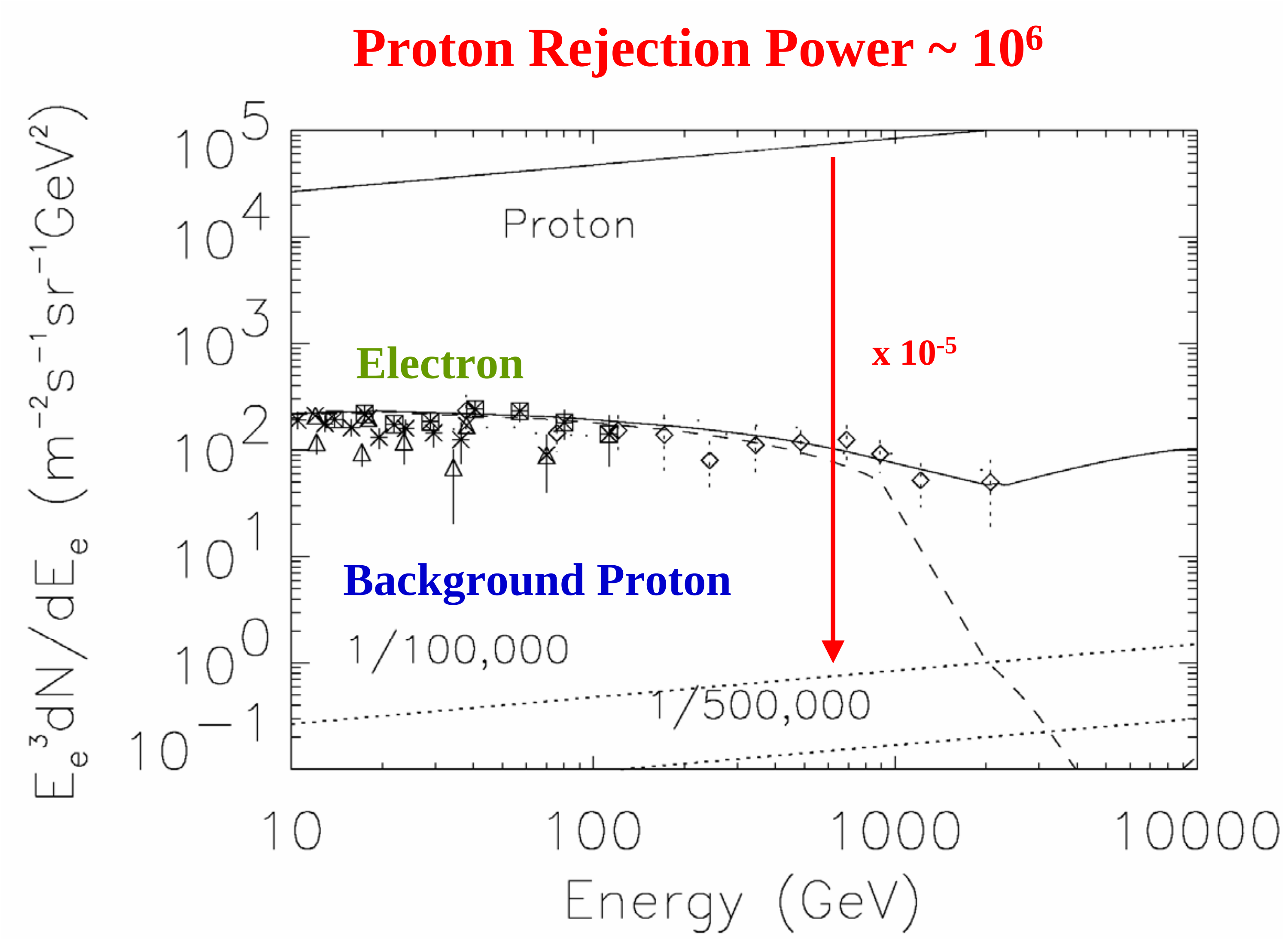
Proton 3 TeV



Proton 3 TeV

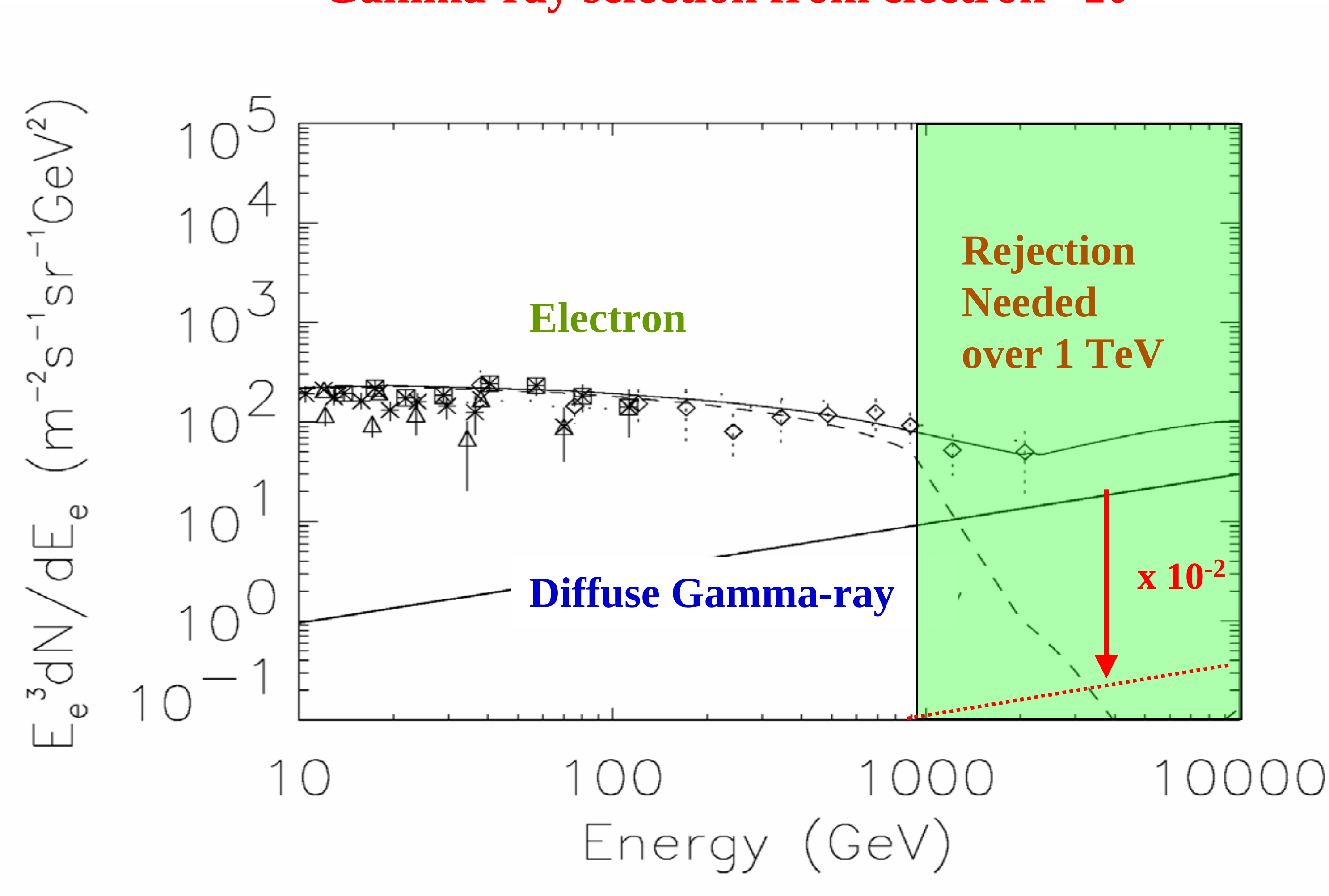


Electron Detection by CALET

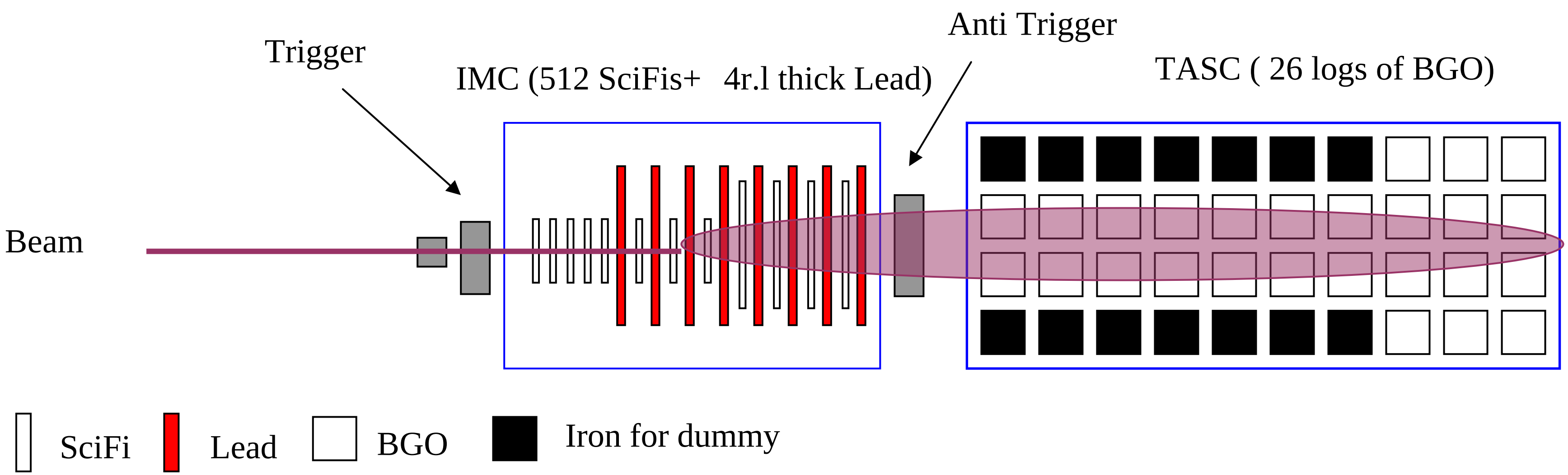


Electron and Gamma-ray Separation

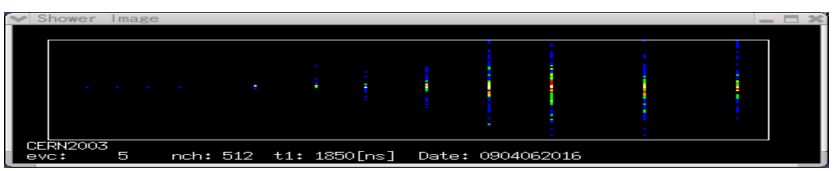
Gamma-ray selection from electron ~10^2

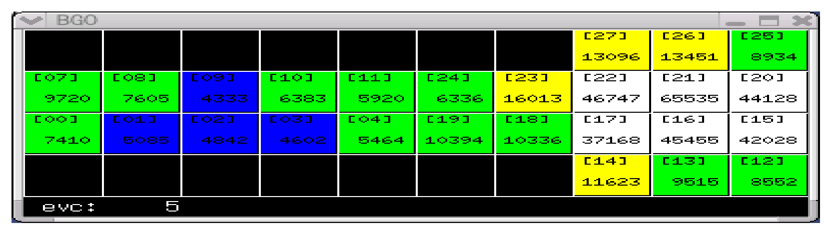


Examples of Observed Showers in Beam Test at CERN



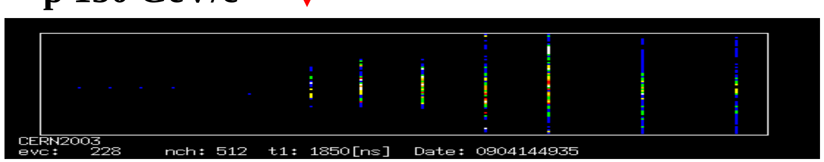
e 100 GeV/c

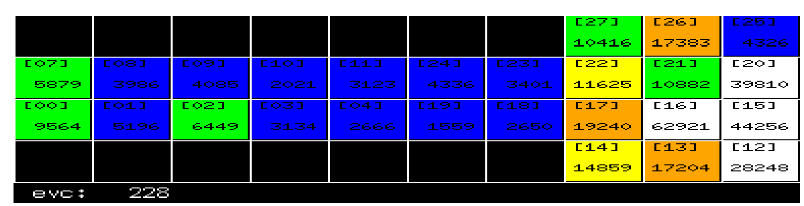




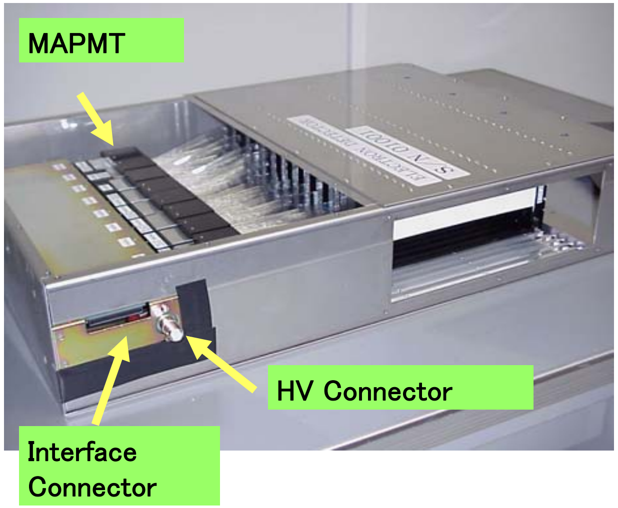
interaction

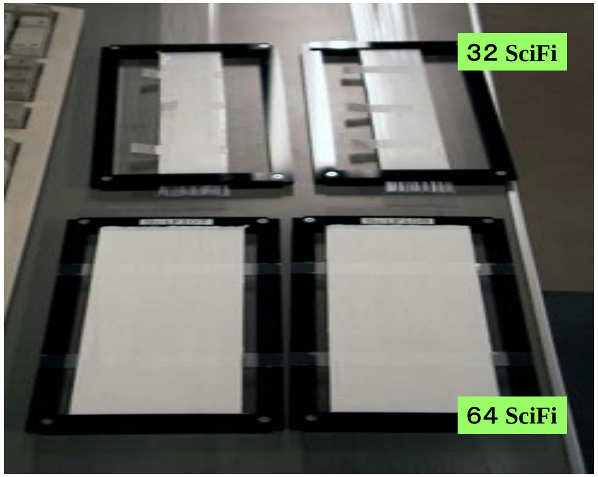
p 150 GeV/c





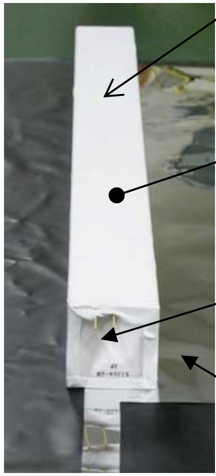
Imaging Calorimeter





SciFi Belts

Total Absorption Calorimeter



BGO Crystal

25mm×25mm×300mm

Teflon Sheet

0.1mm thick×3

Photodiode

S3204-08

Area 18mm×18mm

Aluminized Sheet

12μthick on both side

Pre-amplifier

Beam

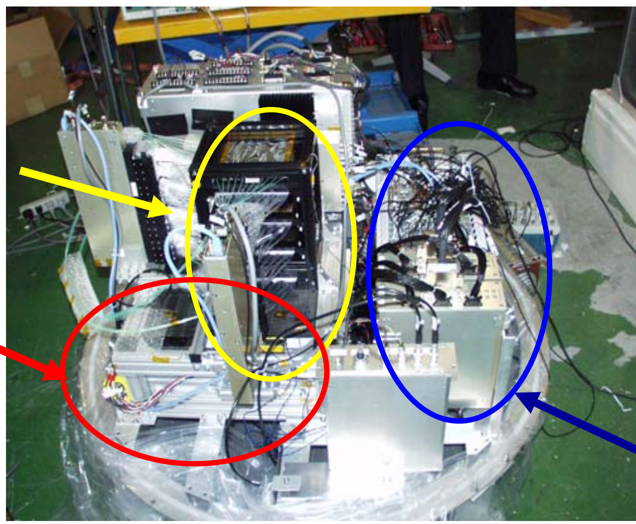
Shaping Amplifier

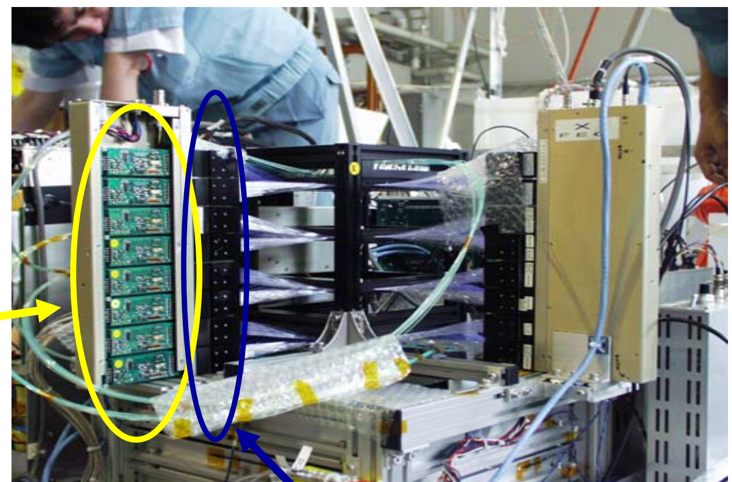
Shaping time ~2μs

BGO Logs and PD

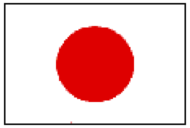
CALET ~1/64 Scale Model for Balloon Experiment in 2006

- ***Effective Area : 128 mm ×128 mm (~164cm^2)***
- ***IMC : 1024ch SciFi (1mm square) + 64-Anode PMT***
- ***TASC : 24ch BGO Logs (2.5 cm ×2.5cm ×30cm) + Si PIN PD***





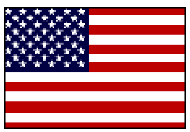
Member List



Japan :

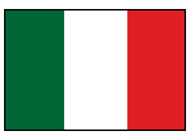
S. Torii(1), N. Hasebe(1), M.Hareyama(1), N.Yamashita(1), T. Tamura(2), N. Tateyama(2), K. Hibino(2), T. Yuda(2), K. Yoshida(2), K. Kashiwagi(2), S.Okuno(2), J. Nishimura(3), T. Yamagami(3) , Y. Saito(3), H. Fuke(3), M.Takayanagi(3), H. Tomida(3), S. Ueno(3), F. Makino(3), M. Shibata(4), Y. Katayose(4), S. Kuramata(5), M. Ichimura(5), Y. Uchihori(6), H. Kitamura(6), K. Kasaharah(7), H. Murakami(8), T. Kobayashi(9), Y. Komori(10), K. Mizutani(11), T. Terasawa(12)

(1) RISE, Waseda University (2) Kanagawa University (3) JAXA (4) Yokohama National University (5)Hirosaki University (6) National Institute of Radiological Sciences (7) Shibaura Institute of Technology (8) Rikkyo University (9) Aoyama Gakuin University (10) Kanagawa University of Human Services (11) Saitama Universit (12) University of Tokyo



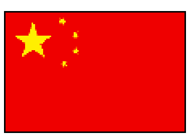
USA:

NASA/GSFC: **R.E.Streitmatter, J.W.Mitchell, L.M.Babier** ***USRA:*** **A. A.Moissev, J.F.Krizmanic**
Louisiana State University: **G.Case, M. L. Cherry, T. G. Guzik, J. B. Isbert, J. P. Wefel**
Washington University in St Louis: W. R. Binns, M. H. Israel, H. S. Krawzczynski
University of Denver : J. F. Ormes



Italy :

University of Siena and INFN:
P.S.Marrocchesi , P.Maestro, M.G.Bagliesi, V.Millucci , M.Meucci , G.Bigongiari , R.Zei
University of Florence: **O. Adriani, P. Papini, P. Spillantini, L. Bonechi, L.E. Vannuccini**
Scuola Normale Superiore & INFN Pisa : **F.Morsani ,F.Ligabue**

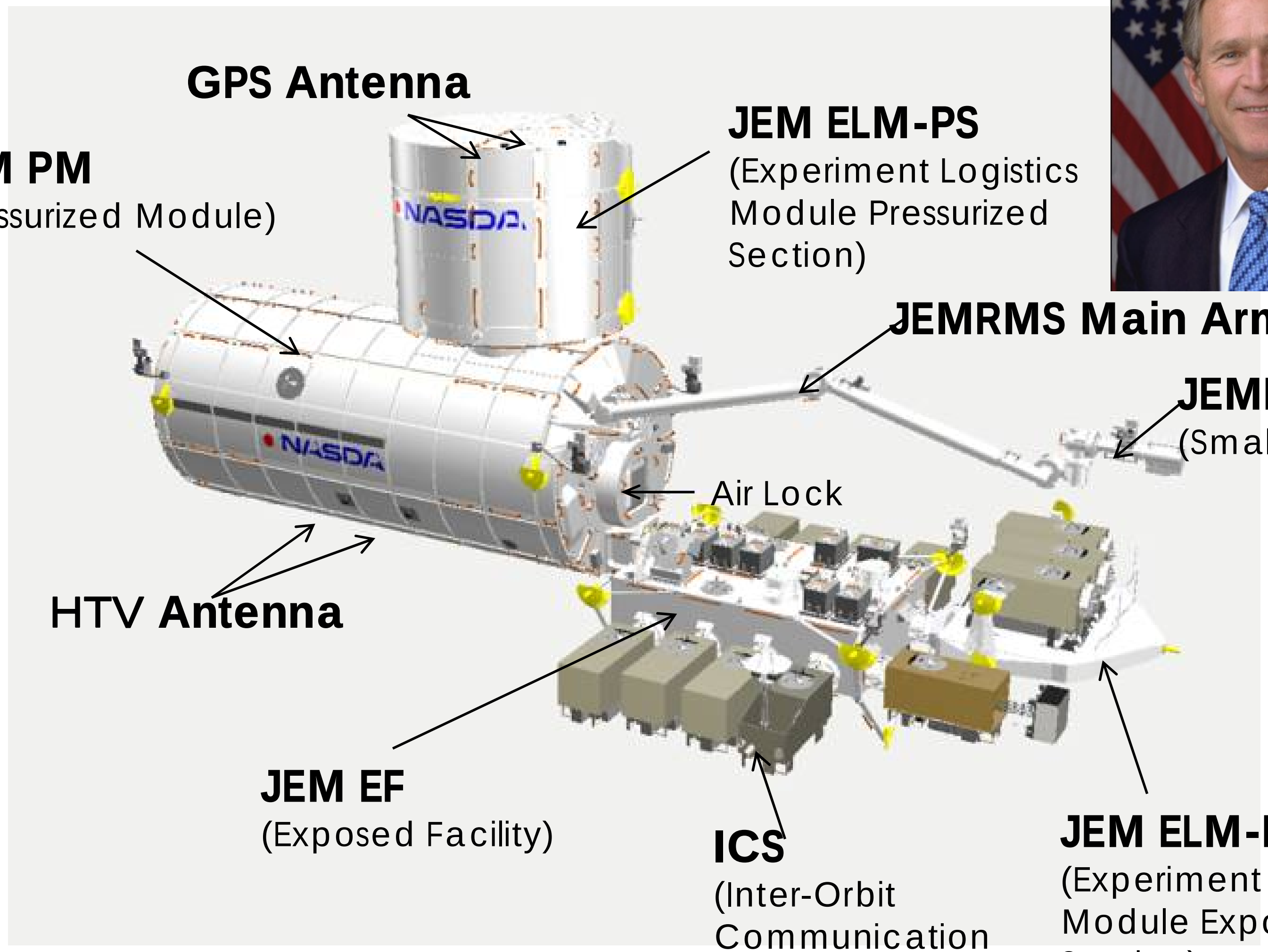


China :

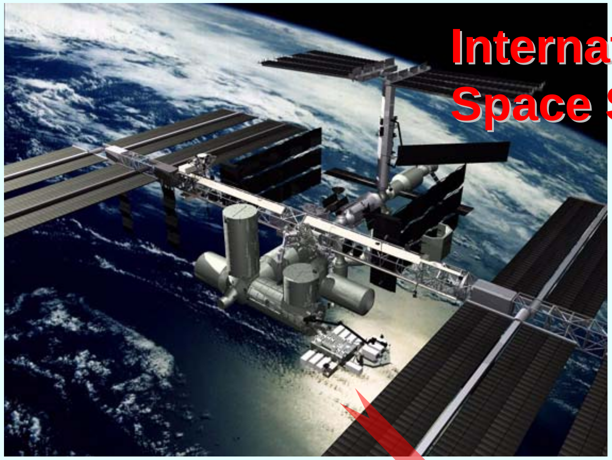
Purple Mountain Observatory, Chinese Academy of Science: **J. Chang, W. Gan, T. Lu**

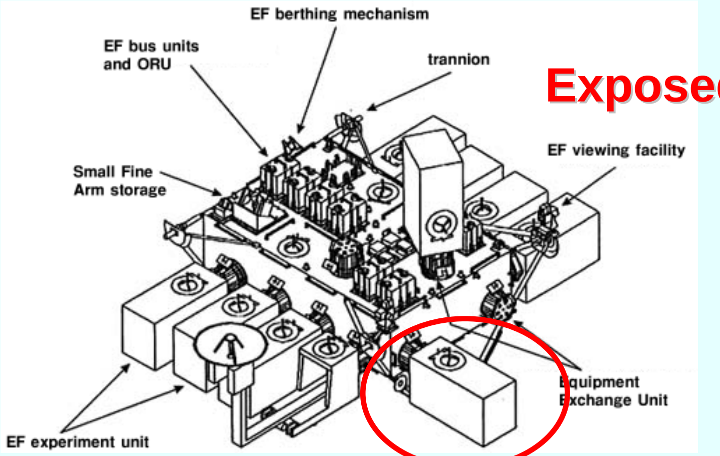
Thanks very much to both !!!

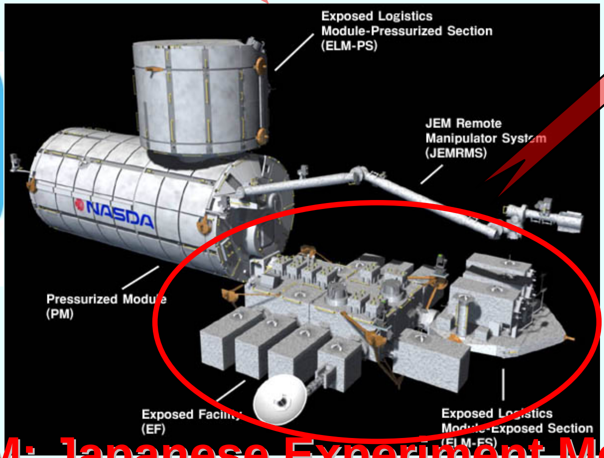
JEM (KIBO) Survived



CALET on JEM/EF Facility







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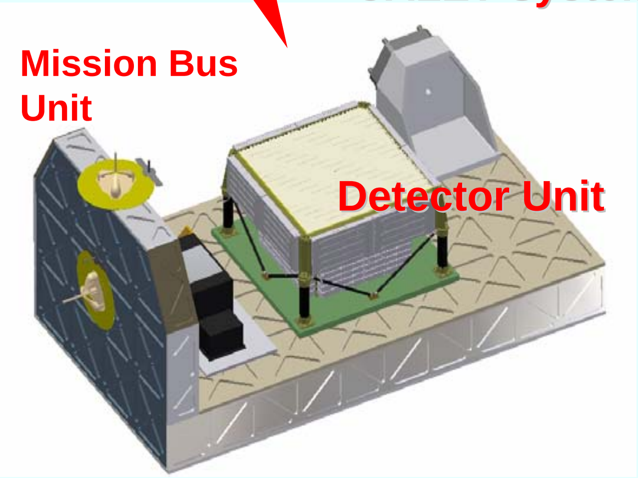
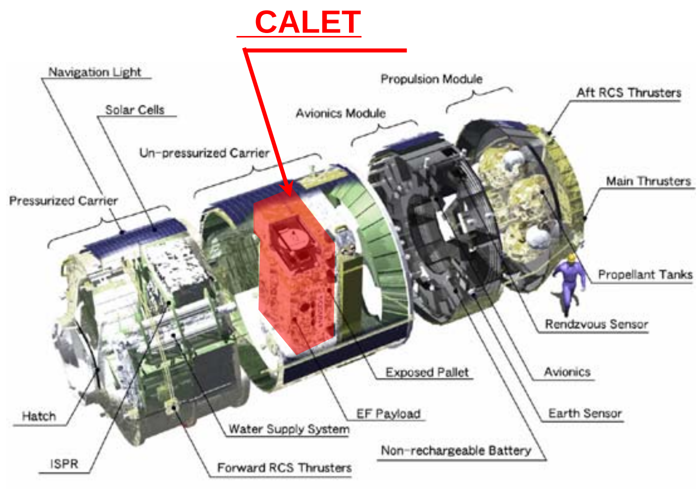


Launching Procedure of CALET

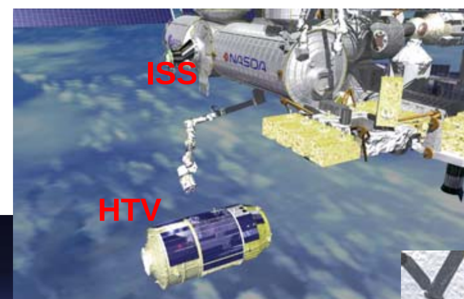


H-IIA Transfer Vehicle (HTV)
(Japanese Carrier)

Launching of H-II Rocket

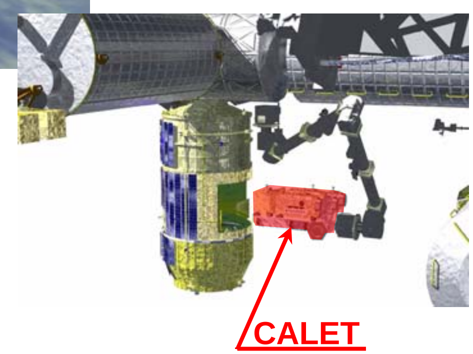
CALET launched by HTV

Separation from H-II



Approach to ISS

Pickup of CALET



Summary and Future Prospects

- ✓ The JEM/EF facility of ISS is very suitable to cosmic ray observation at very high energies with a heavy payload.
- ✓ We have successfully been developing the CALET instrument for JEM/EF facility from the experience of balloon experiments.
- ✓ The CALET has capabilities to observe the electrons up to 10 TeV , gamma-rays in 20 MeV- a few TeV , proton and heavy ions in several 10 GeV - 1000 TeV, for investigation of high energy phenomena in Universe.
- ✓ We have already completed a pre-phase A study in last 6 years, and expect to start operations on the ISS/JEM around 2012.

This work is supported by a part of "Ground-based Research Announcement for Space Utilization" promoted by Japan Space Forum