南極周回気球により観測された電子・陽電子スペクトルとその解釈

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PPB-BETS

PPB: Polar Patrol Balloon
BETS: Balloon borne Electron Telescope with Scintillating fibers

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High-Energy Cosmic-Ray Electrons

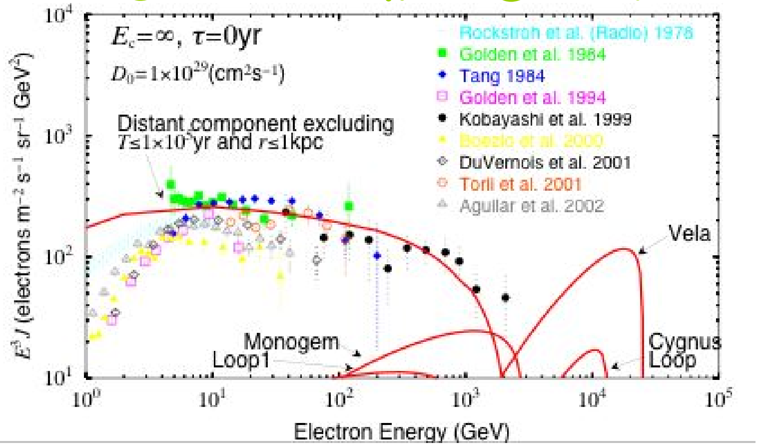
– Identification of nearby cosmic-ray sources (SNRs)

– Investigation of acceleration mechanism

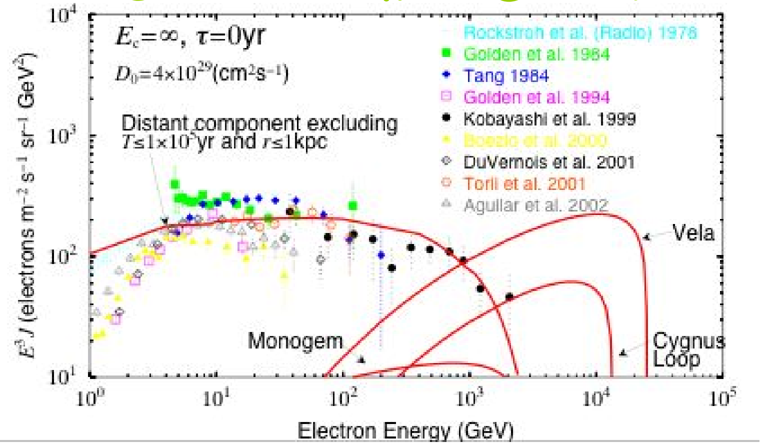
– Investigation of propagation in the Galaxy

Calculated electron energy spectra with the observations

$D=1\times10^{29}cm^2s^{-1}$@1TeV



$D=4\times10^{29}cm^2s^{-1}$@1TeV



Kobayashi et al. 2004

– Search for WIMP dark matter annihilation to e+e-

=> High Energy Electron Observations above 100GeV

Characteristics of Cosmic-Ray Electrons

Electron Energy Loss by
- **Inverse Compton Scattering**
- **Synchrotron Radiation**

Electron Propagation in the Galaxy
- **Diffusion Process**

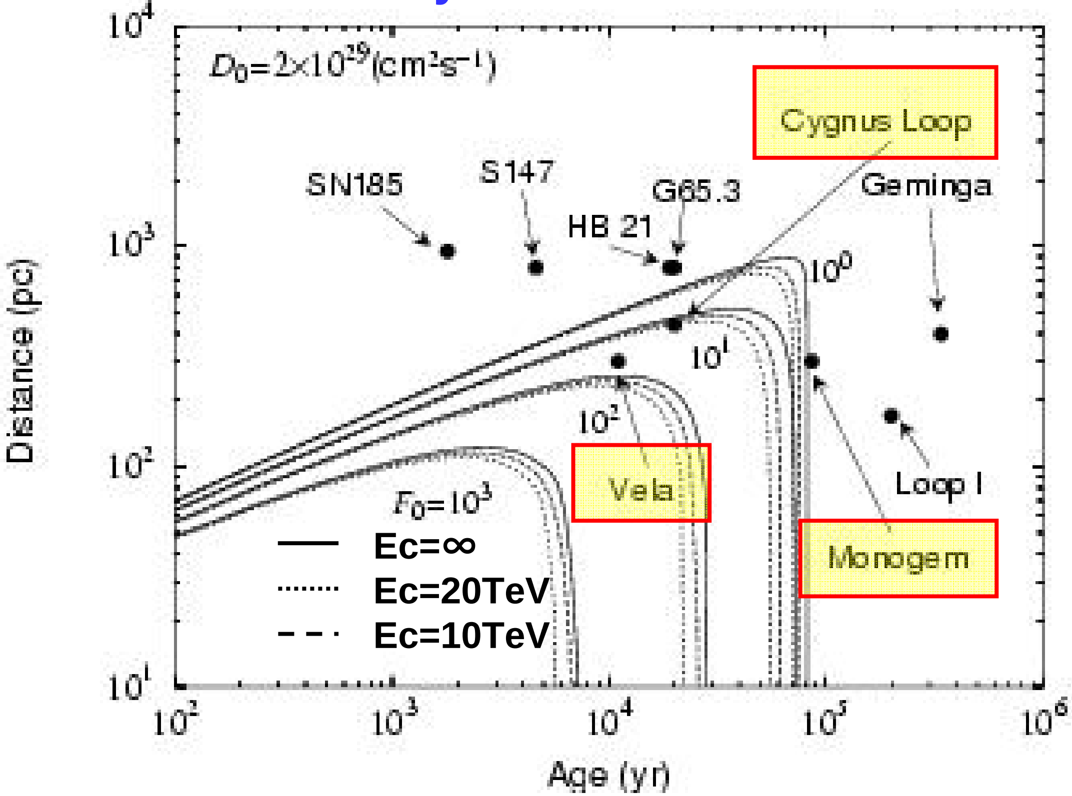
Electron Density Equation

$$\frac{dNe}{dt} - \nabla(D\nabla Ne) - \frac{\partial}{\partial E}(bE^2 Ne) = Q$$

Anisotropy

$$\Delta_i = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} = \frac{3D}{c}\frac{\nabla N_i}{N_i} = \frac{3R_i}{2ct_i}$$

Nearby Source Candidates



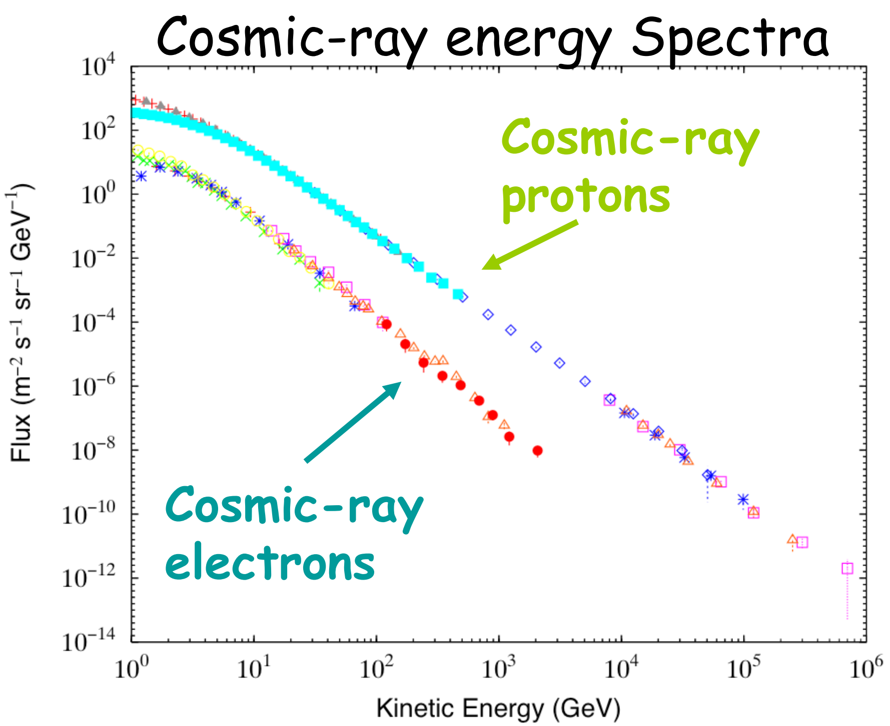
Energy Loss Rate
dE/dt = -bE²

T*(Age) = *1/bE
***R*(Distance)=(*2DT*)$^{1/2}$**

1 TeV Electron Source:
- **Age < 10^5 years**
- **Distance < 1 kpc**

Vela
Cygnus Loop
Monogem
or
Unobserved Sources?

Electron Observation above 100GeV

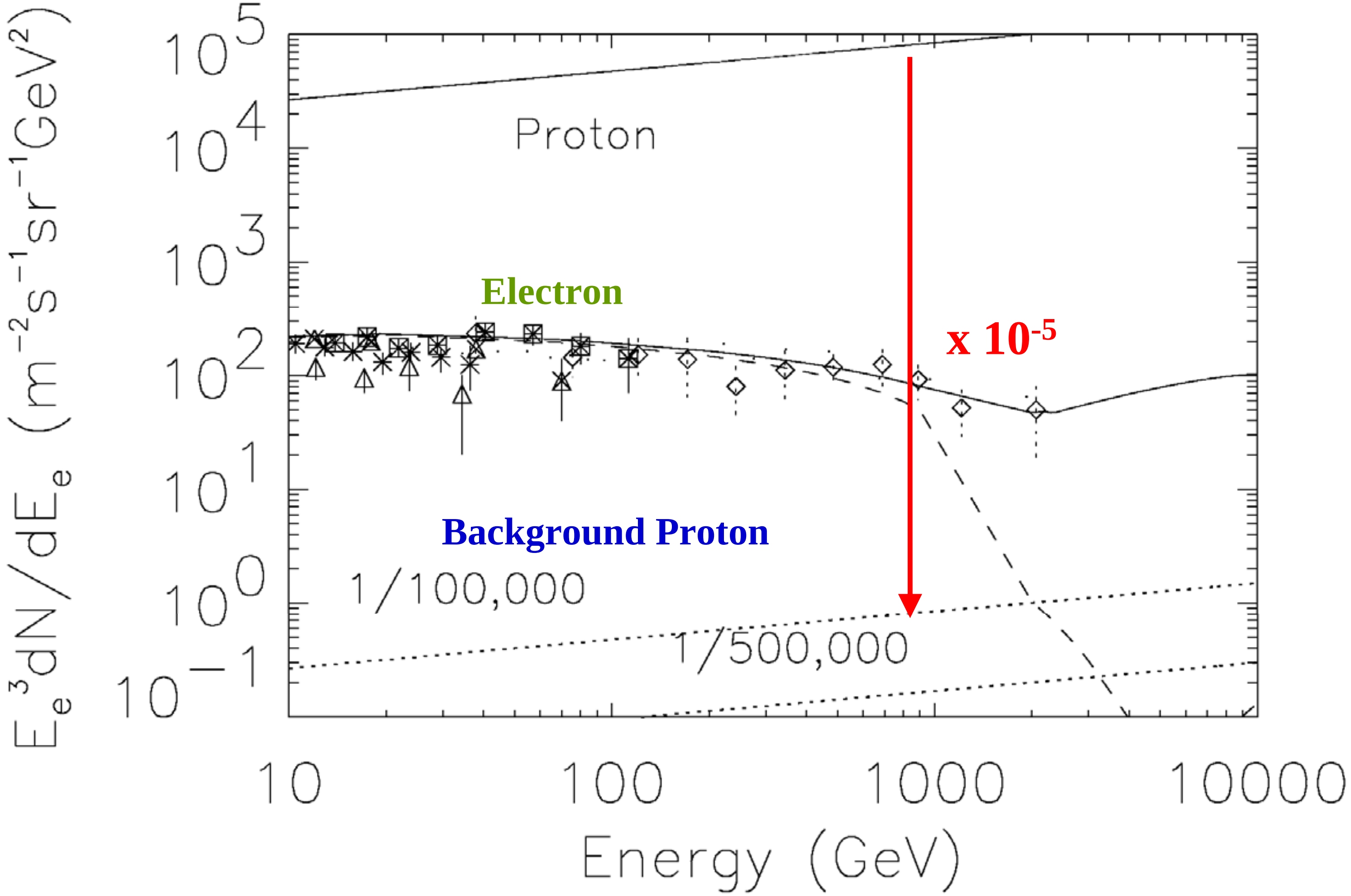


- Flux of electrons:
  ~1% of protons @10GeV
- Spectrum of electrons:
  steeper than protons
  power-law index:
  e:~-3.0, p:-2.7

=> As higher energies,
Lower electron flux
Lager proton backgrounds

Large amount of exposures
with a detector of high proton rejection power

=> Long duration balloon flight with PPB-BETS
by Polar Patrol Balloon in Antarctica



$E_e^3 dN/dE_e$ ($m^{-2}s^{-1}sr^{-1}GeV^2$)
Proton
Electron
x 10^{-5}
Background Proton
1/100,000
1/500,000
Energy (GeV)

The PPB-BETS Experiment

- BETS

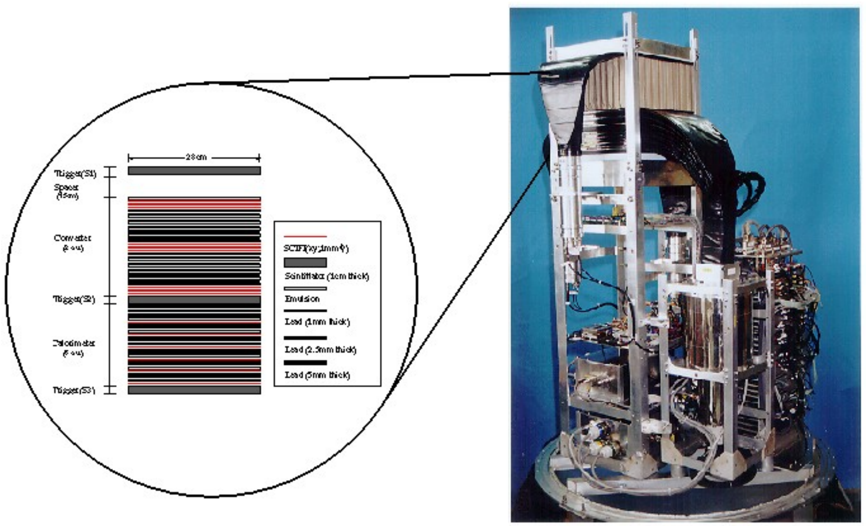
(Balloon-borne Electron Telescope with Scintillating Fibers)
  - Imaging calorimeter with scintillating fiber (SCIFI)
  - 10 ~ 100 GeV cosmic-ray electrons
  - Launched two times (1997,1999) at the Sanriku Balloon Center, Japan

- PPB-BETS
  - Higher energy electron (10 GeV ~ 1 TeV)
  - PPB (Polar-Patrol Balloon)
  - Long duration observation
    - Automatic level control
    - Power supply by solar batteries
    - Data transfer with Iridium satellite phone system
    - …

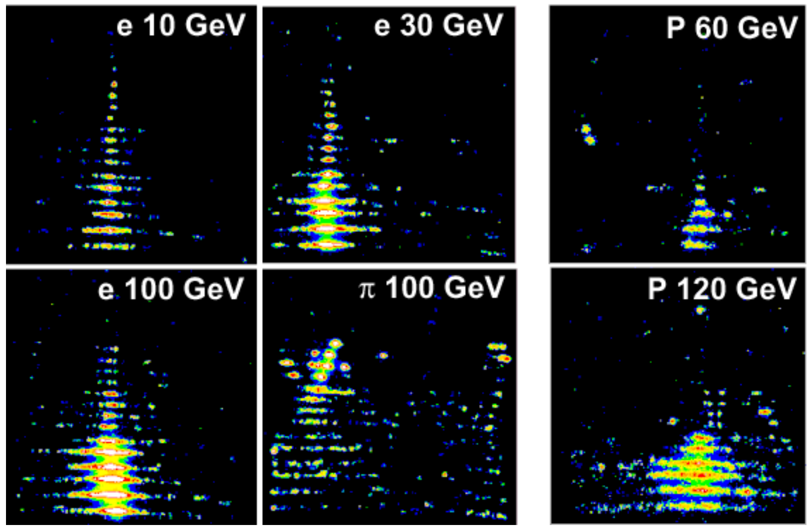
Electron & Gamma-Ray Observation with BETS

BETS: Balloon borne Electron Telescope with Scintillating fibers

- **Development of SciFi/lead imaging calorimeter for electrons**
  NIM 457, 499-508 (2001)
- **Successful observation of electrons in 10-100 GeV**
  ApJ 559, 973-984 (2001)
- **Observation of atmospheric gamma-ray flux with improved BETS**
  Phys Rev D 66, 052004(1-9) (2002)



BET Instrument



Shower Image at CERN

Balloon Flight

- Launched at the Syowa Station, Antarctica
- Level Altitude ~34.6 km
- 13 days flight

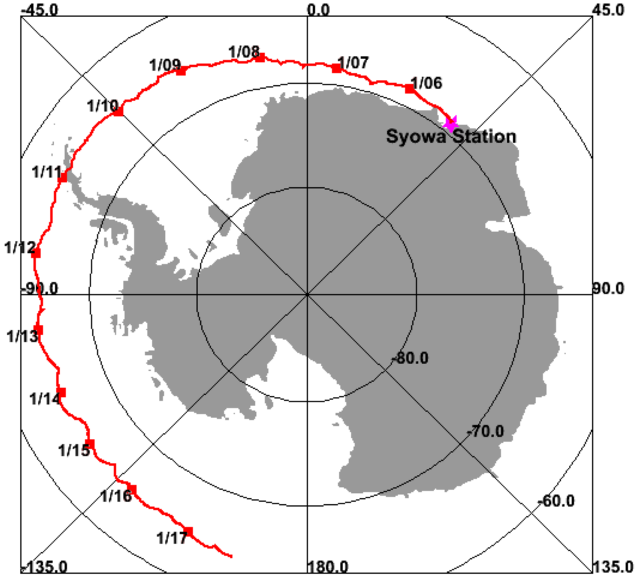
  (Jan. 4, 2004 to Jan. 17)

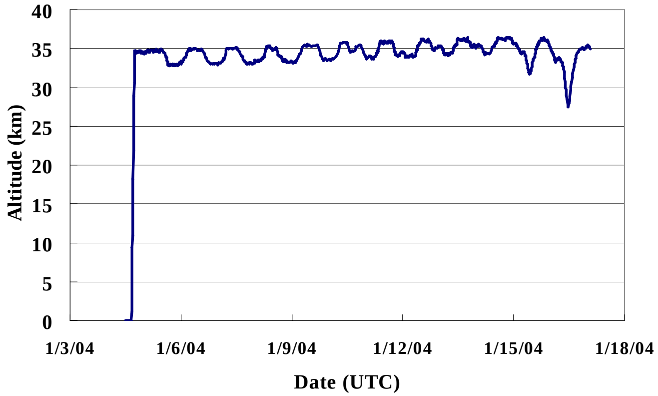
  HE (>100 GeV)

  ～5700 events, (0.02 Hz)

  LE(>10GeV)

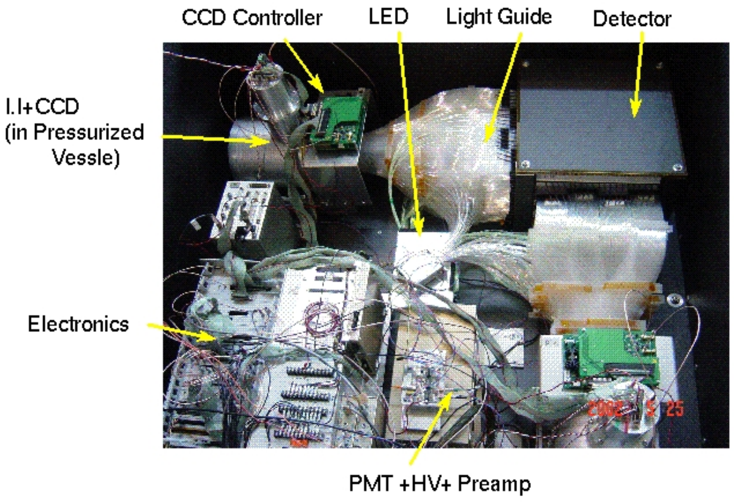
  ～22000 events, (3 Hz)



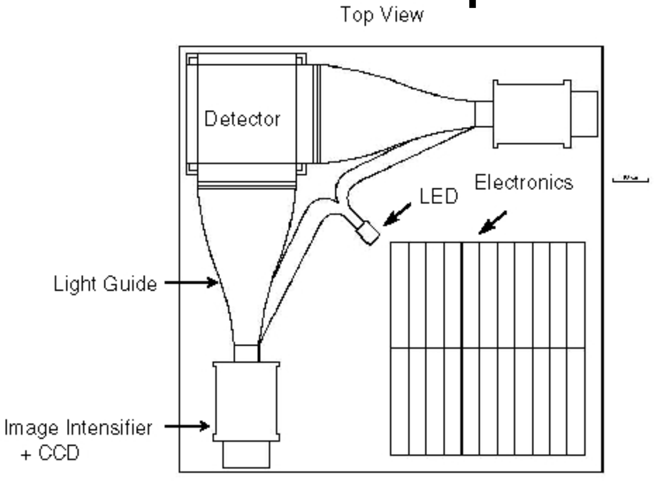


Instrument and Flight in Antarctica

View of PPB-BETS



Schematic Top View



Payload in Antarctica

Basic Parameters of PPB-BETS

Detector Weight	200 kg	including un-pressurized gondola
(Total Weight including ballast for 30 days		500 kg)
Power Consumption	70 W	supplied by solar batteries
Observation Altitude	~35 km	controlled by auto-level system
Data Transfer Rate	2.4 kbps	by the Iridium telephone line
	(64 kbps	by the telemetry to the stations)

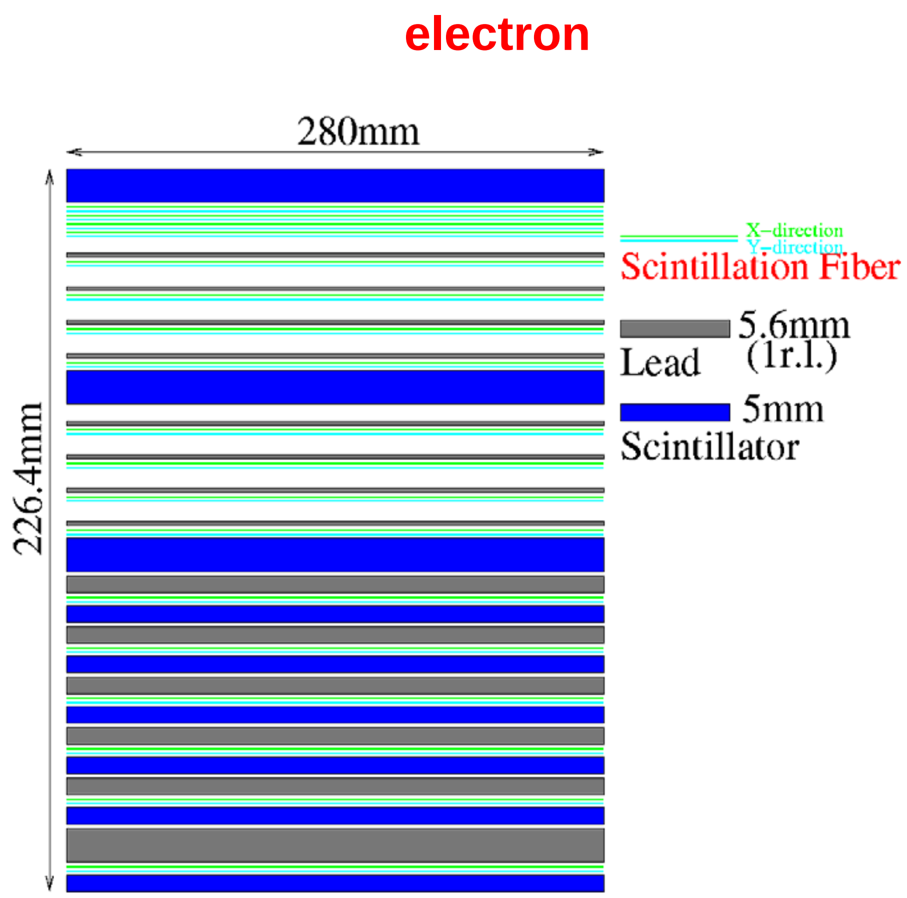
Energy Range	10 ~1000 GeV	by two modes of trigger
Geometrical Factor	550~600 cm^2sr	by simulation (> 100 GeV)
Energy Resolution	12~ 16 %	by plastic scintillators
Angular Resolution	0.35~ 0.6 degrees	by shower image of SciFis

BETS（国内）から PPB−BETS（南極）へ

	BETS	PPB-BETS
エネルギー領域	10 ～ 100 GeV	10 GeV ～ 1 TeV
気球フライト	三陸ブーメラン	南極周回
	4.5時間（1997）	13日間
	8.3時間（1998）	
回収	海上回収	（昭和基地に戻ってきたときのみ）
装置重量	380 kg	200 kg
バラスト	100～150 kg	240 kg
	コマンドコントロール	オートレベルコントロール
真空対策	耐圧容器	部分的に耐圧容器、熱対策、放電対策
電力供給	リチウム電池	太陽電池 + 二次電池
データ記録	テレメトリ（32 kbps）	テレメトリ（64 kbps）
	磁気テープ（5 GB）	イリジウム衛星電話（2.4 kbps）
		シリコンディスク（1 GB）

PPB-BETS Detector "Imaging Calorimeter"

BETS	PPB-BETS
Lead thickness	
7.1 r.l	9 r.l
Number of plastic scintillators	
3	9
Maximum shower energy observed without saturation in CCD	
100 GeV	1000 GeV
Telemetry	Telemetry via Satellite
Battery	Solar Battery



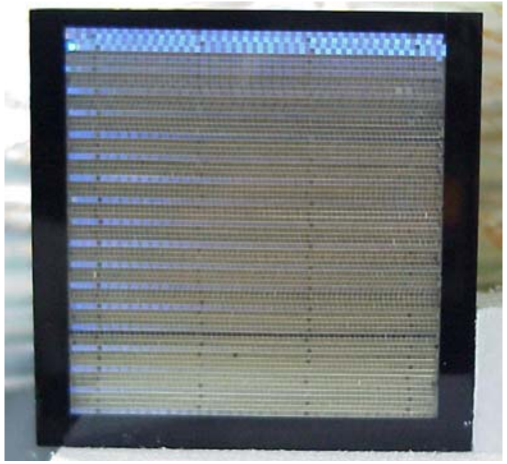
Side view of the detector

Readout from SCIFIs

- SCIFI

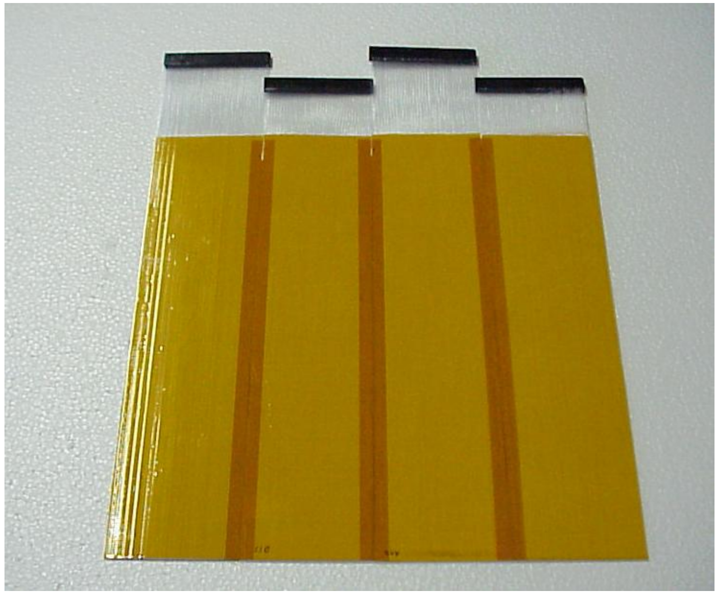
→ Light guide of optical fiber

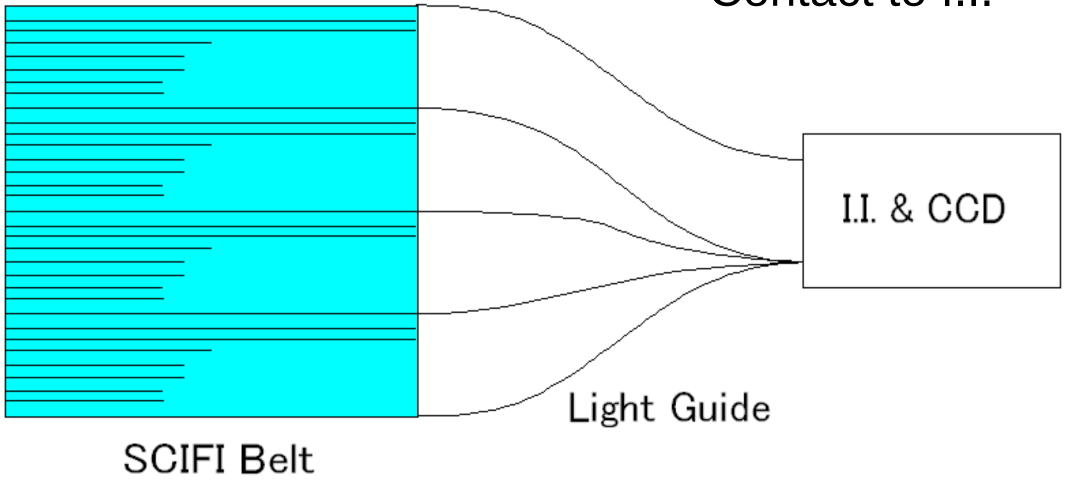
→ Image Intensifier (I.I.) & CCD



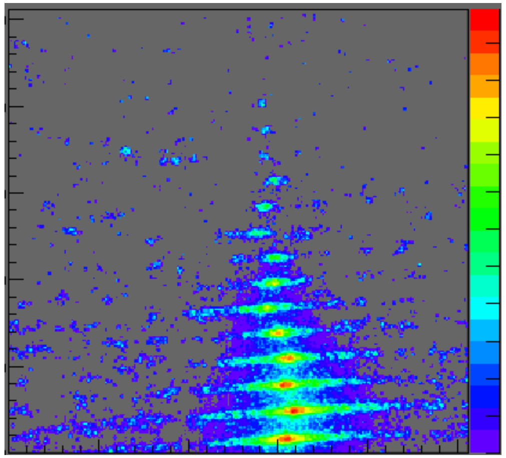
Contact to I.I.

SCIFI belt

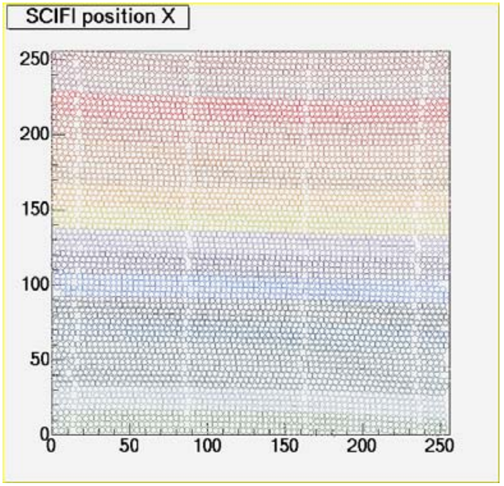




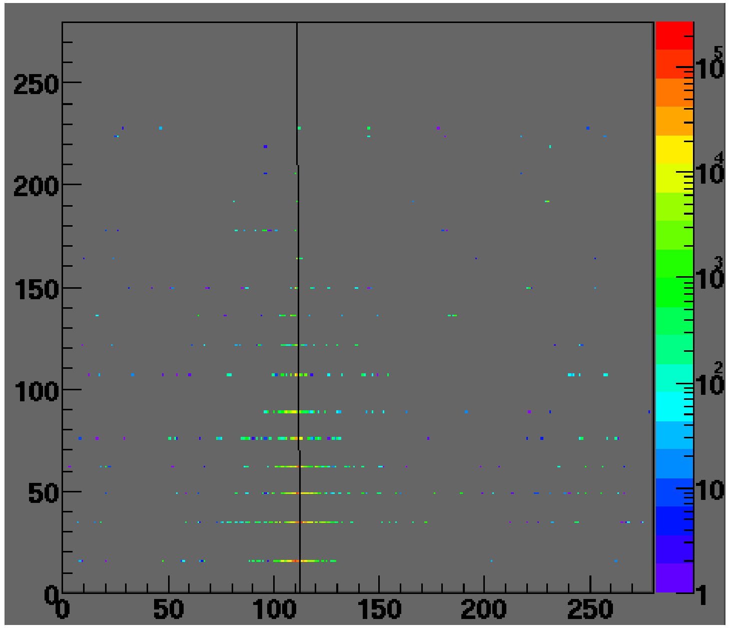
Conversion of CCD Image to Shower Profile in Detector



Raw CCD Image



SciFi Positions in CCD Image.

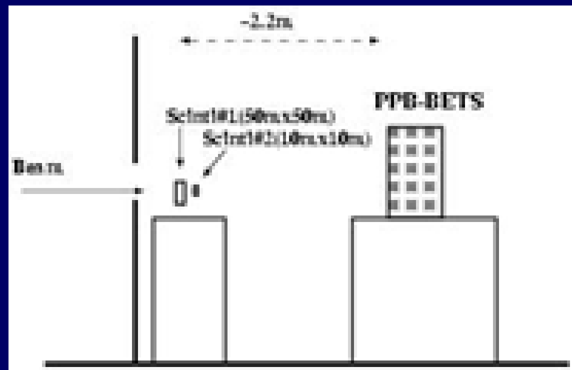


Reconstructed image in the detector space. Colors represent the relative light yield in each SciFi. The black line shows projected shower axis.

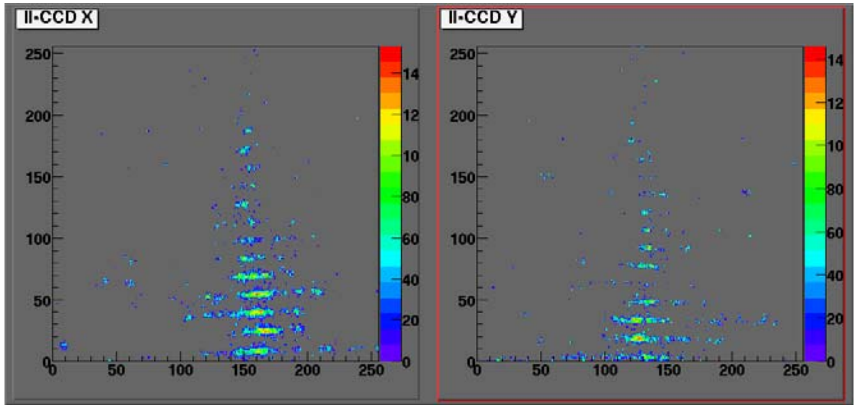
Calibration by Accelerator Beams

CERN-SPS
- October 2001
- Electron: 10 ~ 200 GeV
- Proton: 150 ~ 350 GeV

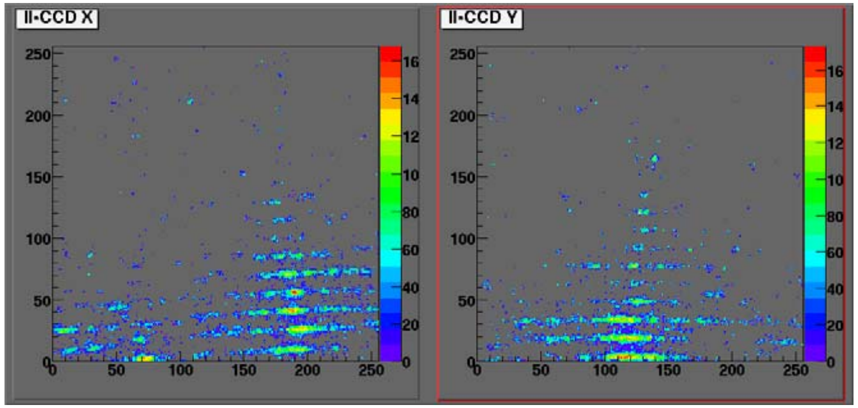
- Electron-Proton discrimination
- Energy Resolution
- Detection Efficiency
- Angluar Resolution
- Data Size



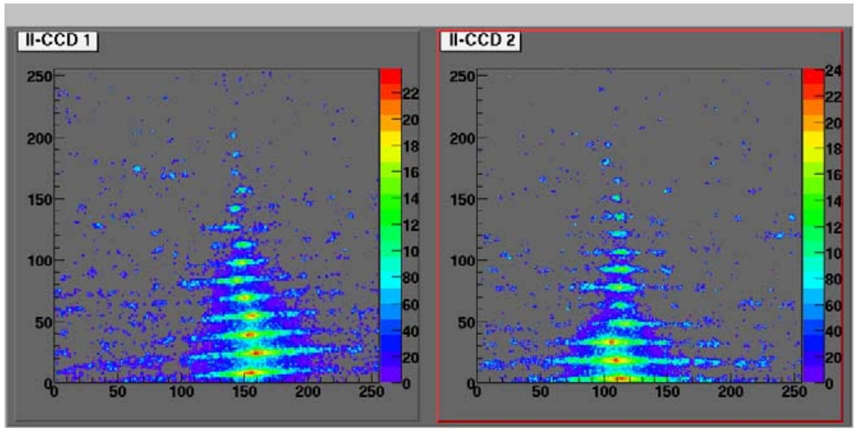
Examples of CCD images



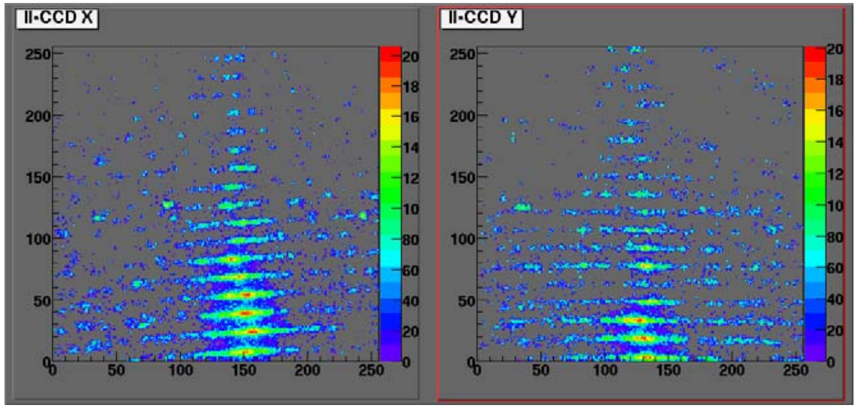
50 GeV electron



150 GeV proton

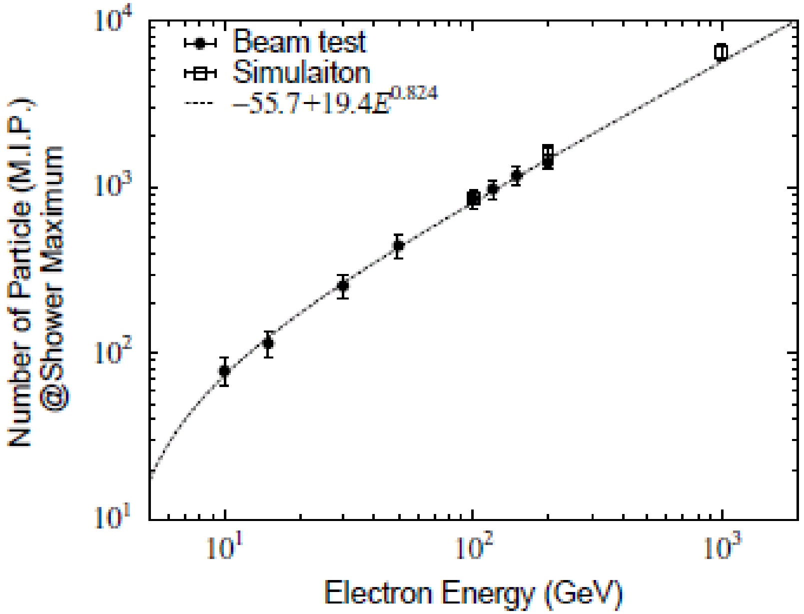


200 GeV electron

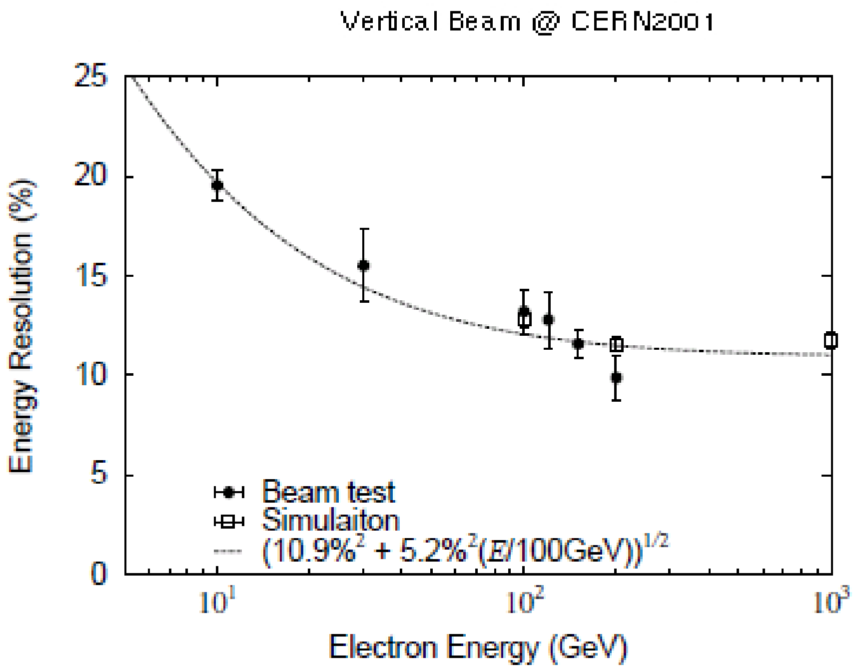


350 GeV proton

Energy Resolution by the Beam Test



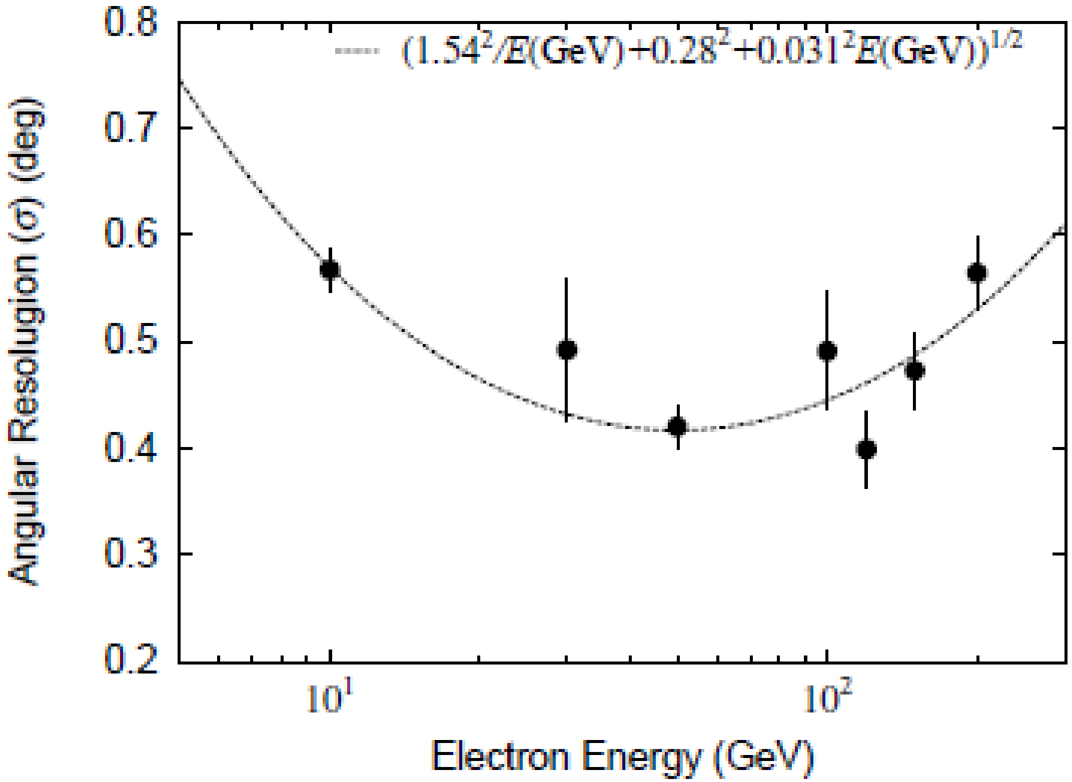
Relation of pulse height and electron beam energy @ 9 r.l.



Dependence of energy resolution on beam energies.

Energy Resolution ~12% @100GeV

Angular Resolution by Beam Test



Selection of Electron Events

Reduction of proton backgrounds:

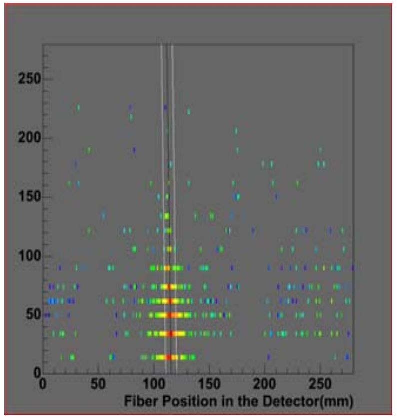
On-board Trigger by the 1st and 2nd levels
~ 95 % (1/20)

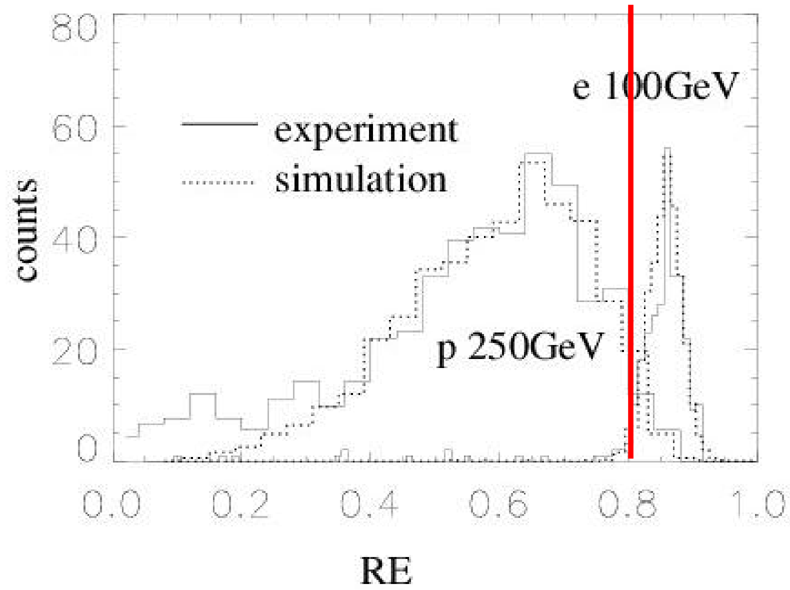
Selection of Contained Events in Detector
~ 90 % (1/10)

Shower Image Analysis
~95 % (1/20)

RE parameter:
Energy Concentration in Shower

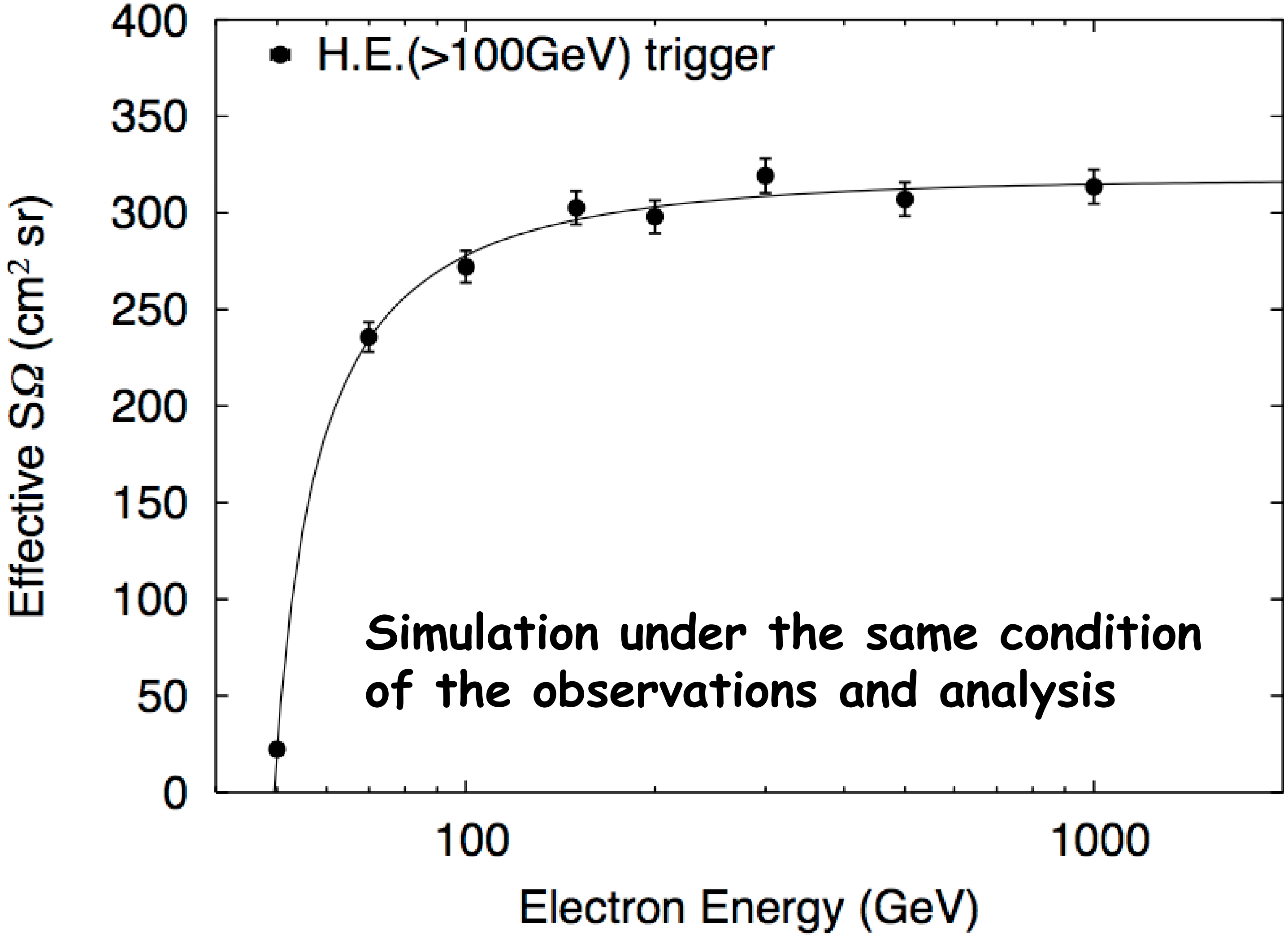
$$RE = \frac{\text{within 5 mm from the axis}}{\text{Total}}$$





Total Rejection Power of Protons: 0.05 x 0.1 x 0.05 = 2.5x 10^{-4} (~1/4000)

Effective Geometrical Factor (SΩ)

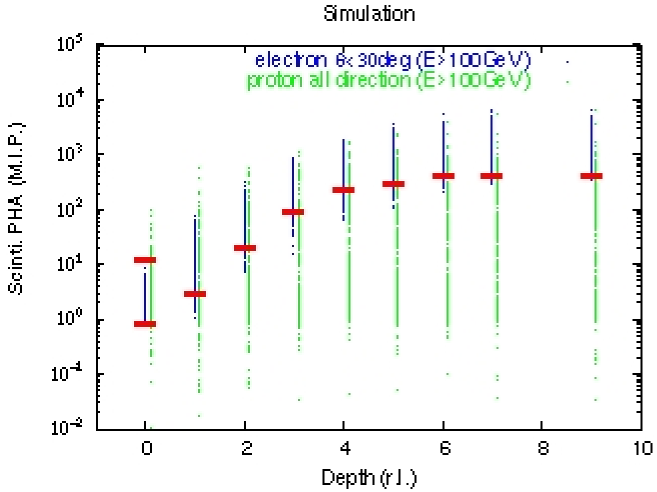


Event Trigger during Flight

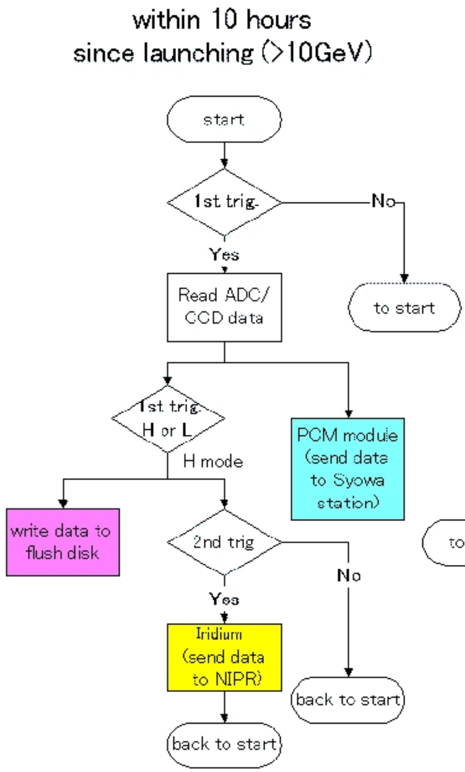
Telemetry via satellite (2.4 kbps):
- **HE trigger mode (>100 GeV)**
  - **~1 electron/ h and 50 backgrounds/h**

Telemetry to the stations (64kbps)
- **LE trigger mode (> 10 GeV)**
  - **~ 100 electrons/h and 2 Hz backgrounds**

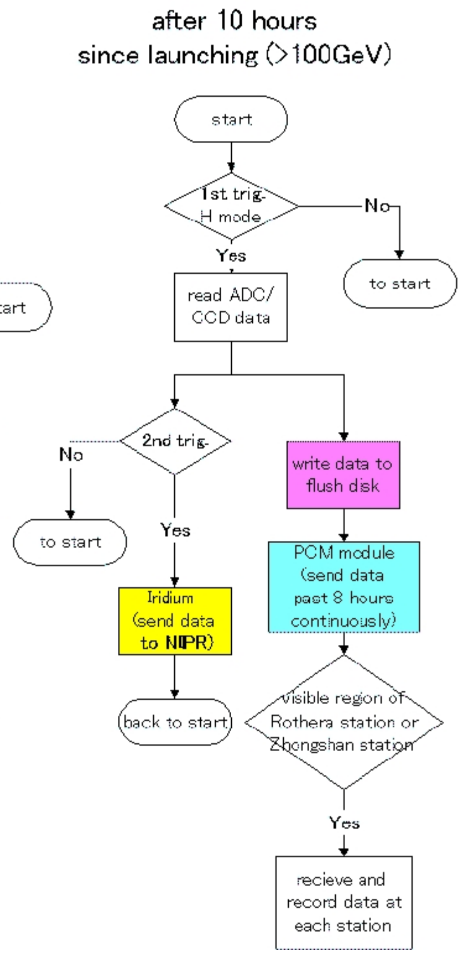
HE 1-st Trigger by Shower Development



LE Trigger mode
for showers> 10 GeV



HE Trigger mode
for showers> 100 GeV



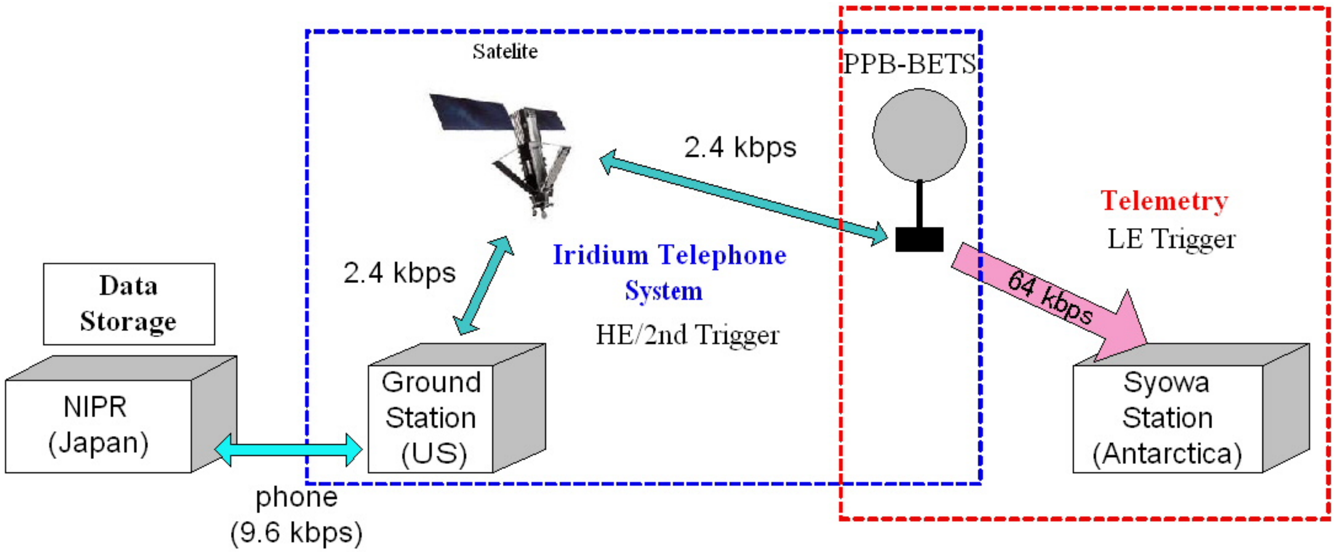
Trigger and Data Transfer System

- Low Energy (LE) Trigger
  - 10 GeV – 100 GeV
  - 10 hours from launching
- High Energy (HE) Trigger
  - 100 GeV – 1 TeV
- 2nd Trigger
  - Software trigger selected from HE

Direct telemetry to Syowa Station

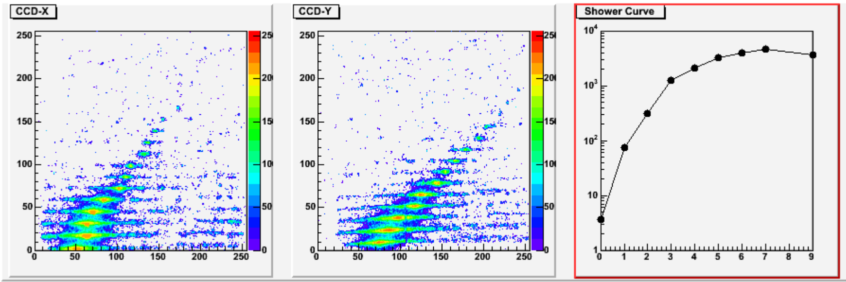
Storage to on-board disk

Iridium satellite telephone

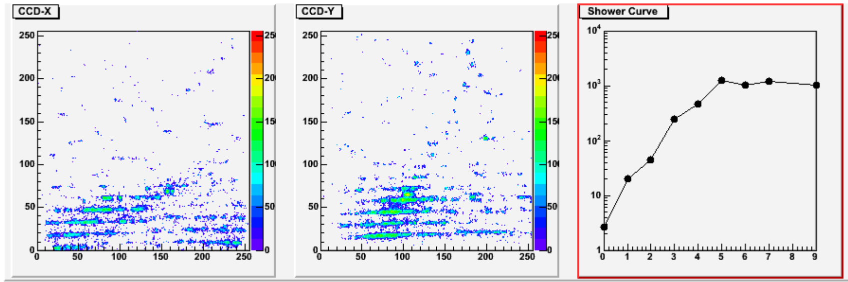


Examples of Observed Events

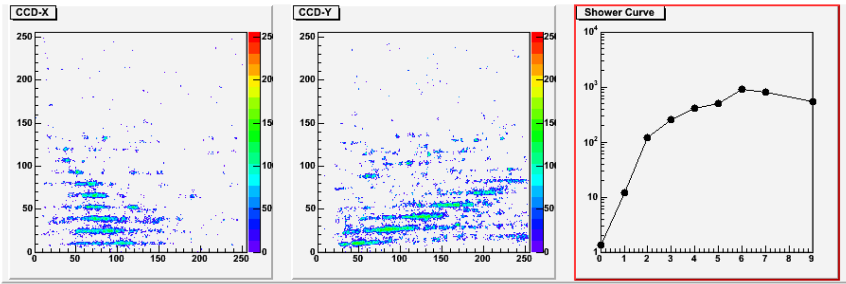
X,Y Image by CCD   Transition Curve



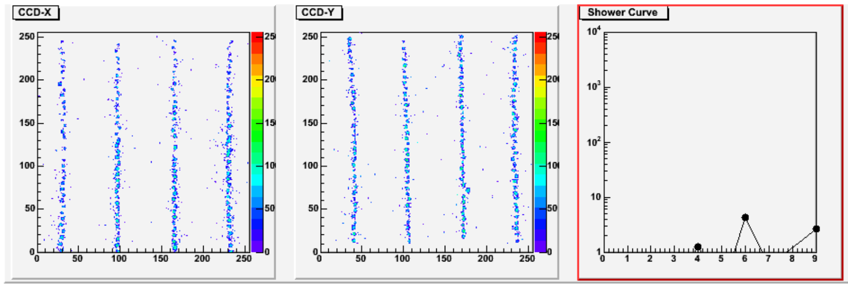
Electron-like Event



Proton-like Event



Proton –like Event

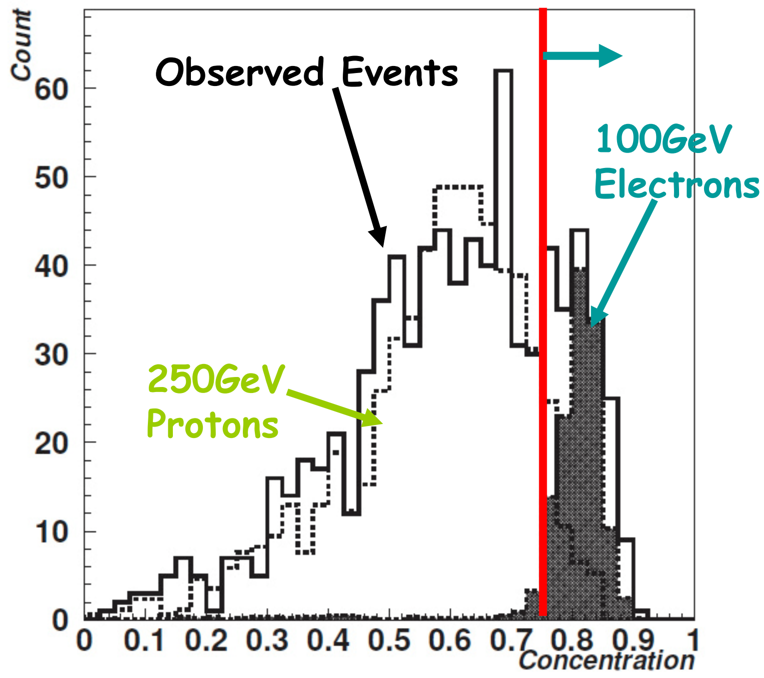


LED Calibration

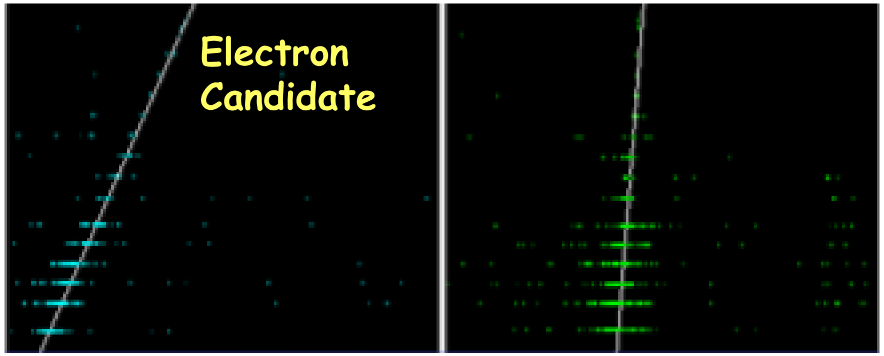
Electron Selection -Proton Rejection-

Proton Rejection Power:
- Onboard Trigger : ~95%
- Contained Events : ~90%
- Energy Concentration : ~95%

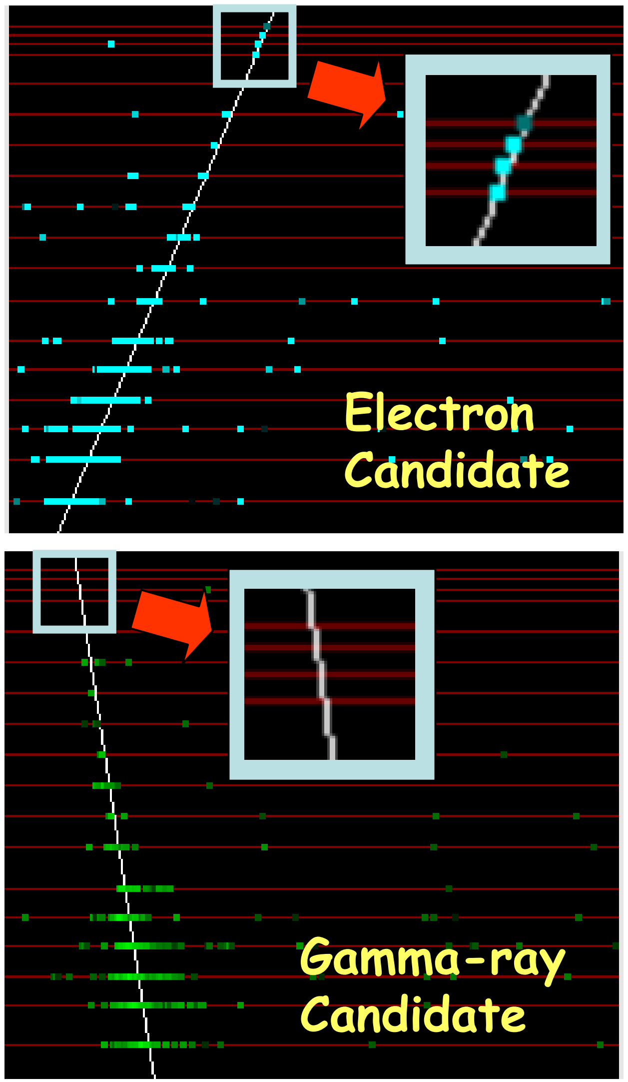
R.E. parameter =
Ratio of Energy deposition within 5mm from the shower axis to the total



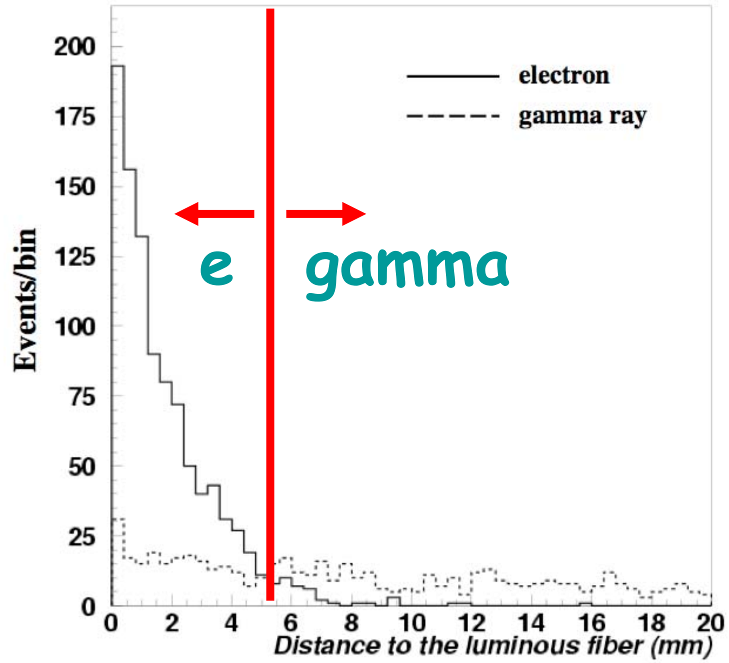
R.E. distributions



Electron Selection -Gamma-ray Rejection-



Fiber signals along the shower axis at top layer
=> Separation between electrons and gamma rays

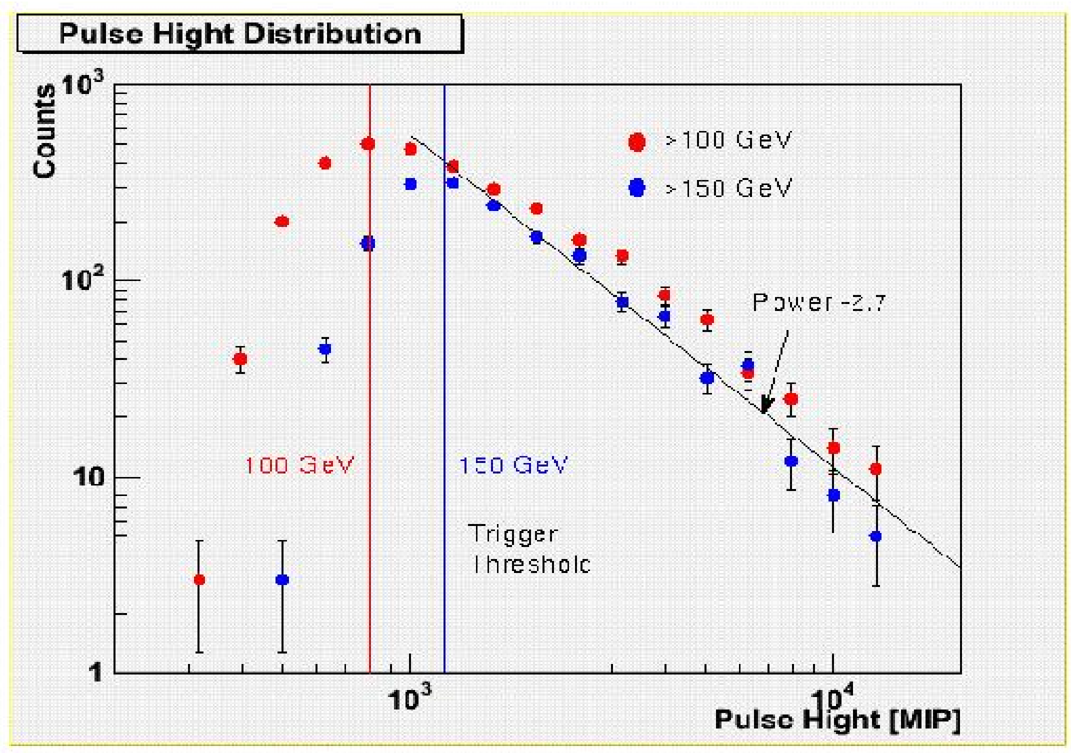


Simulated distributions of the nearest hit fiber positions from the shower axis

Data Analysis: Pulse Height Distribution

Pulse Height Distribution @ 7 r.l.

●● : 2 sets of thresholds on HE trigger



Observed Number of Events

Trigger Mode >100 GeV
3066 events

Trigger Mode > 150 GeV
1637 events

Expected Number of Electrons over 100 GeV
~ 100 Events

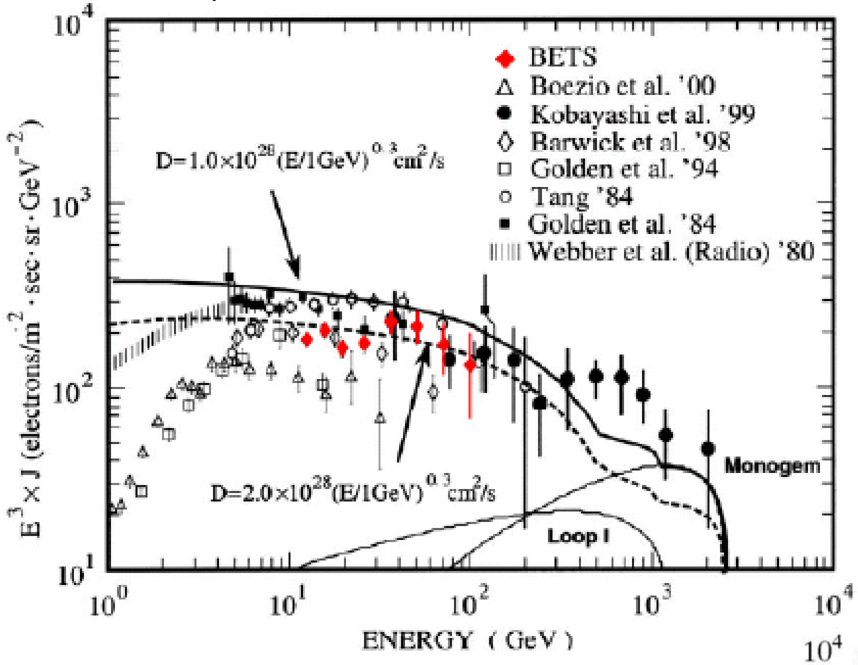
More than one order of total number of BETS observation (4 events)

Derivation of Cosmic-Ray Electron Spectrum

$$\mathbf{F_e(E)} = (\frac{\mathbf{N_e C_{RE} C_{eg}}}{\mathbf{S\Omega T\Delta E}}\mathbf{C_{enh}} - \mathbf{C_{2nd}})\mathbf{C_{atm}}$$

- N_e: The Number of electron candidates
- C_{RE}: Correction factor of proton contamination in the R.E. cut with energy dependence (~0.76)
- C_{eg}: Correction factor of gamma-ray contamination (~0.84)
- C_{enh}: Correction of enhancement of flux due to the energy resolution (0.97)
- C_{2nd}: Correction of secondary electrons in the atmosphere $(1.36\times10^{-5}$ $(m^{-2}s^{-1}sr^{-1}GeV^{-1})$ @100GeV)
- C_{atm}: Correction of energy loss of primary electrons in the overlying atmosphere (1.13)

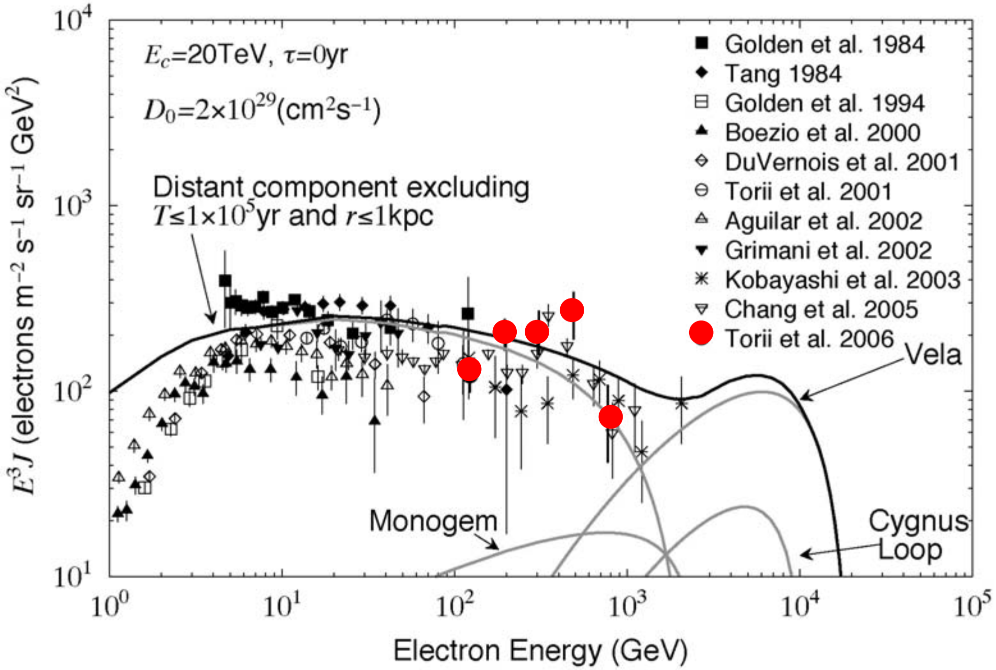
ApJ 559, 973-984 (2001)



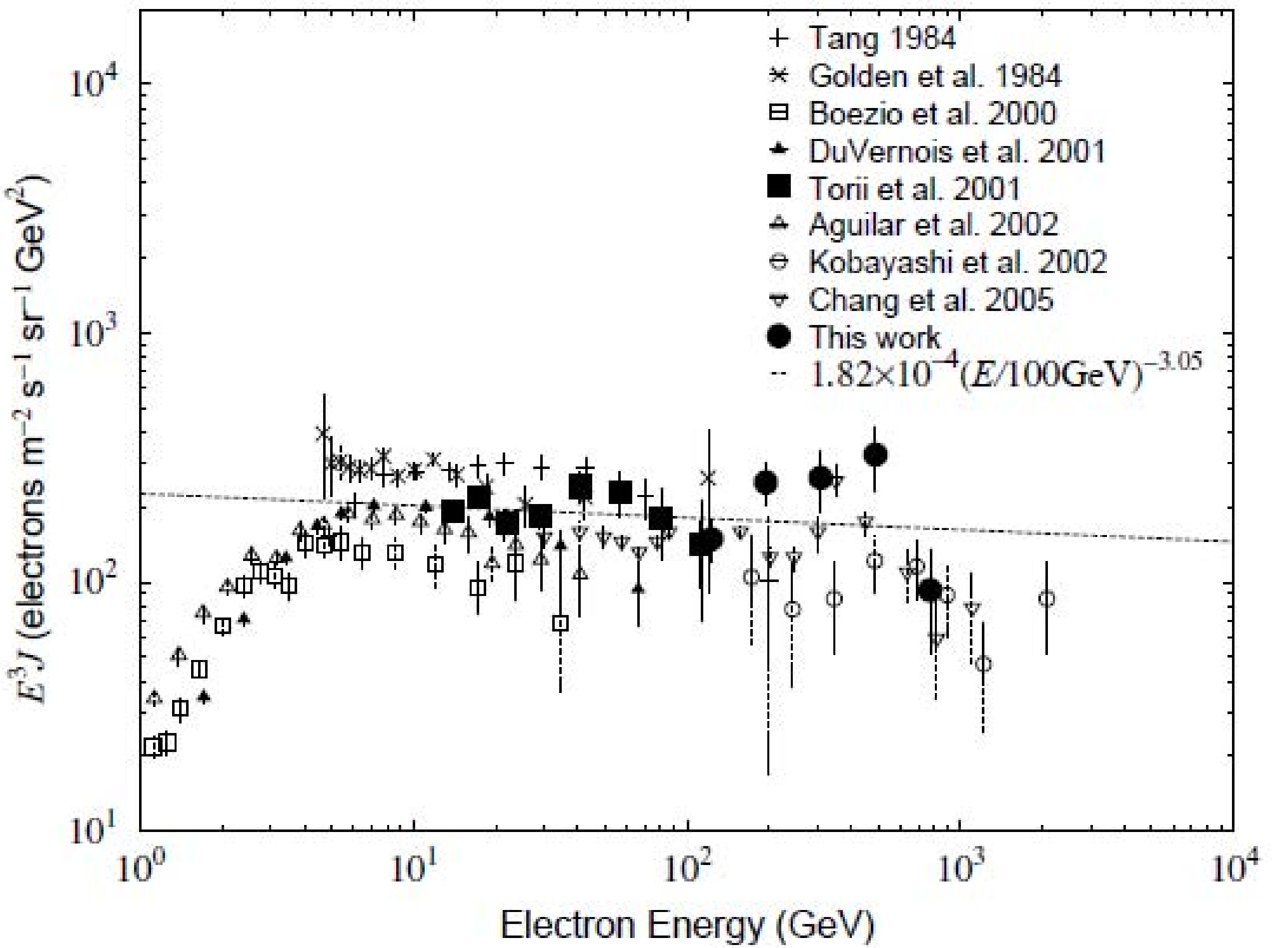
⇐ BETS

arXiv:08/0809.0760(astro-ph)

PPB-BETS (+ATIC2) ⇒

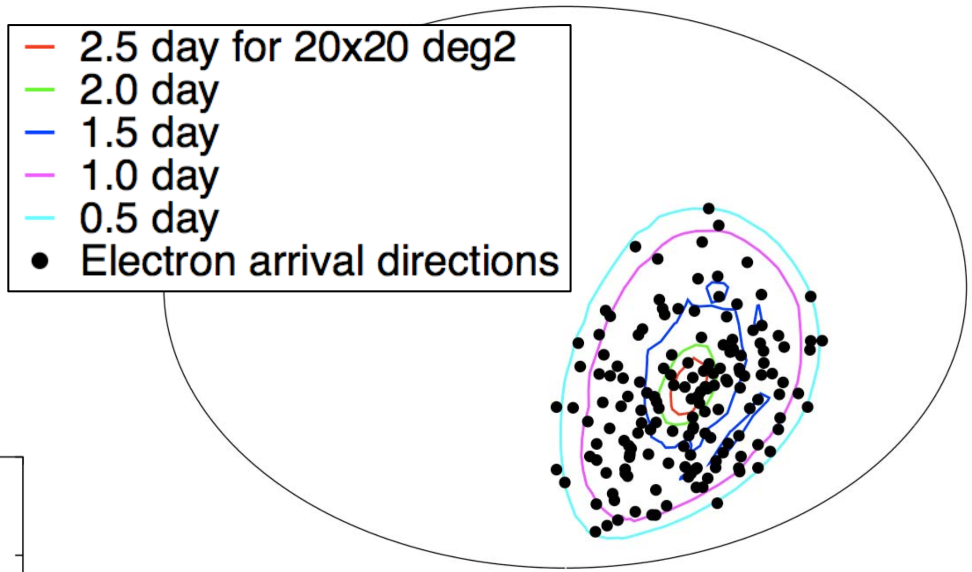


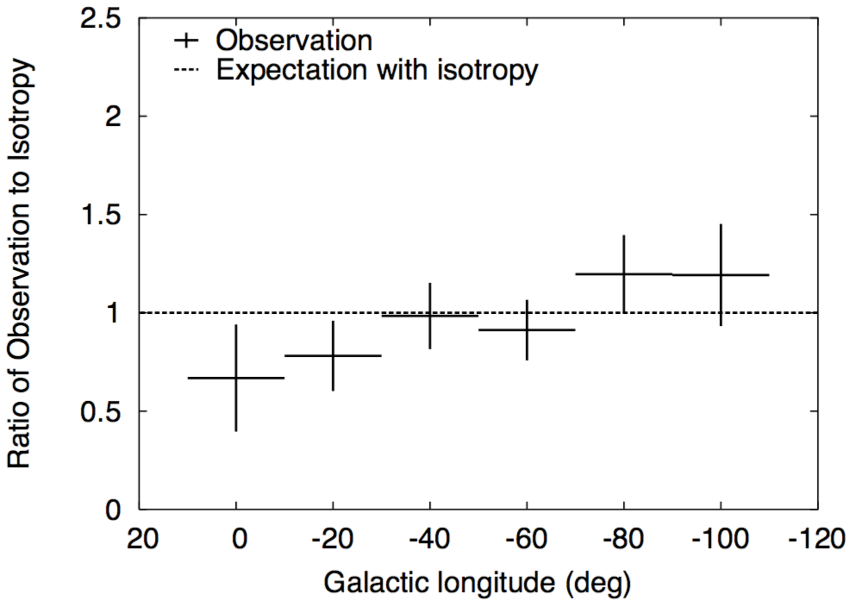
Cosmic-Ray Electron Energy Spectrum



Arrival Directions of Electrons above ~100GeV

Electron (>~100GeV) arrival directions in Galactic coordinate with a contour map of exposure time





Ratio of observation to isotropic distribution along Galactic longitude (Expected anisotropy by a model: ~1%>200GeV)

Vol 000|00 Month 2008|doi:10.1038/nature07477 nature

LETTERS

2008.11.20

An excess of cosmic ray electrons at energies of 300–800 GeV

J. Chang[1,2], J. H. Adams Jr[3], H. S. Ahn[4], G. L. Bashindzhagyan[5], M. Christl[3], O. Ganel[4], T. G. Guzik[6], J. Isbert[6], K. C. Kim[4], E. N. Kuznetsov[5], M. I. Panasyuk[5], A. D. Panov[5], W. K. H. Schmidt[2], E. S. Seo[4], N. V. Sokolskaya[5], J. W. Watts[3], J. P. Wefel[6], J. Wu[4] & V. I. Zatsepin[5]

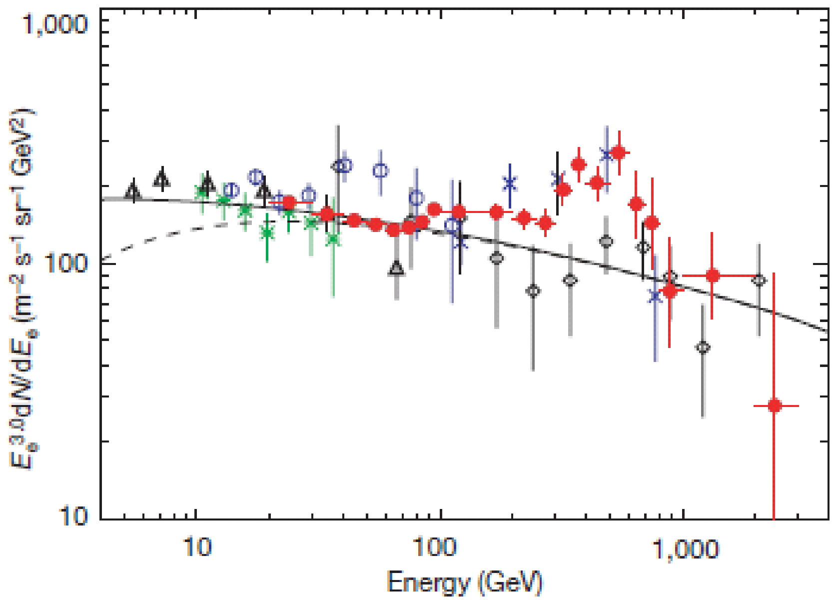
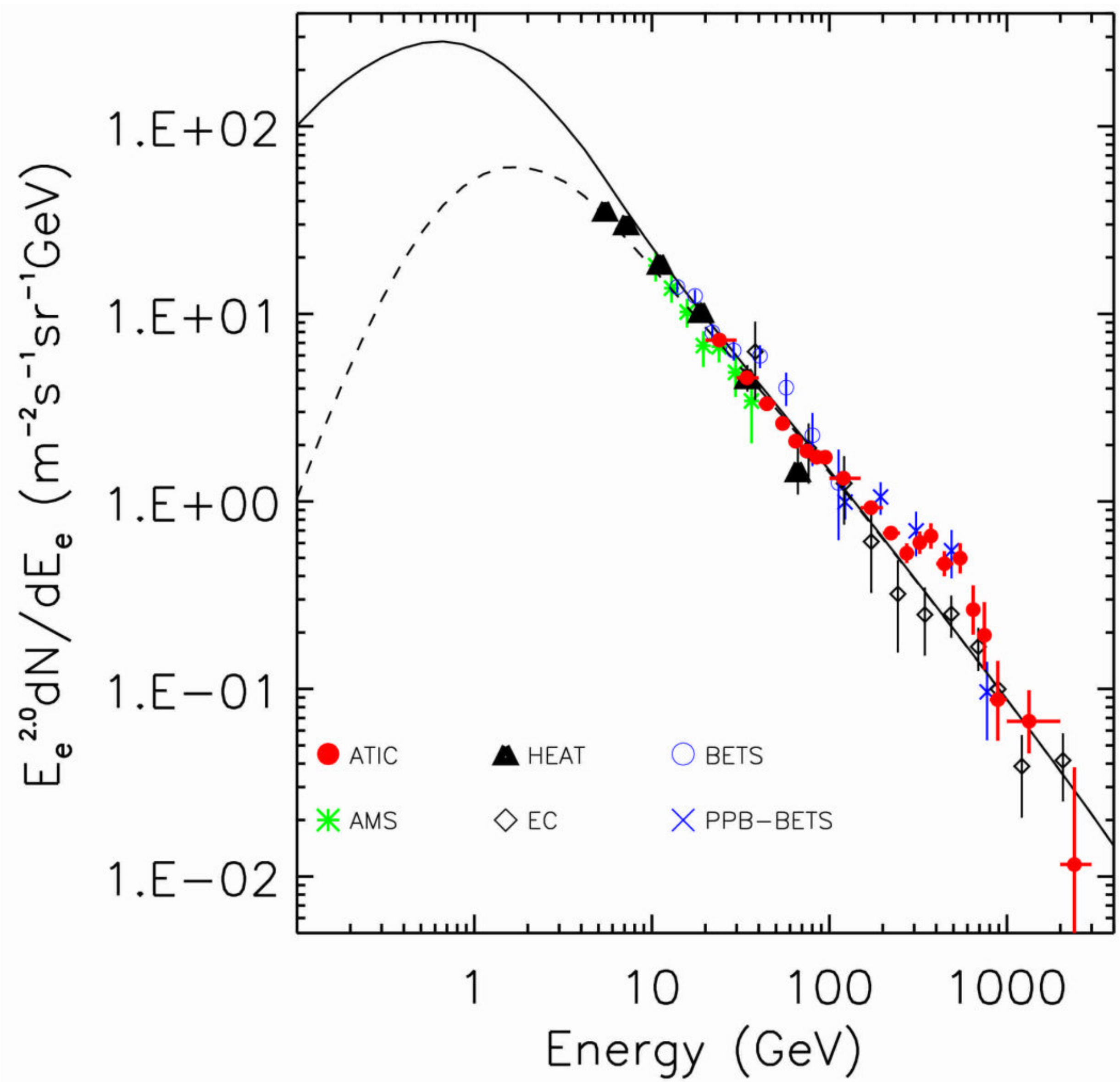


Figure 3 | ATIC results showing agreement with previous data at lower energy and with the imaging calorimeter PPB-BETS at higher energy. The electron differential energy spectrum measured by ATIC (scaled by E^3) at the top of the atmosphere (red filled circles) is compared with previous observations from the Alpha Magnetic Spectrometer AMS (green stars)[31], HEAT (open black triangles)[30], BETS (open blue circles)[32], PPB-BETS (blue crosses)[16] and emulsion chambers (black open diamonds)[4,8,9], with one sigma uncertainties. The GALPROP code calculates a power-law spectral index of −3.2 in the low-energy region (solid curve)[14]. (The dashed curve is the solar modulated electron spectrum and shows that modulation is unimportant above ~20 GeV.) From several hundred to ~800 GeV, ATIC observes an 'enhancement' in the electron intensity over the GALPROP curve. Above 800 GeV, the ATIC data returns to the solid line. The PPB-BETS data also seem to indicate an enhancement and, as discussed in Supplementary Information section 3, within the uncertainties the emulsion chamber results are not in conflict with the ATIC data.



1.E+02
1.E+01
1.E+00
1.E−01
1.E−02
$E_e^{2.0} dN/dE_e$ ($m^{-2}s^{-1}sr^{-1}GeV$)
1
10
100
1000
Energy (GeV)
ATIC
HEAT
BETS
AMS
EC
PPB−BETS

ATIC Observations

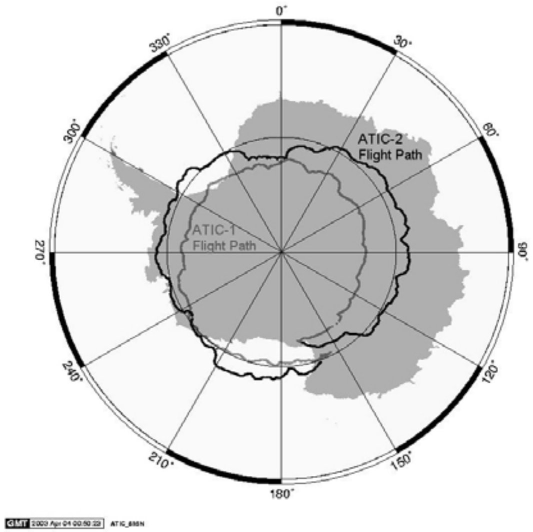
Multiple flights needed to obtain necessary exposure

ATIC-1 during 2000-2001 – 14 days exposure

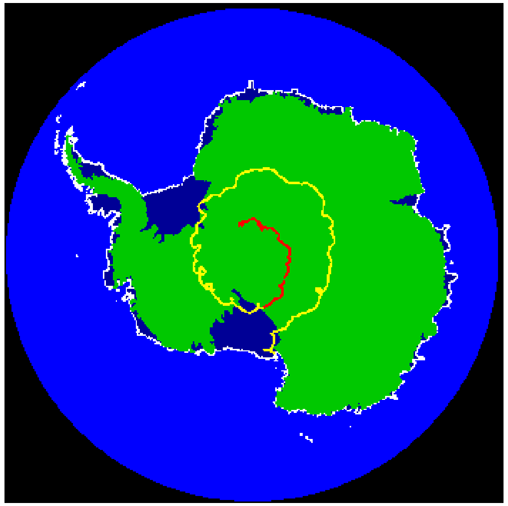
ATIC-2 during 2002-2003 – 17 days exposure

ATIC-4 during 2007-2008 – 19 days exposure

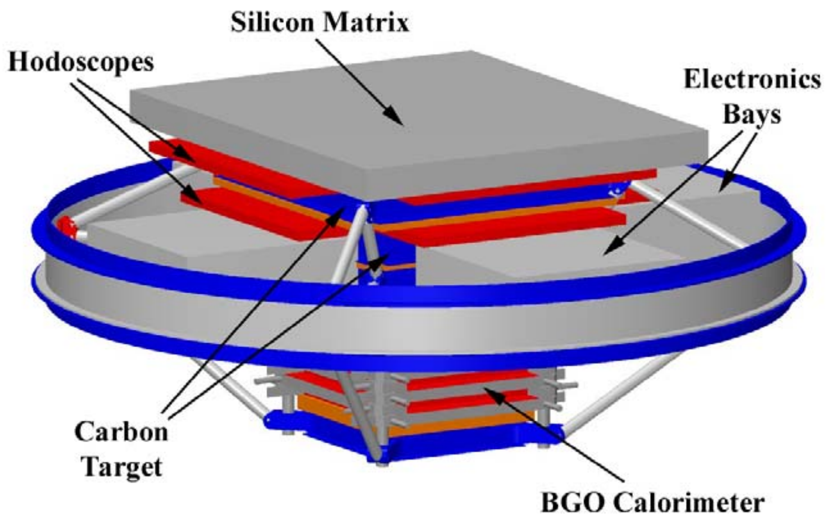
Flight path for ATIC-1 (2000) and ATIC-2 (2002)

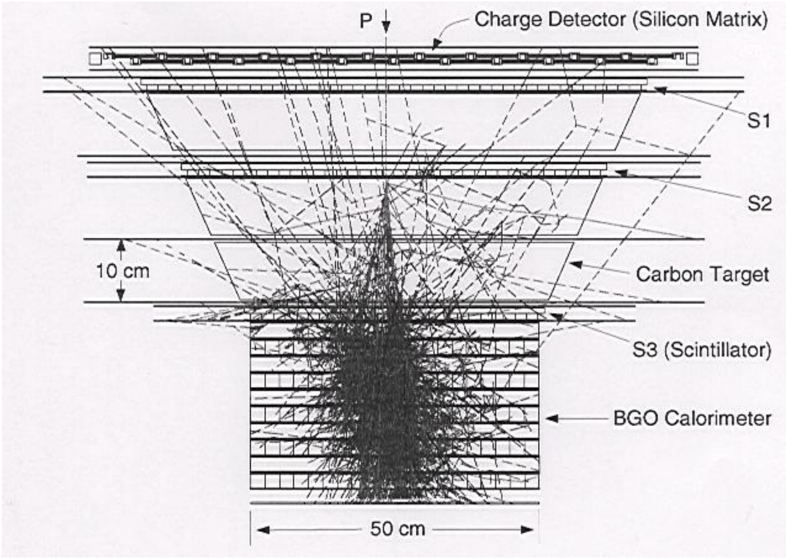


ATIC-4 Flight path (2007-2008)



ATIC Instrument



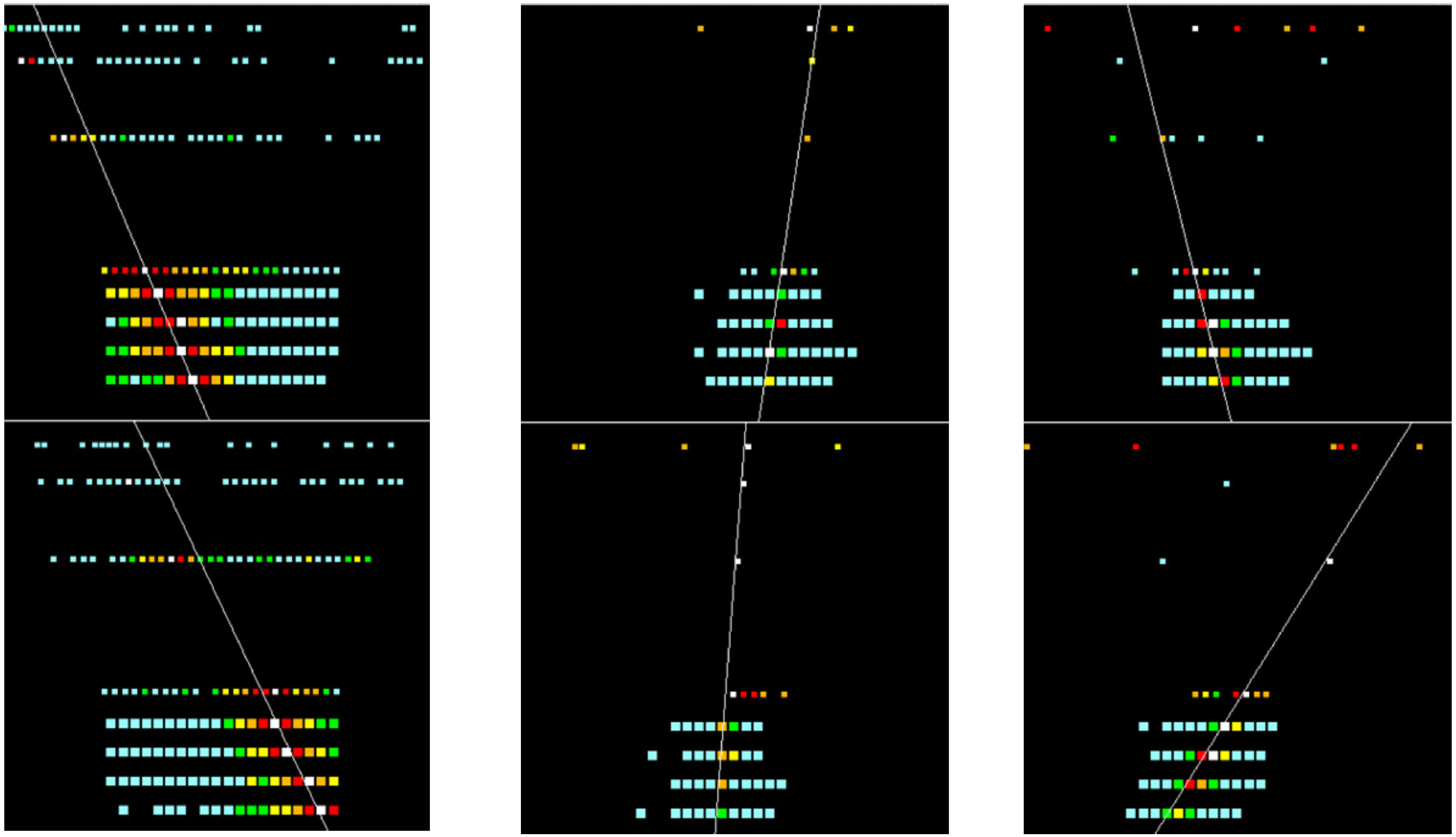


Total weight：
    ～1,500 kg (3,300 lbs),
Total power consumed：
    ＜ 350 Watts (including power conversion efficiency)
Balloon Alititude:
    ~36km
Geometrical factor：
    0.45 m^2 sr (calorimeter top) ～ 0.24 m^2 sr (calorimeter bottom).

Typical (p,e,γ) shower image from ATIC flight data

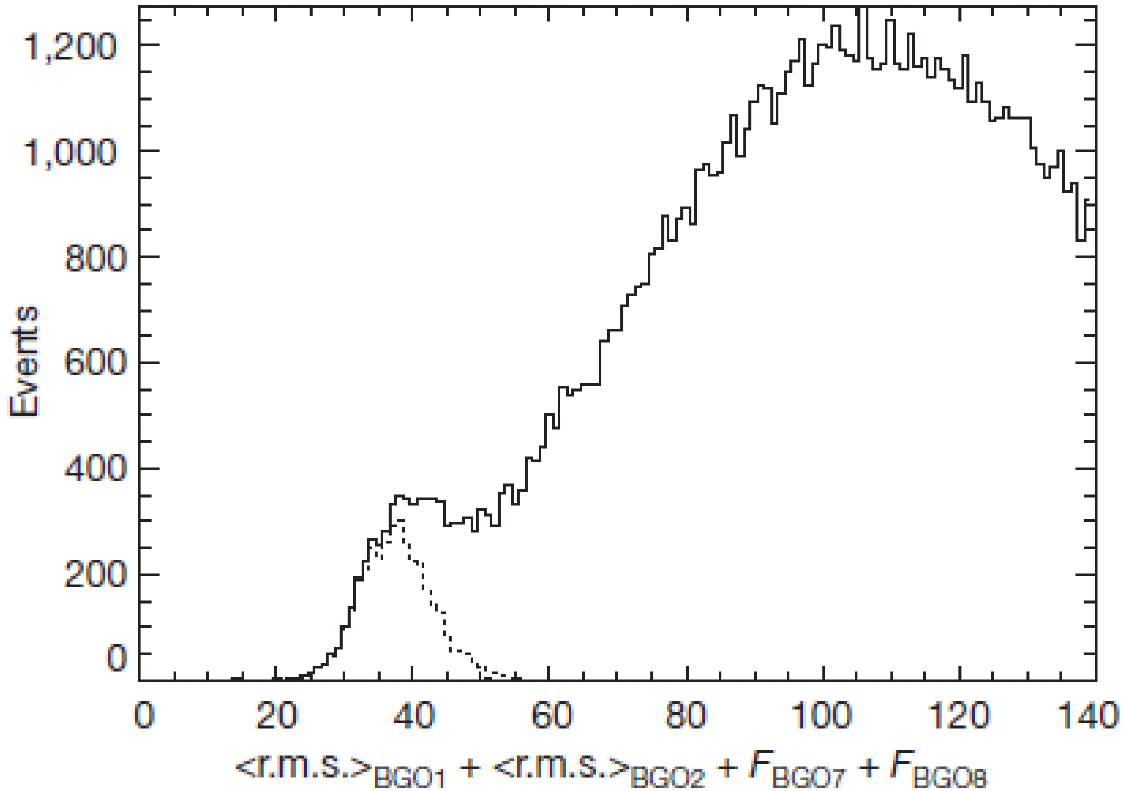
- 3 events, energy deposit in BGO is about 250 GeV
- Electron and gamma-ray showers are narrower than the proton shower
- Gamma-ray shower: No hits in the top detectors around the shower axis

proton electron gamma



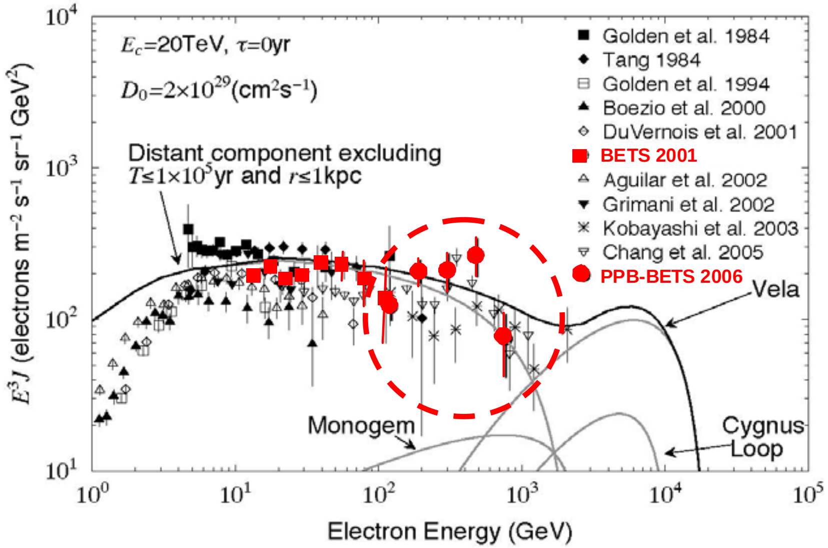
Rejection power ~ 10^{-4}

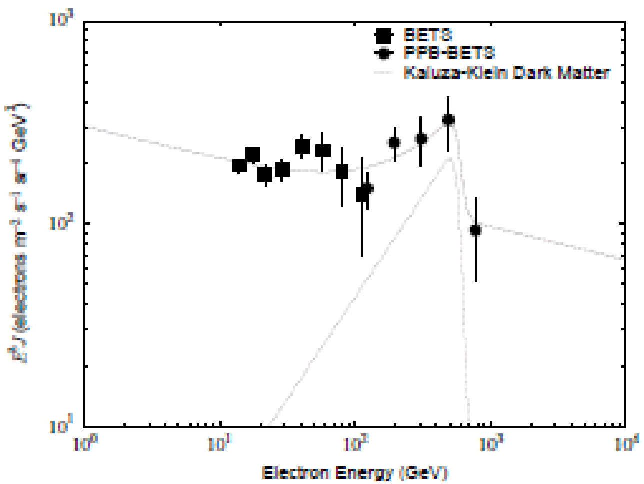
ATIC2 e/p Separation



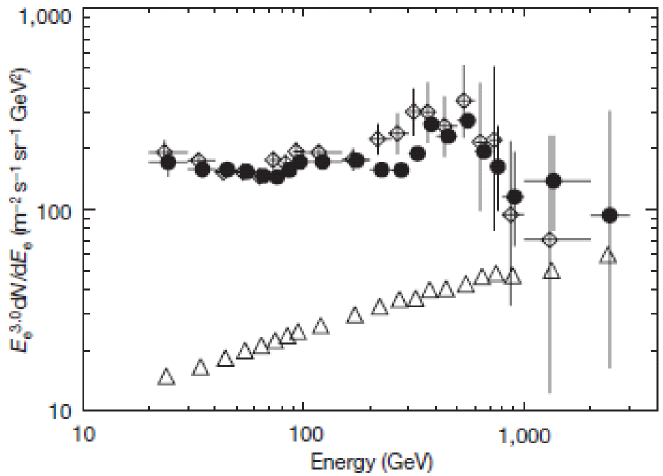
All experiments show excess of Electron flux around 300-800 GeV.

PPB-BETS + BETS

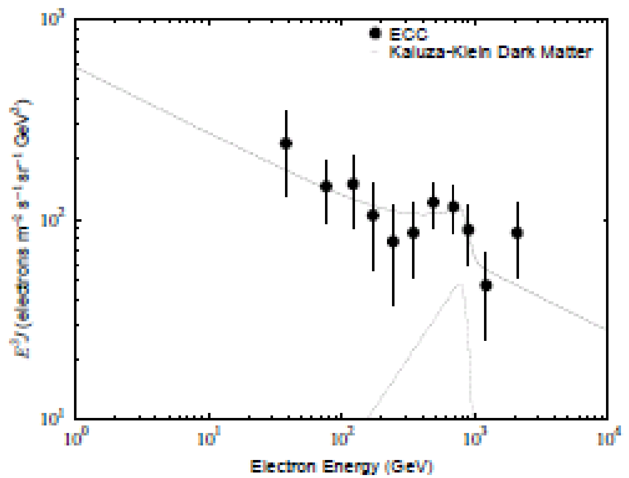




ATIC 1&2

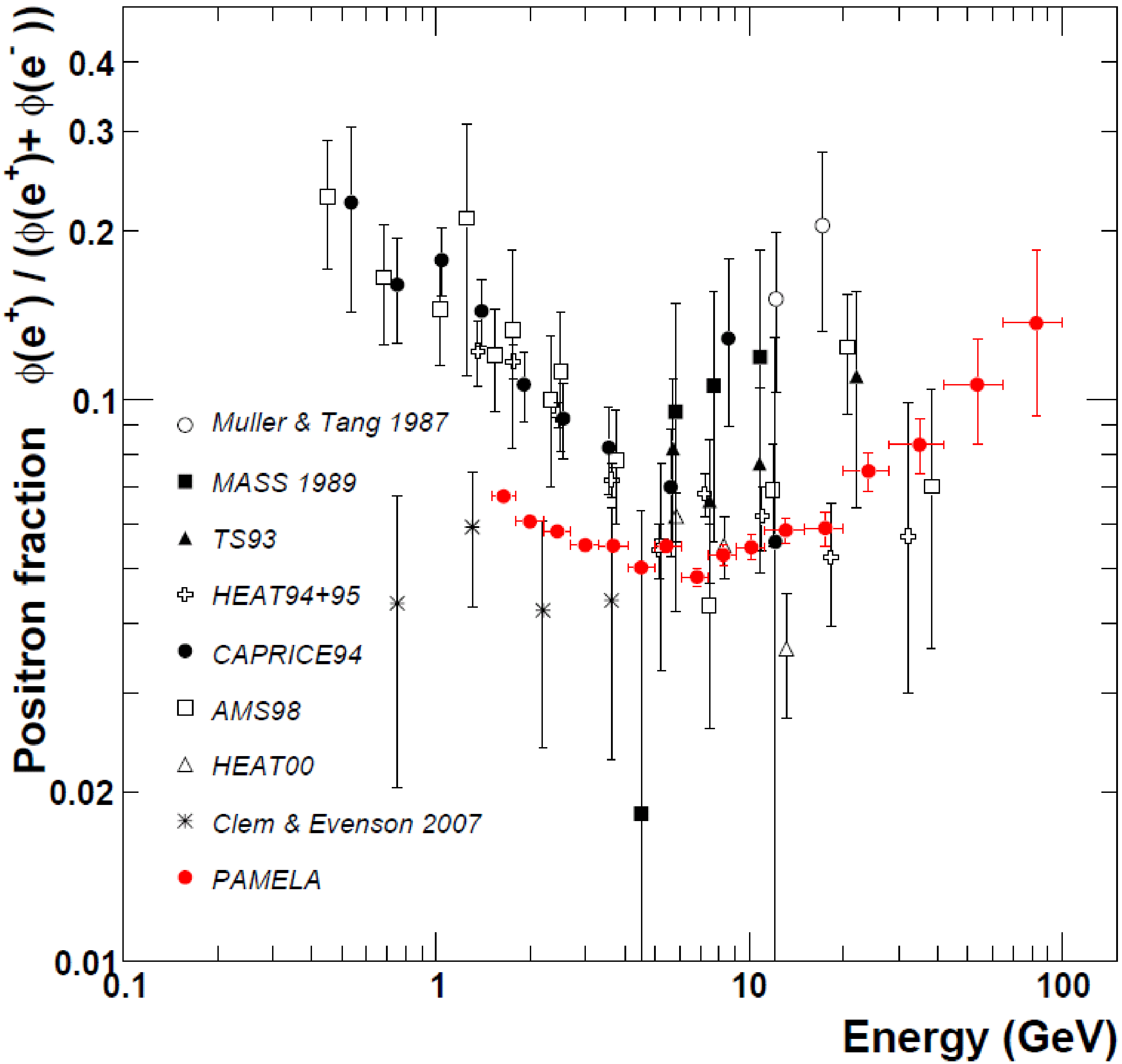


Emulsion Chamber

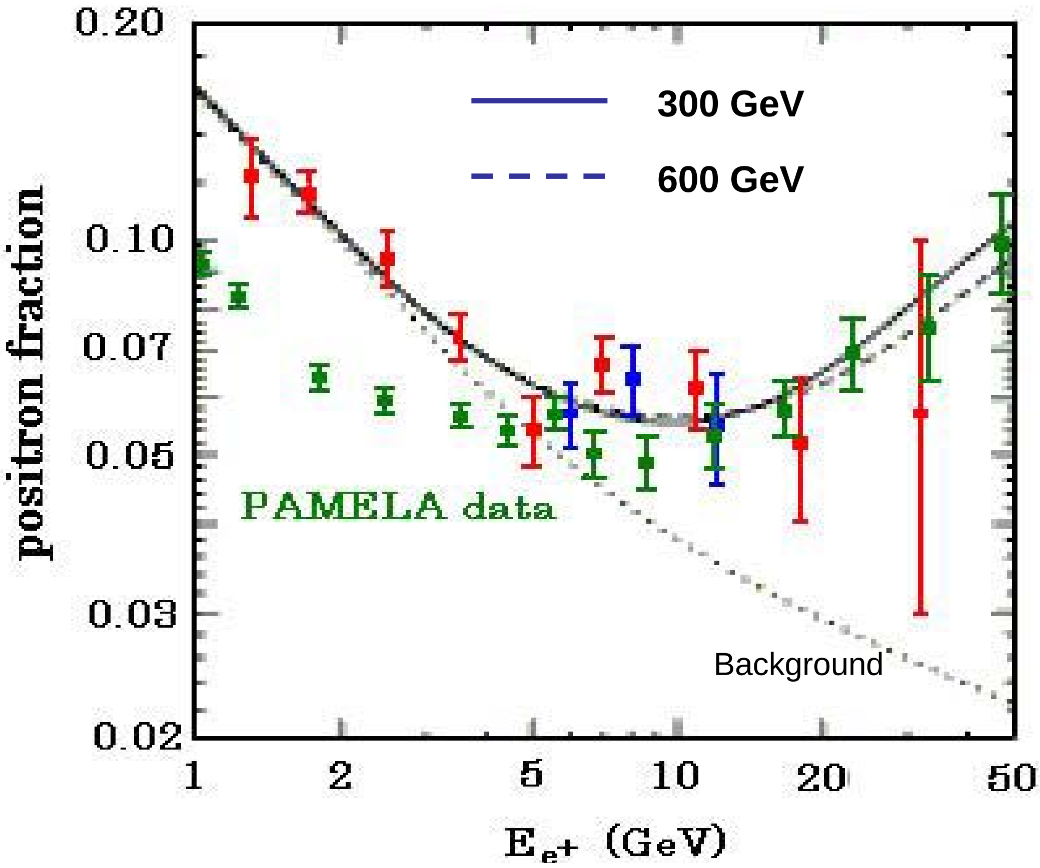


PAMELA Observation of Positron Ratio

arXiv:0819.4995(astro-ph)



PAMELA Data with KK-Dark Matter Expectations



BF~200:
which is consistent with the electron observations

D.Hooper, S.Profumo/ Physics Reports 453 (2007) 29-115

Positrons from Pulsar

D.Hooper astro-ph 0810.1527

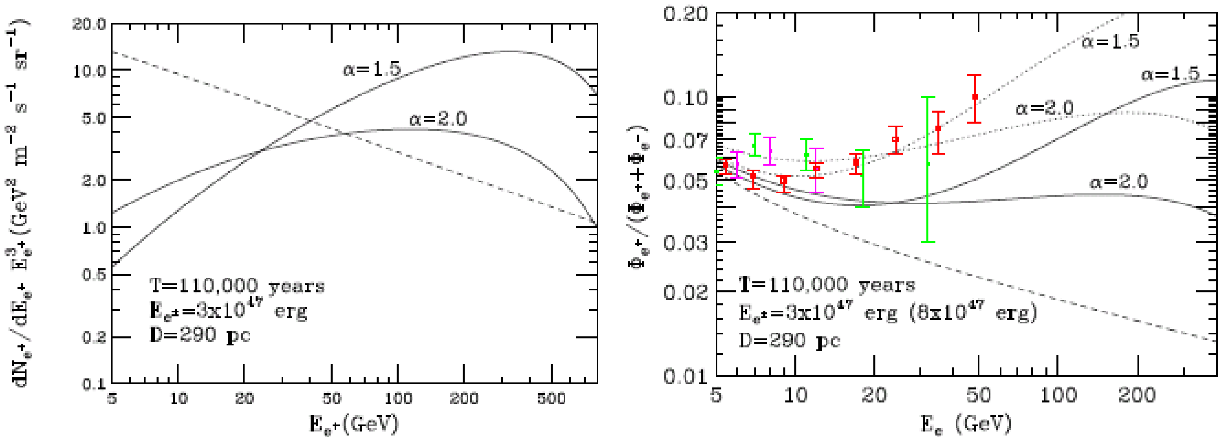


FIG. 3: As in Fig. 2, but from the nearby pulsar B0656+14. The solid lines correspond to an energy in pairs given by 3×10^{47} erg, while the dotted lines require an output of 8×10^{47} erg.

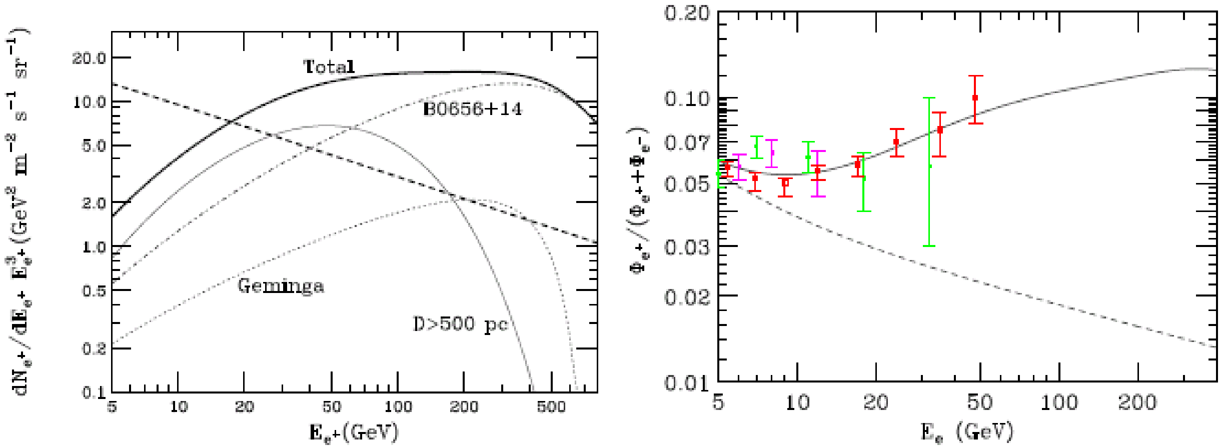


FIG. 4: The positron spectrum and positron fraction from the sum of contributions from B0656+14, Geminga, and all pulsars farther than 500 parsecs from the Solar System.

Anisotropy Expected by Pulsars

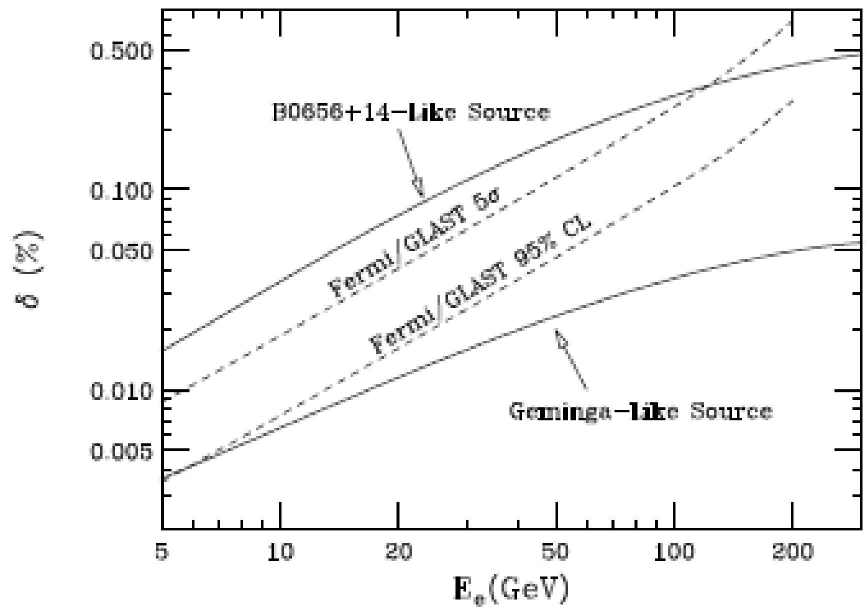
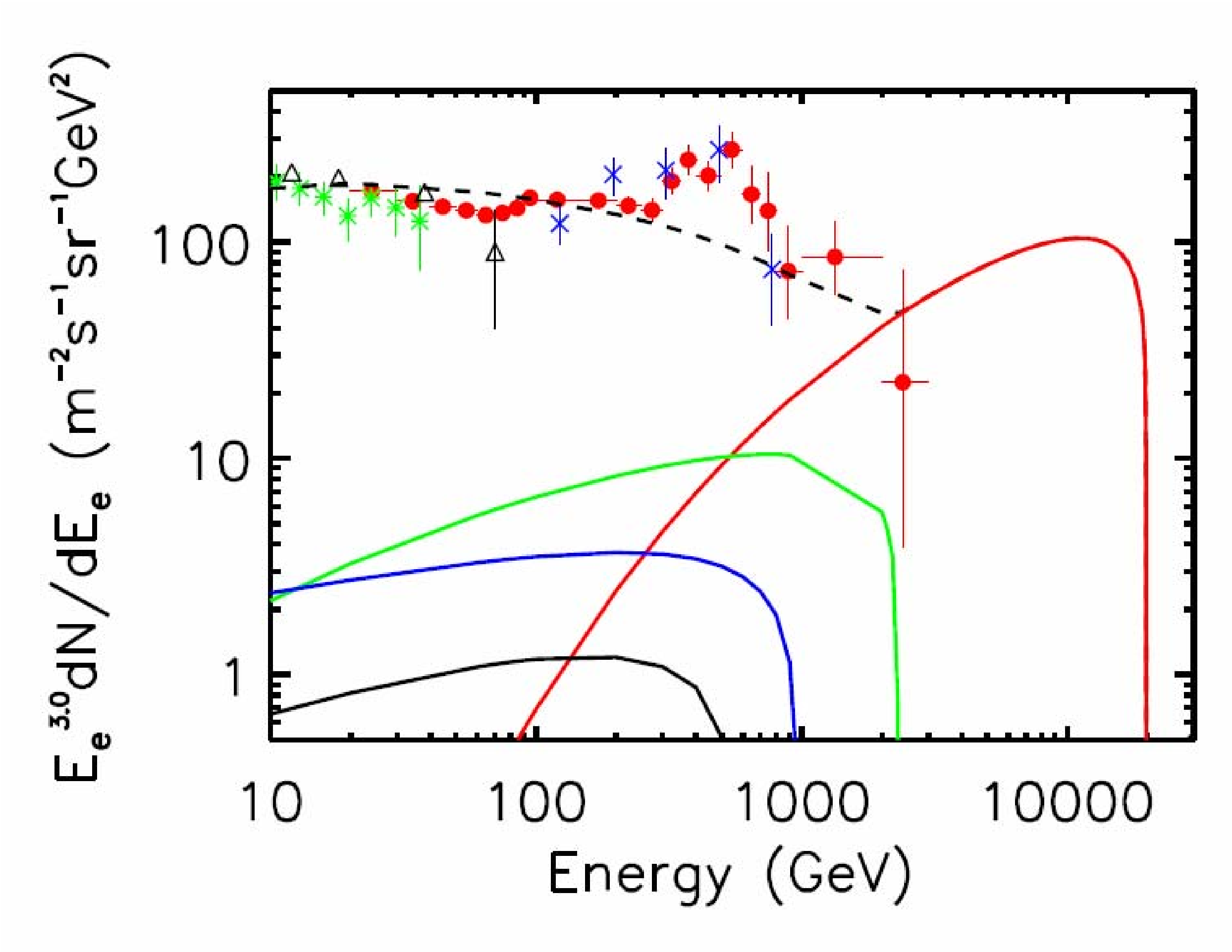


FIG. 5: The dipole anisotropy in the electron+positron spectrum from a source 110,000 years old at a distance of 290 pc (B0656+14-like) and from a source 370,000 years old at a distance of 157 pc (Geminga-like). In each case, we have normalized the energy output to match the PAMELA data and have used a spectral shape of $dN_e/dE_e \propto E_e^{-1.5}\exp(-E_e/600\,\mathrm{GeV})$. Also shown as dashed lines is the sensitivity of the Fermi gamma-ray space telescope to such an anisotropy (after five years of observation). The Fermi sensitivity shown is for the spectrum integrated above a given energy.

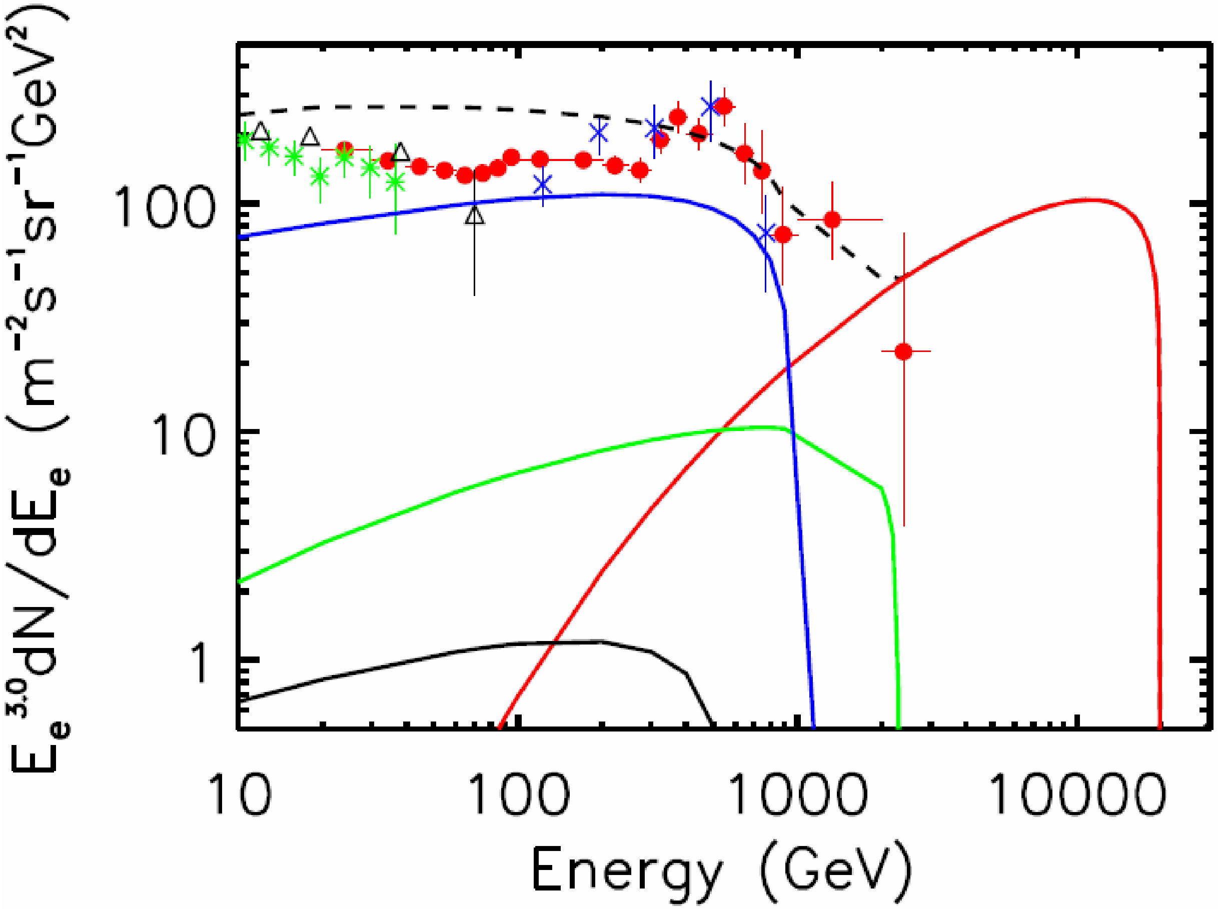


Vela (red)

Monogem (green),

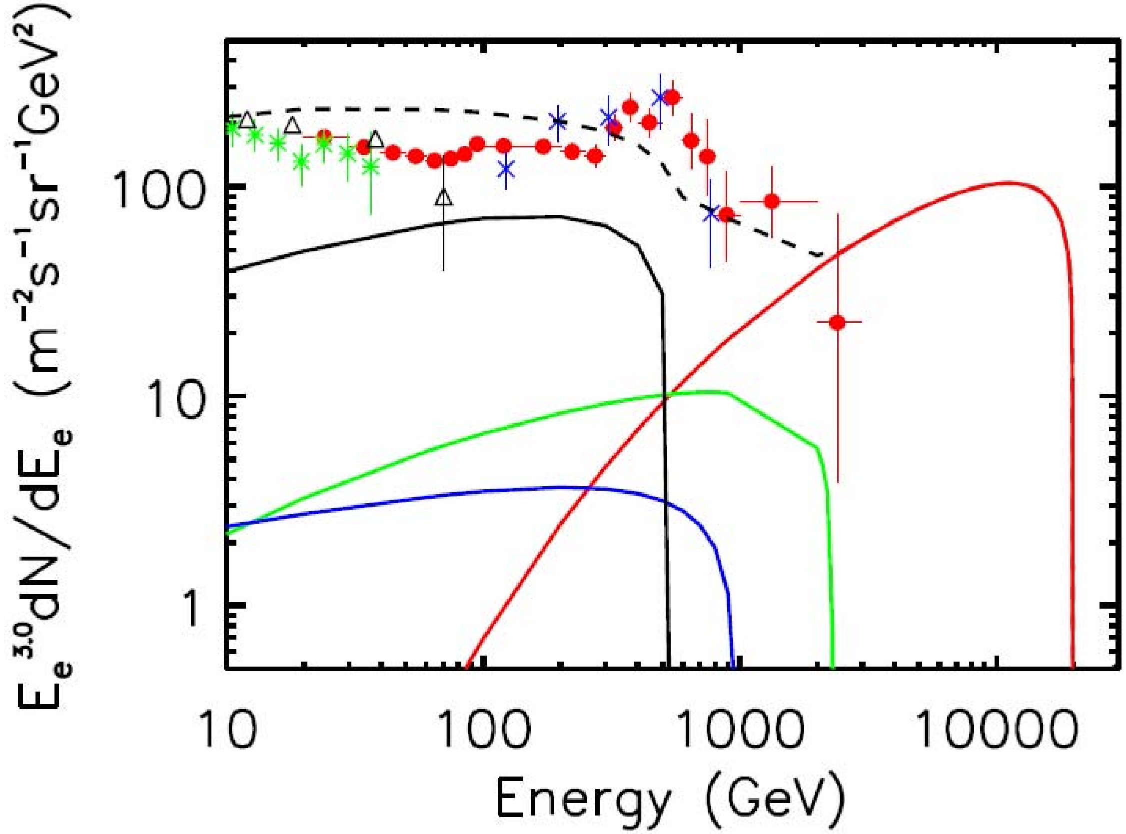
Loop 1 (blue)

Geminga (black)



Loop 1 (blue)

30 times higher



Geminga (black)

60 times higher

Dark Matter Candidates

1. 対消滅によって電子・陽電子対を生成するKK DM
　＝＞ BF=～200
　　　質量 620GeV （PAMELA+ATIC/PPB-BETS)

2. 崩壊によって電子・陽電子対を生成するDM

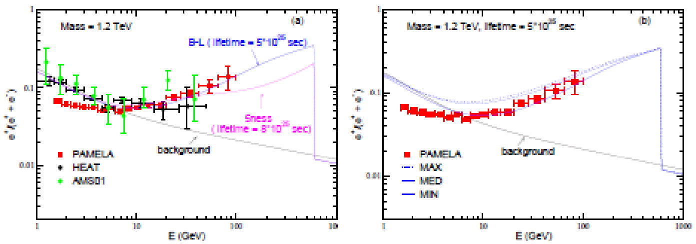


FIG. 1: (a) The predicted positron fraction from A_H decay via the kinetic mixing with $U(1)_{B-L}$ (blue line) and $U(1)_5$ (magenta line), compared with the experimental data [13, 14], including the recent PAMELA results [1]; (b) For $U(1)_{B-L}$ case only, using different sets of parameters in solving

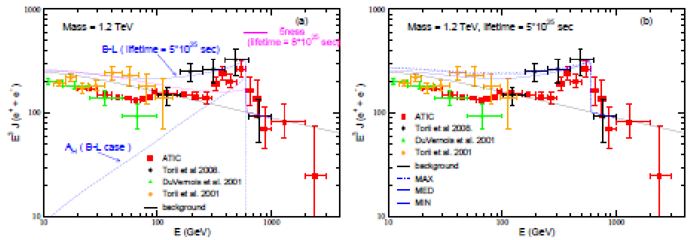


FIG. 2: (a) The predicted $(e^- + e^+)$ spectrum from A_H decay via the kinetic mixing with $U(1)_{B-L}$ (blue line) and $U(1)_5$ (magenta line), compared with the various observational data [15, 16] including the latest ATIC [2] and PPB-BETS [3] results. (b) For $U(1)_{B-L}$ case only, using different sets of parameters in solving diffusion equation.

Decaying Hidden Gauge Boson and the PAMELA and ATIC/PPB-BETS Anomalies

Chuan-Ren Chen[1], Mihoko M. Nojiri[1,3], Fuminobu Takahashi[1] and T. T. Yanagida[1,2]

astro-ph 0810.1527

Life ~ $O(10^{26}$sec)
Mass~ 1.2 TeV

We clearly need more statistics (>10 times) and high e/p experiments in space

Present Observation

- PAMELA
  - positrons ~ 230 GeV (20 cm^2sr x 5 years~3.65 m^2srday)
  - electrons by calorimeter
  - 17 X_0 e/p separation < 10^4

- GLAST
  - electron anisotropy around 10 GeV < 0.1 %
  - CsI Cal. ~10 Xo poor energy resolution + rejection power over 100 GeV

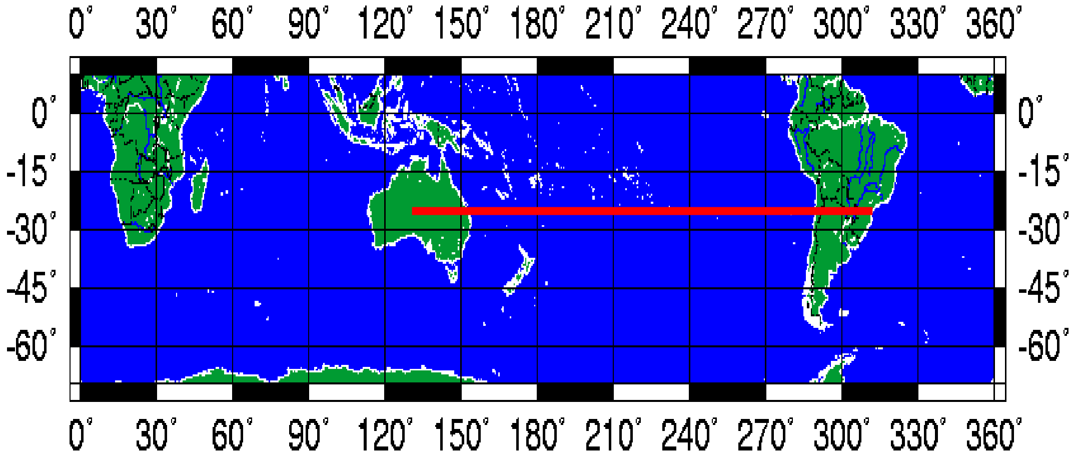
Future

- Long Duration Flight with Polar or Super Pressure Balloon with better e/p Separation
  - bCALET, ECAL, PEBS …. ~2500cm^2sr 50 days

- AMS

- CALET

Flight Plan from Brazil to Australia in 2010



Dream of Flight

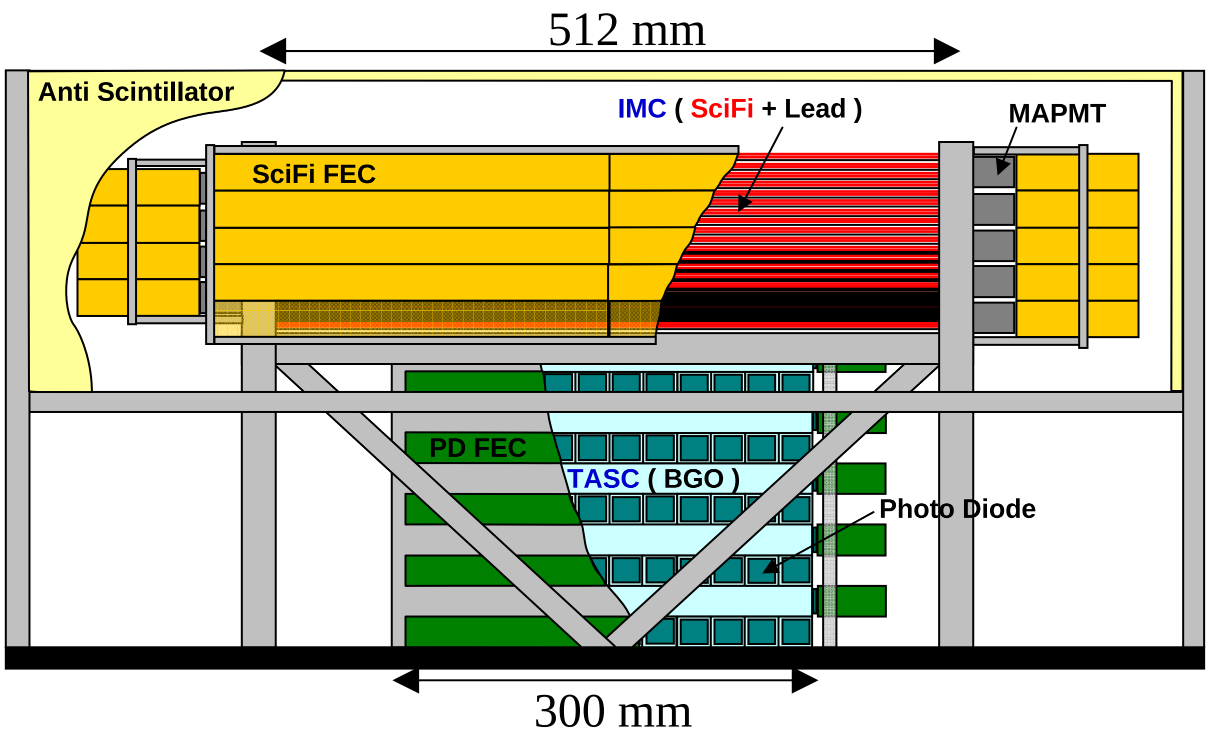
Real Development of Super Pressure Balloon in Japan

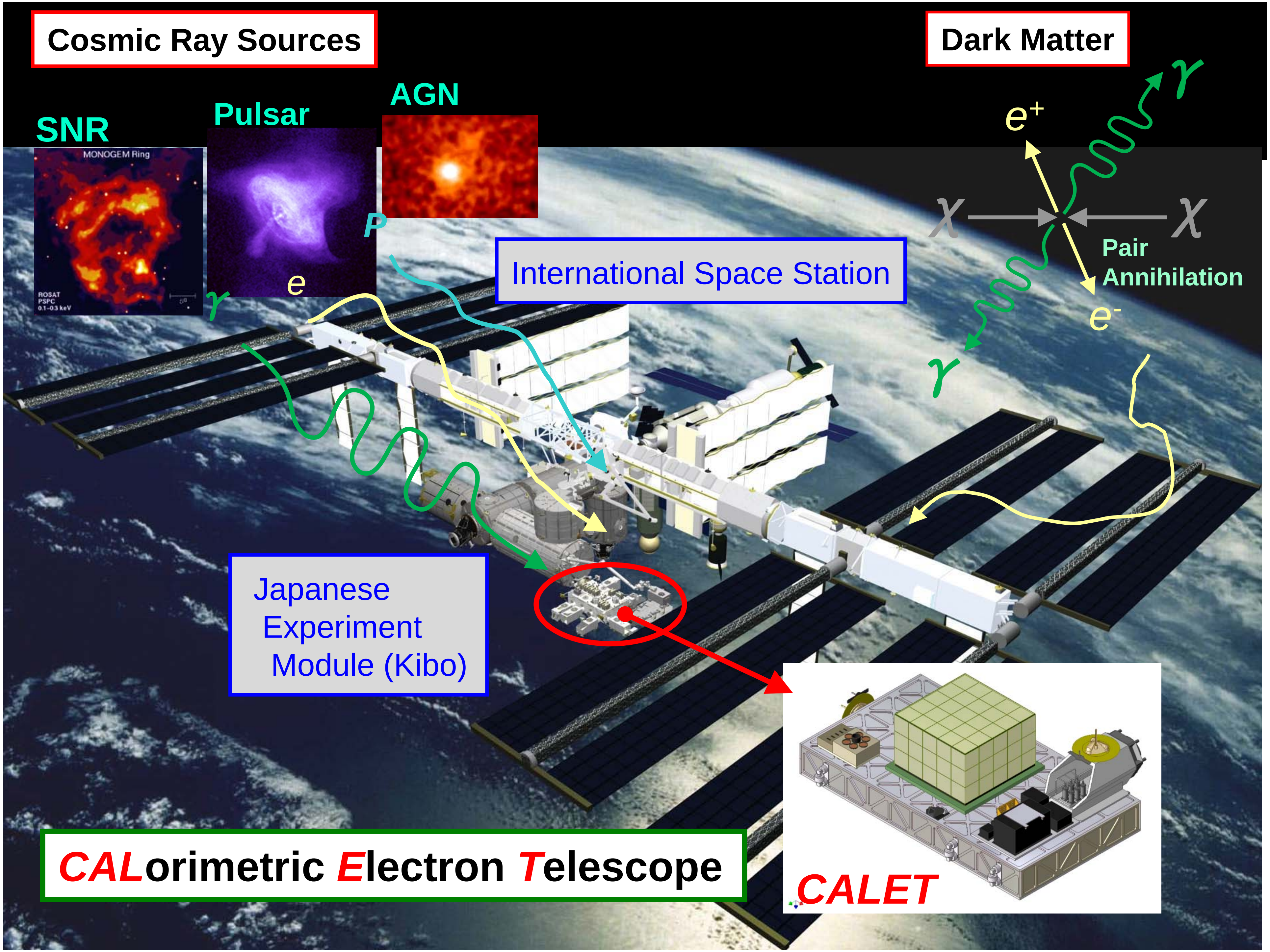
bCALET-3 (CALET ¼ Scale Model)

- Electron observation by super pressure balloon is expected for 50 days in southern hemisphere (Brazil-Australia) by the JAXA balloon campaign.
- The total exposure of 11.5 m^2srday brings us the data of electrons over 100 GeV (in the amount of 7,000 events) up to a few TeV.

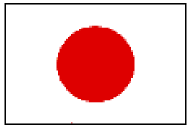
Detector Components

- **Imaging Calorimeter**
  SciFi +PMT: 18,432ch
  (512×18 lys.×2)
  W : 4 r.l.
- **Total Absorption Calorieter**
  BGO+PD: 120 ch
  (12×10 lys., 22.3 r.l.)
- **Anti-coincidence Detector**
- **Unpressurized Bessel**
- **Detector Weight: ~300 kg**
- **Power Consumption : ~200 W**
  (Solar cell + Lithium-ion Rechargeable Battery)
- **GPS + Magnetic Sensor**
- **Telemetry by Iridium System**




Cosmic Ray Sources
Dark Matter
SNR
Pulsar
AGN
MONOGEM Ring
ROSAT
PSPC
0.1–0.3 keV
P
e
γ
e+
e-
χ
χ
Pair
Annihilation
International Space Station
Japanese
Experiment
Module (Kibo)
CALorimetric Electron Telescope
CALET

International Collaboration Team
(as of June 1, 2008)



Waseda University : S. Torii, K.Kasahara, S.Ozawa, S.Udo, N. Hasebe, M.Hareyama, N.Yamashita, O.Okudara , S.Kodaira

JAXA/ISAS : J. Nishimura, T. Yamagami , Y. Saito H. Fuke, M.Takayanagi, H. Tomida, S. Ueno, K.Ebisawa

Kanagawa University : T. Tamura, N. Tateyama, K. Hibino, S.Okuno

Aoyama Gakuin University : A.Yoshida, T.Kobayashi, K.Yamaoka, T.Kotani

Shibaura Institute of Technology : K. Yoshida , A.Kubota, E.Kamioka

ICRR, University of Tokyo : Y.Shimizu, M.Takita, T.Yuda

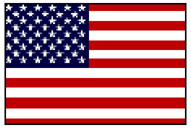
Yokohama National University : Y.Katayose, M.Shibata

Hirosaki University: S. Kuramata, M. Ichimura, ***T okyo Technology Inst.:*** T.Terasawa, Y. Ichisada

National Inst. of Radiological Sciences : Y. Uchihori, H. Kitamura ***Rikkyo University:*** H. Murakami

Kanagawa University of Human Services : Y.Komori ***Saitama University:*** K.Mizutani

Shinshu University : K.Munekata ***Nihon University***: A.Shiomi

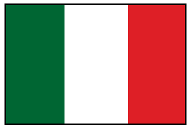


NASA/GSFC: J.W.Mitchell, A.J.Ericson, T.Hams, A. A.Moissev, J.F.Krizmanic, M.Sasaki

Louisiana State University: M. L. Cherry, T. G. Guzik, J. P. Wefel

Washington University in St Louis: W. R. Binns, M. H. Israel, H. S. Krawzczynski

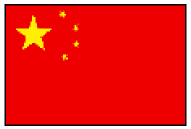
University of Denver: J.F.Ormes



University of Siena and INFN: P.S.Marrocchesi , M.G.Bagliesi, G.Bigongiari, A.Caldaroe, M.Y.Kim, R.Cesshi, P.Maestro, V.Millucci , R.Zei

University of Florence and INFN: O. Adriani, P. Papini, L. Bonechi, E.Vannuccini

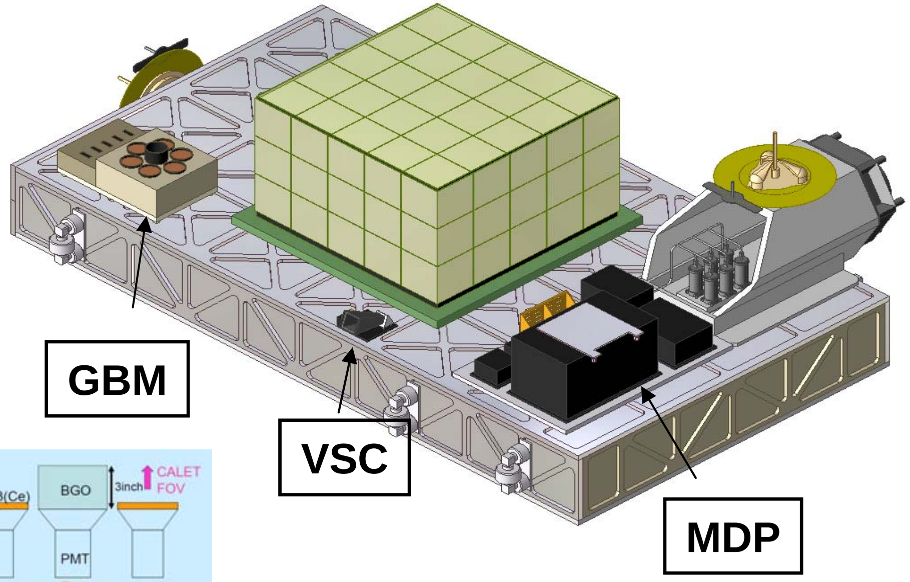
University of Pisa and INFN: C.Avanzini, T.Lotadze, A.Messineo, F.Morsani



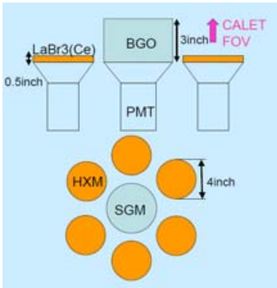
Purple Mountain Observatory: J. Chang, W. Gan, J. Yang

Institute of High Energy Physics: Y.Ma, H.Wang,G.Chen

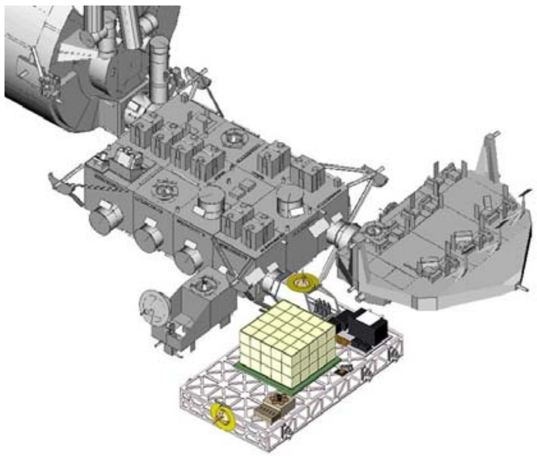
Schematic Structure of the CALET Payload

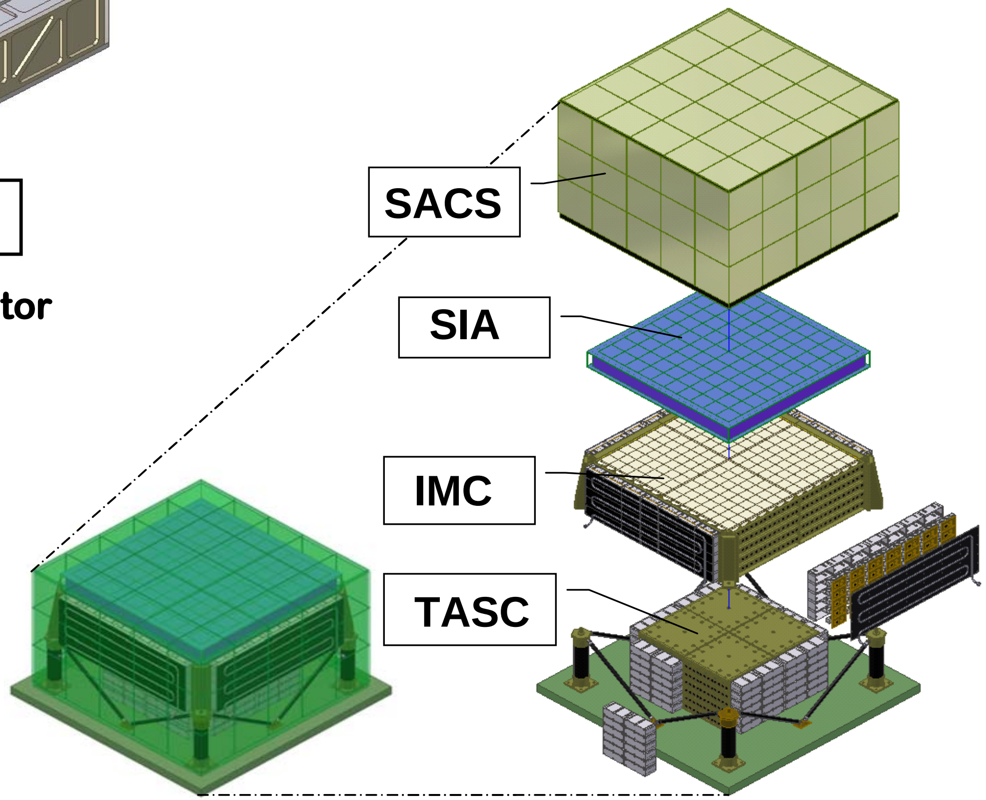


SACS:Scitillator Anti-Coincidence System
SIA: Silicon Pixel Array
IMC: Imaging Calorimeter
TASC: Total Absorption Calorimeter



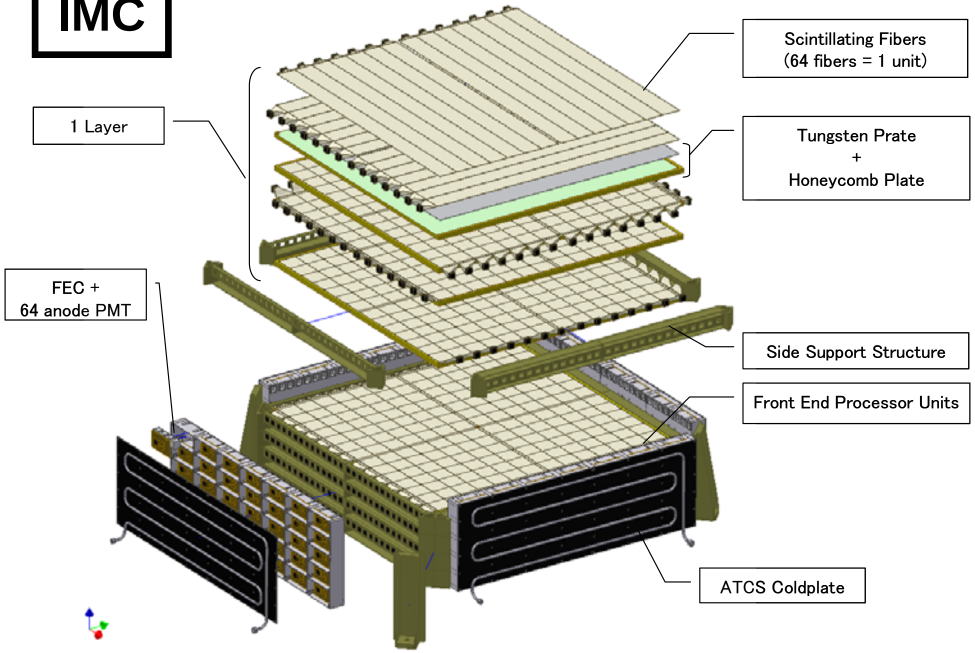
GBM: Gamma-Ray Burst Monitor
VSC: Visual Sky Camera
MDP: Mission Data Processor



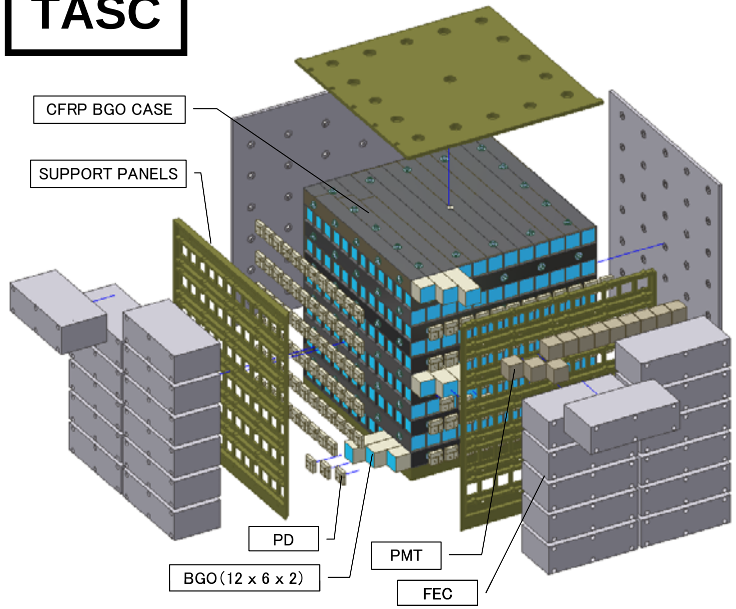


Details of Each Component

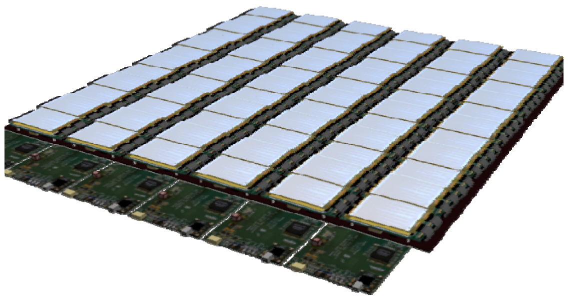
IMC



TASC

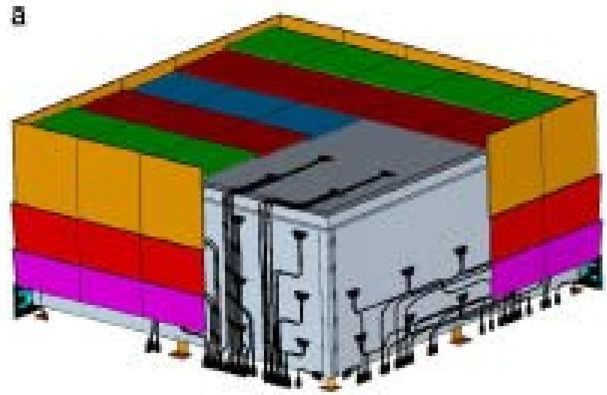


SIA



- Silicon Pixel Array x 2 layers (Pixel ~1cmx 1cm)
- Charge resolution: 0.1e for p, 0.35e for Fe

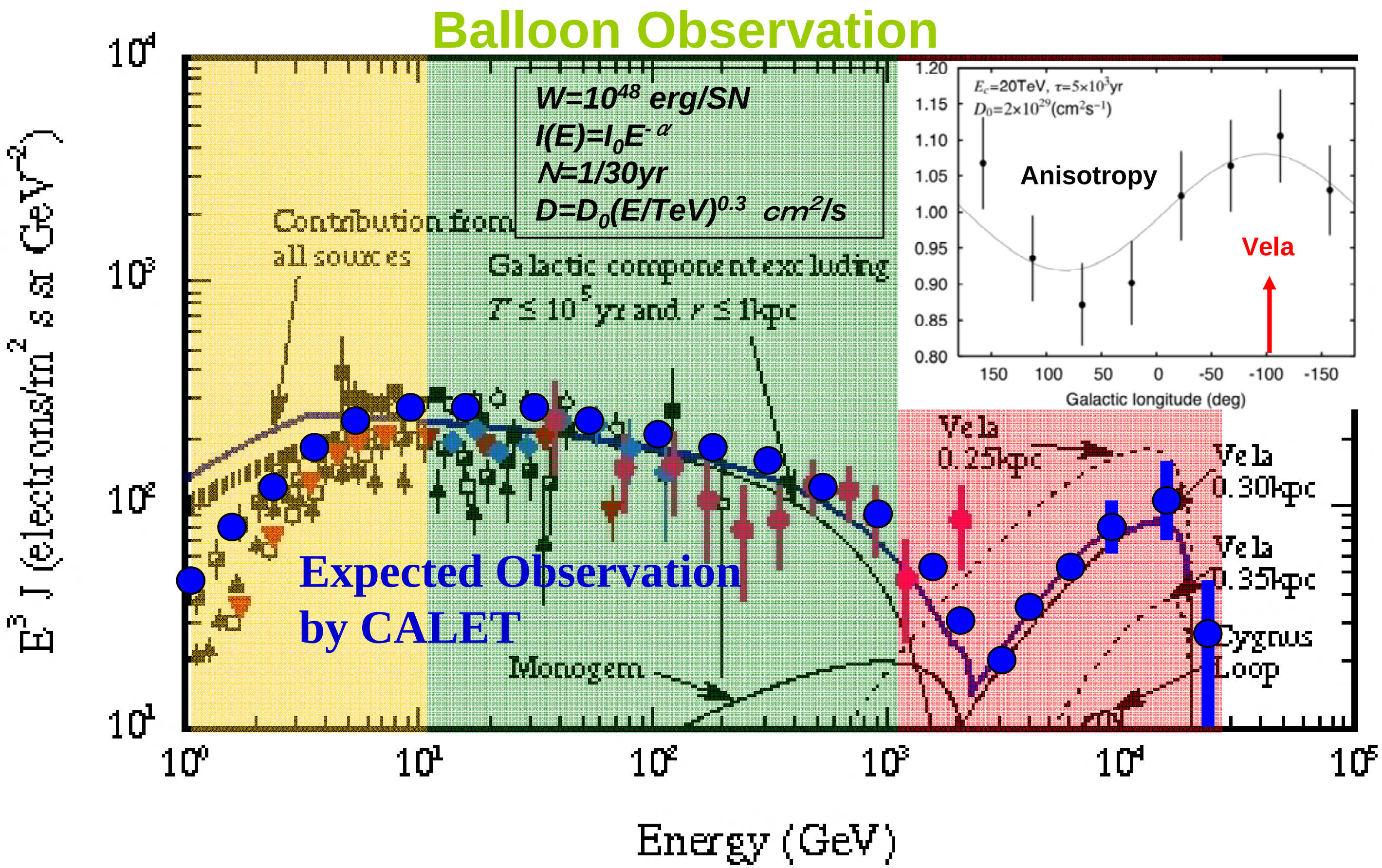
SACS(ACD)



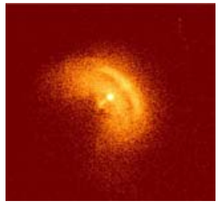
- Segmented Plastic Scintillators for Anti-Coincidence

CALET Electron Observation

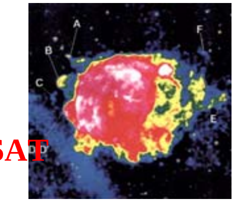
- *Detection of Nearby Sources*
- *Electron Propagation in Our Galaxy*
- *Acceleration by Supernova Shock Wave*
- *Solar Modulation*



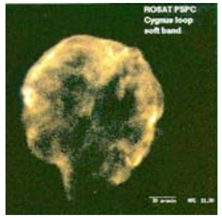
Nearby Source Candidates



Vela
10,000 years
820 ly
Chandra

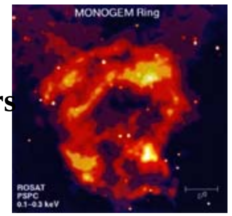


ROSAT



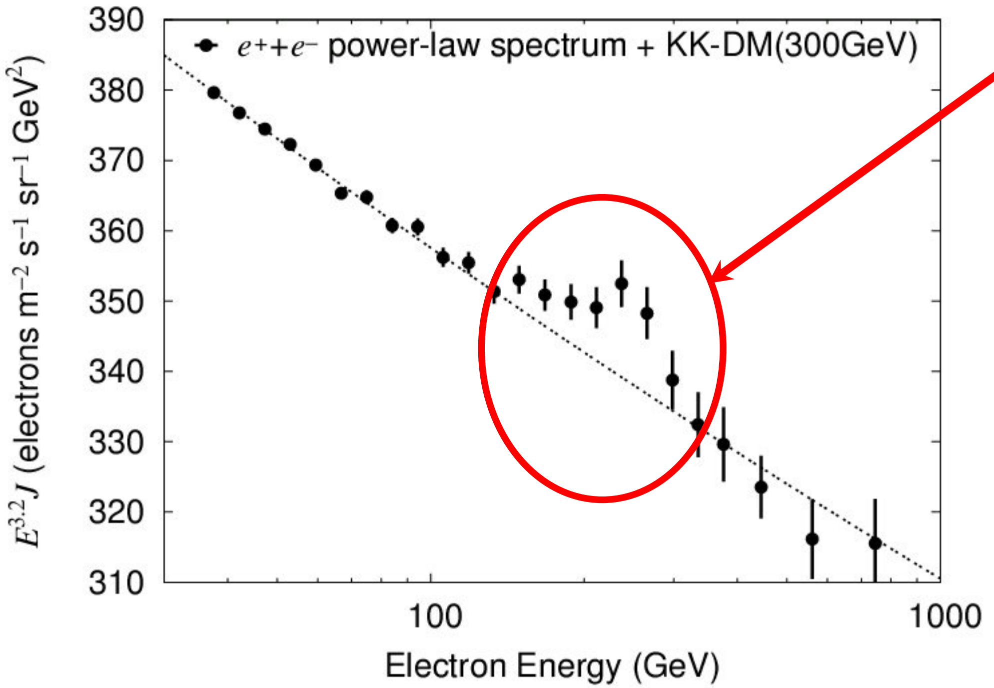
Cygnus Loop
20,000 years
2,500 ly

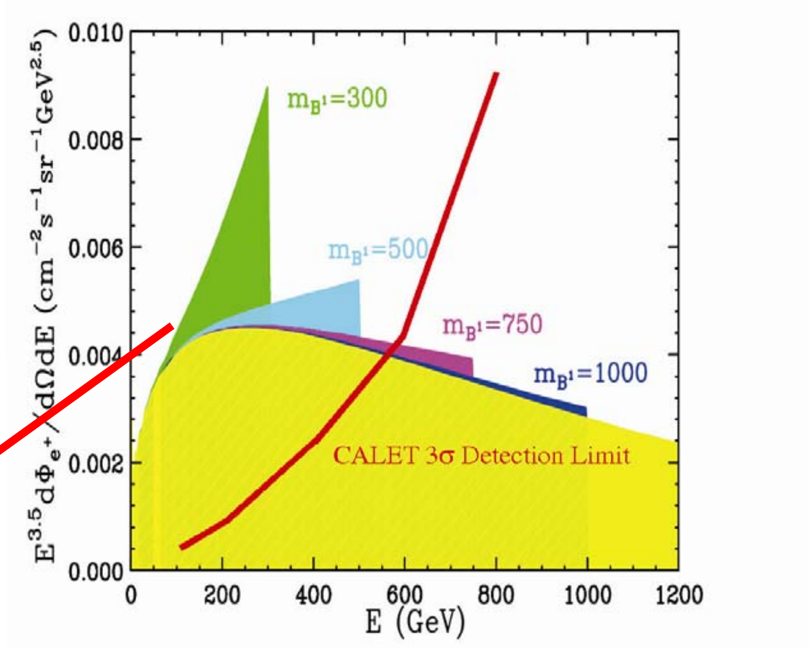
Monogem
86,000 years
1,000 ly



Dark Matter Search by Positrons (+ Electrons)

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





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

Gamma-Ray Observation in 20 MeV~several TeV

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

Wide FOV (~45°) and Large Effective Geometrical Factor (~0.5 m^2 sr)

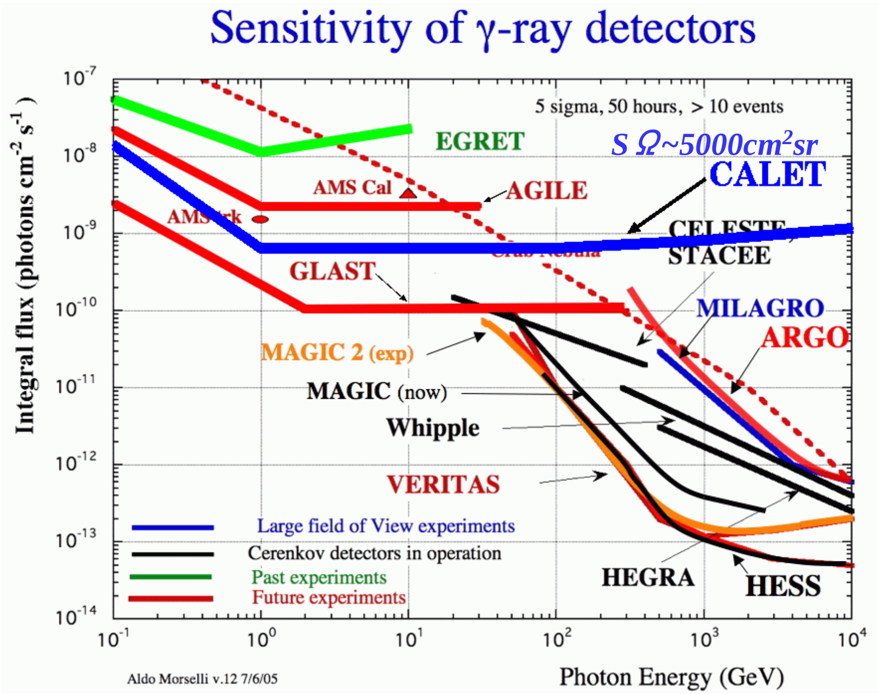
⇒

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

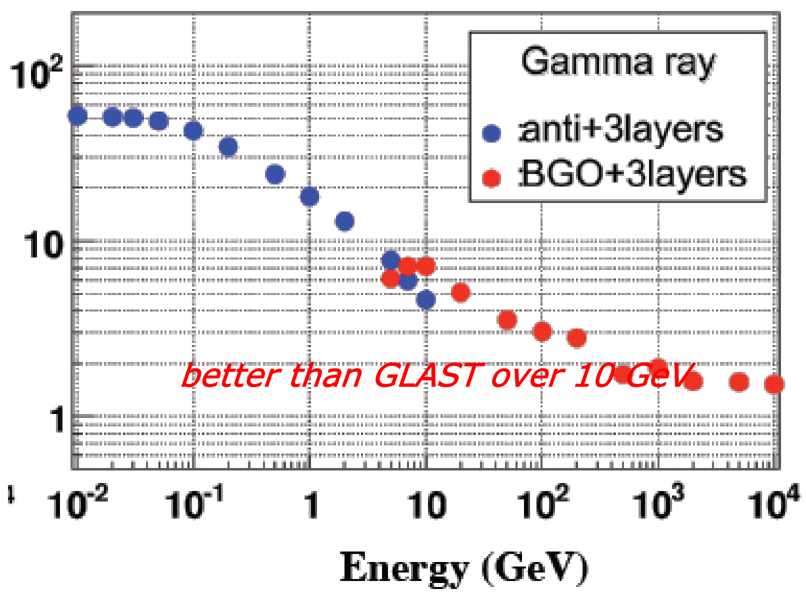
Excellent Energy Resolution (< a few %) over 100 GeV

⇒

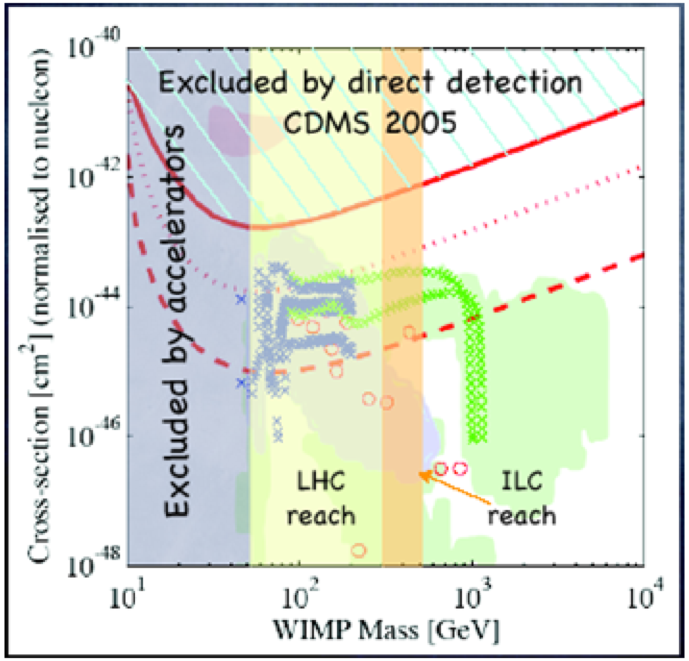
- **Measurement of change of power-law spectral index**
- **Possible detection of line gamma-rays from Neutralino annihilation**



Energy Resolution



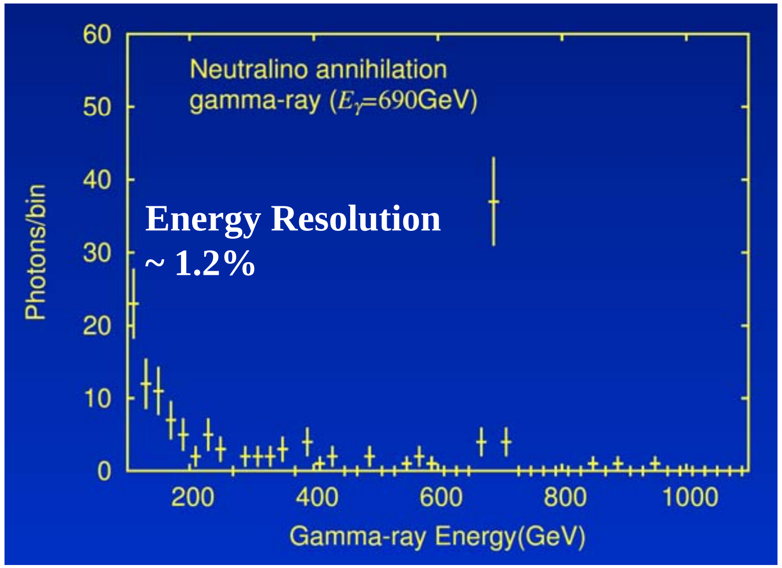
SUSY Dark Matter Search by Gamma-ray Line



WIMP Mass Limit from Direct Observation

- **WIMP mass is likely heavier than several 10 GeV**
- **Future accelerator experiments will cover the mass range in ~ a few 100 GeV**
- **Indirect observation is very promising to see gamma-ray line according to WIMP mass.**

Simulated Signal in CALET for 3 years



- **690 GeV neutralino annihilating to $\gamma\gamma$**
- **Clumpy halo as realized in N-body simulation of Moore et al. (ApJL 1999)**

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

- $m_\chi = 690\mathrm{GeV}$
- $N_\gamma \sigma v = 1.5\times10^{-28}\mathrm{cm^3 s^{-1}}$

CALET Detector Concept

System Requirements

- Large Exposure for Low Flux :
  1000 m^2 sr year （~1m^2 sr ×3 years)
- Excellent Particle Identification:
  Large Mass + Multi-Channel Readout
  Imaging Cal. x Total Absorption Cal.
- Large Dynamic Range in Energy Measurement:
  Large Dynamic Range Read-out System
  High Energy Resolution

Detector Weight:	1450 kg
Absorber Thickness:	31 r.l, ~1.7m.f.p
Geometrical Factor:	~0.7 m^2sr
Power Consumption:	640 W
Data Rate:	300 kbps
Mission Life:	3-5 years

Sub-Components of Detector

SciFi/W Imaging Calorimeter (IMC):

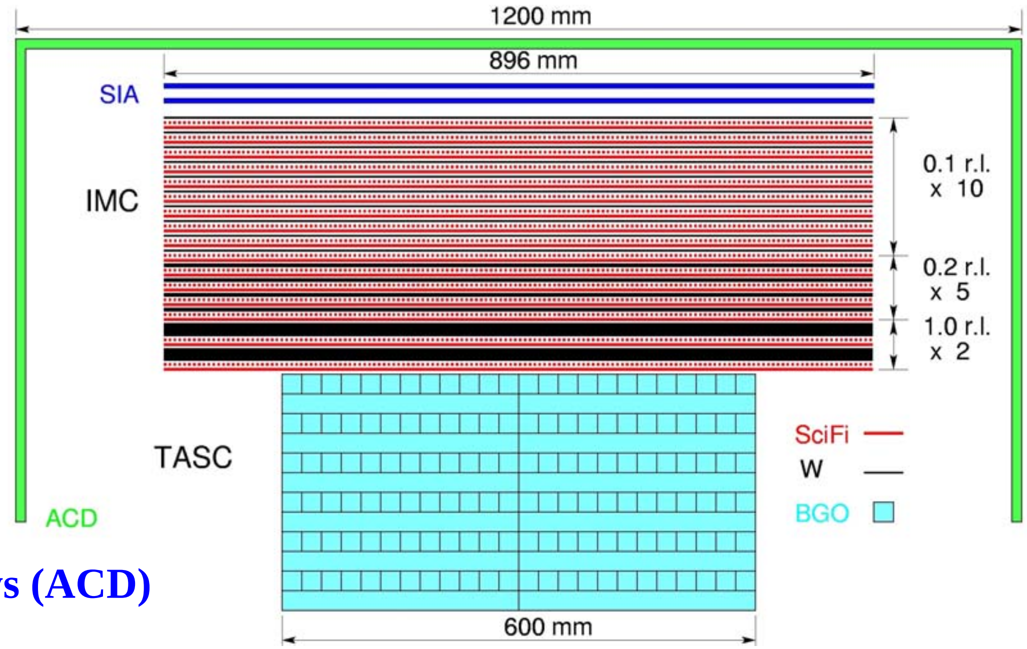
- Area: 90 x 90 cm^2
- SciFi Belt: 1mm square x ~1 m length
  17 layers (x &y)
- Tungsten: 4 r.l , 0.15 m.f.p

Total Absorption Calorimeter (TASC):

- Area : 60 x 60 cm^2
- BGO Log: 2.5 x 2.5 x 30 cm
  6 layers (x & y)
- Thickness: 27 r.l , 1. 5 m.f.p

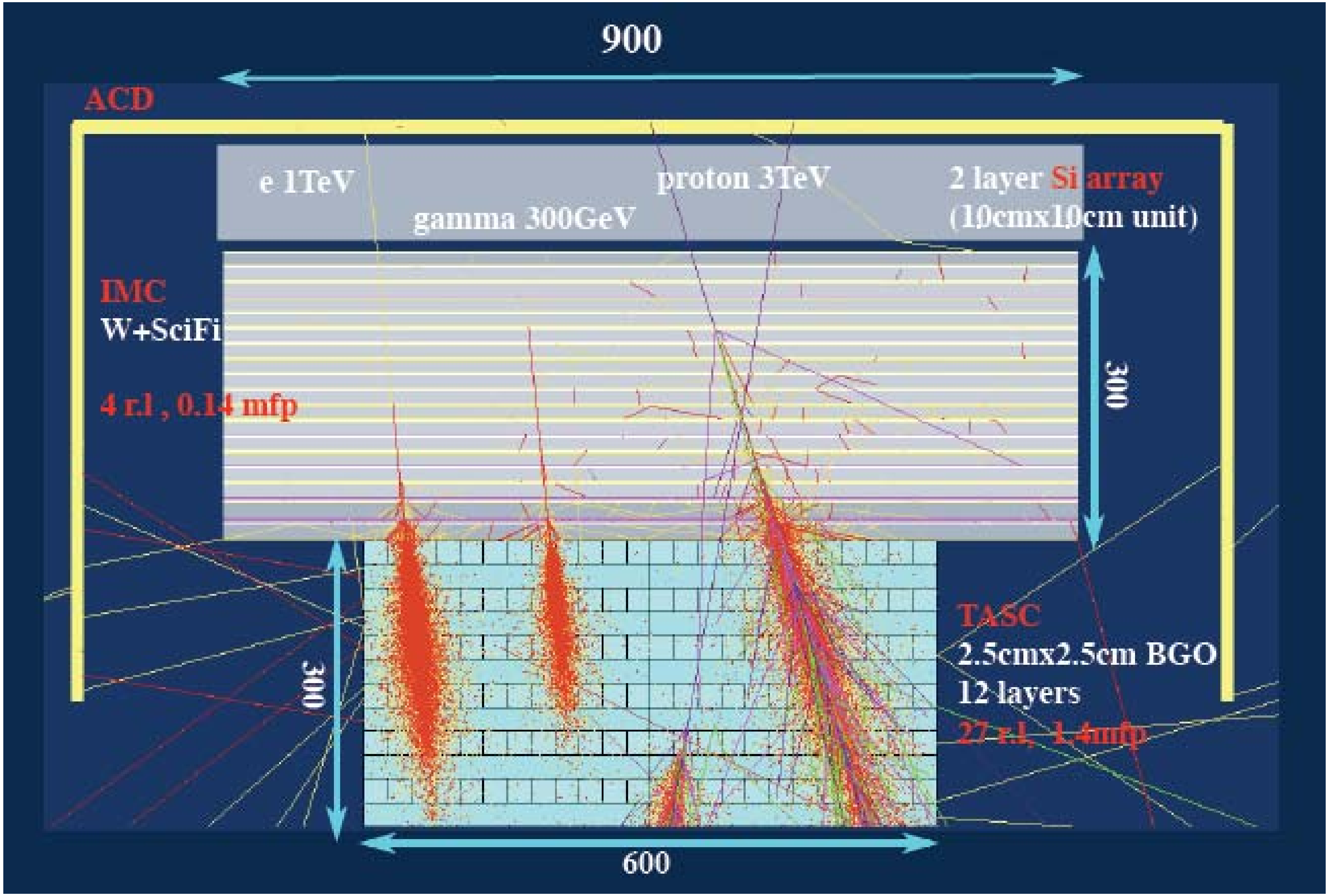
Anti-Coincidence Detector for Gamma-rays (ACD)

Silicon Pixel Array for High Z and Particle ID (SIA)



Schematic Side View of CALET Detector

Examples of Simulation Events

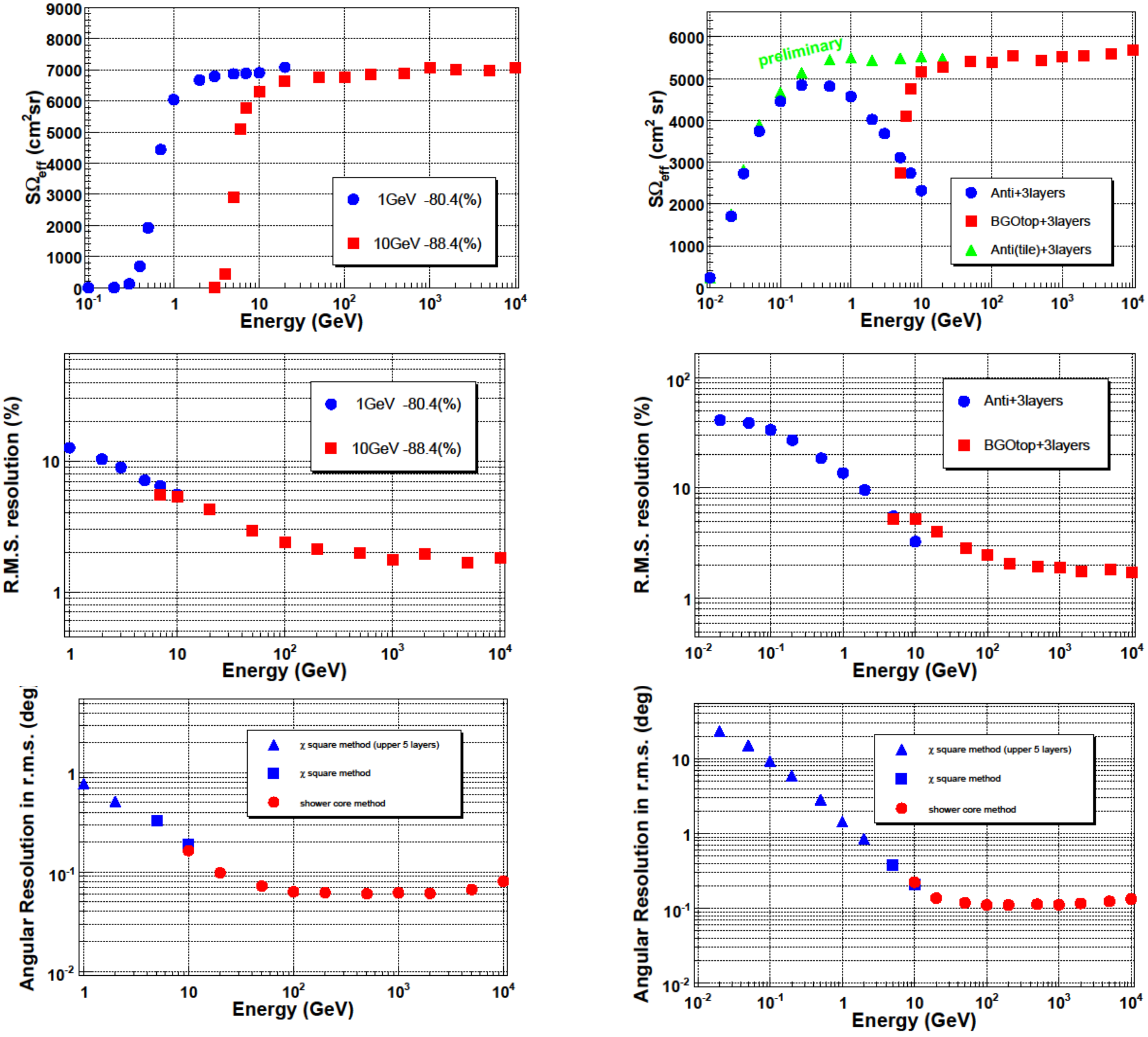


Electrons | **Gamma-rays**

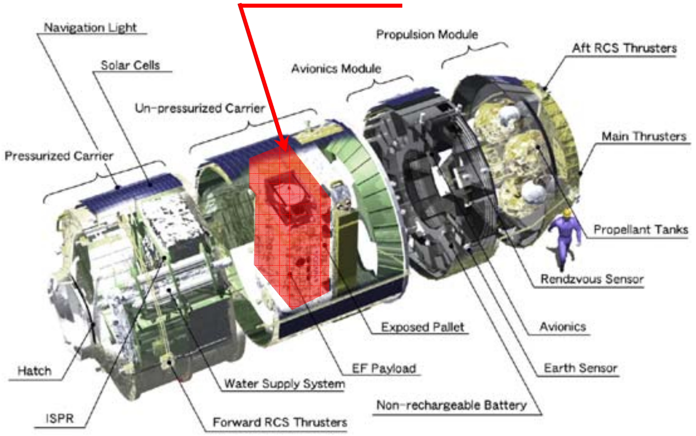
Geometrical Acceptance

Energy Resolution

Angular Resolution



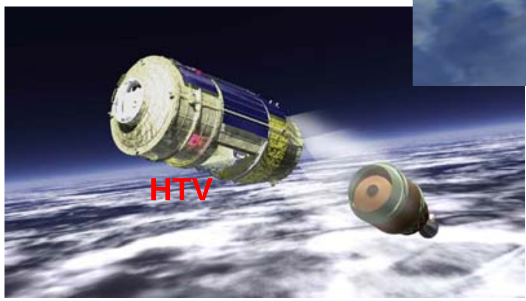
Launching Procedure of CALET



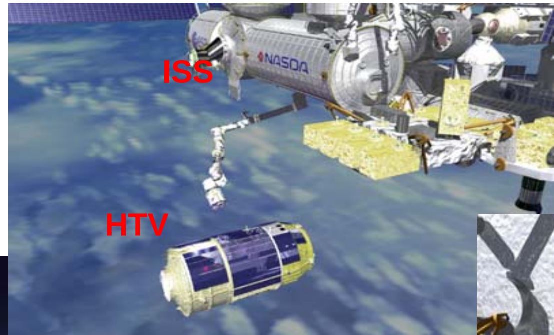
H-IIA Transfer Vehicle (HTV)

CALET launched by HTV

Launching of H-II Rocket

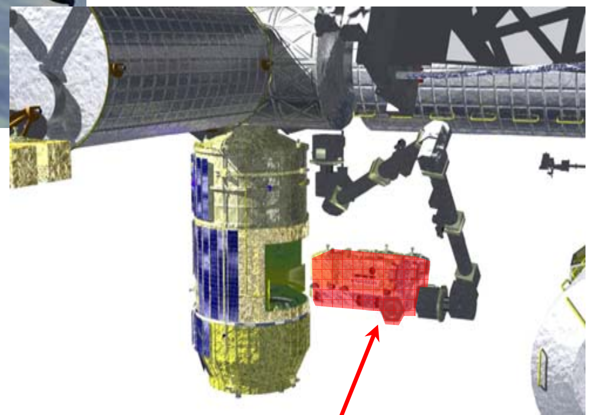


Separation from H-II

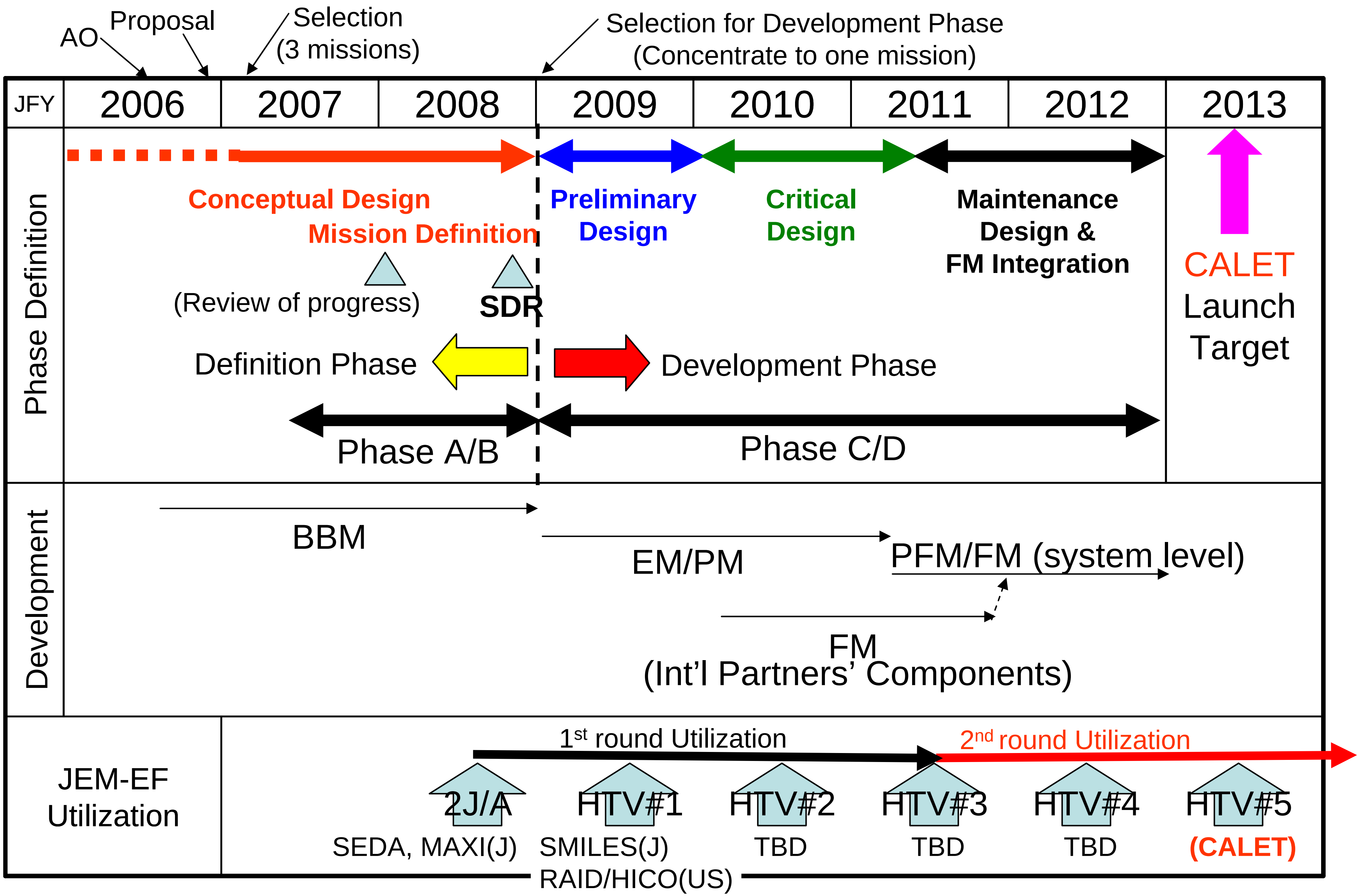


Approach to ISS

Pickup of CALET



CALET Timeline



Summary

- Cosmic-ray electron energy spectrum above 100GeV with PPB-BETS
  - ~100GeV region： consistent with the extrapolation of BETS
  - 100GeV~1TeV region: consistent with ATIC and ECC within statistical errors, considering energy resolution
- Future plan
  - Long duration ballooning will be carried out by a CALET prototype detector for confirming the ATIC anomaly
  - The CALET will bring us a conclusion on the excess of high energy electrons in 300-800 GeV, Dark Matter or Nearby Pulsars

We sincerely thank to the crew of the Syowa station in Antarctica and Sanriku Balloon Center in Japan for their excellent and successful balloon flights.