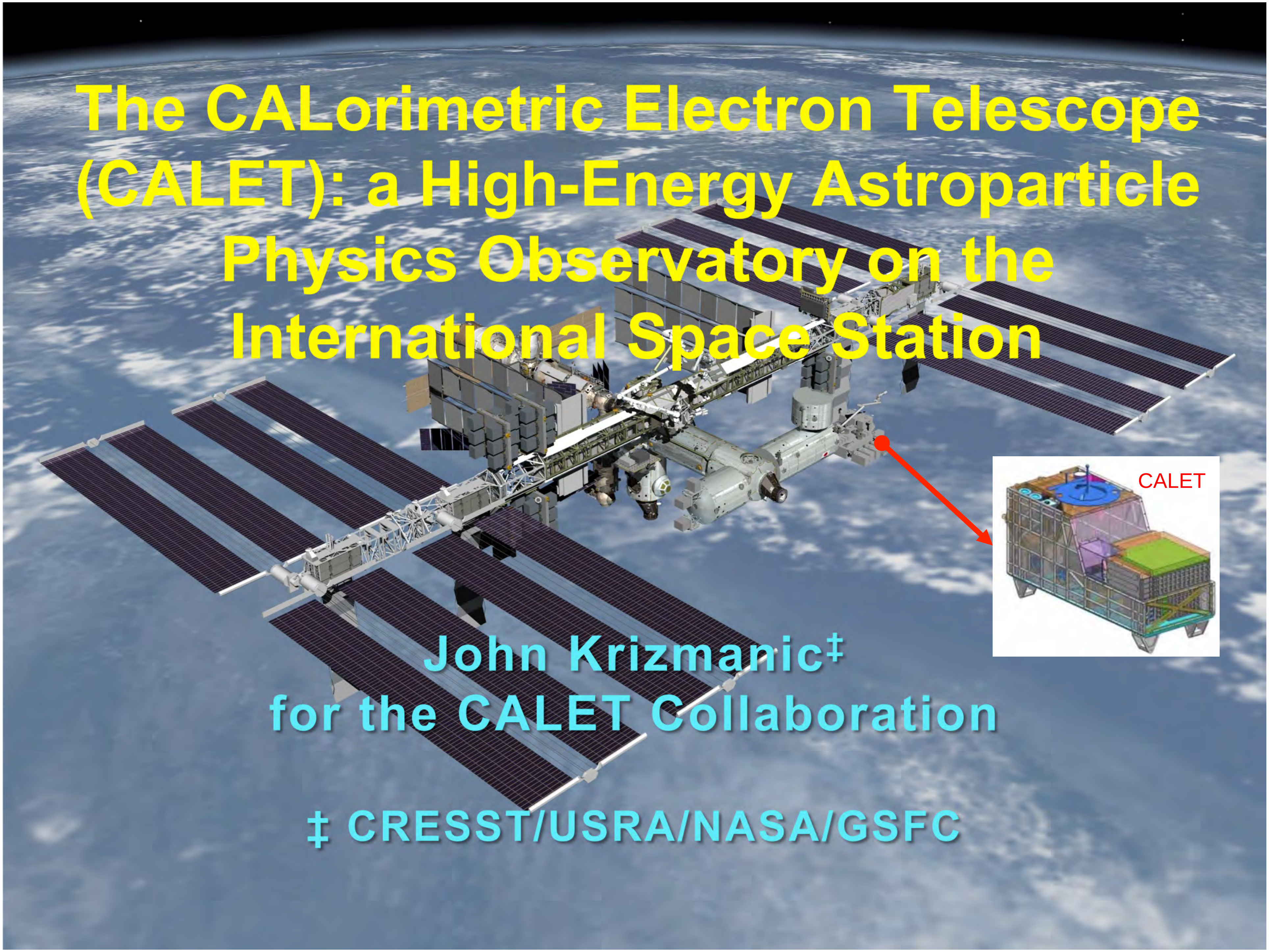
The CALorimetric Electron Telescope (CALET): a High-Energy Astroparticle Physics Observatory on the International Space Station



John Krizmanic[‡]
for the CALET Collaboration

‡ CRESST/USRA/NASA/GSFC

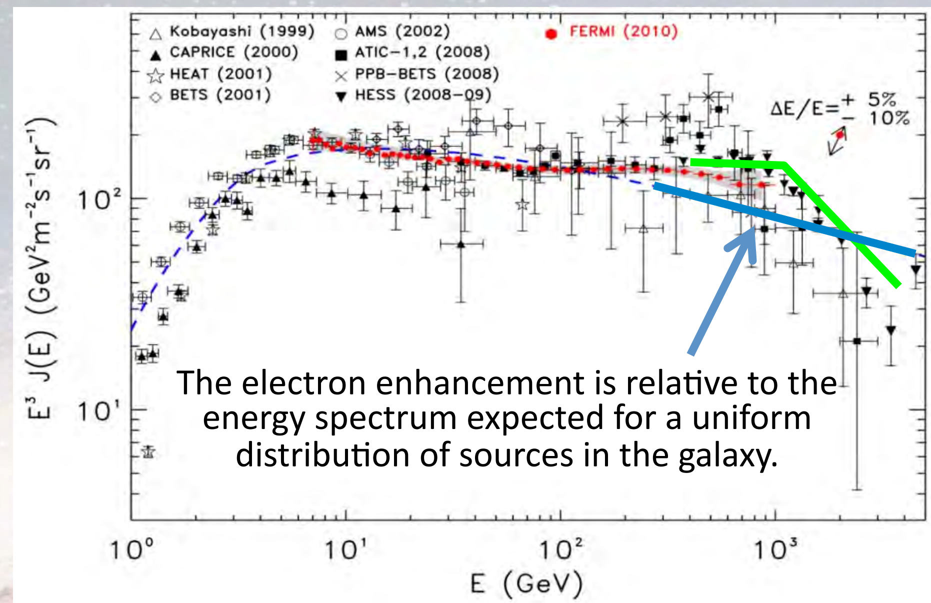
CALET Collaboration Team

O. Adriani[19], Y. Akaike[3], K. Asano[17], M.G. Bagliesi[22], G. Bigongiari[22], W.R. Binns[24], M. Bongi[19], J.H. Buckley[24], G. Castellini[19], M.L. Cherry[9], G. Collazuol[26], K. Ebisawa[5], V. Di Felice[21], H. Fuke[5], A. Gherardi[19], T.G. Guzik[9], T. Hams[10], N. Hasebe[23], M. Hareyama[5], K. Hibino[7], M. Ichimura[2], K. Ioka[8], M.H. Israel[24], A. Javaid[9], E. Kamioka[15], K. Kasahara[23], Y. Katayose[4,25], J. Kataoka[23], R. Kataoka[17], N. Kawanaka[8], M.Y. Kim[22], H. Kitamura[11], Y. Komori[6], T. Kotani[23], H.S. Krawczynski[24], J.F. Krizmanic[10], A. Kubota[15], S. Kuramata[2], T. Lomtadze[20], P. Maestro[22], L. Marcelli[21], P.S. Marrocchesi[22], V. Millucci[22], J.W. Mitchell[10], S. Miyake[28], K. Mizutani[14], A.A. Moiseev[10], K. Mori[5,23], M. Mori[13], N. Mori[19], K. Munakata[16], H. Murakami[23], Y.E. Nakagawa[23], S. Nakahira[5], J. Nishimura[5], S. Okuno[7], J.F. Ormes[18], S. Ozawa[23], P. Papini[19], B.F. Rauch[24], S. Ricciarini[19], Y. Saito[5], T. Sakamoto[1], M. Sasaki[10], M. Shibata[25], Y. Shimizu[4], A. Shiomi[12], R. Sparvoli[21], P. Spillantini[19], M. Takayanagi[5], M. Takita[3], T. Tamura[4,7], N. Tateyama[7], T. Terasawa[3], H. Tomida[5], S. Torii[4,23], Y. Tunesada[17], Y. Uchihori[11], S. Ueno[5], E. Vannuccini[19], J.P. Wefel[9], K. Yamaoka[4,23], S. Yanagita[27], A. Yoshida[1], K. Yoshida[15], and T. Yuda[3]

1) Aoyama Gakuin University, Japan
2) Hirosaki University, Japan
3) ICRR, University of Tokyo, Japan
4) JAXA/SEUC, Japan
5) JAXA/ISAS, Japan
6) Kanagawa University of Human Services, Japan
7) Kanagawa University, Japan
8) KEK, Japan
9) Louisiana State University, USA
10) NASA/GSFC, USA
11) National Inst. of Radiological Sciences, Japan
12) Nihon University, Japan
13) Ritsumeikan University, Japan
14) Saitama University, Japan
15) Shibaura Institute of Technology, Japan
16) Shinshu University, Japan
17) Tokyo Technology Institute, Japan
18) University of Denver, USA
19) University of Florence, IFAC (CNR) and INFN, Italy
20) University of Pisa and INFN, Italy
21) University of Rome Tor Vergata and INFN, Italy
22) University of Siena and INFN, Italy
23) Waseda University, Japan
24) Washington University-St. Louis, USA
25) Yokohama National University, Japan
26) University of Padova and INFN, Italy
27) Ibaraki University, Japan
28)Tokiwa University, Japan

There is something interesting happening with the electron energy spectrum

- It is now relatively well established that there is an enhancement in the electron energy spectrum within the ~200 GeV to ~1000 GeV energy range.
- ATIC, Fermi-LAT and HESS all see an enhancement, but experiment limitations preclude a complete characterization of the feature.



- Electrons at these energies have short lifetimes due to their high energy loss rate and are a sensitive indicator of local (~2 – 3 kpc) sources.
- Possible candidate sources include supernova remnants (SNR), pulsar wind nebulae (PWN) and products from dark matter (DM) annihilation.
- The exact shape of the spectral feature still needs to be refined and details of this shape may help identify the source of the energetic electrons.

What is needed is a reasonably large area instrument designed specifically for GCR electron measurement operated in space for a long period of time.

CALET: Calorimetric Electron Telescope

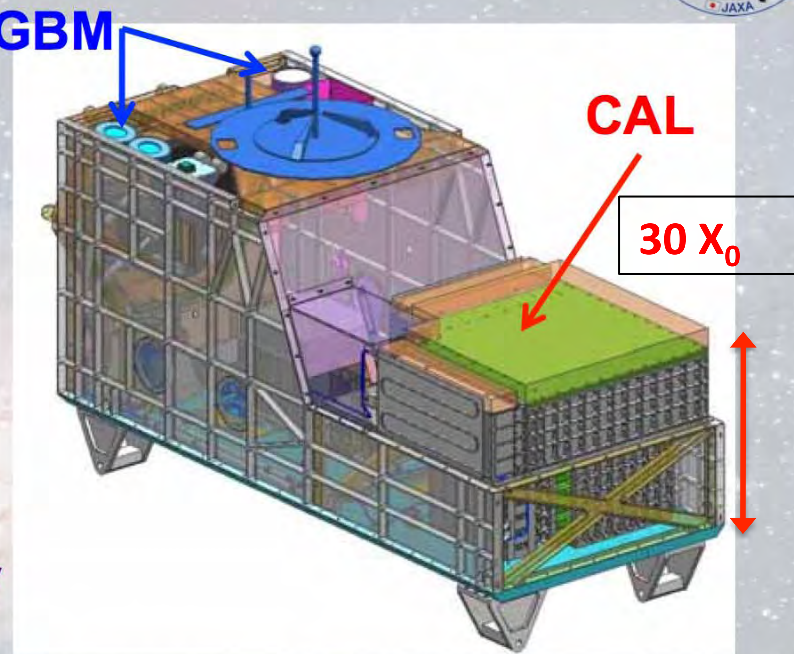
Main Telescope: Calorimeter (CAL)

- Electrons: 1 GeV – 20 TeV
- Gamma-rays: 10 GeV – 10* TeV
  (Gamma-ray Bursts: > 1 GeV)
- Protons and Heavy Ions:
  10's of GeV – 1,000* TeV
- Ultra Heavy (Z>28) nuclei:
  E > 600 MeV/nucleon

Gamma-ray Burst Monitor (CGBM)

- X-rays/Soft Gamma-rays: 7keV – 20MeV

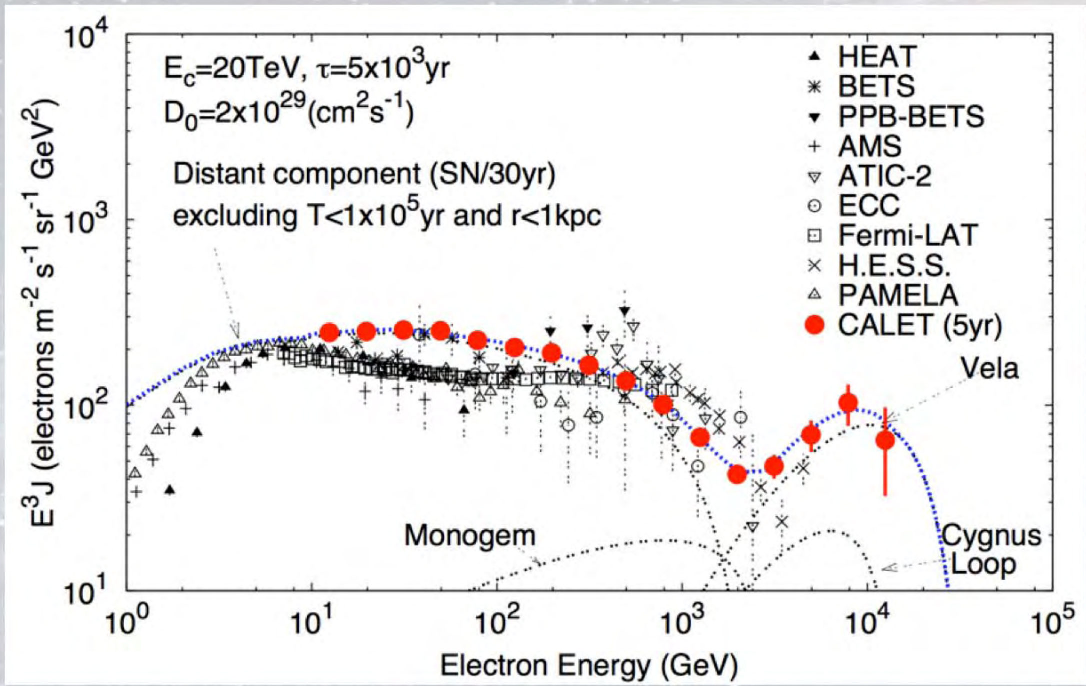
(* statistics dependent)



Science Objectives	Observation Targets
Nearby Cosmic-ray Sources	Electron spectrum in trans-TeV region
Dark Matter	Signatures in electron/gamma energy spectra in 10 GeV – 10 TeV region
Origin and Acceleration of Cosmic Rays	p-Fe over several tens of GeV, Ultra-Heavy Ions
Cosmic –ray Propagation in the Galaxy	B/C ratio up to several TeV /nucleon
Solar Physics	Electron flux below 10 GeV
Gamma-ray Transients	X-rays/Gamma-rays in 7 keV – 20 MeV

CALET could identify nearby cosmic-ray sources

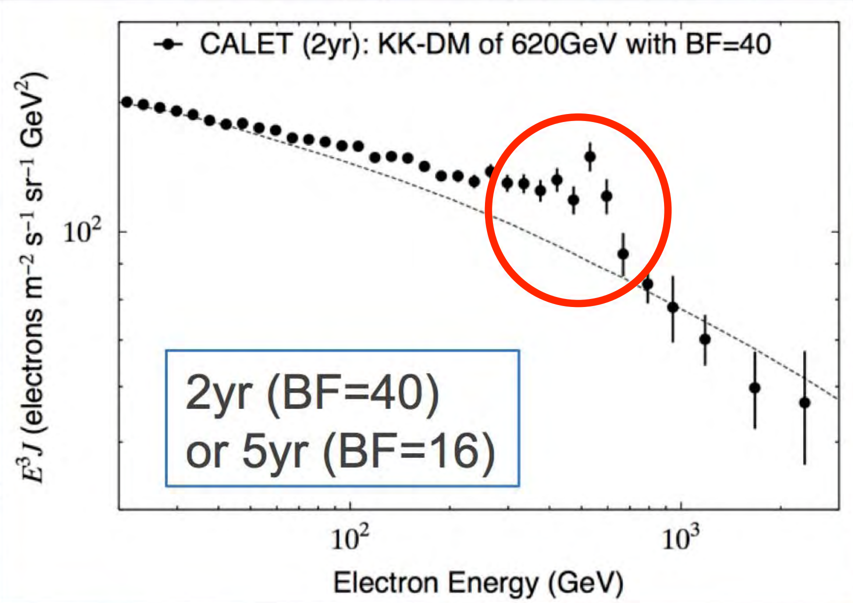
Some nearby sources, e.g. Vela SNR, might leave unique signatures in the electron energy spectrum in the TeV region (Kobayashi et al. 2004).

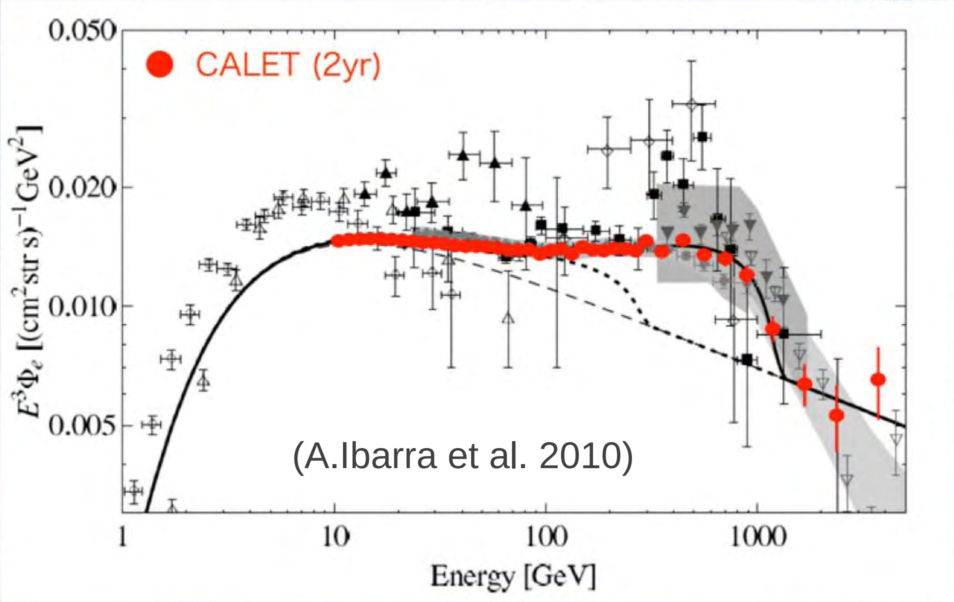


Simulated electron energy spectrum of the CALET for 5yr observations from a SNR scenario model (Kobayashi et al. 2004).

→ Identification of the unique signature from nearby SNRs such as Vela in the electron spectrum by CALET.

Indirect dark matter search by electrons





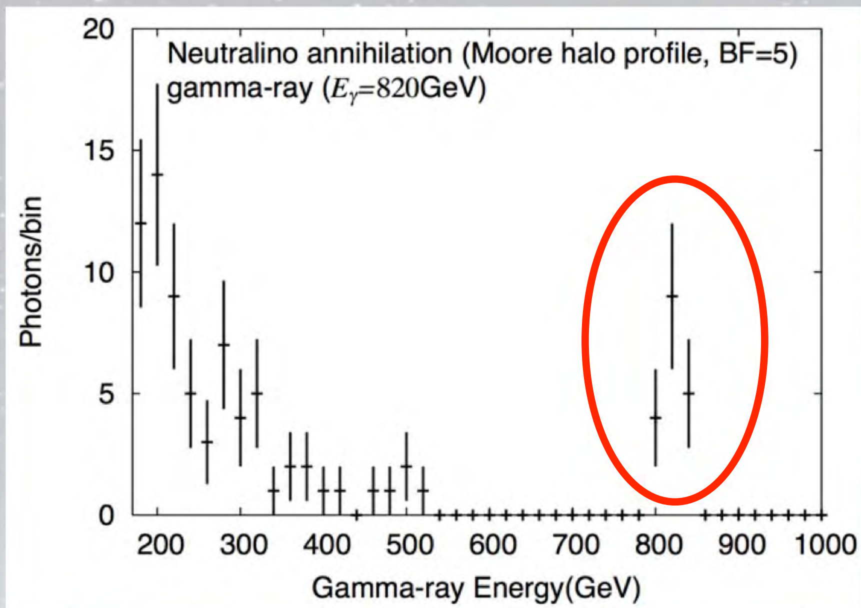
Simulated e^++e^- spectrum for 2yr from Kaluza-Klein dark matter annihilations with m=620GeV and BF=40.

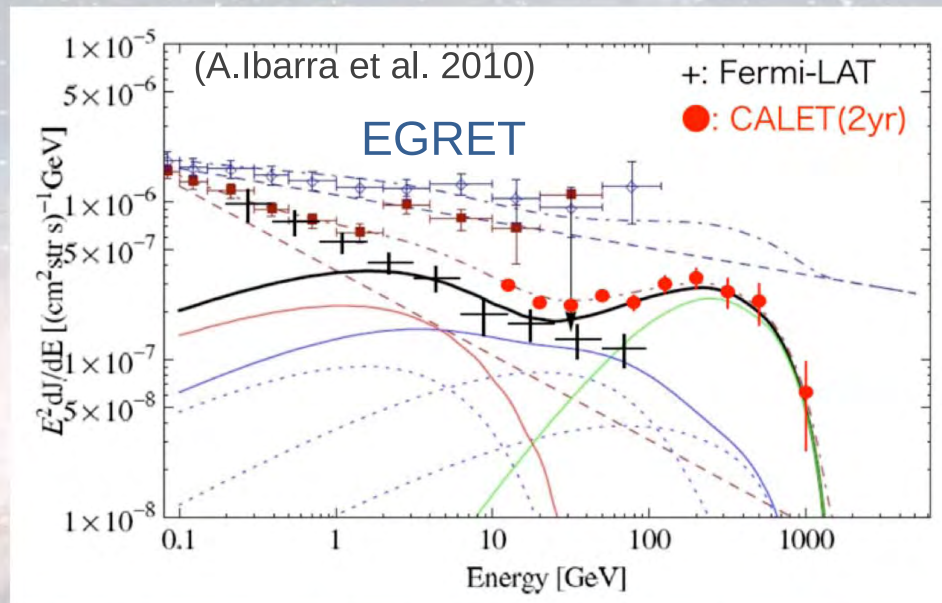
Simulated e^++e^- spectrum for 2yr from decaying dark matter for a decay channel of D.M.-> $l^+l^-\nu$ with m=2.5TeV and τ = 2.1x10^{26} s.

→ CALET has a potential to detect electron + positron signals from dark matter annihilation/decay.

- B.Rauch et al. (Proc. of the 39th COSPAR (Mysore)), CALET measurement of separate electron and positron spectra 5 < E < 20 GeV, using Geomagnetic Field

Indirect dark matter search by gamma rays





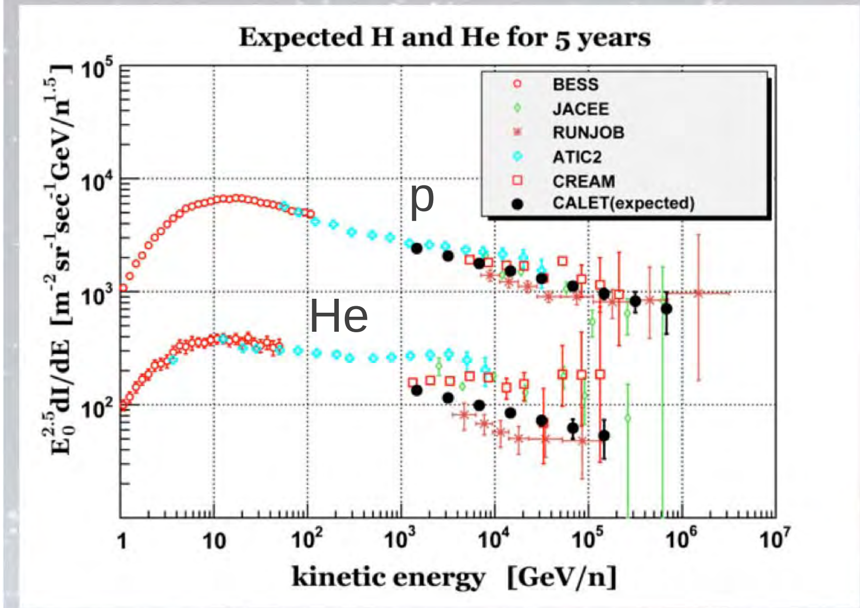
Simulated gamma-ray line spectrum for 2yr from neutralino annihilation toward the Galactic center with m=820GeV, a Moore halo profile, and BF=5.

Simulated extra-galactic gamma-ray spectrum for 2yr from decaying dark matter for a decay channel of D.M.-> $l^+l^-\nu$ with m=2.5TeV and τ = 2.1x10^{26} s.

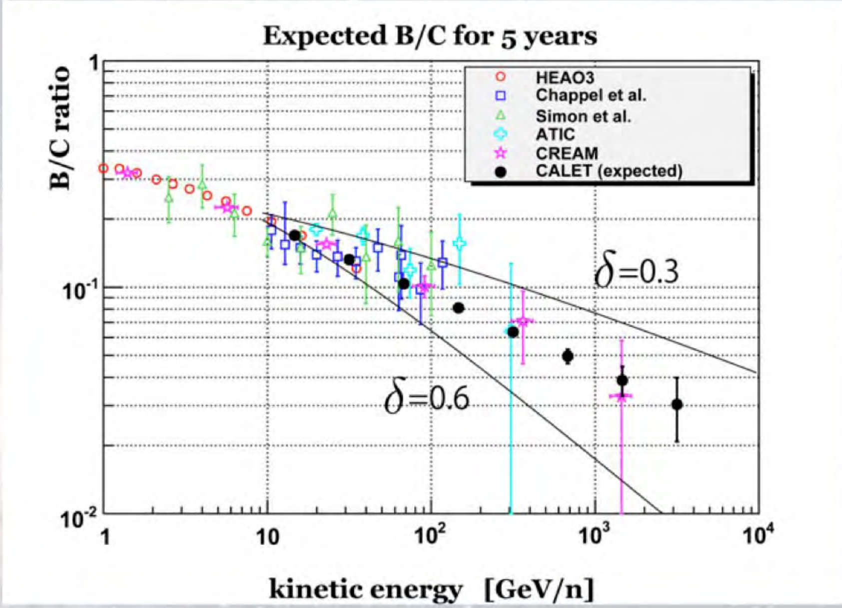
→CALET has a potential to detect gamma-ray signals from dark matter annihilation/decay with the excellent energy resolution of 2%

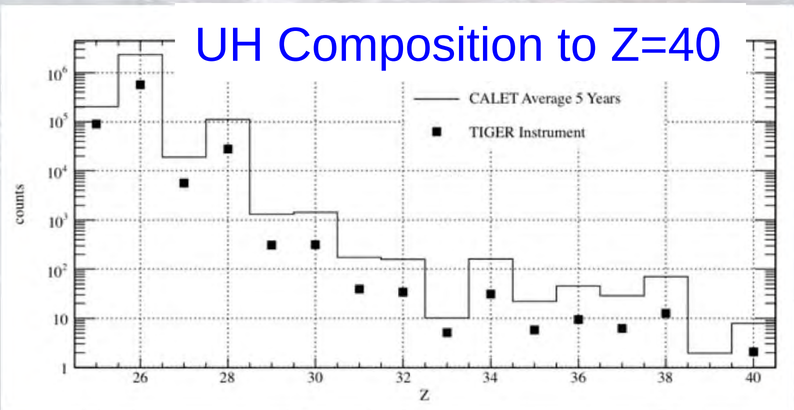
Nuclear components observations

Nuclear spectra of p – Fe to CR knee



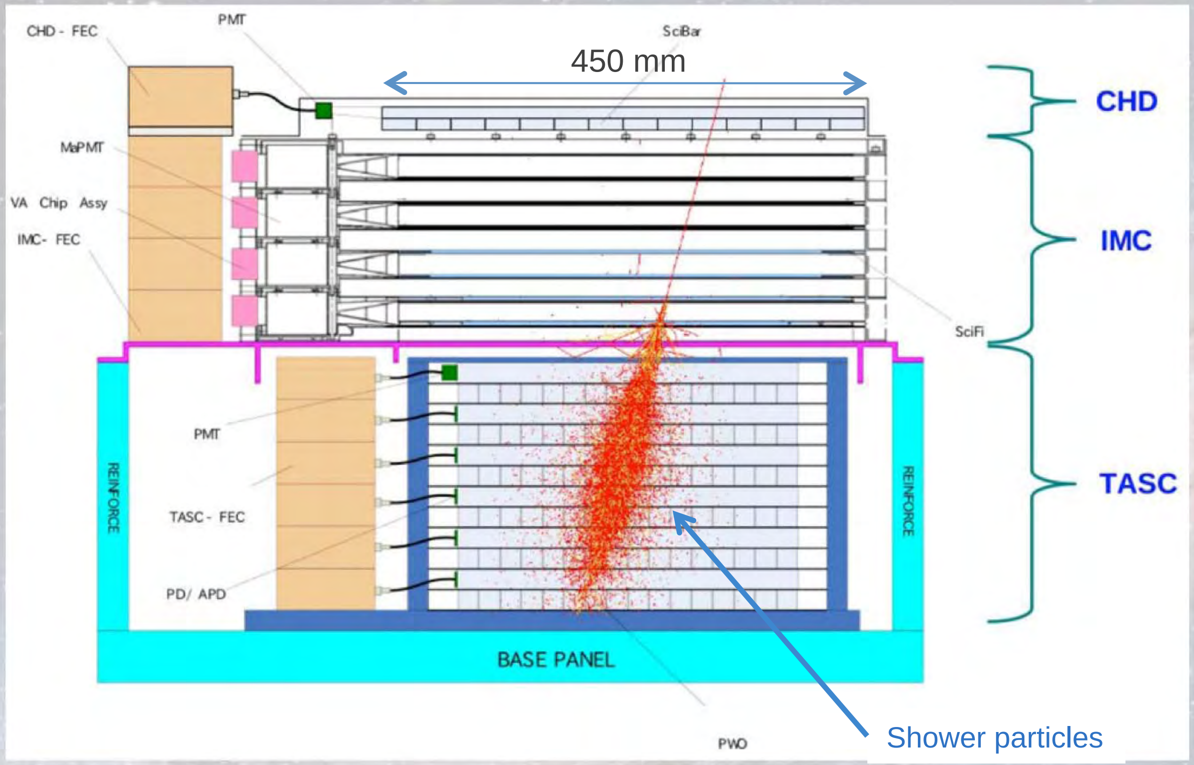
B/C, sub-Fe/Fe ratio





- ✧ Spectral shape and composition to the knee energy region
- ✧ Energy dependence of diffusion coefficient of D_0E^{δ}
- ✧ Much cleaner UH composition than previous balloon experiments

Main Telescope: CAL (Calorimeter)

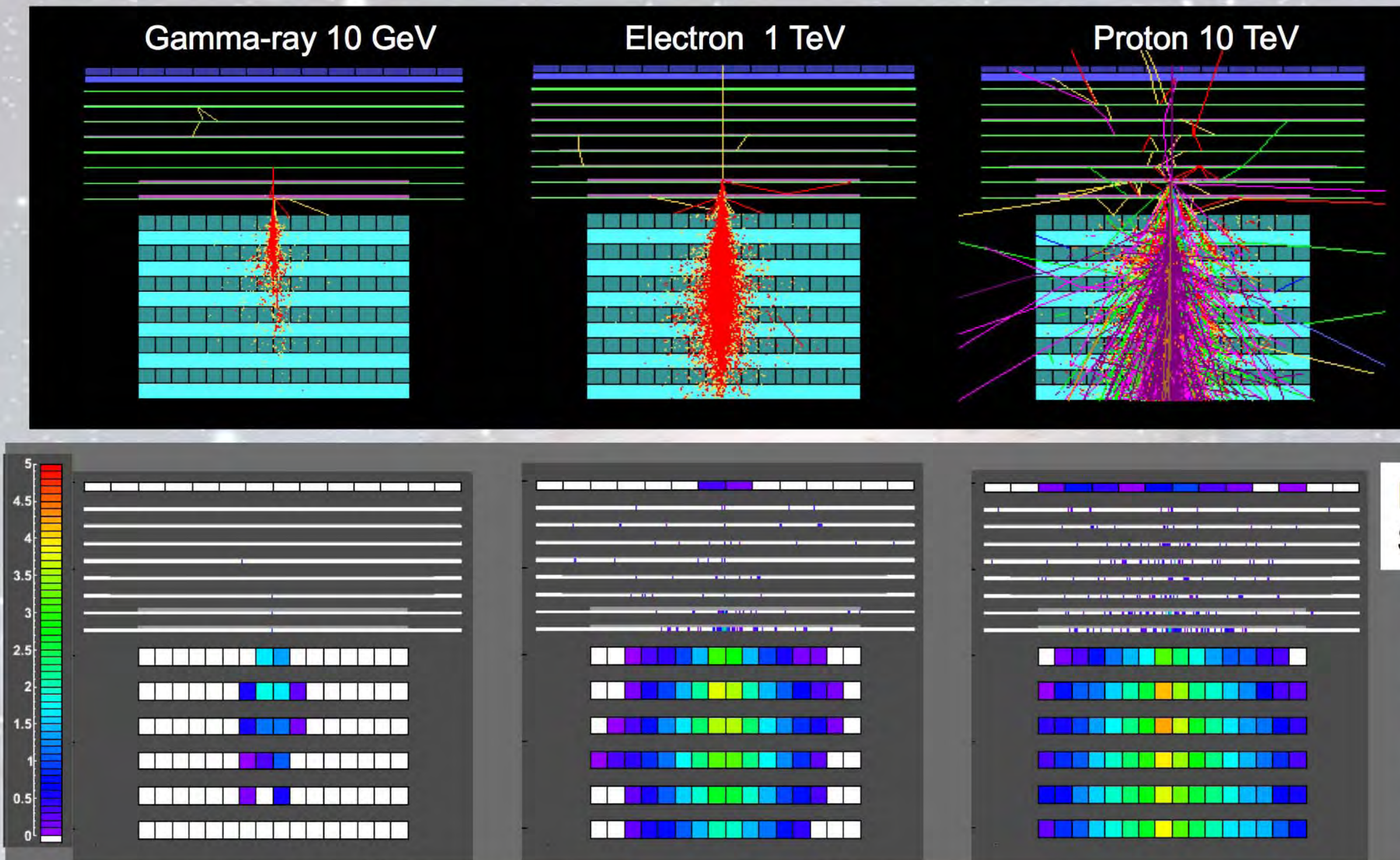


Expected Performance
(from Simulations and/or Beam Tests)

- SΩ :
  1200 cm^2sr for electrons, light nuclei
  1000 cm^2sr for gamma-rays
  4000 cm^2sr for ultra-heavy nuclei*
  * for E > 600 MeV/nucleon
- ΔE/E :
  ~2% (>10 GeV) for e's, γ's
  ~30 % for protons
- e/p separation: 10^{-5}
- Charge resolution: 0.15-0.3 e
- Angular resolution: ~0.1° e's, γ's

	CHD (Charge Detector)	IMC (Imaging Calorimeter)	TASC (Total Absorption Calorimeter)
Function	Charge Measurement (Z=1-46)	Arrival Direction, Particle ID	Energy Measurement, Particle ID
Sensor (+ Absorber)	Plastic Scintillator : 14 × 1 layer (x,y) Unit Size: 32mm x 10mm x 450mm	SciFi : 448 x 8 layers (x,y) = 7168 Unit size: $1mm^2$ x 448 mm **Total thickness of Tungsten: 3 X_0**	PWO log: 16 x 6 layers (x,y)= 192 Unit size: 19mm x 20mm x 326mm **Total Thickness of PWO: 27 X_0**
Readout	PMT+CSA	64 -anode PMT+ ASIC	APD/PD+CSA PMT+CSA (for Trigger)

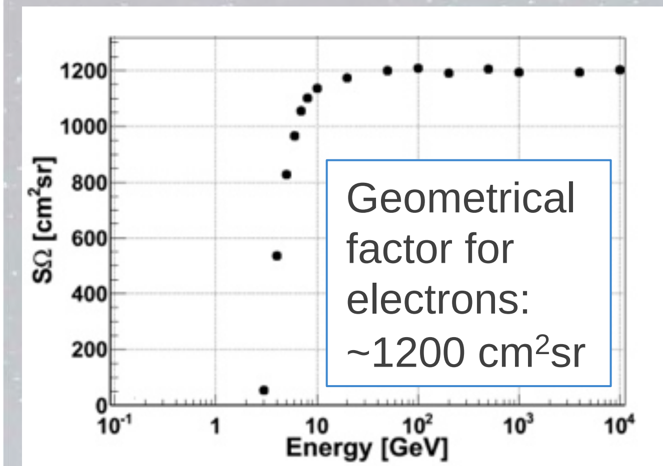
CALET/CAL Shower Imaging Capability (Simulation)



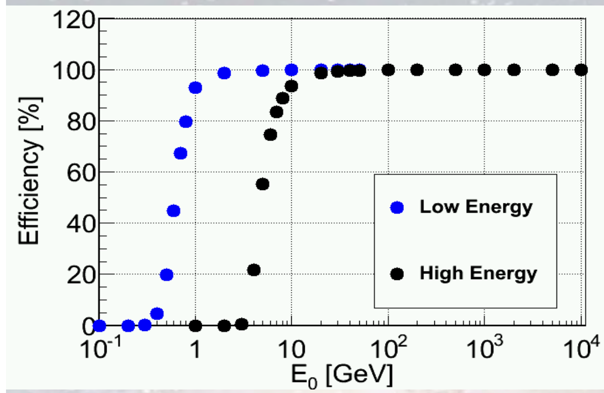
In Detector Space

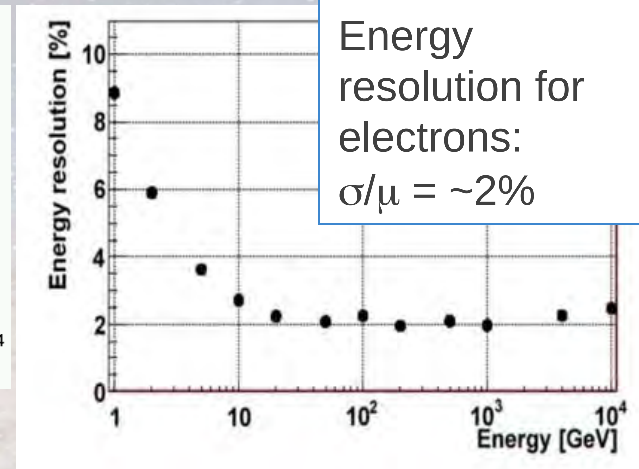
- Proton rejection power > 10^5 can be achieved with the IMC and TASC shower imaging capability.
- Charge of incident particle is determined to ΔZ = 0.15 – 0.3 with the CHD.

CALET/CAL Expected Performance

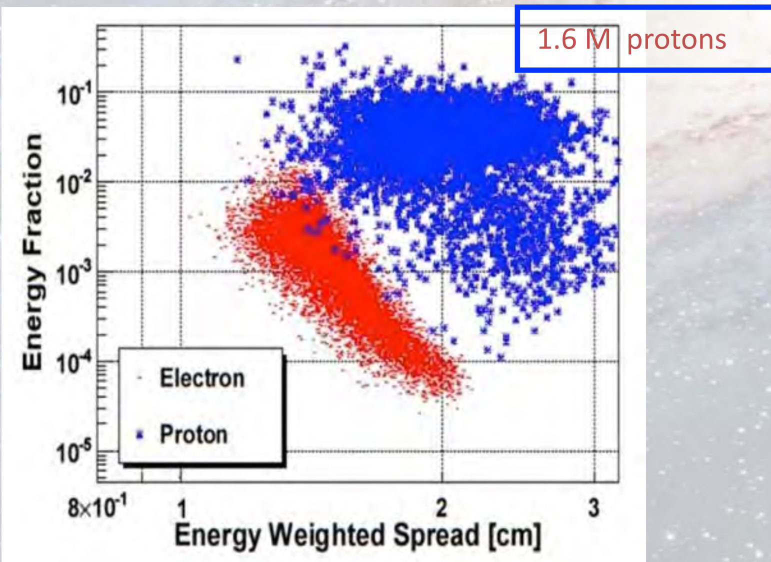


Geometrical factor for electrons: ~1200 cm^2sr

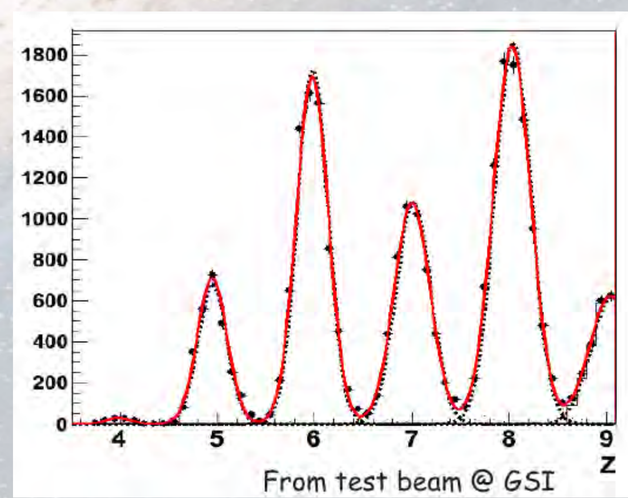




Energy resolution for electrons: σ/μ = ~2%

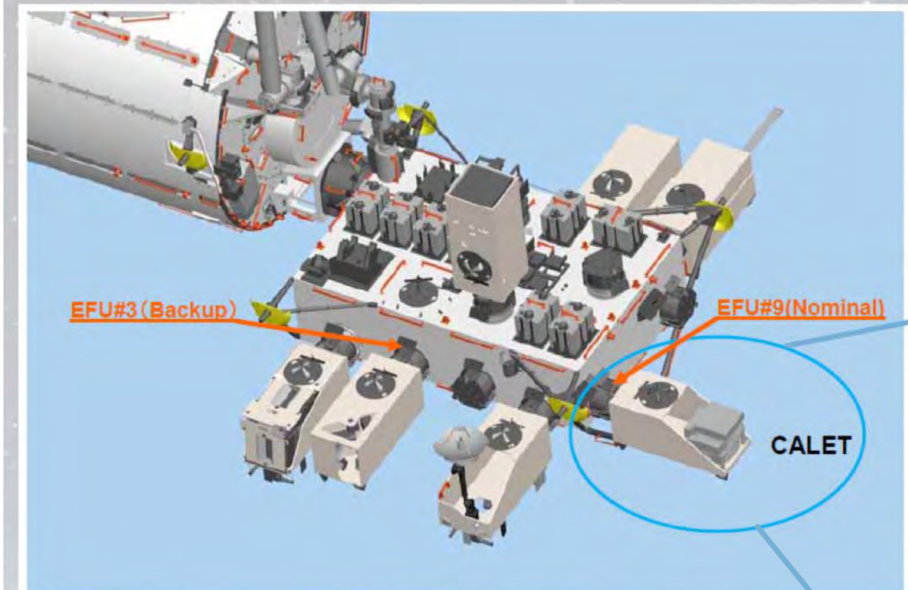


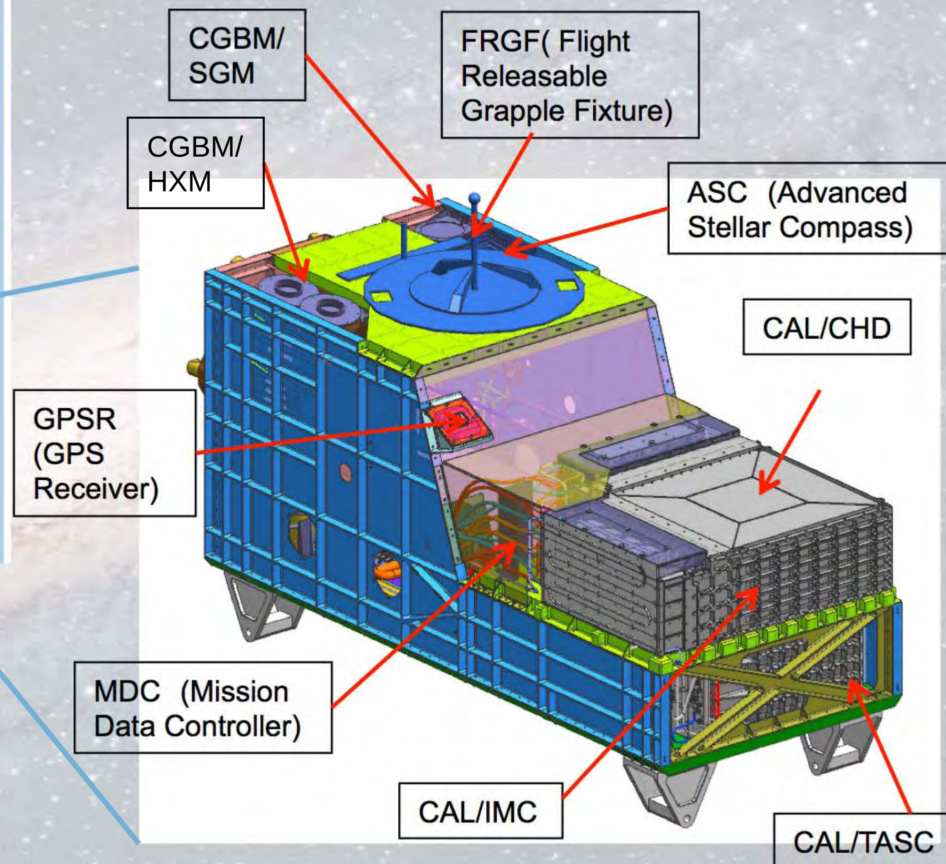
Proton rejection power at 4TeV $>10^5$ with 95% electron retained



Charge resolution: $\Delta Z = 0.15 – 0.3$

CALET Payload Overview





- ✧ Launch carrier: HTV-5
- ✧ Launch target date: CY 2014
- ✧ Mission period: More than 2 years (5 years target)

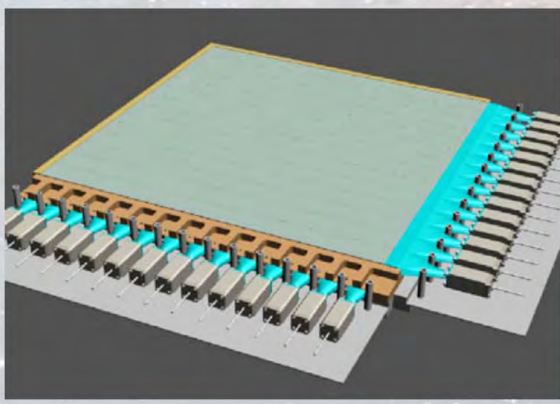
- ✧ Data rate:
  - ➢ Medium data rate: 300 kbps
  - ➢ Low data rate: 20 kbps

- ✧ Mass: 650 kg (Max)
- ✧ Standard Payload Size
- ✧ Power: 650 W (Max)

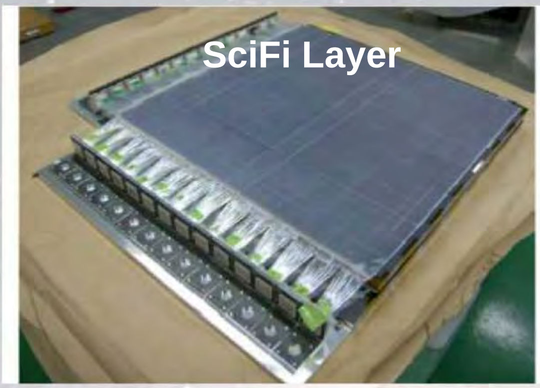
CALET flight hardware is being developed

CHD

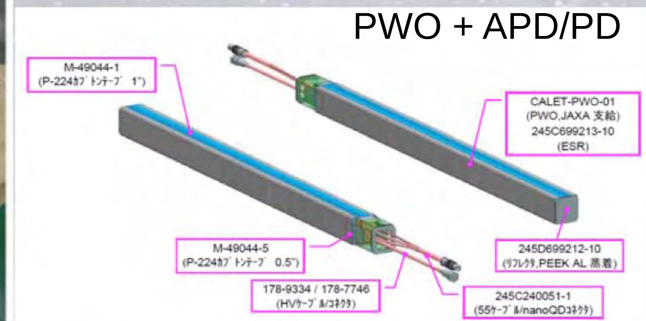
Design Study of Structure

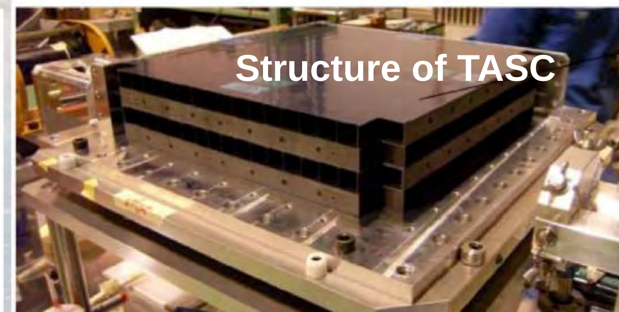


IMC



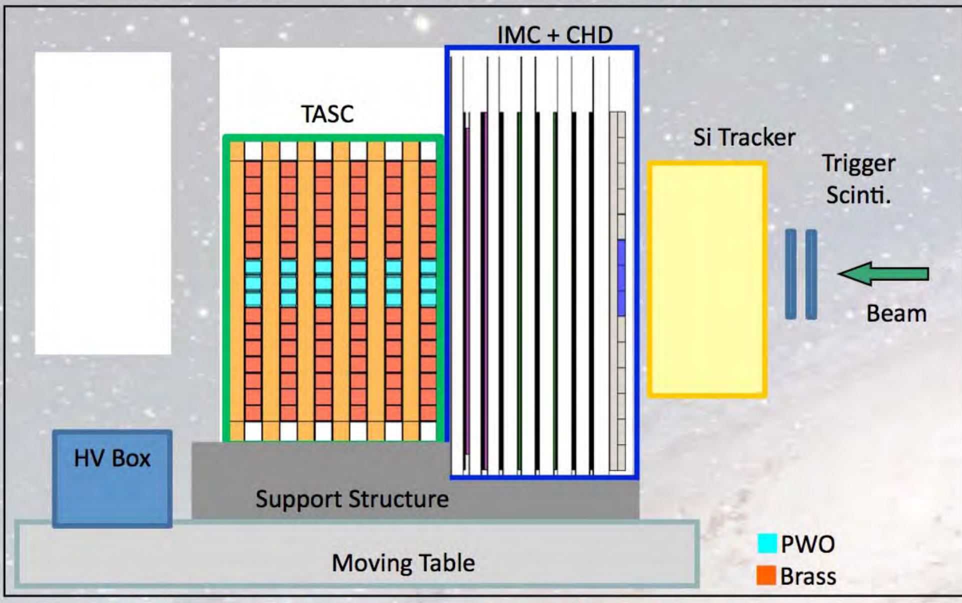
TASC



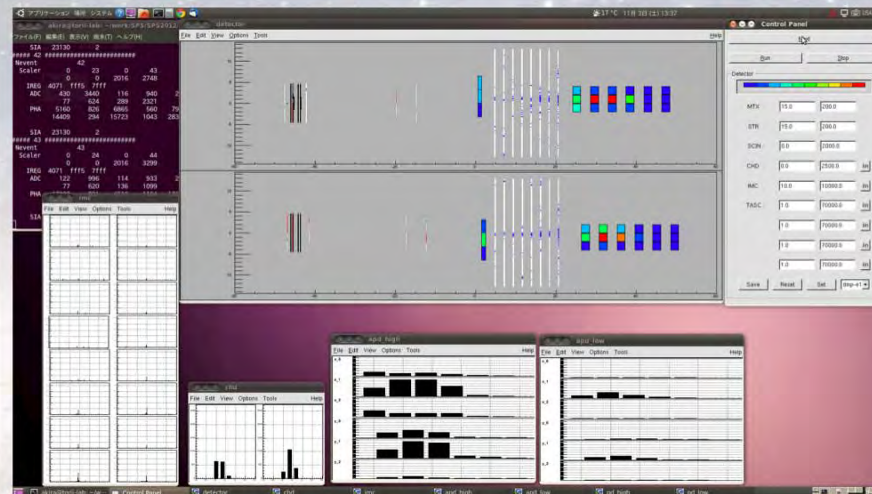


CALET prototype hardware has been tested

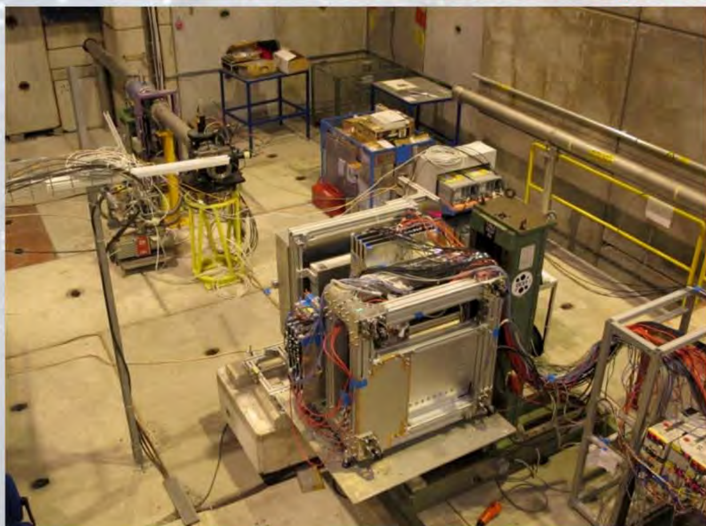
Beam Tests of the Scale-model of CALET in 2009, 2010, 2011, 2012, & 2013

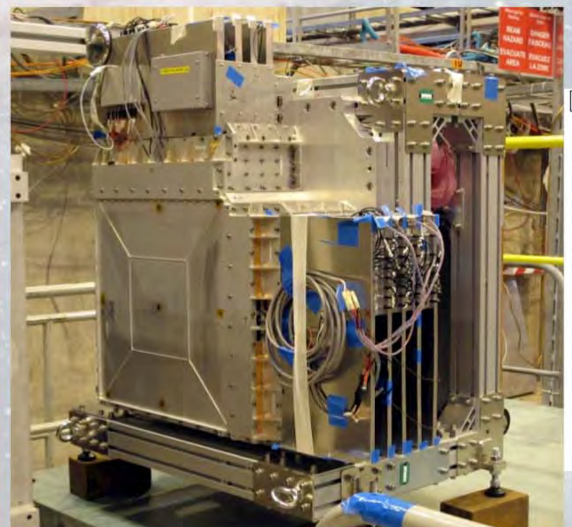


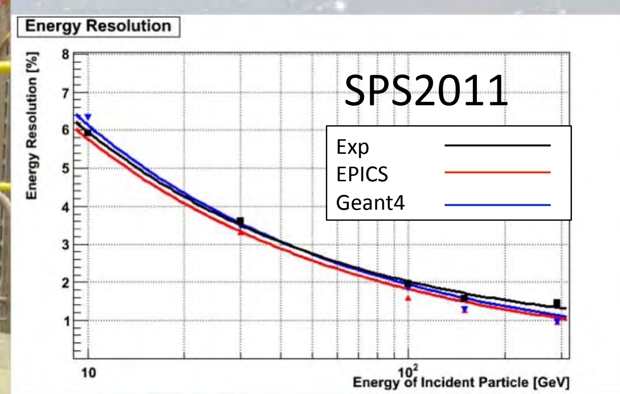
290 GeV Electron Online Display



2012 CERN SPS Test Beam Configuration







Summary

- ✧ CALET is an instrument dedicated to observing, primarily, electrons in the trans-TeV region, that will provide crucial information on nearby sources and dark matter.
  - – Electrons from 1 GeV to 20,000 GeV
  - – Gamma-rays from 10 GeV to 10,000 GeV
  - – Protons and heavy ions (Z < ~28) from 10's of GeV to ~1,000 TeV
  - – Ultra Heavy ion (28 < Z < ~46) for energy greater than ~600 MeV/n
  - ➢ **B.Rauch (Session L14), Predicted CALET Measurements of Ultra-Heavy Cosmic Ray Relative Abundances**
- ✧ The CALET detectors are based upon designs proven during balloon flights (BETS, bCALET) and accelerator beam tests.
  - ➢ **A. Javaid (Session L14), Characterization of CALET prototype lead tungstate calorimeter using CERN beam test data.**
- ✧ Development of the CALET flight hardware is now well underway. **CALET to be delivered to JAXA in October 2013.**
- ✧ The CALET project has been approved for launch in CY2014 by HTV-5 to the Japanese Experiment Module (Kibo).
- ✧ The target mission is 5 years -> electron exposure = 220 m^2 sr days