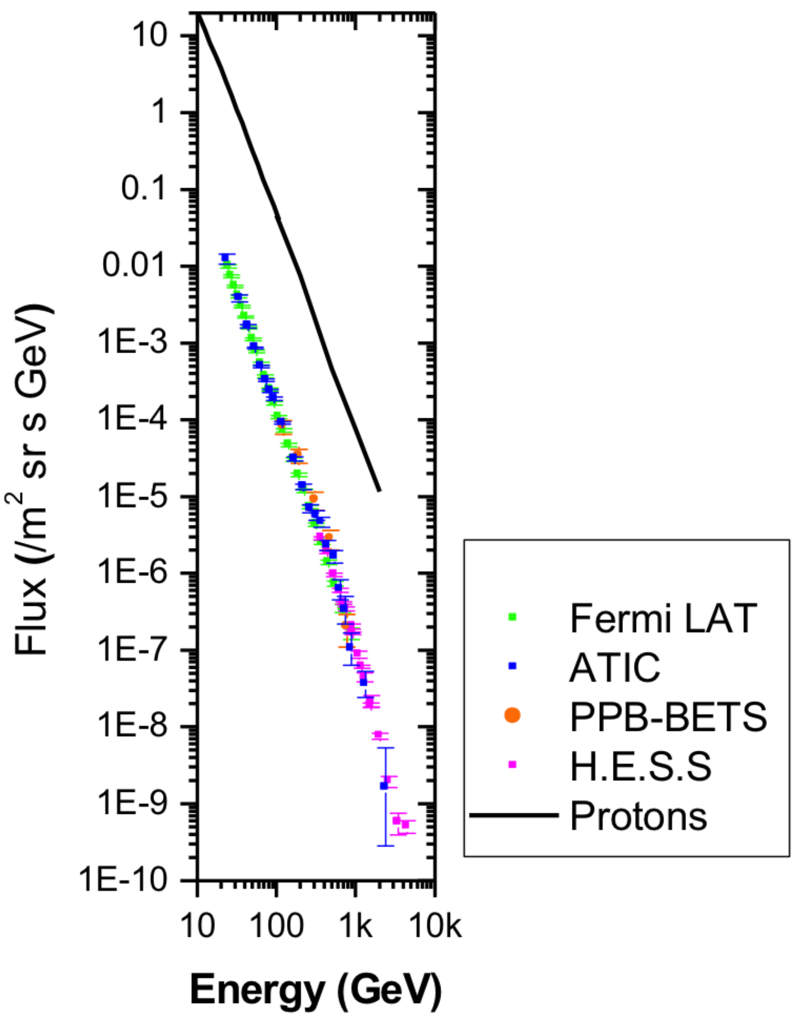
Cosmic Ray Electrons
Cosmic SIG, 2015 April APS Meeting

Brian Flint Rauch
Washington University in St. Louis

Challenges of Measuring High-Energy Electrons

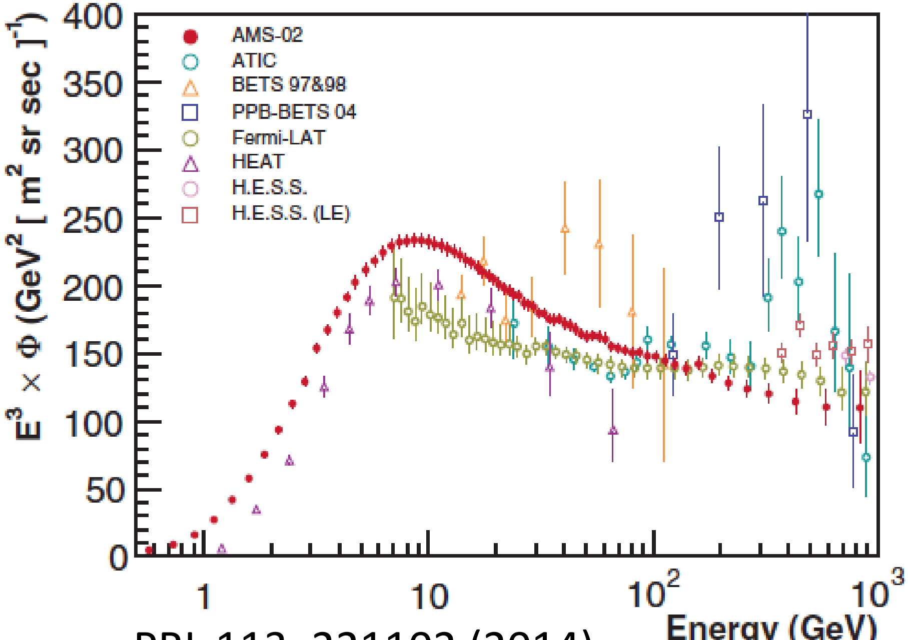


- Cosmic-ray electron energy spectra fall as ~ E^{-3}
  - Rapidly increasing exposures required for higher energies
  - Uncertainties in energy yield comparatively large errors in flux
- Spectra soften rapidly above ~1 TeV due synchrotron and inverse Compton processes
- ≥ TeV electrons must have been accelerated within ~10^5 yrs and originate within at most a few hundred pc
- Protons of the same energy as electrons are more abundant by a factor of ≥ 1000, so proton rejection is vital

Current High-Energy Electron Flux Measurements

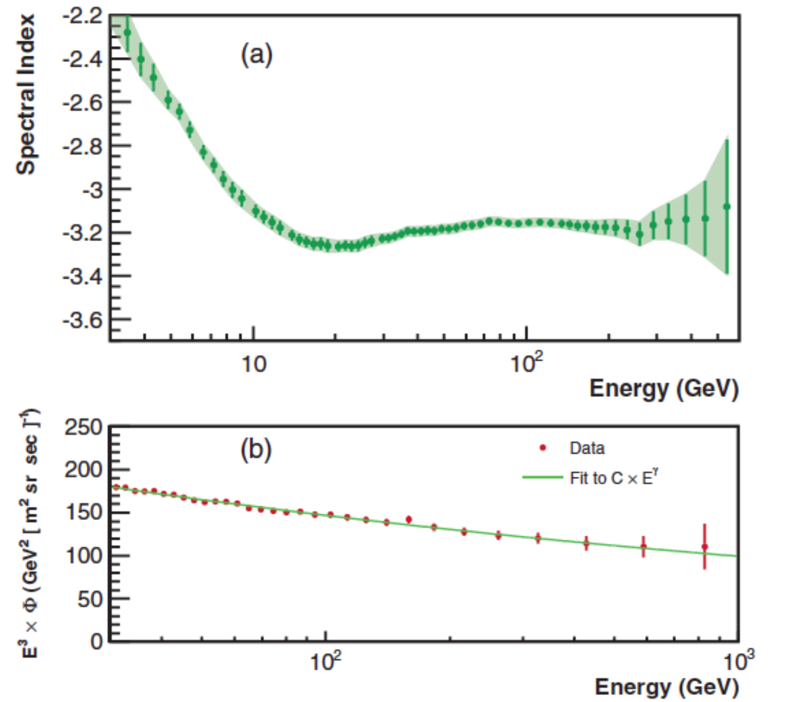
Washington University in St. Louis

Total $e^- + e^+$ Flux



PRL 113, 221102 (2014)

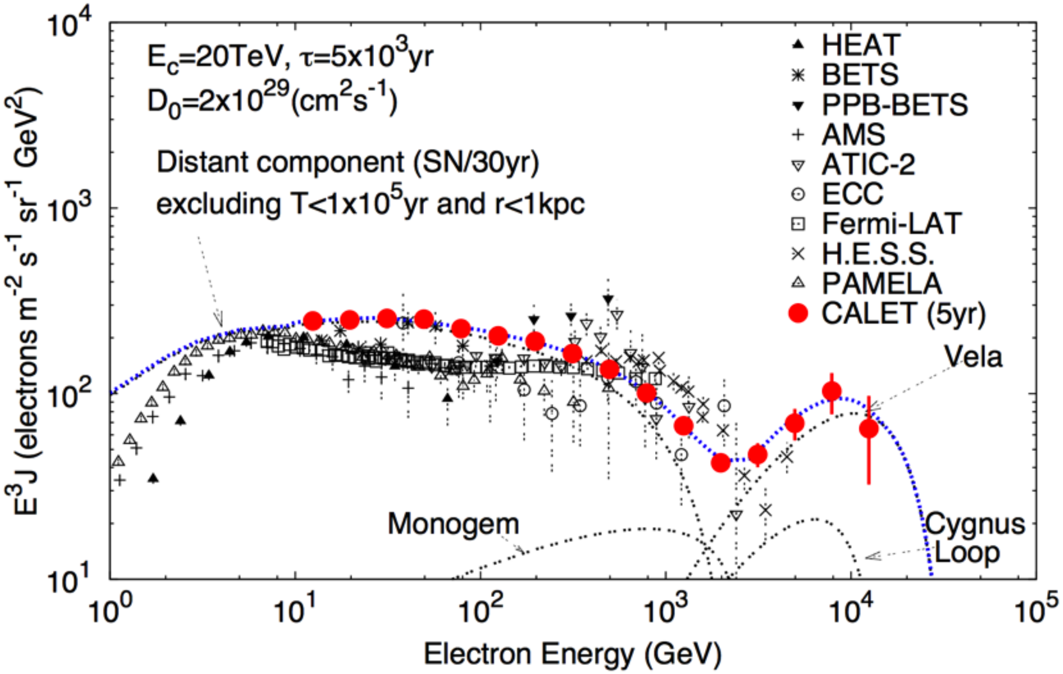
AMS-02 Data Show Power Law ≥ 30.2 GeV



- Recent measurements from Fermi-LAT and AMS-02 do not show the excesses at ~700 GeV reported by ATIC and PPB-BETS
- Fermi-LAT shows slight excess above secondary prediction (GALPROP) above 100 GeV
- HESS data are consistent with Fermi-LAT but well above AMS-02
- Fermi-LAT shows an energy dependent spectral index ~80 GeV – 1 TeV
- AMS-02 data show single power law 30.2 GeV - 1 TeV

CALET Will Search for Nearby Galactic Cosmic-Ray Sources

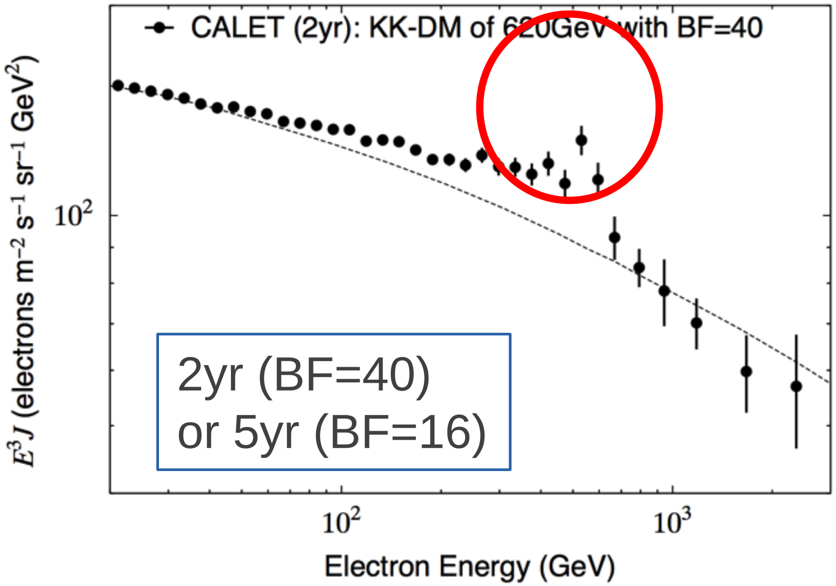
Some nearby sources, e.g. Vela SNR, might leave unique signatures in the electron energy spectrum in the TeV region (Kobayashi et al. 2004).



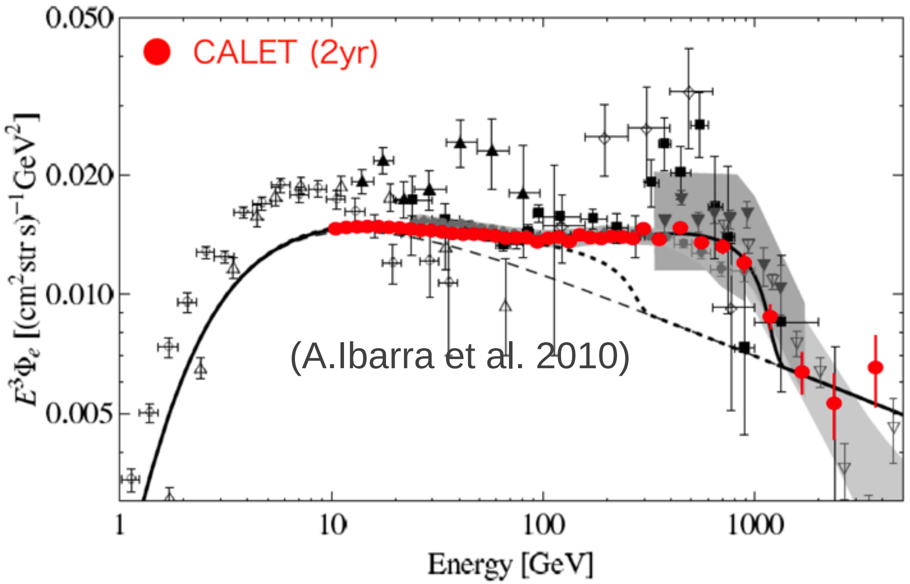
Simulated electron energy spectrum of CALET for 5yr observations from a SNR scenario model (Kobayashi et al. 2004).

→ Potential identification of the unique signatures from nearby SNRs such as Vela in the electron spectrum by CALET.

Indirect Dark Matter Search with Electrons



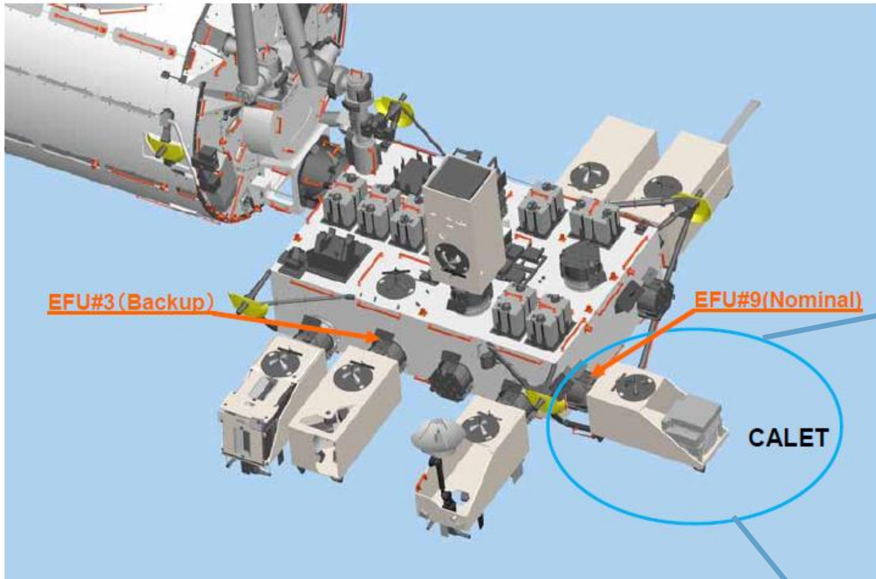
Simulated e^++e^- spectrum for 2yr from Kaluza-Klein dark matter annihilations with m=620GeV and BF=40.

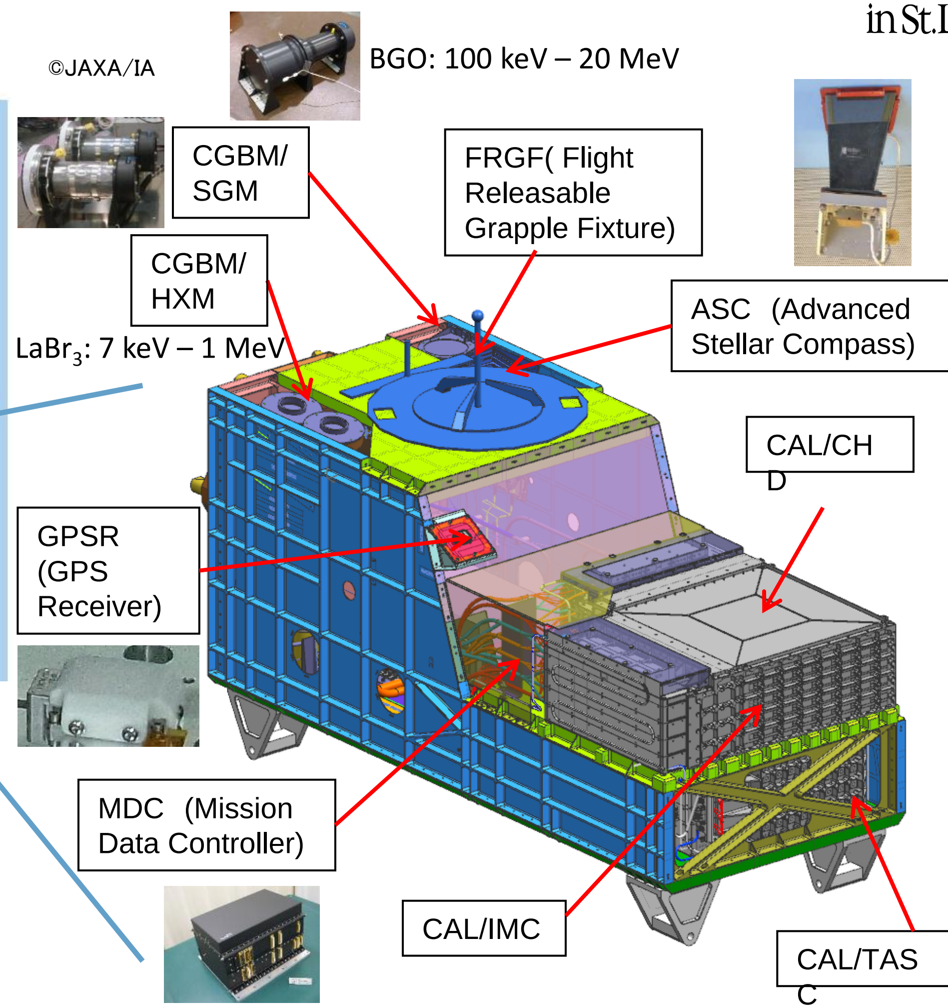


Simulated e^++e^- spectrum for 2yr from decaying dark matter for a decay channel of D.M.-> $l^+l^-\nu$ with m=2.5TeV and τ = 2.1x10^{26} s.

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

CALET Payload Overview

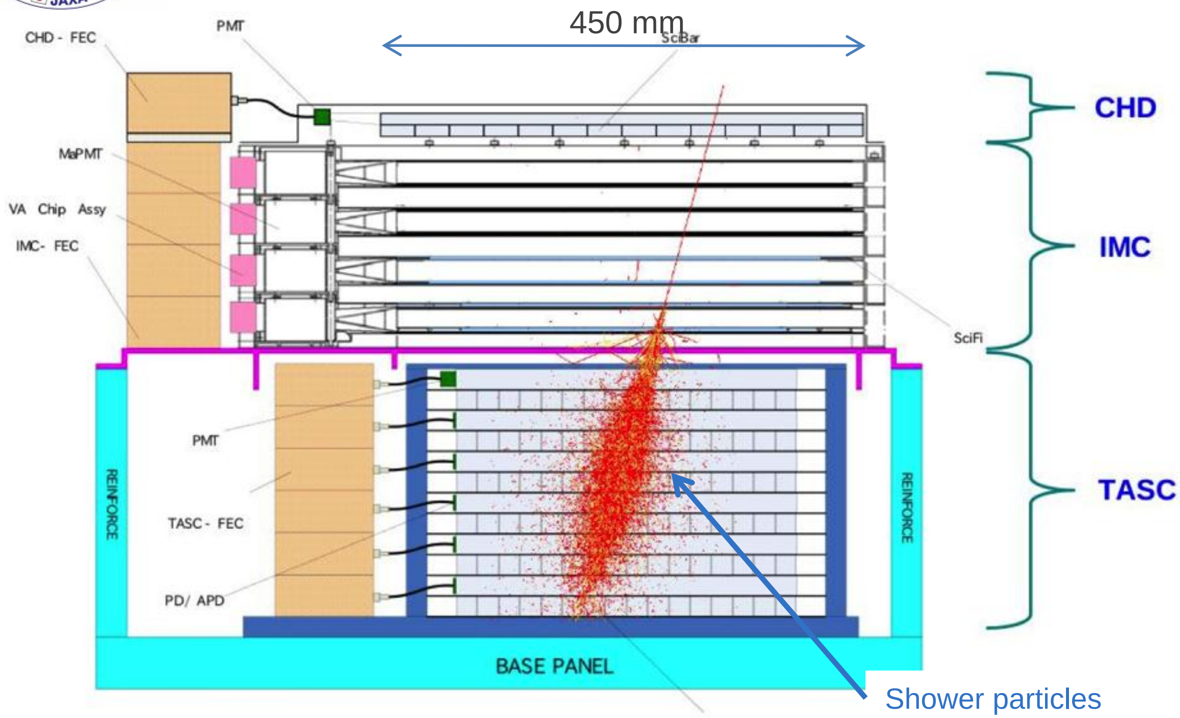




- Launch carrier: HTV-5
- Launch target date: summer 2015
- Mission period: More than 2 years
  - (5 years target)
- Data rate:
  - Medium data rate: 300 kbps
  - Low data rate: 20 kbps

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

Main Telescope: CAL (Calorimeter)

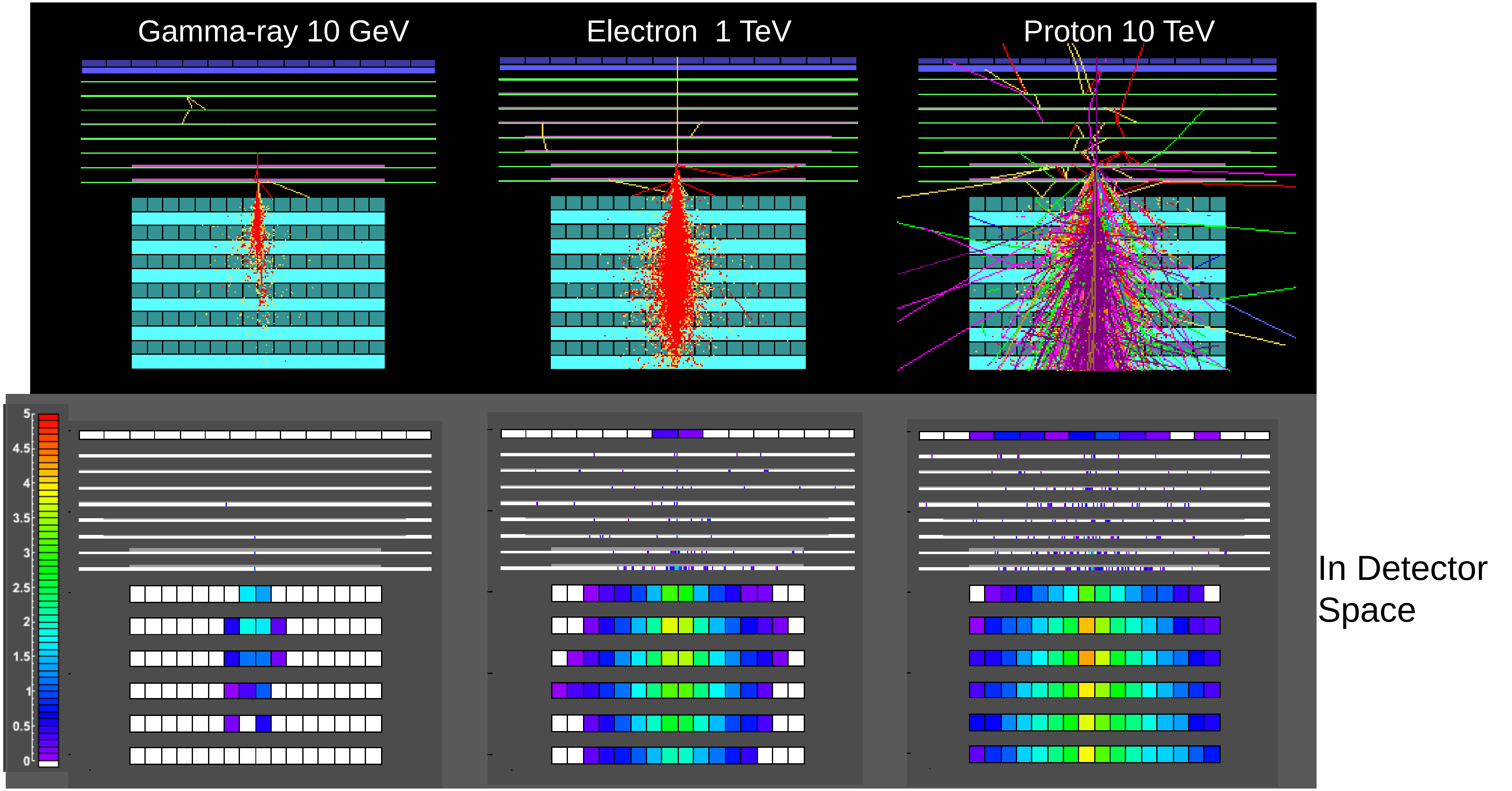


Expected Performance
(from Simulations and/or Beam Tests)

- 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

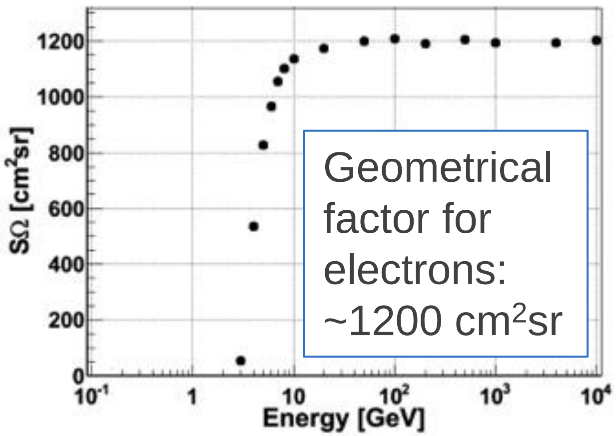
	CHD (Charge Detector)	IMC (Imaging Calorimeter)	TASC (Total Absorption Calorimeter)
Function	Charge Measurement (Z=1-46)	Arrival Direction, Particle ID	Energy Measurement, Particle ID
Sensor (+ Absorber)	Plastic Scintillator : 14 × 1 layer (x,y) Unit Size: 32mm x 10mm x 450mm	SciFi : 448 x 8 layers (x,y) = 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)

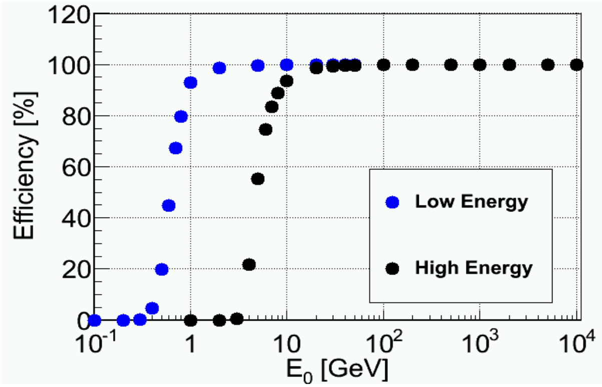


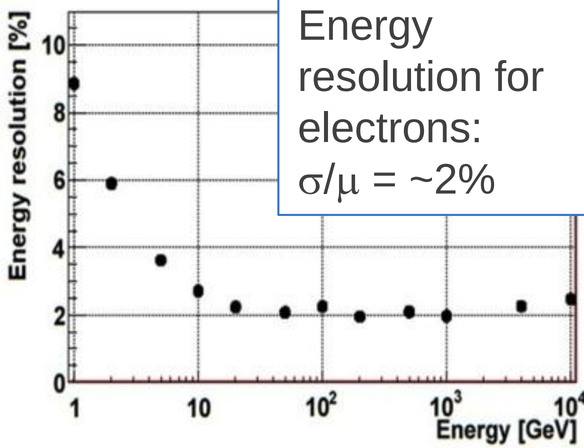
- Proton rejection power > 10^5 can be achieved with the IMC and TASC shower imaging capability.
- Gamma-rays largely excluded with first interaction point below top of CHD.

CALET/CAL Expected Performance



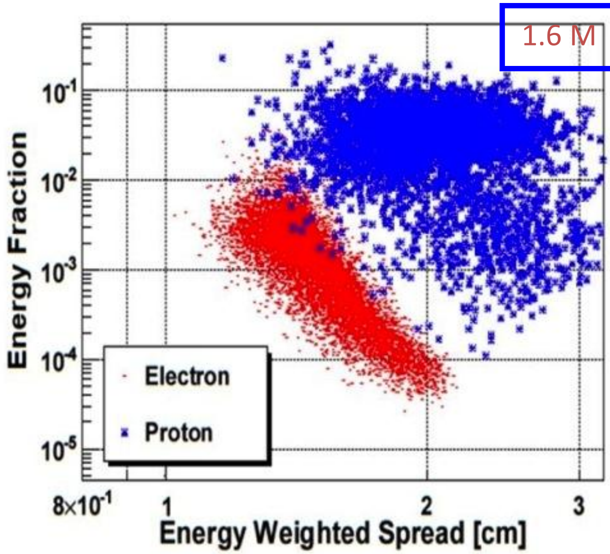
Geometrical factor for electrons: ~1200 cm^{2}sr



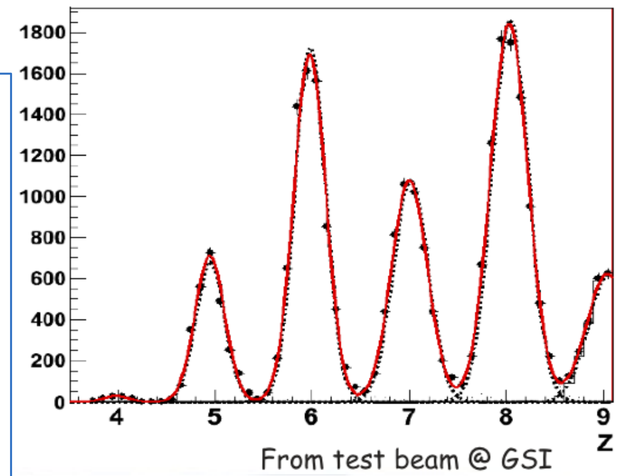


Energy resolution for electrons: σ/μ = ~2%

1.6 M protons



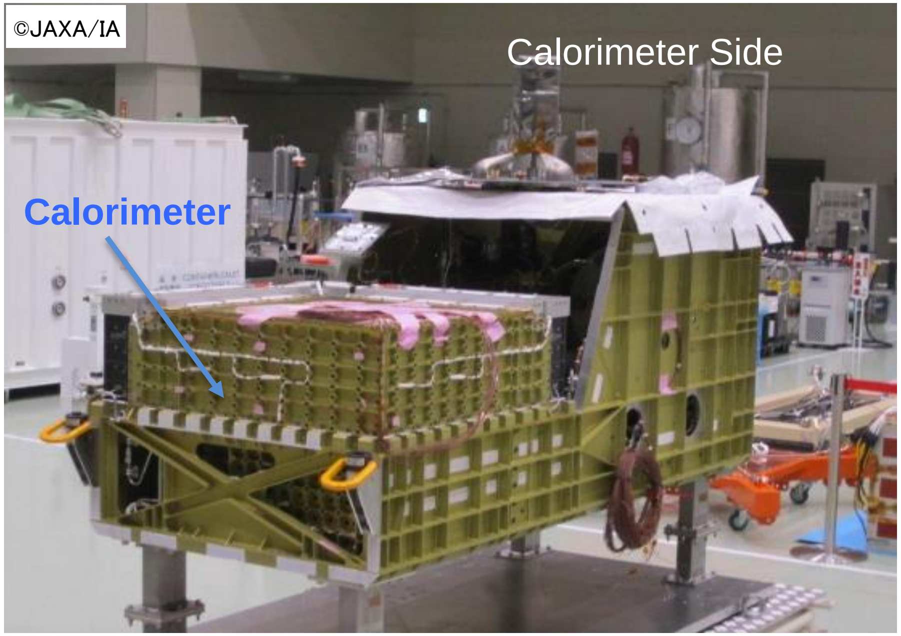
Gamma rays also are a background for electrons, but they are less abundant and mostly eliminated by charge detectors



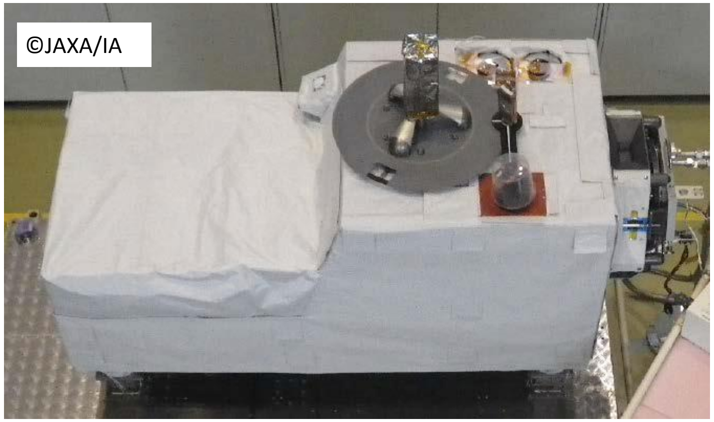
Proton rejection power at 4TeV >10^5 with 95% electron retained

Charge resolution: ΔZ = 0.15 – 0.3

CALET Status



- Final JAXA review completed March 30, 2015
- CALET target launch to ISS JEM-EF on HTV-5 from Tanegashima Space Center, Tanegashima Island, Japan in Summer 2015



Summary

- Cosmic ray electrons lose energy much more rapidly than nuclei -> sources of electrons ≥ 1 TeV must be more local than those of GCR nuclei.
- Electron flux is steeply falling -> errors in energy measurement result in large errors in flux measurement.
- Electrons ≥1000× less than the proton flux at the same energy -> proton rejection vital.
- AMS-02 measured total electron flux is consistent with a single power law from ~30 GeV to ~ 1 TeV, Fermi-LAT is not consistent with single power law but only shows small excess over secondary predictions -> look for signatures of local sources and/or dark matter at higher energies.
- CALET has the energy resolution and proton rejection to measure the total electron flux from 1 GeV to ~20 TeV.
- Launch target for CALET on HTV5 is this summer.