CALET (Calorimetric Electron Telescope)

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- CALET is an instrument primarily dedicated to the observation of electrons in the TeV region to provide crucial information on nearby acceleration sources and perform indirect searches of dark matter.

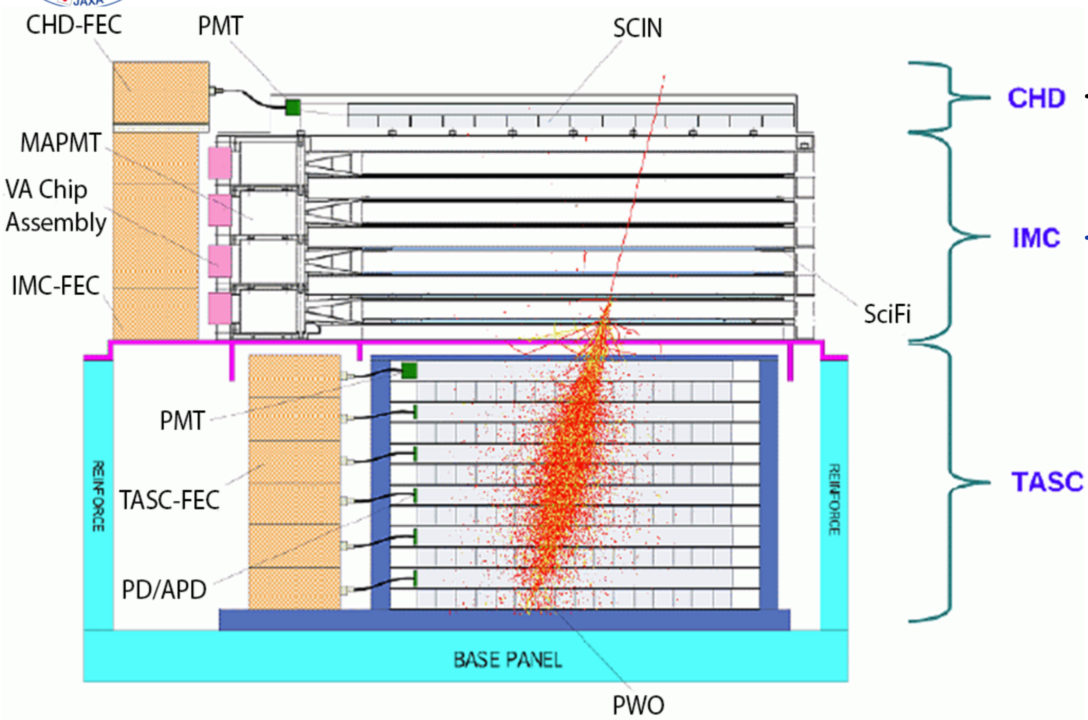
- It will also study cosmic rays from proton to Fe and Ultra Heavy ions (26 < Z < 40). Energy spectra, relative elemental abundances and secondary-to-primary ratios will be measured.

✧ CALET was launched from Tanegashima Space Center on August 19th, 2015 with the Japanese H2-B rocket. The HTV-5 Transfer Module docked on the ISS on August 24th.

✧ CALET is now installed on port #9 of JEM-EF.

✧ An initial 5-years period of observations are planned

CALorimetric Electron Telescope (CALET): INSTRUMENT OVERVIEW



CHD - **CHarge Detector (CHD)**
(Charge Measurement Z=1-40)

IMC - **Imaging Calorimeter (IMC)**
(Particle ID, Direction)

Total Thickness of Tungsten (W) : **$3\ X_0$, $0.1\ \lambda_I$**
Layer Number of Scifi Belts : 8 Layers × 2(X,Y)

TASC - **Total Absorption Calorimeter (TASC)**
(Energy Measurement, Particle ID)

PWO 20mm x 20mm x 320mm
Total Depth of PWO : **$27\ X_0$** (24 cm) , **$1.2\ \lambda_I$**

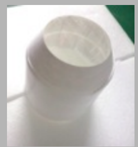
	CHD (Charge Detector)	IMC (Imaging Calorimeter)	TASC (Total Absorption Calorimeter)
Function	Charge Measurement (Z = 1 - 40)	Arrival Direction, Particle ID	Energy Measurement, Particle ID
Sensor (+ Absorber)	Plastic Scintillator : 2 layers Unit Size: 32mm x 10mm x 450mm	SciFi : 16 layers Unit size: 1mm^2 x 448 mm Total thickness of Tungsten: $3\ X_0$	PWO log: 12 layers 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)

CGBM (Calet Gamma-ray Burst Monitor)

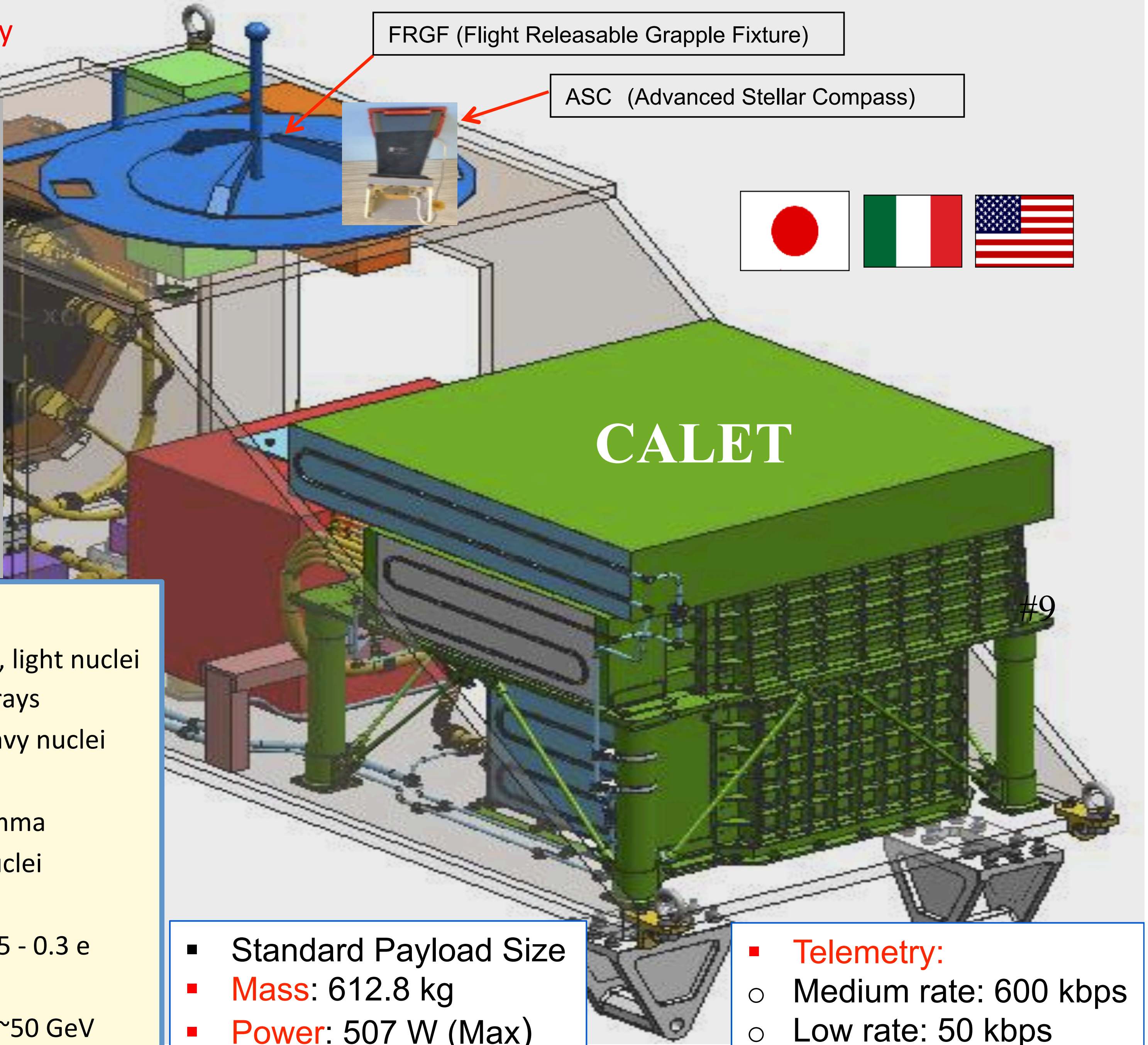
HXM x2
7keV-1MeV

LaBr$_3$(Ce)

SGM x1
0.1-20MeV



BGO



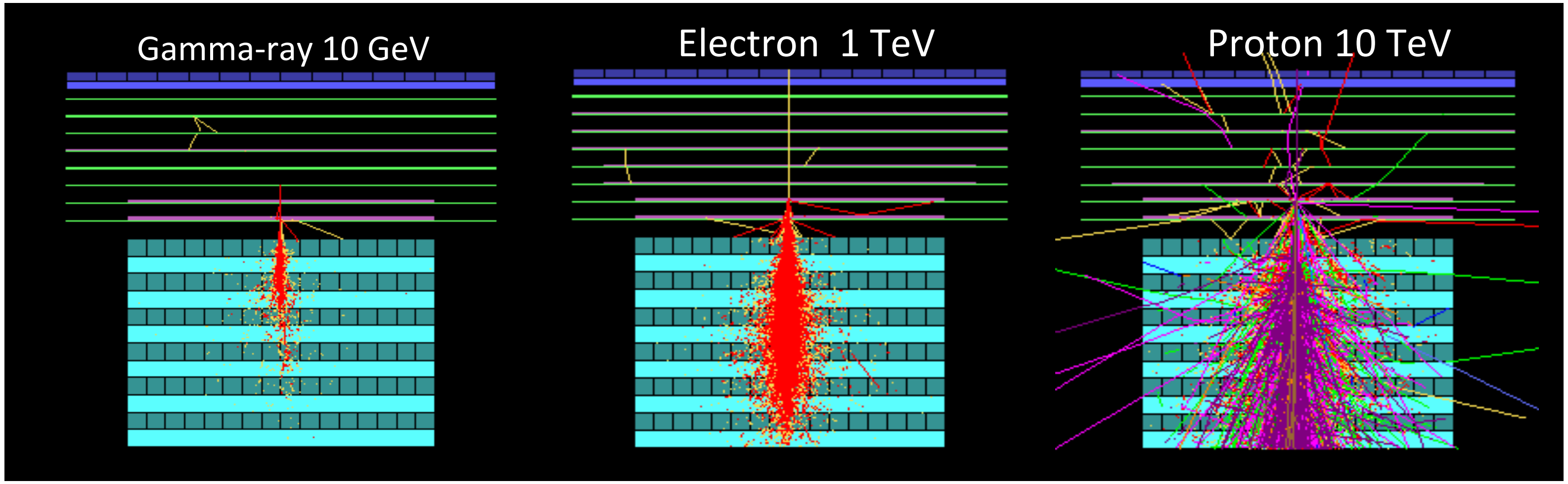
Geometric Factor :
1200 cm^{2}sr for electrons, light nuclei
1000 cm^{2}sr for gamma-rays
4000 cm^{2}sr for ultra-heavy nuclei

- **ΔE/E** :
  ~2% (>10 GeV) for e, gamma
  ~30-35 % for protons, nuclei
- **e/p separation** : 10^{-5}
- **Charge resolution** : 0.15 - 0.3 e
- **Angular resolution** :
  0.2° for gamma-rays > ~50 GeV

- Standard Payload Size
- Mass: 612.8 kg
- Power: 507 W (Max)

- Telemetry:
  - Medium rate: 600 kbps
  - Low rate: 50 kbps

CALET/CAL Shower Imaging Capability



- CALET is equipped with a **thick, homogeneous calorimeter** (TASC) that allows to extend electron measurements into the TeV energy region with total e.m. shower containment.

- Coupled with a **high granularity imaging** pre-shower calorimeter (IMC), it can achieve an excellent electron energy resolution (better than 2% above 100 GeV) and accurately identify the starting point of electromagnetic showers. Combined, TASC+IMC powerfully separate electrons from the abundant protons with a rejection power $\sim 10^5$.

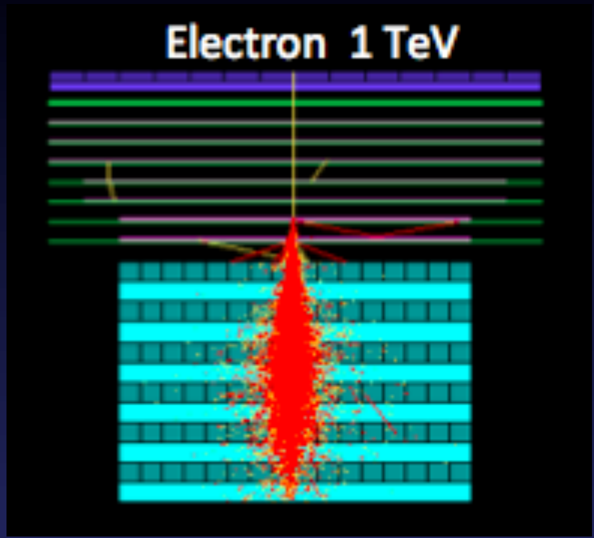
- A dedicated charge detector (CHD) + multiple dE/dx track sampling in the IMC allow to identify individual nuclear elements from proton to Z=40.

CALET Expected Performance with electrons

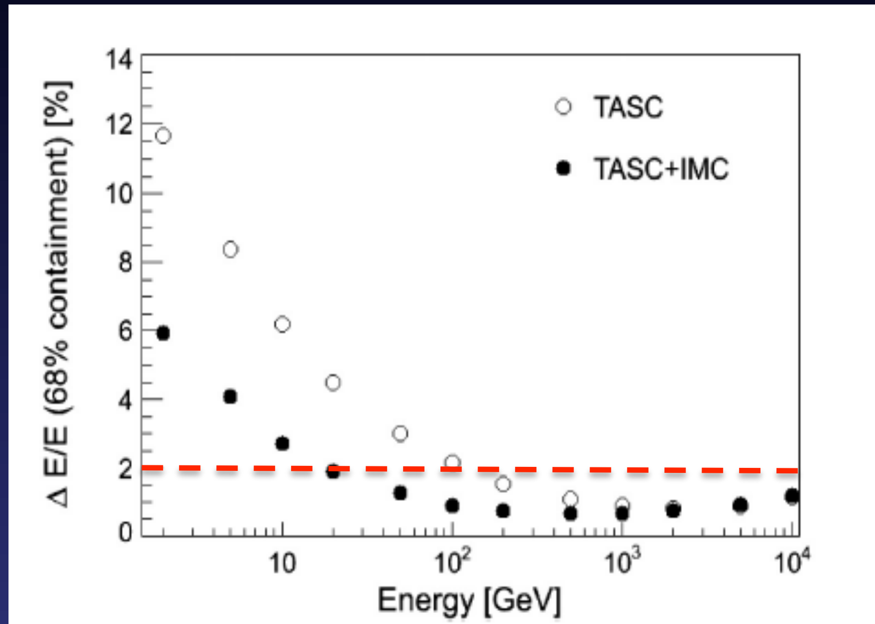
CHD

IMC

TASC

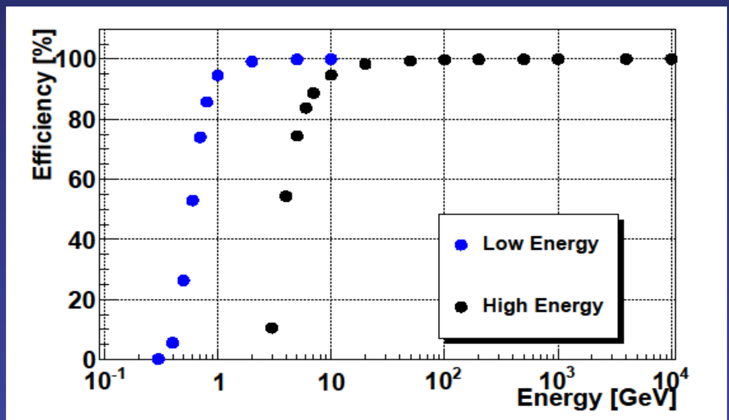


Energy Resolution < 2% above 100 GeV



2%

Detection Efficiency



Proton Rejection factor: 10^5

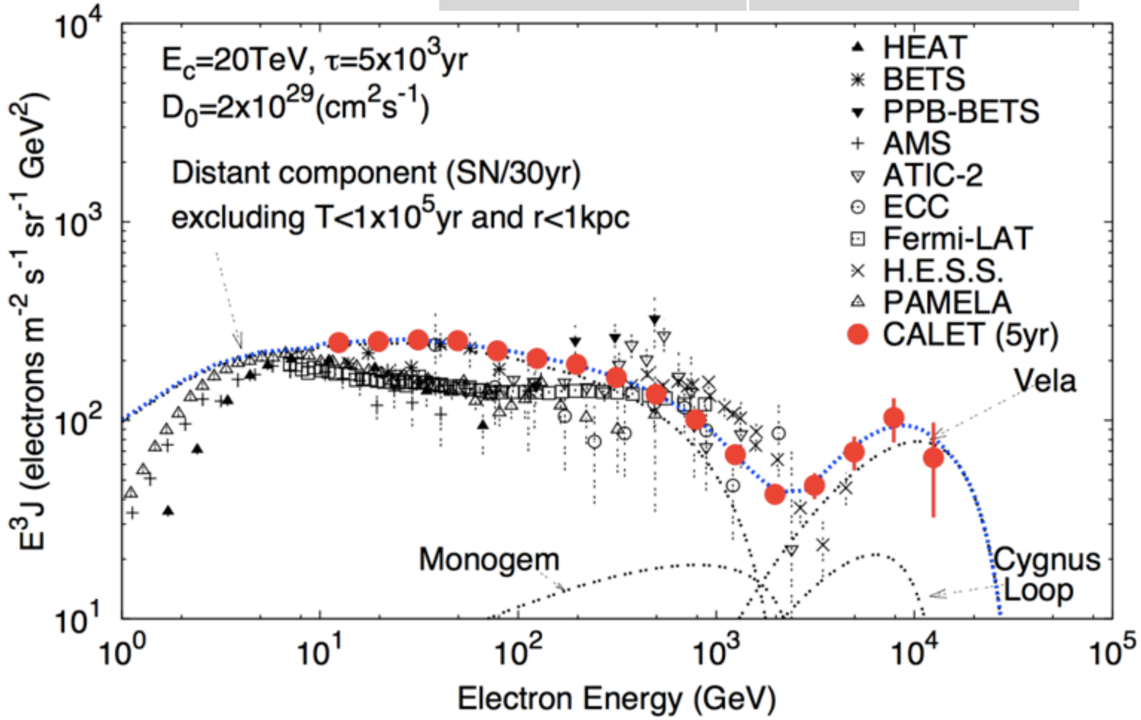
- shower topological cuts in IMC and TASC
- dE/dx from CHD

① CALET Main Target: Identification of Electron Sources

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

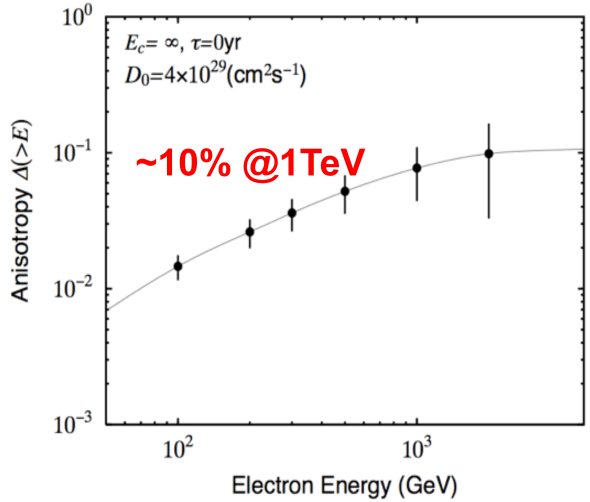
Expected flux for 5 year mission

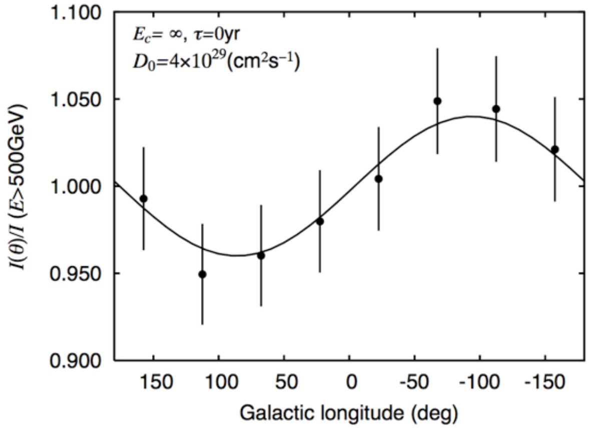
> 10 GeV	~ 2.7×10^7
>100 GeV	~ 2.0×10^5
>1000 GeV	~ 1.0×10^3



Identification of the unique signature from nearby SRNs, such as Vela in the electron spectrum by CALET

Expected Anisotropy from Vela SNR





CALET main science objectives

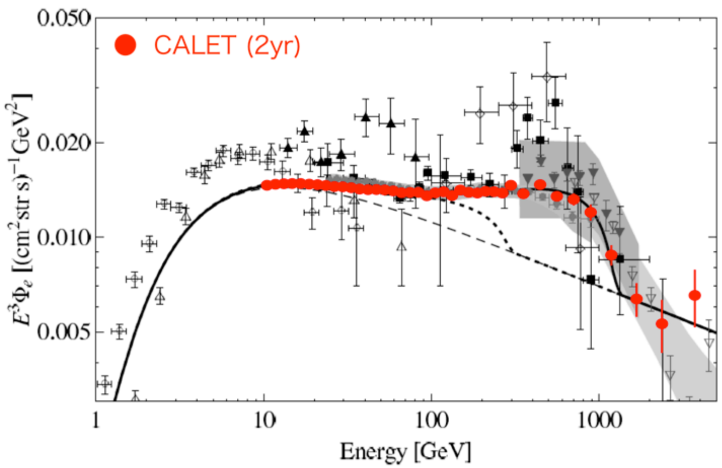
Science Objectives	Observation Targets
① Nearby Cosmic-ray Sources	**Electron spectrum** in trans-TeV region
② Dark Matter	Signatures in **electron/gamma** energy spectra in the 10 GeV – 10 TeV region
③ Origin and Acceleration of Cosmic Rays	**p-Fe** up to the multi-TeV region, Ultra Heavy Nuclei
④ Cosmic–Ray Propagation in the Galaxy	**B/C** ratio up to a few TeV /n
⑤ Solar Physics	**Electron flux** below 10 GeV
⑥ Gamma-ray Transients	Gamma-rays and X-rays in 7 keV – 20 MeV

② Indirect Dark Matter Search with Electrons

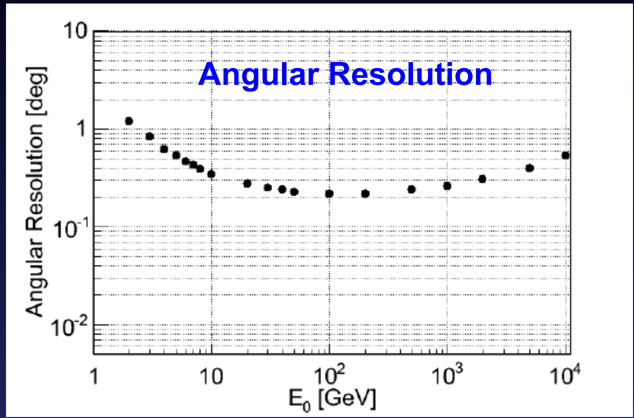
→ CALET has the potential to detect a possible contribution from dark matter annihilation/decay to the shape of the electron (+ positron) spectrum.

Example: Simulated e^++e^- spectrum from dark matter decay into $l^+l^-\nu$ with m=2.5TeV and τ = 2.1x10^{26} s (for 2 yr exposure).

(A.Ibarra et al. 2010)

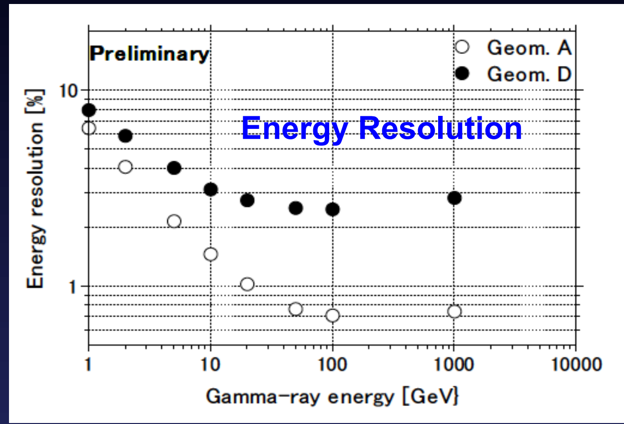


② Indirect Dark Matter Search with Gamma rays



CALET has a better energy resolution than FERMI above 10 GeV. Therefore it can provide a HIGH RESOLUTION measurement of the line-shape of possible signals that FERMI might discover.

better than FERMI above 10 GeV

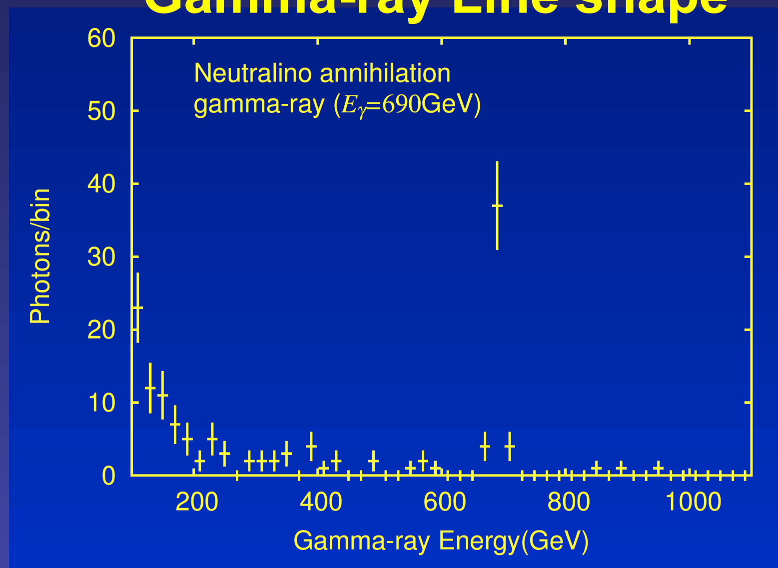


Example:

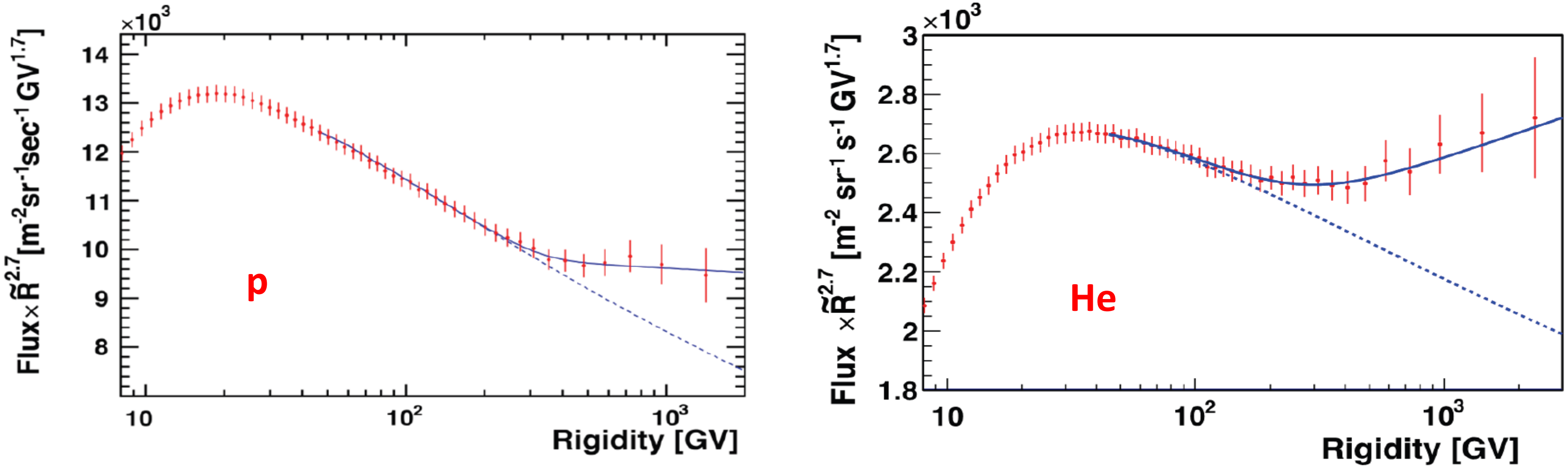
- 690 GeV neutralino annihilating to γγ
- Clumpy halo as realized in N-body simulation of Moore et al. (ApJL 1999)
- Simulated Signal in CALET for 3 years

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

Gamma-ray Line shape



③ Measurements of cosmic nuclei spectra - I



AMS-02 proton and He rigidity spectra

Recent measurements by AMS-02 with p, He (and Li) below MDR seem to confirm the presence of a spectral break in the 200-300 GeV region as reported by PAMELA and CREAM

- CALET will be able to perform an **accurate scan** of the energy region around the spectral break with an energy resolution ~30 % and large GF ~ 0.12 m^2 sr. It will measure the curvature of the spectrum and the position of the spectral break-point for individual elements extending the present measurements to the multi-TeV region.

Measurements of cosmic nuclei spectra – II : the sub-PeV region

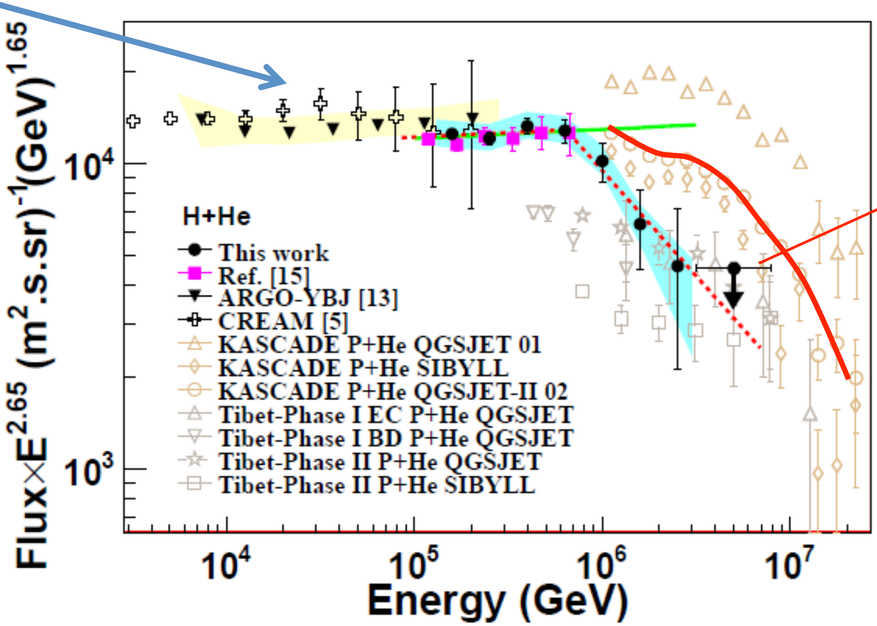
- The KNEE puzzle in the inclusive COSMIC-RAY SPECTRUM:

RECENT INDIRECT MEASUREMENTS BY AIRSHOWERS may suggest **a proton cutoff below 1 PeV?**

ARGO YBJ (+ LHAASO-CT): **high altitude, ultra segmented RPC** + **Cherenkov telescope (Xmax)**
LESS SENSITIVE TO INTERACTION MODELS ?

Superposition with direct CREAM measurement

(P + HE) SPECTRUM



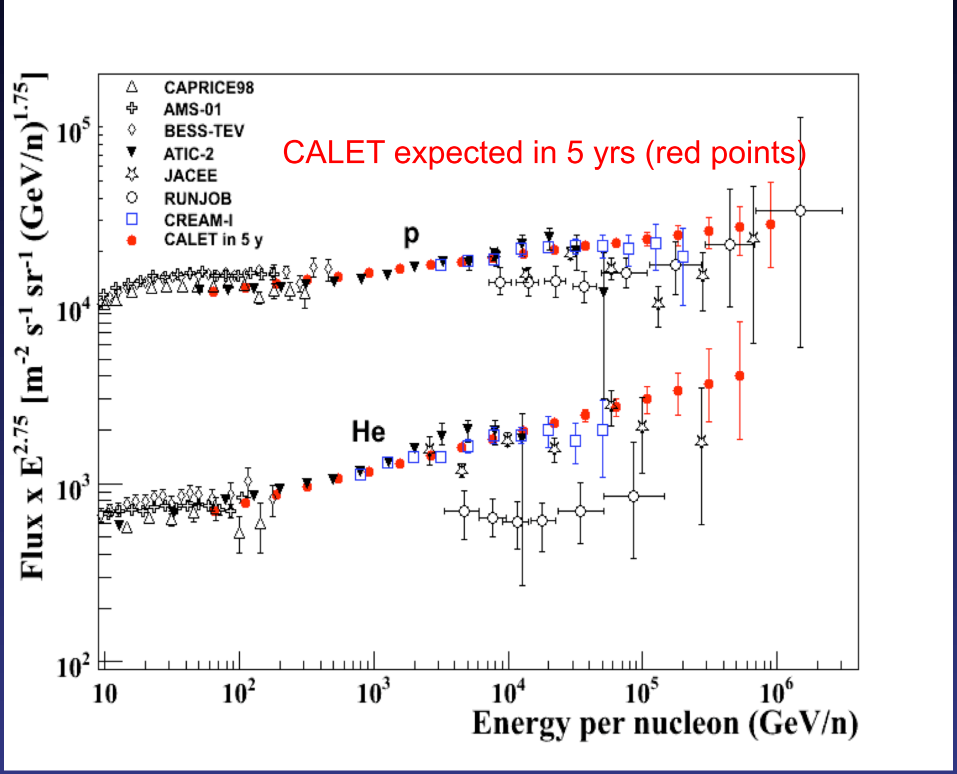
NEW KASKADE ANALYSYS WITH QGSJET-II02

E_cutoff (p+He) = 700 TeV ?

In 5 yrs CALET can perform DIRECT measurements of p and He fluxes in the multi-TeV region.

Proton and He with CALET

Multi-TeV region



CALET Energy reach in 5 years:

- Proton spectrum to ≈ 900 TeV
- He spectrum to ≈ 400 TeV/n

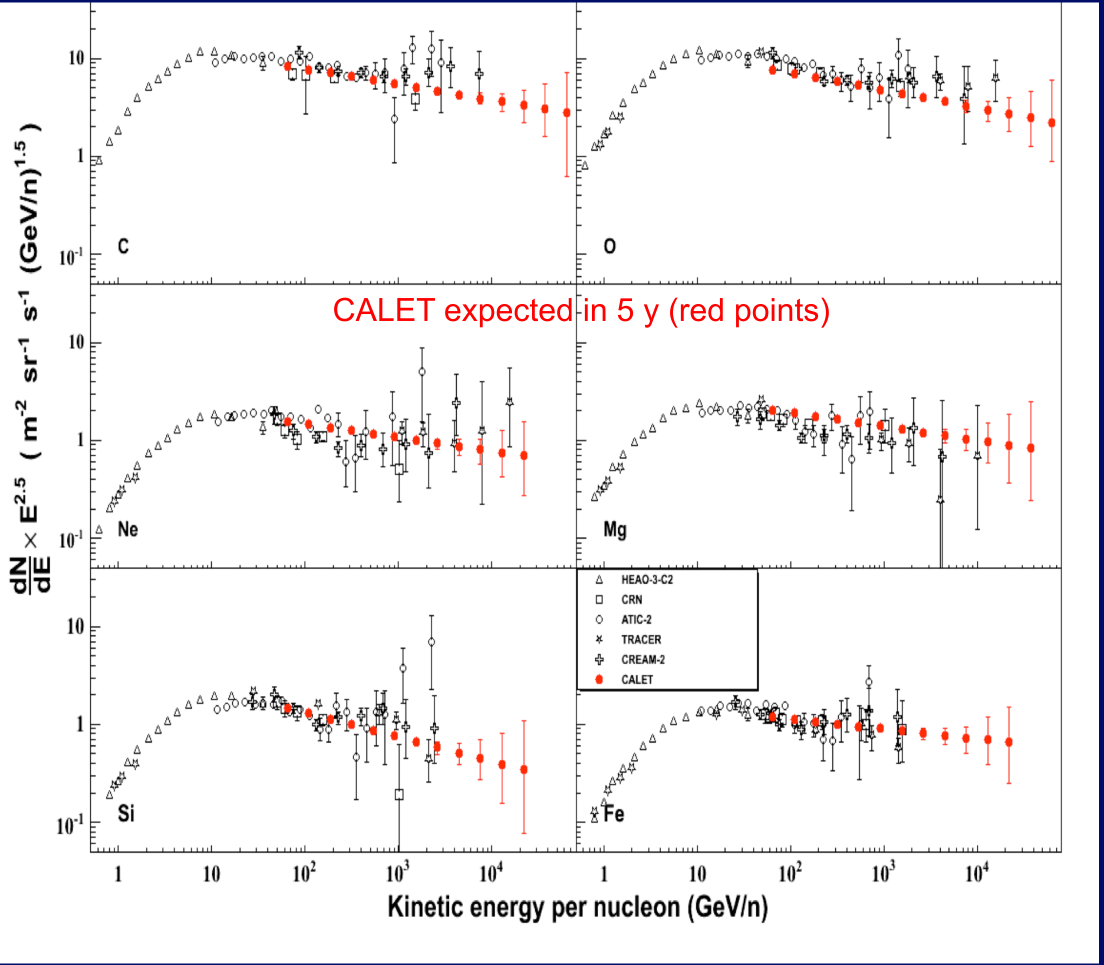
- Are Proton and He slopes different?
- Single power-law or curvature??
- Is there a proton cutoff below 1 PeV?

Requirements for calorimetry:

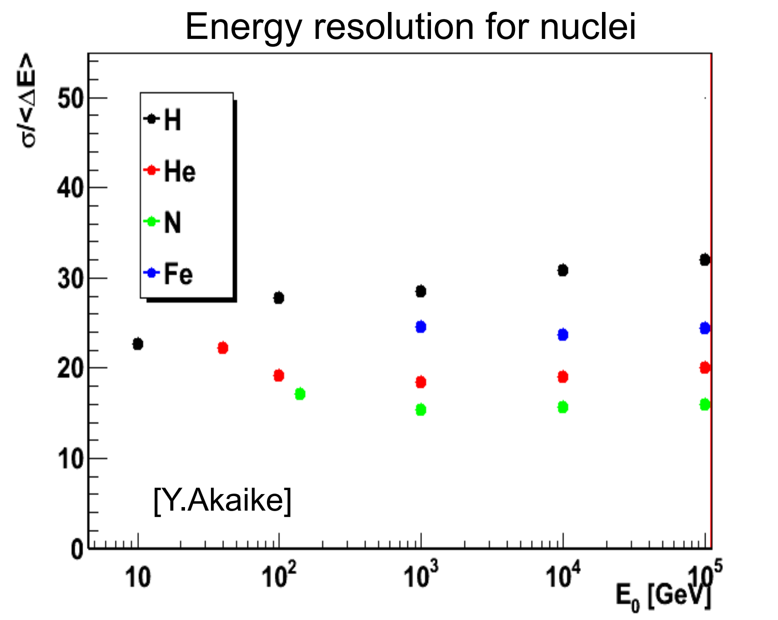
- proton interaction requires > 0.5 λ_{INT}
- energy measurement at 100 TeV scale requires containment of the e.m. core of the hadronic shower i.e.: > 20 X_0

	λ_{INT}	X_0 (normal incidence)
CREAM	0.5 + 0.7	20
CALET	1.3	30
AMS-02	0.5	17

Intermediate nuclei → Fe with CALET in 5 yrs



- is there a spectral cutoff below 1 PeV?
- single power law or spectrum concavity?



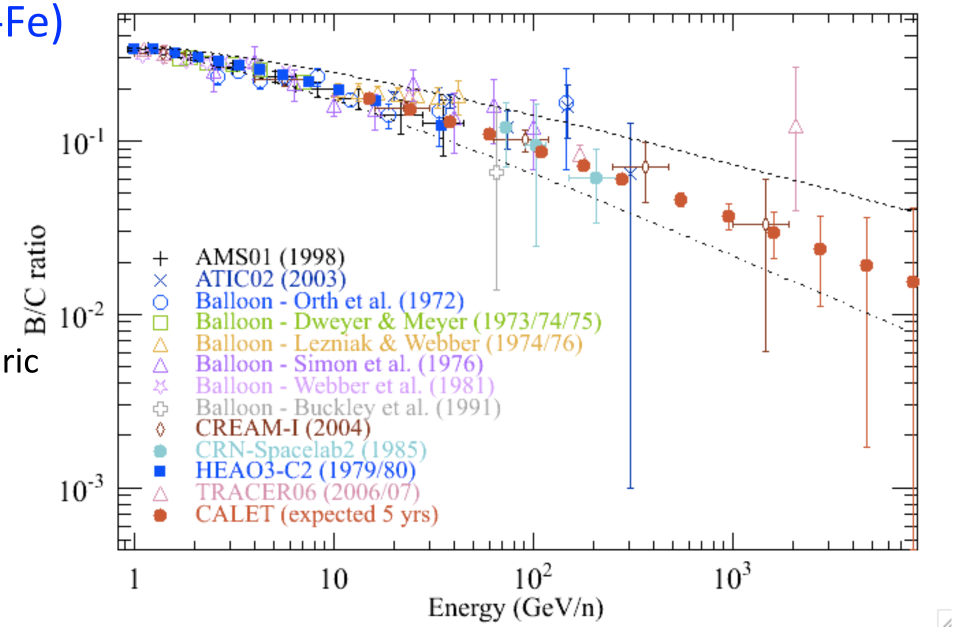
- Spectra of C,O,Ne,Mg,Si to ≈ 20 TeV/n
- B/C ratio to ≈ 4 - 6 TeV/n
- Fe spectrum to ≈ 10 TeV/n

CALET energy reach (5 years)

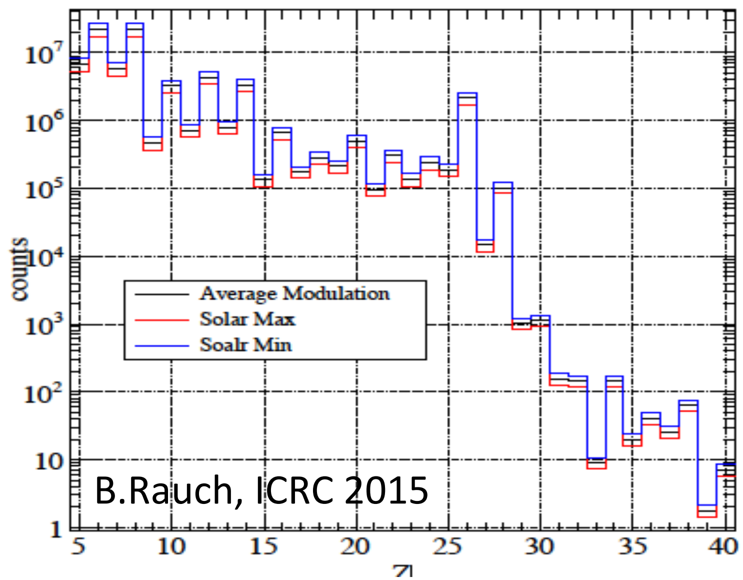
④ Secondary/Primary ratios and Ultra Heavy Nuclei

❑ Secondary to Primary ratio (B/C and Fe/Sub-Fe)

- Energy dependence of diffusion constant: $D \sim E^{\delta}$
- Data below 100 GeV/n indicate δ~0.6. At high energy the ratio is expected to flatten out (otherwise CR anisotropy should be larger than that observed)
- Observation up to several TeV/n free from the atmospheric production of boron by heavier cosmic nuclei



❑ UH Composition to Z=40



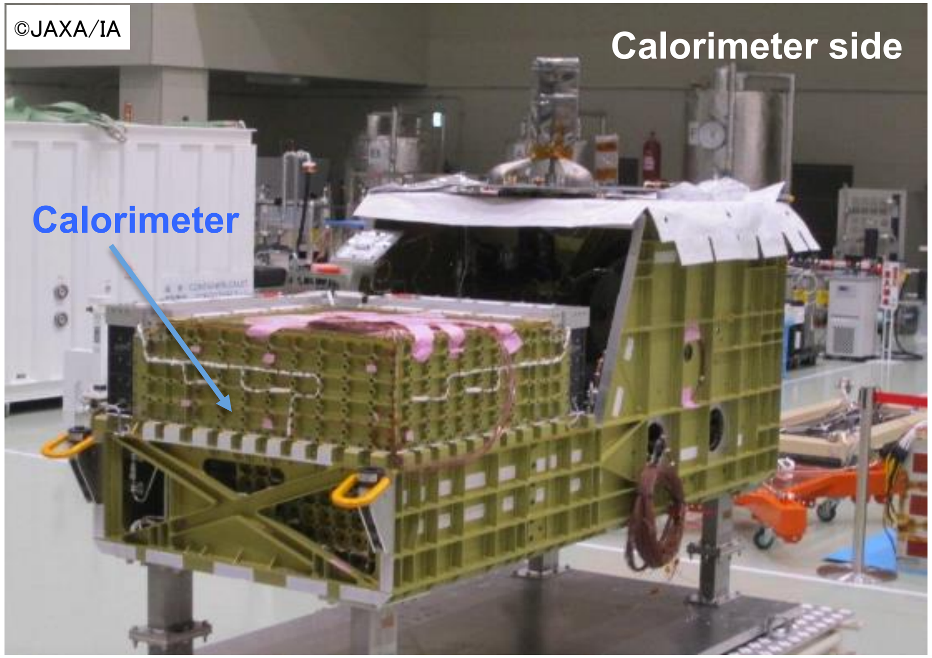
- Dedicated UH trigger: larger trigger acceptance ~ 0.4 m²sr
- Statistcs ≅ 10 x TIGER (with UH trigger)
  ≅ 4 x TIGER (with full geometry and energy reconstruction)
- Cleaner measurements (smaller corrections for hadronic interactions above atmosphere)

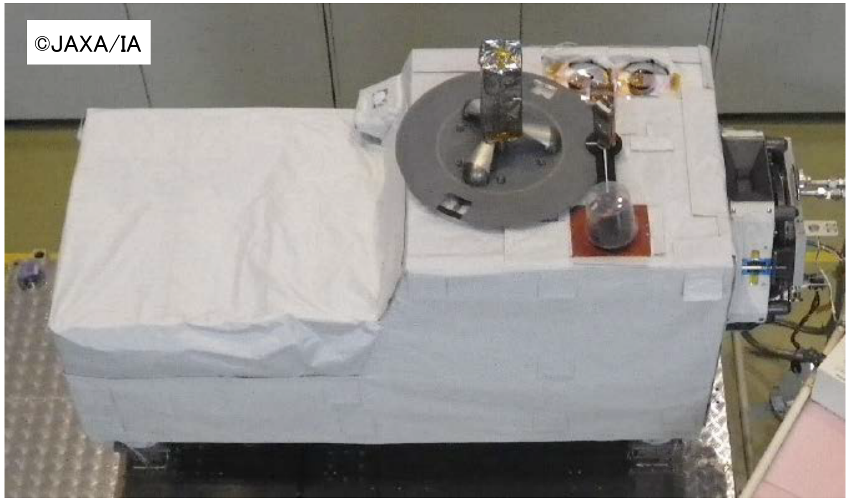
System Test of Flight Model at Tsukuba Space Center

- Acoustic test, Thermal-Vacuum test and EMC test were successfully carried out at Tsukuba Space Center (JAXA)

- After final system function test, the payload was transferred to the launching site (Tanegashima Space Center) in preparation for a launch with HTV-5.

13 m diameter thermal vacuum chamber





CALET is now on the ISS !

① **August 19th**: After a successful launch of the Japanese H2-B rocket by the Japan Aerospace Exploration Agency (JAXA) at 20:50:49 (local time), CALET started its journey from Tanegashima Space Center to the ISS.

② **August 24th:**

The HTV-5 Transfer Vehicle (HTV-5) is grabbed by the ISS robotic arm.

③ **August 24th:**

The HTV-5 docks to the ISS at 6:28 (EDT).

④ **August 25th:**

CALET is emplaced on port #9 of the JEM-EF and data communication with the payload is established.