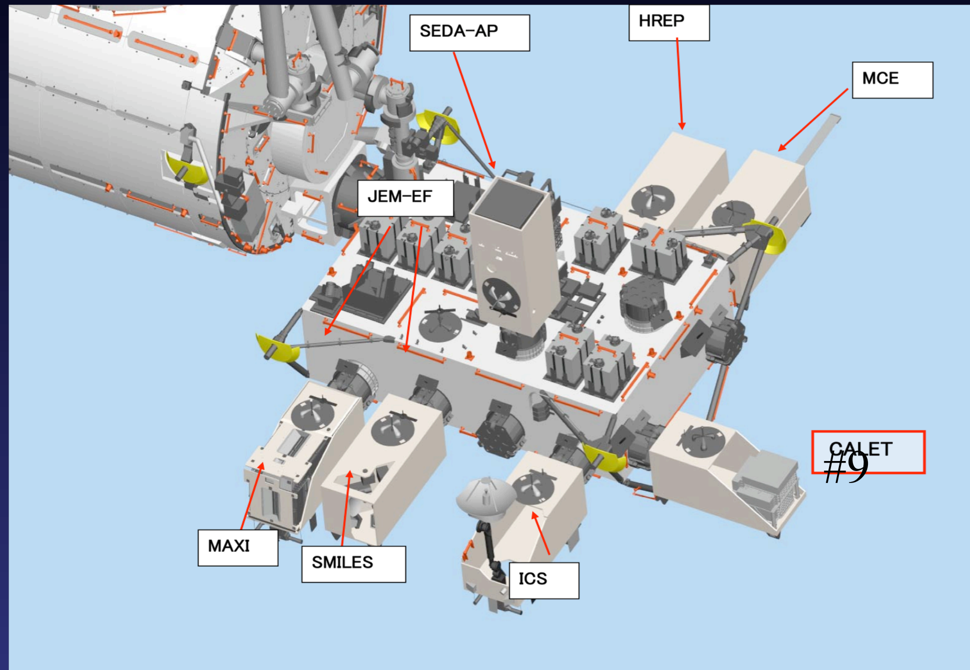
CALorimetric Electron Telescope (CALET)

P. S. Marrocchesi for the CALET Collaboration – RICAP11 – 2011 May 26

- **Instrument:**
  High Energy Electron and Gamma-Ray Telescope
- **Carrier:**
  HTV: H-IIA Transfer Vehicle
- **Attach Point on the JEM-EF: #9**
  for heavy (< 2000 kg) payloads
- **Nominal Orbit:**
  407 km, 51.6° inclination
- **Launch plan:**
  FY 2013
- **Life Time:**
  ≥ 5 years

Firenze
Pisa
Siena
Roma Tor Vergata



1 GeV ~ 20 TeV for electrons

20 MeV ~ TeV for gamma-rays

Weight: 500 kg

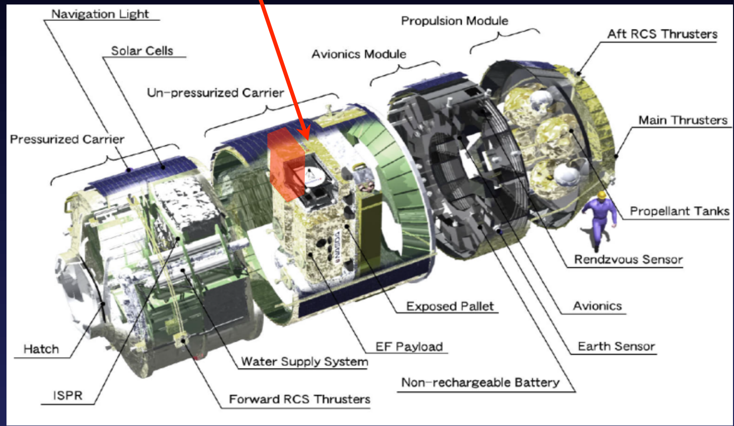
GF (fiducial volume): ~ 0.12 m^2sr

Power Consumption: 640 W

Data Rate: 300 kbps

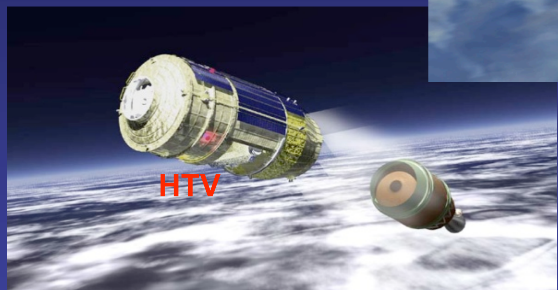
Launching Procedure of CALET

CALET

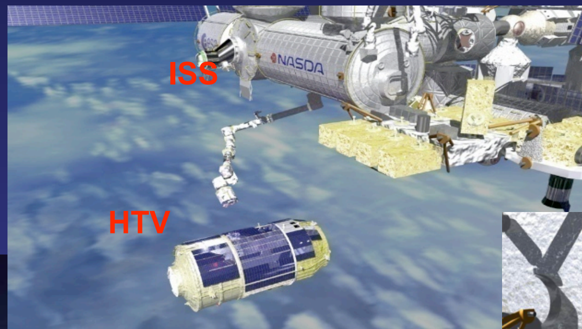


H2-B Transfer Vehicle (HTV)

Launching by
H-IIB Rocket

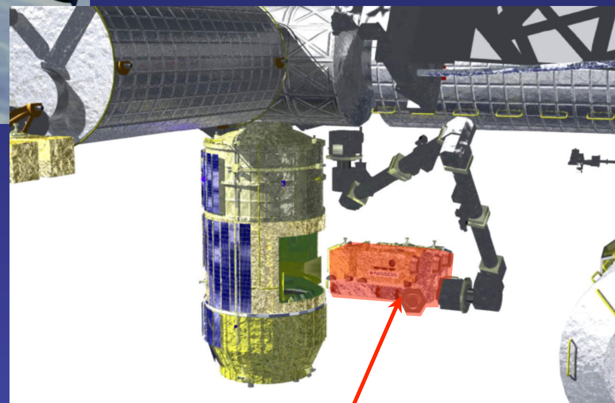


Separation from H2-B



Approach to
ISS

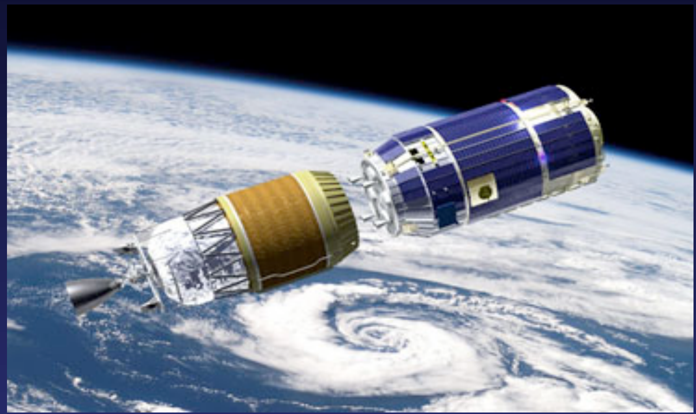
Pickup of CALET



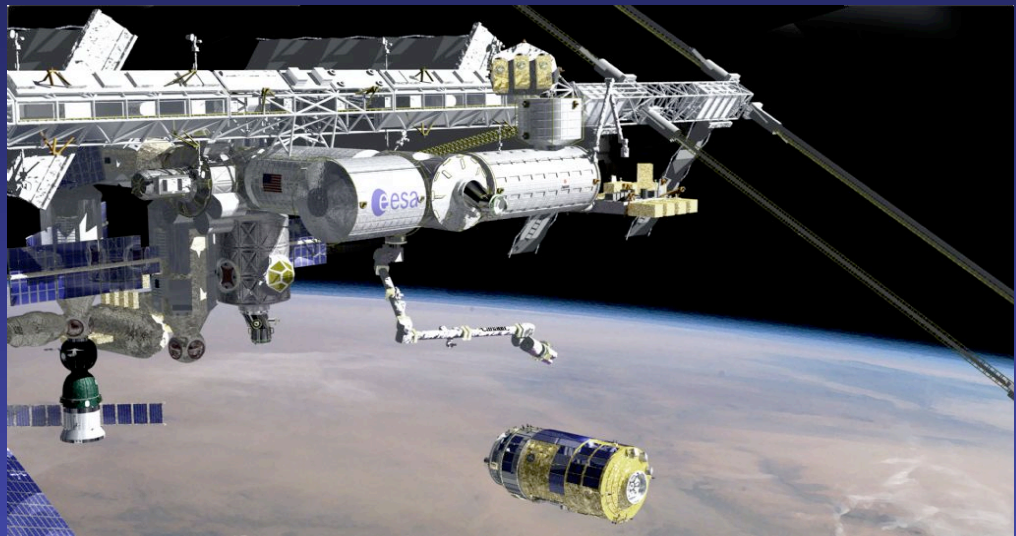
CALET

Launch of the H-IIB Launch Vehicle Test Flight

- Launched on Sep.11, 2009 at Yoshinobu Launch Complex at the Tanegashima Space Center in Japan
- Docked successfully to ISS on Sep. 18, 2009.
- HTV-2 was also launched in Jan, 2011



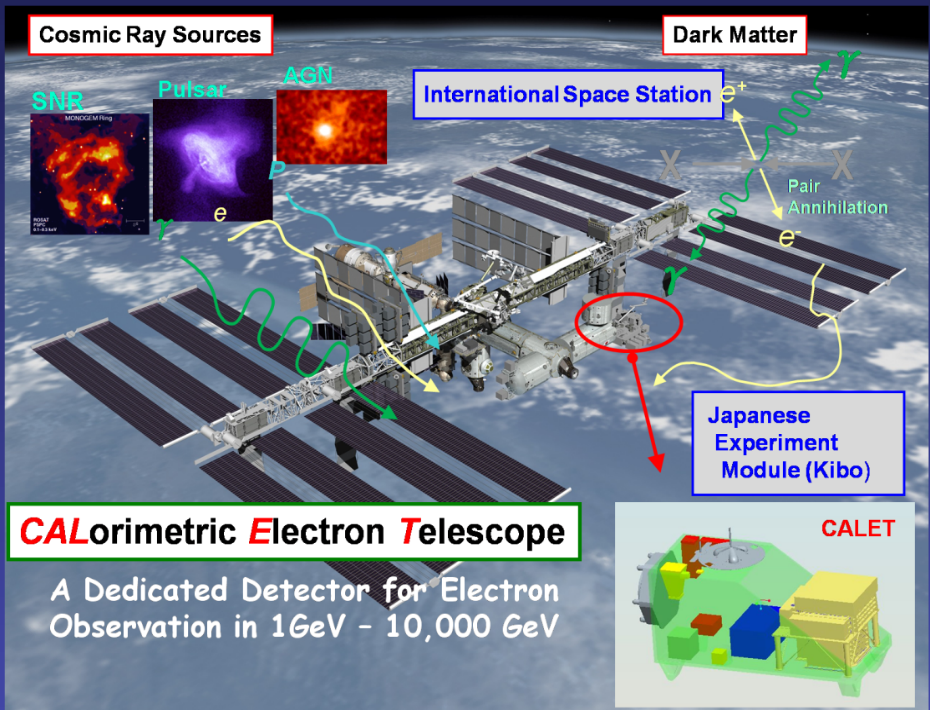
ⓒ JAXA



CALET Overview

☐ Observation

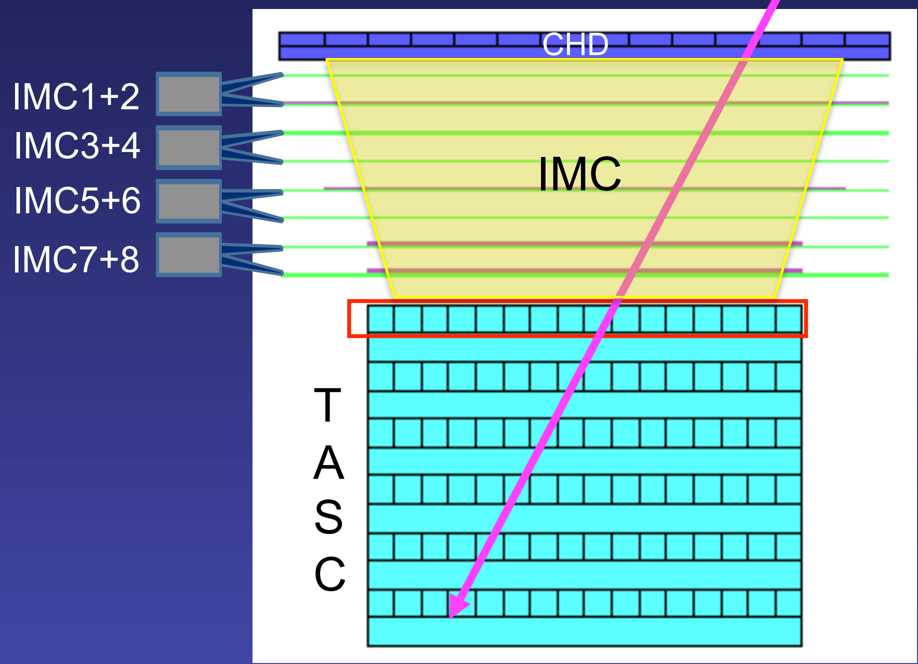
- **Electrons** : 1 GeV - 10 TeV
- **Gamma-rays** : 10 GeV-10 TeV (GRB > 1 GeV)
  + Gamma-ray Bursts : 7 keV-20 MeV
- **Protons, Heavy Nuclei**:
  several 10 GeV- 1000 TeV (per particle)
- **Solar Particles and Modulated Particles in Solar System**: 1 GeV-10 GeV (Electrons)



Instrument

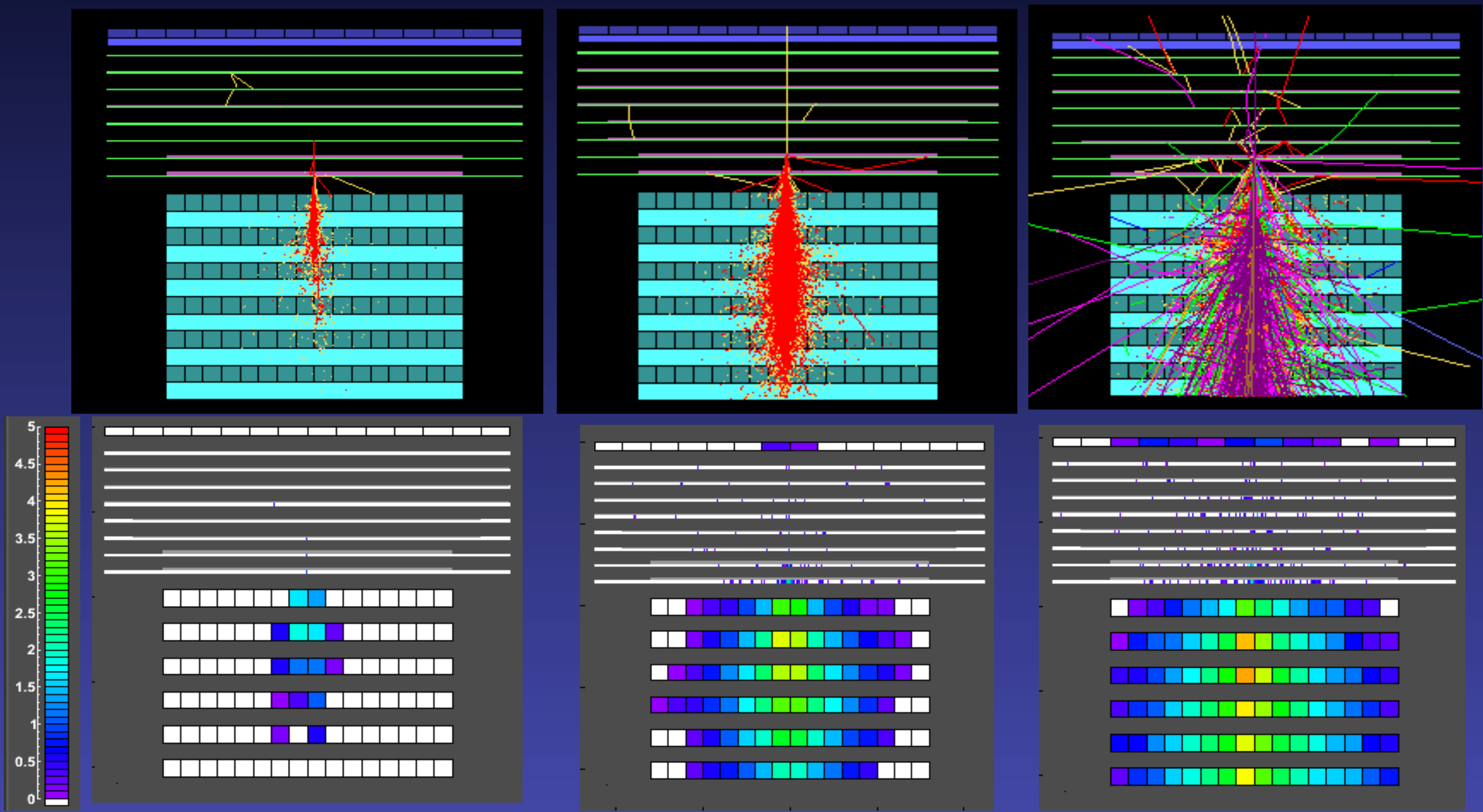
High Energy Electron and Gamma-Ray Telescope:

- **CHarge Detector (CHD)**
  (Charge Measurement in Z=1-40)
- **Imaging Calorimeter (IMC)**
  (Particle ID, Direction)
  Total Thickness of Tungsten (W): 3 X_0 0.11 λ_I
  Layer Number of Scifi Belts: 8 Layers ×
2(X,Y)
- **Total Absorption Calorimeter (TASC)**
  (Energy Measurement, Particle ID)
  PWO 20mm x 20mm x 320mm
  Total Depth of PWO: 27 X_0 (24cm) , 1.35 λ_I



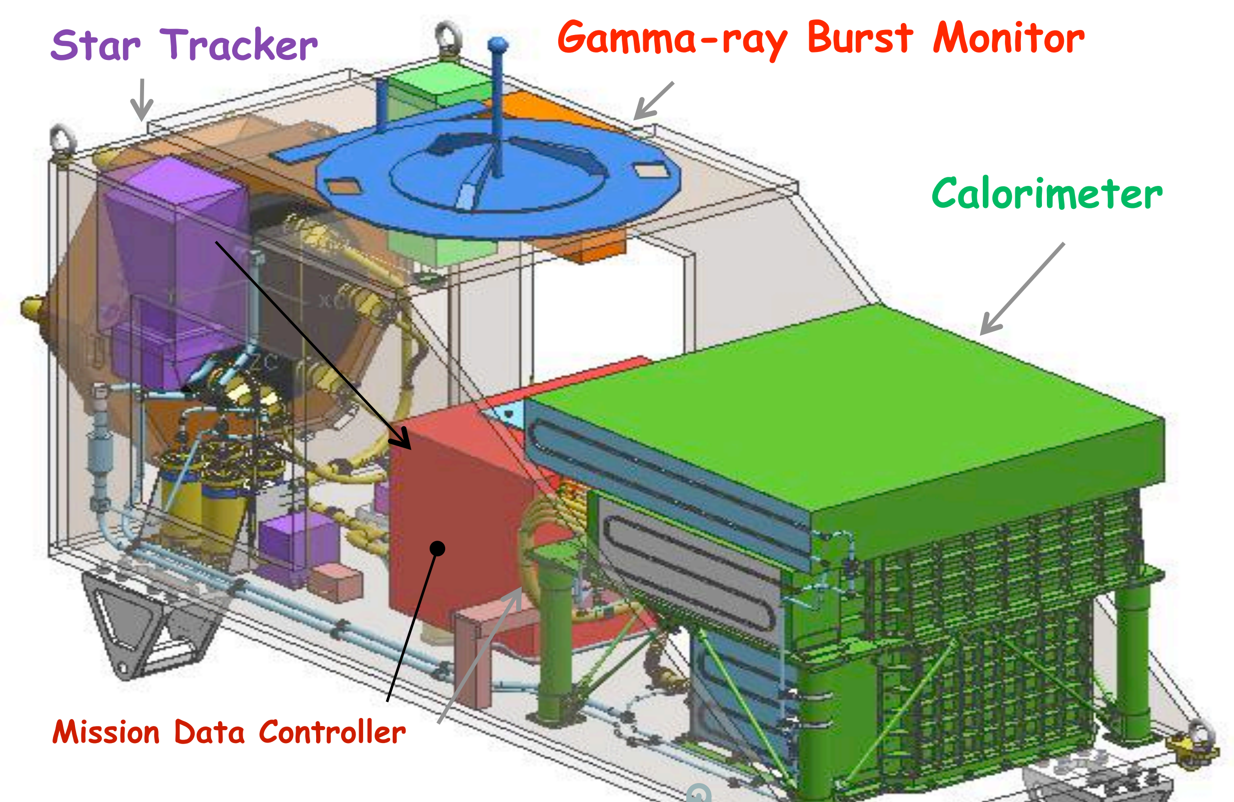
Shower Images

Gamma-ray 10GeV | Electron 1TeV | p 10TeV



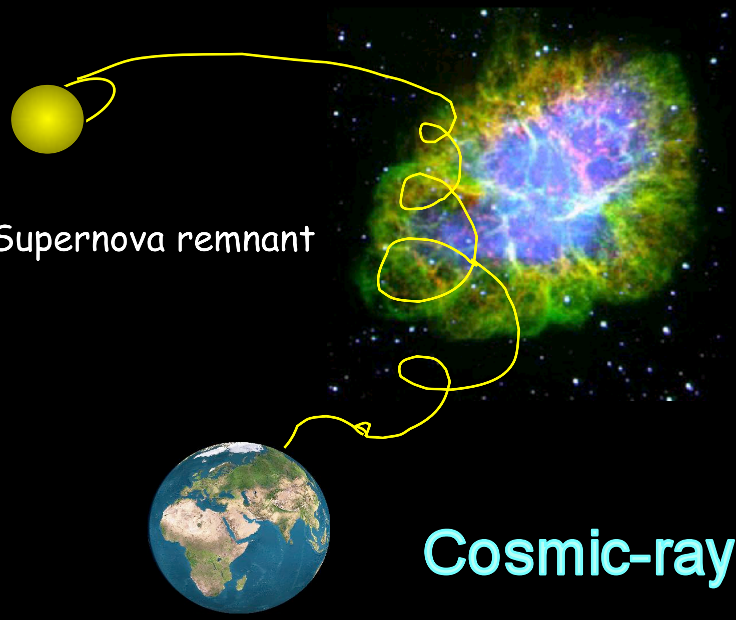
CALET System Design

The CALET mission instrument satisfies the requirements as a standard payload in size, weight, power, telemetry etc. for launching by HTV and for observation at JEM/EF.



Weight : 483.5 kg
Power Consumption: 313W

Origin, Acceleration and Propagation of Galactic Cosmic Rays



Open questions:

- is there a SN acceleration limit?
- does CR elemental composition change with energy?
- what is the energy dependence of the confinment time of CR in the Galaxy?

Cosmic-ray measurements with CALET in 5 yrs

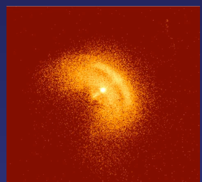
Energy reach	Measurement
➢ Proton spectrum to ≈ 900 TeV	Search of proton knee above 100 TeV
➢ He spectrum to ≈ 400 TeV/n	Different slopes of He and proton spectra
➢ Spectra of C,O,Ne,Mg,Si to ≈ 20 TeV/n	Power law or spectrum curvature?
➢ B/C ratio to ≈ 4 - 6 TeV/n	Energy dependence of escape length
➢ Fe spectrum to ≈ 10 TeV/n	Fe abundance and sub-Fe/Fe ratio vs. E
➢ Trans-Fe elements (26 < Z ≤ 40)	Composition and energy dependence

The electron spectrum above 1 TeV

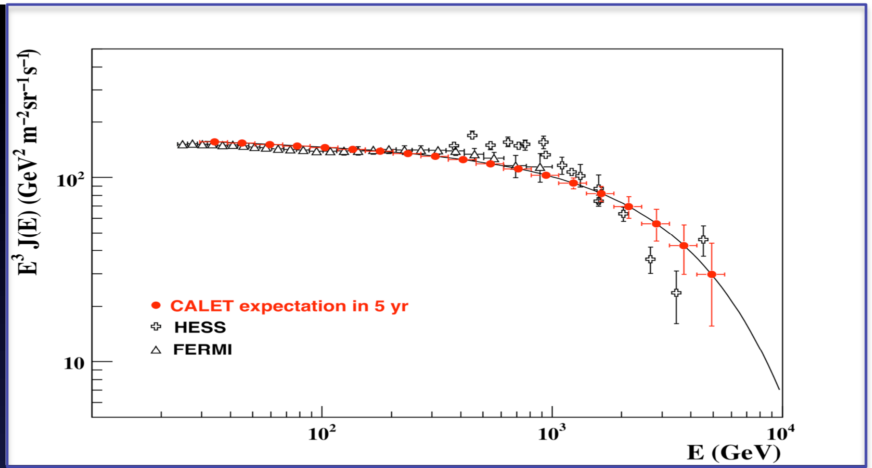
Is there a nearby (< 1 kpc) acceleration source?

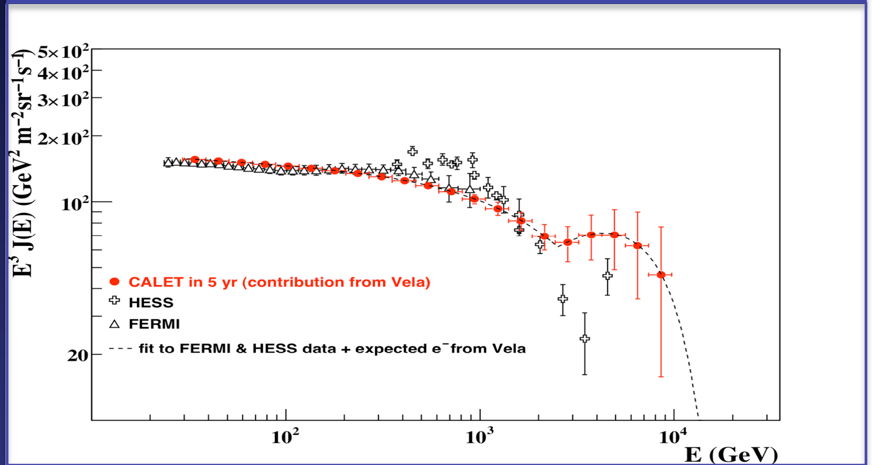
- CALET will explore the **spectral shape beyond 1 TeV** with **low background** (10^5 rejection) and **high energy resolution** (2 - 3%)
- **Anisotropy** measurements to validate possible evidence of nearby source(s)

Nearby Pulsars
or
Dark Matter ?

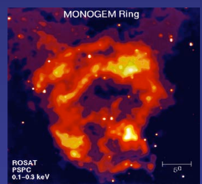


Vela
10,000 years
820 ly
(by CHANDRA)

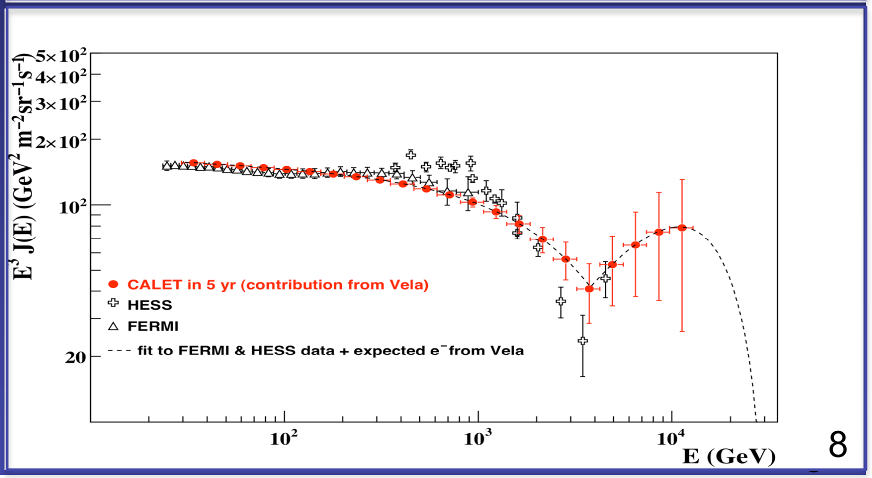




Cygnus Loop
20,000 years
2,500 ly
(by ROSAT)



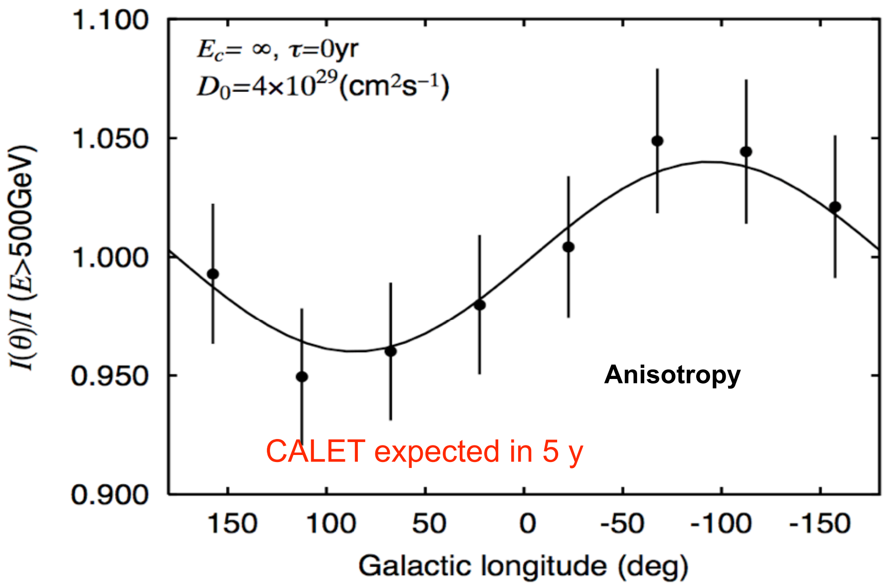
Monogem
86,000 years
1,000 ly

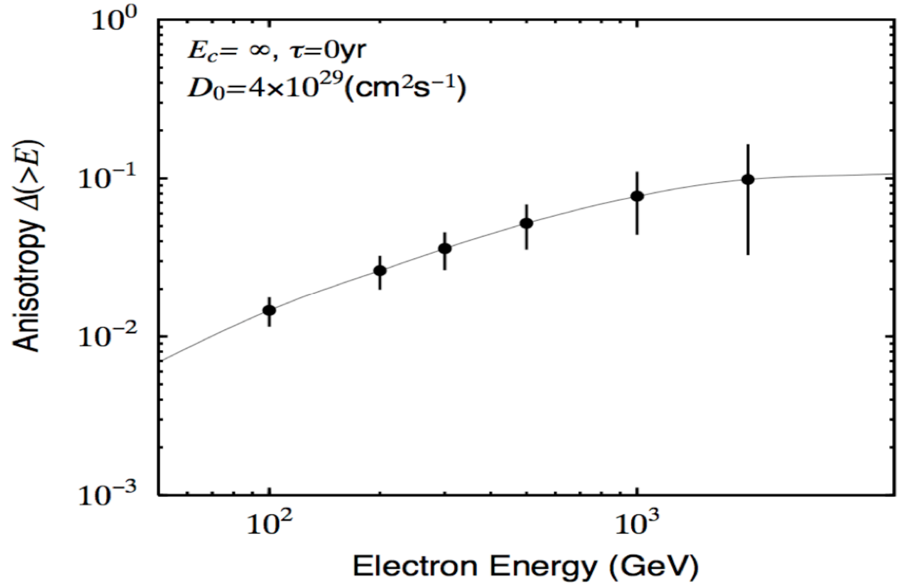


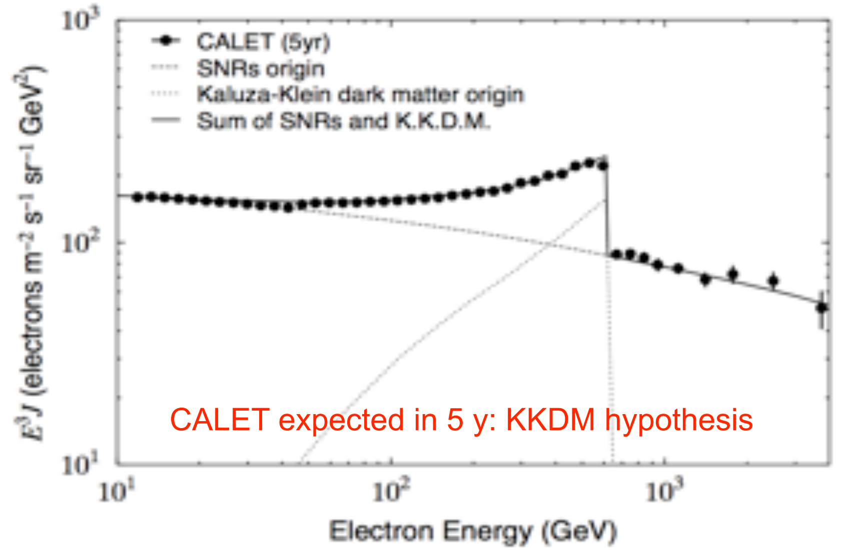
Candidate Nearby Sources
- $T< 10^5$ years
- $L< 1$ kpc

The electron spectrum above 1 TeV

➢ **CALET will perform Anisotropy** measurements to validate possible evidence of nearby source(s)







The electron spectrum below 1 TeV

Accurate **spectral shape** measurements in the regionof the ‘ATIC anomaly’ and of the spectrum down to 1 GeV.

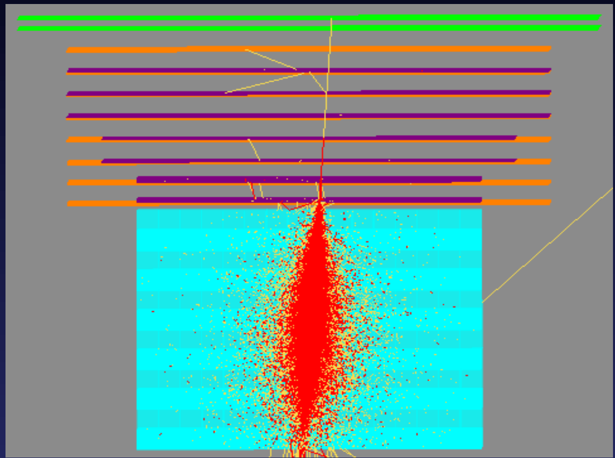
CALET Performance for Electron Observation

Electron 1 TeV

SIA

IMC

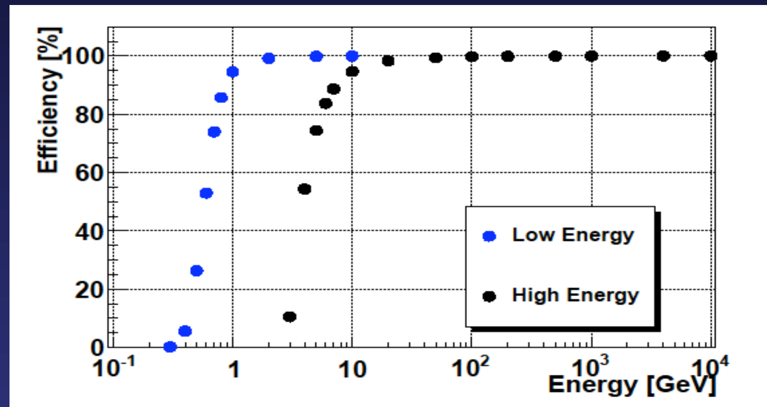
TASC

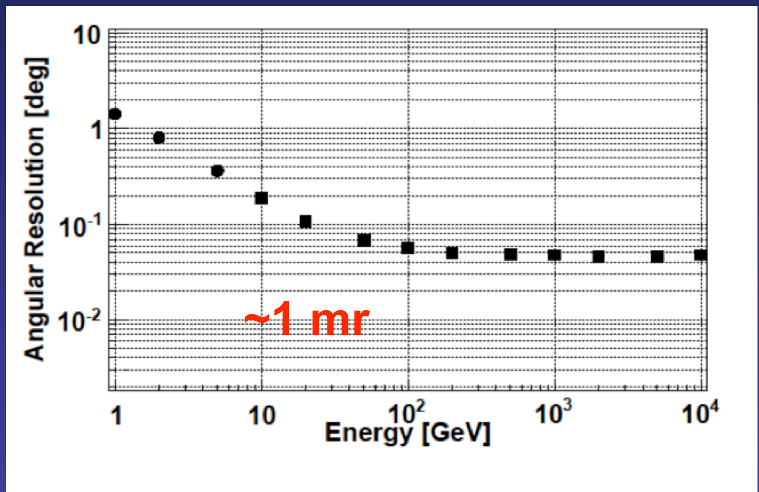


Effective GF:
0.12 m^2sr including fiducial cuts

(500 kg CALET)

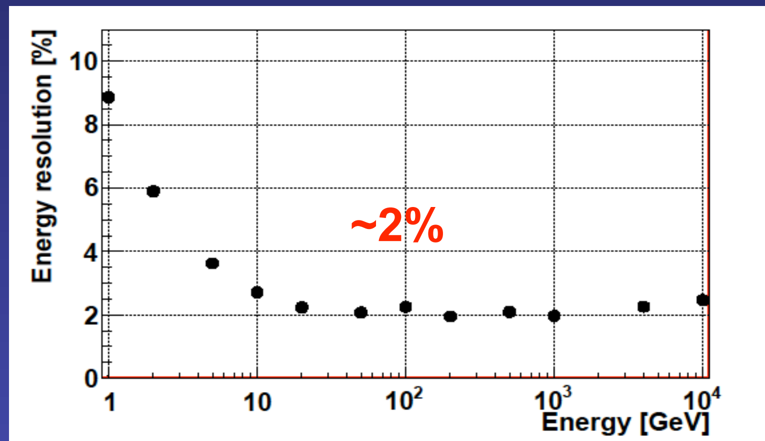
Detection Efficiency



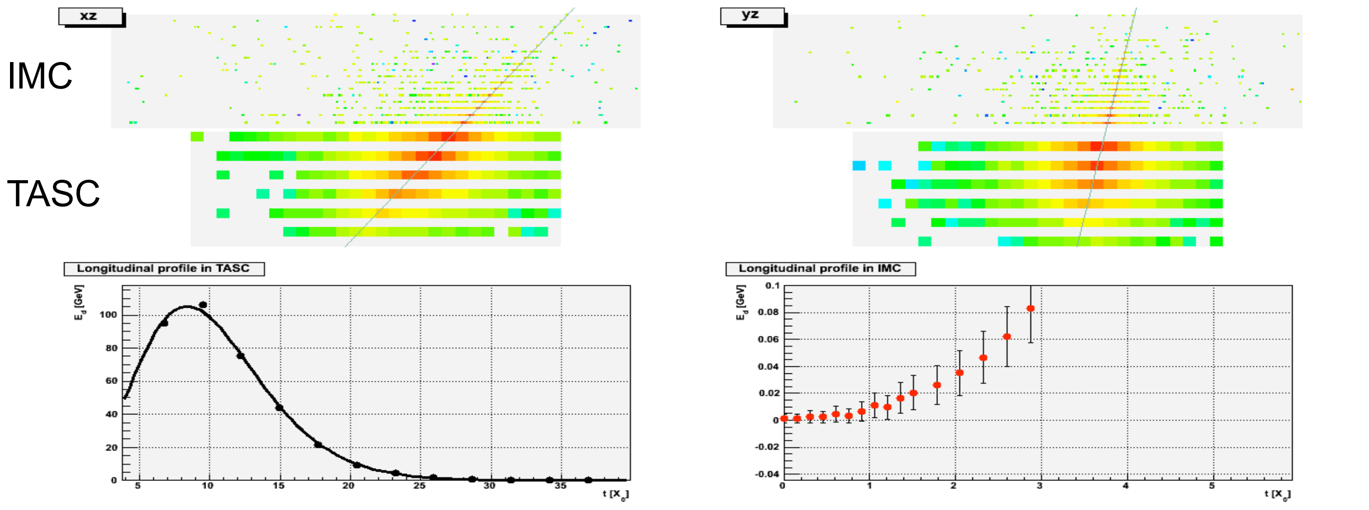


Angular Resolution

Energy Resolution



Rejection of background protons with 2 imaging calorimeters



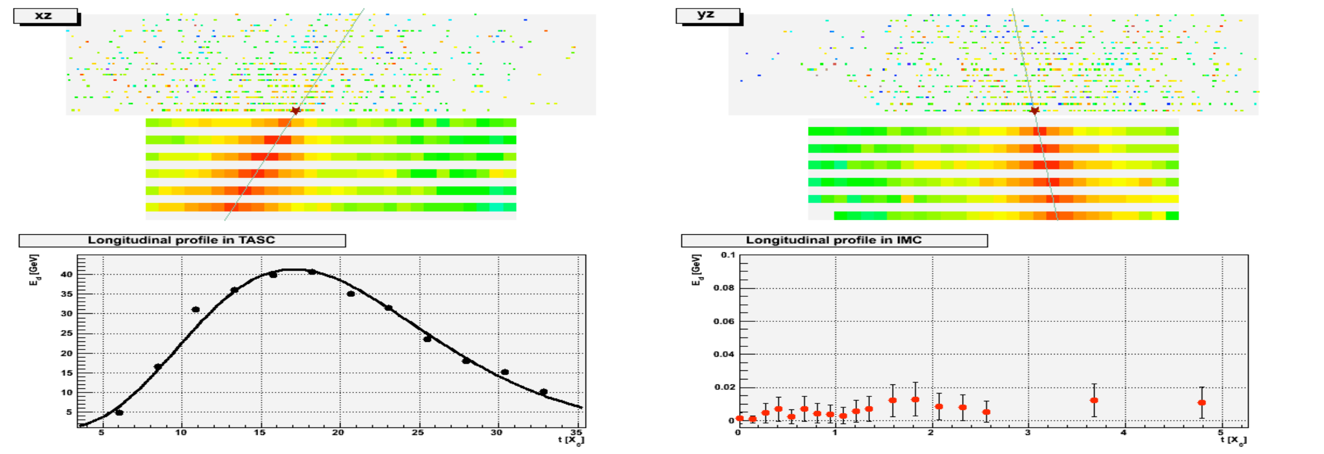
Longitudinal profile in TASC

Longitudinal profile in IMC

400 GeV Electron

e.m. shower starts in IMC

full containment in TASC



1 TeV Proton

minimum ionizing in IMC

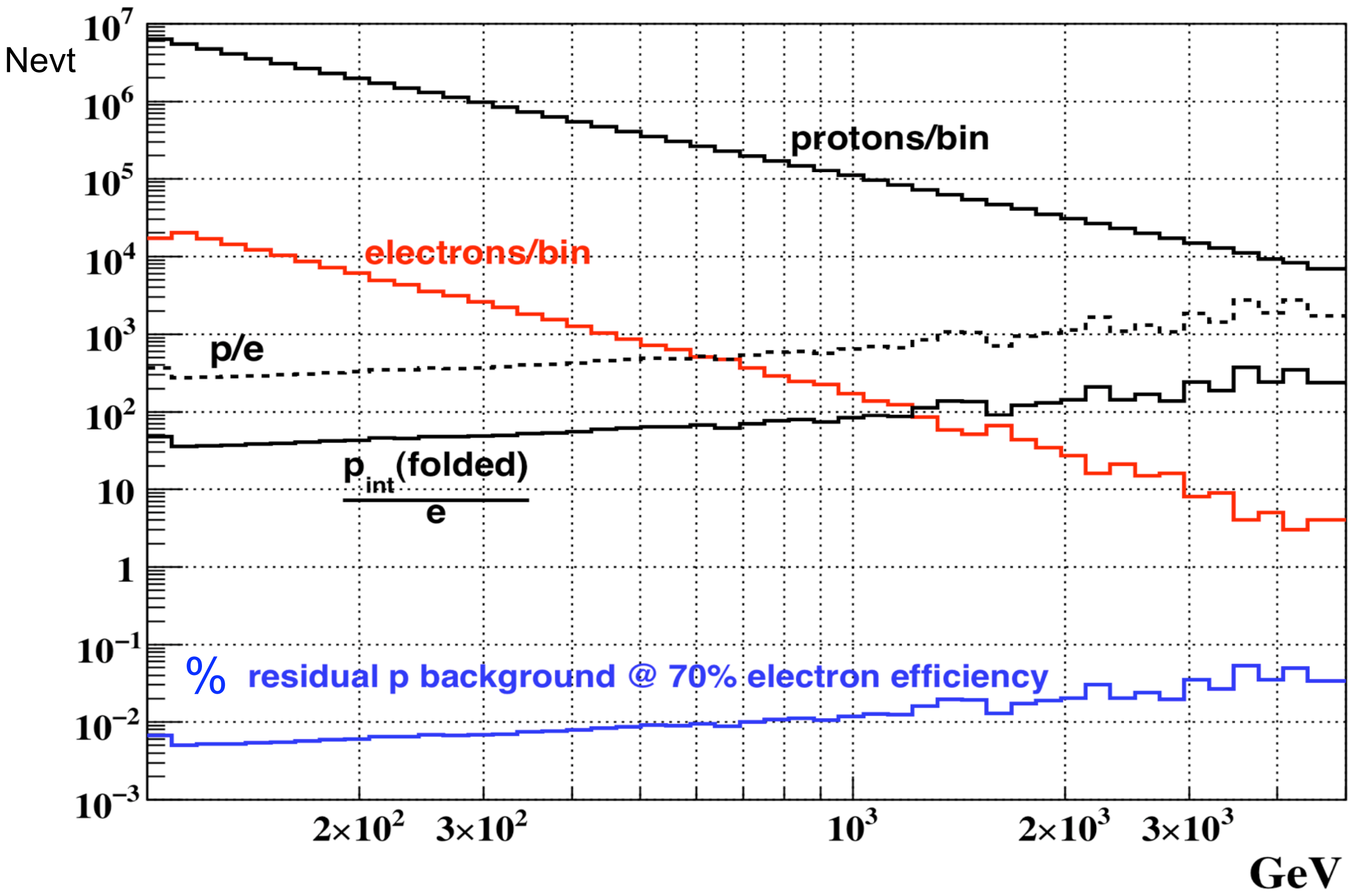
hadr. shower starts in TASC

not full containment

Residual Proton Background

CALET

- Proton differential spectrum as: $E^{-2.70}$
- Electron broken power law: $E^{-3.9}$ as measured by HESS above 1 TeV



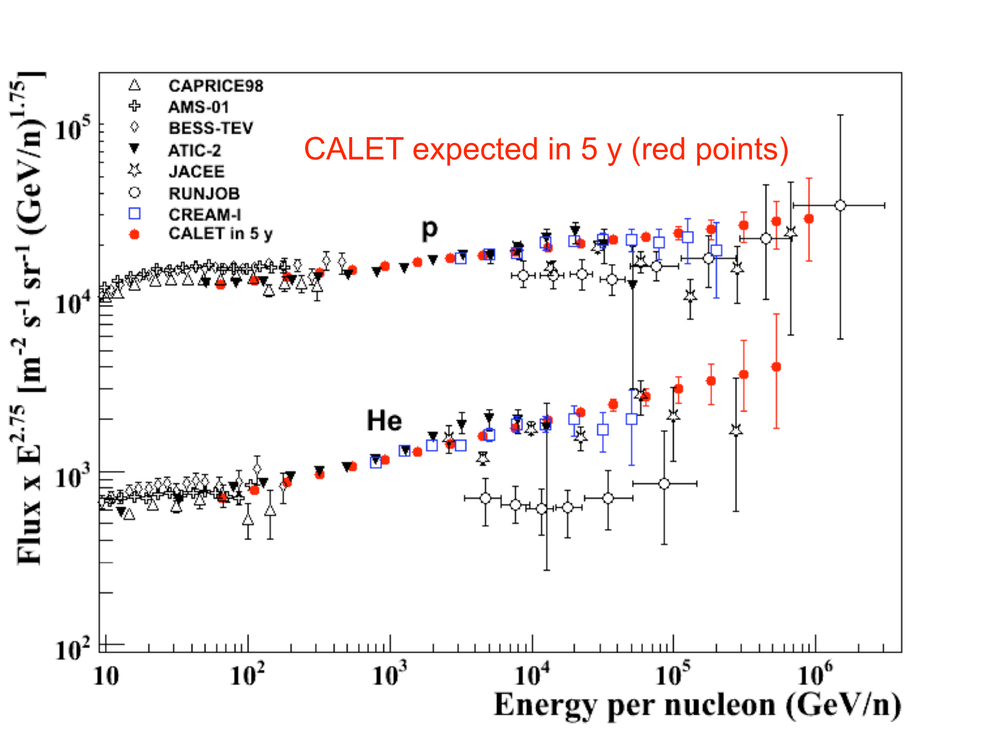
takes into account:

- non-compensating e/h ~ 2.5
- proton resolution ~ 40% (at 1 TeV)

Total Rejection Power (improved cuts in IMC+TASC):
~ 10^5 @ 1 TeV
(~1 % residual protons)
@ 70 % electron efficiency

background:
~1% @ 1 TeV
~8% @ 4 TeV

Proton and He



CALET energy reach in 5 years for p, He

Nucleus	10 events with E (TeV/n) >	5 events with E (TeV/n) >
H	586	893
He	265	416

- Competitors above 10 TeV/n: CREAM
(neither PAMELA nor AMS-02 can cover this region)

Multi-TeV region

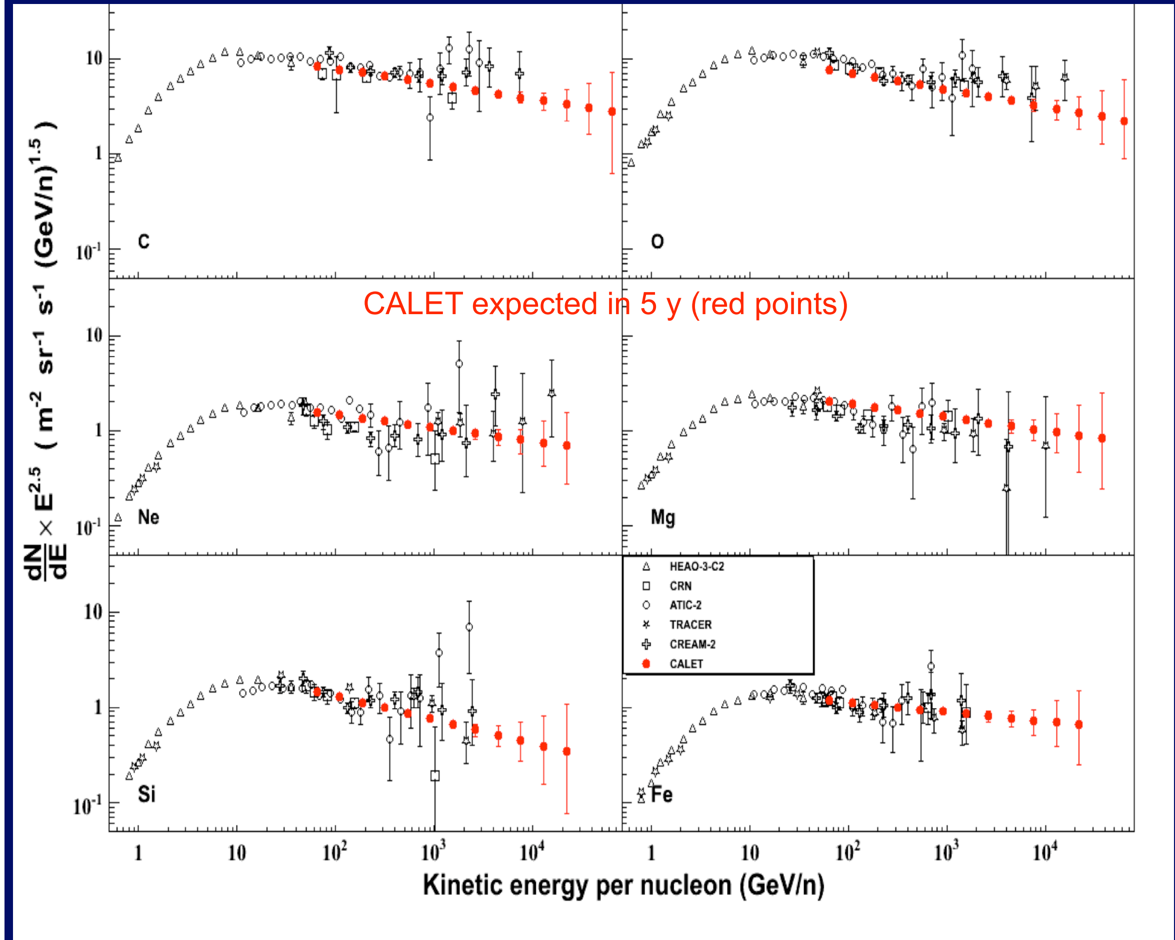
- Proton and He slopes are different?
- Single power-law or curvature?
- Is there a proton cutoff below 1 PeV?

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 shower (as in CREAM) i.e.: > 20 X_0

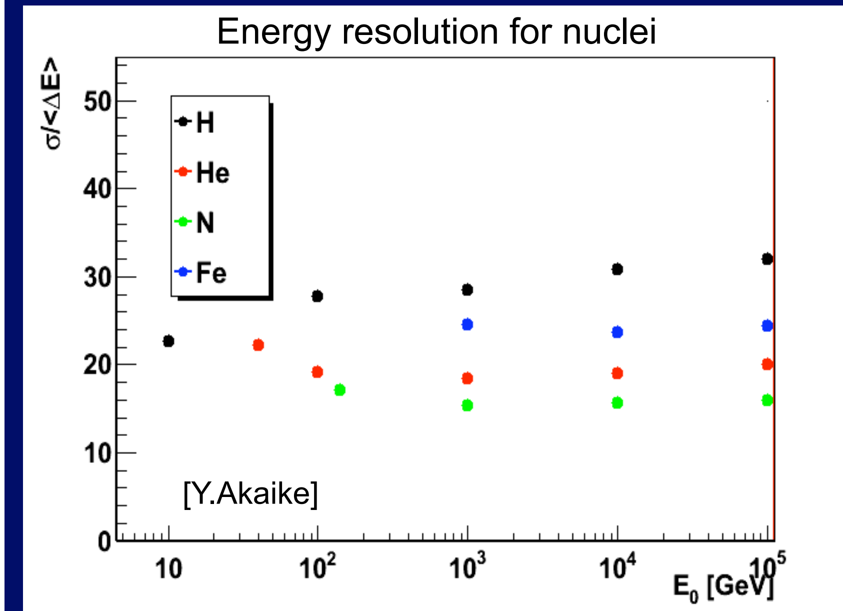
	λ_{INT}	X_0 (normal incidence)
CREAM	0.5 + 0.7	20
CALET	1.5	30
AMS-02	0.5	17

Intermediate nuclei → Fe



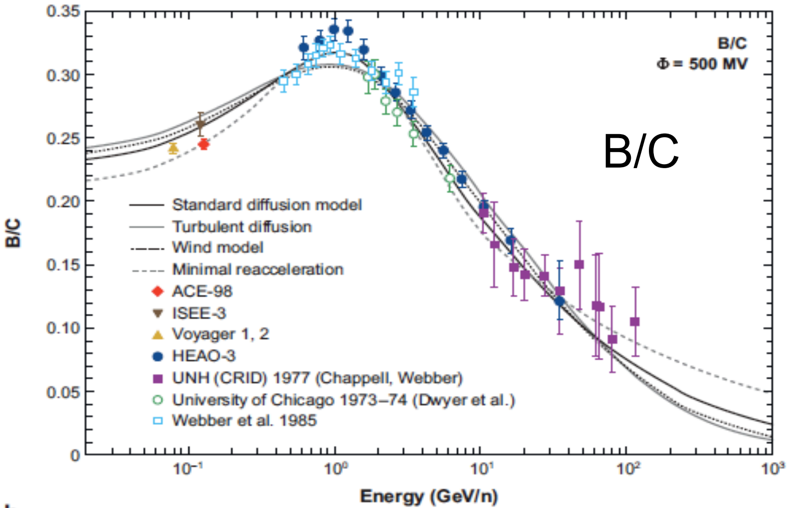
- is there a spectral cutoff below 1 PeV?
- single power law or spectrum concavity?

CALET energy reach
(5 years)

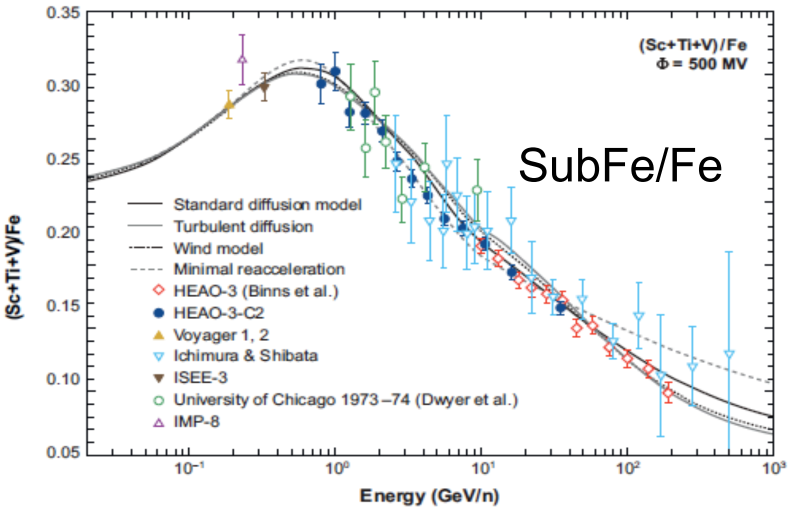


- Competitors above 4 TeV/n: CREAM, TRACER
- below : AMS-02, PAMELA

Secondary/Primary Nuclei Ratio



b



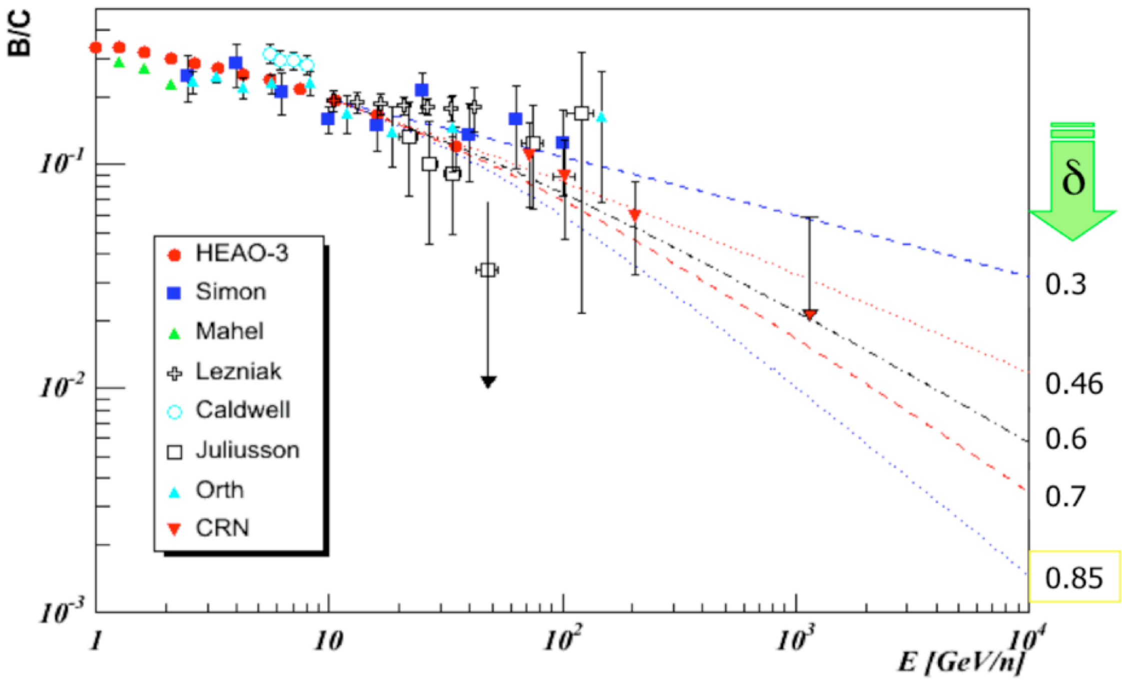
Secondary/primary nuclei ratio in CR is declining for E > 1 GeV/n, not rising !

The measured secondary-to-primary ratios, as a function of E/nucleon, are incompatible with an energy independent τ_{esc}

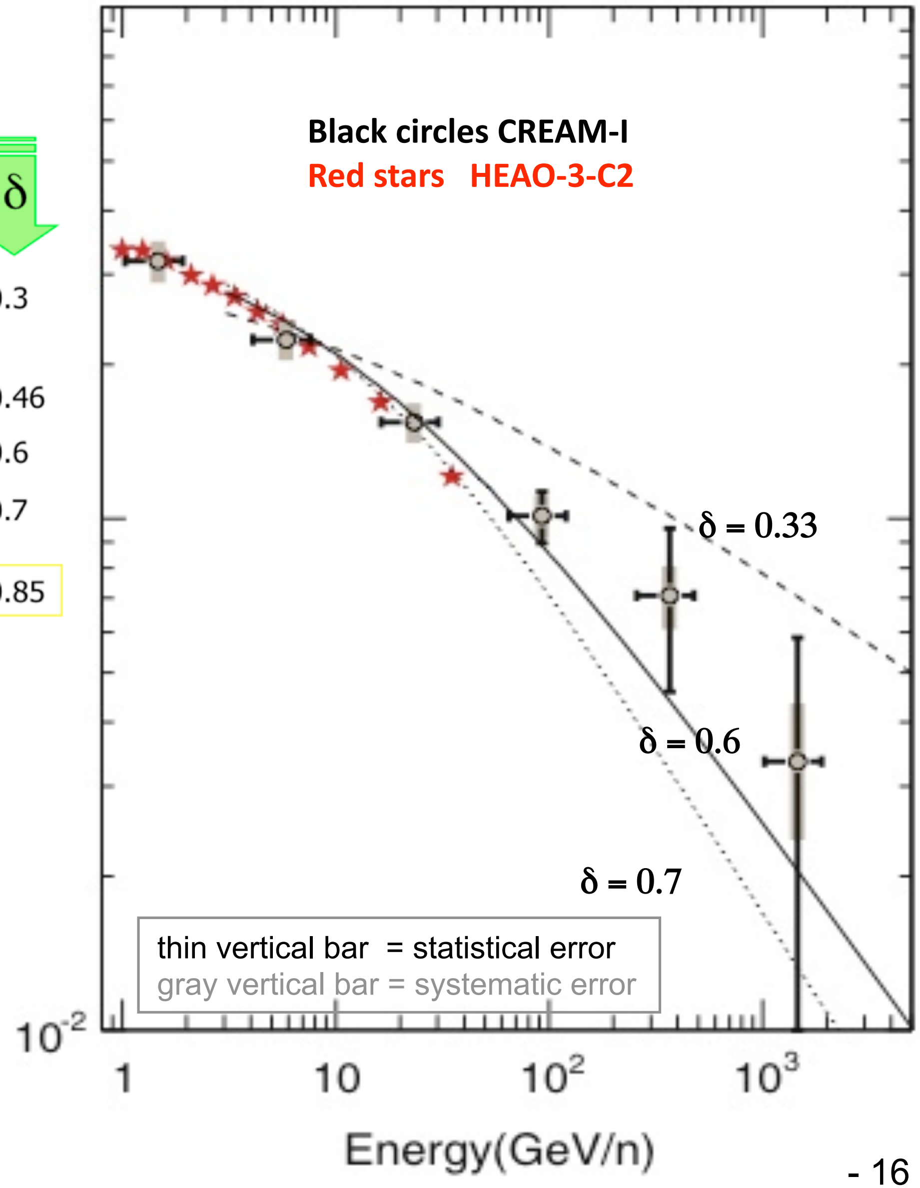
At high energy (E > 100 GeV/n) the S/P ratios measure the **energy dependence of the escape length**:

$$\frac{N_S}{N_P}(E) \cong P_{P\to S}\,\frac{\tau_{esc}(E)}{\tau_{int}} \longrightarrow E^{-\delta}$$

Measurements before CREAM



Measurements above 100 GeV/n with CREAM



Boron to Carbon abundance ratio

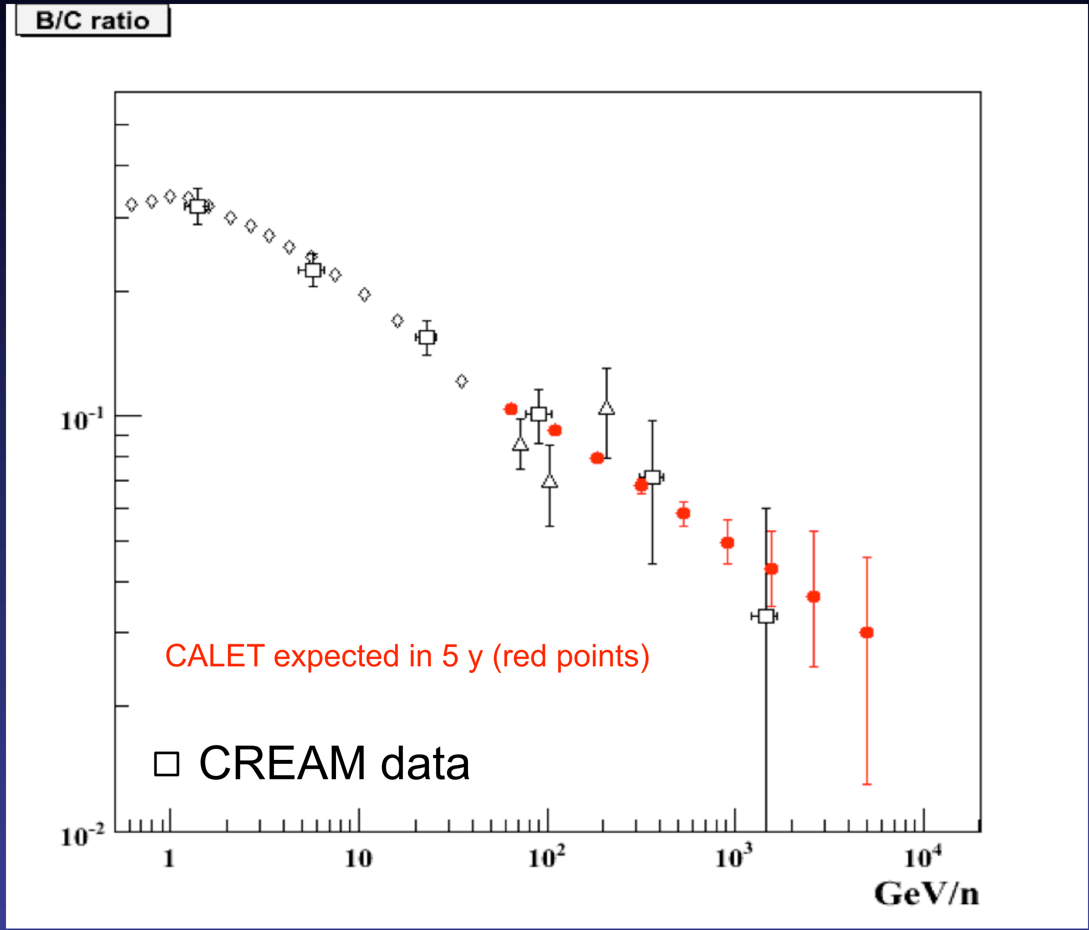
vs. Energy/nucleon

Boron to Carbon ratio with CALET

Energy reach (with 5 y x 0.12 m^2sr):
about 3 TeV/n

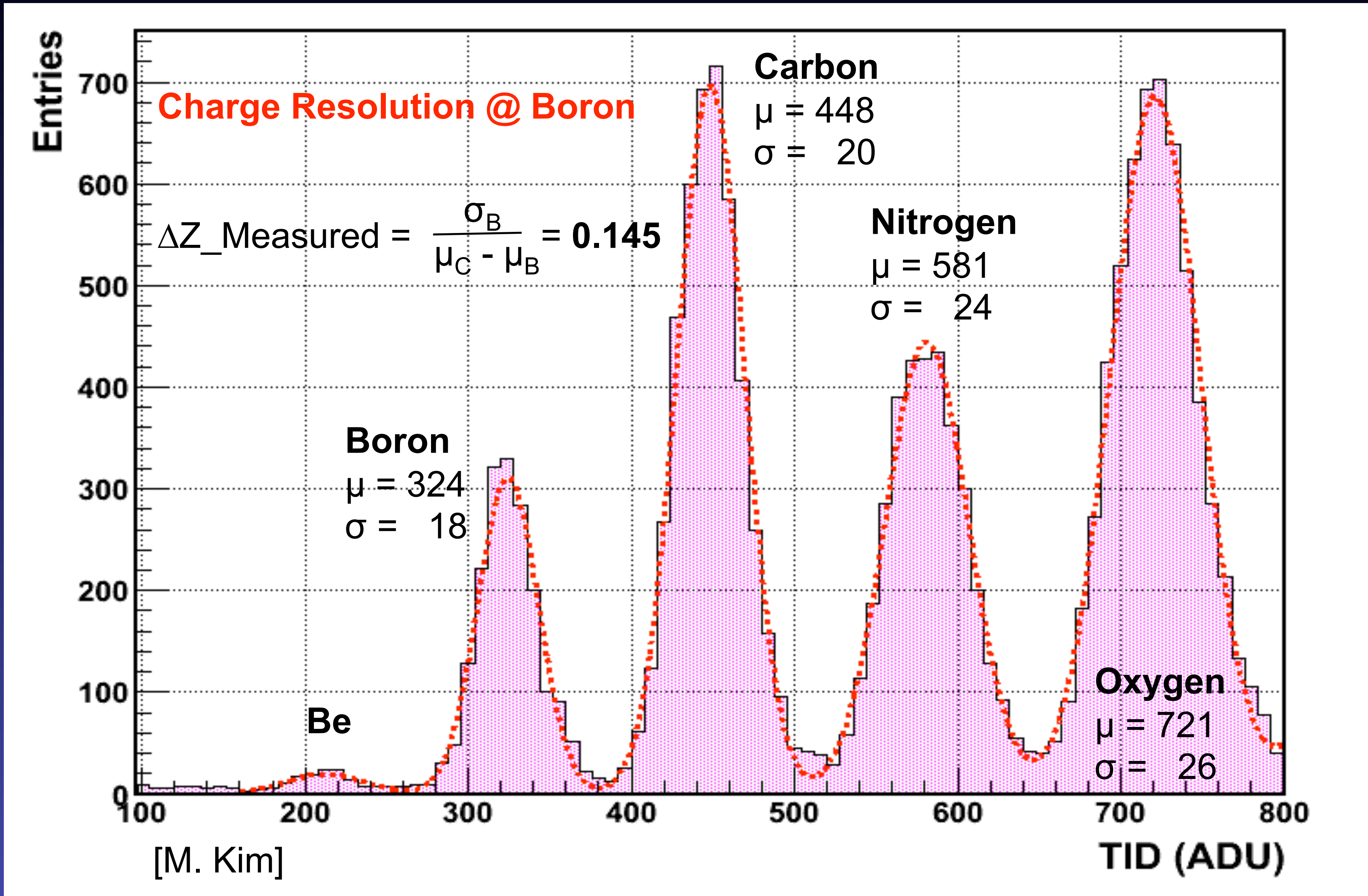
The irreducible background due to the **atmospheric overburden** at flight altitude sets a **limit to** the highest energy points of the **Boron-to-Carbon ratio** obtainable with **measurements on balloons**.

Experiments in space are free from this limitation and CALET is expected to measure the B/C ratio up to several TeV/n



- Competitors above 500 GeV/n: CREAM, TRACER, AMS-02

GSI beam test 2010 at 1.3 GeV/amu: CHD Charge Resolution

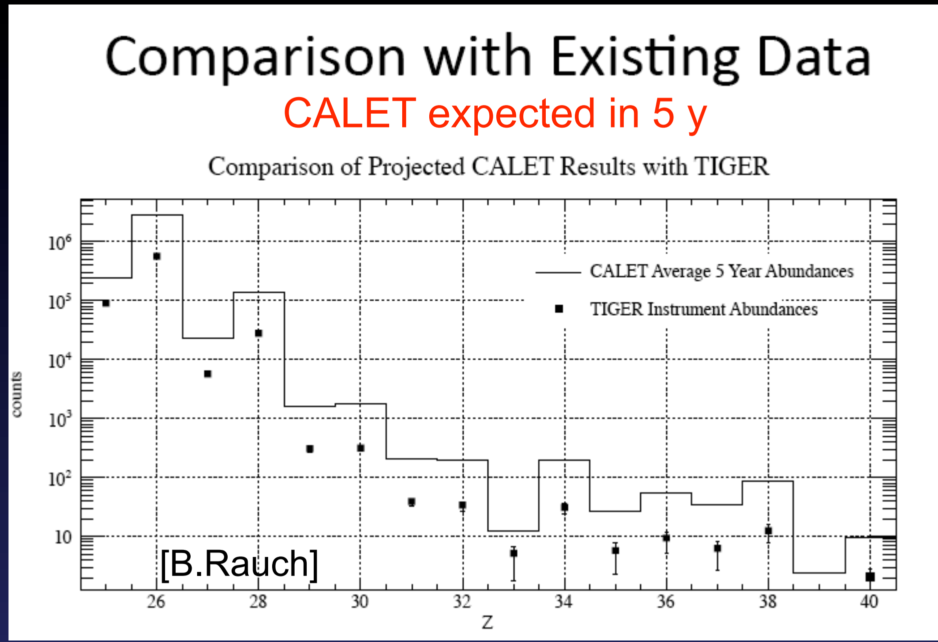


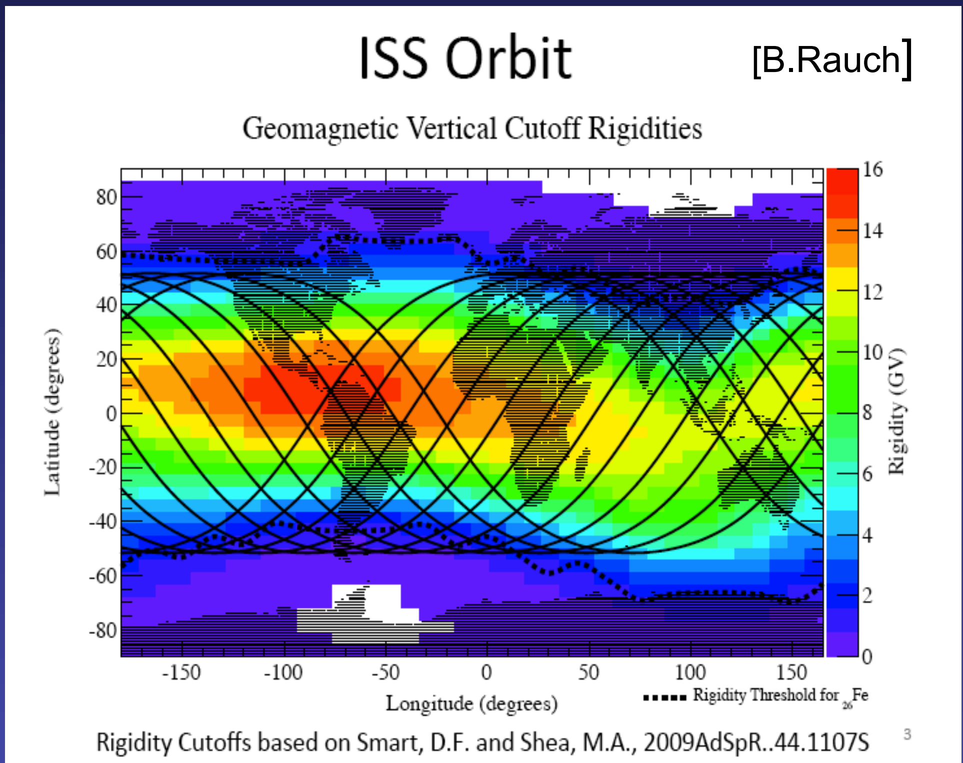
Trans-Fe (Z ≤ 40) elements

➢ Dedicated CHD trigger

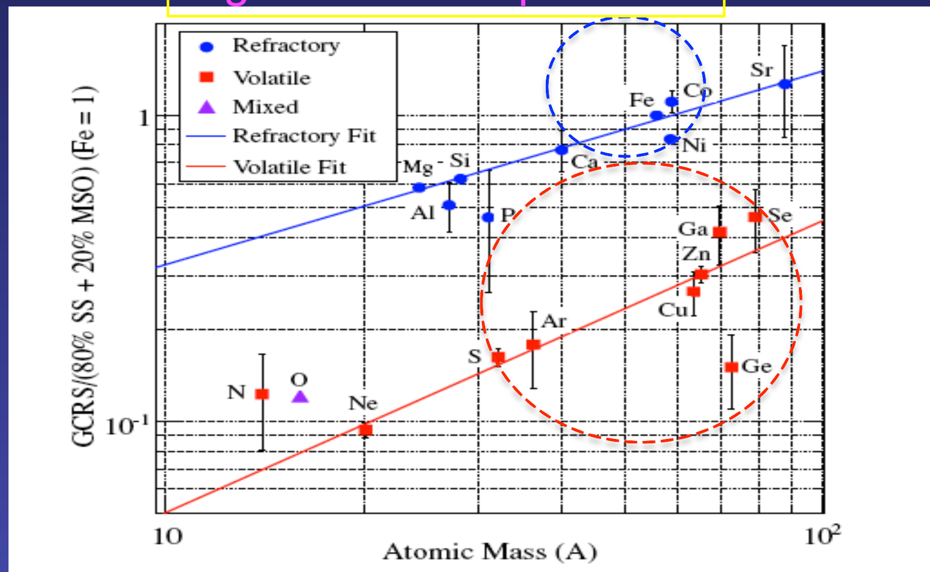
(large trigger acceptance of about 0.33 m^2sr)

- statistics ≅ 8 x TIGER
- ≅ 60 days of Super-TIGER
- cleaner measurements (smaller corrections for hadronic interactions



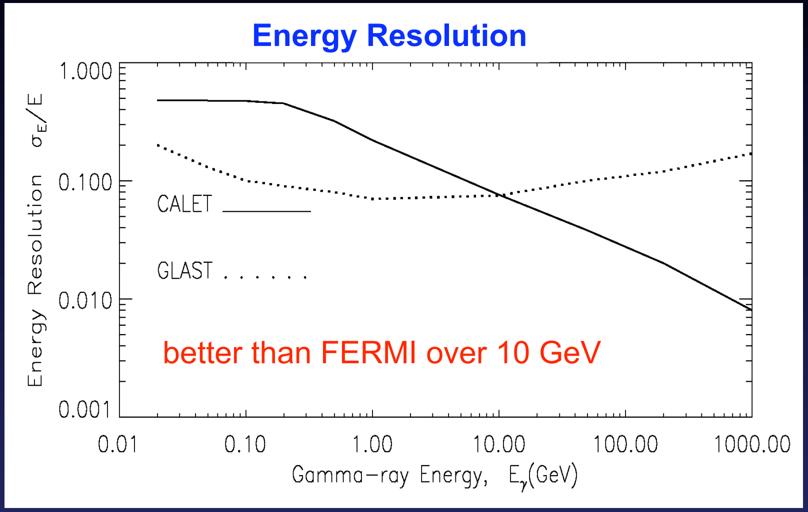


Tiger balloon experiment



Identification of SUSY Dark Matter: Gamma-ray Line shape

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.

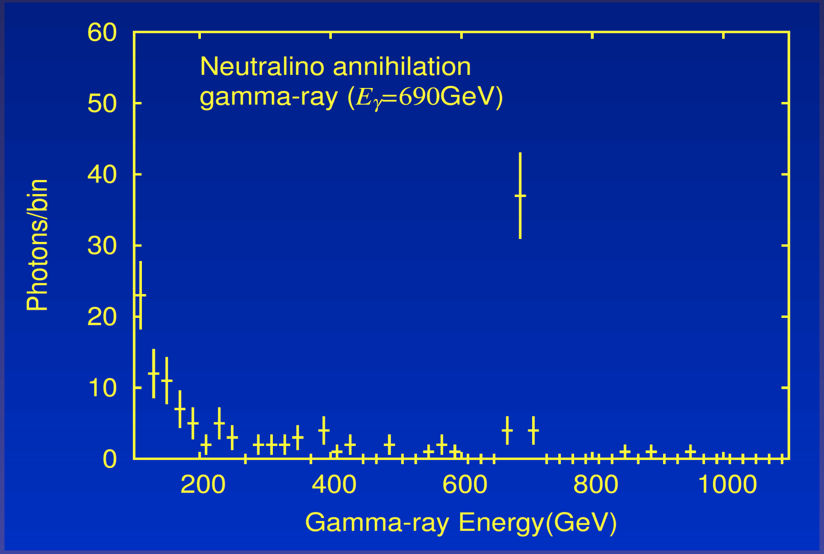


Example:

- **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**

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

Energy Resolution ~1.2%



CALET - International Collaboration Team

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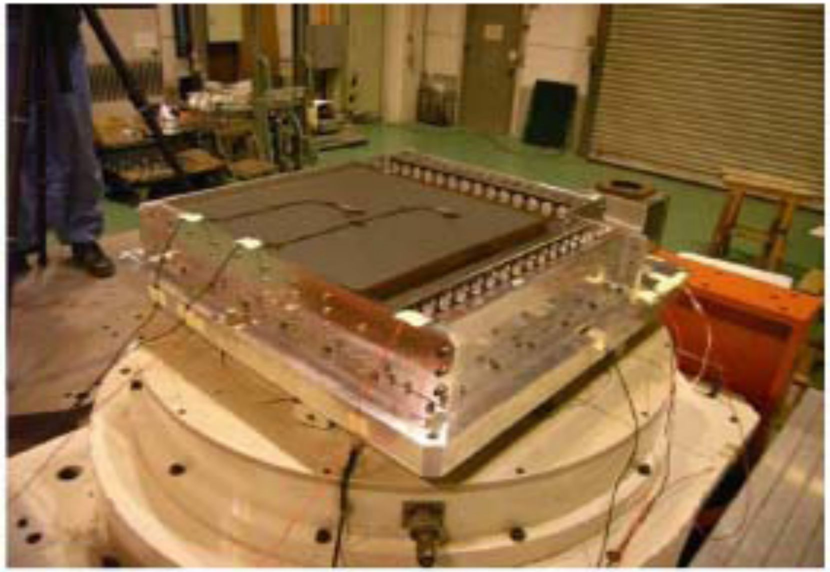
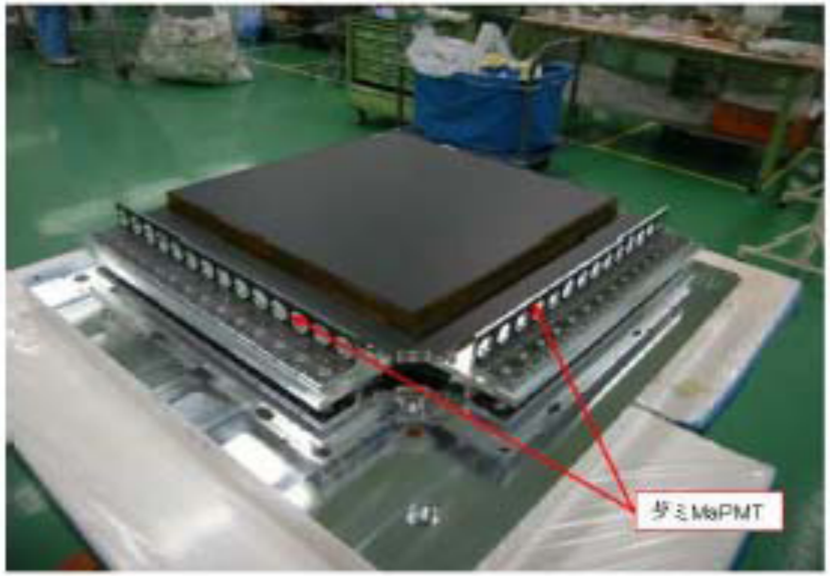
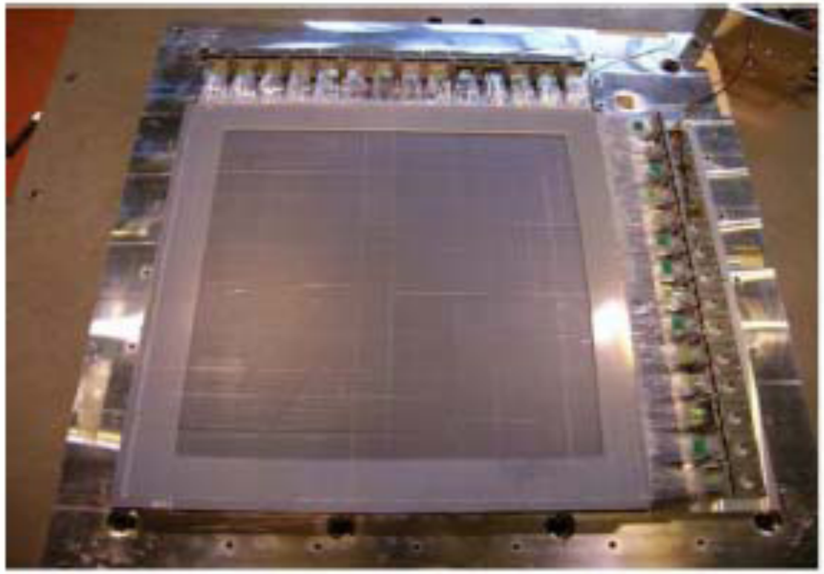
BBM of IMC

Vibration Test of IMC





SciFi Belt Glued on Substrate



PMT and SciFi Connection

BBM of TASC for Vibration Test