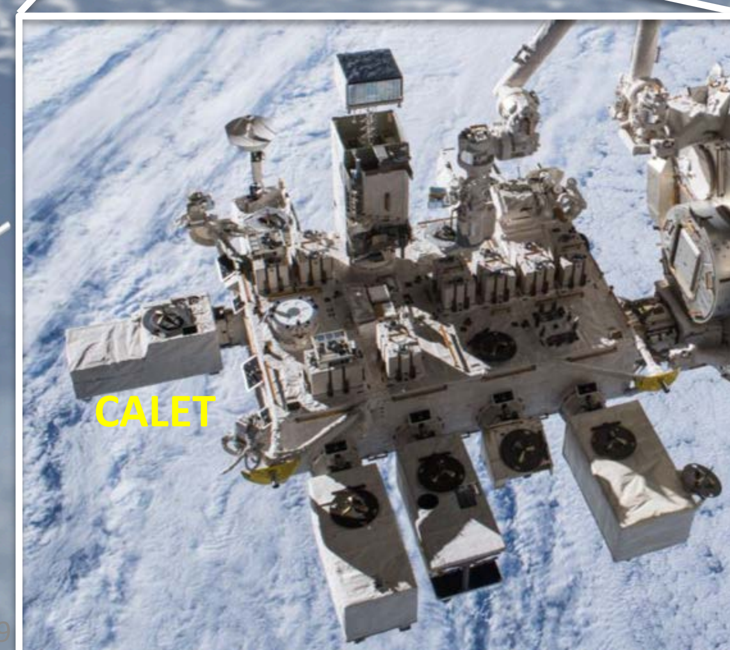
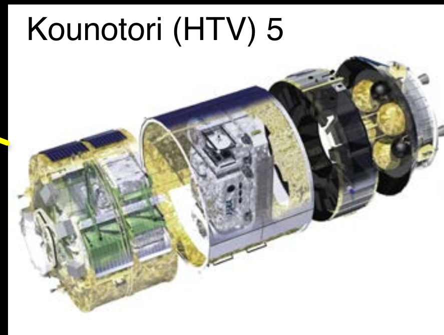
Extended Measurement of Cosmic-Ray Electron and Positron Spectrum from CALET on the ISS

Shoji Torii
Waseda University
& Kanagawa University
for the CALET collaboration

CRD2c 25 July, 2019

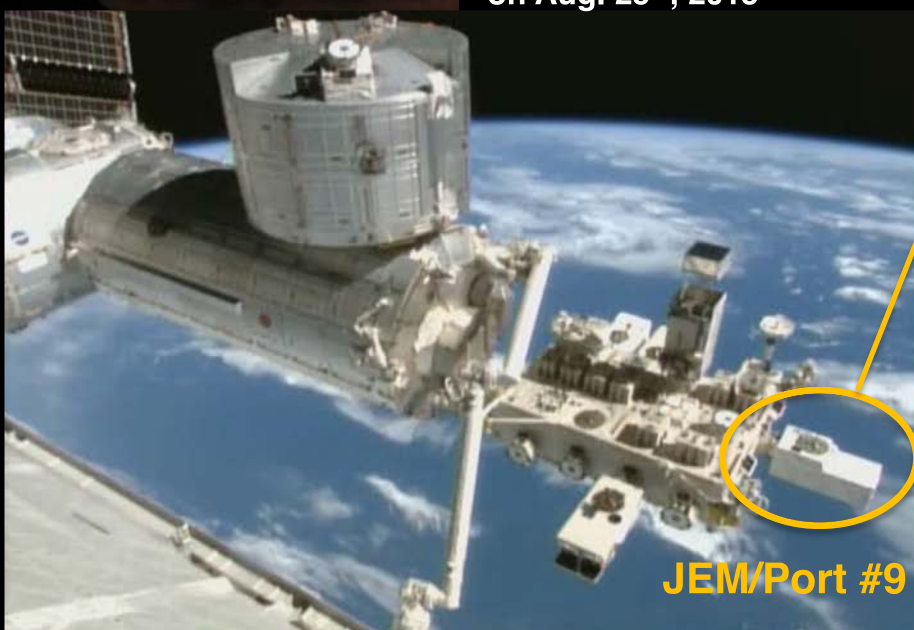


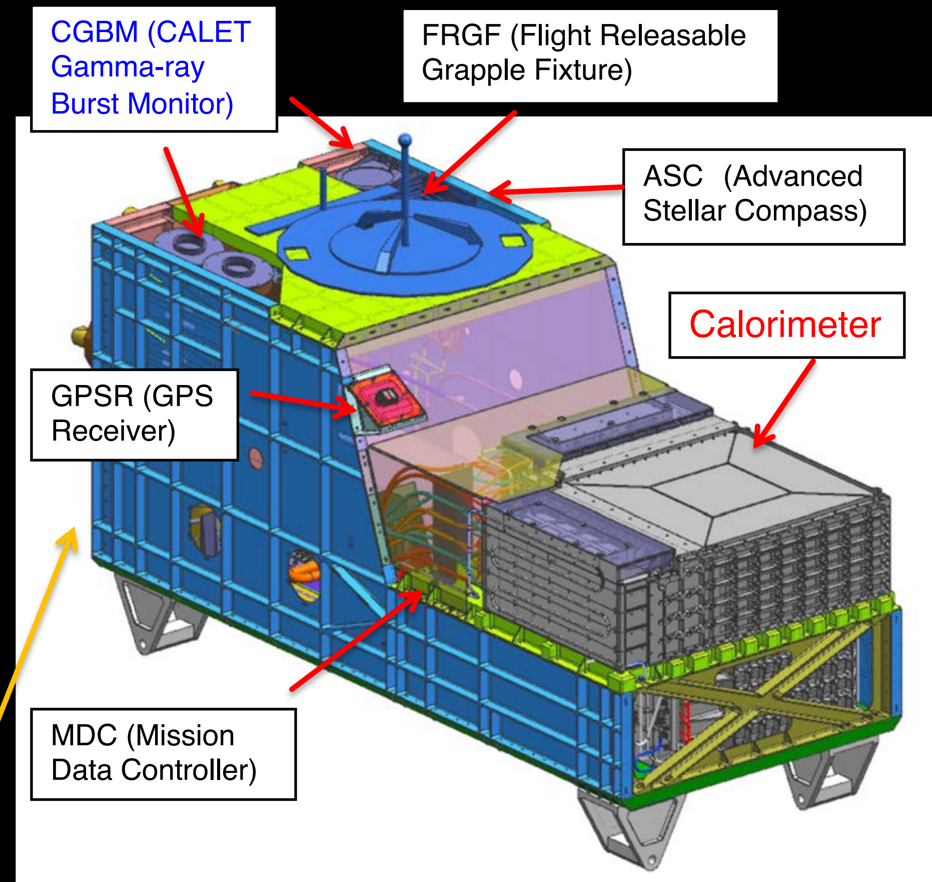
CALET Payload



Launched on Aug. 19th, 2015 by the Japanese H2-B rocket

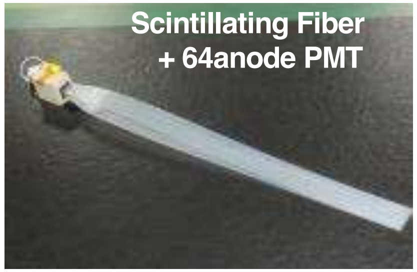
Emplaced on JEM-EF port #9 on Aug. 25th, 2015

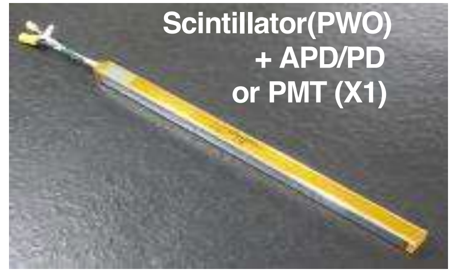




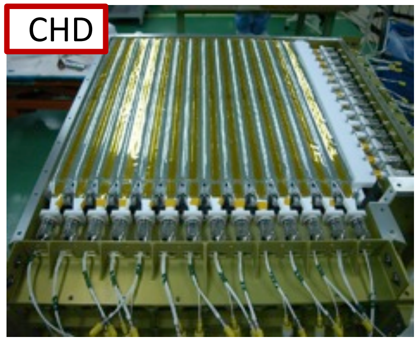
- **Mass: 612.8 kg**
- **JEM Standard Payload Size:**
  1850mm(L) × 800mm(W) × 1000mm(H)
- **Power Consumption: 507 W (max)**
- **Telemetry:**
  Medium 600 kbps (6.5GB/day) / Low 50 kbps

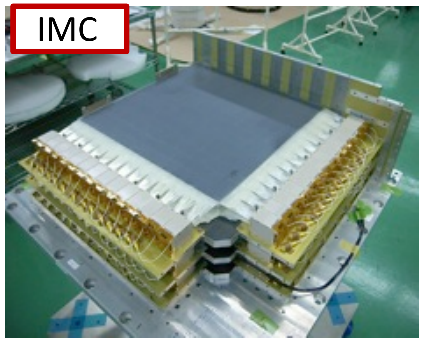
CALET Instrument

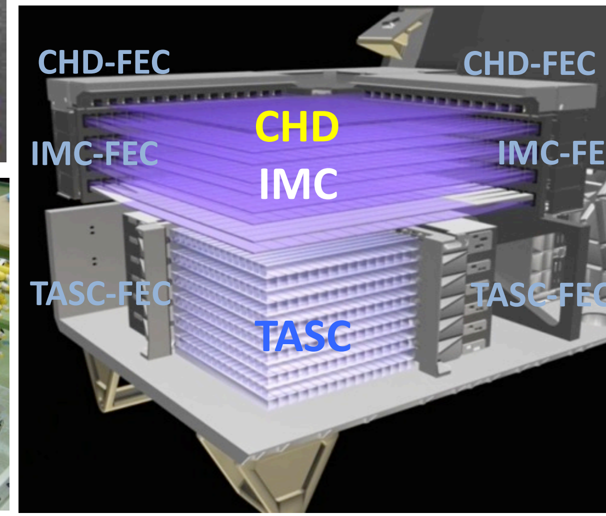




CALORIMETER



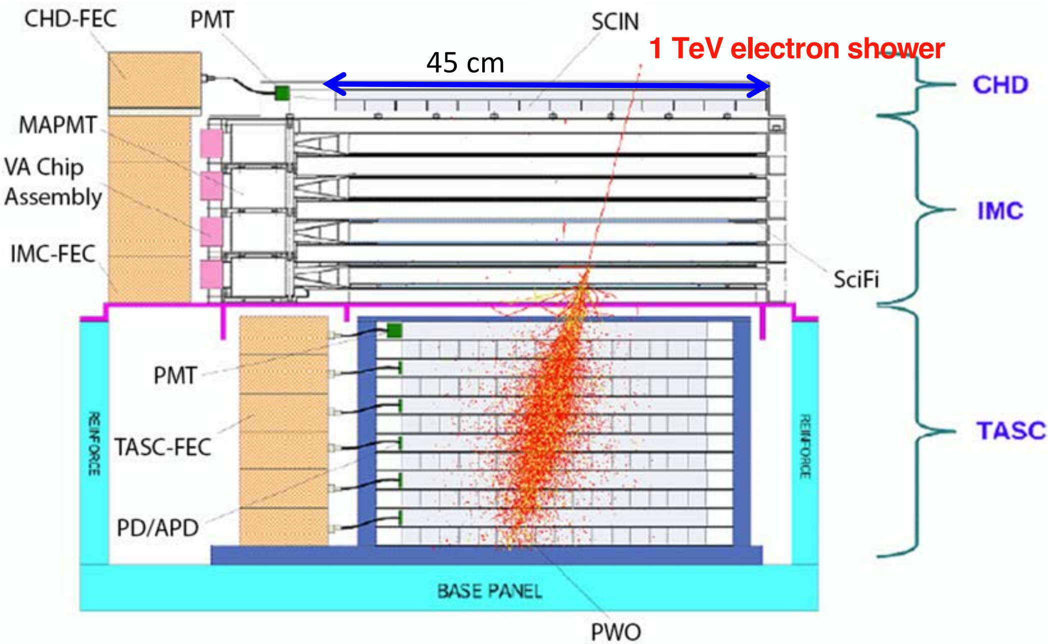




	CHD (Charge Detector)	IMC (Imaging Calorimeter)	TASC (Total Absorption Calorimeter)
Measure	**Charge (Z=1-40)**	**Tracking , Particle ID**	**Energy, e/p Separation**
Geometry (Material)	**Plastic Scintillator 14 paddles x 2 layers (X,Y): 28 paddles Paddle Size: 32 x 10 x 450 mm^3**	**448 Scifi x 16 layers (X,Y) : 7168 Scifi 7 W layers (3X_0): 0.2X_0 x 5 + 1X_0 x2 Scifi size : 1 x 1 x 448 mm^3**	**16 PWO logs x 12 layers (x,y): 192 logs log size: 19 x 20 x 326 mm^3 Total Thickness : 27 X_0 , ~1.2 λ_I**
Readout	**PMT+CSA**	**64-anode PMT+ ASIC**	**APD/PD+CSA PMT+CSA (for Trigger)@top layer**

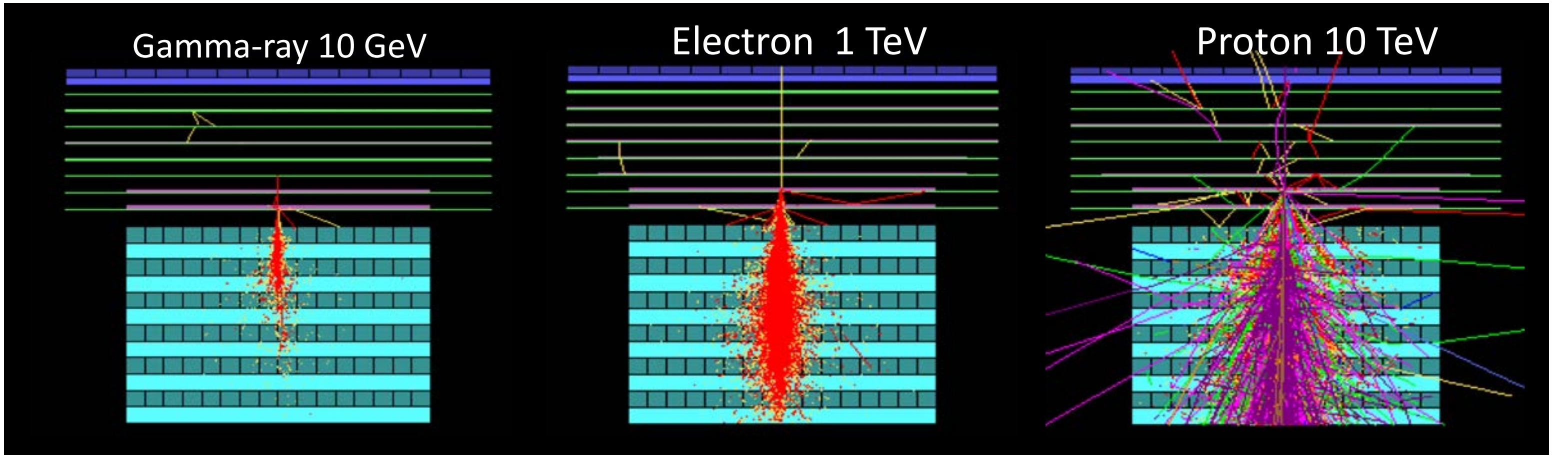
CALET Capability

Field of view: ~ 45 degrees (from the zenith)
Geometrical Factor: ~ 1,040 cm^2sr (for electrons)



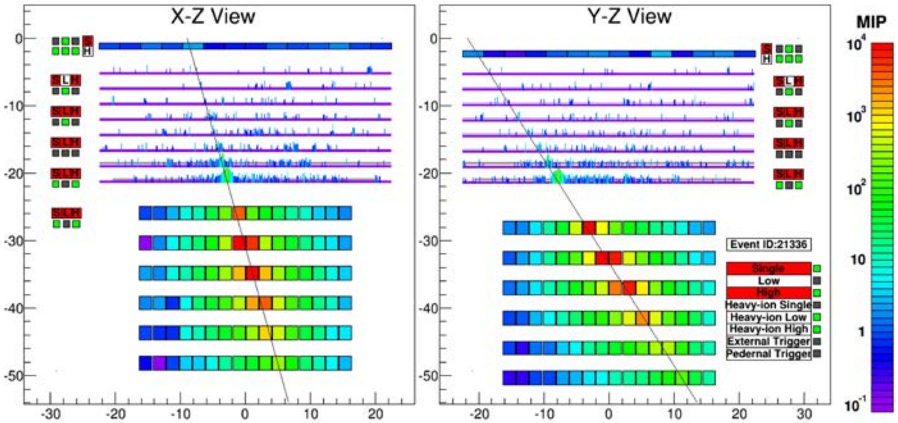
Unique features of CALET

- A dedicated charge detector + multiple dE/dx track sampling in the IMC allow to identify individual nuclear species (Δz~0.15-0.3 e).
- Thick(~30 X_0), fully active calorimeter allows measurements well into the TeV energy region with excellent energy resolution (~2-3%)
- High granularity imaging pre-shower calorimeter accurately identify the arrival direction of incident particles (~0.2°) and the starting point of electro-magnetic showers.
- Combined, they powerfully separate electrons from the abundant protons: contamination is much less than 10 % up to the TeV region.

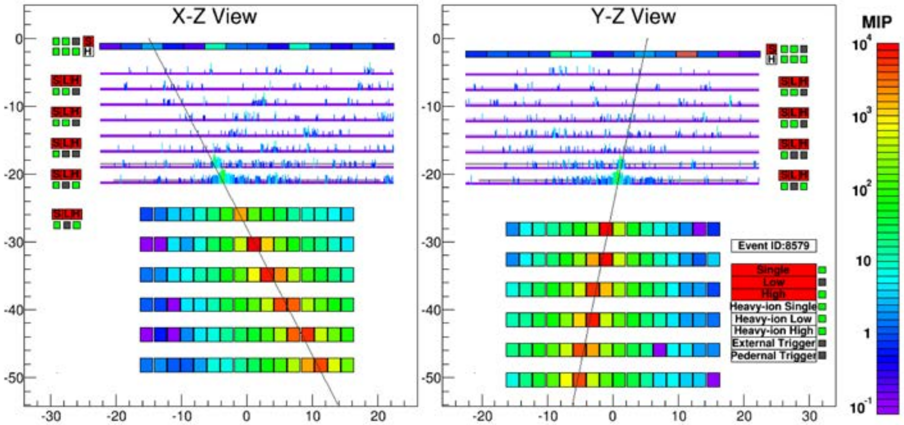


Examples of Event Display

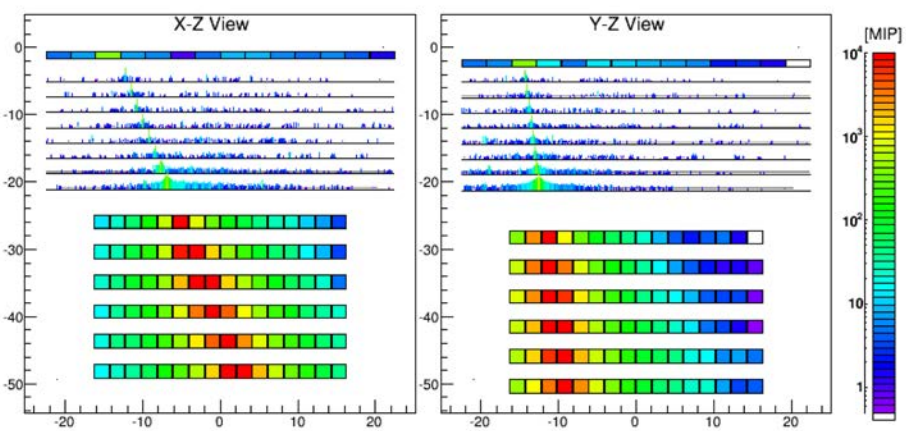
Electron, E=3.05 TeV



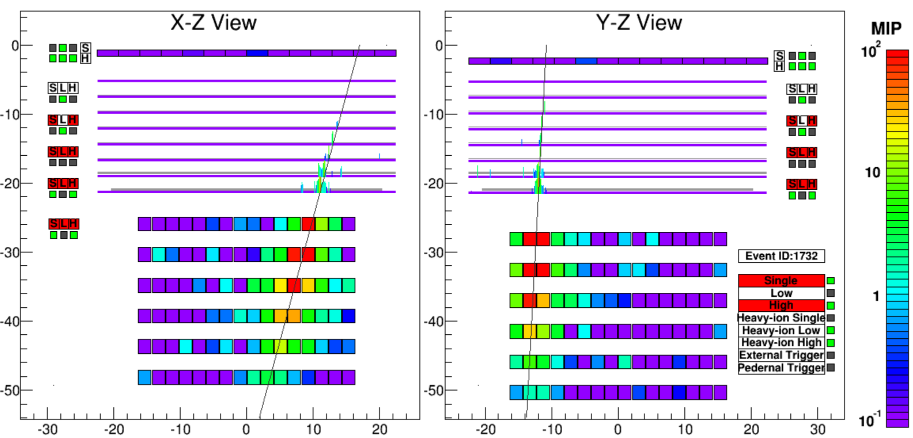
Proton, ΔE=2.89 TeV



Fe, ΔE=9.3 TeV



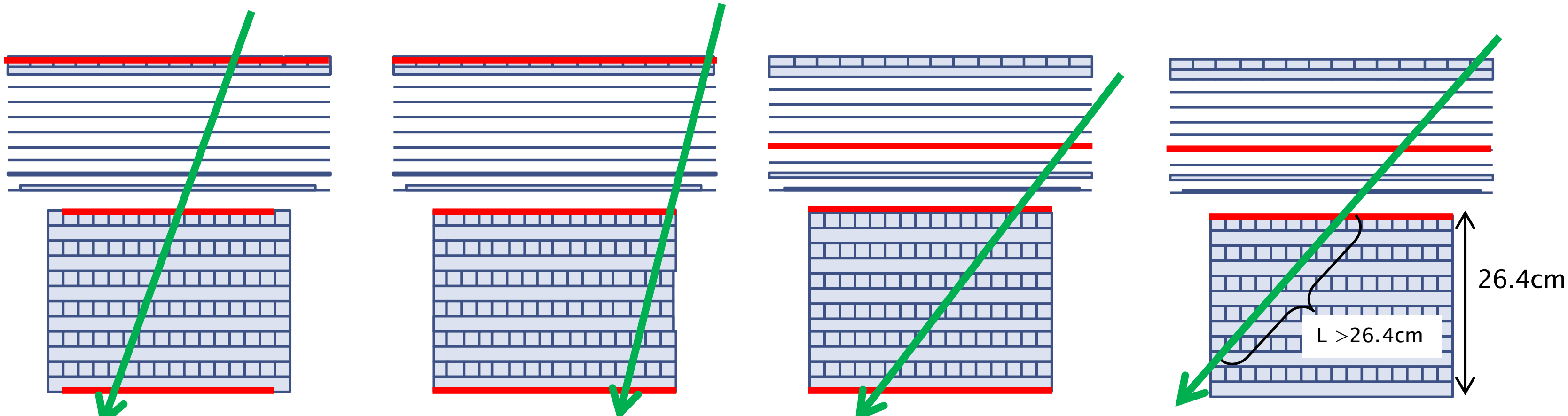
Gamma-ray, E=44.3 GeV



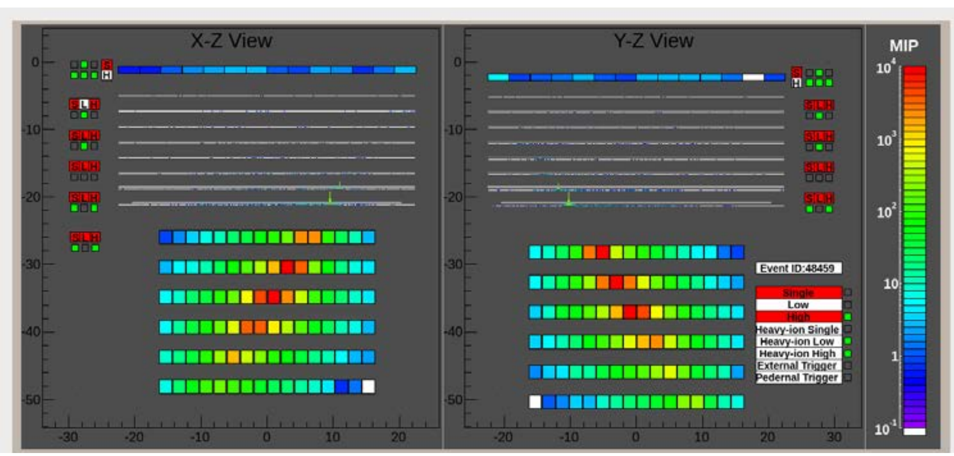
Unit in MIP

Energy Reconstruction for Electromagnetic Showers

(A) Fully-contained (B) Nearly fully-contained (C) Side-incident (D) Side-out

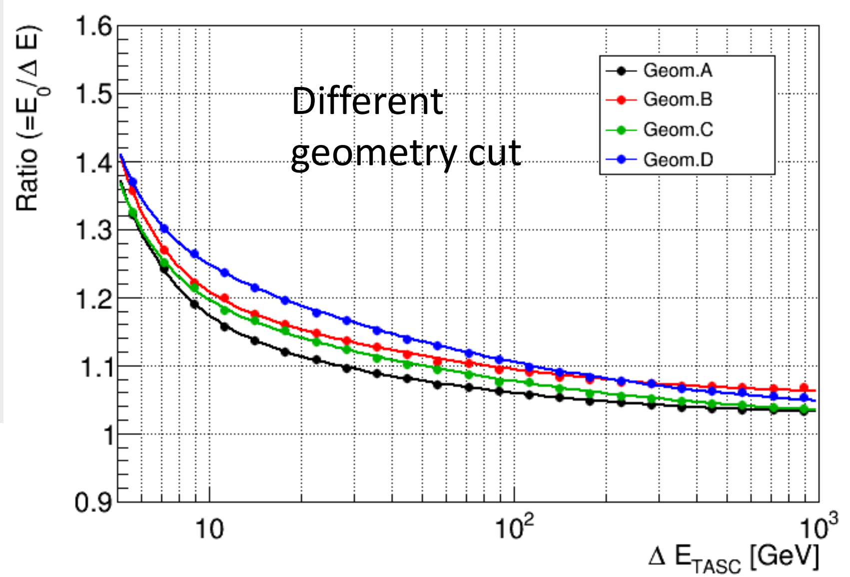


SΩ (cm^2sr) 416 A+B:570 All: 1040



4 TeV electron candidate (well contained)
⇒ very small leakage (~ a few %)

Energy reconstruction factor vs. Energy



Electron Identification

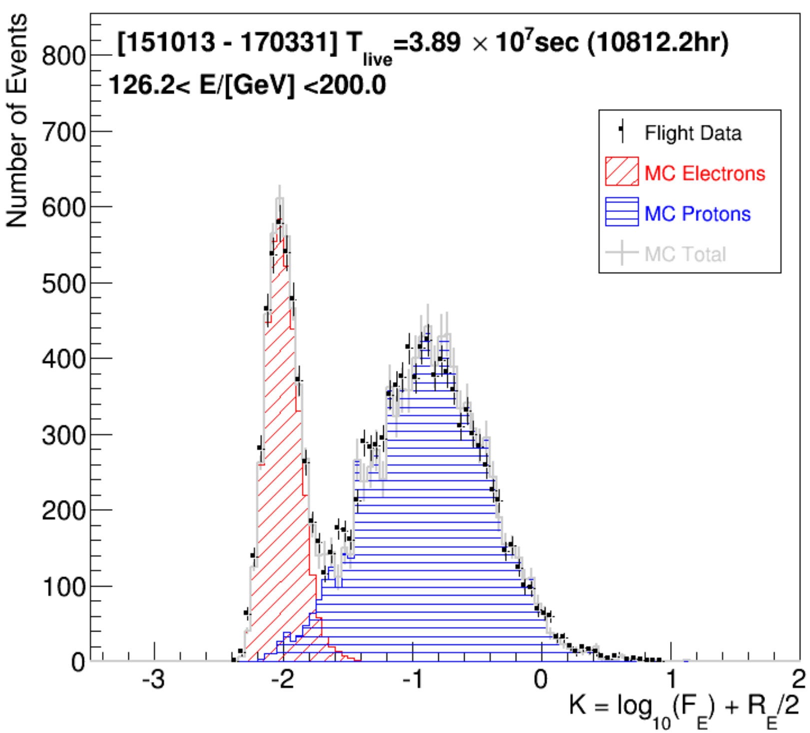
Simple Two Parameter Cut

F_E: Energy fraction of the bottom layer sum to the whole energy deposit sum in TASC

R_E: Lateral spread of energy deposit in TASC-X1

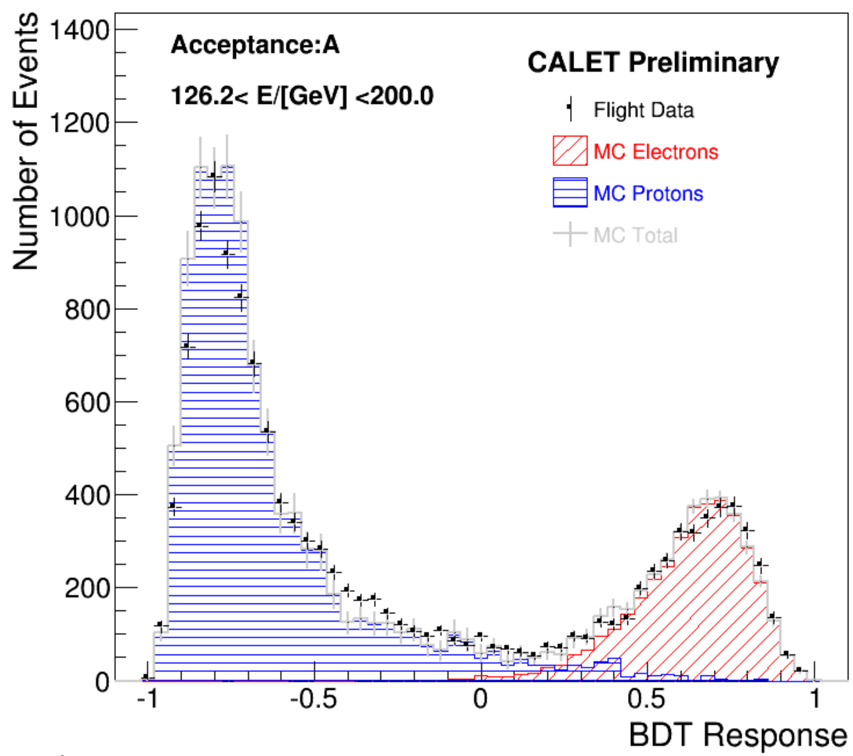
Cut Parameter K is defined as follows:

$$K = \log_{10}(F_E) + 0.5\, R_E\ (/cm)$$



Boosted Decision Trees (BDT)

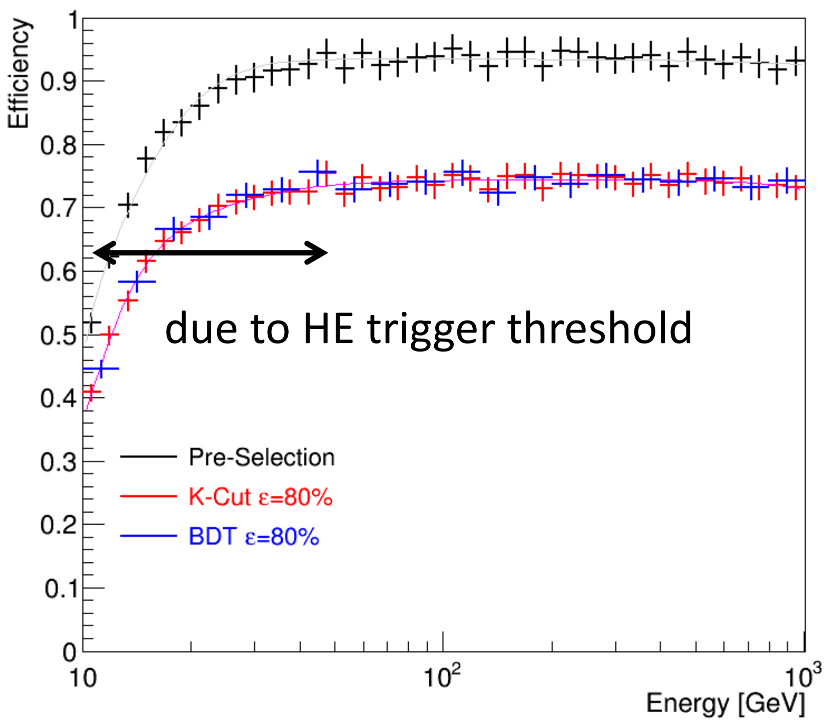
In addition to the two parameters in the left, TASC and IMC shower profile fits are used as discriminating variables.



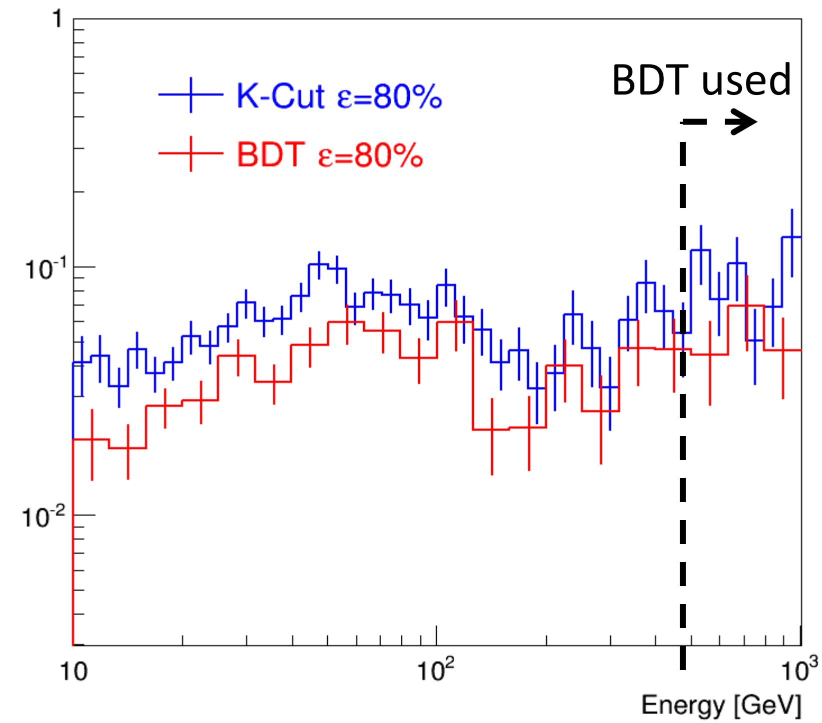
Electron Efficiency and Subtraction of Proton Contamination

- Constant and high efficiency is the key point in our analysis.
- Simple two parameter cut is used in the low energy region while the difference in resultant spectrum are taken into account in the systematic uncertainty.

Energy vs Efficiency by Cut



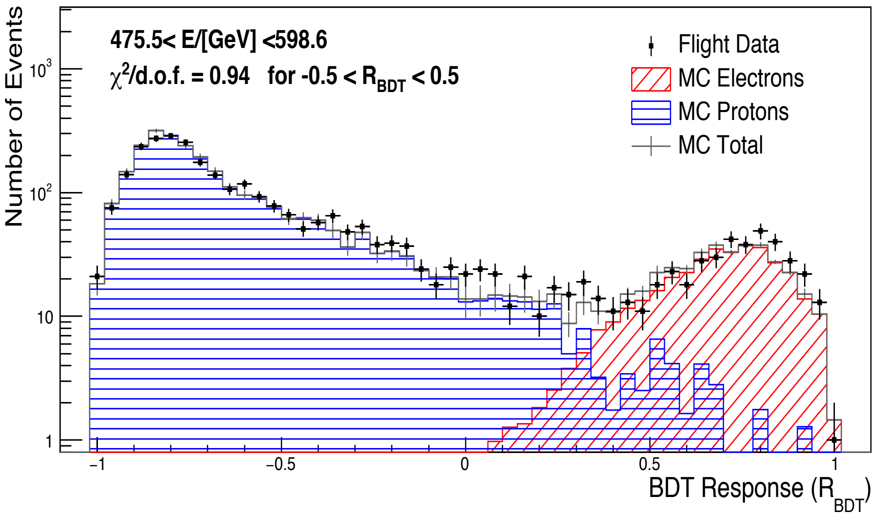
Energy vs Proton Contamination



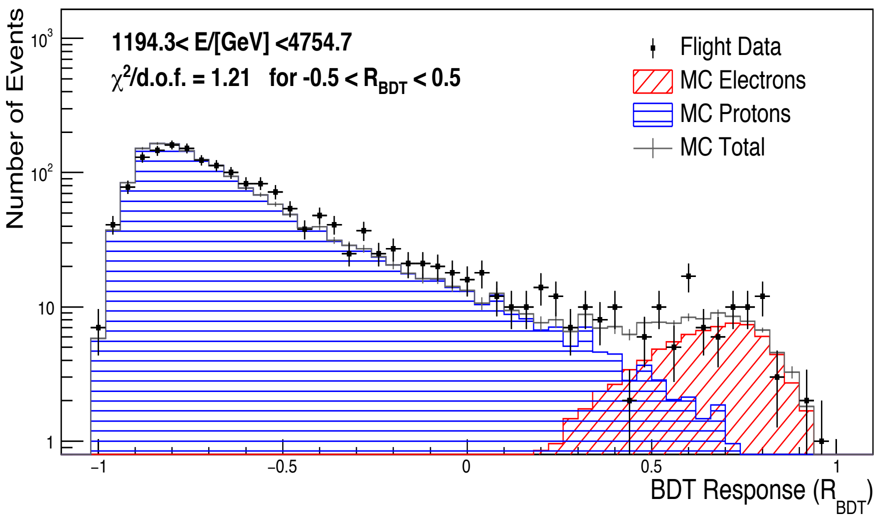
BDT Response Distribution at Higher Energies

In the final electron sample, the resultant contamination ratios of protons are:
 5 % up to 1 TeV ; 10% - 20% in the 1 - 4.8 TeV region
, while keeping a constant high efficiency of 80 % for electrons.

476 < E < 599 GeV



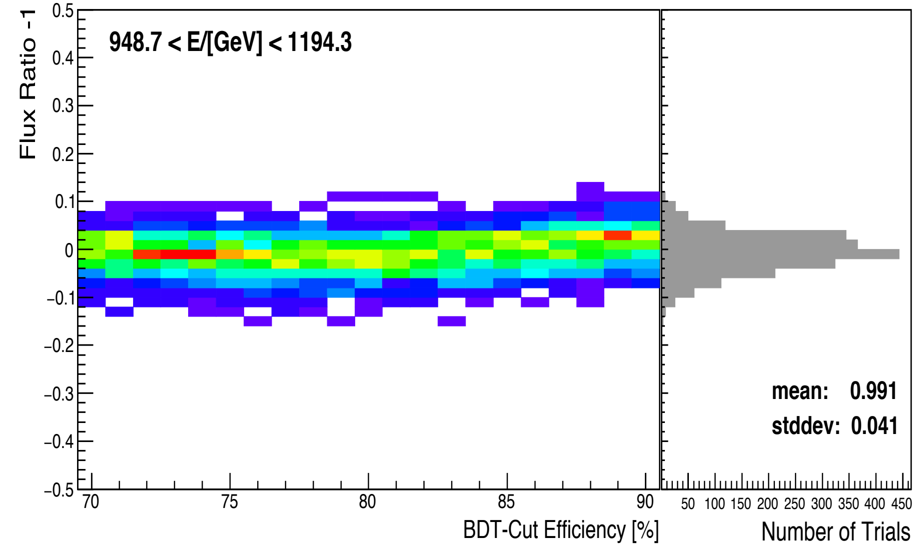
1196 < E < 4755 GeV
(highest energy bin)



Stability of BDT Analysis and Energy Dependence of Systematic Uncertainties

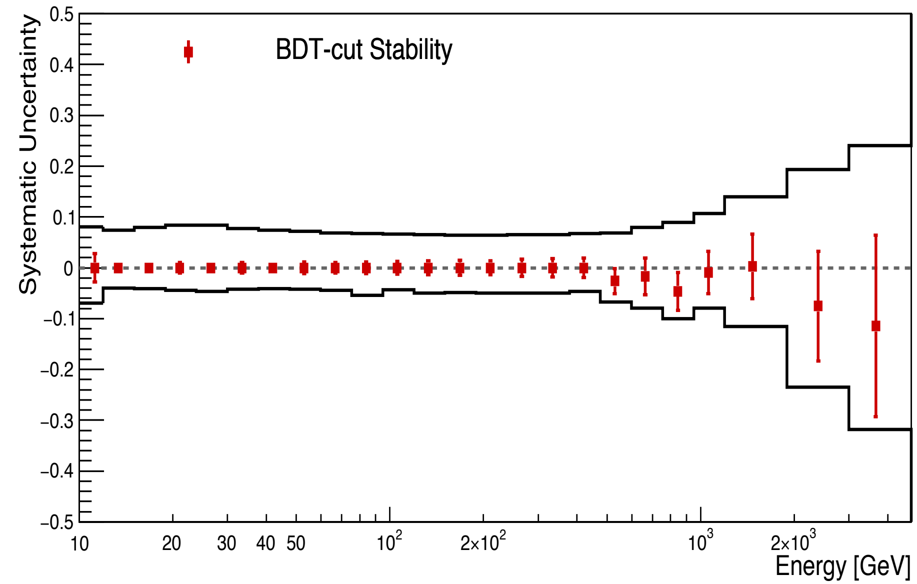
Stability of BDT analysis with respect to independent training samples and BDT -cut efficiency in the 949 < E < 1194 GeV

- Color maps show the flux ratio dependence on efficiency, where the bin value (number of trials) increases as color changes from violet, blue, green, yellow to red.
- A projection onto the Y -axis is shown as a rotated histogram (in gray color).



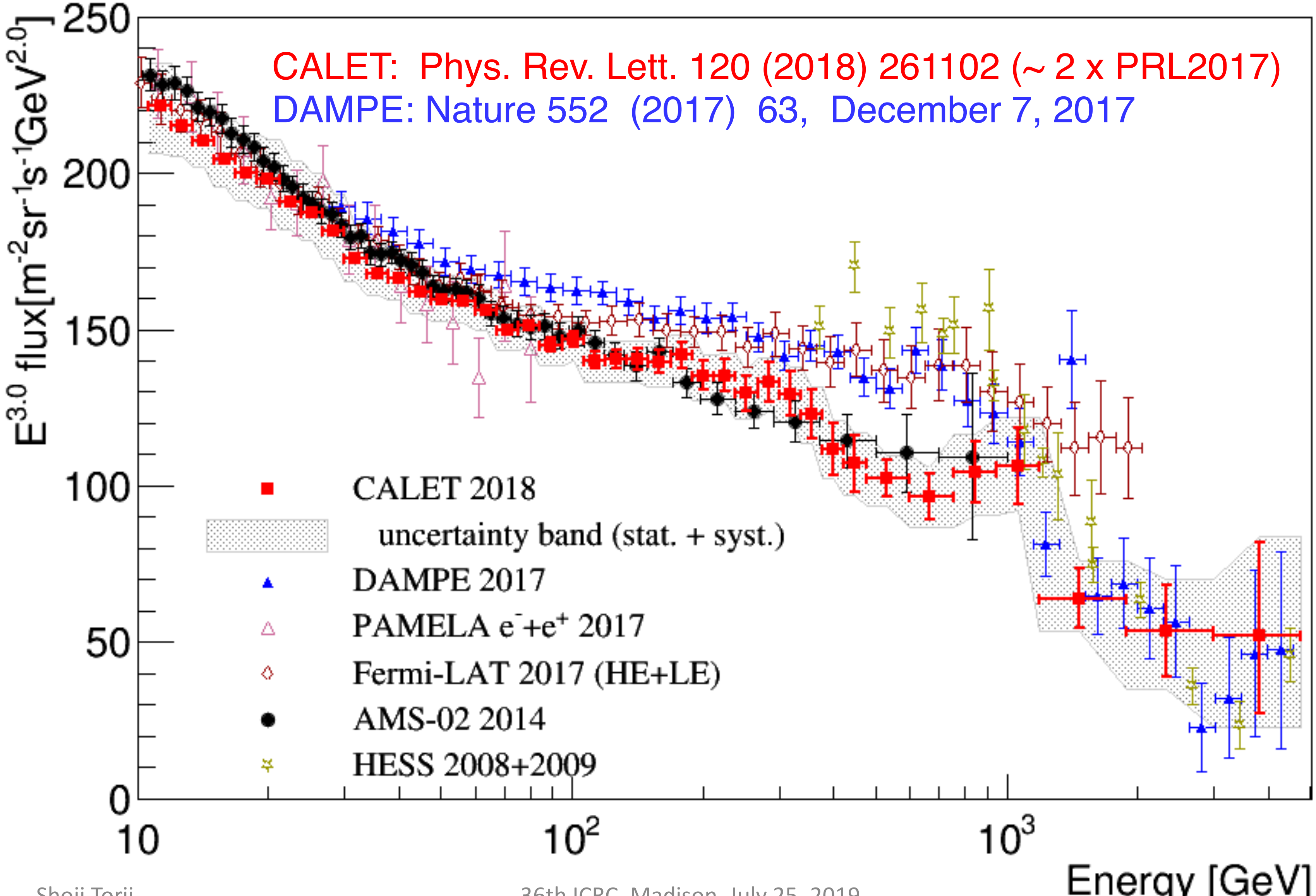
Energy dependence of systematic uncertainties

- The red squares represent the systematic uncertainties stemming from the electron identification based on BDT.
- The bands defined by black lines show the sum in quadrature of all the sources of systematics, except the energy scale uncertainties.



Extended Measurement by Observation over 780 days

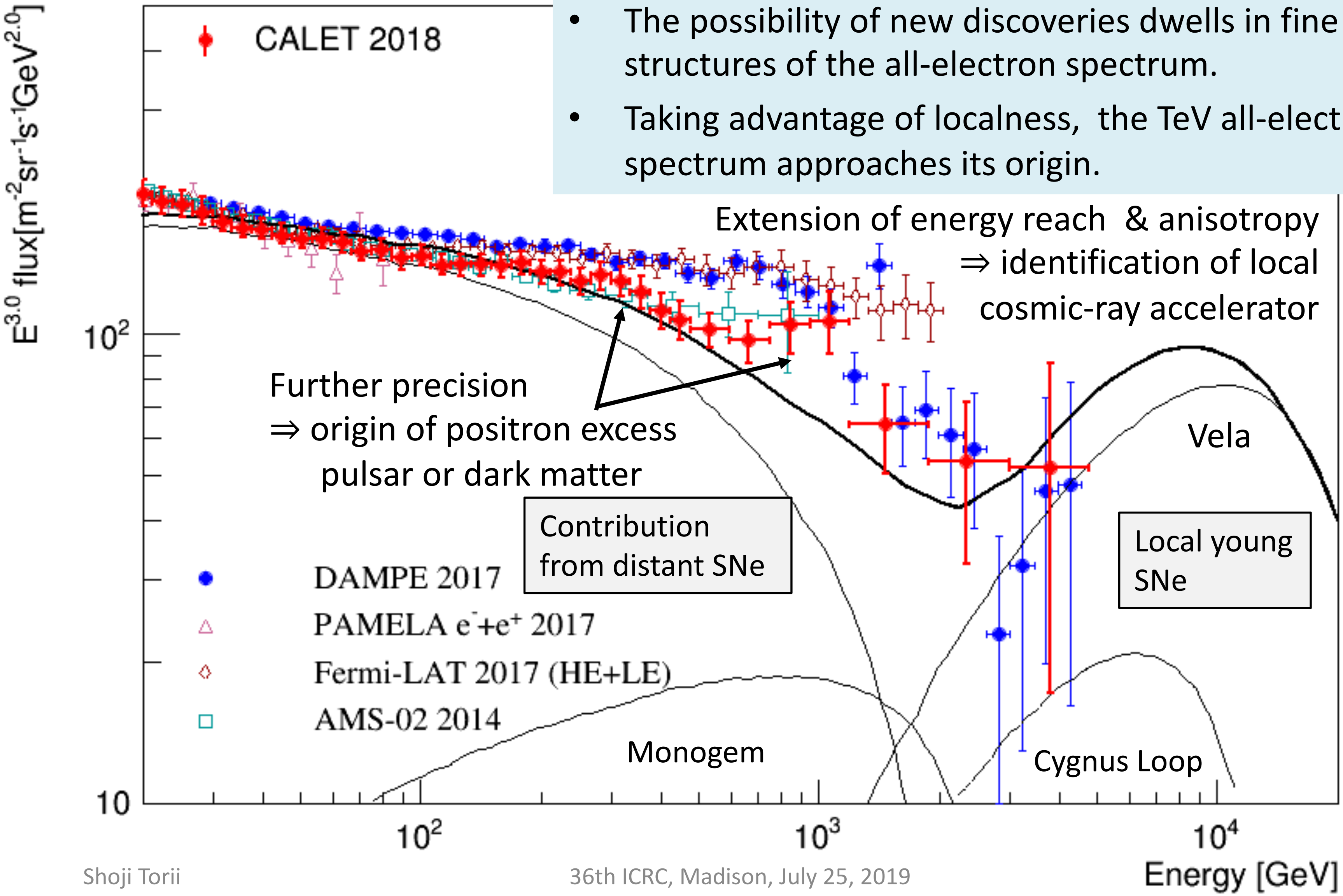
Approximately doubled statistics above 500GeV by using full acceptance of CALET



Prospects for the CALET All-Electron Spectrum

Five years or more observations ⇒ 3 times more statistics, reduction of systematic errors

- The possibility of new discoveries dwells in fine structures of the all-electron spectrum.
- Taking advantage of localness, the TeV all-electron spectrum approaches its origin.



Summary and Future Prospects

- CALET was successfully launched on August 19th, 2015, and is successfully carrying out observations since October 2015 with stable instrument performance.
- As of the end of May, 2019, the exposure amount, SΩT, reached more than 110 m^2 sr day for electron observations over 10 GeV.
- We have reported results of the all-electron (e^++e^-) spectrum in the energy range from 10 GeV to 4.8 TeV.
- Further observations will improve the measurement of electron spectrum by better statistics and a further reduction of the systematic errors, especially in the TeV region.
- We gratefully acknowledge JAXA's contribution to the development of CALET and to the operation on the ISS.