Analysis and Preliminary Results for the Cosmic Ray Electron Spectrum from CALET

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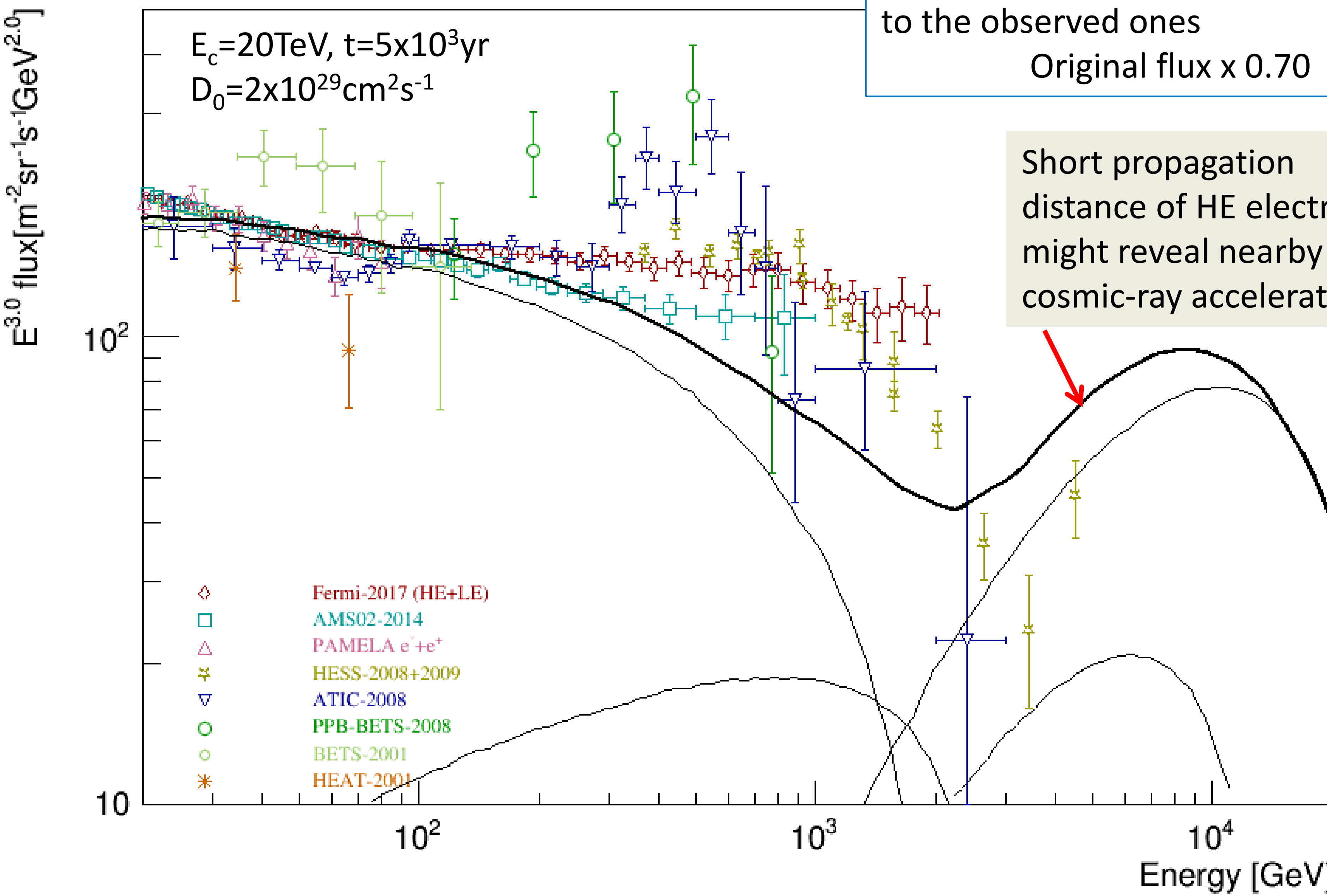
Cosmic-Ray Total Electron Spectrum (e^{+}+e^{-})

Kobayashi et al. ApJ 2004

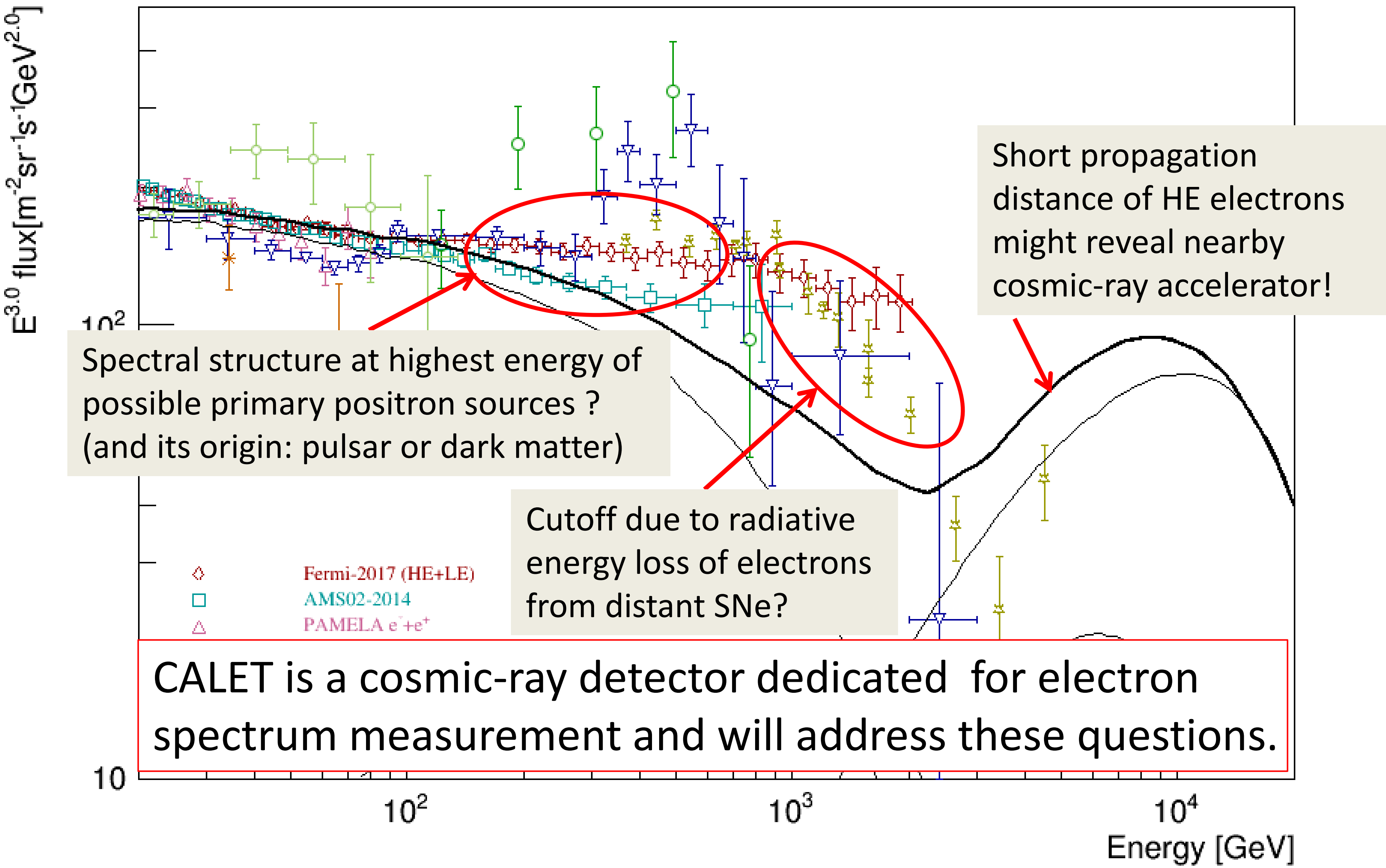
Calculated results normalized to the observed ones
Original flux x 0.70



Short propagation distance of HE electrons might reveal nearby cosmic-ray accelerator!

Cosmic-Ray Total Electron Spectrum (e^{+}+e^{-})

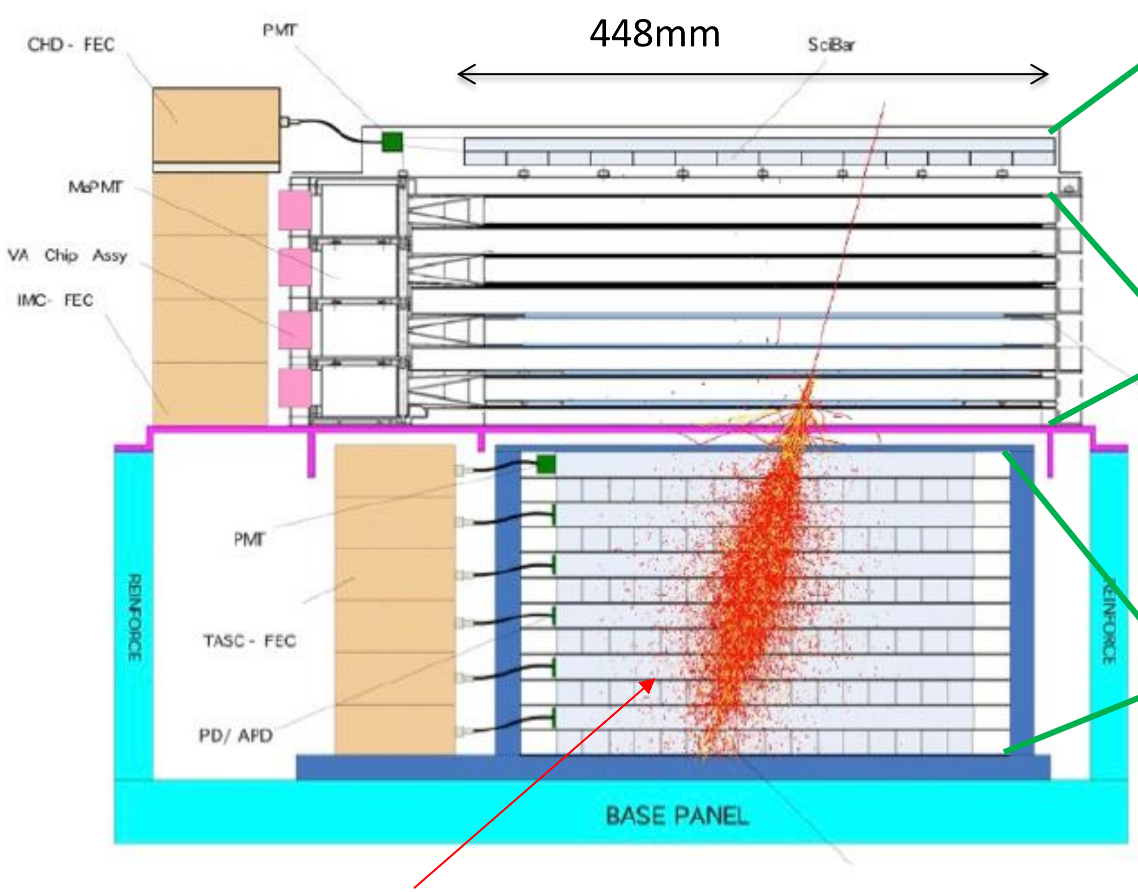
Possible fine structures in total electron (electron + positron) spectrum



CALET is a cosmic-ray detector dedicated for electron spectrum measurement and will address these questions.

CALET-CAL Detector

Fully active thick calorimeter (30X_0) optimized for electron spectrum measurements well into the TeV region



Charge Detector **CHD**

plastic scintillator hodoscope,
absolute charge measurement
(including charge zero)

Imaging Calorimeter **IMC**

SciFi + tungsten plate (3X_0),
reconstruction of shower axis and initial shower development

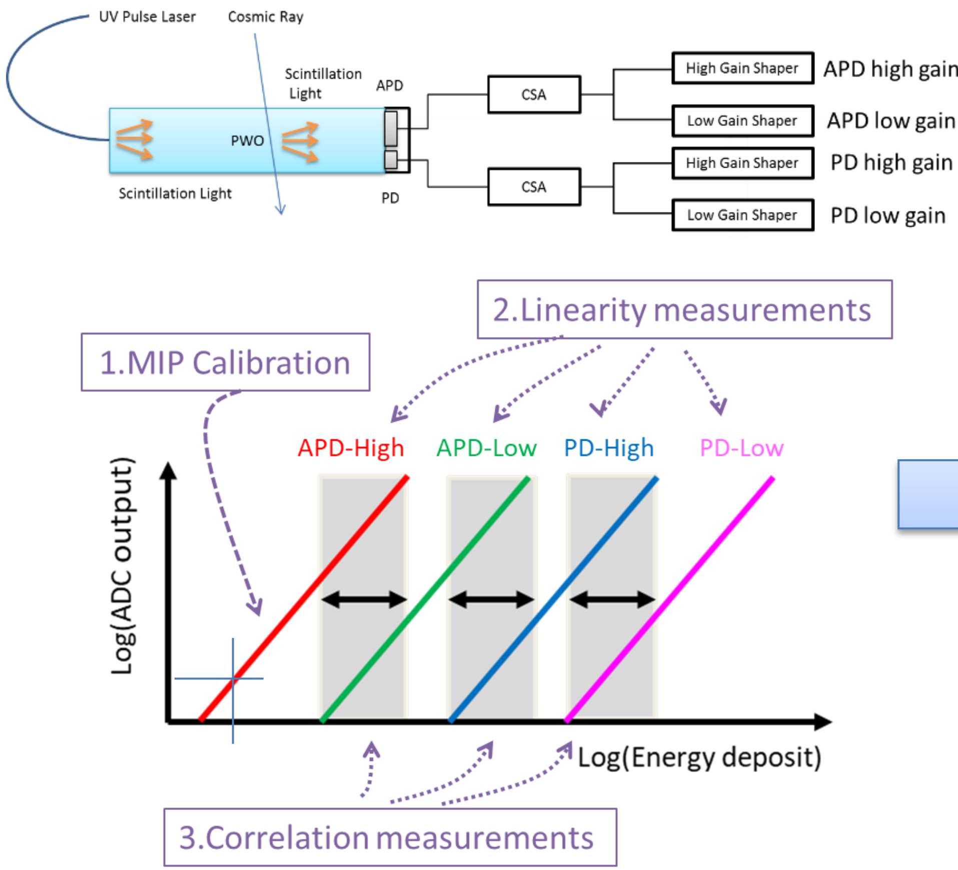
Total Absorption Calorimeter **TASC**

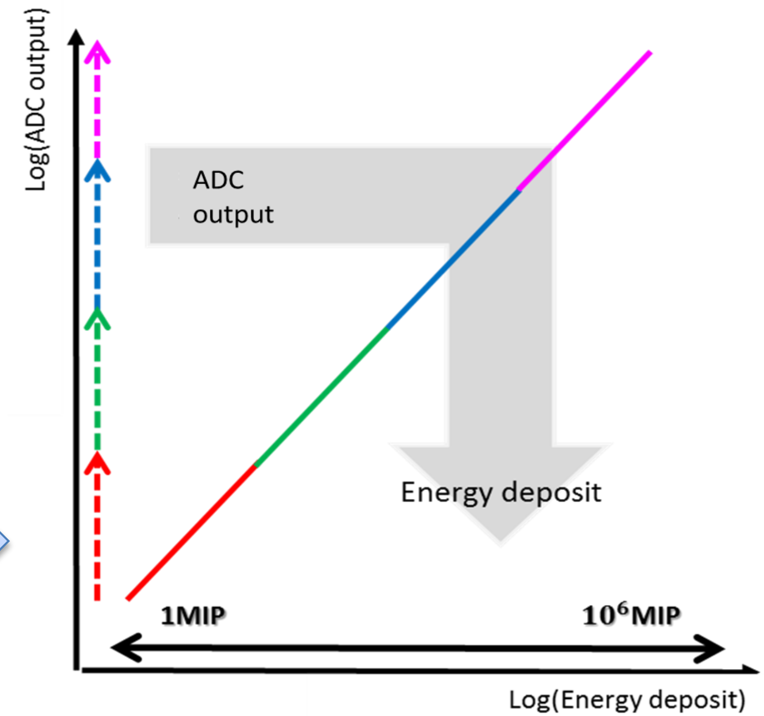
PWO hodoscope (27X0),
energy measurements and particle identification

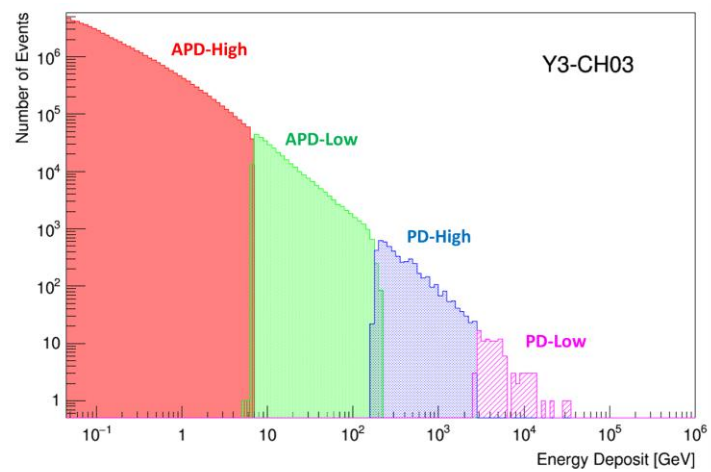
1TeV electron shower is fully contained in TASC
(95% of primary electron energy is actually measured by TASC)

Energy Calibration

CRD037
R.Miyata et al.







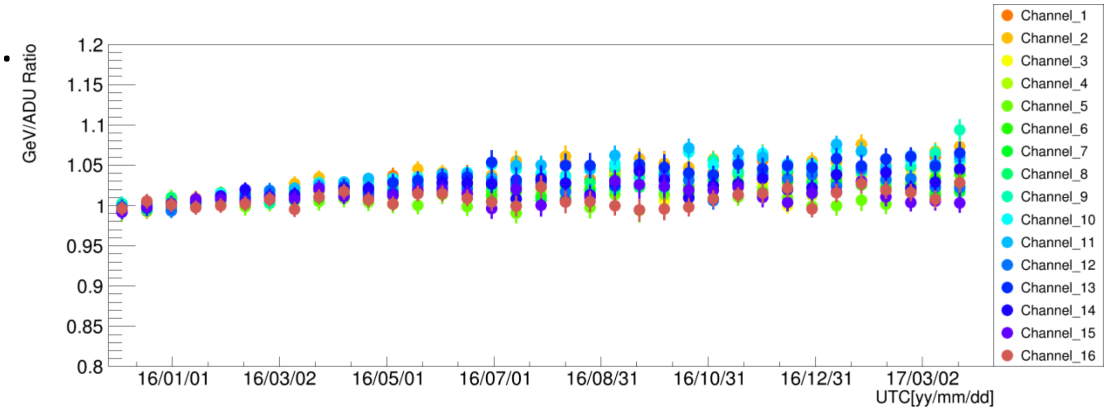
MIP calibration determines absolute scale (ADC unit to energy) while other calibrations are all relatively performed

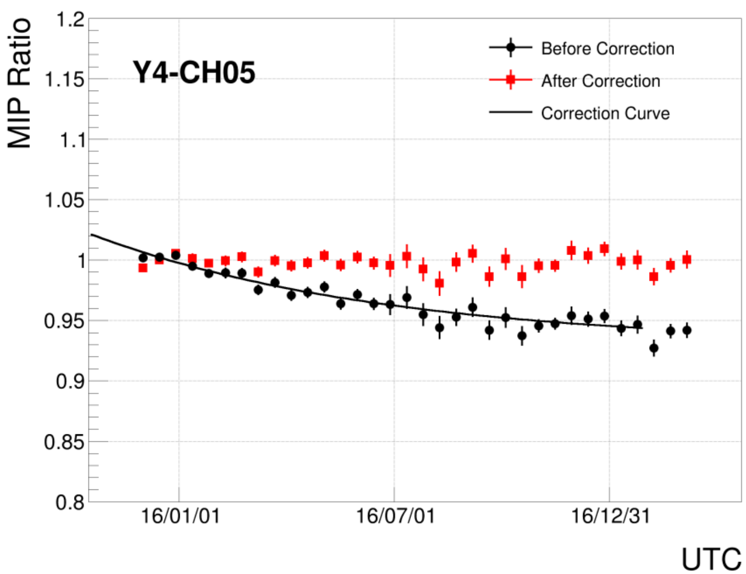
Long-term Stability

CRD038
Y. Komiya et al.

- Temporal variation of detector gain is monitored using MIP peak.
- The gain change rate is less than 0.5% per month on average after one year of operations
- The variations are modeled by appropriate functions and corrected channel by channel.

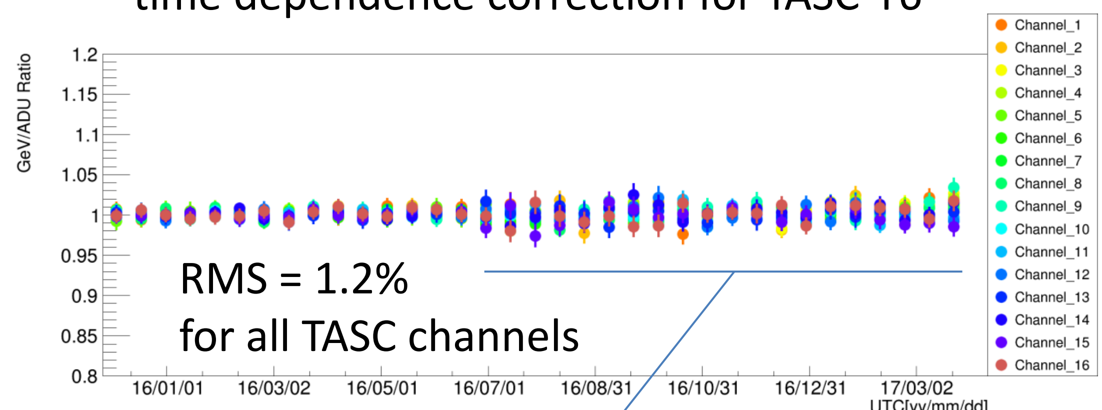
Temporal variation of Conversion Factor





variation rate is getting smaller!

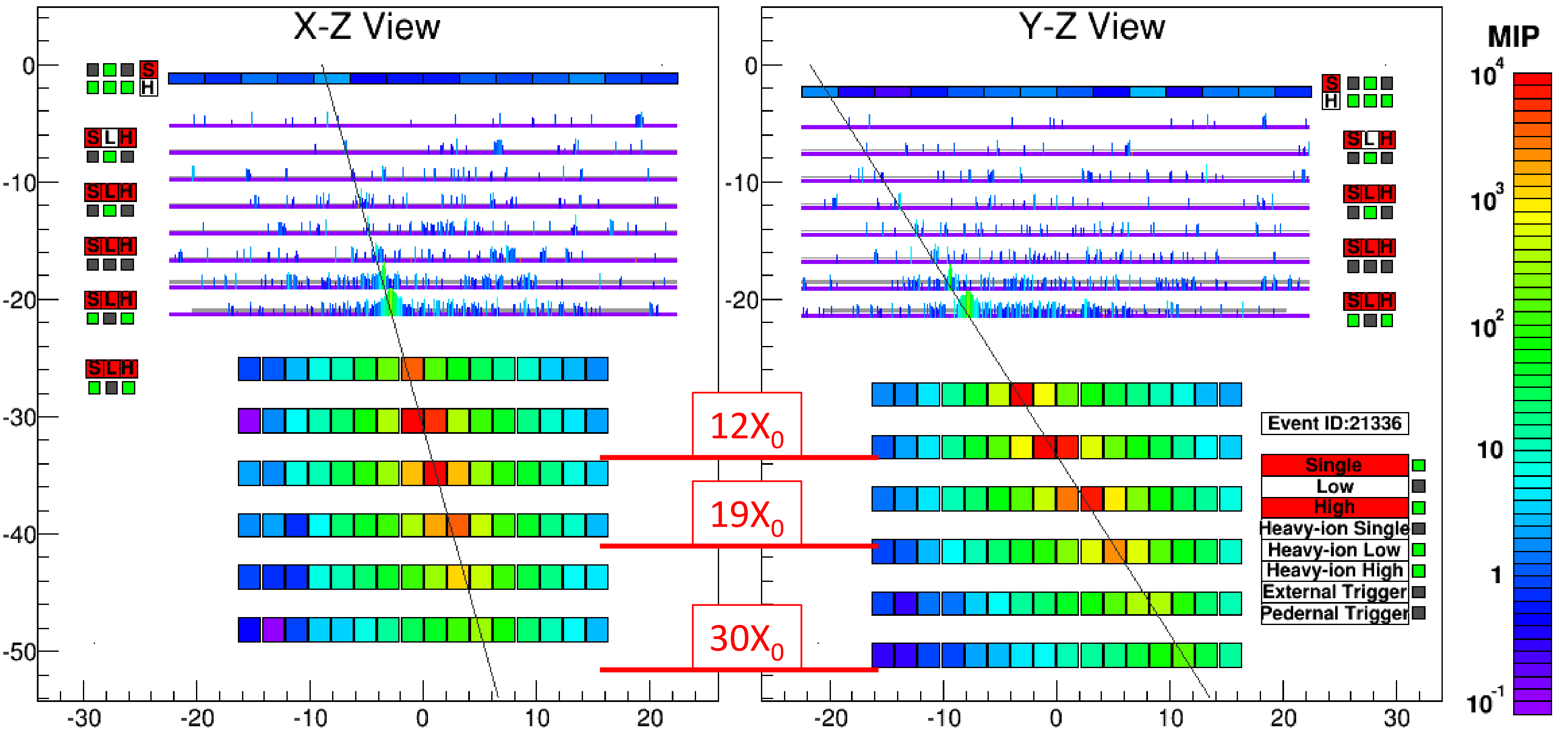
Time variation of conversion factor after time dependence correction for TASC-Y6



due to statistics (less calibration runs) because of stable detector p

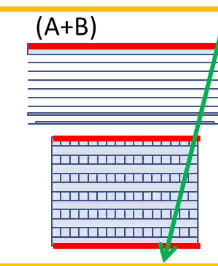
3-TeV Electron Candidate (Flight Data)

E=3.02TeV (TASC Energy deposit sum = 2.89TeV)



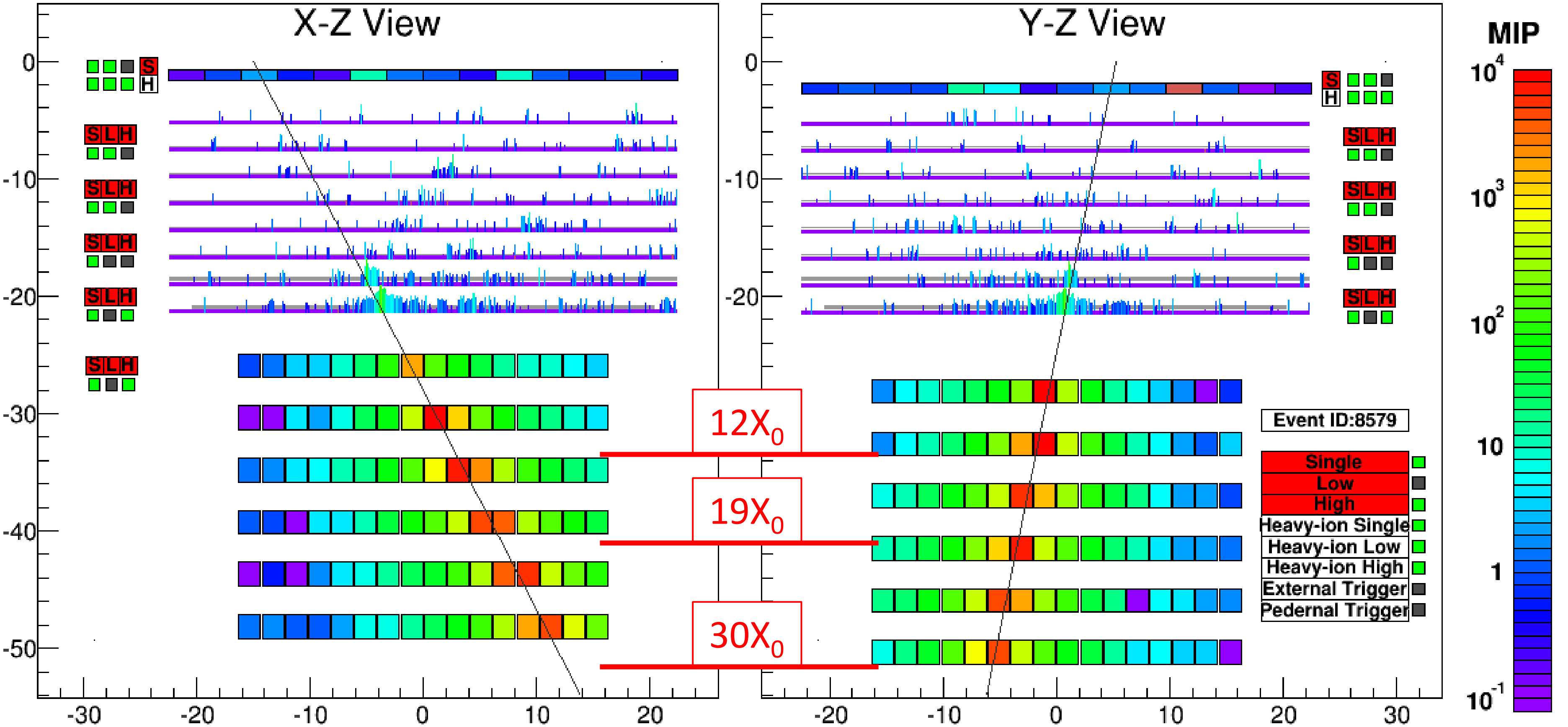
Analyzed Flight Data:

- 536 days (October 13, 2015 to March 31, 2017)
- 55% of full CALET acceptance (Acceptance A+B; 570cm^{2}sr)



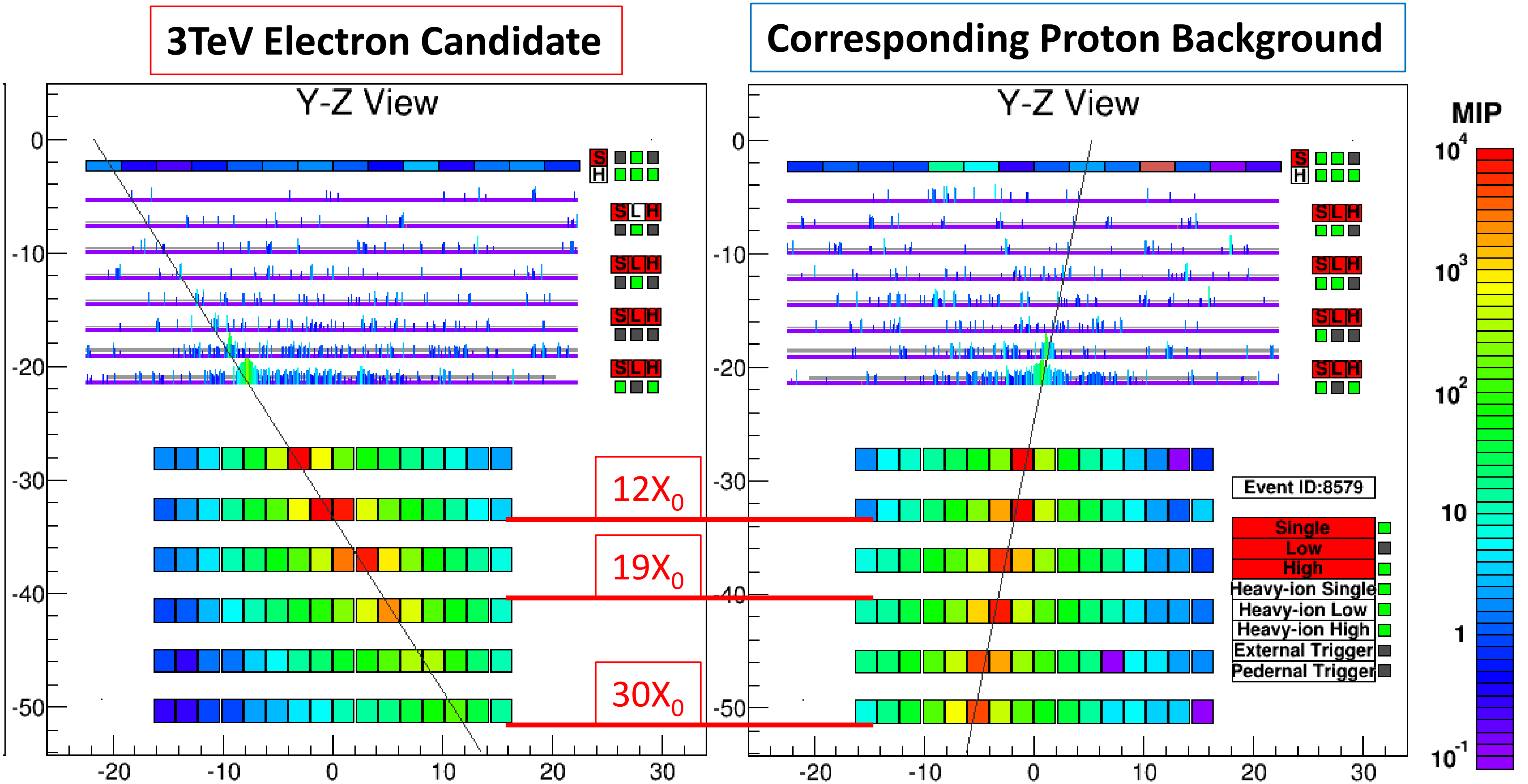
Background Proton Example (Flight Data)

Energy deposit sum = 2.89TeV



1.3 interaction length for protons

Electron/Proton Separation in the TeV Region



Simple and high-efficiency electron identification is possible even at TeV.

⇒ CALET is best suited for observation of possible fine structures in the total electron spectrum.

Event Selection

1. Offline Trigger
2. Acceptance Cut
3. Single Charge Selection
4. Track Quality Cut
5. Shower Development Consistency
6. Electron Identification
    1. Simple two parameter cut
    2. Multivariate Analysis using Boosted Decision Trees (BDT)

Event Selection

Pre-selection:

- Select events with successful reconstructions
- Rejecting heavier particles
- Equivalent sample between flight and MC data

1. Offline Trigger
2. Acceptance Cut
3. Single Charge Selection
4. Track Quality Cut
5. Shower Development Consistency
6. Electron Identification
    1. Simple two parameter cut
    2. Multivariate Analysis using Boosted Decision Trees (BDT)

Electron Identification

CRD127
L. Pacini et al.

Simple Two Parameter Cut

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

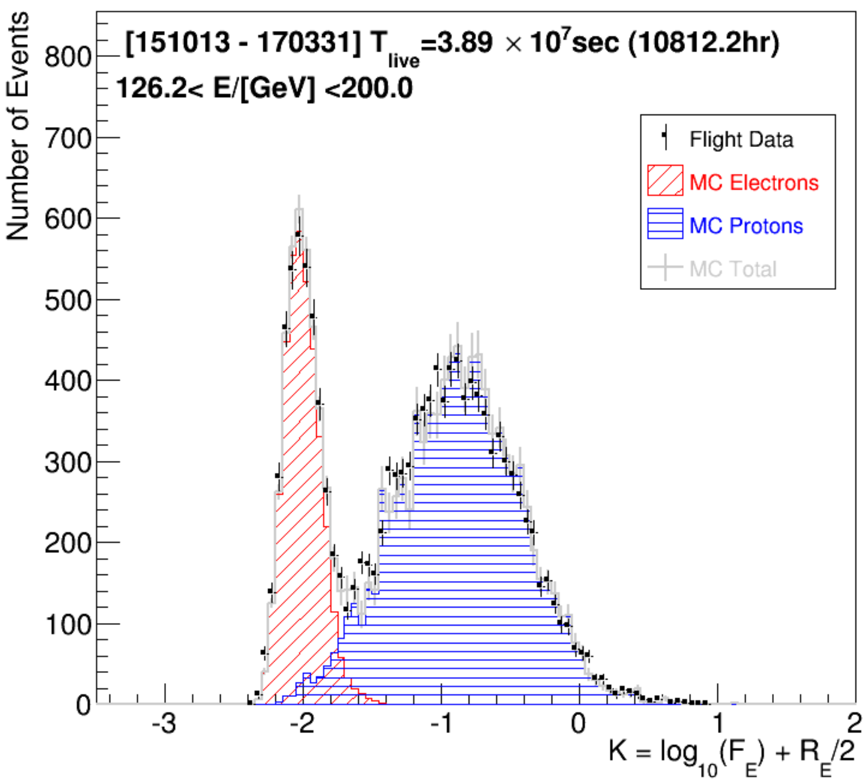
R_E: Lateral spread of energy deposit in TASC-X1

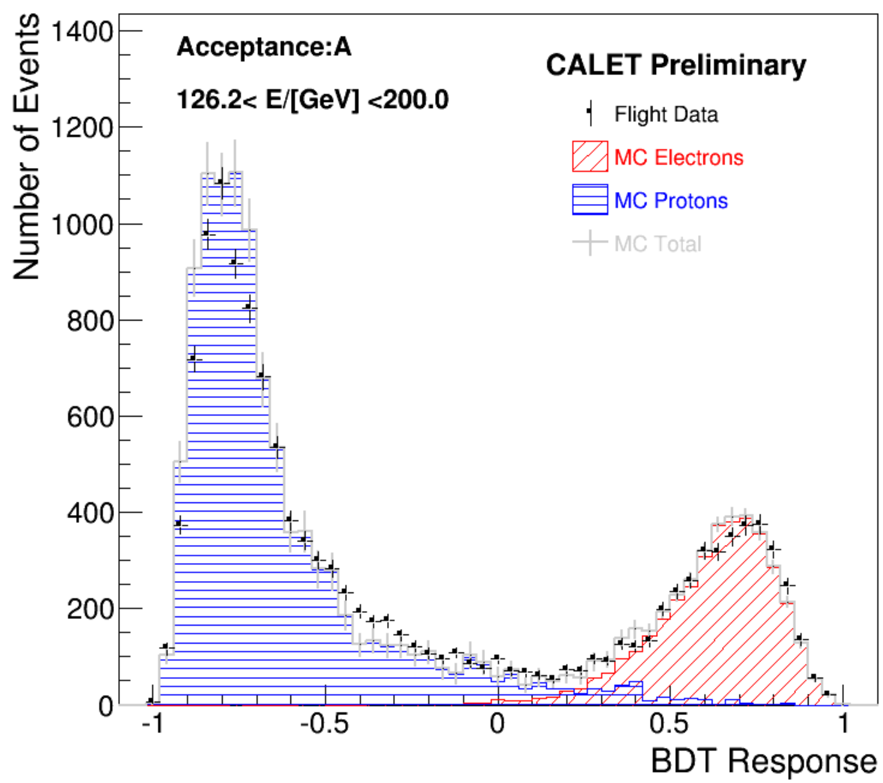
Separation Parameter K is defined as follows:

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

Boosted Decision Trees (BDT)

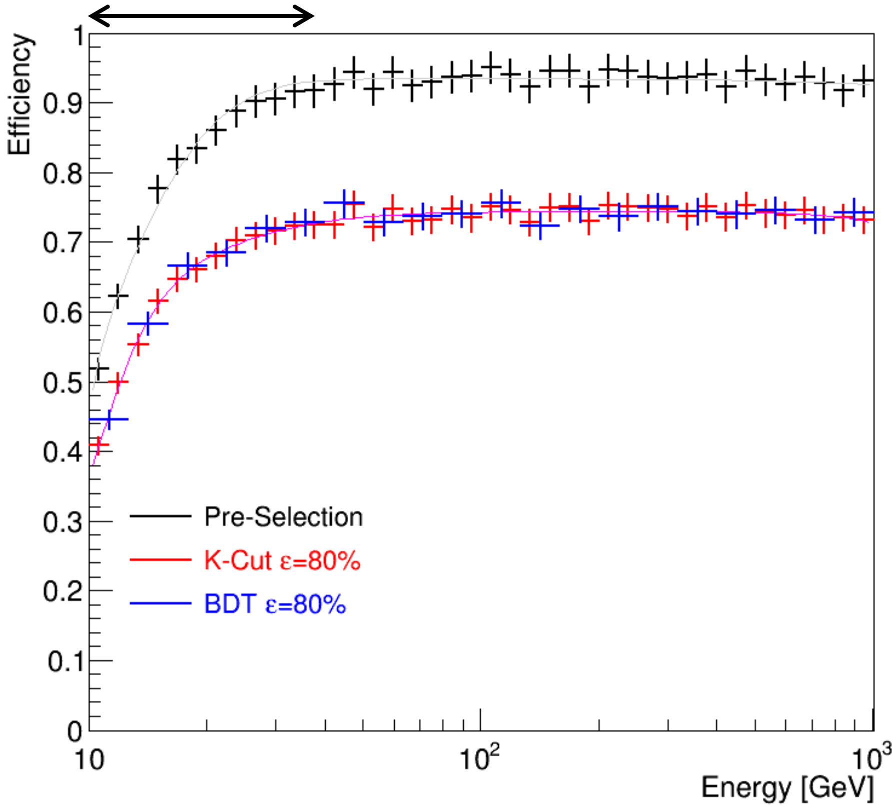
In addition to the two parameters in the left, TASC and IMC shower profile fits are used as discriminating variables.

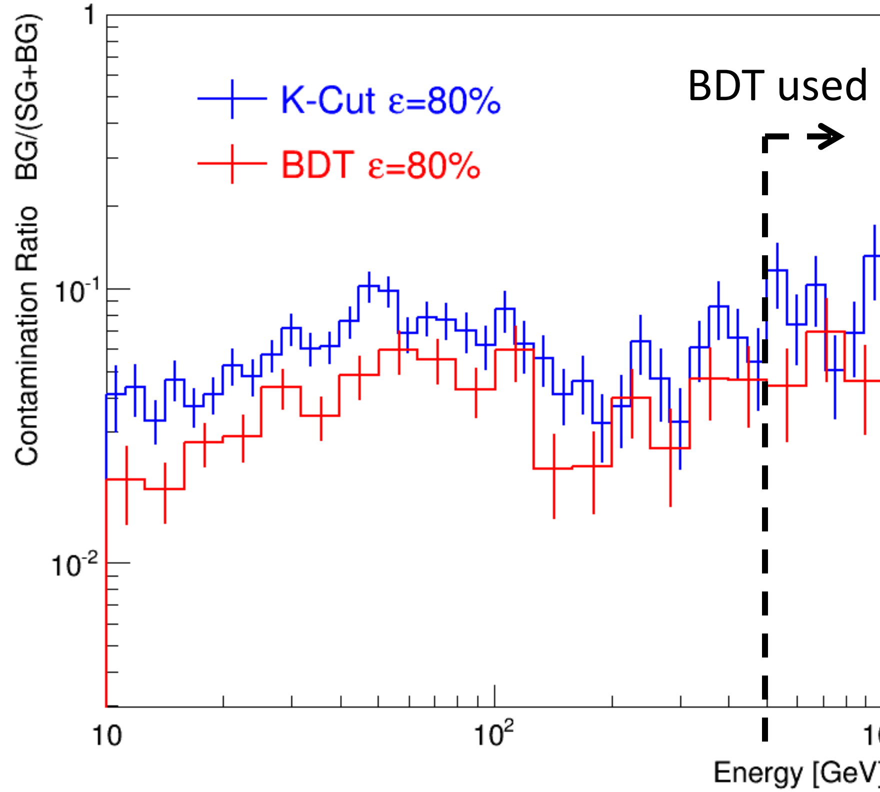




Electron Efficiency and Subtraction of Proton Contamination

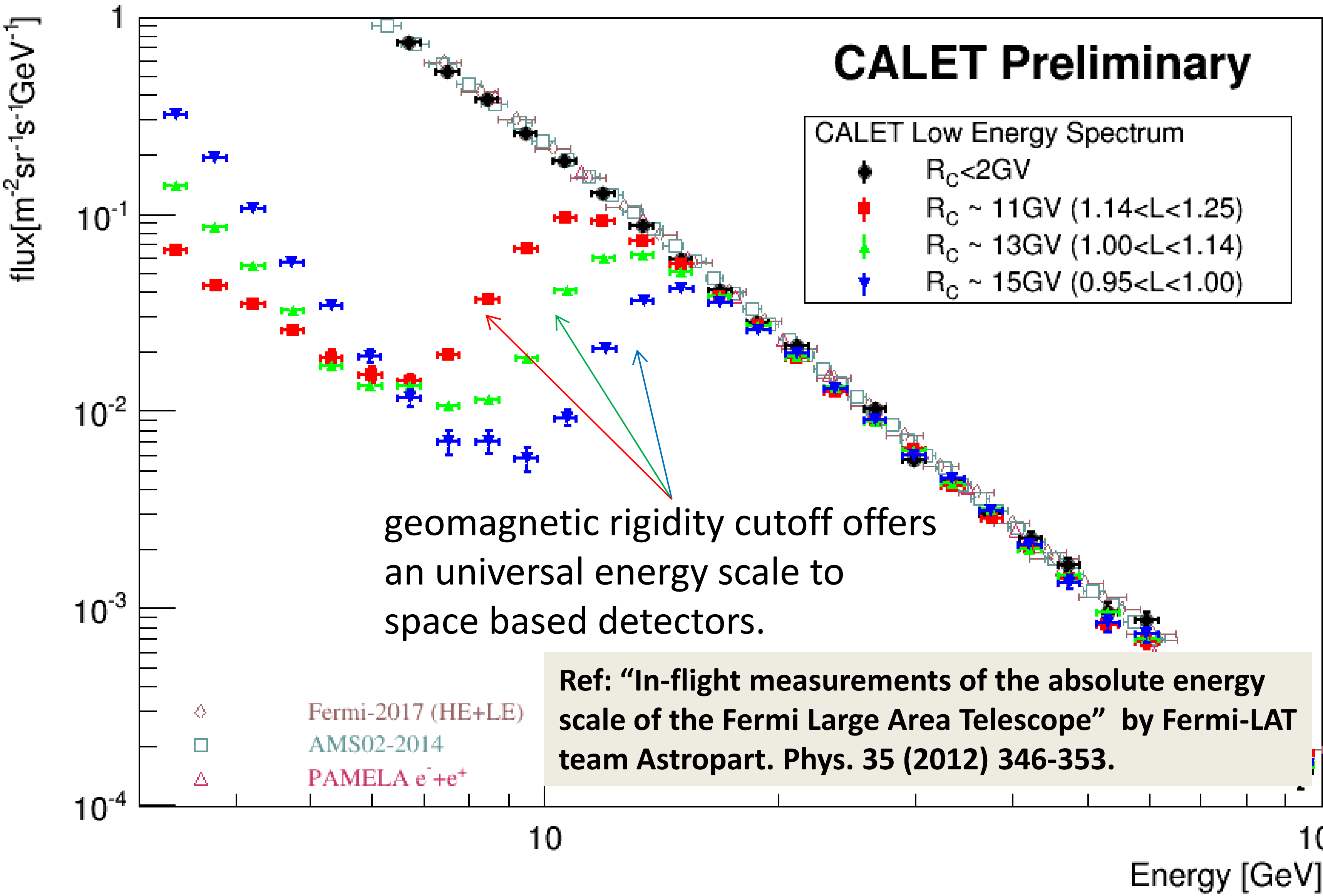
due to HE trigger threshold





- Constant and high efficiency is the key point in our analysis.
- Simple two parameter (BDT) cut is used in the energy region E<500GeV (E>500GeV) while the difference in resultant spectrum between two methods are taken into account in the systematic uncertainty.

Absolute Calibration of Energy Scale using Geomagnetic Rigidity Cutoff

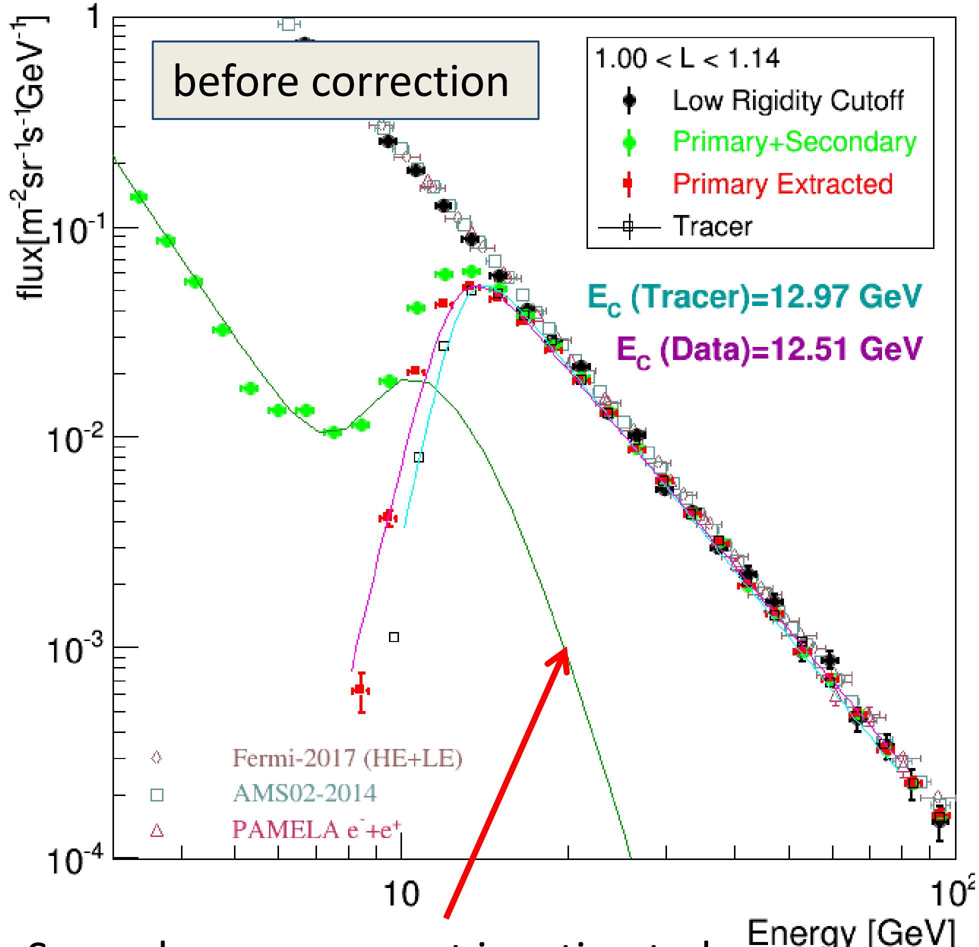


geomagnetic rigidity cutoff offers an universal energy scale to space based detectors.

Ref: "In-flight measurements of the absolute energy scale of the Fermi Large Area Telescope" by Fermi-LAT team Astropart. Phys. 35 (2012) 346-353.

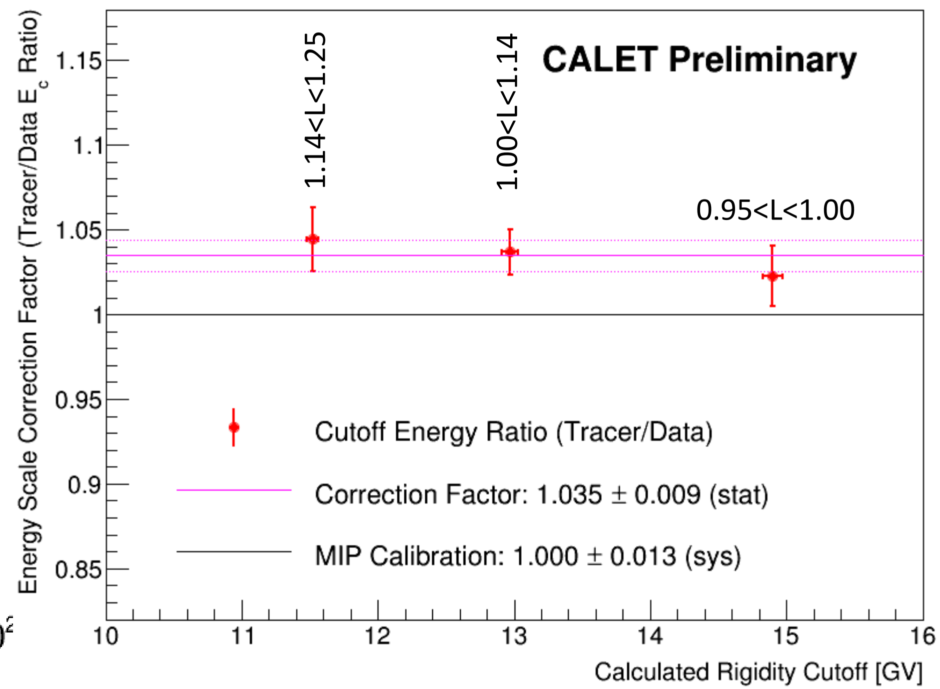
Cutoff Rigidity Measurements and Comparison with Calculation

Measured cutoff rigidity is compared with calculated one (denoted as Tracer) which trace particle in earth's magnetic field (IGRF12).



Secondary component is estimated using azimuthal distributions

- Same analysis performed in 3 different rigidity cutoff regions.



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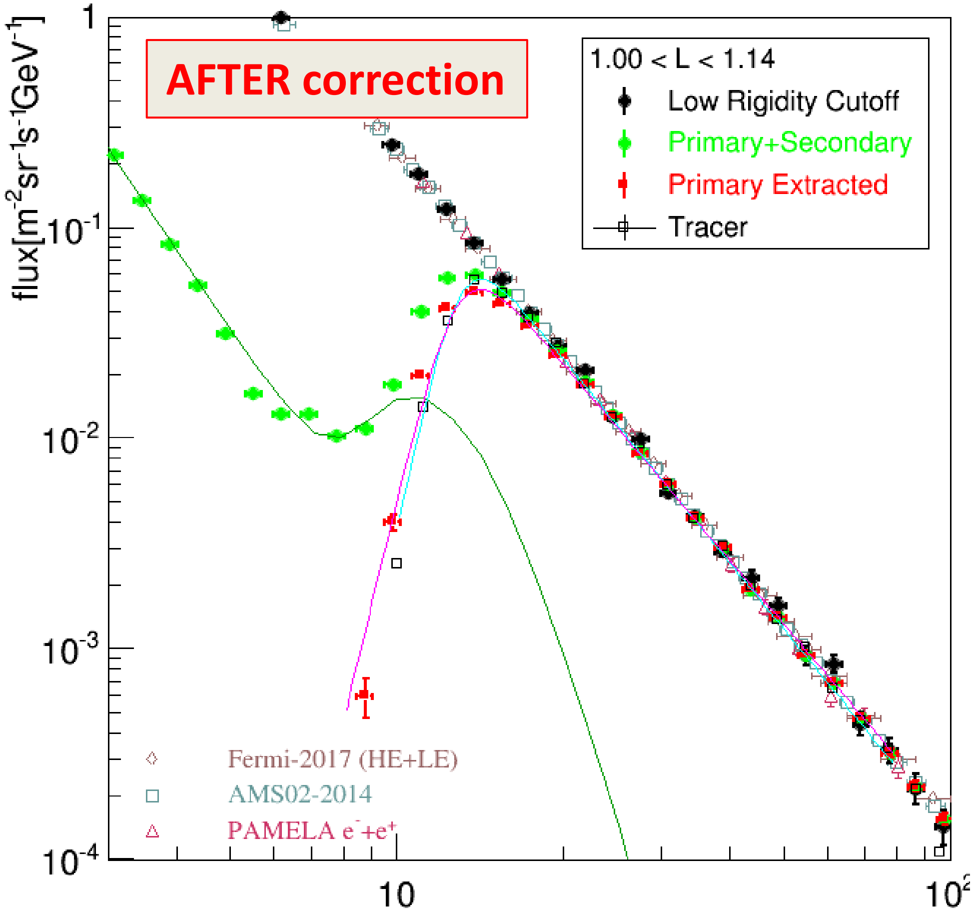
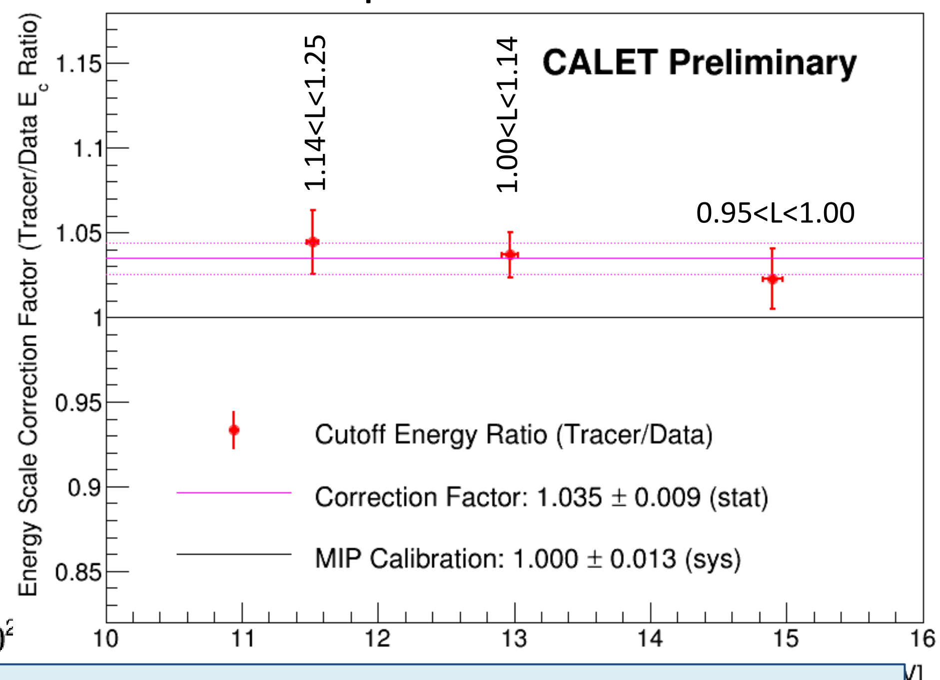


- Same analysis performed in 3 different rigidity cutoff regions.

⇒ Correction factor was found to be **1.035** compared to MIP calibration.



Since universal energy-scale calibration between different instruments is very important, we adopt the energy scale determined by rigidity cutoff to derive our spectrum.

Systematic Uncertainties
(other than energy scale uncertainty)

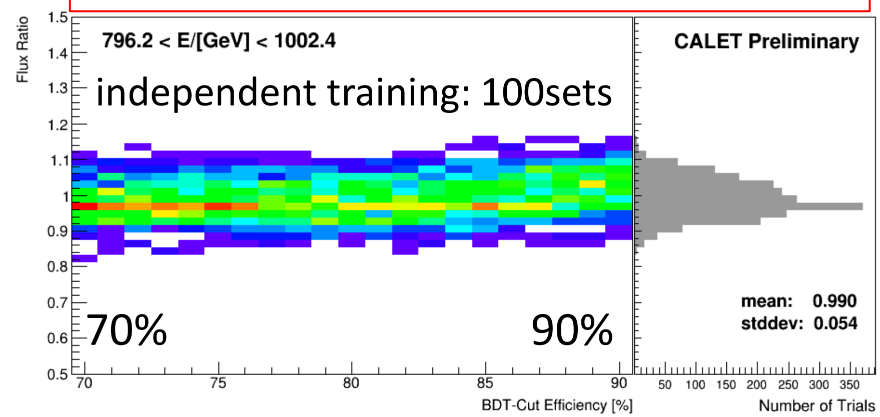
Stability of resultant flux are analyzed by scanning parameter space

Normalization:
- Live time
- Radiation environment
- Long-term stability
- Quality cuts

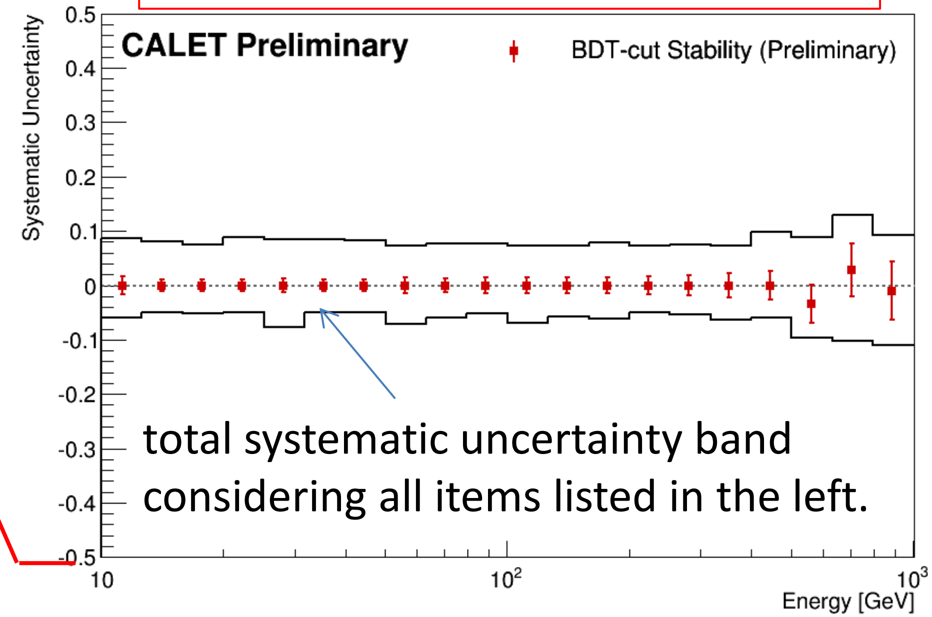
CRD036
P. Maestro et al.

- Energy dependent:
  - 2 independent tracking
  - charge ID
  - electron ID (K-Cut vs BDT)
  - **BDT stability** (vs efficiency & training)
  - MC model (EPICS vs Geant4)

Flux Ratio vs Efficiency for BDT @ 1TeV

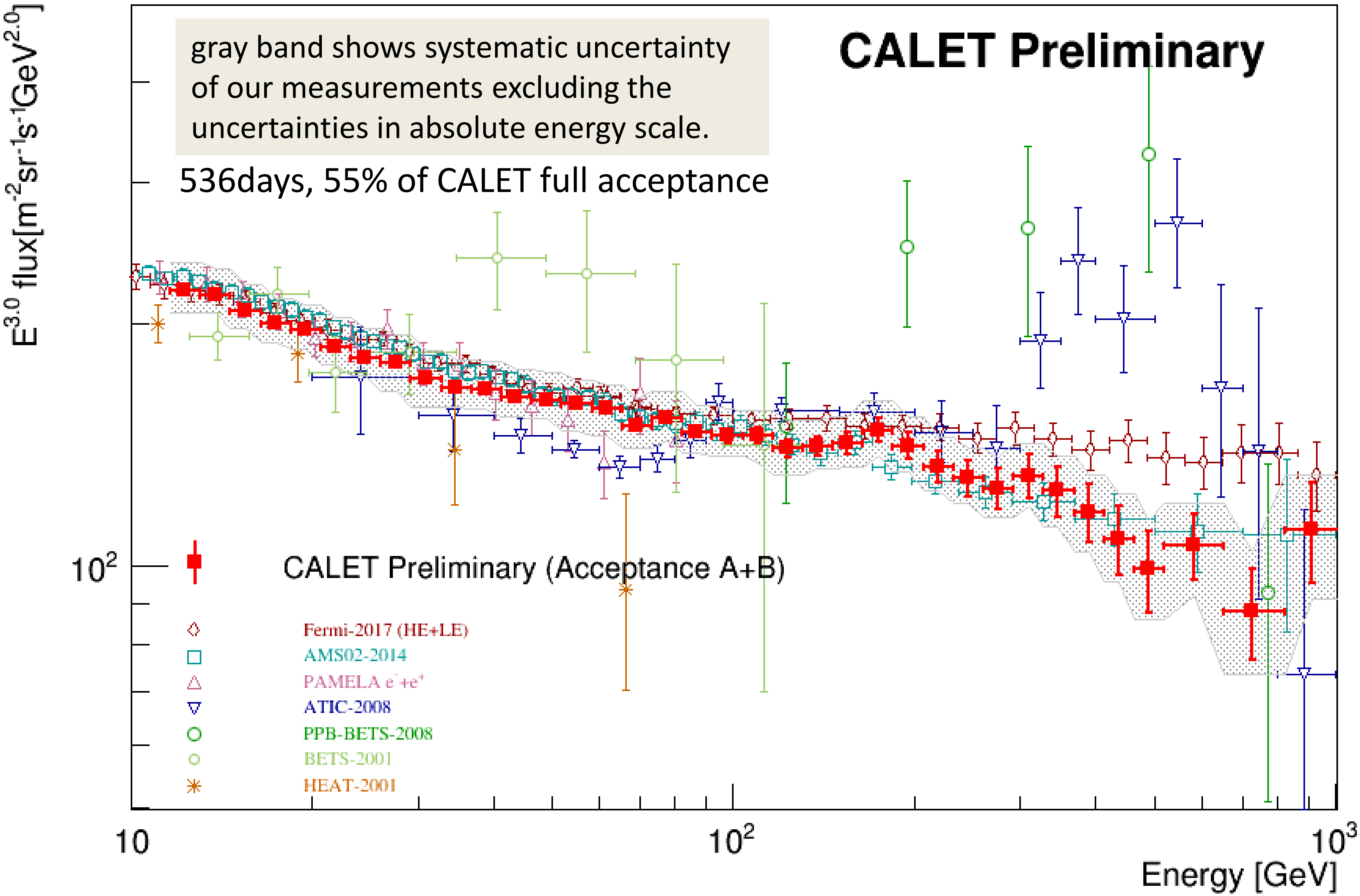


Energy Dependence of BDT stability



Total Electron Spectrum up to 1TeV

Energy scale is determined by absolute calibration using cutoff rigidity (difference from MIP calibration is +3.5%)



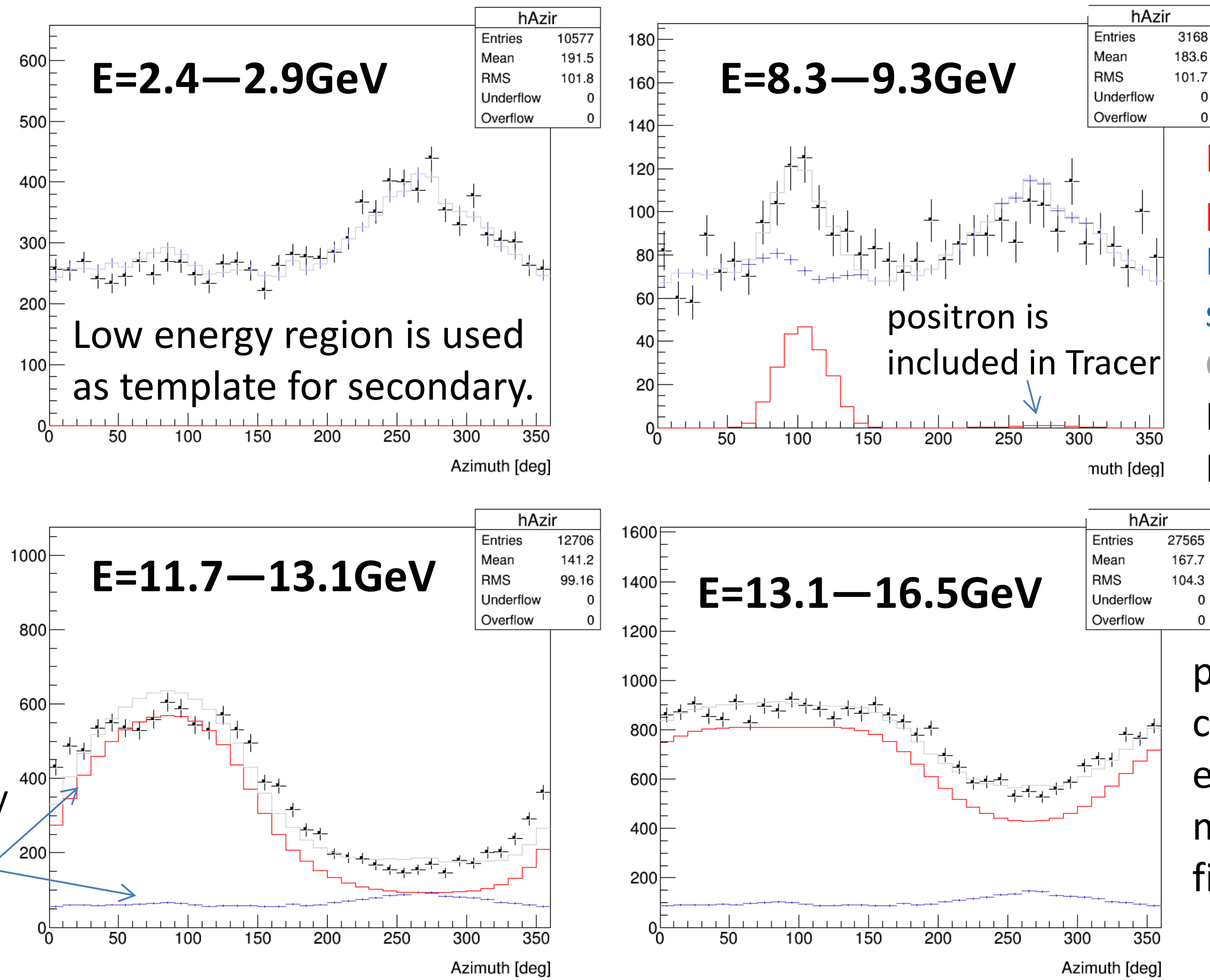
Summary & Prospects

- CALET has been delivering science data since October 2015 with stable instrument performance.
- We have reported a preliminary result of the total electron (e^++e^-) spectrum in the energy range from 10GeV to 1TeV by using about one half of the events (i.e., limited acceptance conditions) observed in 536 days.
- Our statistics will reach nearly an order of magnitude higher than the current analysis in five years.
- We will deepen the analysis to extract the best performance and investigate the TeV region.

backup

Subtraction of Secondary Components based on Azimuthal Distributions

following Fermi-LAT recipe [Ackermann et al. Astropart. Phys. 35 (2012) 346]



RED: (Tracer) primary
Blue: secondary
Gray: sum
Black: Flight Data

azimuthal dependence of secondary component is fixed at low energy while that of primary changes with energy and is estimated by Tracer.

Tracer: particle trace code in the earth's magnetic field (IGRF12)