



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

WASEDA







CALET Collaboration Team



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Cosmic-Ray All-Electron Spectrum (e⁺+e⁻)



Cosmic-Ray All-Electron Spectrum (e⁺+e⁻)

Possible fine structures in all-electron (electron + positron) spectrum





CALET-CAL Detector



Fully active thick calorimeter (30X₀) optimized for electron spectrum measurements well into the TeV region



1TeV electron shower is fully contained in TASC

(95% of primary electron energy is actually measured by TASC)



CALET is an instrument optimized for all-electron spectrum measurements.

⇒ CALET is best suited for observation of possible fine structures in the all-electron spectrum up to the trans-TeV region.





Event Selection

Analyzed Flight Data:

- 627 days (October 13, 2015 to June 30, 2017)
- 55% of full CALET acceptance (Acceptance A+B; 570cm²sr)
- 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)



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Pre-selection:

- Select events with successful reconstructions
- Rejecting heavier particles
- Equivalent sample between flight and MC data
- 5. Shower Development Consistency
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Electron Identification



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:

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

Boosted Decision Trees

In addition to the two parameters making up K, TASC and IMC shower profile fits are used as discriminating variables.





Electron Efficiency and Proton Rejection



- Constant and high efficiency is the key point in our analysis.
- Simple two parameter (BDT) cut is used in the energy region E<475GeV (E>475GeV) while the small difference in resultant spectrum between two methods are taken into account in the systematic uncertainty.
- Contamination is ~5% up to 1TeV, and <15% in the 1—3 TeV region.
 26th E+CRS/35th RCRS



All-Electron Spectrum Measured with CALET from 10 GeV to 3 TeV

CALET: PRL 119 (2017) 181101, 3 November 2017





All-Electron Spectrum Comparison w/ DAMPE

and other space based experiments

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All-Electron Spectrum Comparison w/ DAMPE





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Extending the Analysis to Full Acceptance

Analyzed Flight Data:

- 780 days (October 13, 2015 to November 30, 2017)
- Full CALET acceptance at the high energy region (Acceptance A+B+C+D; 1040cm²sr). In the low energy region fully contained events are used (A+B; 550cm²sr)





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

The energy scale uncertainty does not have energy dependence, because of the full containment of the EM showers well into the TeV region. Errors due to calibration of lower gain ranges are found to be negligible.





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- Divided into 4 sub-periods (195days each)
- spectrum in each sub-period is compared with the one from the whole period.
- standard deviation of the relative difference distribution is taken as systematic uncertainty (1.4%)





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Flux Ratio

-0.3

-0.4 70%

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Flux Ratio vs Efficiency for BDT @ 1TeV 948.7 < E/[GeV] < 1194.3 independent training: 100sets



90%

BDT-Cut Efficiency [%]



mean:

stddev: 0.041

Number of Trials

0.991

Extended Measurement by CALET

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



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Extended Measurement by CALET

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Comparison with DAMPE's result



Comparison with DAMPE's result

What happens if we shifted our energy binning...



Prospects for CALET All-Electron Spectrum

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





Summary and Future Prospects

- □ CALET was successfully launched on Aug. 19, 2015, and the detector is being very stable for observation since Oct. 13, 2015.
- □ As of May 31, 2018, total observation time is 962 days with live time fraction to total time close to 84%. Nearly 630 million events are collected with high energy (>10 GeV) trigger.
- Careful calibrations have been adopted by using "MIP" signals of the noninteracting p & He events, and the linearity in the energy measurements up to 10⁶ MIPs is established by using observed events.
- All electron spectrum has been extended in statistics and in the energy range from 11 GeV to 4.8TeV. This result is published in PRL again on June 2018.
- The consistency between the CALET and AMS-02 all-electron spectrum is an important prerequisite for a study including the positron flux measurement by AMS-02.
- □ The accuracy and energy reach of our spectrum will improve by better statistics and a further reduction of the systematic errors based on the analysis of additional flight data during the ongoing five-year (or more) observation.