CALETによる5年間の 軌道上観測の最新成果

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CALET





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# **CALET** Payload







Launched on Aug. 19<sup>th</sup>, 2015 by the Japanese H2-B rocket

Emplaced on JEM-EF port #9 on Aug. 25<sup>th</sup>, 2015 (JEM-EF: Japanese Experiment Module-Exposed Facility)





- 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

Geometrical Factor: ~ 1,040 cm<sup>2</sup>sr (for electrons)



#### **Unique features of CALET**

 $\Box$ A dedicated charge detector + multiple dE/dx track sampling in the IMC allow to identify individual nuclear species ( $\Delta$ Z~0.15-0.3 e).

□High granularity imaging pre-shower calorimeter accurately identify the arrival direction of incident particles (~0.1°) and the starting point of showers.

**D**Thick(~30  $X_0$ ), fully active calorimeter allows measurements well into the TeV energy region with excellent energy resolution (~2%)

>Combined, they powerfully separate electrons from the abundant protons: contamination is much less than 10 % up to the TeV region.

#### Simulated Shower Profile





# Examples of Event Display (Flight Data)

#### Electron, E=3.05 TeV



fully contained even at 3TeV

#### Proton, $\Delta E=2.89$ TeV X-Z View Y-Z View



clear difference from electron shower in TASC

#### Fe, $\Delta E=9.3$ TeV

#### Gamma-ray, E=44.3 GeV



energy deposit in CHD consistent with Fe

#### no energy deposit before pair production

MIP



Detector performance	Main CALET scientific objectives	
<ul> <li>Geometrical Factor: 1040 cm<sup>2</sup> sr for electrons, light nuclei 1000 cm<sup>2</sup> sr for gamma-rays 4000 cm<sup>2</sup>sr for ultra-heavy nuclei</li> <li>ΔE/E: ~2 % (&gt;10GeV) for e , γ ~30-35% for protons, nuclei</li> <li>e/p separation: ~10<sup>5</sup></li> <li>Charge resolution: 0.15-3 e (p-Fe)</li> <li>Angular resolution: 0.2° for gamma-rays &gt; ~50 GeV</li> </ul>	<ul> <li>Electron observation in 1GeV-20TeV         Design optimized for electron detection:             high energy resolution and large e/p separation power             + e.m. shower containment             Search for Dark Matter and Nearby Sources         </li> <li>Observation of cosmic-rays in 10 GeV-1 PeV             Unraveling the CR acceleration and propagation             mechanism(s)         Detection of transient phenomena in space:         <ul> <li>Gamma-ray burst</li> <li>GW e.m. counterparts</li> <li>Solar modulation</li> <li>Space weather</li> </ul> </li> </ul>	

Scientific Objectives	Observation Targets	Energy Range
CR Origin and Acceleration	Electron spectrum Individual spectra of elements from proton to Fe Ultra Heavy Ions (26 <z≤40) Gamma-rays (Diffuse + Point sources)</z≤40) 	1GeV - 20 TeV 10 GeV - 1000 TeV > 600 MeV/n 1 GeV - 1 TeV
Galactic CR Propagation	B/C and sub-Fe/Fe ratios	Up to some TeV/n
Nearby CR Sources	Electron spectrum	100 GeV - 20 TeV
Dark Matter	Signatures in electron/gamma-ray spectra	100 GeV - 20 TeV
Solar Physics	Electron flux (1GeV-10GeV)	< 10 GeV
Gamma-ray Transients	Gamma-rays and X-rays	7 keV - 20 MeV
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Observation by High Energy Trigger for 1754 day : Oct. 13, 2015 – Jul. 31, 2020 Nearly 5-year observations has been achieved !!

- $\Box$  The exposure, SQT, has reached to ~156 m<sup>2</sup> sr day for electron observations by continuous and stable operations.
- □ Event number of HE triggered events (>10 GeV) is ~1.13 billion with a live time fraction of about 85 %. Total event number triggered over 1 GeV is ~2.43 billion.





# All Electron Spectrum:

### **Comparison between Recent Direct Measurements**

#### CALET Observations: Oct. 13, 2015 - Nov. 30, 2017 (for 780 days) 250 E<sup>3.0</sup> flux[m<sup>-2</sup>sr<sup>-1</sup>s<sup>-1</sup>GeV<sup>2.0</sup>] CALET's spectrum is consistent with AMS-02 below 1 TeV. 1. There are two group of measurements: 2. AMS-02+CALET vs Fermi-LAT+DAMPE, indicating the 200 presence of unknown systematic errors. 150 Current statistics: 100 x 2.3 (~400 events,>1TeV) CALET 2018 PRL 120, 261102 (2018) 50 3. CALET observes flux suppression consistent with DAMPE within errors above 1TeV. No peak-like structure at 1.4 TeV in CALET data, 4. irrespective of energy binning. 10<sup>3</sup> 10<sup>2</sup> 10 Energy [GeV JPS2020 Fall Meeting (online), Sep. 15, 2020

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### Proton Spectrum: Comparison between Recent Direct Measurements

#### CALET Observations: Oct.13,2015- Aug.31,2018 (for 1,056 days)







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# CALET Gamma-ray Sky (>1GeV)



-100

#### Current Topics: Solar atmospheric gamma-rays







# **CALET: Summary and Future Prospects**

- □ As of Jul. 31, 2020, CALET has successfully carried out 1754-day observations with live time fraction to total time close to 85%. Nearly 2.4 billion events collected with low (> 1 GeV) + high energy (> 10 GeV) triggers.
- Accurate calibrations have been performed with non-interacting p & He events + linearity in the energy measurements established up to 1 PeV.
- □ Following results have been achieved by now.
  - Measurement of electron + positron spectrum in 11 GeV 4.8 TeV.
  - Direct measurement of proton spectrum in 50 GeV 10 TeV energy range, spectral hardening observed above a few hundred GeV.
  - Preliminary analysis of primary elements up to Fe.
  - Study on solar modulation over ~5 years.
  - Observation of diffuse and point sources ( + Sun ) of gamma-rays.
  - Gamma-ray burst detections and follow-up observations of GW events in X-ray and gamma-ray bands.
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- □ CALET mission is planed by March 2021 over 5.7 years after launch, and is expected by FY 2024 with the approval by reviewing of the project status.

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JAPAN

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## 2019年12月15日





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# BACKUP

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## All Electron Spectrum: Comparison between Direct & Ground Measurements



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- Search for Dark Matter signature in the electron spectrum structure
  - Detection of unknown primary source of electron and positron: Pulsar(s) or Dark Matter ?

- Investigation of CR nearby sources by electron observations at the TeV region
  - Direct detection of nearby sources
  - Acceleration limit and escape process from SNR





# **Direct Measurement of Proton Spectrum by CALET**

