The CALorimetric Electron Telescope (CALET) Launch and Early On-Orbit Performance

T. Gregory Guzik
for the CALET Collaboration

Louisiana State University
Department of Physics & Astronomy

CALET Collaboration

O. Adriani[25], Y. Akaike[2], K. Asano[7], Y. Asaoka[8,31], M.G. Bagliesi[29], G. Bigongiari[29], W.R. Binns[32], S. Bonechi[29], M. Bongi[25], P. Brogi[29], J.H. Buckley[32], G. Castellini[25], M.L. Cherry[12], G. Collazuol[26], V. Di Felice[28], K. Ebisawa[9], H. Fuke[9], T.G. Guzik[12], T. Hams[3], M. Hareyama[23], N. Hasebe[31], K. Hibino[10], M. Ichimura[4], K. Ioka[11], M.H. Israel[32], A. Javaid[12], K. Kasahara[31], J. Kataoka[31], R. Kataoka[16], Y. Katayose[33], C. Kato[22], N. Kawanaka[30], H. Kitamura[15], H.S. Krawczynski[32], J.F. Krizmanic[2], S. Kuramata[4], T. Lomtadze[27], P. Maestro[29], P.S. Marrocchesi[29], A.M. Messineo[27], J.W. Mitchell[14], S. Miyake[5], K. Mizutani[20], A.A. Moiseev[3], K. Mori[9,31], M. Mori[19], N. Mori[25], H.M. Motz[31], K. Munakata[22], H. Murakami[31], Y.E. Nakagawa[9], S. Nakahira[8], J. Nishimura[9], S. Okuno[10], J.F. Ormes[24], S. Ozawa[31], F. Palma[28], P. Papini[25], A.V. Penacchioni[29], B.F. Rauch[32], S. Ricciarini[25], K. Sakai[3], T. Sakamoto[1], M. Sasaki[3], Y. Shimizu[10], A. Shiomi[17], R. Sparvoli[28], P. Spillantini[25], I. Takahashi[1], M. Takayanagi[9], M. Takita[7], T. Tamura[10], N. Tateyama[10], T. Terasawa[7], H. Tomida[9], S. Torii[8,31], Y. Tunesada[18], Y. Uchihori[15], S. Ueno[9], E. Vannuccini[25], J.P. Wefel[12], K. Yamaoka[13], S. Yanagita[6], A. Yoshida[1], K. Yoshida[21], and T. Yuda[7]

1) Aoyama Gakuin University, Japan
2) CRESST/NASA/GSFC and Universities Space Research Association, USA
3) CRESST/NASA/GSFC and University of Maryland, USA
4) Hirosaki University, Japan
5) Ibaraki National College of Technology, Japan
6) Ibaraki University, Japan
7) ICRR, University of Tokyo, Japan
8) JAXA, Japan
9) JAXA/ISAS, Japan
10) Kanagawa University, Japan
11) KEK, Japan
12) Louisiana State University, USA
13) Nagoya University, Japan
14) NASA/GSFC, USA
15) National Inst. of Radiological Sciences, Japan
16) National Institute of Polar Research, Japan
17) Nihon University, Japan
18) Osaka City University, Japan
19) Ritsumeikan University, Japan
20) Saitama University, Japan
21) Shibaura Institute of Technology, Japan
22) Shinshu University, Japan
23) St. Marianna University School of Medicine, Japan
24) University of Denver, USA
25) University of Florence, IFAC (CNR) and INFN, Italy
26) University of Padova and INFN, Italy
27) University of Pisa and INFN, Italy
28) University of Rome Tor Vergata and INFN, Italy
29) University of Siena and INFN, Italy
30) The University of Tokyo, Japan
31) Waseda University, Japan
32) Washington University-St. Louis, USA
33) Yokohama National University, Japan

CALorimetric Electron Telescope Summary

Science Objectives

- Nearby Cosmic-ray Sources
- Dark Matter
- Origin and Acceleration of Cosmic Rays
- Cosmic –ray Propagation in the Galaxy
- Solar Physics
- Gamma-ray Transients

CAL Measurement Capability

- Electrons: 1 GeV – 20 TeV
- Gamma-rays: 10 GeV – 10*TeV
- Gamma-ray bursts: > 1 GeV
- Heavy ions (1 ≤ Z ≤ 28): 10's GeV – 1,000* TeV
- Ultra Heavy (Z > 28): > 600 MeV/nucleon

HXM x2
7keV-1MeV

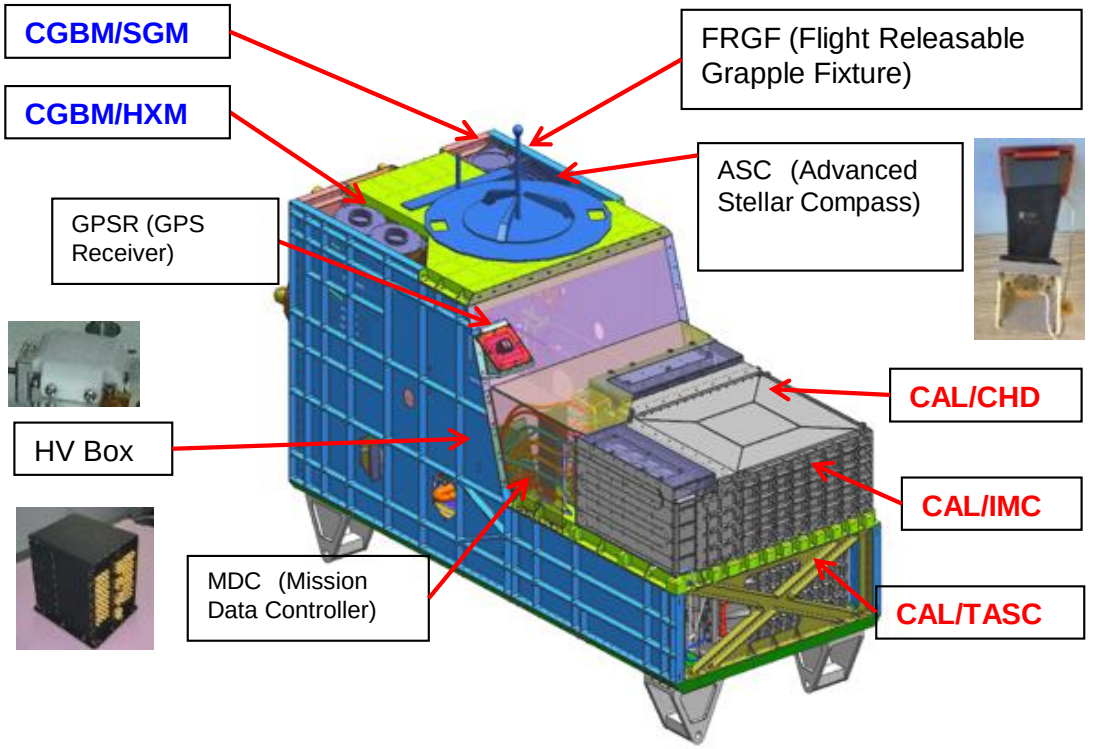
$LaBr_3(Ce)$

SGM x1
0.1-20MeV

BGO

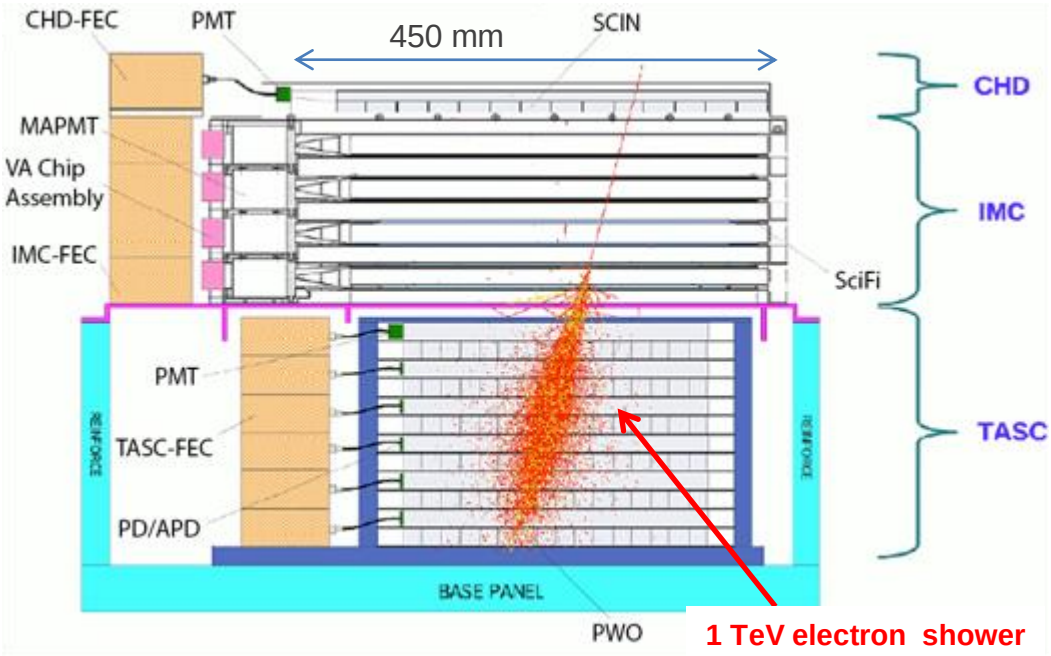
CGBM Measurement Capability

- High energy photons: 7 keV – 20 MeV



CAL Instrument Overview

Field of view: ~ 45 degrees (from the zenith)
Geometrical Factor: 0.12 m^2sr (for electrons)



Unique features of CALET

Thick, fully active calorimeter:
Allows measurements well into the TeV energy region with excellent energy resolution

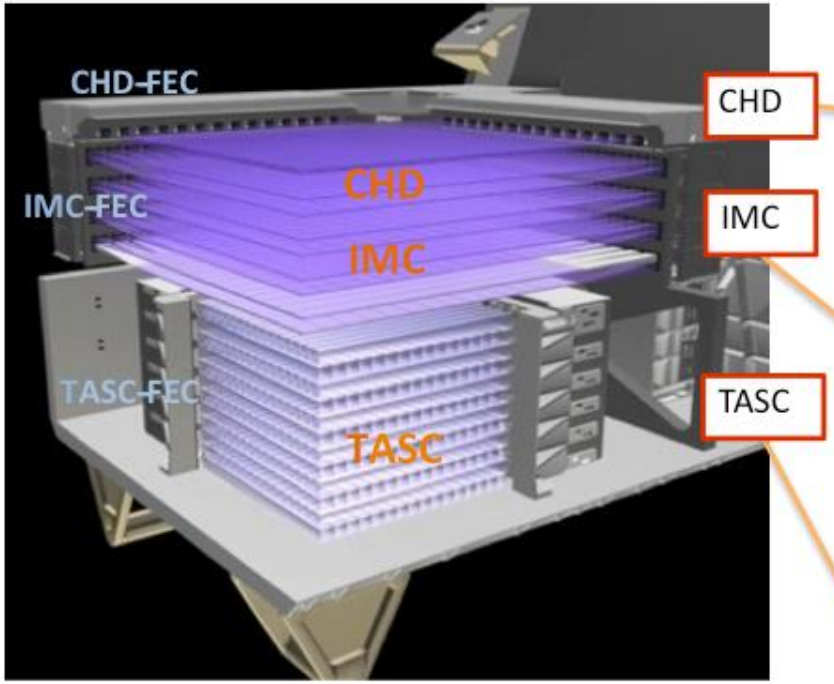
Fine imaging upper calorimeter:
Accurately identify the starting point of electromagnetic showers.

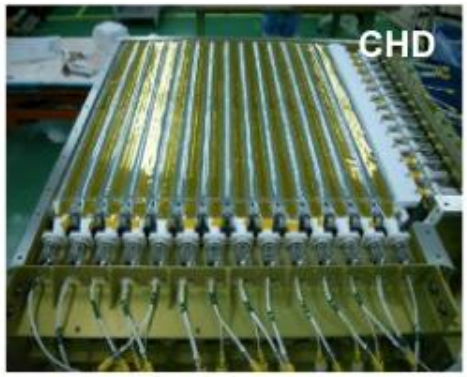
Detailed shower characterization:
Lateral and longitudinal development of showers enables electrons and abundant protons to be powerfully separated.

	CHD (Charge Detector)	IMC (Imaging Calorimeter)	TASC (Total Absorption Calorimeter)
Function	Charge Measurement (Z=1-46)	Arrival Direction, Particle ID	Energy Measurement, Particle ID
Sensor (+ Absorber)	**Plastic Scintillator : 14 × 1 layer (x,y)** Unit Size: 32mm x 10mm x 450mm	**SciFi : 448 x 8 layers (x,y) = 7168** Unit size: 1mm^2 x 448 mm **Total thickness of Tungsten: 3 X_0**	**PWO log: 16 x 6 layers (x,y)= 192** Unit size: 19mm x 20mm x 326mm **Total Thickness of PWO: 27 X_0**
Readout	**PMT+CSA**	**64 -anode PMT+ ASIC**	**APD/PD+CSA** PMT+CSA (for Trigger)

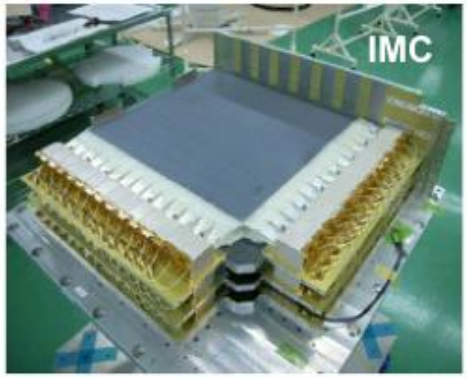
CAL Hardware Components

CAL constituent equipments

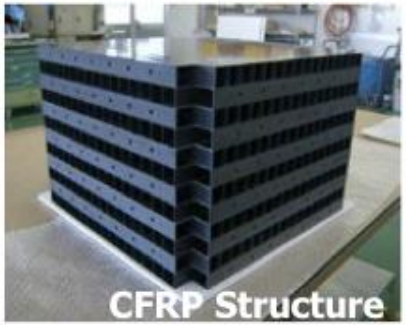


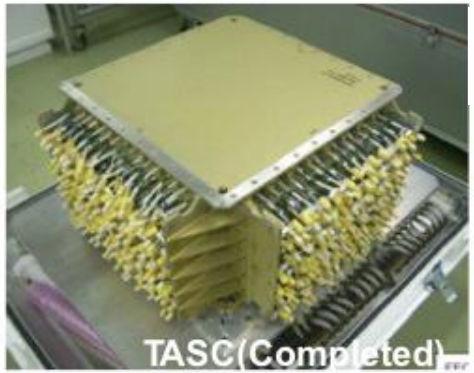


CHD: 14 × 1 layer (x,y)
Unit Size: 32mm x 10mm x 450mm



IMC : 448 x 8 layers (x,y) = 7168
Unit size: 1mm^2 x 448 mm





TASC: 16 x 6 layers (x,y)= 192
Unit size: 19mm x 20mm x 326mm

v040616

CALET is now on the ISS !

① **August 19th**: After a successful launch of the Japanese H2-B rocket by the Japan Aerospace Exploration Agency (JAXA) at 20:50:49 (local time), CALET started its journey from Tanegashima Space Center to the ISS.

② **August 24th:** The HTV-5 Transfer Vehicle（HTV-5) is grabbed by the ISS robotic arm.

③ **August 25th:** The HTV-5 docks to the ISS at 2:28 (JSTT).

④ **August 25th:** CALET is emplaced on port #9 of the JEM-EF and data communication with the payload is established.

Launch to the initial operation (1)

(1) Launch on 8/19 via H-IIB/HTV5. Dock on 8/25 to JEM port 9. No problem for their start up.

(2) Performed the function checkout during 8/25 to 10/8. Confirmed there were no problems on their functions and performances.

(3) Until 11/17, 90 days after the launch, conducted an observation to achieve the minimum mission success and obtained an appropriate amount of data. Since then, the observation has been carried out according to the steady processes.

8/19 L+0 HTV5 launch

8/24 L+5 HTV5 ISS arrived, moored on ISS

HTV-EP JEM-EF moored
CALET JEM-EF#9 attached

8/25 L+6 CALET boot up

機器動作確認

MDC/GPSR/ASC checkout
IMC/CHD/TASC-FEC checkout

8/31 L+12
9/3 L+15
9/4 L+16

HV-BOX/GBM-EBOX/CIRC checkout
System(interlock function) checkout

9/14 L+26
9/15 L+27

Schedule command file loaded

9/18 L+30







Launch to the initial operation (2)

9/22 L+34 CGBM High Voltage checkout

9/24 L+36 Reached required vacuum for Calorimeter

高電圧印加確認

CHD checkout

IMC checkout

TASC checkout

Calorimeter checkout

CGBM detecting function checkout

CALET overall operation checkout

10/5 L+47 Confirmed 72 hours continuous operation

10/8 L+50 **Confirmed functional checkout**

Measurement of the calorimeter Calibration data

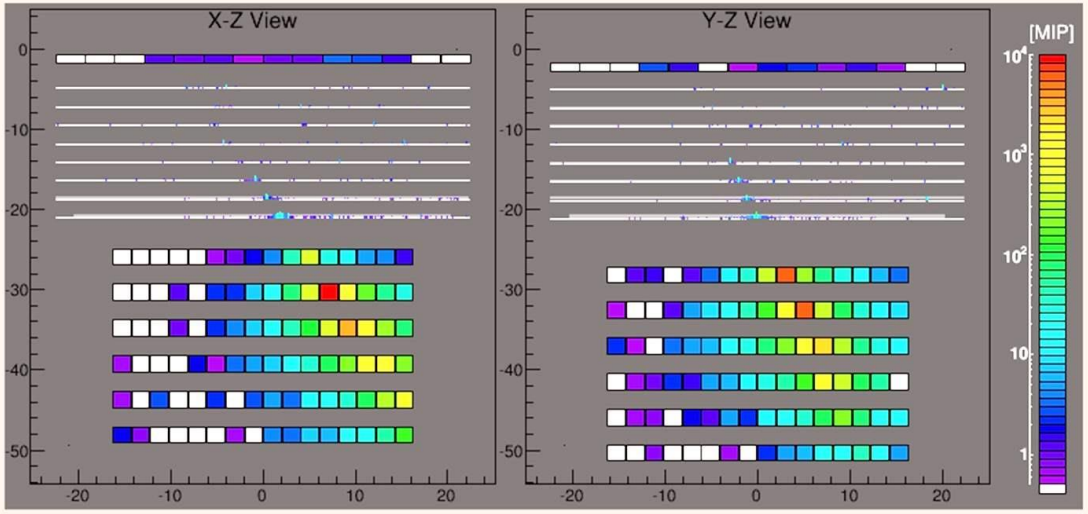
10/20 L+62

Observation for the minimum mission success

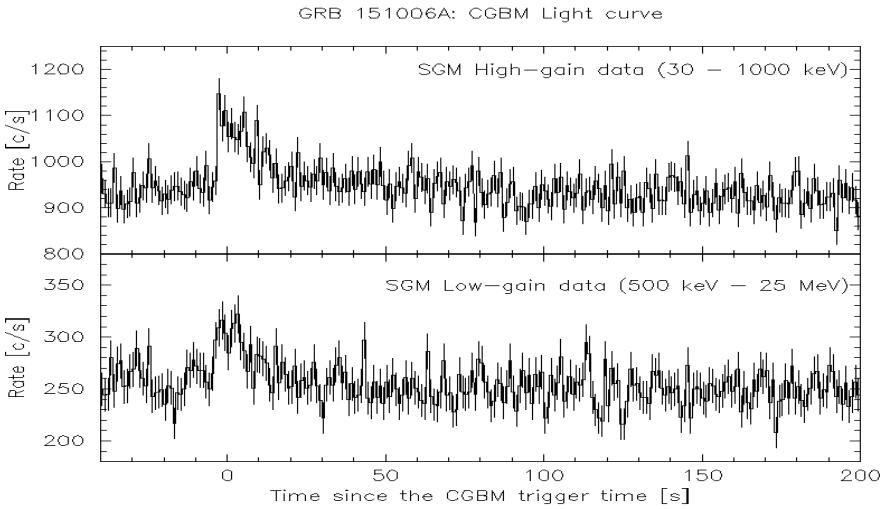
Trial for the steady observation process

11/17 L+90 **End of the initial operation**

Start observation with the steady process



Calorimeter: Electron event around the TeV region(candidate)



CGBM: First observed GRB event light curve(GRB 151006A)

Overview of trigger modes for CALET

High Energy Shower Trigger (HE) →
- High energy electrons (10GeV ～20TeV)
- High energy gamma rays (10GeV ～10TeV)
- Nuclei (a few10GeV～000TeV)

Low Energy Shower Trigger (LE) →
- Low energy electron at high latitude(1GeV ～10GeV)
- GeV gamma-rays originated from GRB (1GeV ～)
- Ultra heavy nuclei (combined with heavy mode)

Single Trigger (Single) →
- For detector calibration : penetrating particle (mainly protons and heliums)

(*) In addition to above 3 trigger modes, heavy modes are defined for each of the above trigger mode. They are omitted here for simple explanation.

Auto Trigger (Pedestal/Test Pulse) →
- For calibration: ADC offset measurement (Pedestal), FEC's response measurement (Test pulse)

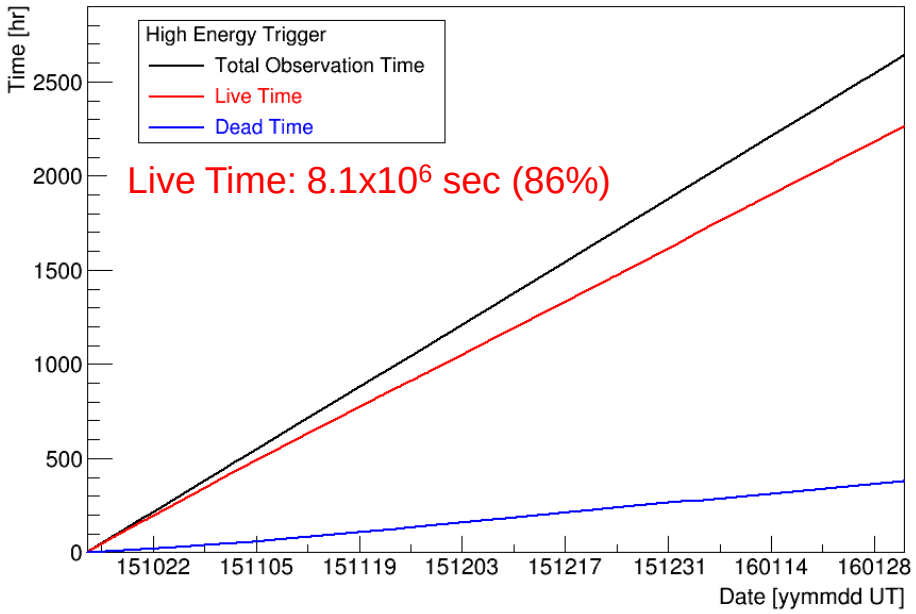
Predominantly, timestamped changes of trigger setting are described in schedule command file. It makes possible to take pedestals, penetrating particles, low energy electrons at high latitude, and other dedicated data in addition to the most important high energy shower data.

Data Acquisition and Observed Event Number

Observing time and event number in high energy trigger mode (>10GeV) for 111 days from 13.10.2015-31.1.2016

- Observing (Live) Time
- Accumulated Event Number

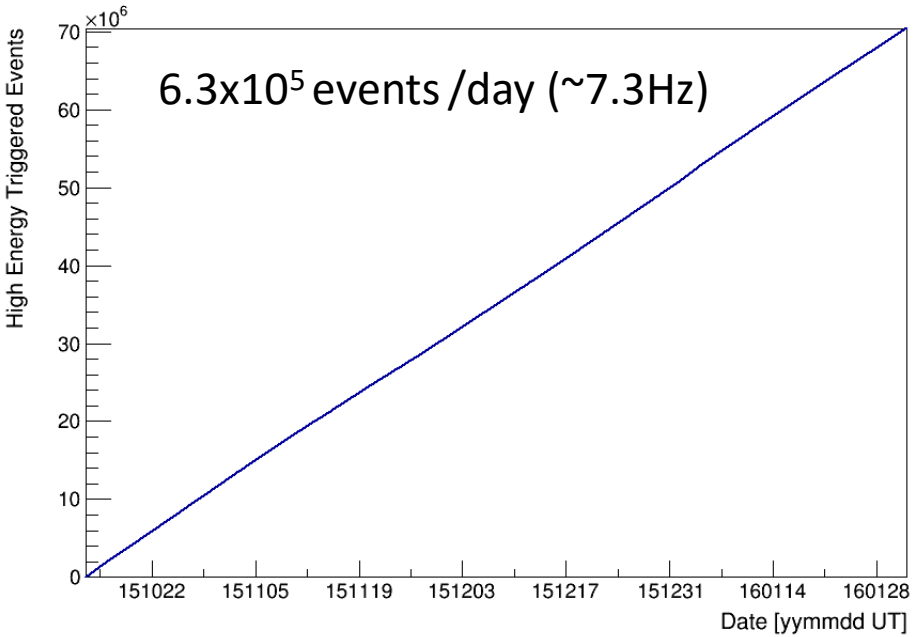
High Energy Trigger



Total observing time reached to 8.1×10^6 sec with 86% live time by 31.1.2016

Up to now, ~1.12×10^7 sec

CALET Observation onboard ISS



Accumulated event number has been ~7×10^7 by 31.1.2016

Up to now, ~10^8 events

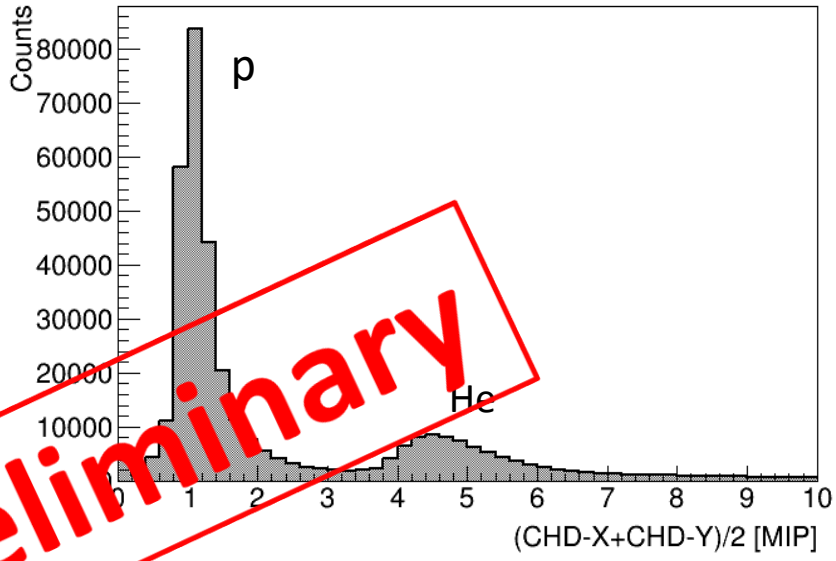
Very Preliminary Charge Histogram

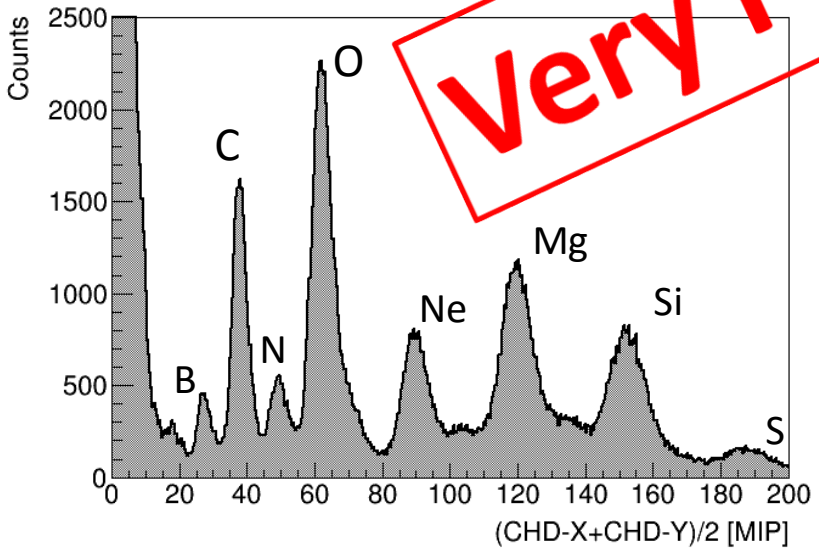
Charge measurement in CHD

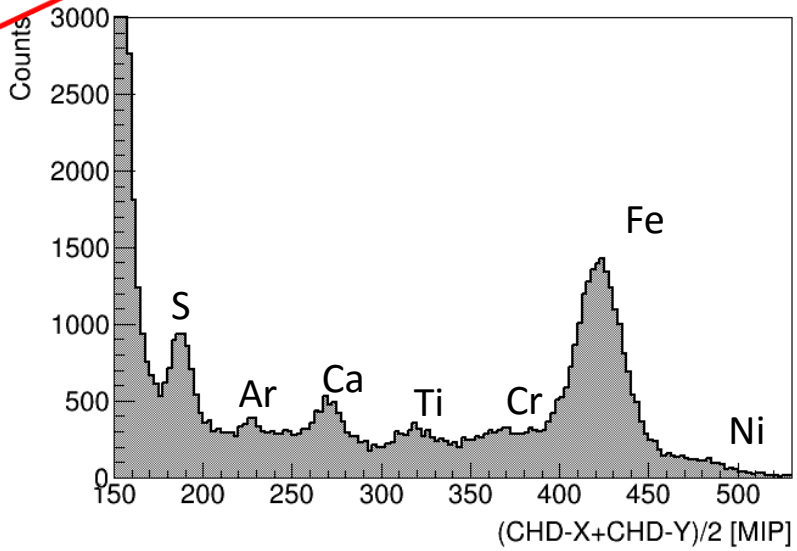
【Analysis method】

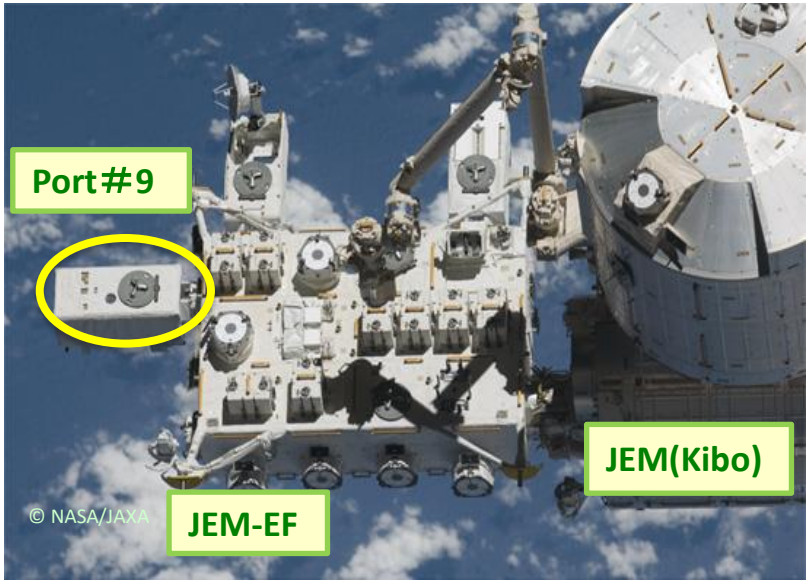
- After determining the incident position of CHD from the reconstructed track in IMC, the average of pulse height (MIP) is measured.
- Charge is corrected by using a track path length related to zenith angle.

We still have relatively poor statistics for odd-Z nuclei that are less abundant and heavier than oxygen. However, the atomic nuclei up to iron are clearly identified with the CHD only. By using additional information from IMC, more precise identification will be performed from now on (Δz = 0.1-0.35 in beam test).









Summary

- CALET was successfully launched on HTV-5 from Tanegashima Space Center on August 19, 2015 at 8:50:49 p.m (JST).
- CALET was successfully berthed to the ISS on August 25th and began a functional check-out phase until the beginning of October 2015.
- CALET completed a calibration and initial operation phase on Nov 17, 2015, whence it began its standard operation phase.
- CALET has measured Cosmic Ray nuclei through iron, Cosmic Ray electrons & positrons, and astrophysical gamma-rays.
- CALET's CGBM has measured the light-curves of 8 GRB's as on Jan 1, 2016.
- From Oct 13, 2015 – Jan 31, 2016 nearly 4.6 x 10^5 electron candidate events over 10 GeV have been observed.