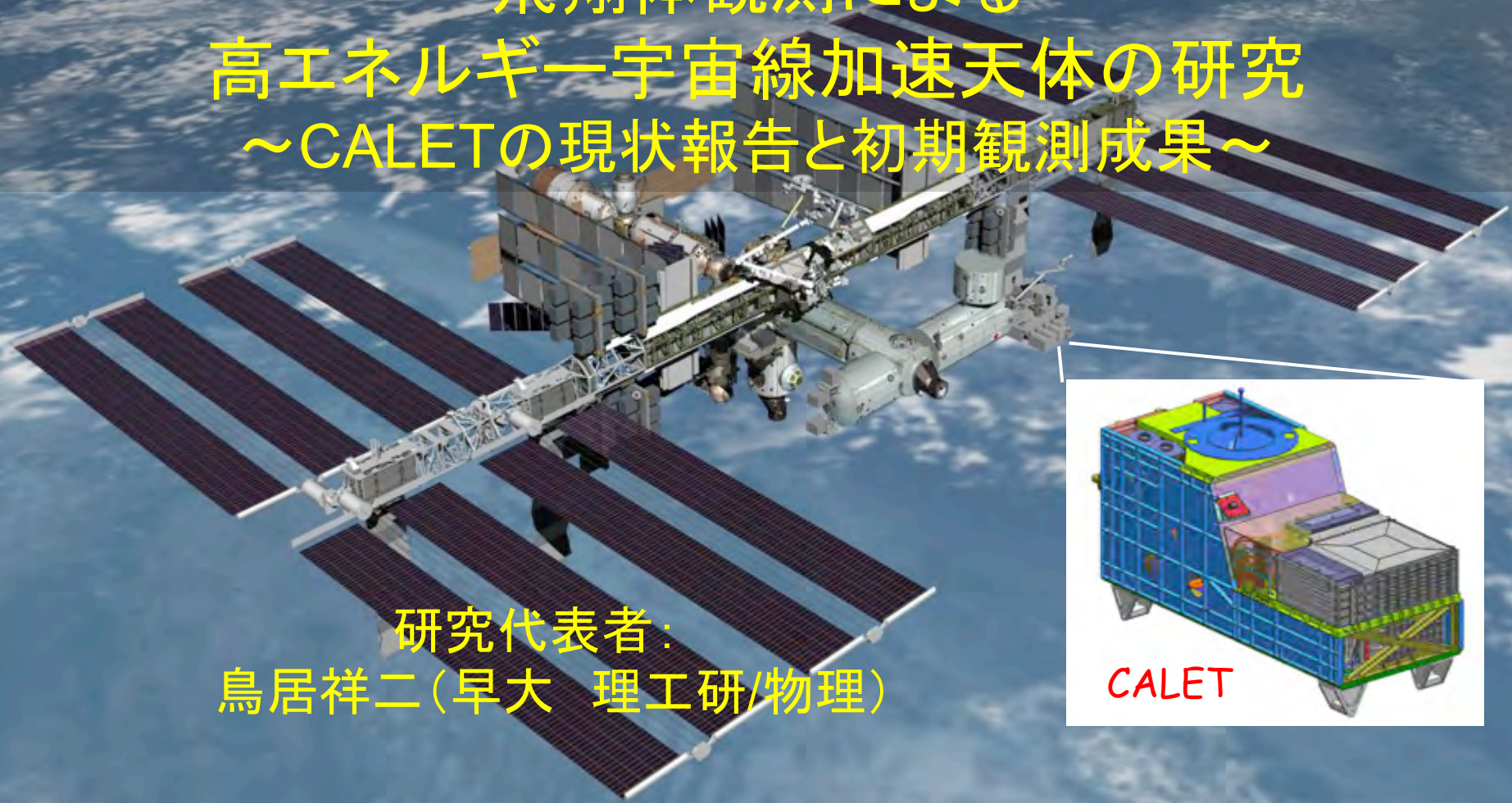
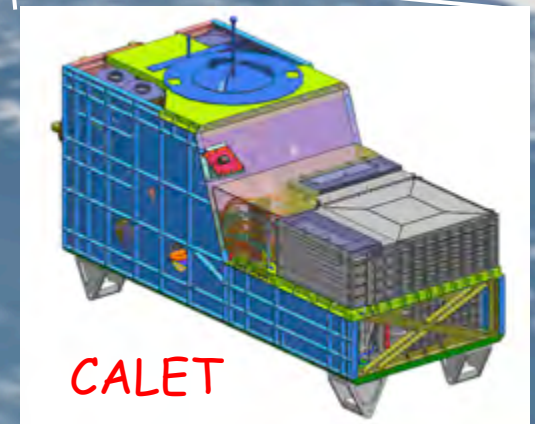




飛翔体観測による 高エネルギー宇宙線加速天体の研究 ～CALETの現状報告と初期観測成果～



研究代表者：
鳥居祥二（早大 理工研/物理）

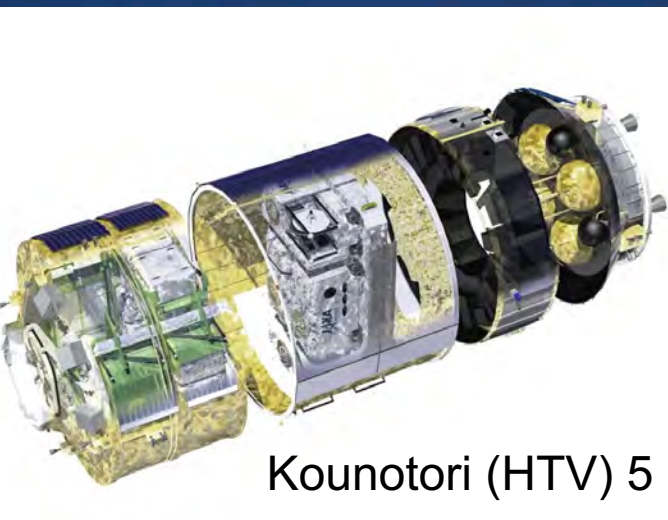




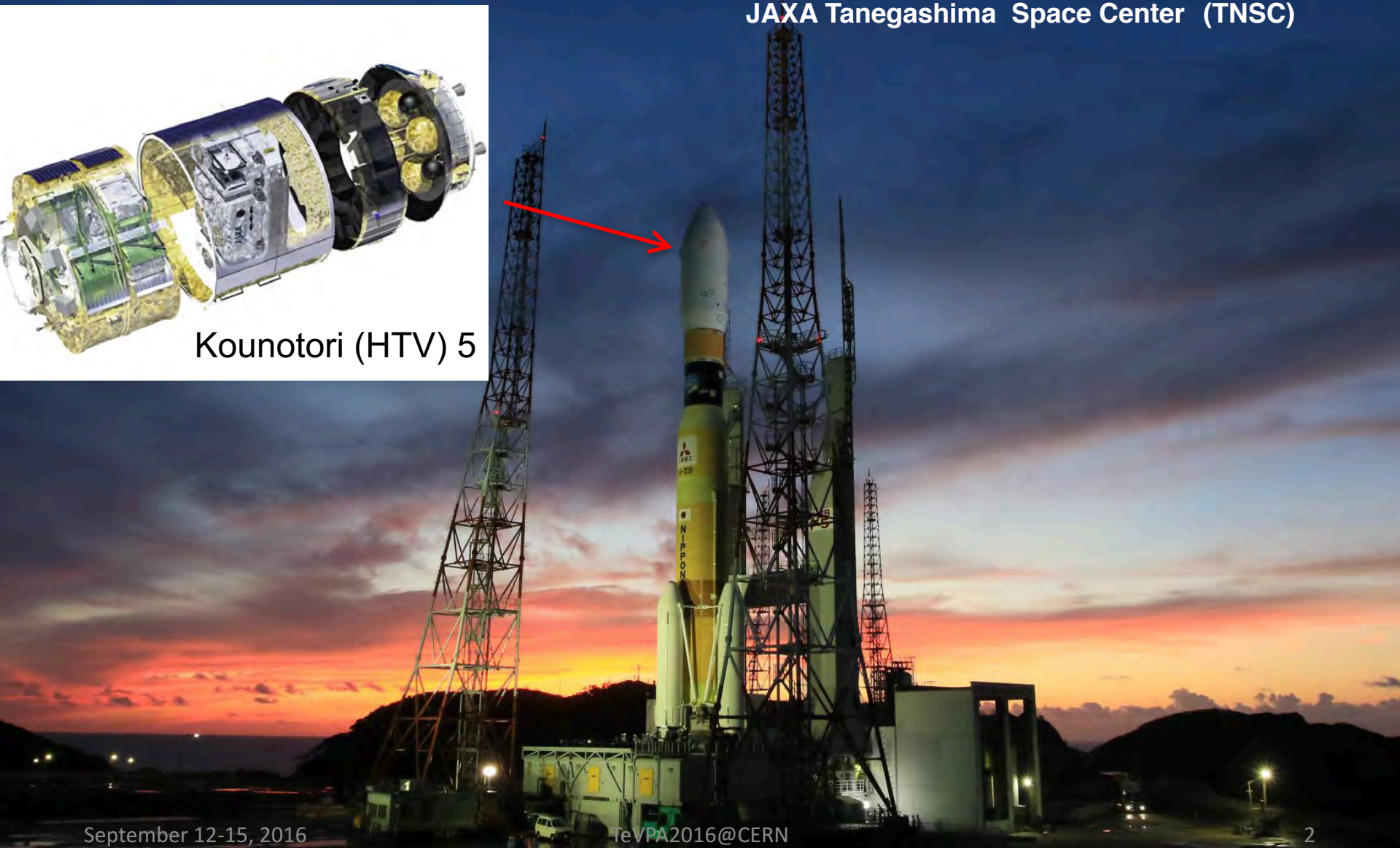
CALET Launch: August 19, 2015 at 12:50:49 (UT)



JAXA Tanegashima Space Center (TNSC)



Kounotori (HTV) 5



共同利用研究概要(2016)

■ 共同研究内容

- CALET観測最適化のためのシミュレーション計算及びデータ解析

■ 発表概要

- CALET観測目的・装置
- 観測現状
- 初期観測データ解析
- まとめと展望

■ 予算 旅費 150千円

支出(予定)内容: 研究打ち合わせ、小研究会

■ 共同利用 計算機(シミュレーション計算)

参加研究者及び研究補助

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宇宙線研究所	寺澤敏夫、浅野勝晃	芝浦工業大学	吉田健二
横浜国立大学	片寄祐作	弘前大学	市村雅一
立命館大学	森正樹	信州大学	宗像一起
茨城大学	柳田昭平		
CRESST/NASA/GSFC	赤池陽水		



CALET collaboration team



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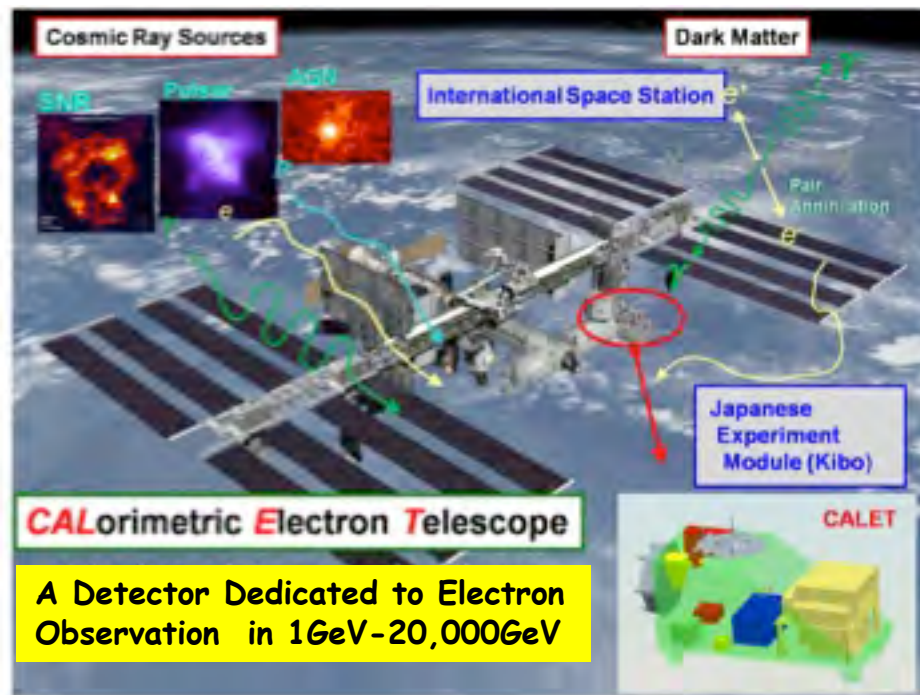
CALETによる科学観測

カロリメータ (CAL)

- 電子: 1 GeV – 20,000 GeV
- ガンマ線: 10 GeV – 10,000 GeV
(ガンマ線バースト: > 1 GeV)
- 陽子・原子核:
数10GeV – 1,000 TeV
- 超重核:
Rigidity Cut 以上のエネルギー

ガンマ線バーストモニタ (CGBM)

- 軟ガンマ線: 100 keV – 20 MeV
- 硬X線: 7keV – 1 MeV



観測目的

観測対象

宇宙線近傍加速源の同定

TeV領域における電子エネルギースペクトル

暗黒物質の探索

電子・ガンマ線の100 GeV-10 TeV領域におけるスペクトルの”異常”

宇宙線の起源と加速機構の解明

電子及び陽子・原子核の精密なエネルギースペクトル、超重核のフラックス

宇宙線銀河内伝播過程の解明

二次核/一次核(B/C)比のエネルギー依存性

太陽磁気圏の研究

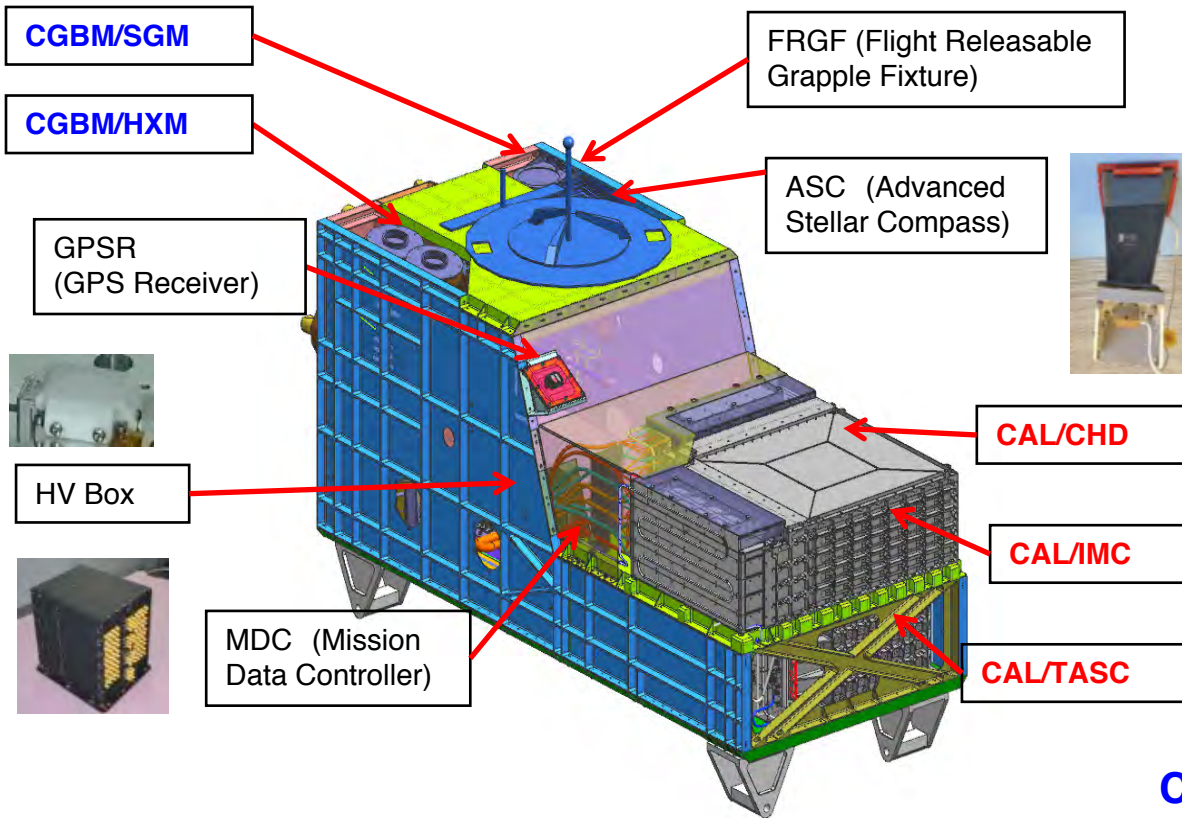
低エネルギー(<10GeV)電子フラックスの長・短期変動

ガンマ線バーストの研究

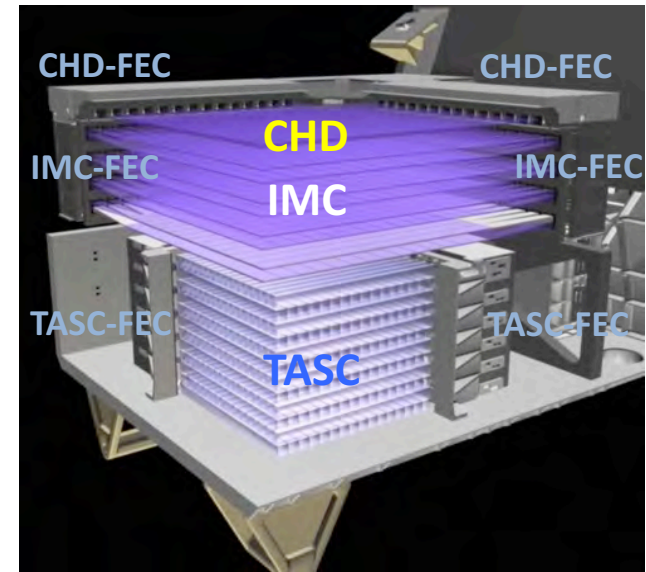
7 keV – 20 MeV領域でのX線・ガンマ線のバースト現象



CALET観測システムの概要



CALORIMETER (CHD/IMC/TASC)



CGBM (CALET Gamma-ray Burst Monitor)

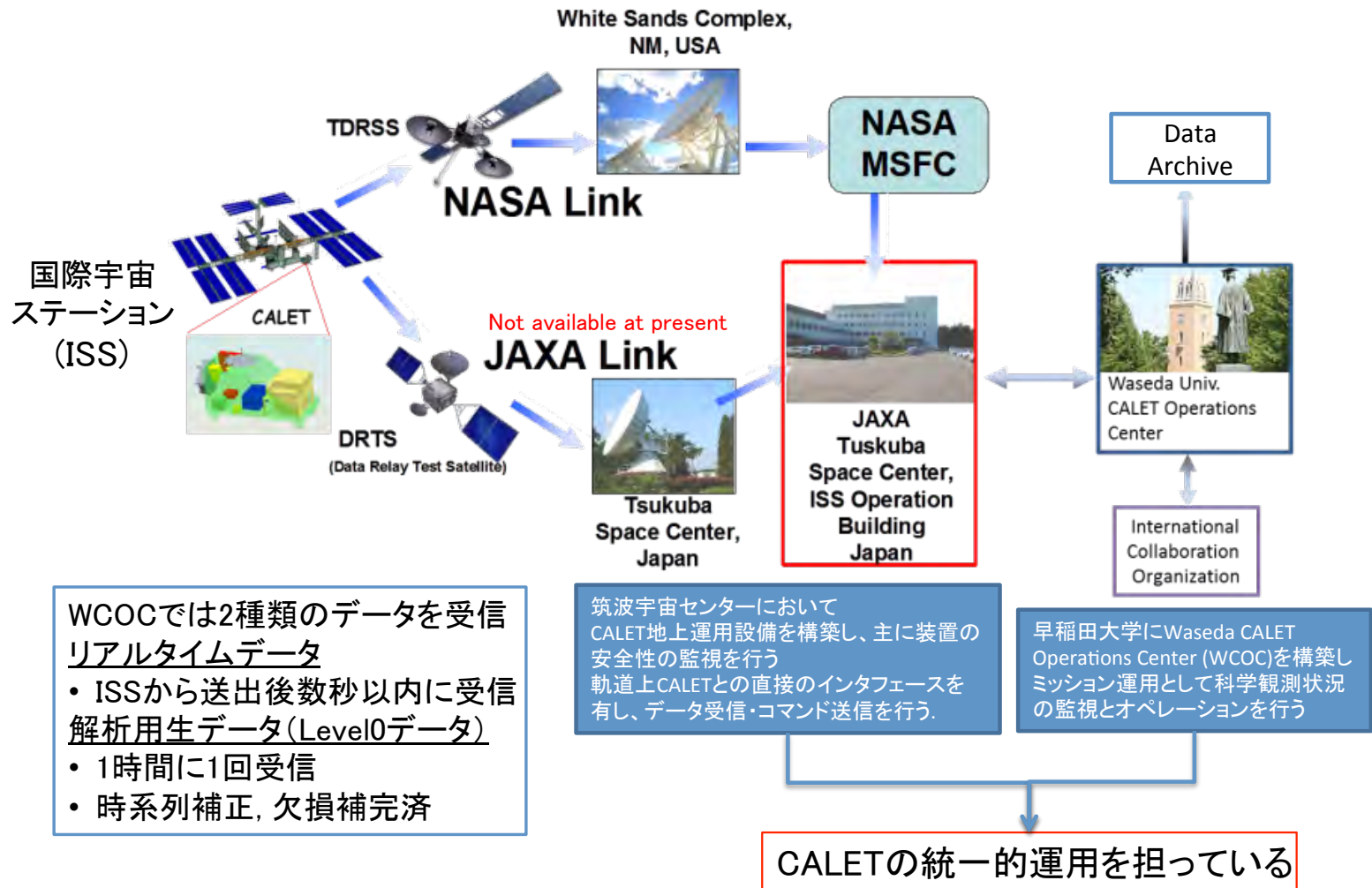
- **質量:** 612.8 kg
- JEM 標準ペイロードサイズ
1850mm(L) × 800mm(W) × 1000mm(H)
- 消費電力: 507 W(max)
- **通信速度:**
中速系 600 kbps (6.5GB/day) 最大: 1 Mbps
低速系 50 kbps





CALETサイエンス運用システム

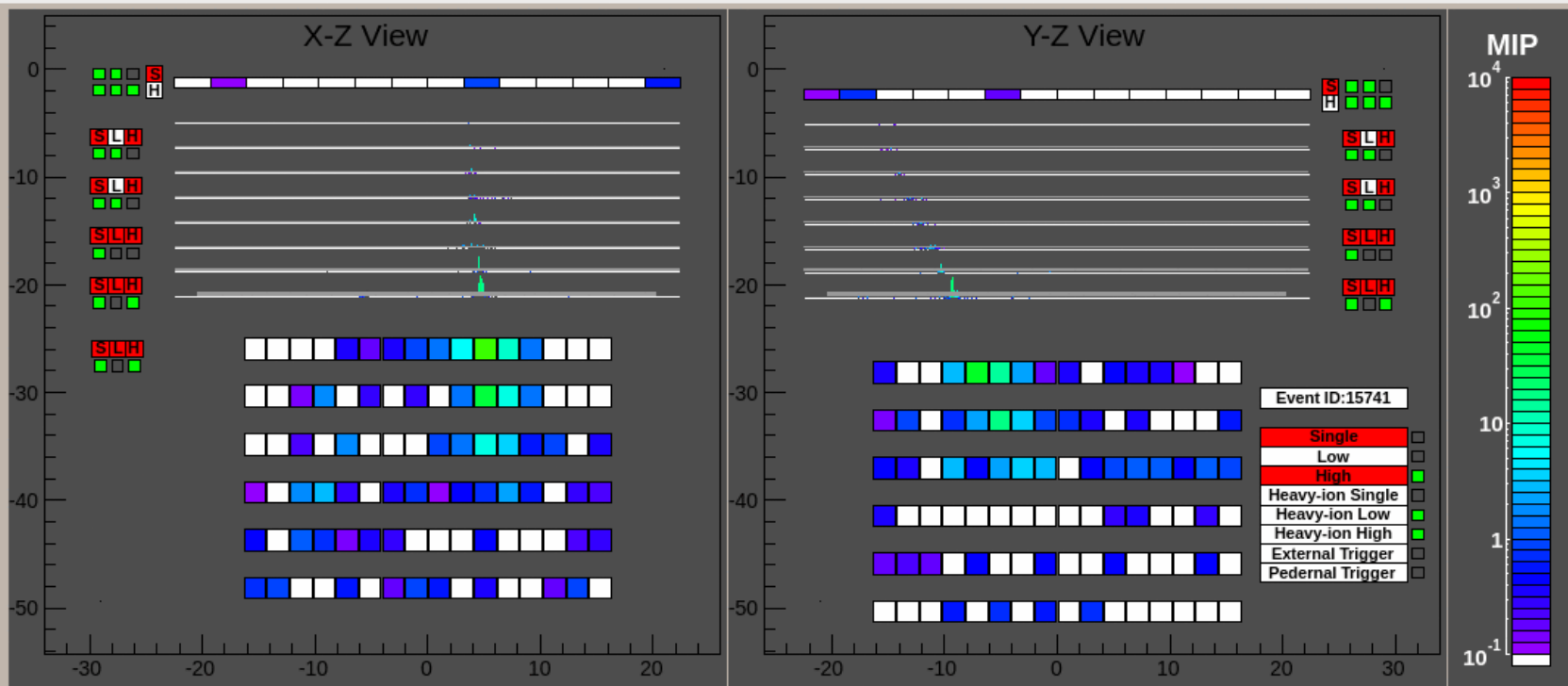
NASAリンクの低速・中速系によりリアルタイムデータ及び欠損補完データ(Level0)のWaseda CALET Operations Center (WCOC) での正常に受信している。



CALETのデータフローとサイエンス運用概念



高エネルギー電子のリアルタイムデータ画像



```
YYMMDDHH:15101303 EventID:1128743511-15741 UTCtime:2015/10/13/03:52:18.41342 KE 7.45[GeV] RE 4.5079[cm] FE 0.0036 Entry: 30883
```

No.	dirX	dirY	dirZ	posX	posY	posZ	chi2_x	Np_x	Chi2_y	Np_y	Zenith[deg]	Azimuth[deg]	color	ID
0	0.07	0.37	0.93	3.26	-17.83	0.00	0.55	7	1.23	8	22.09	-79.64	2	
1	0.05	0.37	0.93	3.82	-17.83	0.00	0.31	7	0.29	8	21.92	-77.90	3	
2	0.05	0.37	0.93	3.82	-17.83	0.00	0.31	7	0.29	8	21.92	-77.90	4	
3	0.07	0.37	0.93	3.25	-17.83	0.00	0.08	8	0.28	8	22.08	-79.67	5	

G	RunMode	TrgMode	PresL	ID-c	Energy	F_E	R_E	K	nIMC_X7X8	nIMC_Y7Y8	nTASC_X1	nIMC_X8	nIMC_Y8	nIncX8-EM	nIncY8-EM	L	nIncX8-SI	nIncY8-SI	L	concX8	concY8
1	101	1	11111	1110	7.446e+00	3.613e-03	4.51	-0.19	1.695e+02	1.362e+02	1.348e+02	6.073e+01	4.777e+01	9.976e-01	2.167e-01	0	9.976e-01	2.167e-01	0	0.6172	0.5651

EntryNum Tracking

MDCTime Energy Itgl

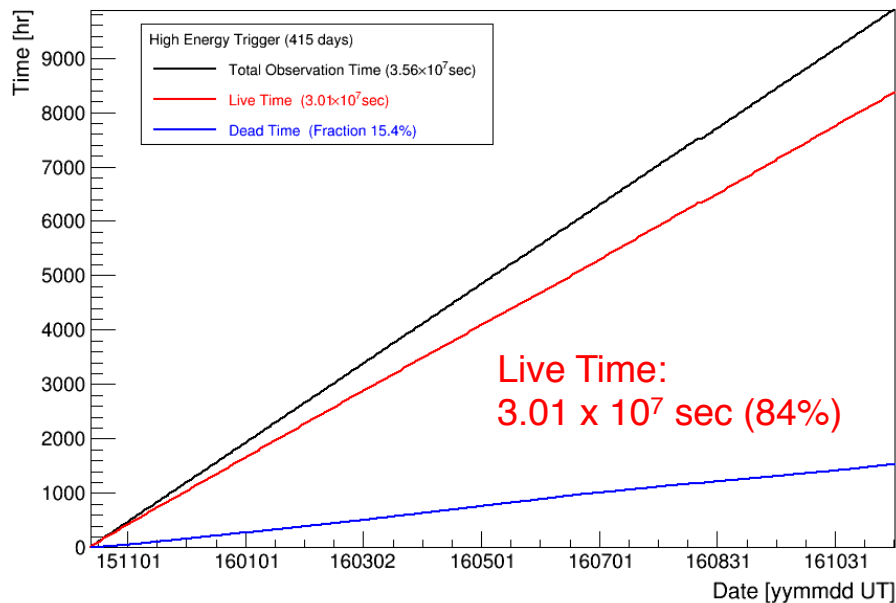
EntryID Prescaling



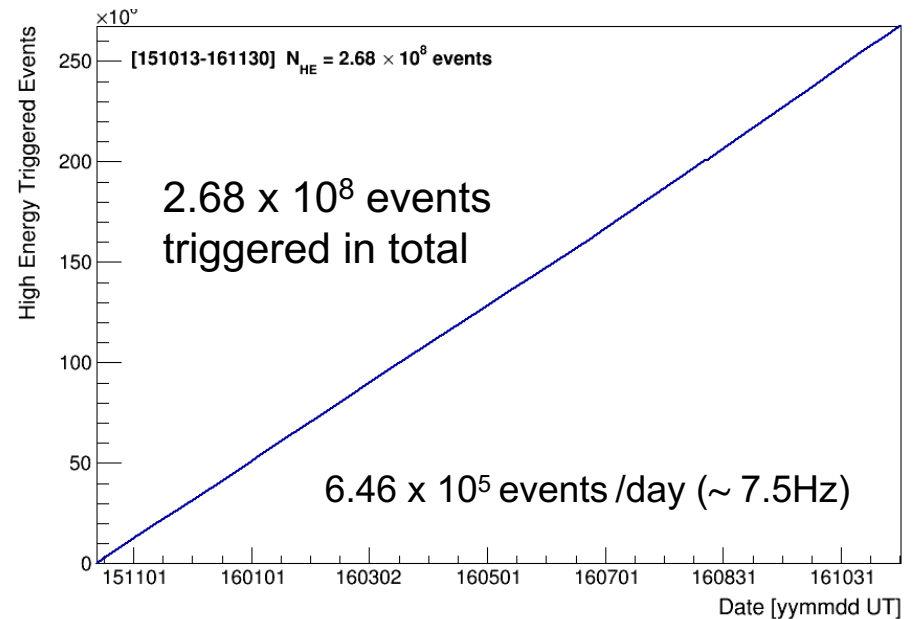
Observation by High Energy Trigger

- Observation by High Energy Trigger for 415 days : Oct. 13, 2015 – Nov.30, 2016
- ▣ The exposure, $S\Omega T$, has reached to $\sim 36.1 \text{ m}^2 \text{ sr day}$. by continuous observation.
 - ▣ Total number of the triggered events is $\sim 270 \text{ million}$ with a live time of 84 %.

Accumulated observation time (live, dead)



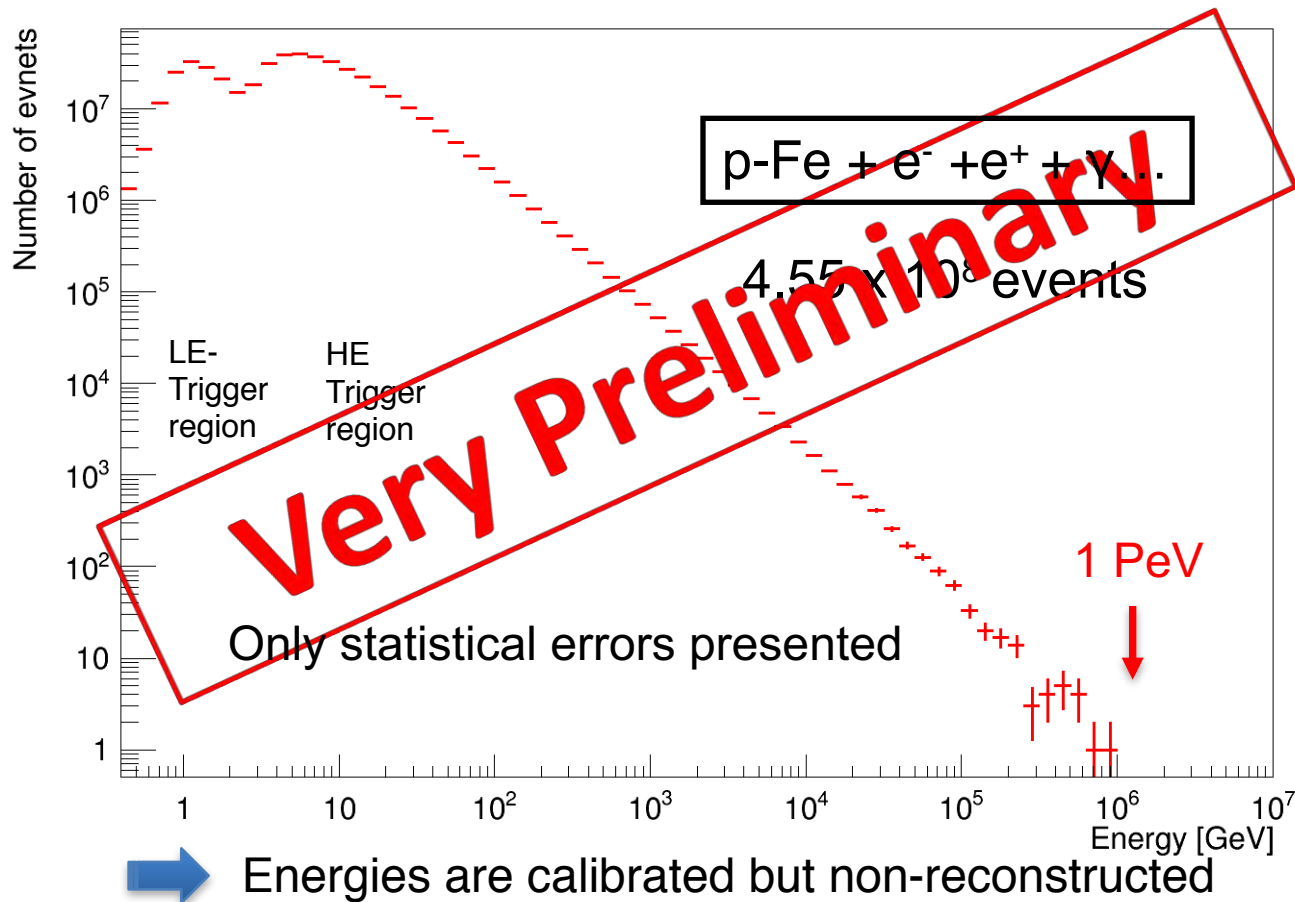
Accumulated triggered event number





Energy Deposit Distribution of All Triggered-Events by Observation for 415 days

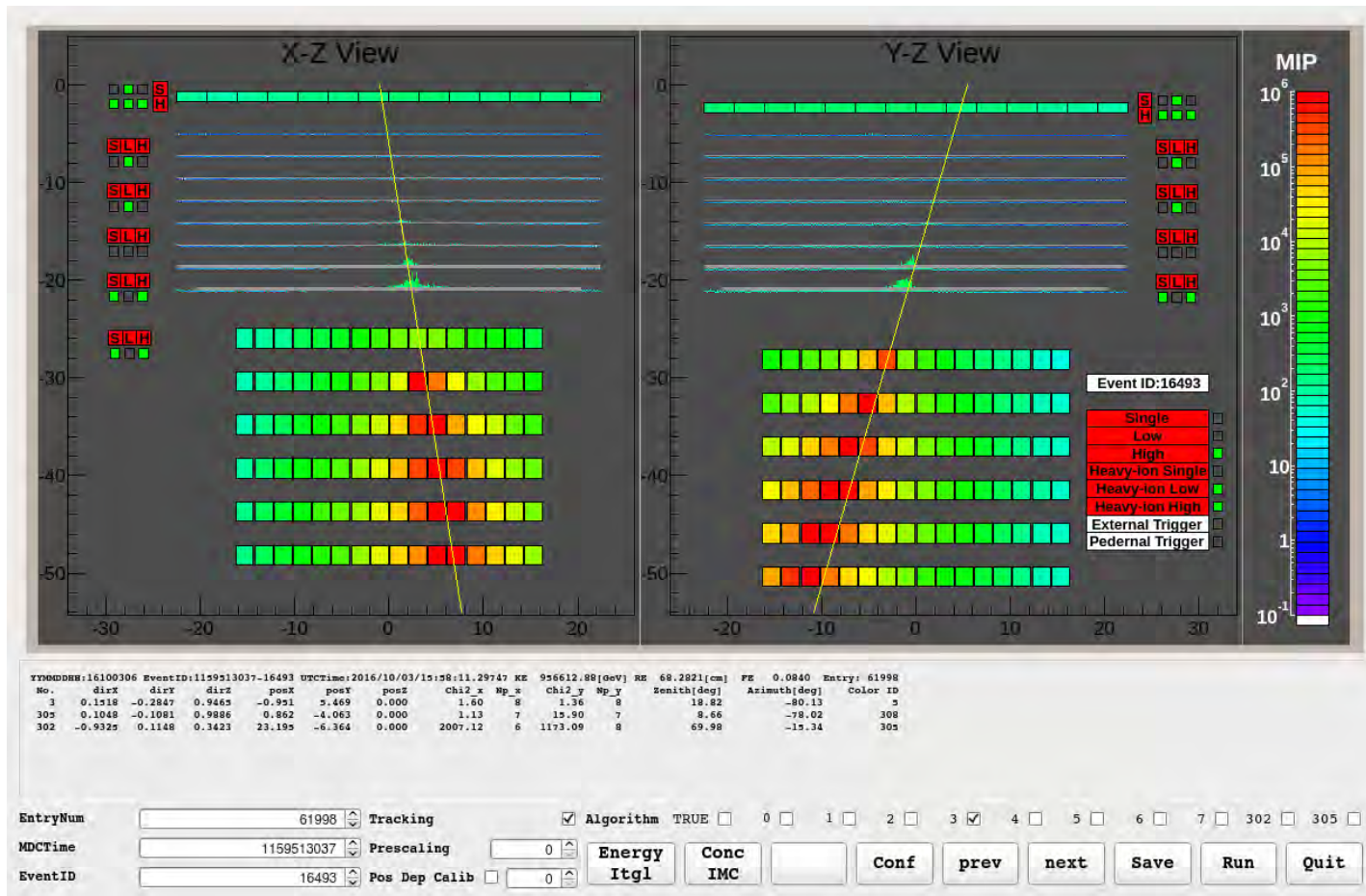
Distribution of deposit energies in TASC observed in 2015.10.13—2016.11.30



The TASC energy measurements have successfully been carried out in the dynamic range of 1 GeV – 1 PeV.

Highest Energy Event ($\Delta E \sim 957$ TeV): An event view of proton candidate

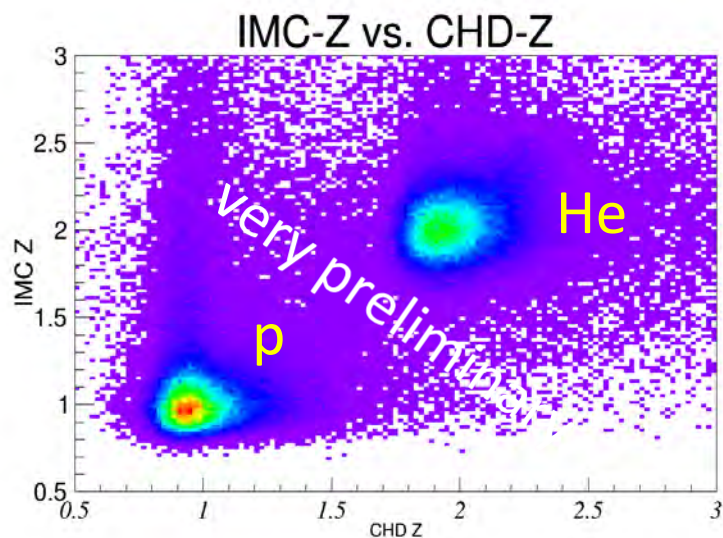
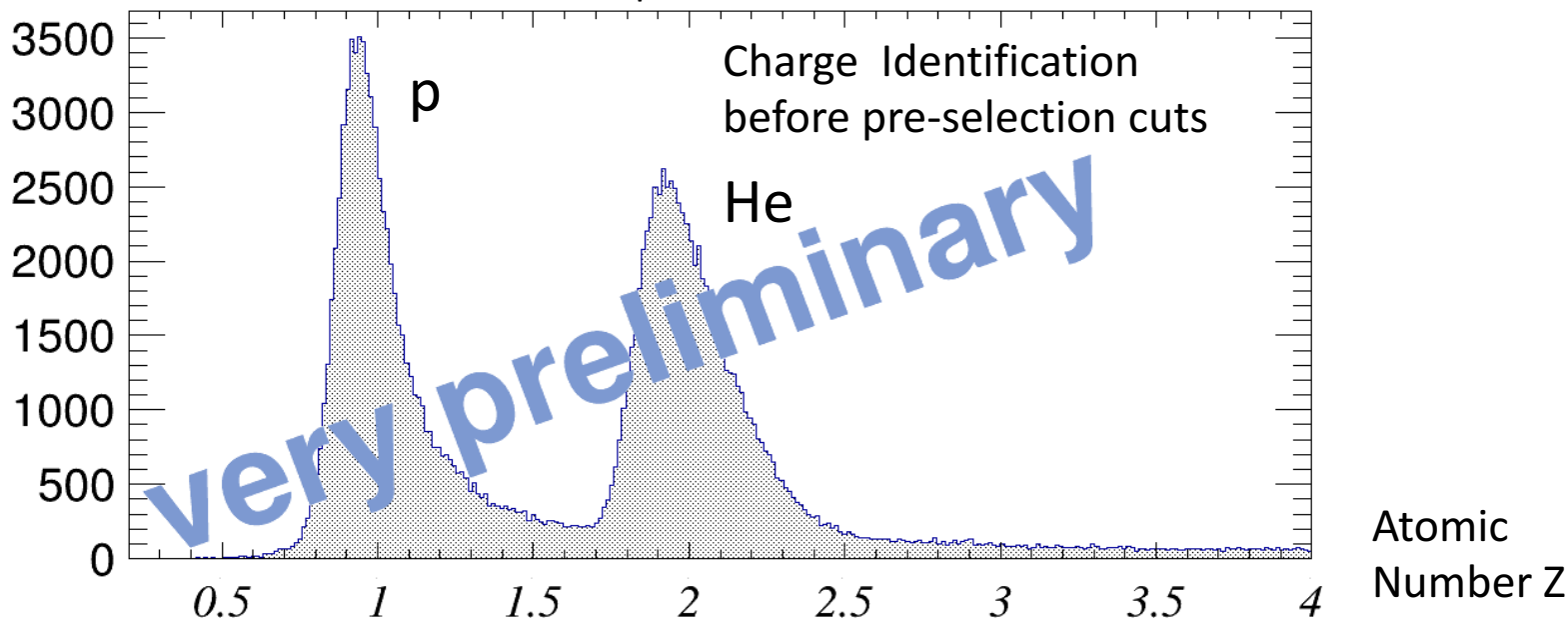
Color Map Range: Maximum = 10^6 MIP, Minimum = 0.1 MIP





Preliminary Nuclei Measurements – p , He –

data selection is NOT representative of elemental abundances



Using multiple dE/dx measurements from the IMC scin/lla/ng fibers (upstream the interaction point), a complementary charge measurement from IMC is plotted vs the CHD charge assignment (abscissa).

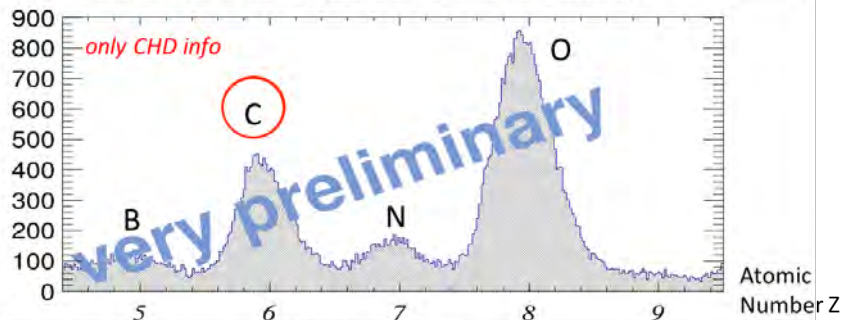
A clear separation between p and He can be seen from preliminary data analysis.



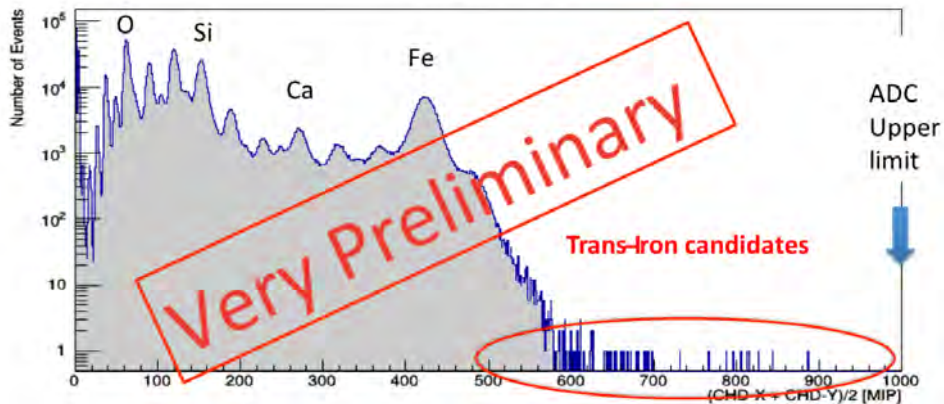
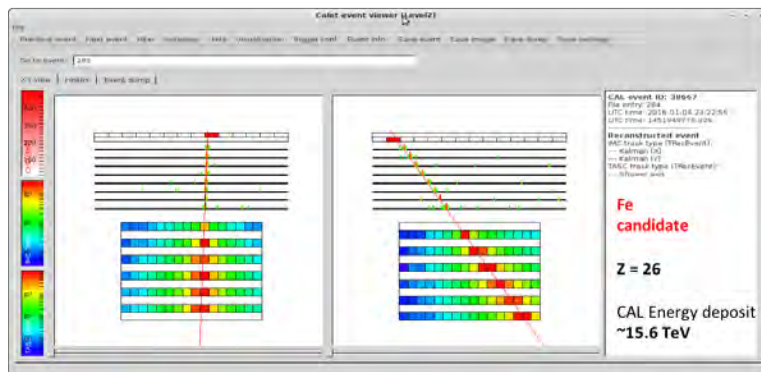
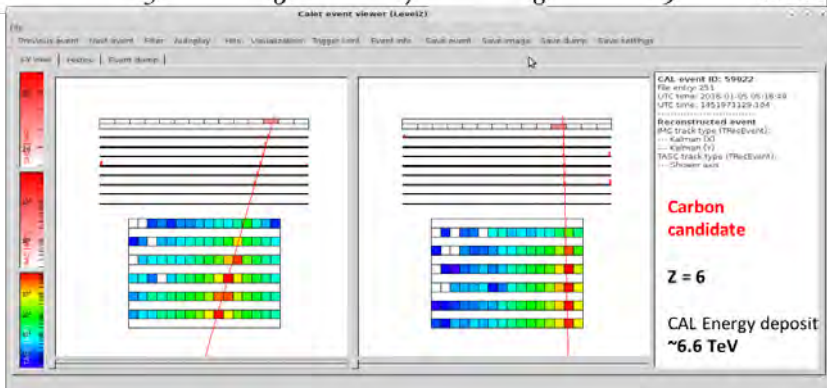
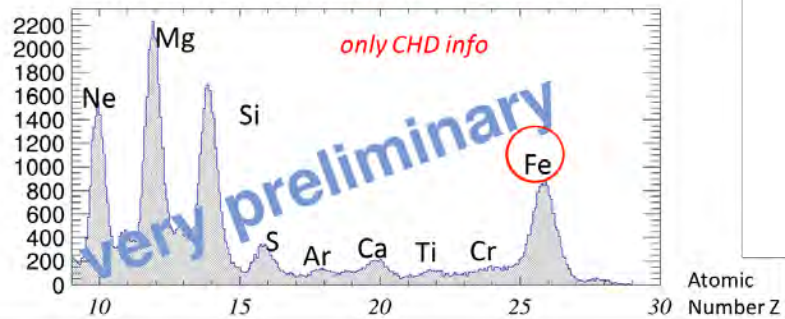
Preliminary Nuclei Measurements – $Z = 3 \sim 40$ –

Charge Identification after pre-selection cuts

data selection is NOT representative of elemental abundances



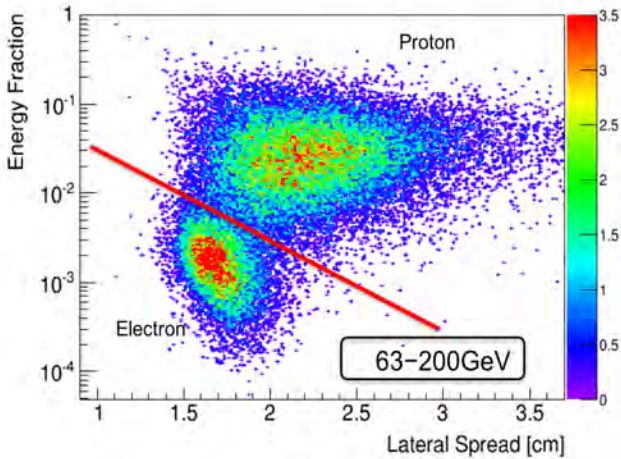
data selection is NOT representative of elemental abundances



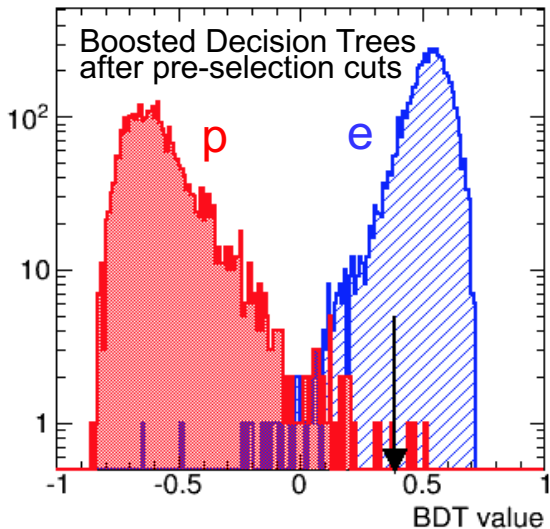


Differential Energy Distribution of the **Electron-Candidates** in 10-1000 GeV by observation for 415 days

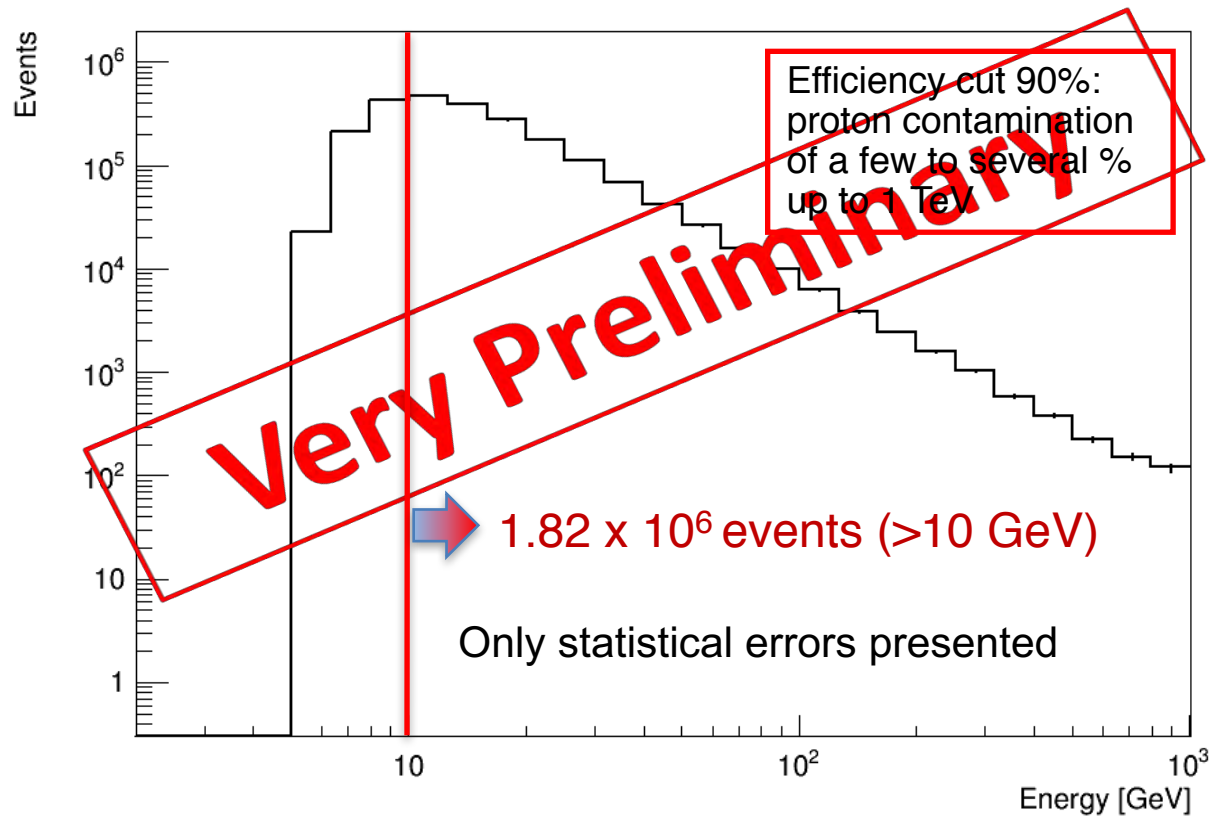
Observation: e/p separation after pre-selection cuts



Simulation: e/p at 1TeV $\sim 1.3 \times 10^5$ with $\sim 90\%$ efficiency for electrons



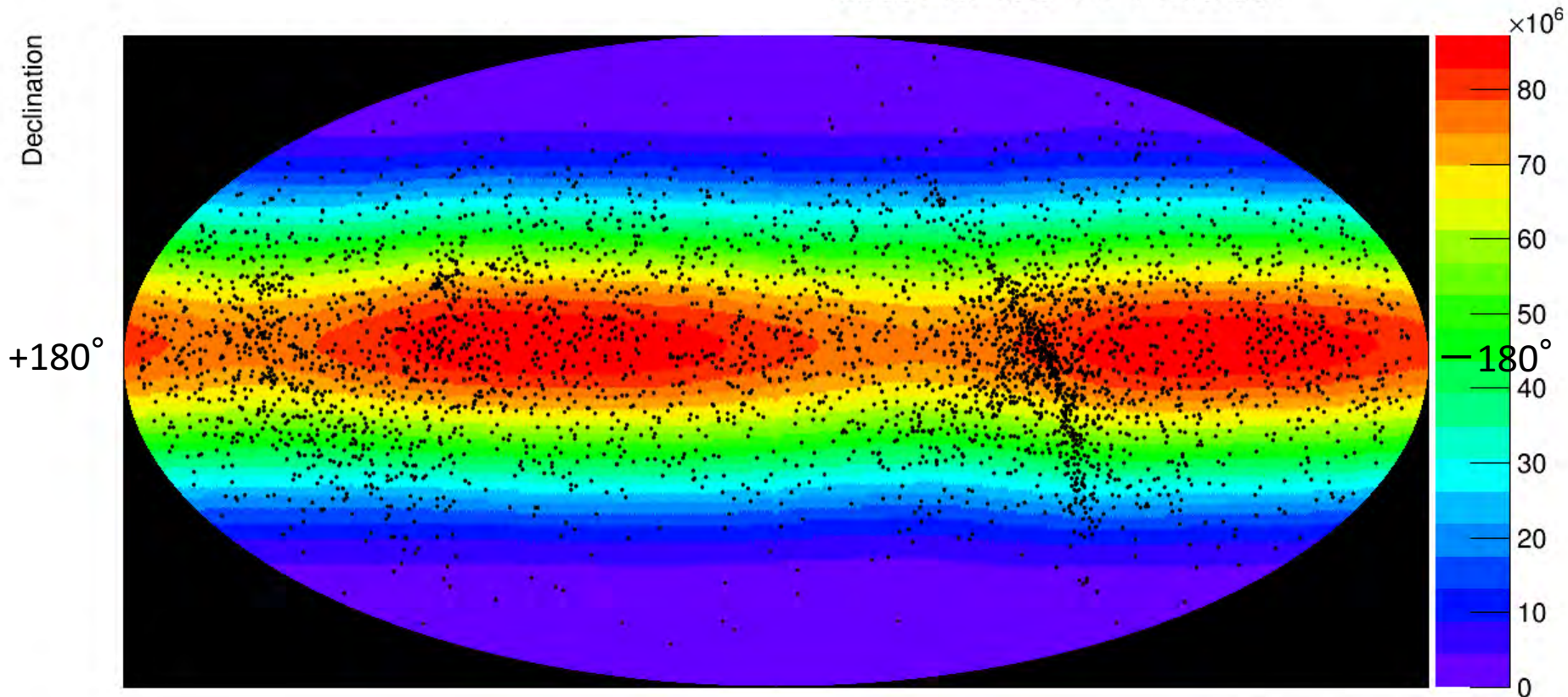
Differential energy distribution reconstructed by using **the electron candidate events** observed in 2015.10.13–2016.11.30



➔ Energies are reconstructed after the calibrations.

Diffuse Gamma-Ray Observation

- Purpose: Sensitivity validation & BG estimation
- Data set: from 151013 to 160531 (232 days)
- Observation Mode: Low Energy Gamma-Ray Trigger



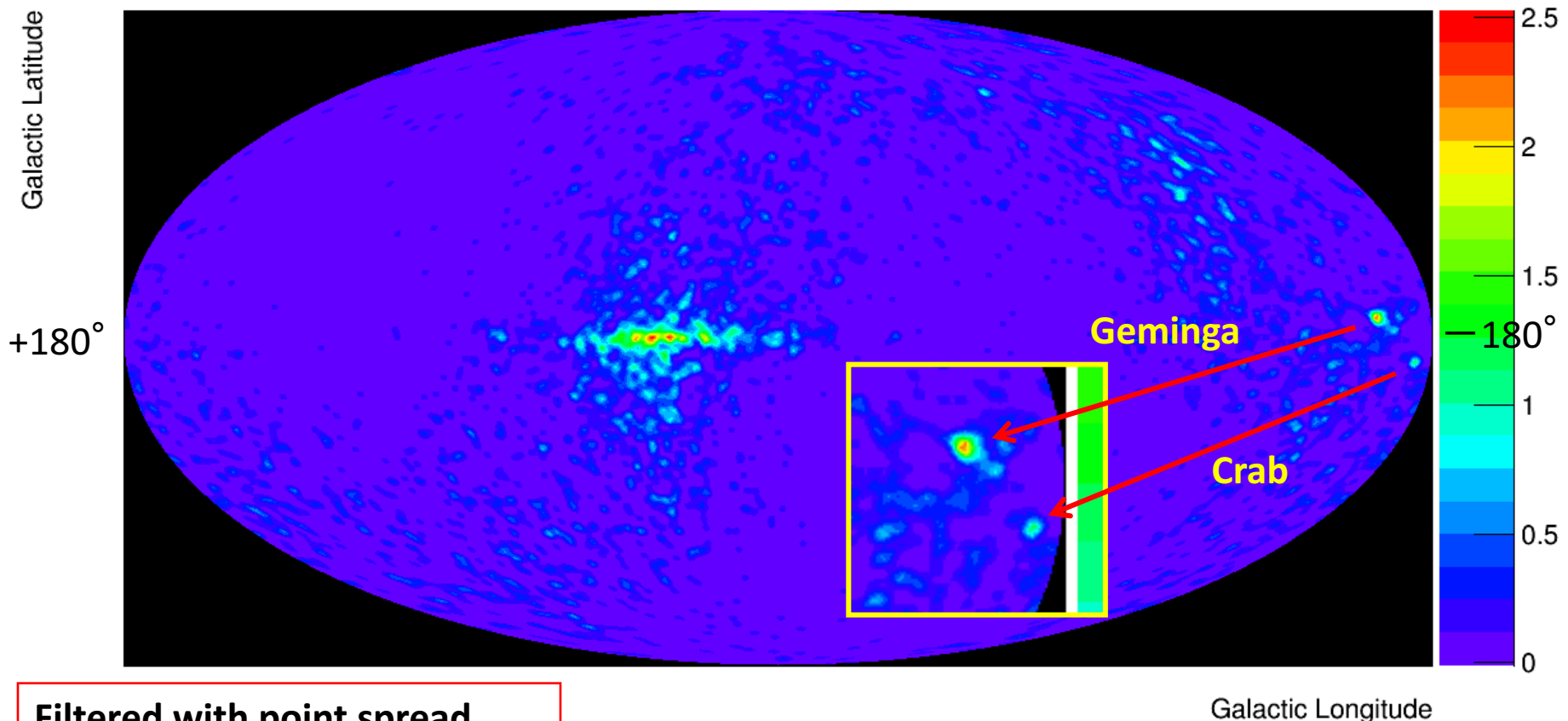
**Black Point: Gamma-ray
event candidates**

**Color Map: Exposure
in 10-12.6GeV in cm^2sec**

Right Ascension

Diffuse Gamma-Ray Observation

- Purpose: Sensitivity validation & BG estimation
- Data set: from 151013 to 160531 (232 days)
- Observation Mode: Low Energy Gamma-Ray Trigger



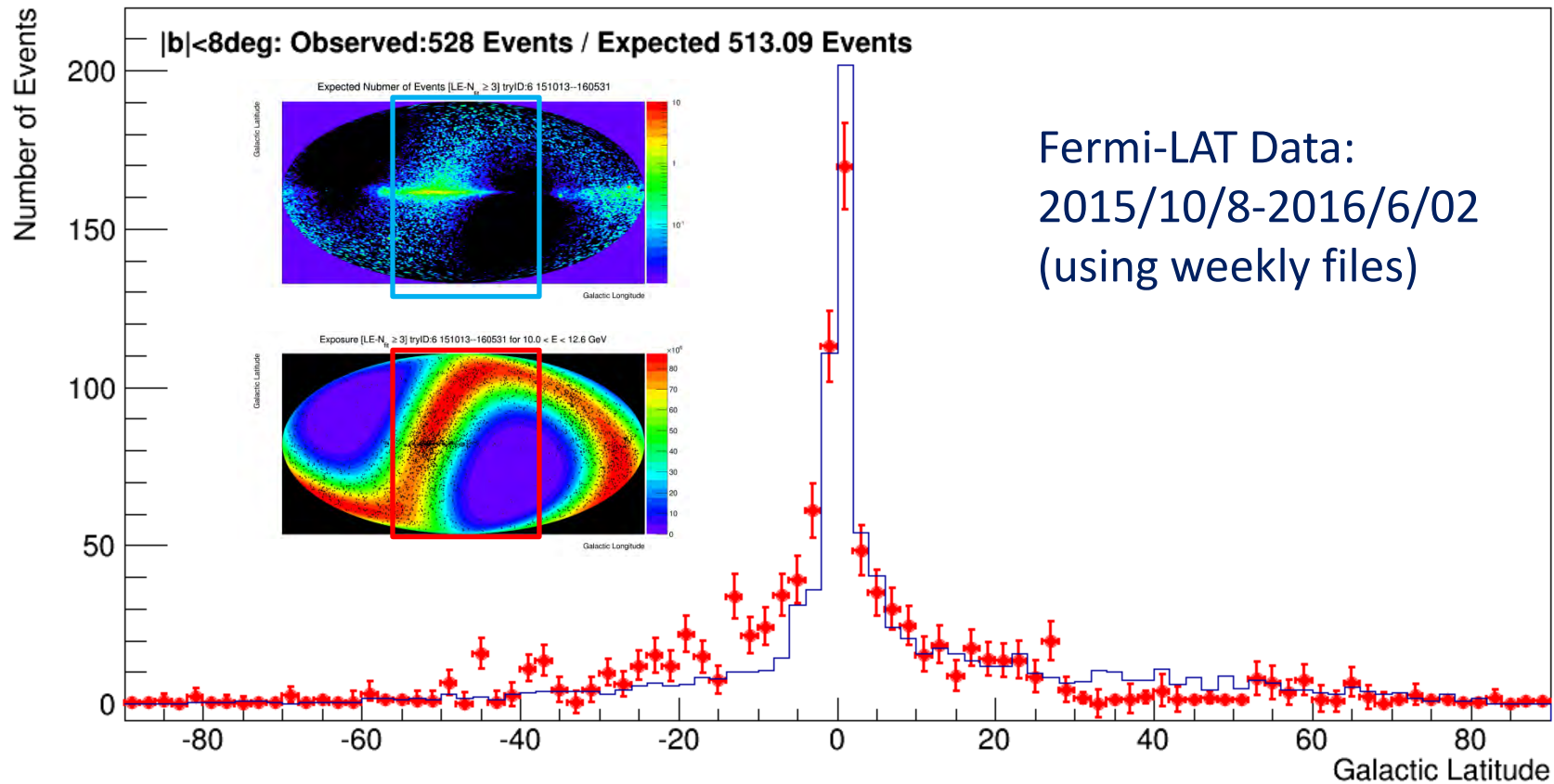
Filtered with point spread functions to see point sources

Geminga and Crab are clearly identified.

Projection to Galactic Latitude ($|l| < 80 \text{deg}$)

And comparison with Fermi-LAT's observation

Galactic Emission [$LE-N_{\text{fit}} \geq 3$] tryID:6 151013--160531 ($|l| < 80 \text{deg}$)



Considering the contribution from point sources, it was actually consistent with expectation. Therefore, it was found that current selection criteria has a validated sensitivity and can be used to set limit on GW counterpart flux.



CALET's first publication NOT for Cosmic Rays

Accepted article online 25 APR 2016

Geophysical Research Letters

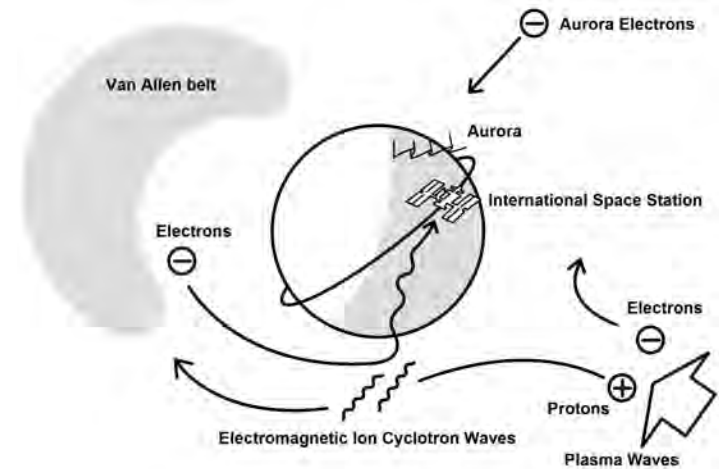
Relativistic electron precipitation at International Space Station: Space weather monitoring by Calorimetric Electron Telescope

Ryoho Kataoka^{1,2}, Yoichi Asaoka³, Shoji Torii^{3,4}, Toshio Terasawa⁵, Shunsuke Ozawa⁴, Tadahisa Tamura⁶, Yuki Shimizu⁶, Yosui Akaike⁴, and Masaki Mori⁷

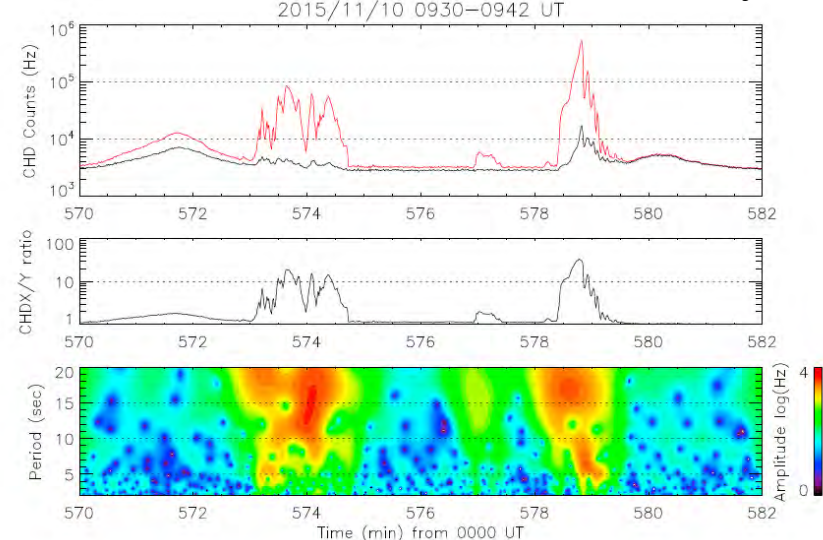
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Abstract The charge detector (CHD) of the Calorimetric Electron Telescope (CALET) on board the International Space Station (ISS) has a huge geometric factor for detecting MeV electrons and is sensitive to relativistic electron precipitation (REP) events. During the first 4 months, CALET CHD observed REP events mainly at the dusk to midnight sector near the plasmapause, where the trapped radiation belt electrons can be efficiently scattered by electromagnetic ion cyclotron (EMIC) waves. Here we show that interesting 5–20 s periodicity regularly exists during the REP events at ISS, which is useful to diagnose the wave-particle interactions associated with the nonlinear wave growth of EMIC-triggered emissions.

Relativistic Electron Precipitation



CHD X and Y count rate increase by REP



Space Weather is now a new topic of the CALET science !!

CALET UPPER LIMITS ON X-RAY AND GAMMA-RAY COUNTERPARTS OF GW 151226

Astrophysical Journal Letters 829 L20, 2016 September 20

The CGBM covered 32.5% and 49.1% of the GW 151226 sky localization probability in the 7 keV - 1 MeV and 40 keV - 20 MeV bands respectively. We place a 90% upper limit of 2×10^{-7} erg cm⁻² s⁻¹ in the 1 - 100 GeV band where CAL reaches 15% of the integrated LIGO probability (~ 1.1 sr). The CGBM 7 σ upper limits are 1.0×10^{-6} erg cm⁻² s⁻¹ (7-500 keV) and 1.8×10^{-6} erg cm⁻² s⁻¹ (50-1000 keV) for one second exposure. Those upper limits correspond to the luminosity of $3\text{-}5 \times 10^{49}$ erg s⁻¹ which is significantly lower than typical short GRBs.

CGBM light curve at a moment of the GW151226 event

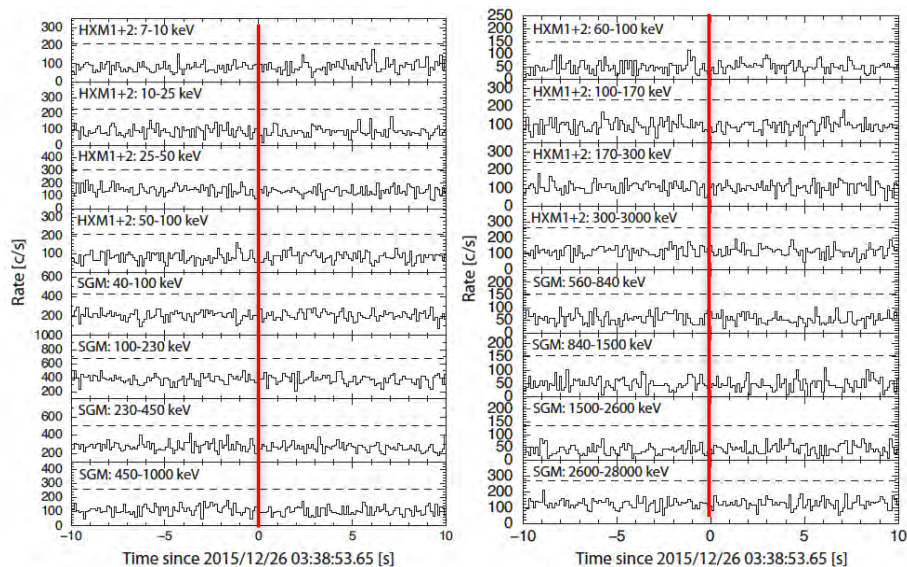


Figure 1. The CGBM light curves in 0.125 s time resolution for the high-gain data (left) and the low-gain data (right). The time is offset from the LIGO trigger time of GW 151226. The dashed-lines correspond to the 5 σ level from the mean count rate using the data of ± 10 s.

Upper limit for gamma-ray burst monitors and Calorimeter

HXM: 7-500 keV

SGM: 50-1000 keV

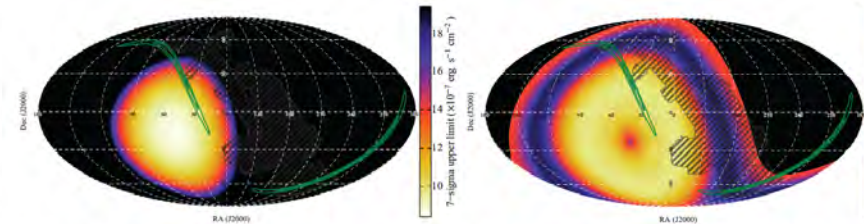


Figure 2. The sky maps of the 7 σ upper limit for HXM (left) and SGM (right). The assumed spectrum for estimating the upper limit is a typical BATSE S-GRBs (see text for details). The energy bands are 7-500 keV for HXM and 50-1000 keV for SGM. The GW 151226 probability map is shown in green contours. The shadow of ISS is shown in black hatches.

Calorimeter: 1-100 GeV

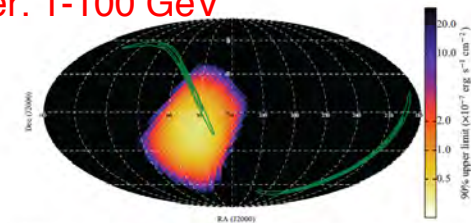


Figure 3. The sky map of the 90% upper limit for CAL in the 1-100 GeV band. A power-law model with a photon index of -1 is used to calculate the upper limit. The GW 151226 probability map is shown in green contours.

under MoU with LVC



まとめと展望

- CALETはTeV領域に及ぶ電子・ガンマ線観測により近傍加速源と暗黒物質の探索を行うほか、陽子・原子核の観測を1000TeV領域まで実施して宇宙線の加速・伝播機構の包括的な解明を行う。さらに、太陽変動やガンマ線バーストのモニター観測を実施する。
- CALET は、2015年8月19日に種子島宇宙センターからHTV5号機に搭載して打ち上げられ、現在まで国際宇宙ステーション日本実験棟「きぼう」の船外実験プラットフォーム#9ポートにおいて、所期の性能を発揮して順調に観測が実施されている。
- 現在早稲田大学CAET Operations Center (WCOC)において、つくば宇宙センター経由でデータ送受信を24時間体制で実施しており、ガンマ線バースト(49events)をふくむ軌道上運用が24時間体制で実施されている。今後は、2年間の観測後にフルサクセスの成功基準達成審査をうけ、その成果により5年間の観測を実現する予定である。
- 現在までに、すでにRelativistic Electron Participatin (REP)の観測や、LIGOが検出した重力波イベントGW151226の電磁波同時観測で成果を上げている。
- 高エネルギー宇宙線の観測においてデータが順調に蓄積されており、データ解析も順調に進展しているので、論文作成を予定している。

本共同研究で実施しているシミュレーション計算はデータの解釈に不可欠であり関係者の皆さんに深く感謝いたします !!