17aEL104-5

Observation of high-energy gamma-rays and gamma-ray bursts by CALET

CALETによる 高エネルギーガンマ線と ガンマ線バーストの観測

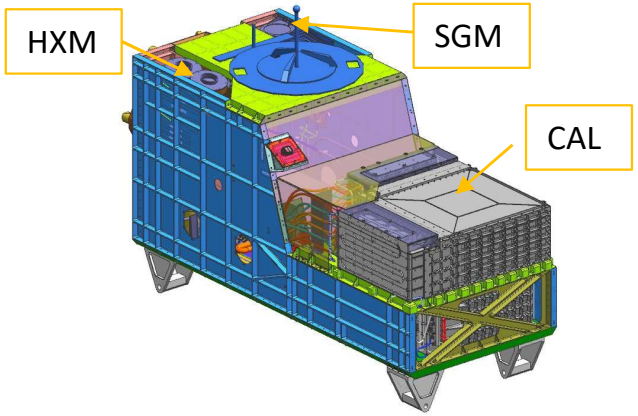
立命館大理工, 青山学院大理工[A], 東大宇宙線研[B], 早大理工総研[C], NASA/GSFC[D], Louisiana State Univ.[E], 他CALETチーム

森 正樹, 川久保雄太[A], 浅岡陽一[B], 鳥居祥二[C], Nick Cannady[D], M.L. Cherry[E], 他CALETチーム

Masaki Mori, for the CALET collaboration

日本物理学会2025年年次大会（広島大学東広島キャンパス）2025年9月16～19日

CALET (CALorimetric Electron Telescope)



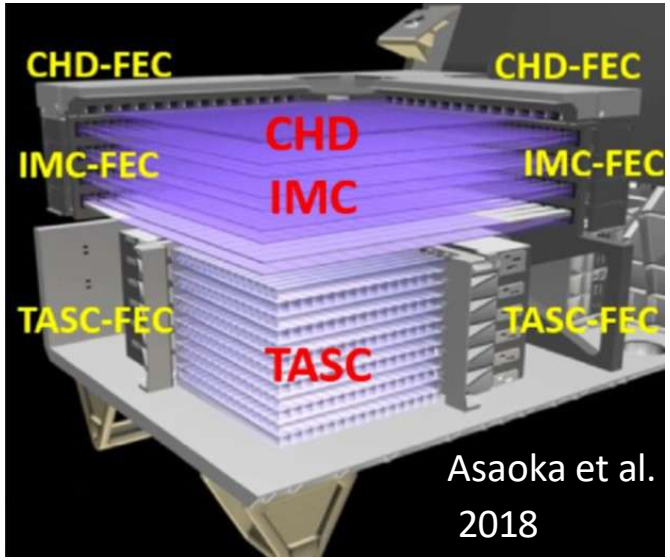
- In operation on the Japanese Experiment Module (JEM) `Kibo'-Exposed Facility of the International Space Station since 2015
- Japan-USA-Italy collaboration

Calorimeter (CAL)

Electrons: 1 GeV - 20 TeV

Gamma rays: 1 GeV – 10 TeV

Protons and nuclei: 10 GeV – 1 PeV



CHD
- charge

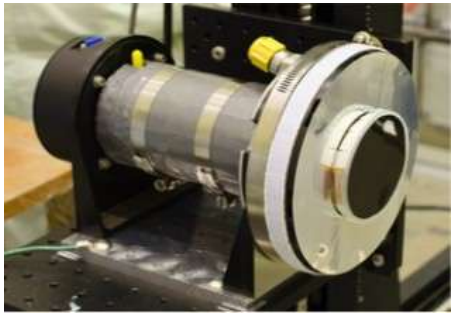
IMC
- tracking
- particle ID

TASC
- energy
- particle ID

High-energy gamma rays

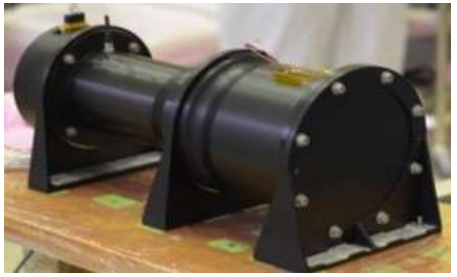
CALET Gamma Ray Burst Monitor (CGBM)

- **Hard X-ray Monitor (HXM)**



7 - 1000 keV
$LaBr_3(Ce)$ + PMT
(2 sets)

- **Soft Gamma-ray Monitor (SGM)**



0.04 – 20 MeV
BGO + PMT
(1 set)

Prompt emission from transients

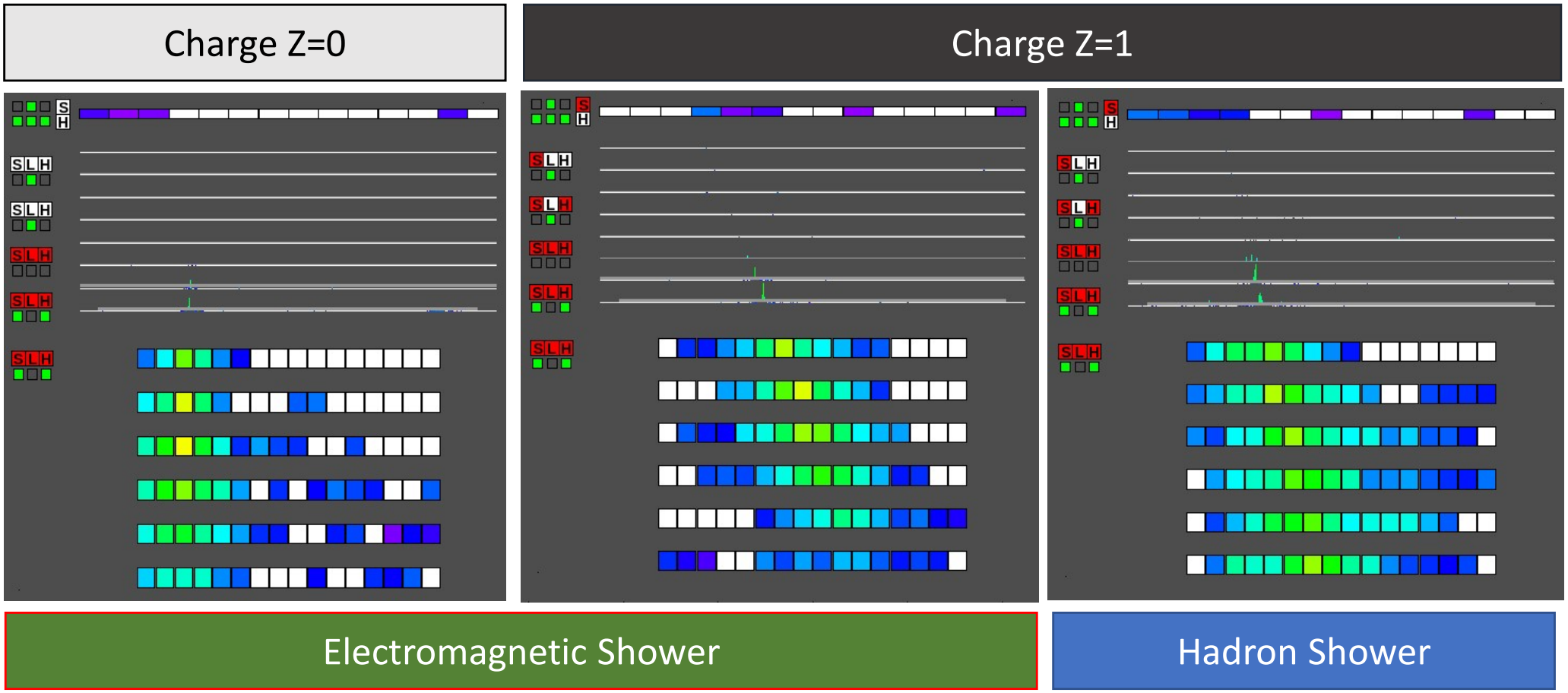
Cannady et al., ApJS 238:5 (2018)

Gamma Ray Event Selection (CAL)

= Electron Selection Cut + Gamma-ray ID Cut w/ Lower Energy Extension

100 GeV Event Examples

gamma-ray | electron | proton



well contained, constant shower development

larger spread

Effective area for gamma rays

Adriani et al., ApJ 933, 85 (2022)

CAL

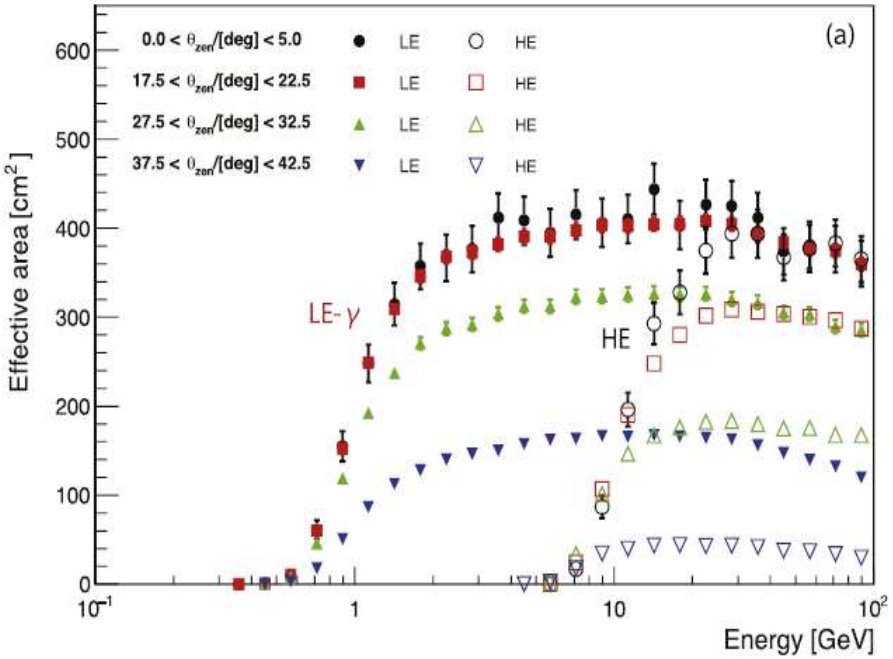


Figure 6. (a) CAL effective area for gamma rays as a function of energy in four zenith angle ranges for both the LEG (CC Track, solid symbols) and HE (EM Track, open symbols) trigger configurations, from Adriani et al. (2018).

CGBM

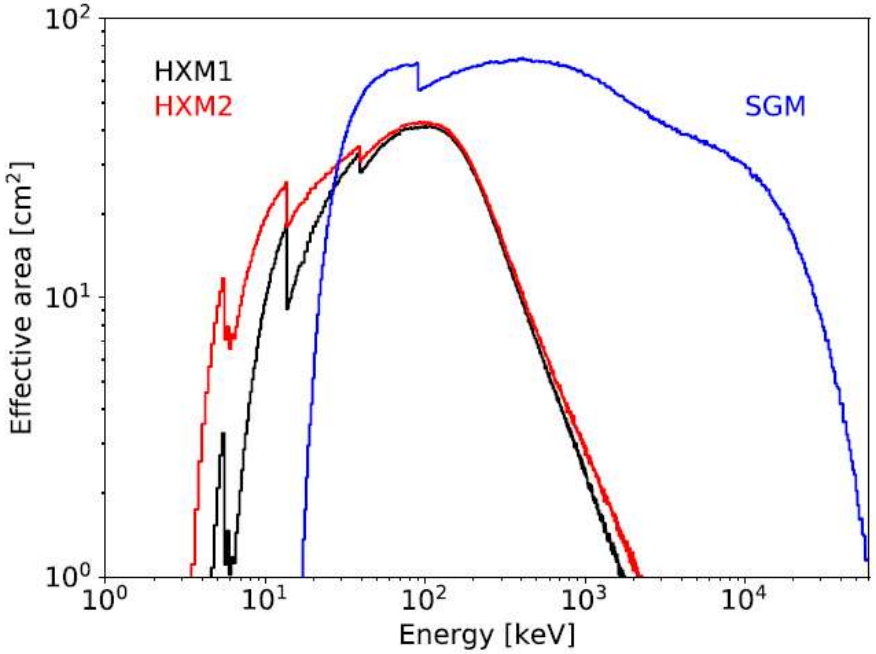
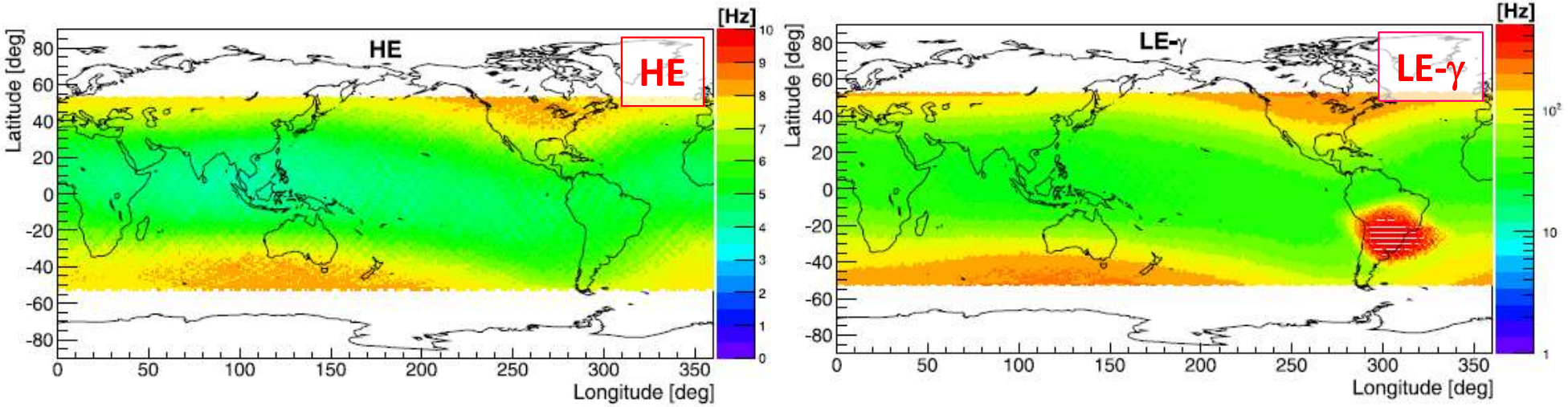


Figure 2. CGBM effective areas vs. gamma-ray energy for the individual HXM1 and HXM2 detectors and for SGM at vertical incidence.

CALET/CAL triggers and gamma-ray observation

Trigger rate vs ISS location

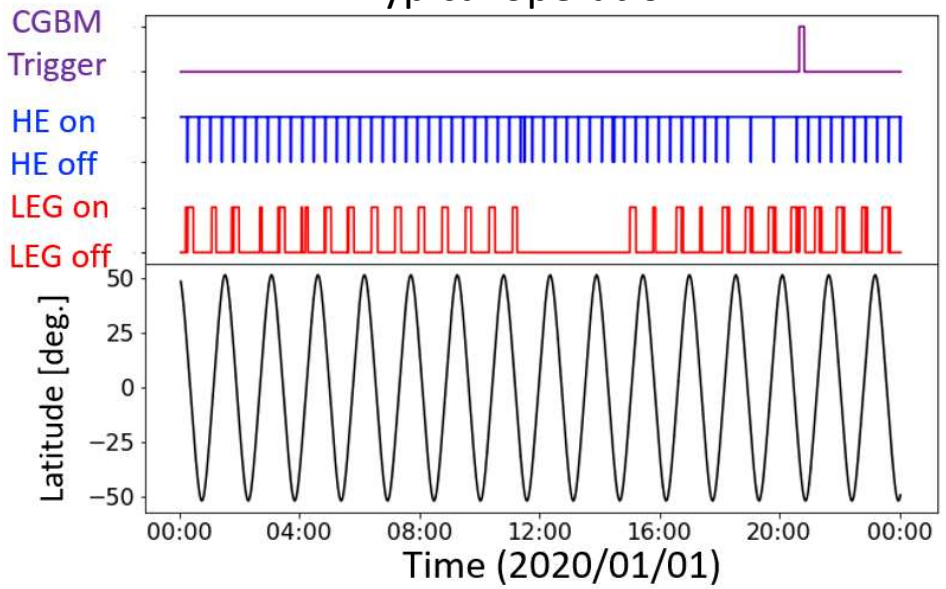
Asaoka et al., Astropart.Phys. 100, 29 (2018)



HE trigger: E_γ > 10 GeV
LE-γ trigger: E_γ > 1 GeV

- HE trigger mode: always ON
- LE-γ mode: ON when geomag.lat. < 20° or CALET Gamma-ray Burst Monitor (CGBM) is triggered

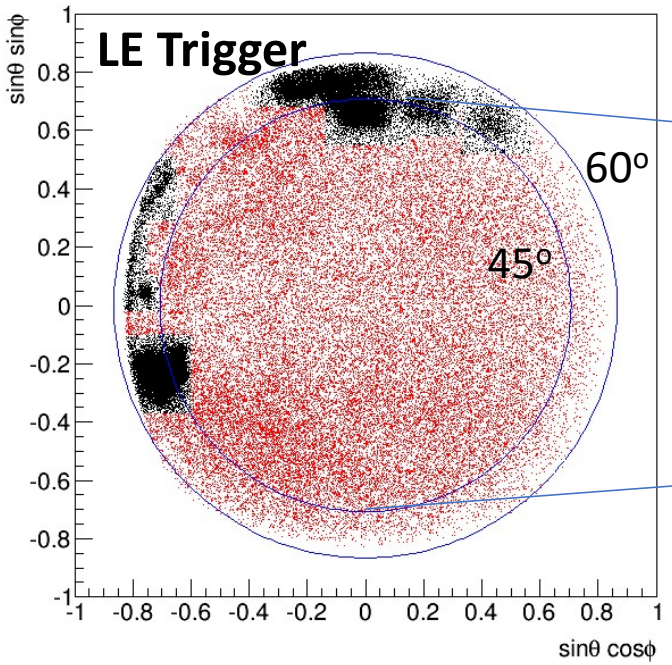
Typical operation



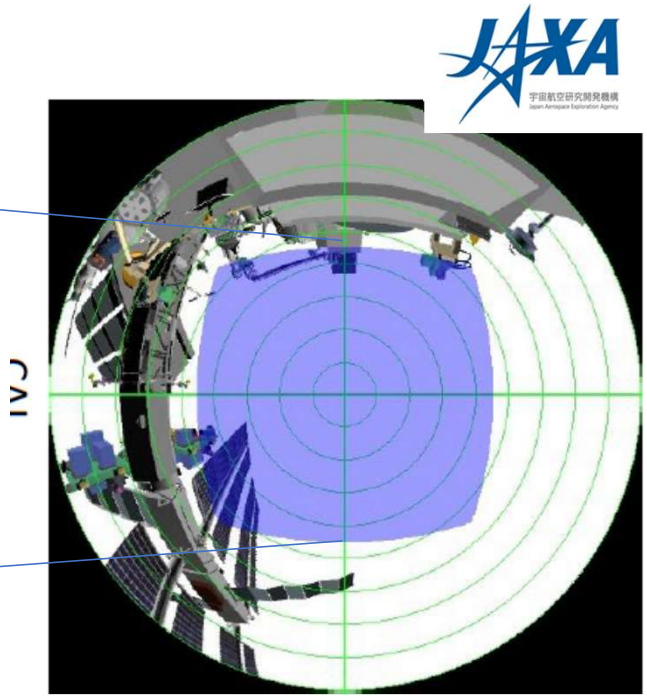
Gamma Ray Event Selection in CAL

= Electron Selection Cut + Gamma-ray ID Cut w/ Lower Energy Extension

It was found that secondary gamma rays produced in ISS structures are dominant source of background.



Gamma-ray candidates in CALET FOV



Fish-eye view of CALET FOV

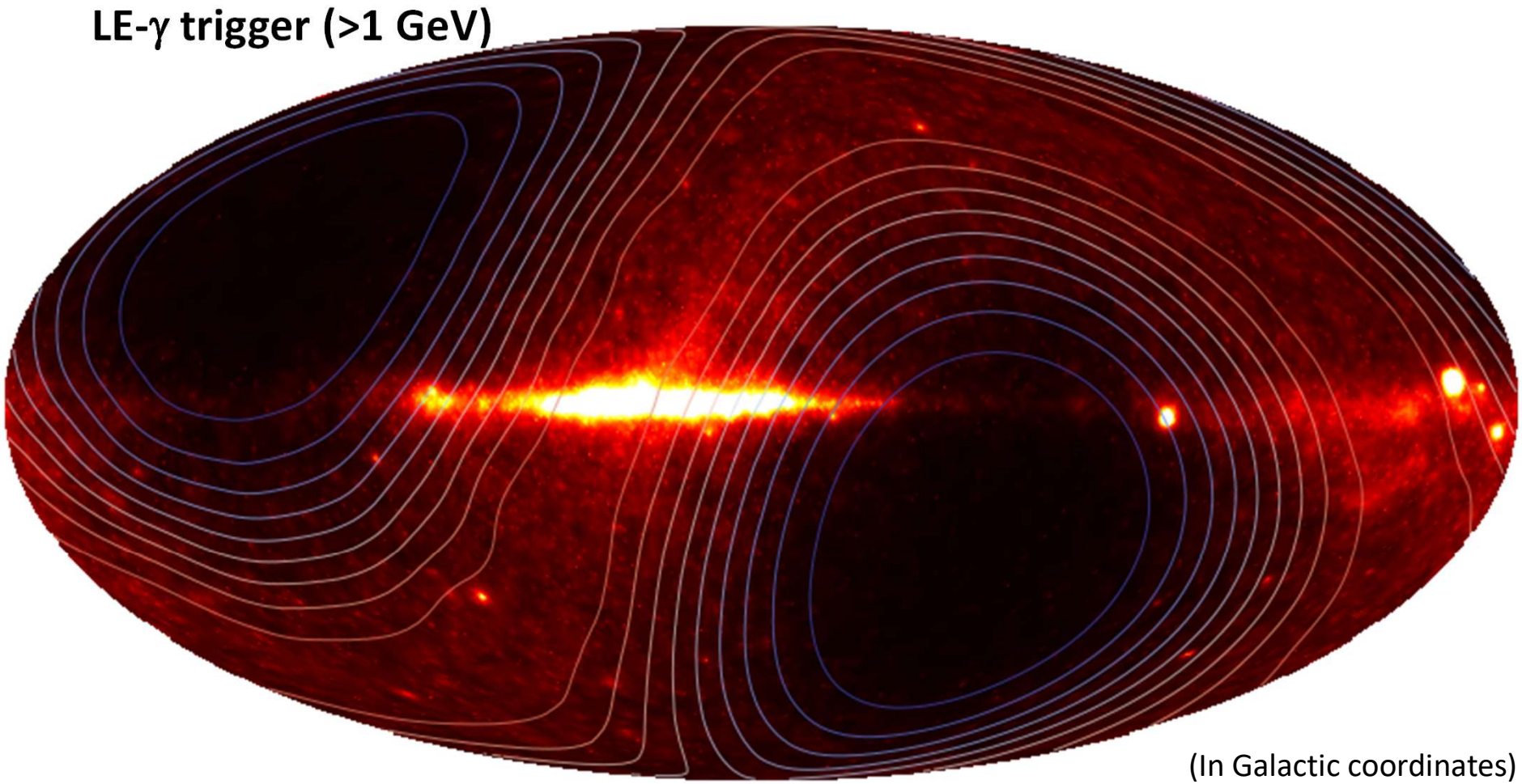
1. Geometry Condition
   - CHD-Top to TASC 1st layer (2cm margin)
2. Preselection
   - Offline trigger
   - Shower concentration
   - Shower starting point
3. Track quality cut
   - Track hits >2
   - matching w/ TASC
4. Electromagnetic shower selection
   - shower shape
5. Gamma-ray ID
   - CHD-veto
6. FOV cut

By removing Black parts, it is possible to reject majority of such background. More sophisticated rejection method is under development.

Gamma-ray skymaps

Preliminary

November 2015 – December 2022



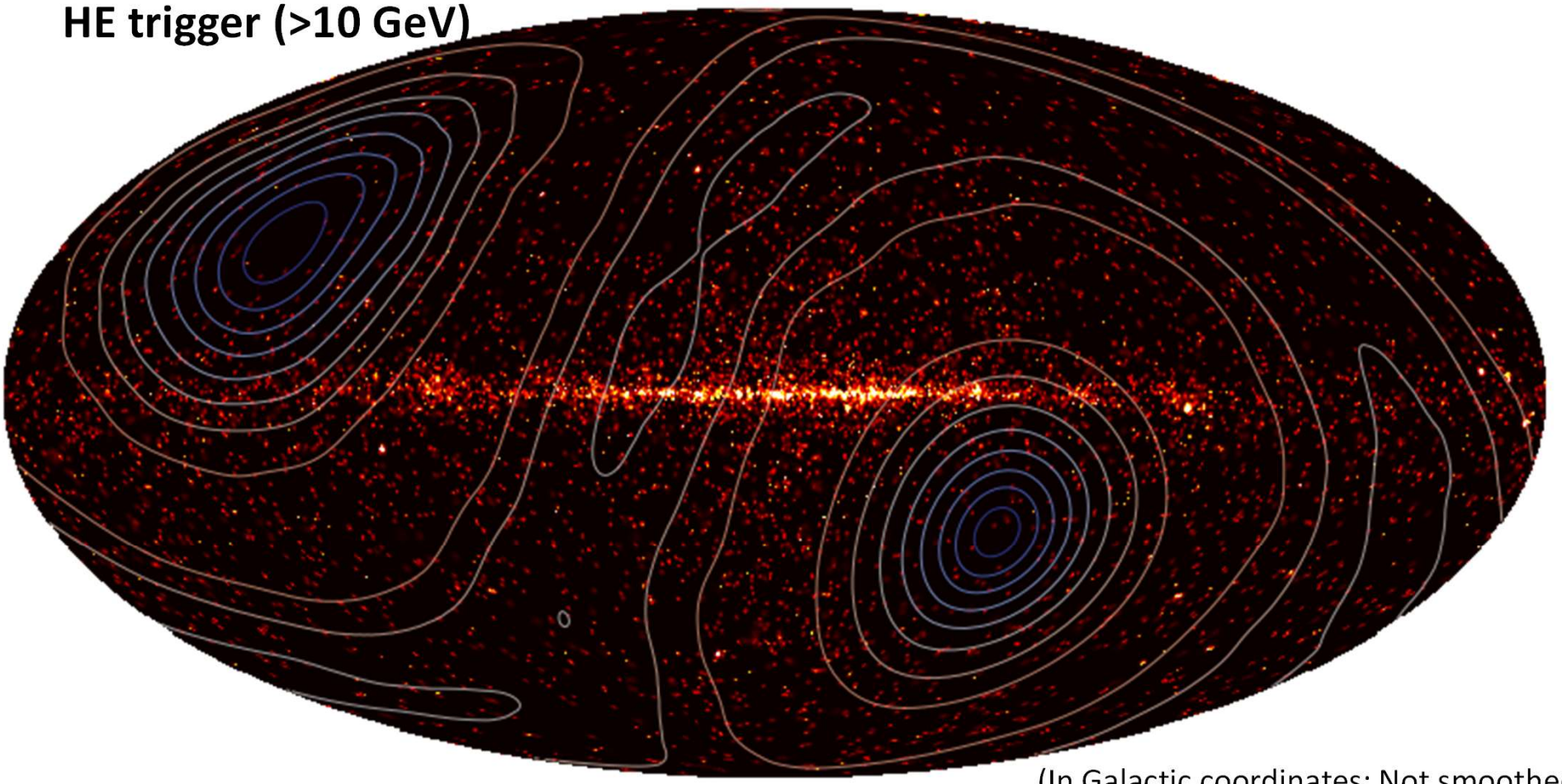
(In Galactic coordinates)

Note: Exposure (shown by contours) is not uniform due to the ISS orbit (inclination 51.6°)

Gamma-ray skymaps

Preliminary

November 2015 – December 2022

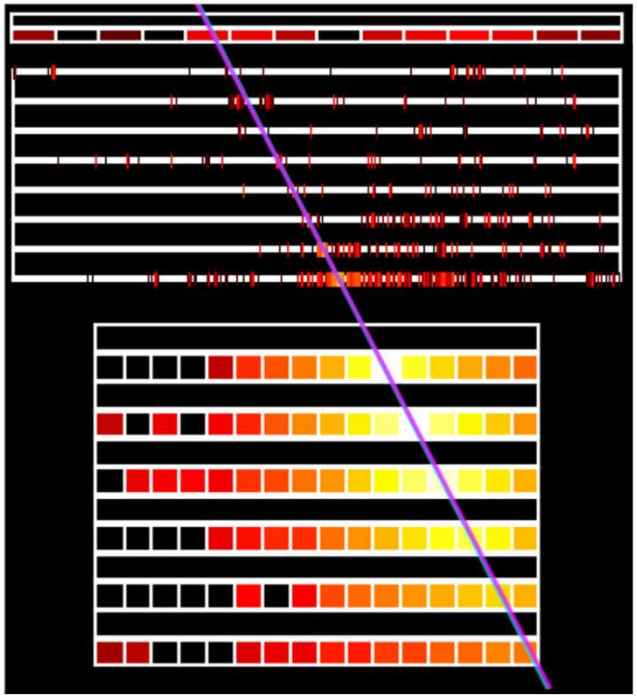


(In Galactic coordinates; Not smoothed)

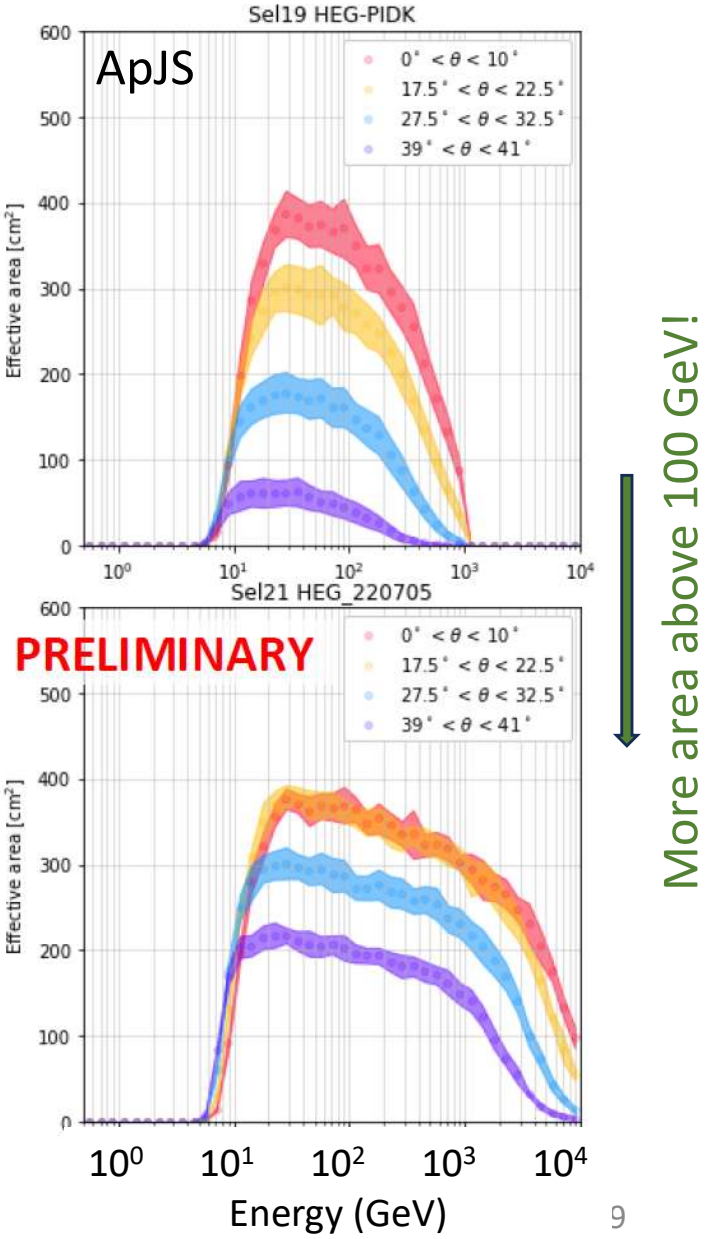
Note: Exposure (shown by contours) is not uniform due to the ISS orbit (inclination 51.6°)

Improvements to HE sensitivity

- At higher energies, charge selection with CHD becomes contaminated with backscattered secondary particles.

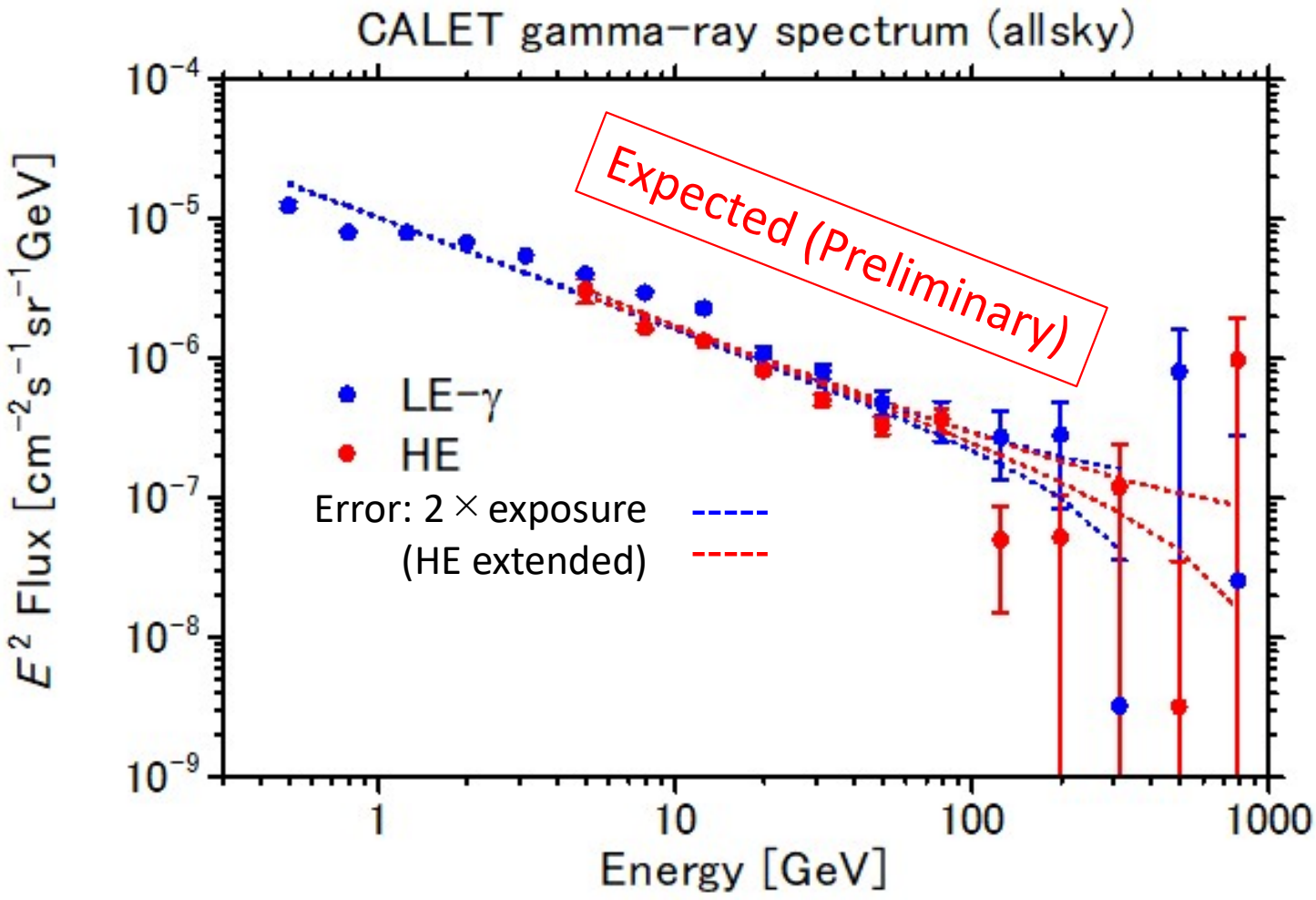


- New selection defined to use looser cuts in CHD and incorporating first two layers of IMC for charged primary rejection
- Preliminary results show significant increase in effective area $E > 100$ GeV
- Testing of selection and contamination being finalized for implementation in all analyses soon!



Gamma-ray spectra will be updated soon!

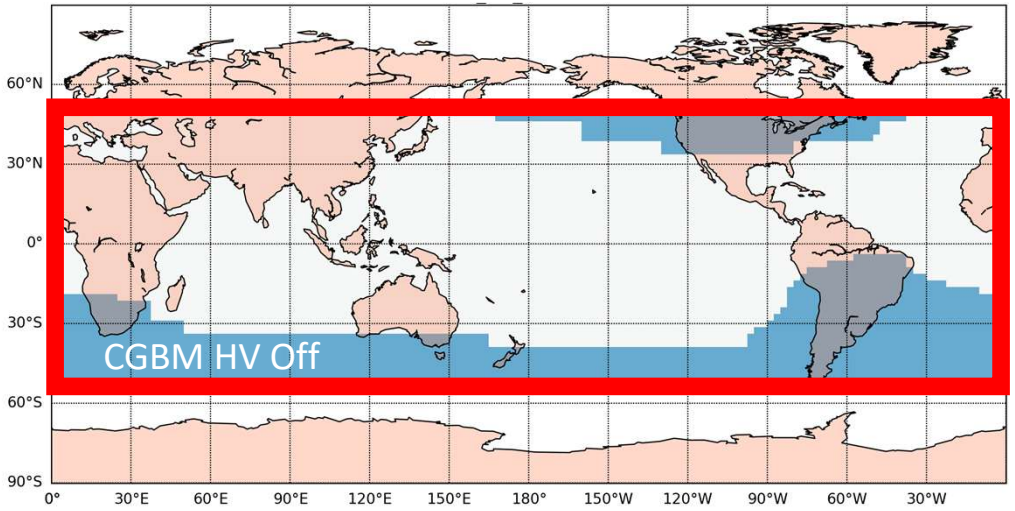
The exposure has increased by 2 times and HE analysis will be updated.



Flight operation of CGBM

CGBM has collected monitor data, and captured event data & alerted onboard triggered events since the observation started in October 2015.

- Collecting monitor data
  - Time History (TH) data
    1/8s, 4 + 4 ch
  - Pulse Height (PH) data
    4s, 102 + 510 ch
  - High voltages are off at high latitude and around SAA



- Onboard trigger & Capturing Event data
  - Calculating signal-to-noise ratio (SNR) every 0.25 s
  - Event data capture
    62.5 μs, 4096 ch x 2
    When SNR exceeds thresholds
  - Event data downlink (3 times/week)

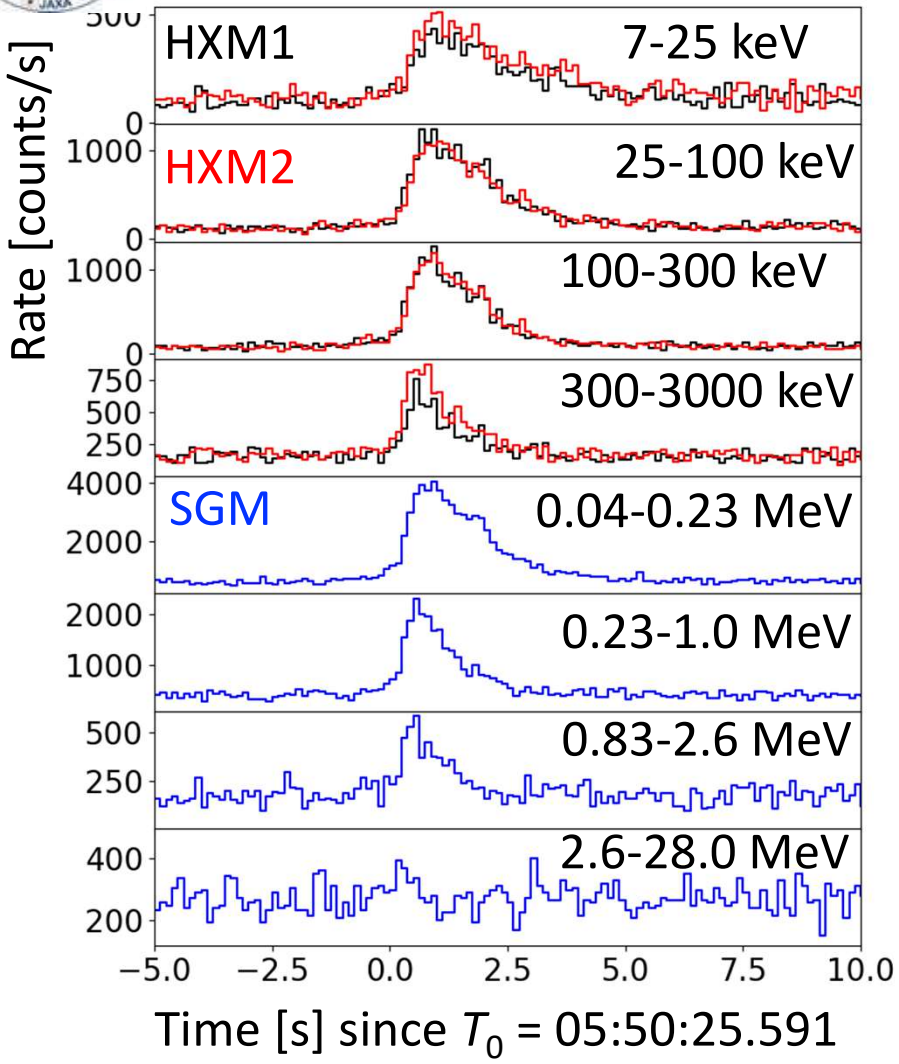
Trigger settings	HXM	SGM
Threshold	8.5 σ	7.0 σ
Energy range	25 - 100 keV	50 – 300 keV

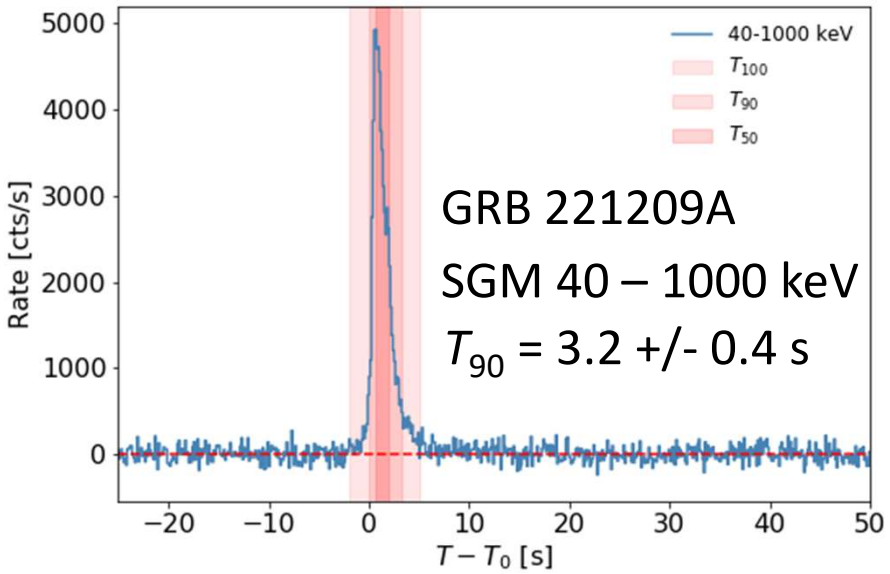
- GCN alert
  - Automatic GCN notice based on real-time TH data (~ 1min)
    TH Light curves are available on the GCN web page (~ 15 mins)
    http://cgbm.calet.jp/cgbm_trigger/flight/
  - GCN circulars and ground processed light curves for confirmed GRBs (~ several days)
    http://cgbm.calet.jp/cgbm_trigger/ground/

GRB observations with CGBM

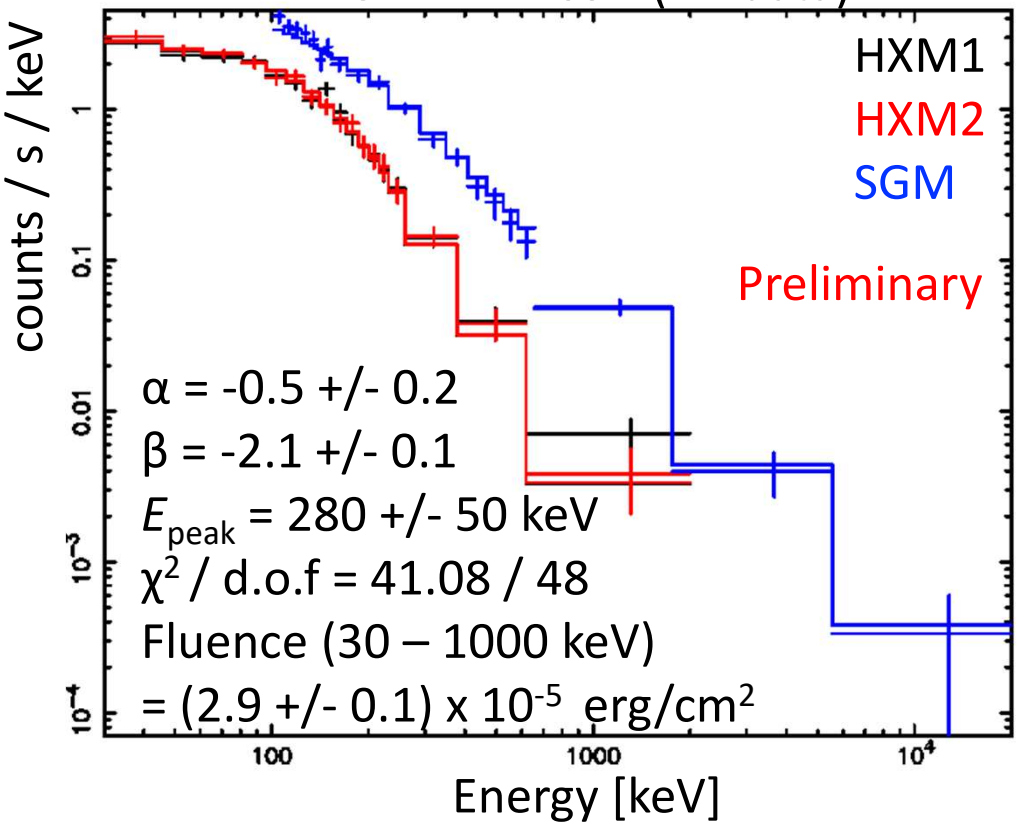
ICRC2025

GRB 221209A (TH data)





GRB 221209A (PH data)



CGBM can observe GRB light curves and spectra in the broad energy bands. CGBM can measure durations and spectral parameters.

Duration distribution of CGBM GRBs

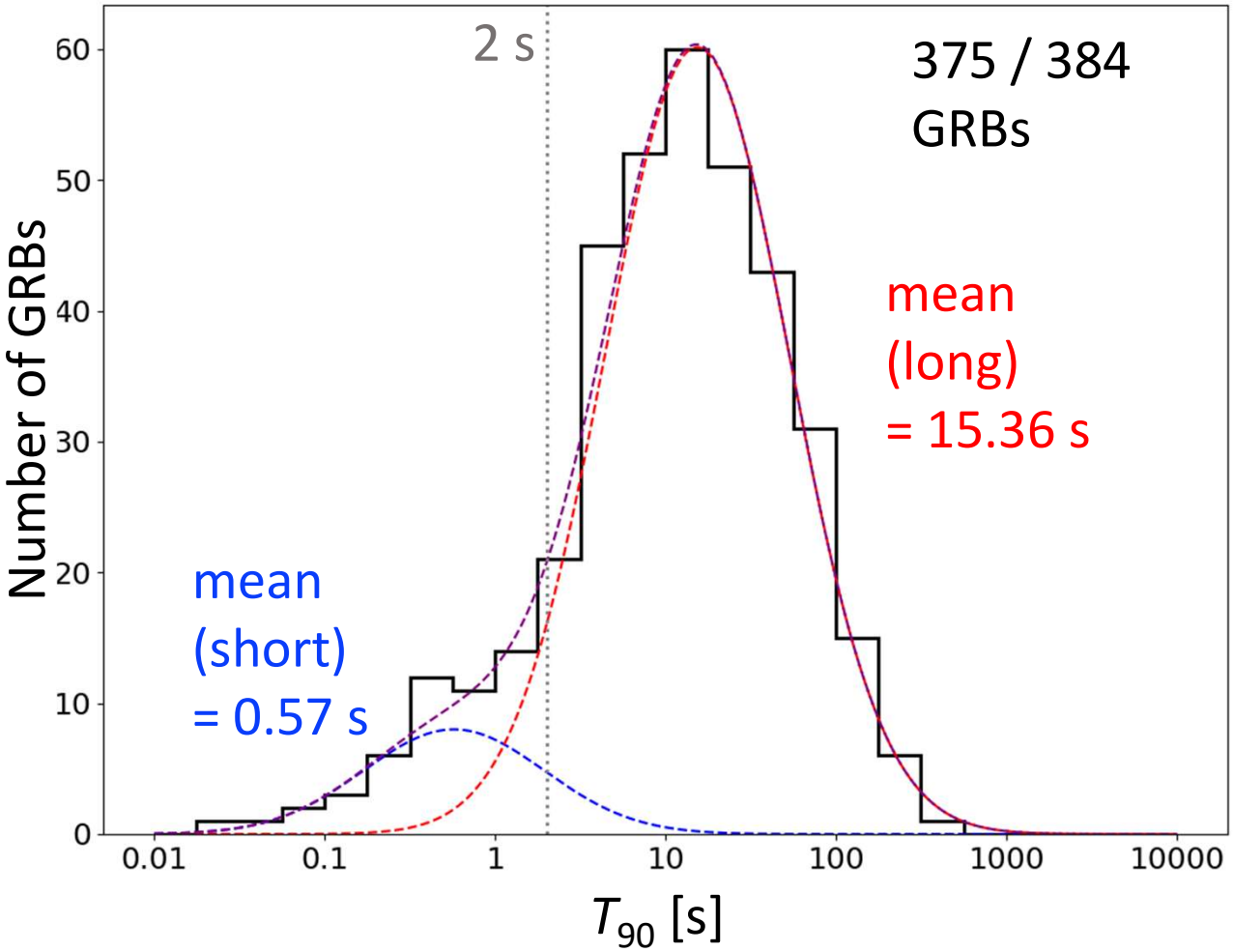
ICRC2025

2015/10/05 ~ 2024/04/30
CGBM has detected 384 GRBs.

T_{90} was measure by SGM in the 40 – 1000 keV bands.

Long ($T_{90} \geq 2$ s): 324 (+9)
Short ($T_{90} < 2$ s): 51

CGBM has observed both long and short GRBs.



T_{90} distribution of CGBM GRBs

In progress & future works:

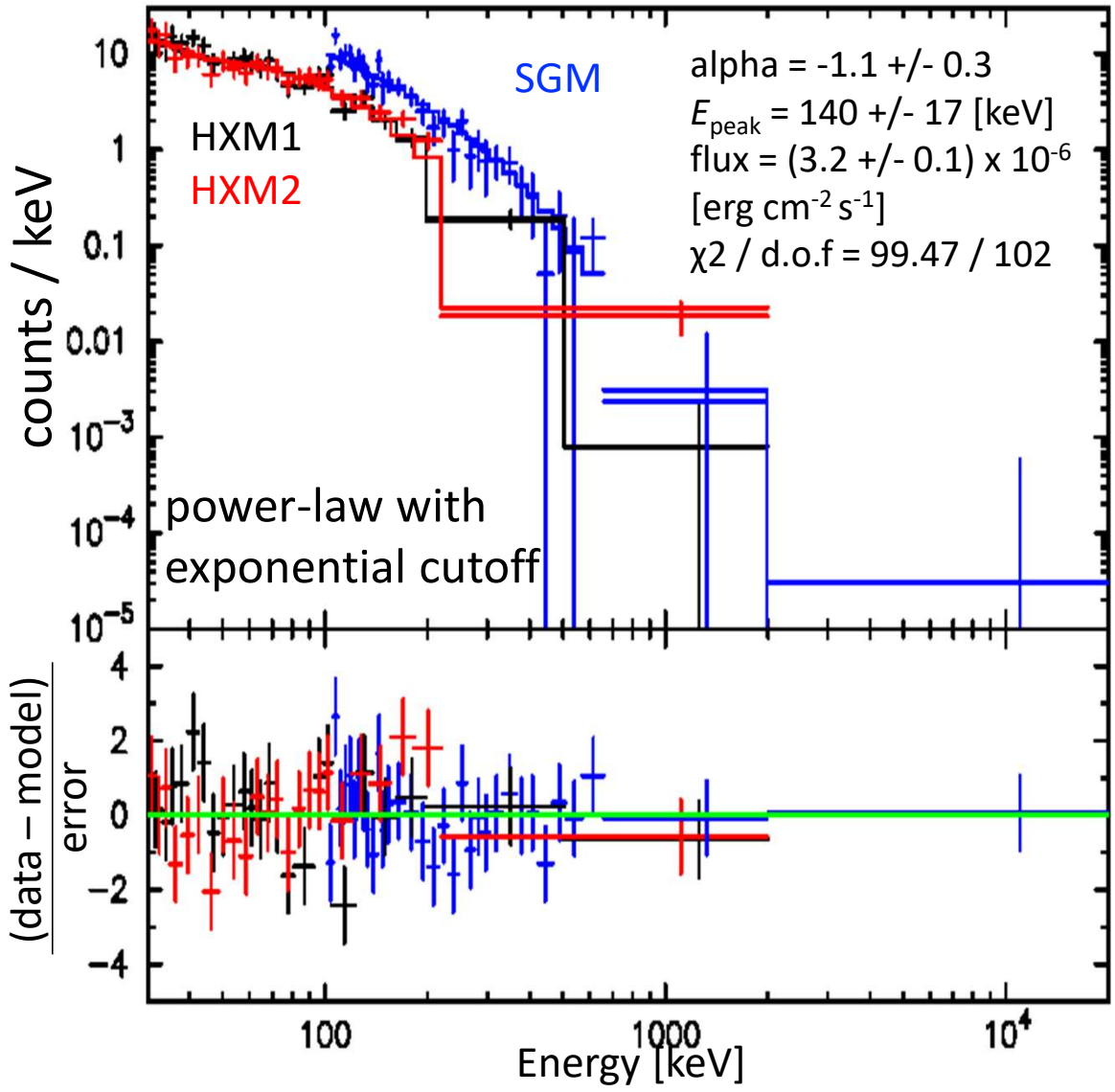
- Flight cross-calibration using GRBs detected by Swift-BAT and CGBM
- Developing HEASARC archive data
- Systematic analysis for the CGBM GRB catalog using HEASARC archive data

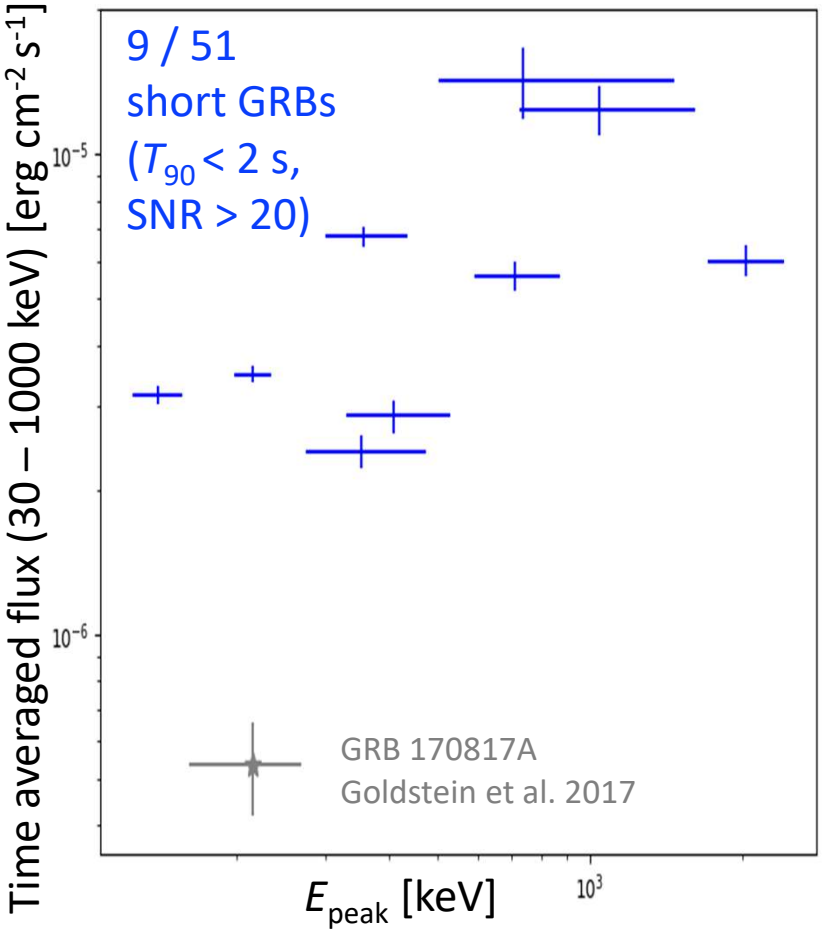
Analysis of short GRBs

Possible electromagnetic counterparts of binary NS mergers

ICRC2025

Example: Time averaged spectra of GRB 180703B

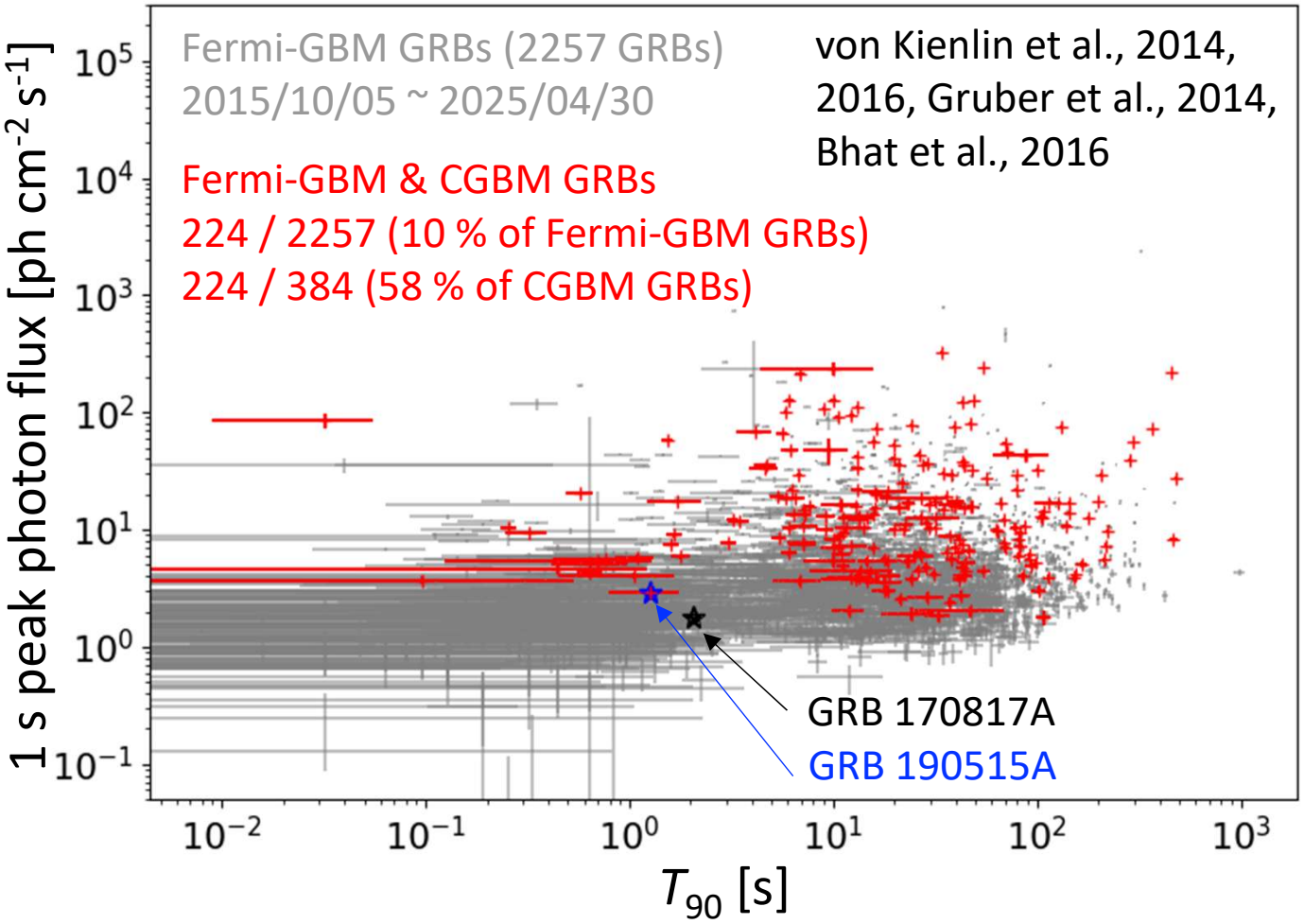




Distribution of time- averaged flux and E_{peak} assumed power-law with exponential cutoff. CGBM detected short GRBs, of which E_{peak} is comparable to GRB 170817A. CGBM requires a flux several times higher than that of GRB 170817A to determine spectral parameters.

CGBM GRBs vs Fermi-GBM GRBs

Distribution of 1 s peak photon flux and T_{90} observed by Fermi-GBM



CGBM has detected GRBs in the high-flux region of Fermi-GBM GRBs.

GRB 190515A was the lowest flux short GRB in GRBs, which was detected in both Fermi-GBM and CGBM. Even the flux of GRB 190515A is twice as high as that of GRB 170817A. Although the detection sensitivity depends on the spectrum of GRB, CGBM needs a few times as high as the flux of GRB 170817A for onboard detection.

During O4, CGBM has been operated and collected data as usual. As of the end of April 2025, 208 significant GW events were reported by LIGO/Virgo/KAGRA. We developed an automated pipeline for targeted searches of GW events in O4 to handle the numerous alerts from LIGO/Virgo/KAGRA. The pipeline calculates SNRs over $T_0 \pm 60$ s in various conditions across energy bands and time intervals.

Summary

- CALET/CAL and CGBM are monitoring the gamma-ray sky continuously since 2015.
- CAL observes gamma rays above 1 GeV and tens of point sources are detected.
- Improvement to increase effective area of CAL above 100 GeV is ongoing.
- CGBM has observed 384 GRBs (2015 Oct-2024 Apr)
- Out of them, 51 short GRBs have been detected.