Analysis of the Galactic Center Excess with CALET Data

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For the CALET Collaboration

The CALET Collaboration as of Jan. 2026

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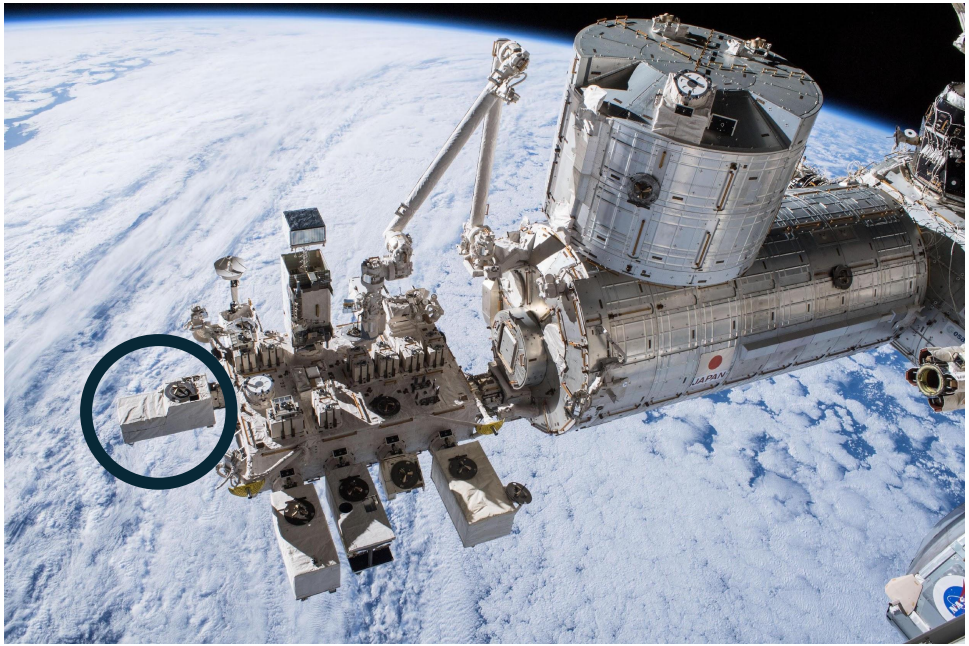
The Goal: GeV Galactic Center Excess

- Observed with high significance in Fermi-LAT data
- SED peak generally found between 1-3 GeV
- Possible Explanations
  - Emission from millisecond pulsars
    - Too faint for LAT to detect as point sources
  - Emission from Dark Matter annihilation
    - Annihilation channels correspond to DM mass

CALET

- CALorimetric Electron Telescope
- ISS JEM-EF, data collection began November 2015
- Two payloads
  - Calorimeter (CAL)
  - CALET Gamma-ray Burst Monitor (CGBM)

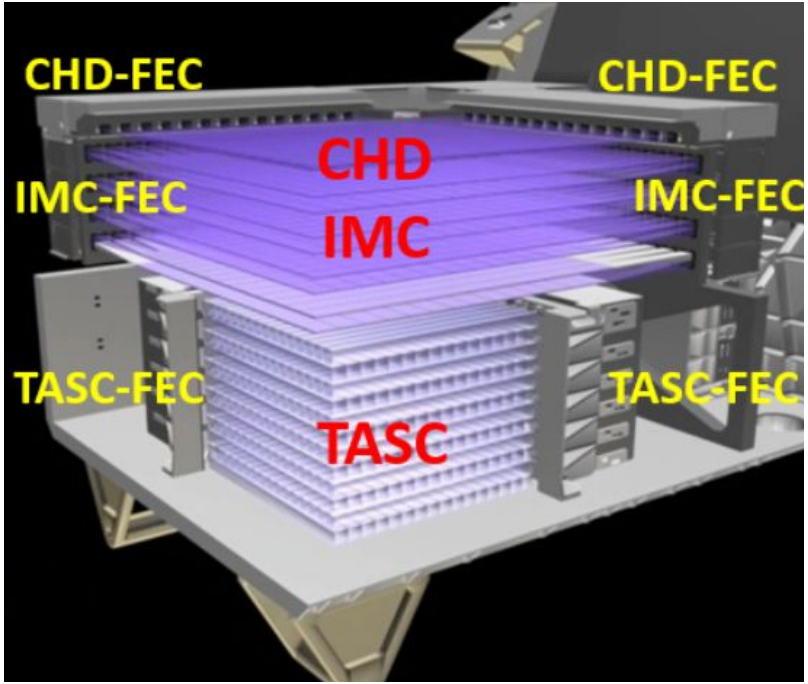


CAL

CHD: Charge Detector
- Charge measurement

IMC: Imaging Calorimeter
- Direction measurement
- Particle identification

TASC: Total Absorption Calorimeter
- Energy measurement
- Particle identification

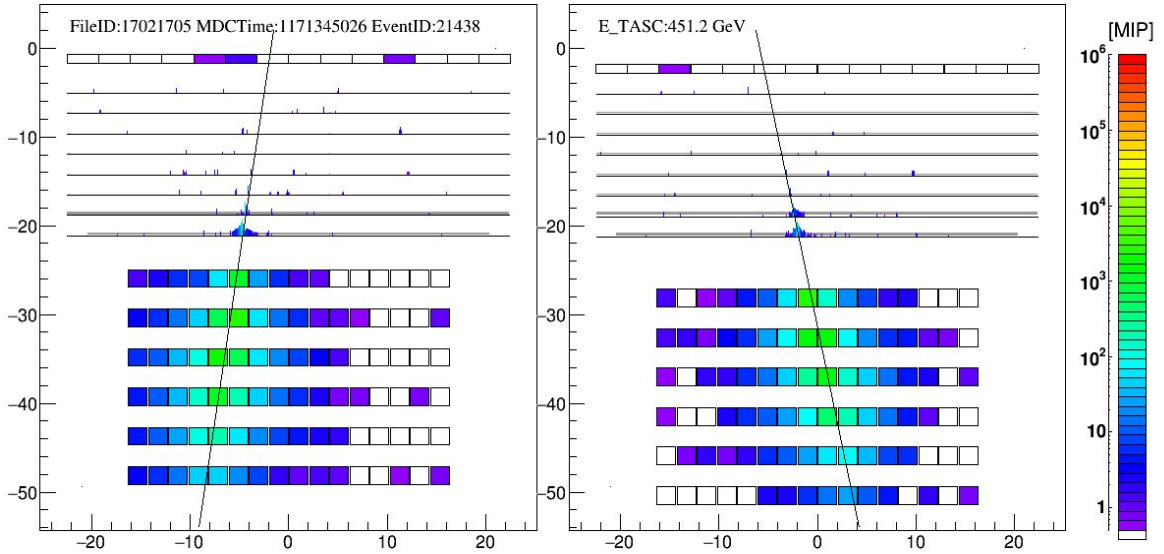


IMC + TASC: 30 electron radiation lengths

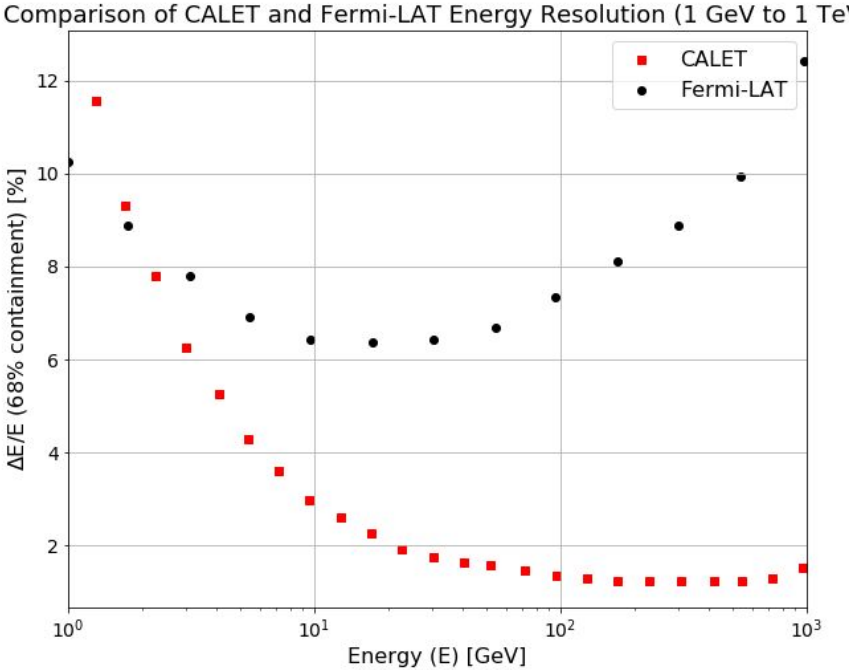
CAL

Low-Energy γ Trigger: Activated at geomagnetic latitudes below 20° (including SAA). Covers >1 GeV

High-Energy Trigger: Always activated. SAA has minimal impact due to high threshold. Covers >10 GeV



Comparisons With Fermi-LAT



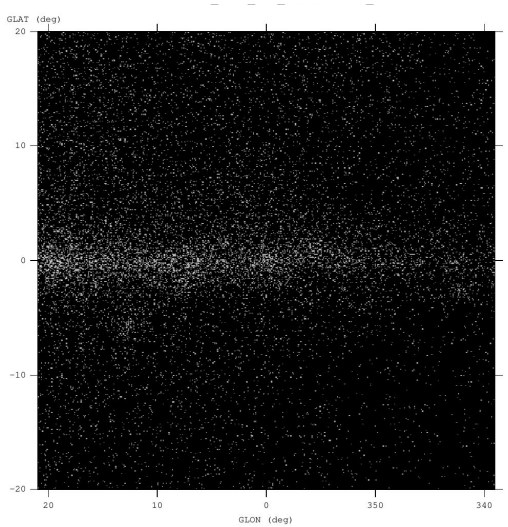
	Fermi-LAT	CAL
FOV (sr)	~2	~<2
Effective Area (cm^2)	~9000	~400
Operational Time (yrs)	17	10
Angular resolution (deg)	~<1 at 2GeV	~1 at 2GeV
	~0.1 at 20GeV	~0.2 at 20GeV
	0.1 at 100GeV	~<0.2 at 100GeV

Fermi-LAT: Pass 8 P8R3_SOURCE_V3, total
CALET: Cannady et al. 2018

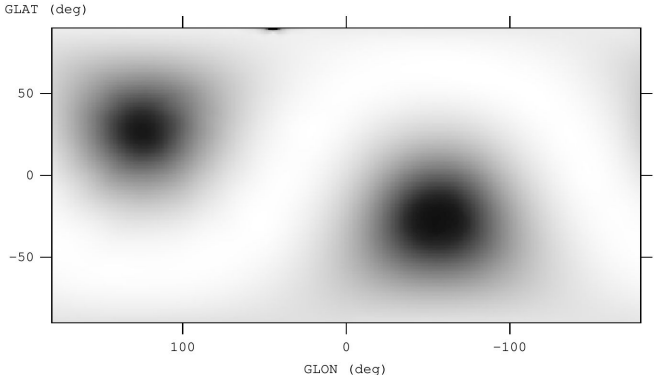
Energy resolution as a function of energy for CALET, including calibration errors (Asaoka et al. 2017), and Fermi-LAT (Pass 8 P8R3_SOURCE_V3, total).

Integration With FermiPy

- CAL data is stored in ROOT files, LAT data is stored in FITS
- 3 CAL files must be added:
  - CAL IRFs
  - CAL counts cube
  - CAL exposure cube
- All 3 match their LAT counterparts in terms of binning and FITS headers so the comparison between CAL and LAT can be as direct as possible



1-10 GeV CAL counts map centered on GC



CAL all-sky exposure map

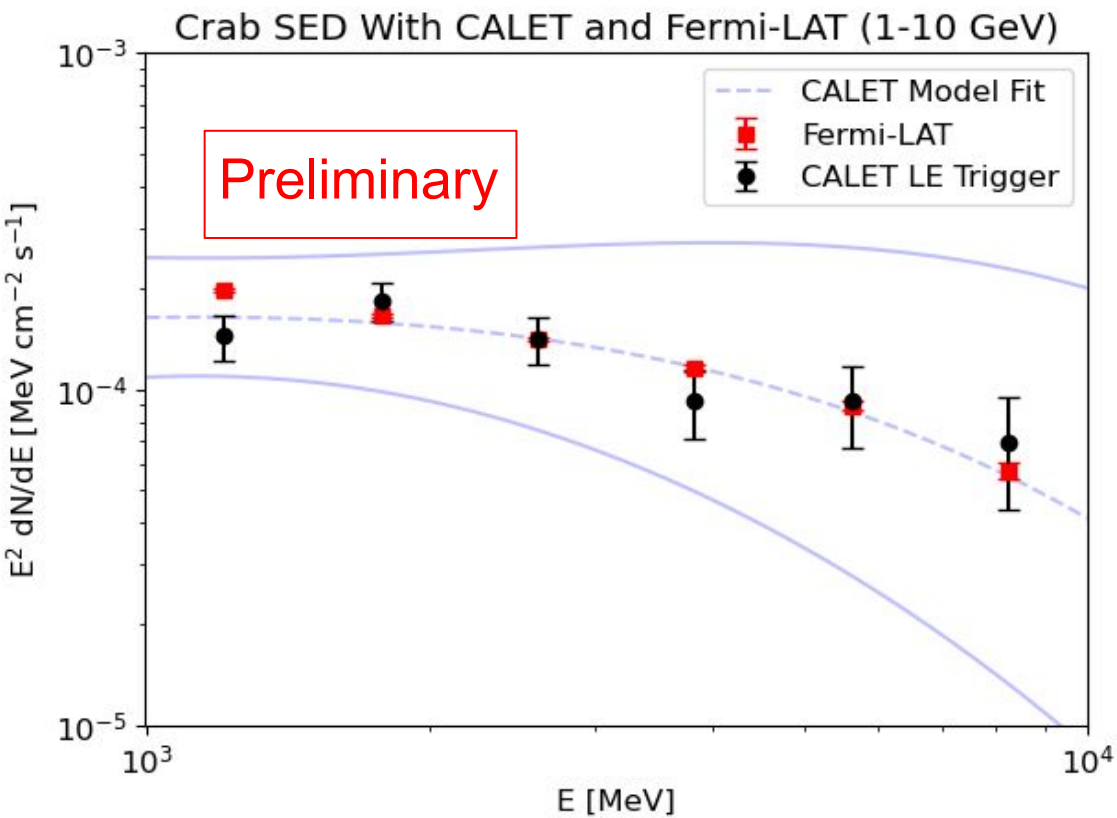
Analysis

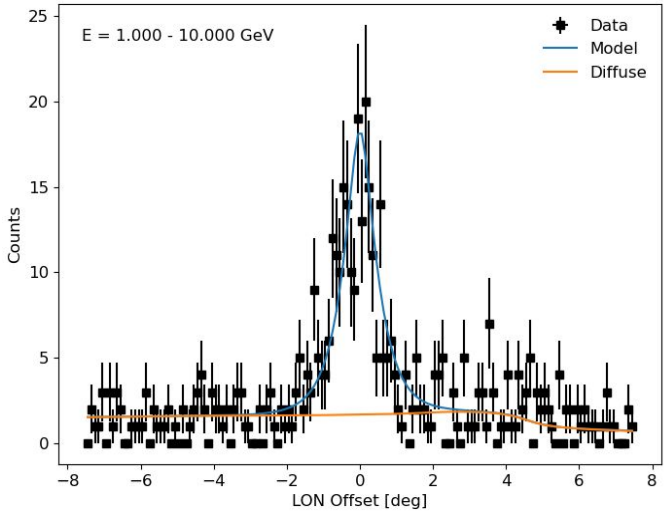
- 1–10 GeV, 6 bins per decade
- Time range: 2015 November 02 to 2022 December 31
- ROI: 15° around source
- GTAnalysis:
  - gta.setup(): Data selection. For CAL this is used to make source maps
  - Free the norm of all sources within 3° of the ROI center
  - Free all parameters of the isotropic and galactic diffuse (gll_iem_v07) components as well as the source under study.
  - gta.fit(): returns the best-fit SED parameters and the full covariance matrix

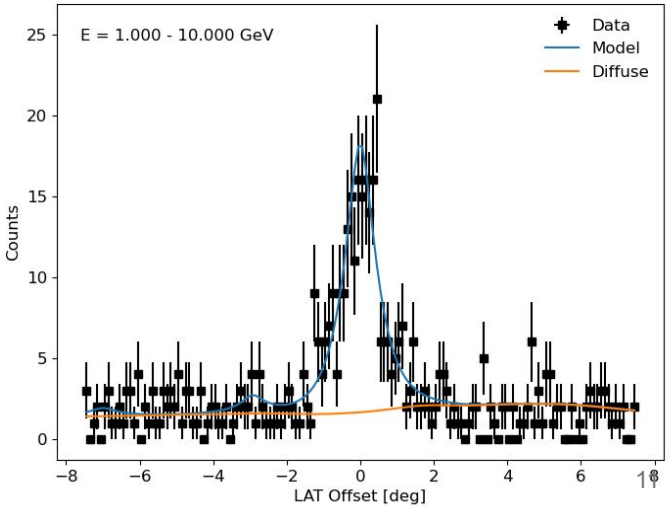
Analysis (Cont.)

- Diagnostic plots can be generated after the fit
  - Counts map
  - Offset of data from source position in Galactic longitude and latitude. Source position is set to 0
- SEDs are plotted to check for consistency between Fermi-LAT and CALET
  - Error bars do not include systematics

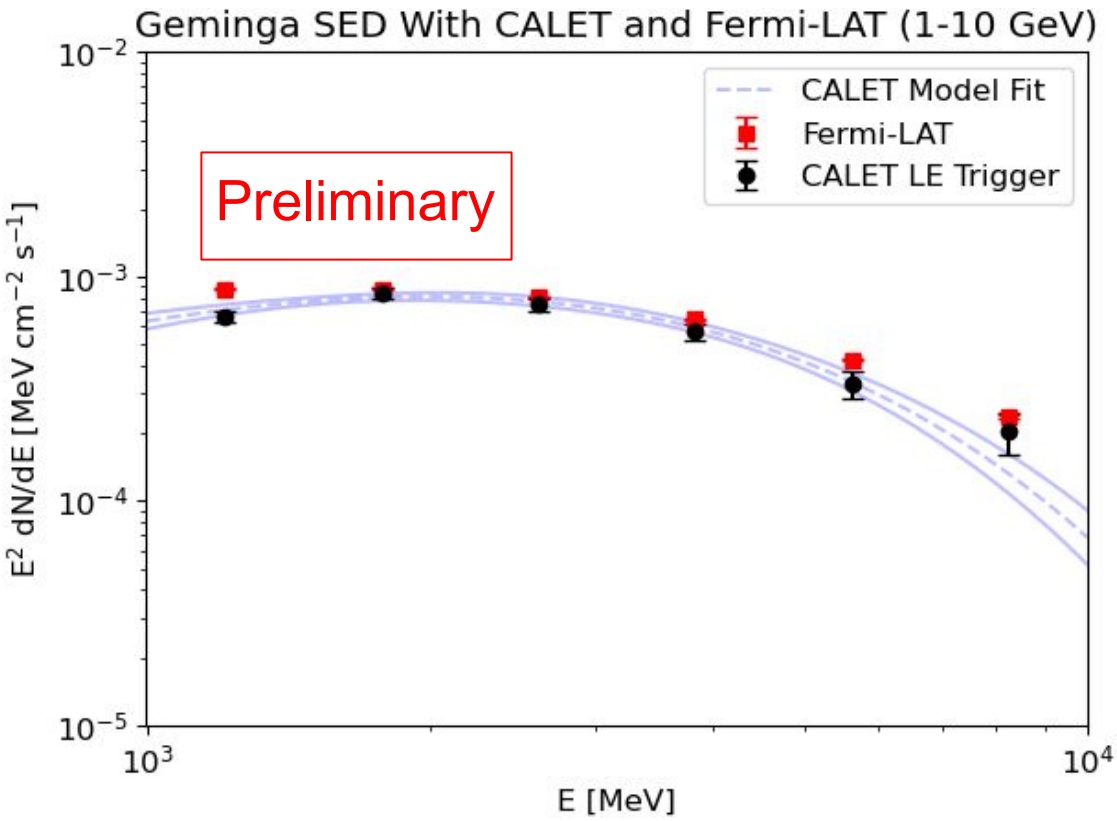
Crab

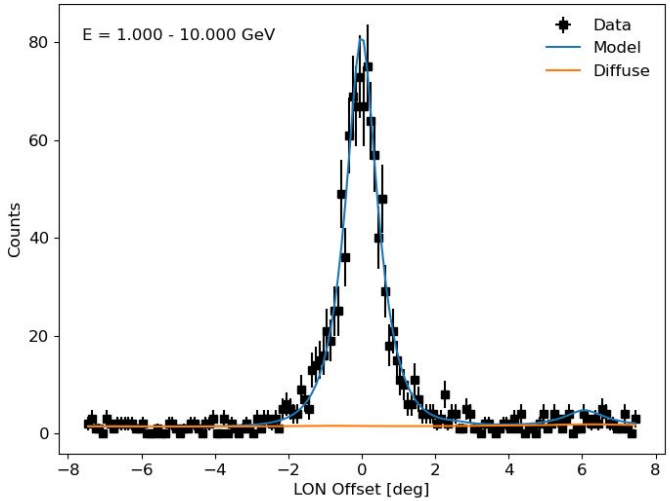

Crab SED With CALET and Fermi-LAT (1-10 GeV)
Preliminary
CALET Model Fit
Fermi-LAT
CALET LE Trigger
E^2 dN/dE [MeV cm^{-2} s^{-1}]
E [MeV]

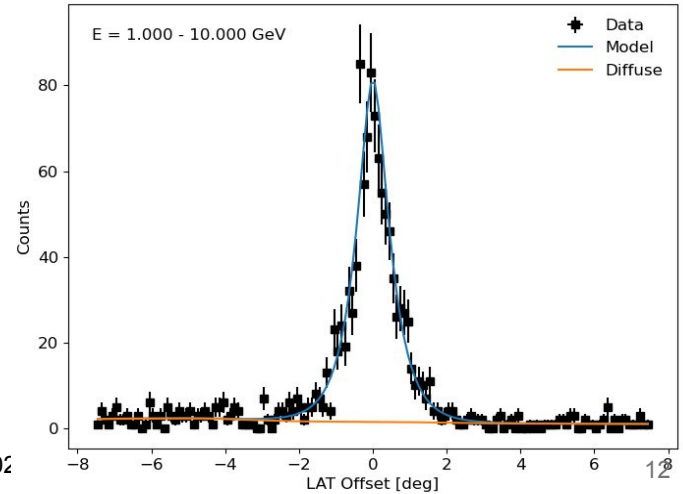

E = 1.000 - 10.000 GeV
Data
Model
Diffuse
Counts
LON Offset [deg]


E = 1.000 - 10.000 GeV
Data
Model
Diffuse
Counts
LAT Offset [deg]

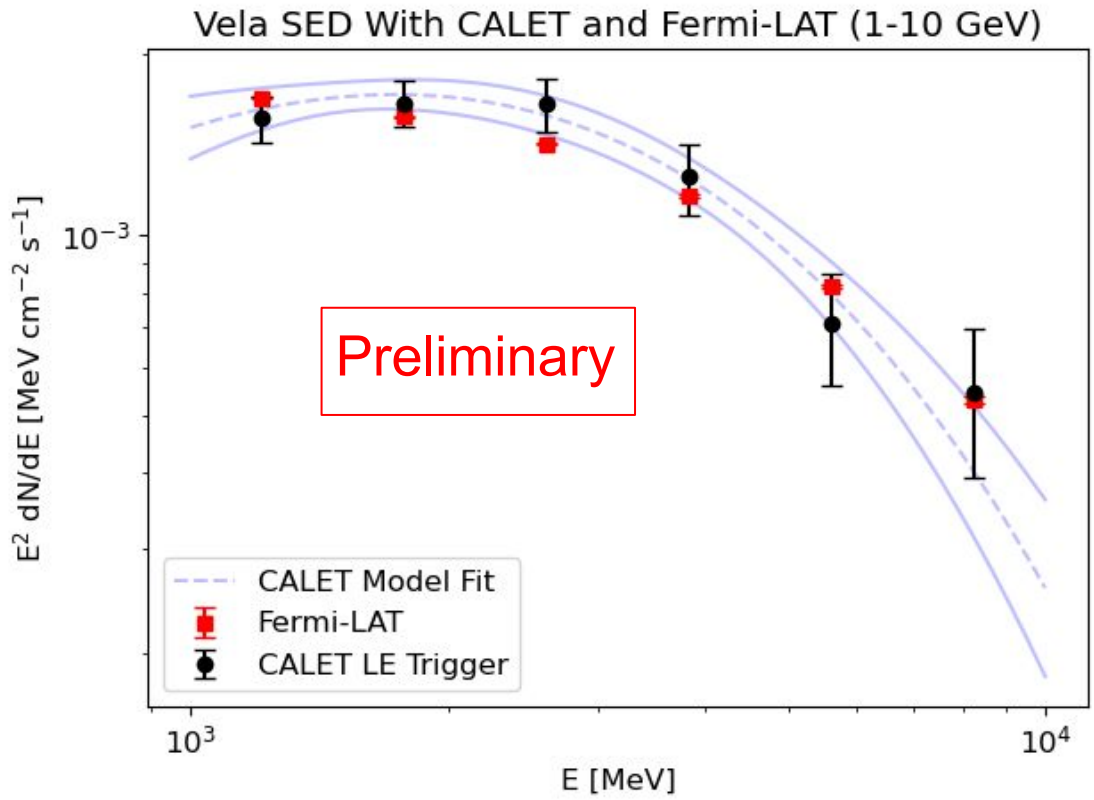
Geminga

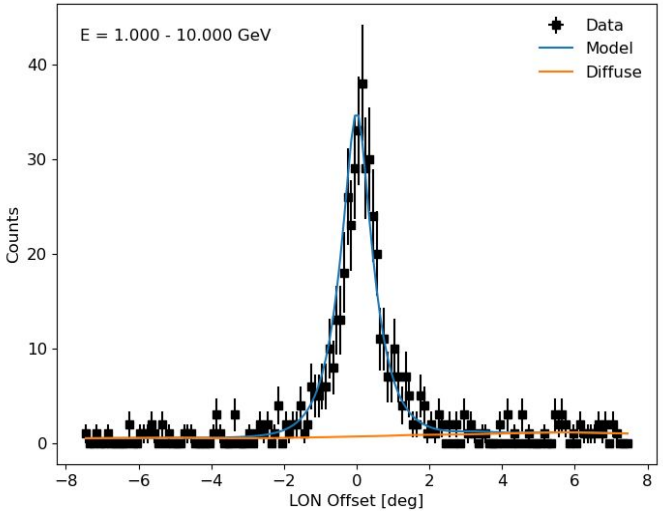

Geminga SED With CALET and Fermi-LAT (1-10 GeV)
Preliminary
CALET Model Fit
Fermi-LAT
CALET LE Trigger
E^2 dN/dE [MeV cm^{-2} s^{-1}]
E [MeV]

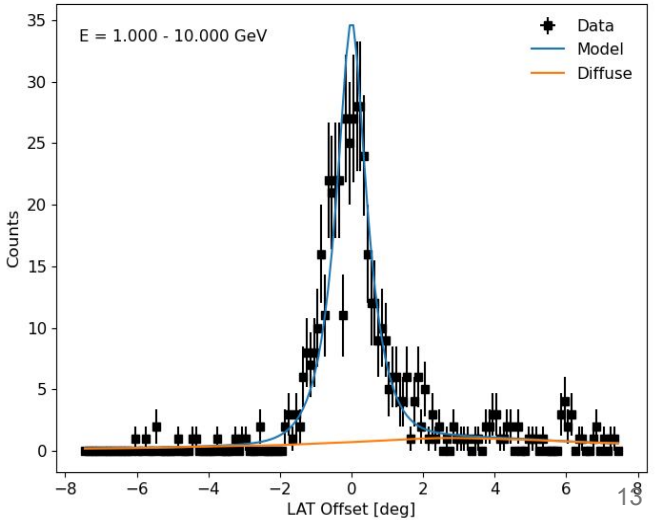

E = 1.000 - 10.000 GeV
Data
Model
Diffuse
Counts
LON Offset [deg]


E = 1.000 - 10.000 GeV
Data
Model
Diffuse
Counts
LAT Offset [deg]

Vela

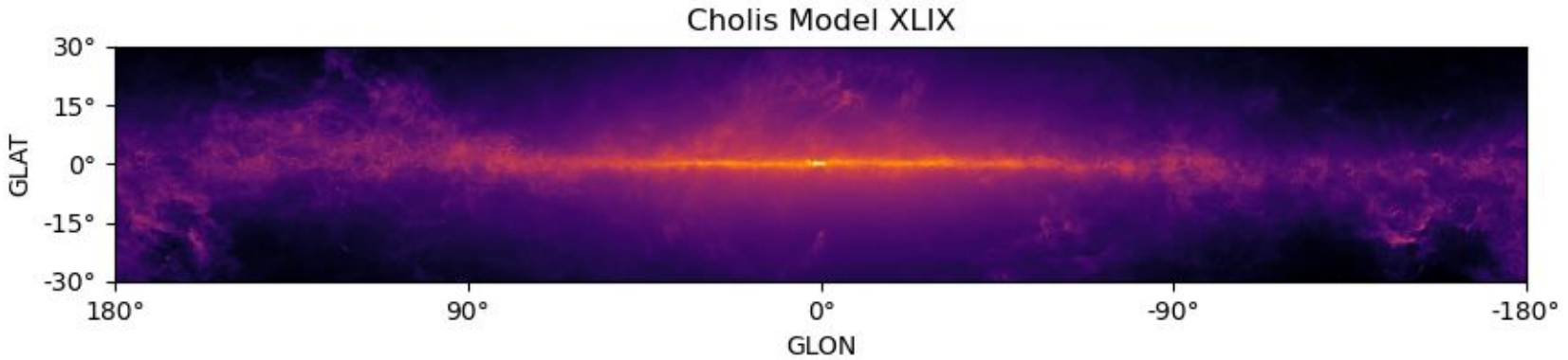

Vela SED With CALET and Fermi-LAT (1-10 GeV)
Preliminary
CALET Model Fit
Fermi-LAT
CALET LE Trigger
E^2 dN/dE [MeV cm^{-2} s^{-1}]
10^{-3}
10^3
10^4
E [MeV]


E = 1.000 - 10.000 GeV
Data
Model
Diffuse
Counts
LON Offset [deg]


E = 1.000 - 10.000 GeV
Data
Model
Diffuse
Counts
LAT Offset [deg]

GCE Analysis

- 40°x40° ROI, 2-20 GeV, 6 bins/decade
- Mask: |b|< 1°, 1° around point sources with TS > 25
- Galactic diffuse emission model: Cholis et al. 2022 Model XLIX



GCE Analysis

We assume the GCE follows a generalized NFW density profile

$$\rho = \frac{\rho_0}{\left(\frac{r}{r_s}\right)^{\gamma}\left(1+\frac{r}{r_s}\right)^{3-\gamma}}$$

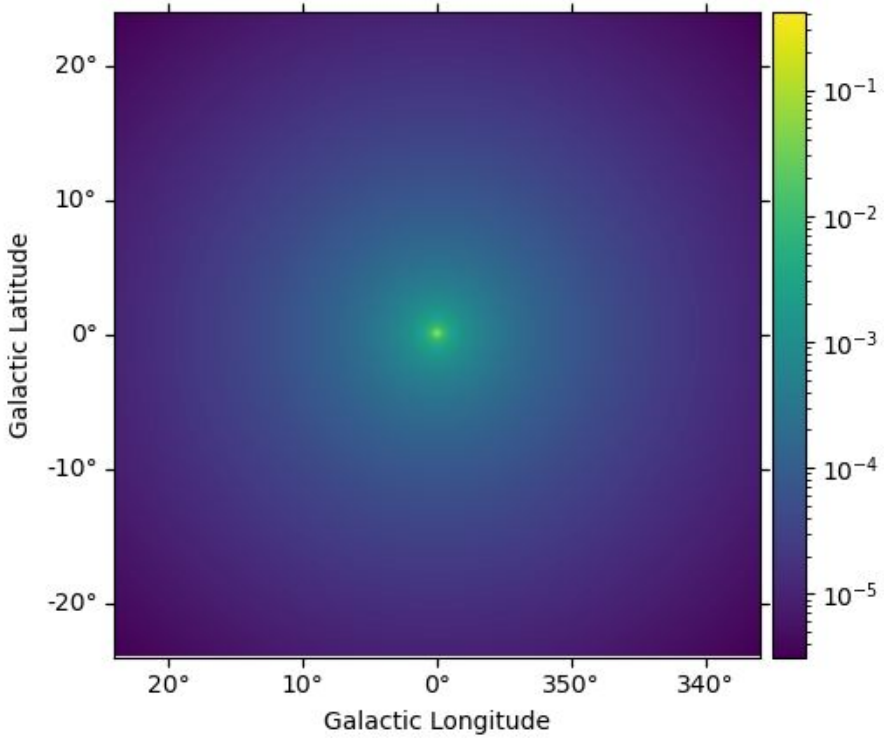
$\gamma = 1.2$, $r_s = 20$ kpc, ρ_0 is a normalization

The spatial distribution is described by the J-Factor

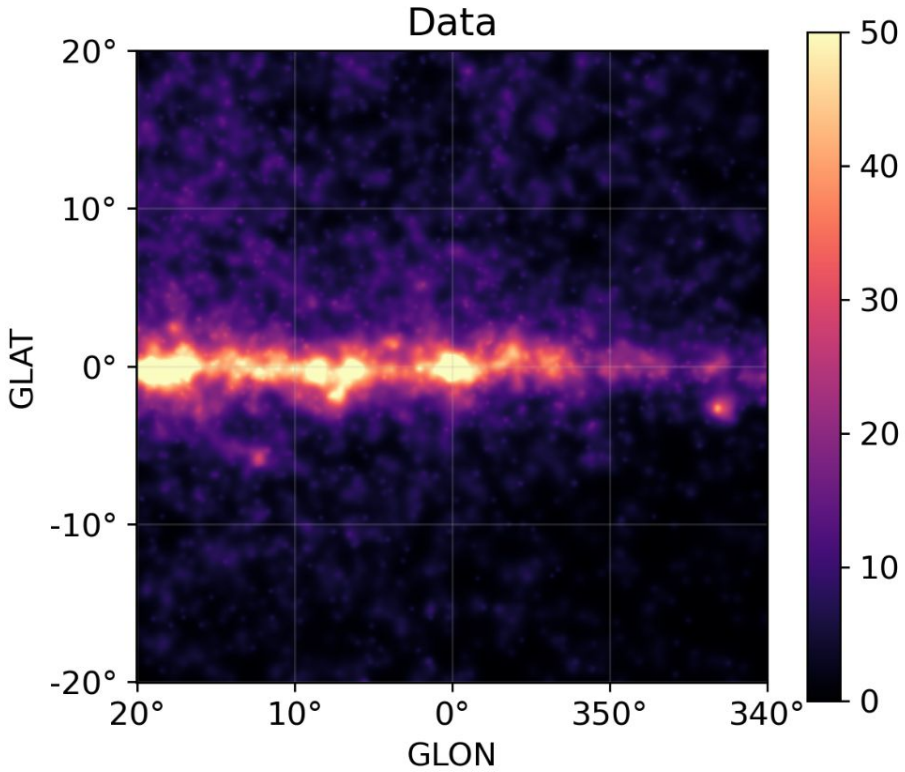
$$\mathcal{J} = \frac{1}{r_\odot}\frac{1}{\rho_\odot^2}\int_{\Delta\Omega} d\Omega \int_{l.o.s.} \rho^2 ds$$

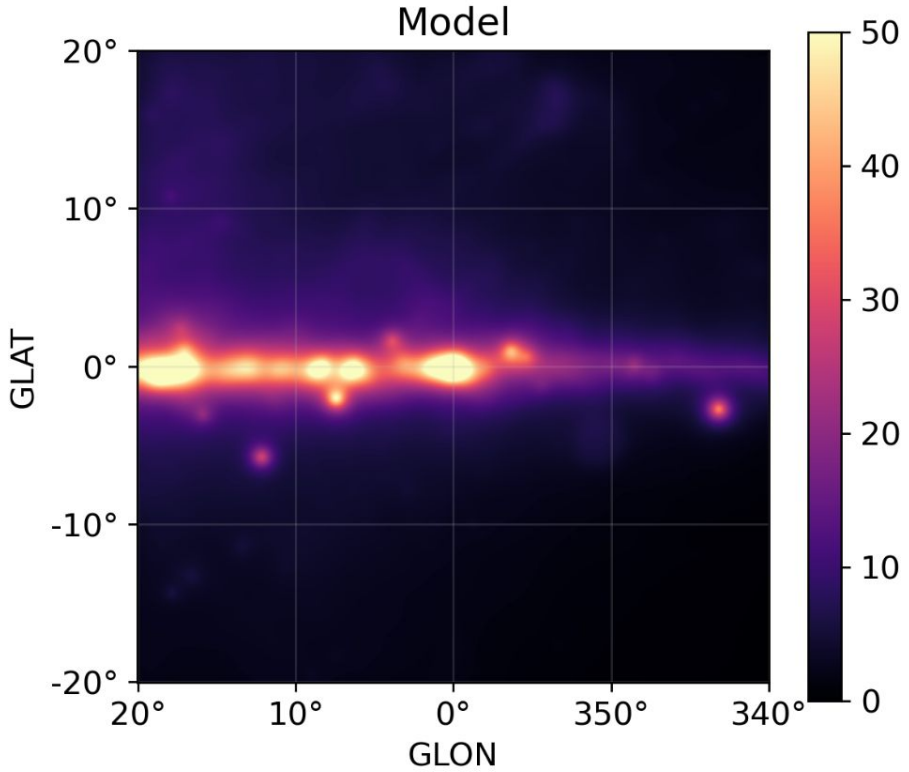
$r_\odot = 8.5$ kpc, $\rho_\odot = 0.4$ GeV/cm^3

GCE Spatial Template

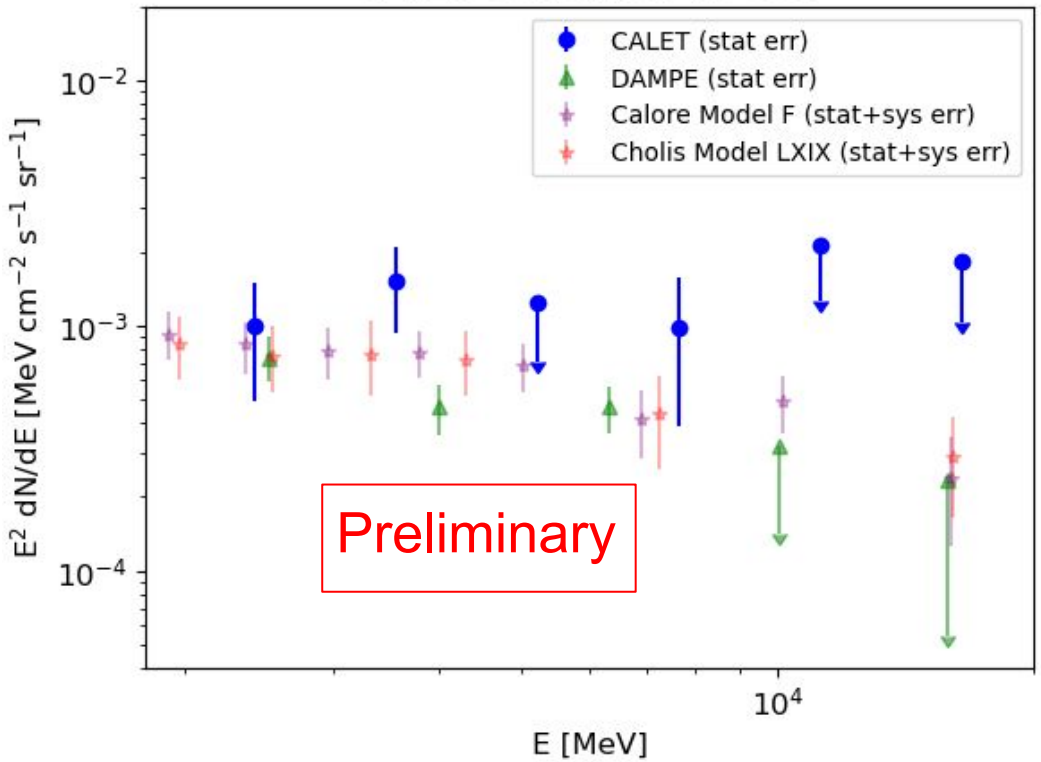


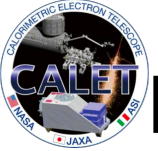
GCE Analysis





GCE Spectral Energy Distribution





Future Work

- Extend observed data set to the end of 2025
- Look above 10 GeV with the higher-efficiency HE trigger

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