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Recent Gamma-ray Results from DAMPE

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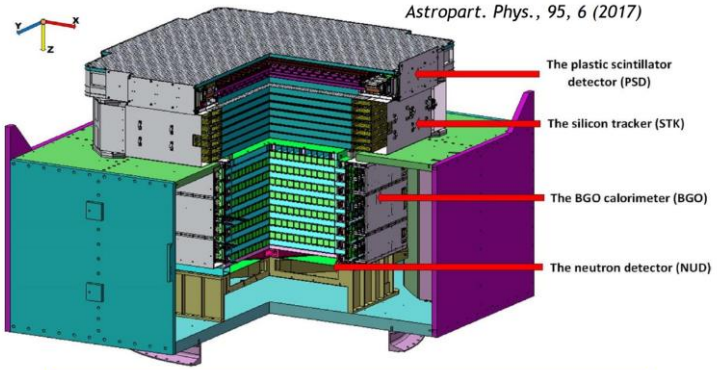
(on behalf of the DAMPE collaboration)

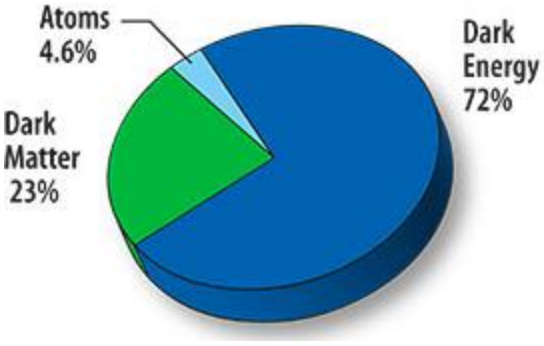
Outline

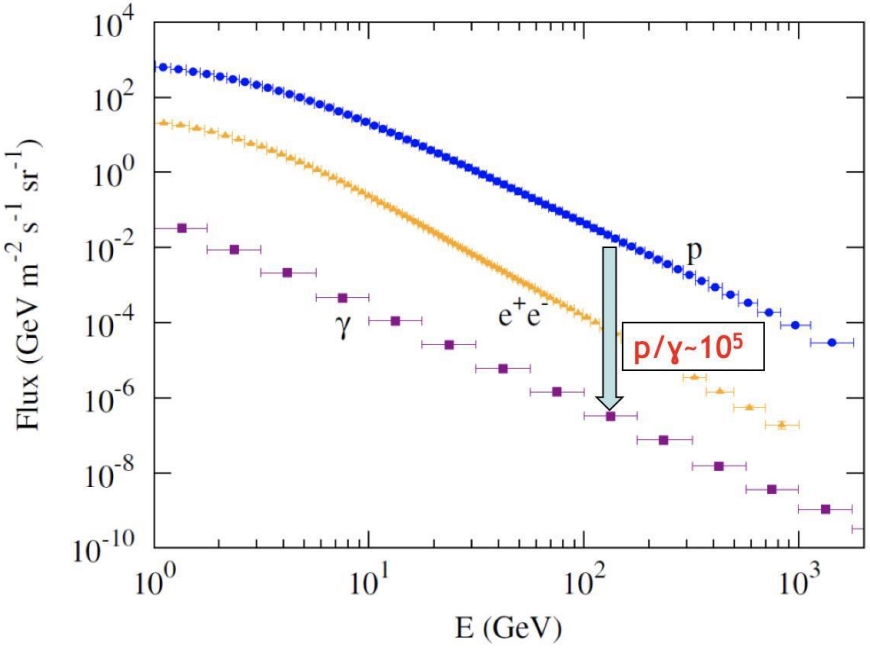
- Introduction
- Calibrations of DAMPE for gamma-ray observation
- Scientific results from DAMPE gamma-ray data
  - Point Sources
  - Fermi Bubbles
  - Galactic Center Excess
  - Gamma-ray Line Search
- Summary



- PSD: charge measuresument via dE/dx and ACD for photons
- STK: track, charge, and photon converter
- BGO: energy measurement, particle (e-p) identification
- NUD: Particle identification

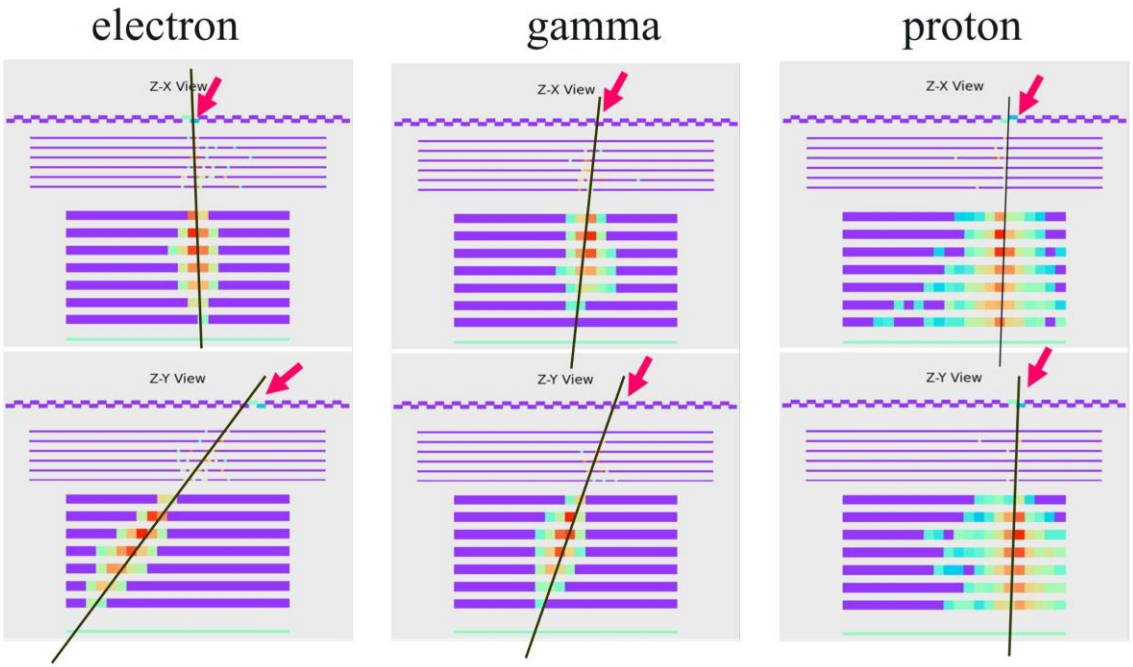
Introduction — gamma-ray observation of DAMPE



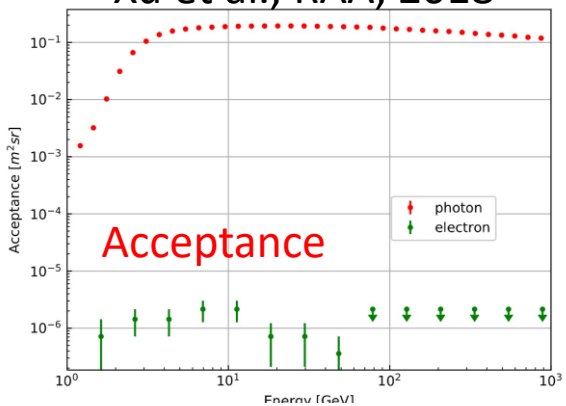


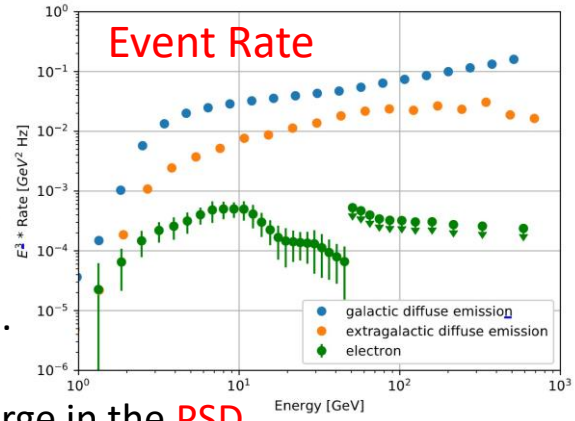
Dark matter detection directly and gamma-ray astronomy are the major scientific goals of DAMPE, but the flux of the gamma rays is orders of magnitude lower (by 3 to 5 orders) compared to that of electrons and protons in the GeV energy band.

Introduction — gamma-ray selection of DAMPE



Xu et al., RAA, 2018





- Distinguish electrons and protons based on the shower in the BGO.
- Reconstruct the direction using the tracker in the STK.
- Differentiate between electrons and gamma rays based on the charge in the PSD.

These steps enable us to distinguish gamma-ray events from the cosmic ray background effectively.

Introduction — performance for gamma-ray observation

- Effective area:

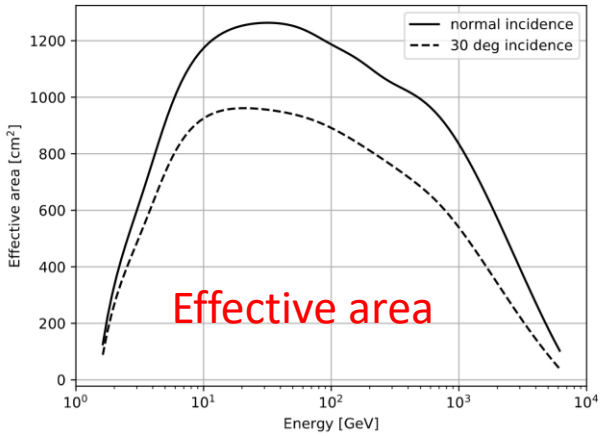
~ 1200 cm^2 @ 10 GeV
~ 1200 cm^2 @ 100 GeV

- Angular resolution:

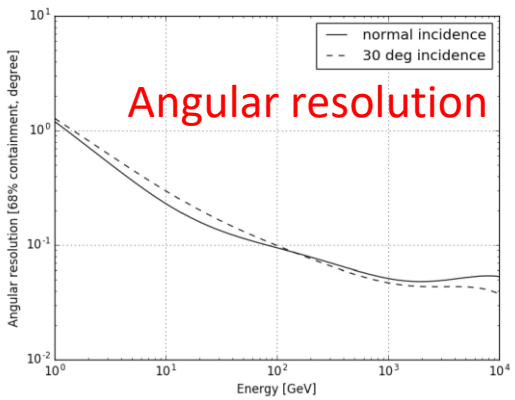
~ 0.3 degree @ 10 GeV
~ 0.1 degree @ 100 GeV

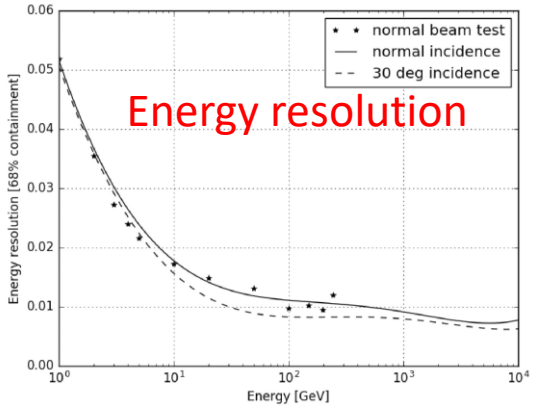
- Energy resolution:

~ 2% @ 10 GeV
~ 1% @ 100 GeV

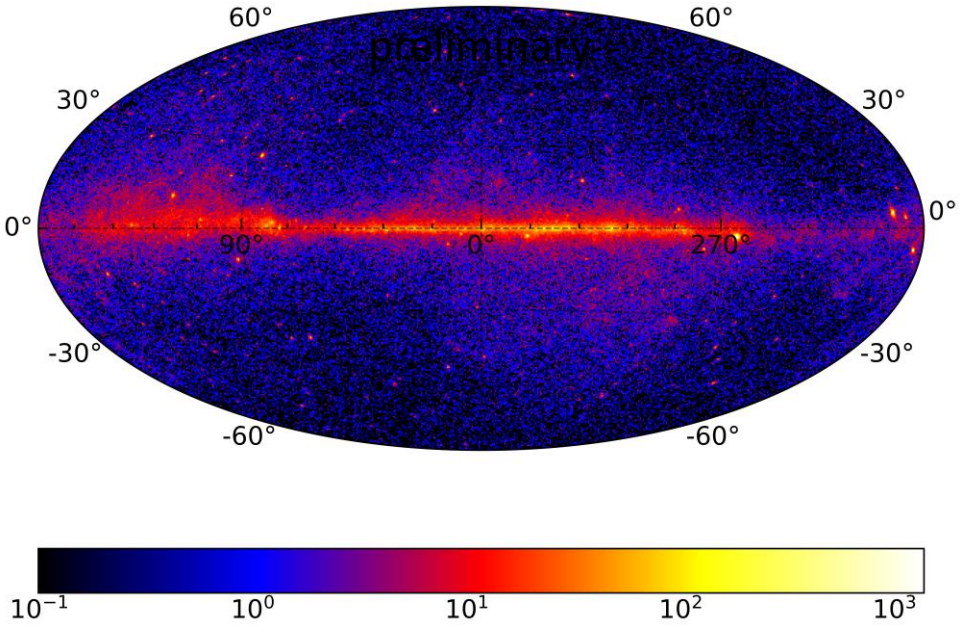


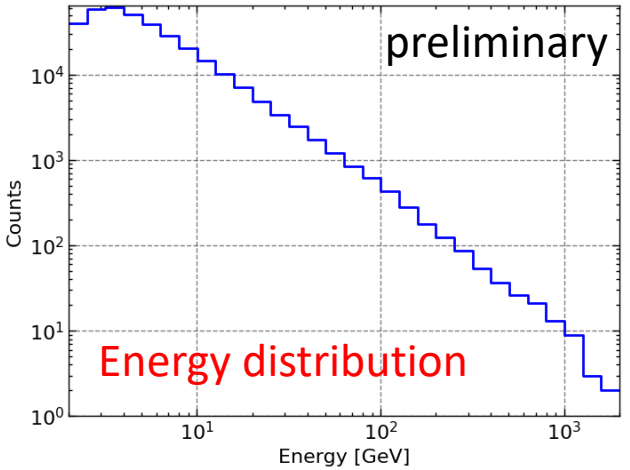
Chang, et al. Astropartic. Phys., 2017

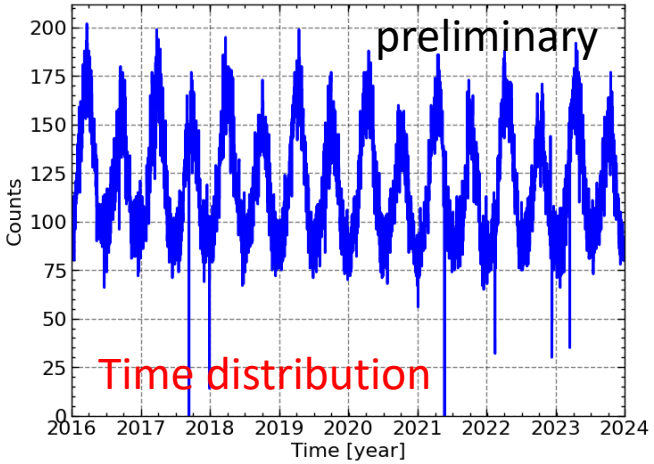




Introduction — 8-yr gamma-ray photons' distribution

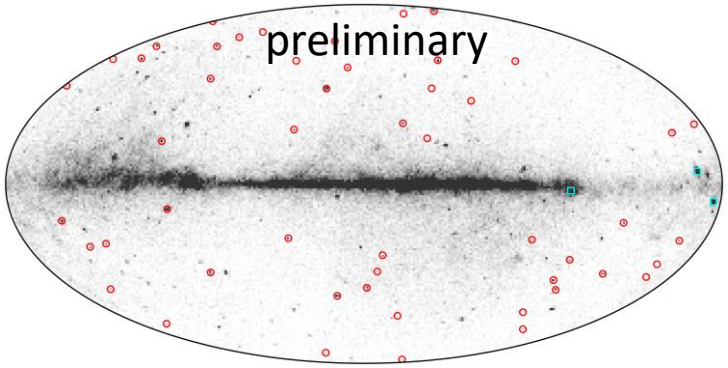


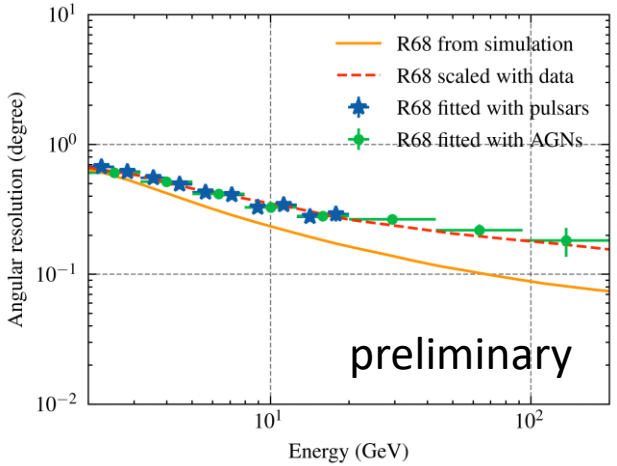




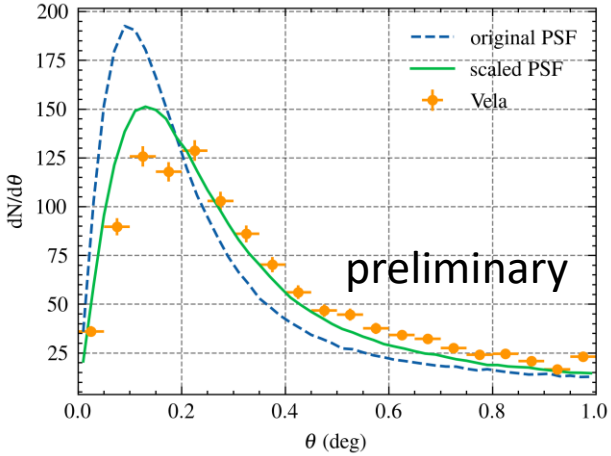
After eight years of operation, DAMPE has recorded over 0.3 million gamma-ray photons ranging from 2 GeV to 2 TeV with 192 million seconds of live-time.

Calibration — PSF Calibration with pulsars and AGNs

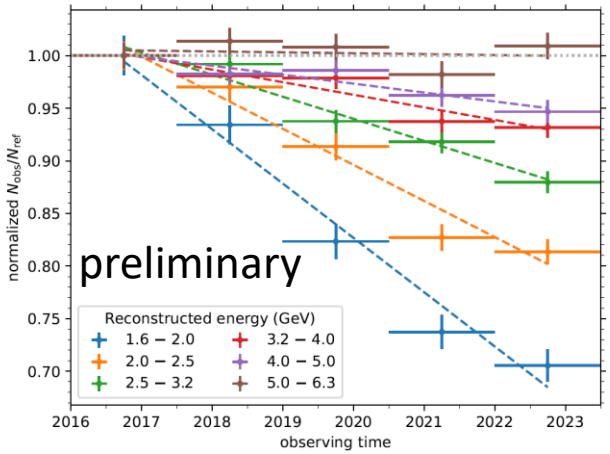


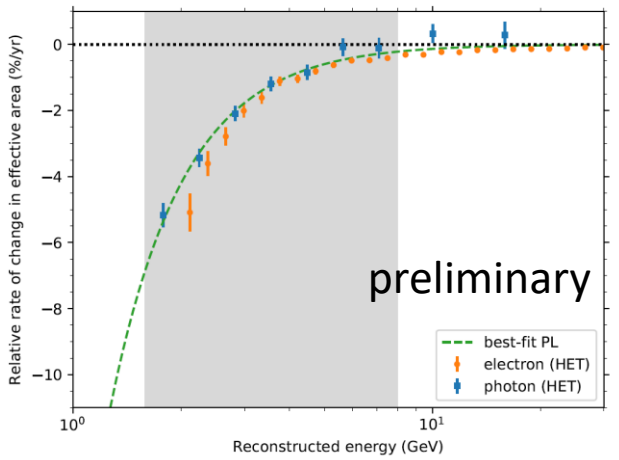


- With data around pulsars and bright AGNs, we calibrated the Point-Spread Function (PSF).
- The calibration improved the angular resolution to closely match the values obtained from observation.
- The angular distribution of the observed data around Vela pulsar shows a significant improvement.

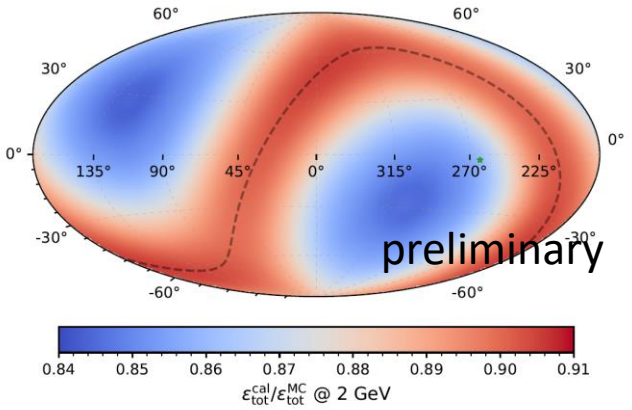


Calibration — The calibration of effective area



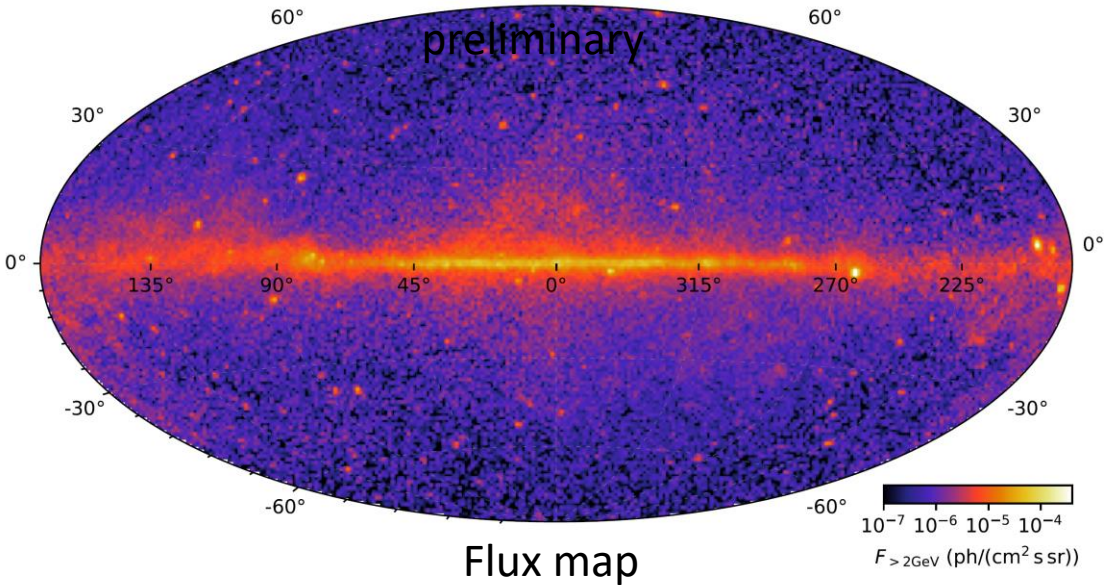


- We observed a significant time variation in the effective area, which can be attributed to the increasing thresholds.
- We calculated data-based correction factors for the effective areas and applied to the exposure maps.
- The calibrated exposure can be ~ 12% smaller than the Monte Carlo one on average at 2 GeV.



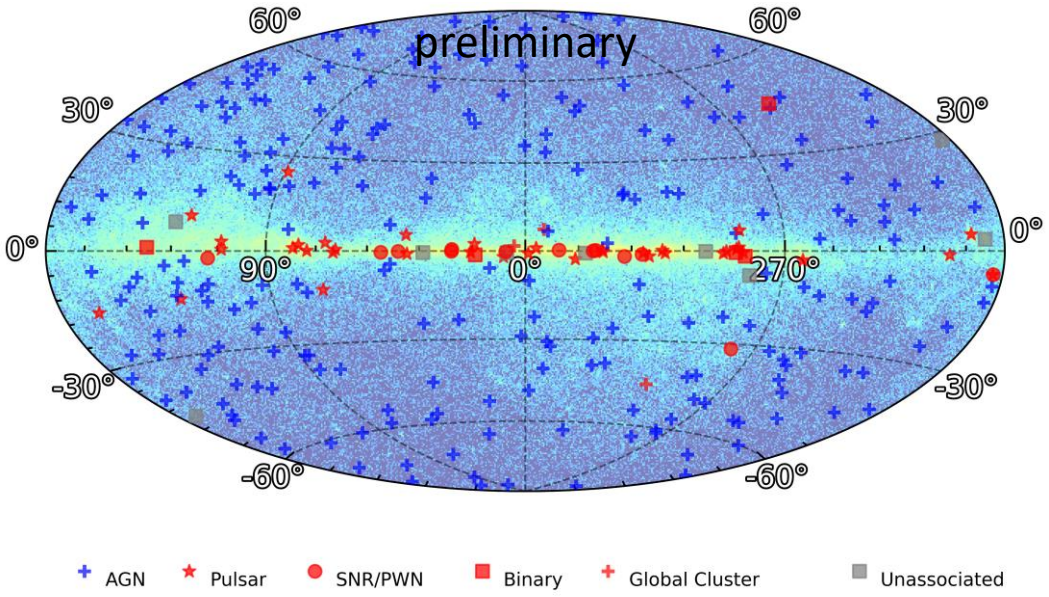
Scientific results from DAMPE gamma-ray data

- Point Sources
- Fermi Bubbles
- Galactic Center Excess
- Gamma-ray Line Search



Flux map

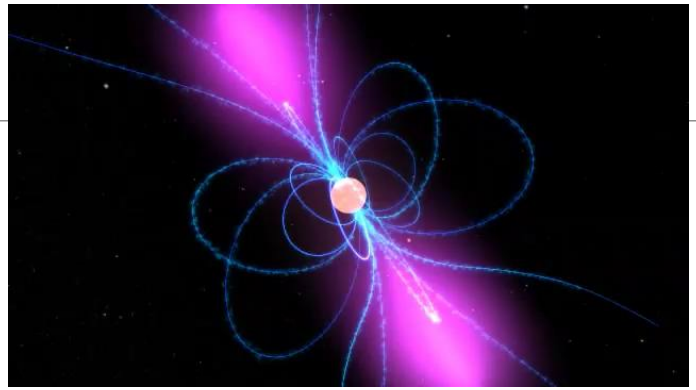
Point Sources



Source type	number
AGN	241
Pulsar	62
SNR/PWN	14
Binary	5
Global cluster	4
Unassociated	10
Total	336

- We use 7.5 yr DAMPE gamma-ray data for point sources searching.
- 336 sources are detected with TS > 25. Most of the sources are AGNs and pulsars.

Point Sources



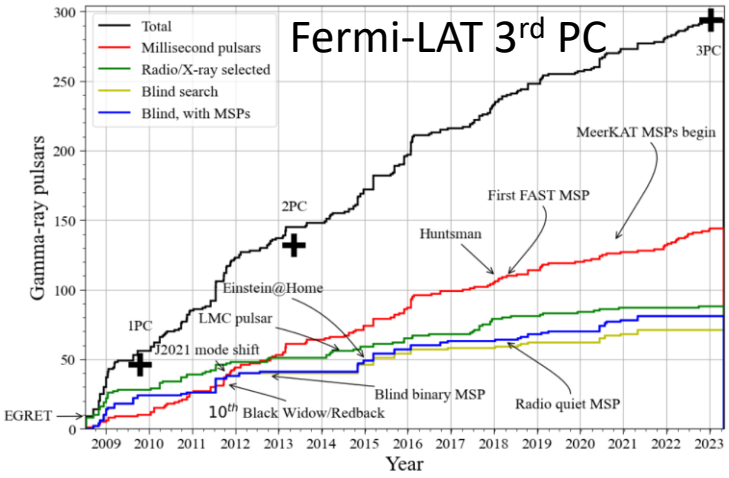
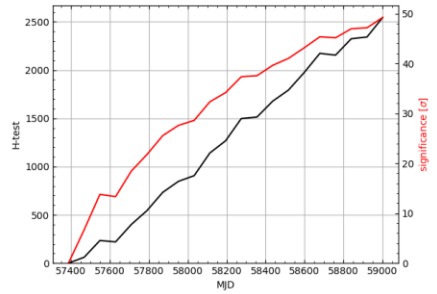
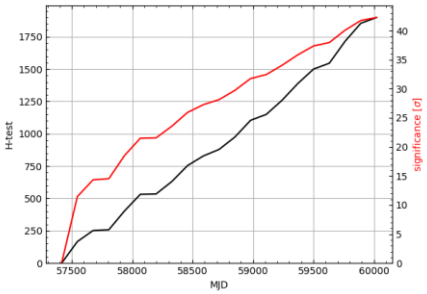
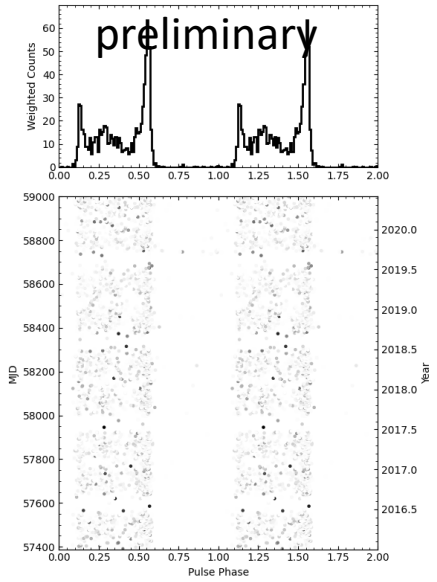
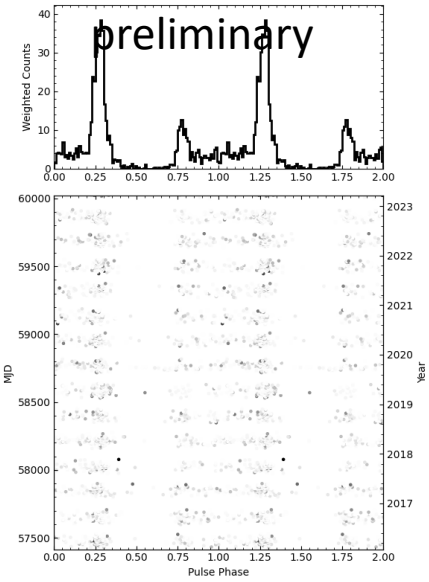


Figure 1. Cumulative number of known gamma-ray pulsars, beginning with the launch of *Fermi*. The crosses show the numbers included in the first (1PC) and second (2PC) catalogs of LAT pulsars and their publication dates. Some key discoveries are highlighted.







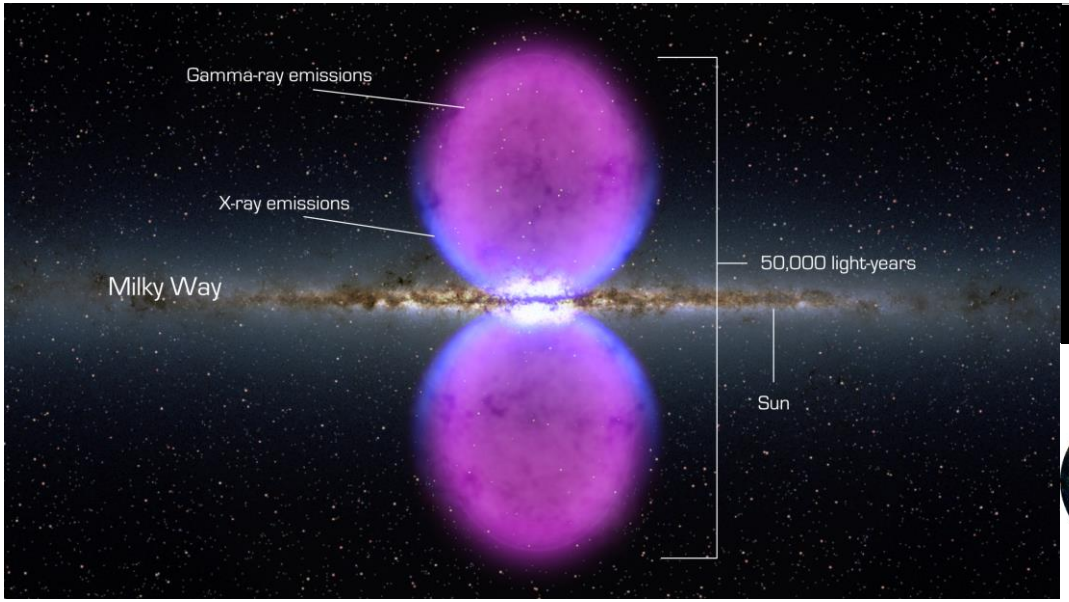


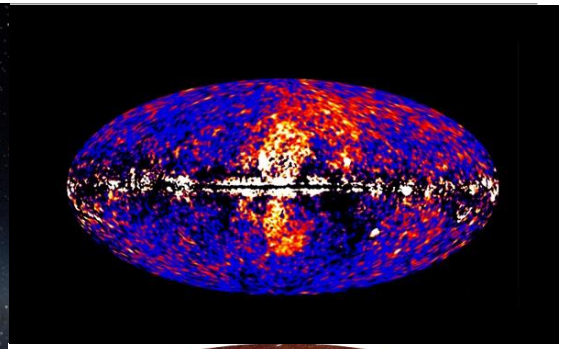
- DAMPE detected 15 pulsars with pulsation at 5σ.

Vela pulsar (**~49 σ**)

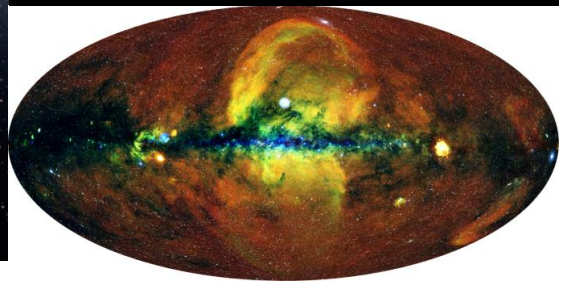
Geminga pulsar (**~42 σ**)

Fermi Bubbles



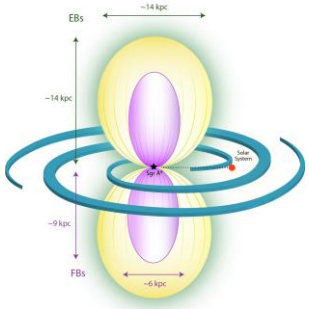


Su et al, 2010, ApJ

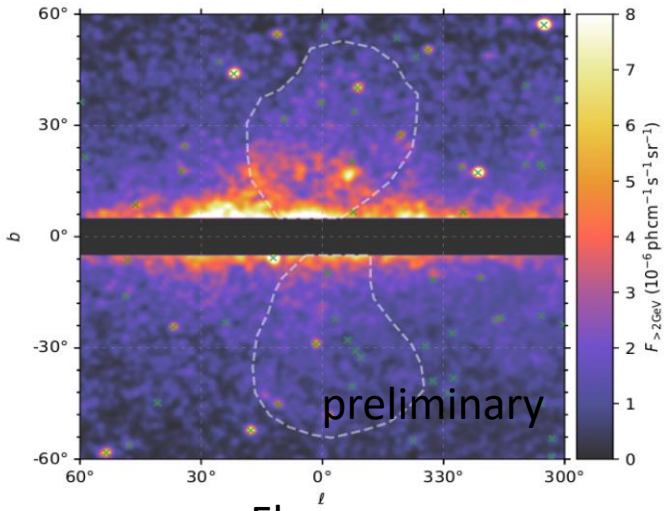


Predehl et al. 2020, Nature

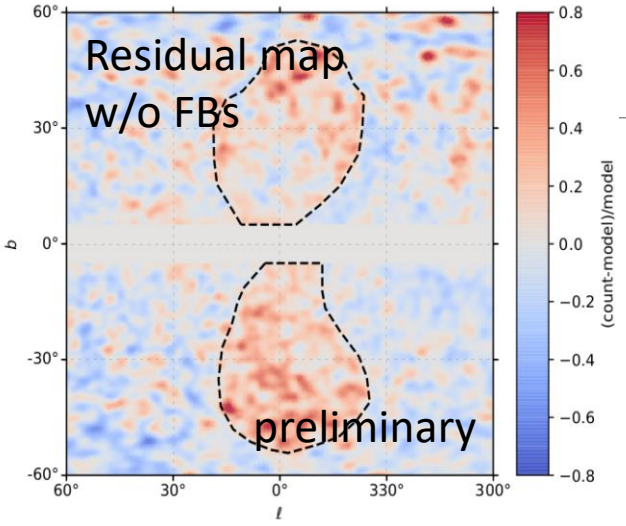
- Fermi bubbles are large structures of gamma-ray emission that extend above and below the Galactic Center of the Milky Way galaxy.
- Similar structures have been detected in X-rays by eROSITA, providing evidence of past activity in the center of the Milky Way.

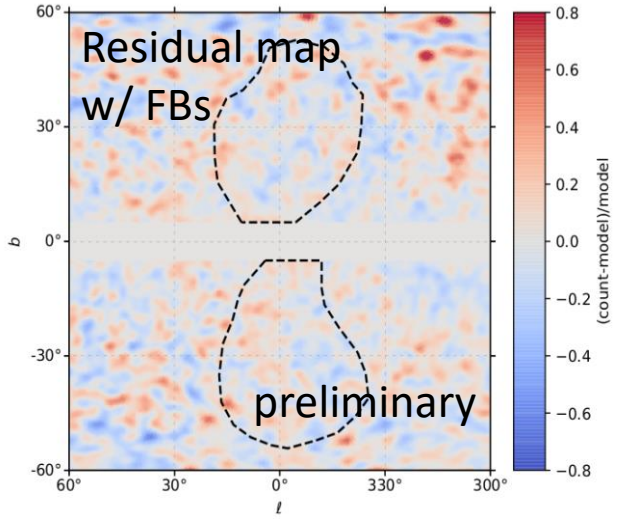


Fermi Bubbles



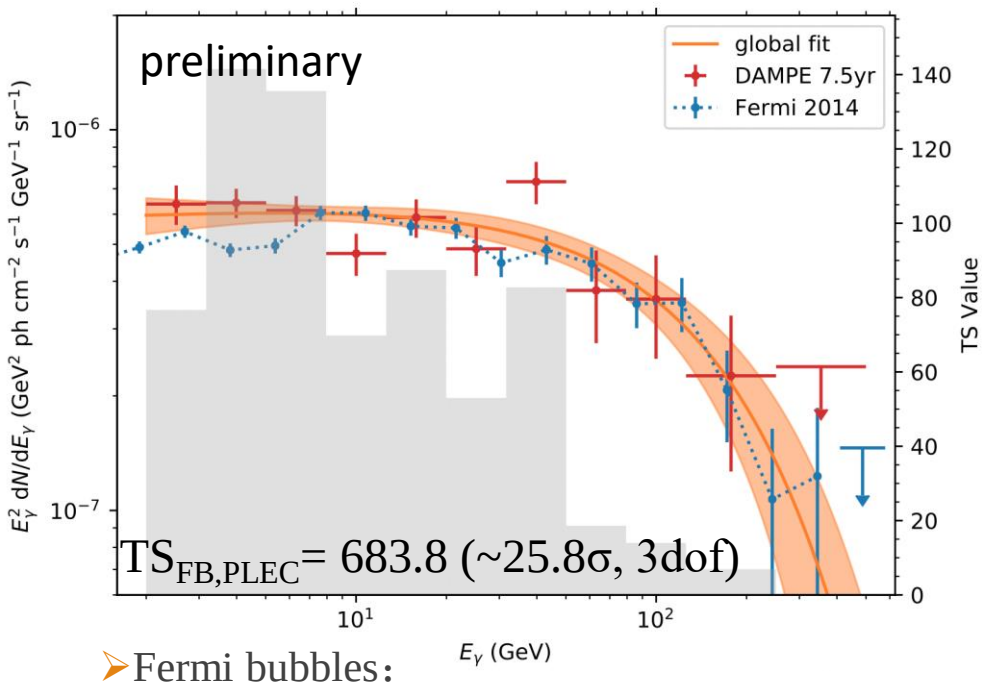
Flux map

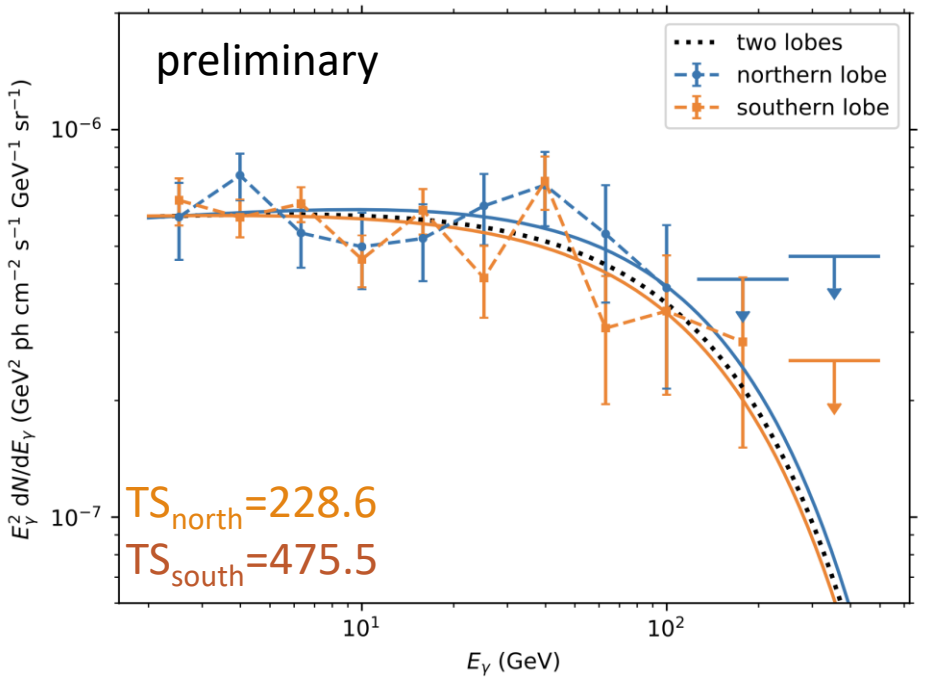




- 7.5yr DAMPE gamma-ray data
- $|l| < 60^\circ$, $5^\circ < |b| < 60^\circ$
- mask 1.5° circular around the point sources
- Models:
  - Fermi bubbles (FBs)
  - Point sources
  - Galactic diffuse emission
  - Isotropic diffuse emission

Fermi Bubbles





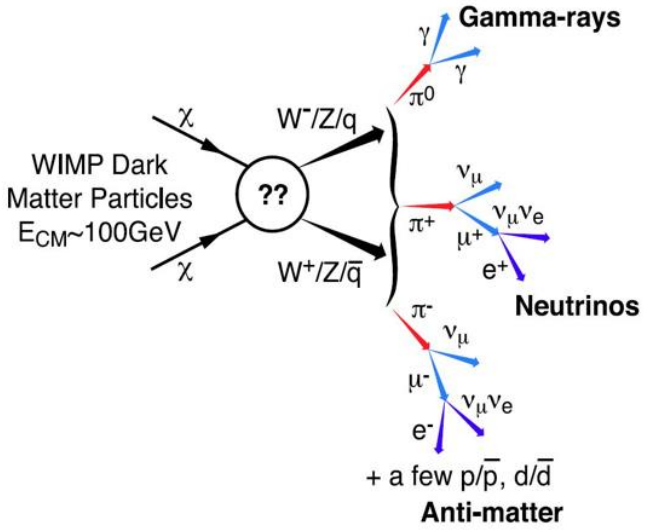
- Fermi bubbles:
  TS$_{FB,PLEC}$= 683.8 (~25.8σ, 3dof), N$_{pred}$= 3019.6; TS$_{FB,bin}$= 686.3 (~25.2σ, 11dof)

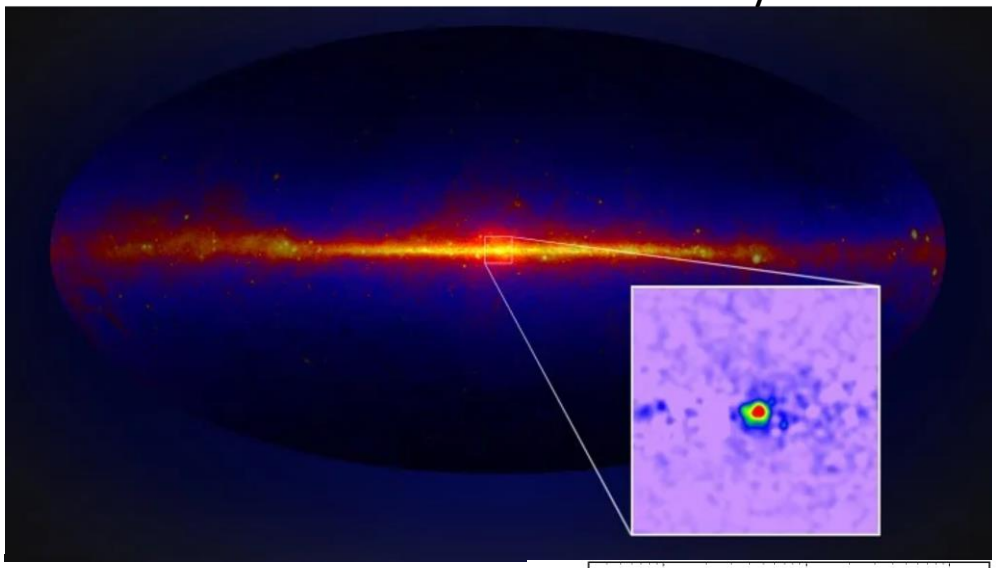
- Spectrum curvature:
  TS$_{curve}$ = 11.2 (~3.3σ,1dof), the Power-Law with E cut-off spectral type is slightly better than the LogParabola (ΔTS~ 5.6)

- Best-fit spectral parameters:
  spectral index=1.96±0.08, cutoff energy E$_{cut}$=149±61 GeV, F$_{>2GeV}$= (2.92±0.17)×10^{-7} ph/cm^2/s/sr

Galactic Center Excess

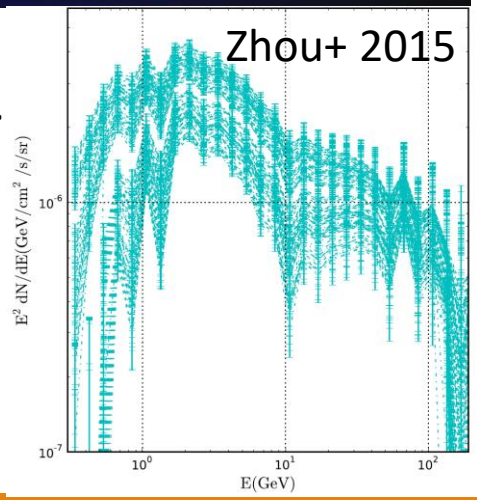
Daylan+ 2014



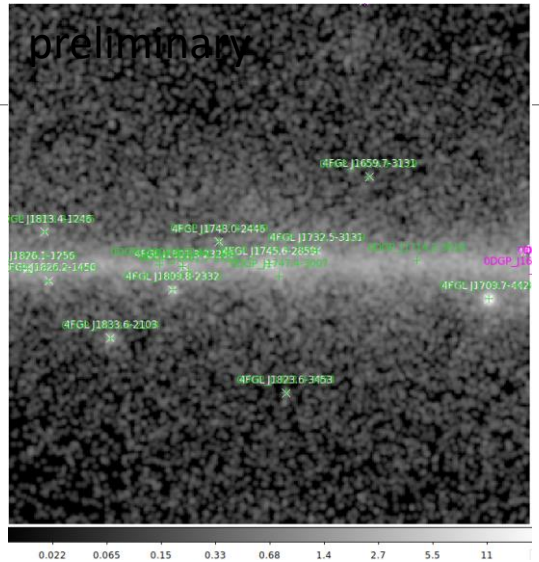


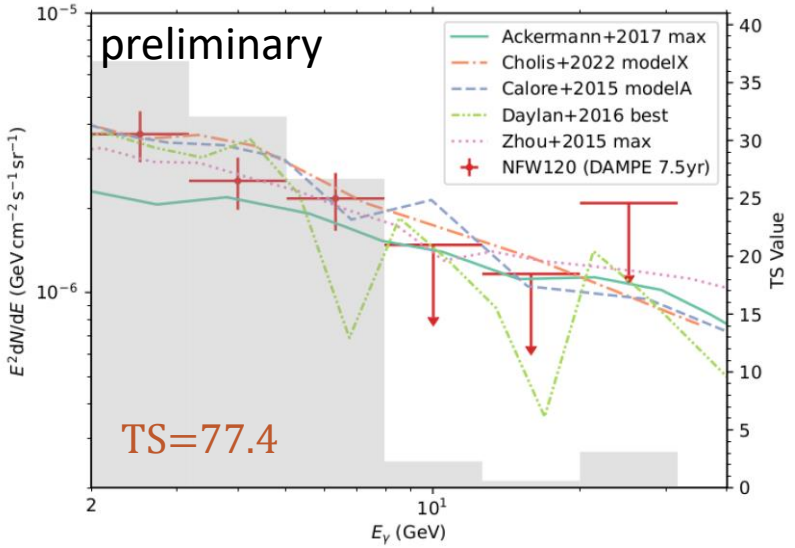
- The self-annihilation of dark matter particles is expected to produce a signature that is detectable in the gamma-ray spectrum.
- The Galactic Center is expected to be the nearest and brightest source of gamma rays resulting from dark matter annihilation.
- Analysis of the Galactic Center halo with Fermi-LAT has uncovered a GeV excess in close to the Galactic Center.

Zhou+ 2015



Galactic Center Excess





- 7.5yr DAMPE gamma-ray data
- $|\ell|<20^\circ$, $1^\circ<|b|<20^\circ$
- mask 1° circular around the point sources
- Models:
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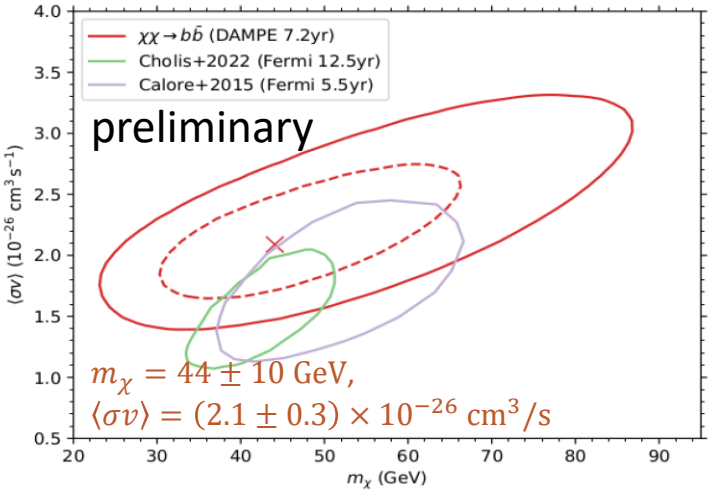
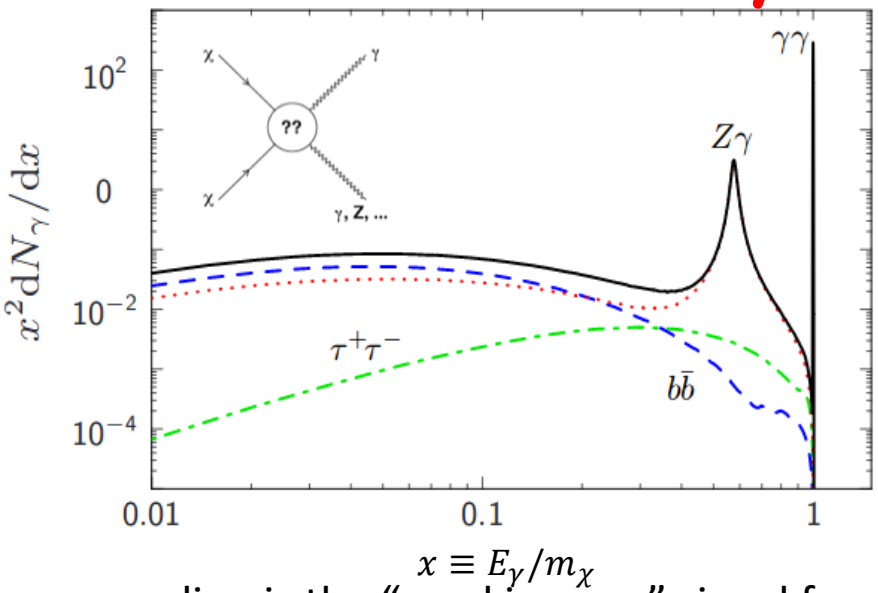
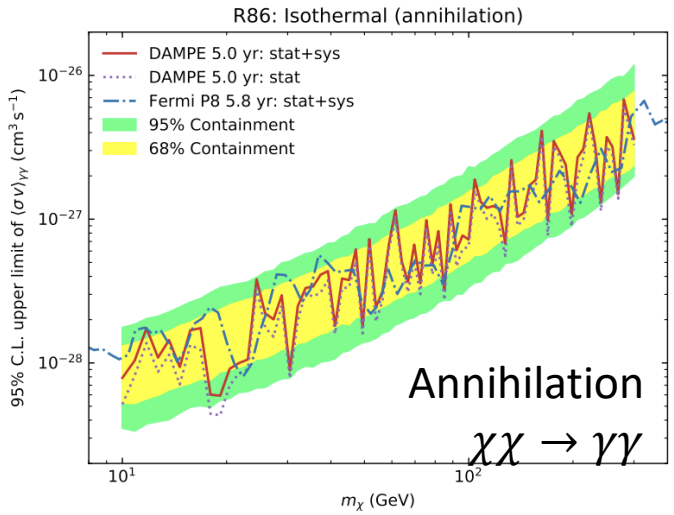
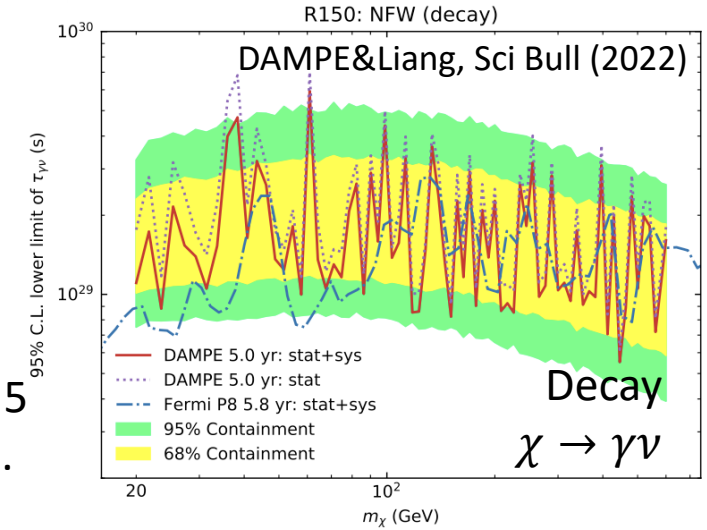
  - Fermi bubbles (FBs)
  - Point sources
  - Galactic diffuse emission
  - Isotropic diffuse emission



Gamma-ray Line Search

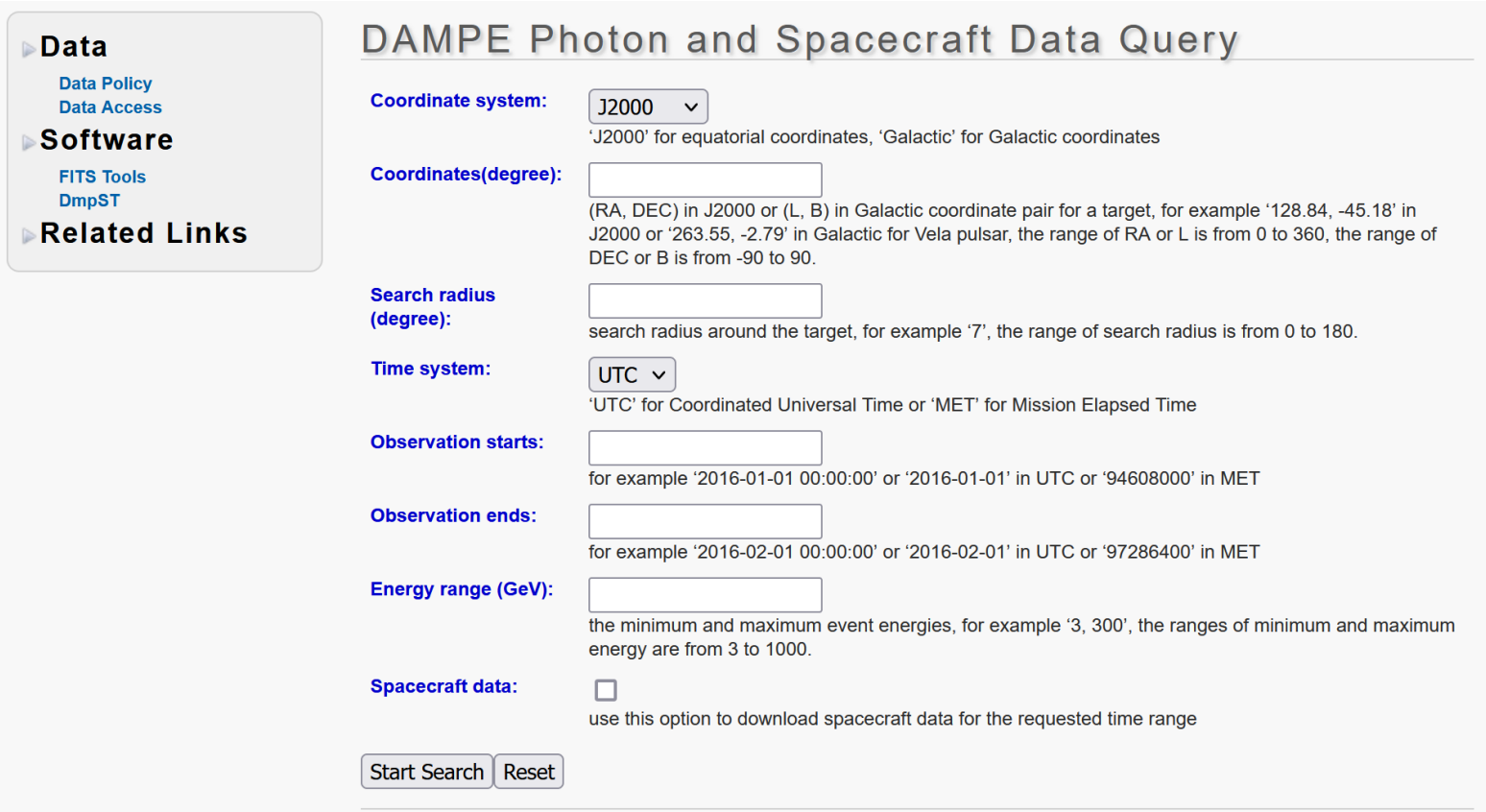






- Gamma-ray line is the "smoking gun" signal for dark matter indirect search.
- The energy resolution of DAMPE is excellent for searching gamma-ray lines.
- We searched for the lines with 5 years data beween 5 and 450 GeV. No significant line signals are detected.
- More data is currently being analyzed.

Data Release Online



https://dampe.nssdc.ac.cn/dampe/dataquerysc.php
http://dgdb.pmo.ac.cn/dampe/

Summary

- After eight years of operation, DAMPE has recorded over 0.3 million gamma-ray photons ranging from 2 GeV to 2 TeV.
- The Point-Spread Function (PSF) and effective area of DAMPE have been calibrated for gamma-ray observation.
- 336 sources have been detected with 7.5 years of gamma-ray data.
- The Fermi Bubbles (FBs) and Galactic Center Excess (GCE) have been detected, with results matching those of Fermi-LAT.
- Gamma-ray lines have been searched for with 5 years of gamma-ray data, and upper limits have been constrained for dark matter.
- Gamma-ray data from DAMPE has been released.

Thanks for your attention