

**High-energy gamma ray
team-A**

**「高エネルギーガンマ線で
暗黒物質を探索しよう」**

3/8~3/11/2016

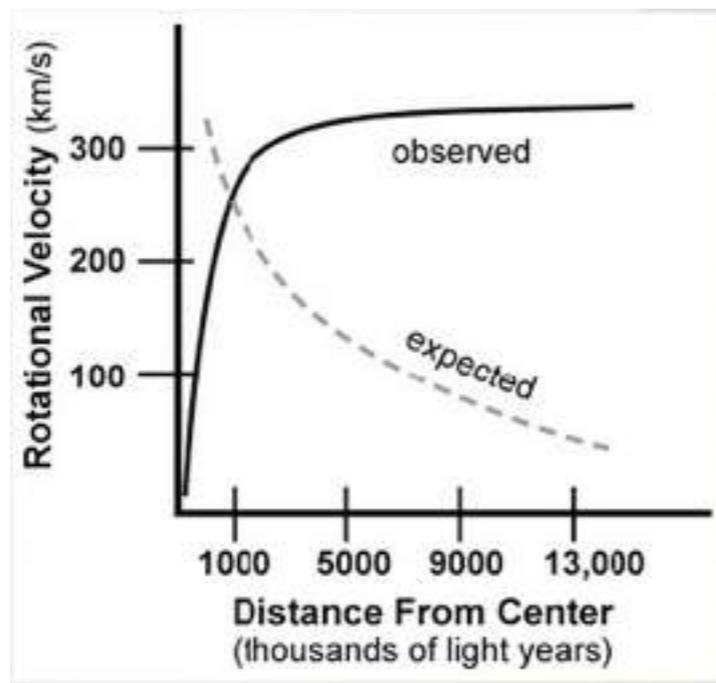
Ryuta Asami / Riho Imai / Haruka Kato / Nobuyuki Kato / Kotone Hieida

Purpose

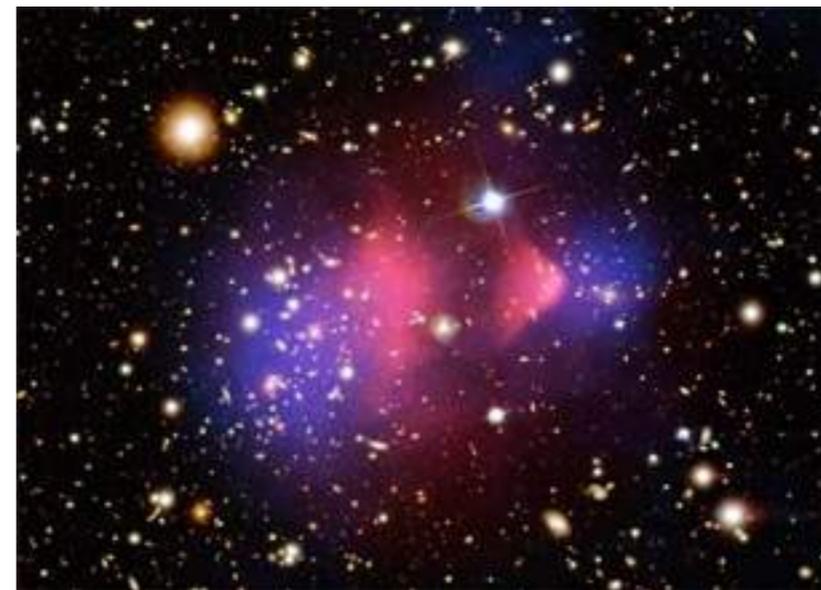
- Finding Dark Matter through Gamma-rays
 - What's Dark Matter?
 - How to observe Gamma-rays?
 - Did we find it through Gamma-rays?
etc....

If there isn't Dark Matter, We can't explain those phenomena.

Galactic rotation curve



Clusters of galaxies



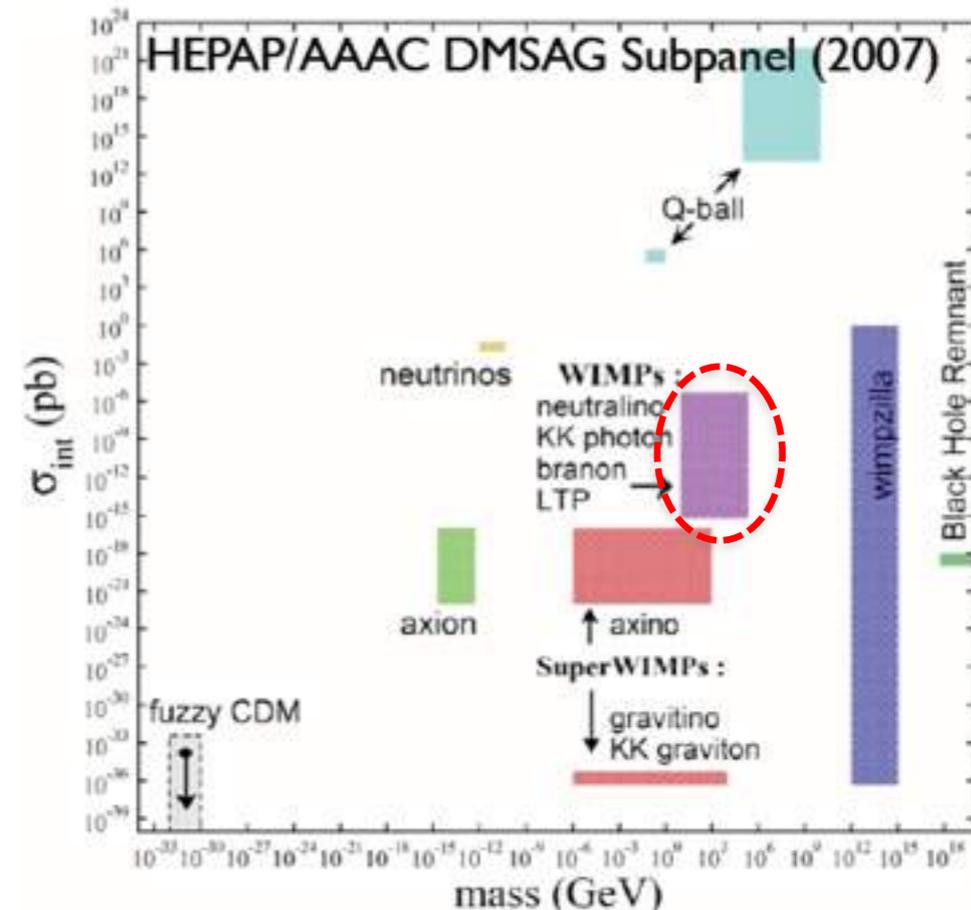
red : gas by X-ray,
blue: matter by gravitational lensing

Dark Matter can explain those phenomena.

Dark Matter candidates



- No known particles are good candidates for dark matter



Here, we focus on

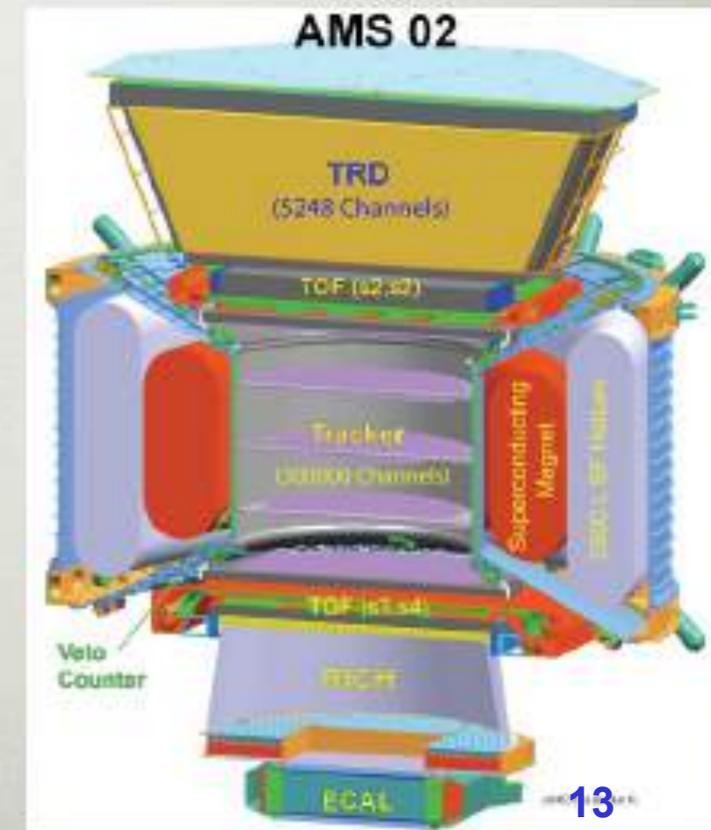
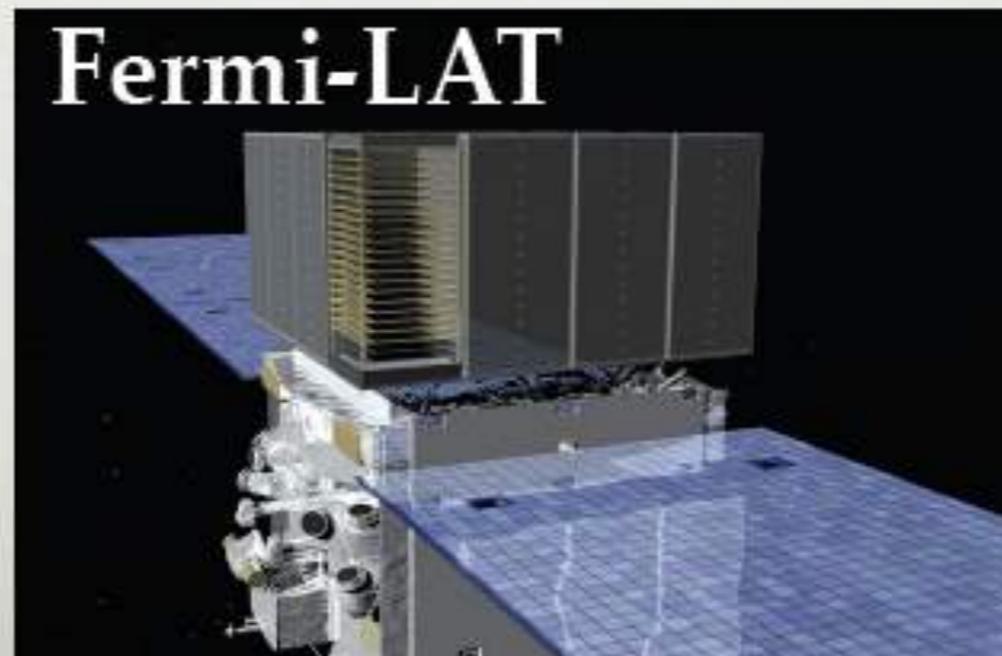
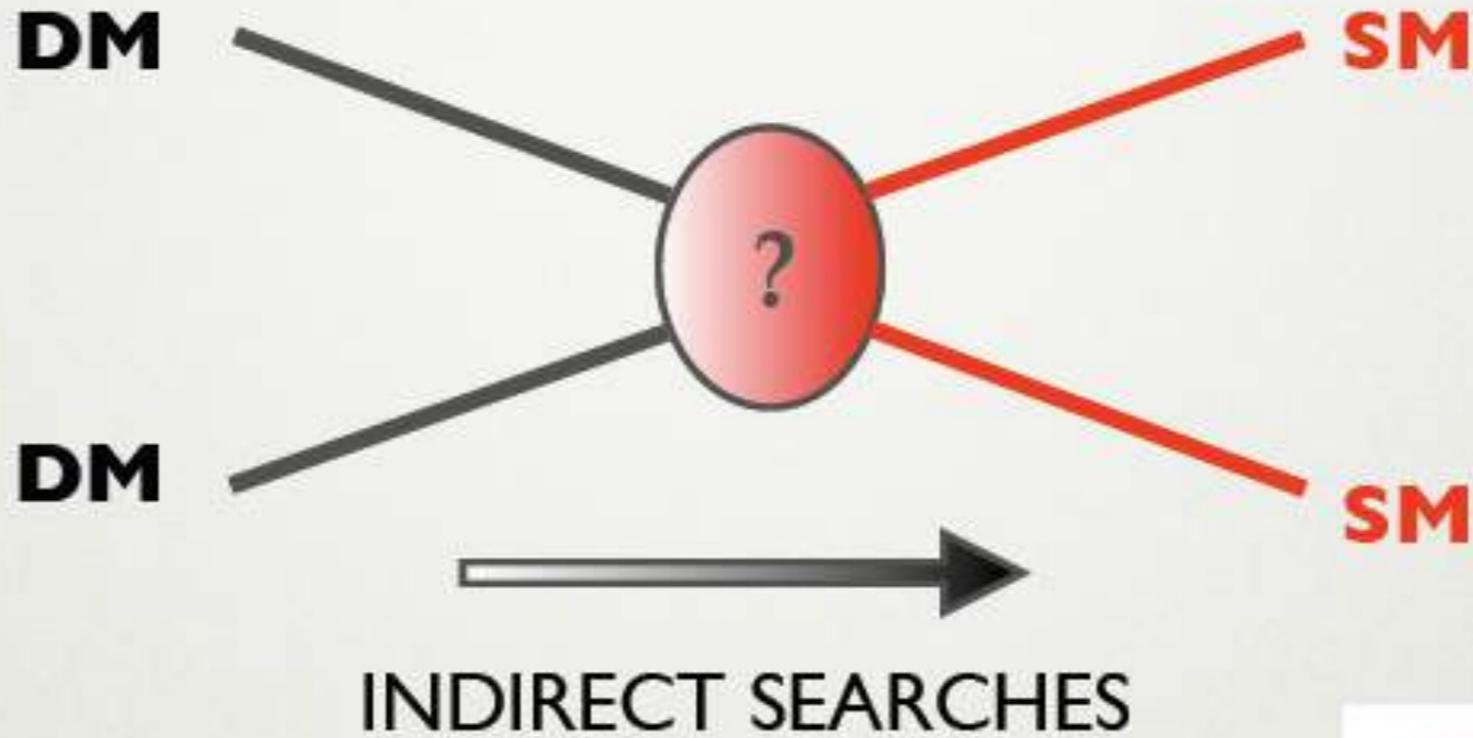
WIMPS

(Weakly Interacting Massive Particles)

“generic” WIMPs has:

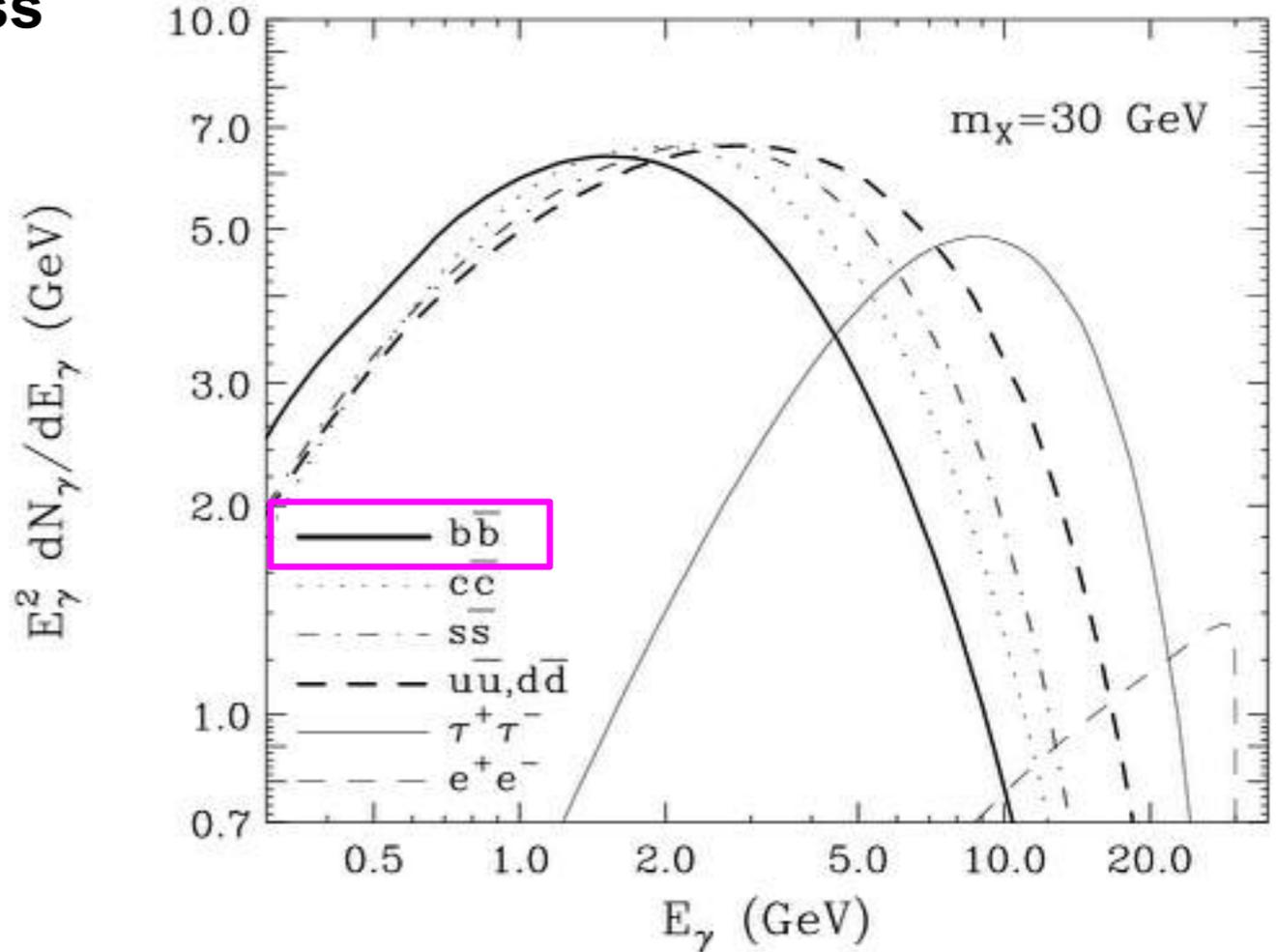
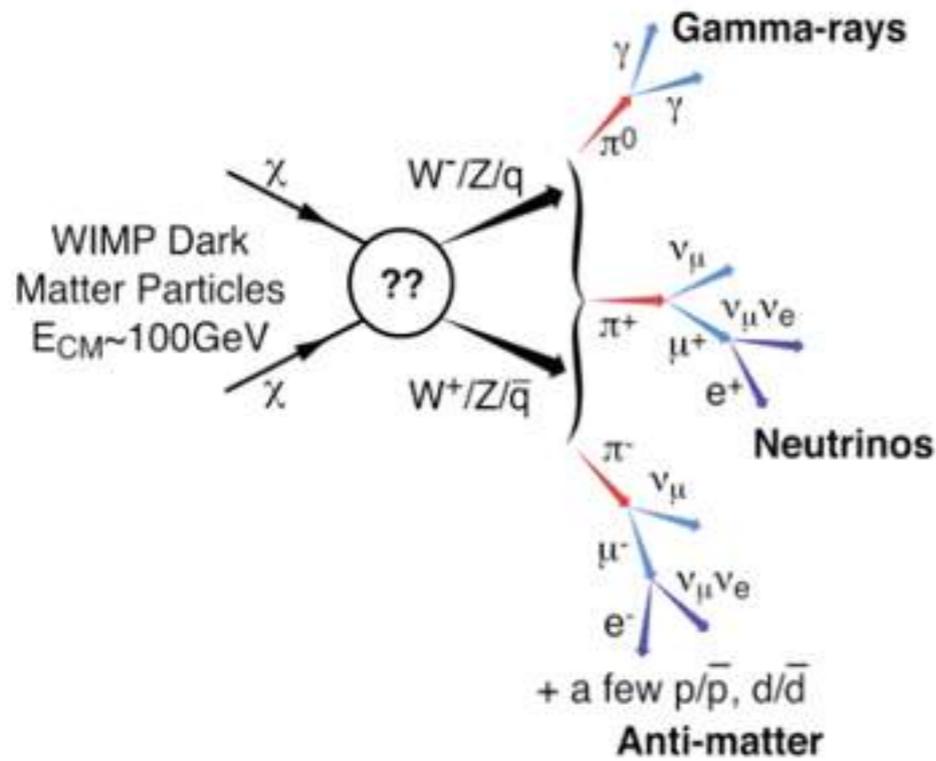
- mass (M_{DM}) ~ 100 GeV
 - annihilation cross section ($\langle\sigma v\rangle$) ~ 10^{-26} cm³/s
- those values are accessible by Fermi!!

DARK MATTER WIMP SEARCHES



Gamma-rays from Dark Matter Annihilation

Continuum with cutoff at WIMP mass



$$\Phi_{WIMP}(E, \Psi) = J(\Psi) \times \Phi^{PP}(E)$$

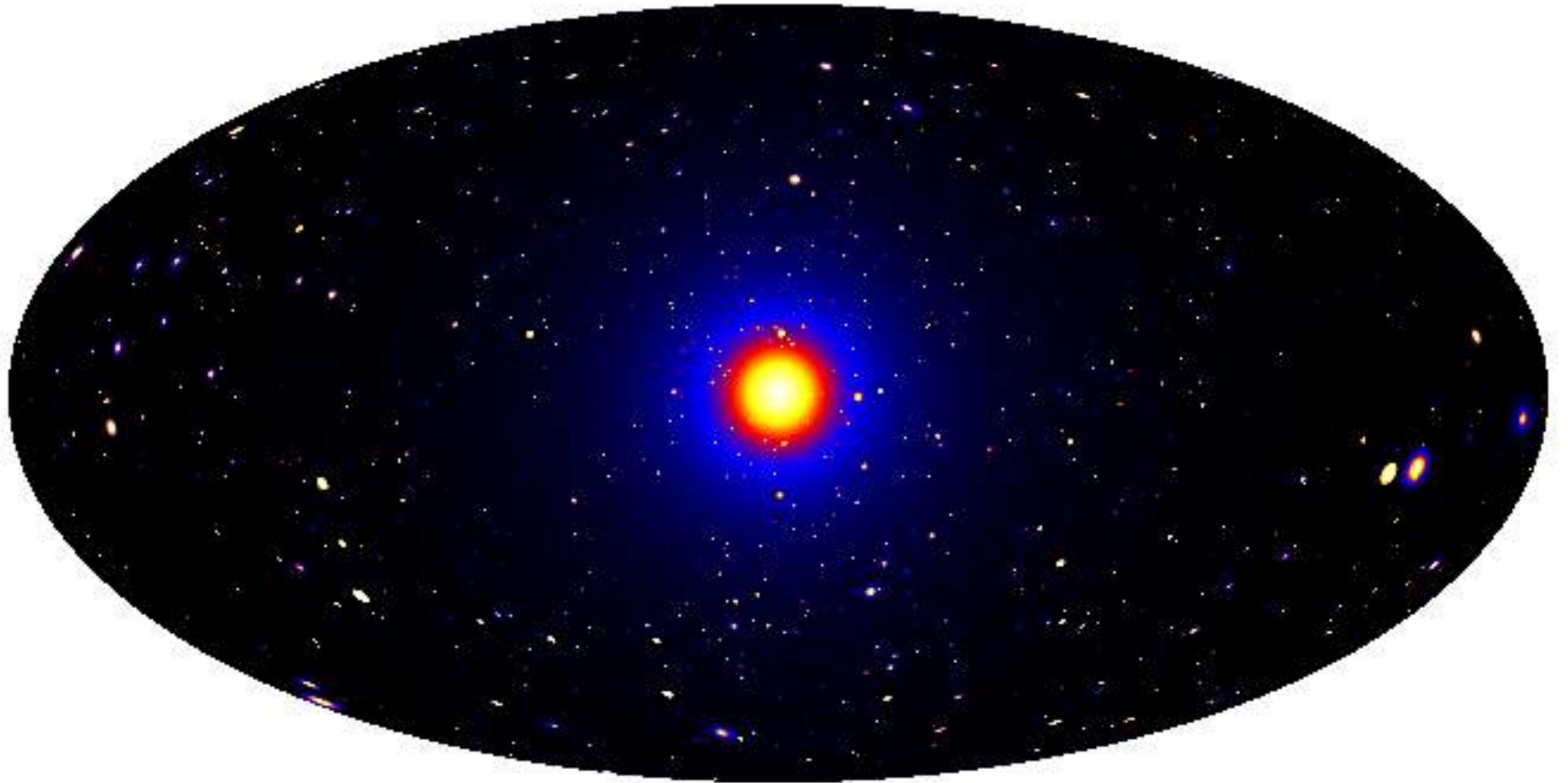
Astrophysical factor

$$J(\Psi) = \int_{l.o.s} dl(\Psi) \rho^2(l)$$

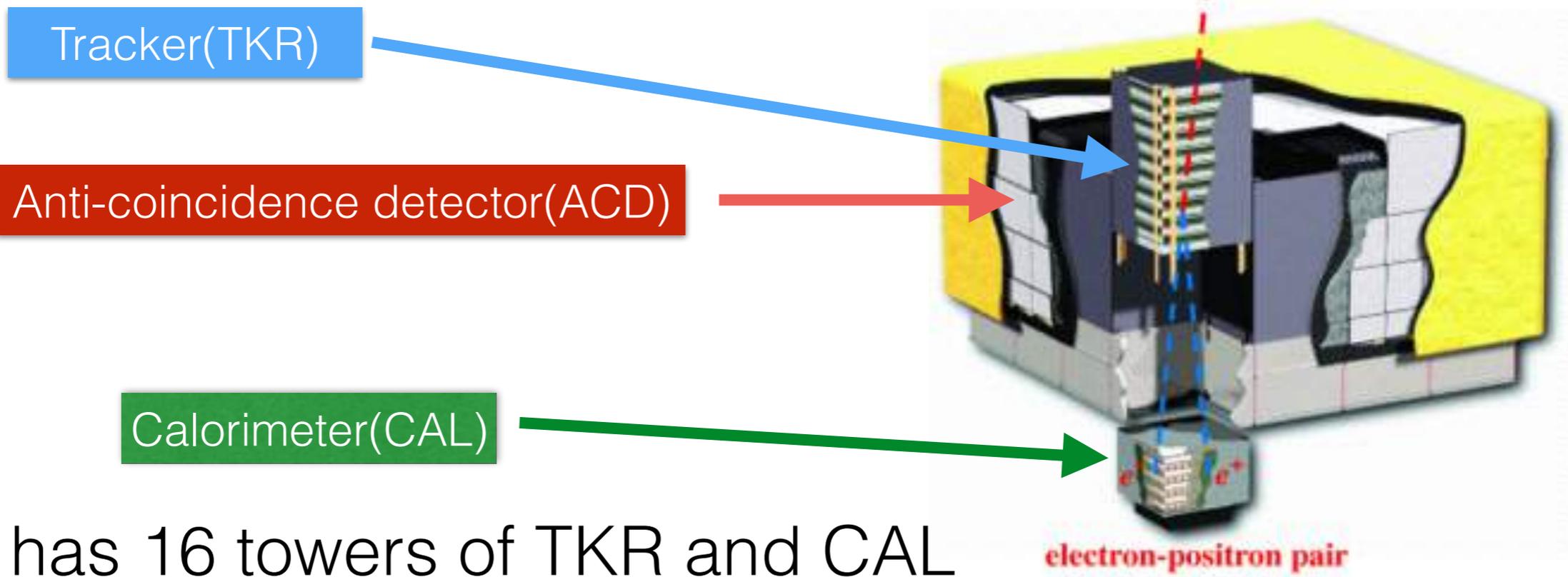
Particle physics factor

$$\Phi^{PP}(E) = \frac{1}{2} \frac{\langle \sigma v \rangle}{m_{WIMP}^2} \sum_f \frac{dN_f}{dE} B_f$$

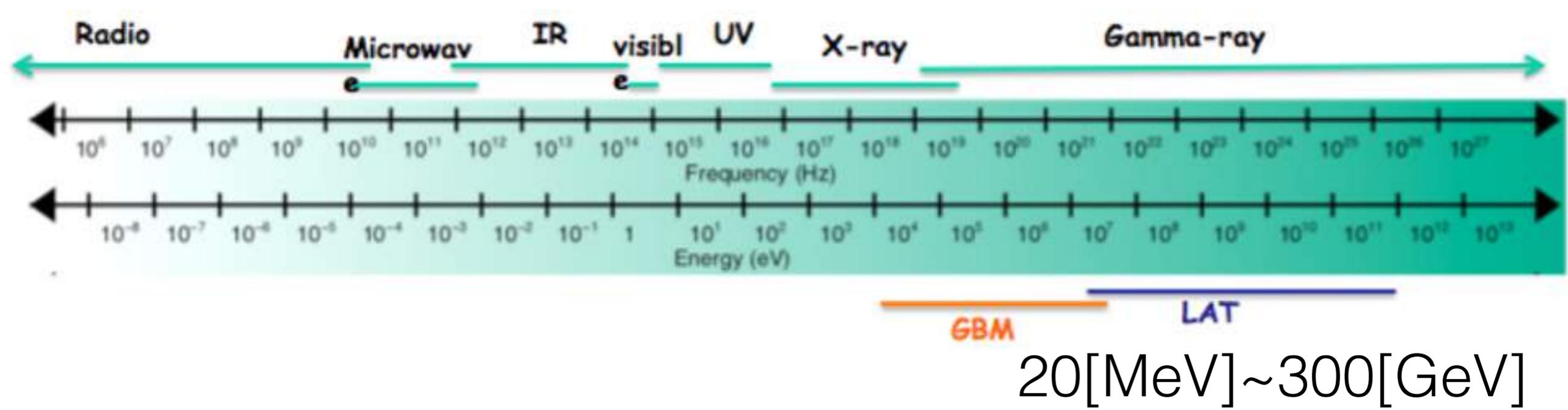
Dark Matter at Galactic center (GC)



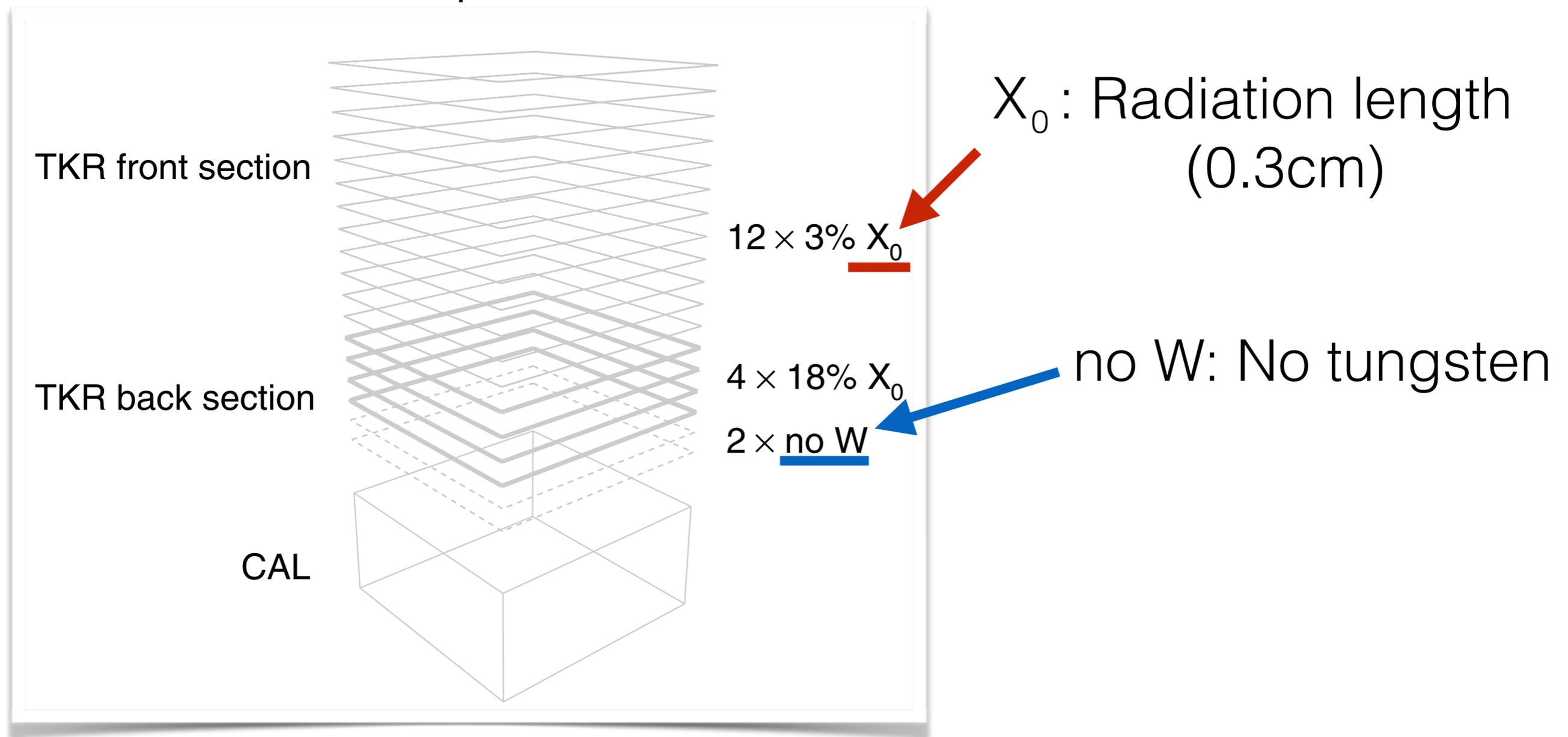
- Large Area Telescope(LAT)



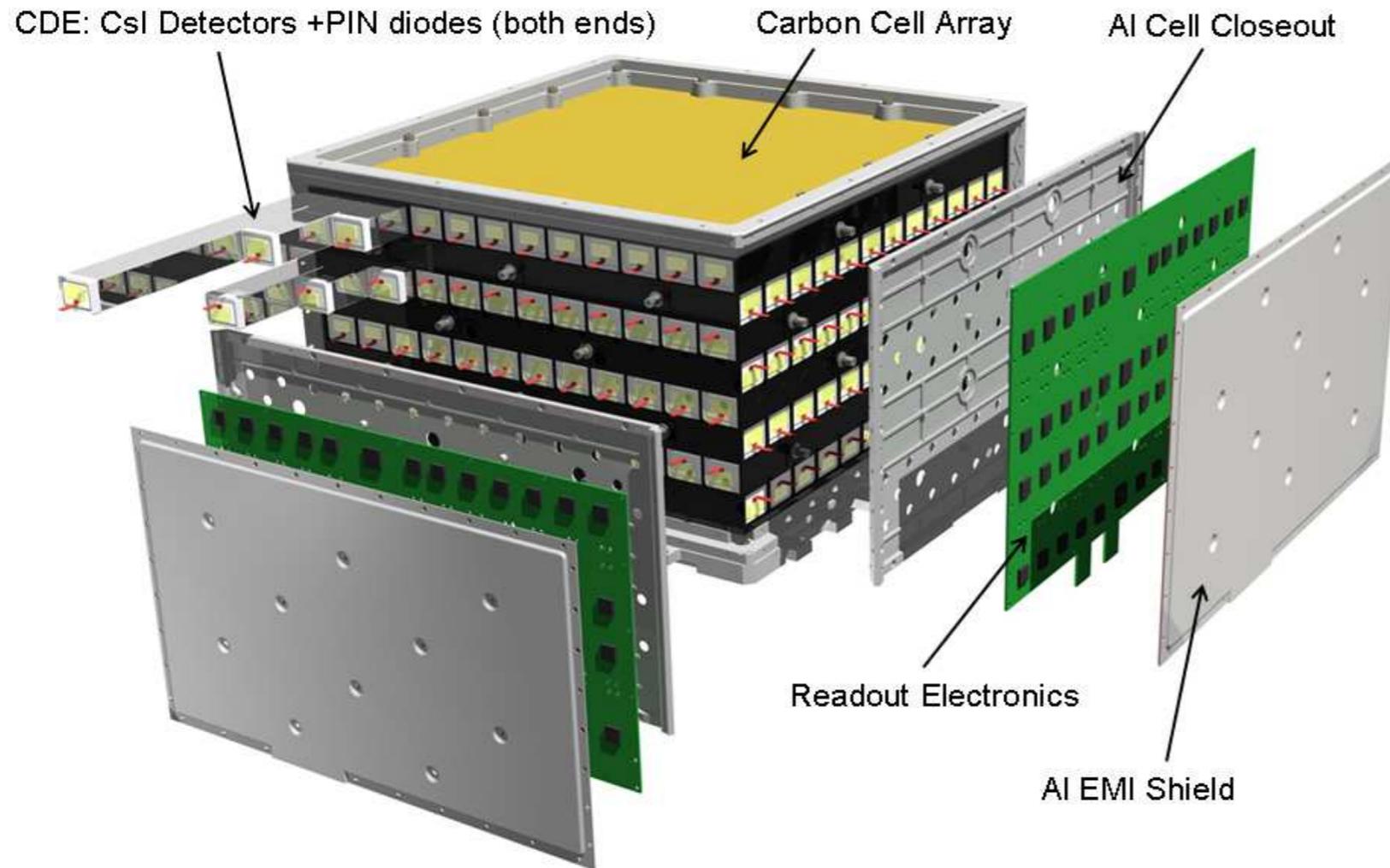
- LAT has 16 towers of TKR and CAL



- LAT tower -Tracker-
- Tracker is a device for determining the trajectory of a charged particle
- Each layer has a tungsten converter foil and silicon strip detectors

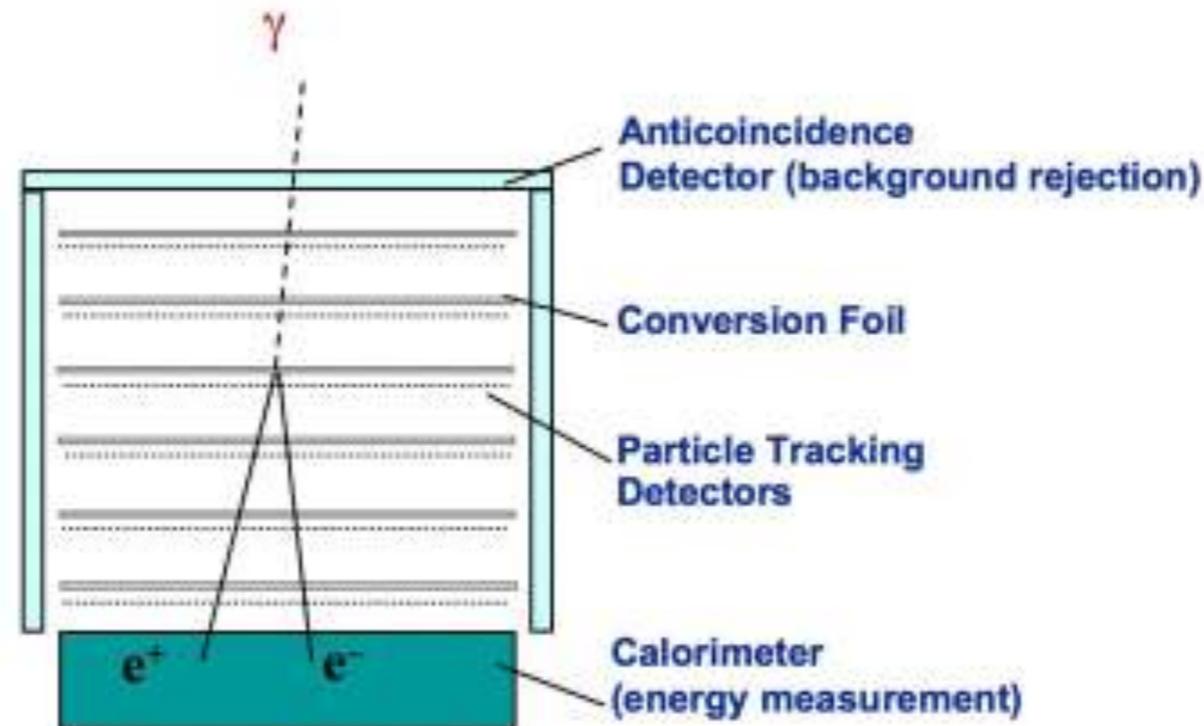
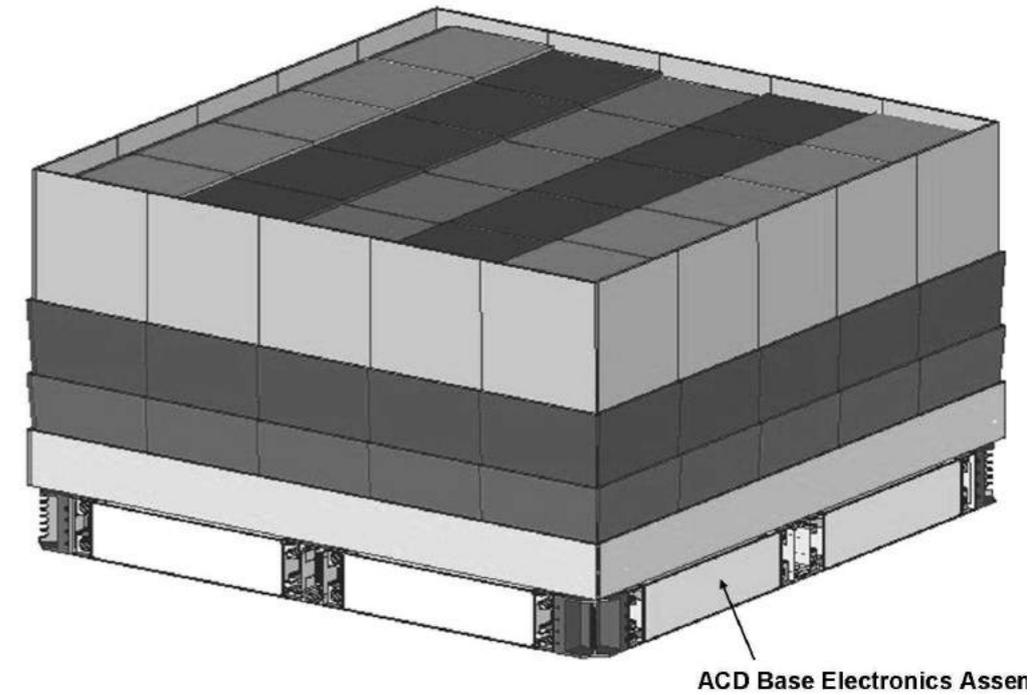


- LAT tower -Calorimeter-



- CAL is composed of logs of CsI scintillation detector
- Reconstruct not only deposited energy but also tracks

- Background rejection -Anti Coincidence Detector-
- Roughly, only $\sim 0.1\%$ of all events are gamma-ray
- LAT towers are wrapped by ACD tiles (plastic scintillators) for background rejection



3.How to search DM?

Prepare data

- Data download
 - > Photon file
 - > Spacecraft file

count map

exposure

model

- Summarize the number of the observed counts

- Summarize the exposure time of the source with Fermi map

- Fitting the observed conditions to the model

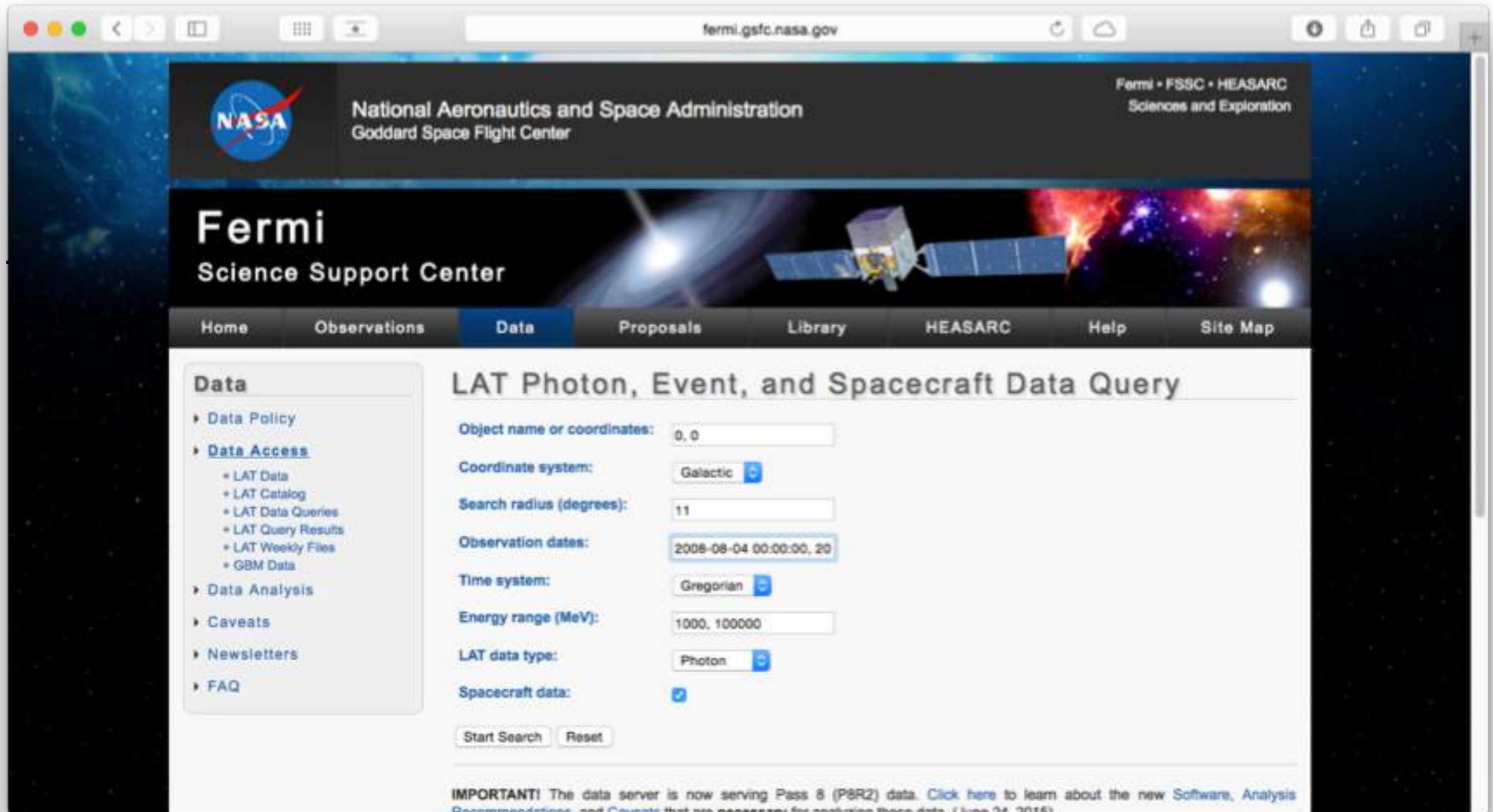
residual map

- counts map-model map

Explore Fermi-LAT data

Data download

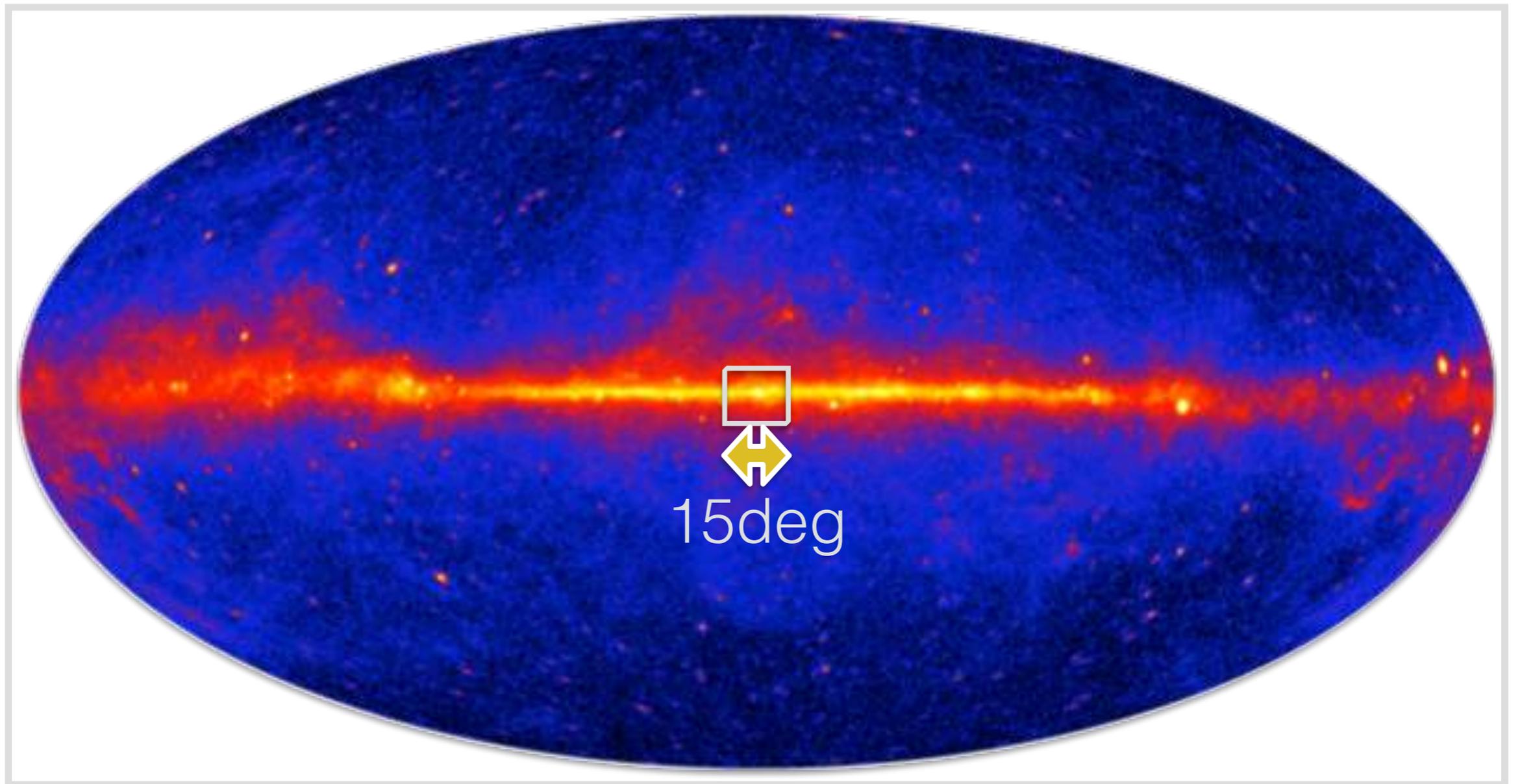
<http://fermi.gsfc.nasa.gov/cgi-bin/ssc/LAT/LATDataQuery.cgi>



The screenshot shows a web browser window displaying the Fermi Science Support Center website. The browser's address bar shows the URL `fermi.gsfc.nasa.gov`. The website header includes the NASA logo and the text "National Aeronautics and Space Administration Goddard Space Flight Center" and "Fermi • FSSC • HEASARC Sciences and Exploration". The main navigation bar has links for Home, Observations, Data (selected), Proposals, Library, HEASARC, Help, and Site Map. The main content area is titled "LAT Photon, Event, and Spacecraft Data Query" and contains a search form with the following fields:

- Object name or coordinates:
- Coordinate system:
- Search radius (degrees):
- Observation dates:
- Time system:
- Energy range (MeV):
- LAT data type:
- Spacecraft data:

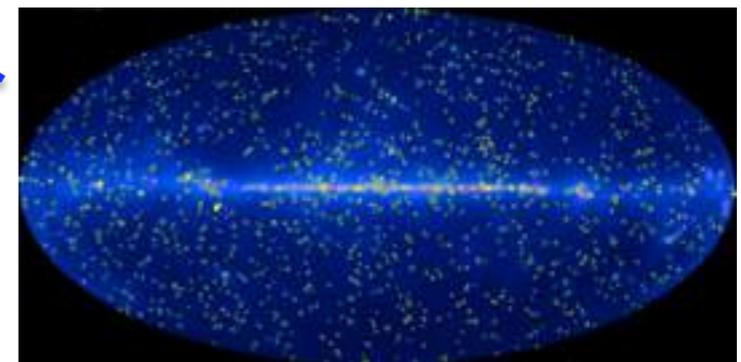
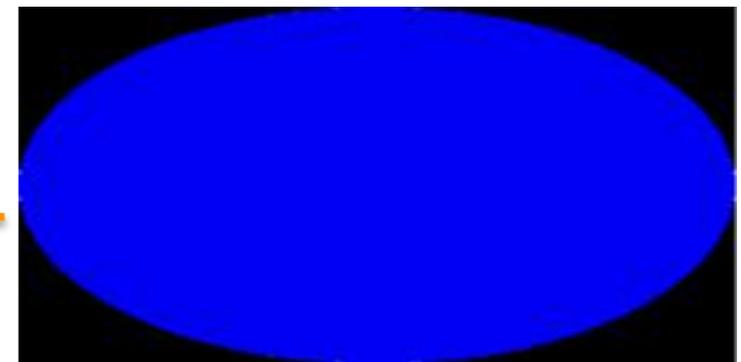
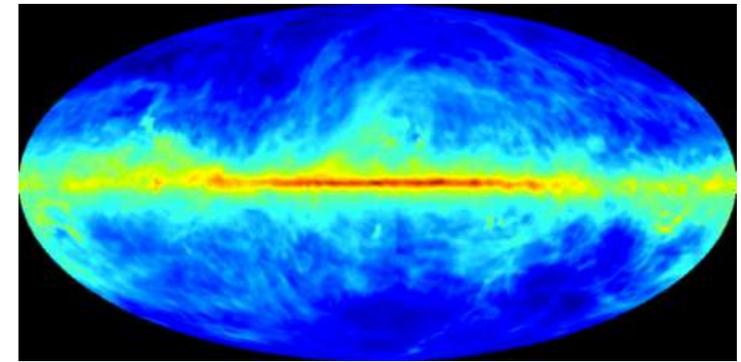
At the bottom of the search form are "Start Search" and "Reset" buttons. A sidebar on the left contains a "Data" menu with links to Data Policy, Data Access (with sub-links for LAT Data, LAT Catalog, LAT Data Queries, LAT Query Results, LAT Weekly Files, and GBM Data), Data Analysis, Caveats, Newsletters, and FAQ. At the bottom of the page, there is an important notice: "IMPORTANT! The data server is now serving Pass 8 (P8R2) data. Click here to learn about the new Software, Analysis Recommendations, and Caveats that are necessary for analyzing these data. (June 24, 2015)".



Energy: 1 GeV ~ 100 GeV

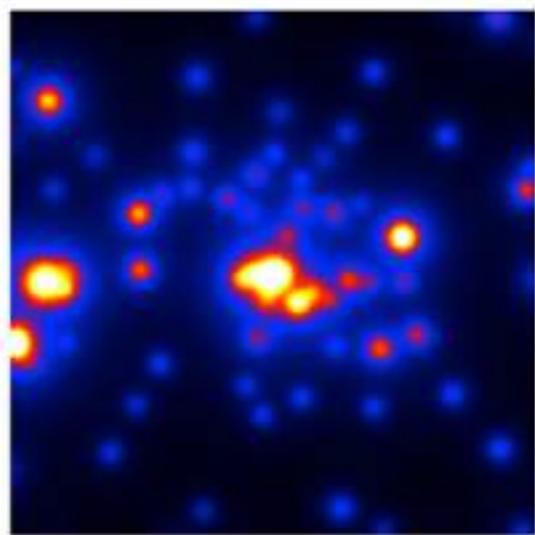
Gamma-ray sky

- Galactic diffuse model
 - > π^0
 - > bremsstrahlung
 - > inverse Compton scattering
- Isotropic diffuse model
- Source model
- Dark matter template

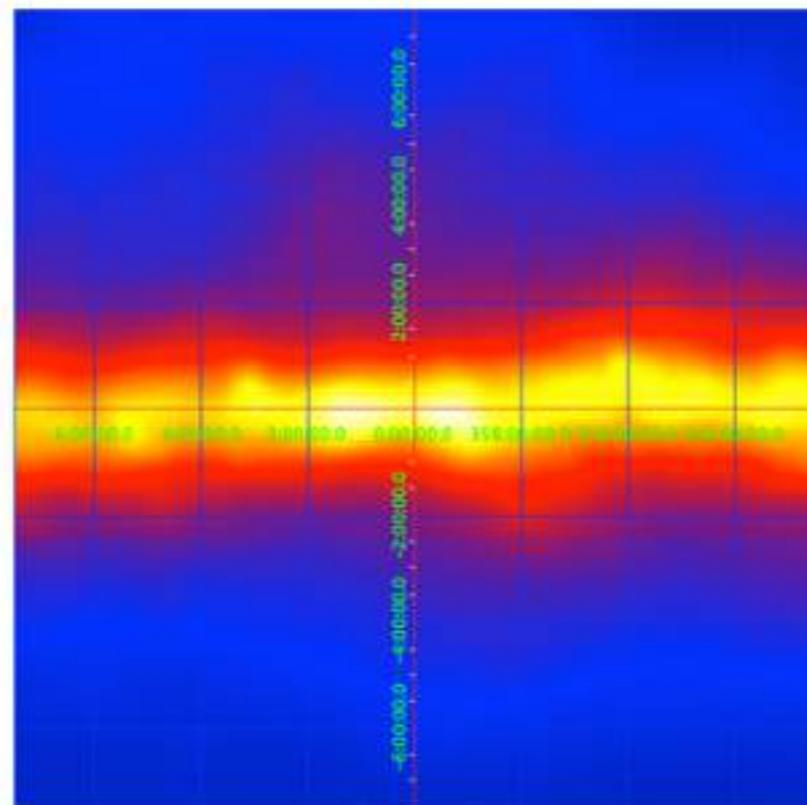


sum model

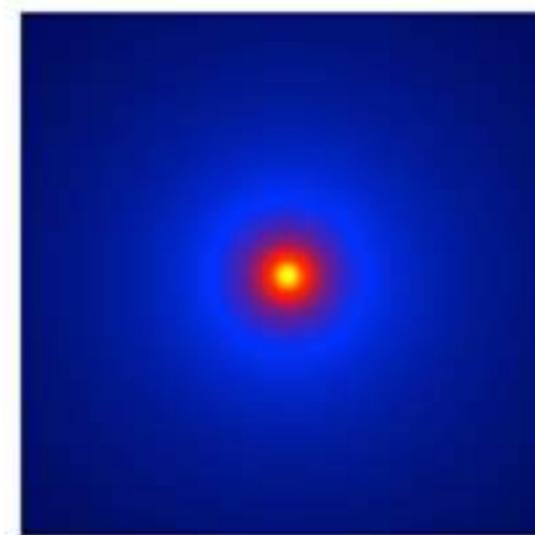
Source model



Galactic latitude

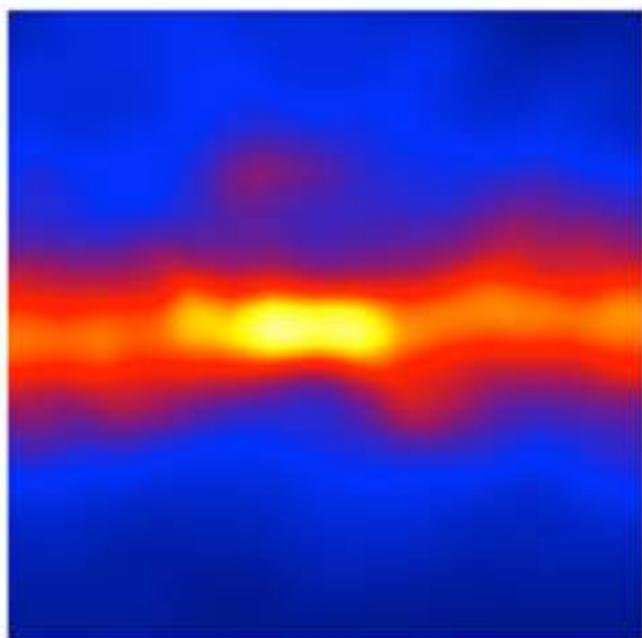


Dark matter template

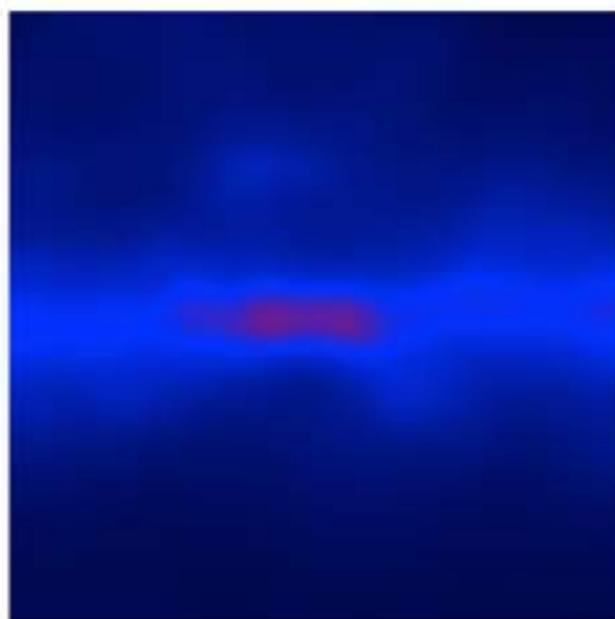


Galactic diffuse model

pi0



bremsstrahlung



inverse Compton scattering



Dark matter at Galactic centre

NFW (Navarro–Frenk–White) profile

$$\rho_{NFW} = \frac{\rho_0}{(r/r_s)(1+r/r_s)}$$

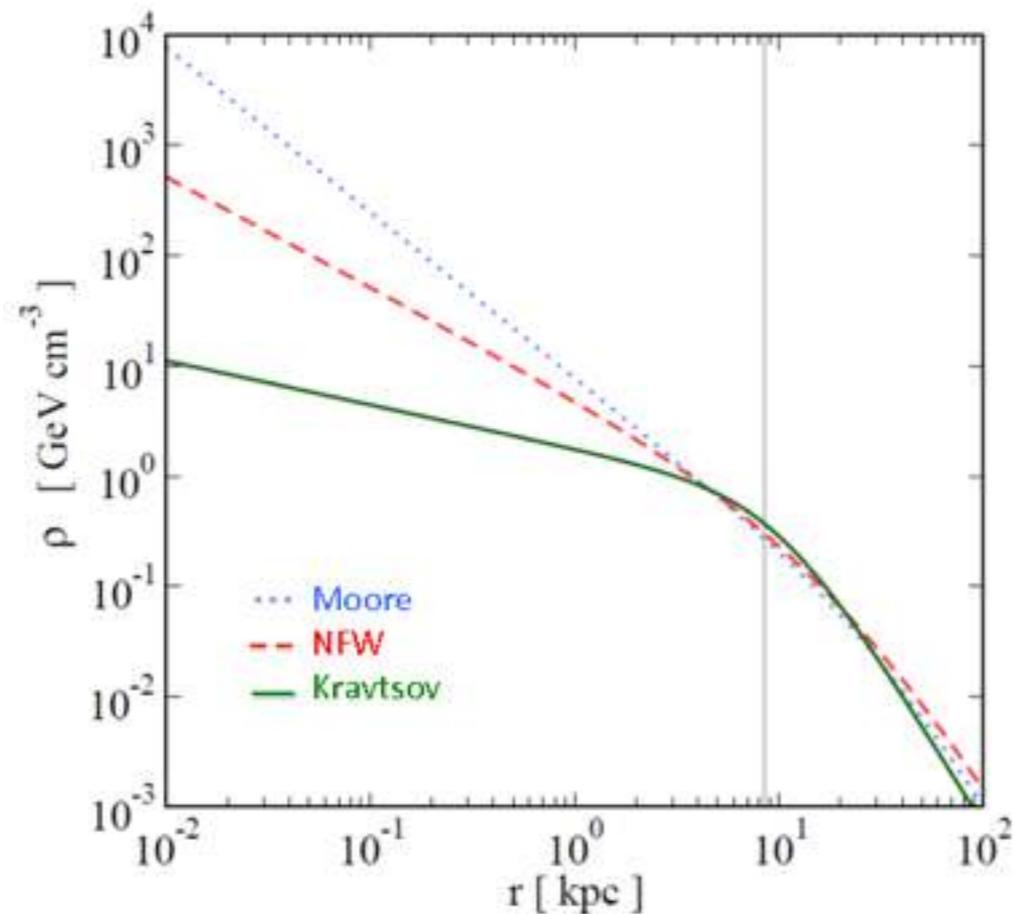
ρ_0 : set 0.3 GeV cm^{-3}
at 8.5 kpc (Sun)

$r_s = 20 \text{ kpc}$

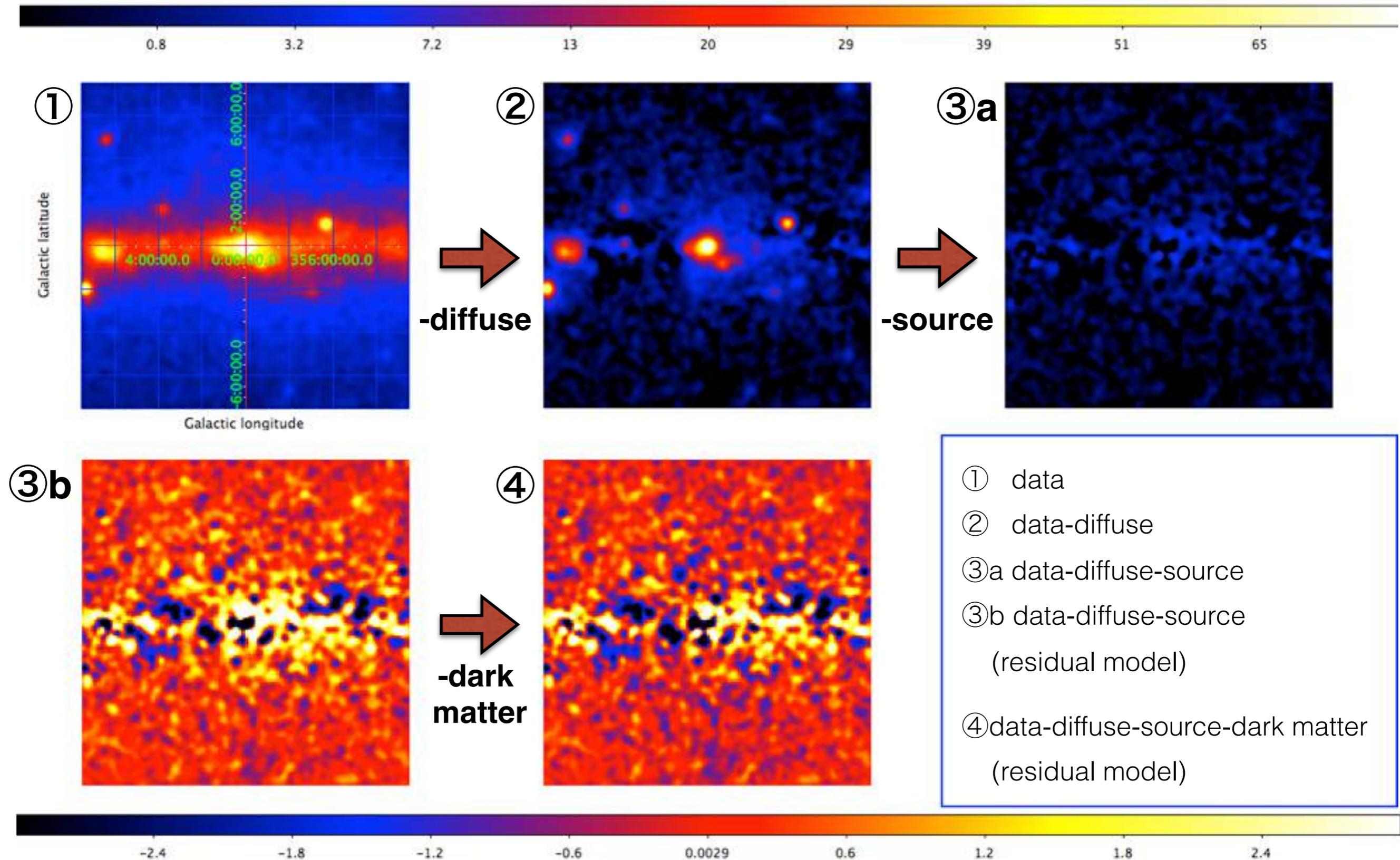
NFW profile at GC

(log scale in gray color)

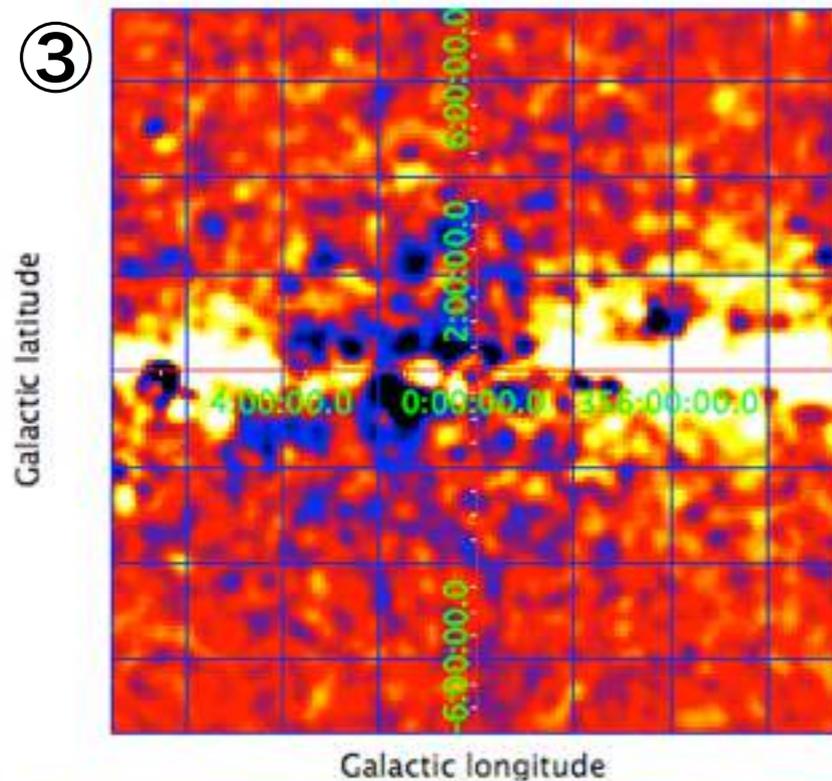
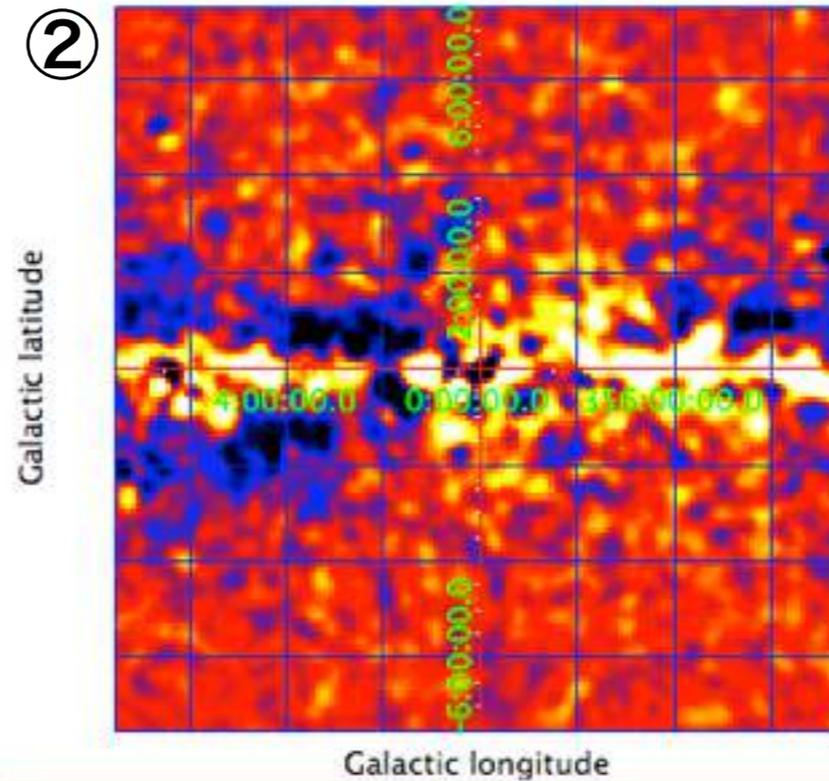
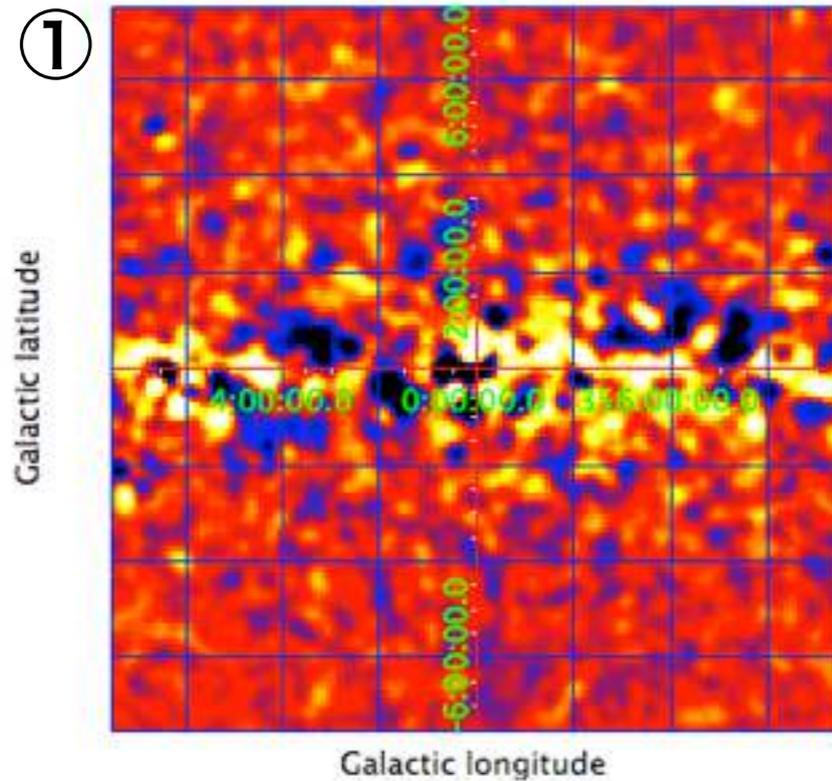
→ **J-factor = $2.42 \times 10^{22} \text{ GeV}^2 \text{ cm}^{-5}$**



Result



Different Diffuse Models

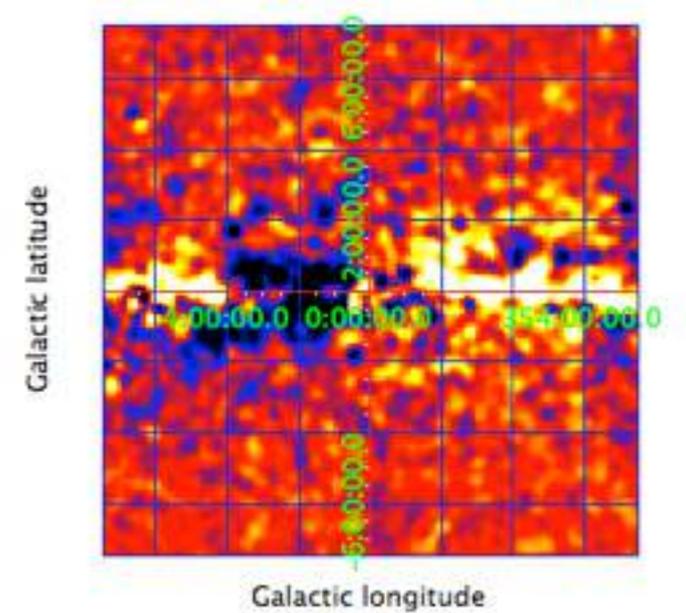
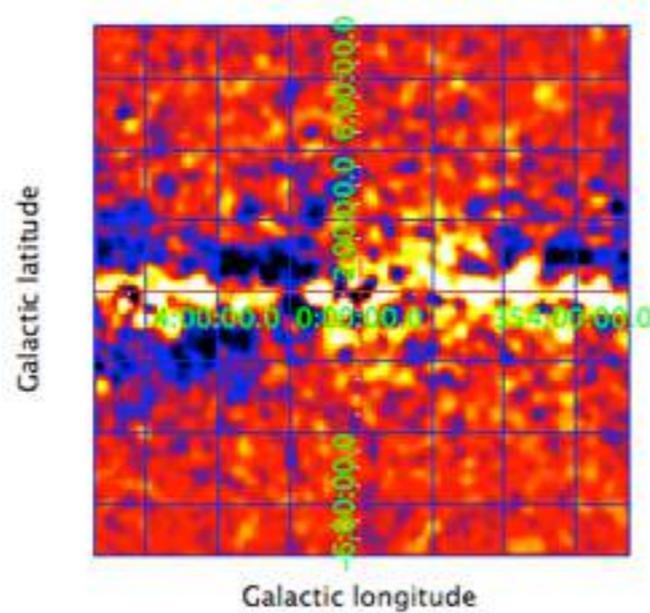
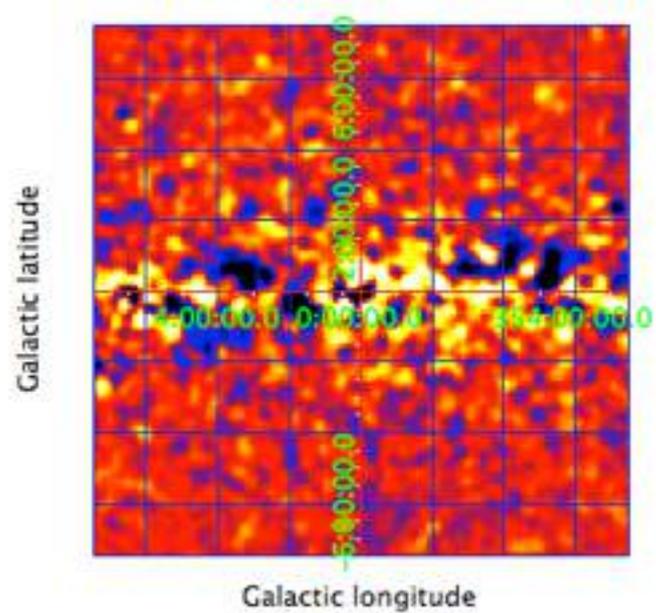
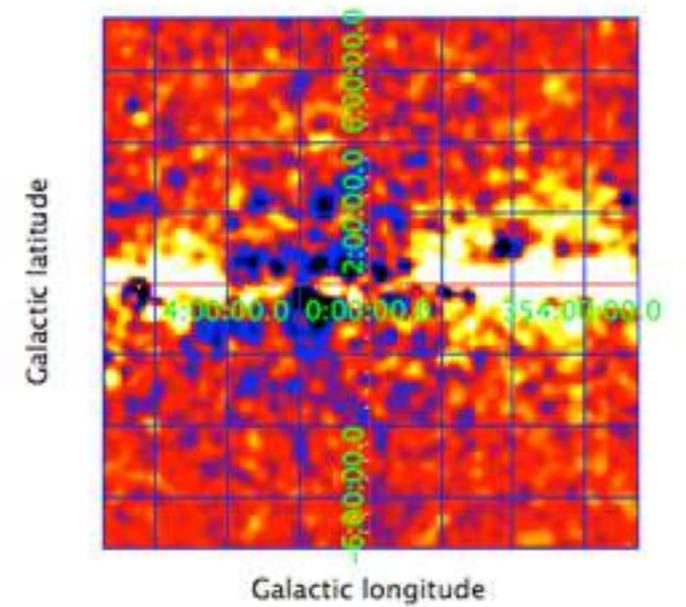
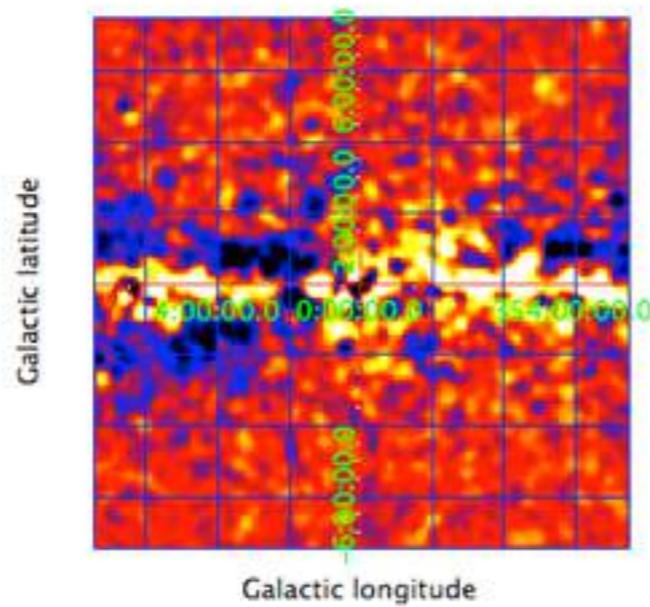
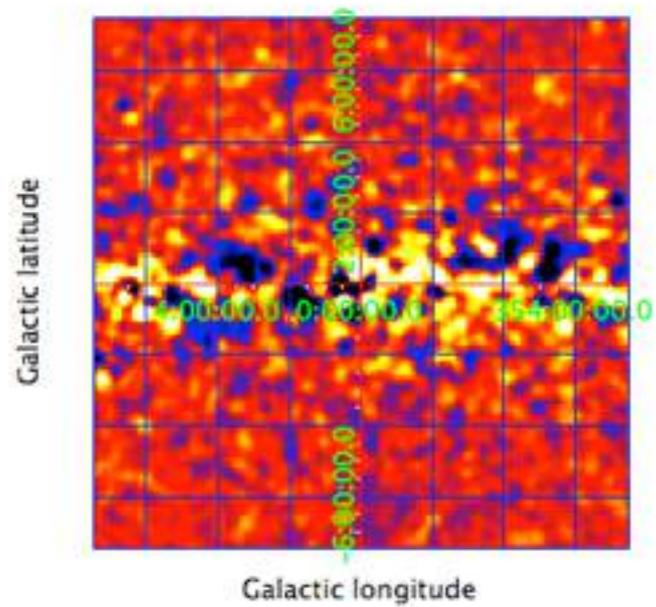


Model

- ① Standard Diffuse Model
- ② Internal New Model
(Under Development)
- ③ Alternative Model



Scaling Diffuse models



-2.4

-1.8

-1.2

-0.6

0.0029

0.6

1.2

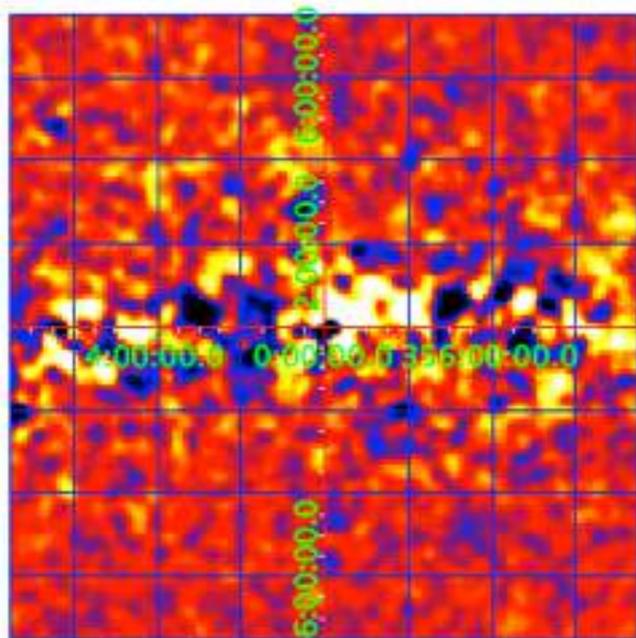
1.8

2.4

Residual Maps

①

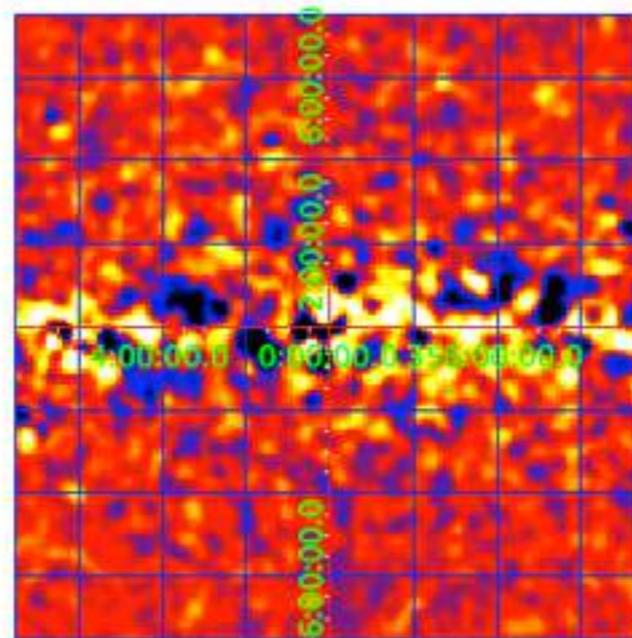
Galactic latitude



Galactic longitude

②

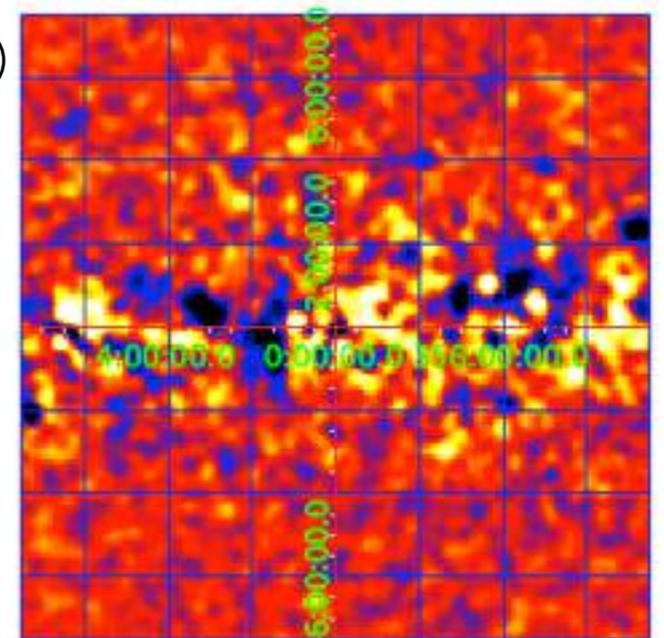
Galactic latitude



Galactic longitude

③

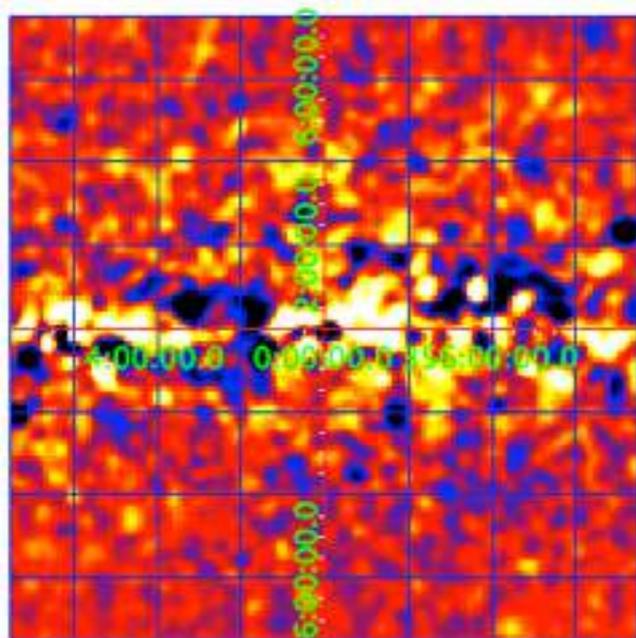
Galactic latitude



Galactic longitude

④

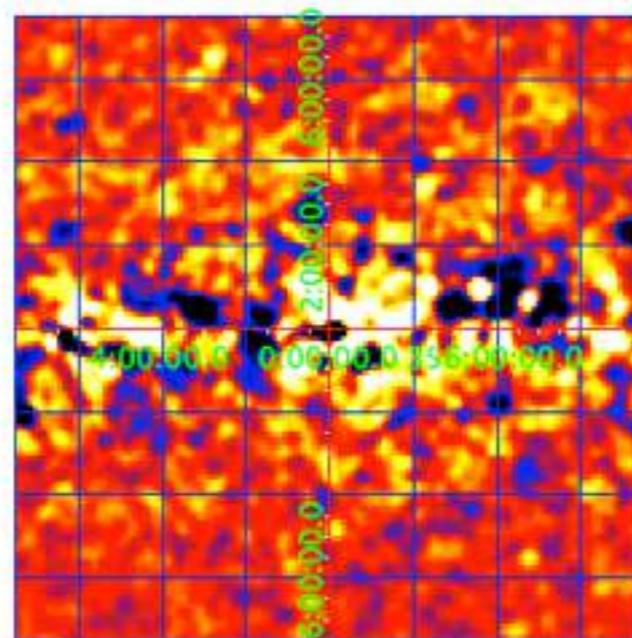
Galactic latitude



Galactic longitude

⑤

Galactic latitude



Galactic longitude

Period

- ① 2008/08/05 ~ 2010/02/01
- ② 2010/02/01 ~ 2011/08/01
- ③ 2011/08/01 ~ 2013/02/01
- ④ 2013/02/01 ~ 2014/08/01
- ⑤ 2014/08/01 ~ 2016/02/01

-2.4

-1.8

-1.2

-0.6

0.0029

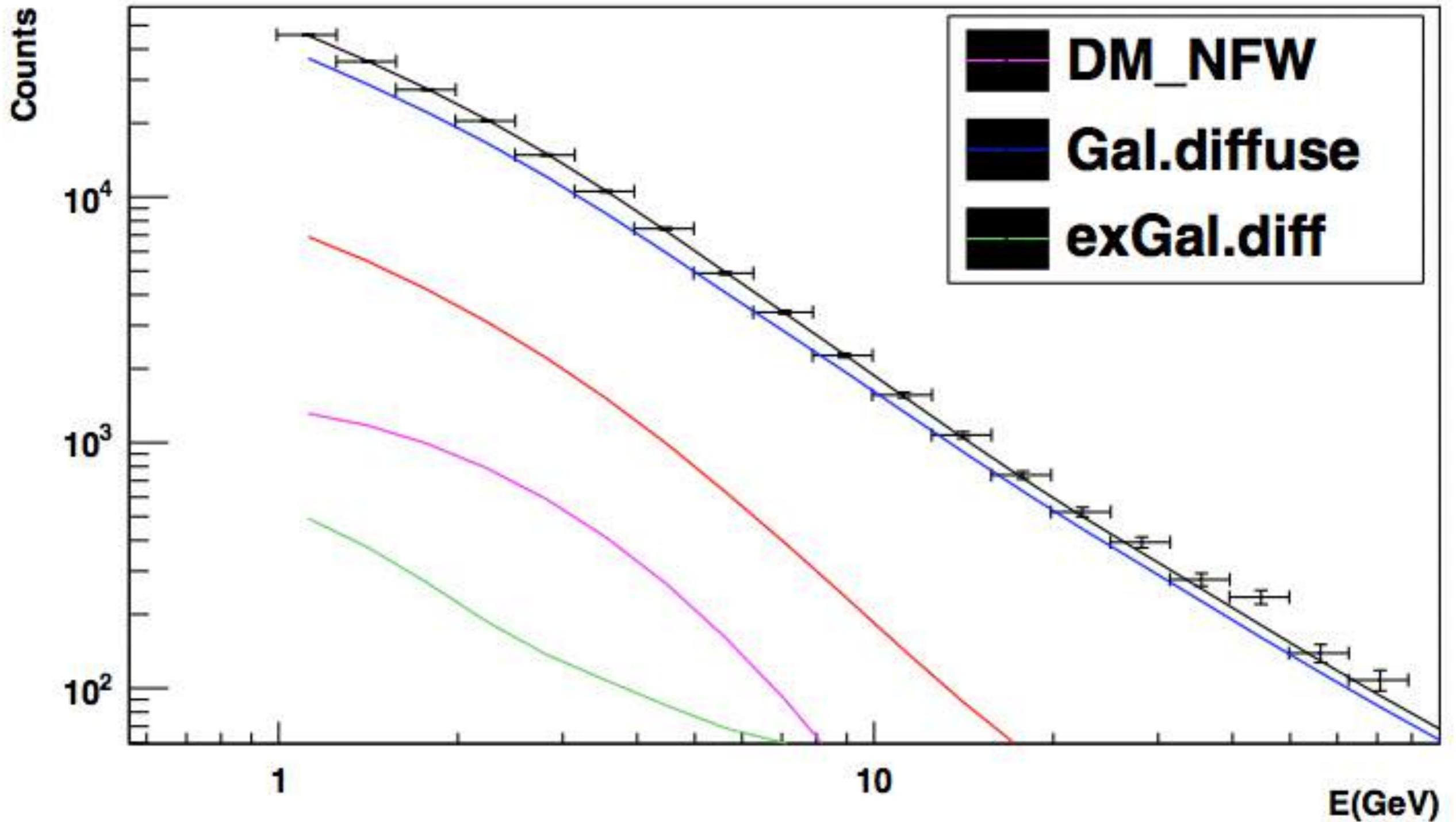
0.6

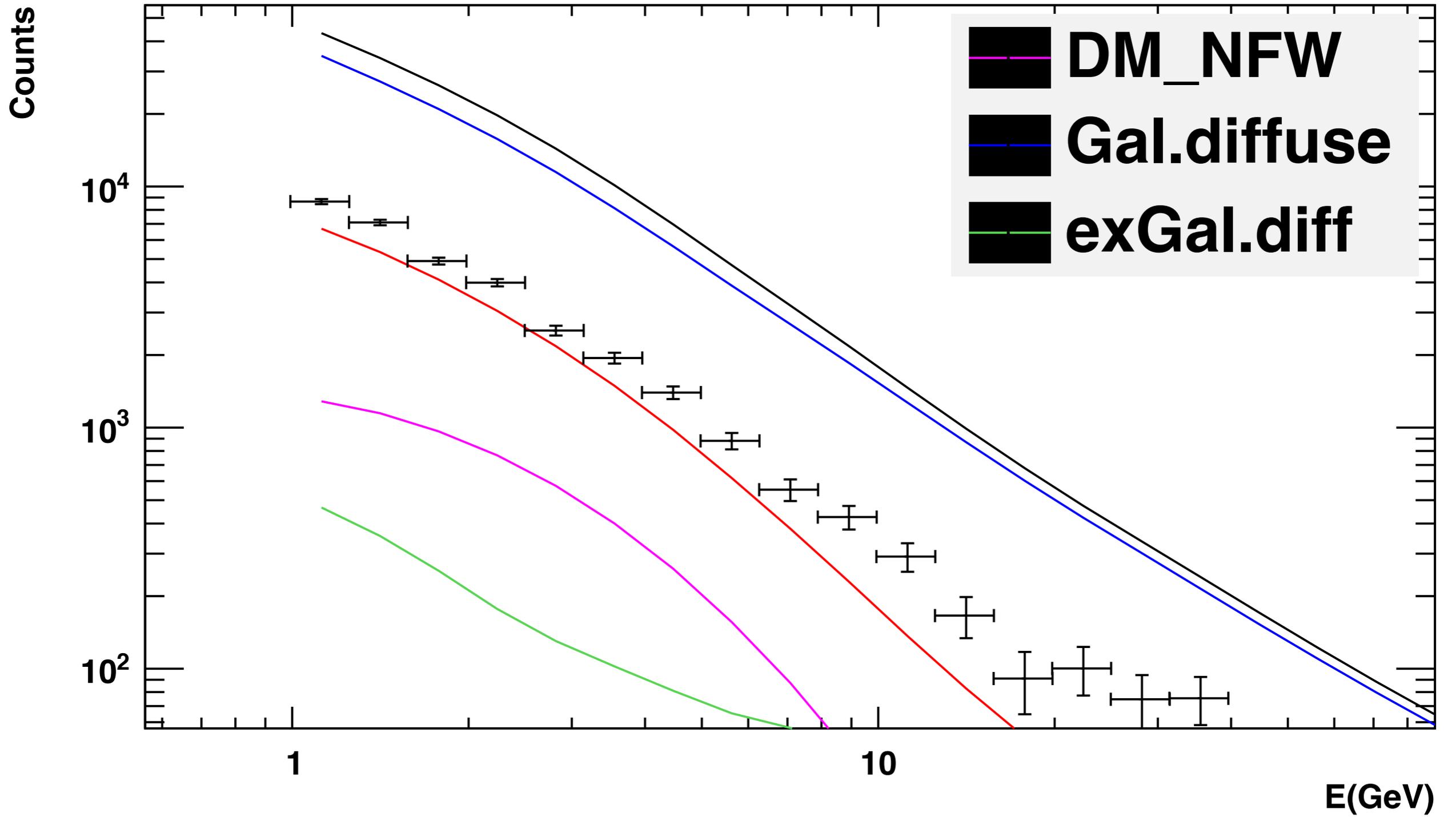
1.2

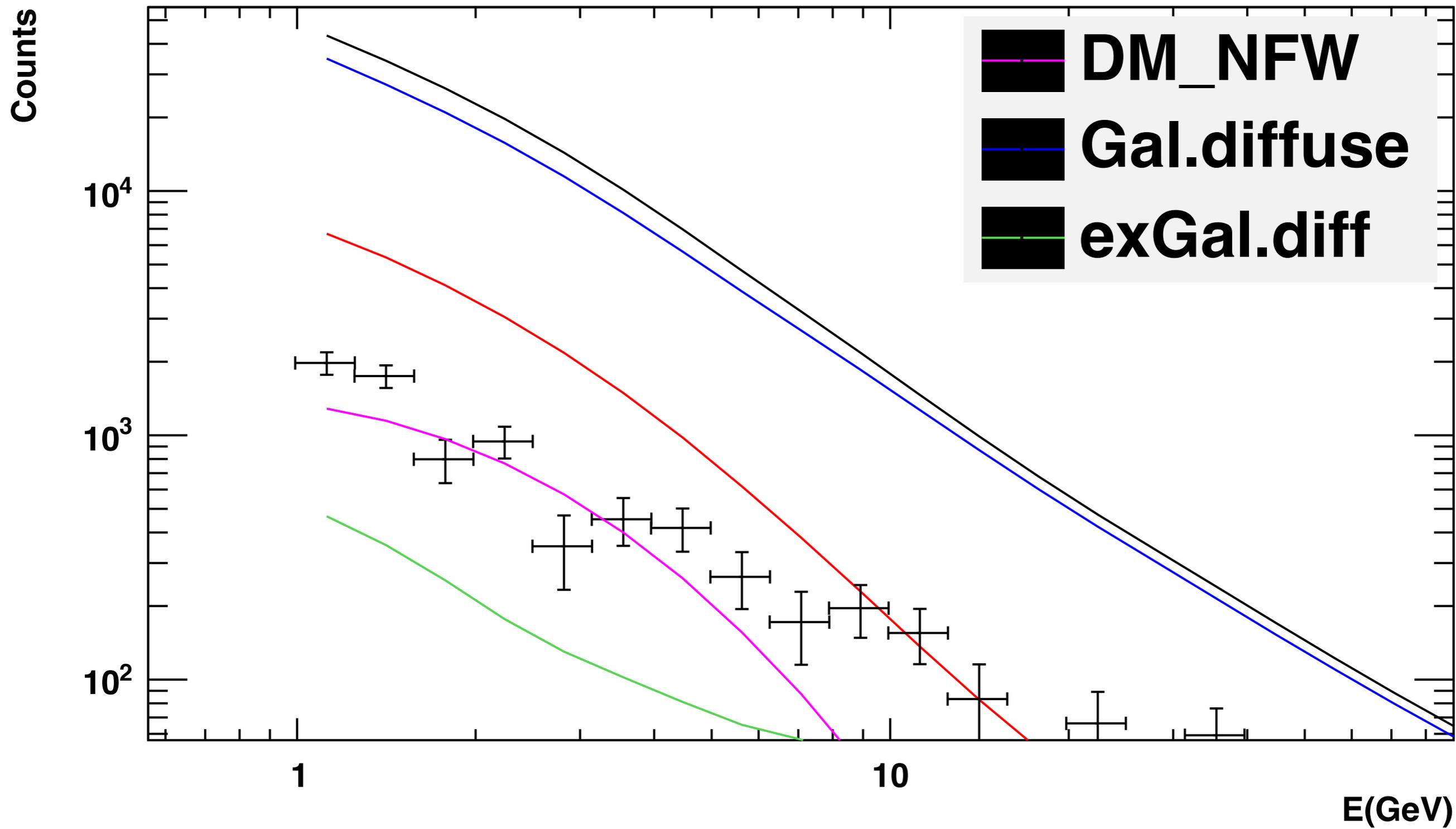
1.8

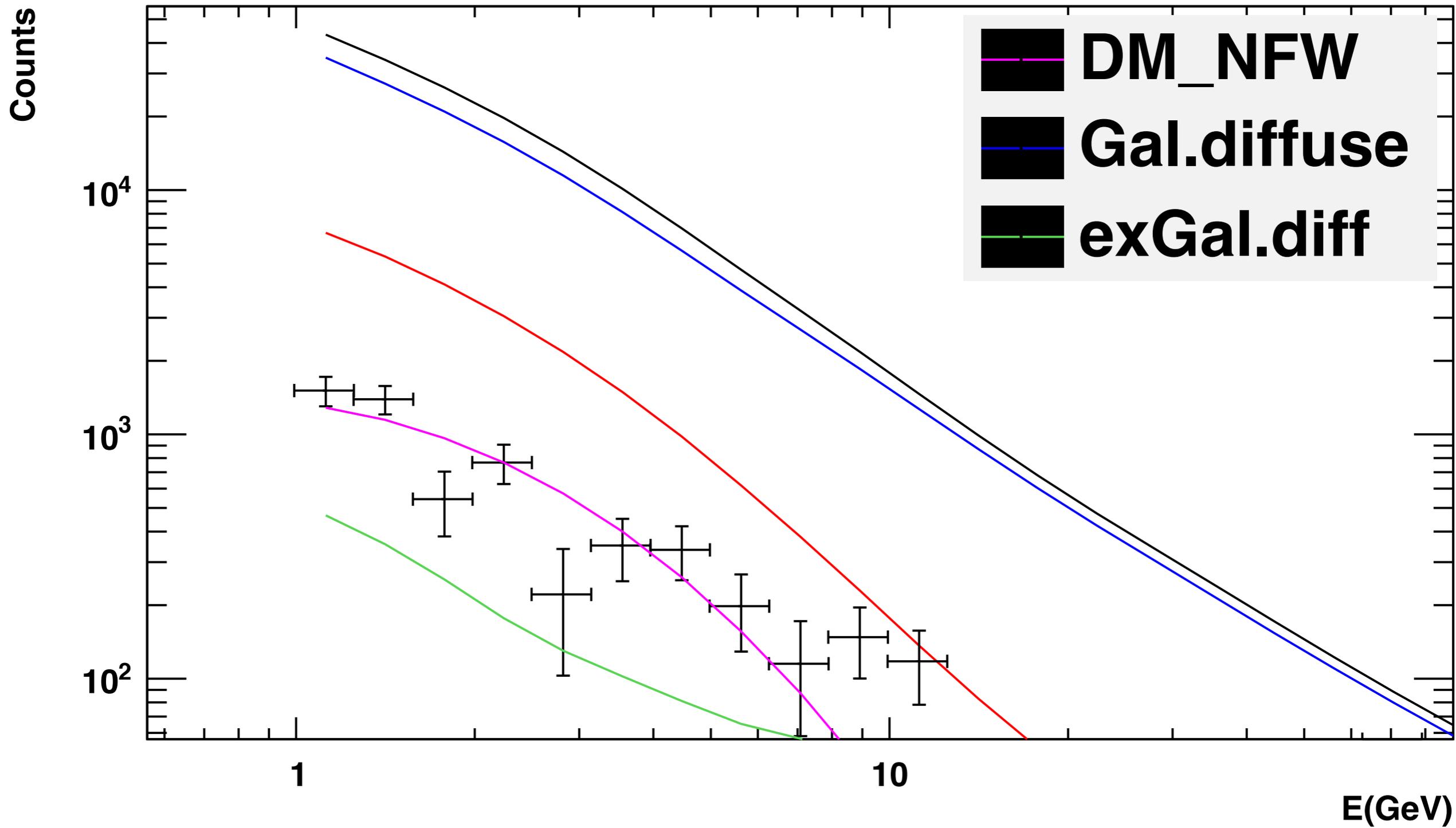
2.4

Count Spectra



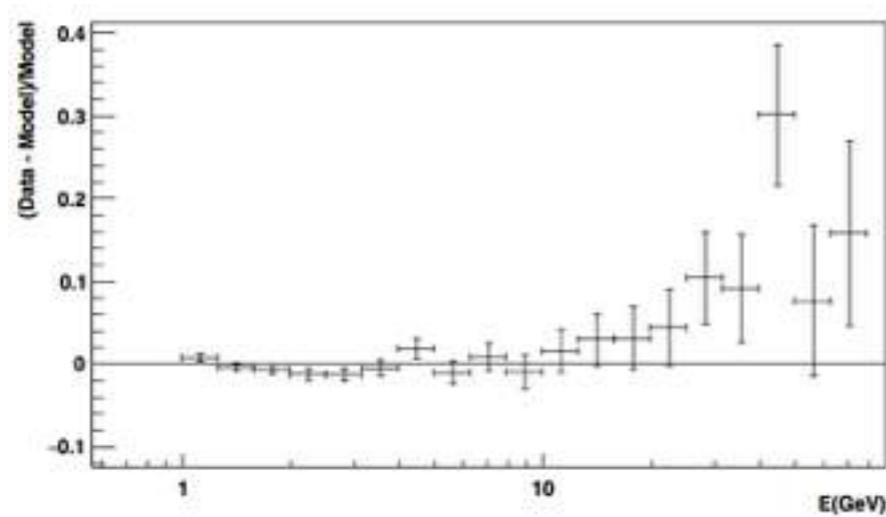




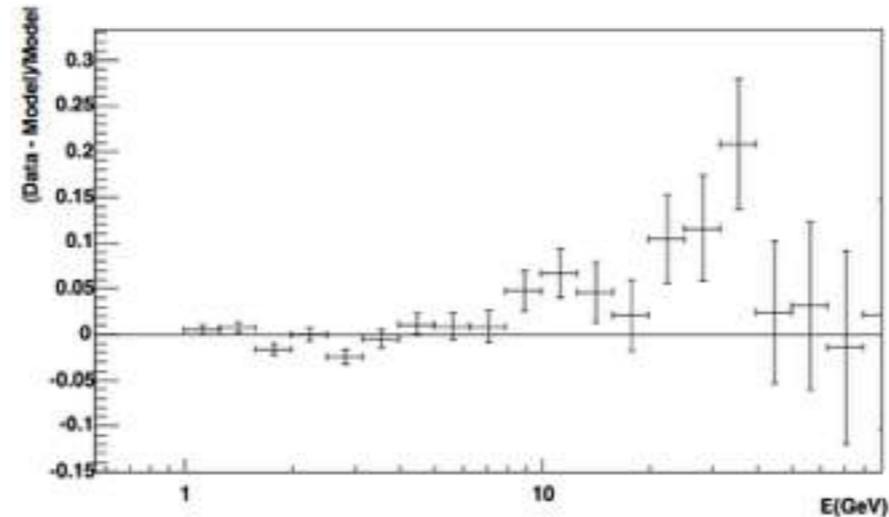


Residual Spectra

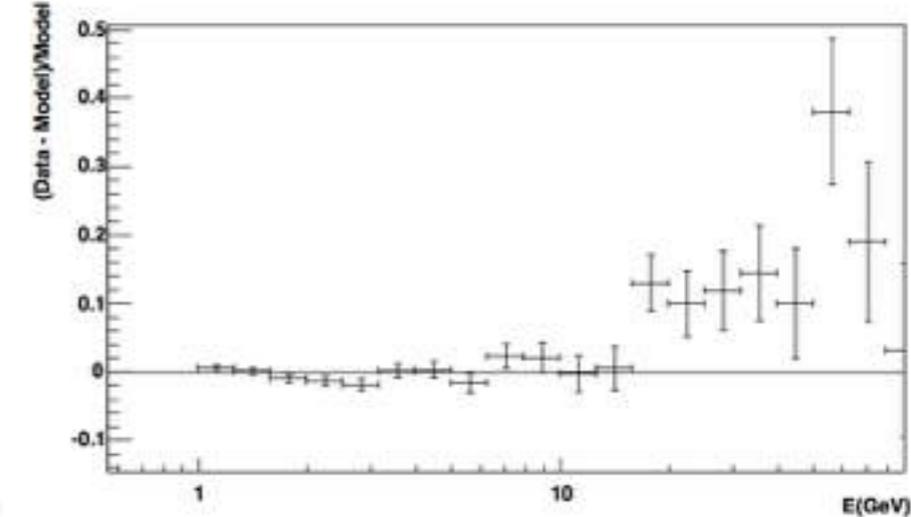
① 2008/08/05 ~ 2010/02/01



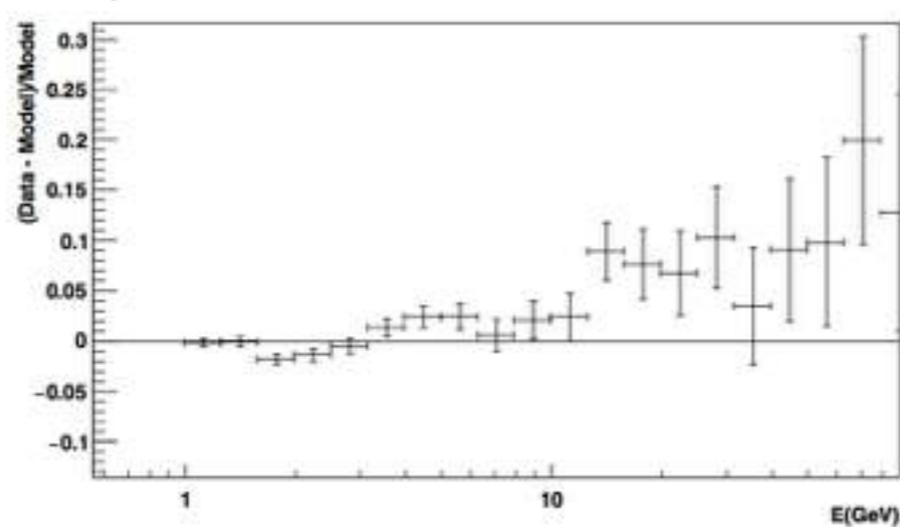
② 2010/02/01 ~ 2011/08/01



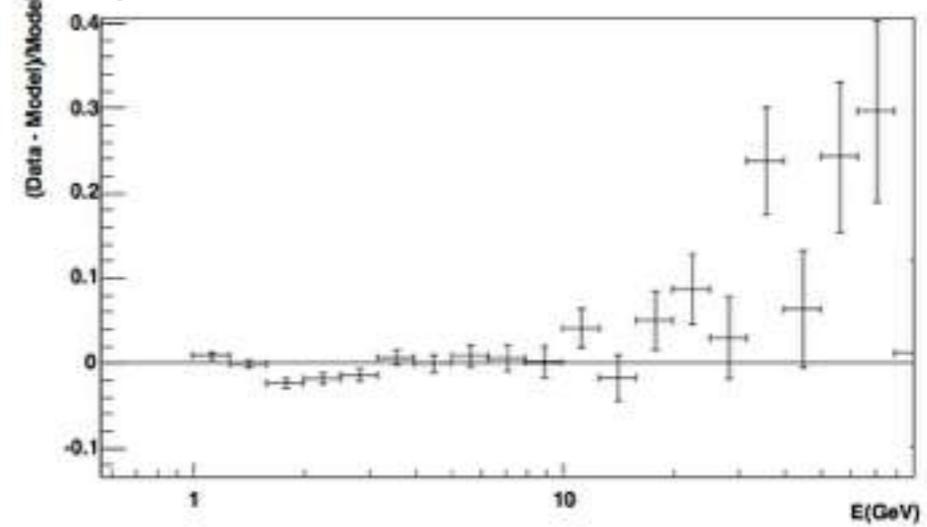
③ 2011/08/01 ~ 2013/02/01



④ 2013/02/01 ~ 2014/08/01

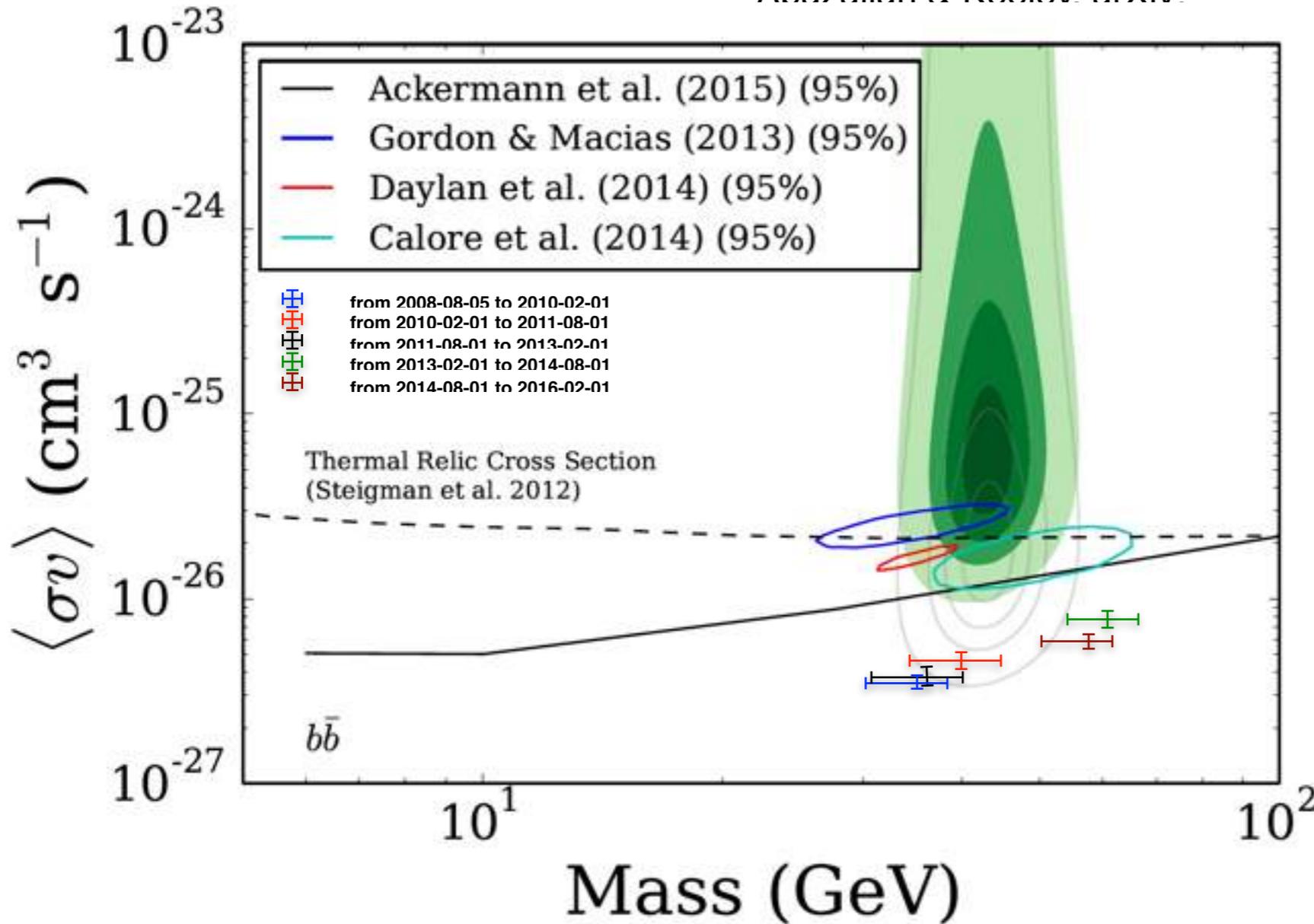


⑤ 2014/08/01 ~ 2016/02/01



DM parameters

Abazajian & Keelev arXiv:



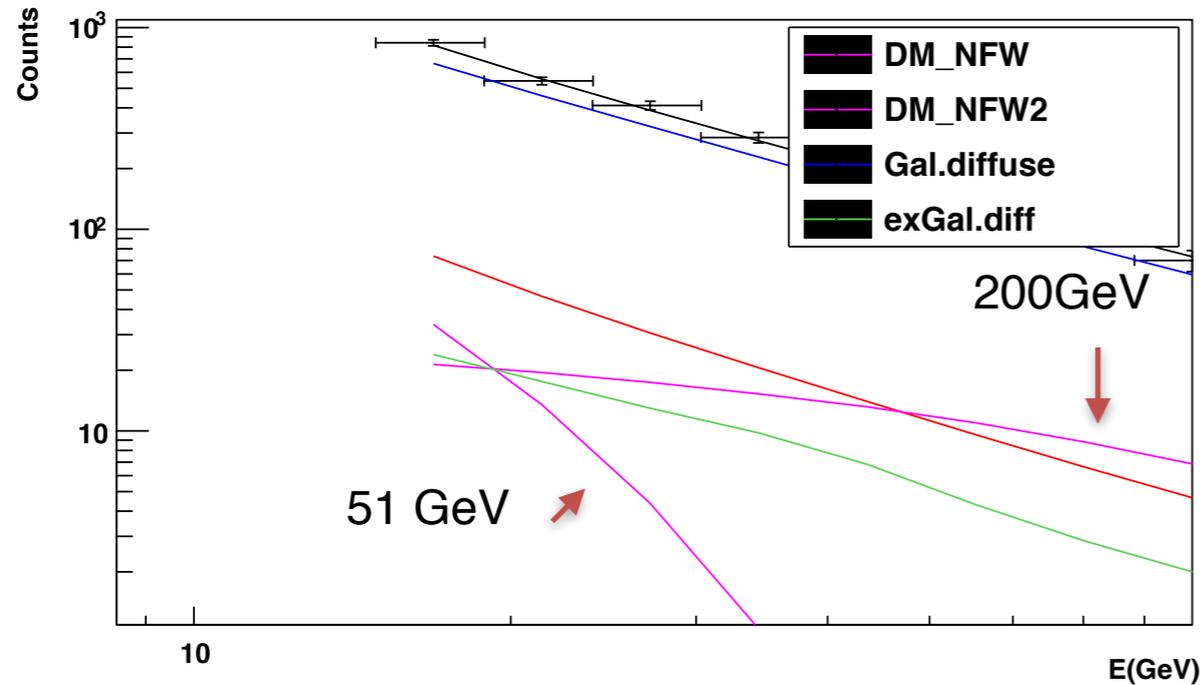
Mass(GeV):

1. 34.0 ± 0.5
2. 39.6 ± 0.4
3. 39.5 ± 0.5
4. 58.9 ± 5.7
5. 56.4 ± 0.6

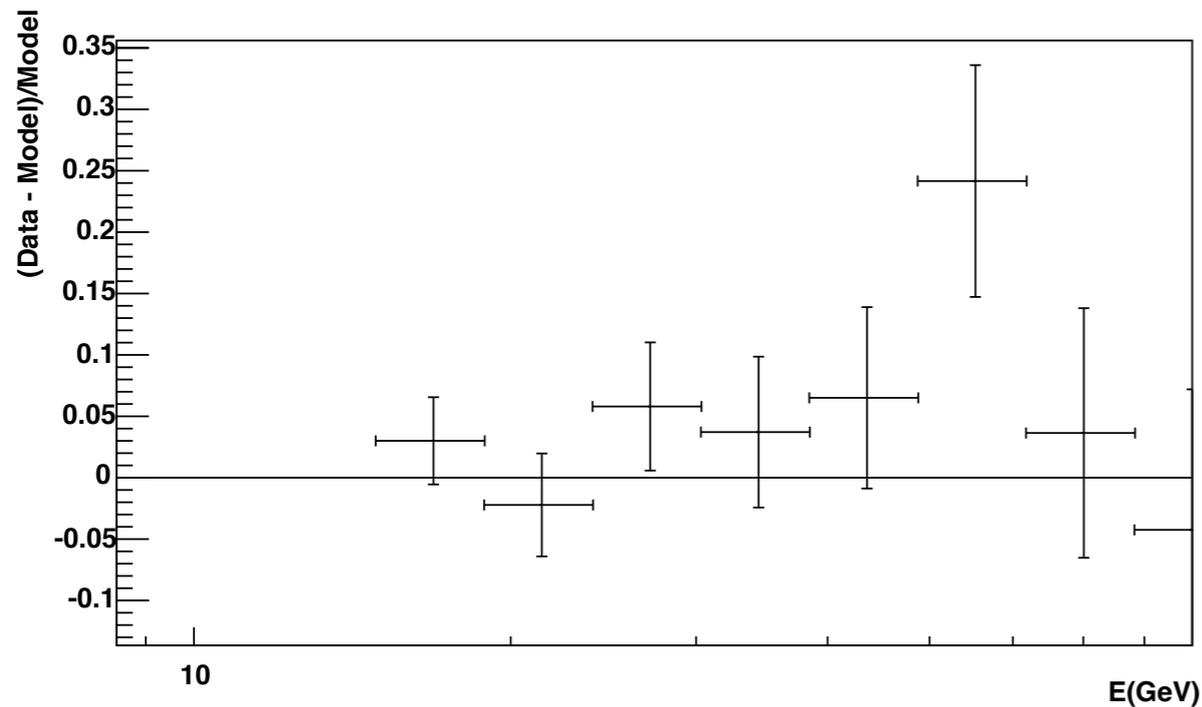
$\langle \sigma v \rangle$ ($\times 10^{-26} \text{ cm}^3 \text{ s}^{-1}$):

1. 0.32 ± 0.05
2. 0.46 ± 0.06
3. 0.39 ± 0.05
4. 0.70 ± 0.08
5. 0.61 ± 0.08

High energy behaviour (7.5 years)



51 GeV & 200 GeV
Dark matter

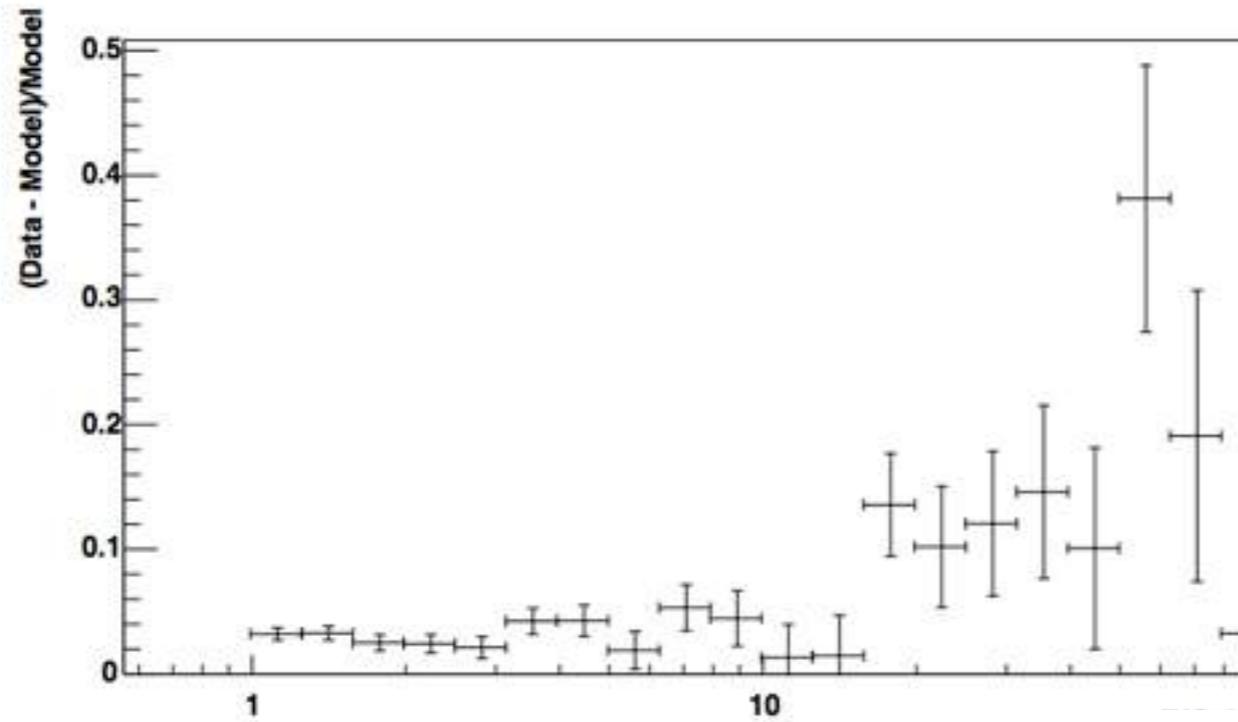


- Peak around 50~60GeV ?

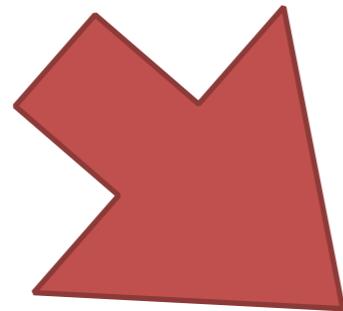
Conclusion

-
- We analysed Fermi LAT data to search for gamma ray emission from Dark Matter
 - We used 7.5 years (1.5 years x 5) data with 1~100 GeV energies
 - We found inconsistency of the data compared to the standard models
 - We believe NFW dark matter model could explain the low energy results
 - It seems that unconsidered gamma ray sources exist

Conclusion



Period: 2011-08-01 to 2013-02-01



Dark Matter

