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

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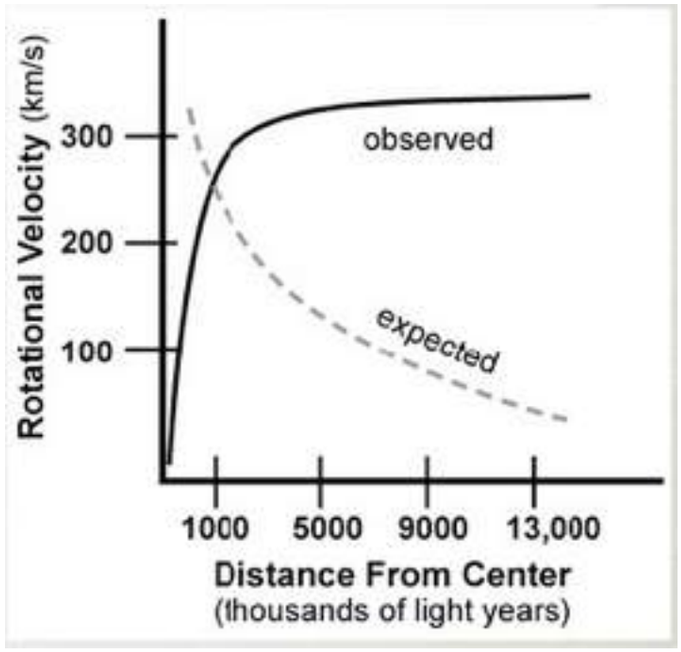
Purpose

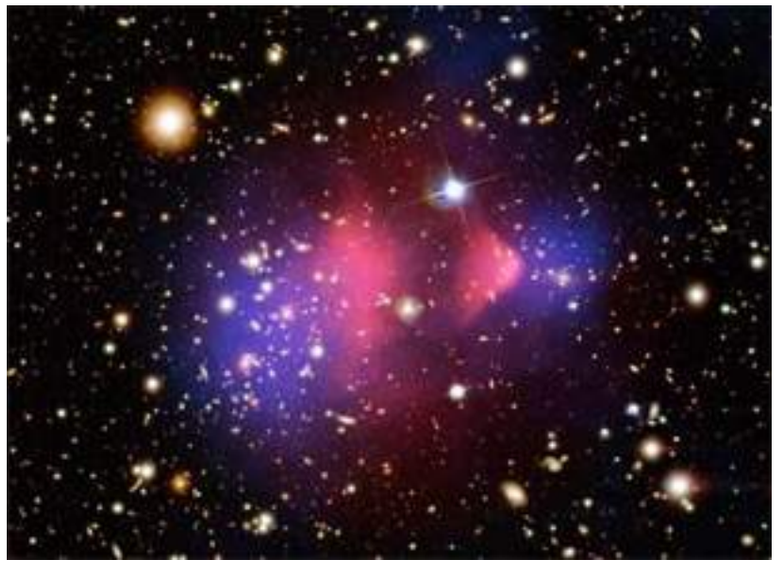
- Finding Dark Matter through Gamma-rays
  - What's Dark Matter?
  - How to observe Gamma-rays?
  - Did we find it through Gamma-rays?
    etc…

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

Galactic rotation curve



Clusters of galaxies

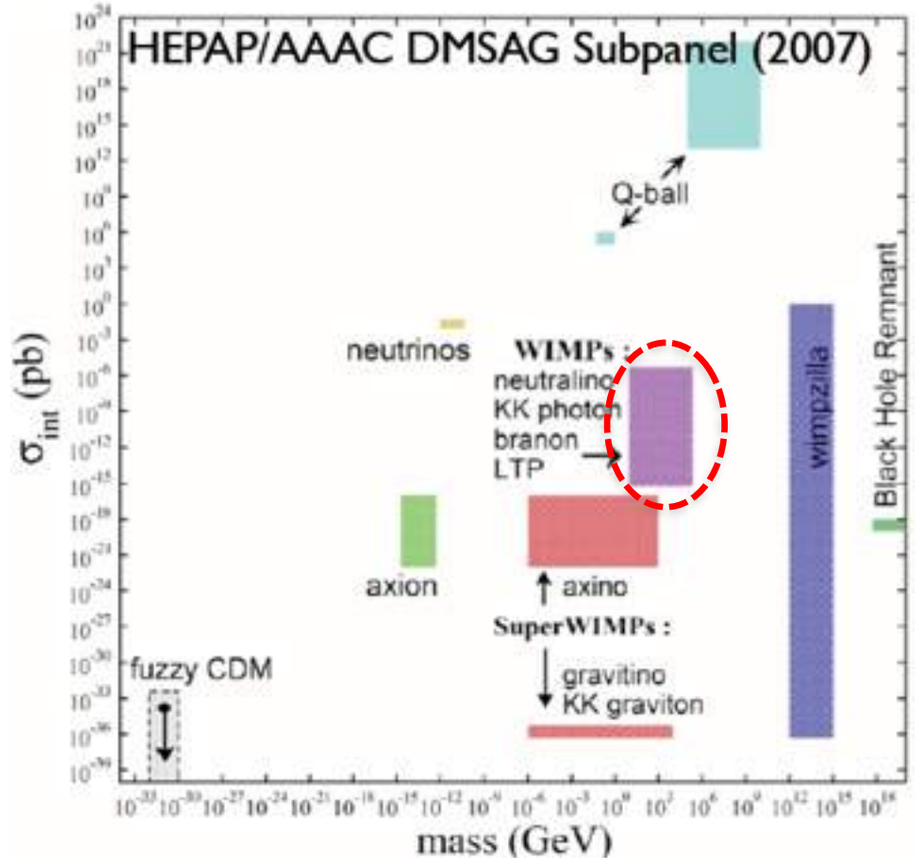


red : gas by X-ray,
blue: matter by gravitational lensing

Dark Matter can explain those phenomena.

Dark Matter candidates

- **No known particles are good candidates for dark matter**



Here, we focus on

WIMPS

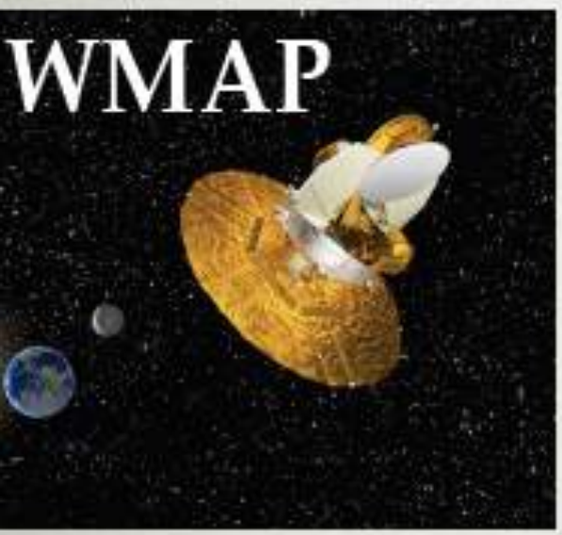
(Weakly Interacting Massive Particles)

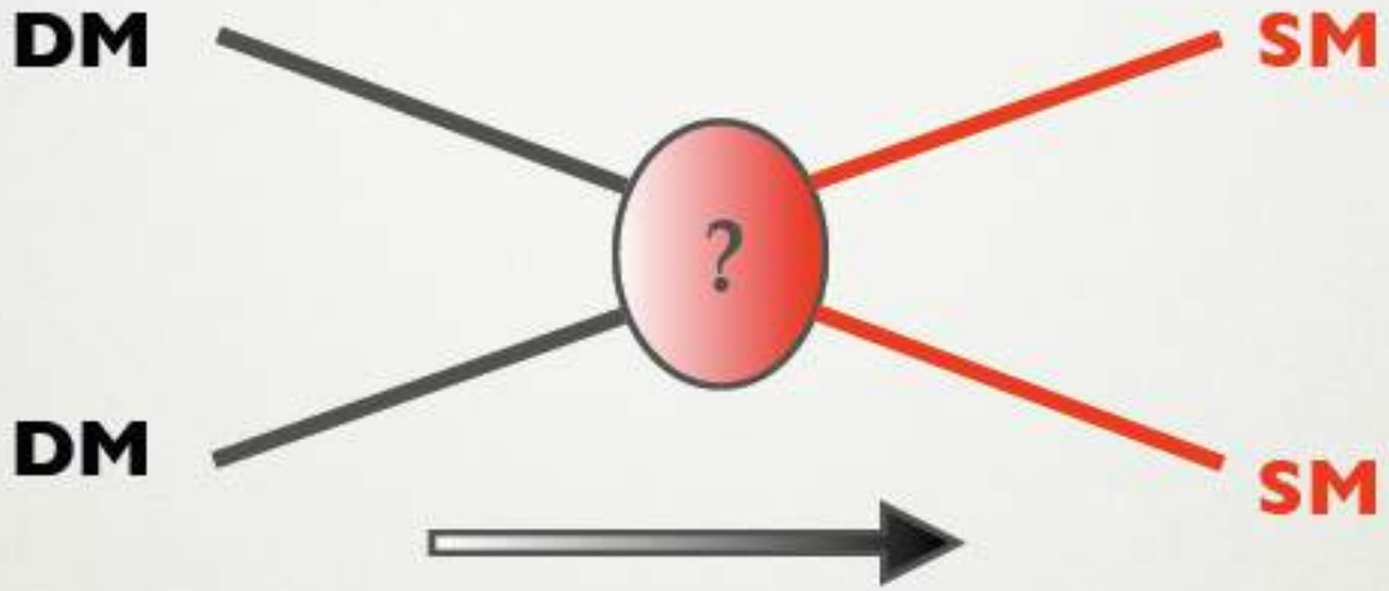
"generic" WIMPs has:

- **mass (M_{DM})~ 100 GeV**
- **annihilation cross section ($\langle\sigma v\rangle$) ~ 10^{-26} cm^3/s**

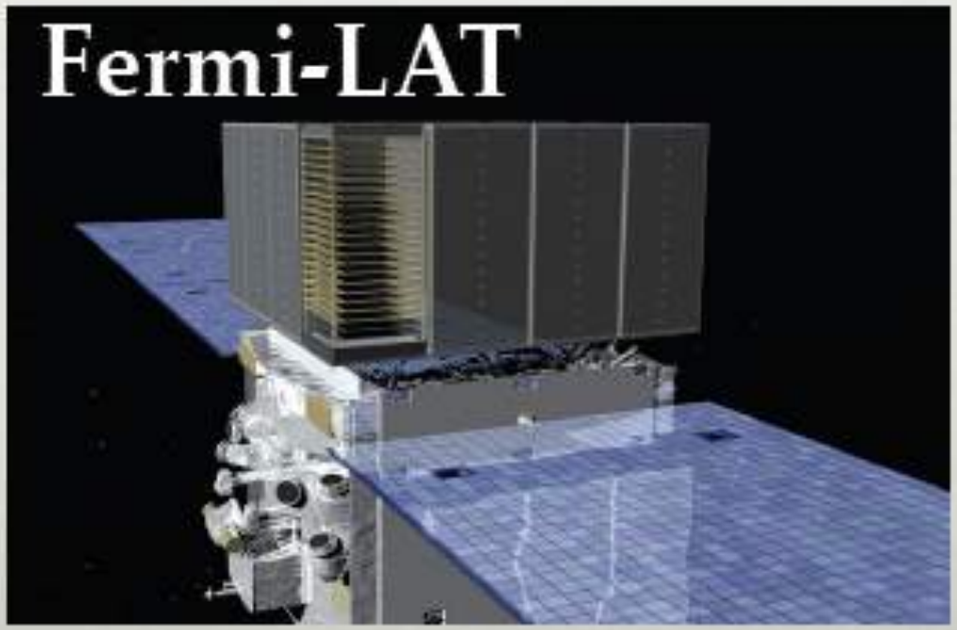
those values are accessible by Fermi!!

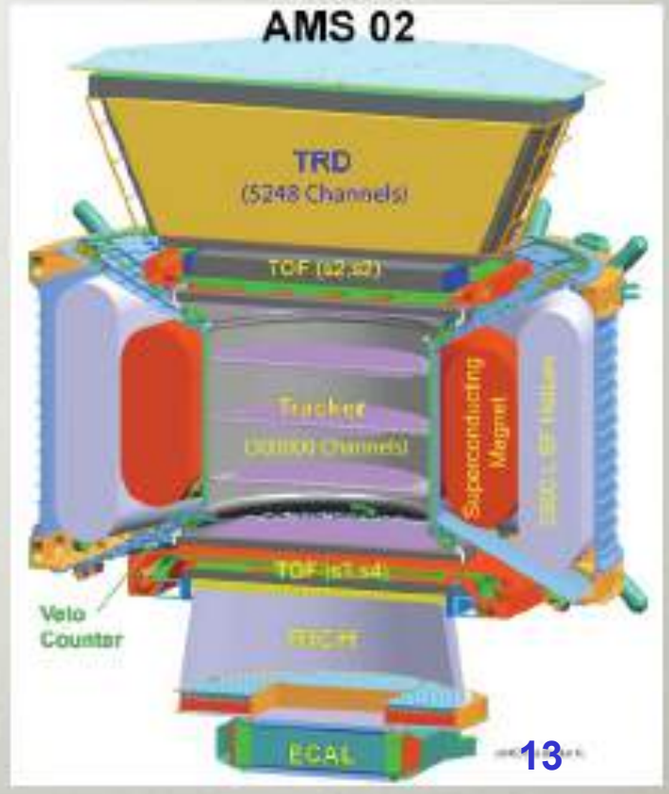
Dark Matter WIMP Searches





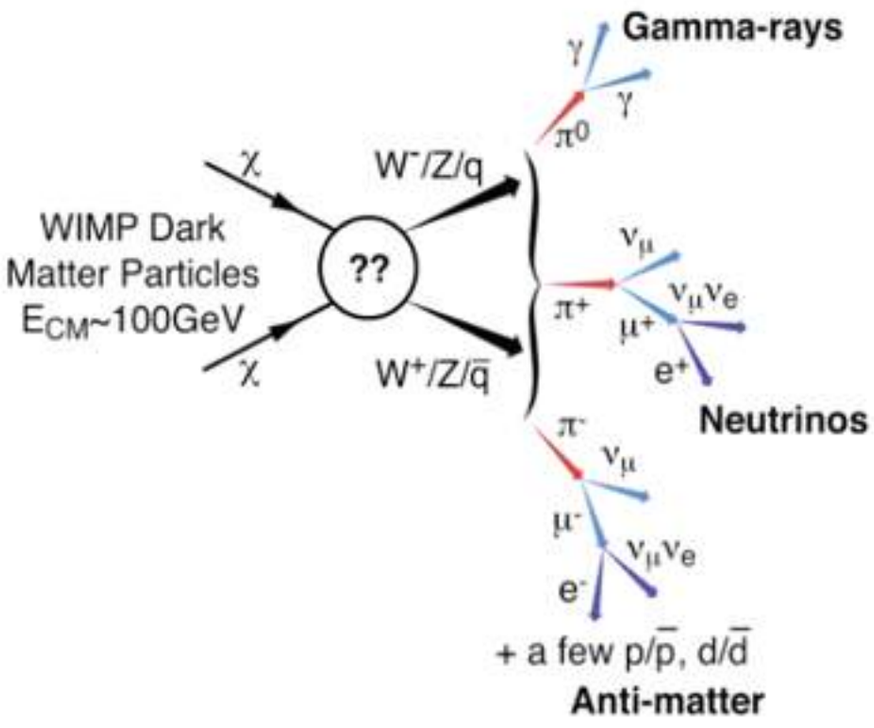
INDIRECT SEARCHES

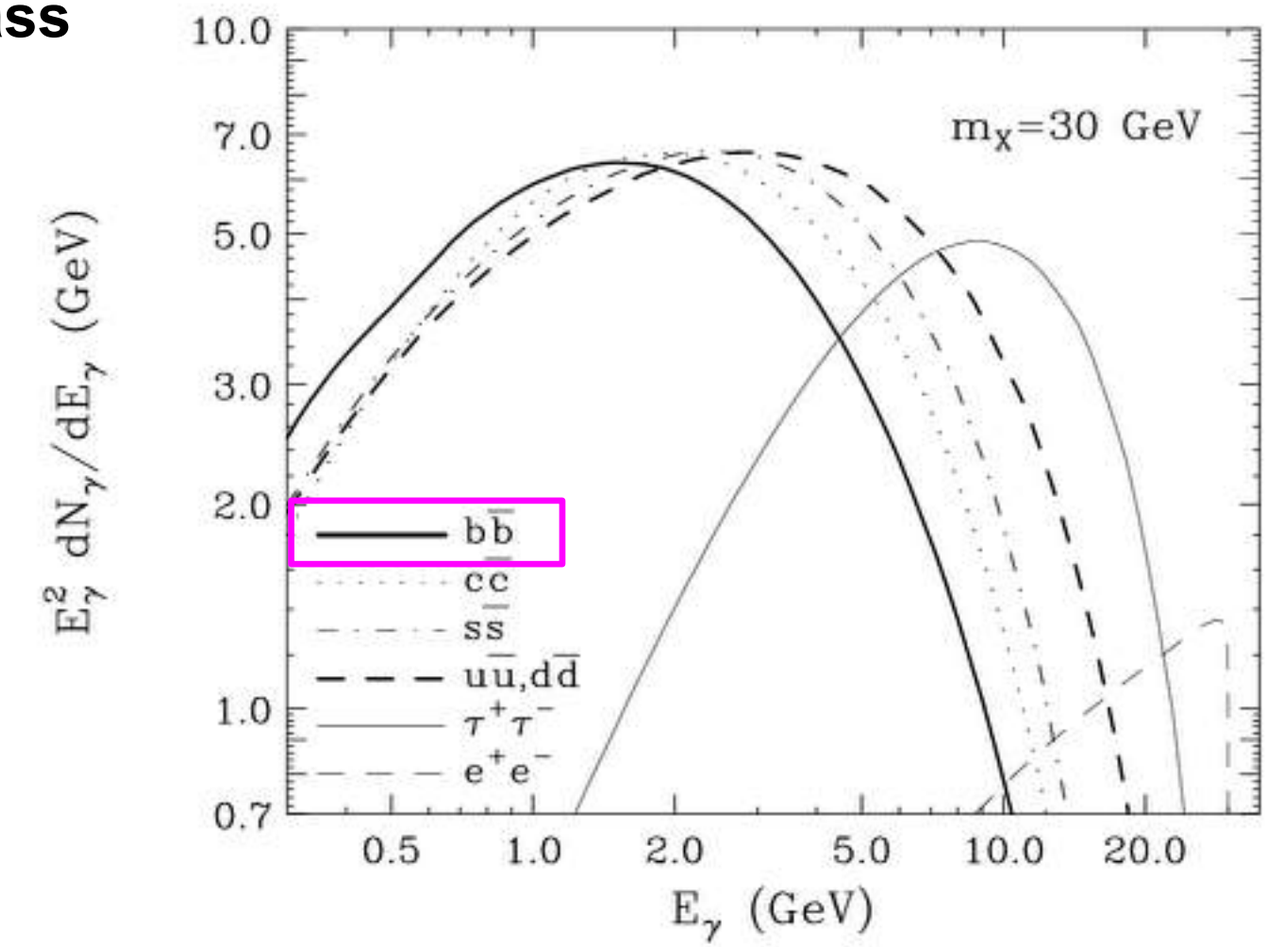




Gamma-rays from Dark Matter Annihilation

Continuum with cutoff at WIMP mass





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

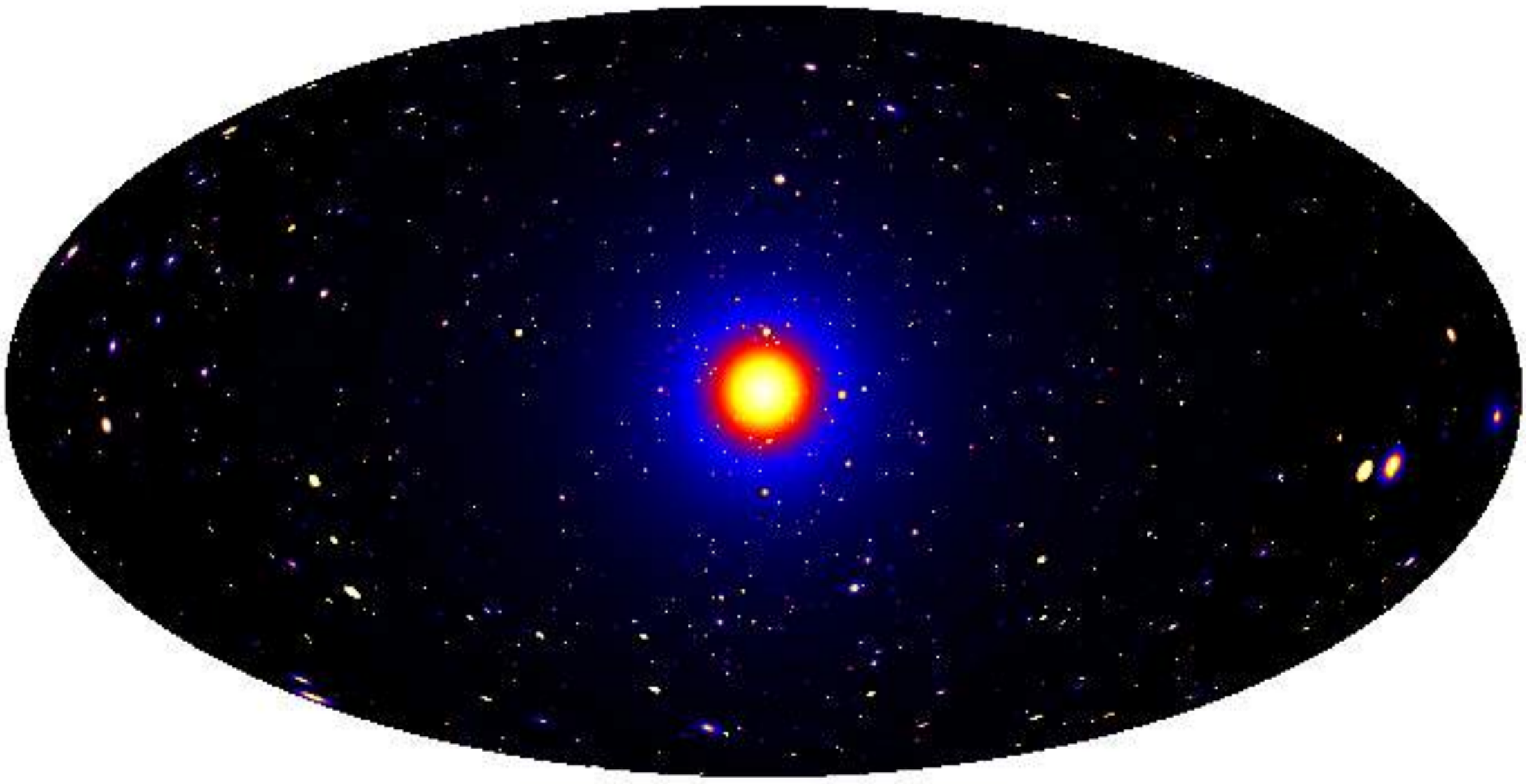
Astrophysical factor

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

Particle physics factor

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

Dark Matter at Galactic center (GC)



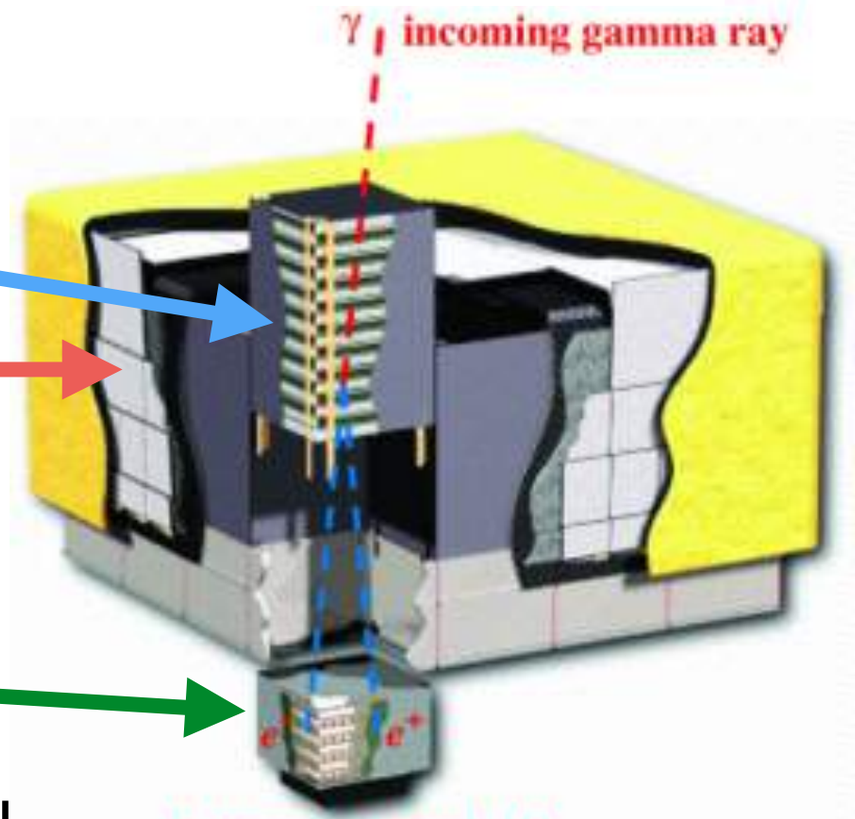
- Large Area Telescope(LAT)

Fermi Gamma-ray Space Telescope

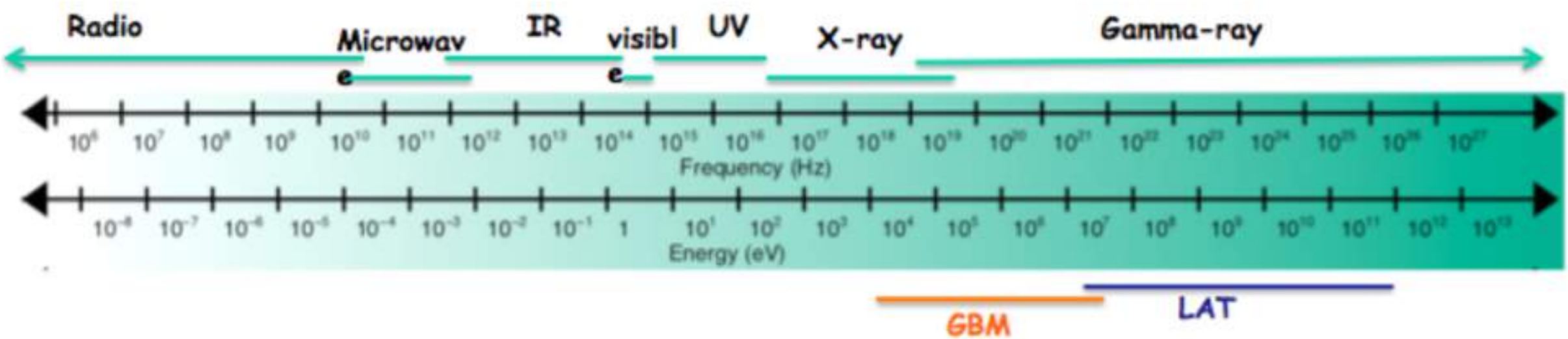
Tracker(TKR)

Anti-coincidence detector(ACD)

Calorimeter(CAL)



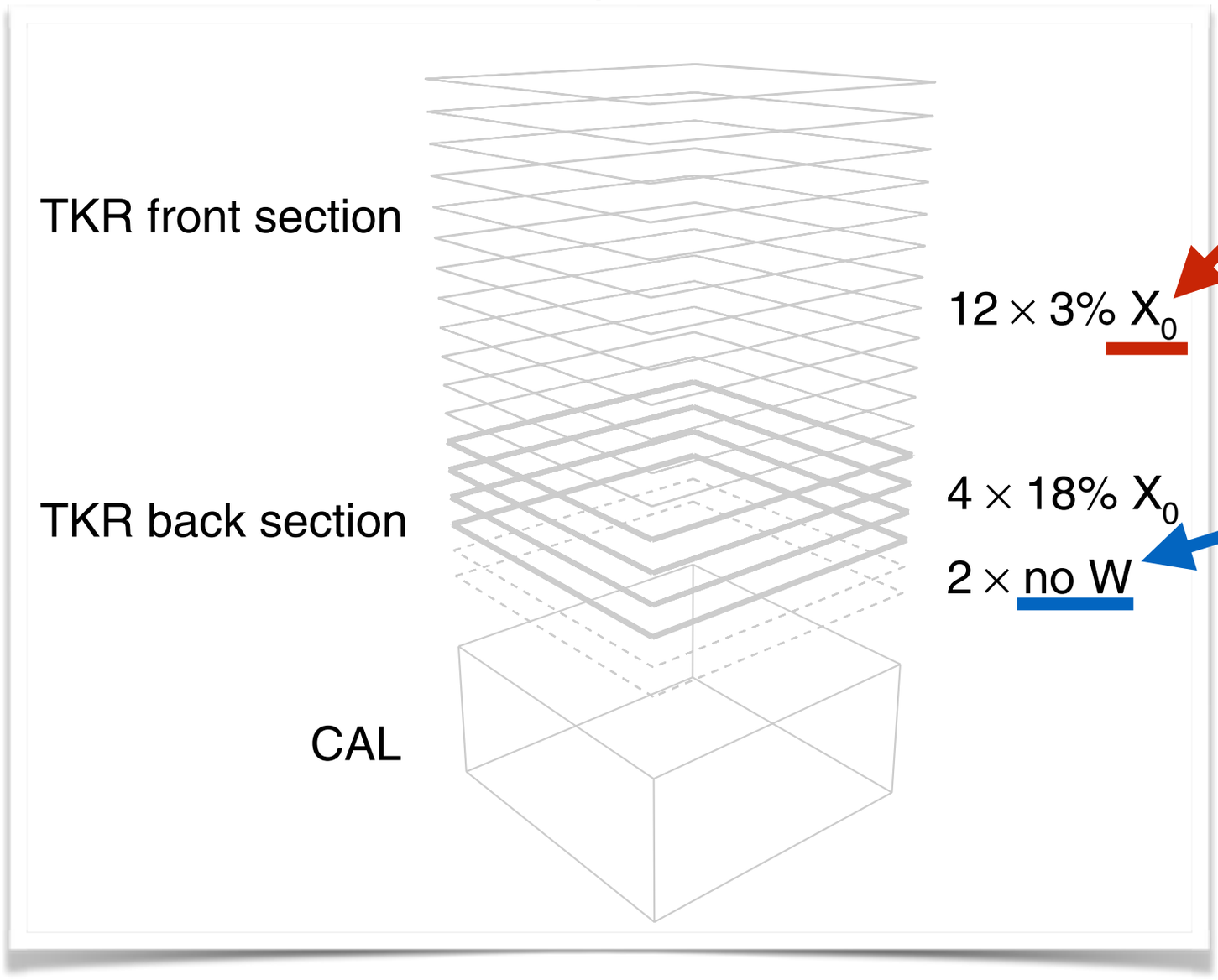
- LAT has 16 towers of TKR and CAL



20[MeV]~300[GeV]

- LAT tower -Tracker-

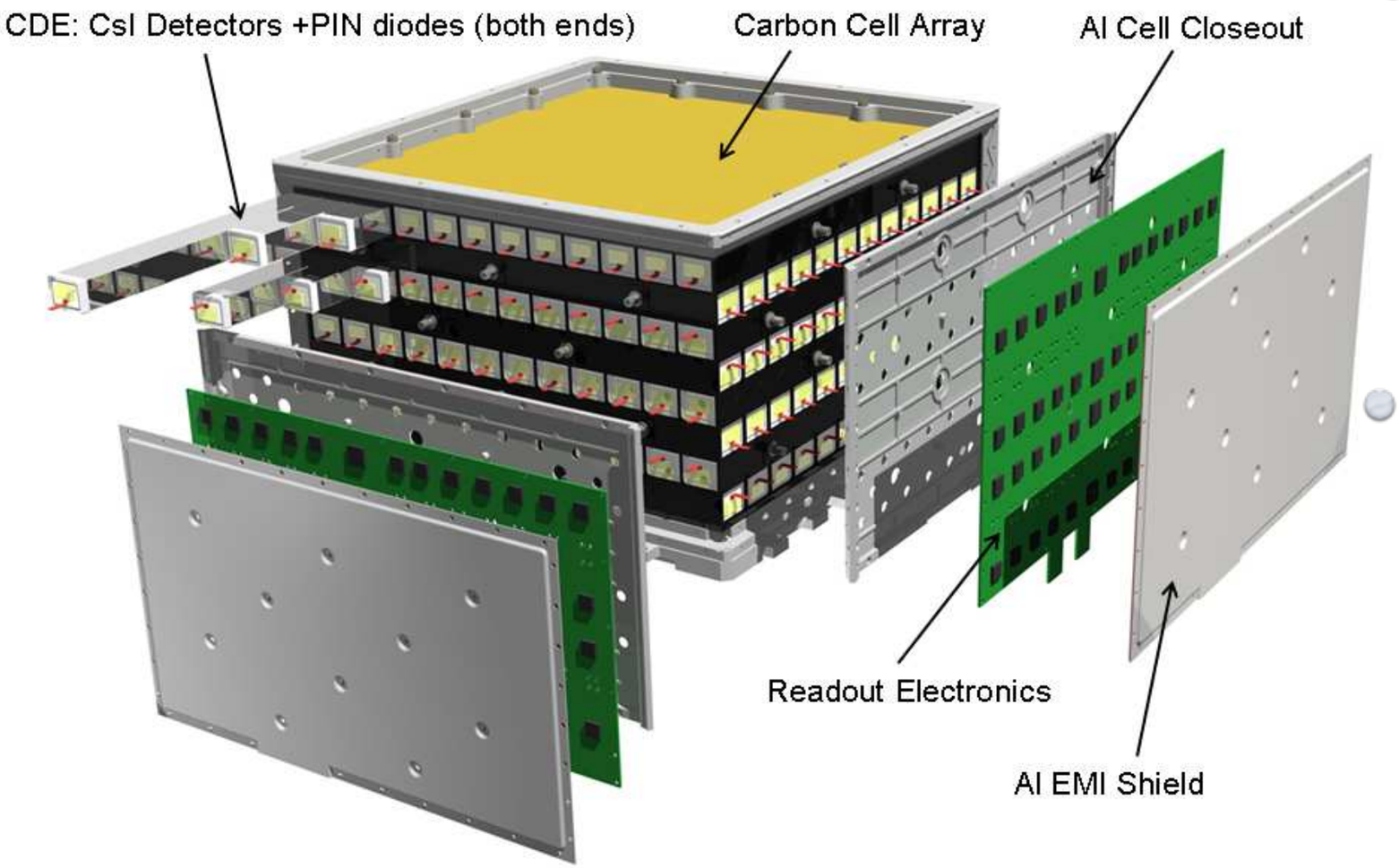
- Tracker is a device for determining the trajectory of a charged particle
- Each layer has a tungsten converter foil and silicon strip detectors



X_0 : Radiation length (0.3cm)

no W: No tungsten

- LAT tower -Calorimeter-

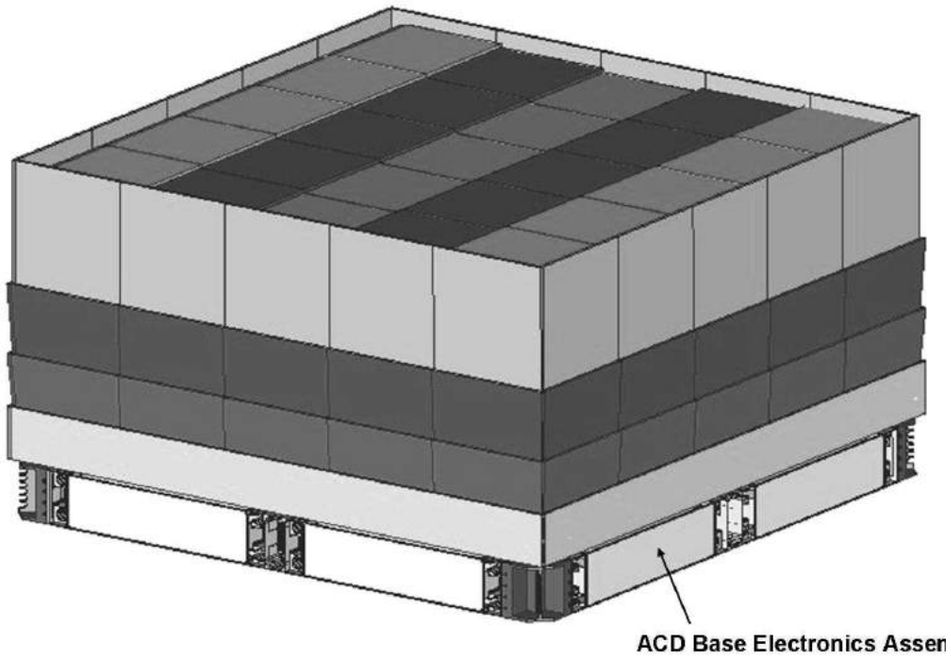


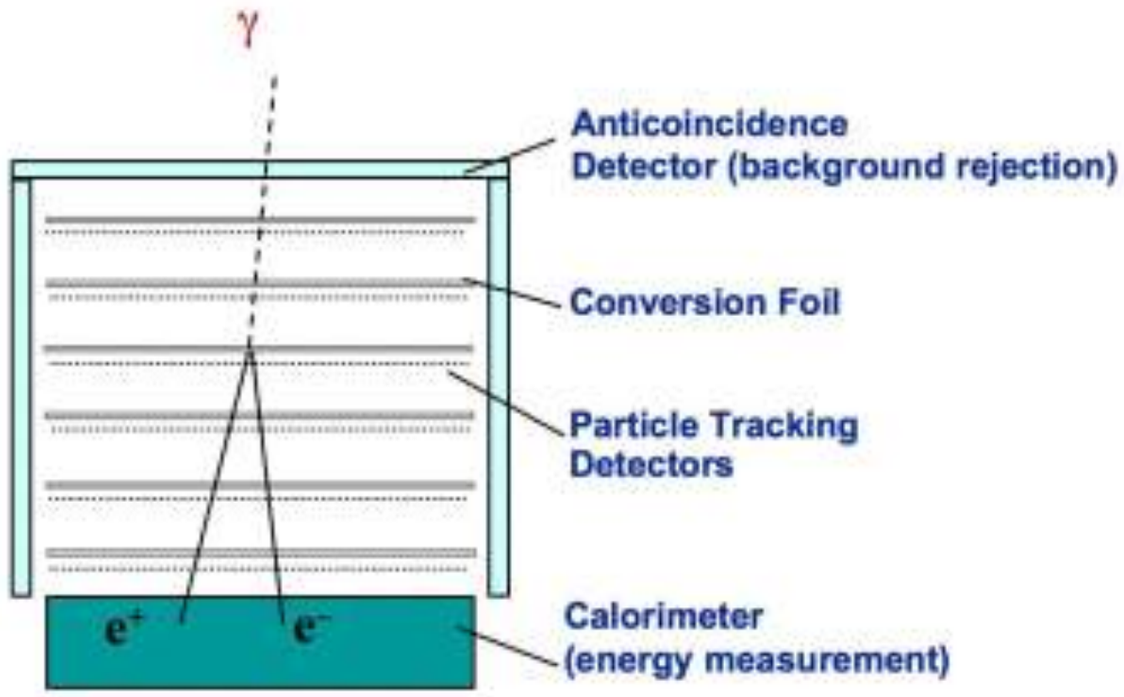
- CAL is composed of logs of CsI scintillation detector
- Reconstruct not only deposited energy but also tracks

- Background rejection -Anti Coincidence Detector-

- Roughly,only ~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?

- Data download
  >Photon file
  >Spacecraft file

Prepare data

count map

- Summarize the n
  of the observed g

exposure

- Summarize the exposure time
  of the source with Fermi
  map

model

- Fitting the observed conditions
  to the model

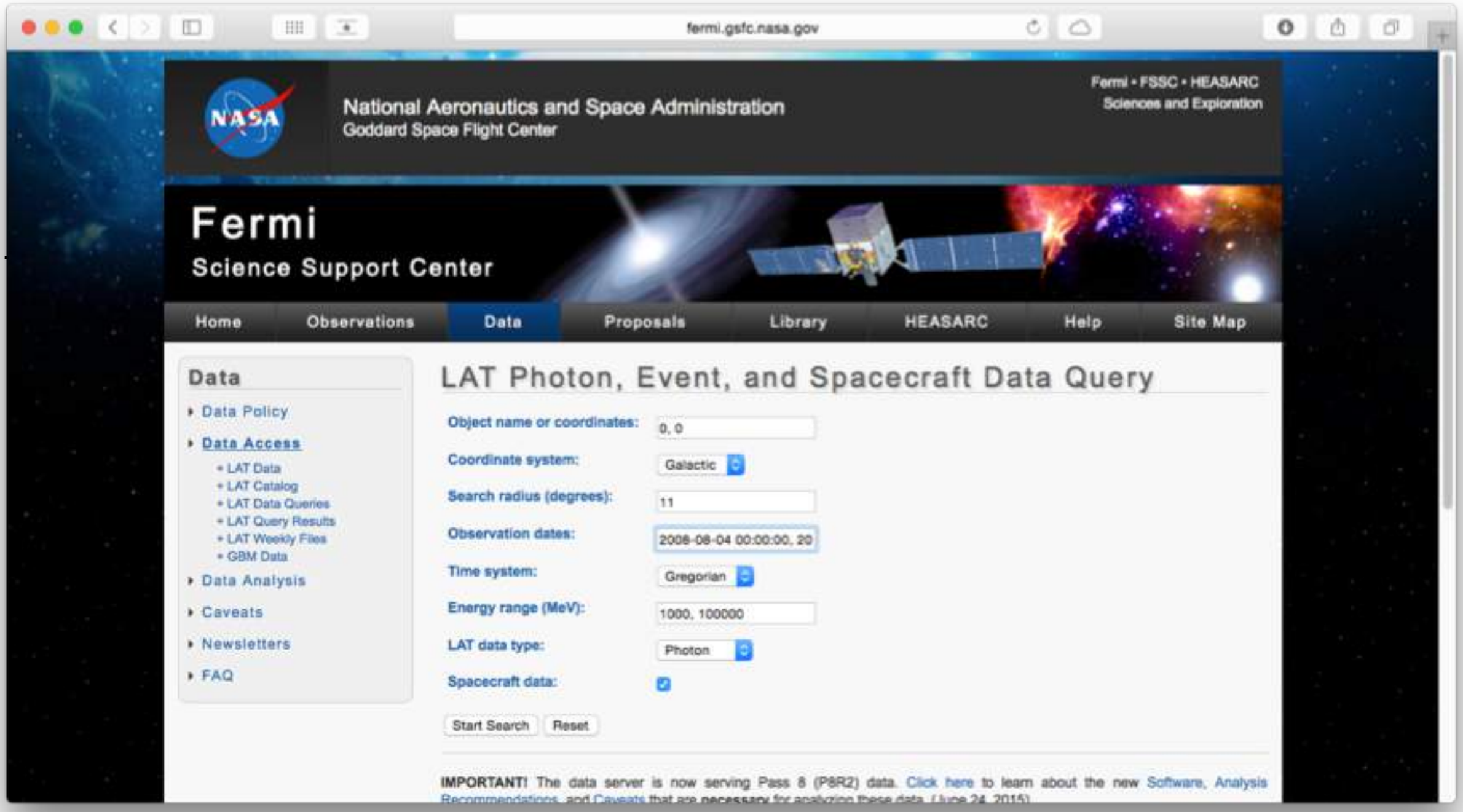
residual map

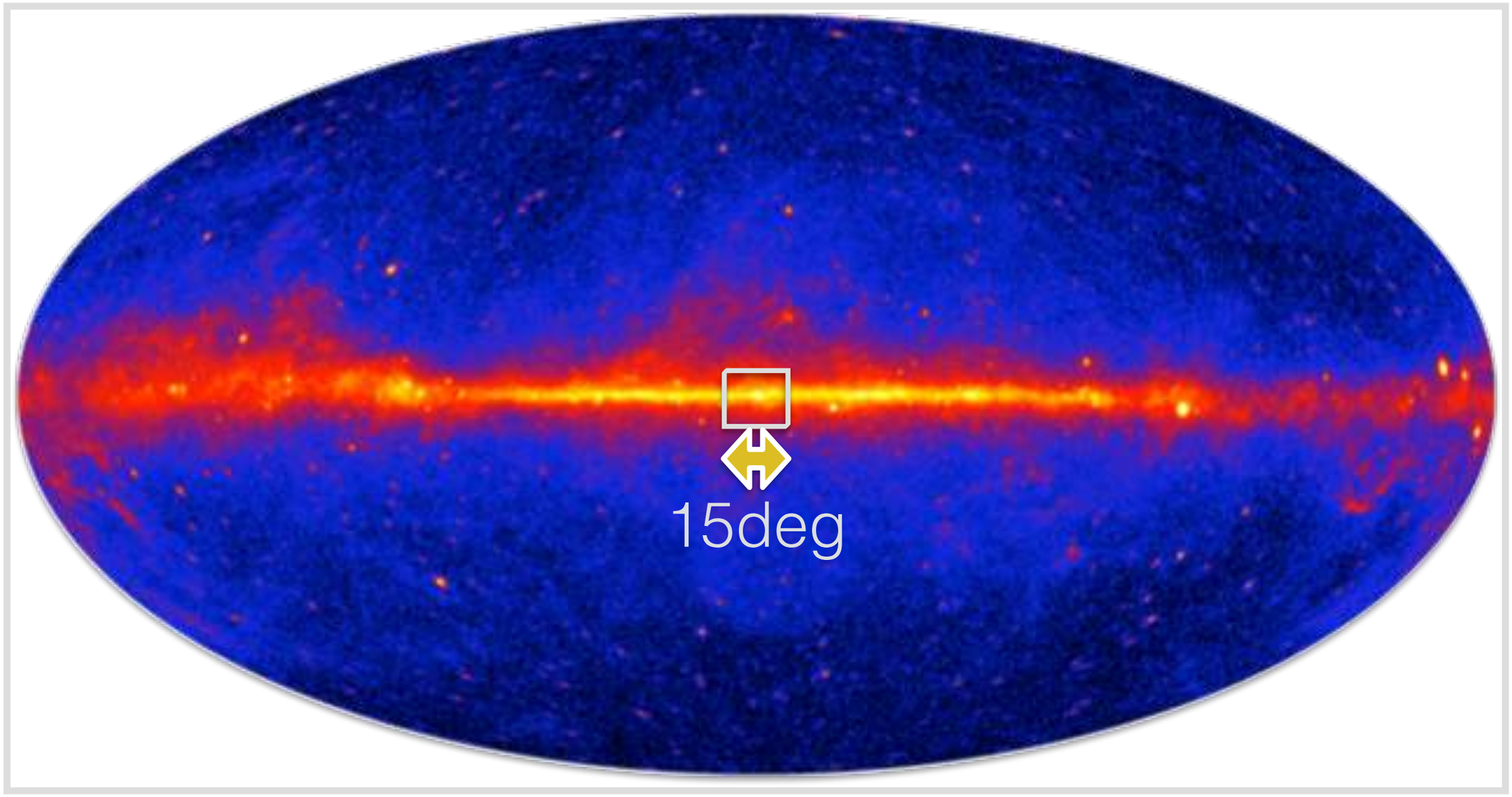
- counts map-model map

Explore Fermi-LAT data

Data download

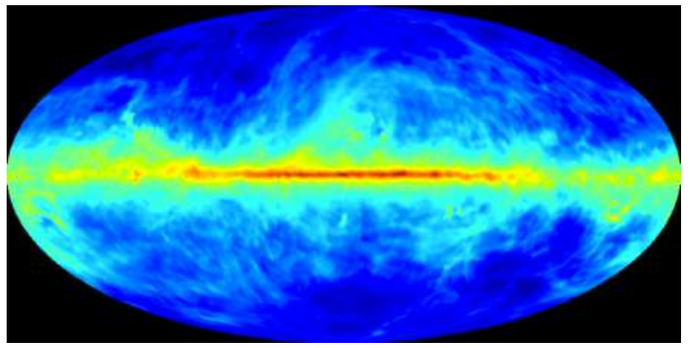
http://fermi.gsfc.nasa.gov/cgi-bin/ssc/LAT/LATDataQuery.cgi



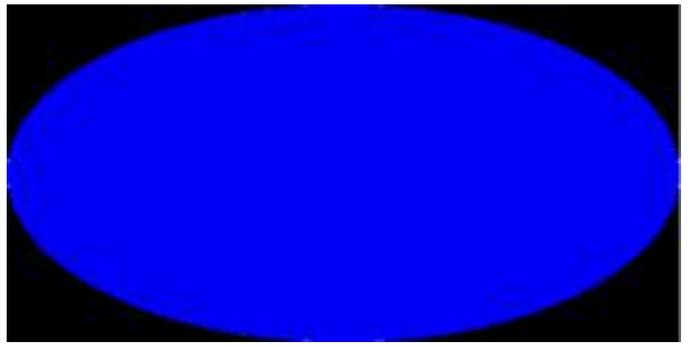


Energy:1GeV~100GeV

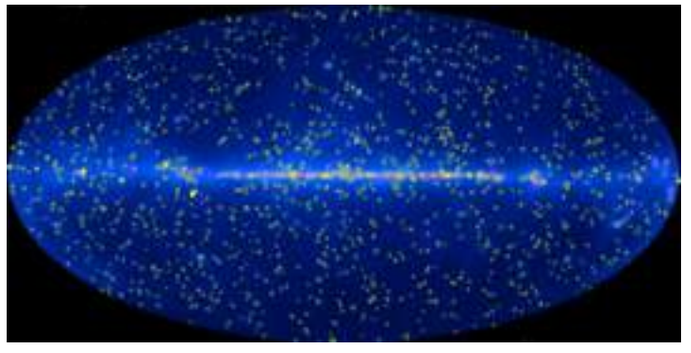
Gamma-ray sky



- Galactic diffuse model
  >pi0
  >bremsstrahlung
  >inverse Compton scattering

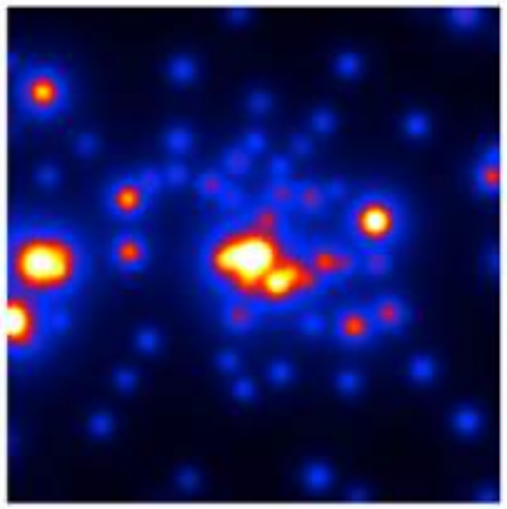


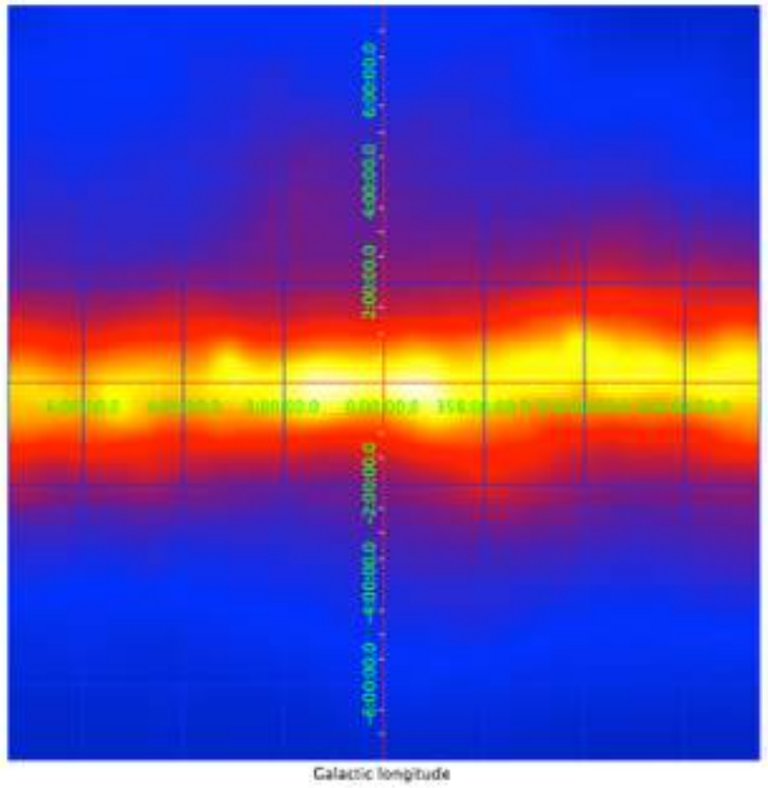
- Isotropic diffuse model
- Source model
- Dark matter template



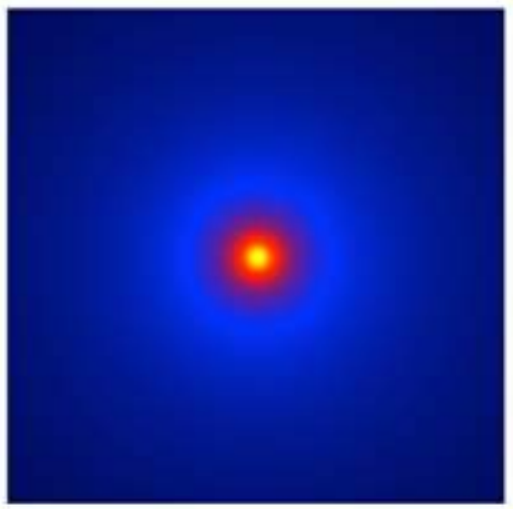
sum model

Source model



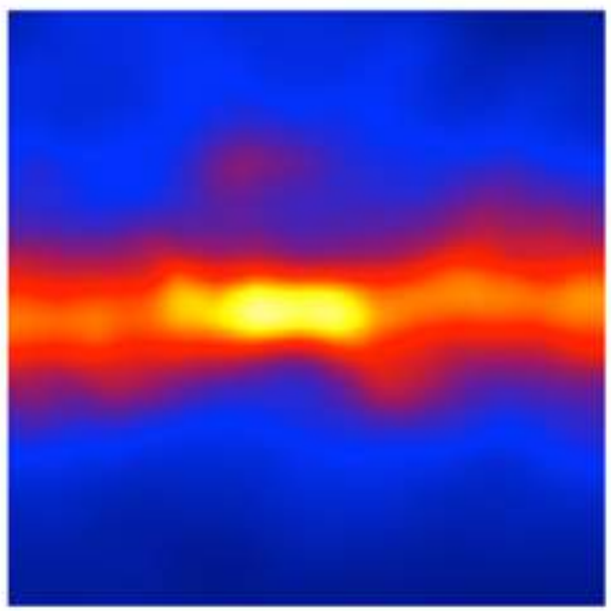


Dark matter template

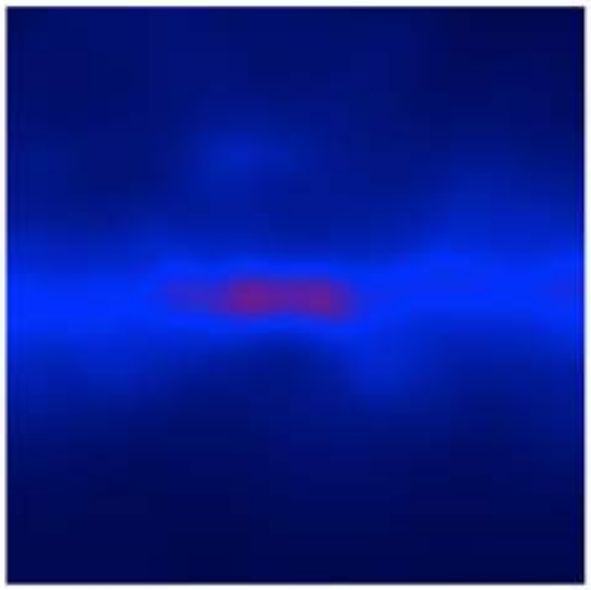


Galactic diffuse model

pi0



bremsstrahlung



inverse Compton scattering

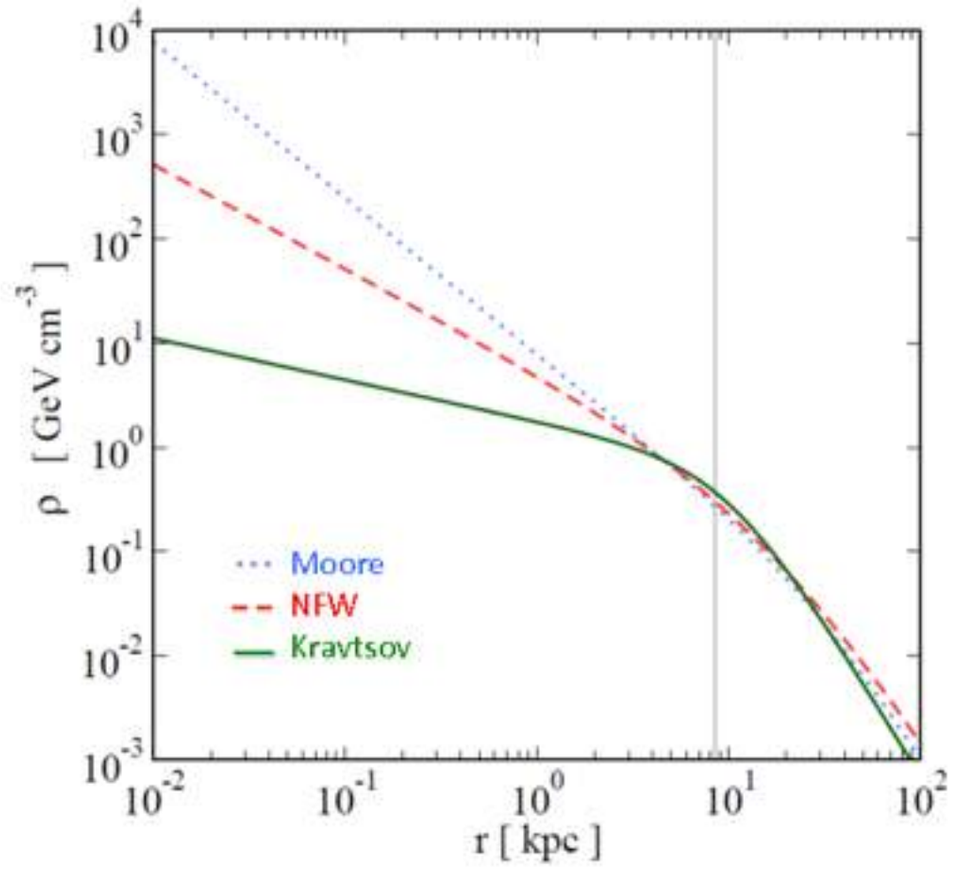
Dark matter at Galactic centre

NFW (Navarro–Frenk–White) profile

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

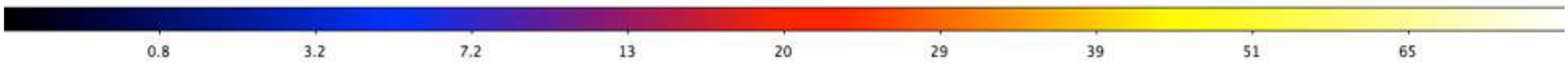
ρ_0 : set 0.3 GeV cm^{-3} at 8.5 kpc (Sun)

r_s = 20 kpc

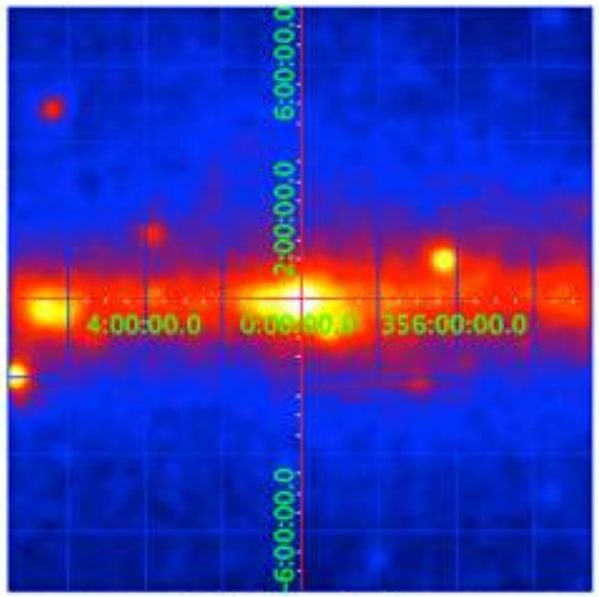


NFW profile at GC
(log scale in gray color)
→ **J-factor = 2.42x10^{22} GeV^2 cm^{-5}**

Result

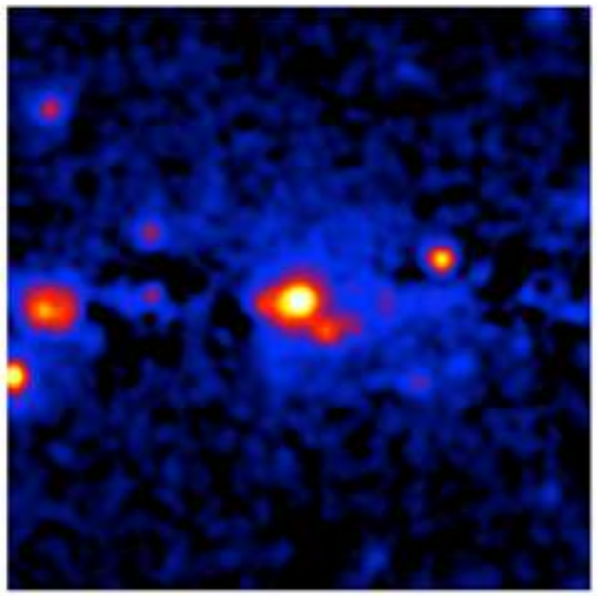


①



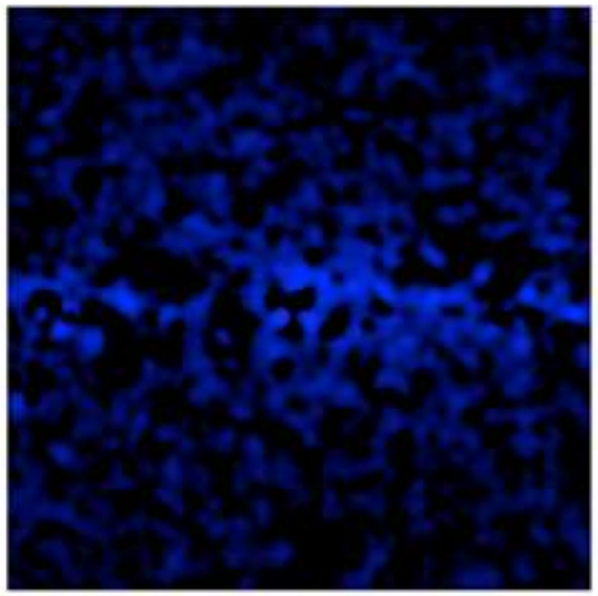
-diffuse

②

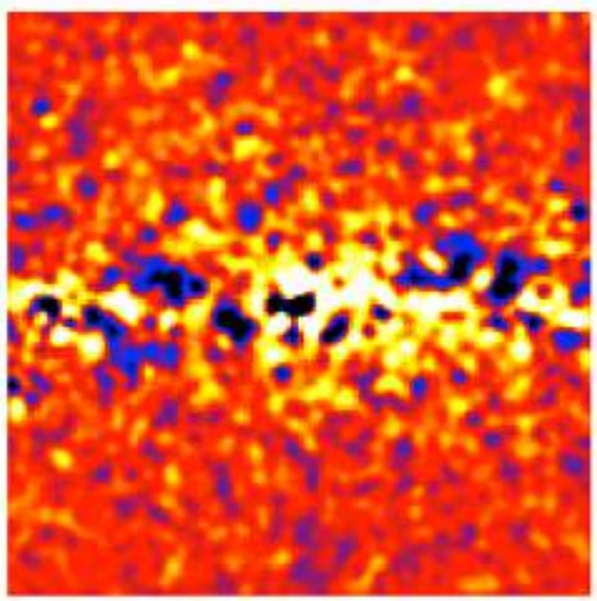


-source

③a

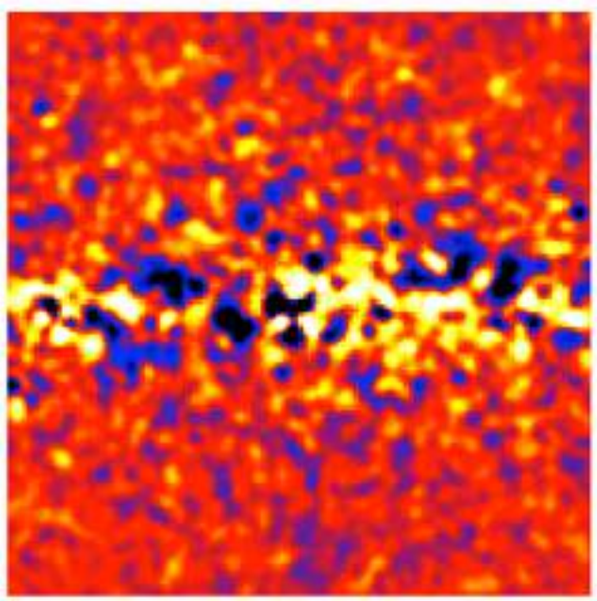


③b



-dark matter

④



① data

② data-diffuse

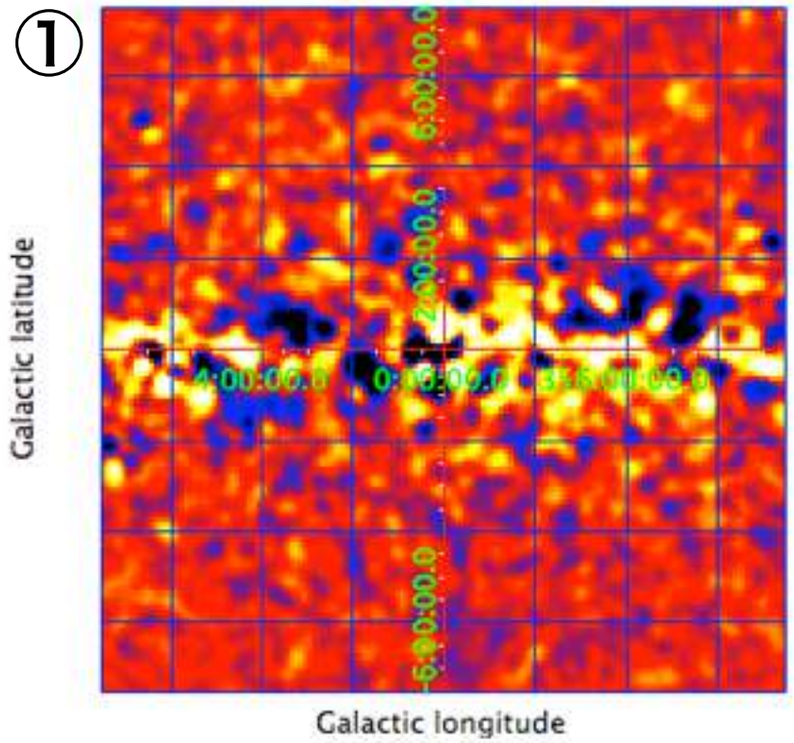
③a data-diffuse-source

③b data-diffuse-source
(residual model)

④data-diffuse-source-dark matter
(residual model)

Different Diffuse Models

①



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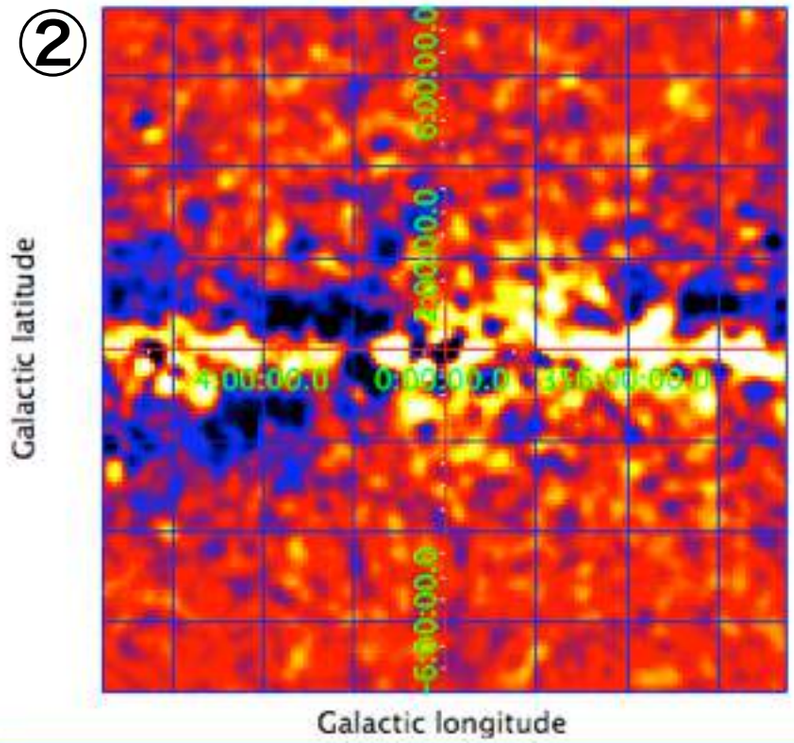
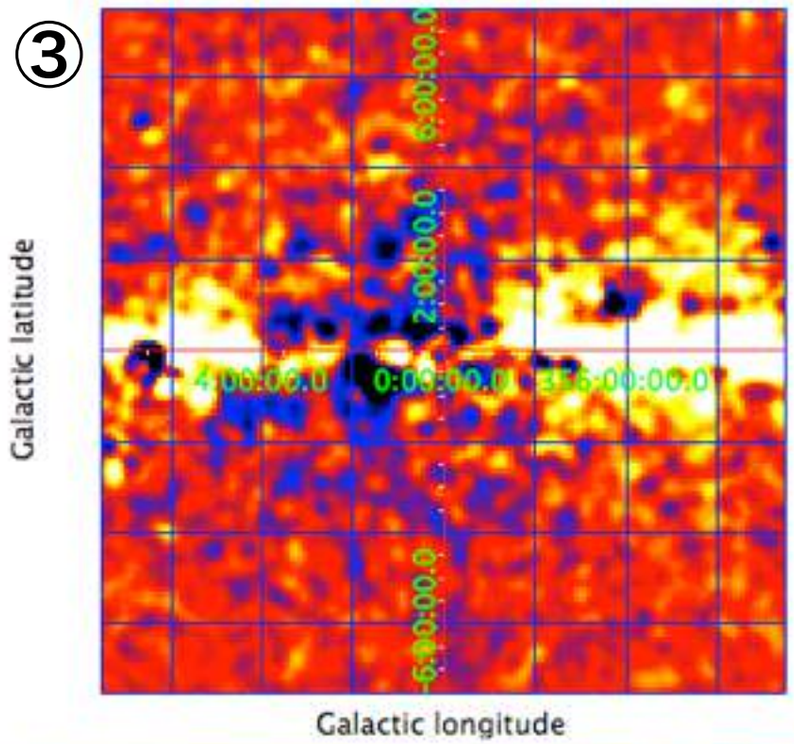


③



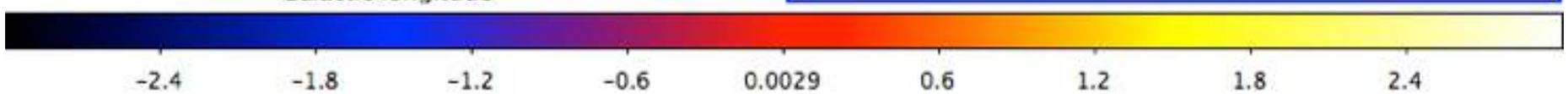
Model

①Standard Diffuse Model

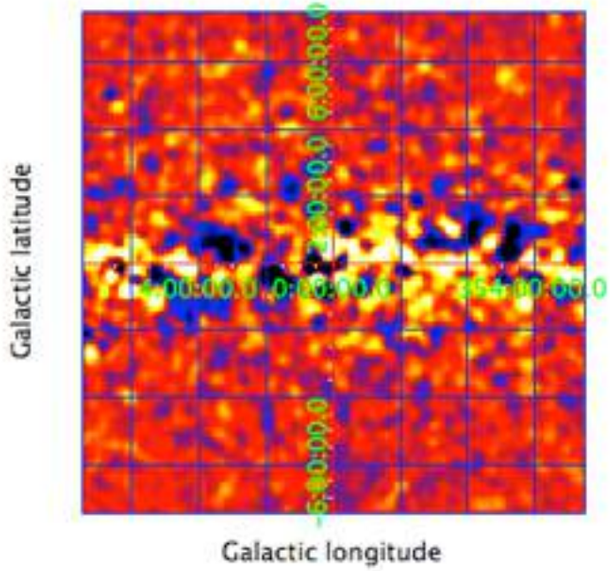
②Internal New Model

(Under Development)

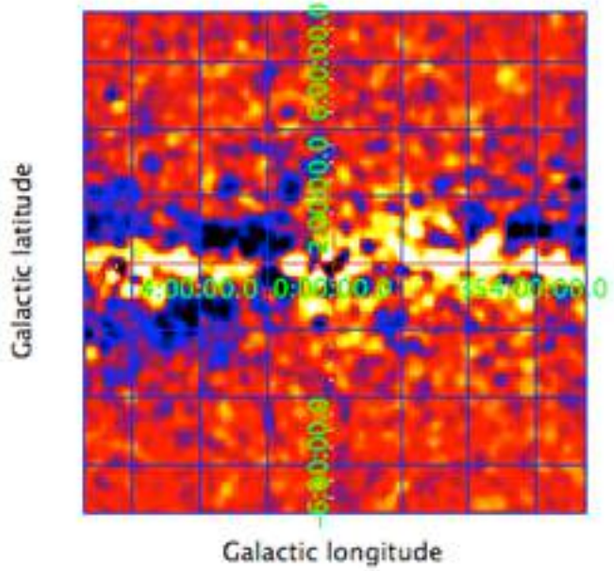
③Alternative Model



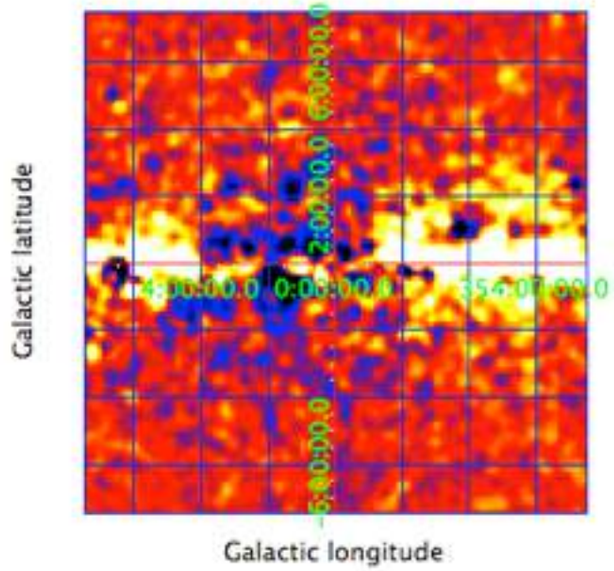
Scaling Diffuse models



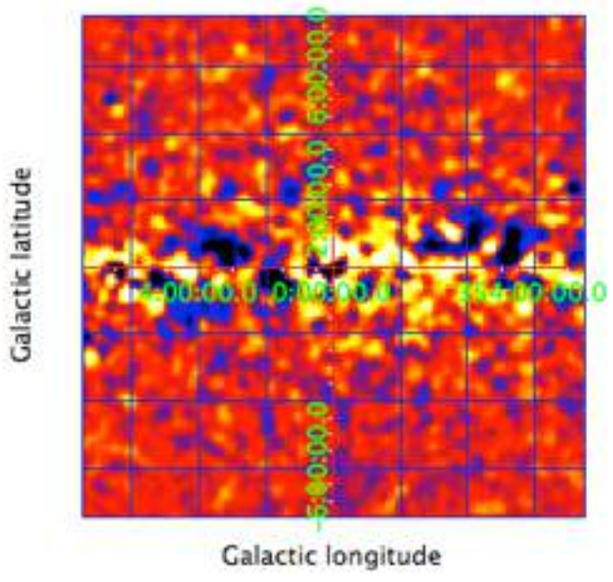
①Standard model



②Internal new model

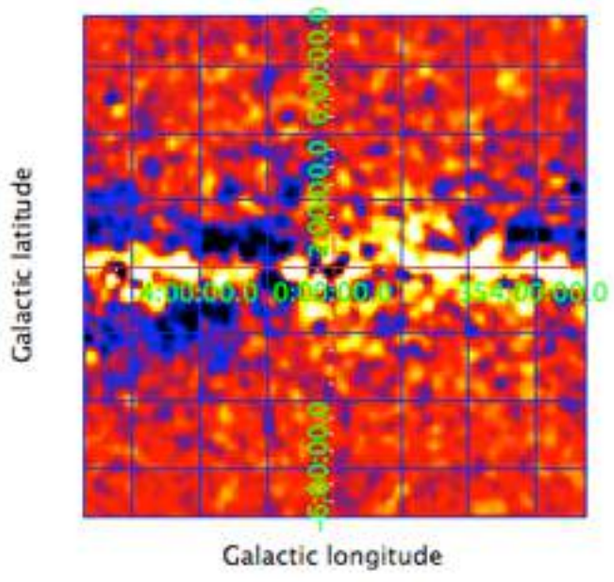


③Alternative model



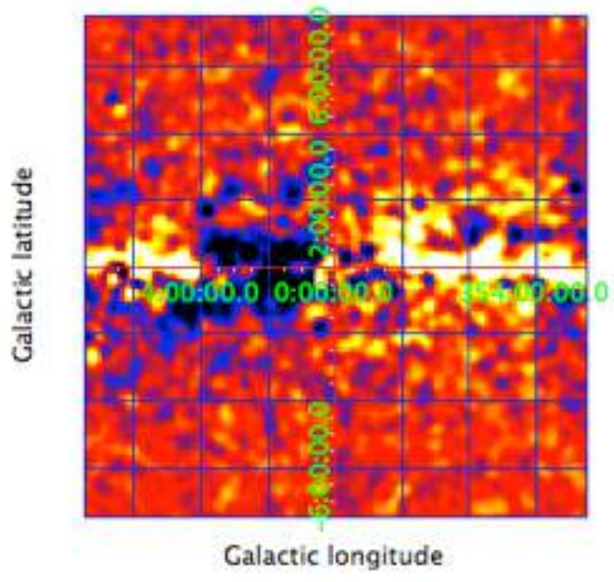
④Standard model

(Normalization free)



⑤Internal new model

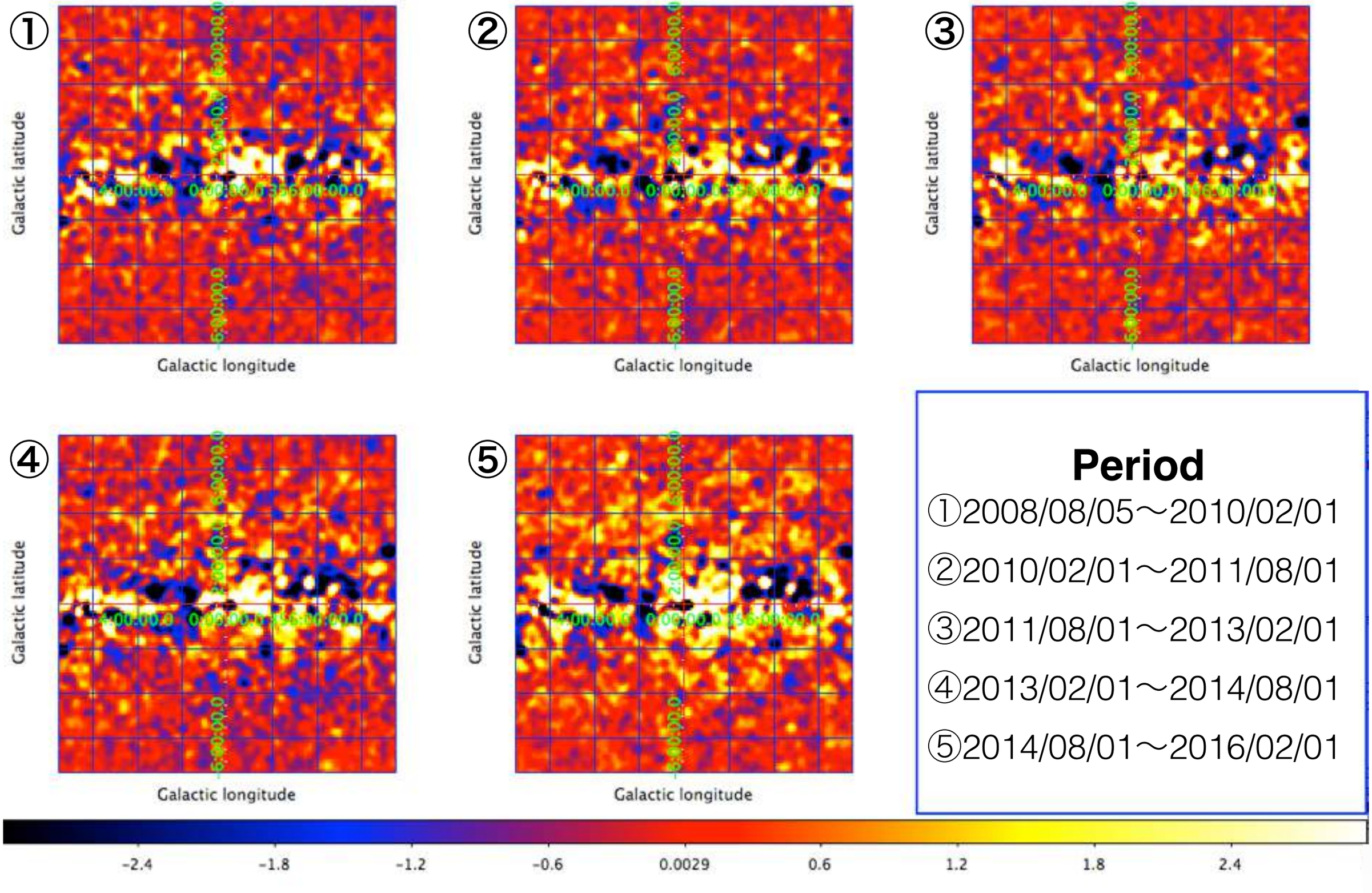
(Normalization free)



⑥Alternative model

(Normalizaition free)

Residual Maps



Period

①2008/08/05～2010/02/01

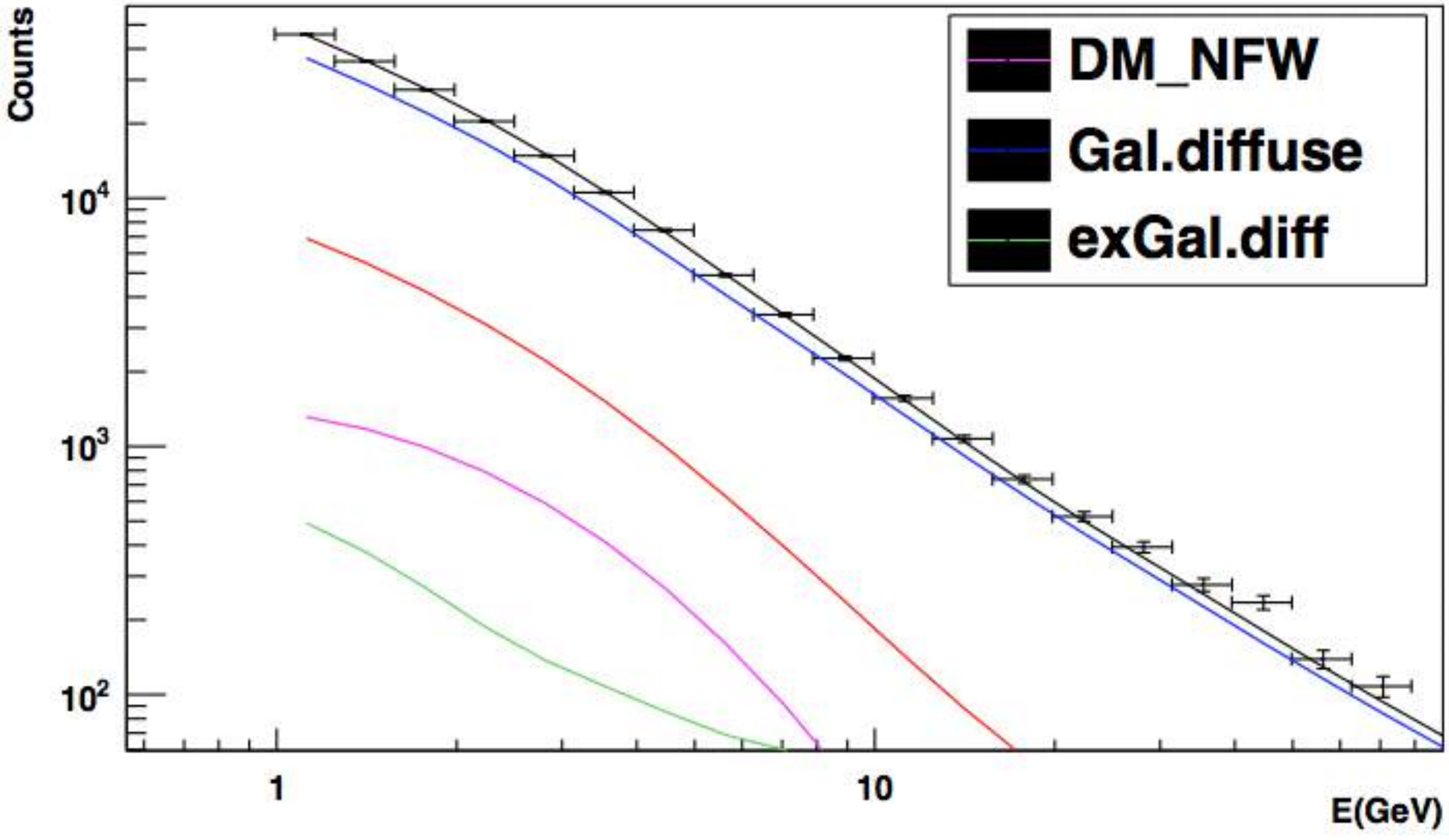
②2010/02/01～2011/08/01

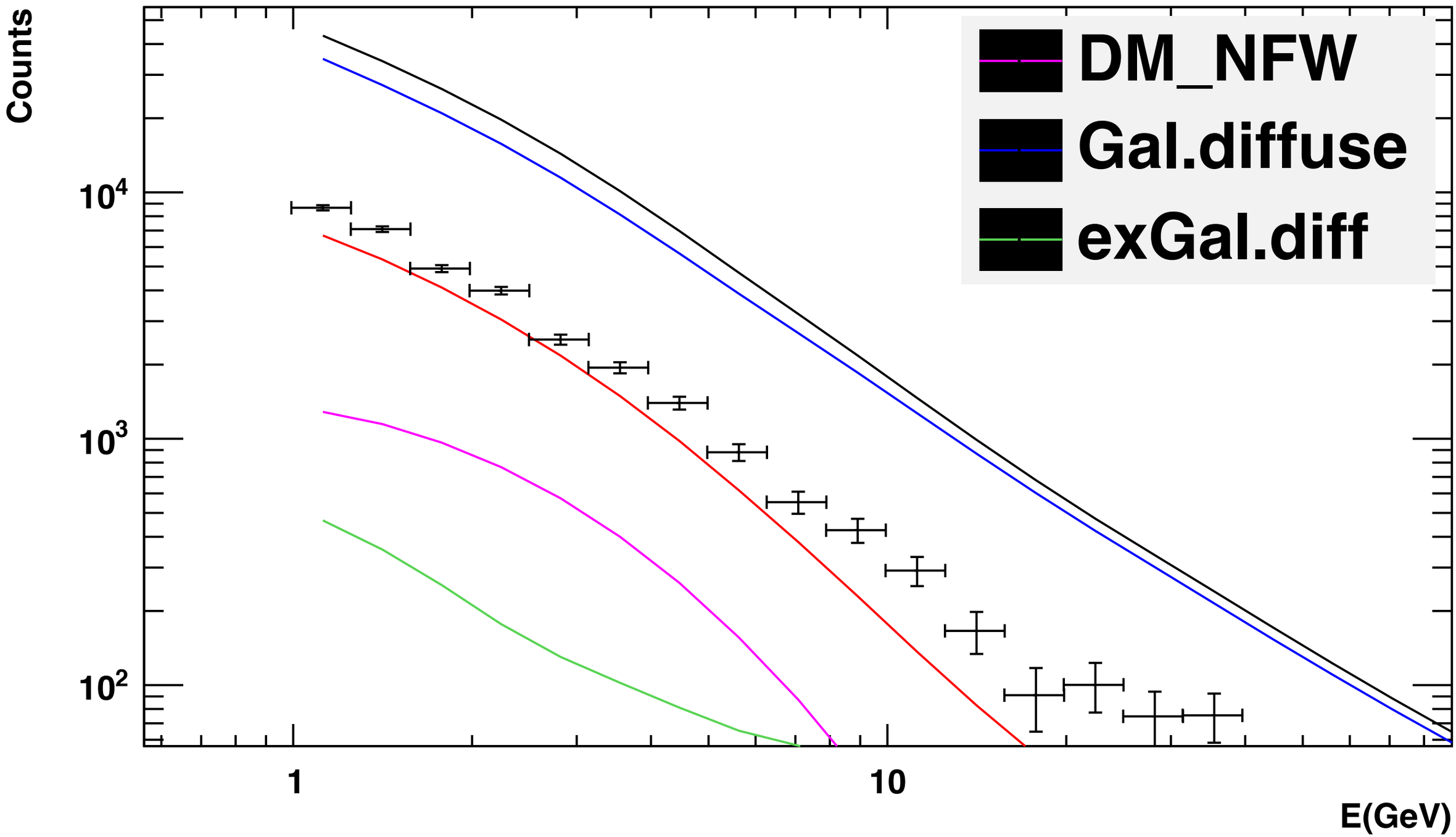
③2011/08/01～2013/02/01

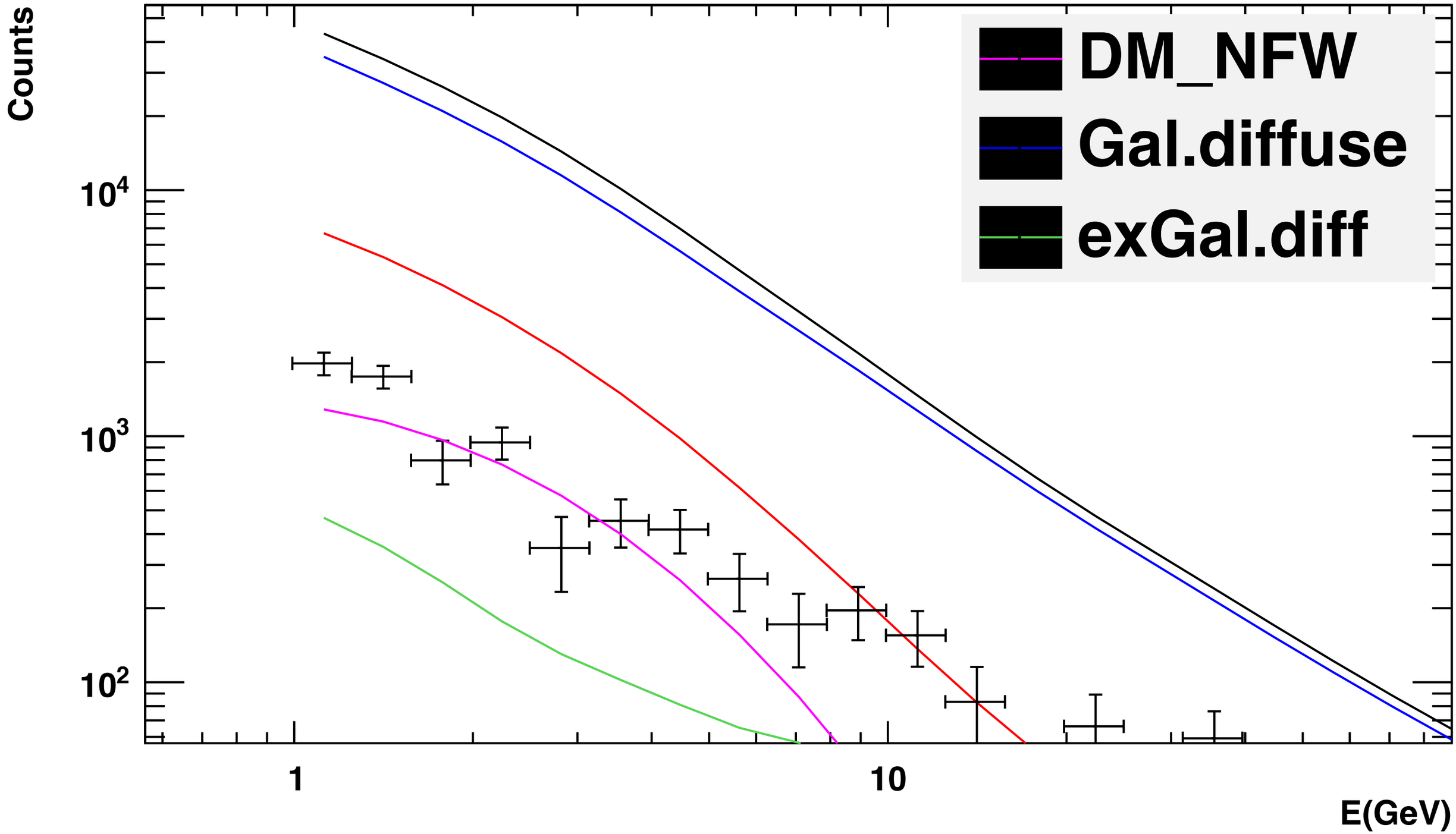
④2013/02/01～2014/08/01

⑤2014/08/01～2016/02/01

Count Spectra




Counts
10^4
10^3
10^2
1
10
E(GeV)
DM_NFW
Gal.diffuse
exGal.diff


Counts
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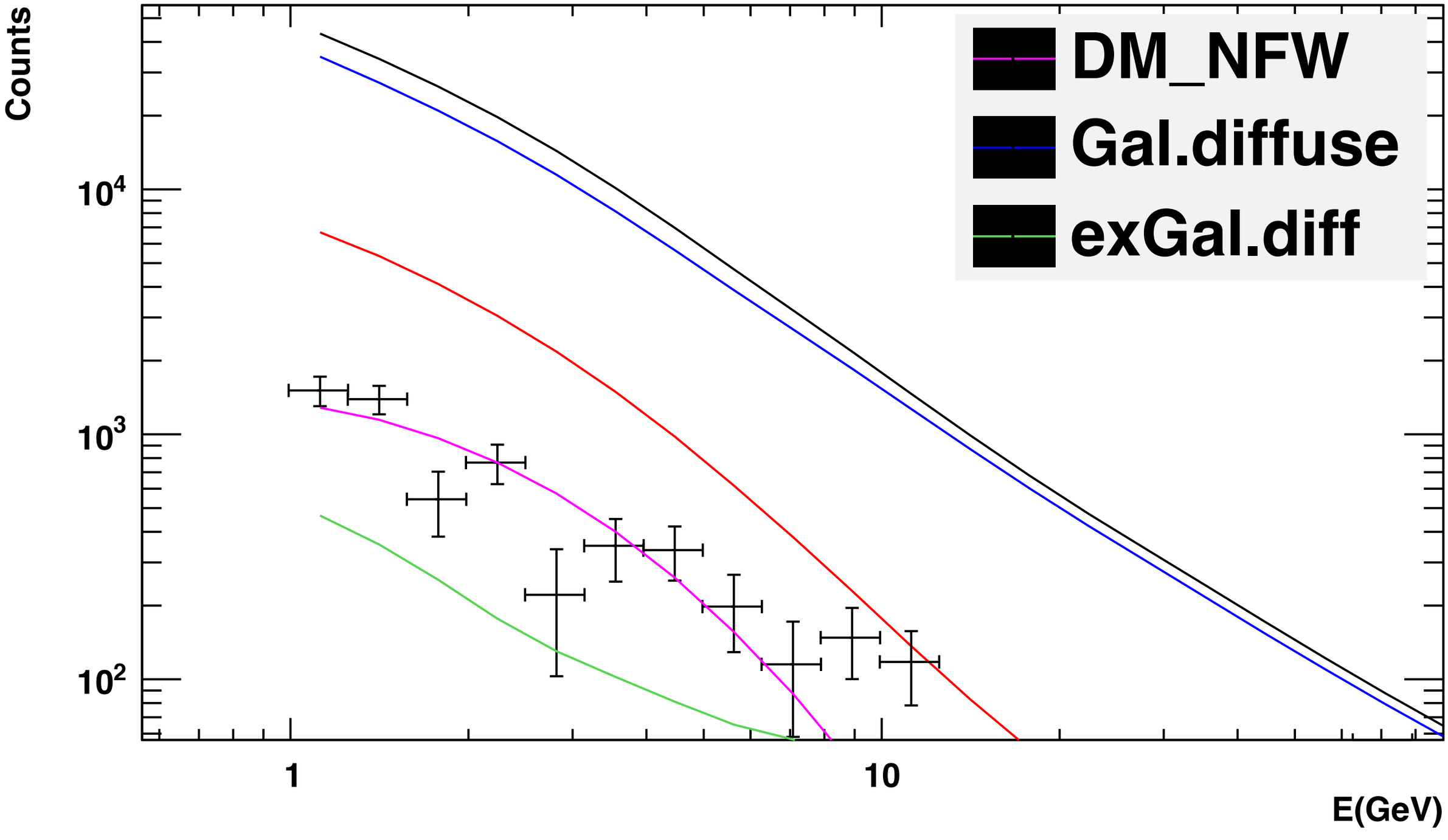
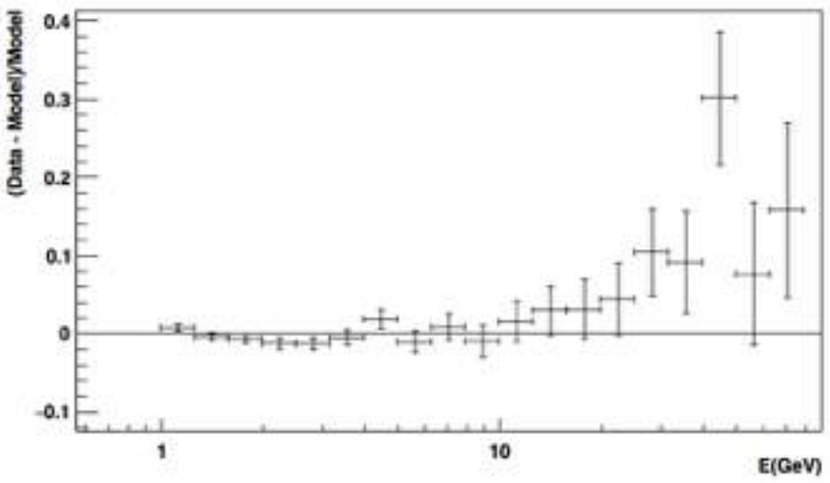
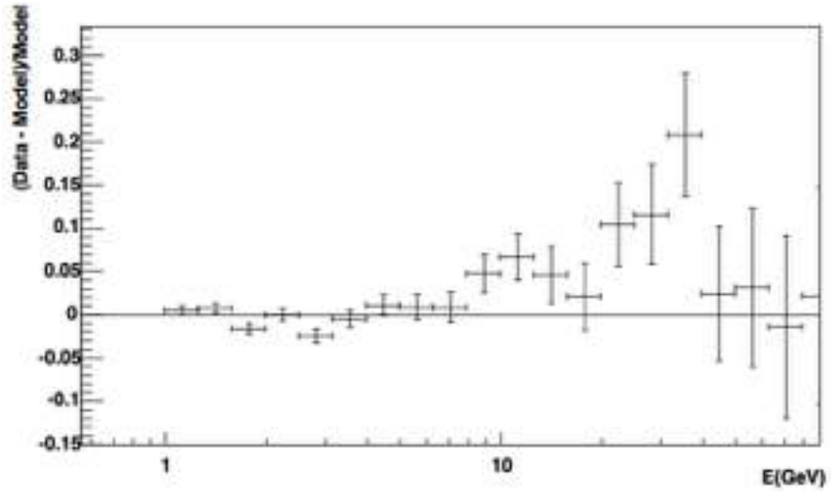

Counts
10^4
10^3
10^2
1
10
E(GeV)
DM_NFW
Gal.diffuse
exGal.diff

Residual Spectra

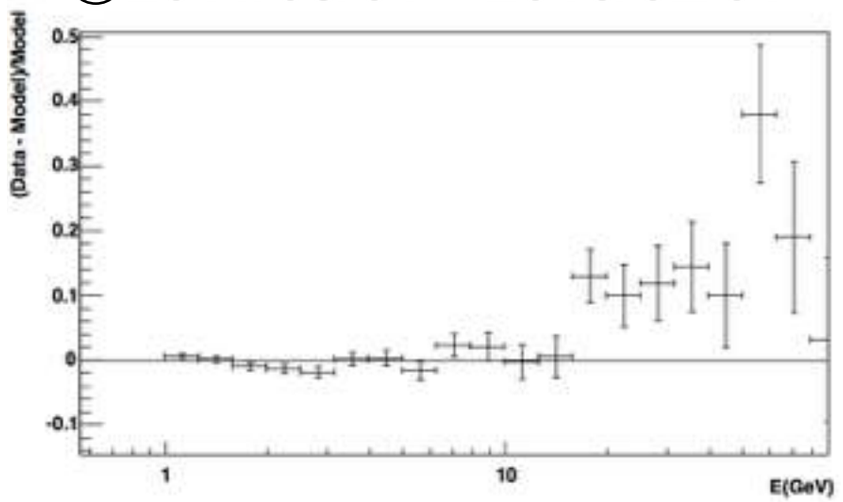
①2008/08/05～2010/02/01



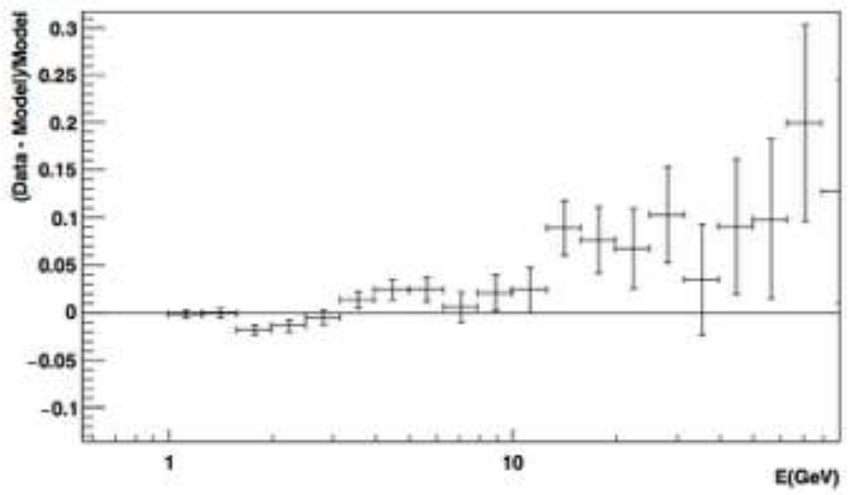
②2010/02/01～2011/08/01



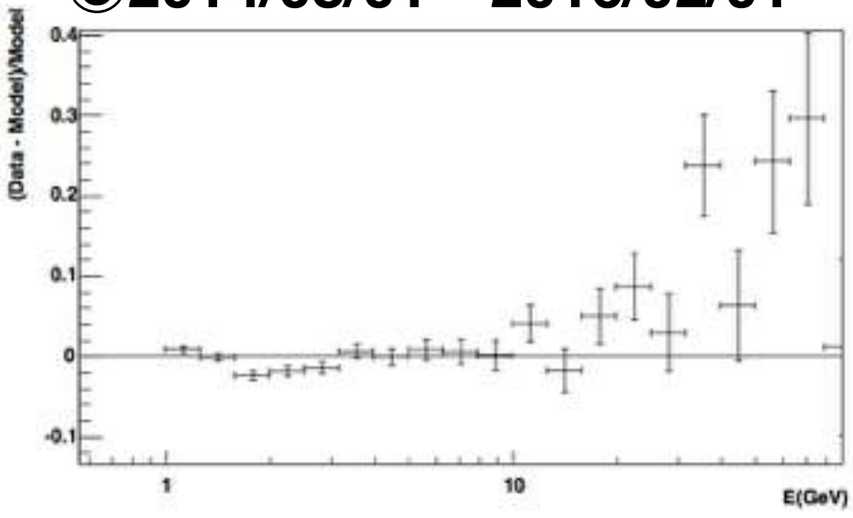
③2011/08/01～2013/02/01



④2013/02/01～2014/08/01

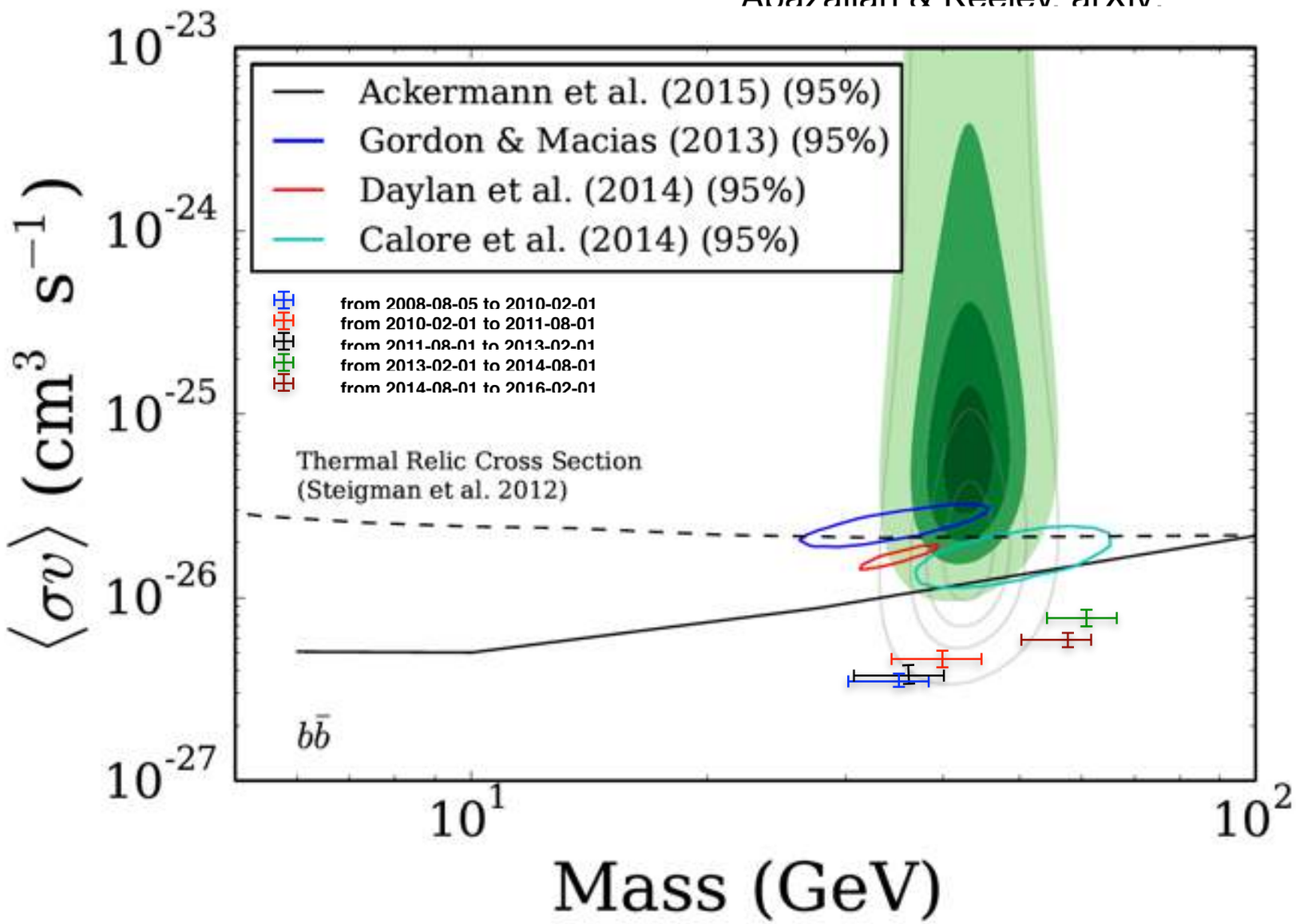


⑤2014/08/01～2016/02/01



DM parameters

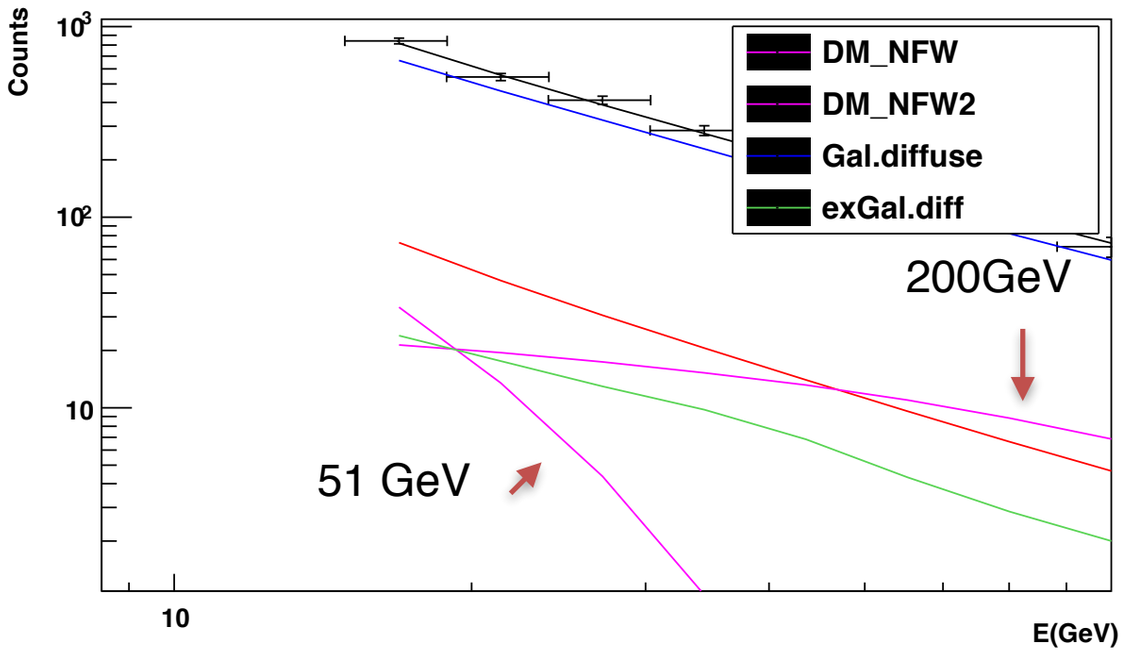
Abazajian & Keeley, arXiv:

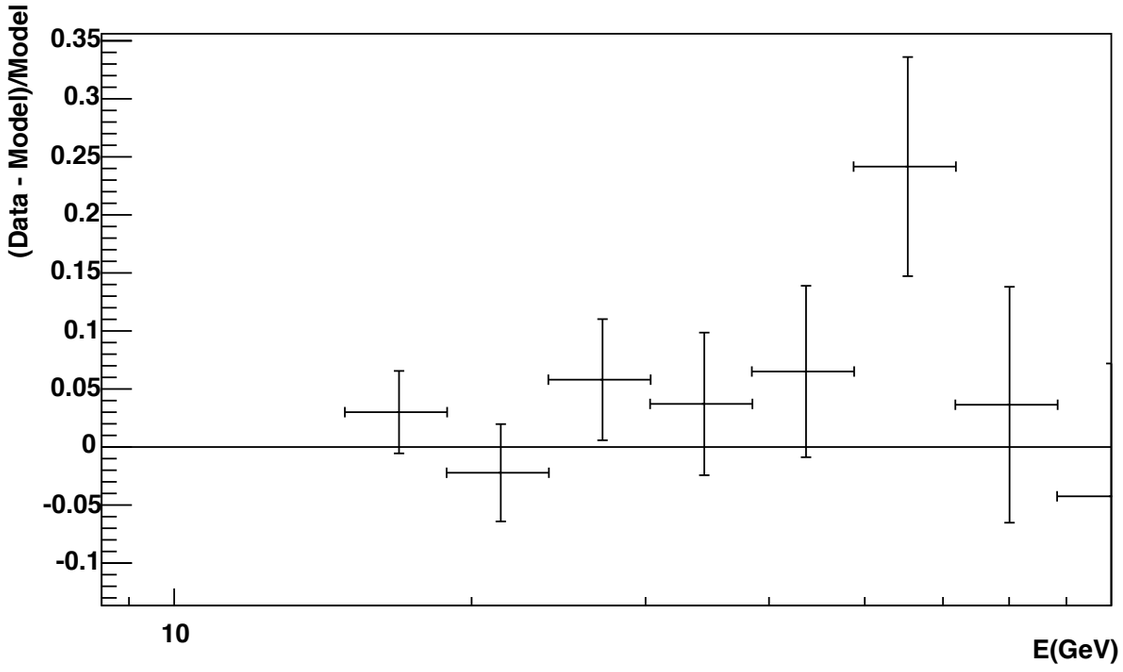


Mass(GeV):
1. 34.0+/-0.5
2. 39.6+/-0.4
3. 39.5+/-0.5
4. 58.9+/-5.7
5. 56.4+/-0.6

<σv>(x10^-26 cm^3 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)





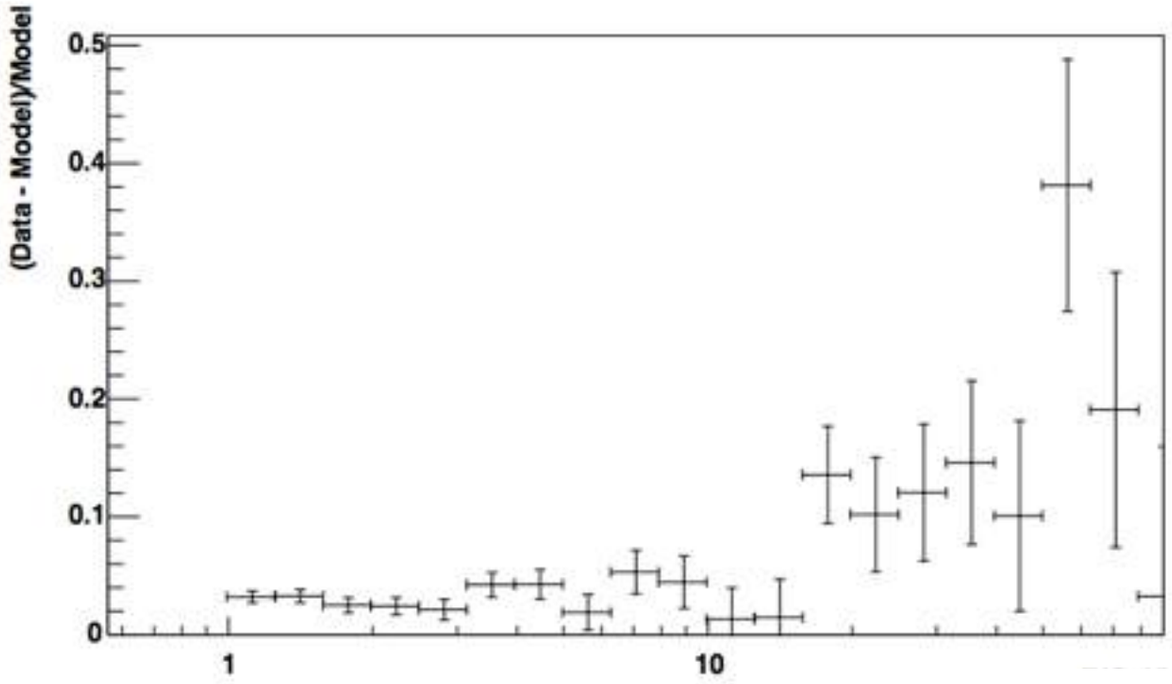
51 GeV & 200 GeV
Dark matter

- Peak around 50~60GeV ?

Conclusion

- We analysed Fermi LAT data to search for gamma ray emission from Dark Matter
- We used 7.5 years(1.5years 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