

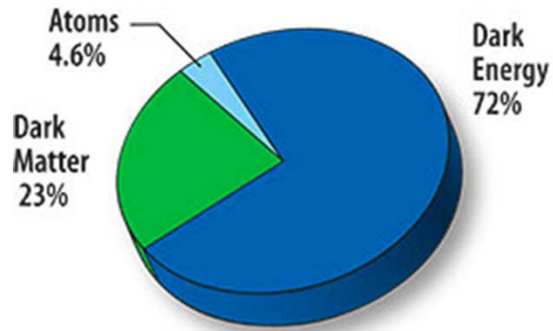
Search for gamma-ray lines in the Galaxy with DAMPE

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(DAMPE collaboration)

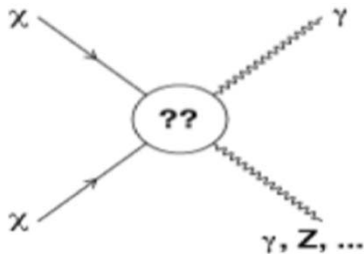


Dark matter (DM) and linelike structure

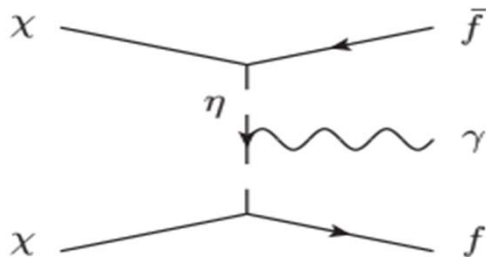


Spectral line

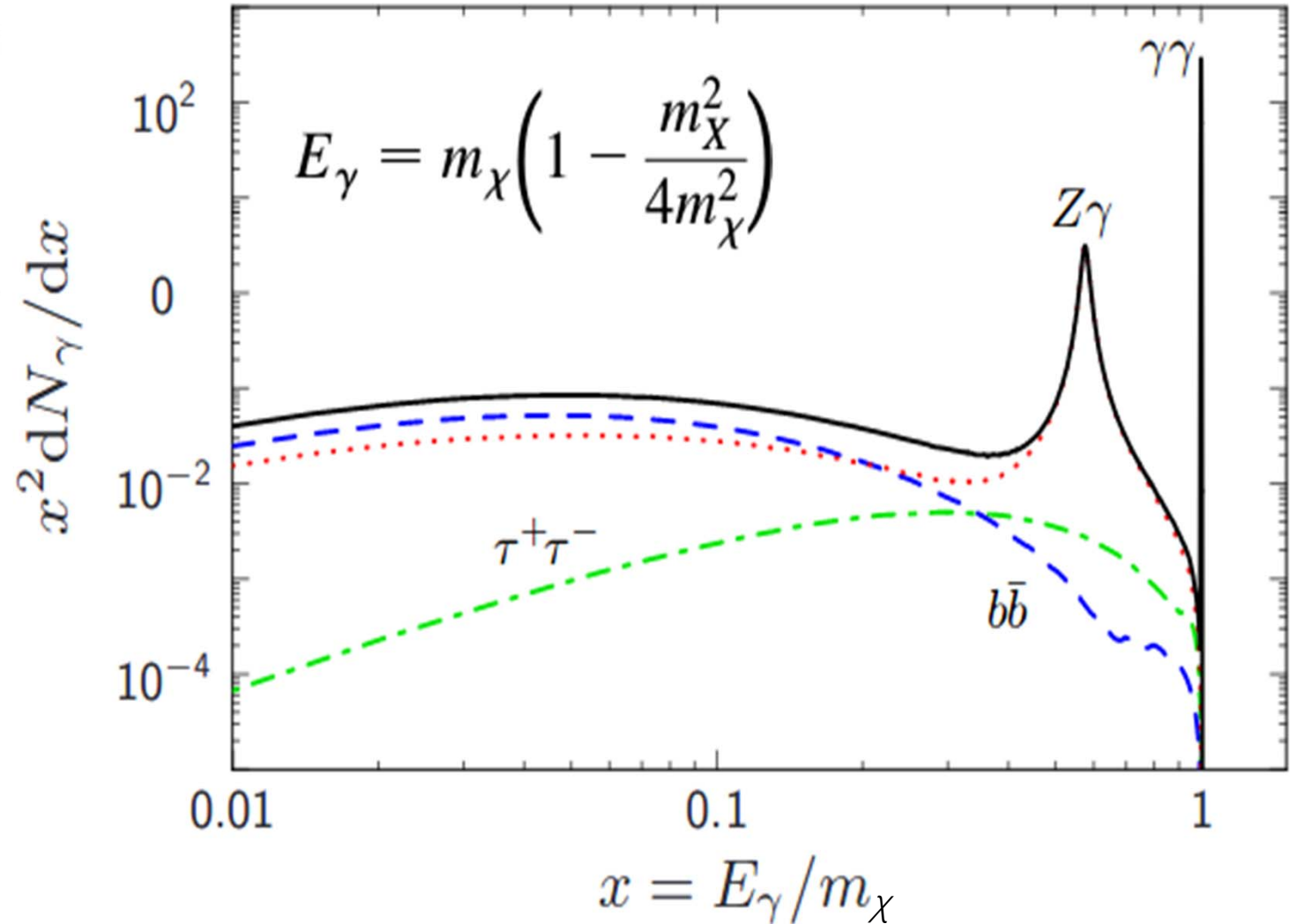
Prompt annihilation into $\gamma\gamma, \gamma Z, \gamma H^0 \dots$
 (also prompt decay into photons)



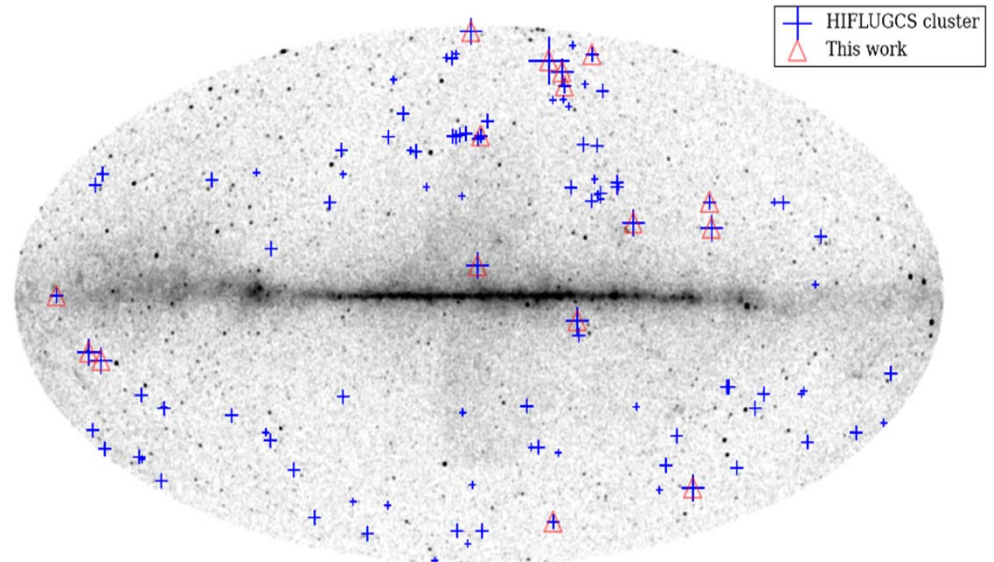
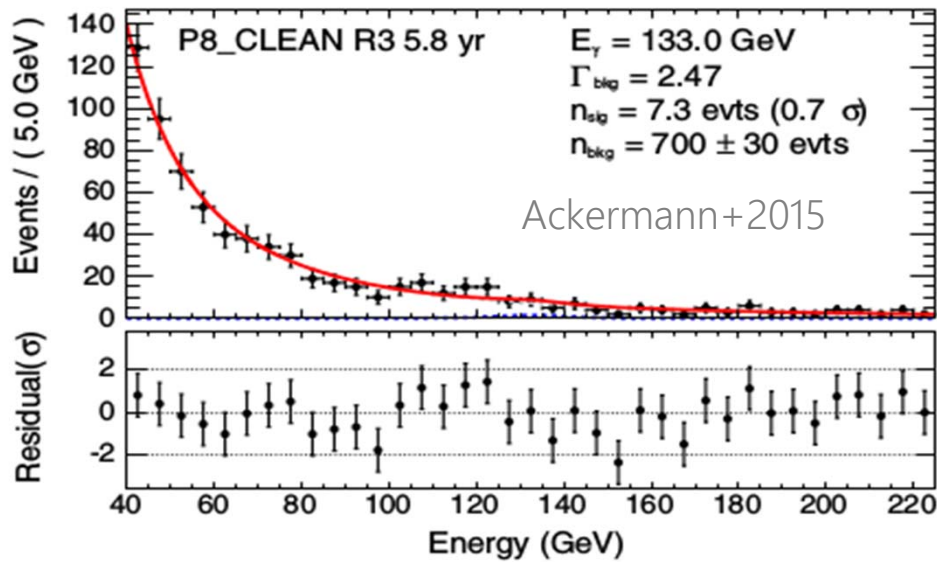
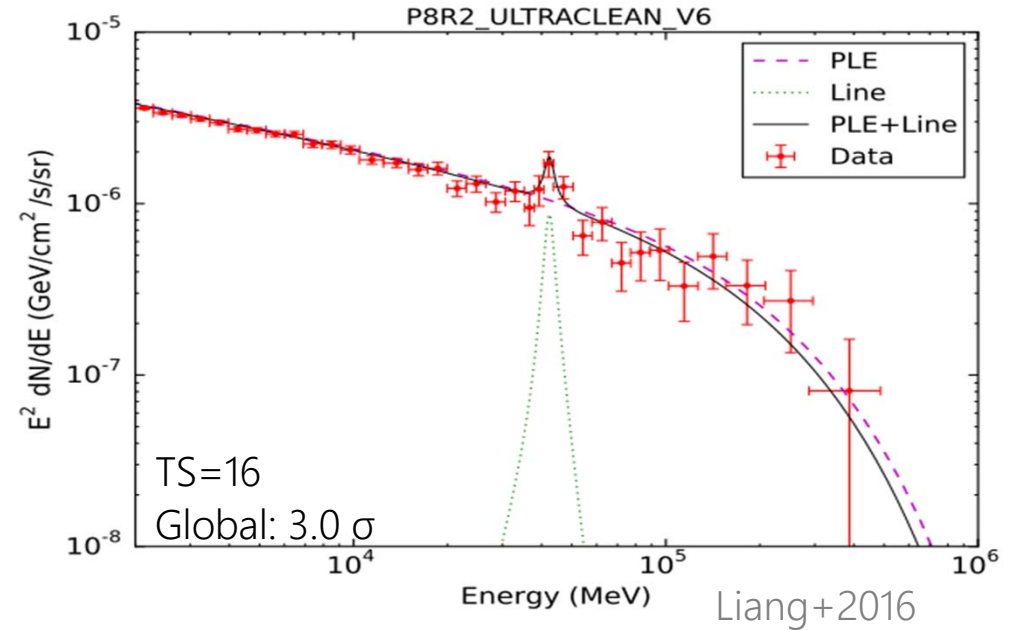
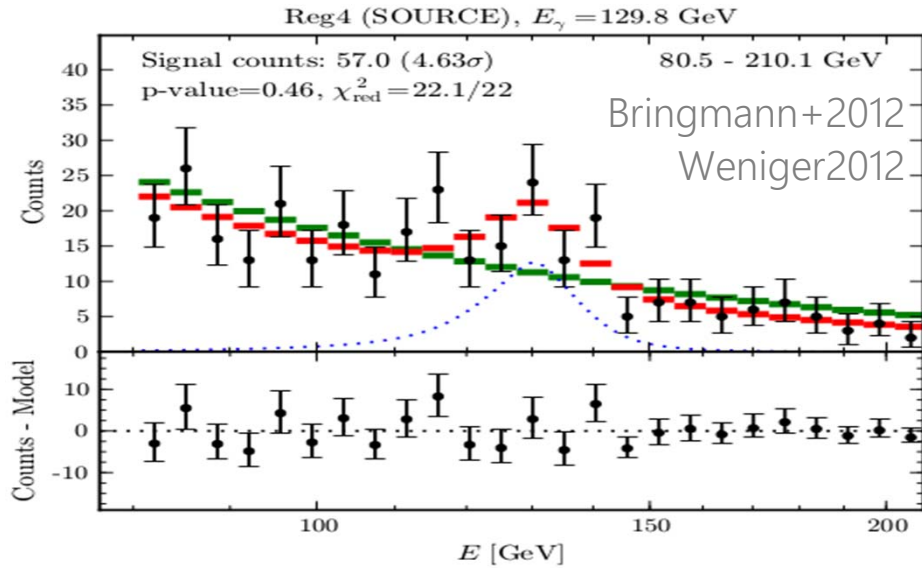
Annihilation or decay



Internal bremsstrahlung
 (Bringmann+2012)

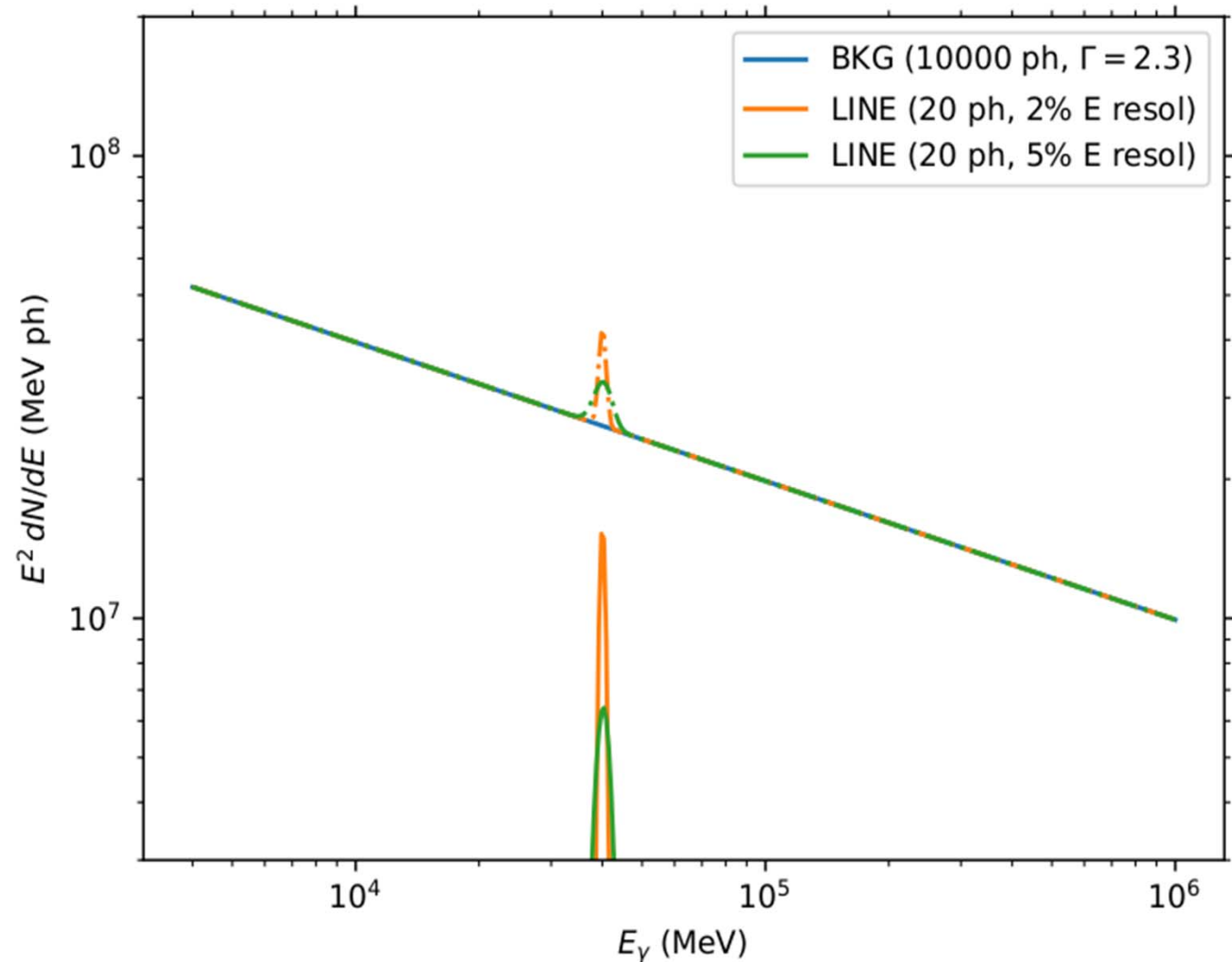


Line searches in Fermi era

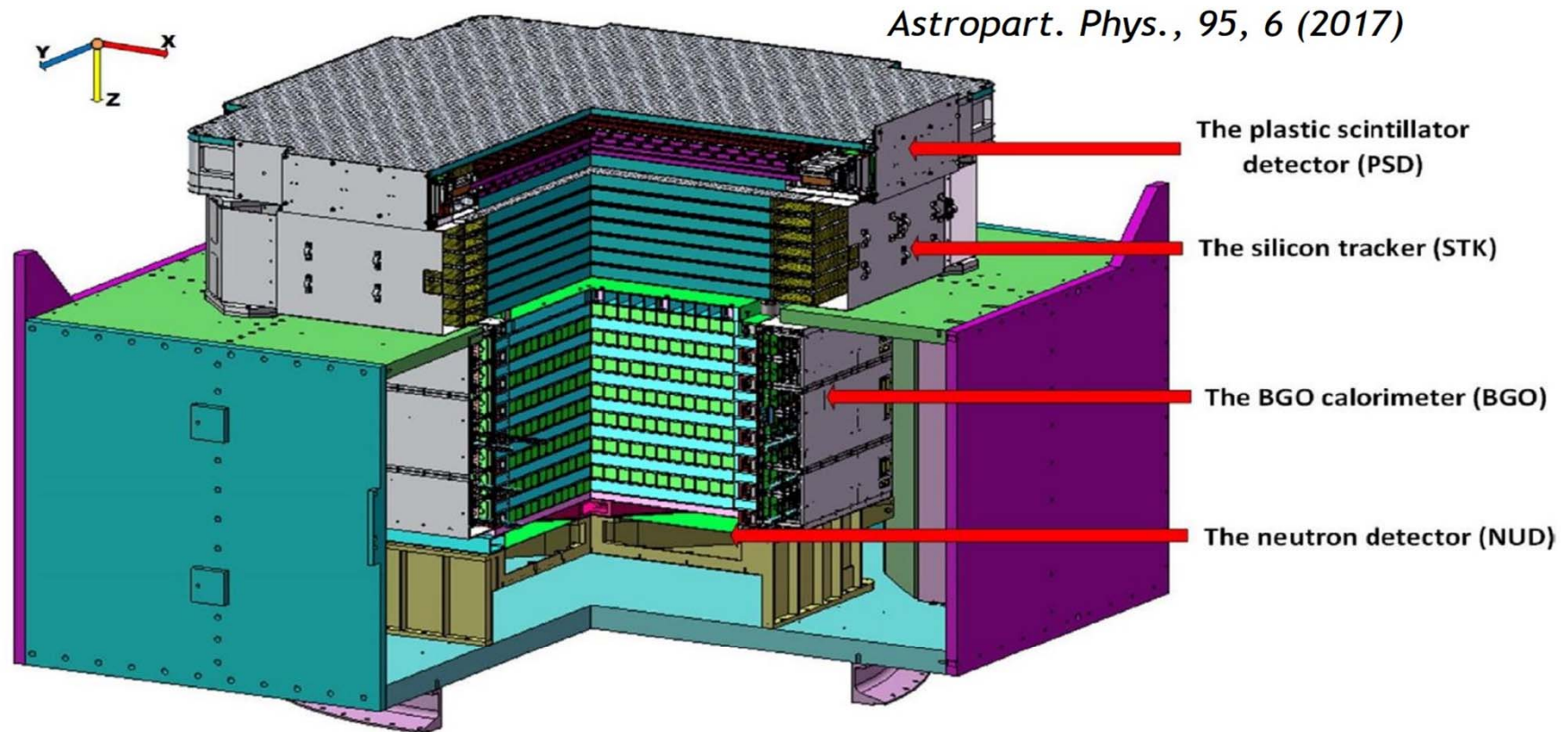


A better energy resolution means a better constraint

The line significance is proportional to the number of photons and inversely to the energy resolution

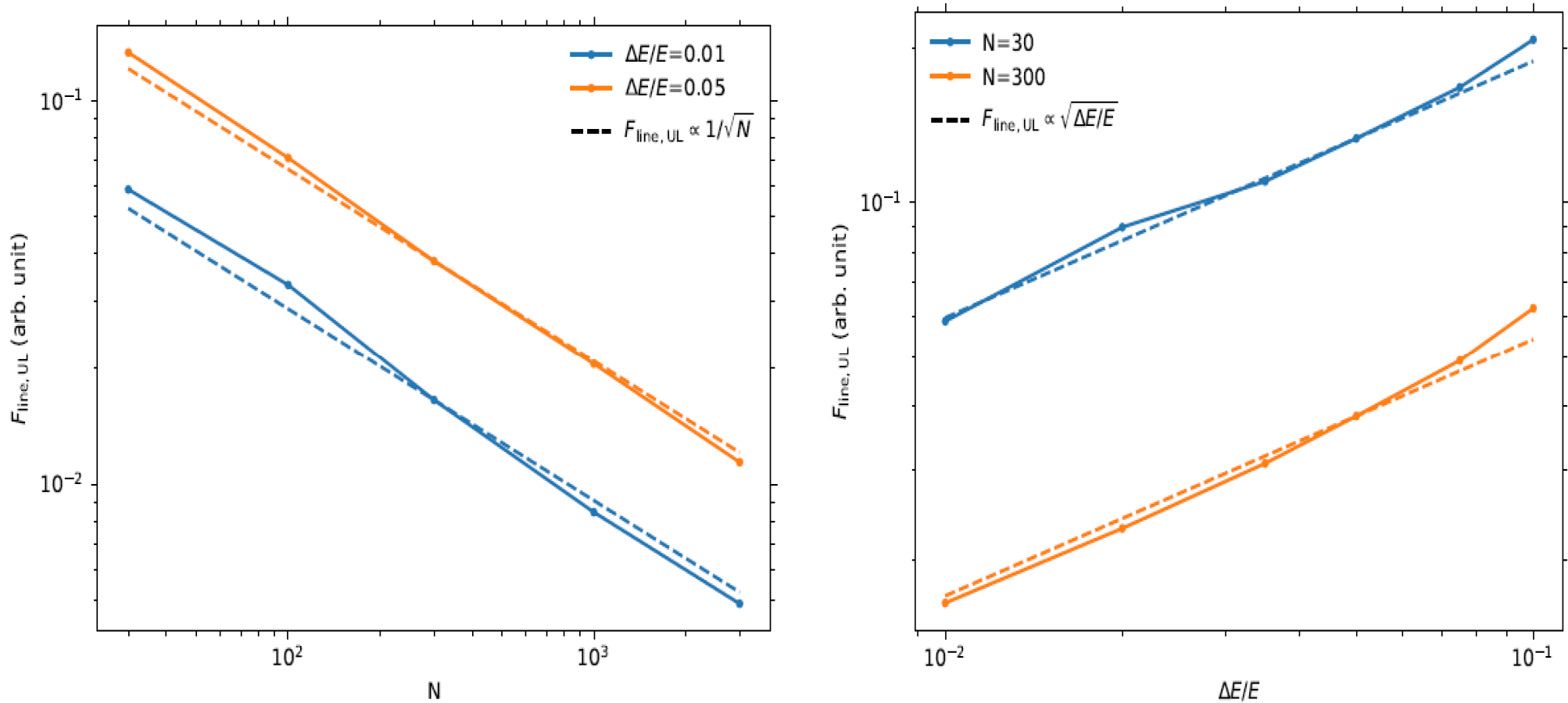


Dark Matter Particle Explorer (DAMPE)



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

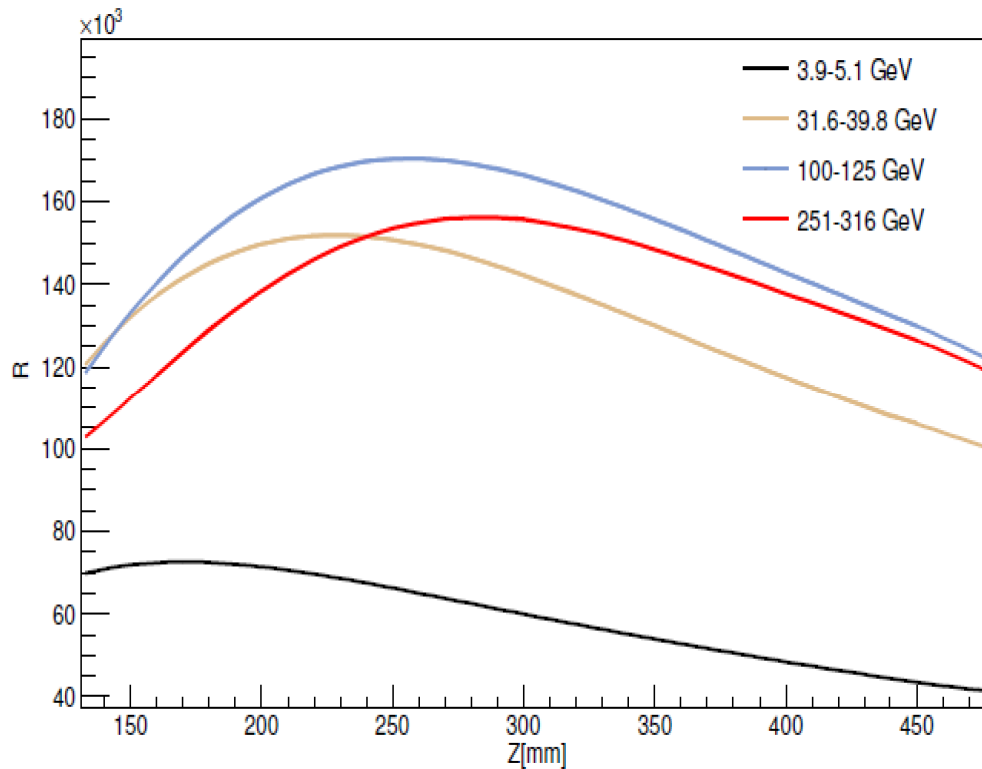
Sensitivity for LineLike Structures



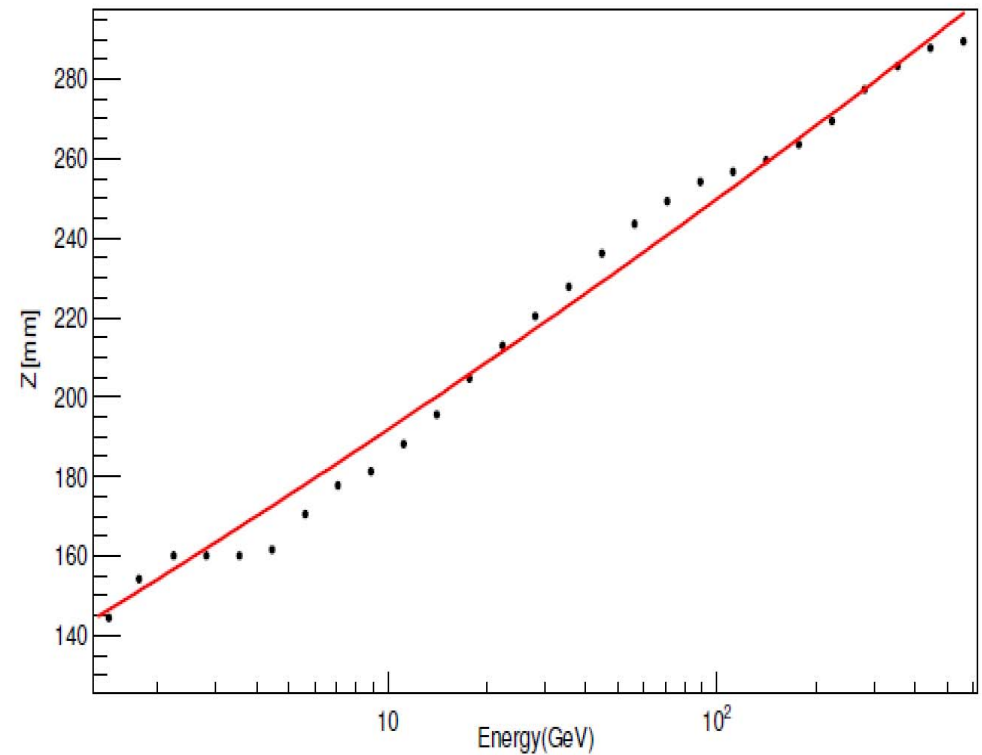
The 95% confidence level upper limits of line flux for different energy resolution (left panel) and photon counts (right panel).

DAMPE gamma-ray data

Develop special gamma-ray data set for line search

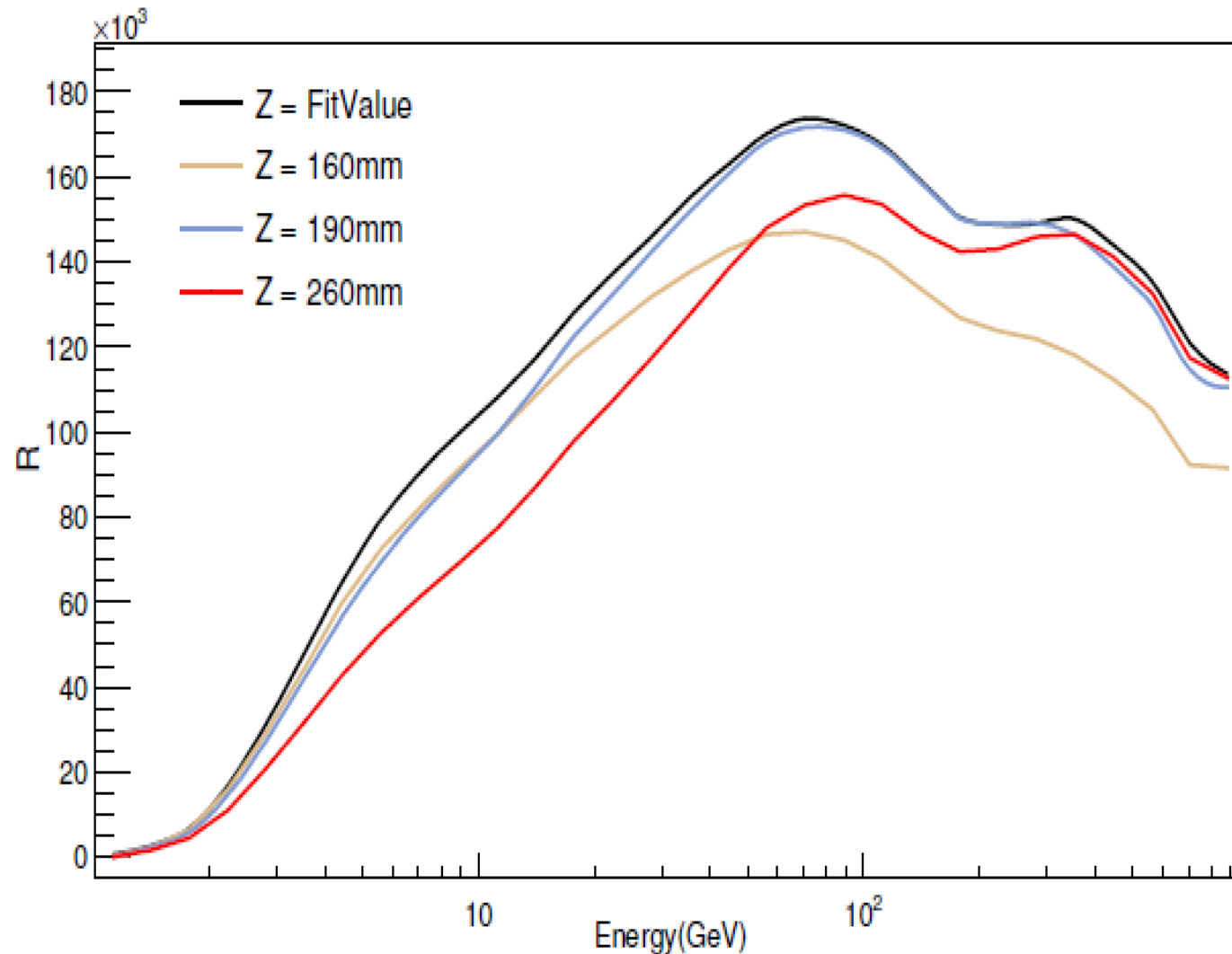


The relationship between the R value and the Z value at different energy



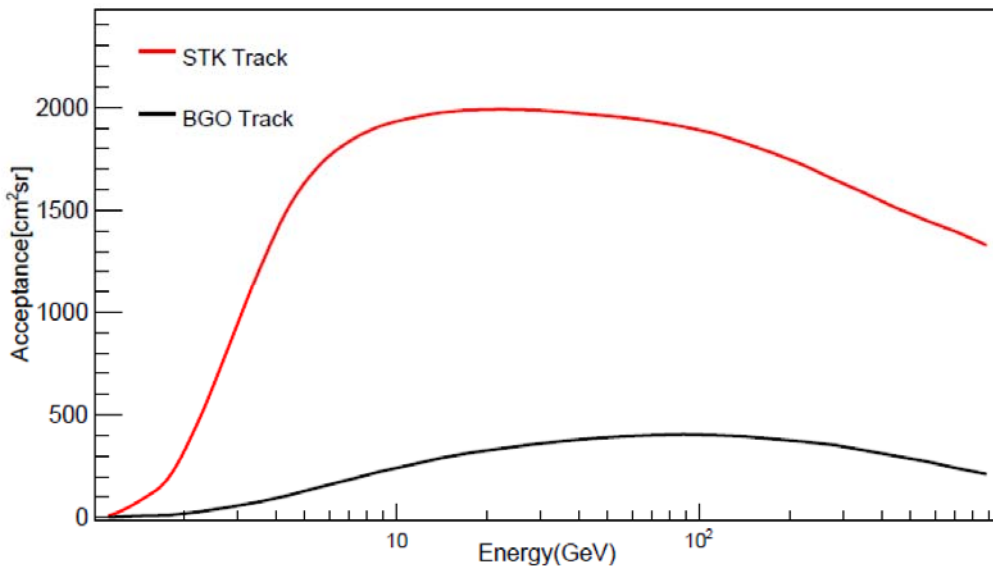
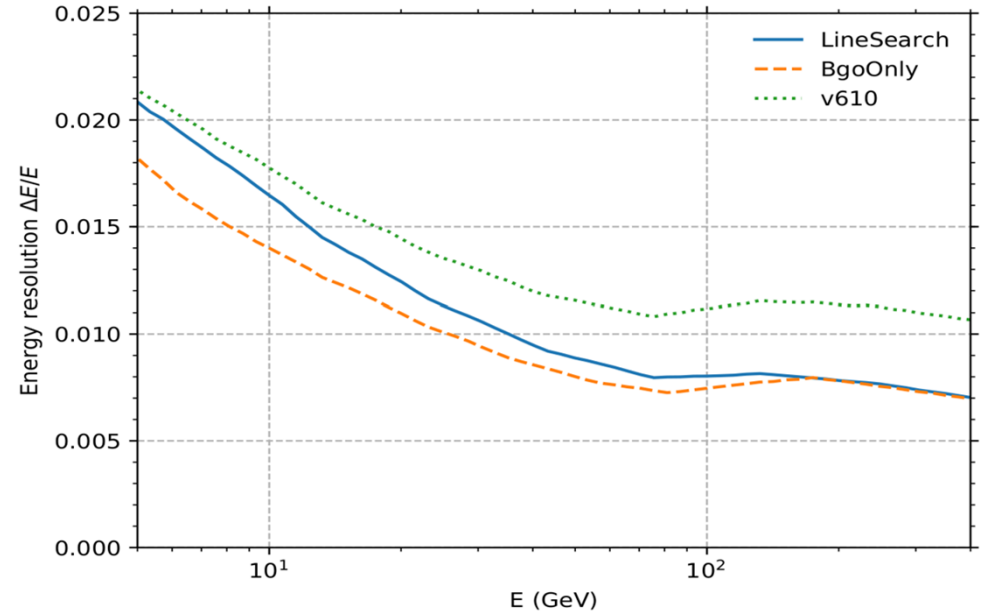
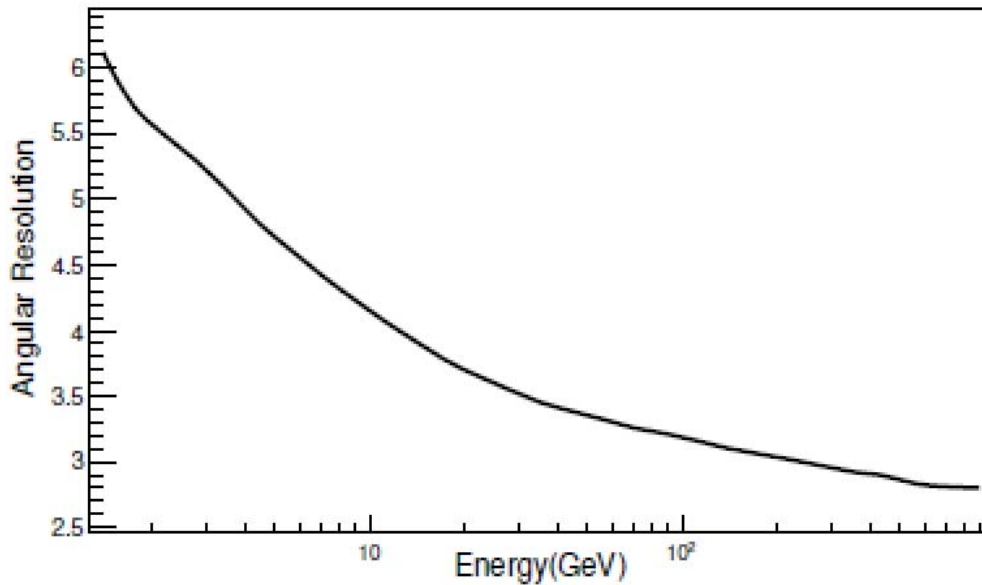
The functional relationship between the optimal Z value and energy at different energy

DAMPE gamma-ray data



LineSearch data(stk track) (~88%):
 A subset of the fiducial photon data set (see Xu+2018 for detail), which optimize the quantity $\epsilon/(\Delta E/E)$ by adjusting the lower bound of the depth Z that events need to pass through.

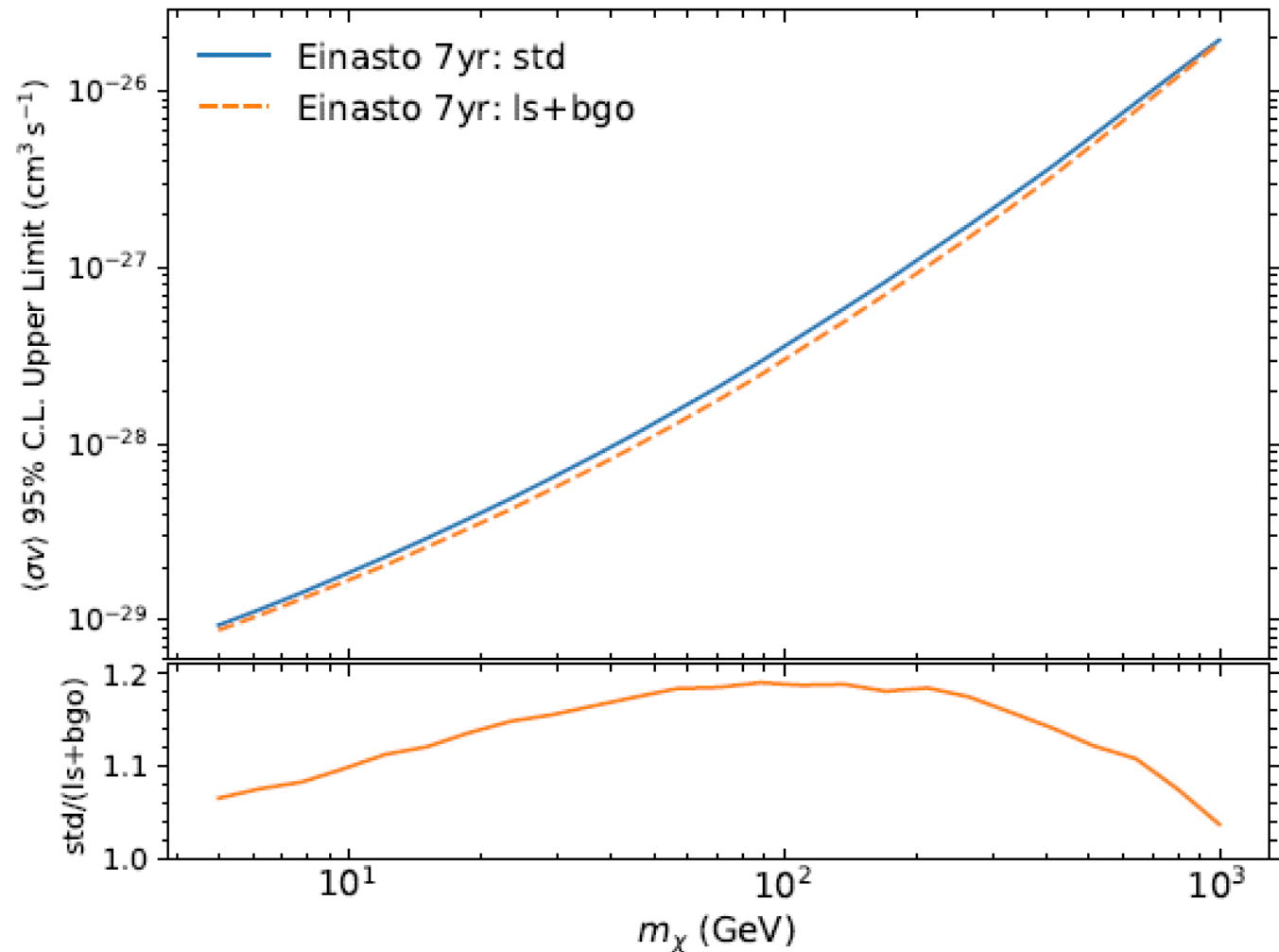
DAMPE gamma-ray data



BgoOnly data (~12%):
 Photons converted in the BGO calorimeter. Events are required to pass through at least the front 8 layers of BGO and survive the veto from the PSD.

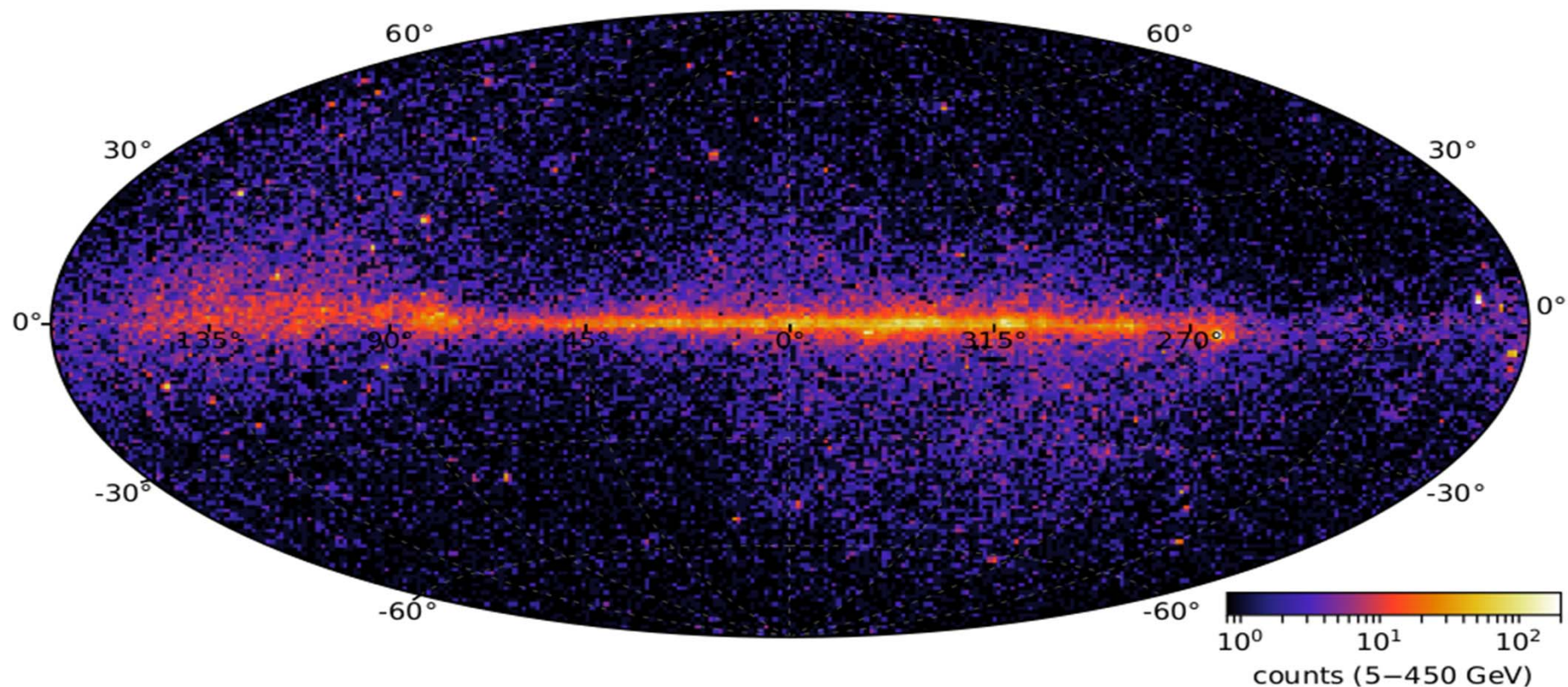
DAMPE gamma-ray data

The constraint with the new data sets is stronger than that using the standard data set with the largest improvement being 20%

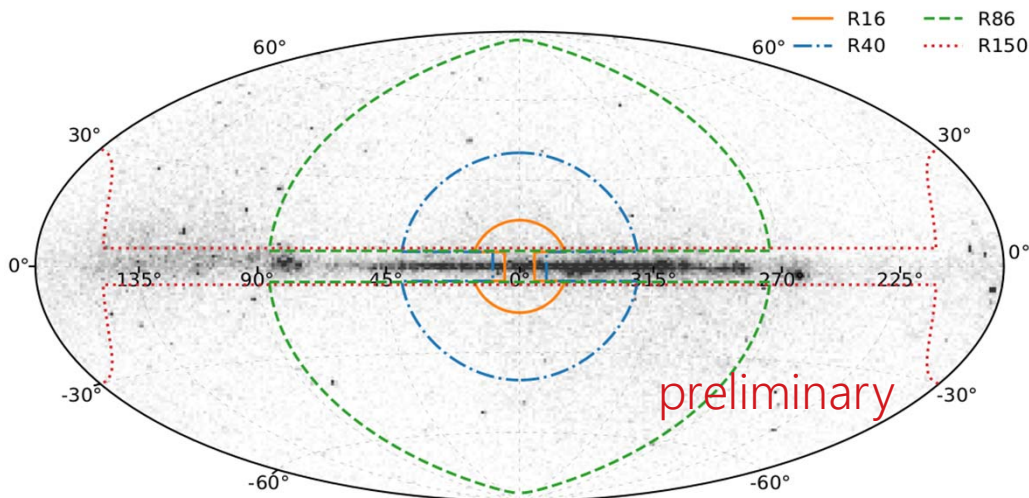
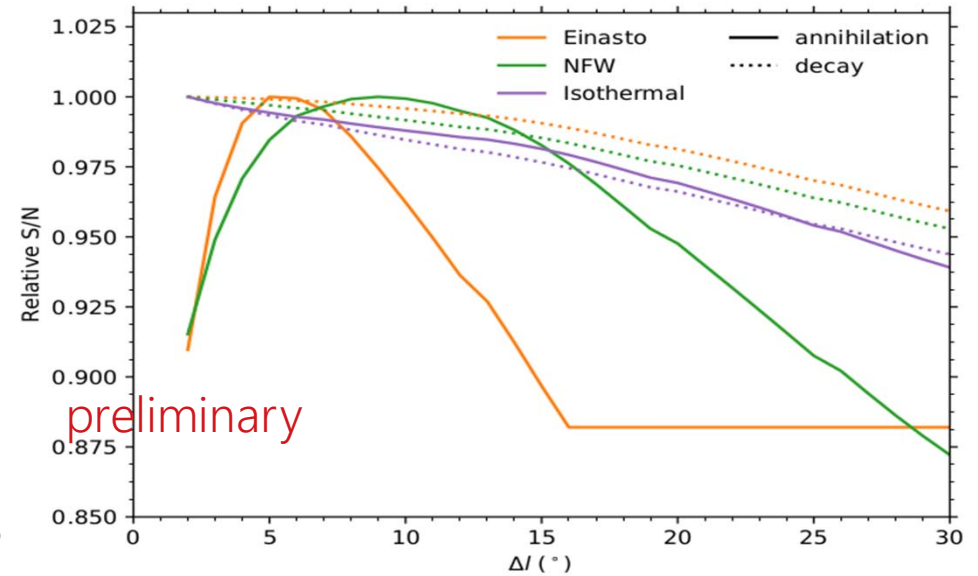
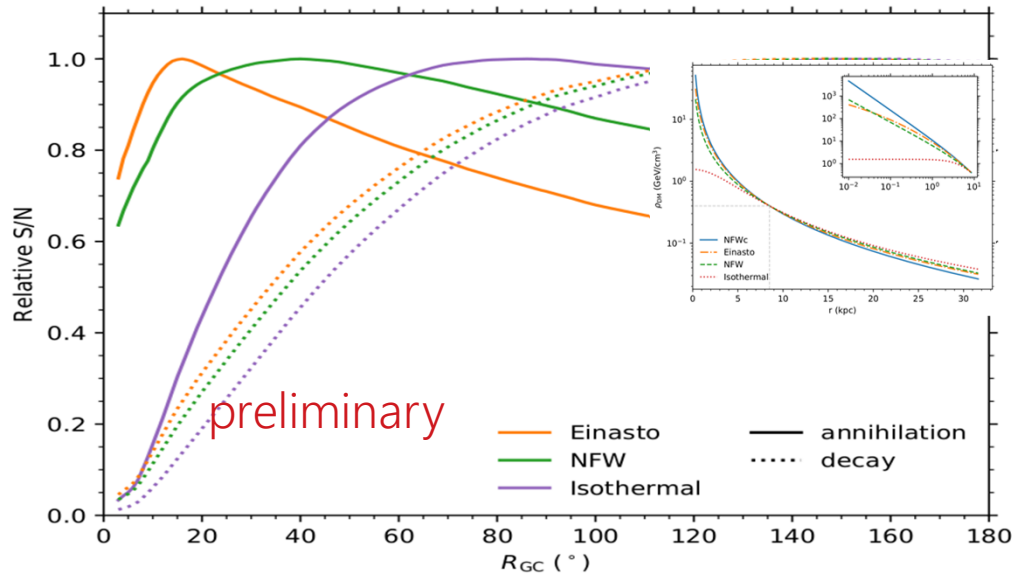


DAMPE gamma-ray data

- LineSearch (LS) and BgoOnly (BGO) data set;
- High energy trigger (HET);
- Five years data;
- Photon energy between 5 and 450 GeV.

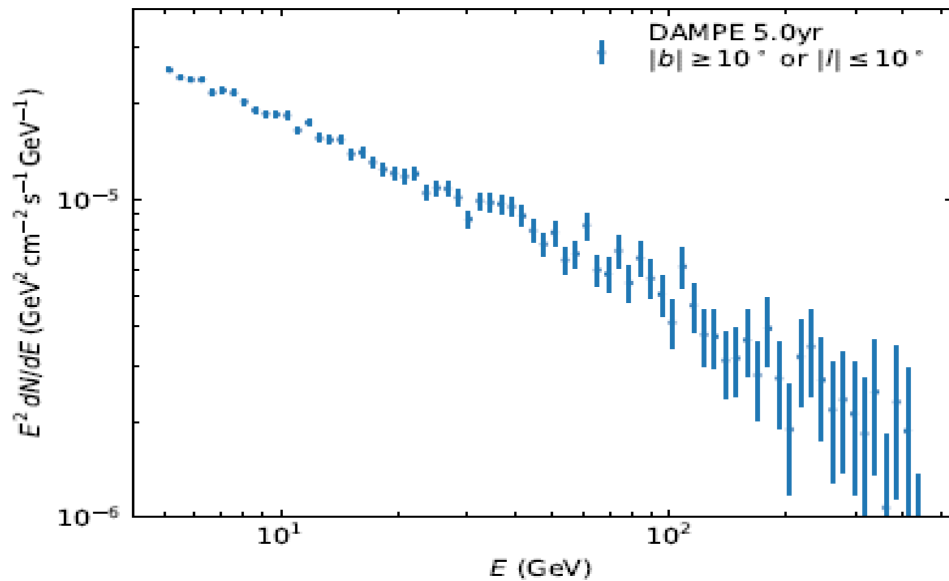
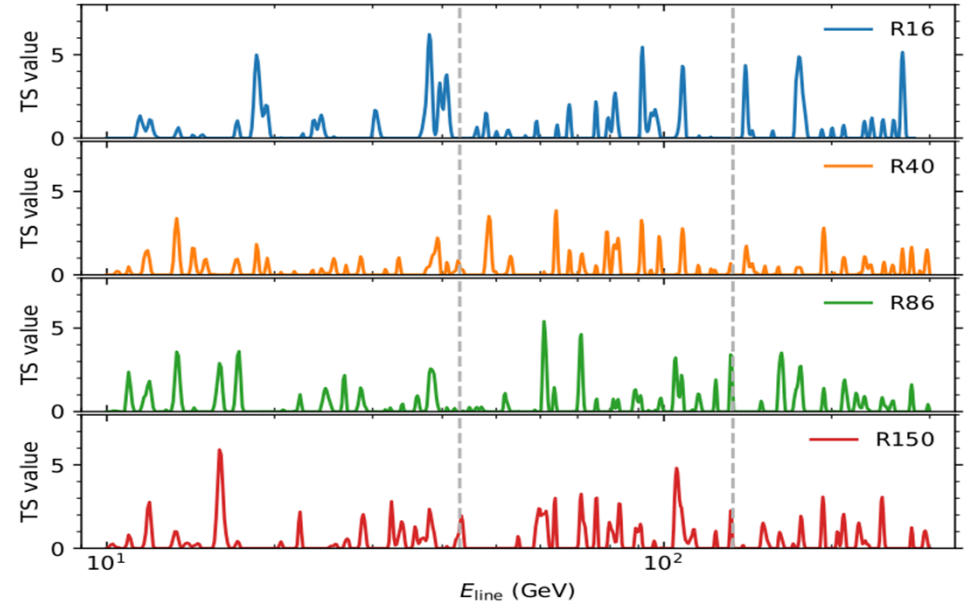
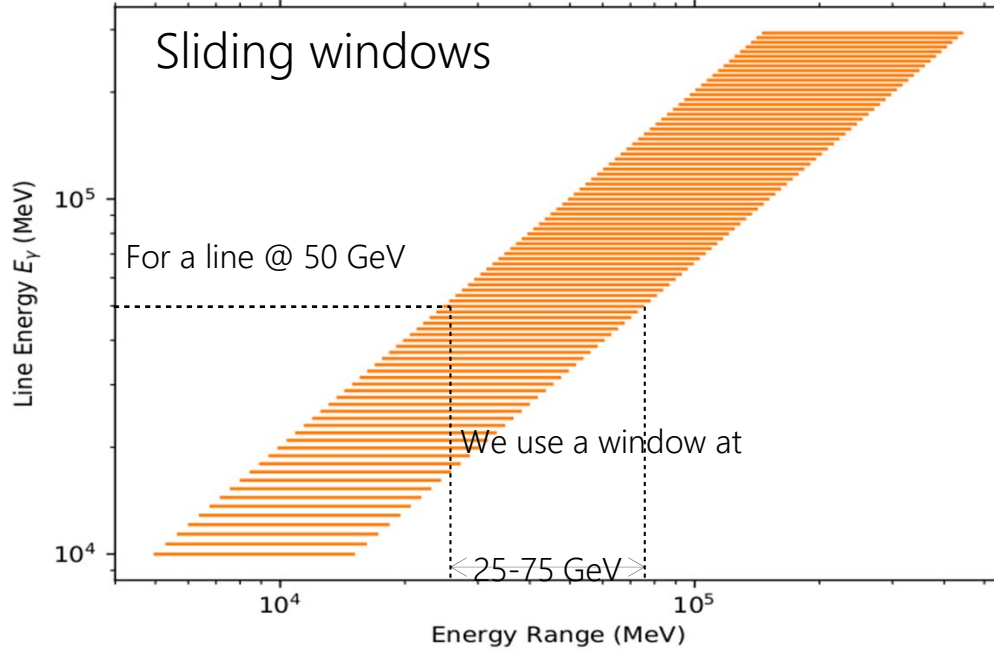


SNR-optimal ROIs for various DM profiles



Make regions of interest (ROIs) optimized for the sensitivity considering different DM density profiles.

Line search in the MW



Unbinned Likelihood:

$$L(\Theta) = L_1(\Theta) \times L_2(\Theta),$$

where 1 and 2 represent the two data sets, and

$$\ln L_k(\Theta) = \sum_{i=1}^{N_{\text{ph},k}} \ln[\bar{\lambda}_k(E_i; \Theta)] - \int_{E_{\text{min}}}^{E_{\text{max}}} \bar{\lambda}_k(E; \Theta) dE$$

Null hypothesis:

$$\bar{\lambda}_{\text{null},k}(E; \Theta) = F_b(E) \bar{e}_k(E)$$

Alternative hypothesis:

$$\bar{\lambda}_{\text{sig},k}(E; \Theta) = F_b(E) \bar{e}_k(E) + \bar{F}_{s,k}(E) \bar{e}_k(E_{\text{line}})$$

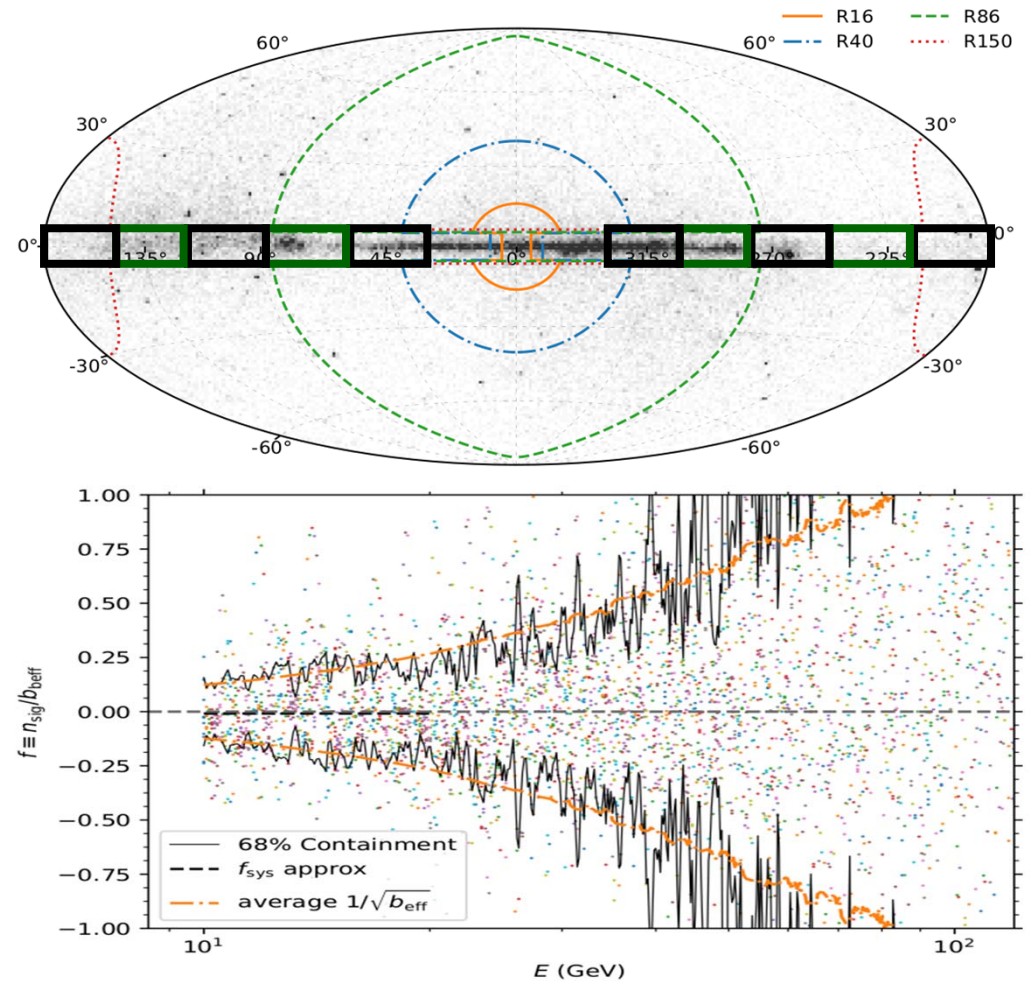
where,

$$F_b(E; N_b, \Gamma) = N_b E^{-\Gamma}$$

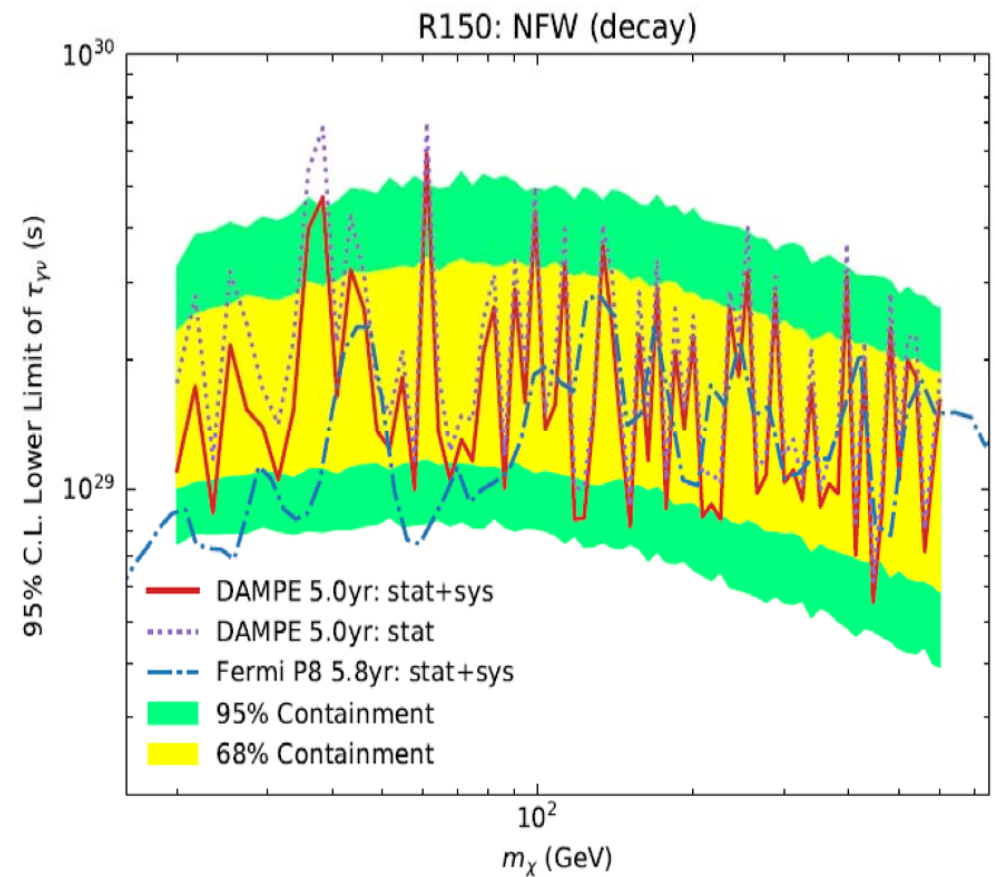
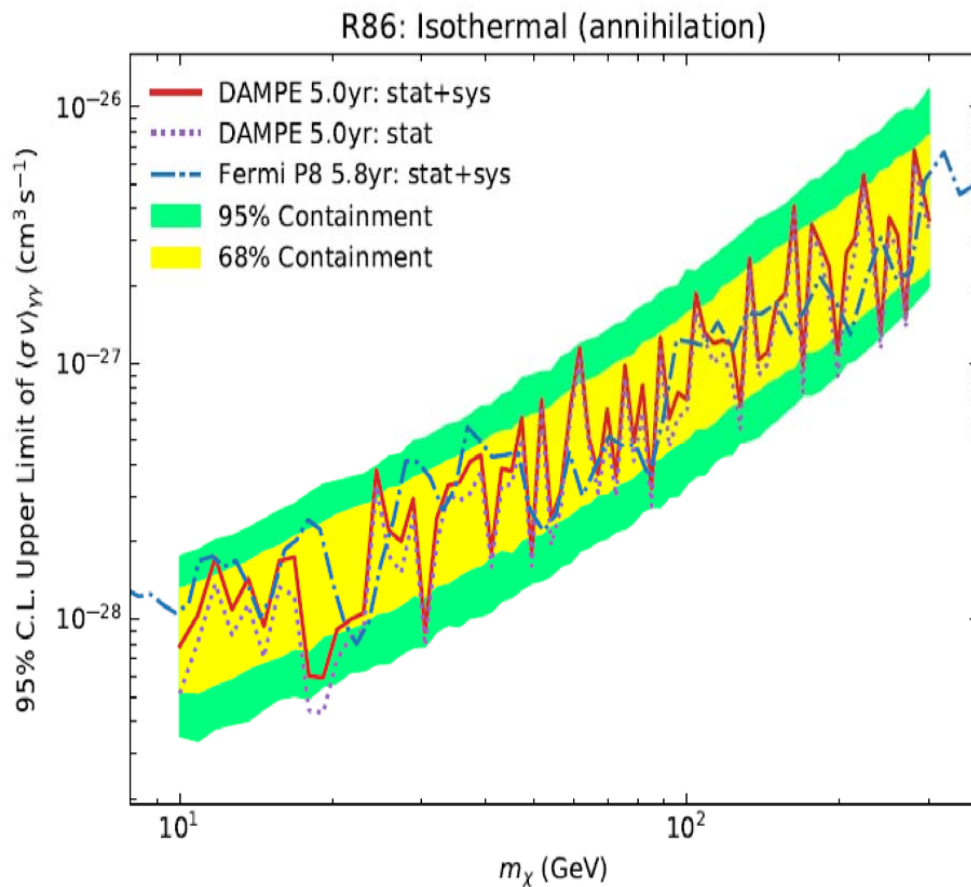
$$\bar{F}_{s,k}(E; N_s, E_{\text{line}}) = N_s \bar{D}_{\text{eff},k}(E; E_{\text{line}}),$$

Evaluate systematic uncertainties

- Fractional signal is defined as $f = n_{\text{sig}}/b_{\text{eff}}$. In the background-only regions, $f = f_{\text{sys}} + f_{\text{stat}}$:
 - Statistical: $f_{\text{stat}} \sim \text{Gauss}(0, 1/\sqrt{b_{\text{eff}}})$;
 - Systematic: $f_{\text{sys}} \sim \text{constant}$.
- Background regions: $30^\circ \times 10^\circ$ boxes along the Galactic plane ($|b| < 5^\circ$ and $|| > 30^\circ$).
- Fractional signal is dominated by statistical uncertainty.



Constraints on the DM parameters



The 95% confidence level constraints for different DM density profiles.

Summary

- We use 5-yr DAMPE photons to search for linelike structures between 10 and 300 GeV in the Milky Way:
 - *Two data sets are developed: the STK events optimized for line searches, and the BGO events;*
 - *Optimal ROIs are derived according to the DM density profiles and the exposure of DAMPE;*
 - *The summed unbinned likelihood with sliding windows technique is adopted;*
 - *Systematic uncertainties are taken into account.*
- We do not find any linelike signal in 5-yr DAMPE photon data, including the 133 GeV and 43 GeV line candidates reported in Fermi-LAT data.
- Our constraints for DM annihilation are comparable to the Fermi-LAT 5.8-yr results. Thanks to smaller systematic uncertainties, we have better constraints for DM decay lifetime below 100 GeV than Fermi-LAT.