Cosmological dark matter annihilation signals: experimental constraints

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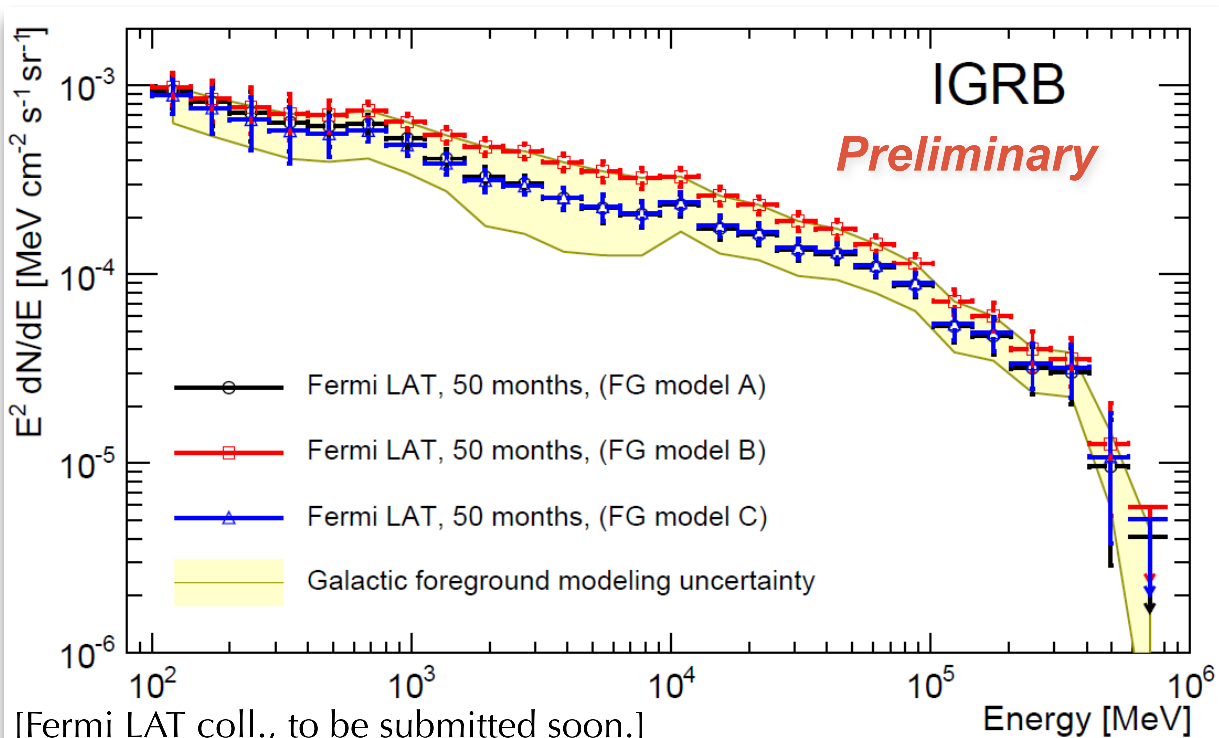
On behalf of the Fermi LAT Collaboration

The measurement

- **100 MeV-820 GeV**
  - **two custom event selections optimized for LOW (<13 GeV) and HIGH (>13 GeV) energies**
  - **detailed modeling of the Galactic Diffuse emission**
  - **Extensive detector-level simulations used for initial estimate of residual cosmic-ray background**

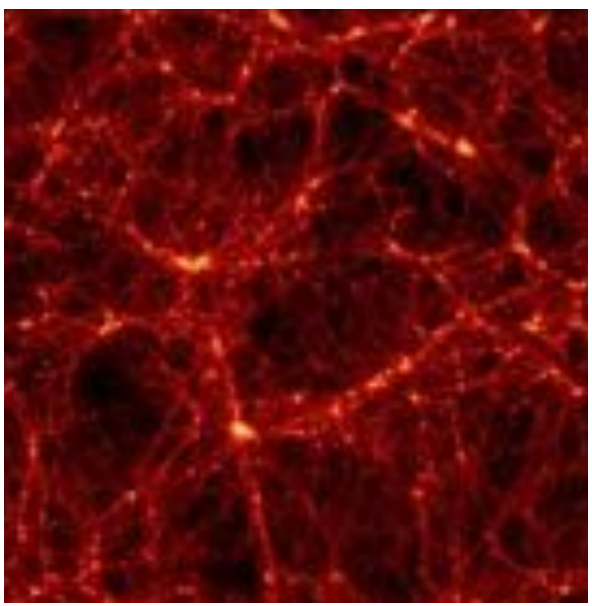
Keith's talk

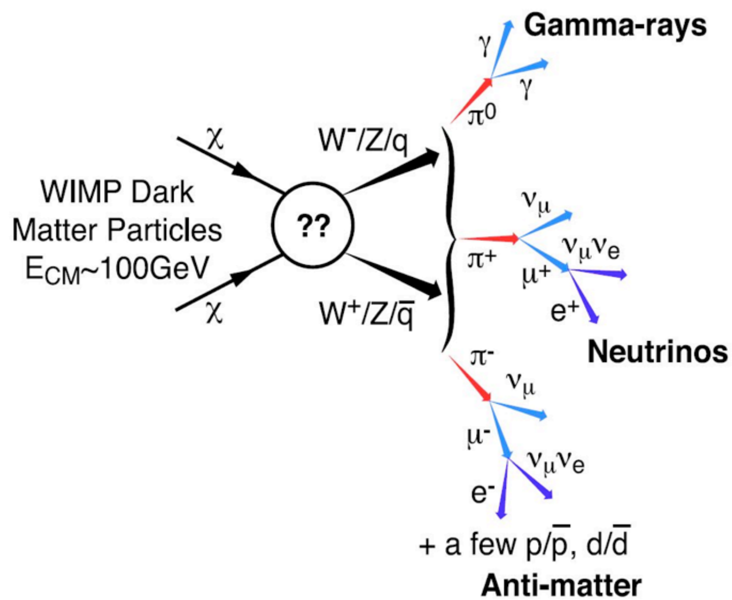


DM searches

- expect contribution from: Blazars, Radio Galaxies, Star Forming Galaxies... and **WIMP annihilations**, if contributing to the gamma ray sky.

- IGRB is a powerful tool to constrain DM annihilations. Both in terms of
  - IGRB spectral fluxes
  - AND angular anisotropy power spectrum (Jenny, Fiorenza, Nicolao, Sheldon, Kev...)





DM search in the IGRB spectral fluxes

- **Challenges:**
  - What is DM *distribution* in the sky - which components contribute to *isotropic* emission?
  - What are DM *clustering* properties at *various (small!) scales* -> determines the amplitude of the DM gamma ray signal (MASC talk)
  - What are the 'guaranteed' (astrophysical) contributions to the isotropic signal (spectral shape and intensity)
  - DM signal WITHIN our Galaxy: could it bias the measurement of the isotropic spectral flux?

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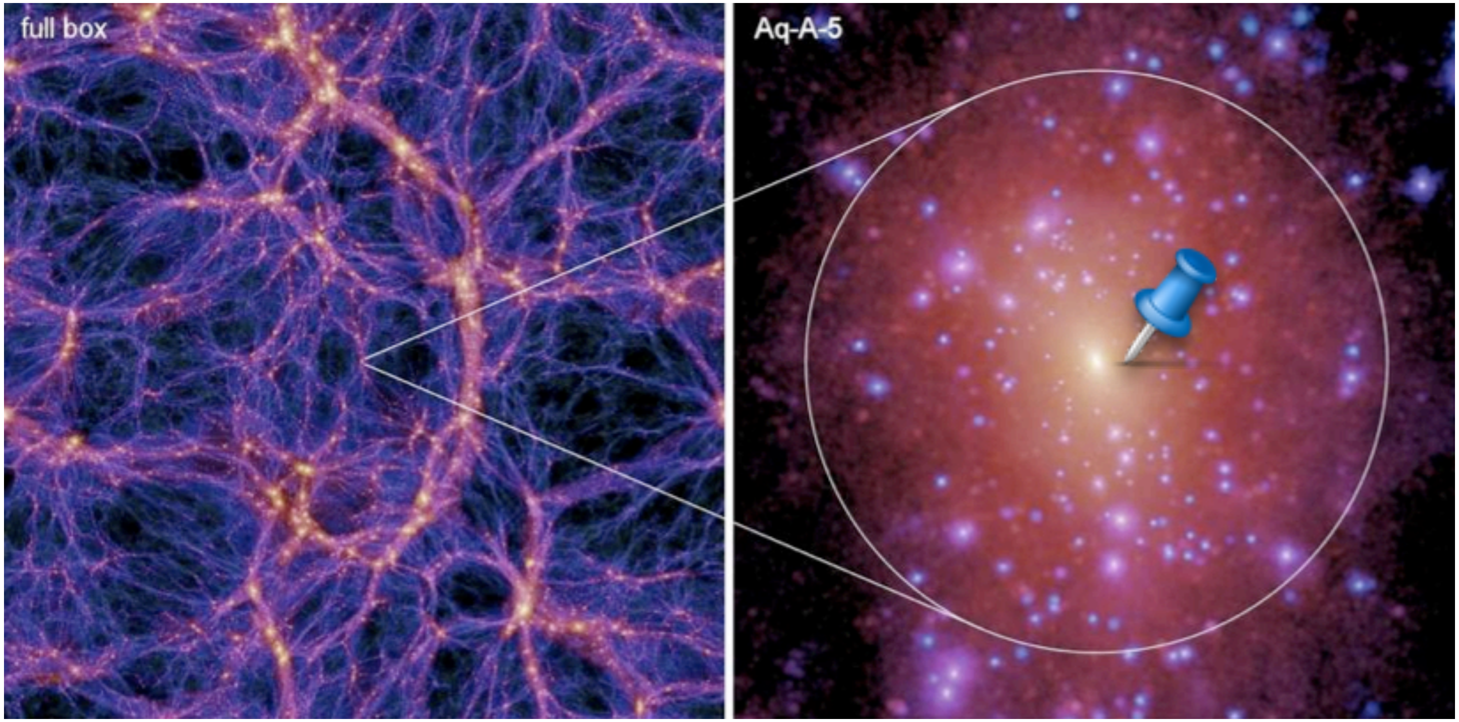
DM distribution

- **DM distribution over *full sky* is *relevant*. Three distinct components:**

  - **smooth Milky Way component (main halo)**
  - **Galactic substructure**
  - **all extragalactic halos -> isotropic on large scales**



[Springel, V.+, MNRAS, 2008.]

Galactic DM distribution

- **Isotropic vs non isotropic components?**
  - **Whole sky residuals of the IGRB measurement are at a <~20% level**
  - **'allowed' level of departure from large scale 'isotropic' DM emission in our analysis.**

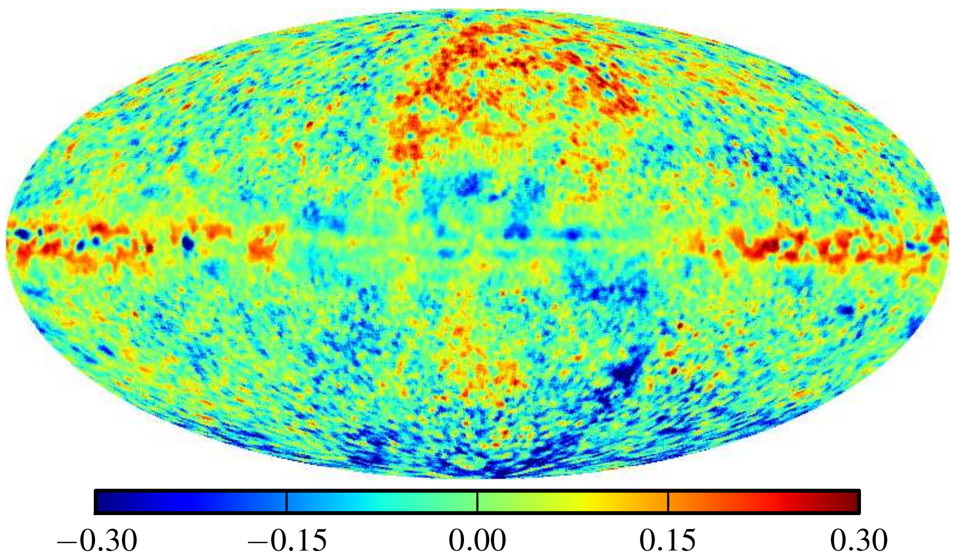
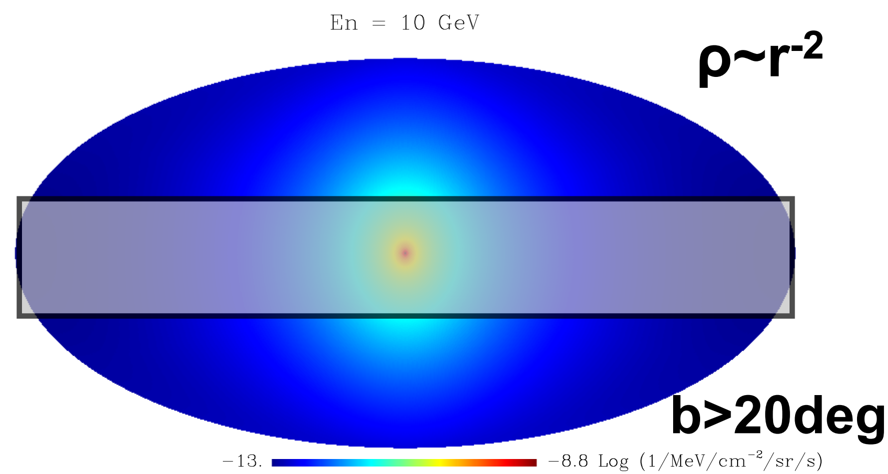


Fig. just an Illustration [taken from 1202.4039, Fermi LAT collaboration APJ (2012)]

Galactic DM distribution

- **Isotropic vs non isotropic components?**
  - smooth DM halo
  - Galactic substructure

DM annihilation intensity of the smooth DM halo varies more than a factor of 16 for latitudes >20 deg.



Galactic DM distribution

- **Isotropic vs non isotropic components?**
  - smooth DM halo
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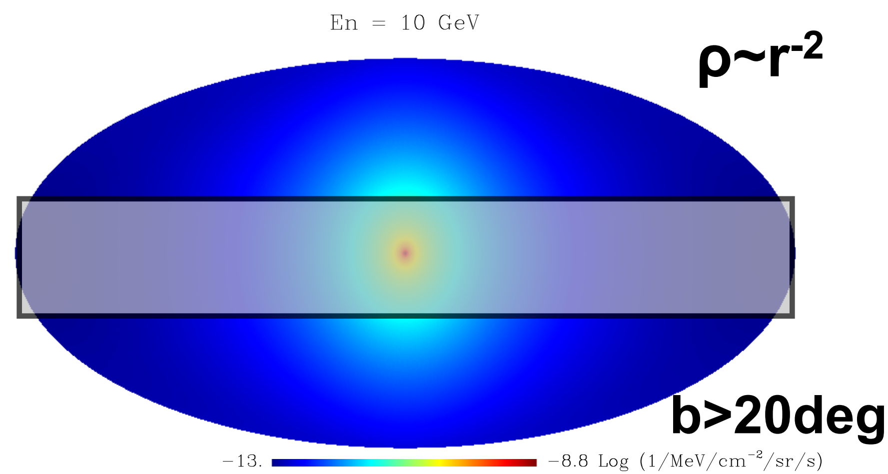
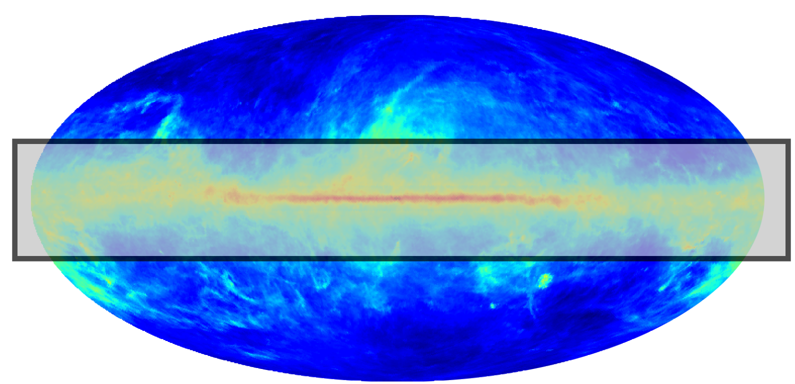
DM annihilation intensity of the smooth DM halo varies more than a factor of 16 for latitudes >20 deg.

-> not included in the isotropic DM signal.



However, it might sufficiently close (in morphology and spectra) to the Galactic diffuse emission - discussed later.



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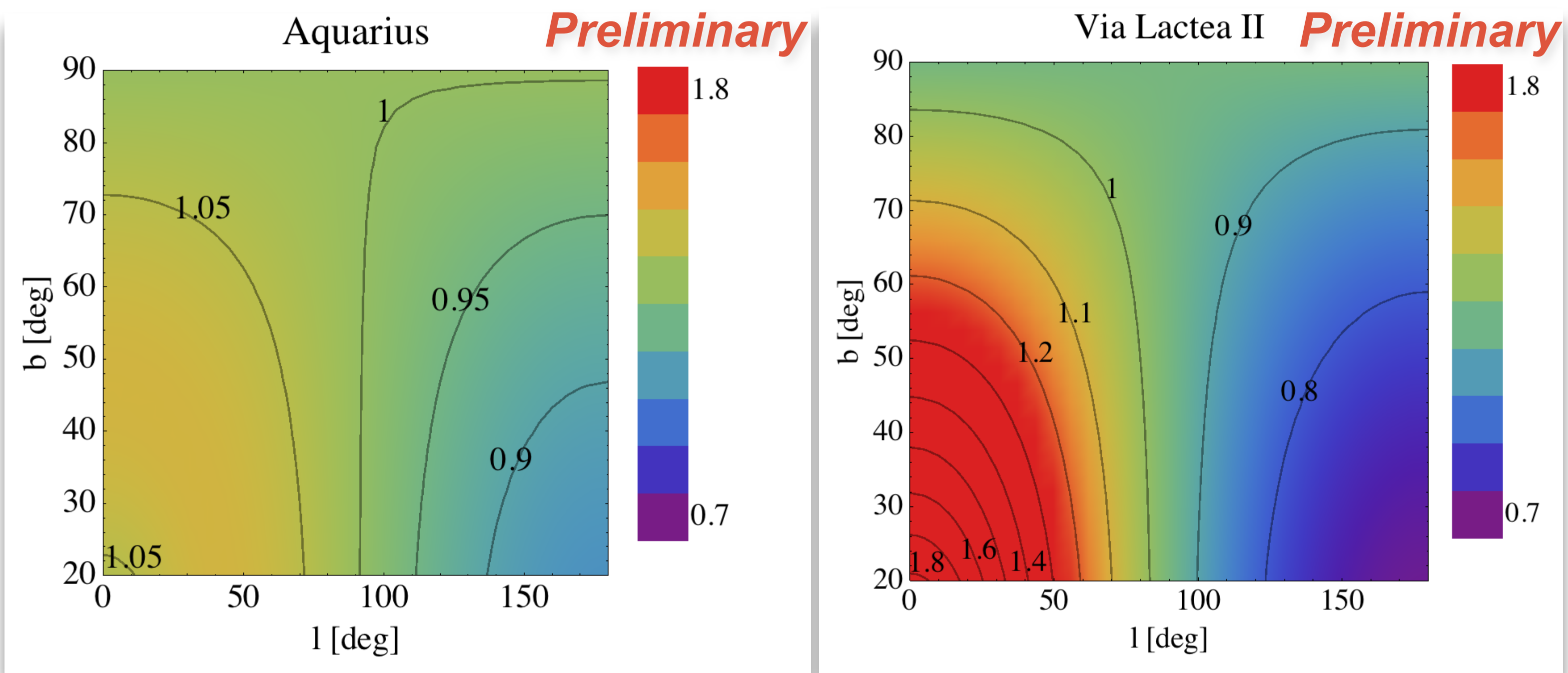

depending on the simulation Galactic substructure is expected to be isotropic at the level of ~10% to 20(80)%. We include it in our isotropic signal with two choices for the overall magnitude.

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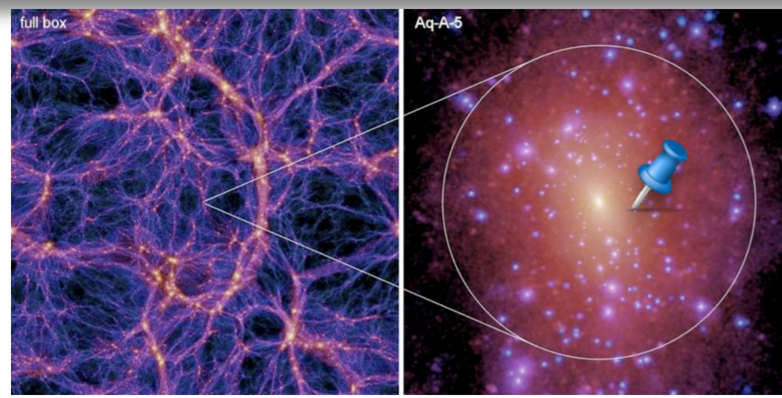
Isotropic DM flux

- **signal strength/recap:**

FLUX from extragalactic DM annihilation

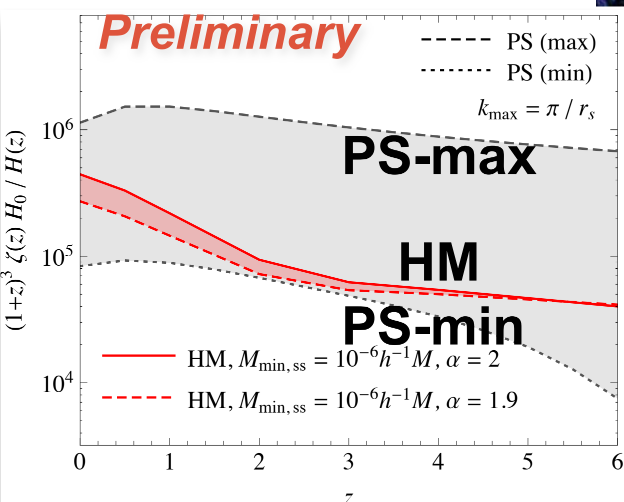
$$\frac{d\phi_\gamma}{dE_0} = \frac{\langle\sigma v\rangle}{8\pi}\frac{c}{H_0}\frac{\bar{\rho}_0^2}{m_{DM}^2}\int dz (1+z)^3 \frac{\Delta^2(z)}{h(z)} \frac{dN_\gamma(E_0(1+z))}{dE} e^{-\tau(z,E_0)}$$

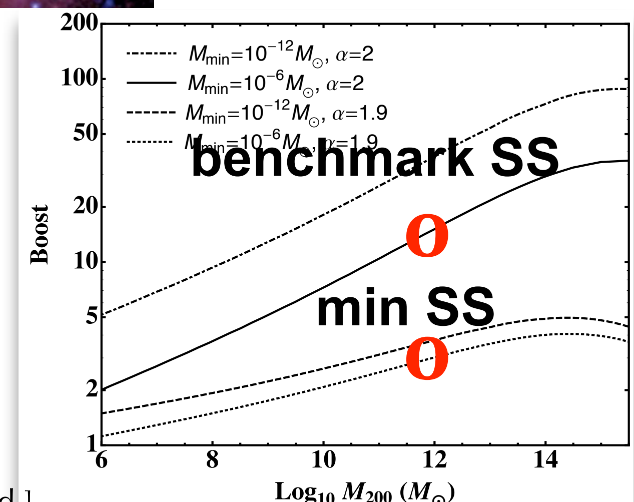
Cosmological signal (halos and subhalos): *benchmark* set by Halo Model, while the *uncertainty band* estimated in the Power Spectrum approach



[Springel, V.+, MNRAS, 2008.]

Galactic substructure: two assumptions used: *benchmark* and a '*MIN*' value.





[MASC&Prada, MNRAS accepted.]

– uncertainty in the signal translates to the uncertainty on constraints of DM cross section

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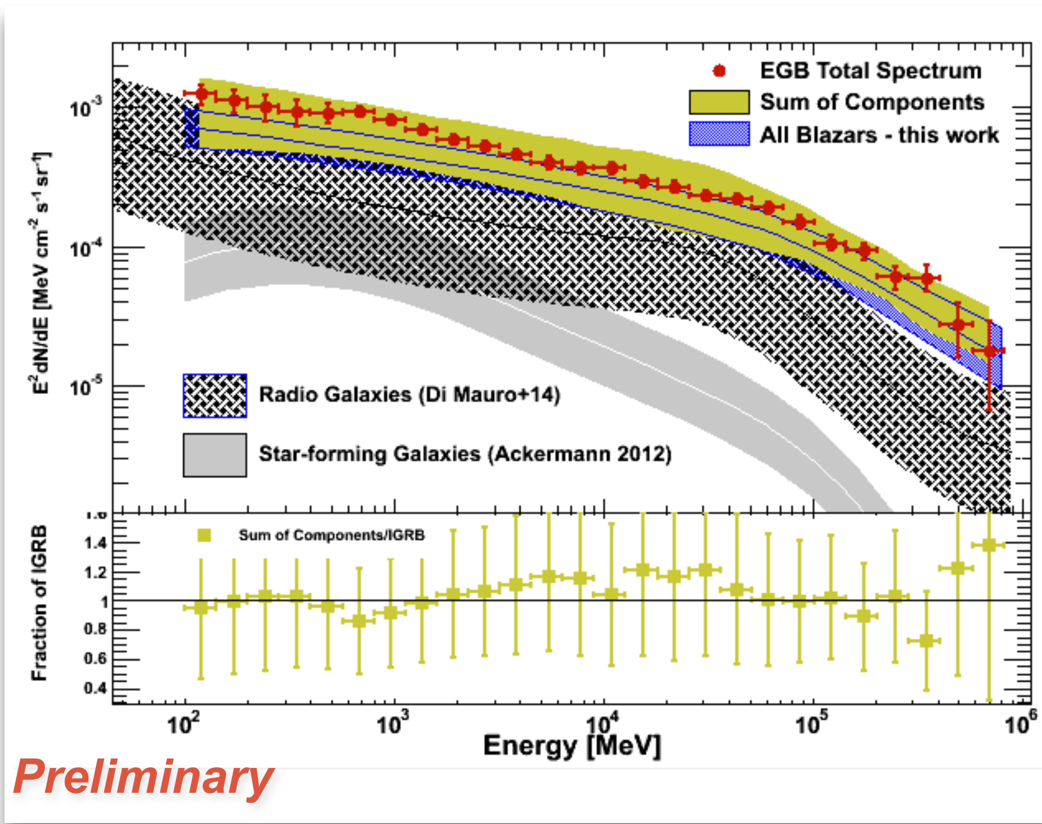
Astrophysical contributions to IGRB

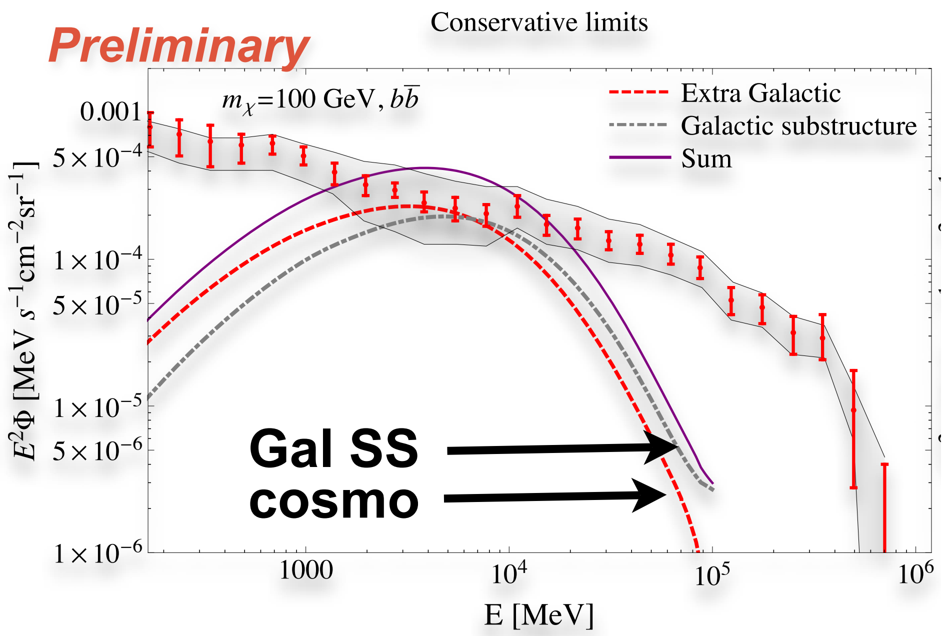
- ***Level of extra Galactic astro contributions active field, not yet settled.***
- ***Minimal*** **'guaranteed' isotropic astrophysical contribution is at the ~50 % level of the signal (Marco, Mattia, Keith, Brian(s), ...)**
- **sets our *strategy* to setting the limits: conservative and optimistic.**

M. Ajello's talk



Approach to setting the limits

- in this work two types of limits: conservative and optimistic.
- the 'true' limits in-between



DM signal does not overshoot the upper edge of the systematics band. CL set by considering the error-bar on the model A (stat+part syst).

No other isotropic contribution to the signal assumed.

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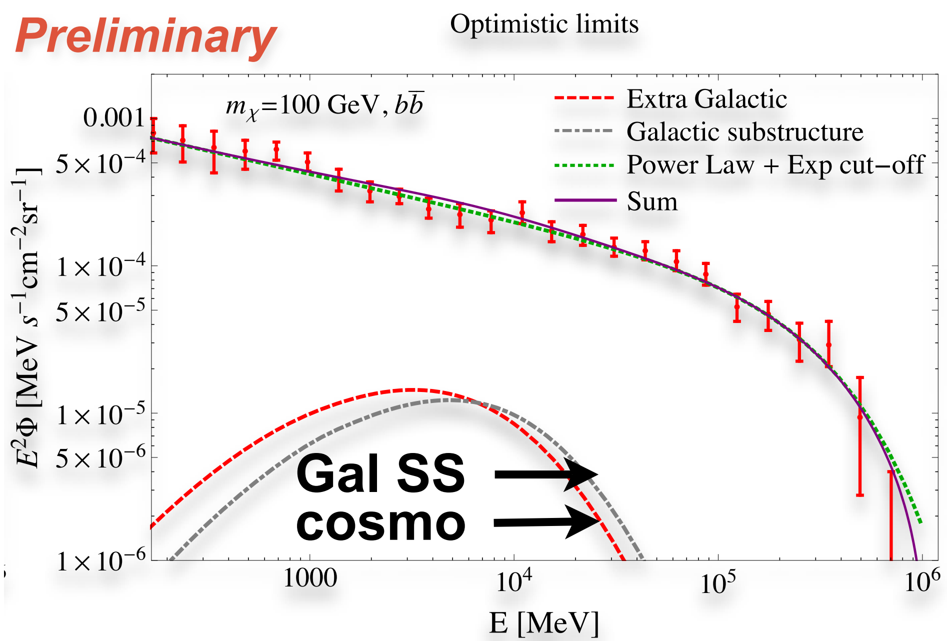
We fit the data with a PL + EXP cut-off, and set limits at the amount to DM which worsens the overall chi2 by 4 (for 2 sigma limits).



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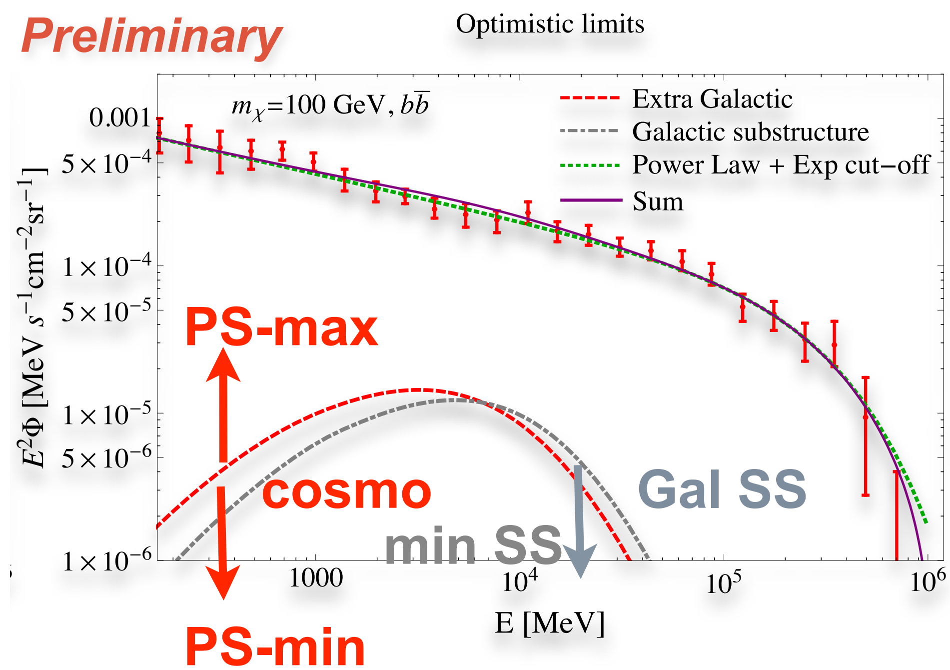
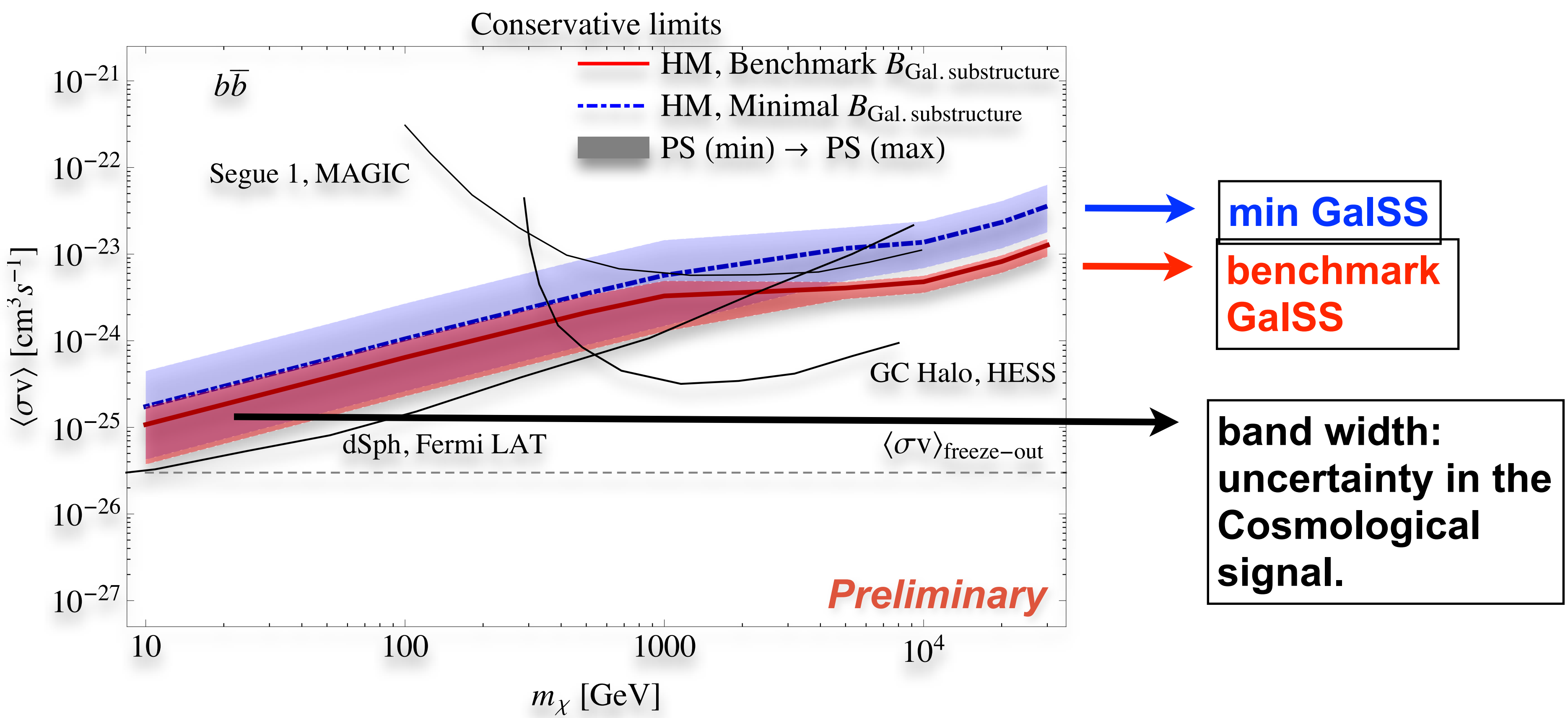


Note: for benchmark parameters Galactic and cosmological signals comparable. At high energies Gal SS dominates (EBL and red-shifting).

Limits

- Limits on the *isotropic* signal (Cosmological and Galactic substructure)



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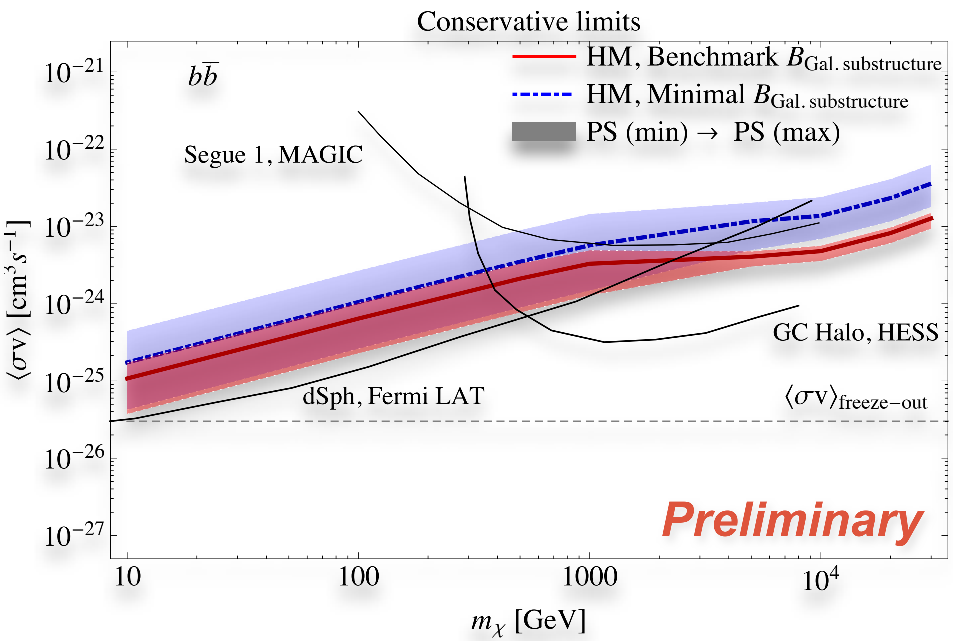

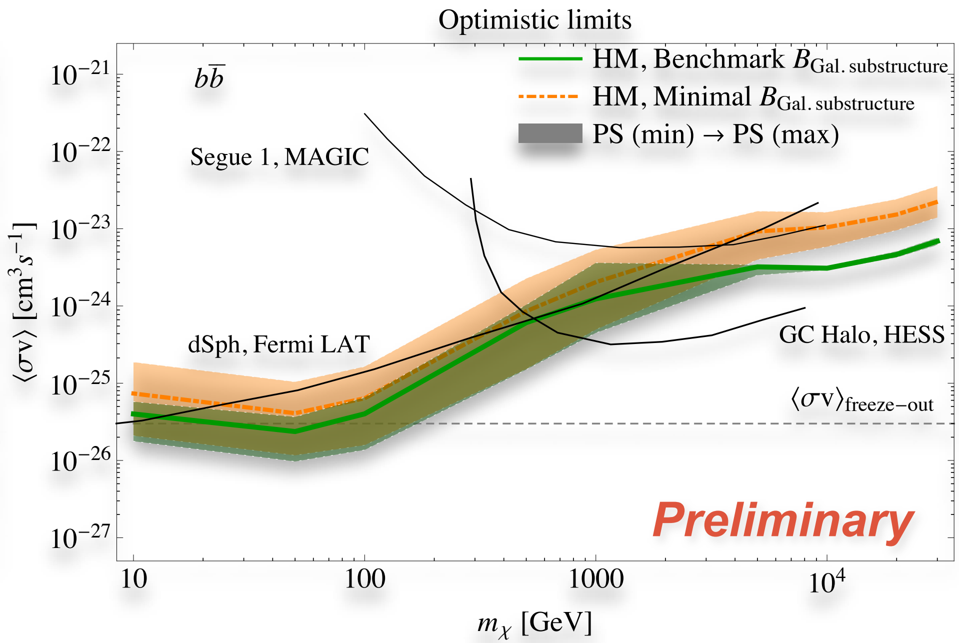

- **The strongest Fermi LAT limits in the >~5 TeV range.**
- **The uncertainty band becomes narrower at higher DM masses, as the DM signal becomes dominated by the Galactic SS.**
- **Good sensitivity to WIMPs in the 10-100 GeV range - potentially might offer a possibility to check the signal detected elsewhere.**

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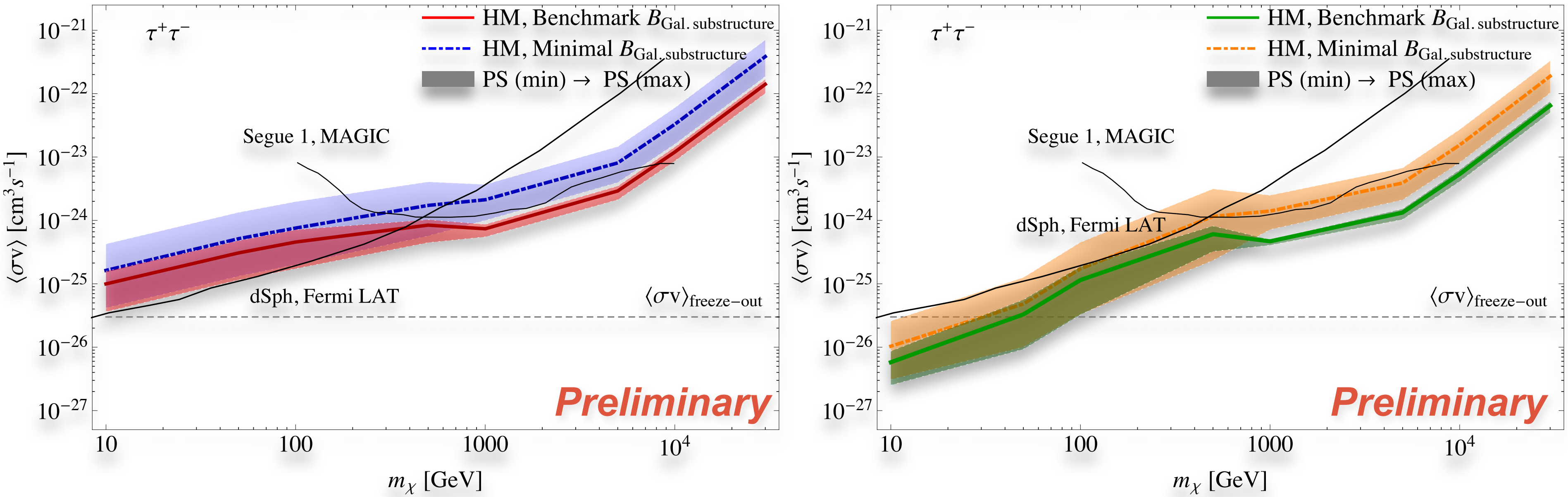

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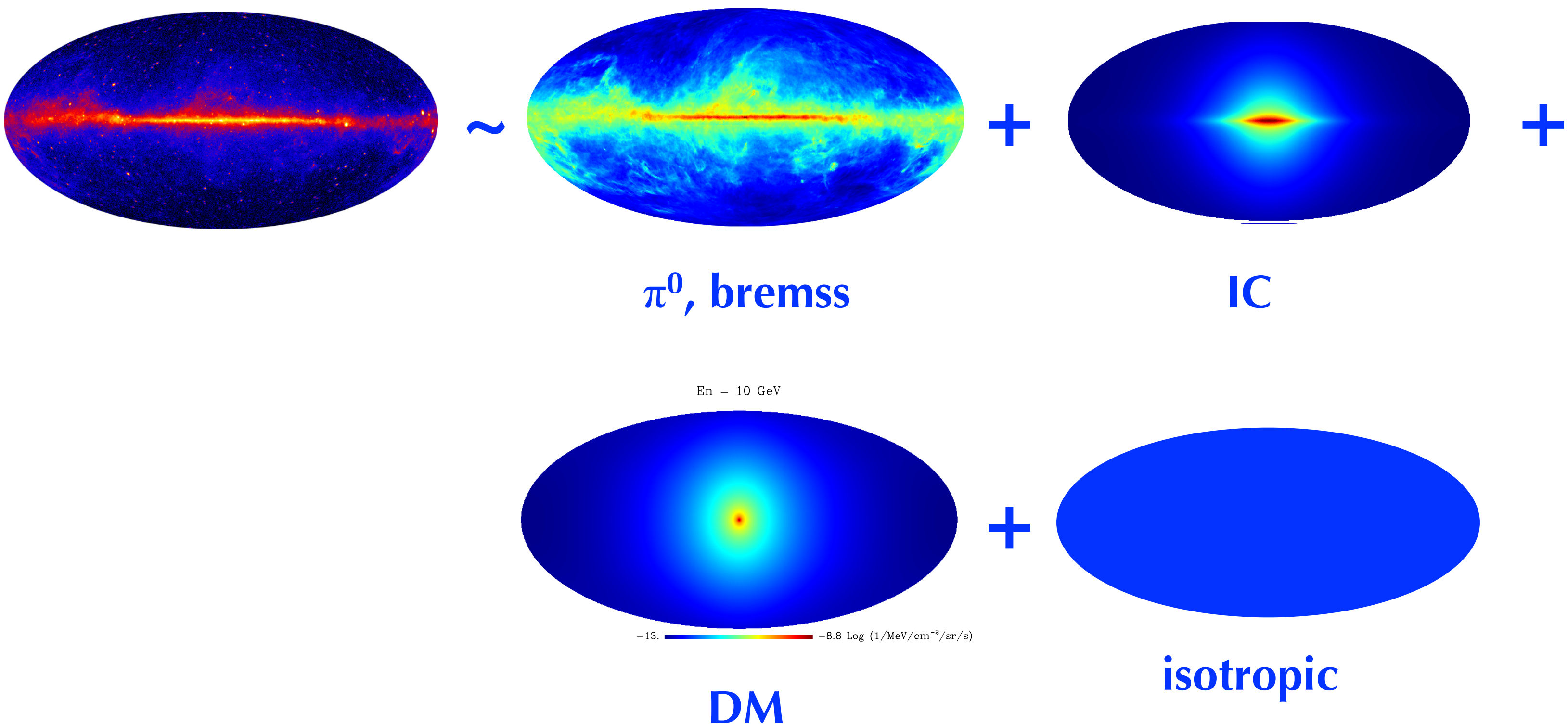
Corresponding Galactic smooth DM component

- **Non isotropic components - smooth DM halo**
  - **degenerate in part with the Galactic diffuse emission**
    - **we explored at what level the DM Galactic smooth counterpart of the isotropic signal impacts the derivation of the IGRB spectrum**



We repeated the original fits used to the derive the IGRB, but this time adding DM galactic template (for which *minimal* Galactic DM content is assumed).

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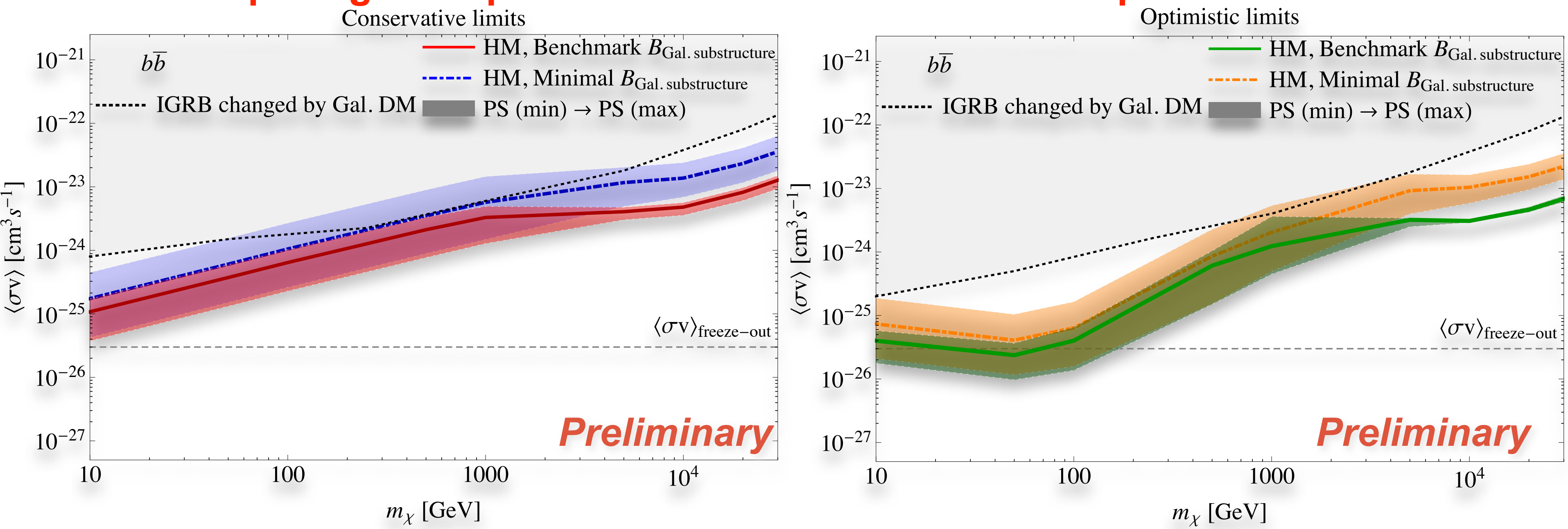

For the cross sections in the gray region DM Galactic smooth signal would significantly alter the IGRB spectrum: 2σ from its syst band (left) or 2σ departure wrt to the IGRB error-bars (right). For most of the exclusion band our procedure is self consistent.

The DM limits in the intersection region are conservative, as IGRB gets lower in the presence of the Galactic smooth component.

Summary

- Derived limits on cosmological DM annihilation using the new IGRB measurement in the 100 MeV- 820 GeV range.
- The strongest LAT limits >5 TeV range and competitive in the 10-100 GeV range.
- Improves upon older LAT work in the following respects:
  - theoretical uncertainty on the DM cosmological clustering *significantly lowered* due to the new way of estimation (power spectrum approach) and advances within the halo model.
  - defined a region in the cross section vs mass range for which the Galactic smooth DM component does not alter the IGRB measurement and the approach applied here is self-consistent.
- Next: account for astrophysical isotropic emission.