Search for heavy dark matter with Fermi LAT

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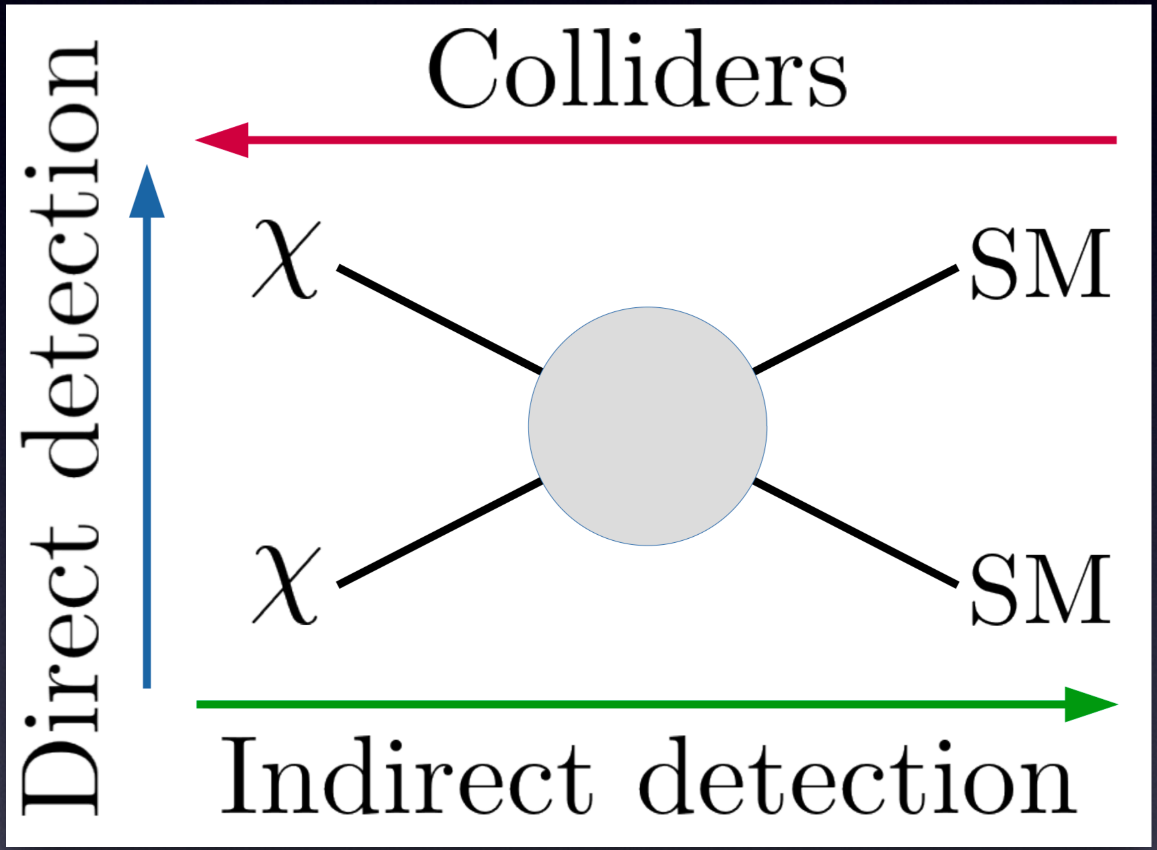
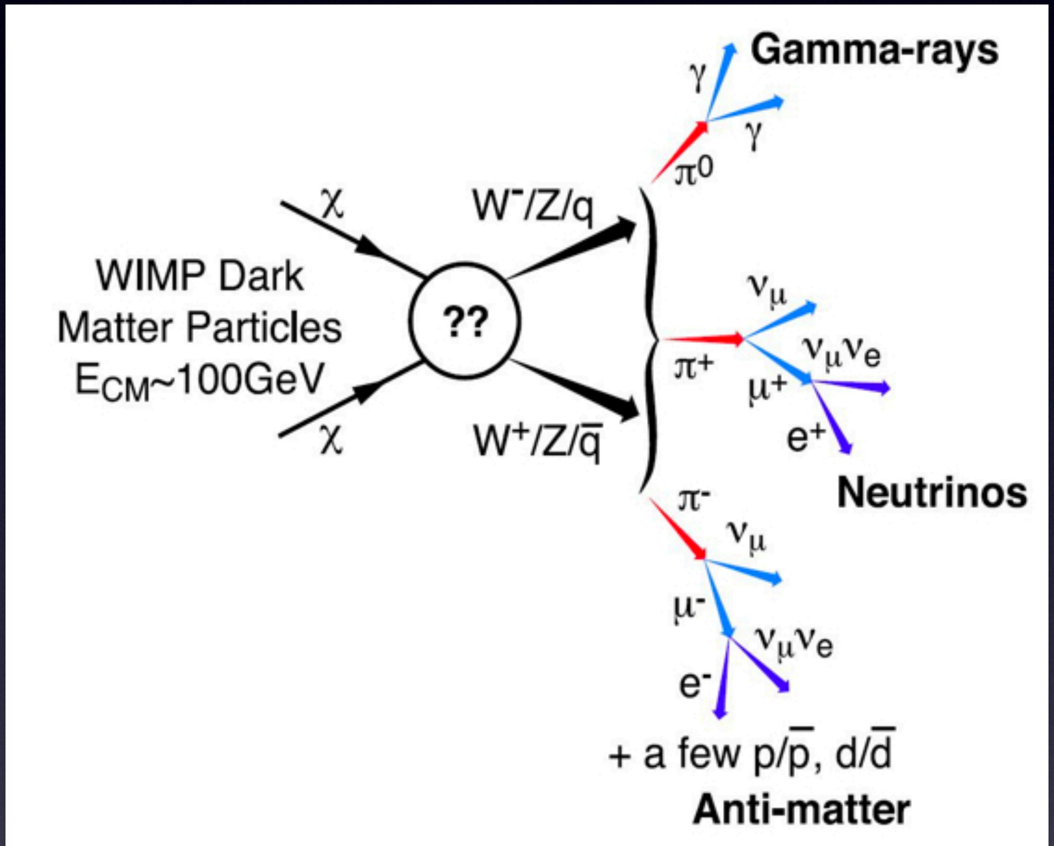
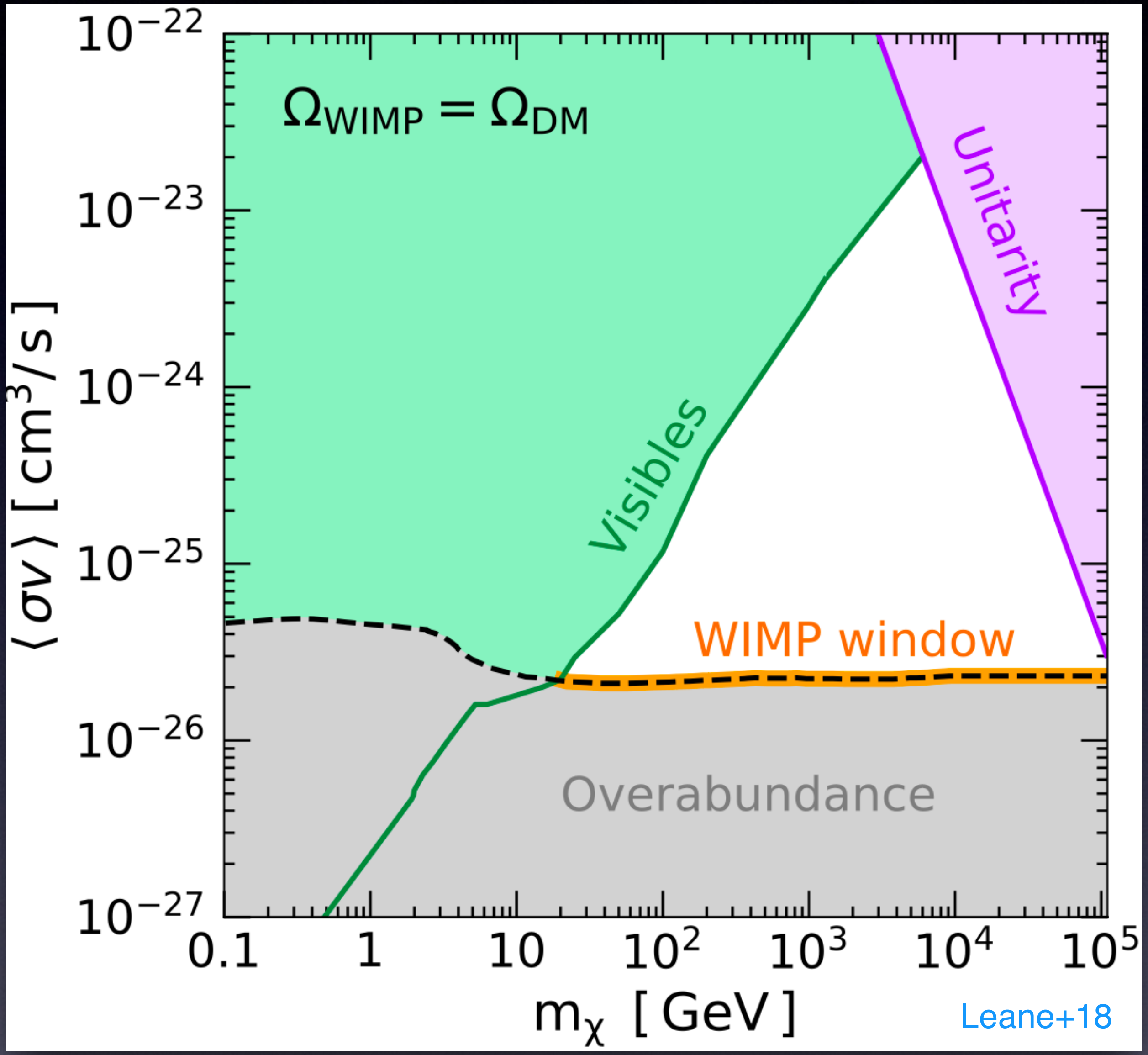
Indirect detection





$$\Phi(E_\gamma, \Omega) = \frac{1}{4\pi}\left(\frac{dN_\gamma}{dE_\gamma}\right) \times \begin{cases} \frac{\langle \sigma v \rangle}{2m_{\rm DM}^2} \int_0^\infty dr \rho(\vec{r})^2 & \text{annihilation} \\ \frac{1}{m_{\rm DM}\tau} \int_0^\infty dr \rho(\vec{r}) & \text{decay} \end{cases}$$

WIMP window

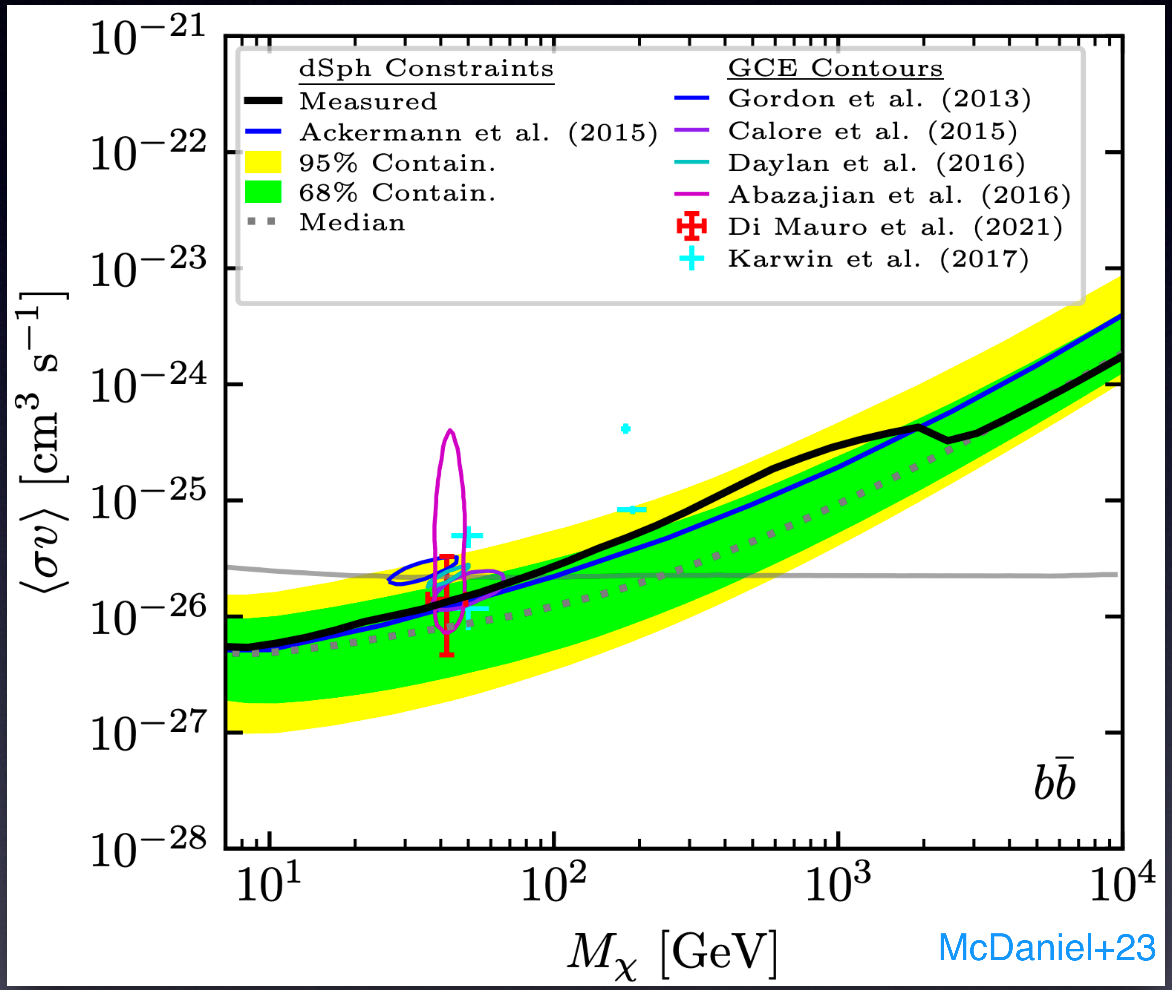


WIMP is not (yet) ruled out

Window is getting smaller

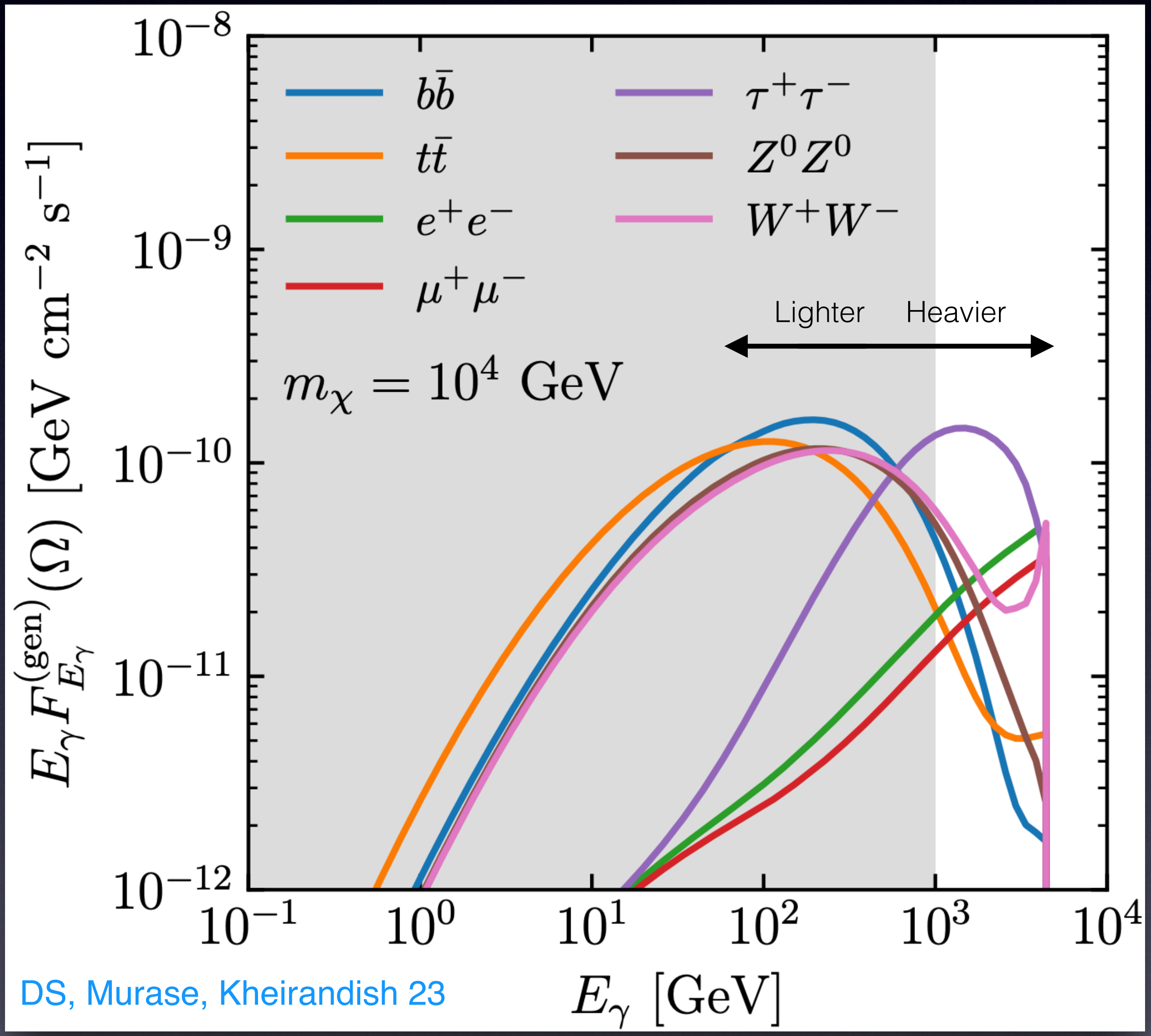
Fermi LAT search for WIMP

- LAT is a pivotal tool to search for WIMP
- Recent stacking analysis of dwarfs are ruling out thermal WIMP parameter space

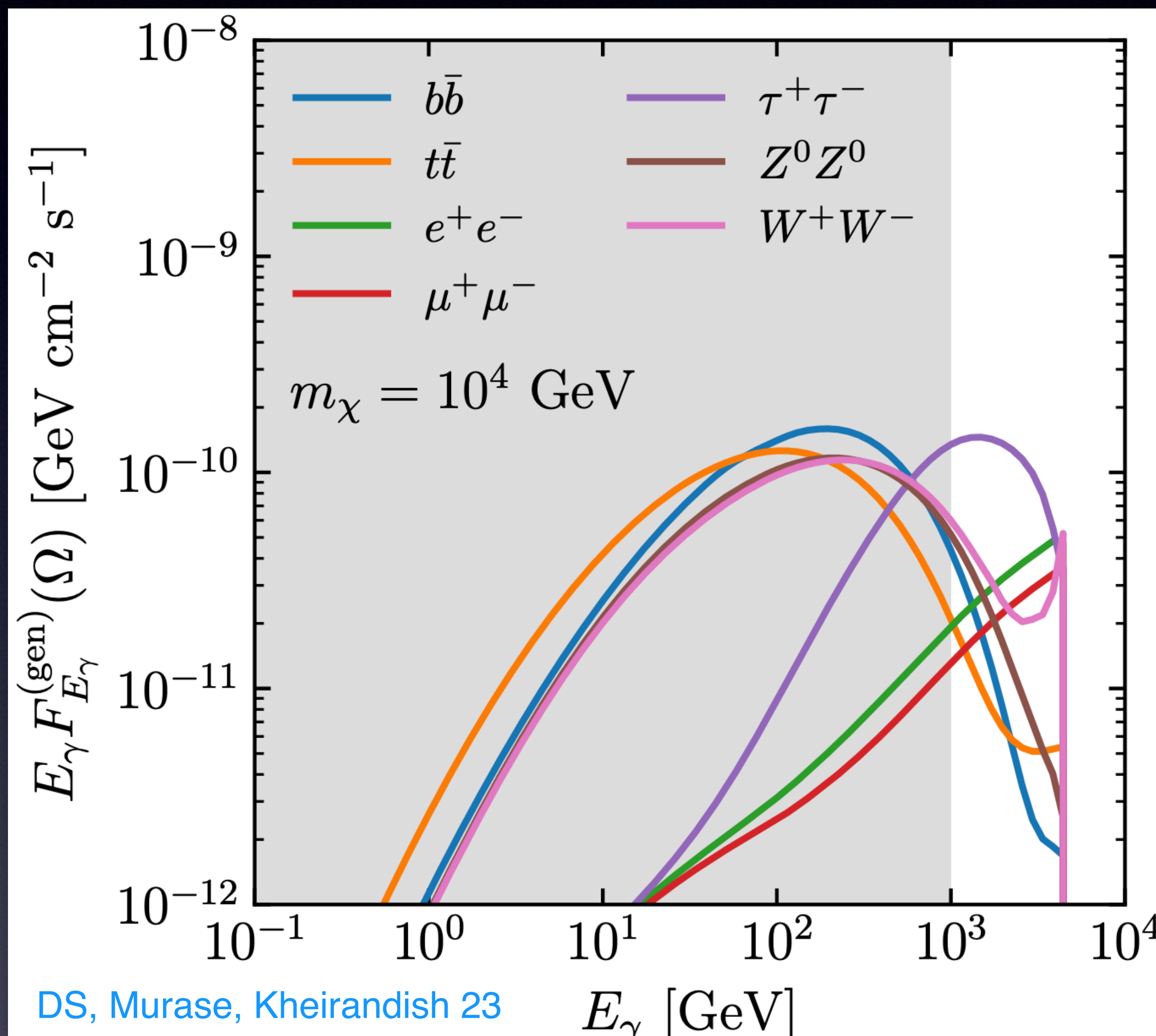


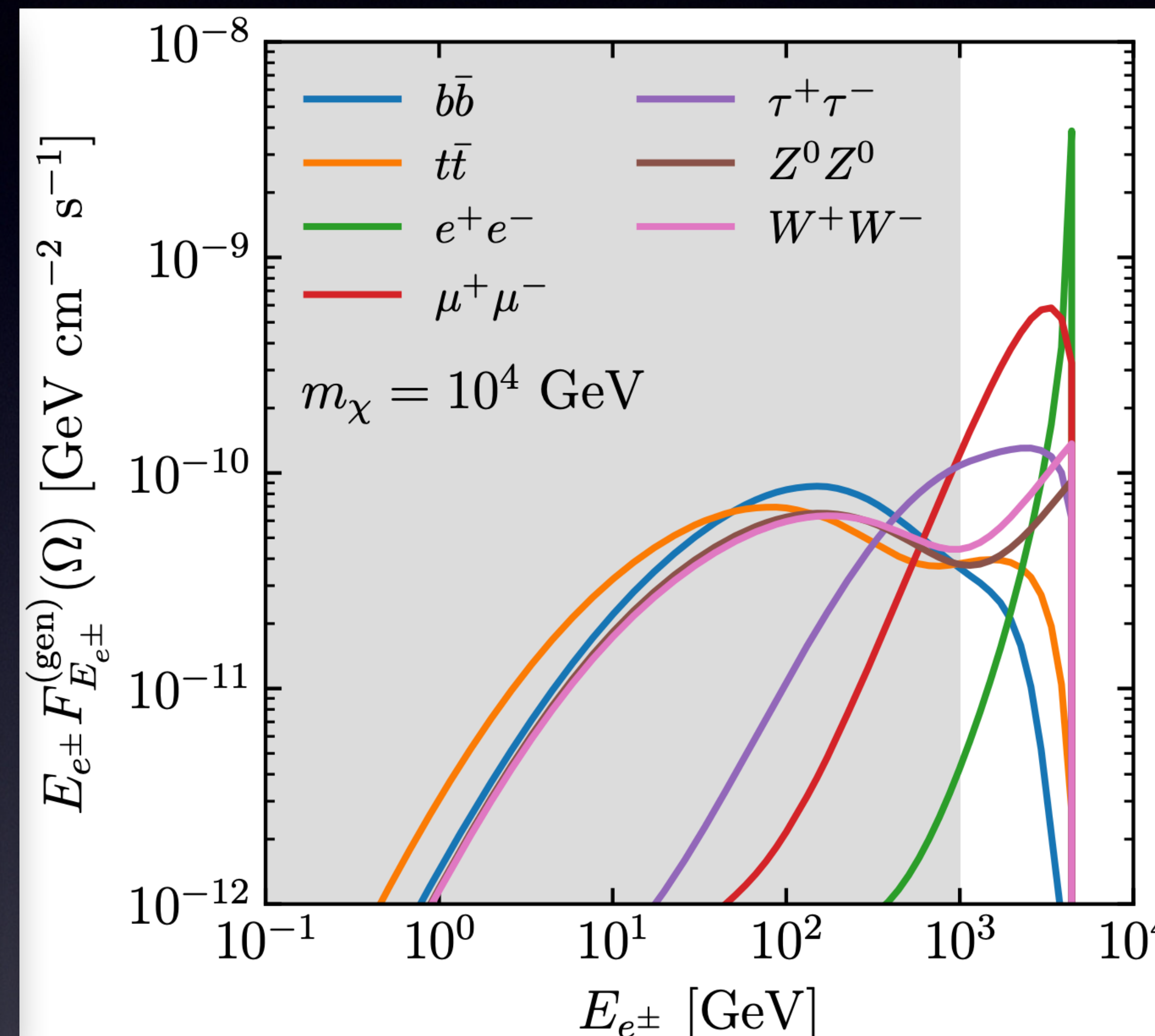
Fermi LAT search for WIMP

- LAT is a pivotal tool to search for WIMP
- Beyond WIMP mass range, LAT sensitivity decreases



Heavy DM also generates high-energy e+/e-





- High-energy e+/e- from DM are often ignored in conventional gamma-ray analysis

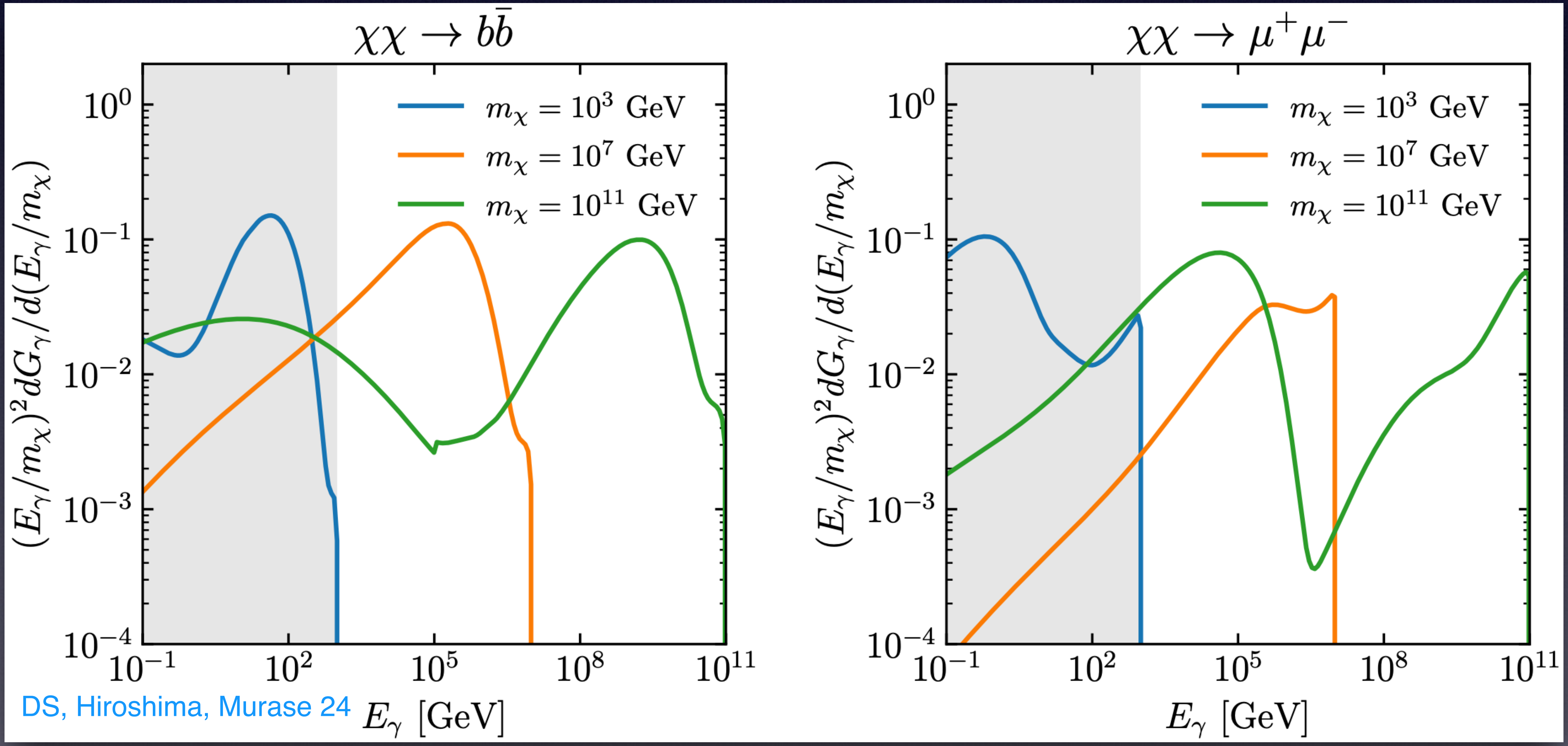
Secondary emissions from HDM e+/e-

- High-energy e+/e- from HDM loss energies (via IC, synchrotron) in the interstellar environment (CMB, IR radiation, B-field etc.)
- Solving the Boltzmann equations

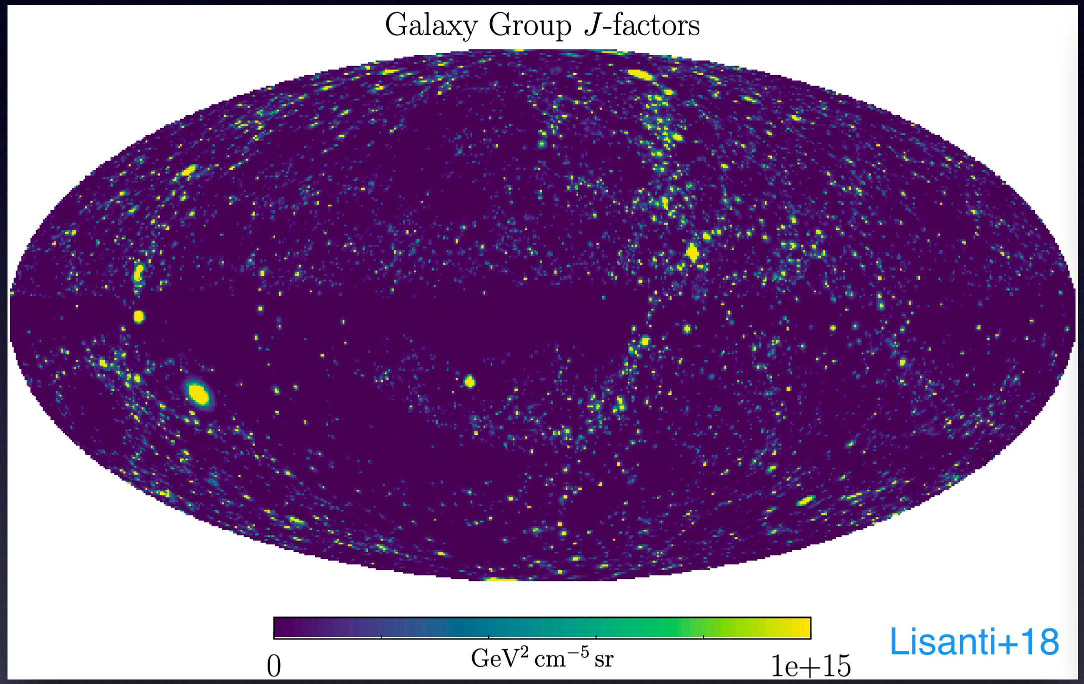
$$
\begin{aligned}
\frac{\partial N_\gamma(E_\gamma)}{\partial t} =& - N_\gamma \int d\varepsilon \frac{dn}{d\varepsilon} \int \frac{d\mu}{2}(1-\mu) c \sigma_{\gamma\gamma}(\varepsilon,\mu) - \frac{N_\gamma}{t_{\mathrm{esc}}} \\
&+ \int dE' N_e\left(E'\right) \int d\varepsilon \frac{dn}{d\varepsilon} \int \frac{d\mu}{2}(1-\mu) c \frac{d\sigma_{\mathrm{IC}}}{dE_\gamma}\left(\varepsilon,\mu,E'\right) \\
&+ \frac{\partial N_\gamma^{\mathrm{syn}}}{\partial t} + Q_\gamma^{\mathrm{inj}}, \\
\frac{\partial N_e(E_e)}{\partial t} =& - N_e \int d\varepsilon \frac{dn}{d\varepsilon} \int \frac{d\mu}{2}(1-\mu) c \sigma_{\mathrm{IC}}(\varepsilon,\mu) \\
&+ \int dE' N_\gamma\left(E'\right) \int d\varepsilon \frac{dn}{d\varepsilon} \int \frac{d\mu}{2}(1-\mu) c \frac{d\sigma_{\gamma\gamma}}{dE_e}\left(\varepsilon,\mu,E'\right) \\
&+ \int dE' N_e\left(E'\right) \int d\varepsilon \frac{dn}{d\varepsilon} \int \frac{d\mu}{2}(1-\mu) c \frac{d\sigma_{\mathrm{IC}}}{dE_e}\left(\varepsilon,\mu,E'\right) \\
&- \frac{\partial}{\partial E}\left[P_{\mathrm{syn}} N_e\right] + Q_e^{\mathrm{inj}}.
\end{aligned}
$$

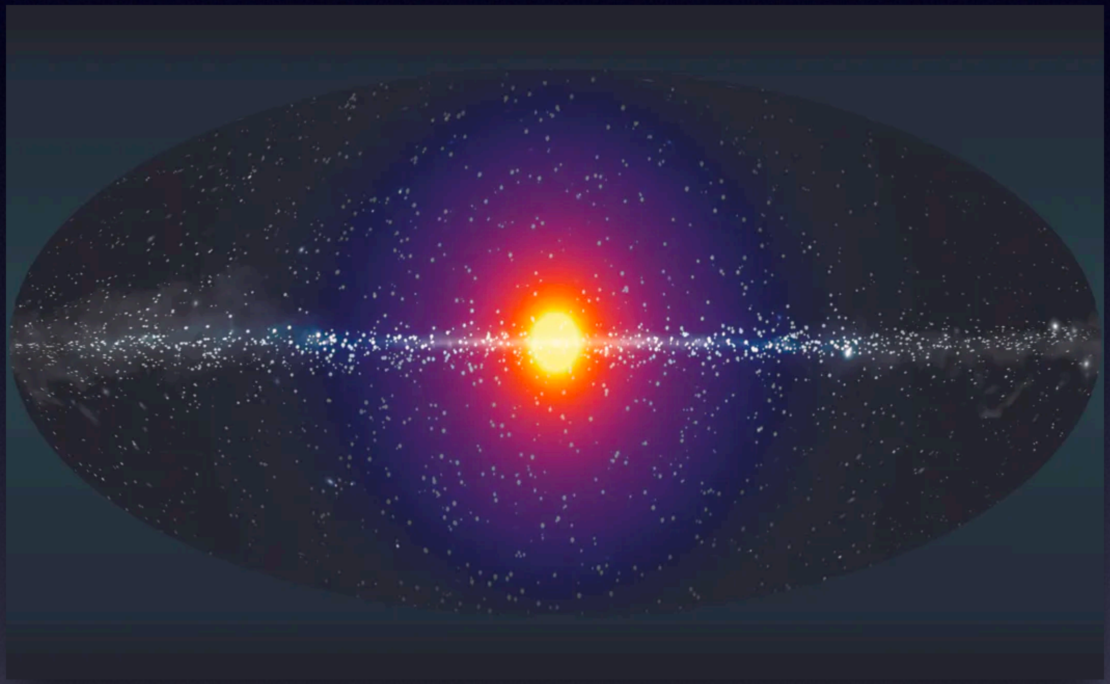
Secondary emissions from HDM e+/e-

- Resulting spectra including inverse Compton/synchrotron radiations could be probed by Fermi LAT
- Dwarf galaxies (Draco):



Where to search for HDM in the gamma-ray sky?



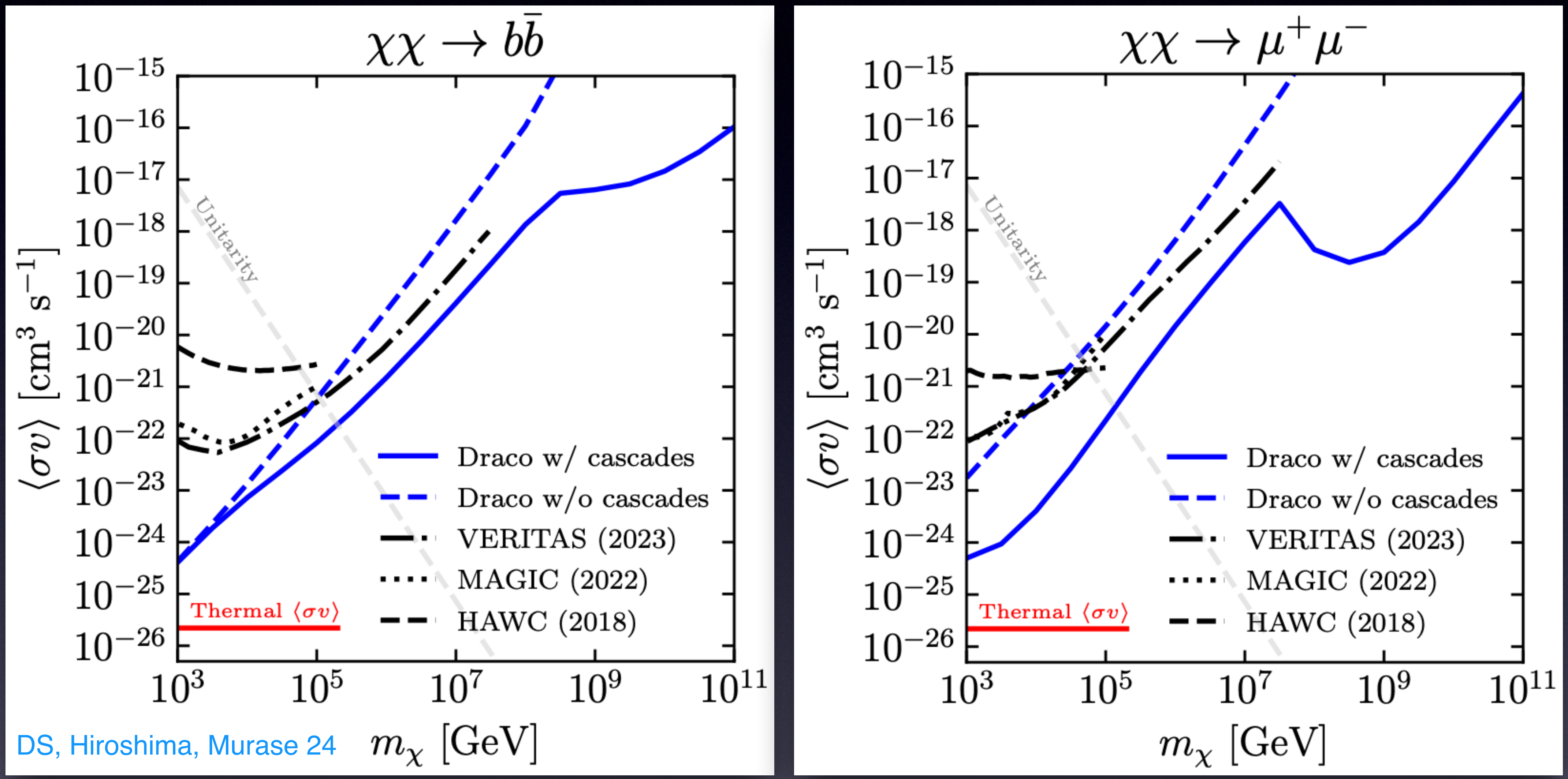


- Nearby halos/subhalos (Dwarf galaxies, galaxy clusters etc.)
- Milky Way halo

Search for HDM in galaxy clusters/dwarf galaxies

- Galaxy clusters [with Kohta Murase, Ali Kheirandish]
  - arXiv:2308.00589 (accepted by JCAP)
- Dwarf galaxies [with Nagisa Hiroshima, Kohta Murase]
  - arXiv:2401.15606 (Fermi interally reviewed, Category II.5 paper)
  - Connected with C02 group

Limits from Draco

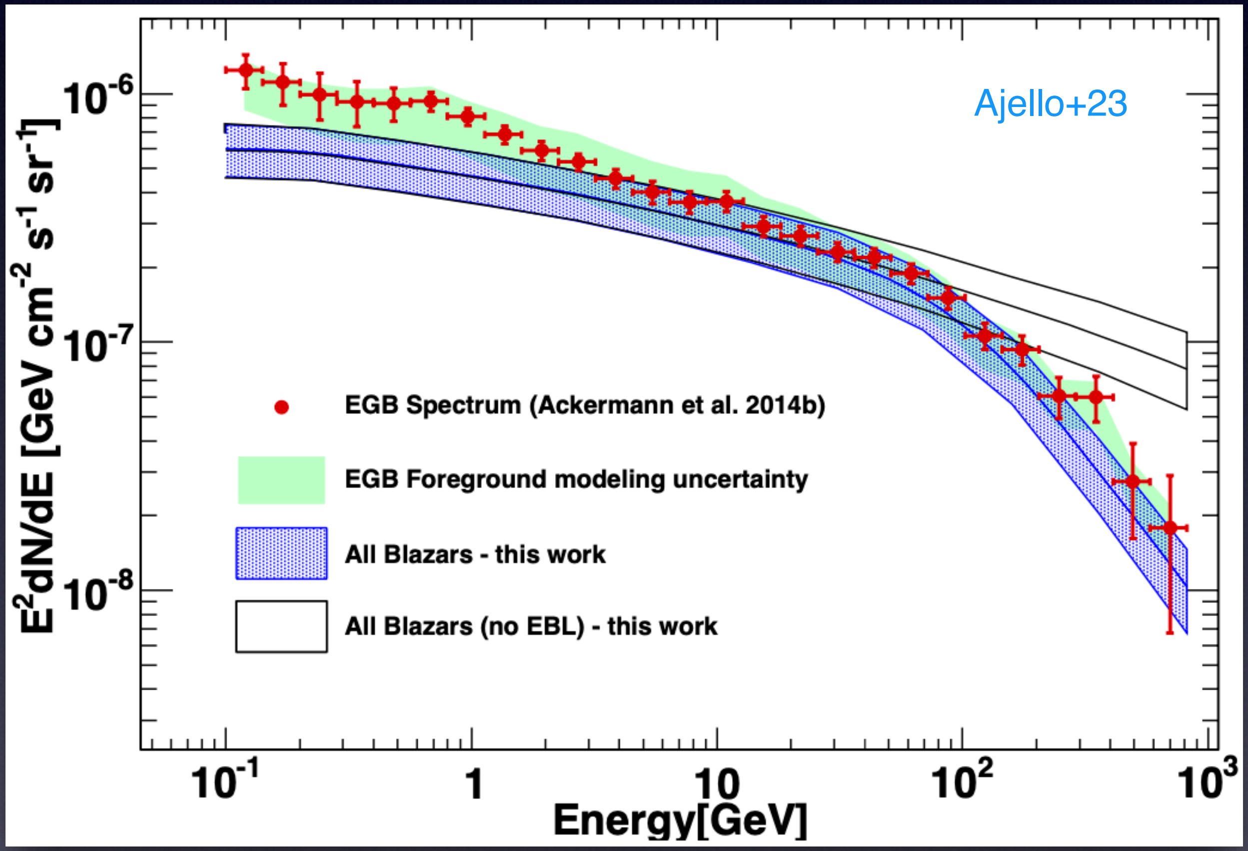


- Competitive limits compared with other high-energy instruments

[See papers for complete limits and systematic uncertainties]

Analysing the MW halo

- Blazars account for ~50% of the EGB photons > 0.1 GeV [Ajello+23]
- Subtract Blazar contribution to obtain stronger limits
  - $\Phi^{\rm EG} \leq \Phi^{\rm iso} - \Phi^{\rm Blazar}$



Summary

- Fermi LAT has been a pivotal tool in the search for WIMP due to its exceptional sensitivity in the GeV energy range.
- By searching for secondary emissions caused by dark matter e+/e-, we can extend the scope of LAT's dark matter search to include more massive candidates.
- We have set competitive constraints on heavy dark matter annihilation/decay using Fermi observation on galaxy clusters and dwarf galaxies.
- Dedicated analysis on the Milky Way halo is on-going.

Thank you!