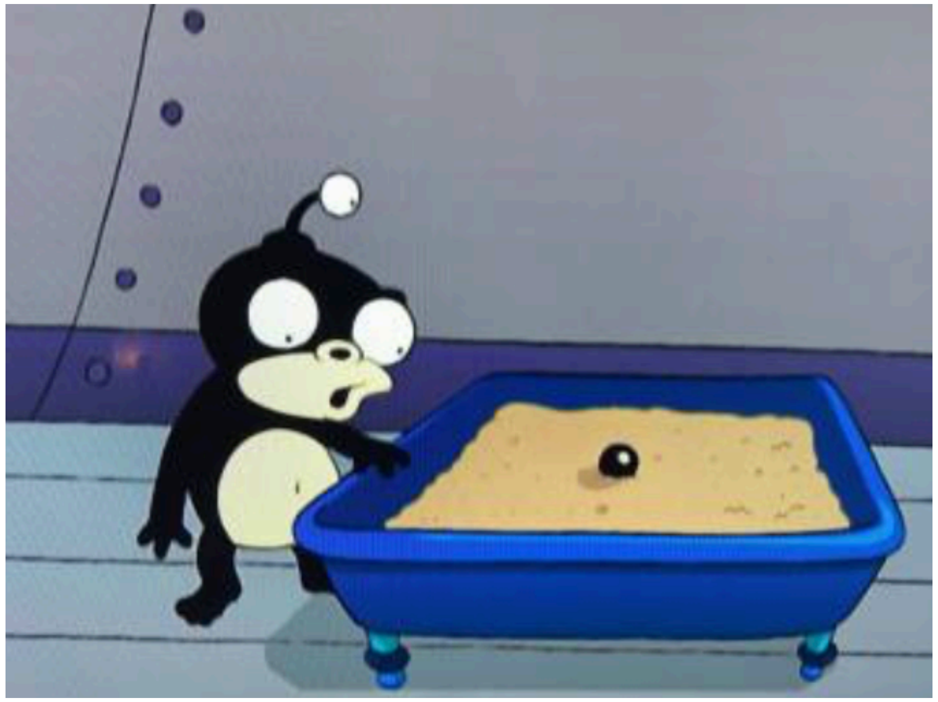
Dark matter signals from the Galactic Halo



Aion Viana, Harm Schoorlemmer, Jim Hinton, Vitor de Souza

MAX-PLANCK-INSTITUT
FÜR KERNPHYSIK
HEIDELBERG

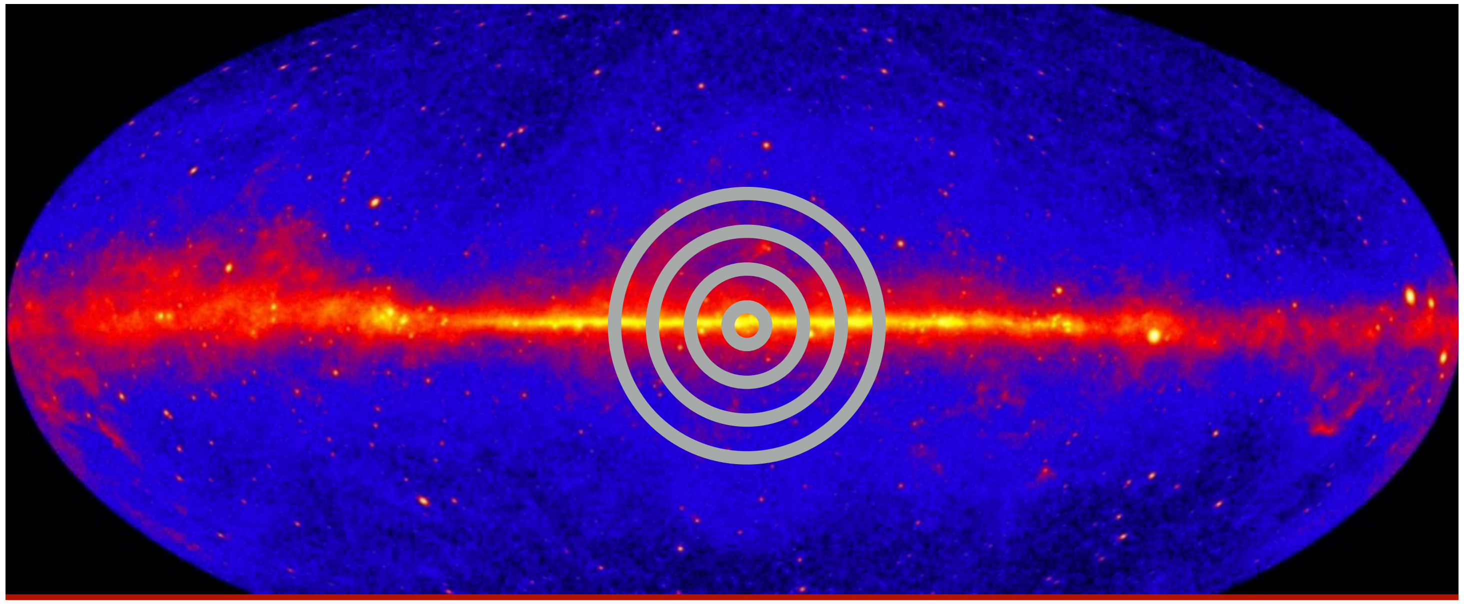
MAX-PLANCK-GESELLSCHAFT

A short author list paper, building upon the white paper and the Astro2020 papers

Contents

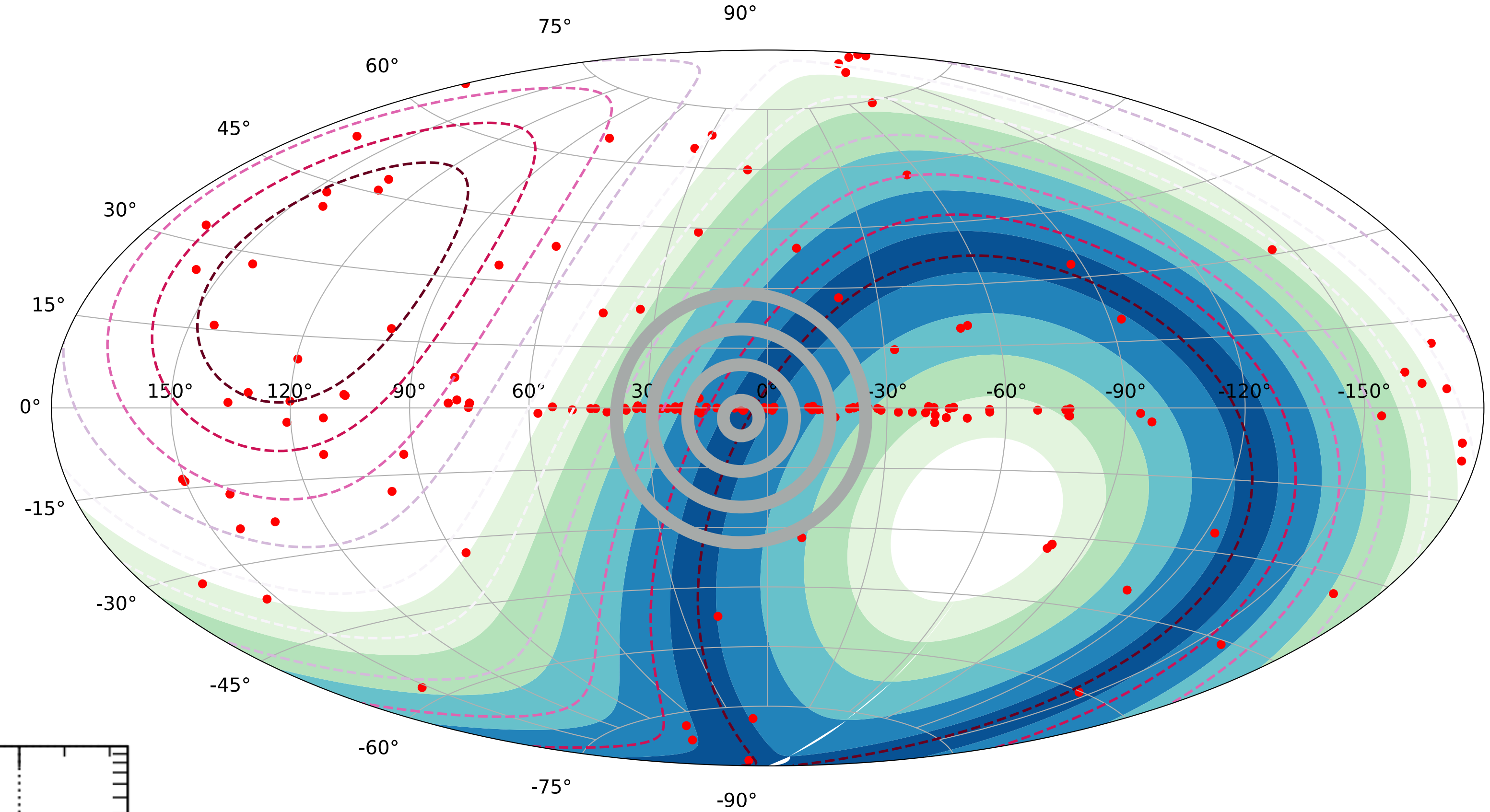
Why look for dark matter in the Galactic Centre?

- Relatively close
- Very massive
- Gamma-ray foreground to deal with
  - Might be less an issue at higher energy

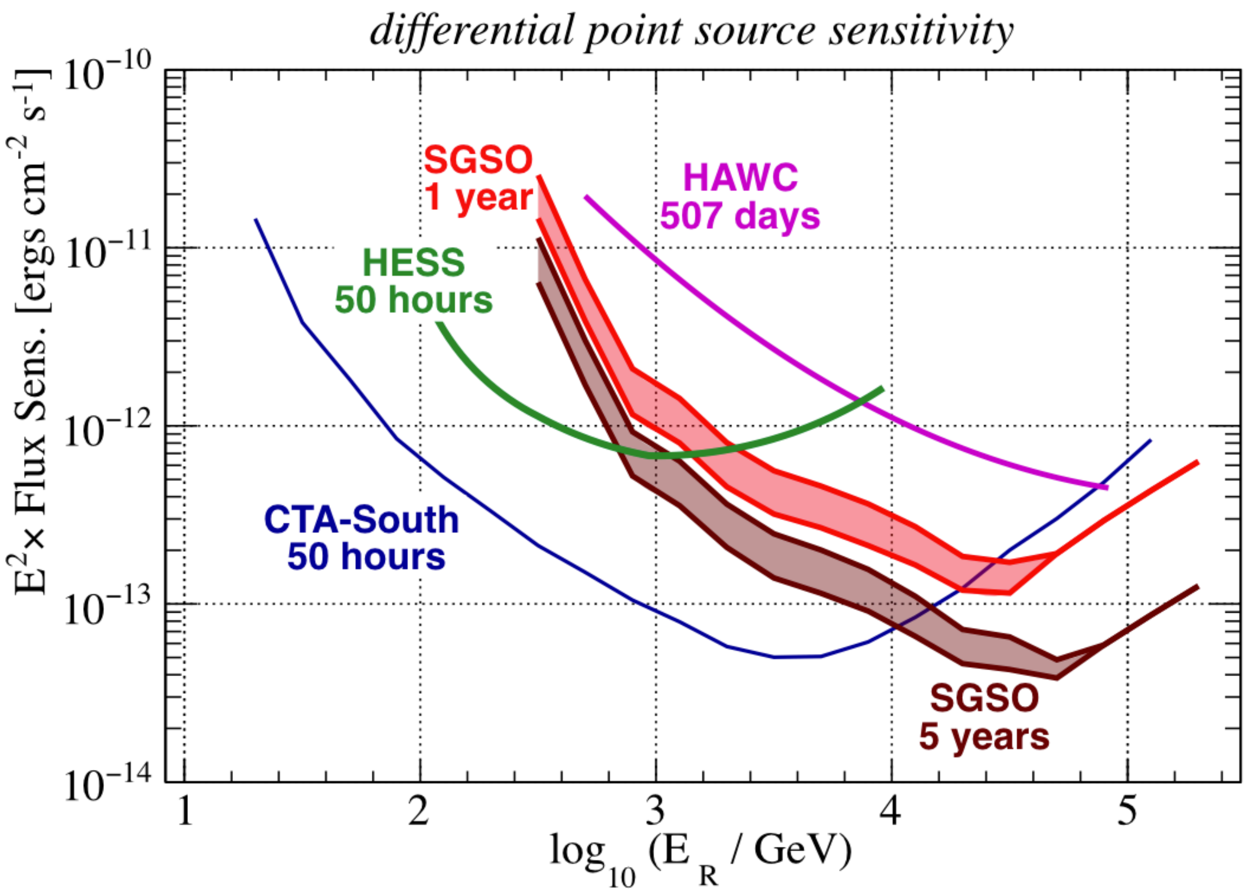


Why look with "SGSO"?

Right hemisphere!

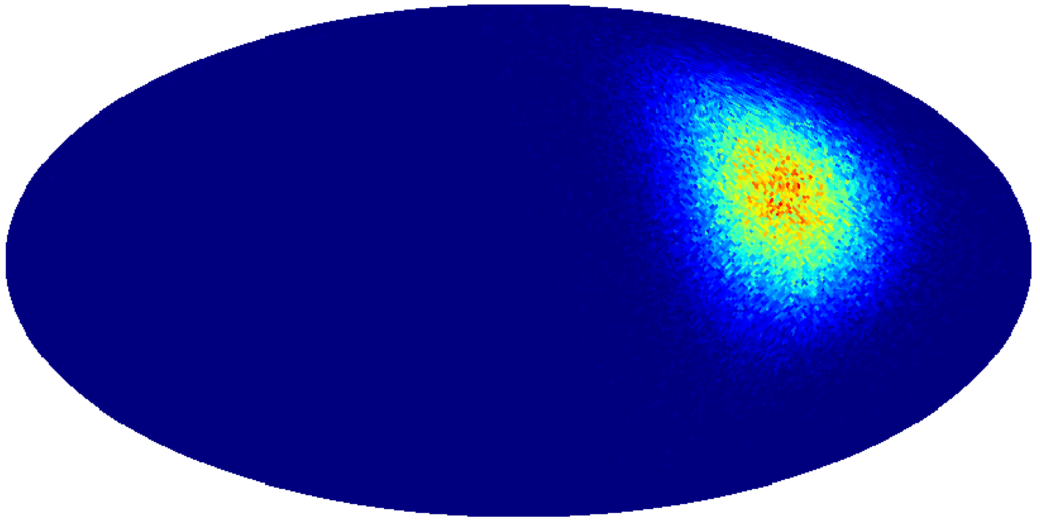


High Energy Reach!*



* if we make it big enough

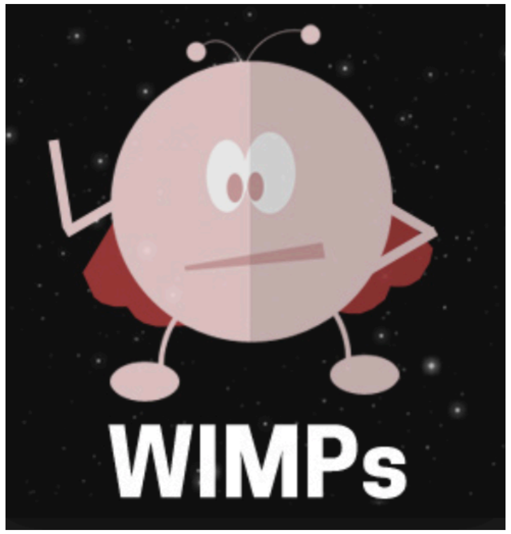
Excellent background determination**



** because of wide field-of-view

What are the signals we are looking for?

- Weakly Interacting Massive Particles
- TeV energy range
- Annihilation & decay



$$\frac{\mathrm{d}\Phi_{\mathrm{Ann}}(\Delta\Omega, E_\gamma)}{\mathrm{d}E_\gamma} = \left(\frac{1}{2}\frac{1}{4\pi}\frac{\langle\sigma v\rangle}{M_{\mathrm{DM}}^2}\frac{\mathrm{d}N}{\mathrm{d}E_\gamma}\right) \times (J(\Delta\Omega)) \ ,$$

$$\frac{\mathrm{d}\Phi_{\mathrm{Dec}}(\Delta\Omega, E_\gamma)}{\mathrm{d}E_\gamma} = \left(\frac{1}{4\pi}\frac{1}{\tau_{\mathrm{DM}} M_{\mathrm{DM}}}\frac{\mathrm{d}N}{\mathrm{d}E_\gamma}\right) \times (D(\Delta\Omega))$$

What are the signals we are looking for?

- Weakly Interacting Massive Particles
- TeV energy range
- Annihilation or decay

gamma-ray flux | particle physics | astro physics

$$\frac{\mathrm{d}\Phi_{\mathrm{Ann}}(\Delta\Omega, E_\gamma)}{\mathrm{d}E_\gamma} = \left(\frac{1}{2}\frac{1}{4\pi}\frac{\langle\sigma v\rangle}{M_{\mathrm{DM}}^2}\frac{\mathrm{d}N}{\mathrm{d}E_\gamma}\right) \times \left(J(\Delta\Omega)\right),$$

$$\frac{\mathrm{d}\Phi_{\mathrm{Dec}}(\Delta\Omega, E_\gamma)}{\mathrm{d}E_\gamma} = \left(\frac{1}{4\pi}\frac{1}{\tau_{\mathrm{DM}} M_{\mathrm{DM}}}\frac{\mathrm{d}N}{\mathrm{d}E_\gamma}\right) \times \left(D(\Delta\Omega)\right)$$

Dark matter density profiles

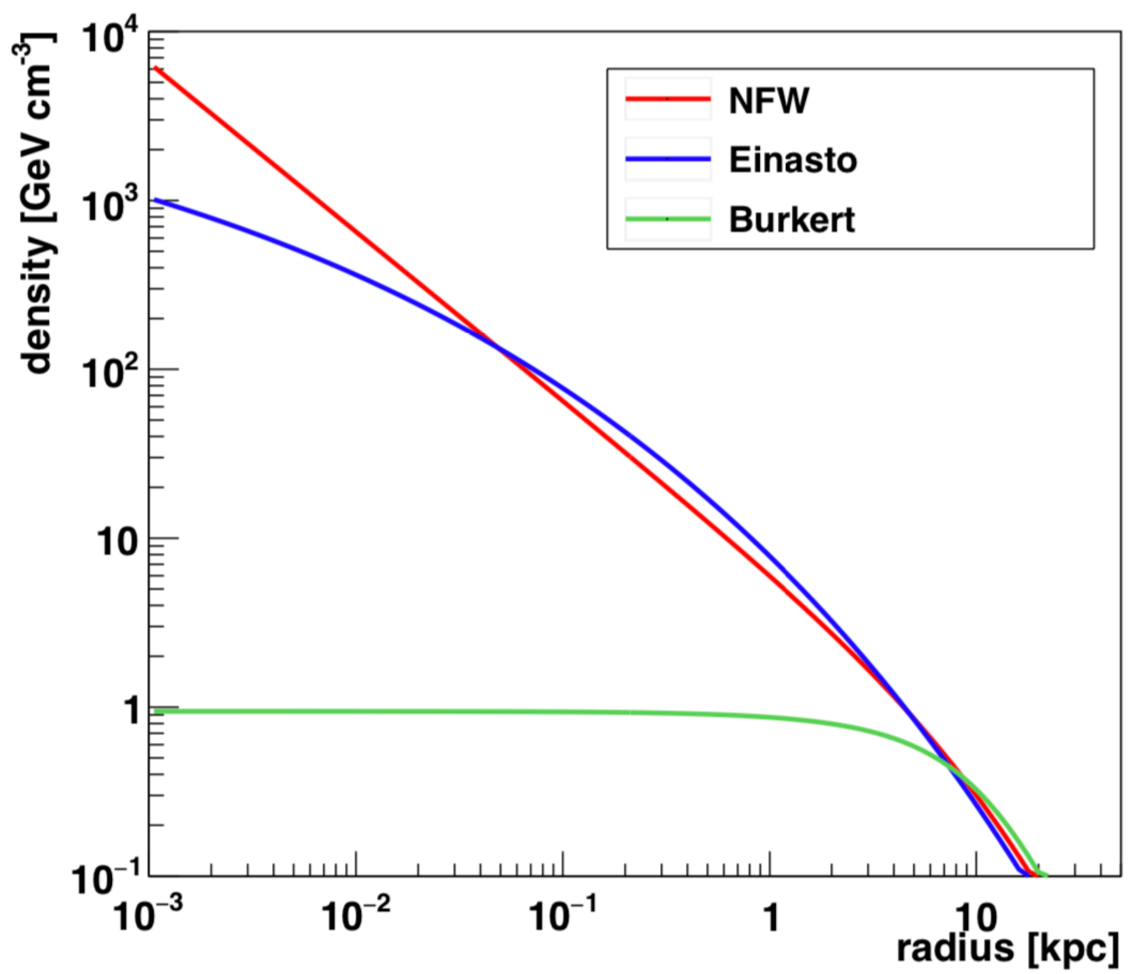
- Normalized to local dark matter density
- rc = 12.69 kpc
- rs = 20 kpc / α=0.17

$$J(\Delta\Omega) = \int_{\Delta\Omega} \int_{\mathrm{l.o.s.}} \mathrm{d}\Omega \, \mathrm{d}s \; \rho^2_{\mathrm{DM}}[r(s,\Omega)] \, ,$$

$$D(\Delta\Omega) = \int_{\Delta\Omega} \int_{\mathrm{l.o.s.}} \mathrm{d}\Omega \, \mathrm{d}s \; \rho_{\mathrm{DM}}[r(s,\Omega)] \, ,$$

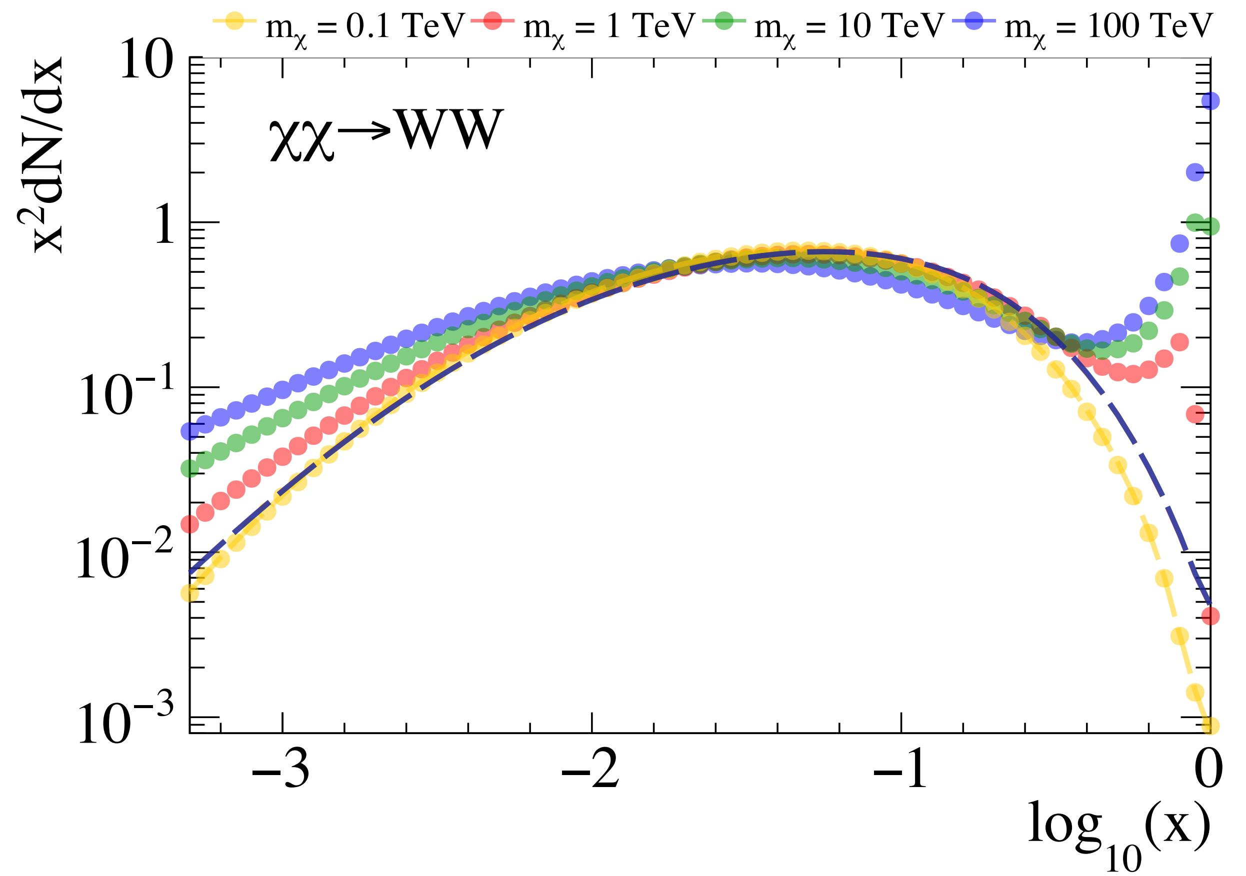
$$\rho_E(r) = \rho_0 \exp\left\{ \frac{-2}{\alpha} \left[\left(\frac{r}{r_s} \right)^{\alpha} - 1 \right] \right\}$$

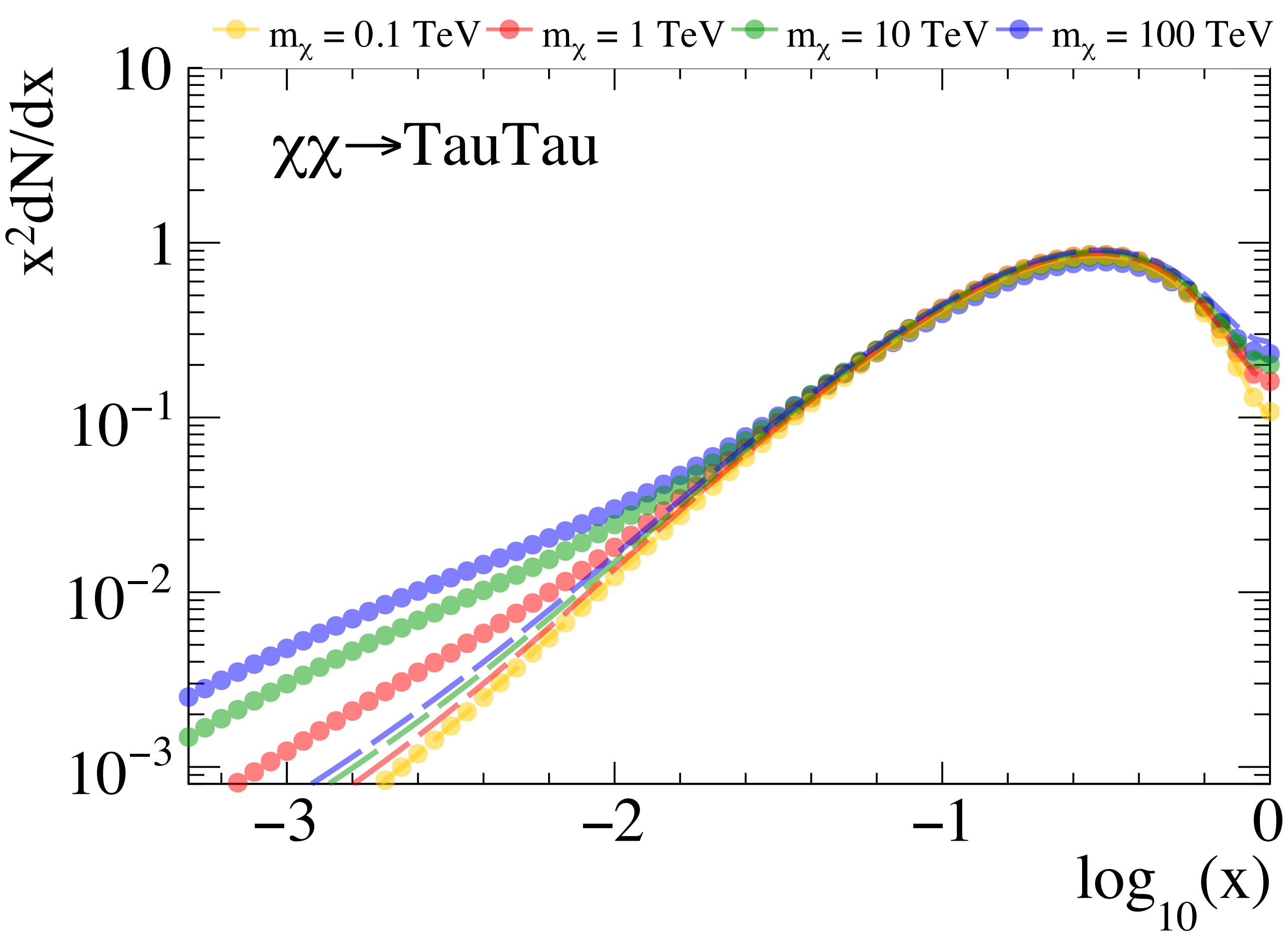
$$\rho_B(r) = \frac{\rho_c r_c^3}{(r + r_c)(r^2 + r_c^2)}$$

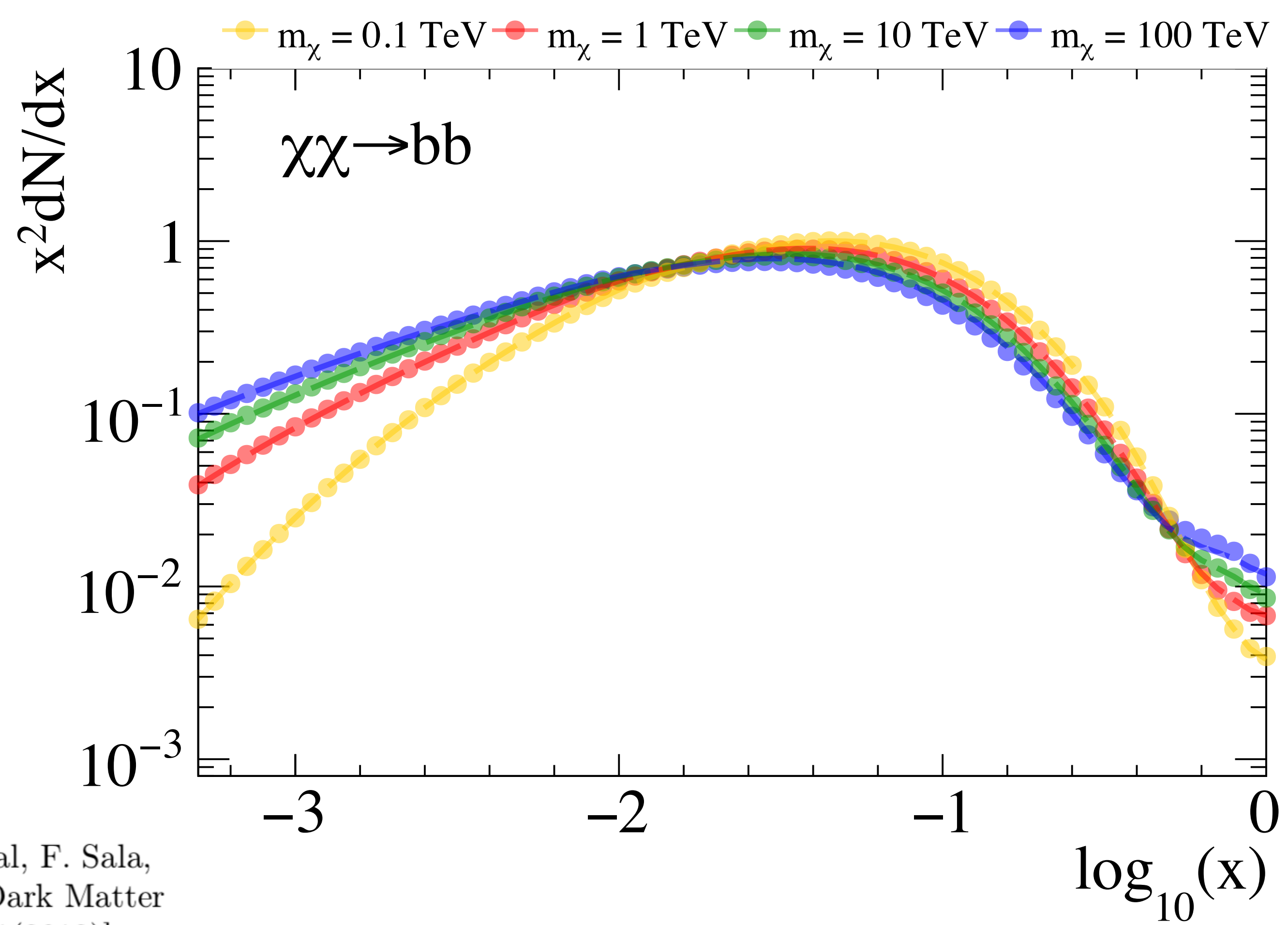


Particle Physics

- Gamma-ray production through PPPC DM ID
- Assumption 100% in one channel





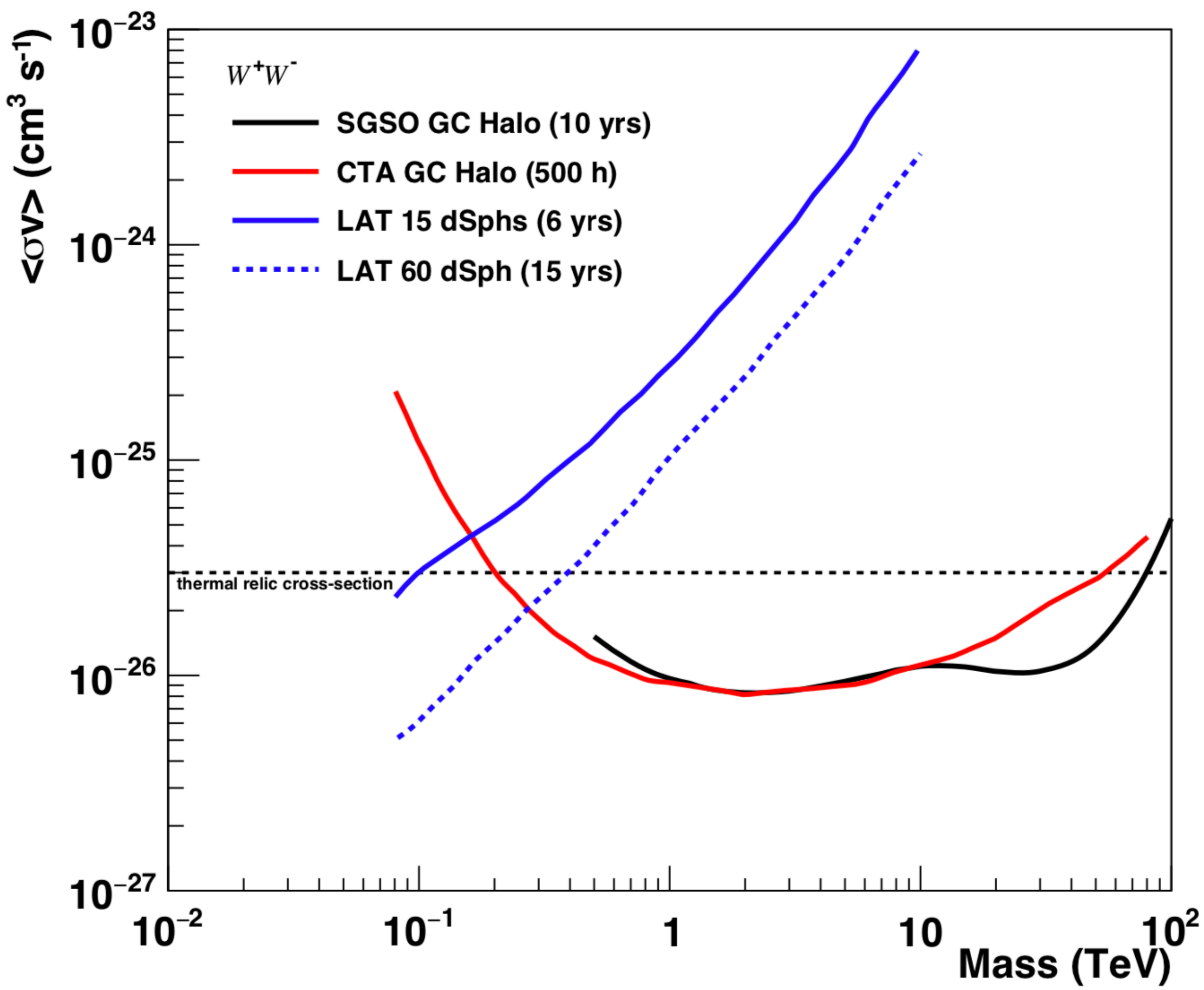


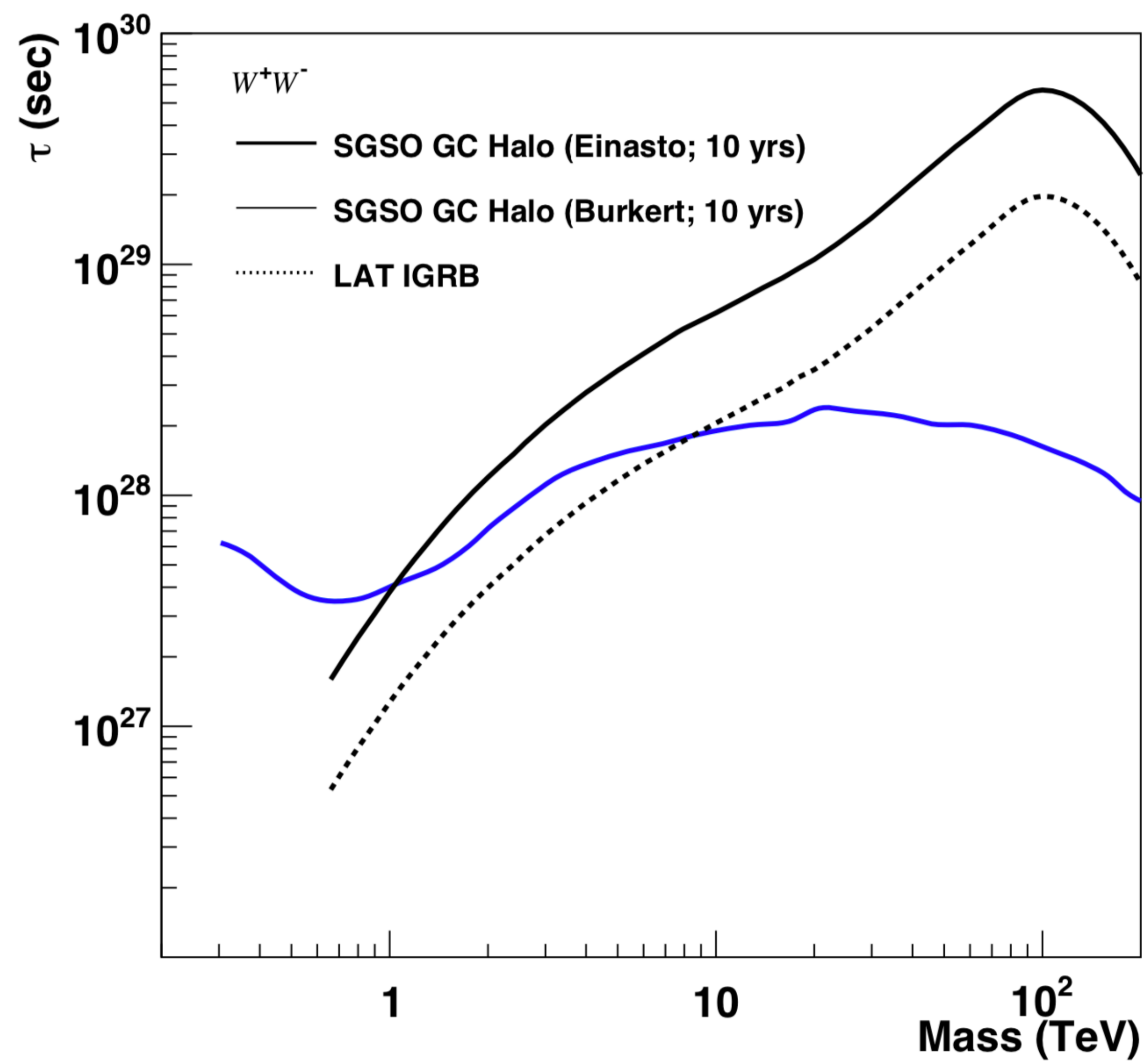
[17] M. Cirelli, G. Corcella, A. Hektor, G. Hutsi, M. Kadastik, P. Panci, M. Raidal, F. Sala, and A. Strumia, "PPPC 4 DM ID: A Poor Particle Physicist Cookbook for Dark Matter Indirect Detection," *JCAP*, vol. 1103, p. 051, 2011. [Erratum: JCAP1210,E01(2012)].

Binned likelihood test

- Take into account both spatial and energy dependence
- Calculate the likelihood of N events given the background.
- Derive 95% CL on <σv> and decay time

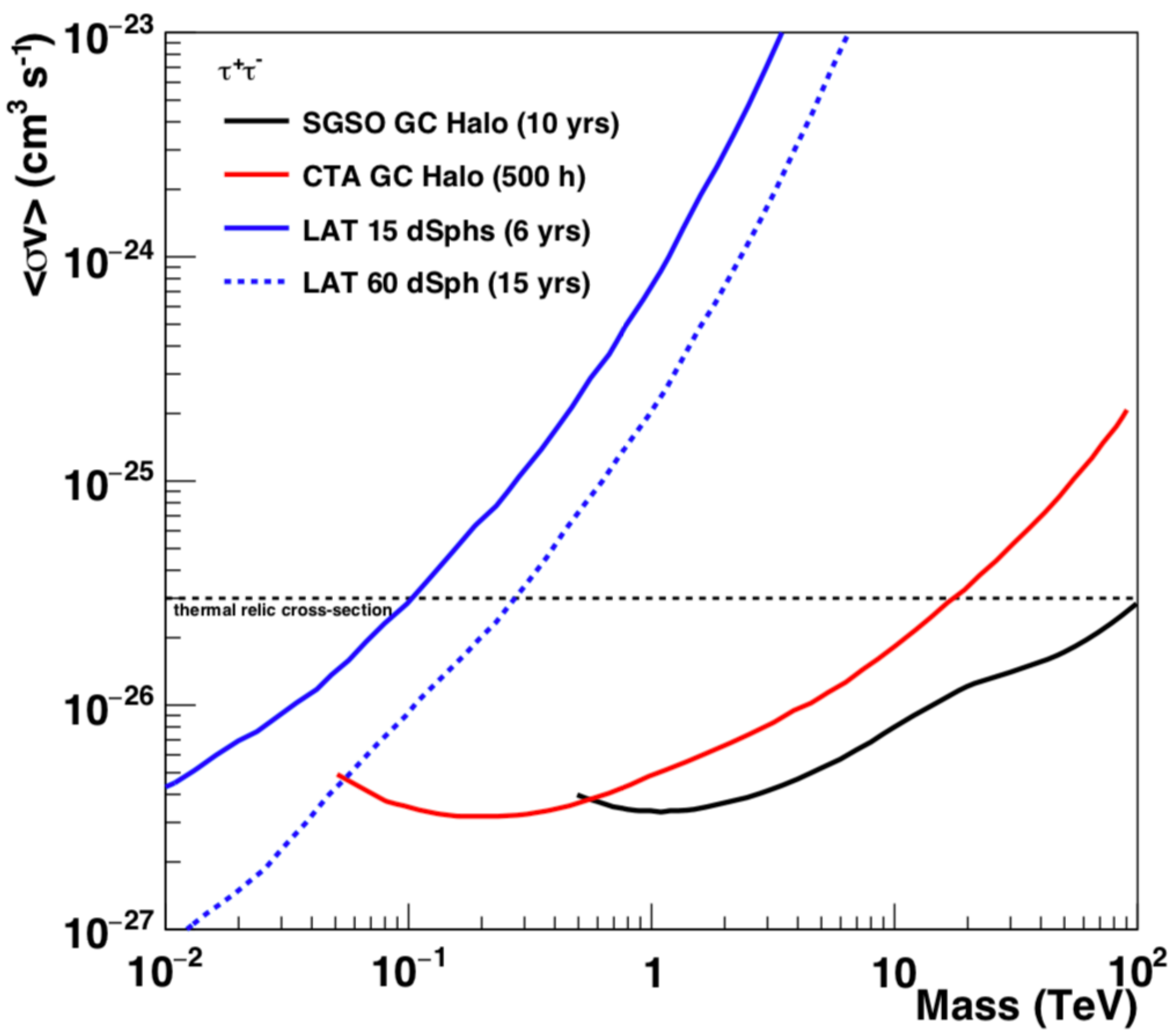
$$N_{ij} = T_{\rm obs} \int_{\Delta E_j} dE_\gamma^r \int_0^\infty dE_\gamma^t \frac{d\Phi_\gamma(\Delta\Omega_i, E_\gamma^t)}{dE_\gamma^t} \times A_{\rm eff}(E_\gamma^t) \times {\rm PDF}(E_\gamma^t, E_\gamma^r)$$

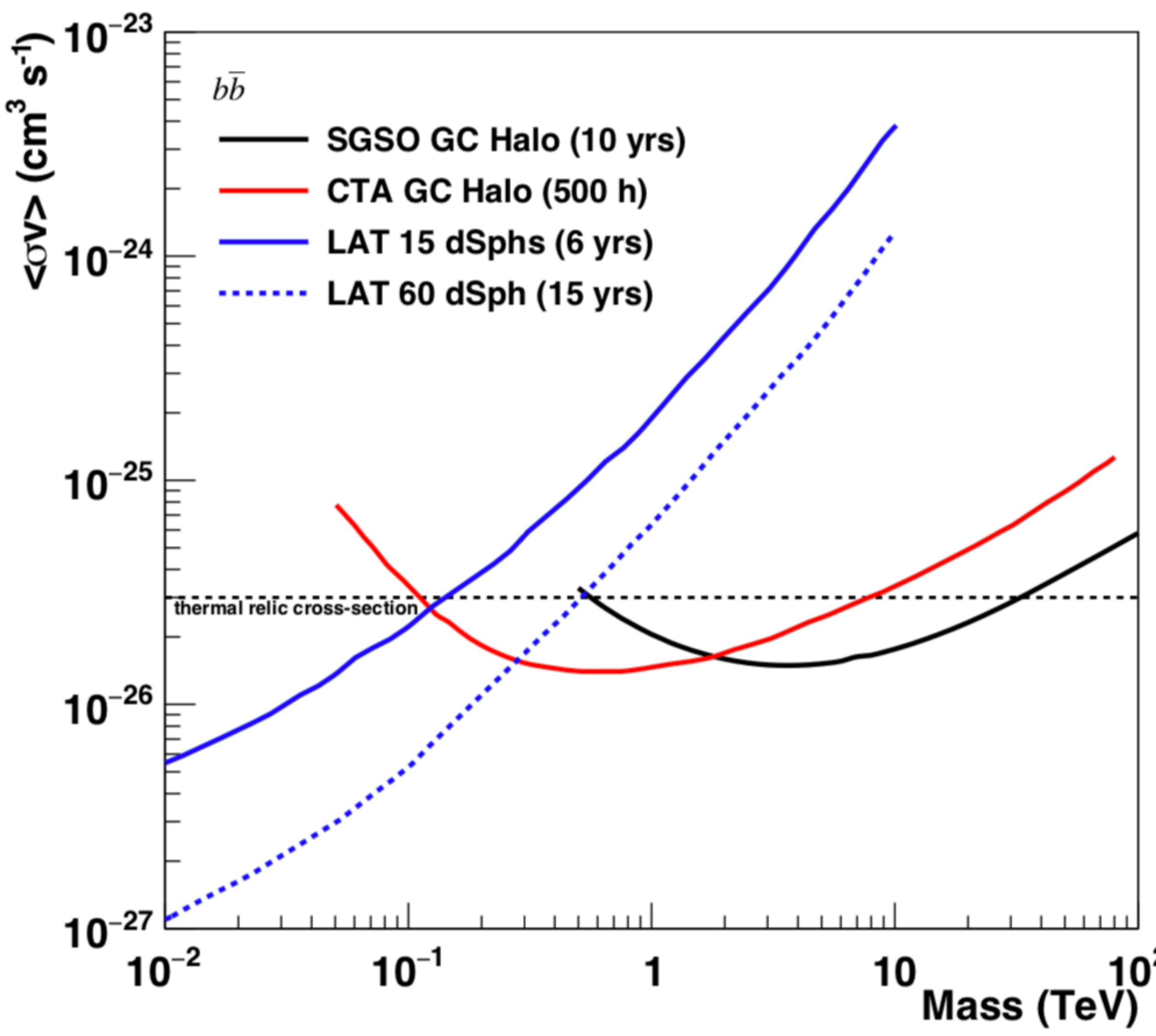




The other channels: annihilation

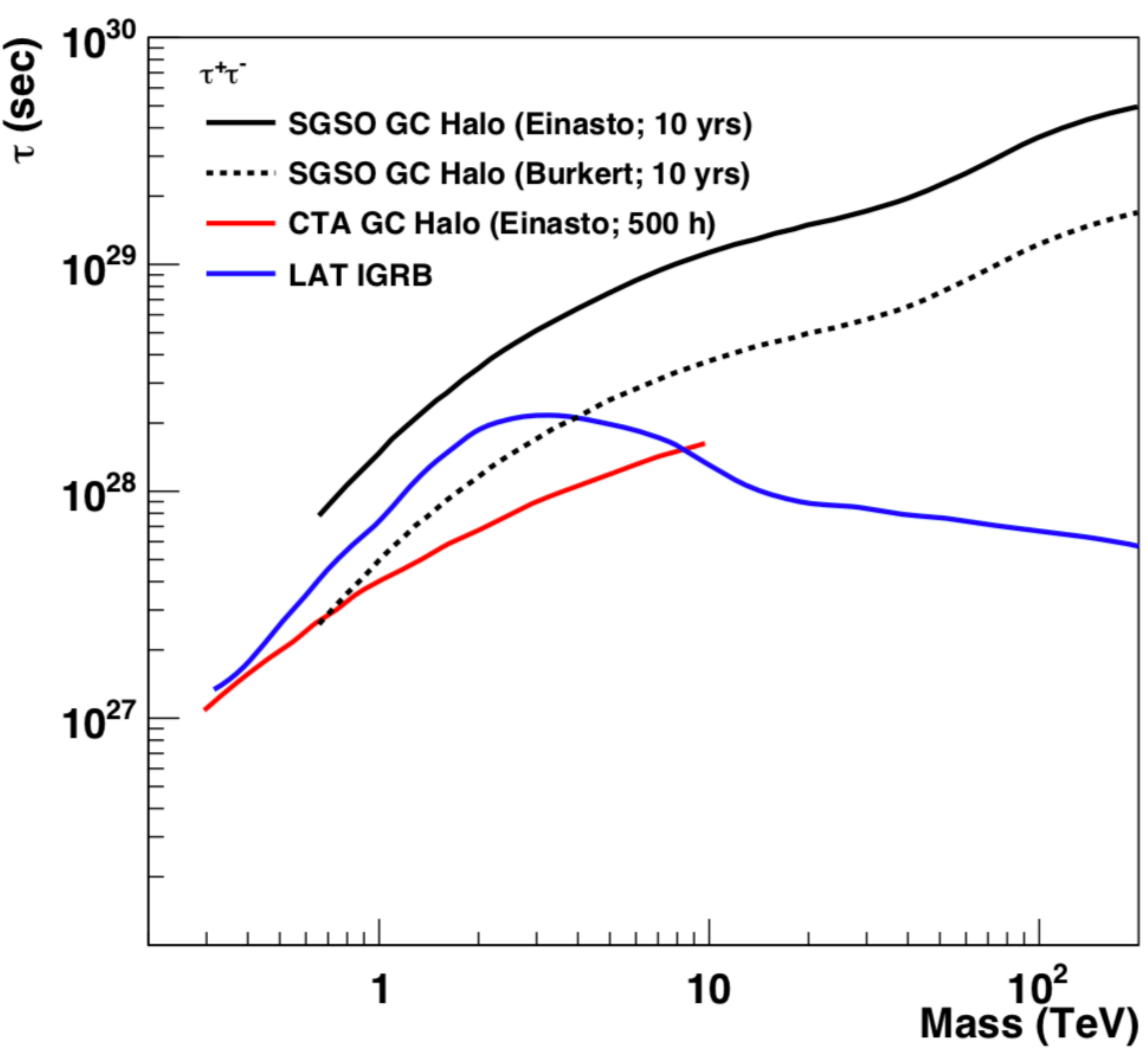
- Typically better sensitivity at higher energies
- Expand the energy range for exclusion of thermal relic cross in most channels

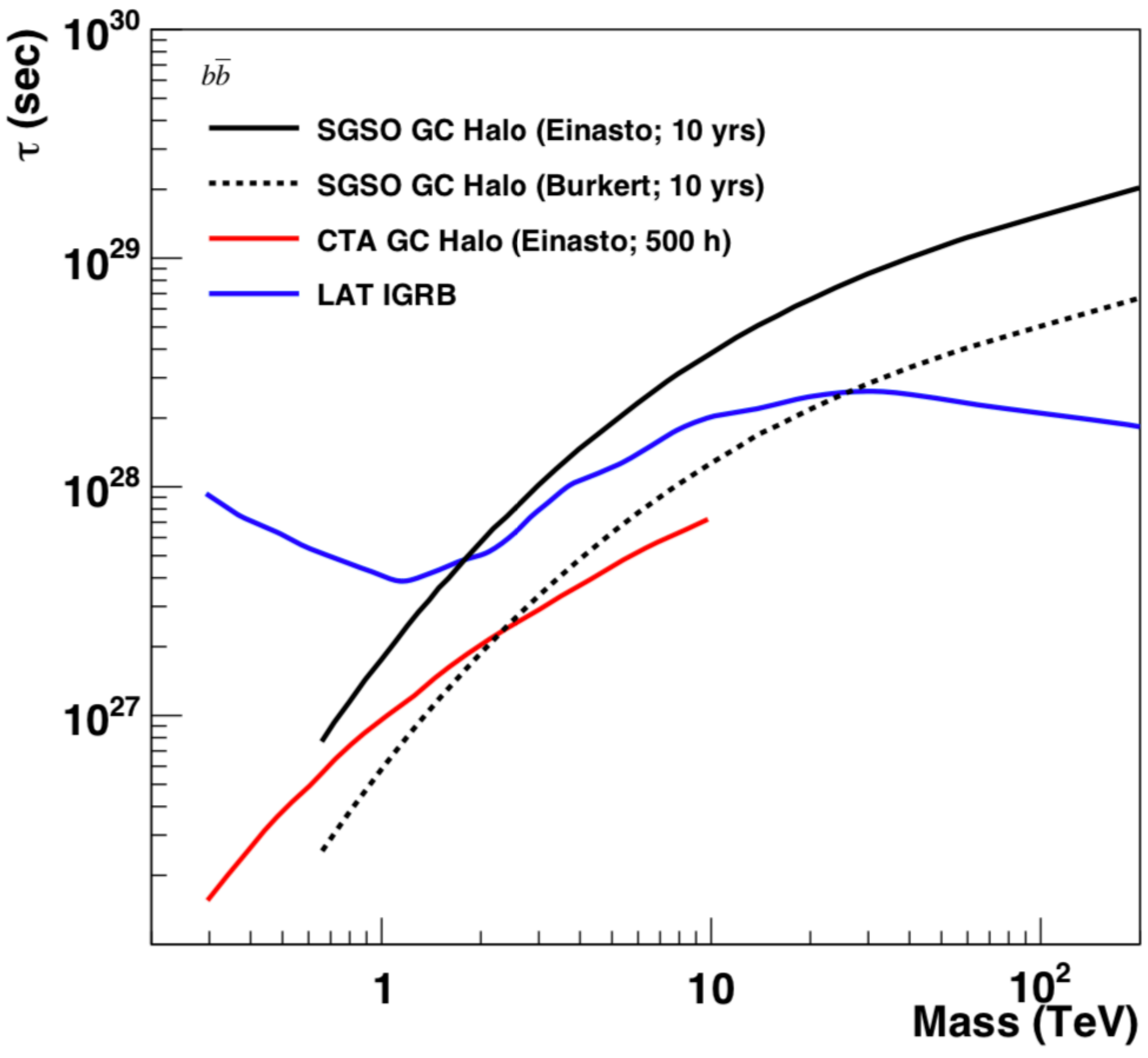




The other channels: decay

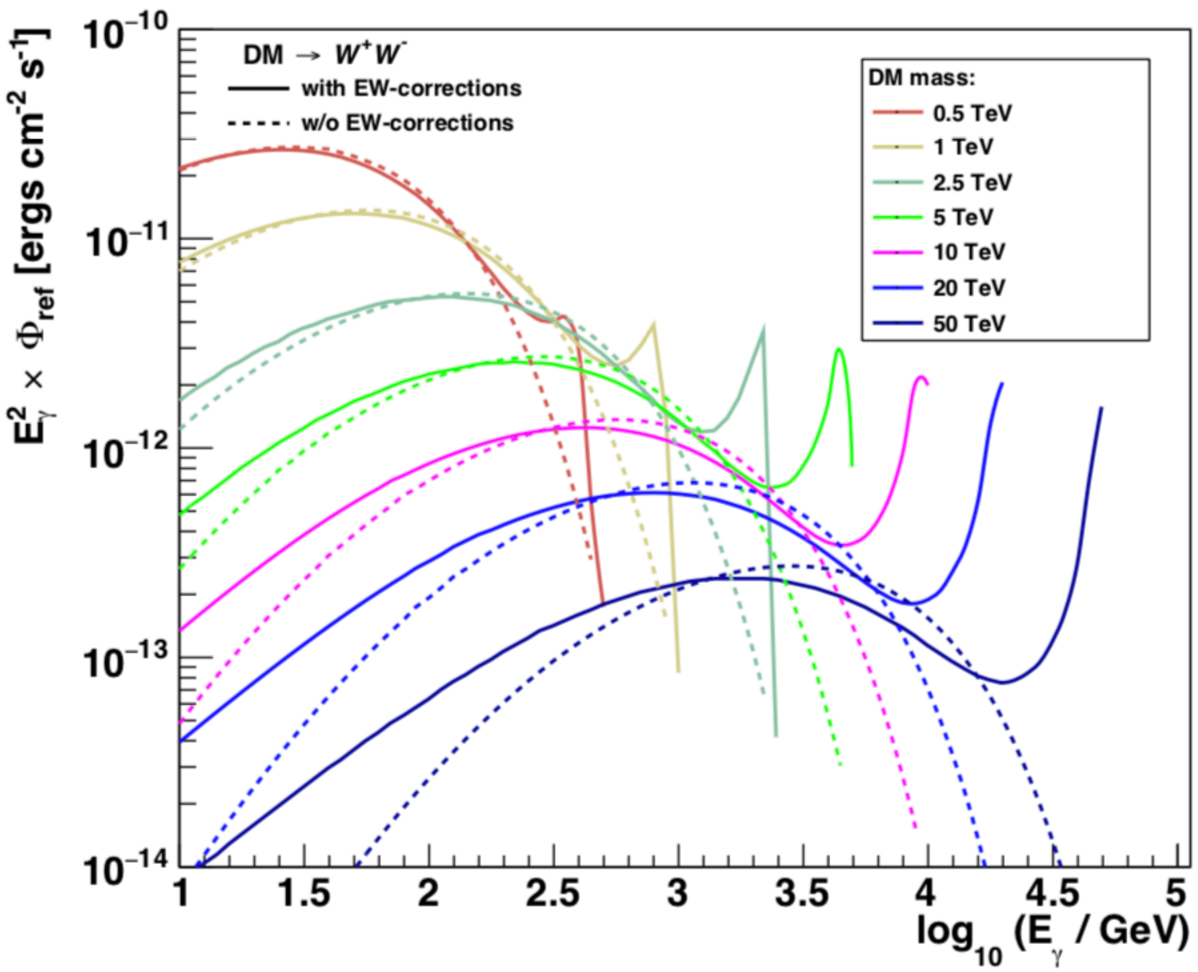
- Most constraining limits at high energy
- Improvement over CTA

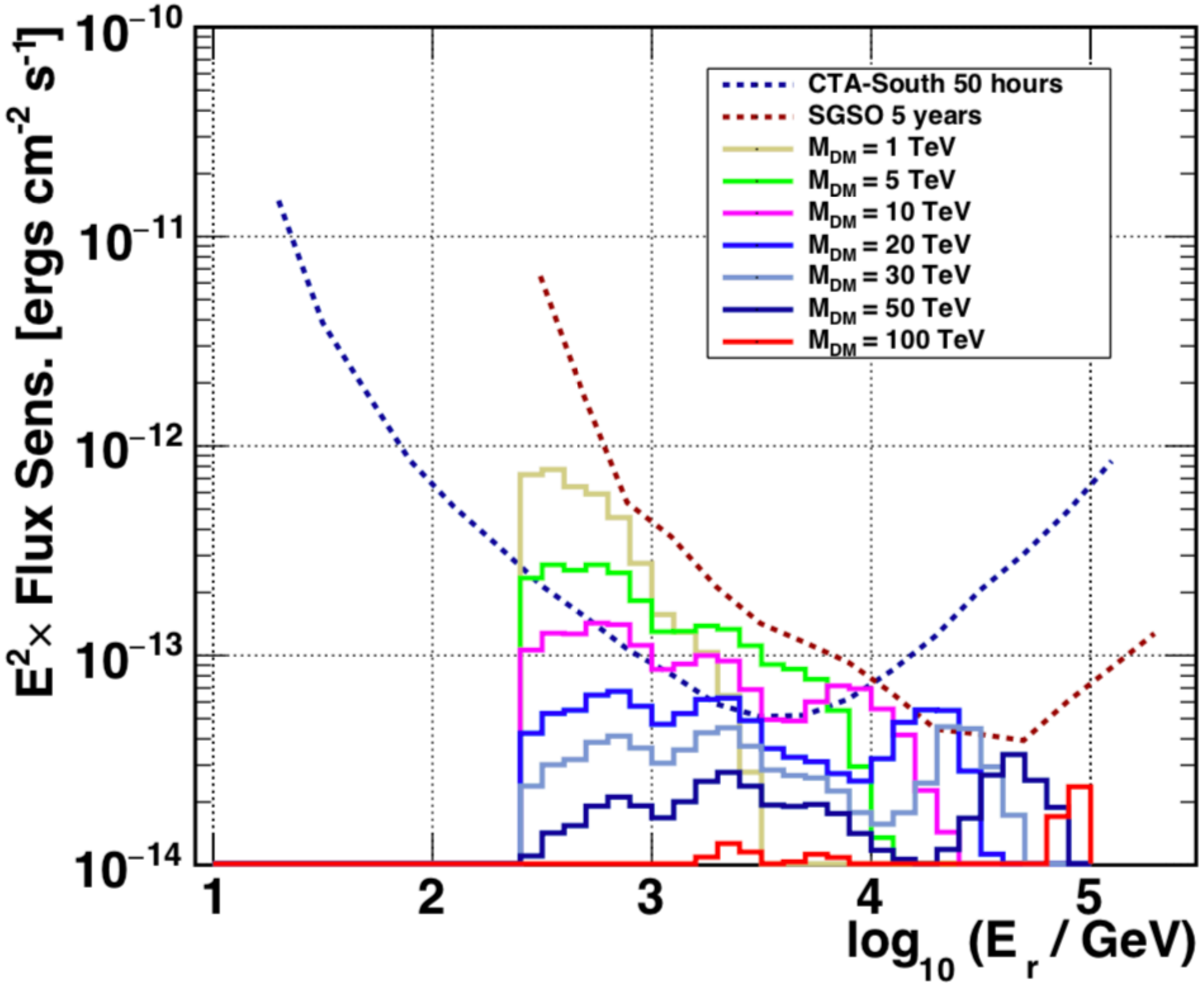




Bonus: Electro-weak corrections

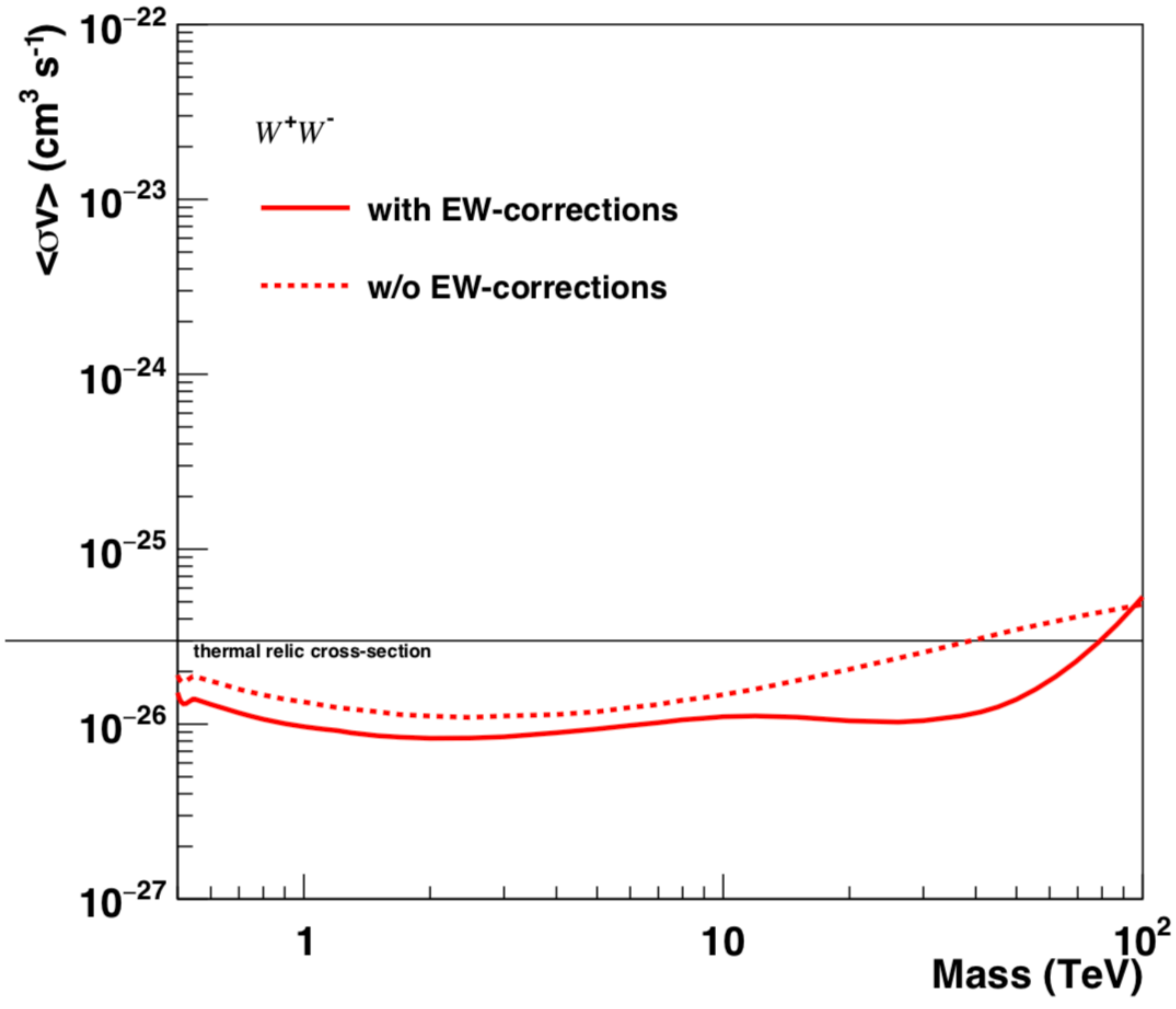
- Above a TeV radiation of W/Z bosons from decay or annihilation product becomes important
- "Line structure" close to DM mass
- Line smeared out, but still visible

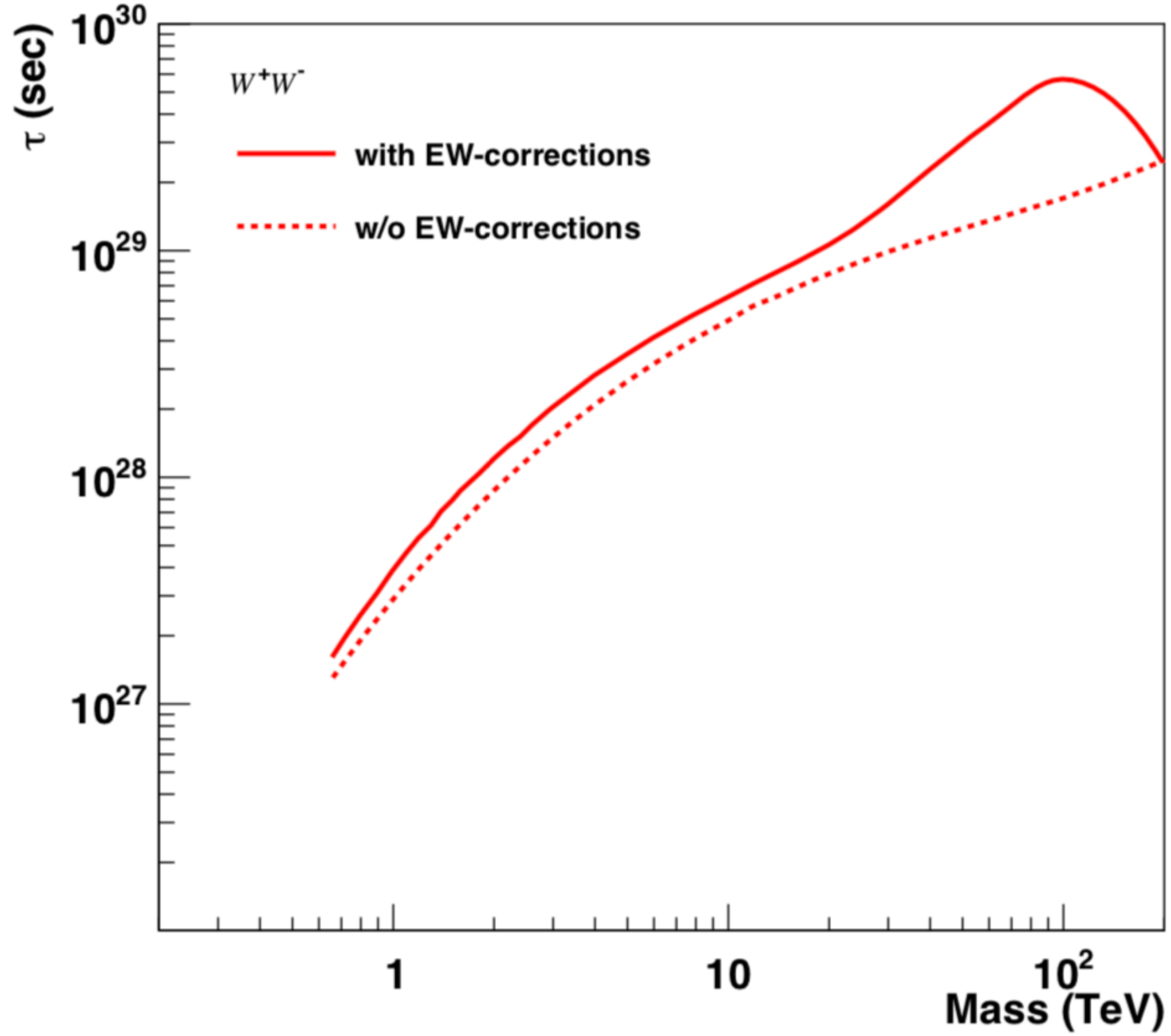




Bonus: Electro-weak corrections

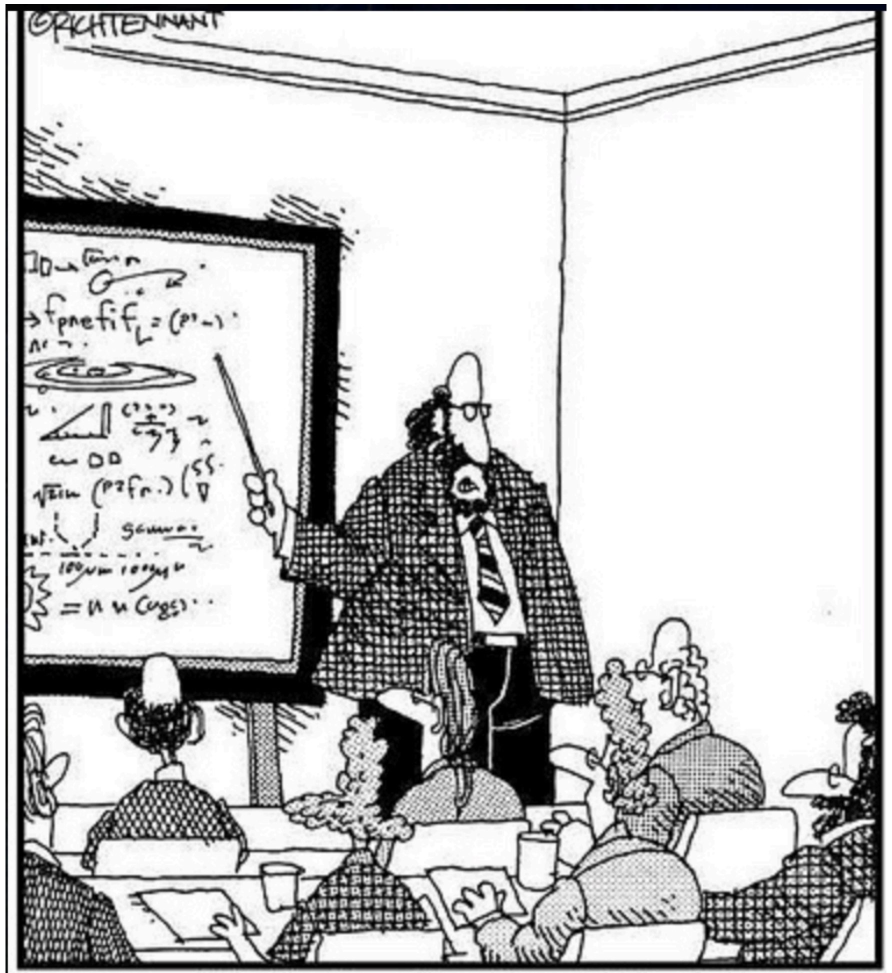
- Above a TeV radiation of W/Z bosons from decay or annihilation product becomes important
- "Line structure" close to DM mass





Conclusion

- It will be great
- Synergy between CTA
  - Energy ranges complement each other
  - Verify results with different systematics
- Need for a sufficiently large array



"Along with 'Antimatter,' and 'Dark Matter,' we've recently discovered the existence of 'Doesn't Matter,' which appears to have no effect on the universe whatsoever."