Potential dark matter signals at neutrino telescopes

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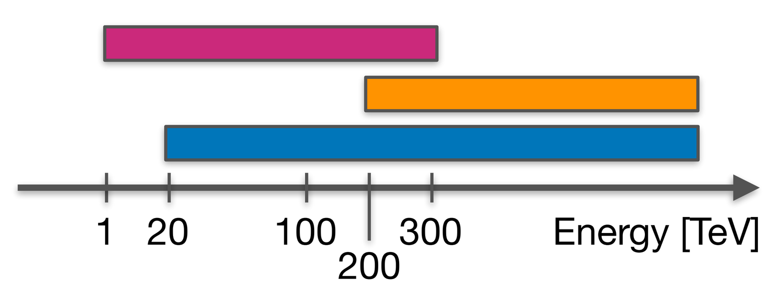
NEUTRINO 2020

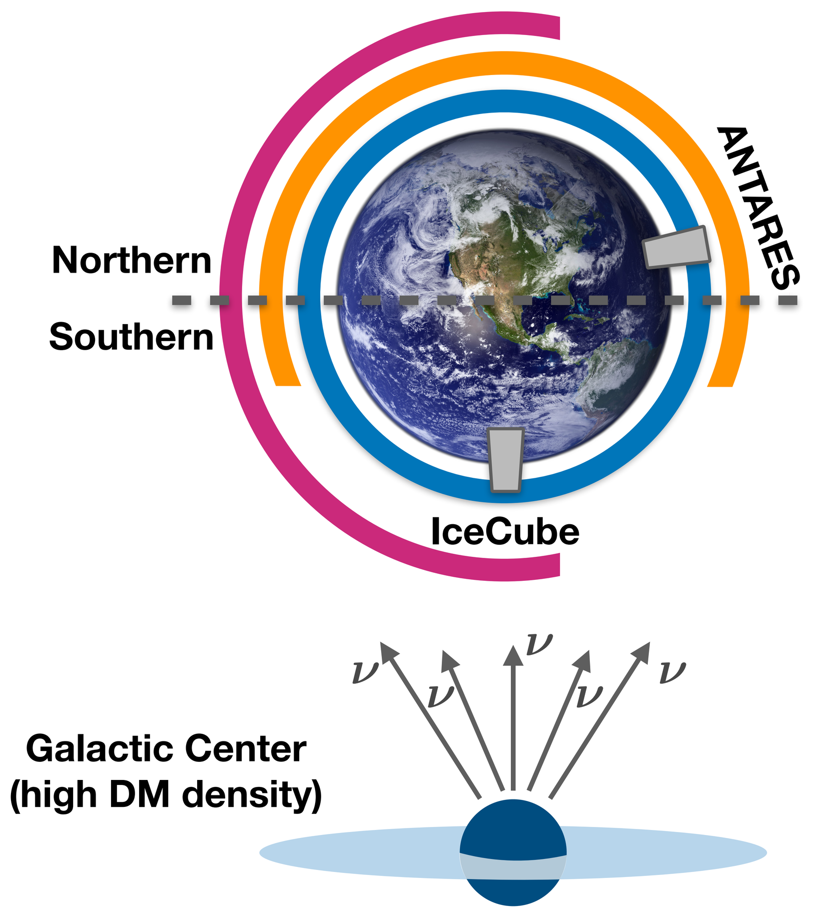
1. Neutrino telescopes data in 2019

7.5-yr High Energy Starting Events (HESE)
- full sky
- high-energy threshold

10-yr Through-going muon neutrinos (TG)
- northern sky only
- very high energy threshold

11-yr ANTARES showers and tracks
- mostly up-going 50 events
- events up to ~ 300 TeV



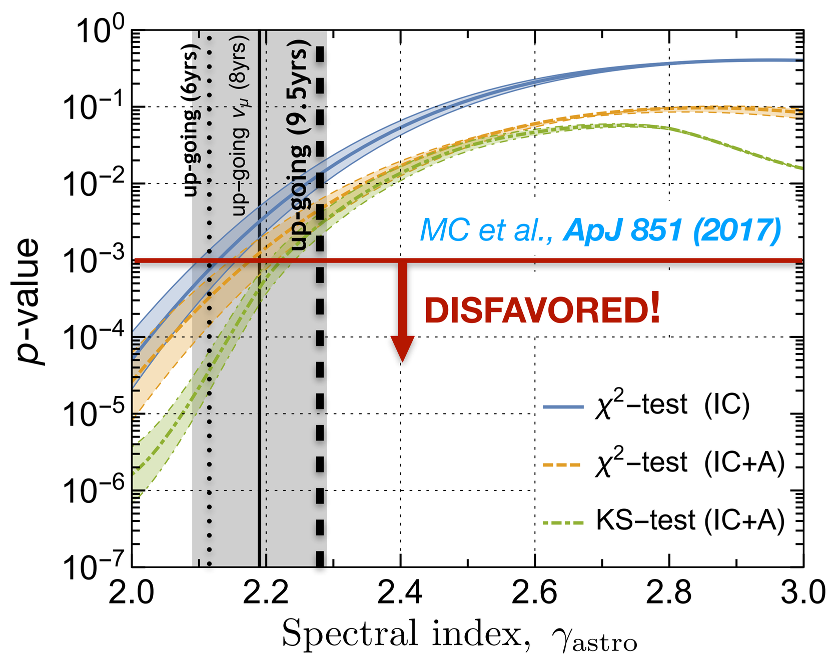


Any tension among these data suggests different components that dominate the neutrino flux at different energies and/or come from different regions of the sky (e.g. galactic component)

2. Tension with a single astrophysical power-law

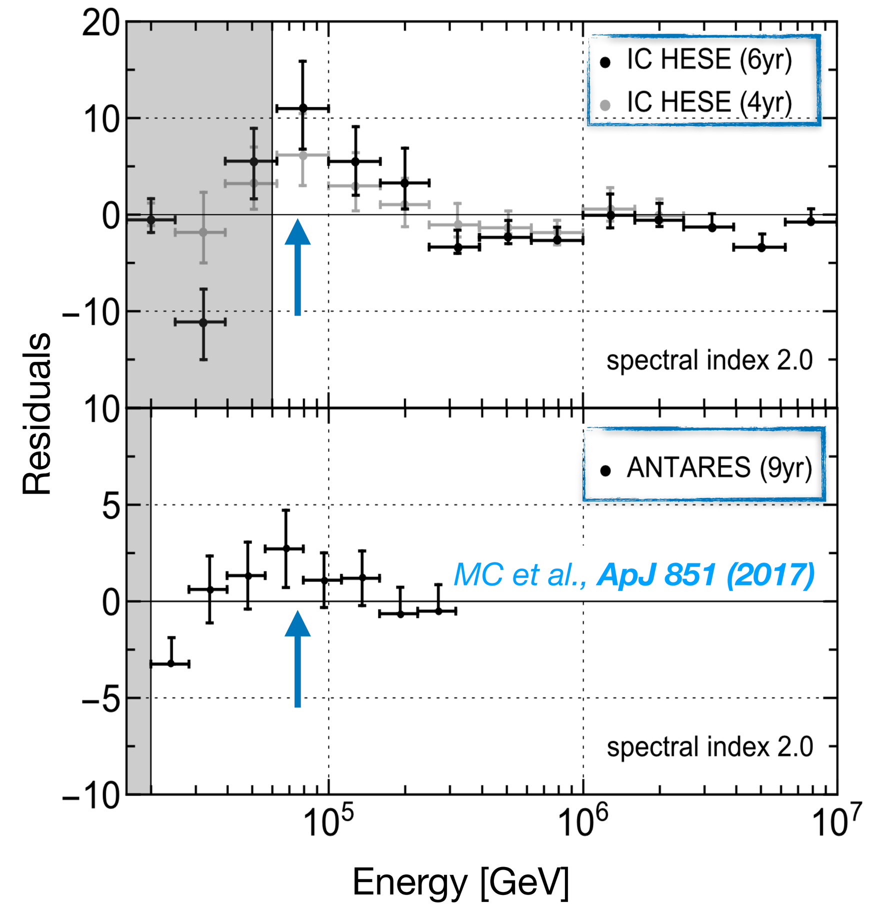
There is a tension at 2σ level between HESE (full sky) and through-going (Northern sky) data under the hypothesis of a single astrophysical component.

Hypothesis test



(combining IceCube and ANTARES)

The low-energy excess



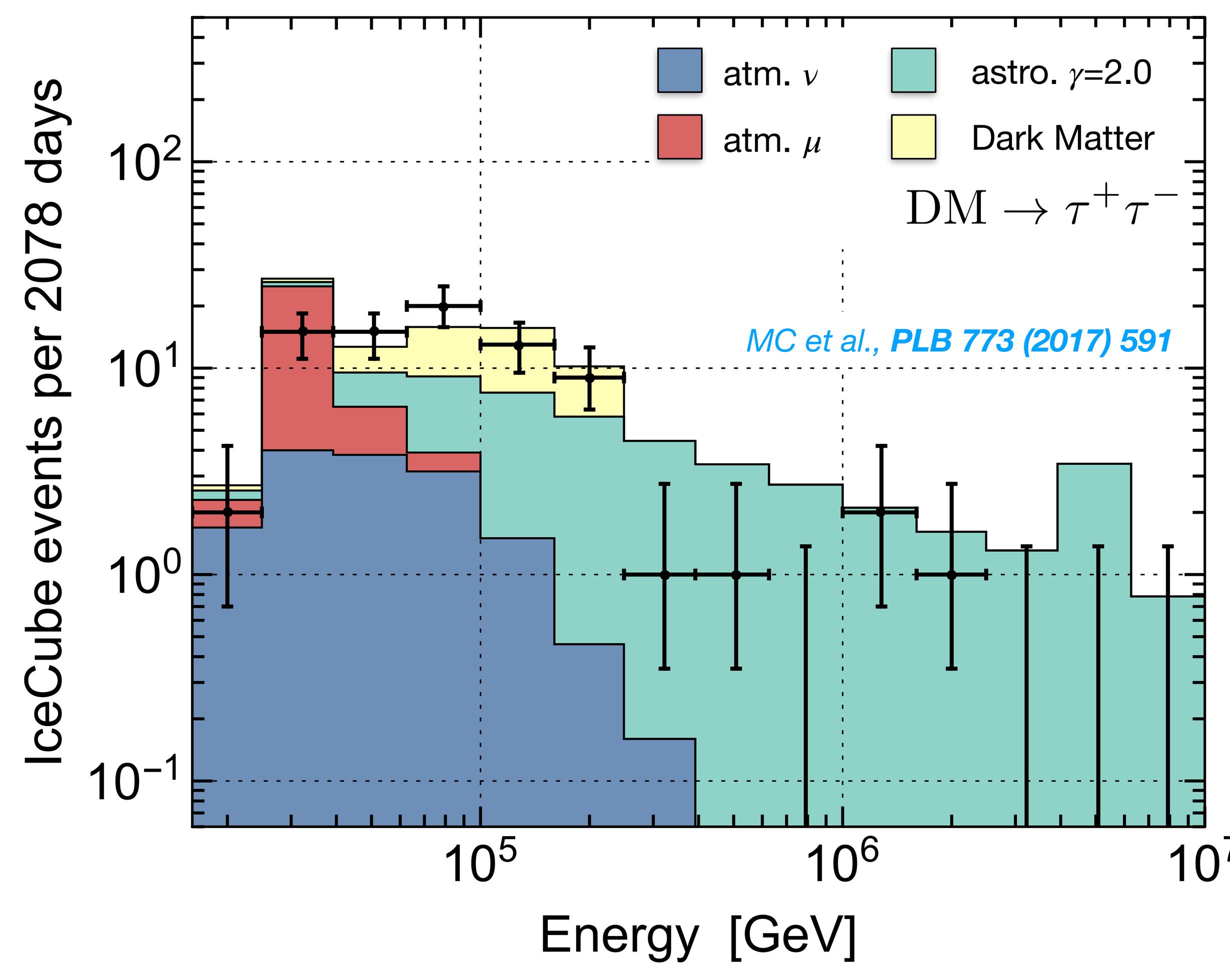
power-law flux: $$\frac{d\Phi_\nu^{\rm astro}}{dE_\nu\, d\Omega} = \Phi_{\rm astro}\, E_\nu^{-\gamma_{\rm astro}}$$

More about spectral index
- Fermi mechanism: $\gamma_{\rm astro} = 2.0$
- p-p sources: $\gamma_{\rm astro} \leq 2.2$
- Blazar TXS 0506+056: $\gamma_{\rm astro} = 2.1 \pm 0.2$

Two-component flux?

3. Dark Matter at 100 TeV?

Best-fit of 6-yr HESE



4. Two-component fit

Our hypothesis

$$\frac{d\Phi_\nu^{\rm signal}}{dE_\nu d\Omega} = \frac{d\Phi_\nu^{\rm astro}}{dE_\nu d\Omega} + \frac{d\Phi_\nu^{\rm DM}}{dE_\nu d\Omega}$$

$A_{\rm eff}(E_\nu,\Omega)$ → *HESE effective area*

Expected number of events

$$\mu = N_T + N_S + N_{NC}$$

Decaying Dark Matter flux

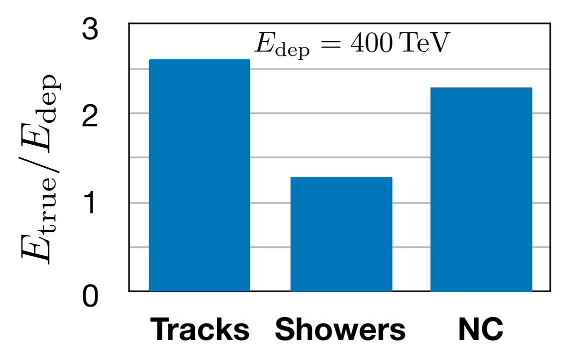
Galactic component

$$\left.\frac{d\Phi_\nu^{\rm DM}}{dE_\nu d\Omega}\right|_{\rm gal.} = \frac{1}{4\pi\, m_{\rm DM}\, \tau_{\rm DM}} \frac{dN_\nu}{dE_\nu} \int_{\rm l.o.s.} ds\, \rho(s,l,b)$$

Extragalactic component

$$\left.\frac{d\Phi_\nu^{\rm DM}}{dE_\nu d\Omega}\right|_{\rm ext.gal.} = \frac{\Omega_{\rm DM}\,\rho_c}{4\pi\, m_{\rm DM}\, \tau_{\rm DM}} \int_0^\infty dz \frac{1}{\mathcal{H}(z)} \left.\frac{dN_\nu}{dE_\nu}\right|_{E_\nu'=E_\nu(1+z)}$$

Main quantities
- NFW DM halo density profile
- Energy spectrum computed with PPPC4 package



Relation between true vs deposited neutrino energy included

Maximum likelihood fit

$$\Phi_{\rm astro},\ \gamma_{\rm astro},\ m_{\rm DM},\ \tau_{\rm DM}$$

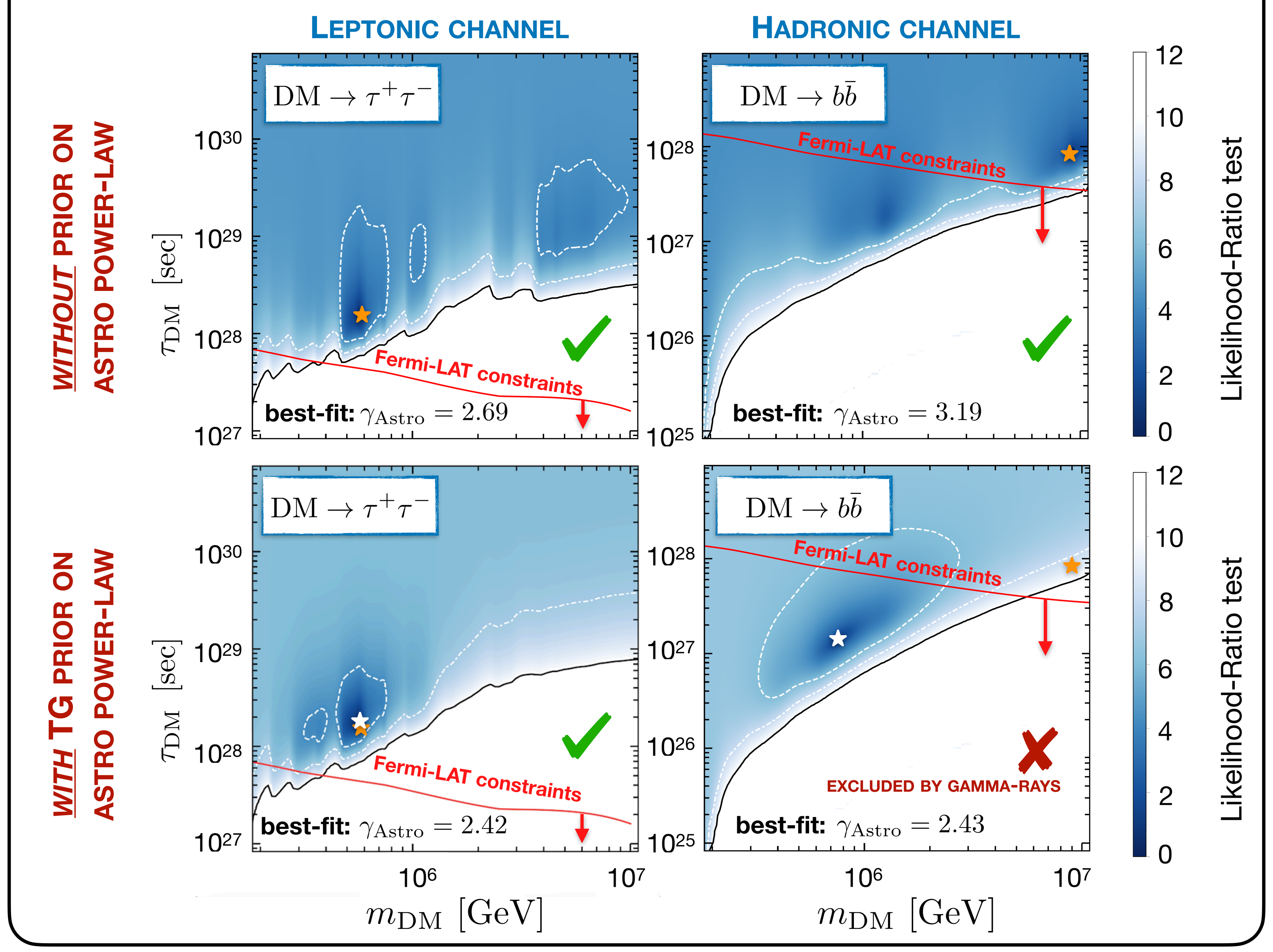
4 free parameters

Binned likelihood

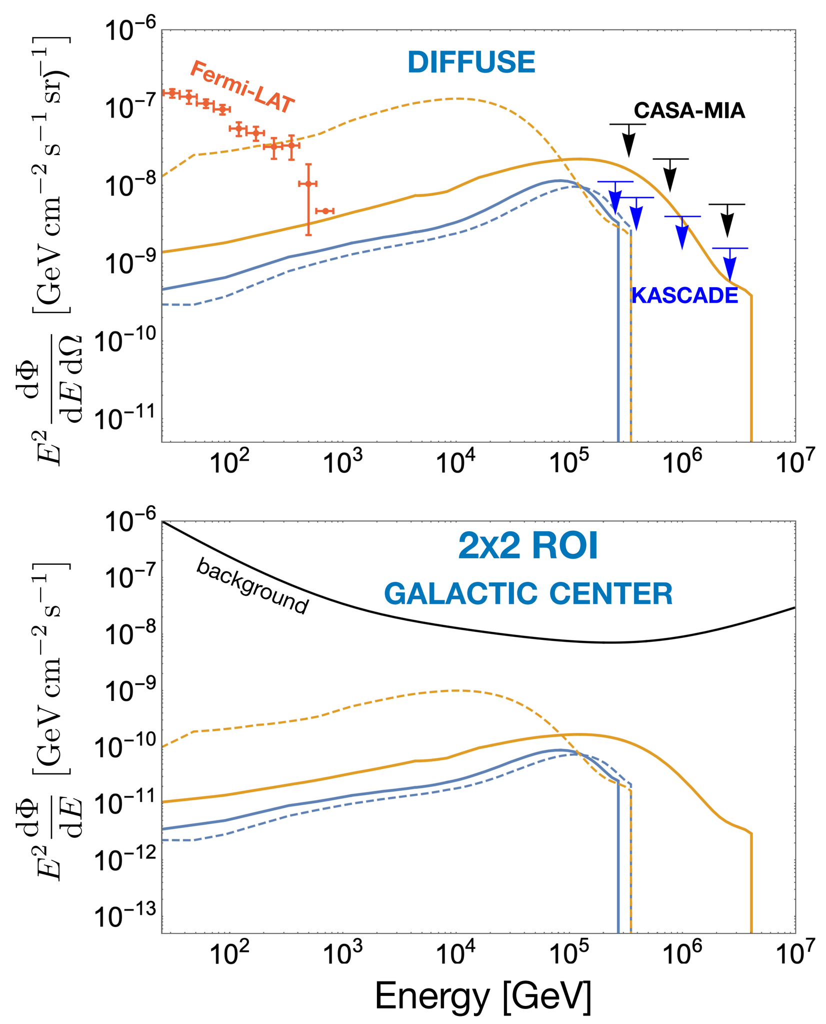
$$\mathcal{L} = \prod_i (\mu_i + b_i)^{n_i} \frac{e^{-(\mu_i+b_i)}}{n_i!}$$

b = atm. background
n = 7.5-yr HESE data

5. Results



6. Future gamma-rays searches



- Diffuse searches provide the strongest constraints on decaying Dark Matter.
- Point-like searches towards the Galactic center (like in CTA) are dominated by background.

CTA sensitivity (50 hours)

Channel	Prior	N_σ CTA sensitivity
$\tau^+\tau^-$	Flat	0.046
	TG data	0.030
$b\bar{b}$	Flat	0.11
	TG data	1.09

Already excluded by Fermi-LAT

Conclusions

We have analyzed the 7.5-year HESE data with decaying Dark Matter + an astrophysical power-law, with and without the through-going muon neutrinos prior.
- A Dark Matter component is preferred at 68% C.L. for some decay channels.
- Multi-messenger analyses are important: leptophilic decay channels are still viable!
- Angular analyses are crucial in order to firmly exclude a Dark Matter component. **See poster #494 by Ariane Dekker!**