Cosmic ray - dark matter scattering
A new signature of dark matter in the gamma ray sky

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“Conventional” DM searches with gamma rays

- Look where DM is abundant and dense
- Look for photons from annihilations or decays

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Can we search for a new, different signature?

- Scattering of galactic cosmic rays off of DM with radiation of final-state photons
- Detection of such photons?

Pros and Cons

Cosmic ray - DM scattering

DM pair annihilation

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- Background difficult ☹

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- Signal $\propto \rho$ ☺

DM pair annihilation

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- Signal $\propto \rho^2$ ☹

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Cosmic ray - DM scattering

- Background difficult ☹
- Signal $\propto \rho$ ☺
- Happens for asymmetric dark matter ☺

DM pair annihilation

- Background difficult ☹
- Signal $\propto \rho^2$ ☹
- Does not happen for asymmetric dark matter ☹

Pros and Cons

Cosmic ray - DM scattering

DM pair annihilation

Rough estimates for a generic WIMP model - m_χ = 100 GeV

Rate per unit target

$$q_{e\chi\to e\chi\gamma} \equiv \left(E \frac{\mathrm{d}\phi_e}{\mathrm{d}E}\Big|_{1\ \mathrm{GeV}} \right) \times \sigma_{e\chi\to e\chi\gamma}$$

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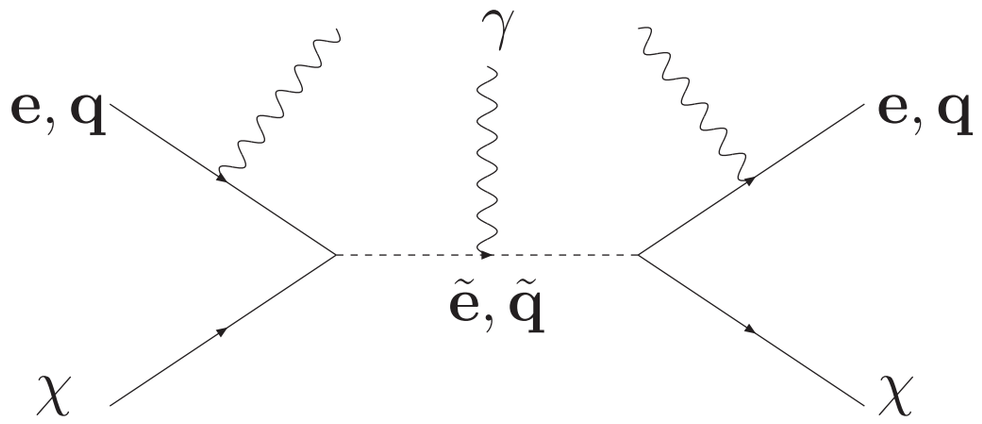
- Too low for models of asymmetric dark matter (usually even further suppressed by the dark sector scale $\Lambda \sim$ TeV)
- Are there models with enhancements?

Cosmic ray - WIMP DM scattering

a familiar supersymmetric model



Two enhancements for this process:

1. when the exchanged selectron (squark) goes on shell
2. log enhancement when the photon is collinear with the electron (quark)

Cosmic ray - WIMP DM scattering

the photon flux

$$\frac{dN}{dE_\gamma} = r_\odot \rho_\odot \bar{J} \frac{1}{M_\chi} \int d\Omega_\gamma \int dE_e \frac{d\phi}{dE_e} \frac{d^2\sigma}{d\Omega_\gamma dE_\gamma}$$

$$\bar{J} = \frac{2\pi}{\Delta\Omega} \int_{\Delta\Omega} d\theta \sin\theta J(\theta) \qquad\qquad \Delta\Omega \sim 10^{-3}$$

$$J(\theta) = \int_0^{2r_\odot} ds \frac{1}{r_\odot \rho_\odot} \rho(r(s,\theta)) f(r(s,\theta))$$

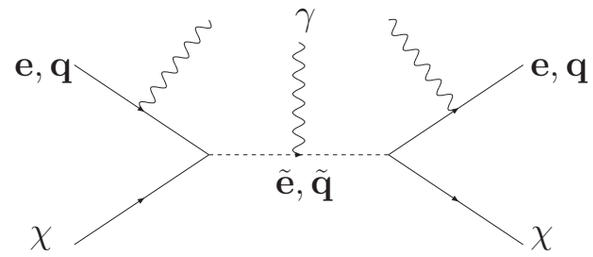
Cosmic ray - WIMP DM scattering

the photon flux

Cosmic ray electron flux

$$\frac{dN}{dE_\gamma} = r_\odot \rho_\odot \bar{J} \frac{1}{M_\chi} \int d\Omega_\gamma \int dE_e \frac{d\phi}{dE_e} \frac{d^2\sigma}{d\Omega_\gamma dE_\gamma}$$

cross section for



angle between emitted photons and cosmic rays incident on DM

$$\bar{J} = \frac{2\pi}{\Delta\Omega} \int_{\Delta\Omega} d\theta \sin\theta J(\theta) \qquad \Delta\Omega \sim 10^{-3}$$

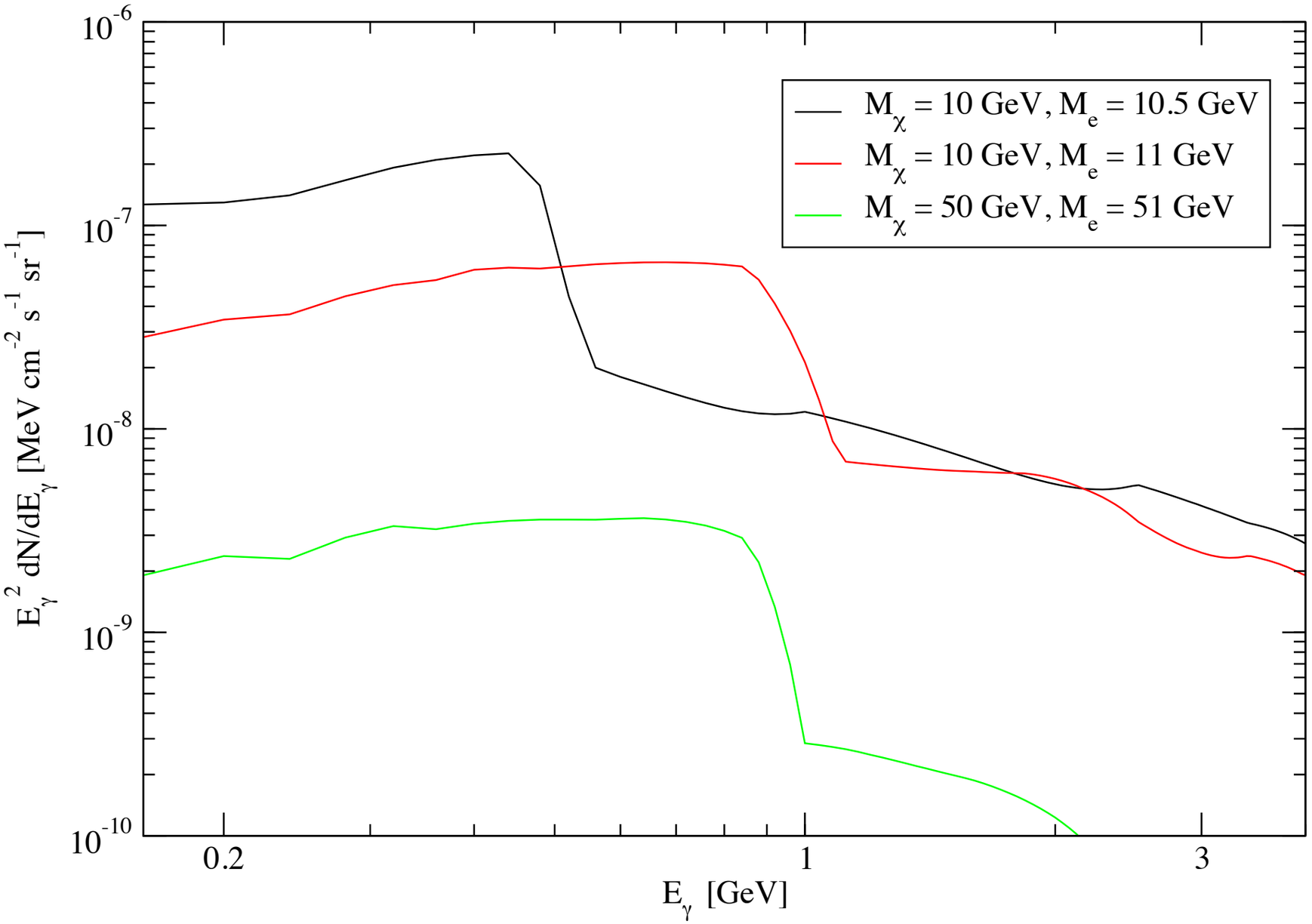
angle of observation from earth

Einasto profile

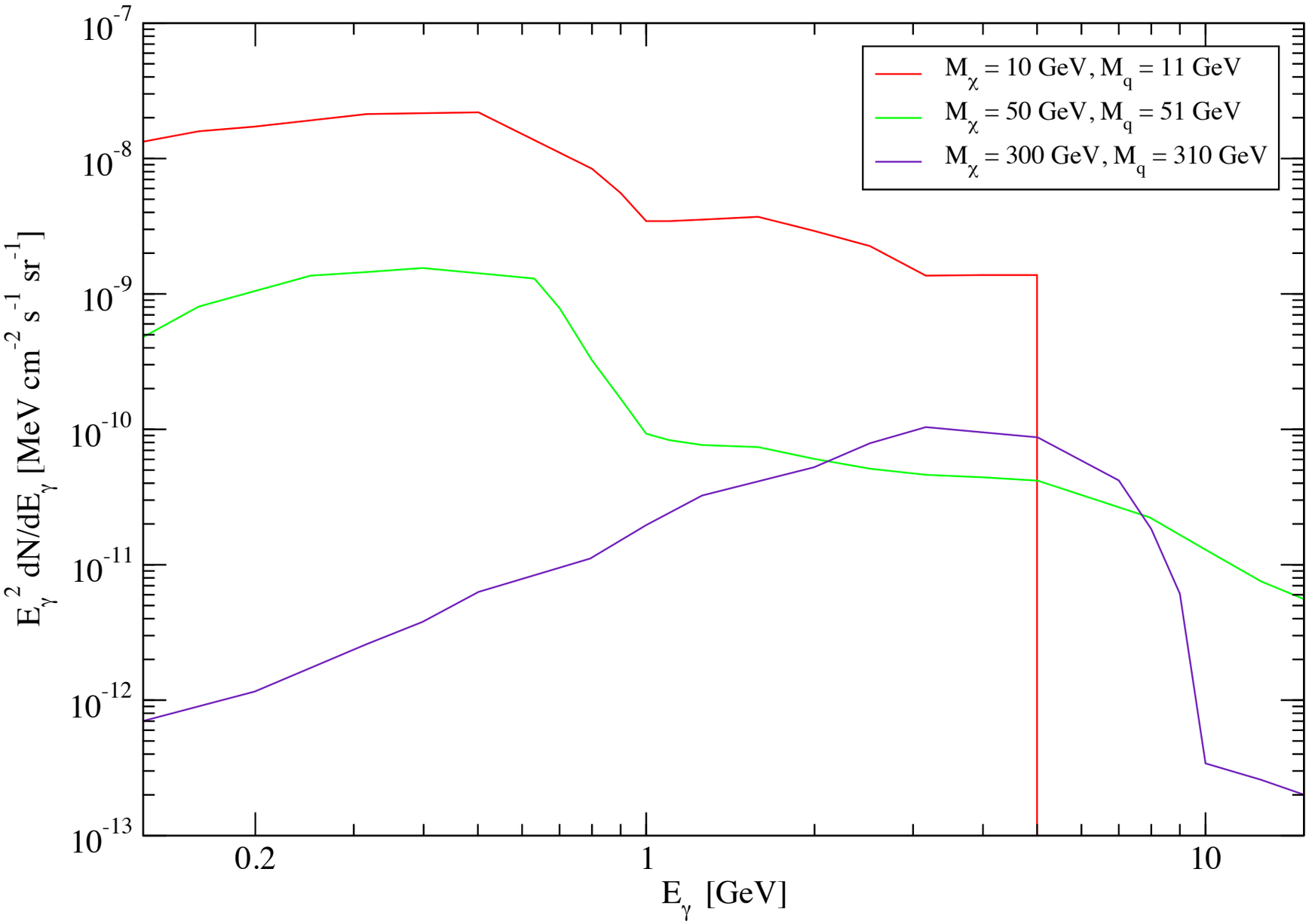
$$J(\theta) = \int_0^{2r_\odot} ds \frac{1}{r_\odot \rho_\odot} \rho(r(s,\theta)) f(r(s,\theta))$$

to account for higher cosmic ray flux in the vicinity of galactic center

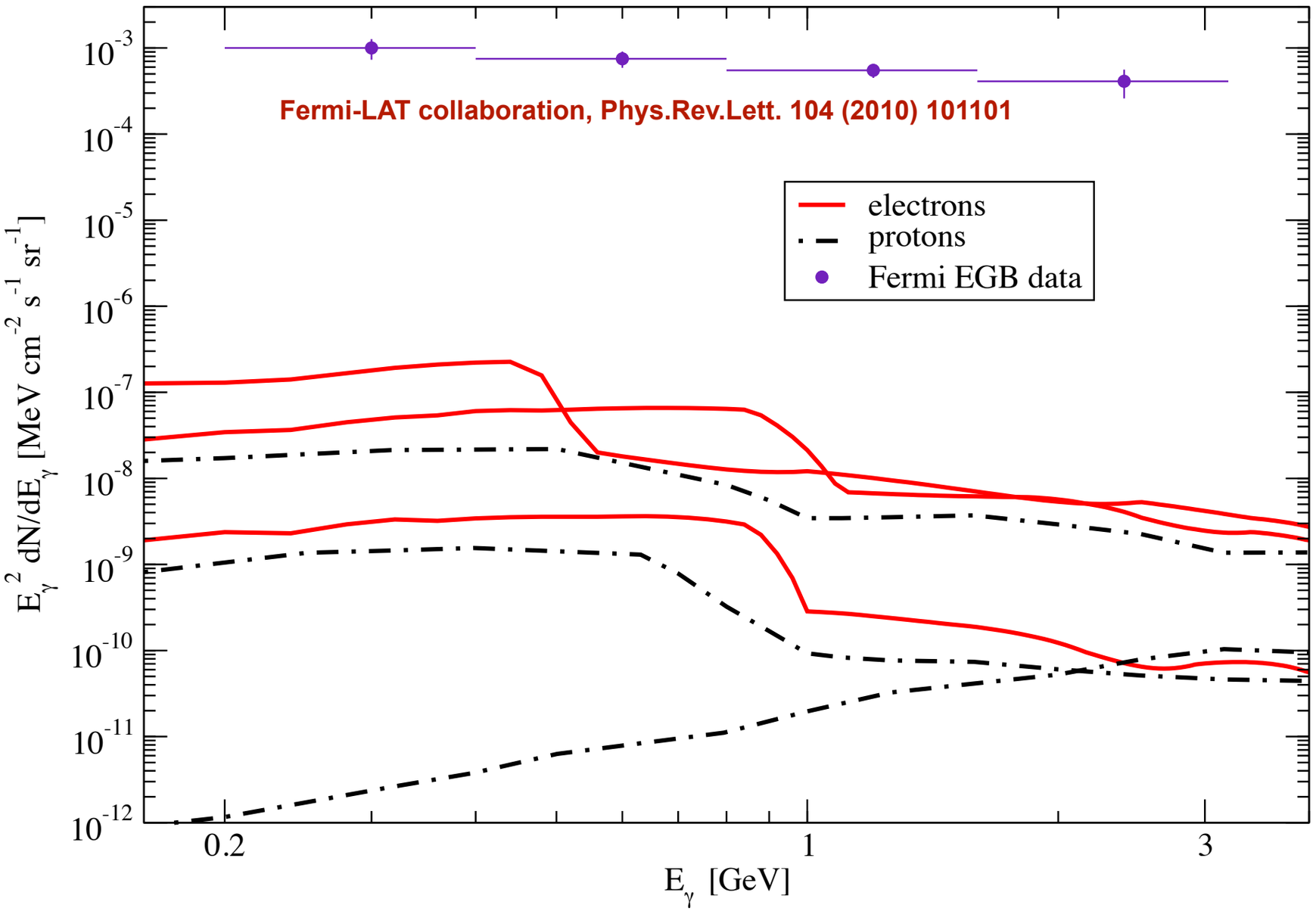
Cosmic ray electrons



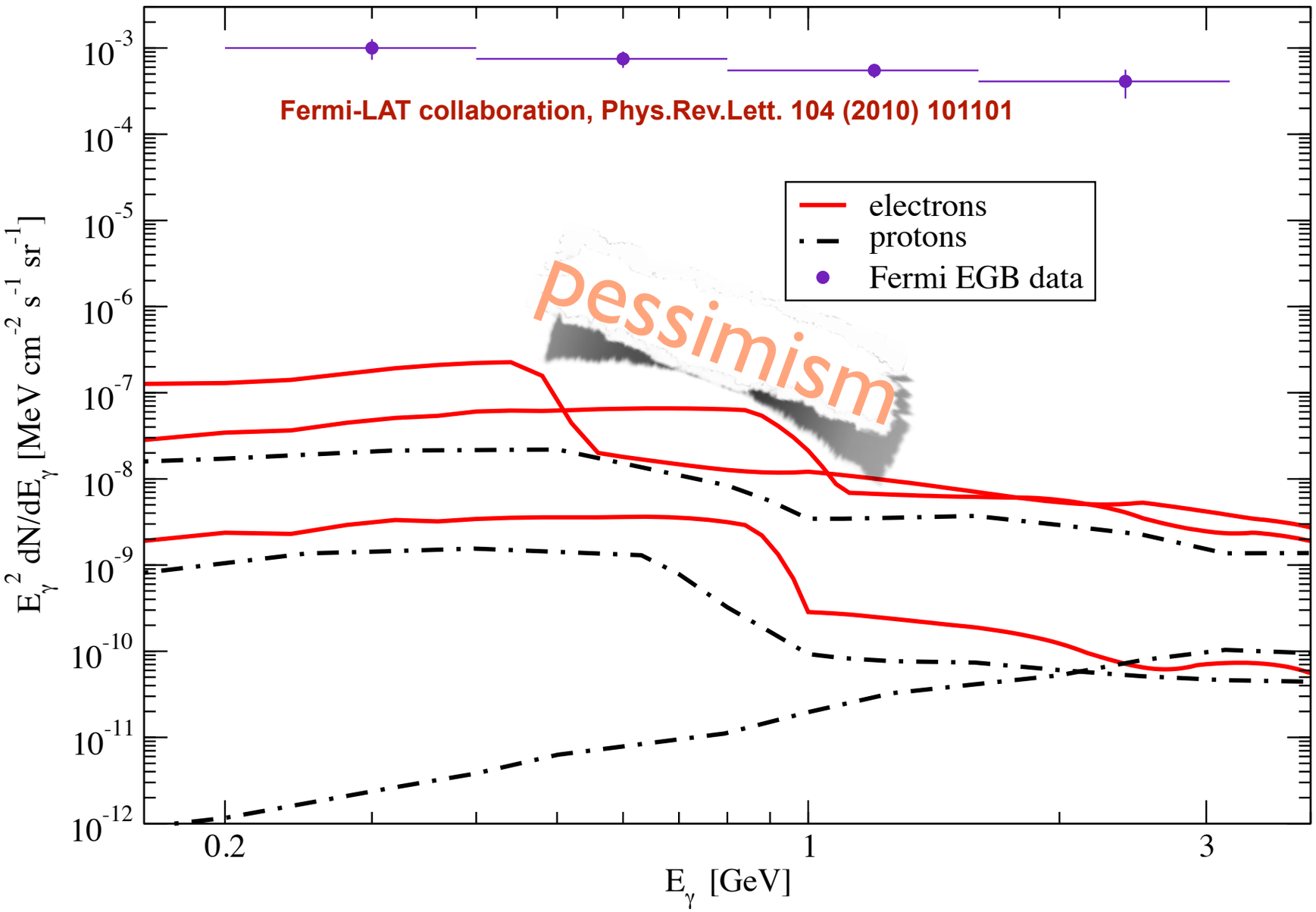
Cosmic ray protons



In context


Fermi-LAT collaboration, Phys.Rev.Lett. 104 (2010) 101101
electrons
protons
Fermi EGB data
$E_\gamma^2\, dN/dE_\gamma$ [MeV cm^{-2} s^{-1} sr^{-1}]
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
0.2
1
3
E_γ [GeV]

In context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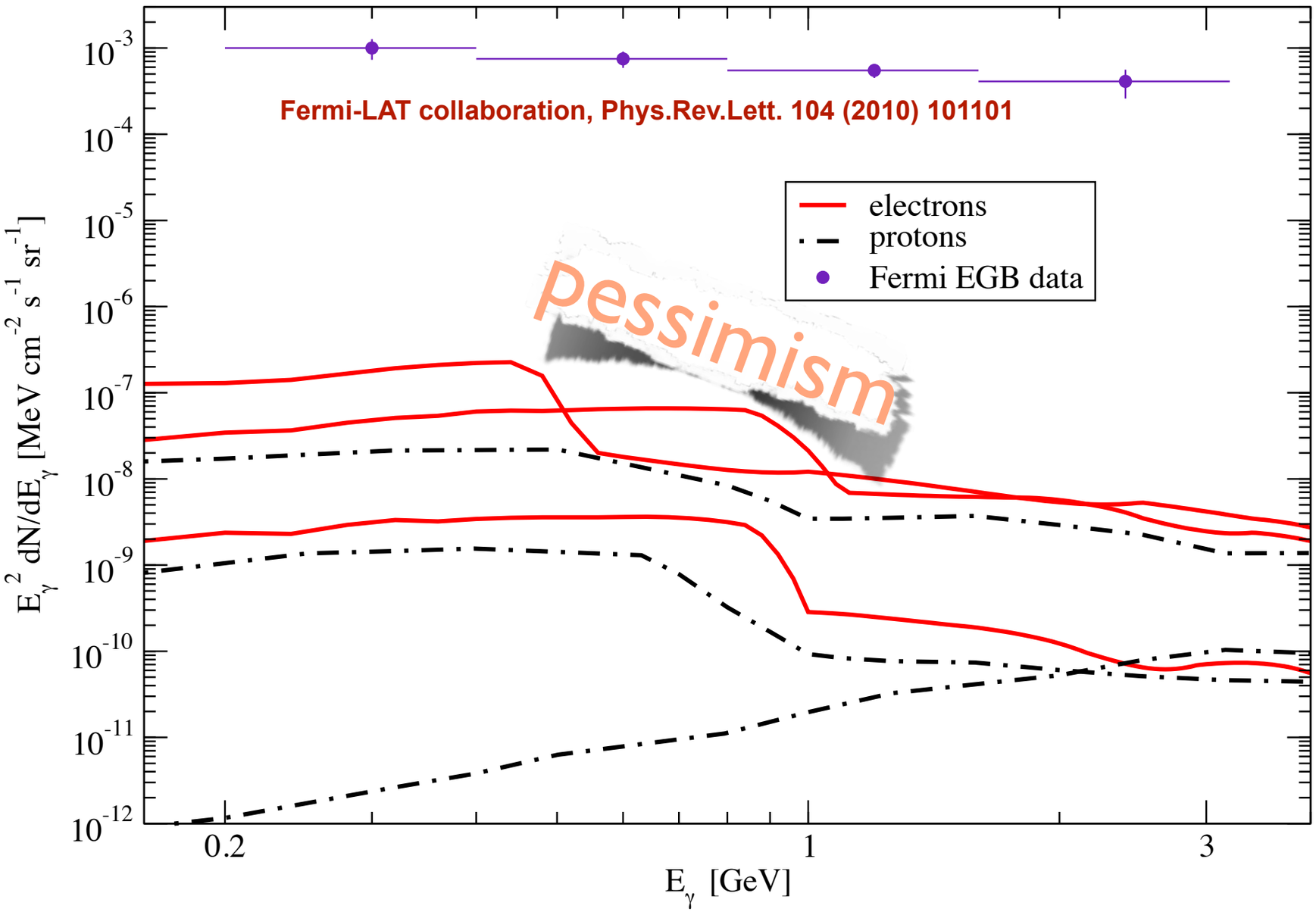
In context

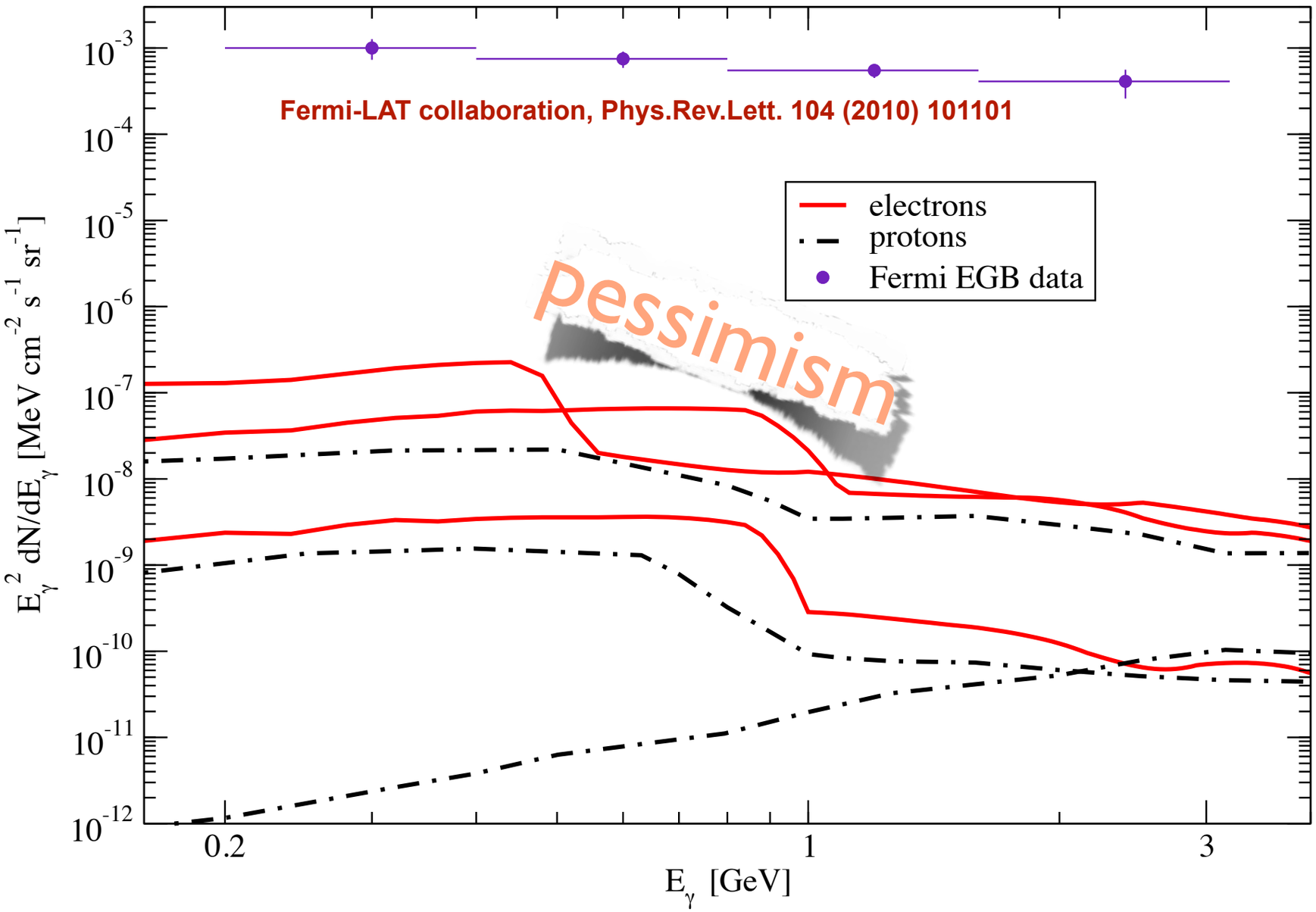


Fermi effective area ~ 10^4 cm^2 , 3 years of observing time ~ 10^8 s, around 1 GeV

$N_S \sim 10^2$, $N_B \sim 10^5$, $N_S/(N_B)^{1/2} \sim 0.3$

Low signal-to-noise, but quite characteristic feature

In context



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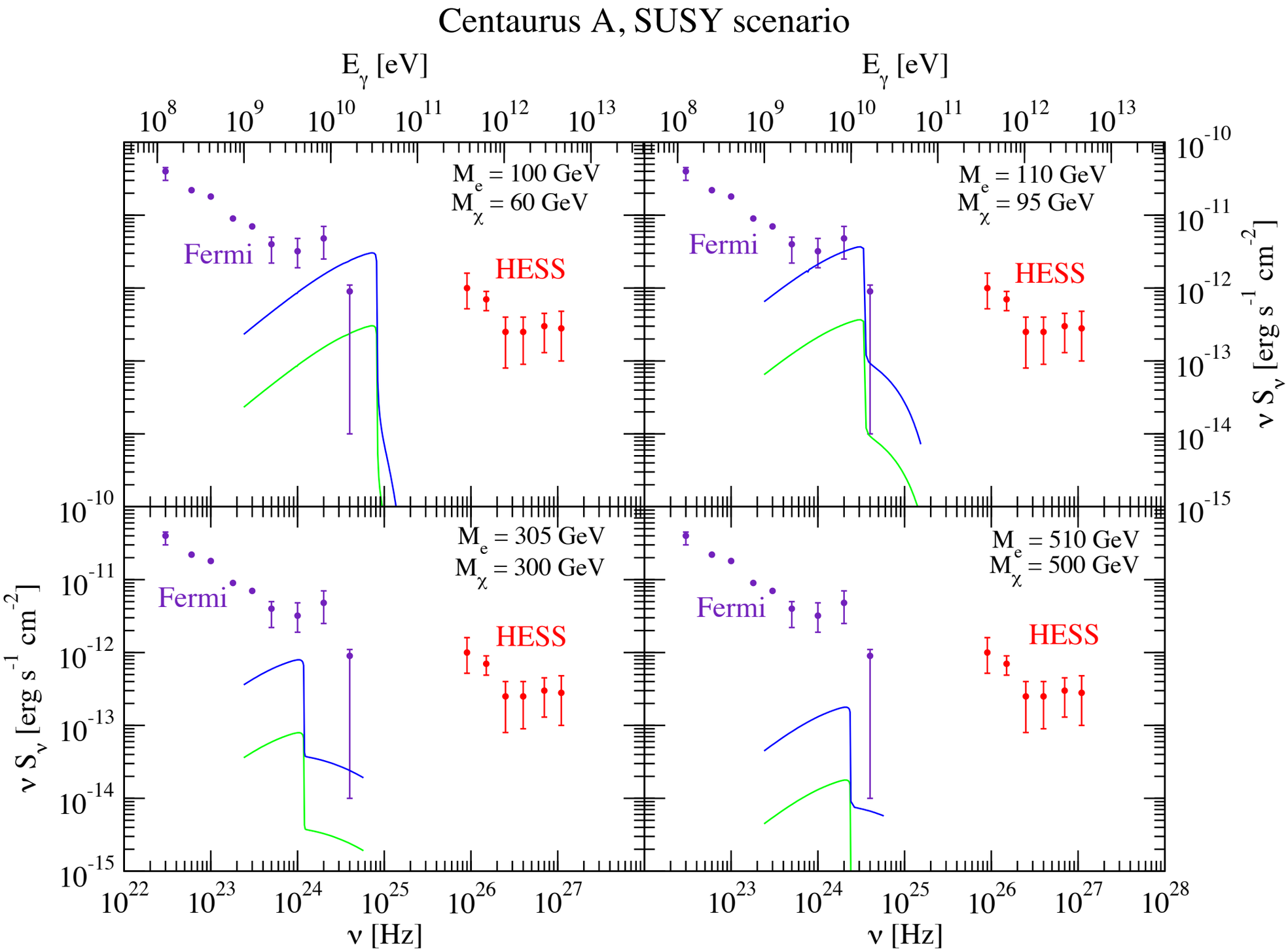
mild optimism

Q: A better place to look at for a similar signature?

A: Active Galactic Nuclei



Gorchtein, Profumo, Ubaldi, Phys.Rev. D82 (2010) 083514

Conclusions

- The gamma-ray signal from scattering of galactic cosmic rays off of dark matter is, in general, subdominant with respect to DM pair annihilation
- In the case of asymmetric dark matter the former is still present (although hard to detect), the latter is not.
- For a specific supersymmetric WIMP model we showed that the signal would have a very distinctive feature, maybe not impossible to detect.