Astrophysical vs. dark matter interpretations of gamma-ray observations in dwarf galaxies

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Based on: arXiv:1807.08740, 1503.02320 (PRL), 1410.2242 (PRD)

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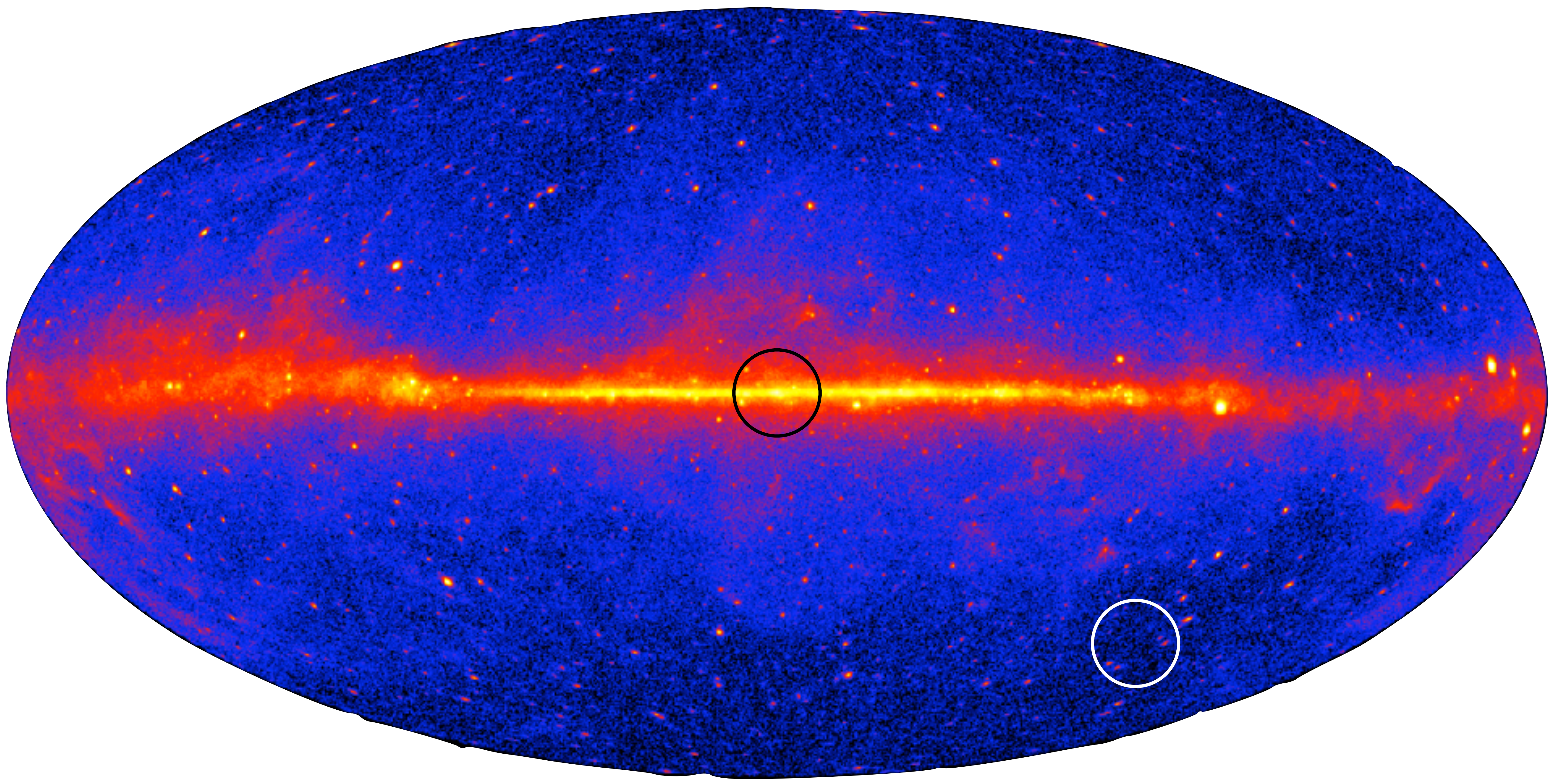
Milky Way dwarf galaxies

Nearby, lots of dark matter ($\log_{10} J \sim 18 - 20$)

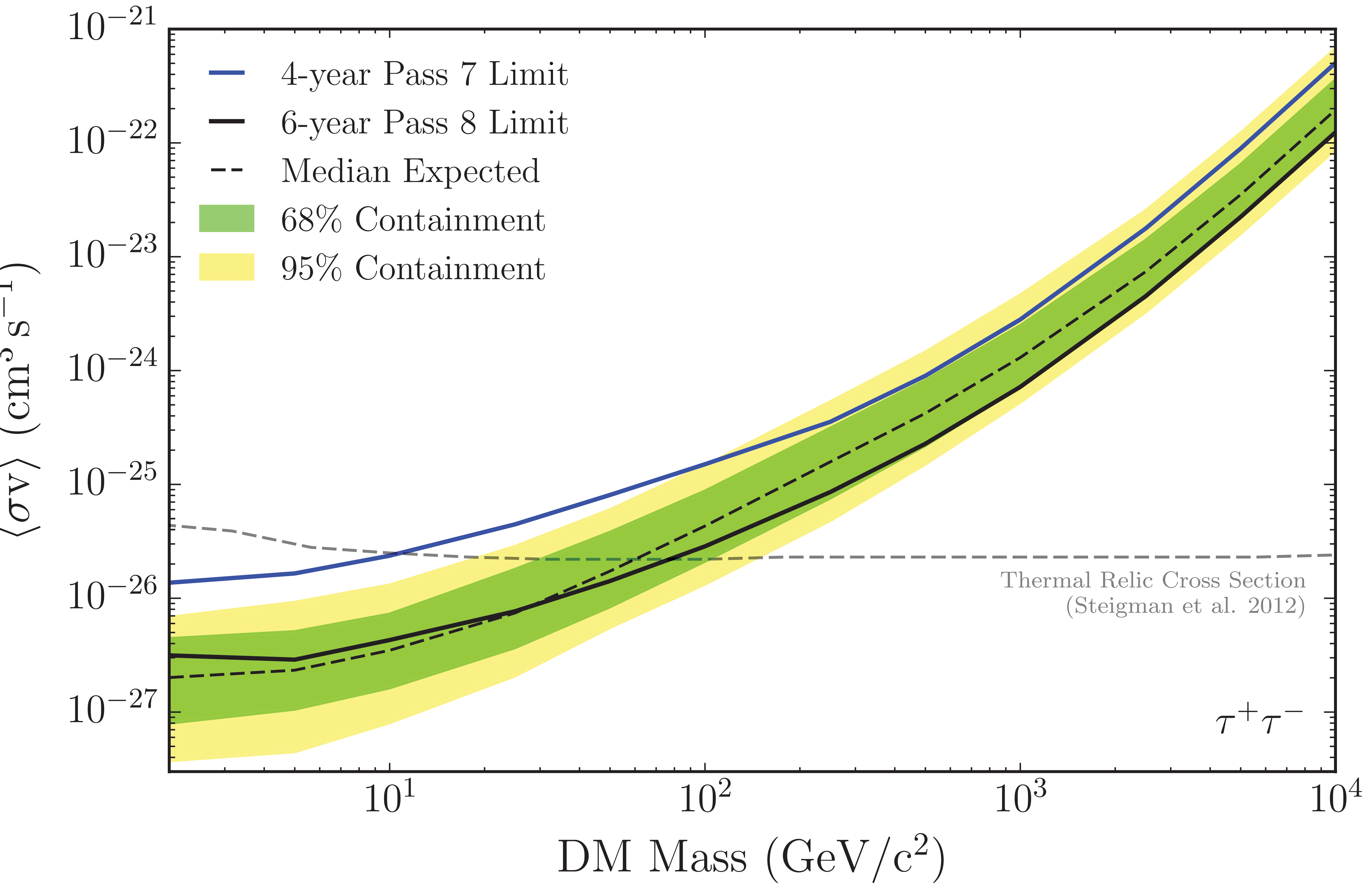
Not much else: no astrophysical background*****

compare to Galactic center



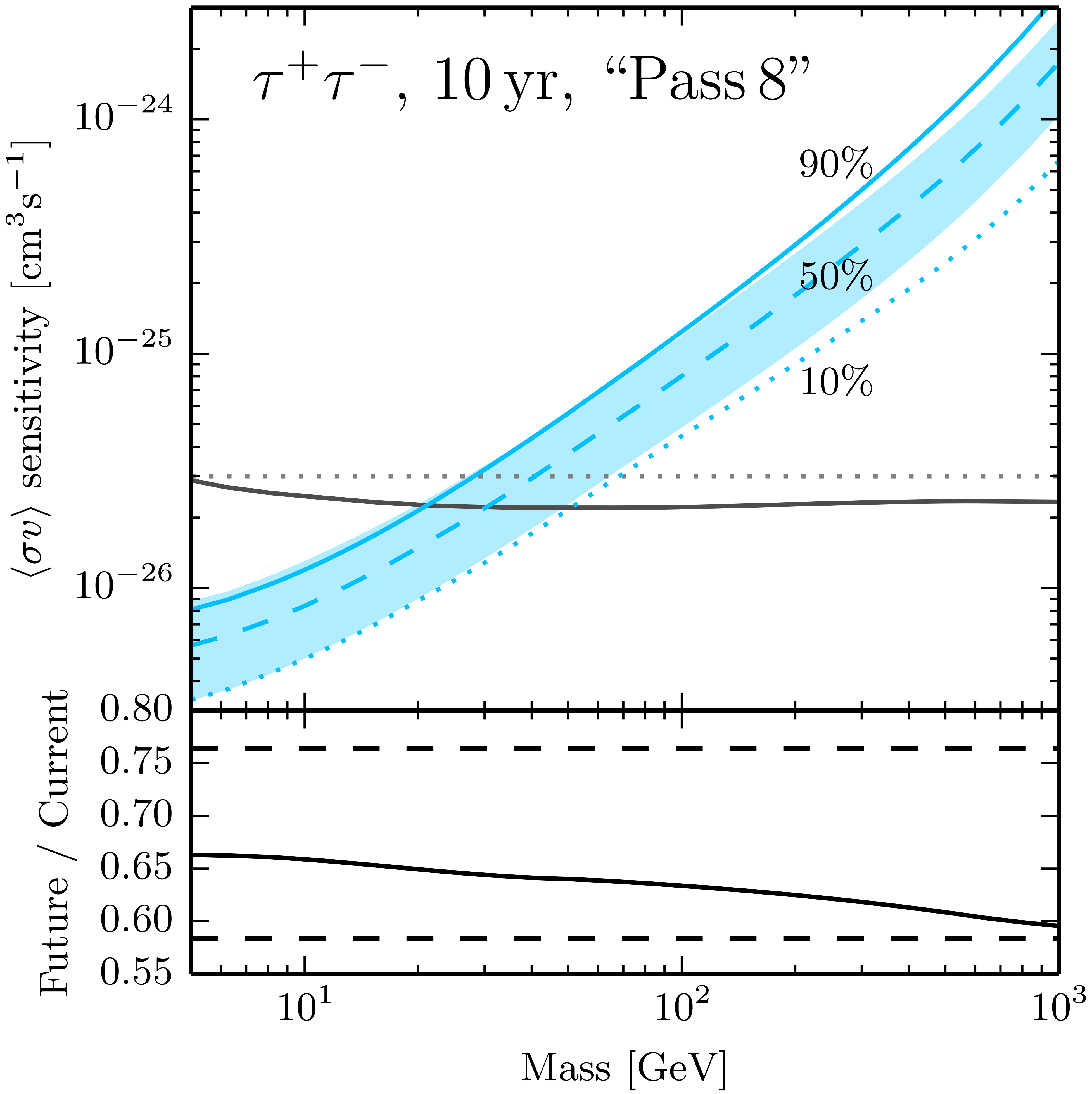
Dwarf searches reach the relic cross section

Cross section limits



Fermi collab 1503.02641 (PRL)

Discovery sensitivity



AGS+ 1410.2242 (PRD)

To discover dark matter annihilation using dwarfs:

1. Gamma-ray data is inconsistent with background

2. Inconsistent with any other possible source
   (e.g. non-DM astrophysics, incorrect diffuse bg models)

3. Consistent with dark matter annihilation
   (compare with other dwarfs, other experiments)

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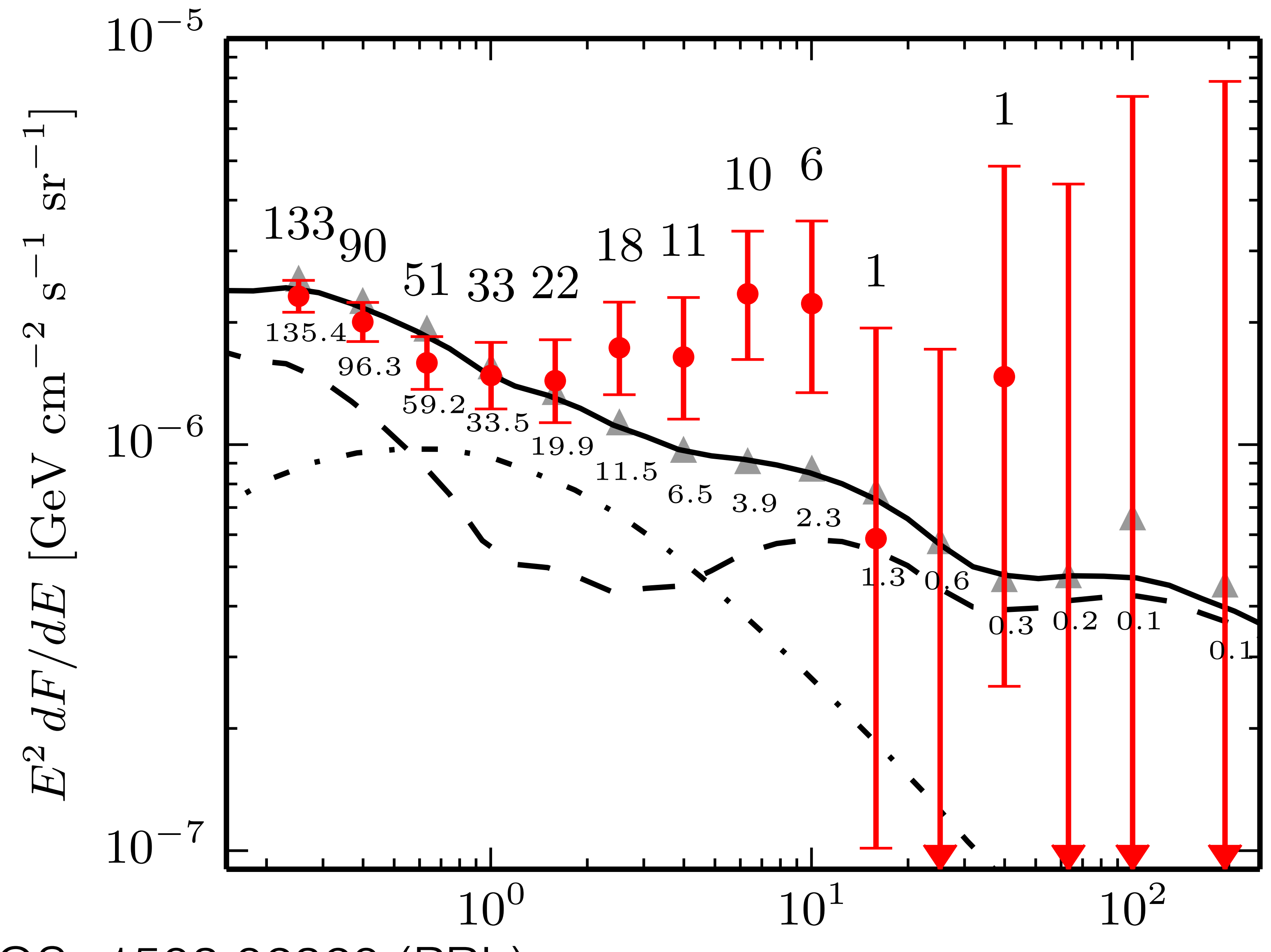
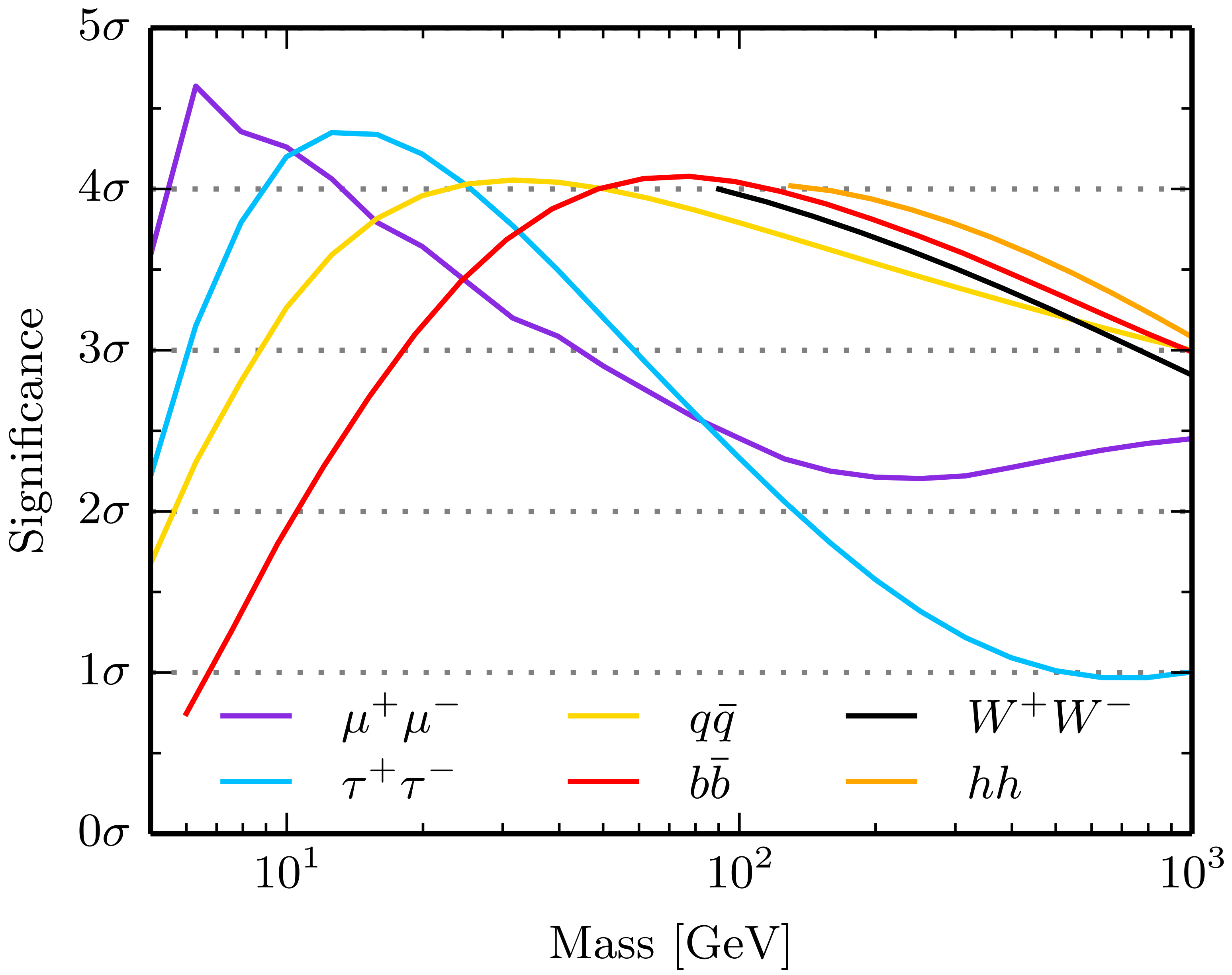
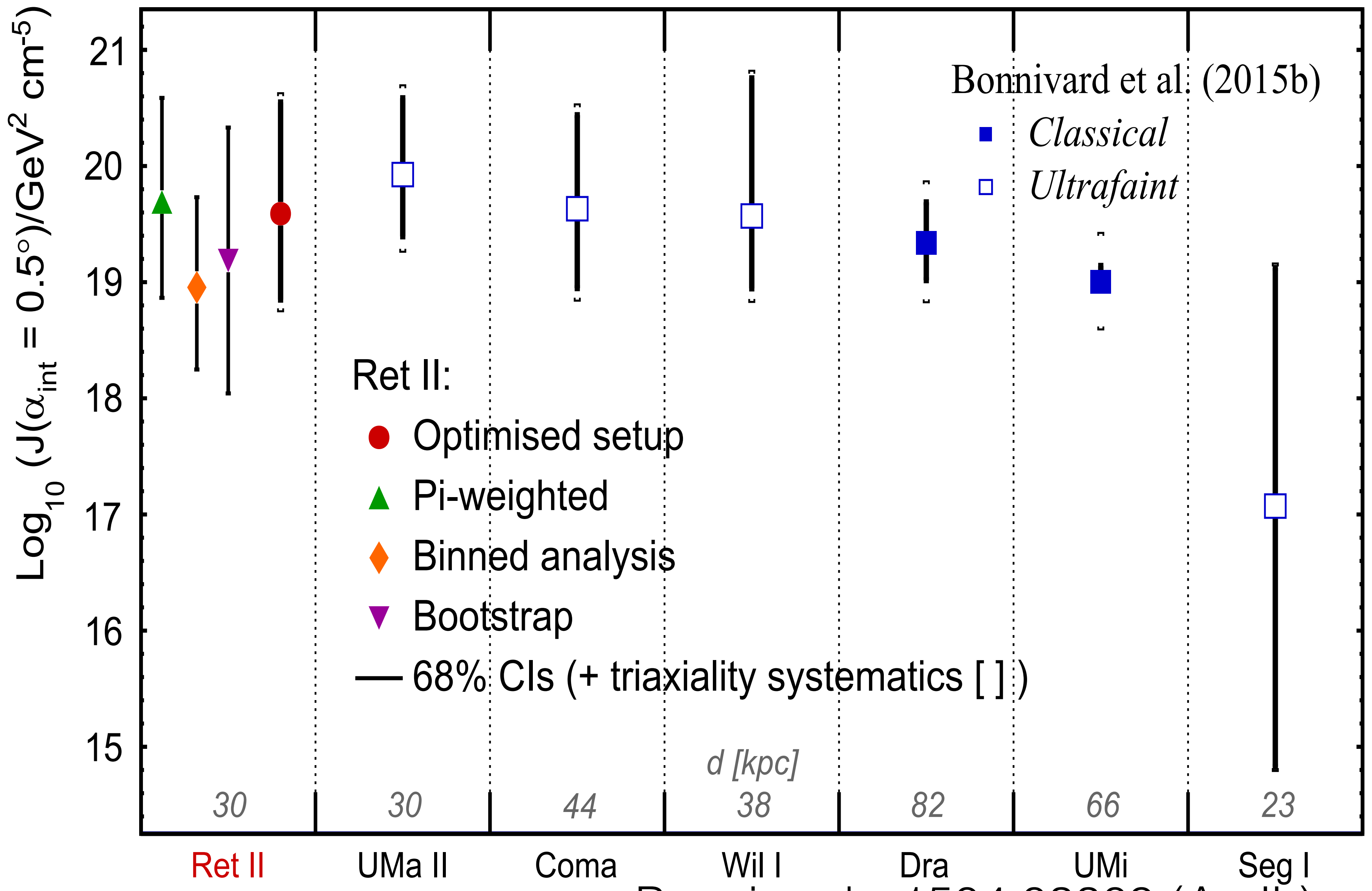
Case study: Reticulum II

6.5 yr Pass 7 Fermi LAT data



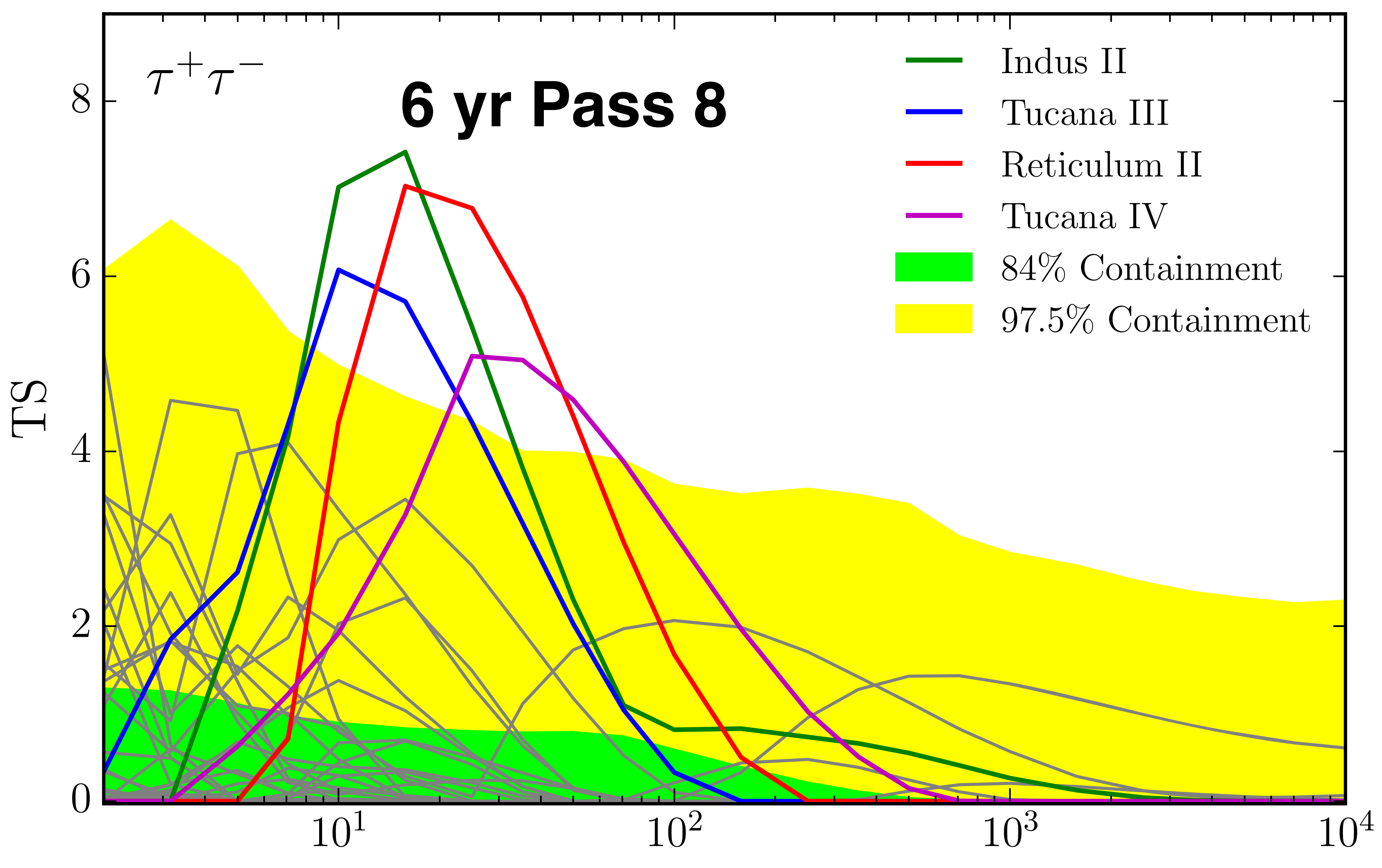
AGS+1503.02320 (PRL)



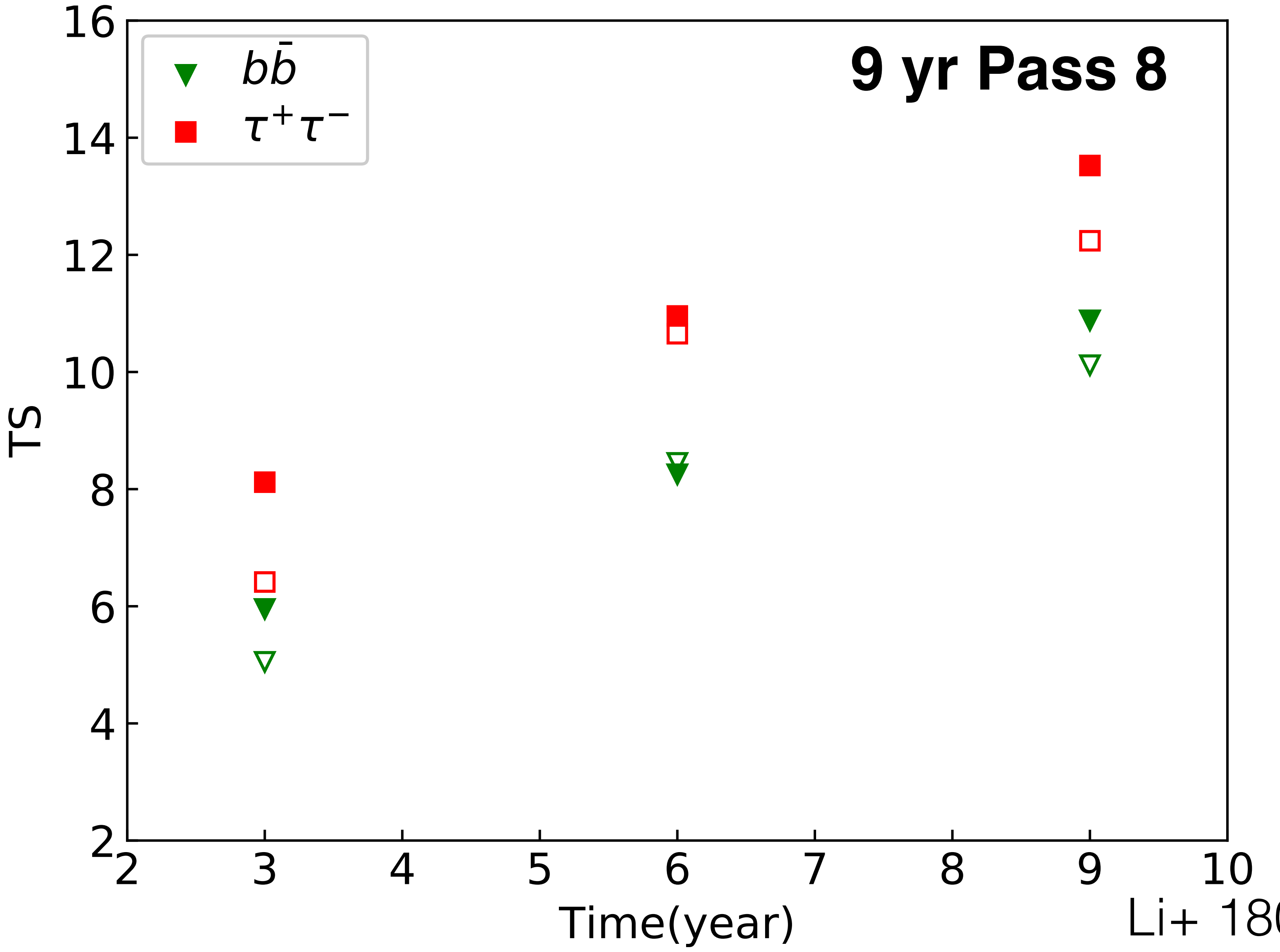


Bonnivard+ 1504.03309 (ApJL)

but much less significant in Pass 8



Albert+ 1611.03184 (ApJ)



Li+ 1805.06612 (PRD)

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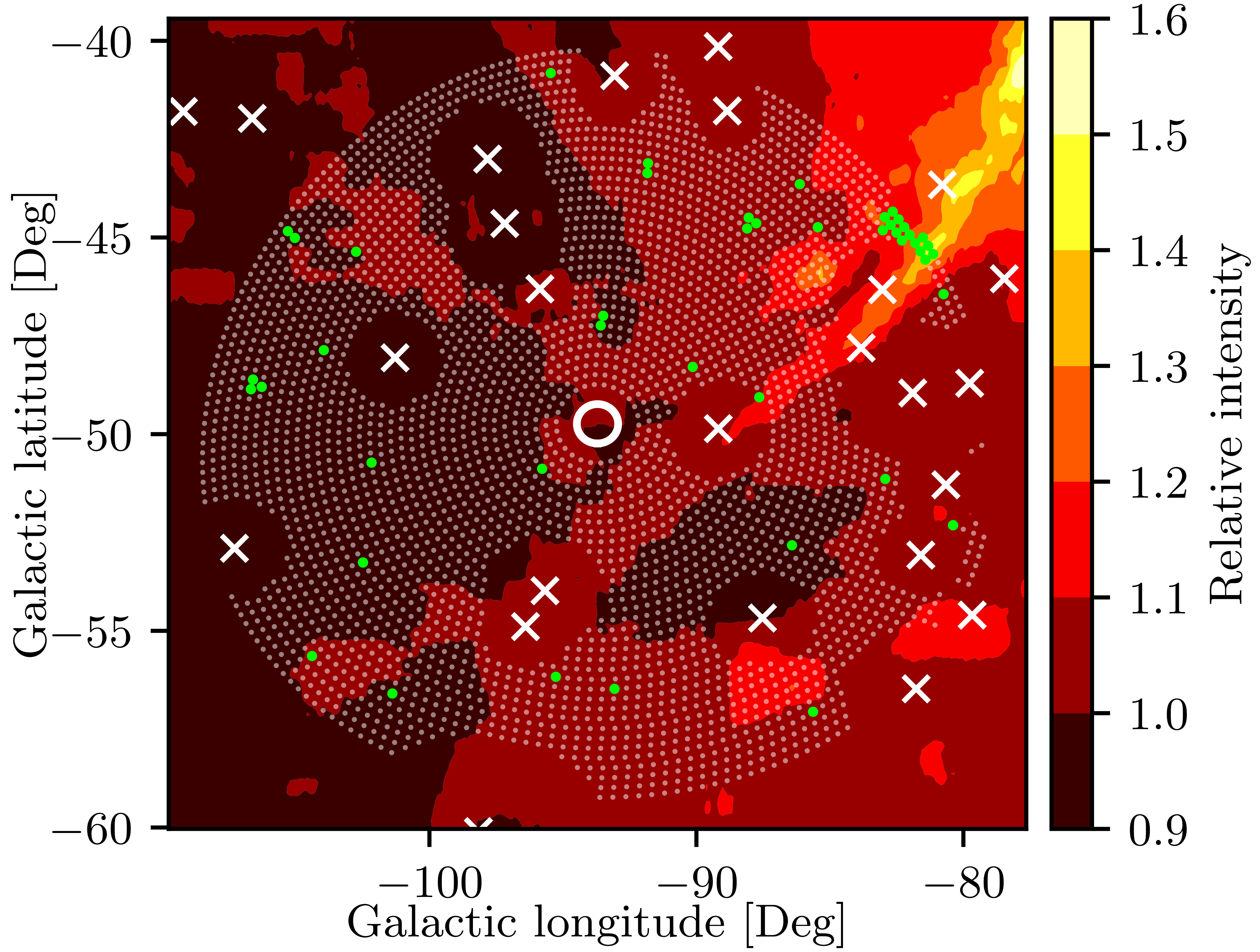
Two ways to model background give two different significances

Diffuse background *model*

- Poisson with given spectrum:
  - “physical” model — cosmic ray interactions in Milky Way, extragalactic integrated isotropic emission, charged particle misidentification
  - No additional non-DM sources along line of sight towards dwarf

p = 0.0001

Empirical background from sampling



p = 0.01

Geringer-Sameth & Koushiappas 1108.2914 (PRL), AGS+ 1410.2242 (PRD), AGS+1503.02320 (PRL)

Two ways to model background give two different significances

Diffuse background *model*

$p = 0.0001$

H_0: No additional source

Empirical background from sampling

$p = 0.01$

H_0: No dark matter annihilation

Can combine *p's* to estimate that at least 99% of such "hot spots" contain point sources above diffuse level

AGS+ 1807.08740

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Assume a new source in direction of dwarf and characterize it

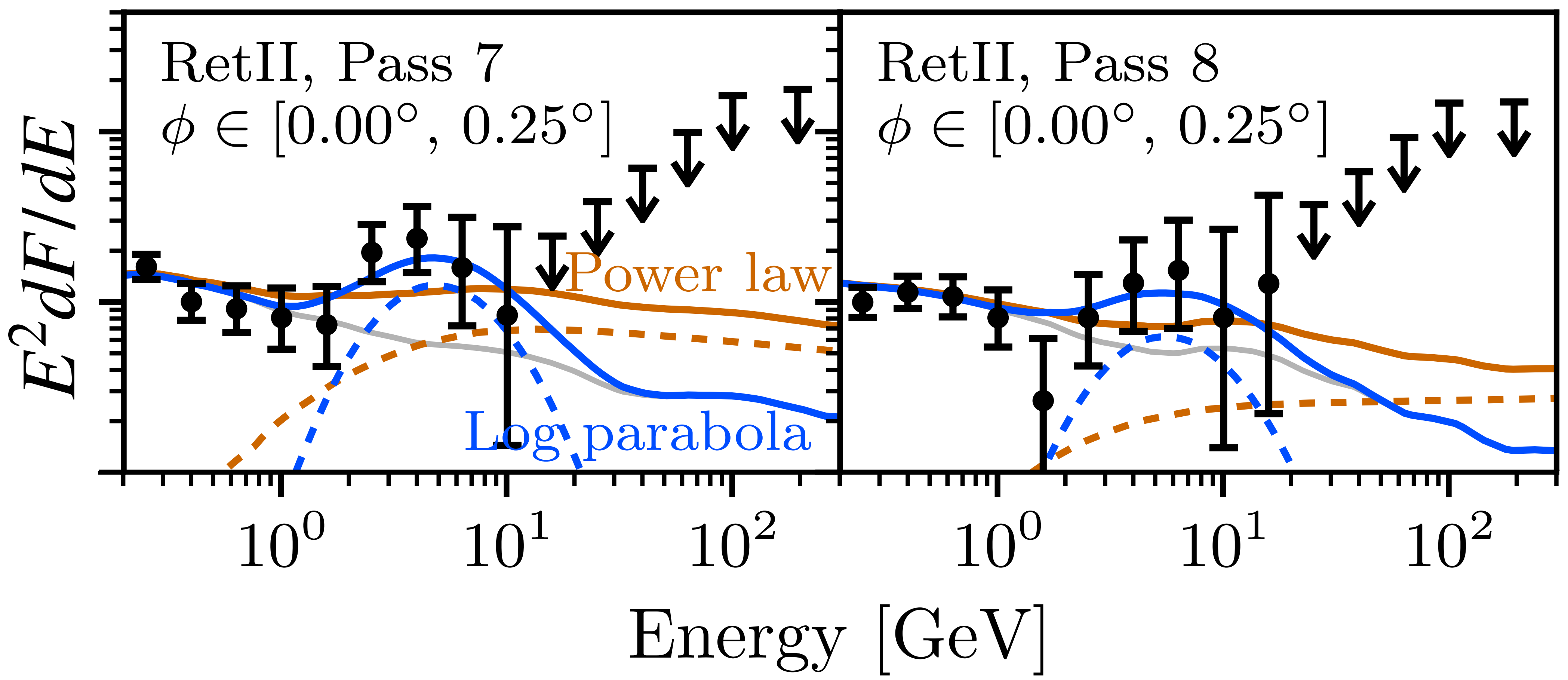
Test designed to distinguish dark matter annihilation from astrophysical sources

$$\frac{dF(E \mid \theta)}{dE} = F_0 \left(\frac{E}{E_0}\right)^{-\alpha-\beta \log(E/E_0)}$$

2*loglike

α		β		F_0 $[10^{-11}\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{GeV}^{-1}]$		$\lambda(\mathbf{X}_\gamma)$		Goodness of fit p value	
Pass 7	Pass 8	Pass 7	Pass 8	Pass 7	Pass 8	Pass 7	Pass 8	Pass 7	Pass 8
−0.70	-1.00^{*a}	1.00^*	0.95	3.0	0.80	2.5	1.3	0.73	0.90
2.09	1.99			10.6	2.8	9.9	4.9	0.025	0.16
Background-only model						19.9	7.0	8.8×10^{-5}	0.027

Spectrum curved at p = 0.025 level



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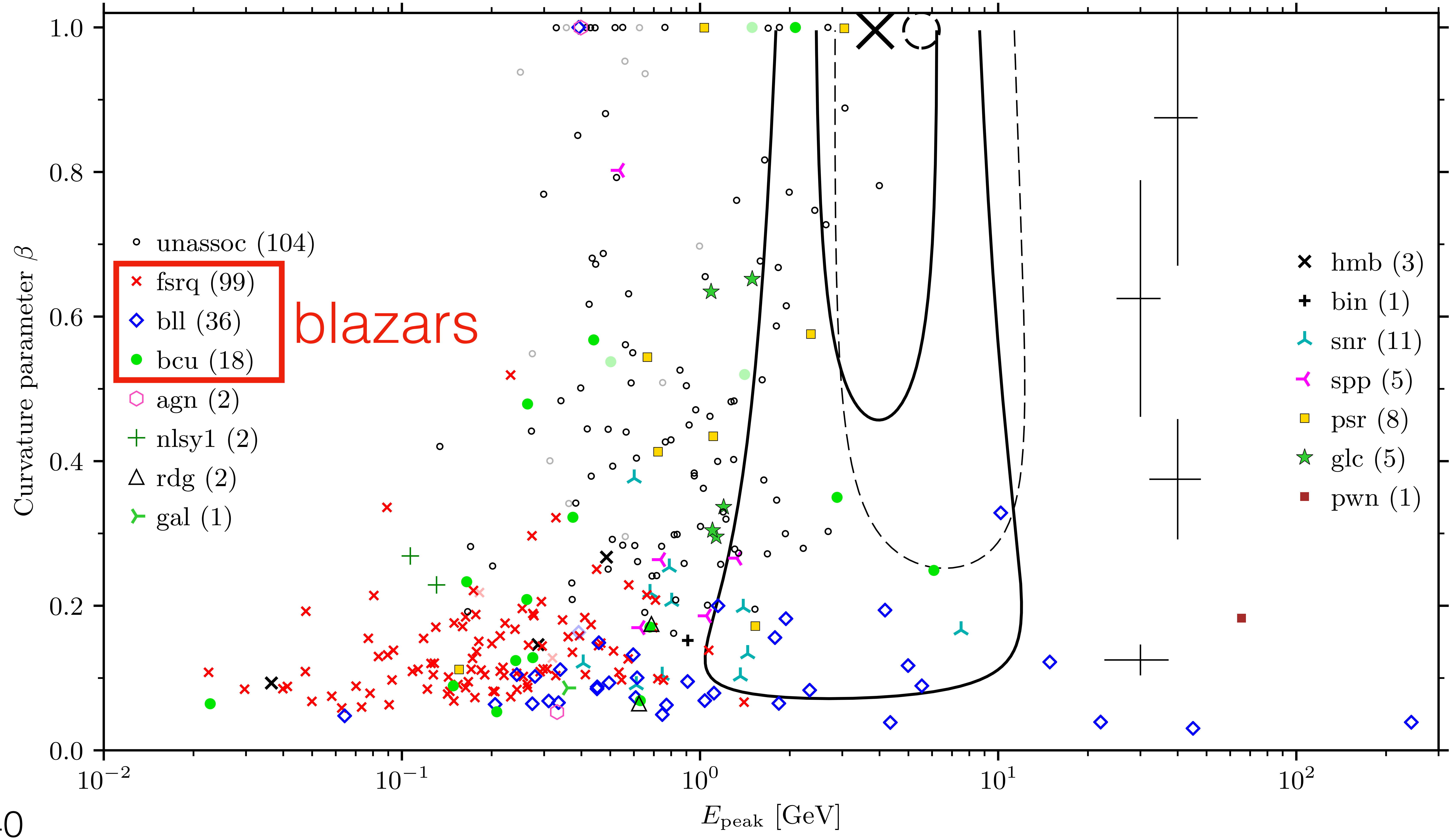
Compare with known classes of gamma-ray sources

$$\frac{dF(E \mid \theta)}{dE} = F_0 \left(\frac{E}{E_0}\right)^{-\alpha-\beta\log(E/E_0)}$$

$E_{\rm peak}$ = energy at peak of SED $E^2 dF/dE$



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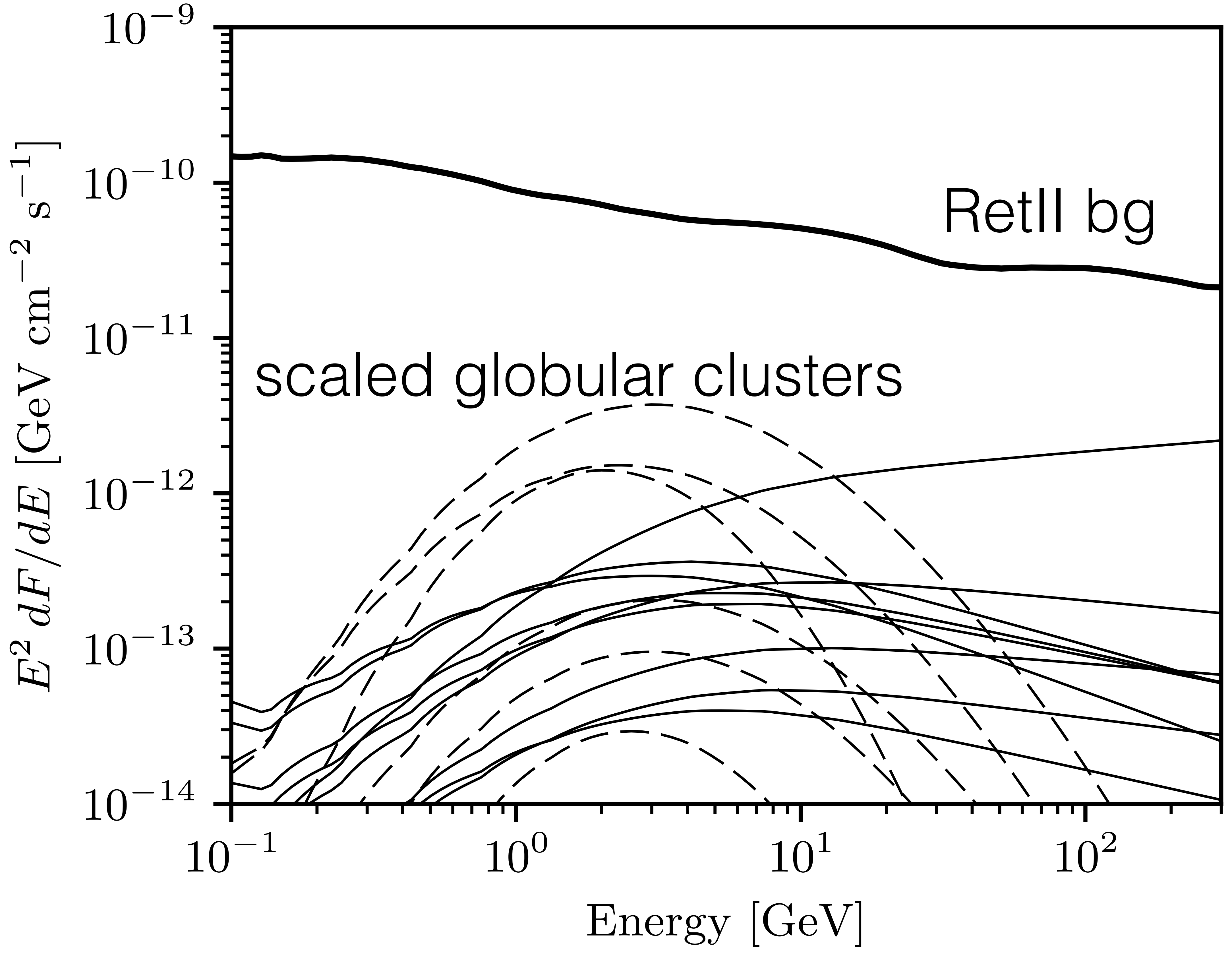
Pulsar population in the dwarf? No



see also Winter+ 1607.06390 (ApJL)

AGS+ 1807.08740

Dwarfs are at the forefront of dark matter detection but advances in analysis are necessary

- Ruling out diffuse bg model is not enough
- Need to distinguish DM annihilation from non-DM source populations without sacrificing sensitivity
- Method applies to any dwarf which is a promising DM target and shows evidence for gamma-ray emission along line of sight
- Applies equally well to any dark matter target where you expect localized emission (e.g. galaxy clusters, groups, dark subhalos)