Fermi Gamma-ray Space Telescope

A Search for Dark Matter Annihilation in Dwarf Spheroidal Galaxies with Pass 8 Data

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on behalf of the
Fermi-LAT Collaboration

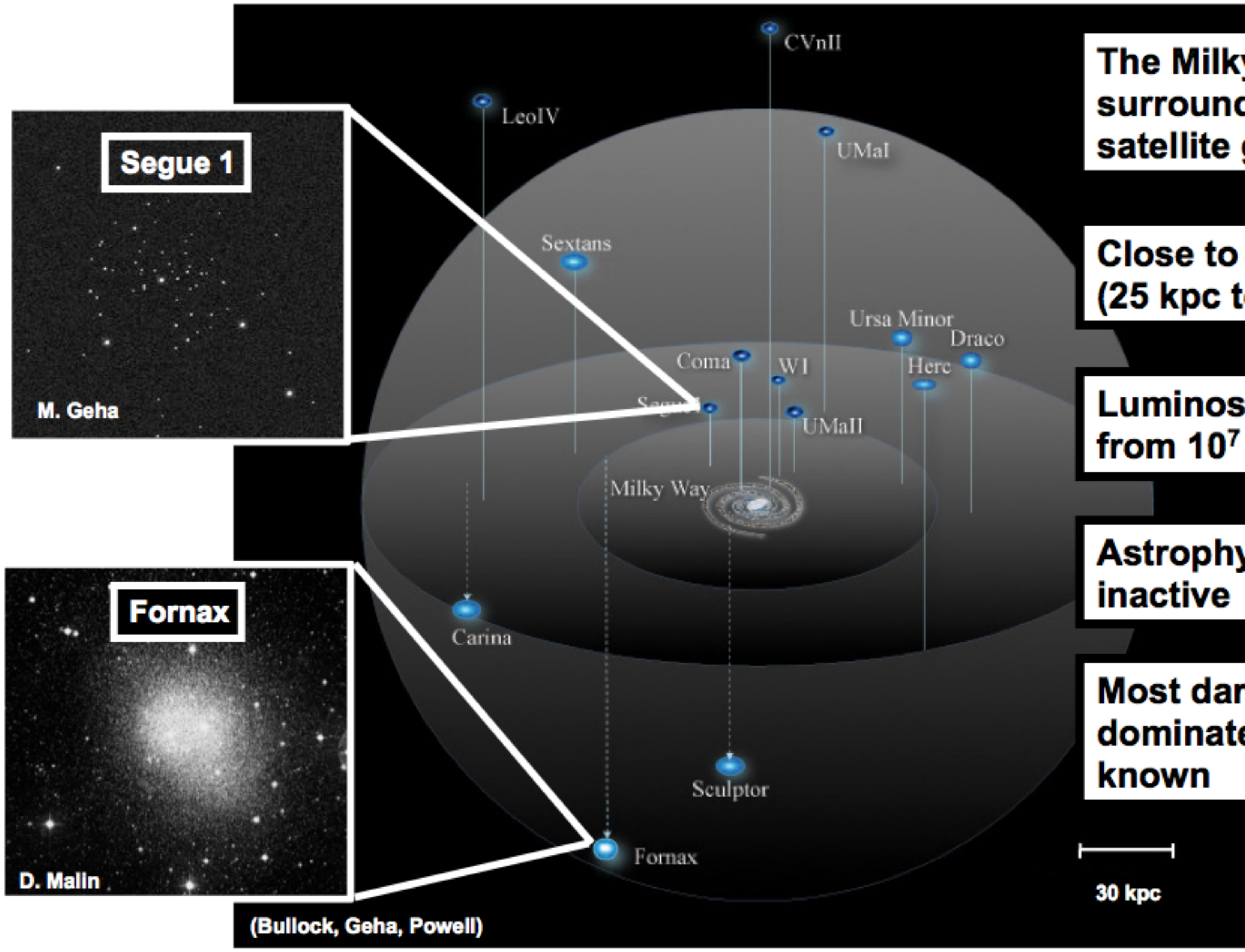
5th Fermi Symposium
October 24, 2014

Stockholm University

Oskar Klein centre

Introduction

Dwarf Spheroidal Galaxies



- **The Milky Way is surrounded by satellite galaxies** ← ~25 known
- **Close to Earth (25 kpc to 250 kpc)**
- **Luminosities range from $10^7\,L_\odot$ to $10^3\,L_\odot$**
- **Astrophysically inactive**
- **Most dark matter dominated objects known**

THEORETICAL YIELD

$$\frac{d\Phi_\gamma}{dE_\gamma} = \underbrace{\frac{1}{4\pi}\frac{\langle\sigma v\rangle}{2m_\chi^2}\sum_f \frac{dN_\gamma^f}{dE_\gamma}B_f}_{\text{particle}}\ \underbrace{\int_{\Delta\Omega} d\Omega \int_{los} \rho^2(l)\ dl(\psi)\ d\Omega}_{\text{astro (“J-factor”)}}$$

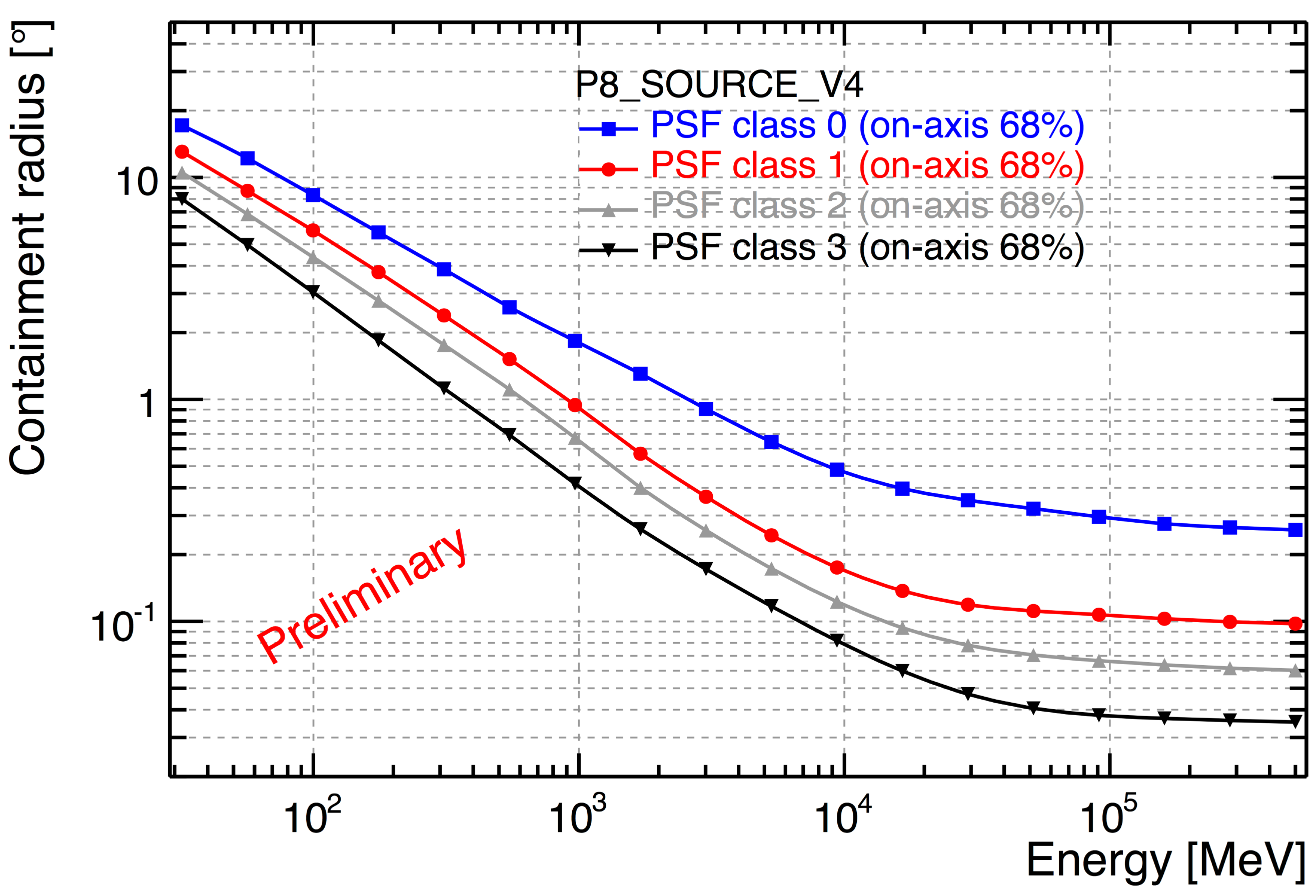
Pass 8

(for more information see P. Bruel's talk from Wednesday)

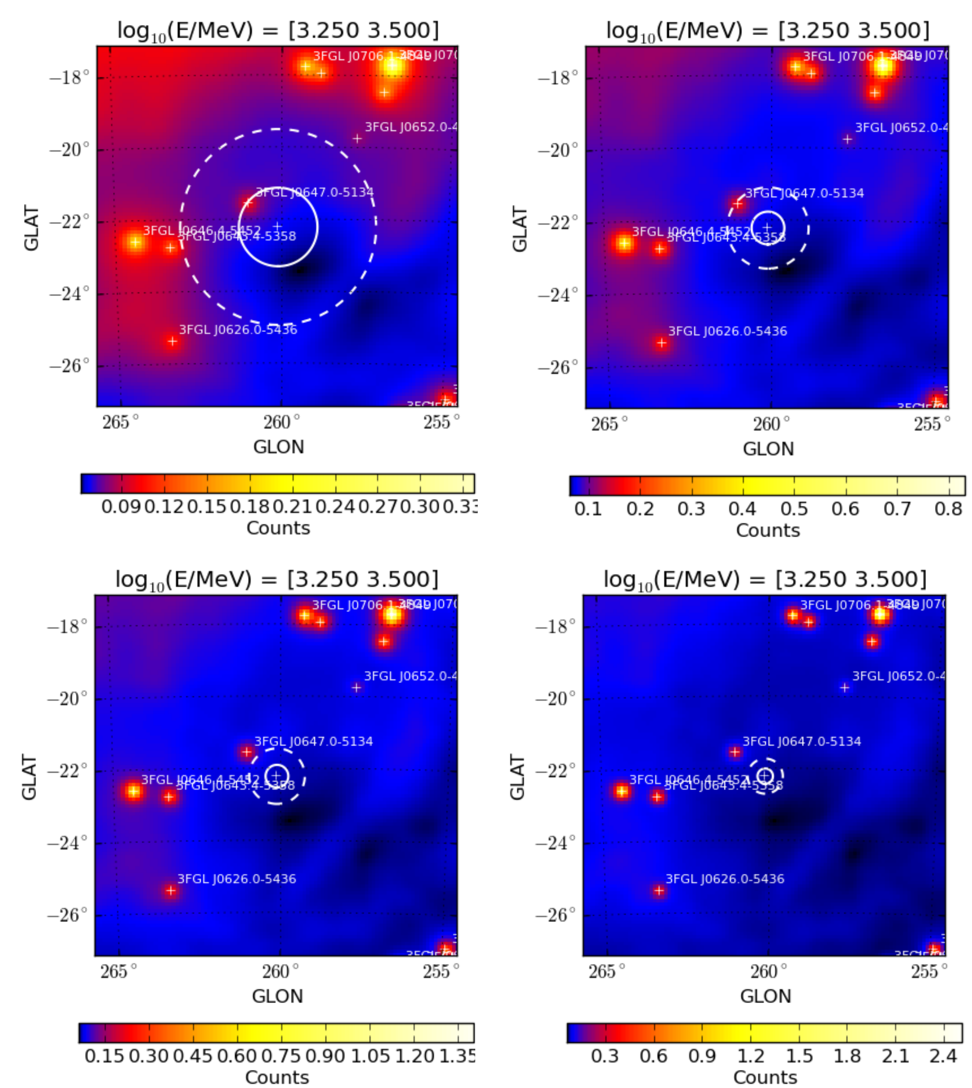
MORE DATA, MORE ACCURACY,

effective area	angular resolution	point-source sensitivity
+25% > 1 GEV	+10-15% > 1 GEV	+40% @ 1-10 GEV

AND MORE INFORMATION!



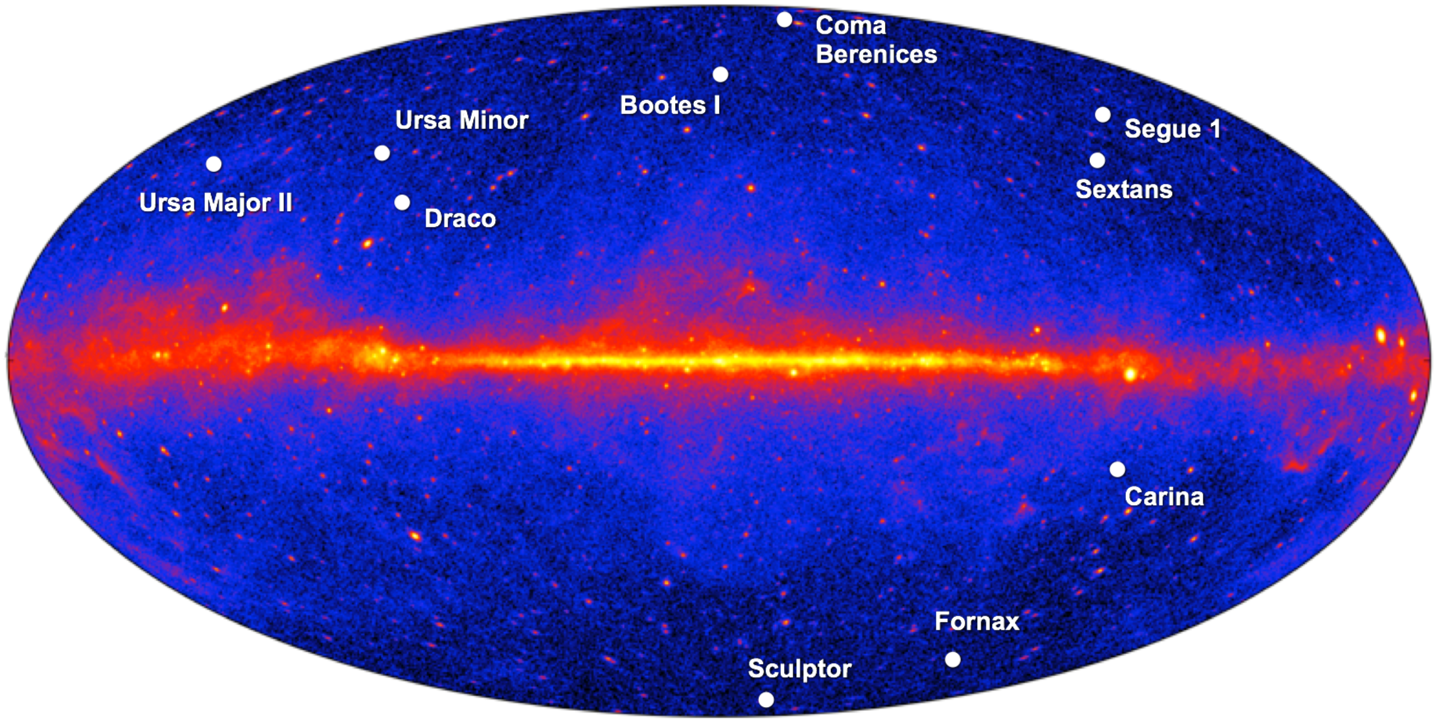
containment in psf classes



Data Set & Technique

FOURTH GENERATION

arXiv	irf	time	targets	joint?
1001.4531	P6	11 mo.	10	no



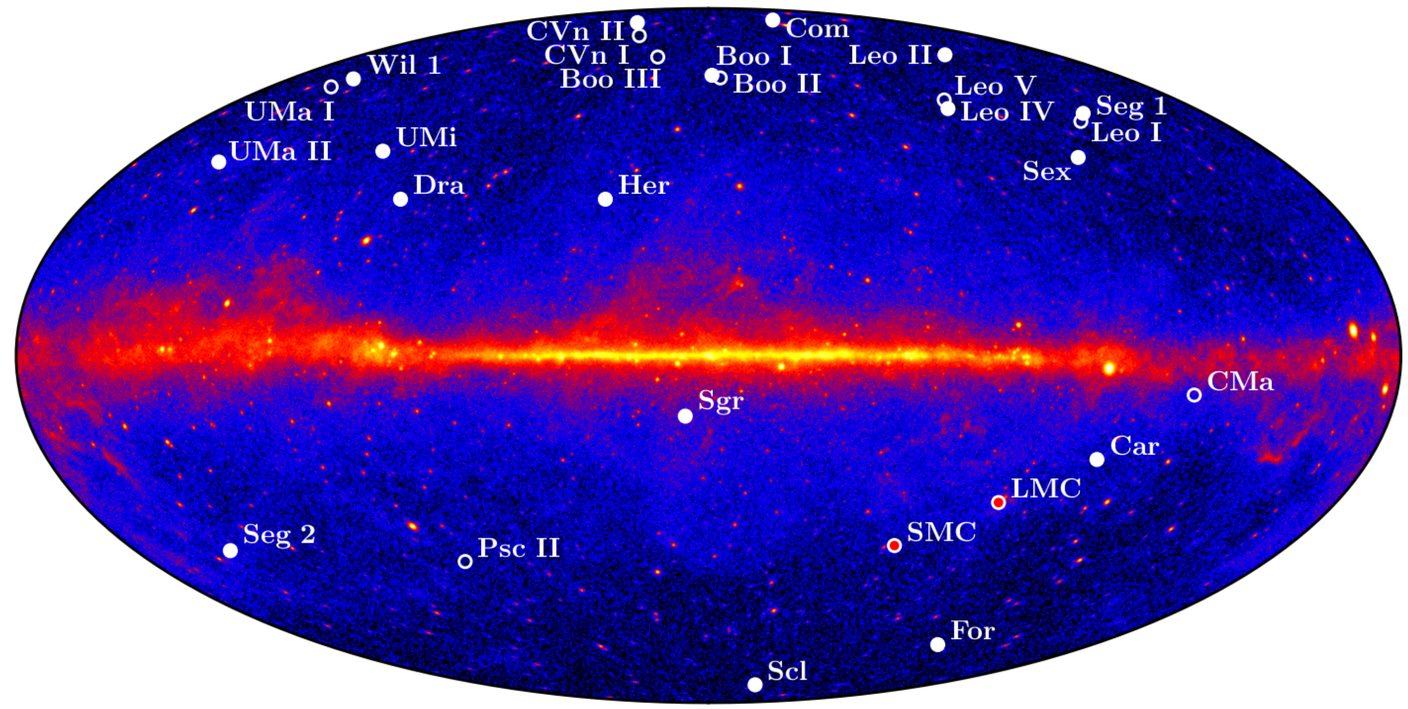
EFFECTIVE LIKELIHOOD

$$L_2(\mathcal{D}|\boldsymbol{\mu}, \boldsymbol{\theta_t}) = L_t^{\mathrm{LAT}}(\mathcal{D}_t|\boldsymbol{\mu}, \boldsymbol{\theta_t})$$

Data Set & Technique

FOURTH GENERATION

arXiv	irf	time	targets	joint?
1001.4531	P6	11 mo.	10	no
1108.3546	P6	24 mo.	10	yes
1310.0828	P7	48 mo.	15	yes



EFFECTIVE LIKELIHOOD

(term accounts for uncertainty in J-factor)

$$L_2(\mathcal{D}|\boldsymbol{\mu},\boldsymbol{\theta_t}) = L_t^{\mathrm{LAT}}(\mathcal{D}_t|\boldsymbol{\mu},\boldsymbol{\theta_t}) \times \frac{1}{\ln(10)\mathrm{J_t}\sqrt{2\pi}\sigma_\mathrm{t}} e^{-(\log_{10}(\mathrm{J_t})-\overline{\log_{10}(\mathrm{J_t})})^2/2\sigma_\mathrm{t}^2}$$

$$L_3(\mathcal{D}|\boldsymbol{\mu},\{\boldsymbol{\theta_t}\}) = \prod_{targets} L_2(\mathcal{D}|\boldsymbol{\mu},\boldsymbol{\theta_t})$$

*(combine information from all targets)

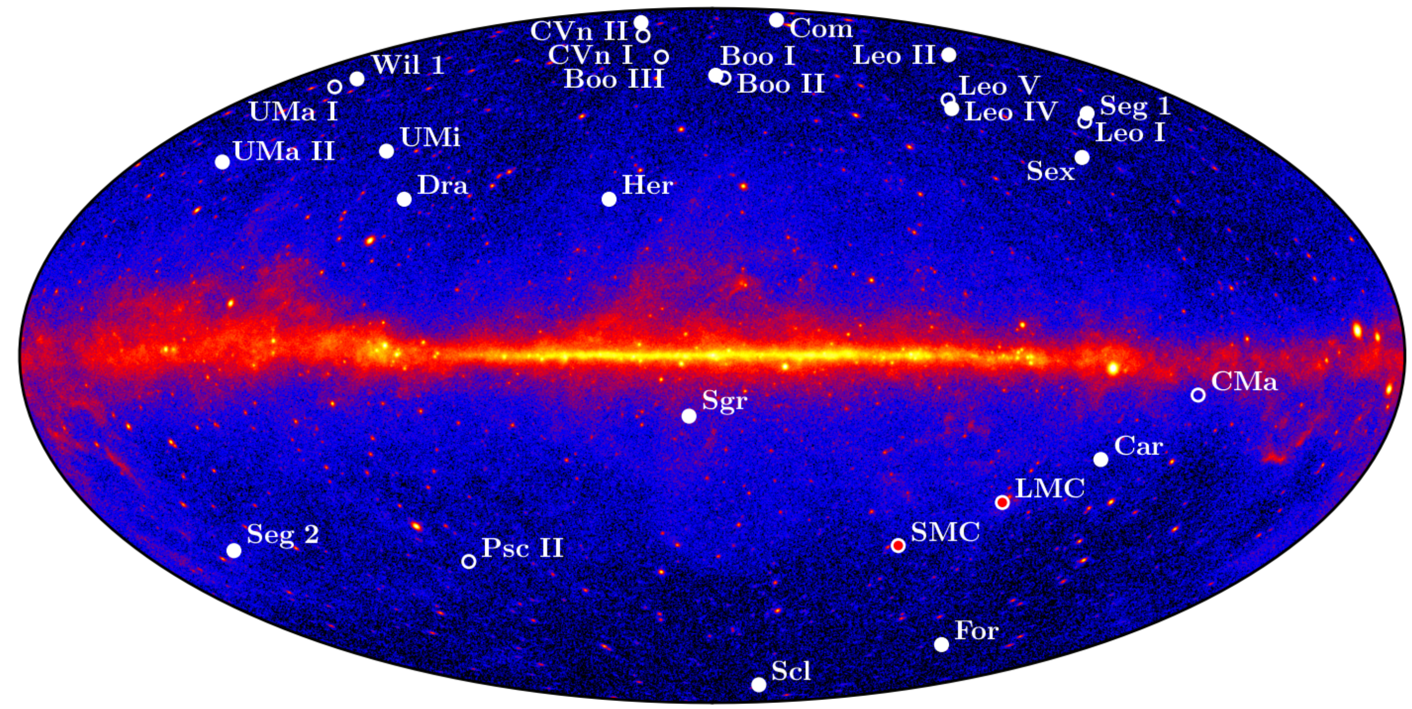
*see talk from Alex on Wednesday, also poster 2.01

Data Set & Technique

FOURTH GENERATION

arXiv	irf	time	targets	joint?
1001.4531	P6	11 mo.	10	no
1108.3546	P6	24 mo.	10	yes
1310.0828	P7	48 mo.	15	yes
	P8	60 mo.	15	yes x2!

[1] The Astrophysical Journal, Volume 712, Issue 1, pp. 147-158 (2010)
[2] Physical Review Letters, vol. 107, Issue 24, id. 241302
[3] Phys.Rev. D89 (2014) 4, 042001



EFFECTIVE LIKELIHOOD

(term accounts for uncertainty in J-factor)

$$L_2(\mathcal{D}|\boldsymbol{\mu}, \boldsymbol{\theta_t}) = L_t^{\mathrm{LAT}}(\mathcal{D}_t|\boldsymbol{\mu}, \boldsymbol{\theta_t}) \times \frac{1}{\ln(10)\mathrm{J_t}\sqrt{2\pi}\sigma_{\mathrm{t}}} e^{-(\log_{10}(\mathrm{J_t}) - \overline{\log_{10}(\mathrm{J_t})})^2/2\sigma_{\mathrm{t}}^2}$$

$$L_3(\mathcal{D}|\boldsymbol{\mu}, \{\boldsymbol{\theta_t}\}) = \prod_{targets} L_2(\mathcal{D}|\boldsymbol{\mu}, \boldsymbol{\theta_t})$$

← *(combine information from all targets)

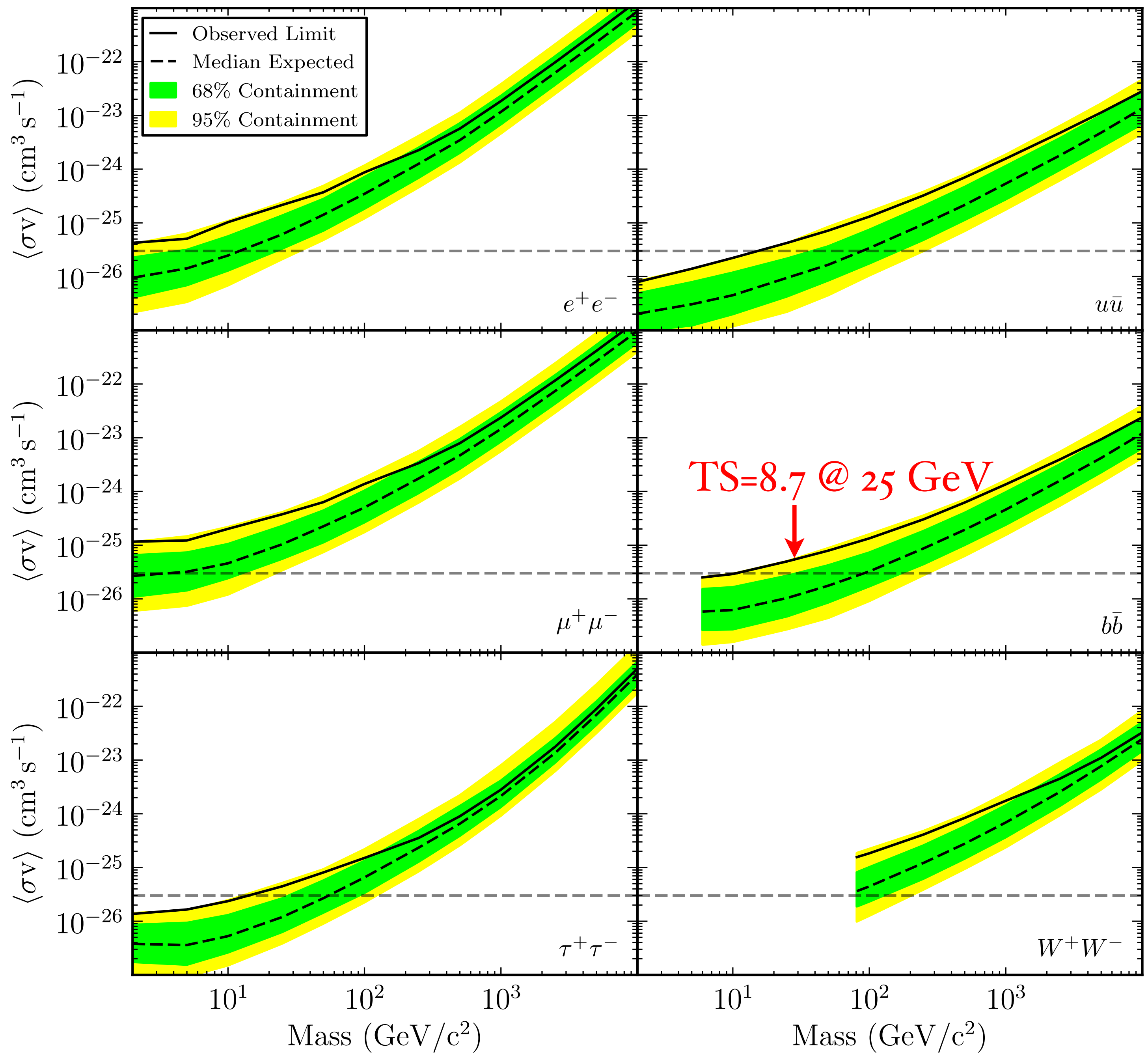
$$L_4(\mathcal{D}|\boldsymbol{\mu}, \{\boldsymbol{\theta_t}\}) = \prod_{classes} L_3(\mathcal{D}_c|\boldsymbol{\mu}, \{\boldsymbol{\theta_t}\})$$

← (combine information from all psf classes)

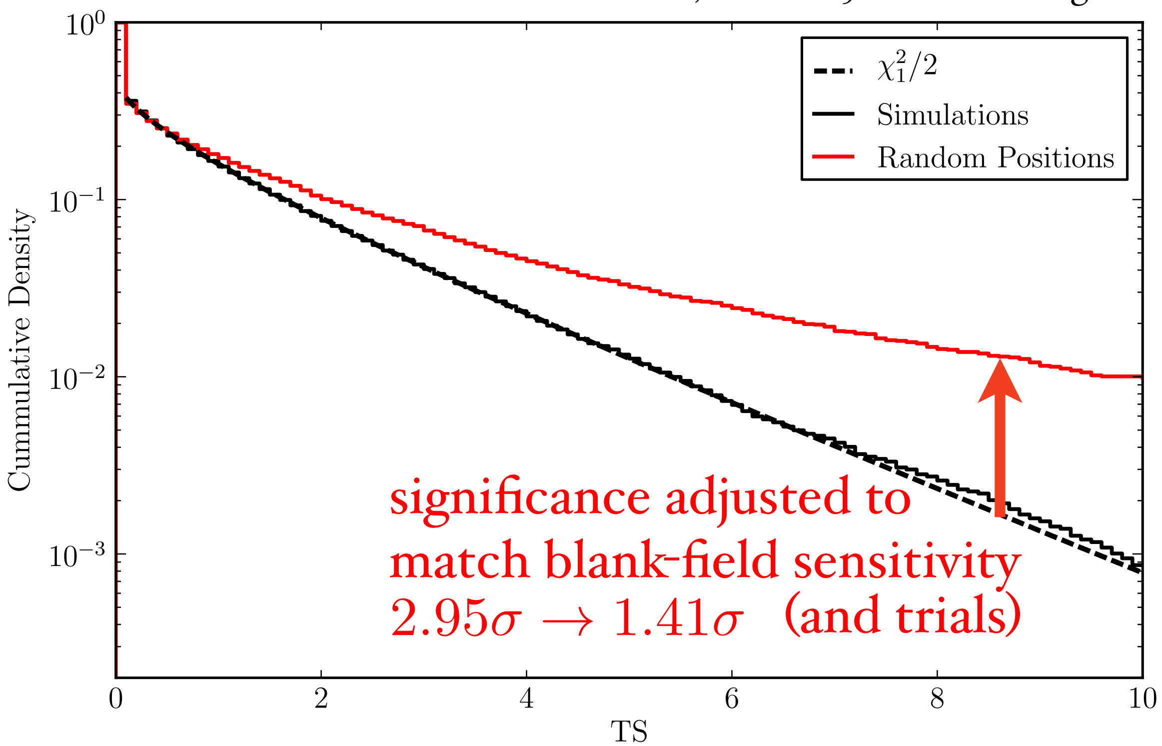
*see talk from Alex on Wednesday, also poster 2.01

Pass 7 Status

Phys.Rev. D89 (2014) 4, 042001



null distribution, fit with 25 GeV b-bbar signal



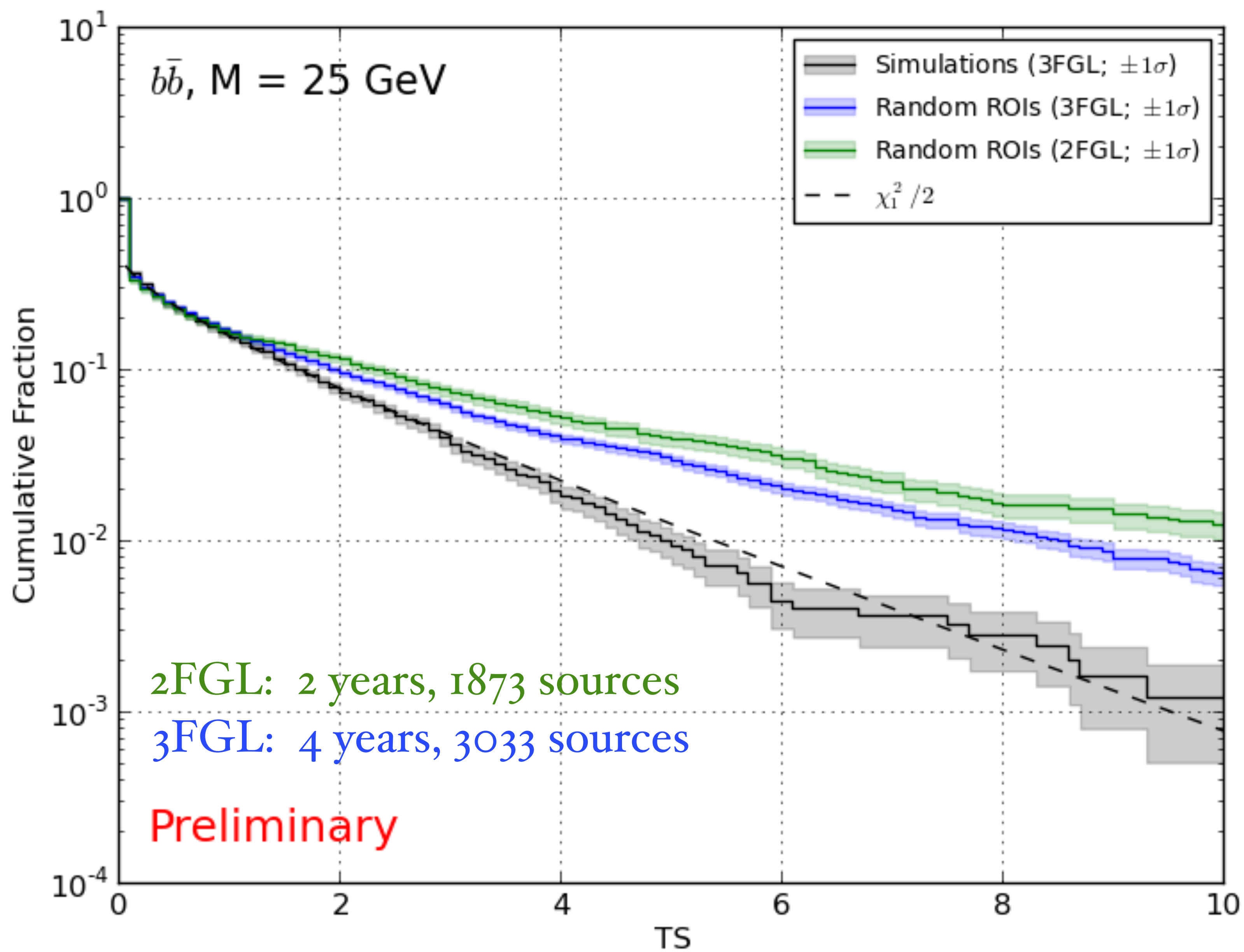
OUTSTANDING ?'S

- What causes the non-asymptotic TS distribution?
- Is the excess dark matter?

Blank Fields

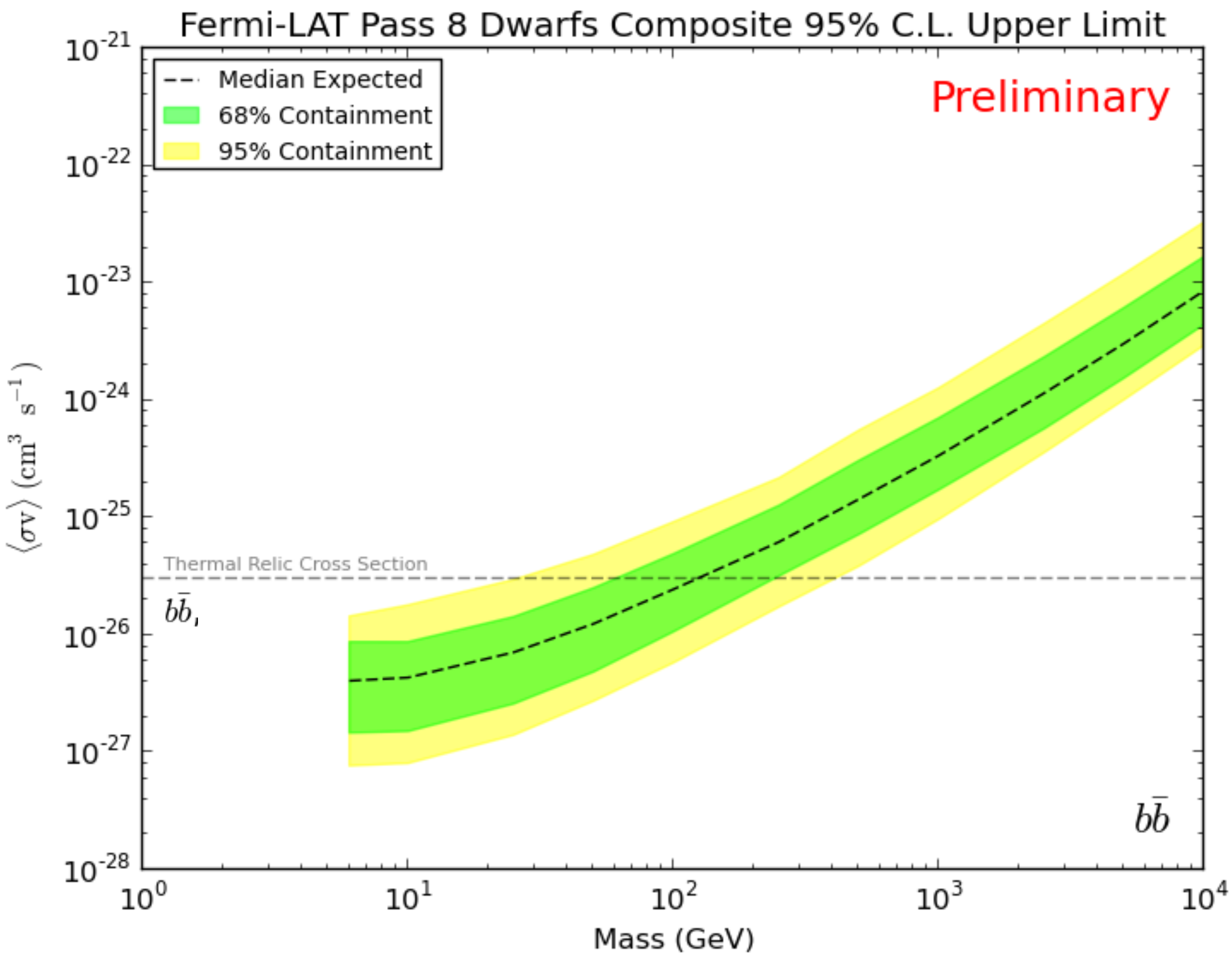
PRIMARY CAUSE?

- Using a more extensive point-source catalog relieves some of the MC-data discrepancy.
- Could be further relieved by adding multi-wavelength sources (e.g. BZCAT, see 1409.1572)



Results

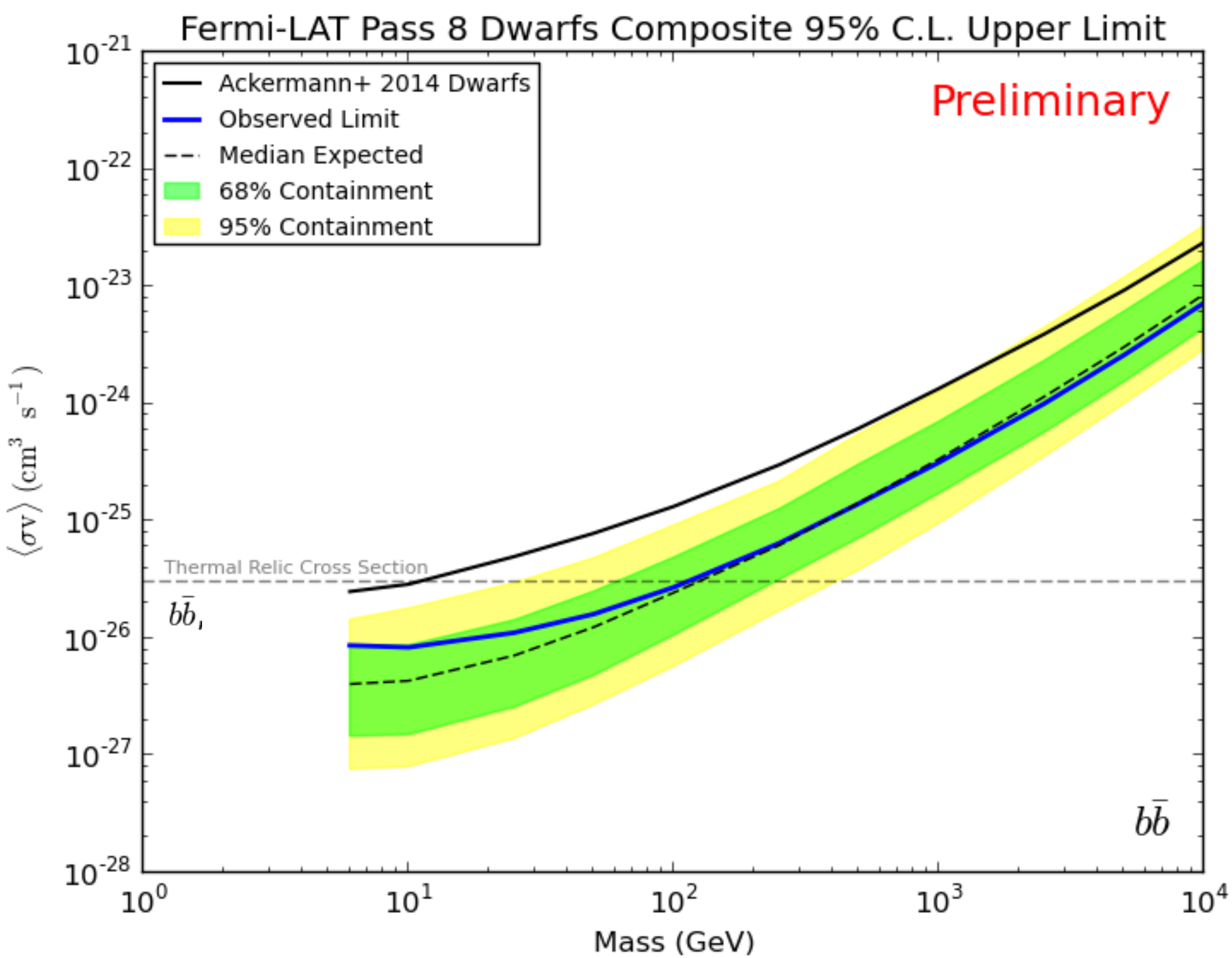
Results
(expected limits)



(bands derived from 300 random blank-sky sets)

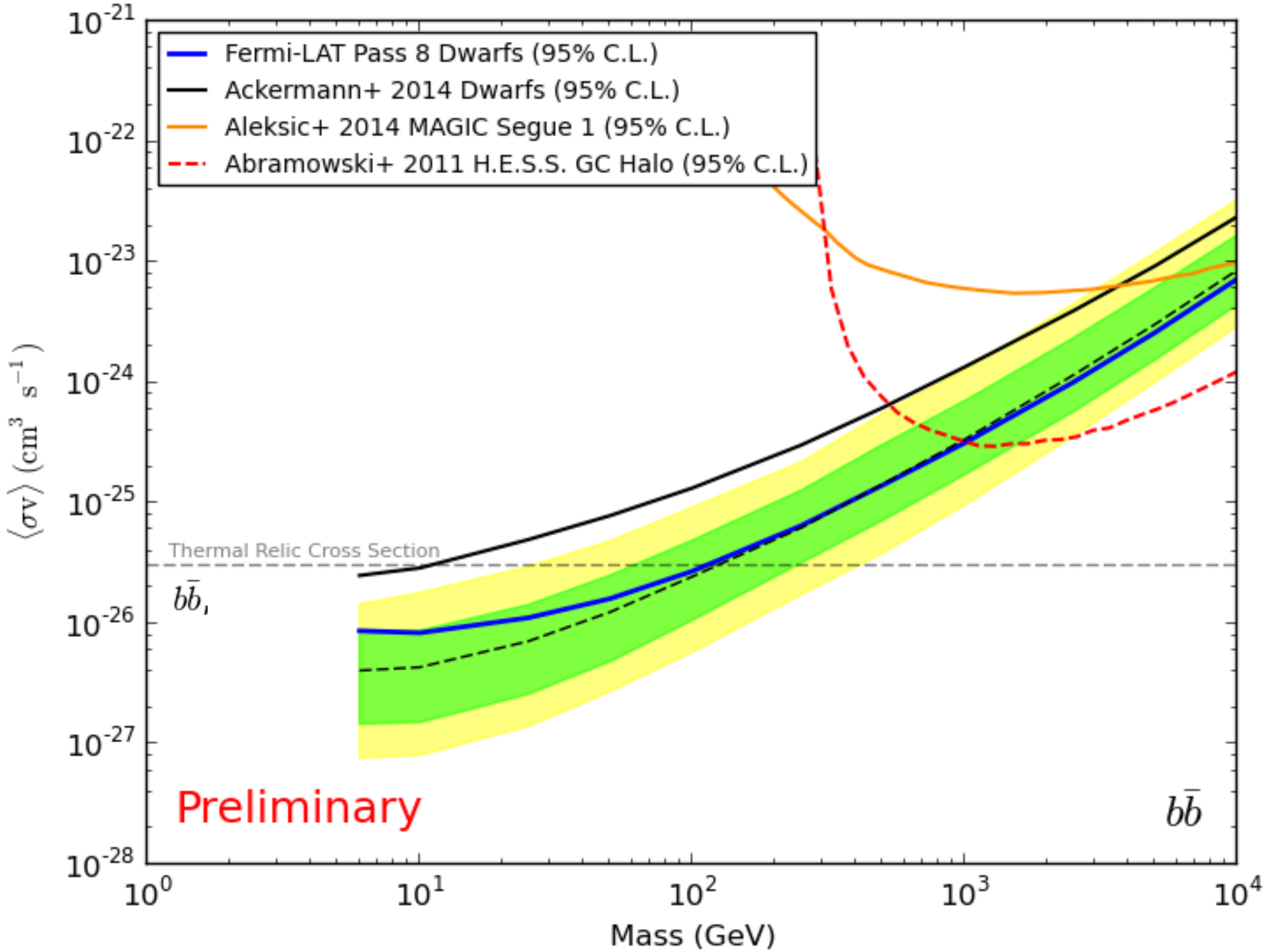
Results

(no significant emission detected)

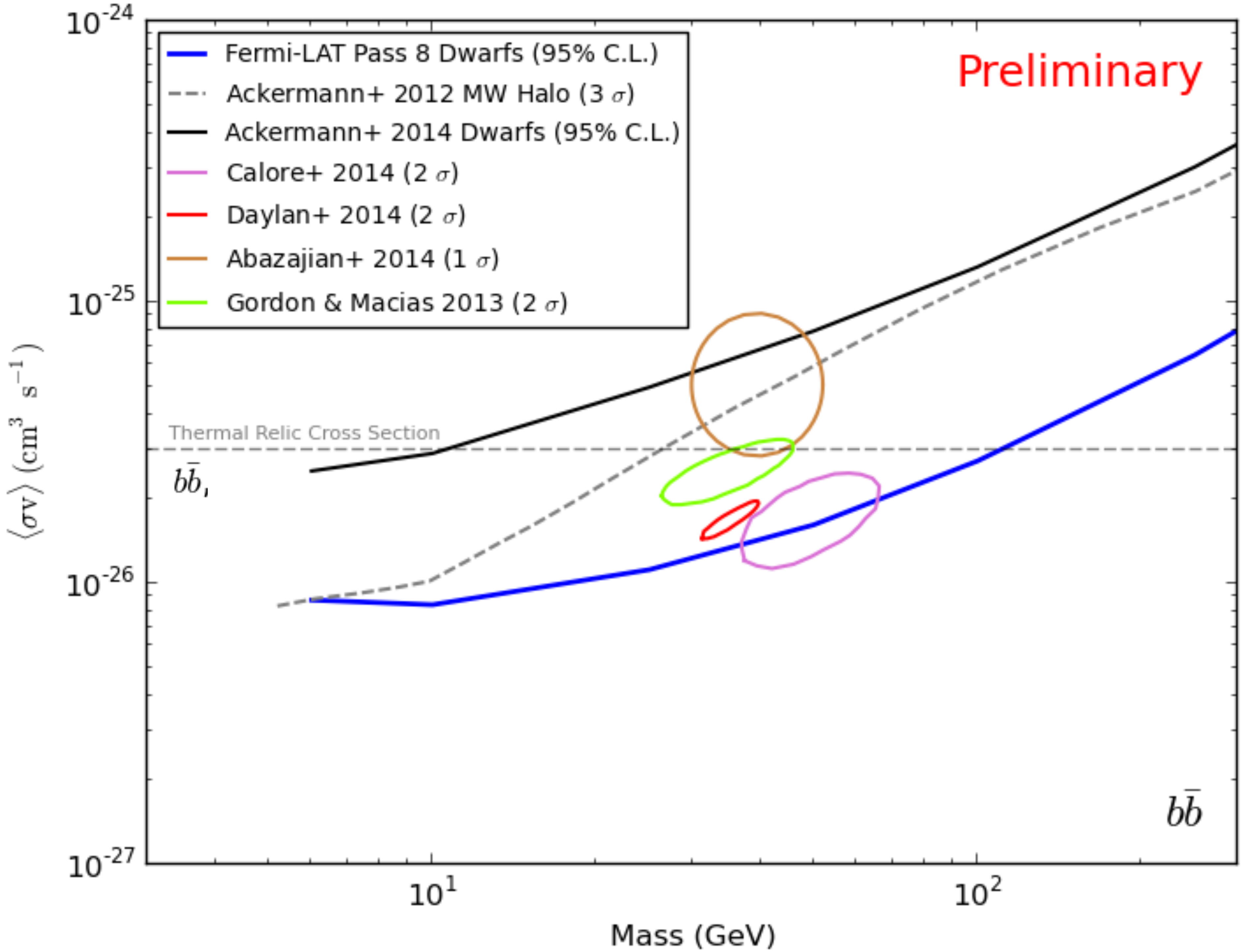


(bands derived from 300 random blank-sky sets)

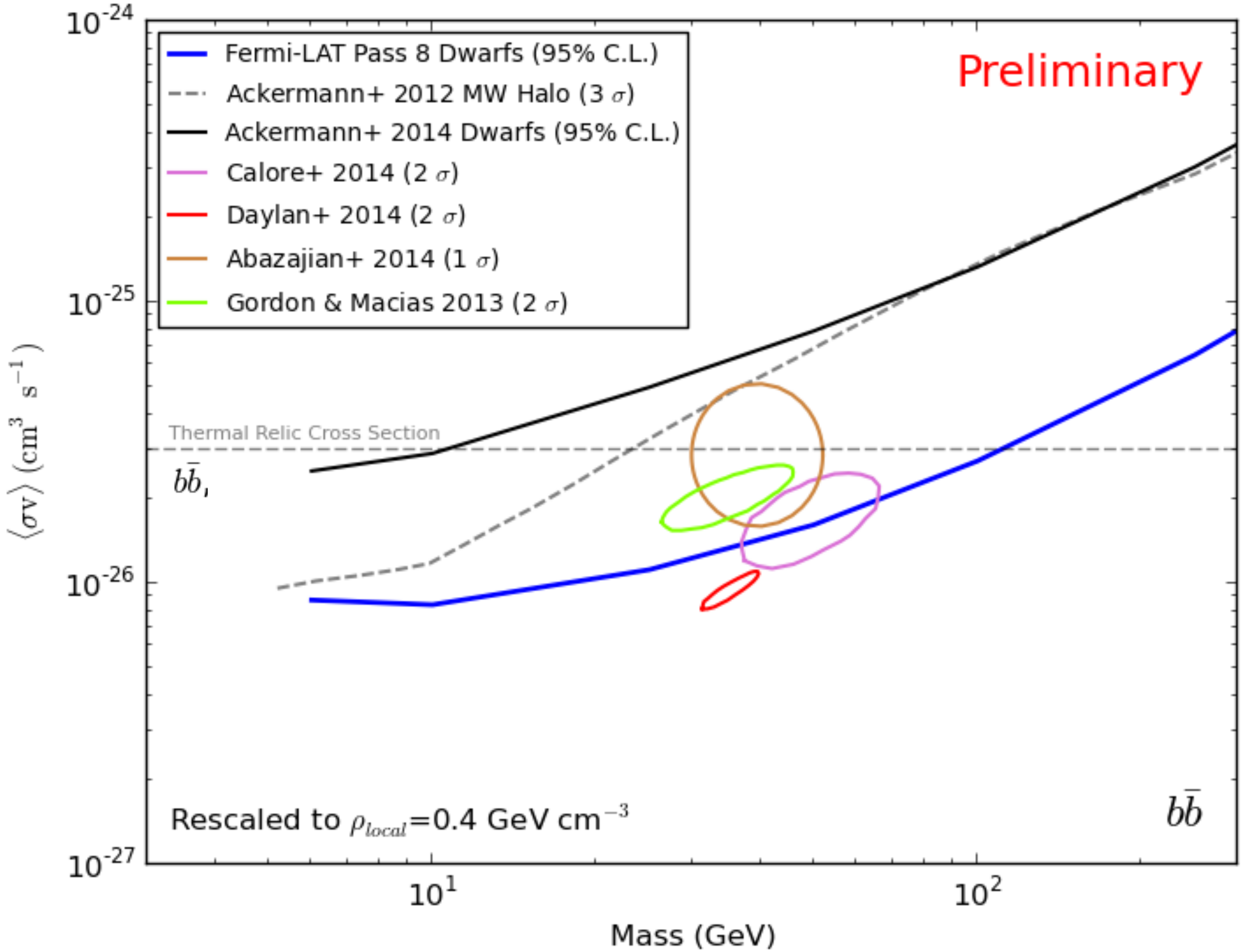
Comparative Limits



Galactic Center Excess (GCE) Compatibility



GCE Compatibility



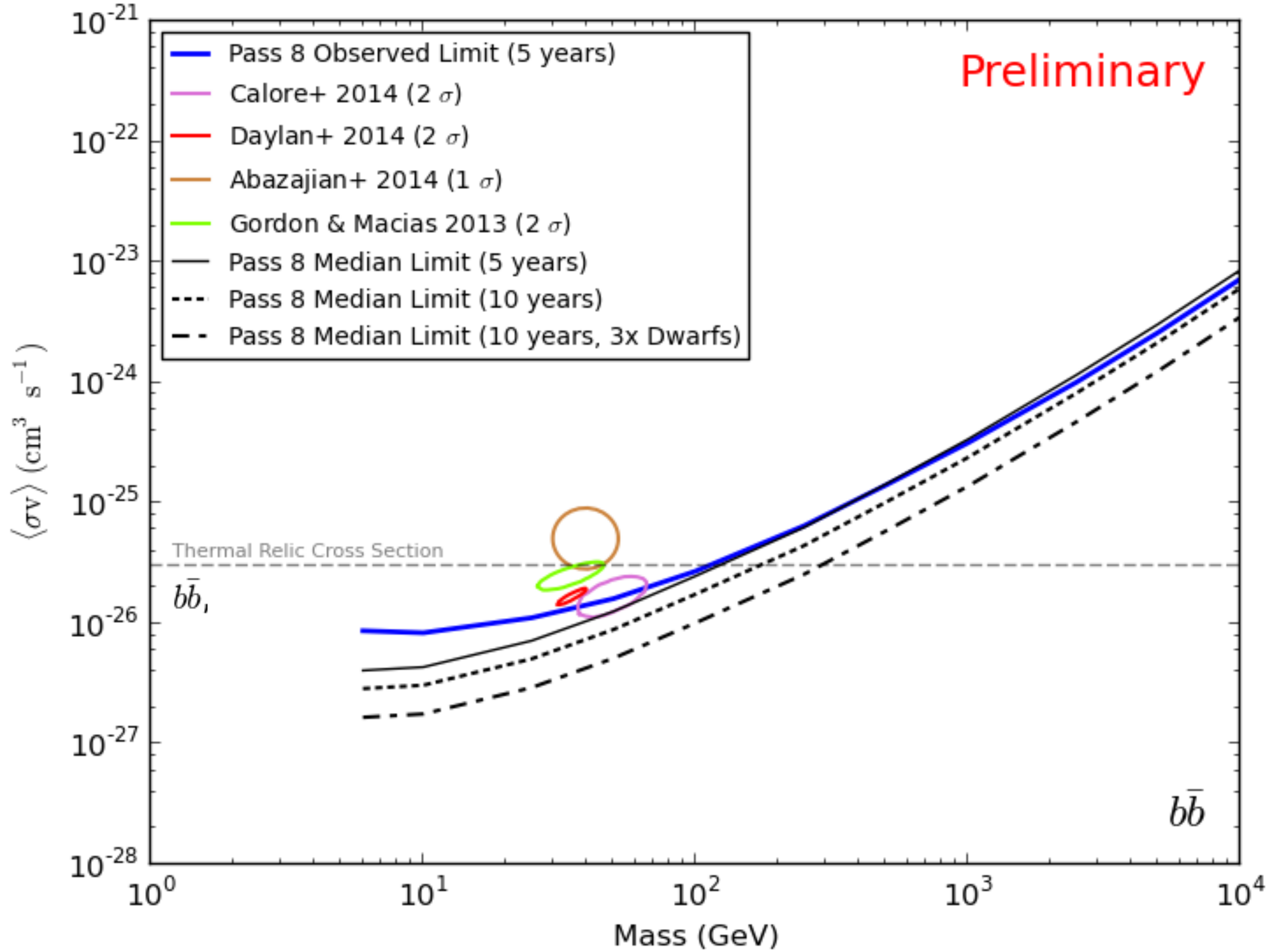
Systematics

NFW vs. Burkert ↓	7 alternative models ↓	bracketing values ↓
Extension*	**Diffuse**	**IRFS**
22%	10%	8%

*depending on CDM trust

@ 100 GeV
WIMP Mass

The Future



Pass 8 Observed Limit (5 years)
Calore+ 2014 (2 σ)
Daylan+ 2014 (2 σ)
Abazajian+ 2014 (1 σ)
Gordon & Macias 2013 (2 σ)
Pass 8 Median Limit (5 years)
Pass 8 Median Limit (10 years)
Pass 8 Median Limit (10 years, 3x Dwarfs)
Preliminary
Thermal Relic Cross Section
$b\bar{b}$,
$b\bar{b}$
$\langle \sigma v \rangle$ (cm^3 s^{-1})
Mass (GeV)
10^{-21}
10^{-22}
10^{-23}
10^{-24}
10^{-25}
10^{-26}
10^{-27}
10^{-28}
10^0
10^1
10^2
10^3
10^4

Conclusion

- Dwarf spheroidals continue to provide extremely robust constraints due to their low astrophysical uncertainty.
- Pass 8 dwarf WIMP limits are now the most stringent below 1 TeV (exclude thermal b-bbar < 100 GeV)
- There is mild tension between the new limits and the galactic center excess WIMP.
- Within the next few years, additional data coupled with new targets should conclusively address the tension, and exclude thermal for some channels up to a few hundreds of GeV.