# THE VERITAS INDIRECT DARK MATTER DETECTION PROGRAM: STATUS AND PROSPECTS

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# VERITAS

## The Very Energetic Radiation Imaging Telescope Array System

### -Mt. Hopkins, Az (1268 m a.s.l)

**Support from:**

**Smithsonian Inst.**
**U.S. NSF**
**U.S. DOE**
**STFC (U.K.)**
**NSERC (Canada)**
**SFI (Ireland)**

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Leeds U.

**Ireland**

Cork Inst. Tech.
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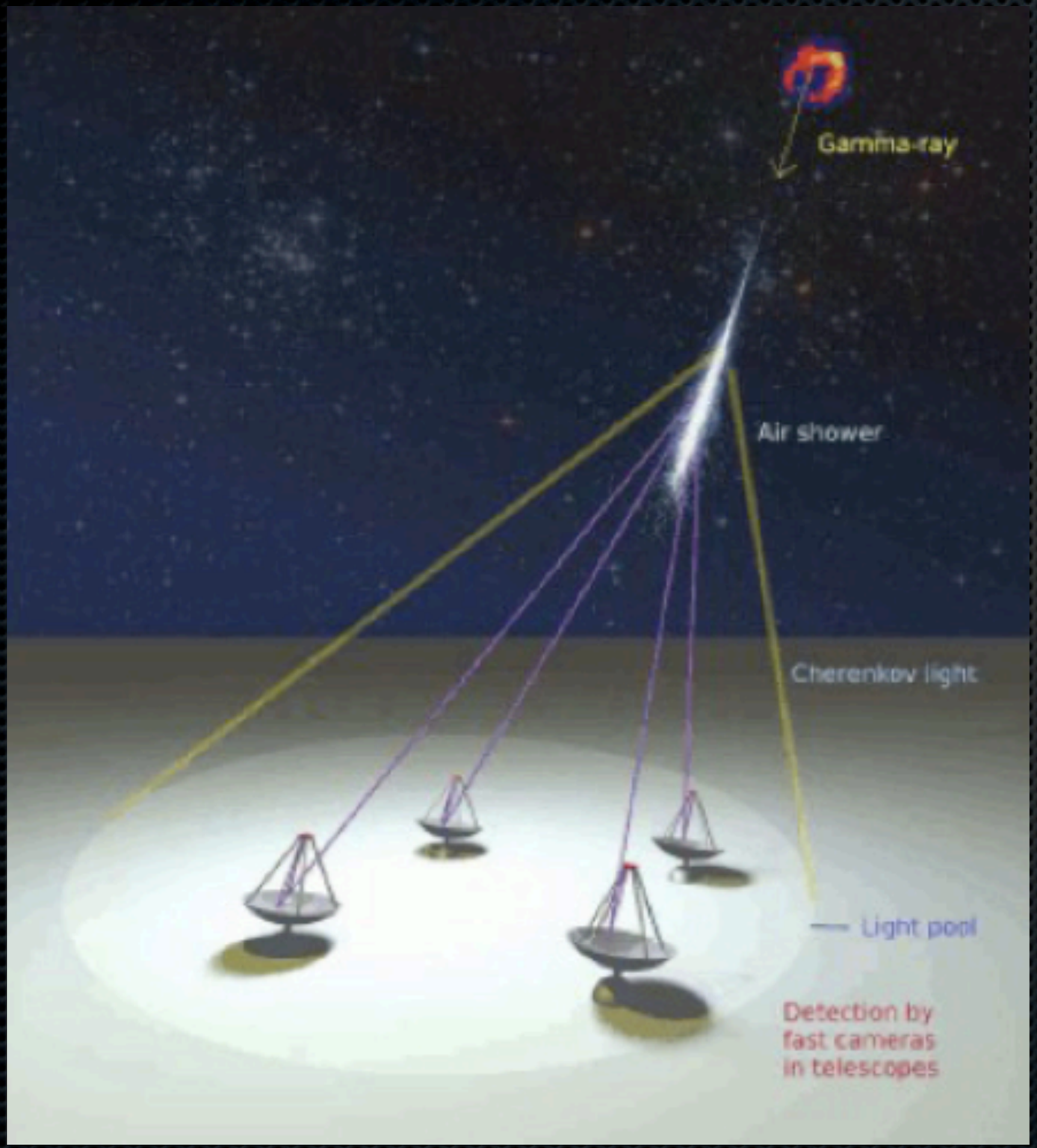
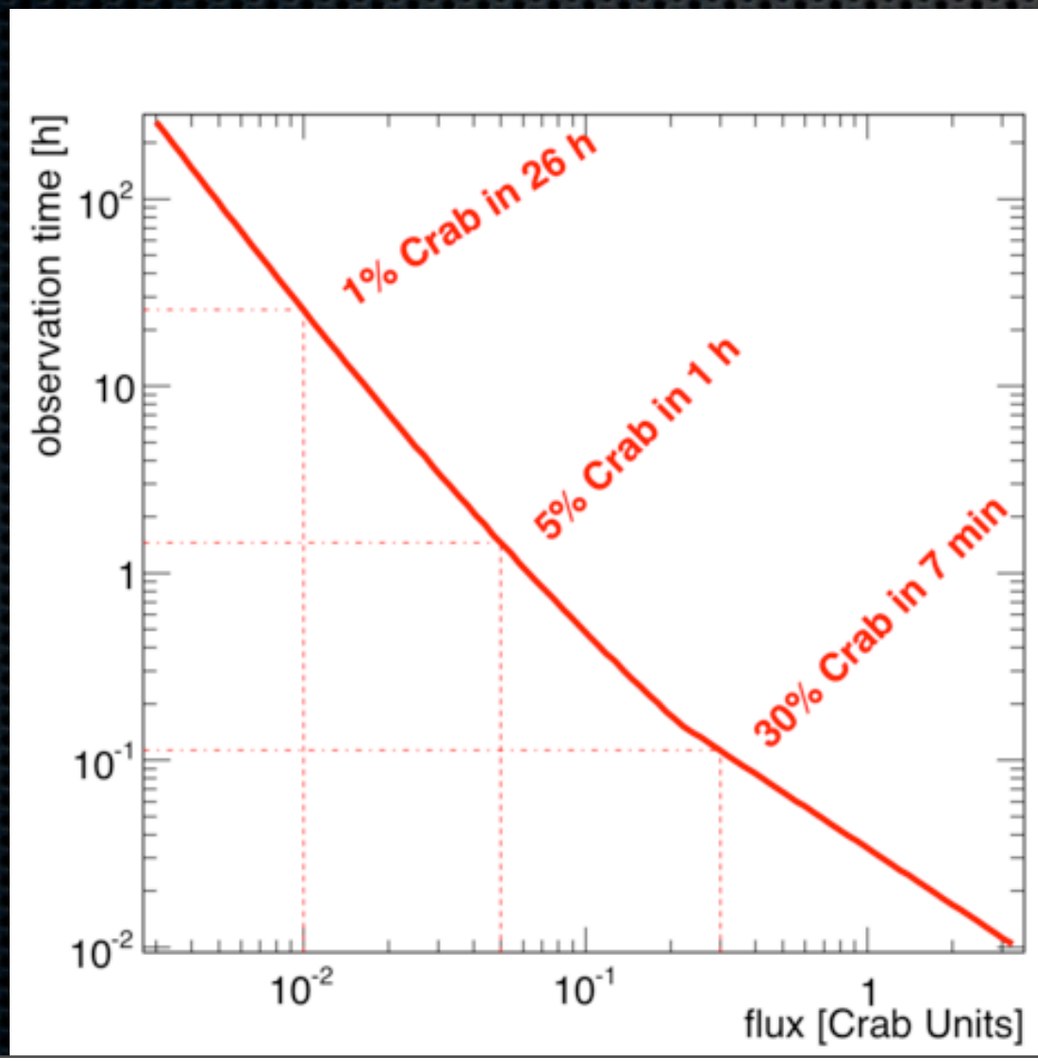
# Imaging Atmospheric Cherenkov Technique:

Primary gamma rays initiate EM showers w particle v>c: Cherenkov pulses



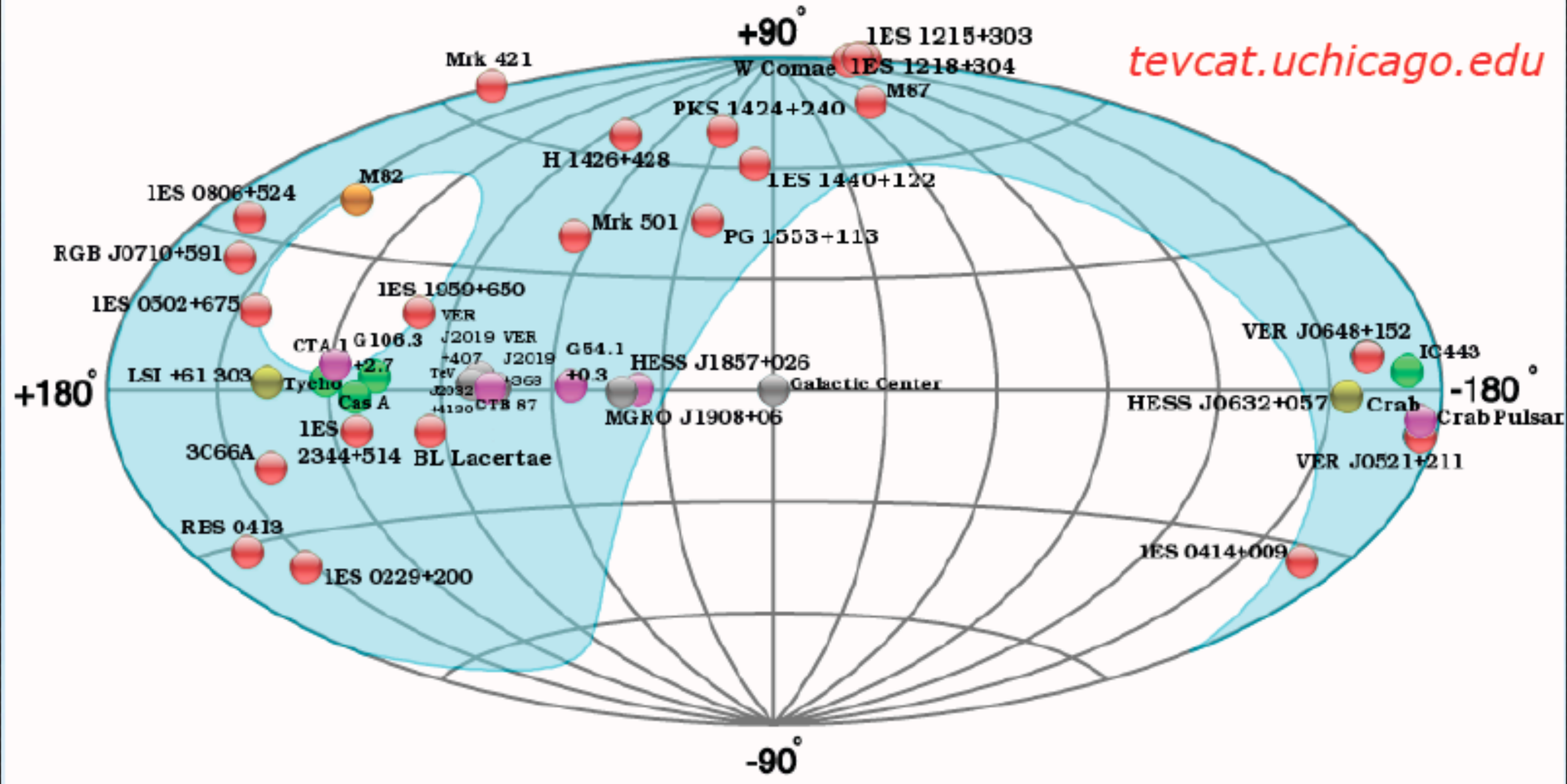
# VERITAS

* energy range: 100 GeV to >30 TeV (spectral reconstruction starts at 150 GeV)
* energy resolution: 15% at 1 TeV
* angular resolution: <0.1 deg at 1 TeV, 0.14 deg at 200 GeV (68% values)
* source location accuracy: <50 arcseconds
* point source sensitivity: 1% Crab in <30h, 10% in <30 min
* observation time per year: 800 hours non-moonlight, ~300 hours moonlight




Approx. VERITAS angular resolution

# The VERITAS Catalog




Wide range of cosmic sources detected: pulsar wind nebulae, supernova remnants, X-ray binaries, many AGN, 1 starburst galaxy, 1 pulsar...

# Indirect Detection of DM w/IACTs

$$\frac{d\phi(E,\vec{\psi},\Delta\Omega)}{dE} = \left[\frac{\langle\sigma v\rangle}{8\pi m_\chi^2}\frac{dN(E,m_\chi)}{dE}\right] J(\vec{\psi},\Delta\Omega)$$

# Indirect Detection of DM w/IACTs

Assume all the $\gamma$s you didnt see is this:

Constrain this

Choose some ppp model to tell you what you should have seen

Find an astronomer to model this for you

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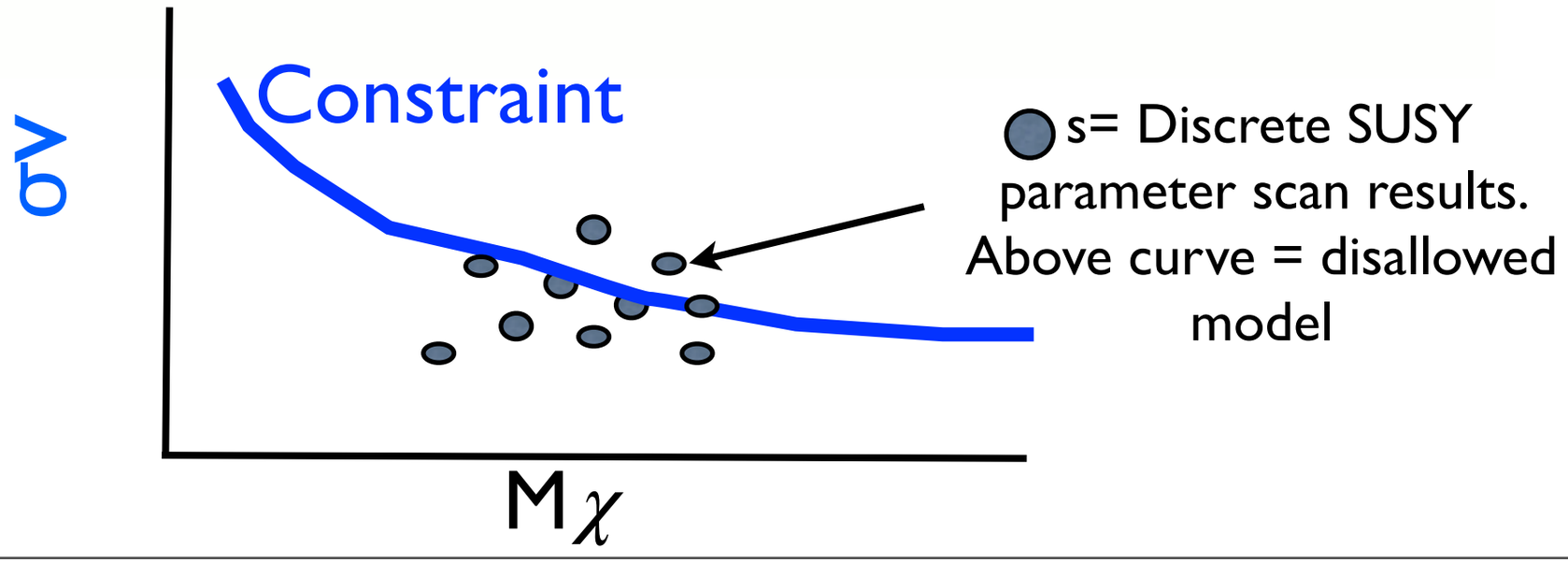
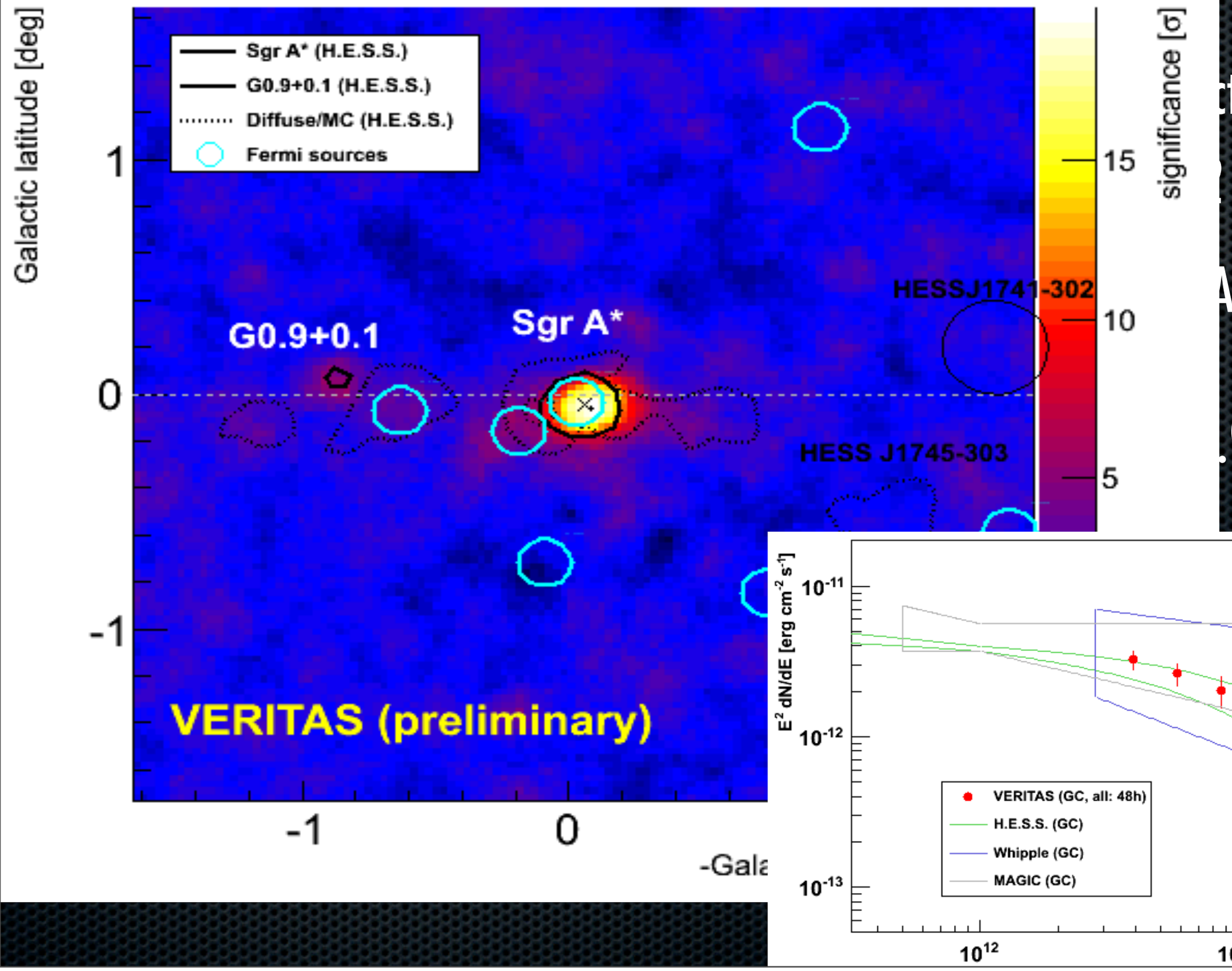


# VERITAS DM Targets

| Target | Advantages | Disadvantages |
|---|---|---|
| Galactic Center | Close by, lots of DM | Large $\gamma$ BG |
| Fermi-LAT UIDs | Possibly local, known gamma-ray sources | Unknown distance, nature |
| Galaxy Clusters | -Largest DM concentrations in universe | -very distant (weak signal)<br>-very extended<br>-possible $\gamma$ BG |
| Dwarf Galaxies | -High Mass/Light<br>-No likely $\gamma$ BG | DM distribution can be very uncertain |

# VERITAS Galactic Center Observations







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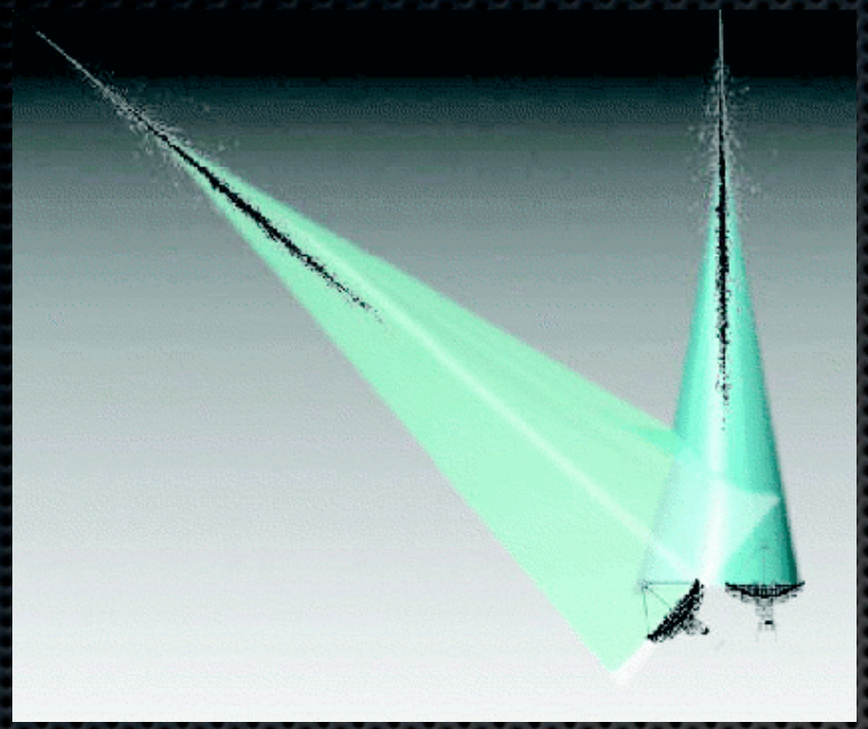
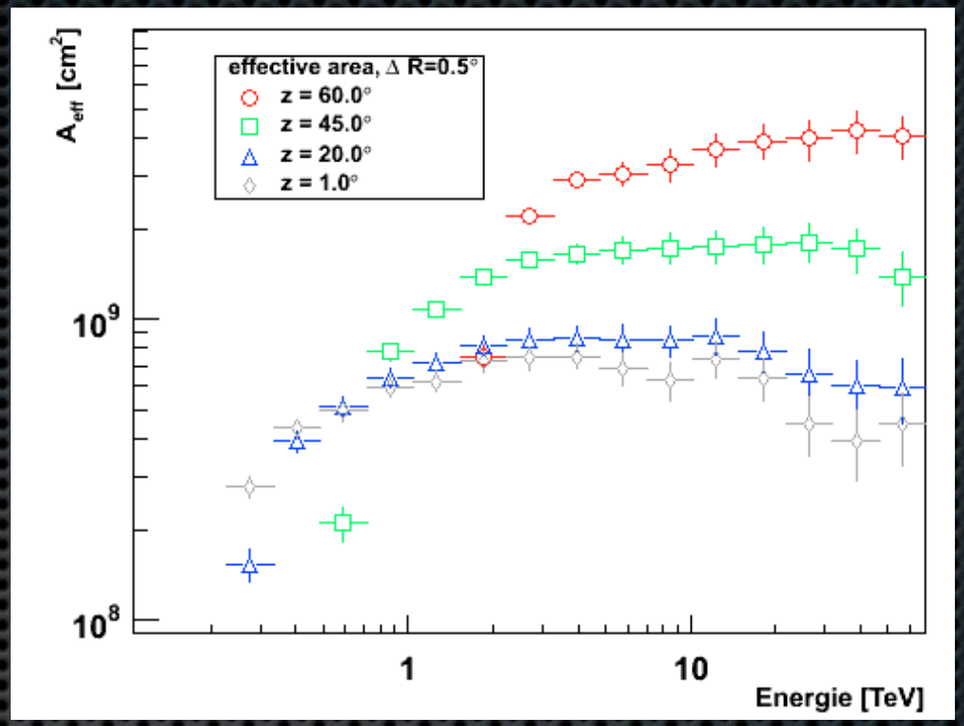
A*

.9+0.1

# Benefits of VERITAS GC Observations

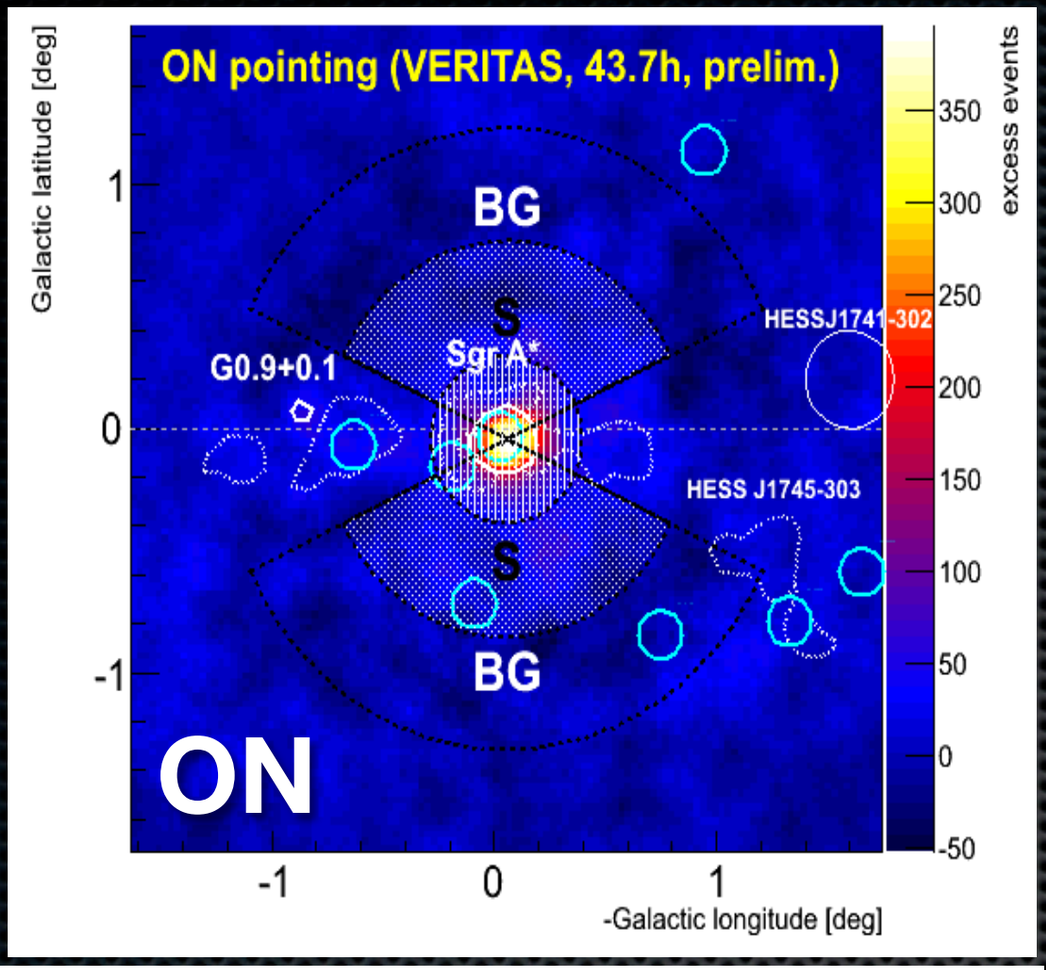


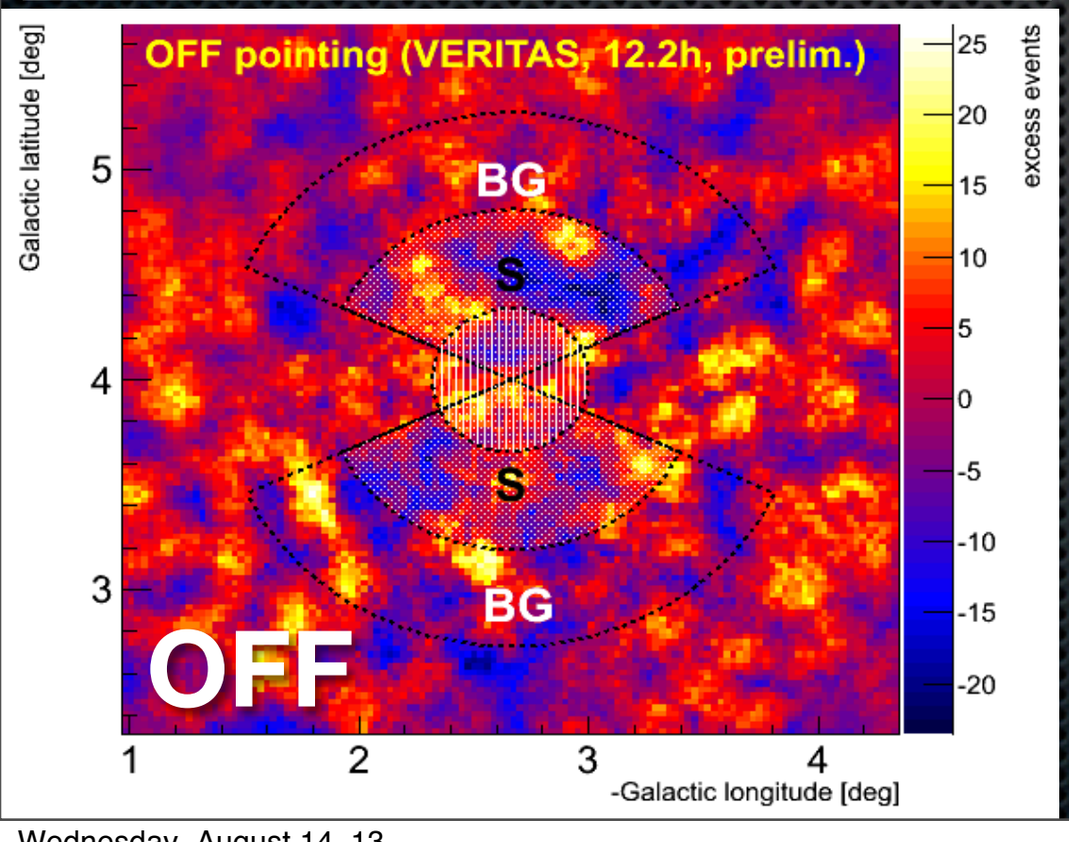



SgrA* is a large zenith angle source for VERITAS: Large energy threshold.....however, increased sensitivity at high E. Drawback of decreased angular resolution overcome by advanced image reconstruction ("disp" method, see Buckley.....)

VERITAS GC Observations are in a unique position to probe the regime favored by higher mass neutralinos (~1 TeV). (130 GeV Higgs points to this possibility?)

# VERITAS Galactic Center Observations

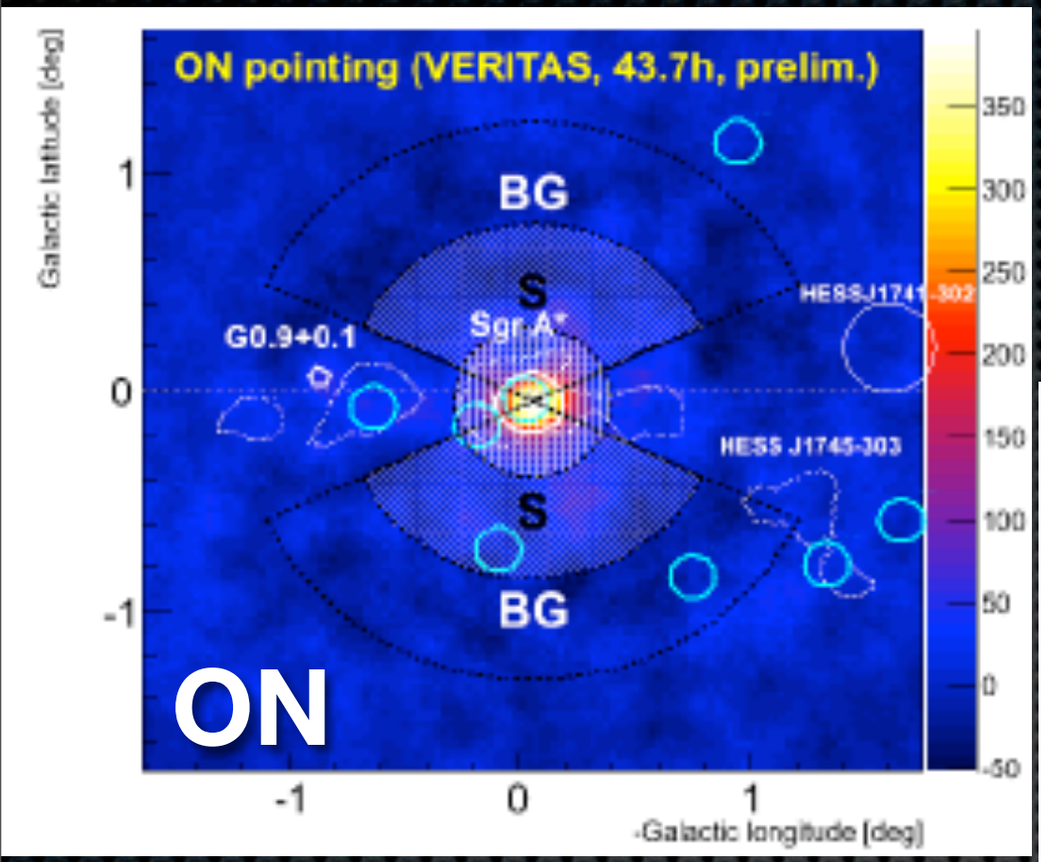


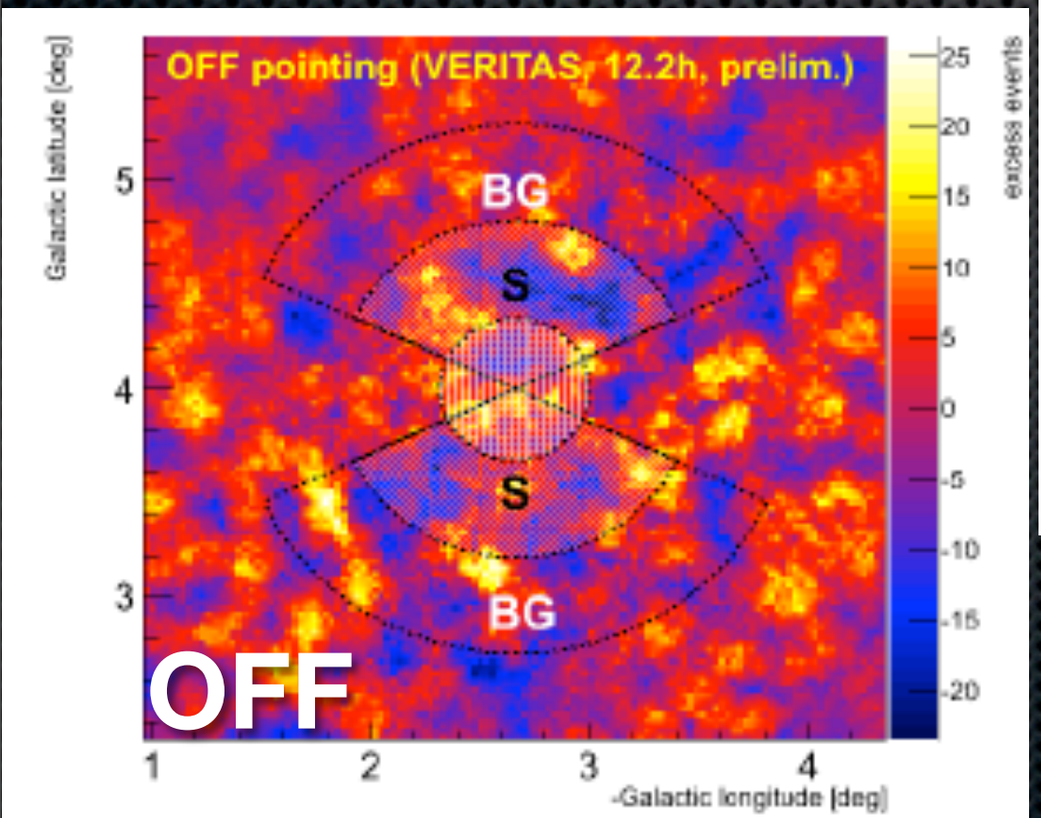




## *Dark Matter Upper Limit Analysis Strategy:*

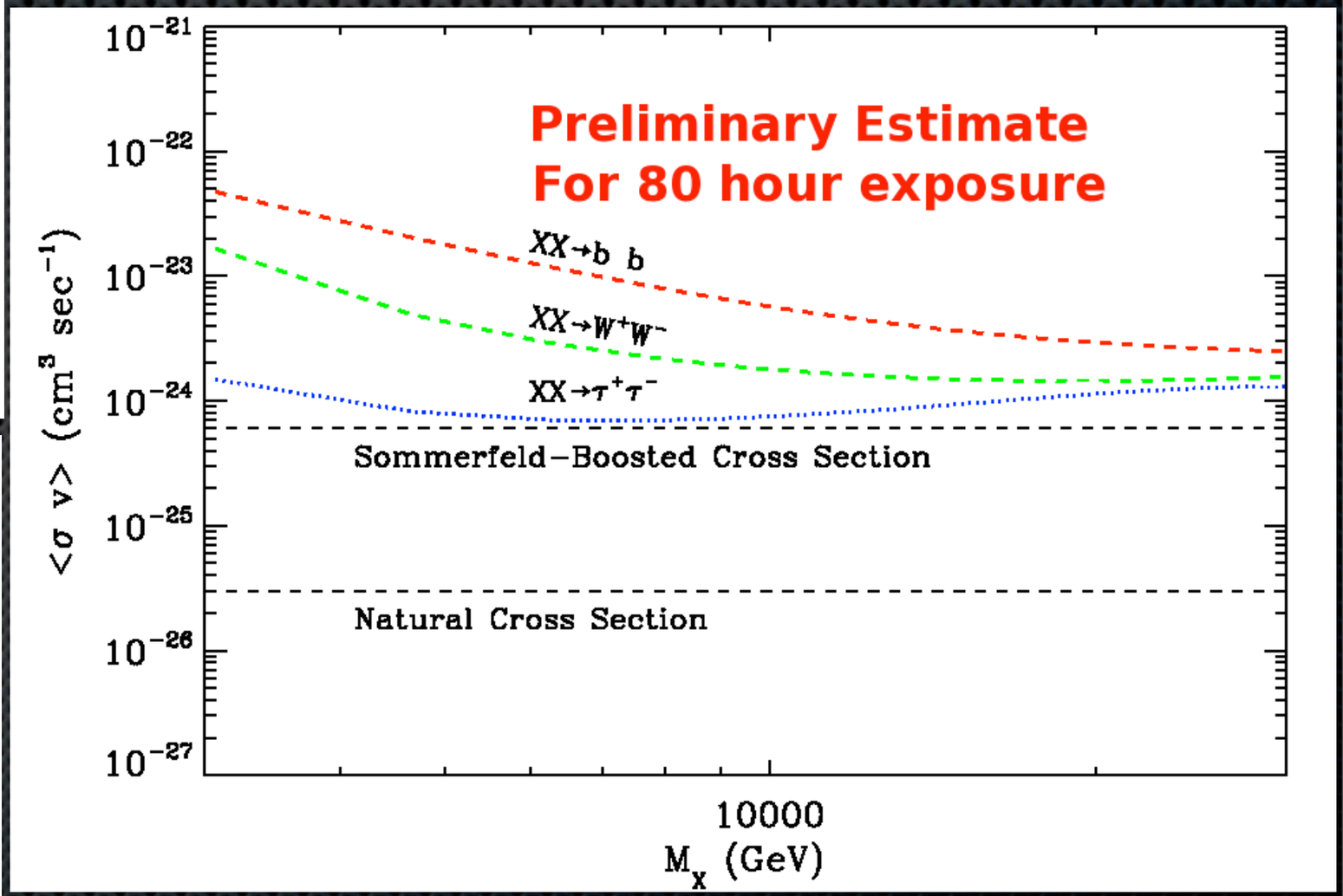
- 2 Seperate Pointings (ON/OFF signal region), also exclude SgrA*
- Define Signal (S) and Background (BG) regions in both pointings
- Use of OFF pointings allows determination of energy dependent acceptance in S/BG regions

# VERITAS Galactic Center Observations




## *Estimate for end of 2013 Season*



# VERITAS Dwarf Spheroidal Observations

Draco, WIllman I, Ursa Minor, Bootes I

(Acciari et al. 2010, ApJ)

-all ~15 hour observations

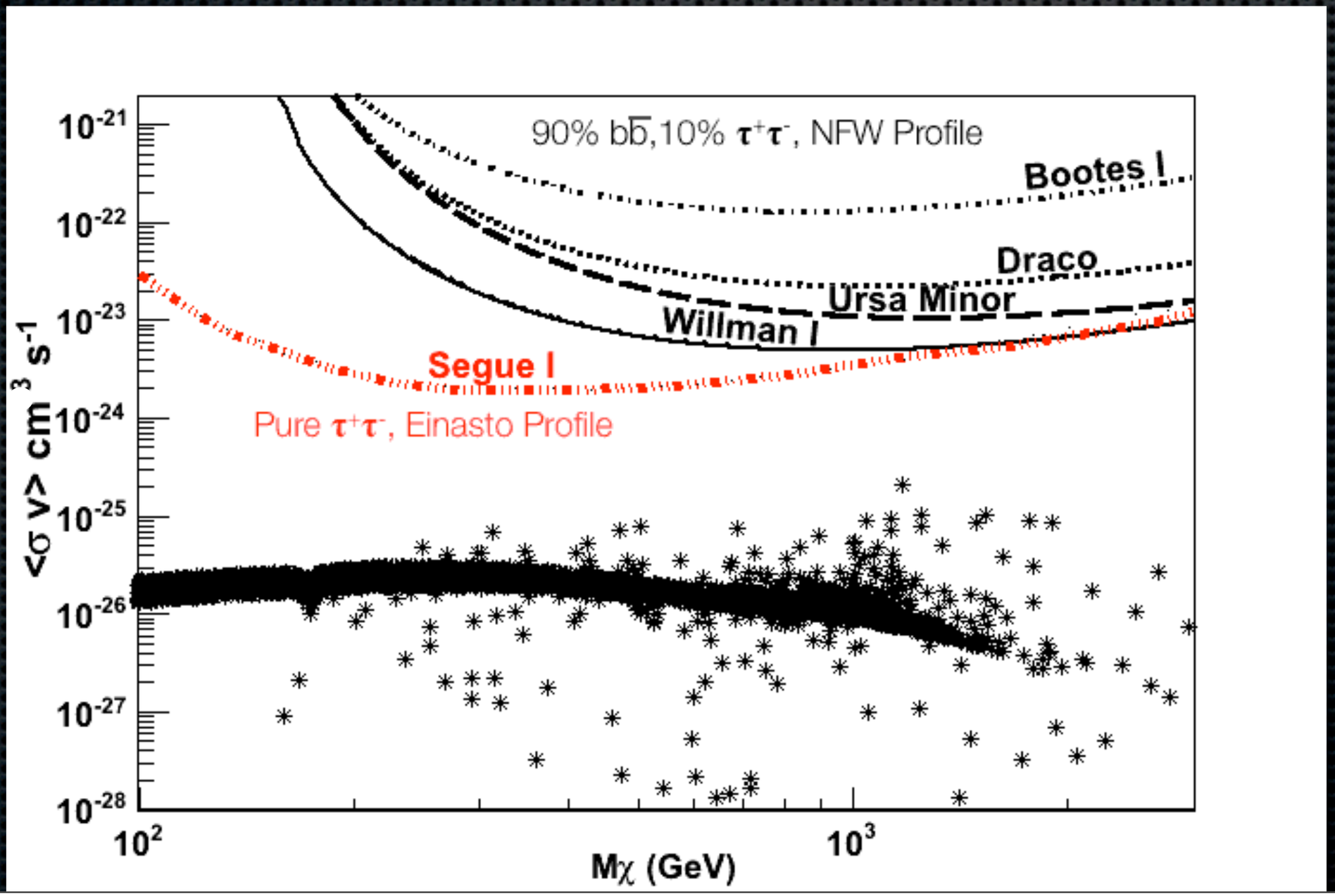
No significant excess from any target

Segue I

(Aliu et al. 2012, ApJ)

~50 hour deep observation

No significant excess from any target

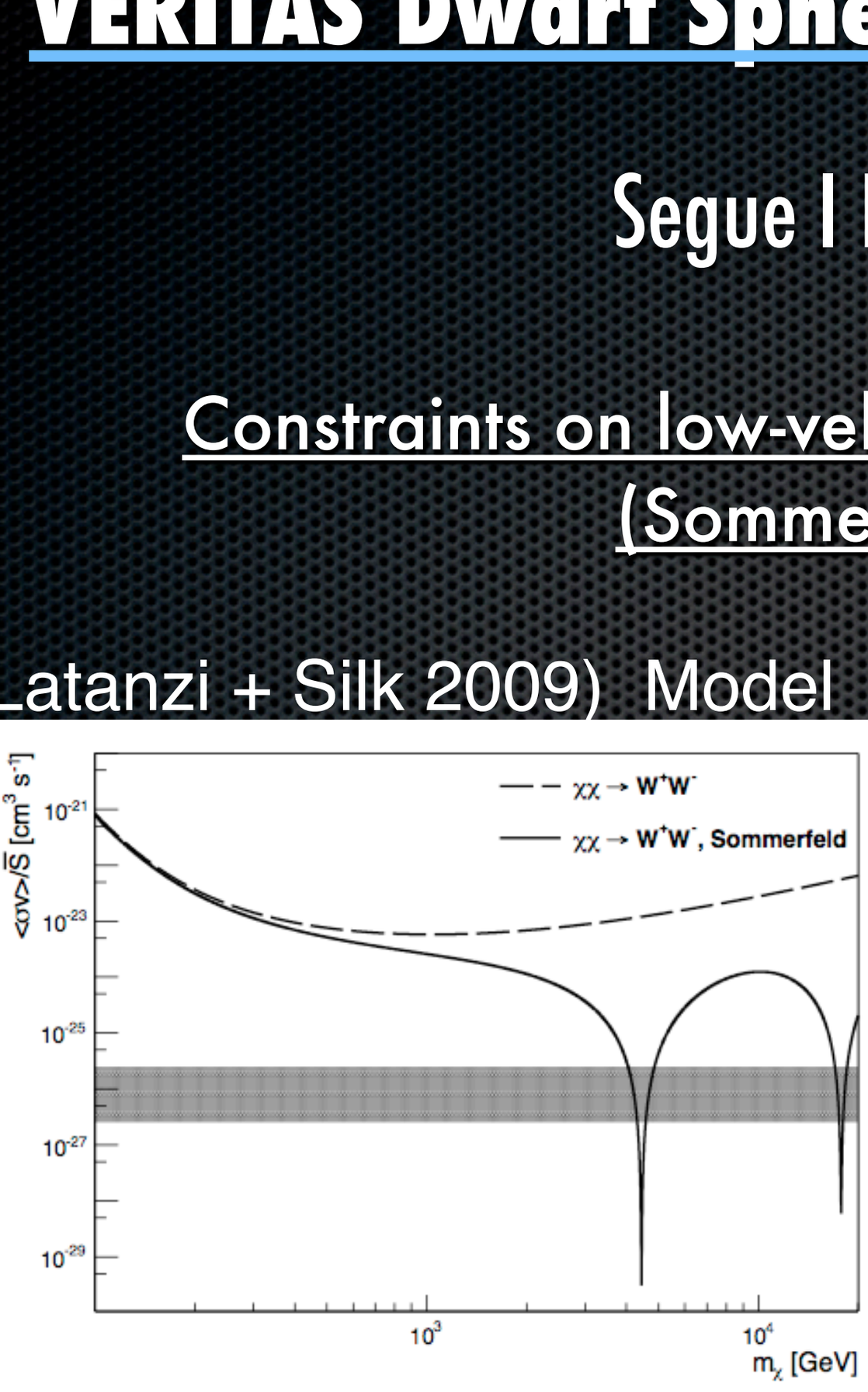


# VERITAS Dwarf Spheroidal Observations

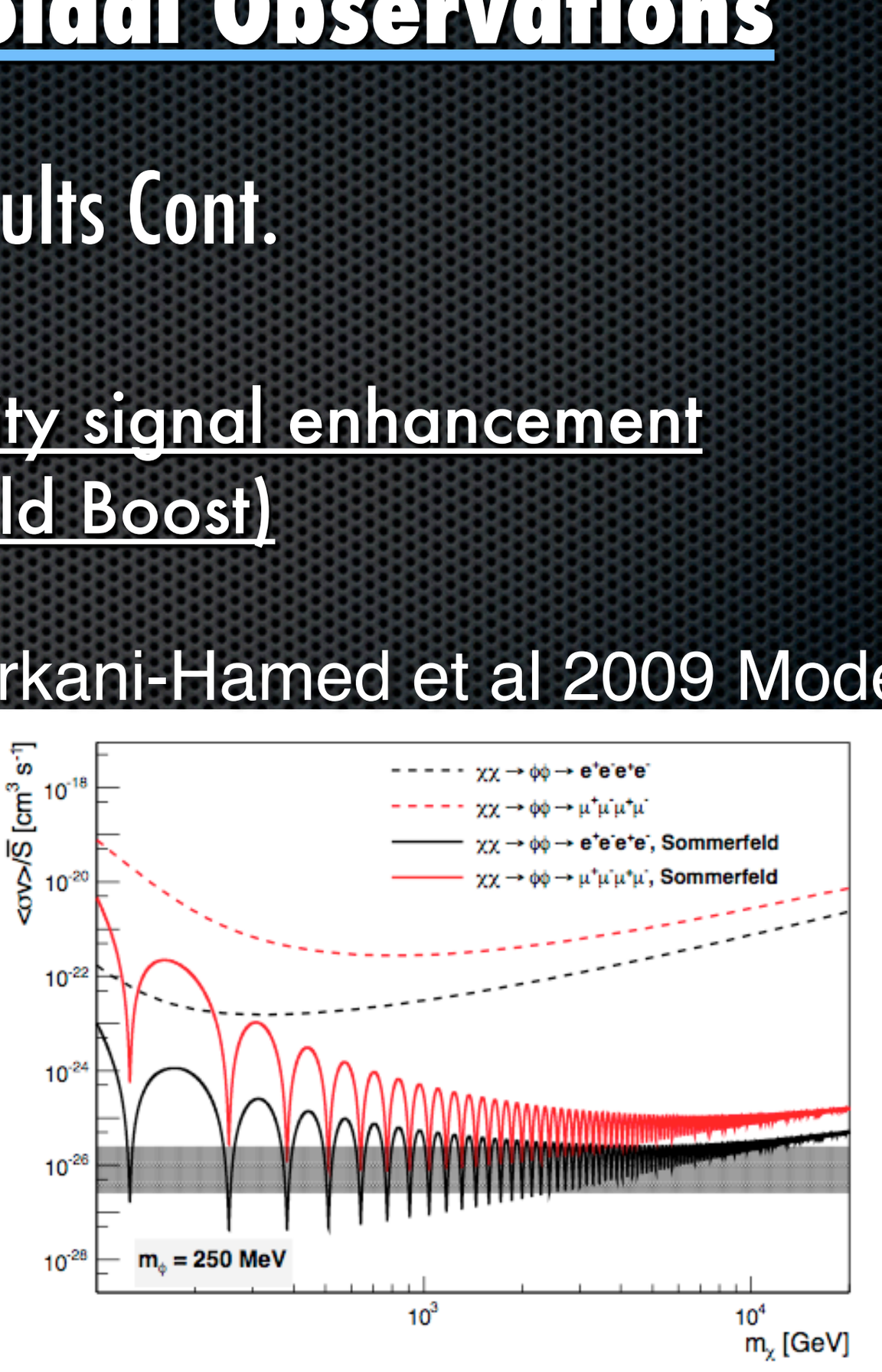
## Segue I Results Cont.

### Constraints on low-velocity signal enhancement (Sommerfeld Boost)

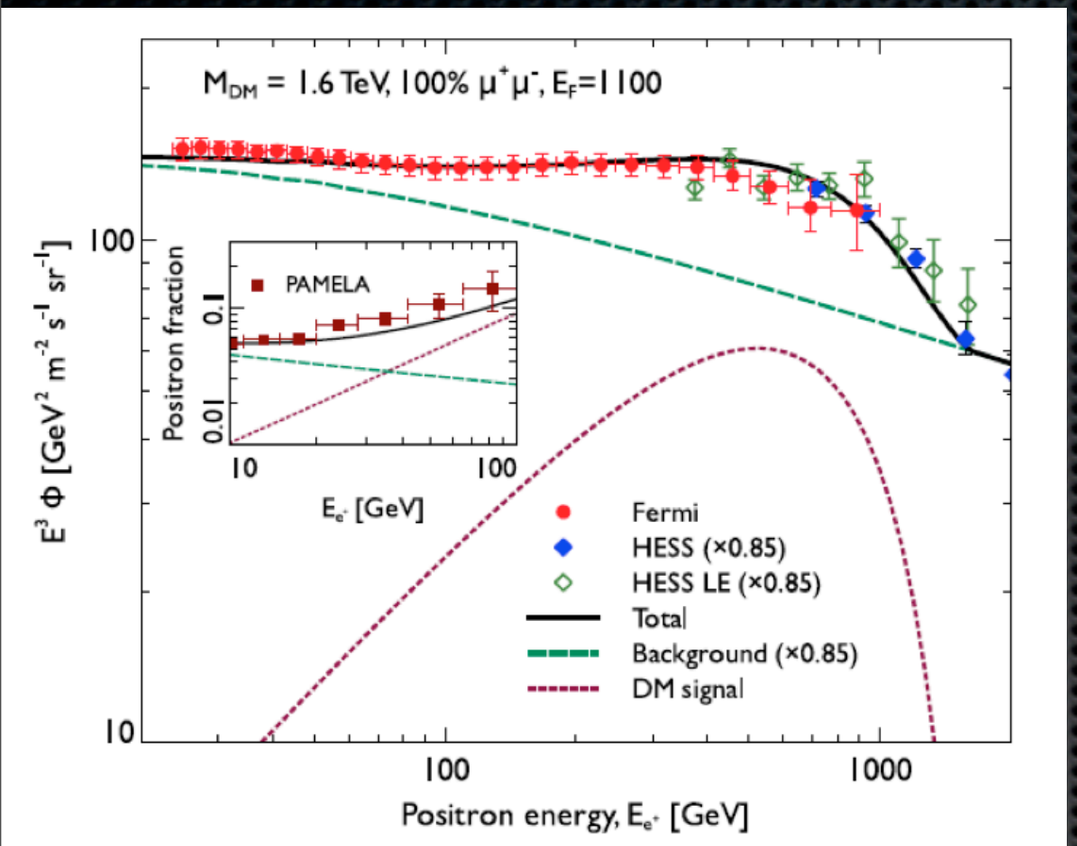
(Latanzi + Silk 2009) Model



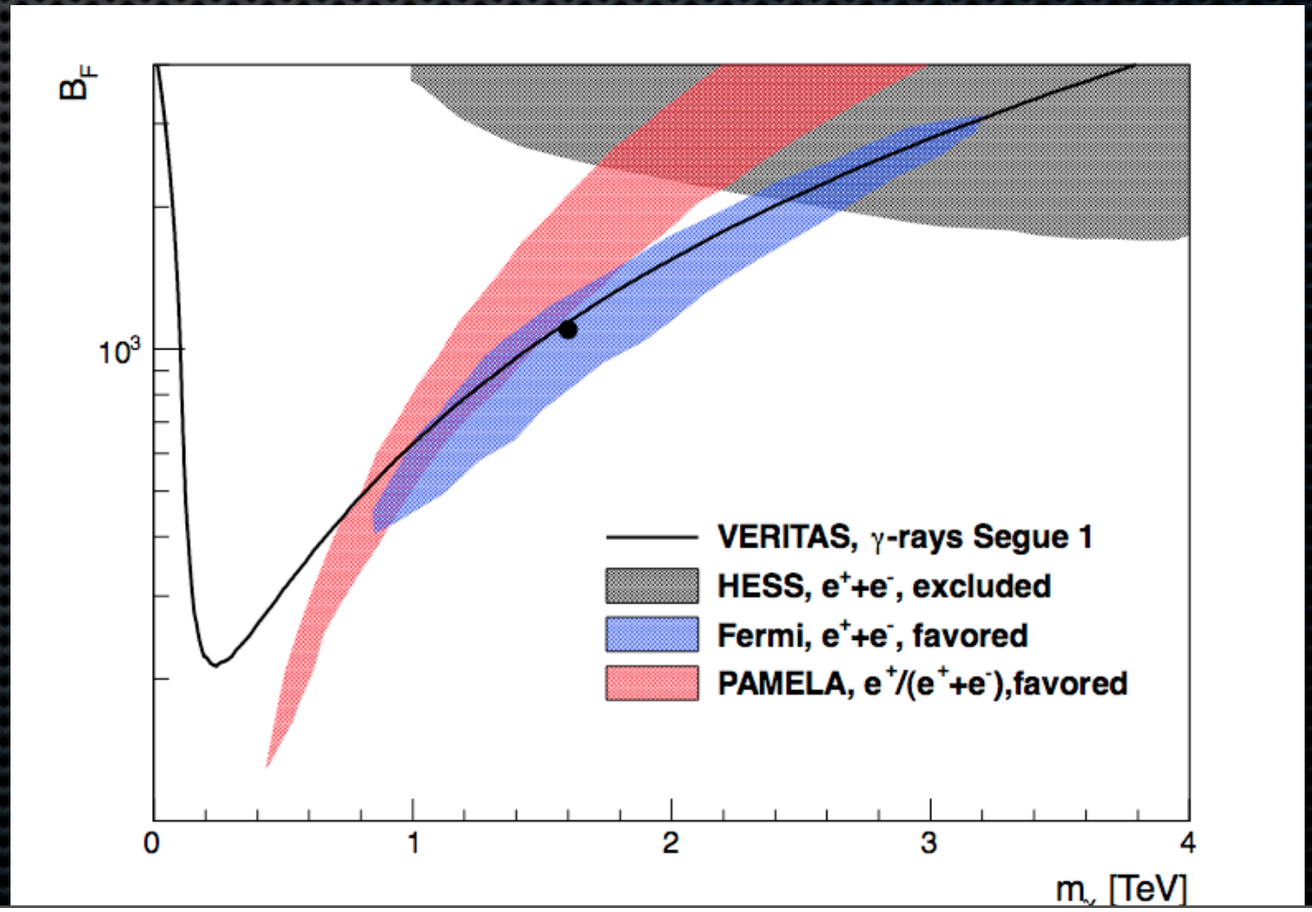

Arkani-Hamed et al 2009 Model



# Constraints on DM explanation of Pamela excess




Bumps in Pamela/Fermi/HESS e+/e- data could be explained by leptophilic DM (annihilation exclusively into muons) (Bergstrom, Edsjo, Zaharijas, 2009)




VERITAS Segue I observations to limit required "boost factor" in such models

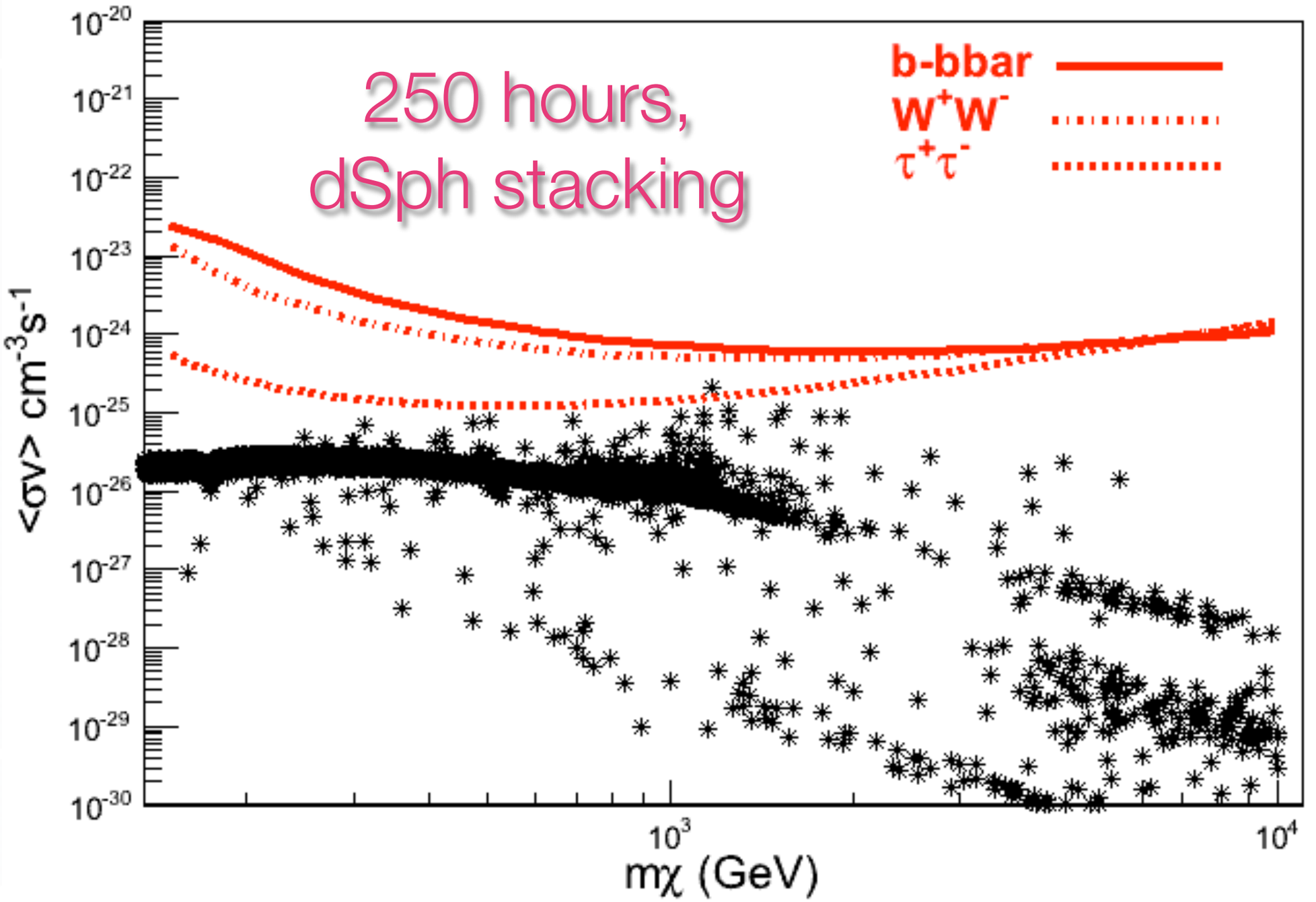
# Work in Progress: DSph Stacking

| DSphs: | (Published) | Additional Time Taken | Total Time |
|---|---|---|---|
| Draco: | (18 hours) | 30 new hours | 48 hours |
| Ursa Minor | (19 hours) | 28 new hours | 47 hours |
| Segue I | (48 hours) | 75 new hours | 123 hours |

***218 hours currently***

**DSph stacking can provide significant increase in sensitivity of $\langle\sigma v\rangle$ limits (A. Garinger-Sameth and S. Koushiappas, Phys. Rev. Lett. 2011)**

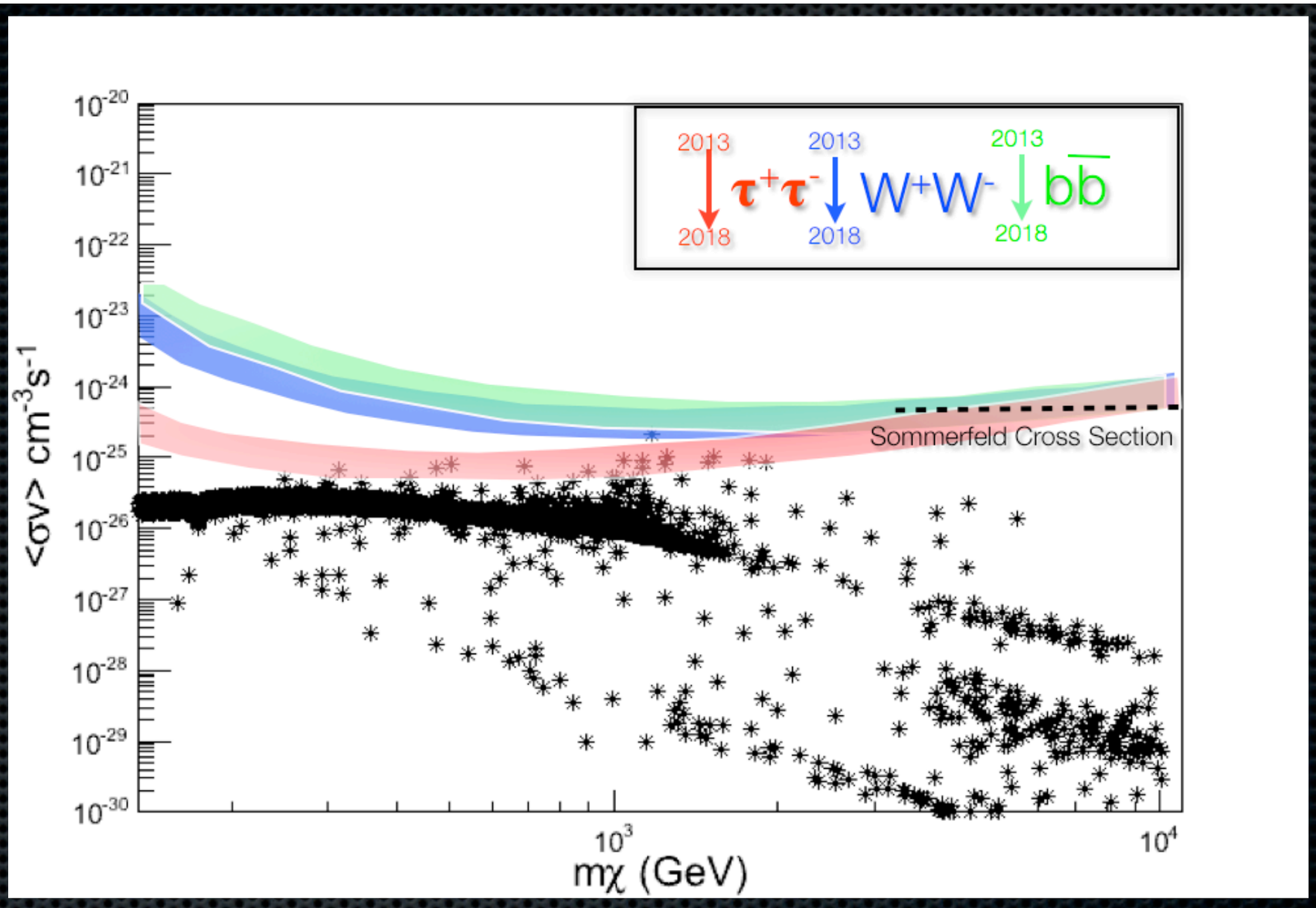
# Work in Progress: DSph Stacking




Sensitivity of <1GeV limits (A. Geringer-Sameth and S. Koushiappas, Phys. Rev. Lett. 2011)

# Estimates for a Fully Realized VERITAS DM Program

## Dwarf Spheroidal Galaxy Stacked Sample




Estimates: 2013: 250 hours total
2018: 1000 hours total

Predictions use no assumed increase in sensitivity due to analysis (conservative)

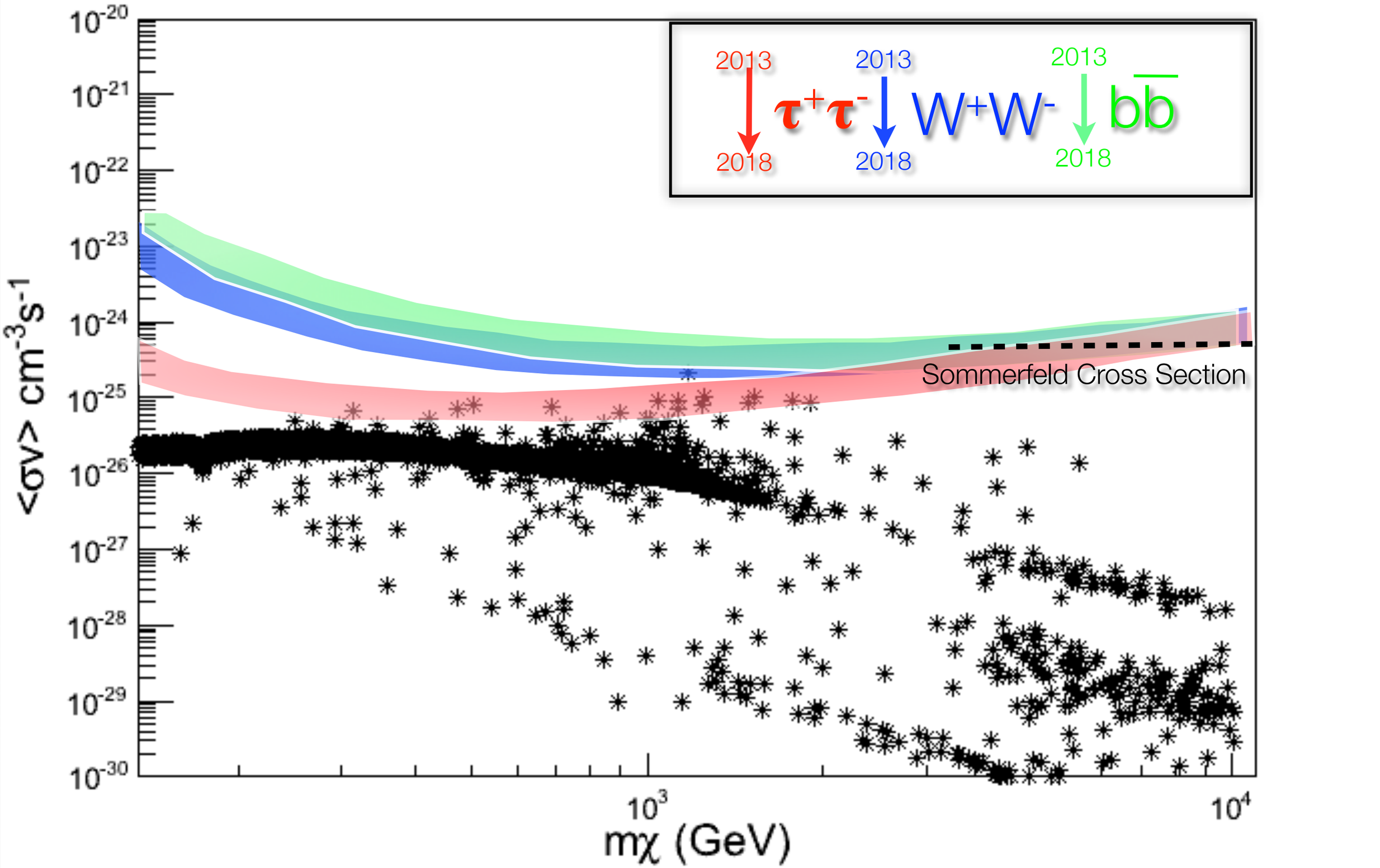
# Comments

-The most important results from the VERITAS DM program are yet to come

-These measurements will greatly compliment lower E constraints by Fermi-LAT, years before CTA is on-line (much less provide analysis)

-Even if hint of signal is seen in direct/collider seraches, no firm association with cosmological dark matter is possible without IACTs

-IACTs probe a unique and model-independent parameter space


2013
2013
2013
τ+τ-
W+W-
bb̄
2018
2018
2018
Sommerfeld Cross Section
<σv> cm-3s-1
10-20
10-21
10-22
10-23
10-24
10-25
10-26
10-27
10-28
10-29
10-30
10³
10⁴
mχ (GeV)