THE VERITAS INDIRECT DARK MATTER DETECTION PROGRAM: STATUS AND PROSPECTS

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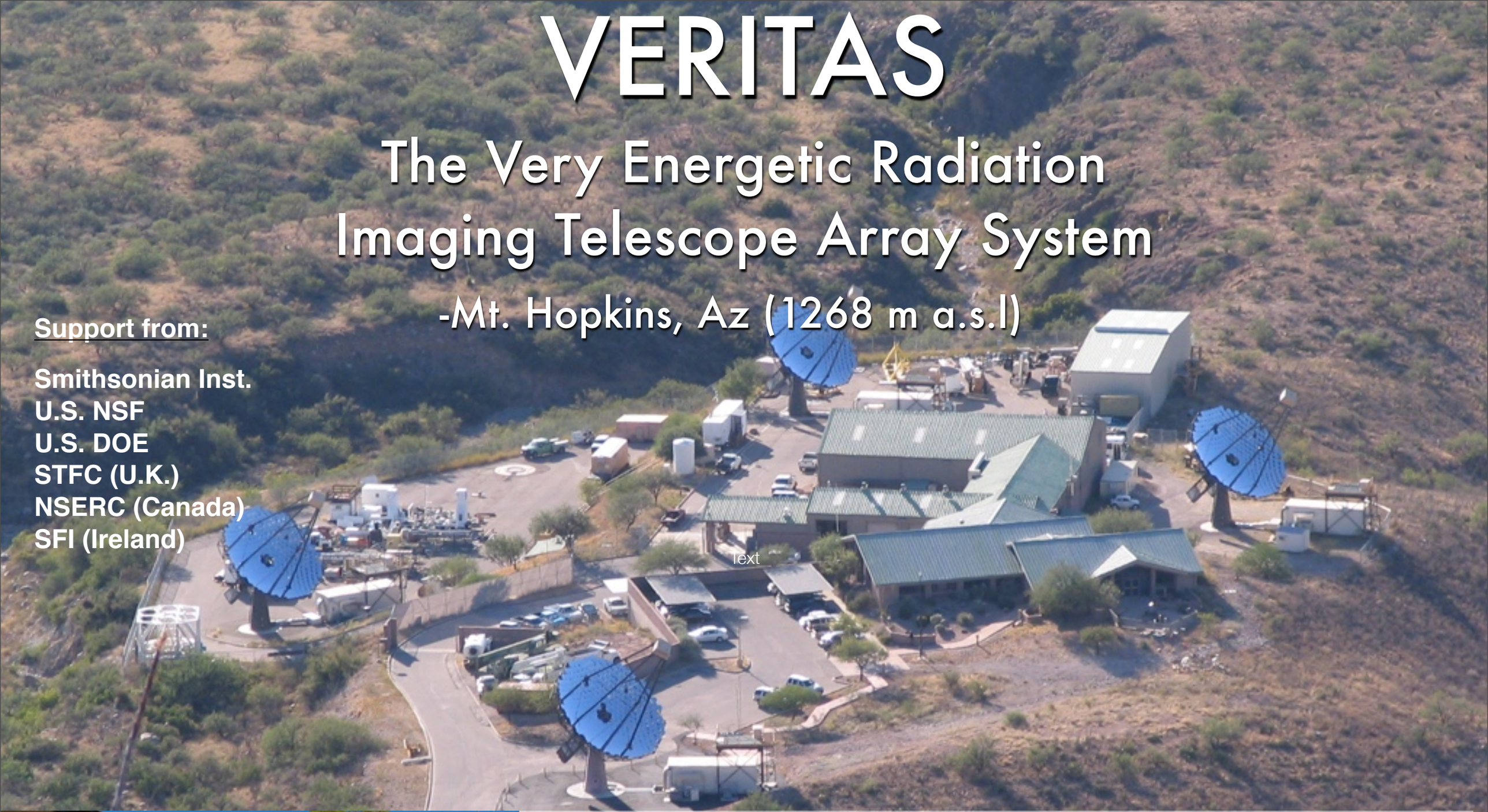
VERITAS

The Very Energetic Radiation Imaging Telescope Array System

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



<u>Support from:</u>

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Text

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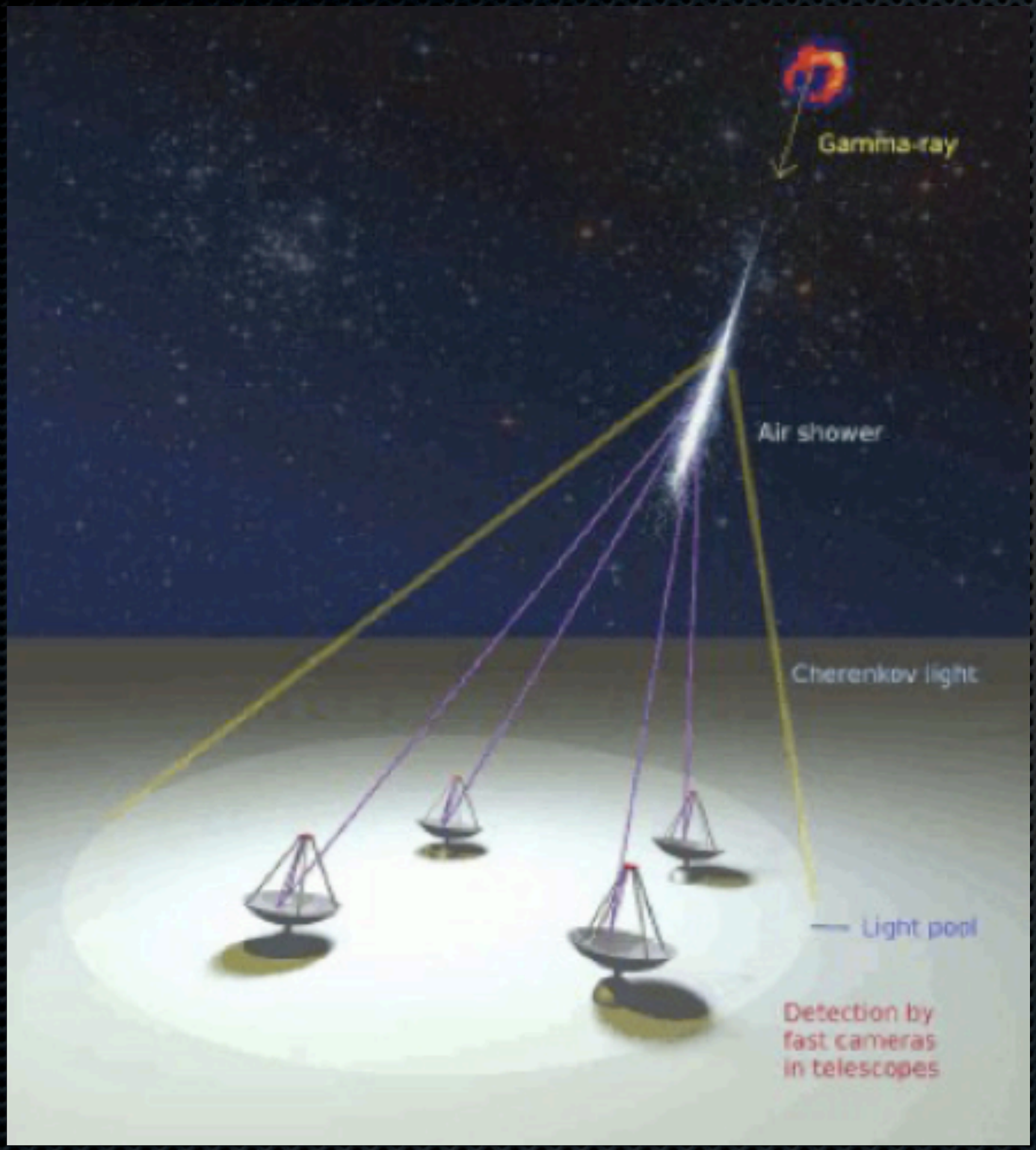
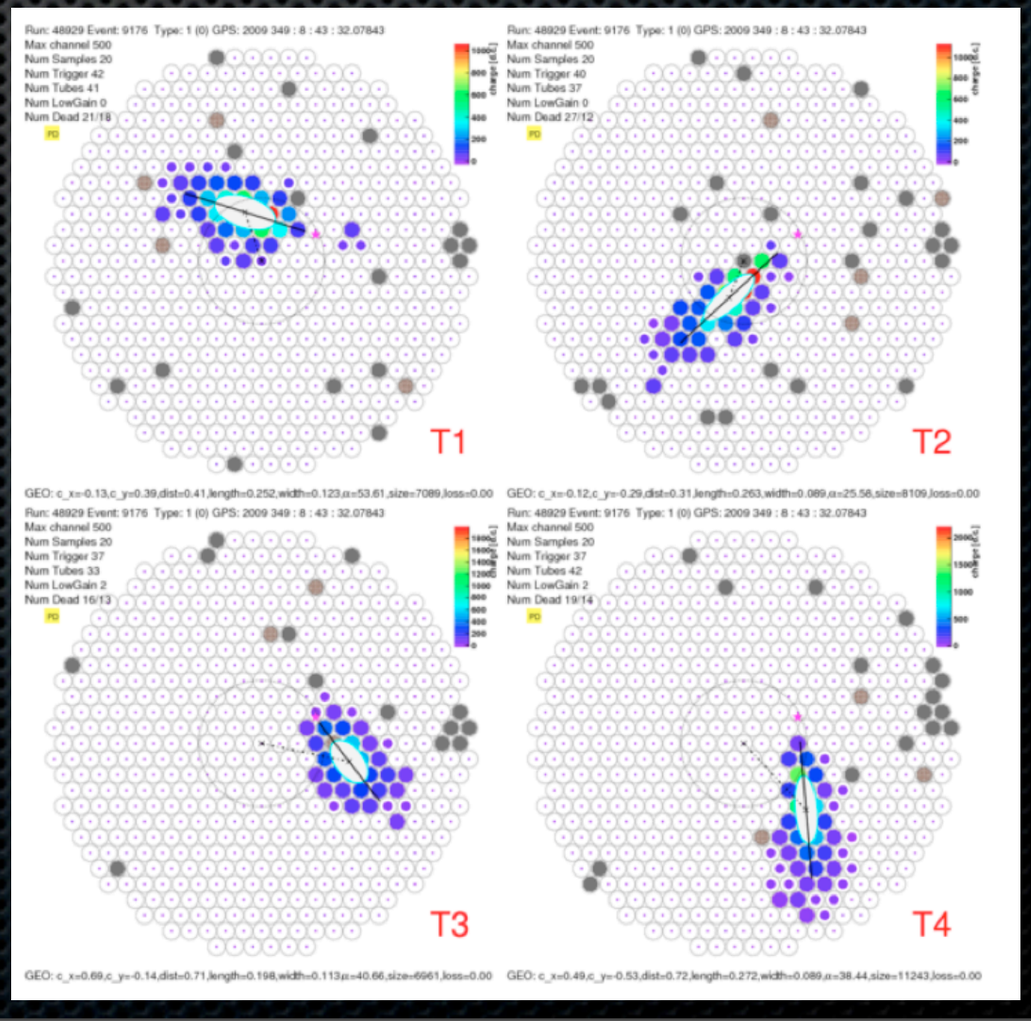
Imaging Atmospheric Cherenkov Technique:

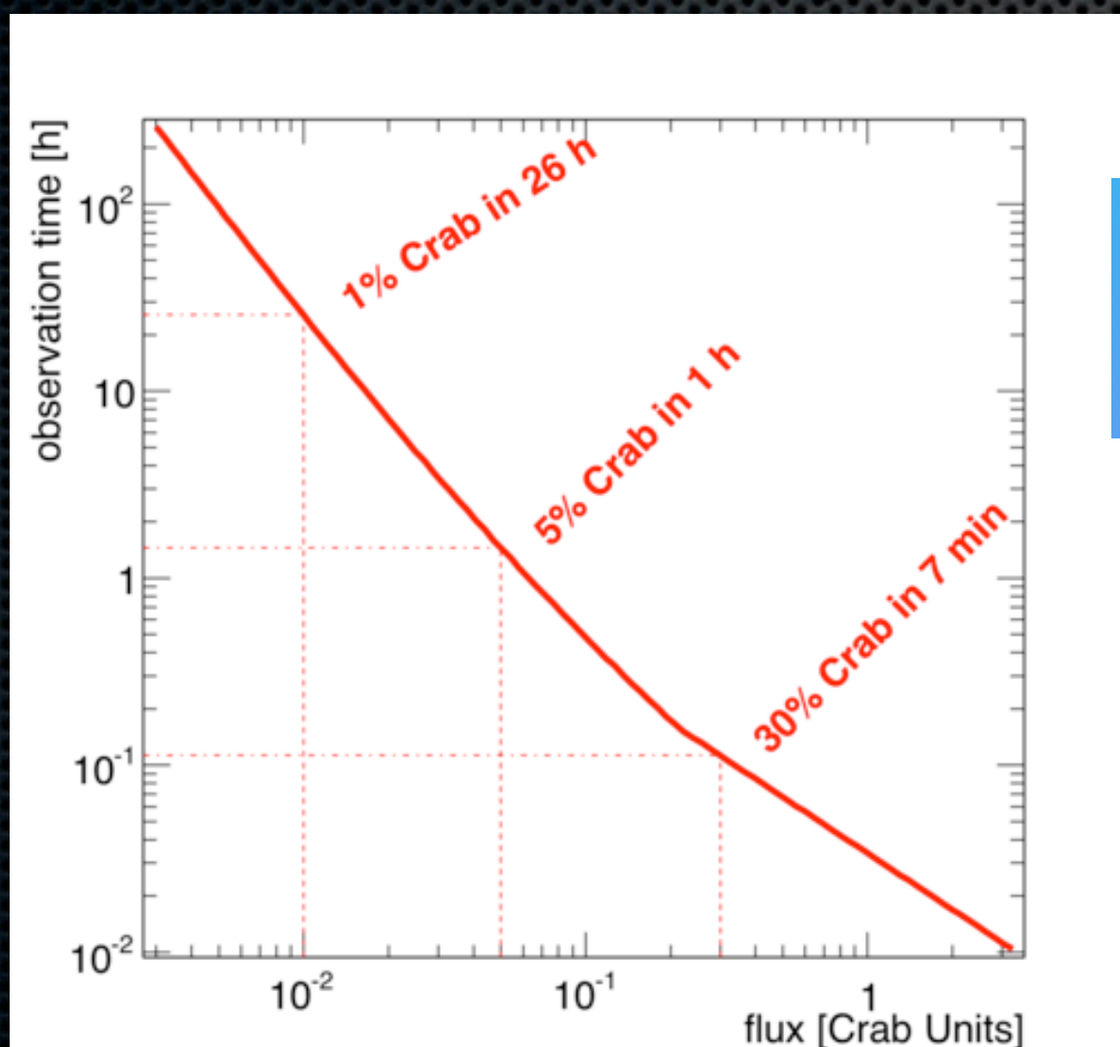
Primary gamma rays initiate EM showers w particle v>c: Cherenkov pulses

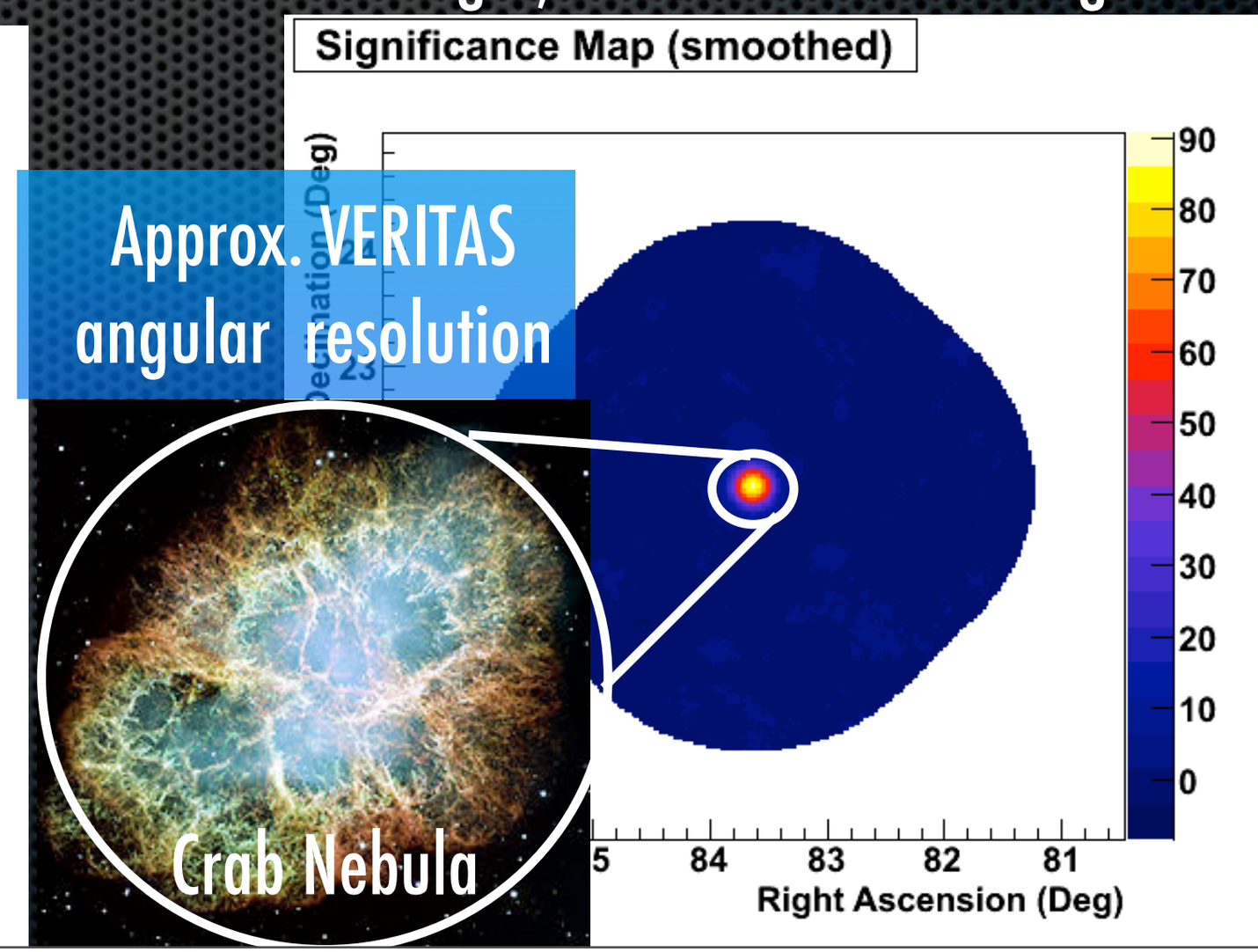




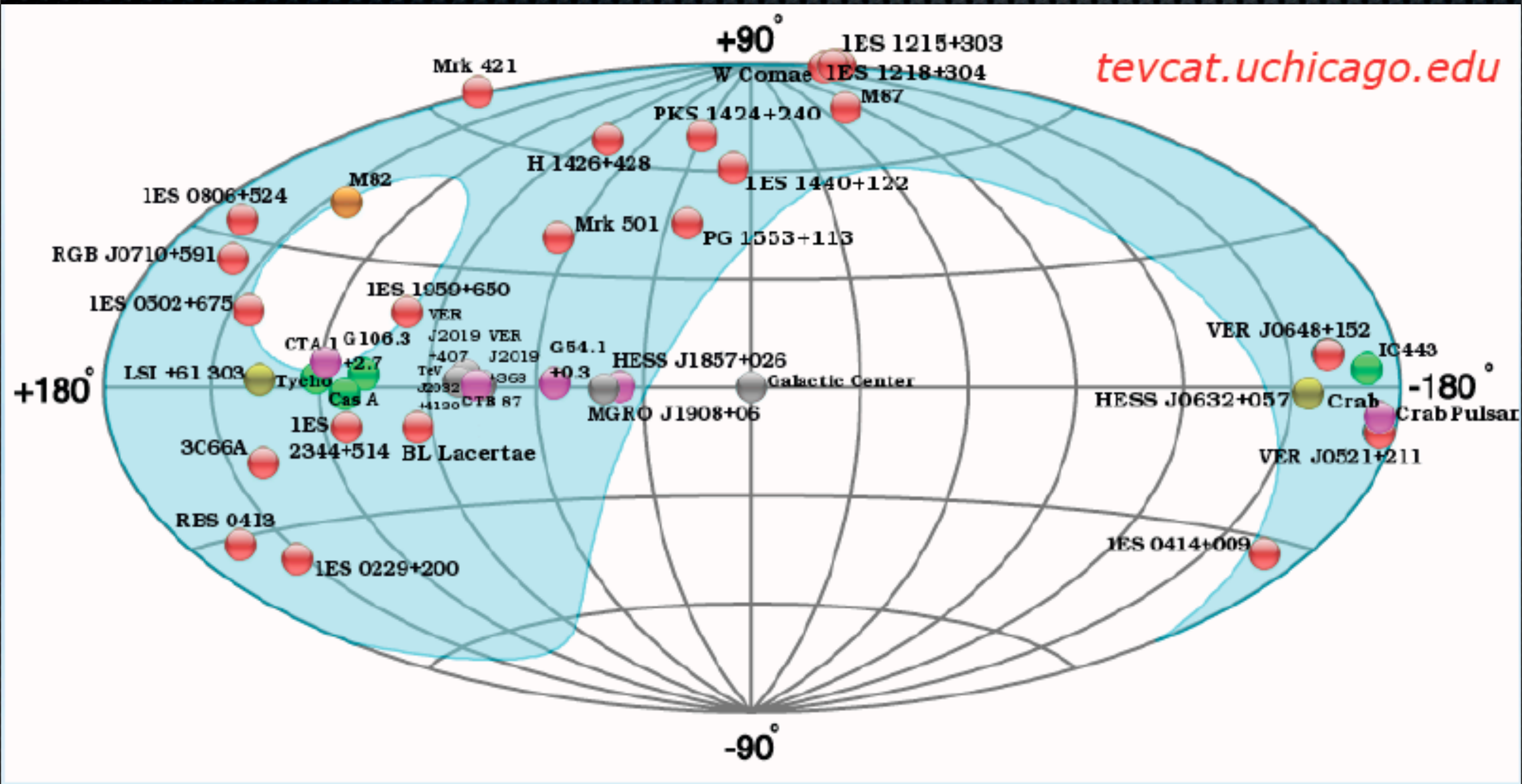
VERITAS

* 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





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 γs 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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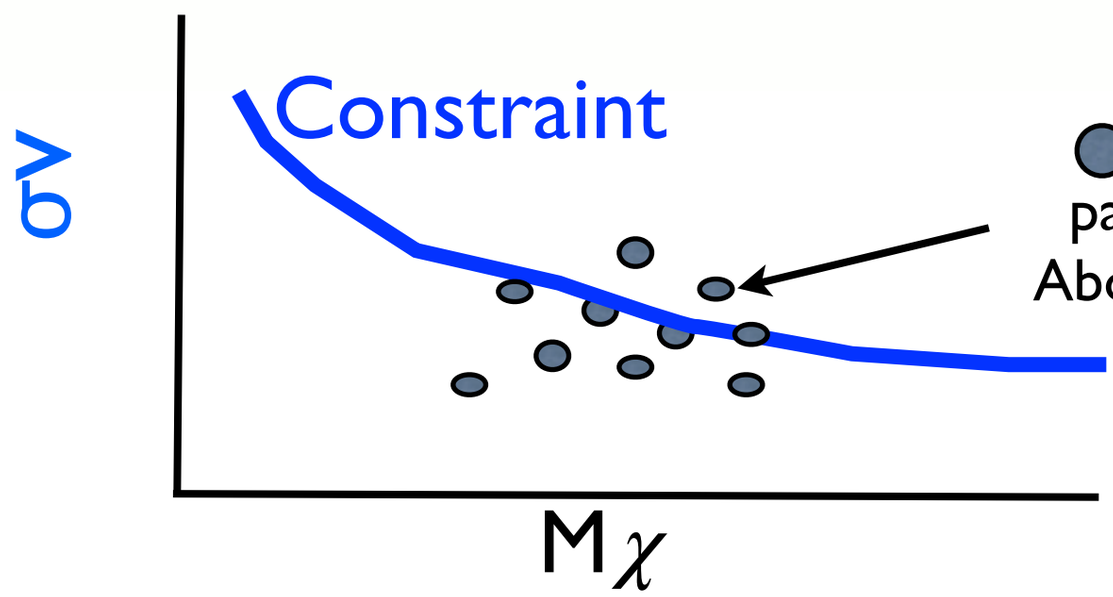
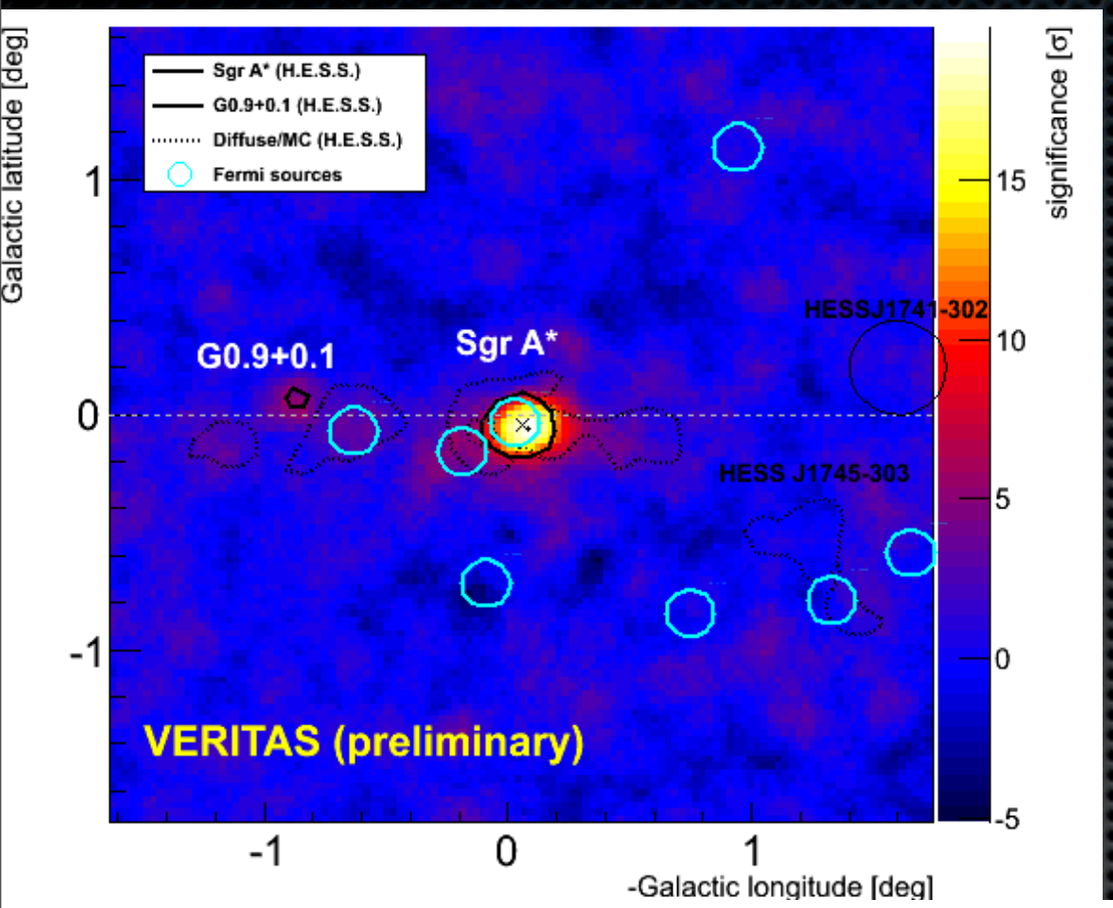


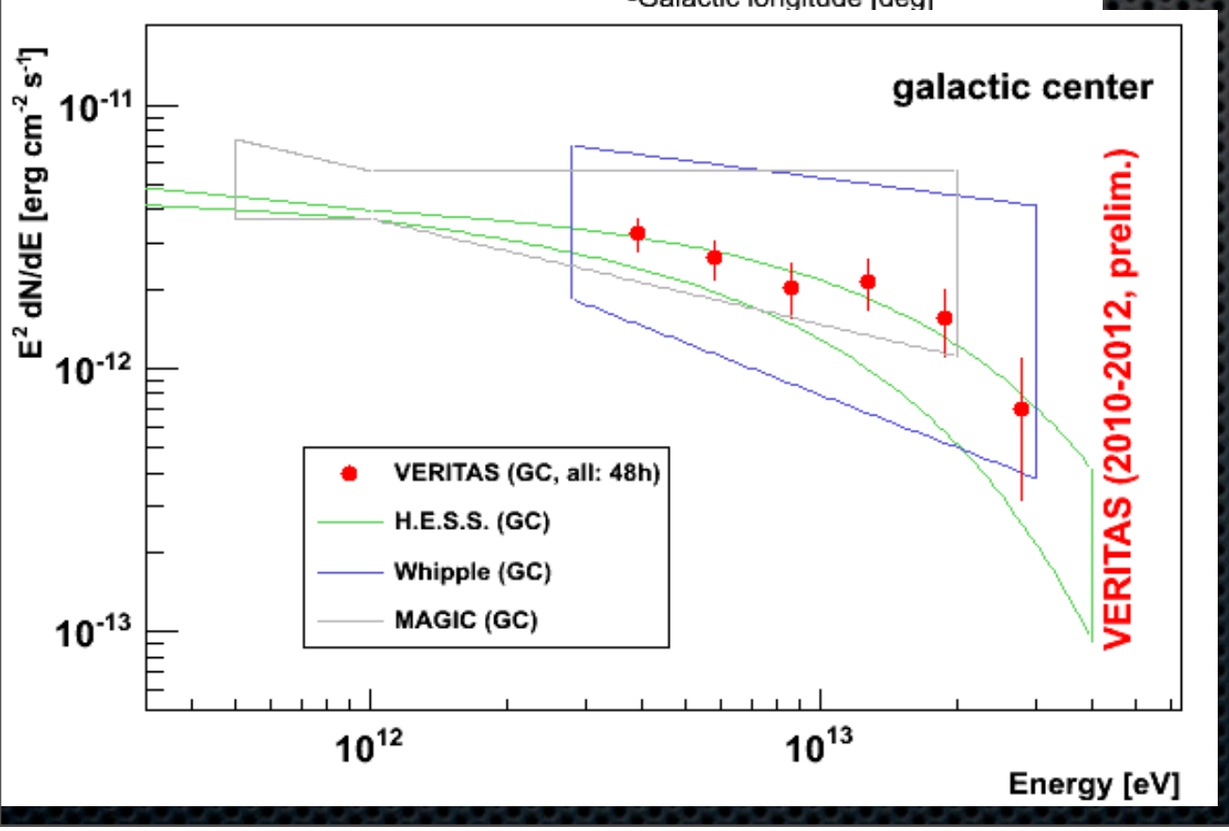
s= Discrete SUSY parameter scan results. Above curve = disallowed model

VERITAS DM Targets

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

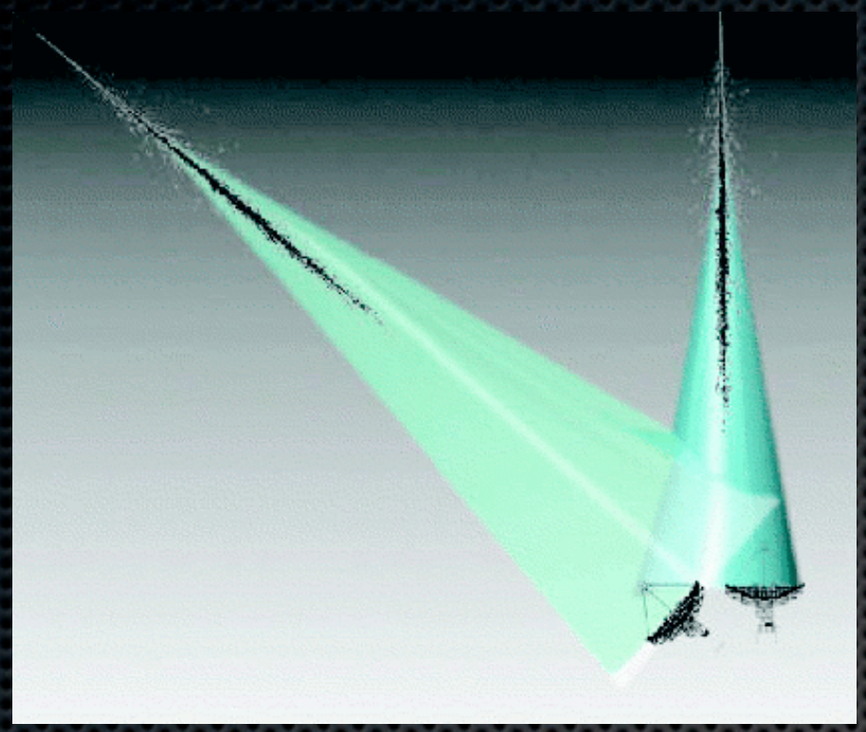
VERITAS Galactic Center Observations

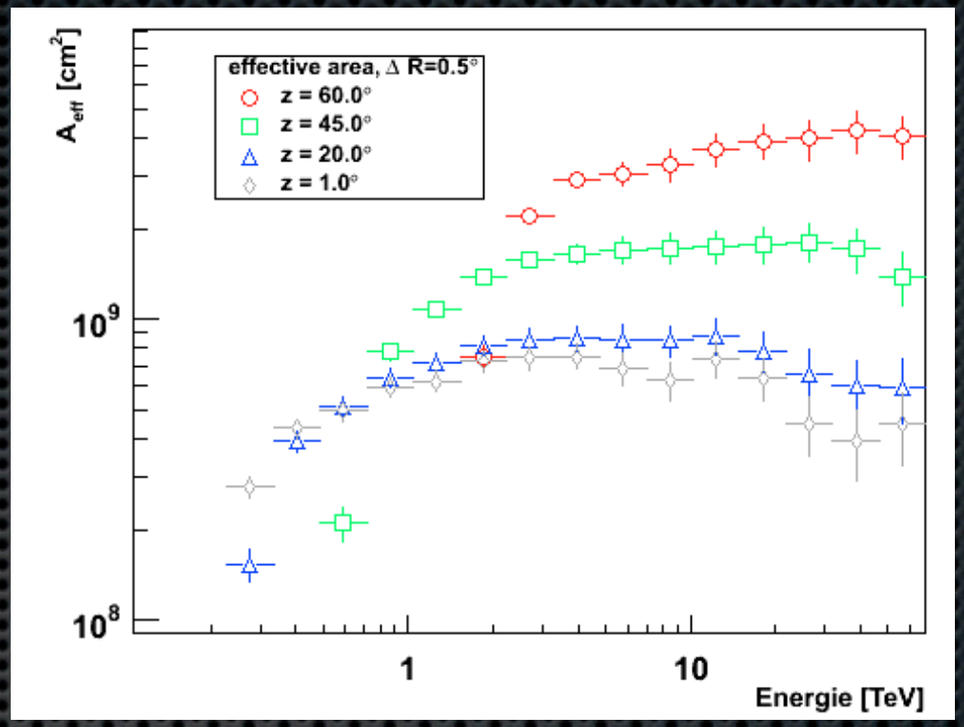




- 46 Hours of quality selected livetime from 2010-2012
- 19σ detection of SgrA*
- Also, excess @ SNR G0.9+0.1
- No Evidence for Variability
- Prelim. Spectrum confirms HESS/Whipple/MAGIC

Benefits of VERITAS GC Observations

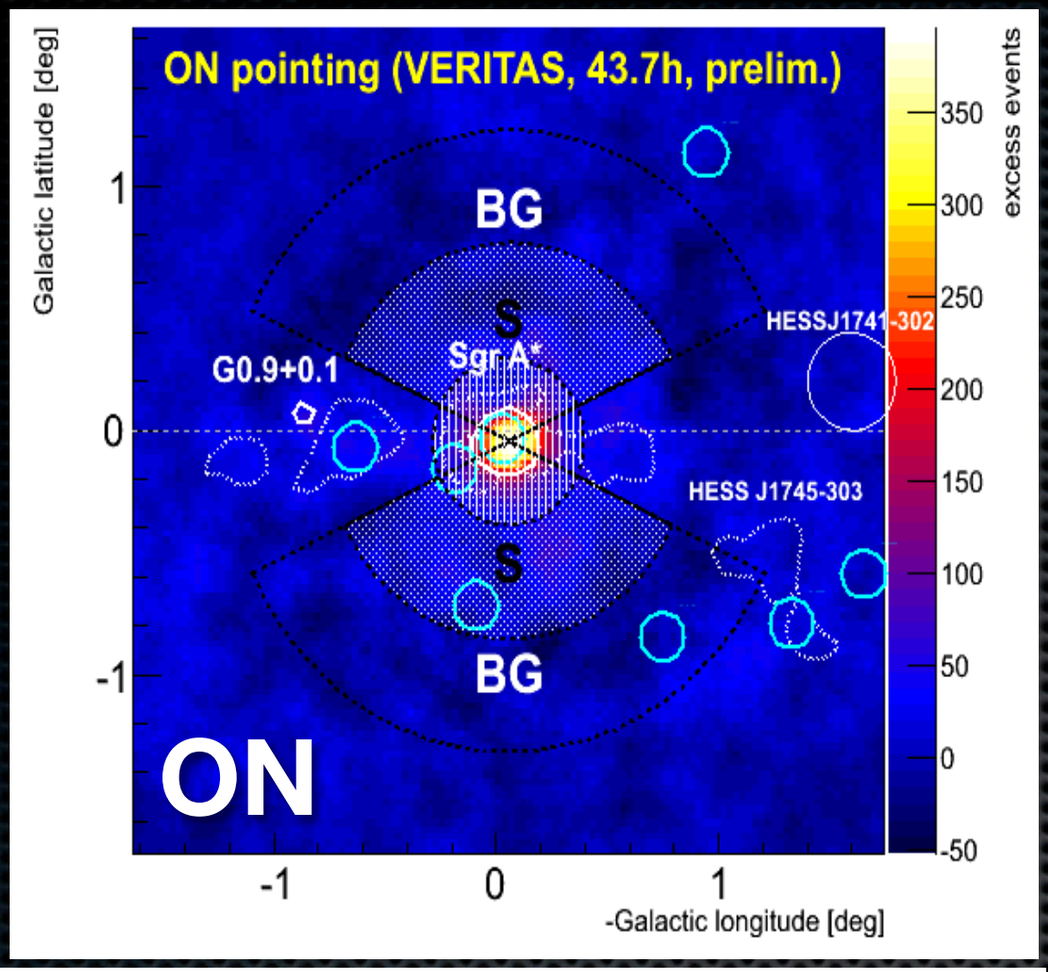


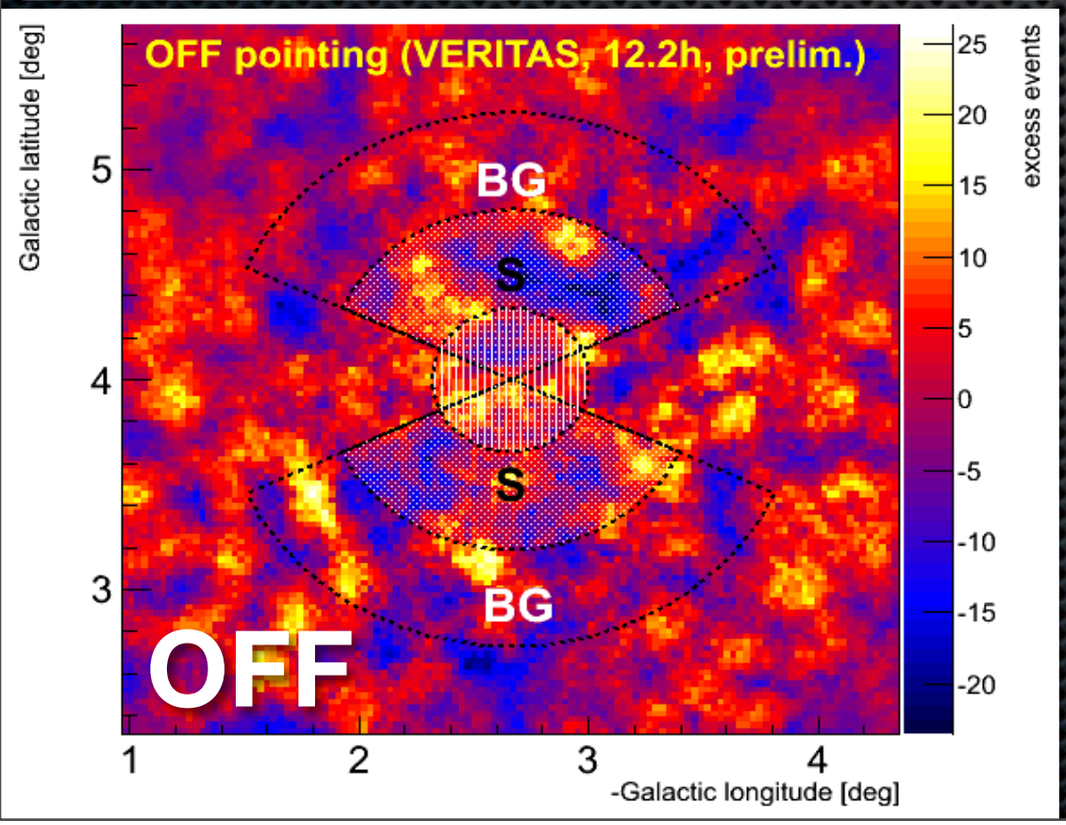


SgrA* is a large zenith angle source for VERITAS: Large energy threshold.....however, increased sensitivity at high E. Drawback of decreased angular resolution overcome by advanced image reconstruction ("disp" method, see Buckley.....)

<u>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?)</u>

VERITAS Galactic Center Observations

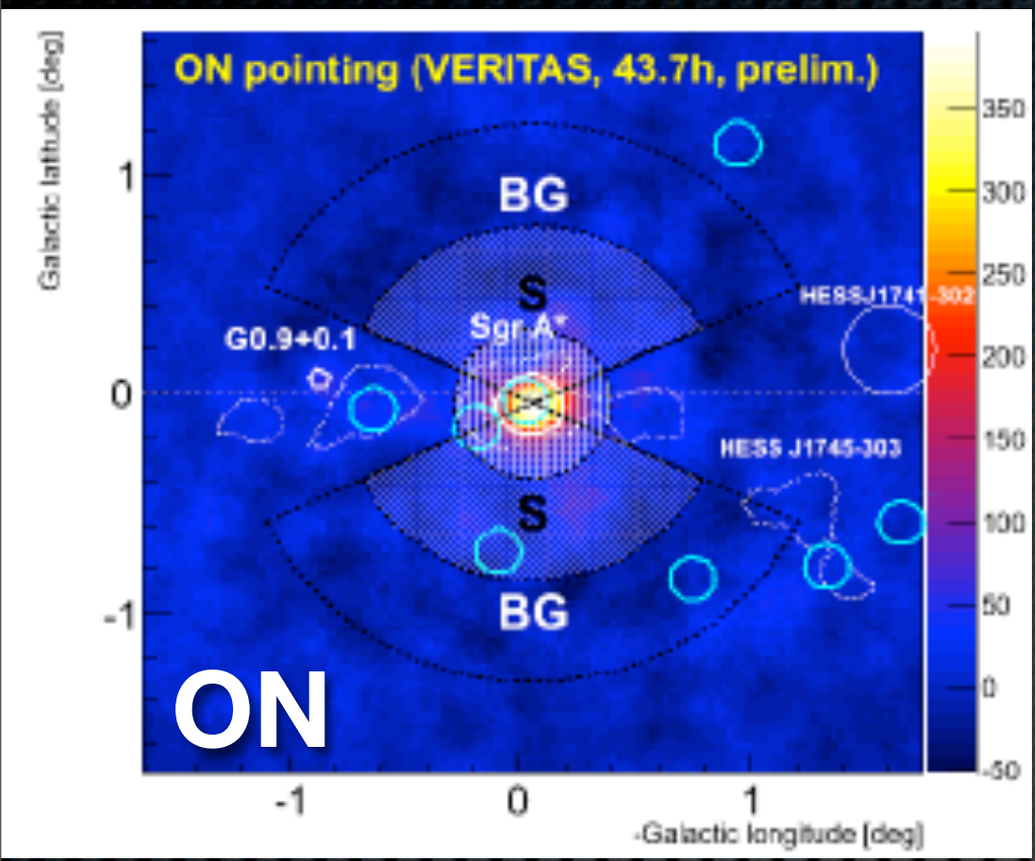


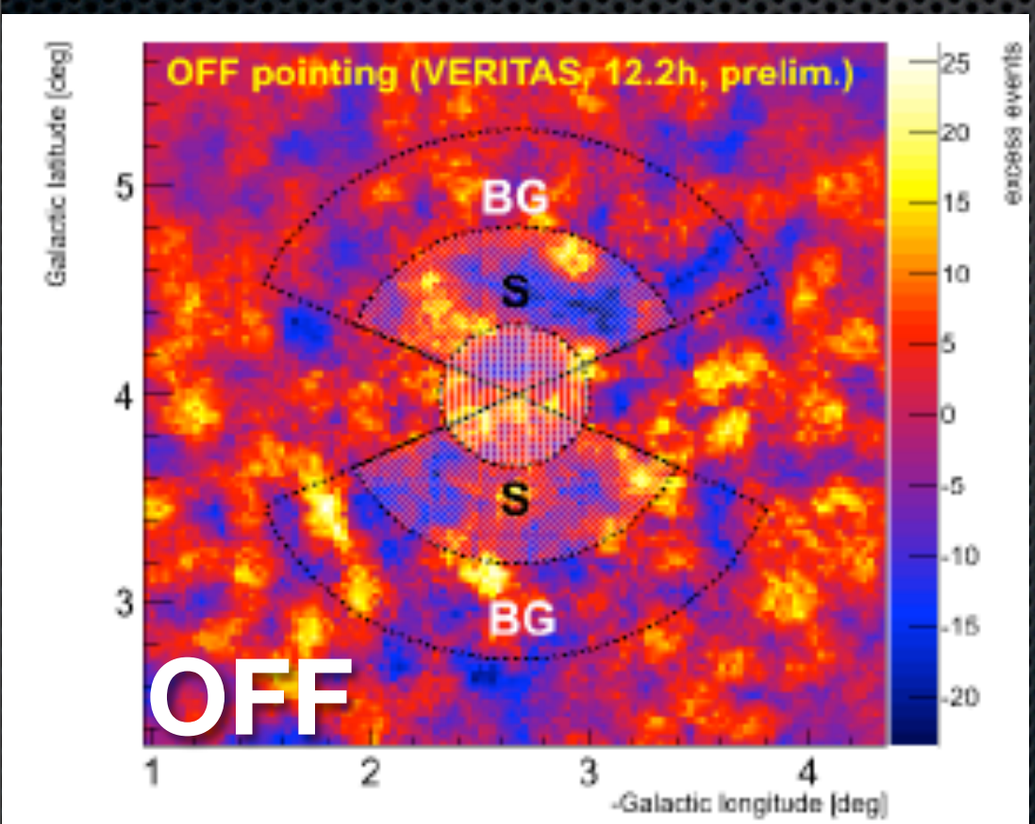


Dark Matter Upper Limit Analysis Strategy:

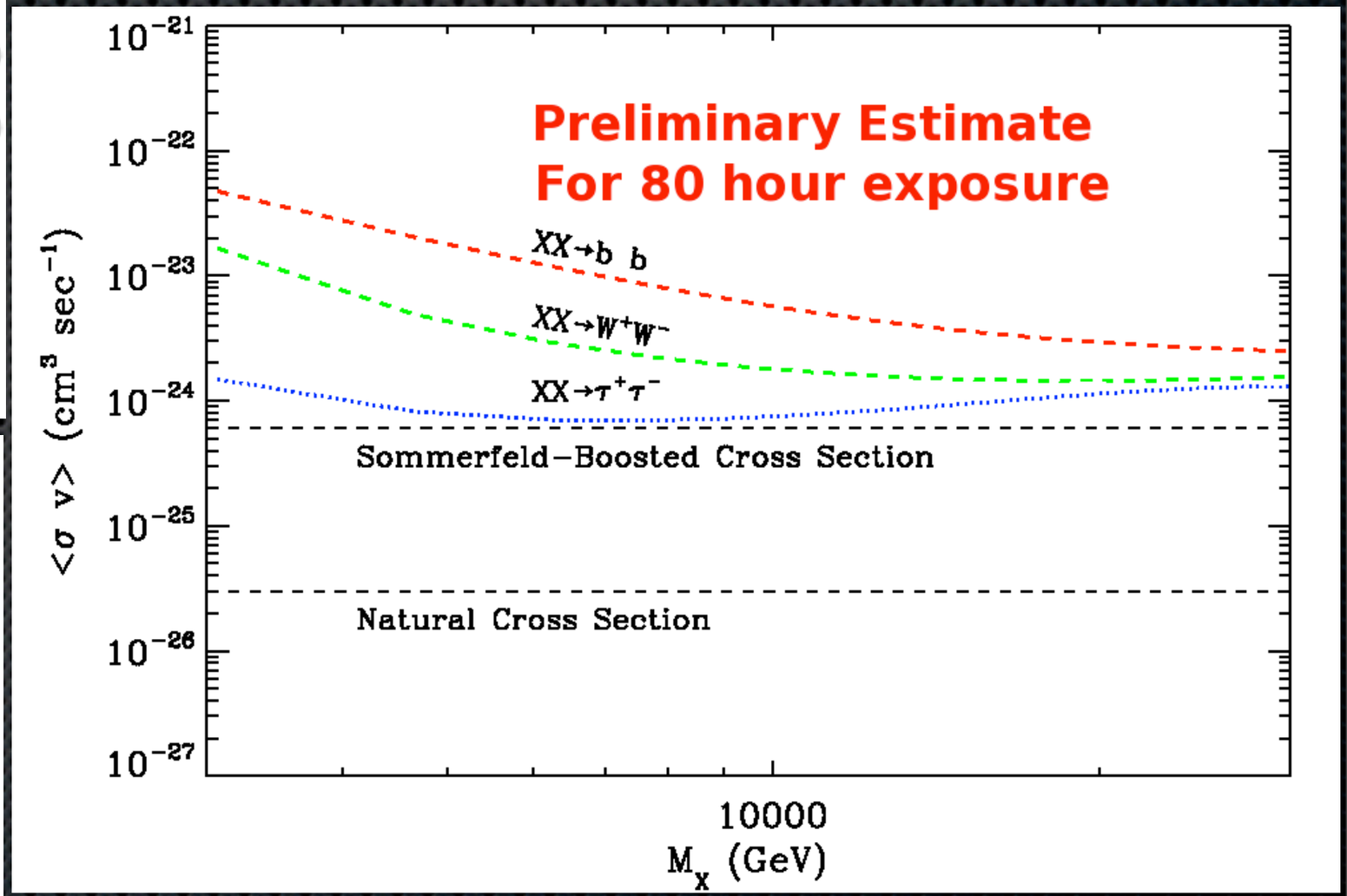
- 2 Seperate Pointings (ON/OFF signal region), also exclude SgrA*
- Define Signal (S) and Background (BG) regions in both pointings
- Use of OFF pointings allows determination of energy dependent acceptance in S/BG regions

VERITAS Galactic Center Observations





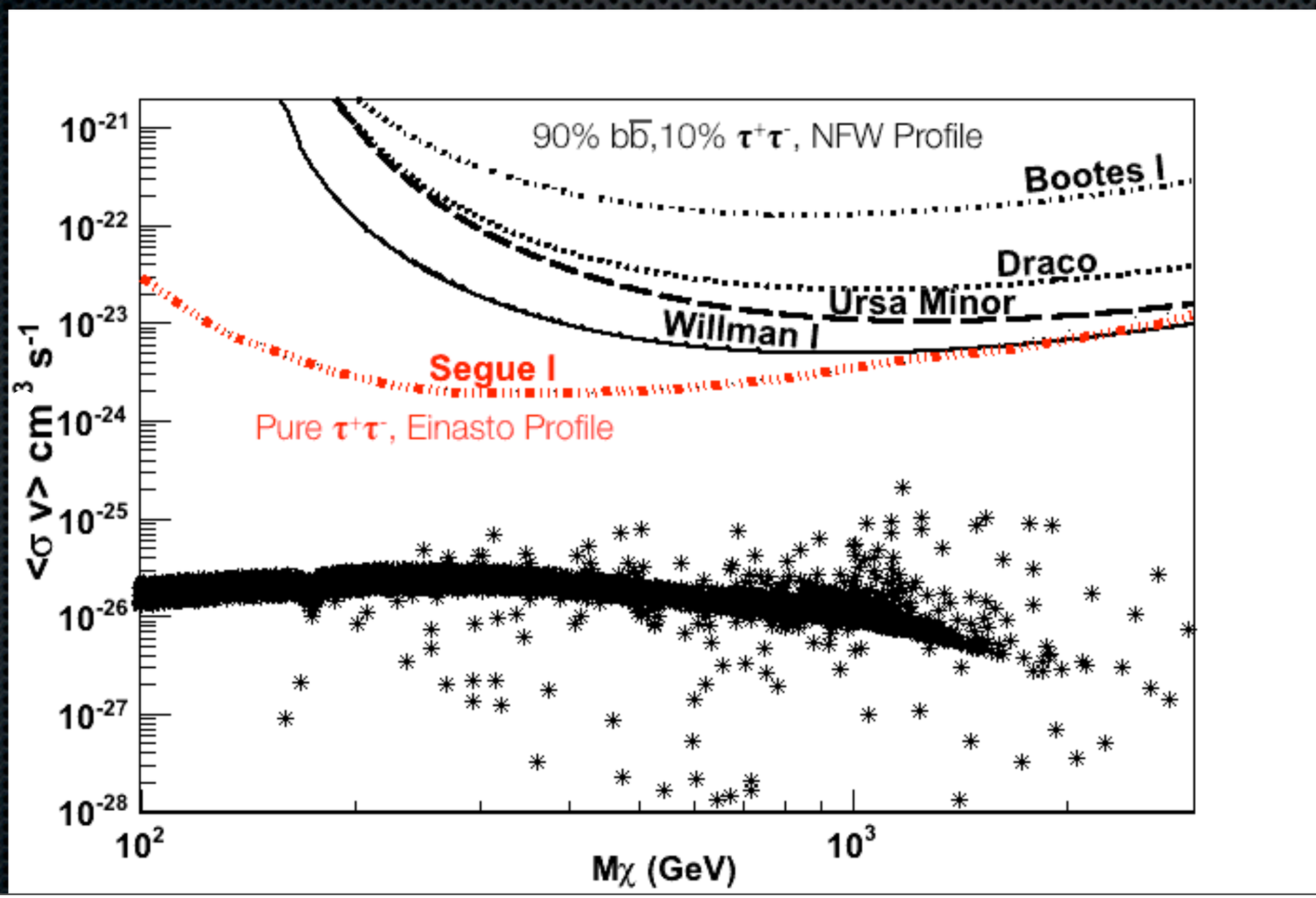
Estimate for end of 2013 Season



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

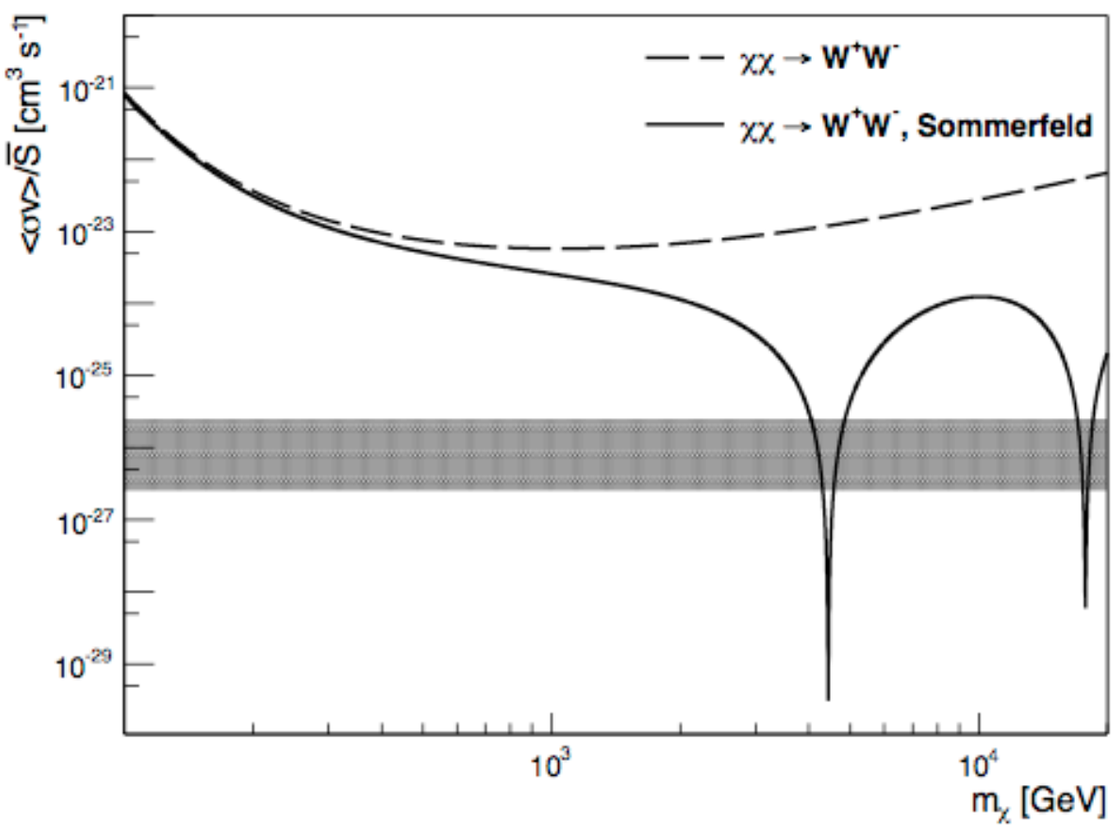


VERITAS Dwarf Spheroidal Observations

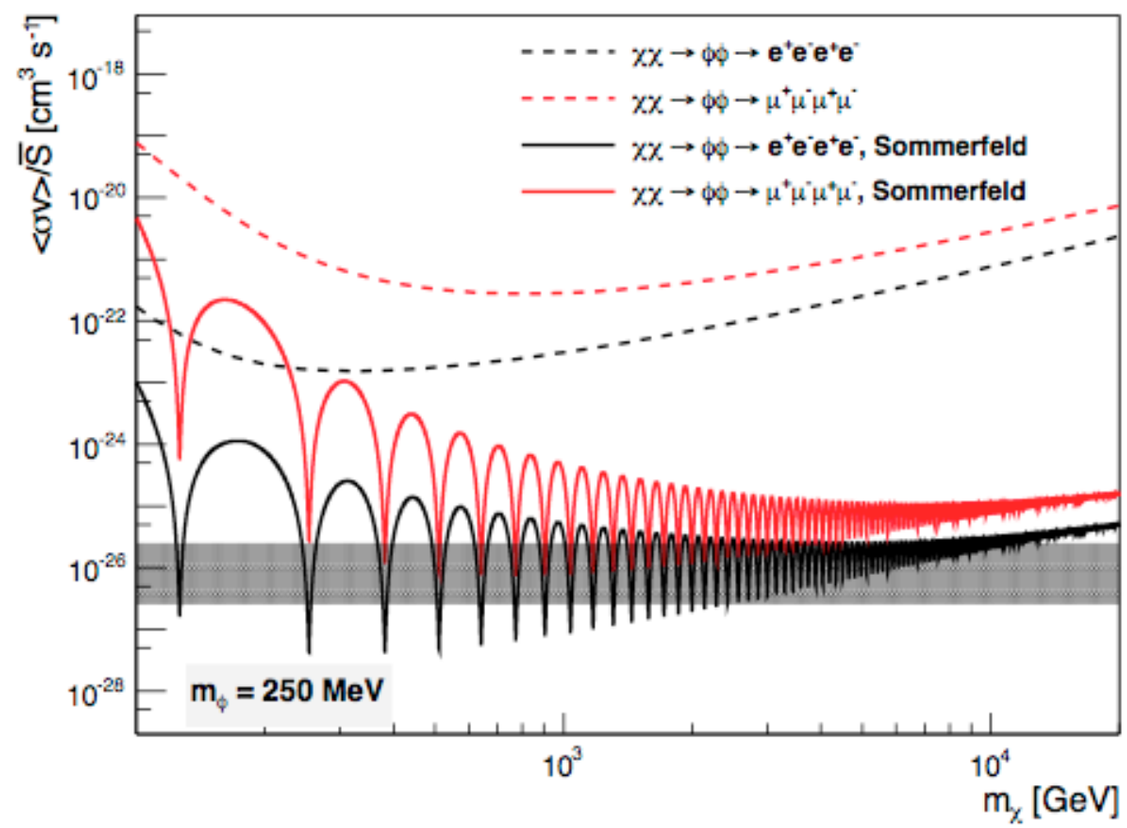
Segue I Results Cont.

Constraints on low-velocity signal enhancement (Sommerfeld Boost)

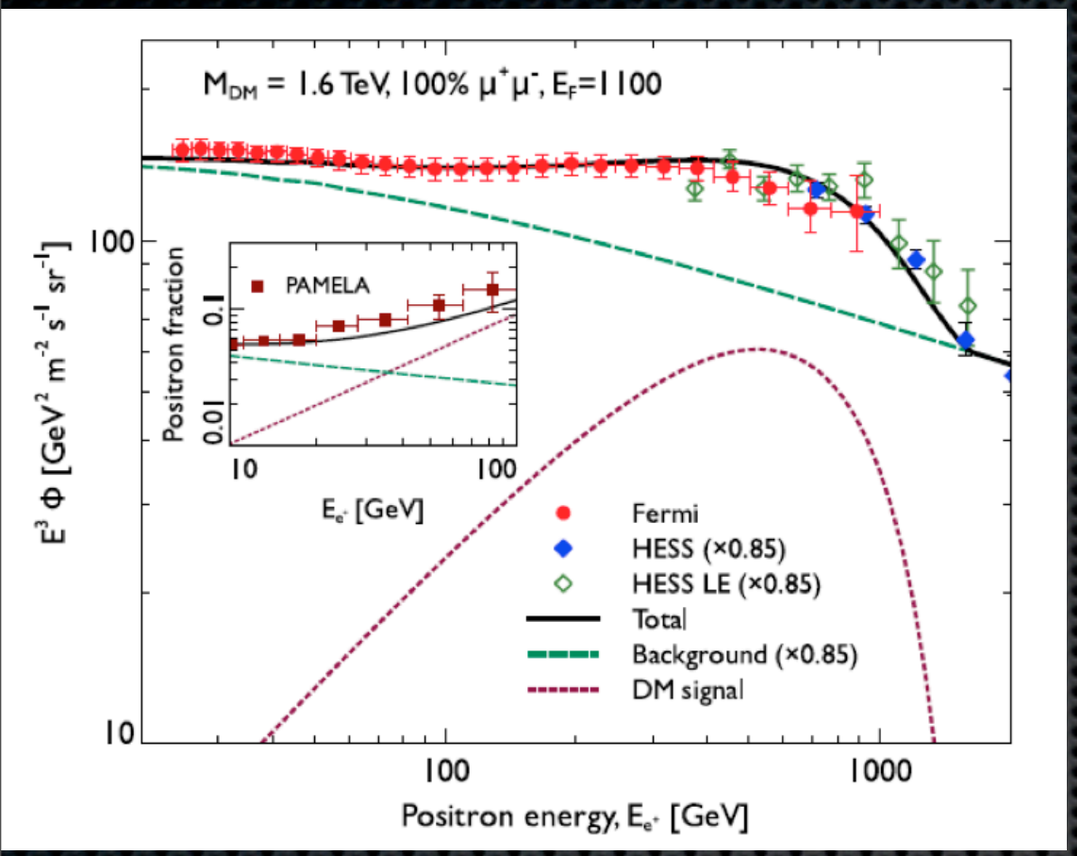
(Latanzi + Silk 2009) Model



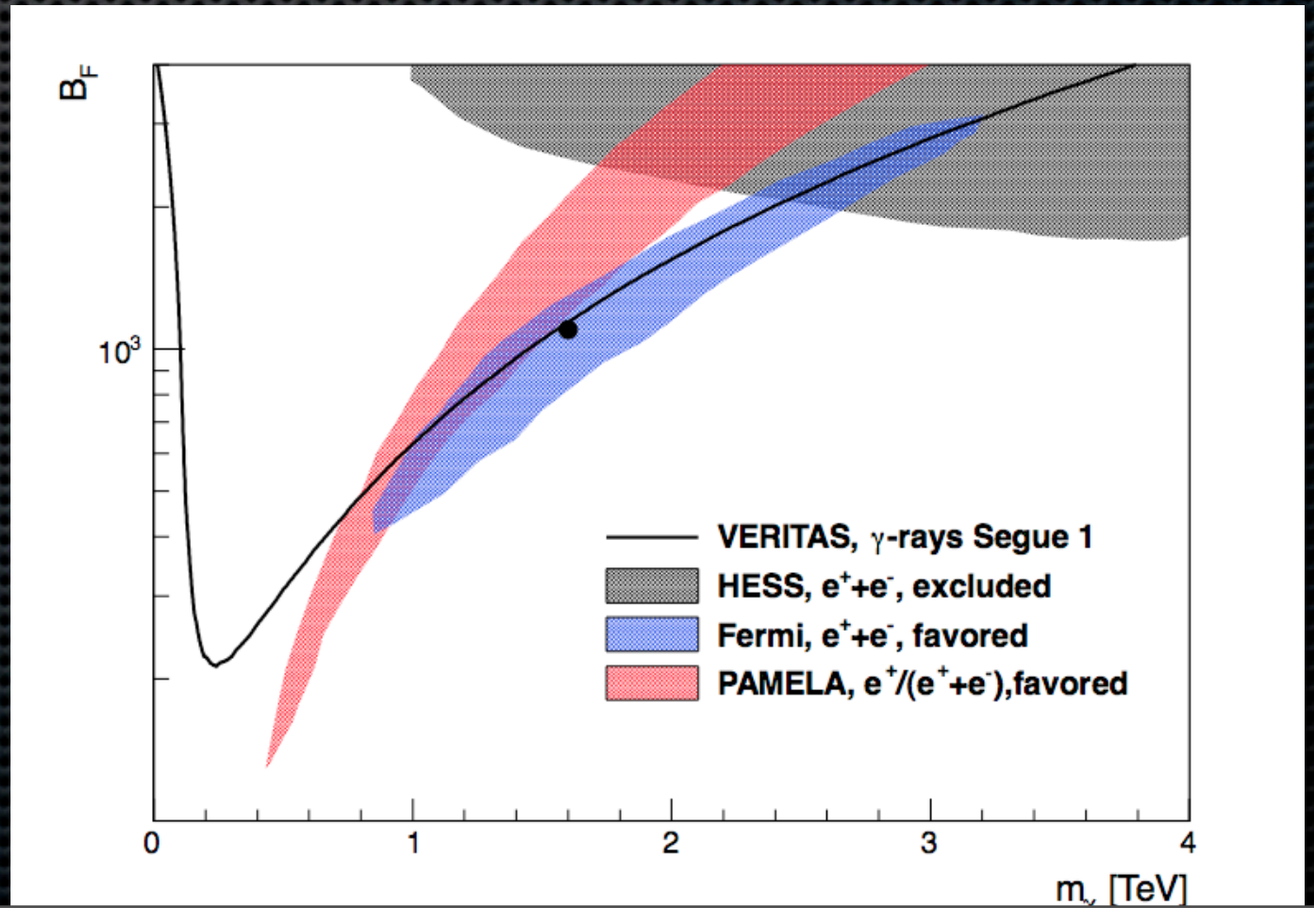
Arkani-Hamed et al 2009 Model



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

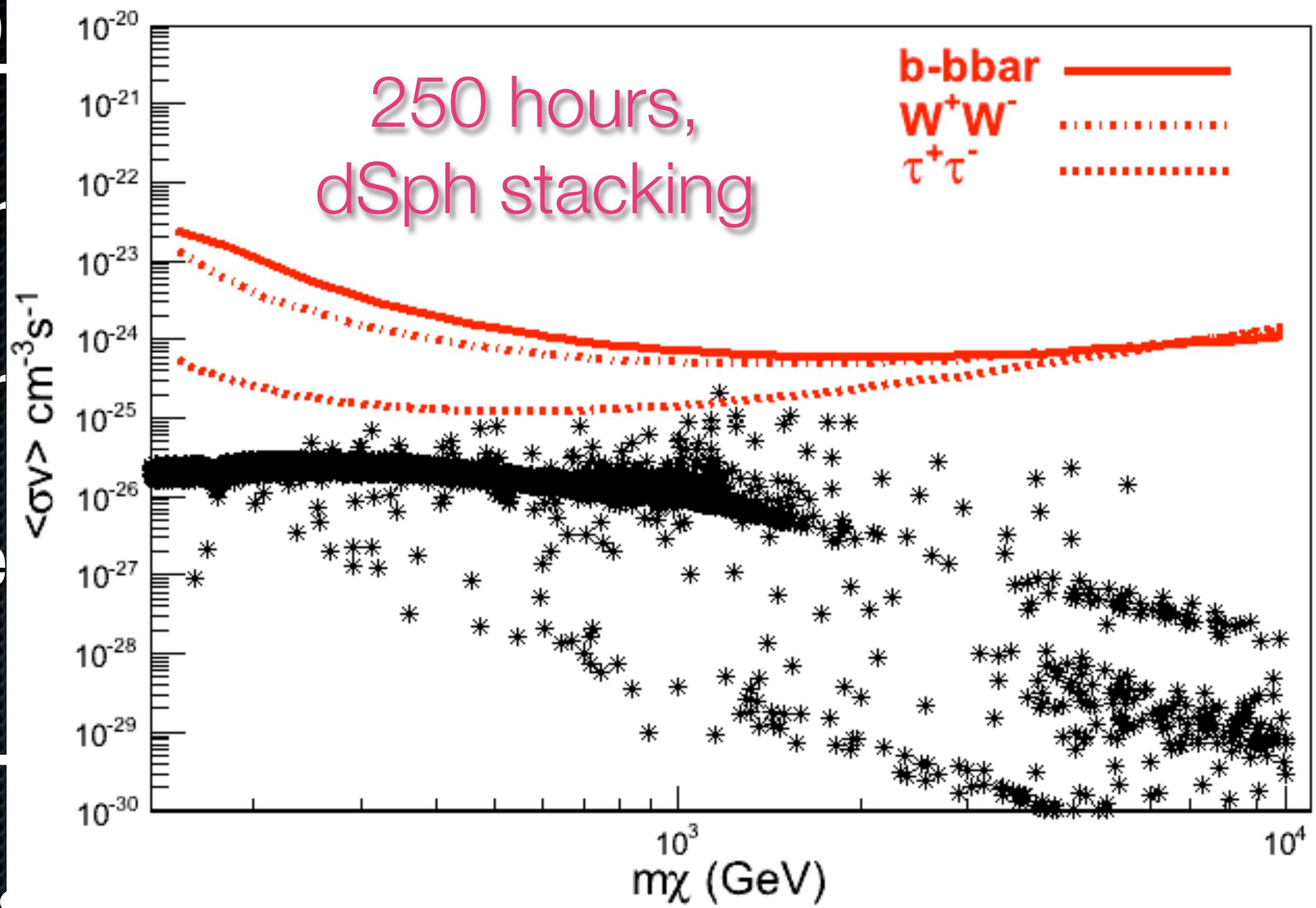
Work in Progress: DSph Stacking

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

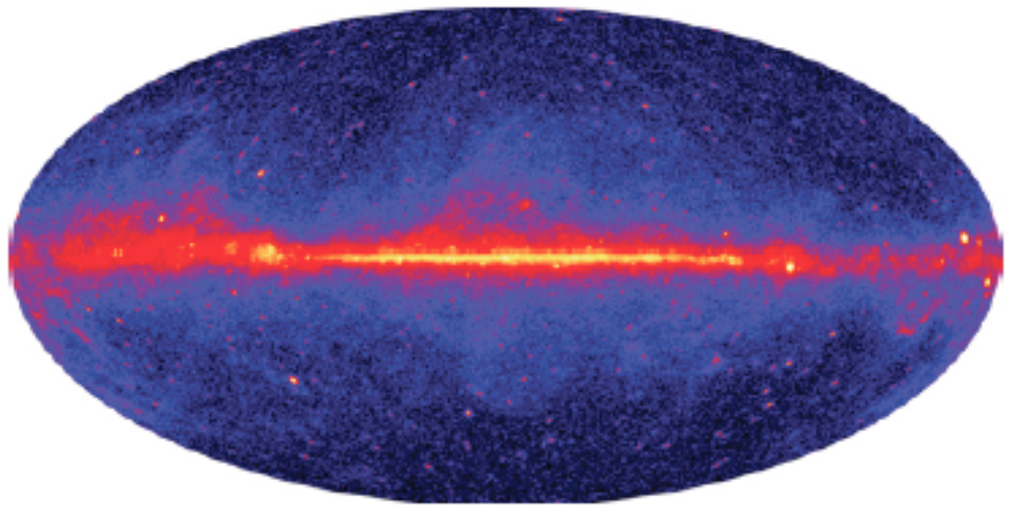
DSph stacking can provide significant increase in sensitivity of <σv> limits (A. Garinger-Sameth and S. Koushiappas, Phys. Rev. Lett. 2011)

Work in Progress: DSph Stacking

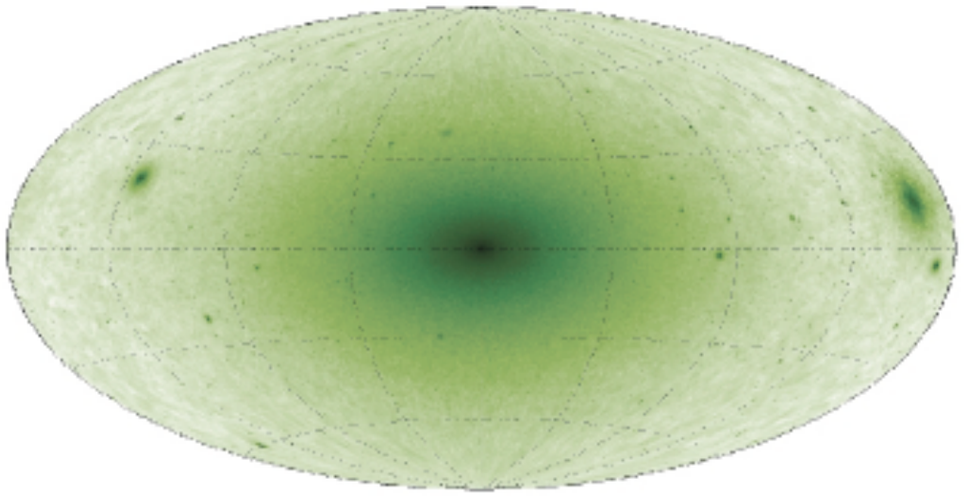


Phys. Rev. Lett. 2011)

Other VERITAS DM Projects



Fermi-LAT 3-yr all-sky map



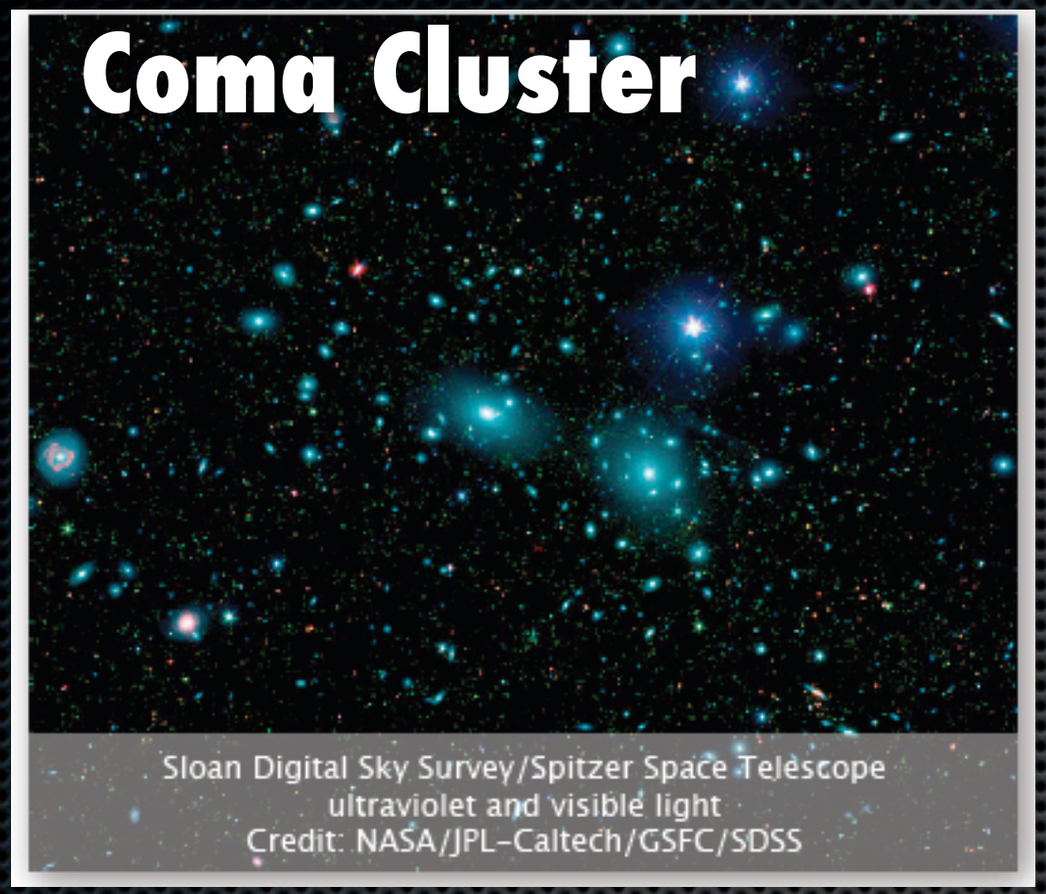
Kuhlen, Diemand & Madau 2008

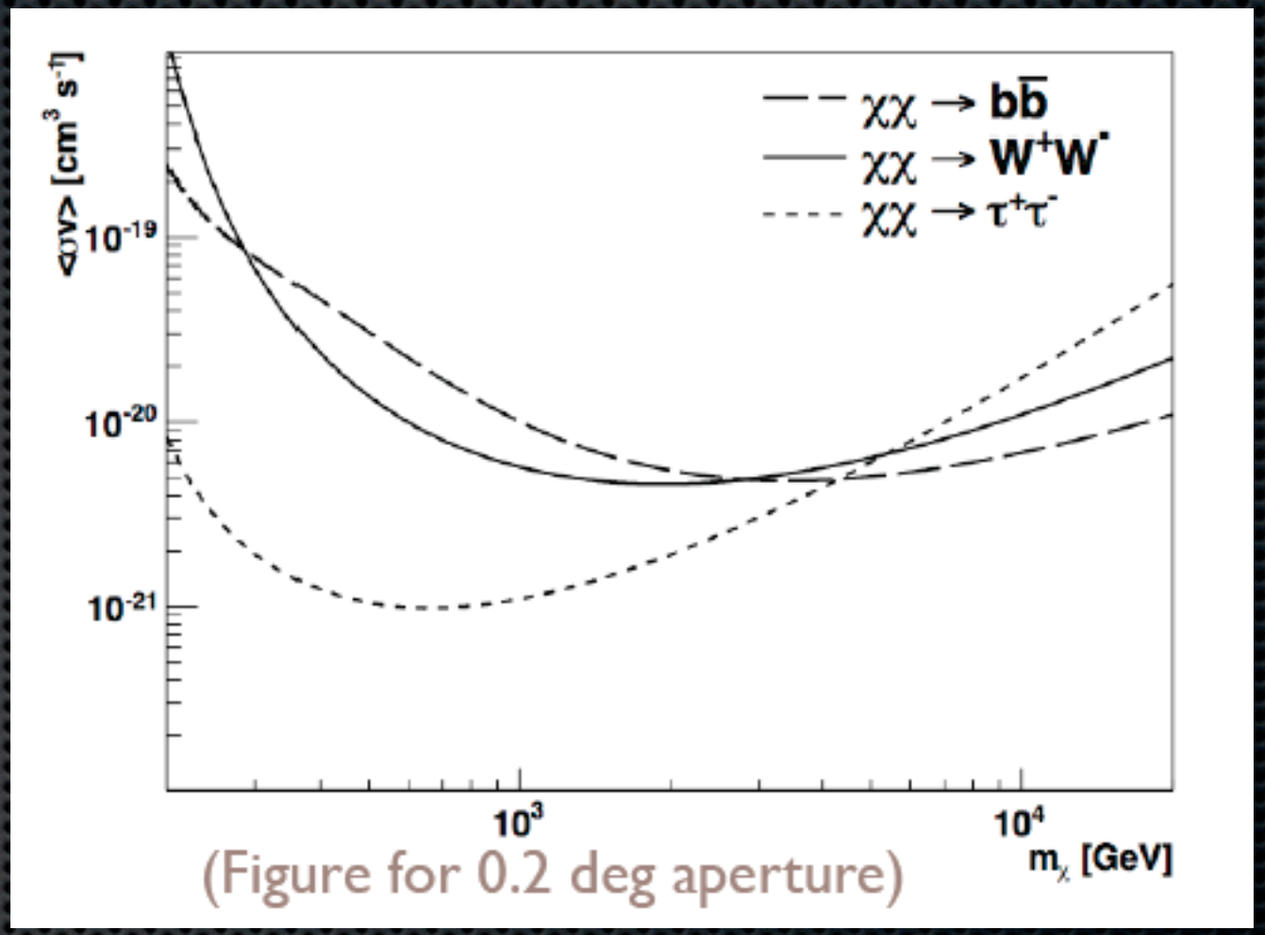
Strategy: Follow up observations of Fermi UIDs with "DM subhalo-like" characteristics:

- $|b| > 10^0$ (exclude gal. plane)
- Fermi-LAT 10-100 GeV detected
- No variability
- No Spectral Curvature
- Hard Spectrum ($\Gamma < 2.0$)

Other VERITAS DM Projects: Coma Cluster

(Aliu et al. 2012 ApJ)





- 19 hour observation, no excess detected
- NFW profile, 0.2^0 radius chosen for DM limit
- $\langle\sigma v\rangle$ limits ~ 10^-21 for $\tau^+\tau^-$ channel

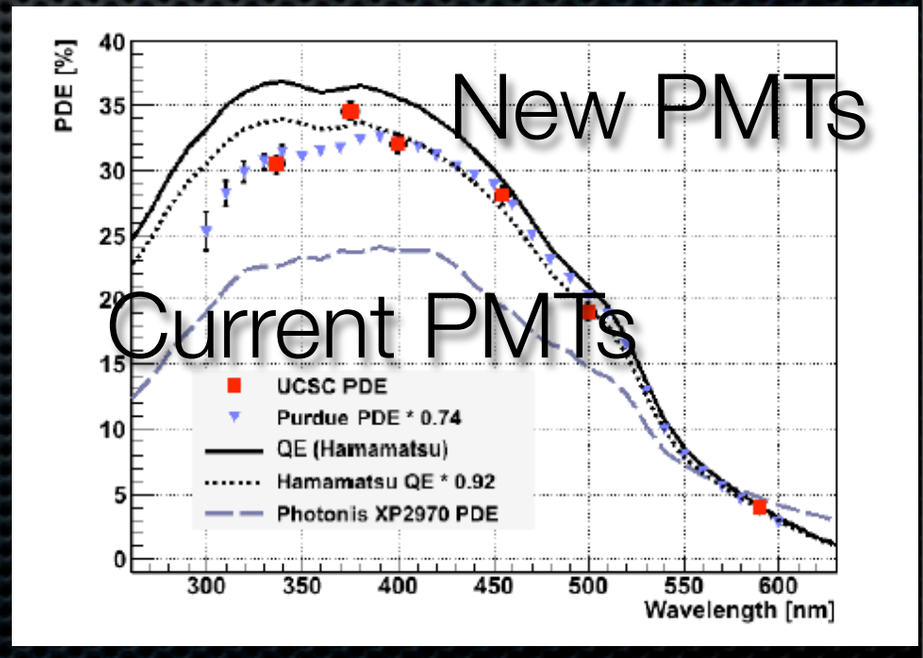
Looking to the Near Future:

VERITAS Upgrade Completed 2012:

Advanced Trigger System: (lower threshold, better noise rejection)

-**Cameras Upgraded** with high QE PMTs

Increased Sensitivity will allow VERITAS to provide further reaching constraints on both continuum and line searches



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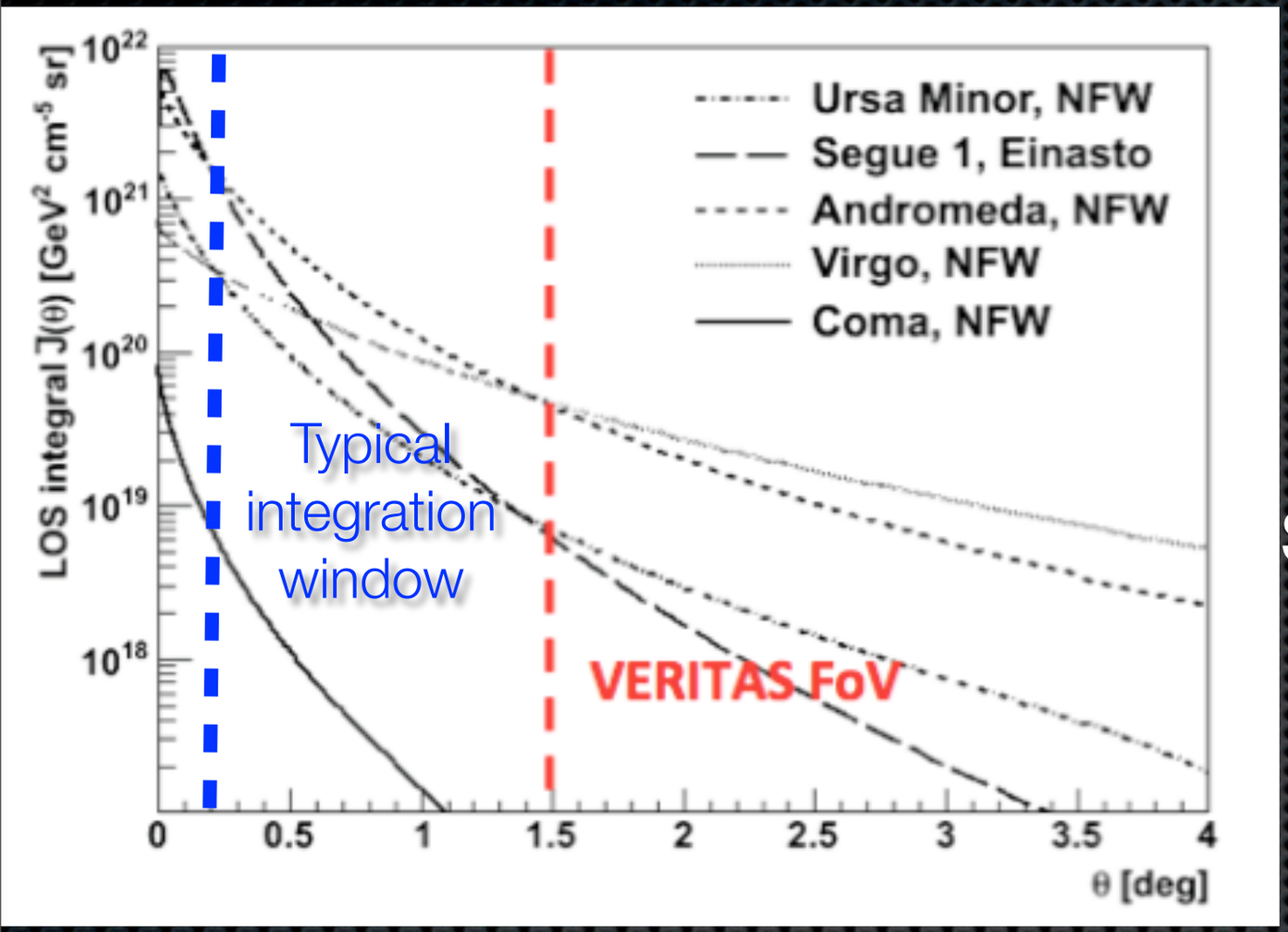
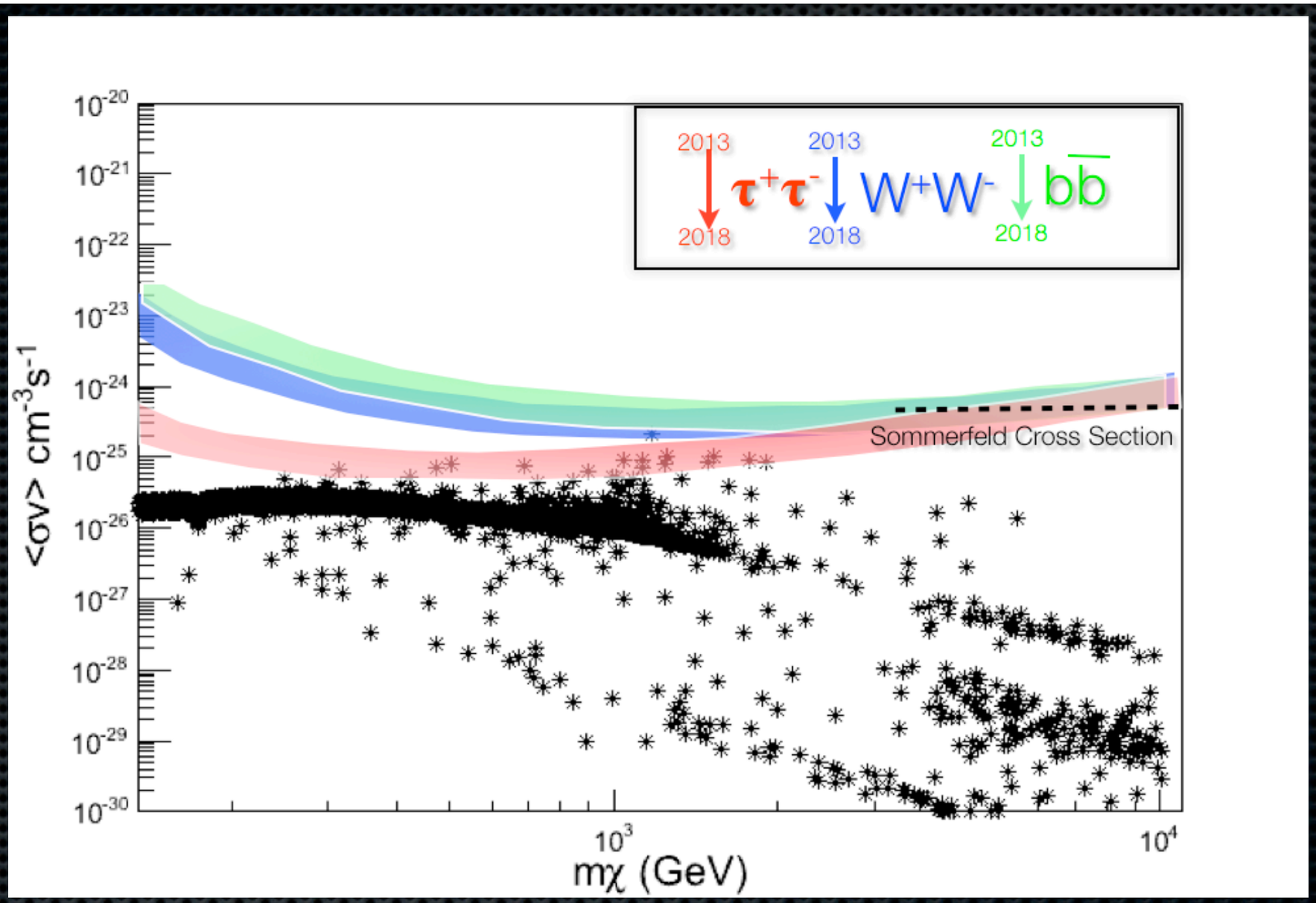


New analysis techniques (in mature stage) are offering increased extended analysis sensitivity. Will offer ability to provide increased constraints on galaxy clusters

Additionally, investigation of new image analysis methods for VERITAS are indicate a potential increase in sensitivity of 2-3x for both current and archival data.

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)

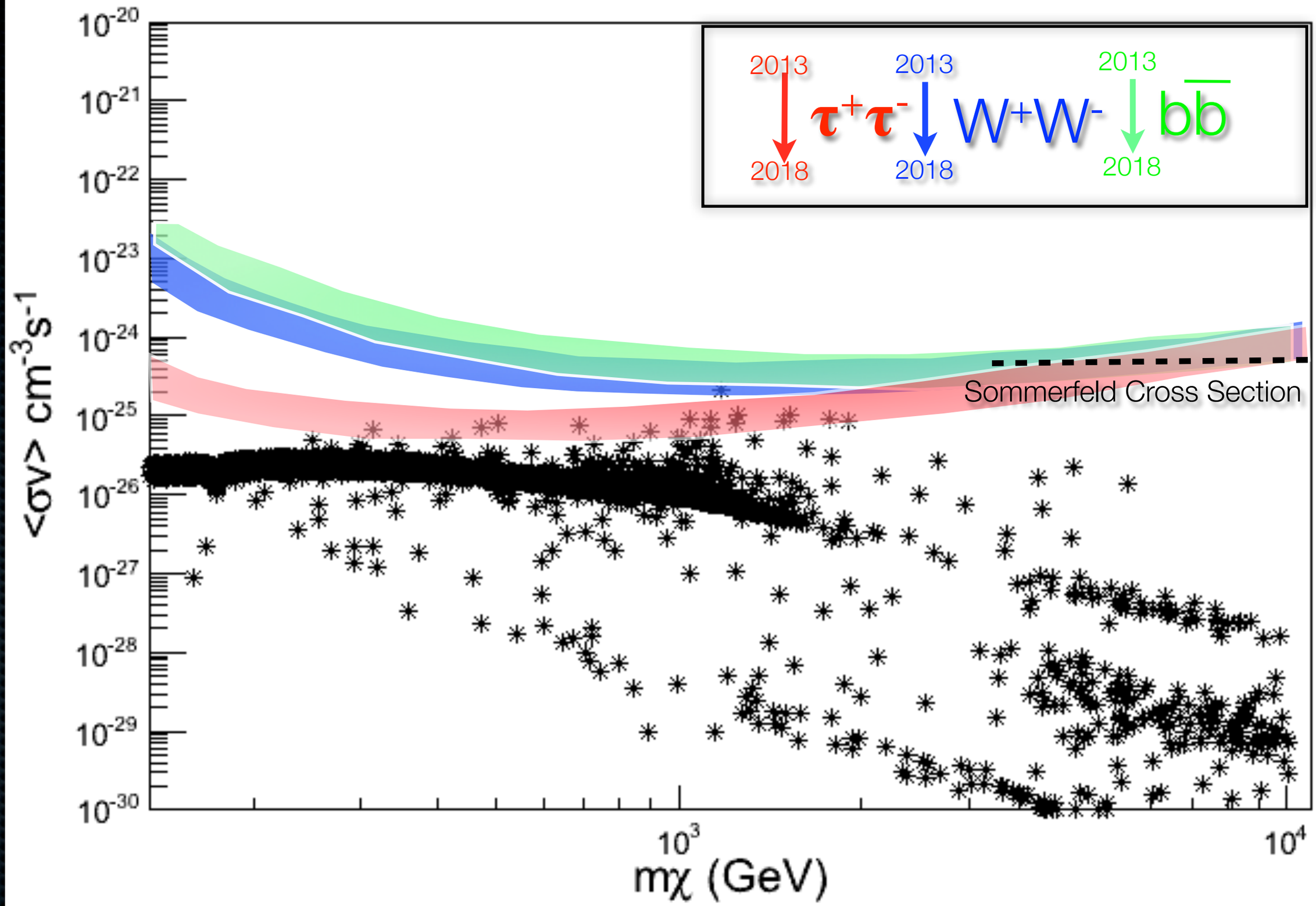
Comments

-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
2018
$\tau^+\tau^-$
2013
2018
W^+W^-
2013
2018
$b\bar{b}$
Sommerfeld Cross Section
10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^{-24}
10^{-25}
10^{-26}
10^{-27}
10^{-28}
10^{-29}
10^{-30}
$\langle\sigma v\rangle$ cm^{-3}s^{-1}
10^3
10^4
$m\chi$ (GeV)