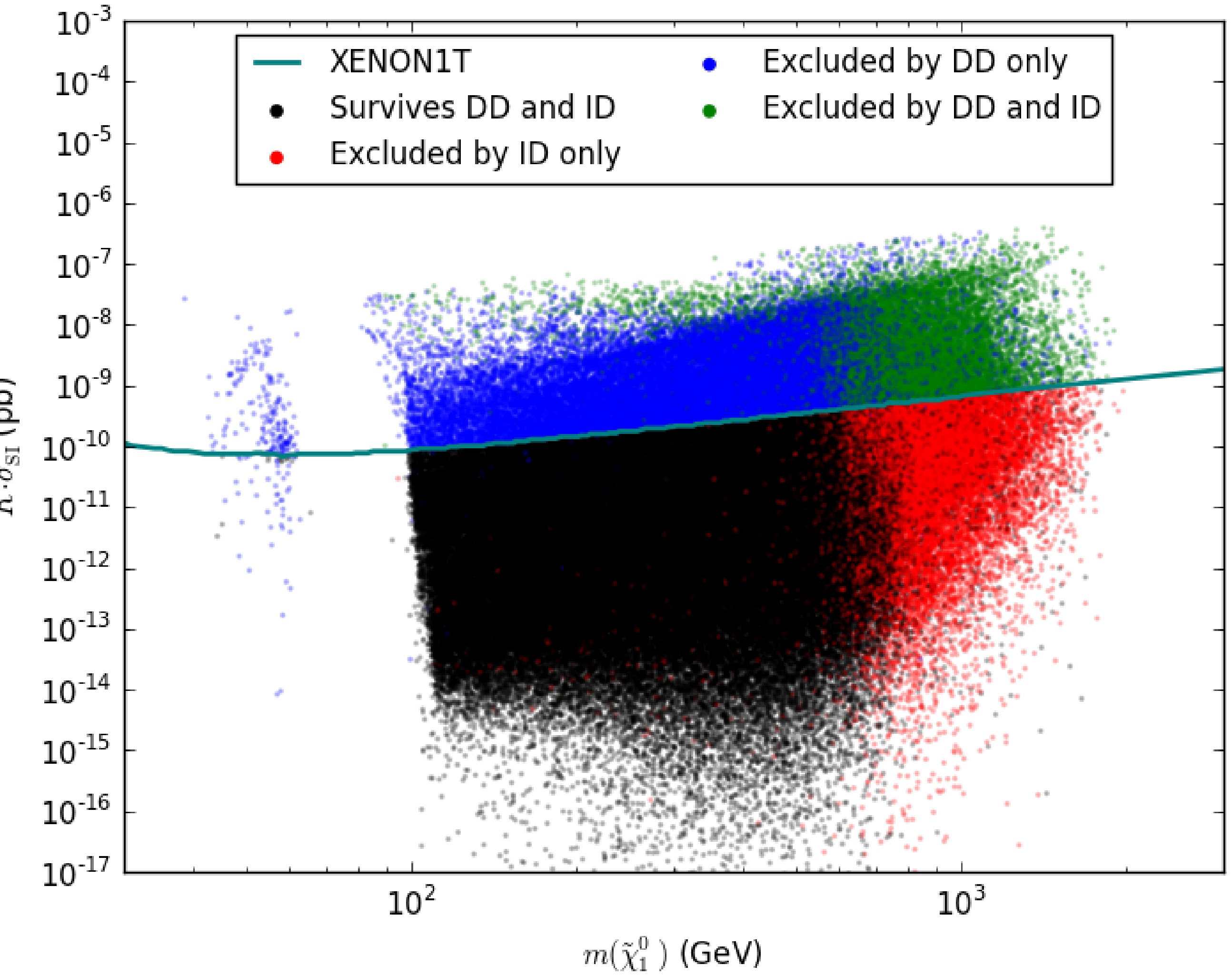
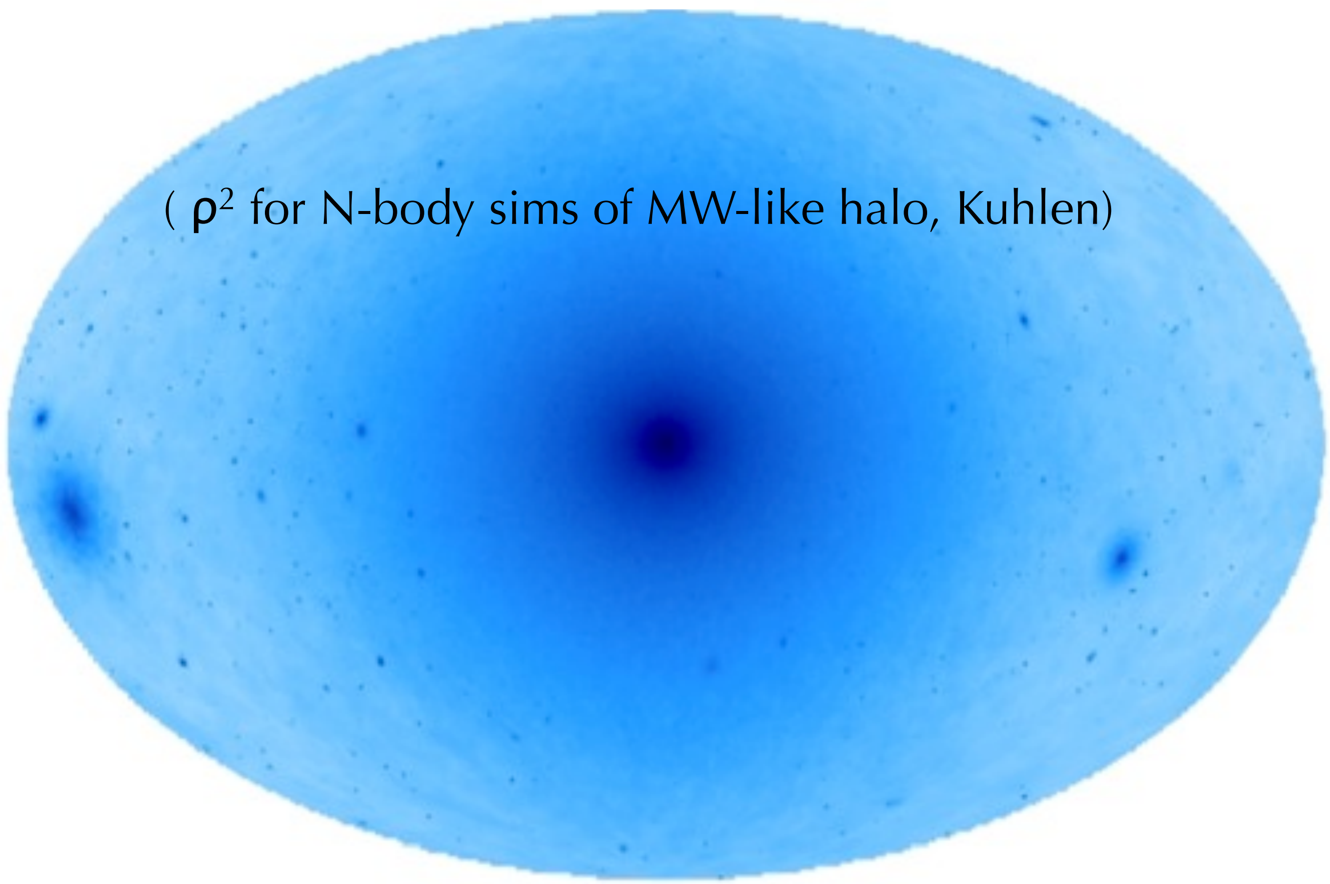
CF2: Indirect Detection Summary



(pMSSM scans, Cotta, Cahill-Rowley, Drlica-Wagner, Funk, Hewett, Ismail, Rizzo, Wood)

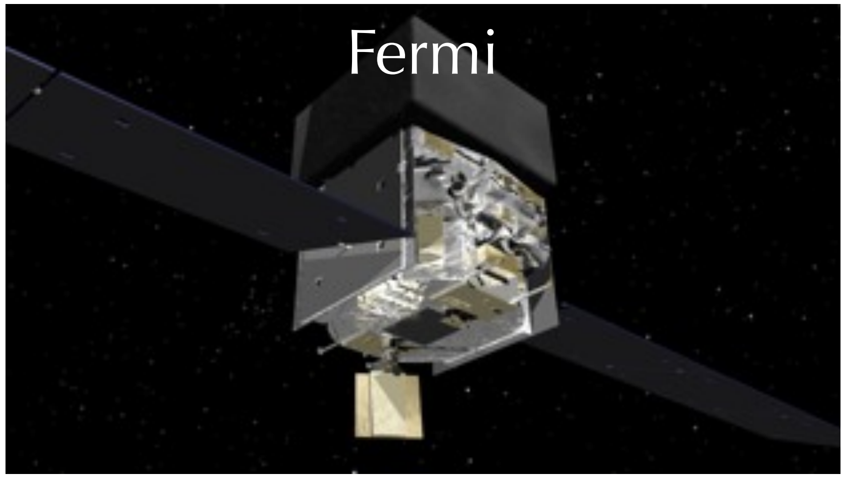


(ρ^2 for N-body sims of MW-like halo, Kuhlen)

Jim Buckley
Washington University in St. Louis

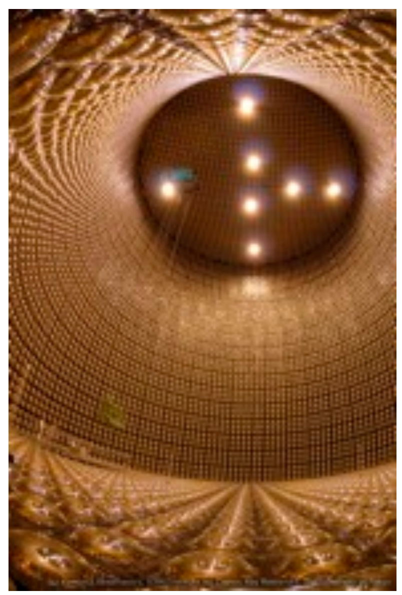
for CF2: Doug Cowen, Stefano Profumo, JB conveners

Detection Techniques

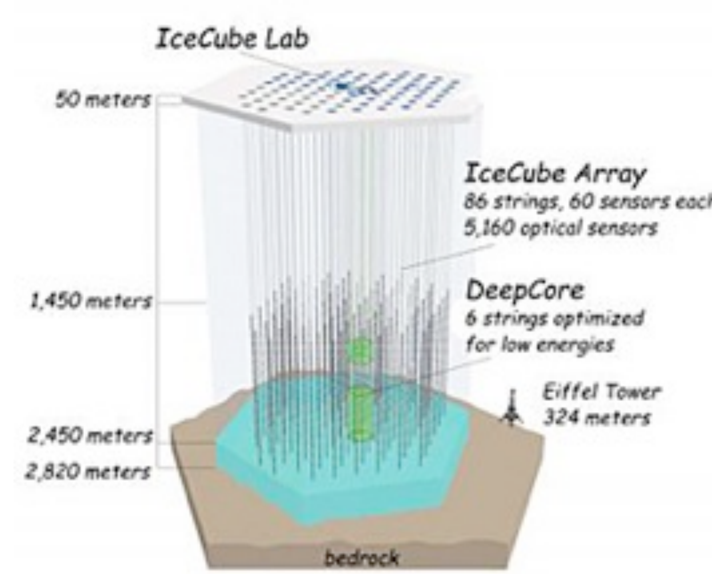


γ

Super-K

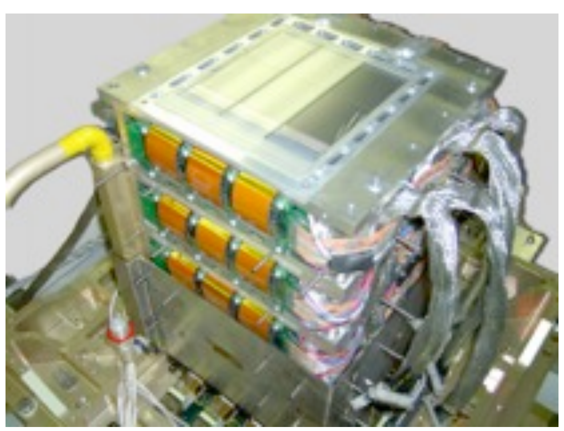


ν



ICECUBE

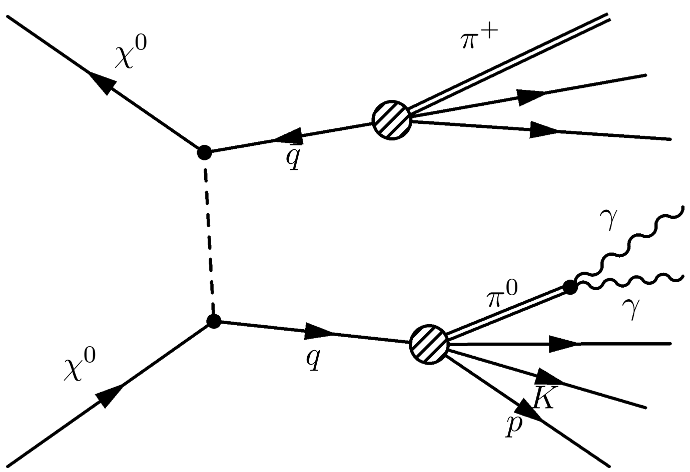
PAMELA

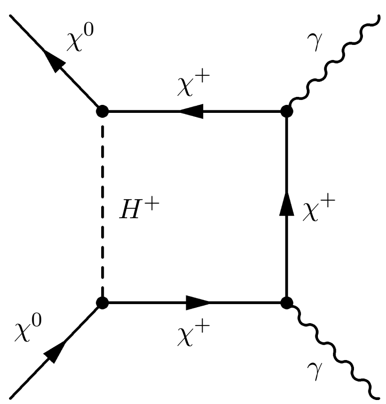


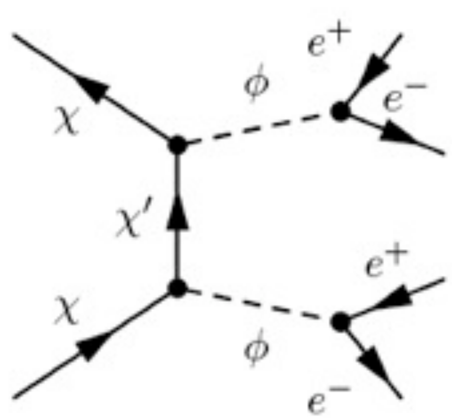
$e^-, e^+, p, \bar{p}$

AMS

Annihilation Channels







Annihilation Channel	Secondary Processes	Signals	Notes
$\chi\chi \rightarrow q\bar{q},\ gg$	$p, \bar{p}, \pi^{\pm}, \pi^0$	p, e, ν, γ	
$\chi\chi \rightarrow W^+W^-$	$W^{\pm} \rightarrow l^{\pm}\nu_l,\ W^{\pm} \rightarrow u\bar{d} \rightarrow \pi^{\pm},\ \pi^0$	p, e, ν, γ	
$\chi\chi \rightarrow Z^0Z^0$	$Z^0 \rightarrow l\bar{l},\ \nu\bar{\nu},\ q\bar{q} \rightarrow$ pions	p, e, γ, ν	
$\chi\chi \rightarrow \tau^{\pm}$	$\tau^{\pm} \rightarrow \nu_\tau e^{\pm}\nu_e,\ \tau \rightarrow \nu_\tau W^{\pm} \rightarrow p, \bar{p}$, pions		e, γ, ν
$\chi\chi \rightarrow \mu^+\mu^-$		e, γ	Rapid energy loss of μs in sun before decay results in sub-threshold νs
$\chi\chi \rightarrow \gamma\gamma$ $\chi\chi \rightarrow Z^0\gamma$	 Z^0 decay	γ γ	Loop suppressed Loop suppressed
$\chi\chi \rightarrow e^+e^-$		e, γ	Helicity suppressed
$\chi\chi \rightarrow \nu\bar{\nu}$		ν	Helicity suppressed (important for non-Majorana WIMPs?)
$\chi\chi \rightarrow \phi\bar{\phi}$	$\phi \rightarrow e^+e^-$	$e^{\pm}$	New scalar field with $m_\chi < m_q$ to explain large electron signal and avoid overproduction of p, γ

Dark Matter Intro

Gravitational effect of DM is visible in many astrophysical settings.

Bullet cluster image shows gravitational mass inferred from lensing (blue) and X-ray emission from baryonic matter (red).

Not modified gravity, not gas - dark matter behaves like stars, weakly interacting particles

$$\text{From WMAP}: \; \Omega_{\mathrm{DM}} h^2 = 0.1123 \pm 0.0035$$

For a thermal relic of the big bang, the larger the annihilation cross section the longer the DM stays in equilibrium and the larger the Boltzmann suppression $\sim e^{-m_\chi/kT}$ before freeze-out.

$$\Omega_\chi \approx \frac{0.1}{h^2}\left(\frac{3\times 10^{-26}\mathrm{cm}^3\mathrm{sec}^{-1}}{\langle\sigma v\rangle}\right)$$

** Gamma-ray production by annihilation in the present universe is closely correlated to decoupling cross section in the early universe*

Key Findings

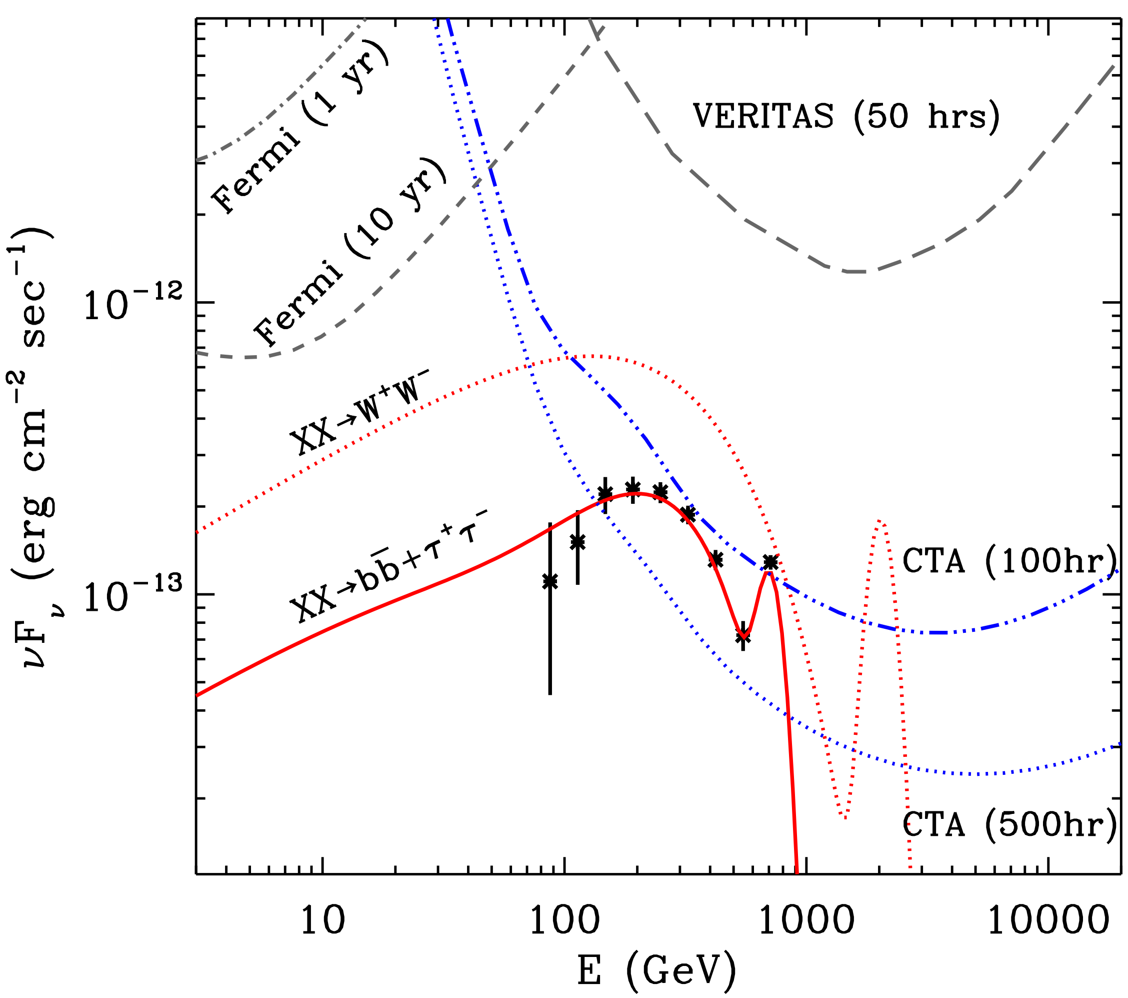
Disclaimer: Not an exhaustive list of key Indirect DM science initiatives!
(10 minutes can't do justice to amazing breadth of work)

- CTA, with the U.S. enhancement would provide a powerful new tool for searching for WIMP dark matter, and would complement other methods
- Future Neutrino experiments like the PINGU enhancement to IceCube/DeepCore offer the possibility of a smoking-gun signal (high energy neutrinos from the sun), and may provide some of the best constraints on spin dependent cross sections.
- Other astrophysical constraints such as low-frequency radio (synchrotron from electrons) or X-rays (inverse Compton scattering by electrons) can provide very powerful tests for Dark matter annihilation for certain annihilation channels, competitive with existing bounds.
- Detailed theoretical studies with PMSSM, contact operators, realistic halo models are resulting in quantitative estimates of sensitivity
- Key technology developments overlap with Direct Detection and Collider experiments.

Theory

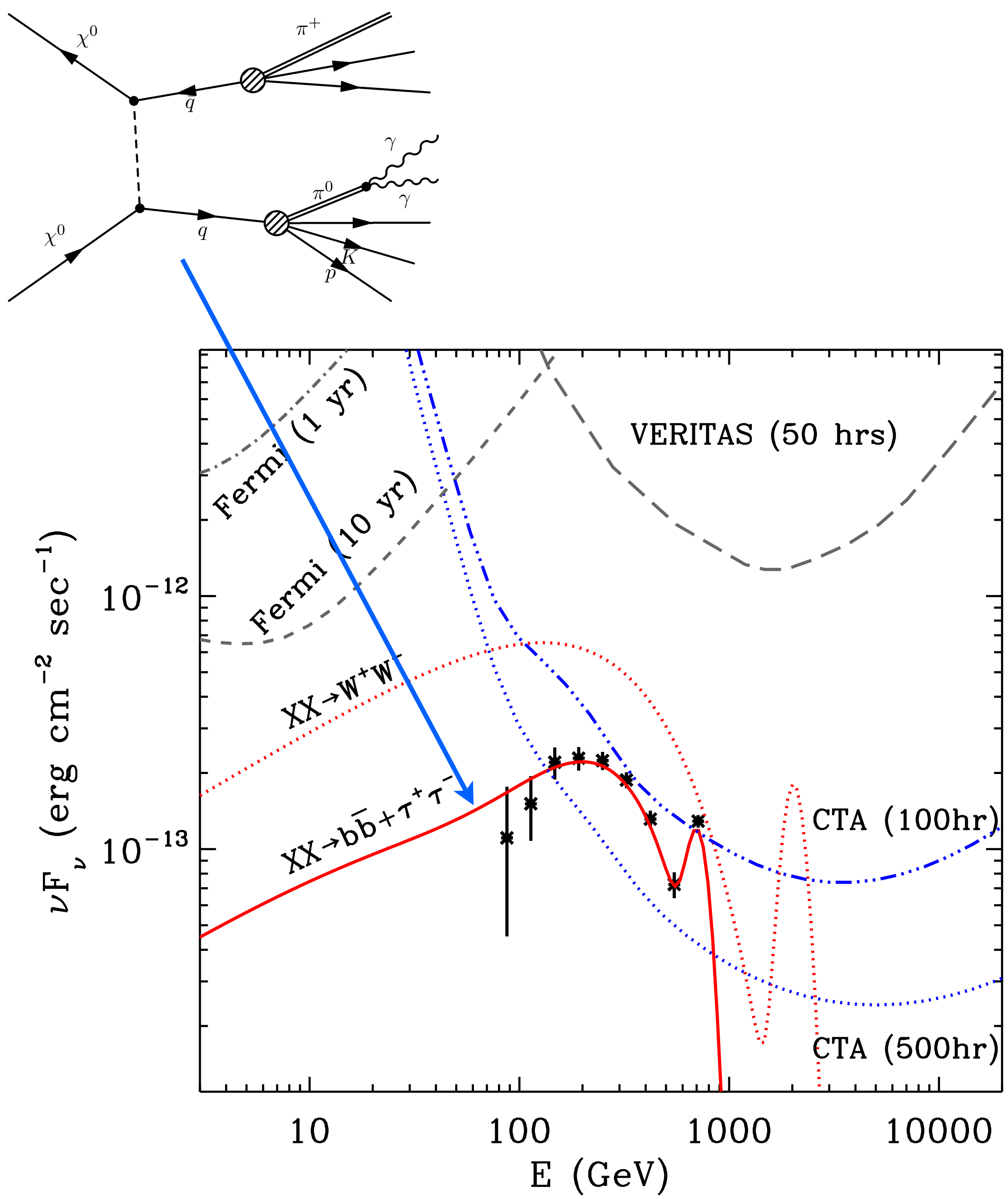
Gamma-rays from DM

$$E_\gamma \Phi_\gamma(\theta) \approx 10^{-10} \underbrace{\left(E_{\gamma,\mathrm{TeV}} \frac{dN}{dE_{\gamma,\mathrm{TeV}}} \right) \left(\frac{\langle \sigma v \rangle}{10^{-26} \mathrm{cm}^{-3} \mathrm{s}^{-1}} \right) \left(\frac{100\,\mathrm{GeV}}{M_\chi} \right)^2}_{\text{Particle Physics Input}} \underbrace{J(\theta)} \ \mathrm{erg\,cm^{-2} s^{-1} sr^{-1}}$$



Gamma-rays from DM

$$E_\gamma \Phi_\gamma(\theta) \approx 10^{-10} \underbrace{\left(E_{\gamma,\mathrm{TeV}} \frac{dN}{dE_{\gamma,\mathrm{TeV}}}\right) \left(\frac{\langle\sigma v\rangle}{10^{-26}\mathrm{cm}^{-3}\mathrm{s}^{-1}}\right) \left(\frac{100\,\mathrm{GeV}}{M_\chi}\right)^2}_{\text{Particle Physics Input}} \underbrace{J(\theta)} \;\mathrm{erg\,cm^{-2}s^{-1}sr^{-1}}$$



Gamma-rays from DM

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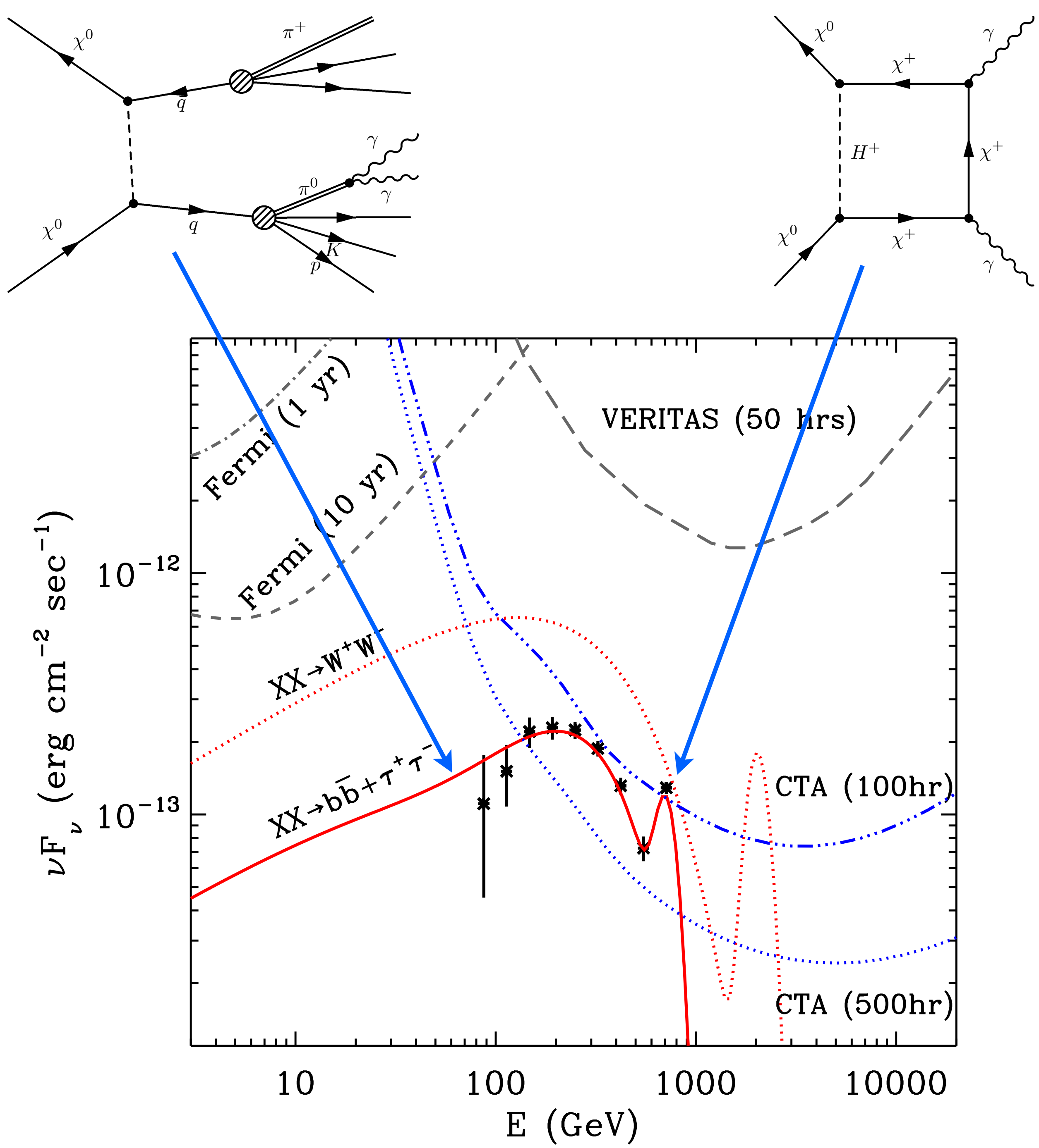
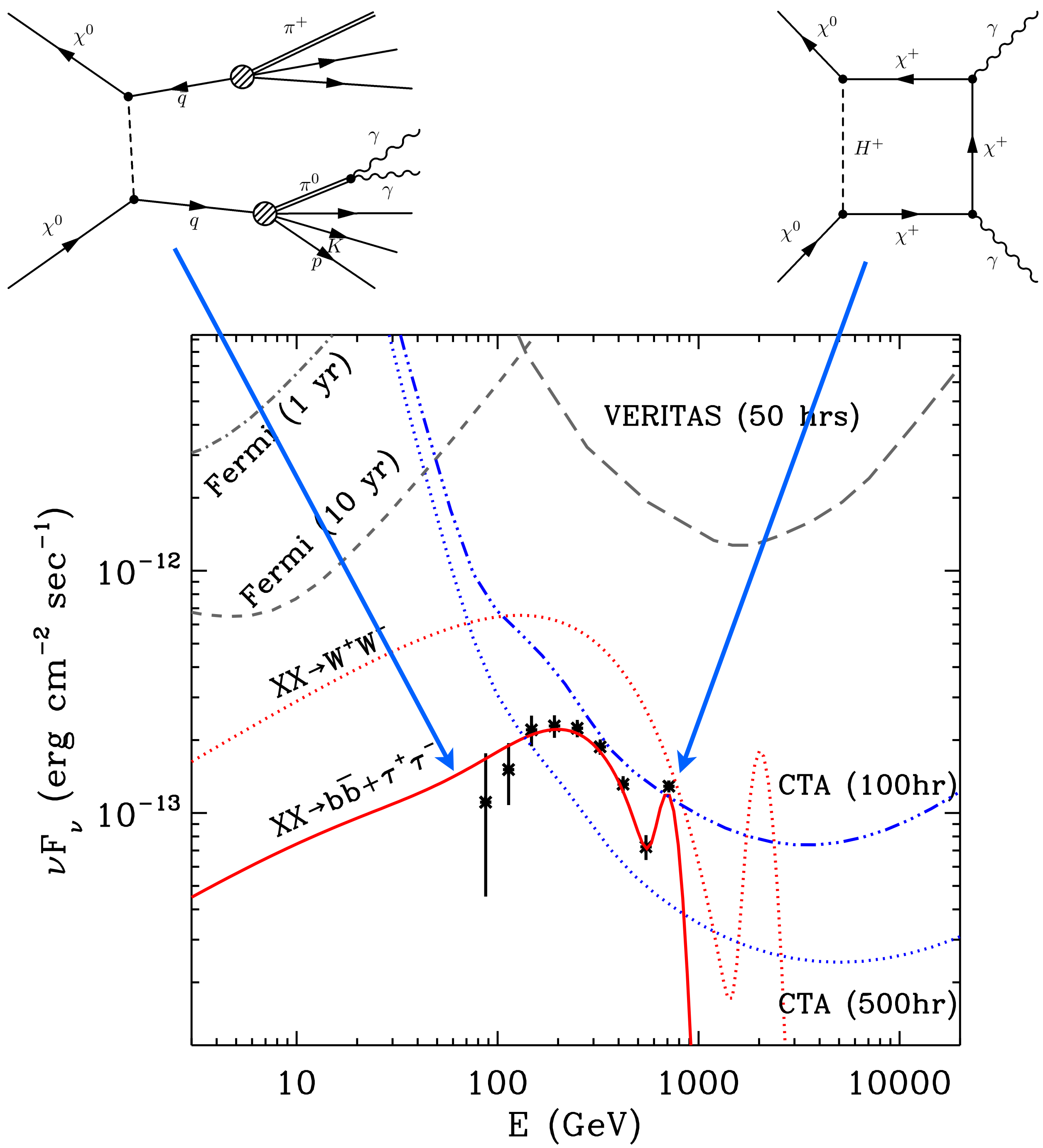
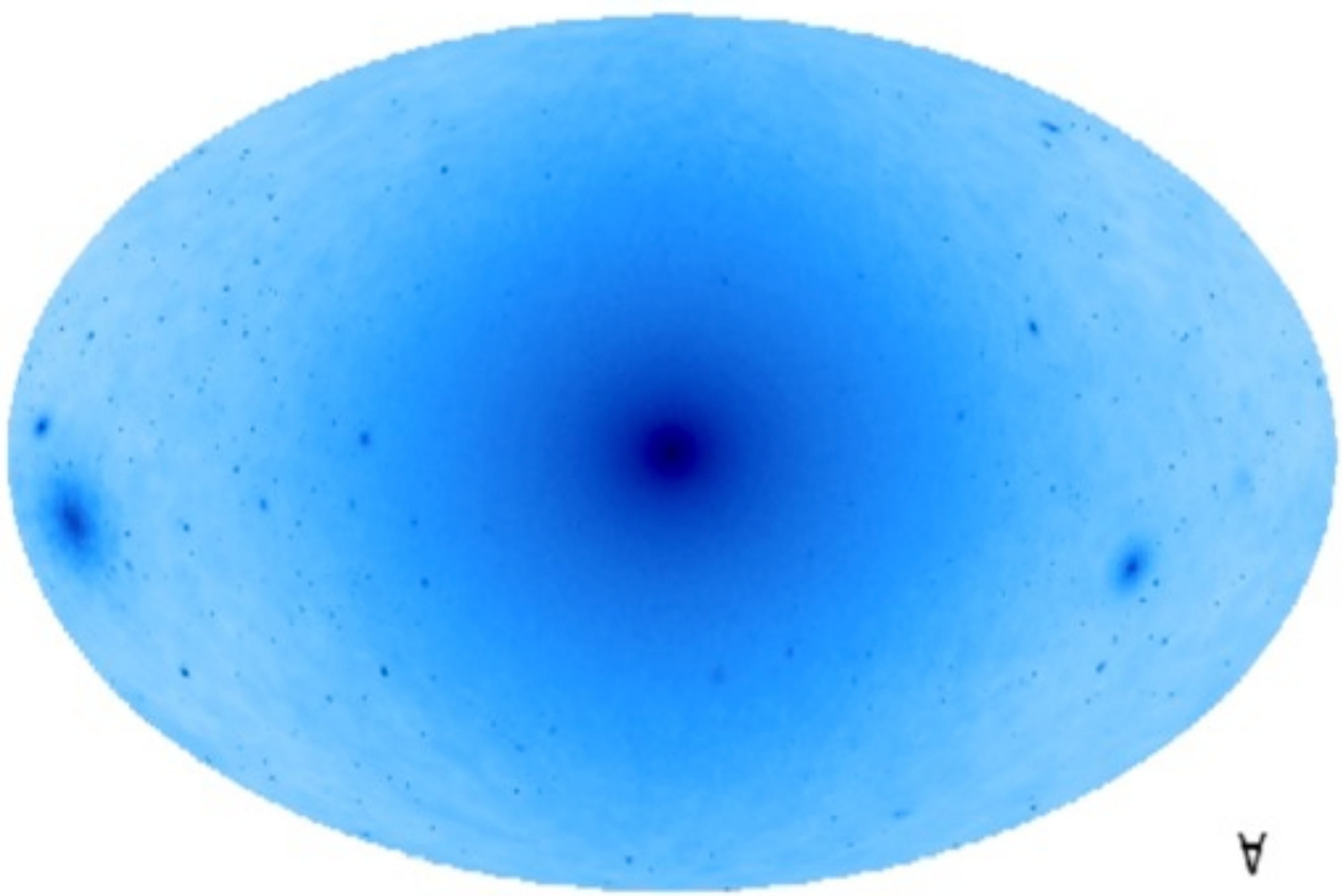


Gamma-rays from DM

$$E_\gamma \Phi_\gamma(\theta) \approx 10^{-10} \underbrace{\left(E_{\gamma,\mathrm{TeV}} \frac{dN}{dE_{\gamma,\mathrm{TeV}}}\right) \left(\frac{\langle \sigma v \rangle}{10^{-26}\mathrm{cm}^{-3}\mathrm{s}^{-1}}\right) \left(\frac{100\,\mathrm{GeV}}{M_\chi}\right)^2}_{\text{Particle Physics Input}} \underbrace{J(\theta)} \;\mathrm{erg\,cm^{-2}s^{-1}sr^{-1}}$$

$$J(\theta) = \underbrace{\frac{1}{8.5\,\mathrm{kpc}} \left(\frac{1}{0.3\,\mathrm{GeV/cm^3}}\right)^2 \int_{\text{line of sight}} \rho^2(l)dl(\theta)}_{\text{Astrophysics/Cosmology Input}}$$





Line-of-sight integral of ρ^2 for a Milky-Way-like halo in the VL Lactea II ΛCDM N-body simulations (Kuhlen et al.)

CTA Gal. Cen. Projection: Basic Results

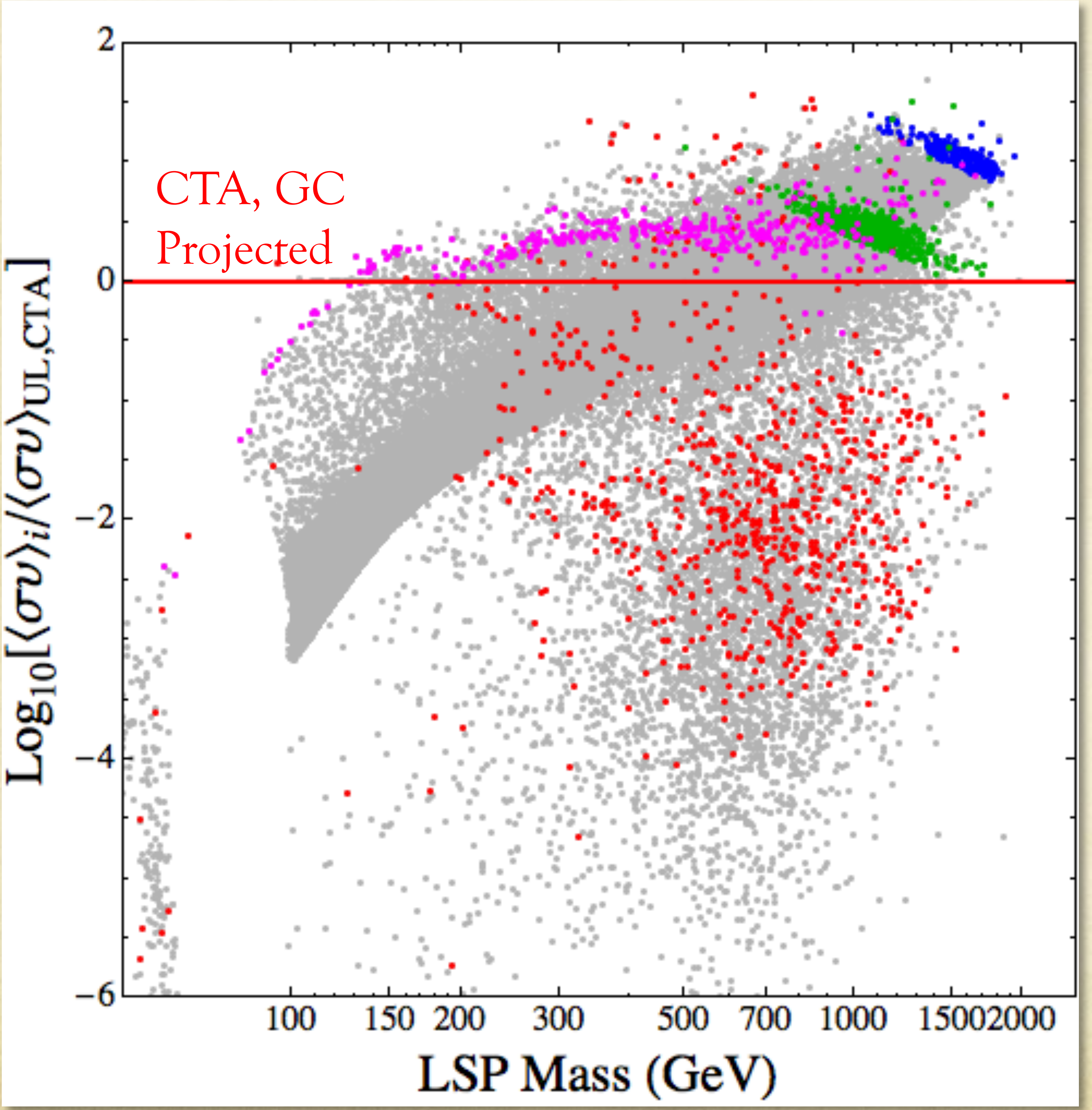


Figure of merit:

$$\frac{\langle\sigma\upsilon\rangle_{\mathrm{therm}}}{\langle\sigma\upsilon\rangle_{\mathrm{UL,\ CTA}}}$$

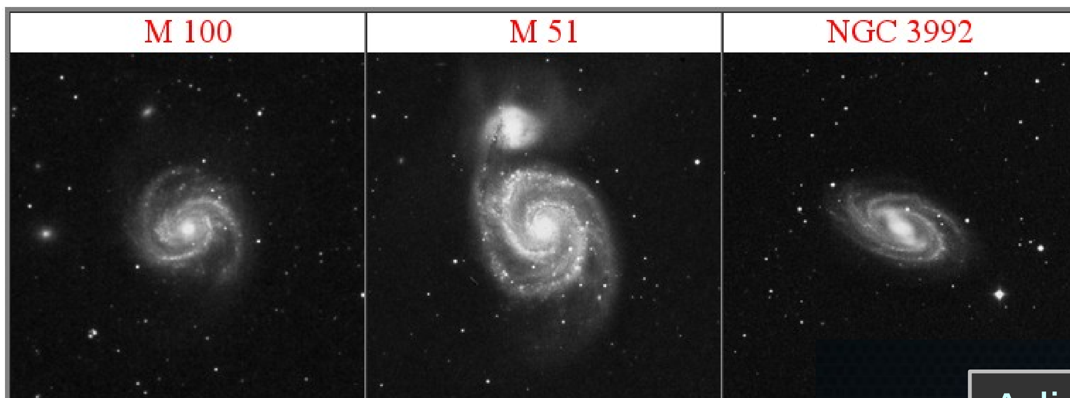
CTA covers about 20% of the full model set...

More Importantly:

CTA covers ~ ALL WMAP saturating neutralinos except for p-wave annihilating binos

(Cotta for Cahill-Rowley, Drlica-Wagner, Funk, Hewett, Ismail, Rizzo,

Baryonic Feedback

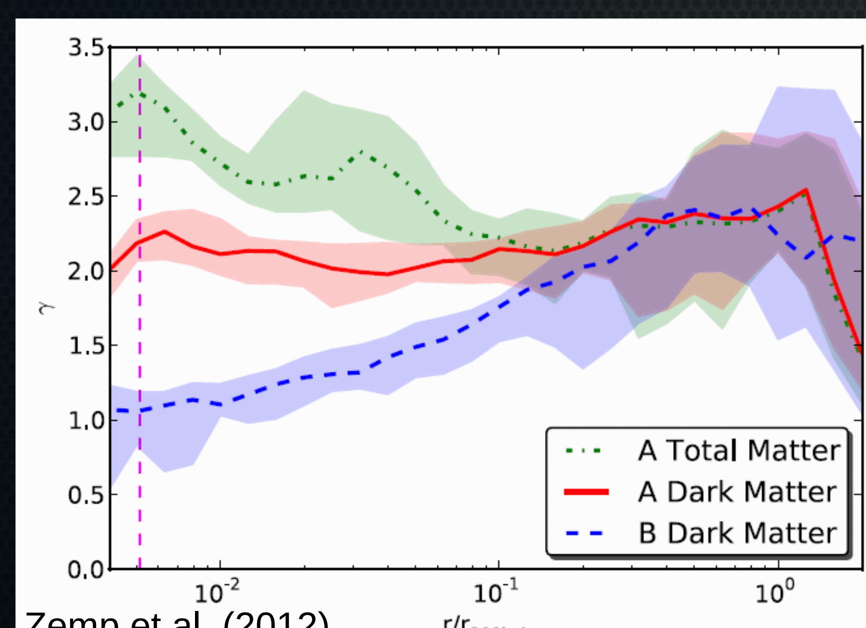


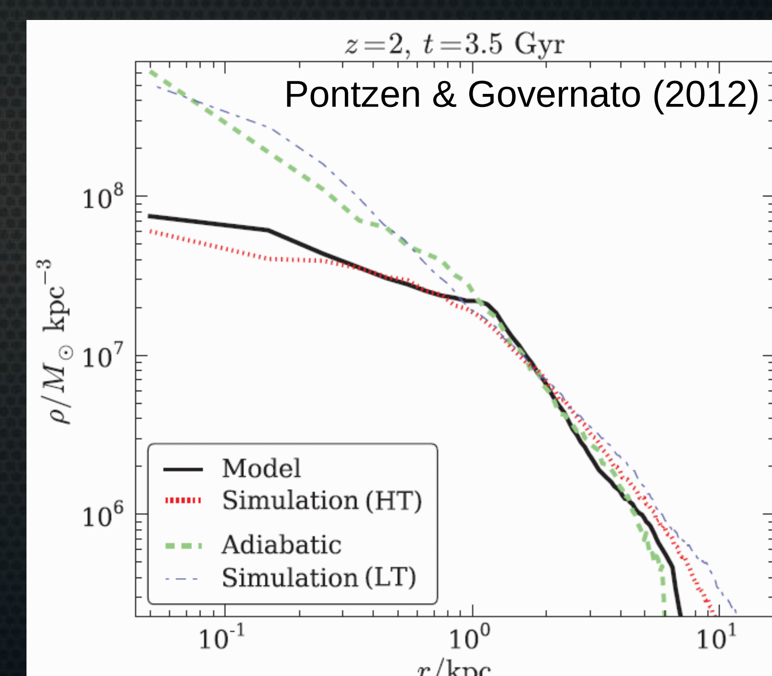
- Adding Baryons to N-body simulations starting to give amazing results - similar morphology, Tully-Fisher relation.

- But jury is out on effects on Milky Way-like (or Dwarf) halos.

Adiabatic contraction steepens the DM profile and **increases central DM densities**.

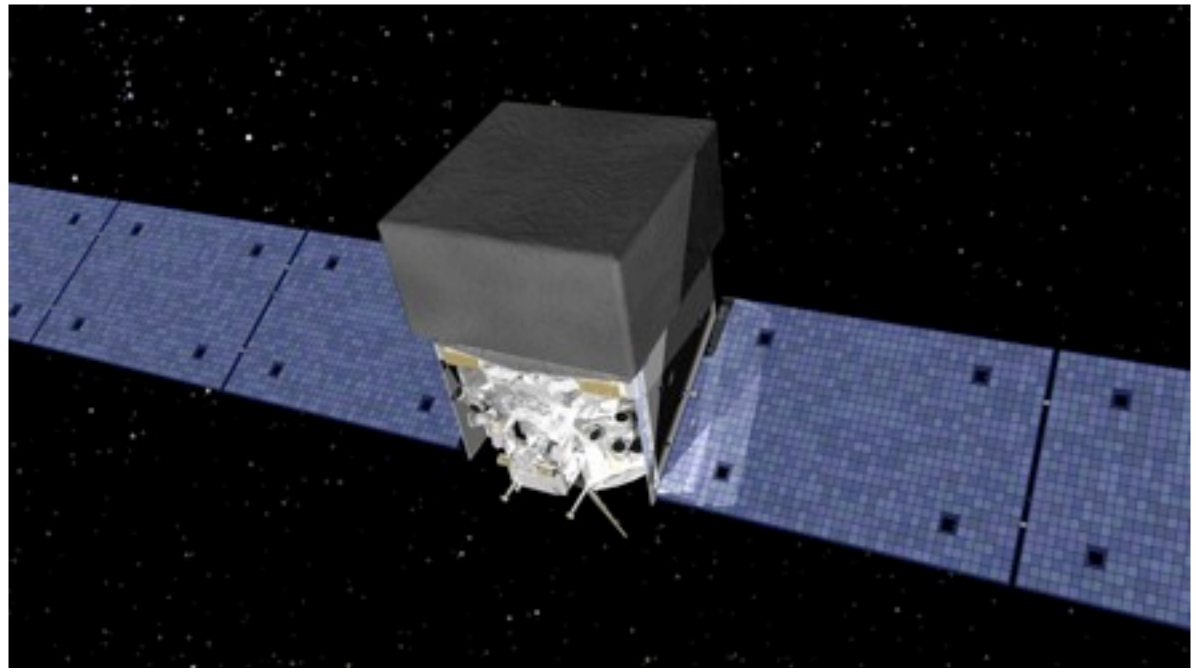
Impulsive supernova (or AGN) feedback **removes DM from the center** and flattens the DM cusp.



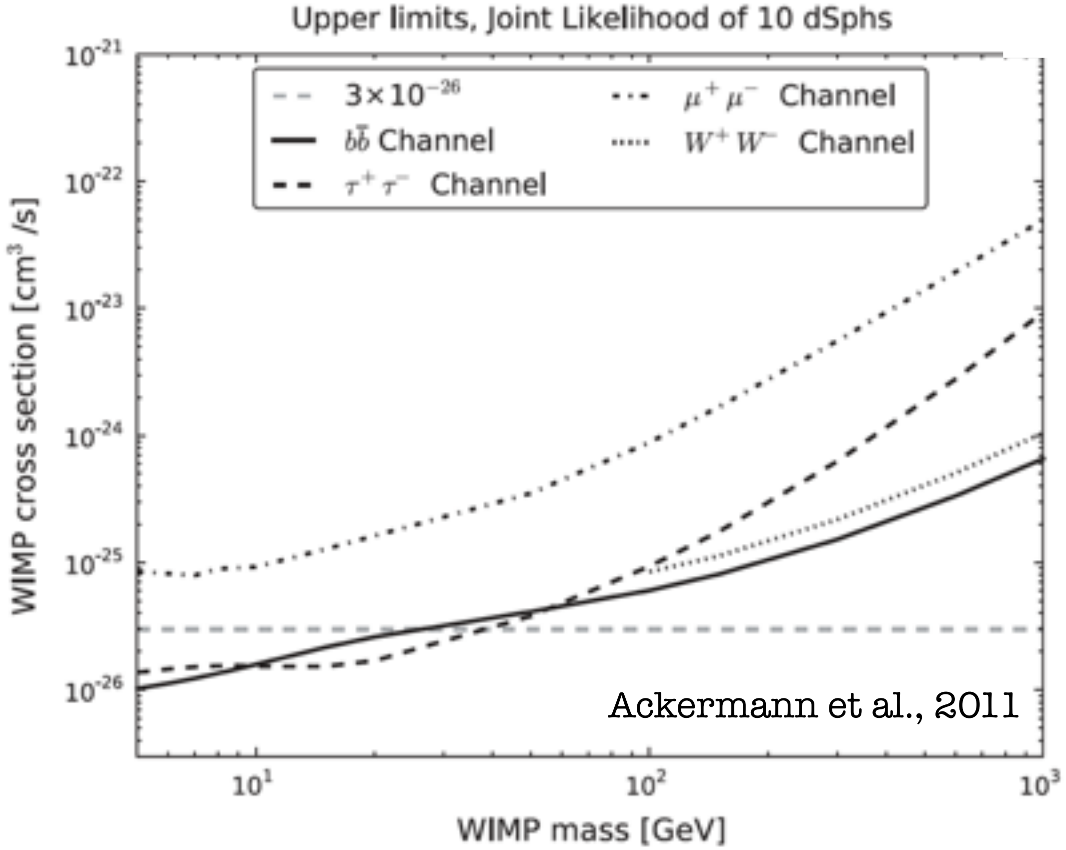


Gamma-Ray Experiments

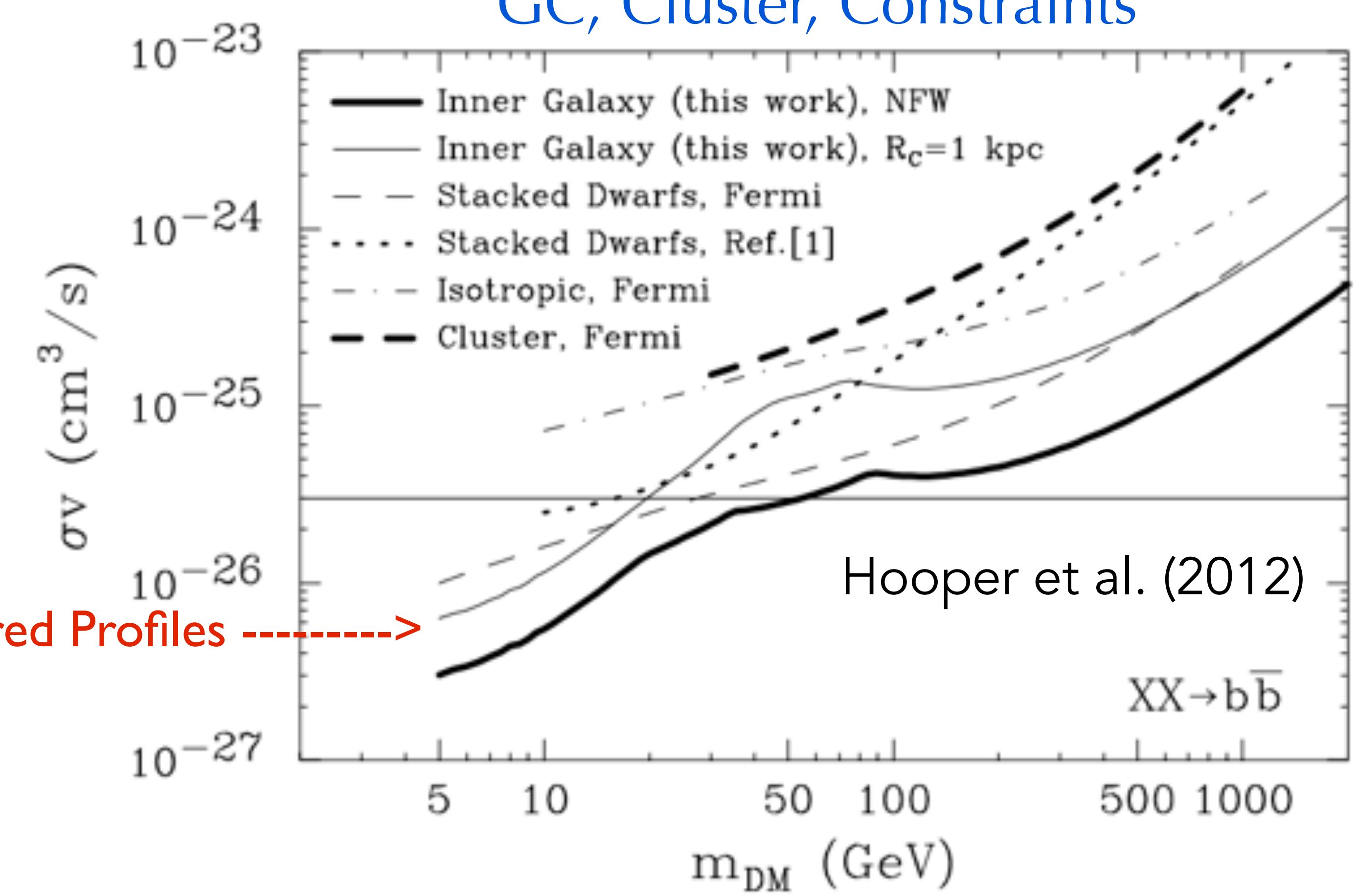
Fermi LAT



Dwarf Constraints

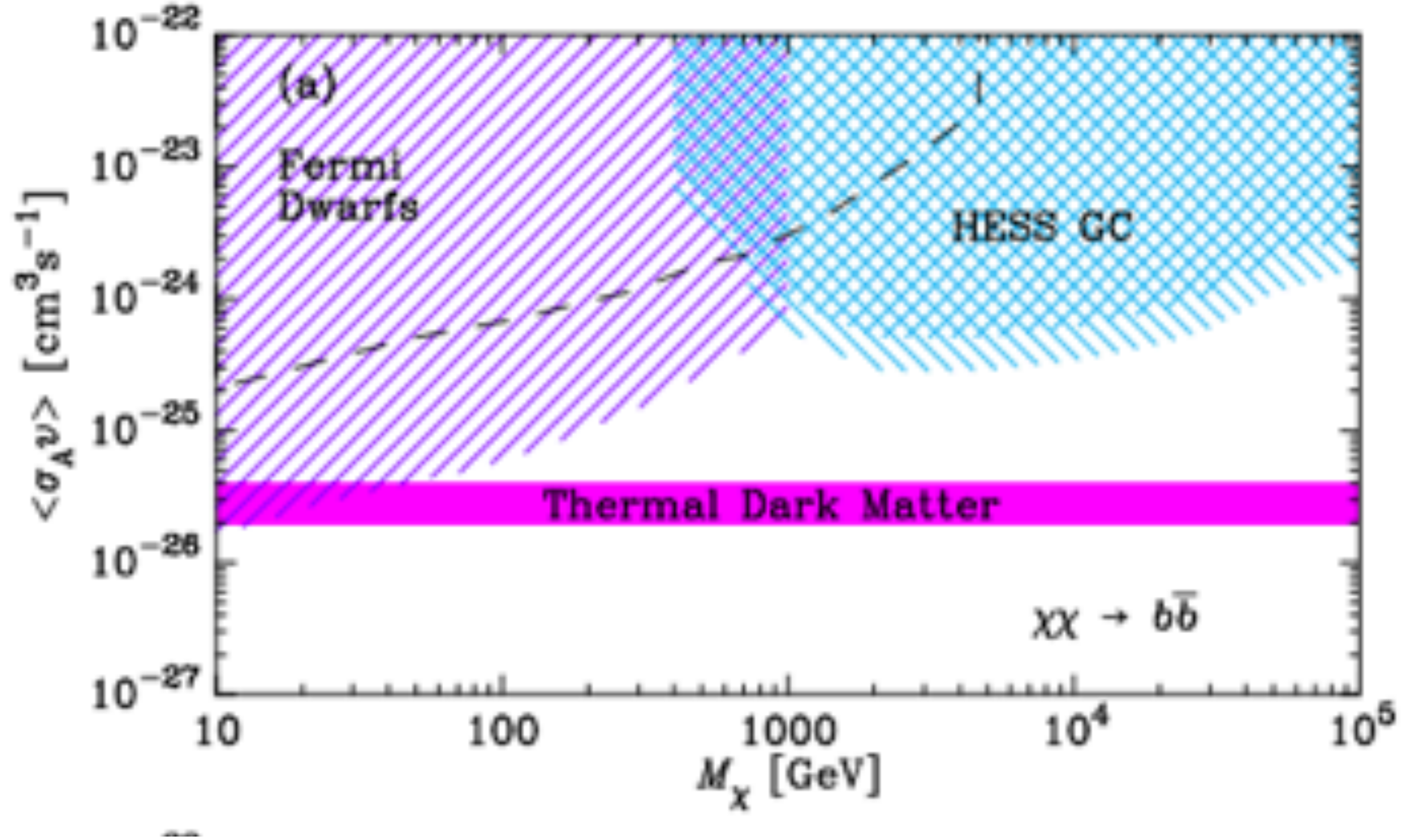


GC, Cluster, Constraints

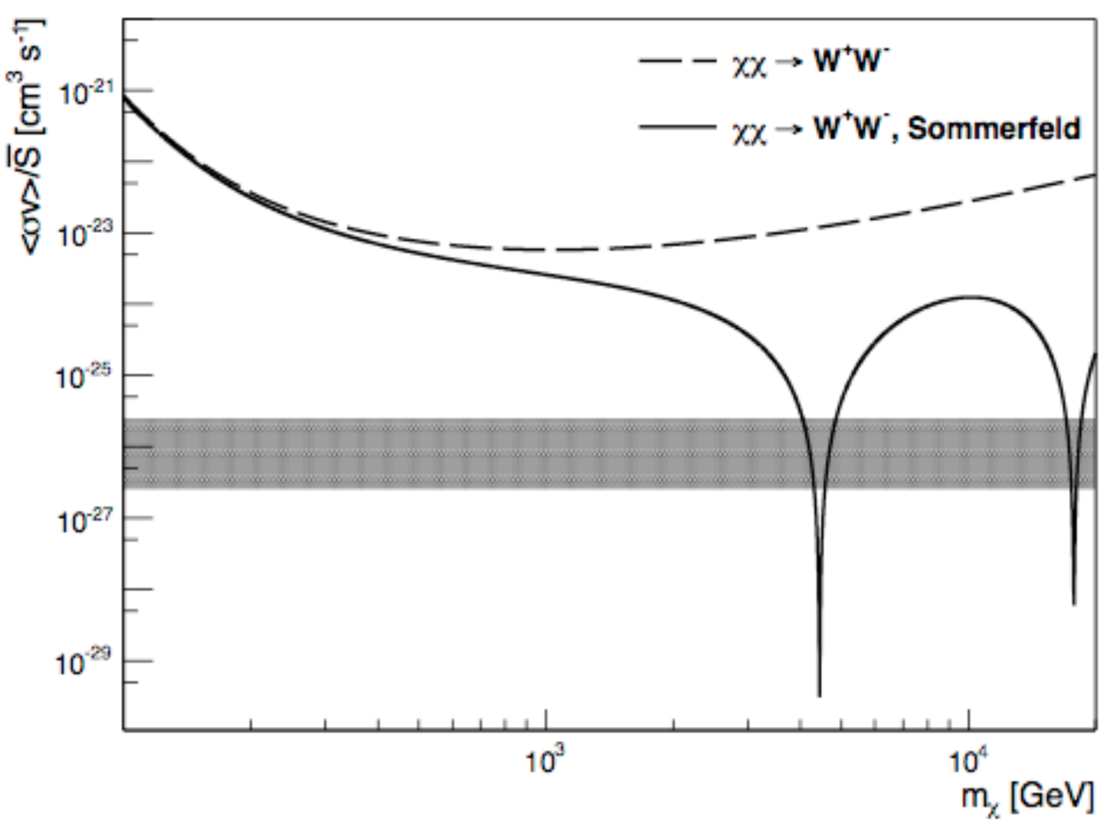


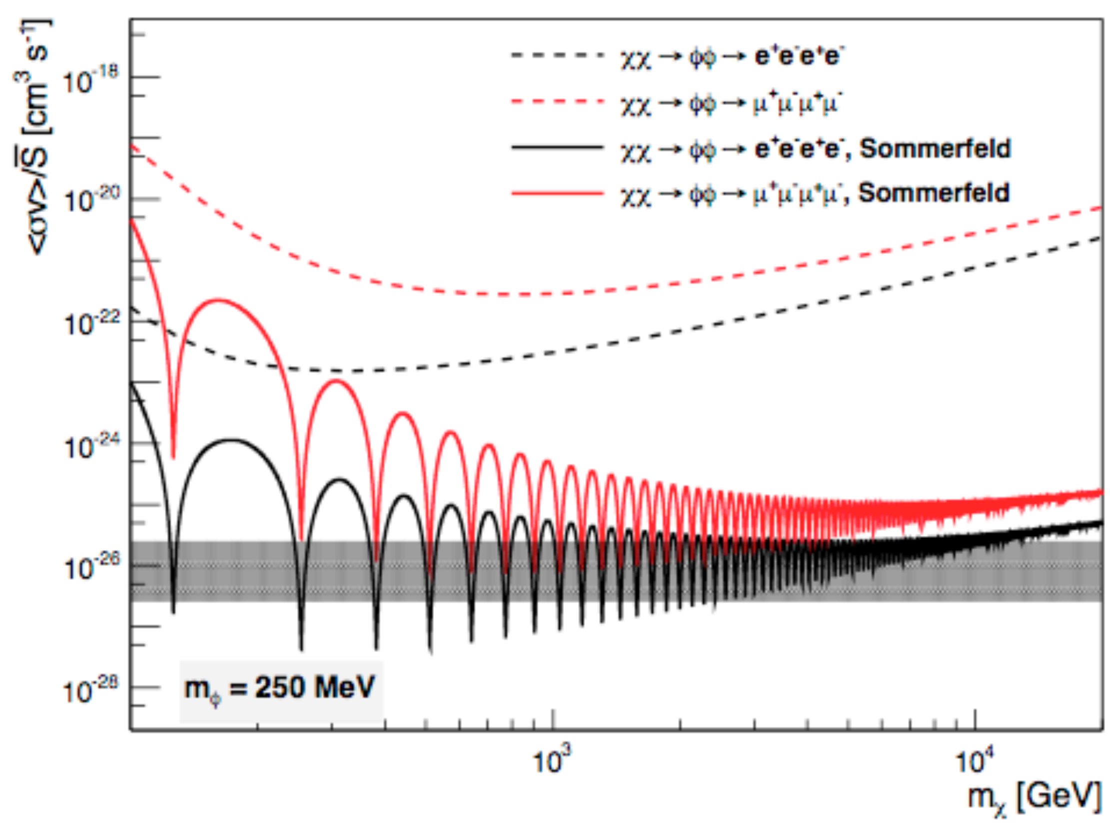
Cored Profiles --------->

HESS GC Constraints



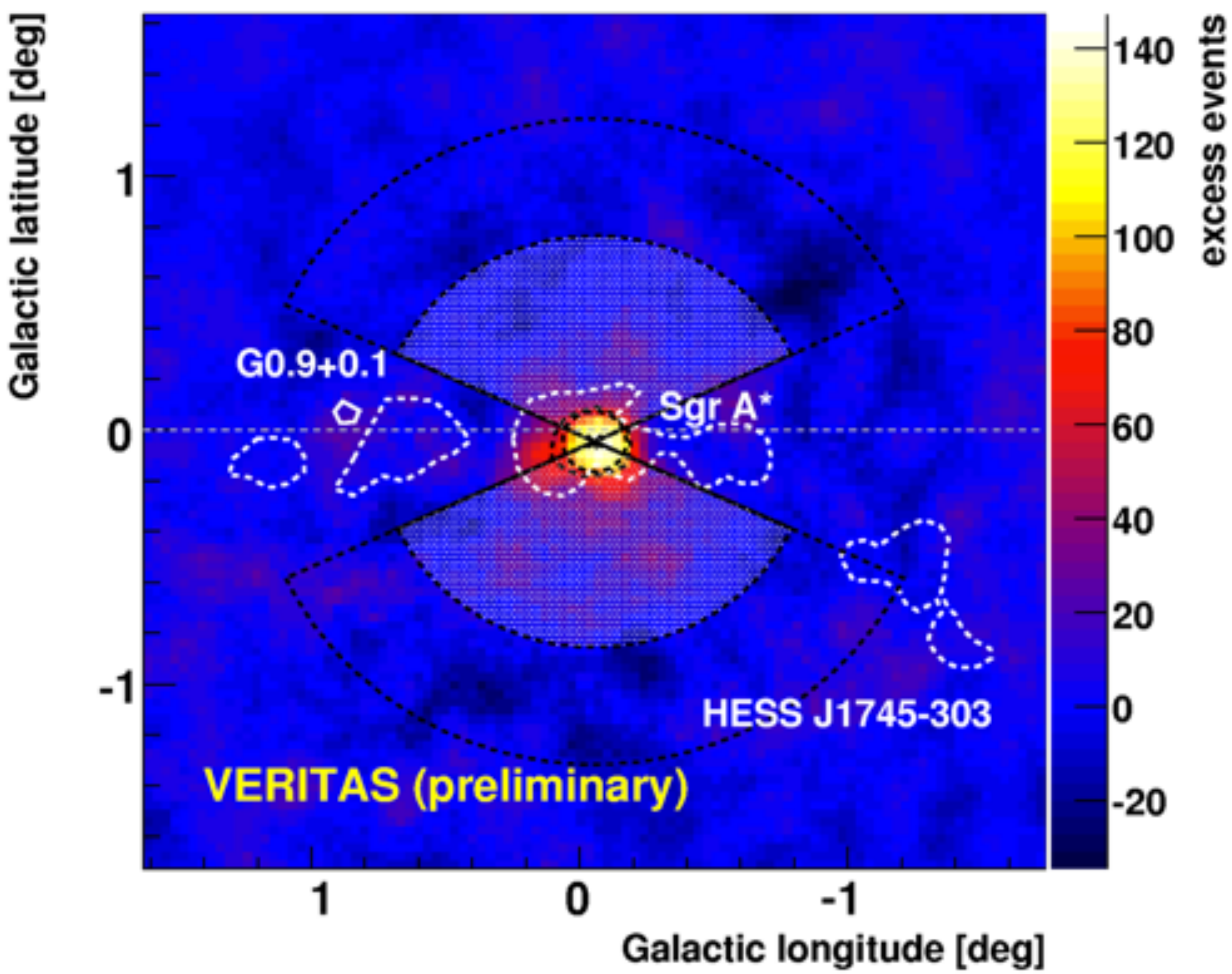
VERITAS





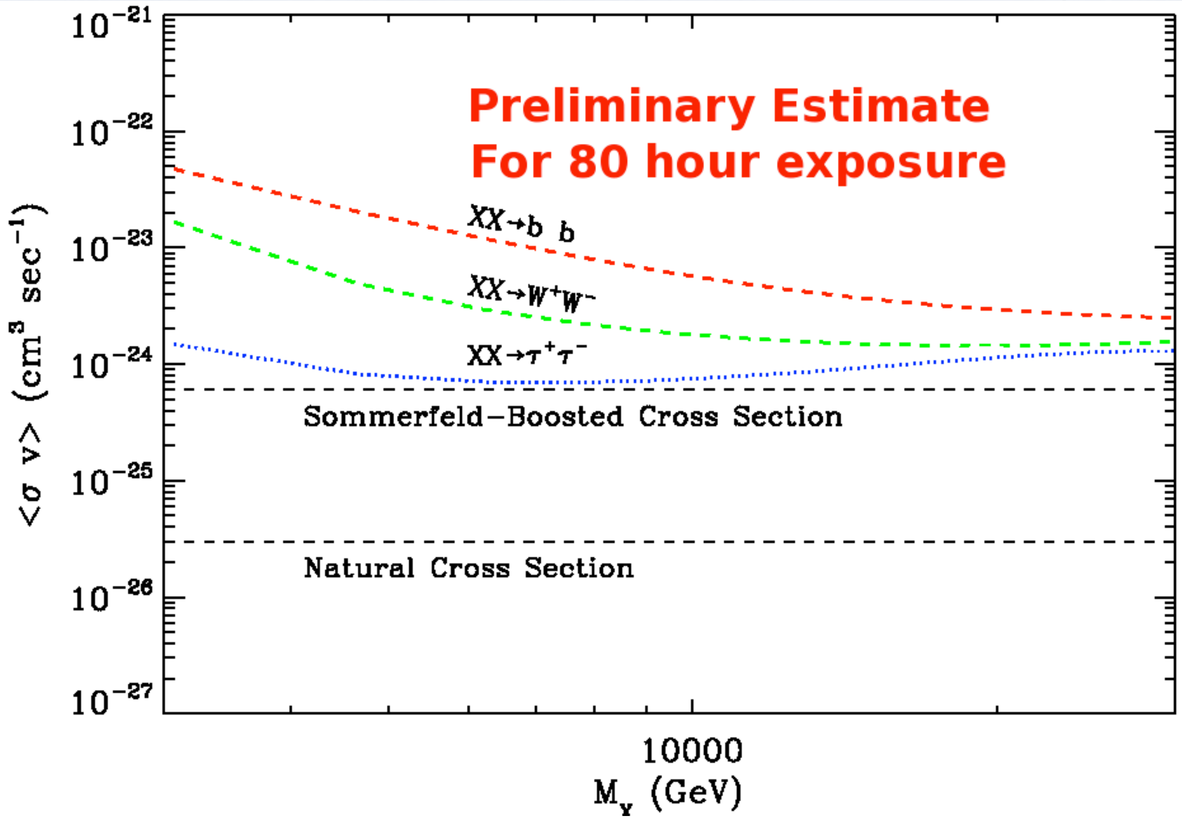
- Current results on Segue extrapolated assuming 5 more years of data

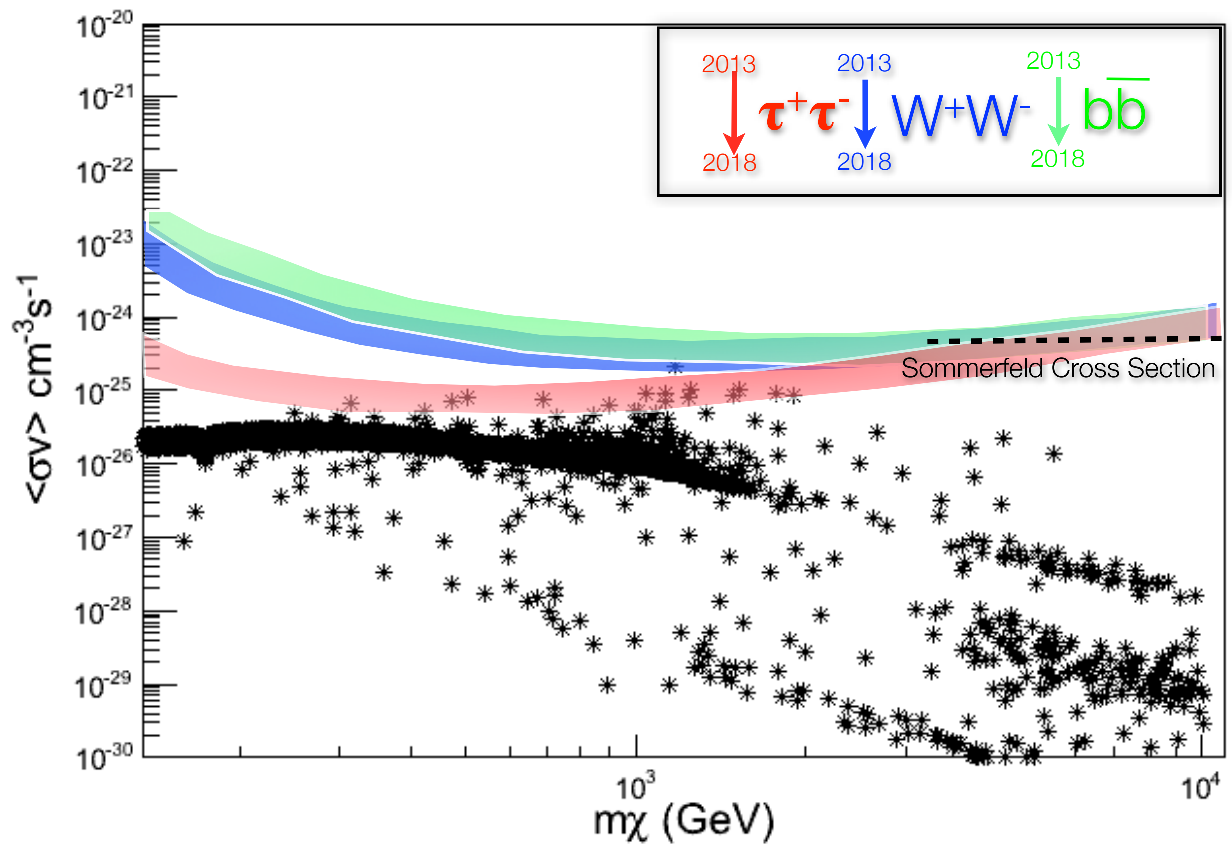
VERITAS Projections



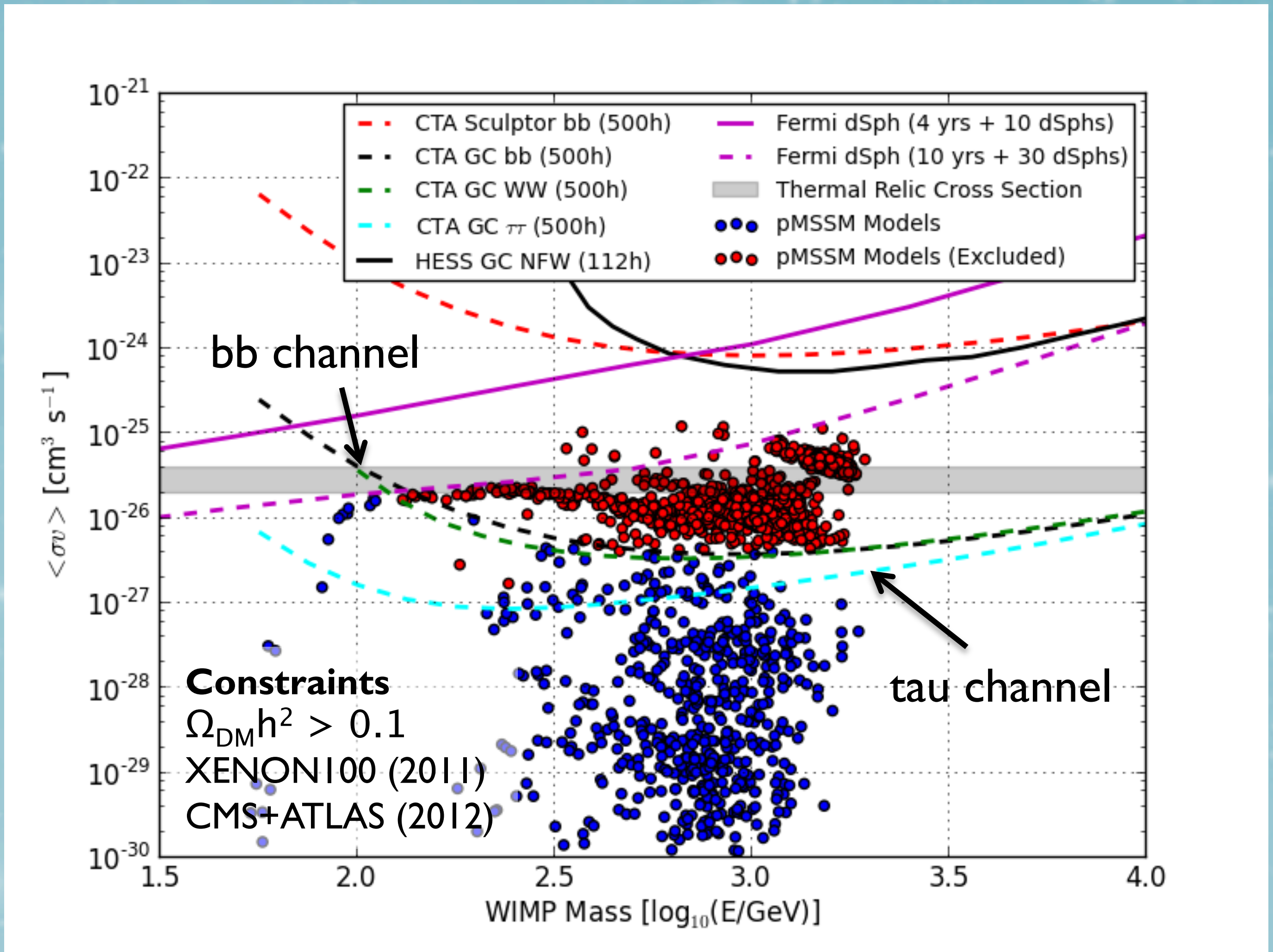
(Talk by A. Smith)

- With another 5 years, can push limits with VERITAS down into interesting cross-section regime



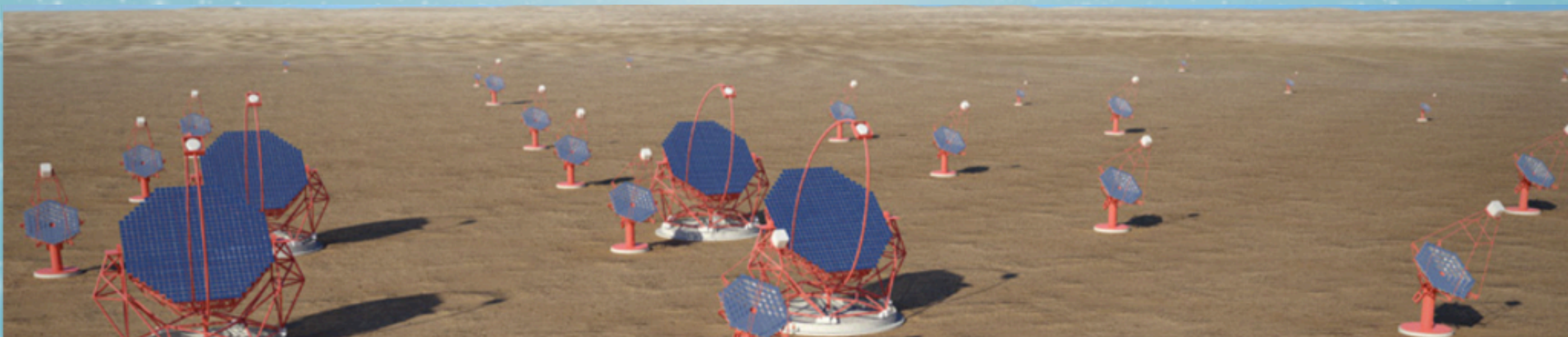


CTA

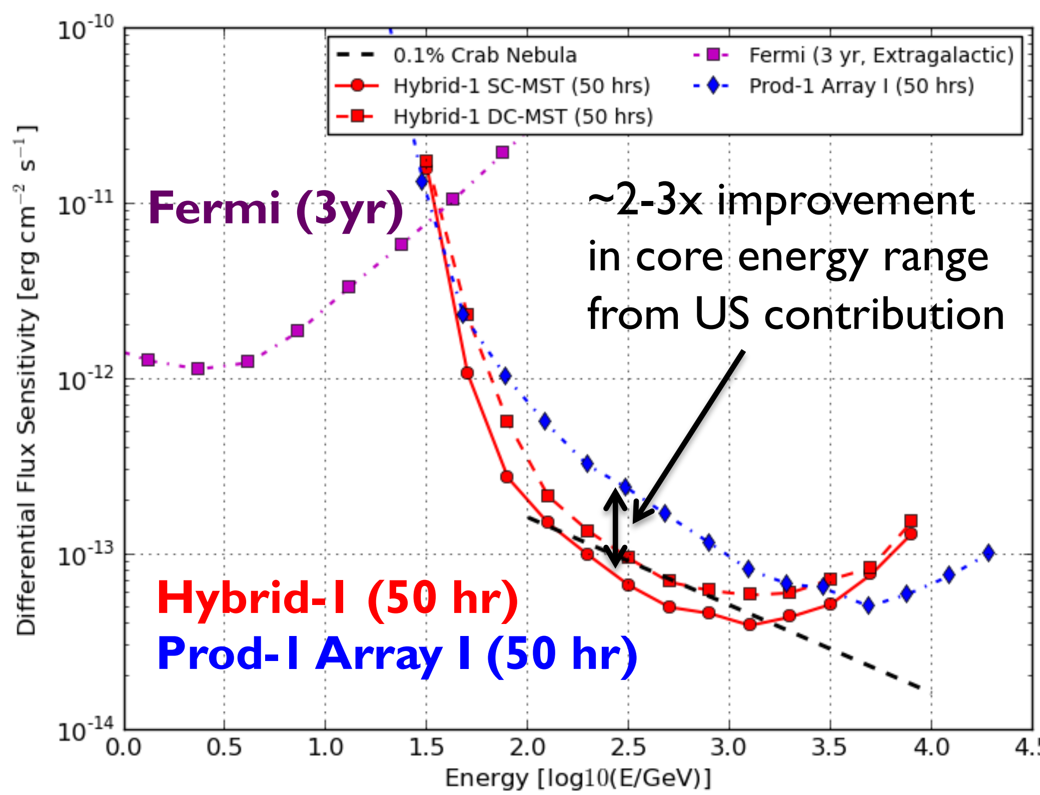


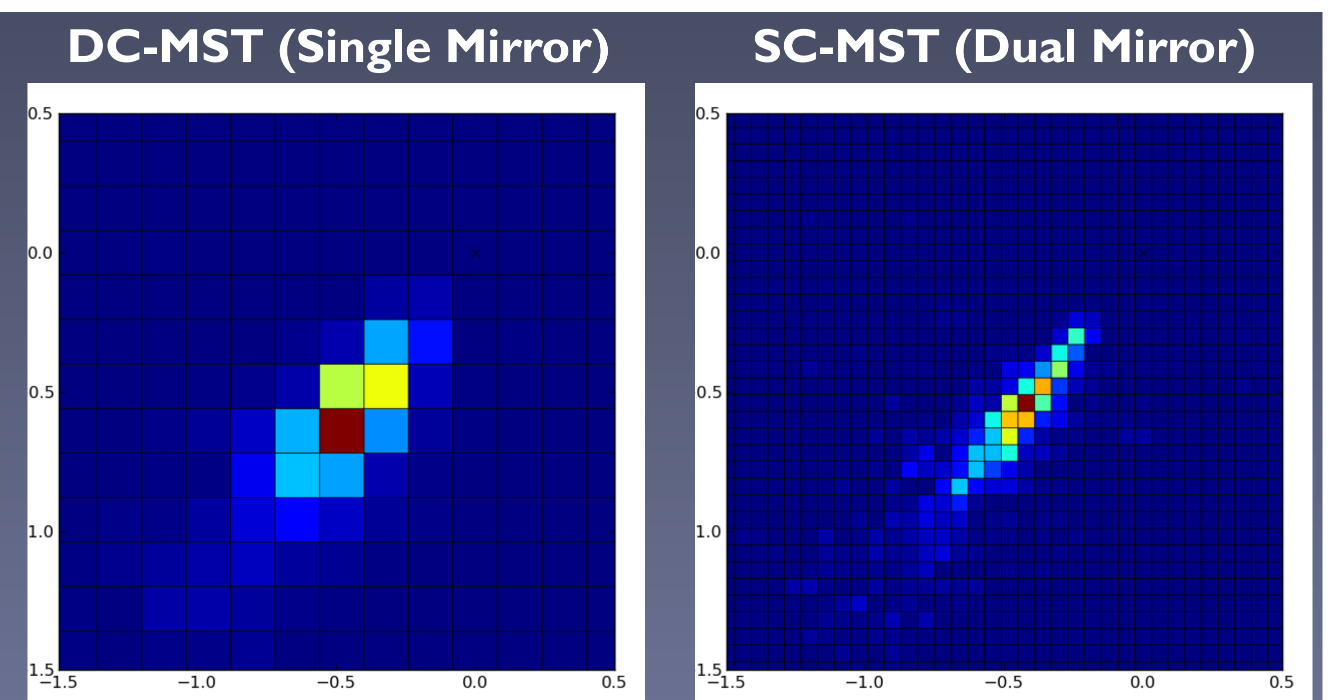
(M.Wood and A. Drlica-Wagner)

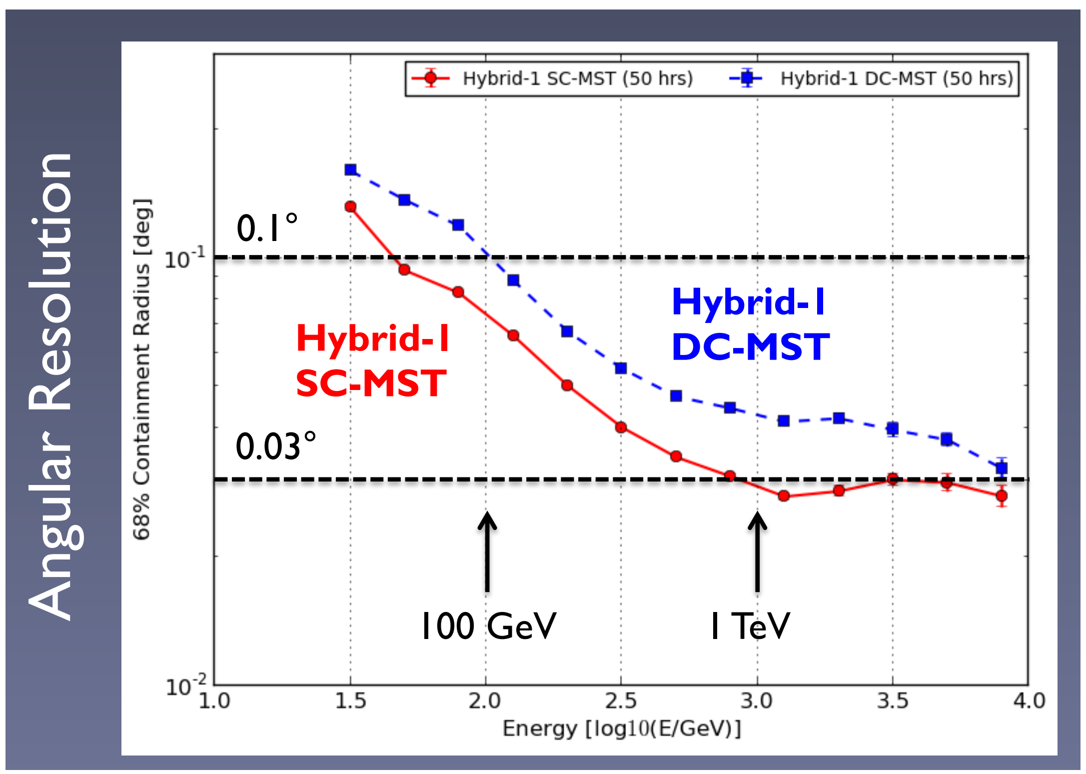
(JB)



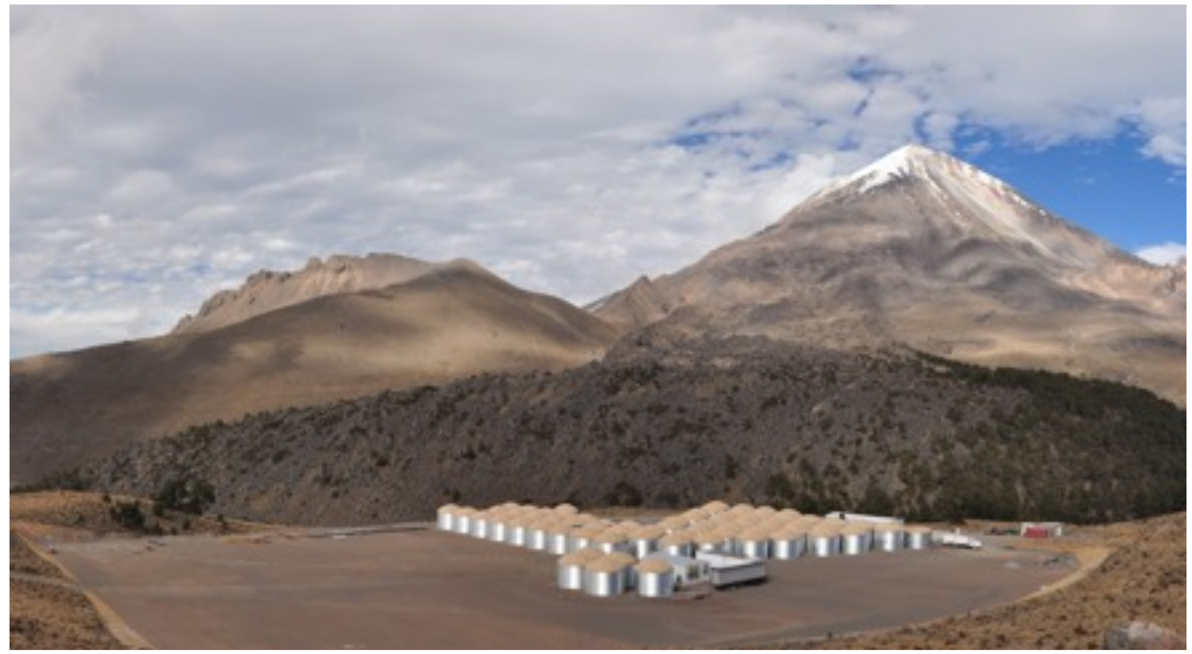
U.S. Contribution to CTA

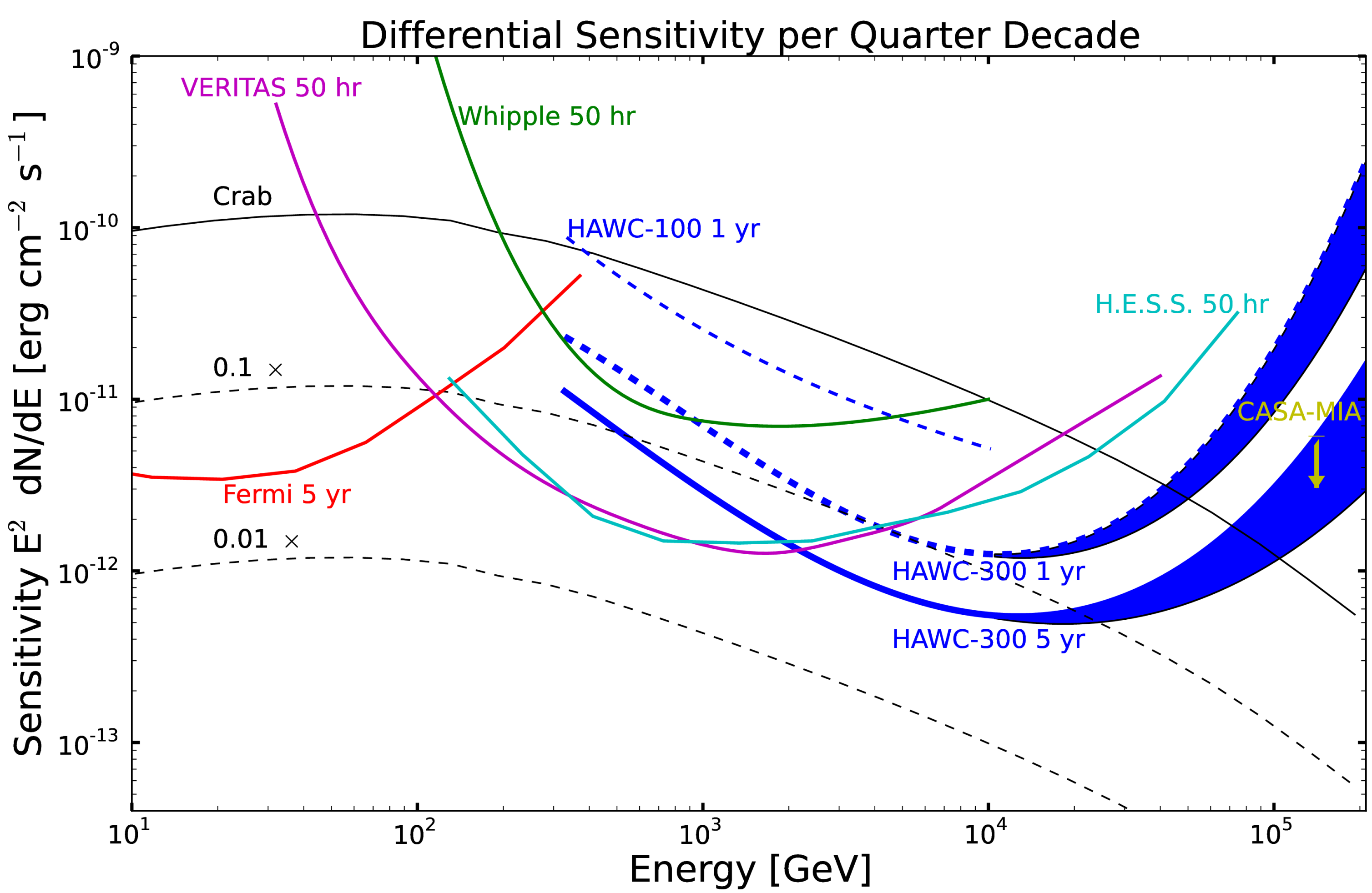




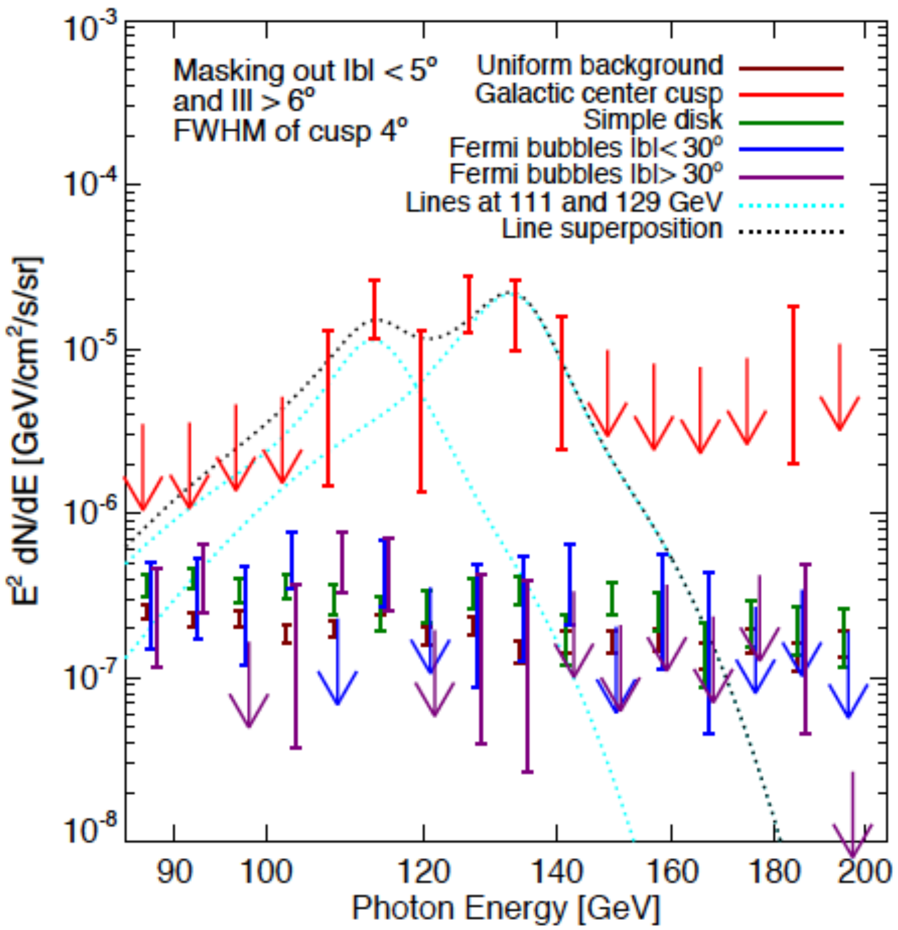


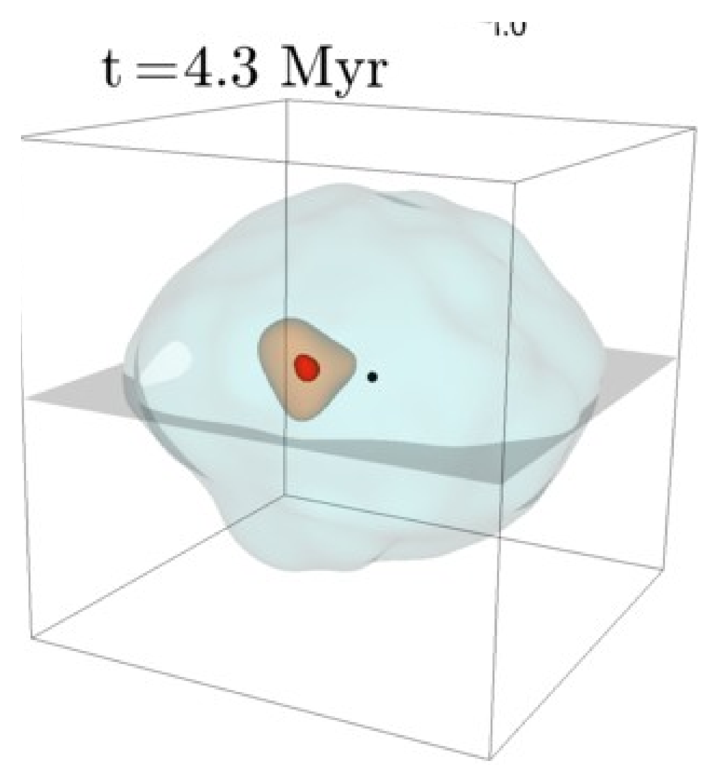
HAWC



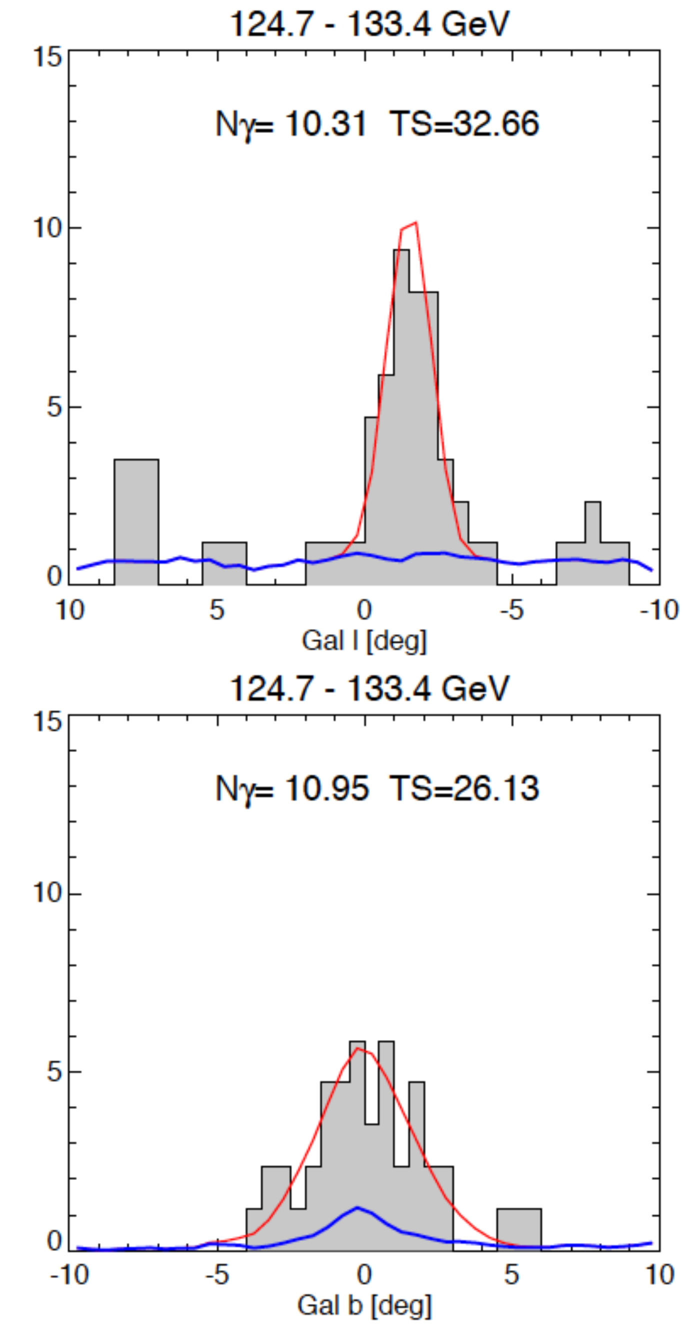

Differential Sensitivity per Quarter Decade
Sensitivity E^2 dN/dE [erg cm^{-2} s^{-1}]
Energy [GeV]
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^1
10^2
10^3
10^4
10^5
VERITAS 50 hr
Whipple 50 hr
Crab
HAWC-100 1 yr
H.E.S.S. 50 hr
0.1 ×
CASA-MIA
Fermi 5 yr
0.01 ×
HAWC-300 1 yr
HAWC-300 5 yr

Fermi Line(s)





(Kuhlen)

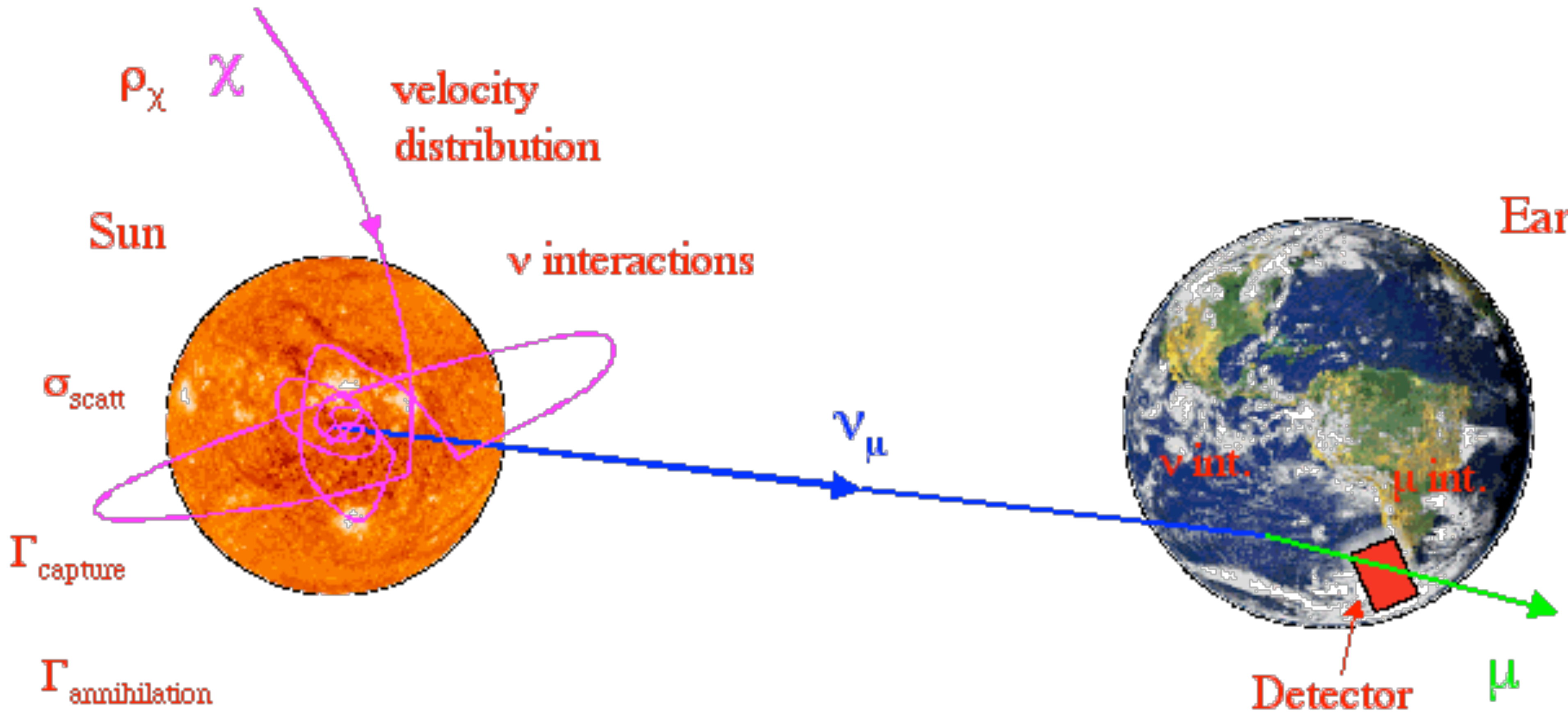


- Fermi line (Meng Su) - hint of line in the spectrum of emission close to GC but offset - consistent with N-body+baryonic simulations (M. Kuhlen)

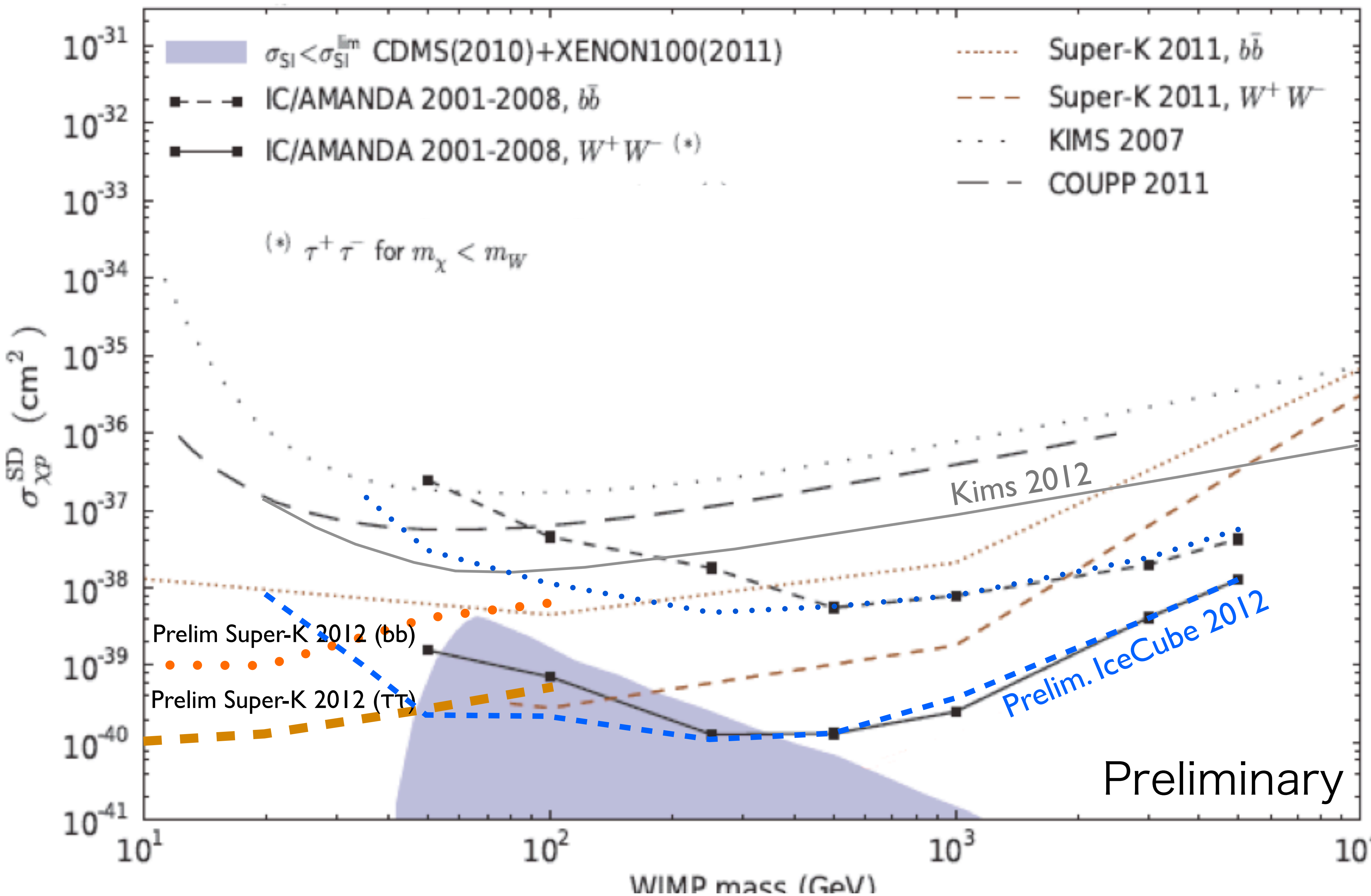
Neutrino Experiments

Neutrino Capture by Sun

- The sun is a big proton target that can accumulate WIMPs as they scatter off of the nuclei, are captured, and annihilate giving high energy neutrinos that can be detected at the earth

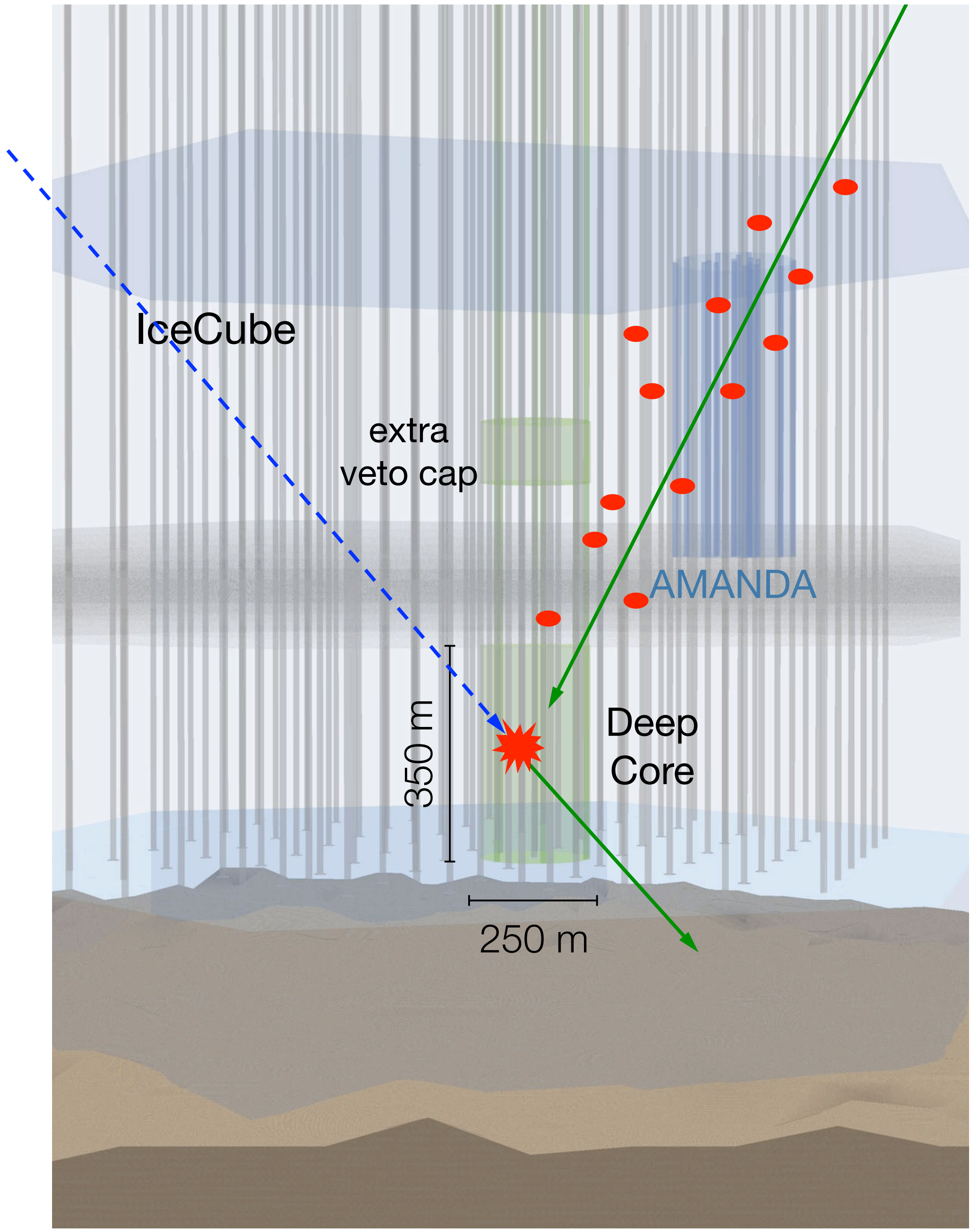


Neutrino SD Limits

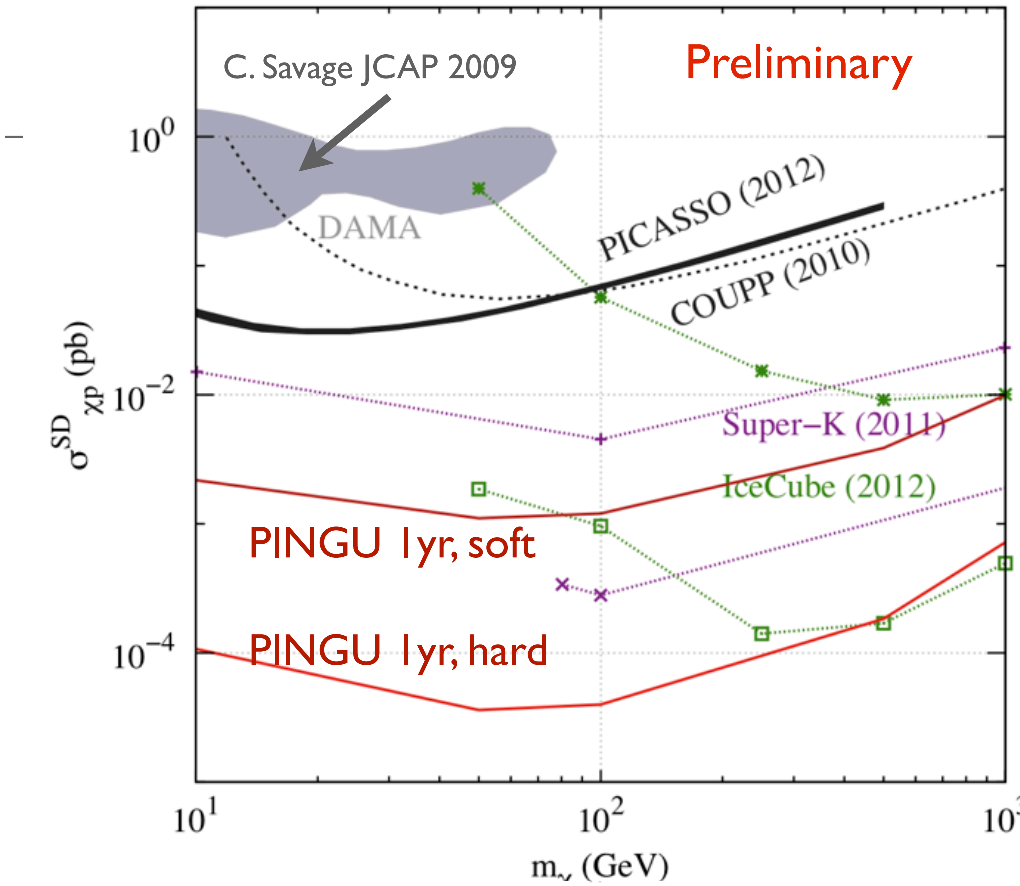


- Super-K and IceCube updated using contained events - lower threshold.

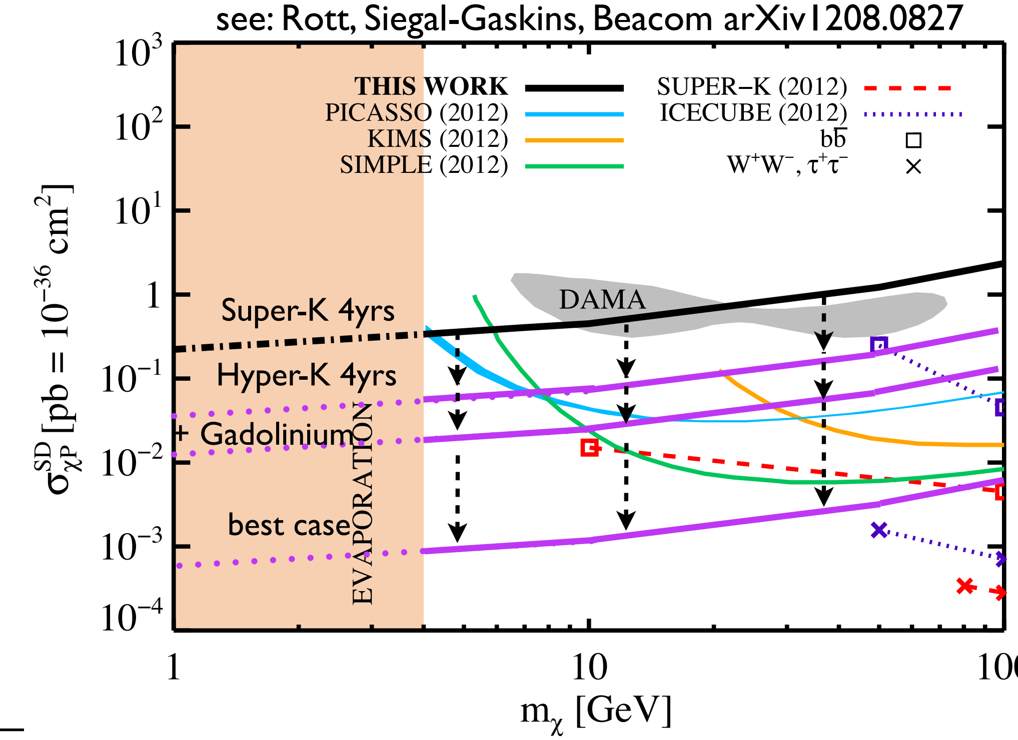
Future Neutrino Detectors



Adapted Rott, Tanaka, Itow JCAP09(2011)029 to

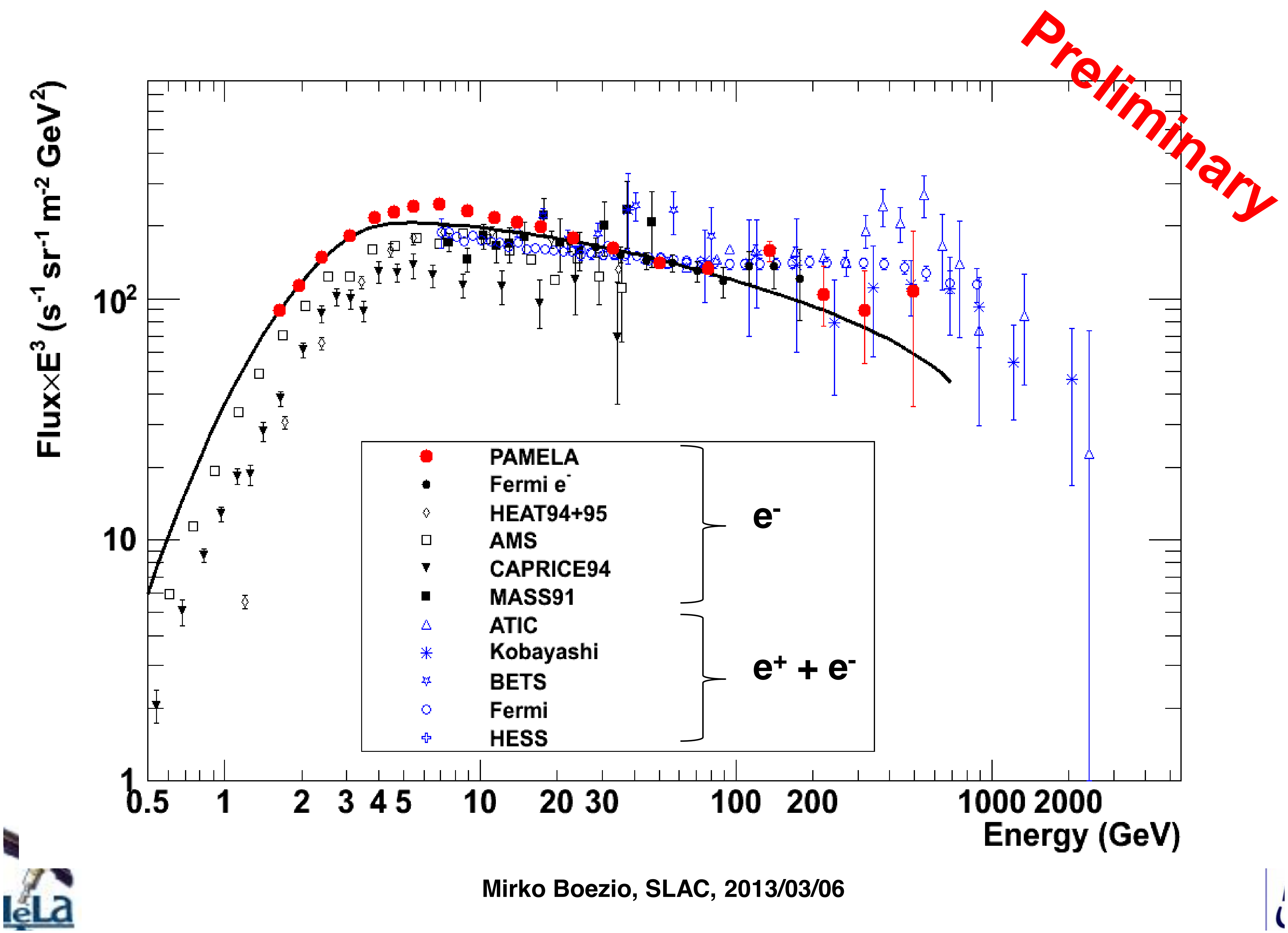


see: Rott, Siegal-Gaskins, Beacom arXiv1208.0827

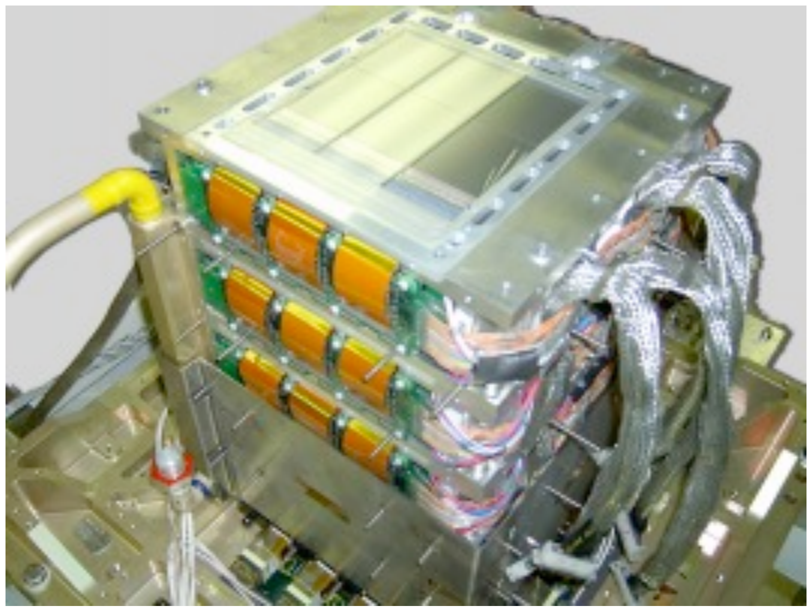


Cosmic-Ray Antimatter Experiments

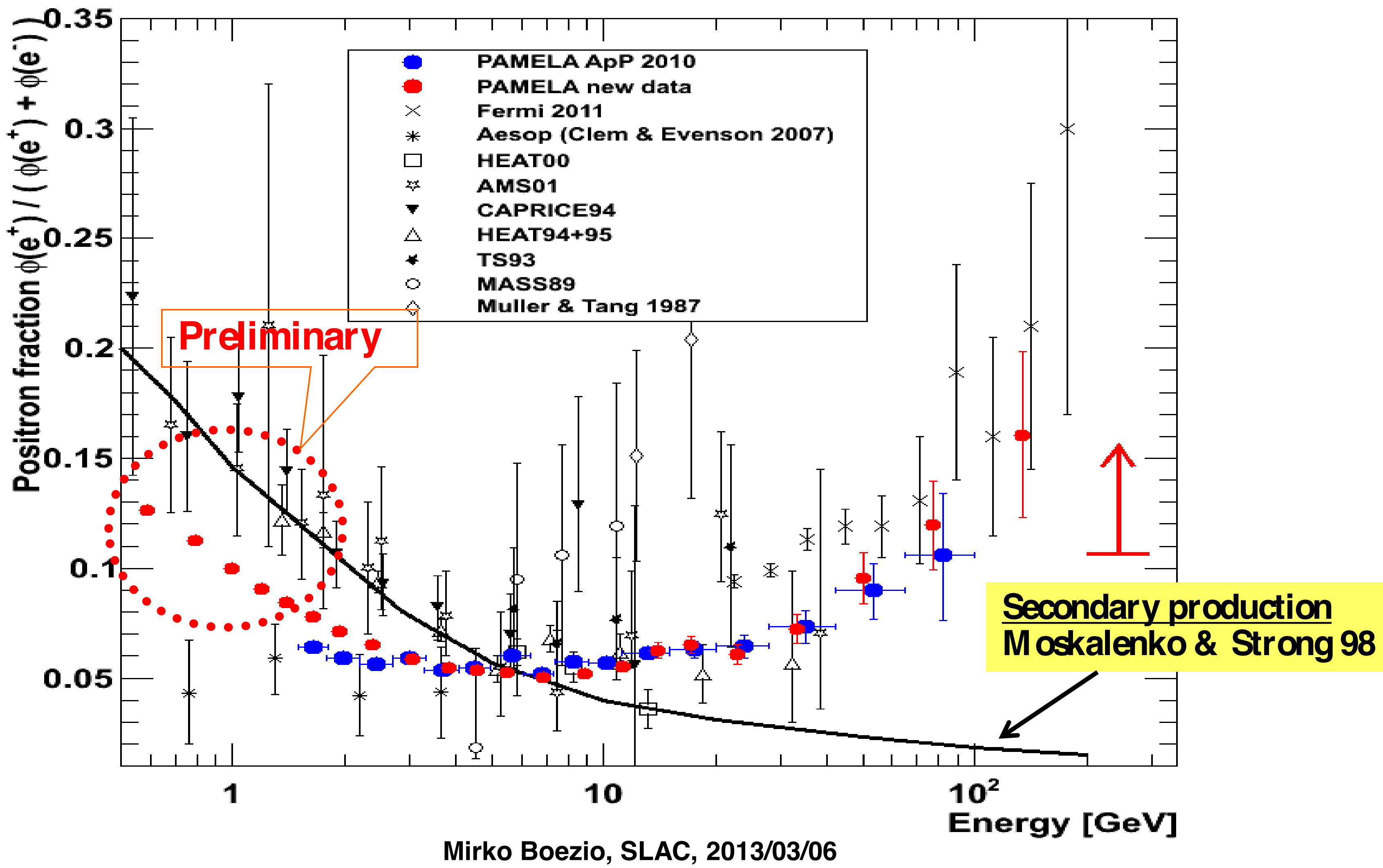
Electron Spectrum



Positron Results

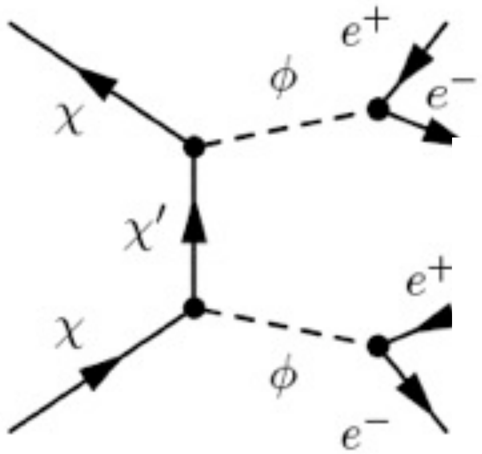


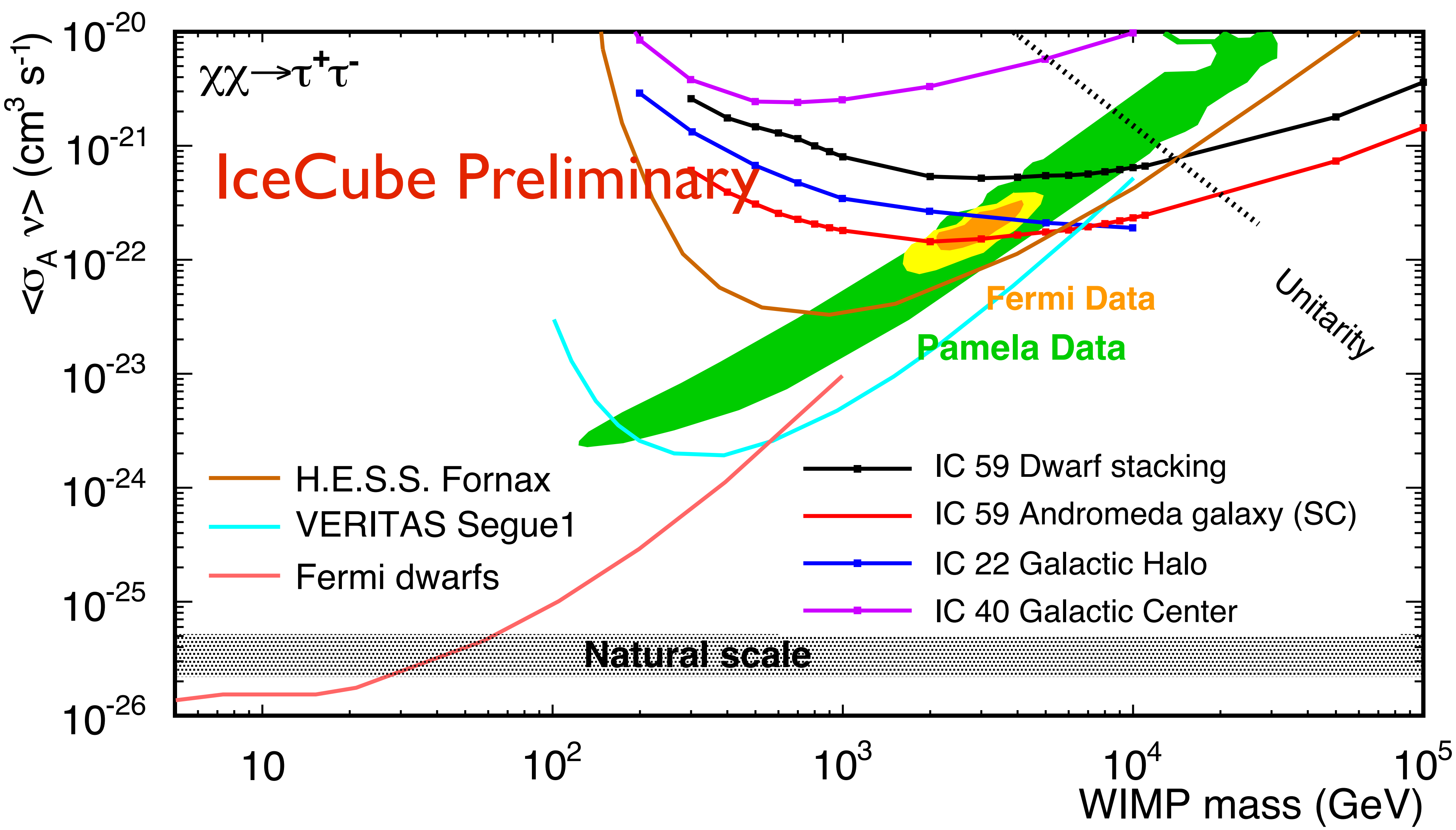
Positron to Electron Fraction



- Refinements in Pamela results, confirmation by Fermi using geomagnetic field, AMS results coming soon!

\gamma Constraints on e^+/e^-

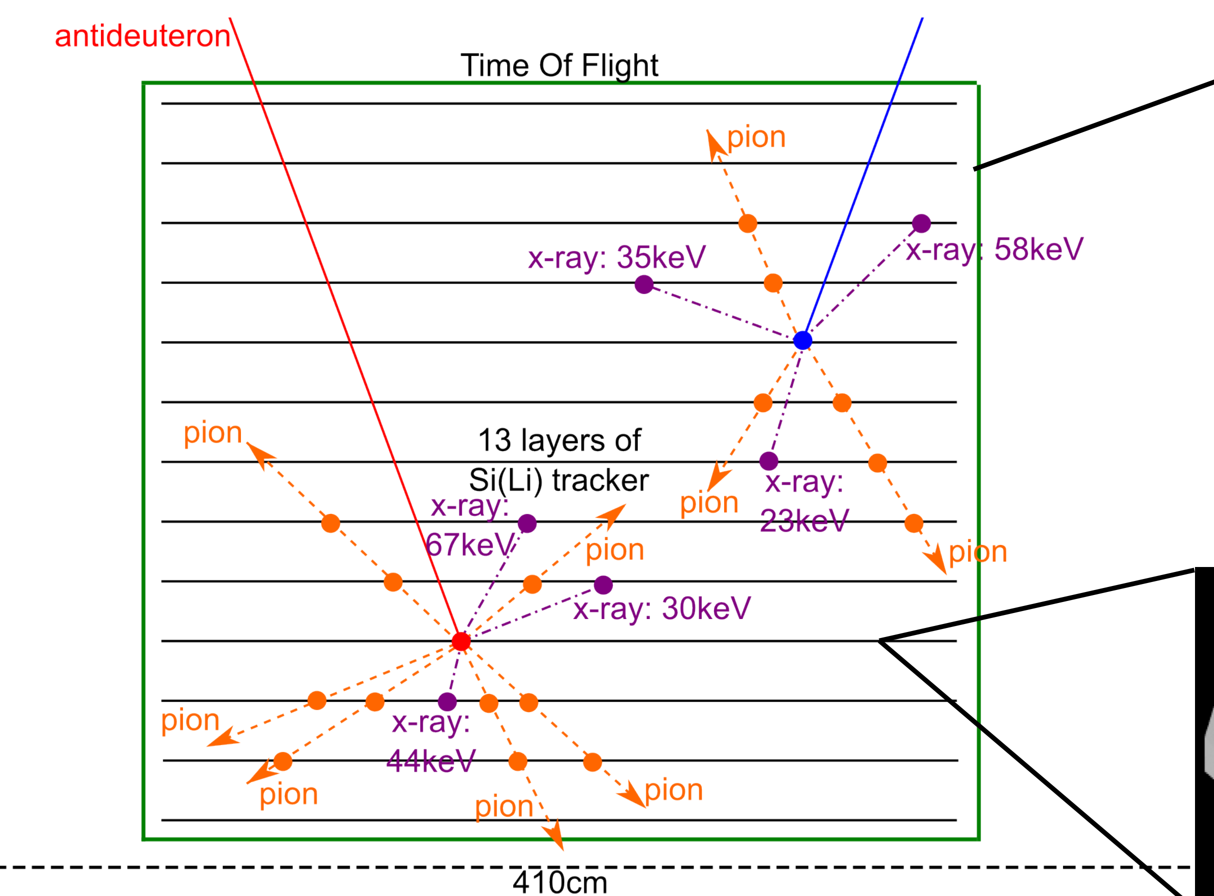


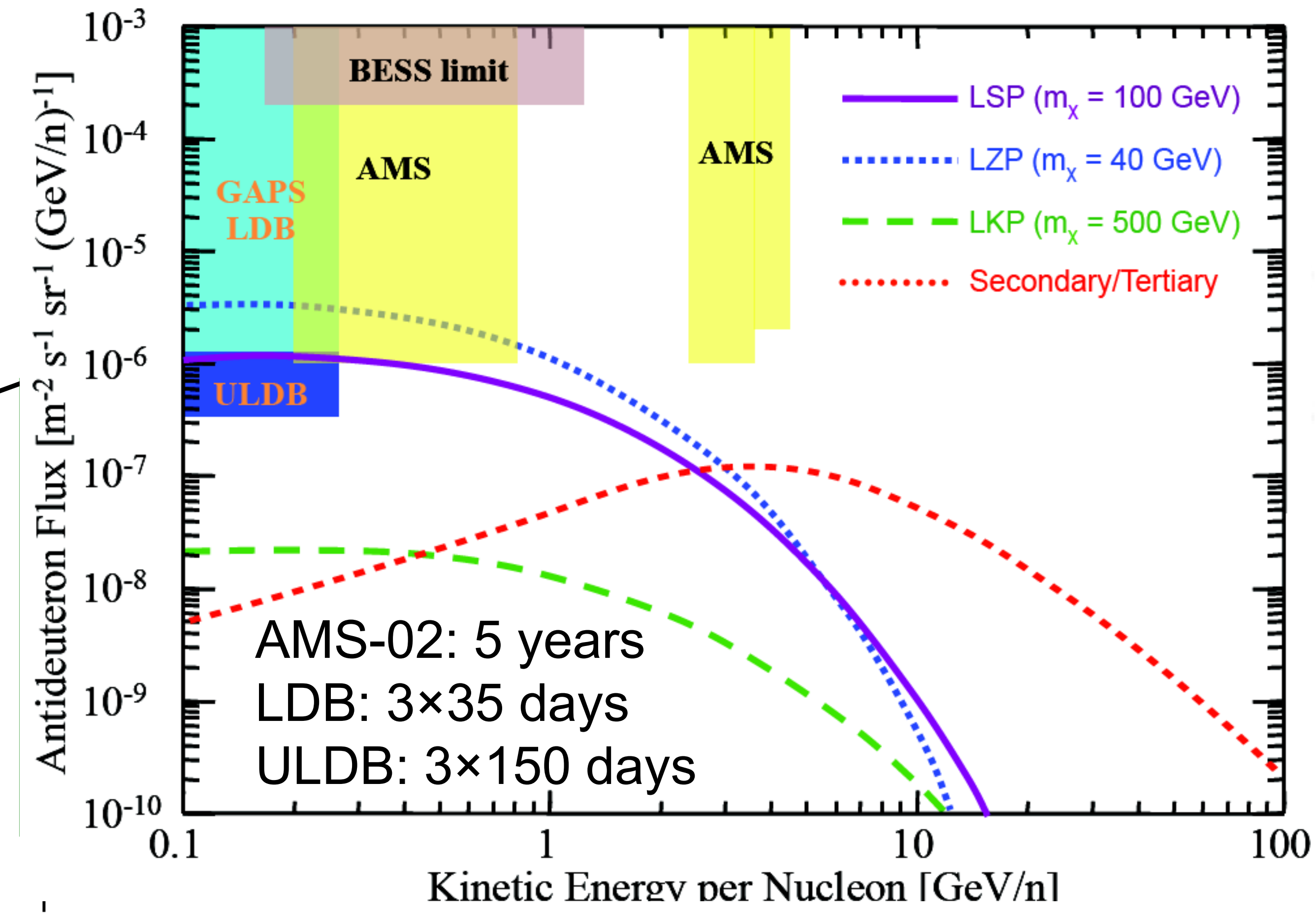


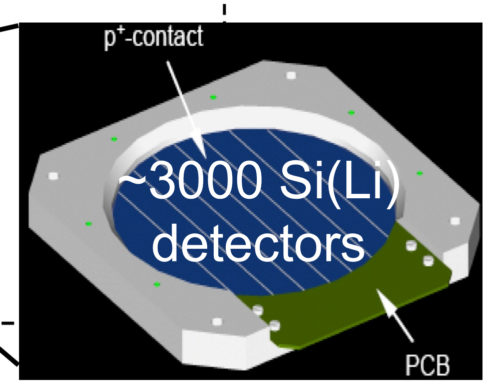
- Fermi, VERITAS, and IceCube constraints all cut into a dark matter interpretation for the Pamela/Fermi e+/e- measurements.

GAPS

(talk by P. von Doetinchem)



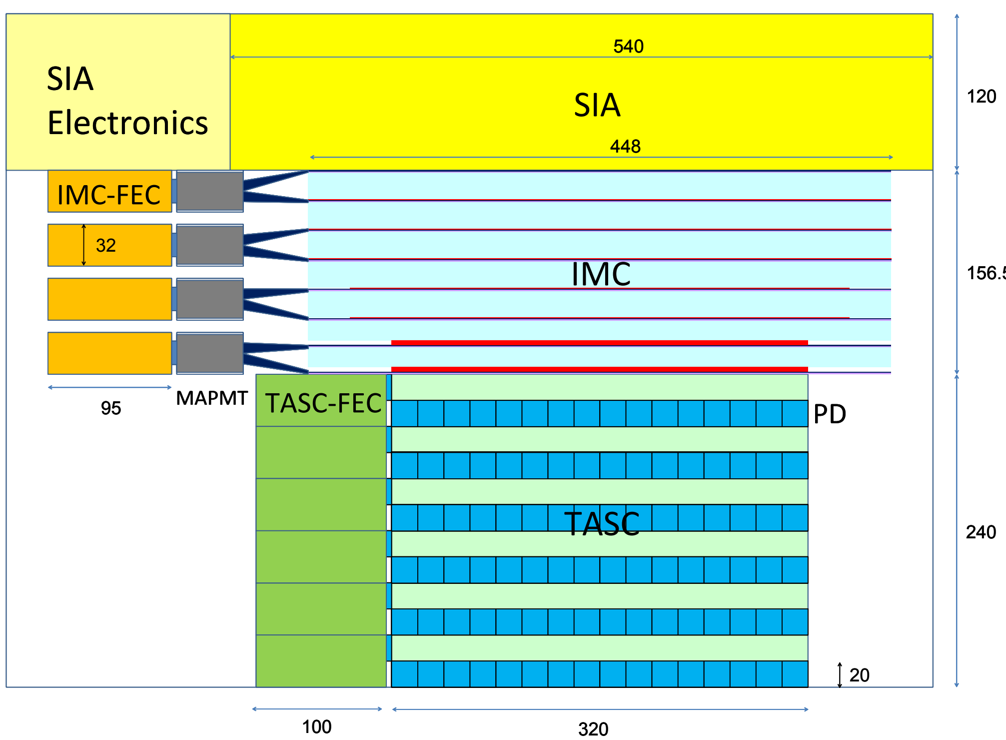




- GAPs looks for anti-deuterons (hard to produce as CR secondaries), uses TOF, X-rays from short-lived exotic atom, pion star from annihilation

CALET Overview

❑ **Observations**
- **Electrons** : 1 GeV -10,000 GeV
- **Gamma-rays** : 10 GeV -10,000 GeV (GRB > 1 GeV)
  + Gamma-ray Bursts : 7 keV-20 MeV
- **Protons, Heavy Nuclei**:
  several 10 GeV- 1000TeV (per particle)
- **Solar Particles and Modulated Particles in Solar System**: 1 GeV-10 GeV (Electrons)



S. Torii, COSPAR 2010

Instrument

- Imaging Calorimeter (Particle ID, Direction)

Total Thickness of Tungsten (W) : 3 X_0

Layer Number of Scifi Belts : 8 Layers ×2(X,Y)

- Total Absorption Calorimeter (Energy Measurement, Particle ID)

PWO 20mmx20mmx320mm

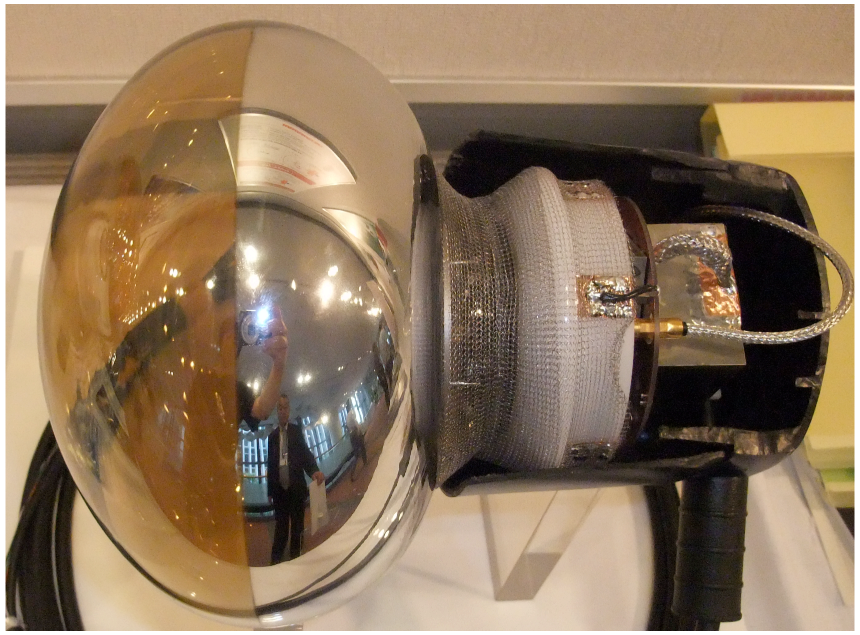
Total Depth of PWO : 27 X_0 (24cm)

- Silicon Pixel Array (by Italy) (or a substitute) (Charge Measurement in Z=1-35)

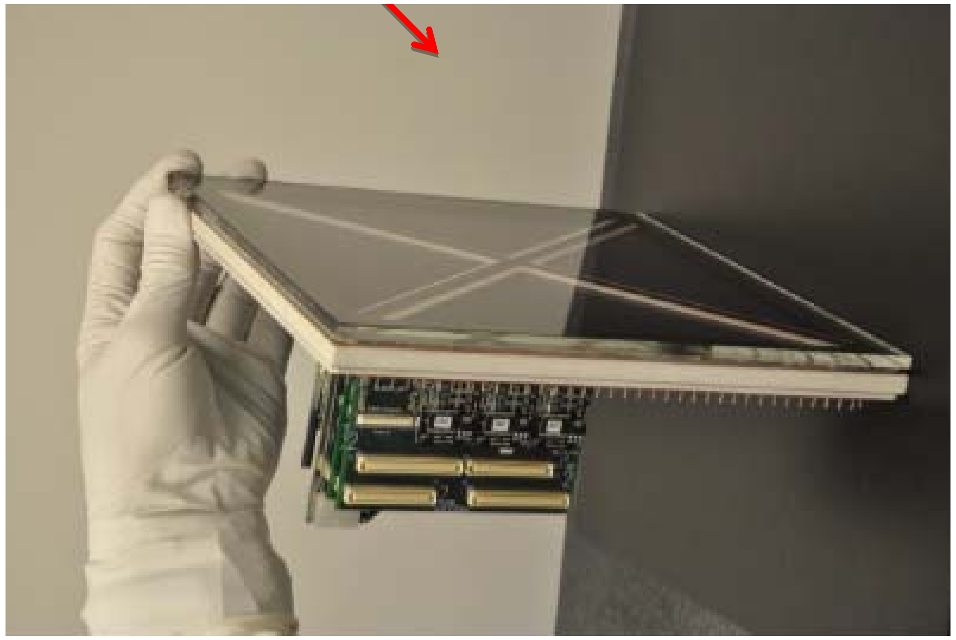
Silicon Pixel 11.25mmx11.25mmx0.5mm

2 Layers with a coverage of 54 x54 cm^2

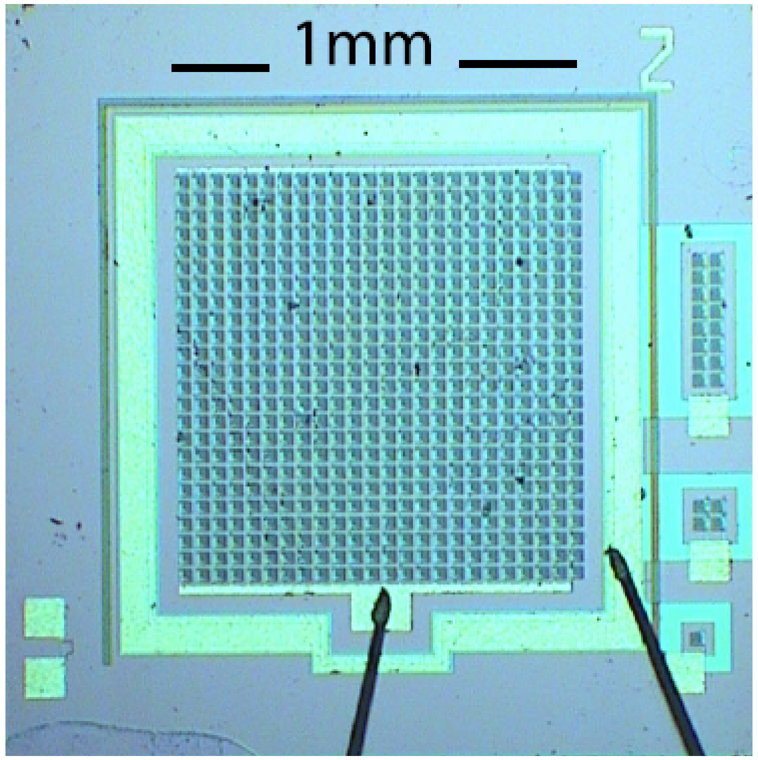
Technical Developments



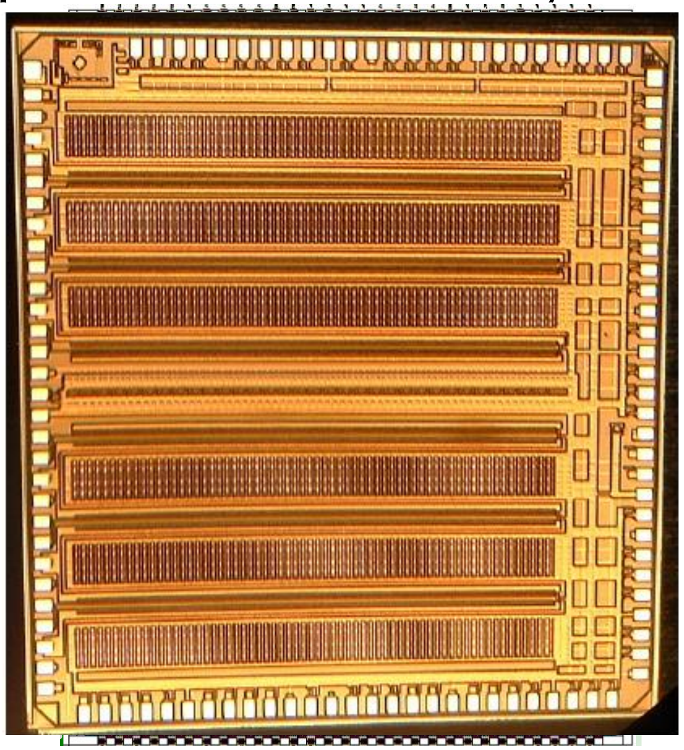
Large-Area HPMT (Masashi Yokoyama)



LAPPD psec timing, 8″ square photodetector, (K. Byrum)



SiPMs, (N. Otte)

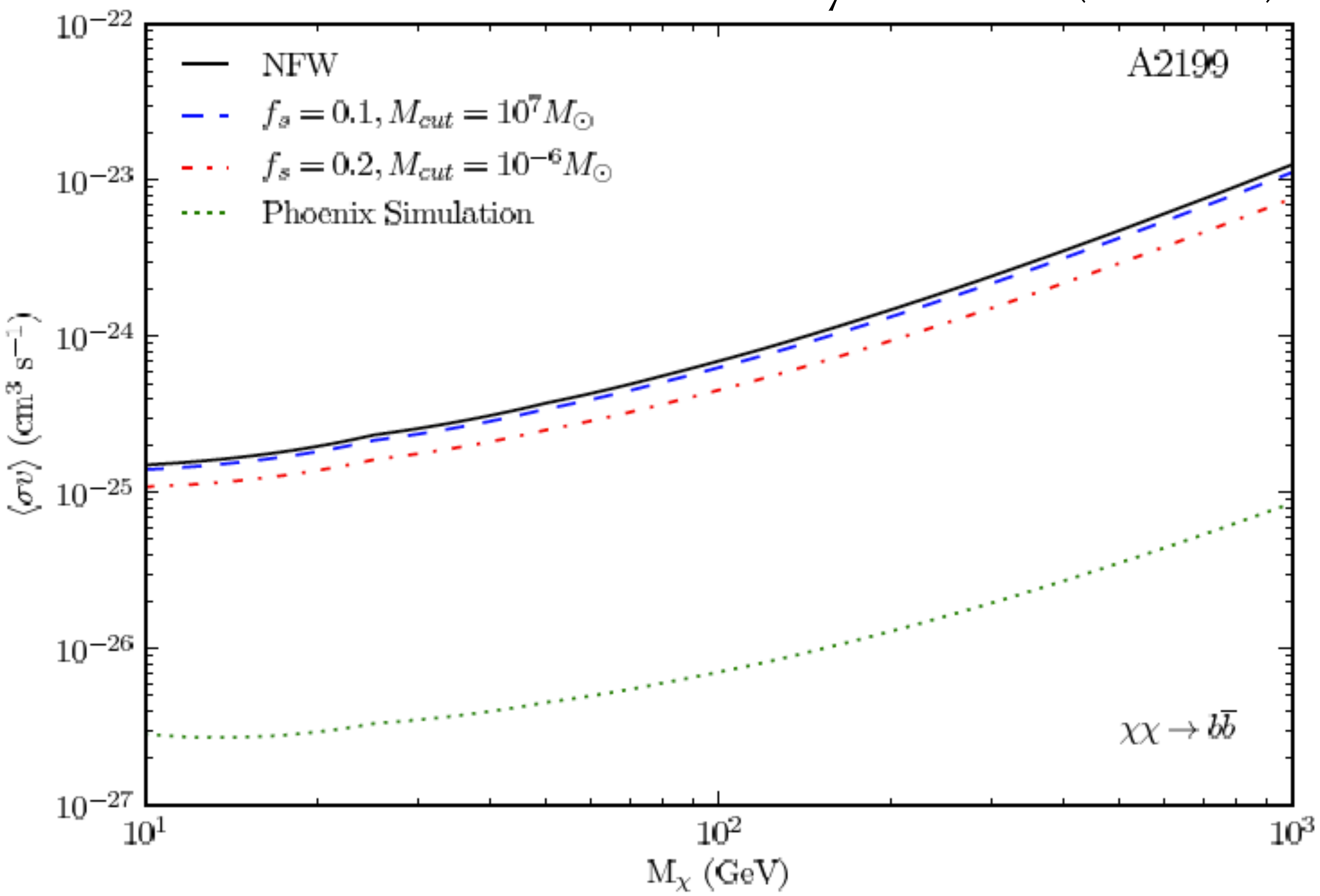


- Analog pipeline ASICs (K. Nishimura)

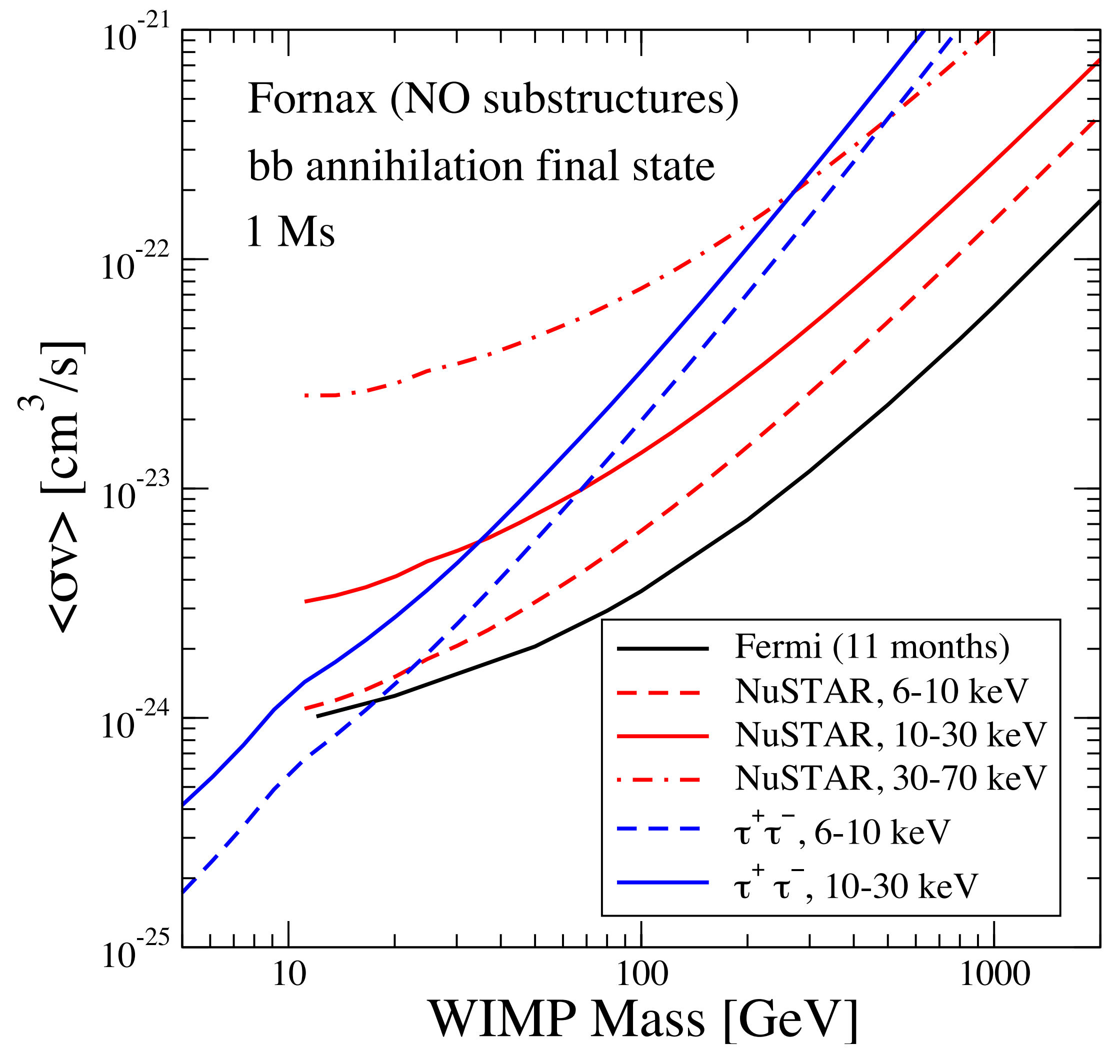
Astrophysical Constraints

X-Ray (NuSTAR) constraints on Fornax cluster compared with Fermi gamma-ray constraints

Radio Constraints on Galaxy Cluster (A2199)



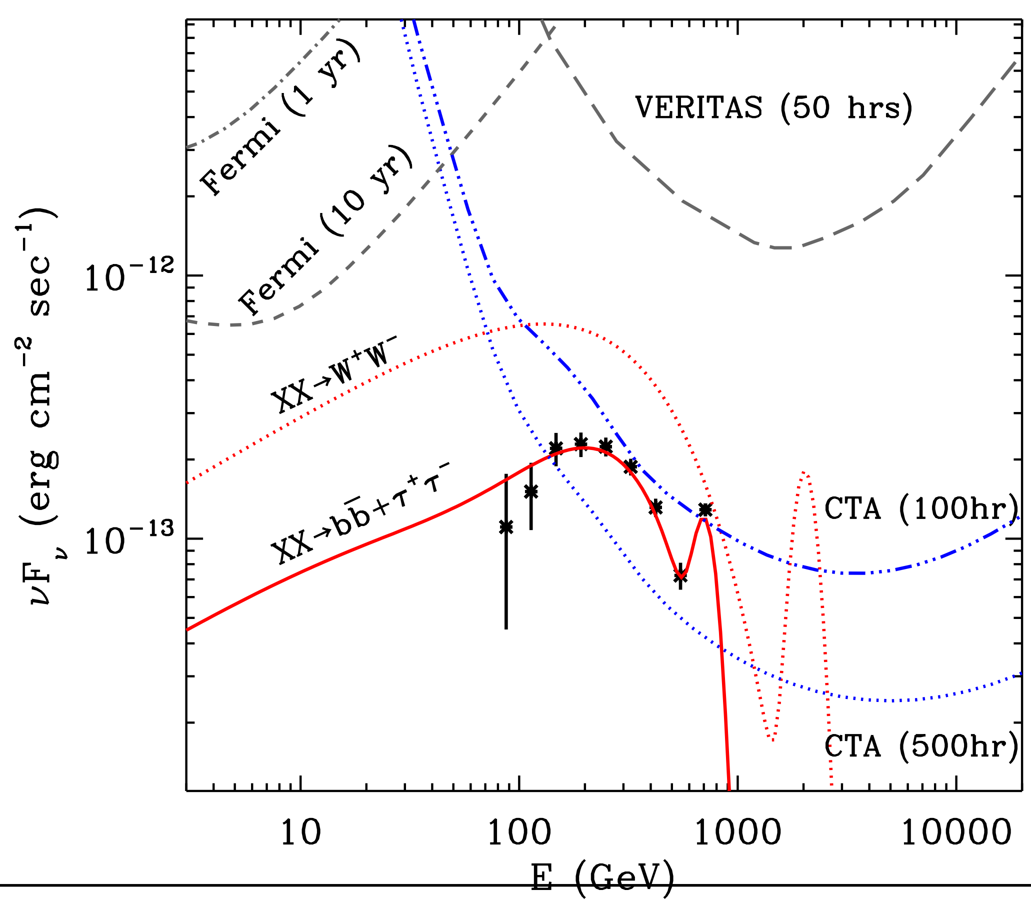
(Talk by T. Jeltema)

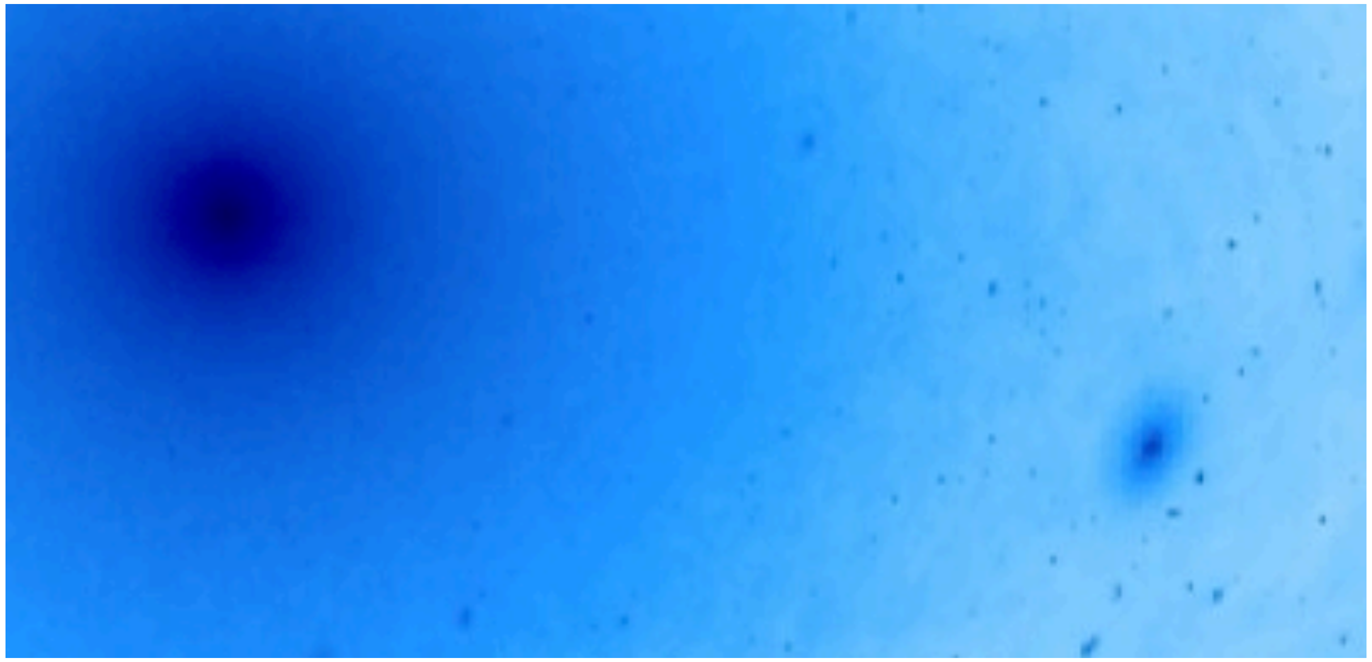


- In cases where the magnetic field and diffusion is understood, radio constraints on DM can be used.

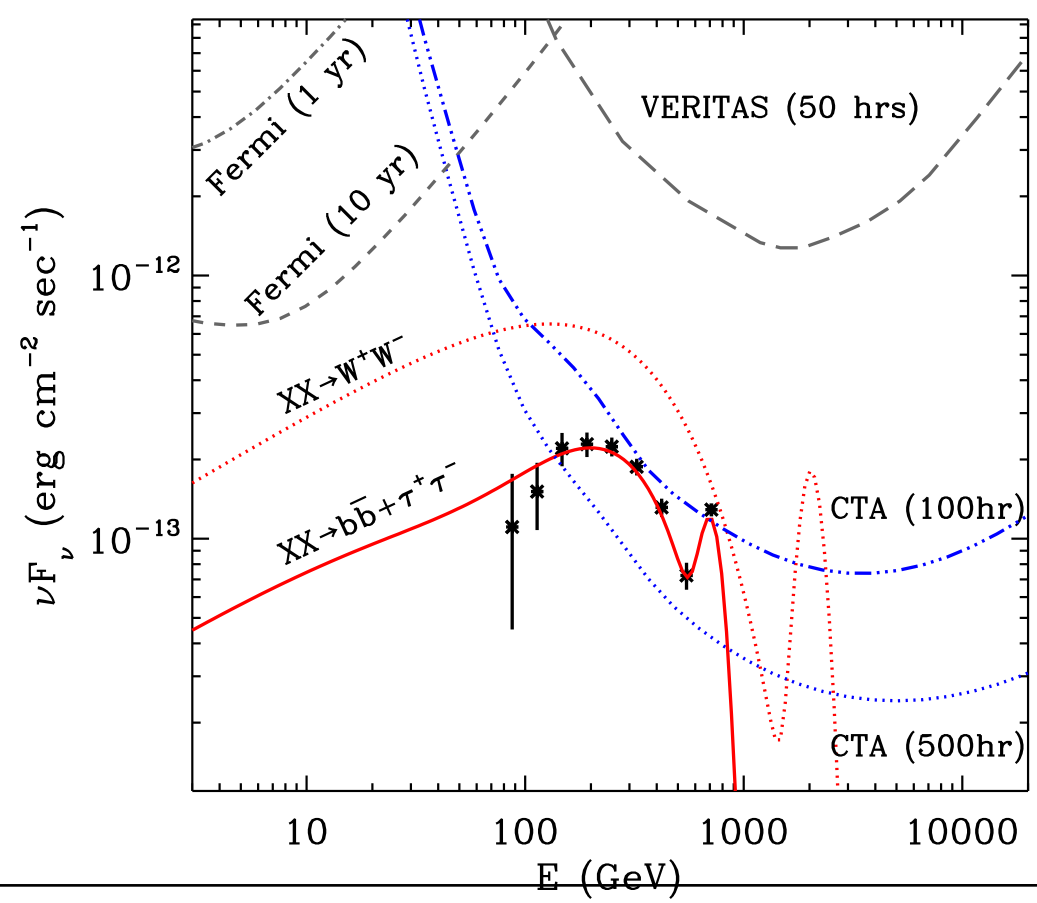
- Electrons will IC scatter CMB photons, producing a measurable X-ray signal and DM

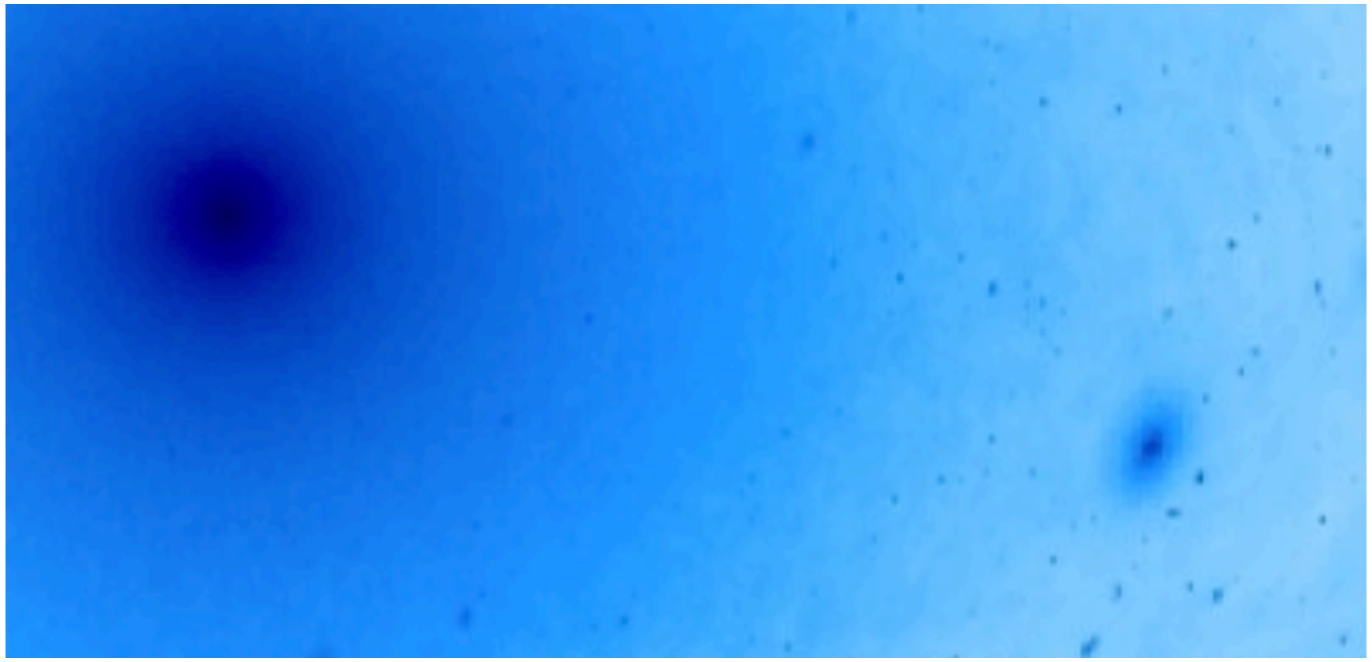
Moving Forward





Moving Forward





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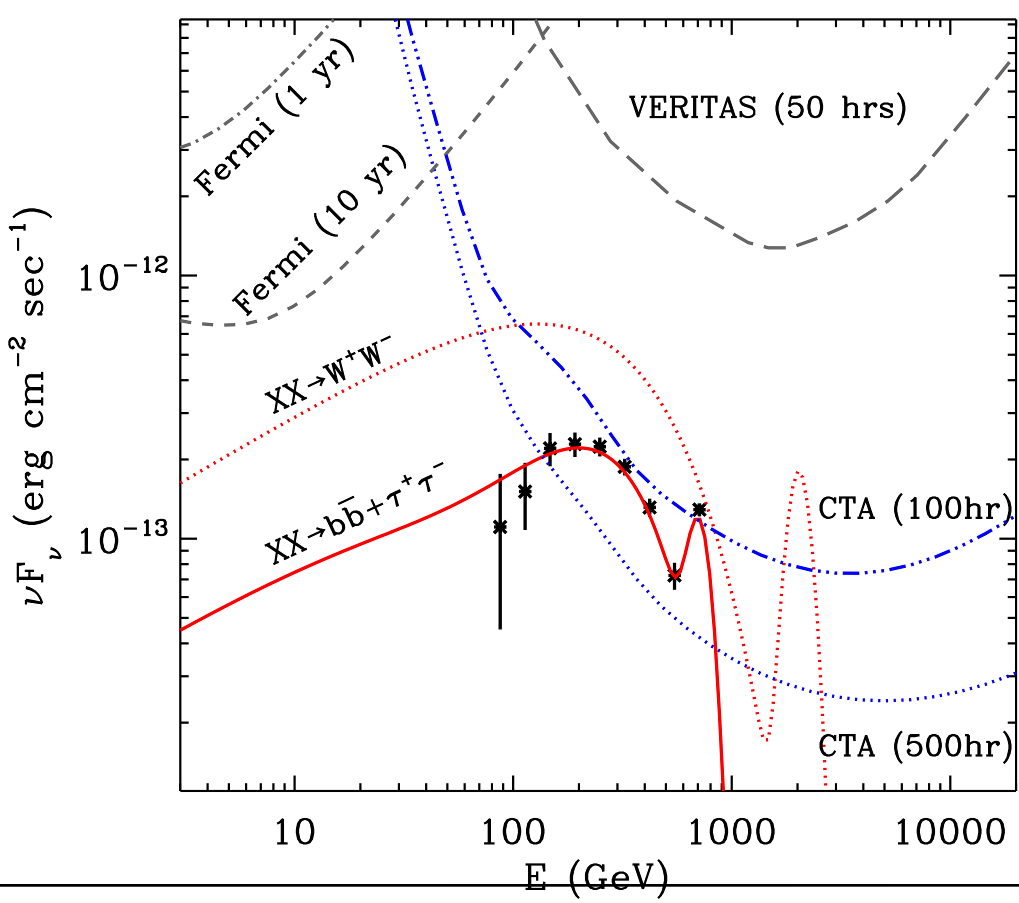

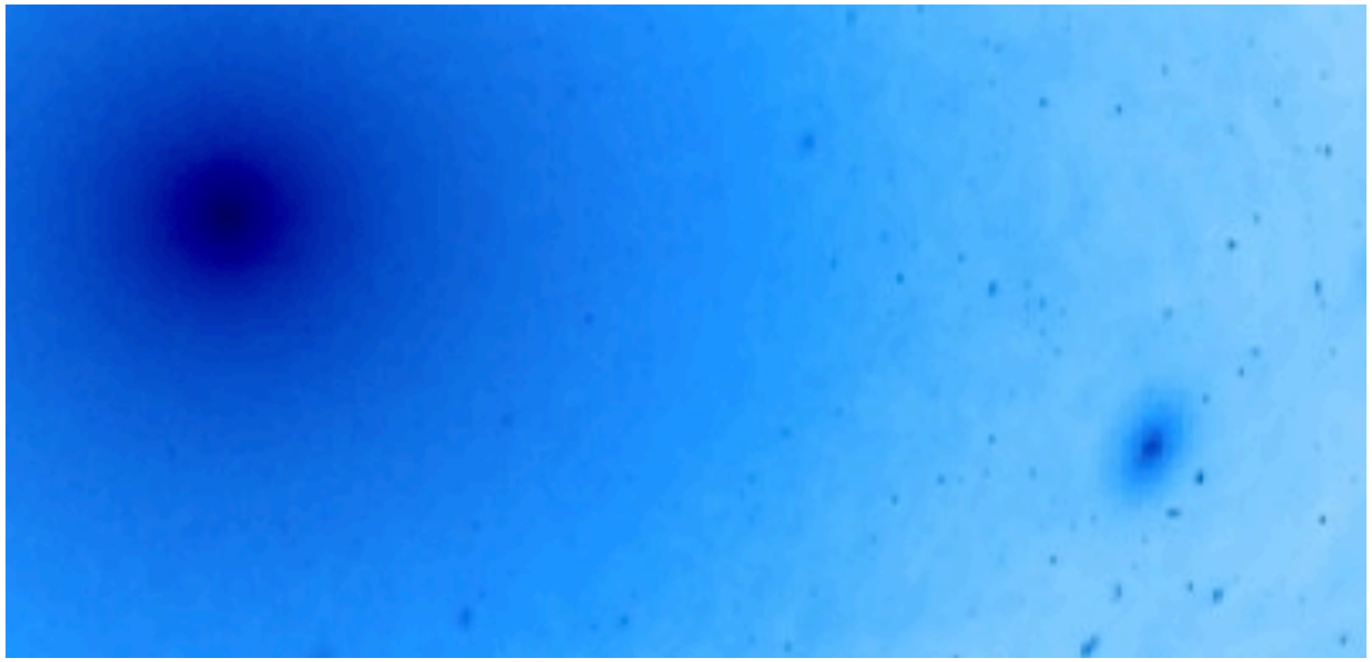

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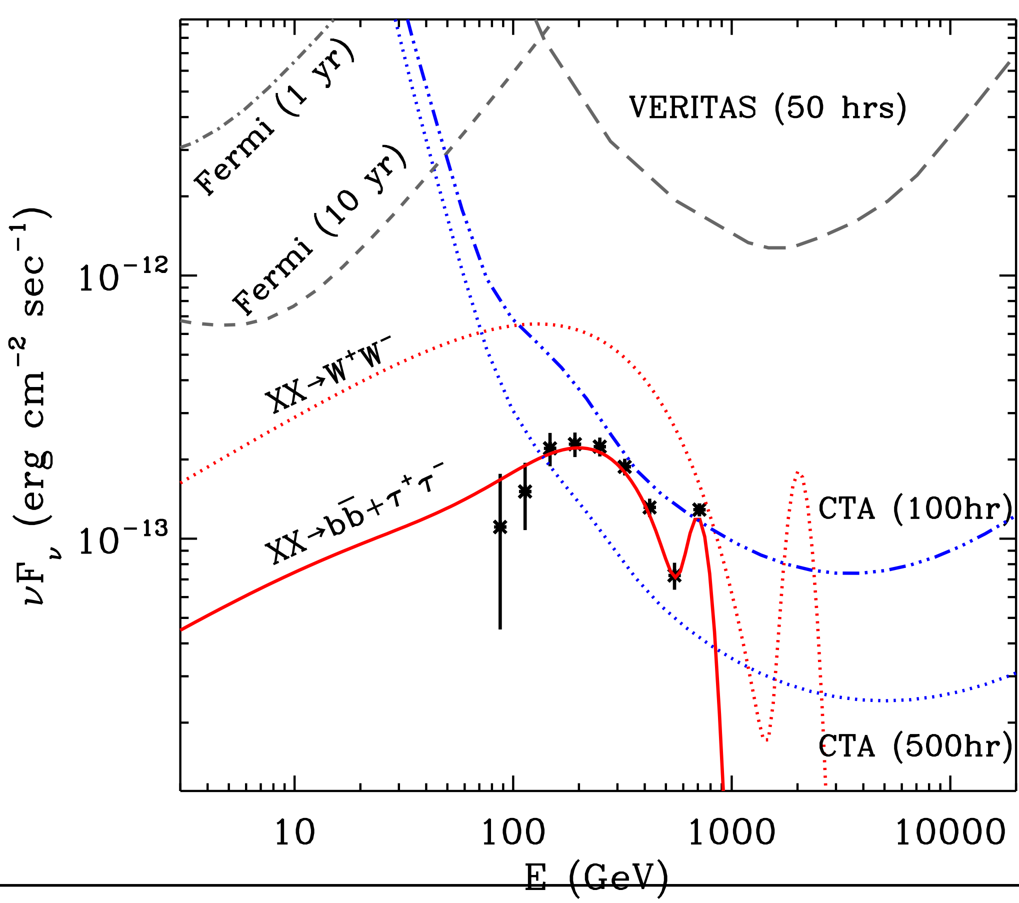

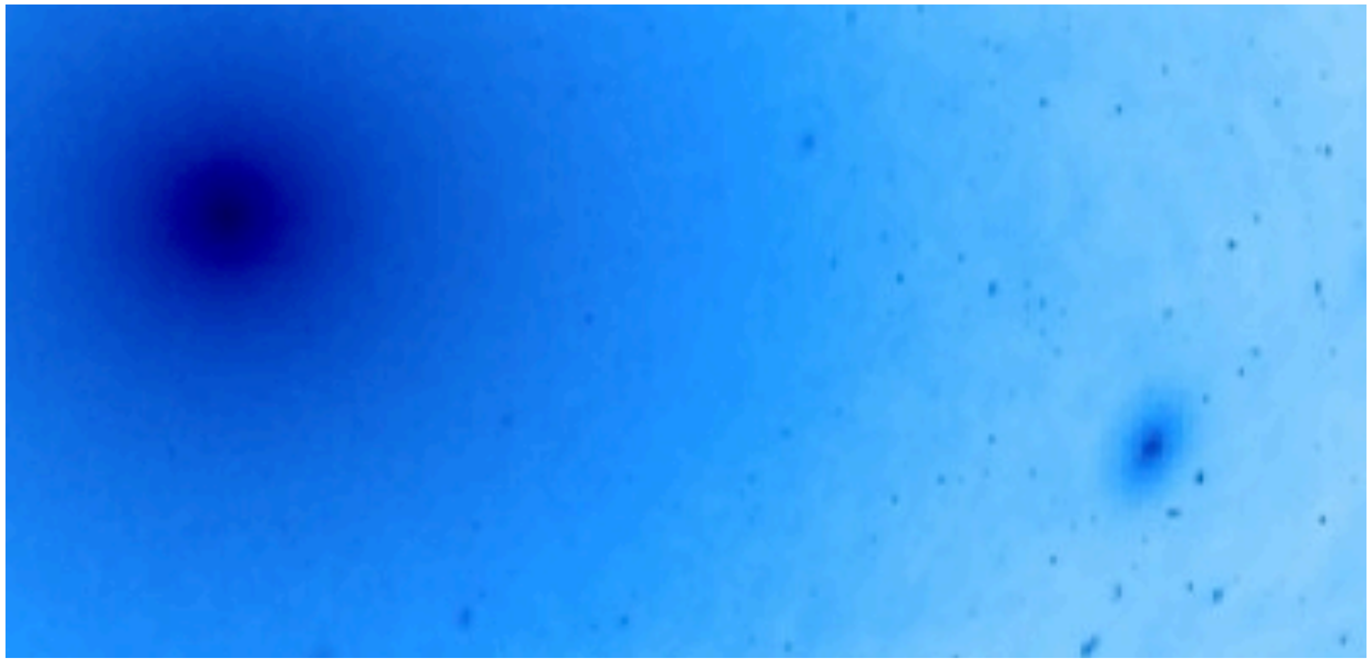

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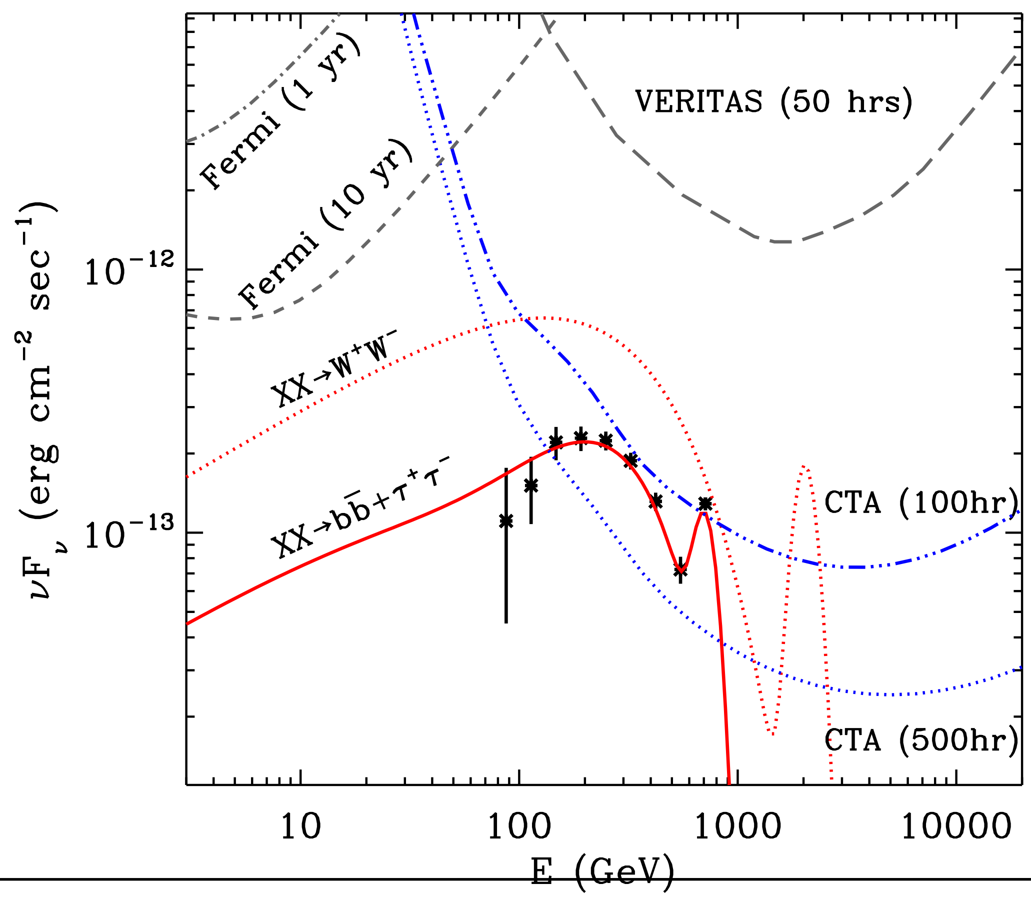

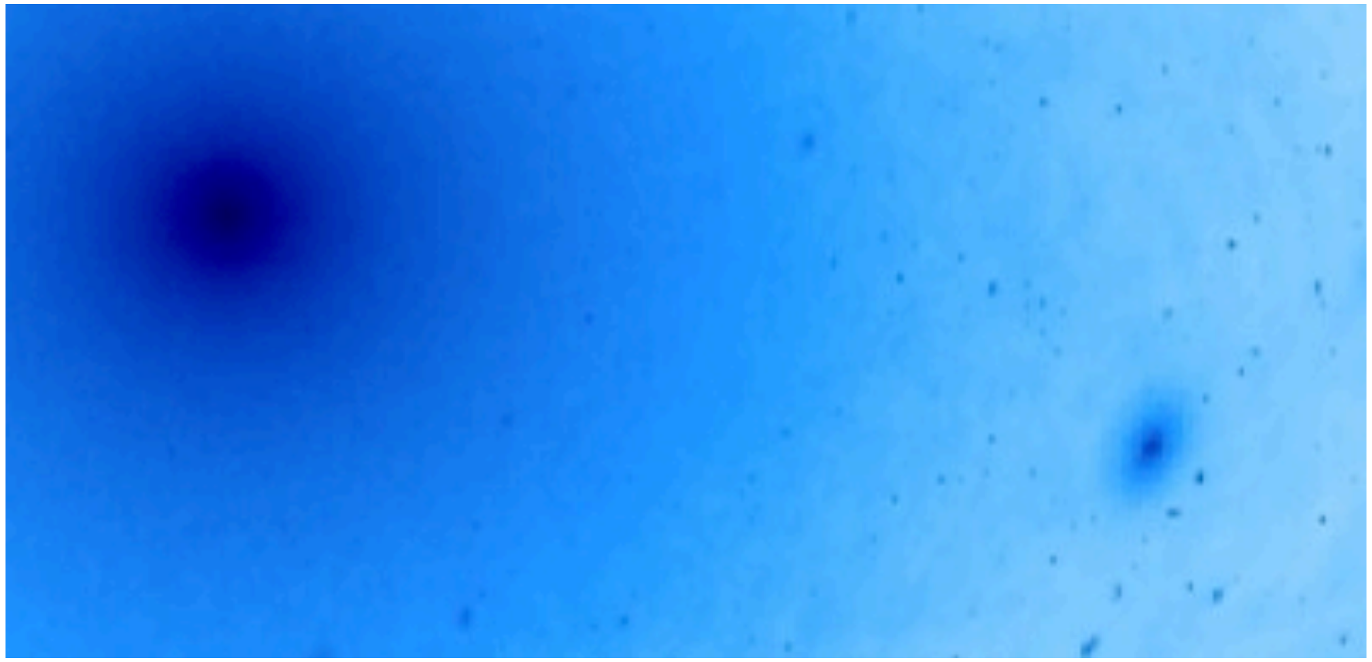

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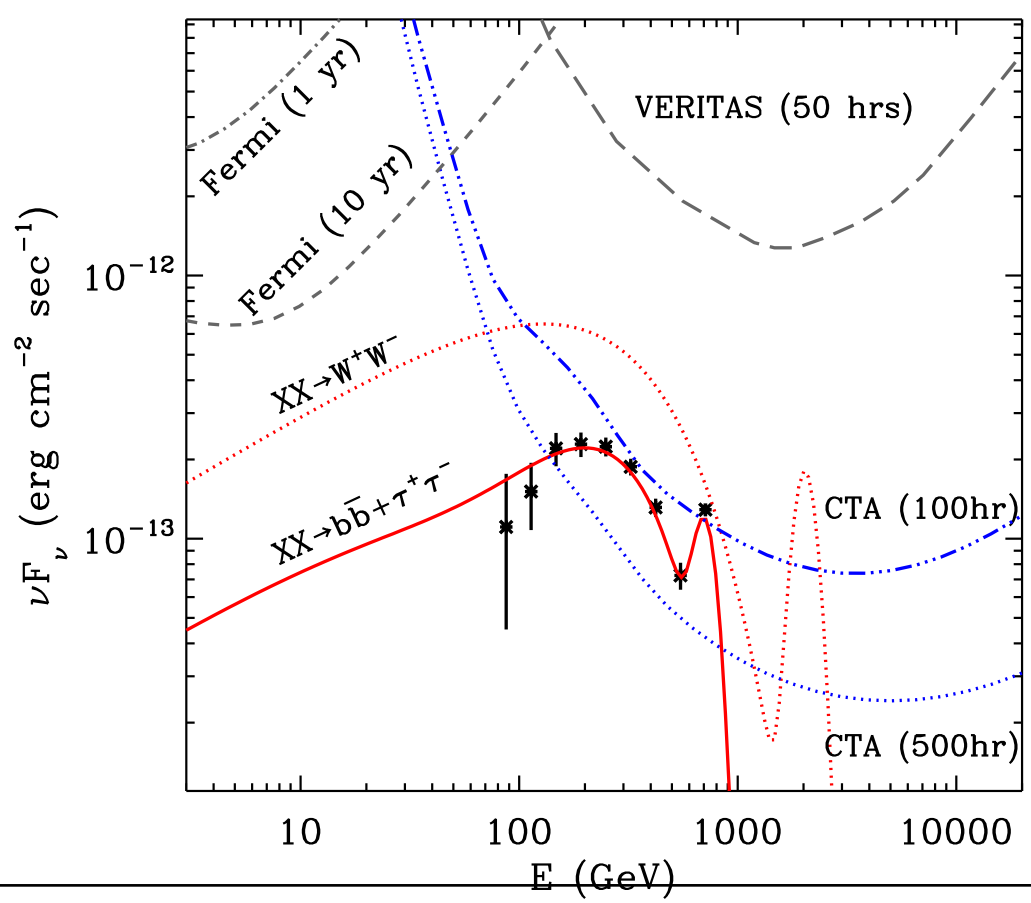

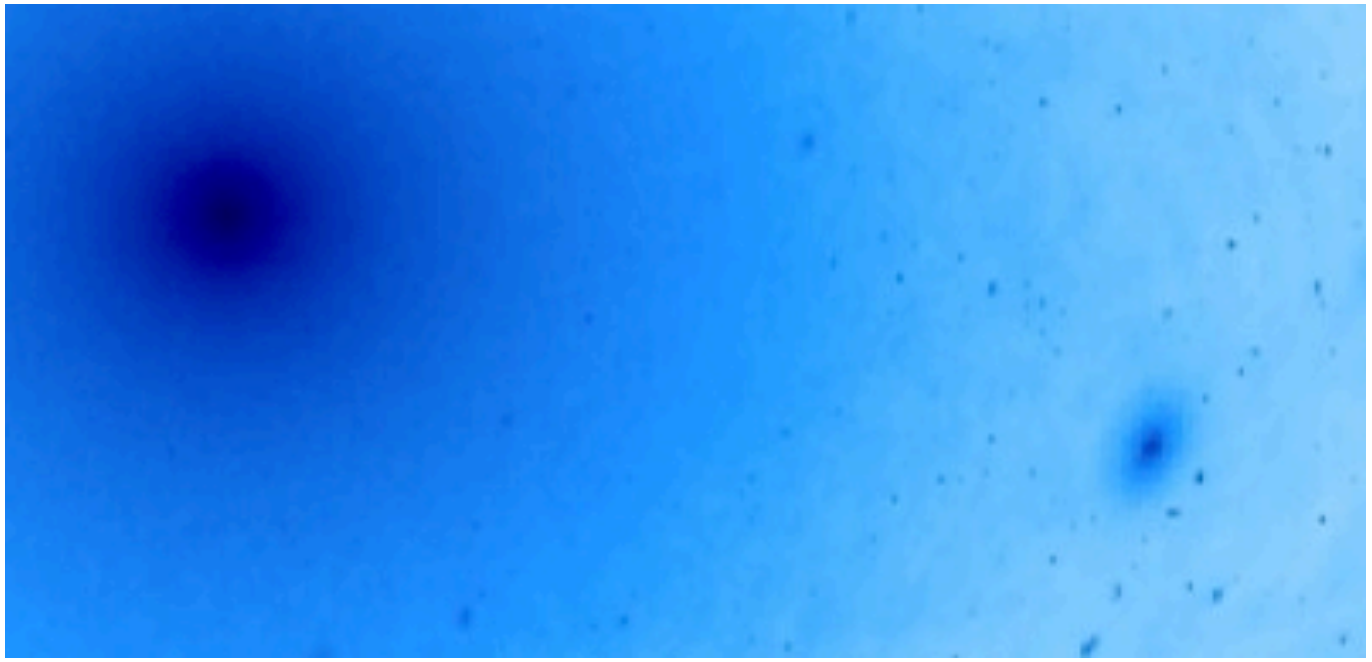

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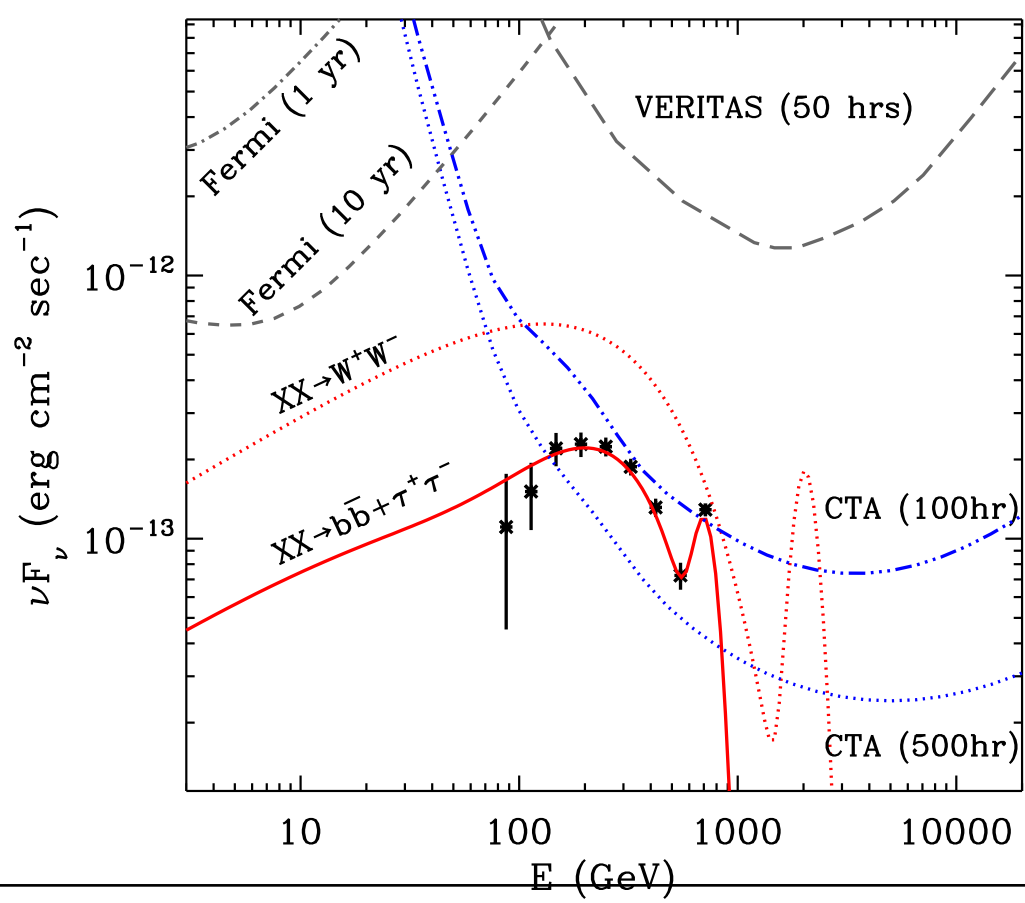

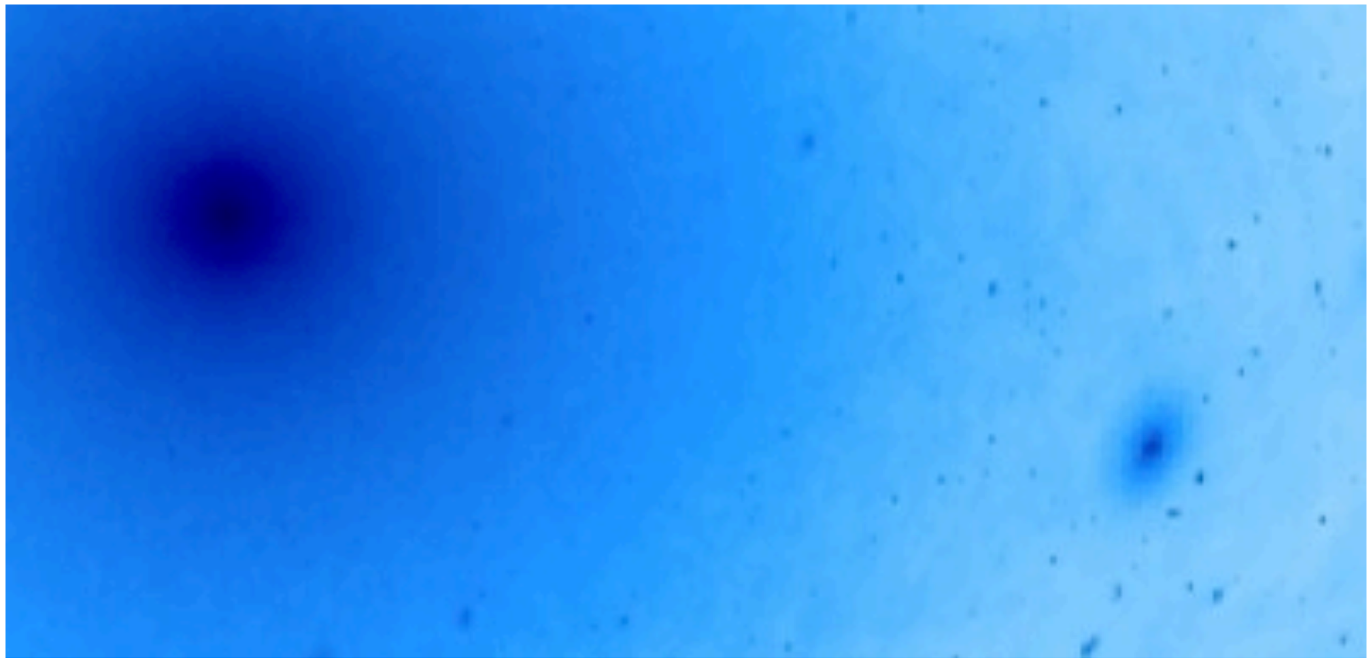

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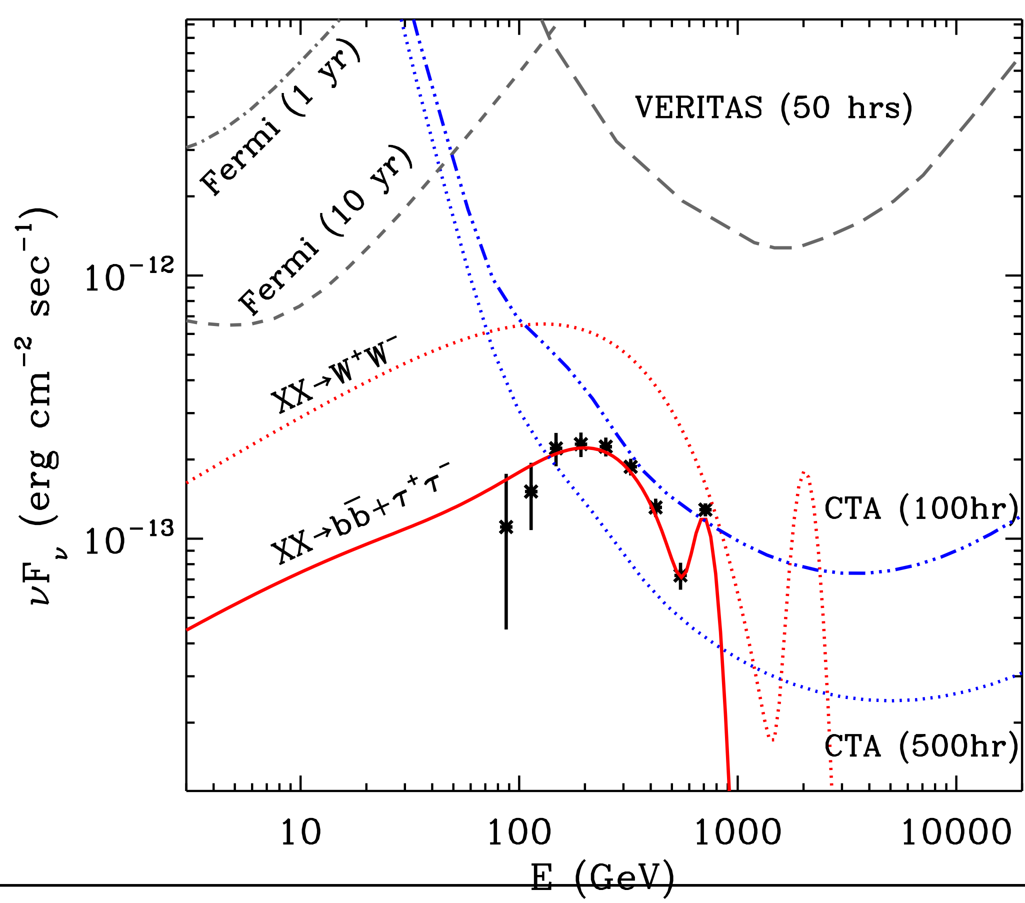

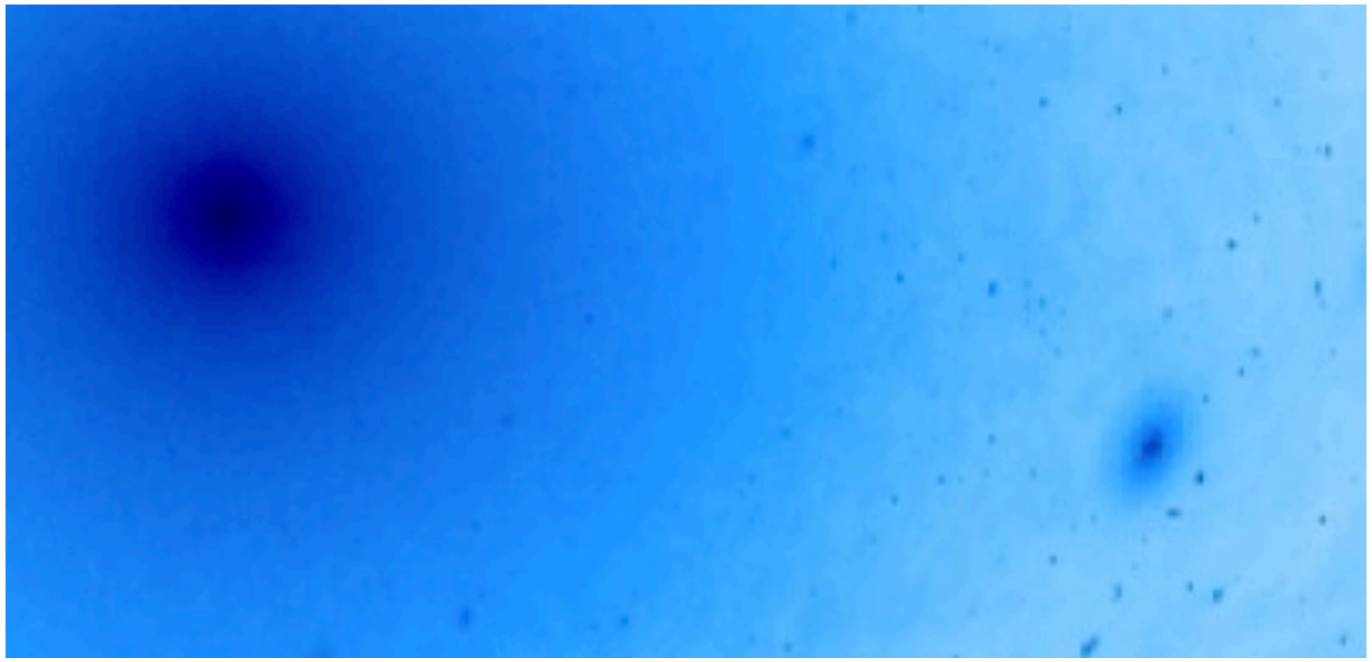

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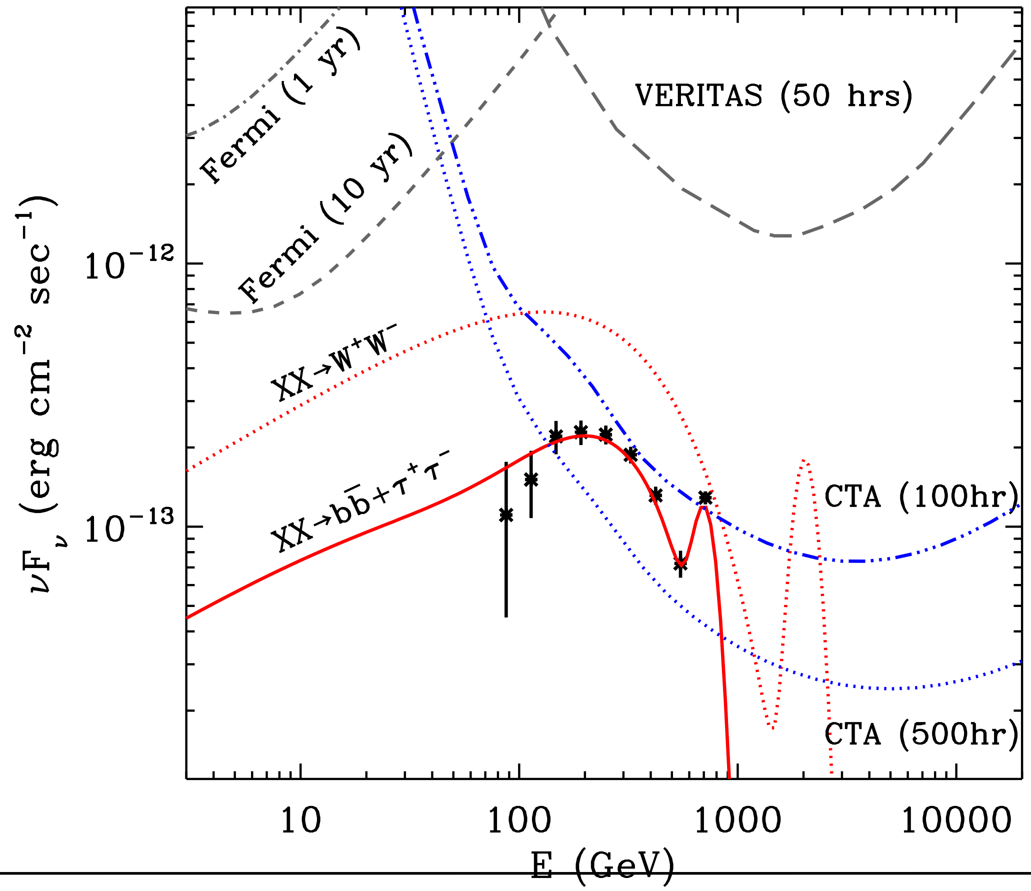
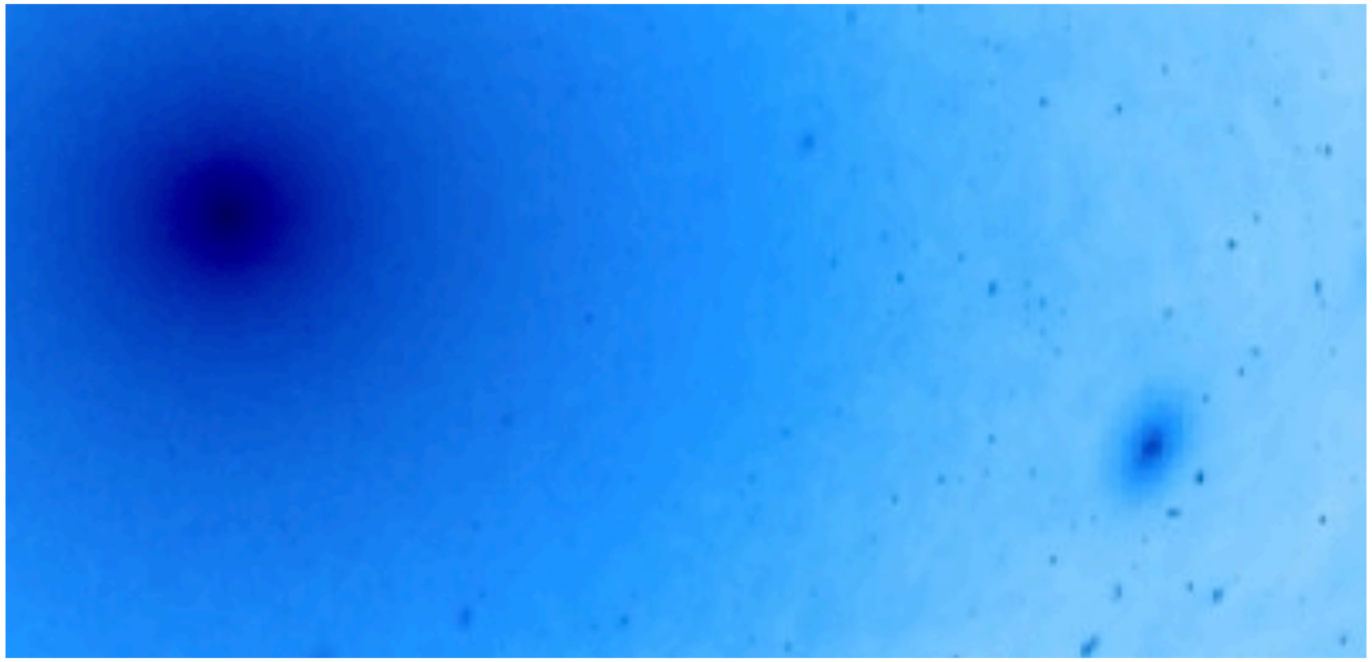
- *Imagine:* What if we turn the techniques of HEP toward the sky and measure spectrum of annihilation (the same in two regions), and make an image of DM halos!

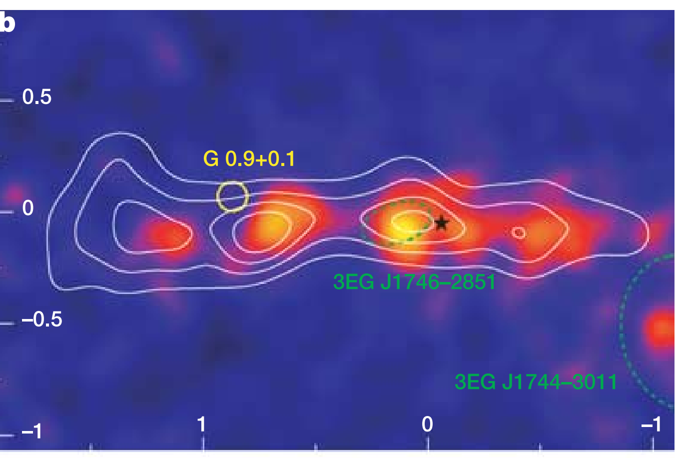




Top 10 Myths

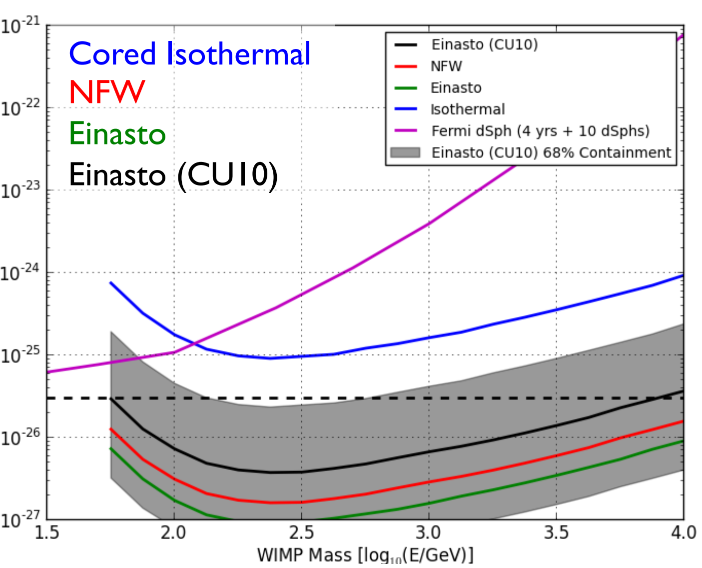
- Astrophysical backgrounds make indirect detection impossible

How bad are astrophysical backgrounds? Total γ-ray flux (1-3 GeV) within $1^\circ \sim 1\times10^{-7}\mathrm{cm}^{-2}\,\mathrm{s}^{-1} \Rightarrow \langle\sigma v\rangle = 1.6\times10^{-25}\,\mathrm{cm}^{3}\mathrm{s}^{-1}$ (*Tim Linden's talk*)



- At very high energies, fewer backgrounds

- Uncertainties in Halo profiles mean that gamma-ray limits are wildly uncertain!
  - For GC this is worse than for Dwarfs, but may only amount to an order of magnitude uncertainty (see talk by Alex Drlica Wagner, Ferrer)

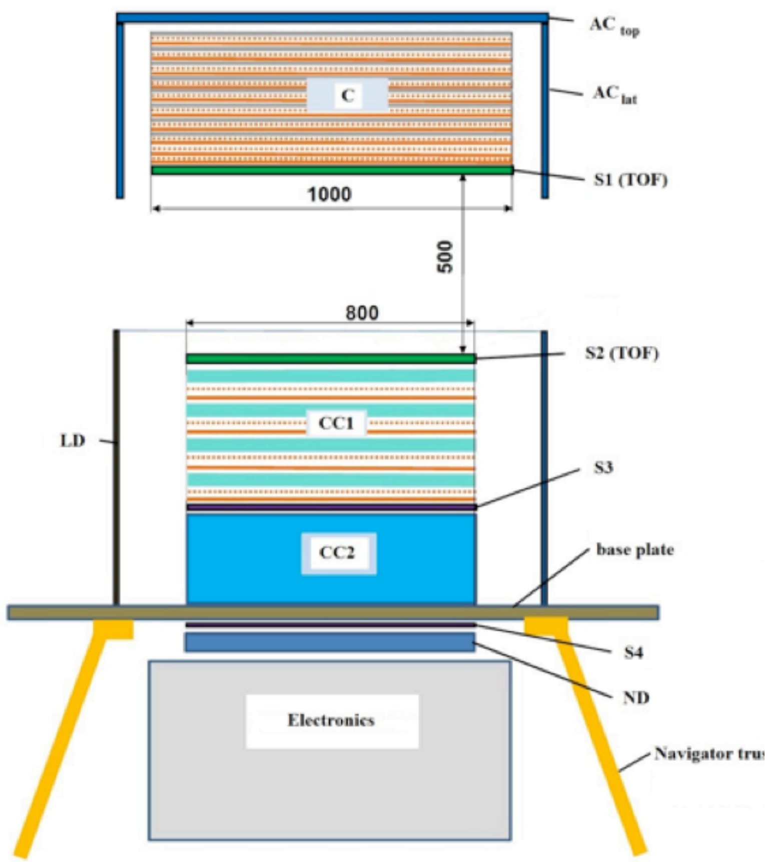


- Gamma-ray, Neutrino and Cosmic-Ray antimatter do other Astrophysics besides Dark Matter
  - So do big, wide-field optical telescopes.
  - We can live with that! Supermassive black holes, pulsars, supernova remnants, EBL and LIV probes, numerous papers and theses

Backup Slides

GAMMA-400

GAMMA-400 Concept



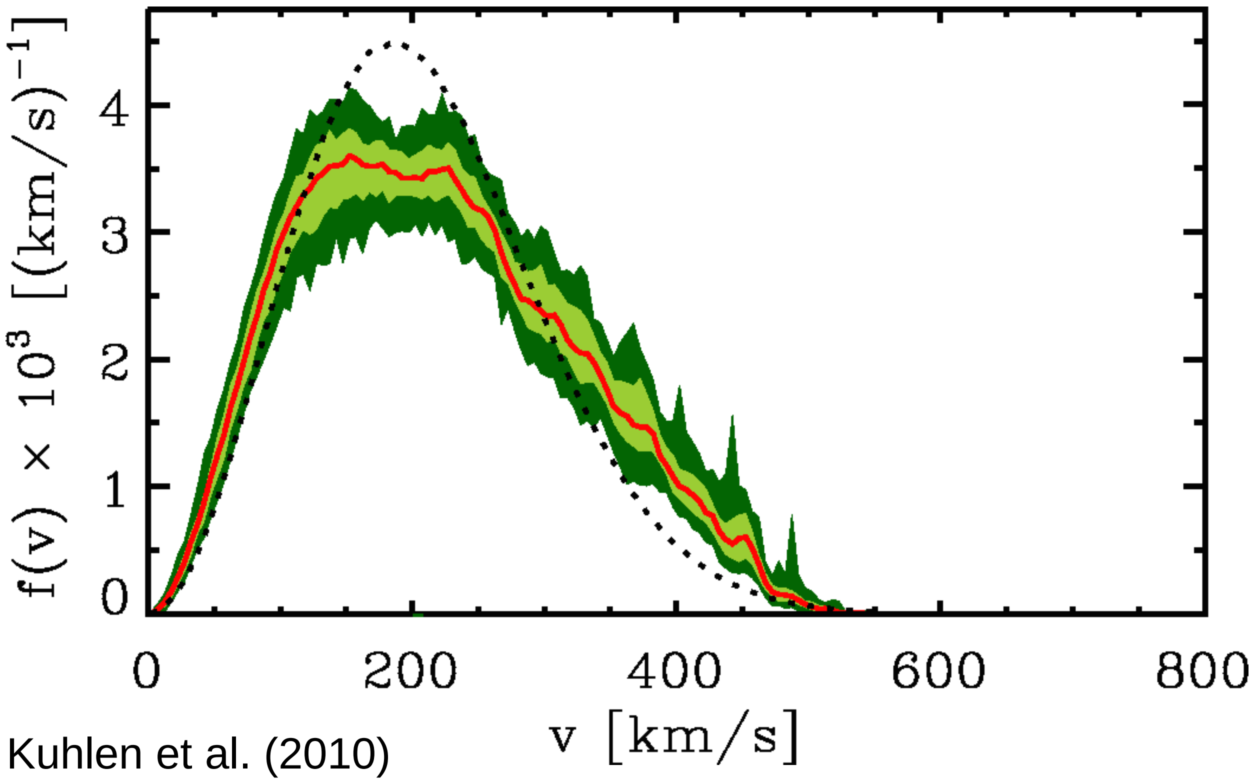
Energy range	100 MeV – 3000 GeV
Field-of-view, sr (E > 1 GeV)	~1.2
Effective area, cm^2 (E > 1 GeV)	~4,000 (~6,000)
Energy resolution (E > 10 GeV)	~1%
Angular Resolution (E >100 GeV)	~0.01°
Converter-tracker thickness	~ 1X_0
Calorimeter thickness	~ 25 X_0
Proton rejection factor	~ 10^6
Telemetry downlink volume, GB/day	100
Total mass, kg	2,600
Maximum dimensions, m	2.0 x 2.0 x 3.0
Power consumption, W	2,000

Alexander Moiseev Cosmic Frontier Workshop SLAC March 6-8 2013

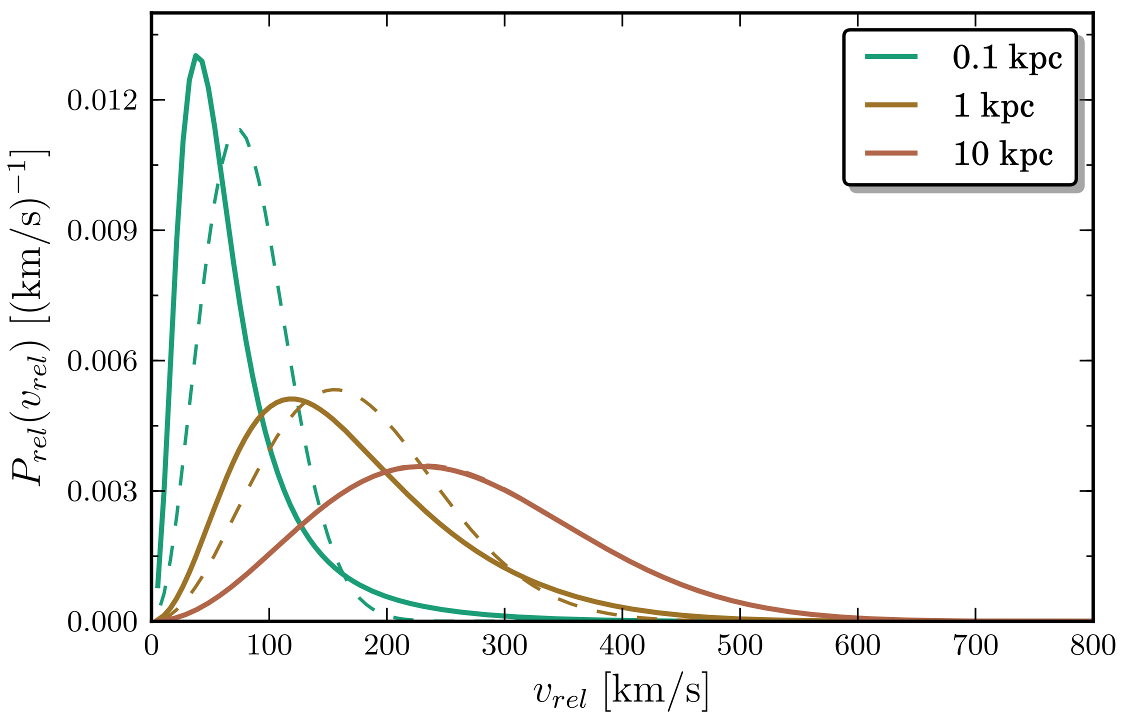
5

- Gamma-400 may provide important capability for high angular resolution, or energy resolution measurements

Velocity Distribution



Kuhlen et al. (2010)

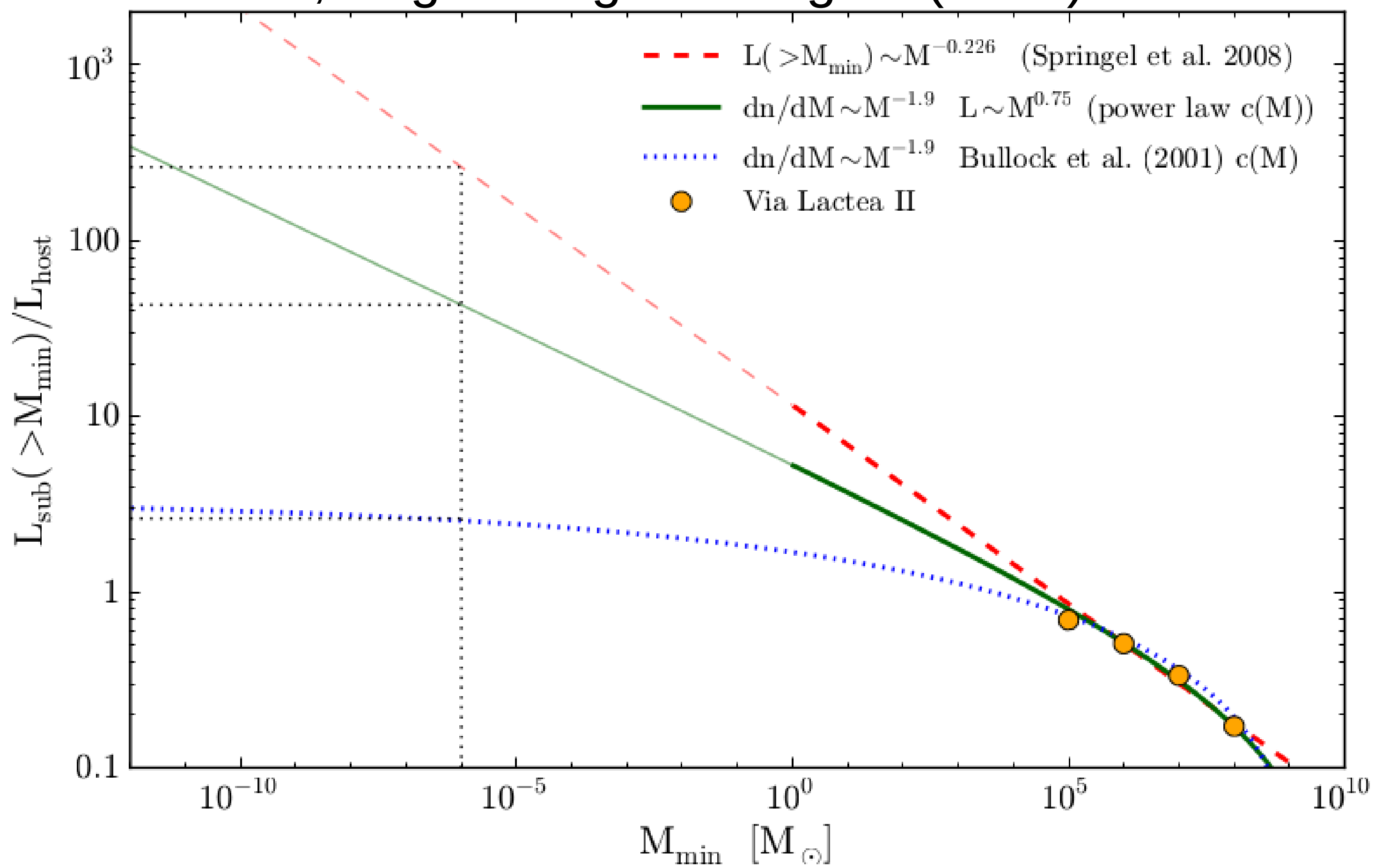


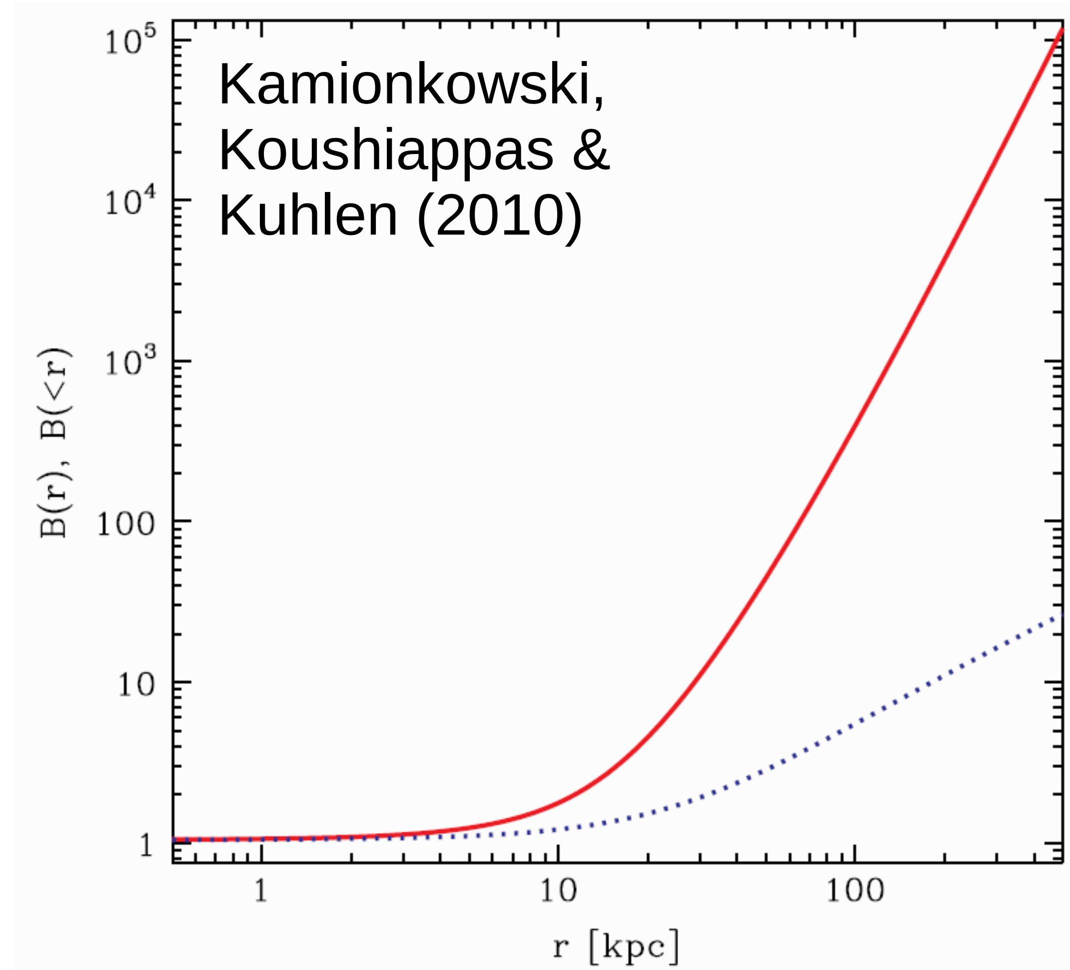
FF, D. Hunter 13

- Local velocity distribution important for Direct Detection, but velocity distribution in halo center can be important for ID with velocity dependent <σv>
- Talks on N-body and theoretical progress in determining distribution - important for >2 TeV observations to GC or Leptophillic DM.

N-Body Simulations

Kuhlen, Vogelsberger & Angulo (2012)

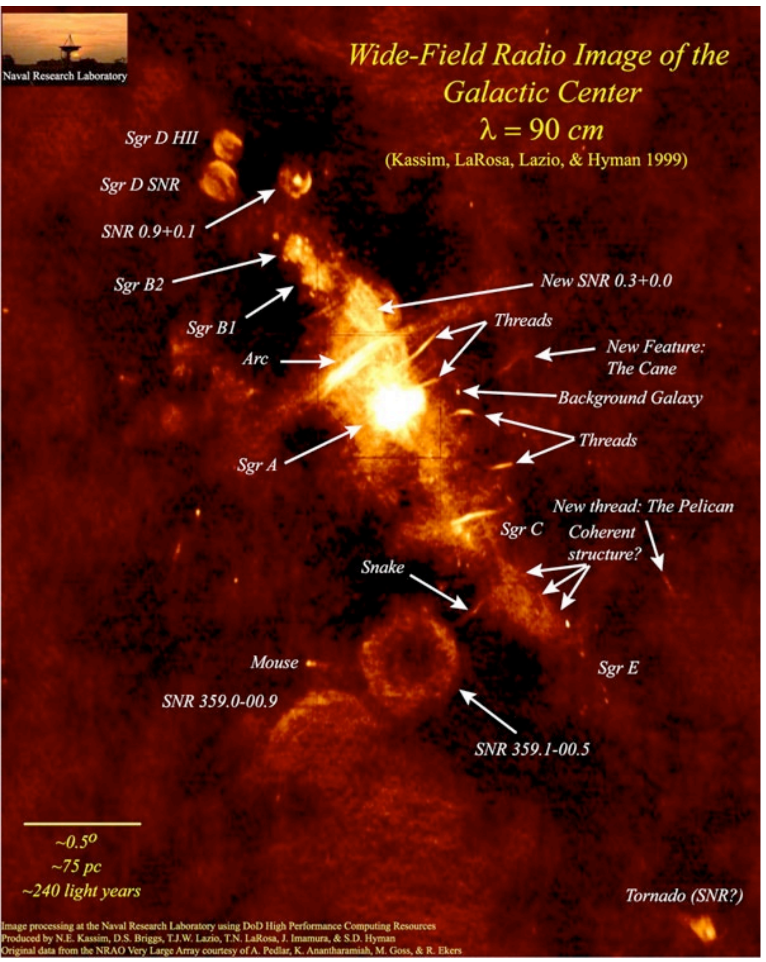




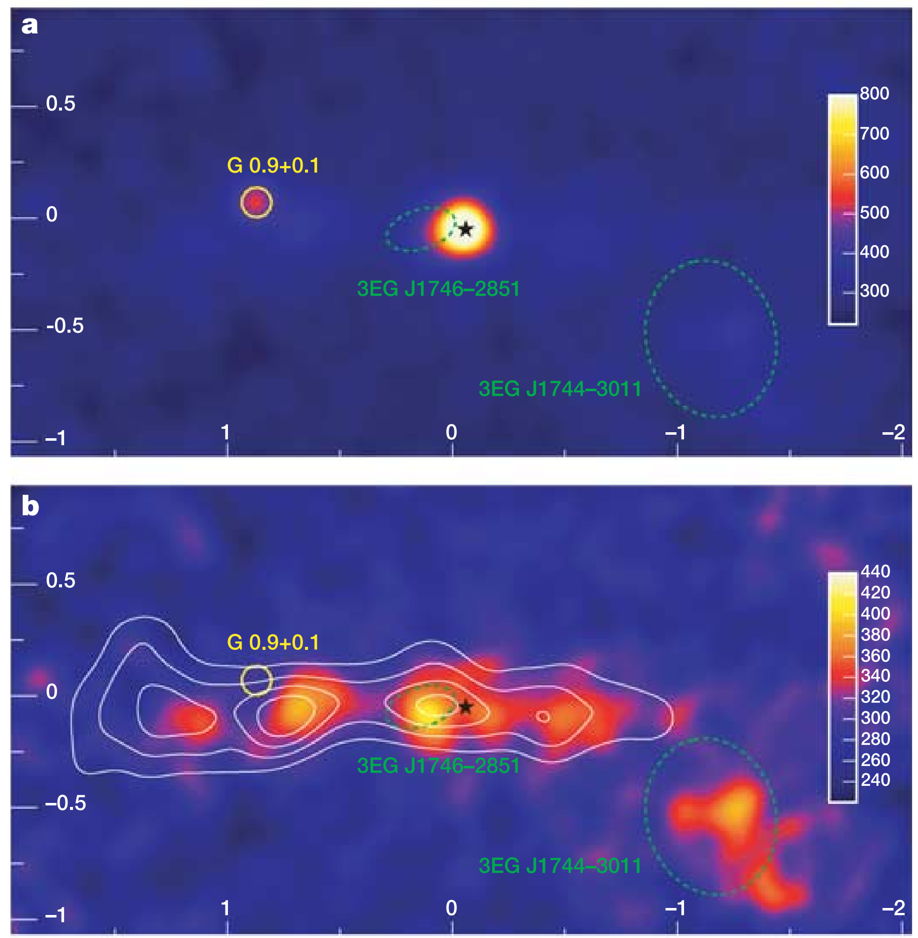
- Since signal is ~ρ^2, substructure of halos could give large boosts in signal. While this is likely to be a factor for Galaxy clusters, probably not a big factor in inner galaxy (but extrapolating mass function and roll of Baryons are tricky)

Galactic Center Region

Radio (90 cm)

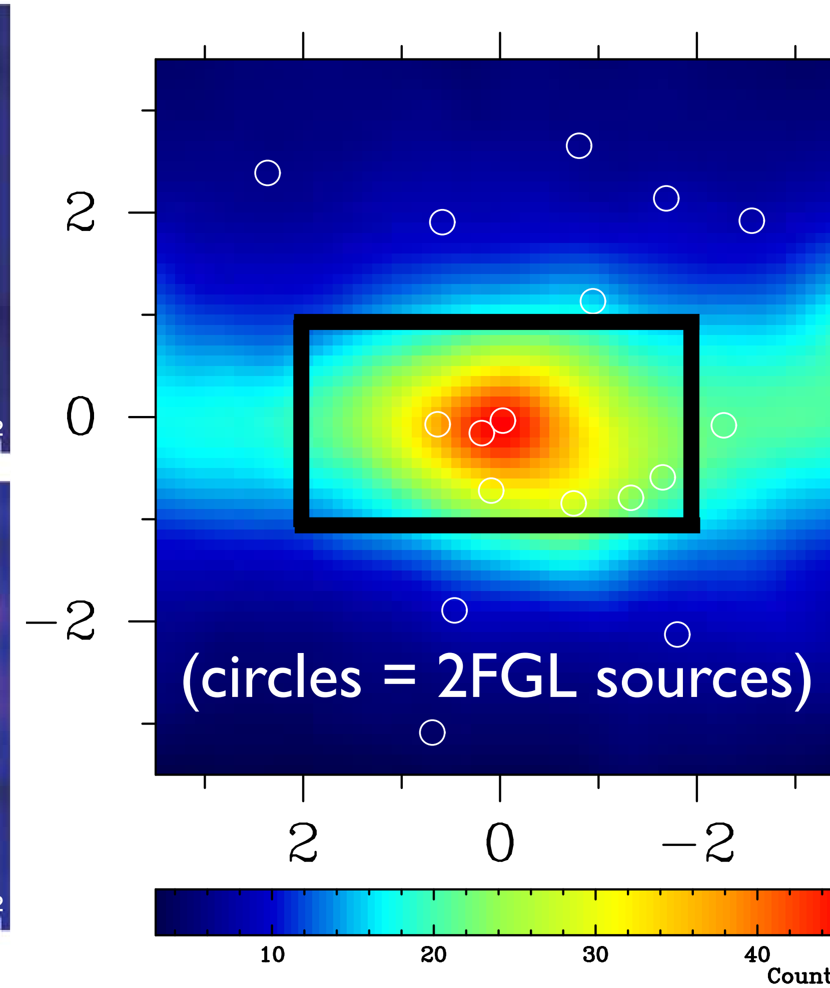


HESS Gamma-Ray (~1 TeV)



Aharonian et al. 2006

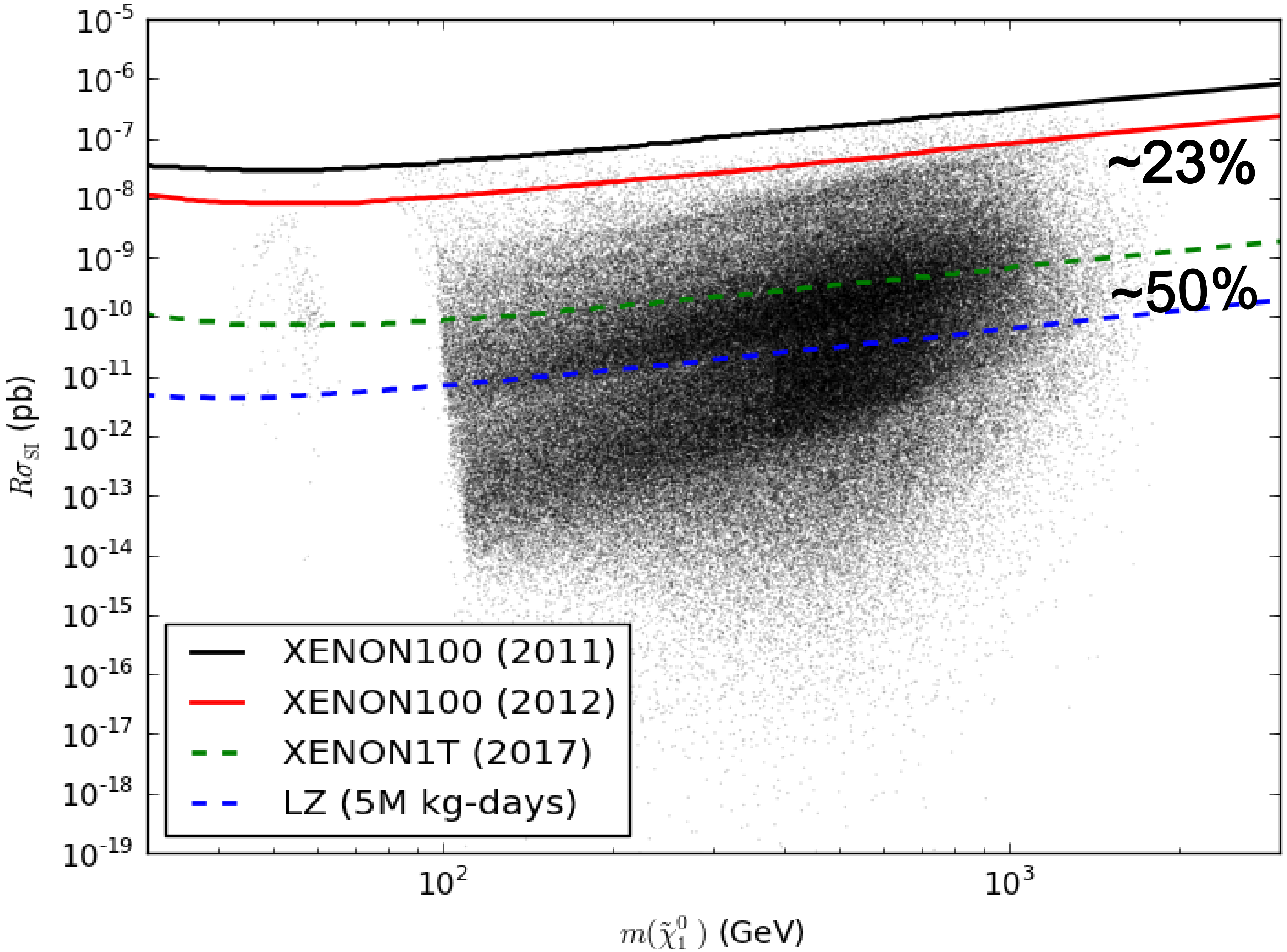
Fermi Gamma-Ray (~1 GeV)



Abazajian & Kaplinghat 2012

- Talks by J. Siegal-Gaiskins and T. Linden on GC region

Direct Detection bounds

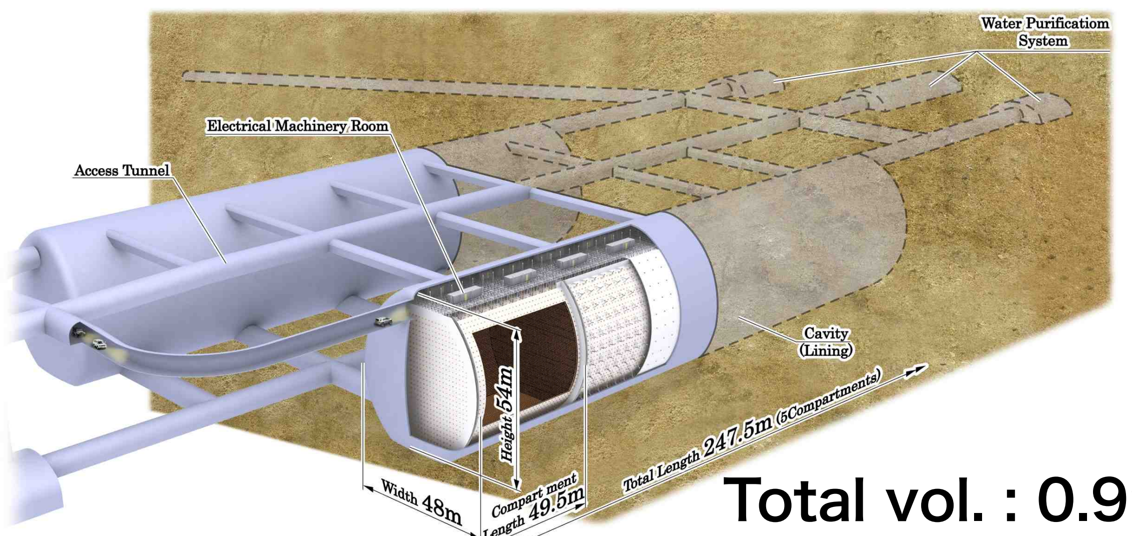


Electron Experiments

Experiment	Detectors	E Range (GeV)	Exposure ($\mathrm{m^2 sr\, s}$)	Calorimeter Material	Depth	Layers	Magnet Spectrometer B_{ave}	σ_x	length
PPB-BETs	EC	10-800	$\sim 4 \times 10^4$	Pb/SF?	9 X_0	36	N/A		
ATIC	EC	10-100,000	$\sim 3 \times 10^5$	BGO	18 X_0		N/A		
HESS	EC	6-8000 300-800	$\sim 8 \times 10^7$ $\sim 2 \times 10^7$	Air	27 X_0	∞	N/A		
Fermi LAT	EC	20-1000	$\sim 3\times10^7$ (181 days)	CsI(Tl)	8.6 X_0		Earth's Field		
PAMELA	EC, MS	50-300 (e^+) 10-700 (e^-)	$\sim 1.5 \times 10^5$ (850 days) $\sim 2.1 \times 10^5$ (1200 days)	W/Si	16 X_0	22	0.4 T	~ 7 μm	40.5 cm/ 6 layers
HEAT	EC, MS, TRD	5-50	$\sim 1.3 \times 10^3$	Pb/PS	9 X_0	10	1 T	70 μm	61 cm/18 layers
Future Experiments									
AMS	EC, MS, TRD, RICH		$\sim 4.5\times10^7$ (5 yr)	Pb/SF		18	0.125 T	10 μm	/8 layers
CALET	EC	10-10,000	$\sim 2 \times 10^7$ (5 yr)	$PbWO_4$	27 X_0		N/A		
VERITAS	EC,MS	100-10,000	$\sim 10^7$	Air	27 X_0	∞	Moon Shadow		

Hyper-Kamiokande

Hyper-Kamiokande



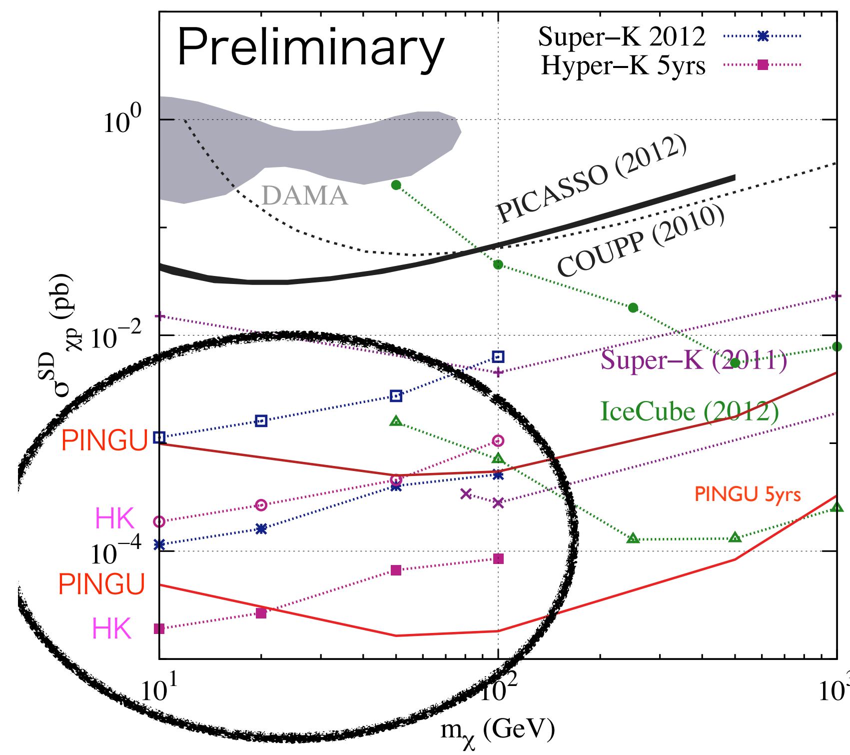
LoI : arXiv 1109.3262

Total vol. : 0.99 Mton

Fiducial vol. : 0.56 Mton

Photo-sensors : 99,000 PM

25 times larger than Super-K



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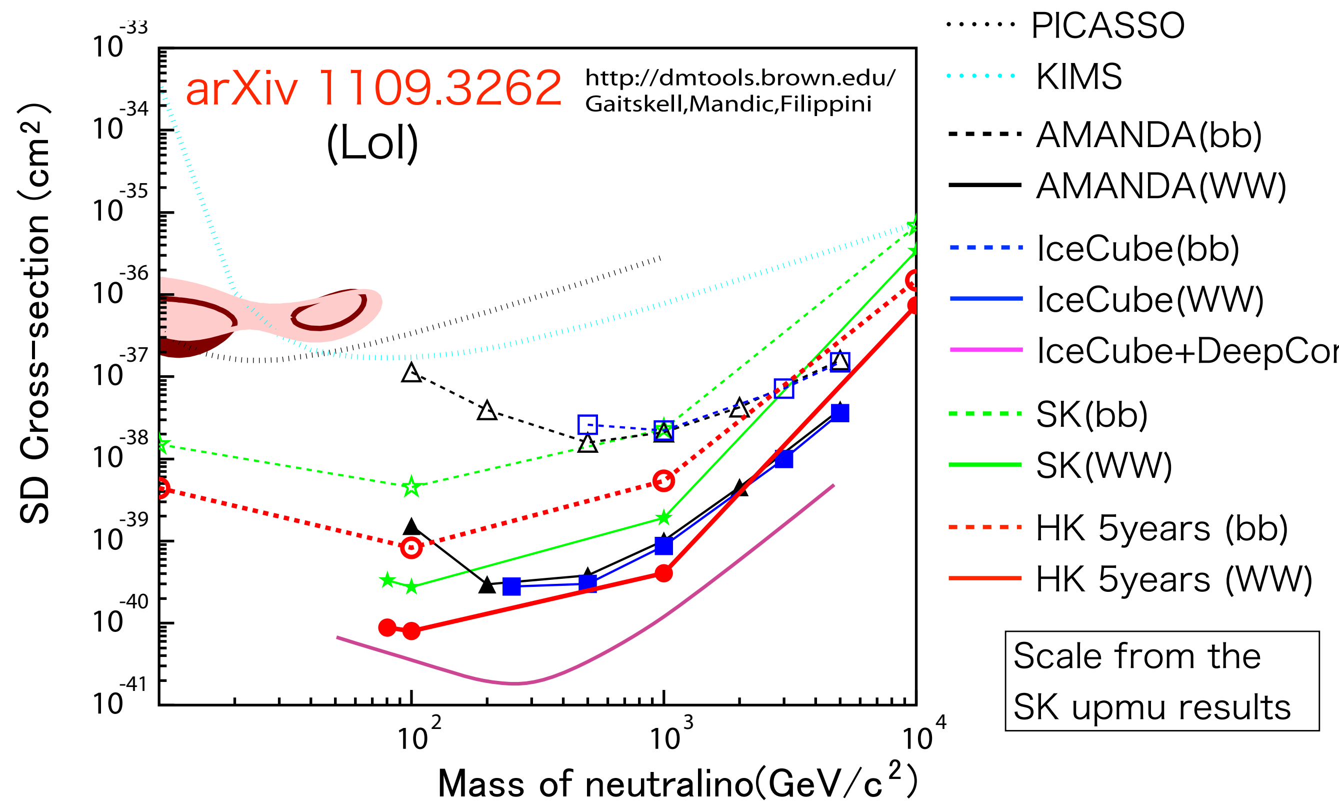
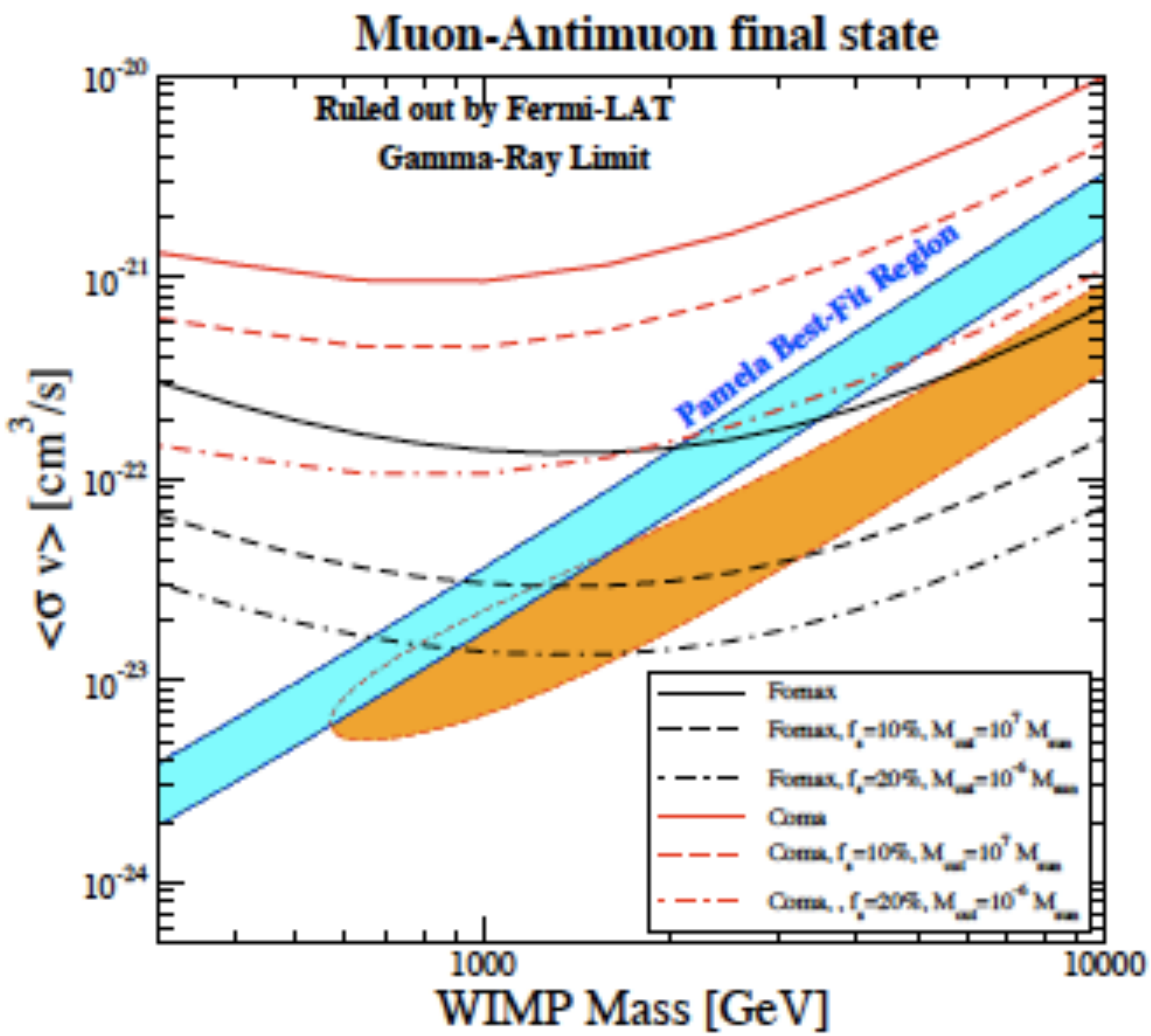


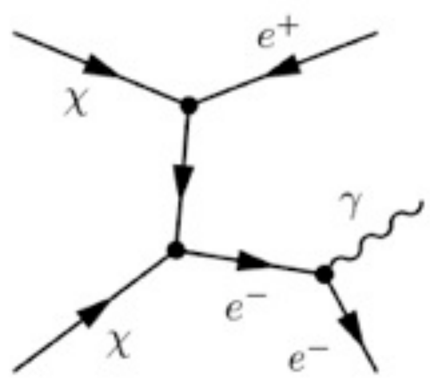


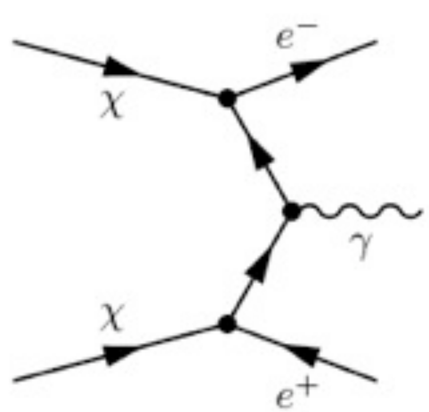
Muon-Antimuon final state
Ruled out by Fermi-LAT
Gamma-Ray Limit
Pamela Best-Fit Region
10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^{-24}
<σ v> [cm^3/s]
1000
10000
WIMP Mass [GeV]
Fornax
Fornax, f_s=10%, M=10^7 M
Fornax, f_s=20%, M=10^{-6} M
Coma
Coma, f_s=10%, M=10^7 M
Coma, , f_s=20%, M=10^{-6} M

Boosting Electrons

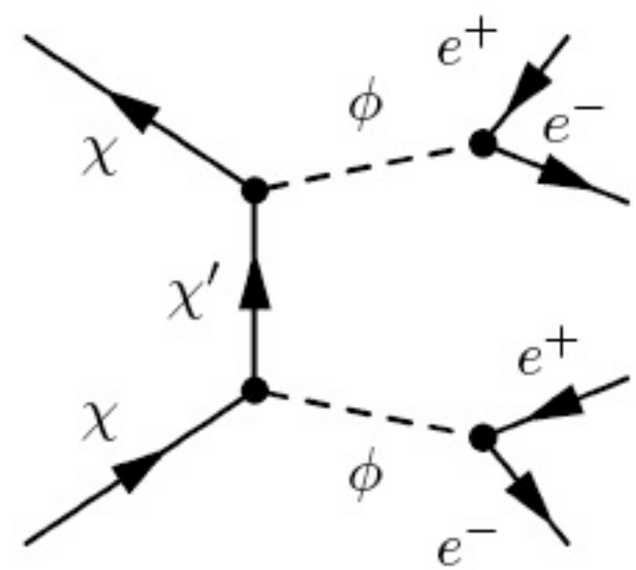
Annihilation into light leptons is helicity suppressed with respect to annihilation into heavier fermions

$$R \sim \underbrace{\left(\frac{m_e}{m_f}\right)}_{\text{spin flip penalty}} \underbrace{\left(\frac{m_\chi^2 - m_e^2}{m_\chi^2 - m_f^2}\right)^2}_{\text{phase space}}$$





New scalar fields with appropriate mass can allow electron-production, but make hadronic production kinematically forbidden. Sommerfeld enhancement by exchange of ϕ can result in a further boost in cross section



Internal bremmstrahlung can circumvent helicity suppression, but electromagnetic IB gives gamma-rays near kinematic maximum and $W^\pm, Z$ bremmstrahlung can overproduce antiprotons

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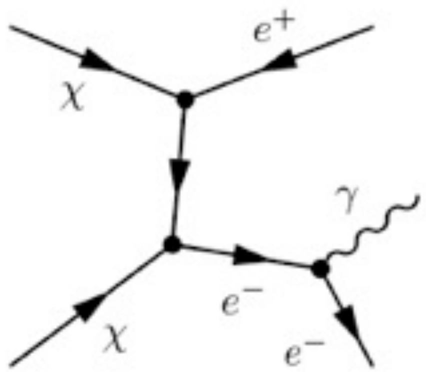

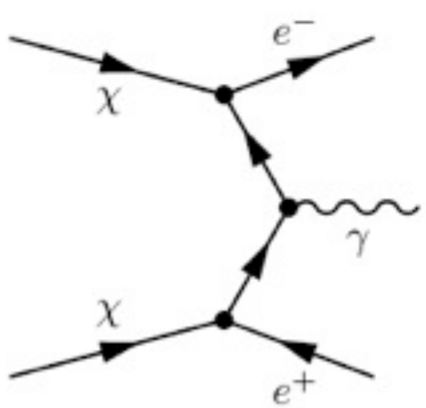

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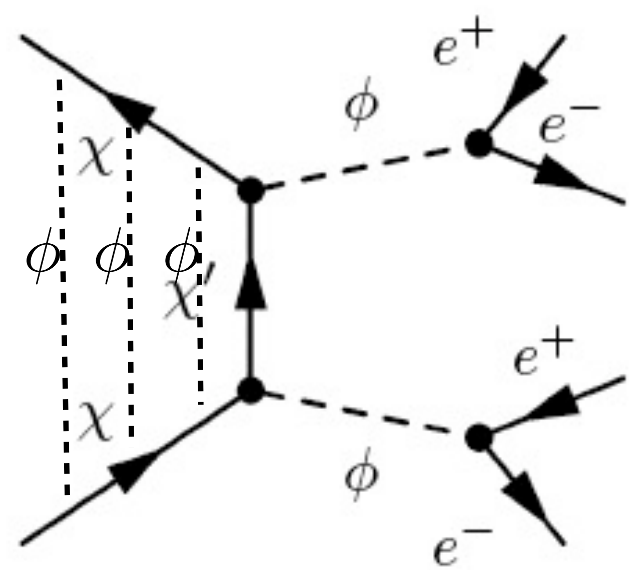

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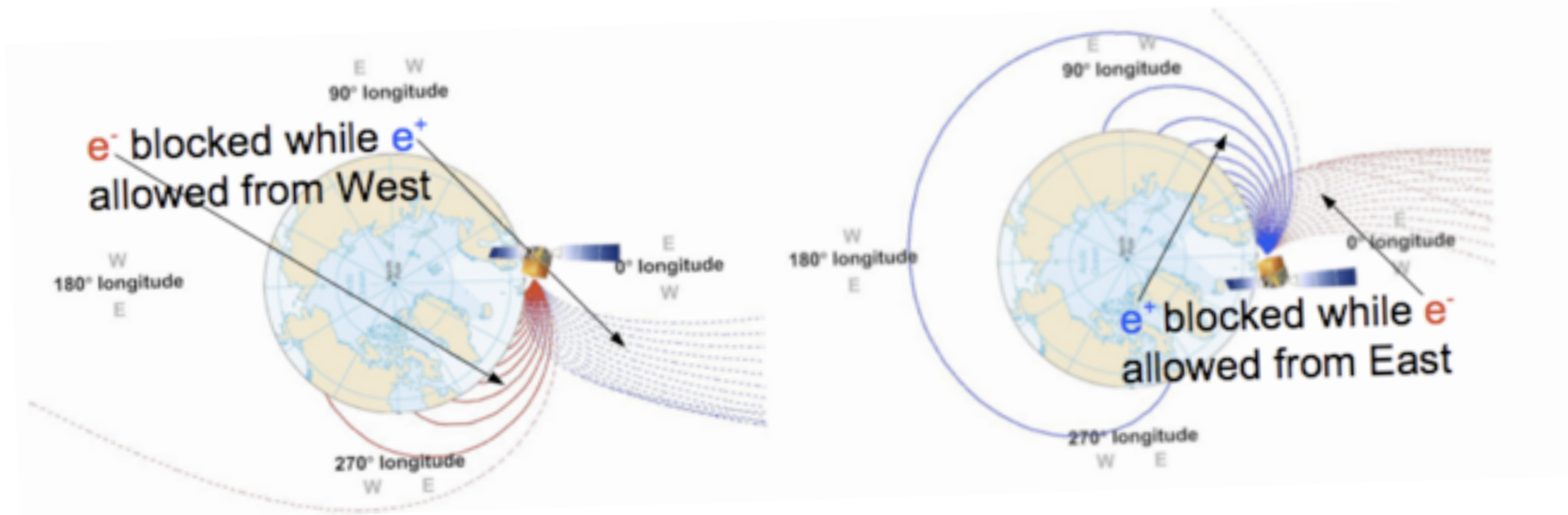
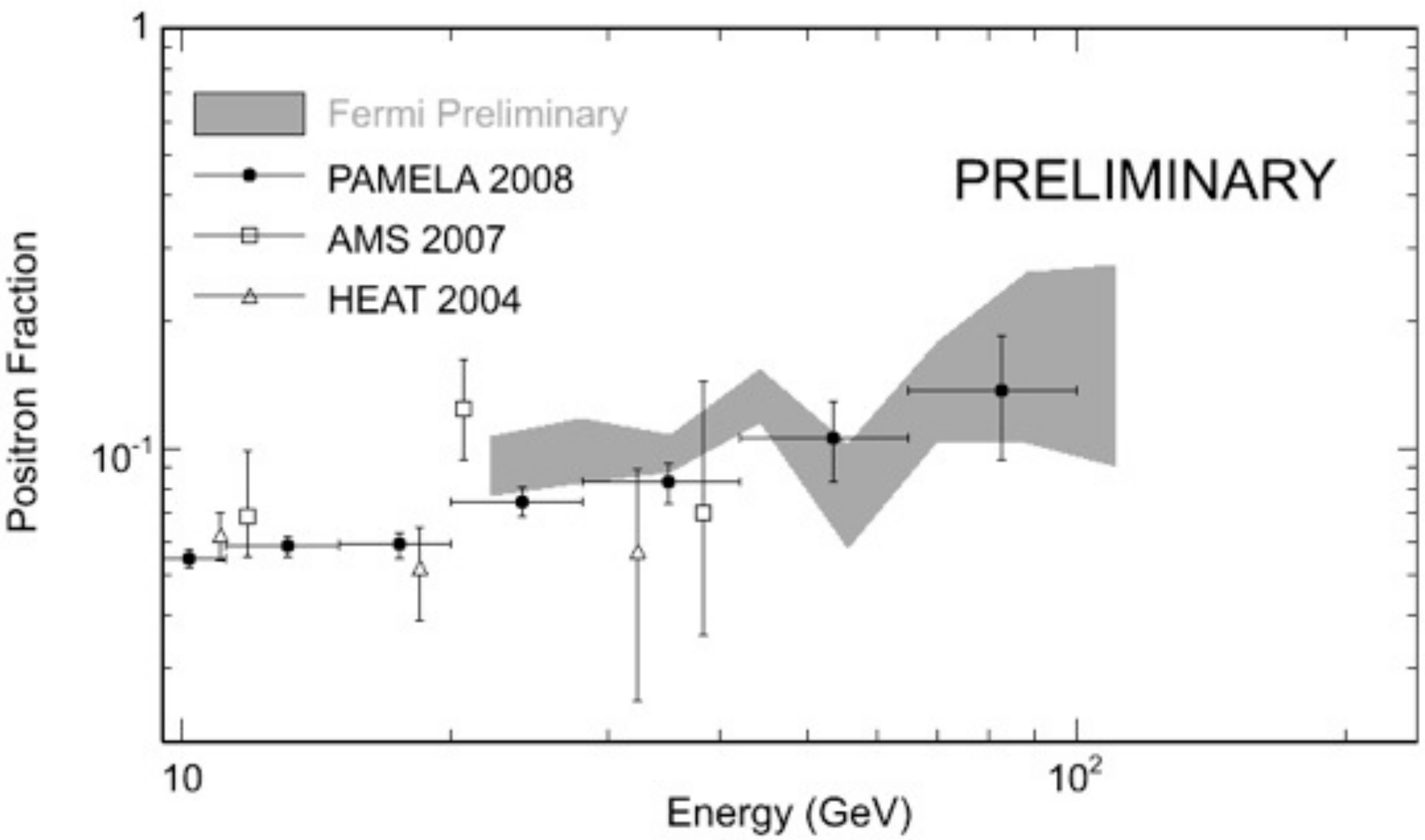
Fermi Positron Fraction





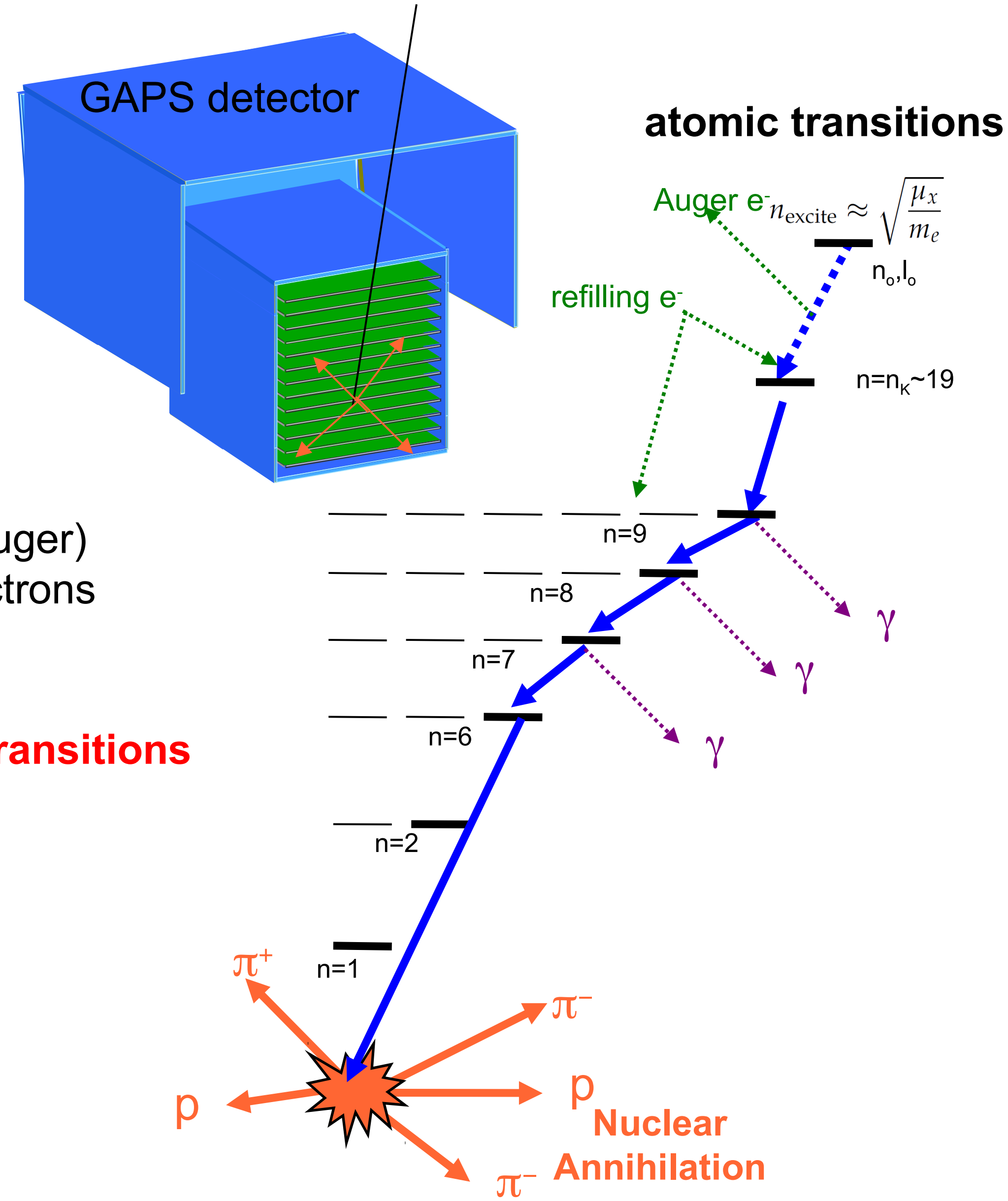
Mitthumsiri, W. et al., Fermi Symposium, May 2011

- Muller and Tang proc. 19th ICRC, 2, 378 (1985) used Earth's magnetic field as a natural magnet spectrometer for first balloon measurements of positron fraction from 10-20 GeV (showing an excess that was not apparent in the more sensitive HEAT measurements)

- Recent preliminary result from Fermi agree with PAMELA positron spectrum

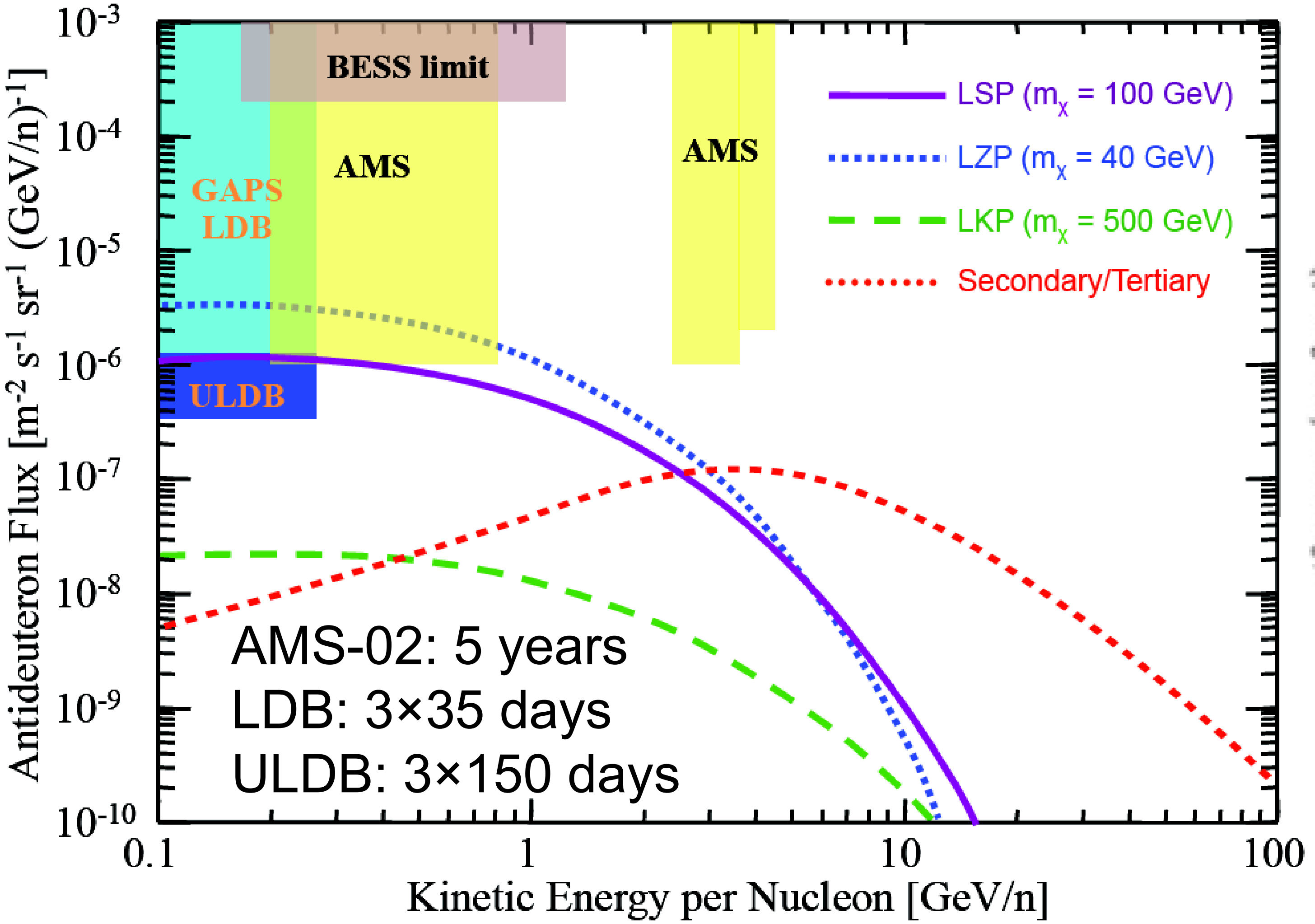
Novel approach for antideuteron identification

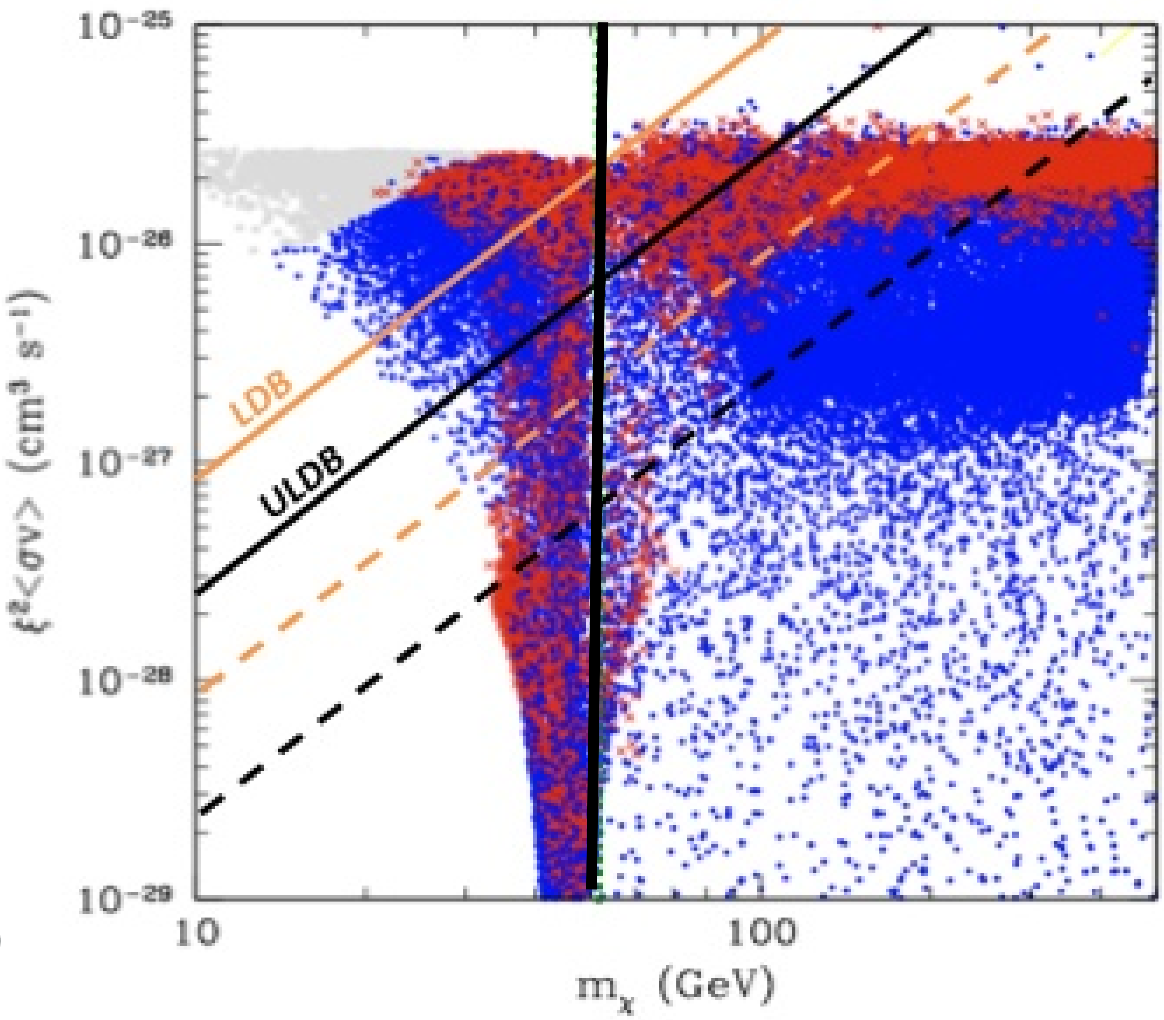
- antideuteron slows down and stops in material
- large chance for creation of an excited exotic atom ($E_{kin} \sim E_I$)
- deexcitation:
  - fast ionisation of bound electrons (Auger) → complete depletion of bound electrons
  - Hydrogen-like exotic atom (nucleus+antideuteron) deexcites via **characteristic X-ray transitions**
- nucleus-antideuteron annihilation: **pions and protons**
- exotic atomic physics understood (tested in KEK 2004/5 testbeam)

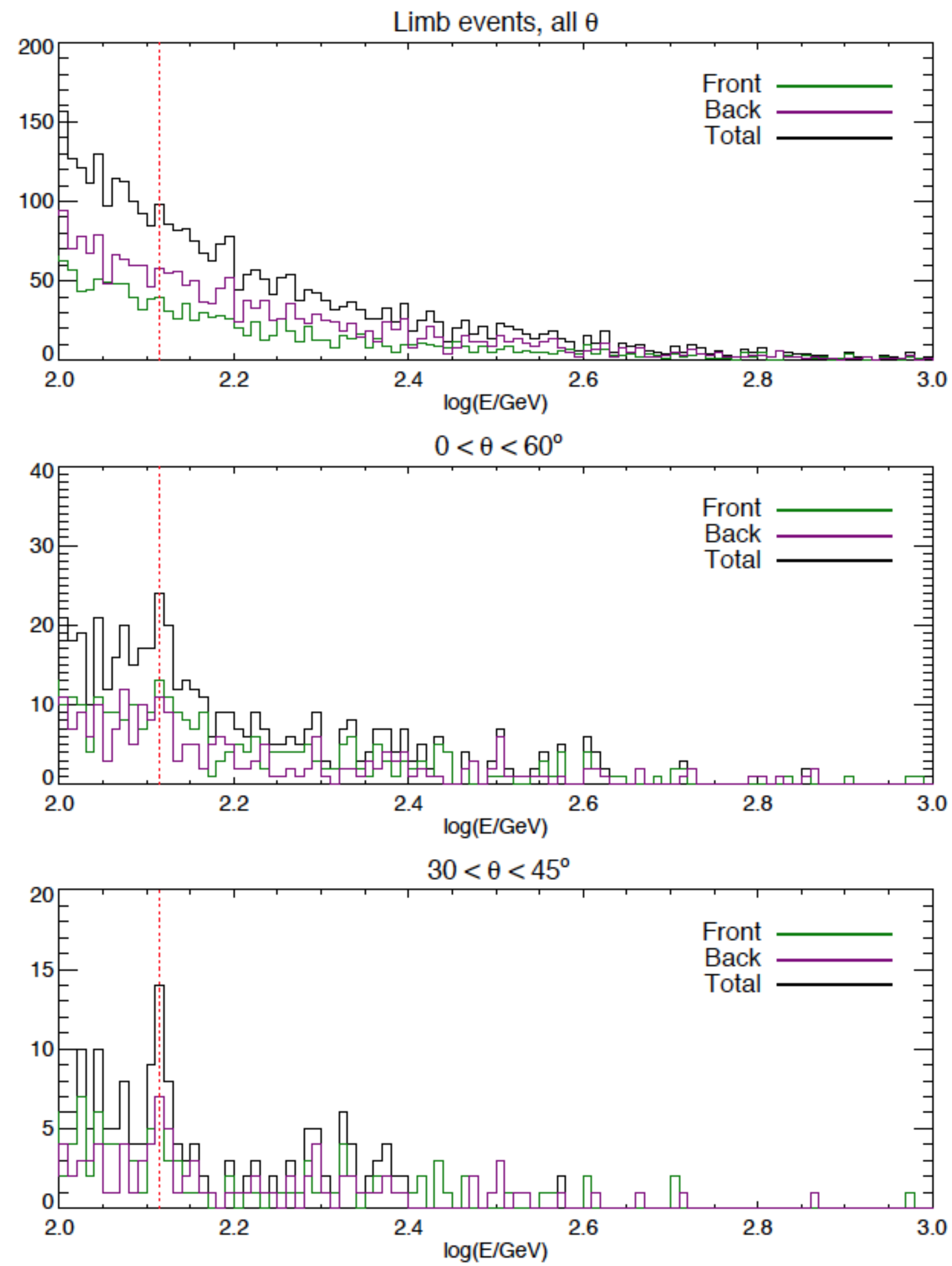


Ph. von Doetinchem GAPS March 13 - p6

GAPS

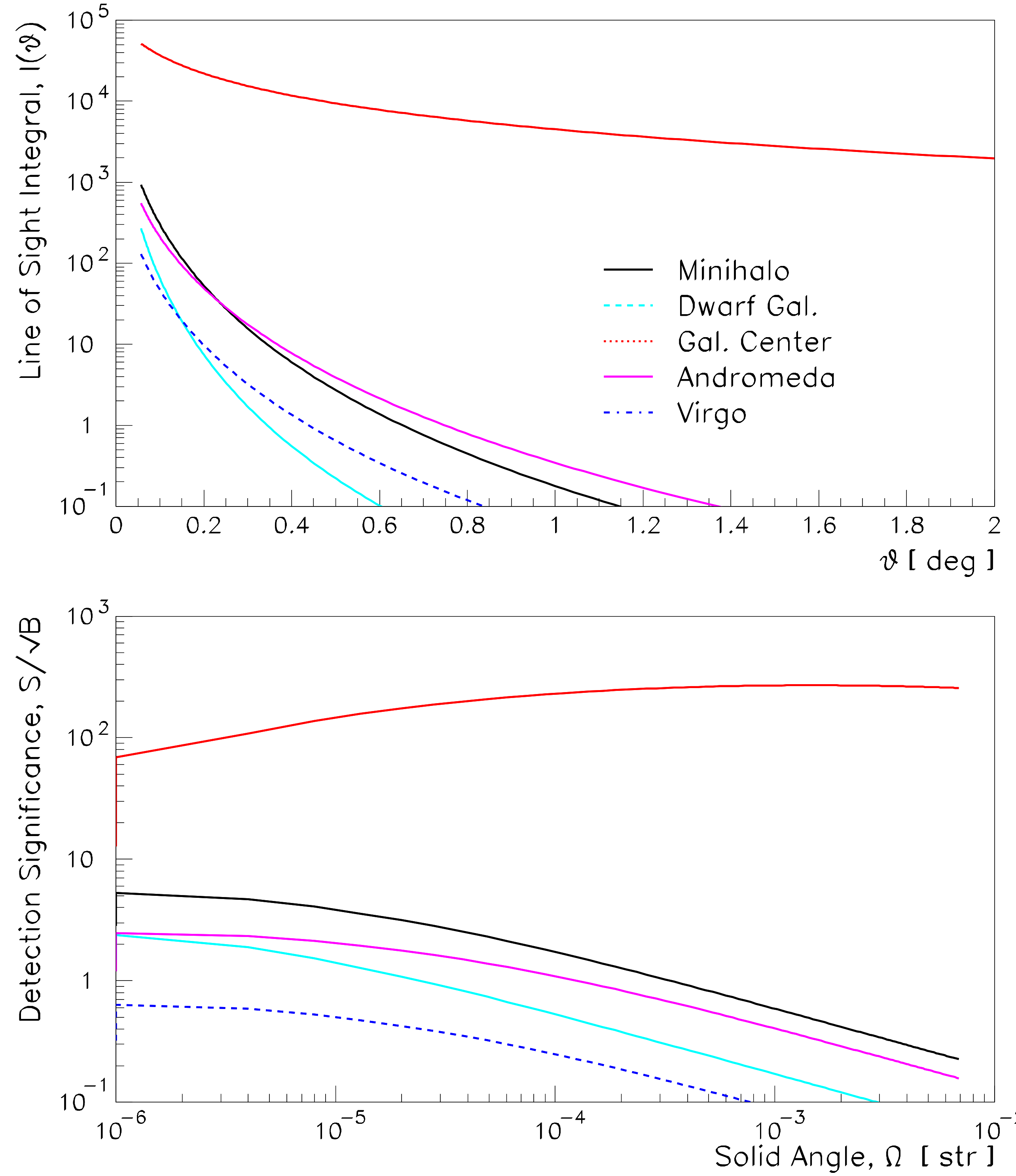

BESS limit
AMS
AMS
GAPS
LDB
ULDB
LSP (m_χ = 100 GeV)
LZP (m_χ = 40 GeV)
LKP (m_χ = 500 GeV)
Secondary/Tertiary
AMS-02: 5 years
LDB: 3×35 days
ULDB: 3×150 days
Antideuteron Flux [m^{-2} s^{-1} sr^{-1} $(GeV/n)^{-1}$]
Kinetic Energy per Nucleon [GeV/n]
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
0.1
1
10
100


LDB
ULDB
$\xi^2\langle\sigma v\rangle$ (cm^3 s^{-1})
m_χ (GeV)
10^{-25}
10^{-26}
10^{-27}
10^{-28}
10^{-29}
10
100

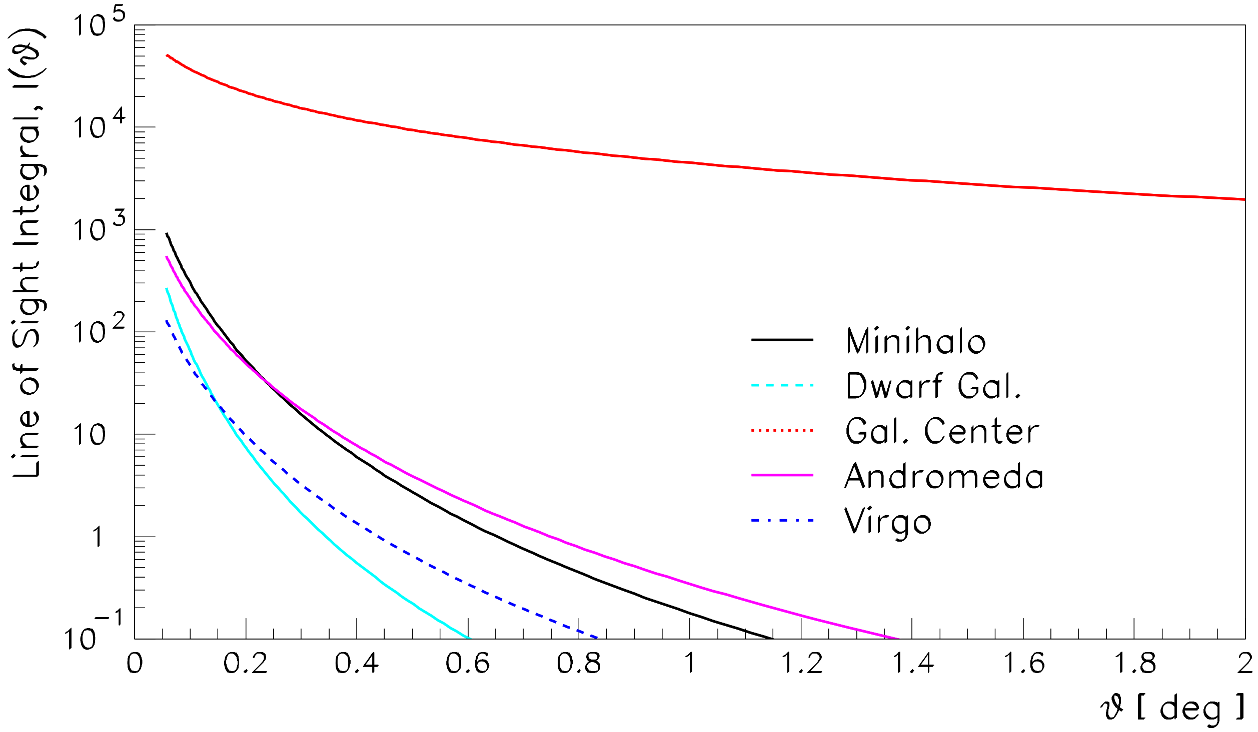


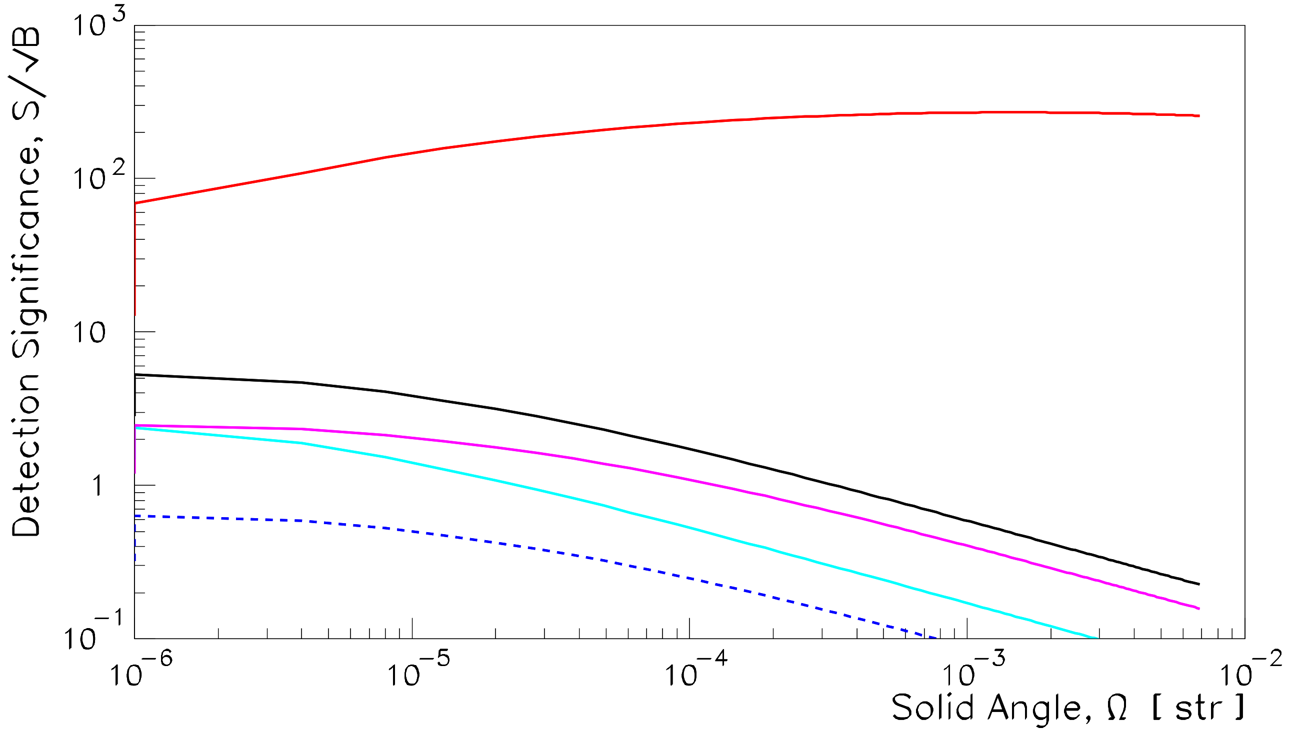
- Earth limb photons.

Where to Look?

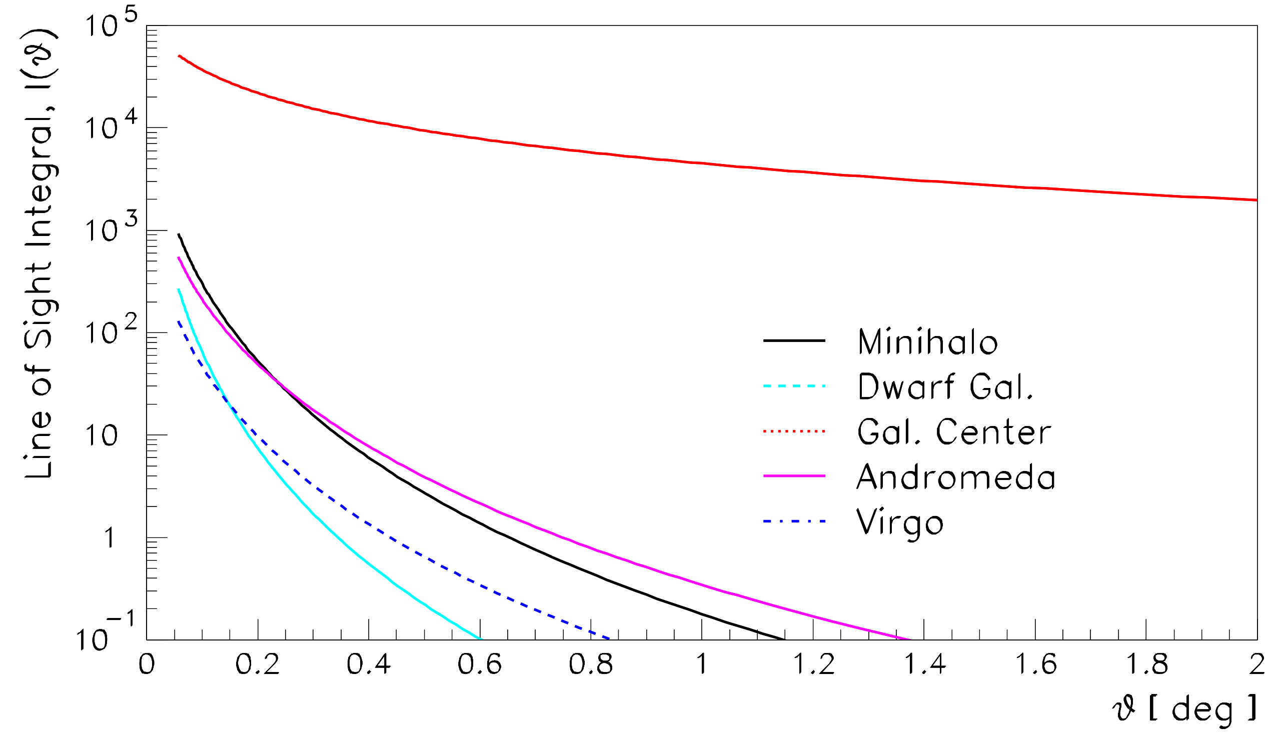


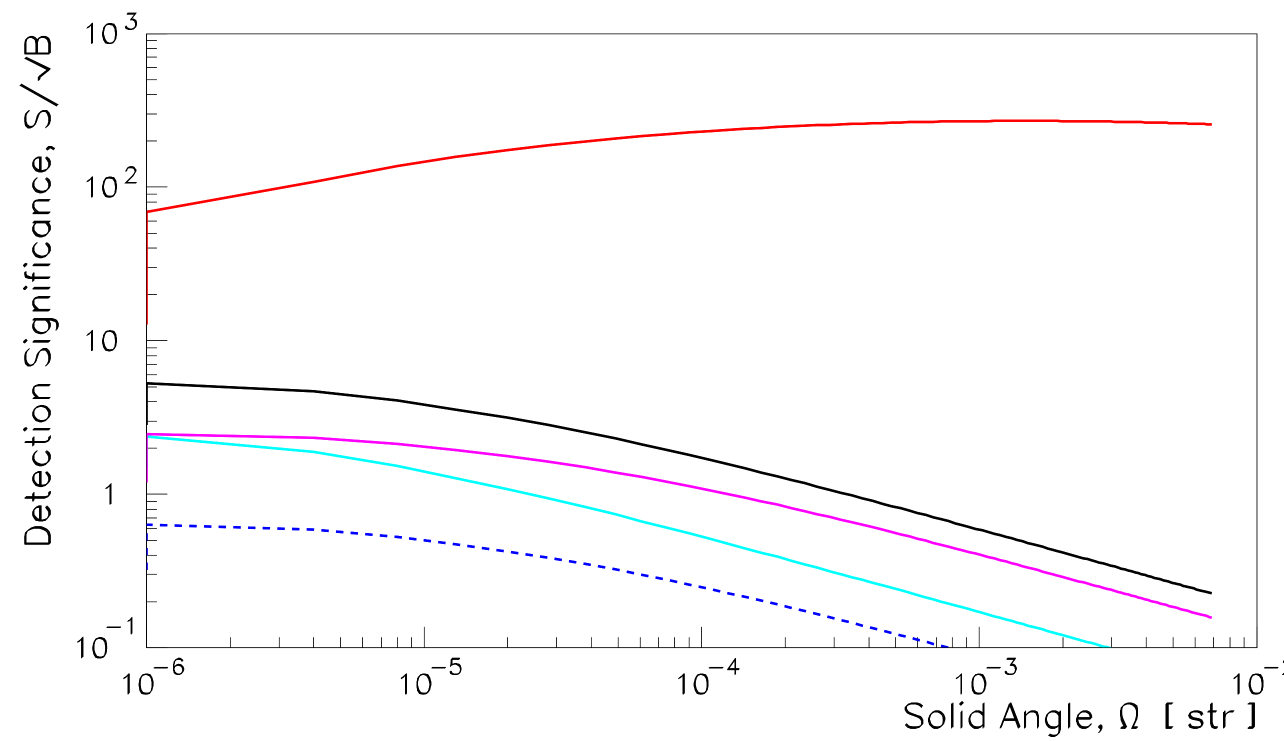
Where to Look?



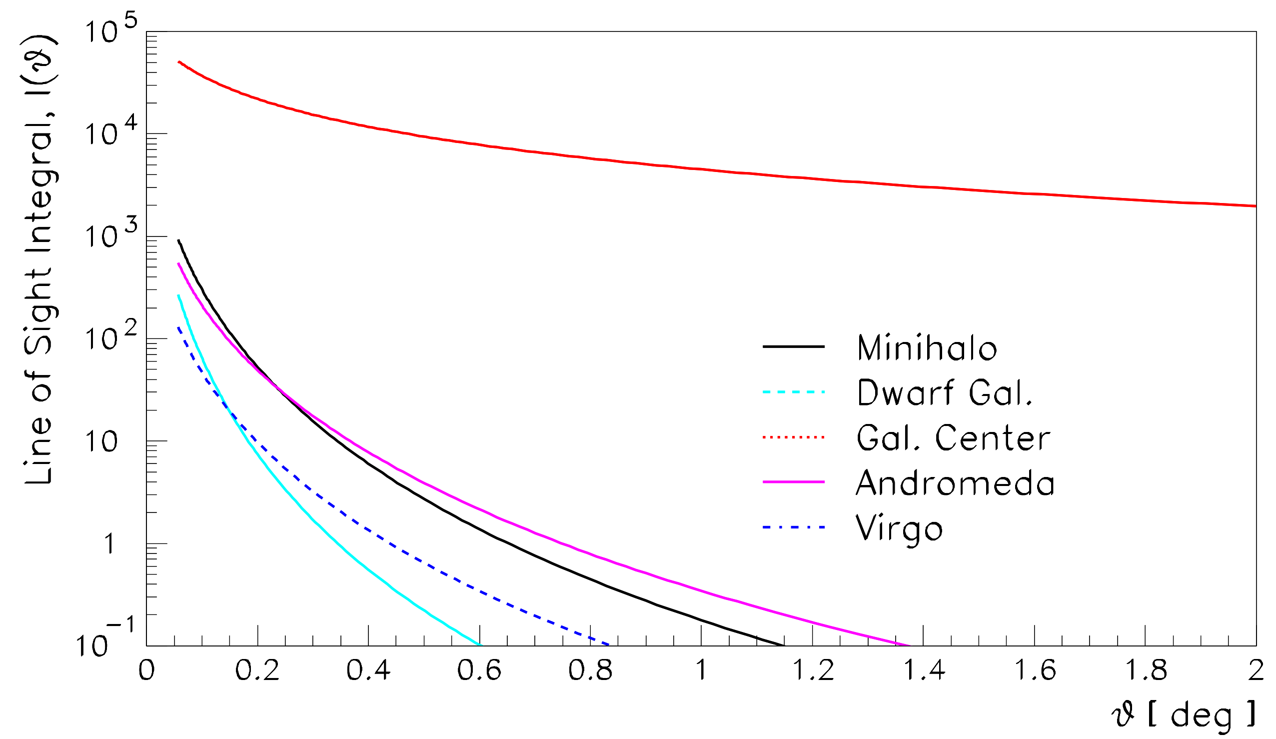


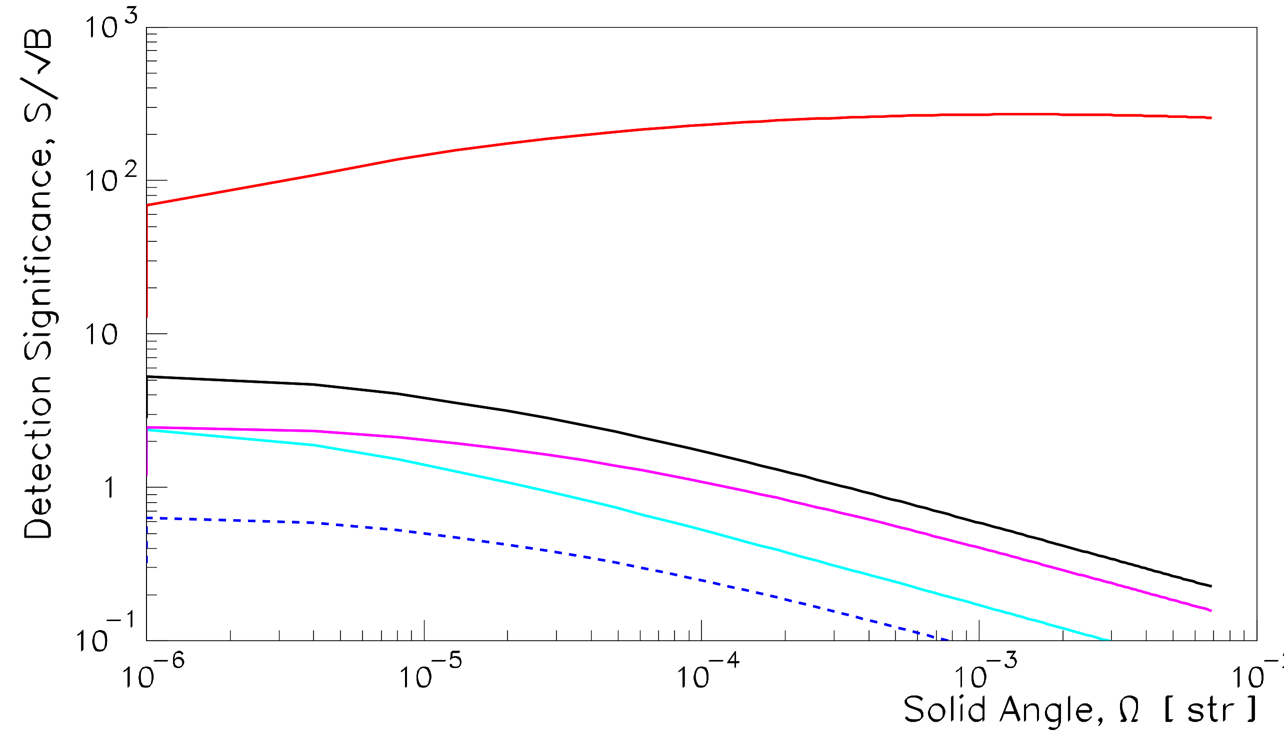
Where to Look?

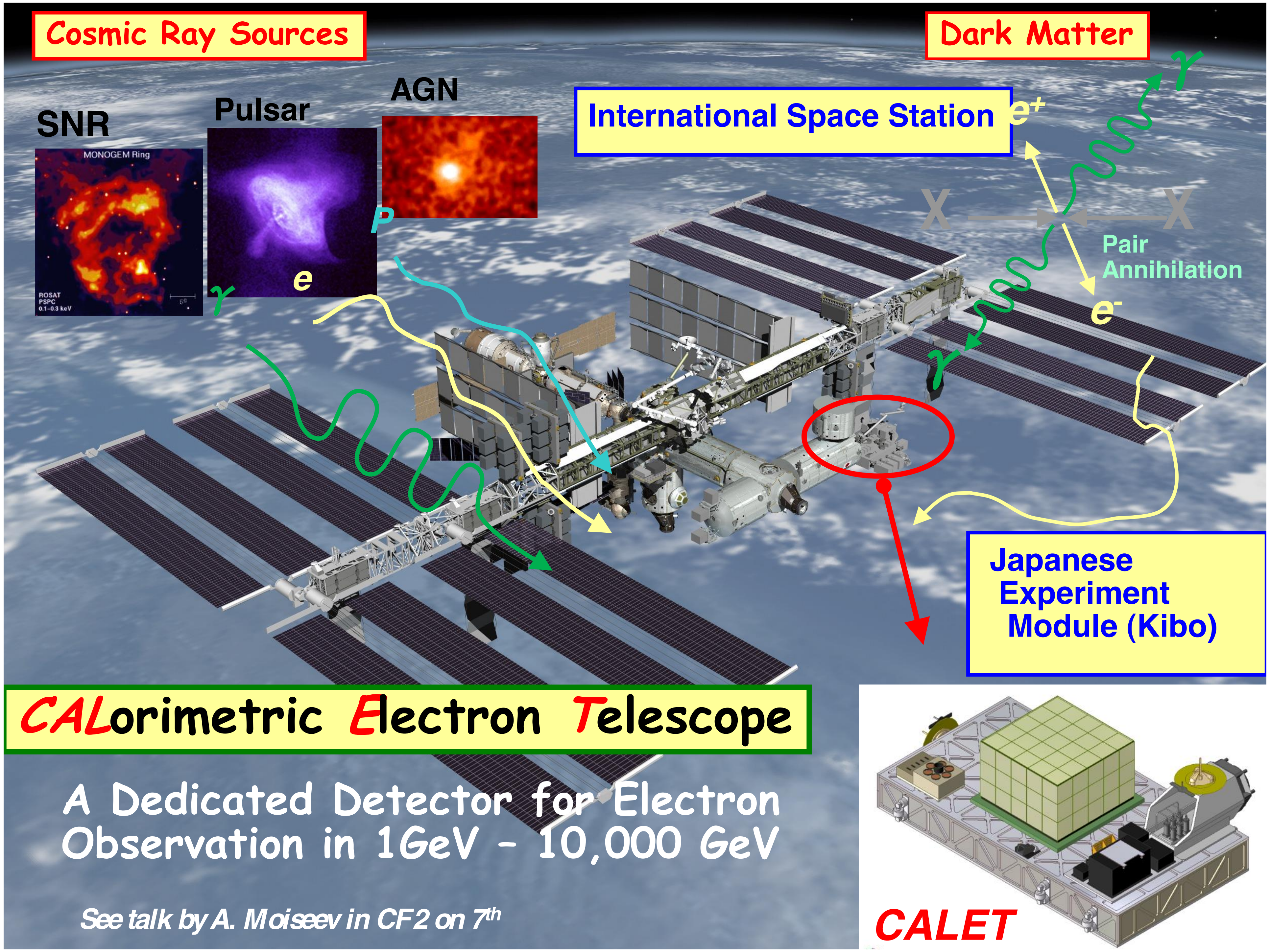




Where to Look?





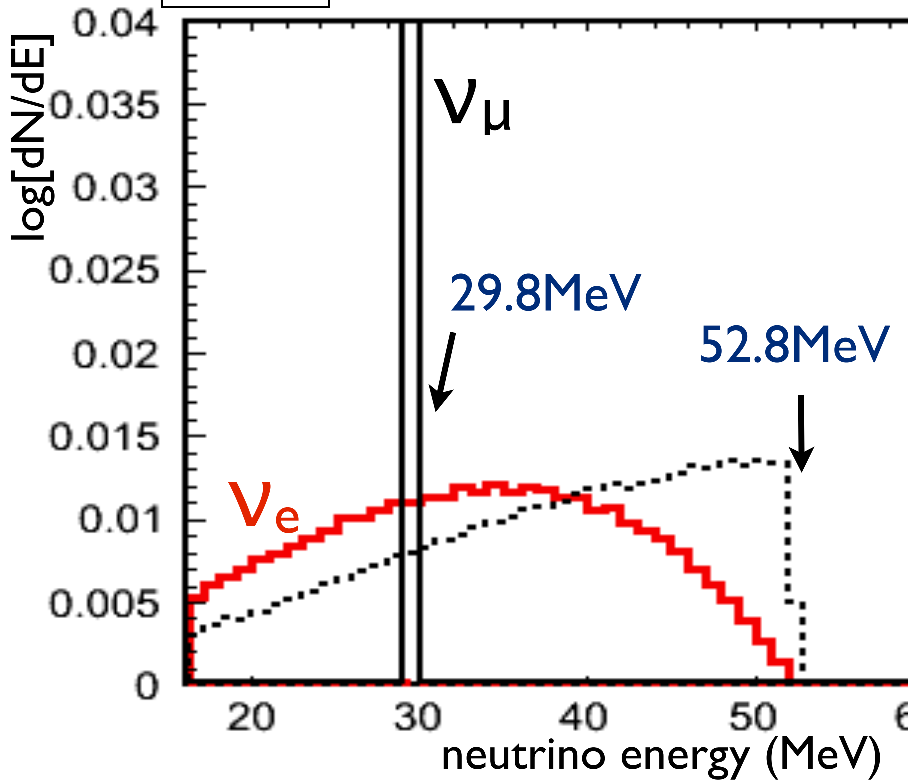

Cosmic Ray Sources
Dark Matter
SNR
Pulsar
AGN
MONOGEM Ring
ROSAT PSPC 0.1–0.3 keV
International Space Station
e+
γ
P
e
X
X
Pair Annihilation
e-
Japanese Experiment Module (Kibo)
CALorimetric Electron Telescope
A Dedicated Detector for Electron Observation in 1GeV – 10,000 GeV
See talk by A. Moiseev in CF2 on 7th
CALET

Charged pions at rest producing neutrinos up to E=52.8MeV

Decay At Rest

$$\pi^+ \longrightarrow \mu^+ \nu_\mu$$

$$\mu^+ \longrightarrow e^+ \nu_e \bar{\nu}_\mu$$

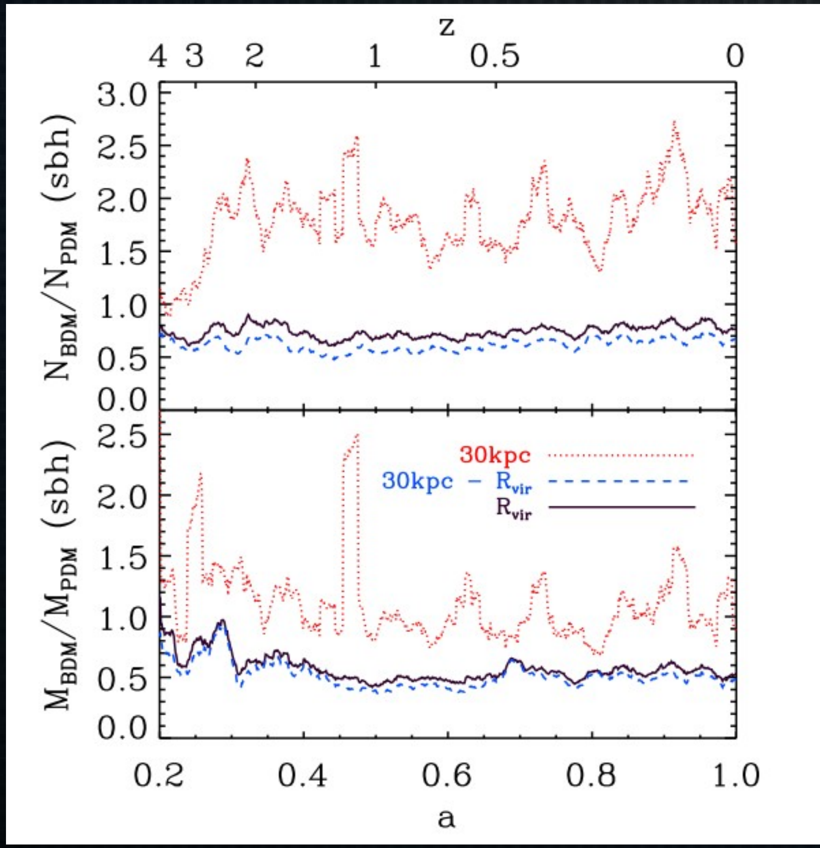


Beyond DM-only: including baryonic physics

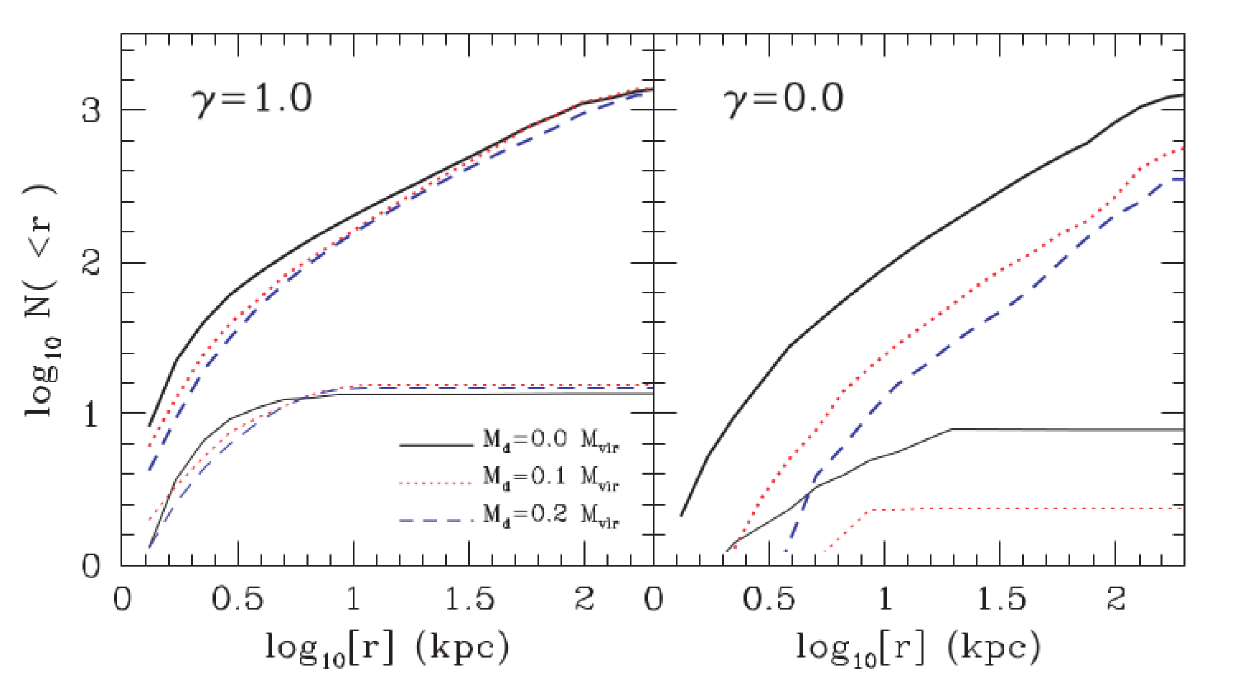
Often not even the sign of the effect is known...

Baryonic condensation in the centers of satellite halos makes them more resilient to tidal disruption and **increases abundance of inner subhalos**.

The deeper host halo potential, satellite cusp removal, and disk passages enhance tidal stripping and **reduce the number of surviving subhalos**.



Romano-Diaz et al. (2010)



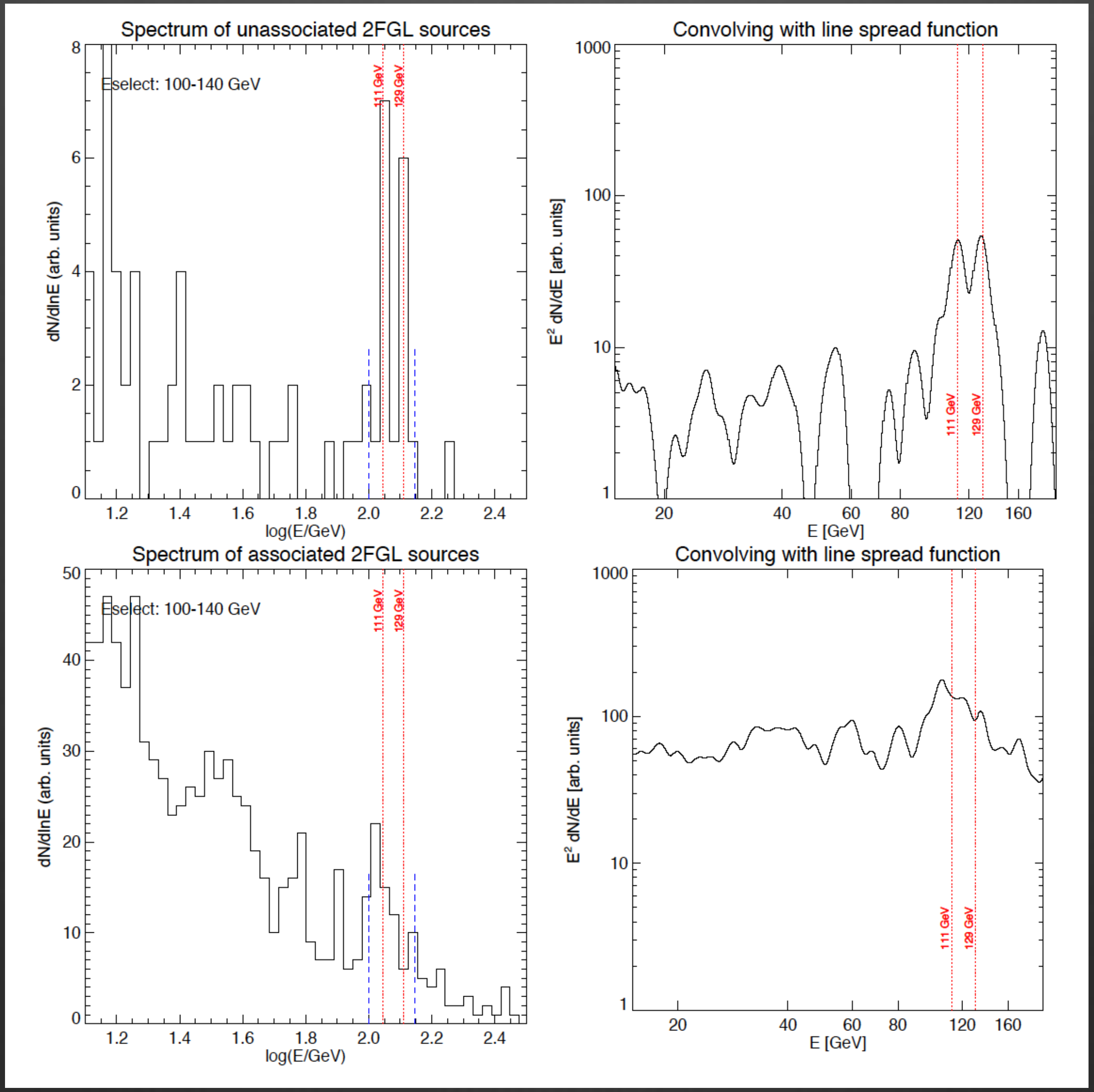
Peñarrubia et al. (2010)

Snowmass Process

- Contributed Papers from collaborations, groups and individuals
- 30 page CF summaries (due Summer 2013)
- 30 page CF summary (due by Minnesota meeting)
- 30 page Snowmass-wide Summary (written by Frontier conveners)

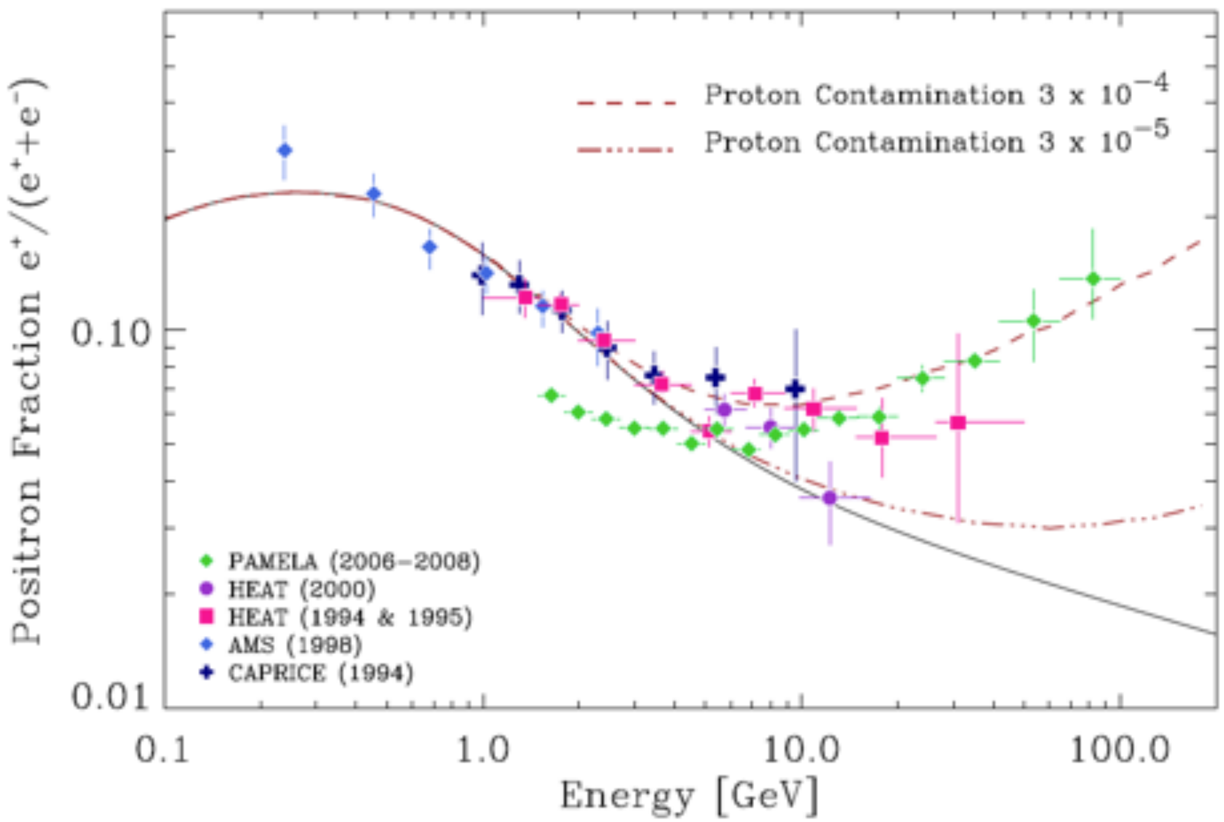
Fermi Lines

DOUBLE GAMMA-RAY LINES FROM UNASSOCIATED FERMI-LAT SOURCES



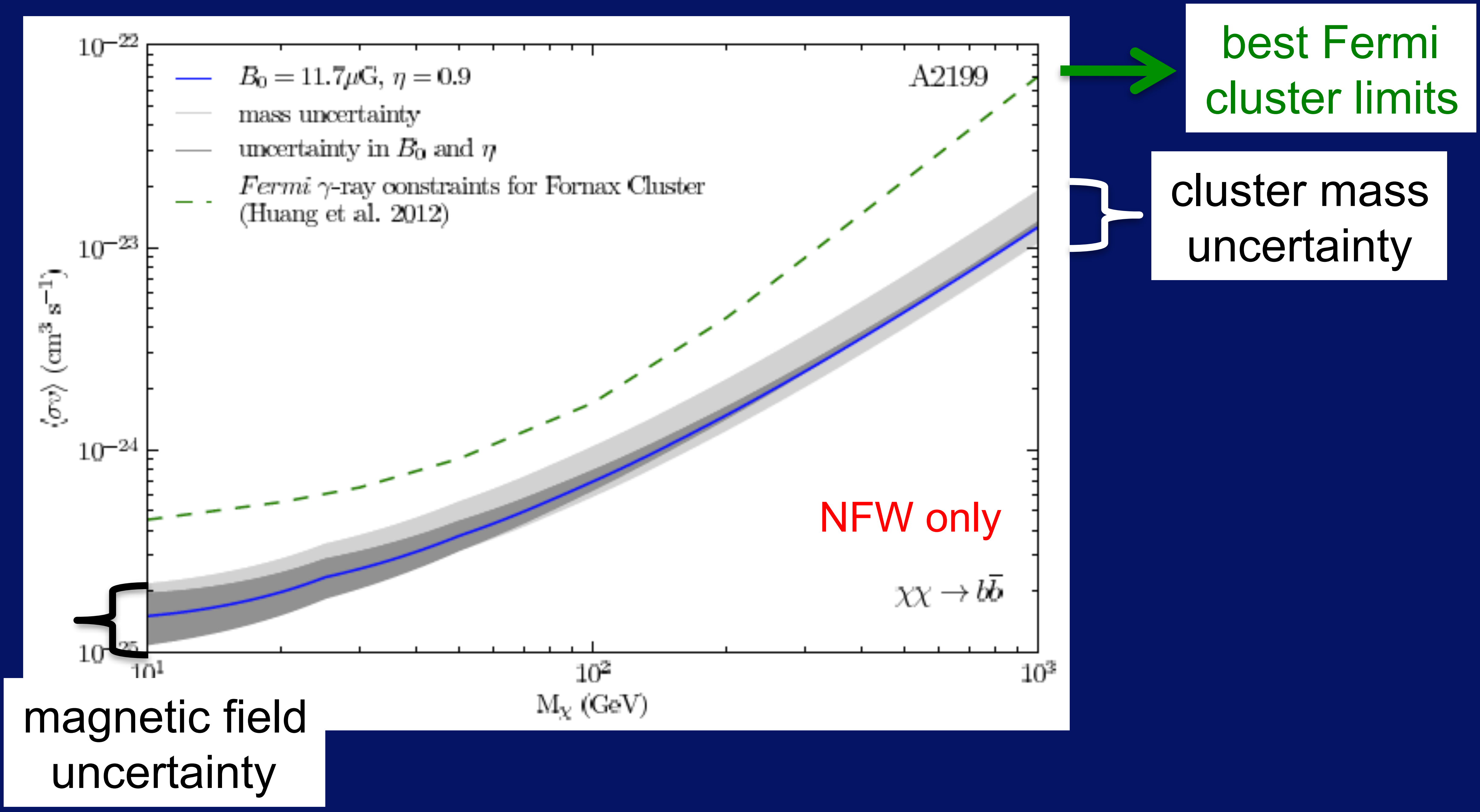
Su & Finkbeiner (arXiv:1207.7060)

Problems with Positrons



- Schubnell (2009; arXiv:0905.0444) points out that old measurements (pre 1990) showed rise in positron fraction - found to be a problem with instruments using small permanent magnets and limited particle ID.
- Intensity of CR protons exceeds that of positrons by a factor of 5×10^4 above 10 GeV.
- PAMELA, originally designed to include a TRD, suffers from lack of strong particle discrimination.
- EC power is limited by the irreduceable background from single pi^0 that mimic electromagnetic showers

Dark Matter Annihilation Limits

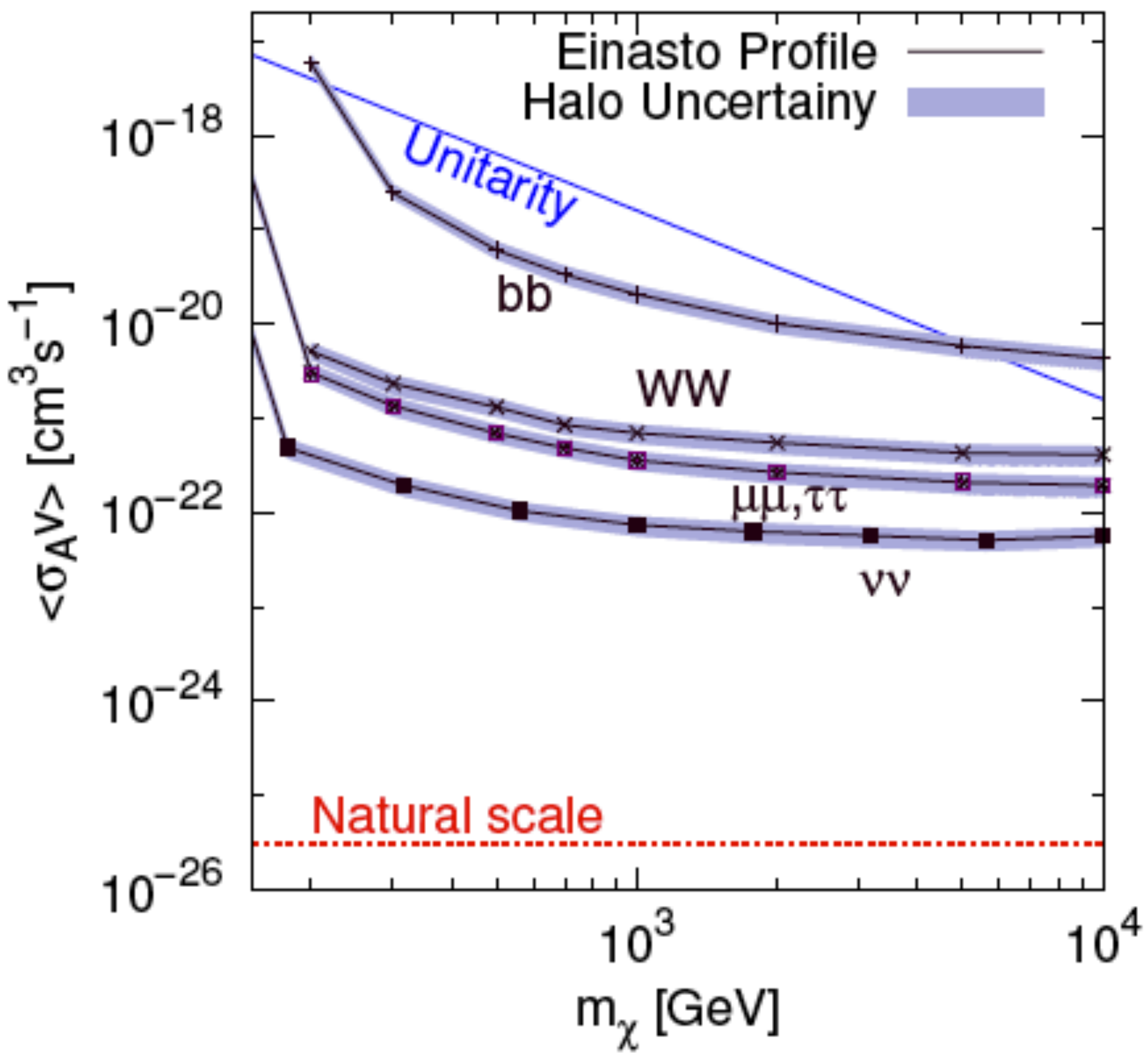


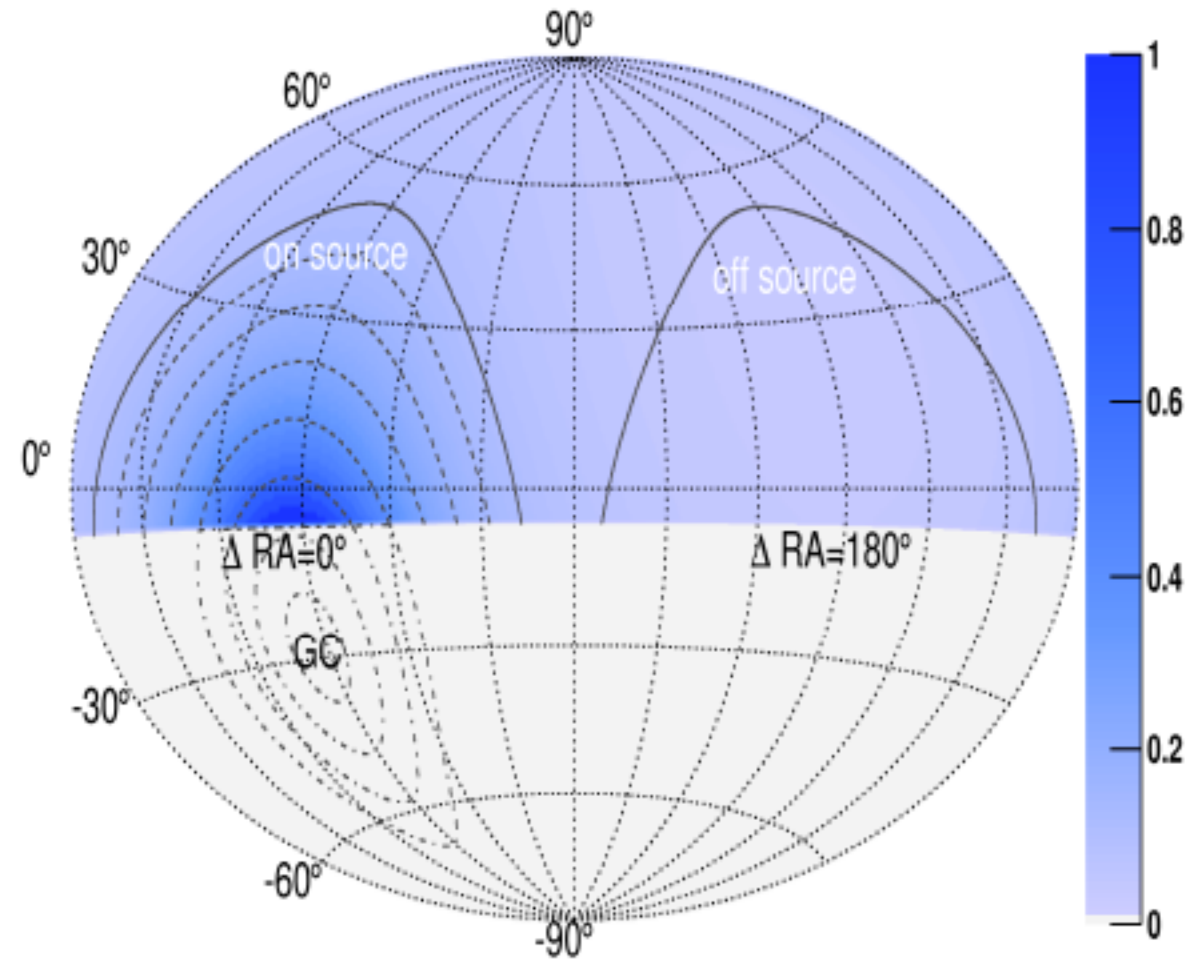
Storm, Jeltema, Profumo, & Rudnick 2012

Neutrinos from GC Region

$$J(\psi) = \int_0^{l_{\max}} \frac{\rho^2(\sqrt{R_{\rm sc}^2 - 2lR_{\rm sc}\cos\psi + l^2})}{R_{\rm sc}\rho_{\rm sc}^2} d$$

$$\frac{d\phi_\nu}{dE} = \frac{\langle\sigma_A v\rangle}{2} J(\psi) \frac{R_{\rm sc}\rho_{\rm sc}^2}{4\pi m_\chi^2} \frac{dN_\nu}{dE},$$

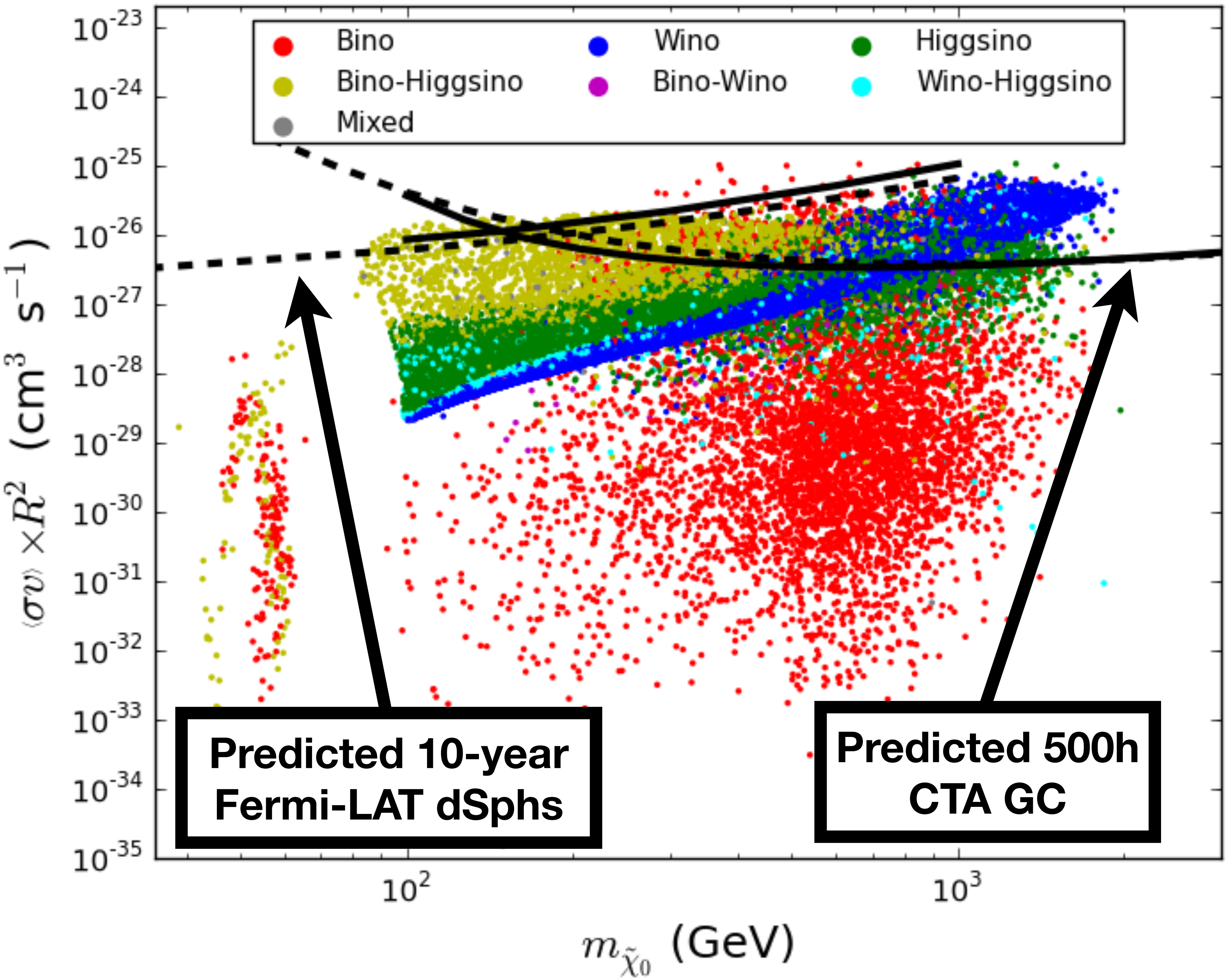




$$\Delta N = \left(N_{\rm on}^{\rm bkg} + N_{\rm on}^{\rm sig}\right) - \left(N_{\rm off}^{\rm bkg} + N_{\rm off}^{\rm sig}\right),$$

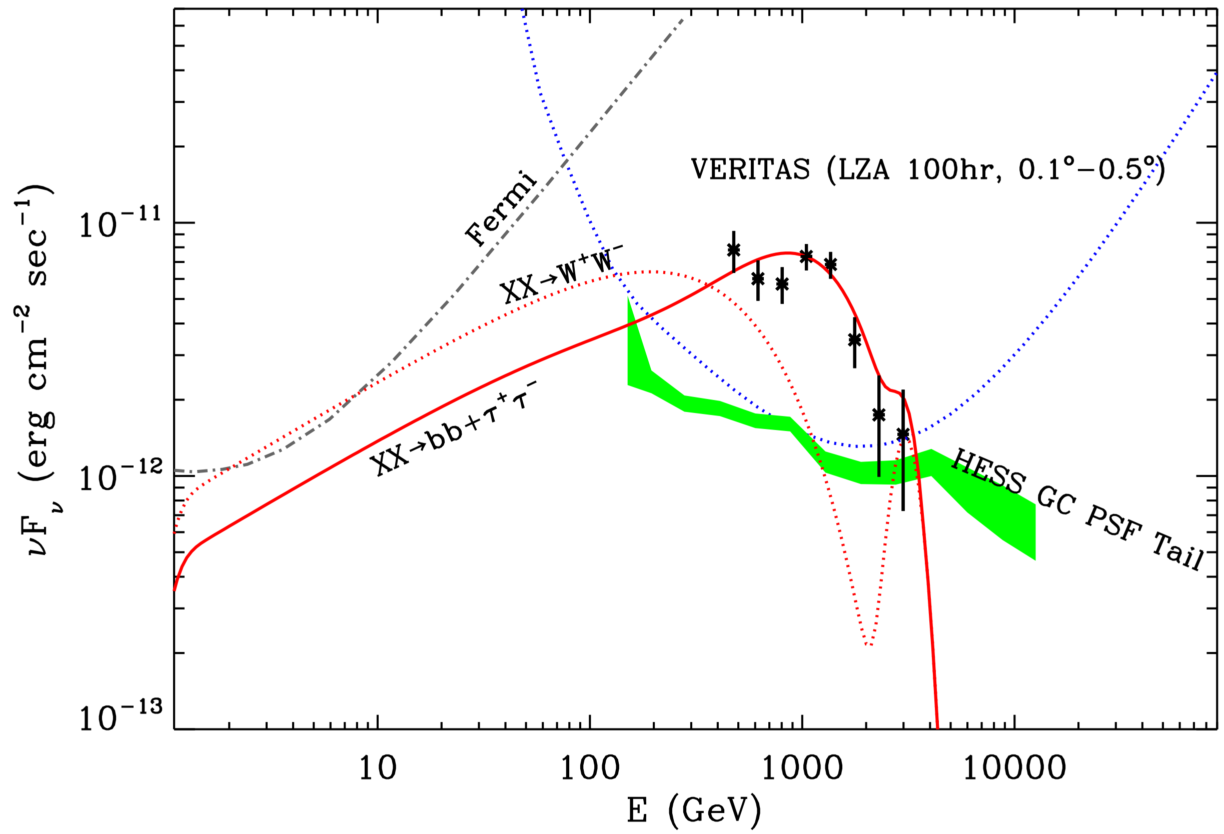
Abbasi et al. (for the ICECUBE collaboration) (Jan 17, 2011 arXiv: 1101.3359)

CTA Constraints.



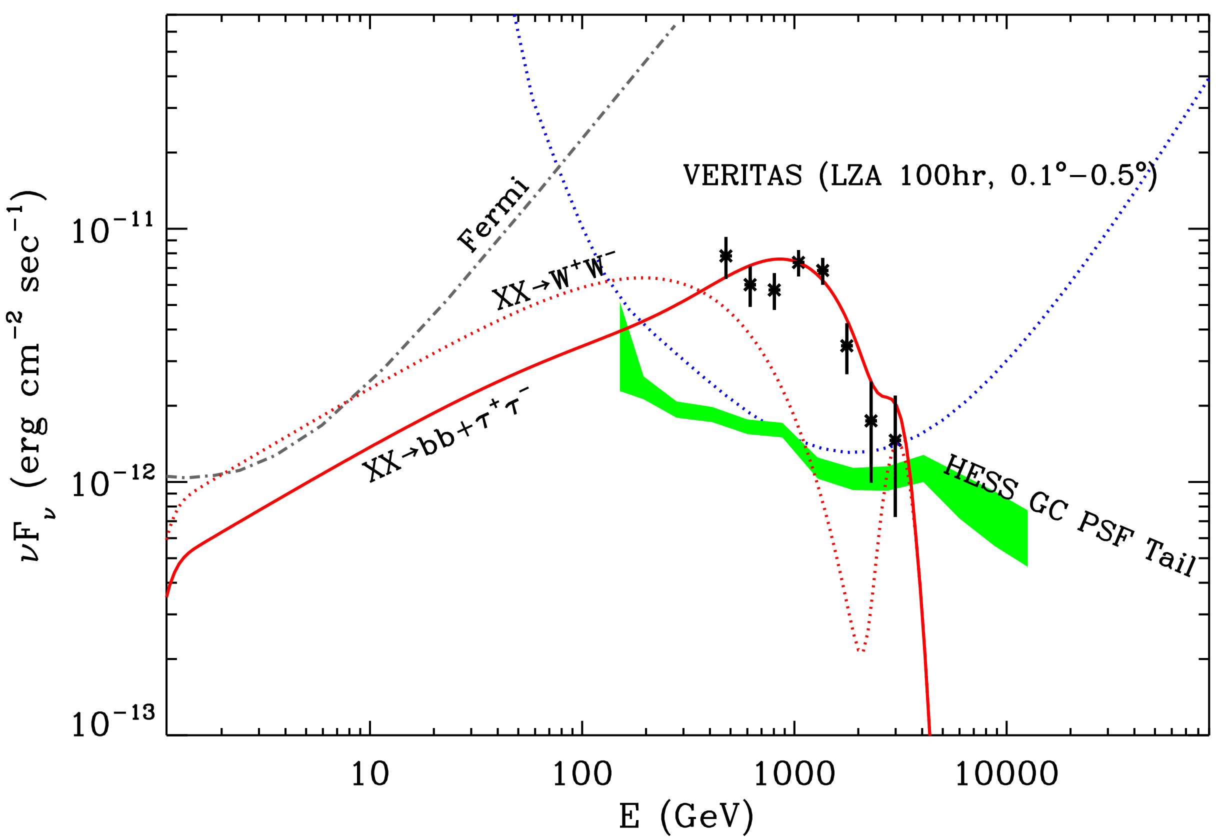
- Alex Drlica-Wagner

GC DM Prospects



VERITAS sensitivity to GC region excluding point source for 3 TeV neutralinos with ~x10 boost (Sommerfeld or Astrophysical boost)

GC DM Prospects



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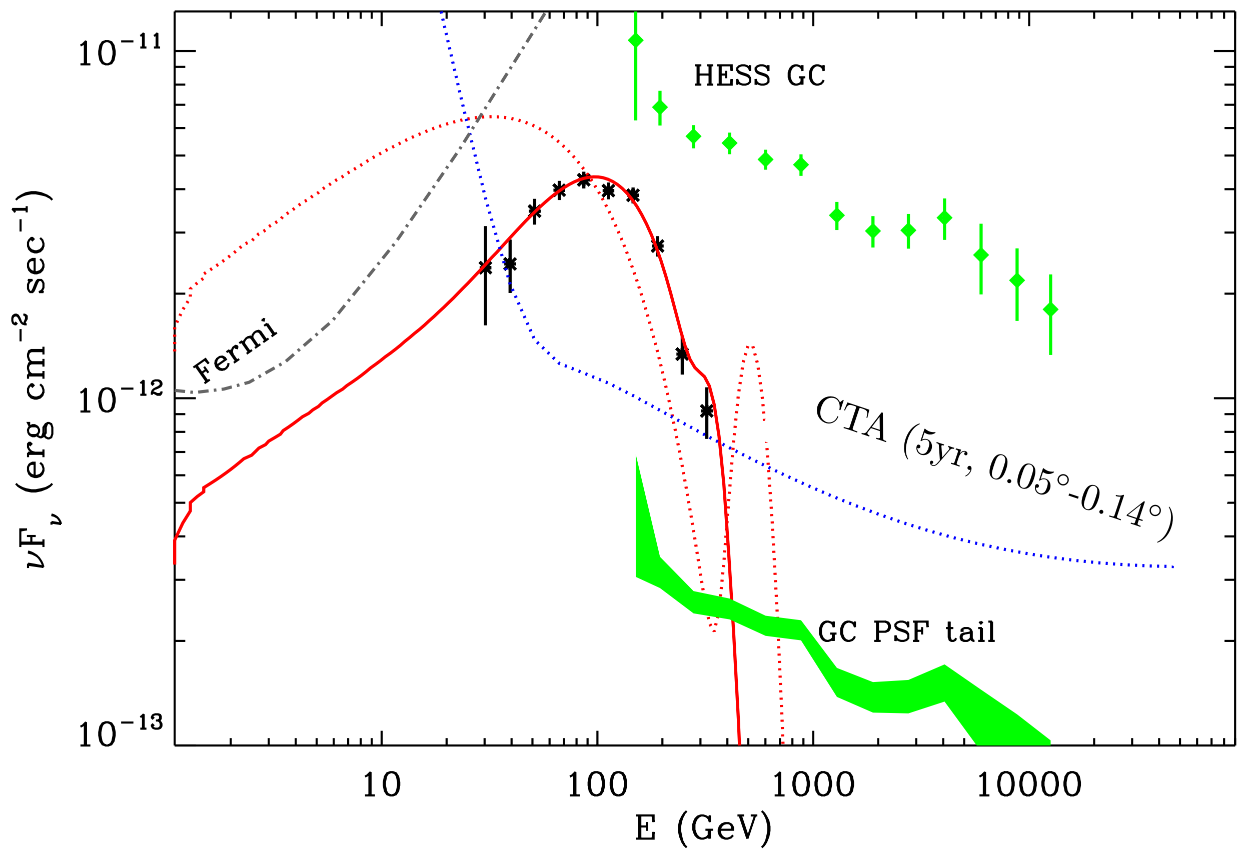
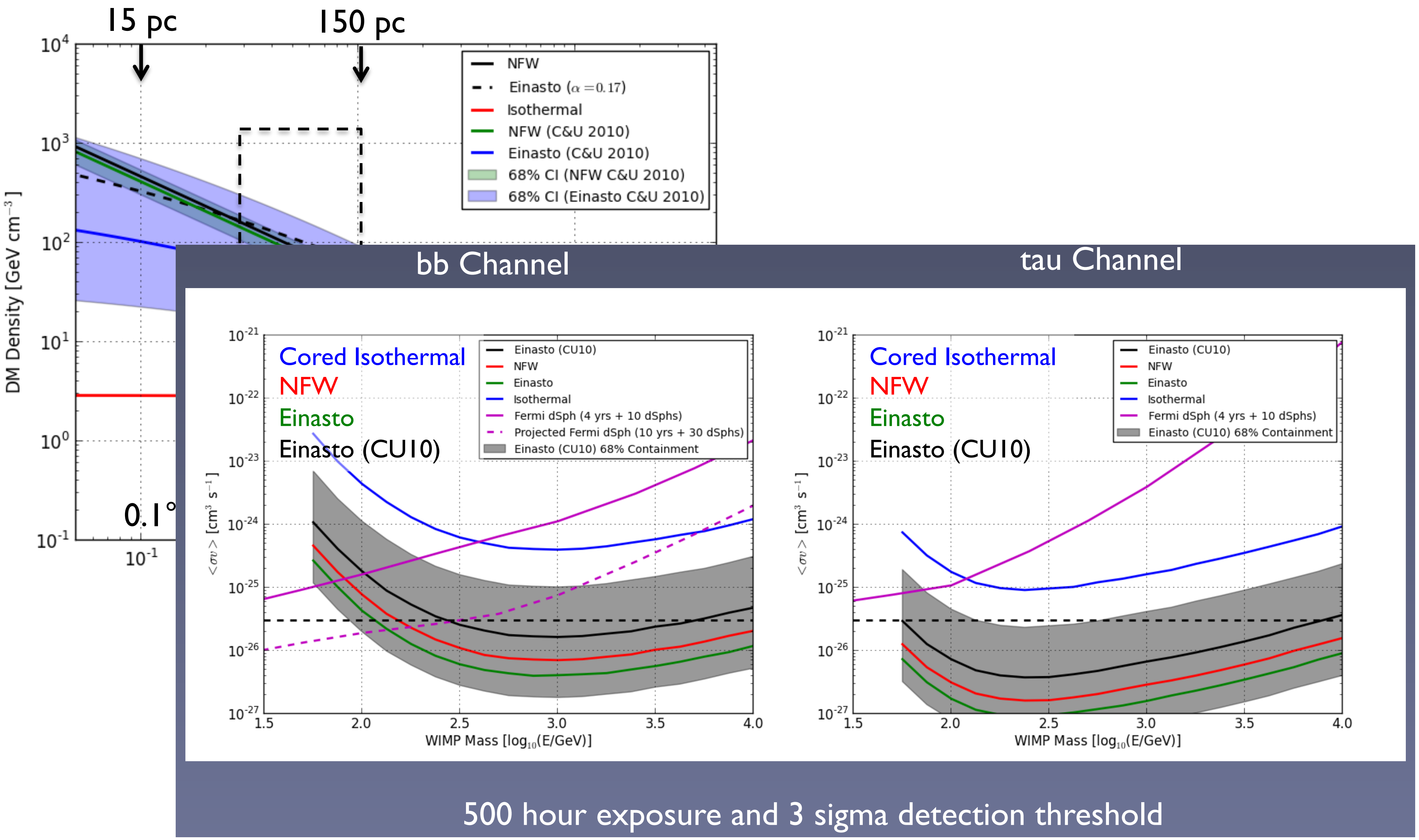


CTA can detect ~>100-200 GeV neutralinos with no boost

Angular resolution + sensitivity + southern hemisphere

Halo Uncertainties



500 hour exposure and 3 sigma detection threshold