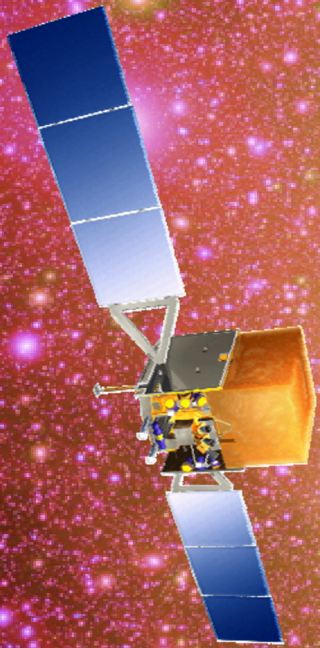
Testing astroparticle physics with the Fermi Large Area Telescope



Aldo Morselli
INFN Roma Tor Vergata

February 18 2011 Virtual Institute of Astroparticle Physics


The LAT at 2 Years
Happy 2nd Birthday, Fermi!
11 June 2008

Fermi is Making a Major Impact

Science, December 2009

THE

RUNNERS-UP >>

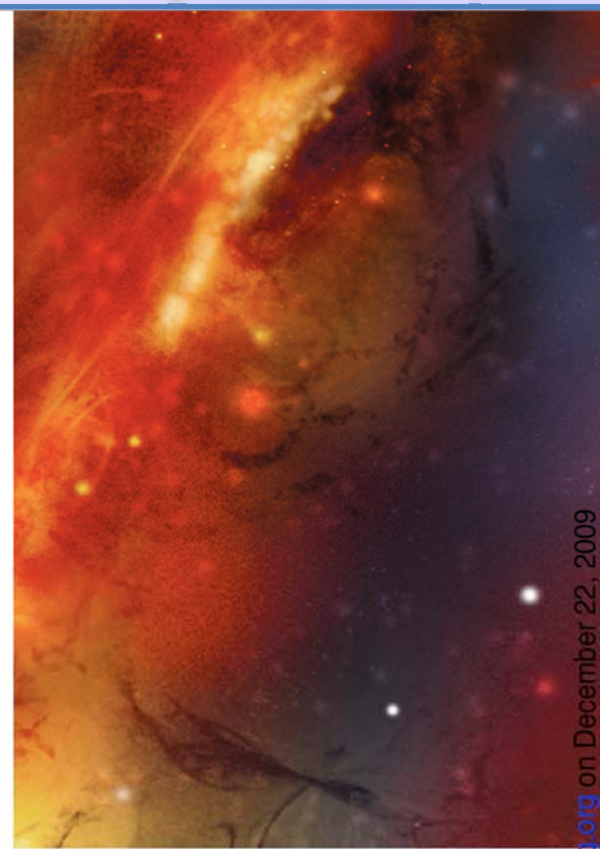
Opening Up the Gamma Ray Sky

LIKE A LIGHTHOUSE BLINKING IN THE NIGHT, A pulsar appears to flash periodically as it spins in space, sweeping a double cone of electromagnetic radiation across the sky. Since the discovery of the first pulsar 4 decades ago, astronomers have detected hundreds more of these enigmatic objects from the pulsing radio waves they emit. Now, astronomers have opened a new channel of discovery—the highly energetic gamma ray spectrum—to find pulsars that radio observations could not detect. The advance, part of a torrent of recent gamma ray observations, is giving researchers an improved understanding of how pulsars work, along with a rich haul of new pulsars that could help in the quest to detect gravitational waves.

The findings come from the Fermi Gamma-ray Space Telescope, which has been mapping the gamma ray universe since it was launched by NASA in June 2008. Combing through data the telescope collected in its first few months, an international team discovered 16 new pulsars; strong gamma ray pulsations from eight previously known pulsars with spin times of milliseconds, proving that these objects pulse brightly at gamma wavelengths as well as in the radio range; and high-energy gamma rays from the globular cluster 47 Tucanae indicating that the cluster harbors up to 60 millisecond pulsars.

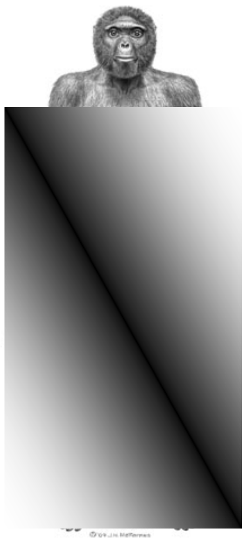
Those Fermi results might be just the beginning. Armed with their new knowledge of pulsar behavior, researchers are checking whether some of the unidentified gamma ray sources Fermi has detected might be pulsars. In November alone, teams of astronomers in the United States and France discovered five new millisecond pulsars by training ground-based radio telescopes on candidate objects Fermi had pointed out—a much more targeted search technique than scanning the sky blindly with ground-based radio telescopes.

Gamma ray beams of pulsars are believed to be wider than their radio beams, so in principle a space-based gamma ray telescope should be more likely to encounter and discern a pulsar's sweep than a radio telescope on Earth is. However, Fermi's forerunner—



the Compton Gamma Ray Observatory, which flew from 1991 to 2000—did not have much luck finding these objects. What has made the difference is Fermi's high sensitivity, which enables it to detect pulsations that would have been too faint for Compton.

Already, the discoveries are shedding new light on the physics of pulsars. Researchers

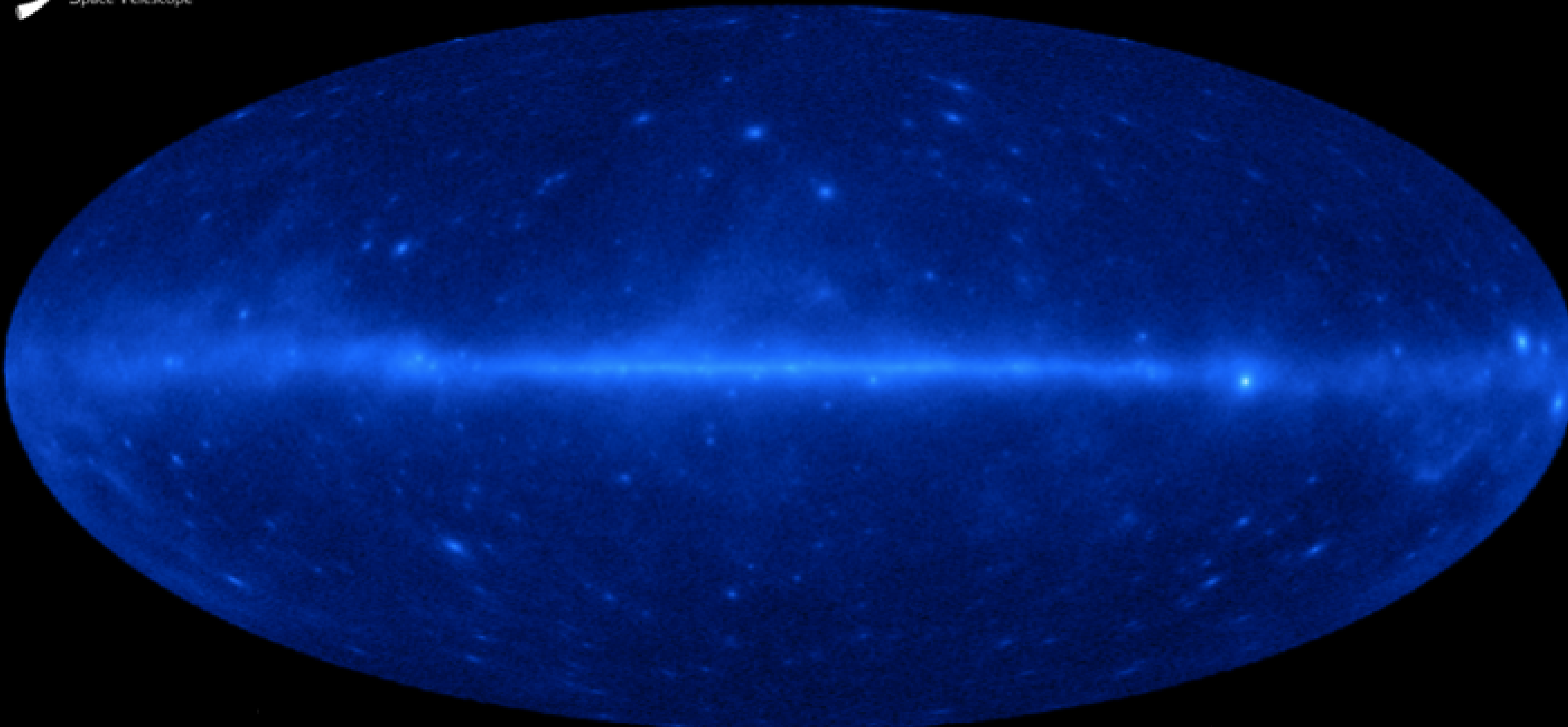


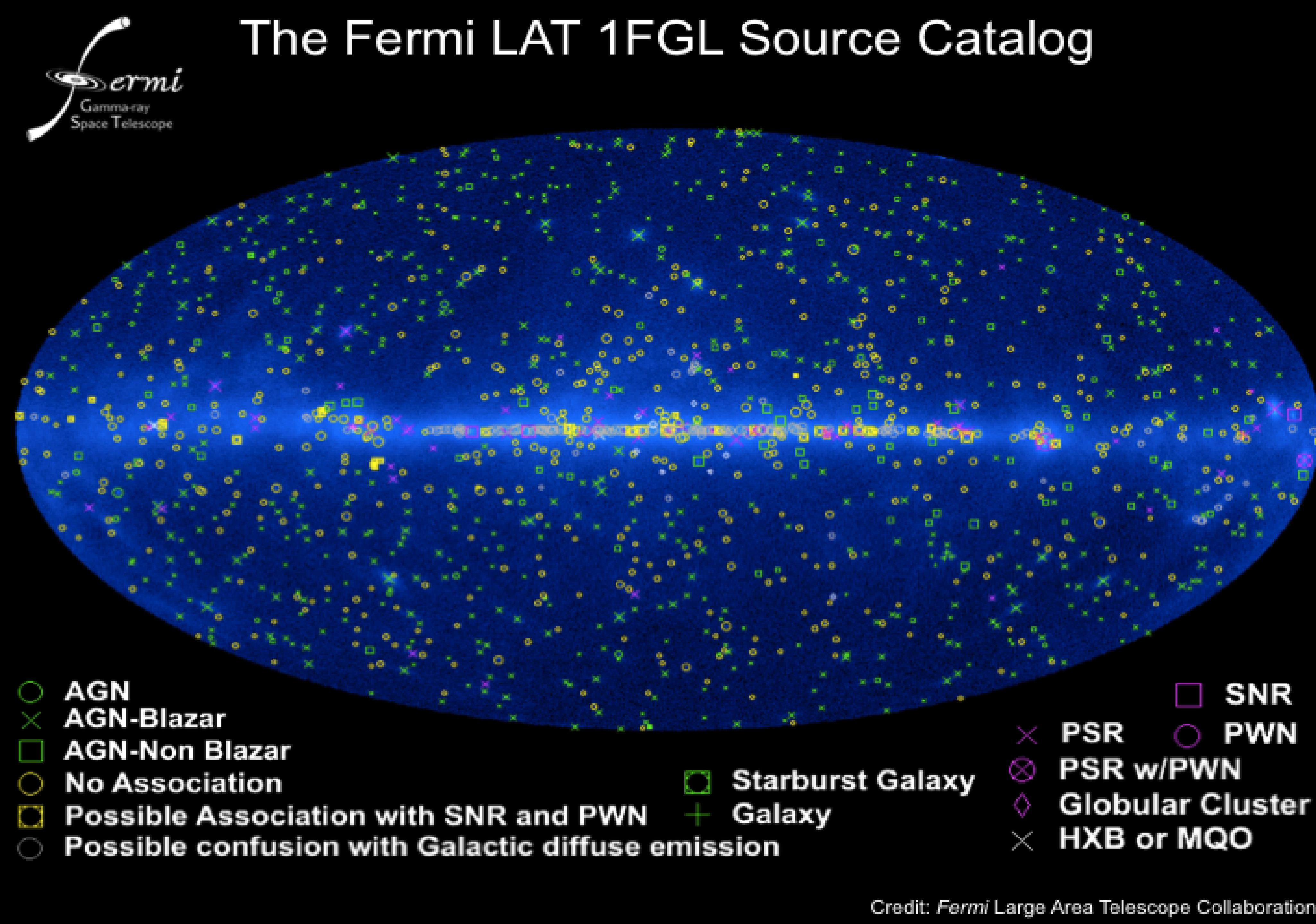
Breakthrough of the Year was the reconstruction of the 4.4-million-year-old ***Ardipithecus ramidus*** skeleton

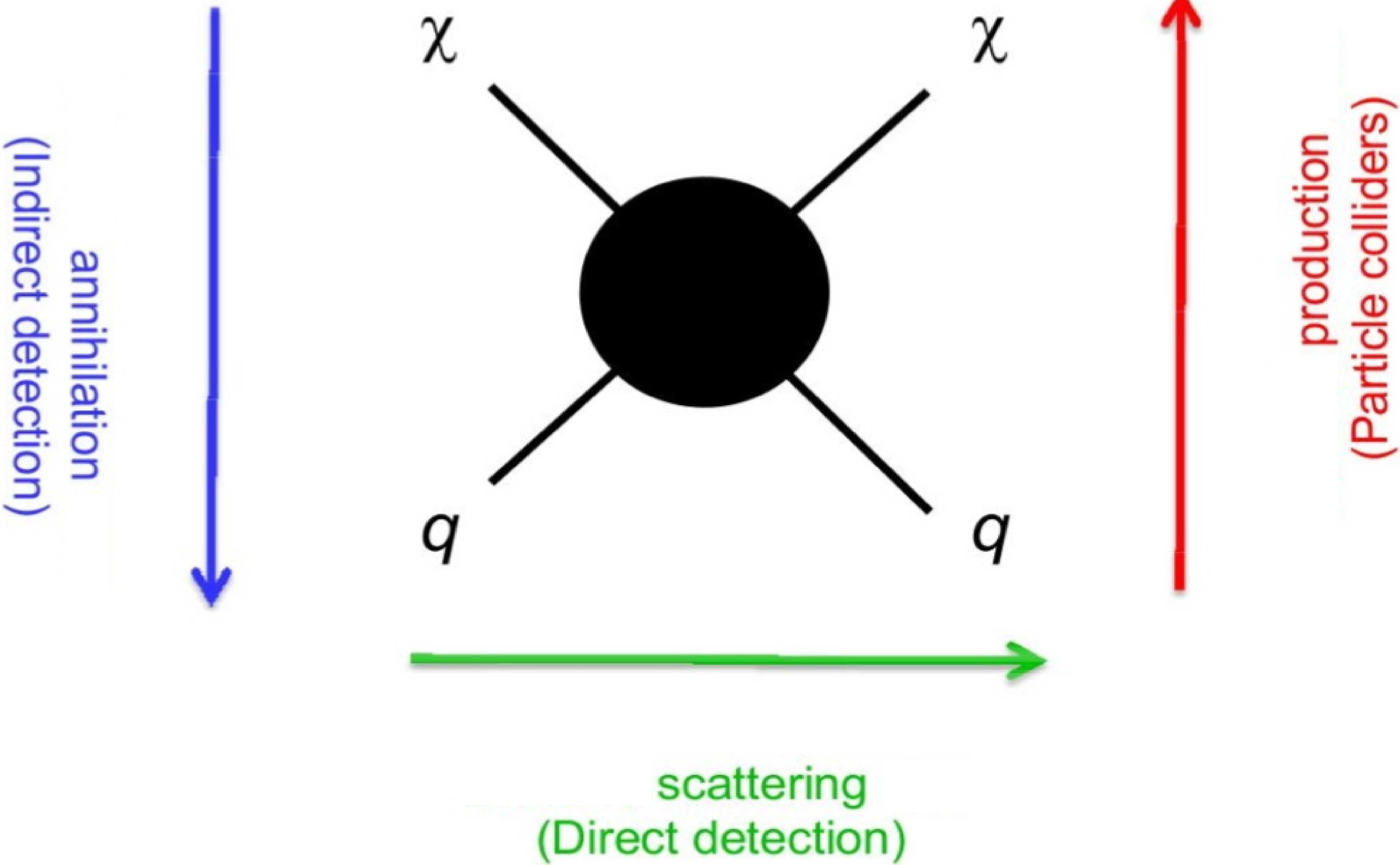
2011 Bill Atwood, Peter Michelson, and the Fermi Gamma Ray Space Telescope LAT team

- The 2011 Rossi Prize is awarded to Bill Atwood, Peter Michelson, and the Fermi Large Gamma Ray Space Telescope LAT team for enabling, through the development of the Large Area Telescope, new insights into neutron stars, supernova remnants, cosmic rays, binary systems, active galactic nuclei, and gamma-ray bursts.

The Fermi LAT 1FGL Source Catalog




The Fermi LAT 1FGL Source Catalog
Fermi
Gamma-ray Space Telescope
AGN
AGN-Blazar
AGN-Non Blazar
No Association
Possible Association with SNR and PWN
Possible confusion with Galactic diffuse emission
Starburst Galaxy
Galaxy
SNR
PSR
PWN
PSR w/PWN
Globular Cluster
HXB or MQO
Credit: Fermi Large Area Telescope Collaboration


χ
χ
q
q
annihilation
(Indirect detection)
production
(Particle colliders)
scattering
(Direct detection)

Neutralino WIMPs

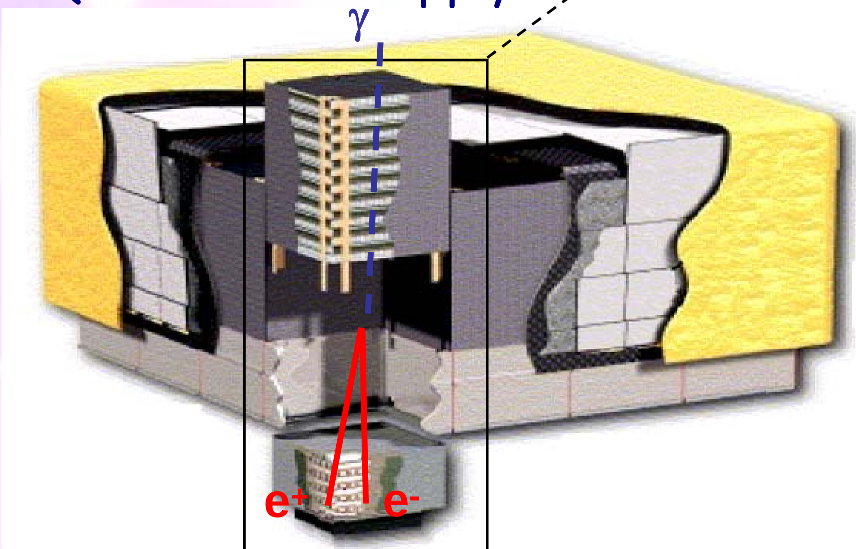
Assume χ present in the galactic halo

- χ is its own antiparticle **=>** can annihilate in galactic halo producing gamma-rays, antiprotons, positrons….
- Antimatter not produced in large quantities through standard processes (secondary production through p + p **-->** anti p + X)
- So, any extra contribution from exotic sources (χ χ annihilation) is an interesting signature
- ie: χ χ --> anti p + X
- Produced from (e. g.) χ χ **-->** q / g / gauge boson / Higgs boson and subsequent decay and/ or hadronisation.

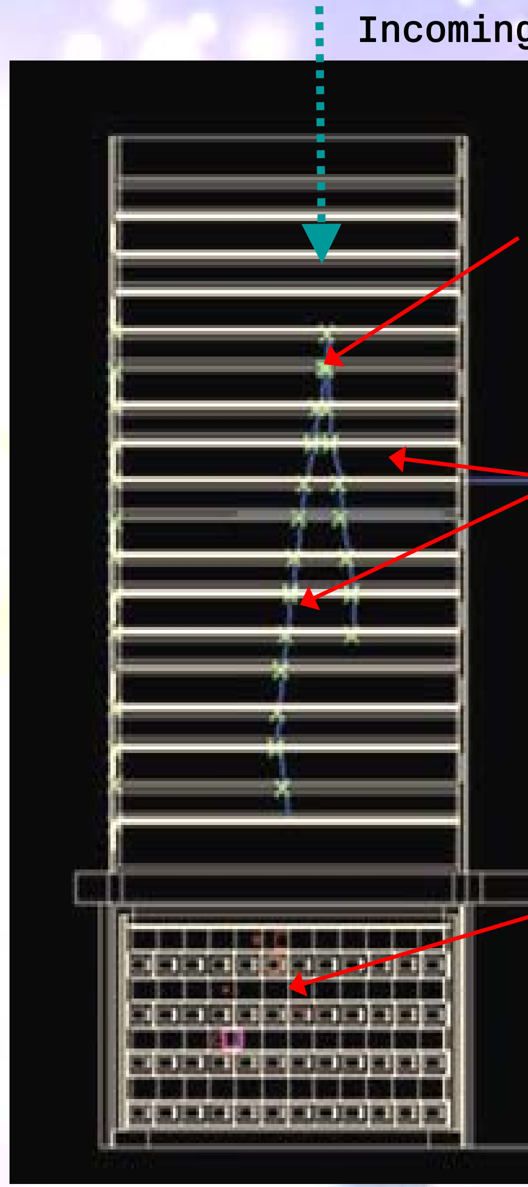
How Fermi LAT detects gamma rays

4 x 4 array of identical towers with:

- Precision Si-strip tracker (TKR)
  - With W converter foils
- Hodoscopic CsI calorimeter (CAL)
- DAQ and Power supply box



An anticoincidence detector around the telescope distinguishes gamma-rays from charged particles



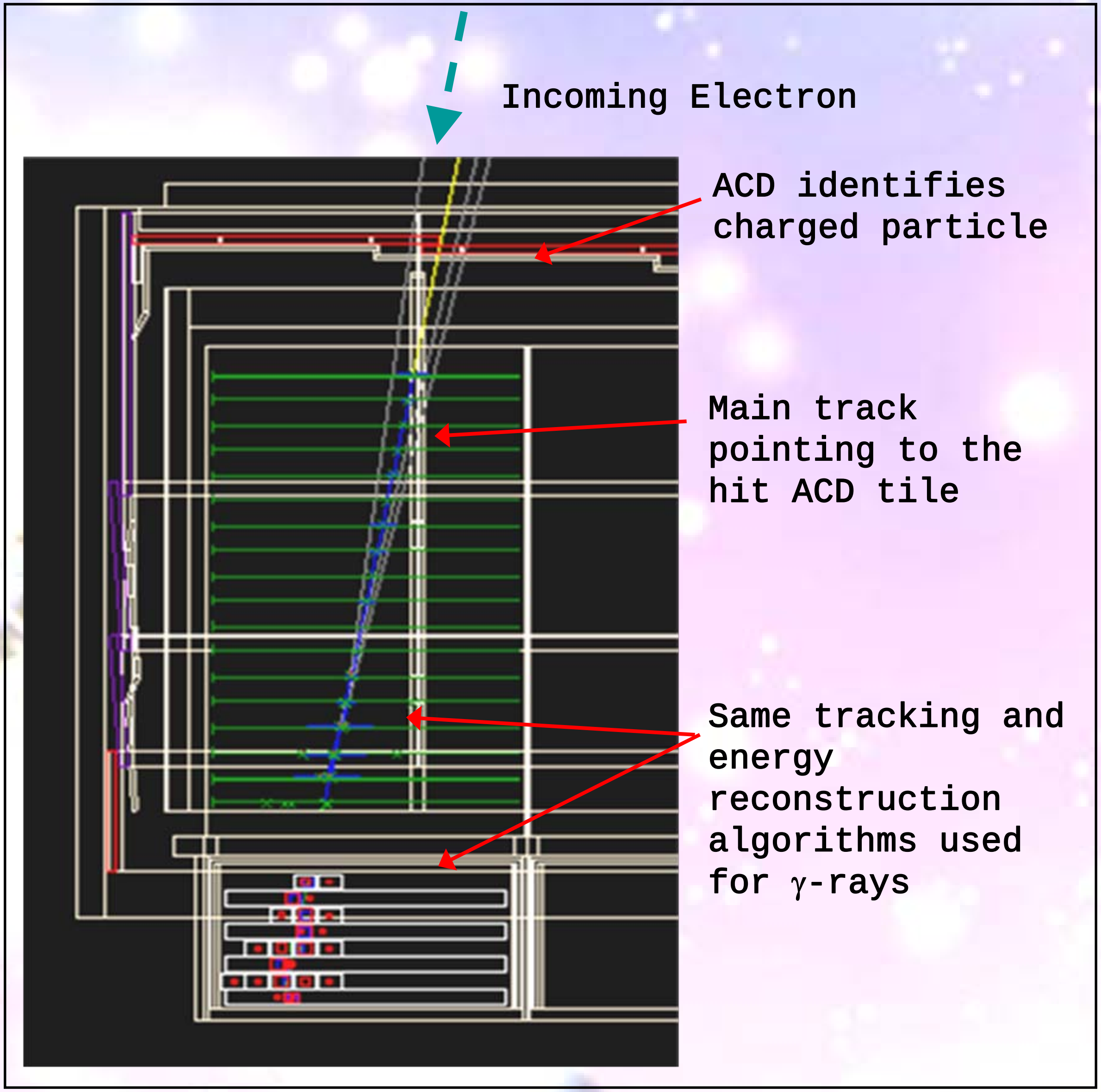
How Fermi LAT detects electrons

Trigger and downlink

- LAT triggers on (almost) every particle that crosses the LAT
  - ~ 2.2 kHz trigger rate
- On board processing removes many charged particles events
  - But keeps events with more that 20 GeV of deposited energy in the CAL
  - ~ 400 Hz downlink rate
- Only ~1 Hz are good γ-rays

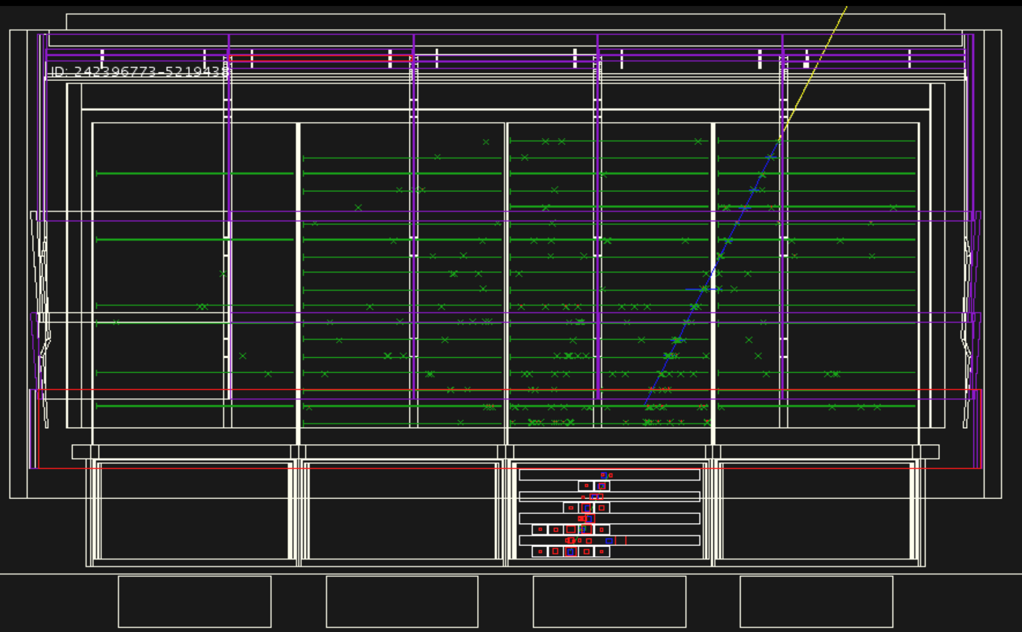
Electron identification

- The challenge is identifying the good electrons among the proton background
  - Rejection power of 10^3 – 10^4 required
  - Can not separate electrons from positrons

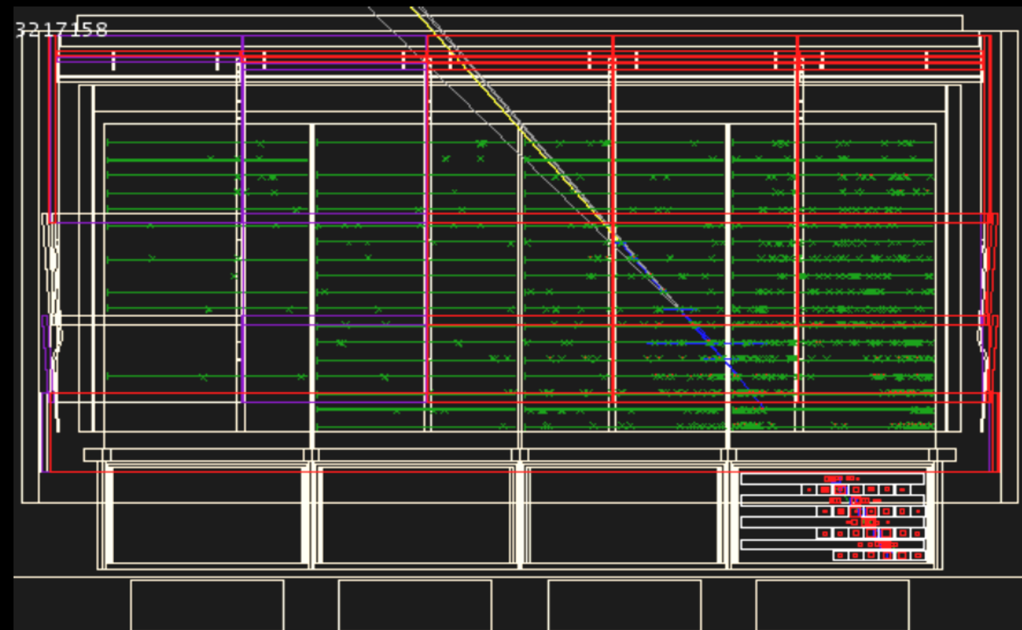


Event topology

A candidate electron (recon energy 844 GeV)



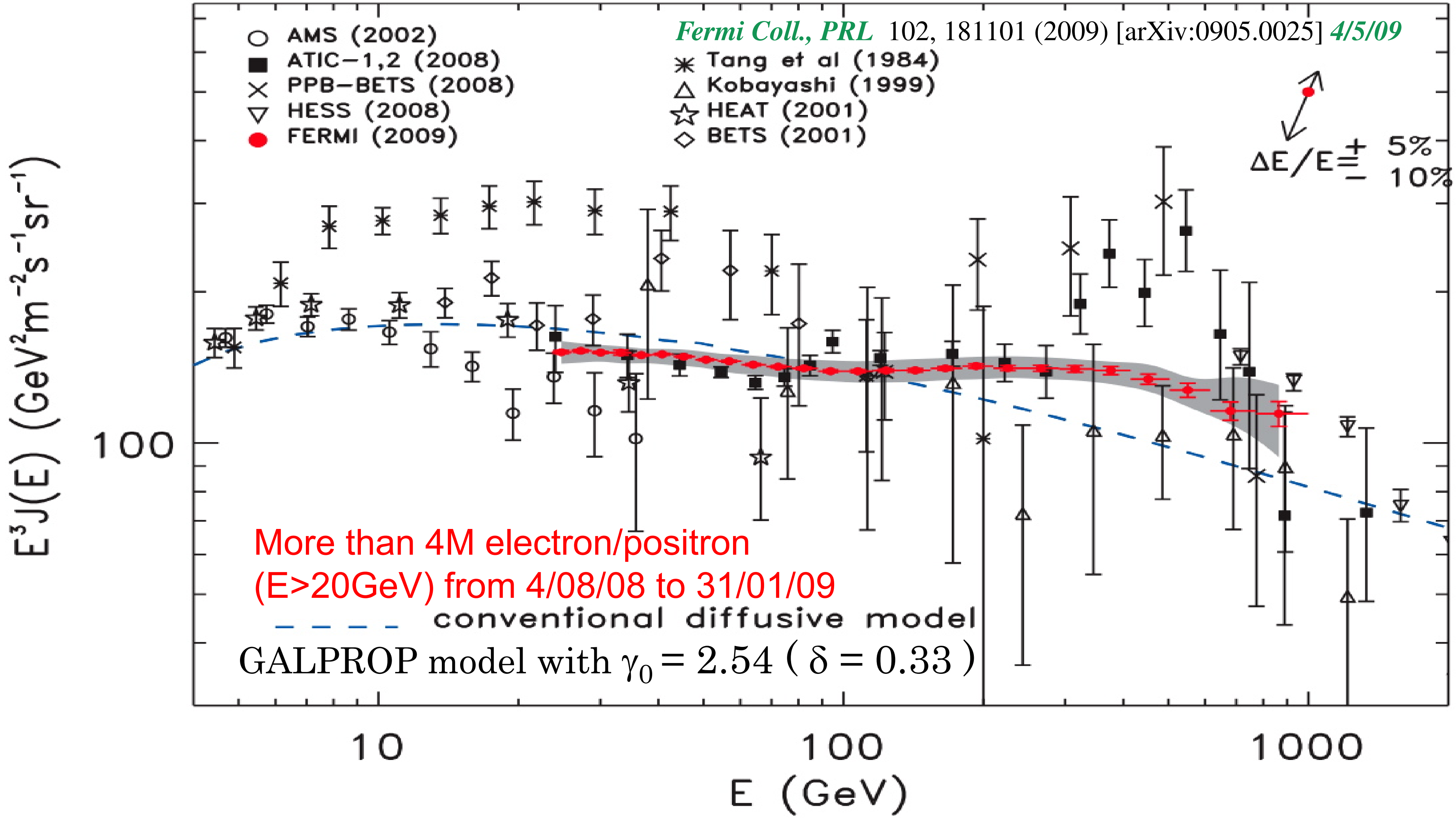
A candidate hadron (raw energy > 800 GeV)



- TKR: clean main track with extra-clusters very close to the track
- CAL: clean EM shower profile, not fully contained
- ACD: few hits in conjunction with the track

- TKR: small number of extra clusters around main track
- CAL: large and asymmetric shower profile
- ACD: large energy deposit per tile

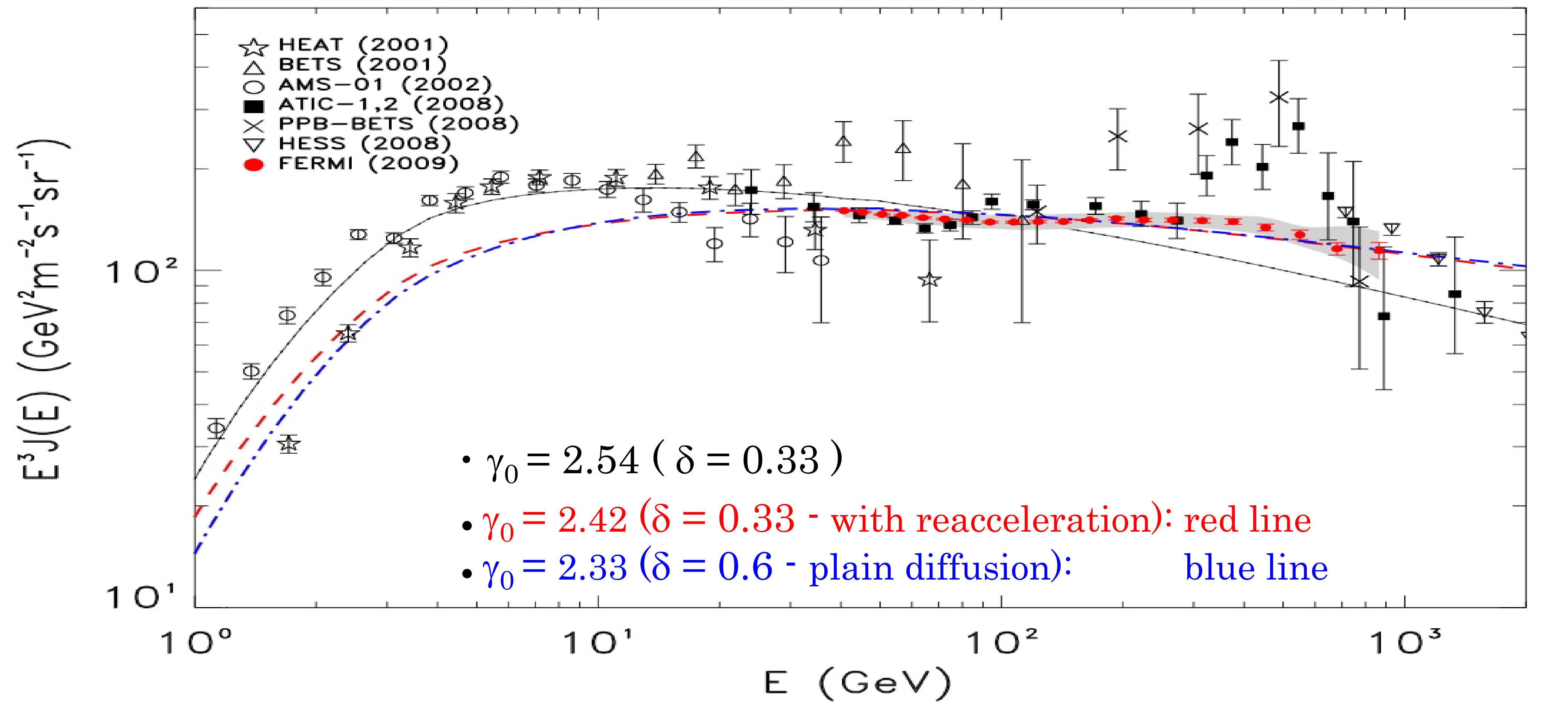
Fermi-LAT CRE data vs the conventional *pre-Fermi* model



Although the feature @~600 GeV measured by ATIC is not confirmed

<u>Some changes are still needed with respect to the *pre-Fermi conventional mode*</u>

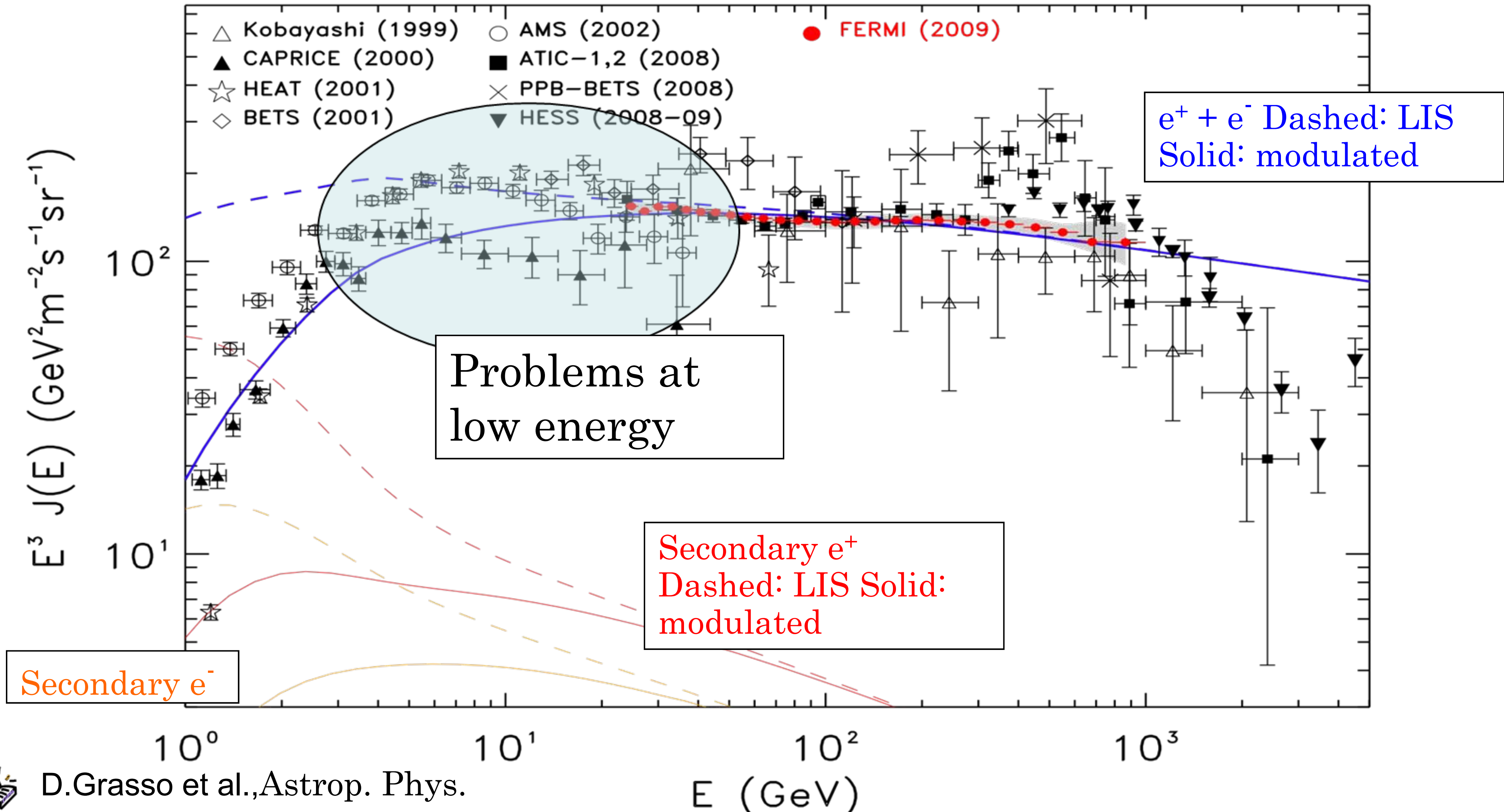
Cosmic Ray Electron propagation models



Model #	D_0 (cm^2s^{-1})	δ	z_h (kpc)	γ_0	N_{e^-} $(m^{-2}s^{-1}sr^{-1}GeV^{-1})$	γ_0^p
0	3.6×10^{28}	0.33	4	2.54	1.3×10^{-4}	2.42
1	3.6×10^{28}	0.33	4	2.42	1.3×10^{-4}	2.42
2	1.3×10^{28}	0.60	4	2.33	1.3×10^{-4}	2.1

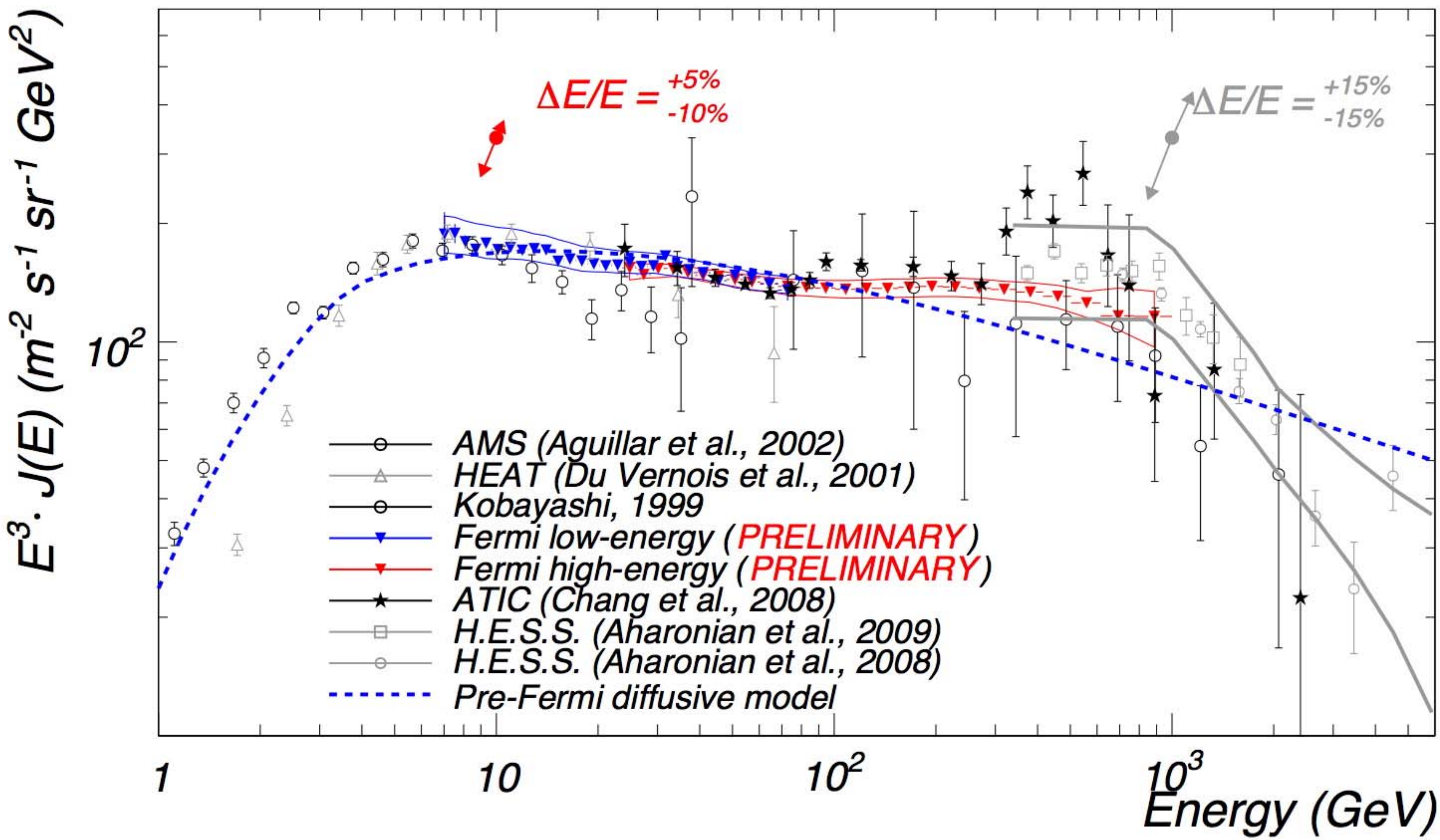
Models 0 and 1 account for CR re-acceleration in the ISM, while 2 is a plain-diffusion model. All models assume ©$_0$ = 1.6 below 4 GeV.

“Conventional” model with injection spectrum 1.60/2.42 (break at 4 GeV)



D.Grasso et al.,Astrop. Phys. [arXiv:0905.0636]

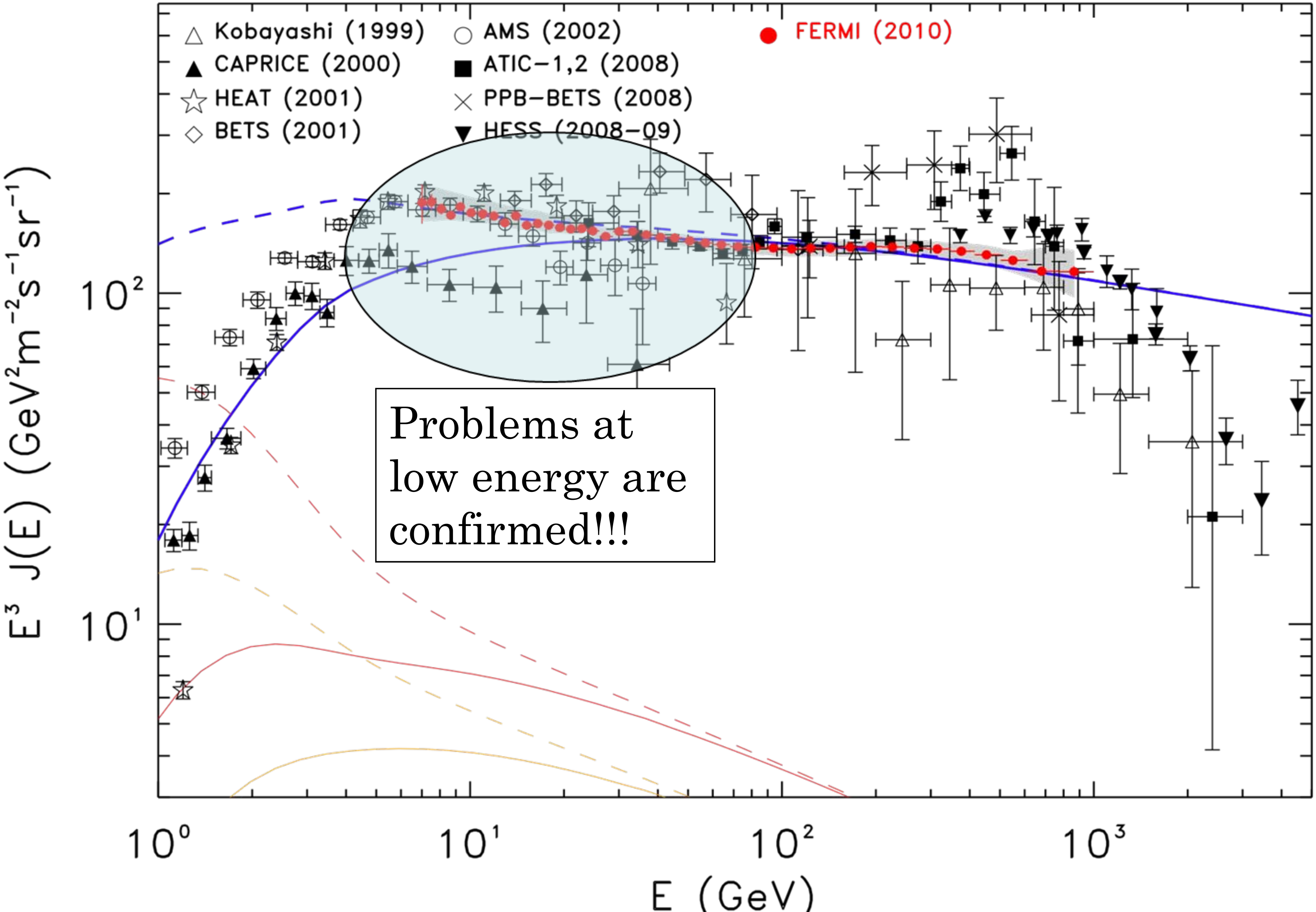
new : Fermi Electron + Positron spectrum



Extended Energy Range (7 GeV - 1 TeV) One year statistics (8M evts)

Fermi LAT Coll. Physical Review D, 82 092004 (2010) [arXiv:1008.3999]

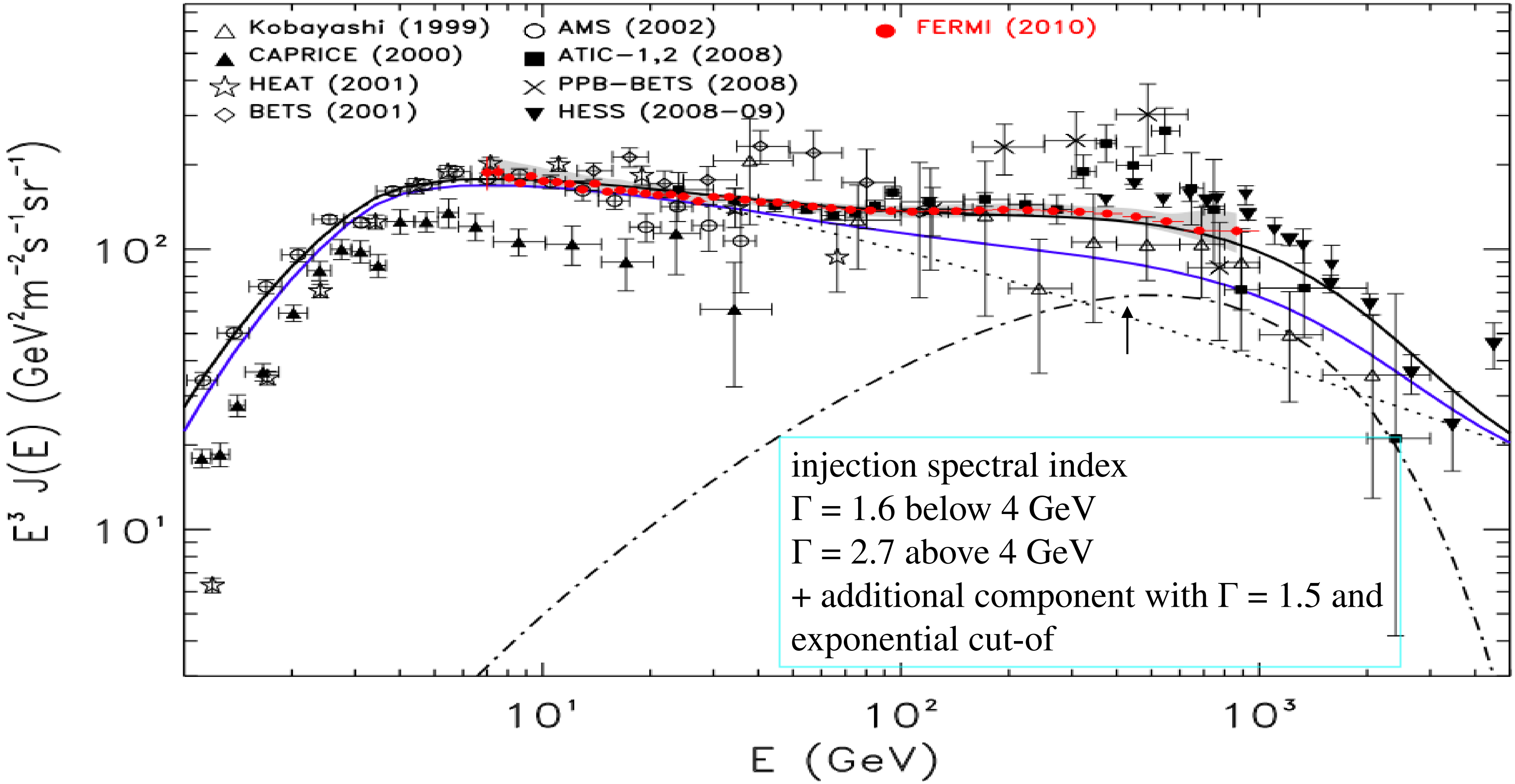
New Fermi-LAT data at low energy



Problems at low energy are confirmed!!!

Fermi LAT Coll. Physical Review D, 82 092004 (2010) [arXiv:1008.3999]

Electron spectrum and a conventional GALPROP model +...



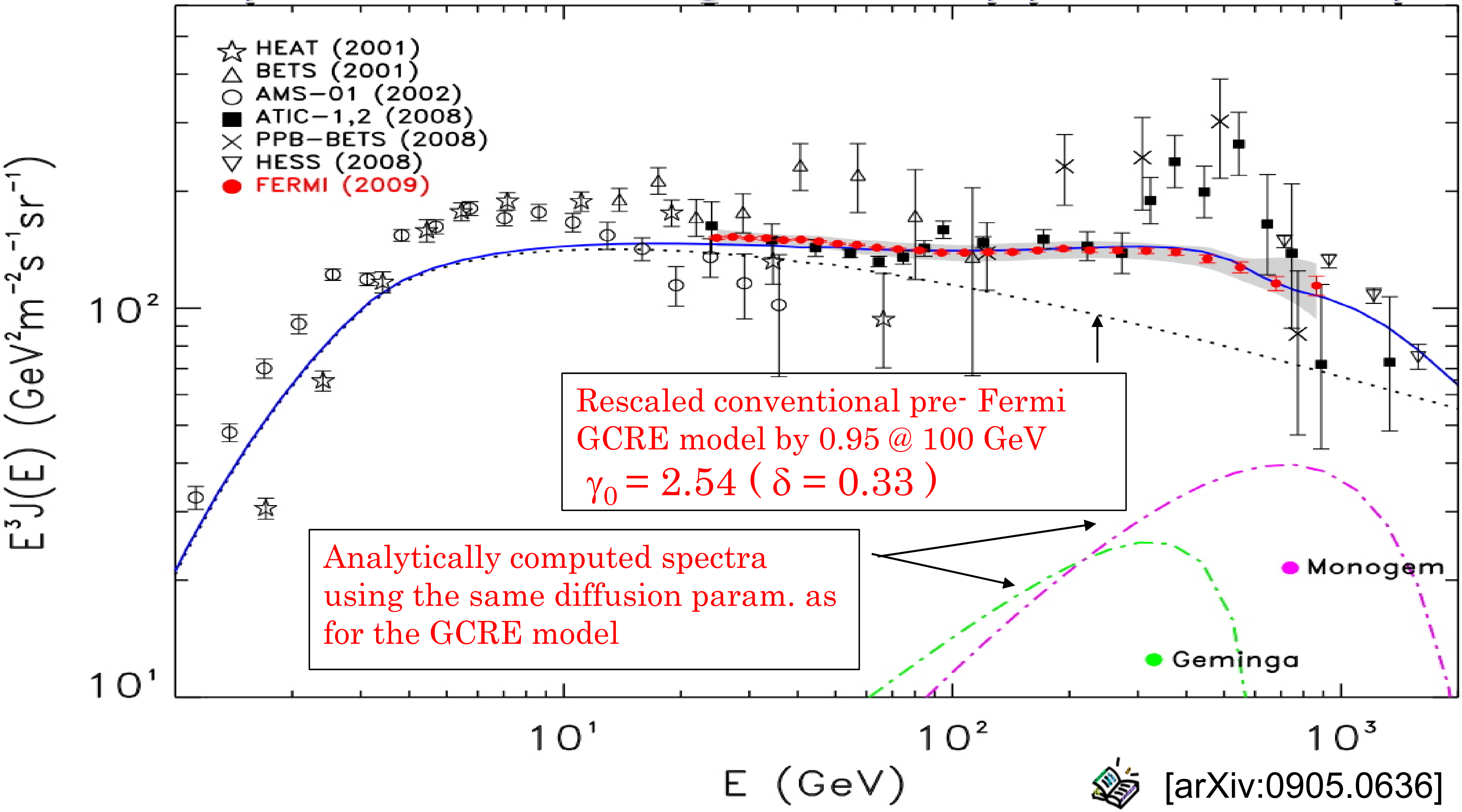
Hard to get a good fit with a single-component diffusive model

Good fit possible with an additional high-energy component

If it is an e+/e− (e. g. nearby pulsars or dark matter), the Fermi spectrum and Pamela positron fraction can be simultaneously fitted

Fermi LAT Coll. Physical Review D, 82 092004 (2010) [arXiv:1008.3999]

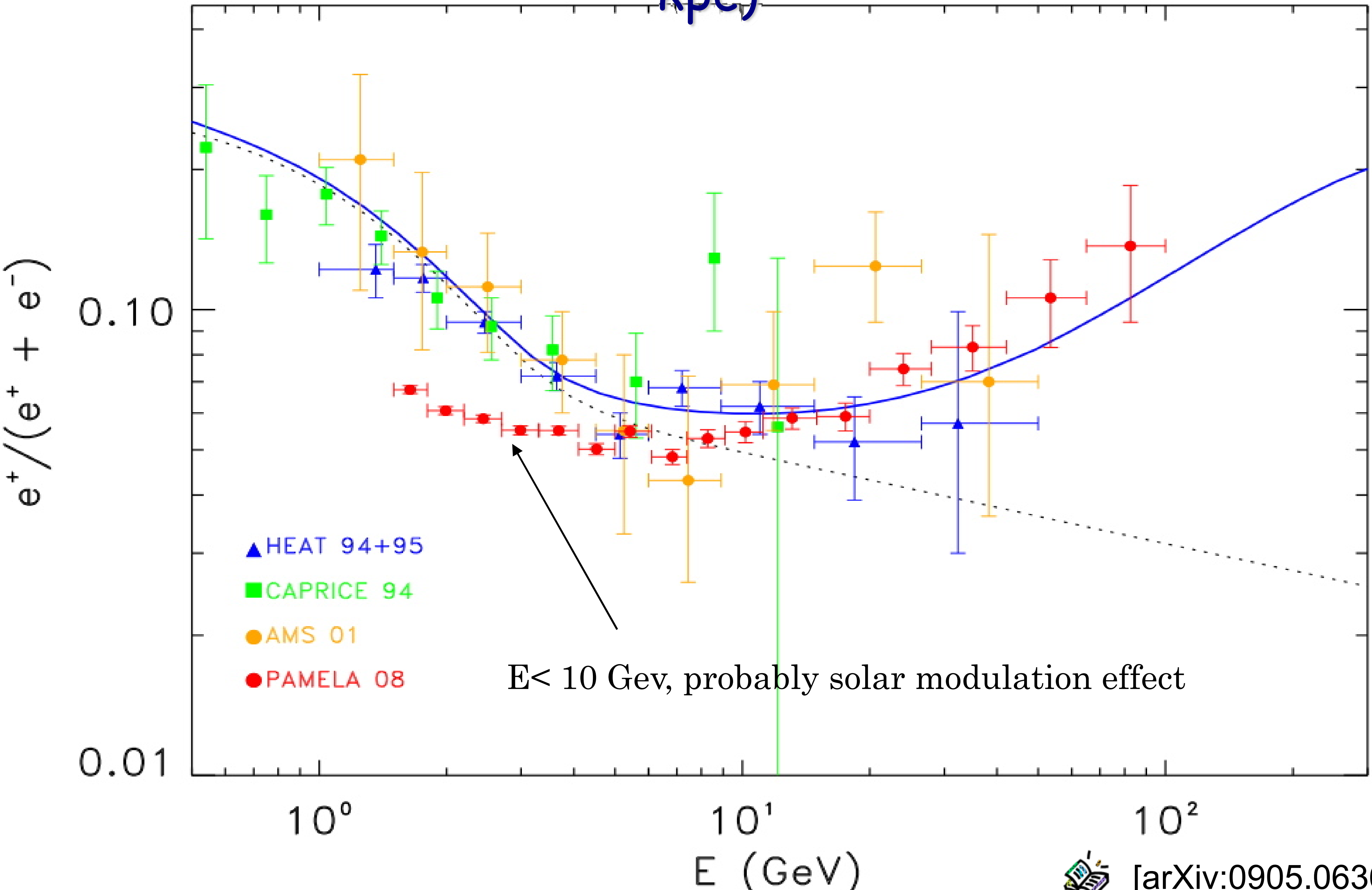
The CRE spectrum accounting for nearby pulsars (d < 1 kpc)



[arXiv:0905.0636]

This particular model assumes: 40% $e^{\pm}$ conversion efficiency for each pulsar
• pulsar spectral index $\Gamma = 1.7$ $E_{cut} = 1$ TeV . Delay = 60 kyr

The positron ratio accounting for nearby pulsars (d < 1 kpc)



[arXiv:0905.0636]

Pulsars

1. On purely energetic grounds they work (relatively large efficiency)

2. On the basis of the spectrum, it is not clear
    1. The spectra of PWN show relatively flat spectra of pairs at Low energies but we do not understand what it is
    2. The general spectra (acceleration at the termination shock) are too steep

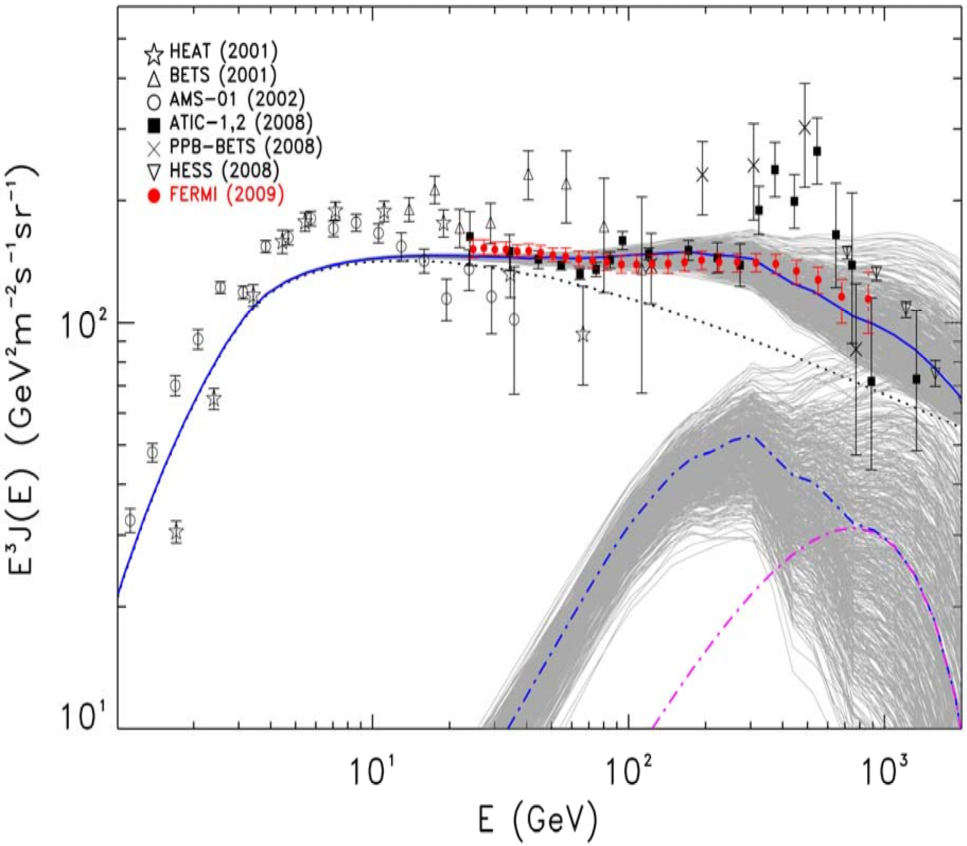
The biggest problem is that of escape of particles from the pulsar

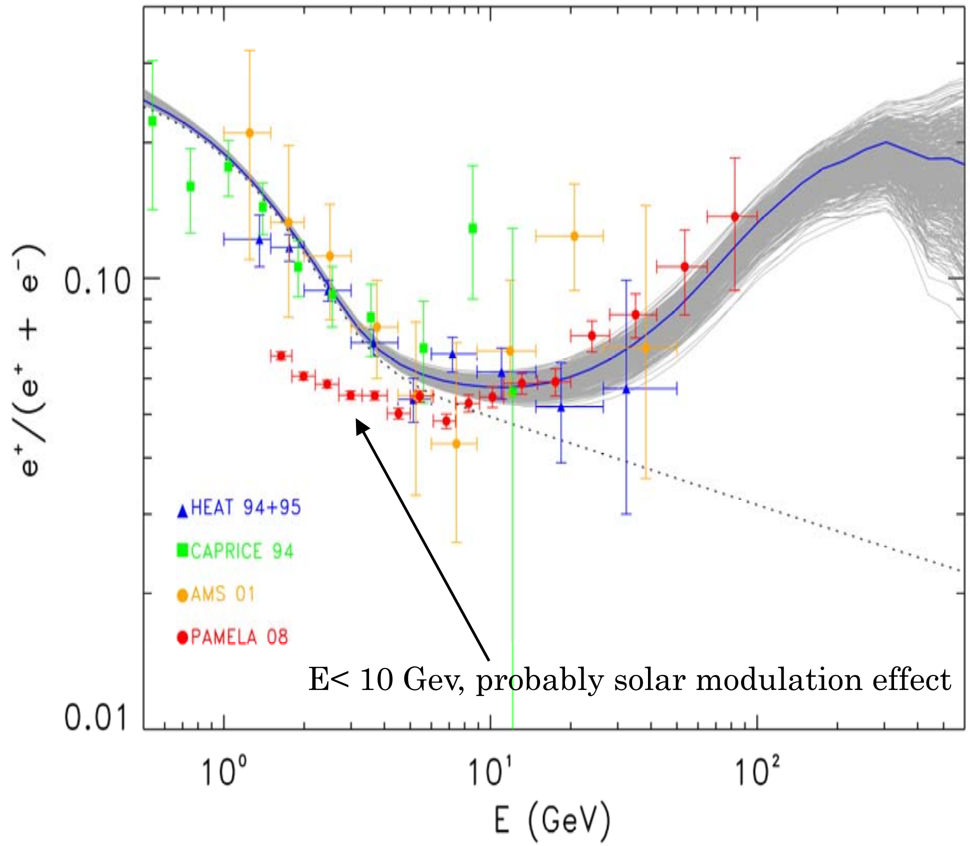
1. Even if acceleration works, pairs have to survive losses
2. And in order to escape they have to cross other two shocks

New Fermi data on pulsars will help to constrain the pulsar models

What if we randomly vary the pulsar parameters relevant for e+e- production?

(*injection spectrum, e+e- production efficiency, PWN “trapping” time*)

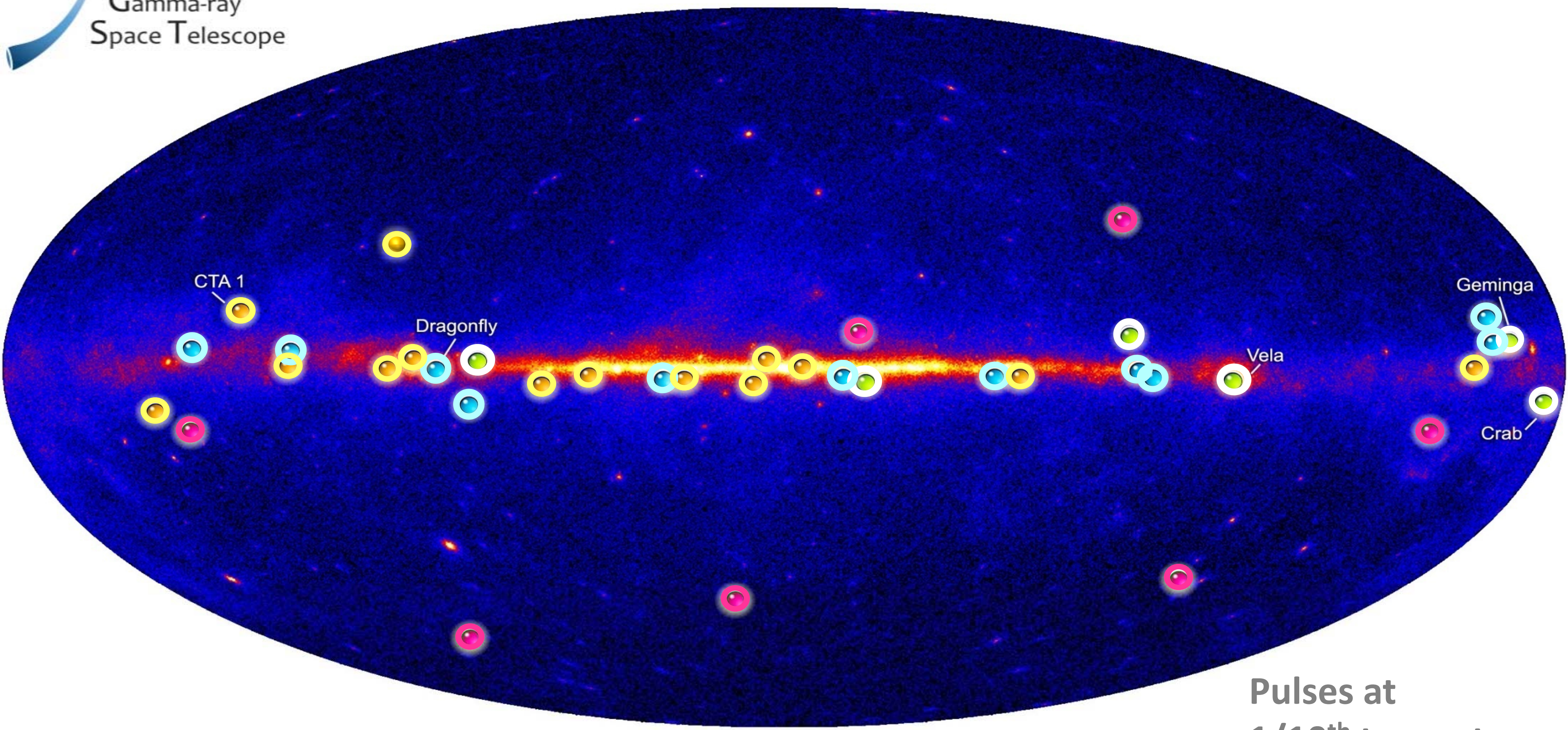




Under reasonable assumptions, electron/positron emission from pulsars offers a viable interpretation of Fermi CRE data which is also consistent with the HESS and Pamela results.

[arXiv:0905.0636]

65 Gamma-Ray Pulsars, with 24 from blind searches

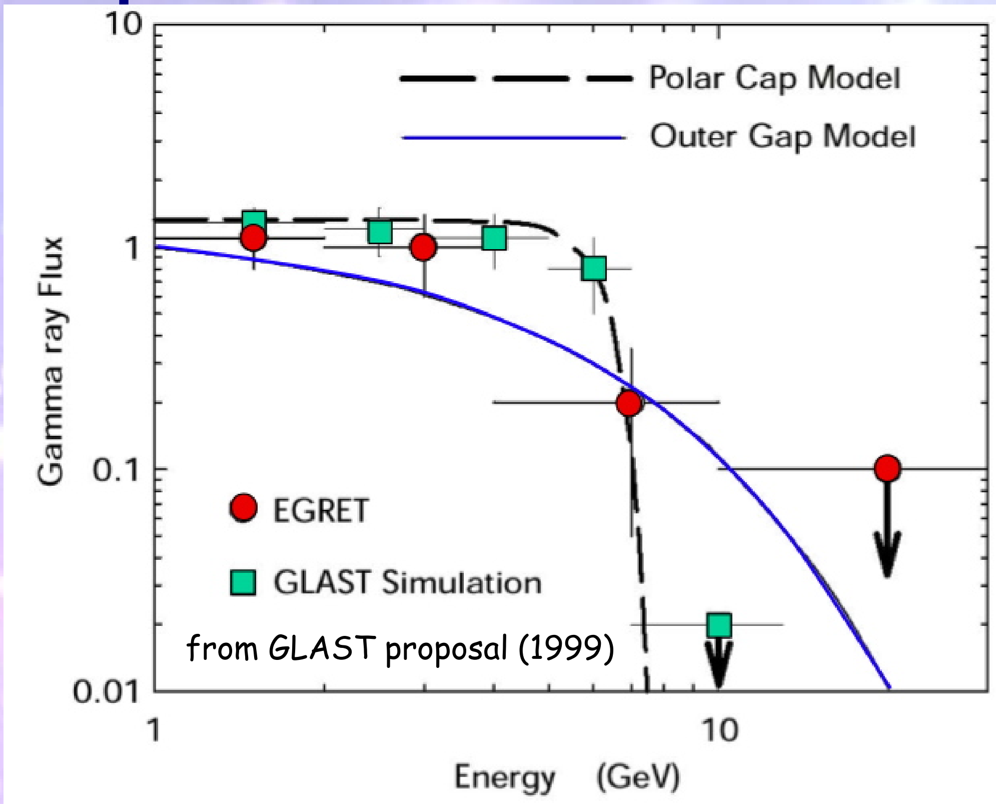


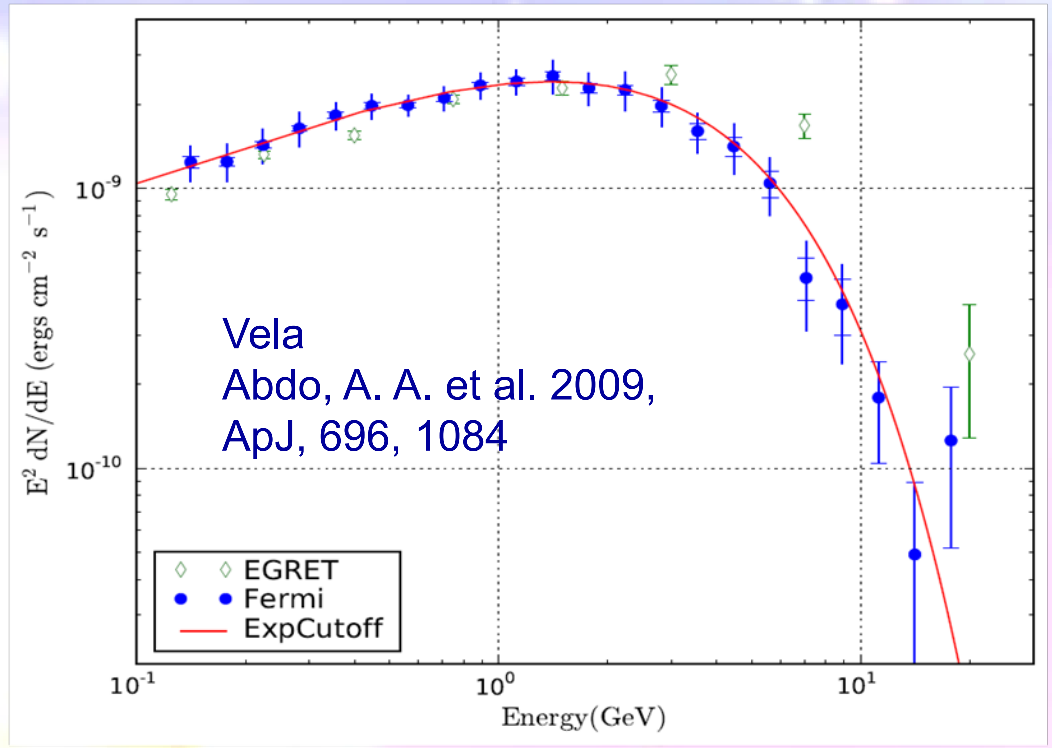
Pulses at $1/10^{th}$ true rate

The Pulsing γ-ray Sky

- New pulsars discovered in a blind search
- Millisecond radio pulsars
- Young radio pulsars
- Pulsars seen by Compton Observatory EGRET instrument

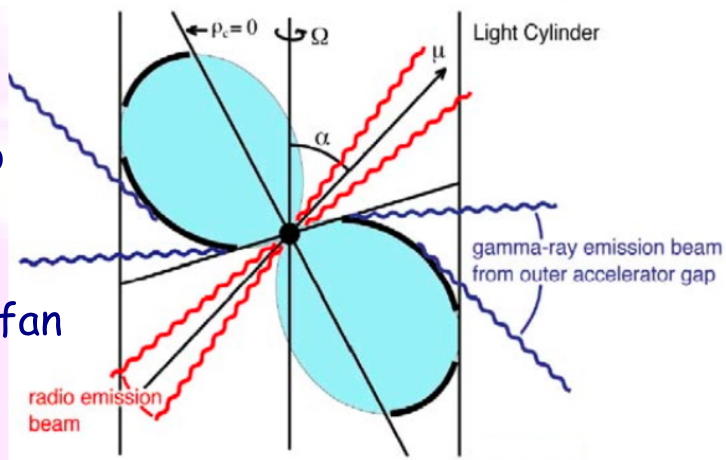
Spectral measurements and emission models





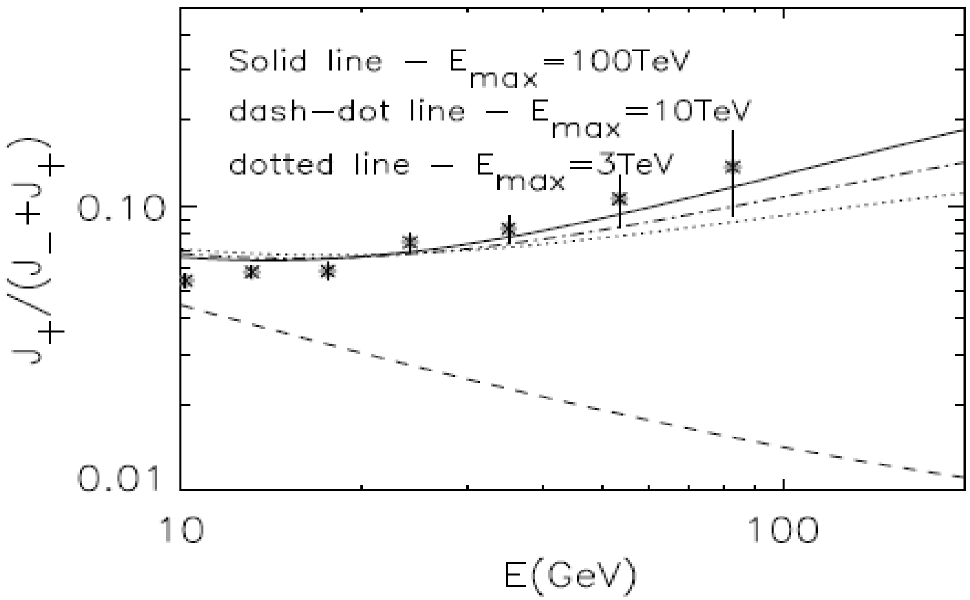
Evidence of γ-ray emission in the outer magnetopshere due to absence of super-exponential cutoff

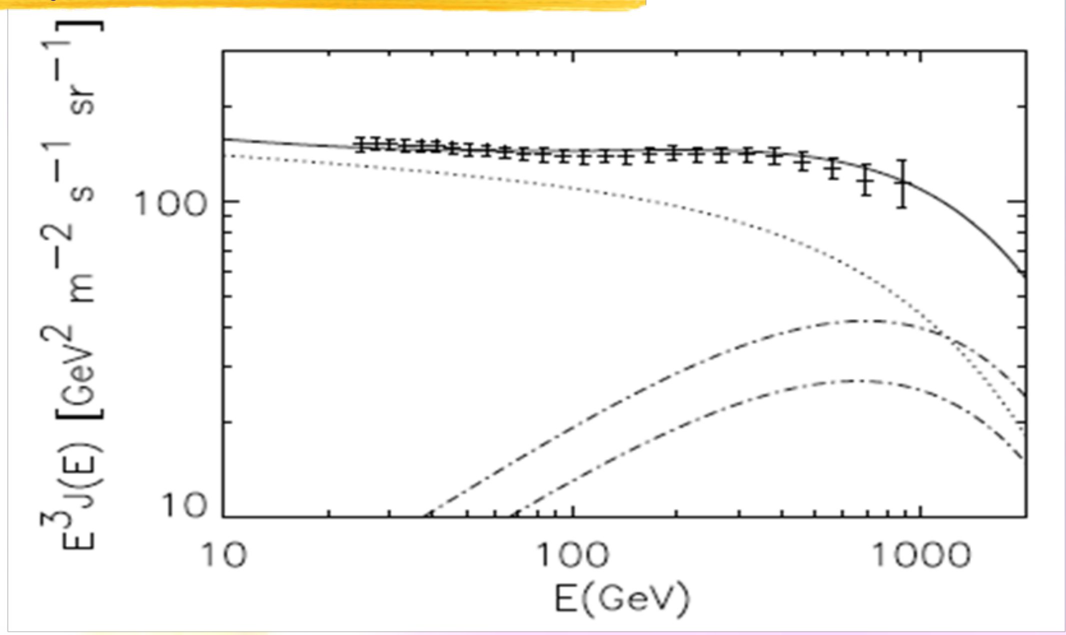
- –Radio and γ-ray fan beams separated
- – γ-ray only PSRs



QuickTime™ and a
Sorenson Video 3 decompressor
are needed to see this picture.

other Astrophysical solution





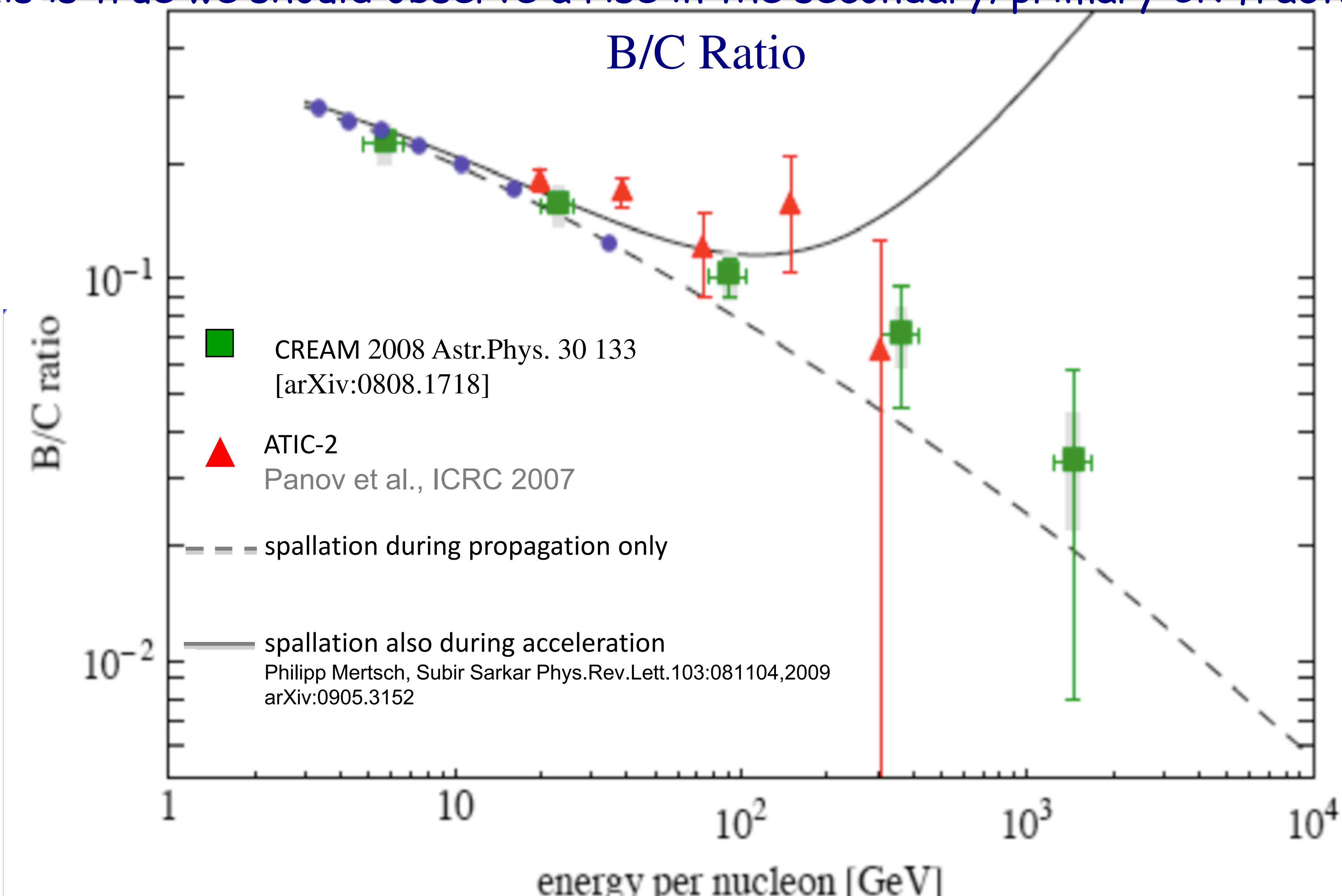
- Positrons created as secondary products of hadronic interactions inside the sources
- Secondary production takes place in the same region where cosmic rays are being accelerated

-> Therefore secondary positron have a very flat spectrum, which is responsible, after propagation in the Galaxy, for the observed positron excess

Blasi, arXiv:0903.2794

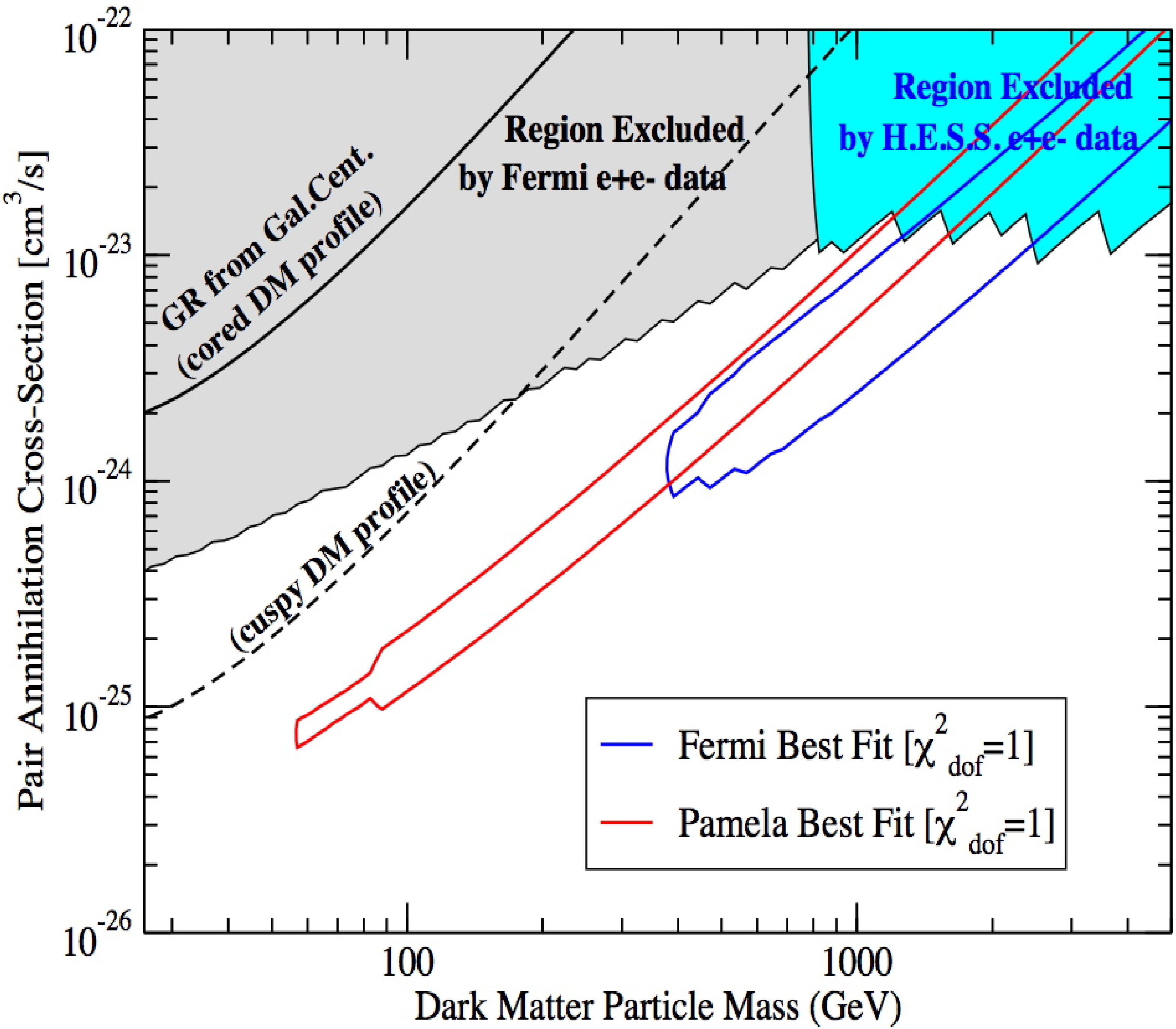
Positrons created as secondary products of hadronic interactions inside the sources (2)

if this is true we should observe a rise in the secondary/primary CR fraction



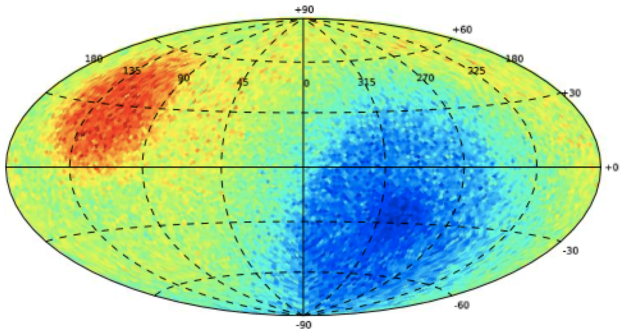
Lepto-philic Models

here we assume a democratic dark matter pair-annihilation branching ratio into each charged lepton species: 1/3 into e+e-, 1/3 into μ+ μ- and 1/3 into τ+ τ- Here too antiprotons are not produced in dark matter pair annihilation.

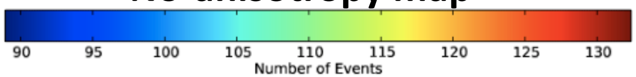


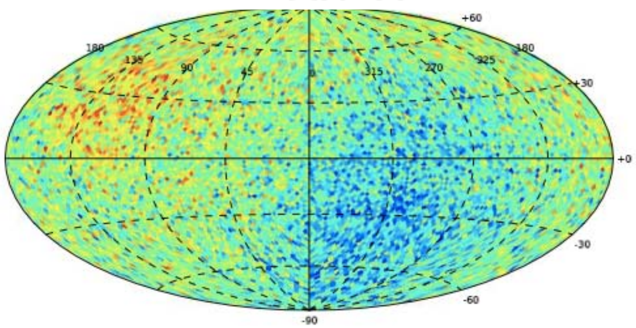
[arXiv:0905.0636]

Cosmic Ray Electrons Anisotropy

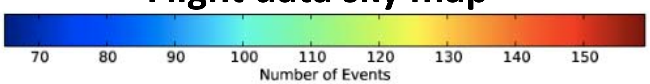


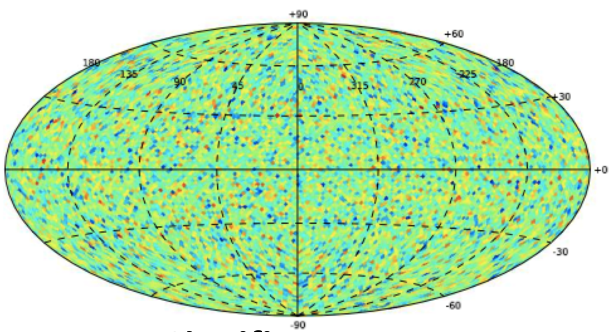
No-anisotropy map



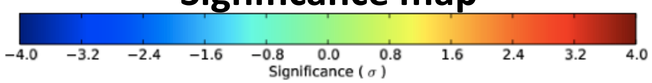


Flight data sky map





Significance map

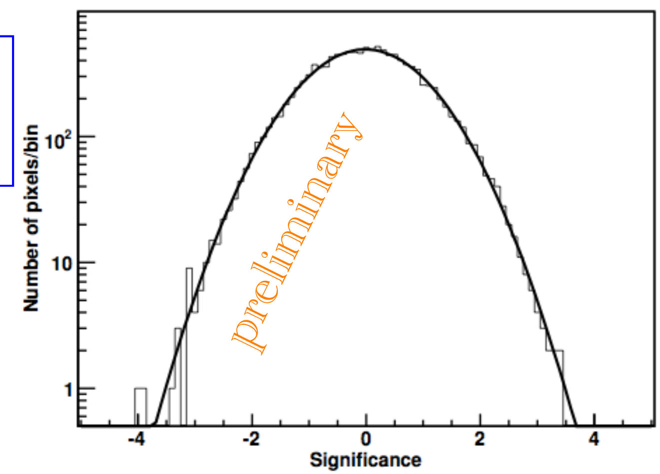


More than 1.6 million electron events with energy above 60 GeV have been analyzed on anisotropy

•Upper limit for the dipole anisotropy has been set to 0.5 - 5% depending on the energy

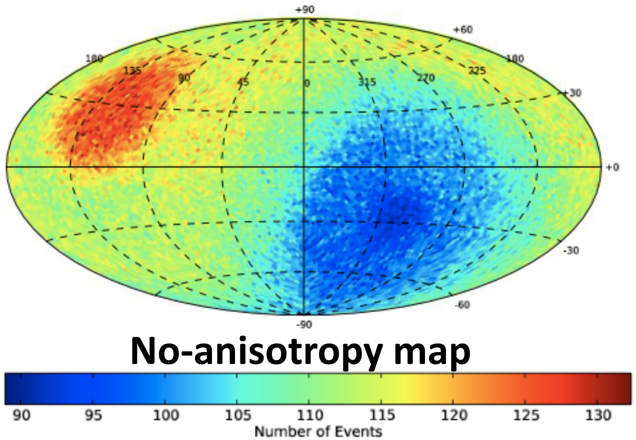
• Upper limit on fractional anisotropic excess ranges from a fraction to about one percent depending on the minimum energy and the anisotropy's angular scale

Distribution of significance, fitted by a Gaussian →

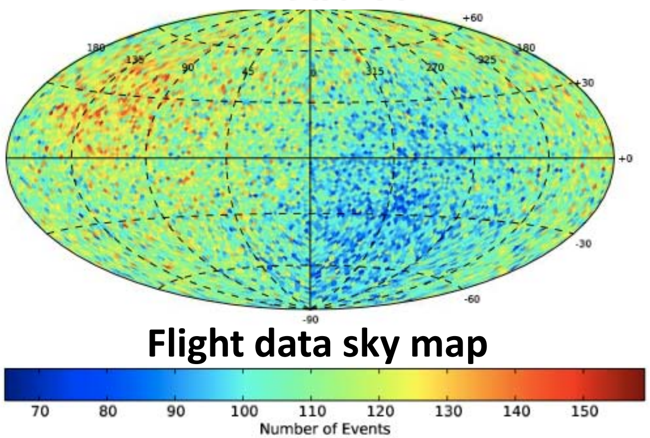


Fermi Coll. Physical Review D 82, 092003 (2010) [arXiv:1008.5119]

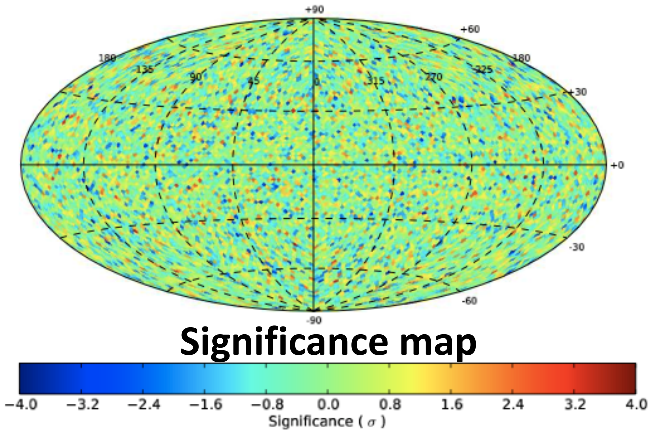
Cosmic Ray Electrons Anisotropy



No-anisotropy map



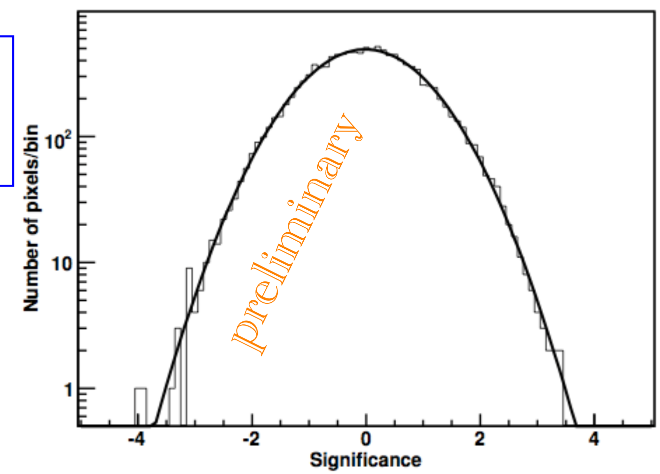
Flight data sky map



Significance map

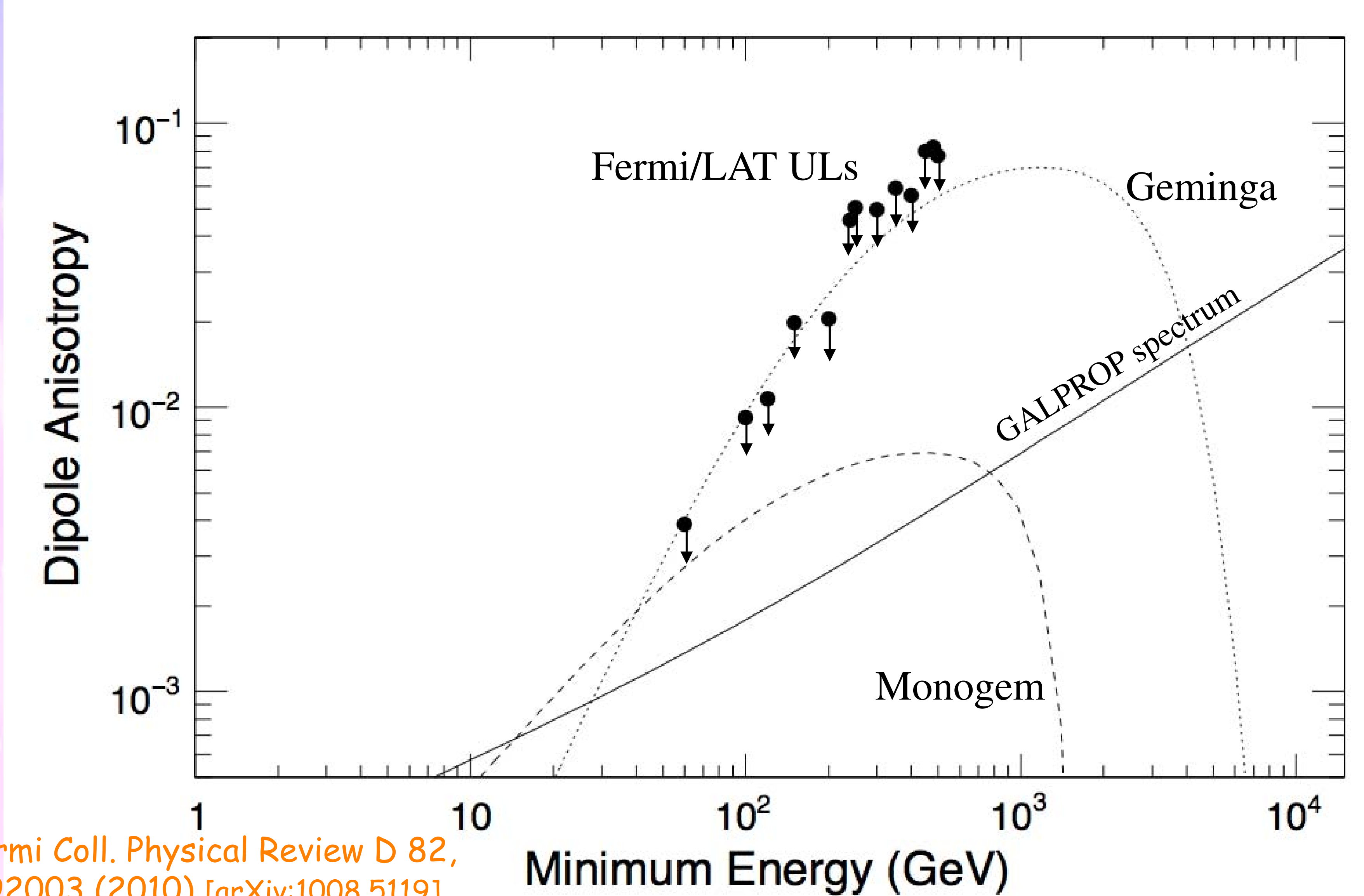
the levels of anisotropy expected for Vela-like and Monogem-like sources (i.e. sources with similar distances and ages) seem to be higher than the scale of anisotropies excluded by the results However, it is worth to point out that the model results are affected by large uncertainties related to the choice of the free parameters

Distribution of significance, fitted by a Gaussian →



Fermi Coll. Physical Review D 82, 092003 (2010) [arXiv:1008.5119]

electron + positron expected anisotropy in the directions of Monogem and Geminga



Fermi Coll. Physical Review D 82, 092003 (2010) [arXiv:1008.5119]

Search Strategies

Satellites:

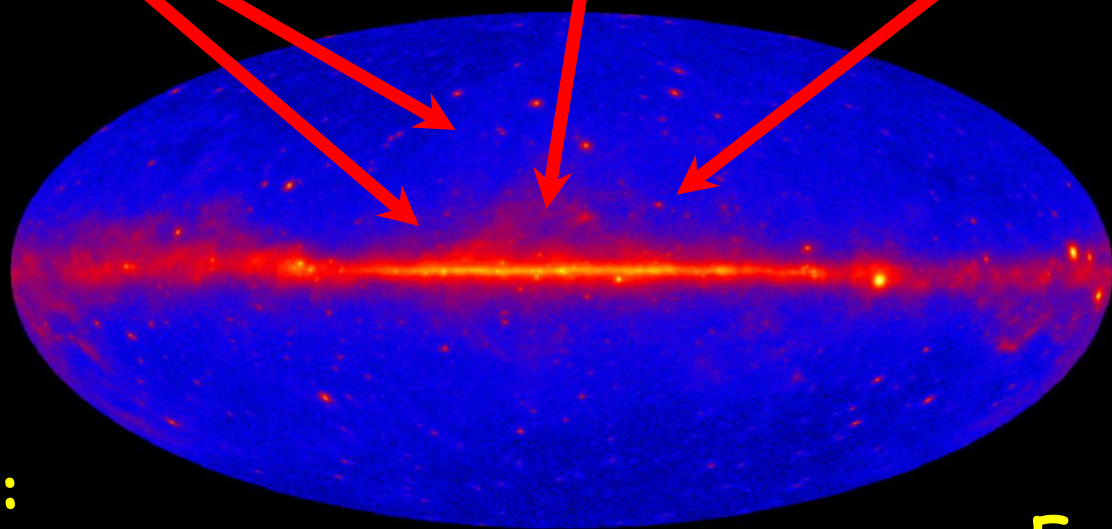
Low background and good source id, but low statistics

Galactic center:

Good statistics but source confusion/diffuse background

Milky Way halo:

Large statistics but diffuse background



And electrons!

and

Anisotropies

Spectral lines:

No astrophysical uncertainties, good source id, but low statistics

Galaxy clusters:

Low background but low statistics

Extra-galactic:

Large statistics, but astrophysics,galactic diffuse background

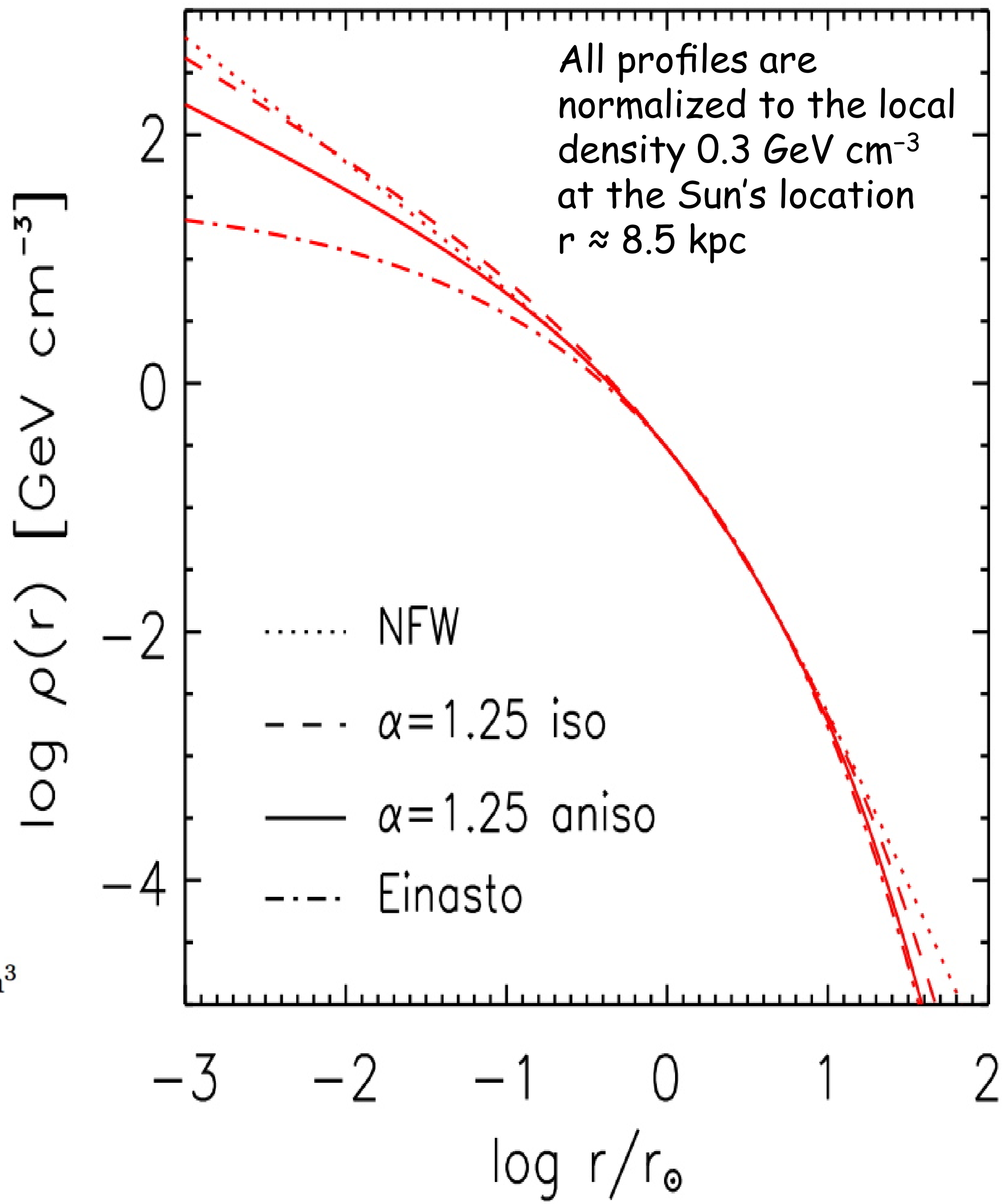
-launch sensitivities published in Baltz et al., 2008, JCAP 0807:013 [astro-ph/0806.291

Milky Way Dark Matter Profiles

$$\rho(r) = \rho_{\odot} \left[\frac{r_{\odot}}{r}\right]^{\gamma} \left[\frac{1 + (r_{\odot}/r_s)^{\alpha}}{1 + (r/r_s)^{\alpha}}\right]^{(\beta-\gamma)/\alpha}$$

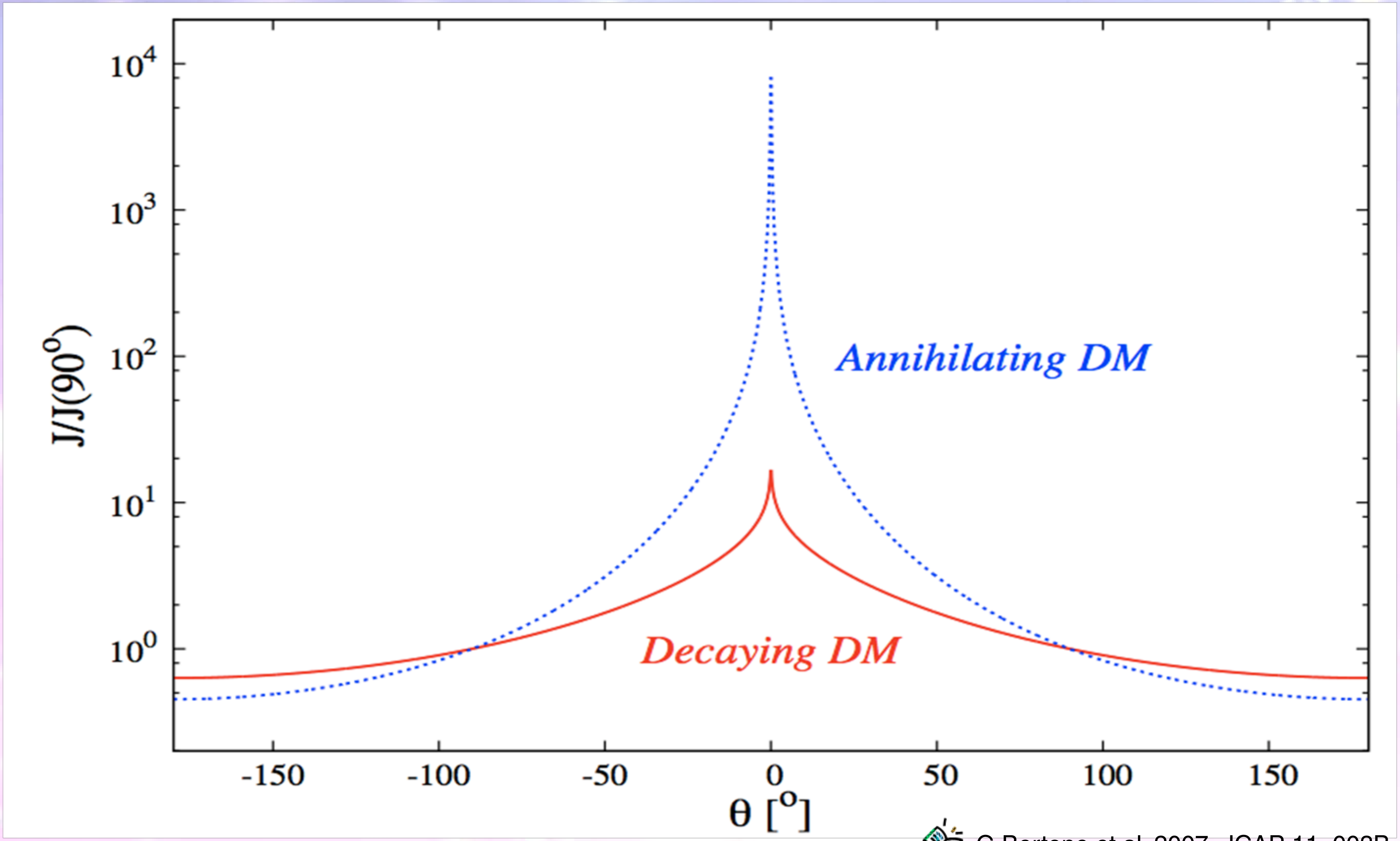
Halo model	α	β	γ	r_s in kpc
Cored isothermal	2	2	0	5
Navarro, Frenk, White	1	3	1	20
Moore	1	3	1.16	30

Einasto | $\alpha = 0.17$ $r_s = 20\,\text{kpc}$ $\rho_s = 0.06\,\text{GeV/cm}^3$



A.Lapi et al. arXiv:0912.1766

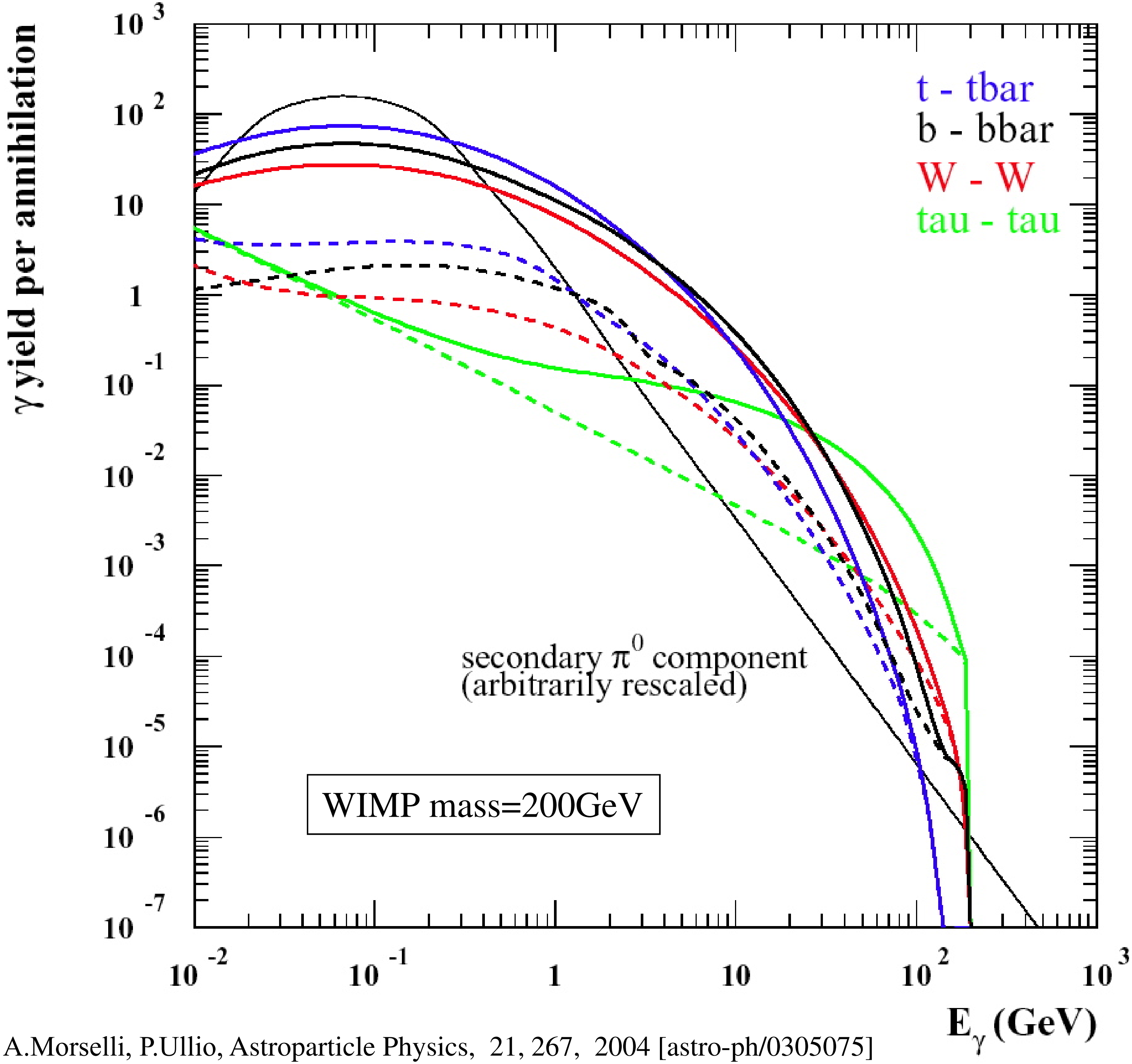
Different spatial behaviour for decaying or annihilating dark matter



G.Bertone et al. 2007, JCAP 11, 003B

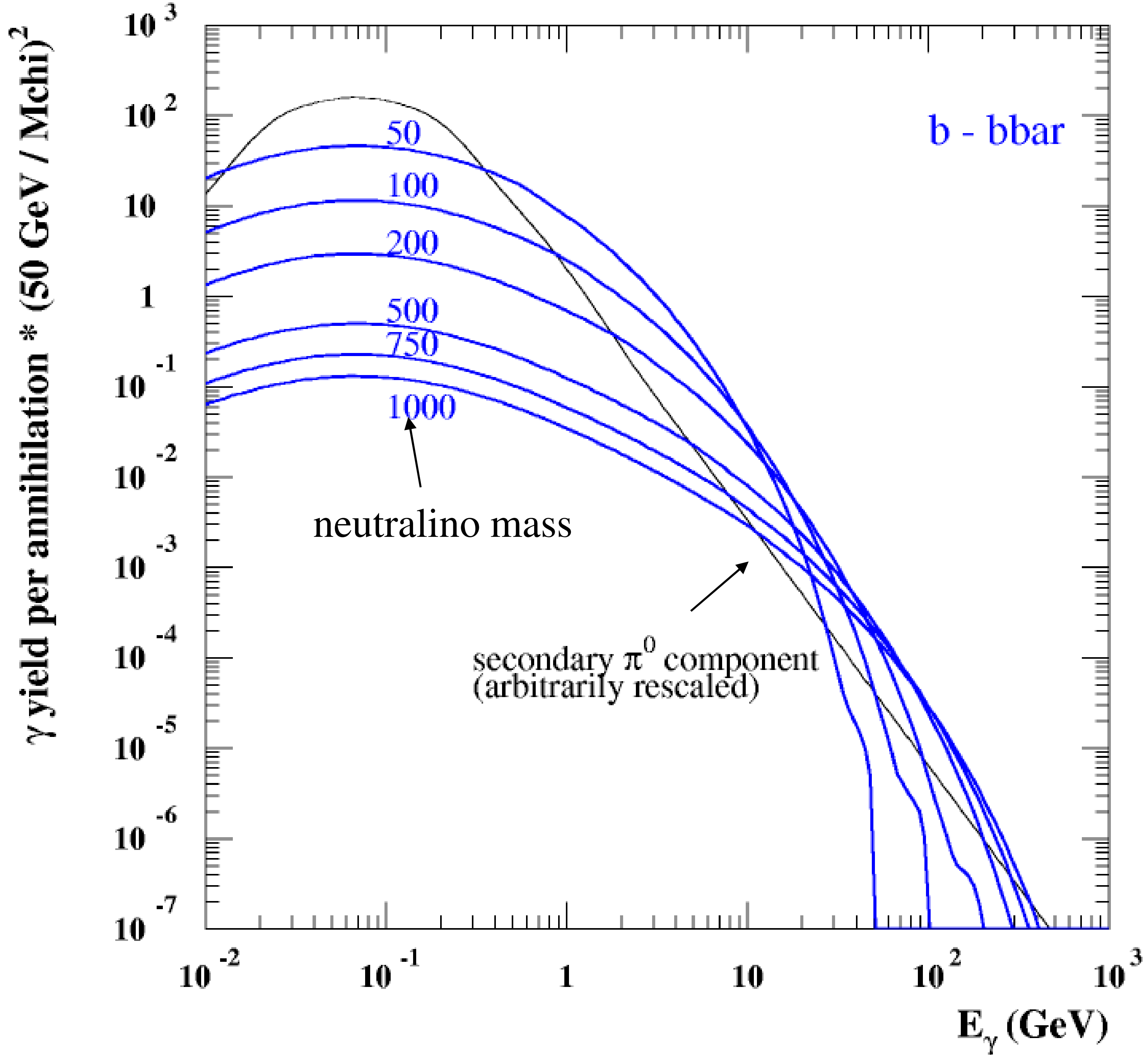
The angular profile of the gamma-ray signal is shown, as function of the angle θ to the centre of the galaxy for a Navarro-Frenk-White (NFW) halo distribution for decaying DM, solid (red) line, compared to the case of self-annihilating DM, dashed (blue) line

Differential yield for each annihilation channel



A.Cesarini, F.Fucito, A.Lionetto, A.Morselli, P.Ullio, Astroparticle Physics, 21, 267, 2004 [astro-ph/0305075]

Differential yield for b bar



A.Cesarini, F.Fucito, A.Lionetto, A.Morselli, P.Ullio, Astroparticle Physics, 21, 267-285, 2004 [astro-ph/0305075]

Search for Dark Matter in the Galactic Center

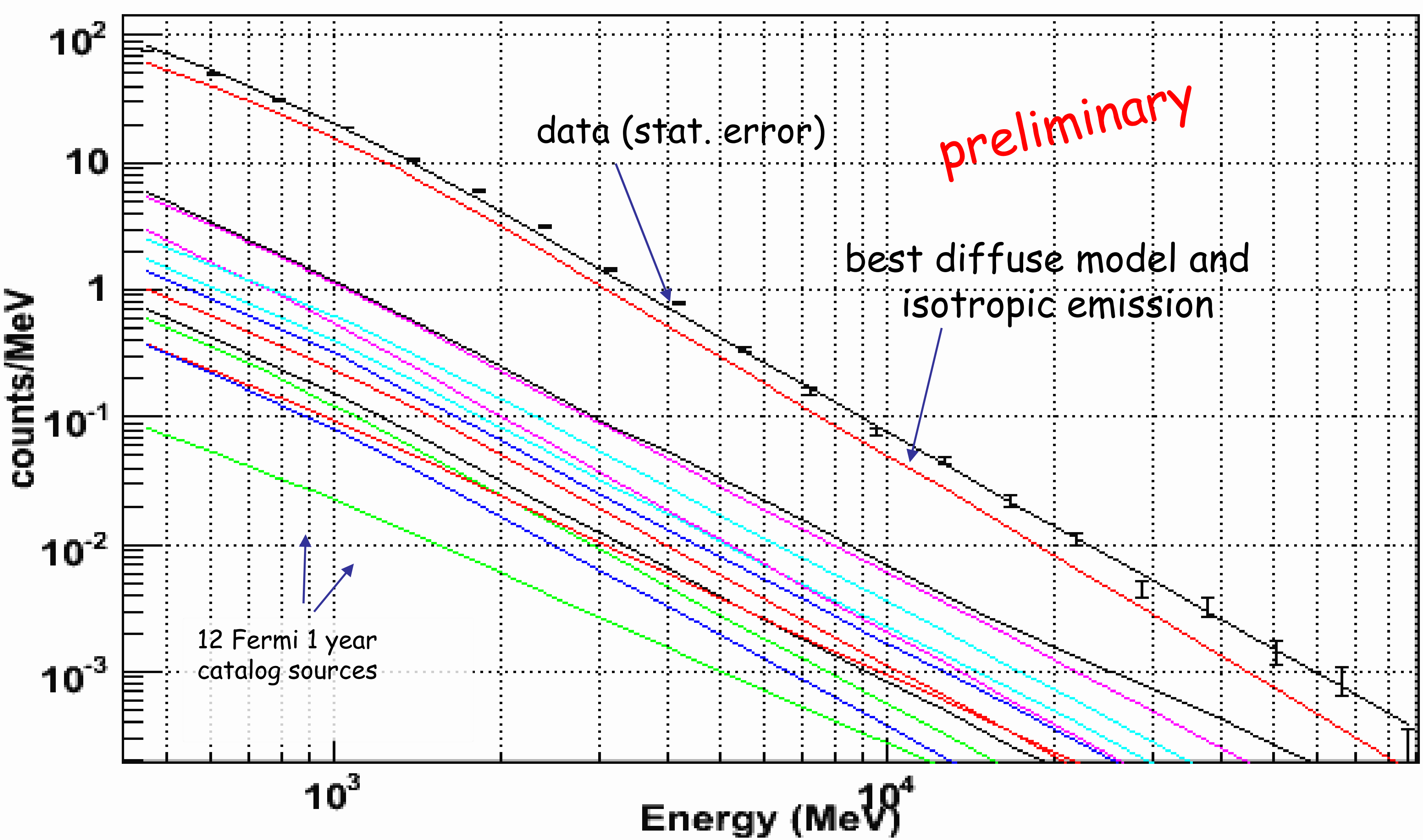
- Steep DM profiles ⇒ Expect large DM annihilation/decay signal from the GC!
- Good understanding of the astrophysical background is crucial to extract a potential DM signal from this complicated region of the sky:
  - source confusion: energetic sources near to or in the line of sight of the GC
  - diffuse emission modeling: uncertainties on the intensity and spectra of the CRs and distribution of gas and radiation field targets along the line of sight

Preliminary Analysis

7° x 7° Region Of Interest centered at RA=266.46° Dec=-28.97°

- 11 months of data
- events from 400 MeV to 100 GeV
- IRFs Pass6_v3
- Diffuse Class events, converting in the front part of the tracker
- Model of the Galactic Center includes:
- 11 sources from Fermi 1st year Catalog (inside or very near the ROI)
- Galactic and Extragalactic Diffuse Background
- Binned likelihood analysis using the GTLIKE tool, developed by the Fermi/LAT collaboration

Spectrum (E> 400 MeV, 7° x7° region centered on the Galactic Center analyzed with binned likelihood analysis)



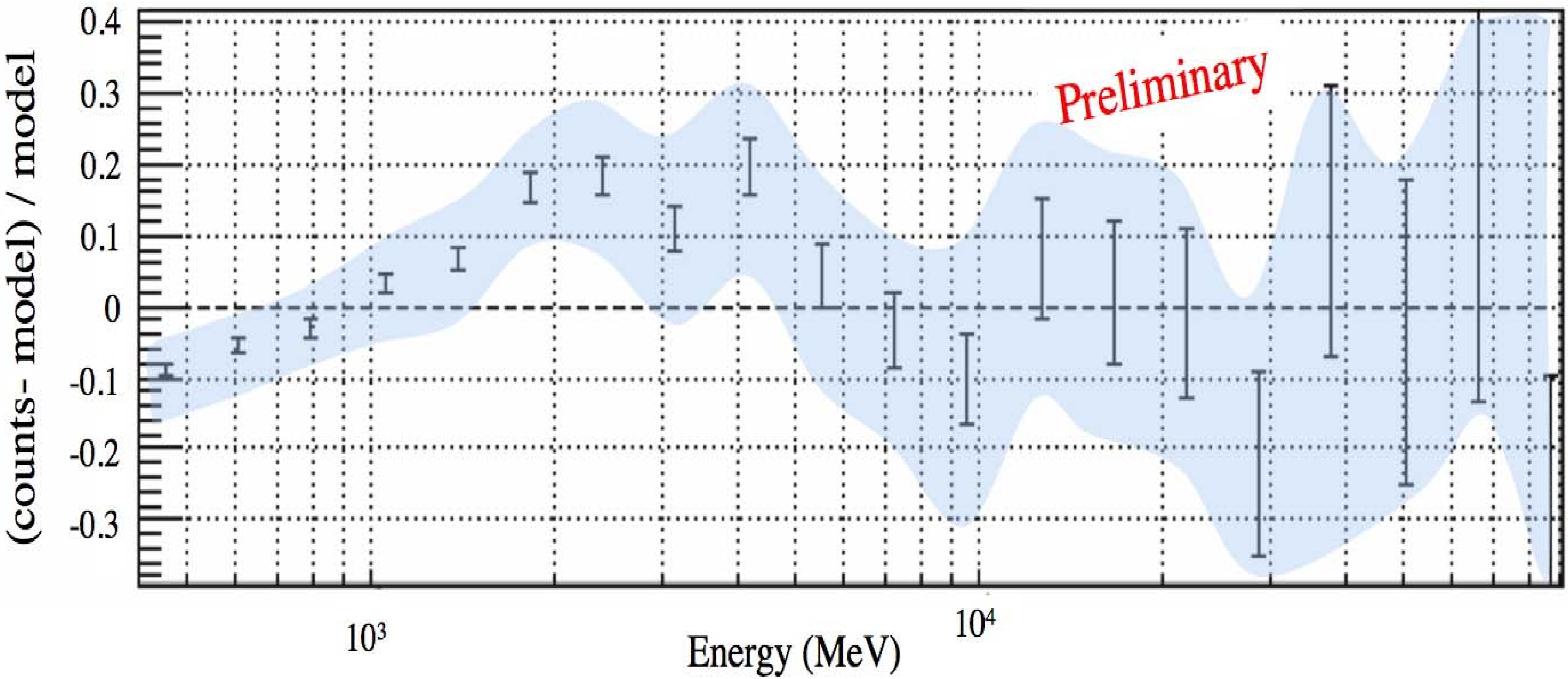
V.Vitale, A.Morselli on behalf of the Fermi LAT Coll., arXiv:0912.3828

GC Residuals

7° x7° region centered on the Galactic Center

11 months of data, E >400 MeV, front-converting events analyzed with binned likelihood analysis)

- The systematic uncertainty of the effective area (blue area) of the LAT is ~10% at 100 MeV, decreasing to 5% at 560 MeV and increasing to 20% at 10 GeV

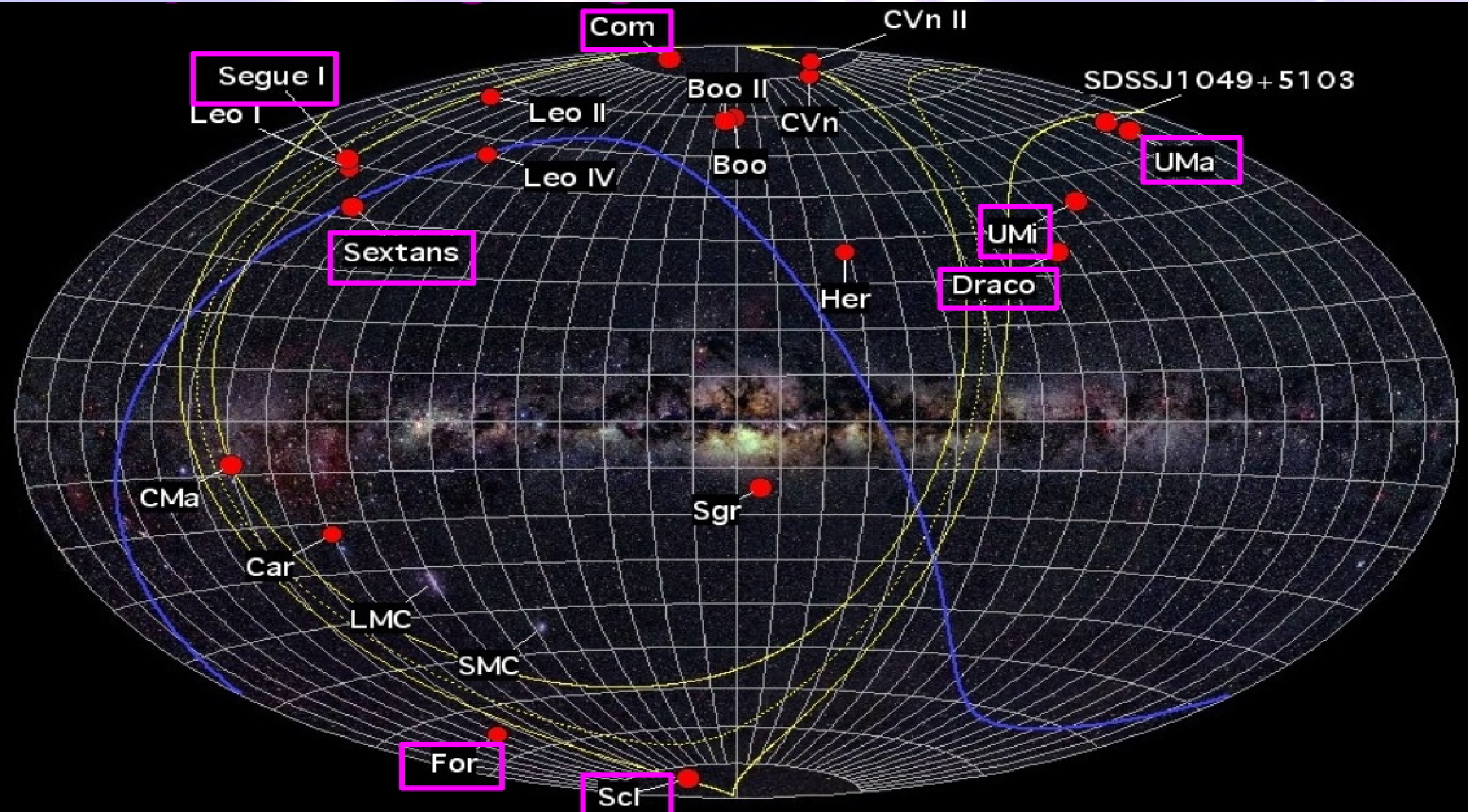


V.Vitale, A.Morselli on behalf of the Fermi LAT Coll., arXiv:0912.3828

Search for Dark Matter in the Galactic Center

- Model generally reproduces data well within uncertainties. The model somewhat under-predicts the data in the few GeV range (spatial residuals under investigation)
- Any attempt to disentangle a potential dark matter signal from the galactic center region requires a detailed understanding of the conventional astrophysics and instrumental effects
- More prosaic explanations must be ruled out before invoking a contribution from dark matter if an excess is found (e.g. modeling of the diffuse emission, unresolved sources, ...)
- Analysis in progress to updated constraints on annihilation cross section

Dwarf spheroidal galaxies (dSph) : promising targets for DM detection



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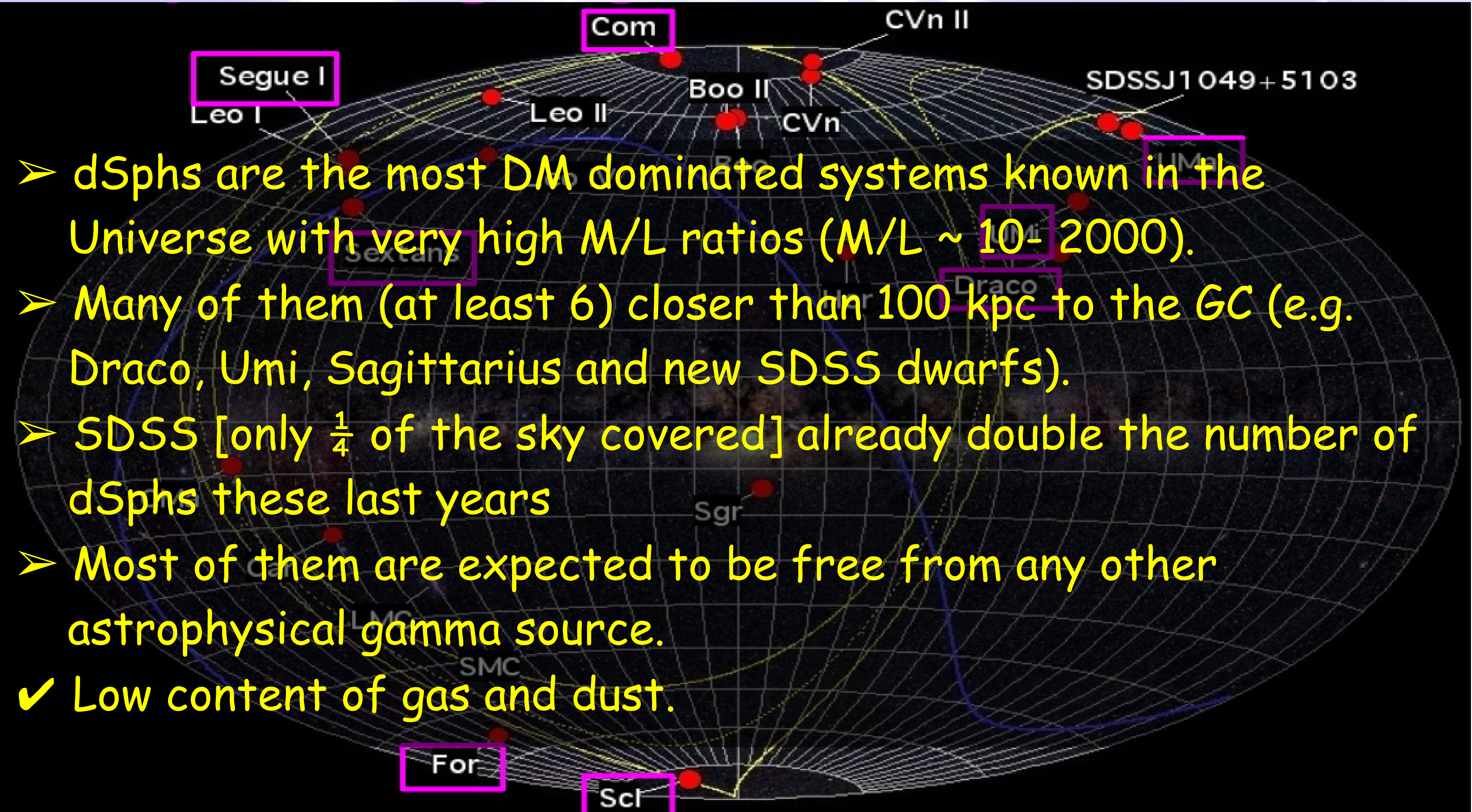
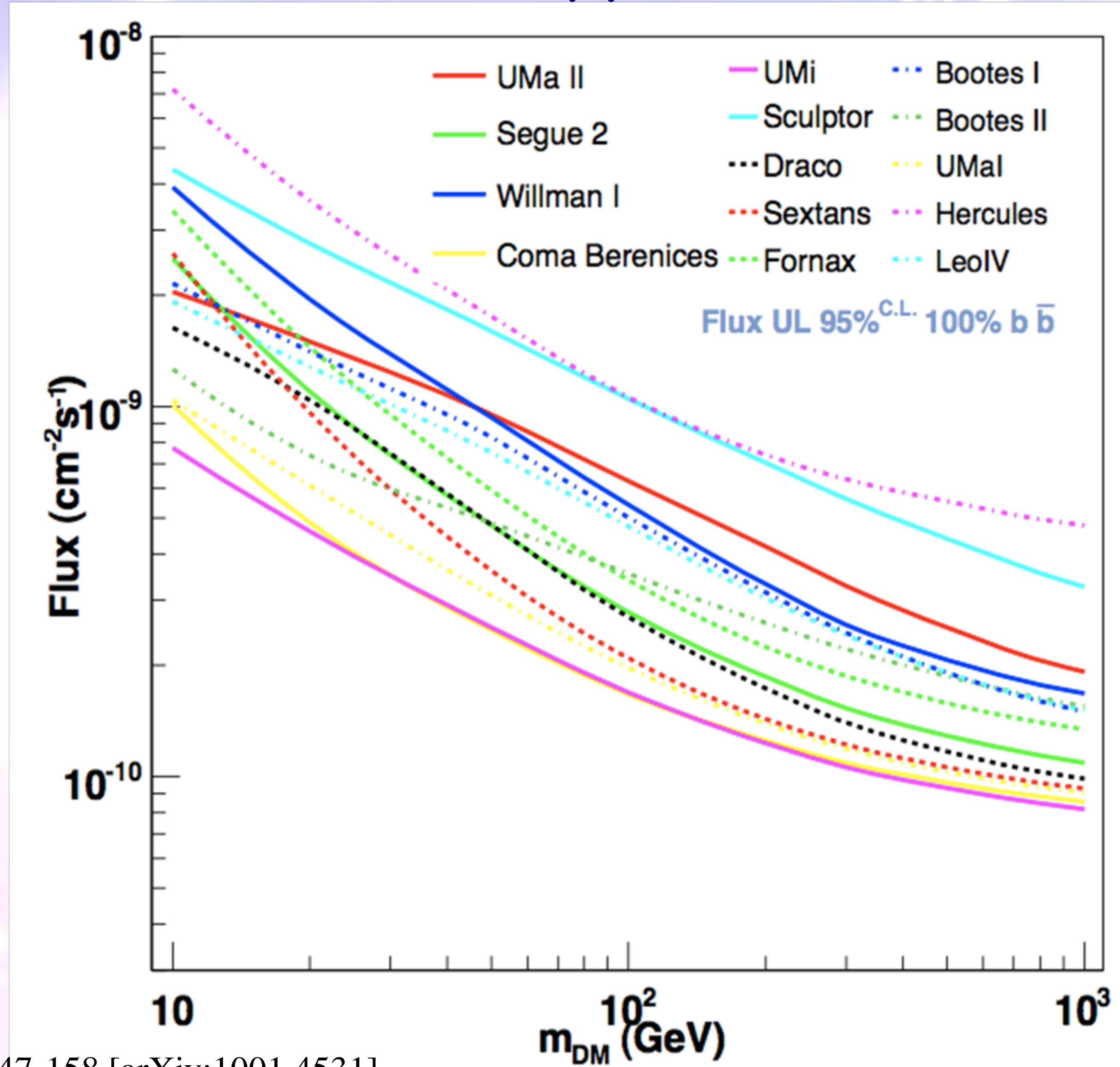


- ➢ dSphs are the most DM dominated systems known in the Universe with very high M/L ratios (M/L ~ 10- 2000).
- ➢ Many of them (at least 6) closer than 100 kpc to the GC (e.g. Draco, Umi, Sagittarius and new SDSS dwarfs).
- ➢ SDSS [only $\frac{1}{4}$ of the sky covered] already double the number of dSphs these last years
- ➢ Most of them are expected to be free from any other astrophysical gamma source.
- ✔ Low content of gas and dust.

Dwarf Spheroidal Galaxies upper-limits

No detection by Fermi with 11 months of data. 95% flux upper limits are placed for several possible annihilation final states.

- Flux upper limits are combined with the DM density inferred by the stellar data(*) for a subset of 8 dSph (based on quality of stellar data) to extract constraints on <σv> vs WIMP mass for specific DM models



(*) stellar data from the Keck observatory (by Martinez, Bullock, Kaplinghat)

Fermi Coll. ApJ 712 (2010) 147-158 [arXiv:1001.4531]

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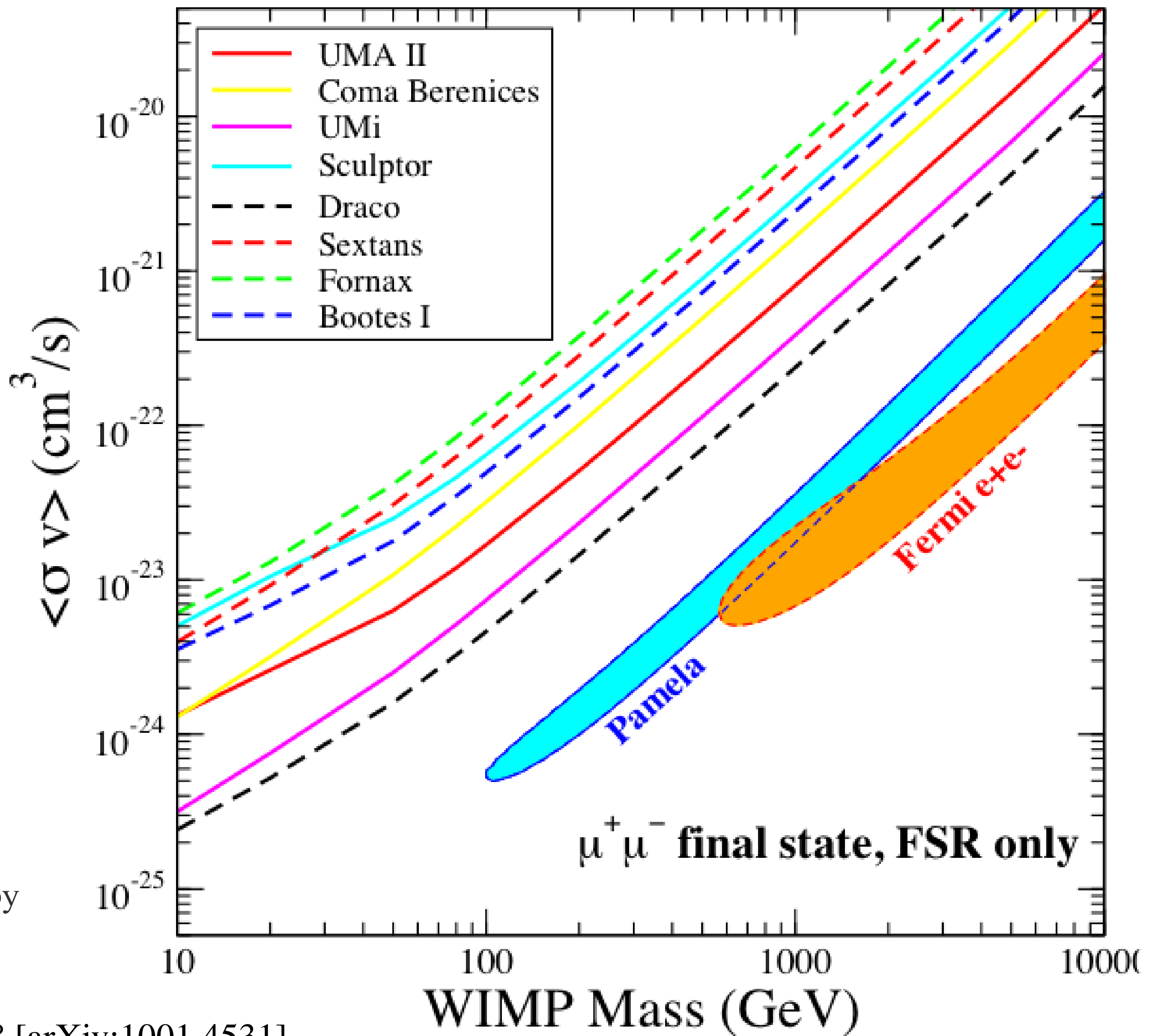

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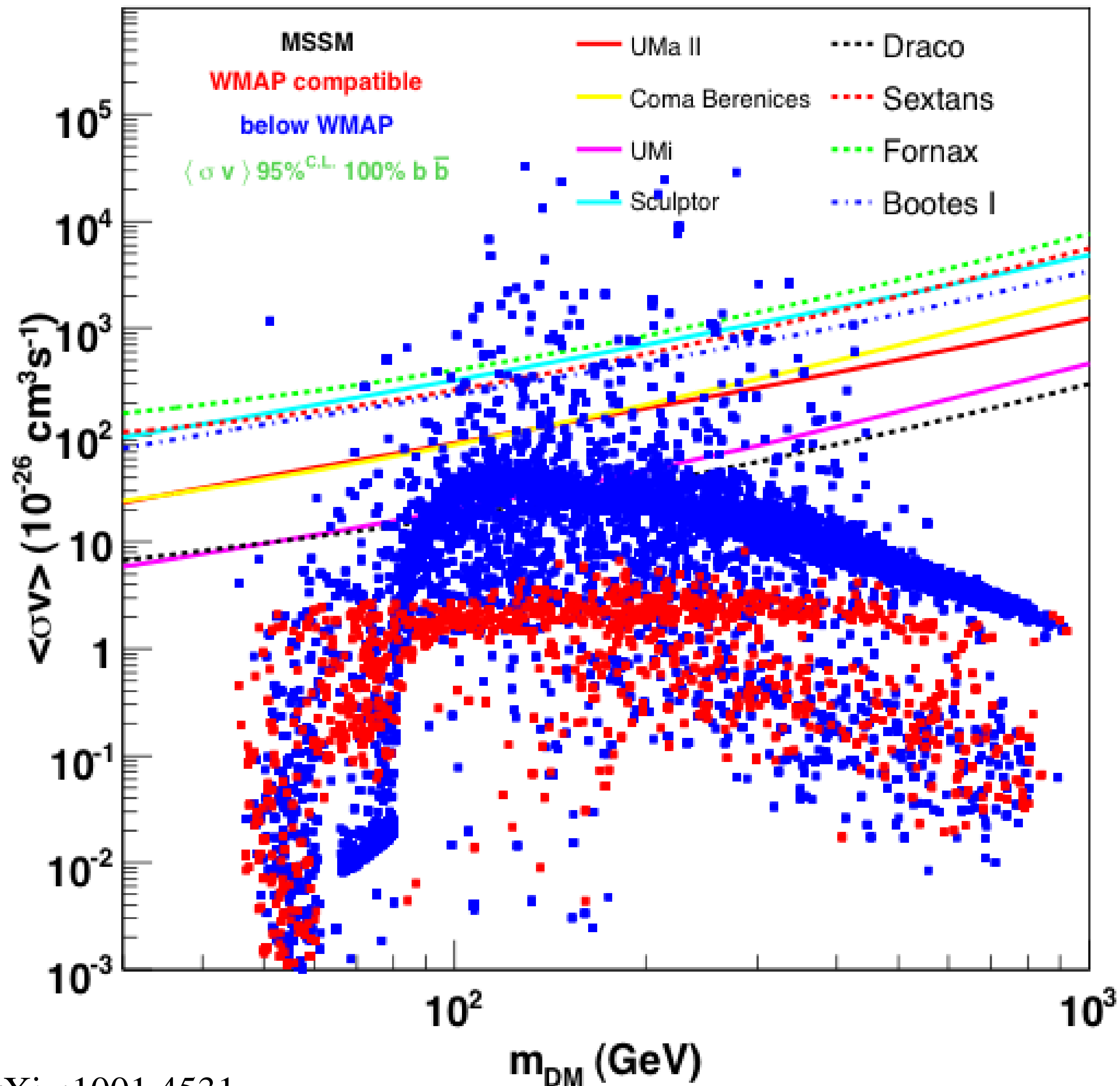


Fermi Coll. ApJ 712 (2010) 147-158 arXiv:1001.4531

Inverse Compton Emission and Diffusion in Dwarfs

- We expect significant IC gamma-ray emission for high mass WIMP models annihilating to leptonic final states.
- The IC flux depends strongly on the uncertain/unknown diffusion of cosmic rays in dwarfs.
- We assume a simple diffusion model similar to what is found for the Milky Way

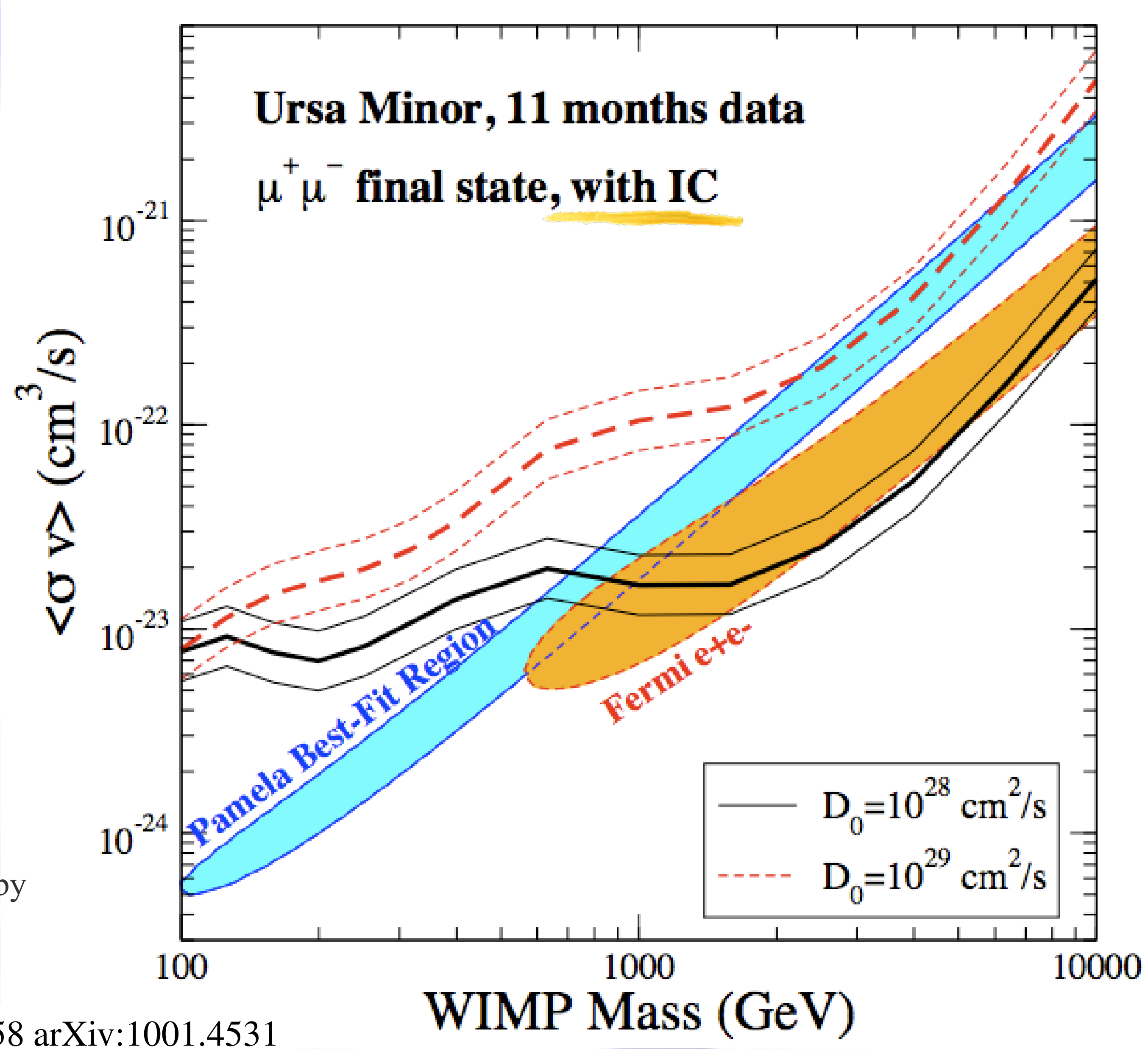
$D(E) = D_0 E^{1/3}$ with $D_0 = 10^{28}$ cm^2/s

(only galaxy with measurements, scaling to dwarfs ??)

Dwarf Spheroidal Galaxies upper-limits

Exclusion regions already cutting into interesting parameter space for some WIMP models

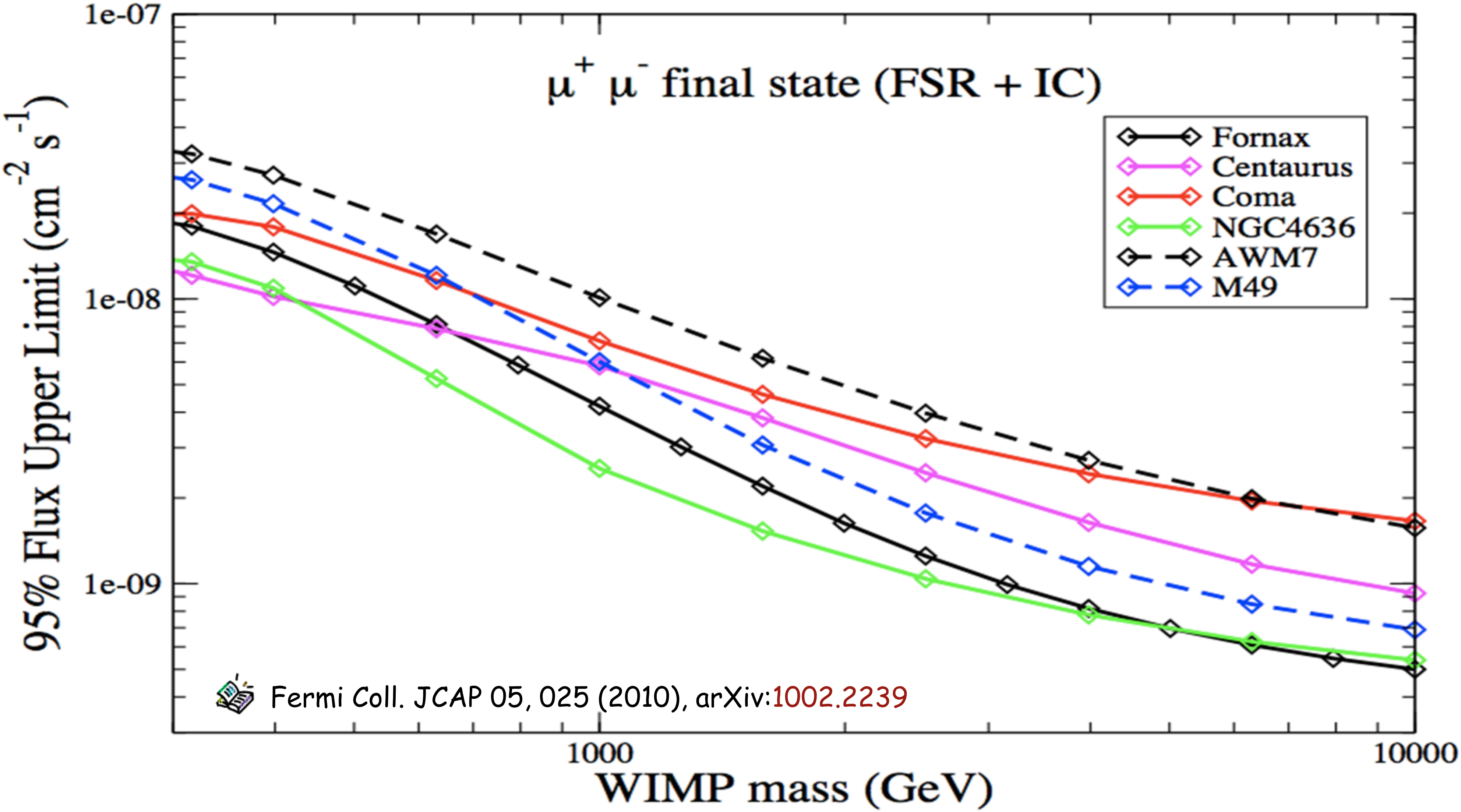
Stronger constraints can be derived if IC of electrons and positrons from DM annihilation off of the CMB is included, however diffusion in dwarfs is not known ⇒ use bracketing values of diffusion coefficients from cosmic rays in the Milky Way



(*) stellar data from the Keck observatory (by Martinez, Bullock, Kaplinghat)

Fermi Coll. ApJ 712 (2010) 147-158 arXiv:1001.4531

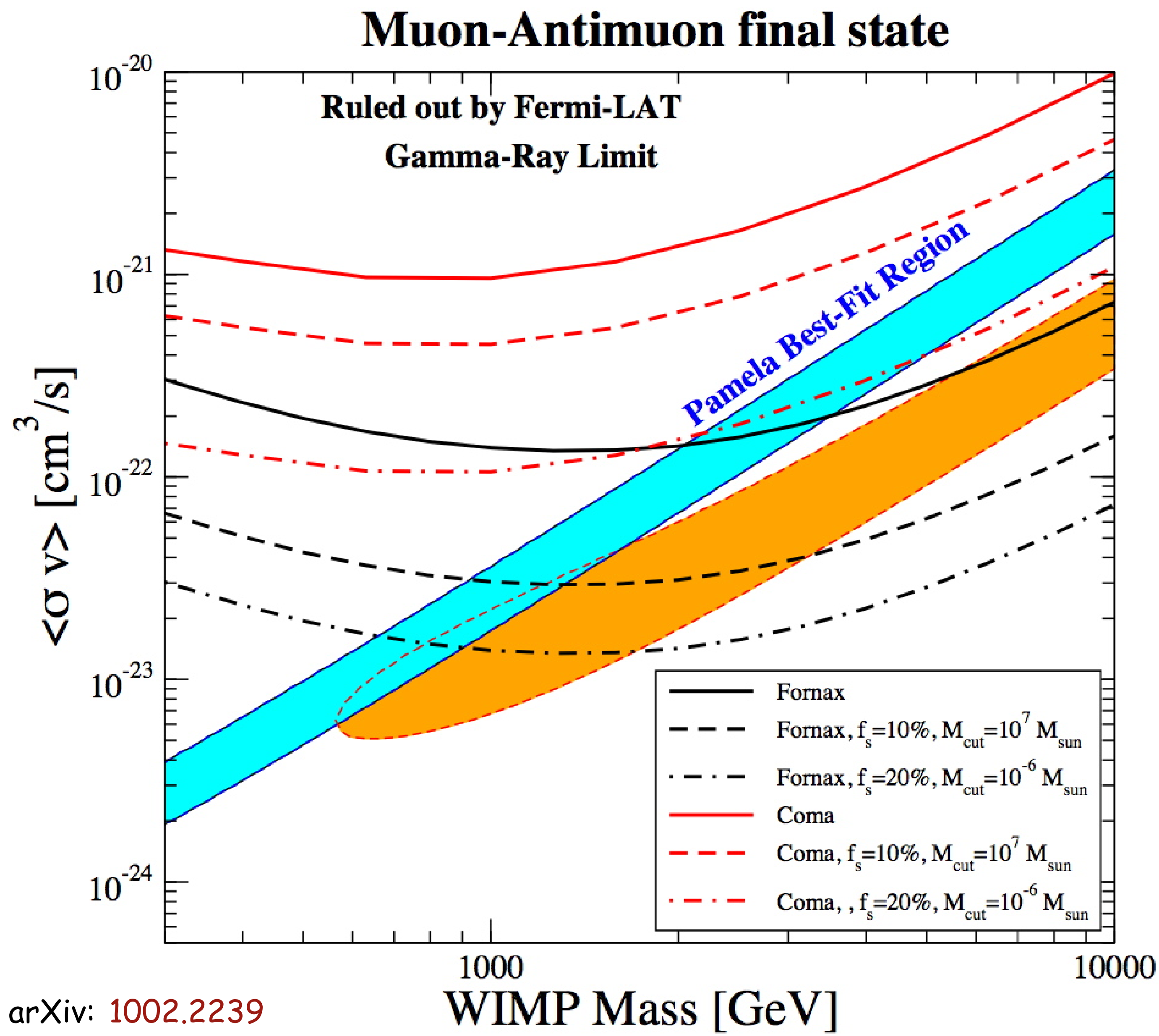
Galaxy Clusters upper-limits



Flux upper limits as a function of particle mass for an assumed μ+μ- final state, including the contributions of both FSR and IC gamma-ray emission

Galaxy Clusters upper-limits

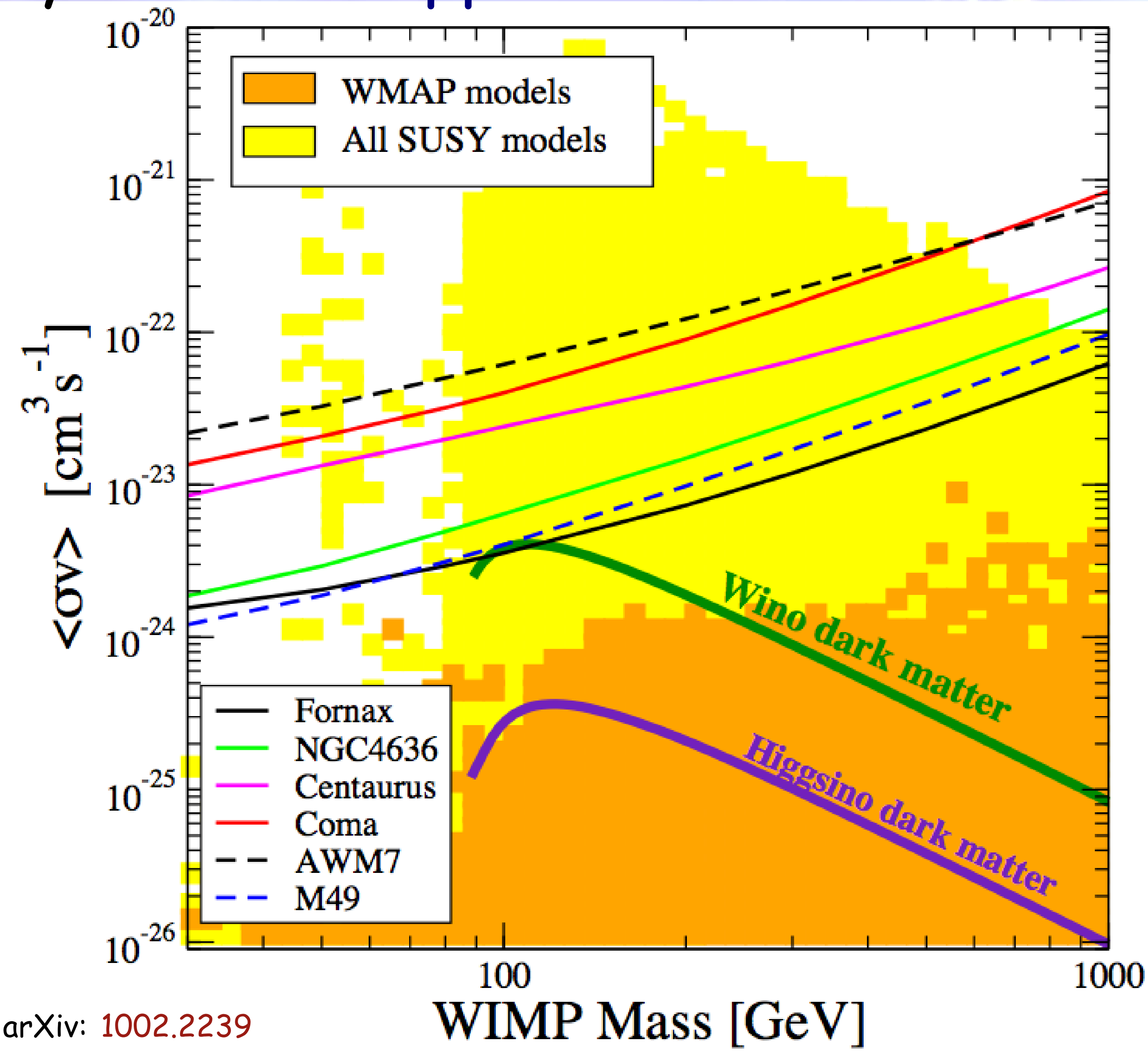
Stronger constraints on leptophilic DM models can be derived with galaxy clusters when the IC contribution off the CMB of secondary electrons (from DM annihilation) is included



Fermi Coll. JCAP 05, 025 (2010), arXiv: 1002.2239

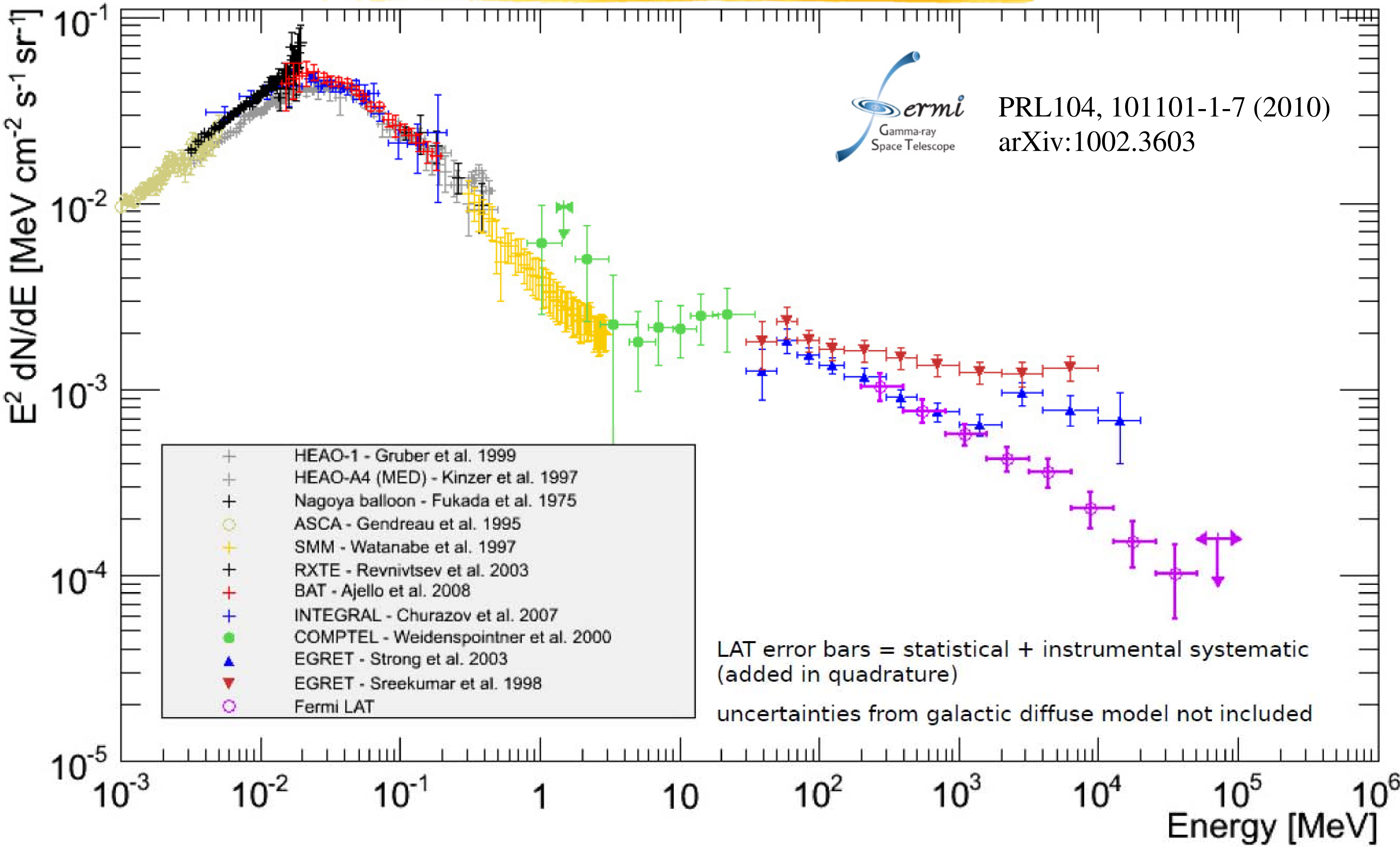
Galaxy Clusters upper-limits

- Constraints for a b-bbar final state are weaker than or comparable to (depending on the assumption on substructures) the ones obtained with dSph

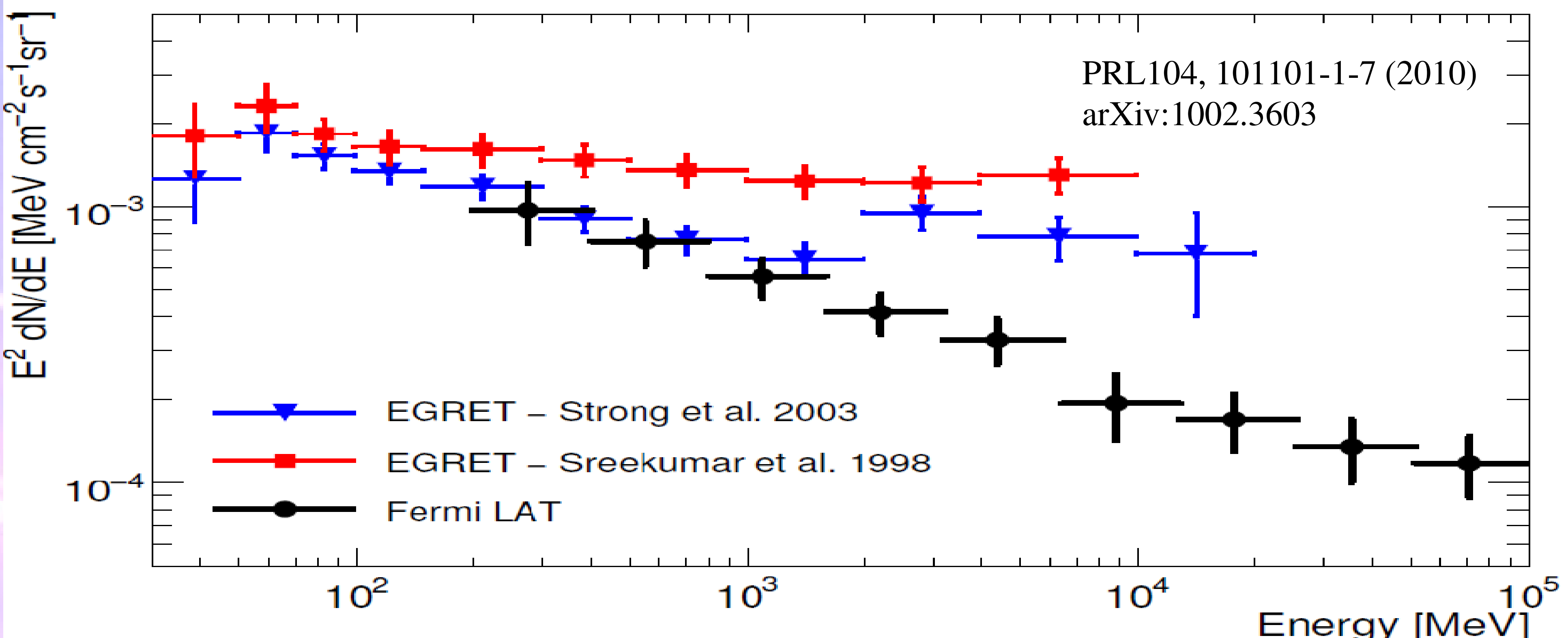


Fermi Coll. JCAP 05, 025 (2010), arXiv: 1002.2239

SED of the isotropic diffuse emission (1 keV-100 GeV)

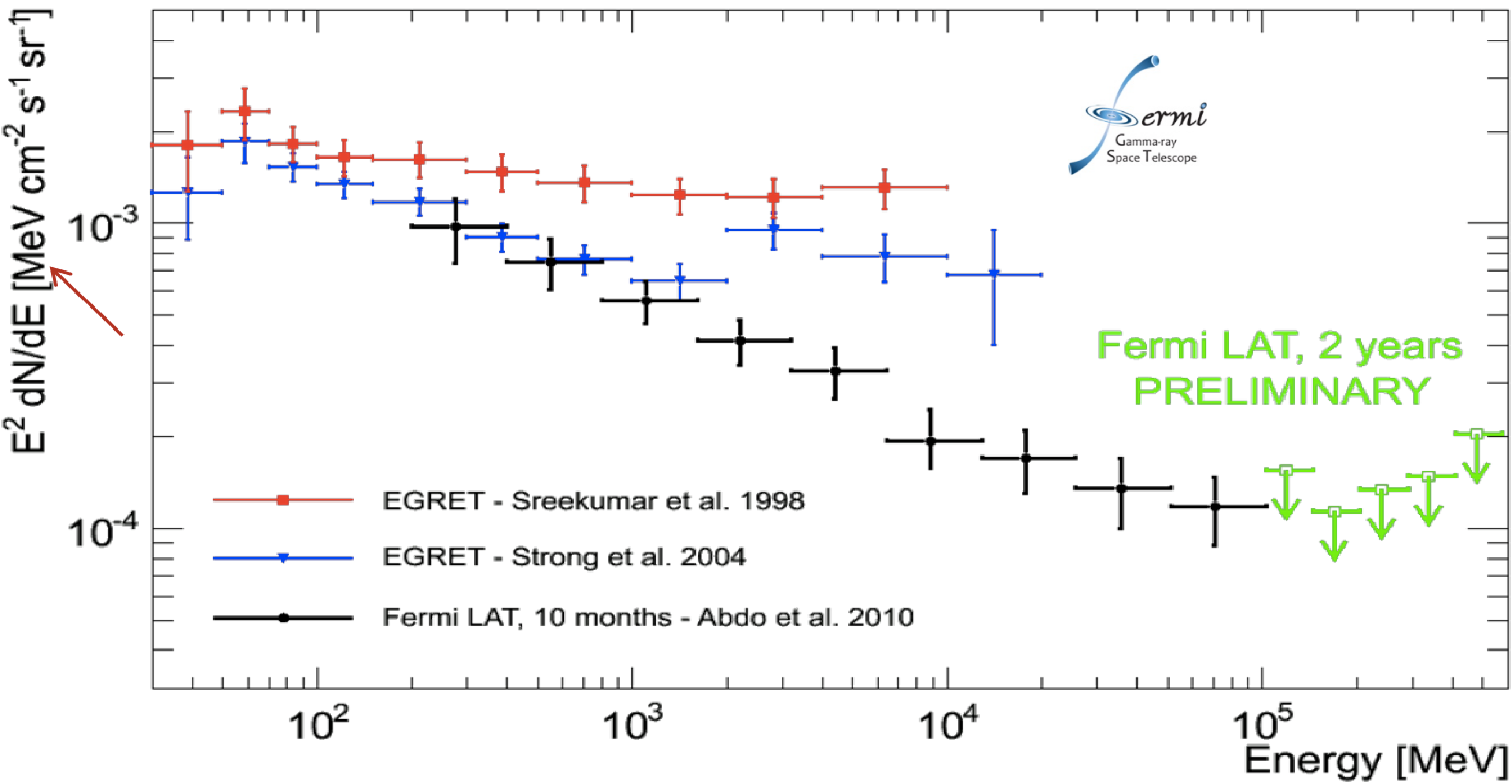


SED of the isotropic diffuse emission (1 keV-100 GeV)



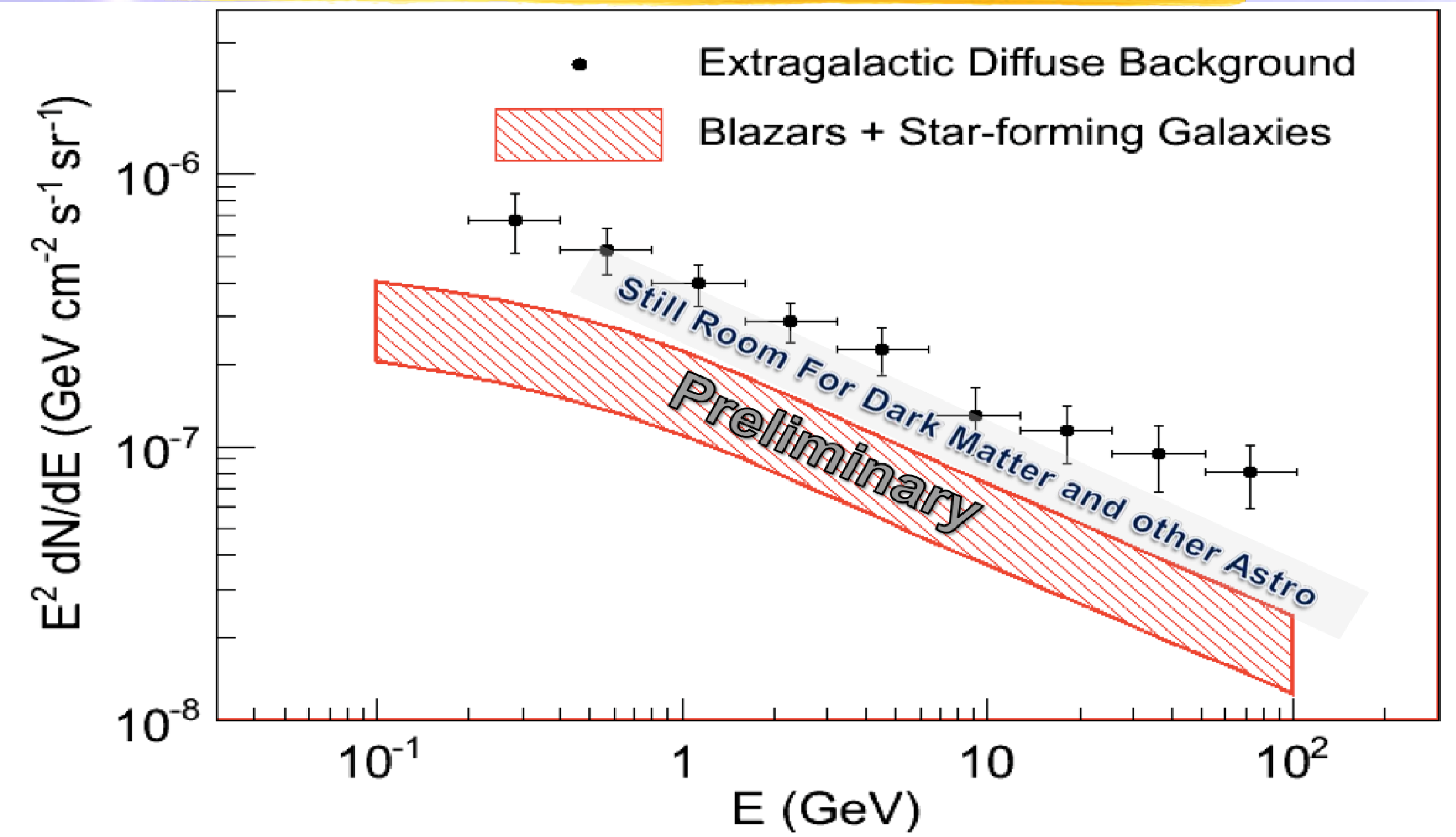
	Flux, E>100 MeV	spectral index
Fermi LAT	**1.03 +/- 0.17**	**2.41 +/- 0.05**
EGRET (Sreekumar et al., 1998)	1.45 +/- 0.05	2.13 +/- 0.03
EGRET (Strong et al. 2004)	1.11 +/- 0.10	
LAT + resolved sources below EGRET sensitivity	1.19 +/- 0.18	2.37 +/- 0.05
	x 10^{-5} cm^{-2} s^{-1} sr^{-1}	

SED of the isotropic diffuse emission (1 keV-100 GeV)



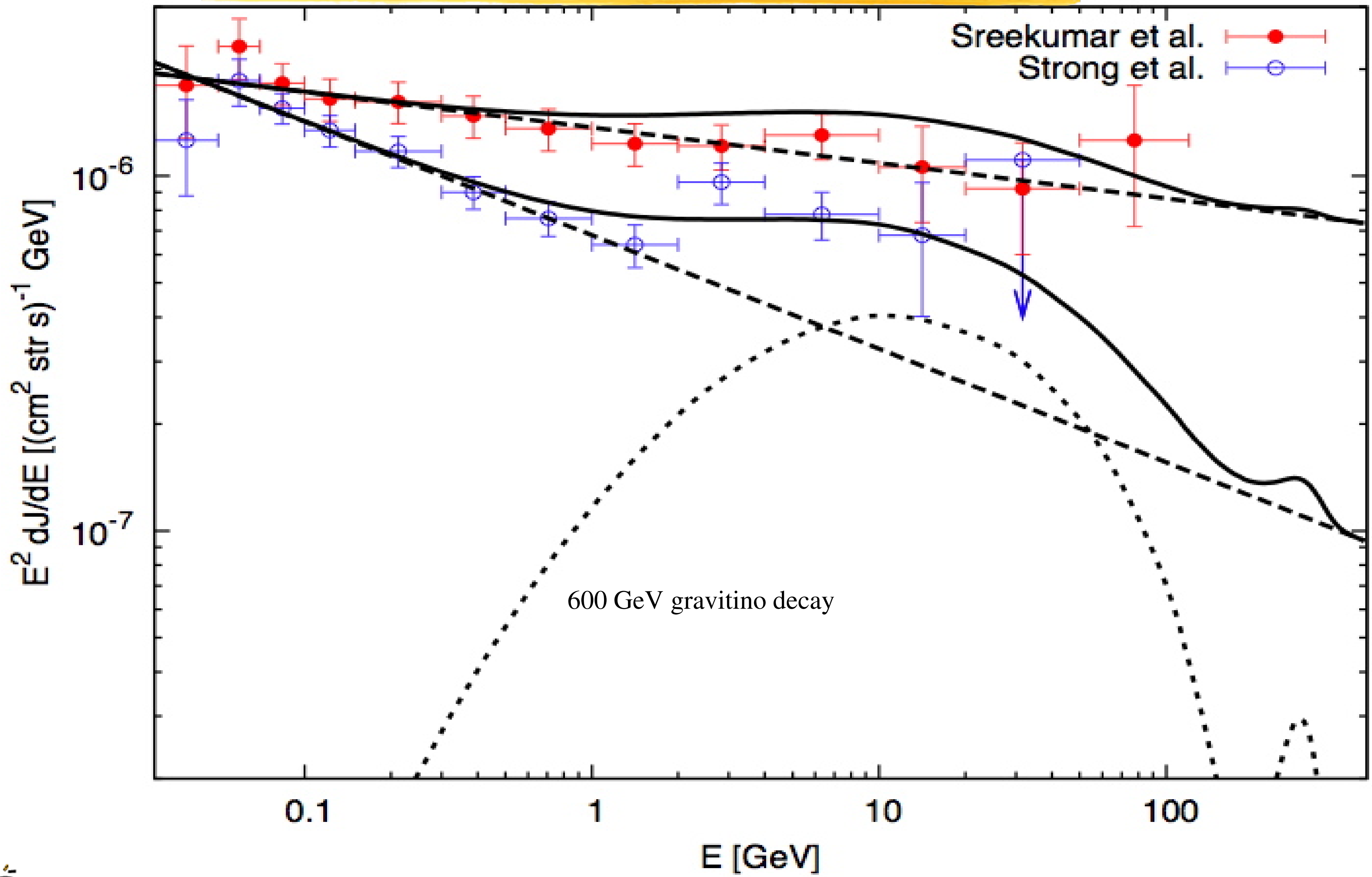
For E> 100 GeV the limits are 95% upper limits and include a 20% uncertainty on the LAT effective area at high energies

Comparison of the Extragalactic Diffuse γ-ray Background to Calculations of Contributions from Blazars + Star-forming Galaxies



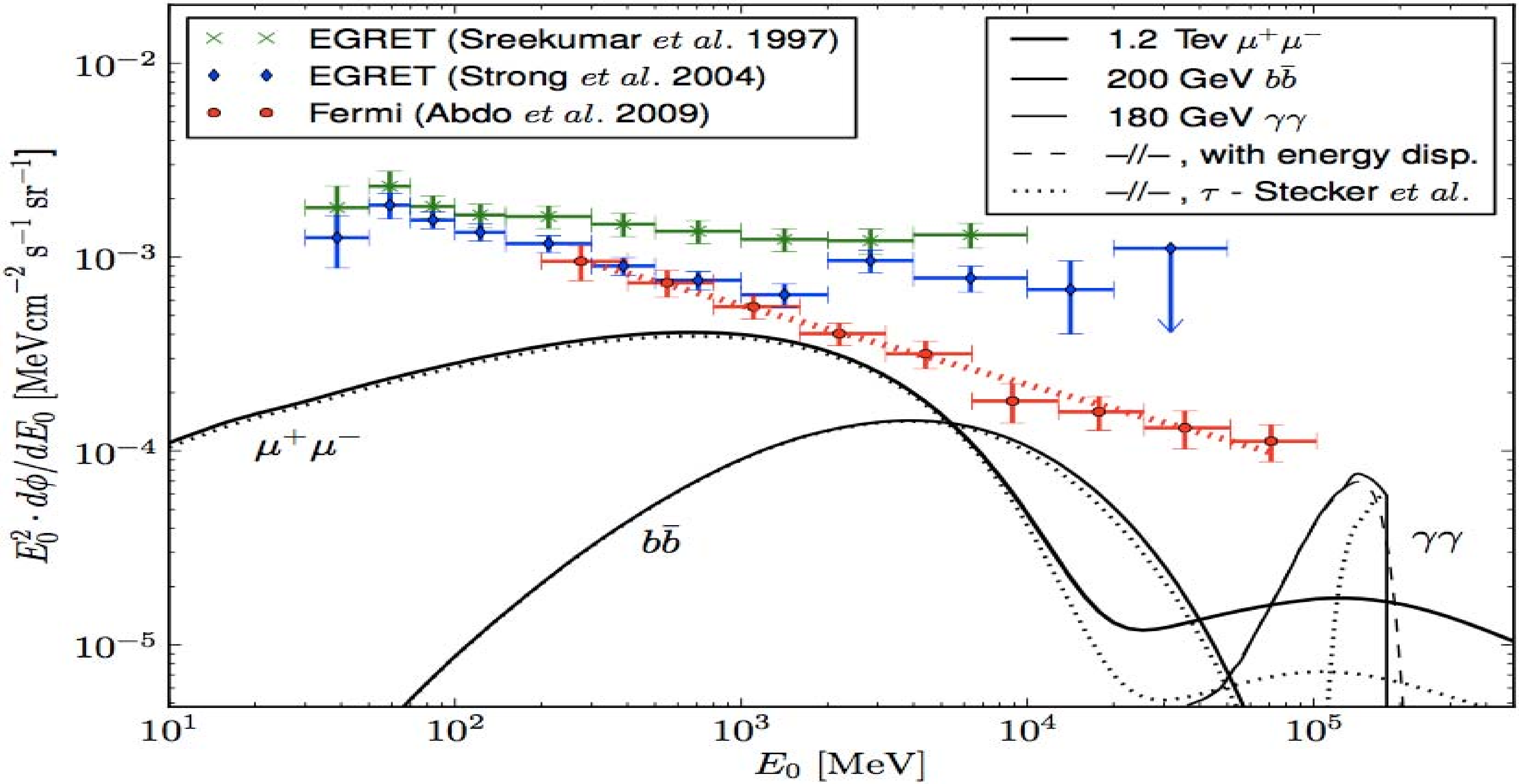
Blazars: Abdo, A. A., et al. [Fermi Coll.] 2010, ApJ. **720**, 435
Star forming galaxies : Fermi Coll. in preparation

extragalactic gamma-ray spectrum



W. Buchmüller, A. Ibarra, T. Shindou, F. Takayama, D. Tranl, arXiv:0906.1187

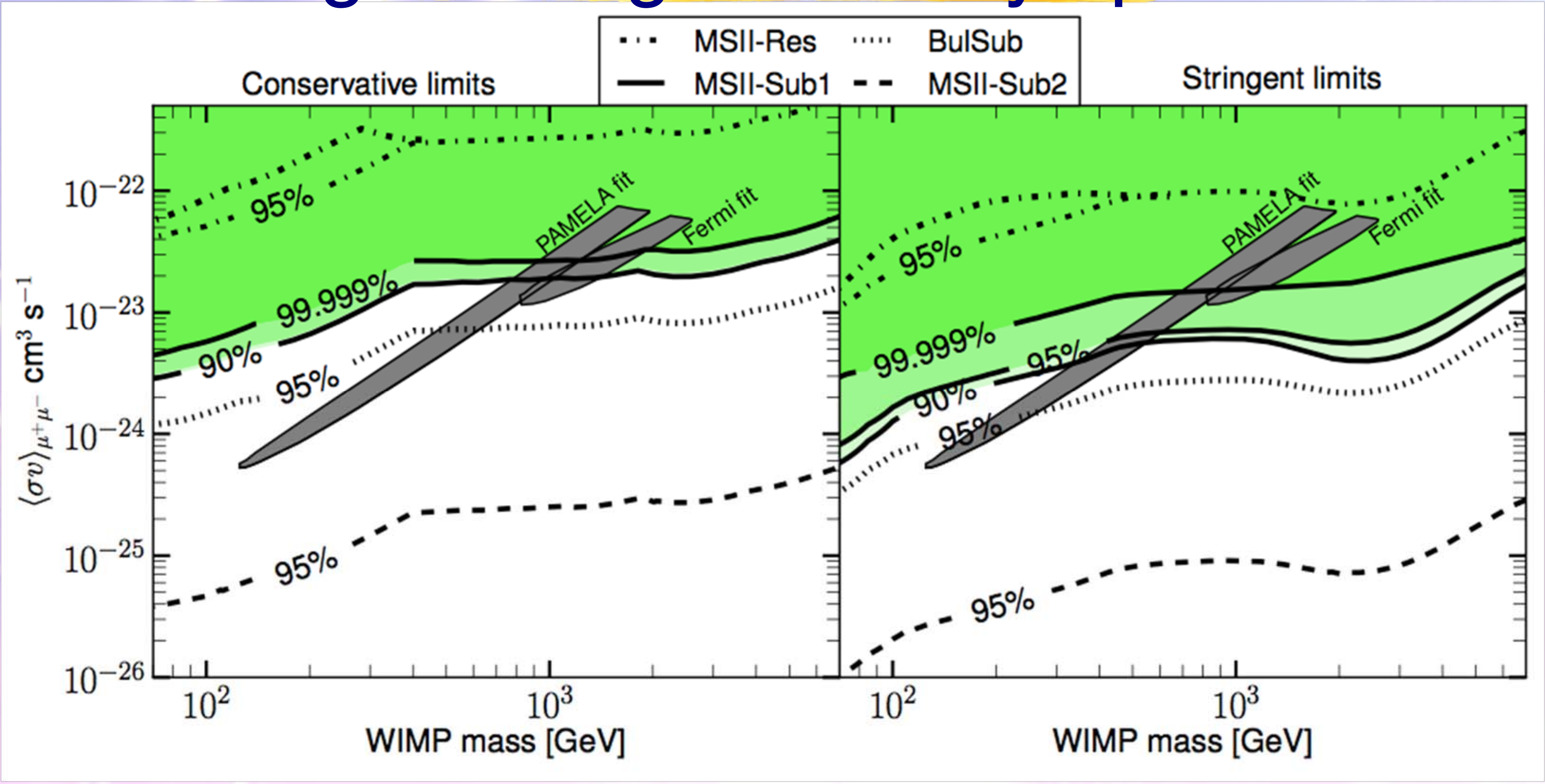
extragalactic gamma-ray spectrum



Fermi Coll. JCAP 04 (2010) 014 arXiv:1002.4415

others possible contributions to the extragalactic gamma-ray spectrum

extragalactic gamma-ray spectrum

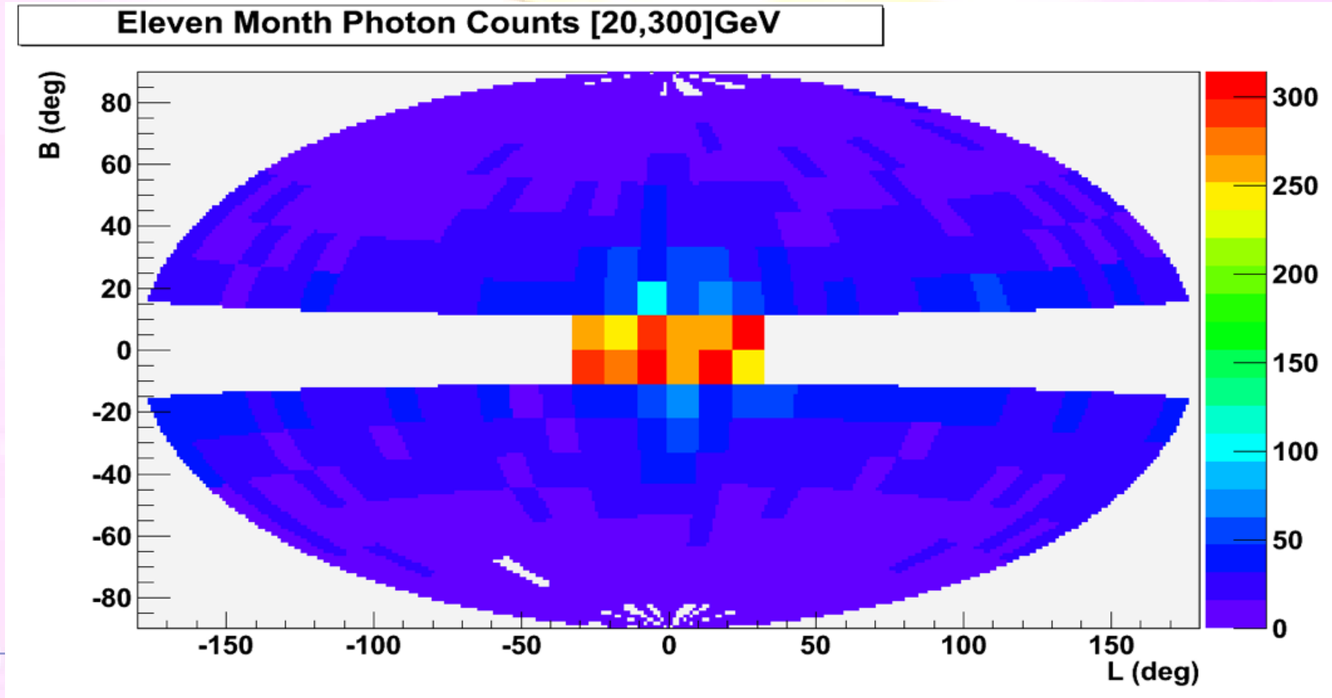


Fermi Coll. JCAP 04 (2010) 014 arXiv:1002.4415

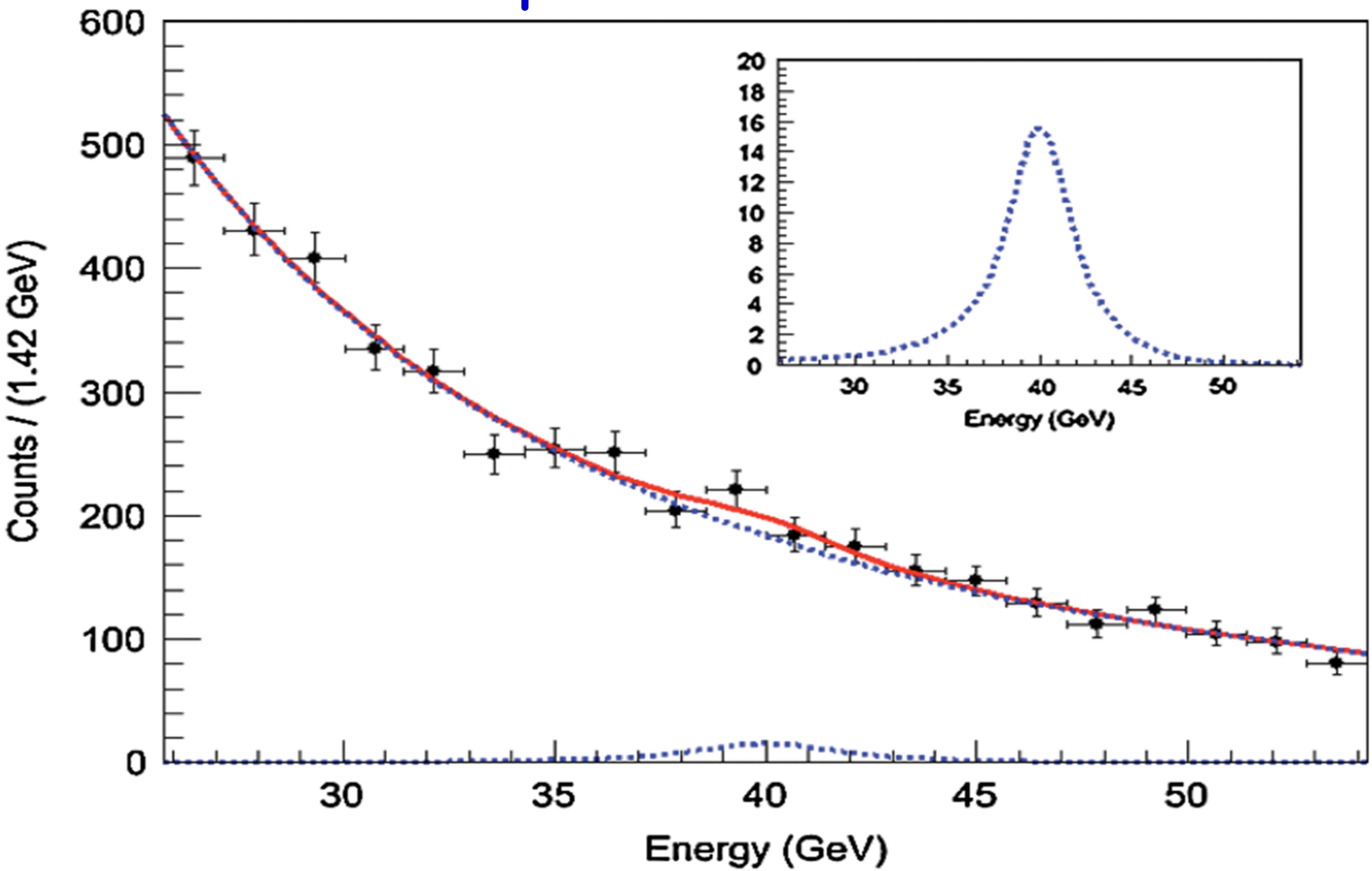
limits on dark matter annihilation into μ+μ− final states

Search for Spectral Gamma Lines

- Smoking gun signal of dark matter
- Search for lines in the first 11 months of Fermi data (30-200 GeV en.range)
- Search region |b|>10° and 30° around galactic center
- For the region within 1° of the GC, no point source removal was done as this would have removed the GC
- For the remaining part of the ROI, point sources were masked from the analysis using a circle of radius 0.2 deg
- The data selection includes additional cuts to remove residual charged particle contamination.



Wimp lines search



Search for Spectral Gamma Lines

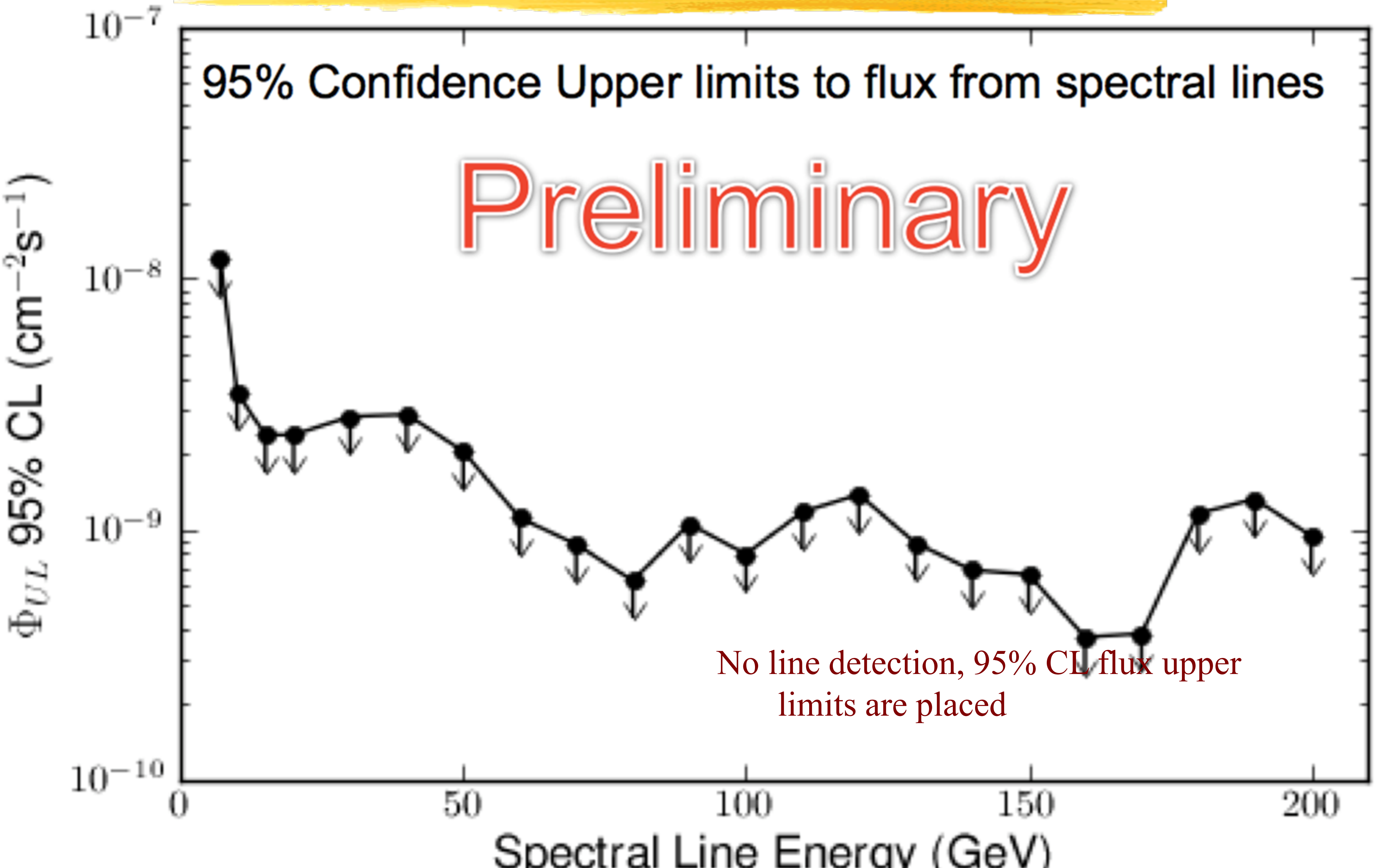
DM annihilation

QuickTime™ and a
BMP decompressor
are needed to see this picture.

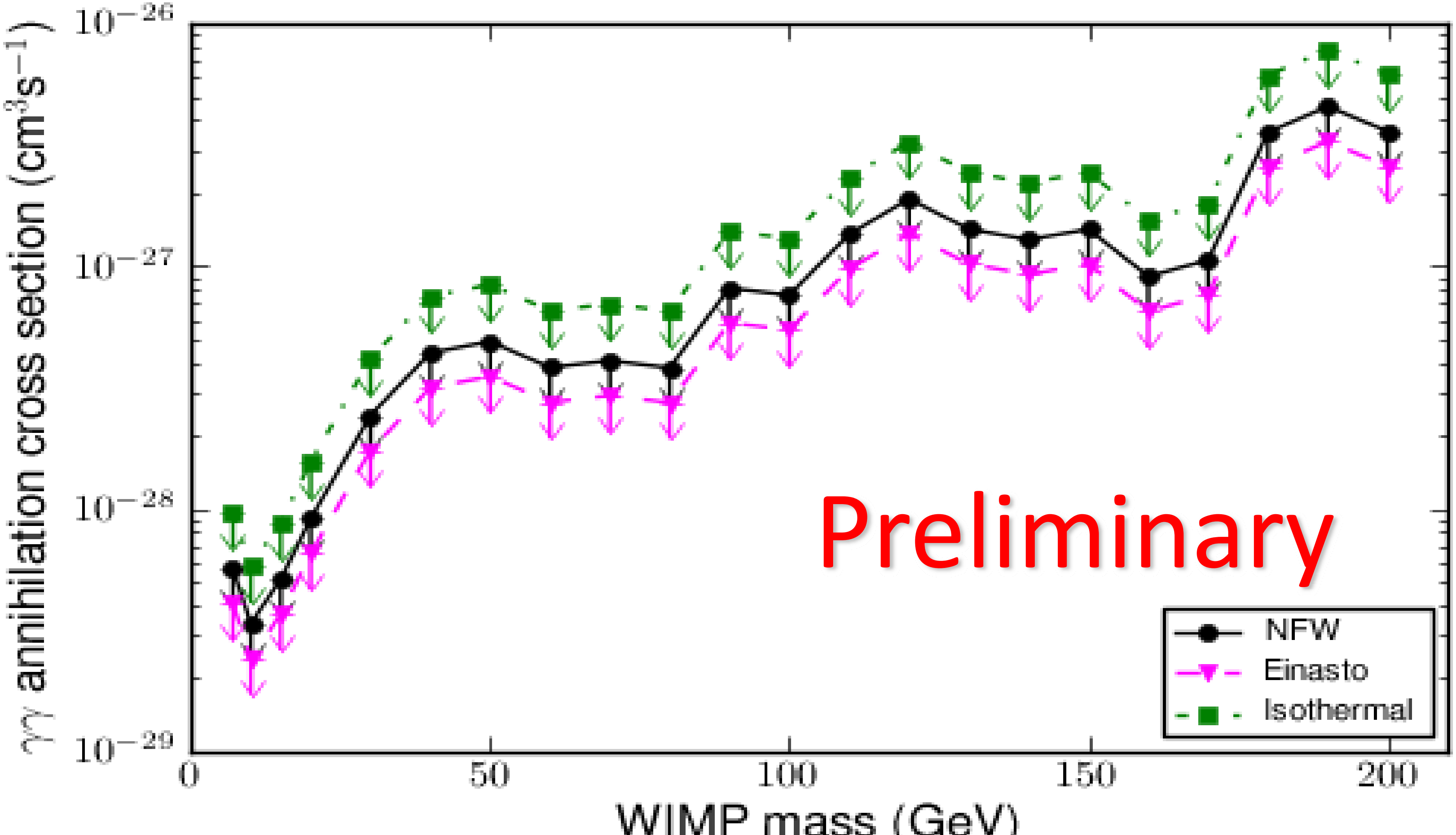
No line detection, 95% CL flux upper limits are placed

Fermi LAT Coll. PRL 104, 091302-08 (2010), arXiv:1001.4836

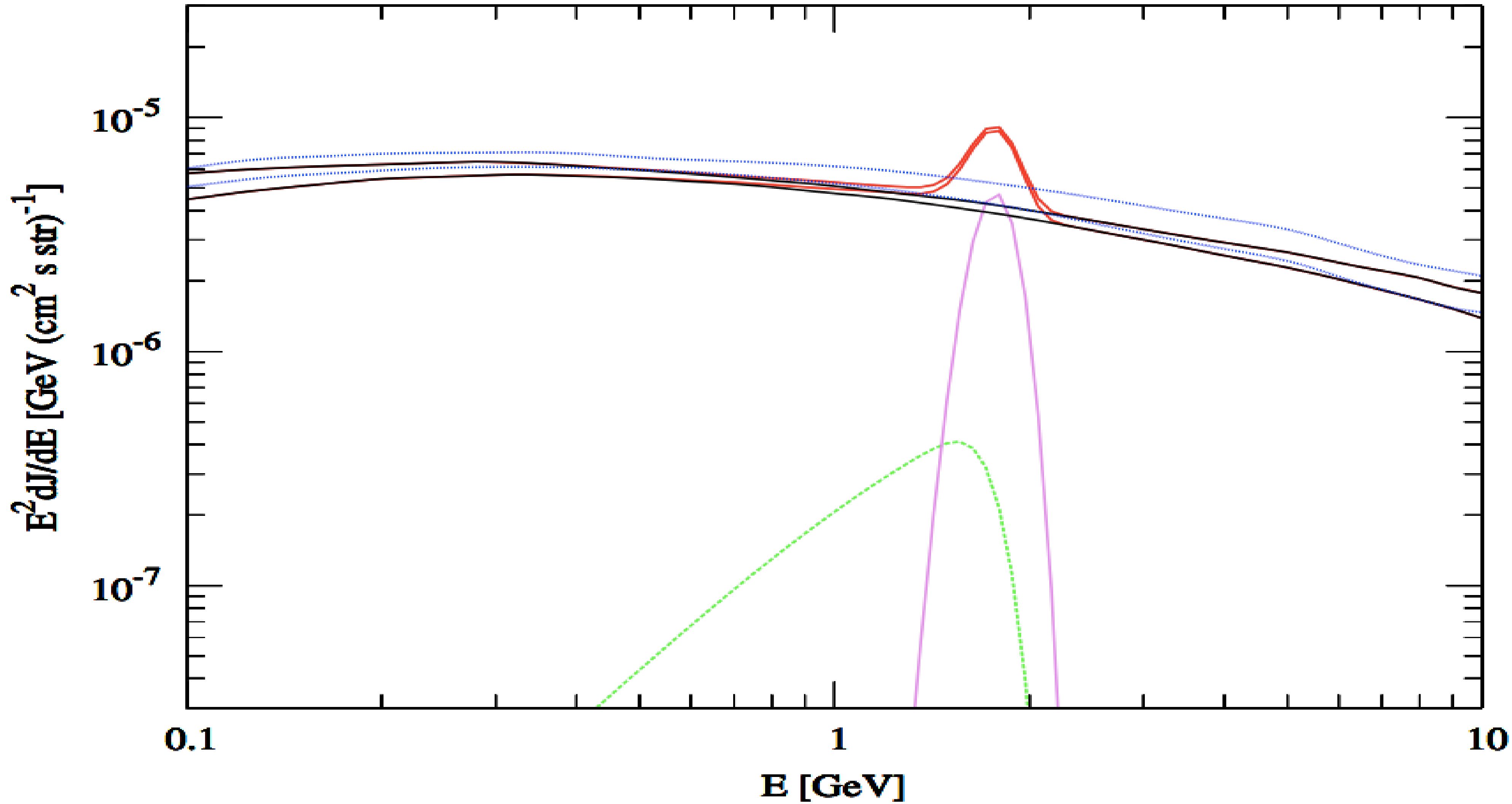
Search for Spectral Gamma Lines



Fermi LAT 23 Month γγ -Cross-section limits 7 GeV - 200 GeV



Gamma-ray detection from gravitino dark matter decay in the $\mu\nu$SSM



Ki-Young Choi, Daniel E.Lopez-Fogliani, Carlos Munoz, Roberto Ruiz de Austri, arXiv:0906.3681

Search for Spectral Gamma Lines

decaying DM particles

QuickTime™ and a
BMP decompressor
are needed to see this picture.

No line detection, 95% CL flux
upper limits are placed

Fermi LAT Coll. PRL 104, 091302-08 (2010), arXiv:1001.4836

Conclusion:

The Electron+positron spectrum (CRE) measured by Fermi-LAT is significantly harder than previously thought on the basis of previous data

Adopting the presence of an extra e^{+} primary component with ~ 1.5 spectral index and E_{cut} ~ 1 TeV allow to consistently interpret Fermi-LAT CRE data (improving the fit), HESS and PAMELA

Such extra-component can be arise if the secondary production takes place in the same region where cosmic rays are being accelerated (to be tested with future B/C measurements)

- or by pulsars for a reasonable choice of relevant parameters (to be tested with future Fermi pulsars measurements)
- or by annihilating dark matter for model with $M_{DM} \approx 1$ TeV

•Improved analysis and complementary observations (CRE **anisotropy**, spectrum and angular distribution of diffuse γ, DM sources search in γ) are required to possibly discriminate the right scenario.

2nd Conclusion : Gamma

- No discovery (yet)....

- .... however promising constraints on the nature of DM have been placed

(exclusion of a lot of DM models that explain the origin of the Fermi/Pamela lepton excess)

- In addition to increased statistics, better understanding of the astrophysical and instrumental background will improve our ability to reliably extract a potential signal of new physics or set stronger constraints

- Further improvements are anticipated for analysis that benefits from multi-wavelength observations (for example galactic center, dwarf spheroidal galaxies and DM satellites)

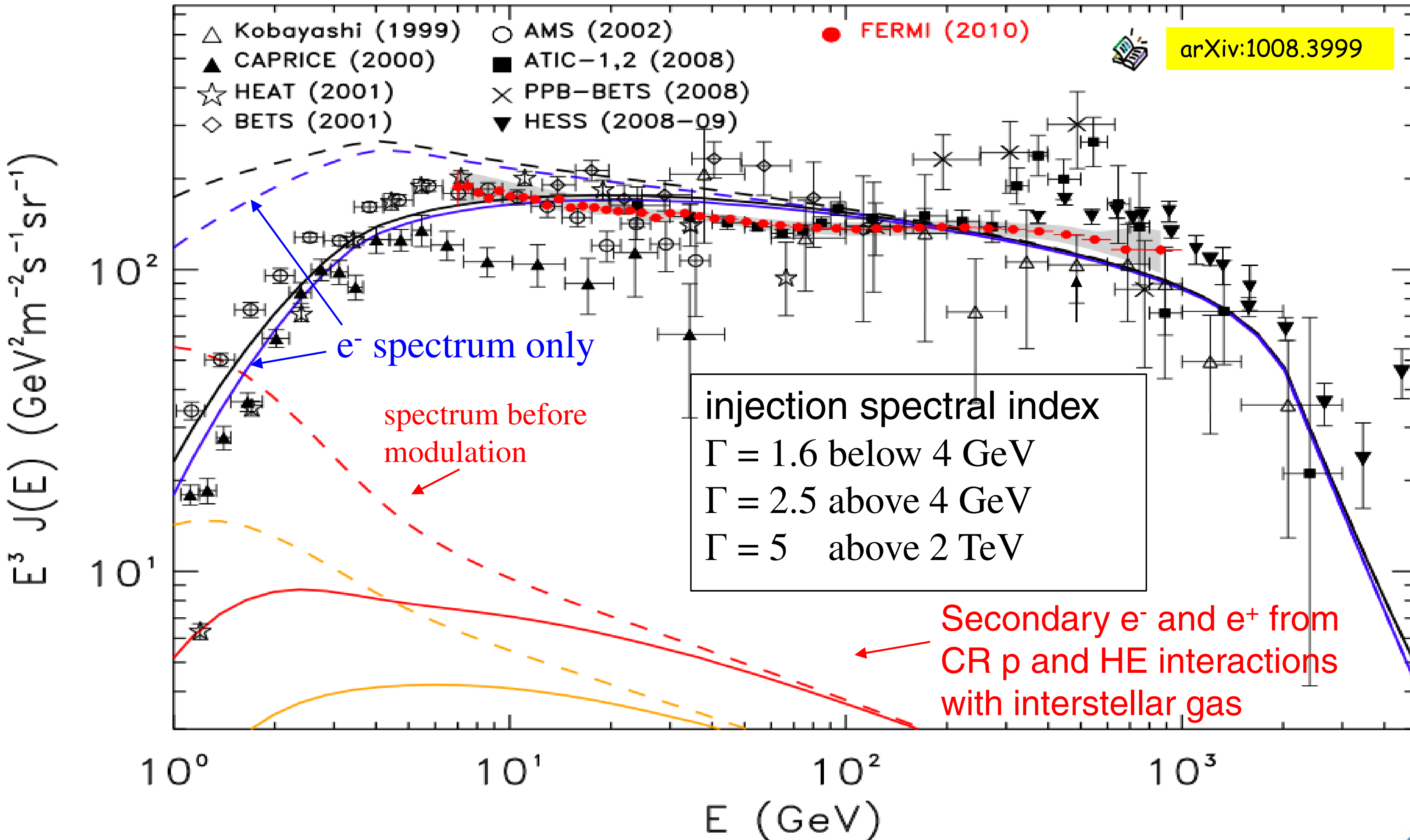
NEXT FERMI SYMPOSIUM 9-12 May 2011 in Rome

you are all invited !

http://fermi.gsfc.nasa.gov/science/symposium/2011/

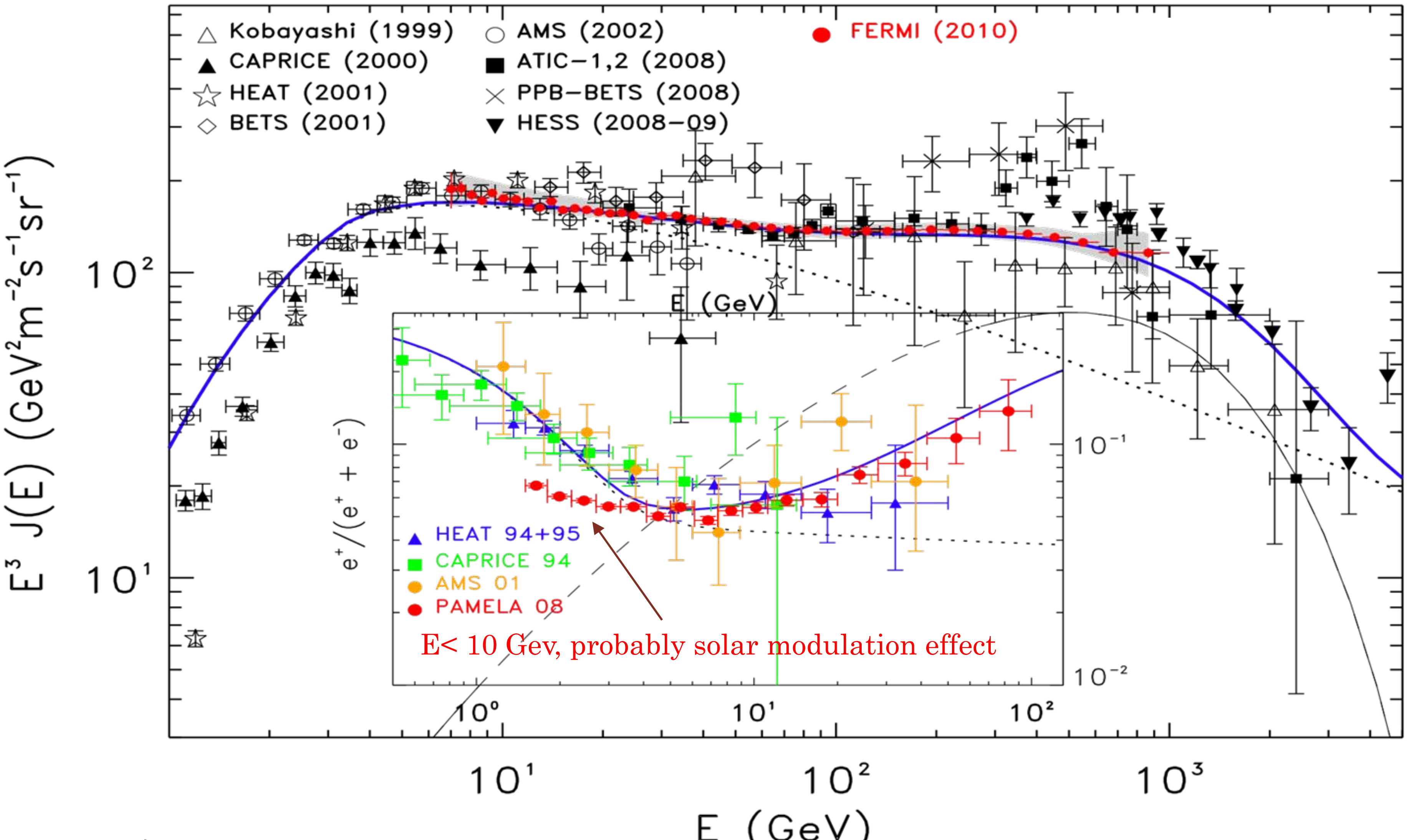
thank you !

Electron spectrum and a conventional GALPROP model



The solar modulation was treated using the force-field approximation with Φ = 550 MV

An extra-component with injection index = 1.5 and an exponential cutoff at 1 TeV gives a good fit of all datasets!

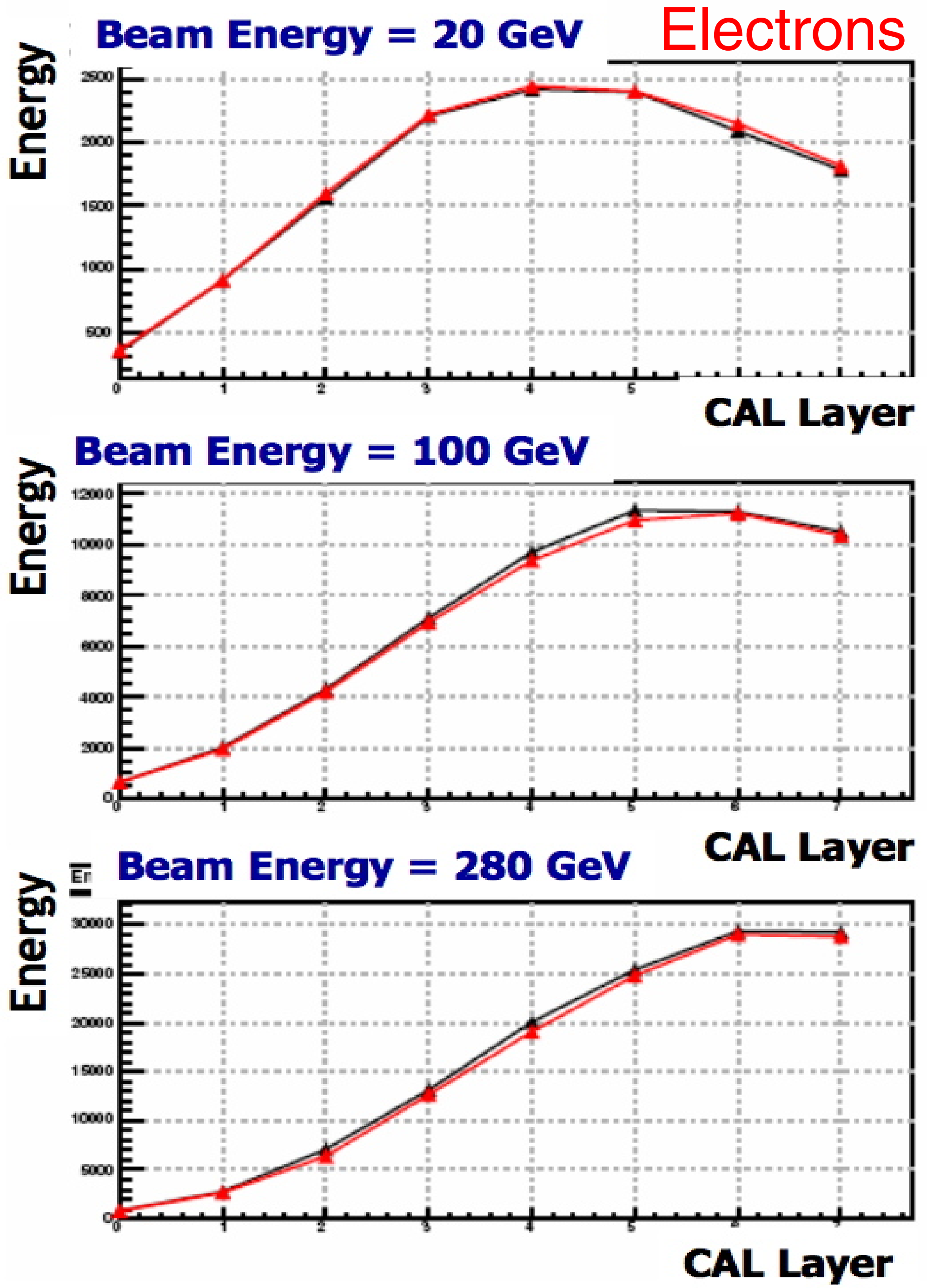


Fermi LAT Coll. Physical Review D, accepted [arXiv:1008.3999]

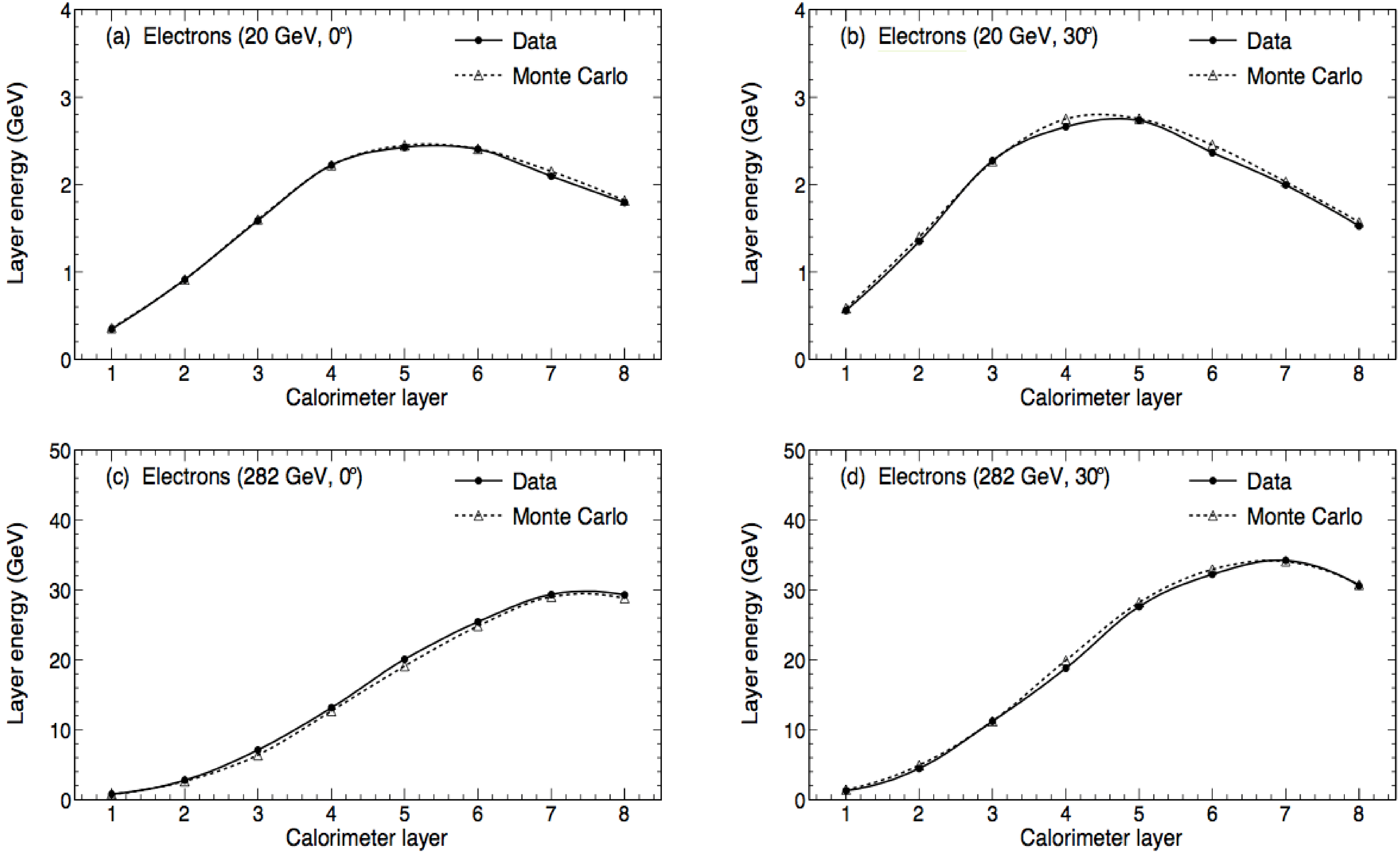
Energy reconstruction

Reconstruction of the most probable value for the event energy:
- based on calibration of the response of each of 1536 calorimeter crystals
- energy reconstruction is optimized for each event
-calorimeter imaging capability is heavily used for fitting shower profile -
-tested at CERN beams up to 280 GeV with the LAT Calibration Unit

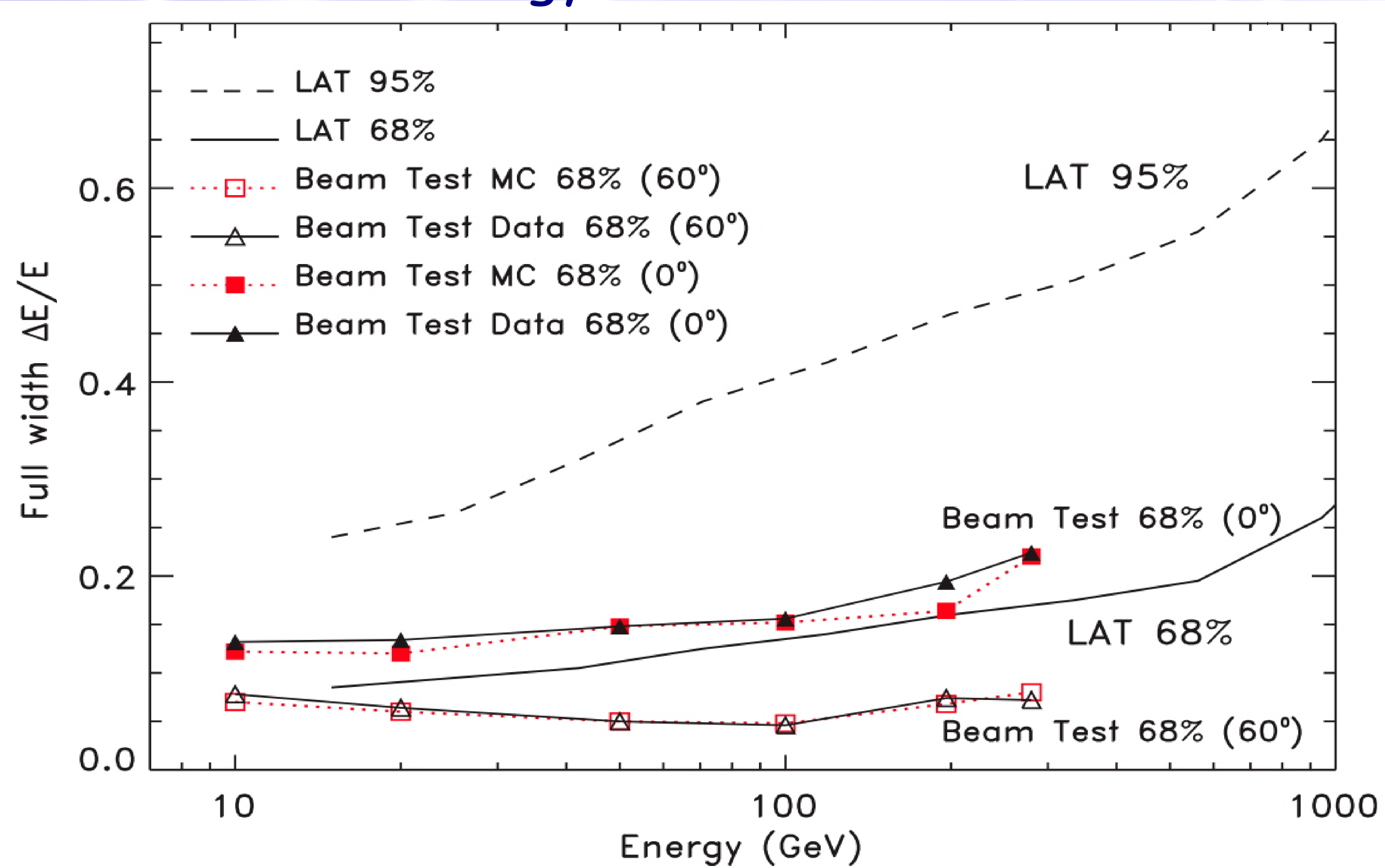
Very good agreement between shower profile in beam test data (red) and Monte Carlo (black)



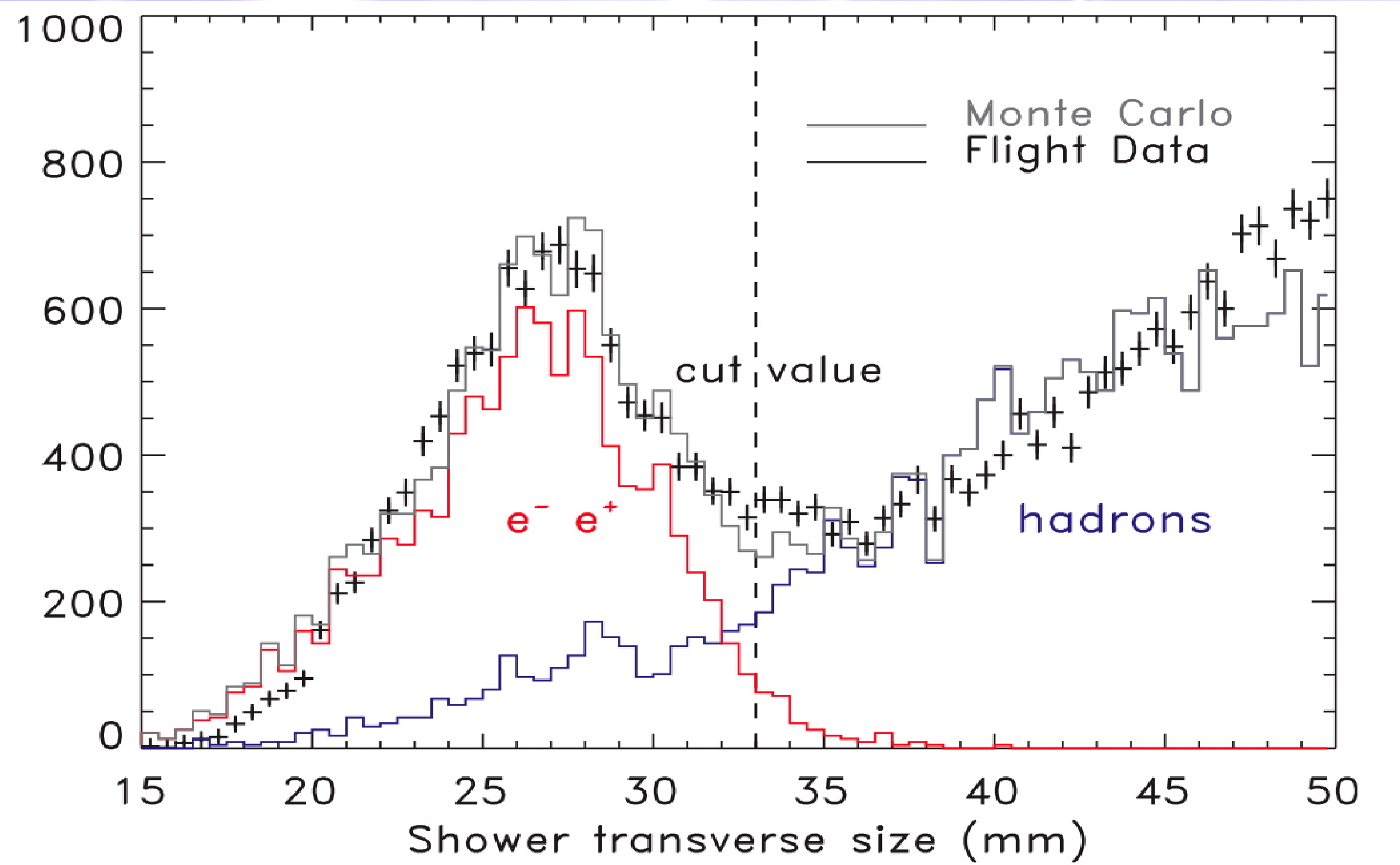
Energy reconstruction



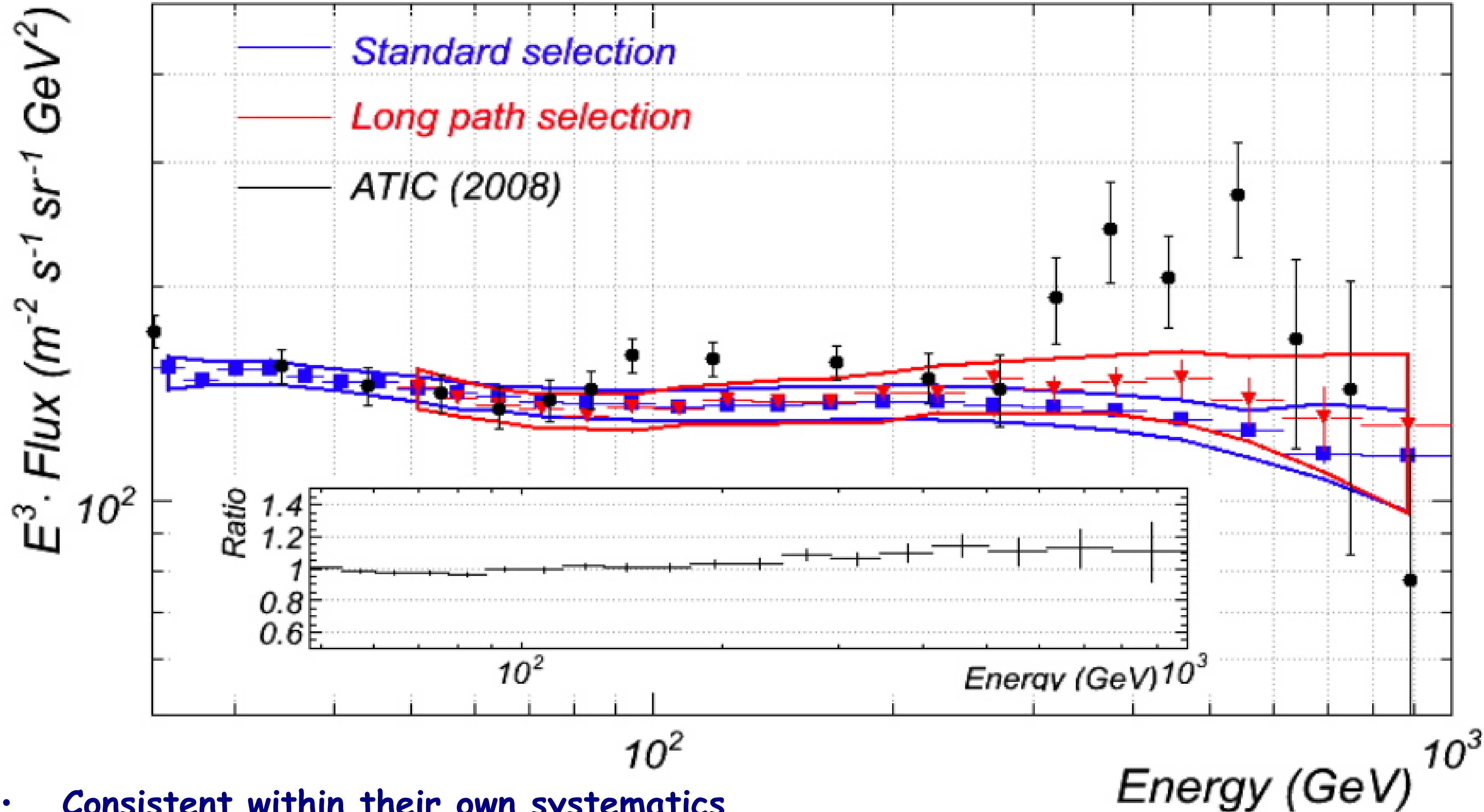
Fermi LAT Energy resolution for electrons



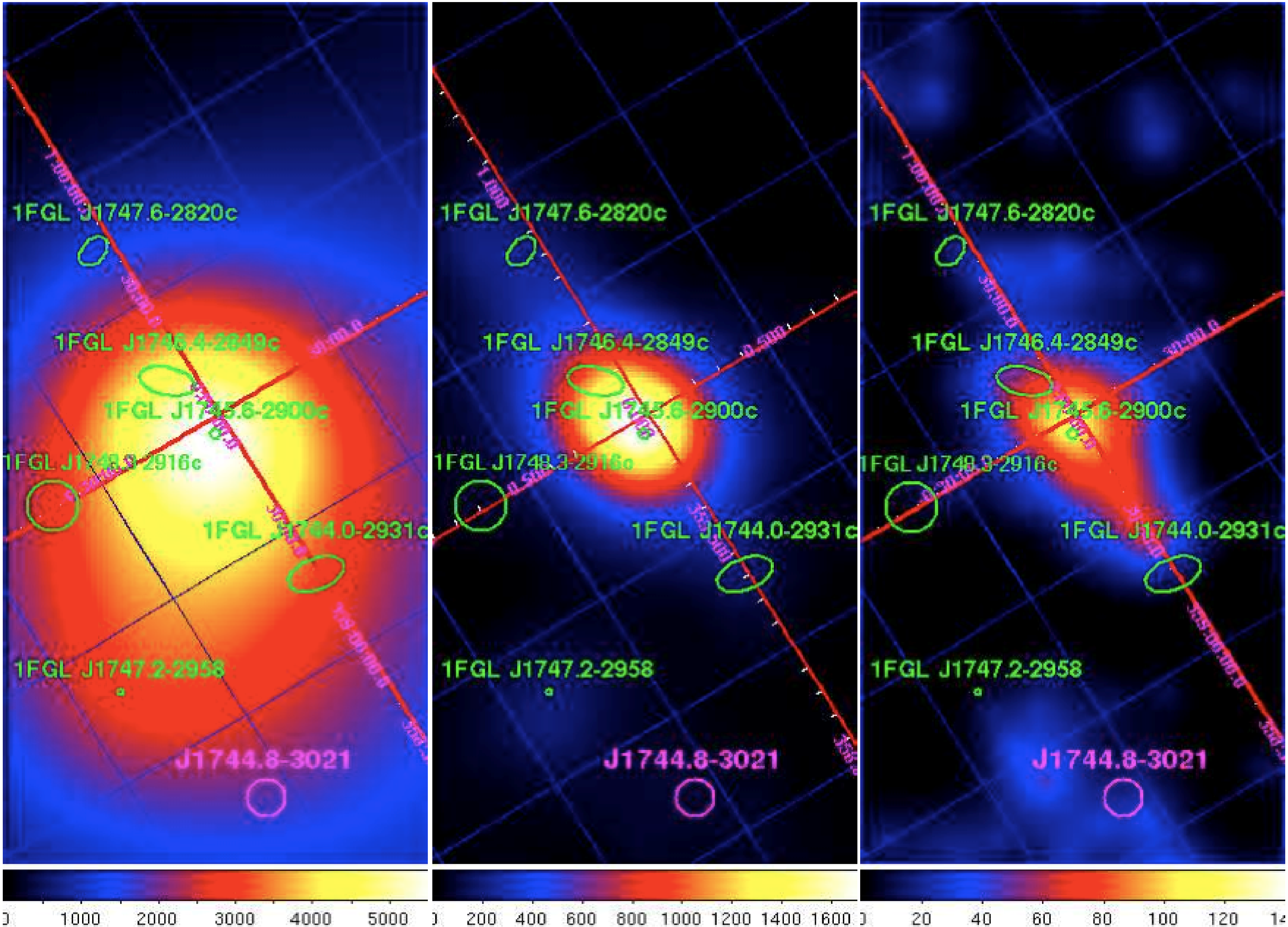
Distribution of the transverse sizes of the showers (above 150 GeV) in the calorimeter



Comparison of standard and high-X0 spectra



- **Consistent within their own systematics**

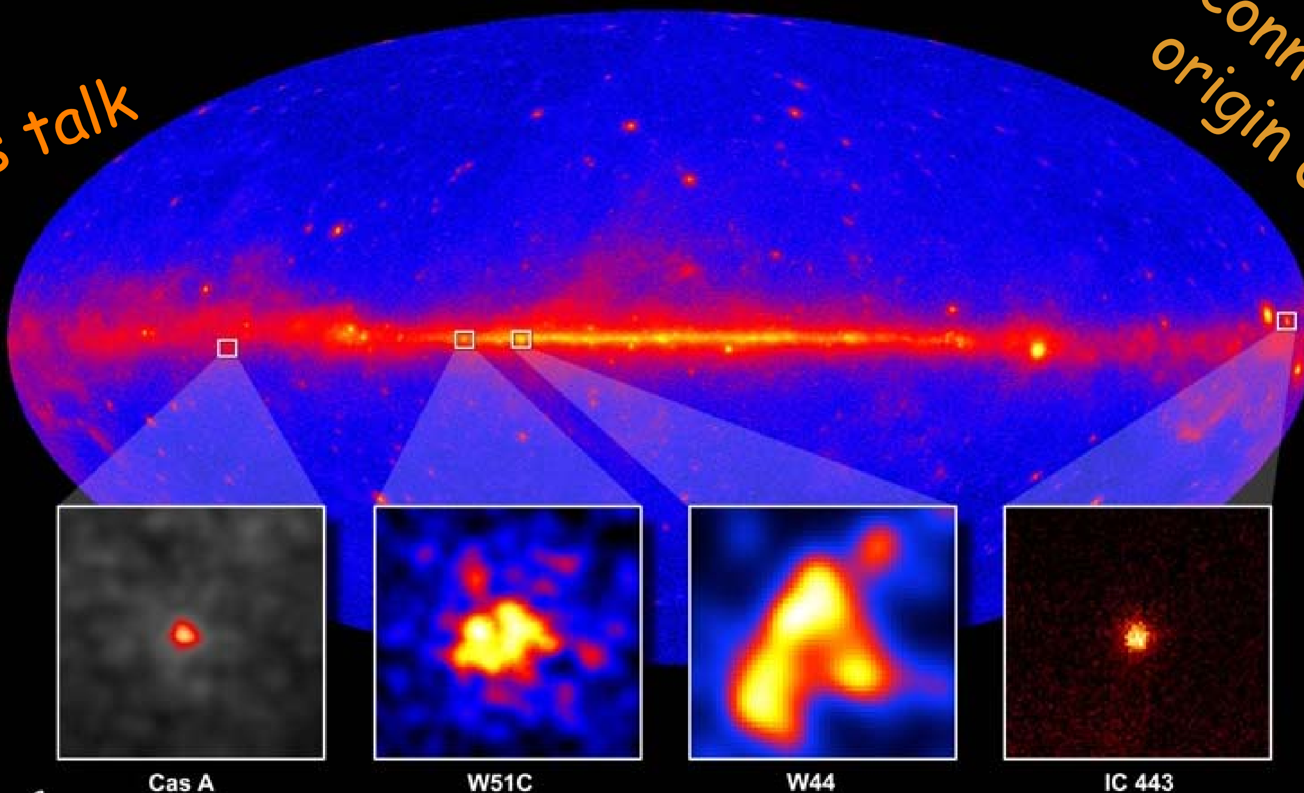


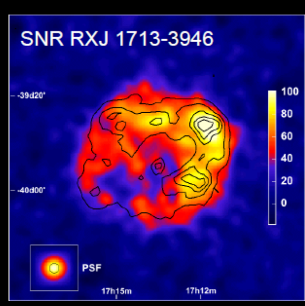
Chernyakova et al. arXiv:1009.2630

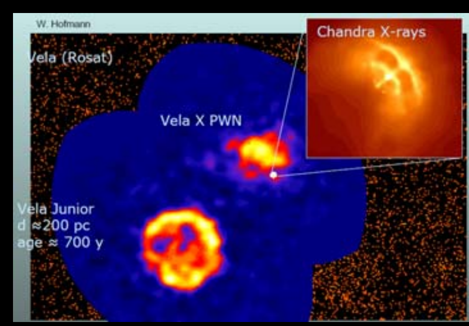
Galactic Super Nova Remnants : Fermi observations

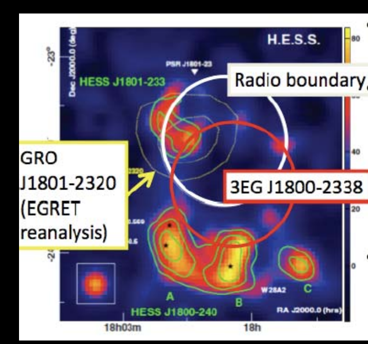
Olaf Reimer's talk just after

connection to the origin of Cosmic Rays

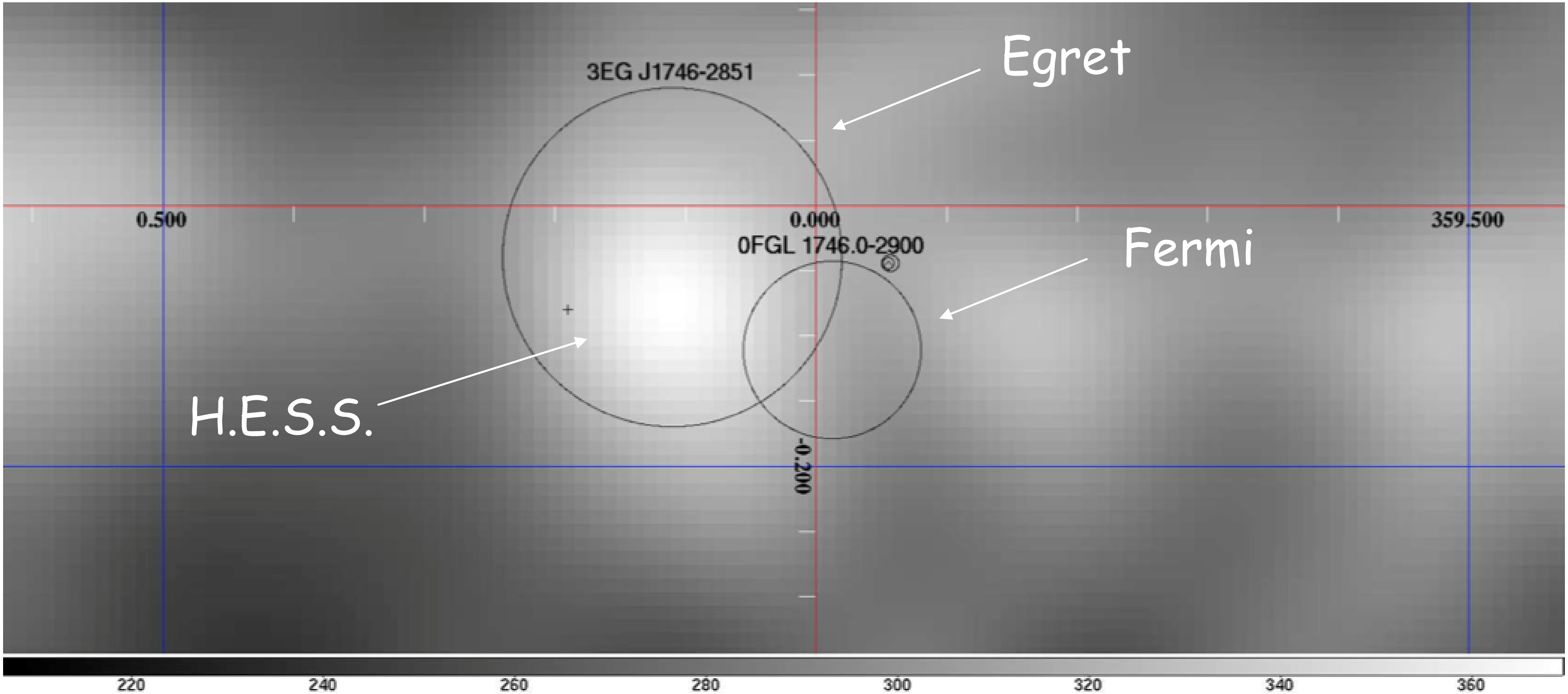






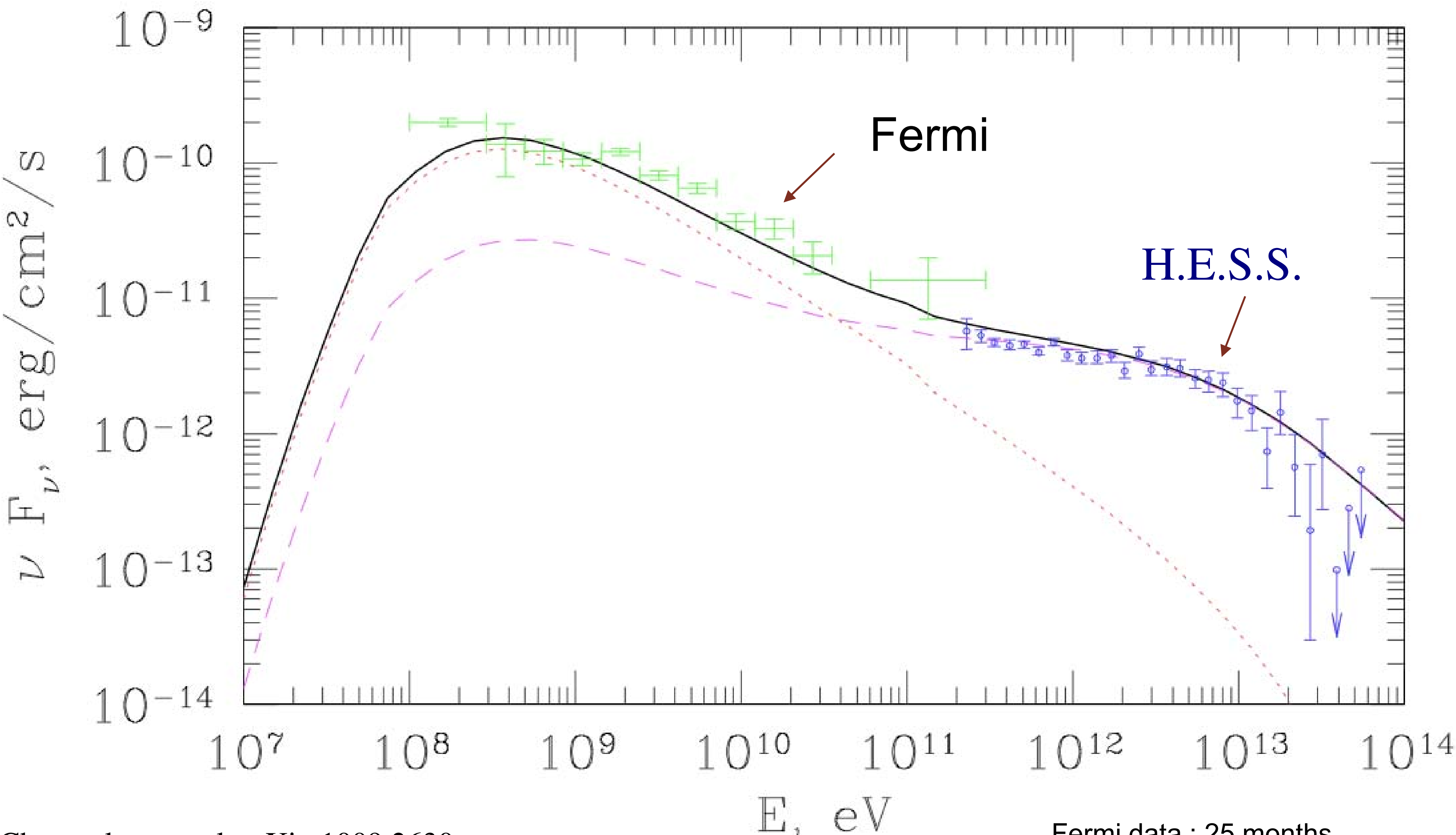


Fermi, H.E.S.S., Egret views of the Galactic Center



J. Cohen-Tanugi, M. Pohl, O. Tibolla, E. Nuss [Fermi Coll.] 31 ICRC

Fermi and H.E.S.S. Galactic Center Source



Chernyakova et al. arXiv:1009.2630

Fermi data : 25 months

Dwarf Spheroidal Galaxies upper-limits

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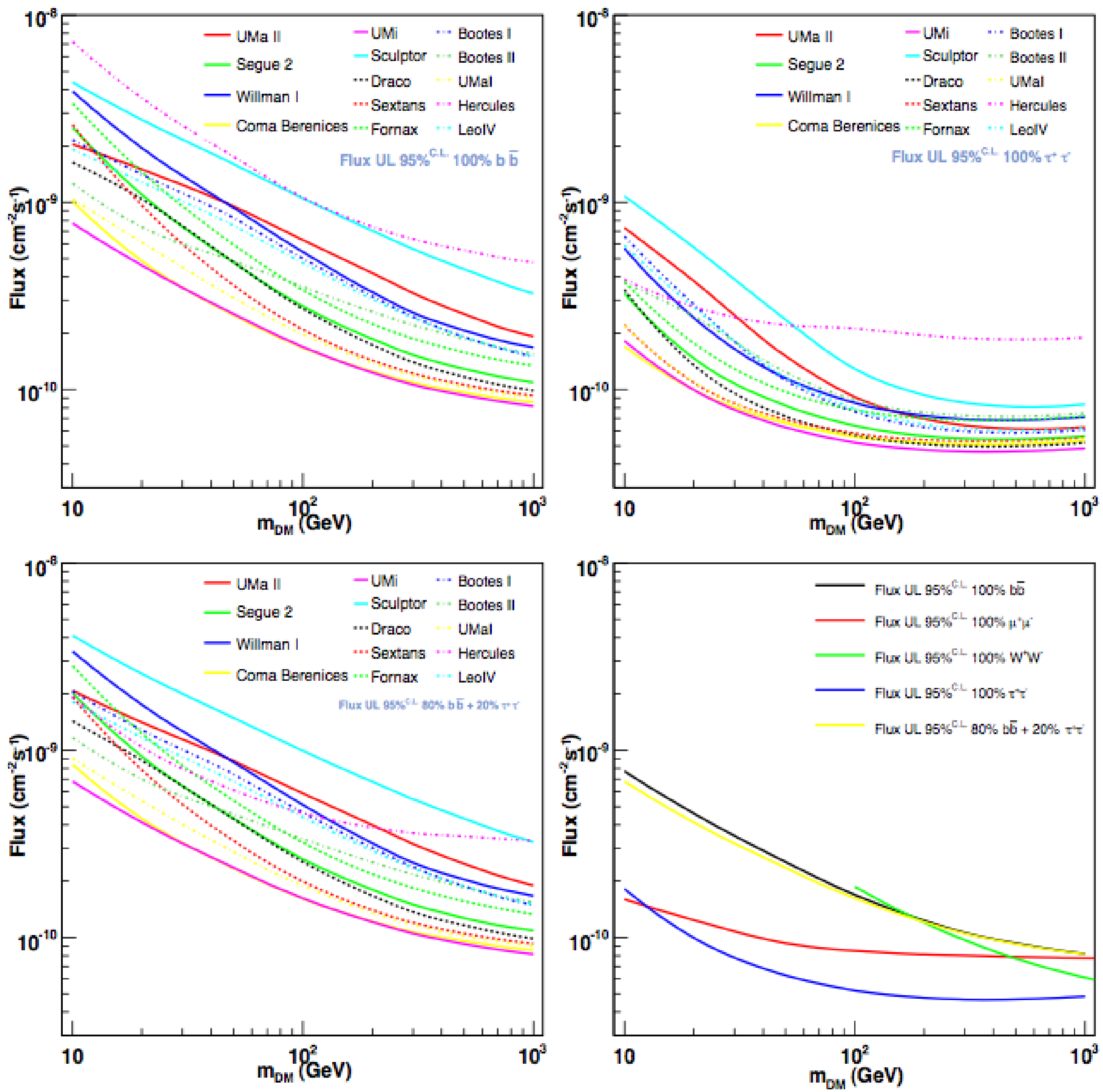

(*) stellar data from the Keck observatory (by Martinez, Bullock, Kaplinghat)

Fermi Coll. ApJ 712 (2010) 147-158 [arXiv:1001.4531]

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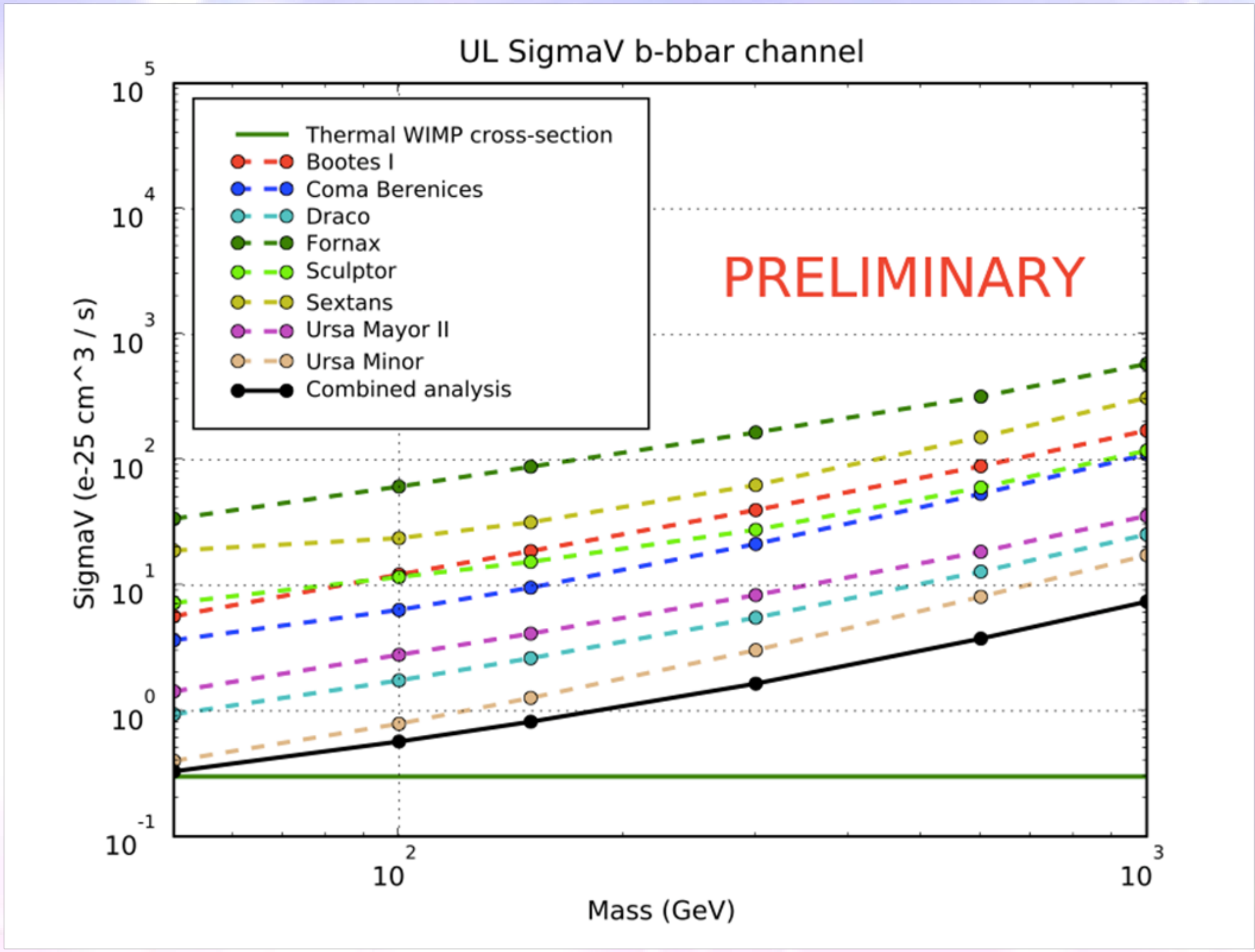


(*) stellar data from the Keck observatory (by Martinez, Bullock, Kaplinghat)

Fermi Coll. ApJ 712 (2010) 147-158 [arXiv:1001.4531]

One of the Possible Explanations

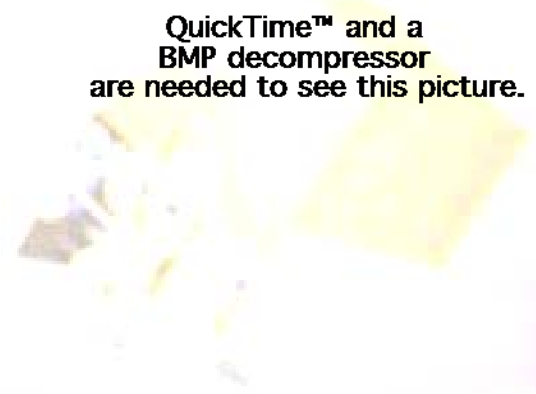
Counts Spectra of the model components

Residuals: (Exp.Data- Model)/Model

Red = galactic diffuse
Green = DM 40GeV b-b bar
Blue = 1FGL J1745.6-2900

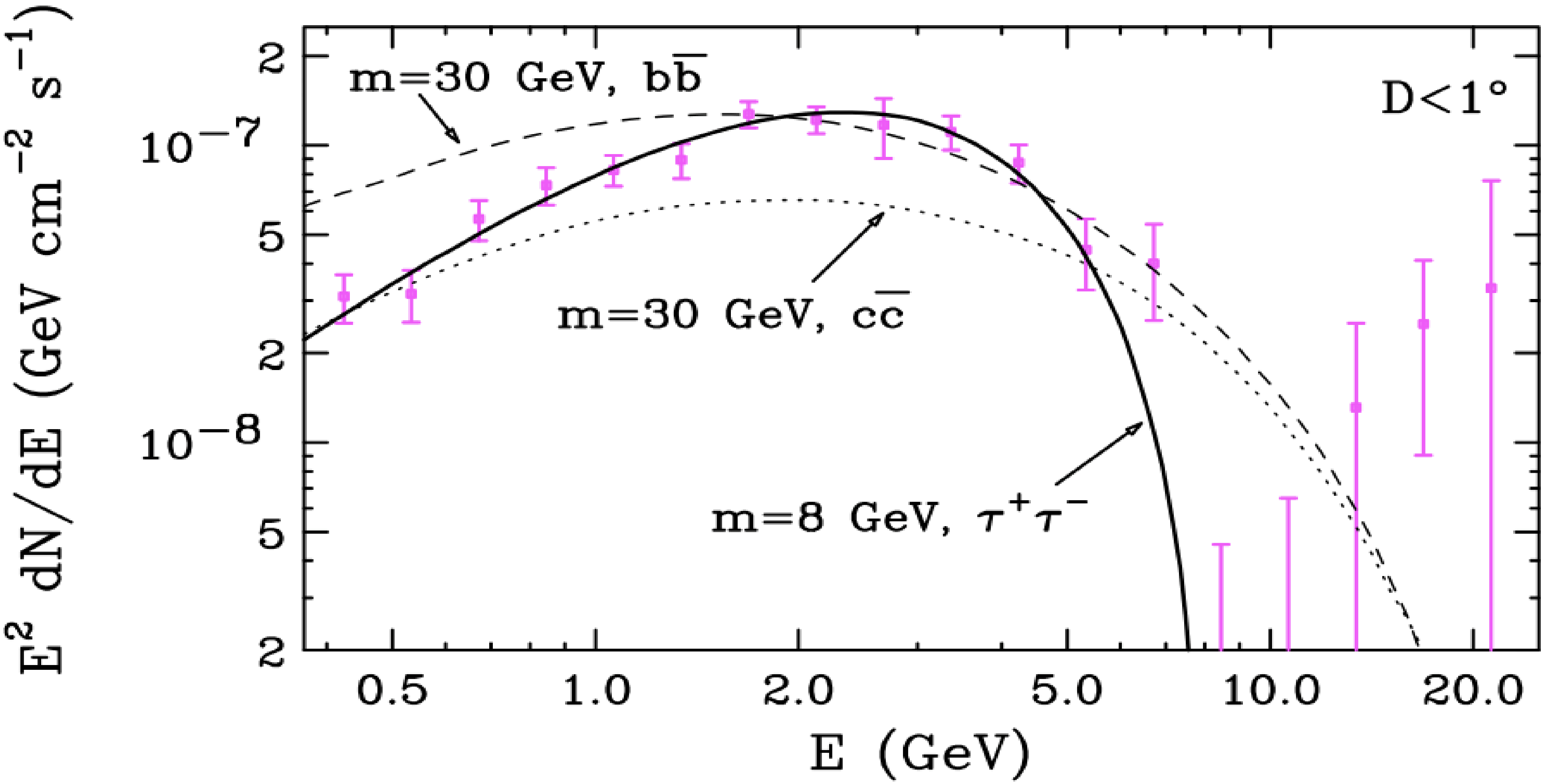
preliminary

preliminary



This model contains a Navarro-Frank-White DM component,
annihilating in b-anti b, with mass = 40 GeV;
No structure left in the residuals at 1.5-6 GeV

Dark Matter Signal from the Galactic Center ?

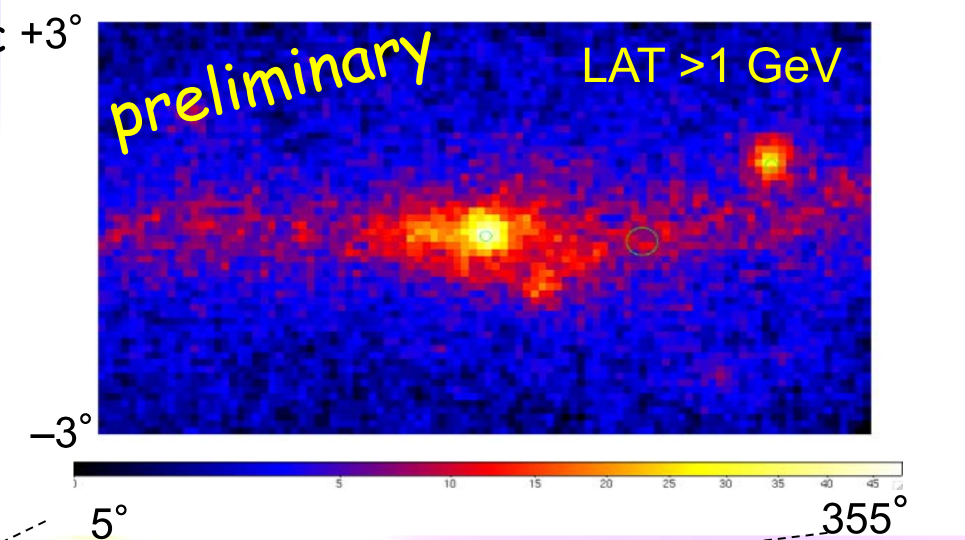


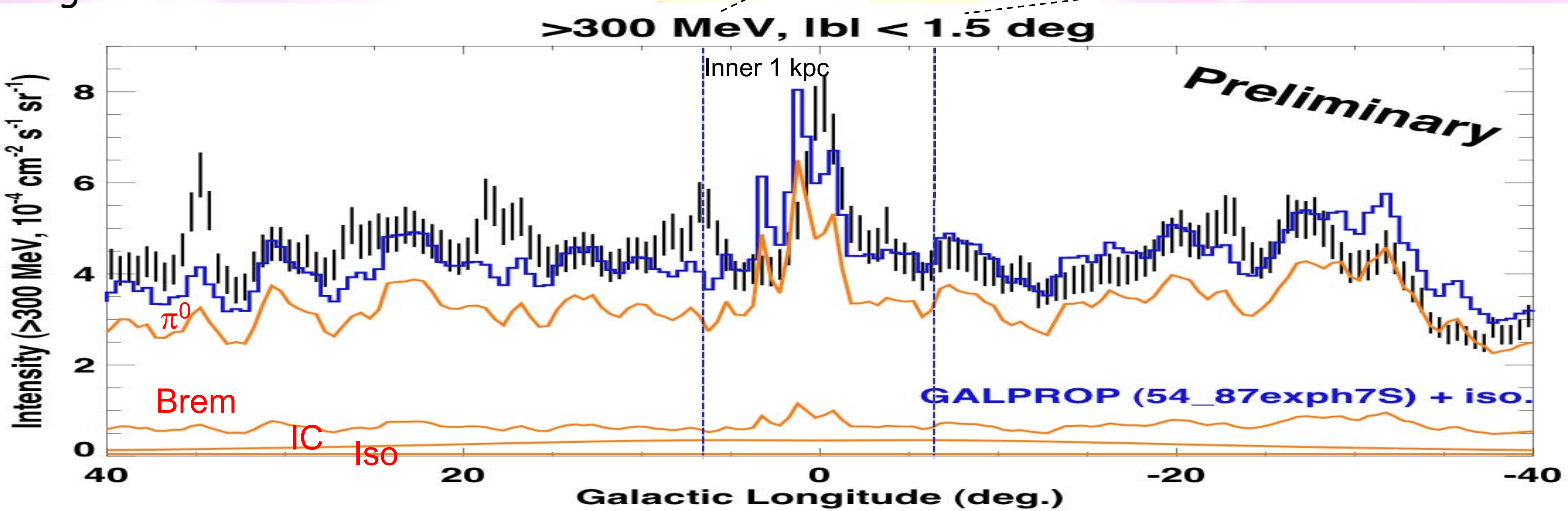
Dan Hooper and Lisa Goodenough, arXiv:31010.2752

systematic uncertainties and diffuse model uncertainties cannot be ignored !

Fermi LAT Observations of the GC

- Extragalactic Diffuse modelled as an isotropic emission with a template spectrum.
- Red and blue profiles do not include point sources
- The diffuse gamma-ray intensity in the GC region is intense & not dominated by the GC region
- Systematic uncertainties in the GC contribution remain large, interstellar radiation and gas





S.Digel, Fermi Symp, Fermi LAT Coll. in preparation