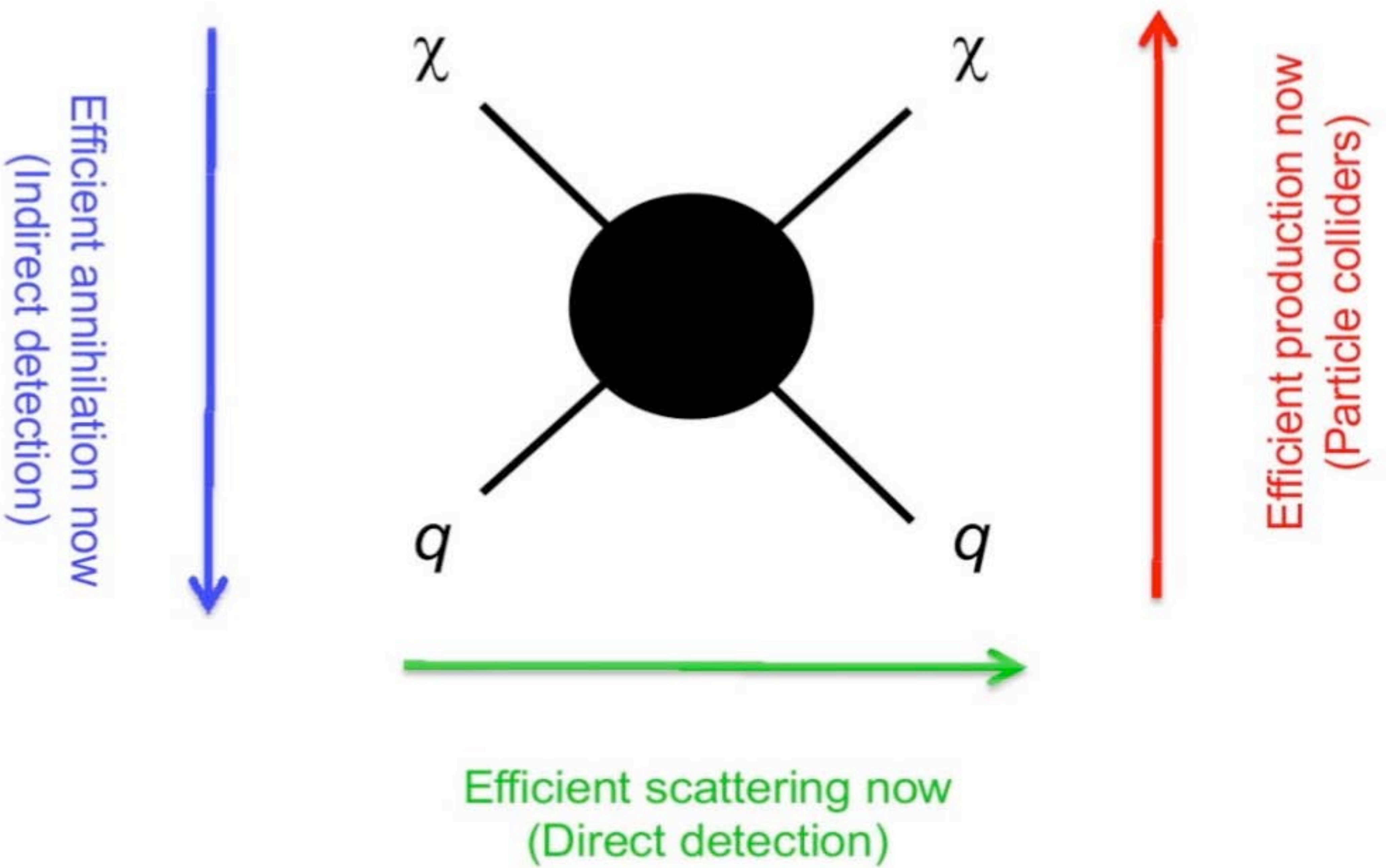
Search for Dark matter in the sky in the Fermi, Atic and Pamela era

Aldo Morselli

INFN Roma Tor Vergata

5th Patras Workshop on Axions, WIMPs and WISPs, Durham 13-17 July 2009



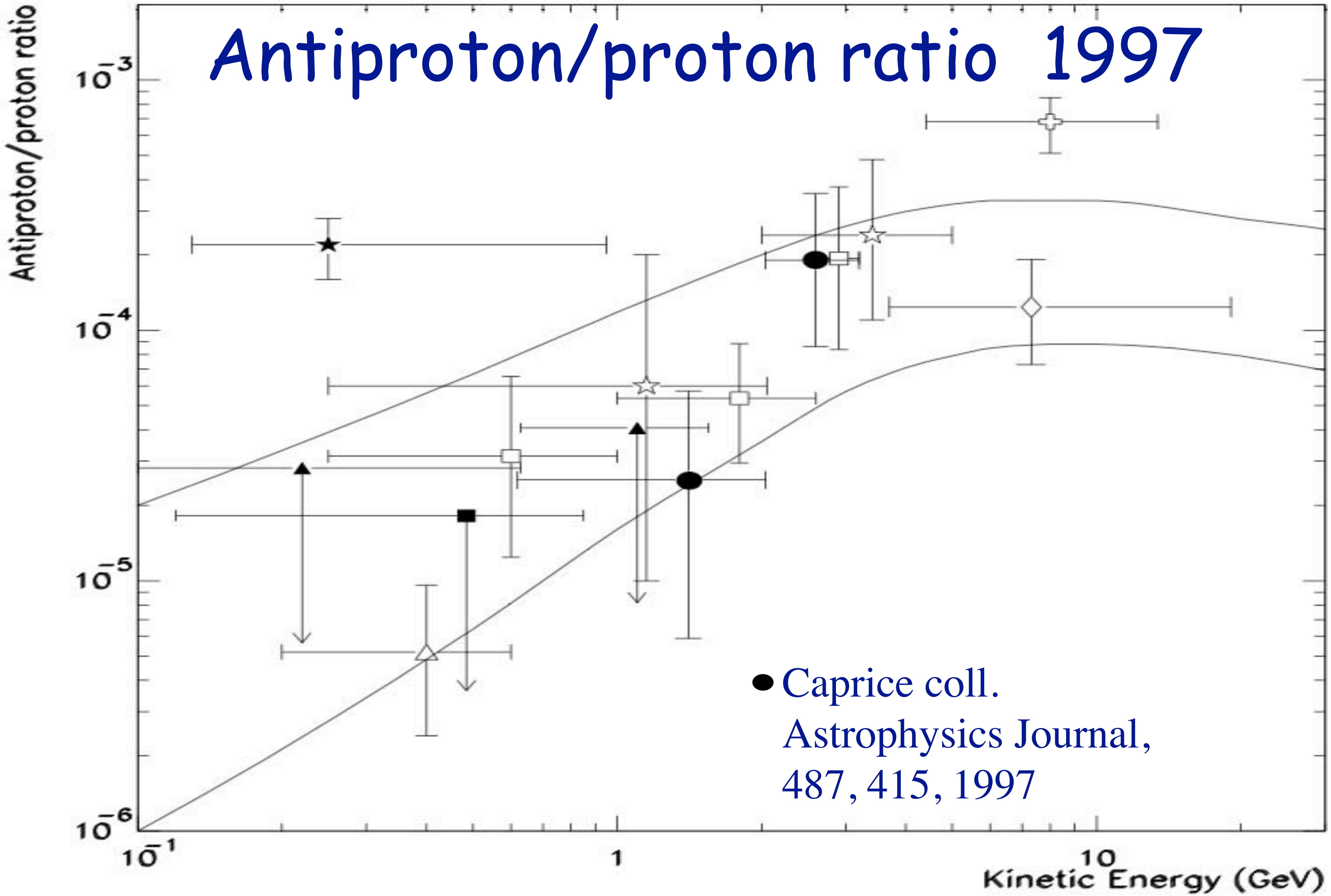
Efficient annihilation now
(Indirect detection)
χ
χ
q
q
Efficient production now
(Particle colliders)
Efficient scattering now
(Direct detection)

Neutralino WIMPs

Assume χ present in the galactic halo

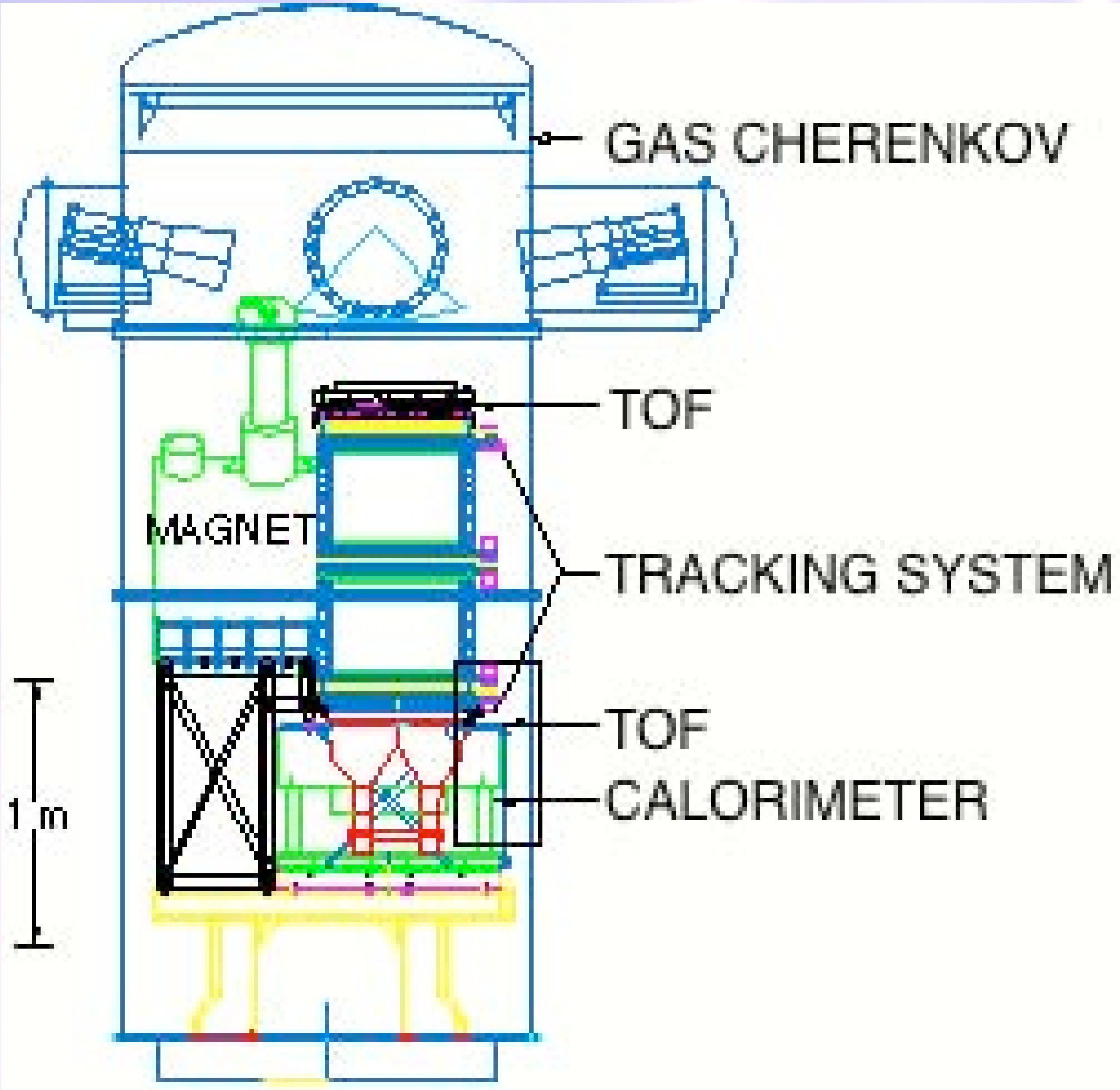
- χ is its own antiparticle **=>** can annihilate in galactic halo producing gamma-rays, antiprotons, positrons….
- Antimatter not produced in large quantities through standard processes (secondary production through p + p **-->** anti p + X)
- So, any extra contribution from exotic sources ($\chi\chi$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

Antiproton/proton ratio 1997

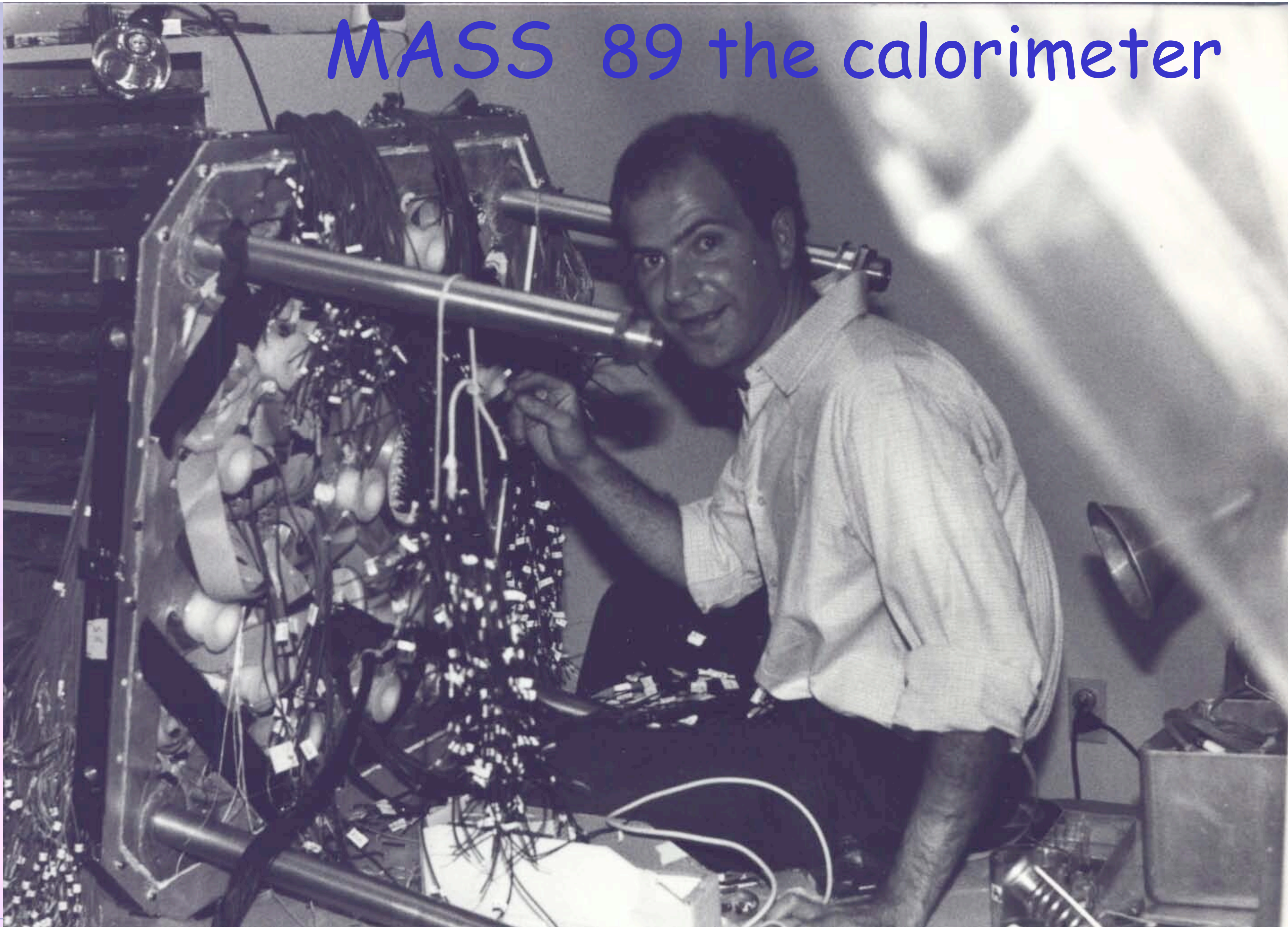


- Caprice coll. Astrophysics Journal, 487, 415, 1997

MASS Matter Antimatter Space Spectrometer



MASS 89 the calorimeter




MASS 89 flight


MASS 89 flight

MASS 89

PAMELA

Payload for **A**ntimatter **M**atter **E**xploration and **L**ight Nuclei **A**strophysics

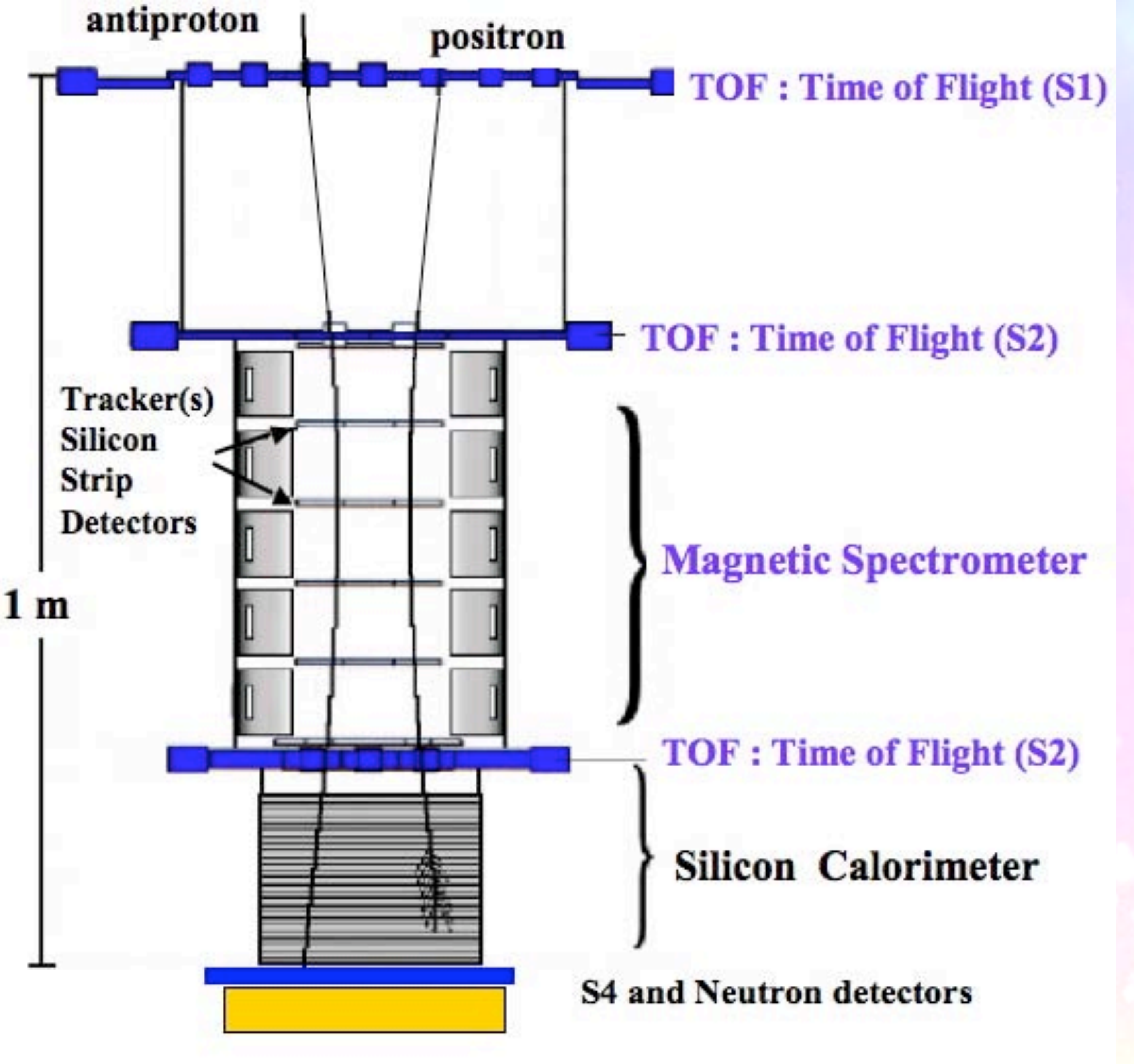
In orbit on June 15, 2006, on board of the DK1 satellite by a Soyuz rocket from the Bajkonour launch site.

First switch-on on June 21 2006

From July 11 Pamela is in continuous data taking mode

Pamela

Separating p from e^-

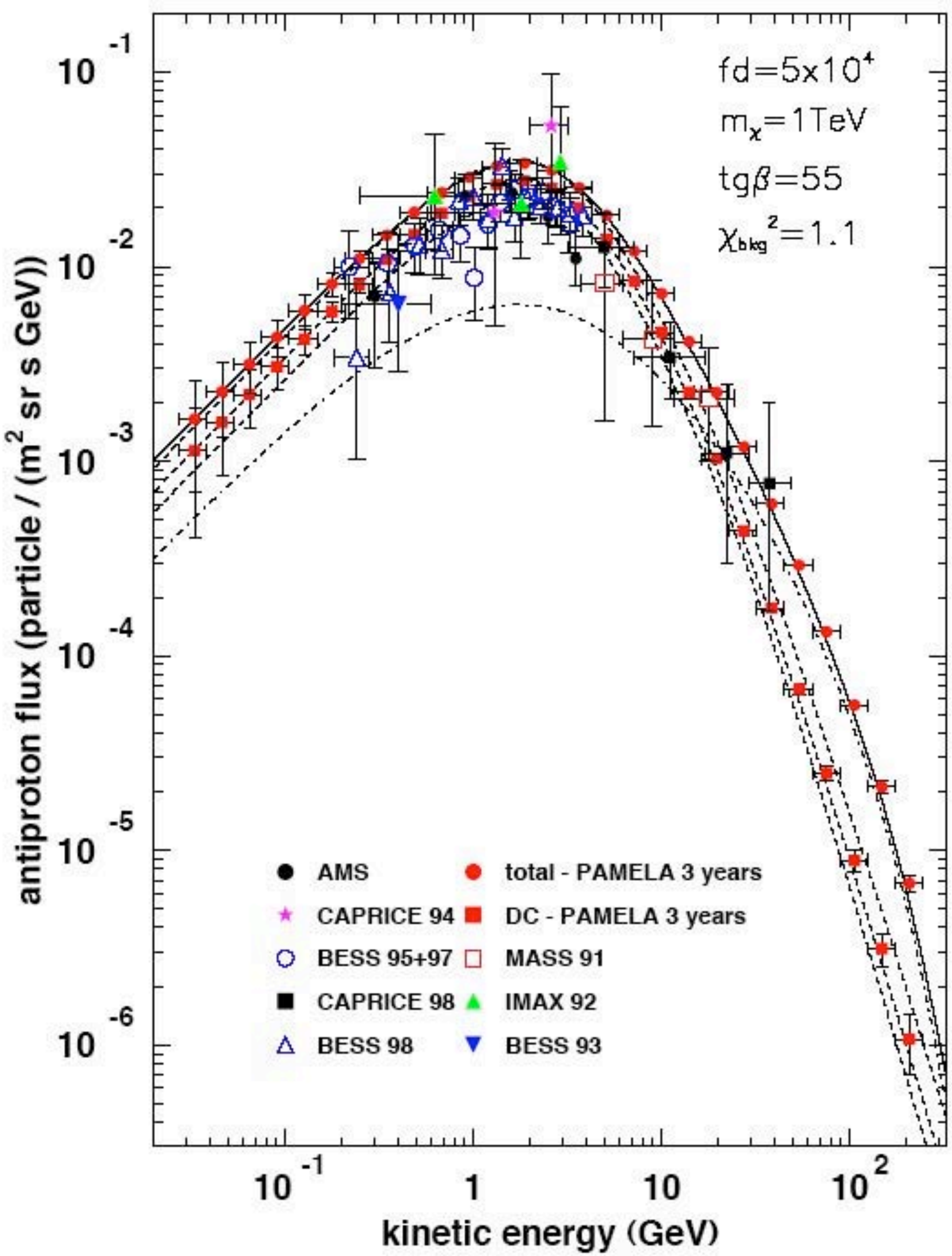


PAMELA: Cosmic-Ray Antiparticle Measurements: Antiprotons

an example in mSUGRA

fd: Clumpiness factors needed to disentangle a neutralino induced component in the antiproton flux

f = the dark matter fraction concentrated in clumps
d = the overdensity due to a clump with respect to the local halo density

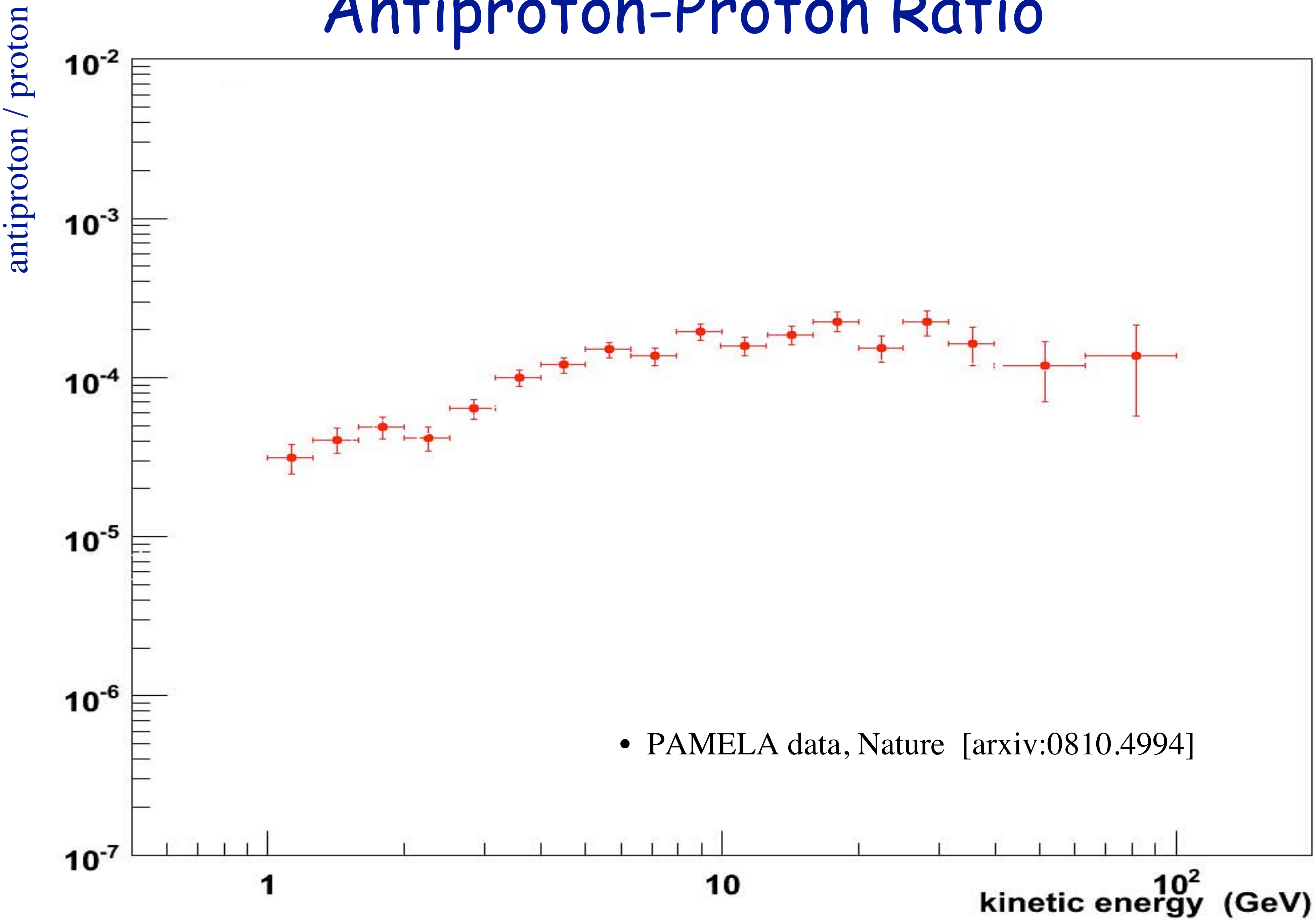


A.Lionetto, A.Morselli, V.Zdravkovic
JCAP09(2005)010 [astro-ph/0502406]

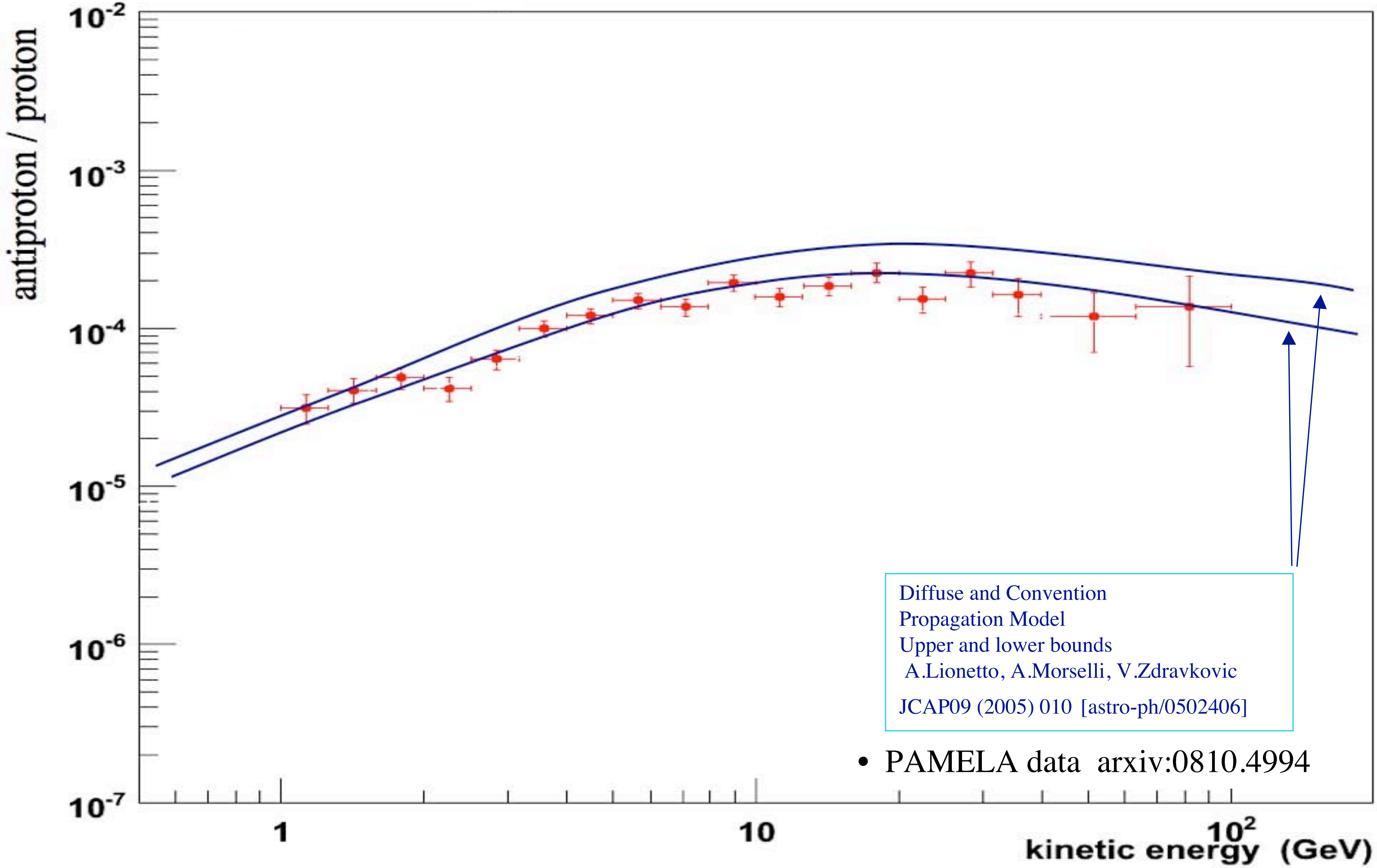
- ~ 3 years from PAMELA launch

- Launched in orbit on June 15, 2006, on board of the DK1 satellite by a Soyuz rocket from the Bajkonour cosmodrom.

Antiproton-Proton Ratio

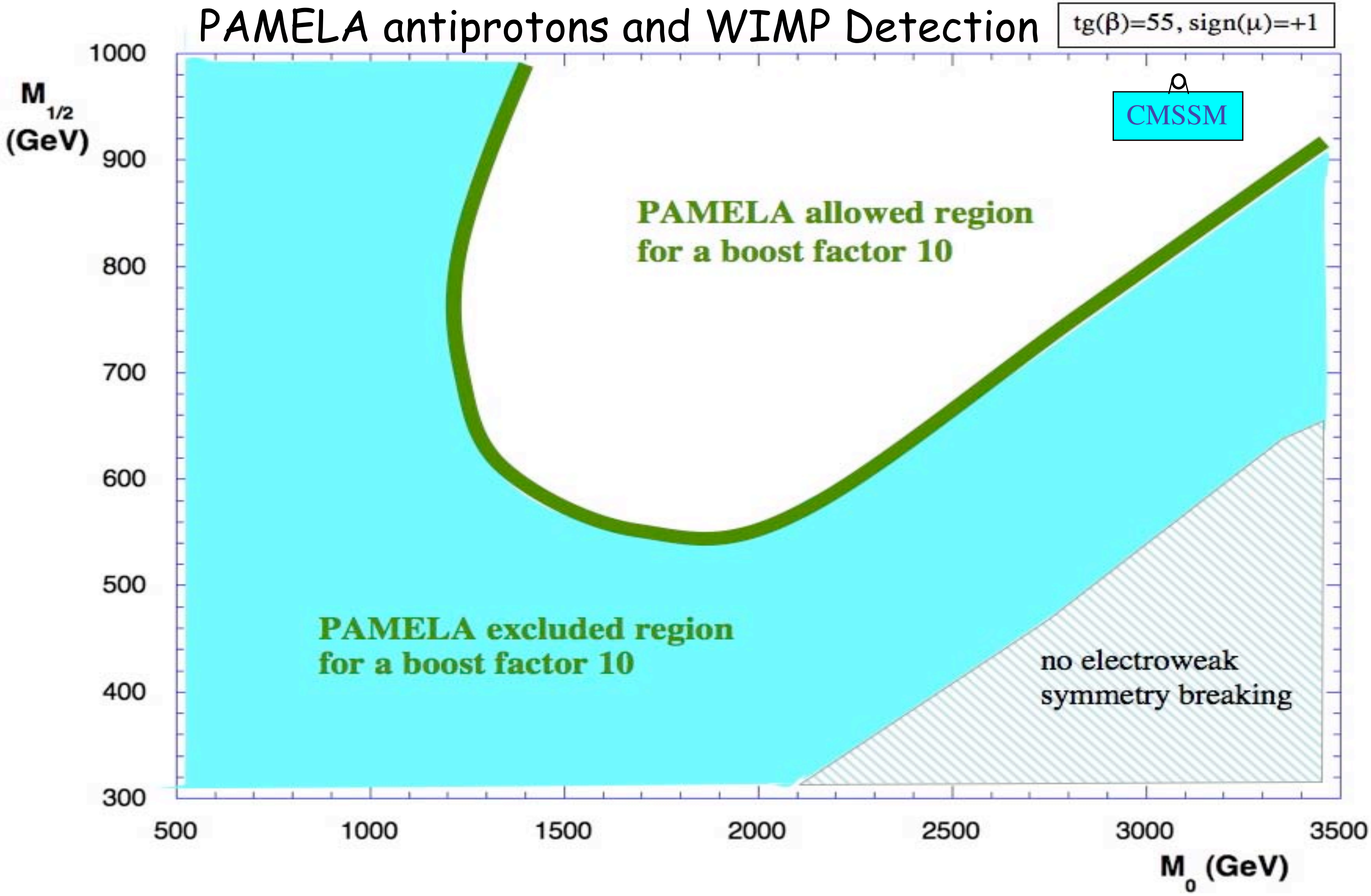


Antiproton-Proton Ratio

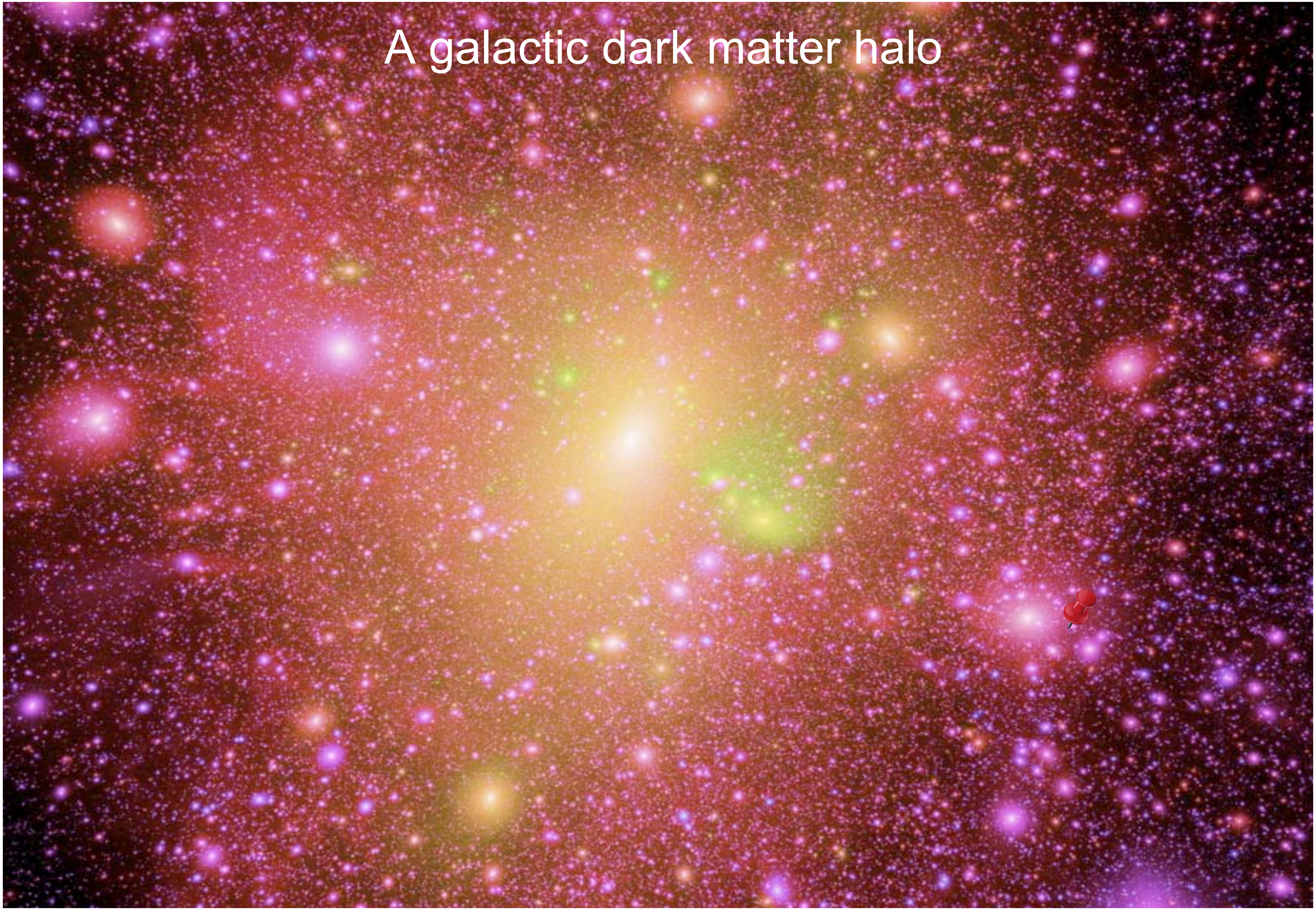


• PAMELA data arxiv:0810.4994

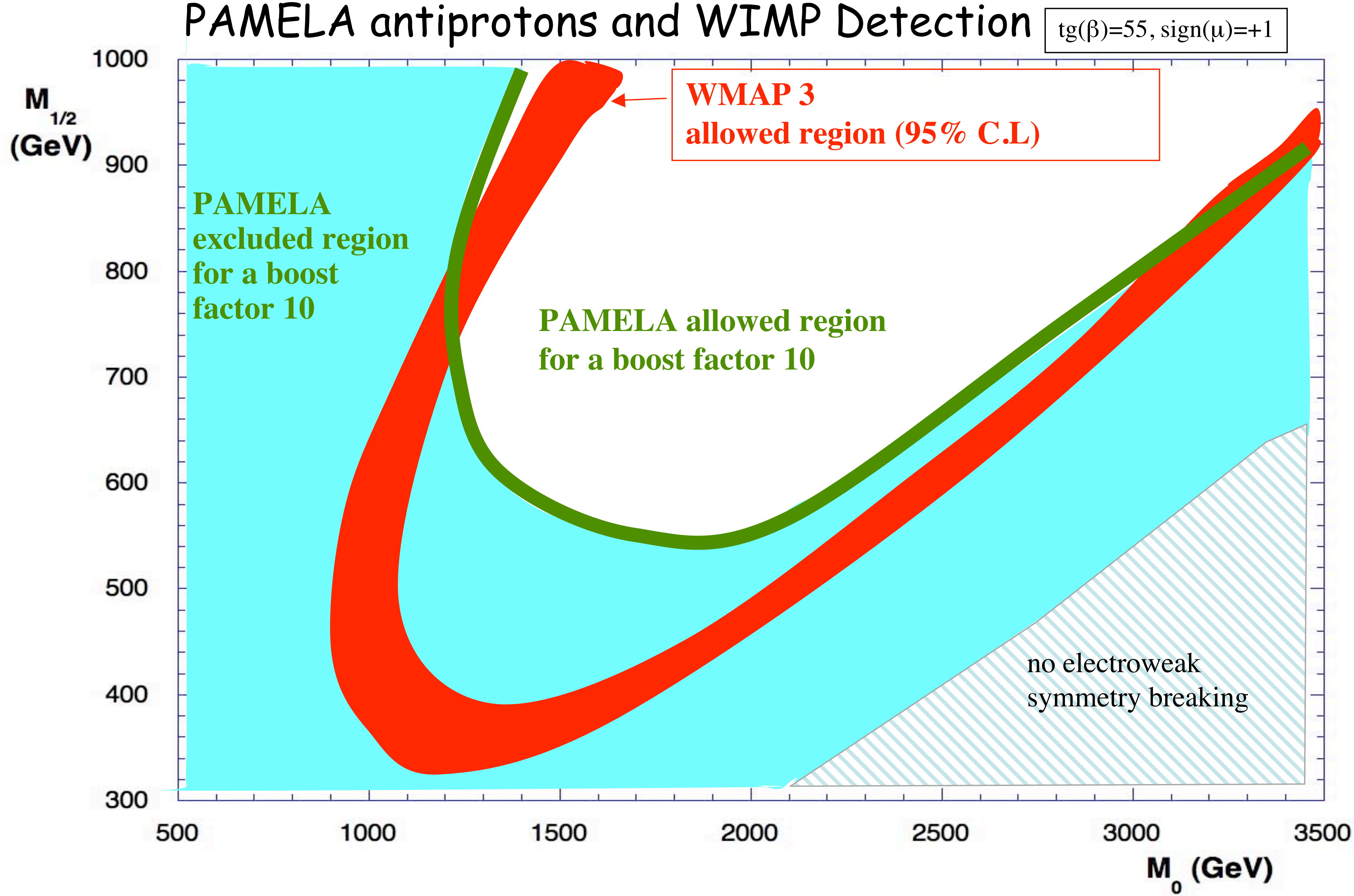
PAMELA antiprotons and WIMP Detection



A galactic dark matter halo

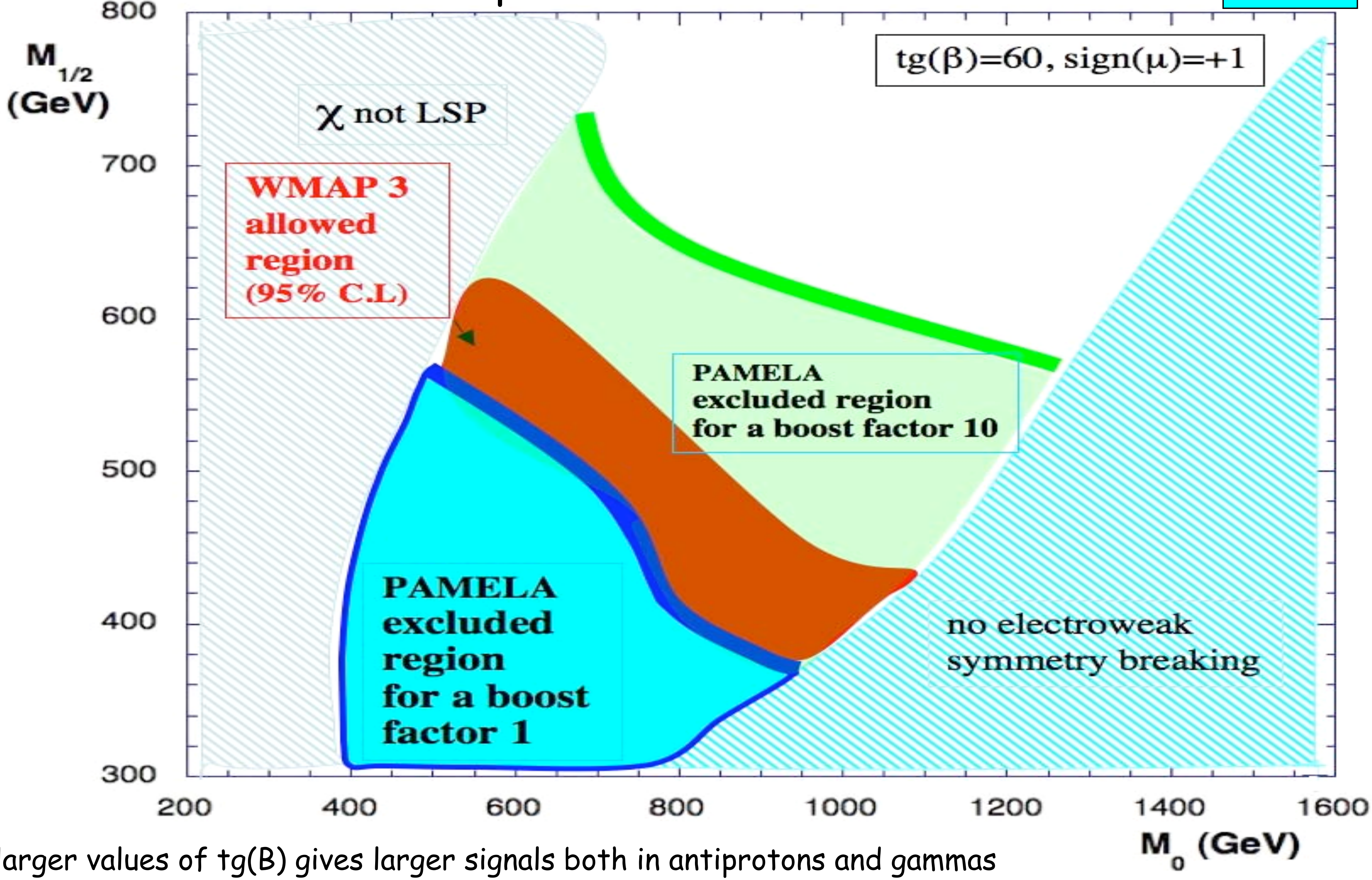


PAMELA antiprotons and WIMP Detection



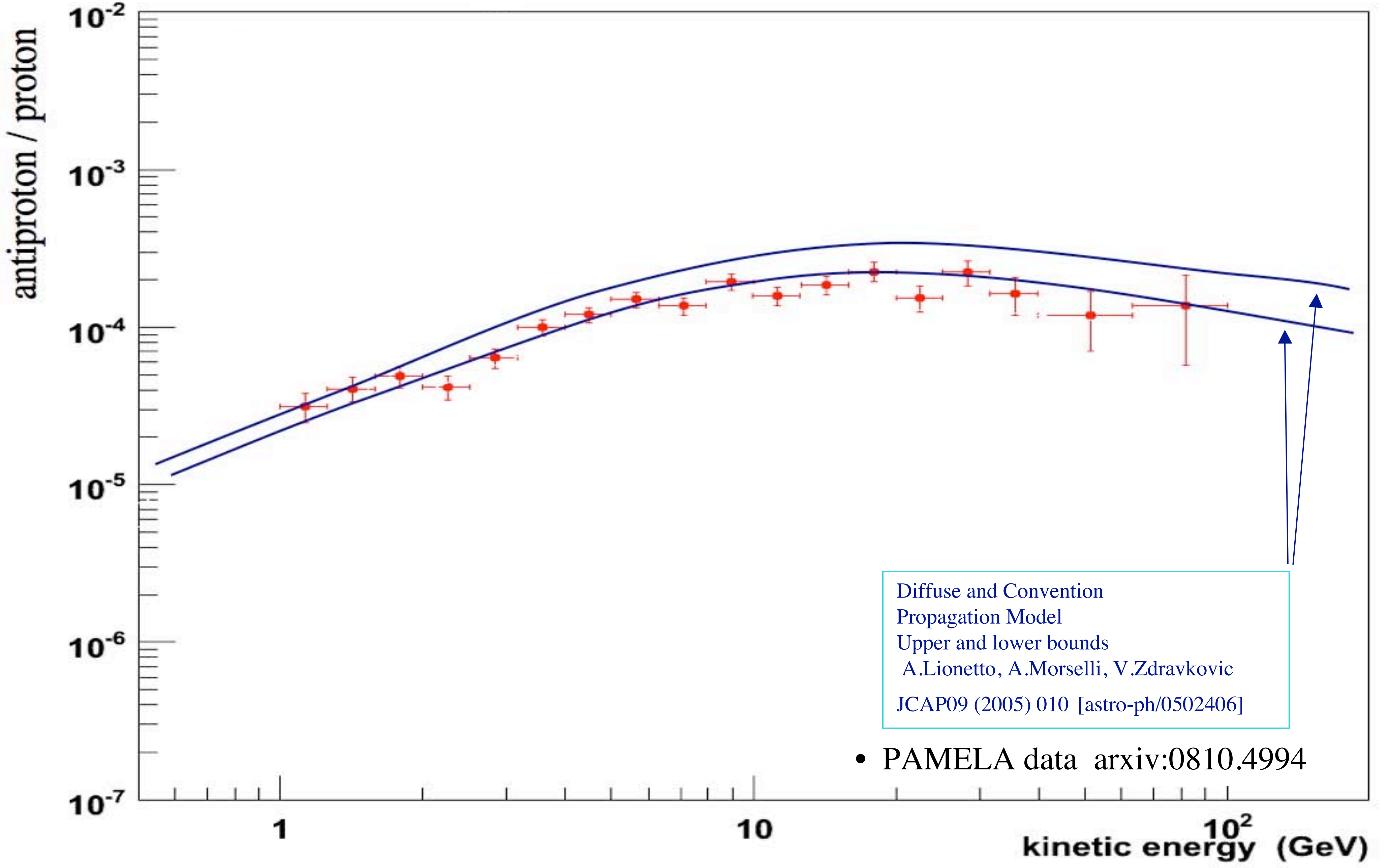
PAMELA antiprotons and WIMP Detection

CMSSM



larger values of tg(B) gives larger signals both in antiprotons and gammas

Antiproton-Proton Ratio



Propagation Equation for Cosmic Rays

$$\frac{\partial \psi(\mathbf{r},p,t)}{\partial t} = q(\mathbf{r},p) + \nabla \cdot (D_{xx}\nabla\psi - \mathbf{V}\psi) + \frac{\partial}{\partial p} p^2 D_{pp} \frac{\partial}{\partial p} \frac{1}{p^2} \psi - \frac{\partial}{\partial p}\left[\dot{p}\psi - \frac{p}{3}(\nabla \cdot \mathbf{V})\psi\right] - \frac{1}{\tau_f}\psi - \frac{1}{\tau_r}\psi$$

convection velocity field that corresponds to galactic wind and it has a cylindrical symmetry, as the geometry of the galaxy. It's z-component is the only one different from zero and increases linearly with the distance from the galactic plane

loss term: fragmentation

loss term: radioactive decay

diffusion coefficient in the impulse space, quasi-linear MHD:

$D_{pp}(D_{xx}, v_A)$

diffusion coefficient is function of rigidity

$$D_{xx} = \beta D_0 (\rho/\rho_0)^\delta$$

primary spectra injection index

$$dq(p)/dp \propto p^{-\gamma}$$

implemented in Galprop (Strong & Moskalenko, available on the Web)

[astro-ph/0502406]

Cosmic Ray Electron propagation models

They generally assume:

- Power-law source spectrum $N_e(E) \qquad E^{-\#_0}$
- Power-law diffusion coefficient (normalised to match CR nuclear data) $D = D_0 \left(\frac{E}{E_0} \right)^{-\delta}$
- Continuos source distribution in the Galactic Disk

For E > 10 GeV solar modulation, re-acceleration, convection have negligible effects. Only synchrotron and IC energy losses matter. Under those conditions

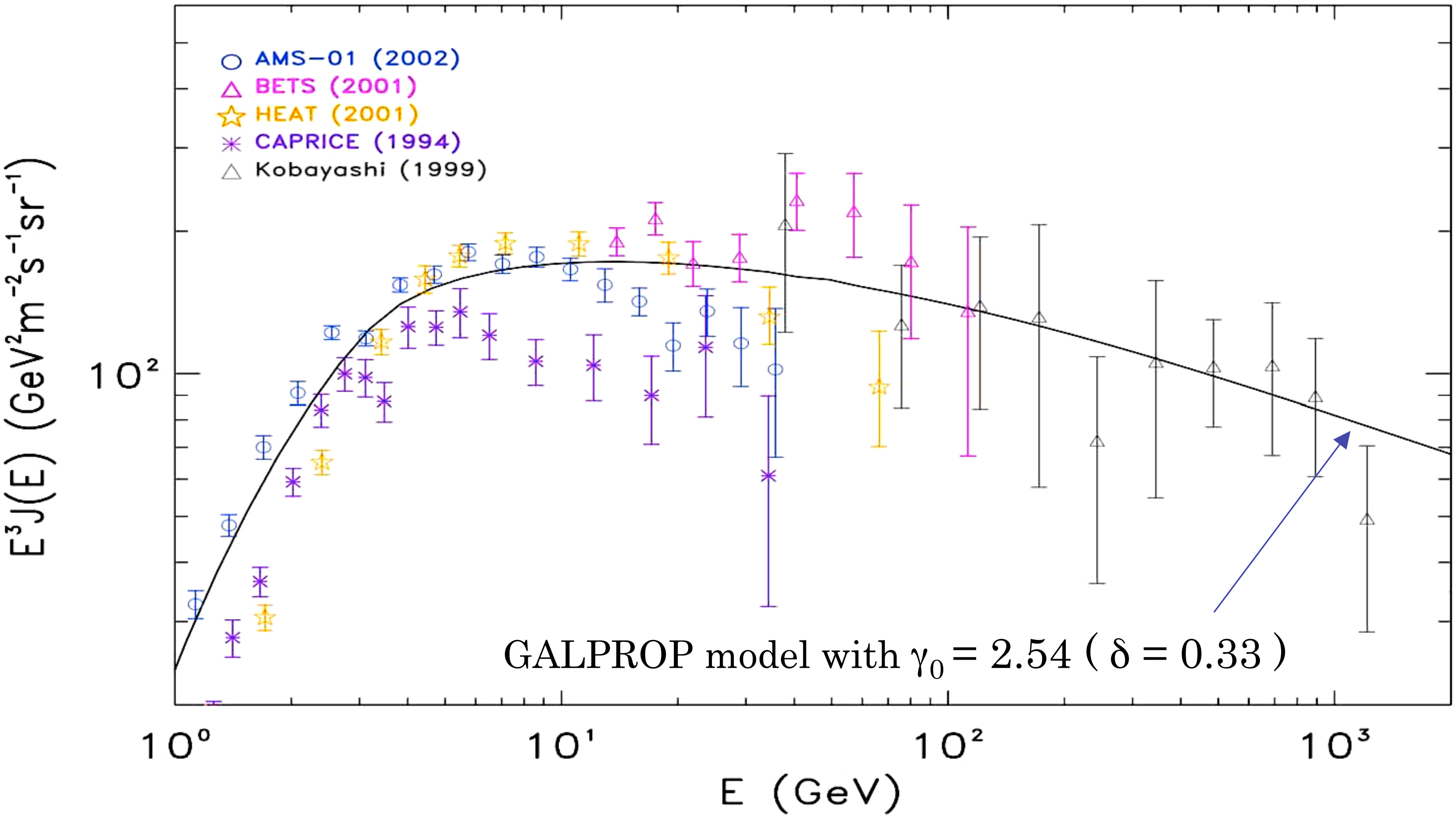
$$N_e(E) \propto E^{-(\gamma_0 + \frac{\delta}{2} + \frac{1}{2})}$$

This is only for illustrative purposes. All models here have been computed with GALPROP accounting for all effects !!

See http://galprop.stanford.edu/web_galprop/galprop_home.html

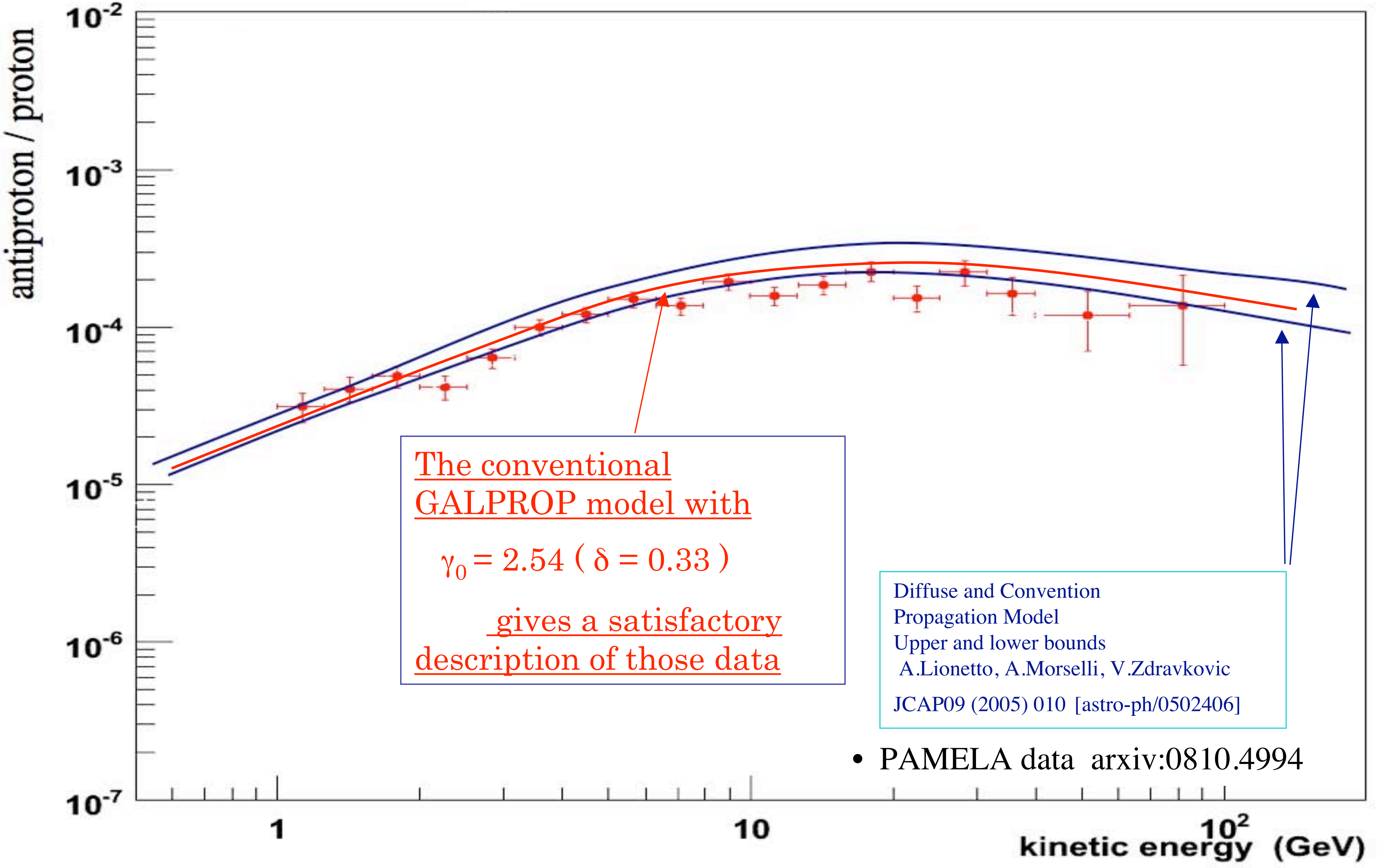
The situation before 2008

Electron + positron spectrum

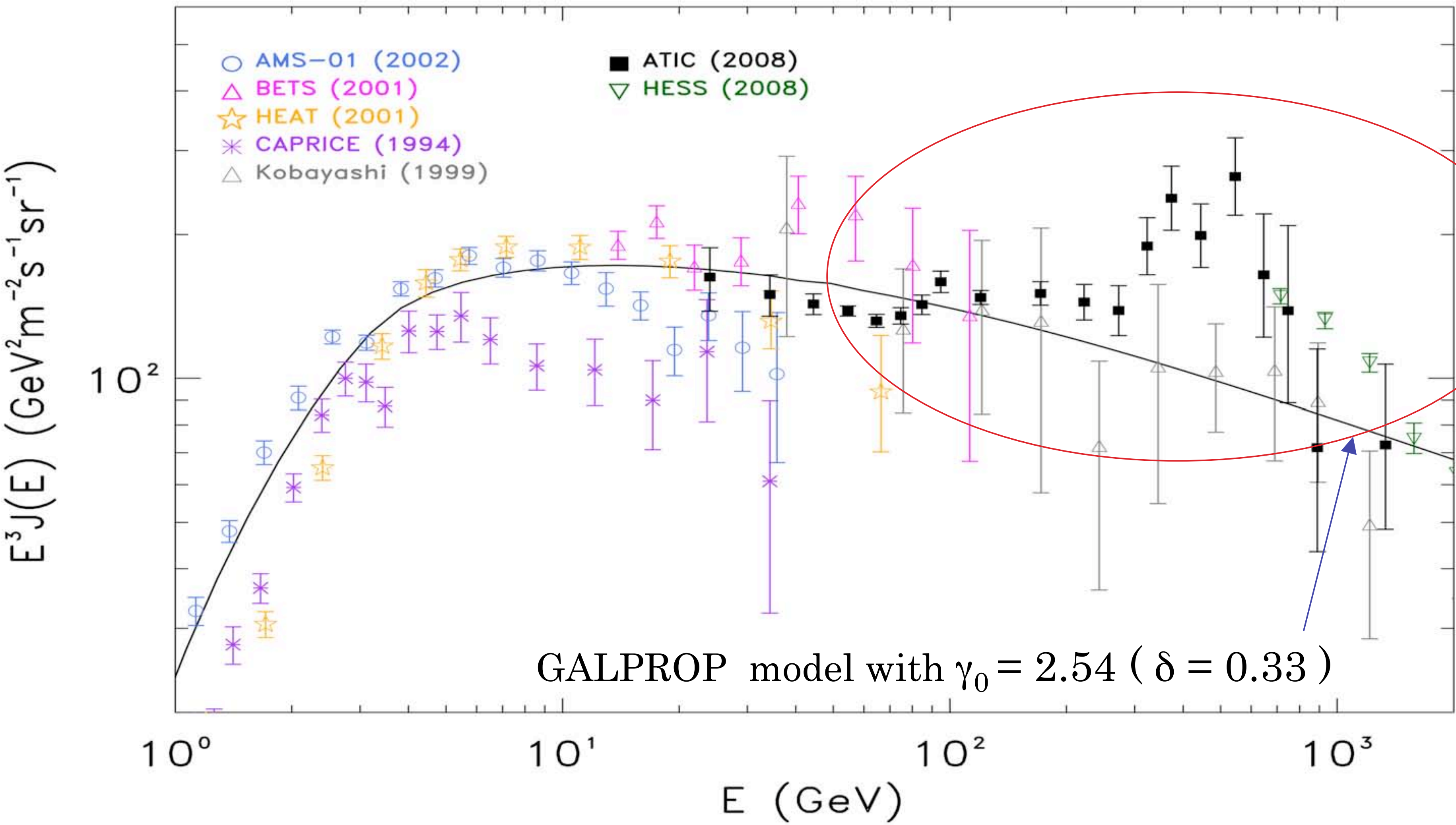


Data were compatible with conventional large-scale Galactic models of CRs tuned to fit gamma-ray data and other observables

Antiproton-Proton Ratio

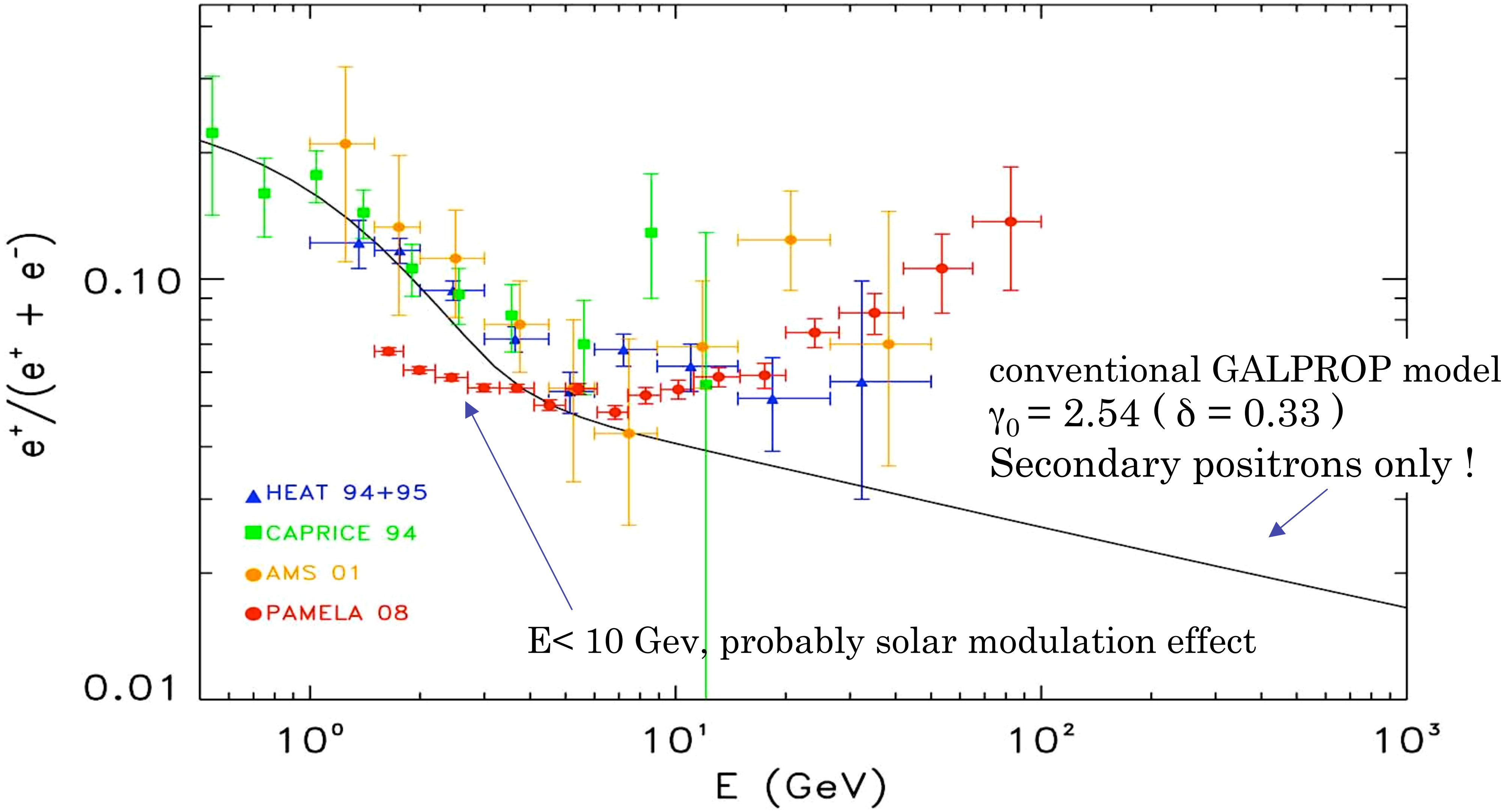


2008: Results from ATIC and HESS



Data clearly call for major changes to the conventional model:
Nearby sources (e.g. pulsar) or dark matter annihilation/decay models have been proposed to explain those data

2009: PAMELA results



$e^+/(e^+ + e^-) \propto E^{-\gamma p + \gamma_0 - \delta}$ γp: proton source power-index

It improves only adopting very soft electron spectra (high γ_0)

some articles about the positron excess

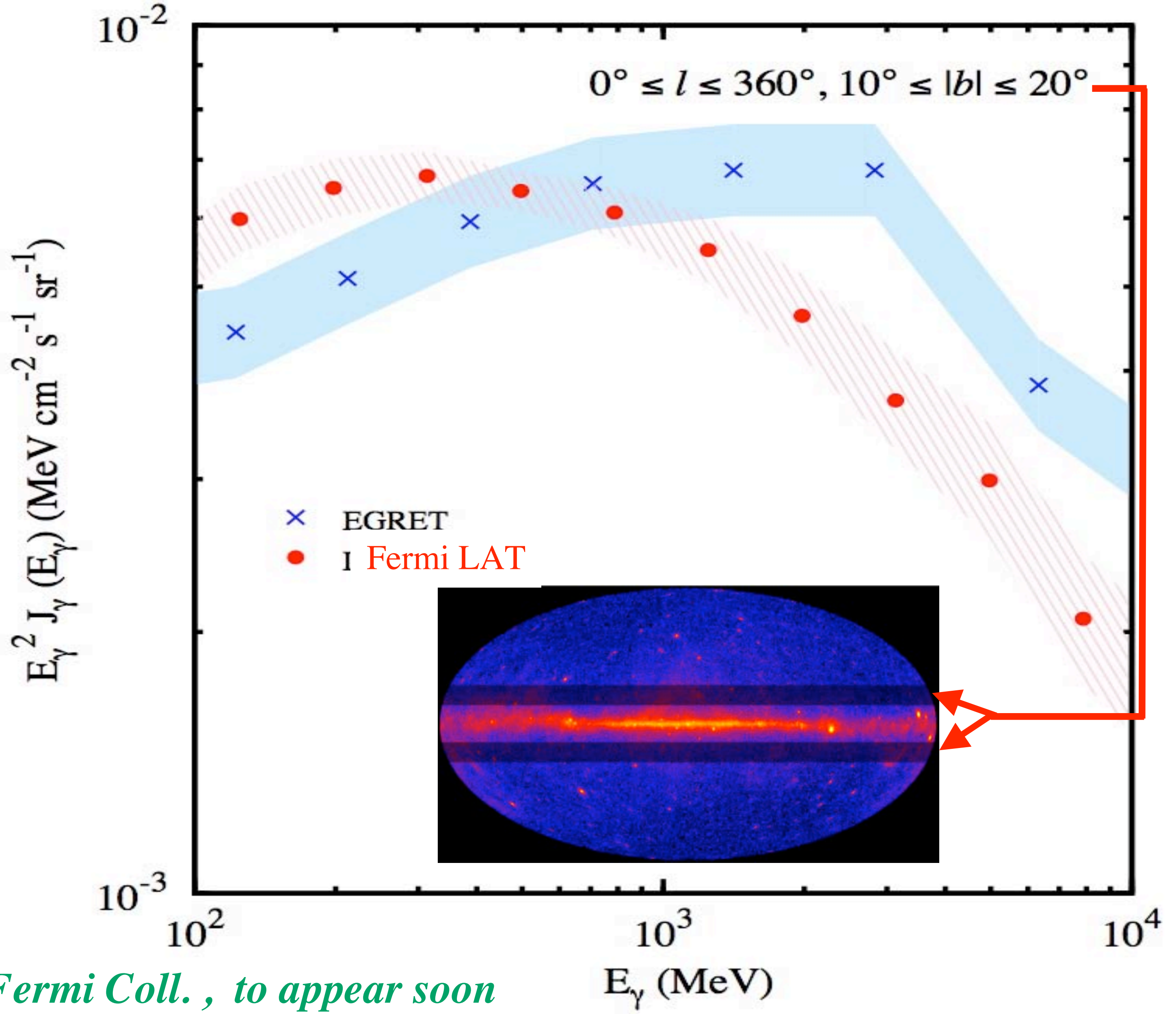
1. **arXiv:0901.3474** **Cosmic Ray Positrons from Cosmic Strings** Robert Brandenberger, Yi-Fu Cai, Wei Xue, Xinmin Zhang
2. **arXiv:0901.2556** **Positrons and antiprotons from inert doublet model dark matter** Emmanuel Nezri, Michel H.G. Tytgat, Gilles Vertongen
3. **arXiv:0901.1520** **On the cosmic electron/positron excesses and the knee of the cosmic rays - a key to the 50 years' puzzle?** Hong-Bo Hu, Qiang Yuan, Bo Wang, Chao Fan , Jian-Li Zhang , Xiao-Jun Bi
4. **arXiv:0812.4851** **A Gamma-Ray Burst for Cosmic-Ray Positrons with a Spectral Cutoff and Line**Kunihito Ioka
5. **arXiv:0812.4555** **Is the PAMELA Positron Excess Winos?** Phill Grajek, Gordon Kane, Dan Phalen, Aaron Pierce, Scott Watson
6. **arXiv:0812.4457** **Dissecting Pamela (and ATIC) with Occam's Razor: existing, well-known Pulsars naturally account for the "anomalous" Cosmic-Ray Electron and Positron Data** Stefano Profumo
7. **arXiv:0812.4272** **Study of positrons from cosmic rays interactions and cold dark matter annihilations in the galactic environment** Roberto A. Lineros thesis
8. **arXiv:0812.3895** **Gamma-ray and Radio Constraints of High Positron Rate Dark Matter Models Annihilating into New Light Particles** Lars Bergstrom, Gianfranco Bertone, Torsten Bringmann, Joakim Edsjo, Marco Taoso
9. **arXiv:0812.2102** **A Relativistic Electron-Positron Outflow from a Tepid Fireball**Katsuaki Asano, Fumio Takahara
10. **arXiv:0812.0219** **Neutrino Signals from Annihilating/Decaying Dark Matter in the Light of Recent Measurements of Cosmic Ray Electron/Positron Fluxes** Junji Hisano, Masahiro Kawasaki, Kazunori Kohri, Kazunori Nakayama
11. **arXiv:0811.0477** **High-energy Cosmic-Ray Positrons from Hidden-Gauge-Boson Dark Matter** Chuan-Ren Chen, Fuminobu Takahashi, T. T. Yanagida

11\. **arXiv:0811.3526** **Status of indirect searches in the PAMELA and Fermi era** Aldo Morselli, Igor Moskalenko

12. **arXiv:0811.0250** **Cosmic-Ray Positron from Superparticle Dark Matter and the PAMELA Anomaly** Koji Ishiwata, Shigeki Matsumoto, Takeo Moroi
13. **arXiv:0810.5344** **The PAMELA Positron Excess from Annihilations into a Light Boson** Ilias Cholis, Douglas P. Finkbeiner, Lisa Goodenough, Neal Weiner
14. **arXiv:0810.4846** **Possible causes of a rise with energy of the cosmic ray positron fraction** Pasquale Dario Serpico
15. **arXiv:0810.2784** **TeV Gamma Rays from Geminga and the Origin of the GeV Positron Excess** Hasan Yuksel , Matthew D. Kistler Todor Stanev
16. **arXiv:0810.1892** **Positron/Gamma-Ray Signatures of Dark Matter Annihilation and Big-Bang Nucleosynthesis** Junji Hisano, Masahiro Kawasaki, Kazunori Kohri, Kazunori Nakayama
17. **arXiv:0810.1527** **Pulsars as the Sources of High Energy Cosmic Ray Positrons** Dan Hooper, Pasquale Blasi, Pasquale Dario Serpico
18. **arXiv:0809.5268** **Galactic secondary positron flux at the Earth** T. Delahaye, F. Donato , N. Fornengo , J. Lavalle , R. Lineros , P. Salati , R. Taillet ,
19. **arXiv:0809.2601** **Two dark matter components in N_{DM}MSSM and dark matter extension of the minimal supersymmetric standard model and the high energy positron spectrum in PAMELA/HEAT data** Ji-Haeng Huh, Jihn E. Kim, Bumseok Kyae
20. **arXiv:0809.2491** **On the 511 keV emission line of positron annihilation in the Milky Way** N. Prantzos
22. **arXiv:0809.0792** **Gamma rays and positrons from a decaying hidden gauge boson** Chuan-Ren Chen, Fuminobu Takahashi, T. T. Yanagida
23. **arXiv:0808.3867** **Minimal Dark Matter predictions and the PAMELA positron excess**Marco Cirelli, Alessandro Strumia
24. **arXiv:0808.3725** **New Positron Spectral Features from Supersymmetric Dark Matter - a Way to Explain the PAMELA Data?**Lars Bergstrom, Torsten Bringmann, Joakim Edsjo


~ 1 year from Fermi launch
11 June 2008

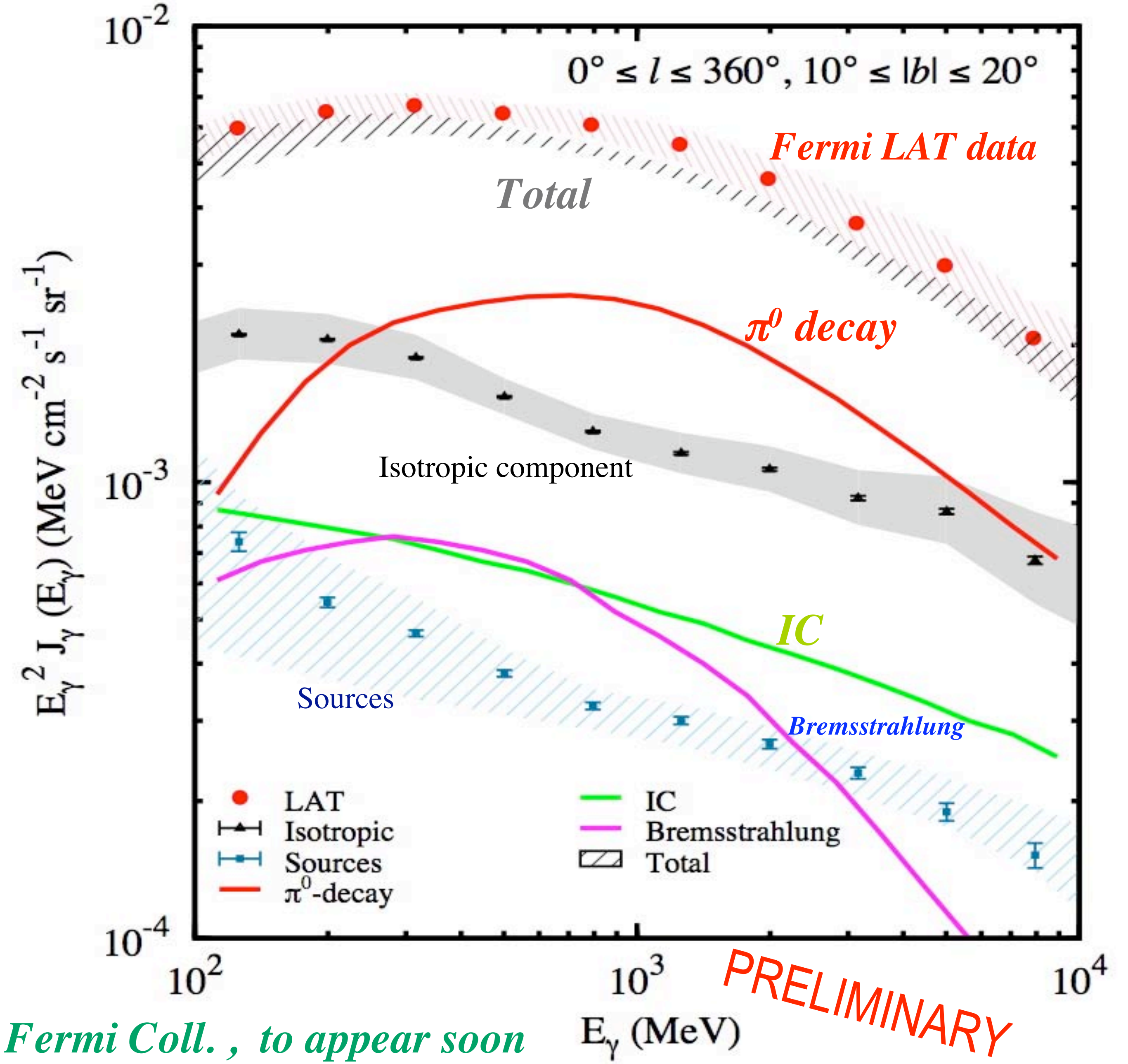
The Galactic Diffuse Emission



Fermi Coll. , to appear soon

- Spectra shown for mid-latitude range → GeV excess in this region of the sky is not confirmed.
- Sources are not subtracted but are a minor component.
- LAT errors are dominated by systematic uncertainties and are currently estimated to be ~10% → this is preliminary.

2009: Fermi-LAT diffuse gamma-ray spectrum first measurements



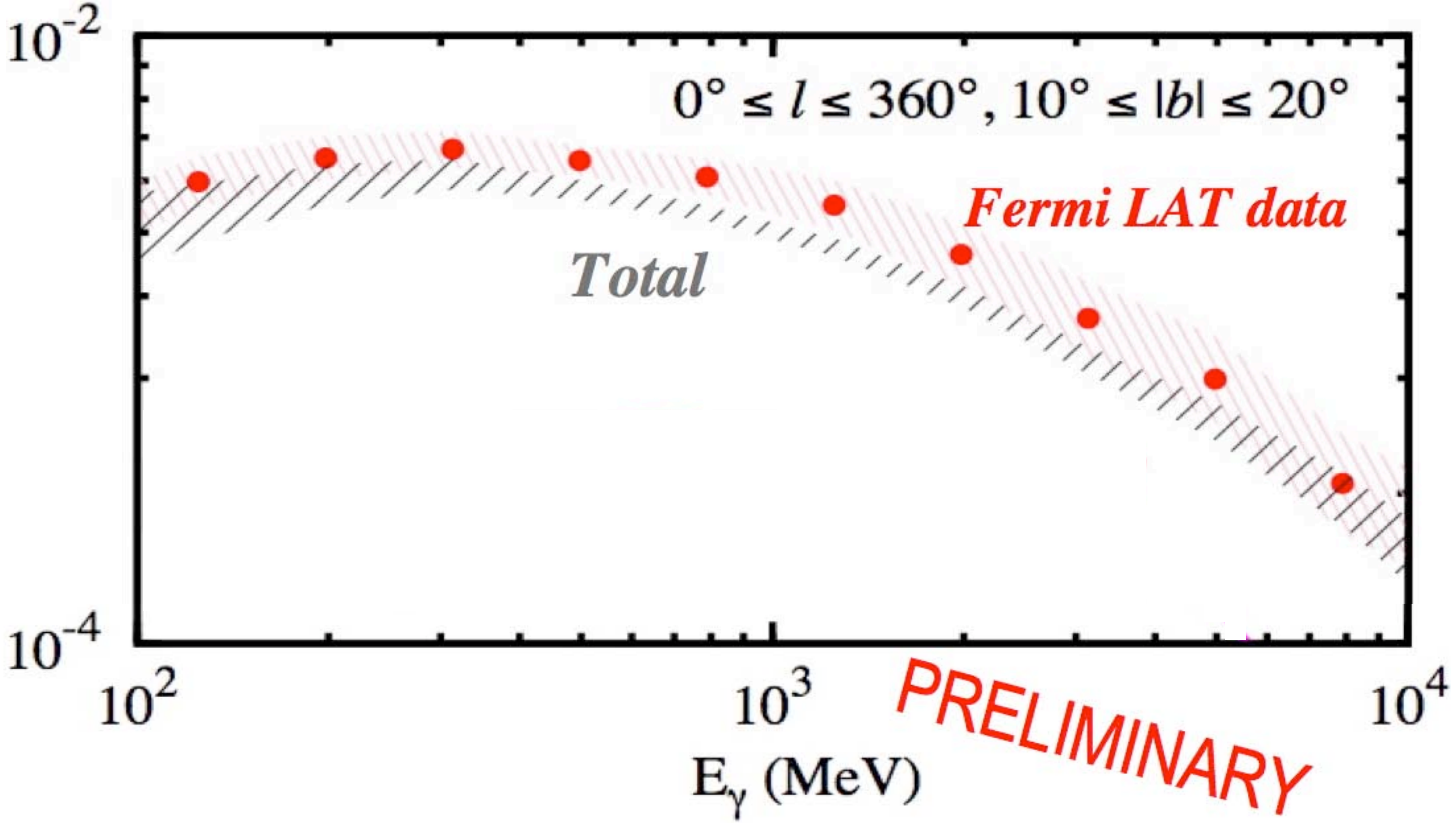
Fermi Coll. , to appear soon

EGRET GeV excess was not observed ⇒ Conventional models (based on the locally measured CR fluxes) can be used

The conventional model with $\gamma_0 = 2.54$ ($\delta = 0.33$) gives a satisfactory description of Fermi-LAT gamma-ray data

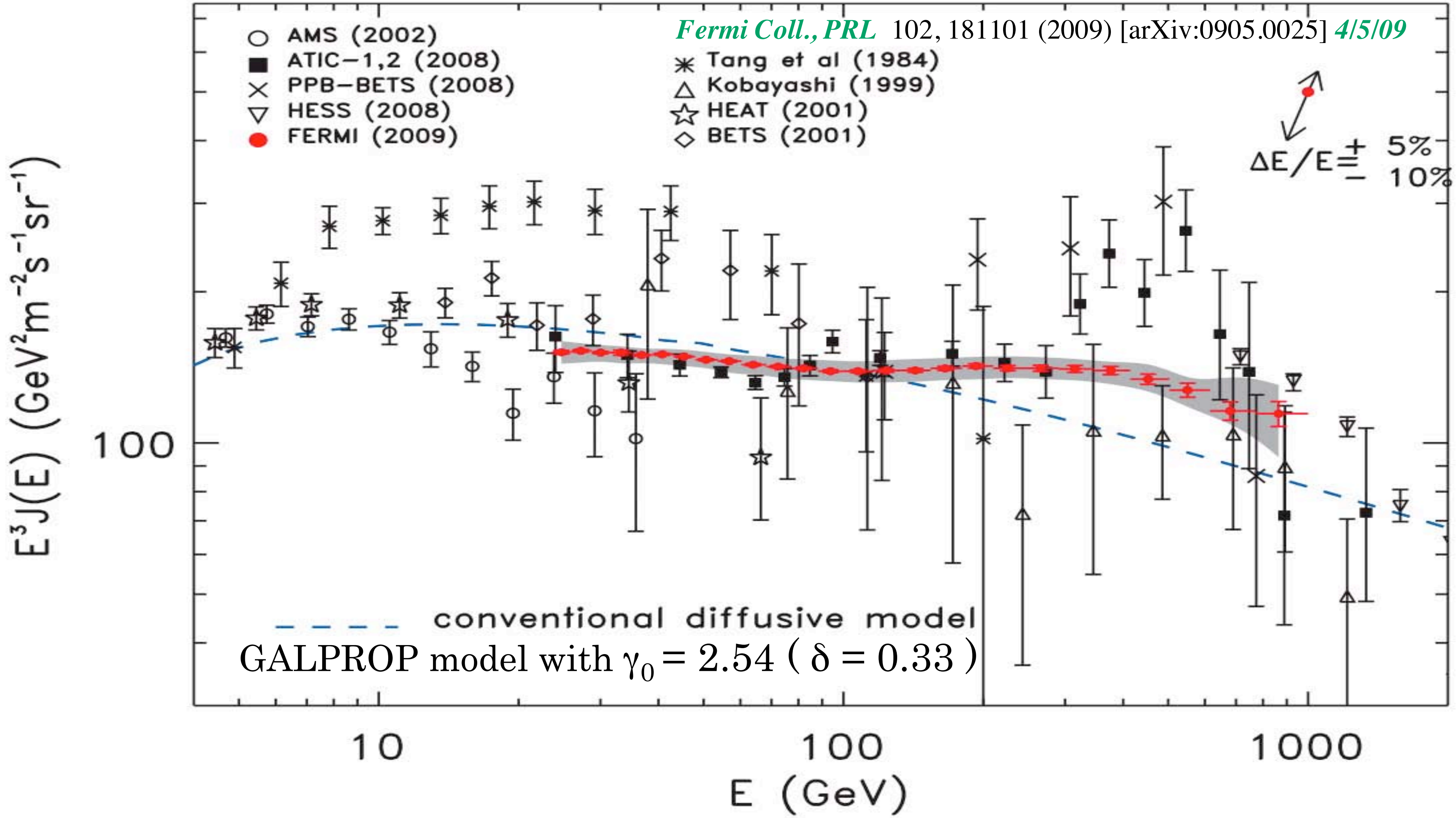
Conventional model are weakly affected by small changes in the electron spectrum.

2009: Fermi-LAT diffuse gamma-ray spectrum first measurements



see: Gamma-ray detection from gravitino dark matter decay in the μνSSM arXiv:0906.368

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



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

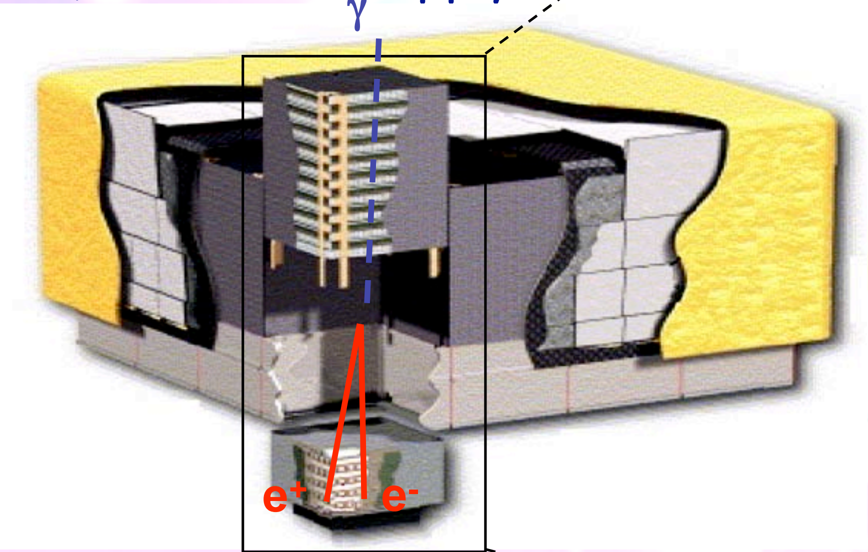
<u>Some changes are still needed respect to the *pre-Fermi conventional model*</u>

(

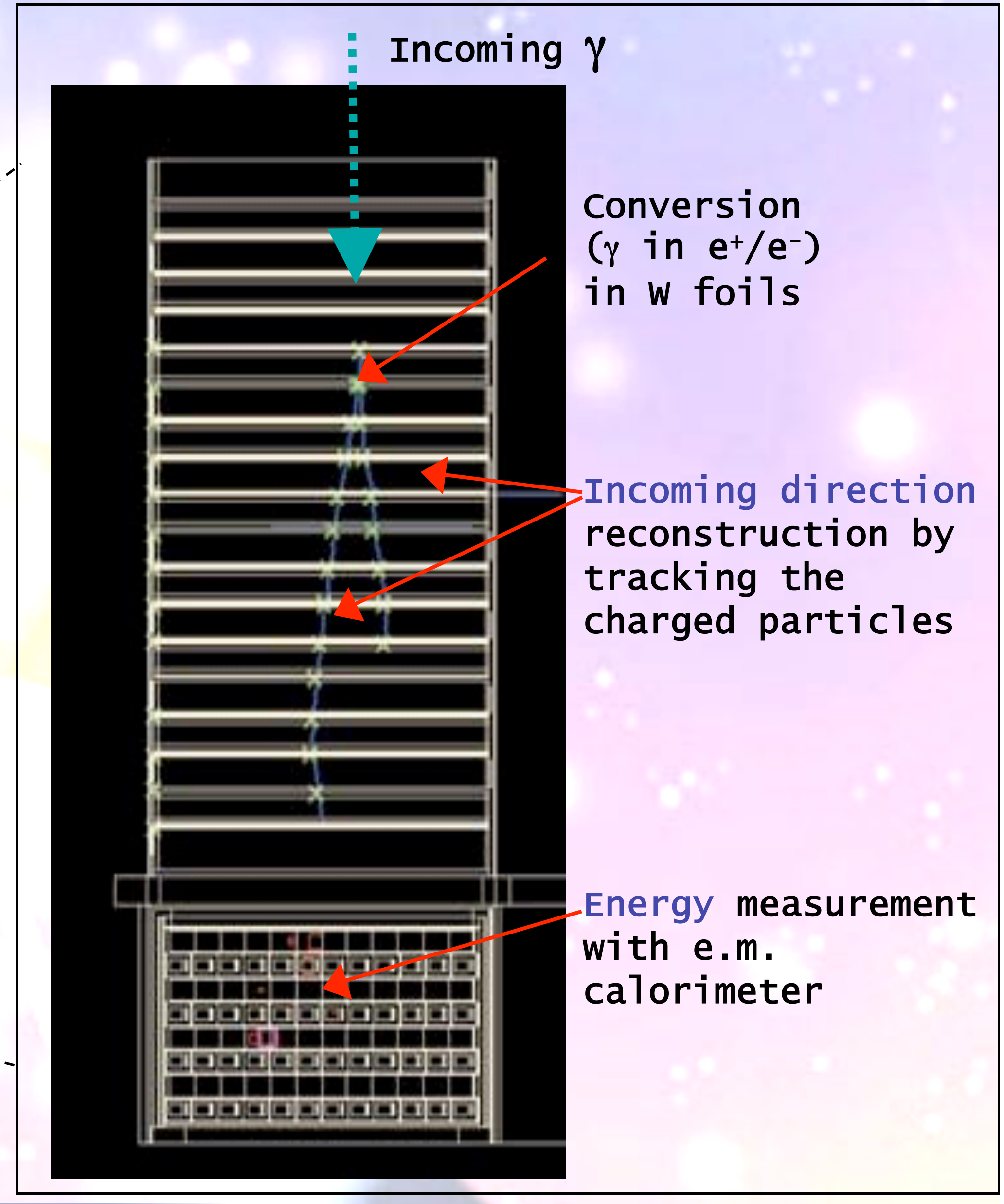
How Fermi LAT detects gamma rays

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



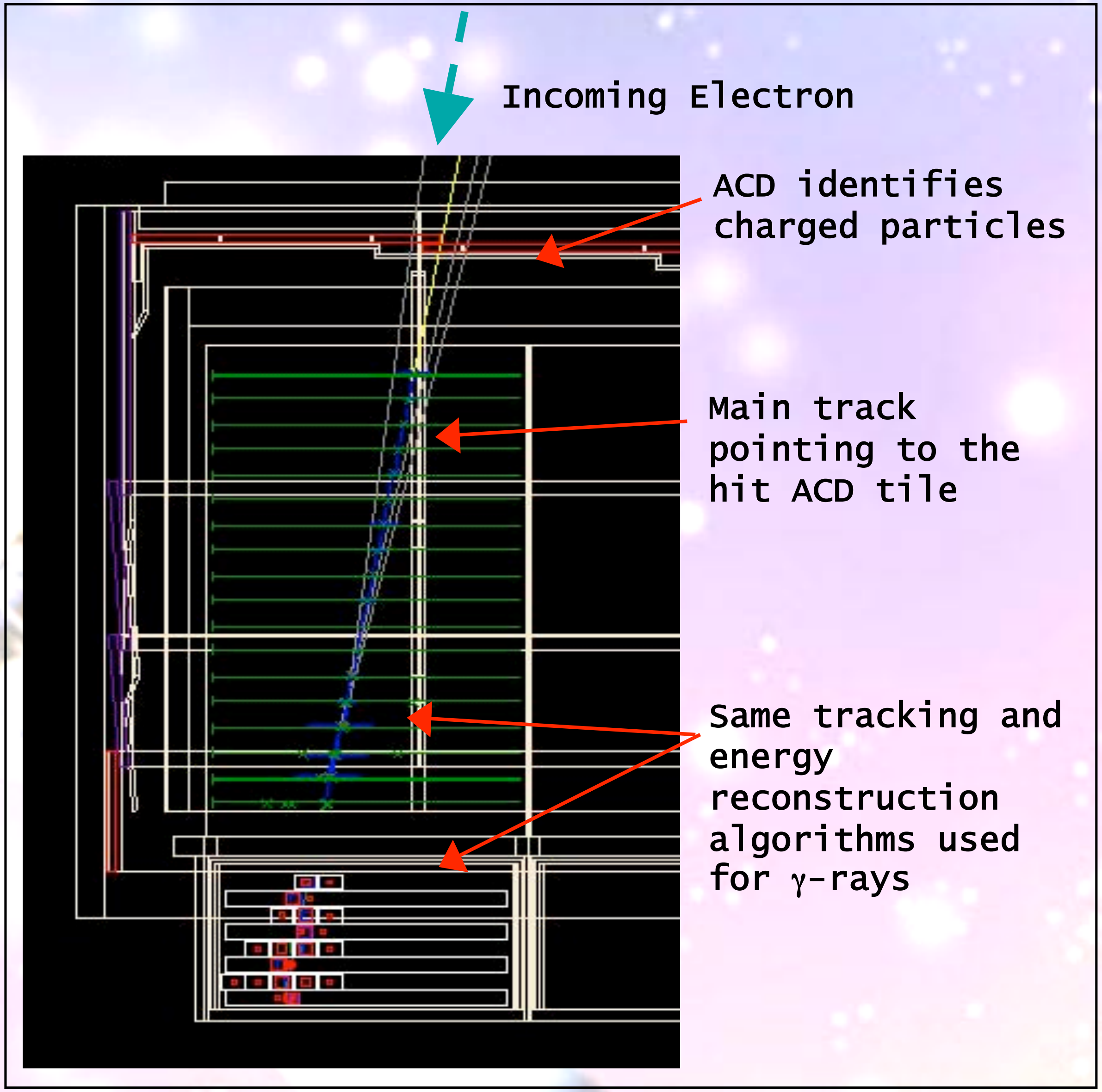
How Fermi LAT detects electrons

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

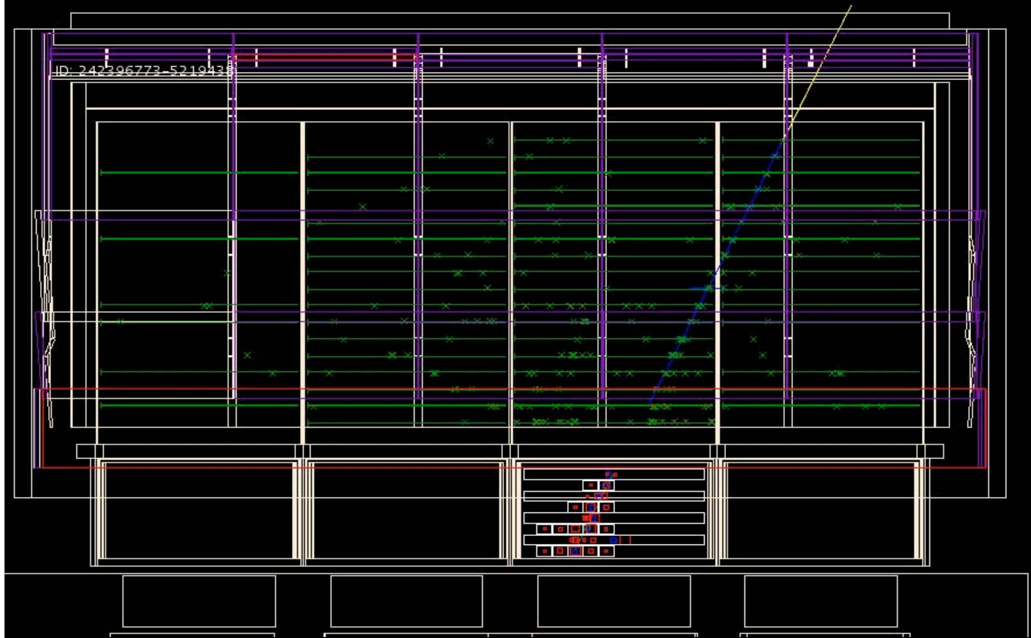
Electron identification

- 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



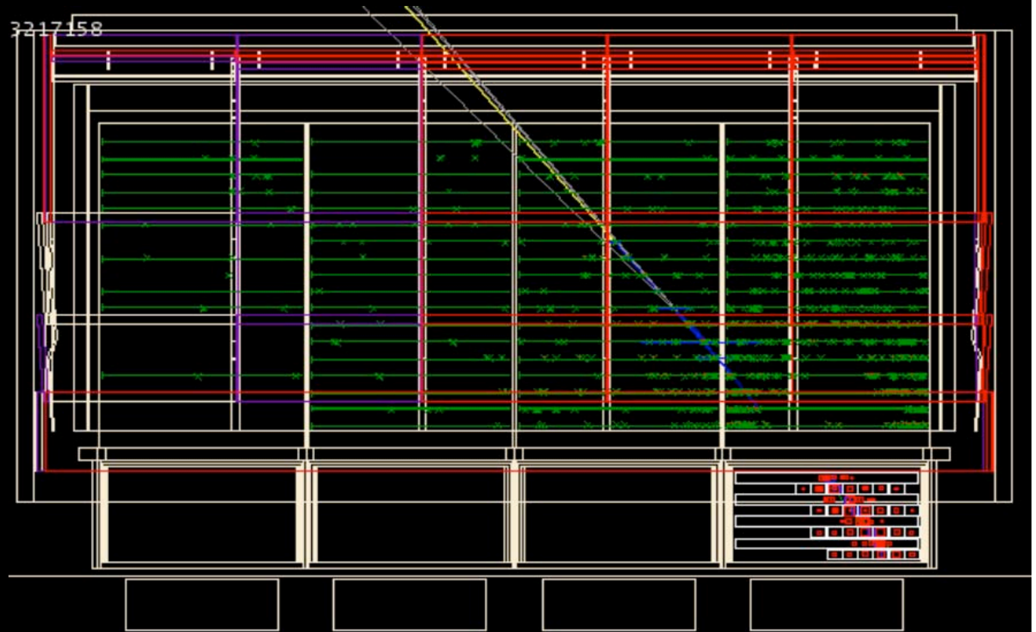
Event topology

A candidate electron
(recon energy 844 GeV)



- 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

A candidate hadron
(raw energy > 800 GeV)

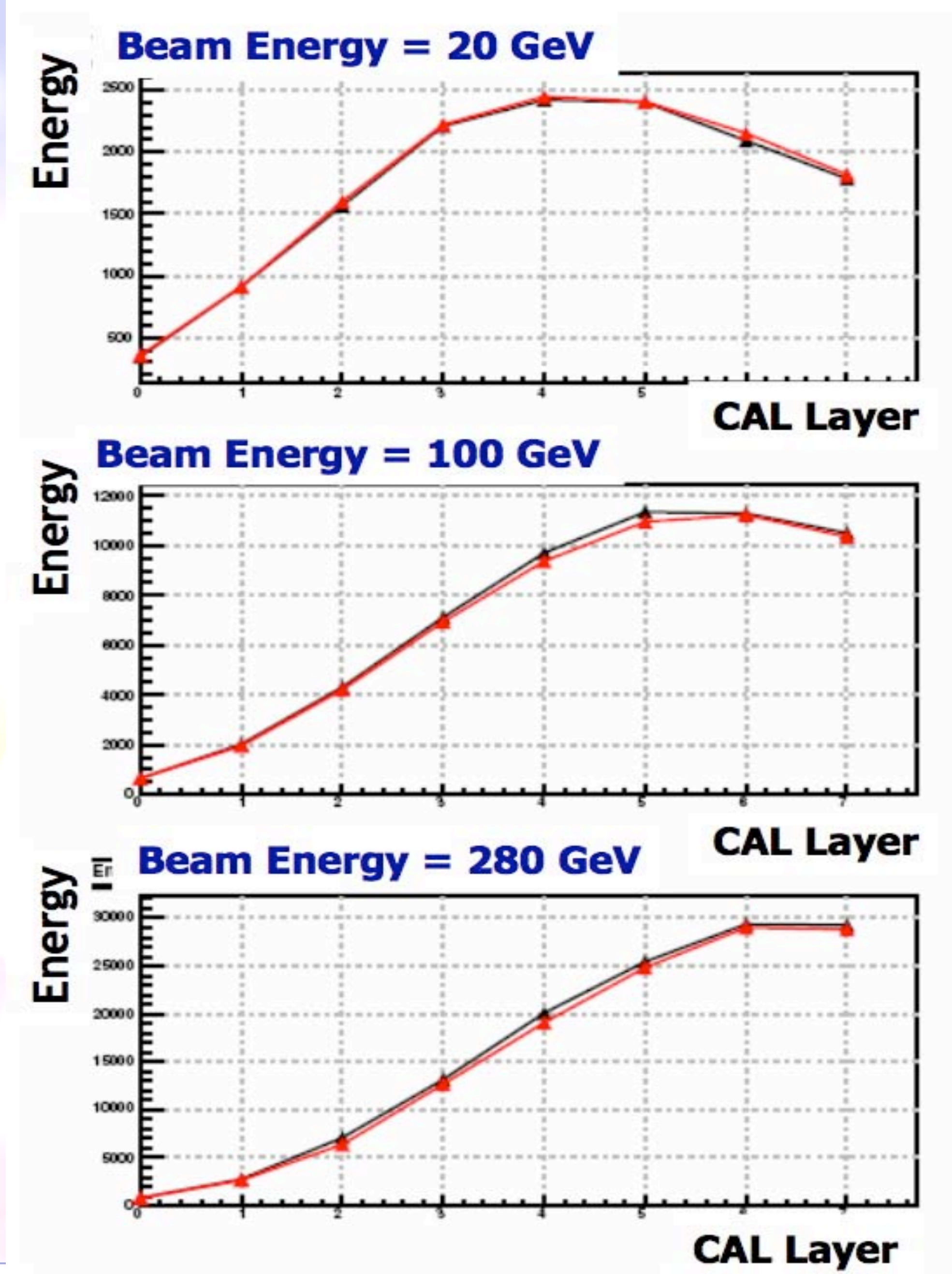


- TKR: small number of extra clusters around main track
- CAL: large and asymmetric shower profile
- ACD: large energy deposit per tile

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)



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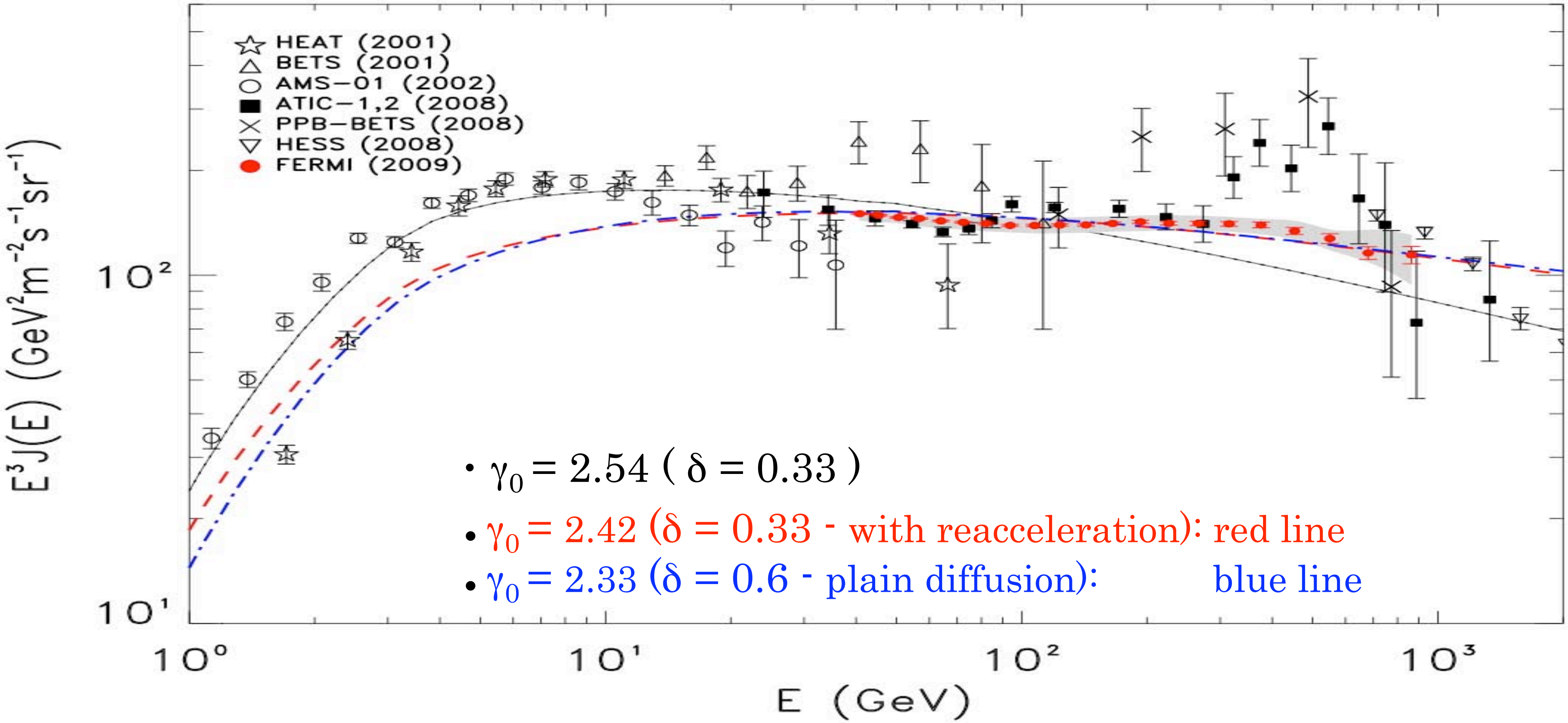
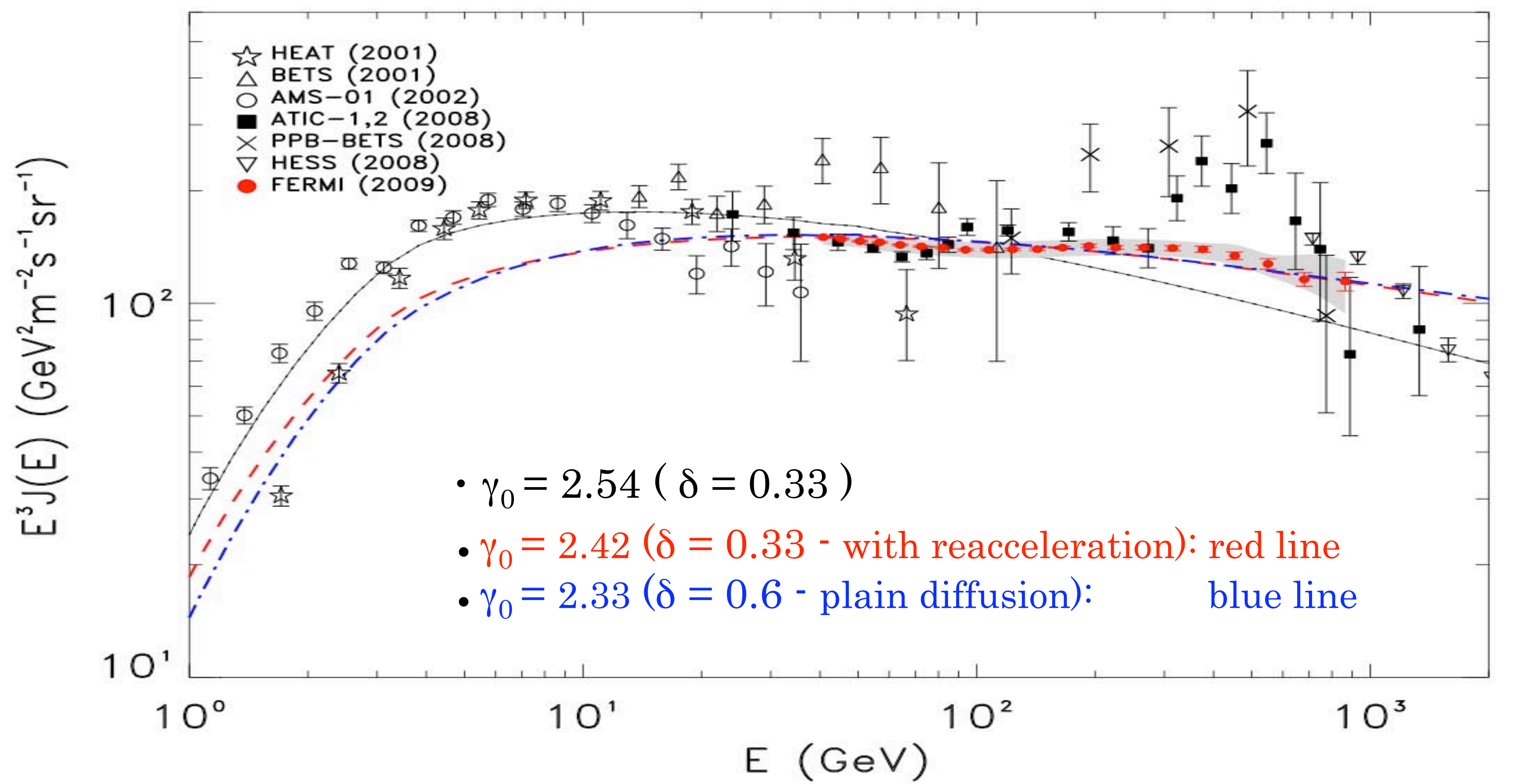
Cosmic Ray Electron propagation models



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 γ_0 = 1.6 below 4 GeV.

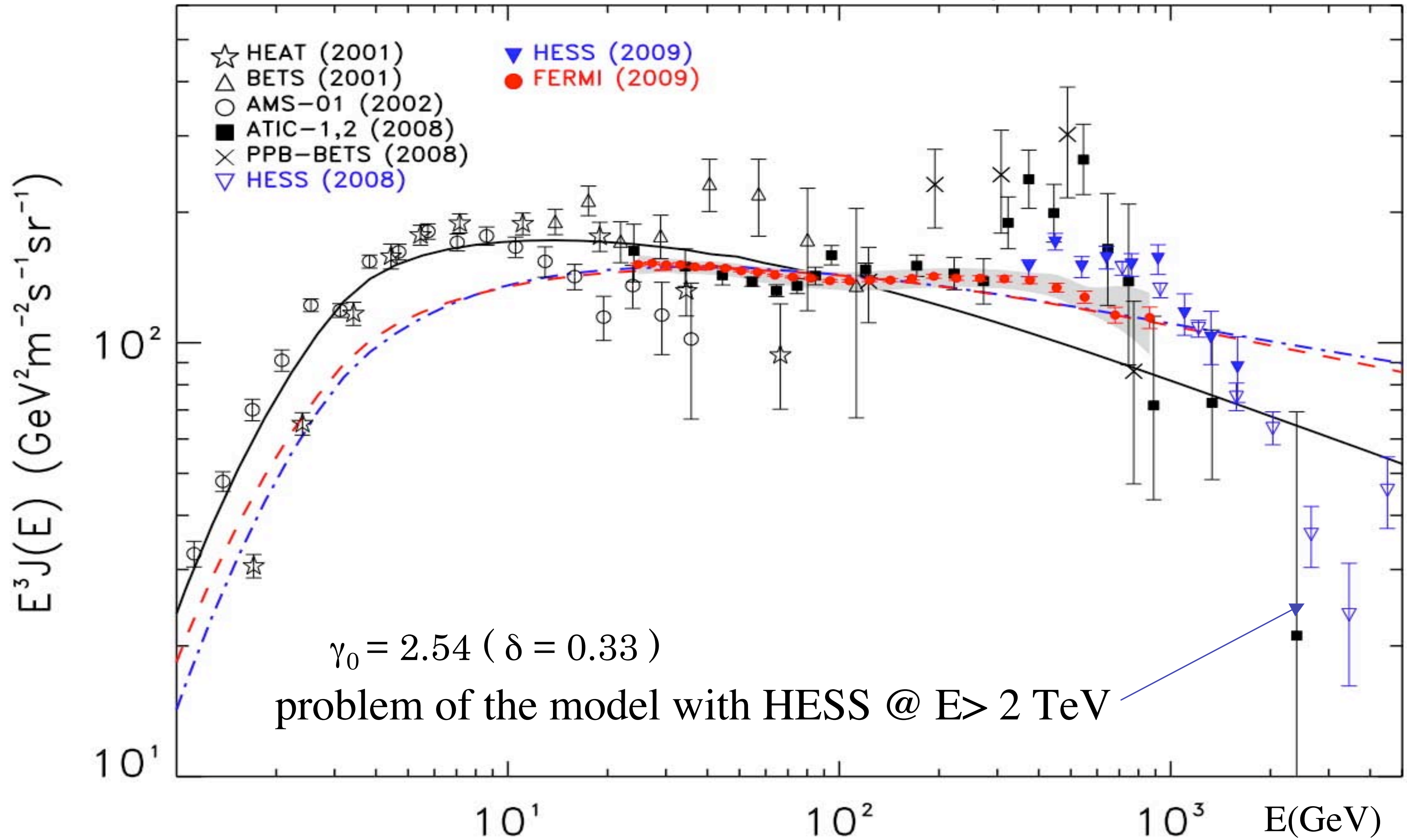
A simple interpretation of Fermi-LAT CRE spectrum



Numerical models of propagation of CR electrons can be tuned to fit Fermi data assuming an **harder injection index**:

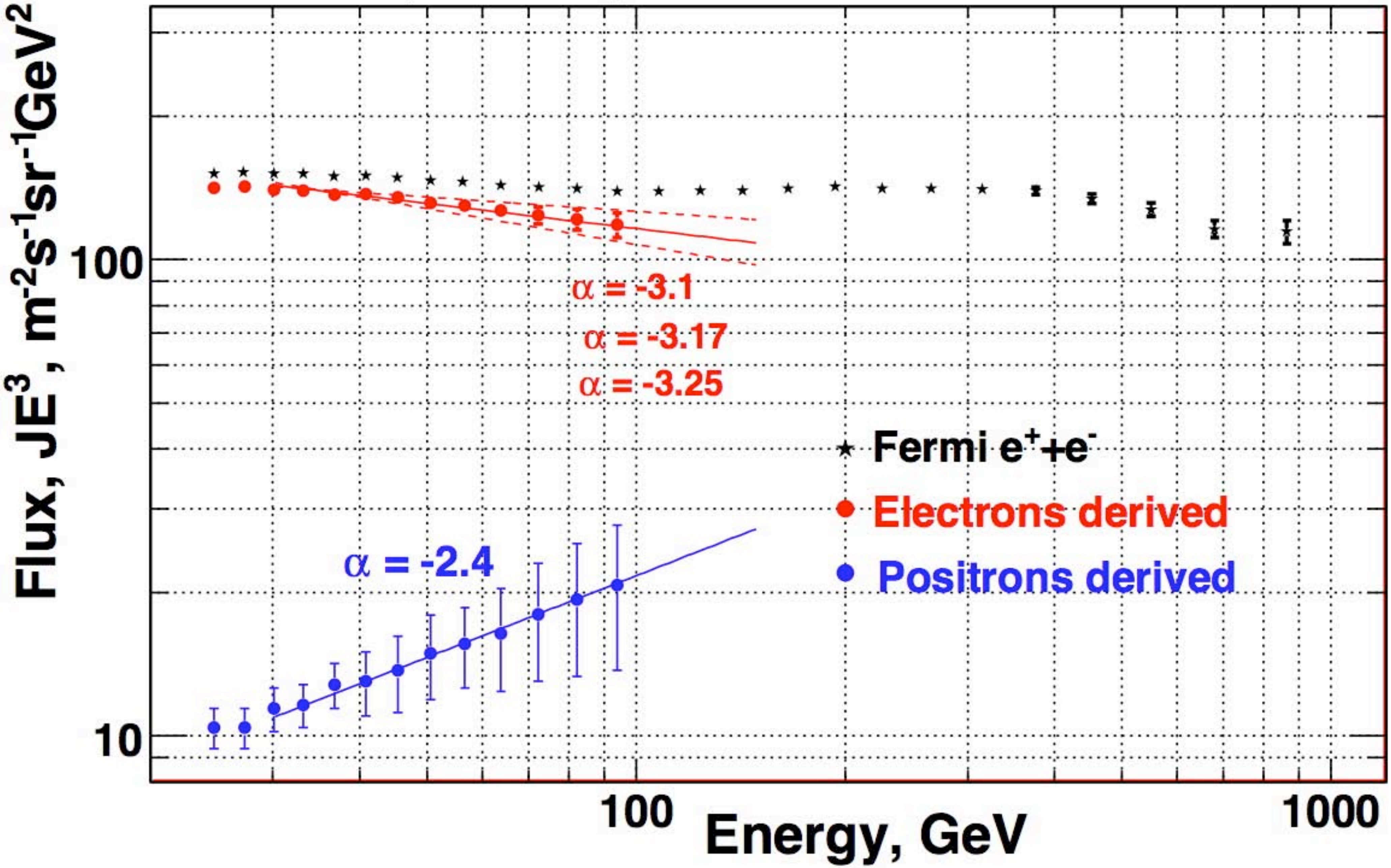
- <u>Problems: These tuned models are in tension with low-energy and HESS data</u> (no big problems with gamma-ray data - *work in progress*)

Fermi & HESS data vs the conventional *pre-Fermi* model



cutoff in the CRE source spectrum or breakdown of the source spatial continuity?

Electron and positron spectra derived from Fermi and Pamela



Primary electrons in Cosmic Rays

JOURNAL OF GEOPHYSICAL RESEARCH VOL. 70, NO. 11 JUNE 1, 1965

Letters

Observation of the Cosmic Ray Electron-Positron Ratio from 100 Mev to 3 bev in 1964

R. C. HARTMAN AND PETER MEYER

Enrico Fermi Institute for Nuclear Studies and Department of Physics University of Chicago, Chicago, Illinois

R. H. HILDEBRAND

Argonne National Laboratory and University of Chicago Chicago, Illinois

nent. In 1963, *DeShong, Hildebrand, and Meyer* [1964] reported the results of an experiment designed to measure this ratio in the energy interval from 100 to 1000 Mev. They found an excess of negative electrons which led them to conclude that the electron component consists mainly of directly accelerated particles. Their

- Now, ~45 years later PAMELA excess in positron fraction

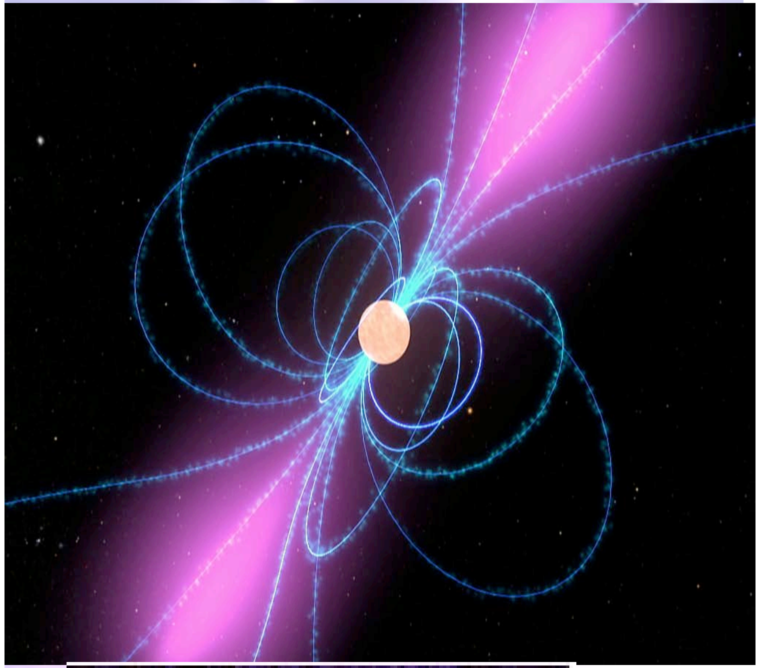
  and Fermi results on the

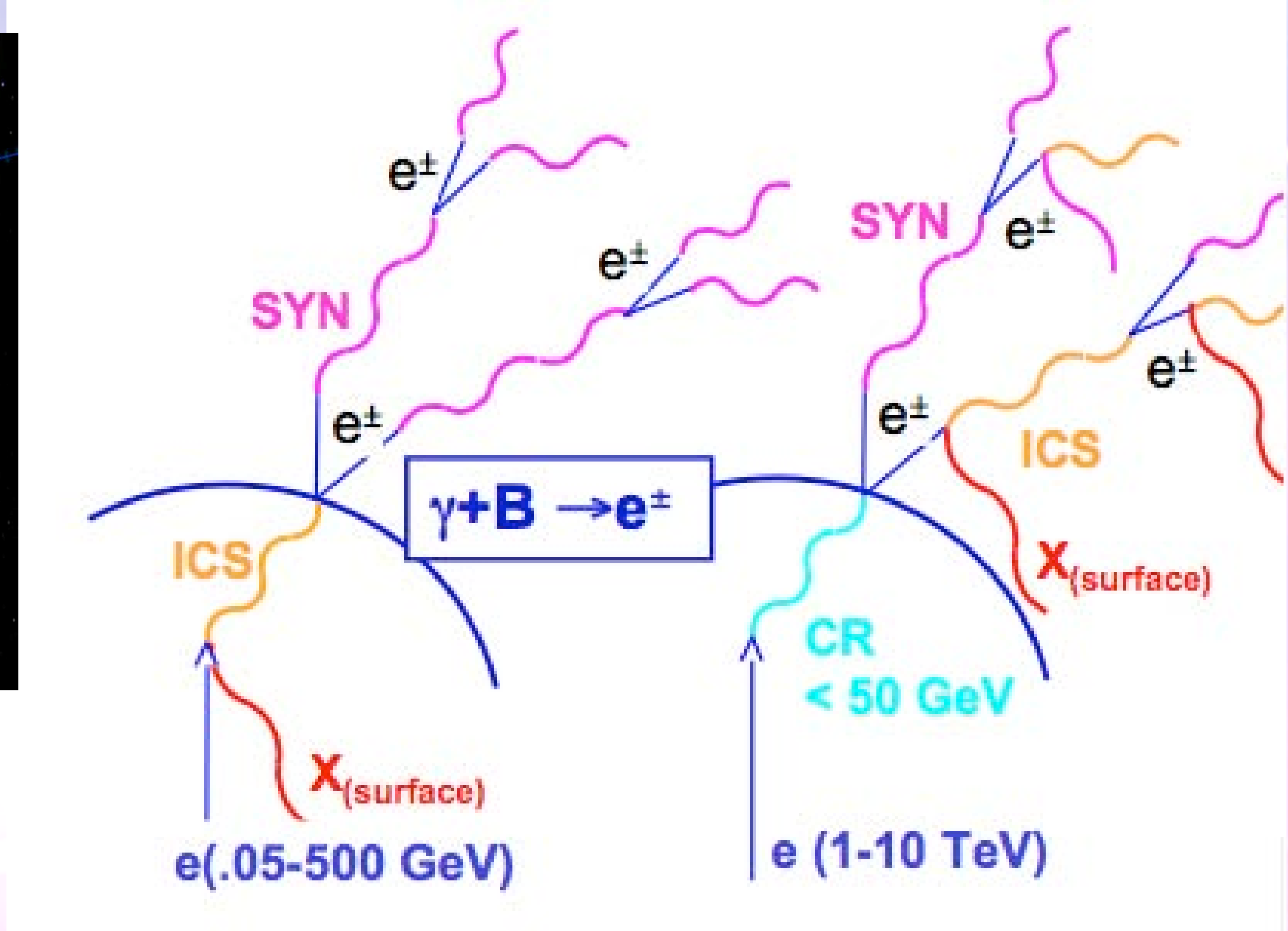
  electron+positron spectrum

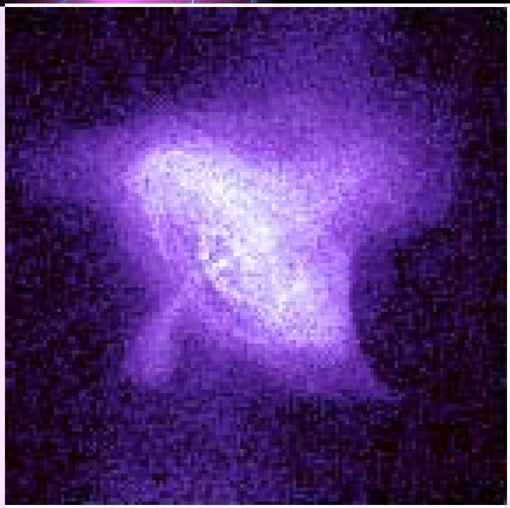
  unavoidably testifies the presence of ***primary positrons*** in CRs

which are the sources of the primary positrons ?

Pulsars as sources of $e^{-/+}$ pairs

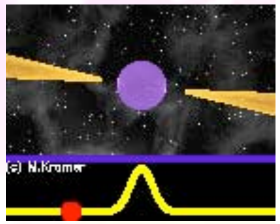




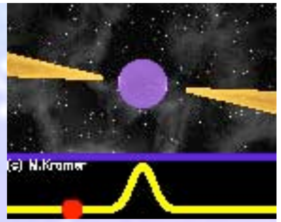


Crab Pulsar Wind Nebula (PWN)

$e^{\pm}$ pairs are produced in the magnetosphere and accelerated by the electric fields and/or the pulsar wind.

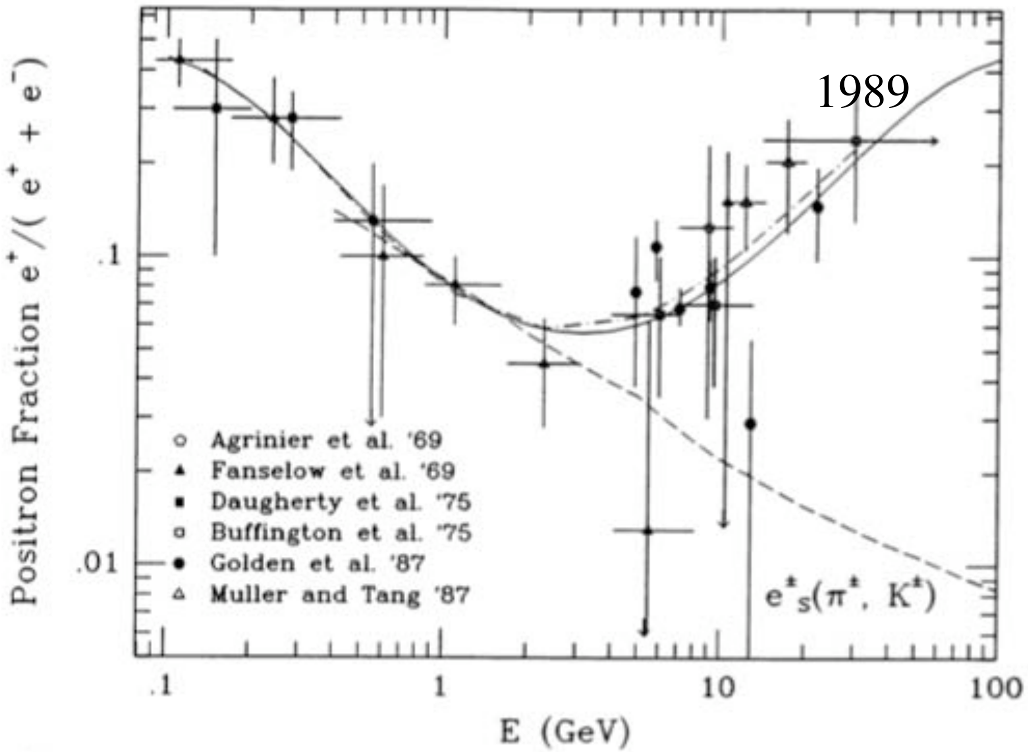


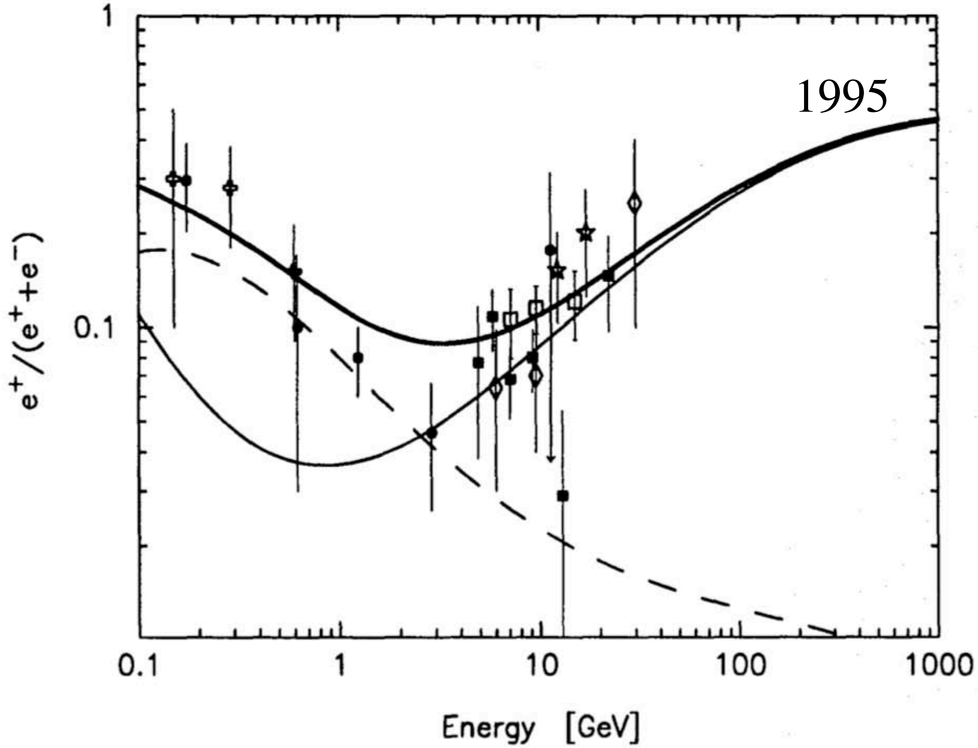
Pulsars as sources of $e^{-/+}$ pairs



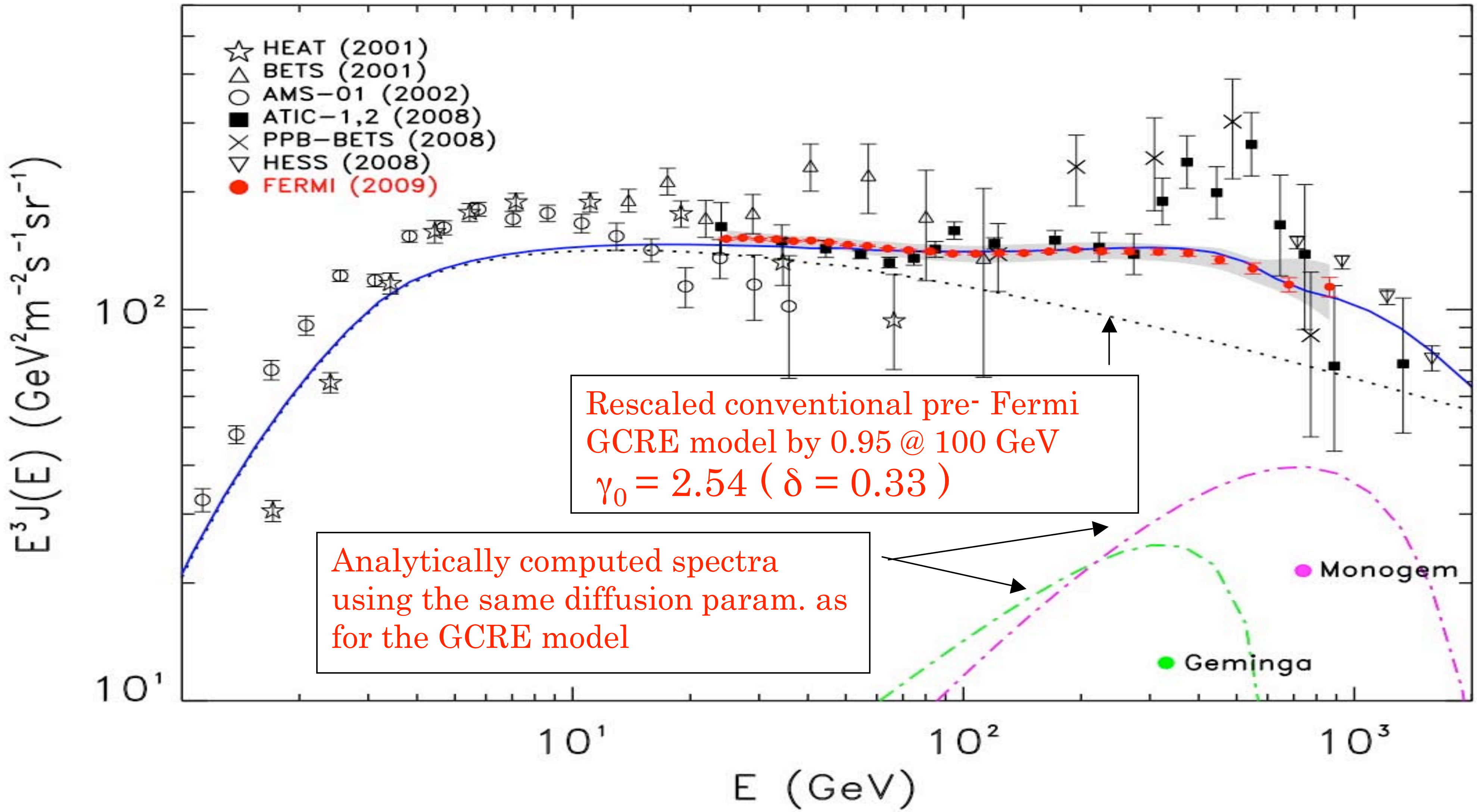
not a new idea

- A.Boulares APJ 342 (1989) 807-813
- T. Kobayashi, Y. Komori, K. Yoshida and J. Nishimura, ApJ 601 (2004) 340.
- Aharonian et al., A&A 294 (1995) L41
- A. M. Atoyan, F. A. Aharonian, and H. J. Volk, Phys. Rev. D52 (1995) 3265.



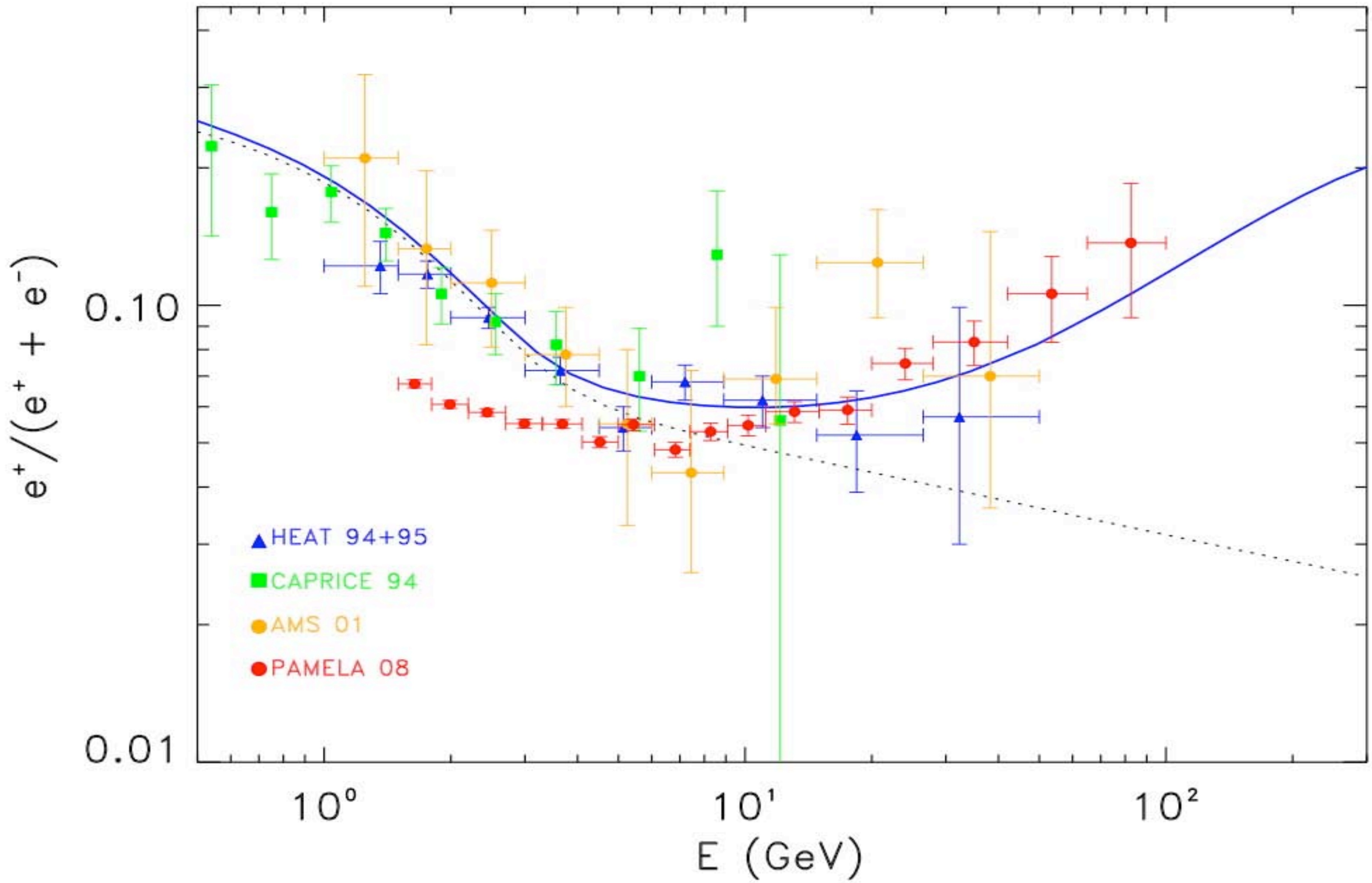


The CRE spectrum accounting for nearby pulsars (d < 1 kpc)



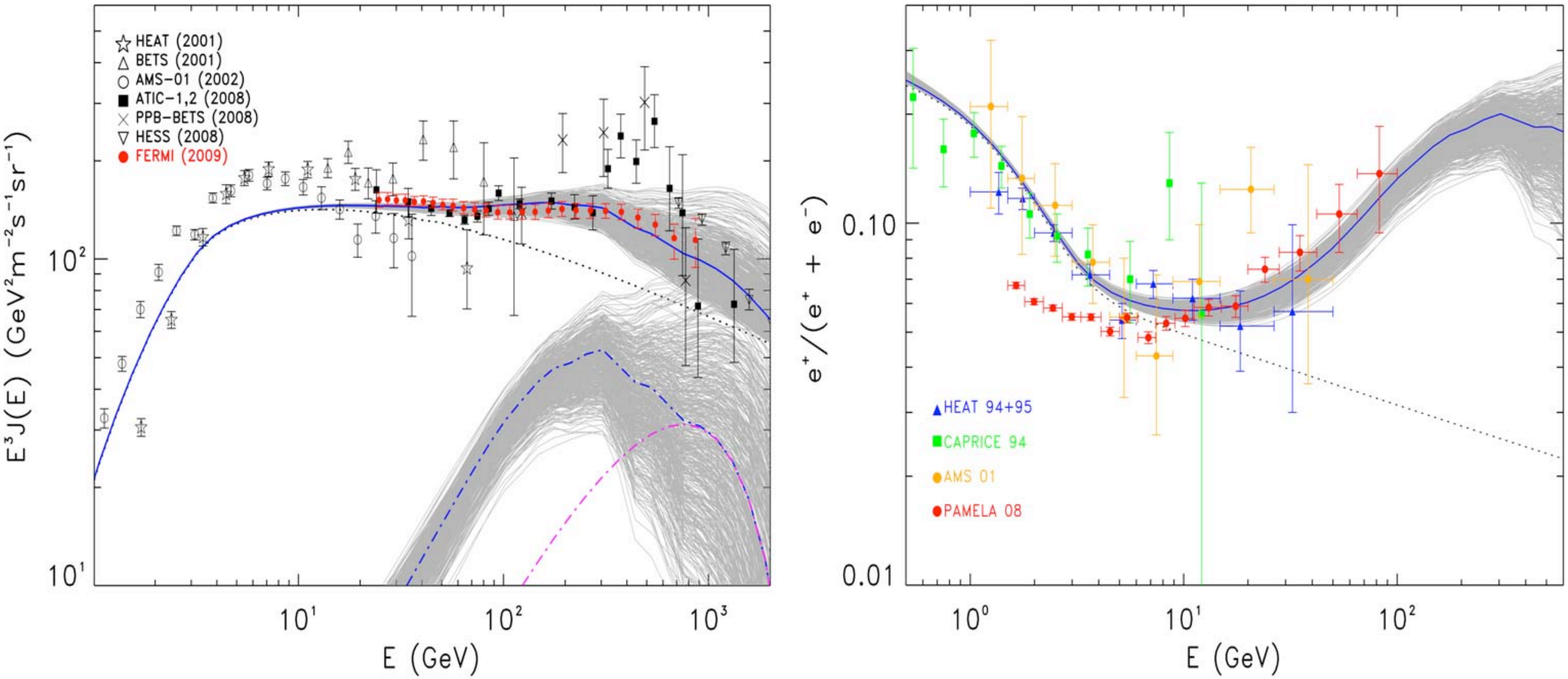
This particular model assumes: 40% $e^{\pm}$ conversion efficiency for each pulsar
- pulsar spectral index $\Gamma = 1.7$ $E_{cut} = 1$ TeV . Delay = 60 kyr

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



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

(injection spectrum, e+e- production efficiency, PWN "trapping" time)



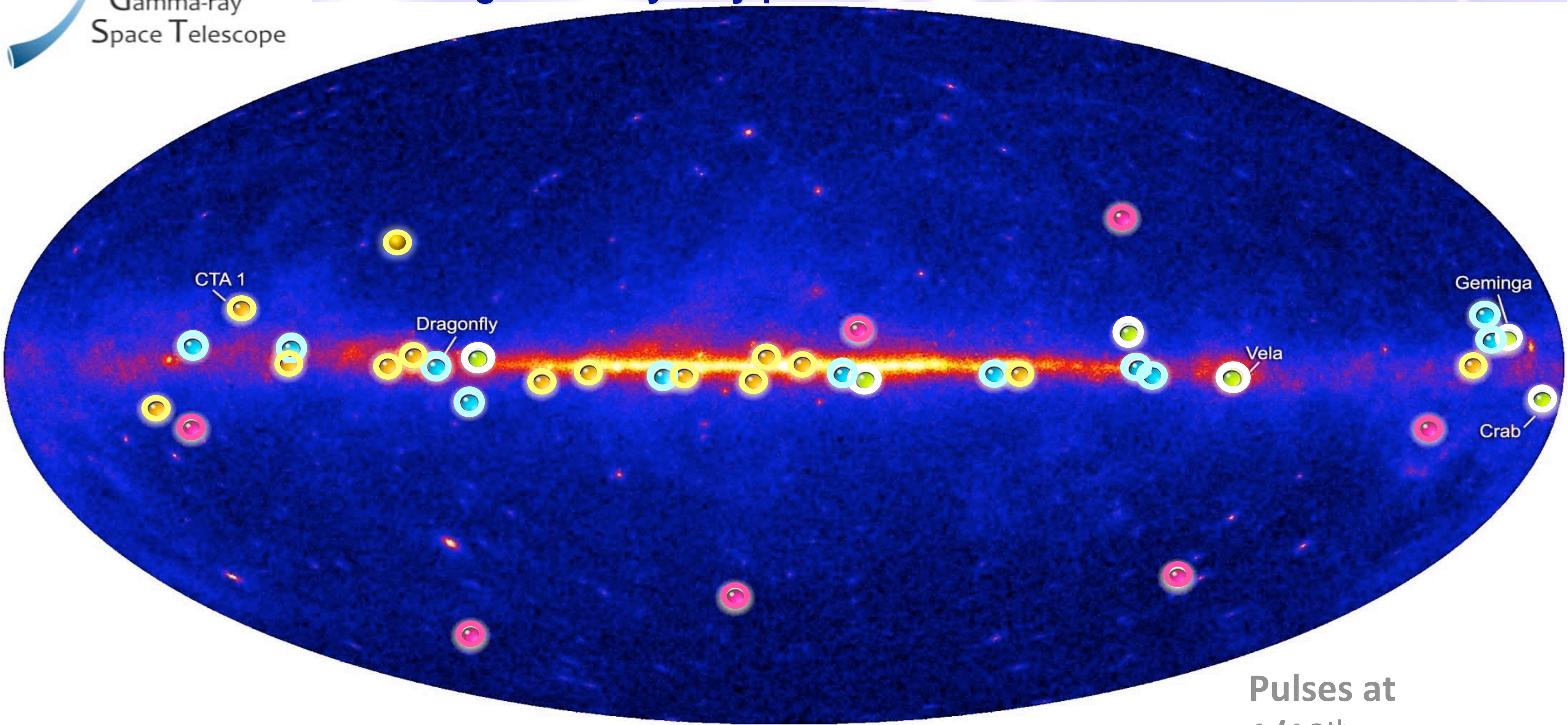
Under reasonable assumptions, electron/positron emission from pulsars offers a viable interpretation of Fermi CRE data which is also consistent with the HESS and Pamela results.

[arXiv:0905.0636]

The Pulsing γ-ray Sky

33 gamma-ray and radio pulsars (including nine ms psrs)

16 gamma-ray only pulsars



Pulses at
1/10th true rate

Fermi Pulsar Detections

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

Pulsars

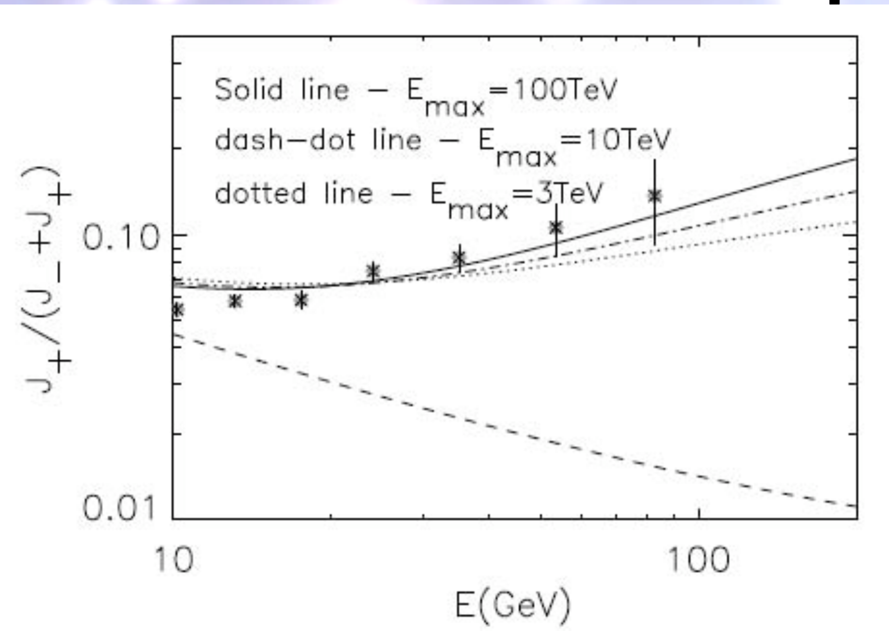
1. On purely energetic grounds they work (relatively large efficiency)

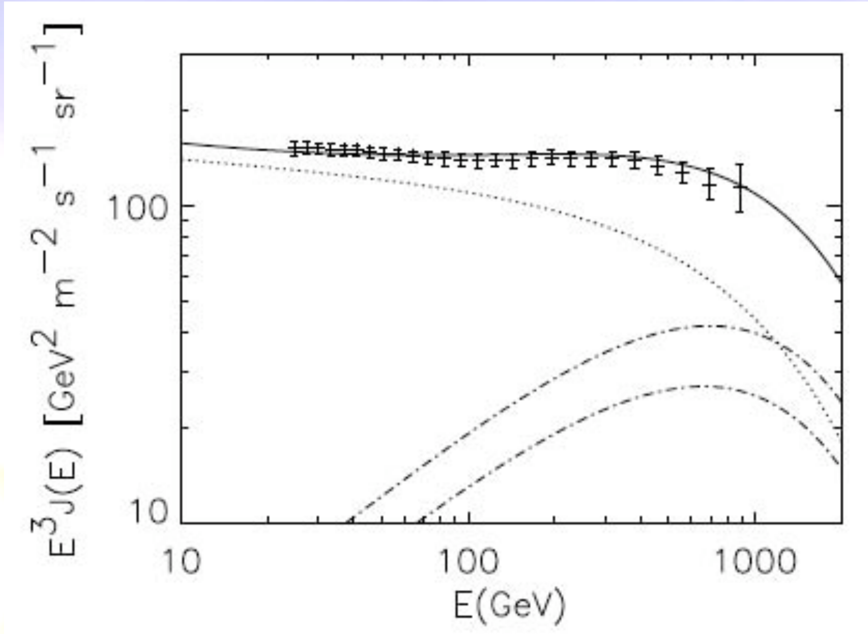
2. On the basis of the spectrum, it is not clear
   1. The spectra of PWN show relatively flat spectra of pairs at Low energies but we do not understand what it is
   2. The general spectra (acceleration at the termination shock) are too steep

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

other Astrophysical solution





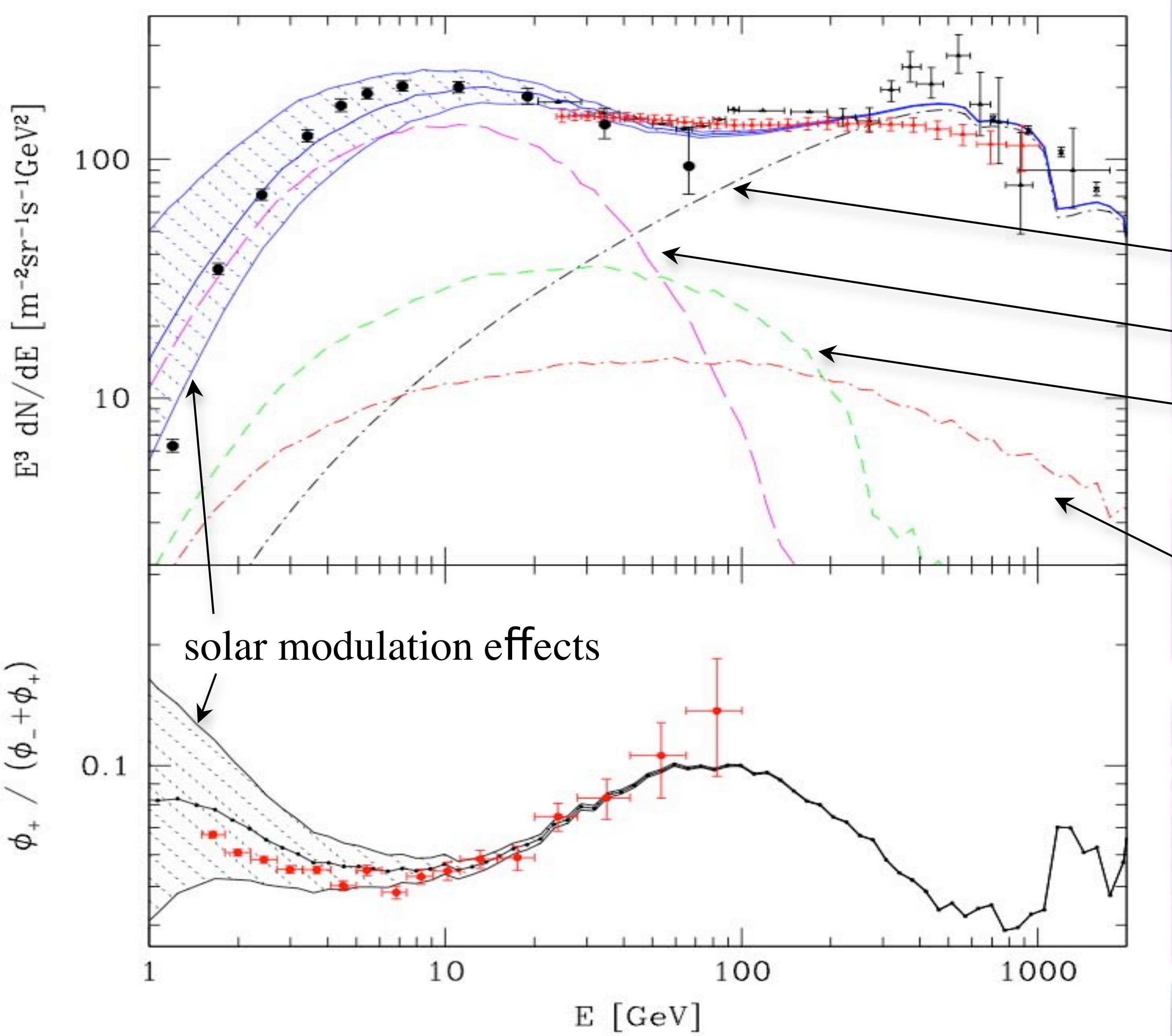
• Positrons created as secondary products of hadronic interactions inside the sources

• 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

$e^+/(e^++e^-)$ ratio and e^- spectrum from Supernova Remnants



Contribution from nearby KNOWN young SNRs: Geminga, Monogem, Vela LoopI and Cygnus Loop

Primary arm electrons

Primary disk electrons with nearby sources excluded

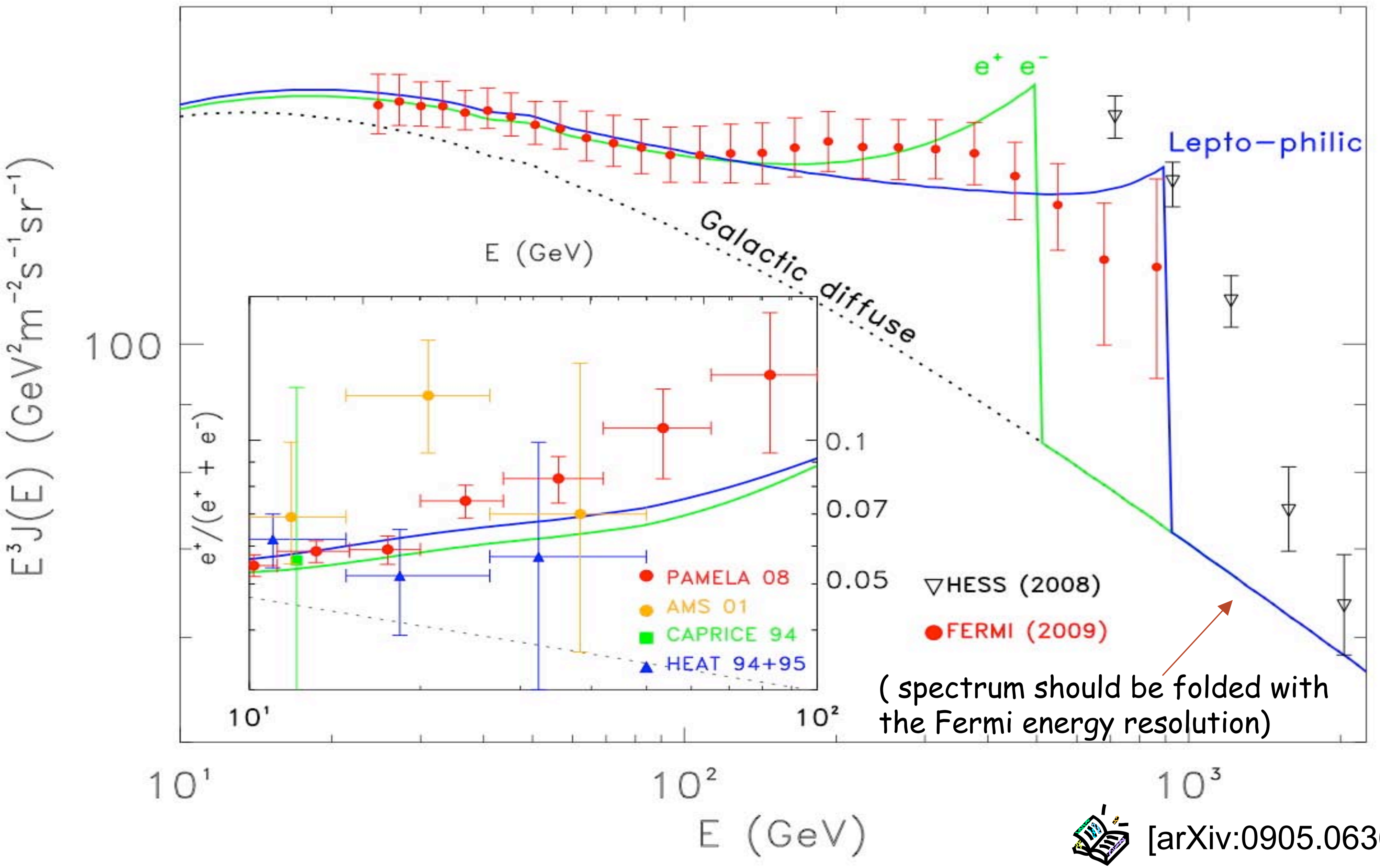
secondary positrons

Piran, Shaviv, Nakar

astro-ph/0902.0376

astro-ph/0905.0904

Predictions for the CRE spectrum from two specific dark matter models

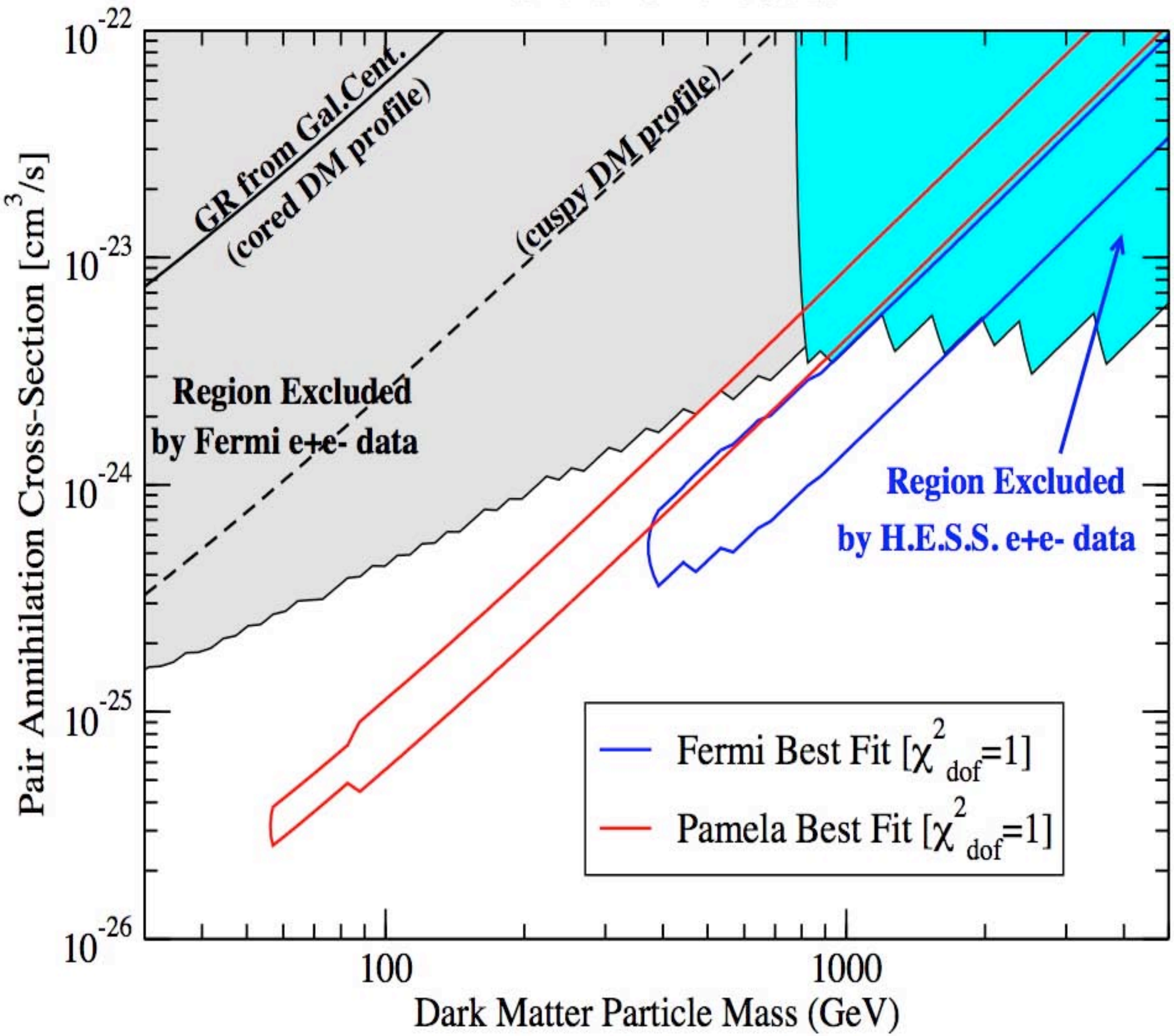


(spectrum should be folded with the Fermi energy resolution)

[arXiv:0905.0636]

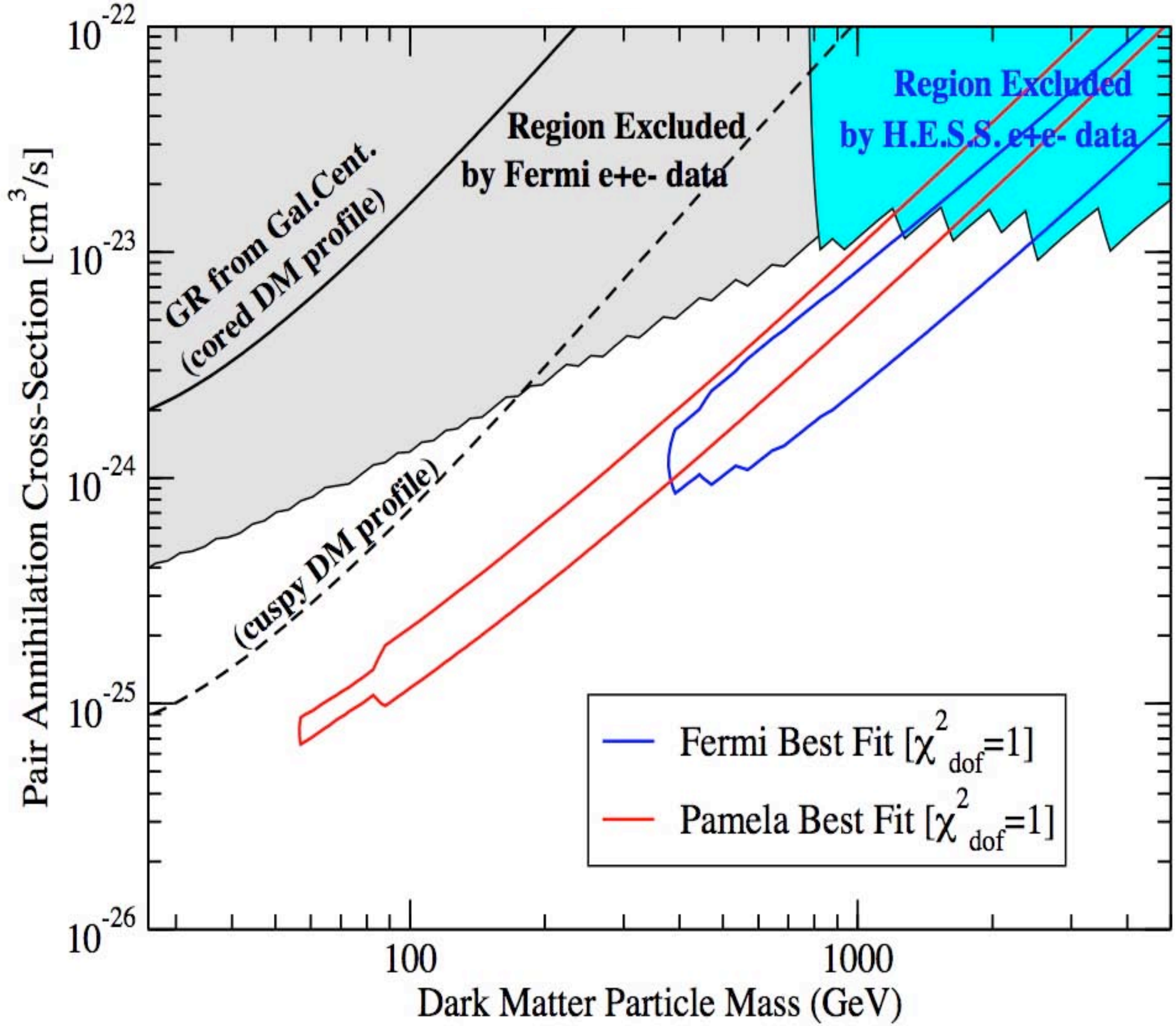
Pure e+e- Models

the dark matter pair annihilation always yields a pair of monochromatic e+e-, with injection energies equal to the mass of the annihilating dark matter particle



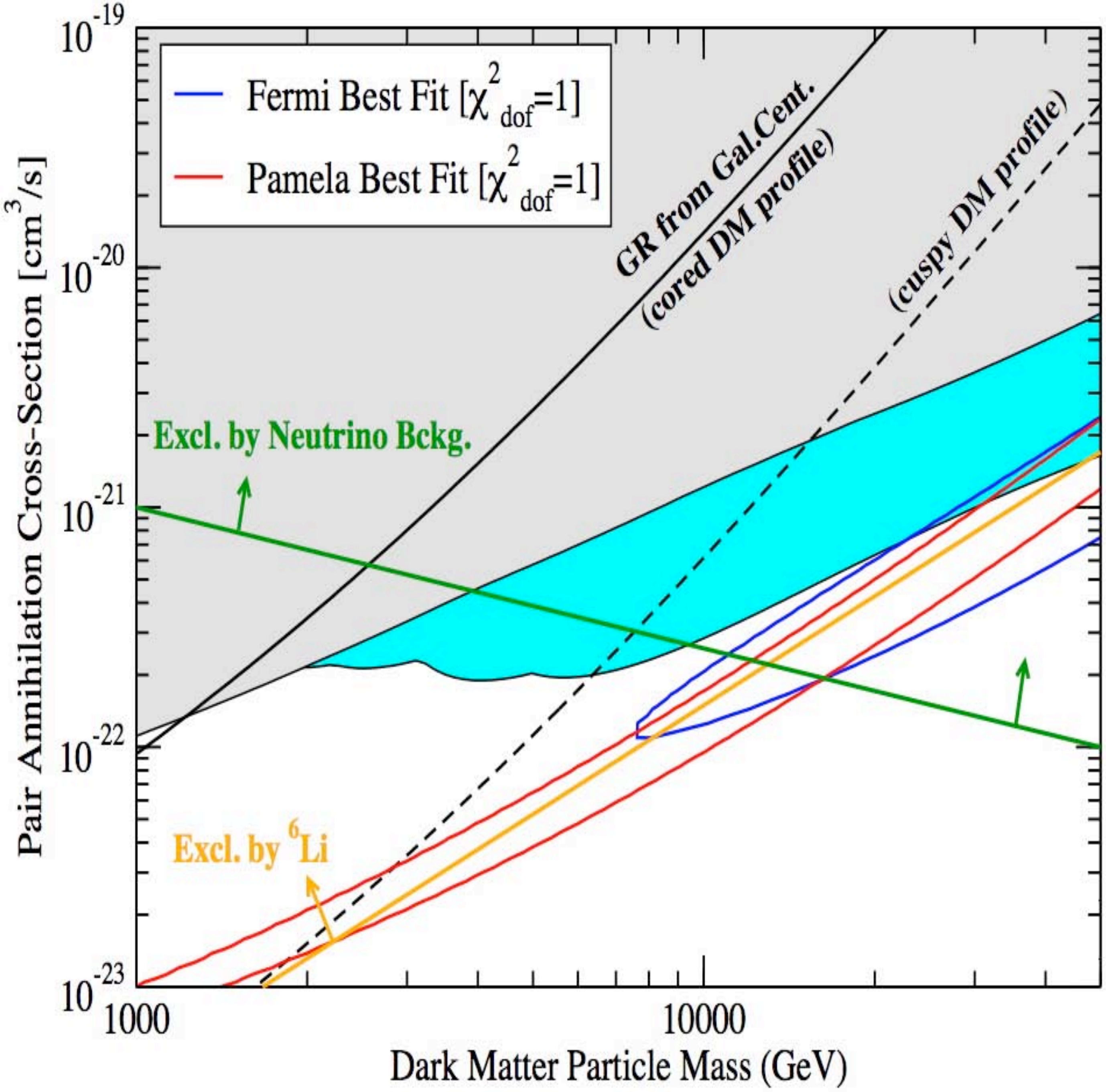
Lepto-philic Models

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.

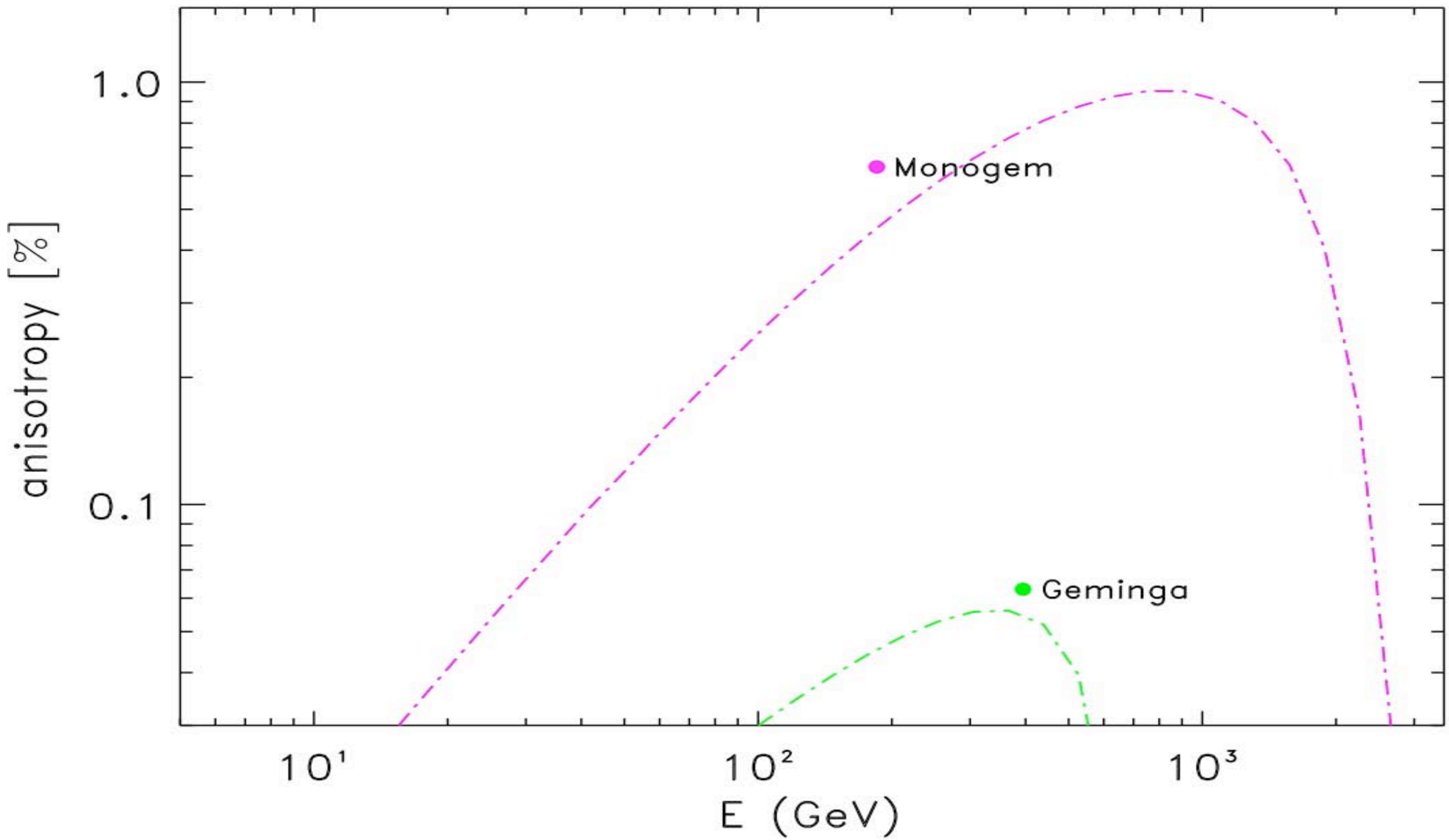


Super-heavy Models (ann. in gauge bosons)

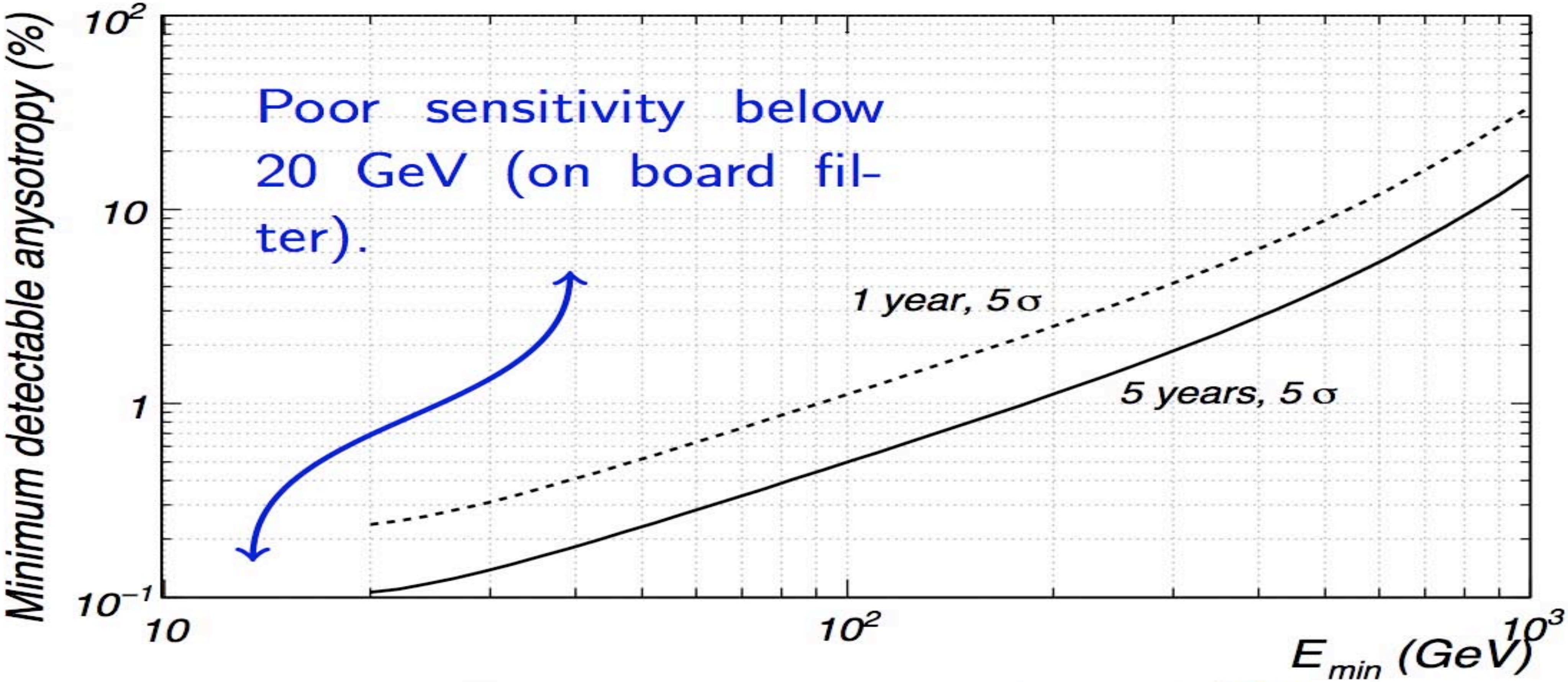
Super-heavy dark matter models: antiprotons can be suppressed below the PAMELA measured flux if the dark matter particle is heavy (i.e. in the multi-TeV mass range), and pair annihilates e.g. in weak interaction gauge bosons. Models with super-heavy dark matter can have the right thermal relic abundance, e.g. in the context of the minimal supersymmetric extension of the Standard Model



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

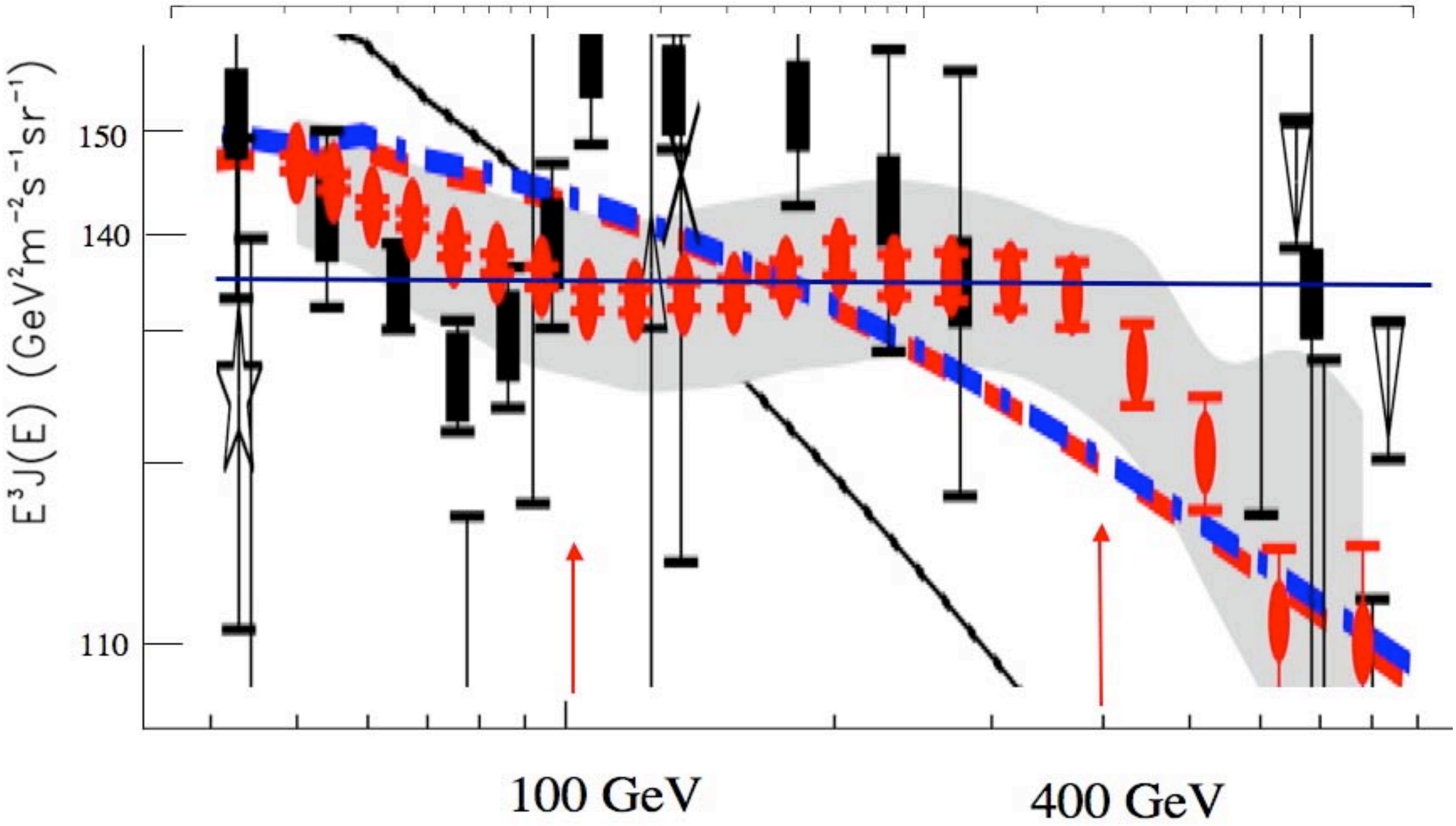


Measurement of anisotropies: statistics

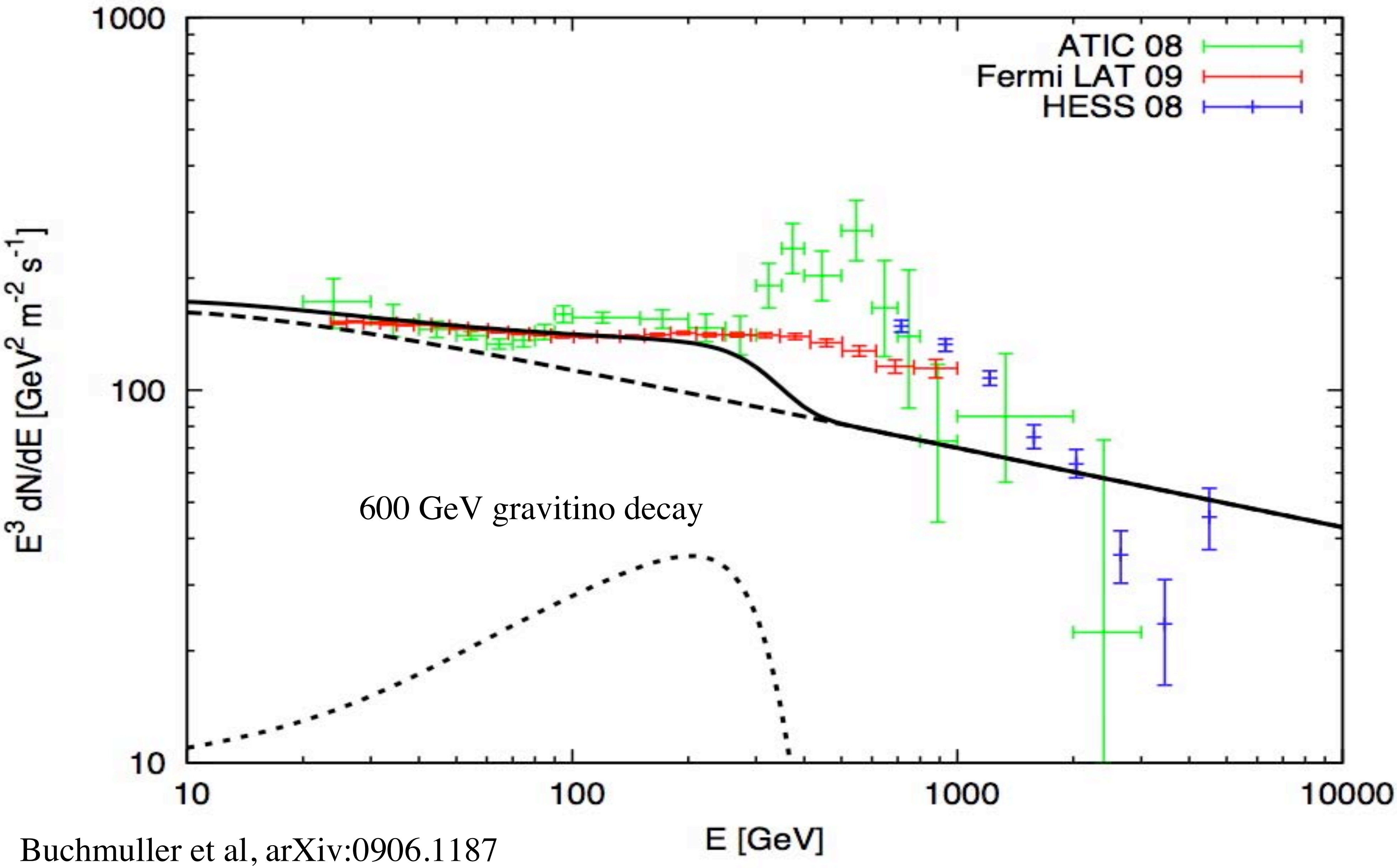


- Statistical limit for the integral anisotropy set by $\delta = \frac{\sqrt{2}N_\sigma}{\sqrt{N_{\mathrm{events}}}}$
- The plot includes all the instrument effects:
- Energy-dependent effective geometry factor;
- Instrumental dead time and duty cycle, On board filter.
- Room for improvements with a better event selection!

Fermi-LAT Cosmic ray Electron spectrum

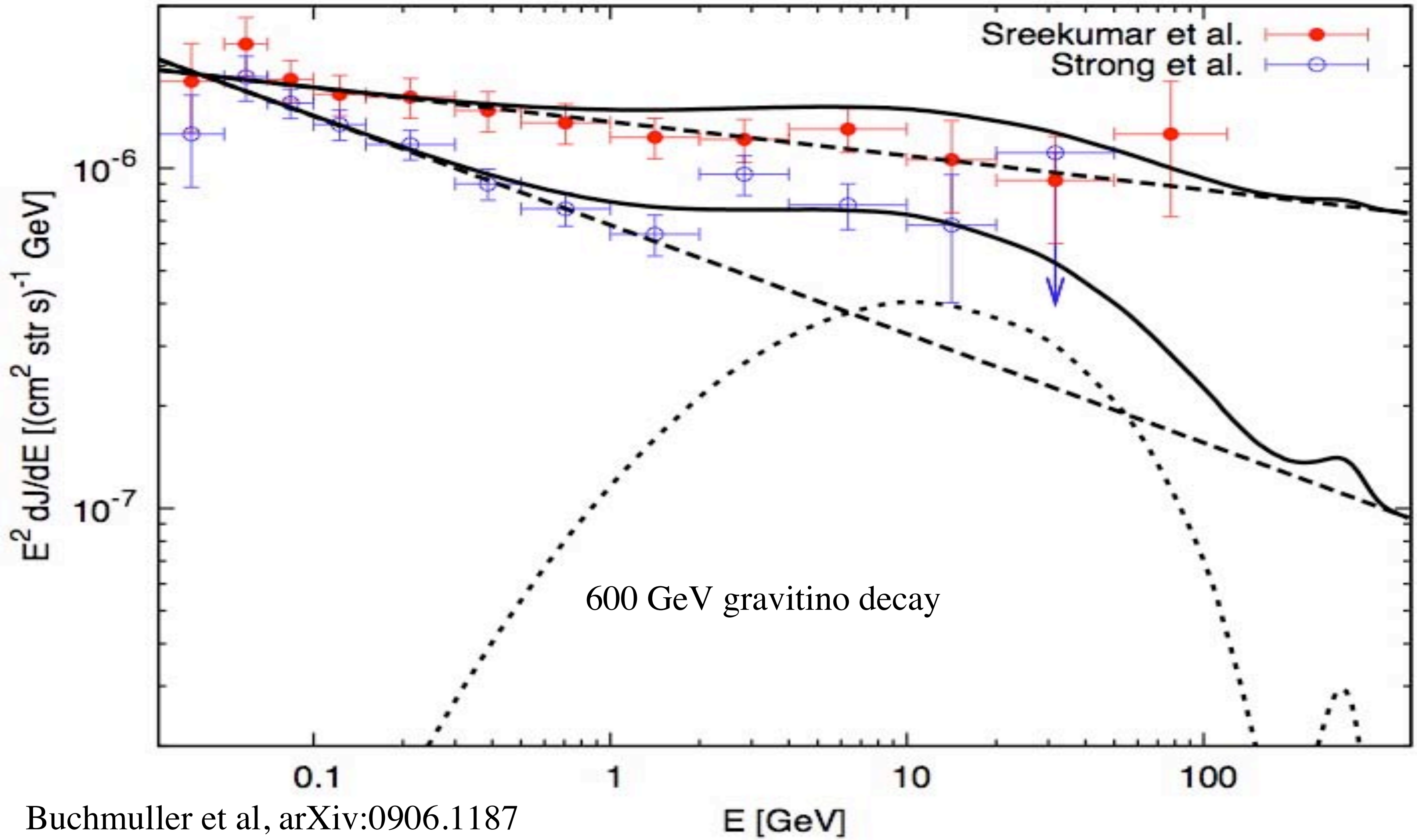


Cosmic ray Electron spectrum



Buchmuller et al, arXiv:0906.1187

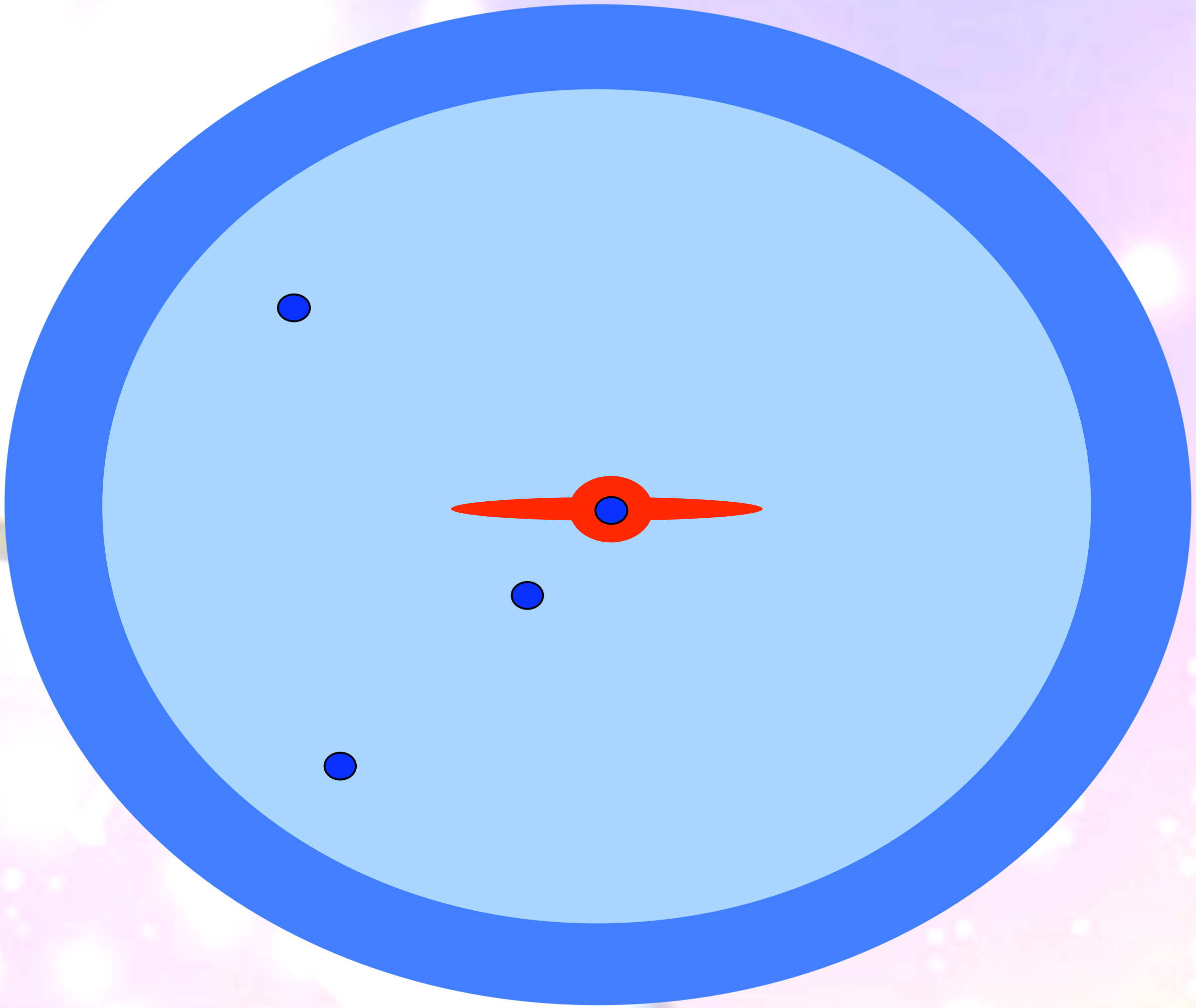
extragalactic gamma-ray spectrum



Buchmuller et al, arXiv:0906.1187

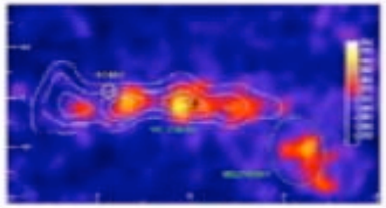
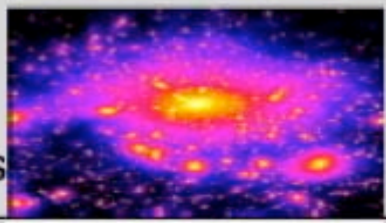
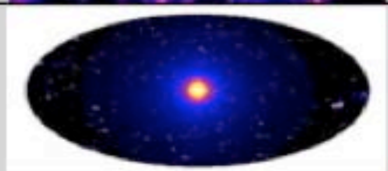
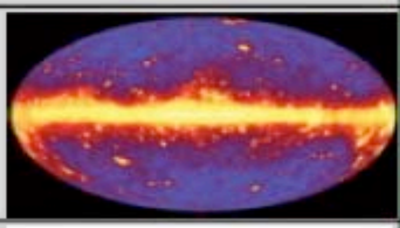
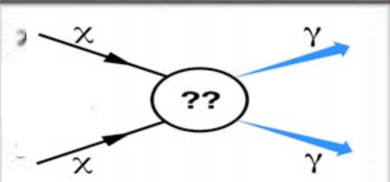
Where should we look for Dark Matter with FERMI ?

- Galactic center
- Galactic satellites
- Galactic halo
- Extra-galactic

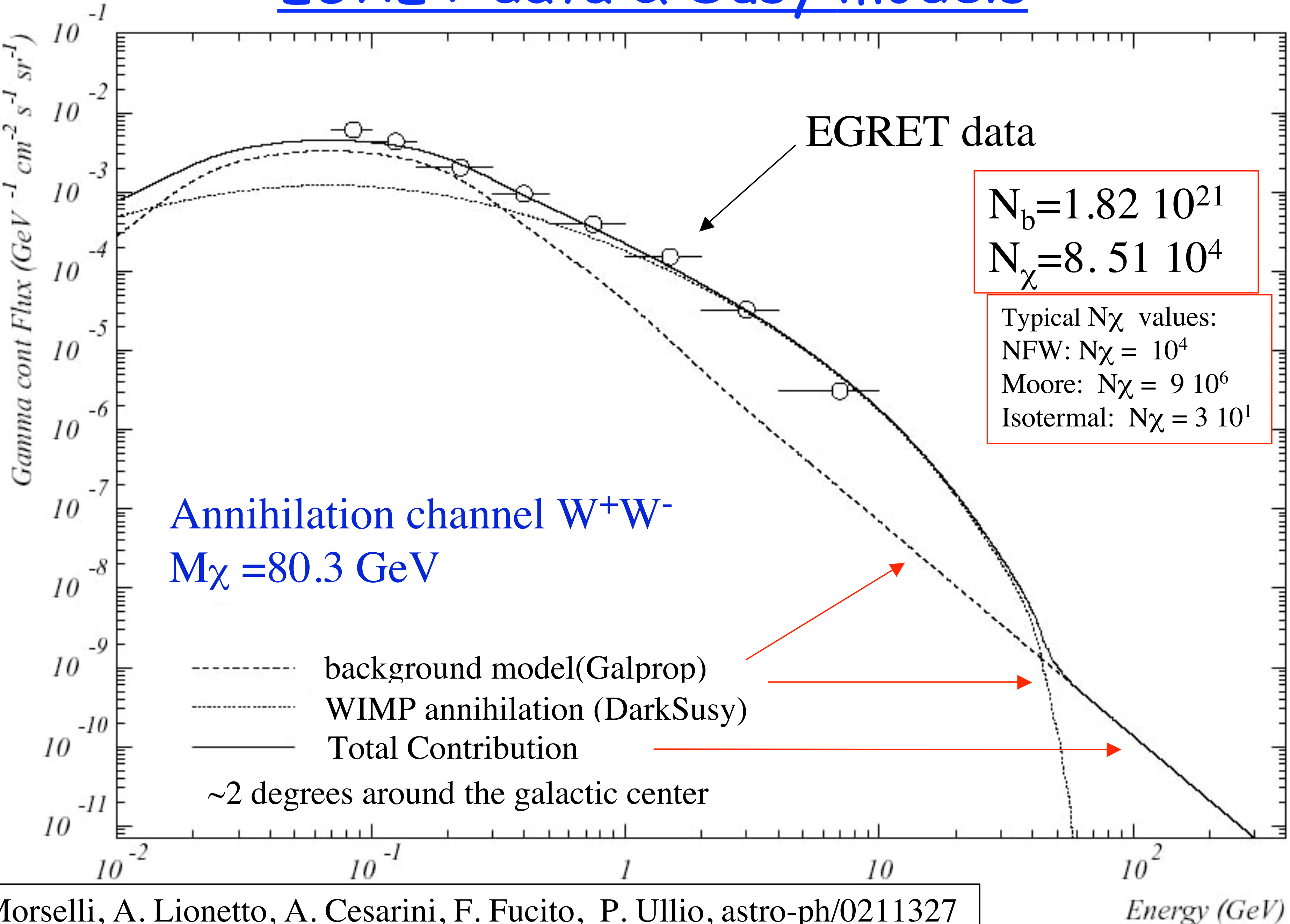


Fermi Gamma-ray Space Telescope

How the GLAST-LAT* telescope could help to disentangle the Dark Matter puzzle ?

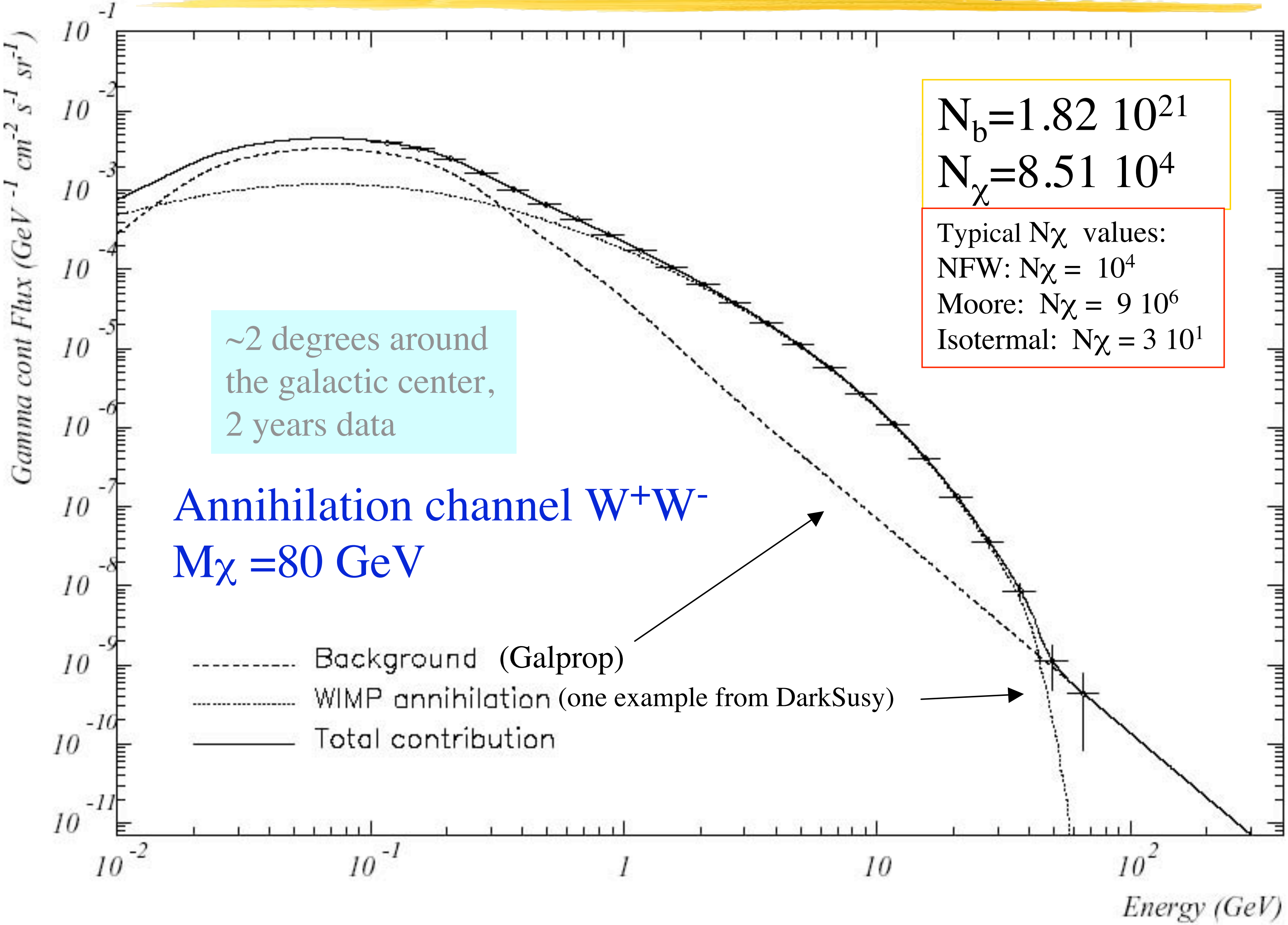
Search Technique	advantages	challenges
Galactic center 	Good Statistics	Source confusion/Diffuse background
Satellites, Subhalos, Point Sources 	Low background, Good source id	Low statistics
Milky Way halo 	Large statistics	Galactic diffuse background
Extra-galactic 	Large Statistics	Astrophysics, galactic diffuse background
Spectral lines 	No astrophysical uncertainties, good source id	Low statistics

EGRET data & Susy models



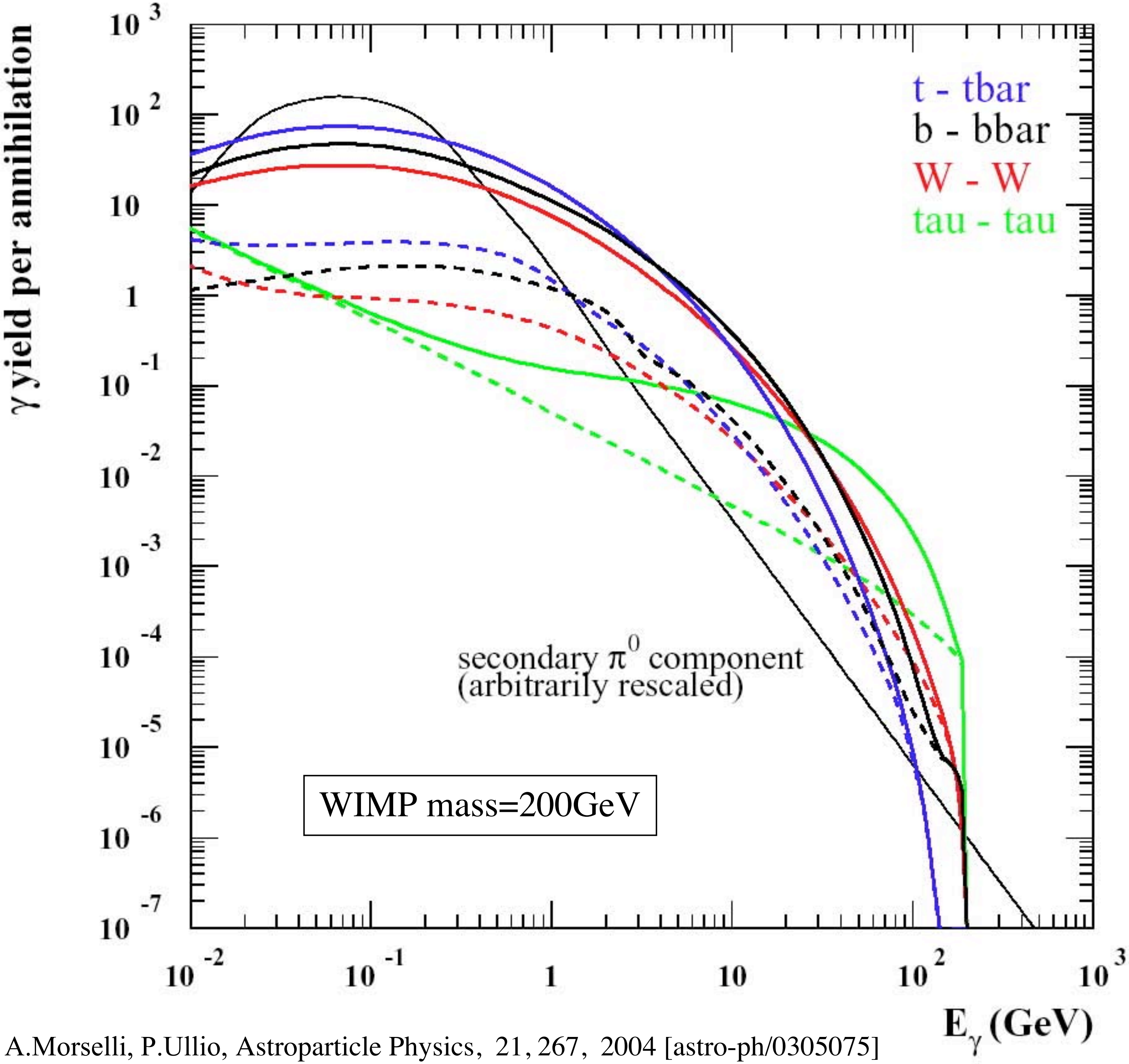
A.Morselli, A. Lionetto, A. Cesarini, F. Fucito, P. Ullio, astro-ph/0211327

Fermi Expectation & Susy models



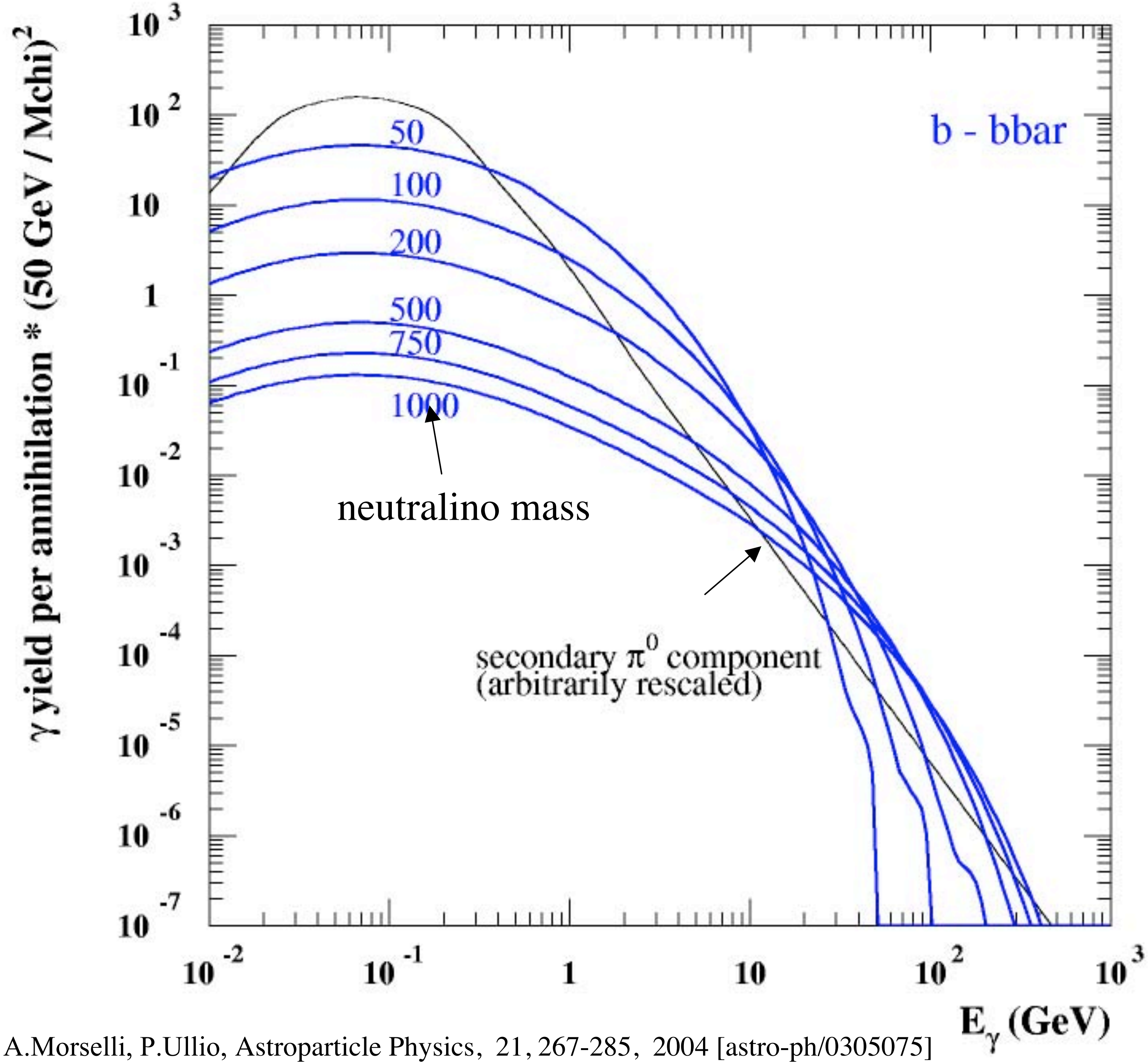
A.Cesarini, F.Fucito, A.Lionetto, A.Morselli, P.Ullio, Astroparticle Physics, 21, 267-285, June 2004 [astro-ph/0305075]

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

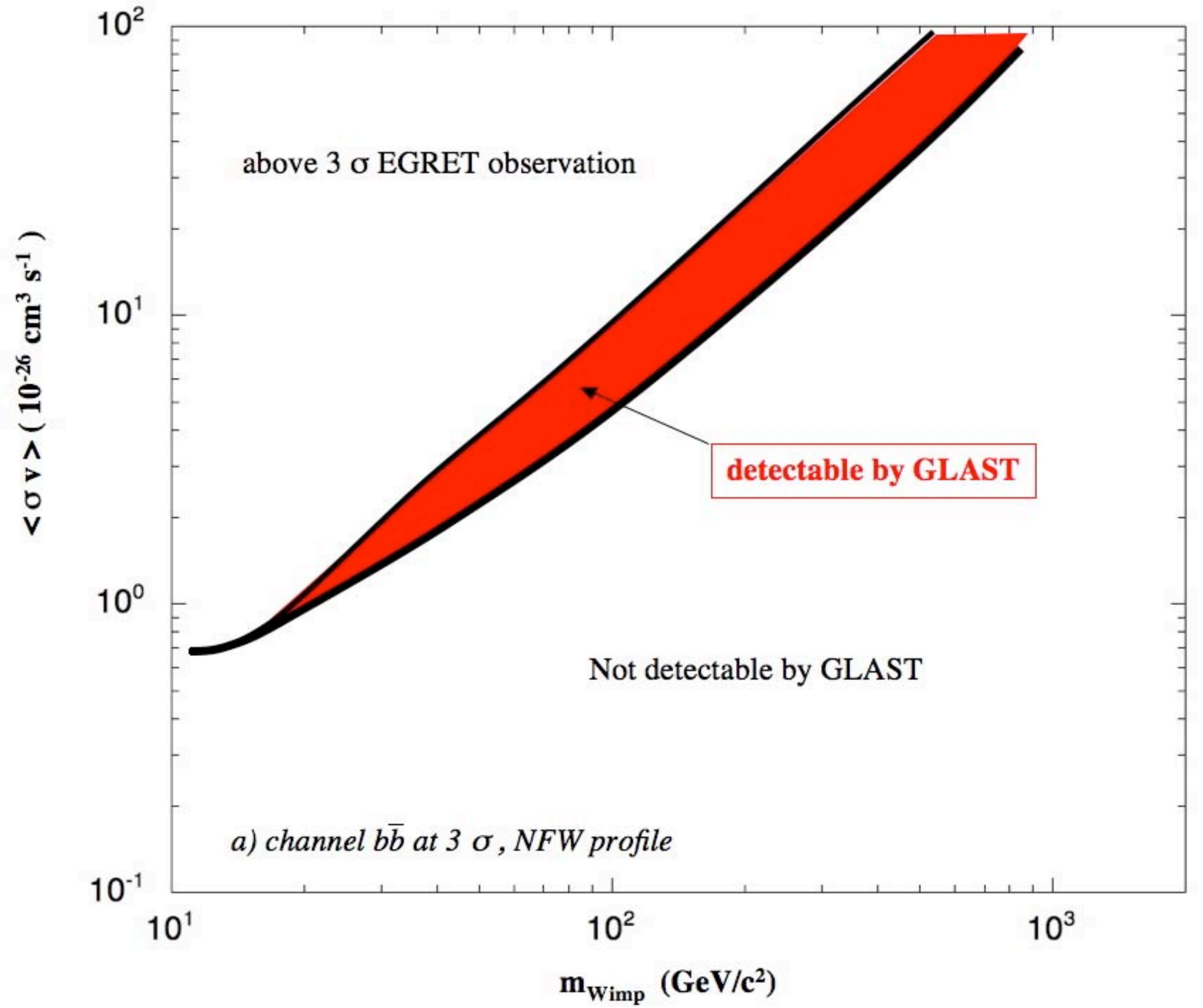


A.Cesarini, F.Fucito, A.Lionetto, A.Morselli, P.Ullio, Astroparticle Physics, 21, 267-285, 2004 [astro-ph/0305075]

Model independent results for the GC

after the Fermi Galactic Diffuse Emission data

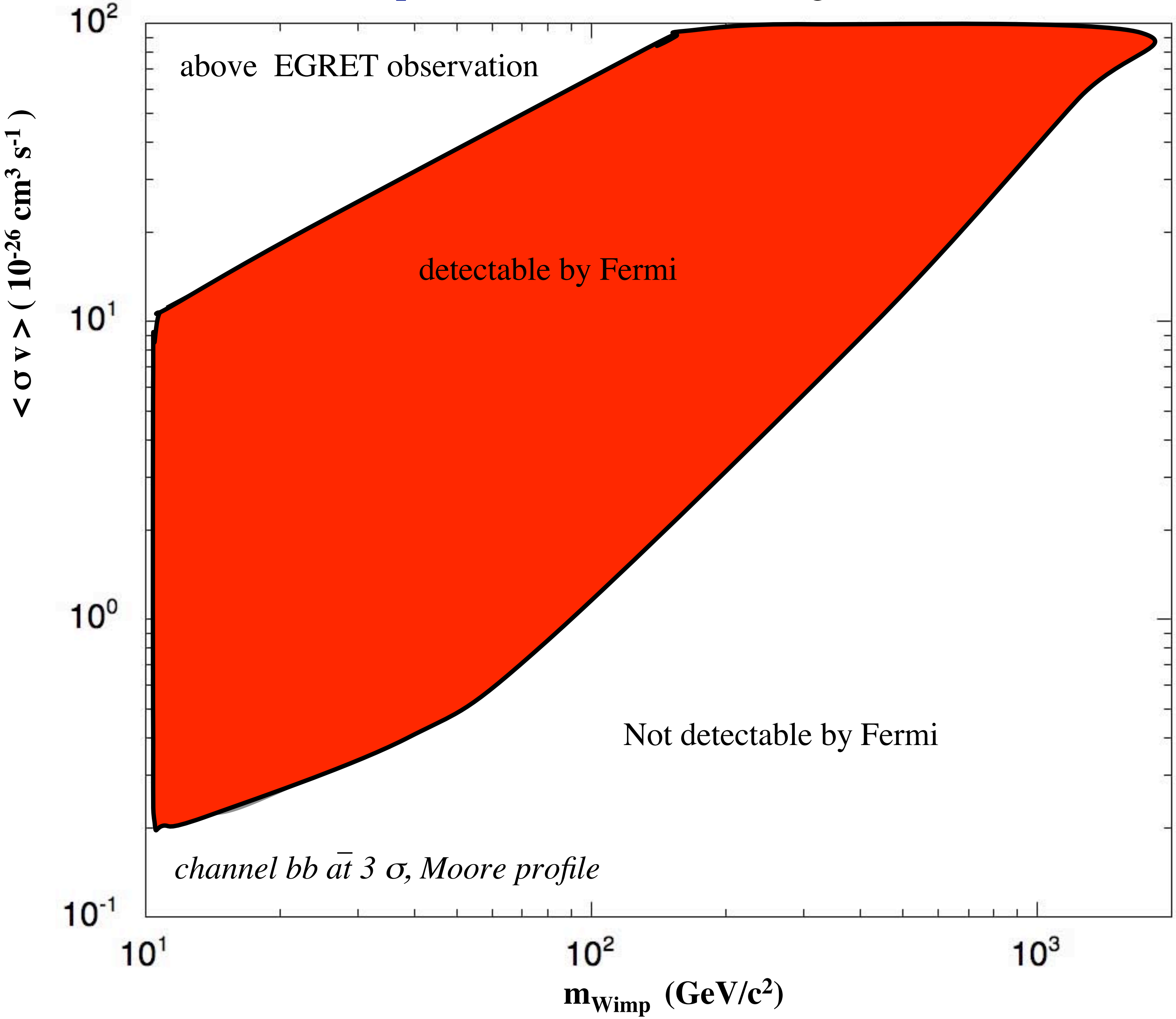
5 years of operations, truncated NFW



upated from arXiv:0806.2911

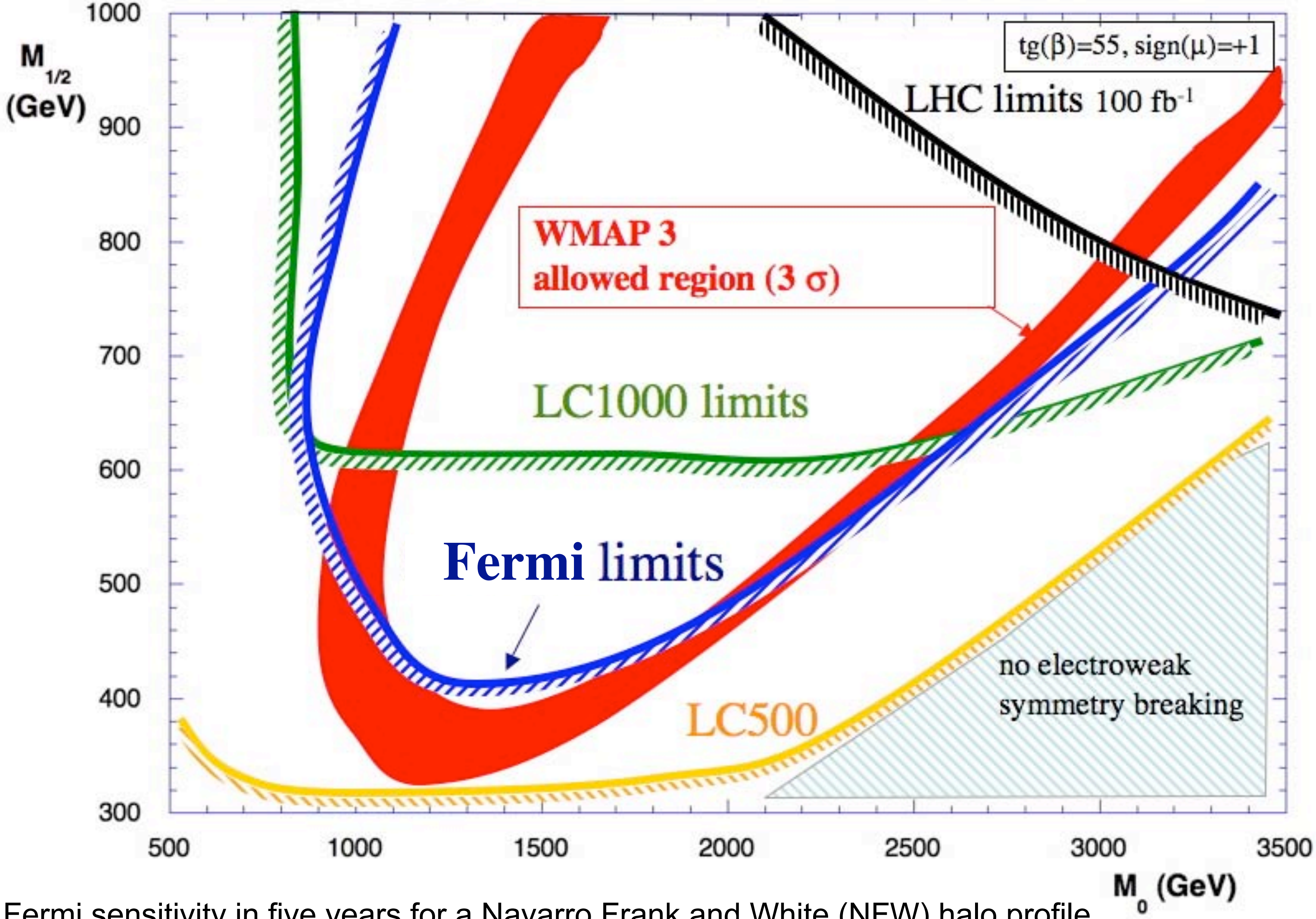
Model independent results for the Sagittarius Dwarft

after the Fermi Galactic Diffuse Emission data



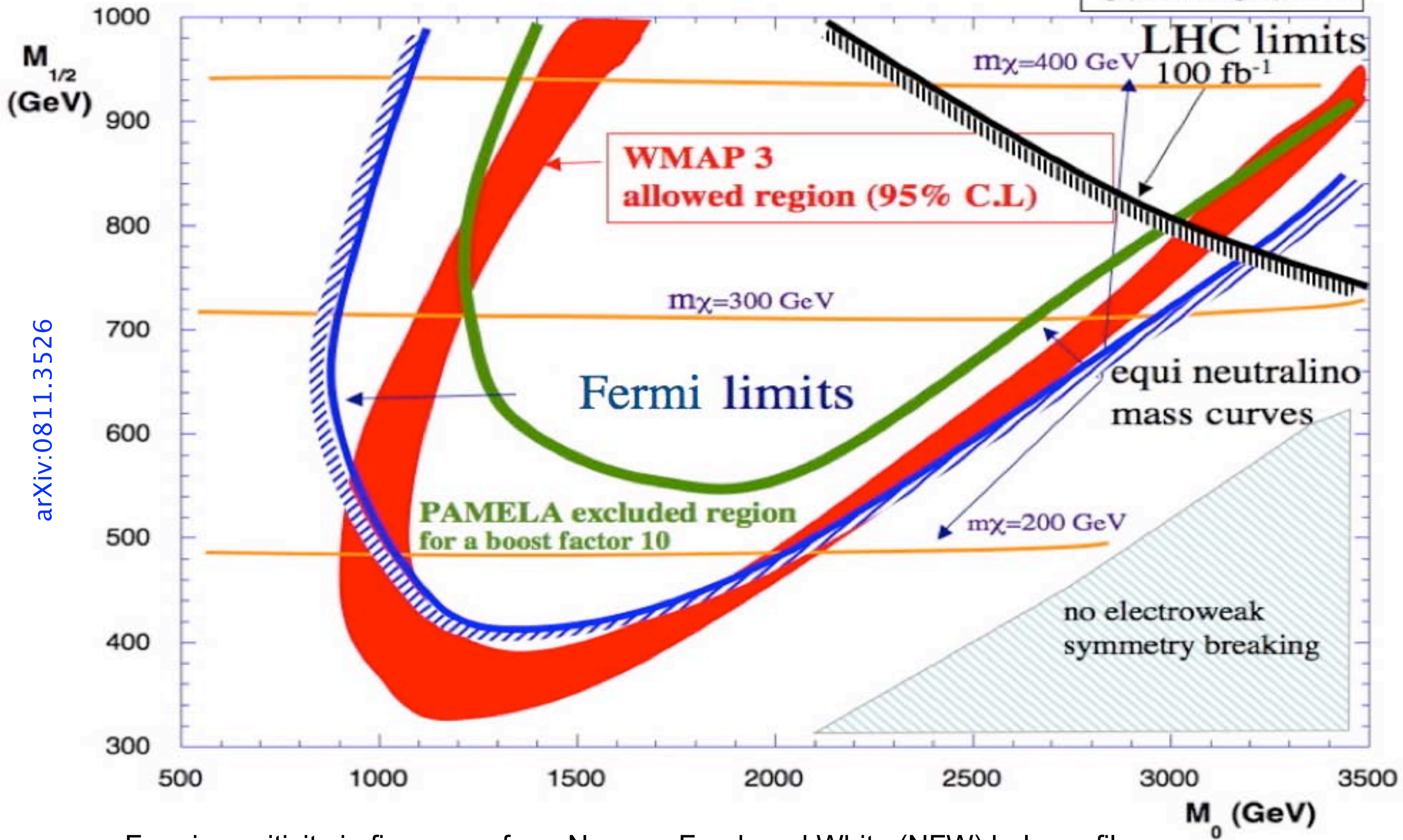
upated from arXiv:0806.2911

Fermi and LHC WIMP Detection Sensitivity



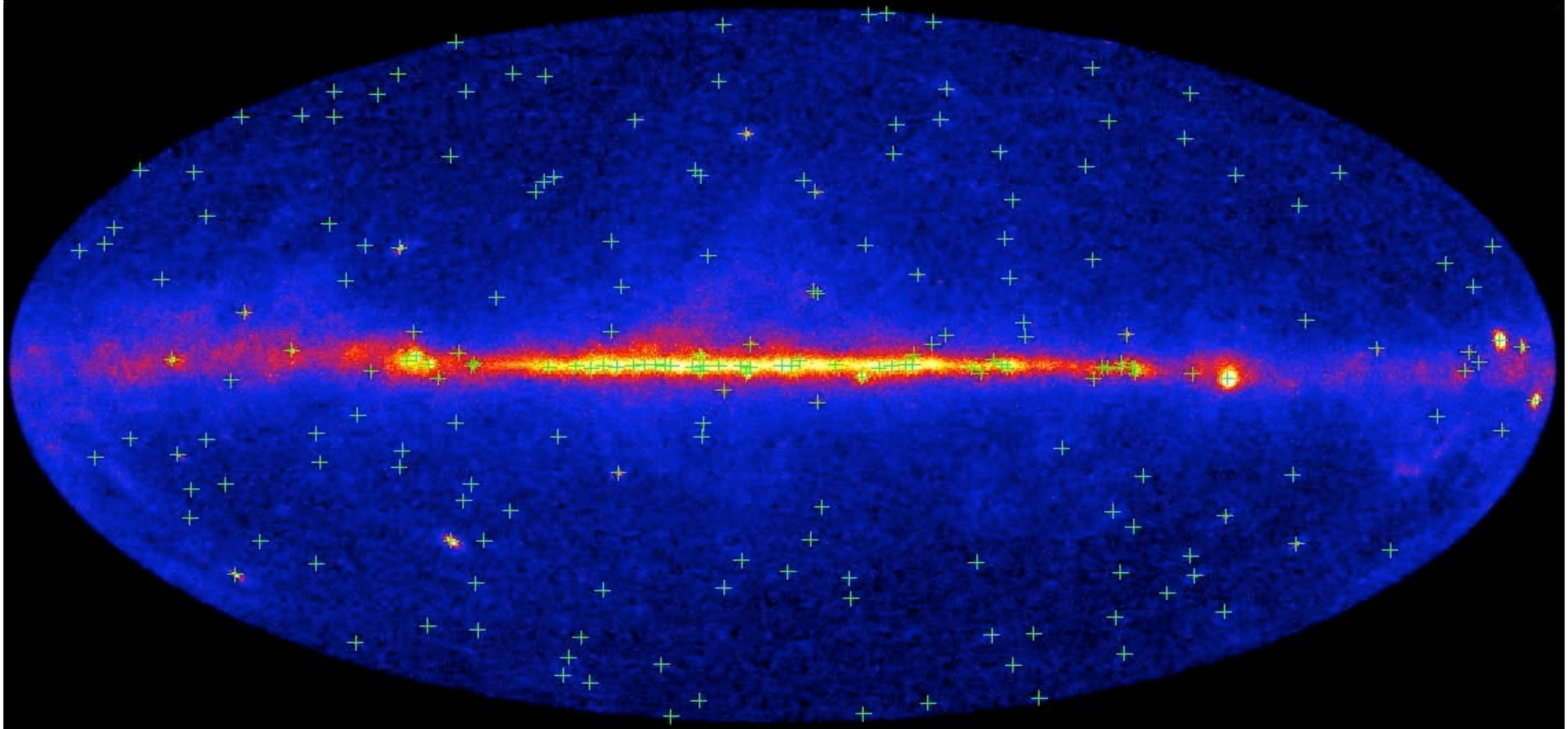
Fermi sensitivity in five years for a Navarro Frank and White (NFW) halo profile

Fermi, PAMELA and LHC WIMP Detection Sensitivity



Fermi sensitivity in five years for a Navarro Frank and White (NFW) halo profile

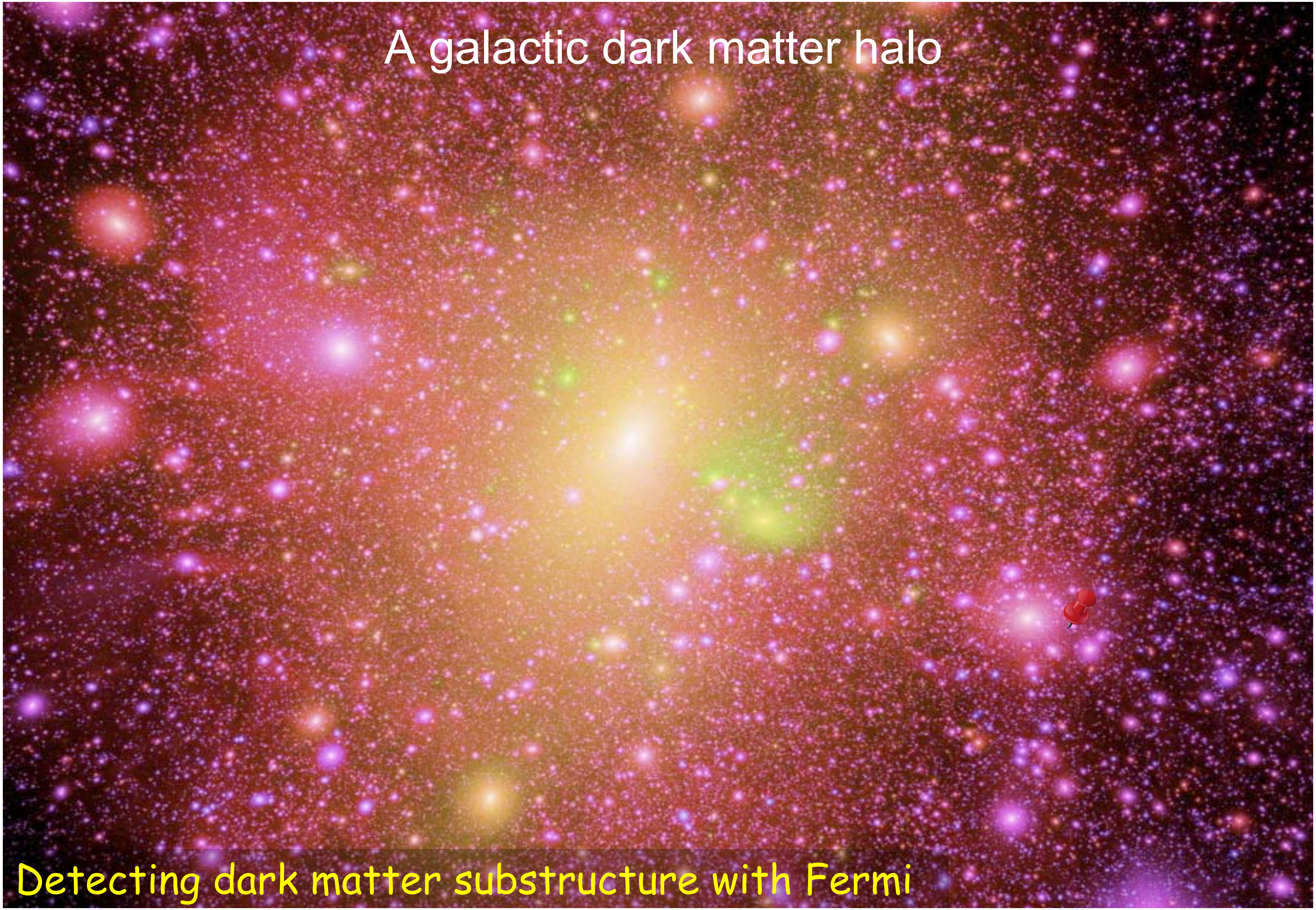
205 Preliminary Fermi LAT Bright Sources



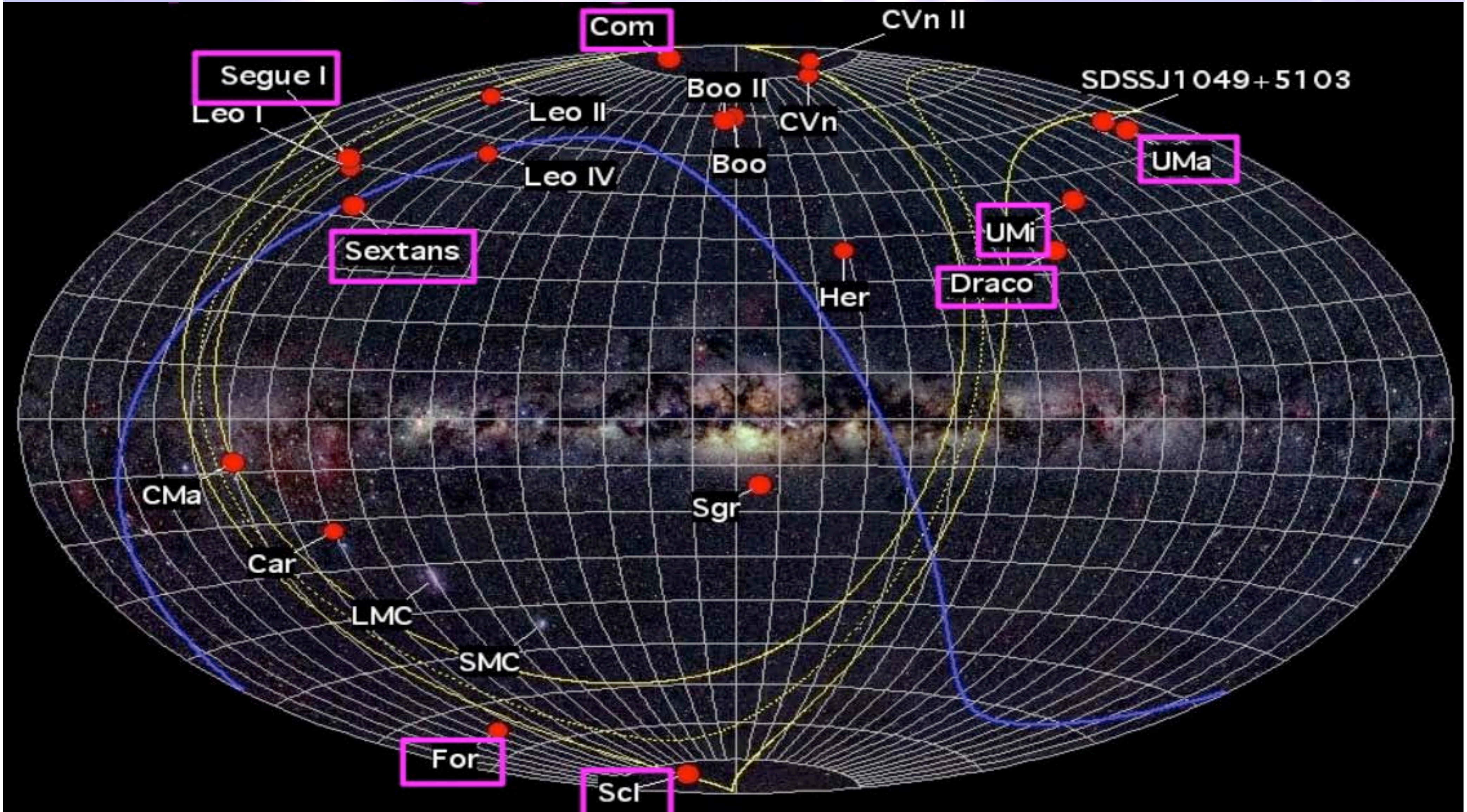
Crosses mark source locations, in Galactic coordinates.

205 Preliminary LAT Bright Sources - Some Information

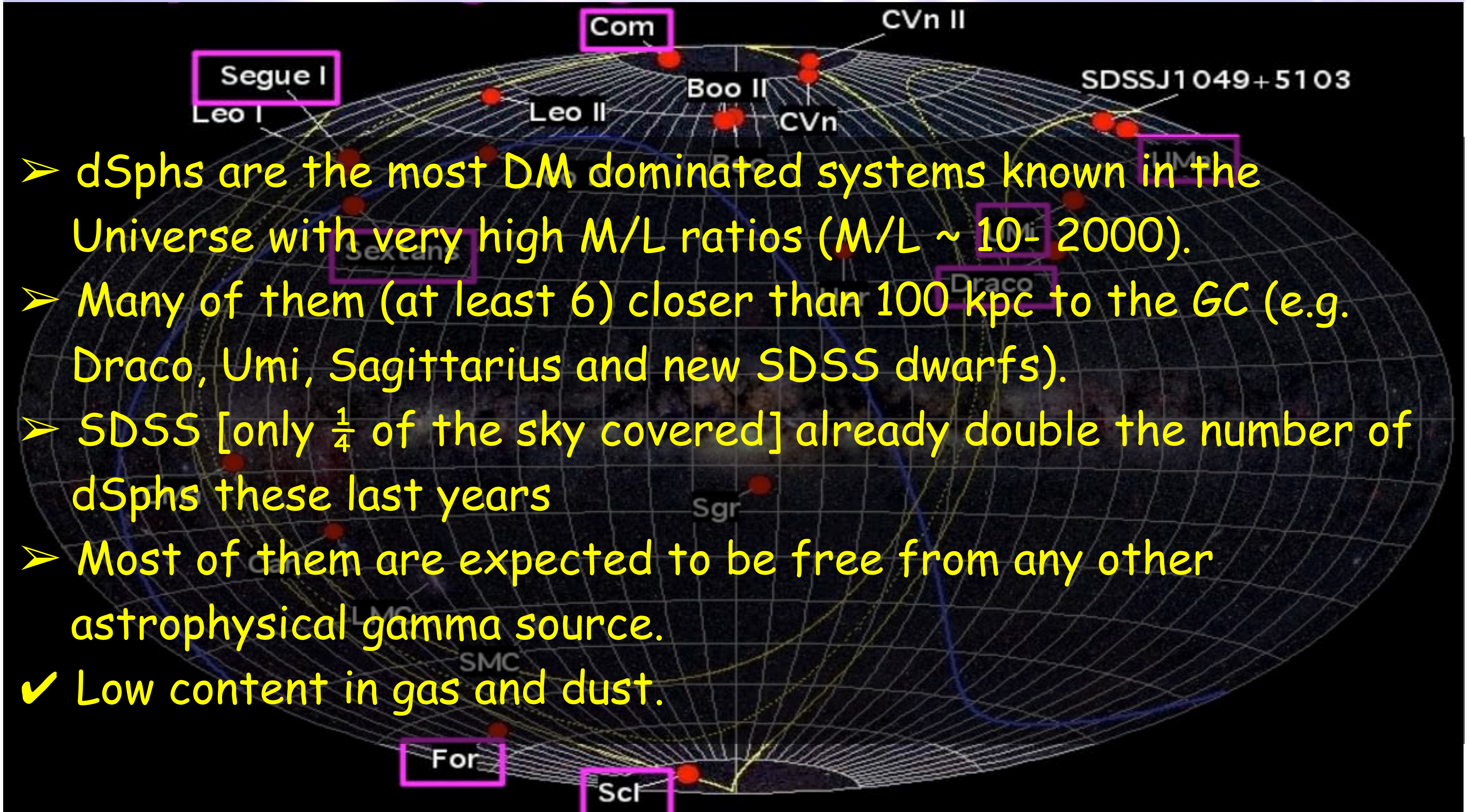
- EGRET on the Compton Observatory found fewer than 30 sources above 10 σ in its lifetime.
- Typical 95% error radius is less than 10 arcmin. For the brightest sources, it is less than 3 arcmin. Improvements are expected.
- About 1/3 of the sources show definite evidence of variability.
- More than 30 pulsars are identified by gamma-ray pulsations.
- Over half the sources are associated positionally with blazars. Some of these are firmly identified as blazars by correlated multiwavelength variability.
- Over 40 sources have no obvious associations with known gamma-ray emitting types of astrophysical objects.


A galactic dark matter halo
Detecting dark matter substructure with Fermi

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

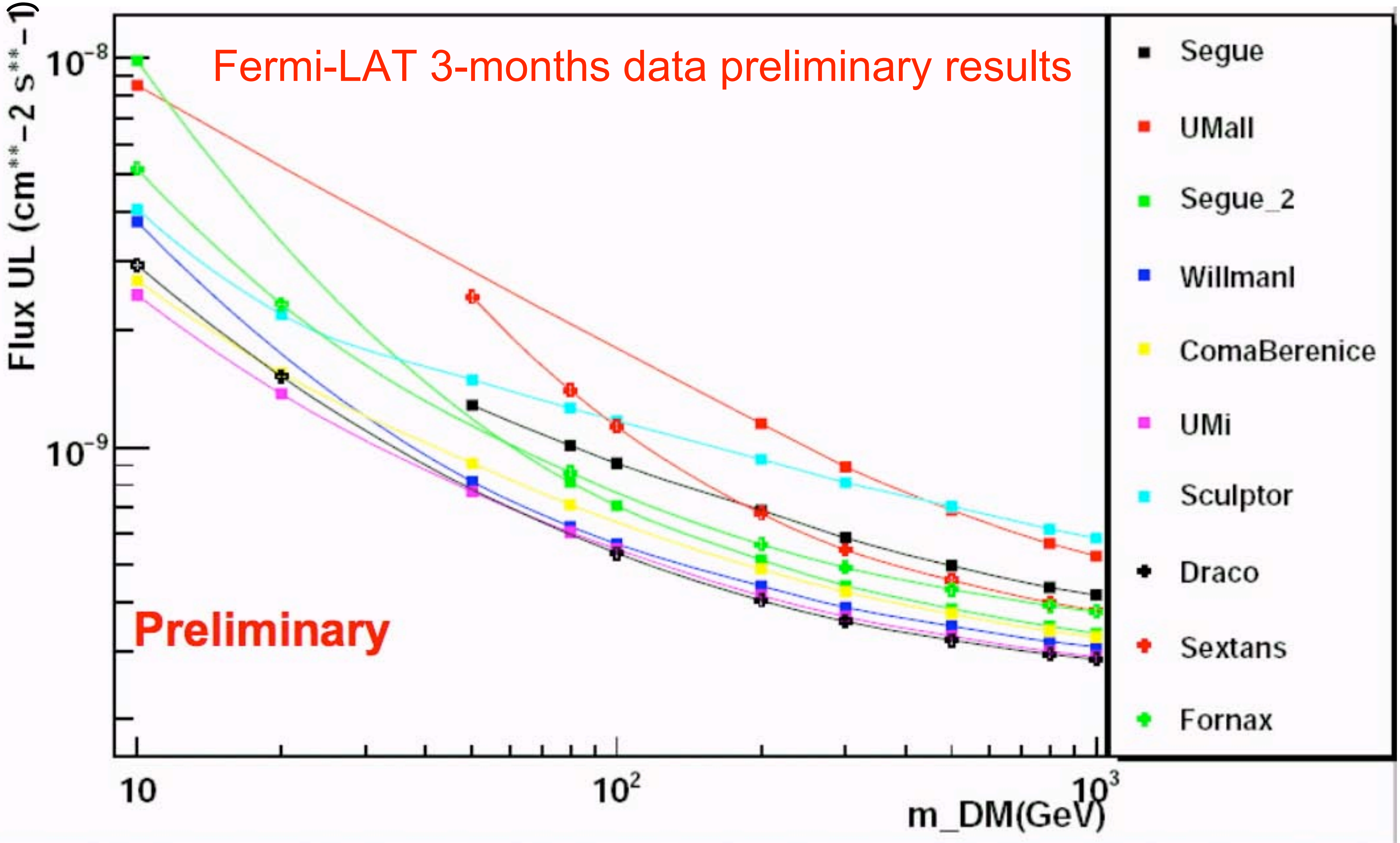


Dwarf spheroidal galaxies (dSph) : promising targets for DM detection

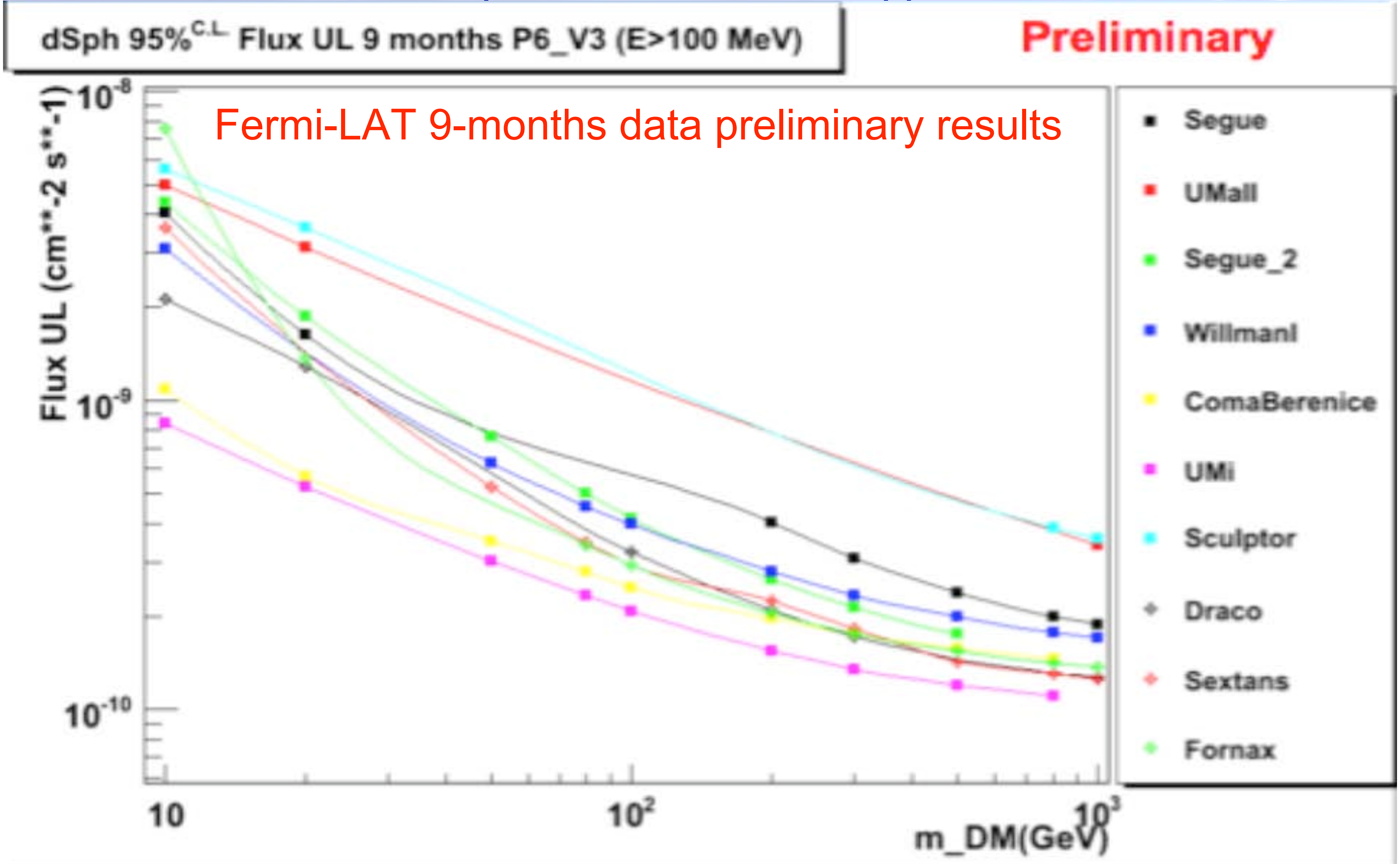


- ➢ dSphs are the most DM dominated systems known in the Universe with very high M/L ratios (M/L ~ 10- 2000).
- ➢ Many of them (at least 6) closer than 100 kpc to the GC (e.g. Draco, Umi, Sagittarius and new SDSS dwarfs).
- ➢ SDSS [only $\frac{1}{4}$ of the sky covered] already double the number of dSphs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

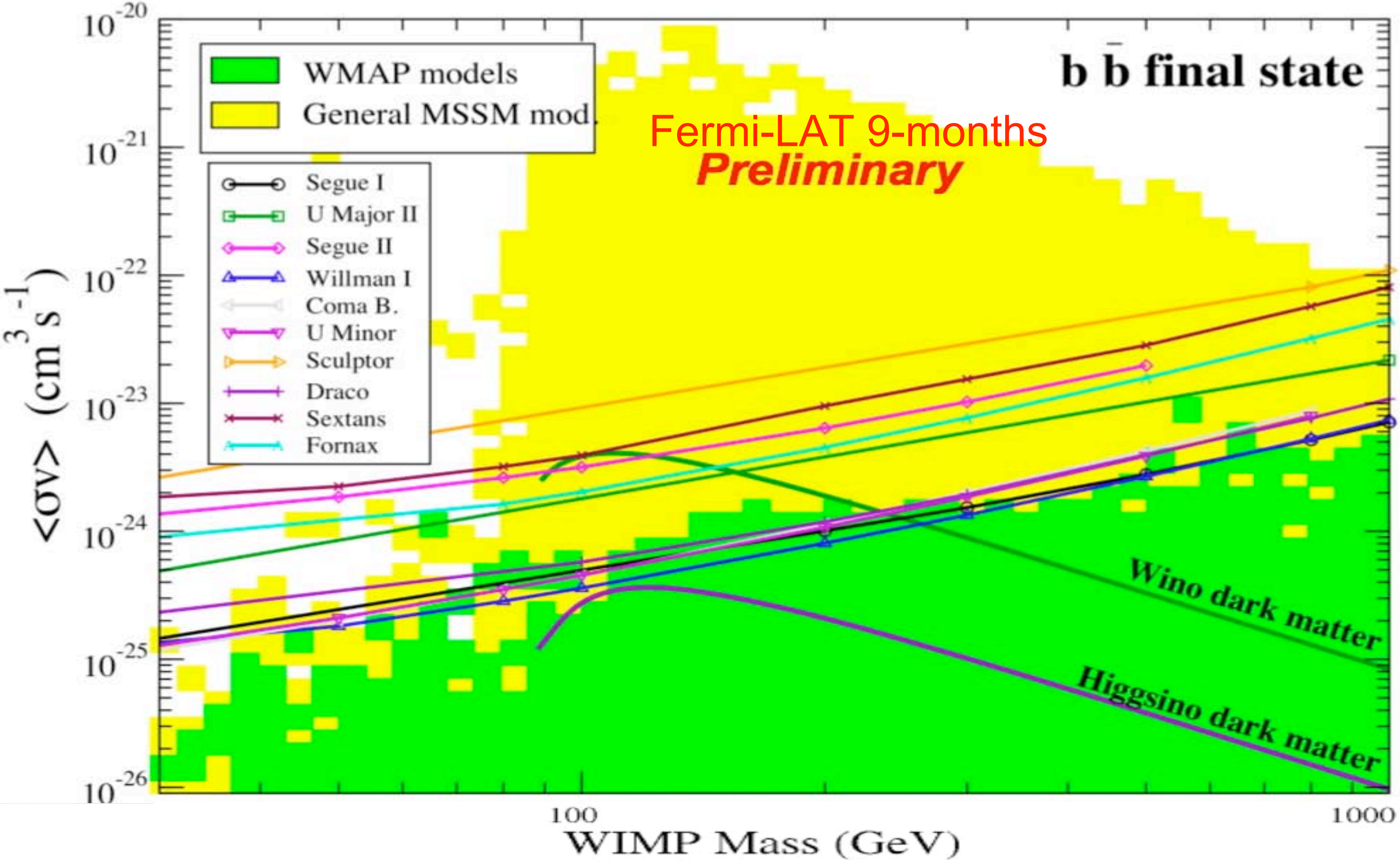
Dwarf Spheroidal Galaxies upper-limits



Dwarf Spheroidal Galaxies upper-limits



Annihilation cross-section upper-limits in Dwarf Spheroidal Galaxies



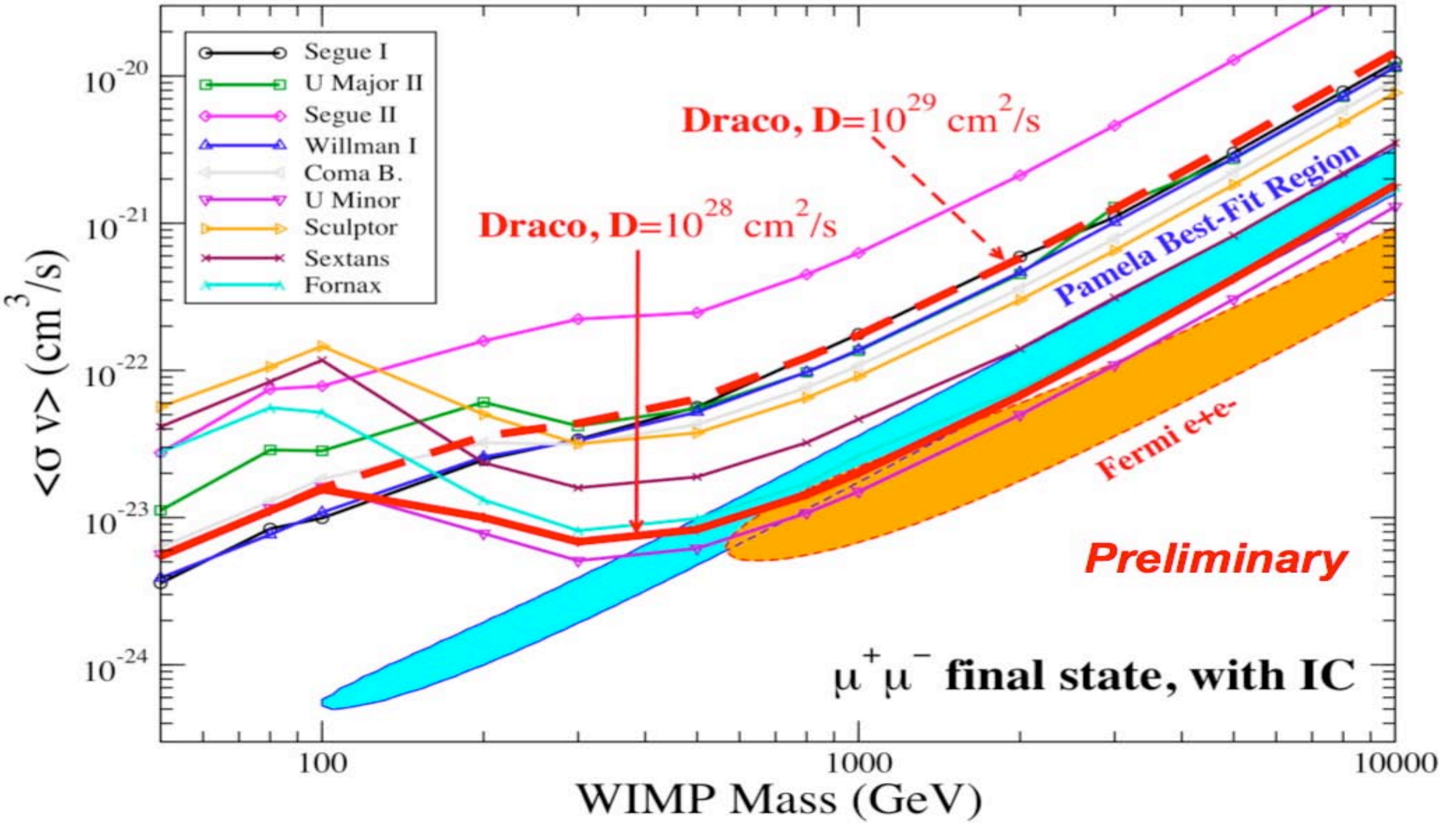
Inverse Compton Emission and Diffusion in Dwarfs

- 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 ??)

Constraints Including IC Emission



Combined constraints for Final State Radiation (FSR) plus IC with reference diffusion model $D_0 = 10^{28}$ cm^2/s

New Data is Forthcoming

Electron Spectrum:

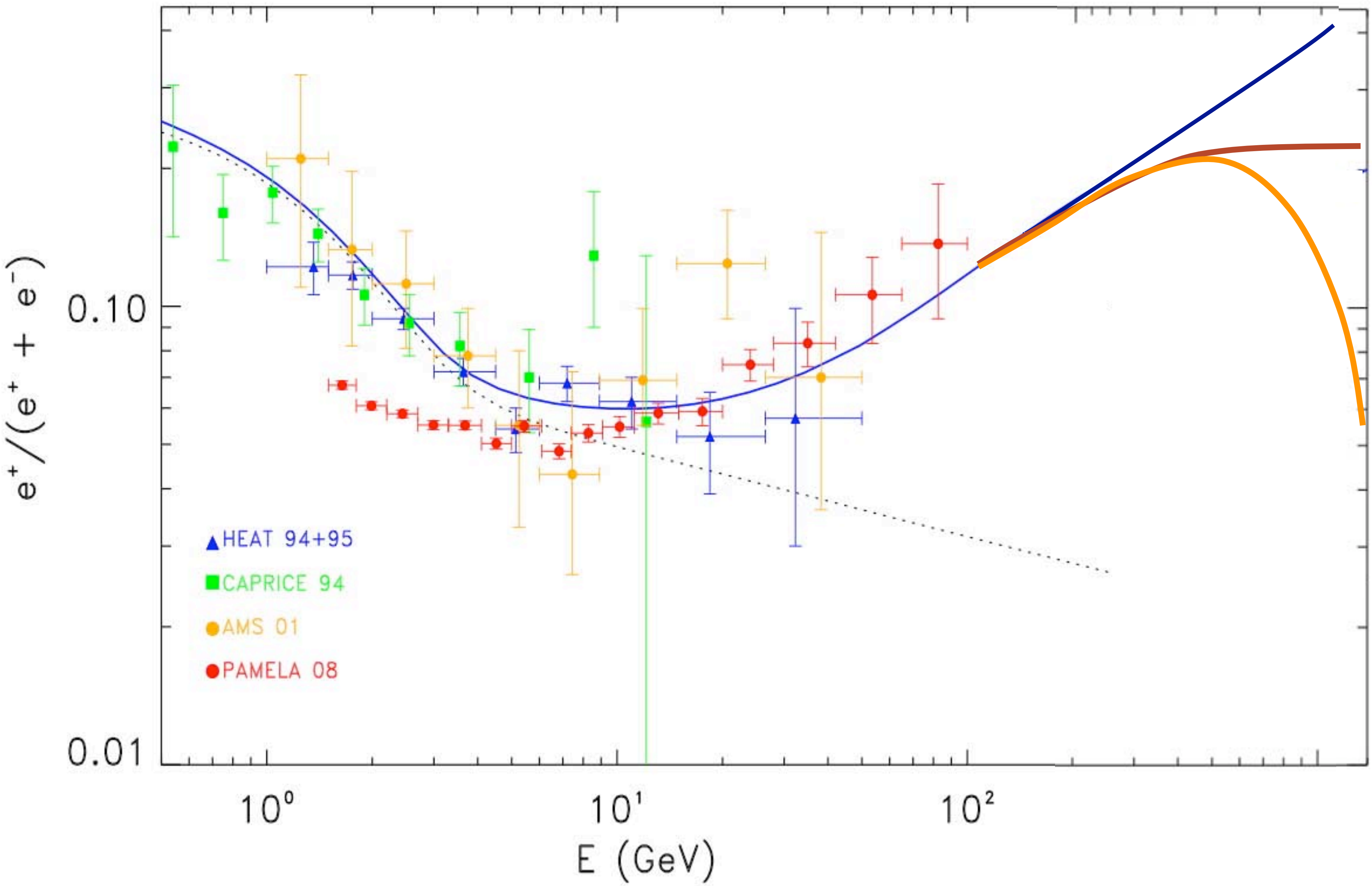
- **PAMELA & FERMI (GLAST)** (taking data in space);
- **ATIC-4** (had successful balloon flight,under analysis);
- **CREST** (new balloon payload under development);
- **AMS-02** (launch date TBD);
- **CALET** (proposed for ISS);
- **ECAL** (proposed balloon experiment).

Comparison of High-Energy Electron Missions

Mission	Upper Energy (TeV)	Collecting Power (m^2sr)	Calorimeter Thickness (X_0)	Energy Resolution (%)
CALET	20	0.75	30.8	< 3 (over 100 GeV)
PAMELA	0.25 (spectrometer) 2 (calorimeter)	0.0022 0.04	16.3	5.5 (300 GeV) 12 (300 GeV) 16 (1TeV)
GLAST	0.7	2.1 (100 GeV) 0.7 (700 GeV)	8.3	6 (100 GeV) 16 (700 GeV)
AMS-02	0.66 (spectrometer) 1 (calorimeter)	0.5 0.06 (100 GeV) < 0.04 (1 TeV)	16.0	< 3 (over 100 GeV)

Positron / Electron Separation: **PAMELA & AMS-02**

the positron ratio



Conclusion:

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

Adopting the presence of an extra $e^{\pm}$ primary component with ~ 2.4 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 originated by pulsars for a reasonable choice of relevant parameters

- 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.

In September 2009 Fermi data will be open to the community
You are all invited to join !

thank you for the attention !