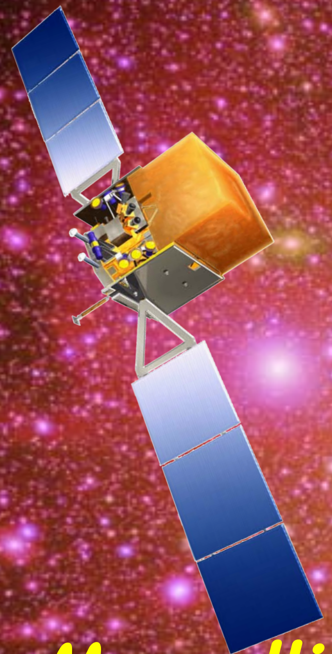
Indirect DarkMatter Measurements

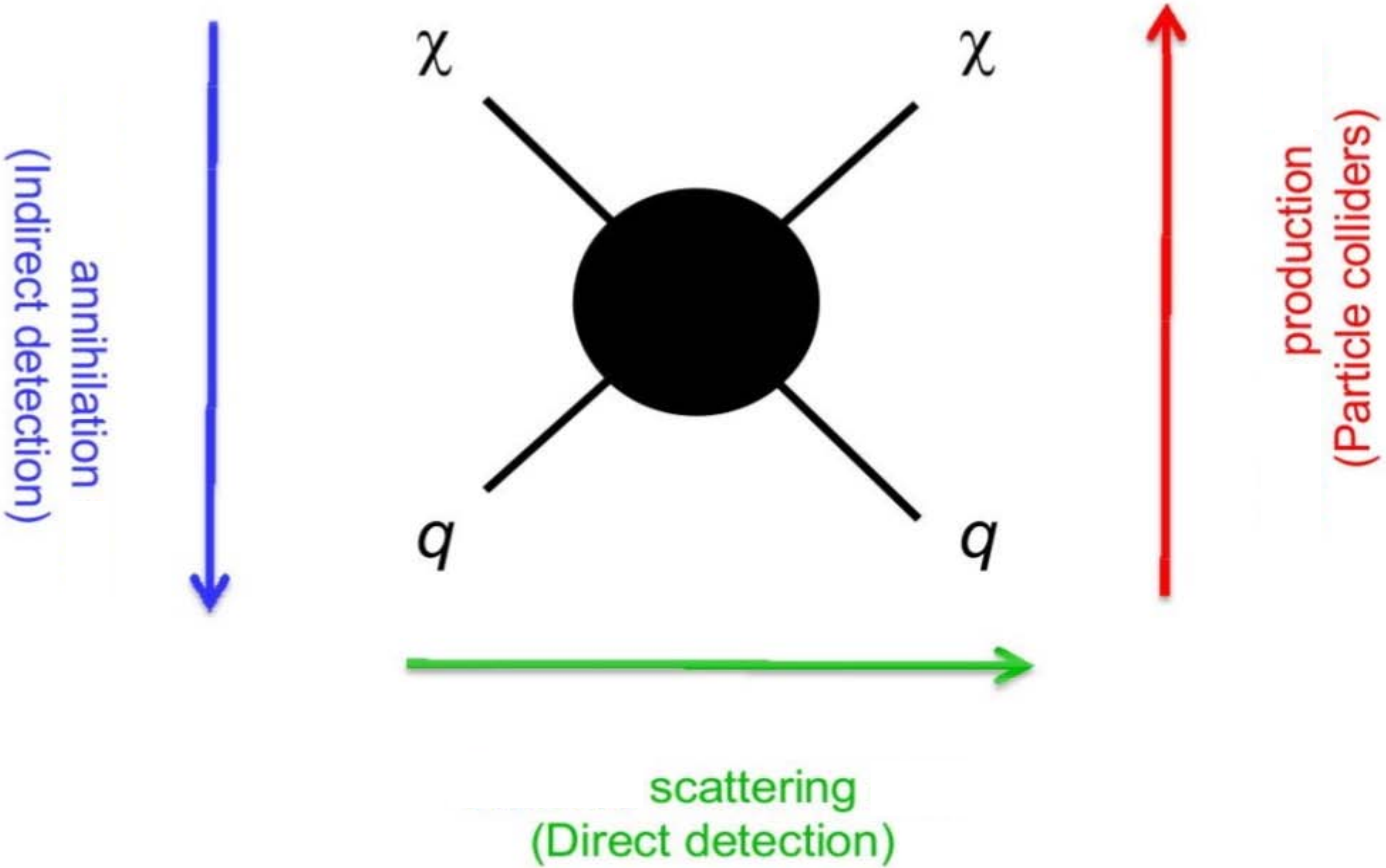


Aldo Morselli

INFN Roma Tor Vergata

1st International Workshop on LHC Era Physics (LHEP2010)

Nanning, China on Nov. 15-19, 2010


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….

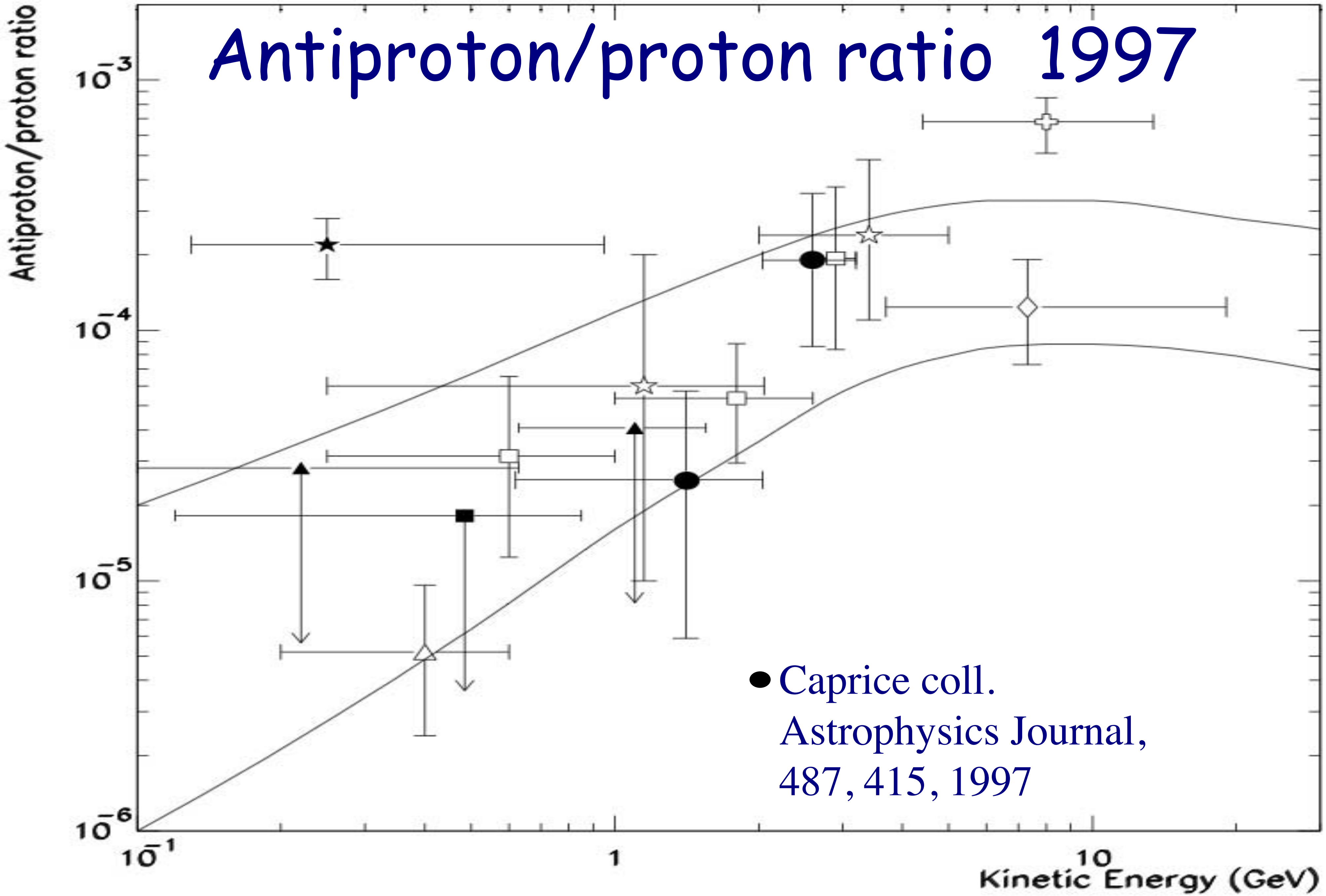
• Antimatter not produced in large quantities through standard processes (secondary production through p + p **-->** anti p + X)

• So, any extra contribution from exotic sources ($\chi\,\chi$ 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

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

diffusion coefficient in the impulse space, quasi-linear MHD: $D_{pp}(D_{xx}, v_A)$

loss term: radioactive decay

diffusion coefficient is function of rigidity

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

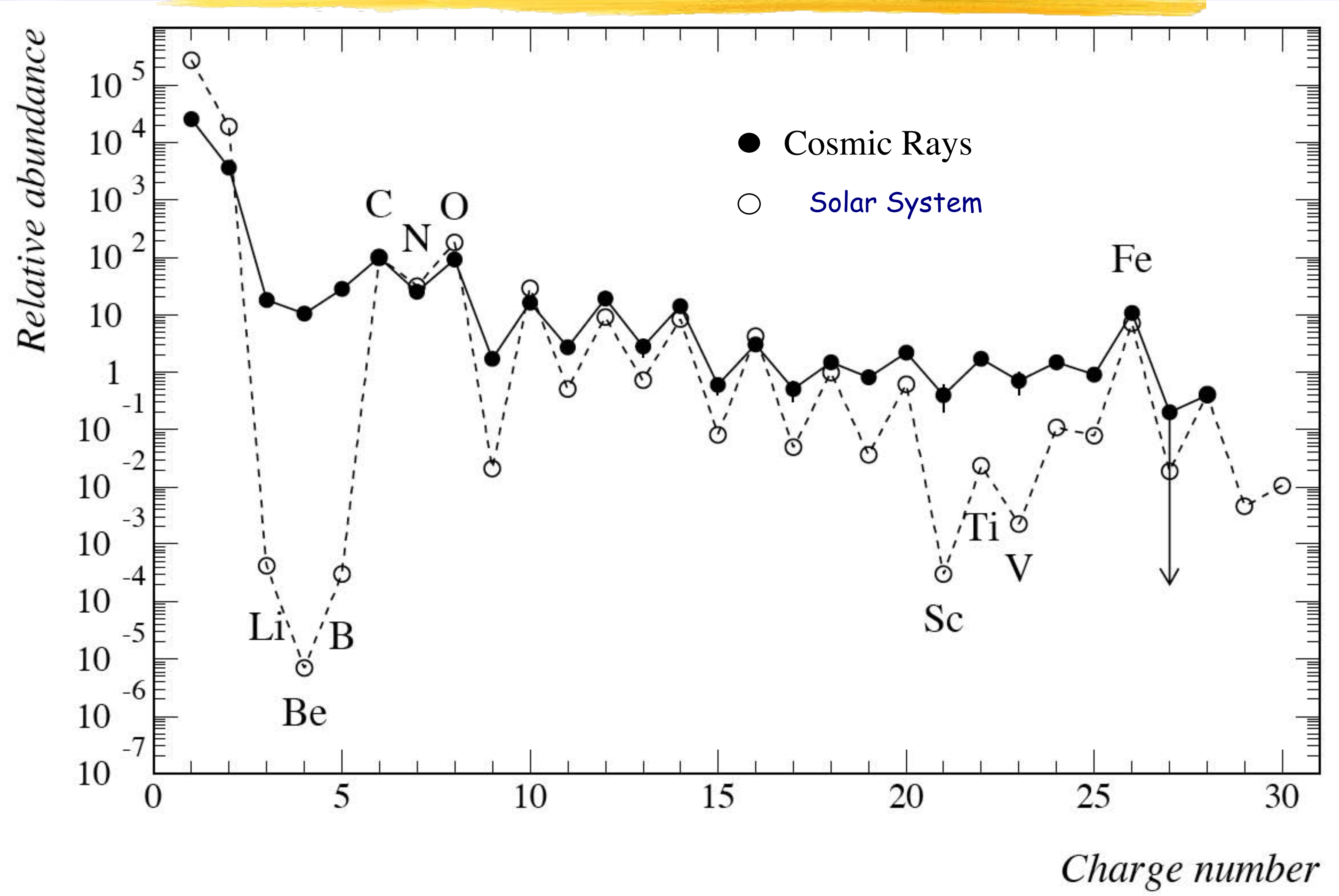
primary spectra injection index

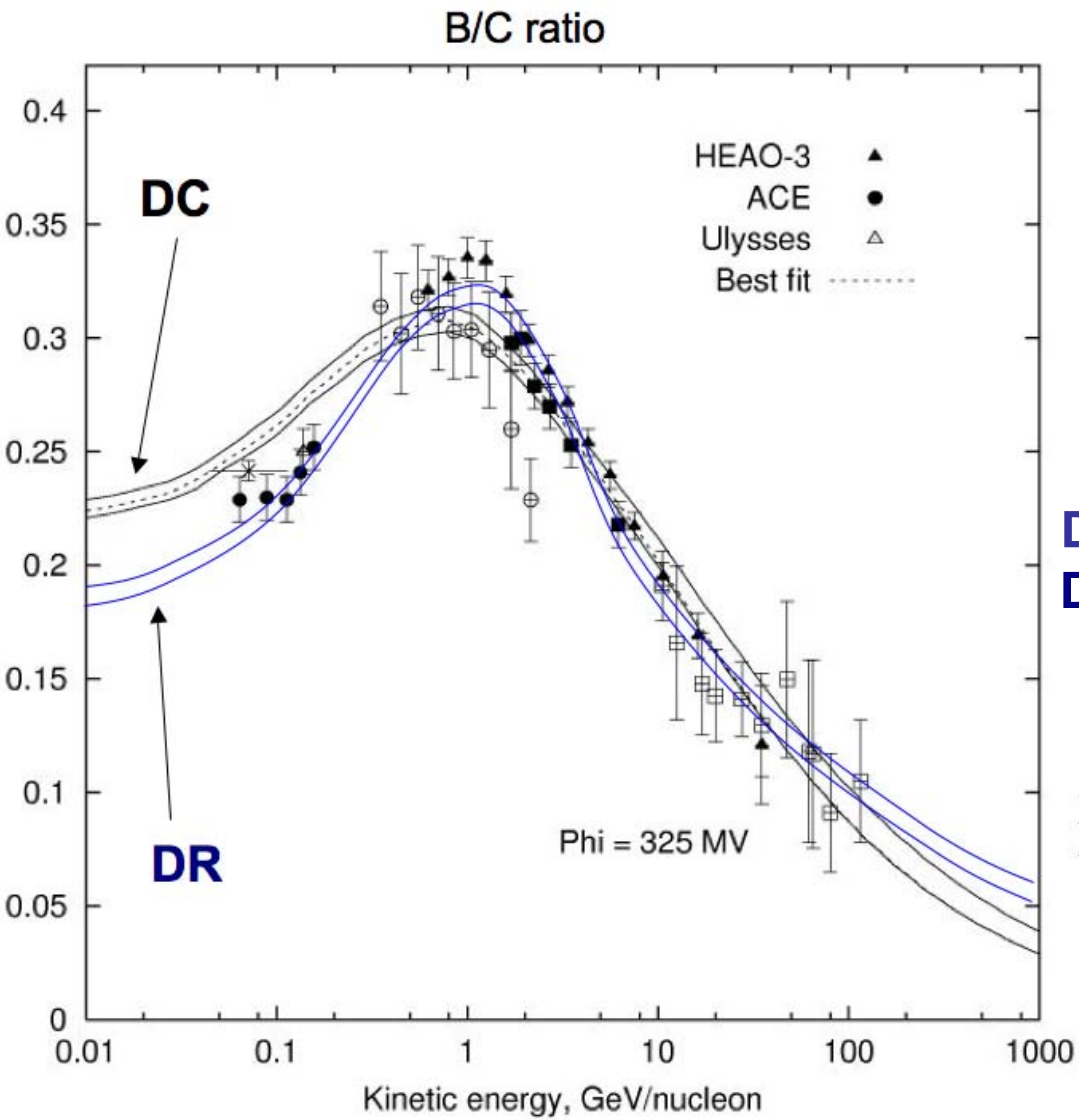
$$dq(p)/dp \propto p^{-\gamma}$$

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

[astro-ph/0502406]

Comparison between the cosmic rays and the Solar System element composition, both relative to Carbon





Enveloping curves of all the good fits of the experimental B/C data

Dashed line: Best fit

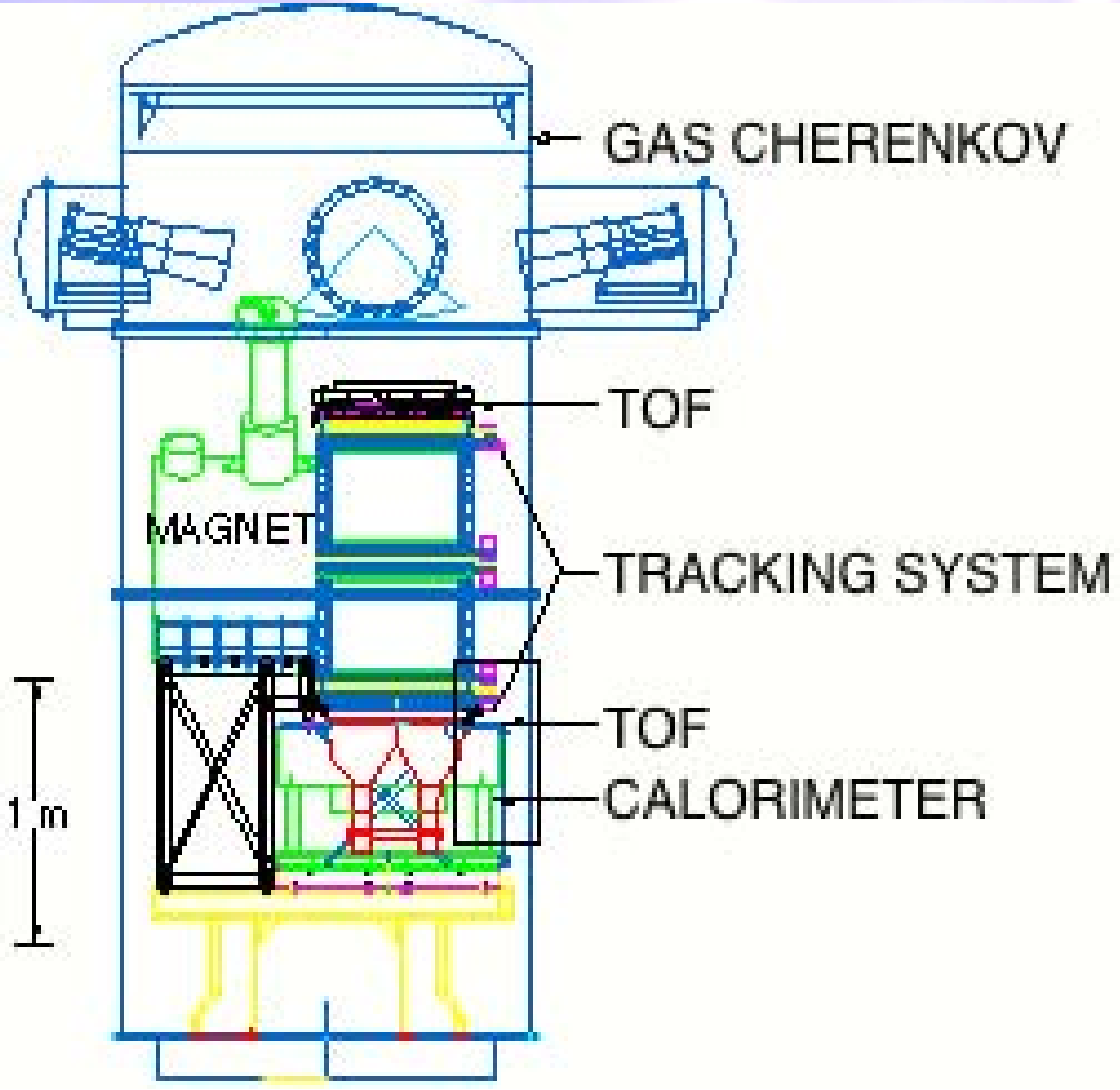
DR: diffusion+ reacceleration

DC: diffusion+convection

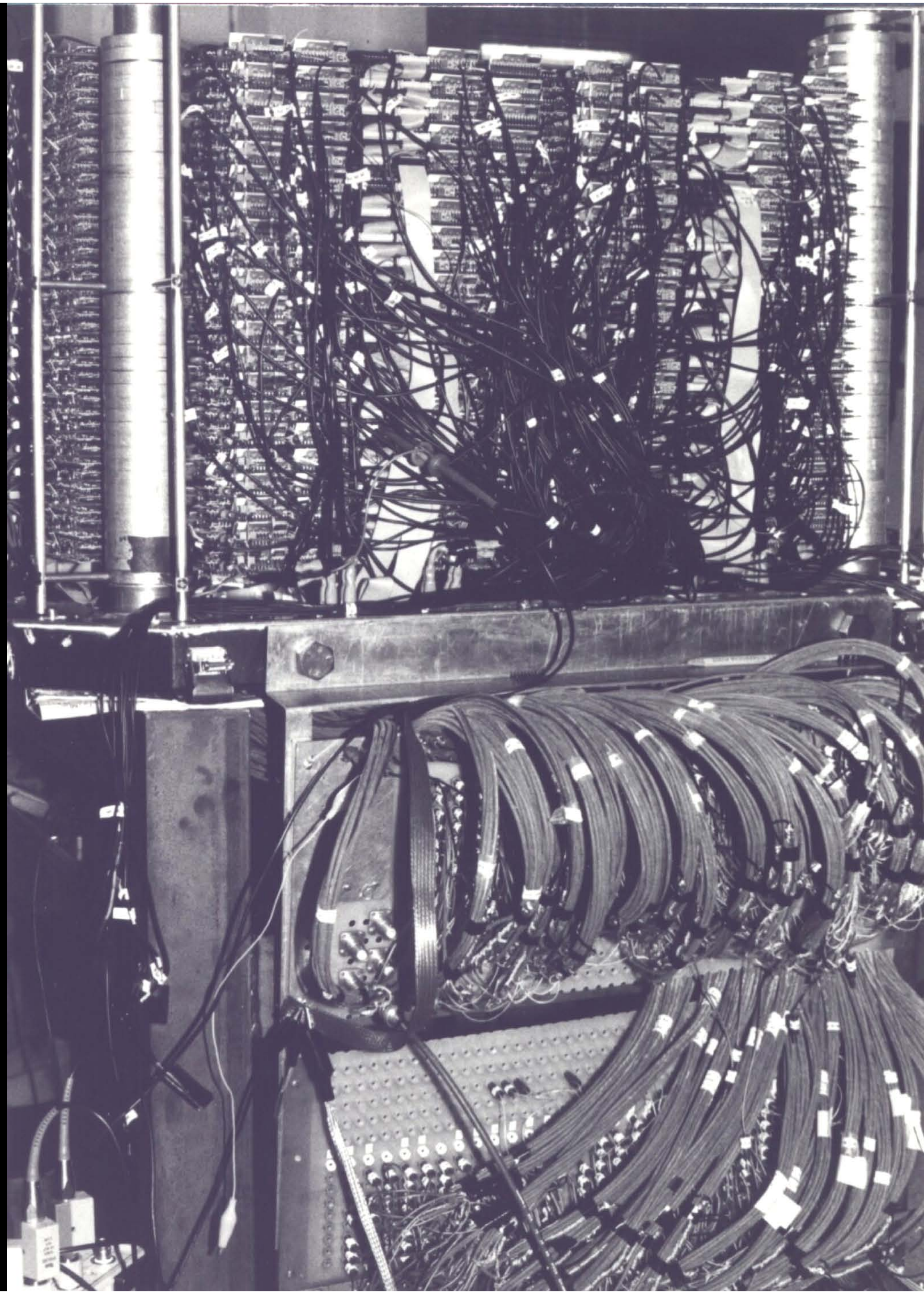
In DC model problem with the ACE data at low energy

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

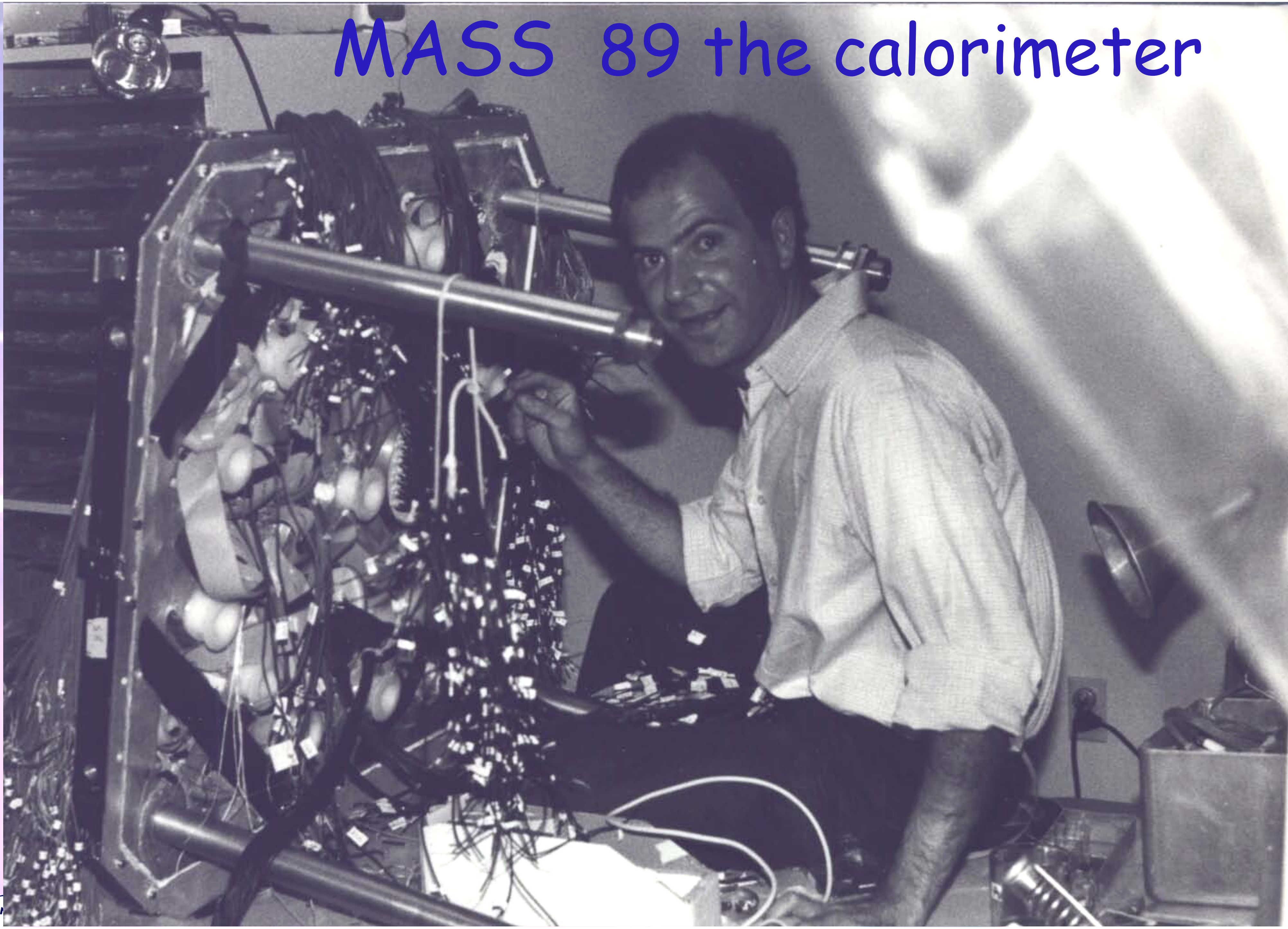
MASS Matter Antimatter Space Spectrometer



the MASS89 Calorimeter



MASS 89 the calorimeter



from Las Cruces to Prince Albert


HOLD


MASS 89 flight


MASS 89 flight


MASS 89

PAMELA

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

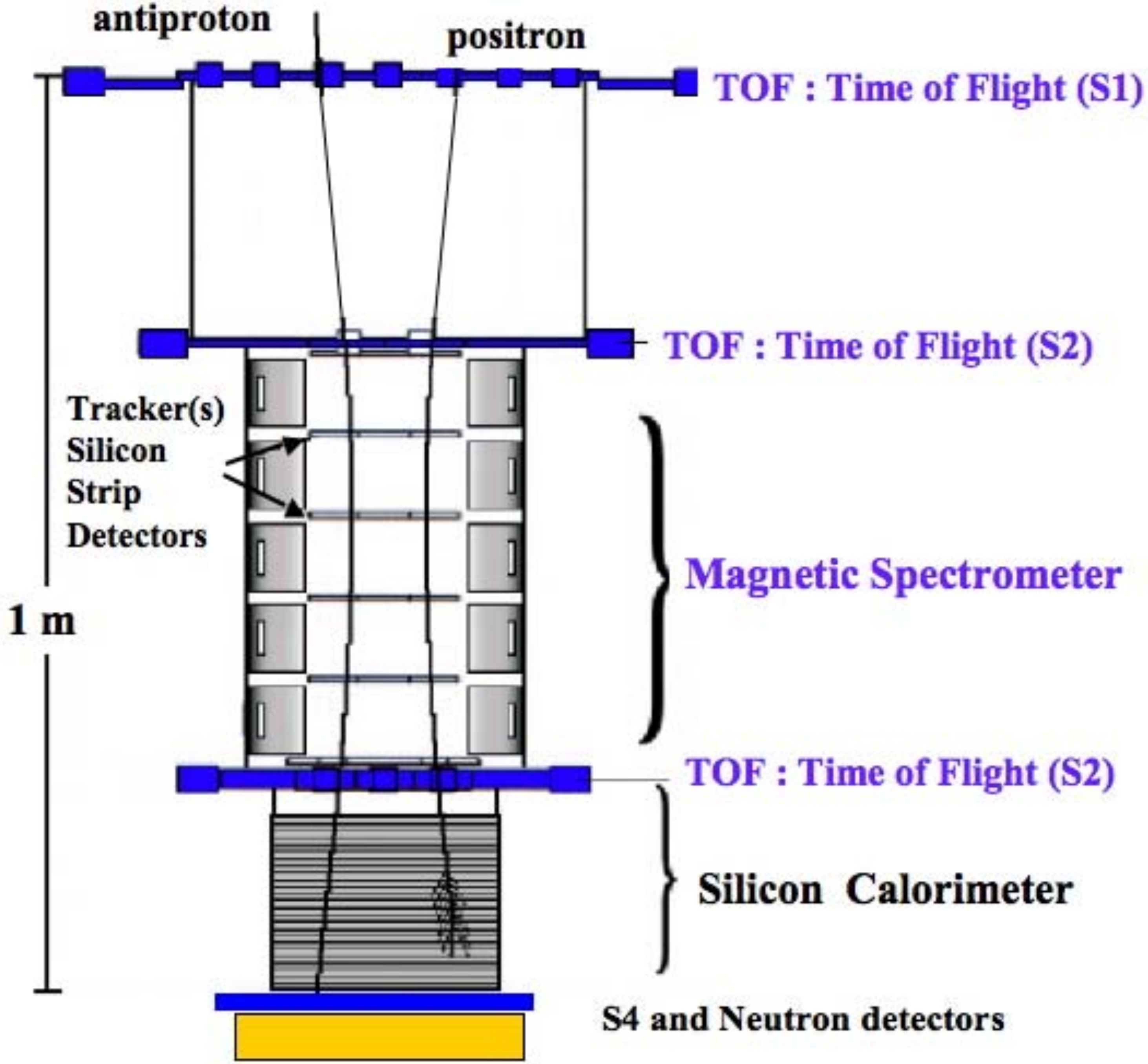
In orbit on June 15, 2006, on board of the DK1 satellite by a Soyuz rocket from the Bajkonour launch site.

First switch-on on June 21 2006

From July 11 Pamela is in continuous data taking mode

Pamela

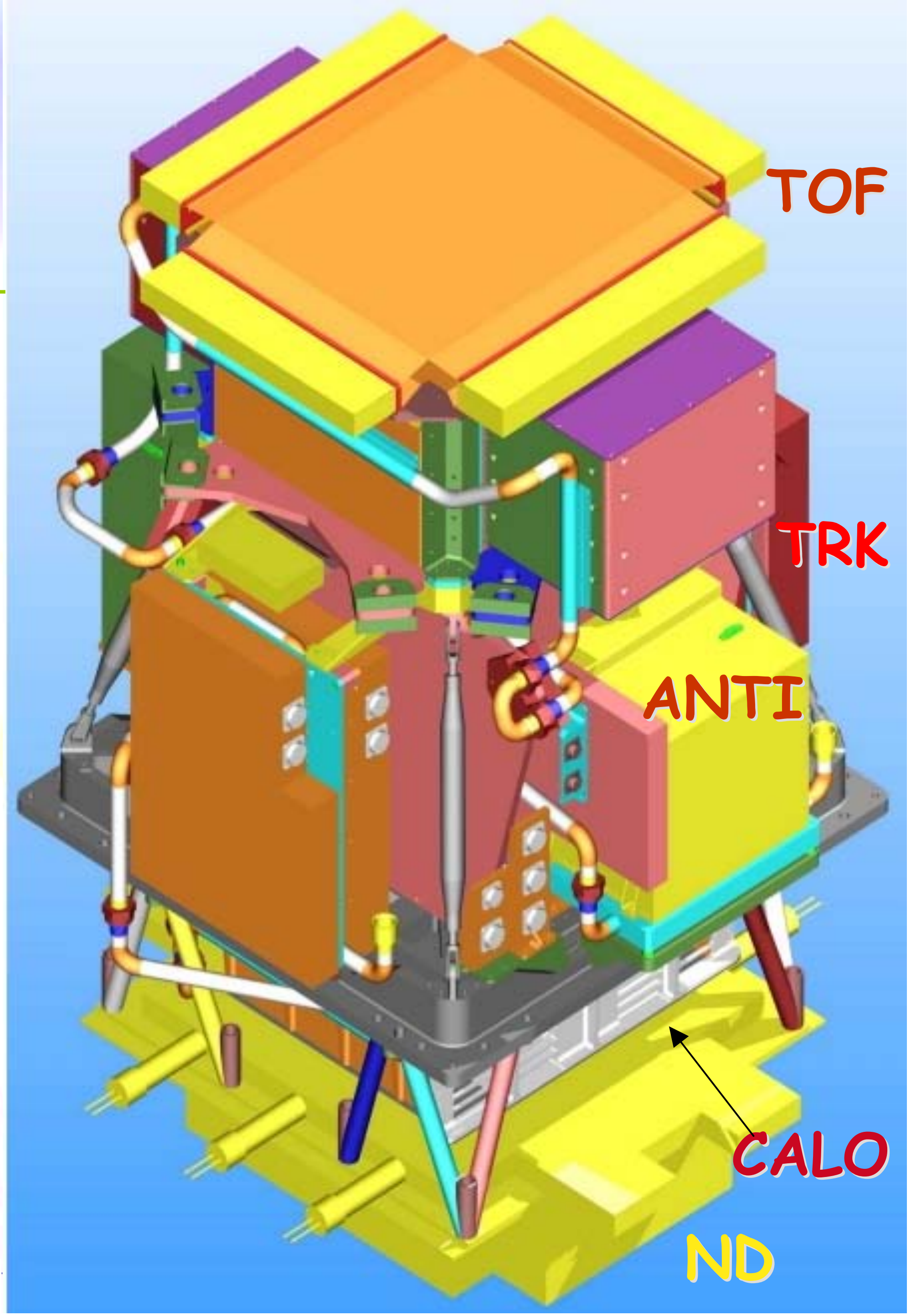
Separating p from e^-



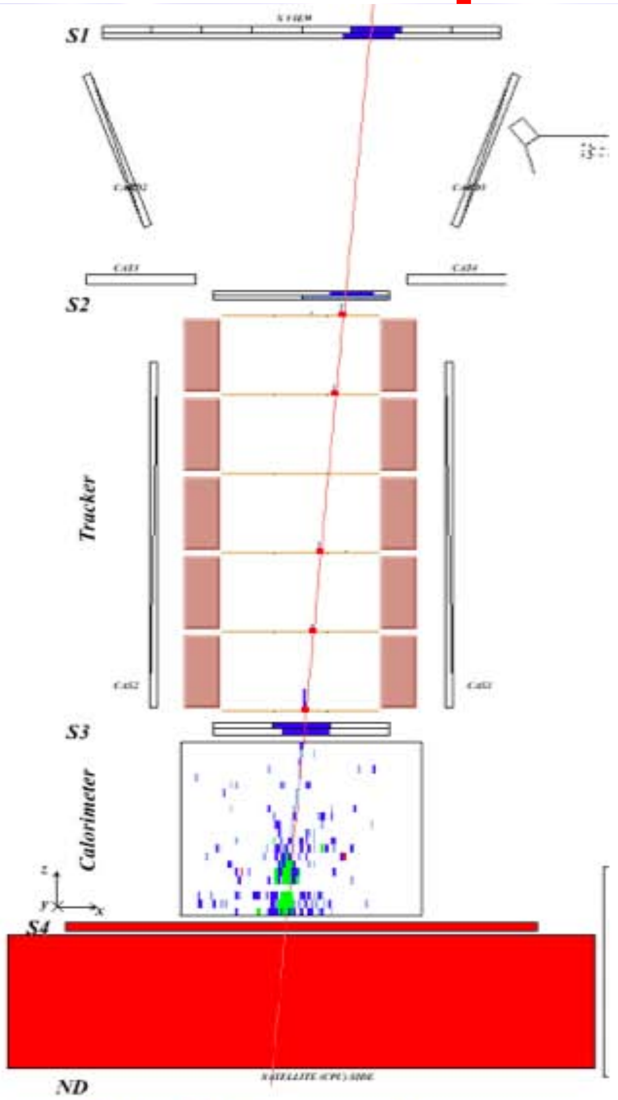
Pamela

- Protoni 80 MeV – 700 GeV
- Antiprotoni 80 MeV –190 GeV
- Elettroni 50 MeV – 2 TeV
- Positroni 50 MeV - 270 GeV
- Nuclei < 700 GeV/n
- Limite per Antinuclei 10^{-8}

- Massa del rivelatore 440 Kg
- Potenza 355 W
- MDR – 770 GV



Antiparticle identification



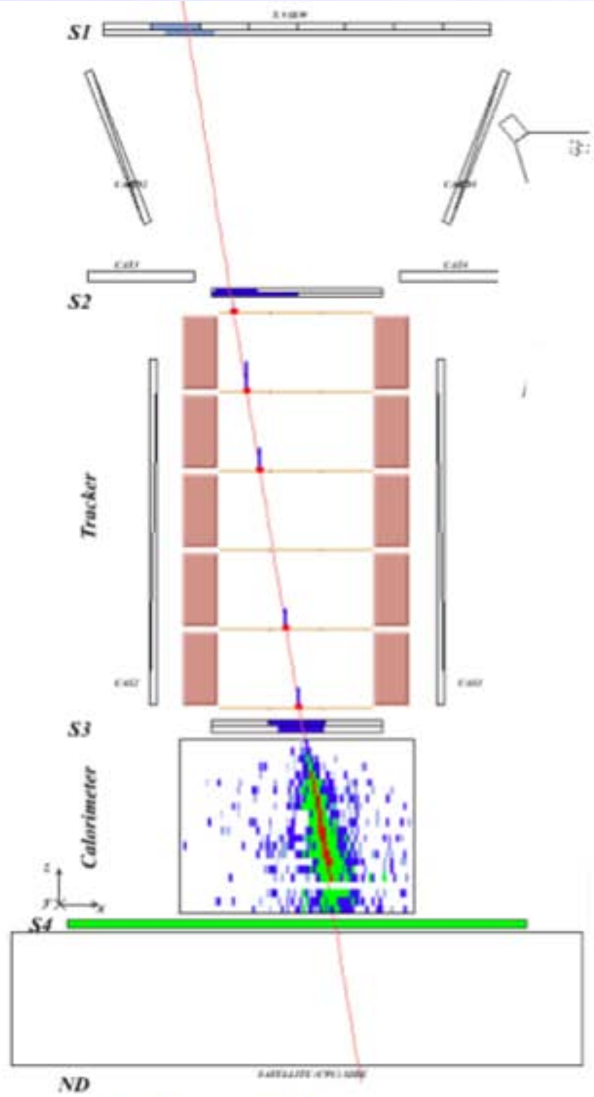
Antiproton
(NB: $e^-/\bar{p}$ ~ 10^2)

Time-of-flight:
trigger, albedo rejection, mass determination (up to 1 GeV)

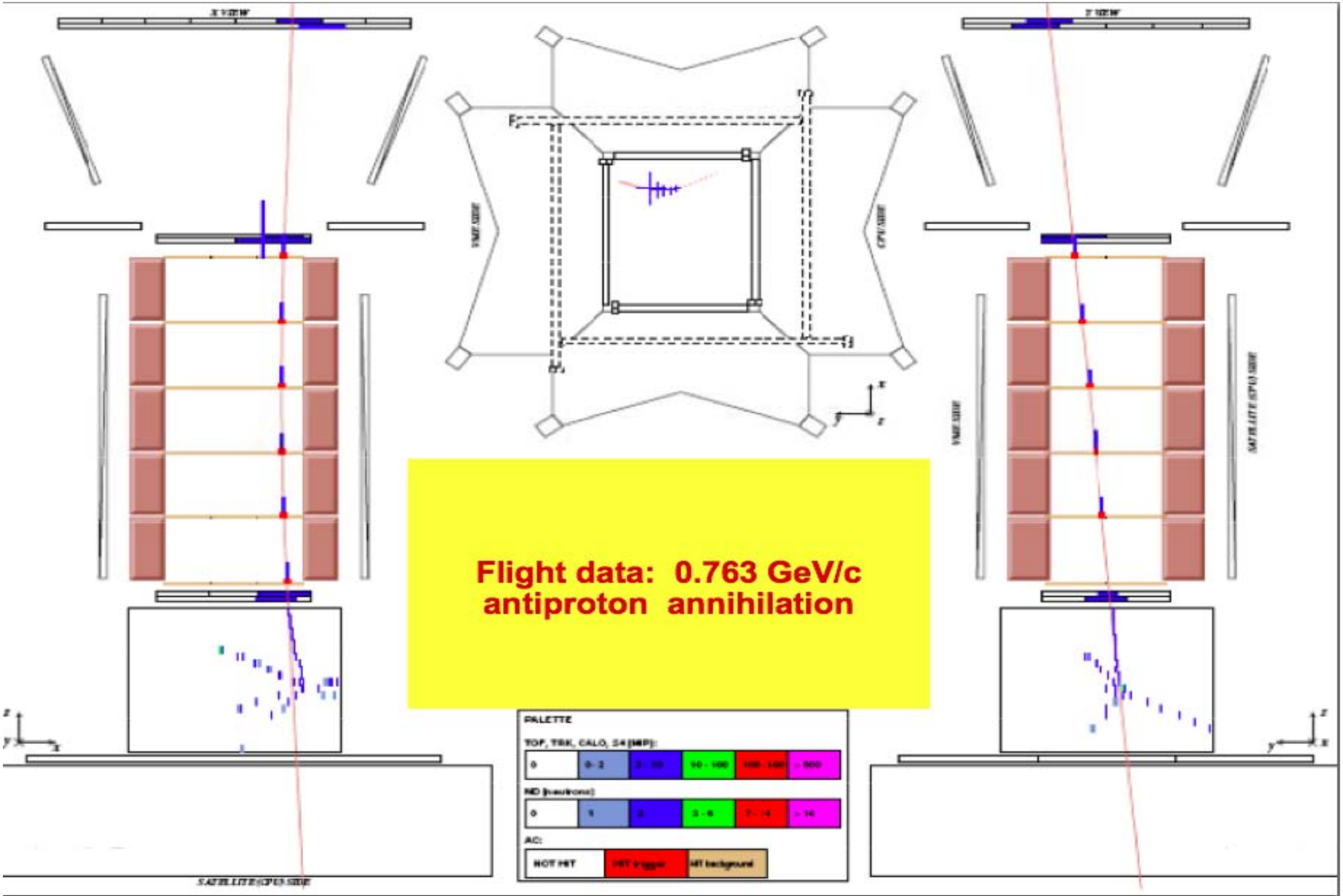
Bending in spectrometer:
sign of charge

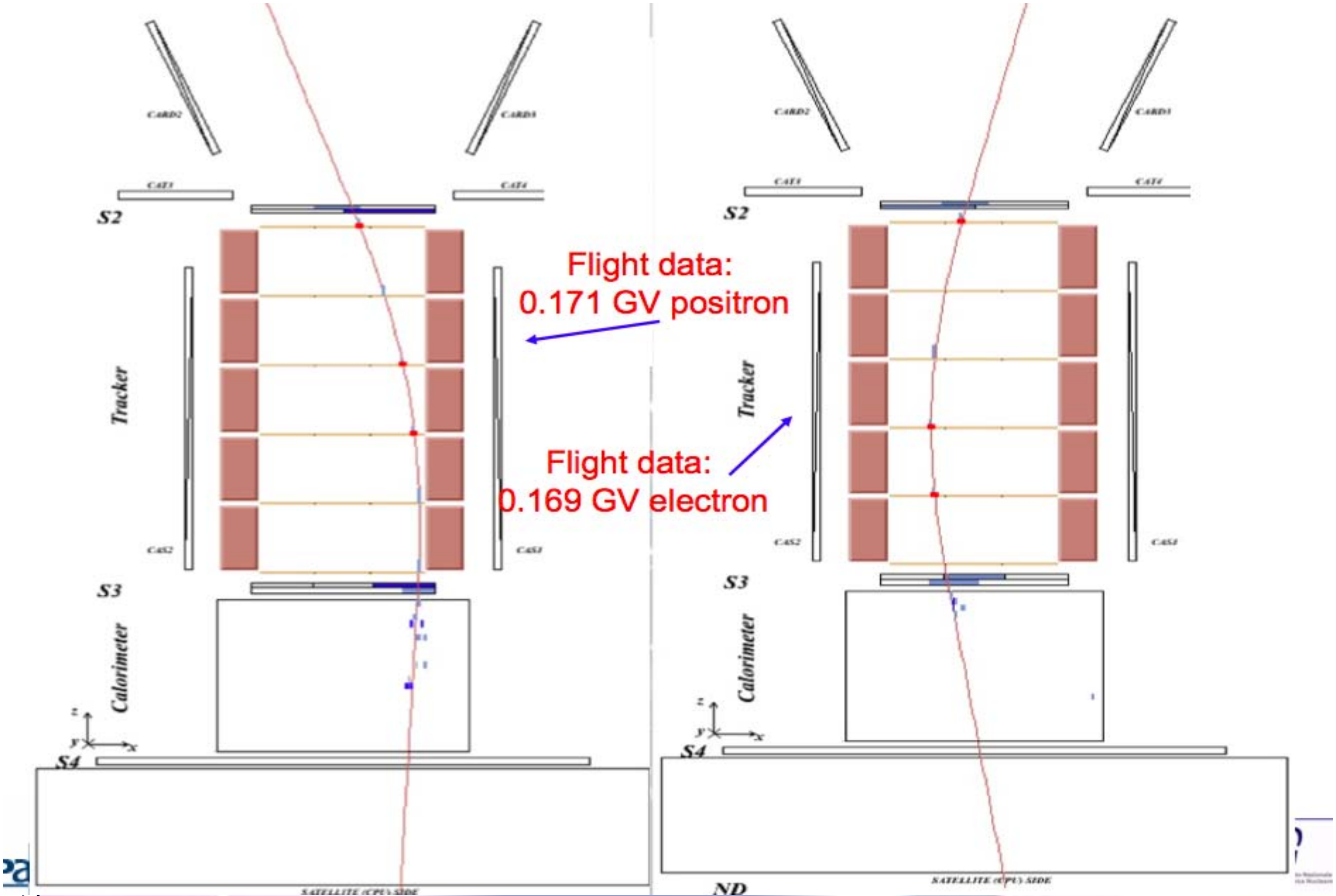
Ionisation energy loss (dE/dx):
magnitude of charge

Interaction pattern in calorimeter:
electron-like or proton-like, electron energy



Positron
(NB: p/e^+ ~10^{3-4})

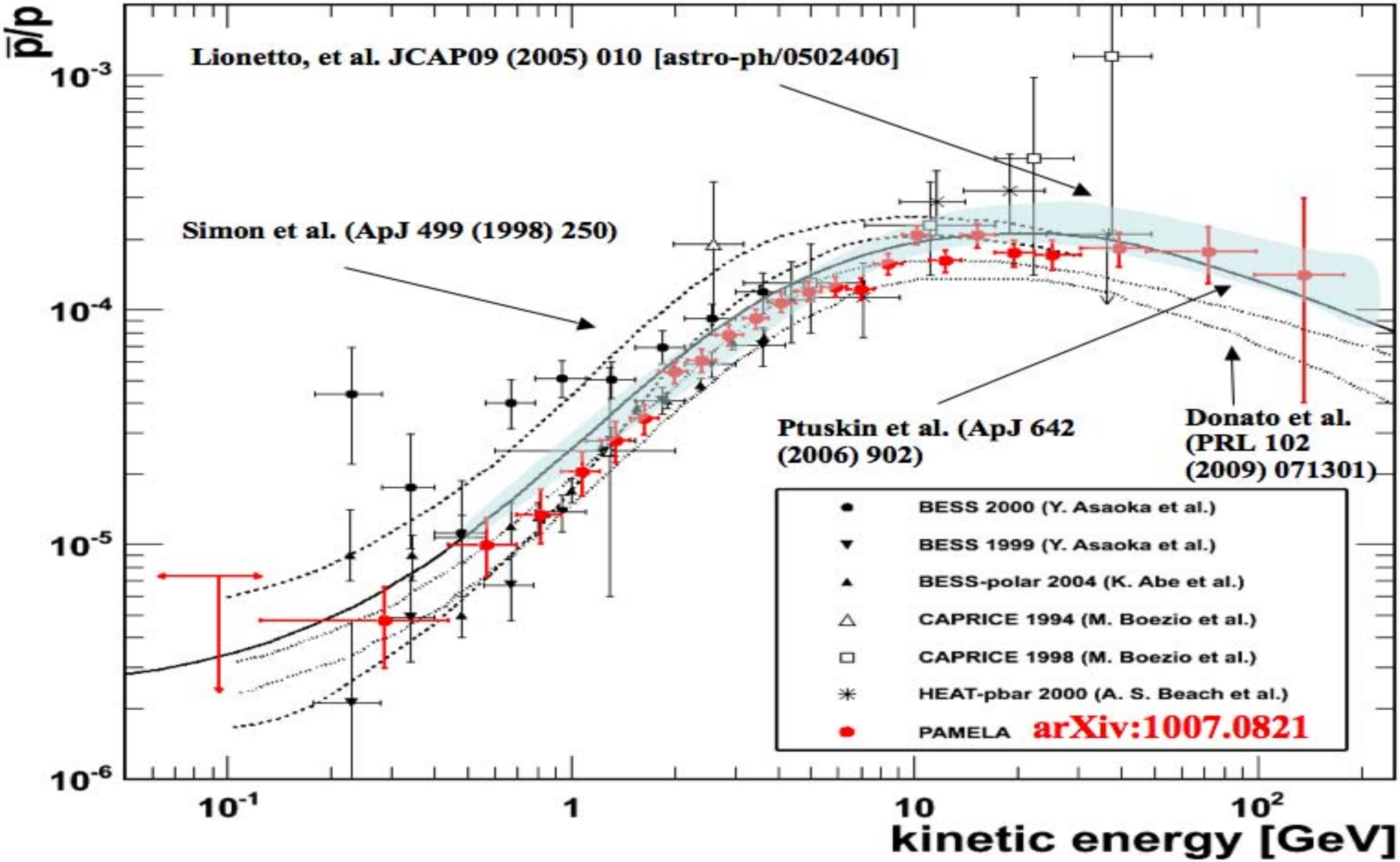

Flight data: 0.763 GeV/c
antiproton annihilation
PALETTE
TOF, TRK, CALO, S4 (MIP):
ND (neutrons):
AC:
NOT HIT


S2
Tracker
S3
Calorimeter
S4
Flight data:
0.171 GV positron
Flight data:
0.169 GV electron
ND

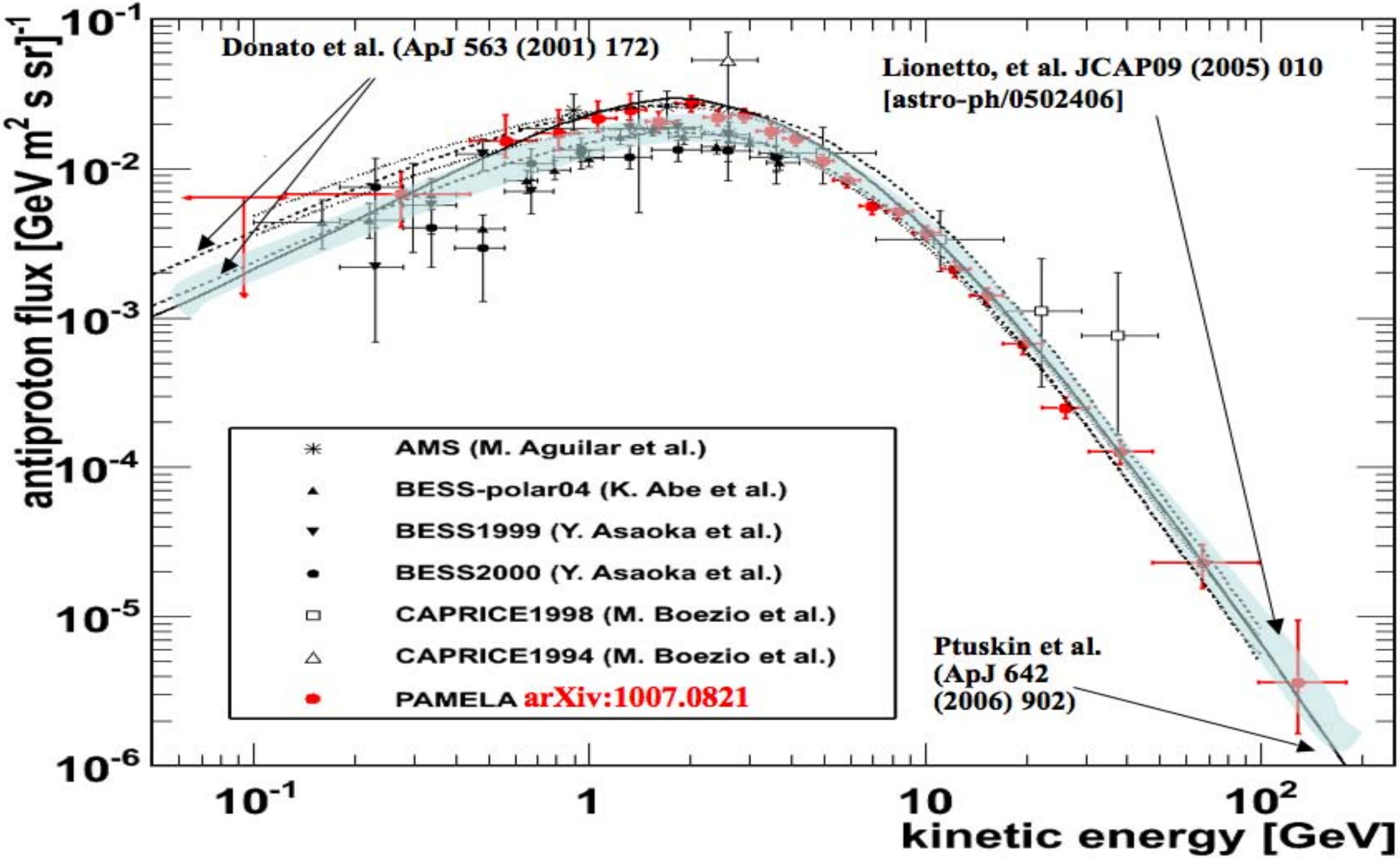
- ~ 4 years from PAMELA launch

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

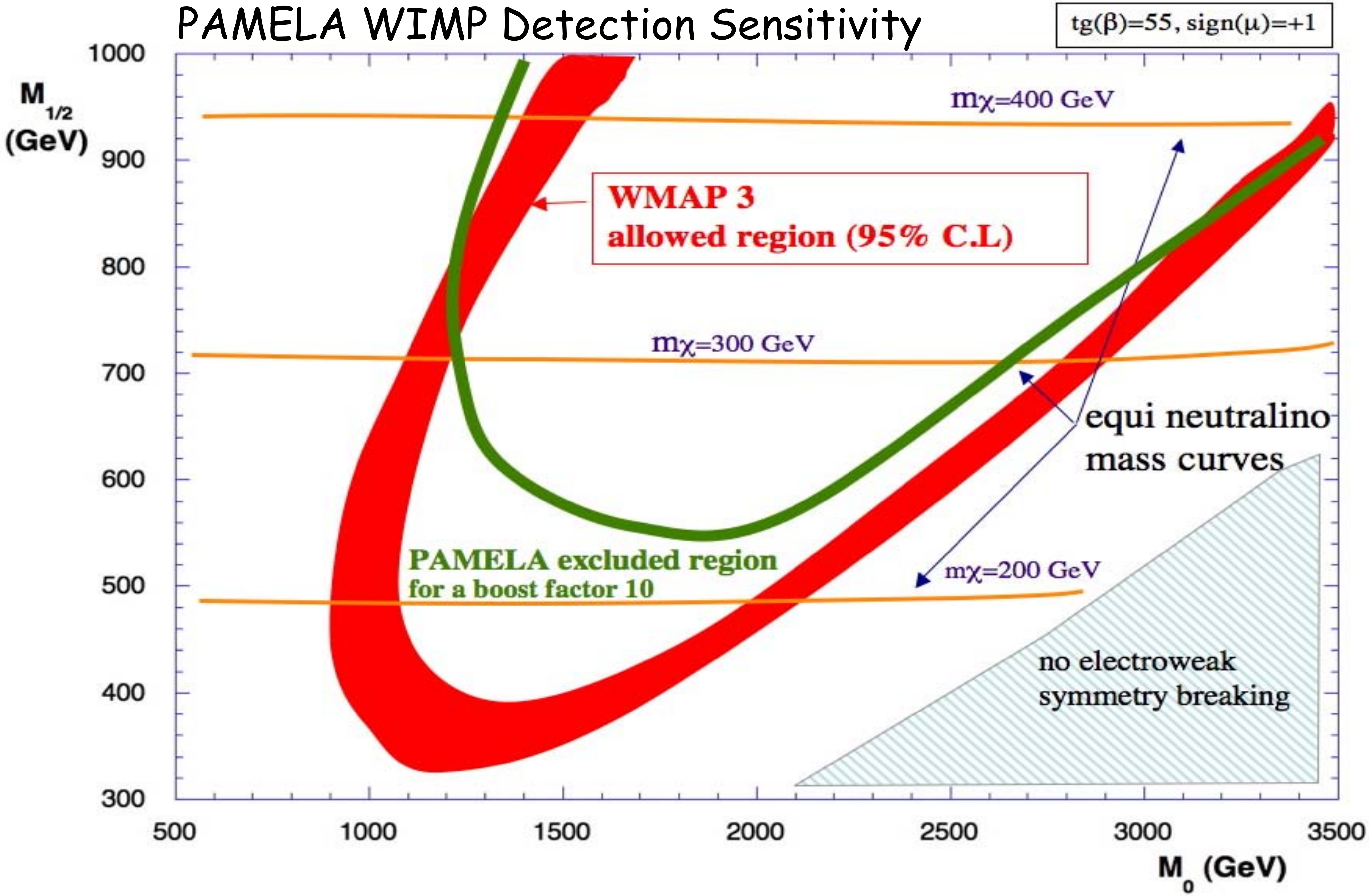
Antiproton-Proton Ratio



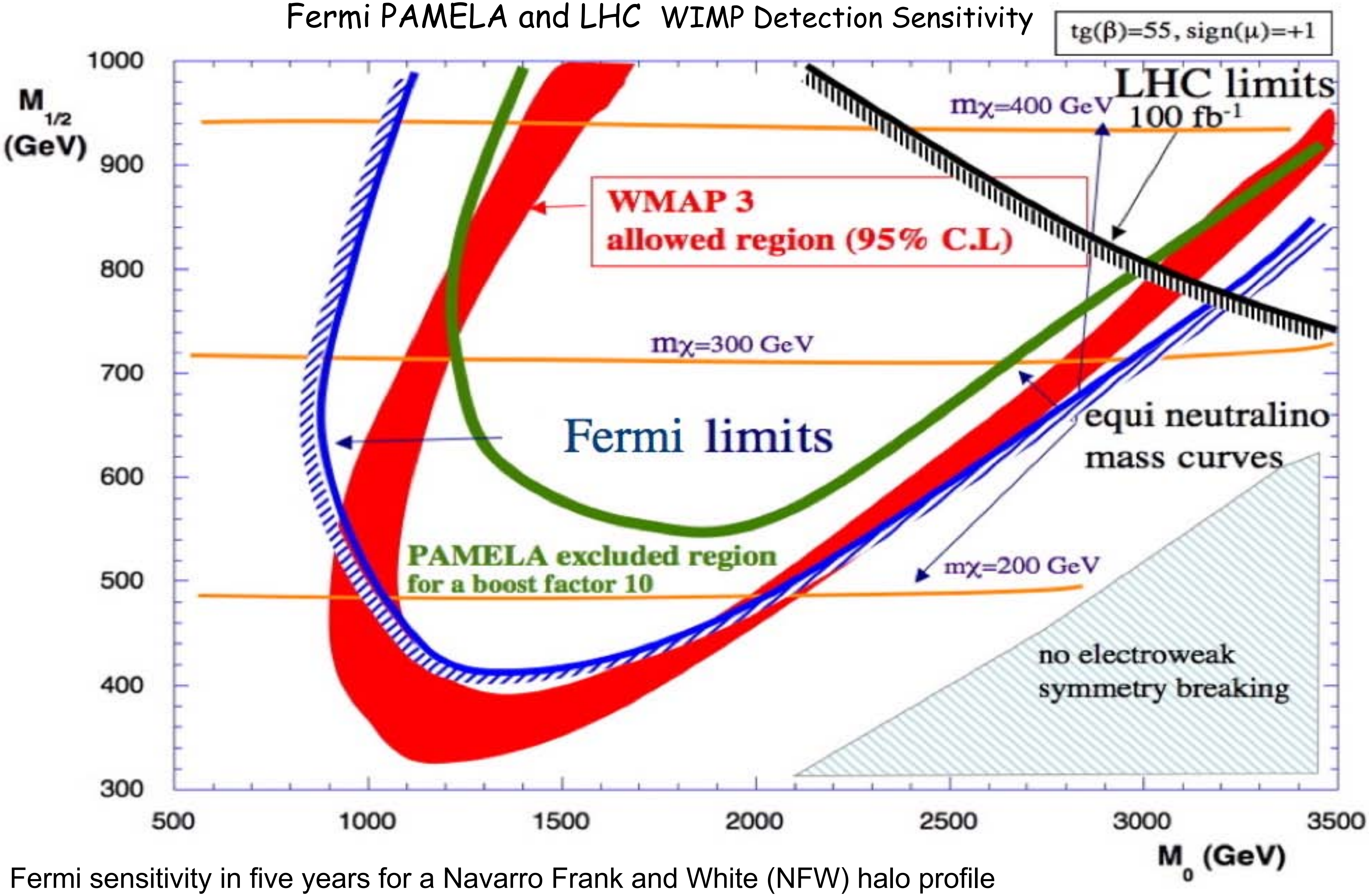
Antiproton flux



PAMELA WIMP Detection Sensitivity



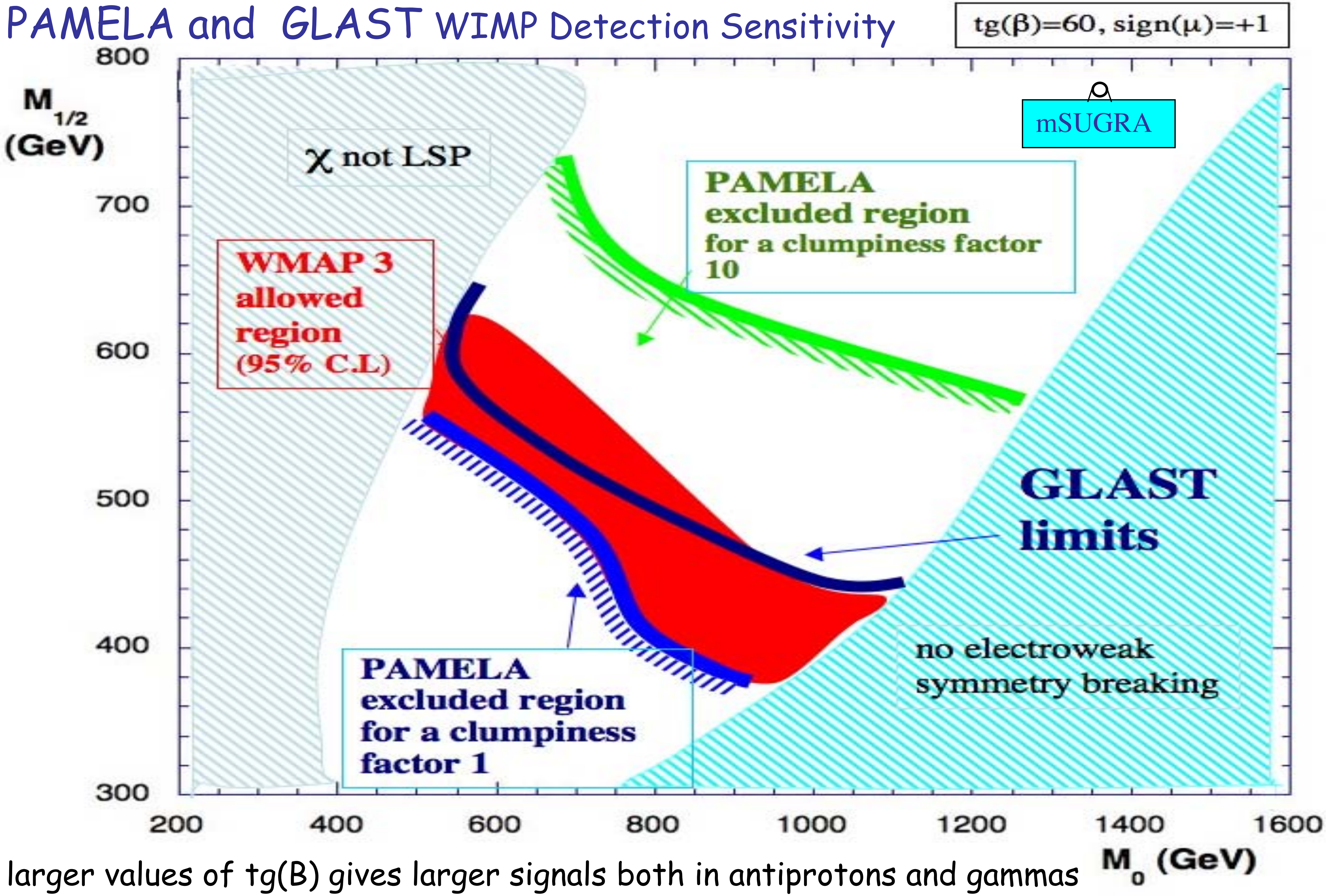
Fermi PAMELA and LHC WIMP Detection Sensitivity



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

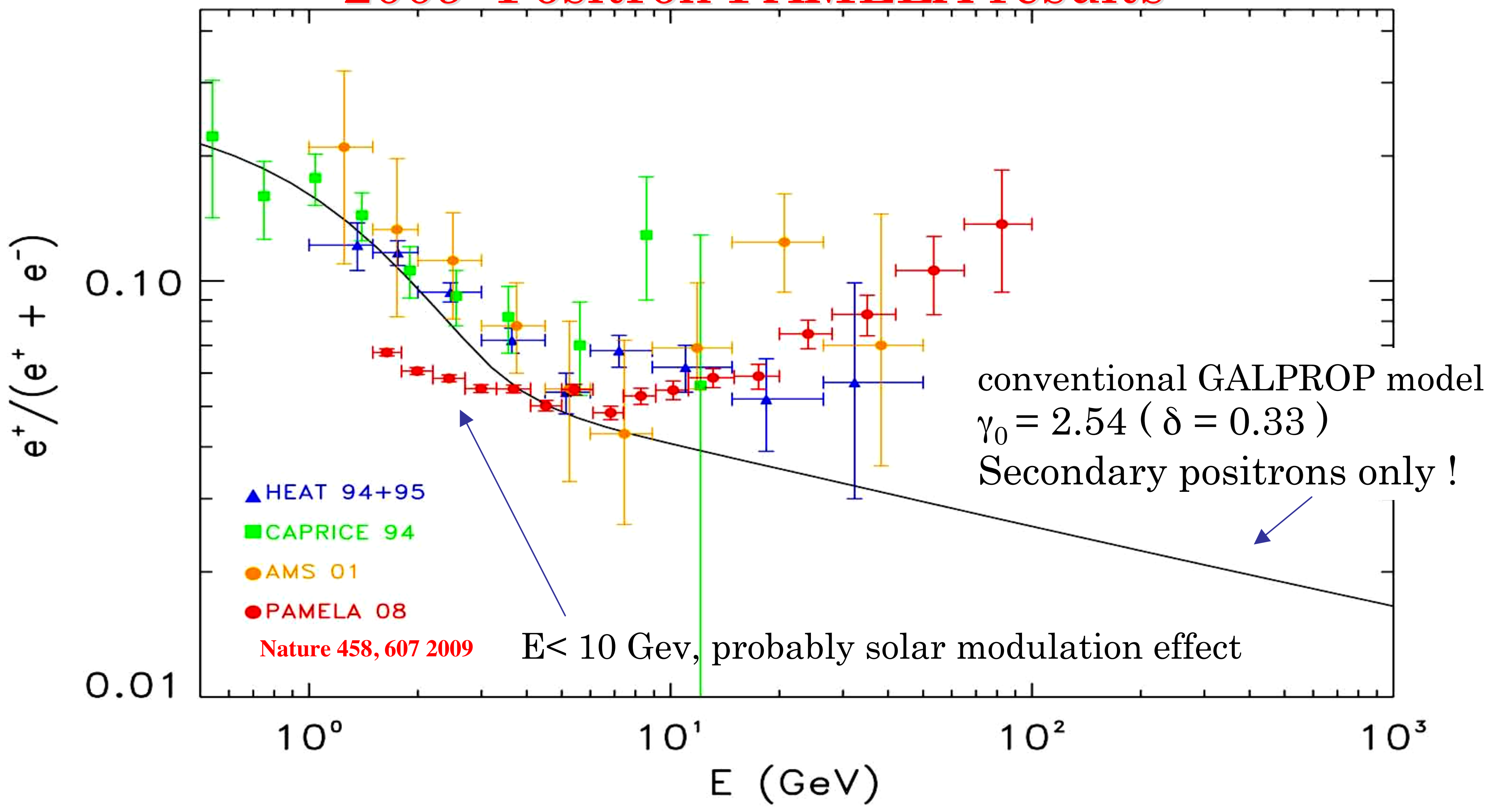
arXiv:0811.3526

PAMELA and GLAST WIMP Detection Sensitivity



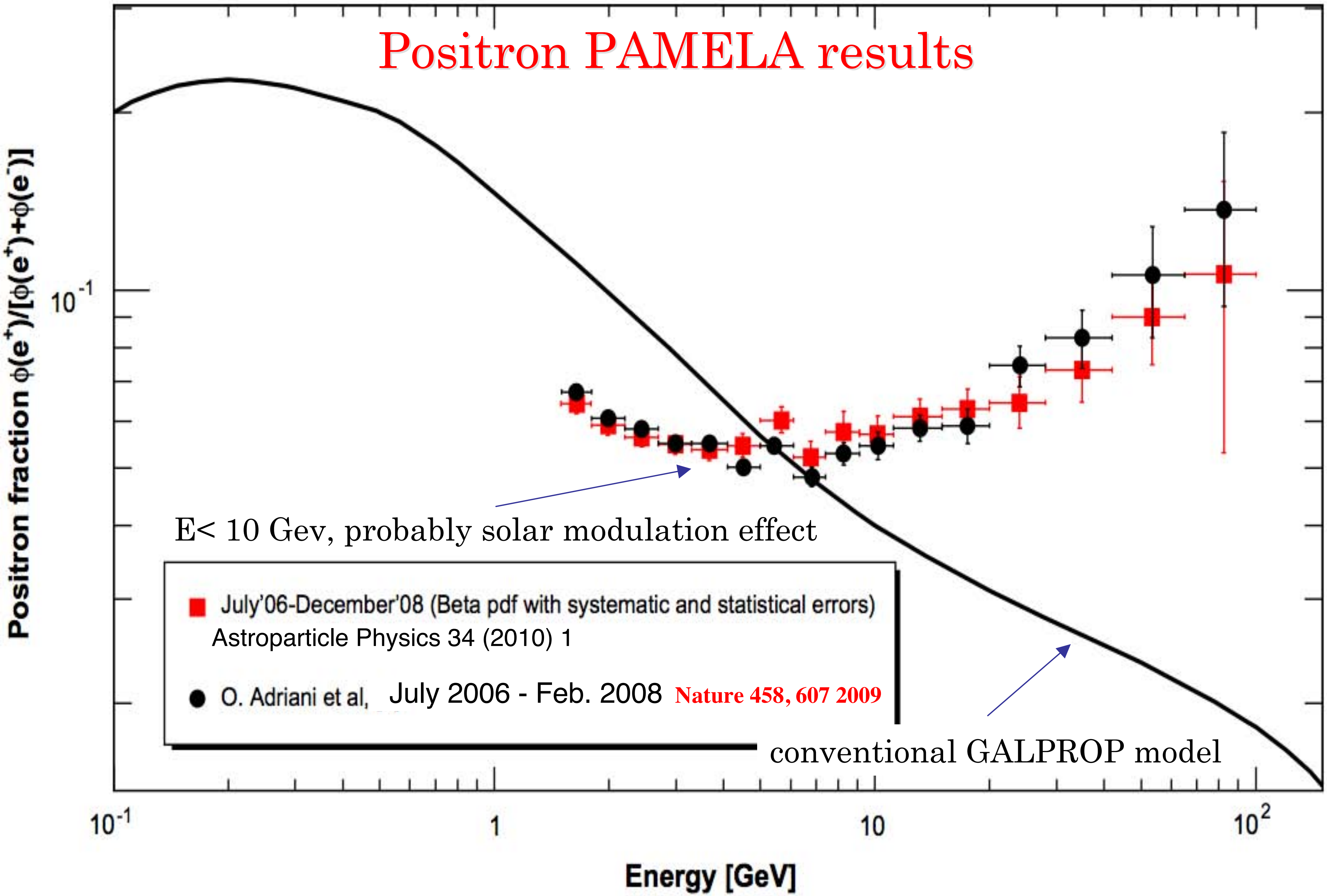
larger values of tg(B) gives larger signals both in antiprotons and gammas

2009: Positron PAMELA results

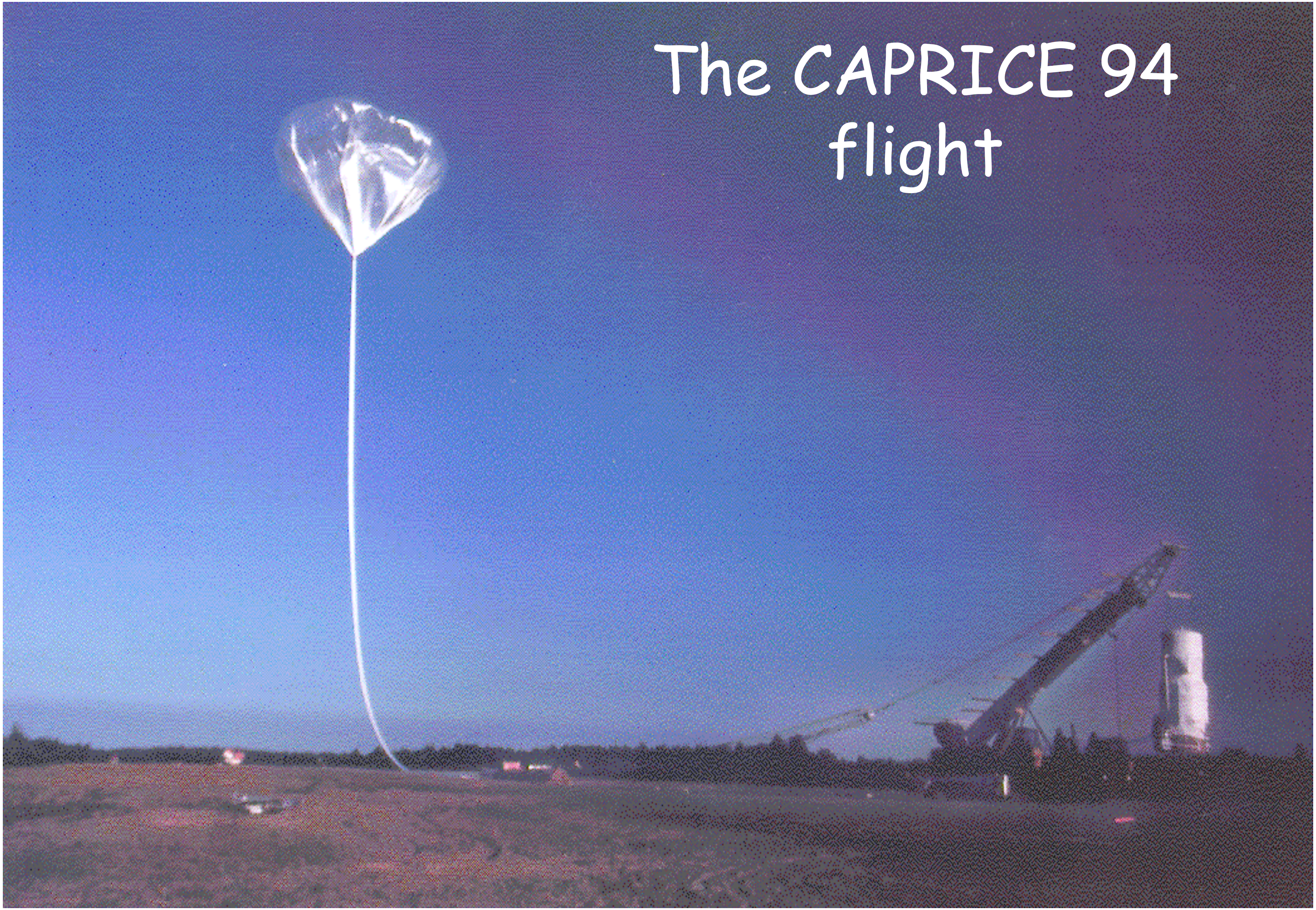


$e^+/(e^+ + e^-) \propto E^{-\gamma_p + \gamma_0 - \delta}$ γ_p: proton source power-index

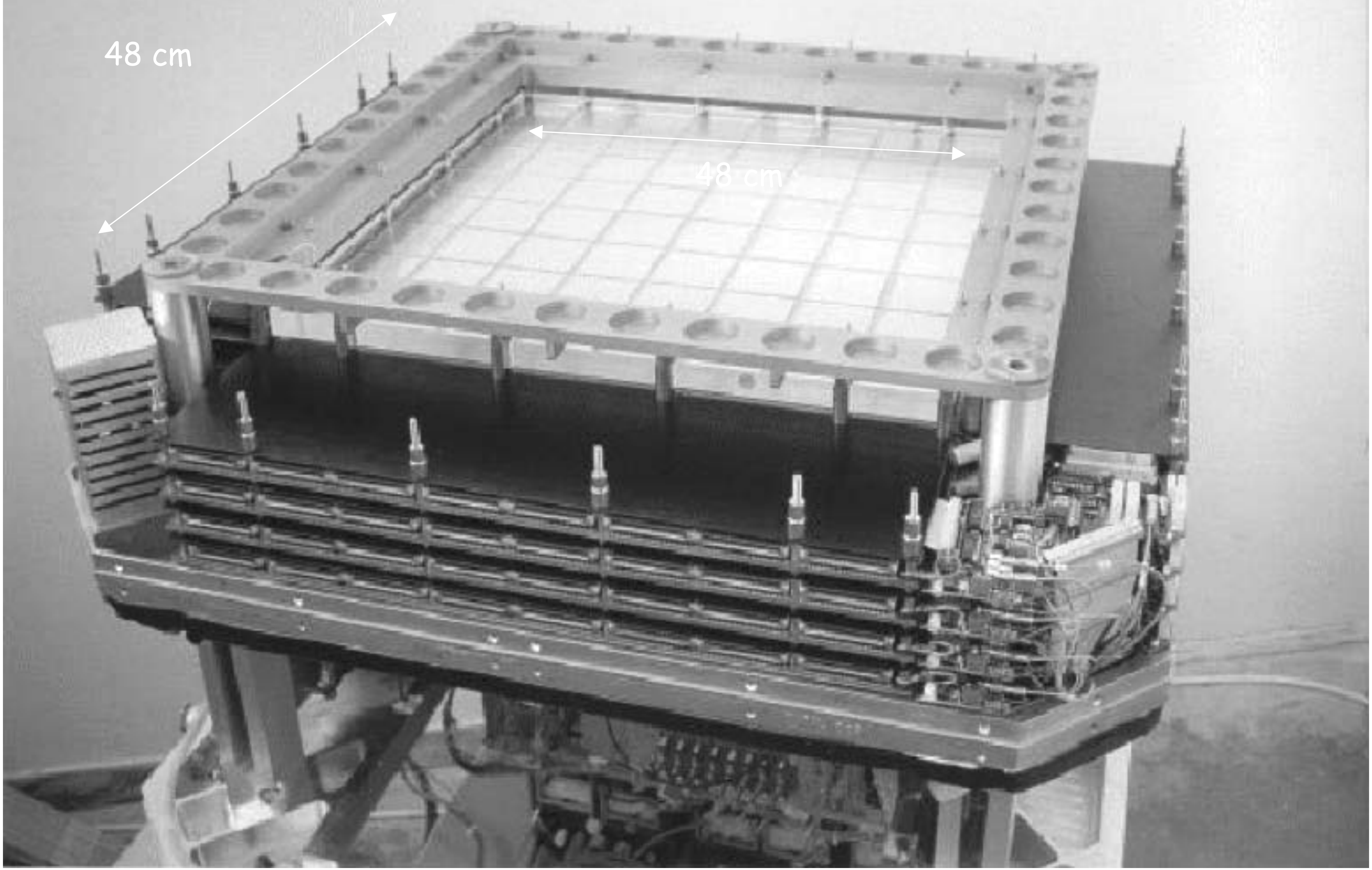
It improves only adopting very soft electron spectra (high γ_0)



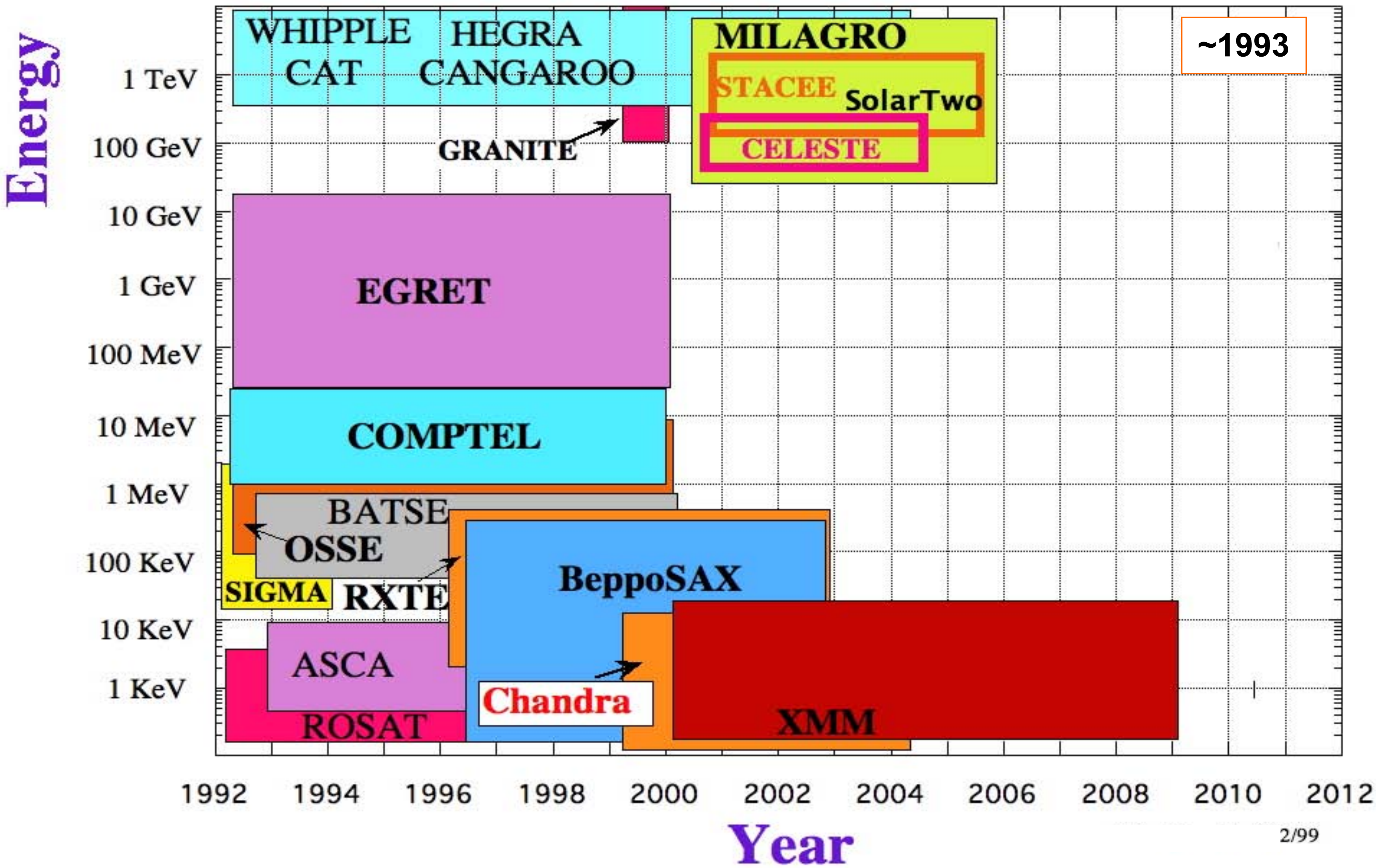
Positron PAMELA results
Positron fraction φ(e+)/[φ(e+)+φ(e-)]
10^-1
E< 10 Gev, probably solar modulation effect
July'06-December'08 (Beta pdf with systematic and statistical errors)
Astroparticle Physics 34 (2010) 1
O. Adriani et al, July 2006 - Feb. 2008 Nature 458, 607 2009
conventional GALPROP model
10^-1
1
10
10^2
Energy [GeV]


The CAPRICE 94
flight

The TS93 and CAPRICE silicon-tungsten imaging calorimeter.



High Energy Gamma Experiments Experiments



Nuclear Instruments and Methods in Physics Research A 354 (1995) 547–552

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

ELSEVIER

The GILDA mission: a new technique for a gamma-ray telescope in the energy range 20 MeV–100 GeV

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[b] *Dept. of Physics, II Univ. of Rome "Tor Vergata" and INFN, Italy*
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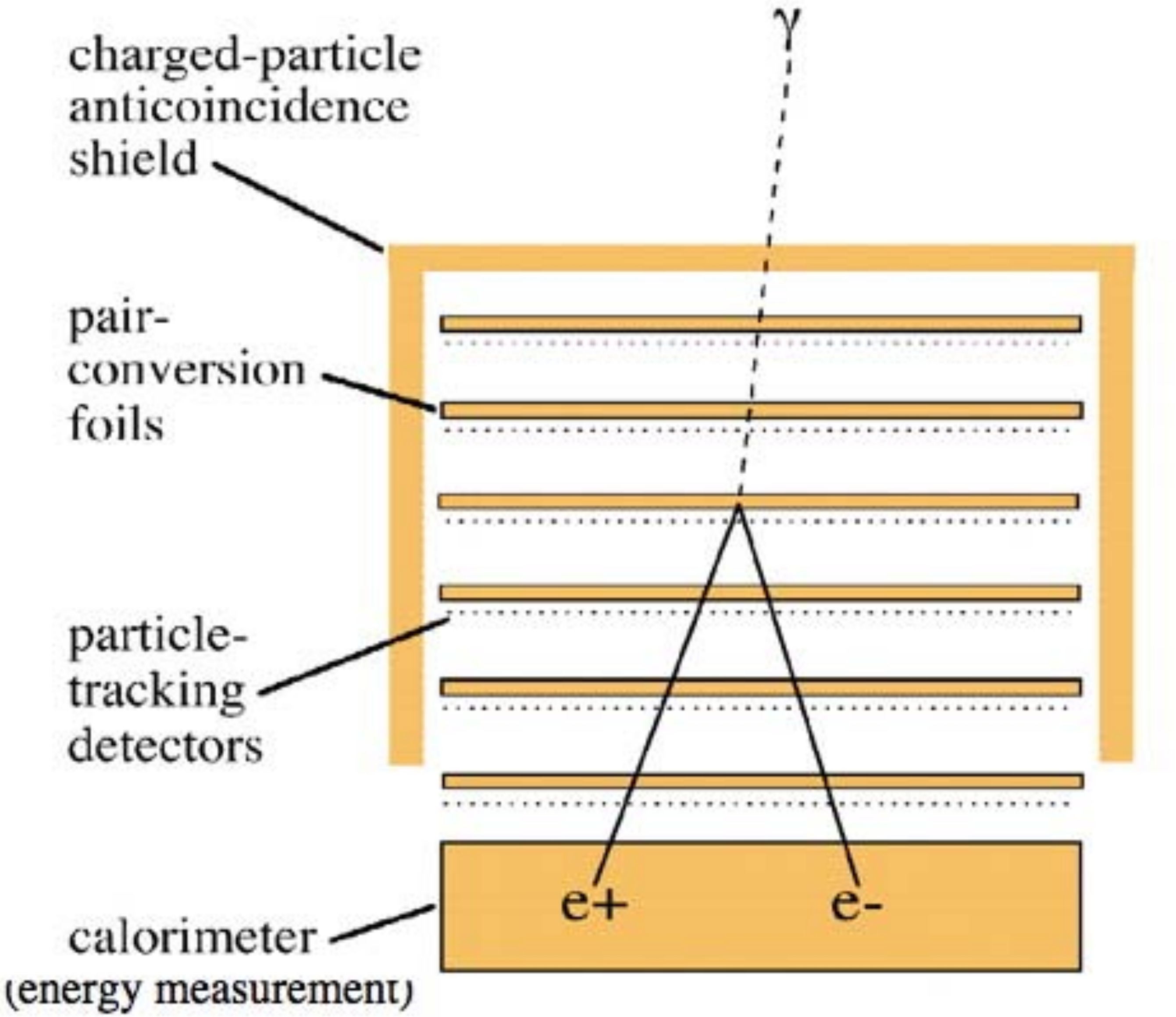
[d] *INFN Laboratori Nazionali di Frascati, Italy*
* Corresponding author

Received 5 August 1994

Abstract

In this article a new technique for the realization of a high energy gamma-ray telescope is presented, based on the adoption of silicon strip detectors and lead scintillating fibers. The simulated performances of such an instrument (GILDA) are significatively better than those of EGRET, the last successful experiment of a high energy gamma-ray telescope, launched on the CGRO satellite, though having less volume and weight.

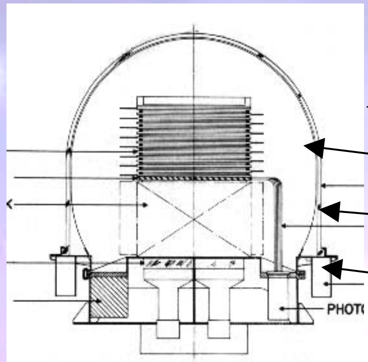
Elements of a pair-conversion telescope



- photons materialize into matter-antimatter pairs:

  E_γ --> $m_{e^+}c^2 + m_{e^-}c^2$

- electron and positron carry information about the direction, energy and polarization of the γ-ray



SAS-2
11/1972-7/1973

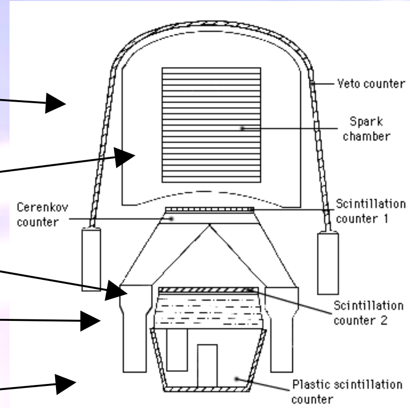
Anti-Coincidence Dome

Spark Chamber

Trigger Telescope

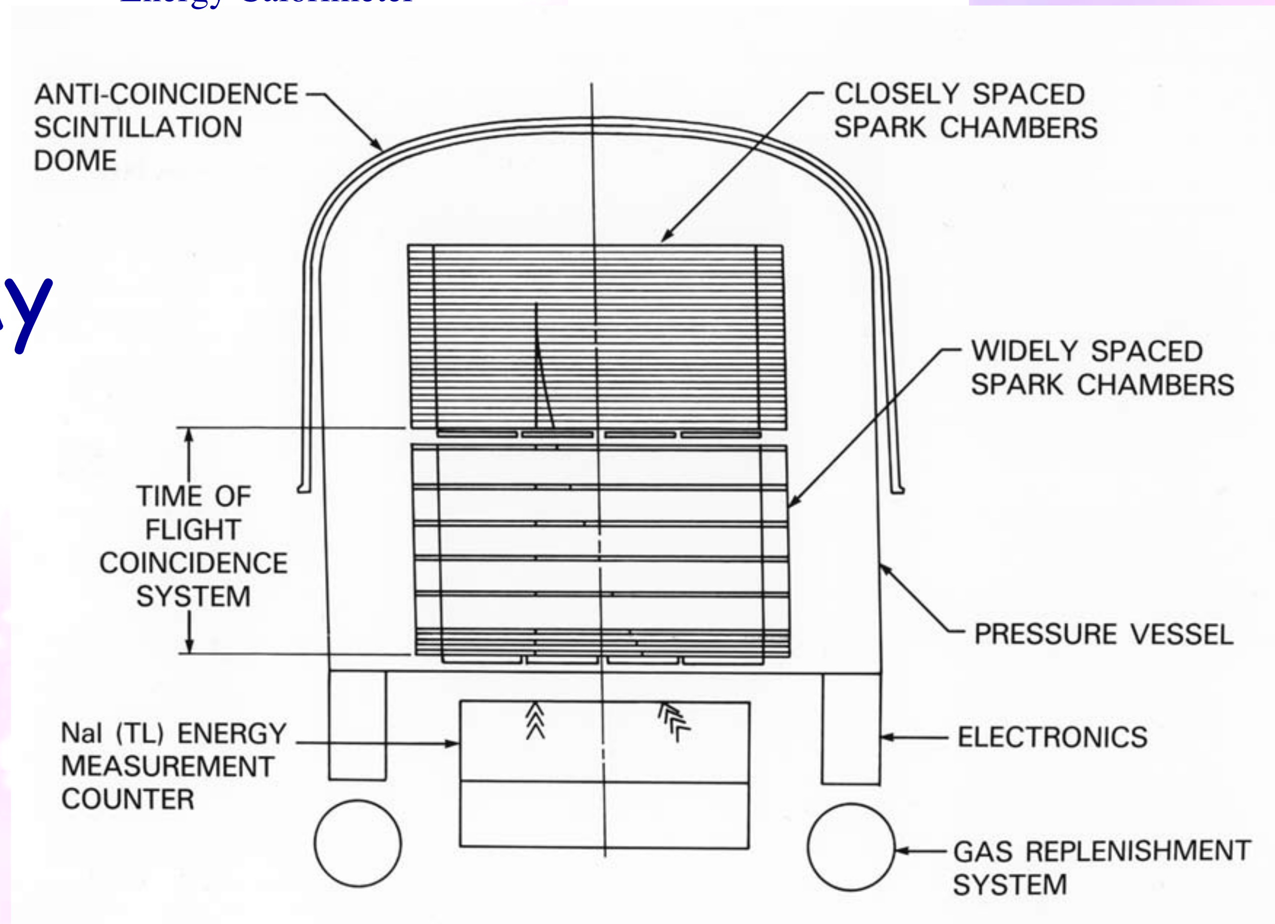
Cerenkov Counter

Energy Calorimeter

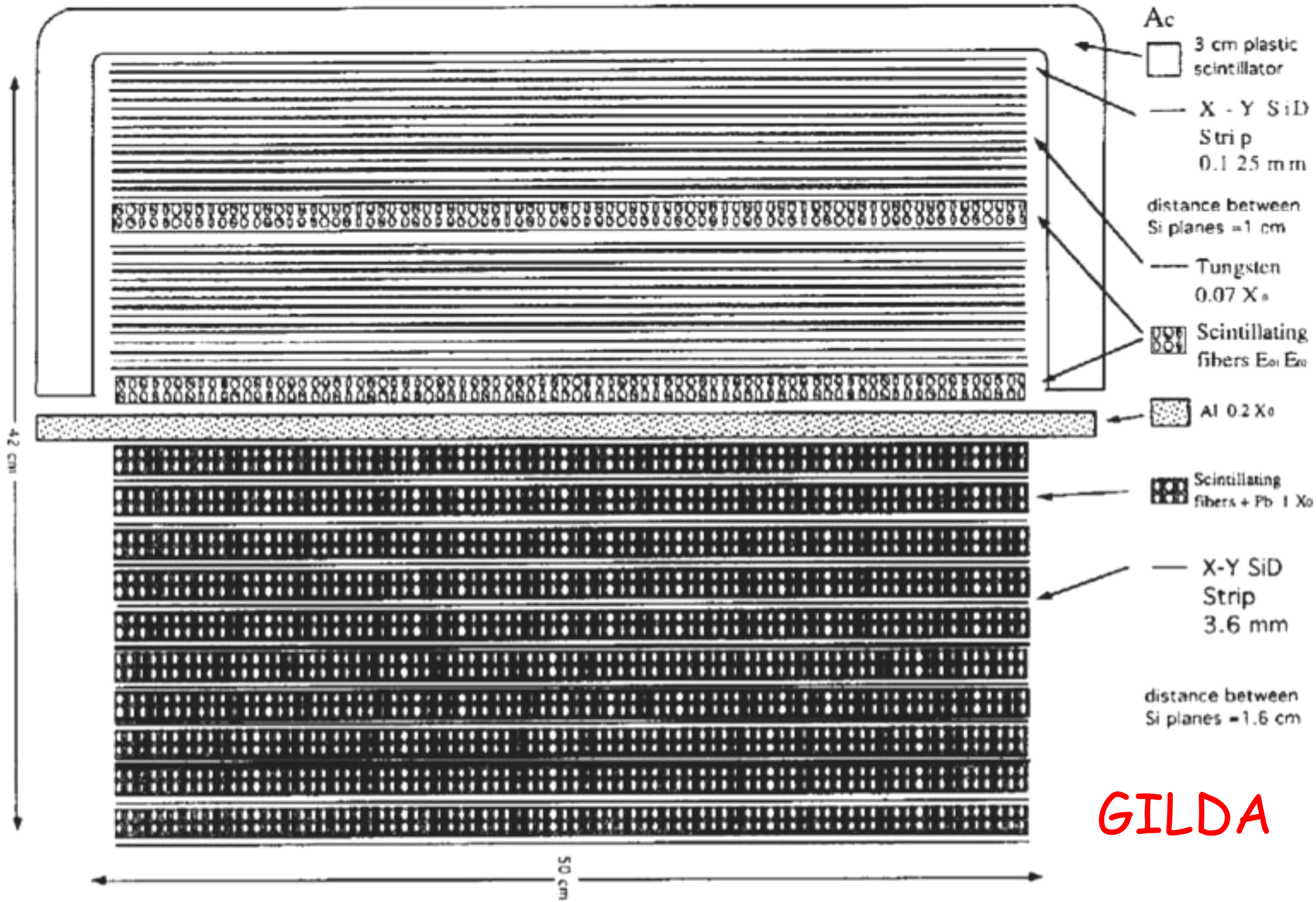


Cos-B
8/1975-4/1982

The gamma-ray missions



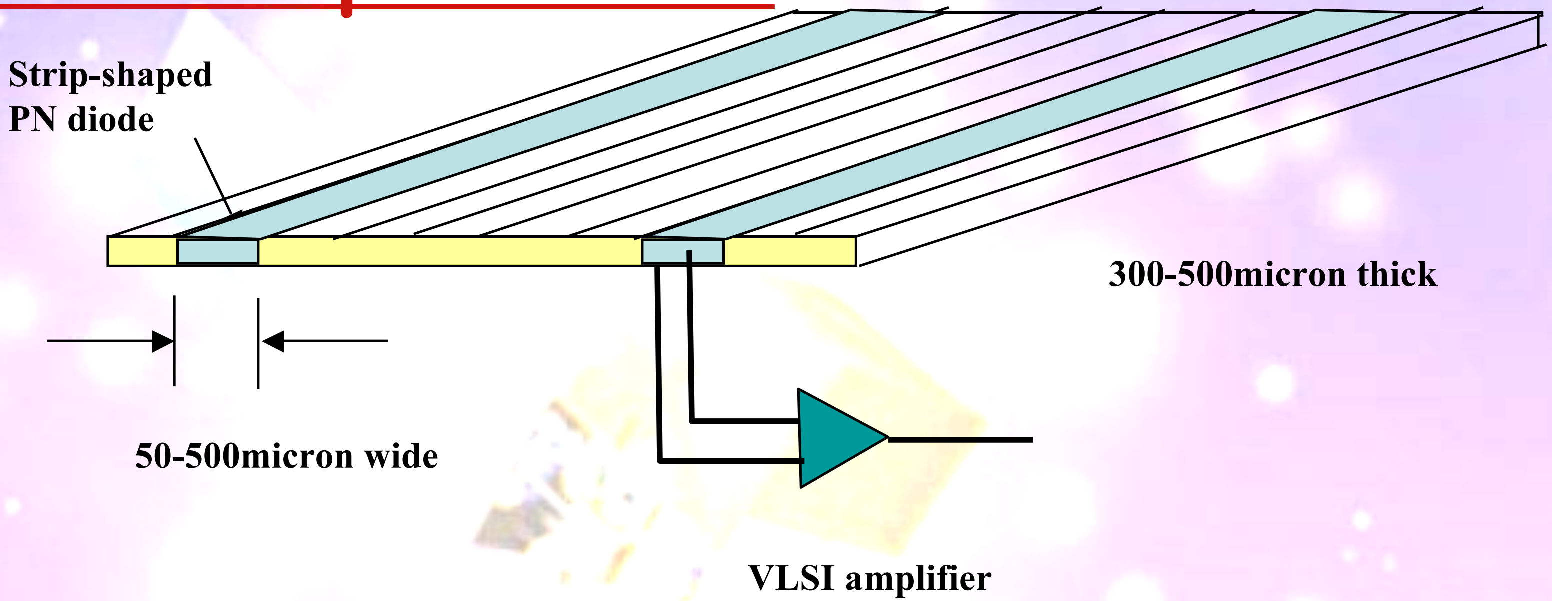
EGRET
4/1991-1999


Ac
3 cm plastic scintillator
X - Y SiD Strip 0.1 25 mm
distance between Si planes =1 cm
Tungsten 0.07 X
Scintillating fibers
Al 0.2 X0
Scintillating fibers + Pb 1 X0
X-Y SiD Strip 3.6 mm
distance between Si planes =1.6 cm
42 cm
50 cm

GILDA

New Detector Technology

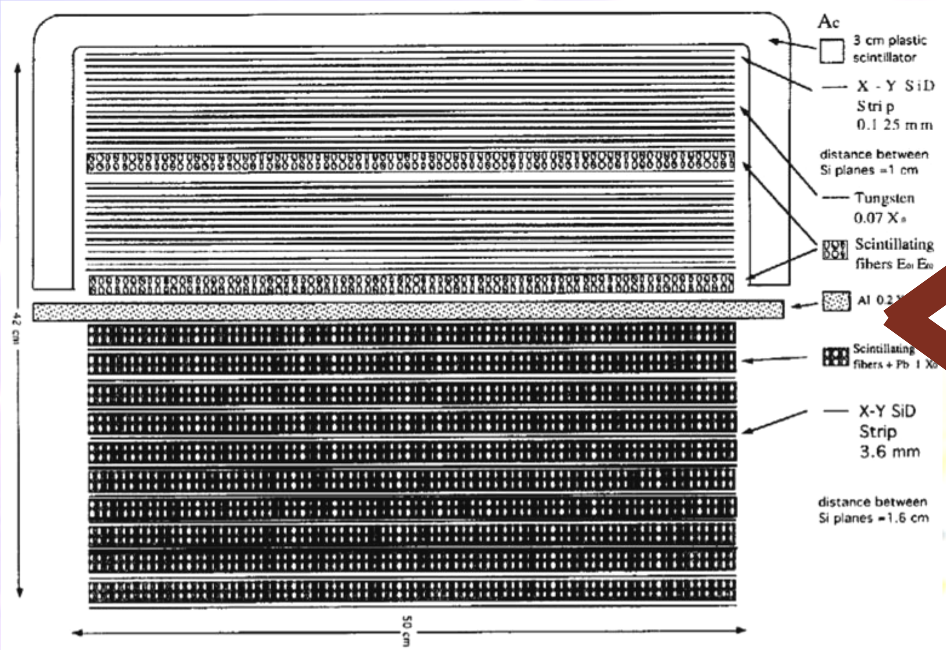
- **Silicon strip detector**



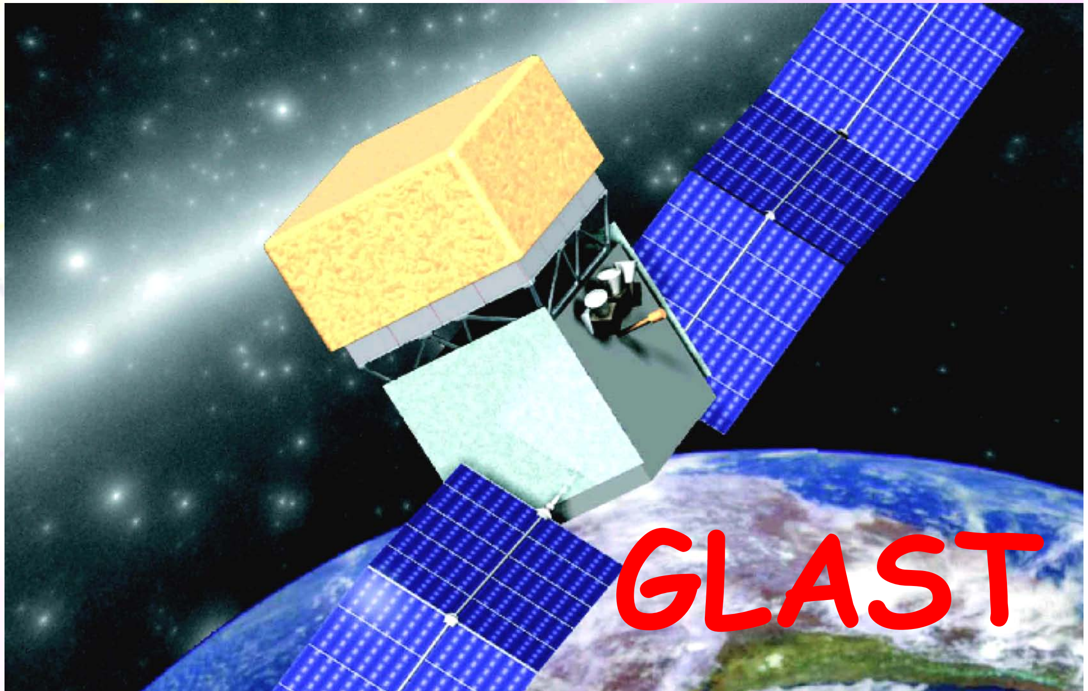
Stable particle tracker that allows micron-level tracking of gamma-rays

Well known technology in Particle Physics experiments.
Used by our collaboration in balloon experiments (MASS, TS93, CAPRICE), on MIR Space Station (SilEye) and on satellite (NINA)

GILDA


Ac
3 cm plastic scintillator
X - Y SiD Strip 0.125 mm
distance between Si planes =1 cm
Tungsten 0.07 X₀
Scintillating fibers
Al
Scintillating fibers + Pb 1 X₀
X-Y SiD Strip 3.6 mm
distance between Si planes =1.6 cm
42 cm
50 cm


agile
Astro-rivelatore Gamma
a Immagini Leggero
INAF
INFN
Alenia
telespazio


GLAST


The LAT at 2 Years
Happy 2nd Birthday, Fermi!

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.

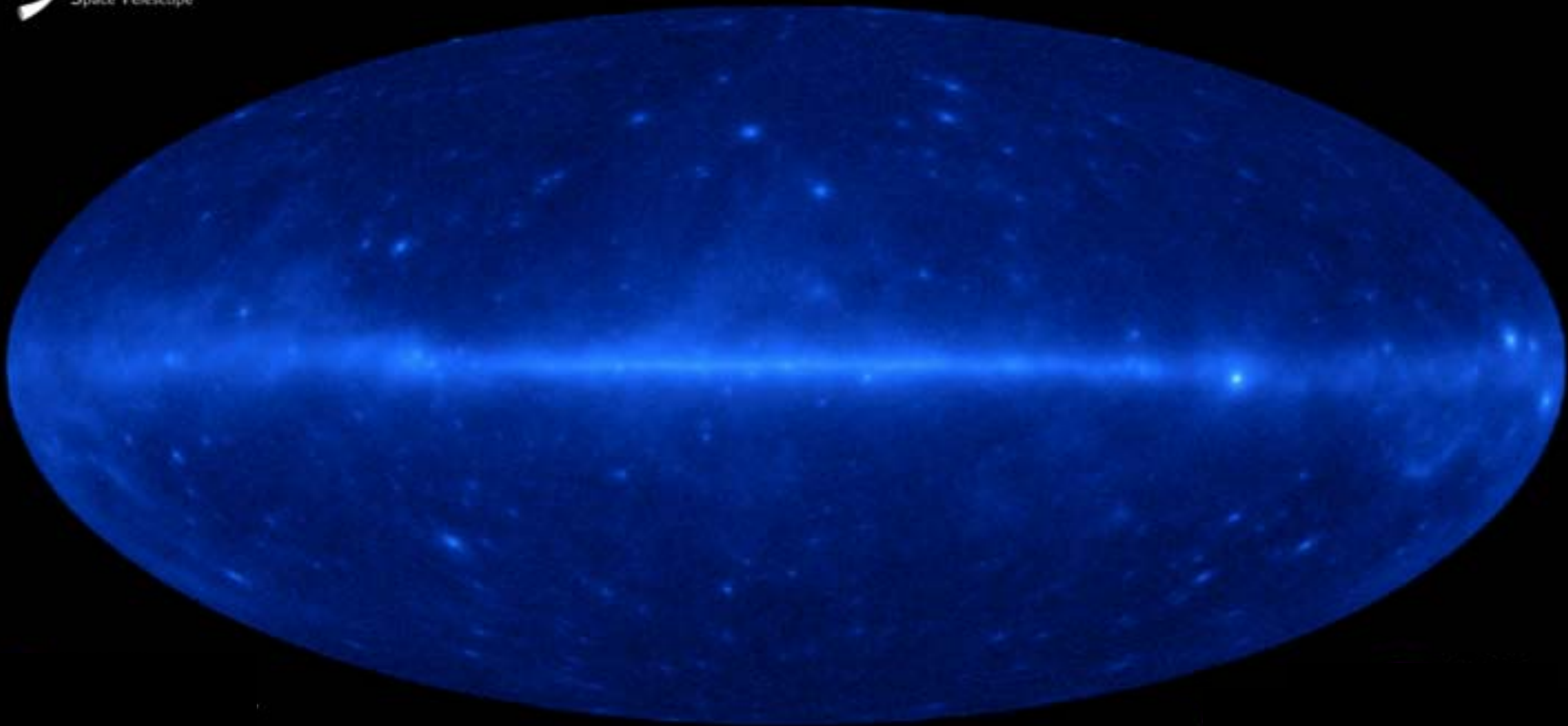
Already, the discoveries are shedding new light on the physics of pulsars. Researchers

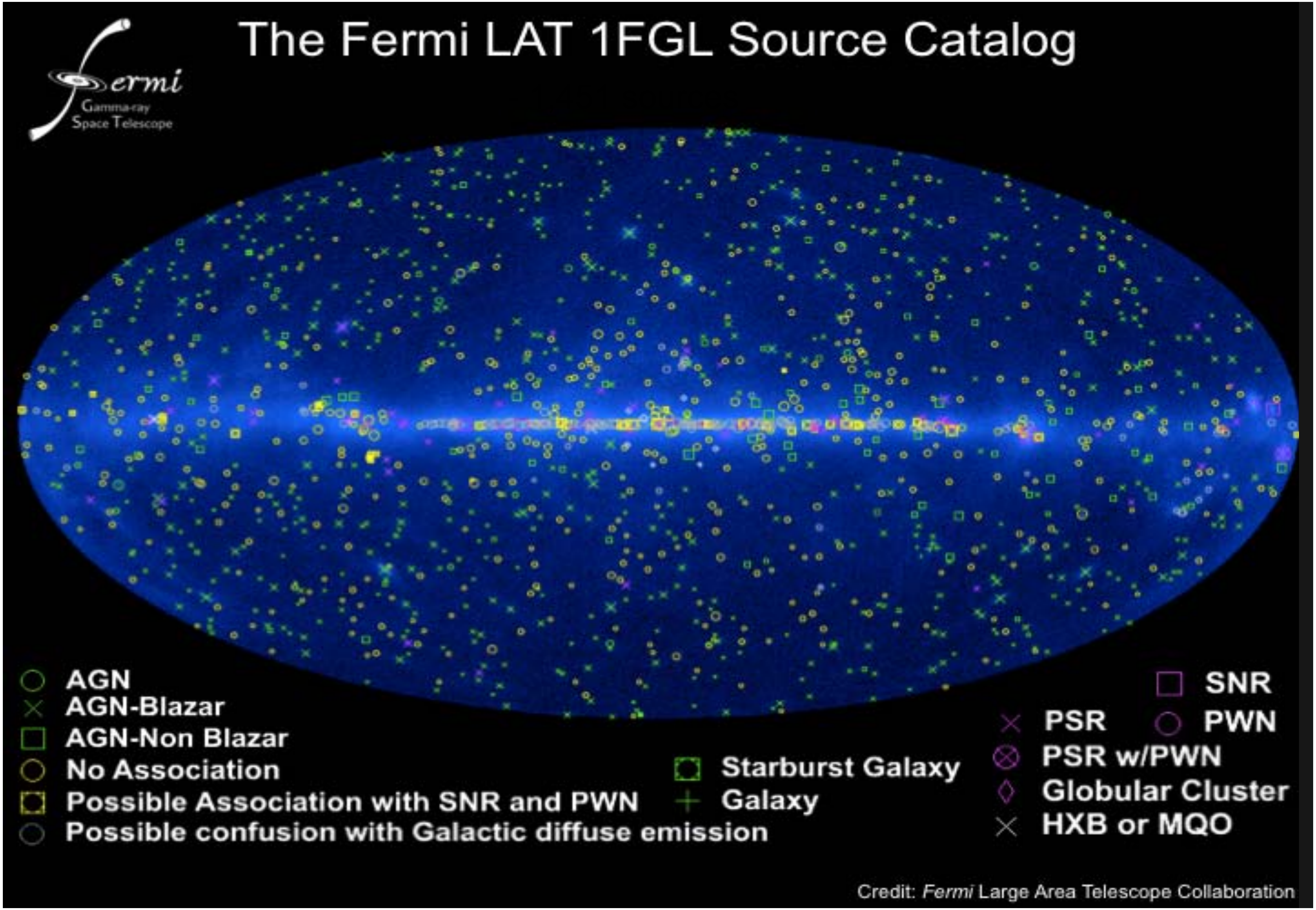
CE

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

The Fermi LAT 1FGL Source Catalog

Fermi
Gamma-ray
Space Telescope

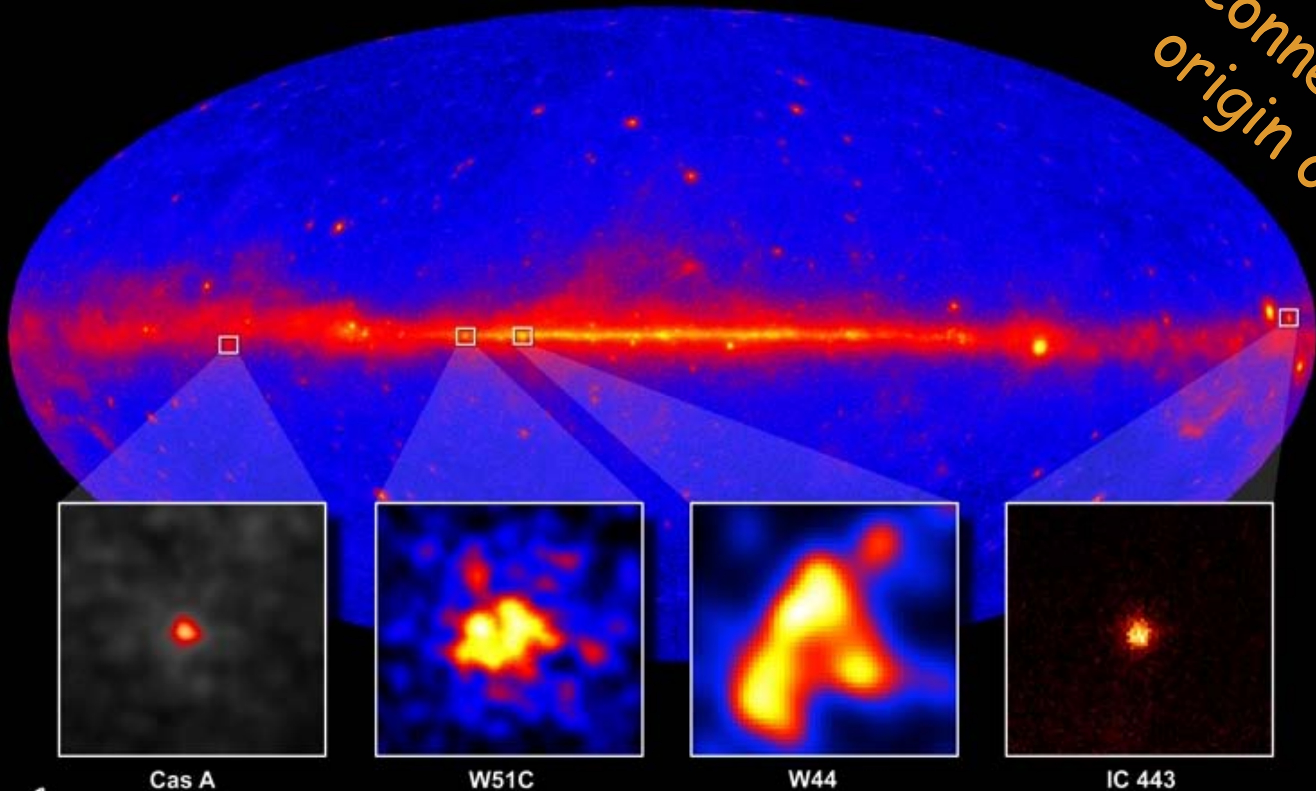


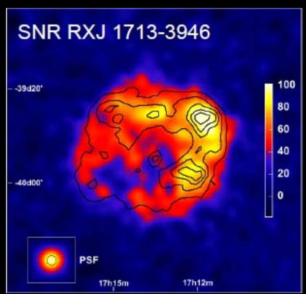


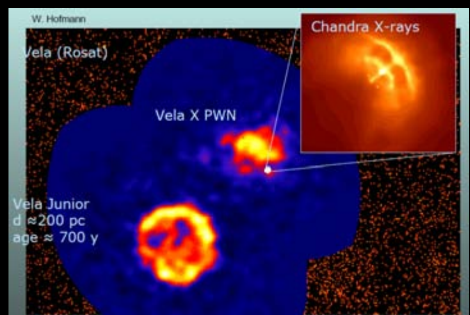
The Fermi LAT 1FGL Source Catalog
Fermi
Gamma-ray
Space Telescope
AGN
AGN-Blazar
AGN-Non Blazar
No Association
Possible Association with SNR and PWN
Possible confusion with Galactic diffuse emission
Starburst Galaxy
Galaxy
SNR
PSR
PWN
PSR w/PWN
Globular Cluster
HXB or MQO
Credit: Fermi Large Area Telescope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

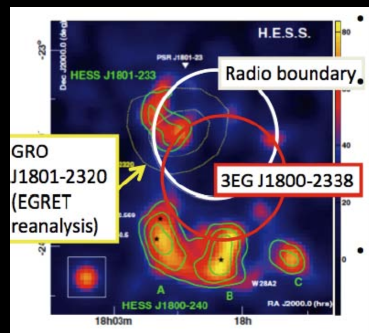
Galactic Super Nova Remnants : Fermi observations

connection to the origin of Cosmic Rays





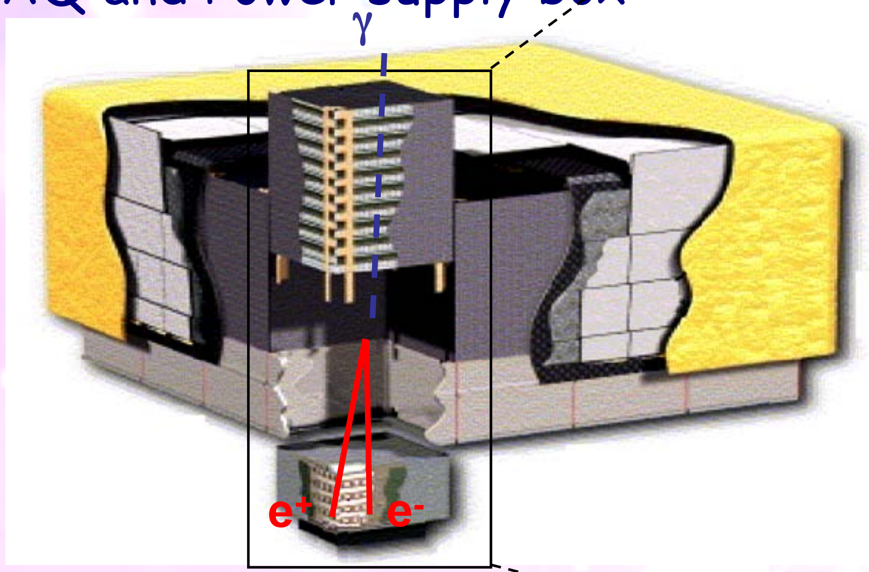


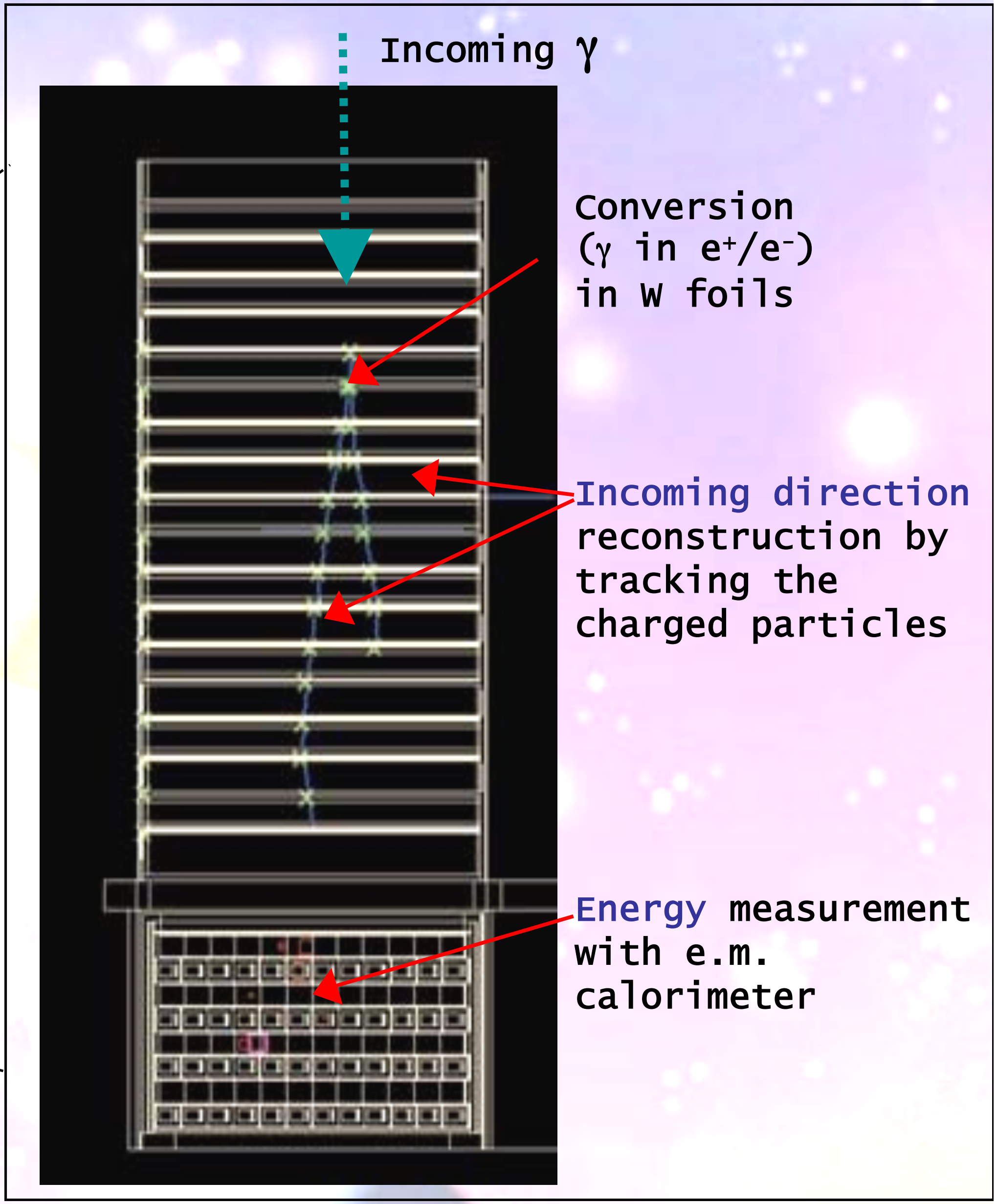


How Fermi LAT detects gamma rays

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

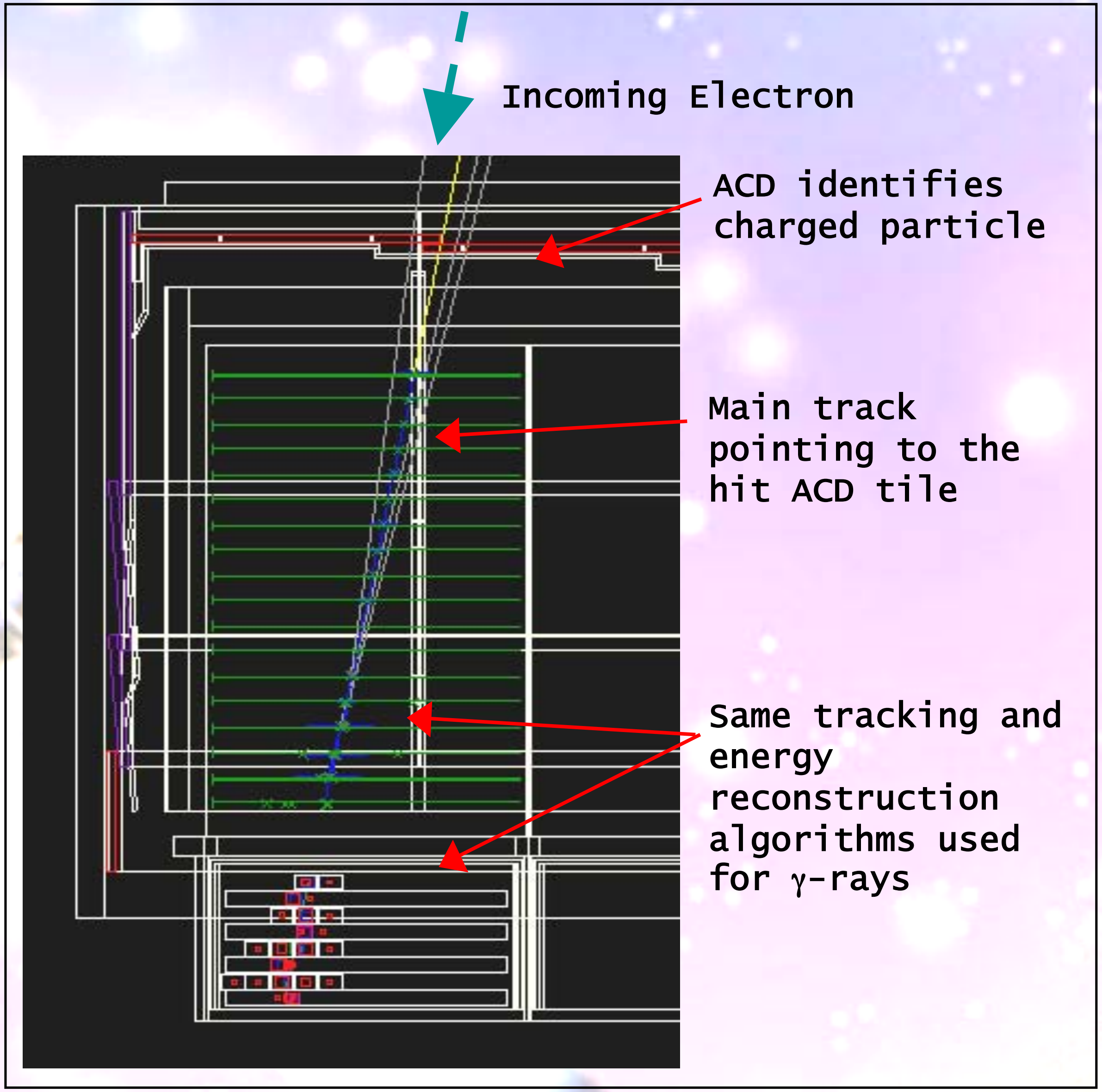
How Fermi LAT detects electrons

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

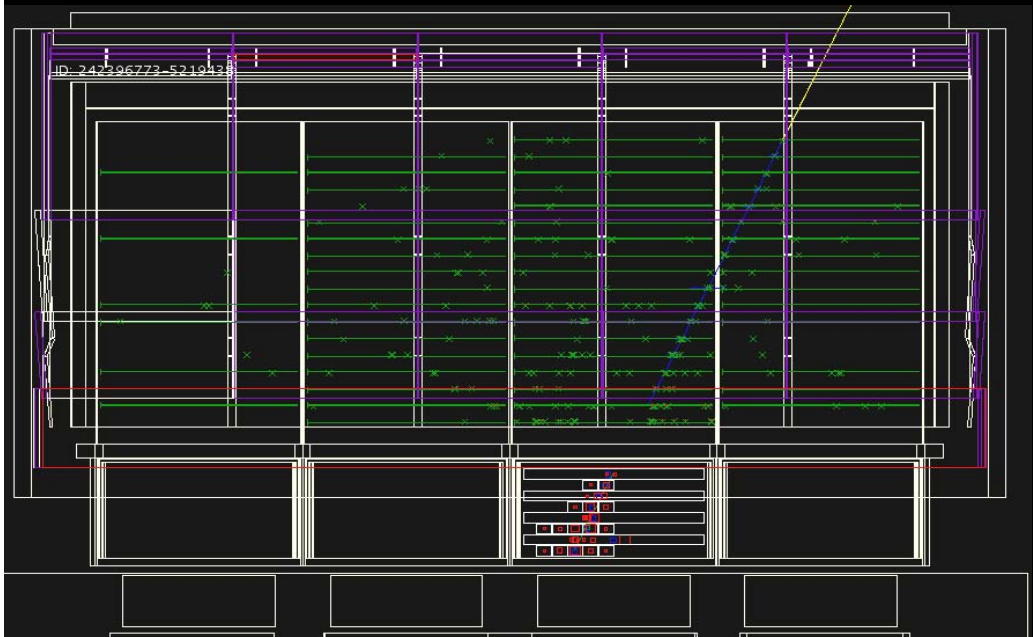
Electron identification

- 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

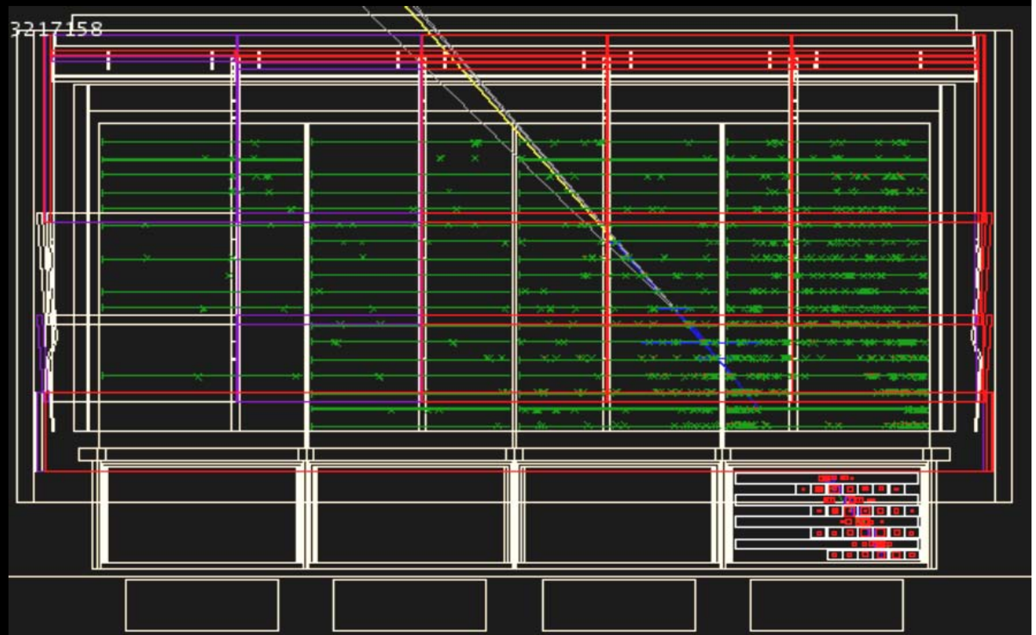


Event topology

A candidate electron
(recon energy 844 GeV)



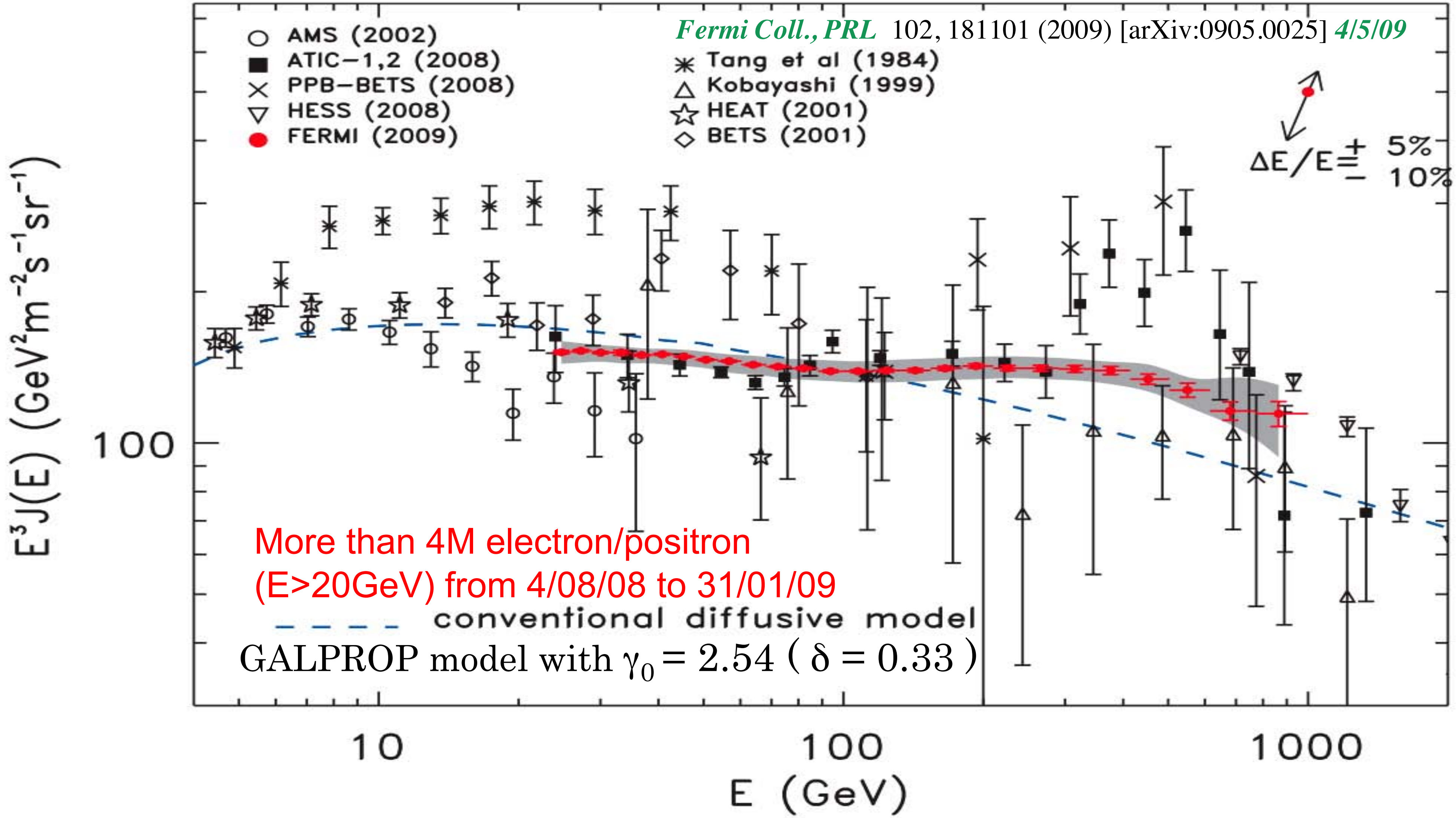
A candidate hadron
(raw energy > 800 GeV)



- 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

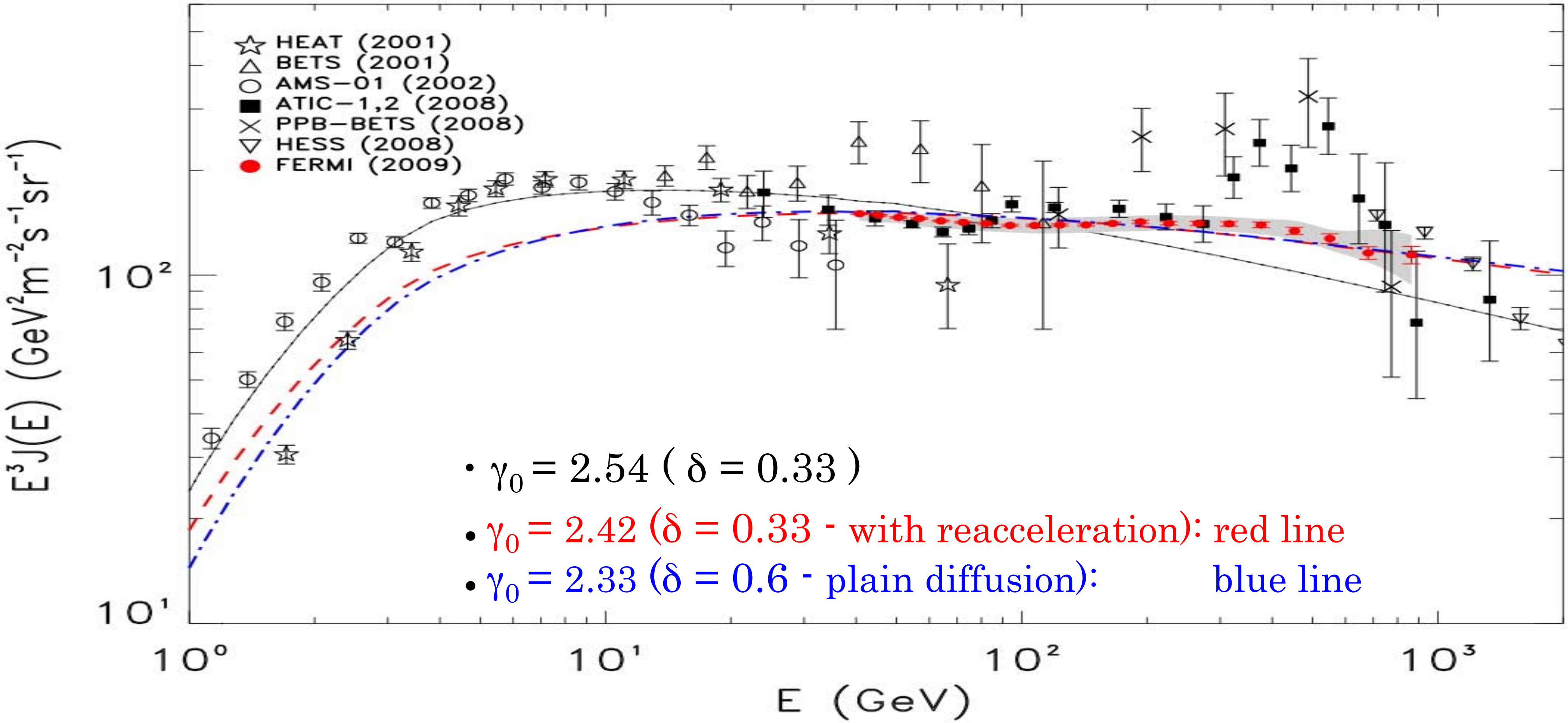
Fermi-LAT CRE data vs the conventional *pre-Fermi* model



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

Some changes are still needed with respect to the *pre-Fermi conventional mode*

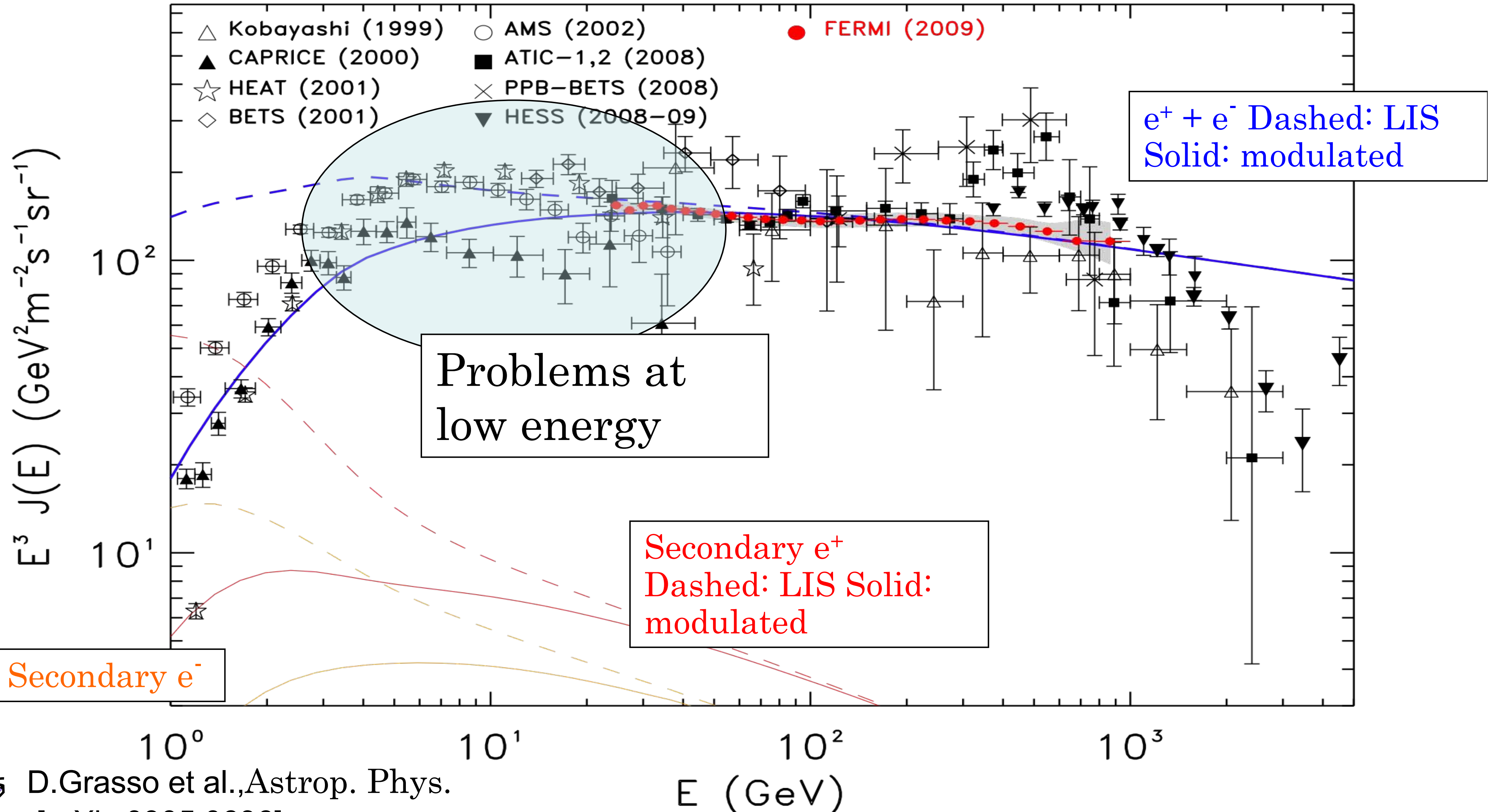
Cosmic Ray Electron propagation models



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

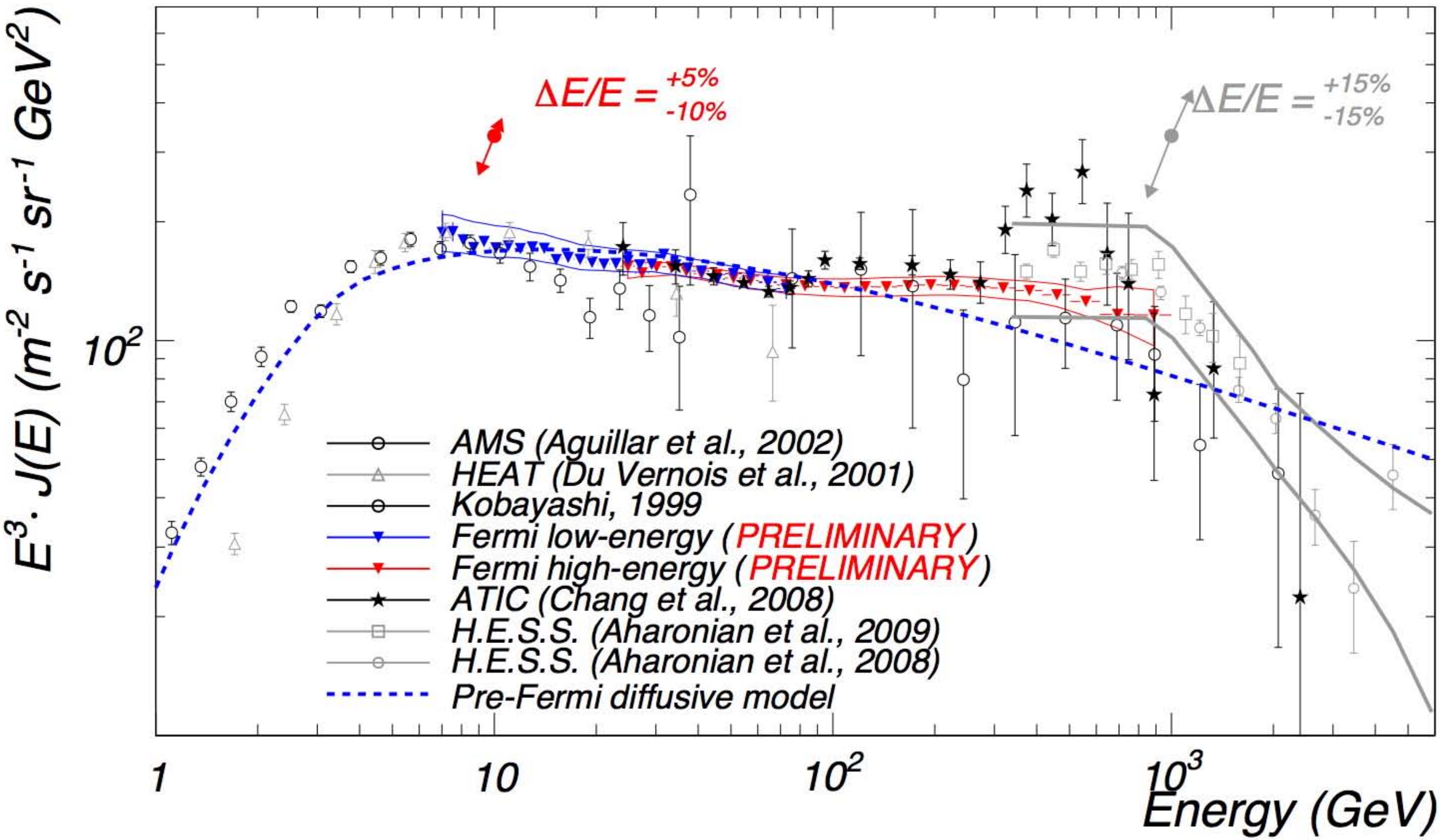
Models 0 and 1 account for CR re-acceleration in the ISM, while 2 is a plain-diffusion model. All models assume γ_0 = 1.6 below 4 GeV.

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



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

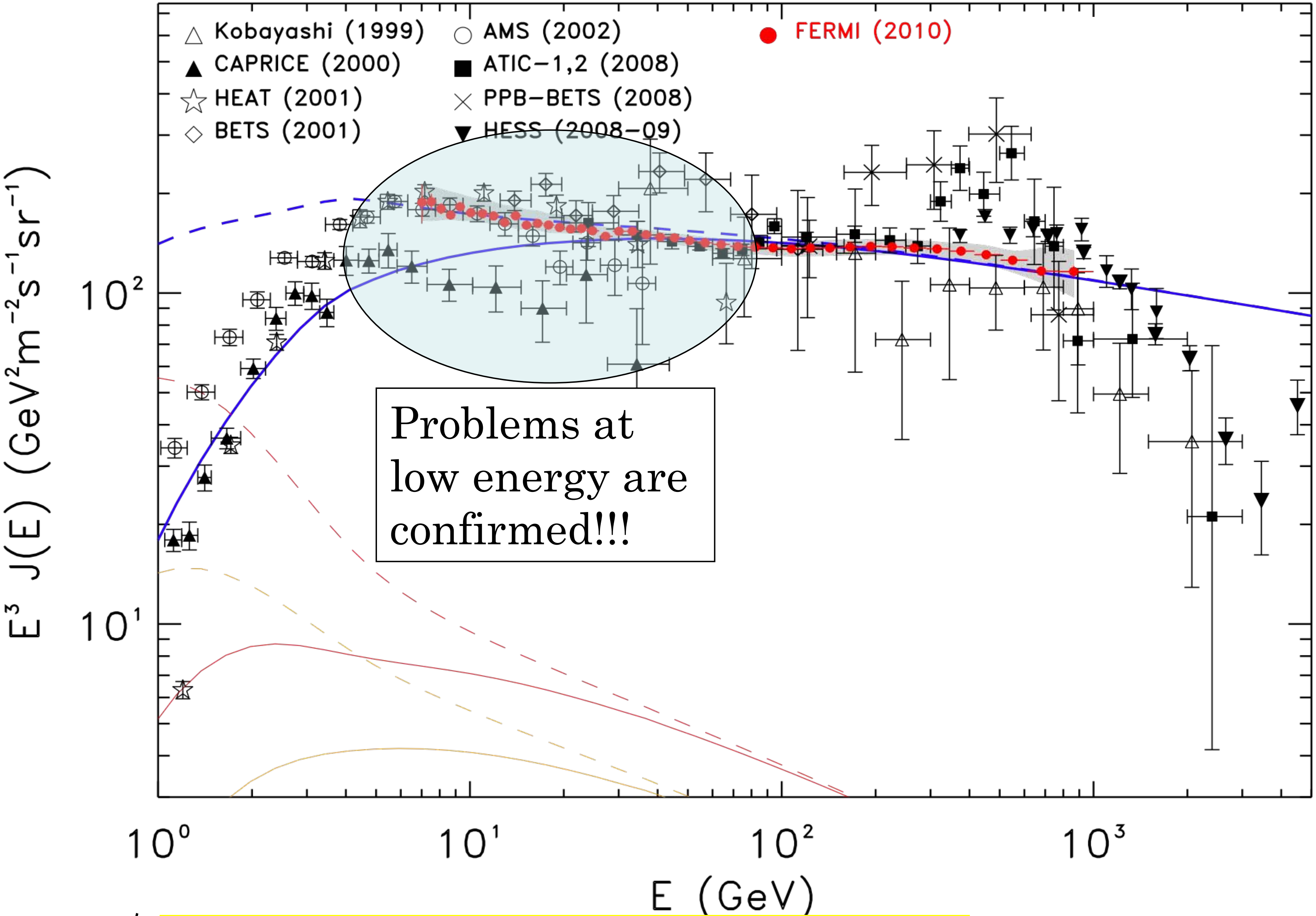
new : Fermi Electron + Positron spectrum



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

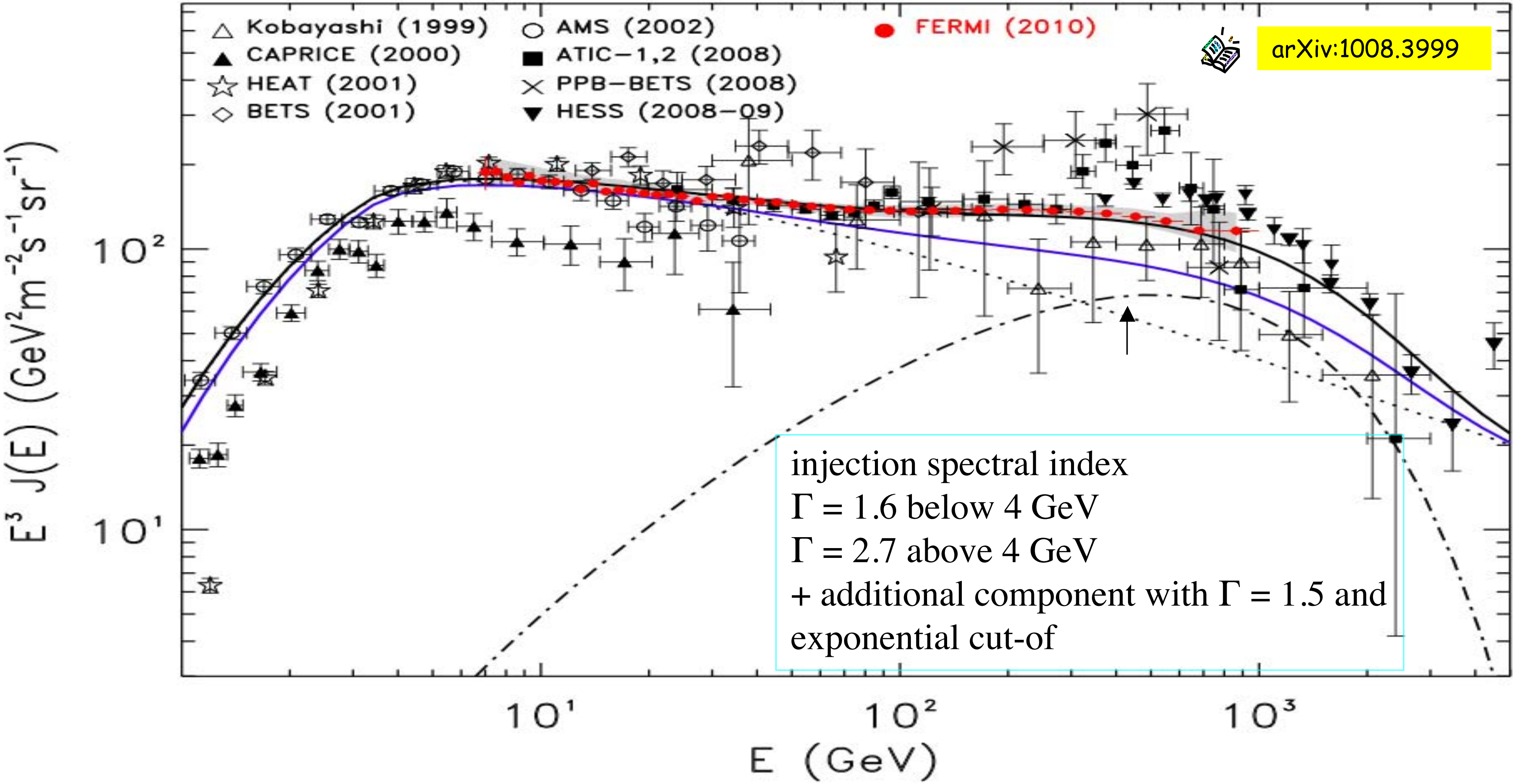
Fermi LAT Coll. Physical Review D, accepted [arXiv:1008.3999]

New Fermi-LAT data at low energy



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

Electron spectrum and a conventional GALPROP model +...

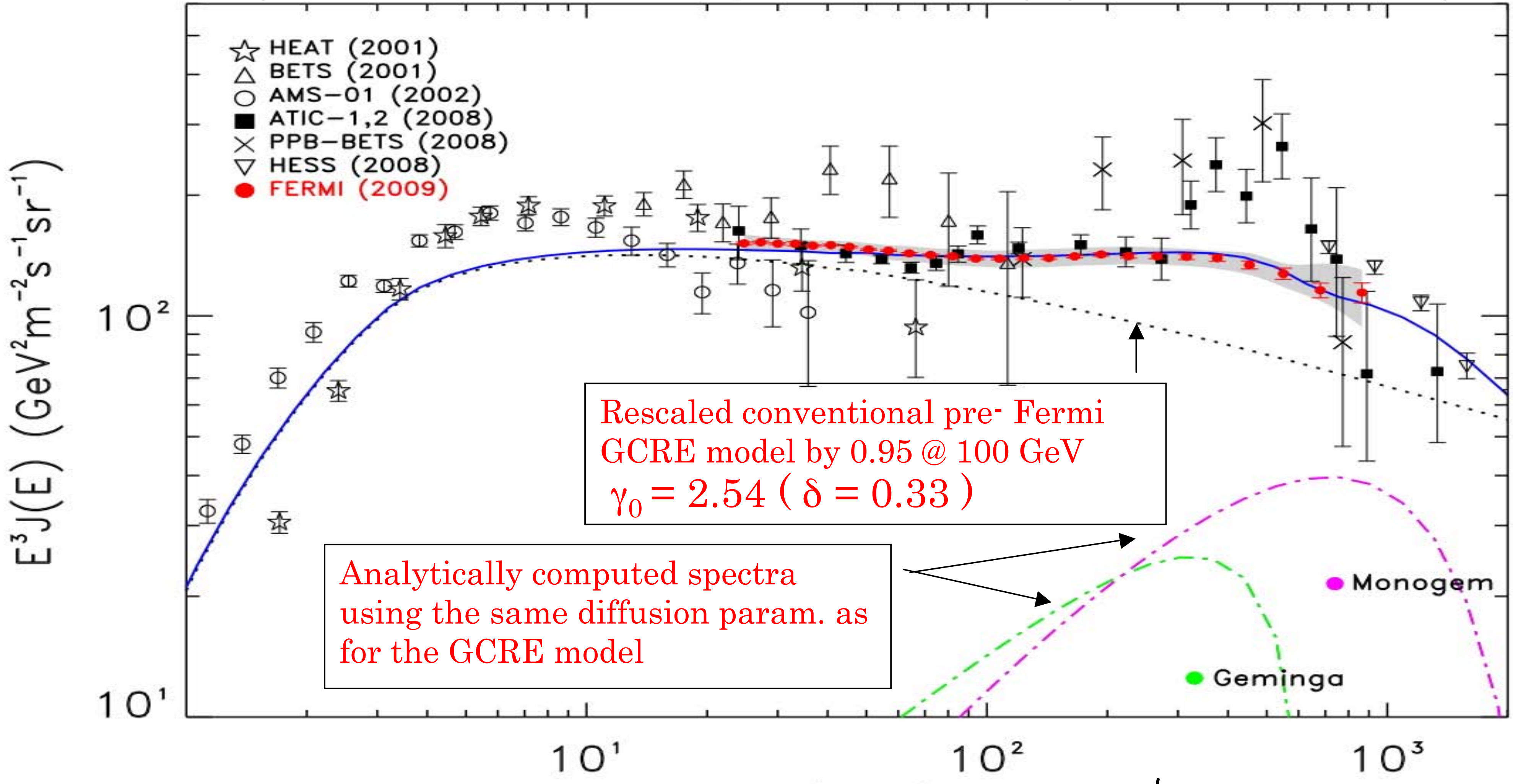


Hard to get a good fit with a single-component diffusive model

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

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

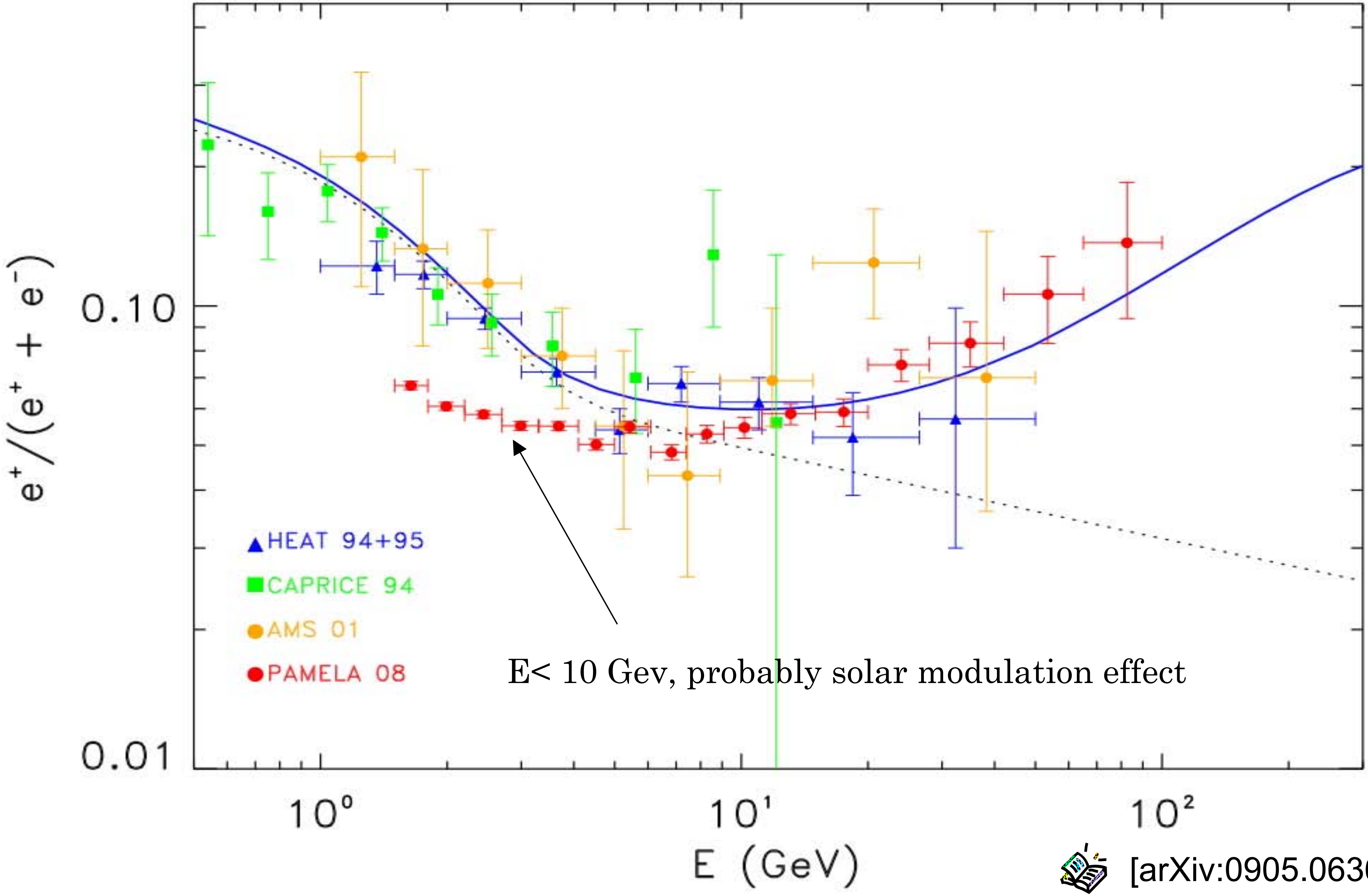


[arXiv:0905.0636]

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)

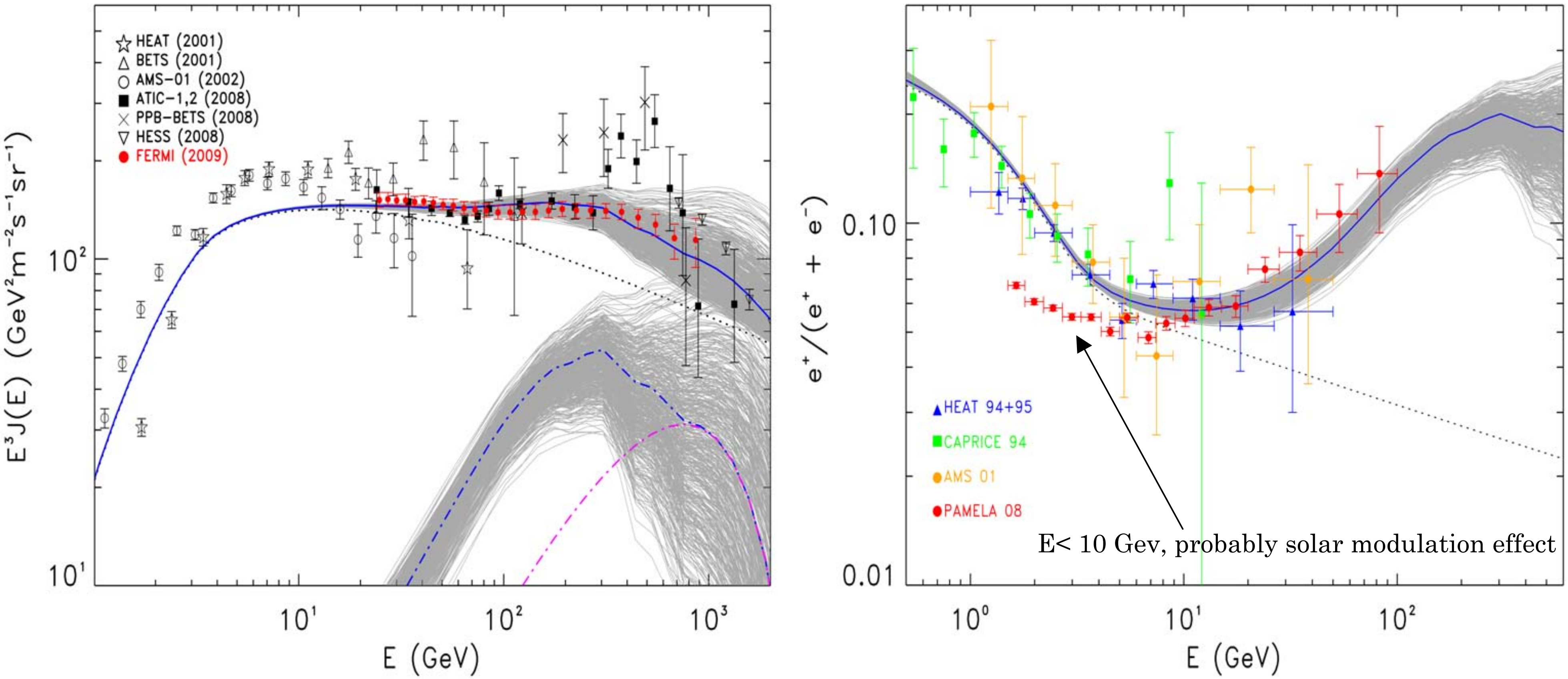
2. On the basis of the spectrum, it is not clear
   1. The spectra of PWN show relatively flat spectra of pairs at Low energies but we do not understand what it is
   2. The general spectra (acceleration at the termination shock) are too steep

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?

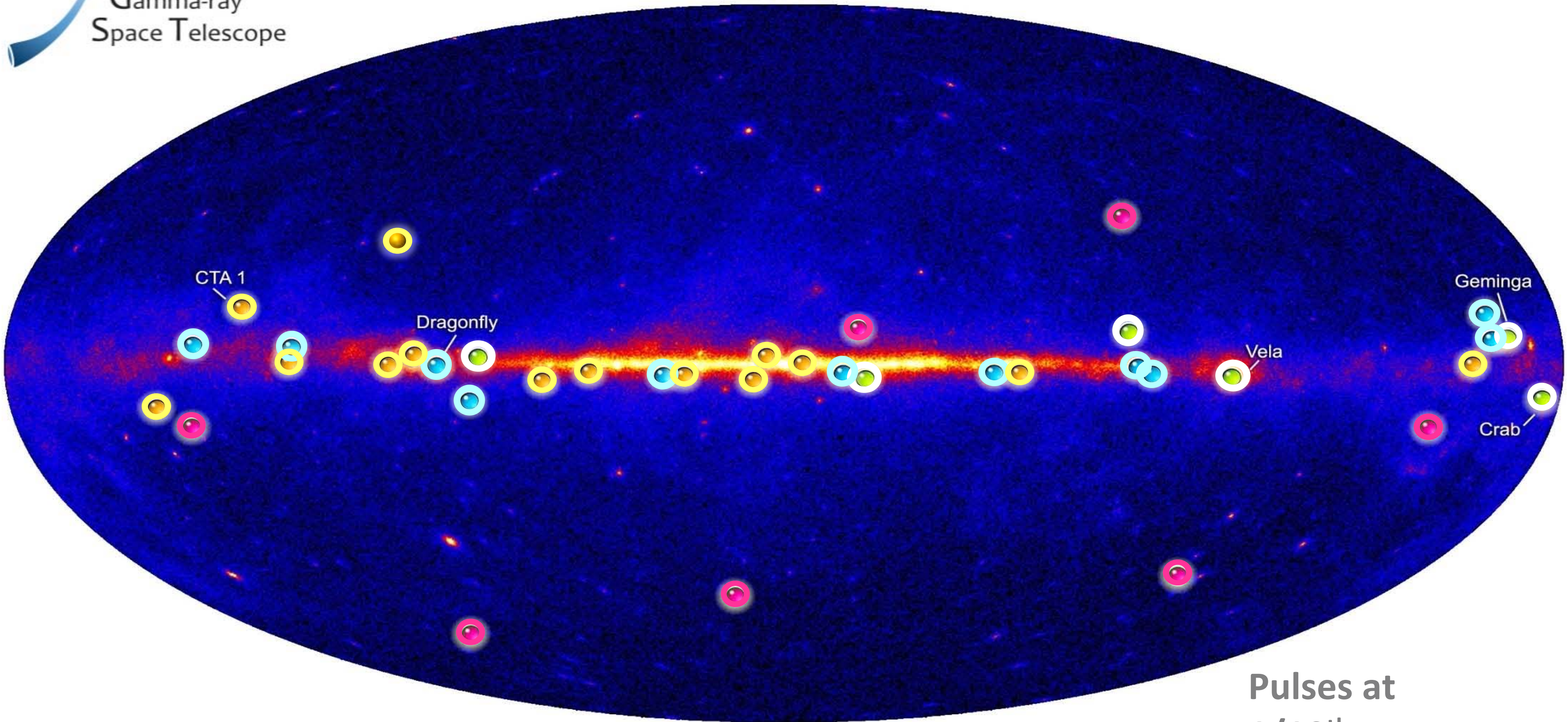
(injection spectrum, e+e- production efficiency, PWN "trapping" time)



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

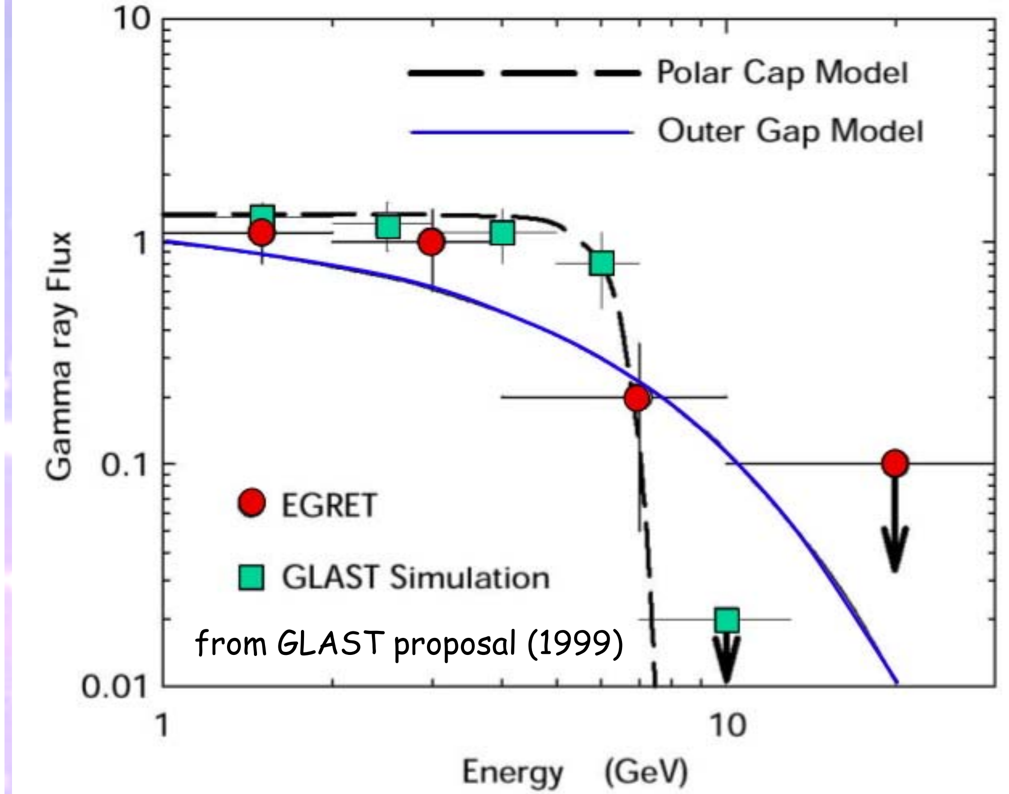


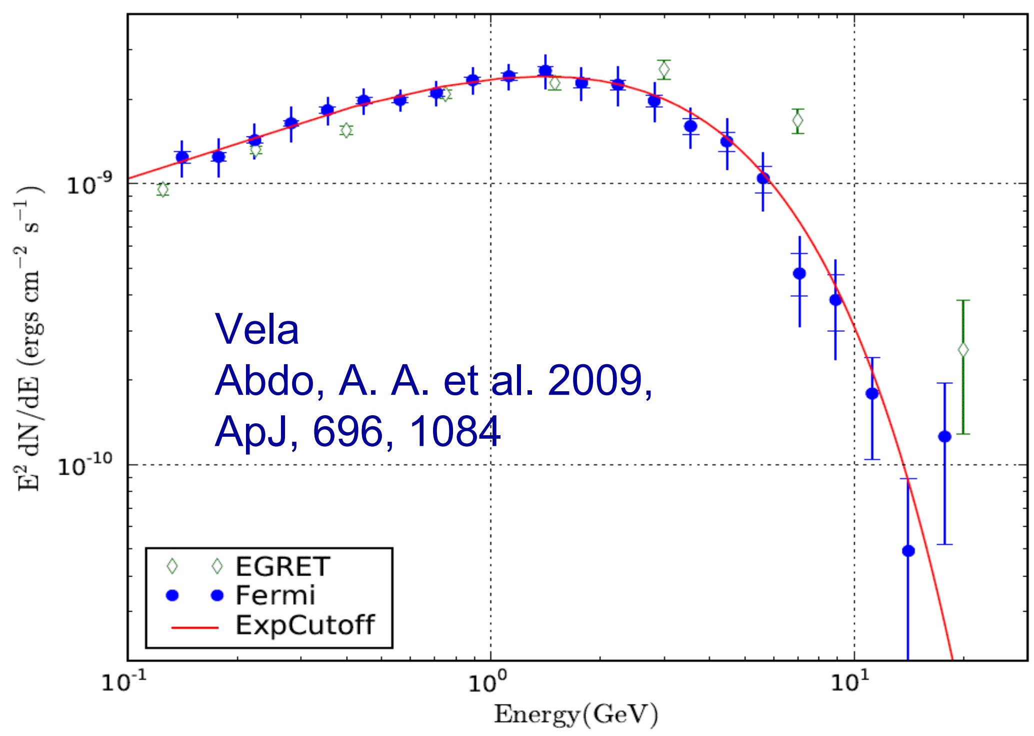
Pulses at 1/10th true rate

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

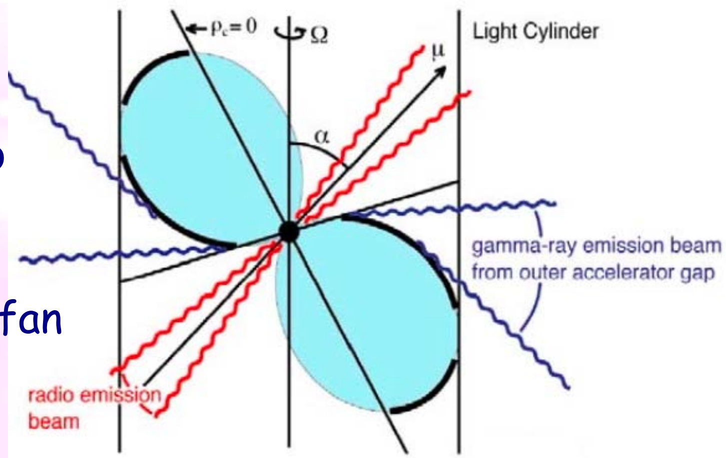
Spectral measurements and emission models



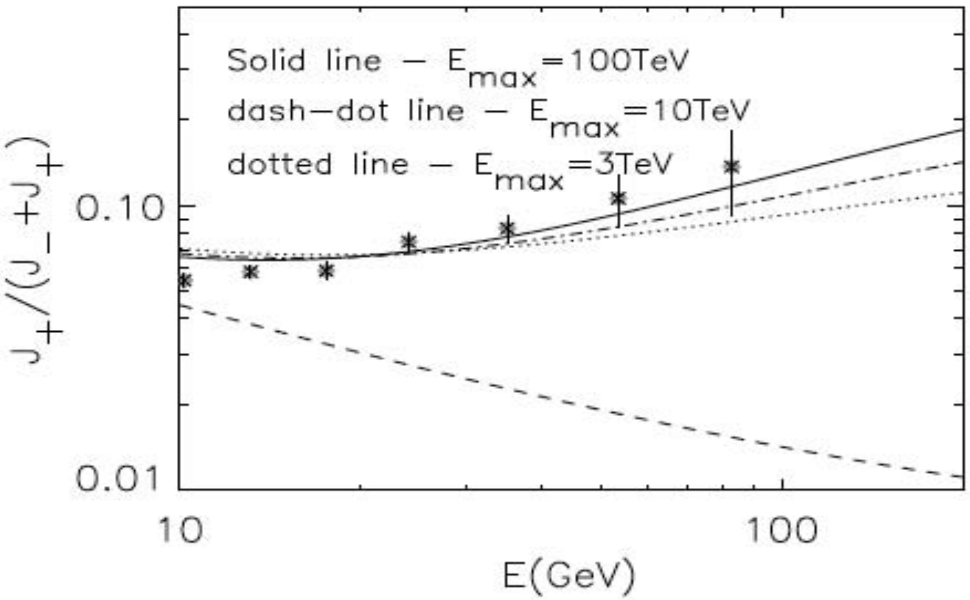


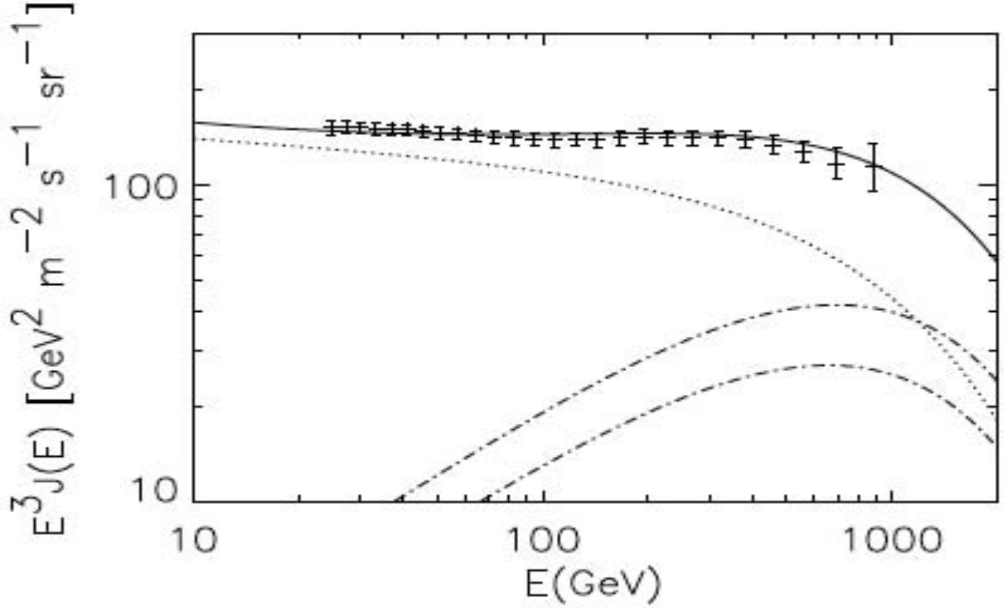
Evidence of γ-ray emission in the outer magnetopshere due to absence of super-exponential cutoff

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



other Astrophysical solution





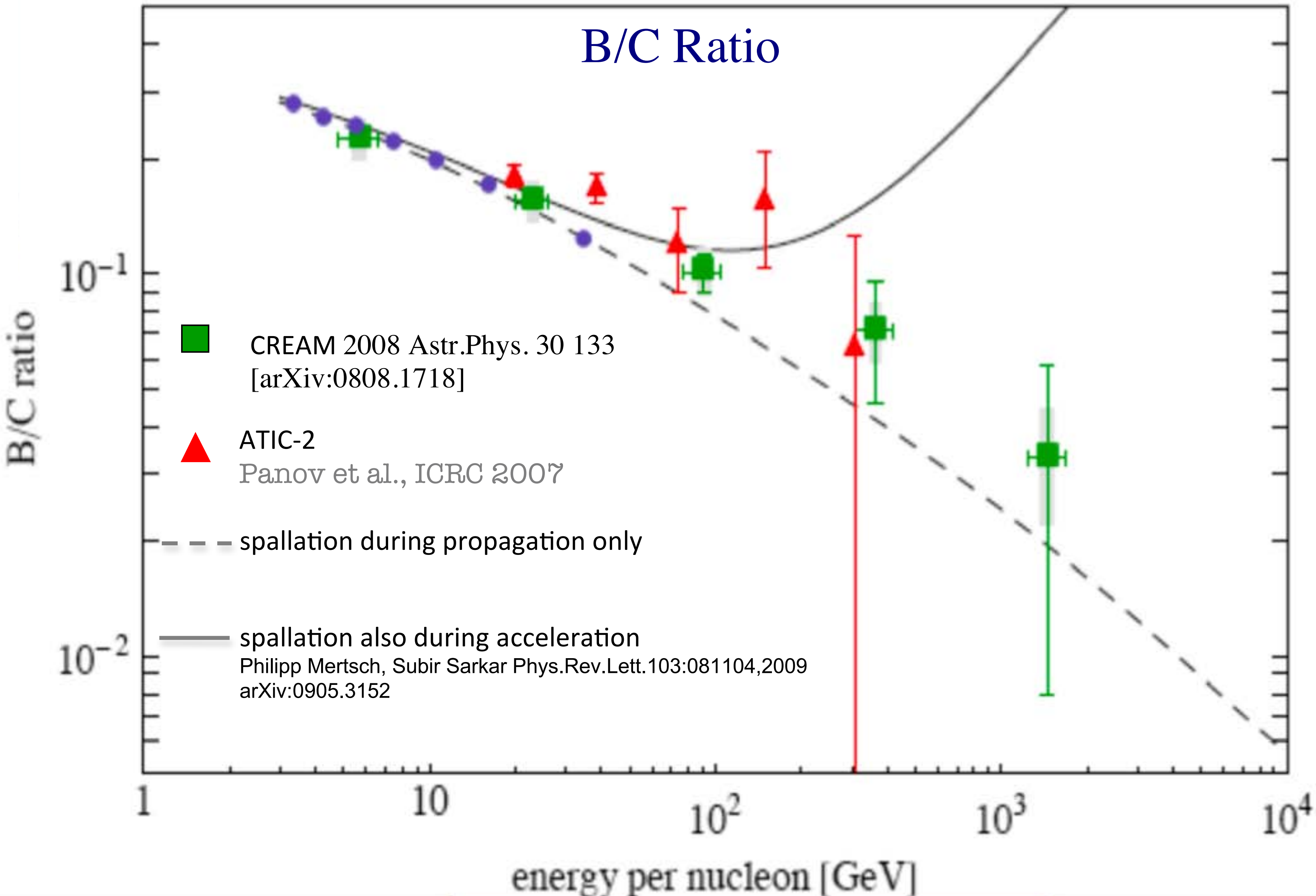
- Positrons created as secondary products of hadronic interactions inside the sources
- Secondary production takes place in the same region where cosmic rays are being accelerated

-> 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

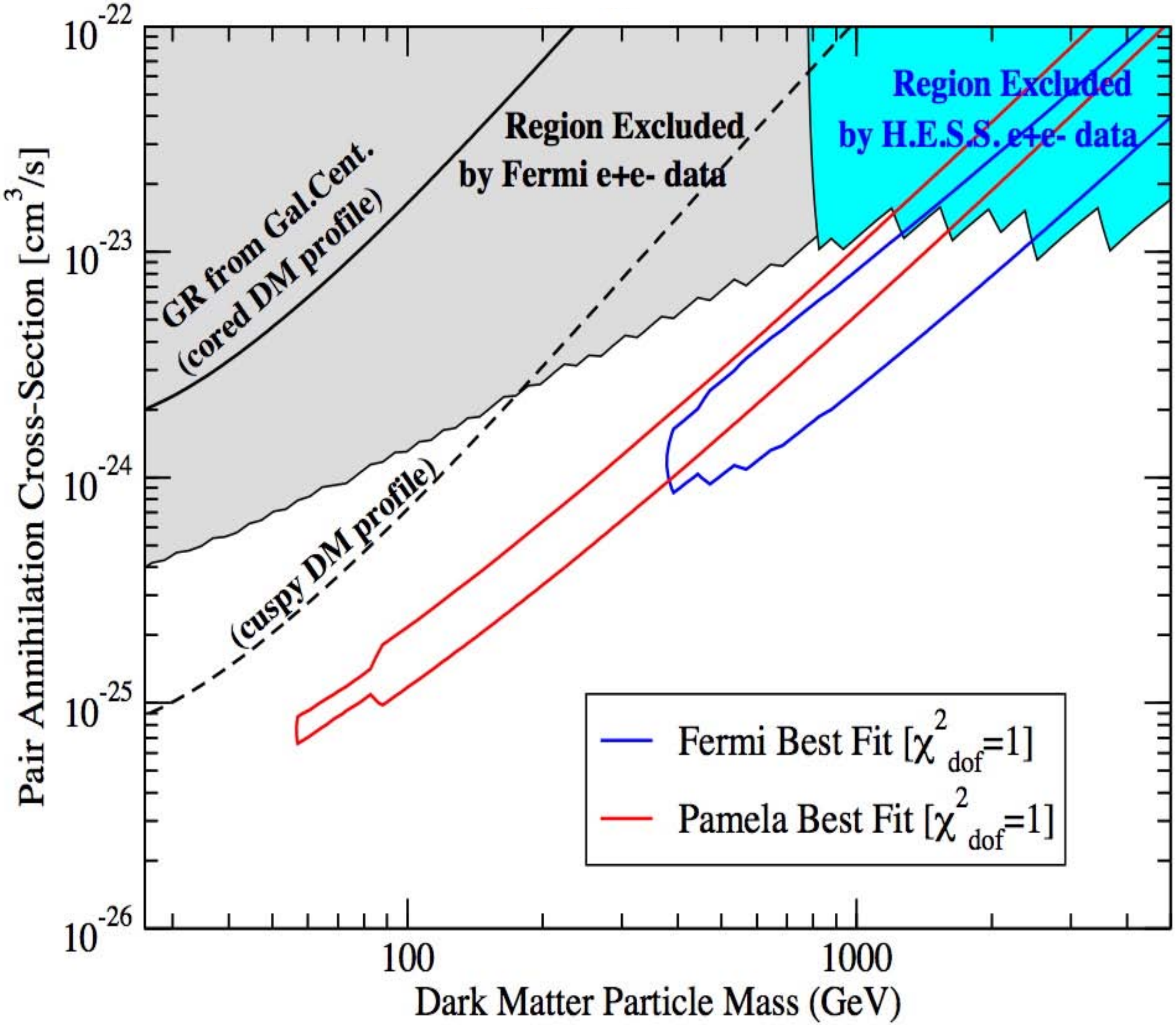
Positrons created as secondary products of hadronic interactions inside the sources (2)

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



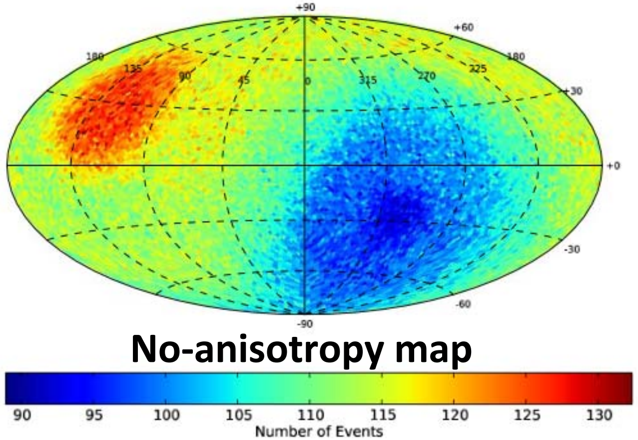
Lepto-philic Models

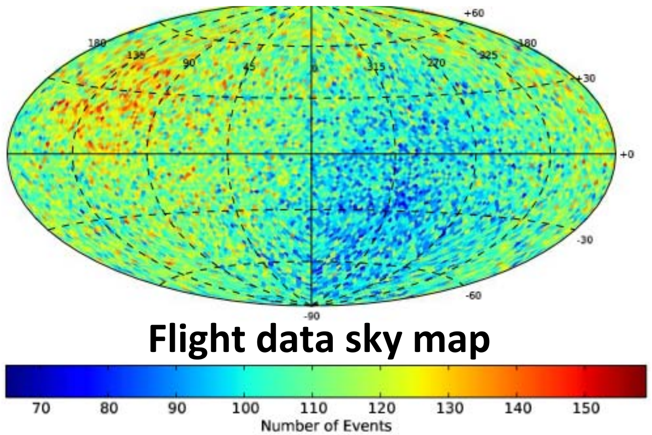
here we assume a democratic dark matter pair-annihilation branching ratio into each charged lepton species: 1/3 into e+e-, 1/3 into μ+ μ- and 1/3 into τ+τ-   Here too antiprotons are not produced in dark matter pair annihilation.

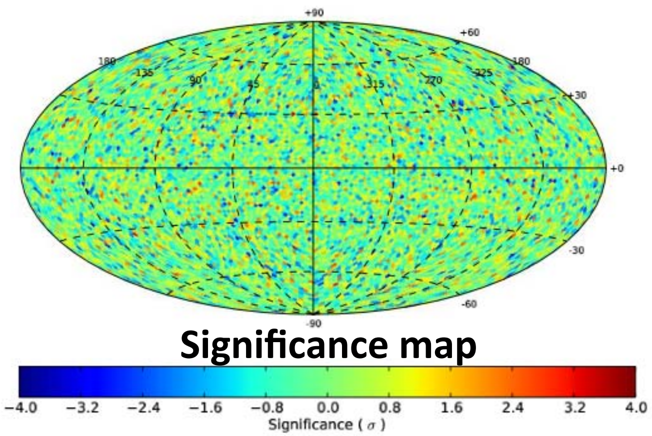


[arXiv:0905.0636]

Cosmic Ray Electrons Anisotropy



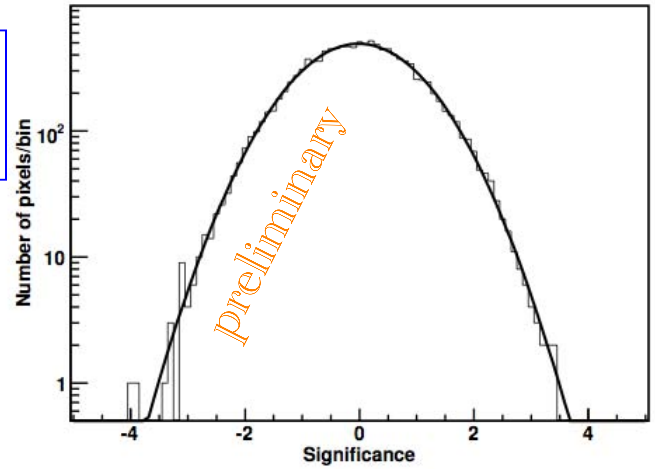




More than 1.6 million electron events with energy above 60 GeV have been analyzed on anisotropy

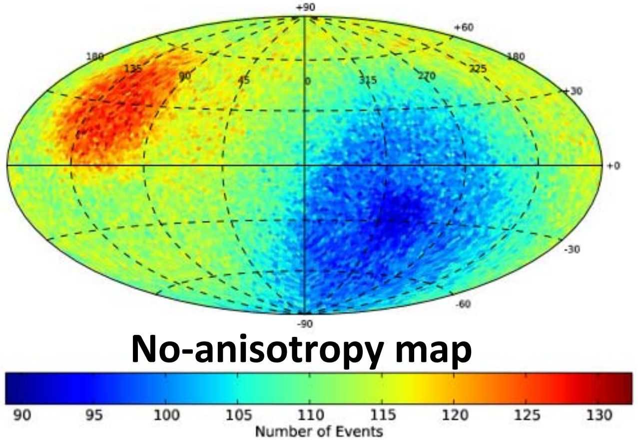
- **Upper limit for the dipole anisotropy has been set to 0.5 – 5% depending on the energy**
- **Upper limit on fractional anisotropic excess ranges from a fraction to about one percent depending on the minimum energy and the anisotropy's angular scale**

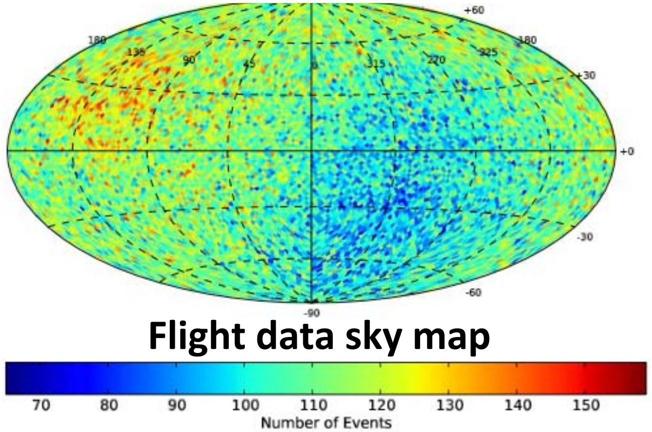
Distribution of significance, fitted by a Gaussian →

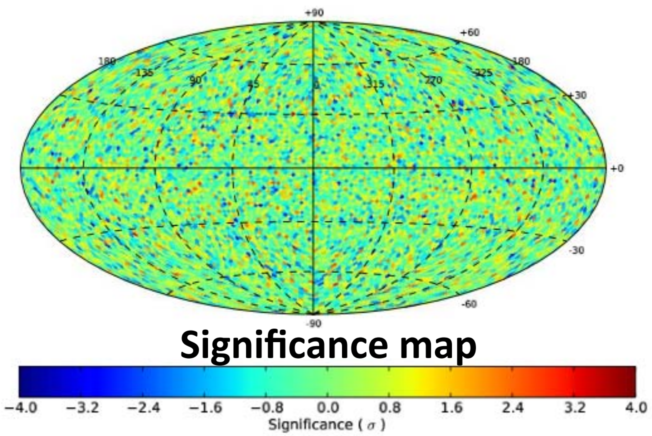


Fermi Coll.
Phys. Rev. D accepted
[arXiv:1008.5119]

Cosmic Ray Electrons Anisotropy

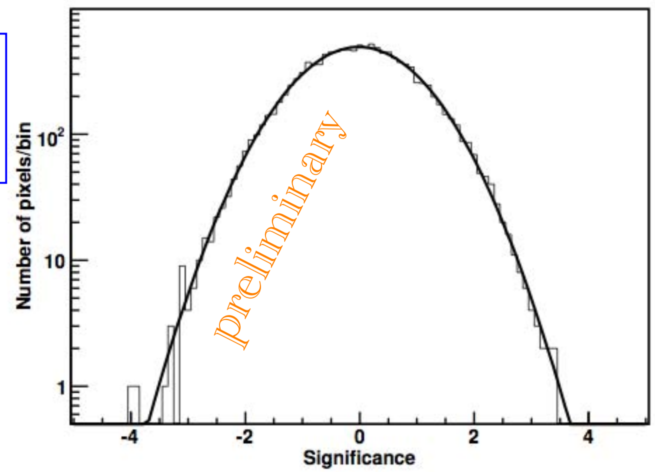






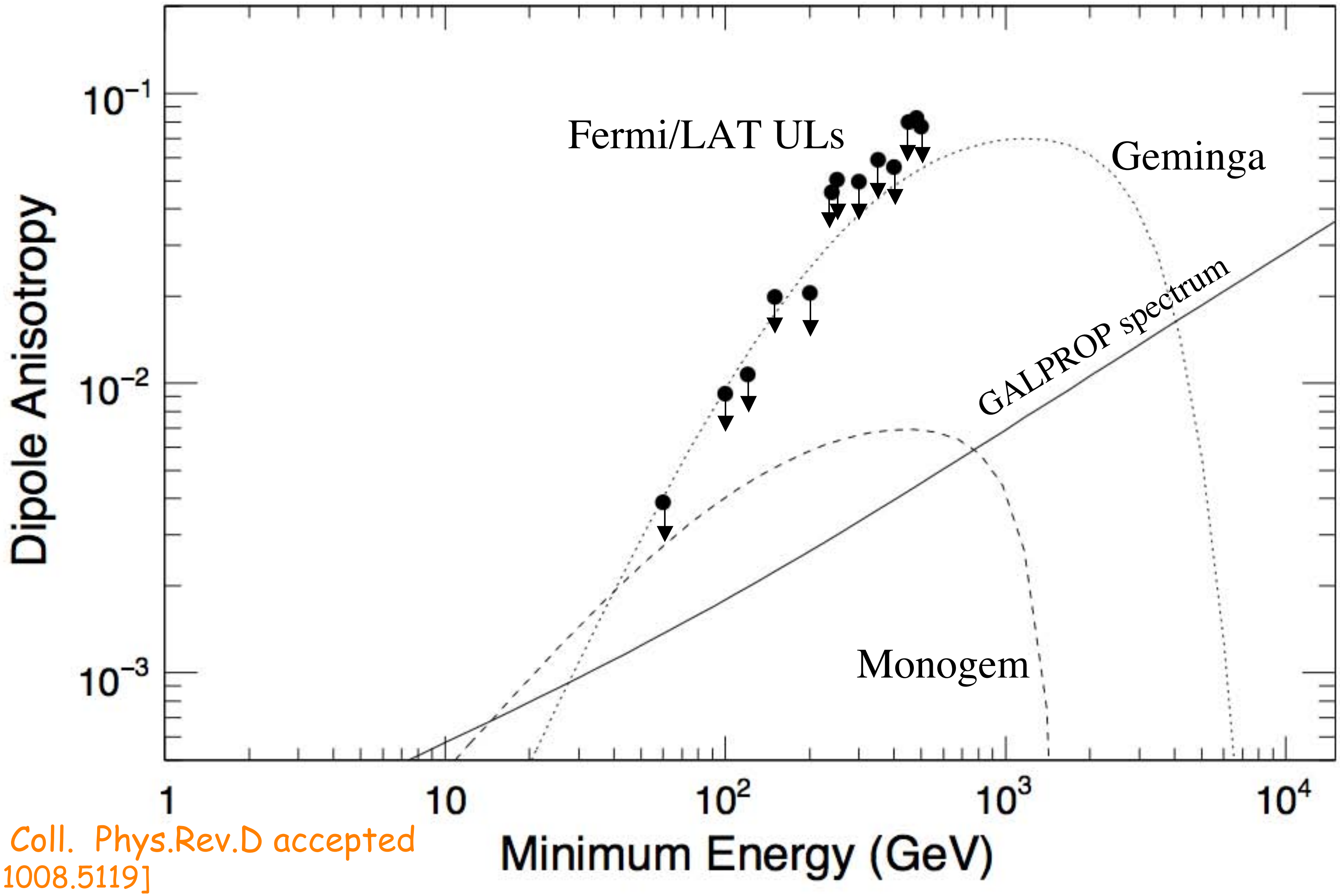
the levels of anisotropy expected for Vela-like and Monogem-like sources (i.e. sources with similar distances and ages) seem to be higher than the scale of anisotropies excluded by the results However, it is worth to point out that the model results are affected by large uncertainties related to the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

Distribution of significance, fitted by a Gaussian →



Fermi Coll.
Phys. Rev. D accepted
[arXiv:1008.5119]

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



Fermi Coll. Phys.Rev.D accepted [arXiv:1008.5119]

Search Strategies

Satellites:

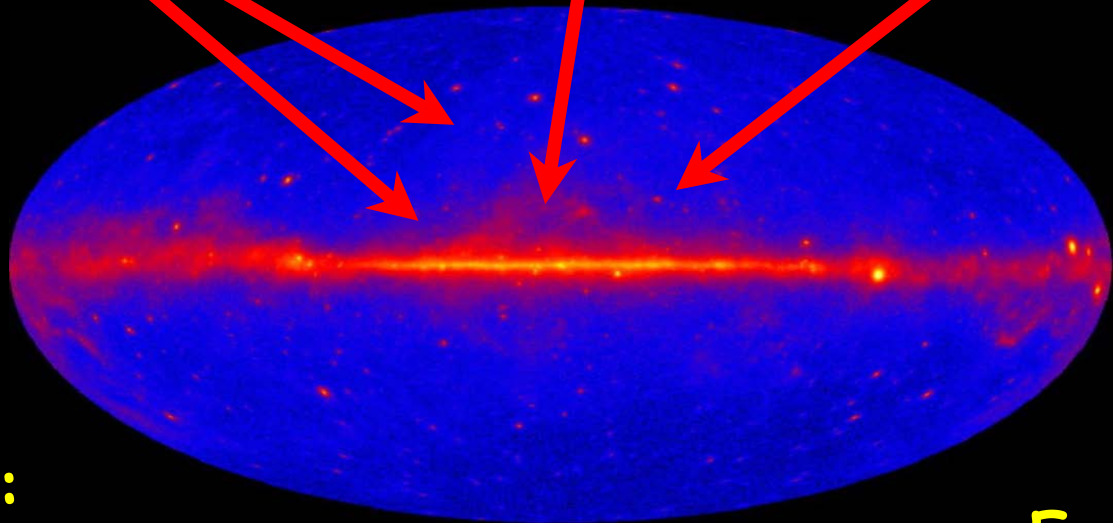
Low background and good source id, but low statistics

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

Pre-launch sensitivities published in Baltz et al., 2008, JCAP 0807:013 [astro-ph/0806.2911]

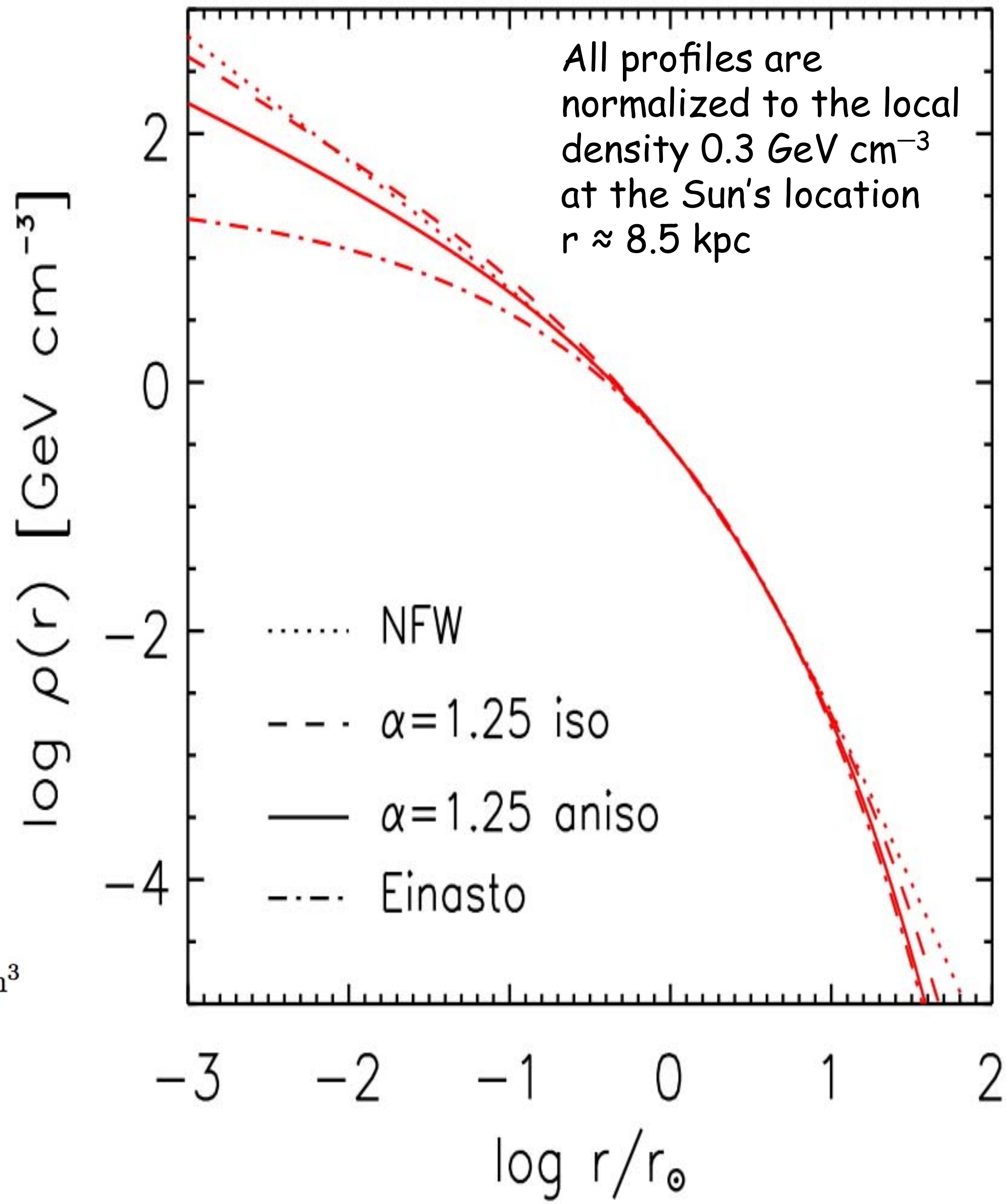
Milky Way Dark Matter Profiles

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

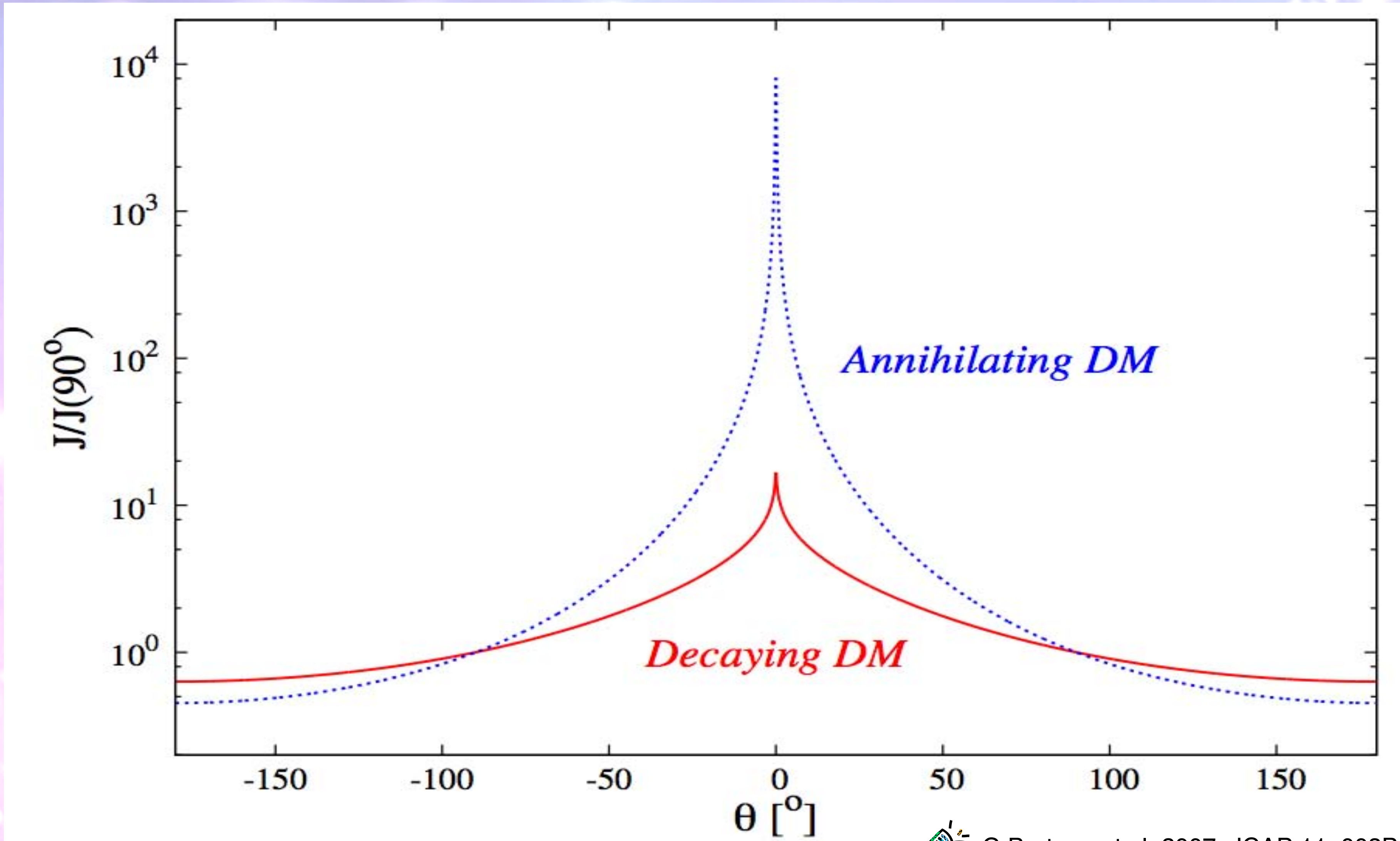
Halo model	α	β	γ	r_s in kpc
Cored isothermal	2	2	0	5
Navarro, Frenk, White	1	3	1	20
Moore	1	3	1.16	30

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

A.Lapi et al. arXiv:0912.1766



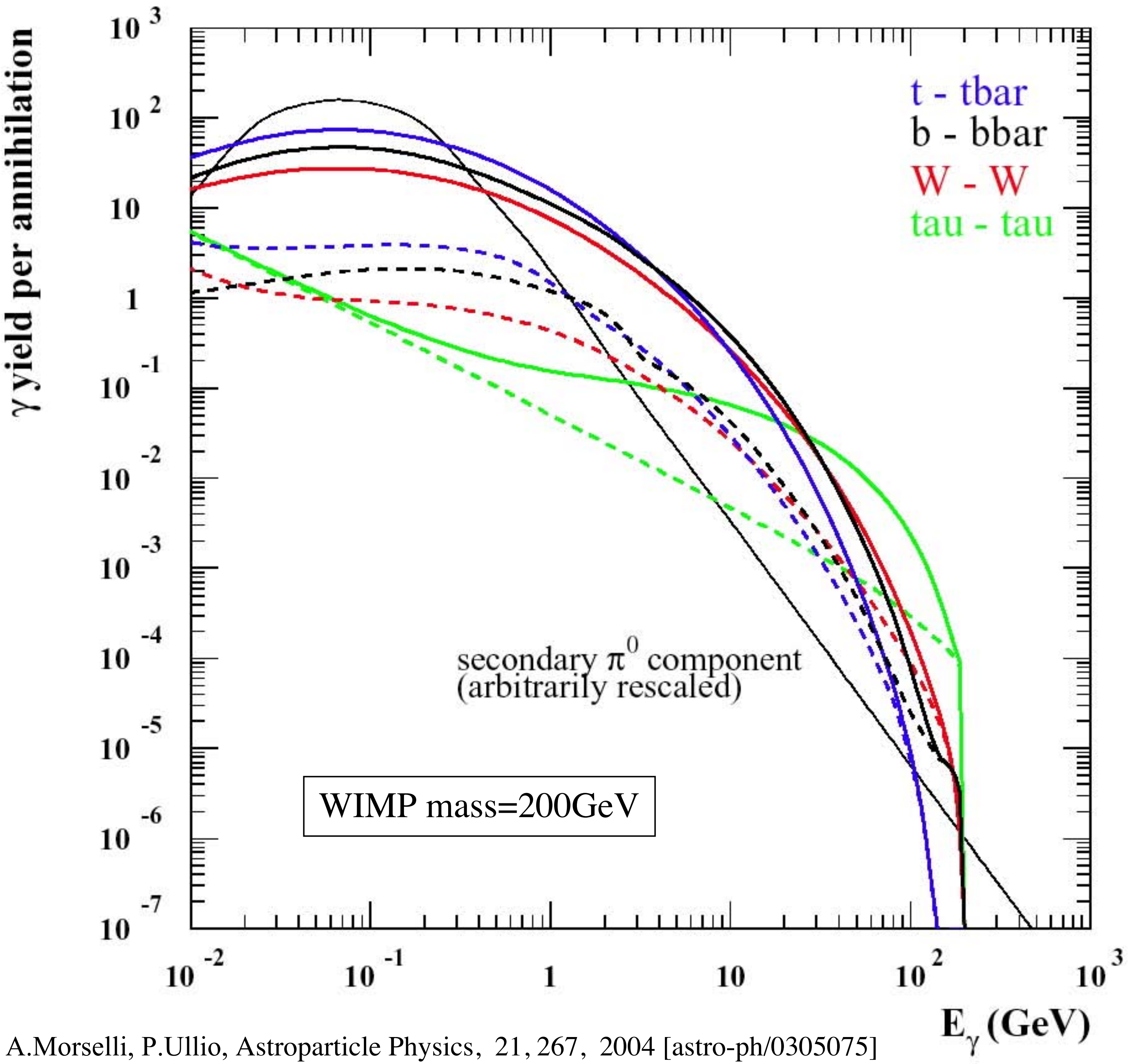
Different spatial behaviour for decaying or annihilating dark matter



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

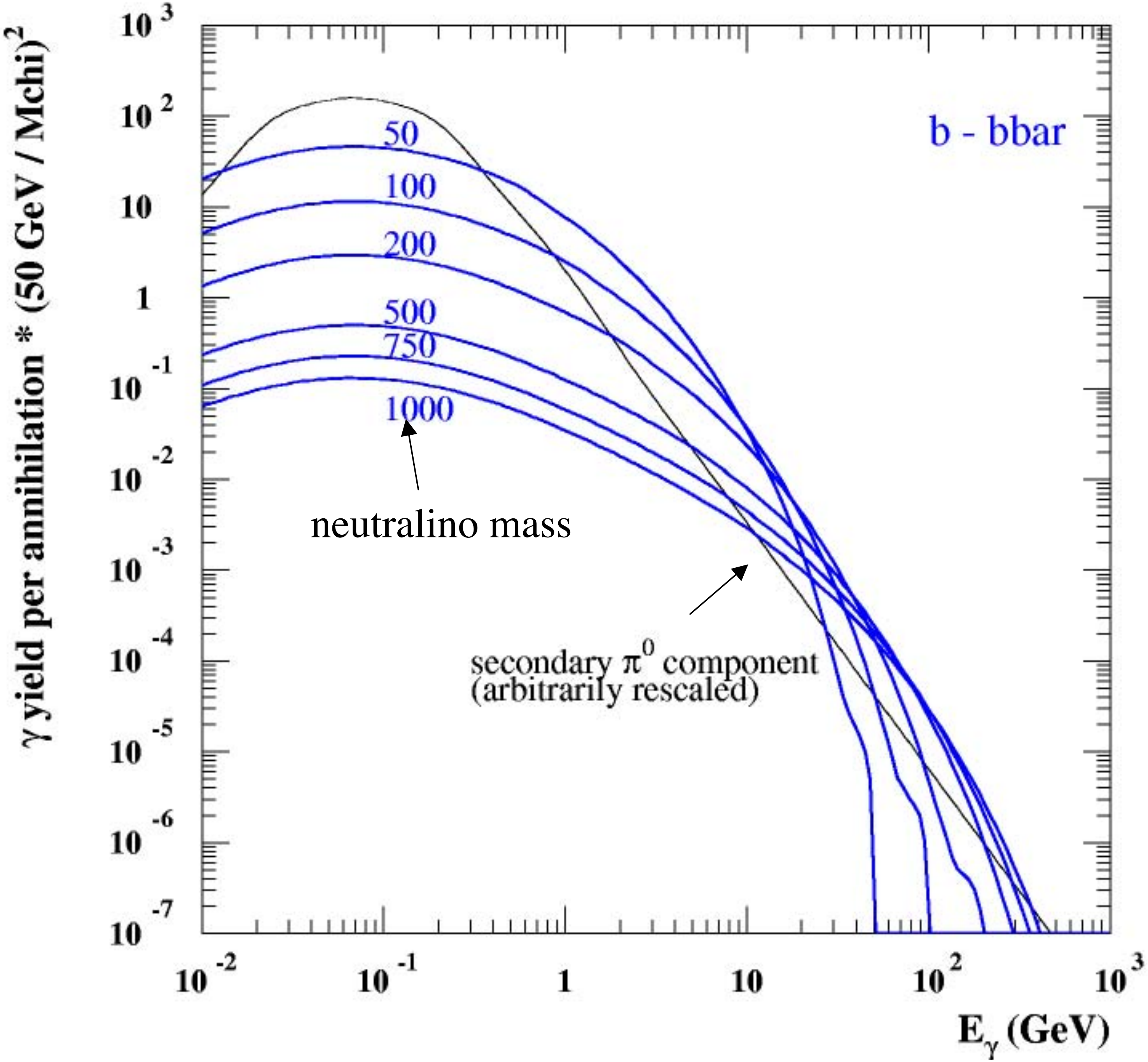
The angular profile of the gamma-ray signal is shown, as function of the angle θ to the centre of the galaxy for a Navarro-Frenk-White (NFW) halo distribution for decaying DM, solid (red) line, compared to the case of self-annihilating DM, dashed (blue) line

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



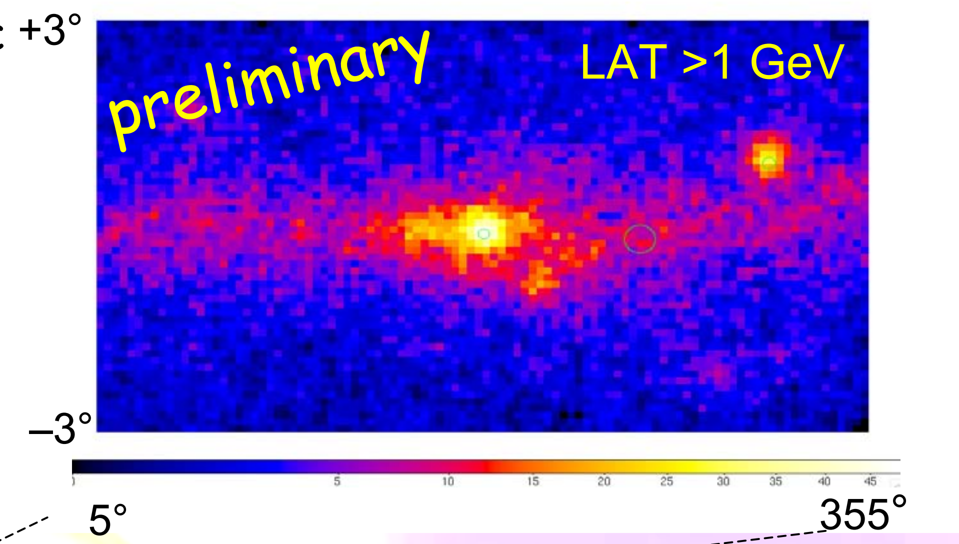
A.Cesarini, F.Fucito, A.Lionetto, A.Morselli, P.Ullio, Astroparticle Physics, 21, 267-285, 2004 [astro-ph/0305075]

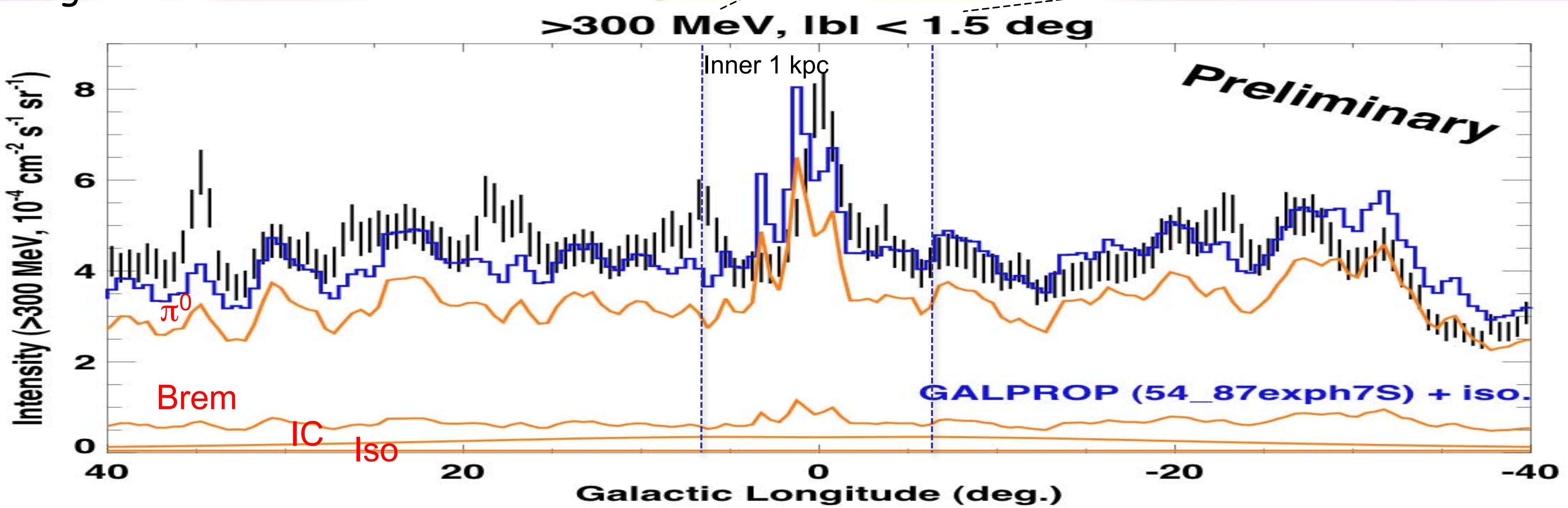
Search for Dark Matter in the Galactic Center

- 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

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





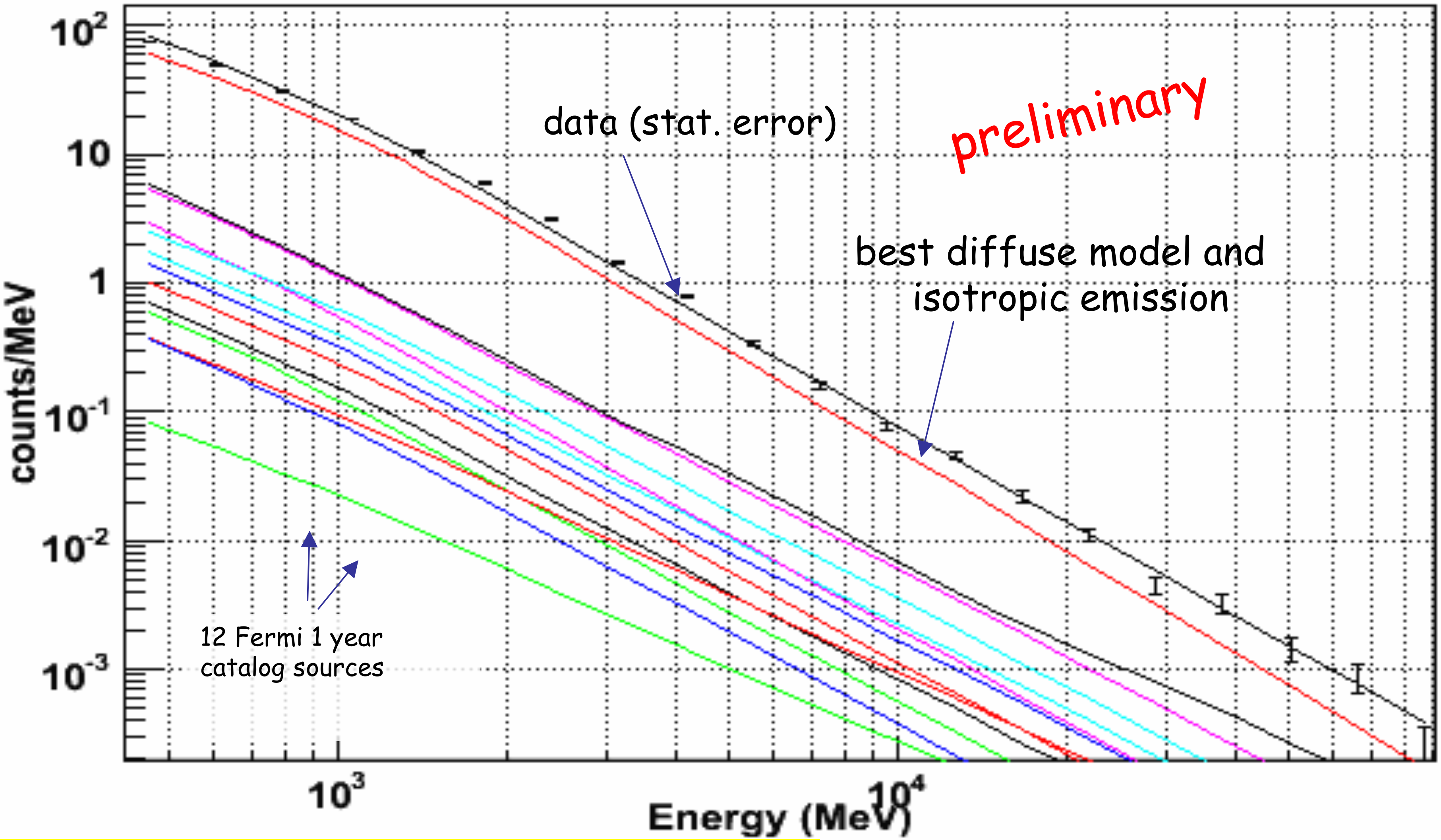
S.Digel, Fermi Symp, Fermi LAT Coll. in preparation

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)

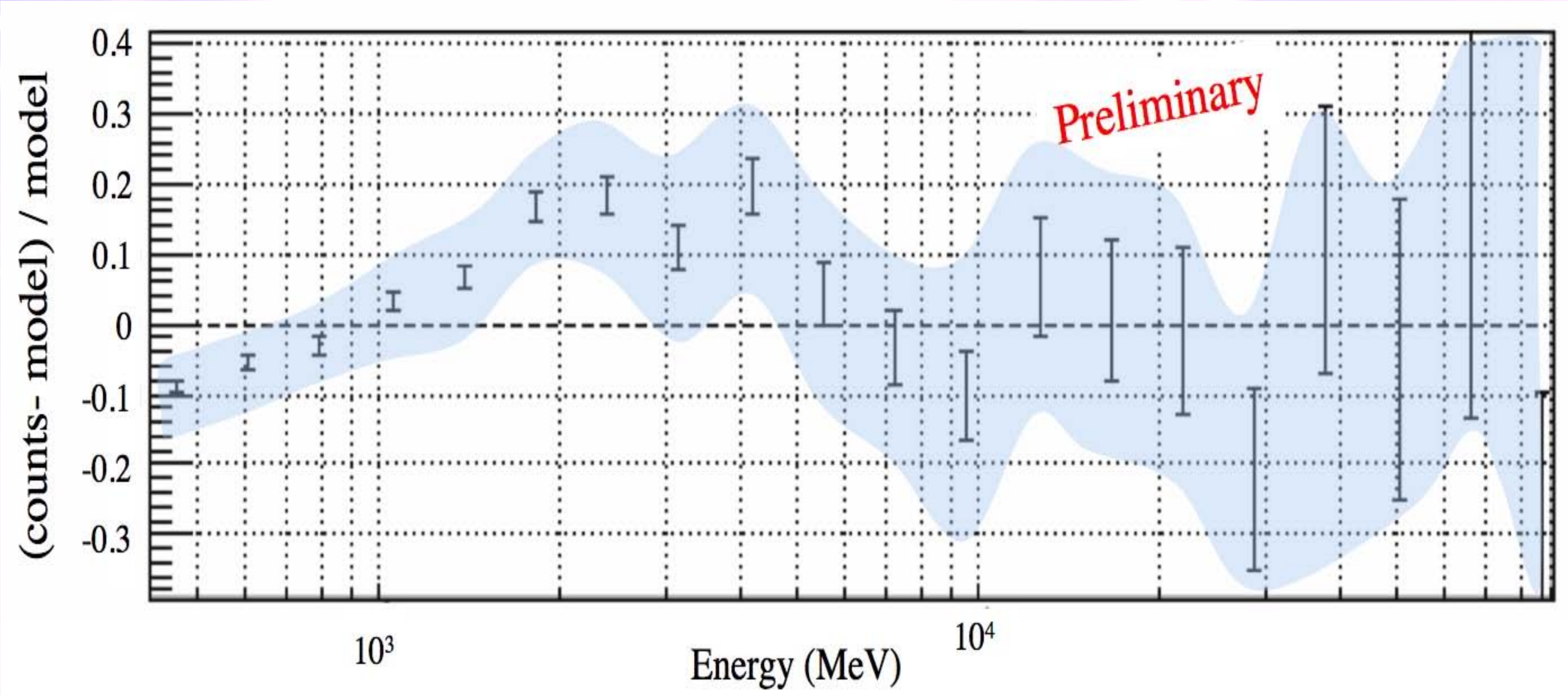


Fermi LAT Coll. in preparation, Fermi Symp. arXiv:0912.3828

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

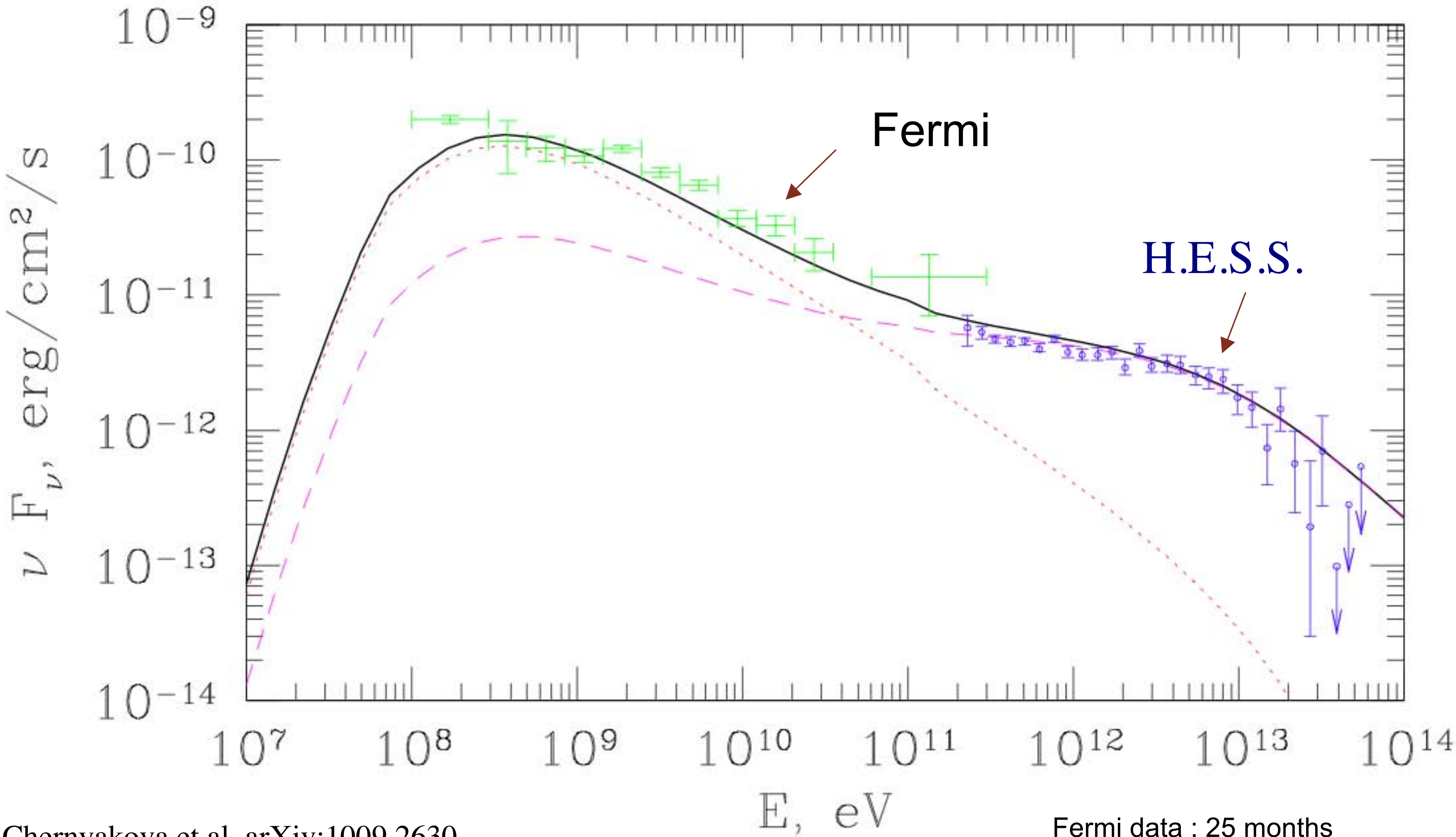


Fermi LAT Coll. in preparation, Fermi Symp. arXiv:0912.3828

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

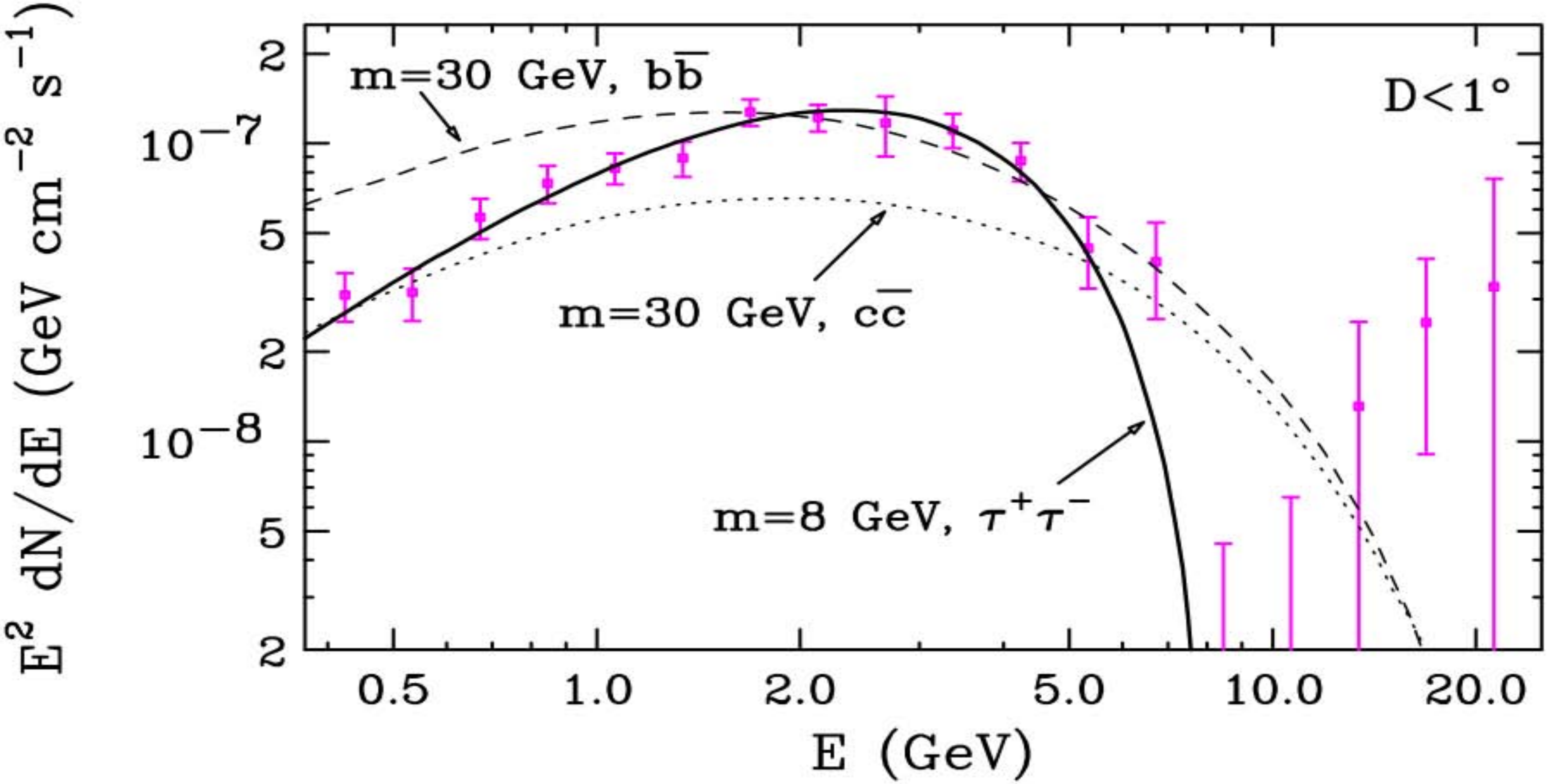
Fermi and H.E.S.S. Galactic Center Source



Chernyakova et al. arXiv:1009.2630

Fermi data : 25 months

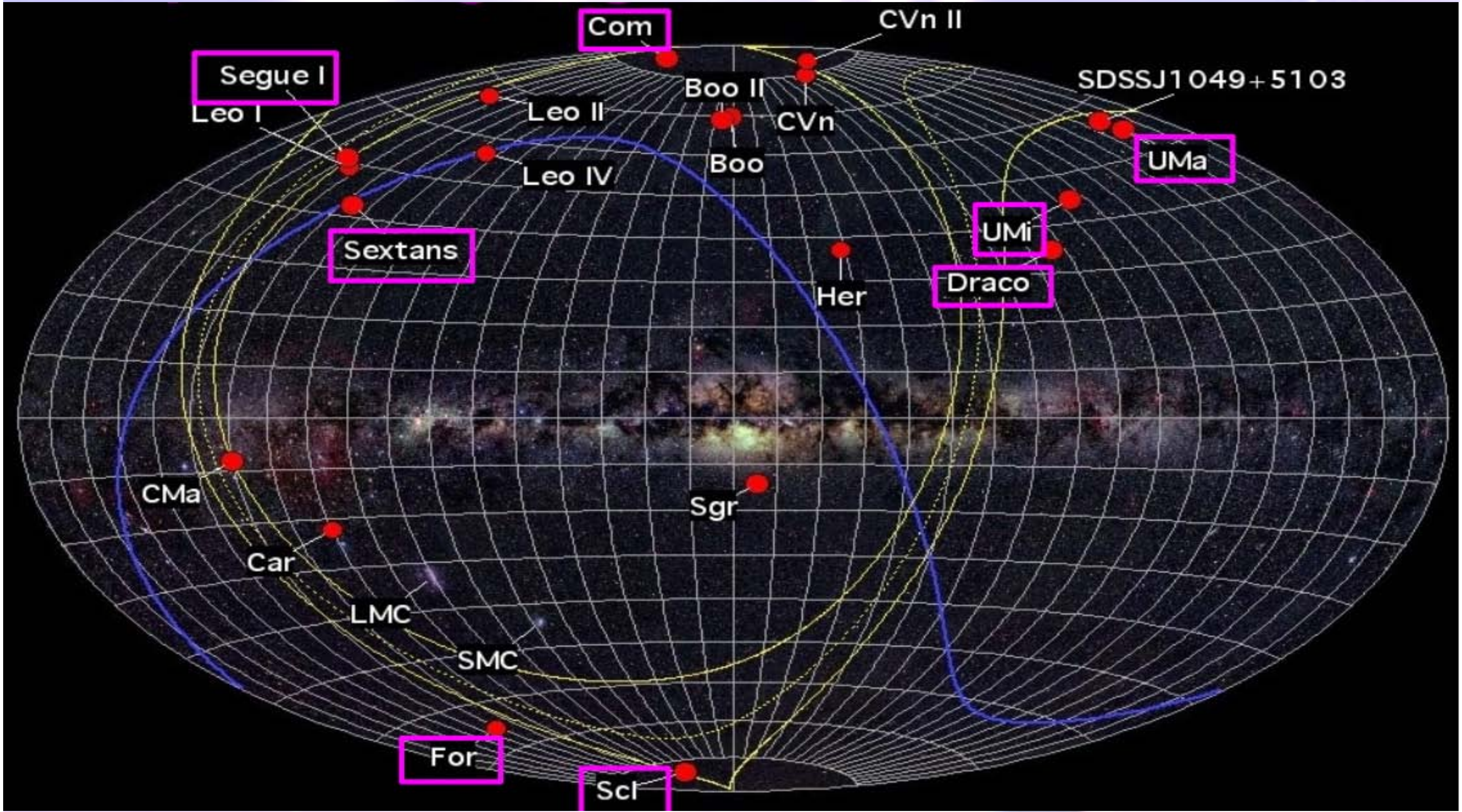
Dark Matter Signal from the Galactic Center ?



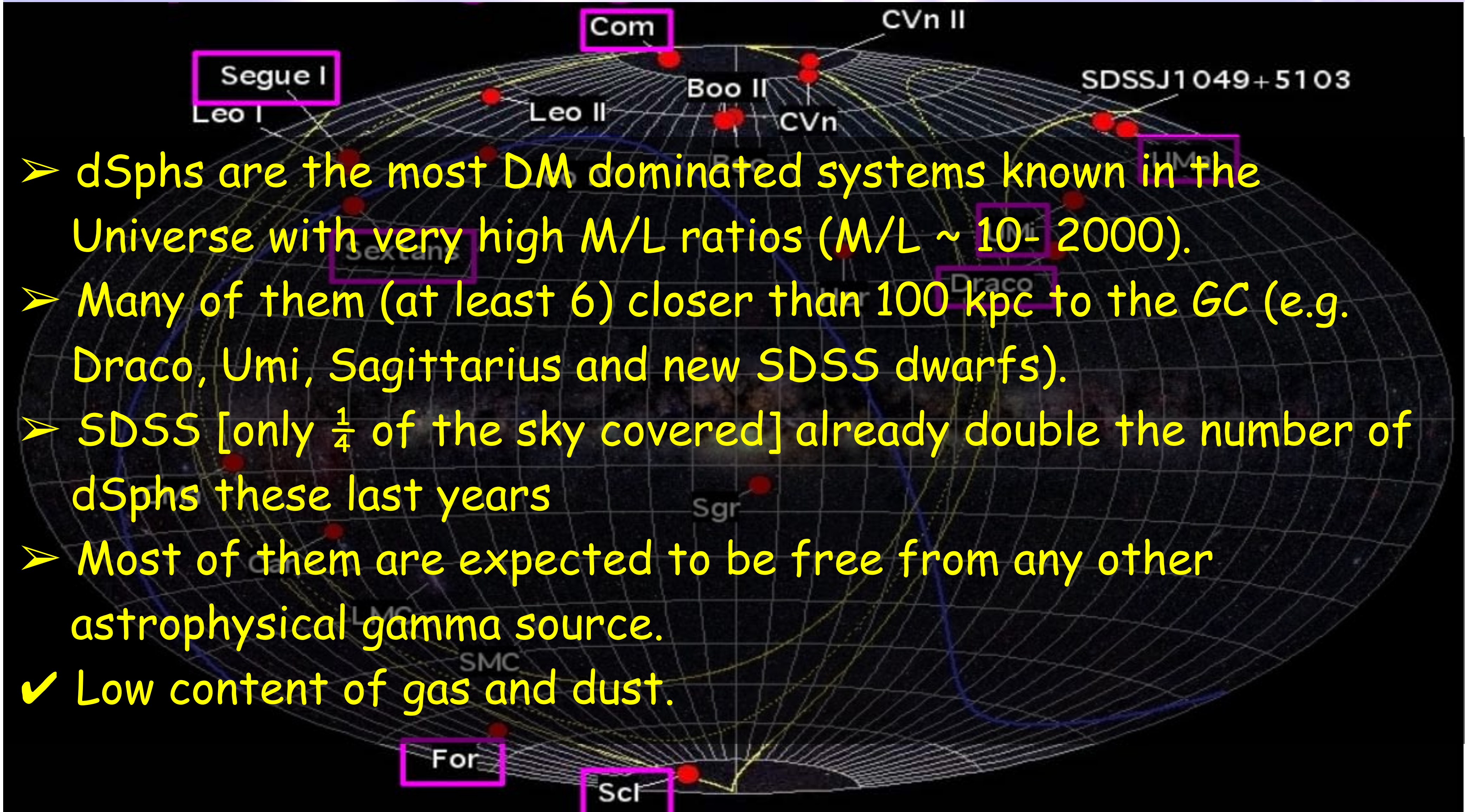
Dan Hooper and Lisa Goodenough, today arXiv:31010.2752

systematic uncertainties and diffuse model uncertainties cannot be ignored !

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



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



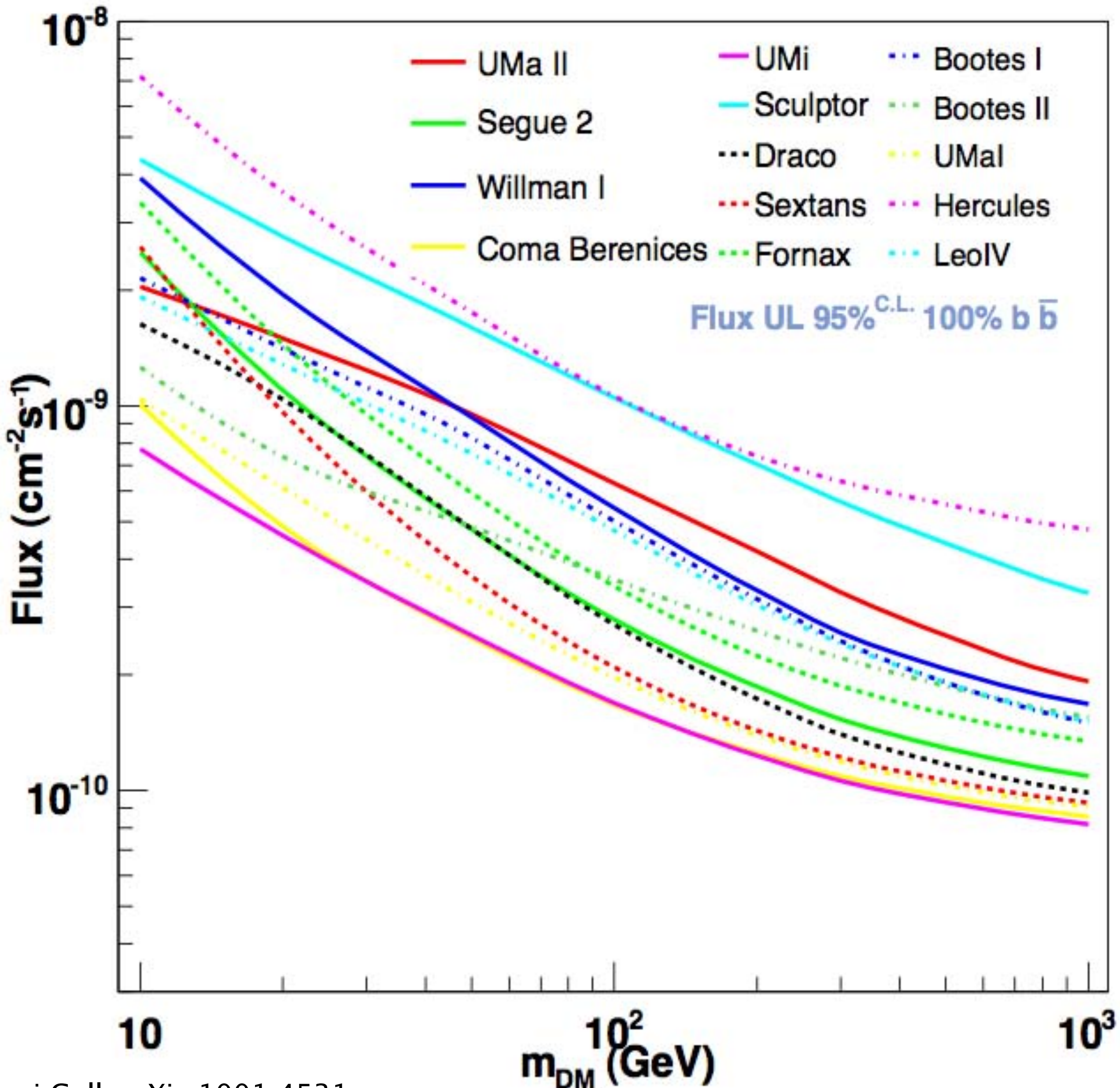
- ➢ dSphs are the most DM dominated systems known in the Universe with very high M/L ratios (M/L ~ 10- 2000).
- ➢ Many of them (at least 6) closer than 100 kpc to the GC (e.g. Draco, Umi, Sagittarius and new SDSS dwarfs).
- ➢ SDSS [only $\frac{1}{4}$ of the sky covered] already double the number of dSphs these last years
- ➢ Most of them are expected to be free from any other astrophysical gamma source.
- ✔ Low content 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. arXiv:1001.4531

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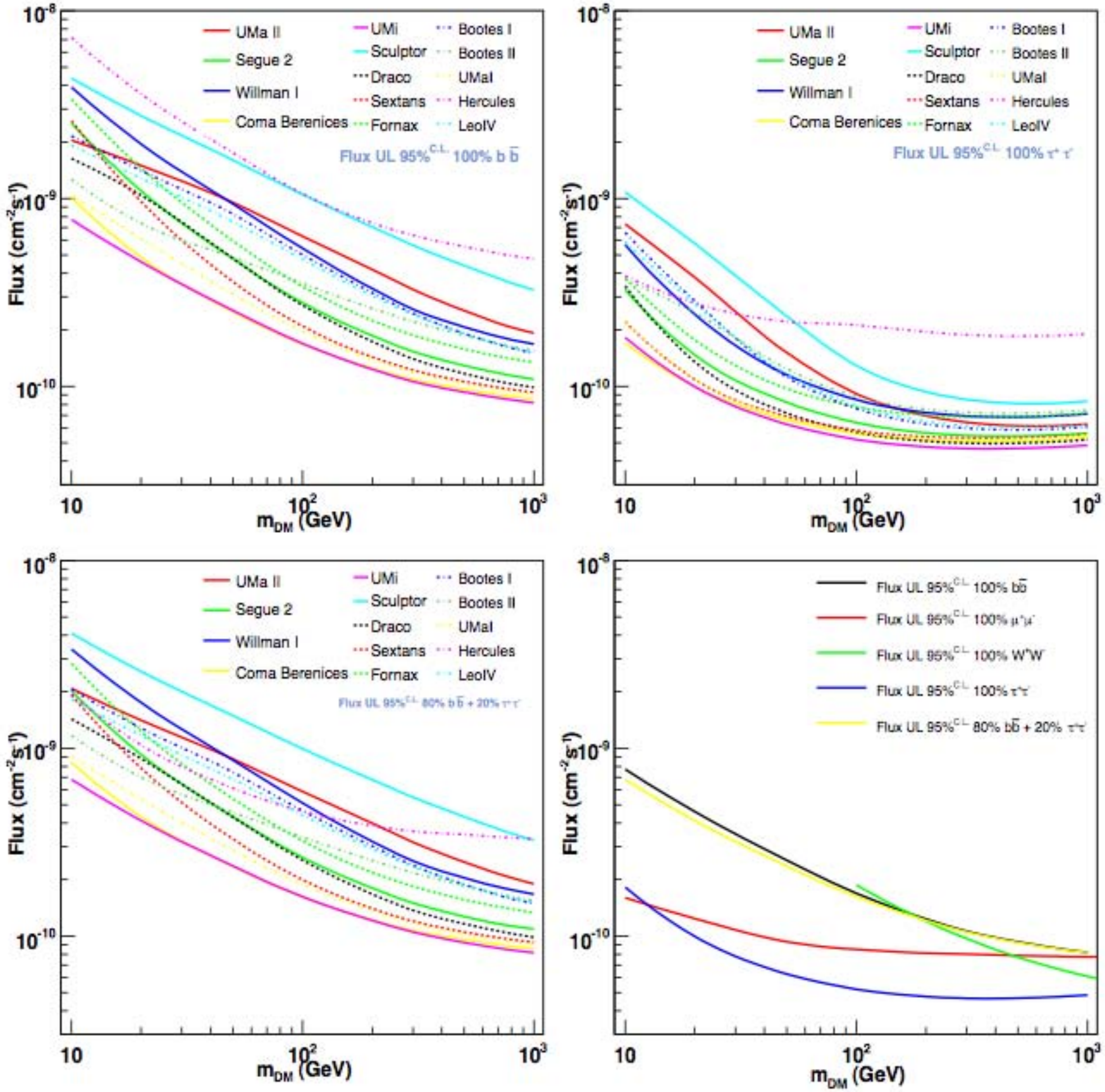

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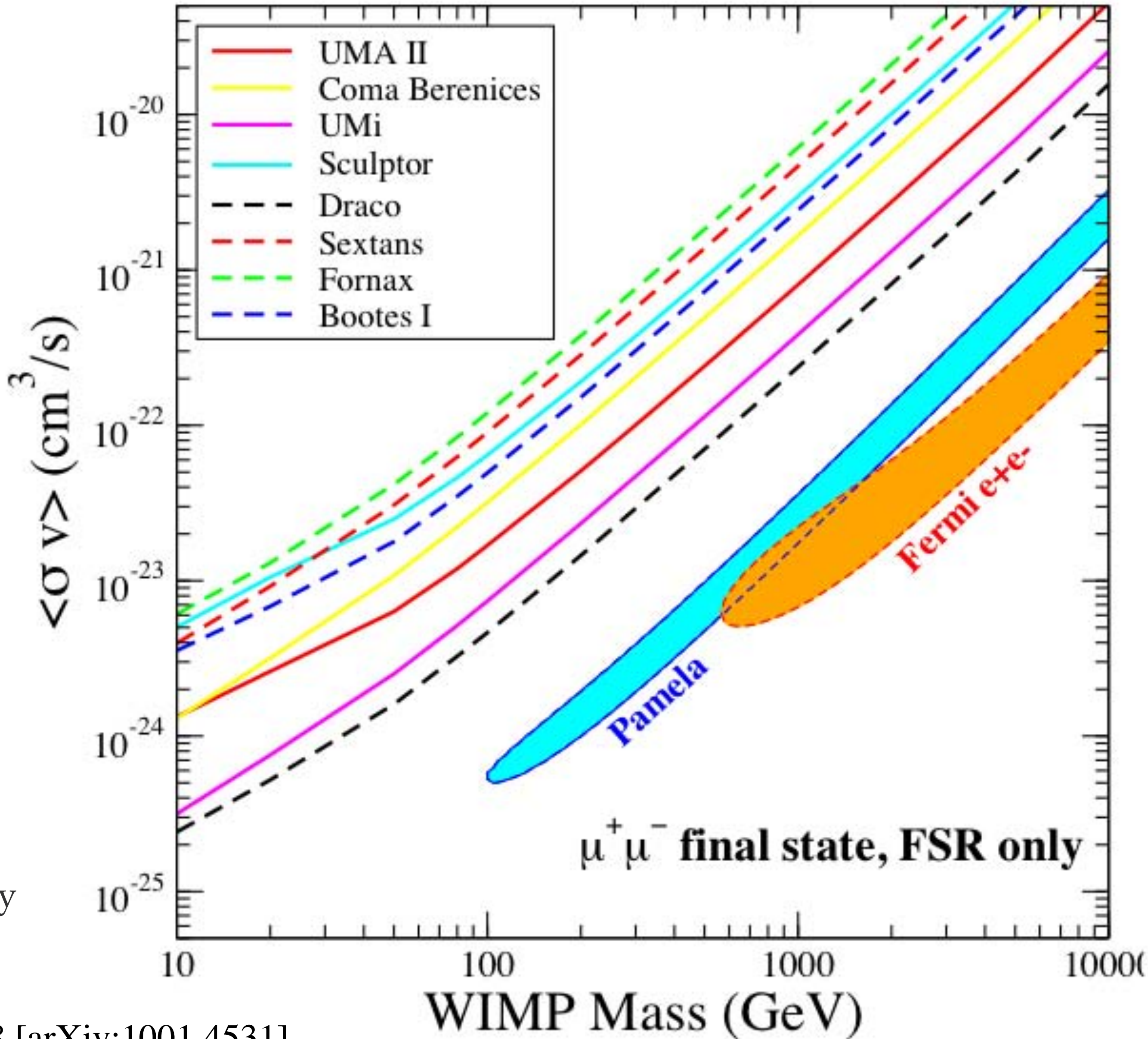

Fermi Coll. ApJ 712 (2010) 147-158 [arXiv:1001.4531]

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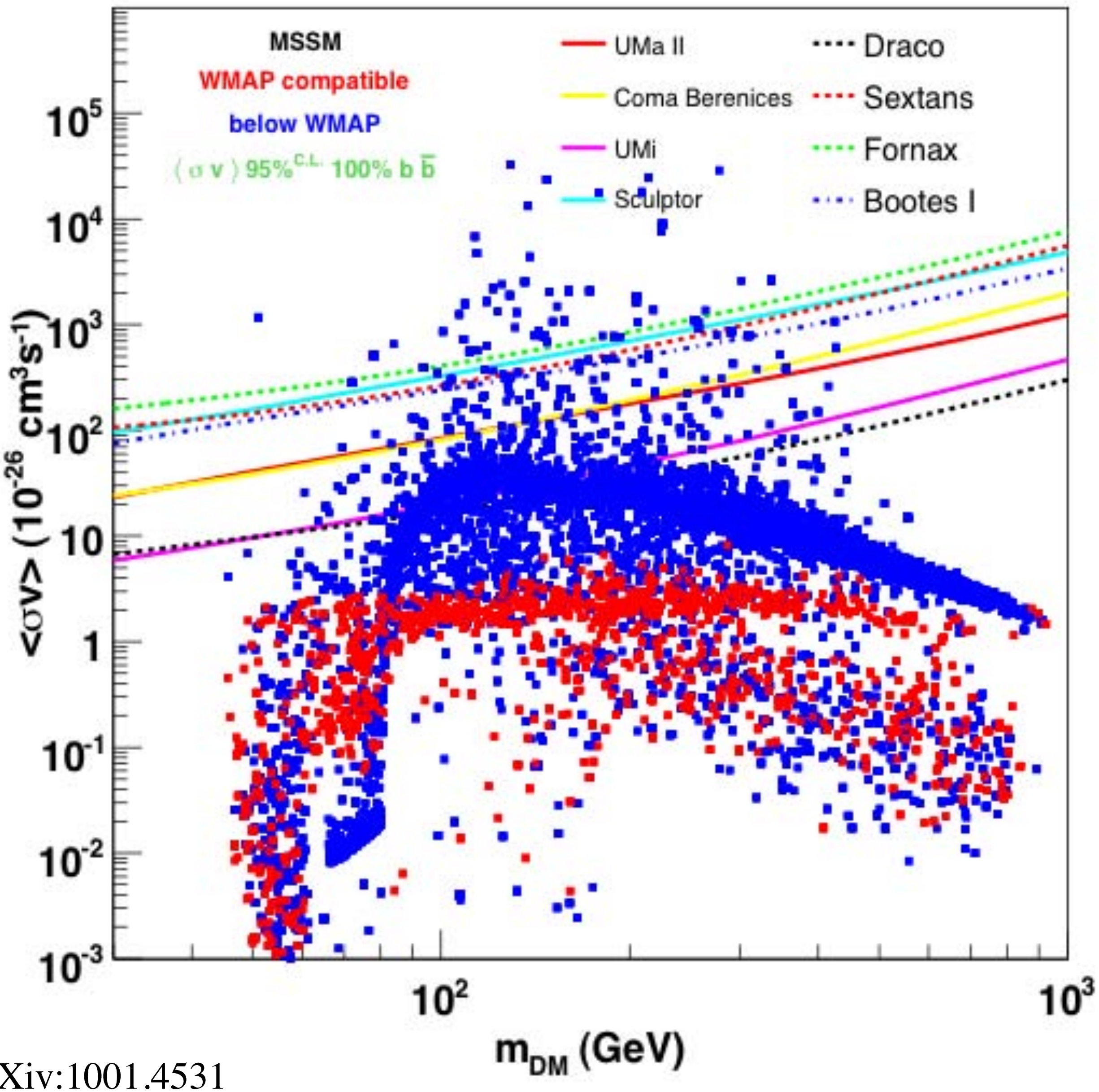


Fermi Coll. ApJ 712 (2010) 147-158 arXiv:1001.4531

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 ??)

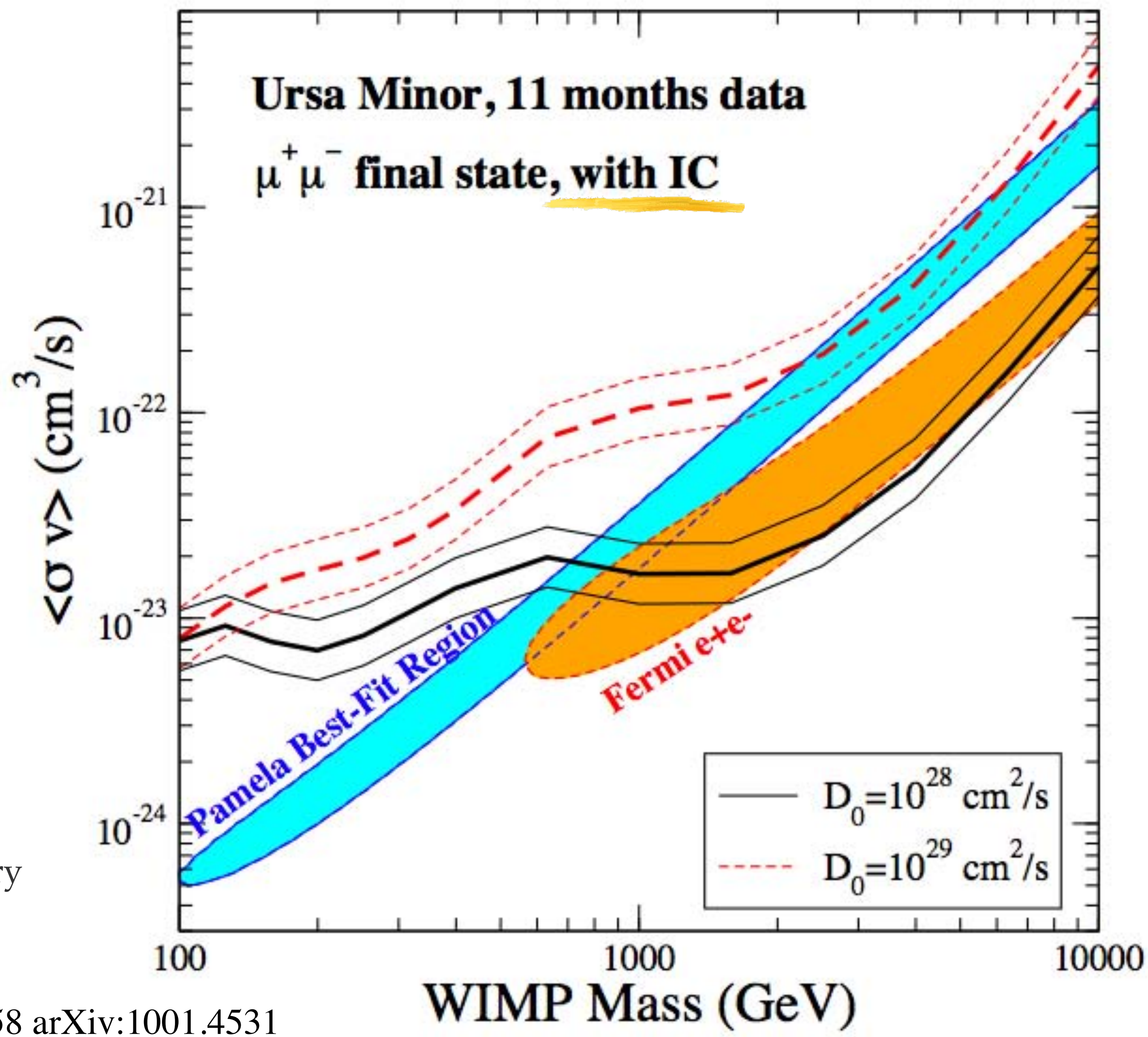
Dwarf Spheroidal Galaxies upper-limits

Exclusion regions

already cutting into interesting parameter space for some WIMP models

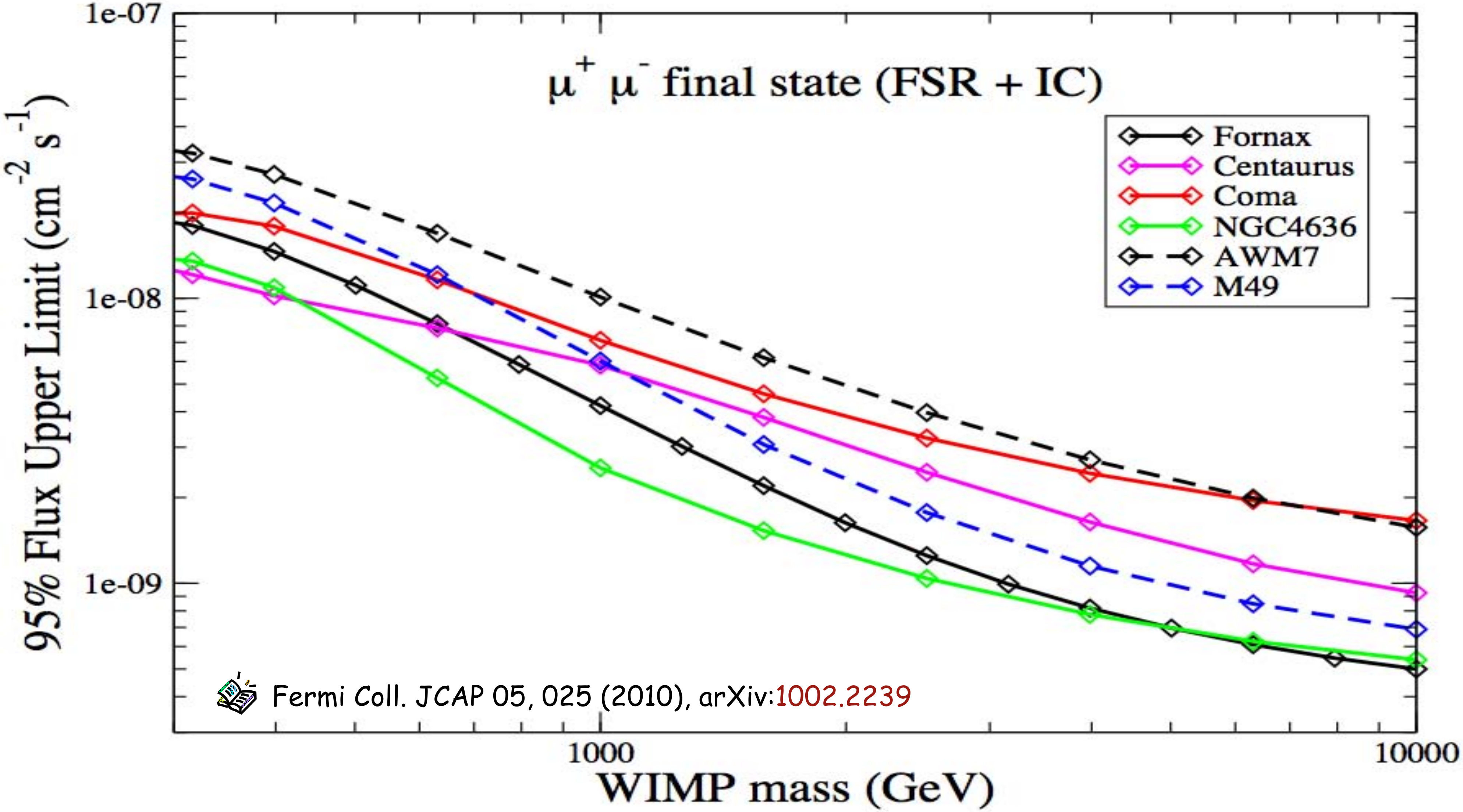
Stronger constraints can be derived if IC of electrons and positrons from DM annihilation off of the CMB is included, however diffusion in dwarfs is not known ⇒ use bracketing values of diffusion coefficients from cosmic rays in the Milky Way

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



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

Galaxy Clusters upper-limits

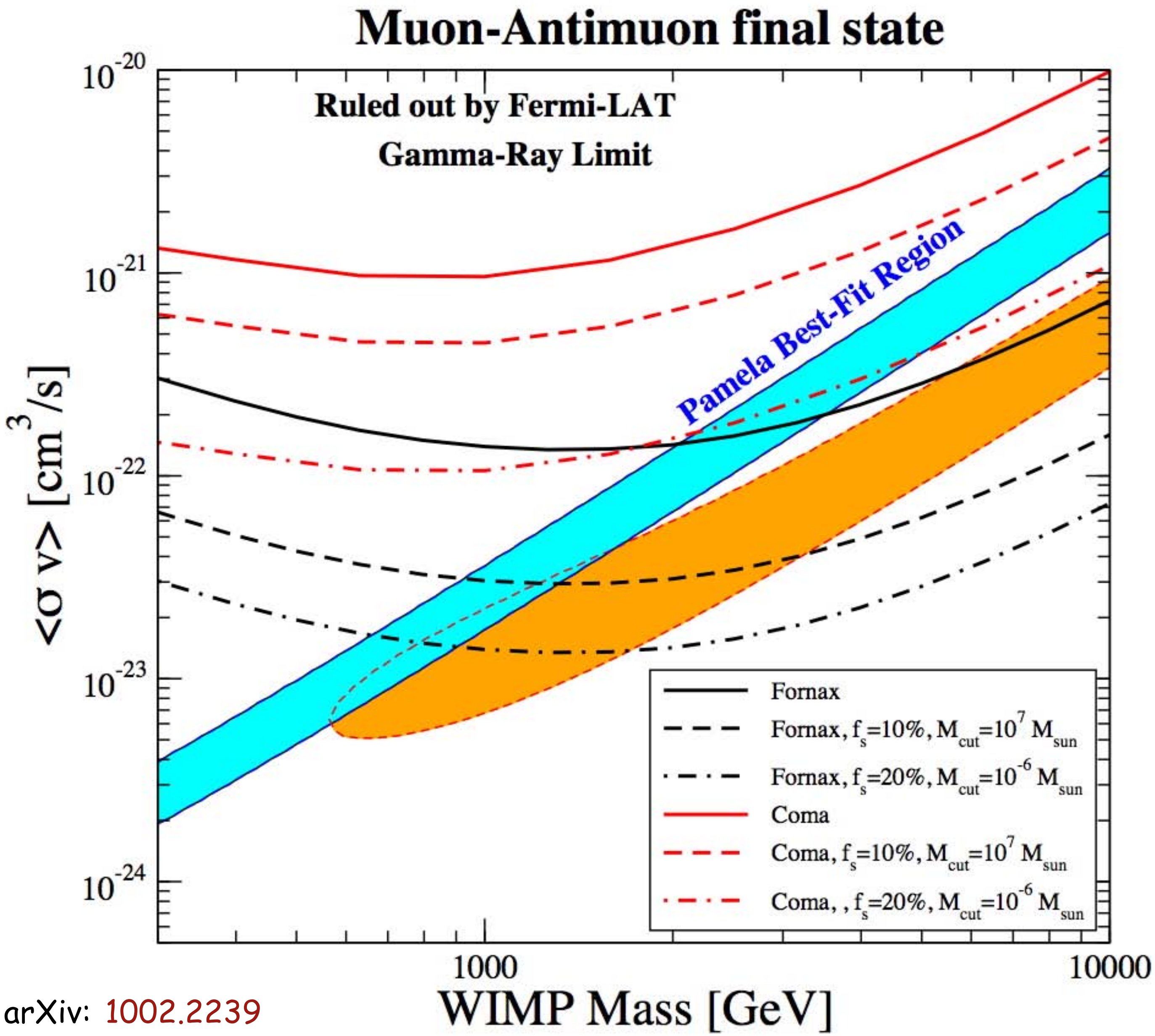


Fermi Coll. JCAP 05, 025 (2010), arXiv:1002.2239

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

Galaxy Clusters upper-limits

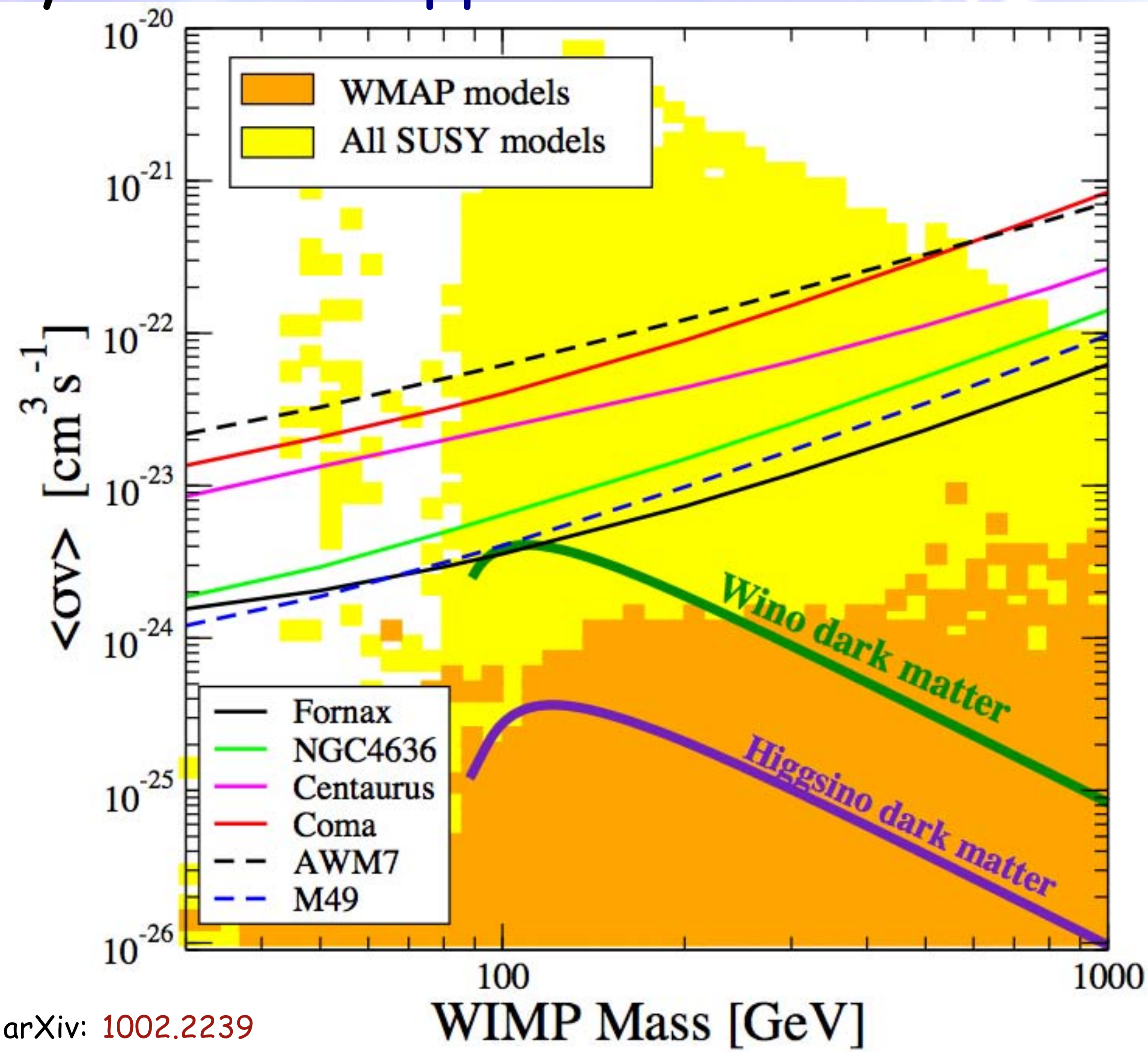
Stronger constraints on leptophilic DM models can be derived with galaxy clusters when the IC contribution off the CMB of secondary electrons (from DM annihilation) is included



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

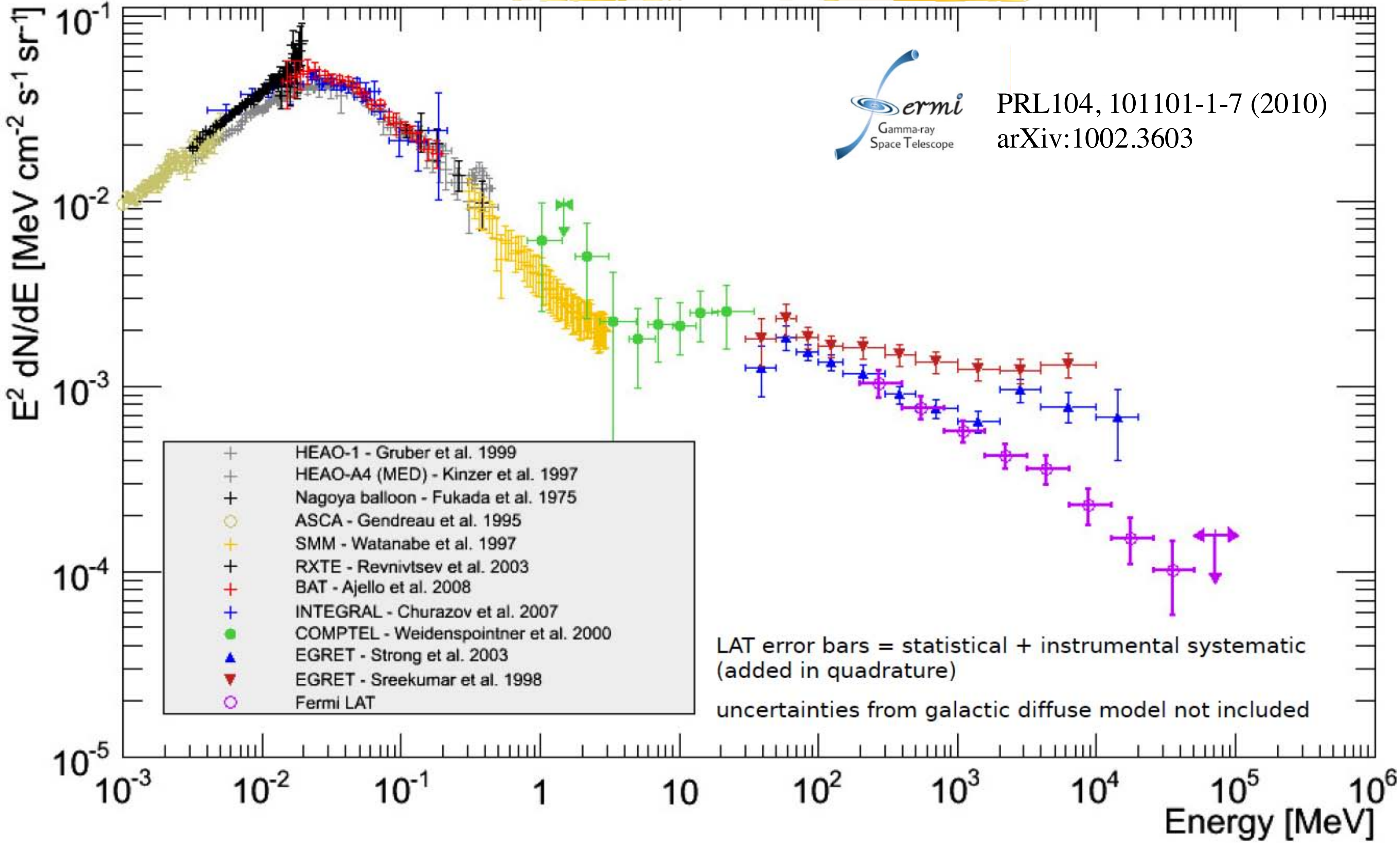
Galaxy Clusters upper-limits

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

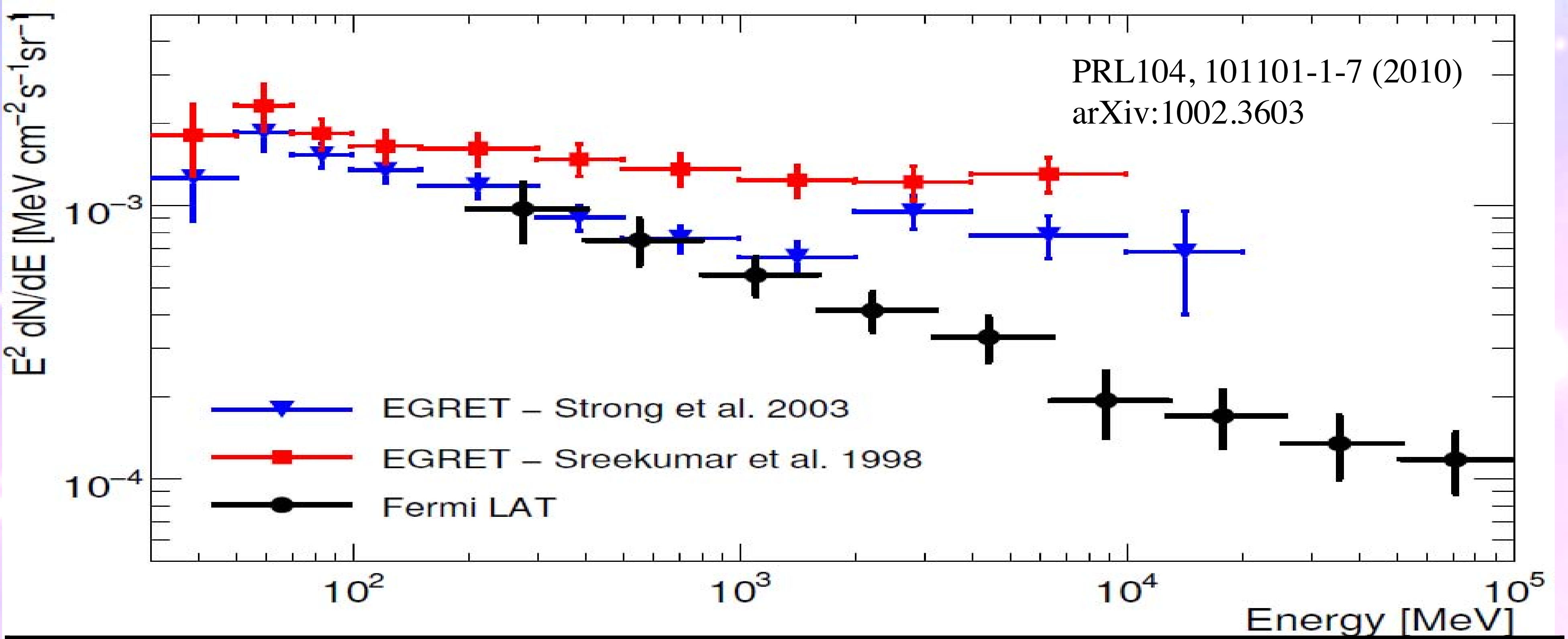


Fermi Coll. JCAP 05, 025 (2010), arXiv: 1002.2239

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

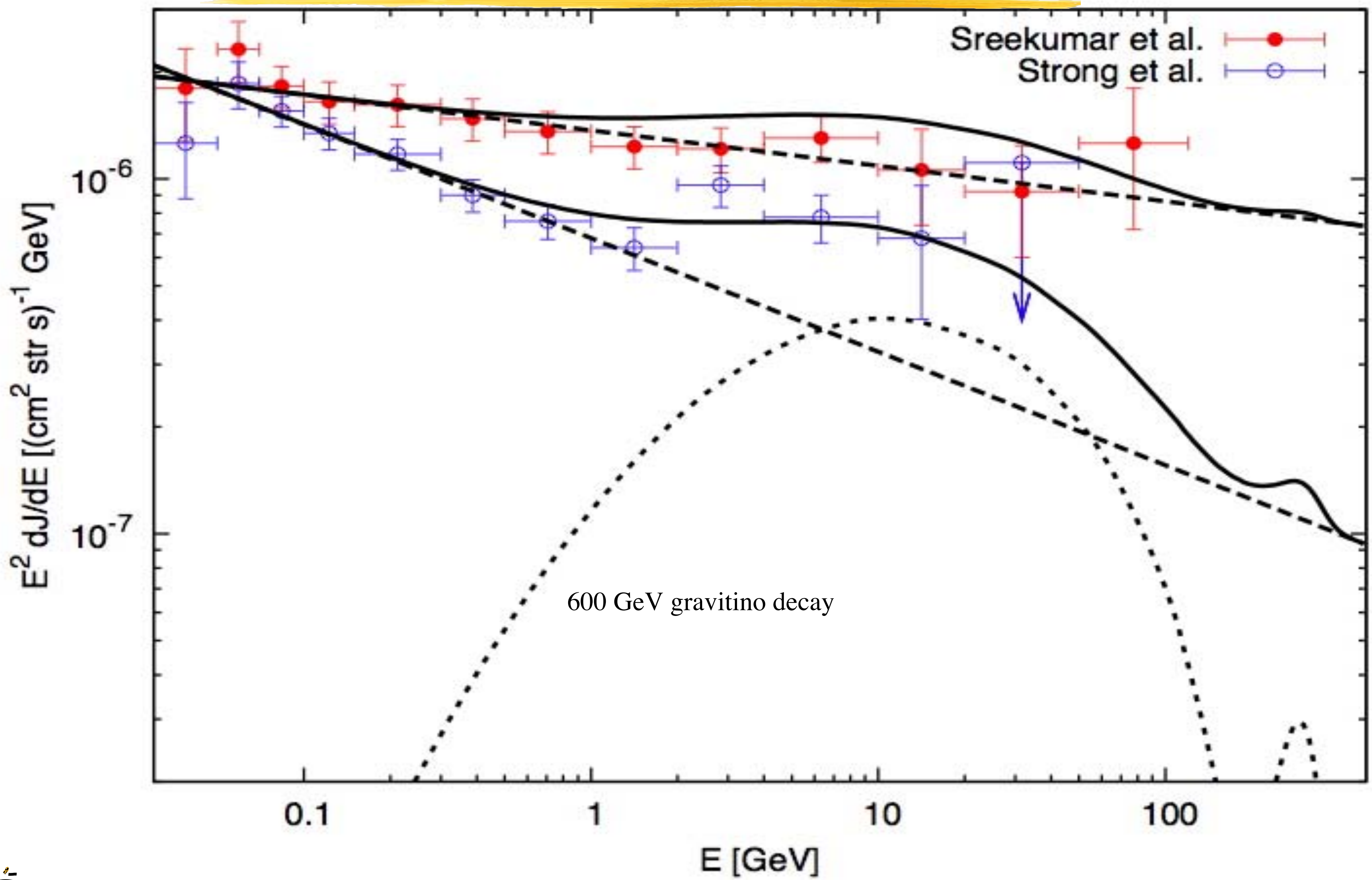


SED of the isotropic diffuse emission (1 keV–100 GeV)



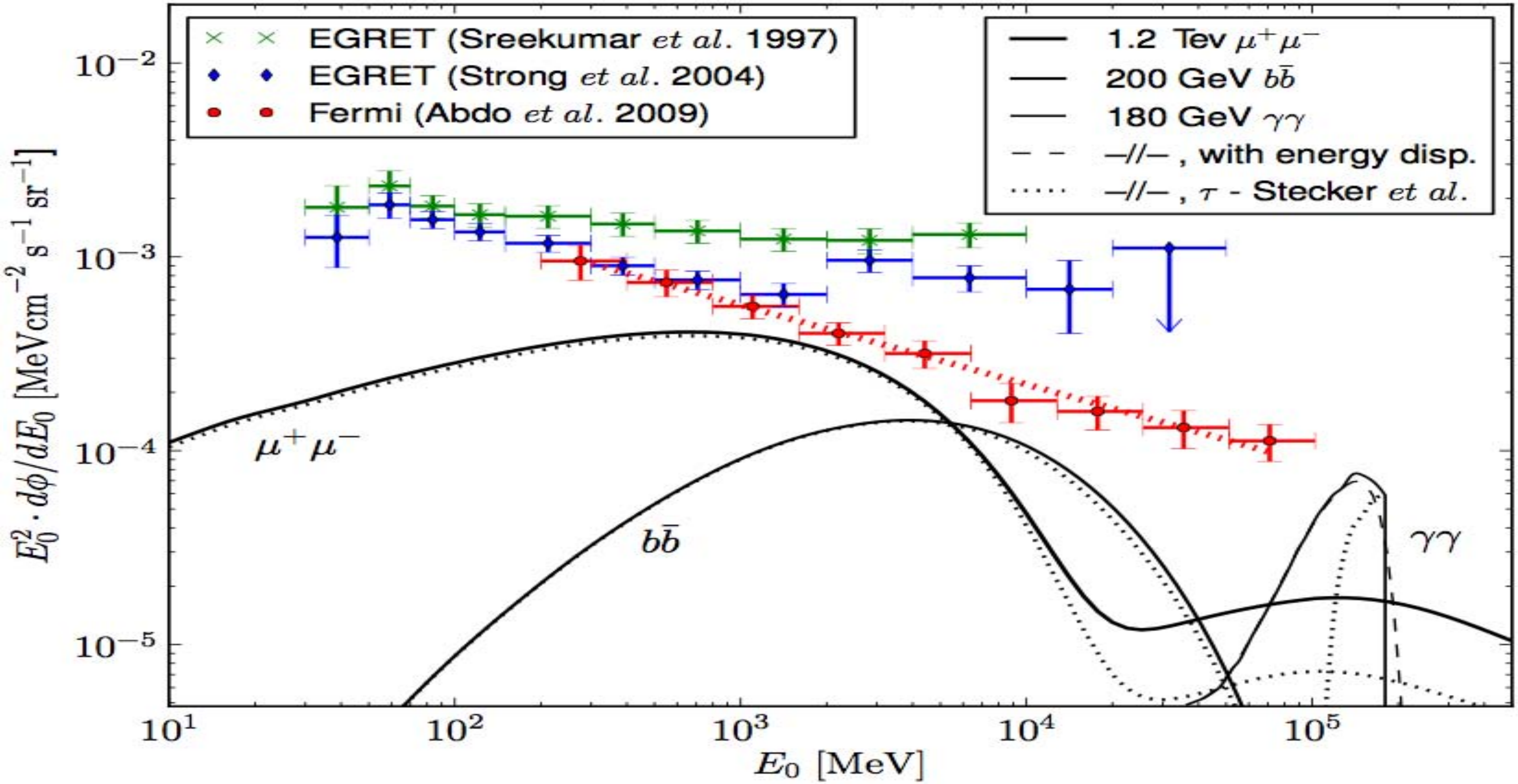
	Flux, E>100 MeV	spectral index
Fermi LAT	**1.03 +/- 0.17**	**2.41 +/- 0.05**
EGRET (Sreekumar et al., 1998)	1.45 +/- 0.05	2.13 +/- 0.03
EGRET (Strong et al. 2004)	1.11 +/- 0.10	
LAT + resolved sources below EGRET sensitivity	1.19 +/- 0.18	2.37 +/- 0.05
	x 10^{-5} cm^{-2} s^{-1} sr^{-1}	

extragalactic gamma-ray spectrum



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

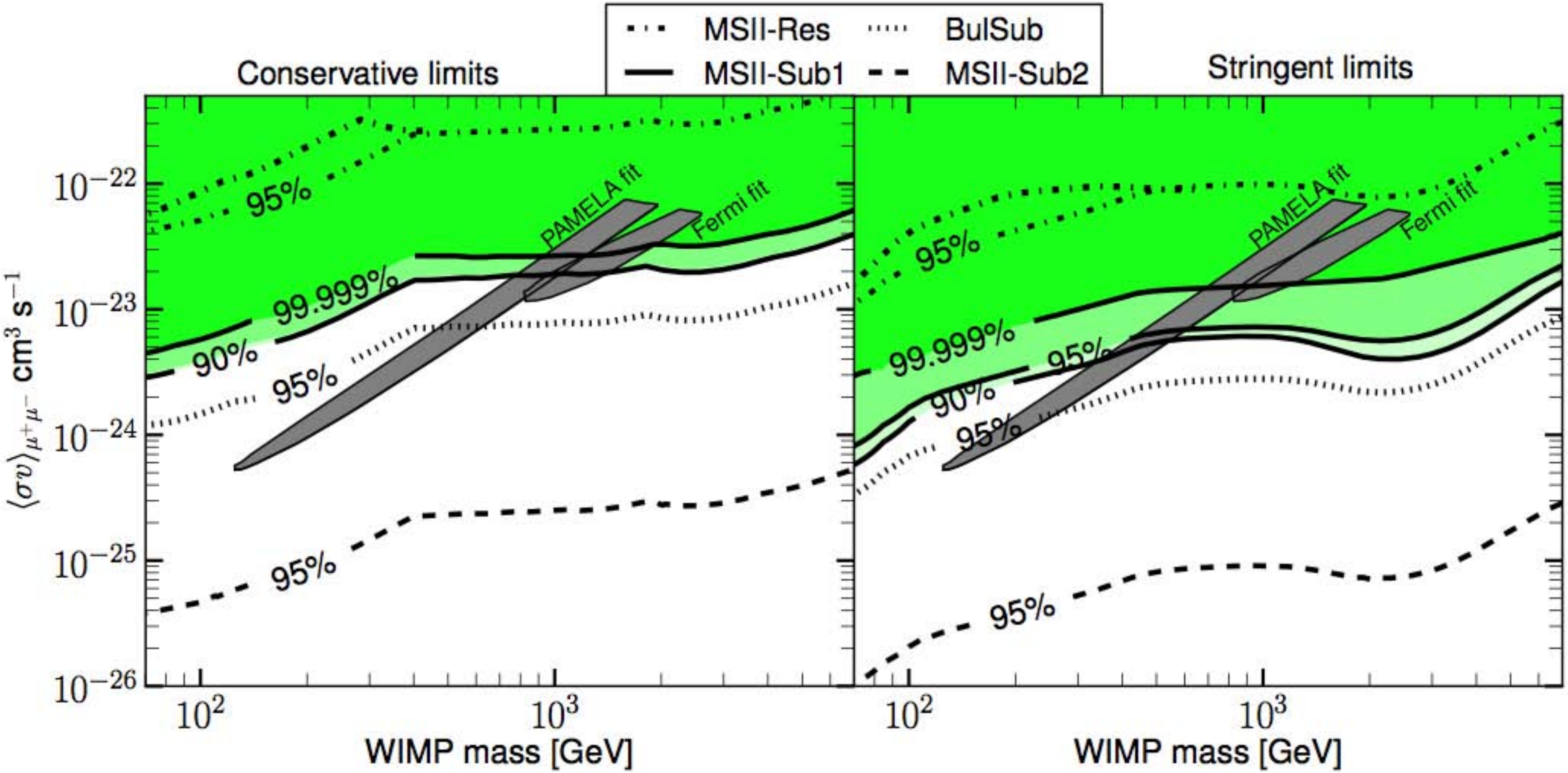
extragalactic gamma-ray spectrum



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

others possible contributions to the extragalactic gamma-ray spectrum

extragalactic gamma-ray spectrum

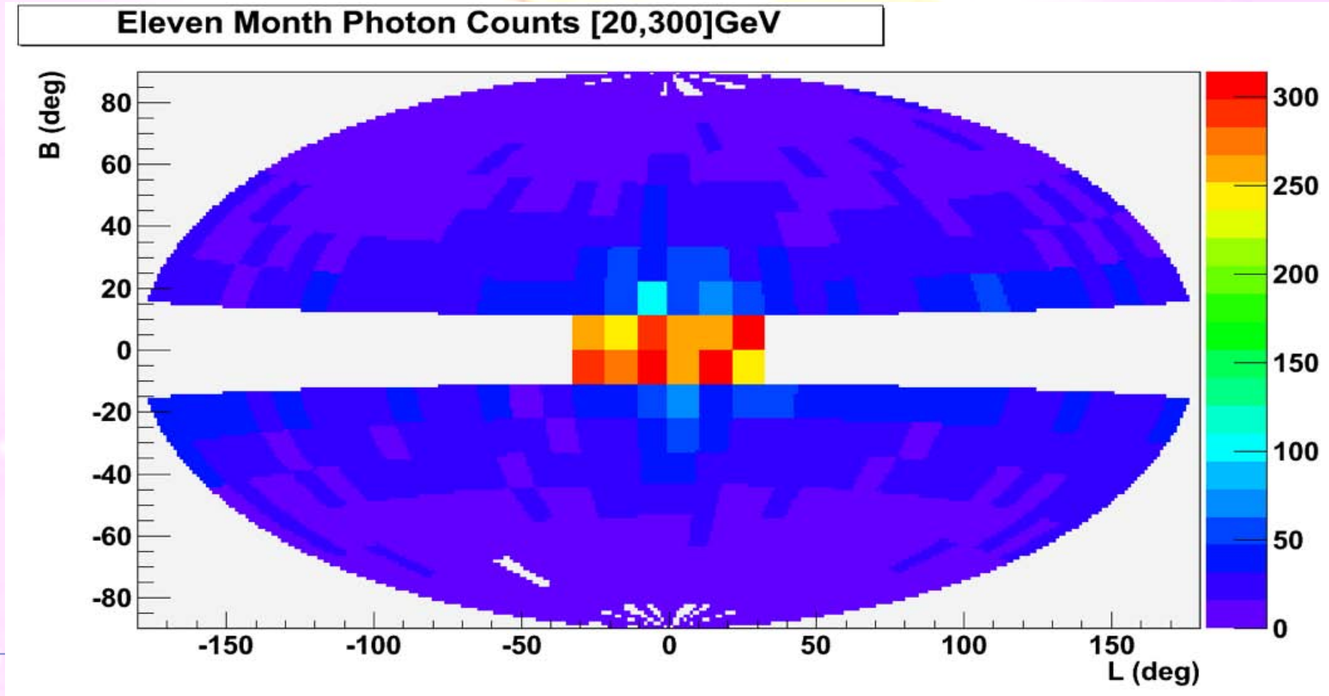


Fermi Coll. JCAP 04 (2010) 014 arXiv:1002.4415

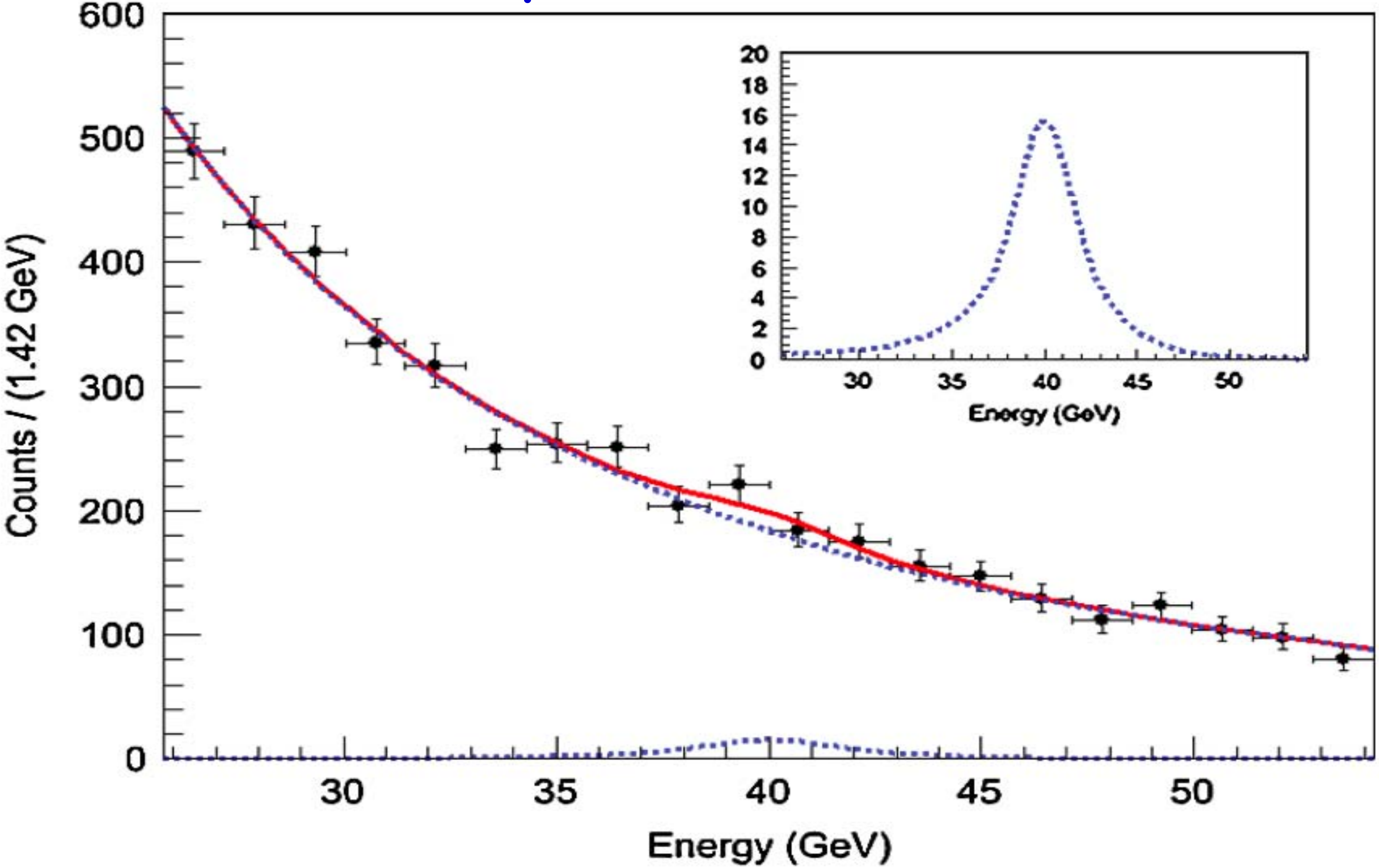
limits on dark matter annihilation into $\mu+\mu-$ final states

Search for Spectral Gamma Lines

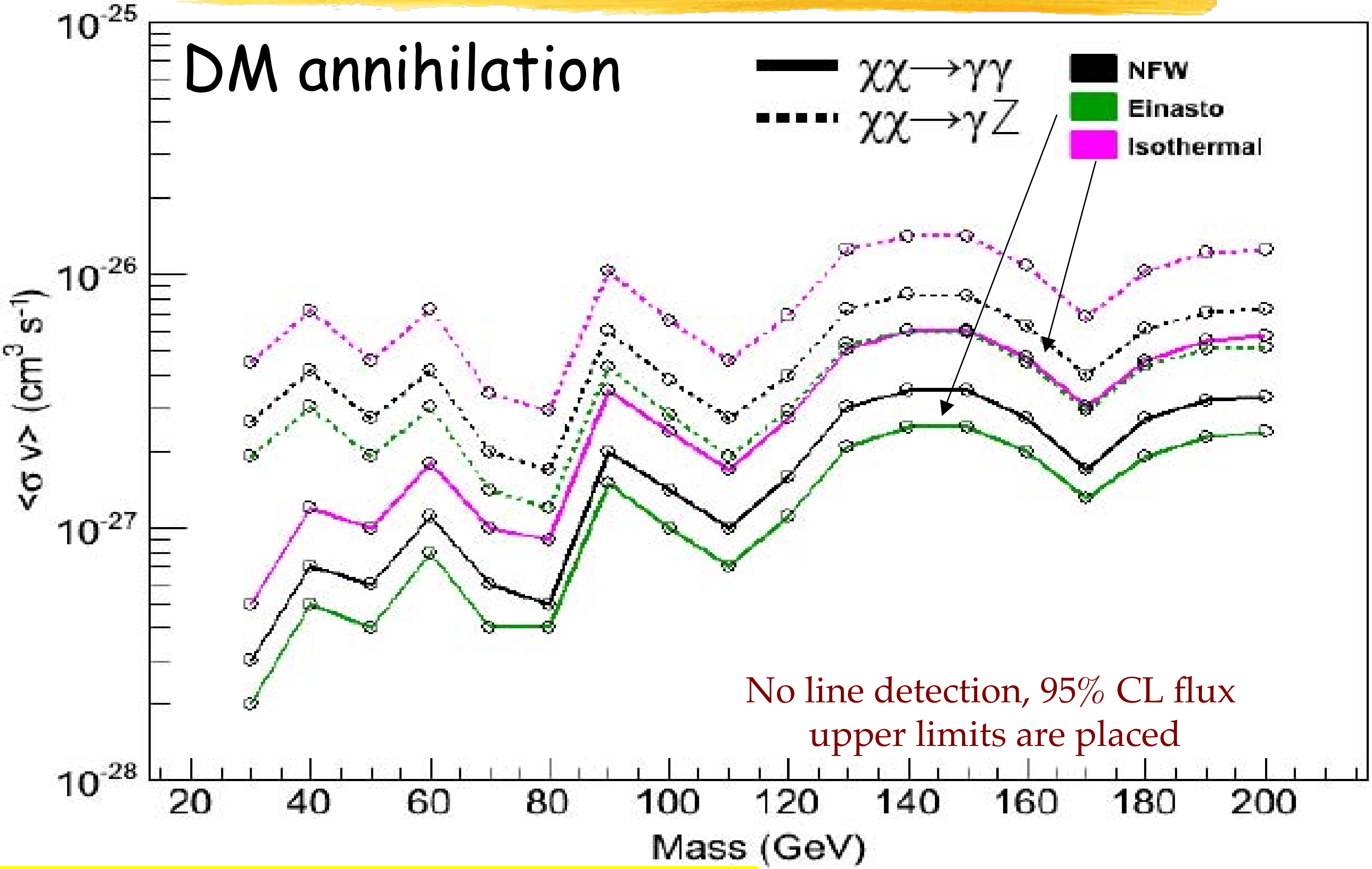
- Smoking gun signal of dark matter
- Search for lines in the first 11 months of Fermi data (30-200 GeV en.range)
- Search region |b|>10° and 30° around galactic center
- For the region within 1°of the GC, no point source removal was done as this would have removed the GC
- For the remaining part of 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

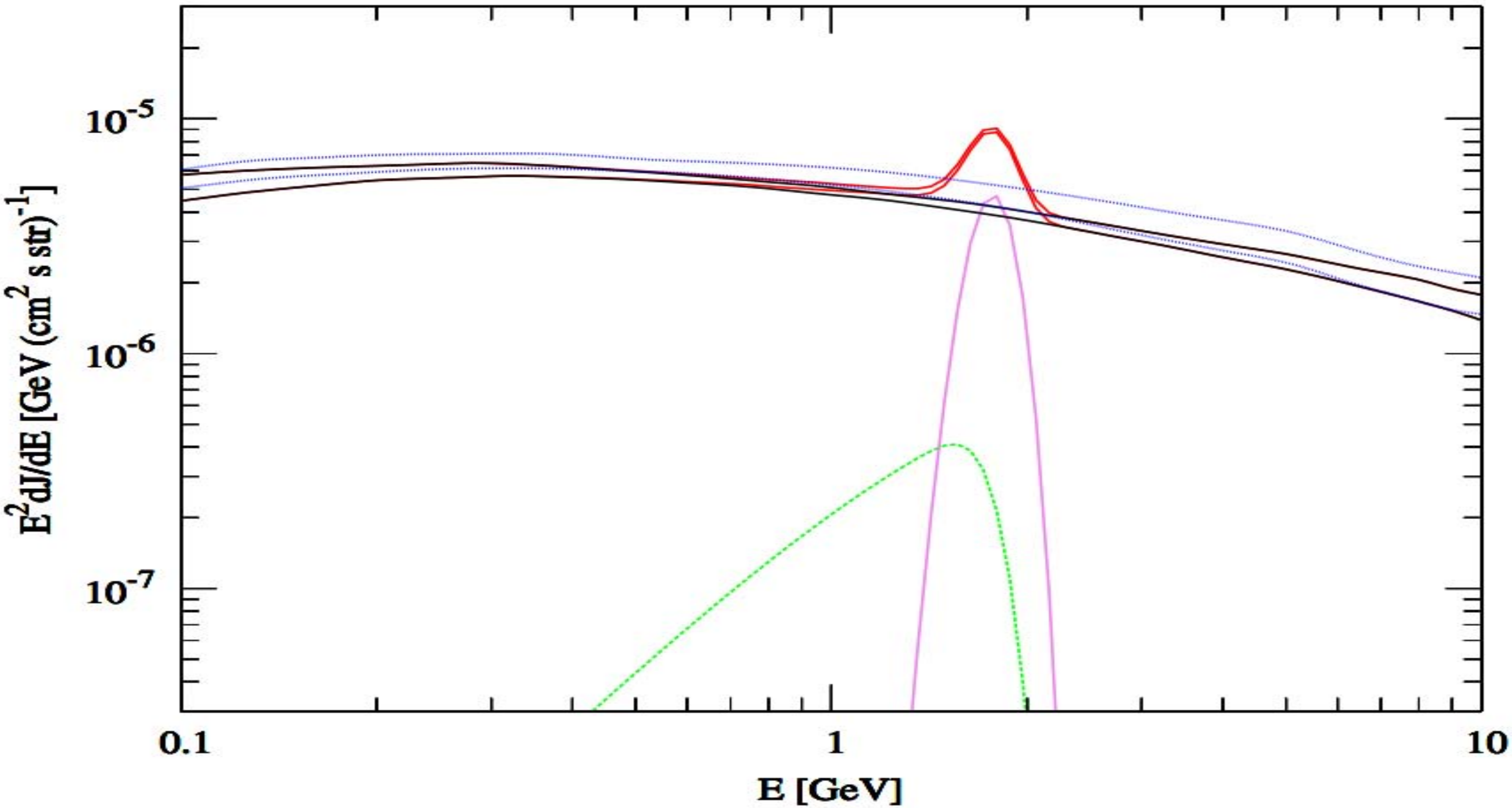


Search for Spectral Gamma Lines



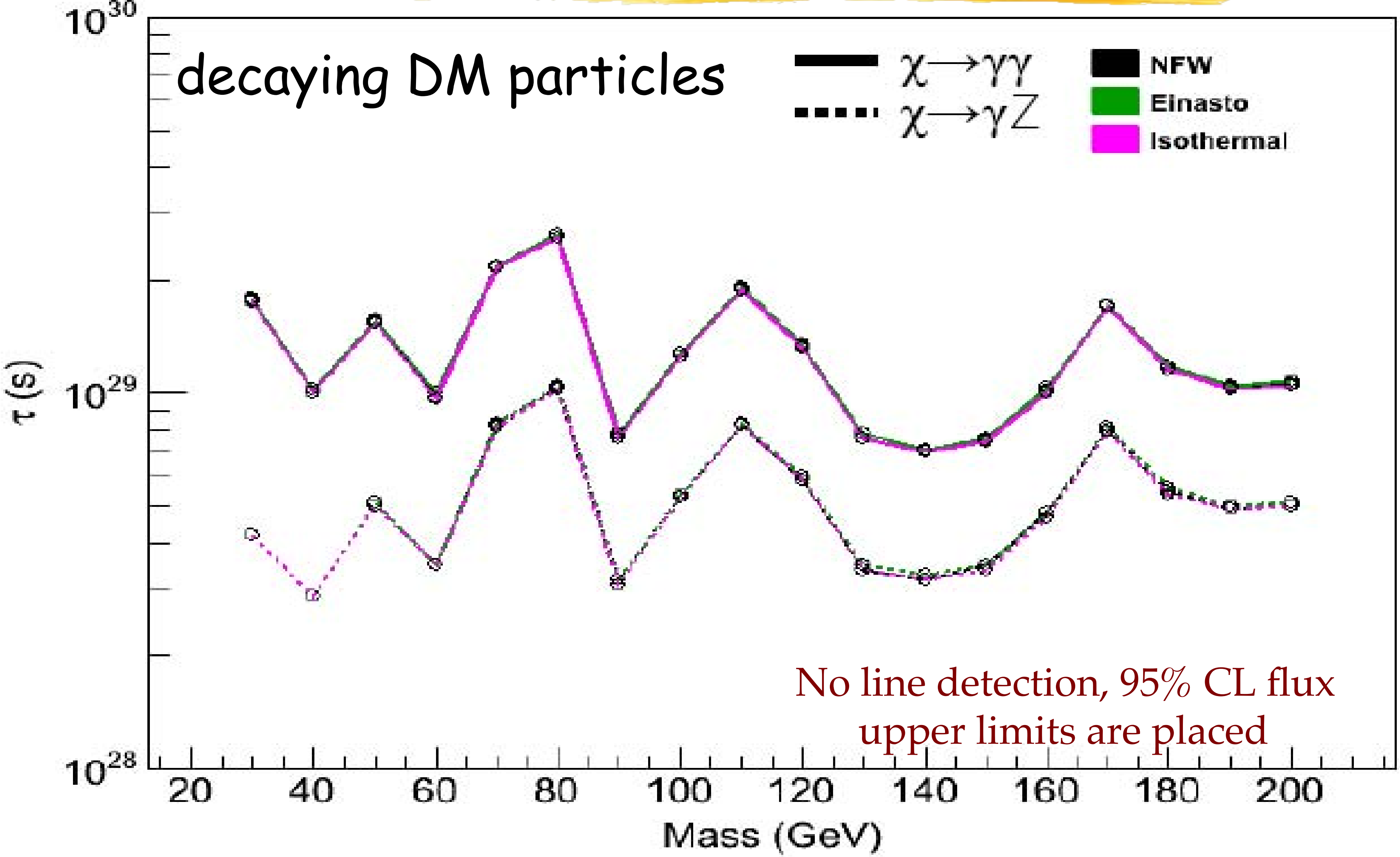
Fermi LAT Coll. PRL 104, 091302-08 (2010), arXiv:1001.4836

Gamma-ray detection from gravitino dark matter decay in the μνSSM

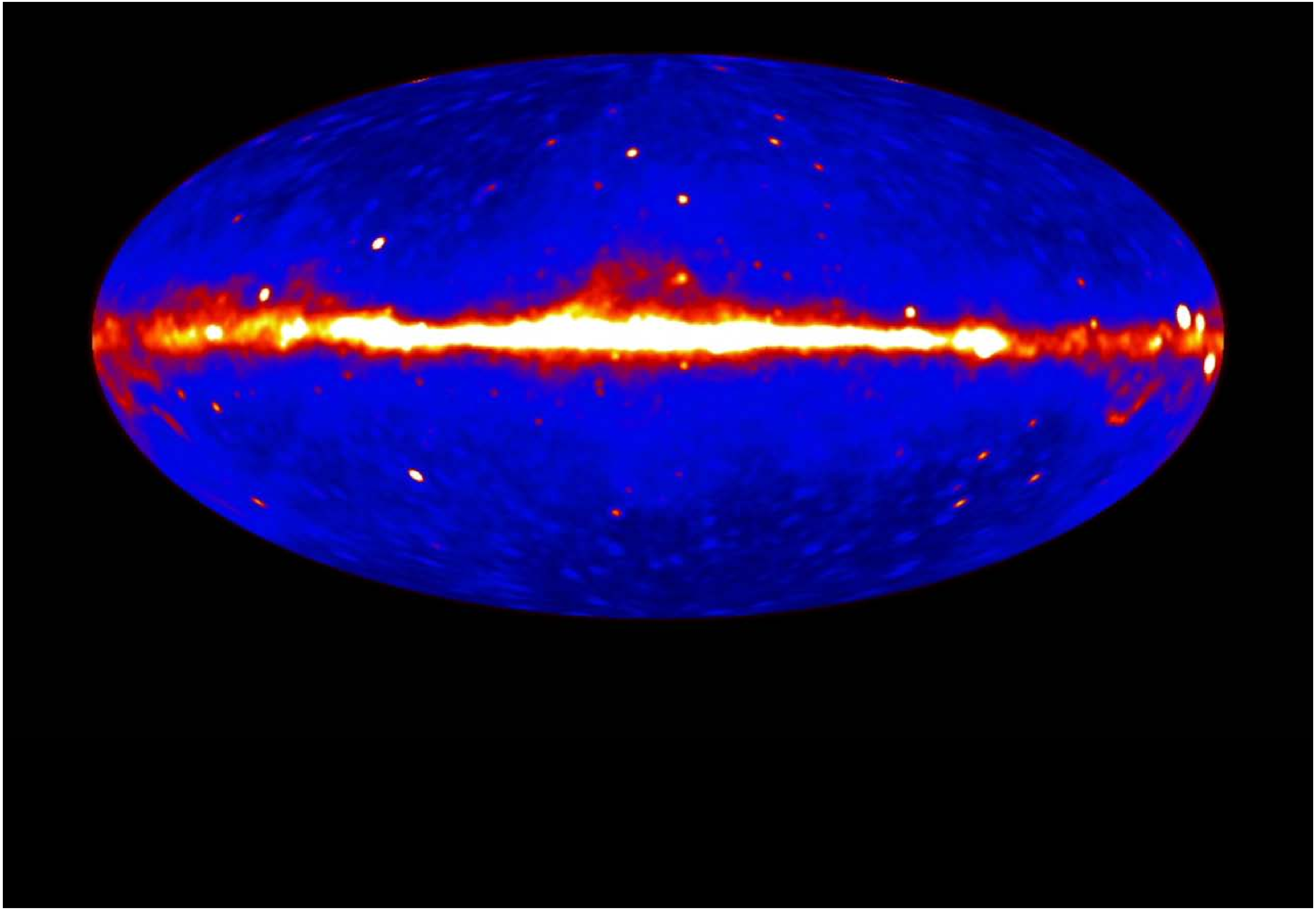


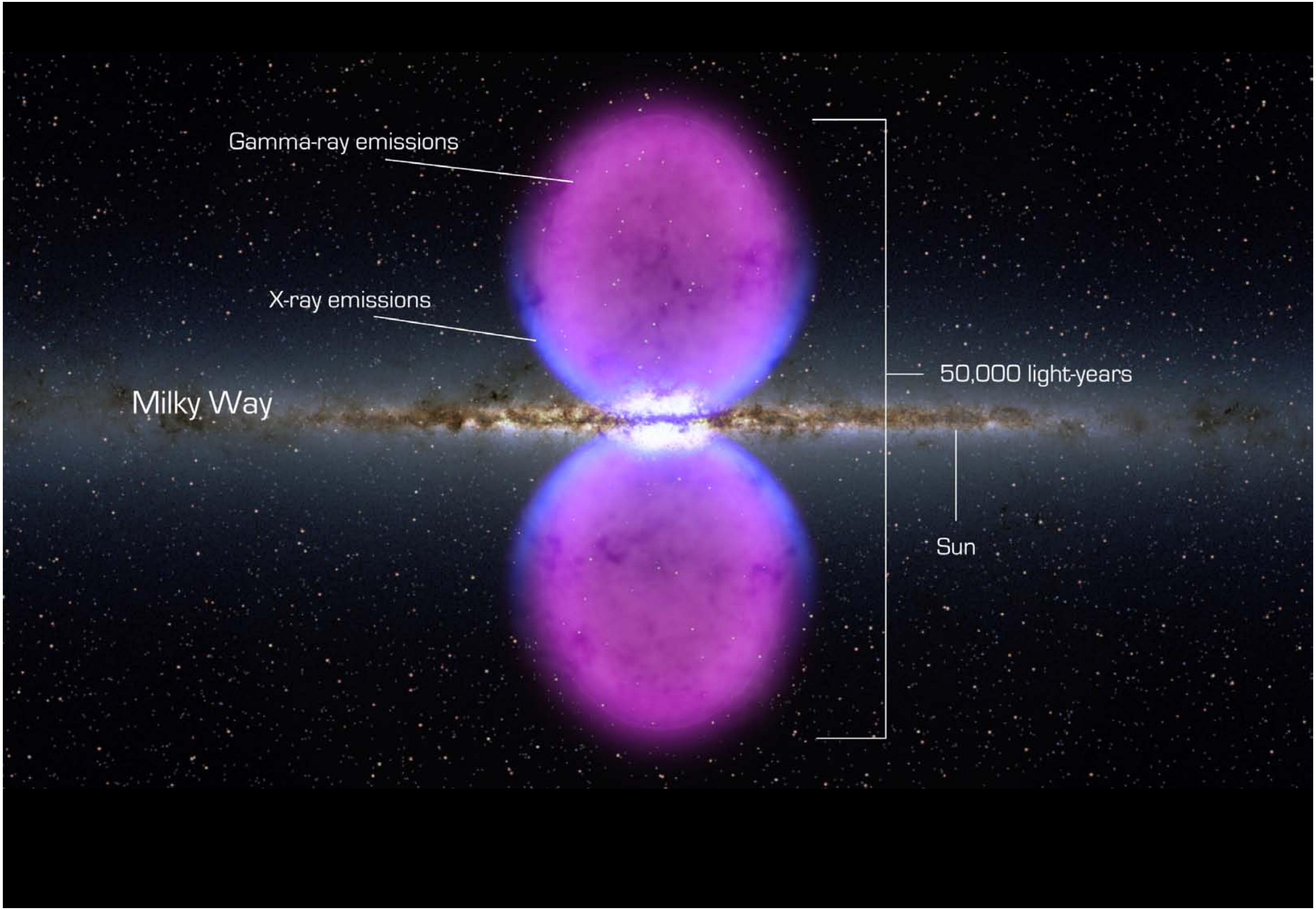
Ki-Young Choi, Daniel E.Lopez-Fogliani, Carlos Munoz, Roberto Ruiz de Austri, arXiv:0906.3681

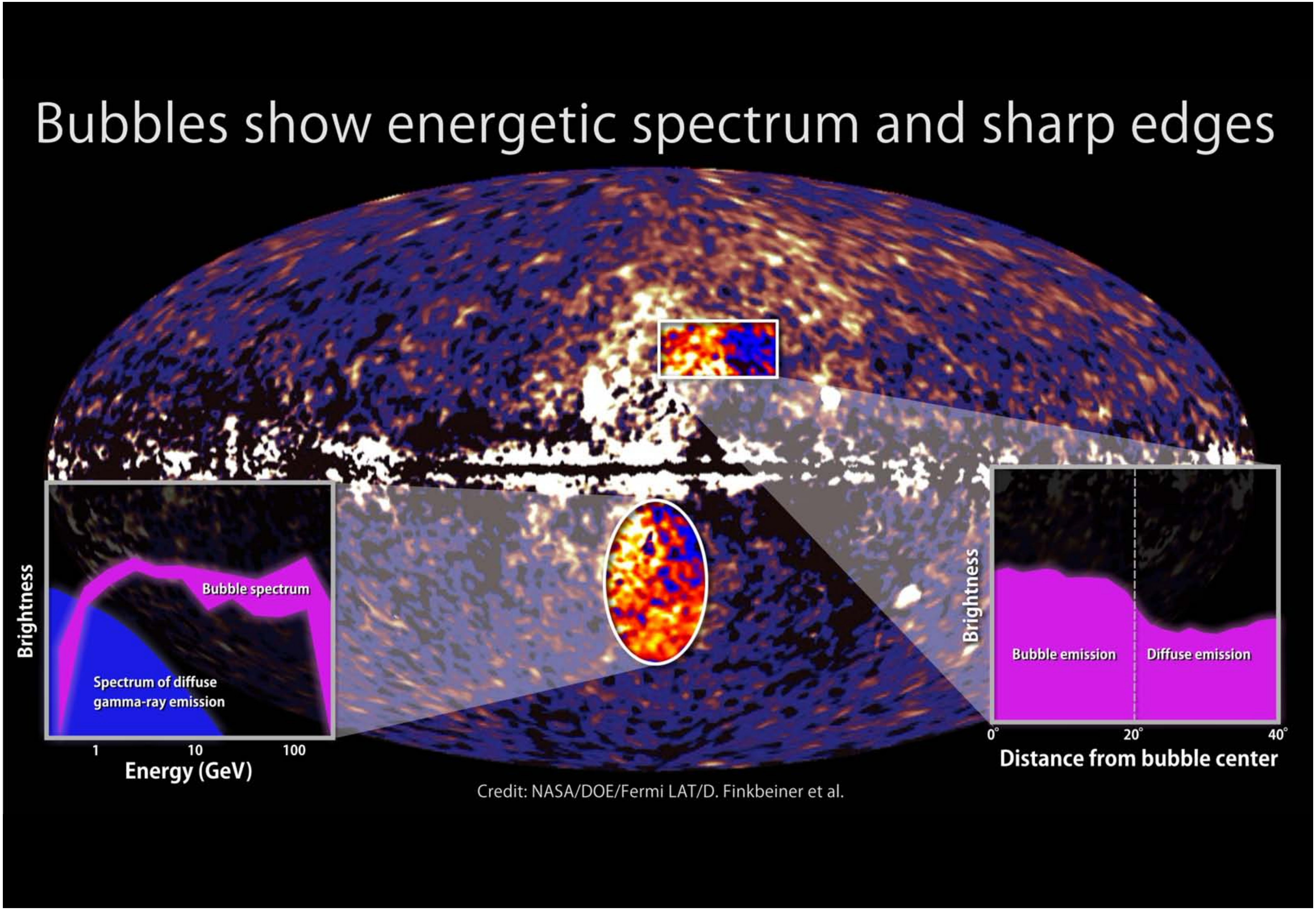
Search for Spectral Gamma Lines



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




Gamma-ray emissions
X-ray emissions
50,000 light-years
Milky Way
Sun



Bubbles show energetic spectrum and sharp edges
Brightness
Bubble spectrum
Spectrum of diffuse
gamma-ray emission
1
10
100
Energy (GeV)
Brightness
Bubble emission
Diffuse emission
0°
20°
40°
Distance from bubble center
Credit: NASA/DOE/Fermi LAT/D. Finkbeiner et al.

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)

New Data is Forthcoming

Electron Spectrum:

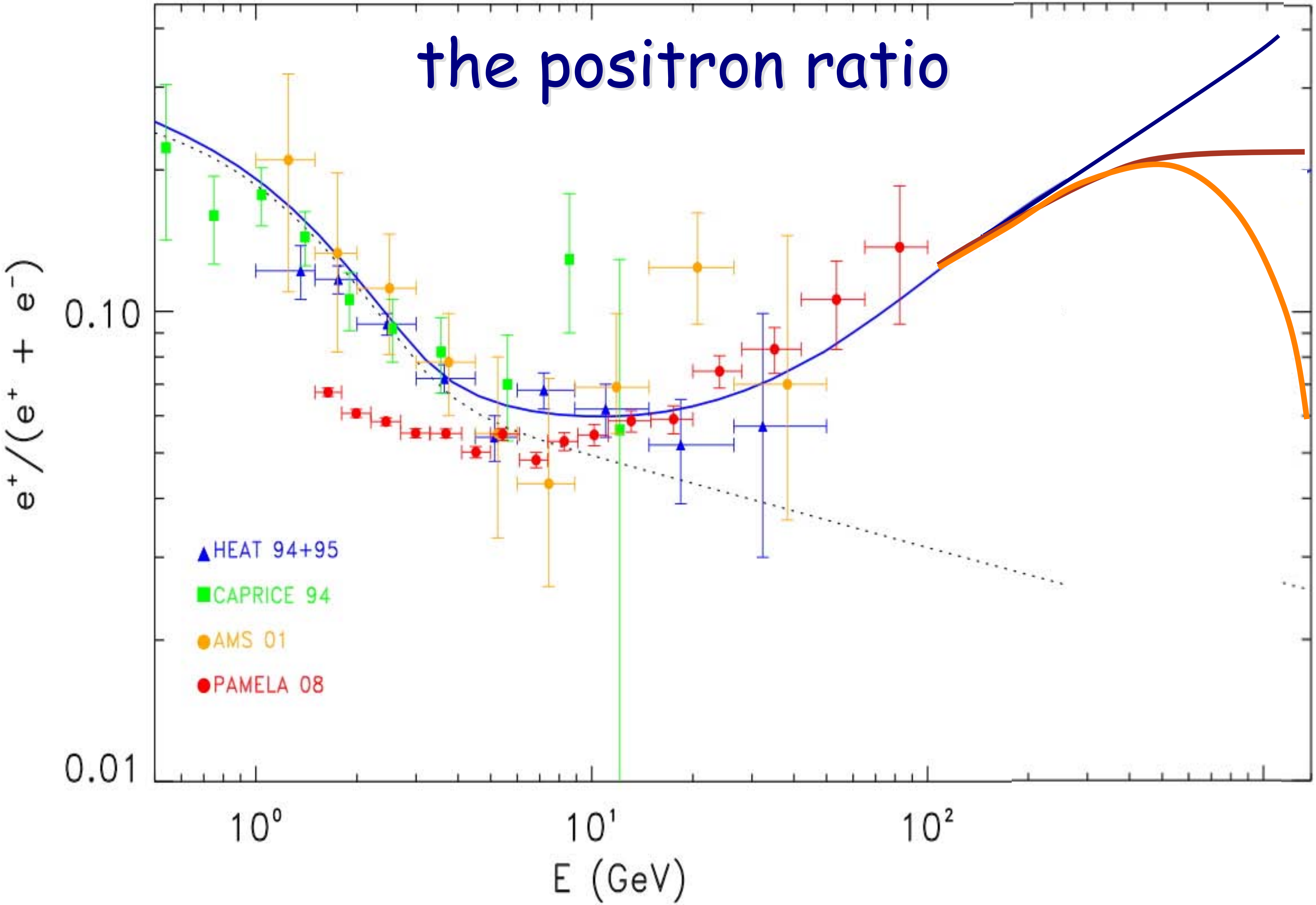
- **PAMELA & FERMI (GLAST)** (taking data in space);
- **ATIC-4** (had successful balloon flight,under analysis);
- **CREST** (new balloon payload under development);
- **AMS-02** (launch date TBD);
- **CALET** (proposed for ISS);
- **ECAL** (proposed balloon experiment).

Comparison of High-Energy Electron Missions

Mission	Upper Energy (TeV)	Collecting Power ($m^2 sr$)	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)

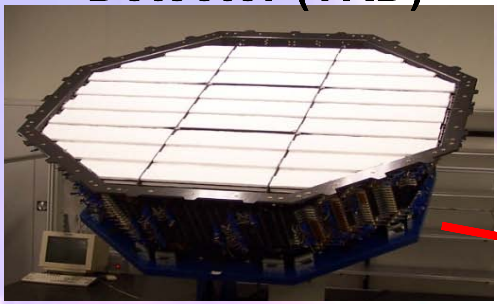
Positron / Electron Separation: **PAMELA & AMS-02**

the positron ratio

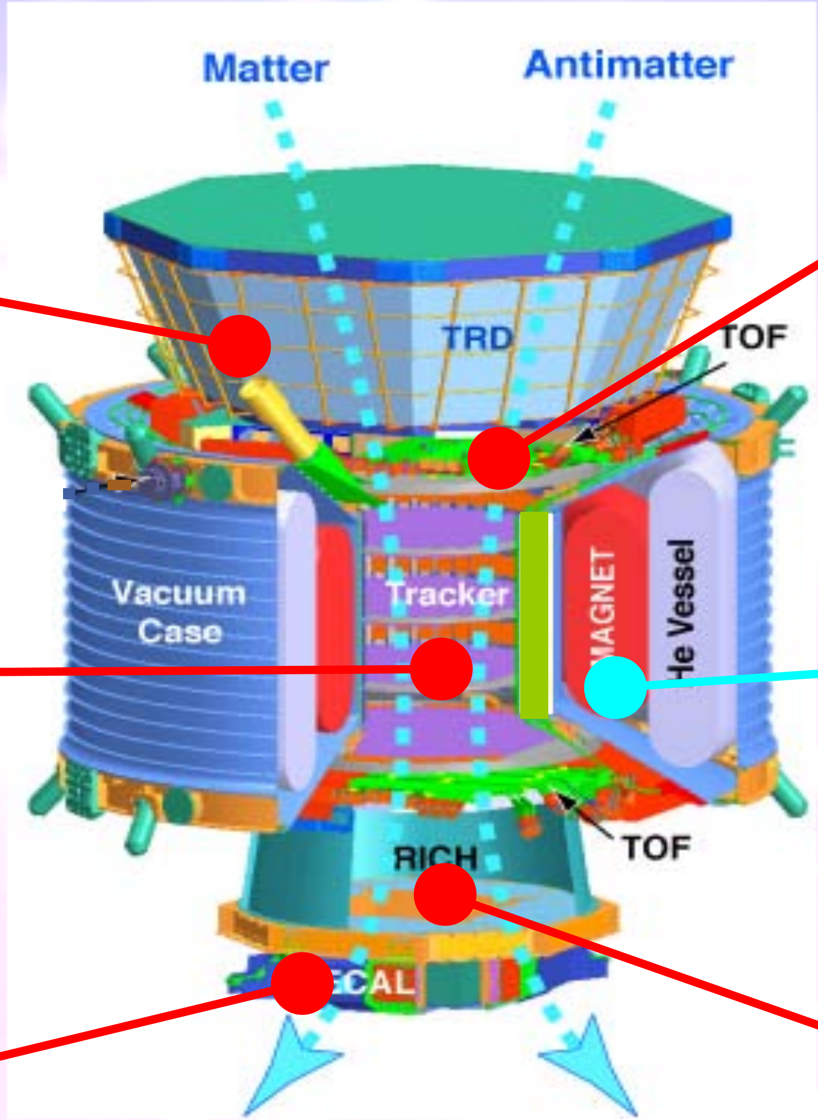


AMS Detector on ISS

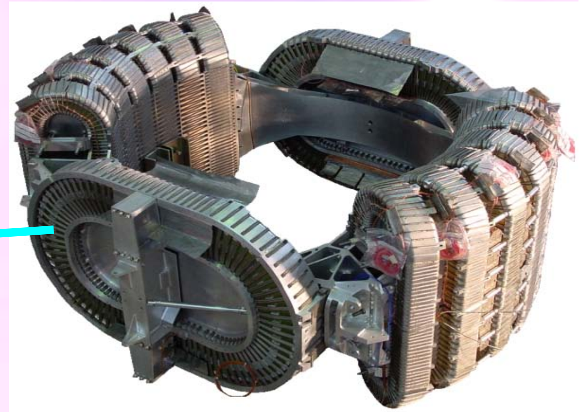
Transition Radiation Detector (TRD)



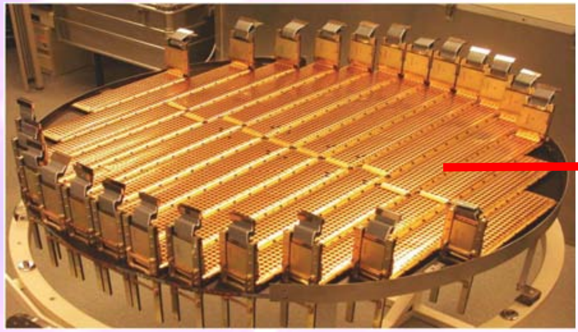
Time of Flight Detector (TOF)



Magnet

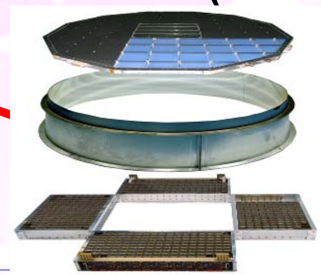


Silicon Tracker

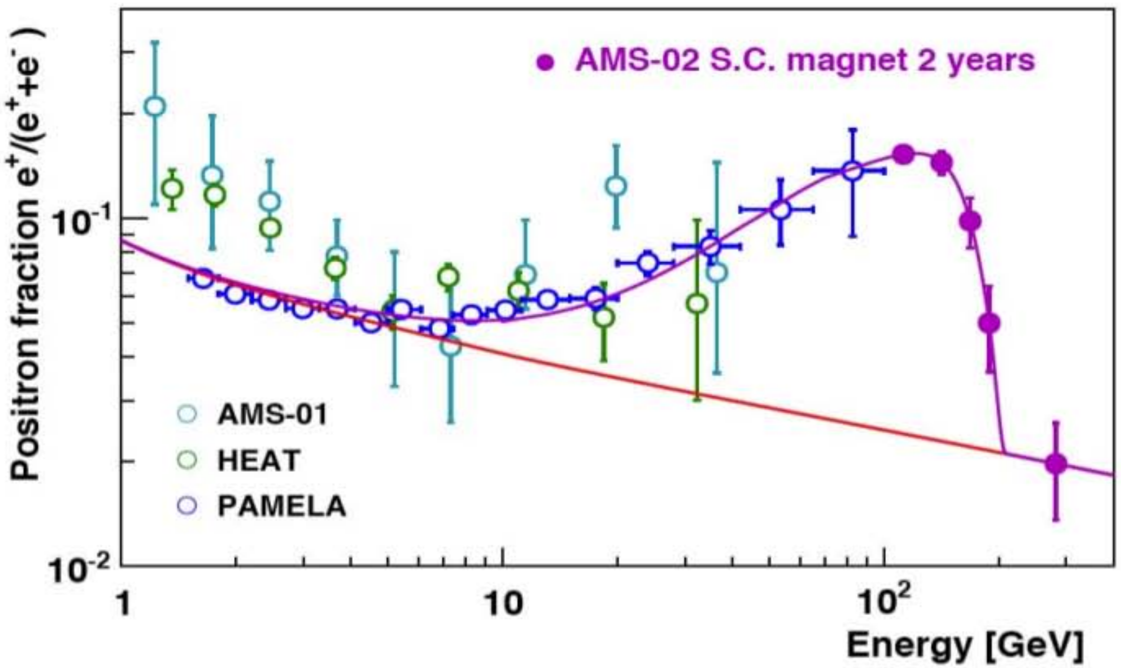


Electromagnetic Calorimeter (ECAL)

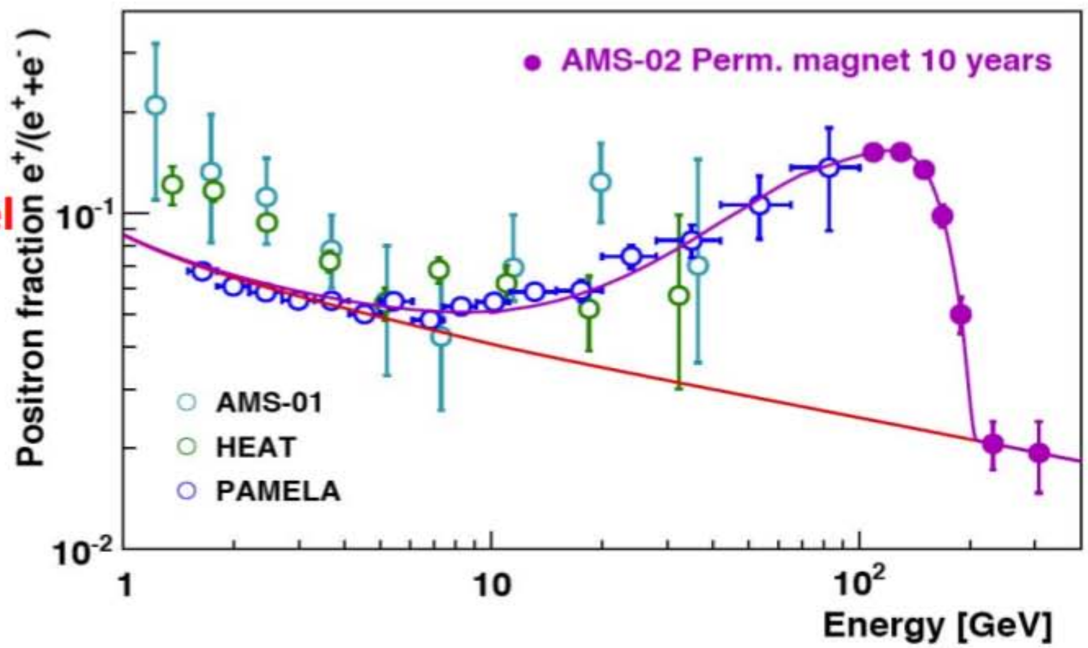
Ring Image Cerenkov Counter (RICH)



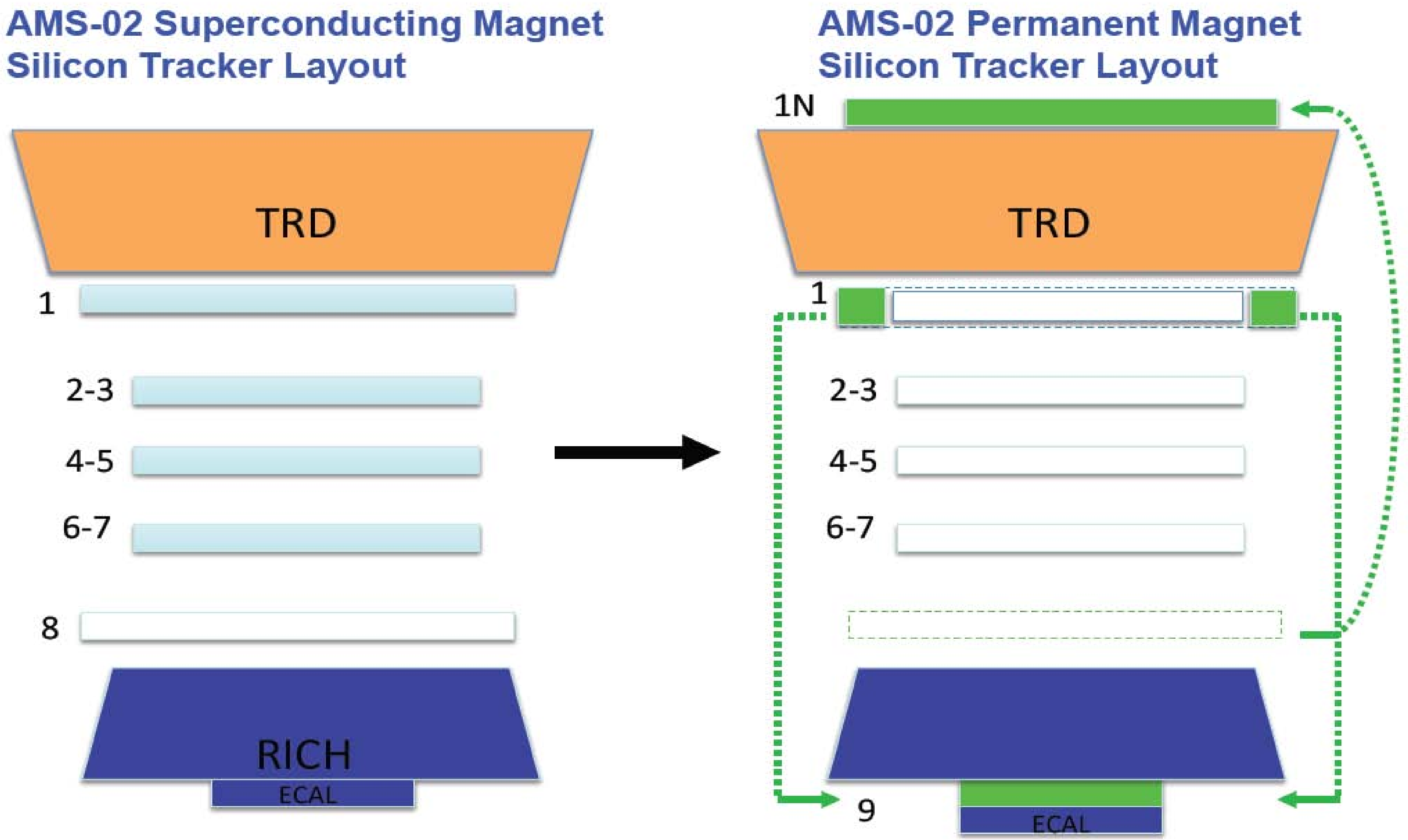
Size: 3m x 3m x 3m
Weight: 7 tons



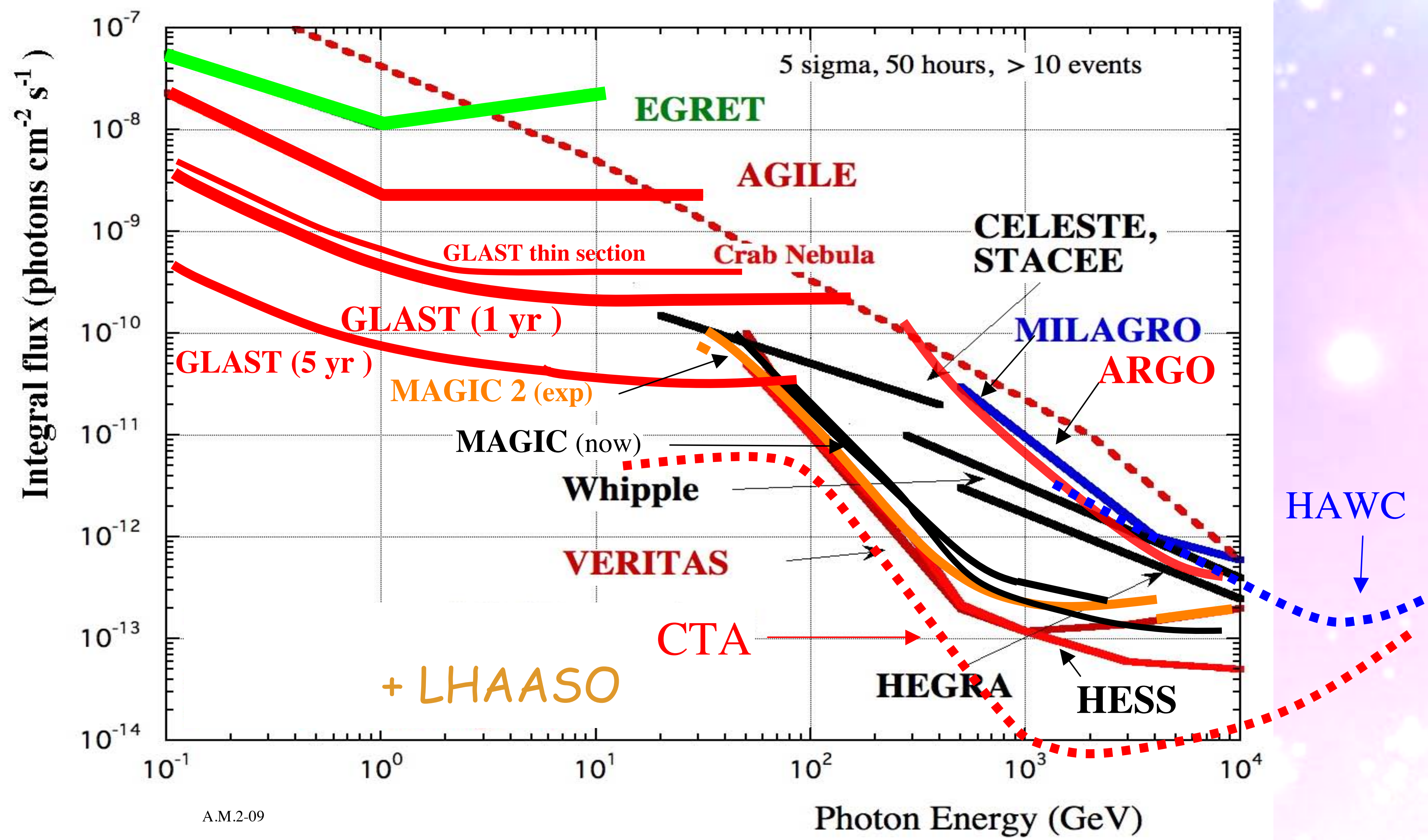
AMS sensitivity esponse to a 200 GeV Dark Matter candidate in the e+e- channel



AMS-02 new configuration



Sensitivity of γ-ray detectors



High galactic latitudes (background Φ_b=2 10^{-5} γ cm^{-2} s^{-1} sr^{-1} $(100\ MeV/E)^{1.1}$). Cerenkov telescopes sensitivities (Veritas, MAGIC, Whipple, Hess, Celeste, Stacee, Hegra) are for 50 hours of observations. Large field of view detectors sensitivities (AGILE, GLAST, Milagro, ARGO) are for 1 year of observation.

NEXT FERMI SYMPOSIUM
9-12 May 2011
in Rome

you are all invited !

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

thank you !