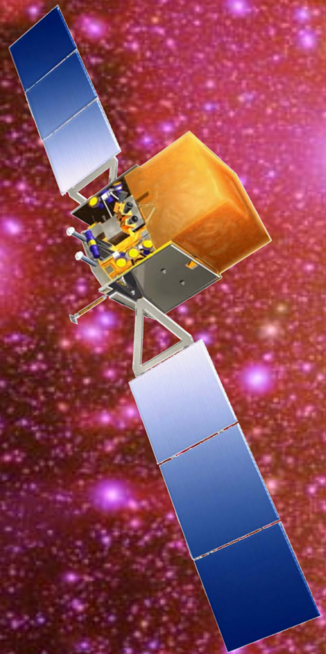
Search for Dark Matter in Space



Aldo Morselli

INFN Roma Tor Vergata

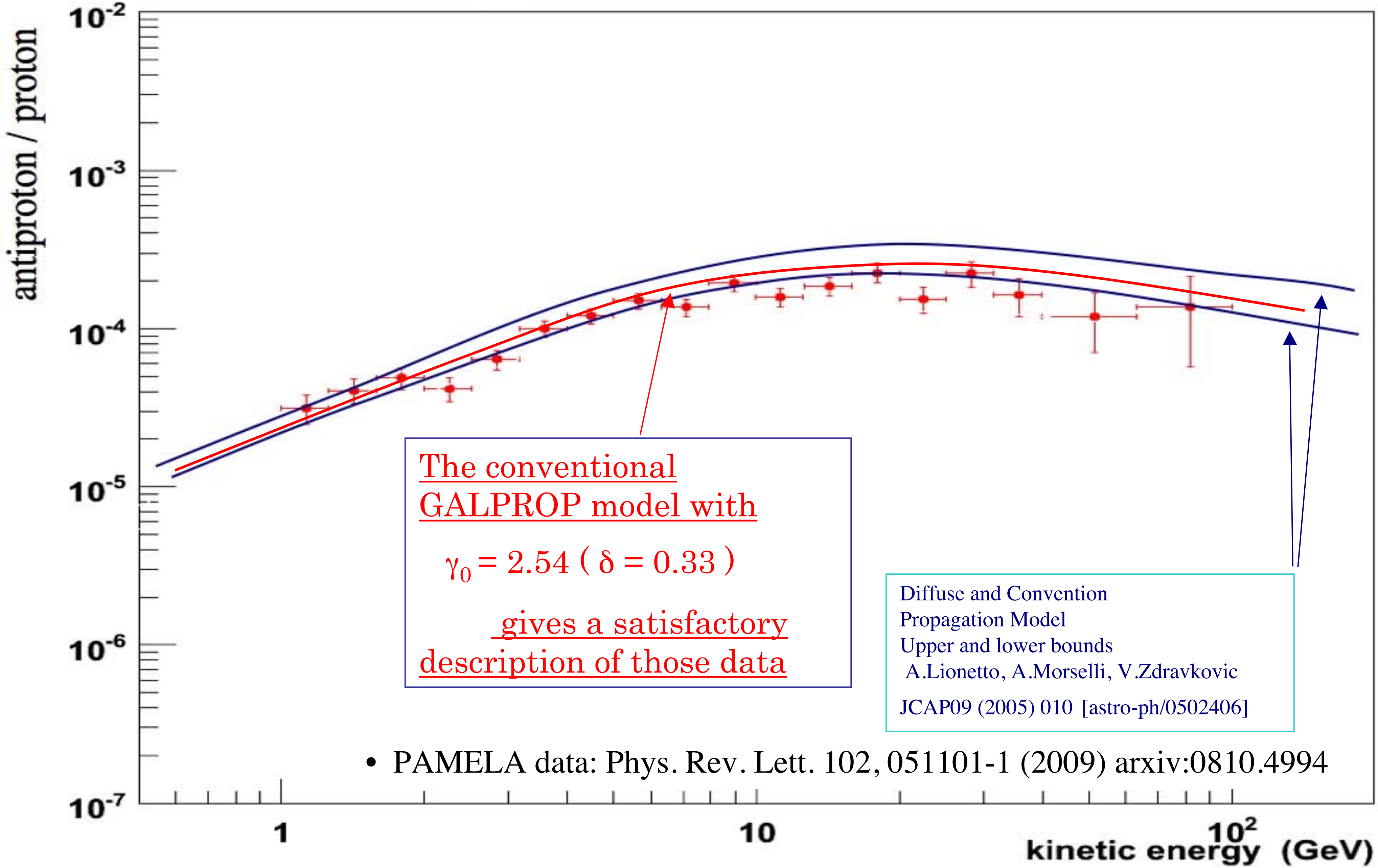
Informal Monday afternoon discussion

GGI

- ~ 4 years from PAMELA launch

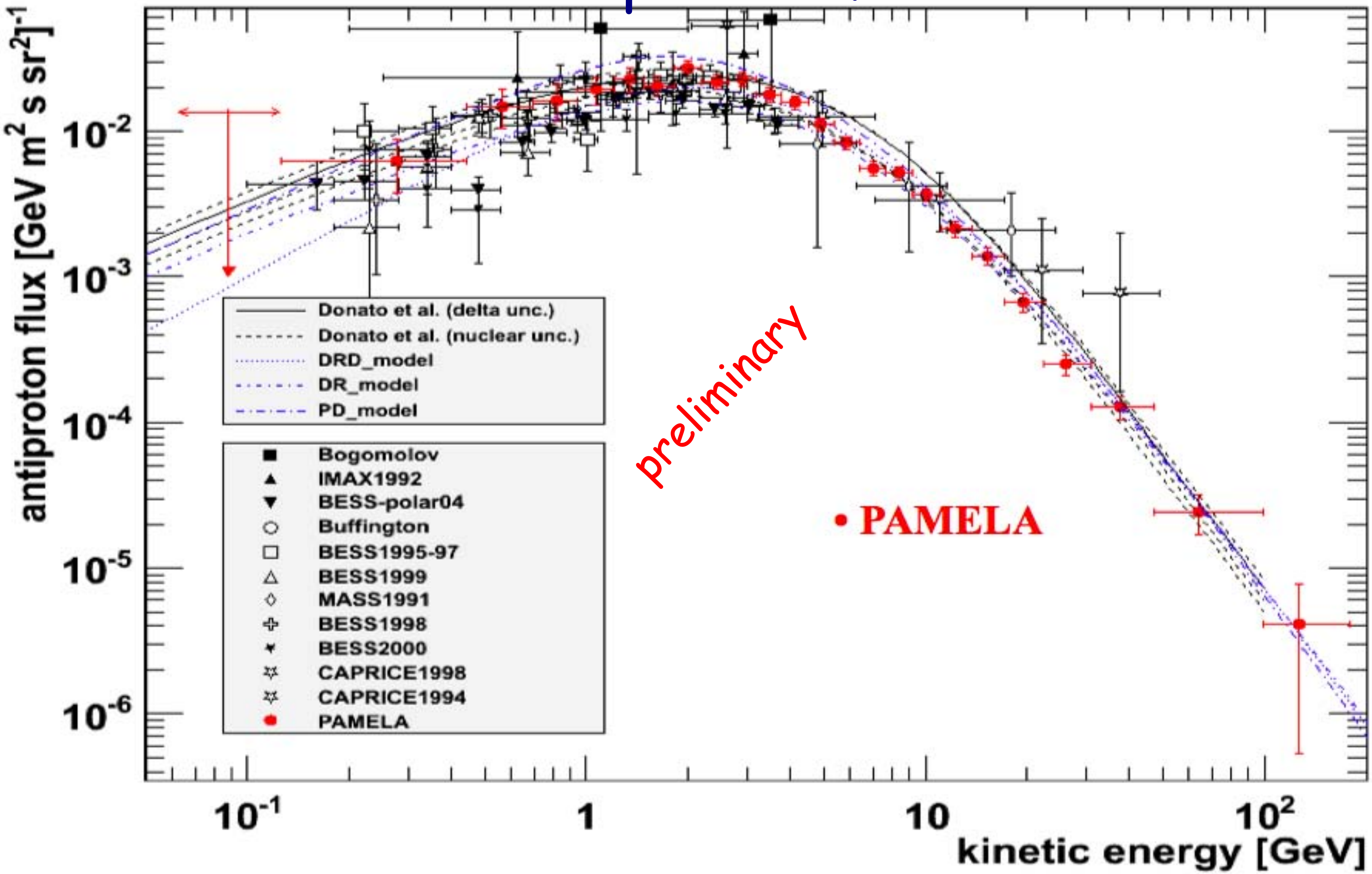
- Launched in orbit on June 15, 2006, on board of the DK1 satellite by a Soyuz rocket from the Bajkonour cosmodrom.

Antiproton-Proton Ratio

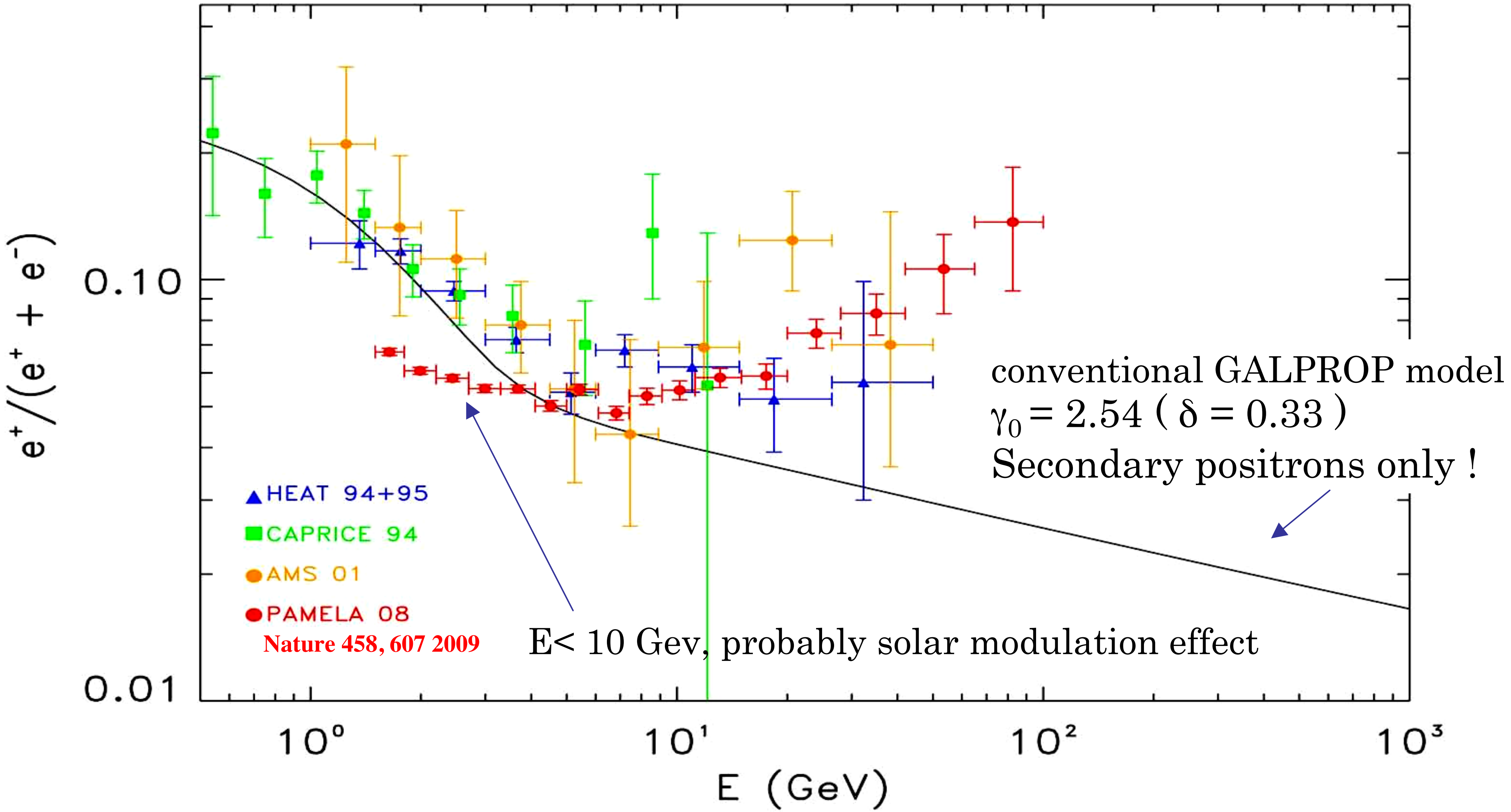


- PAMELA data: Phys. Rev. Lett. 102, 051101-1 (2009) arxiv:0810.4994

Antiproton flux



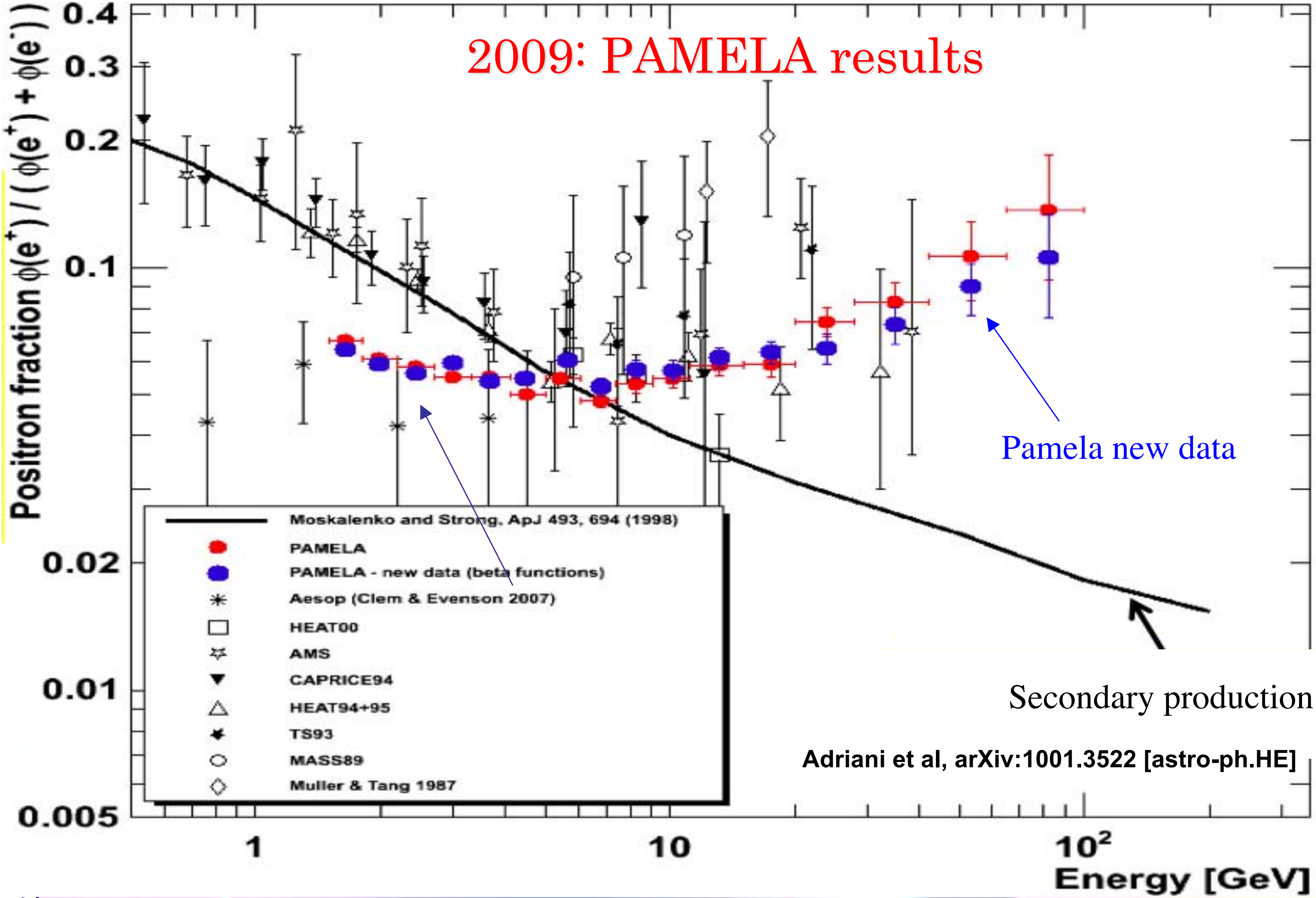
2009: PAMELA results



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

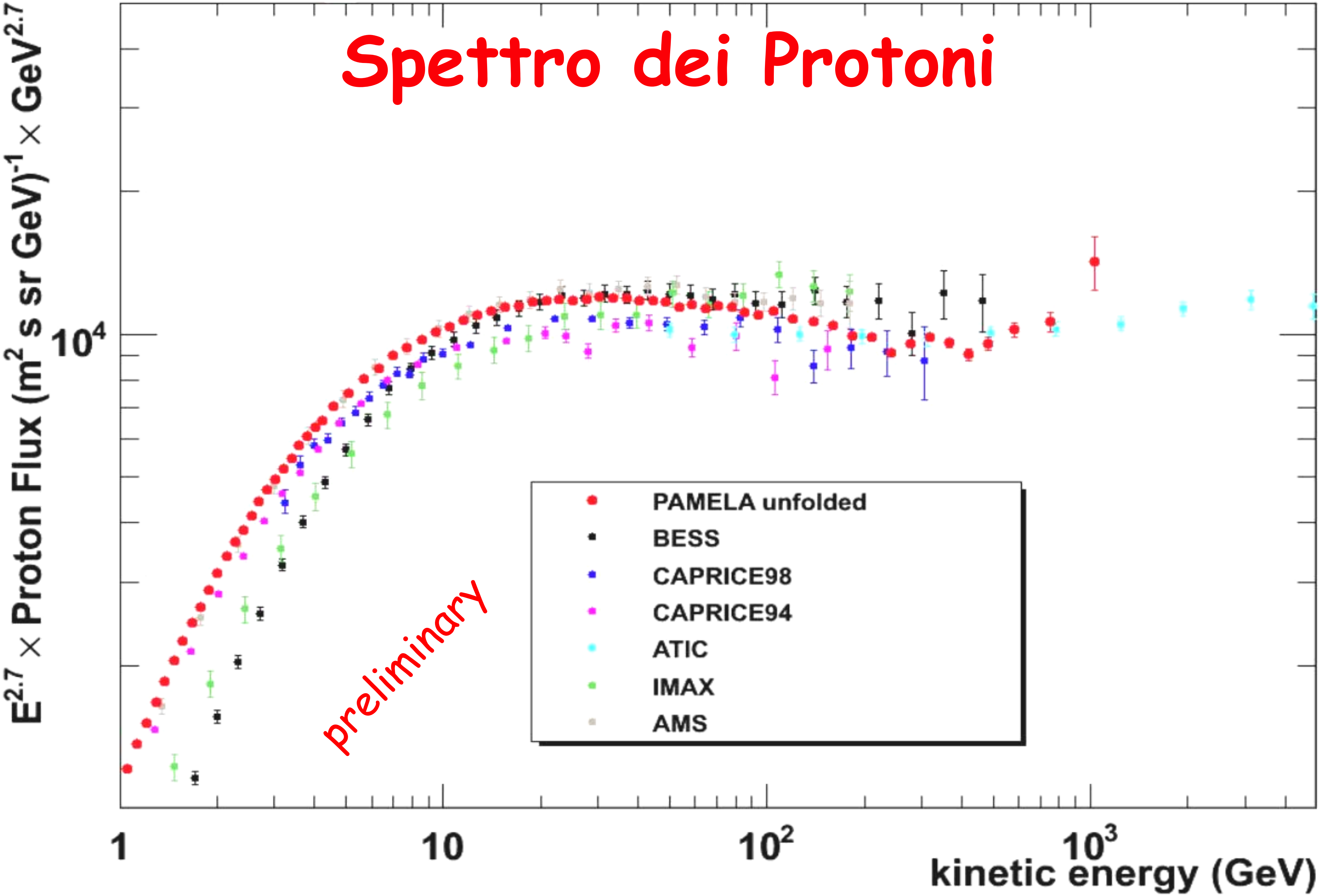
It improves only adopting very soft electron spectra (high γ_0)

2009: PAMELA results

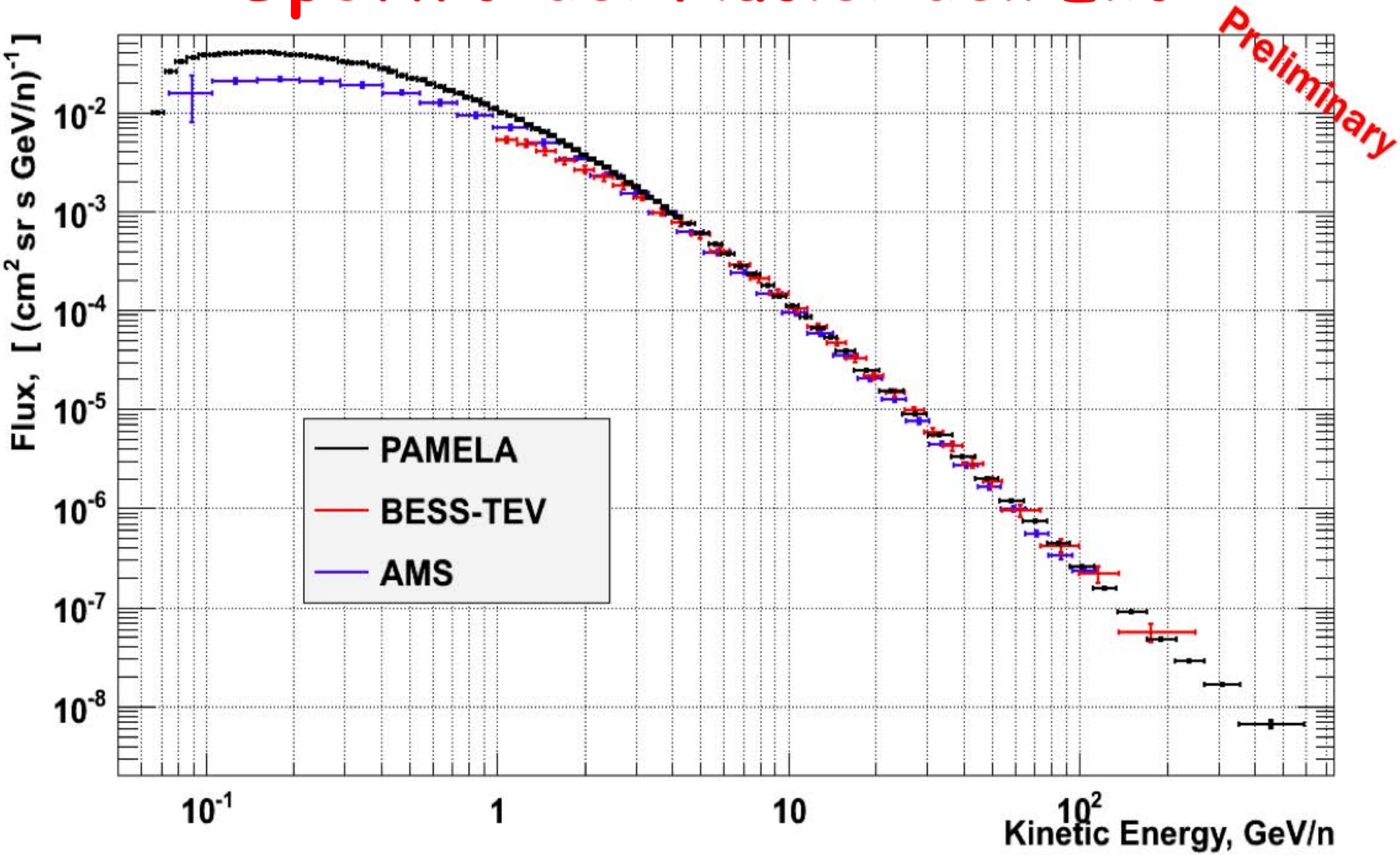


Adriani et al, arXiv:1001.3522 [astro-ph.HE]

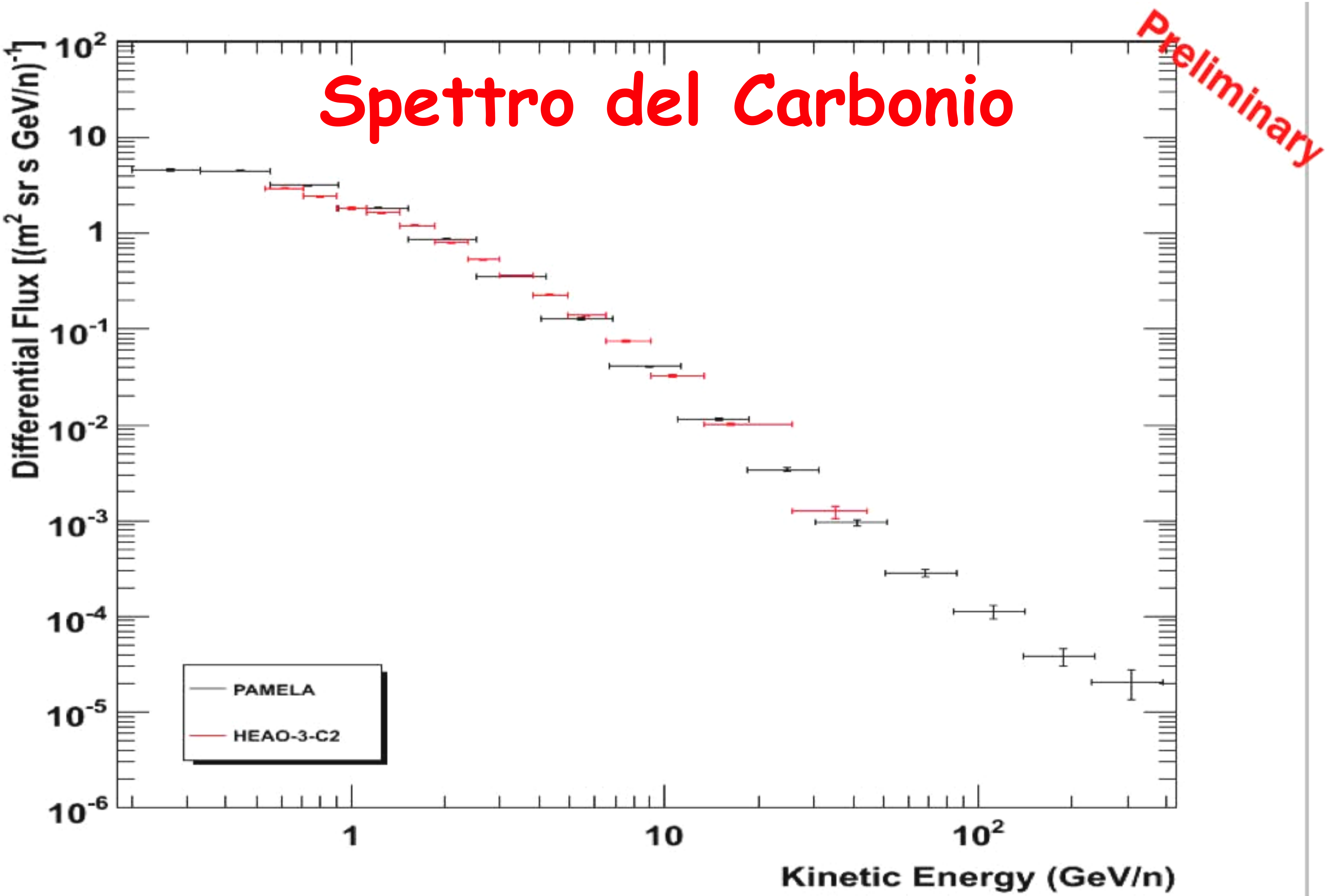
Spettro dei Protoni

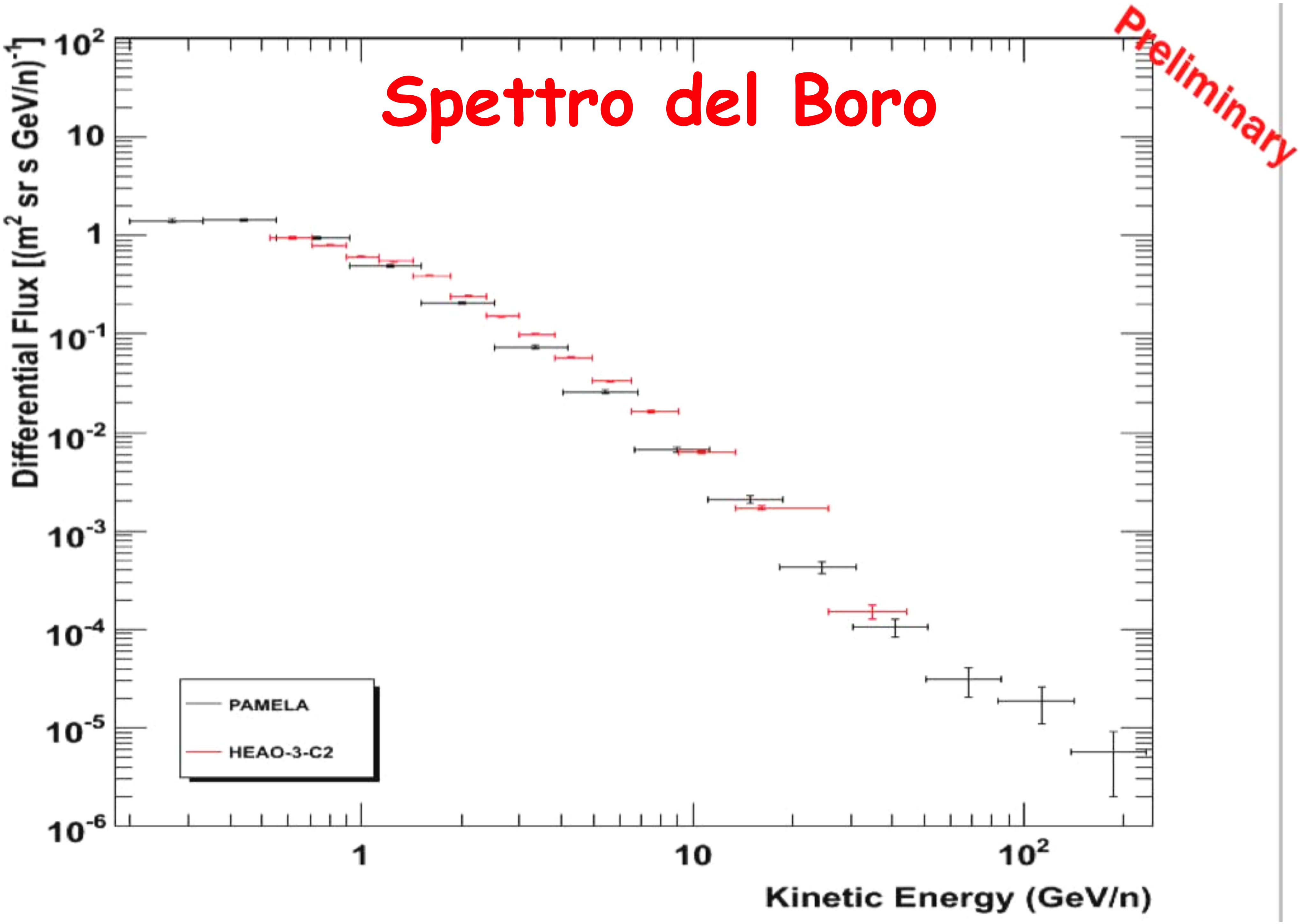


Spettro dei Nuclei dell'Elio



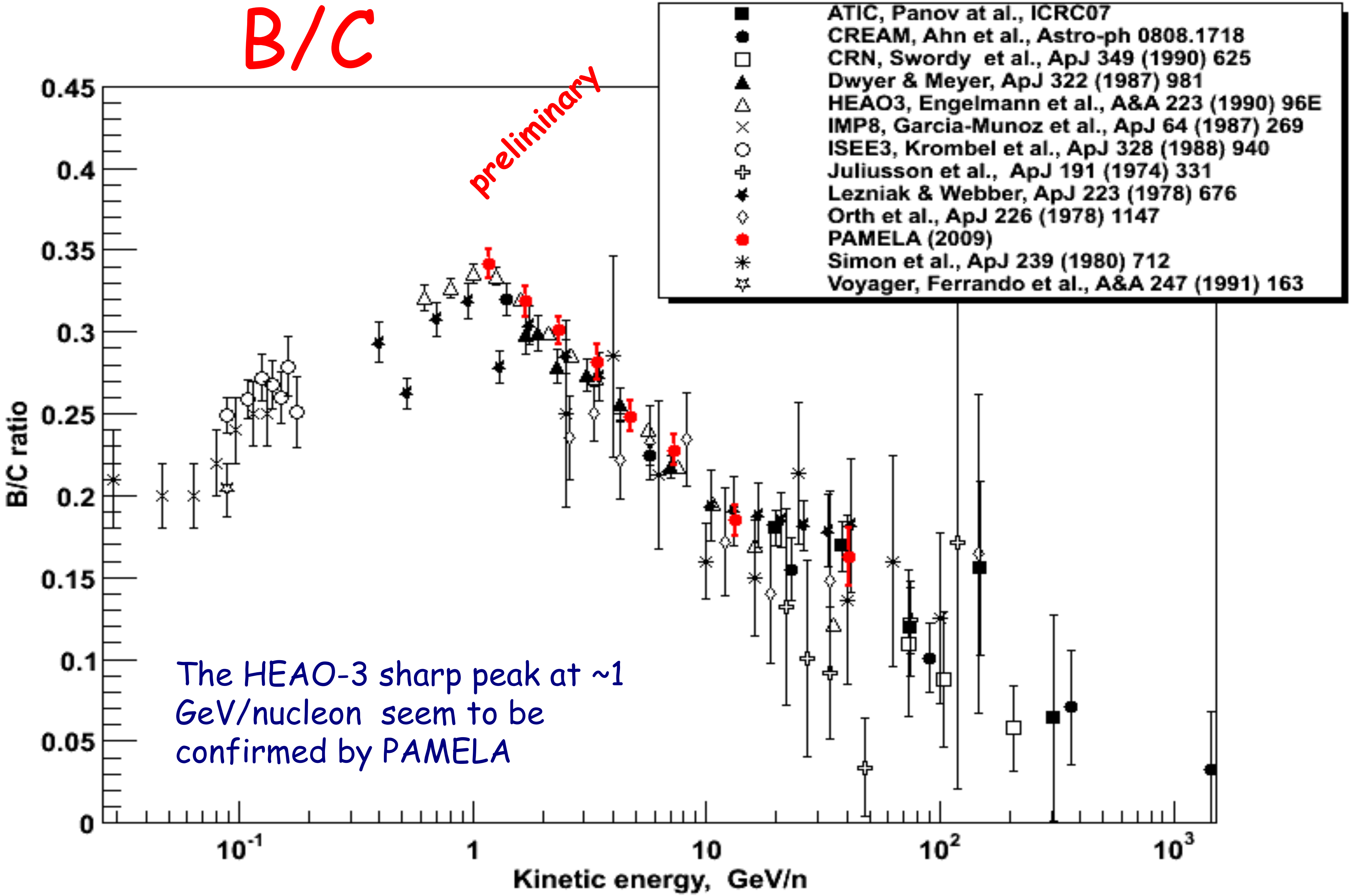
Spettro del Carbonio



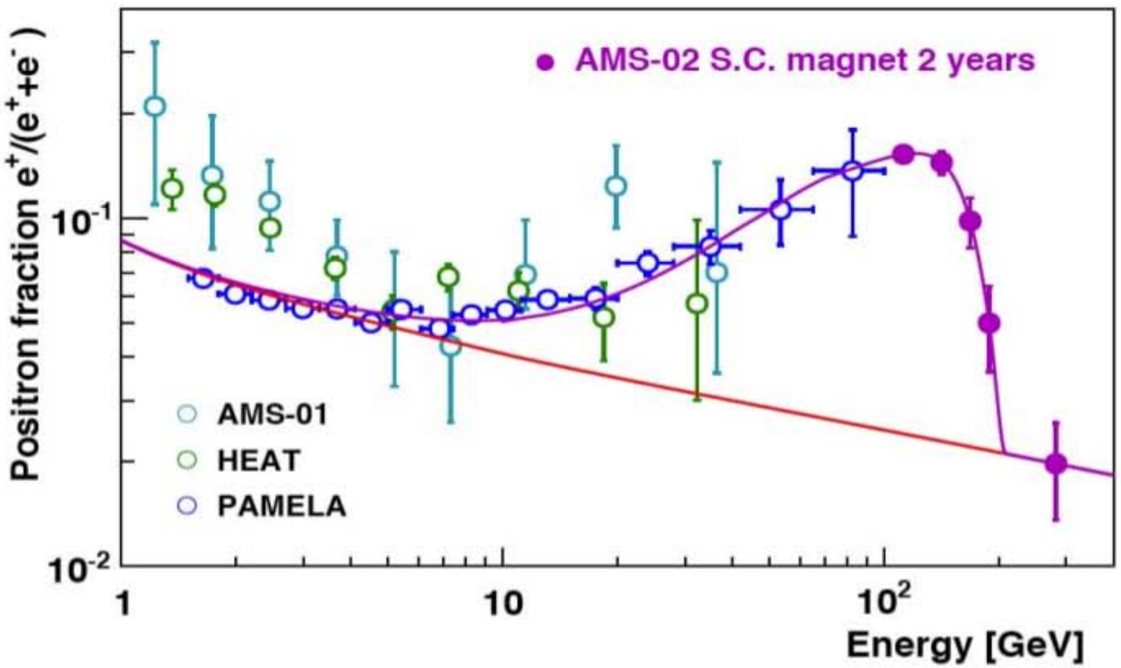


Spettro del Boro
Preliminary
Differential Flux [(m^2 sr s GeV/n)$^{-1}$]
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
1
10
10^2
Kinetic Energy (GeV/n)
PAMELA
HEAO-3-C2

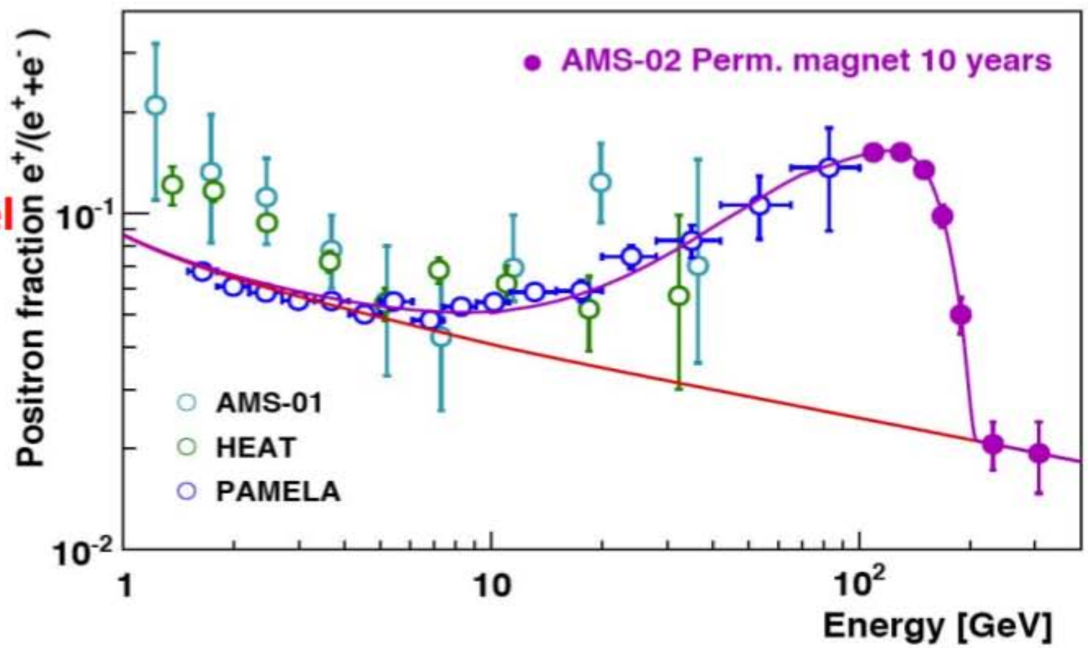
B/C



The HEAO-3 sharp peak at ~1 GeV/nucleon seem to be confirmed by PAMELA

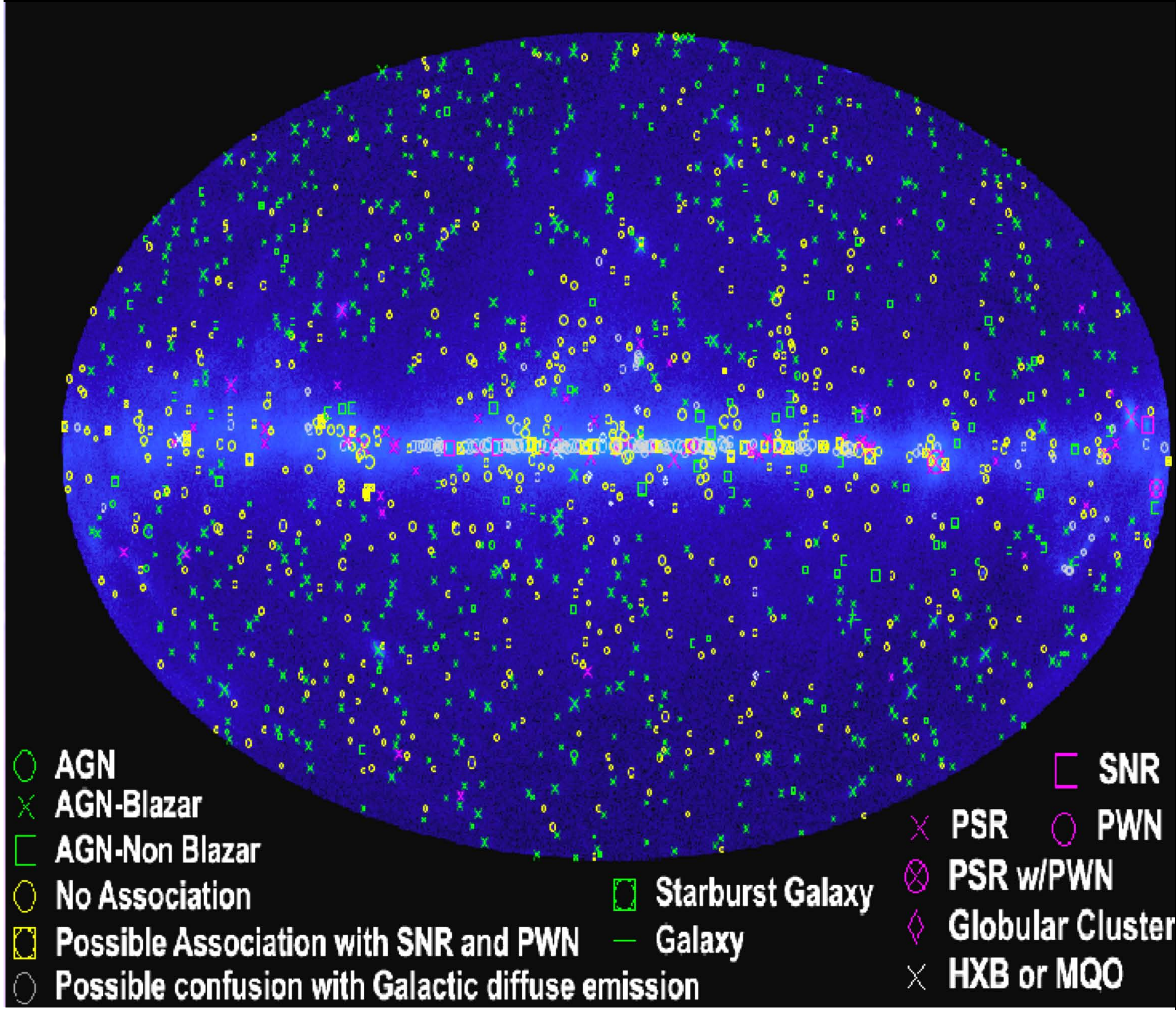


AMS sensitivity esponse to a 200 GeV Dark Matter candidate in the e+e- channel




11 June 2008

First Fermi LAT Catalogs



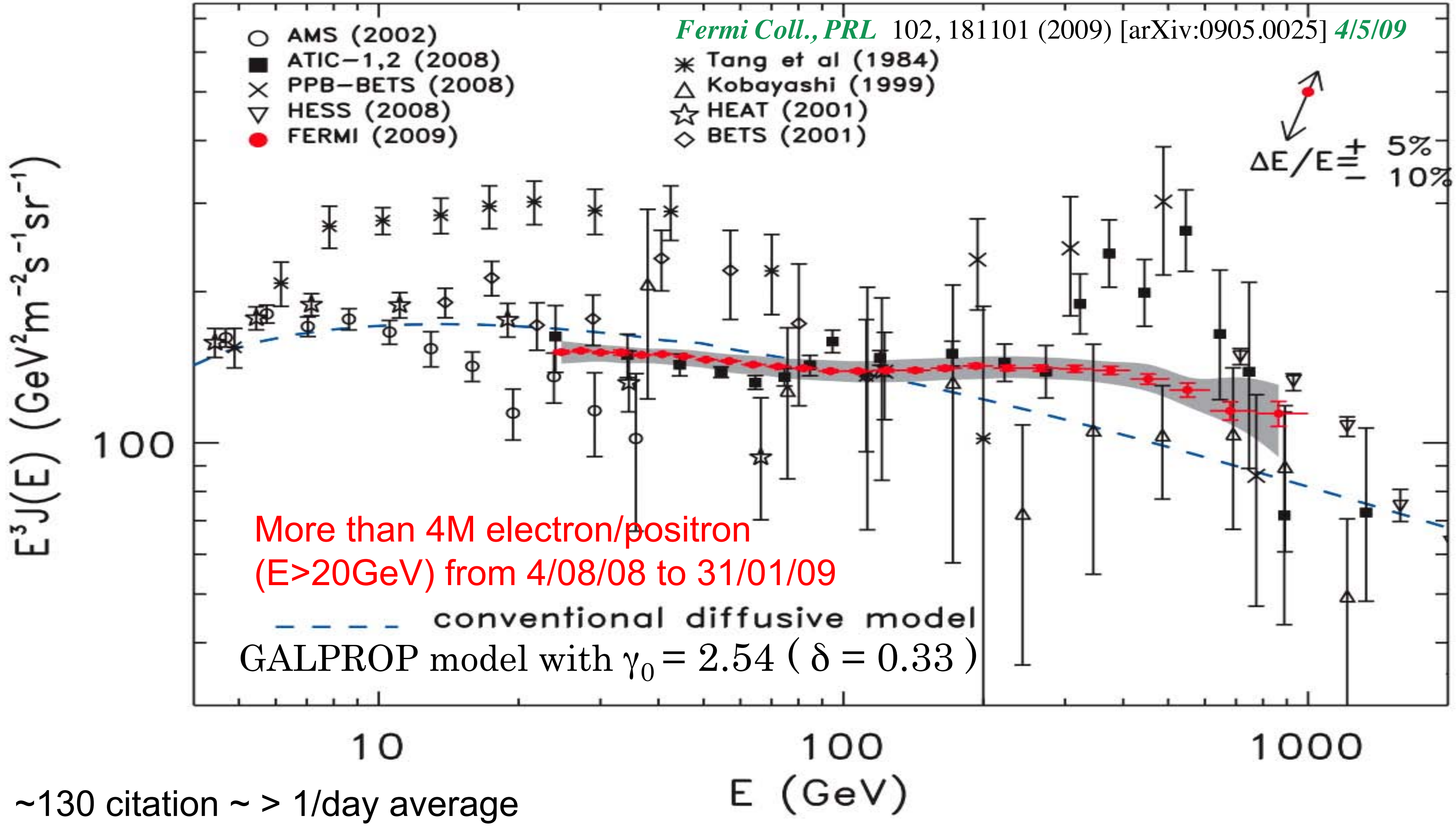
1451 sources

Fermi Large Area Telescope First Source Catalog arXiv:1002.2280, 2010 ApJS accepted. (1FGL)contains **1451** sources detected and characterized in the 100 MeV to 100 GeV, first 11 months data.

The First Catalog of Active Galactic Nuclei Detected by the Fermi Large Area Telescope arXiv: 1002.0150, includes **671** gamma-ray sources at high Galactic latitudes (|b| > 10 deg), with TS> 25 and associated statistically with AGNs.

The First Fermi Large Area Telescope Catalog of Gamma-ray Pulsars 2010ApJS..187..460A . Contains **46** high-confidence pulsed detections using the first six months of data

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

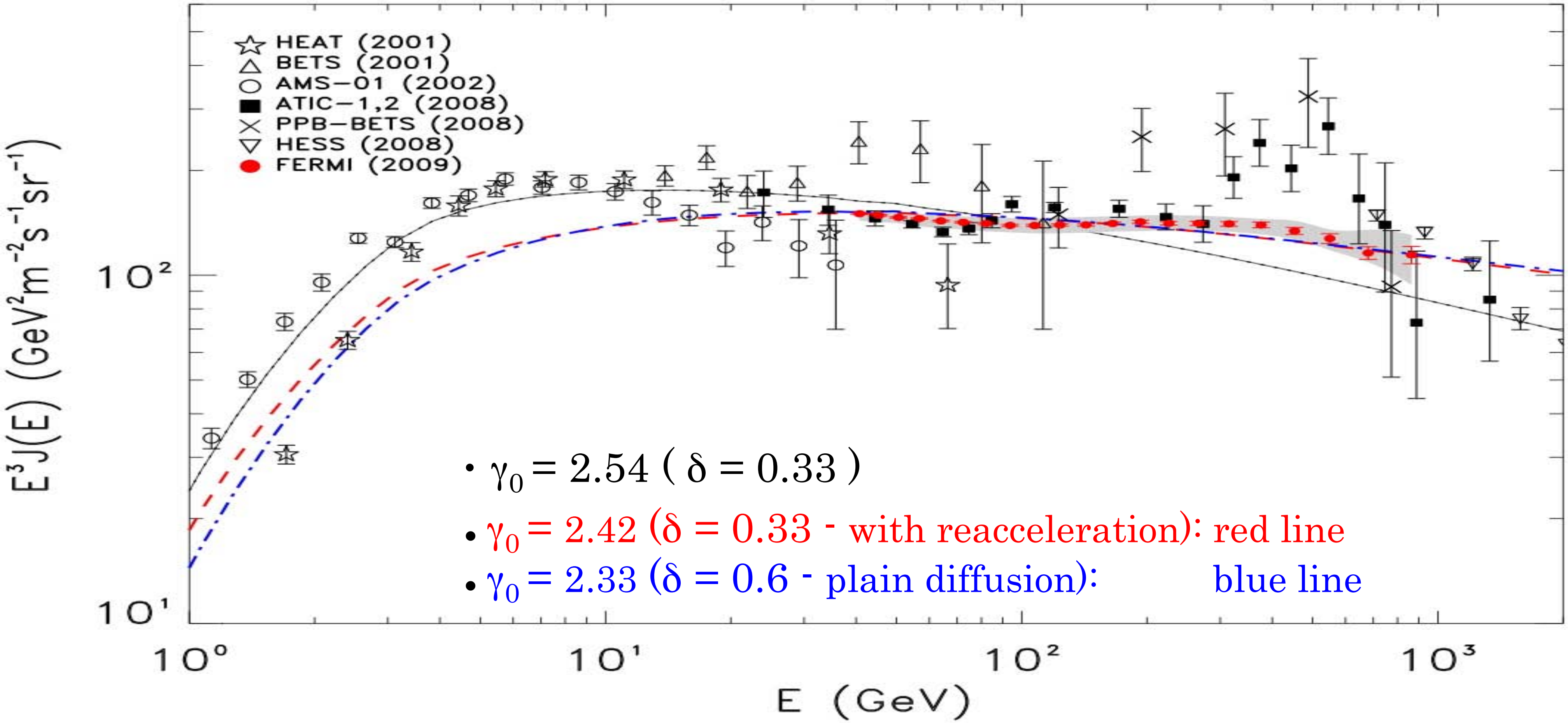


~130 citation ~ > 1/day average

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>

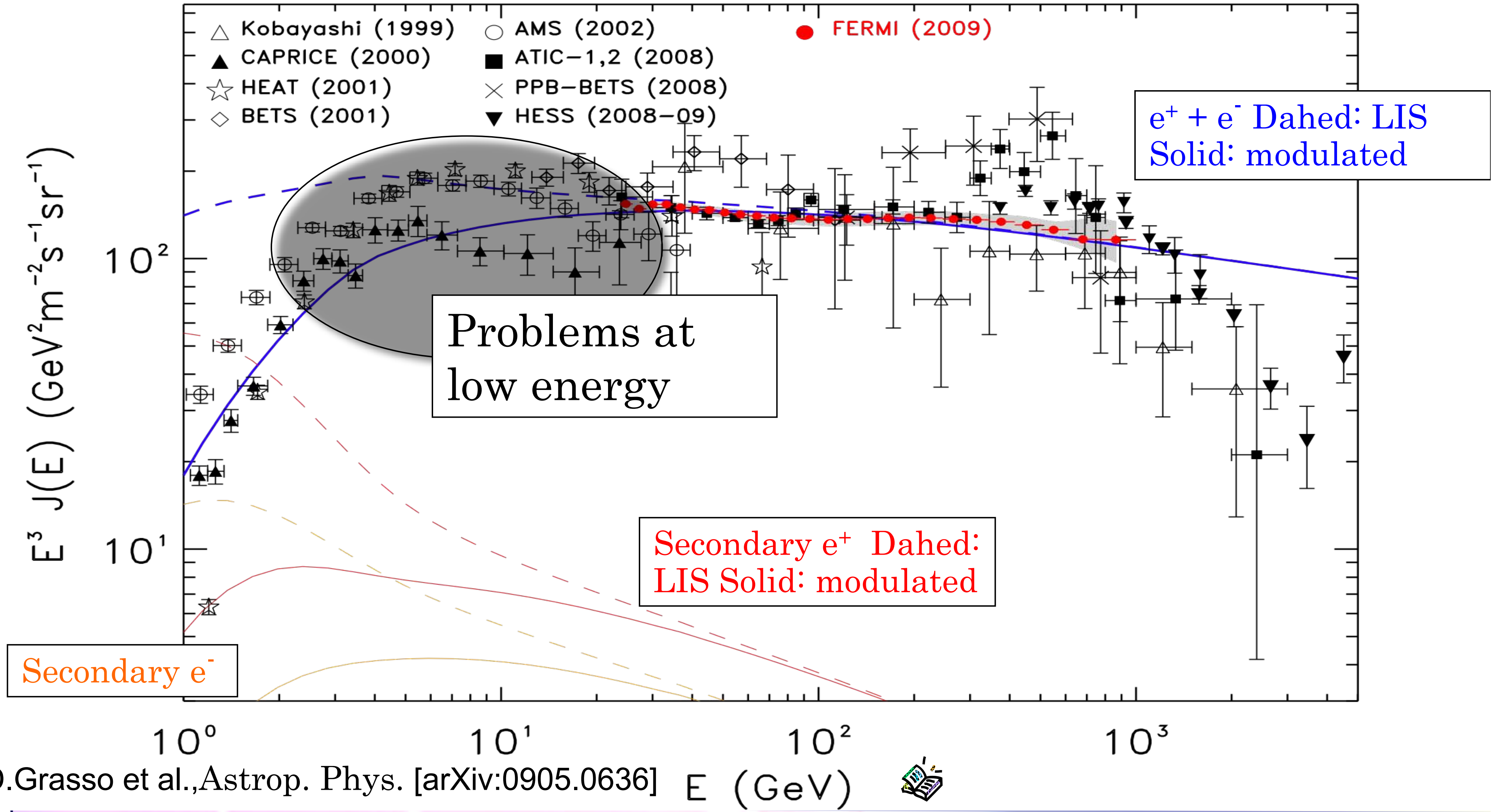
Cosmic Ray Electron propagation models



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

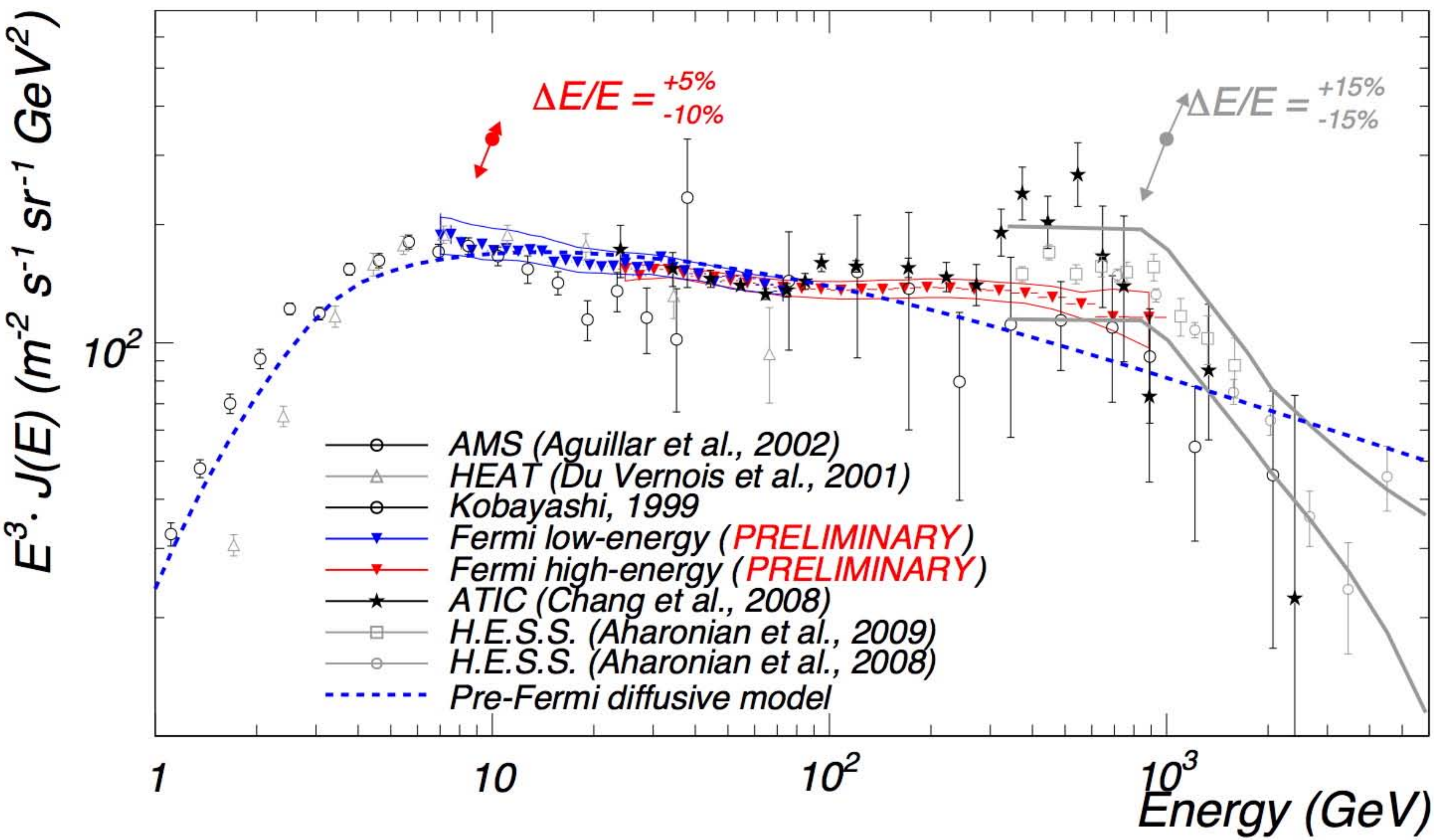
Models 0 and 1 account for CR re-acceleration in the ISM, while 2 is a plain-diffusion model. All models assume γ_0 = 1.6 below 4 GeV.

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



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

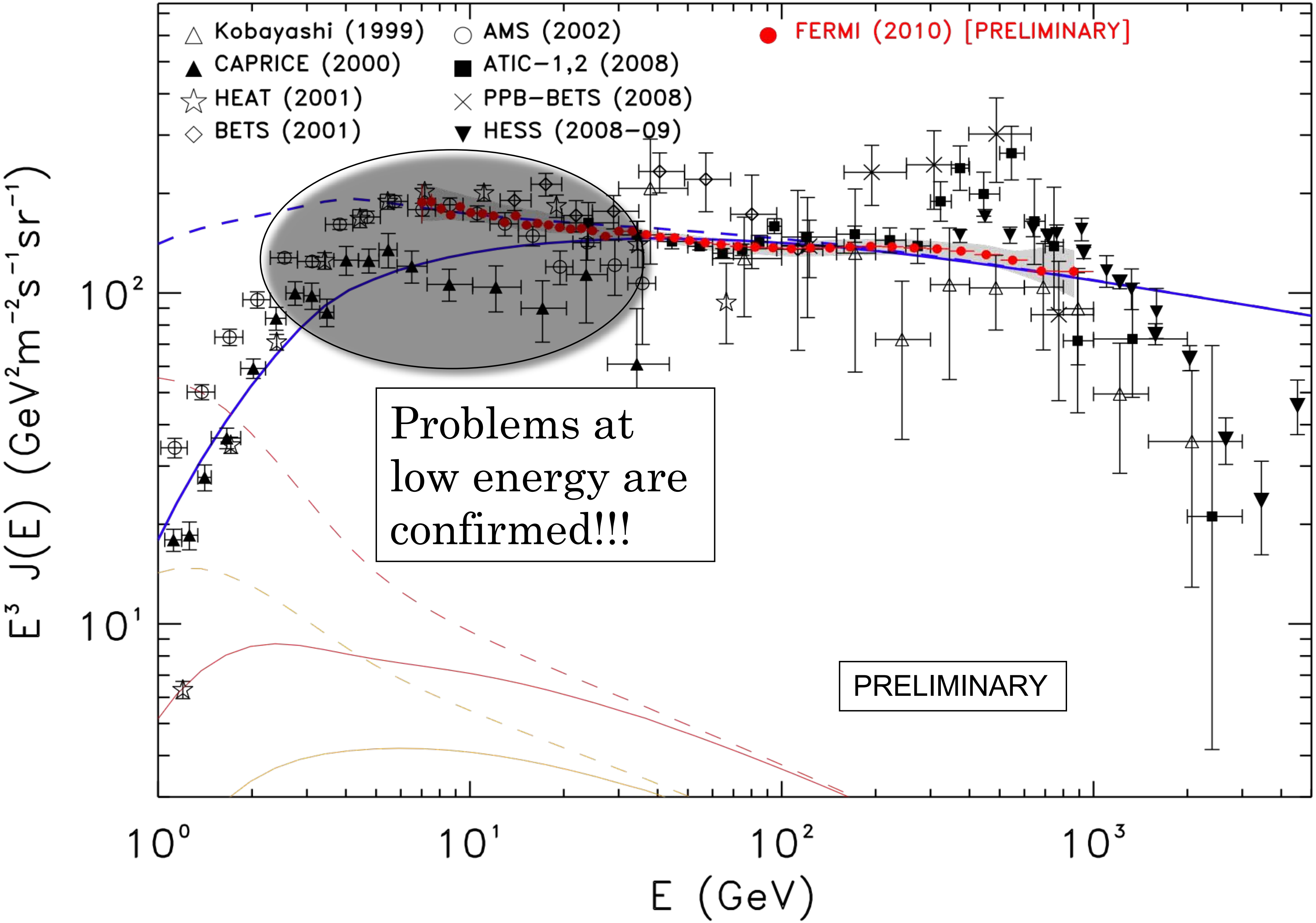
new : Fermi Electron + Positron spectrum (end 2009)



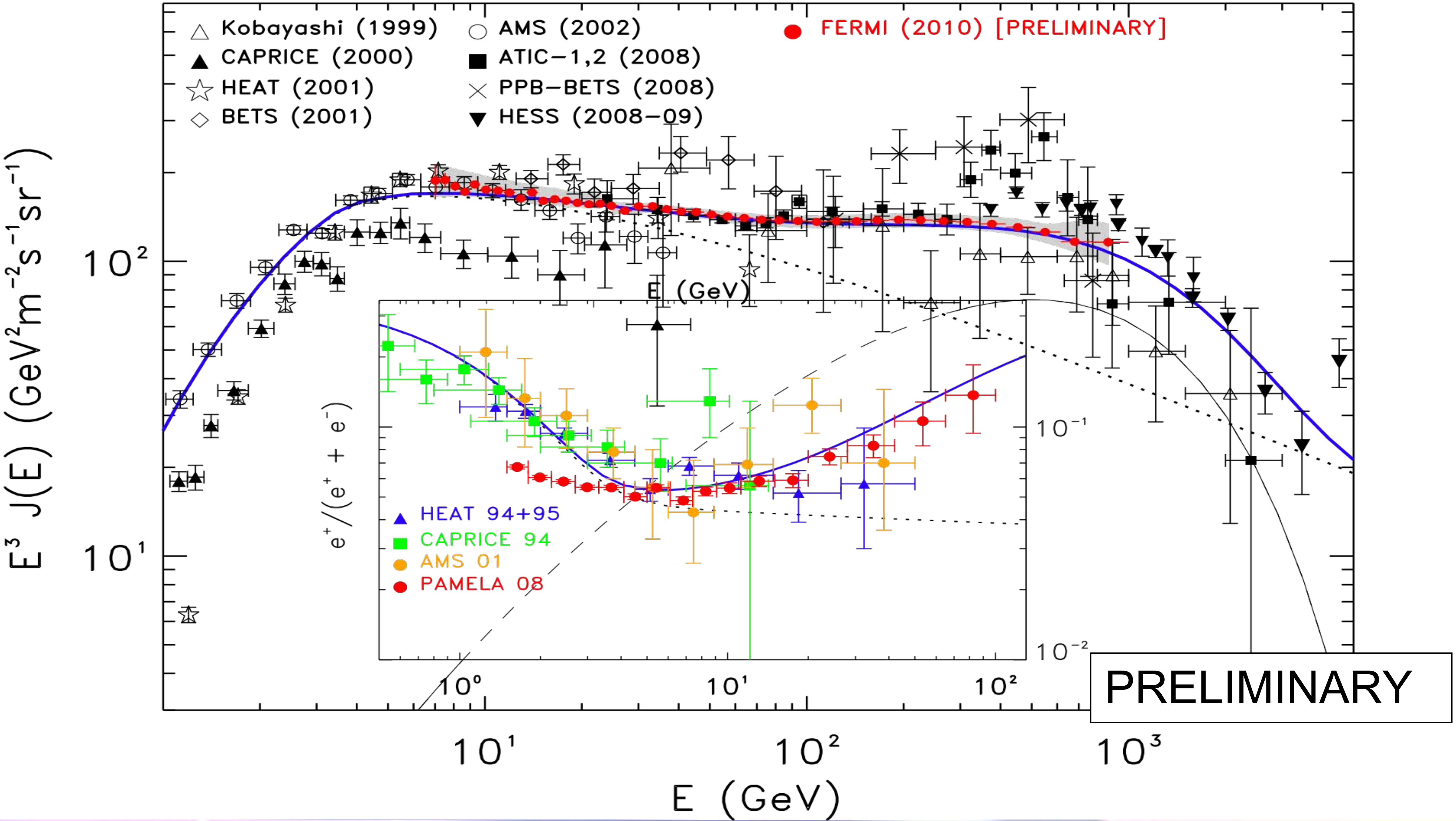
Extended Energy Range (7 GeV – 1 TeV) One year statistics (8M evts)

Fermi LAT Coll. in preparation

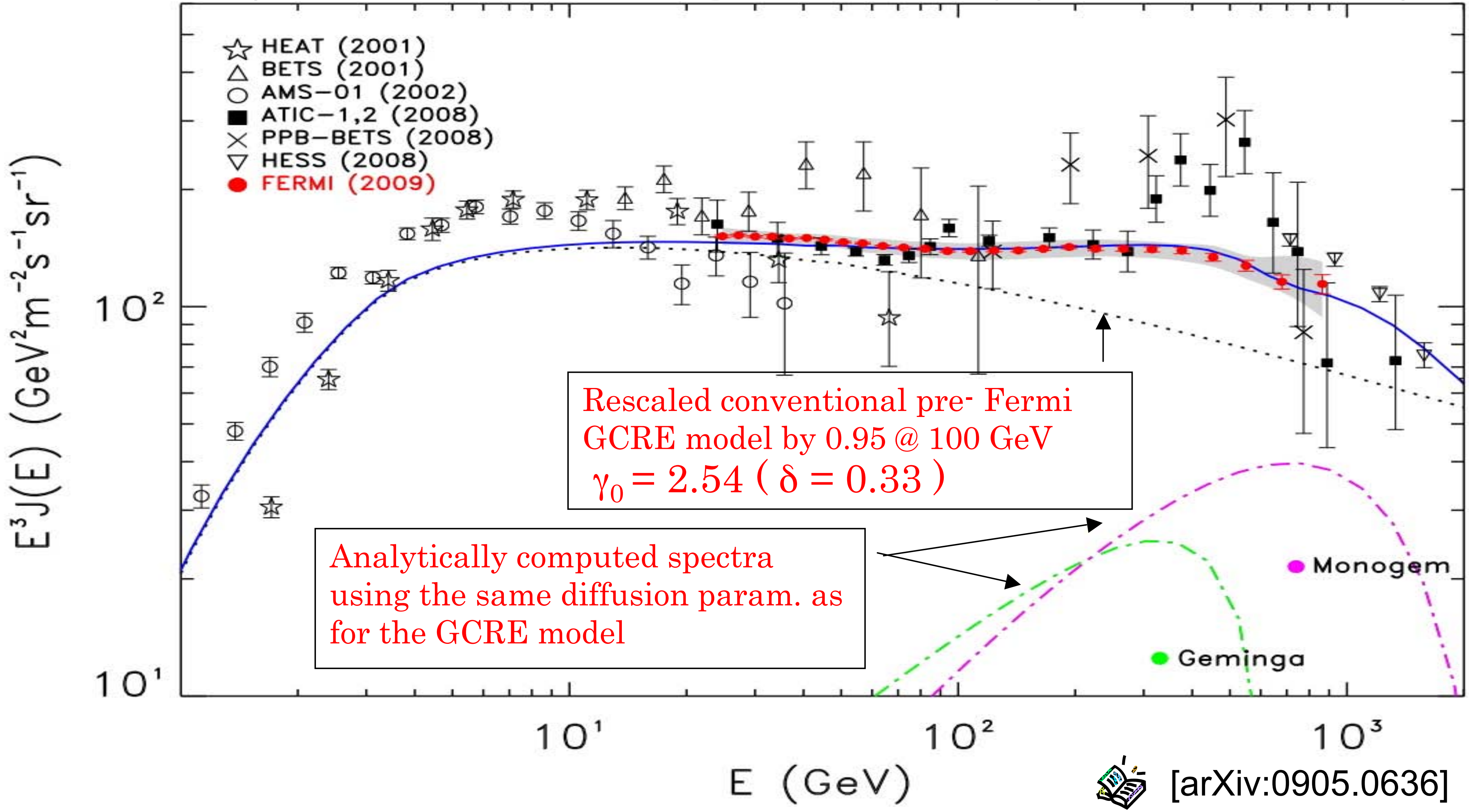
New Fermi-LAT data at low energy



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



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

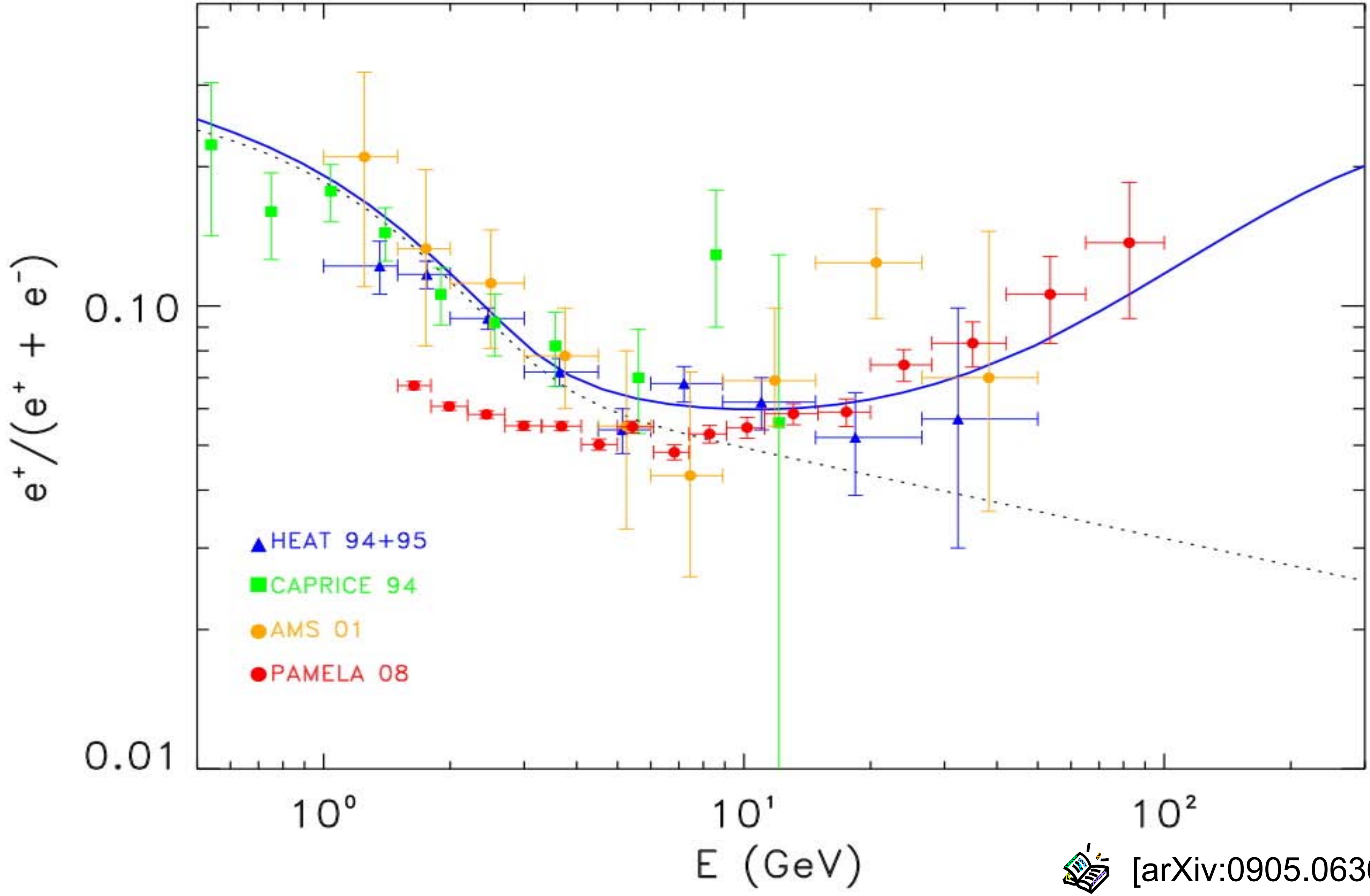


[arXiv:0905.0636]

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)

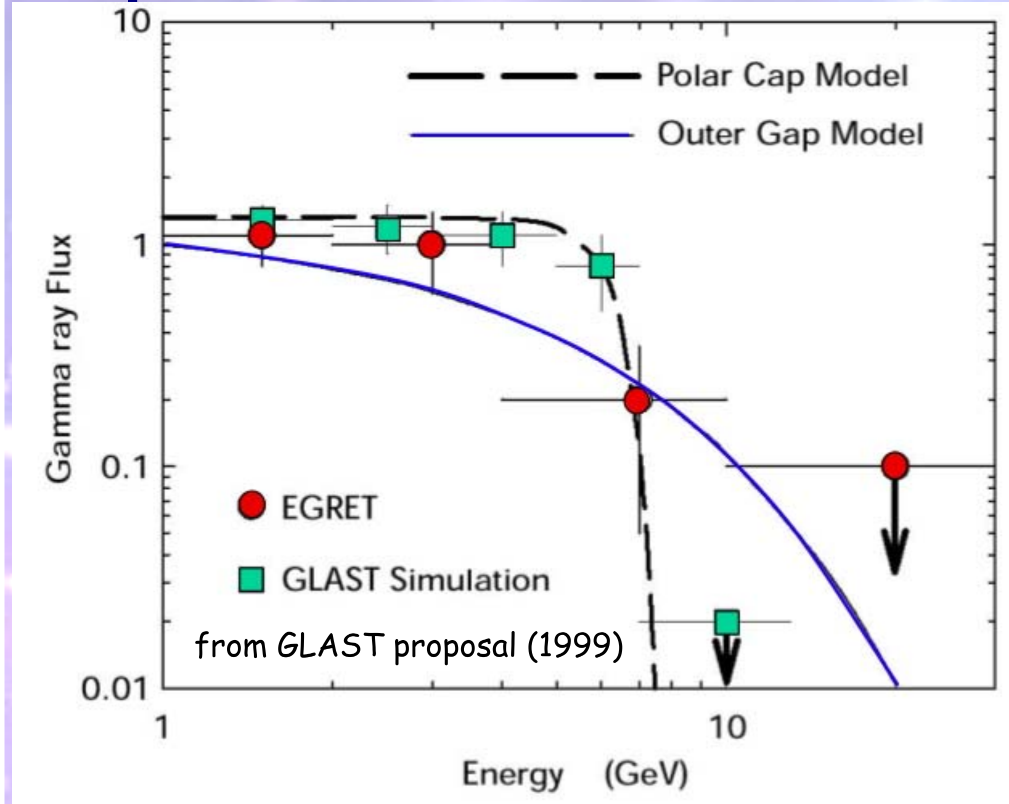
2. On the basis of the spectrum, it is not clear
    1. The spectra of PWN show relatively flat spectra of pairs at Low energies but we do not understand what it is
    2. The general spectra (acceleration at the termination shock) are too steep

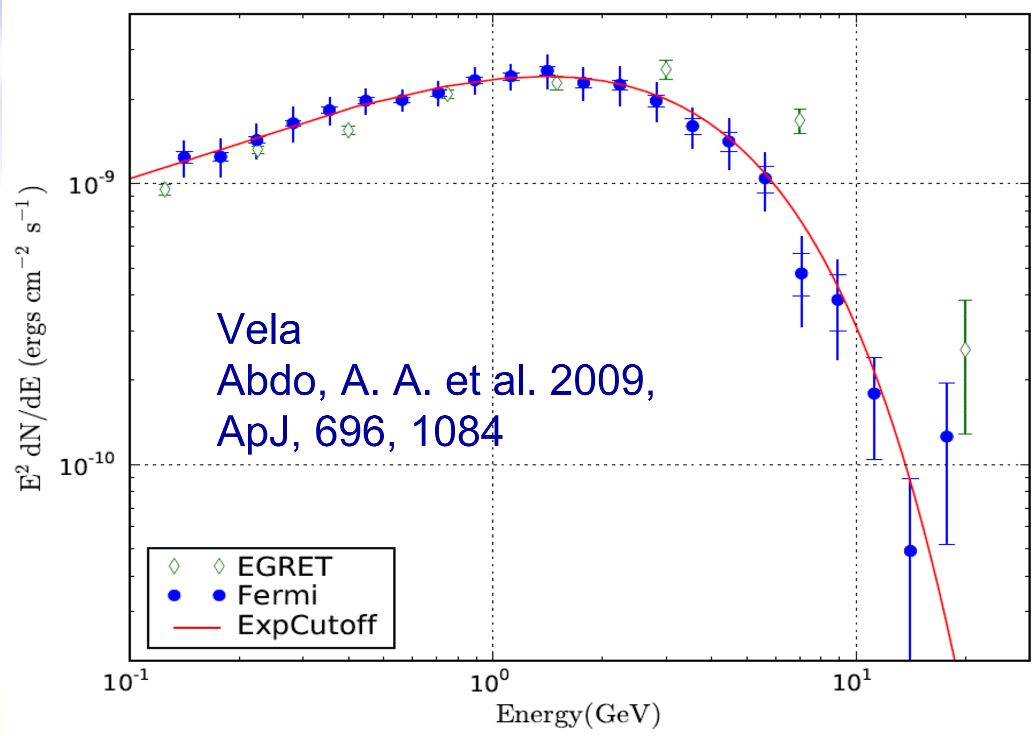
The biggest problem is that of escape of particles from the pulsar

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

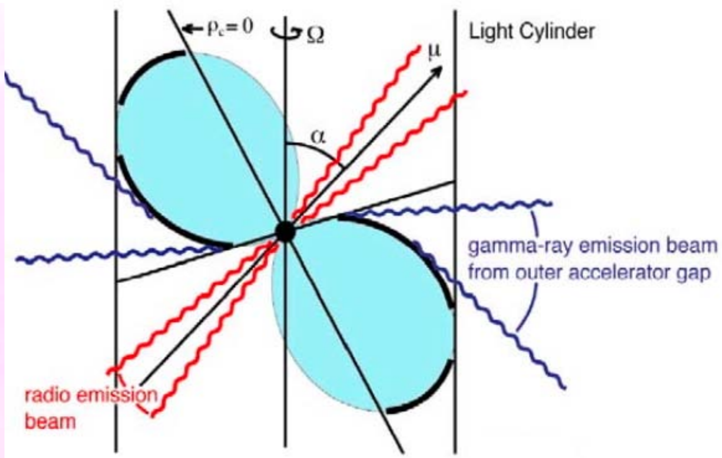
Spectral measurements and emission models

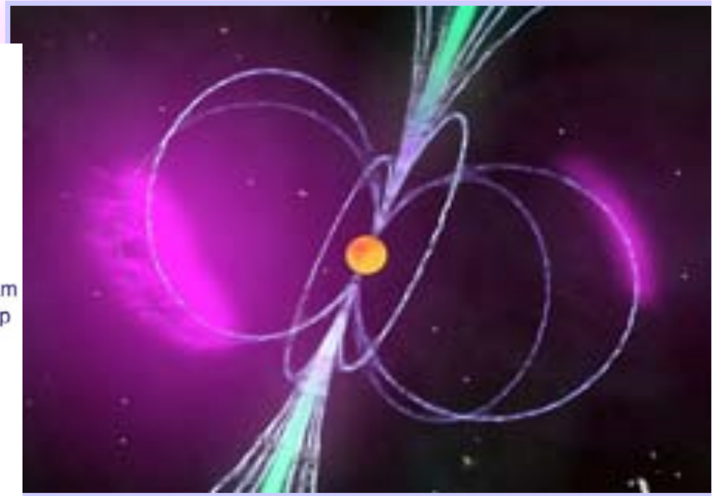




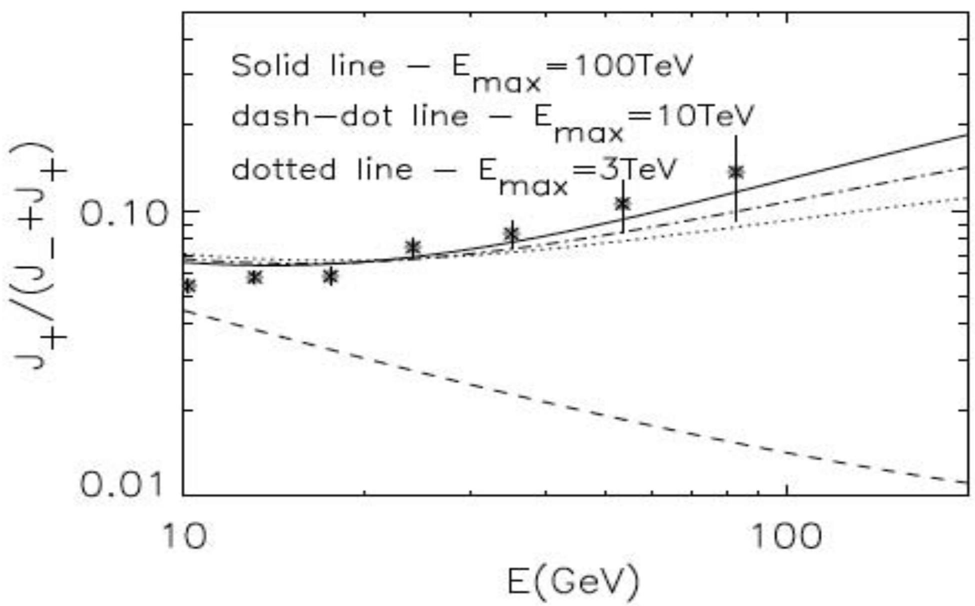
Evidence of γ-ray emission in the outer magnetopshere due to absence of super-exponential cutoff

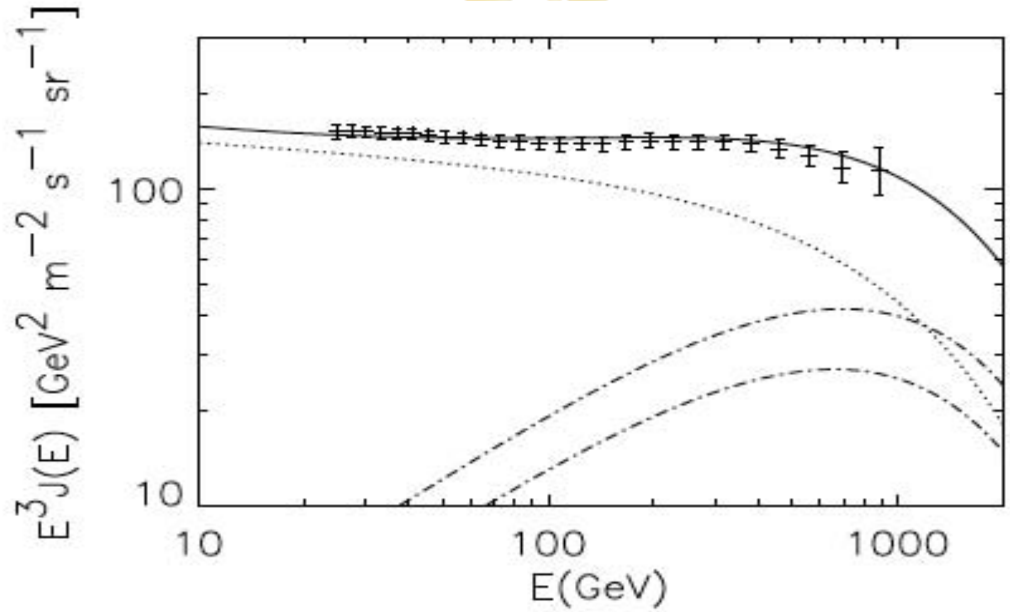
- Radio and γ-ray fan beams separated
- γ-ray only PSRs





other Astrophysical solution



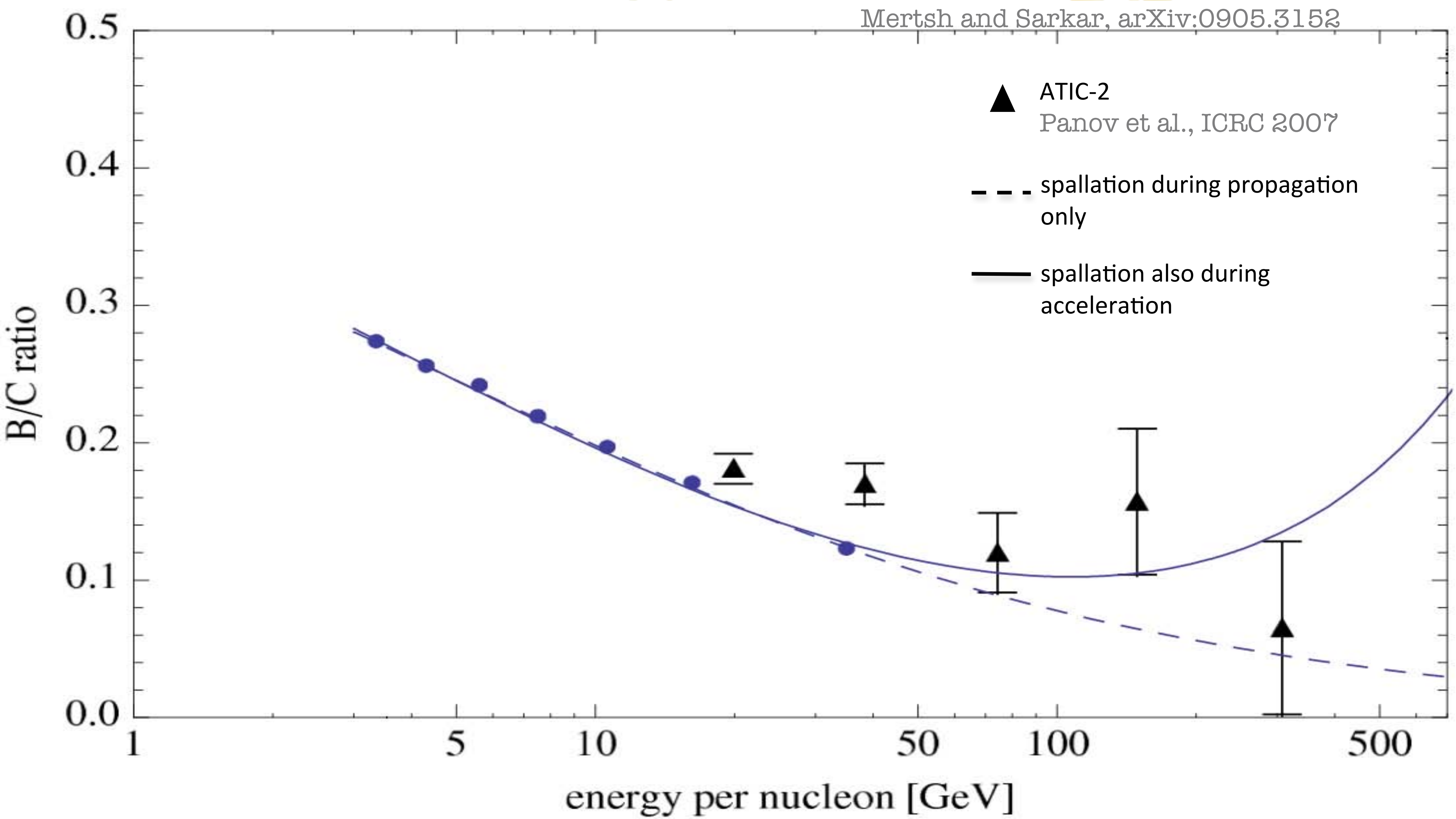


- Positrons created as secondary products of hadronic interactions inside the sources
- Secondary production takes place in the same region where cosmic rays are being accelerated

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

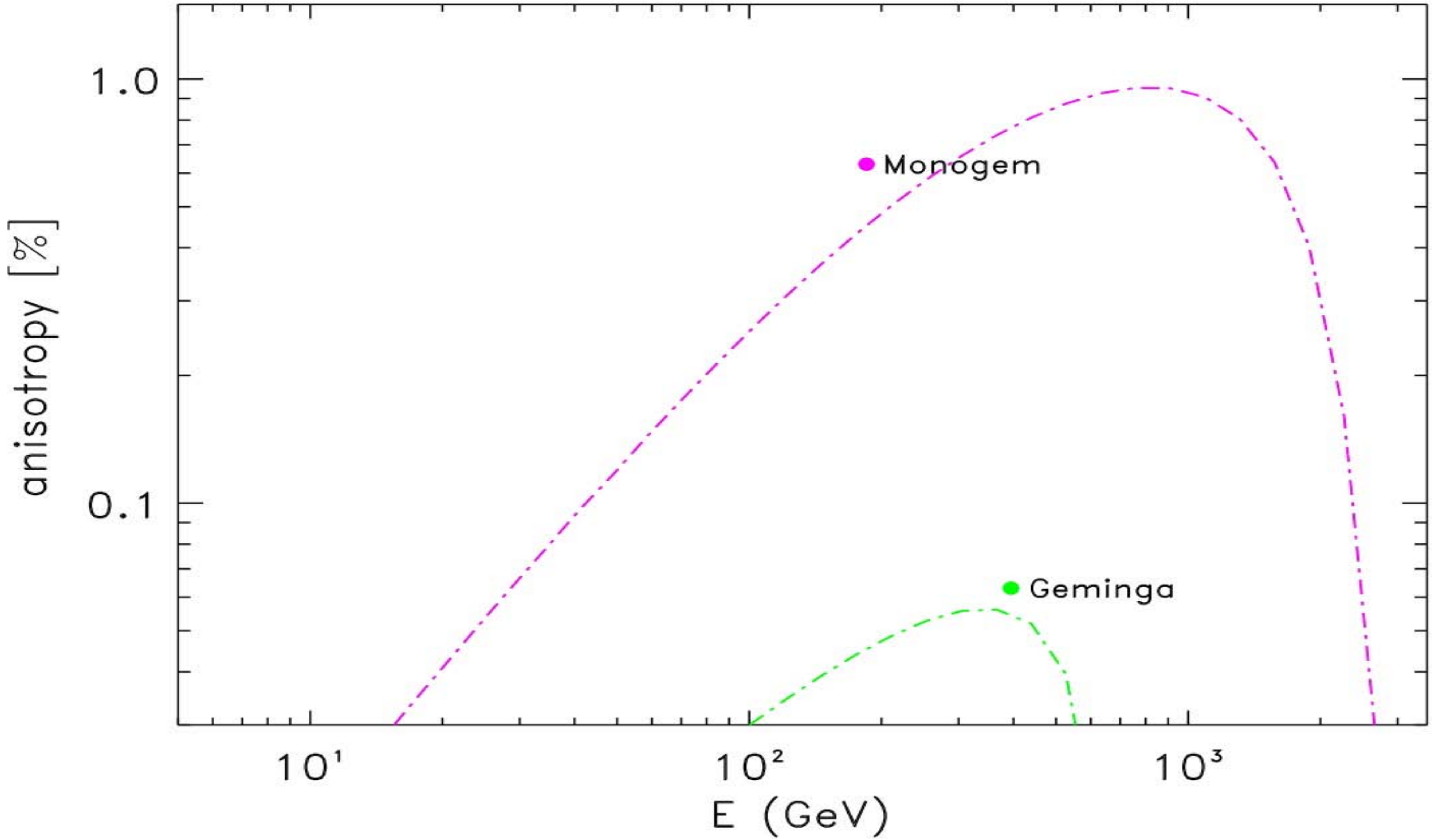
Blasi, arXiv:0903.2794

Boron-to-Carbon Ratio

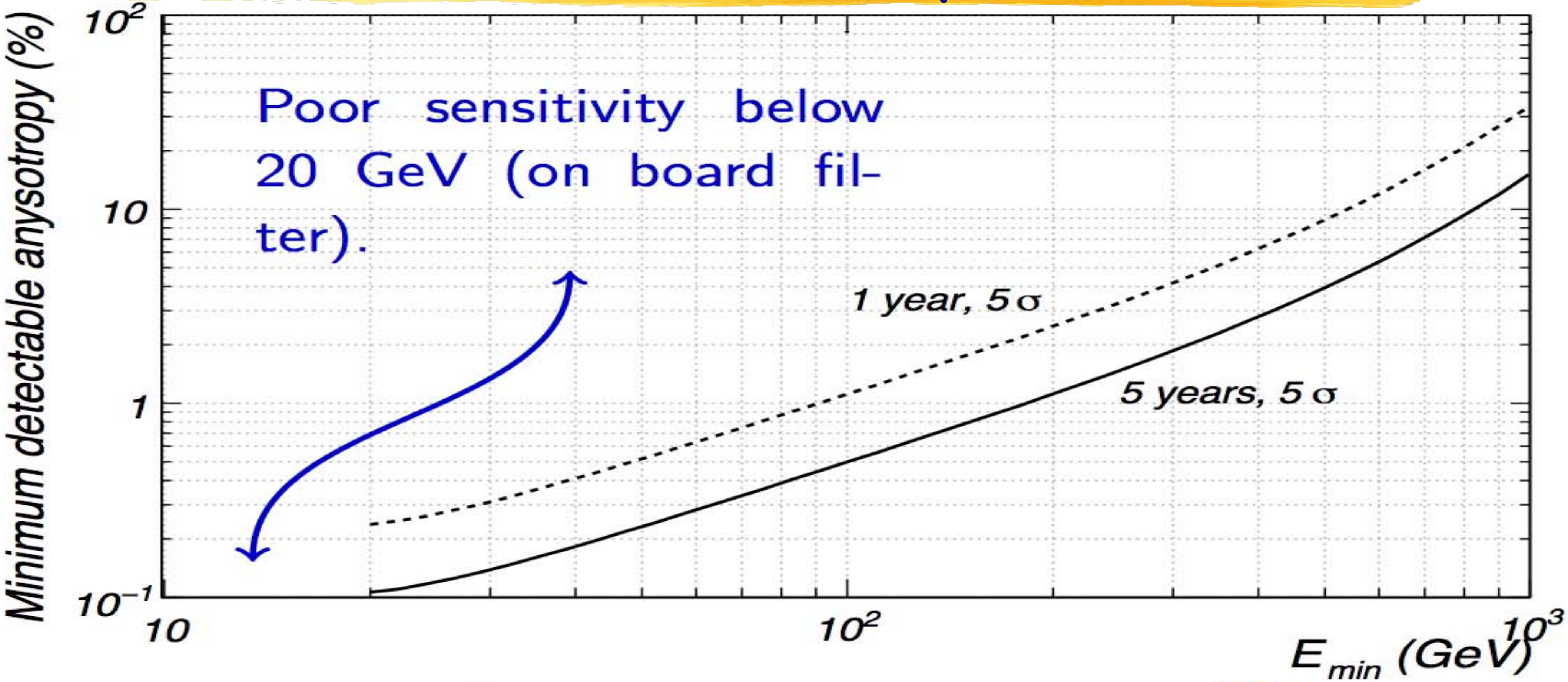


A rise would rule out the DM and pulsar explanation of the PAMELA positron excess.

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

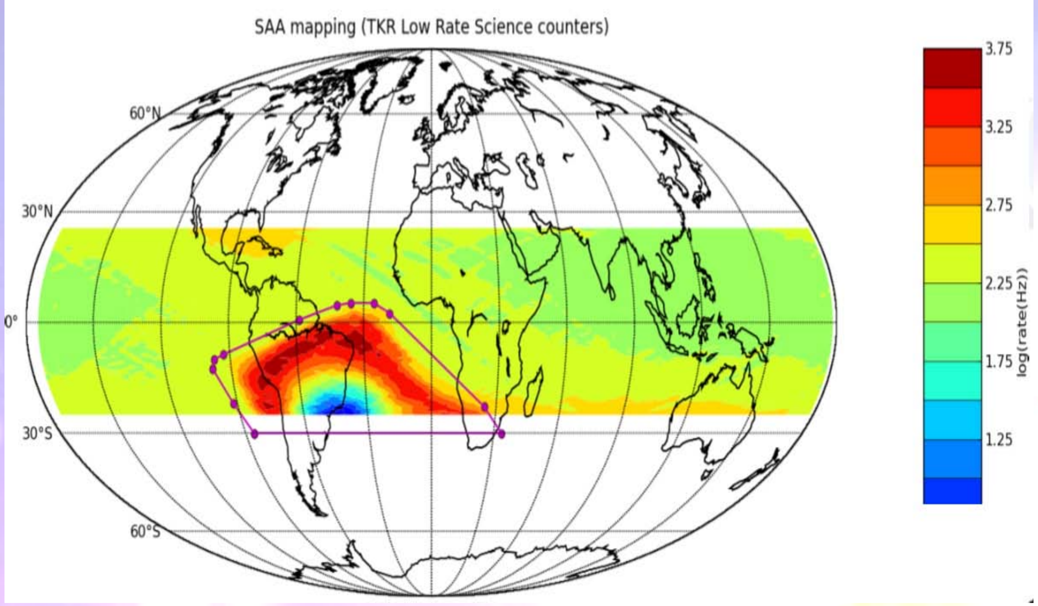


Measurement of anisotropies: statistics

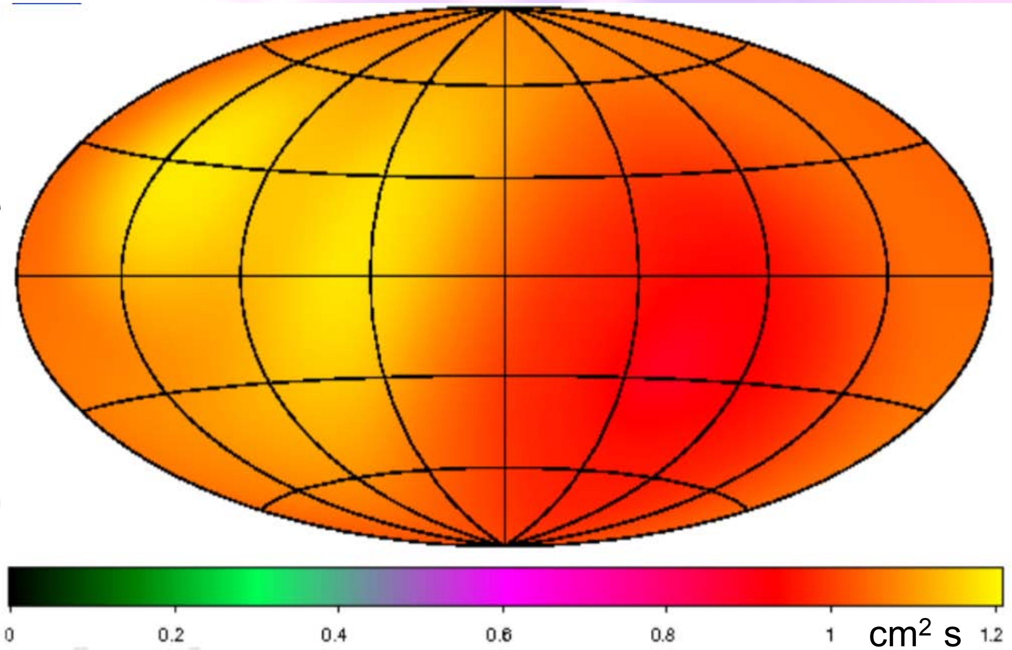


- Statistical limit for the integral anisotropy set by $\delta = \frac{\sqrt{2}N_\sigma}{\sqrt{N_{events}}}$
- The plot includes all the instrument effects:
- Energy-dependent effective geometry factor;
- Instrumental dead time and duty cycle, On board filter.
- Room for improvements with a better event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

Measurements of anisotropies: systematics



Terrestrial coordinates (South Atlantic Anomaly clearly visible). Fermi does not take science data within the SAA polygon.



Exposure map

For gammas, after three months of mission (used for the bright source list).

It will not be very different for the electrons and for longer time periods.

- ≈ 25% disuniformity in the exposure map induced by the SAA.

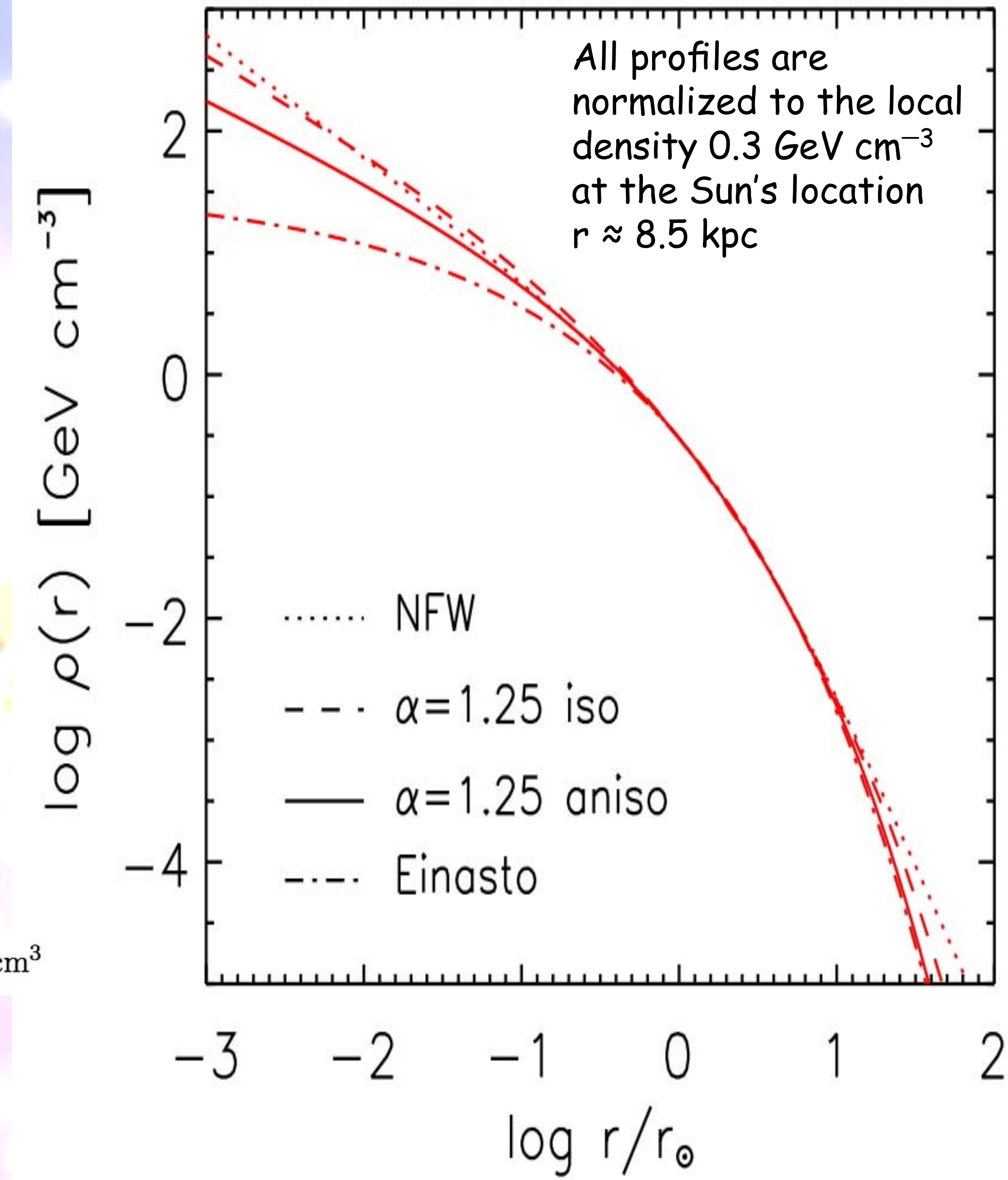
Measuring a 0.1% anisotropy requires a knowledge of the exposure map at the ≈ 0.1% level.

Milky Way Dark Matter Profiles

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

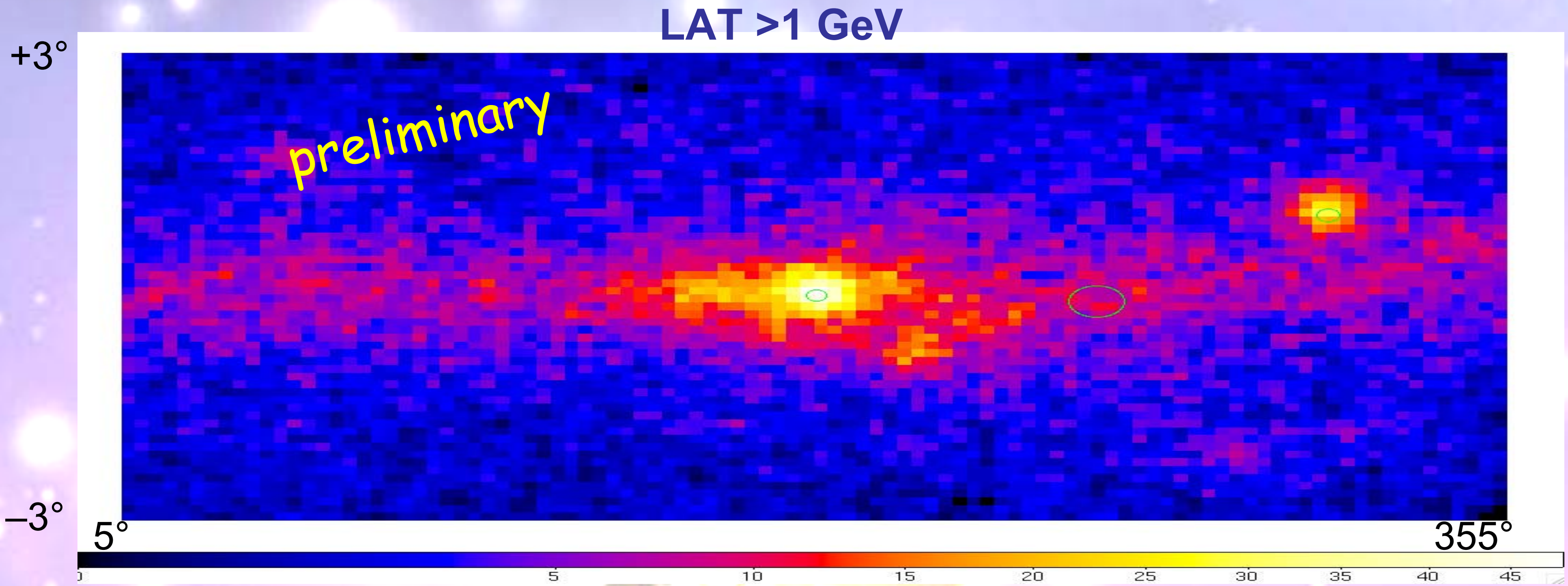
Halo model	α	β	γ	r_s in kpc
Cored isothermal	2	2	0	5
Navarro, Frenk, White	1	3	1	20
Moore	1	3	1.16	30

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

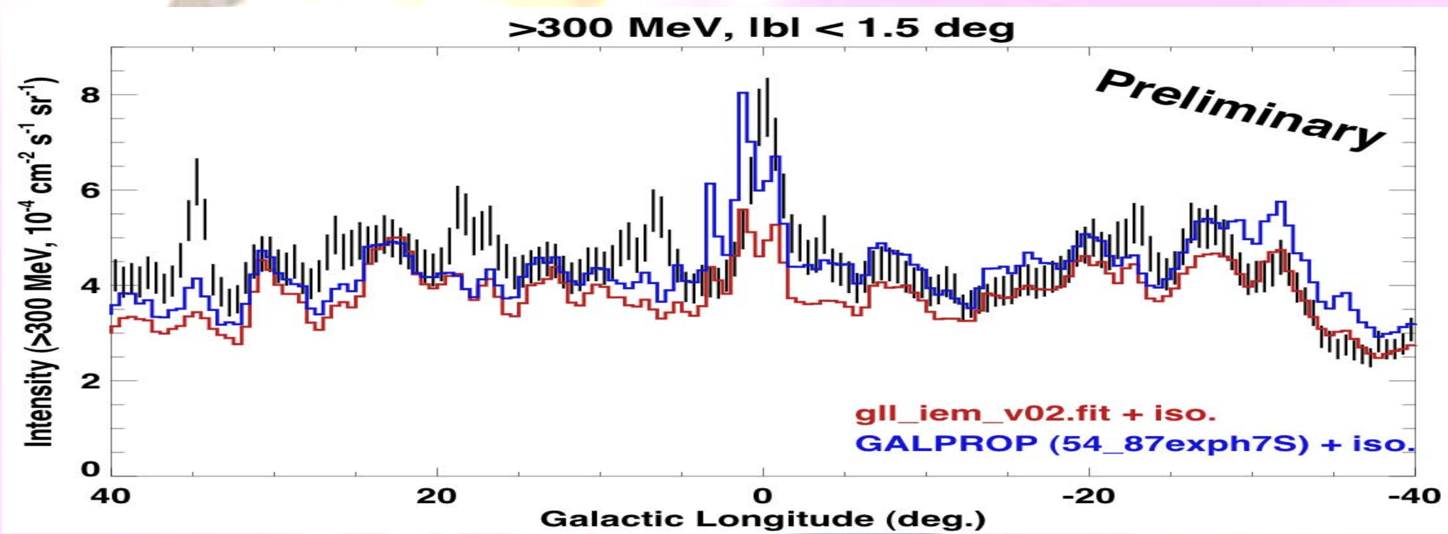


A.Lapi et al. arXiv:0912.1766

Fermi LAT Observations of the GC

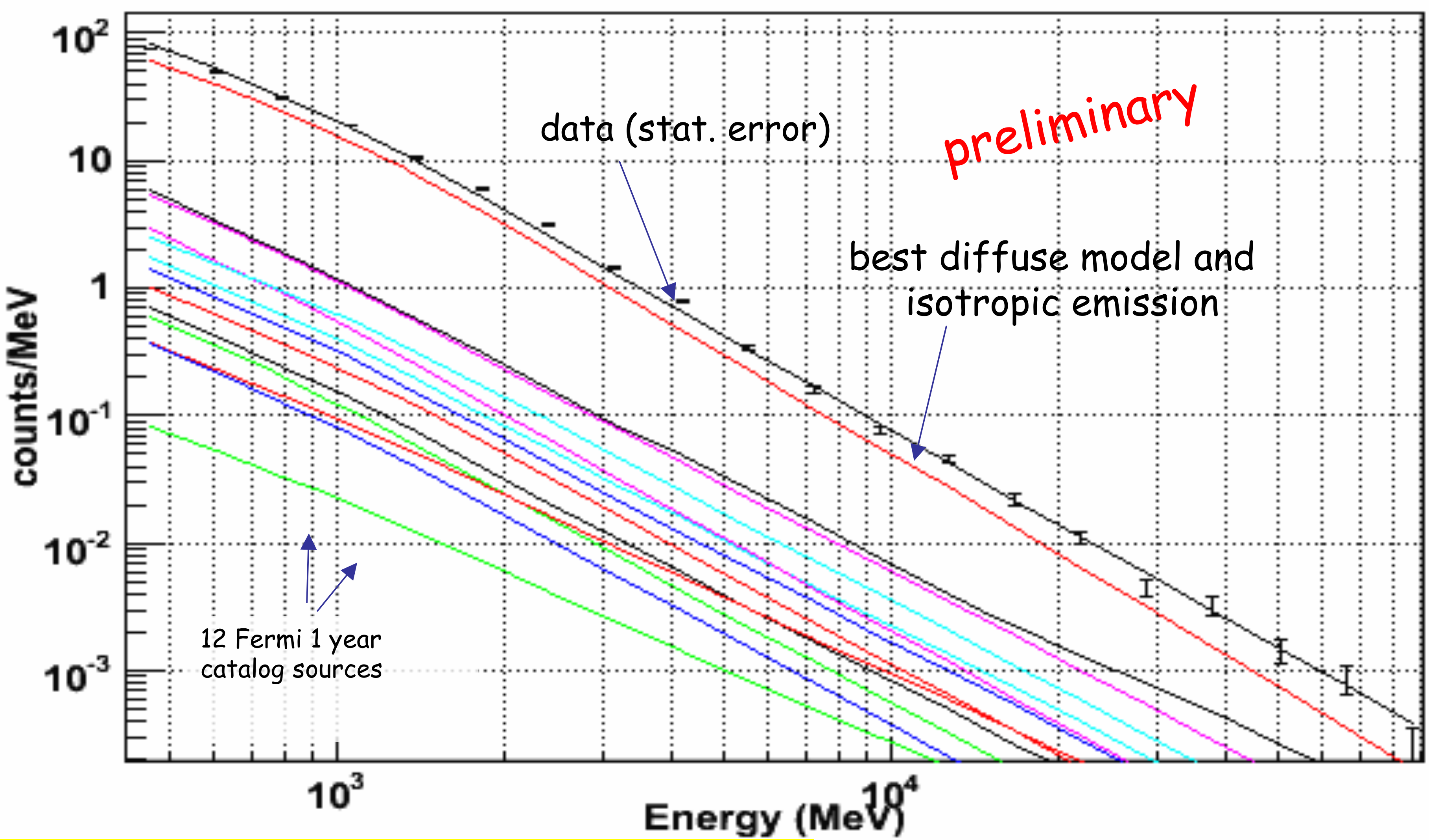


12-month data set, Diffuse class,
Front only
smoothed with σ = 0.1°
BSL source location circles overlaid



Fermi LAT Coll. in preparation

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

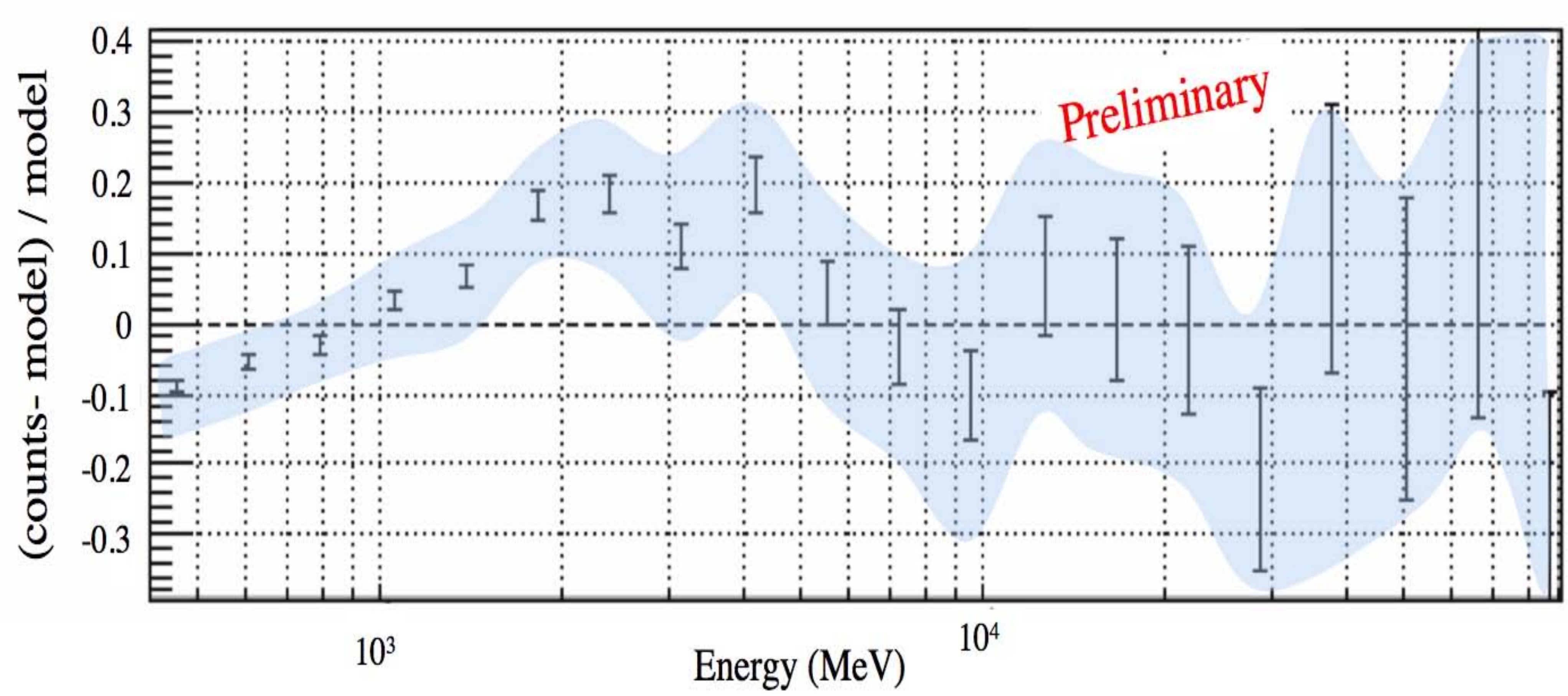


Fermi LAT Coll. in preparation, Fermi Symp. arXiv:0912.3828

GC Residuals

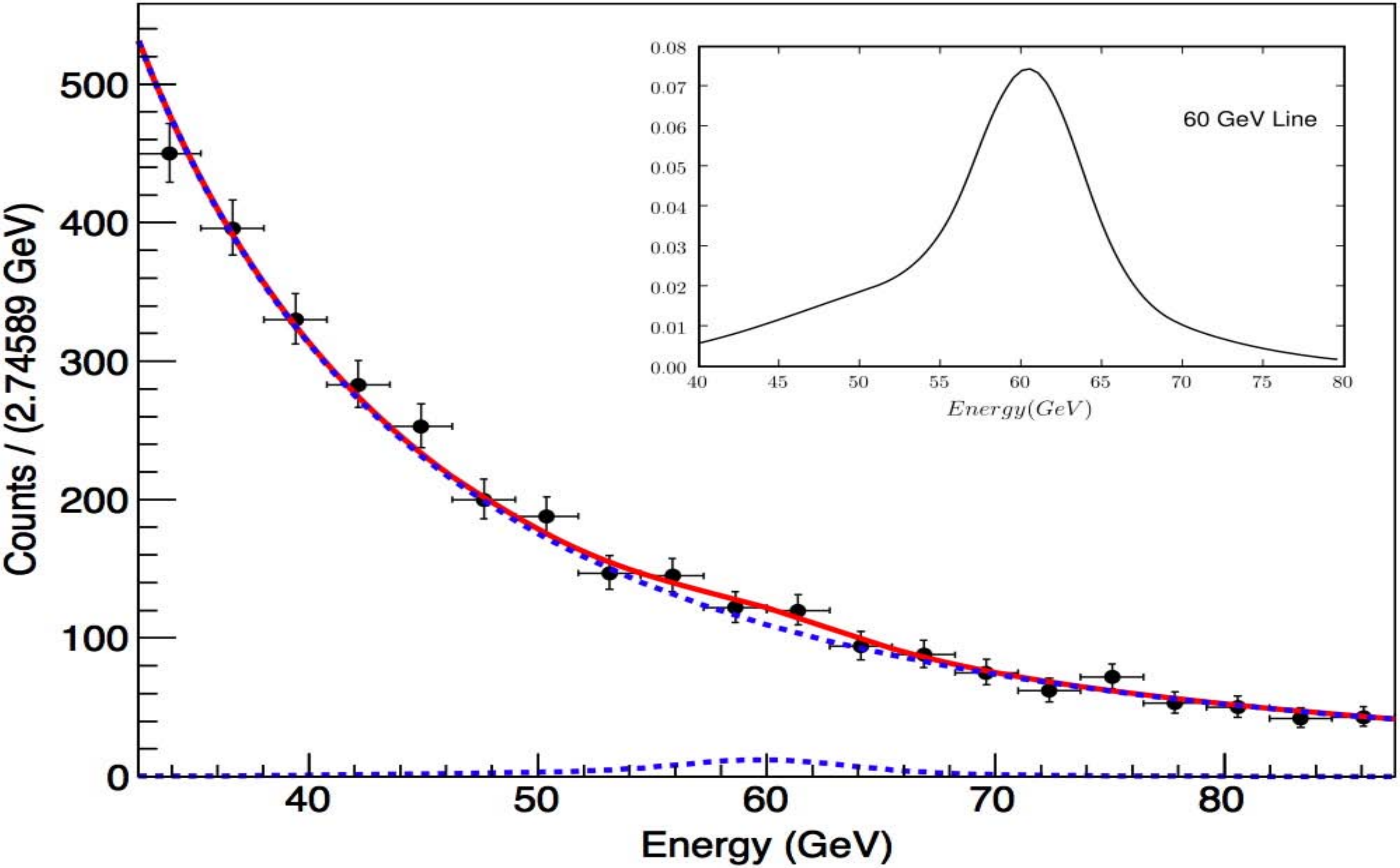
7°x7° region centered on the Galactic Center
11 months of data, E >400 MeV, front-converting events
analyzed with binned likelihood analysis)

- 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

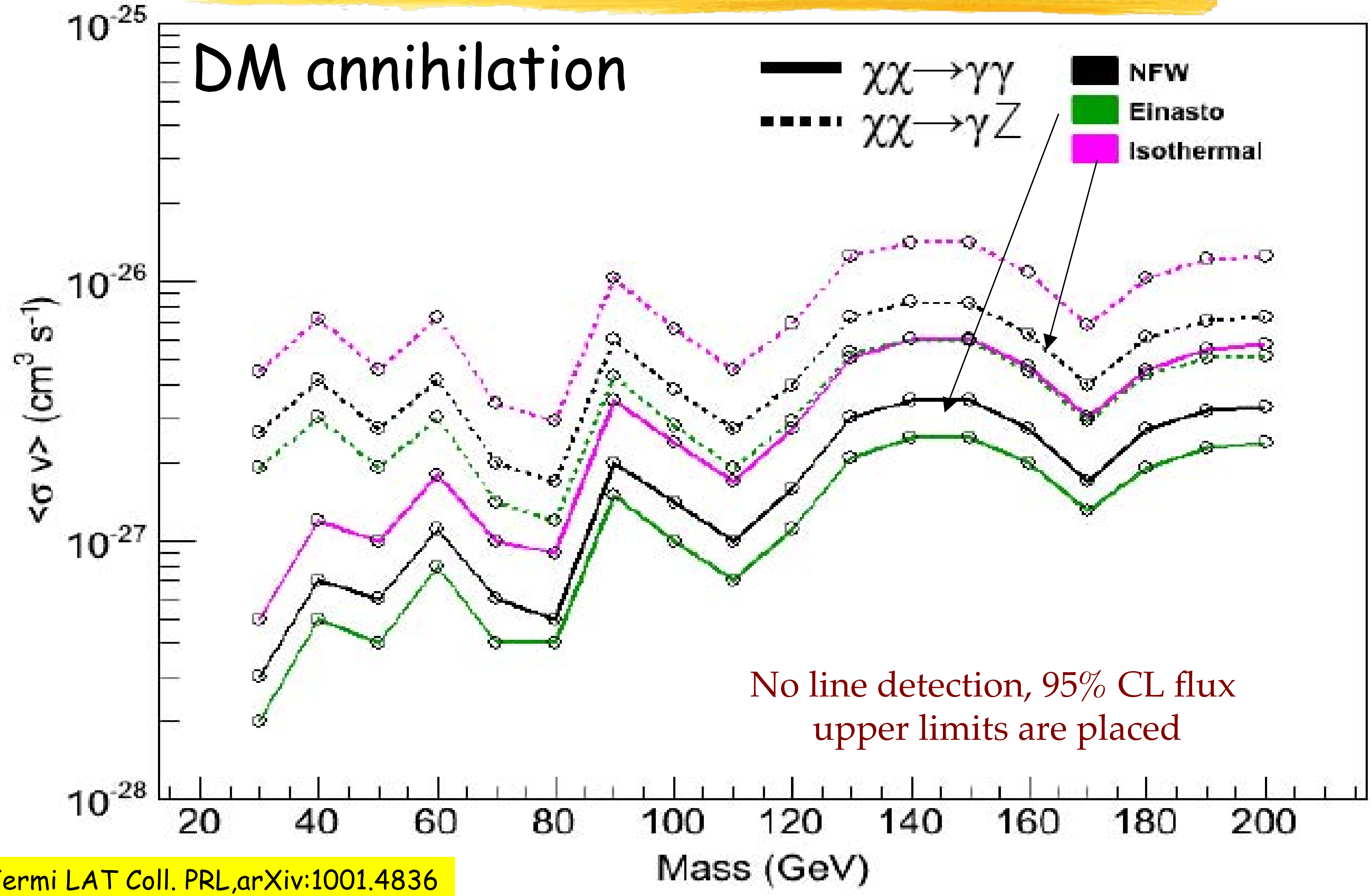


Fermi LAT Coll. in preparation, Fermi Symp. arXiv:0912.3828

Wimp lines search

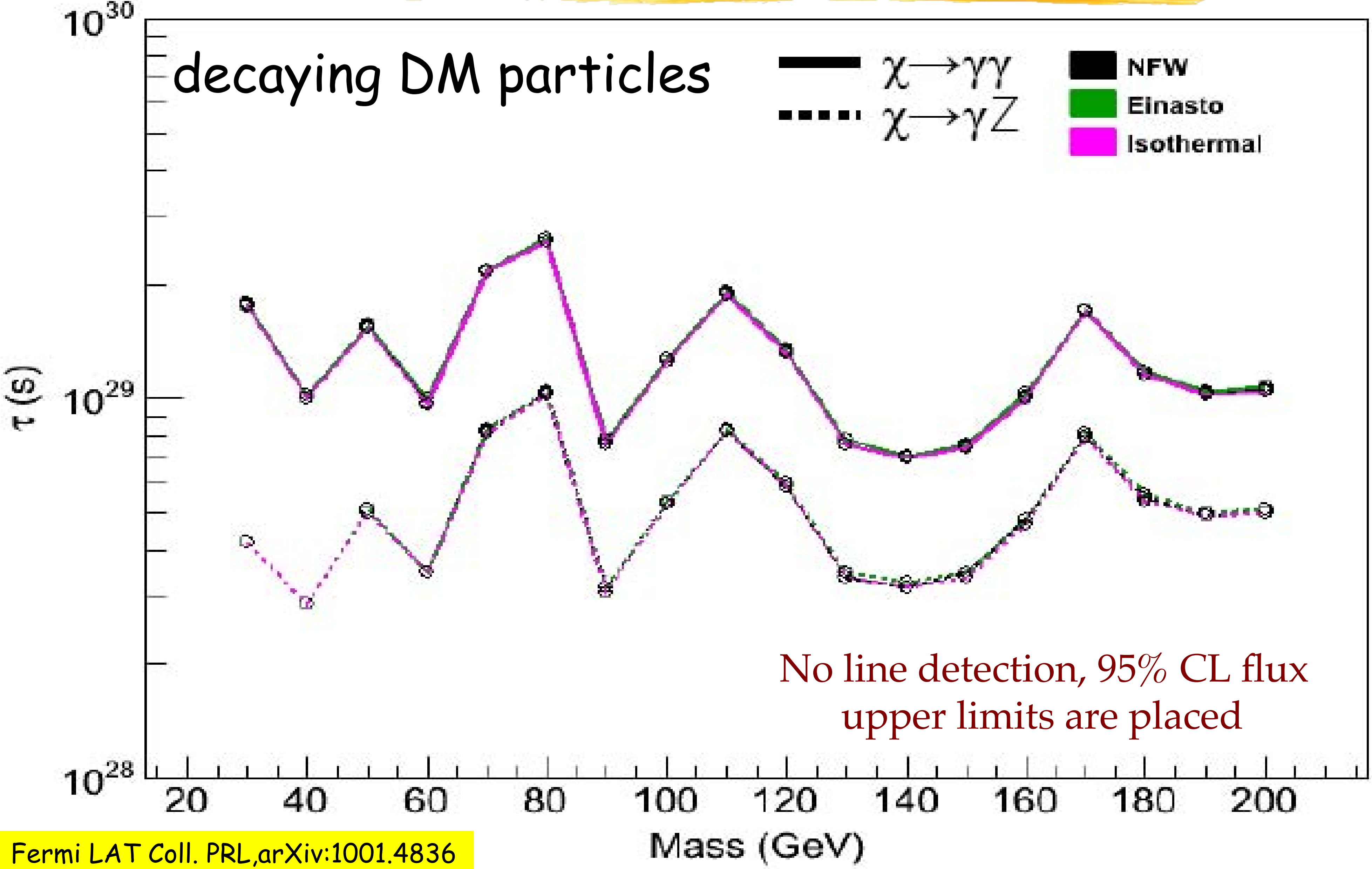


Search for Spectral Gamma Lines



Fermi LAT Coll. PRL,arXiv:1001.4836

Search for Spectral Gamma Lines



Fermi LAT Coll. PRL,arXiv:1001.4836

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