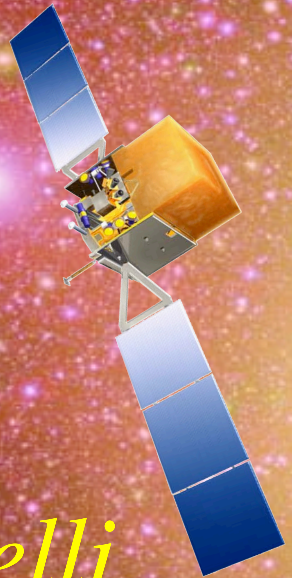
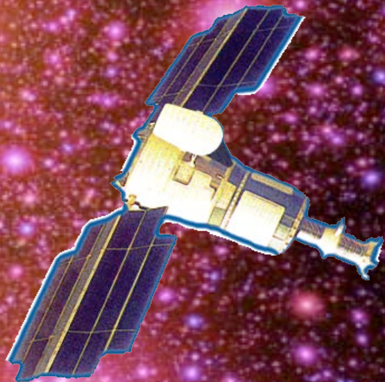
Indirect searches in the PAMELA and Fermi era





Aldo Morselli

INFN,

Sezione di Roma Tor Vergata

Springel, Wang, Volgensberger, Ludlow, Jenkins, Helmi, Navarro, Frenk & White '08

The Galileo Galilei Institute for Theoretical Physics
Arcetri, Florence

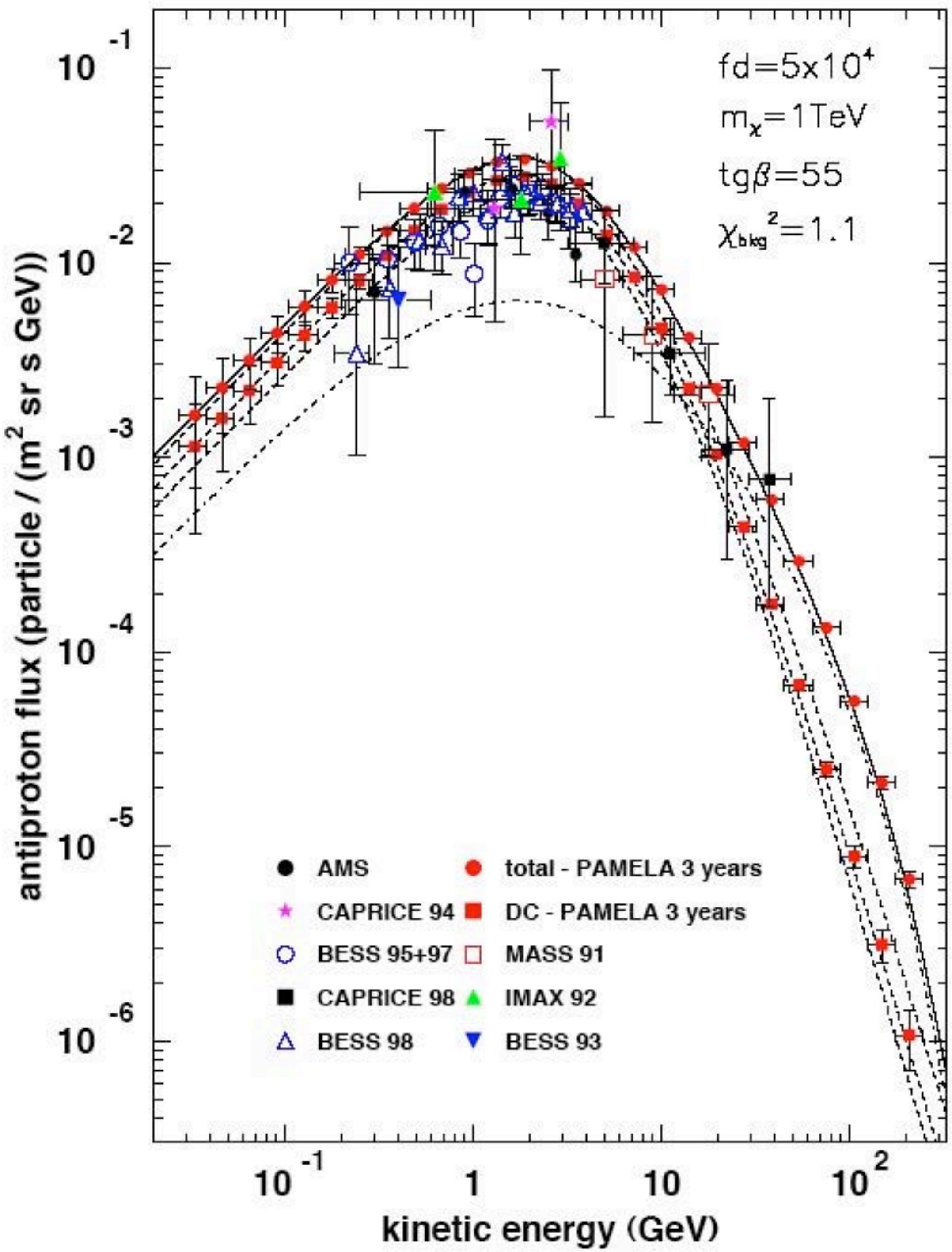
INFN

PAMELA: Cosmic-Ray Antiparticle Measurements: Antiprotons

an example in mSUGRA
5 years simulation

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



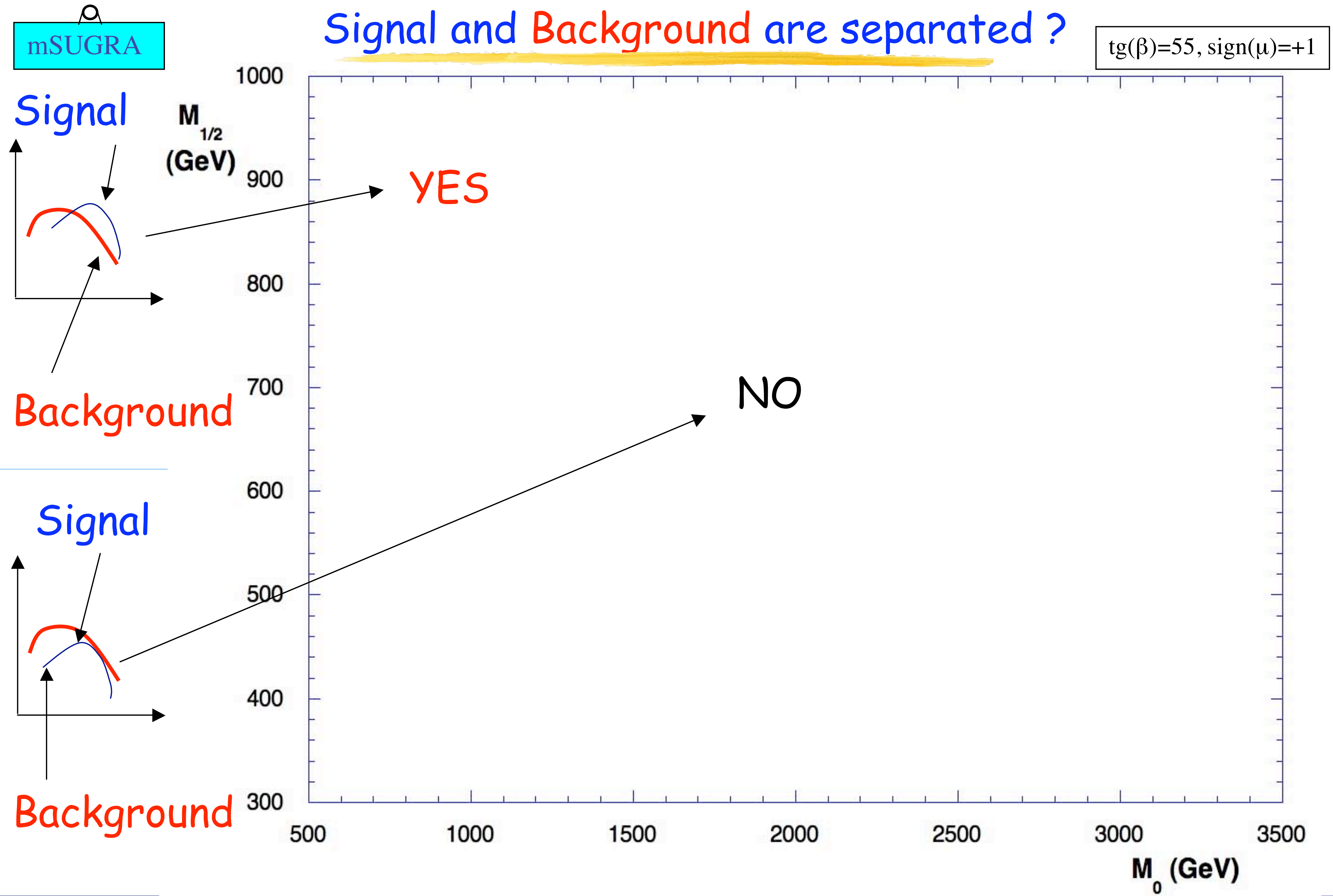
A.Lionetto, A.Morselli, V.Zdravkovic
JCAP09(2005)010 [astro-ph/0502406]

Supersymmetry introduces free parameters:

In the MSSM, with Grand Unification assumptions, the masses and couplings of the SUSY particles as well as their production cross sections, are entirely described once 5 parameters are fixed:

- $M_{1/2}$ the mass parameter of supersymmetric partners of gauge fields (gauginos)
- μ the higgs mixing parameters that appears in the neutralino and chargino mass matrices
- m_0 the common mass for scalar fermions at the GUT scale
- A the trilinear coupling in the Higgs sector
- $\tan\beta = v_2 / v_1 = \langle H_2 \rangle / \langle H_1 \rangle$ the ratio between the two vacuum expectation values of the Higgs fields

Signal and Background are separated ?

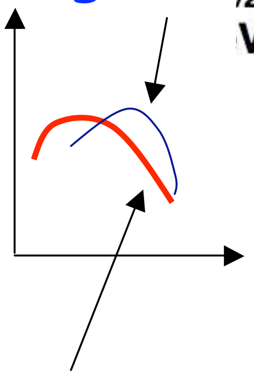


mSUGRA

Signal and Background are separated ?

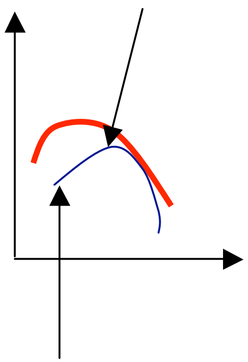
tg(β)=55, sign(μ)=+1

Signal

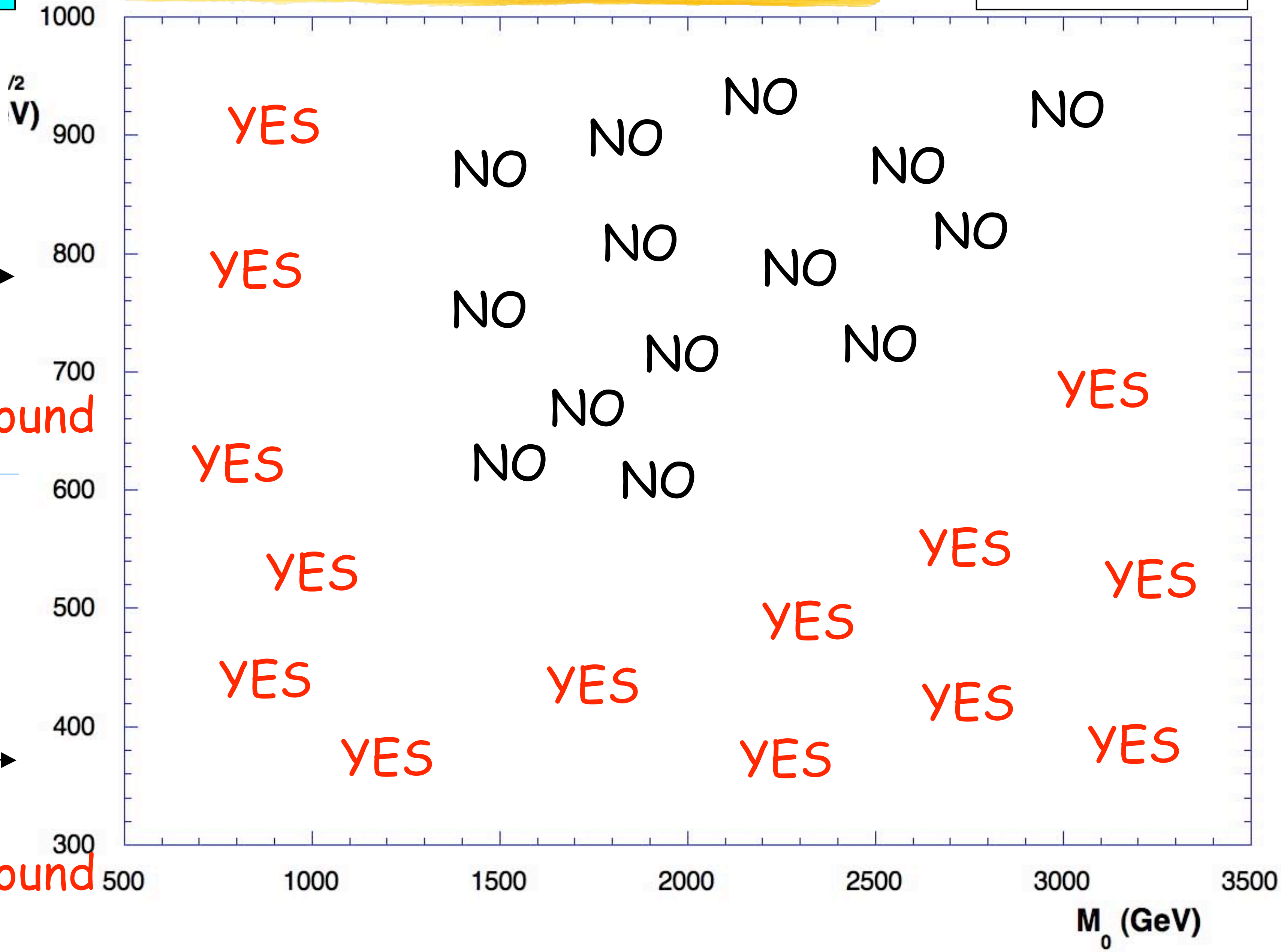


Background

Signal



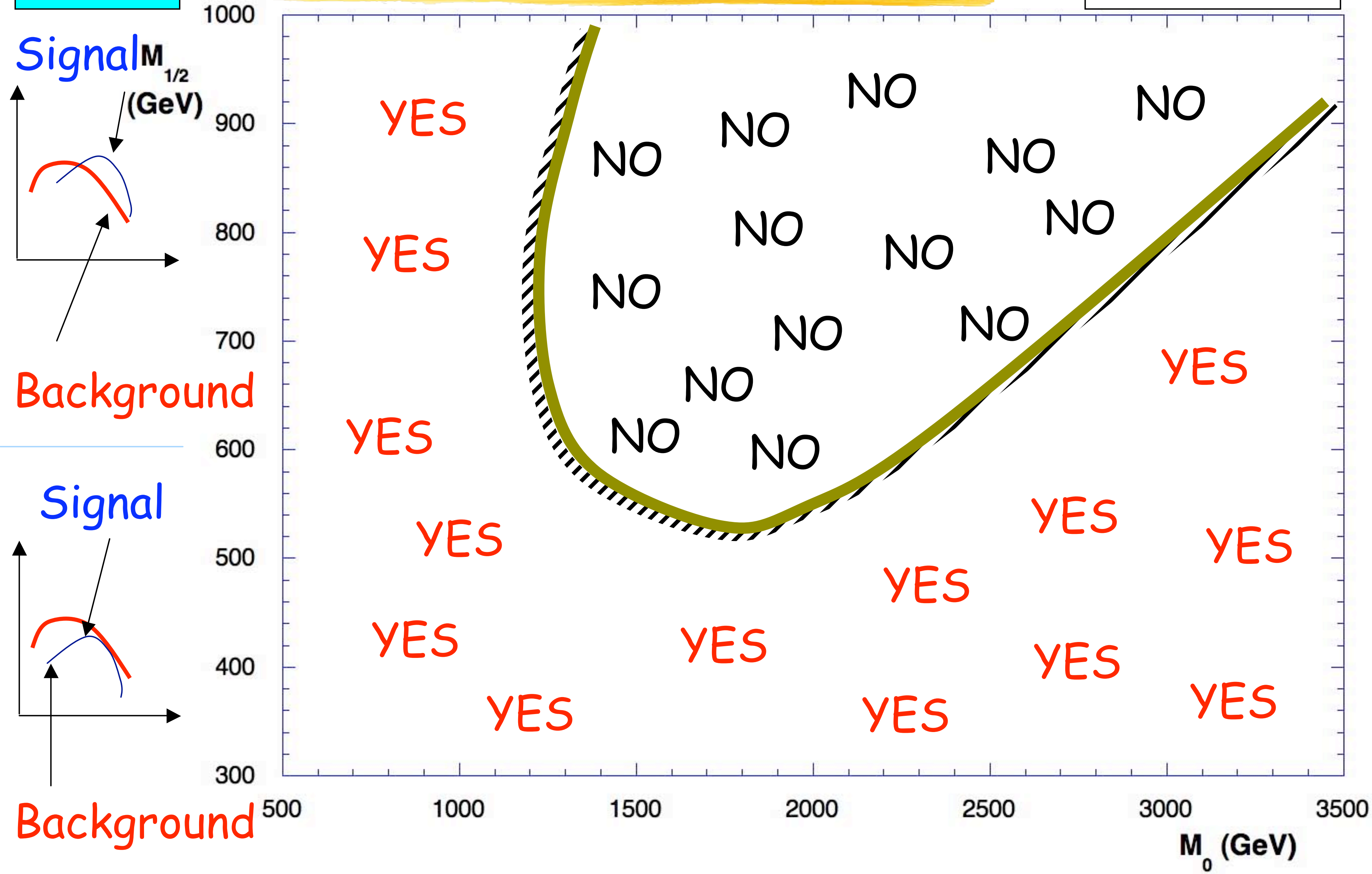
Background



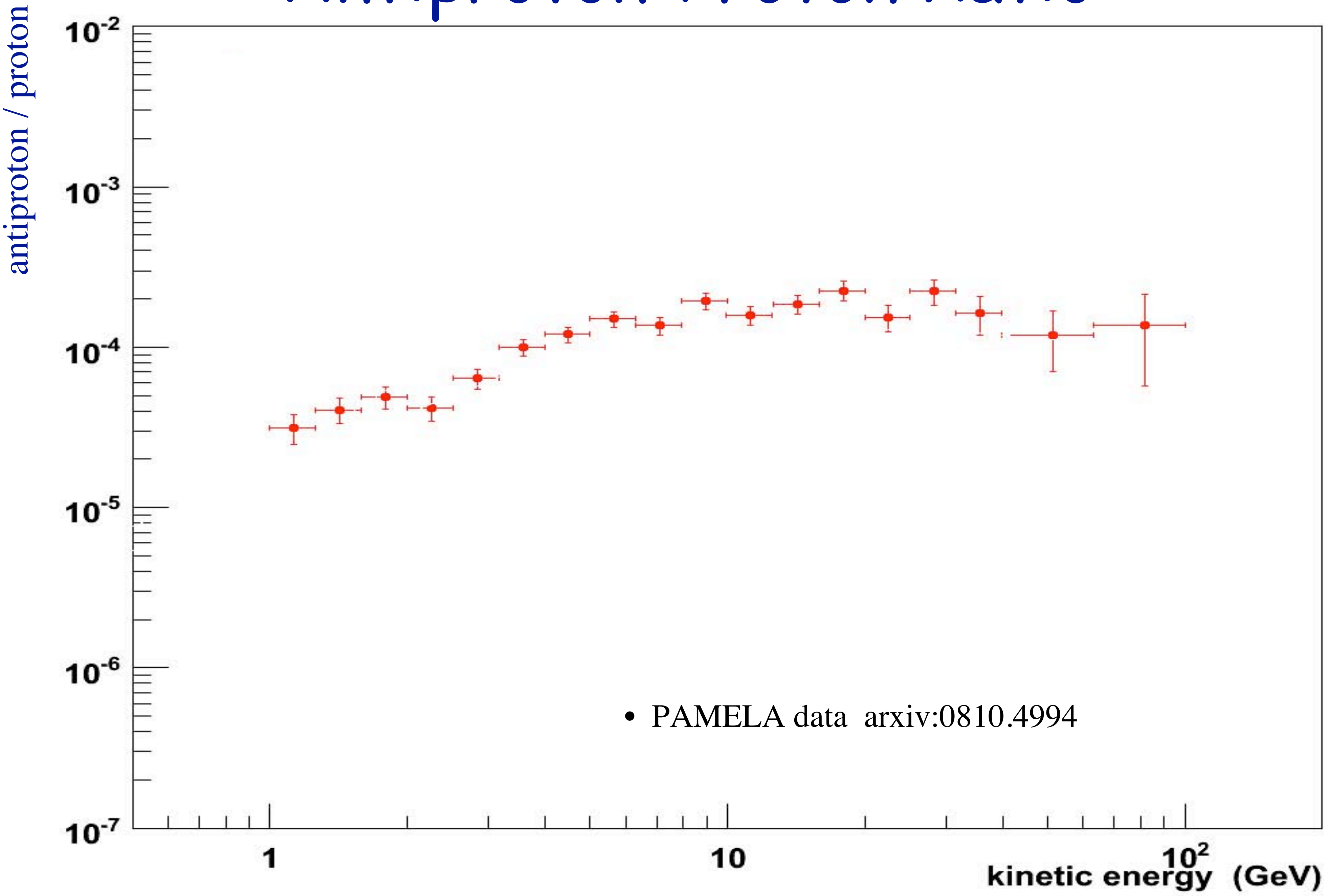
mSUGRA

Signal and Background are separated ?

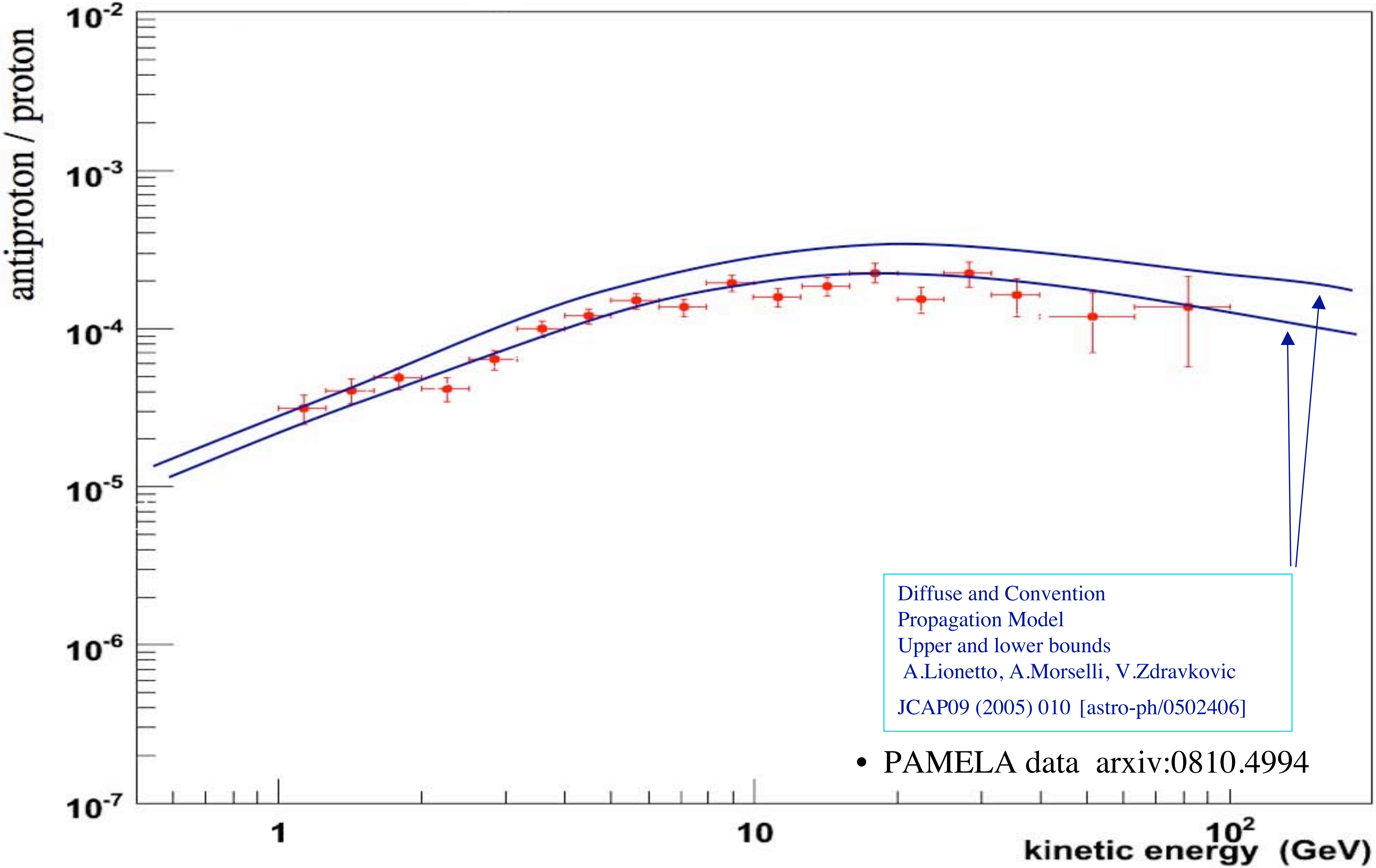
tg(β)=55, sign(μ)=+1



Antiproton-Proton Ratio

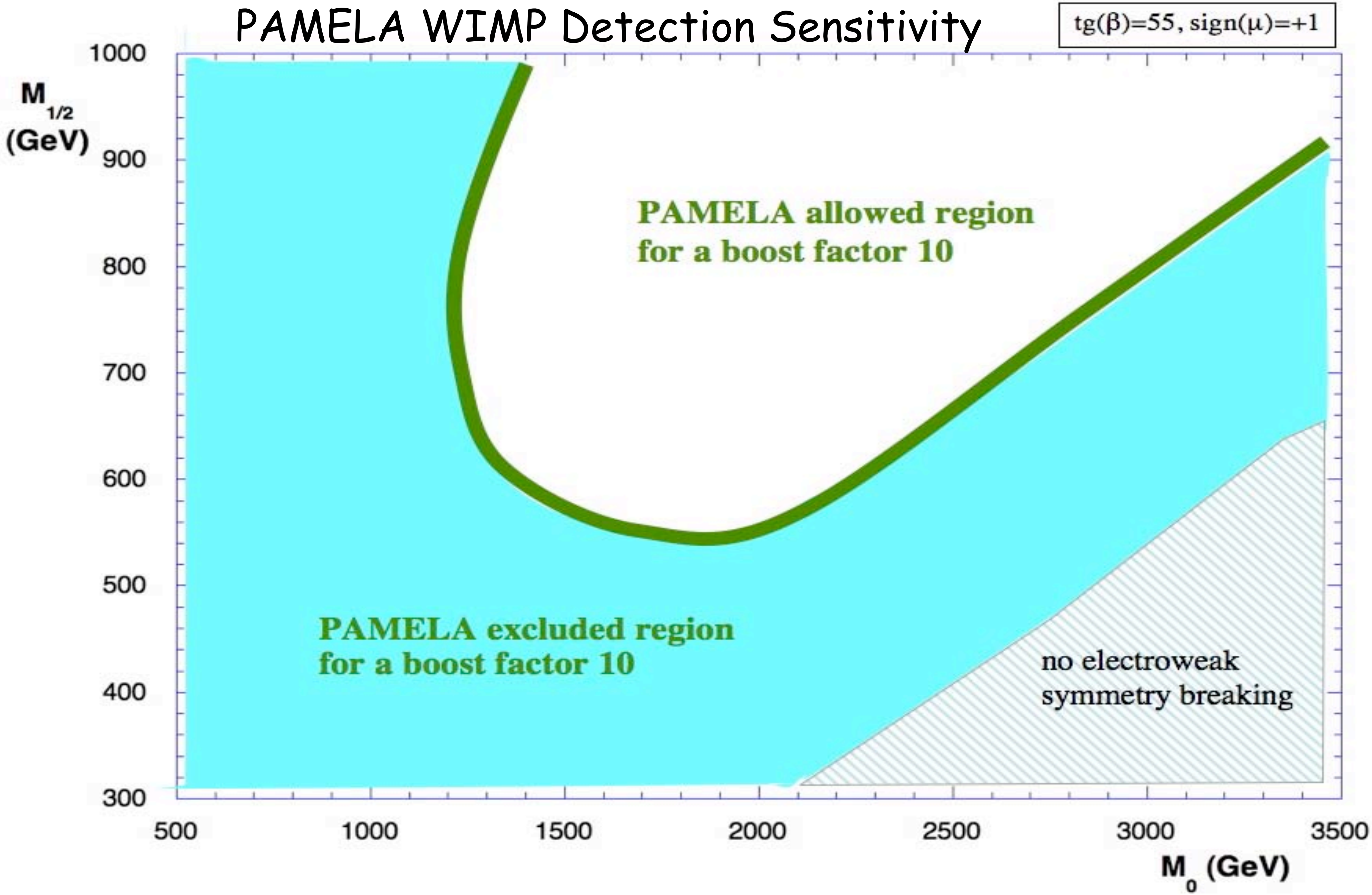


Antiproton-Proton Ratio

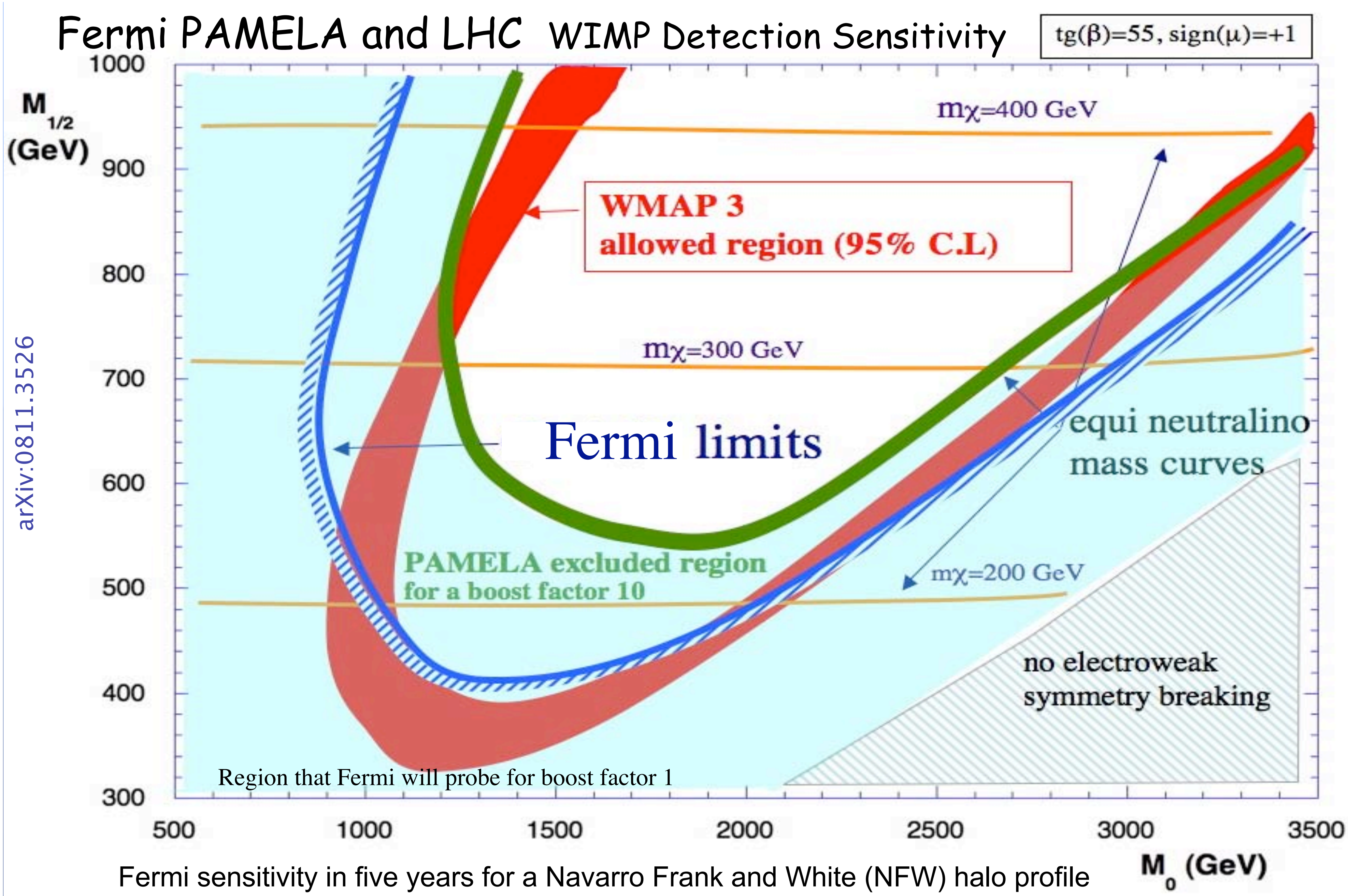


- PAMELA data arxiv:0810.4994

PAMELA WIMP Detection Sensitivity



Fermi PAMELA and LHC WIMP Detection Sensitivity

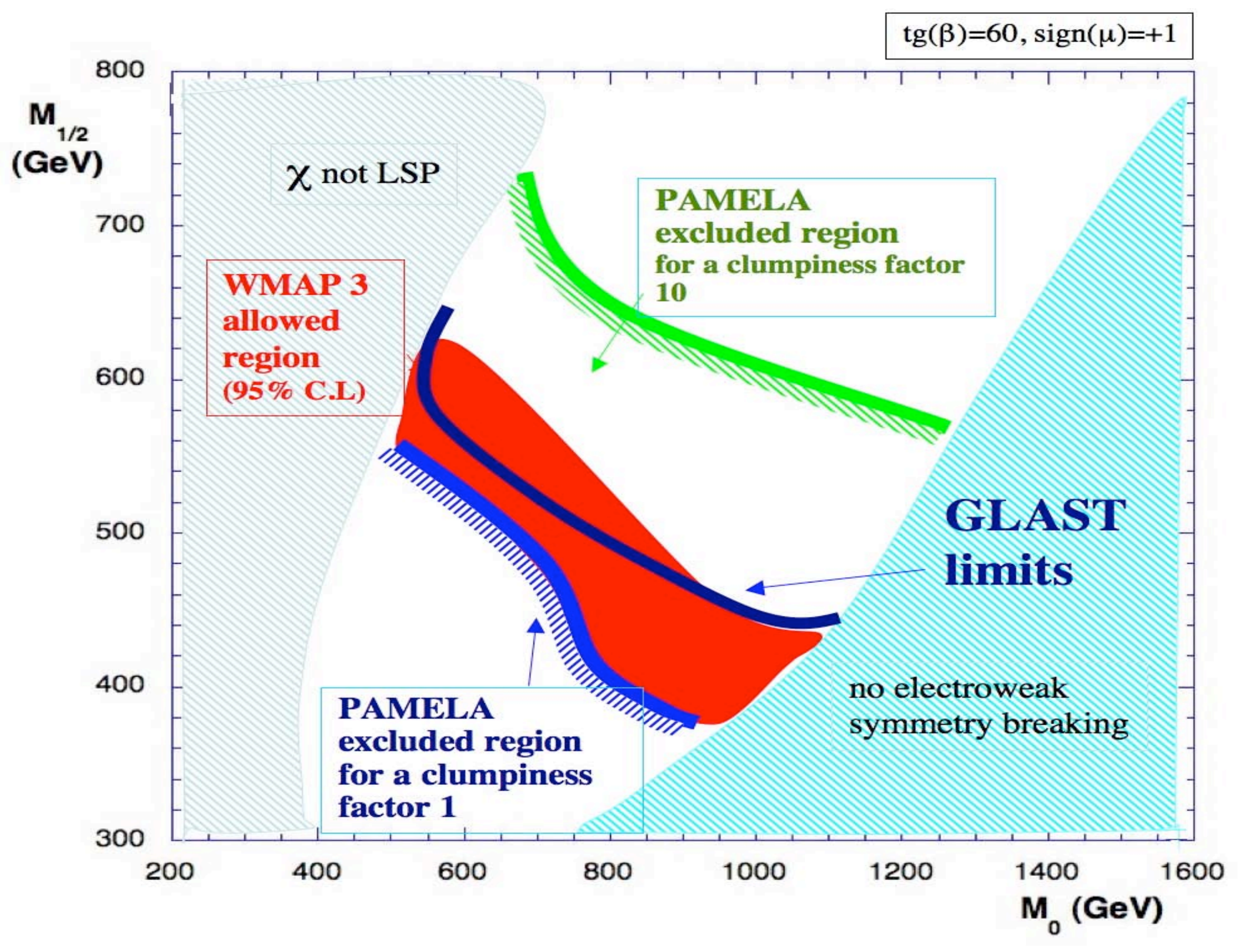


Fermi sensitivity in five years for a Navarro Frank and White (NFW) halo profile

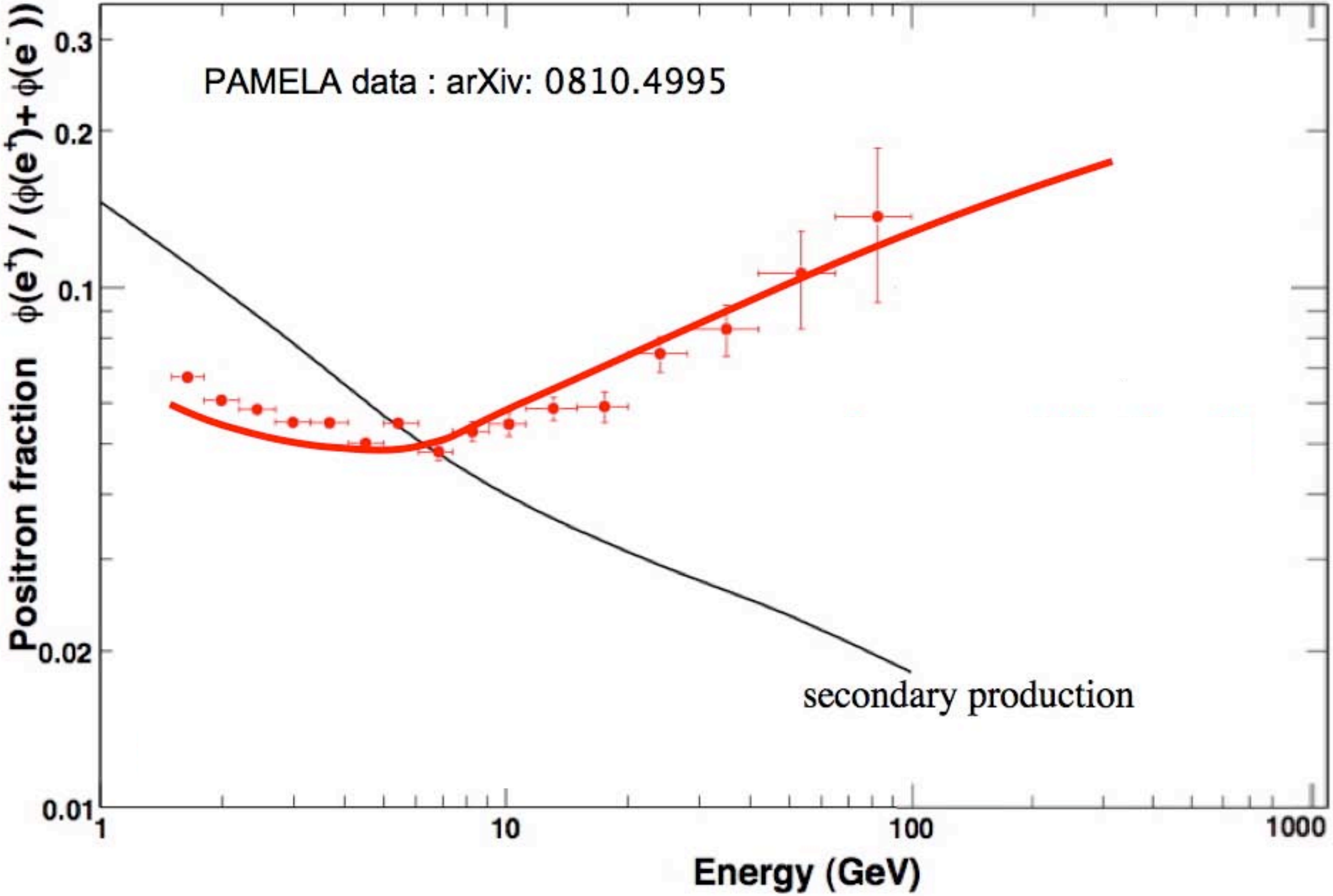
mSUGRA

PAMELA WIMP Detection Sensitivity

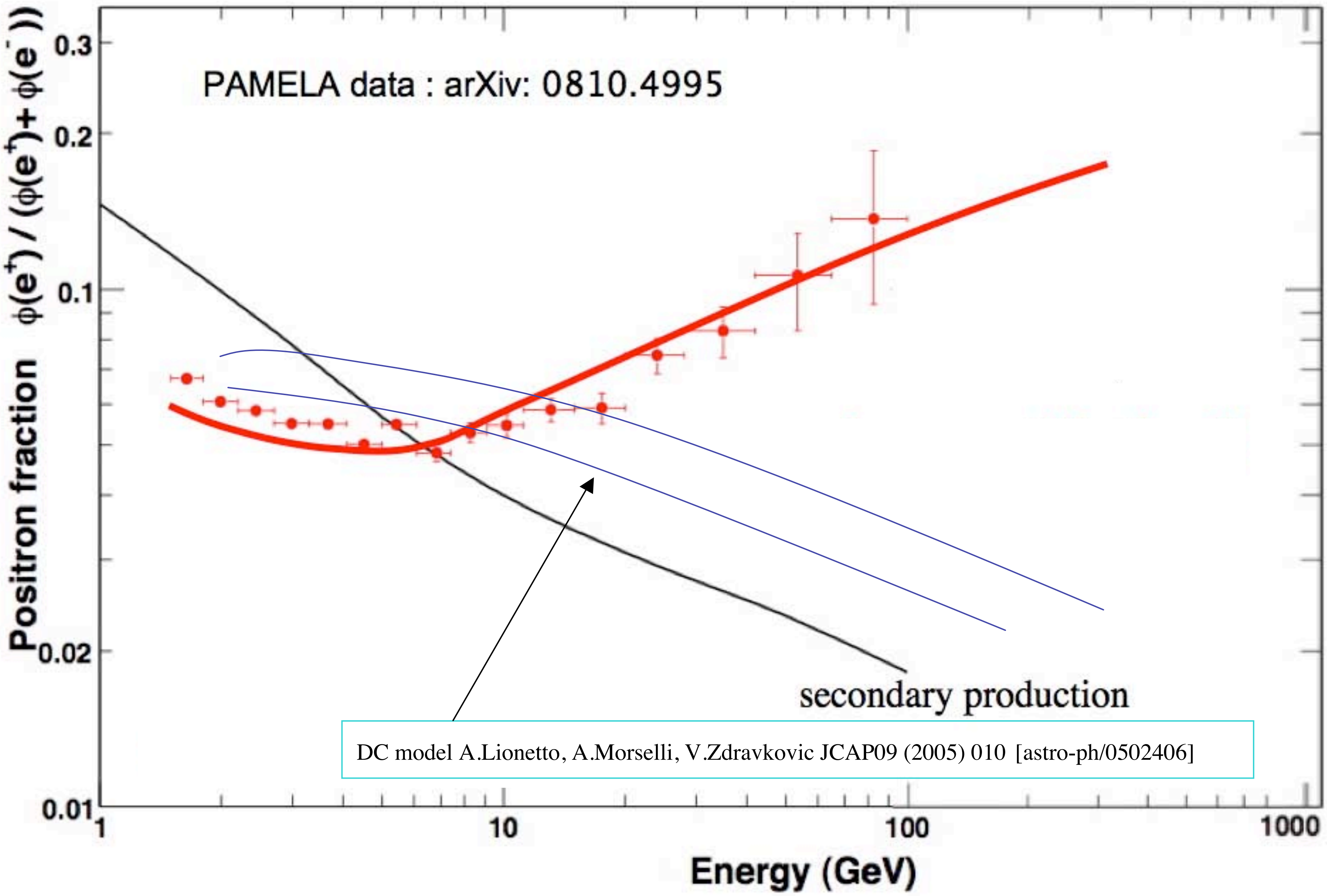
larger values of tg(B) gives larger signals both in antiprotons and gammas



Positron ratio

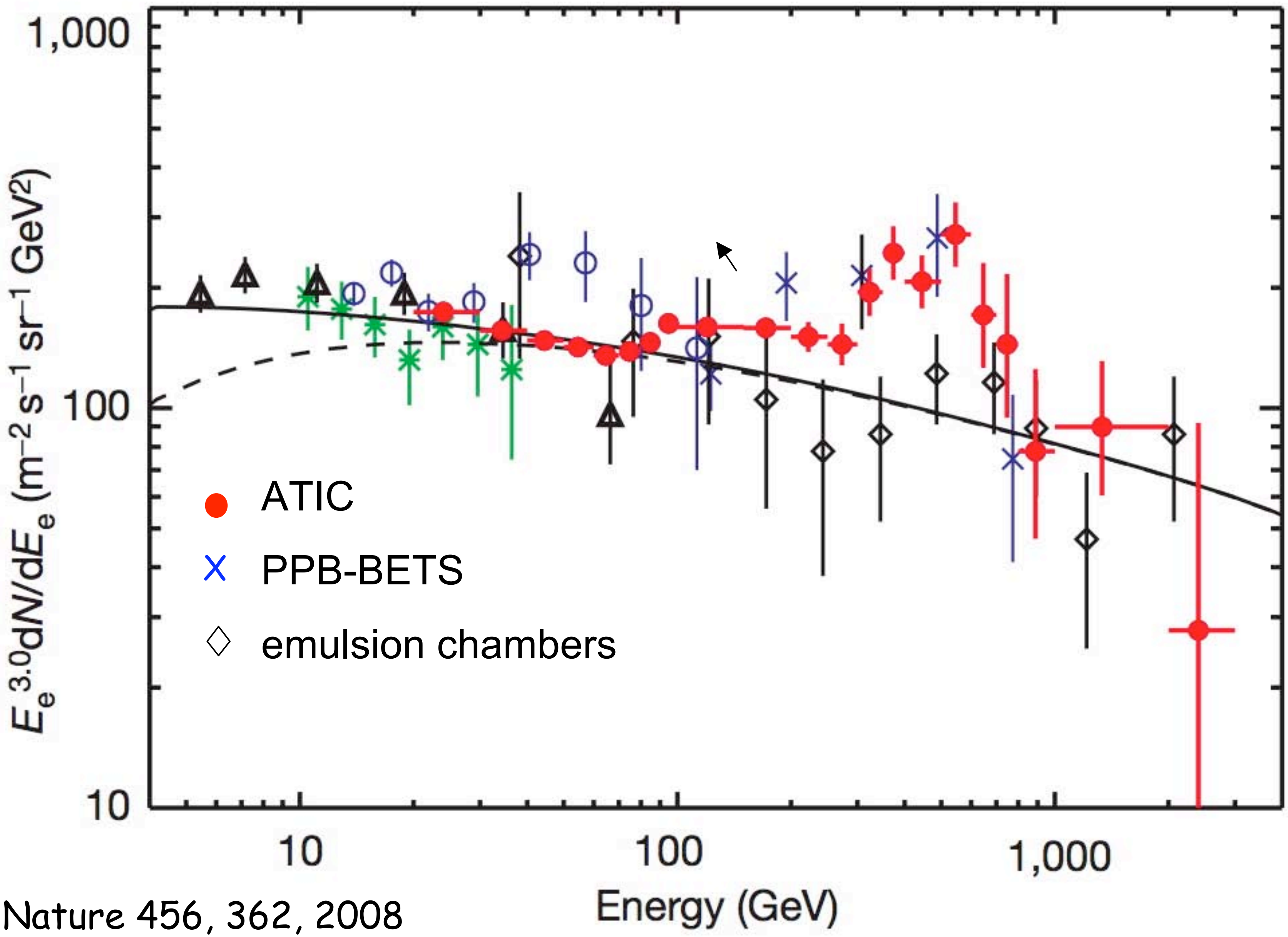


Positron ratio



electron + positron flux

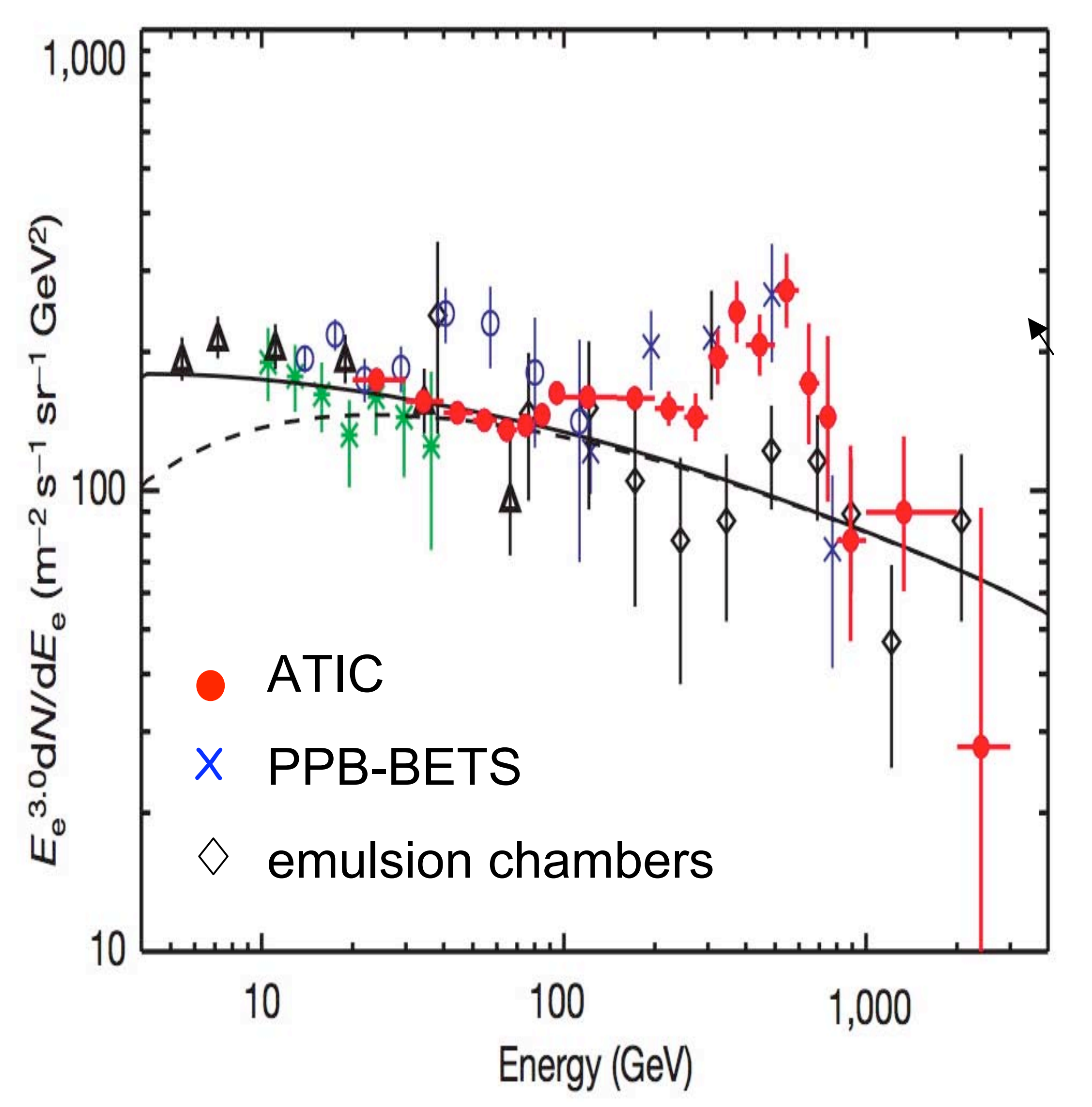
excess at about 300-600 GeV
by ATIC and PPB-BETS

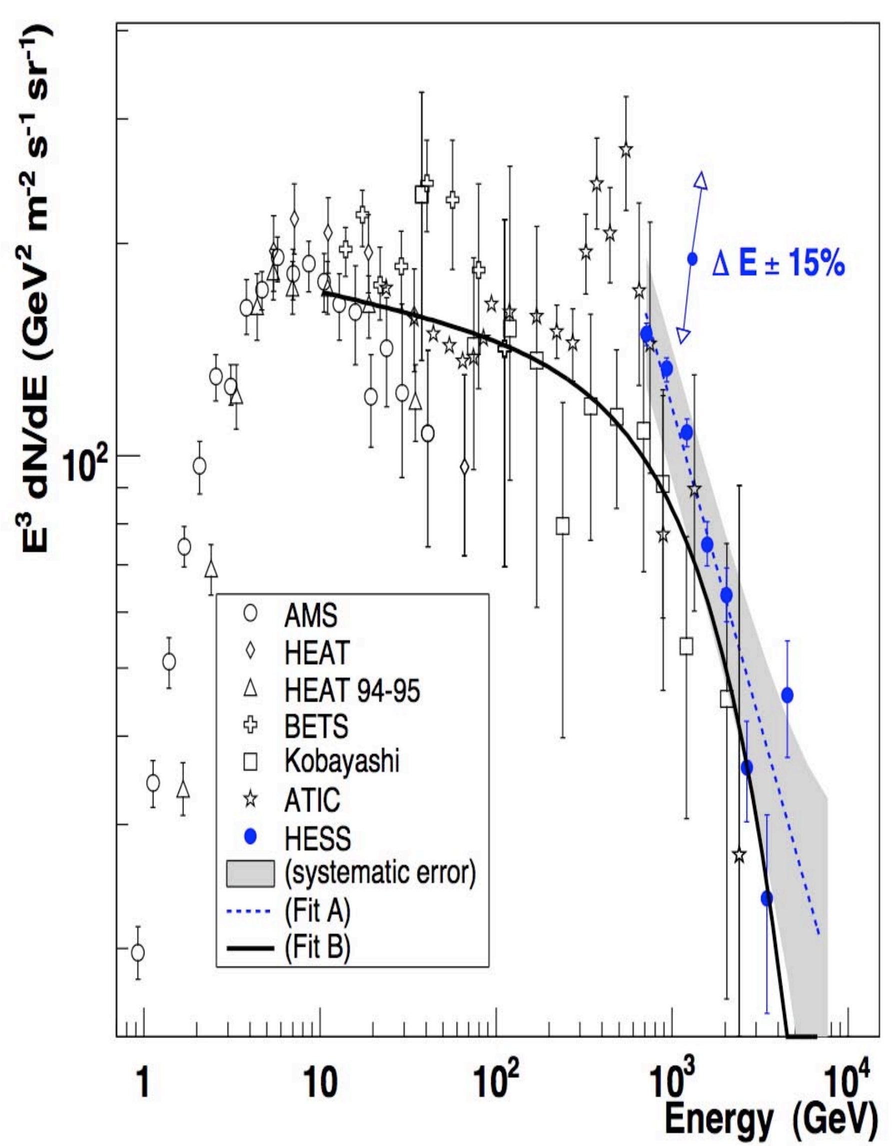


Nature 456, 362, 2008

electron + positron flux

excess at about 300-600 GeV
by ATIC and PPB-BETS and HESS results





Nature 456, 362, 2008

H.E.S.S. Coll. arXiv:0811.3894

some articles about the positron excess

arXiv:0902.0071 **PAMELA/ATIC anomaly from the meta-stable extra dark matter component and the leptophilic Yukawa interaction** Bumseok Kyae

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:0812.0219 **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
10. 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

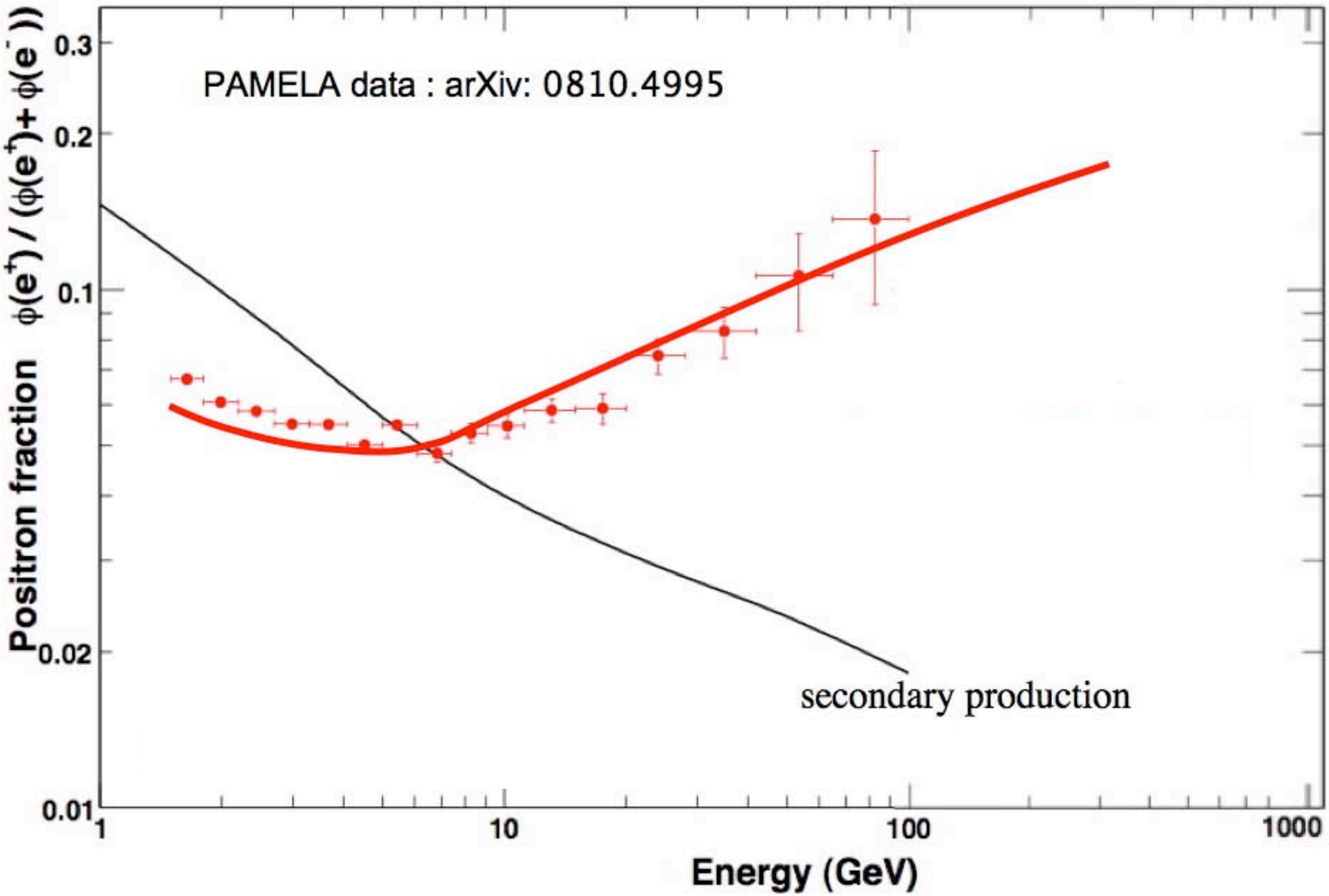
21. arXiv:0809.0792 **Gamma rays and positrons from a decaying hidden gauge boson** Chuan-Ren Chen, Fuminobu Takahashi, T. T. Yanagida

22. arXiv:0808.3867 **Minimal Dark Matter predictions and the PAMELA positron excess**Marco Cirelli, Alessandro Strumia

23. arXiv:0808.3725 **New Positron Spectral Features from Supersymmetric Dark Matter - a Way to Explain the PAMELA Data?**Lars Bergstrom, Torsten Bringmann, Joakim Edsjo

24. arXiv:0811.3744 **Gamma-ray and radio tests of the e+e- excess from DM annihilations** Gianfranco Bertone, Marco Cirelli, Alessandro Strumia, Marco Taoso

Positron ratio

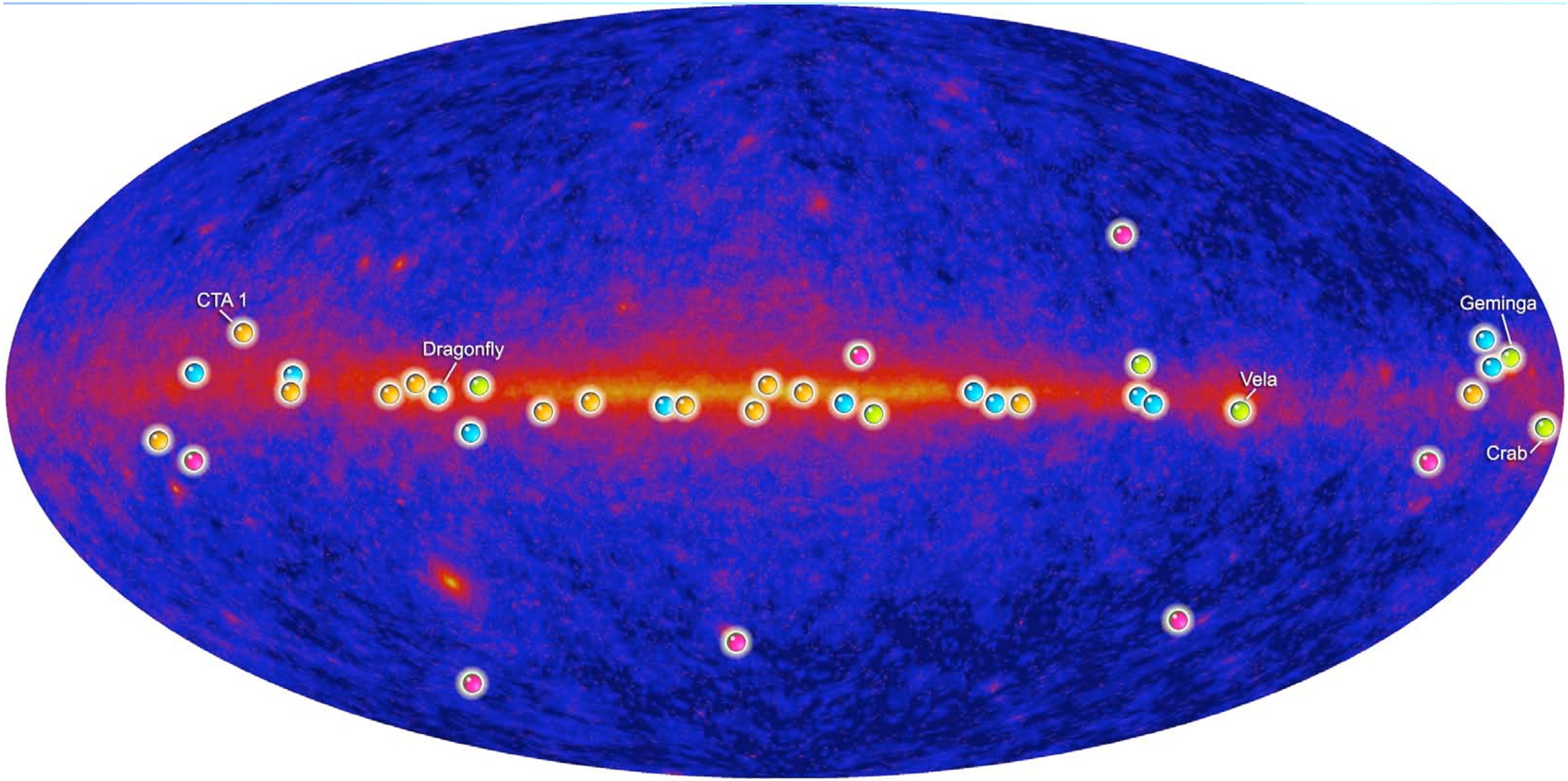


Millisecond pulsars detected by *Fermi*

PULSAR	PERIOD (ms)	PERIOD DERIV. (10^{-20} s/s)	D (kpc)	Edot (erg/s)	# PHOTONS	H-TEST TS	CHANCE PROB
J0030+0451	4.86	1	0.317	3.44E+33	361	306.8	< 4e-08
J0218+4232	2.32	7.74	3.2	2.44E+35	455	12	0.0084
J0437-4715	5.76	5.73	0.15	1.18E+34	166	89.1	< 4e-08
J0613-0200	3.06	0.96	0.48	1.32E+34	549	60	< 4e-08
J1024-0719	5.16	1.85	0.53	5.31E+33	135	14	0.0038
J1744-1134	4.07	0.89	0.48	5.21E+33	1014	25.1	5.04E-05
J2124-3358	4.93	2.1	0.25	6.91E+33	277	577	< 4e-08

- Search for pulsations at radio period in first 4 months of Fermi LAT data using radio ephemerides
- Detection of pulsations from 7 millisecond pulsars - 5 with high significance
- Confirmation of pulsations from PSR J0218+4232 but with lower significance

Carmelo Sgrò



Fermi Pulsar Detections

12 ● New pulsars discovered in a blind search
7 ● Millisecond radio pulsars
13 ● Young radio pulsars (pulsing in Gamma-rays alone)
6 ● Pulsars seen by Compton Observatory EGRET instrument

Fermi has found 12 previously unknown pulsars (orange).
detected gamma-ray emissions from known radio pulsars (magenta, cyan)
and from known or suspected gamma-ray pulsars identified by EGRET (green)

(known pulsars ~ 1800)

New Data is Forthcoming

Electron Spectrum:

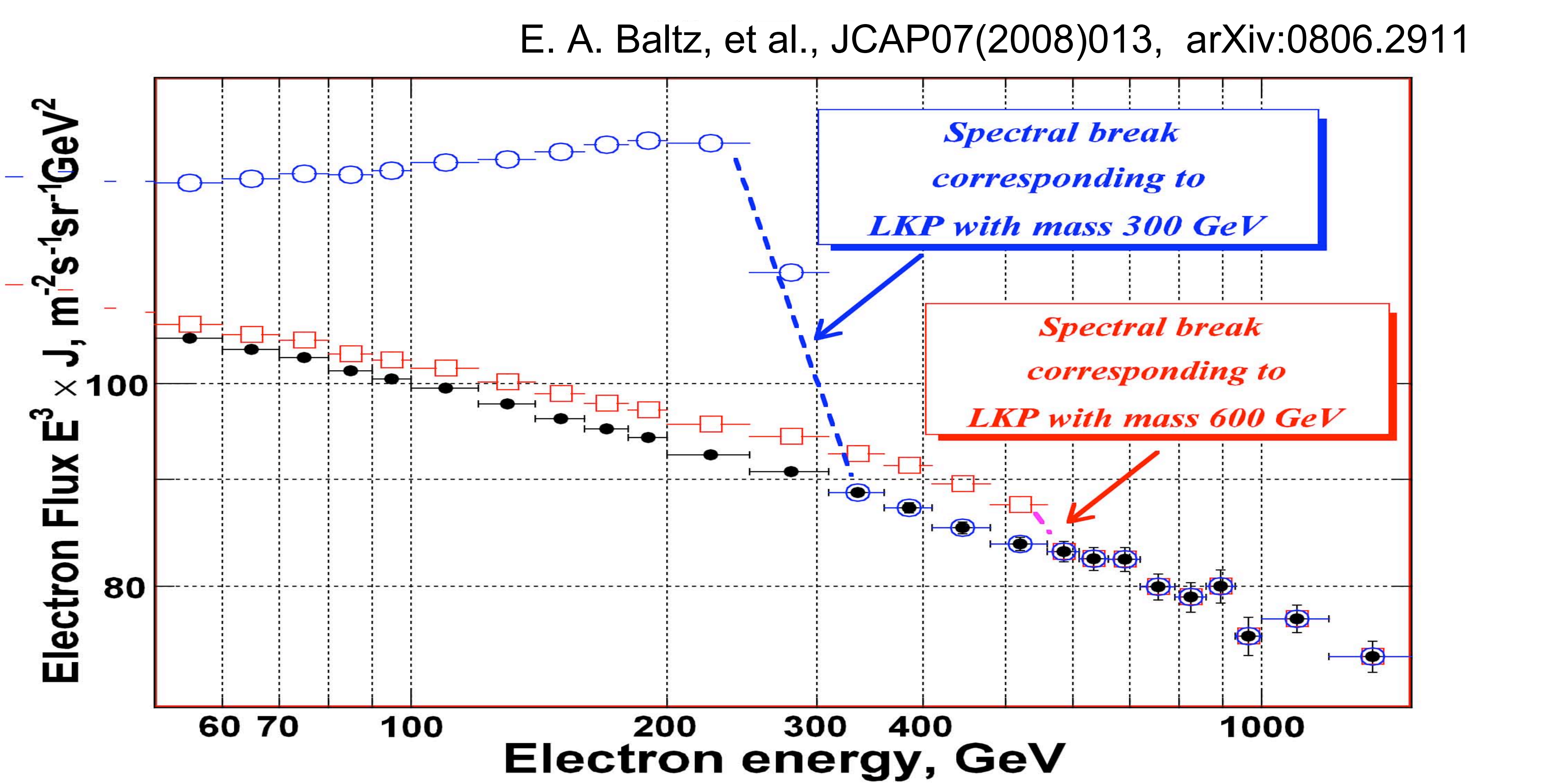
- **PAMELA & FERMI (GLAST)** (taking data in space);
- **ATIC-4** (had successful balloon flight,under analysis);
- **CREST** (new balloon payload under development);
- **AMS-02** (launch date TBD);
- **CALET** (proposed for ISS);
- **ECAL** (proposed balloon experiment).

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**

5 years of GLAST LAT observation, clump at 100 pc, $D_0 = 10^{28}$ cm^2/s



for a NFW DM distribution with boost factor of 5 and ρ_{local} = 0.4 GeV cm^{-3}

Fermi measurements of the total lepton flux with large statistics will be able to distinguish a gradual change in slope with a sharp cutoff with high confidence

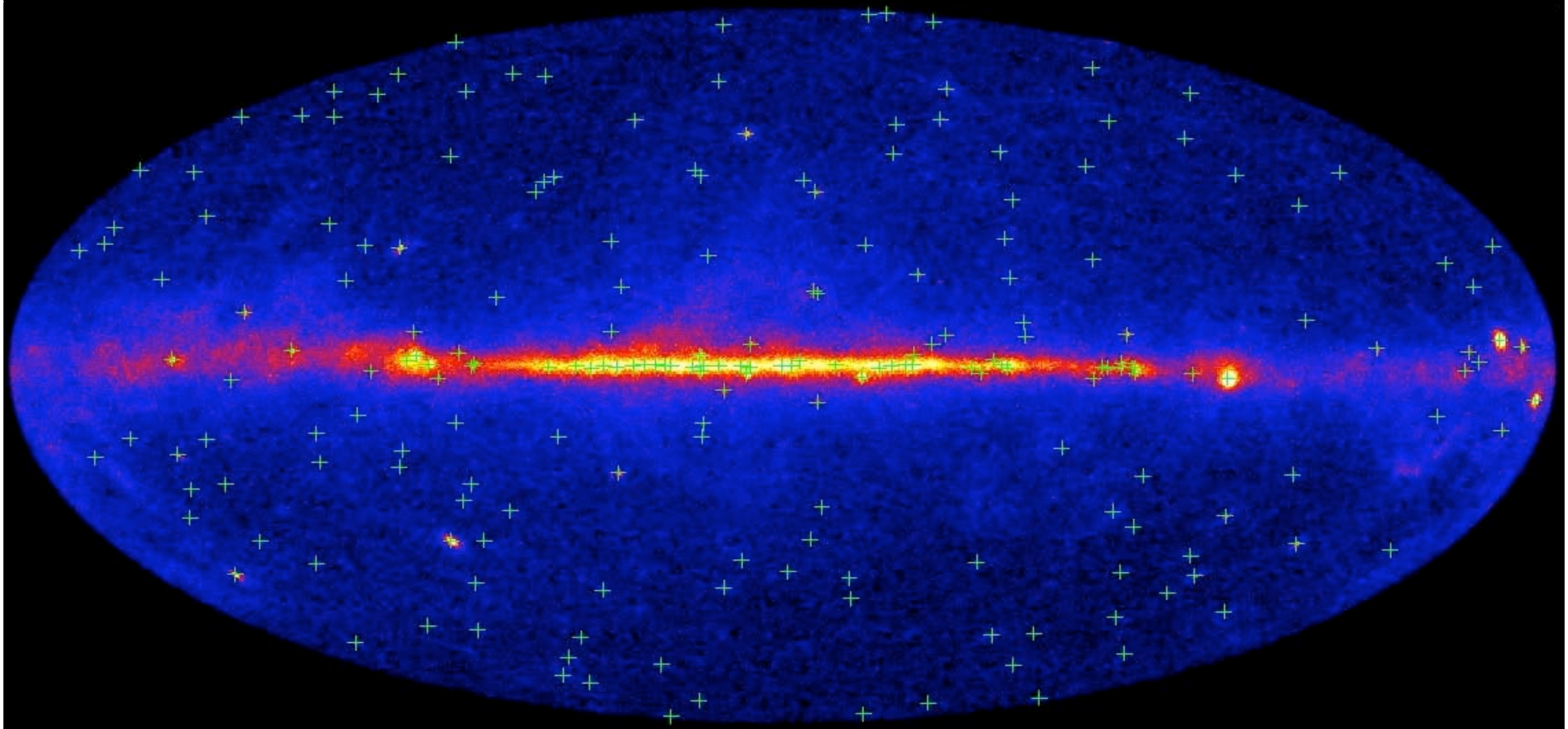
- The key to understanding the origin of the excess in the ratio is the accurate measurement of positron and electron fluxes separately.
- To confirm the DM signature, we should look into the signal in HE pbars (PAMELA) and gamma-rays and electron total flux (Fermi (GLAST)). ← RICAP 09
- If this is an astrophysical source of positrons, it should be quite close and we should probably be able to see it with Fermi.

Fermi

Gamma-ray Space Telescope

At Six Months

205 Preliminary Fermi LAT Bright Sources

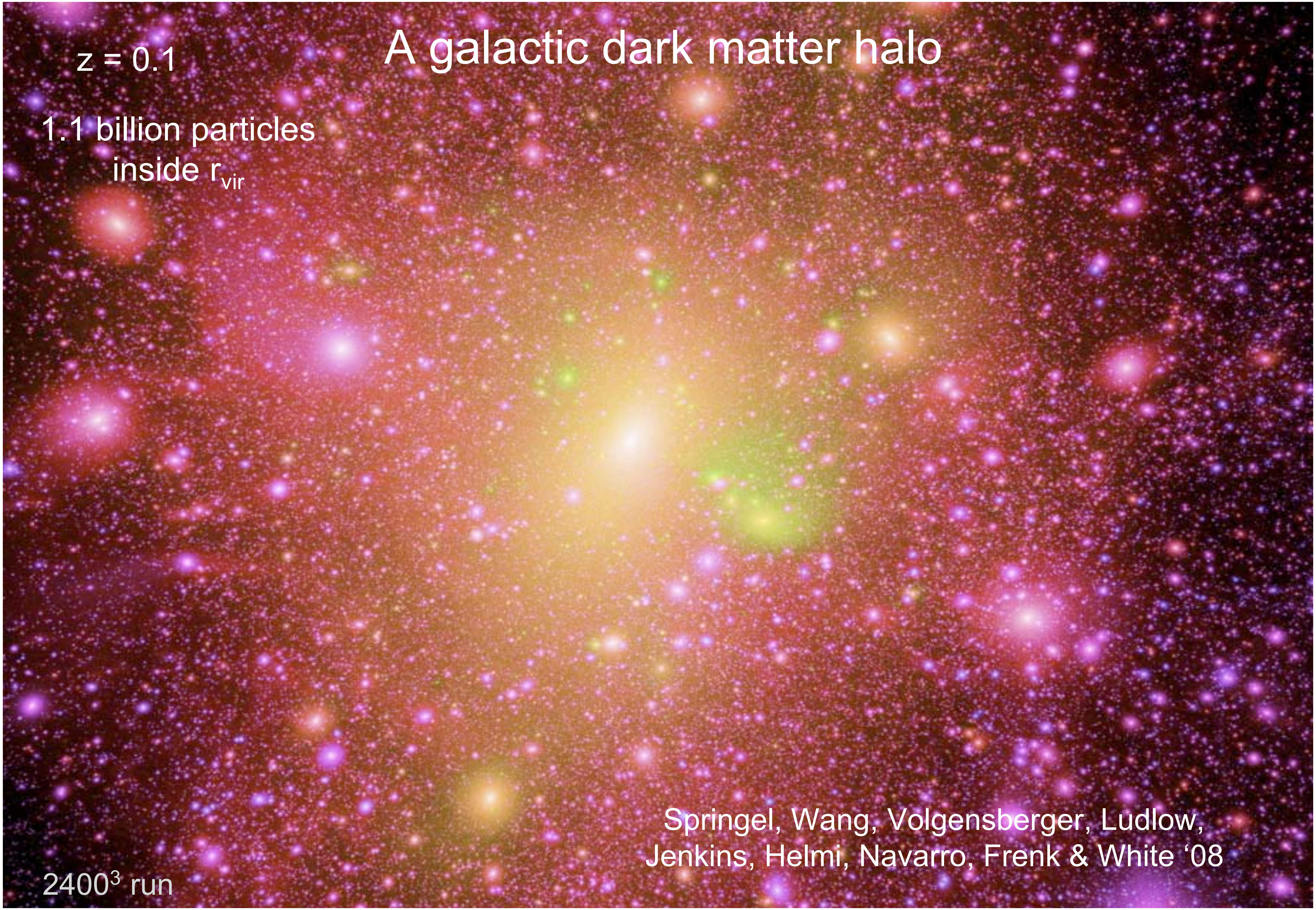


Crosses mark source locations, in Galactic coordinates.

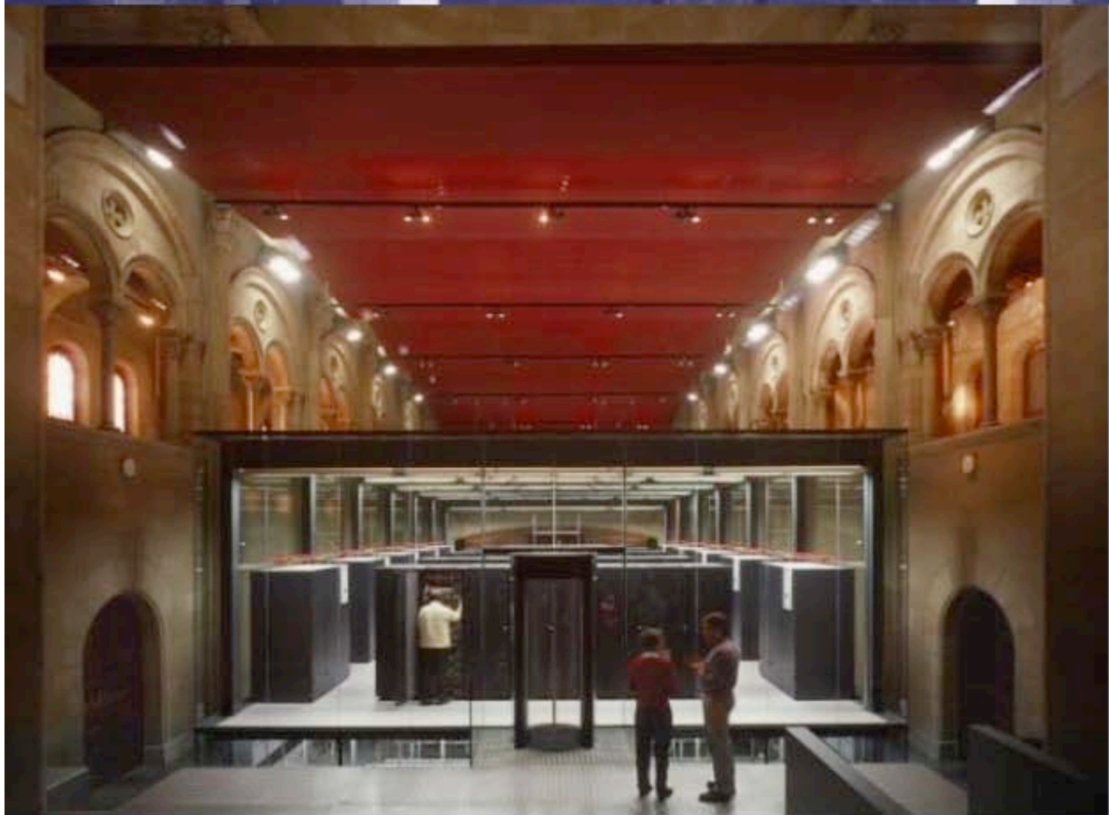
Fermi Coll. Submitted to ApJS arXiv:0902.1340

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.**
- **Additional results on many of these sources in** 213th AAS Meeting — Long Beach, CA**.**


A galactic dark matter halo
z = 0.1
1.1 billion particles inside r_{vir}
Springel, Wang, Volgensberger, Ludlow, Jenkins, Helmi, Navarro, Frenk & White ‘08
2400^3 run

Mare Nostrum simulation (with baryons)



- MareNostrum Supercomputer

  - 5th biggest supercomputer of the world (Top500 November 2006. (Now is 23rd)

  -1st supercomputer in Europe.(until last year, now 2nd)

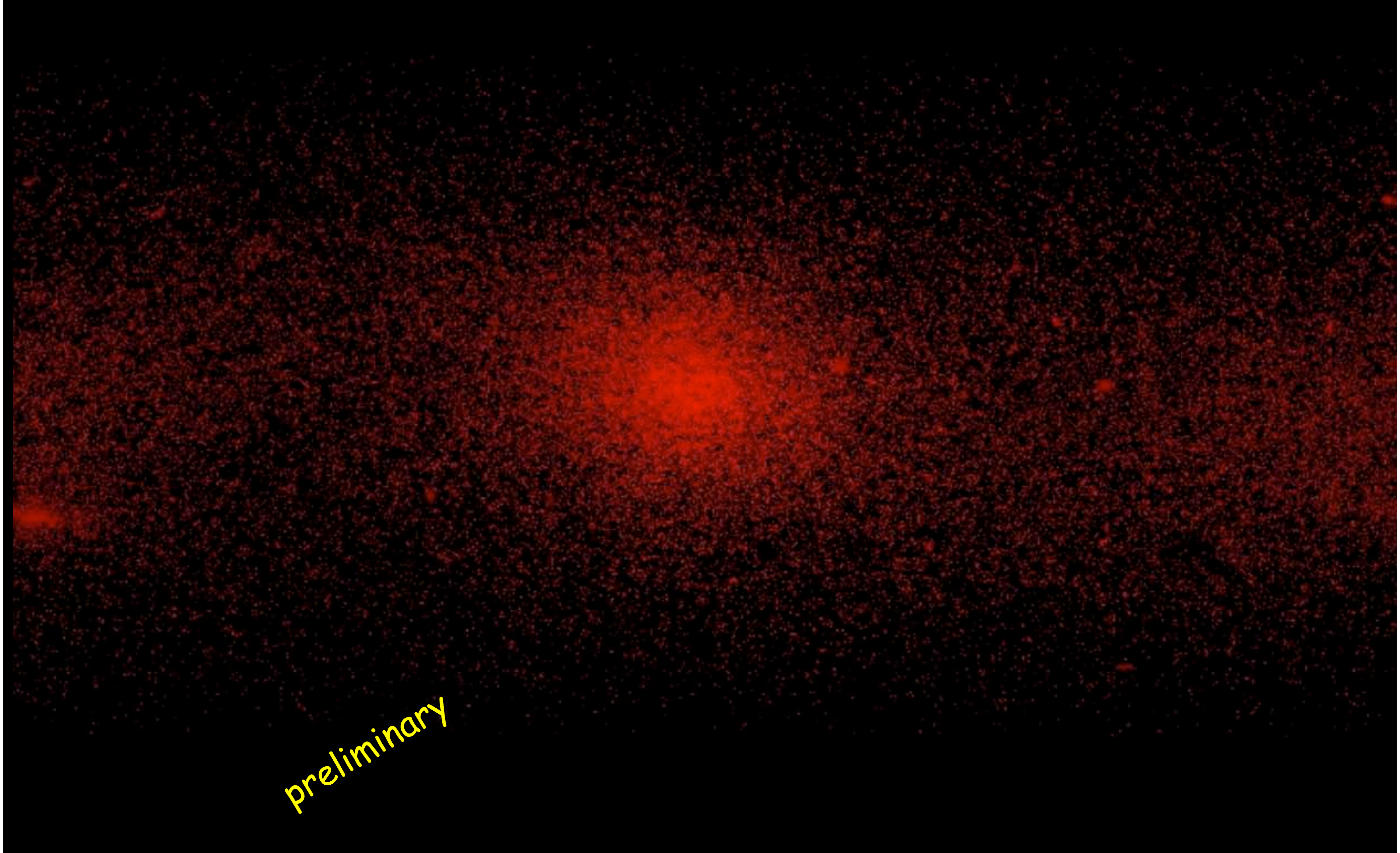
  -10,240 PPC processors and 20 TeraBytes Memory

  -280+90 Tbytes disk space.

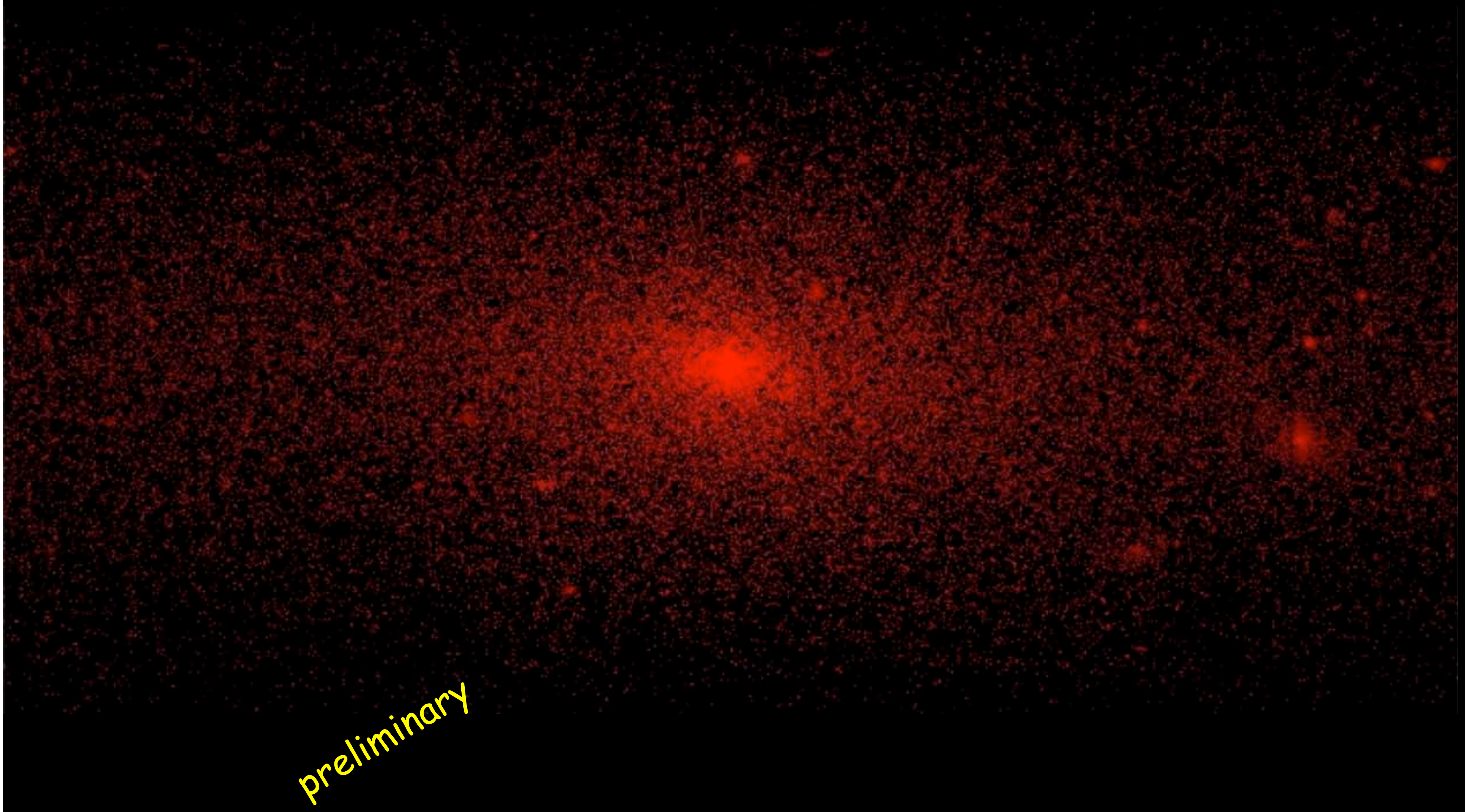
-More than **6,000,000 CPU** hours (680 years) used for this project since 2005.

The Marenostrum Numerical Cosmology Project

Mare Nostrum simulation (without baryons)

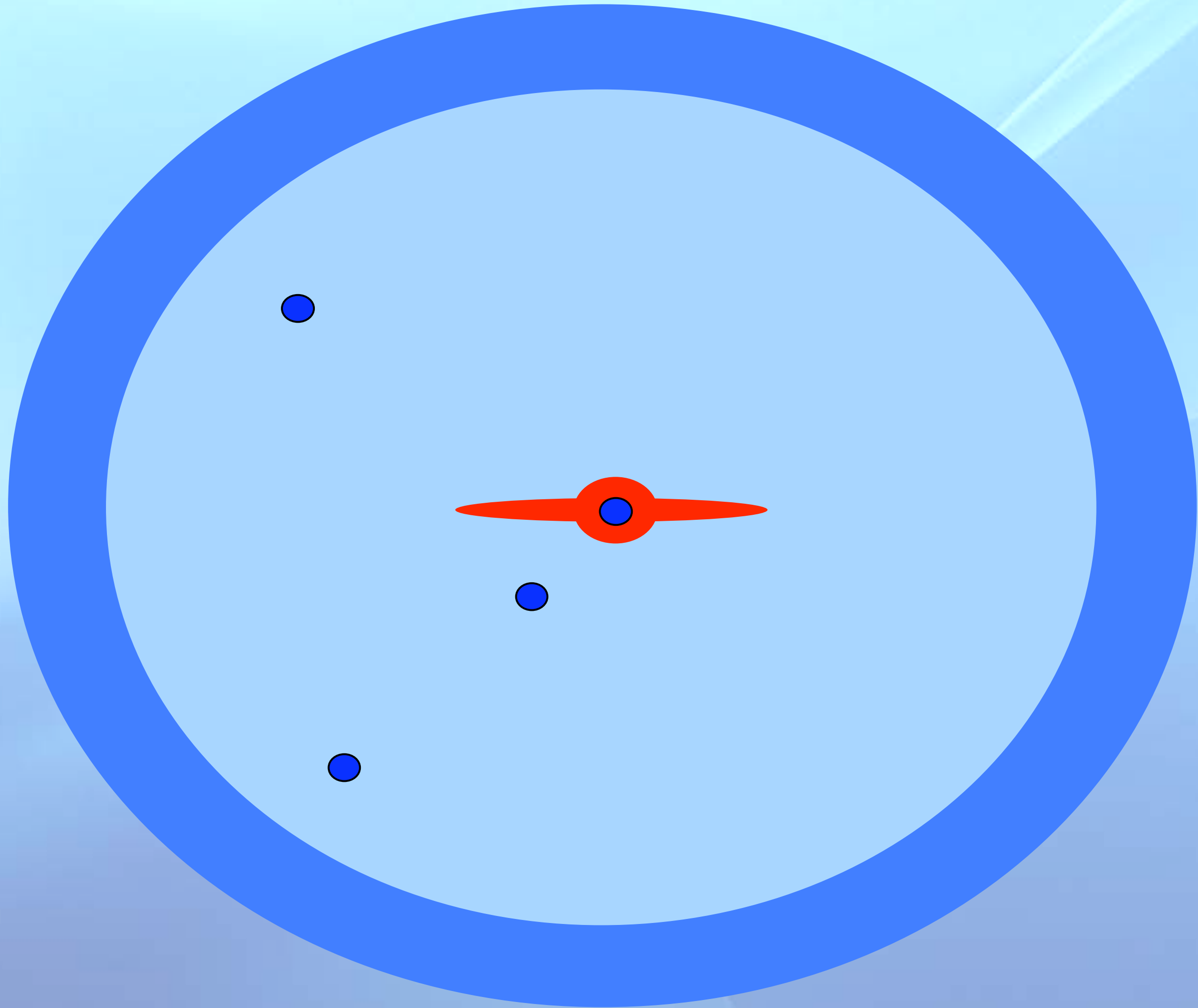


Mare Nostrum simulation (with baryons)

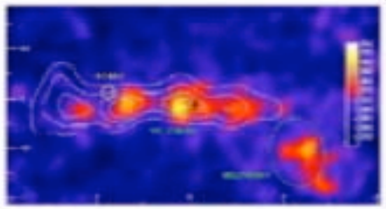
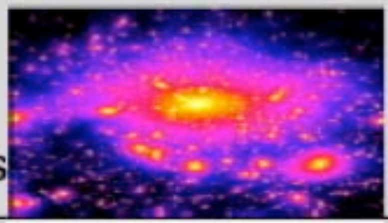
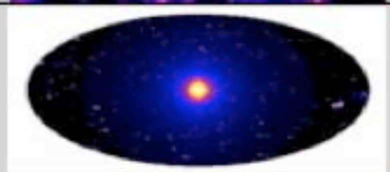
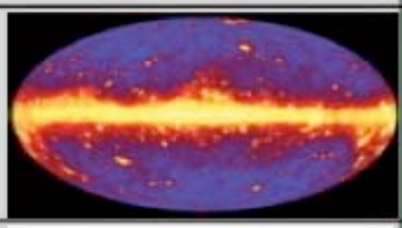
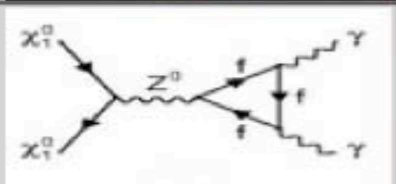


Where should we look for WIMPs with FERMI ?

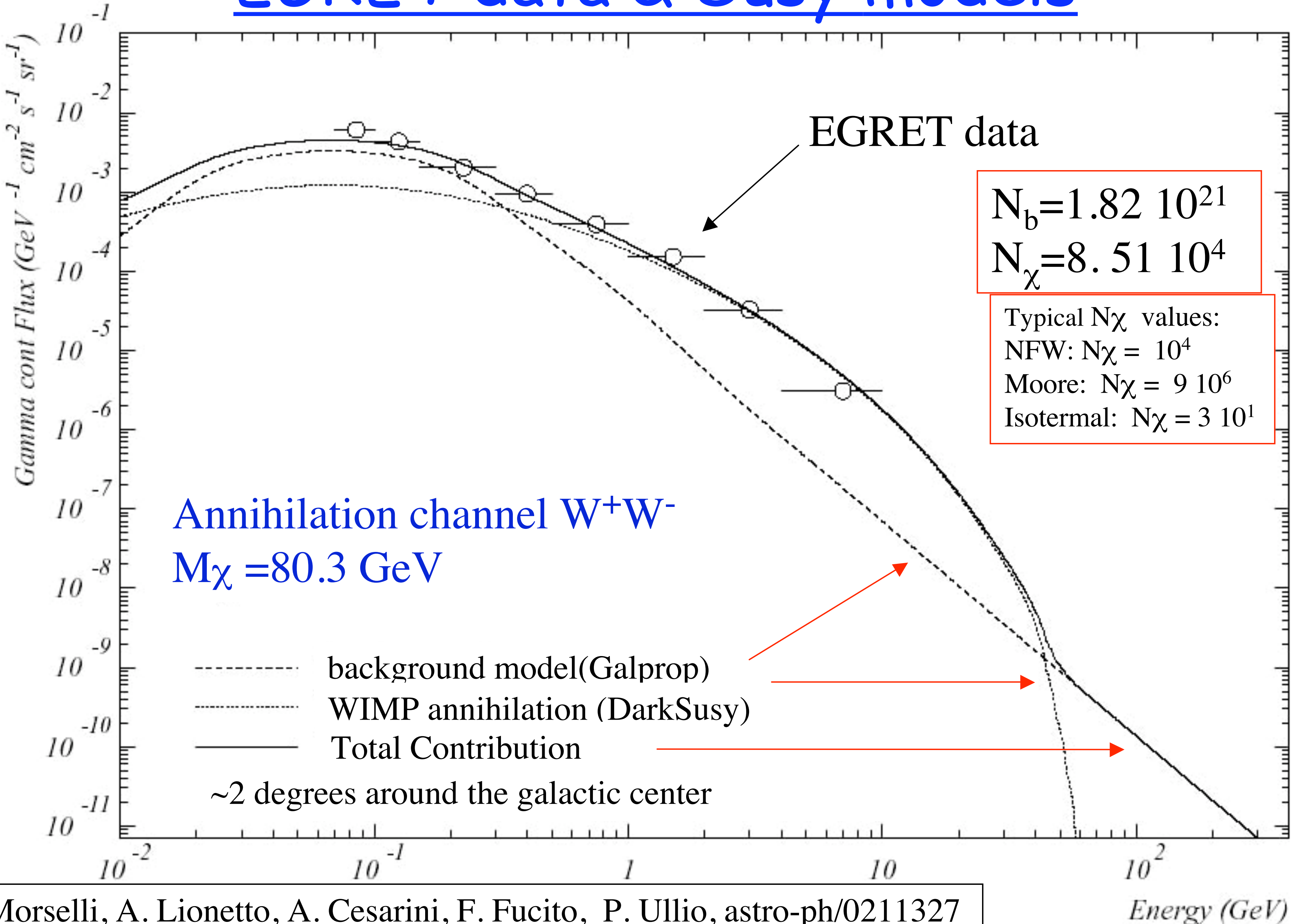
- Galactic center
- Galactic satellites
- Galactic halo
- Extra-galactic



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

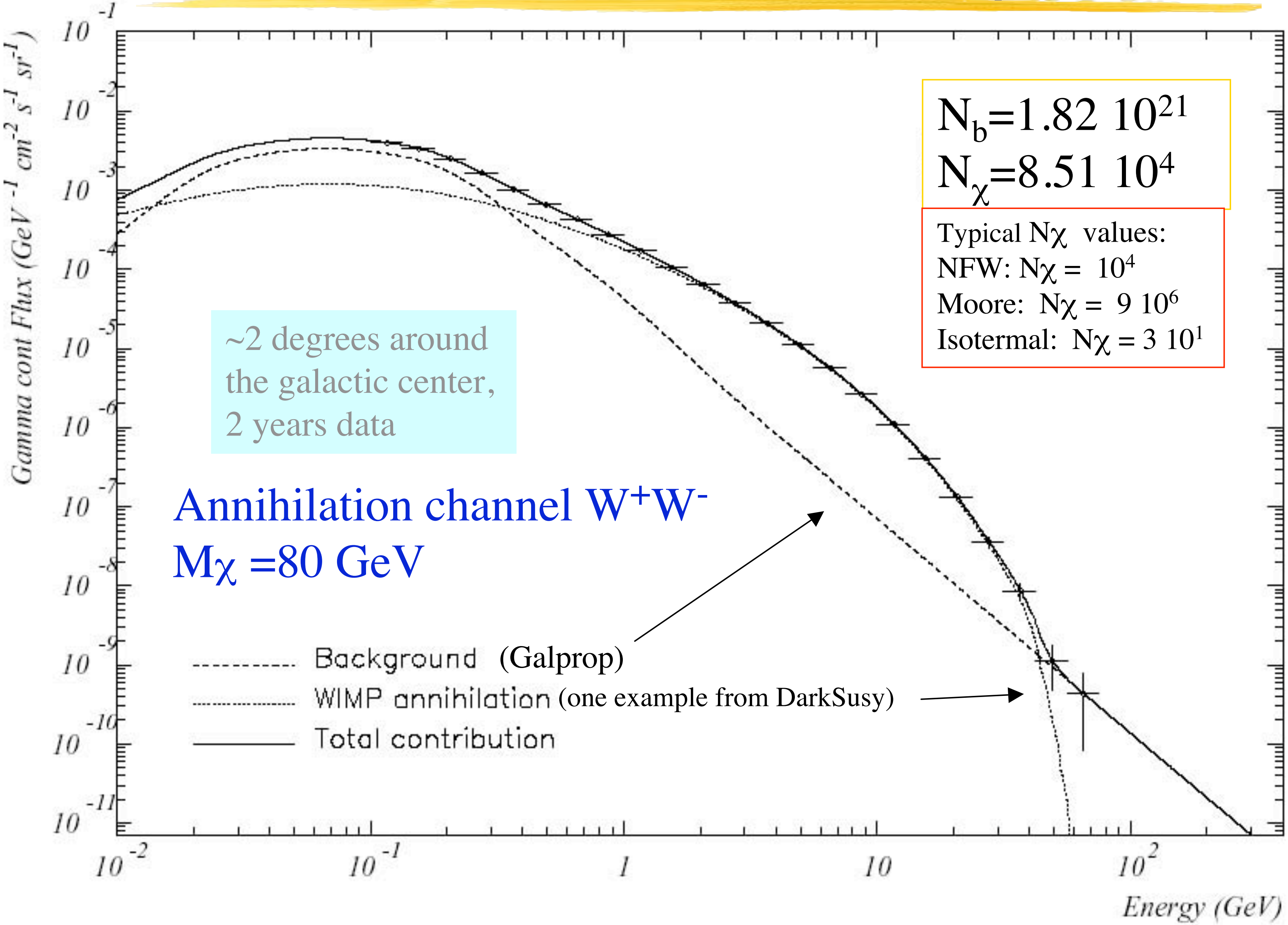
Search Technique	advantages	challenges
Galactic center 	Good Statistics	Source confusion/Diffuse background
Satellites, Subhalos, Point Sources 	Low background, Good source id	Low statistics
Milky Way halo 	Large statistics	Galactic diffuse background
Extra-galactic 	Large Statistics	Astrophysics, galactic 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

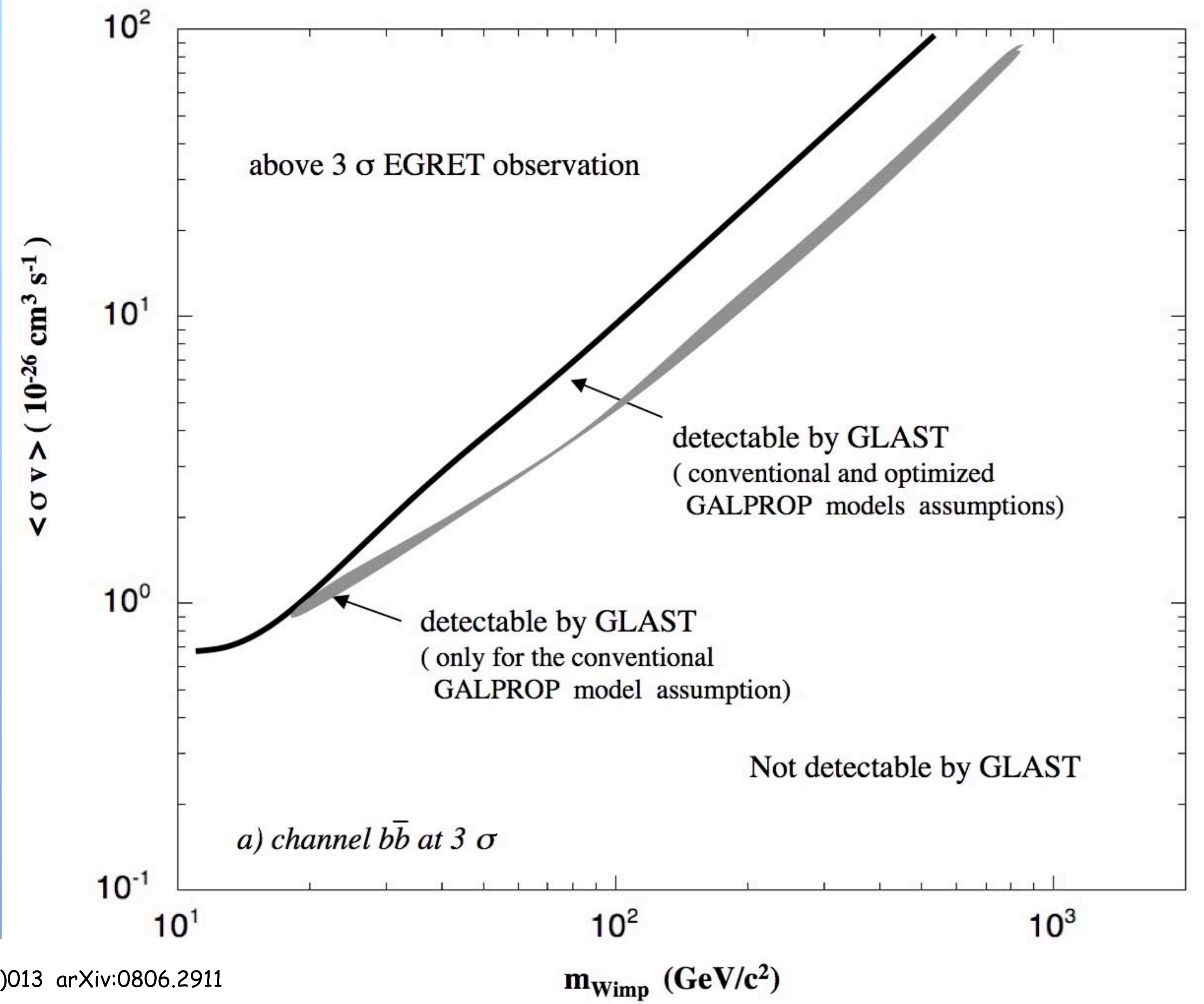
Fermi Expectation & Susy models



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

Model independent results for the GC

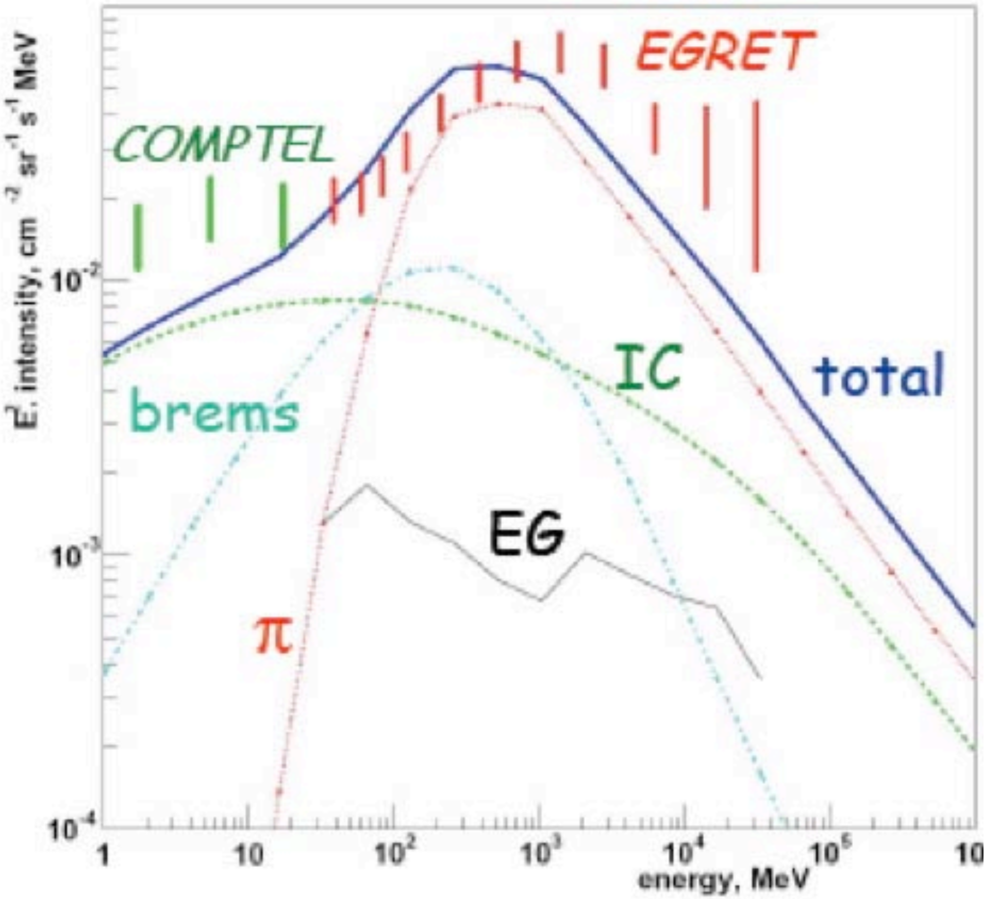
5 years of operations, truncated NFW



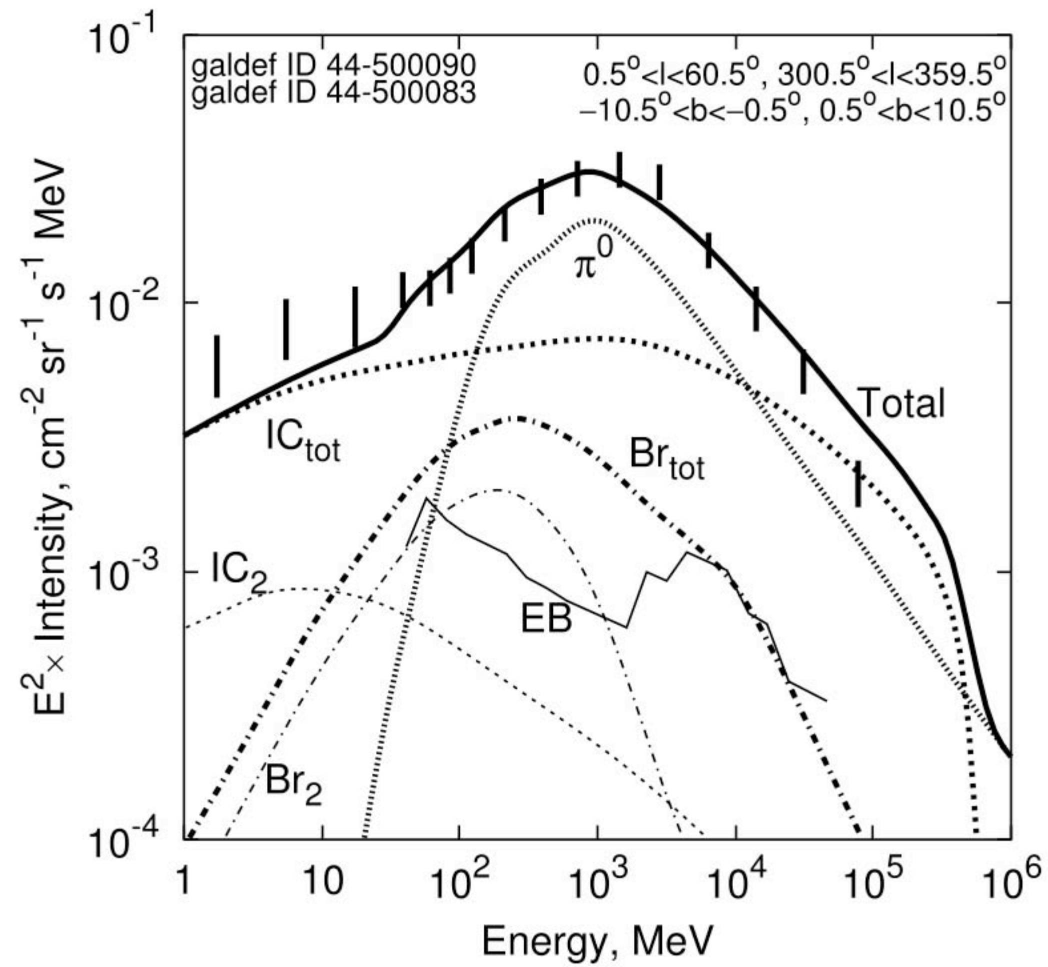
Baltz et. al, JCAP07(2008)013 arXiv:0806.2911

Gamma-ray background

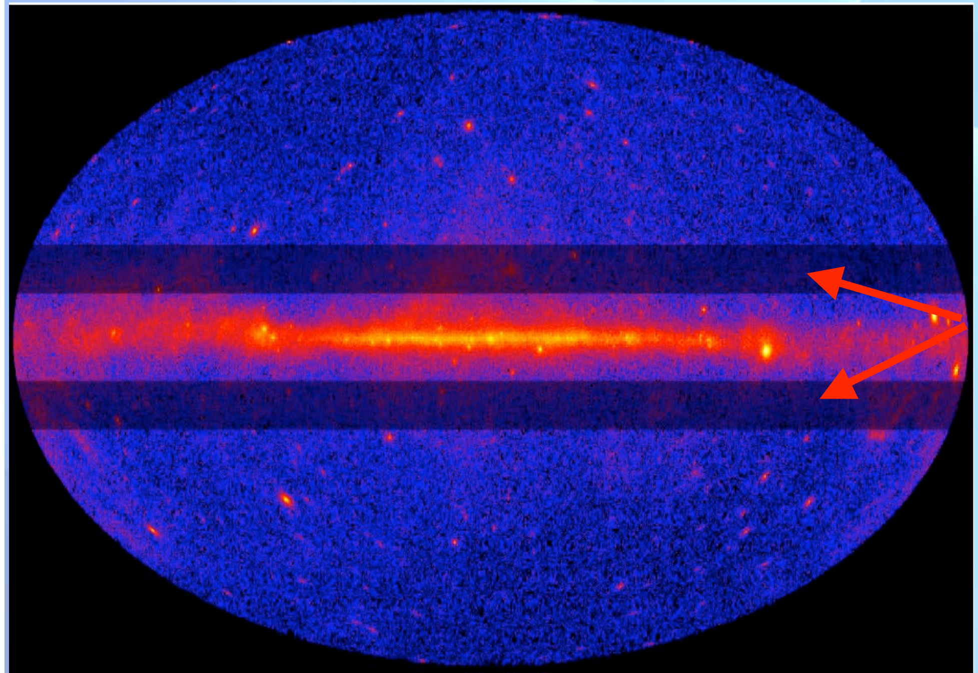
Galprop Conventional model

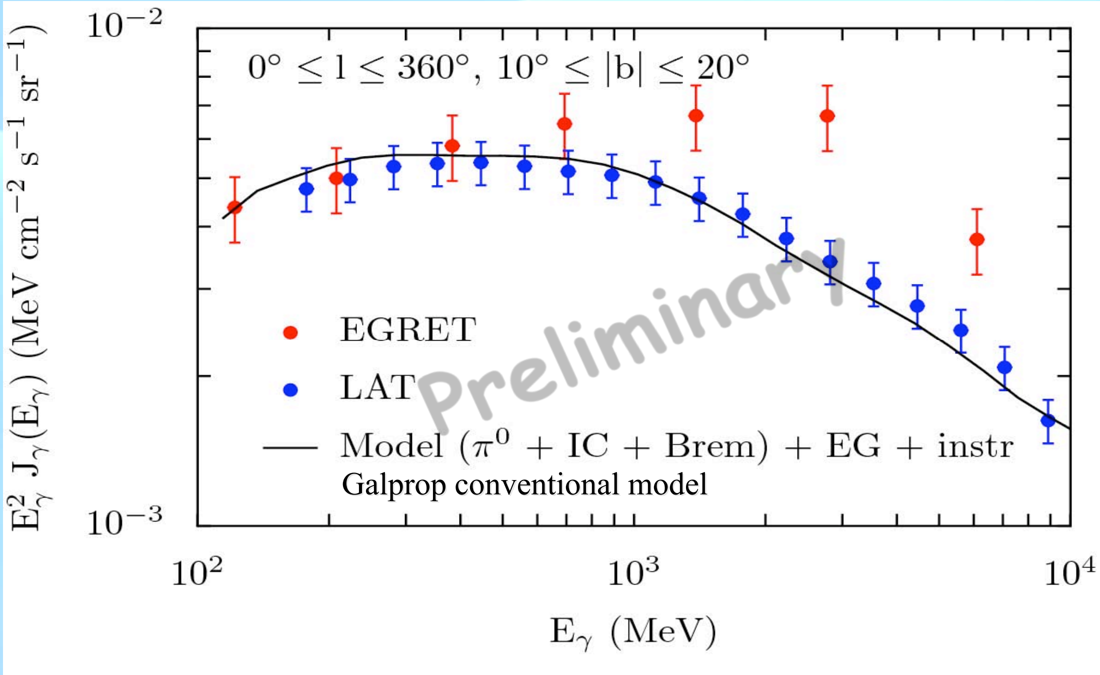


Optimized: a model based on a renormalized CR proton flux (to fit antiprotons) and a CR electron flux



The Galactic Diffuse Emission



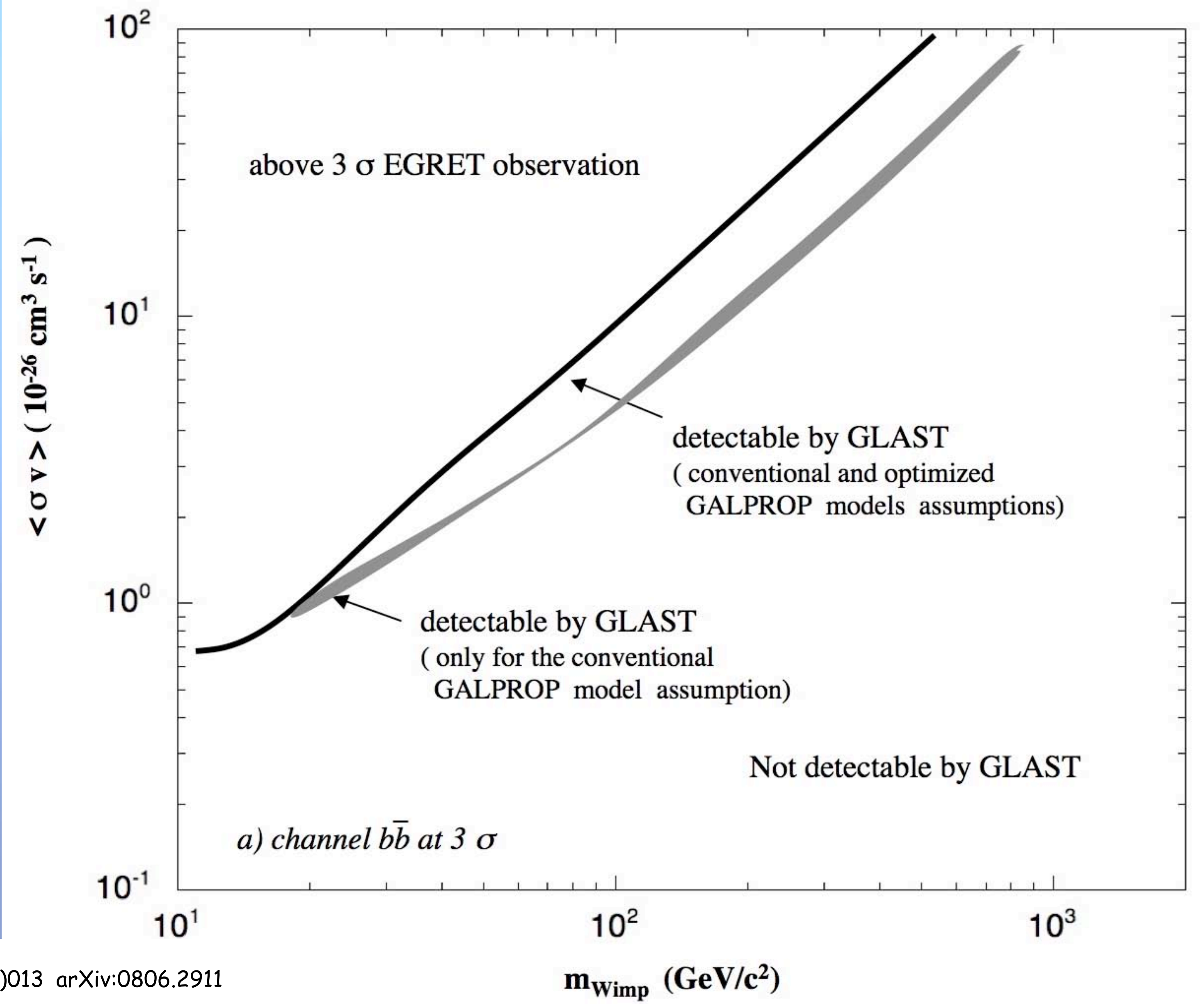


- Spectra shown for mid-latitude range → GeV excess in this region of the sky is not confirmed.
- Sources are not subtracted but are a minor component.
- LAT errors are dominated by systematic uncertainties and are currently estimated to be ~10% → this is preliminary.
- EGRET data is prepared as in Strong, et al. 2004 with a 15% systematic error assumed to dominate (Esposito, et al. 1999).
- EG + instrumental is assumed to be isotropic and determined from fitting the data at |*b*| > 10°.
- In order to use it for constraining DM one needs to understand the background model uncertainties which is a non trivial problem (we are working on that).

see talk of Guðlaugur Jóhannesson for the Fermi LAT collaboration

Model independent results for the GC

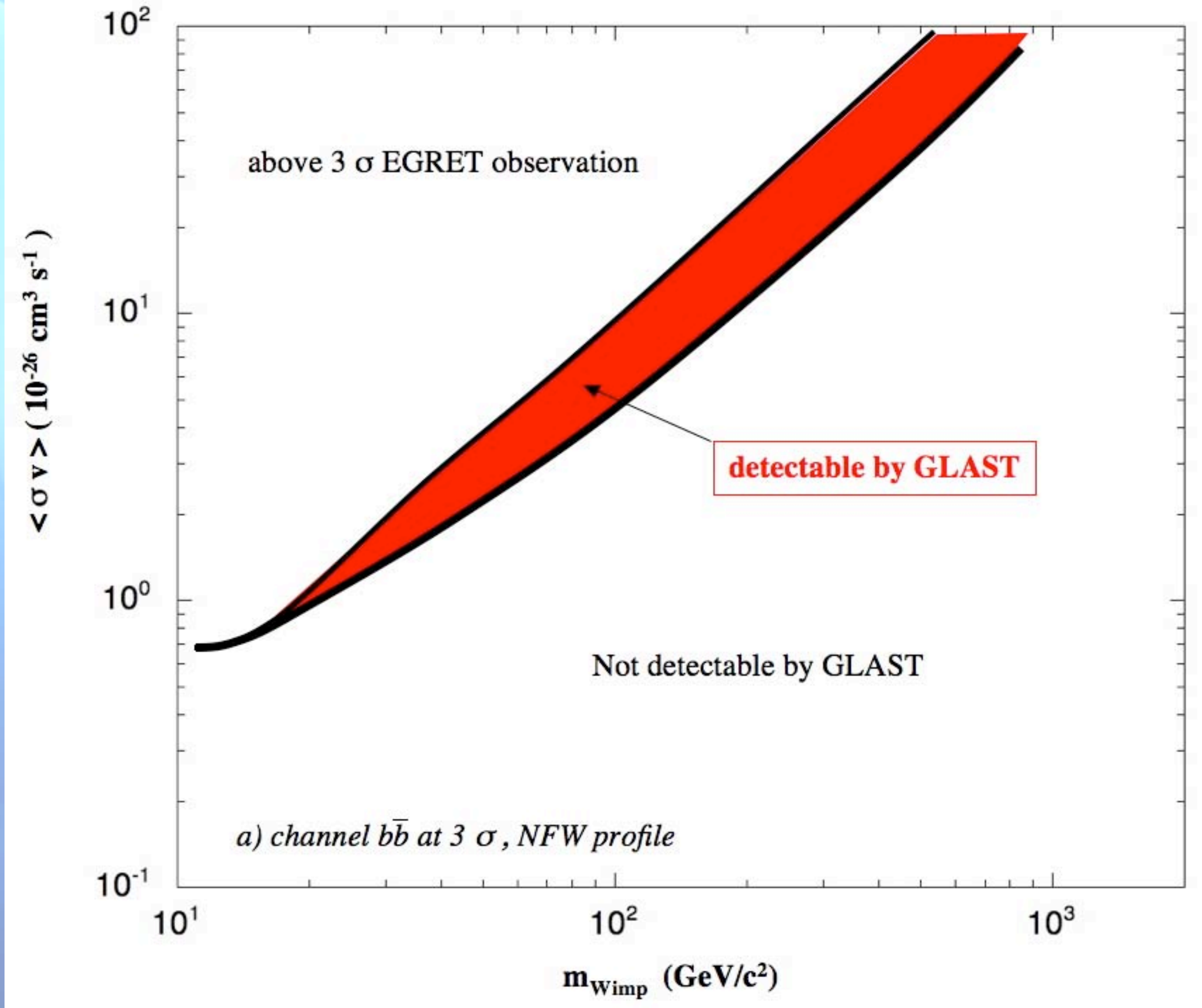
5 years of operations, truncated NFW



Baltz et. al, JCAP07(2008)013 arXiv:0806.2911

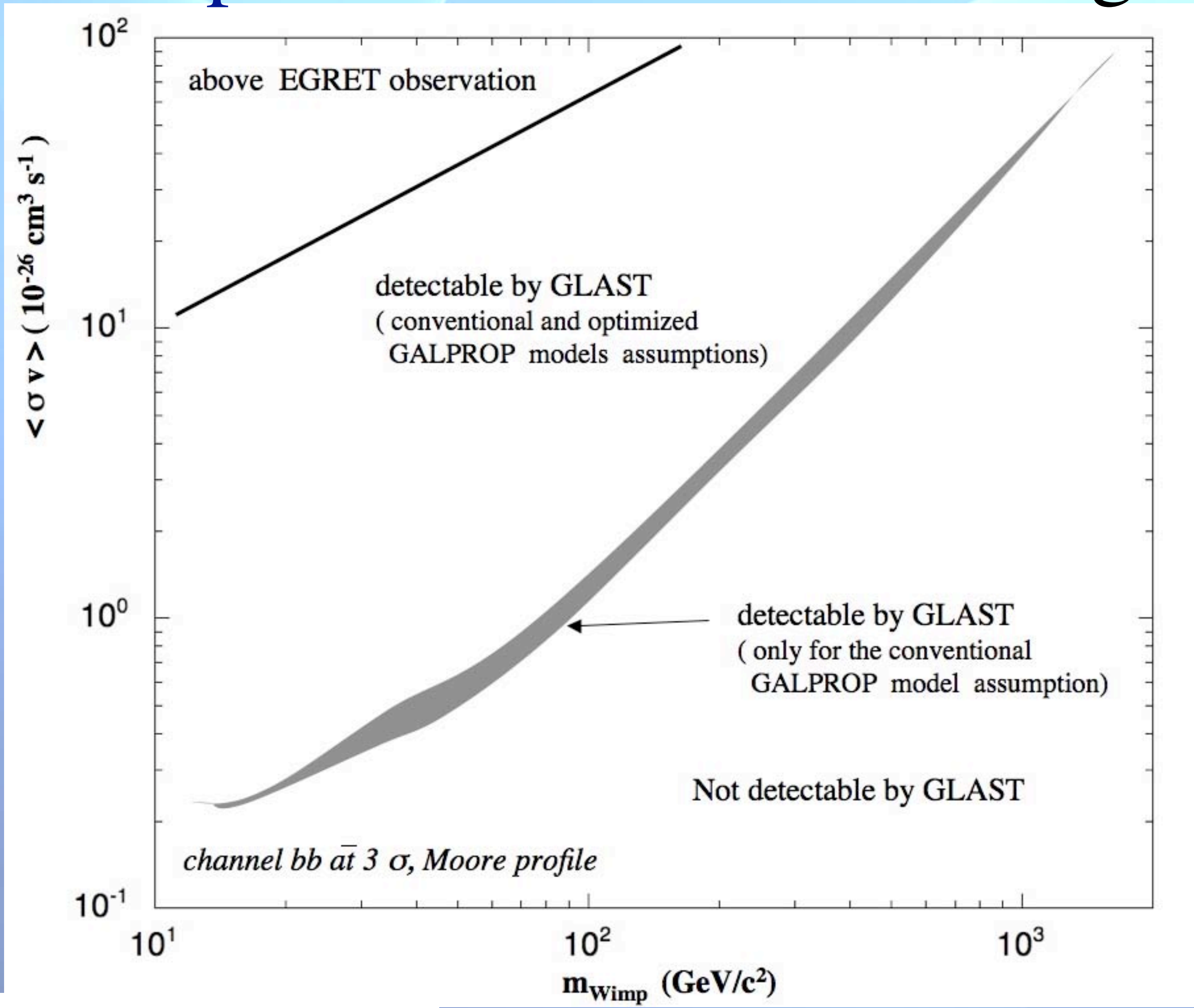
Model independent results for the GC

after the Fermi Galactic Diffuse Emission data



5 years of operations, truncated NFW

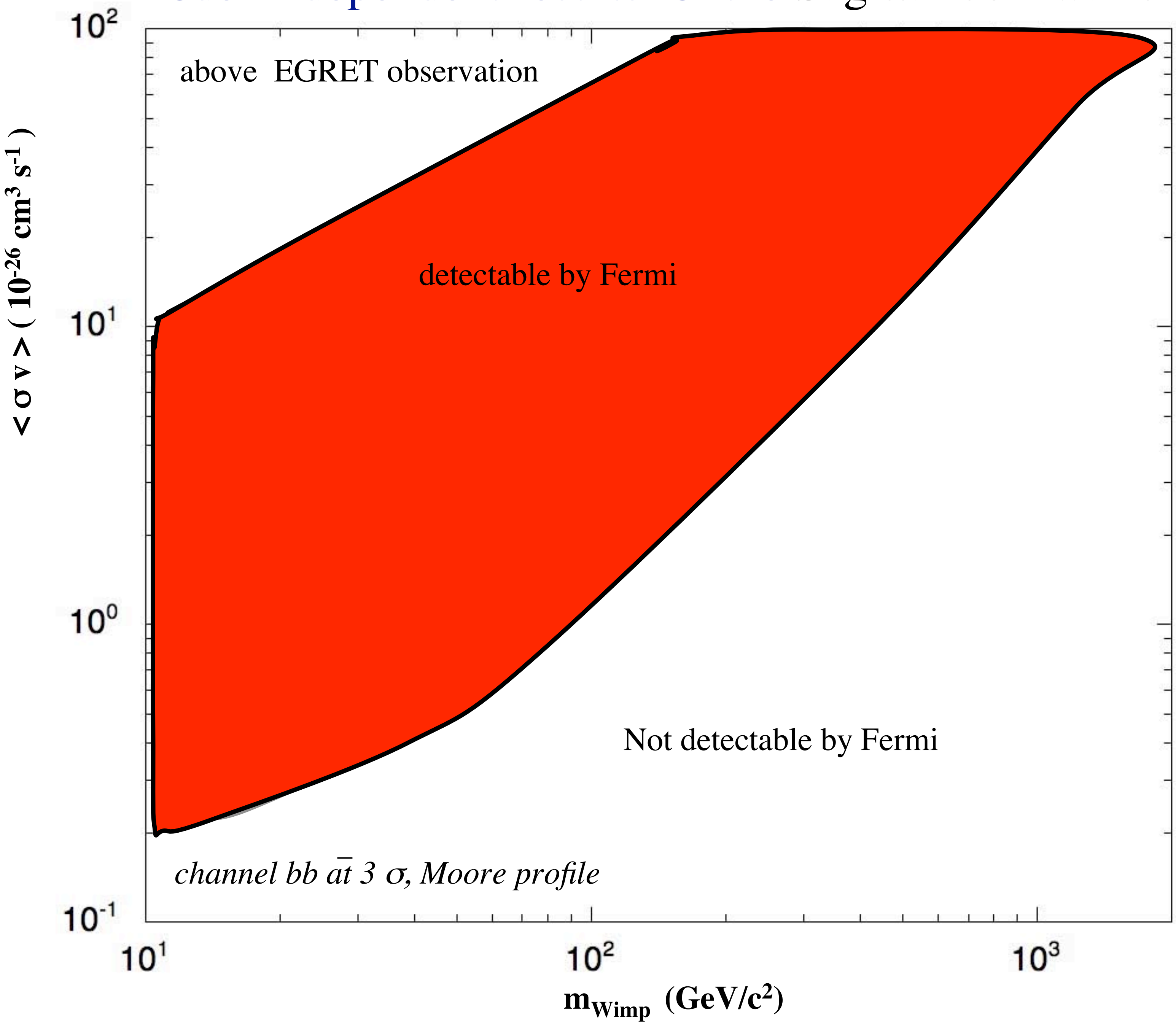
Model independent results for the Sagittarius



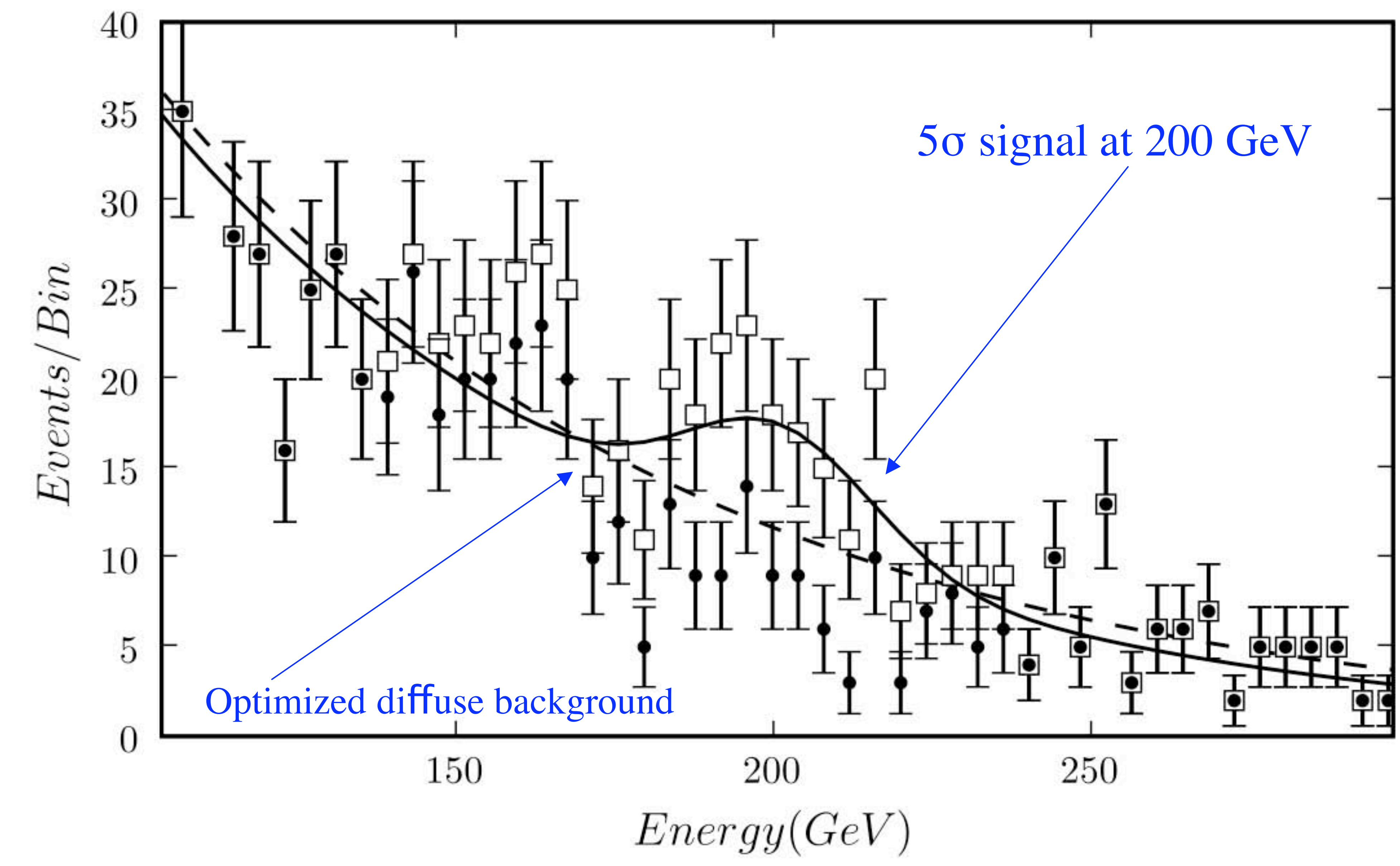
Baltz et. al, JCAP07(2008)013 arXiv:0806.2911

Model independent results for the Sagittarius Dwarft

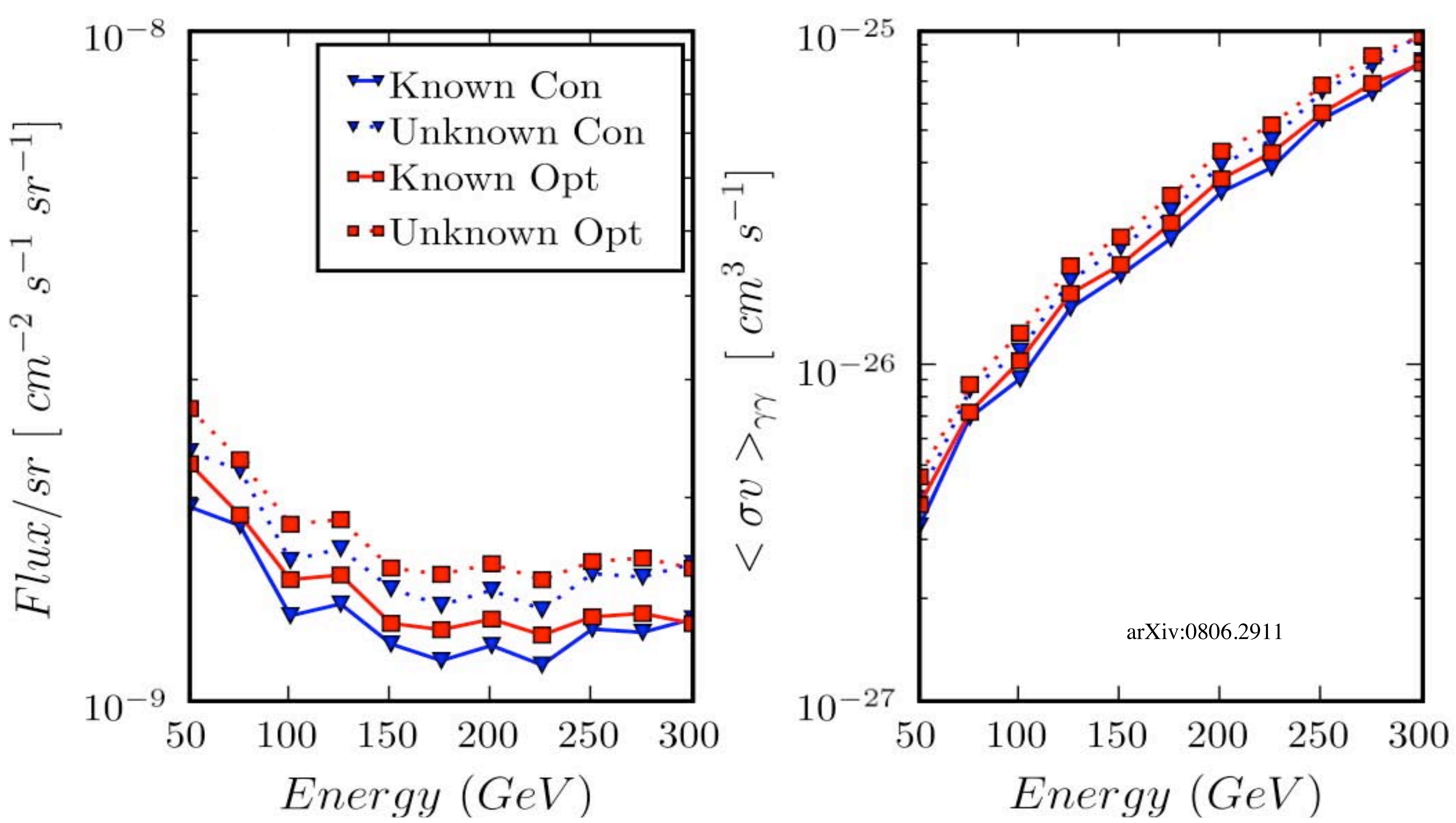
after the Fermi Galactic Diffuse Emission data



Optimized diffuse background and a 5 σ line signal at 200 GeV



5 σ sensitivity contours to line signal (5 years)



con: conventional Galactic background model   opt: Optimized Galactic background model

Conclusion:

- Astrophysics of cosmic rays and related topics is a very dynamic field:

expect many breakthroughs and discoveries soon !

- Intermediate latitude γ-ray spectra can be explained by cosmic-ray propagation models based on local cosmic-ray nuclei and electron spectra. The EGRET GeV excess is not seen in this region of the sky with the Fermi LAT.
- Work to analyse and understand diffuse emission over the entire sky is in progress.
- Fermi has started to probe interesting regions of the supersymmetric parameter space.

More statistics and the high energy all -electron spectra will expand these regions.


Ricap 09
http://ricap09.roma2.infn.it/
Roma International Conference on Astro-Particle physics at
University of Roma Tor Vergata - May 13-15, 2009
you are all invited
more results from PAMELA and FERMI will be presented
thank you for the attention !