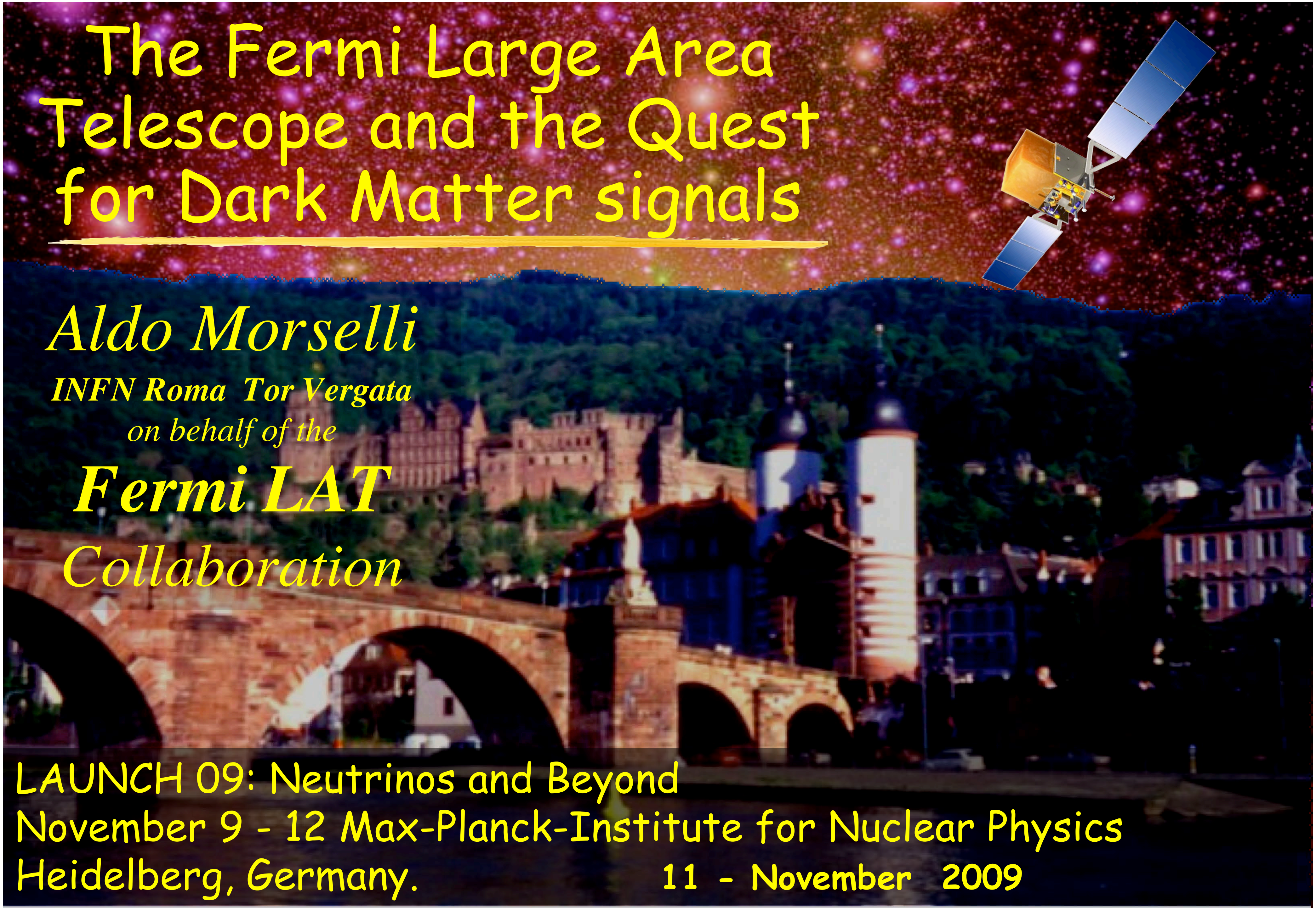
The Fermi Large Area Telescope and the Quest for Dark Matter signals



Aldo Morselli

INFN Roma Tor Vergata

on behalf of the

Fermi LAT

Collaboration

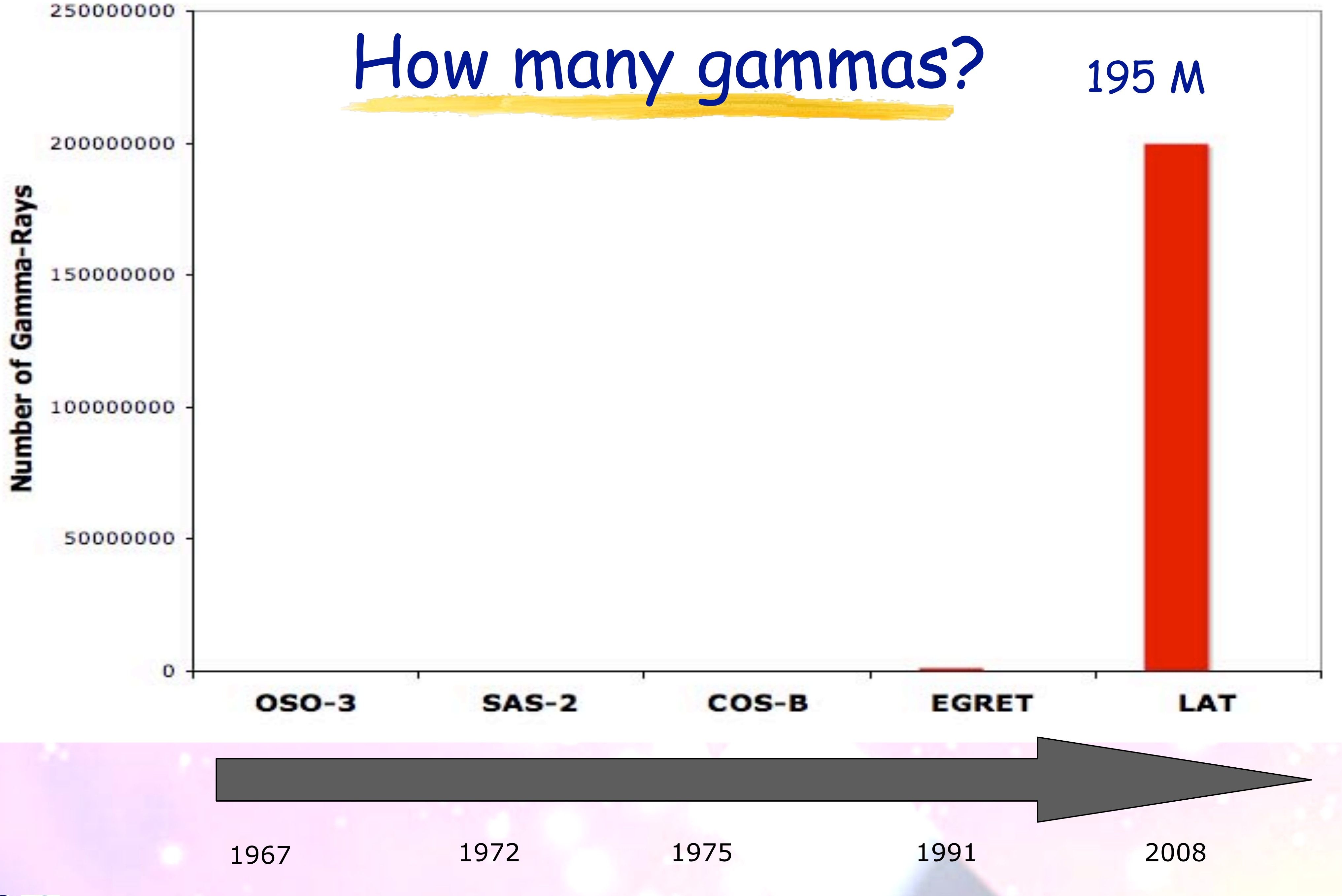
LAUNCH 09: Neutrinos and Beyond
November 9 - 12 Max-Planck-Institute for Nuclear Physics
Heidelberg, Germany. **11 - November 2009**

second title : Latest news from

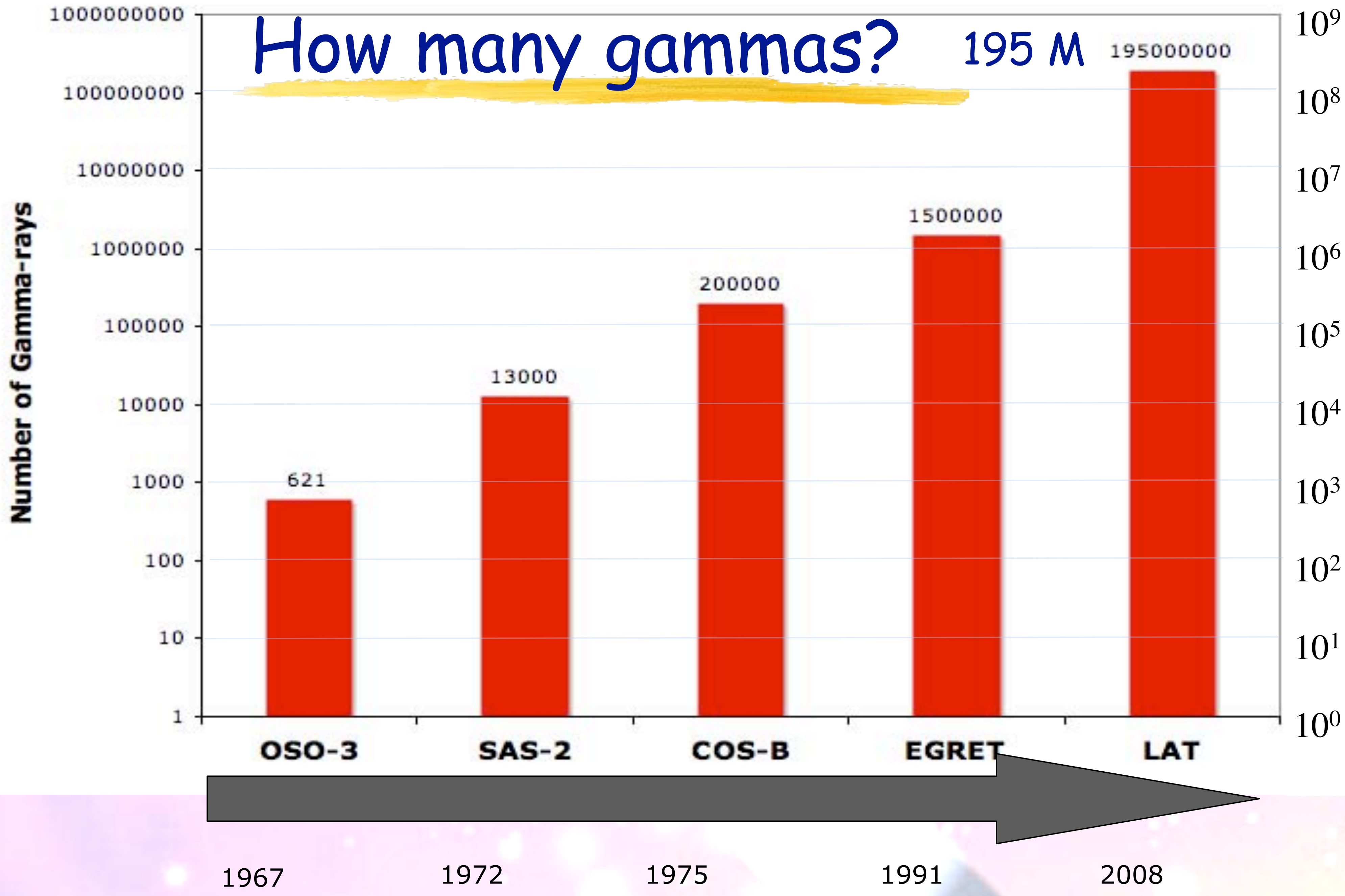
http://fermi.gsfc.nasa.gov/science/symposium/2009/

How many gammas?

195 M

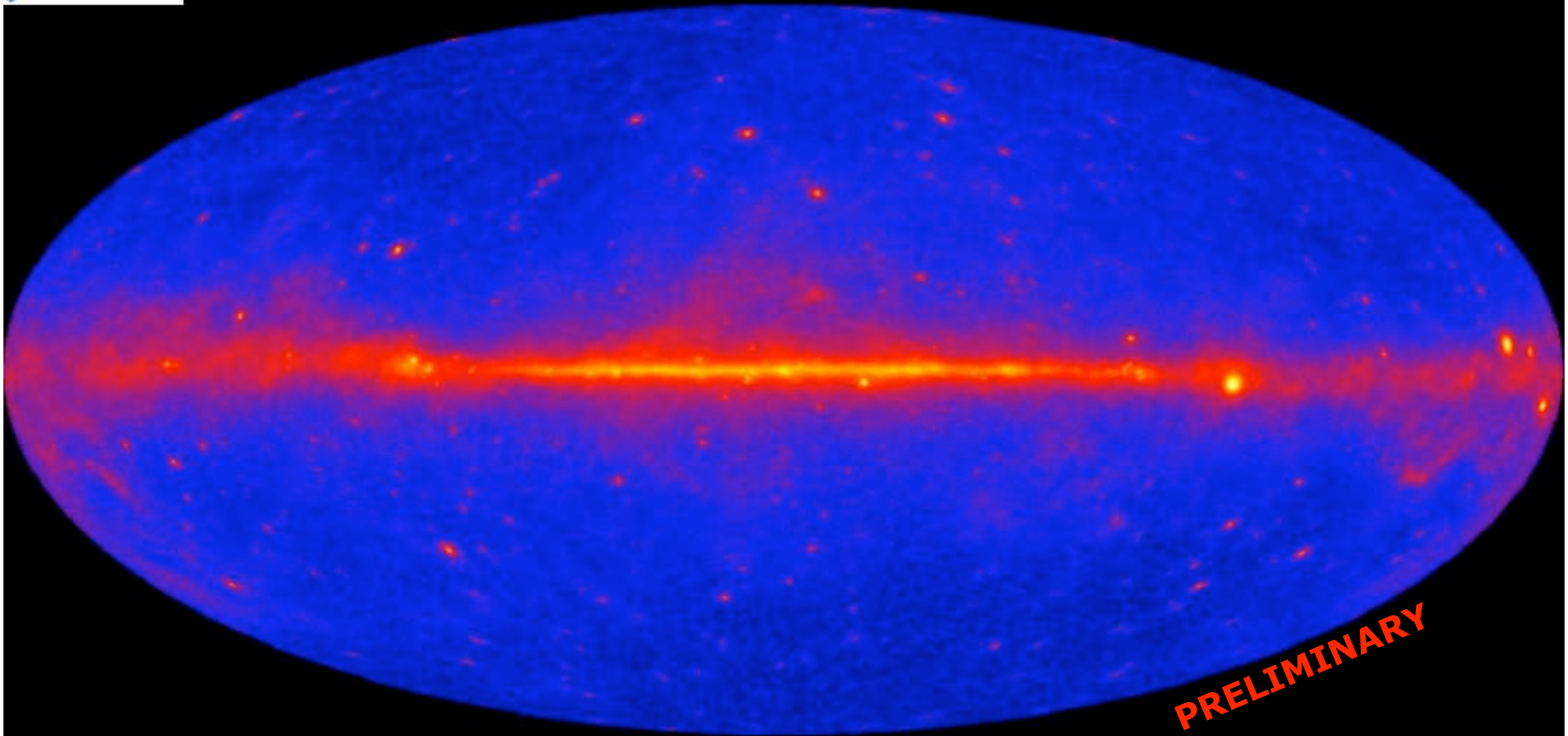


How many gammas?



First Fermi LAT Catalog (11 month, release: end of November)

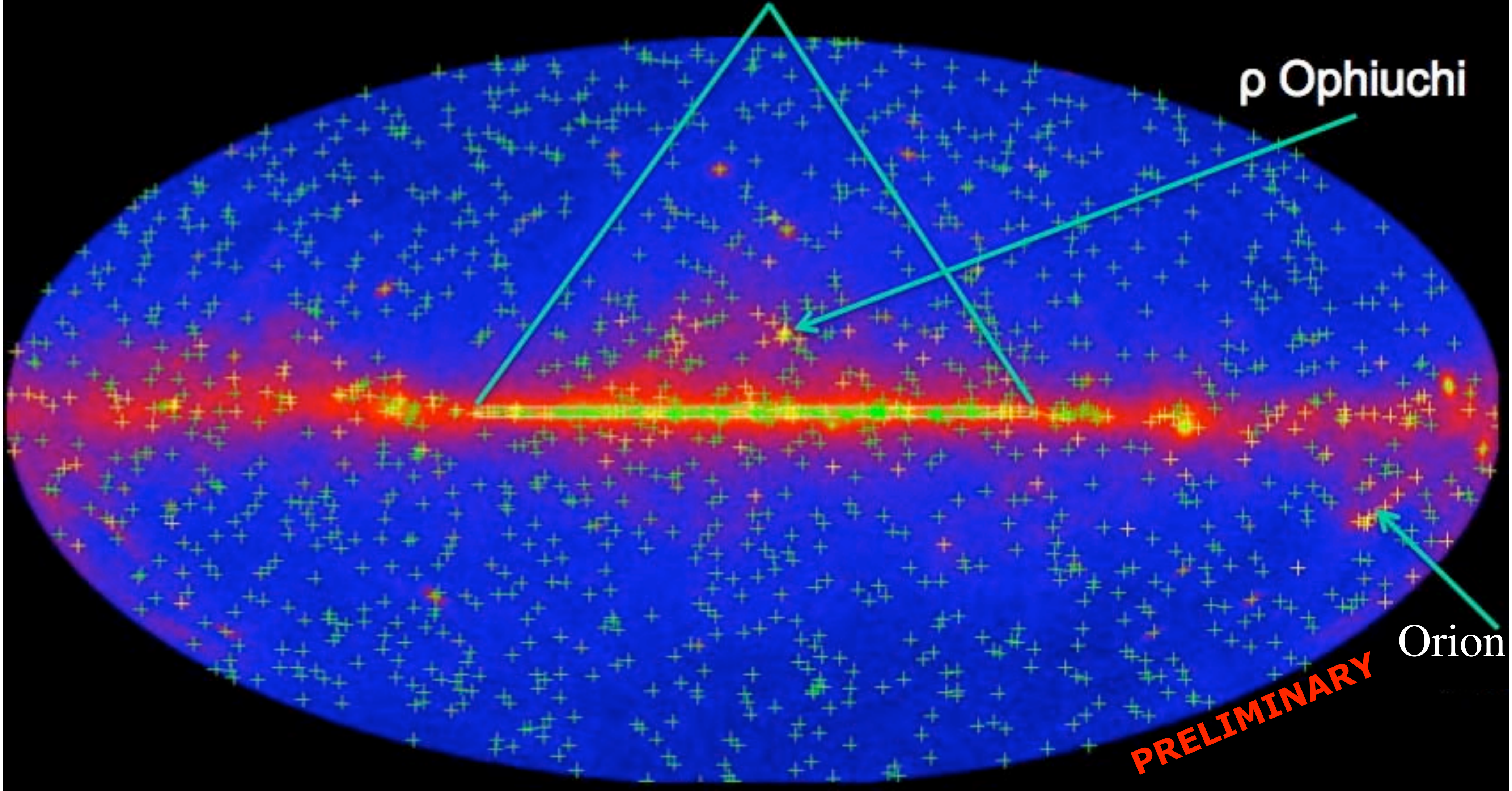
> 1000 LAT sources



- Front > 200 MeV, Back > 400 MeV, log color scale
- Galactic coordinates, Aitoff projection

First Fermi LAT Catalog

The Galactic ridge (|lat| < 1°, |lon| < 60°) has serious difficulties: sources are close to each other, are not high above the background below 3 GeV, and the Galactic diffuse model is very uncertain there. We now plan to set Galactic ridge sources apart entirely (some 120 sources), and warn against using them without detailed analysis. Of course there are still many true sources in there, including pulsars and SNRs.

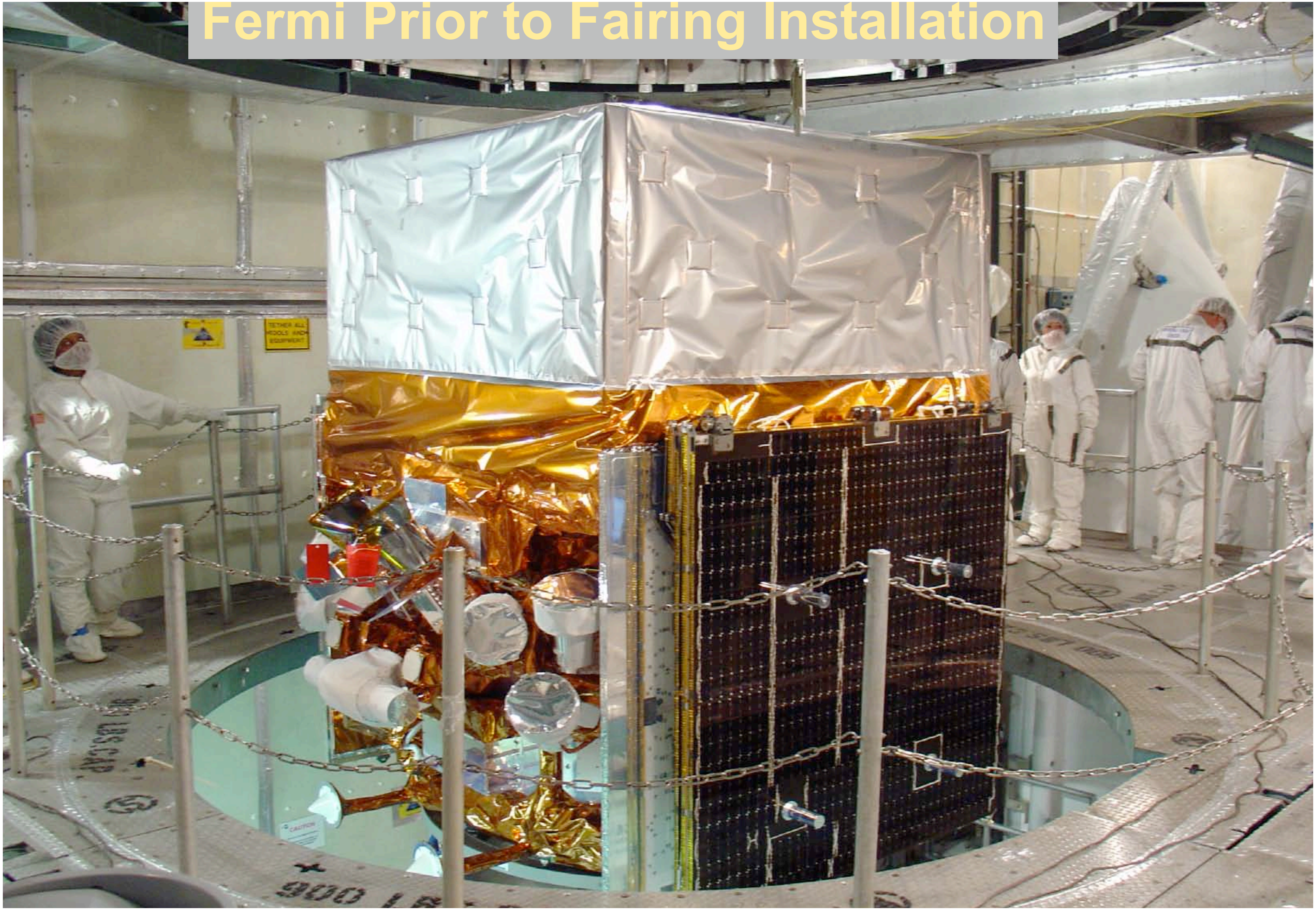


First Fermi LAT Catalog (11 month, release: end of November)

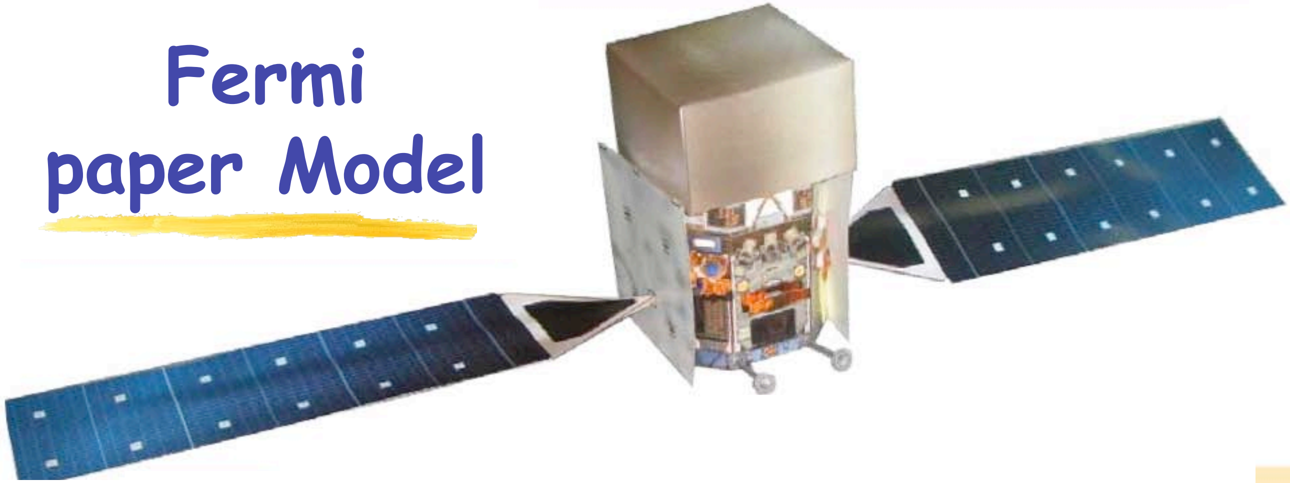
> 1000 LAT sources

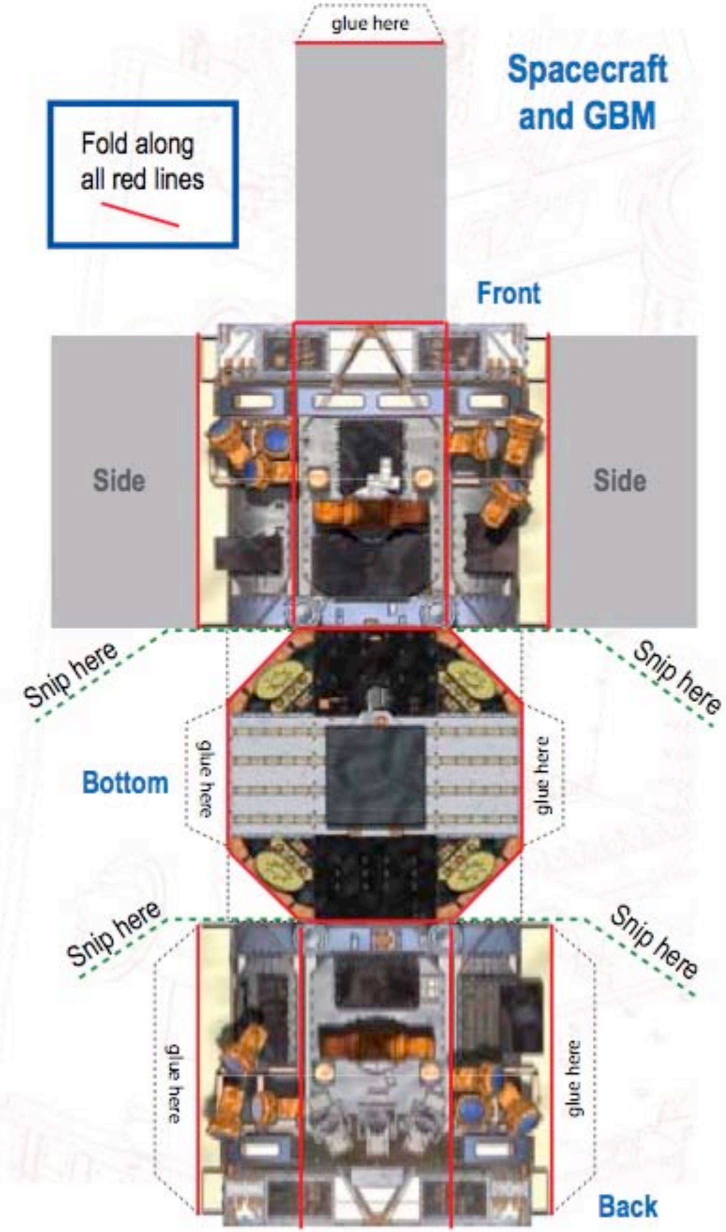
- Typical 95% error radius is 10'.
- Absolute accuracy is better than 1'
- About 250 sources show evidence of variability
- Half the sources are associated positionally, mostly with blazars and pulsars
- Other classes of sources exist in small numbers (XRB, PWN, SNR, starbursts, globular clusters, radio galaxies, narrow-line Seyferts)

Fermi Prior to Fairing Installation



Fermi paper Model





- http://people.roma2.infn.it/~aldo/GLASTpaperModel.pdf

Fermi Gamma-ray Space Telescope

Fermi
inside the Delta 2


11 June 2008


11 June 2008

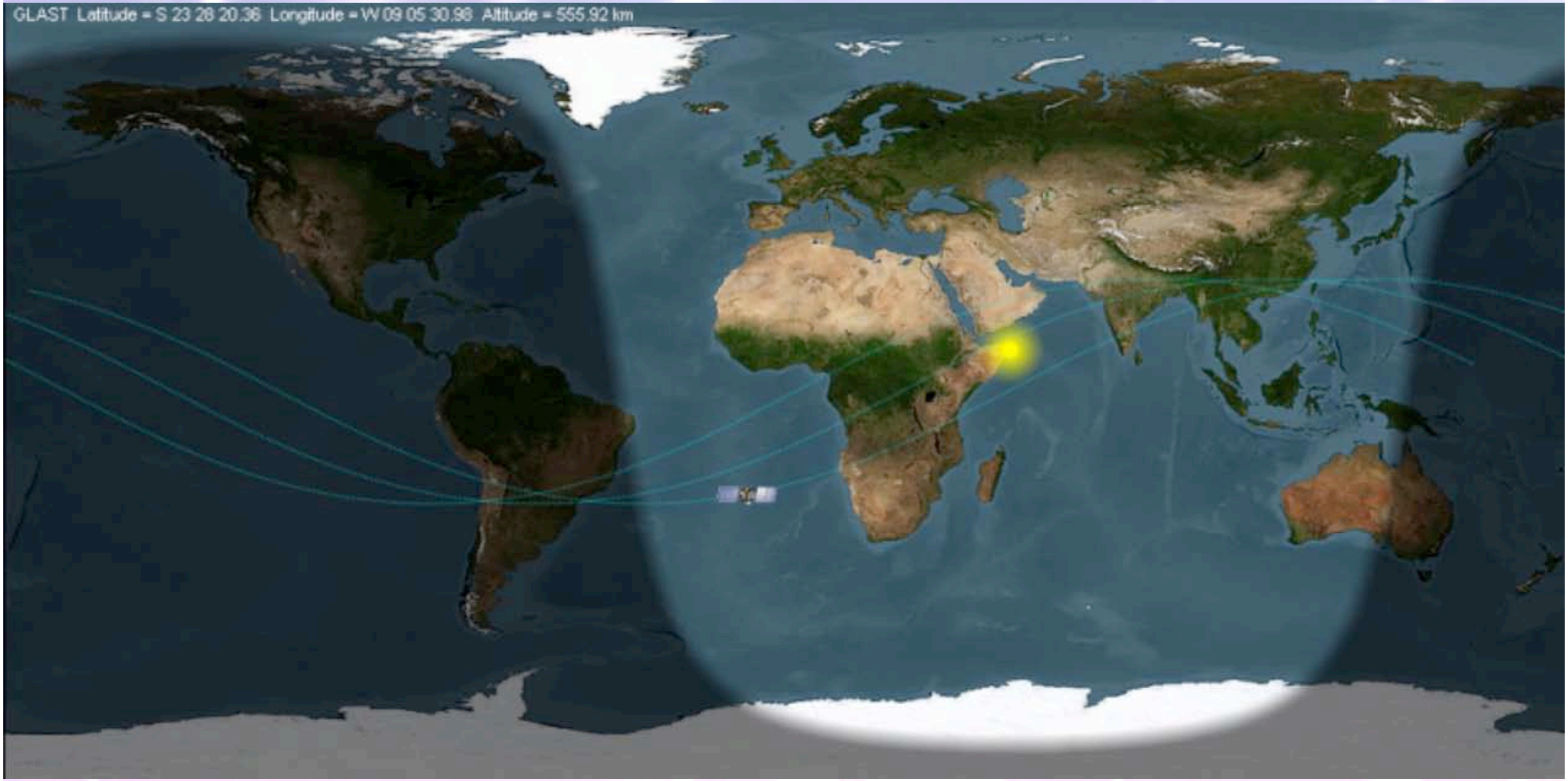

11 June 2008


11 June 2008


11 June 2008

11 June 2008

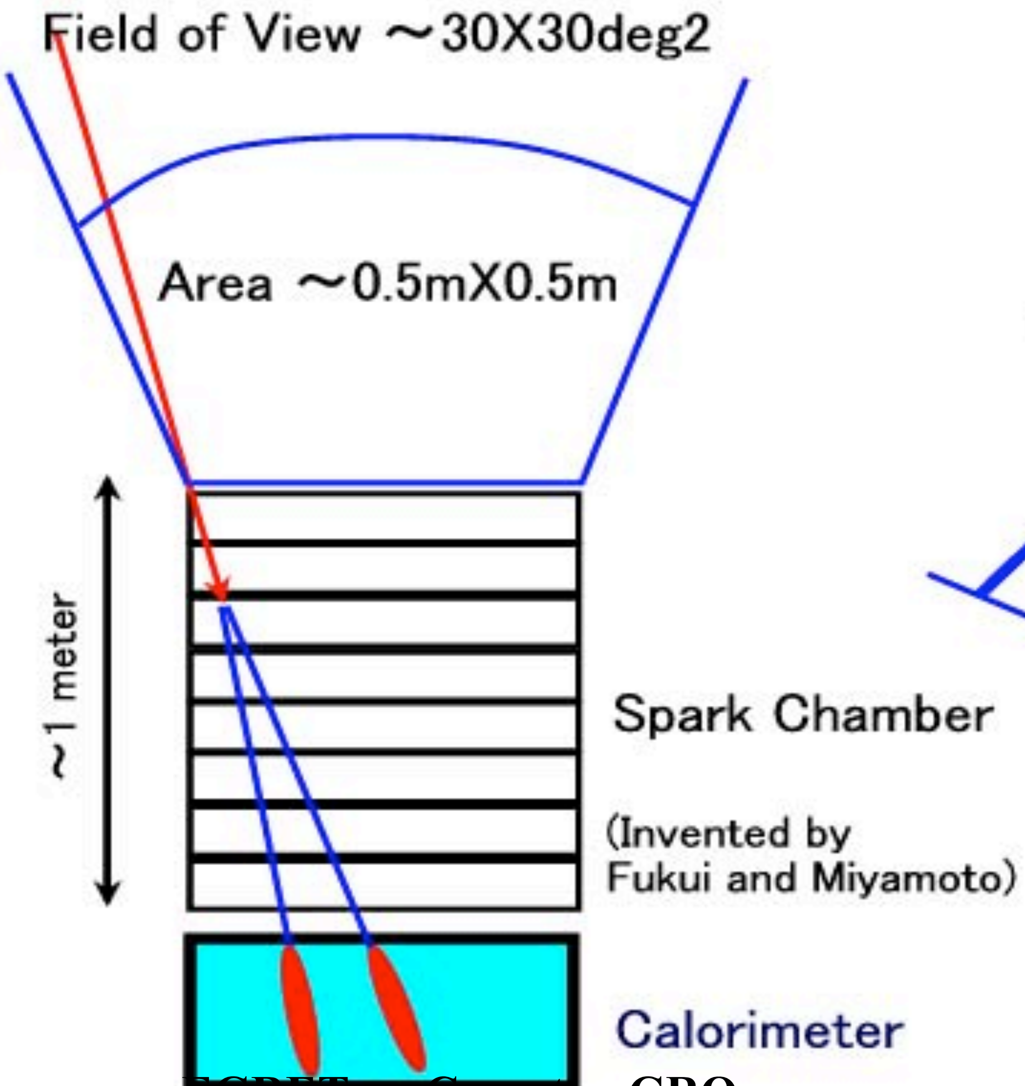
Fermi in orbit



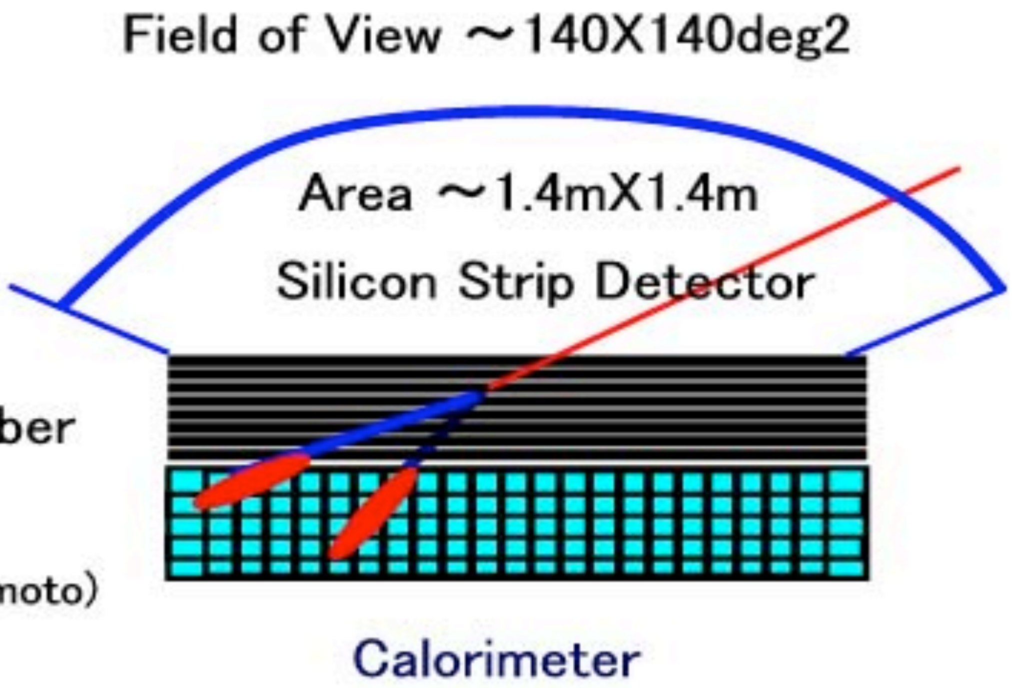
- Track the satellite: http://observatory.tamu.edu:8080/Trakker
- Watch Fermi as it orbits over you home town:

http://www.nasa.gov/mission pages/GLAST/news/glast online.html

EGRET(Spark Chamber) VS. GLAST(Silicon Strip Detector)



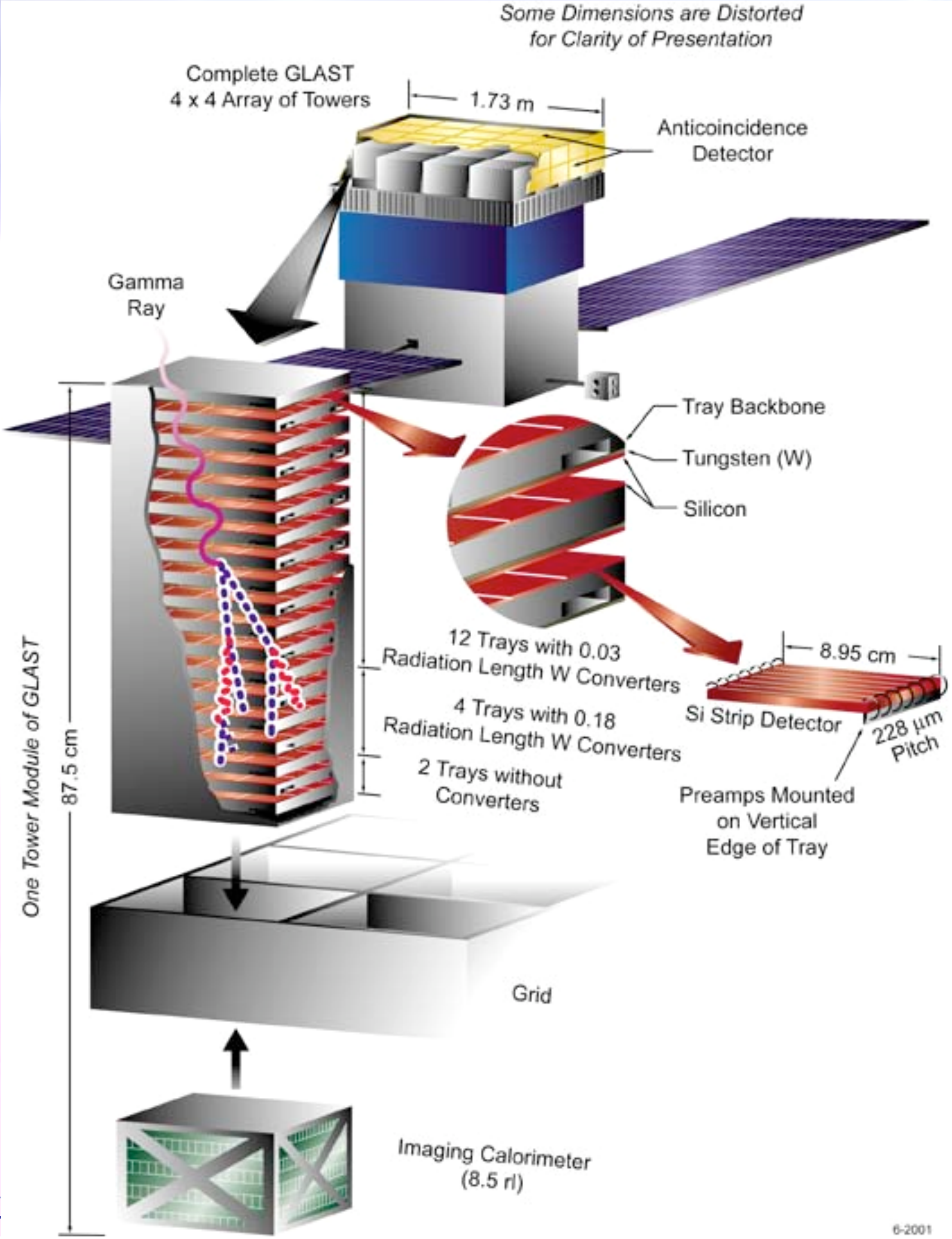
EGRET on Compton GRO
(1991-2000)

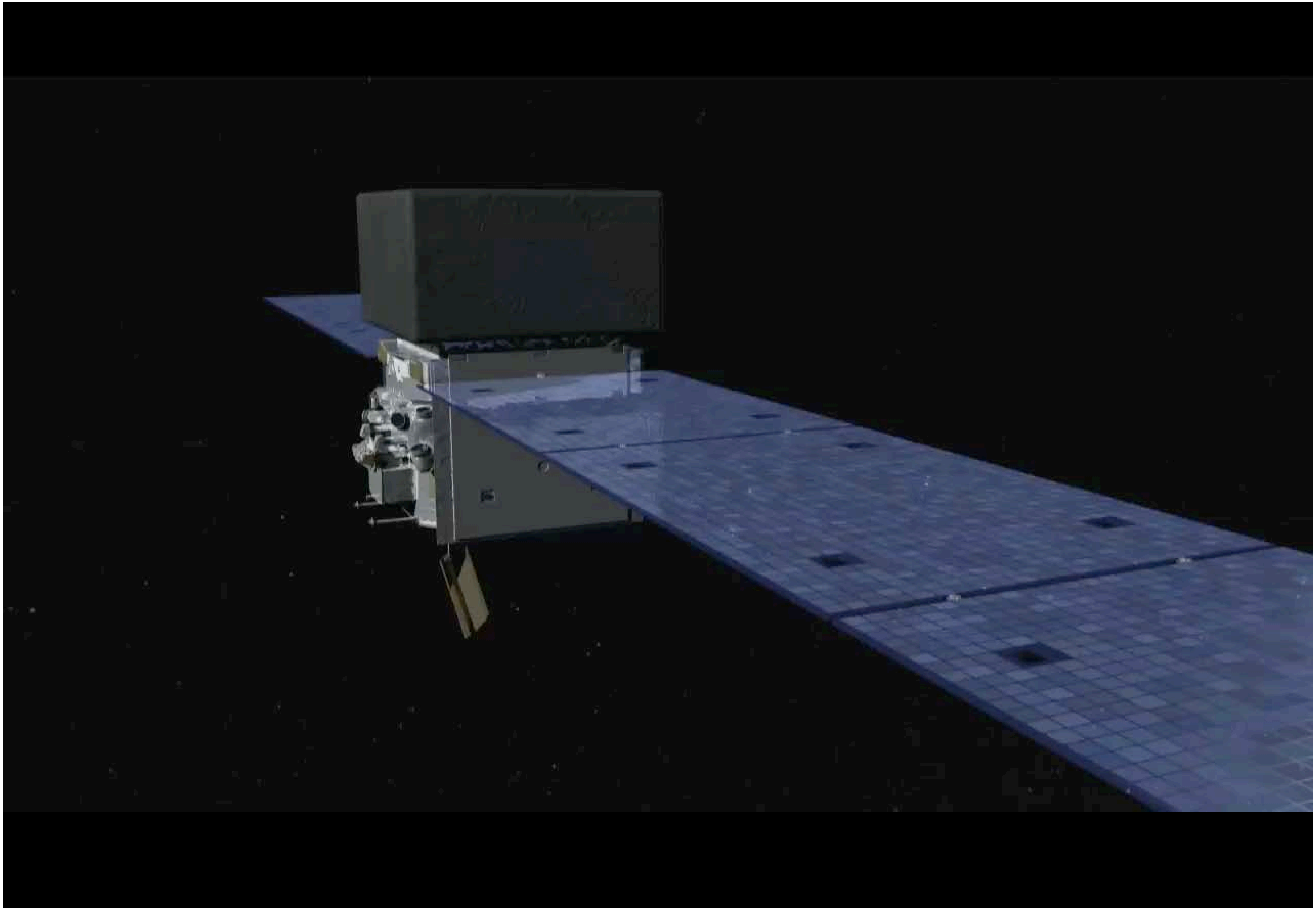


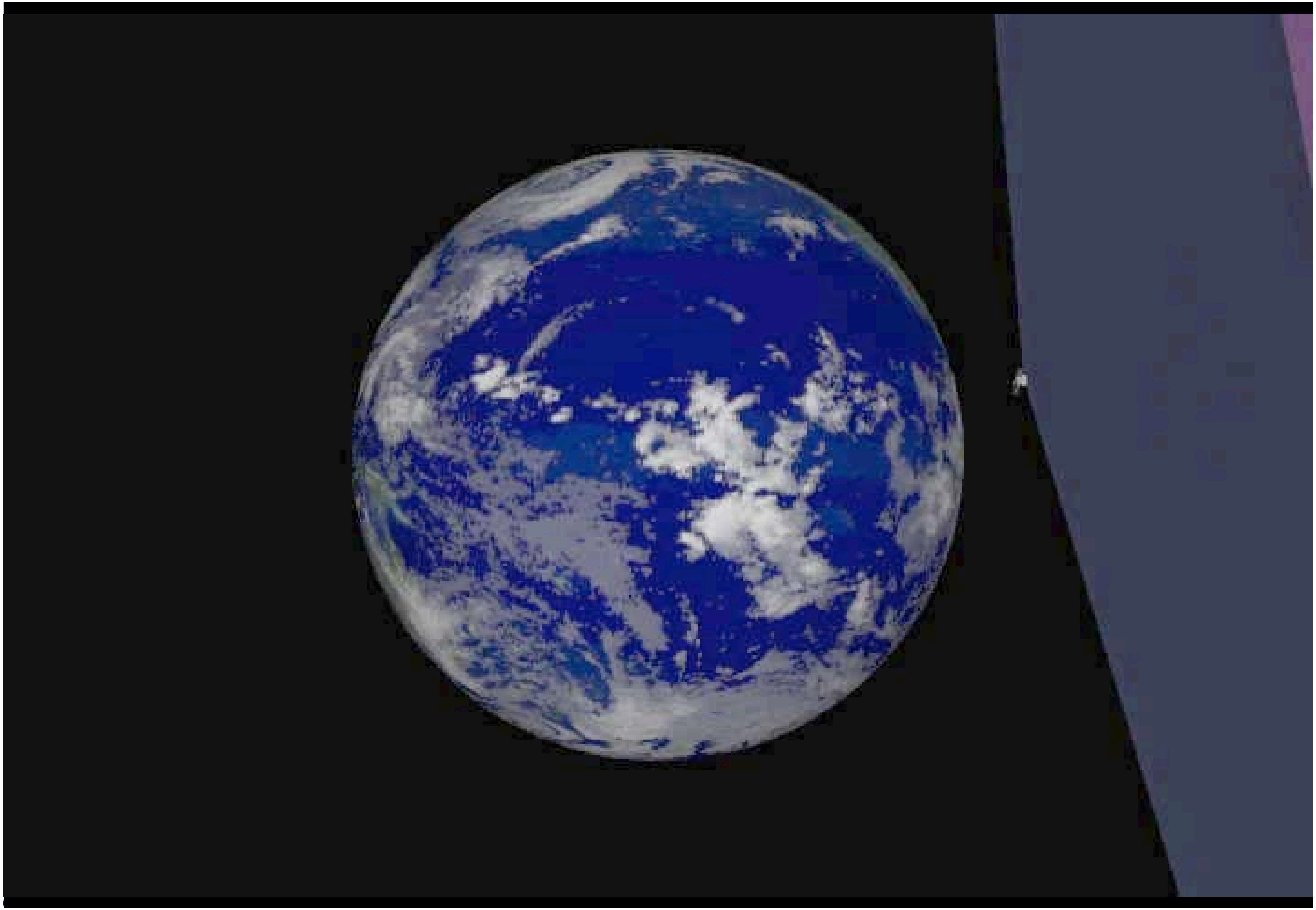
GLAST Large Area Telescope
(2006-2015)

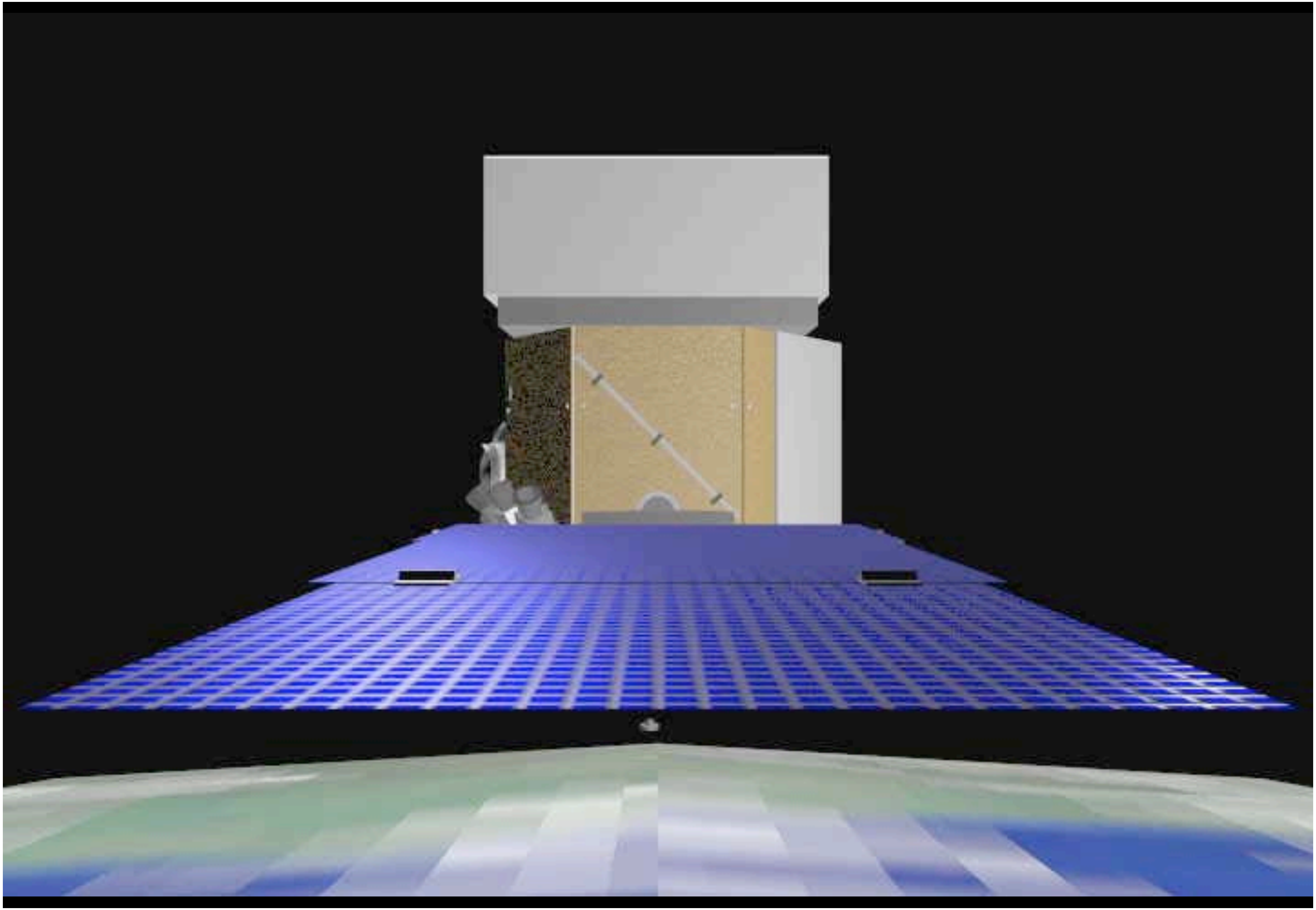
Gamma-Ray Large Area Space Telescope

GLAST Scheme

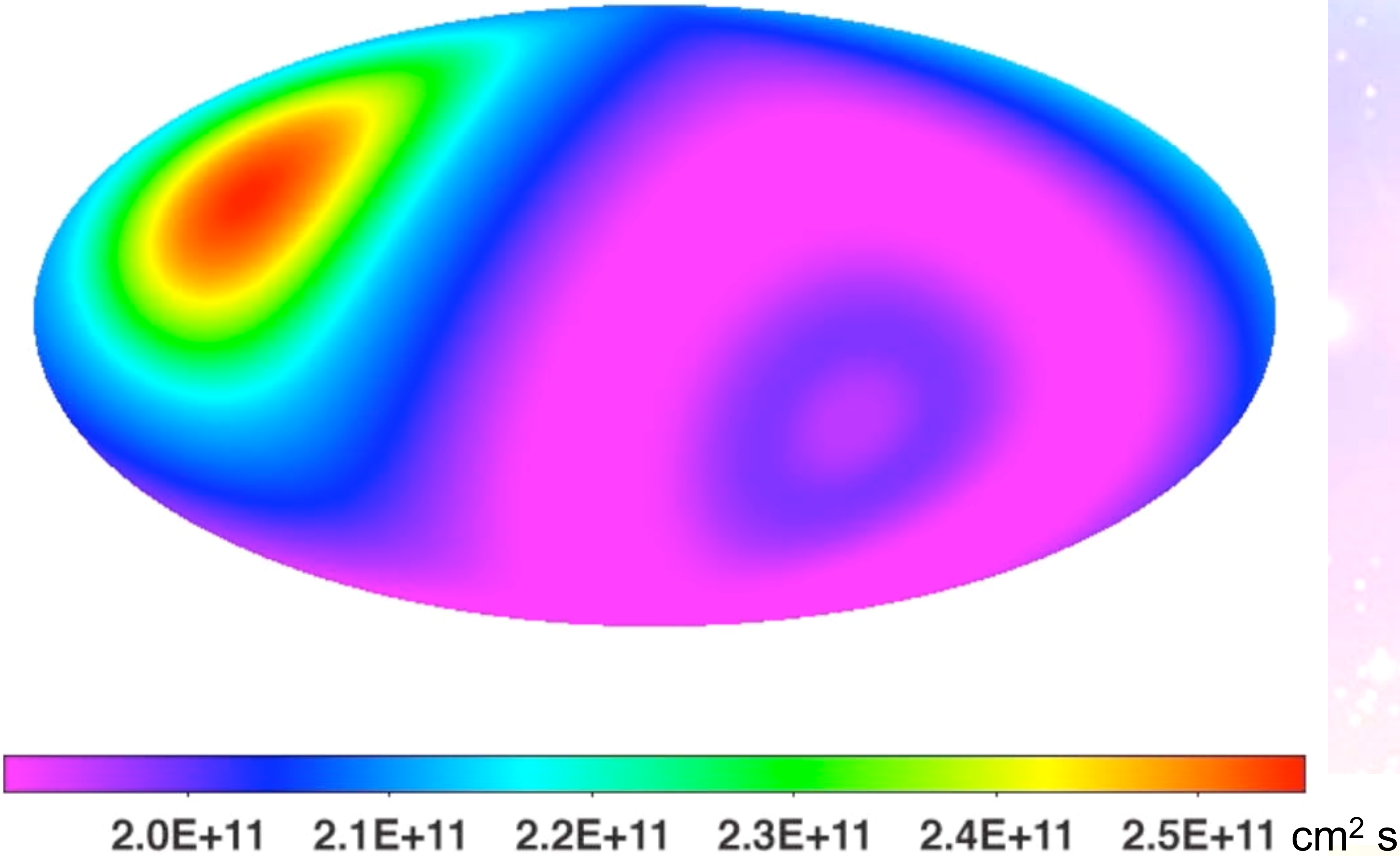








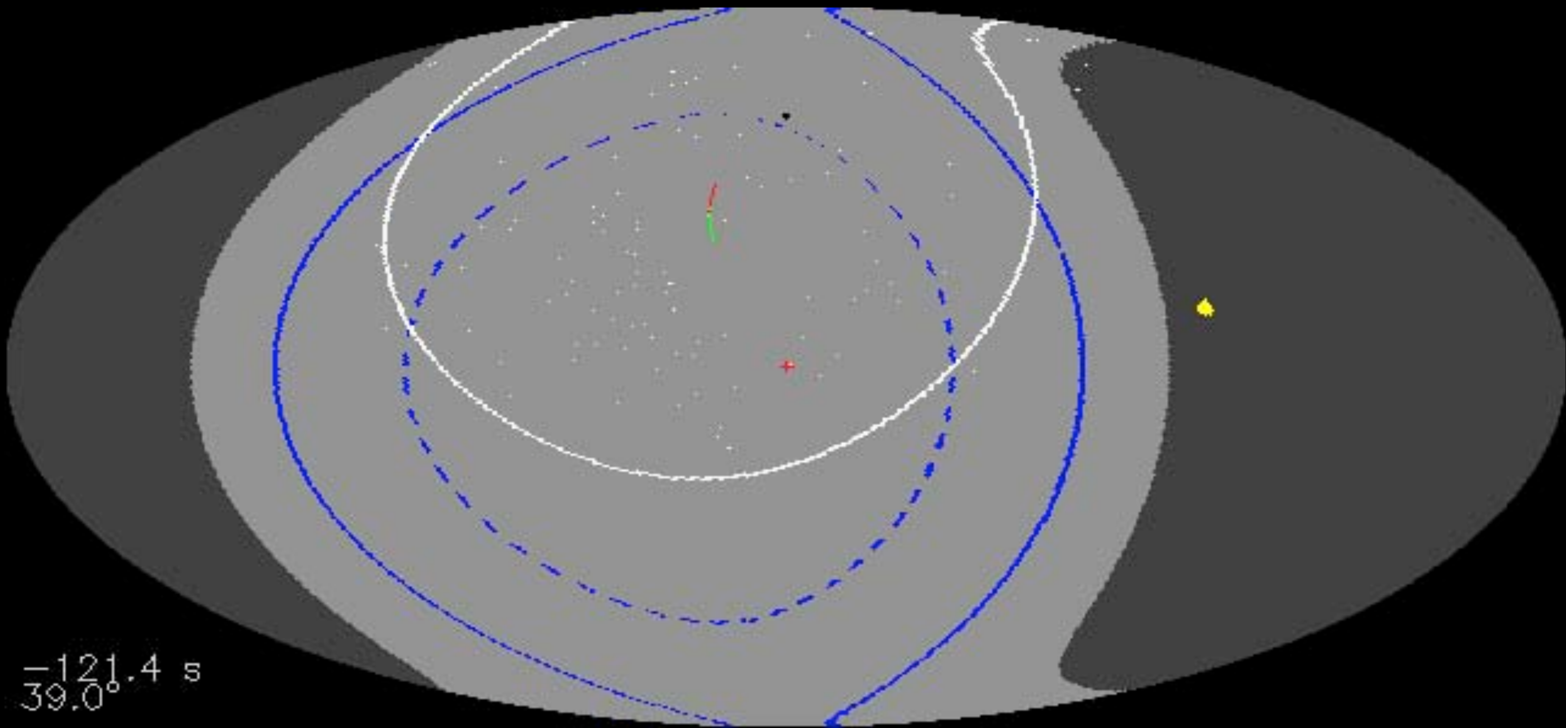
Simulated Fermi LAT exposure for five years of all-sky scanning at 100 GeV



GRB 090902B - Autonomous Repoint Request

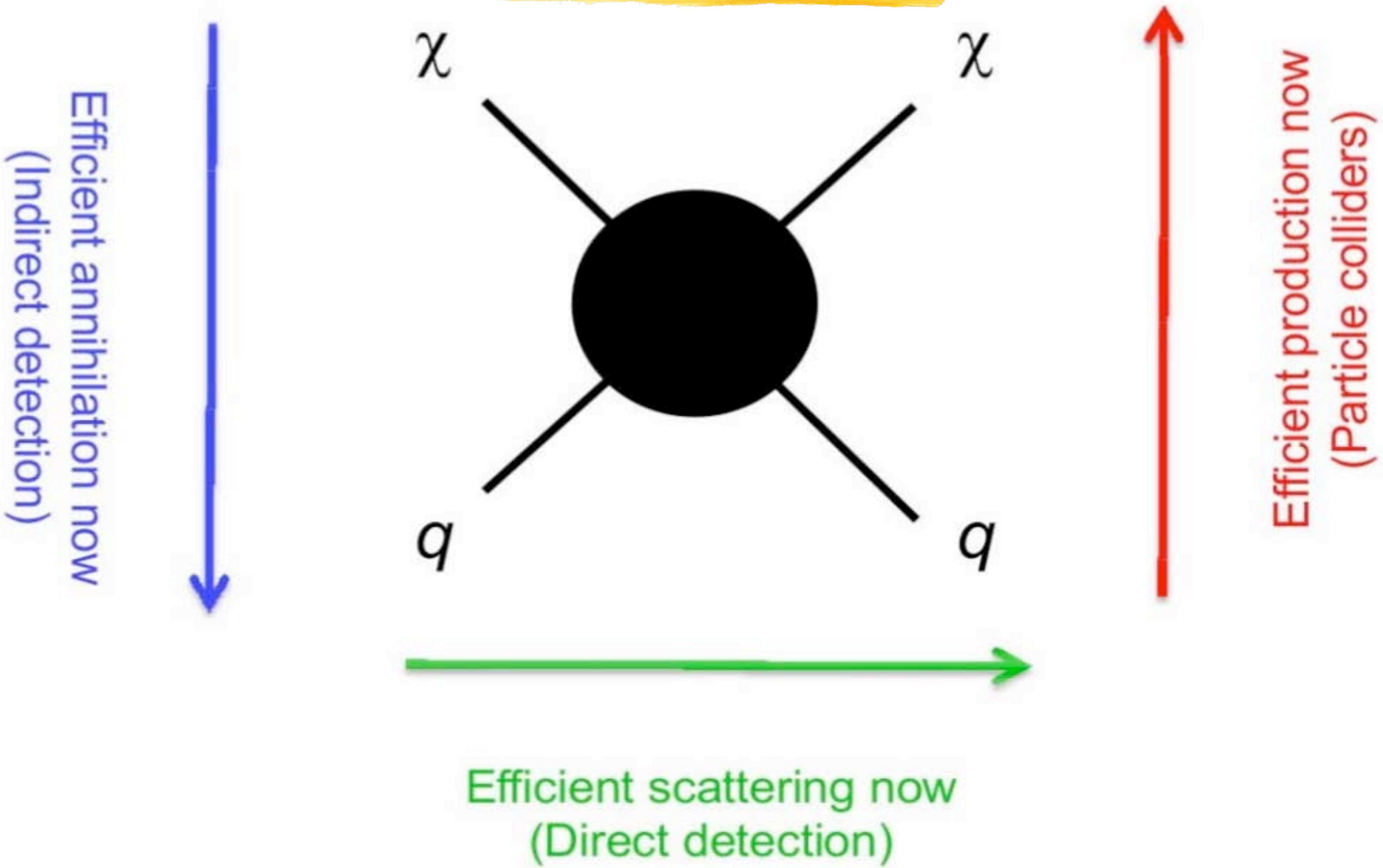
LAT pointing in celestial coordinates from -120 s to 2000 s

- **Red cross = GRB 090902B**
- **Dark region = occulted by Earth (θ_z>113°)**
- **White line = LAT FoV (±66°)**
- **Blue lines = 20° (Earth avoidance angle) / 50° above horizon**
- **White points = LAT transient events (no cut on zenith angle)**



Public data → GRB090902B paper submitted to ApjL, arXiv:0909.2470

Dark Matter Search

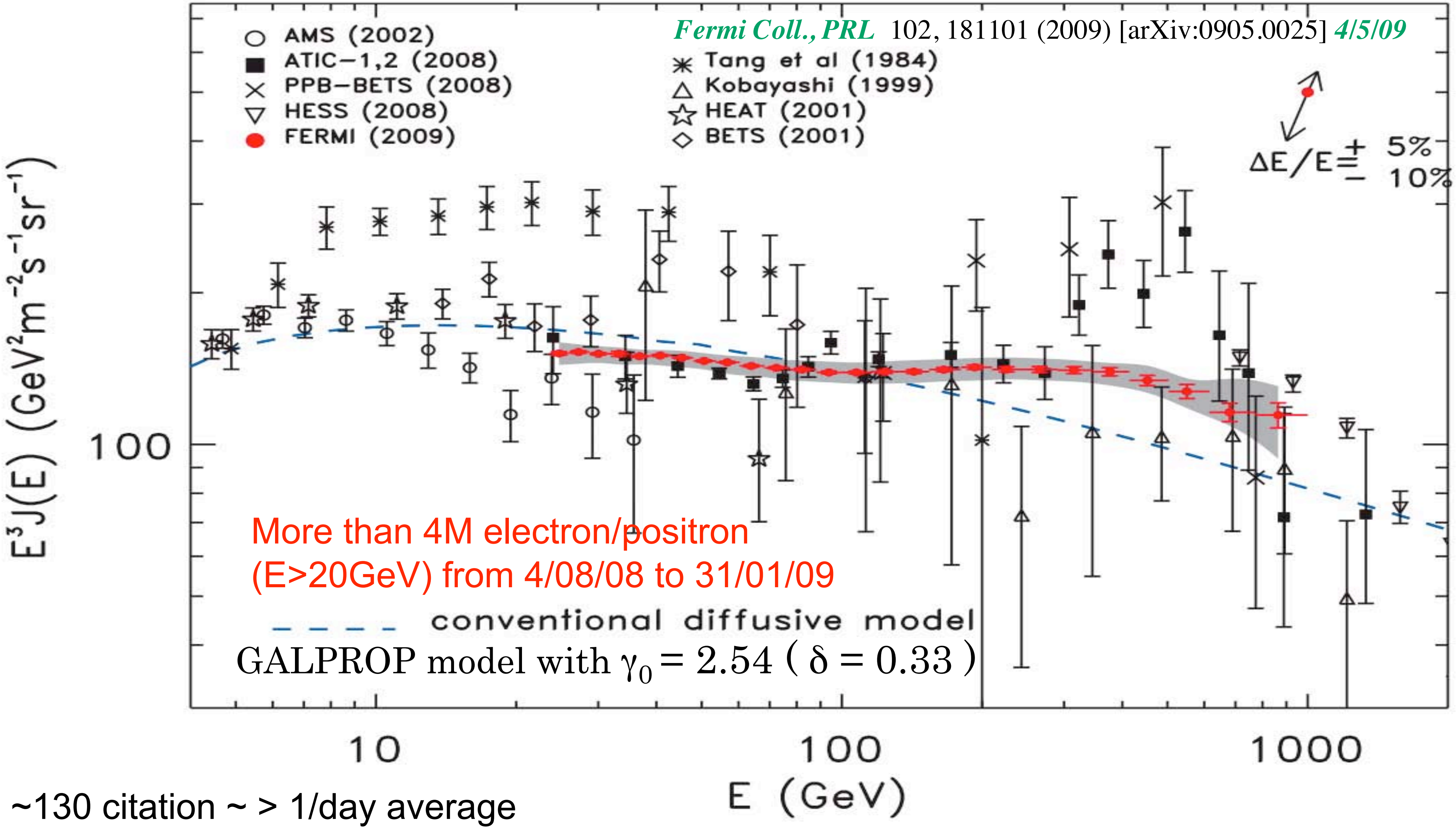


Neutralino WIMPs

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.

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



~130 citation ~ > 1/day average

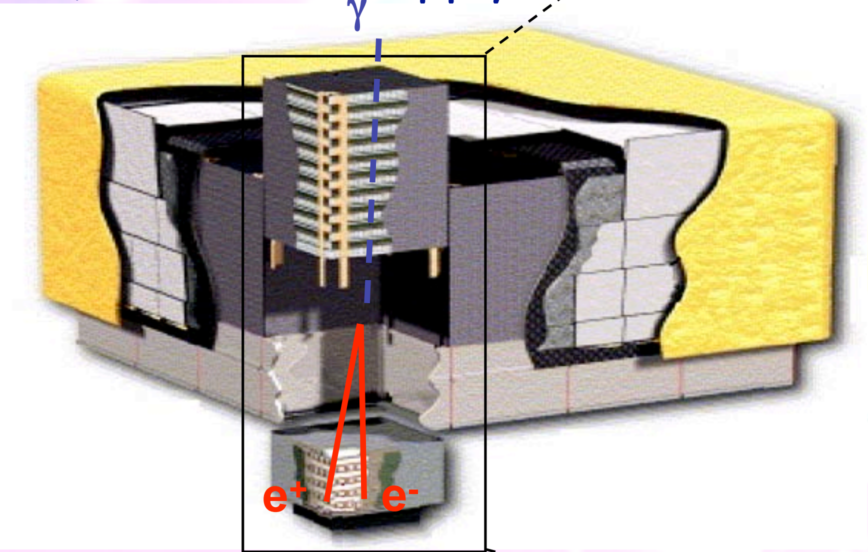
Although the feature @~600 GeV measured by ATIC is not confirmed

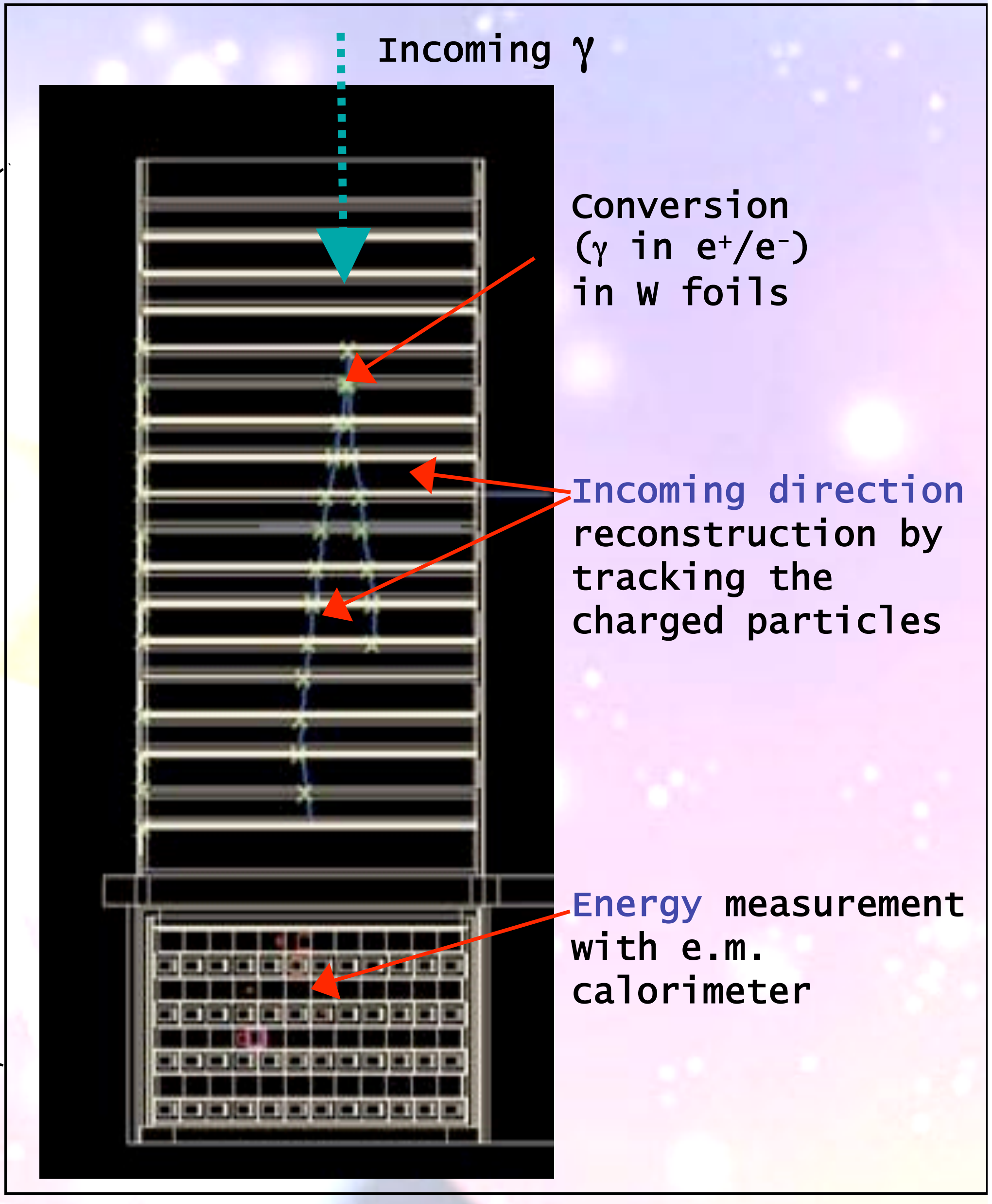
Some changes are still needed respect to the *pre-Fermi conventional model*

How Fermi LAT detects gamma rays

4 x 4 array of identical towers with:

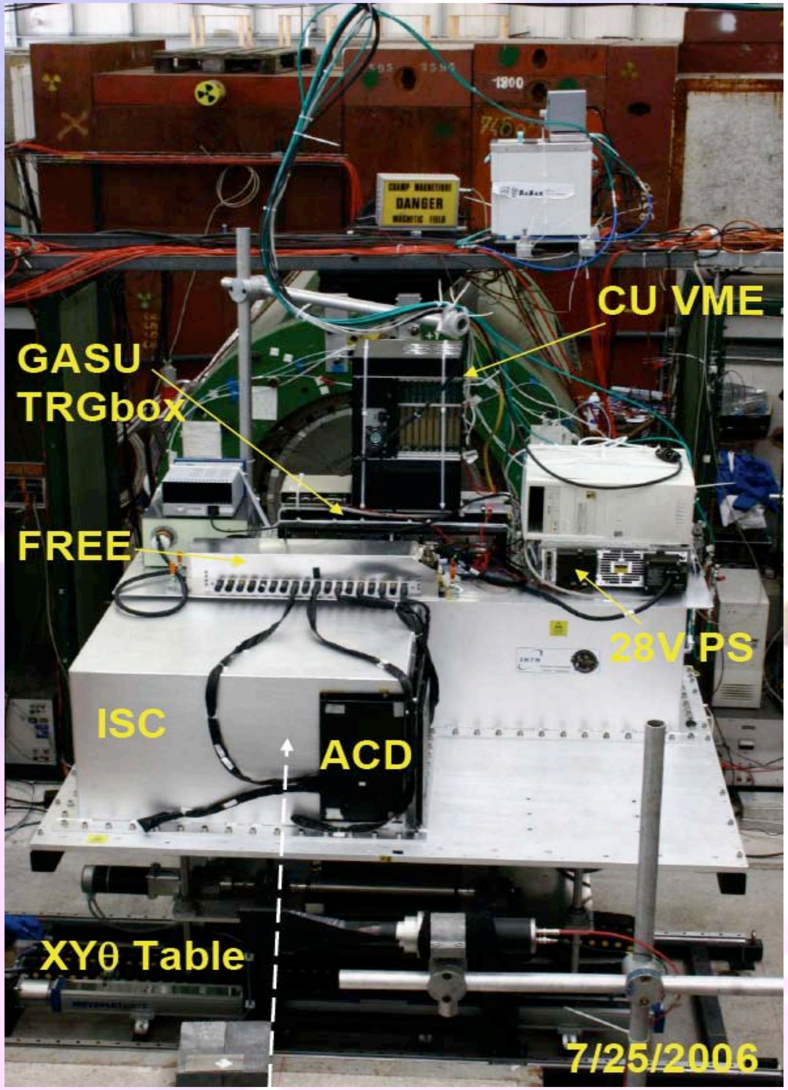
- Precision Si-strip tracker (TKR)
  - With W converter foils
- Hodoscopic CsI calorimeter (CAL)
- DAQ and Power supply box





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

The CERN Beam Test Campaign

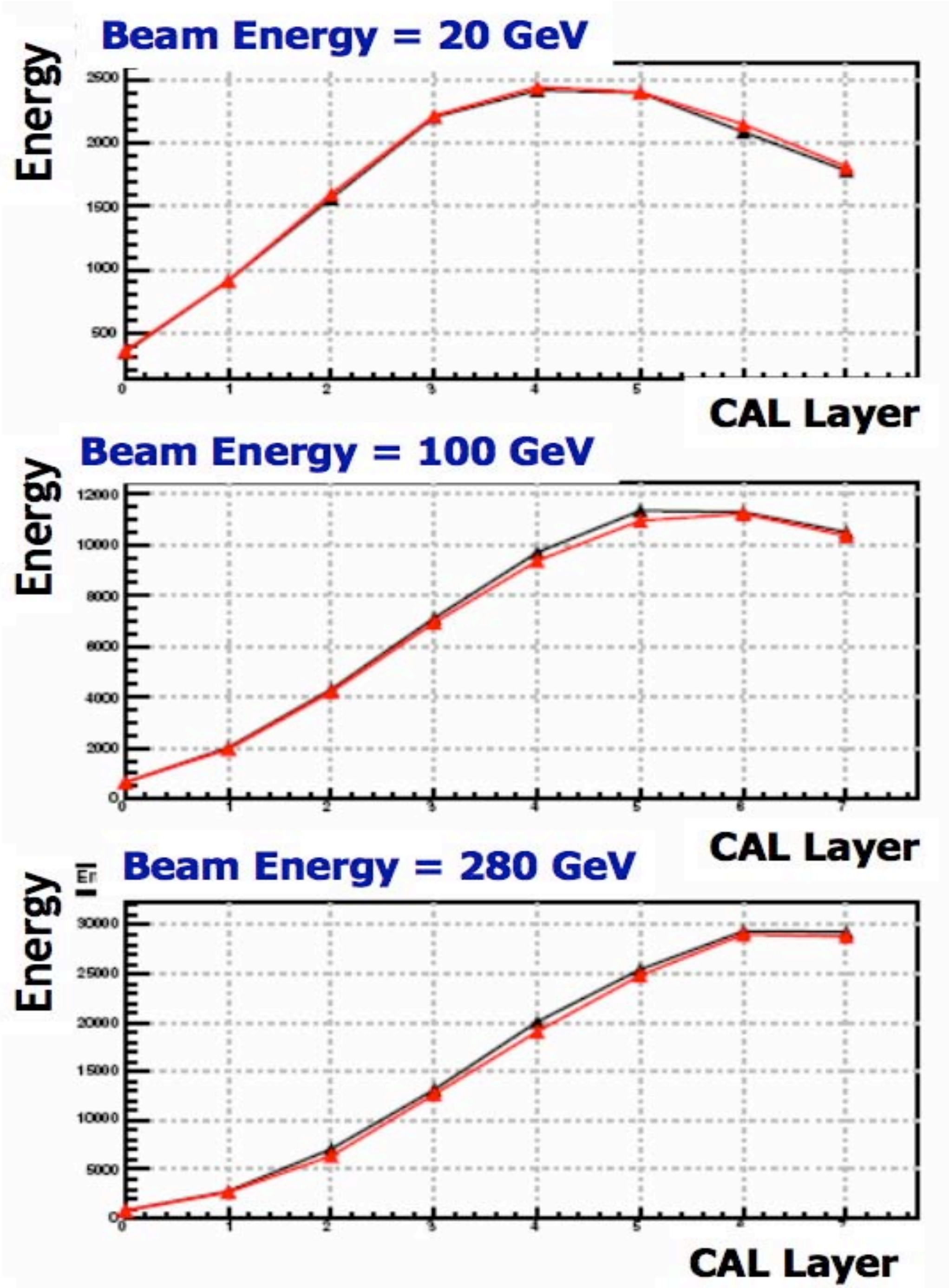


- 4 weeks at PS/T9 area (26/7-23/8)
  - Gammas @ 0-2.5 GeV
  - Electrons @ 1,5 GeV
  - Positrons @ 1 GeV (through MMS)
  - Protons @ 6,10 GeV (w/ & w/o MMS)
- 11 days at SPS/H4 area (4/9-15/9)
  - Electrons @ 10,20,50,100,200,280 GeV
  - Protons @ 20,100 GeV
  - Pions @ 20 GeV
- Data, data, data…
  - 1700 runs, 94M processed events
  - 330 configurations (particle, energy, angle, impact position)
  - Mass simulation
- A very dedicated team
  - 60 people worked at CERN
  - Whole collaboration represented

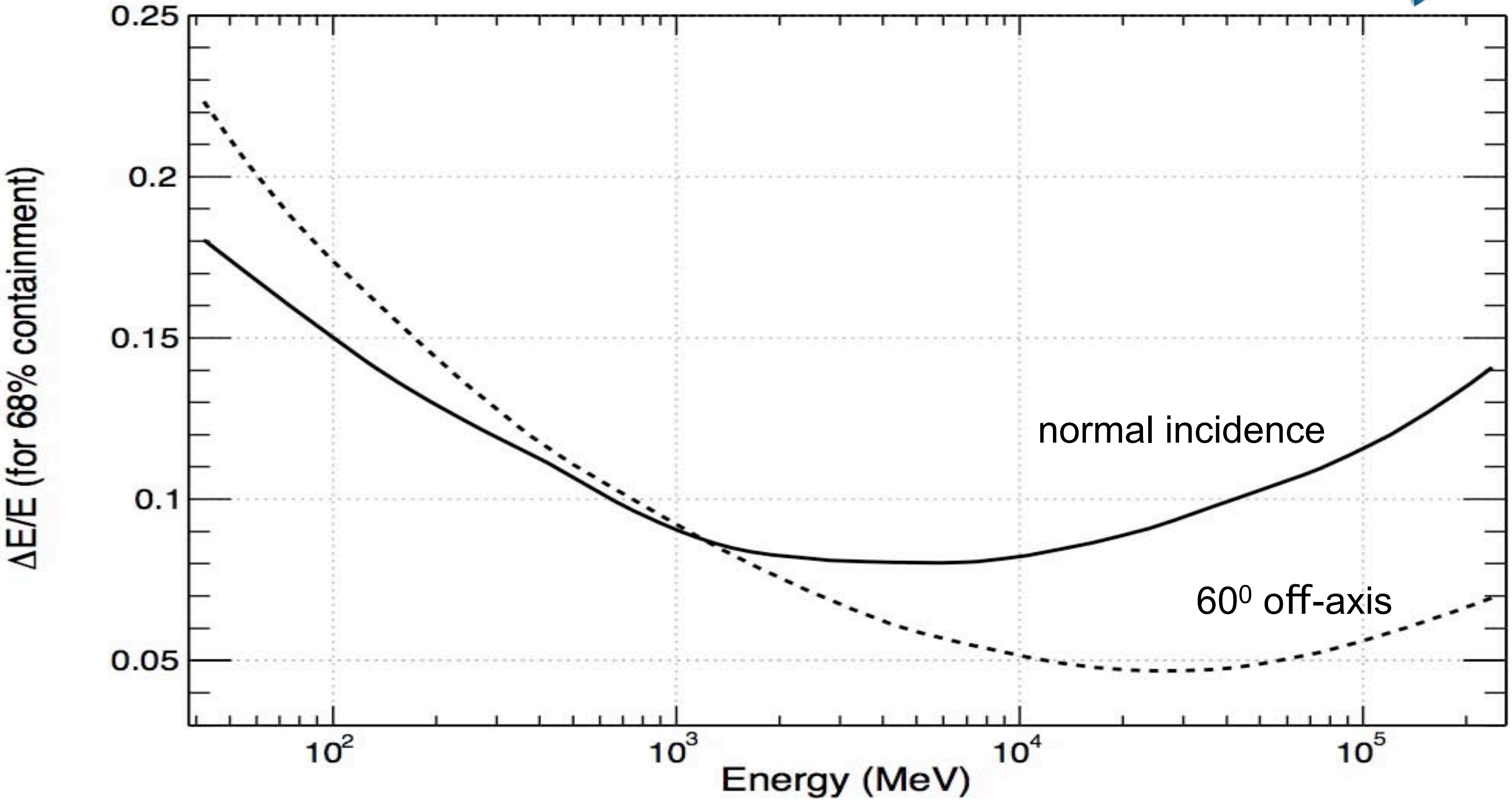
Energy reconstruction

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

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

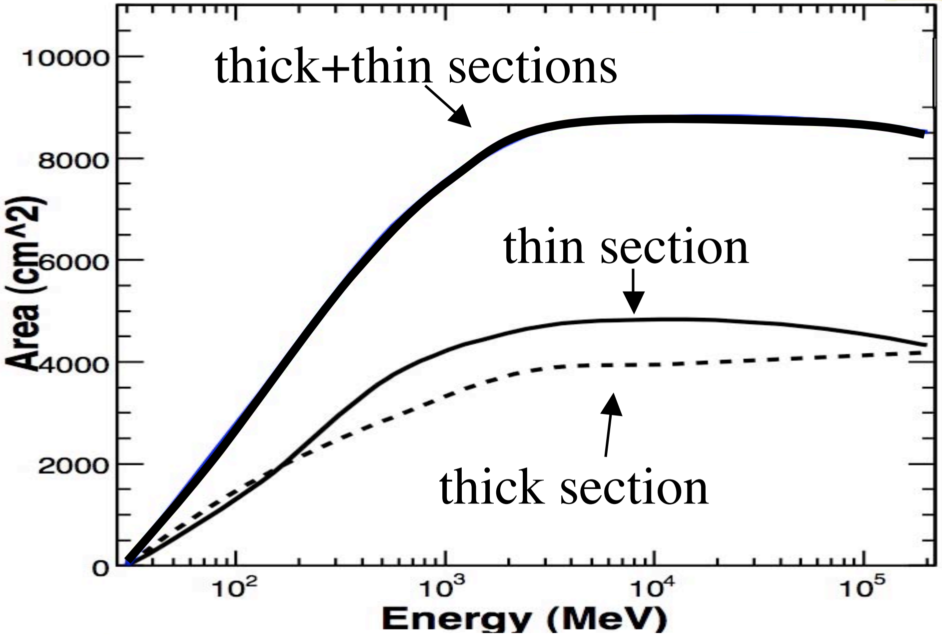


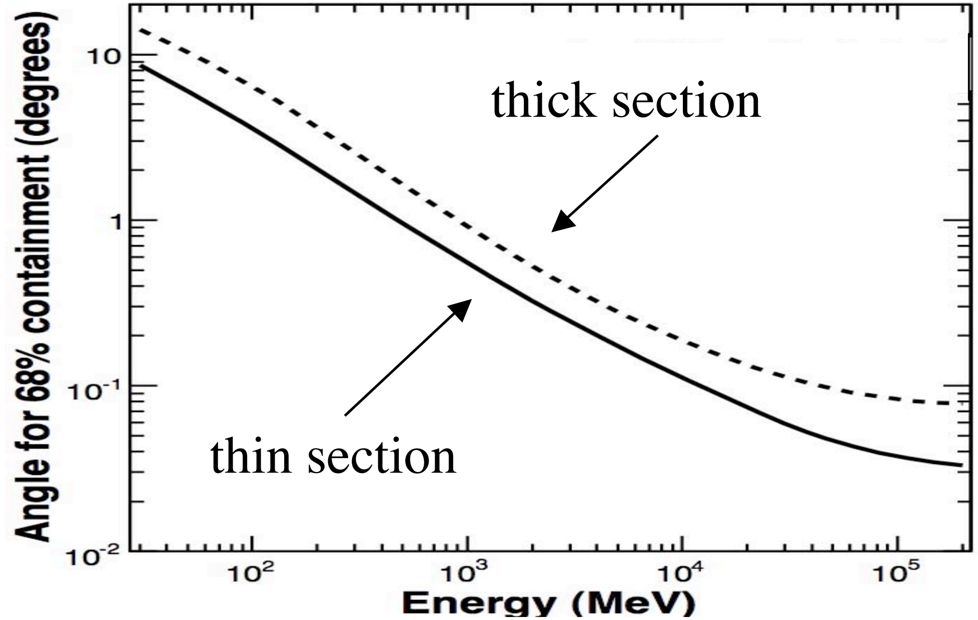
Energy Resolution

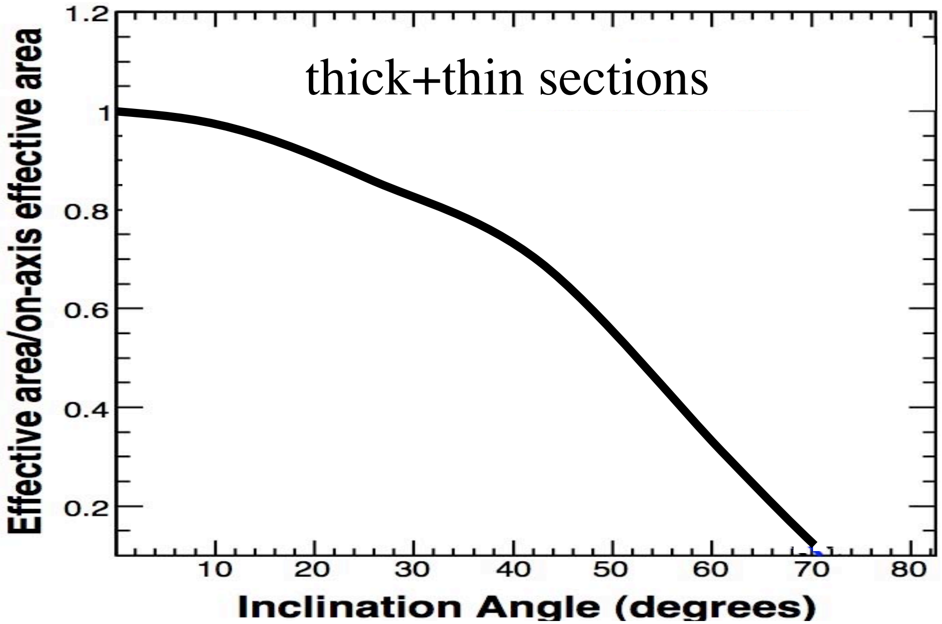


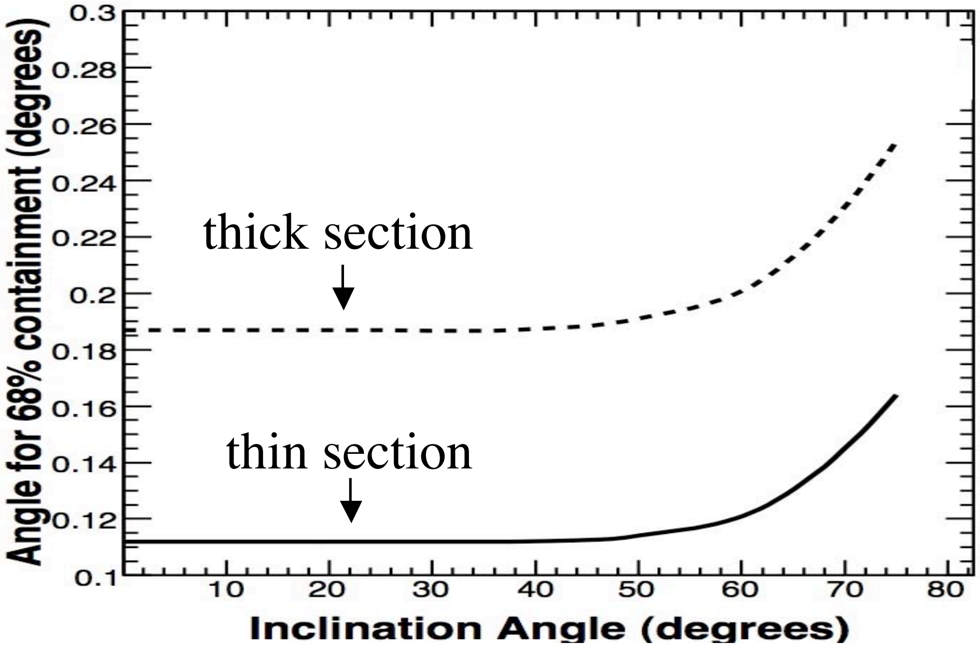
The LAT sensitivity extends to higher energies (> 300 GeV) than that of any previous space-based gamma-ray mission, opening the unexplored energy range above 30 GeV. The energy range of the LAT will overlap those of the next generation ground-based TeV gamma-ray instruments, allowing for inter-calibration between the LAT and these instruments.

Fermi LAT MC Derived Performance









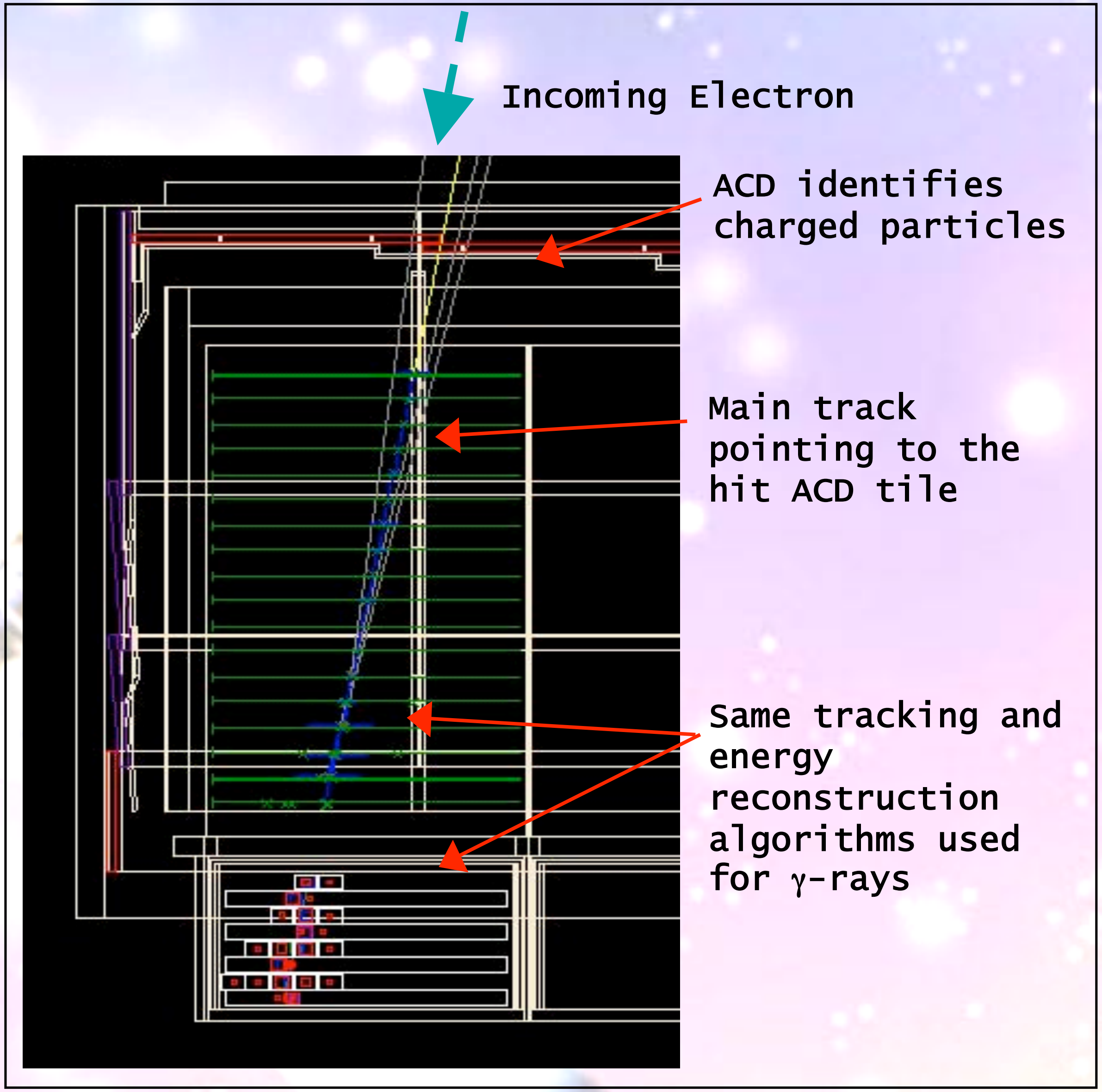
How Fermi LAT detects electrons

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

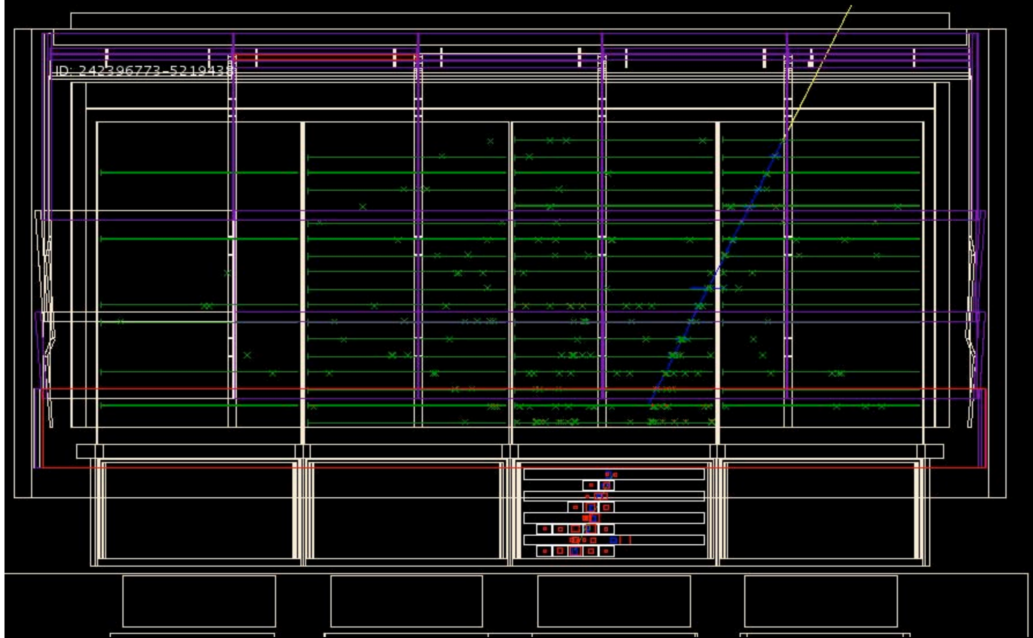
Electron identification

- 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

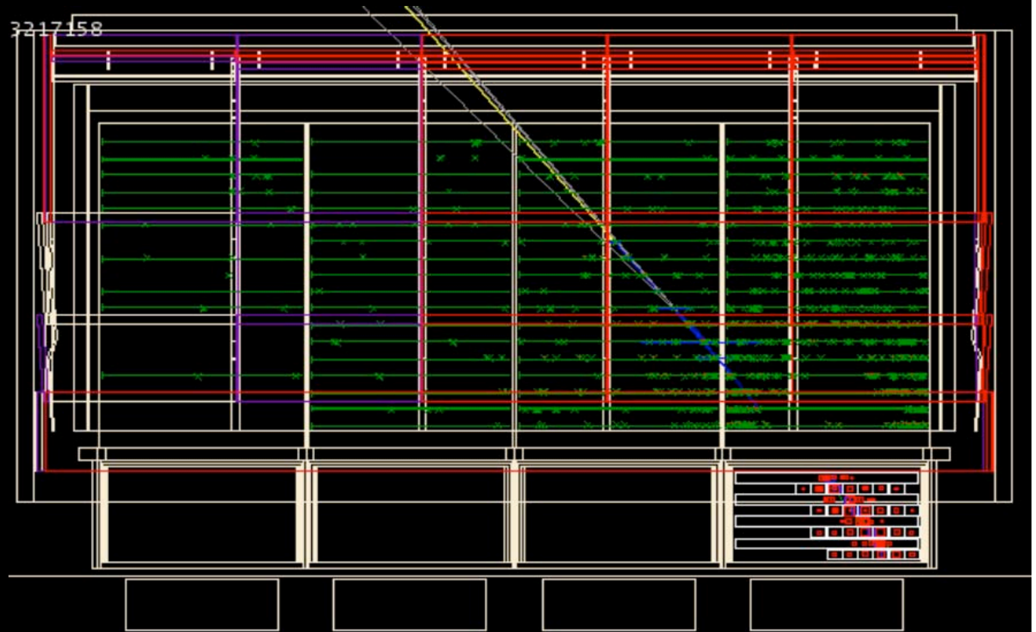


Event topology

A candidate electron
(recon energy 844 GeV)



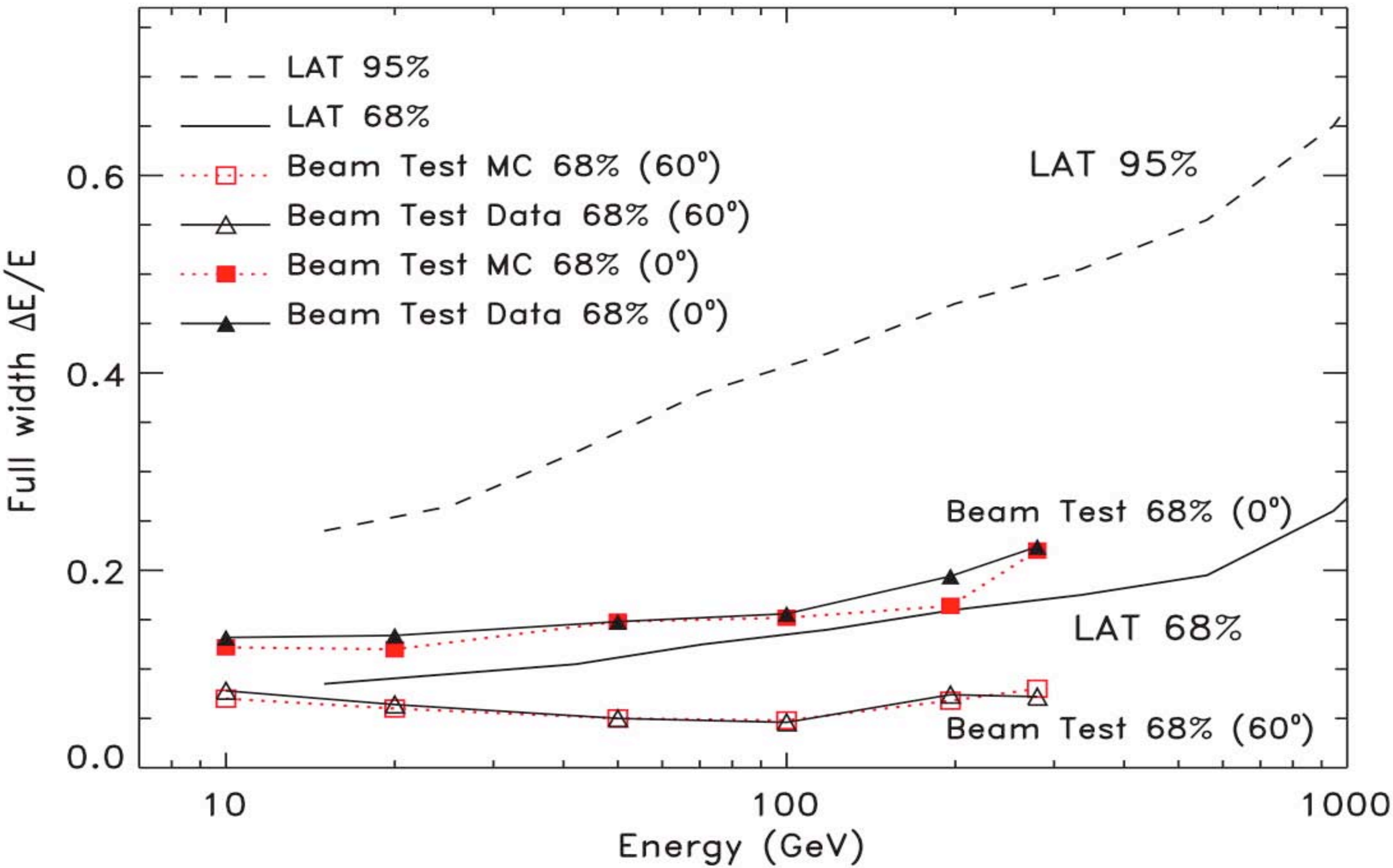
A candidate hadron
(raw energy > 800 GeV)



- 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 Energy resolution for electrons



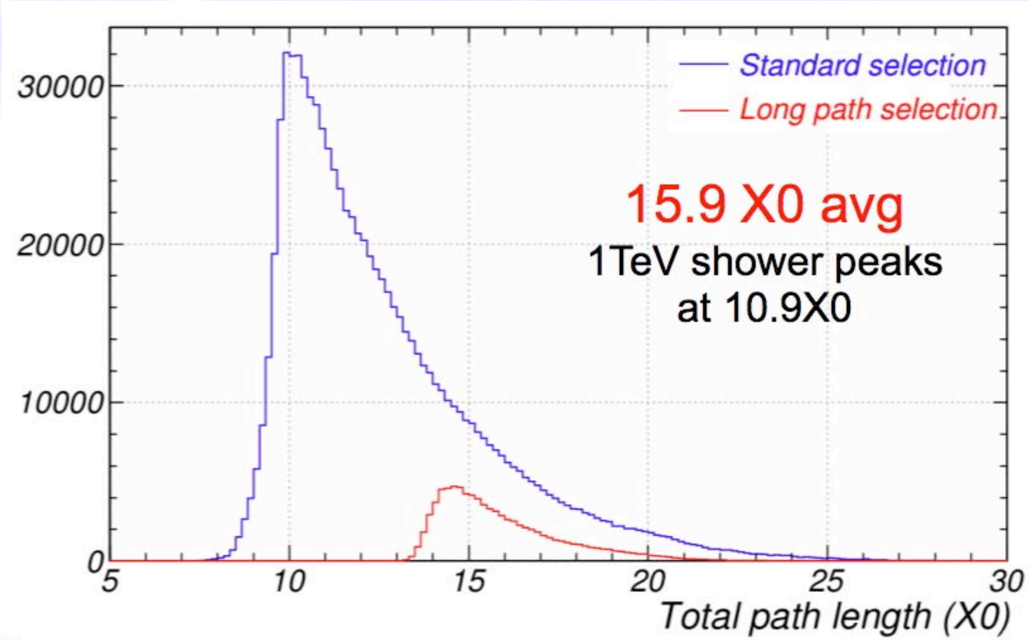
Energy resolution checks - High X0 events

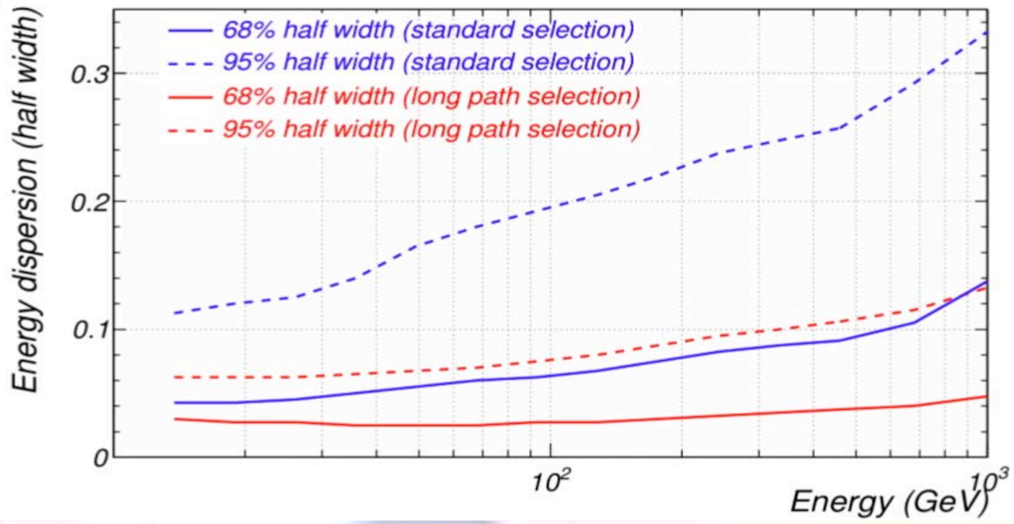
Select subsample of events with long path-length (HI-X0) X0>13

12 X0 in CAL + minimum track length in TKR + events contained in a single CAL module

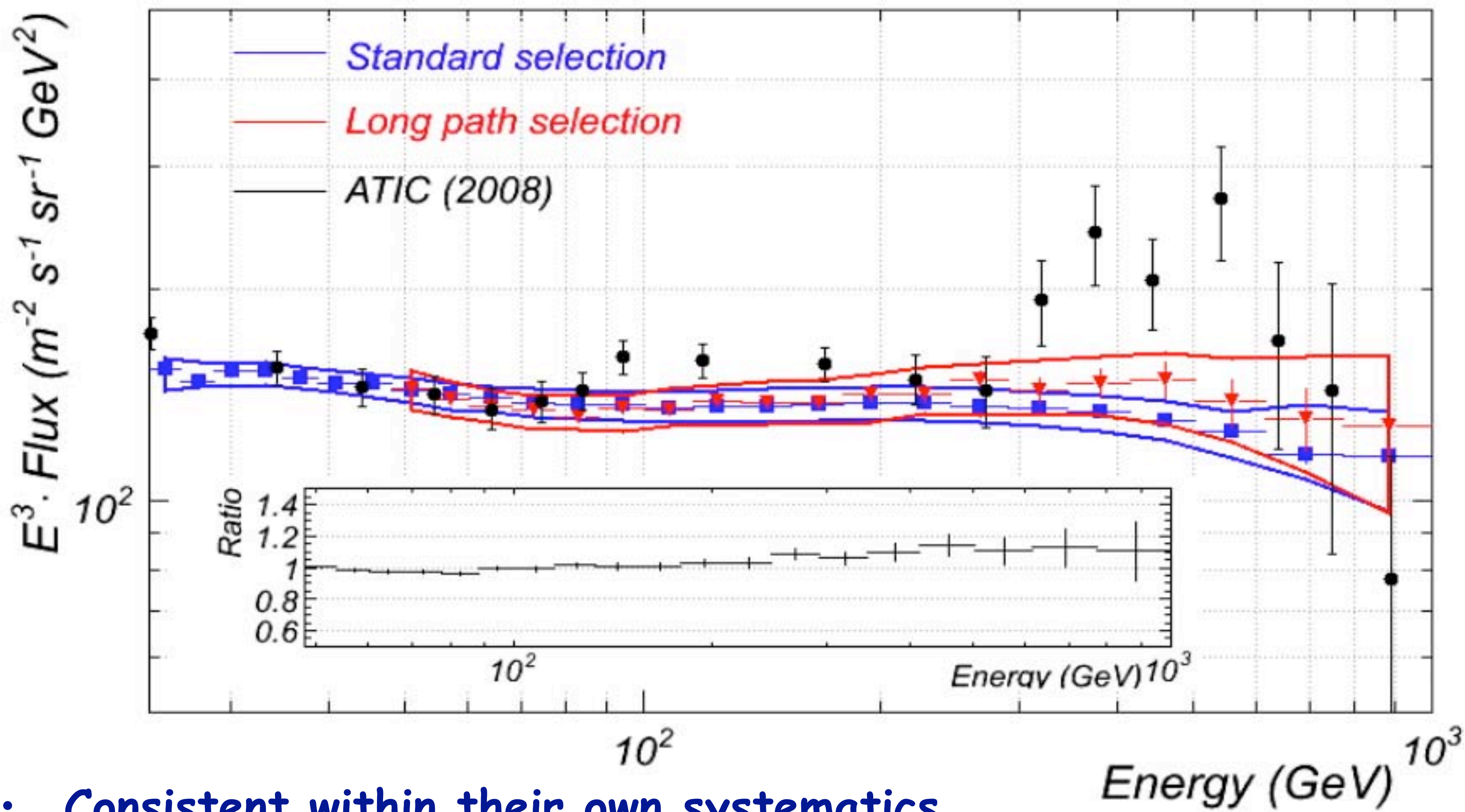
Energy resolution
Down to 5% at 1 TeV
(68% containment half-width)

Instrument acceptance to ~ 5% of standard and limited to a specific portion of instrument phase space
->Much higher systematics



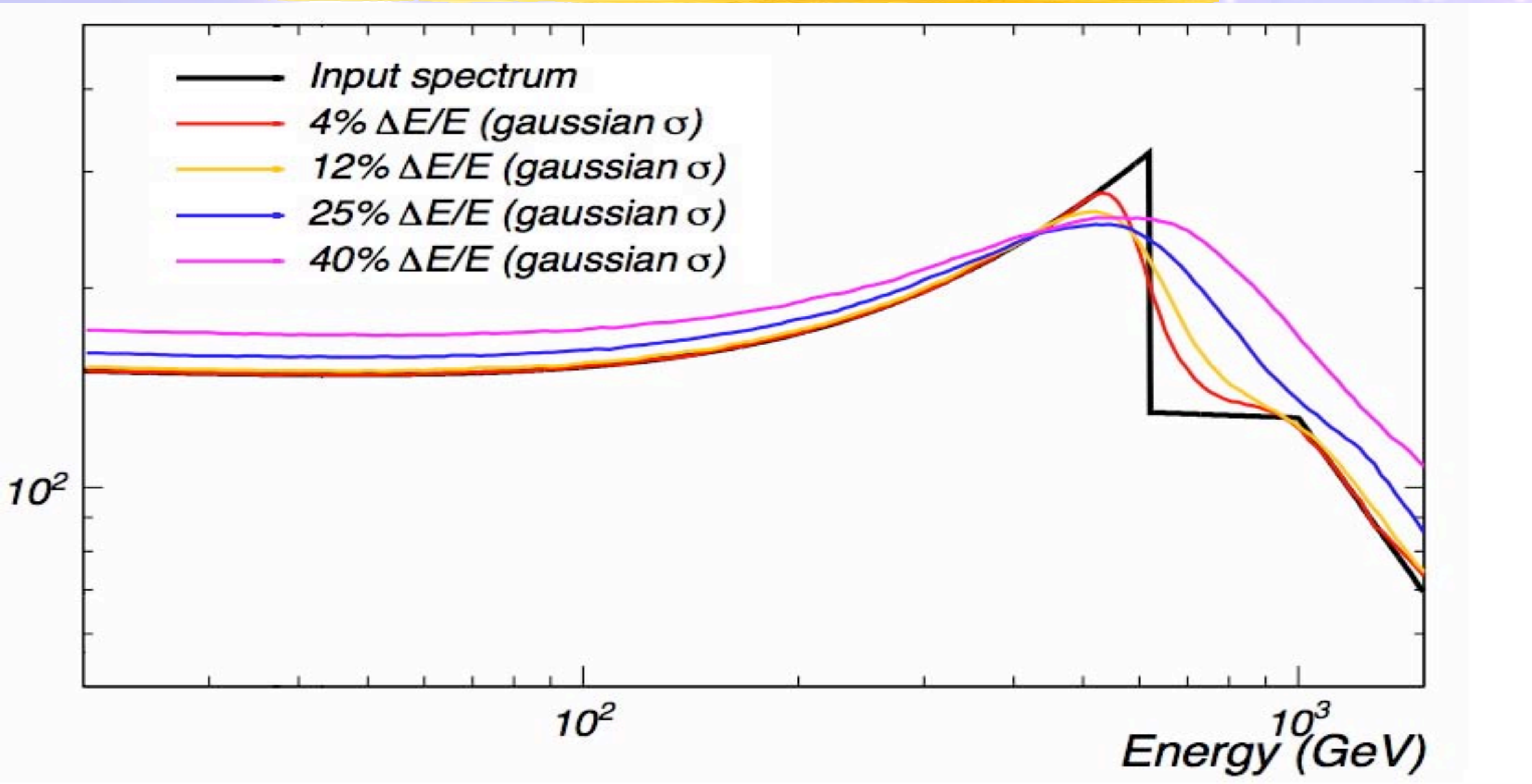


Comparison of standard and high-X0 spectra



- **Consistent within their own systematics**

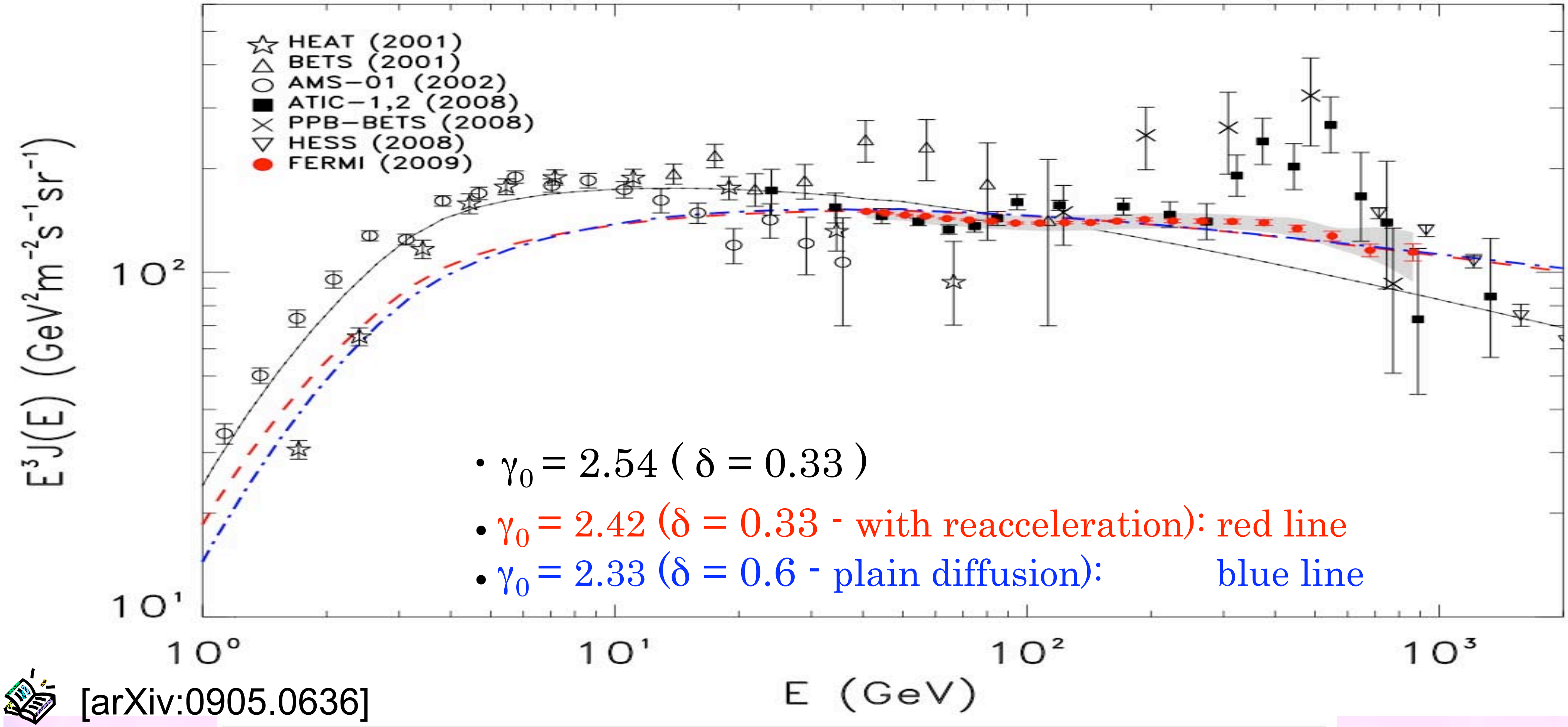
Simulation of LAT response to spectral features with artificially worsened resolution



➔ the Fermi LAT energy resolution is adequate to detect prominent spectral features

➔ the Fermi spectrum is NOT dependent on the energy resolution of the bulk of the events

Cosmic Ray Electron propagation models



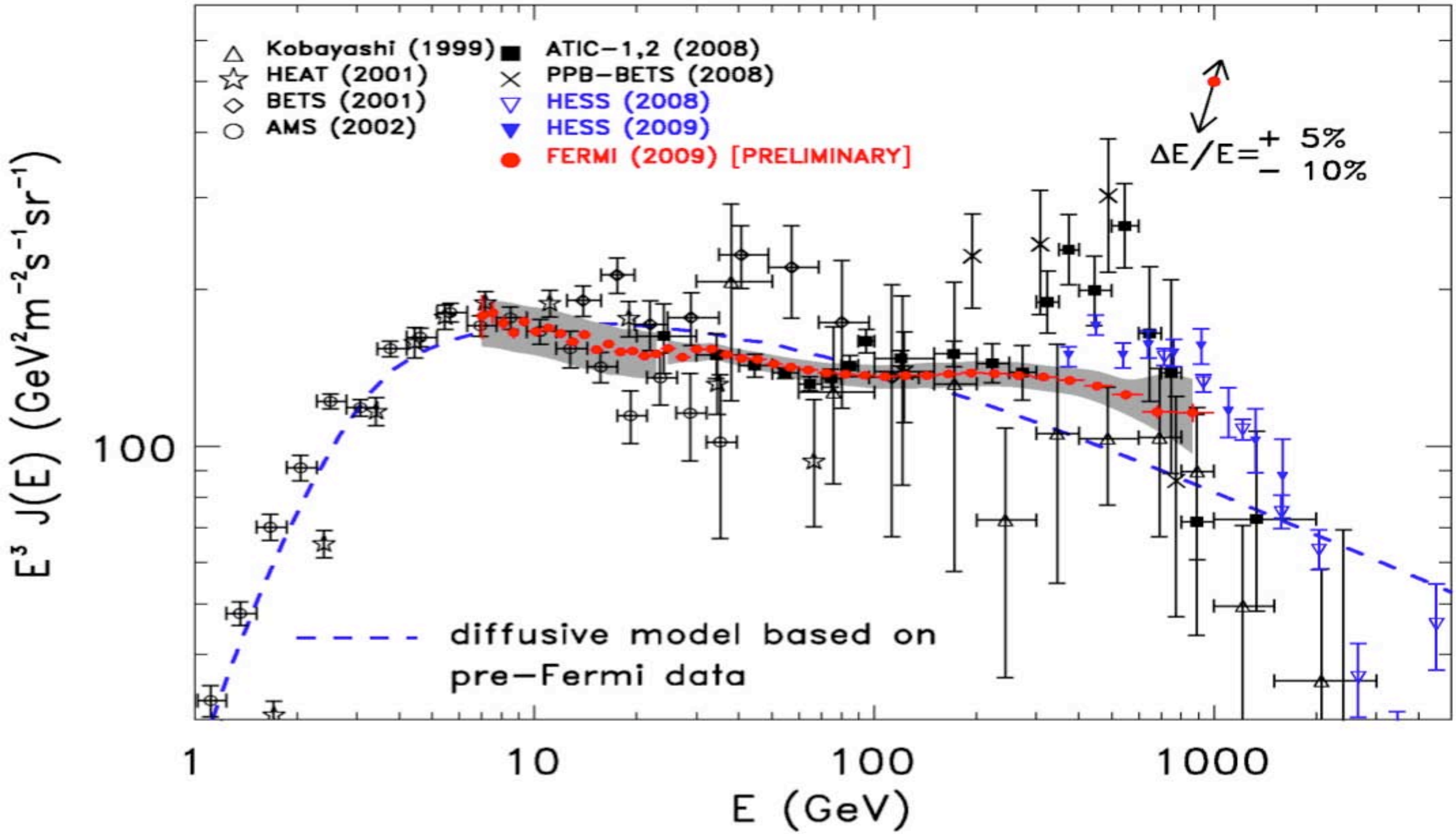
- $\gamma_0 = 2.54$ ($\delta = 0.33$)
- $\gamma_0 = 2.42$ ($\delta = 0.33$ - with reacceleration): red line
- $\gamma_0 = 2.33$ ($\delta = 0.6$ - plain diffusion): blue line

[arXiv:0905.0636]

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.

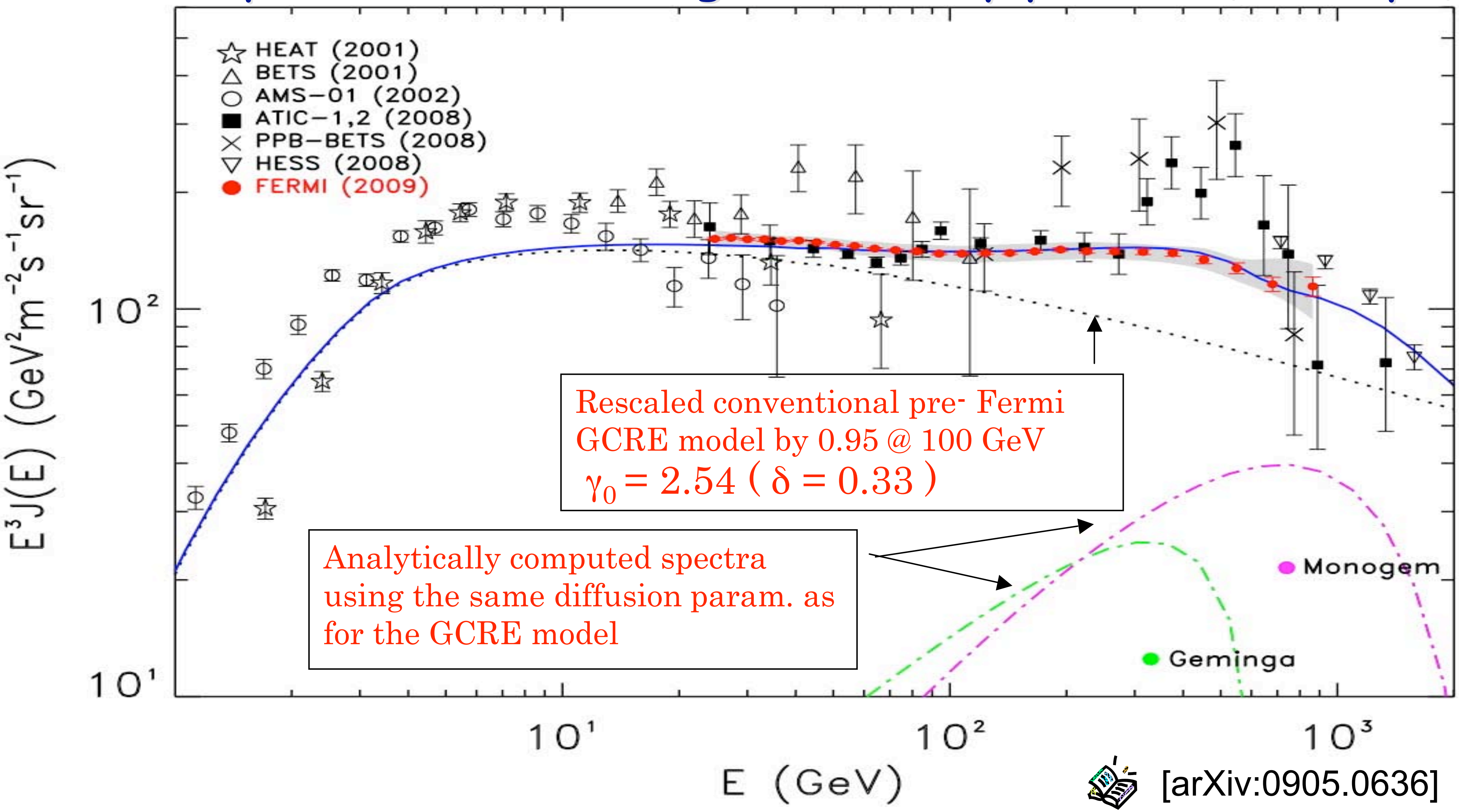
new : Fermi Electron + Positron spectrum in October 2009



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

L.Latronico Fermi Symposium

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

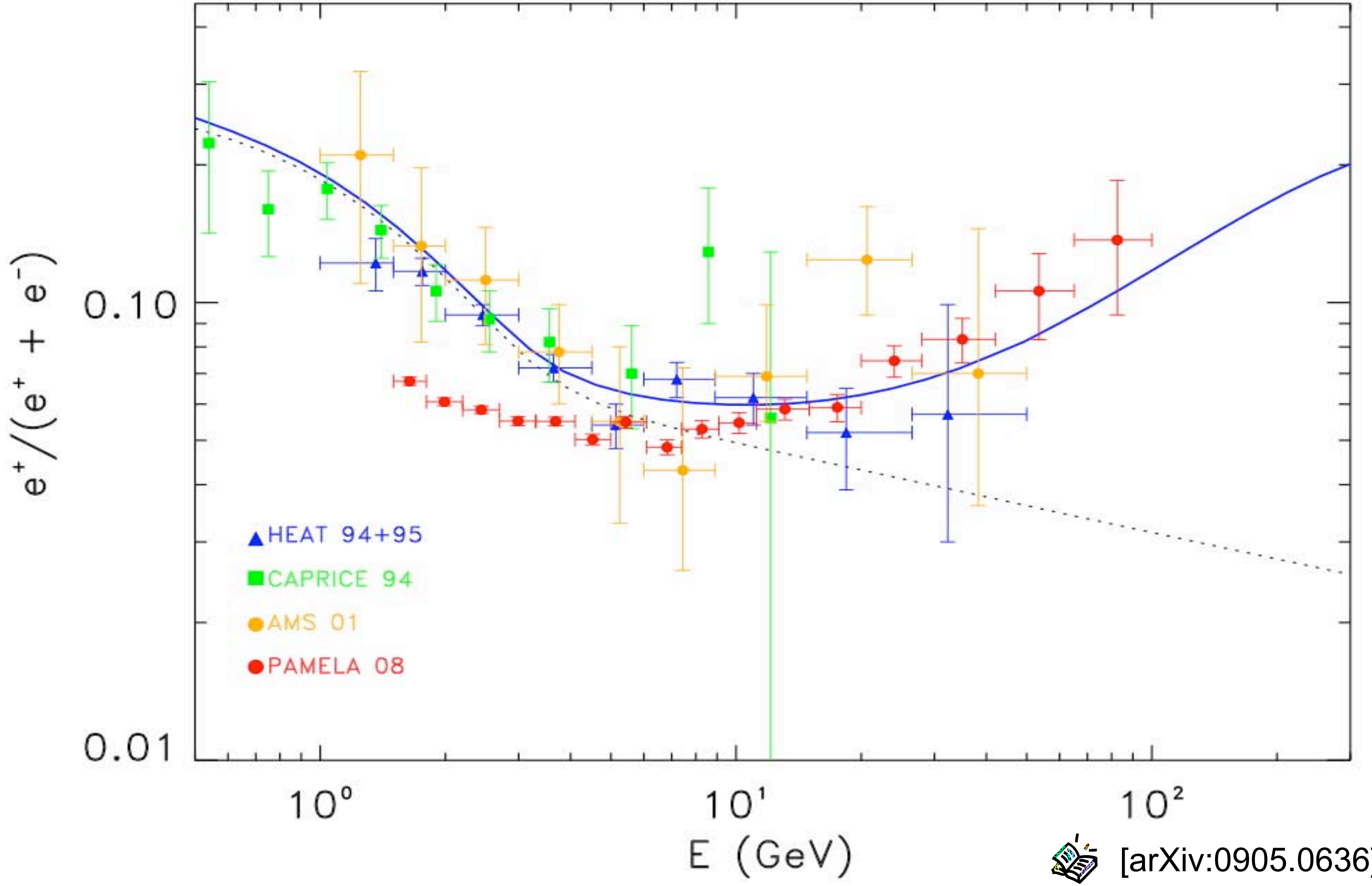


[arXiv:0905.0636]

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

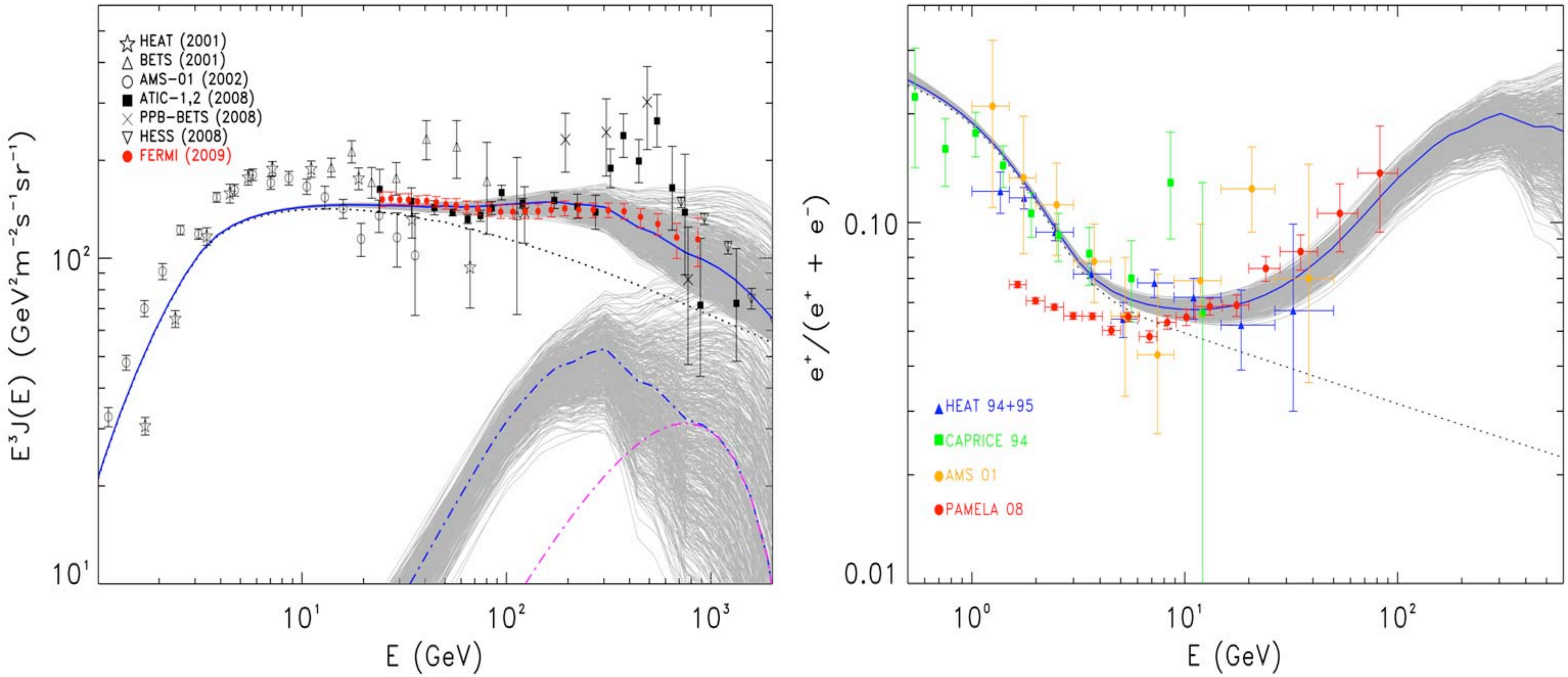
the positron ratio accounting for nearby pulsars (d < 1 kpc)



[arXiv:0905.0636]

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

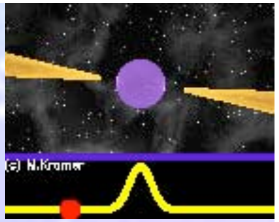
(*injection spectrum, e+e- production efficiency, PWN "trapping" time*)



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.

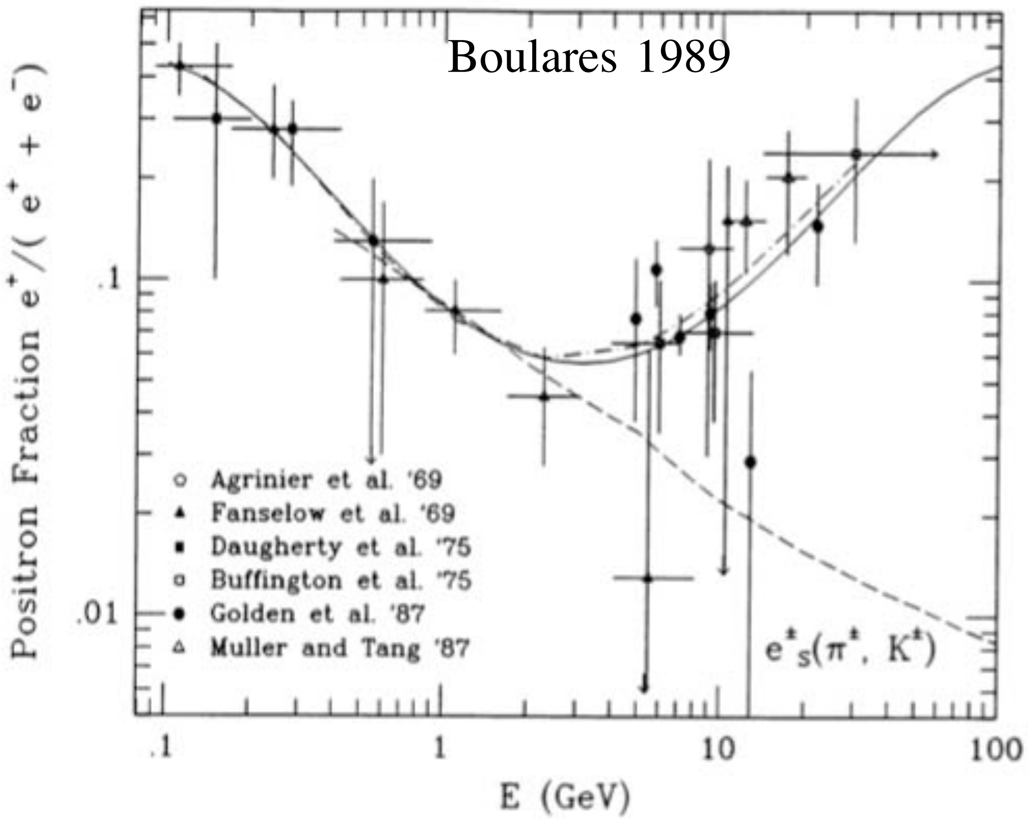
[arXiv:0905.0636]

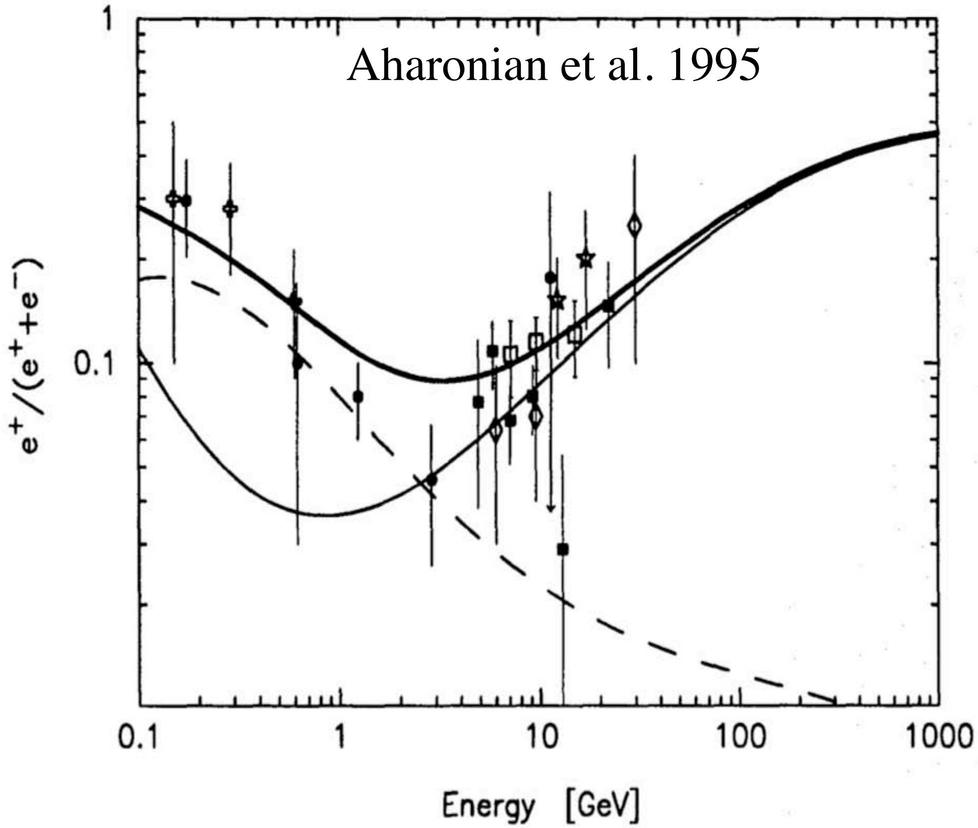
Pulsars as sources of $e^{-/+}$ pairs



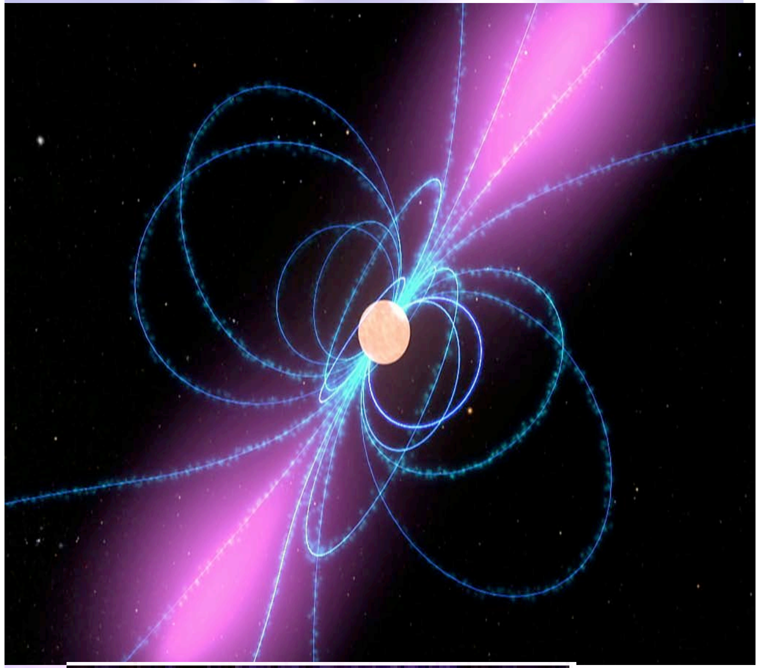
not a new idea

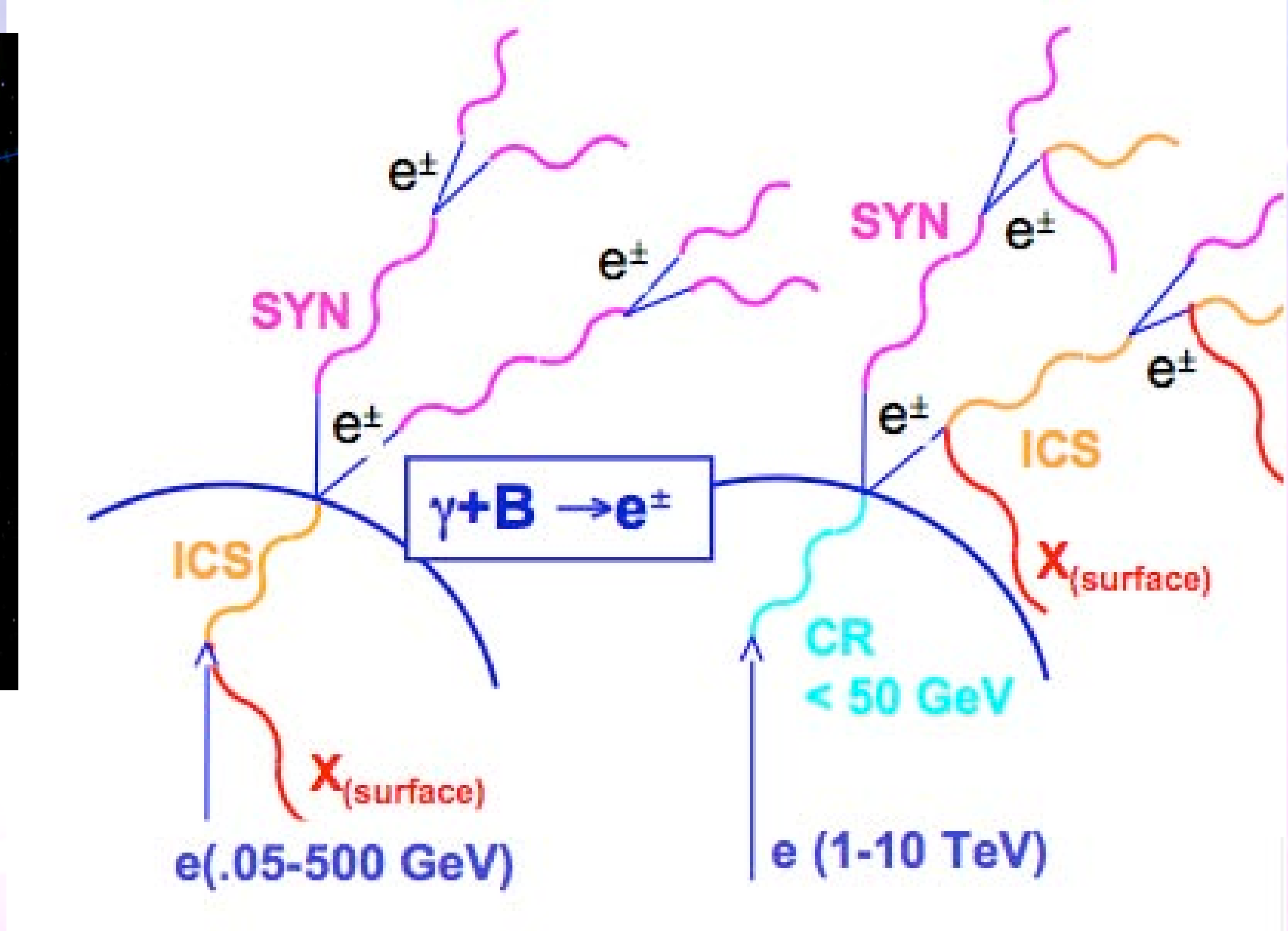
- A.Boulares APJ 342 (1989) 807-813
- Aharonian et al., A&A 294 (1995) L41
- A. M. Atoyan, F. A. Aharonian, and H. J. Volk, Phys. Rev. D52 (1995) 3265.
- T. Kobayashi, Y. Komori, K. Yoshida and J. Nishimura, ApJ 601 (2004) 340.

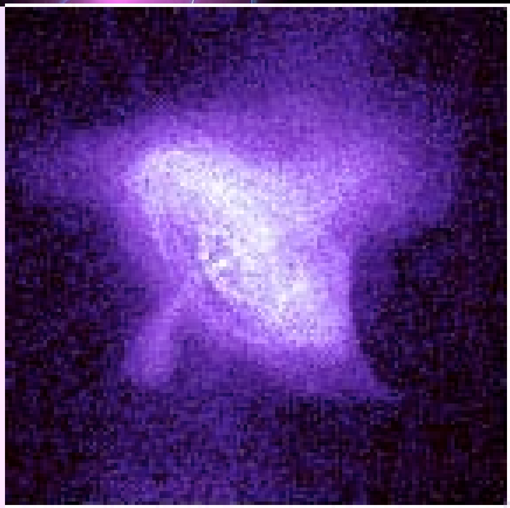




Pulsars as sources of $e^{-/+}$ pairs

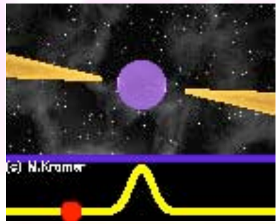




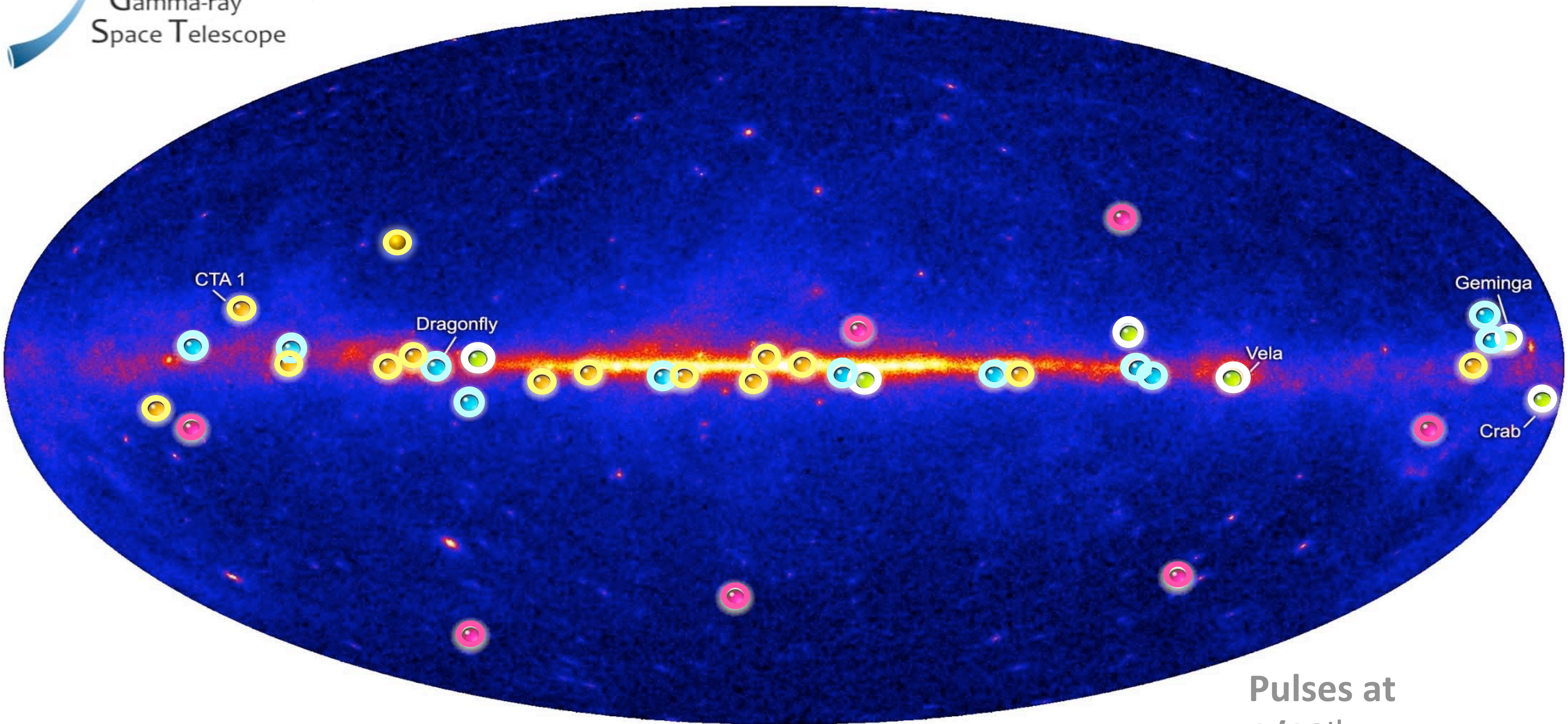


Crab Pulsar Wind Nebula (PWN)

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



16 Gamma-Ray Pulsars Through Blind Frequency Searches
Science 325 (5942), 840-844
A Population of Gamma-Ray Millisecond Pulsars Seen with Fermi
Science 325 (5942), 848-852 (14 August 2009)



Pulses at 1/10th true rate

The Pulsing γ-ray Sky

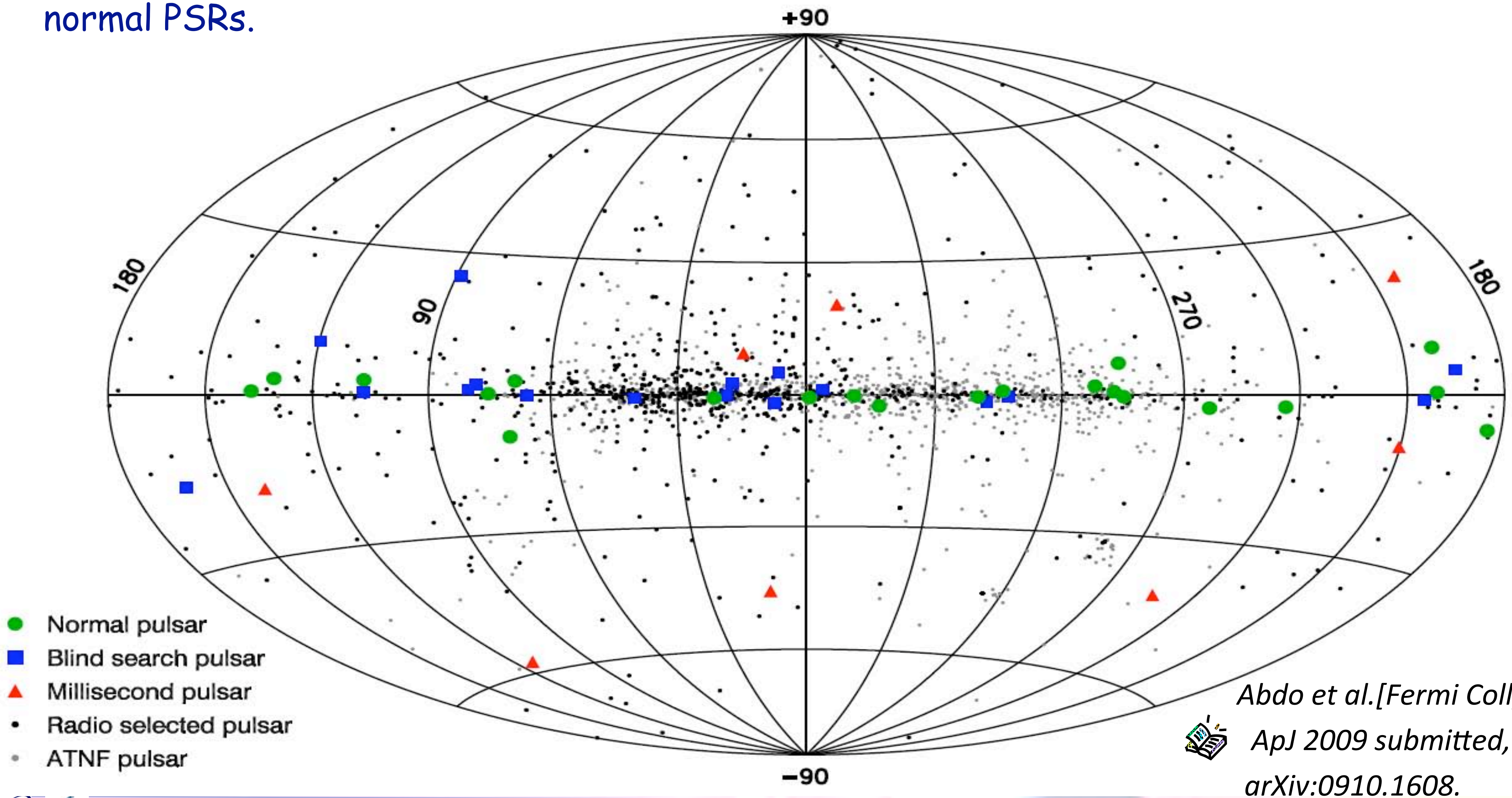
- New pulsars discovered in a blind search
- Millisecond radio pulsars
- Young radio pulsars
- Pulsars seen by Compton Observatory EGRET instrument


Science
14 August 2009 | $10
Fermi
Detecting Gamma-Ray Pulsars
AAAS

The pulsar catalog

In addition to the search for new pulsars, 762 known pulsars with ephemerides were searched for pulsations in nine months of data.

=> 46 pulsars were detected: 16 blind search PSRs, 8 radio-loud MSPs, 22 radio-loud normal PSRs.



Abdo et al.[Fermi Coll], ApJ 2009 submitted, arXiv:0910.1608.

Pulsars

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

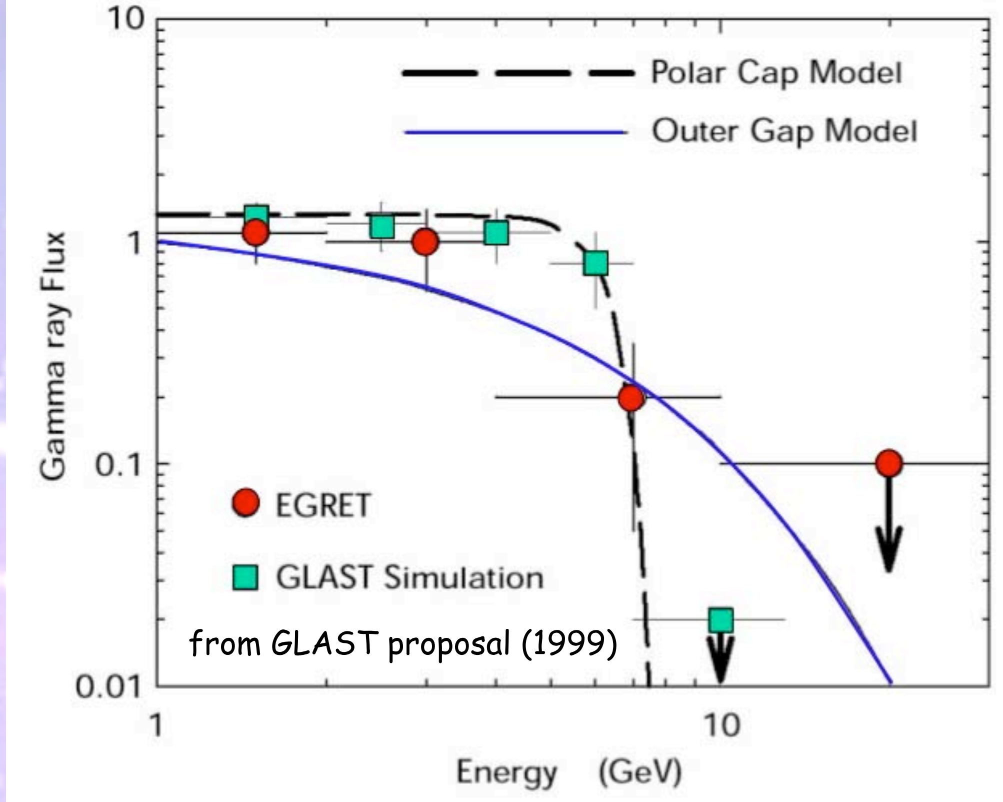
2. On the basis of the spectrum, it is not clear
   1. The spectra of PWN show relatively flat spectra of pairs at Low energies but we do not understand what it is
   2. The general spectra (acceleration at the termination shock) are too steep

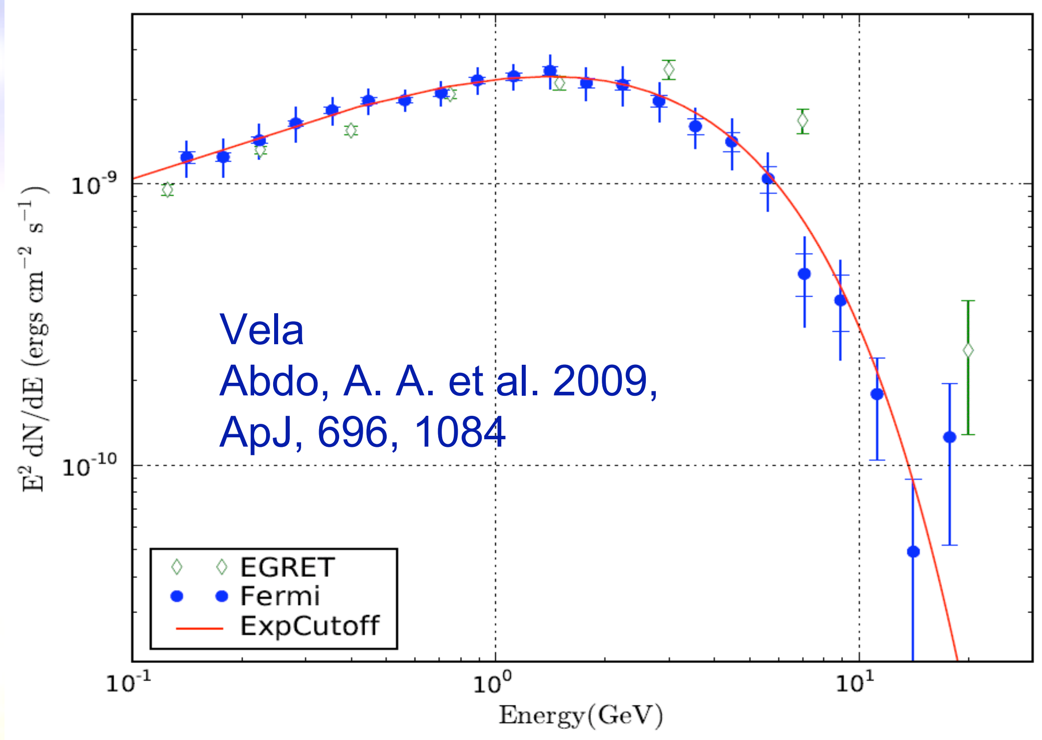
The biggest problem is that of escape of particles from the pulsar

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

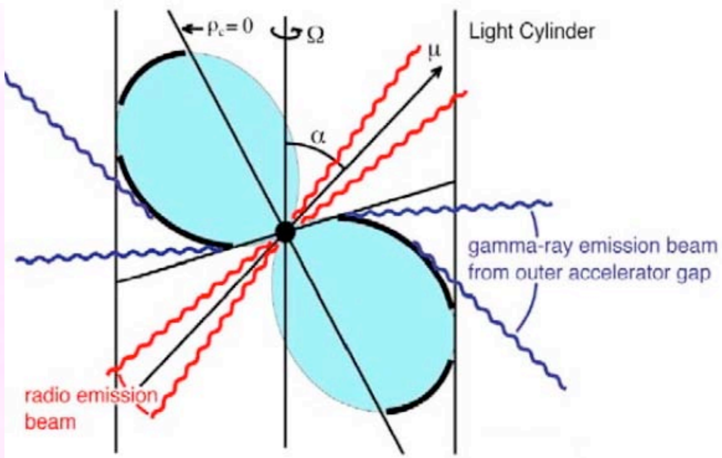
Spectral measurements and emission models

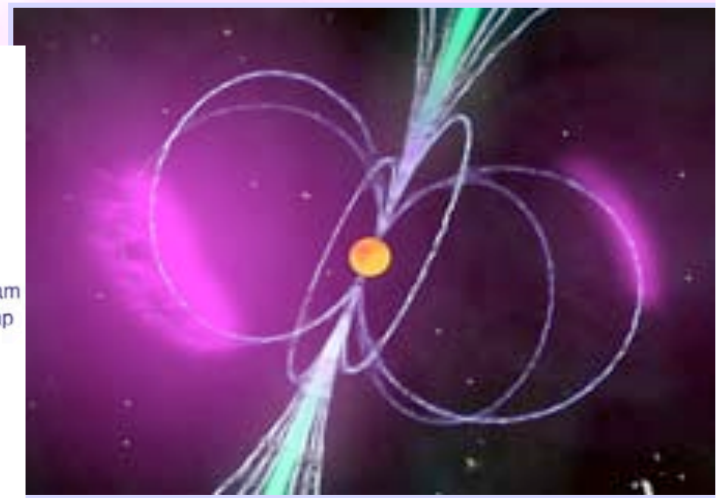




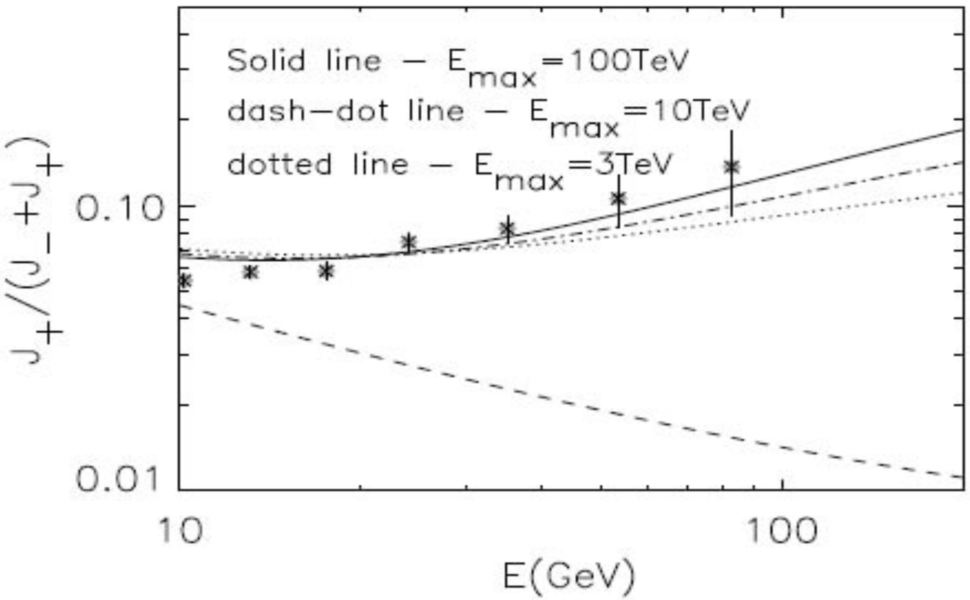
Evidence of γ-ray emission in the outer magnetopshere due to absence of super-exponential cutoff

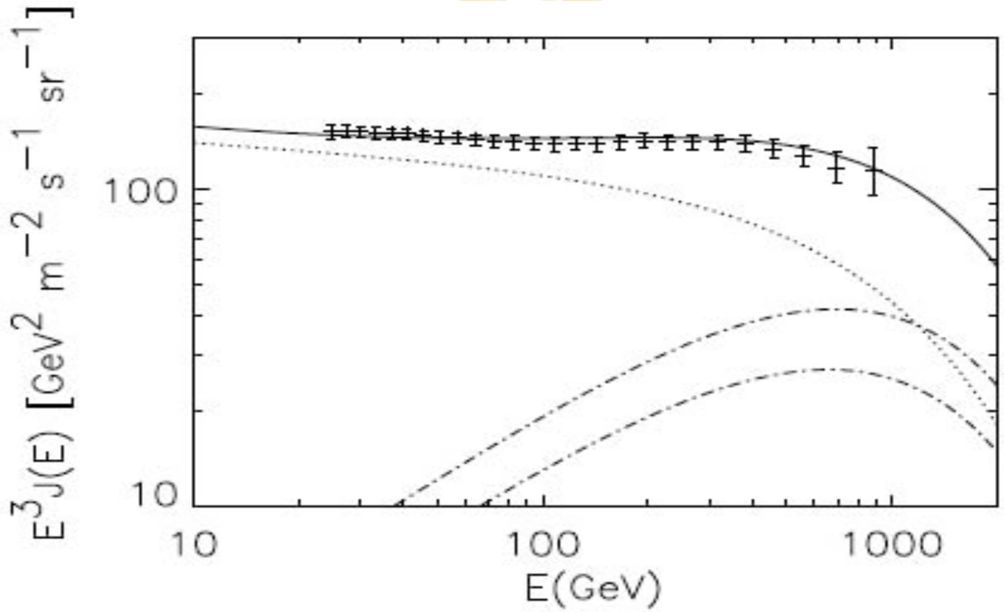
- Radio and γ-ray fan beams separated
- γ-ray only PSRs





other Astrophysical solution



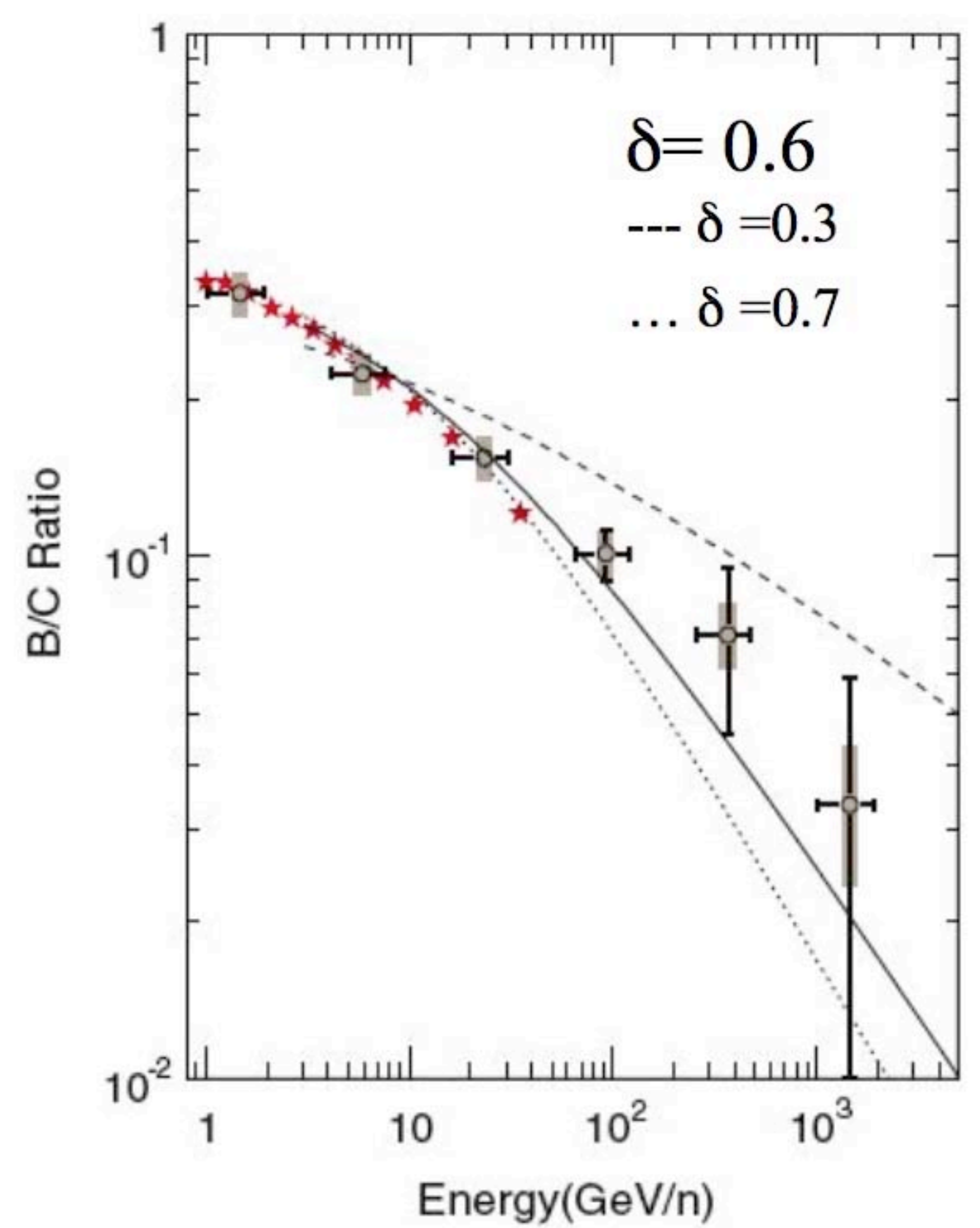


- Positrons created as secondary products of hadronic interactions inside the sources
- Secondary production takes place in the same region where cosmic rays are being accelerated

-> 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

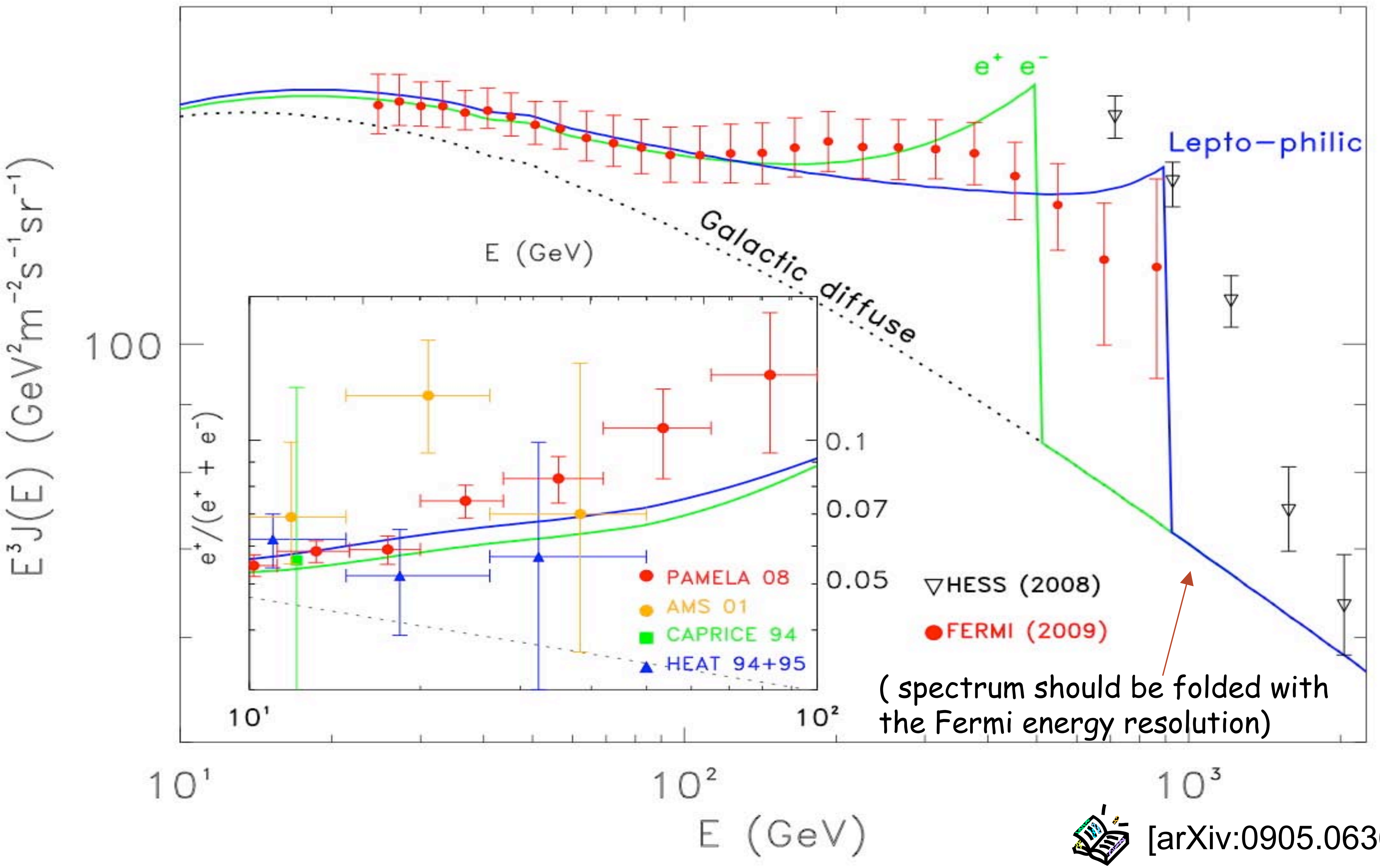
Boron-to-Carbon Ratio



CREAM: Ahn et al. 2008, Astroparticle Phys. **30**, 133

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

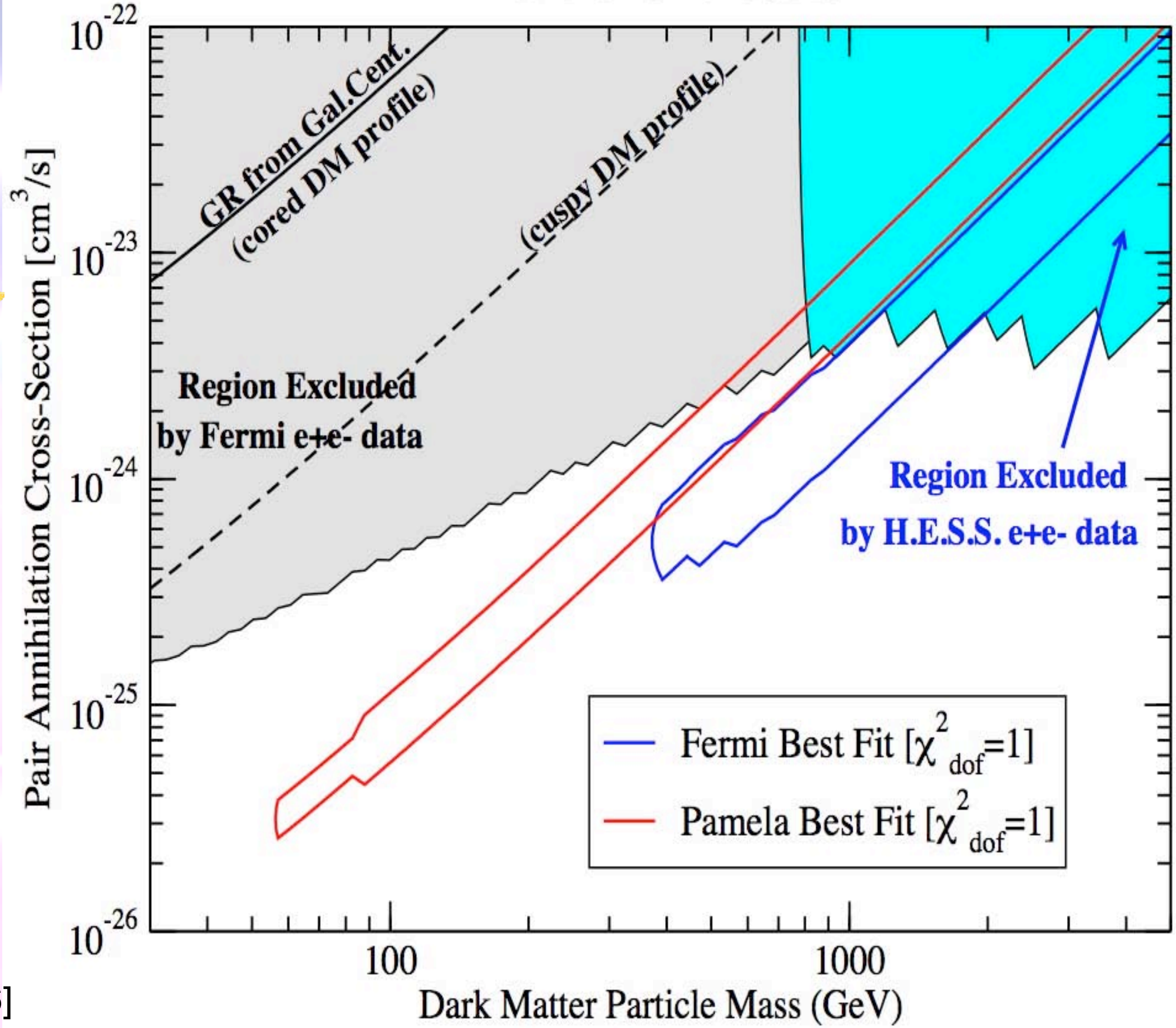
Predictions for the CRE spectrum from two specific dark matter models



[arXiv:0905.0636]

Pure e+e- Models

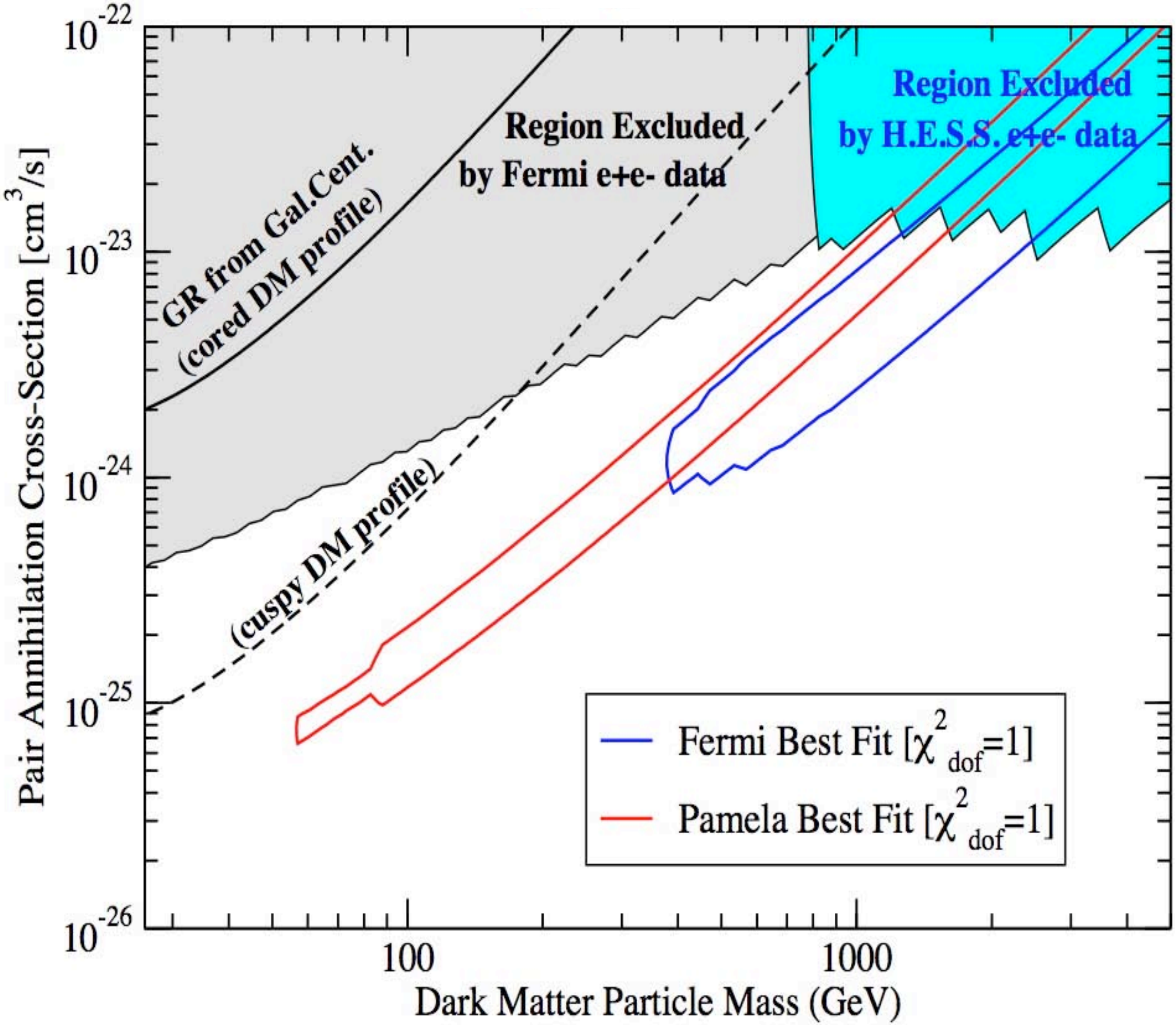
the dark matter pair annihilation always yields a pair of monochromatic e+e-, with injection energies equal to the mass of the annihilating dark matter particle



[arXiv:0905.0636]

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.

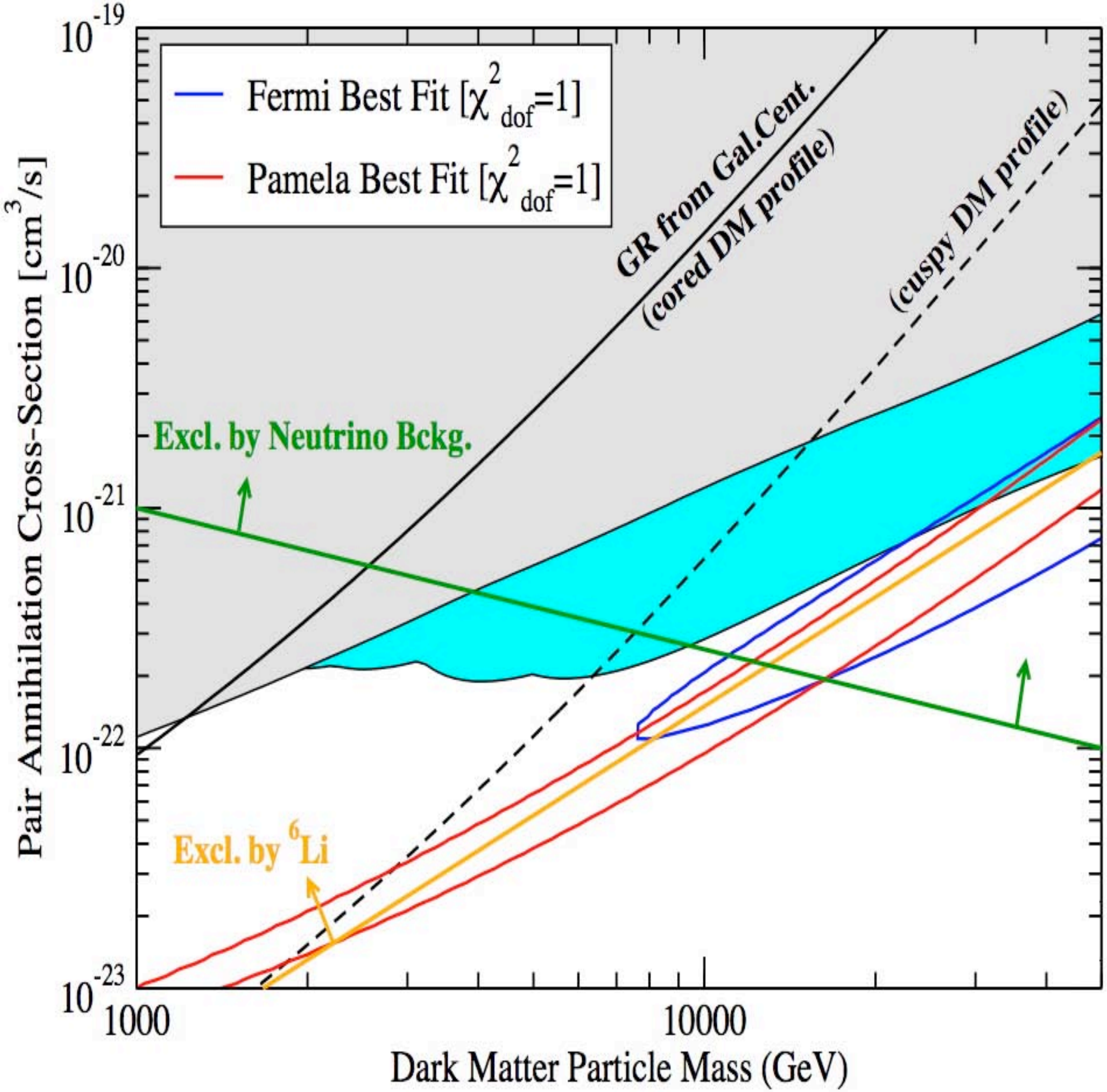


[arXiv:0905.0636]

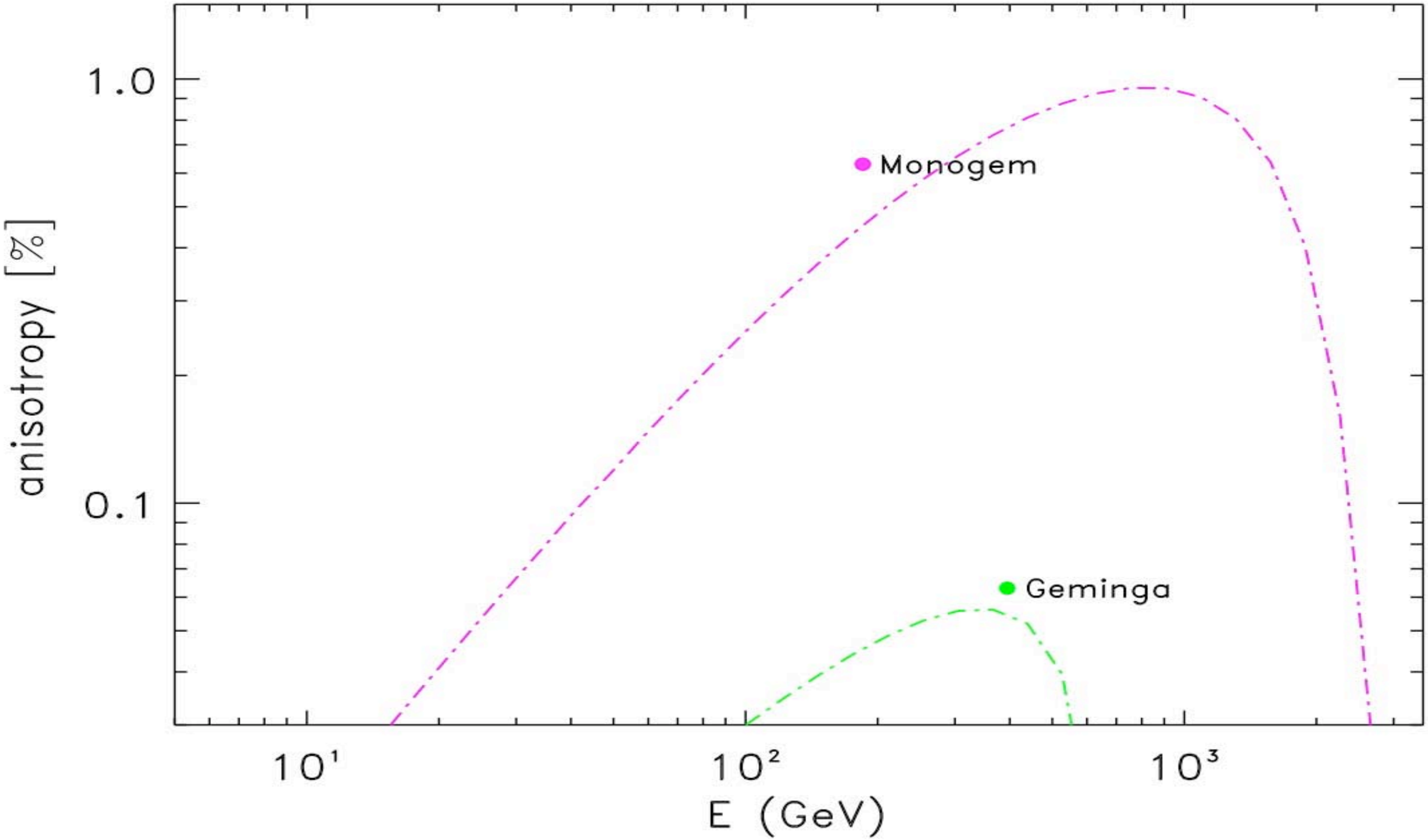
Super-heavy Models (ann. in gauge bosons)

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

[arXiv:0905.0636]

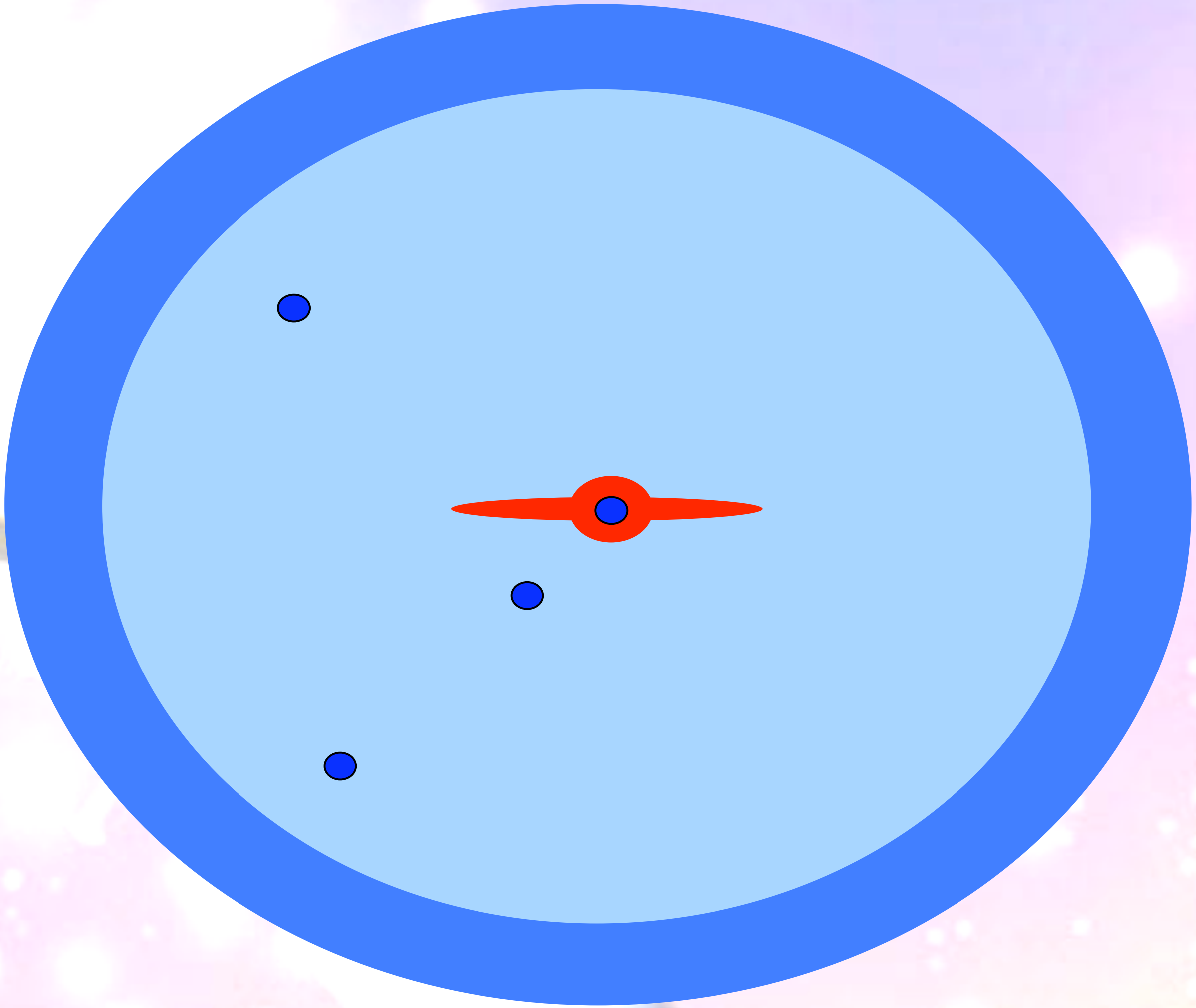


electron + positron expected anisotropy in the directions of Monogem and Geminga



Where should we look for Dark Matter with FERMI ?

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



Search Strategies

Satellites:

Low background and good source id, but low statistics

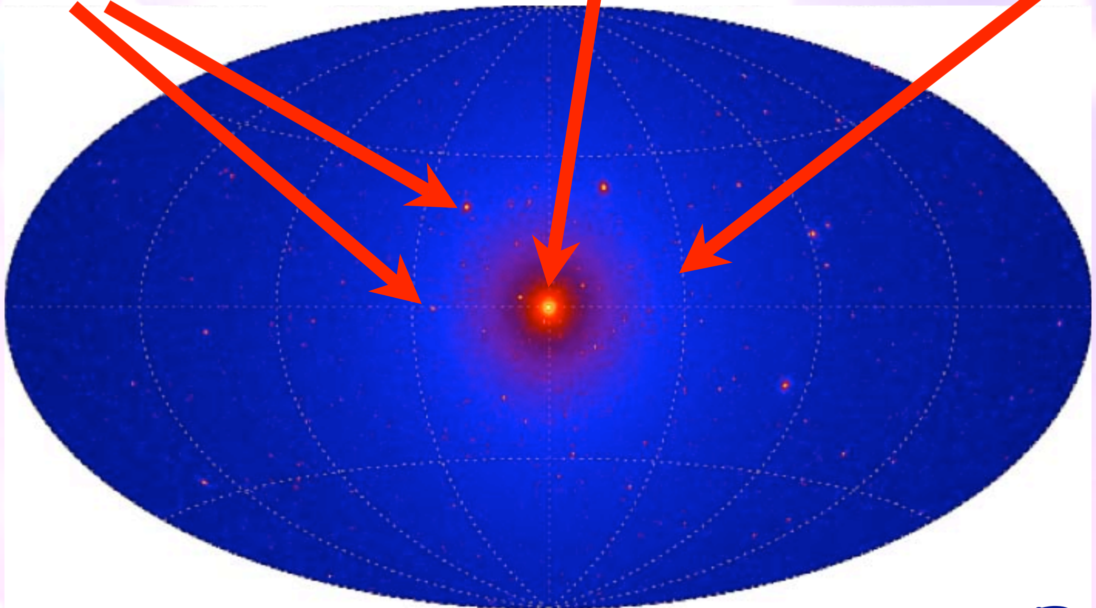
Galactic center:

Good statistics but source confusion/diffuse background

Milky Way halo:

Large statistics but diffuse background

All-sky map of gamma rays from DM annihilation arXiv:0908.0195 (based on Via Lactea II simulation)



And electrons! and Anisotropies

Spectral lines

No astrophysical uncertainties, good source id, but low statistics

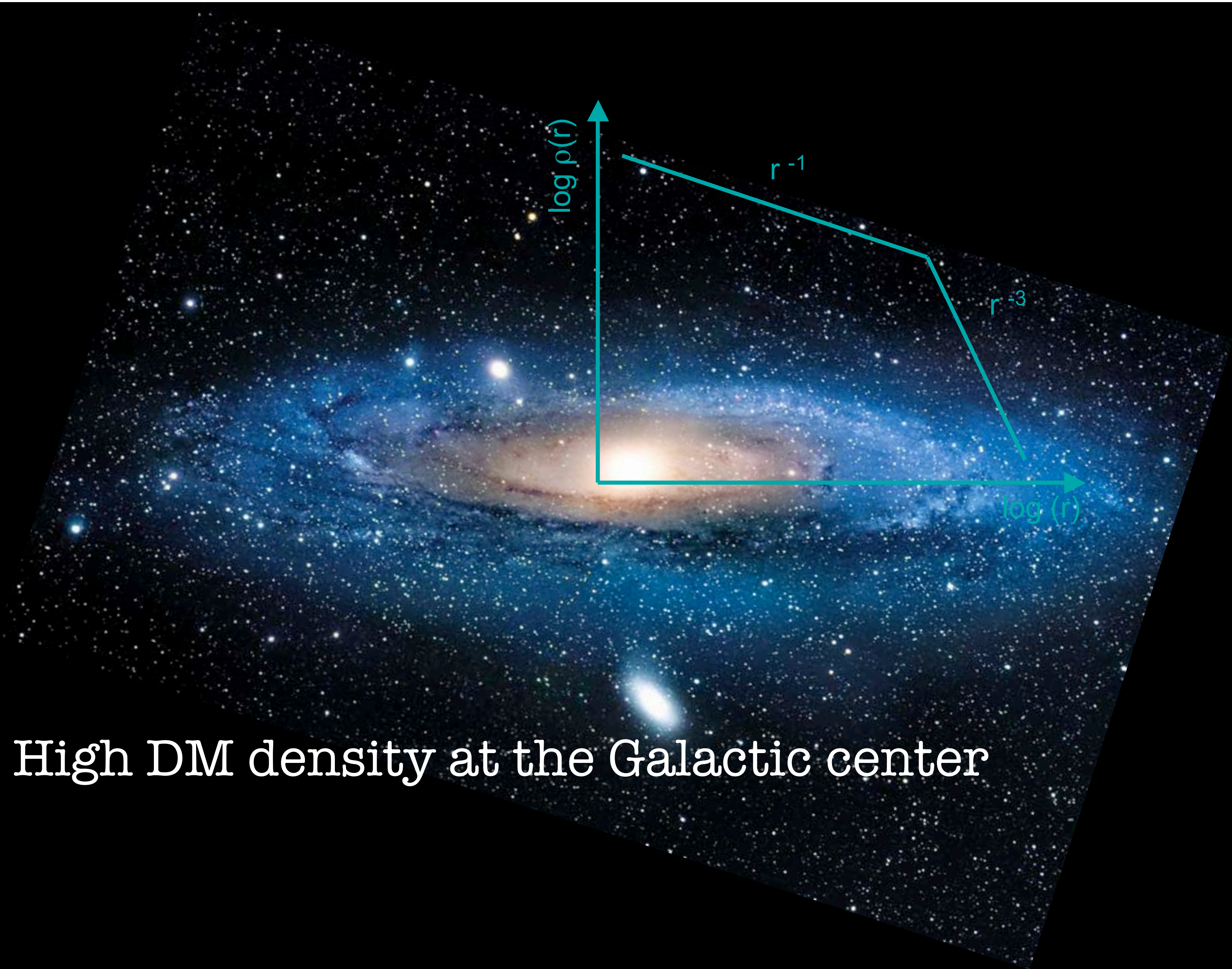
Galaxy clusters:

Low background but low statistics

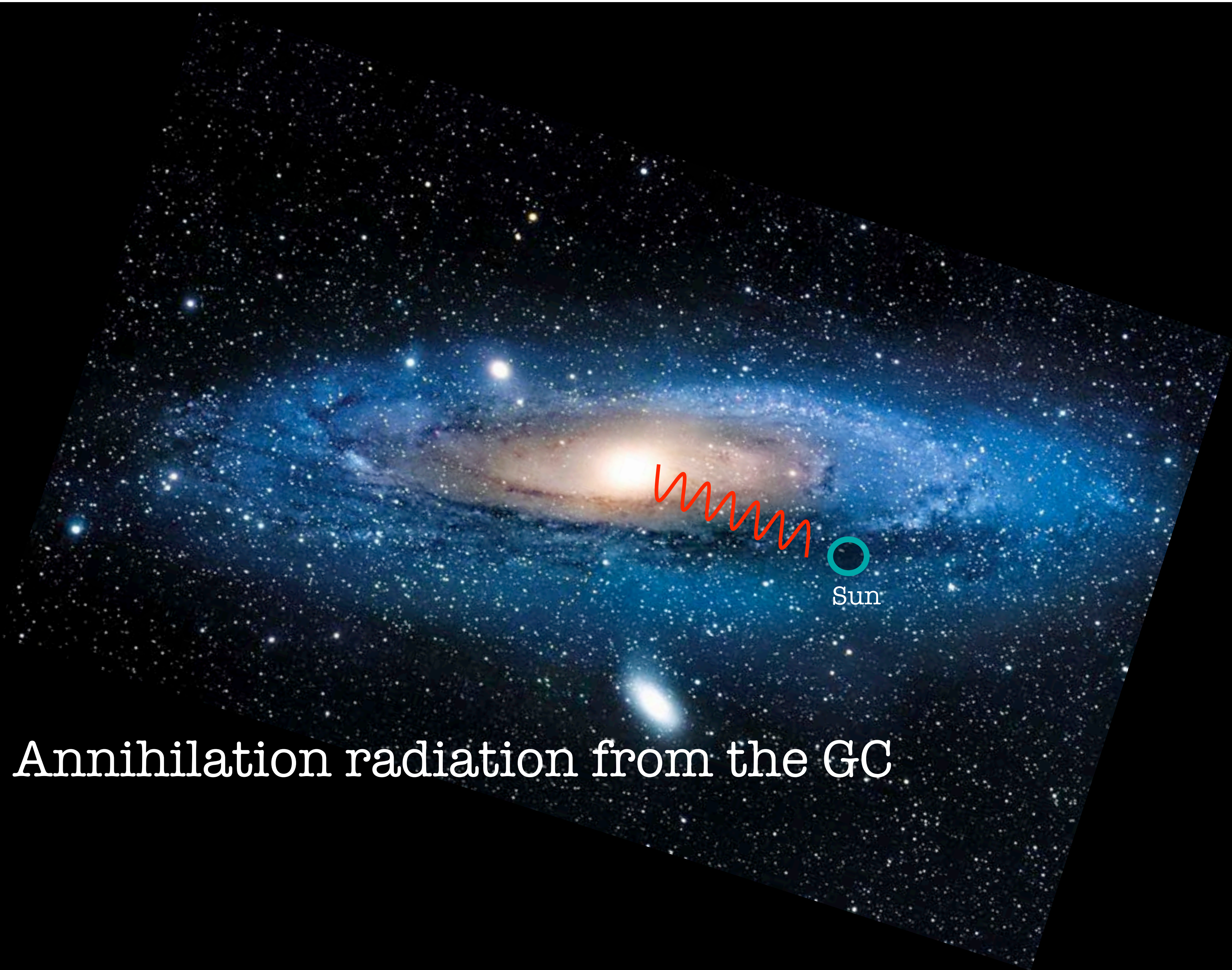
Extra-galactic:

Large statistics, but astrophysics,galactic diffuse background

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



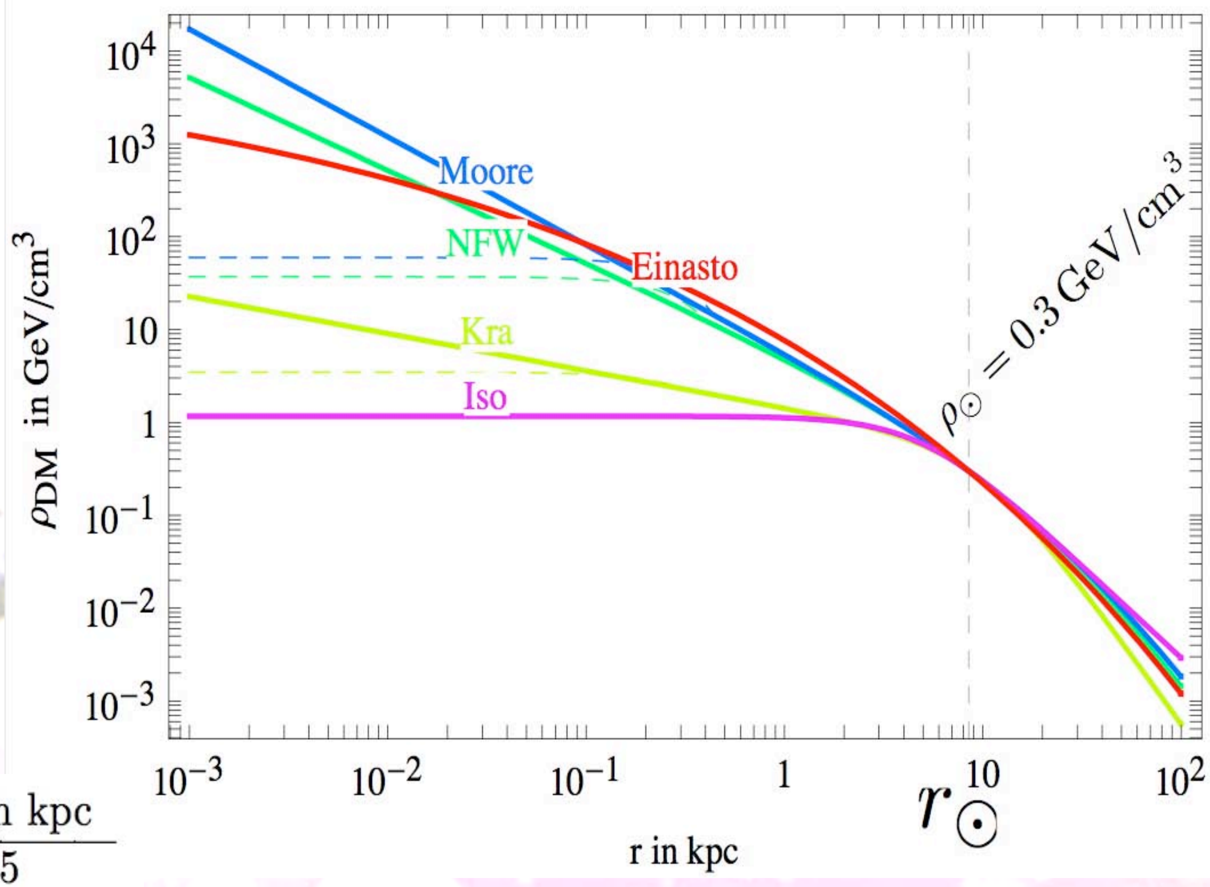
High DM density at the Galactic center



Annihilation radiation from the GC

The Galactic Center possible profiles

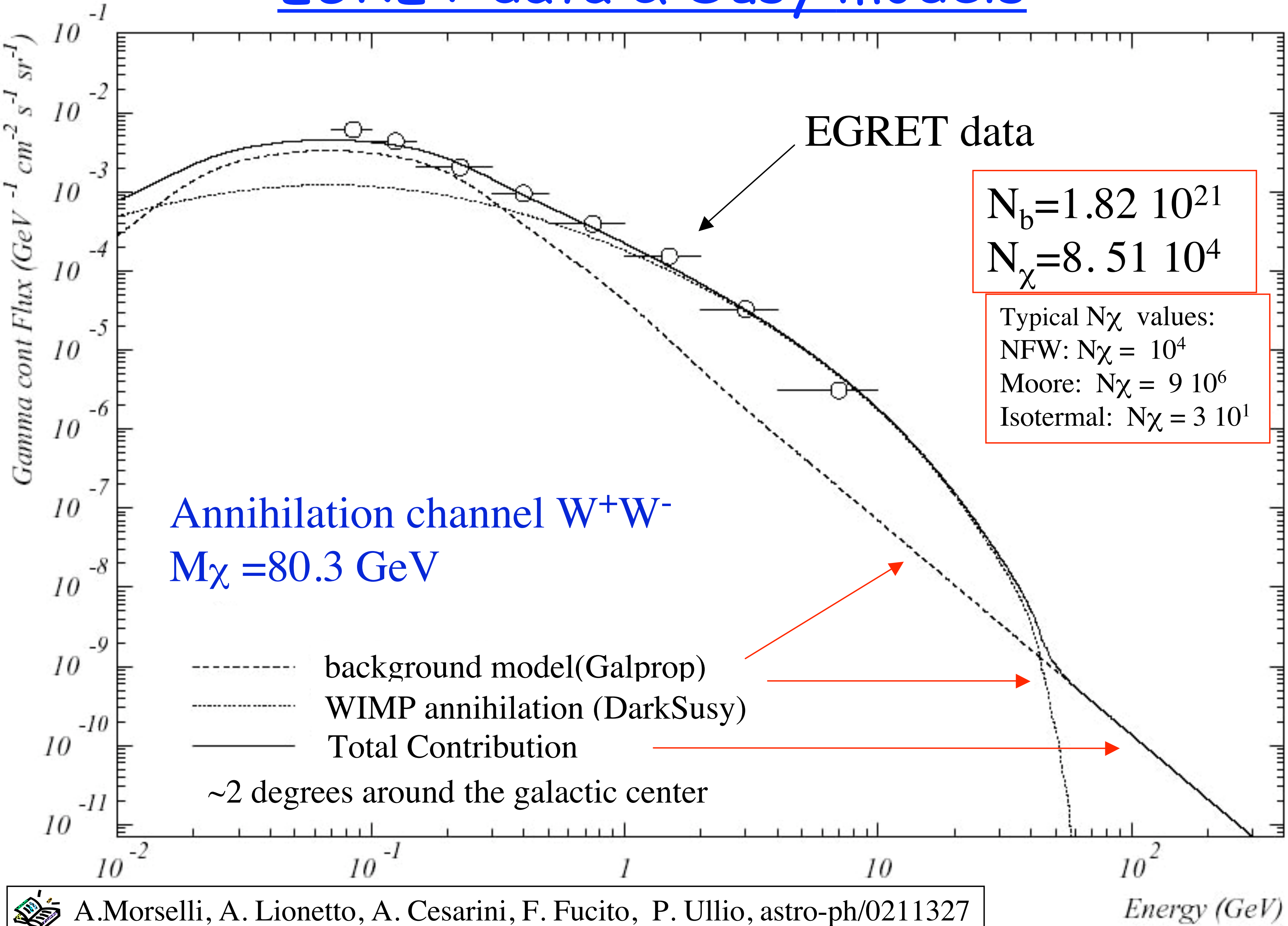
$$\rho(r) = \rho_\odot \left[\frac{r_\odot}{r}\right]^\gamma \left[\frac{1+(r_\odot/r_s)^\alpha}{1+(r/r_s)^\alpha}\right]^{(\beta-\gamma)/\alpha}$$



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

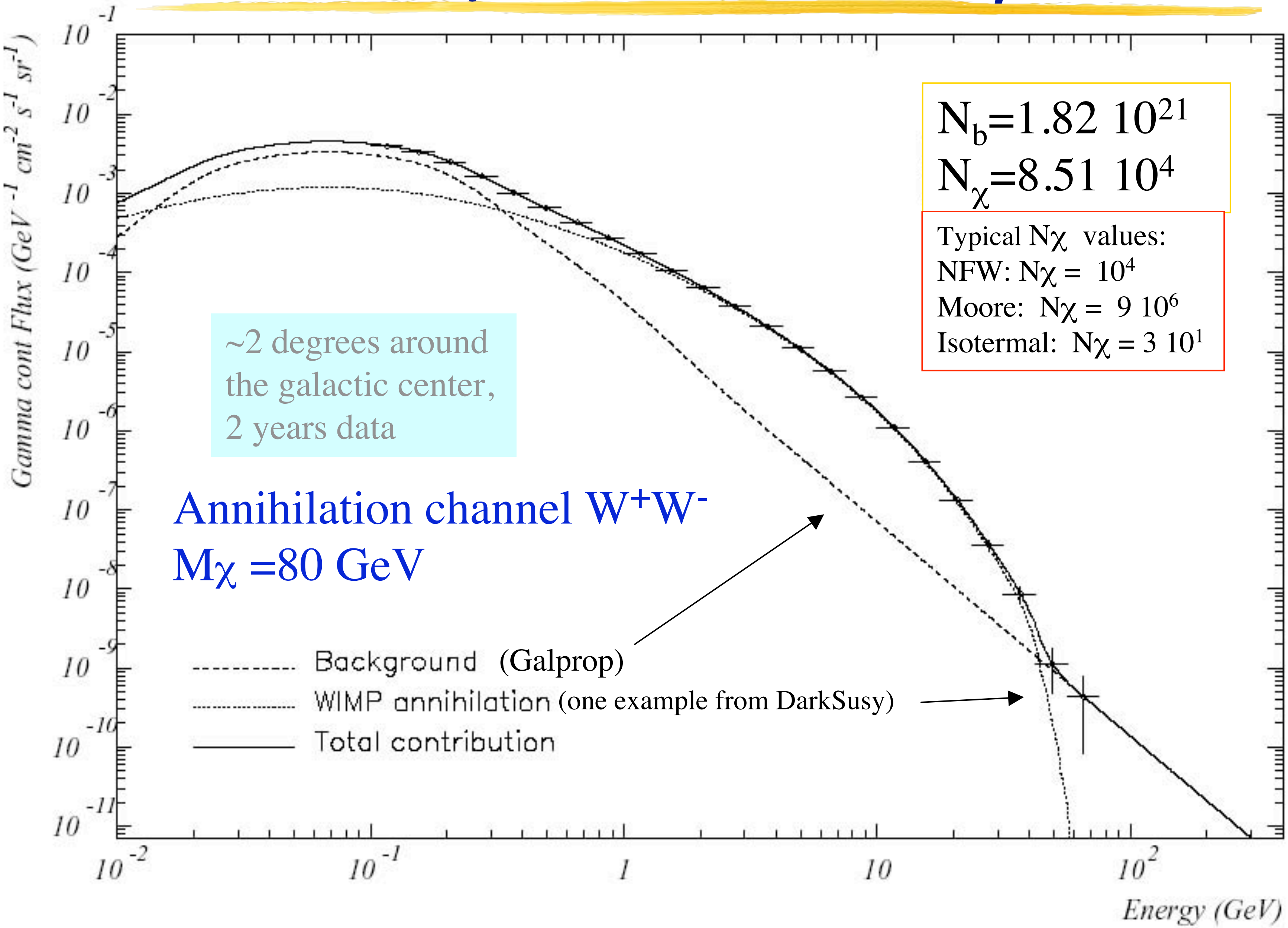
Einasto | $\alpha = 0.17$ $r_s = 20\,\text{kpc}$ $\rho_s = 0.06\,\text{GeV/cm}^3$

EGRET data & Susy models



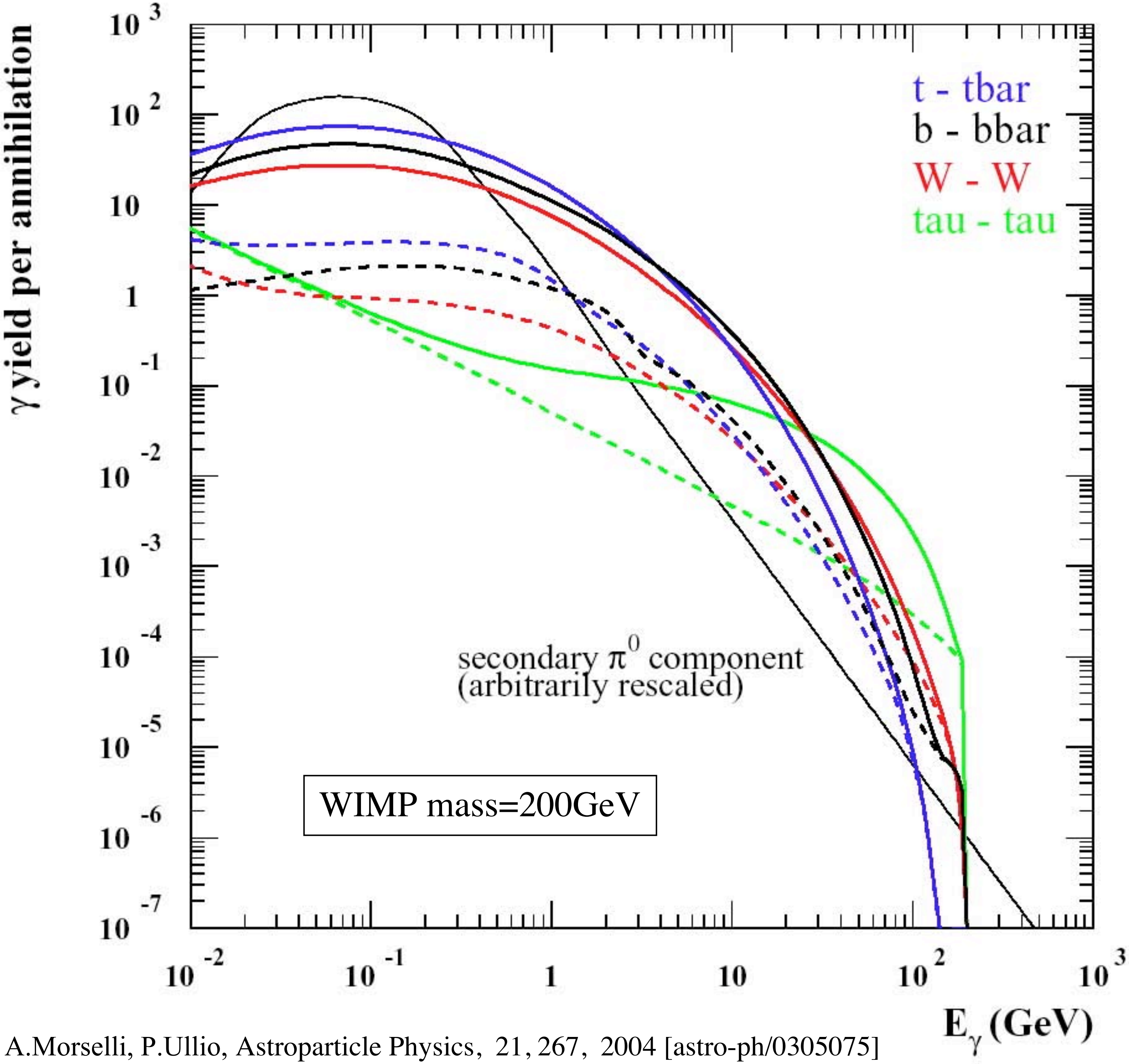
A.Morselli, A. Lionetto, A. Cesarini, F. Fucito, P. Ullio, astro-ph/0211327

Fermi Expectation & Susy models



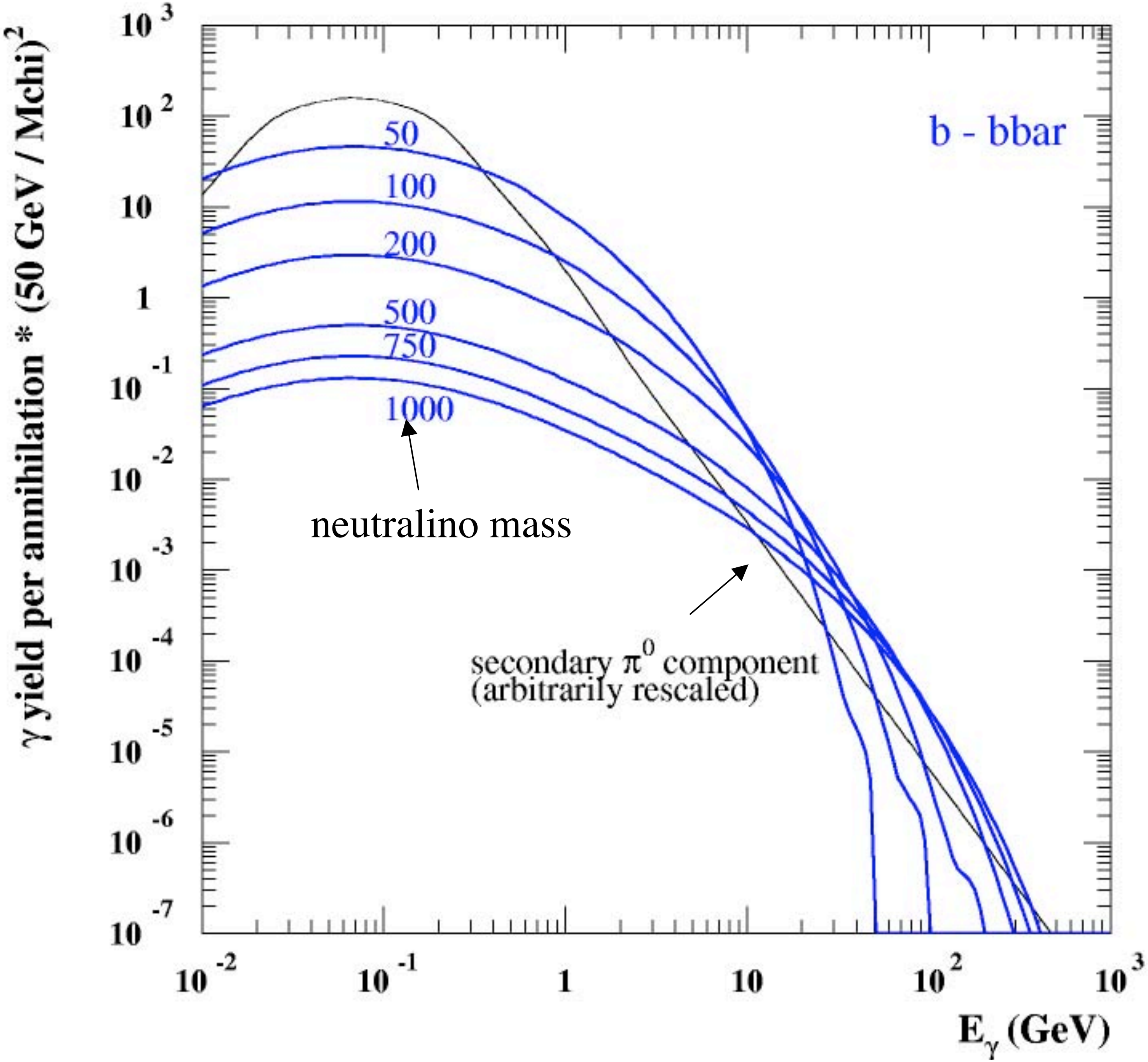
A.Cesarini, F.Fucito, A.Lionetto, A.Morselli, P.Ullio, Astroparticle Physics, 21, 267-285, June 2004 [astro-ph/0305075]

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

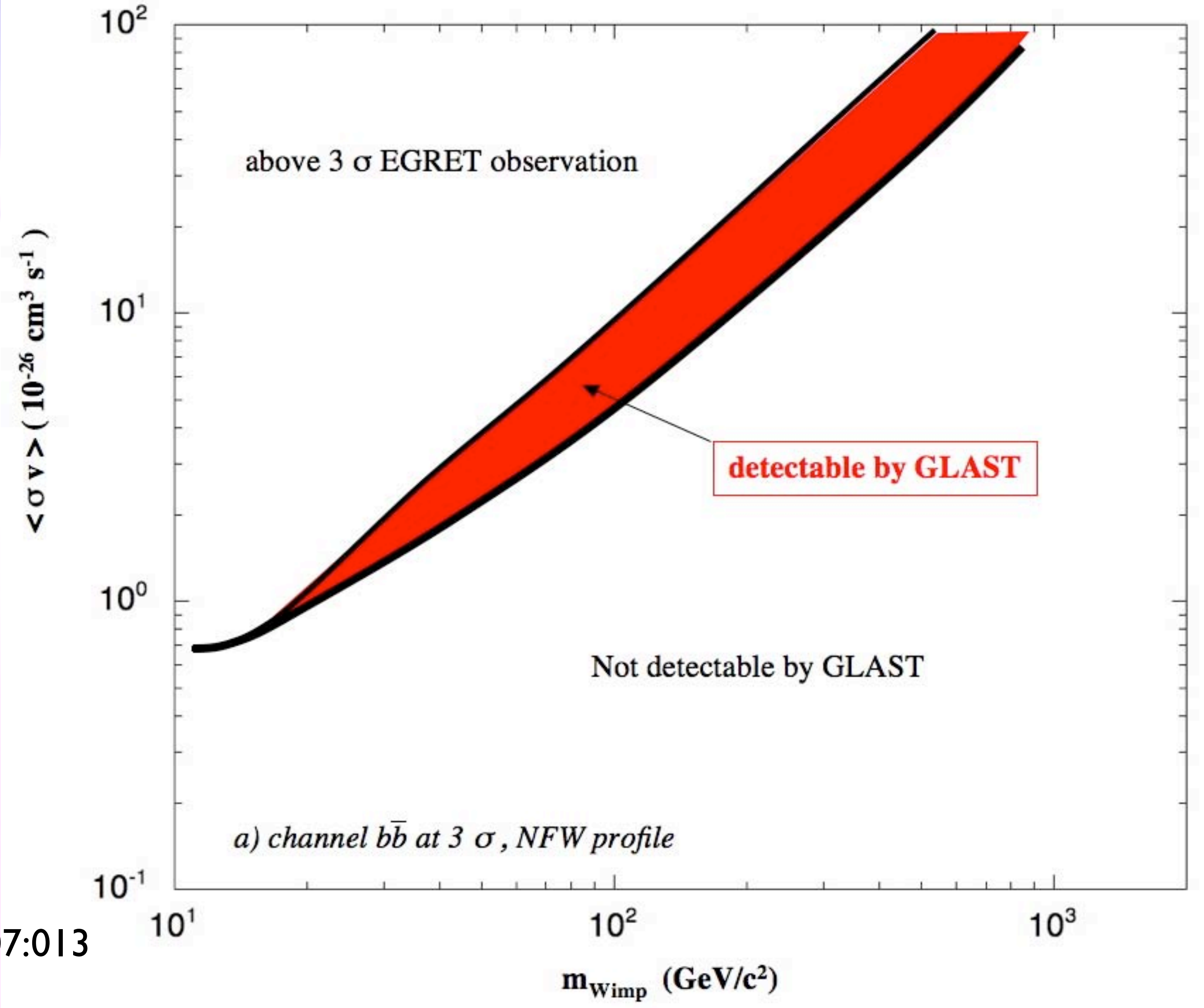


A.Cesarini, F.Fucito, A.Lionetto, A.Morselli, P.Ullio, Astroparticle Physics, 21, 267-285, 2004 [astro-ph/0305075]

Model independent results for the GC

after the Fermi Galactic Diffuse Emission data

5 years of operations, truncated NFW

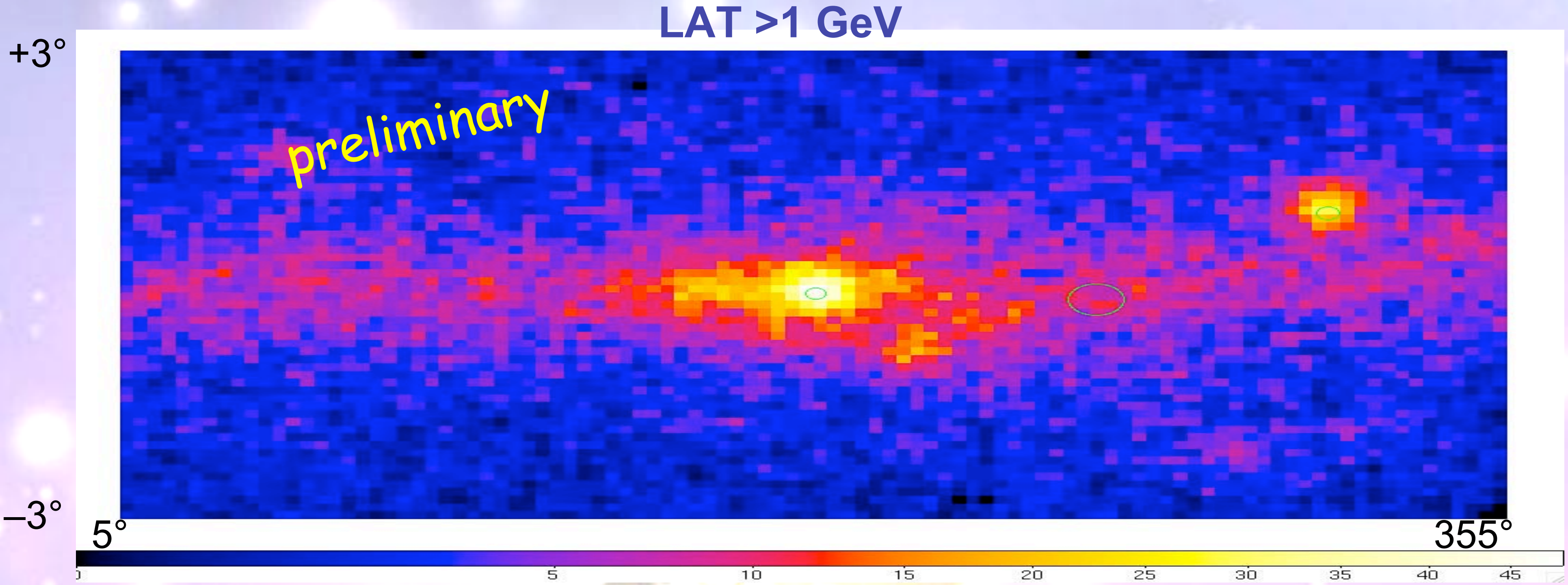


Pre-launch sensitivities
Baltz et al., 2008, JCAP 0807:013
[astro-ph/0806.2911]

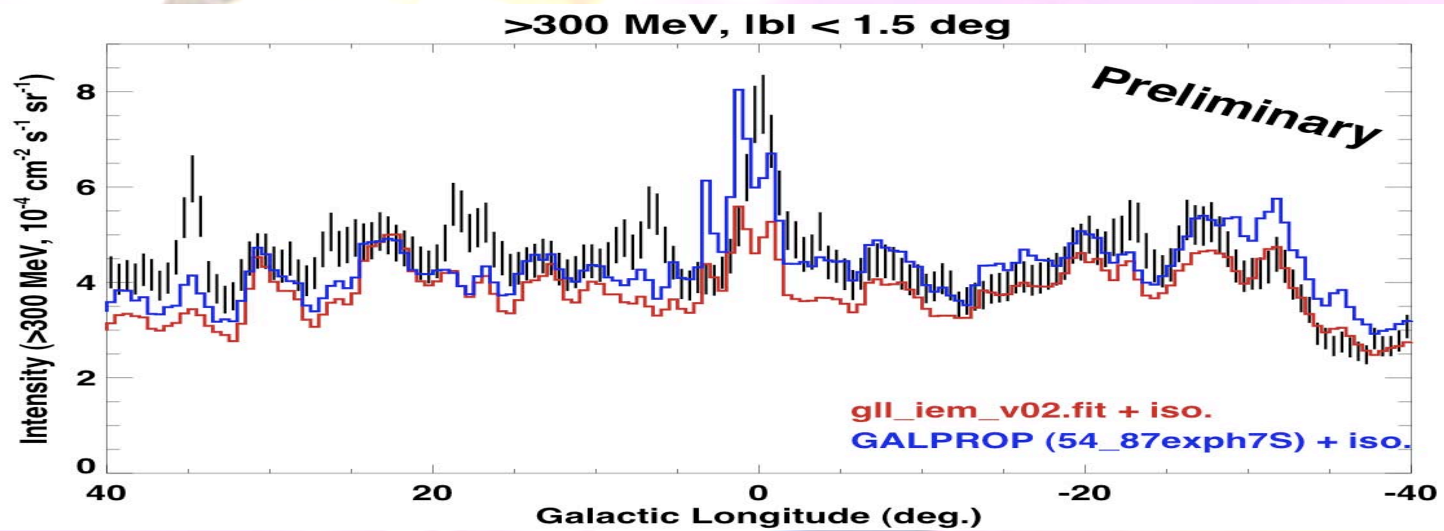
Search for DM in the GC

- 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 in the integration over the line of sight in the direction of the GC, very difficult to model

Fermi LAT Observations of the GC

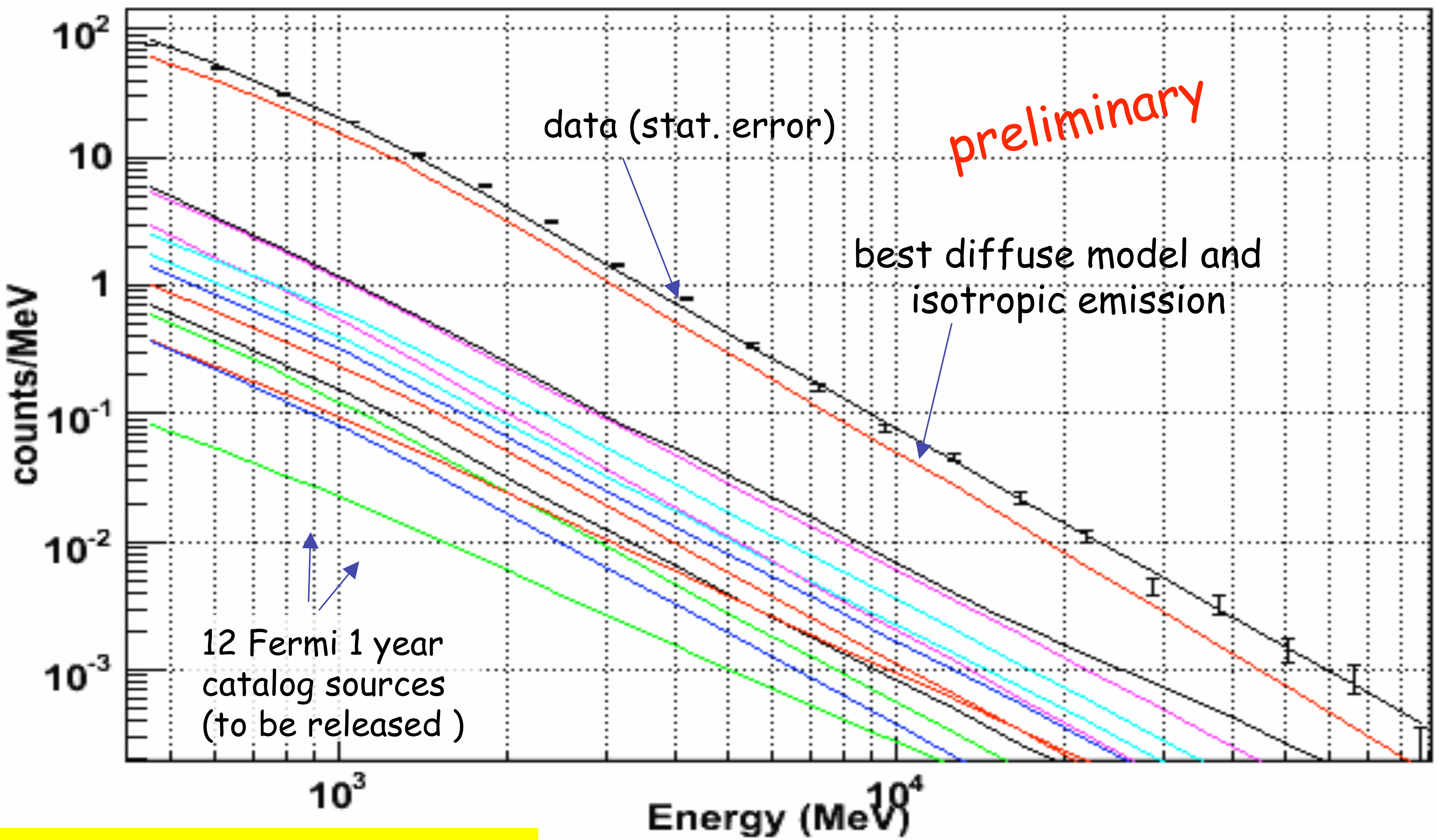


12-month data set, Diffuse class,
Front only
smoothed with σ = 0.1°
BSL source location circles overlaid



S.Digel, Fermi Symp.

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

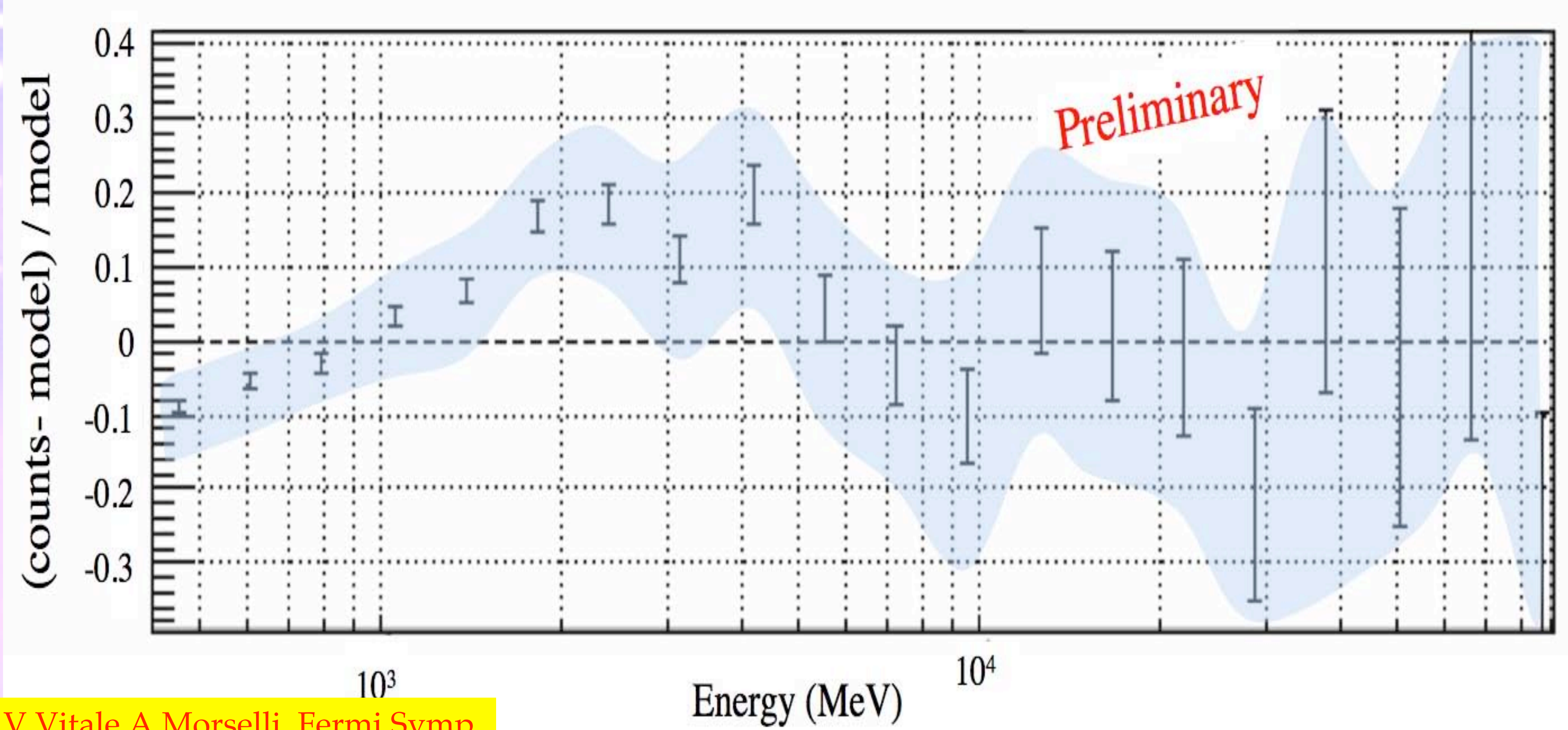


V.Vitale A.Morselli Fermi Symp.

GC Residuals

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

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



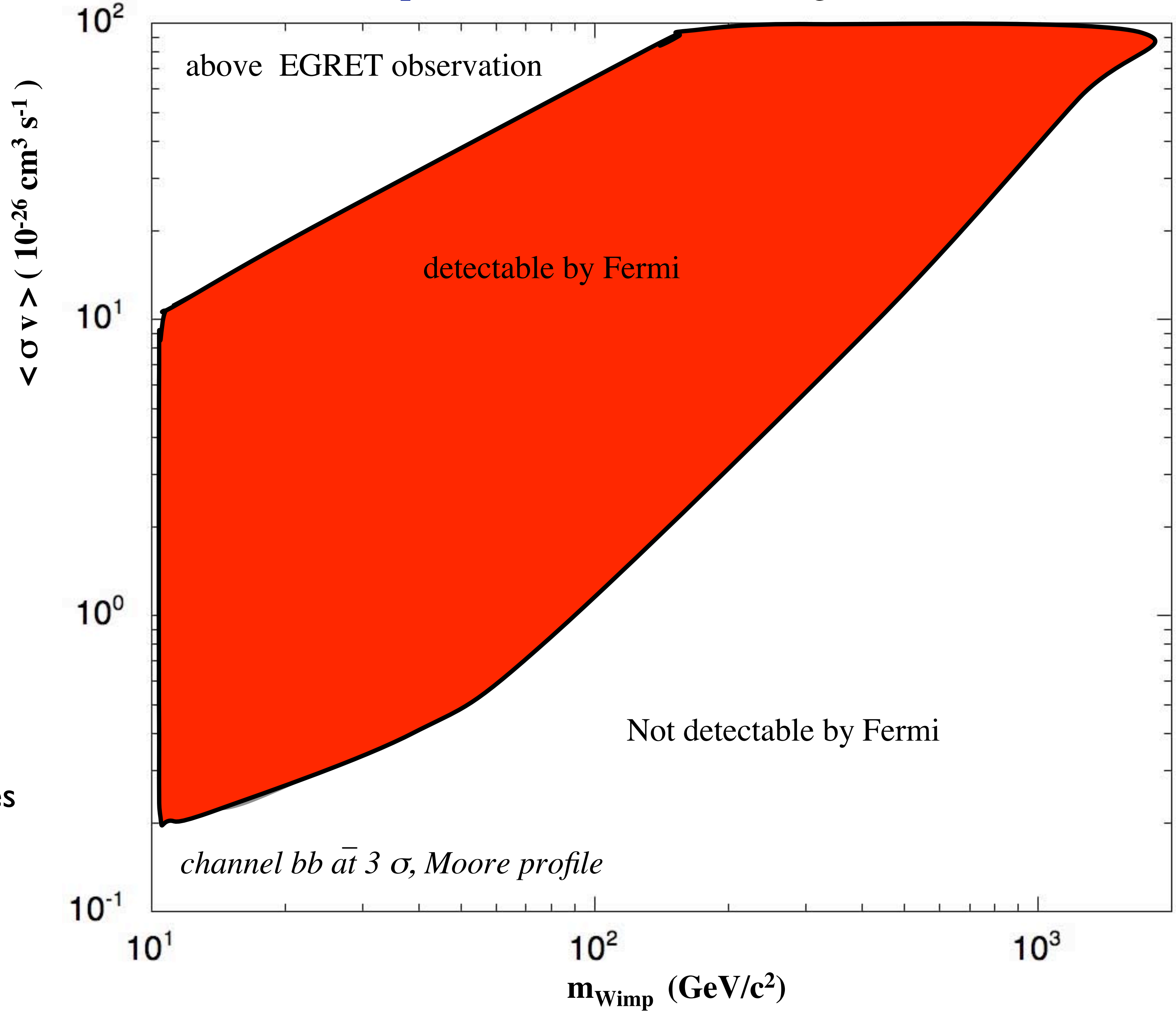
V.Vitale A.Morselli Fermi Symp.

Search for DM in the GC

- 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
- 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

after the Fermi Galactic Diffuse Emission data

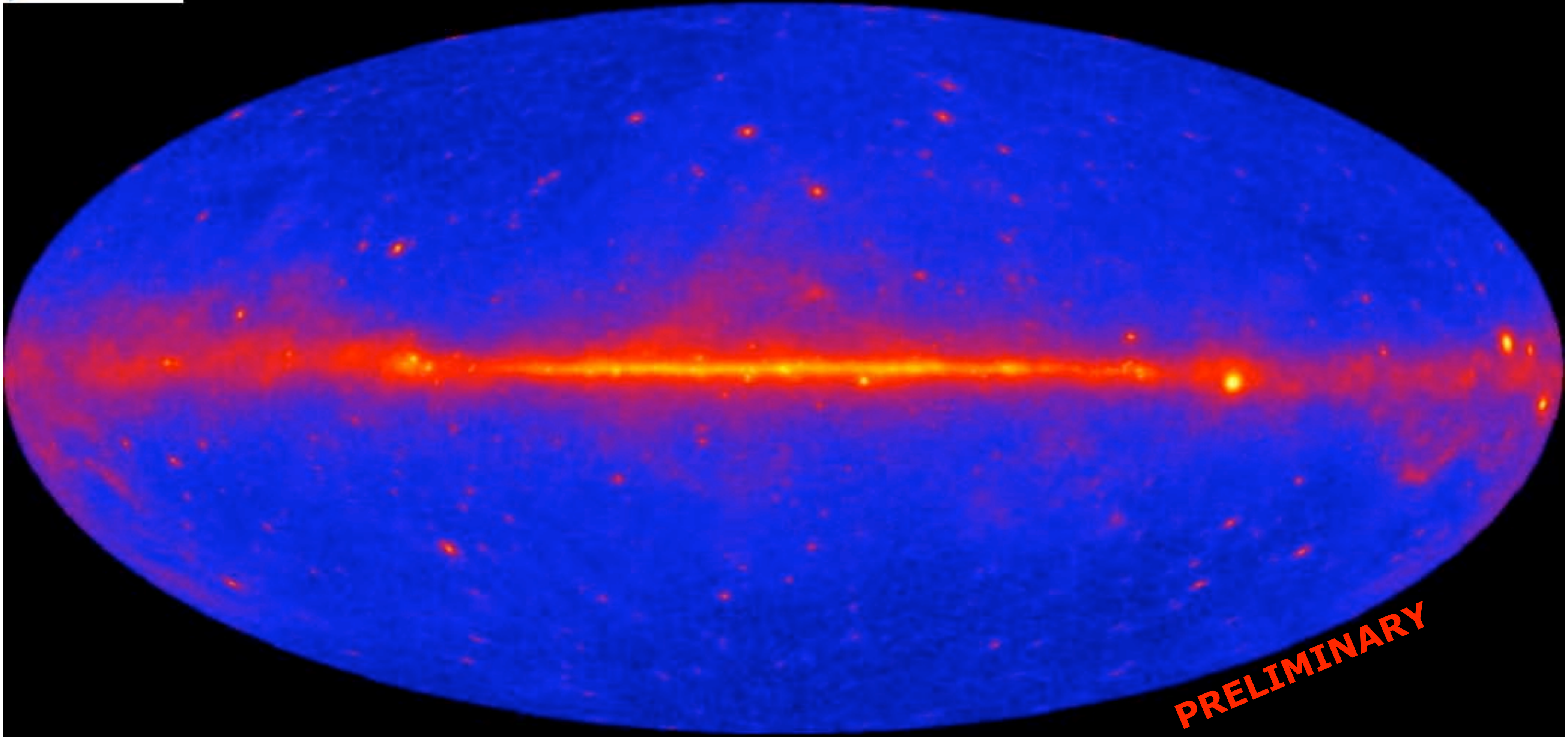
Model independent results for the Sagittarius Dwarft



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

First Fermi LAT Catalog (11 month, release: end of November)

> 1000 LAT sources



- Front > 200 MeV, Back > 400 MeV, log color scale
- Galactic coordinates, Aitoff projection

First Fermi LAT Catalog (11 month, release: end of November)

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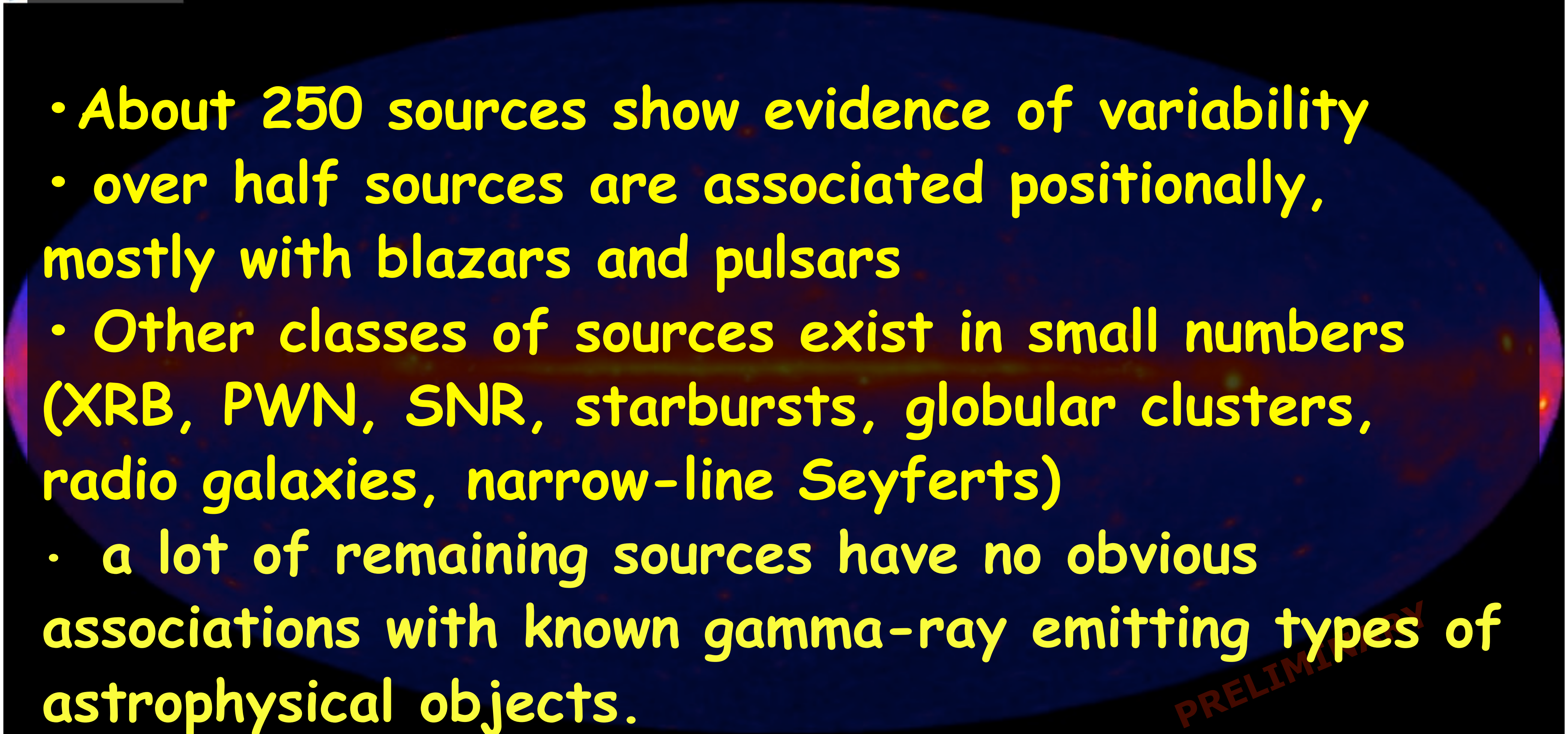
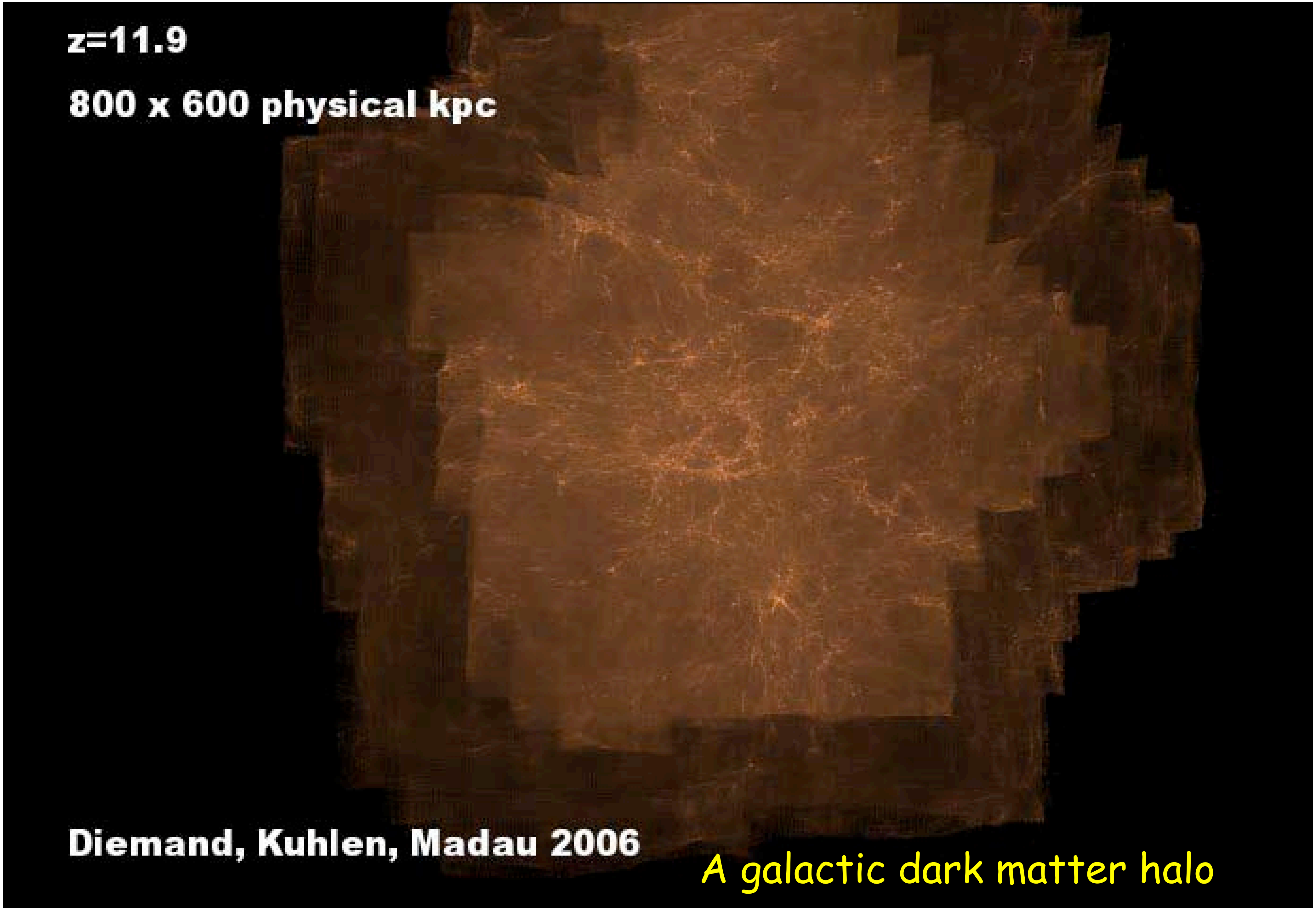
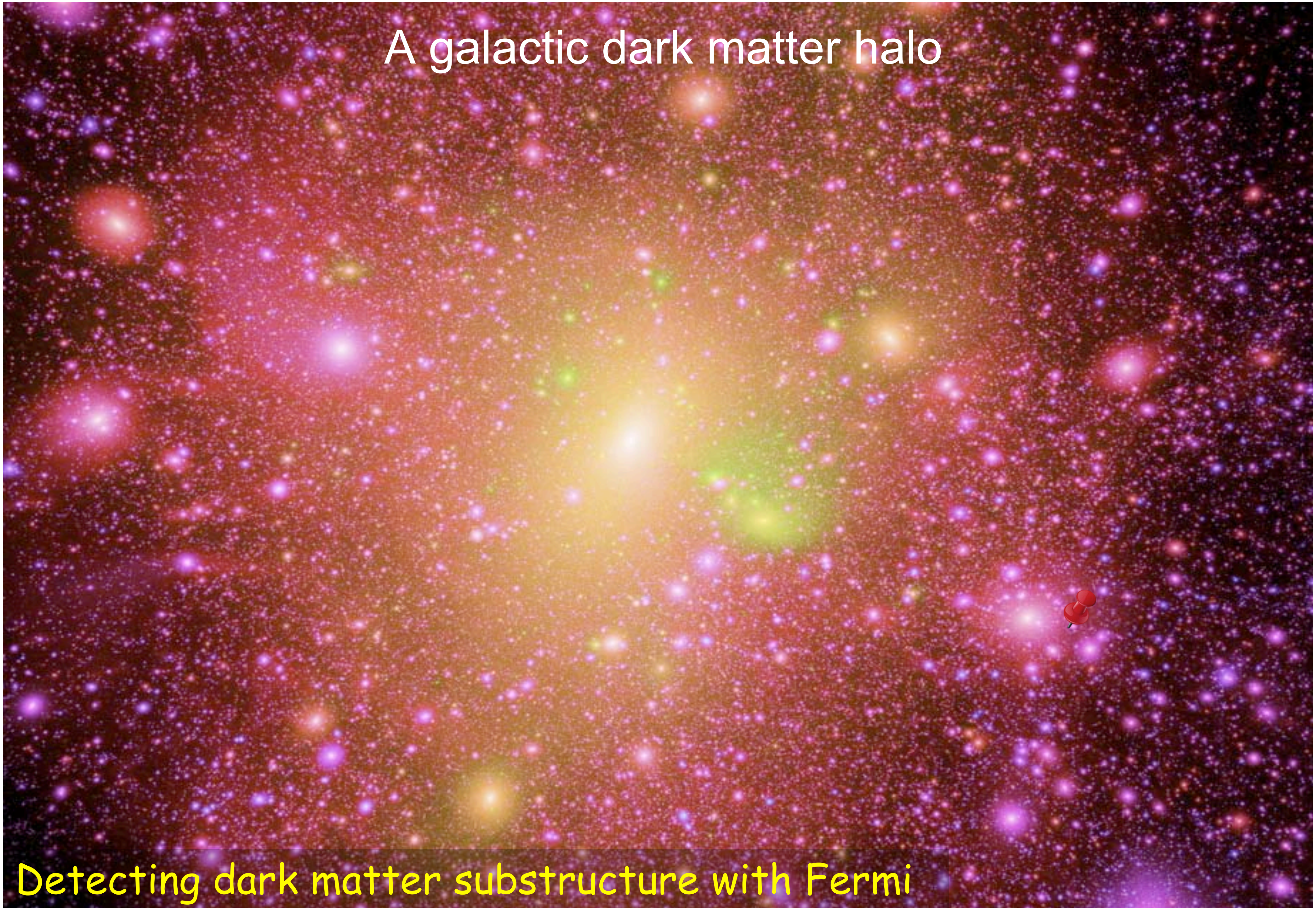


- About 250 sources show evidence of variability
- over half sources are associated positionally, mostly with blazars and pulsars
- Other classes of sources exist in small numbers (XRB, PWN, SNR, starbursts, globular clusters, radio galaxies, narrow-line Seyferts)
- a lot of remaining sources have no obvious associations with known gamma-ray emitting types of astrophysical objects.

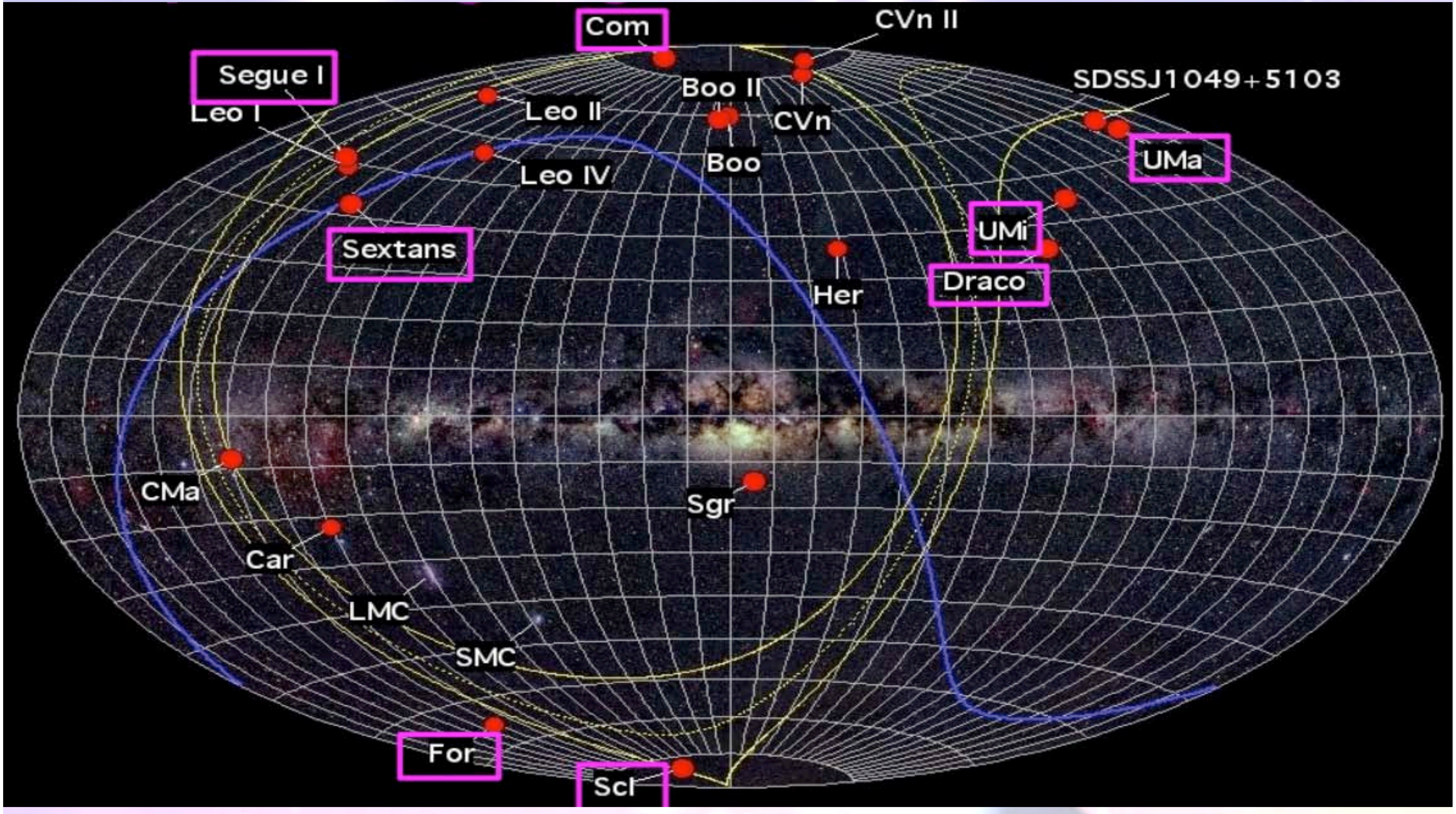
- Front > 200 MeV, Back > 400 MeV, log color scale
- Galactic coordinates, Aitoff projection



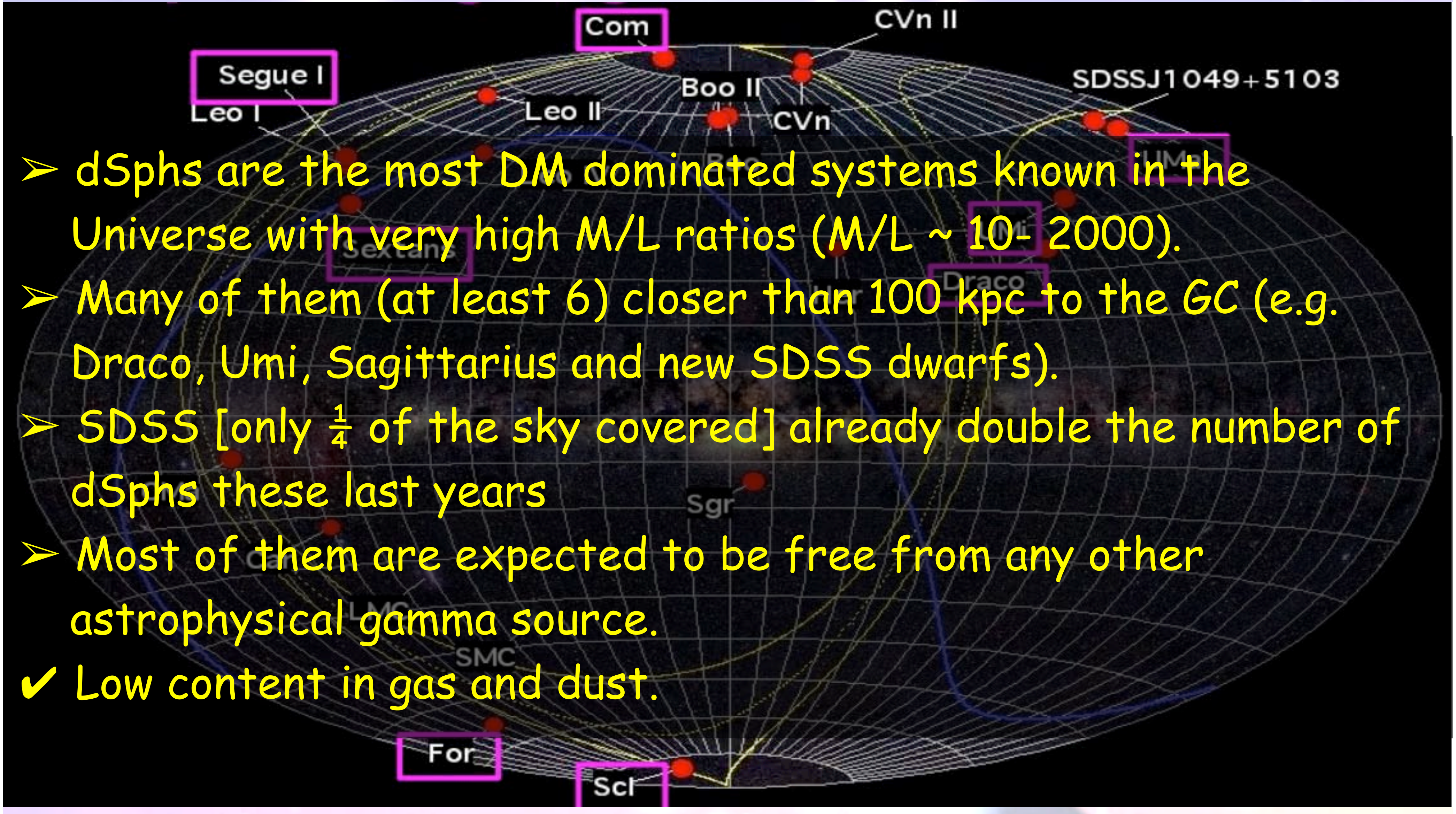
A galactic dark matter halo


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

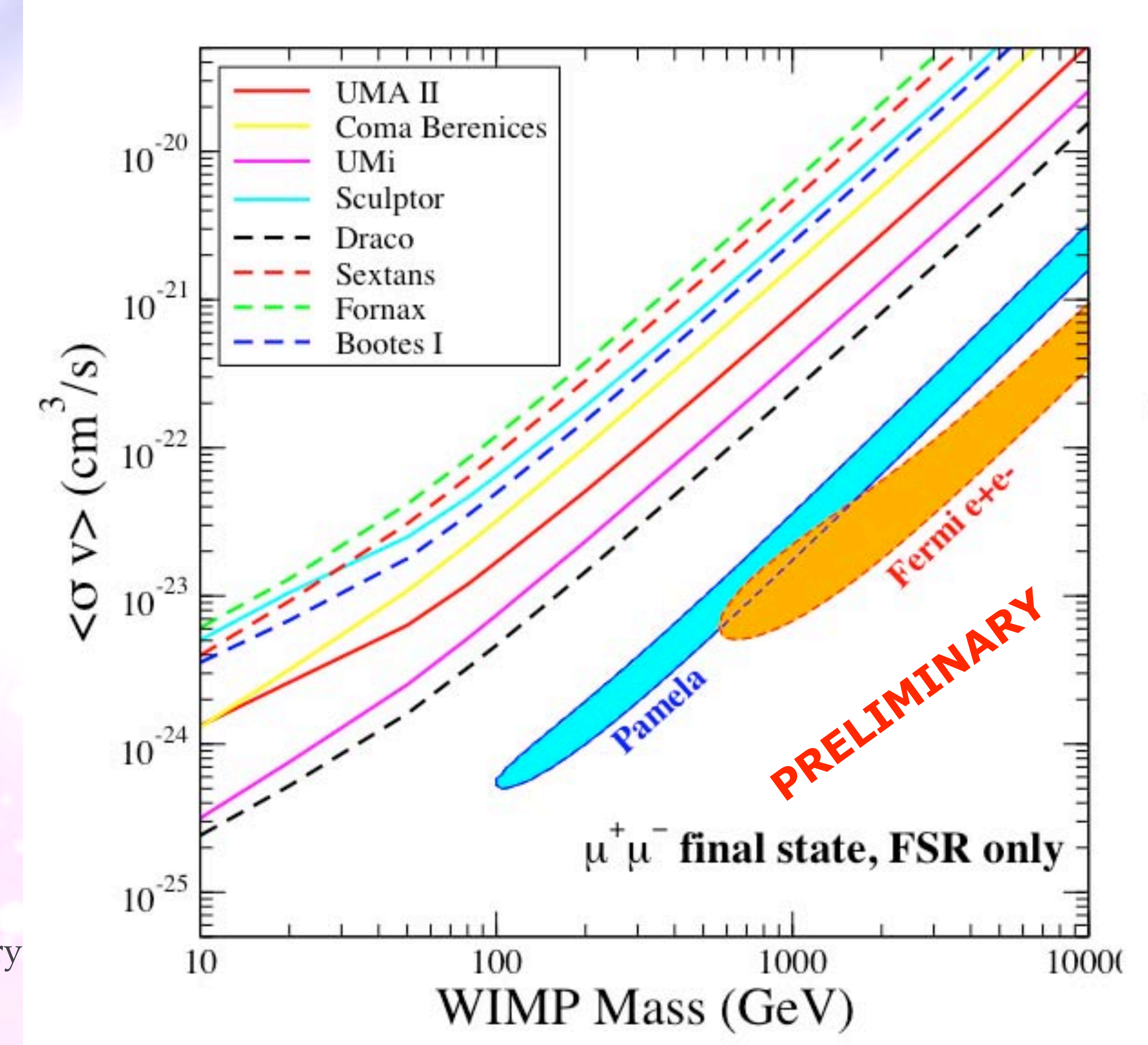


- ➢ dSphs are the most DM dominated systems known in the Universe with very high M/L ratios (M/L ~ 10- 2000).
- ➢ Many of them (at least 6) closer than 100 kpc to the GC (e.g. Draco, Umi, Sagittarius and new SDSS dwarfs).
- ➢ SDSS [only $\frac{1}{4}$ of the sky covered] already double the number of dSphs 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

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 $<\sigma v>$ vs WIMP mass for specific DM models



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

C. Farnier Fermi Symp.

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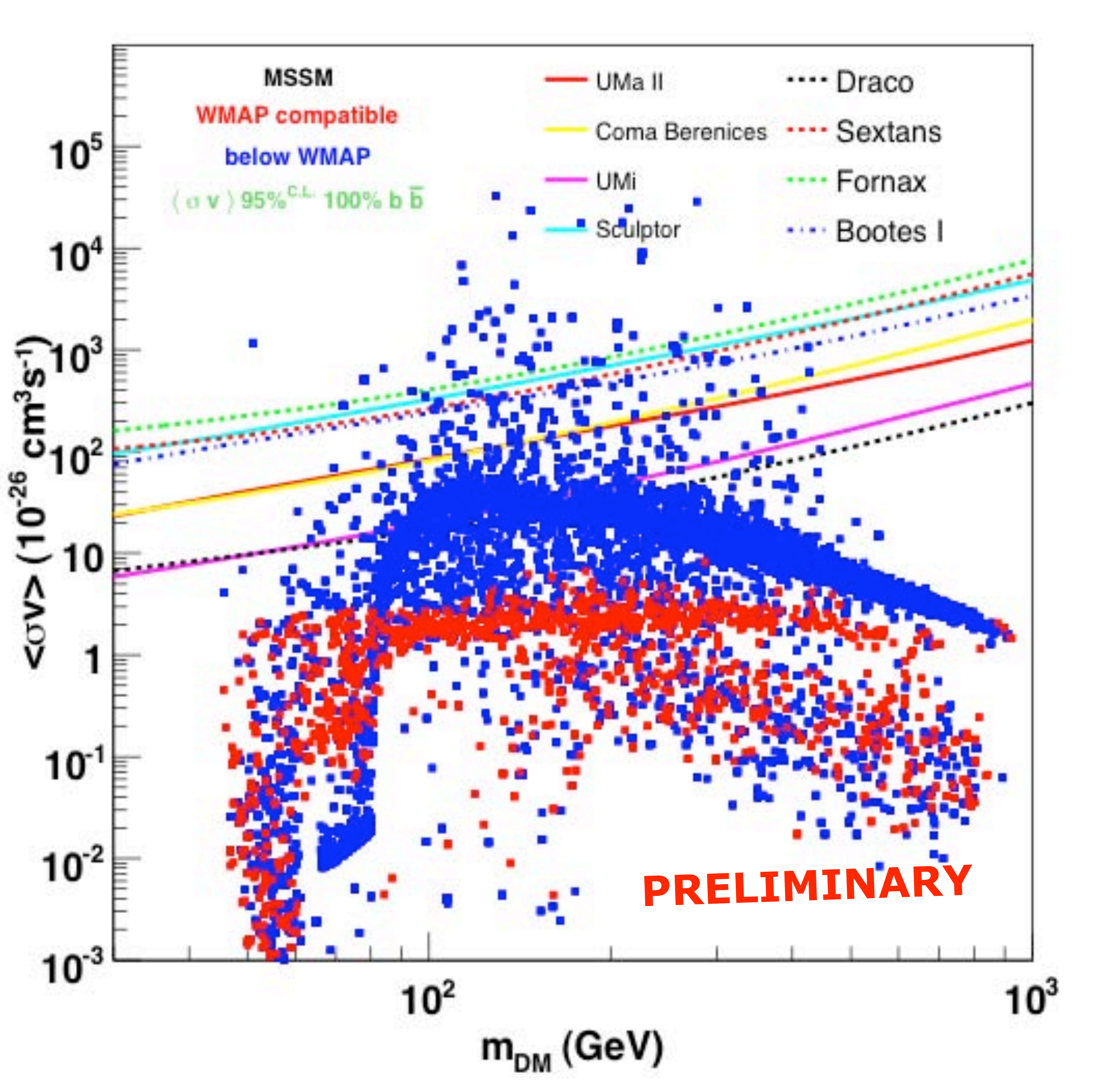


Inverse Compton Emission and Diffusion in Dwarfs

- 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 $D_0 = 10^{28}\ cm^2/s$

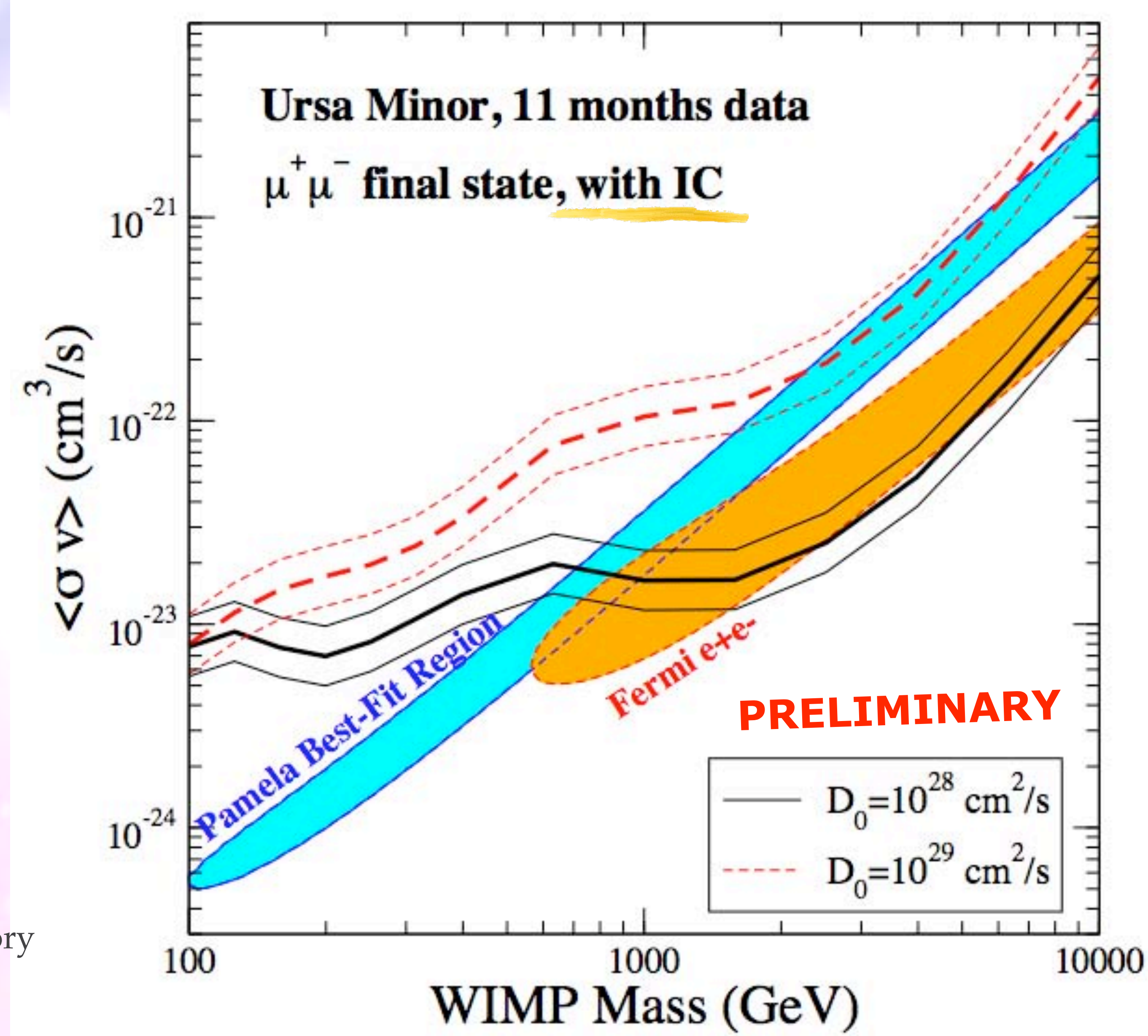
(only galaxy with measurements, scaling to dwarfs ??)

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)



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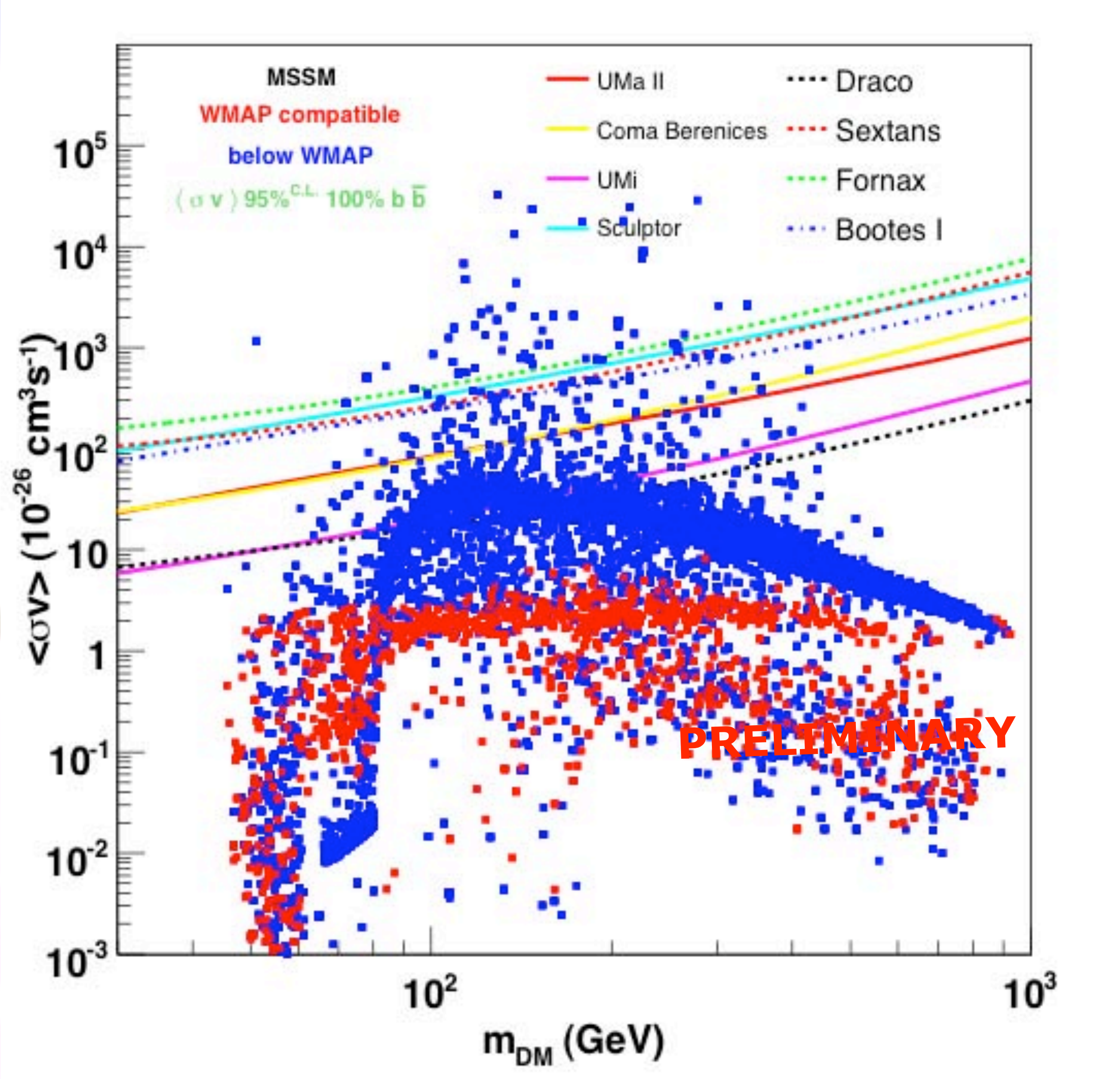
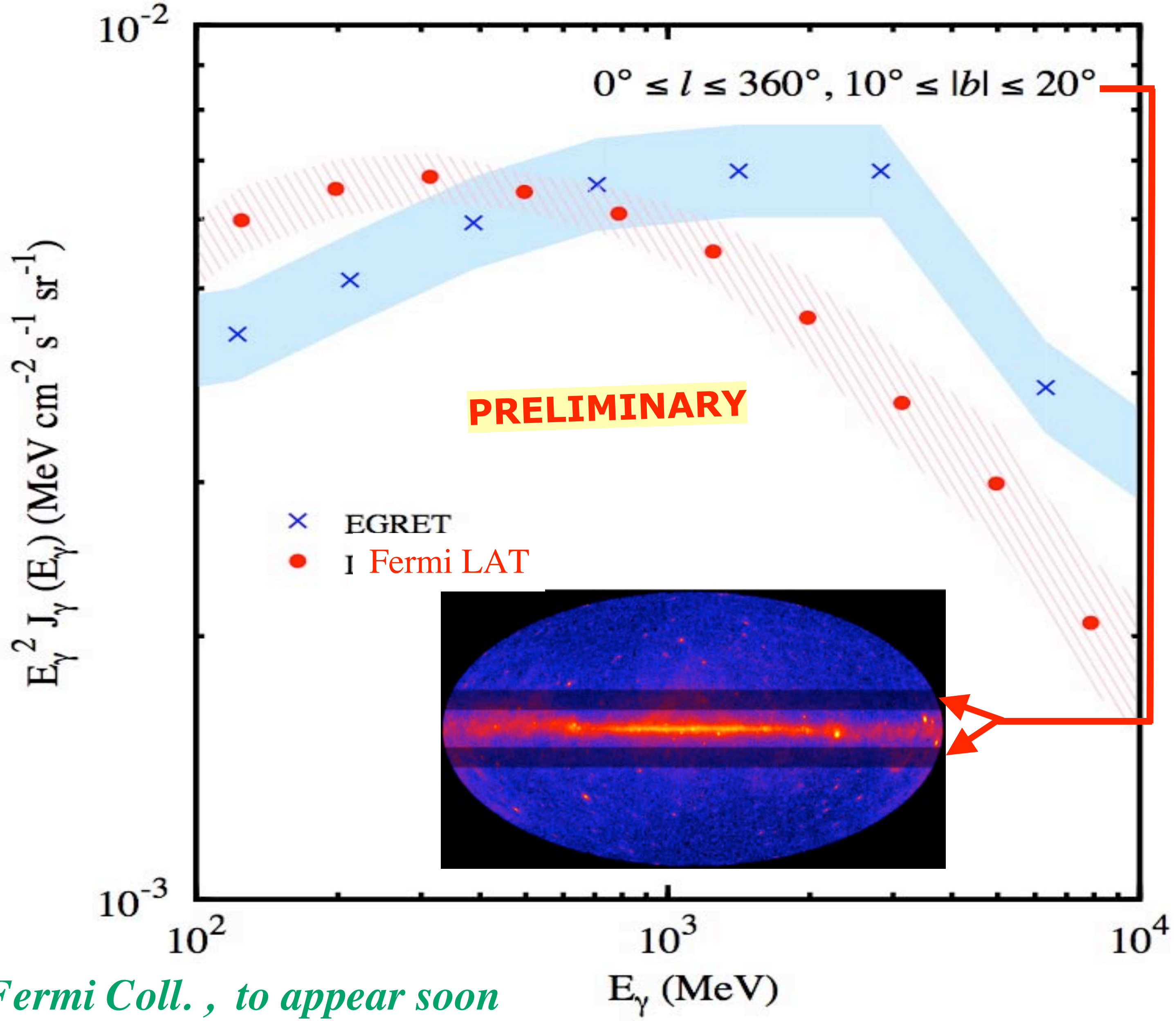


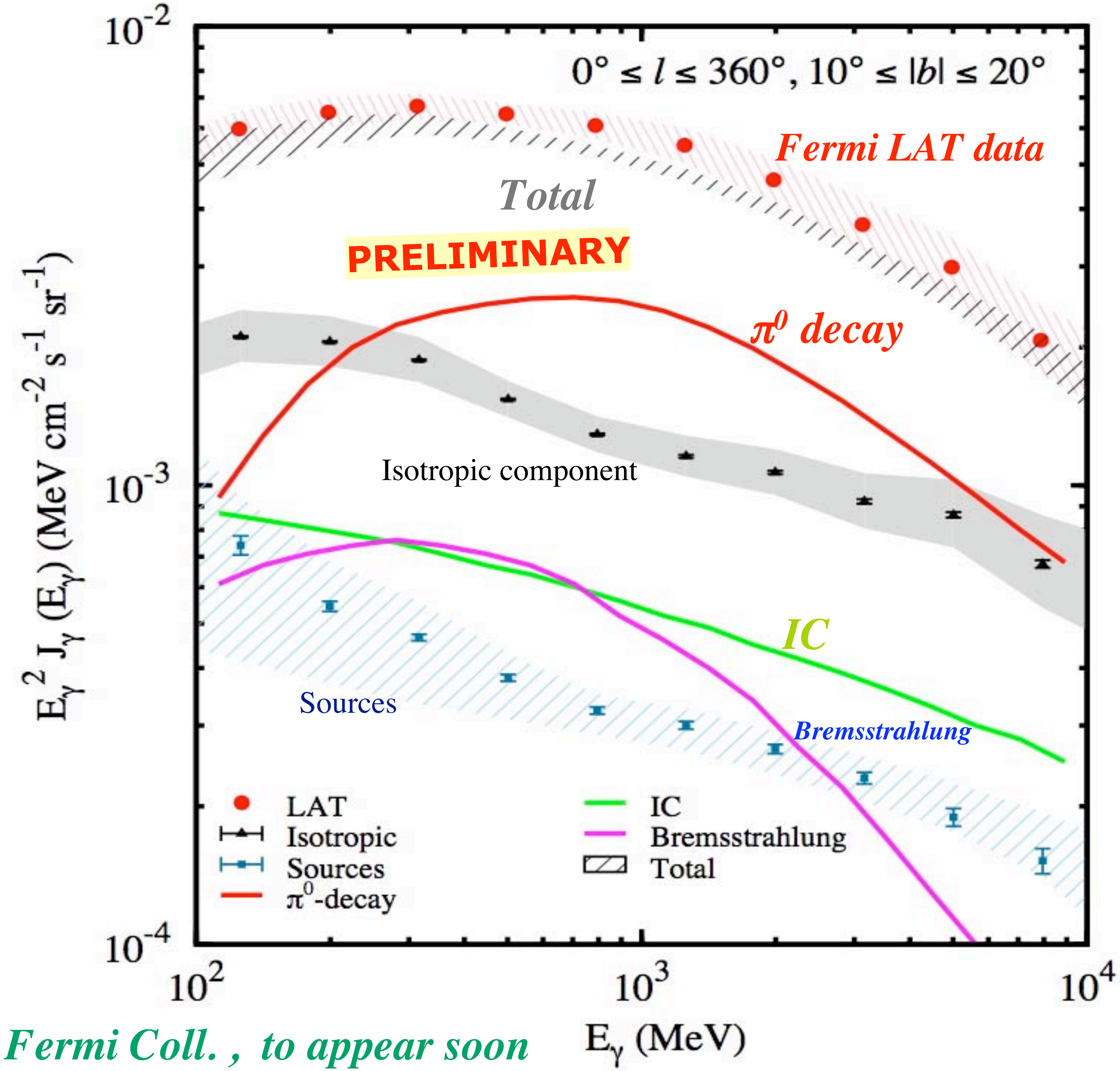
The Galactic Diffuse Emission



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



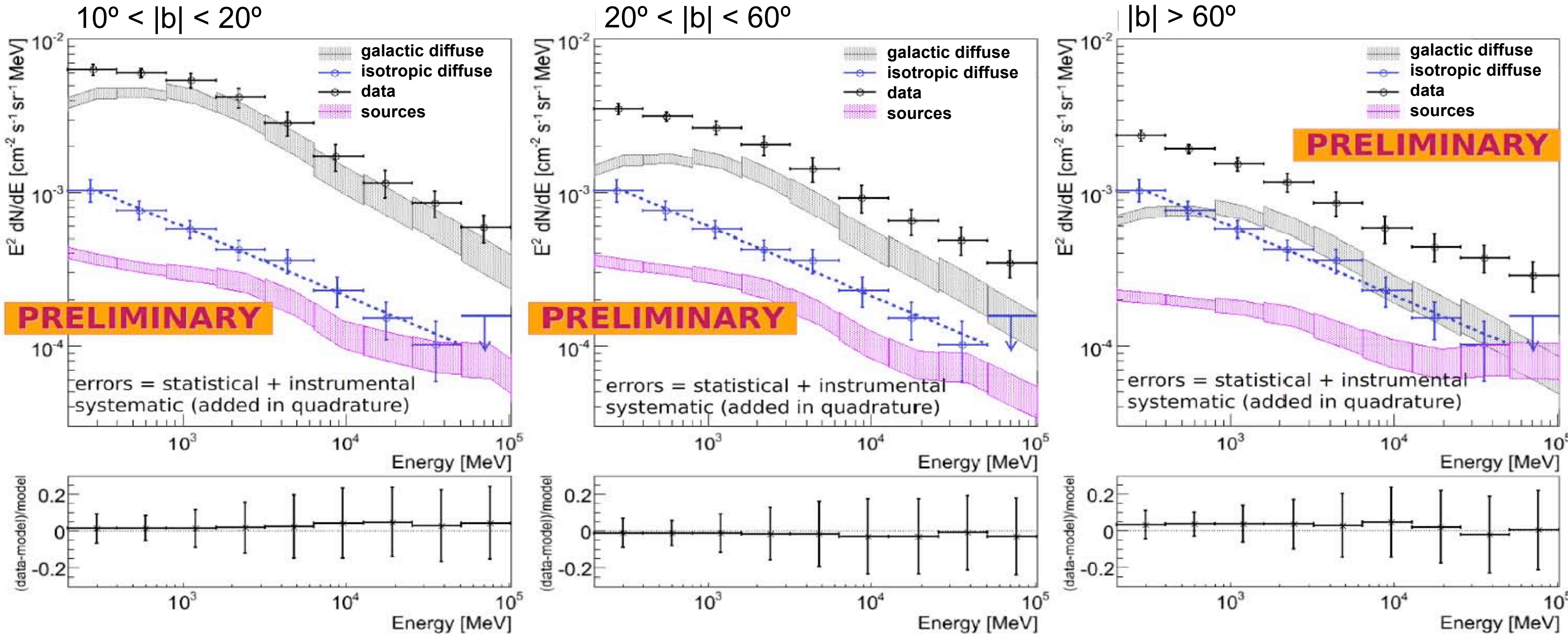
Fermi Coll. , to appear soon

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.

The LAT isotropic diffuse flux (200 MeV – 100 GeV)



Low galactic latitudes High galactic latitudes Galactic poles

Galactic diffuse flux (from fit)

LAT data

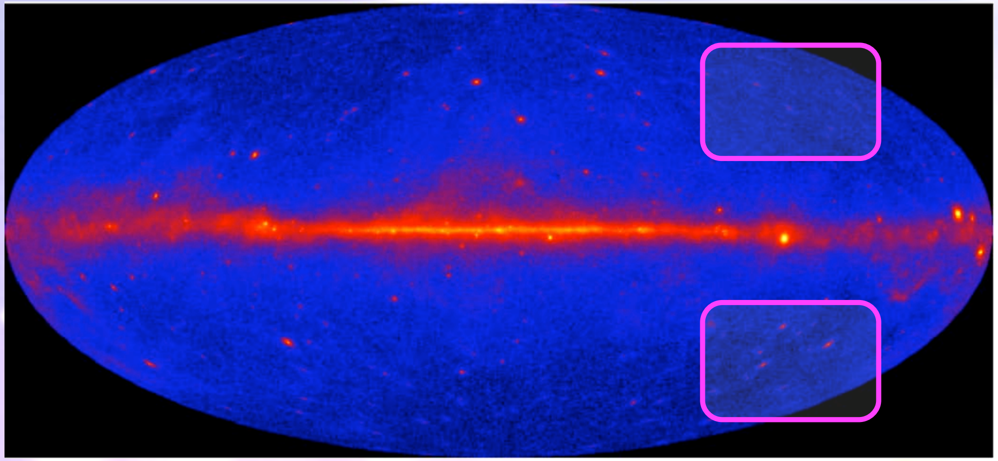
Total point source contribution (from fit)

Isotropic diffuse emission (isotropic component from fit, residual CR background subtracted)

Power law fit to isotropic diffuse emission with index $\gamma = 2.45$

error bars / bands:
statistical error + LAT effective area uncertainty + residual background contamination uncertainty

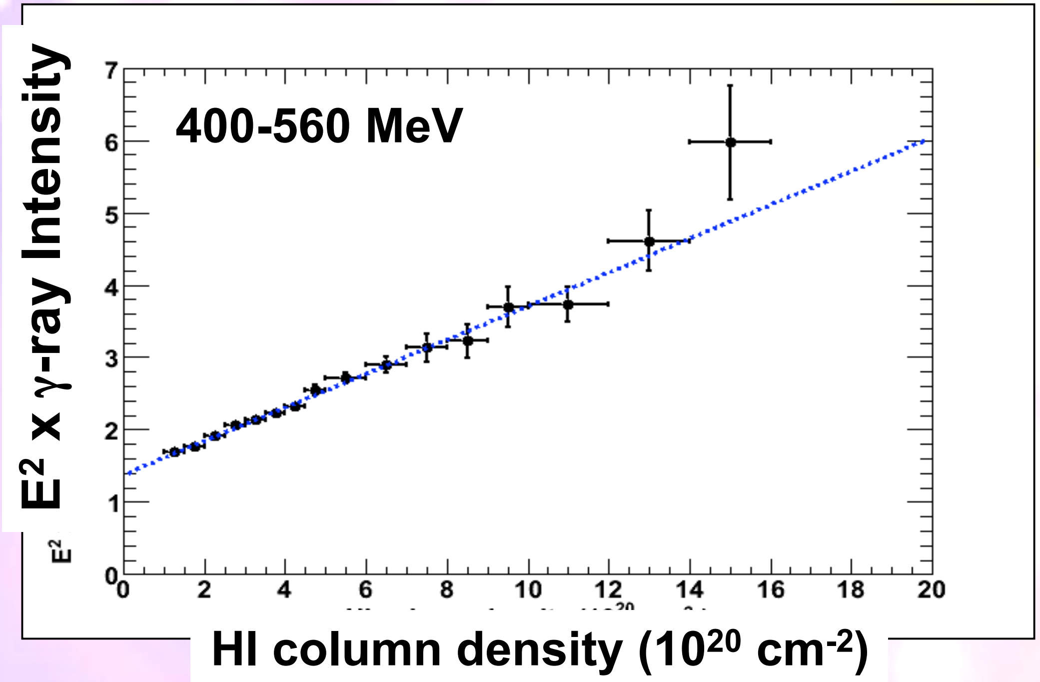
Accurate Measurements of Local CRs

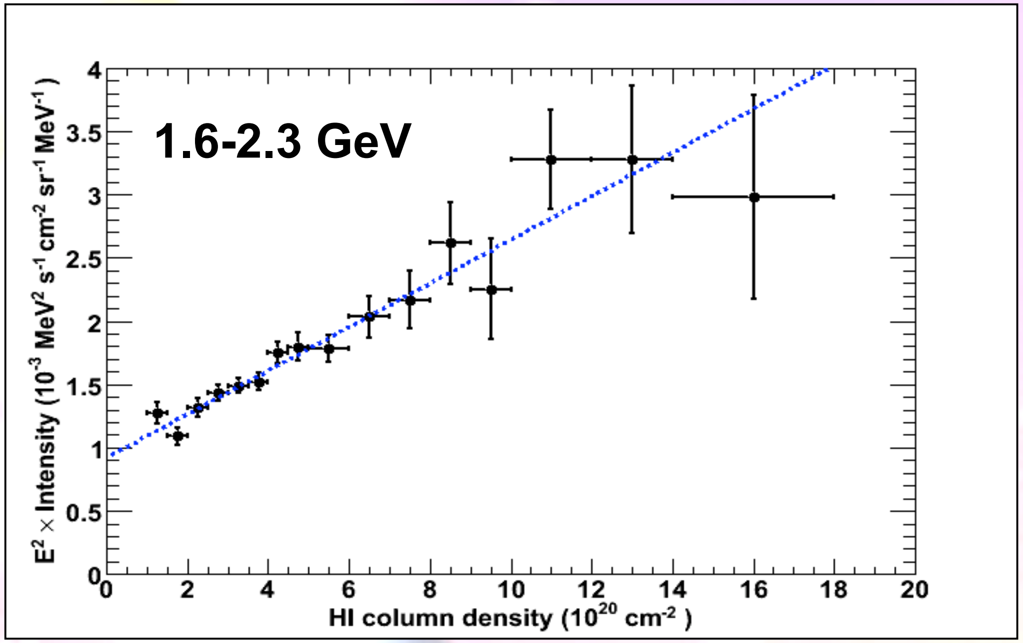


Mid-high lat. region in 3rd quadrant:

- **small contamination of IC and molecular gas**
- **correlate γ-ray intensity and HI gas column density**

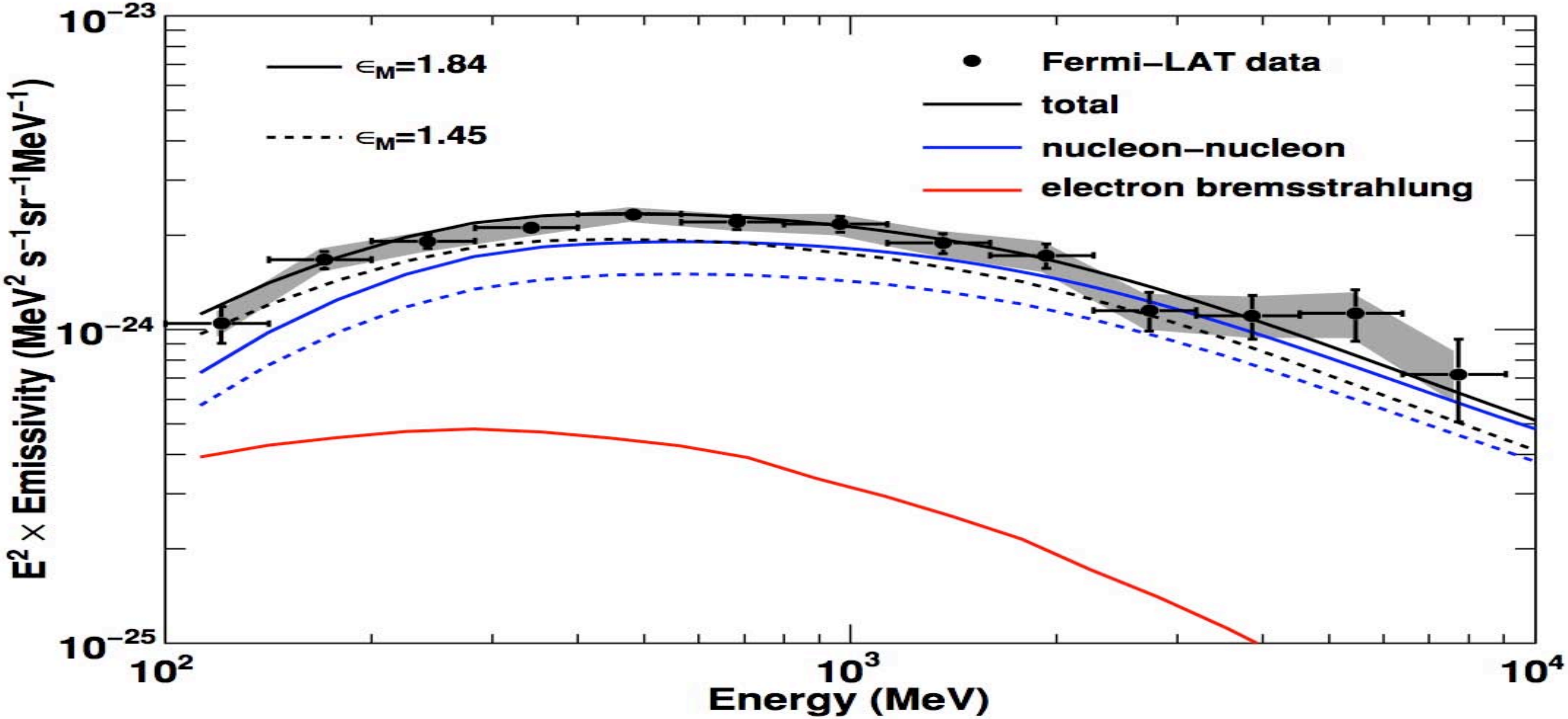
Abdo et al. [Fermi Coll.]
ApJ 703 (2009) 1249-1256
(arXiv:0908.1171)





Diffuse emission
Accurate Measurement of Local CRs

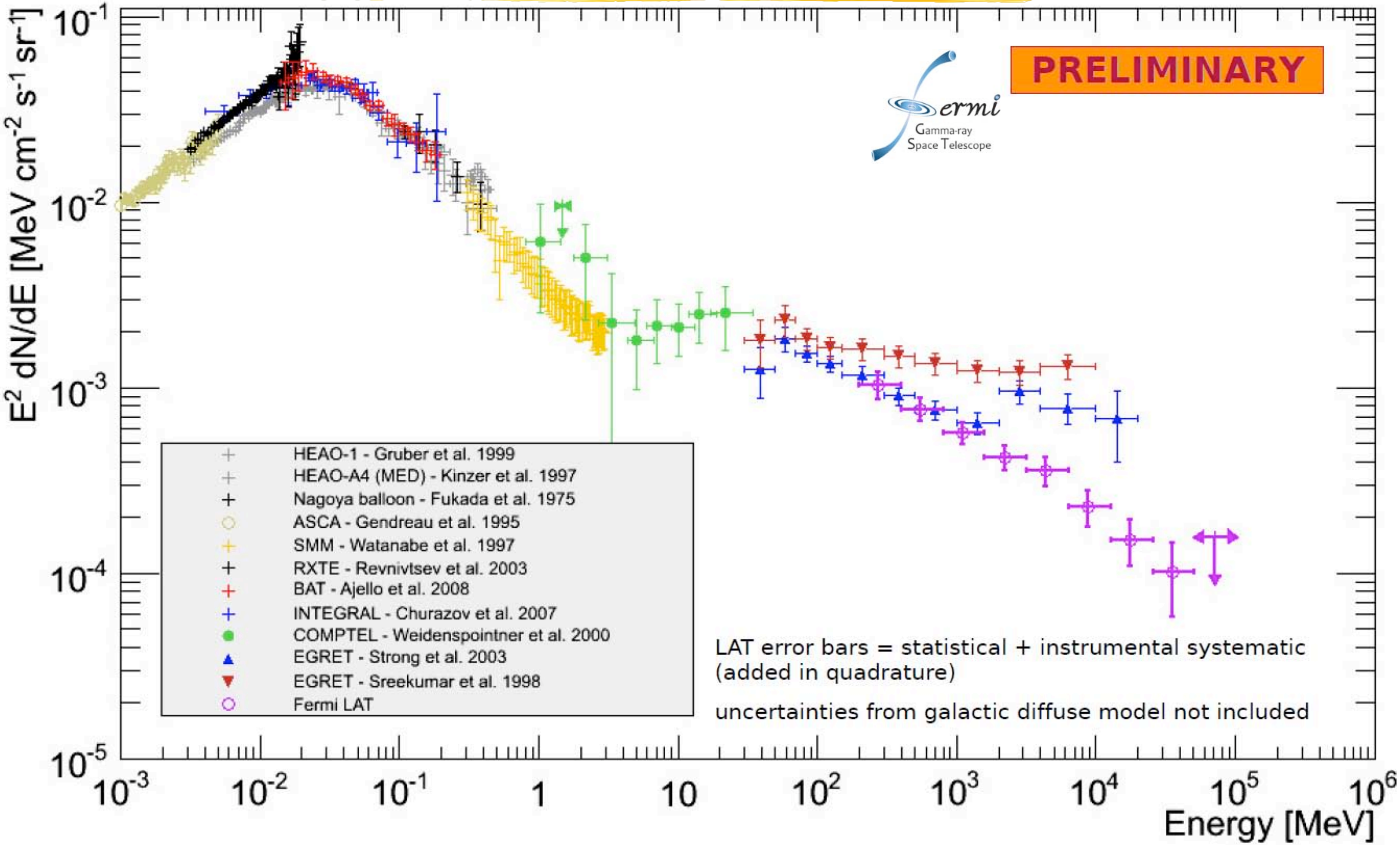
- **Best quality γ-ray emissivity spectrum in 100 MeV-10 GeV (Tp = 1-100 GeV)**
- **Agree with the model prediction from the local interstellar spectrum (LIS)**



Prove that local CR nuclei spectra are close to those directly measured at the Earth

Fermi Coll. ApJ 703 (2009) 1249-1256 [arXiv:0908.1171]

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



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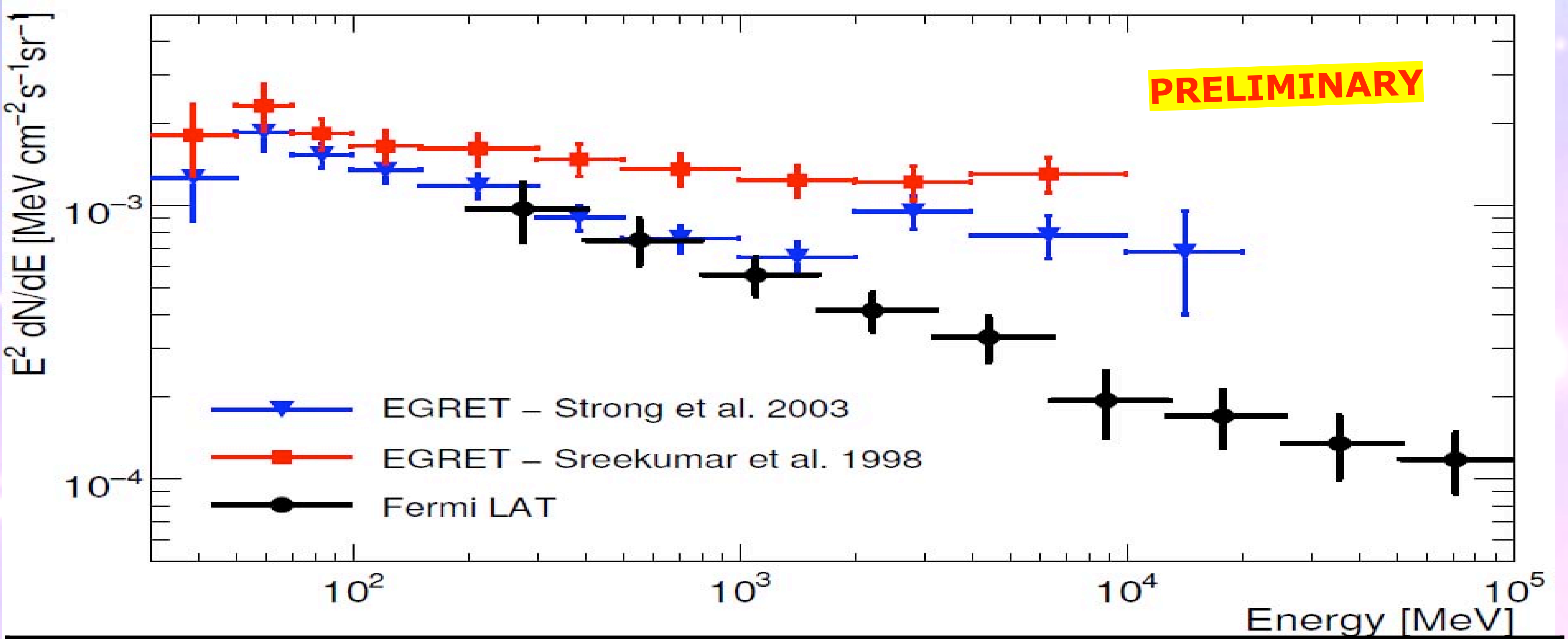
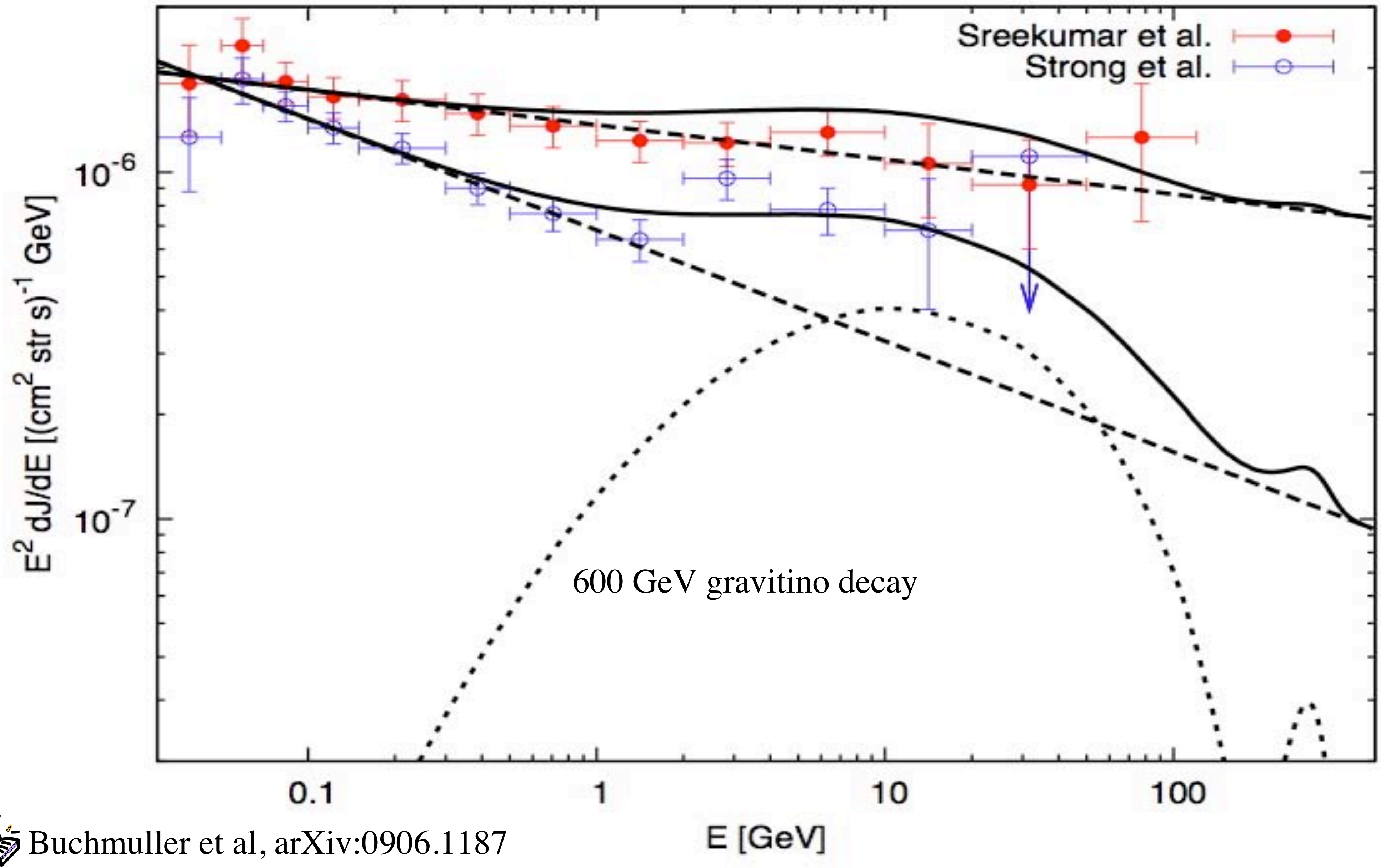


	Flux, E>100 MeV	spectral index
Fermi LAT	**1.03 +/- 0.17**	**2.41 +/- 0.05**
EGRET (Sreekumar et al., 1998)	1.45 +/- 0.05	2.13 +/- 0.03
EGRET (Strong et al. 2004)	1.11 +/- 0.10	
LAT + resolved sources below EGRET sensitivity	1.19 +/- 0.18	2.37 +/- 0.05
	$\times 10^{-5}$ cm^{-2} s^{-1} sr^{-1}	

M.Ackermann Fermi Symp.

extragalactic gamma-ray spectrum

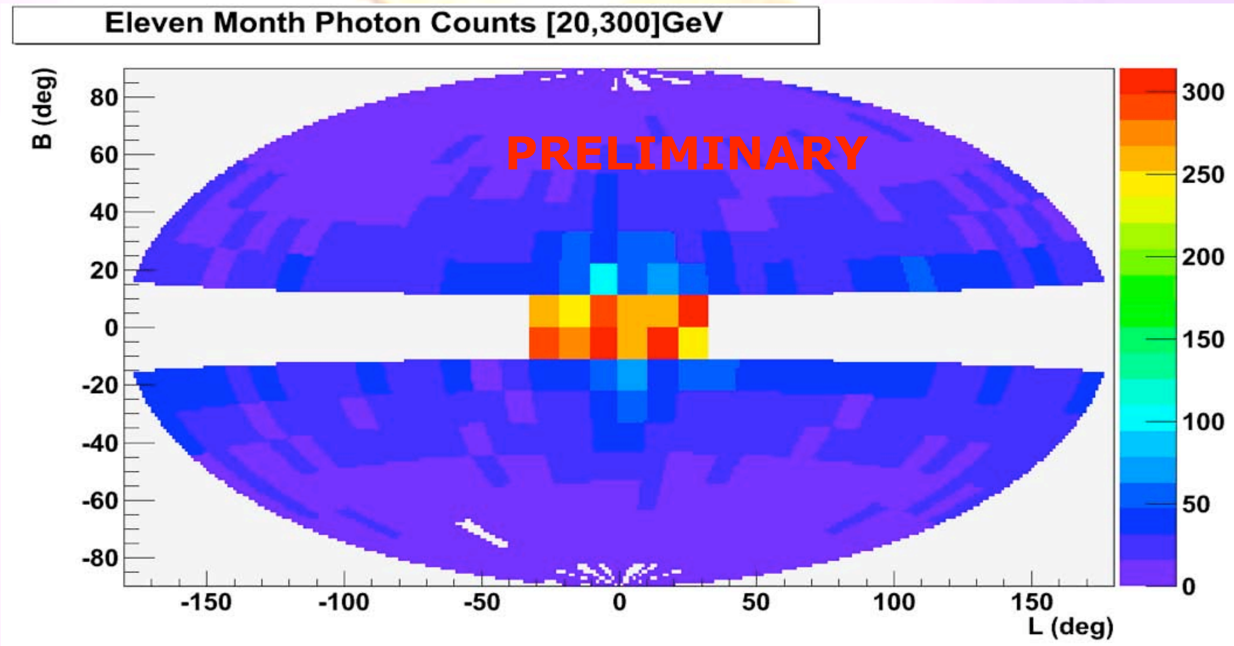


Buchmuller et al, arXiv:0906.1187

Search for Spectral Gamma Lines

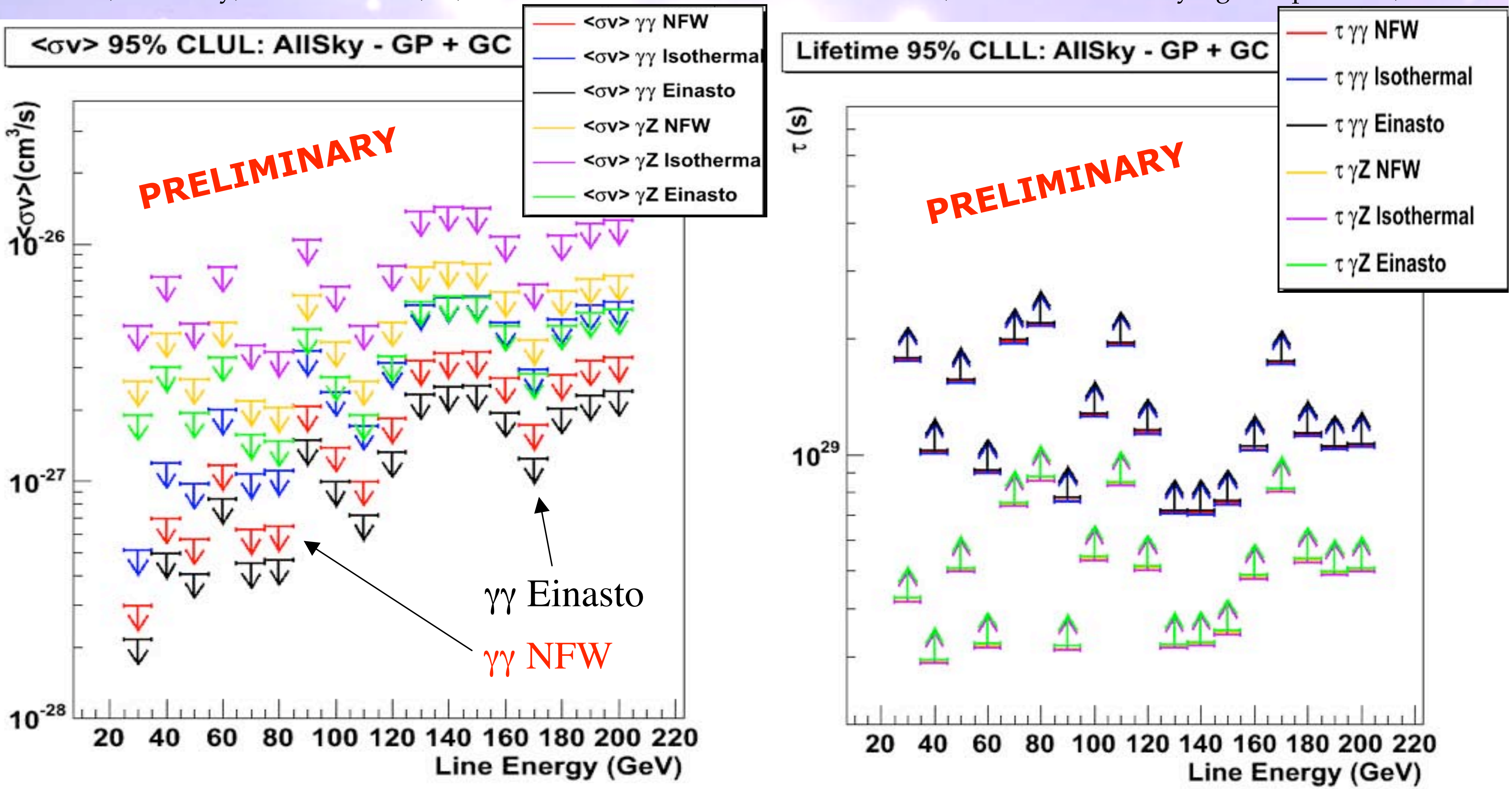
➡ Smoking gun signal of dark matter

- Search for lines in the first 11 months of Fermi data in the 30-200 GeV energy range
- Search region
  - |b|>10° and 30° around galactic center
- Remove point sources (for |b|>10°). The data selection includes additional cuts to remove residual charged particle contamination.



Search for Spectral Gamma Lines

- No line detection, 95% CL flux upper limits are placed
  - For each energy (WIMP mass) the flux ULs are combined with the integral over the line of sight of the DM density^2 (or density) to extract UL (LL) on the annihilation cross section <σv> (or lifetime for decaying DM particles)

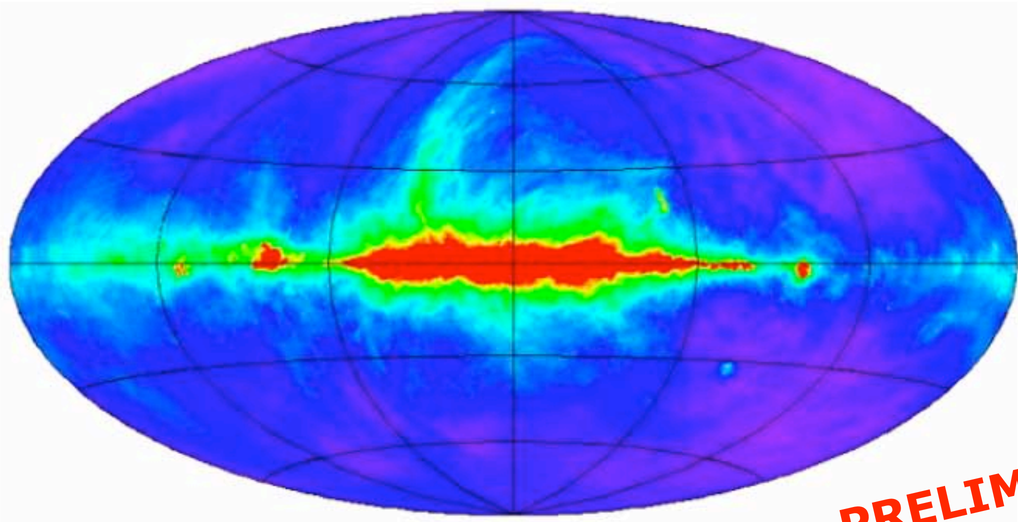


Y.Edmonds, Fermi Symp.

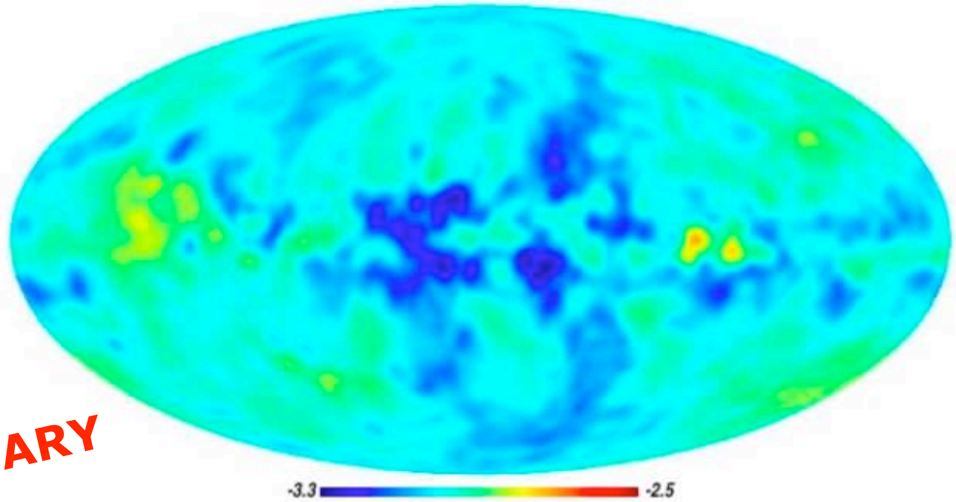
Loop I region

hot gas superbubble possibly reheated by successive supernova explosions

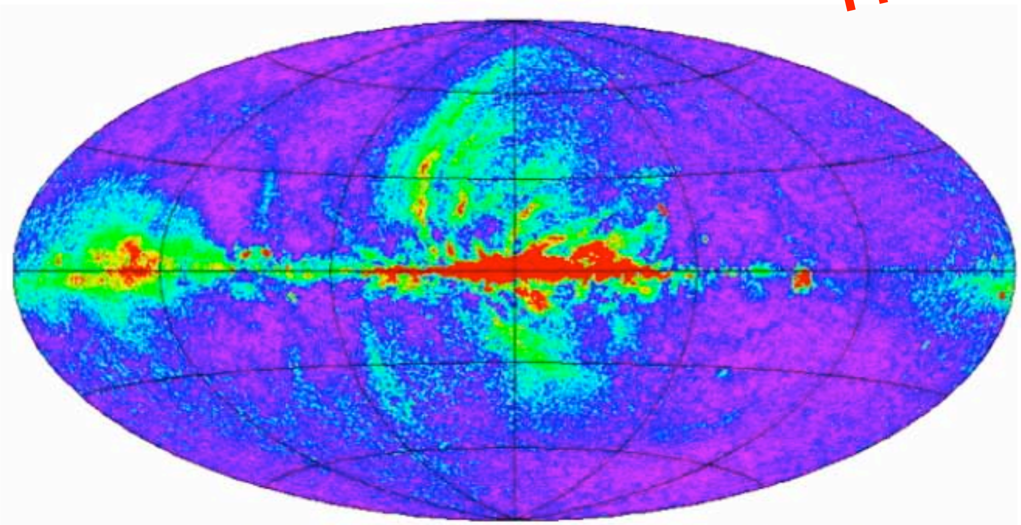
408MHz, Haslam *et al.*, 1981



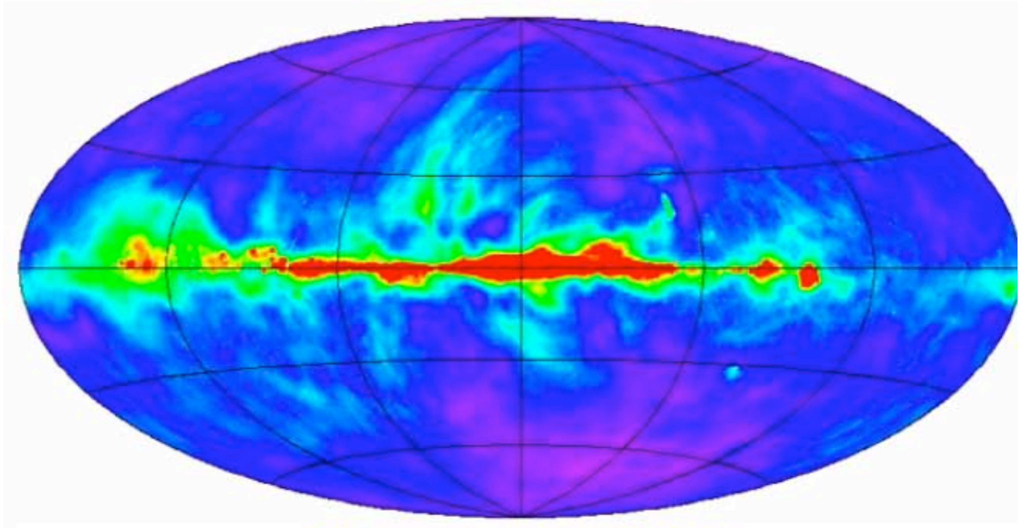
Synchrotron spectral index between 408MHz and 23GHz
Miville-Deschênes *et al.*, 2008



PRELIMINARY



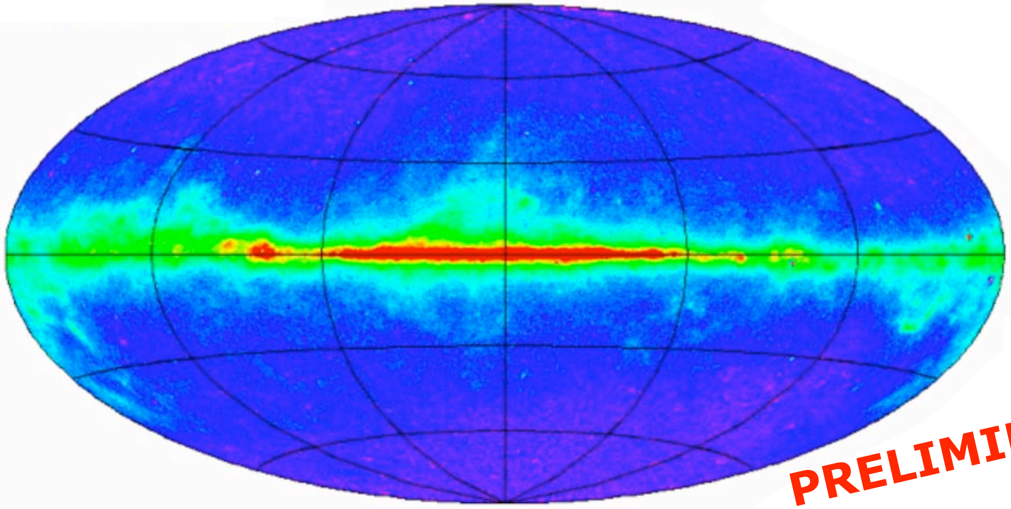
WMAP polarized emission at 23GHz, Page *et al.*, 2007



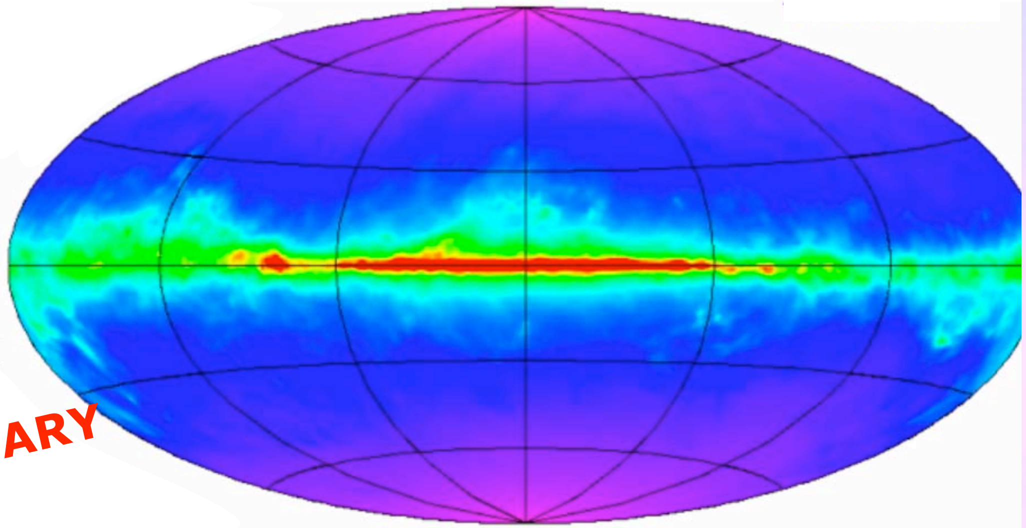
Synchrotron emission at 23GHz
Miville-Deschênes *et al.*, 2008

Loop I region

Fermi-LAT counts map for E>300MeV with sources removed

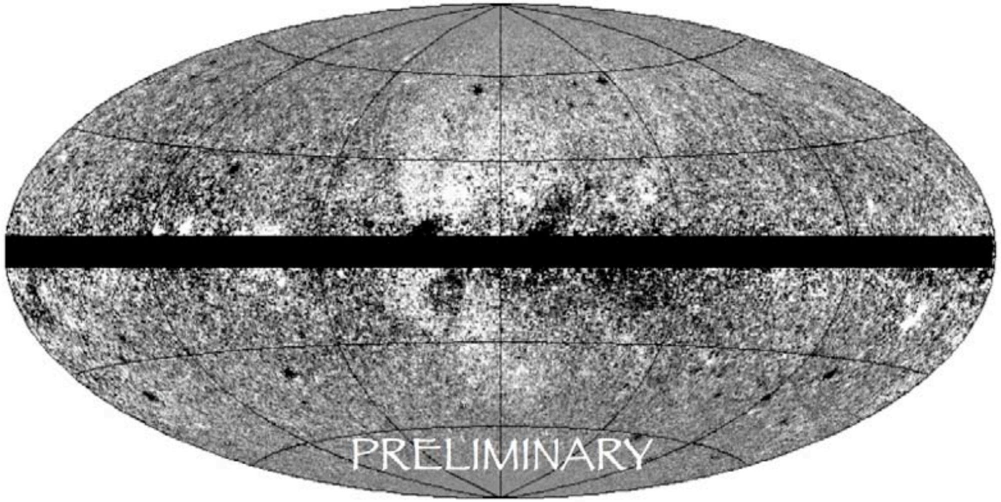


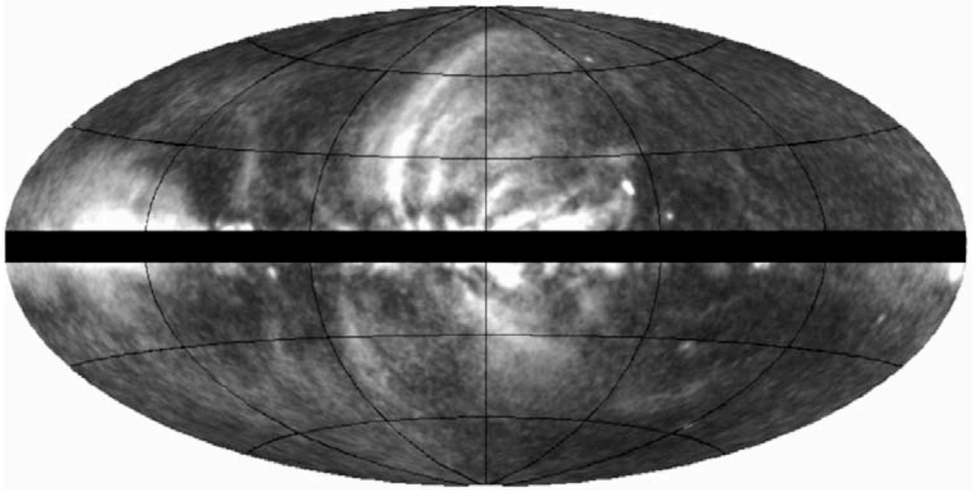
diffuse model counts prediction for E>300 MeV



PRELIMINARY

Residual map (data-model) for photons with E>300 MeV

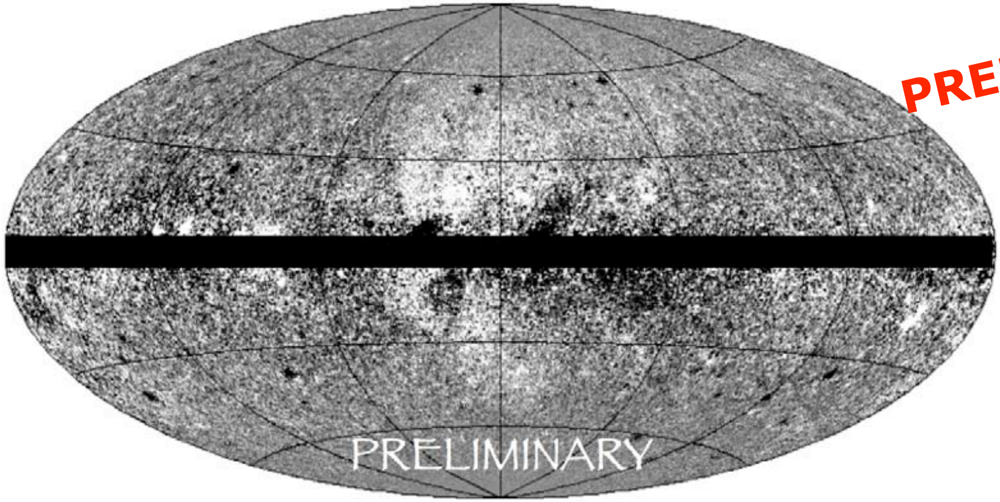




WMAP 23GHz polarized intensity convolved with Fermi-LAT PSF for E>300 MeV

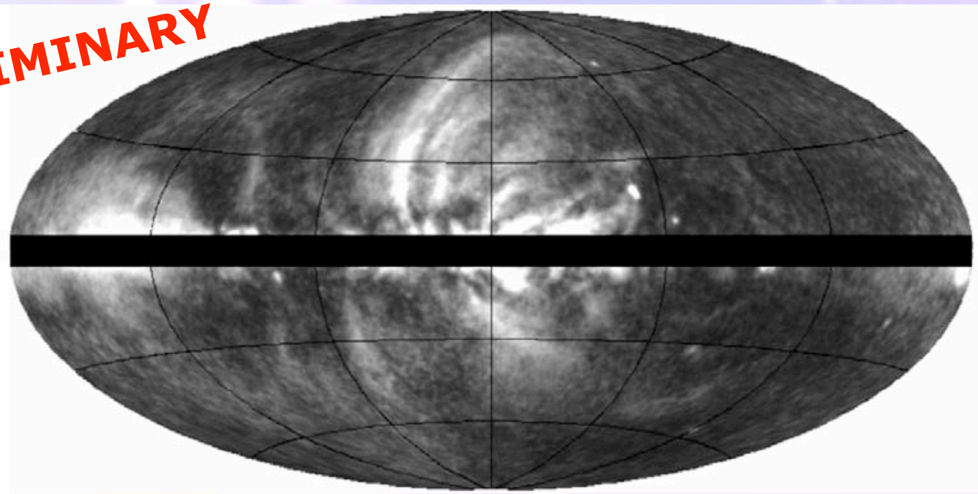
Loop I region

Residual map (data-model) for photons with E>300 MeV



convolved WMAP 23GHz polarized intensity

PRELIMINARY



- The spatial relation between the radio and γ -ray data suggests that synchrotron- emitting hard electrons also produce γ rays by upscattering the local radiation field.
- A bremsstrahlung origin is less likely because of the hardness of the γ rays and because the excess better coincides with the radio spur than with the dense rim of compressed atomic hydrogen.

Inverse Compton emission from the Milky Way (as calculated by GALPROP) together with this fainter local excess linked with Loop I can fully account for the Fermi-LAT data. It seems that no obvious haze or additional diffuse structure is needed.

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 ~ 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 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
- 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)

Announcement for SciNeGHE 2010

8th Workshop on Science with the New Generation High Energy Gamma-ray Experiments

Gamma-ray astrophysics in the multimessenger context

TRIESTE, 8-10 September 2010

see you there !!!