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2045-12

Joint ICTP-INFN-SISSA Conference: Topical Issues in LHC Physics

29 June - 2 July, 2009

Science from the first 10 months of observations from the Fermi Large AreaTelescope

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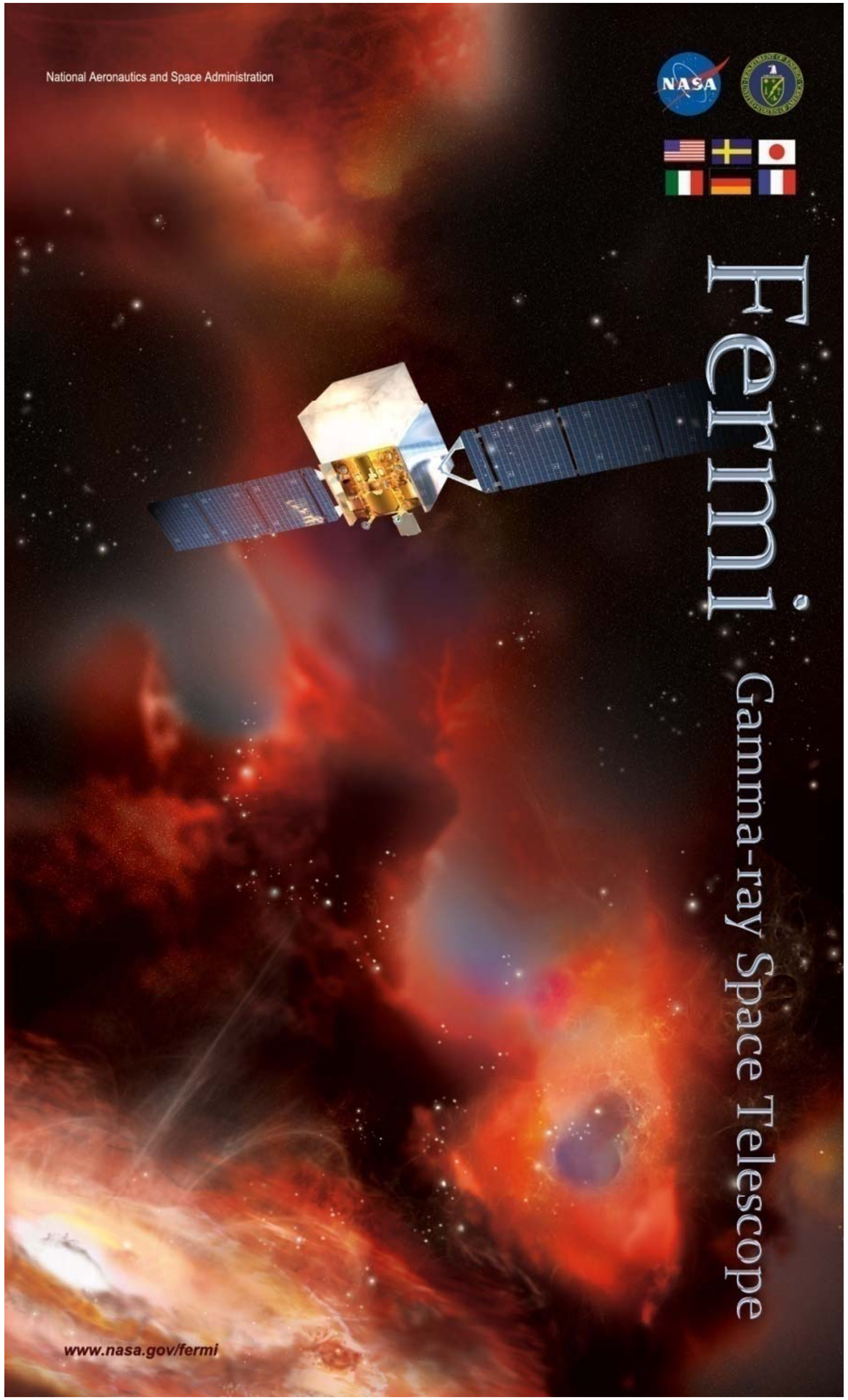


Science from the first 10 months of observations from the Fermi Large Area Telescope

Francesco Longo (INFN Trieste)
Francesco.longo@ts.infn.it

on behalf of the Fermi LAT Collaboration

July 2 2009 - ICTP Trieste

Outline

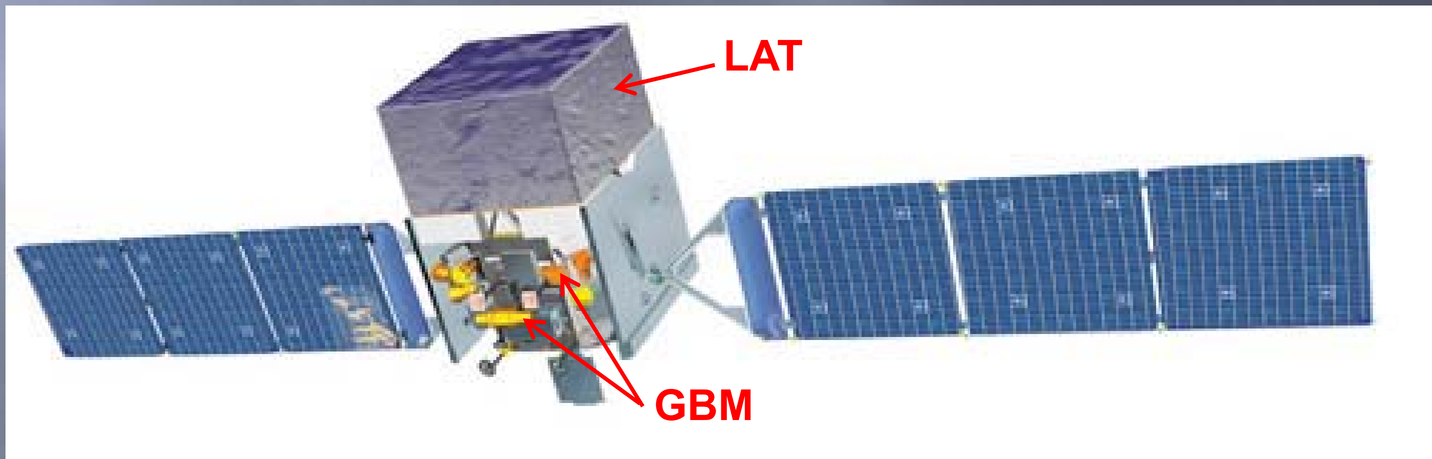
- ❑ Introduction to the Fermi Gamma-ray Space Telescope
- ❑ The Large Area Telescope
- ❑ Astrophysical results
  - – Solar System sources
  - – Galactic Sources and Galactic diffuse emission
  - – Active Galactic Nuclei
  - – Gamma-ray Bursts
- ❑ The “electron” spectrum
  - – Interpretations
- ❑ Dark Matter capabilities
- ❑ Conclusions

Exploring the High- Energy Universe

- **gamma rays provide a direct view into Nature's largest accelerators (neutron stars, black holes)**

- **gamma rays probe cosmological distances**
(e.g., $\gamma + \gamma_{EBL} \rightarrow e^{+} + e^{-}$)

- **huge leap in key capabilities, including a largely unexplored energy range; great potential for discovery: e.g. dark matter**



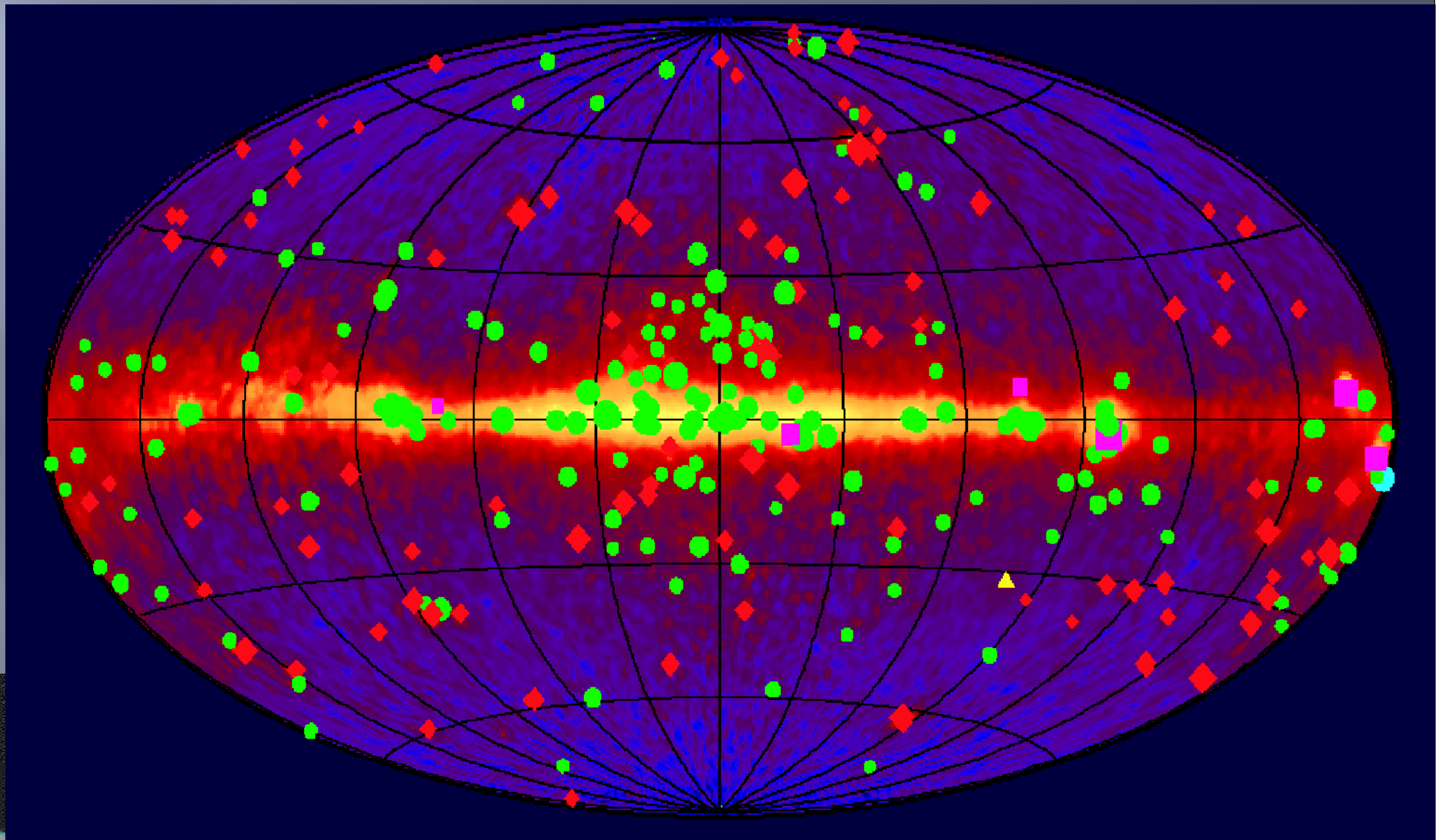
Two instruments: Large Area Telescope (LAT), 20 MeV - >300 GeV
Gamma-ray Burst Monitor (GBM), 8 keV - 40 MeV

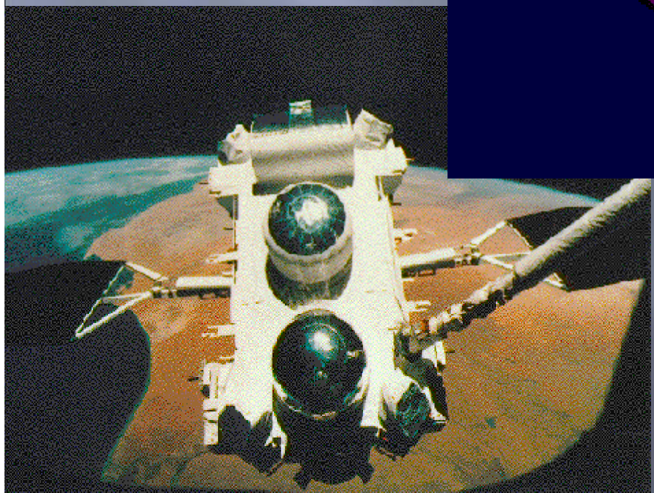
Compton Observatory / EGRET legacy

April 5, 1991 – June 4, 2000

3rd EGRET catalog

- AGN - blazars
- unidentified
- pulsars
- LMC





CERN COURIER

IOP

CERN COURIER

Jul 8, 2008

GLAST in orbit to explore extreme universe

The Gamma-Ray Large Area Space Telescope (GLAST) was launched by NASA on 11 June from the Cape Canaveral Air Force Station in Florida. GLAST is a next-generation, high-energy, gamma-ray observatory, designed to explore some of the most energetic phenomena in the universe and enhance knowledge of fundamental physics, astronomy and cosmology. It is an international, multi-agency mission with important contributions from research institutions in France, Germany, Italy, Japan, Sweden and the US.

symmetry breaking
extra dimensions of particle physics
A joint Fermilab/SLAC publication

Happy birthday, Fermi Gamma-ray Space Telescope

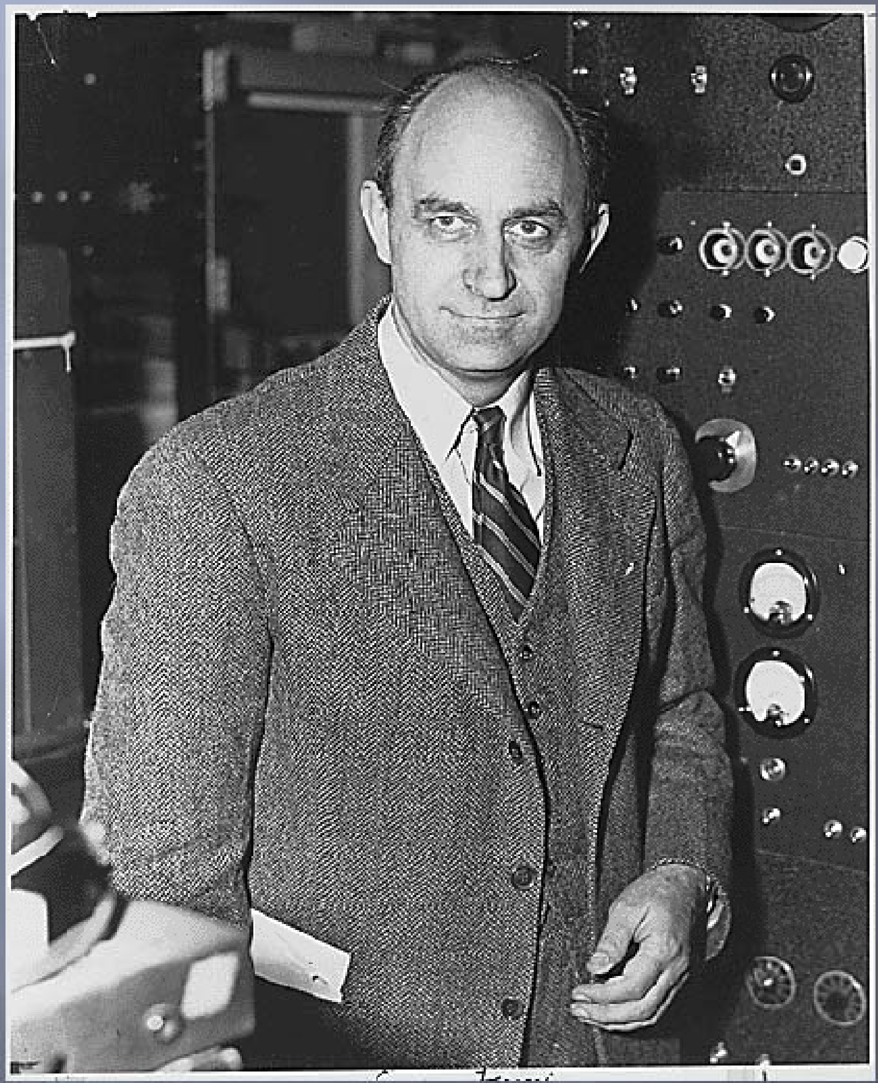
June 11, 2009 | 12:56 pm

Today marks one year since the Fermi Gamma-ray Space Telescope was launched into orbit. Since then, the telescope has discovered a whole new set of pulsars, gained a new view of cosmic jets, seen the most extreme gamma-ray blasts ever, created new sky maps in gamma-rays, shown that blazars are more complex than previously thought, observed a mysterious excess of high-energy electrons from space that could be from pulsars or possibly a sign of dark matter, and spotted gamma-ray bursts that lasted for half an hour rather than the expected few minutes.

The Fermi Gamma-ray Space Telescope launched one year ago. (Photo: NASA)

Happy birthday, Fermi Gamma-ray Space Telescope!

Fermi Gamma-ray Space Telescope



GLAST renamed *Fermi* by NASA on August 26, 2008

http://fermi.gsfc.nasa.gov/

Enrico Fermi (1901-1954) was an Italian physicist who immigrated to the United States. He was the first to suggest a viable mechanism for astrophysical particle acceleration. This work is the foundation for our understanding of many types of sources to be studied by NASA's Fermi Gamma-ray Space Telescope, formerly known as GLAST.

In addition to his direct connection to the science, Fermi holds special significance to the U.S. Department of Energy, the Italian Space Agency, and the Italian Particle Physics Agency (INFN), three of the major contributors to the mission. "

Fermi LAT science

20 MeV - > 300 GeV

> several x 10^3 AGNs
blazars and radiogal = f(θ,z)
evolution z < 5
Sag A*

10-20 GRB/year
GeV afterglow
spectra to high energy

γ-ray binaries
pulsar winds
μ-quasar jets

Possibilities
starburst galaxies
galaxy clusters
measure EBL
unIDs

Dark Matter
neutralino lines
sub-halo clumps; e^+ + e^- spectrum

Cosmic rays and clouds
acceleration in Supernova remnants
OB associations
propagation (Milky Way, M31, LMC, SMC)
Interstellar mass tracers in galaxies

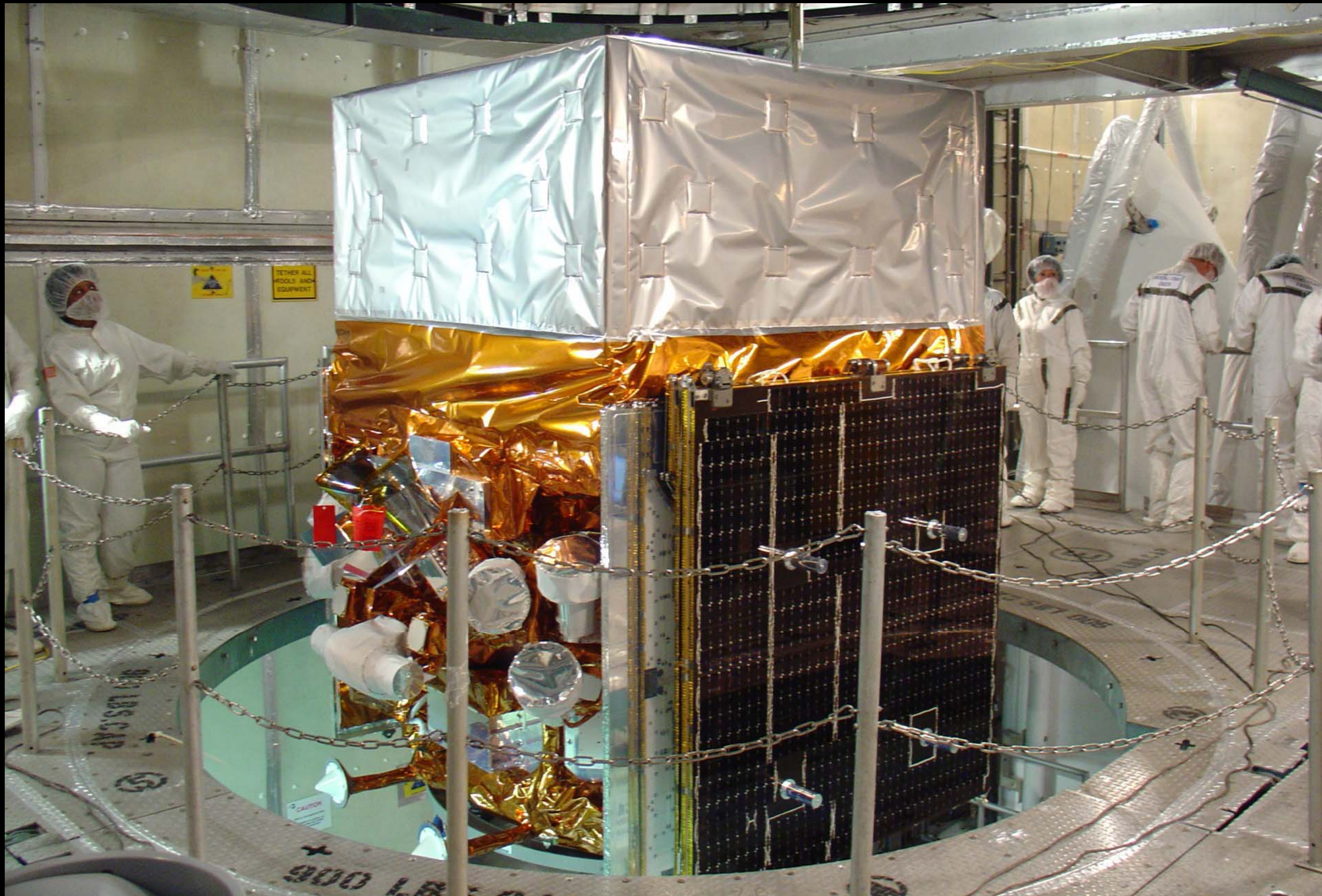
Pulsars
emission from radio and X-ray pulsars
blind searches for new Gemingas
magnetospheric physics
pulsar wind nebulae

Some Questions Fermi is addressing

- How do super massive black holes in Active Galactic Nuclei create powerful jets of material moving at nearly light speed? What are the jets made of?
- What are the mechanisms that produce Gamma-Ray Burst (GRB) explosions? What is the energy budget?
- What is the origin of the cosmic rays that pervade the galaxy?
- How does the Sun generate high-energy gamma-rays in flares?
- How has the amount of starlight in the Universe changed over cosmic time?
- What are the unidentified gamma-ray sources found by EGRET?
- What is the mysterious dark matter?

The Fermi Large Area Telescope

The Fermi gamma-ray observatory



The Gamma-ray Observatory

Large AreaTelescope (LAT)
20 MeV - >300 GeV

Gamma-ray Burst Monitor (GBM)
NaI and BGO Detectors
8 keV - 40 MeV

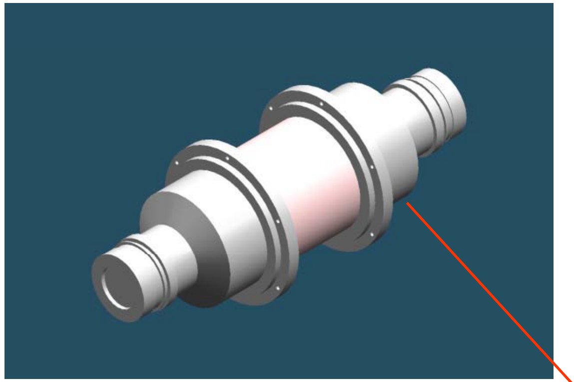
KEY FEATURES

- **Huge field of view**
  - **LAT: 20% of the sky at any instant; in sky survey mode, expose all parts of sky for ~30 minutes every 3 hours**
  - **GBM: whole unocculted sky at any time.**
- **Huge energy range, <u>>7 decades!</u>**
  - **including largely unexplored band 10-100 GeV**
- **Very small deadtime, <1us absolute timing accuracy**
- **Large leap in all key capabilities**
- **Great discovery potential**

Gamma-ray Burst Monitor (GBM)

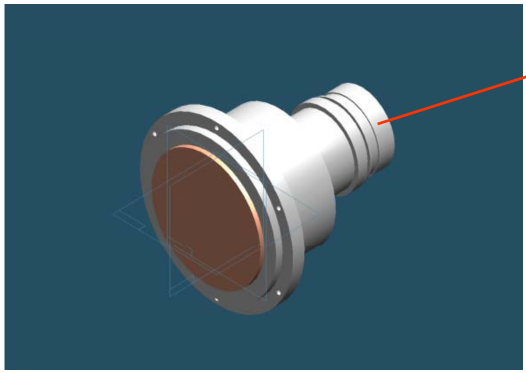
MSFC, MPE, Los Alamos collaboration

Bismuth Germanate (BGO) Scintillation Detector

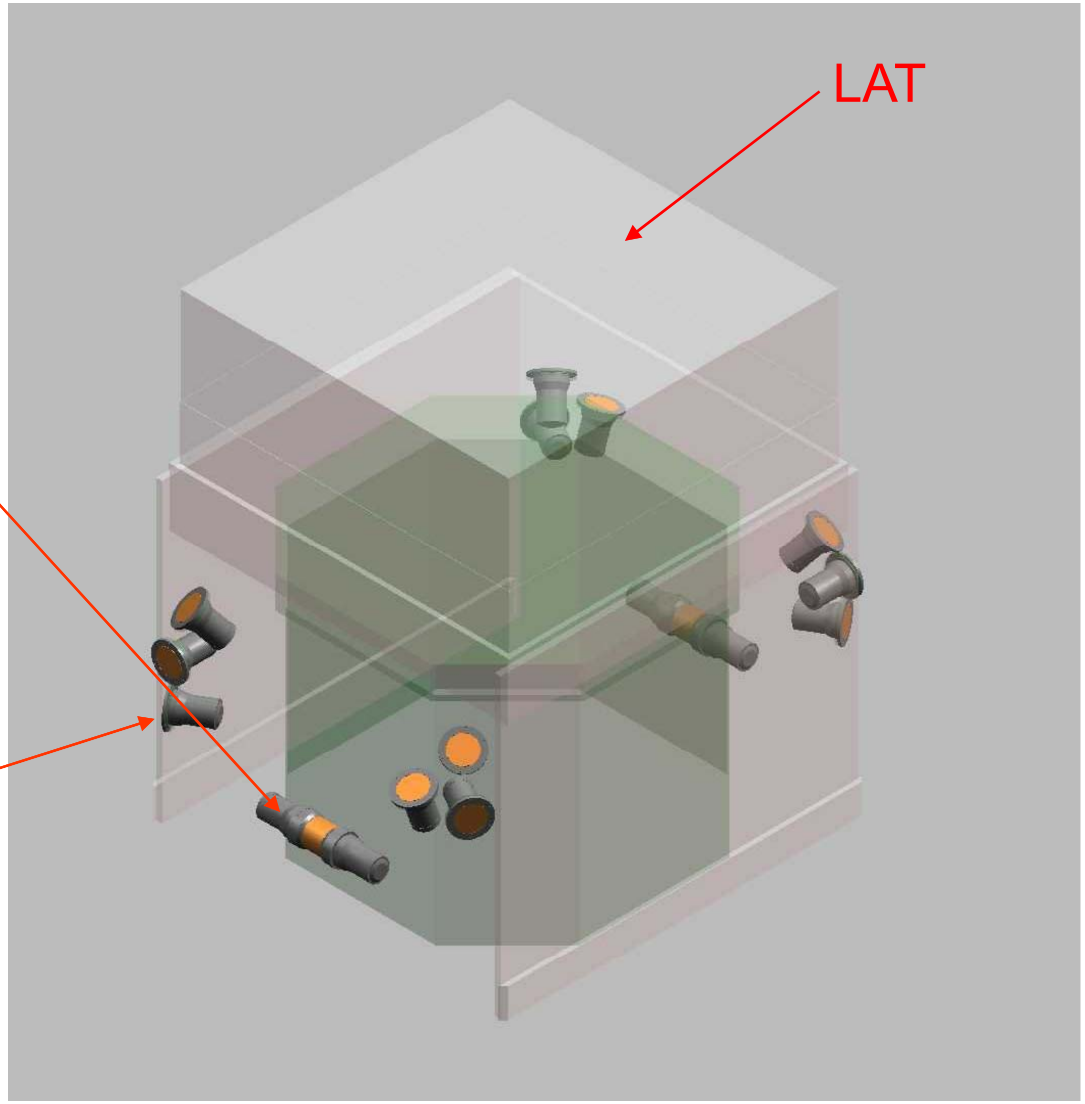


– spectral coverage: 150 keV – 40 MeV

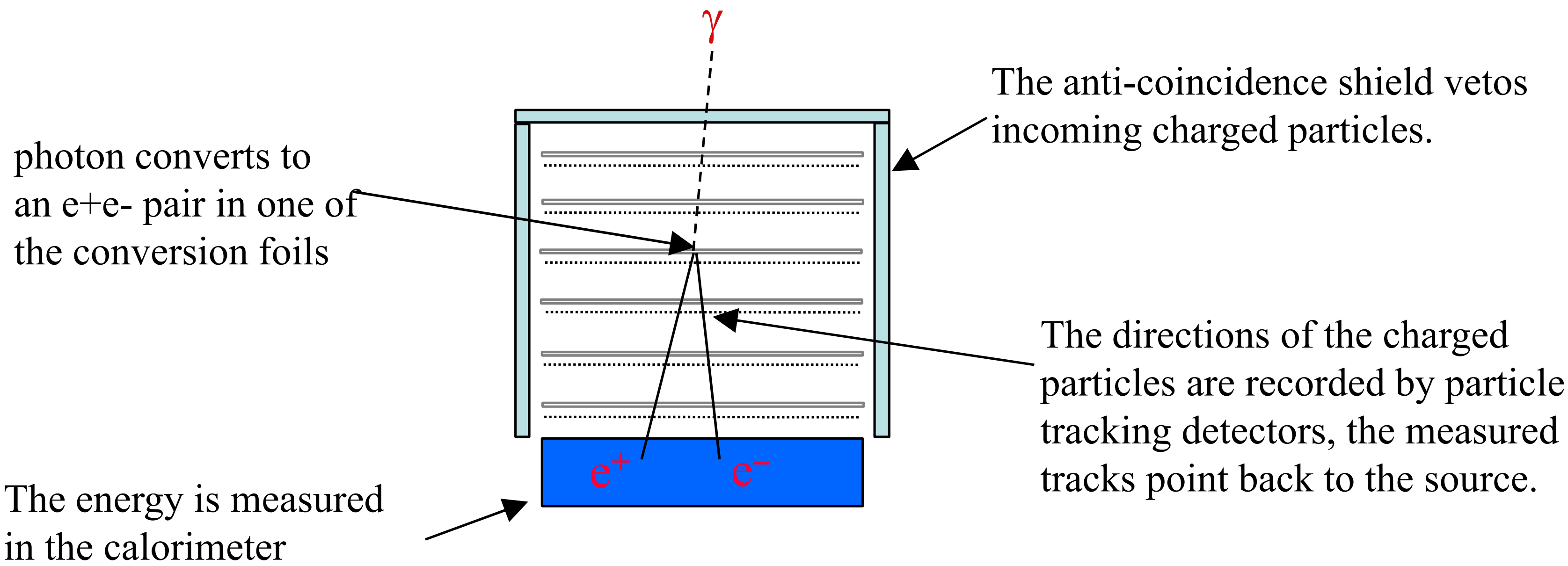
(12) Sodium Iodide (NaI) Scintillation Detectors



– spectral coverage: 8 keV – 1 MeV



Pair Conversion Technique

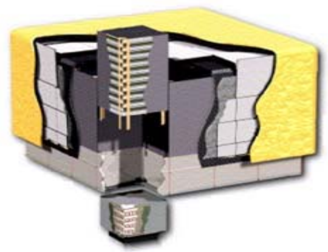


Tracker: angular resolution is determined by:
multiple scattering (at low energies) => Many thin layers
position resolution (at high energies) => fine pitch detectors

Calorimeter:
Enough X_0 to contain shower, shower leakage correction.

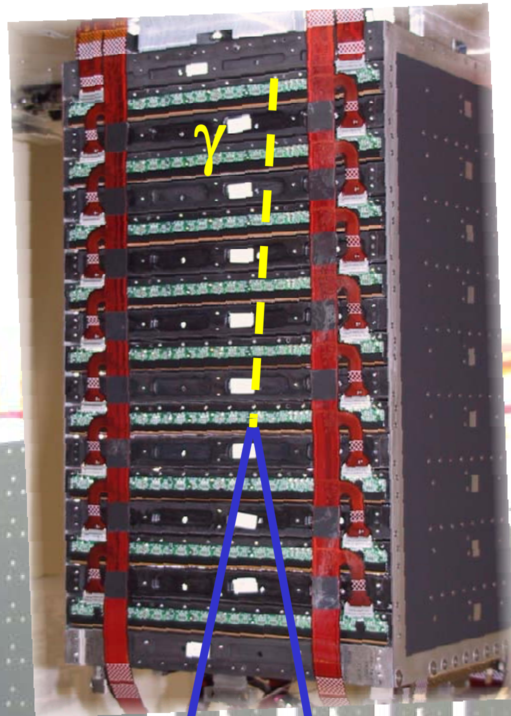
Anti-coincidence detector:
Must have high efficiency for rejecting charged particles, but not veto gamma-rays

Overview of the Large Area Telescope

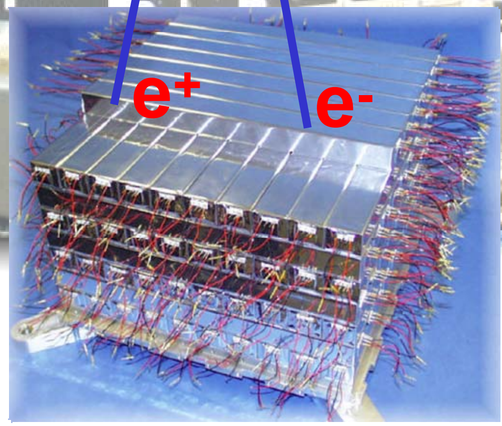


LAT:
- modular - 4x4 array
- 3ton – 650watts

Anti-Coincidence (ACD):
- Segmented (89 tiles + 8 ribbons)
- Self-veto @ high energy limited
- **0.9997 detection efficiency**



Tracker/Converter (TKR):
- Si-strip detectors
- ~80 m^2 of silicon (total)
- W conversion foils
- **1.5 X0 on-axis**
- 18XY planes
- **~10^6 digital elx chans**
- Highly granular
- High precision tracking
- Average plane PHA



Calorimeter (CAL):
- 1536 CsI(Tl) crystals
- **8.6 X0 on-axis**
- large elx dynamic range (2MeV-60GeV per xtal)
- **Hodoscopic (8x12)**
- Shower profile recon
- leakage correction
- EM vs HAD separation

LAT Collaboration – an HEA-HEP partnership

~390 Members
(~95 Affiliated Scientists, 68 Postdocs, and 105 Graduate Students)

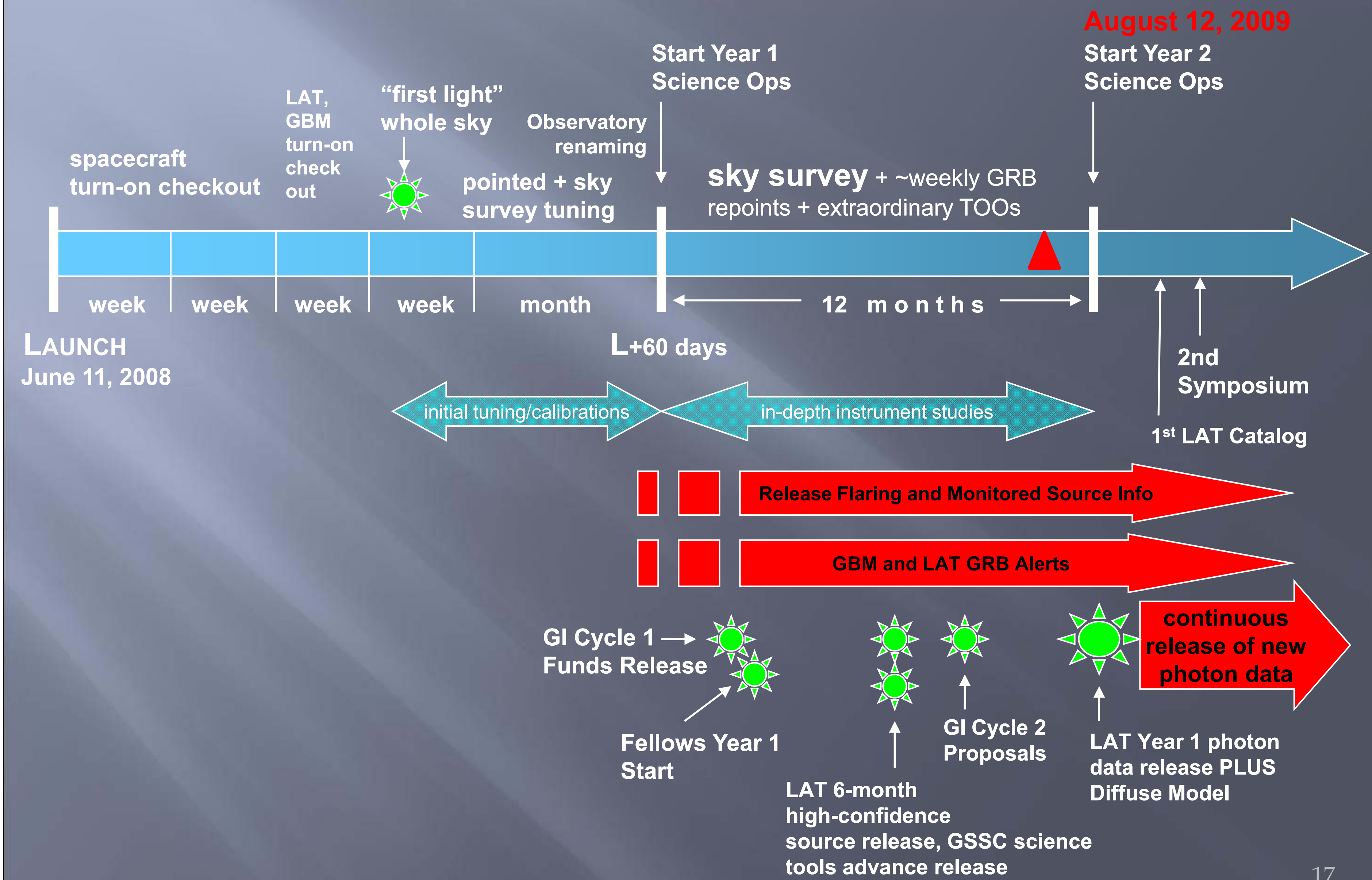
- **France**
  - CNRS/IN2P3, CEA/Saclay
- **Italy**
  - INFN, ASI, INAF
- **Japan**
  - Hiroshima University
  - ISAS/JAXA
  - RIKEN
  - Tokyo Institute of Technology
- **Sweden**
  - Royal Institute of Technology (KTH)
  - Stockholm University
- **United States**
  - Stanford University (SLAC and HEPL/Physics)
  - University of California, Santa Cruz - Santa Cruz Institute for Particle Physics
  - Goddard Space Flight Center
  - Naval Research Laboratory
  - Sonoma State University
  - The Ohio State University
  - University of Washing

Sponsoring Agencies

Department of Energy
National Aeronautics and Space Administration

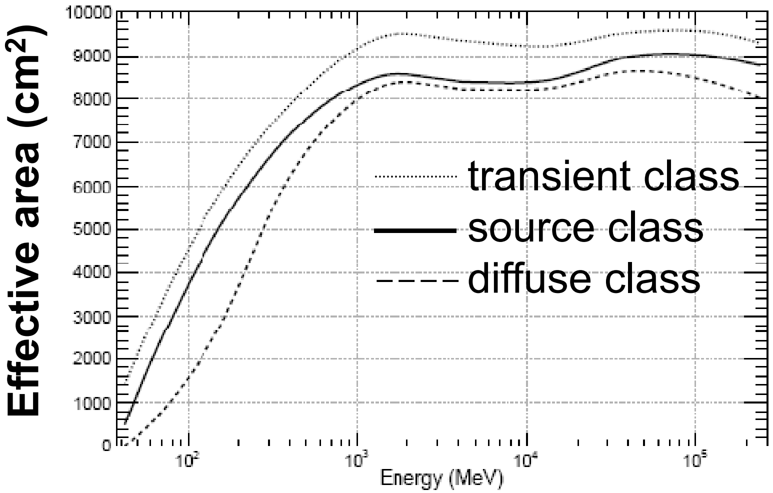
CEA/Saclay	ASI
IN2P3/CNRS	INFN
MEXT	K. A. Wallenberg Foundation
KEK	Swedish Research Council
JAXA	Swedish National Space Board

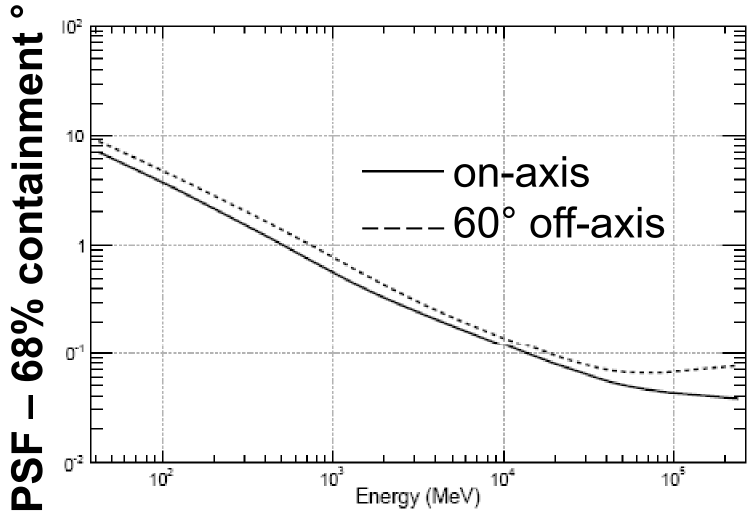
Year 1 Science Operations Timeline Overview

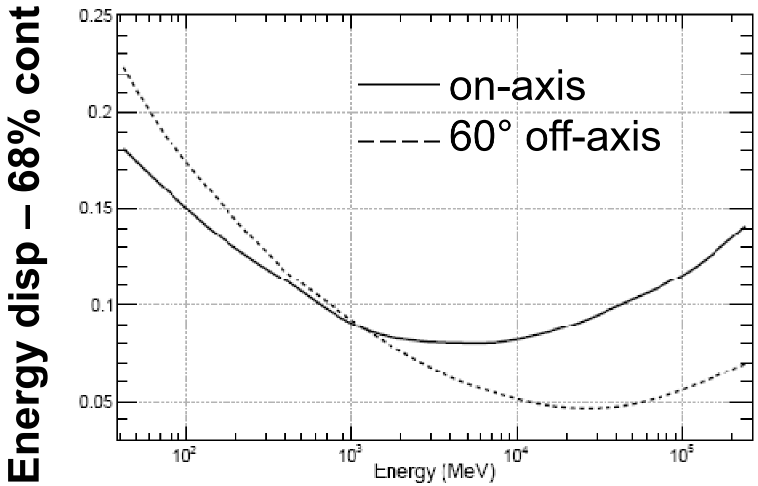



June 11, 2008

Instrument Response Functions





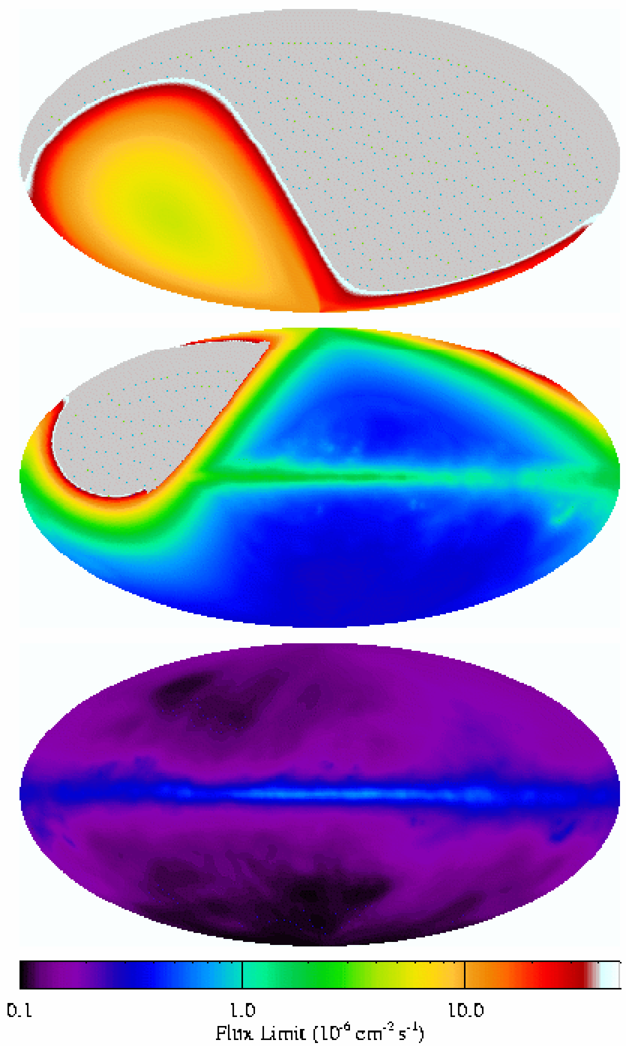


The Large Area Telescope on the Fermi Gamma-ray Space Telescope
Atwood, W. B. et al. 2009, ApJ, 697, 1071 doi: 10.1088/0004-637X/697/2/1071

Post-launch performance tuning on-going

➢ IRF update for public data release + future updates

Observation mode

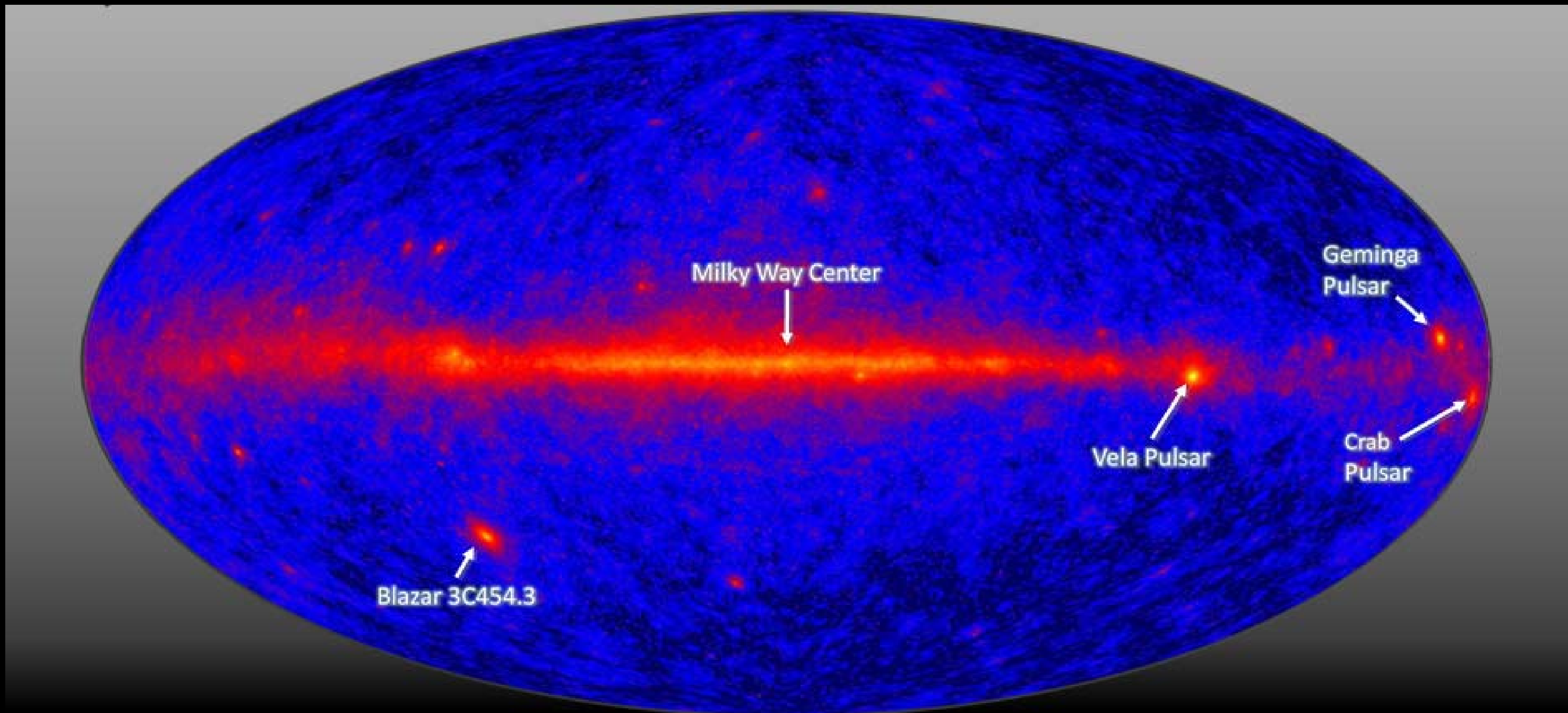


The field of view of the LAT is huge > 20% of the sky.

Rocking mode provides an efficient way of observing the entire sky with reasonably uniform exposure on timescales of hours.

more exposure → greater sensitivity
more coverage → excellent for monitoring the sky on timescales from hours to years

Fermi LAT Science Highlights

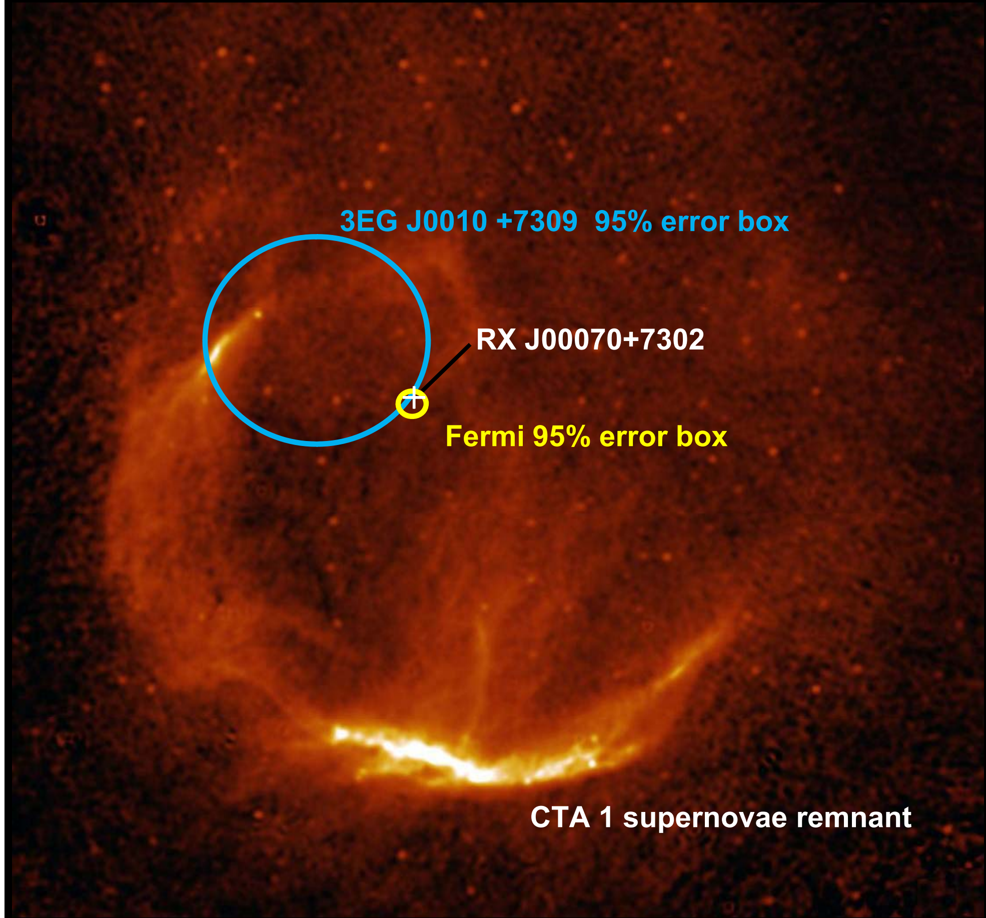


First-Light Sky map: initial 4 days of sky survey
has already achieved EGRET 1 yr source sensitivity

See http://www.nasa.gov/mission_pages/GLAST/news/glast_findings_media.html for the full press release information

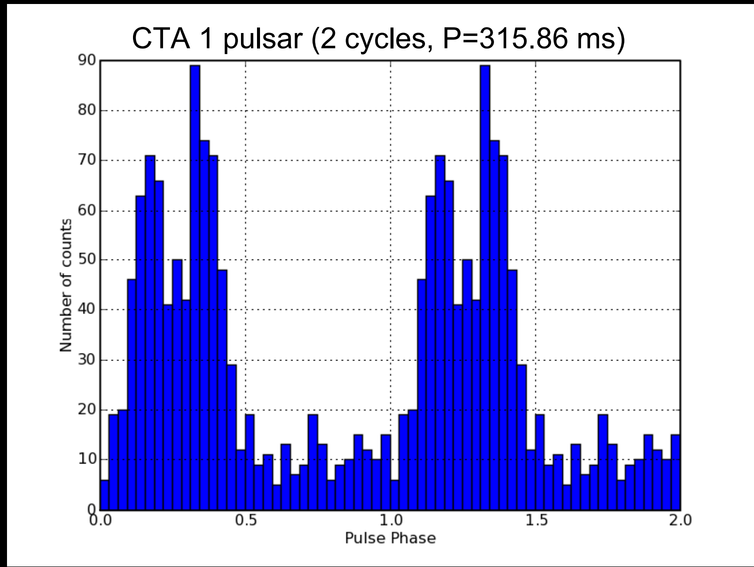
http://www.nasa.gov/fermi

Fermi Telescope Discovers Gamma-Ray-Only Pulsar



A 10,000-year-old stellar corpse, called a pulsar, is the first one discovered through its "blinking" in gamma rays, by NASA's Fermi Gamma-ray Space Telescope

16-10-2008

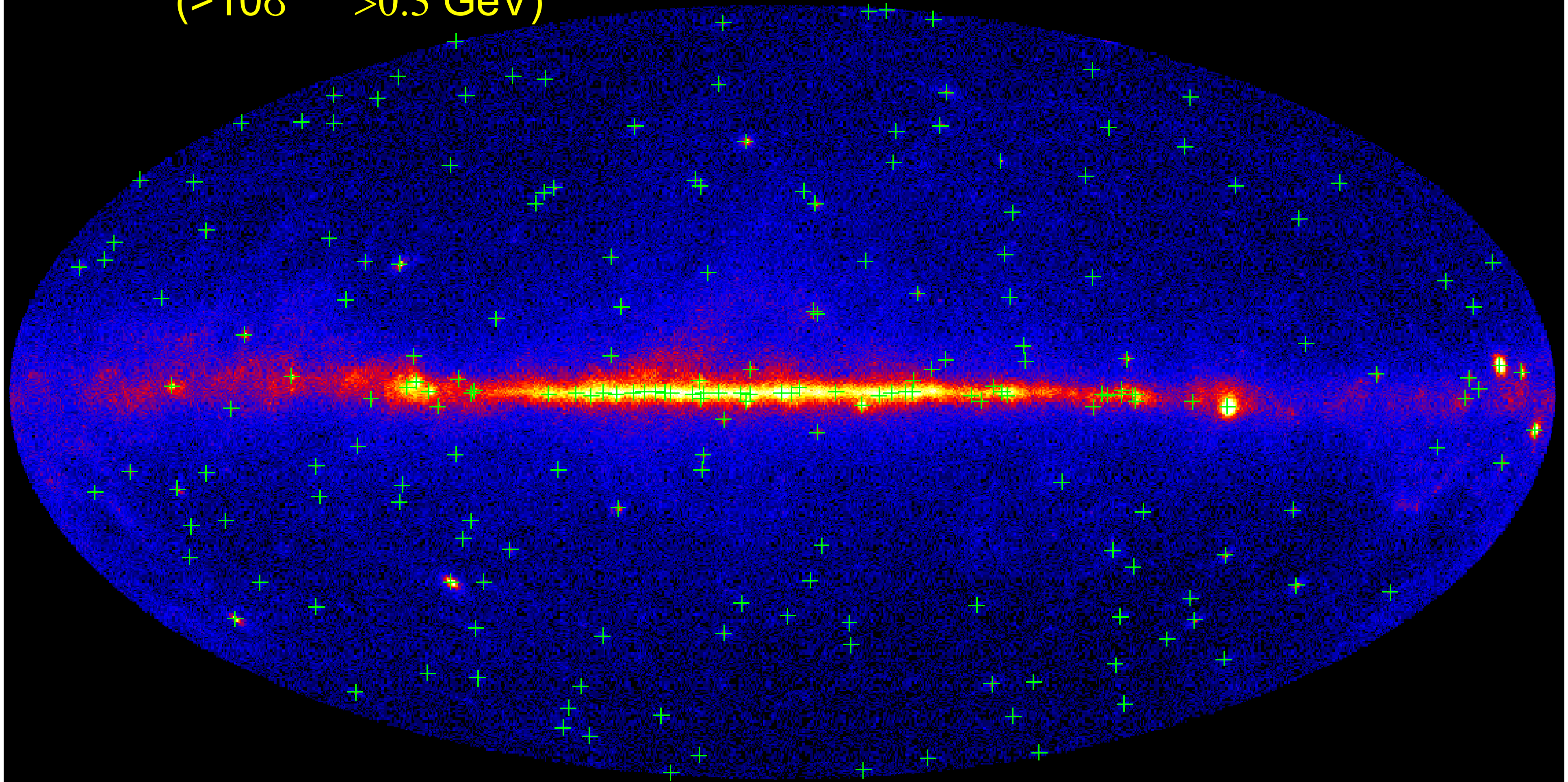


- γ-ray source at *l,b* = 119.652, 10.468; 95% error circle radius =0.038° contains the X-ray source RX J00070+7302, central to the PWN, superimposed on the radio map at 1420 MHz.
- pulsar off-set from center of radio SNR; rough estimate of the lateral speed of the pulsar is ~450 km/s
- spin-down luminosity ~10^{36} erg s^{-1}, sufficient to supply the PWN with magnetic fields and energetic electrons.
- exhibits all characteristics of a young high-energy pulsar (characteristic age ~1.4×10^4 yr), which powers a synchrotron pulsar wind nebula embedded in a larger SNR.

First 10 months results

3 months: 205 LAT Bright Sources

(>10σ >0.3 GeV)



Fermi Large Area Telescope Bright Gamma-ray Source List

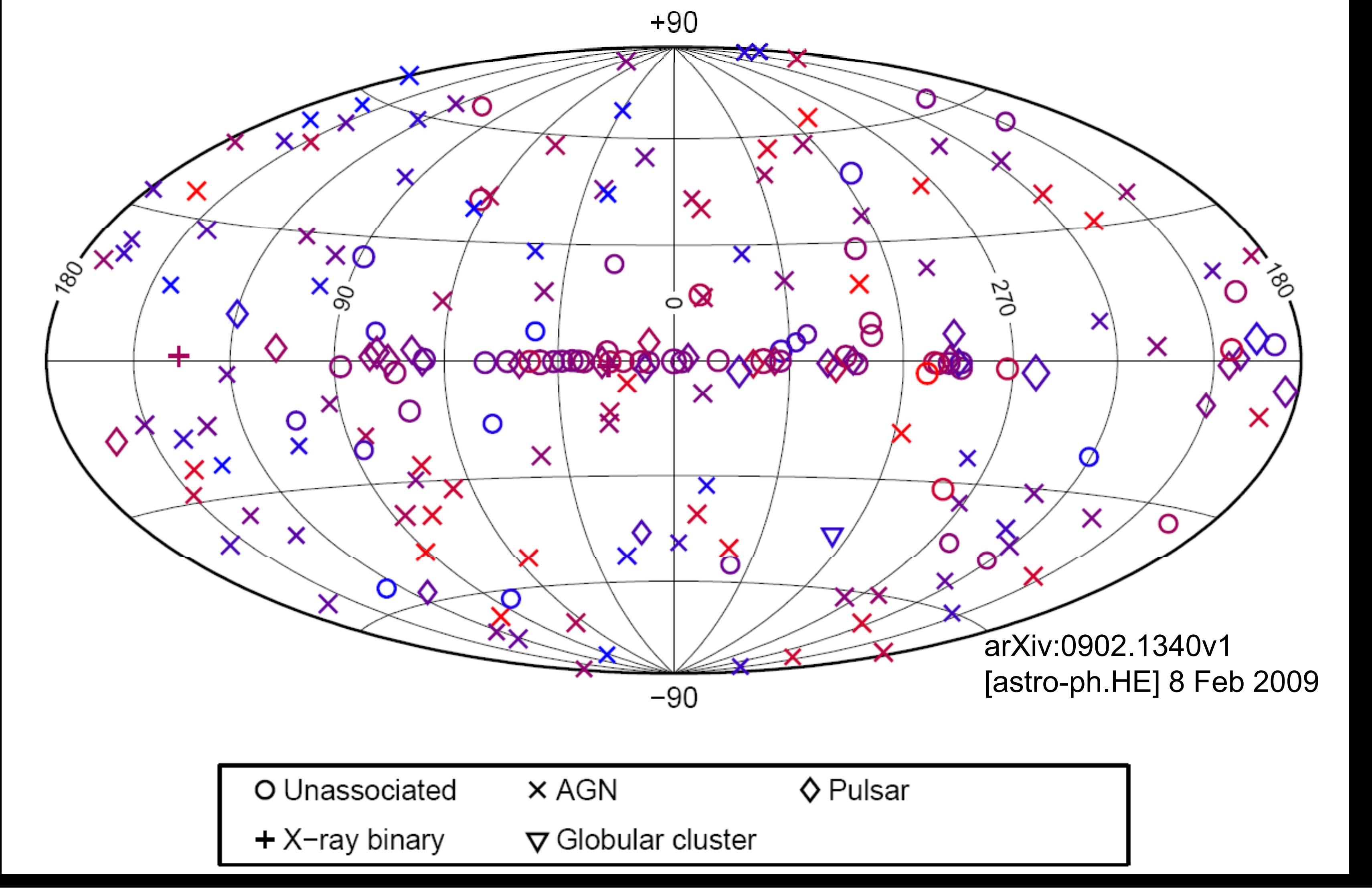
Abdo, A. A. et al. 2009, Ap J Suppl *submitted*, arXiv: [0902.1340]

Bright AGN Source List from the First Three Months of the Fermi Large Area Telescope Sky Survey

Abdo, A. A. et al. 2009, Ap J *submitted*, arXiv: [0902.1559]

LAT High Confidence Bright Source list

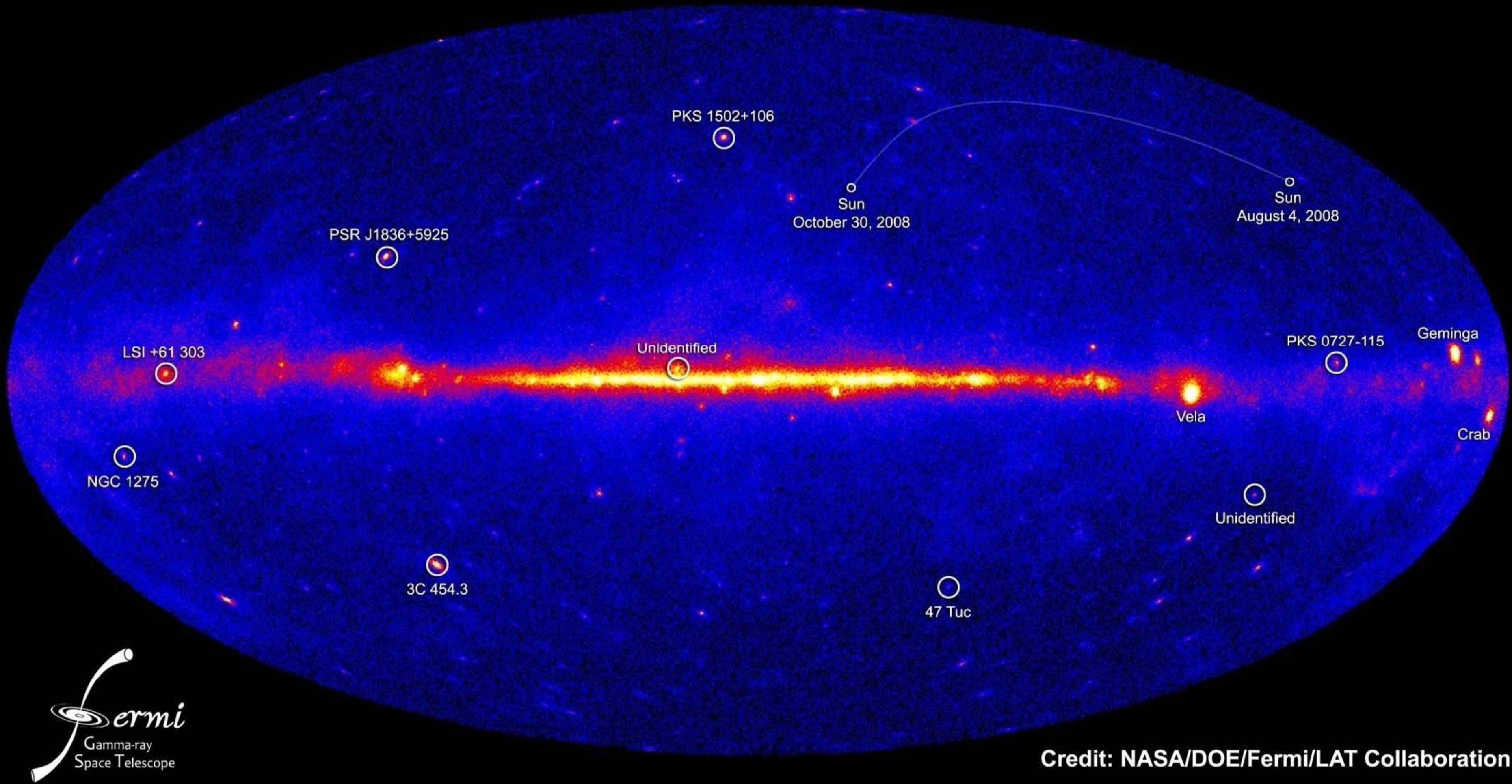
3 months LAT data - 2.8M selected events over 100MeV
206 sources with > 10 σ significance
only 60 associated with EGRET sources – variability!



arXiv:0902.1340v1
[astro-ph.HE] 8 Feb 2009

NASA's Fermi telescope reveals best-ever view of the gamma-ray sky

11-3-2009



5 top sources within our Galaxy
- the quiet sun (moving in the map)
- LSI +61 303 - a high-mass X-ray binary
- PSR J1836+5925 – a gamma-ray-only pulsar
- 47 Tucanae – a globular cluster of stars
- unidentified, new and variable, 0FGL J1813.5-1248

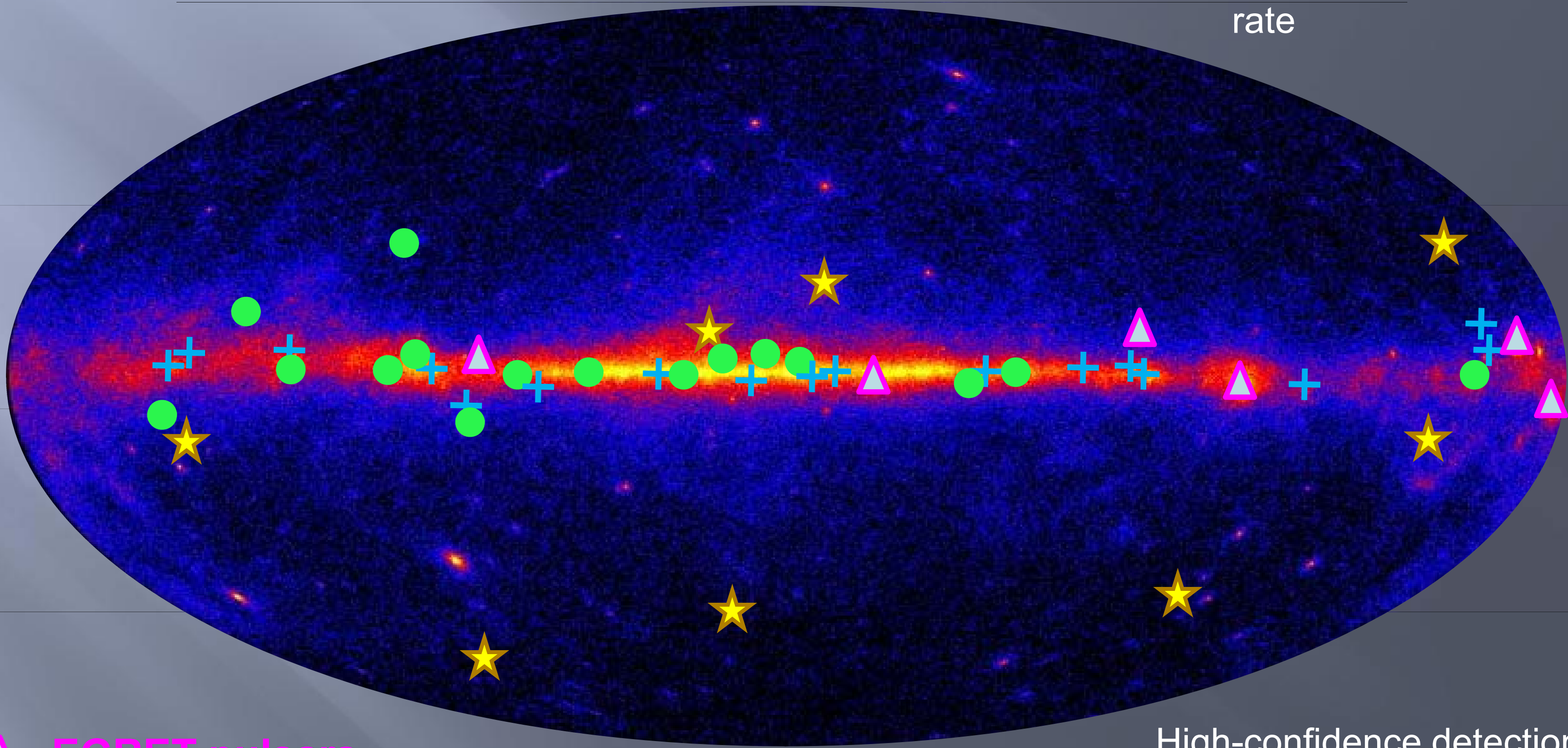
5 top sources beyond our Galaxy
- NGC 1275 – the Perseus A galaxy
- 3C 454.3 – a wildly flaring blazar
- PKS 1502+106 – a flaring 10.1 billion ly away blazar
- PKS 0727-115 – a quasar
- unidentified known, 0FGL J0614.3-3330

Fermi Pulsars

31 gamma-ray and radio pulsars (including 8 ms psrs)

16 gamma-ray only pulsars

Pulses at 1/10th real rate



△ EGRET pulsars

+ young pulsars discovered using radio ephemeris

● pulsars discovered in blind search

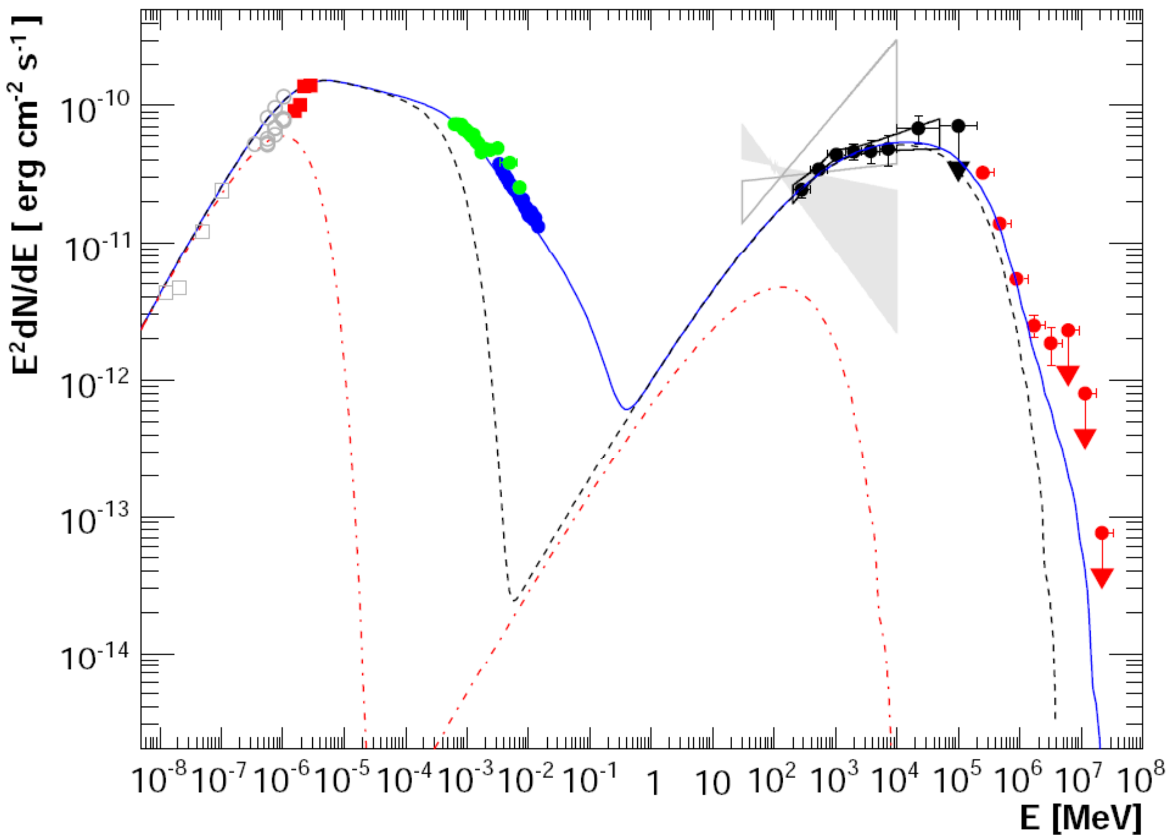
★ millisecond pulsars discovered using radio ephemeris

High-confidence detections through 2/28/2009

Spectral Coverage

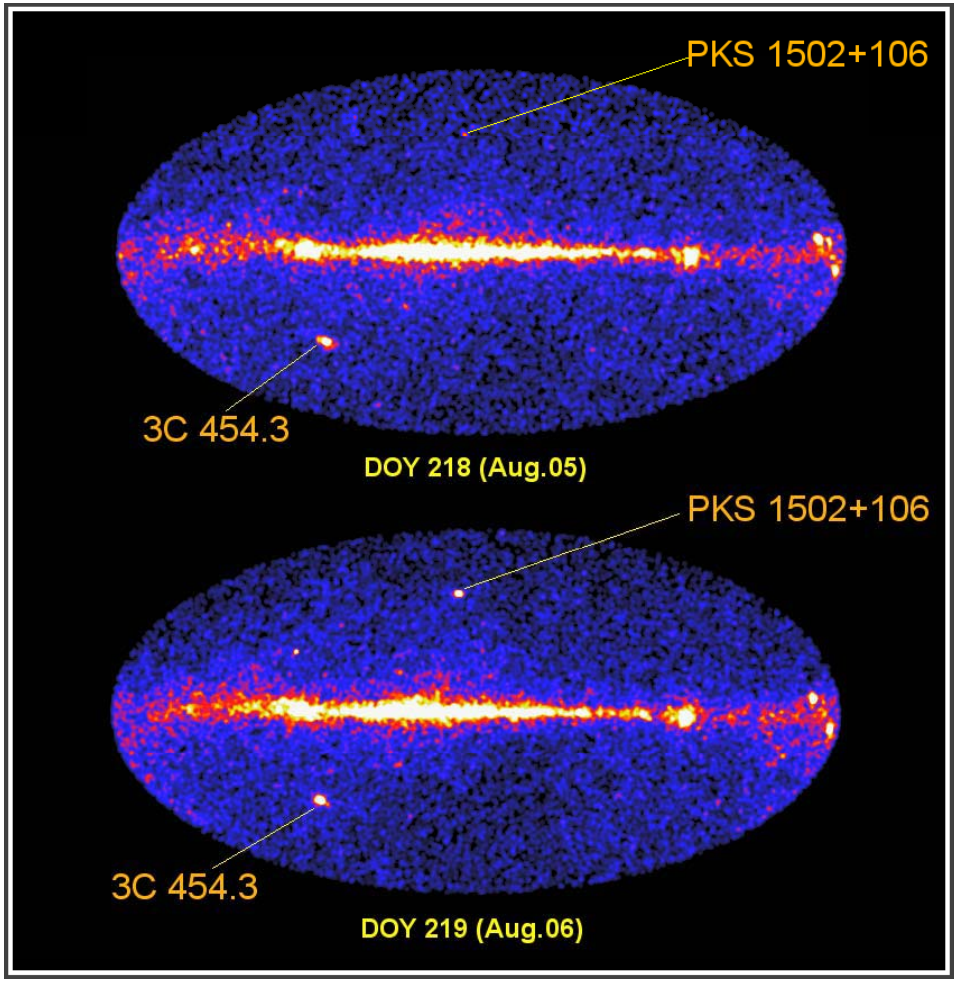
LAT energy range is very broad (20 MeV - 300 GeV), includes the largely unexplored range between 10 and 100 GeV

Allows ground-based TeV data to be combined with the space-based GeV data



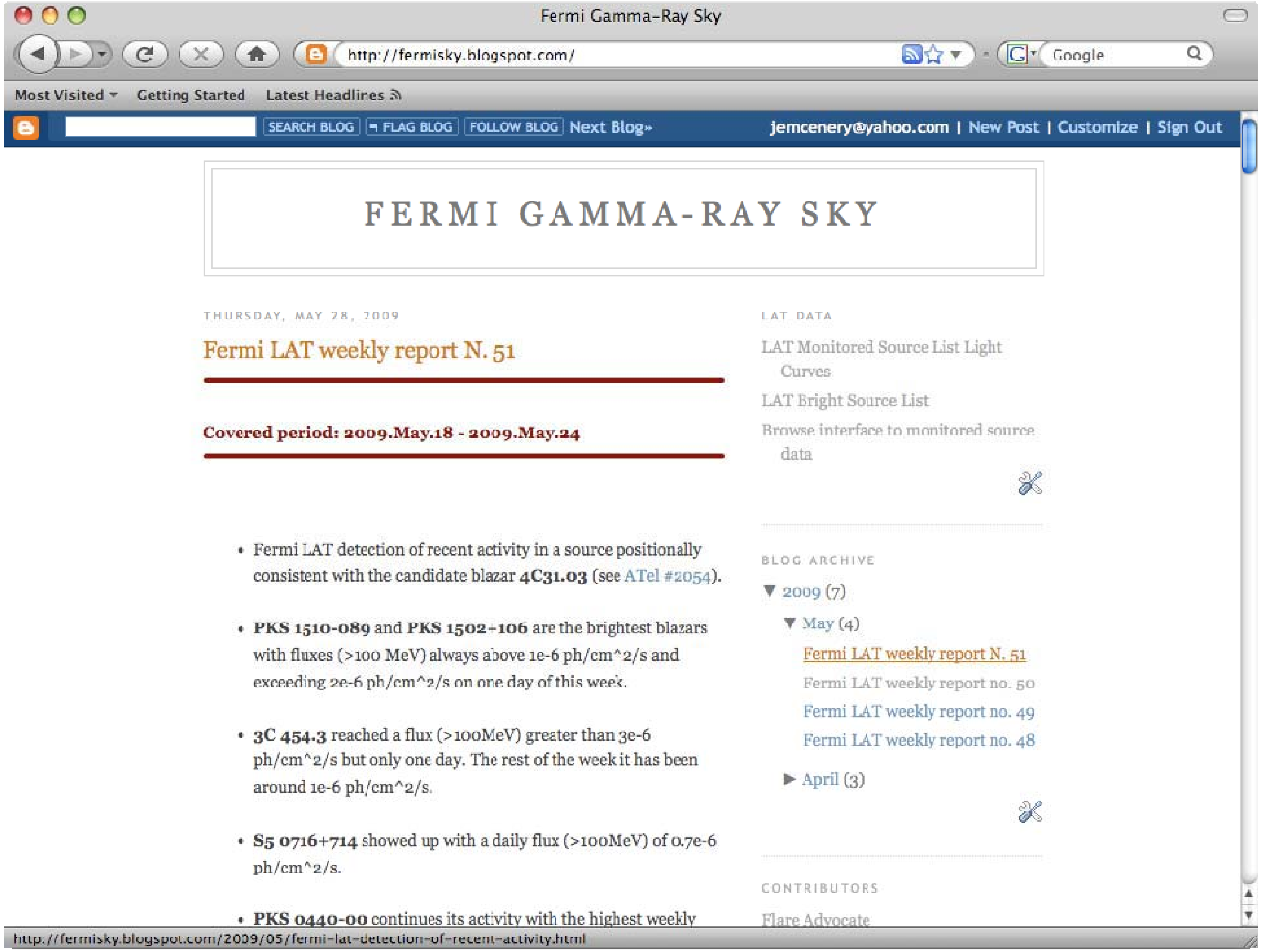
SED for PKS 2155-304

The flaring and variable sky



- **Automated search for flaring sources on 6 hour, 1 day and 1 week timescales.**
- **29 Astronomers telegrams**
  - **Discovery of new gamma-ray blazars PKS 1502+106, PKS 1454-354**
  - **Flares from known gamma-ray blazars: 3C454.3, PKS 1510-089,3C273, AO 0235+164, PSK 0208-512, 3C66A, PKS 0537-441**
  - **Galactic plane transients: J0910-5041, 3EG J0903-3531**

The Fermi Sky Blog



Fermi Sees Most Extreme Gamma-ray Blast Yet

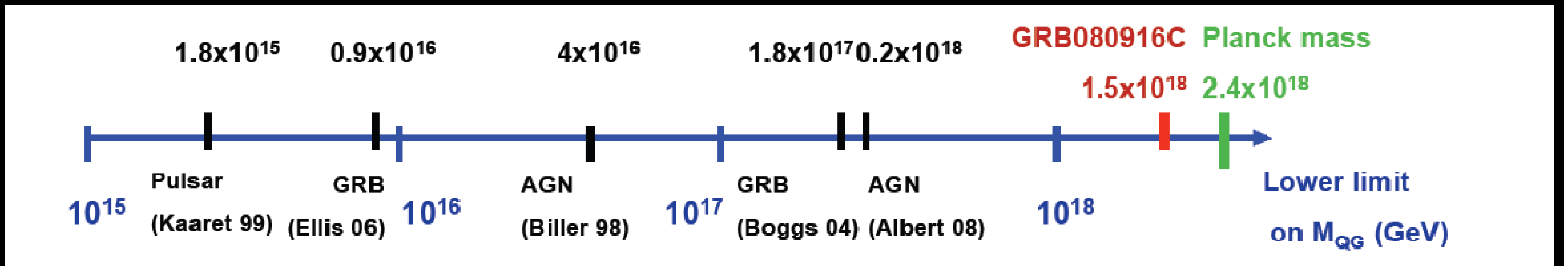
located at 12B light years from us using observations of optical afterglow by the GROND observatory

The first burst to be seen in high-res by the Fermi telescope had the greatest total energy, the fastest motions and the highest-energy initial emissions ever seen

19-2-2009

GRB080916C
Large fluence (2.4×10^{-4} erg/cm^2)
& redshift ($z = 4.35 \pm 0.15$)
$\Rightarrow$ record breaking

- $E_{\gamma,iso} \approx 8.8\times10^{54}$ erg $\approx 4.9\ M_{\odot}c^2$
- $\Gamma_{min} \approx 890 \pm 20$
- $M_{QG} > 1.5 \times 10^{18}$ (GeV)



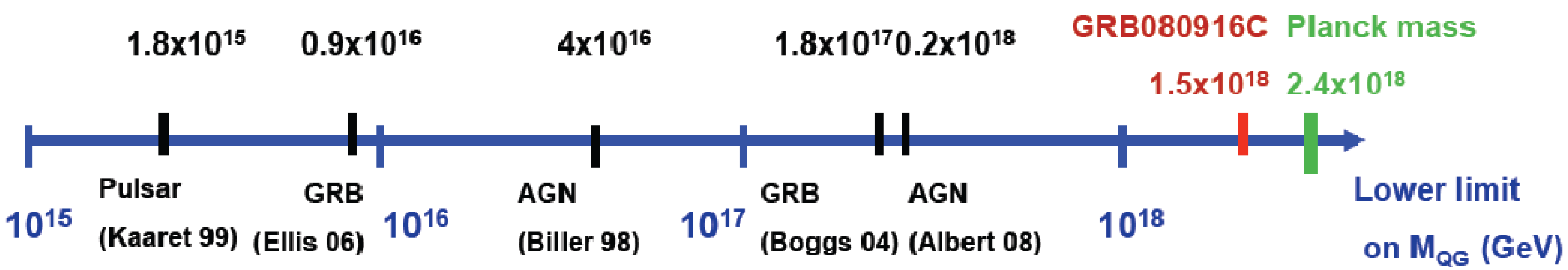
Fermi sets a new constraint on the QG energy scale

- Some QG models postulate violation of Lorentz invariance: $v_\gamma(E_\gamma) \neq c$ (G. Amelino-Camelia, 1998)
- A high-energy photon E_h would arrive after (or possibly before in some models) a low-energy photon E_l emitted simultaneously (J. Ellis et al, 2008, Jacob & Piran, 2008)

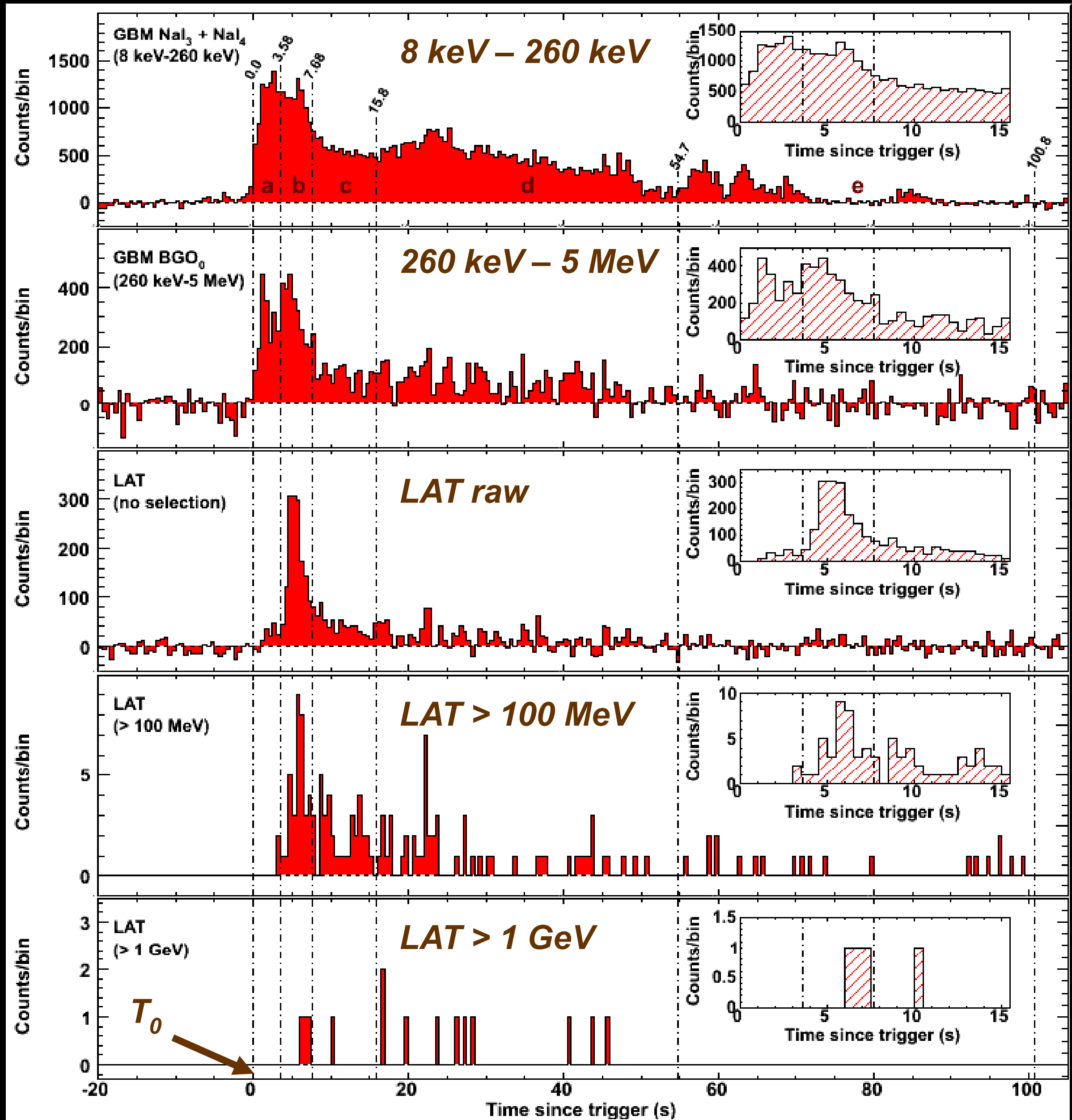
$$\Delta t = \frac{(1+n)}{2H_0} \frac{E_h^n - E_l^n}{(M_{QG,n}c^2)^n} \int_0^z \frac{(1+z')^n}{\sqrt{\Omega_m(1+z')^3 + \Omega_\Lambda}} dz'$$

- GRB080916C: highest energy photon (13 GeV) arrived 16.5 s after low-energy photons started arriving (= the GRB trigger)

➢ a conservative lower limit: $M_{QG,1} > (1.50 \pm 0.20) \times 10^{18}$ GeV/c^2



GRB 080916C - LAT and GBM light curves



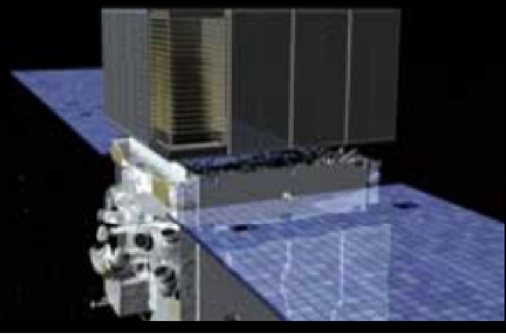
- For the first time, can study time structure > tens of MeV, 14 events above 1 GeV
- First low-energy GBM peak is not observed at LAT energies
- z = 4.35 +/0.15
- High energy emission delayed
- The bulk of the emission of the 2nd peak is moving toward later times as the energy increases
- Clear signature of spectral evolution

Science Express,
19 Feb 2009, pg 1

The electron spectrum

NASA's Fermi Explores High-energy *Space Invaders*

Since its launch last June, NASA's Fermi Gamma-ray Space Telescope has discovered a new class of pulsars, probed gamma-ray bursts and watched flaring jets in galaxies billions of light-years away. Today at the American Physical Society meeting in Denver, Colo., Fermi scientists revealed new details about high-energy particles implicated in a nearby cosmic mystery.



Physics: Cosmic light matter probes heavy dark matter

May 4, 2009

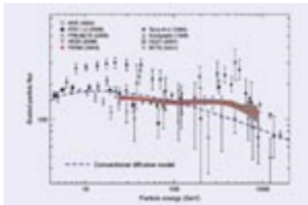
New results from the Fermi Gamma-Ray Space Telescope, the most precise to date in the energy range 20 GeV to 1 TeV, should help resolve whether cosmic rays composed of the lightest charged particles, i.e., electrons and positrons, come from dark matter or some other astrophysical source.

[Viewpoint on Phys. Rev. Lett. **102,** 181101 (2009)]

CERN COURIER

Jun 8, 2009

Fermi measures the spectrum of cosmic-ray electrons and positrons



Spectrum

The Fermi Gamma-Ray Telescope can find out about more than gamma rays. It has now provided the most accurate measurement of the spectrum of cosmic-ray electrons and positrons. These results are consistent with a single power-law, but visually they suggest an excess emission from about 100 GeV to 1 TeV. The additional source of electrons and positrons could come from nearby pulsars or dark-matter annihilation.

SLAC today

High-energy Electrons Could Come from Pulsars—or Dark Matter

by Michael Wall

Something in our galactic neighborhood seems to be producing large numbers of high-energy electrons, according

An artist's conception of the Fermi Gamma-ray Space Telescope. (Image: NASA.)

Lights Out for Dark Matter Claim?

By Adrian Cho
*Science*NOW Daily News
2 May 2009

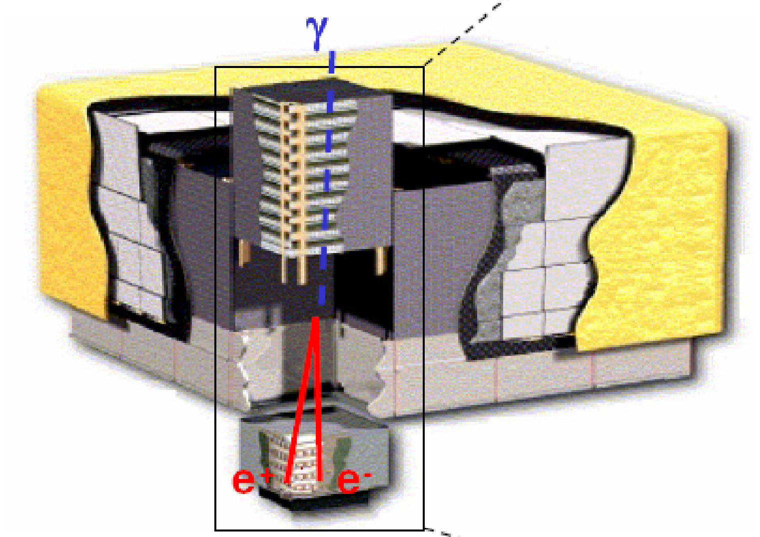
Last November, data from a balloon-borne particle detector circling the South Pole revealed a dramatic excess of high-energy particles from space--a possible sign of dark matter, the mysterious substance whose gravity seems to hold our galaxy together. But satellite data reported today stick a pin in that

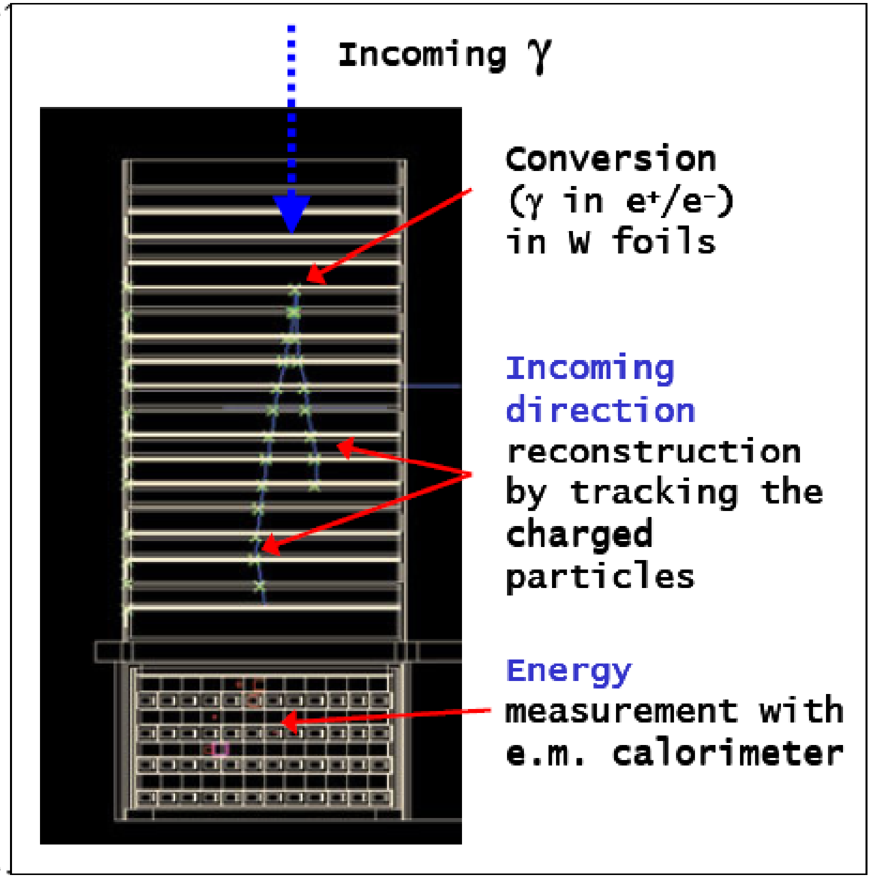
+ Enlarge Image

LAT as Gamma-ray detector

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

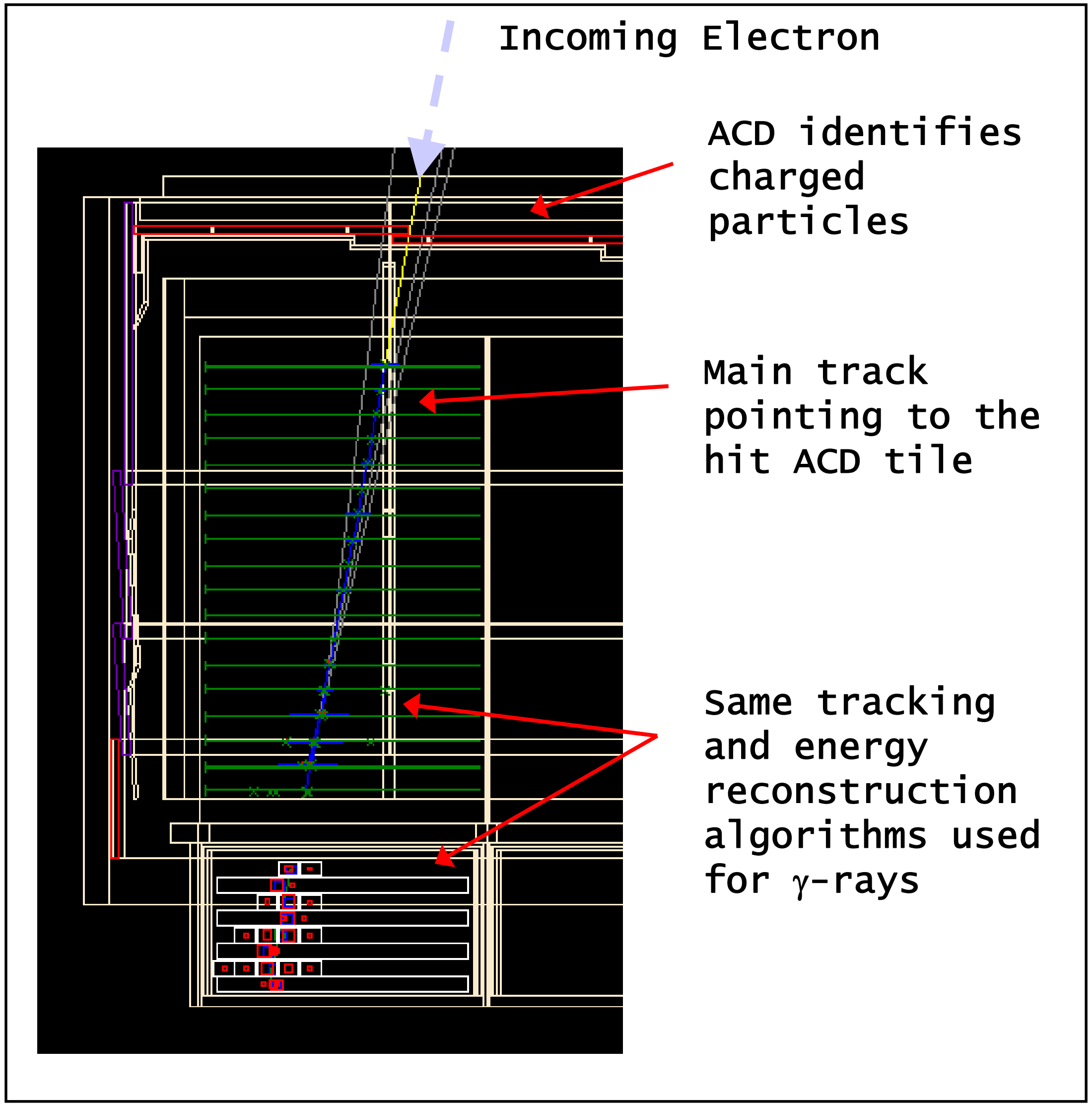
How the LAT detects electrons

Trigger and downlink

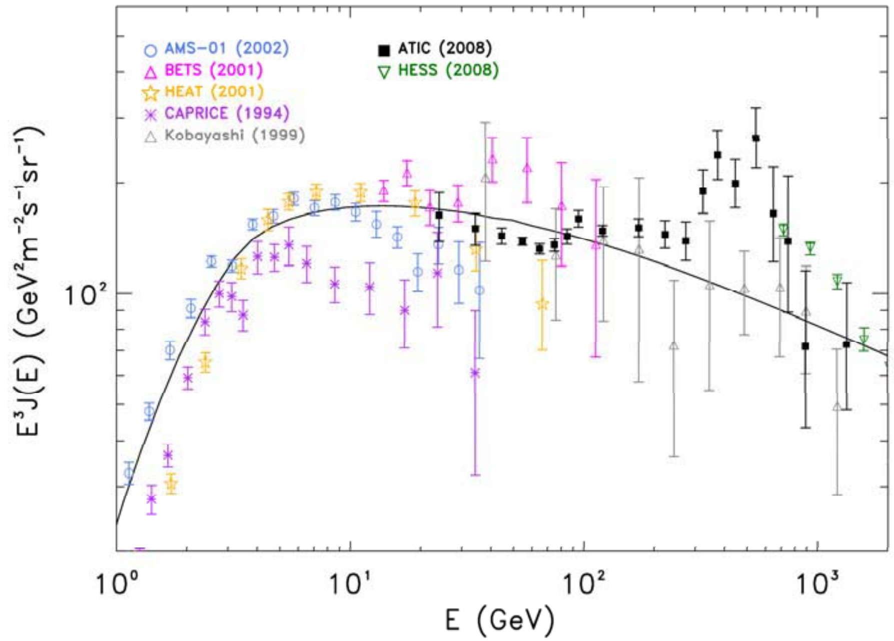
- Very versatile and configurable
  - Triggering on ~ all particles that cross the LAT
    - Including electrons
- On board filtering to fit bandwidth
  - Remove many charged particles
  - Keeps all events with more than 20 GeV in the CAL

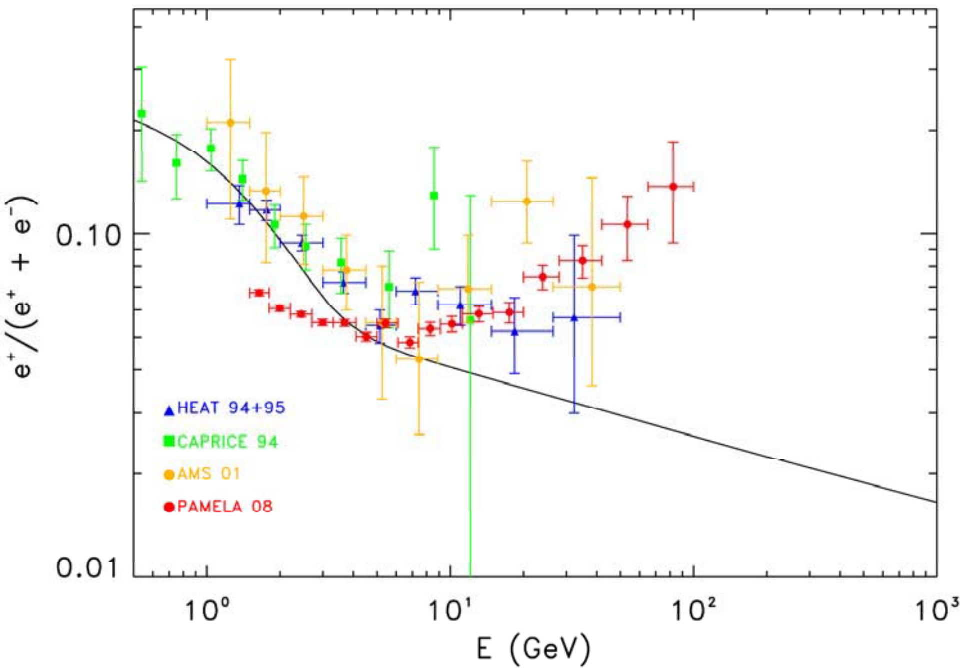
Electron identification

- 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
  - → Dedicated high energy electron event selection



High Energy measurements in 2008

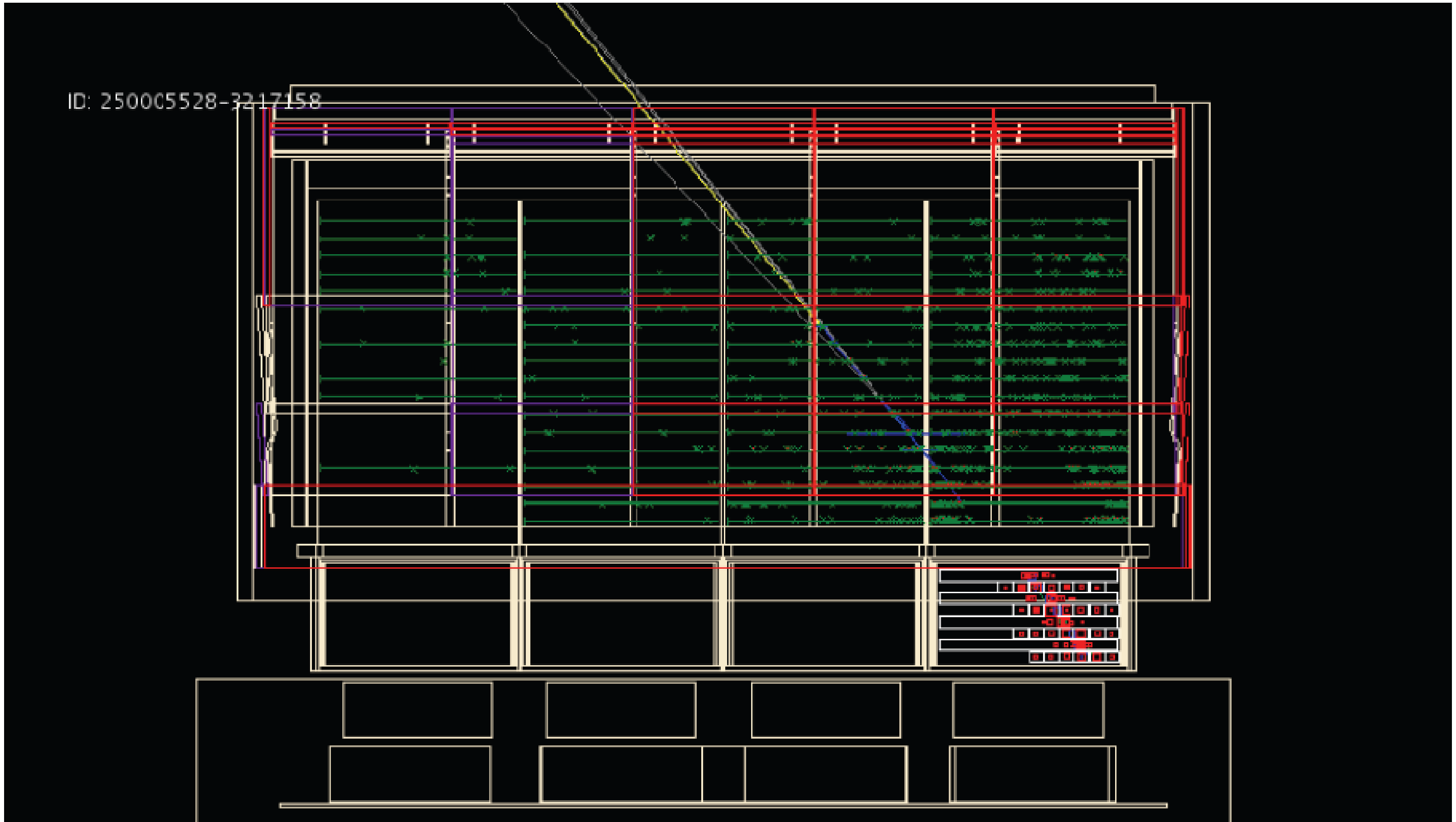




- ❑ **Spectral features in the ($e^+ + e^-$) spectrum**
  - – **possible excess around 600 GeV reported by ATIC and PPB-BETS**
  - – **spectral cutoff measured by H.E.S.S. around 1 TeV**
- ❑ **Pamela reports an increase in the positron fraction**

- ❑ **More than 200 papers in the last year**
- ❑ **Local source of electrons – astrophysical? Dark Matter?**

Astrophysics ⟷ High Energy Physics



CalEnergyRaw
8.228e+05

CTBBestEnergy
1.026e+06

CTBBestEnergyProb
0.146

TkrNumTracks
5

CalCsIRLn
10.9

CTBBestZDir
-0.387

CTBTKRHEEProb
N/A

CTBCALHEEProb
N/A

CalLRmsAsym
0.00419

CalTrSizeTkrT95
1022.6

CalTransRms
34.4

Tkr1CoreHC
1

Tkr1Hits
6

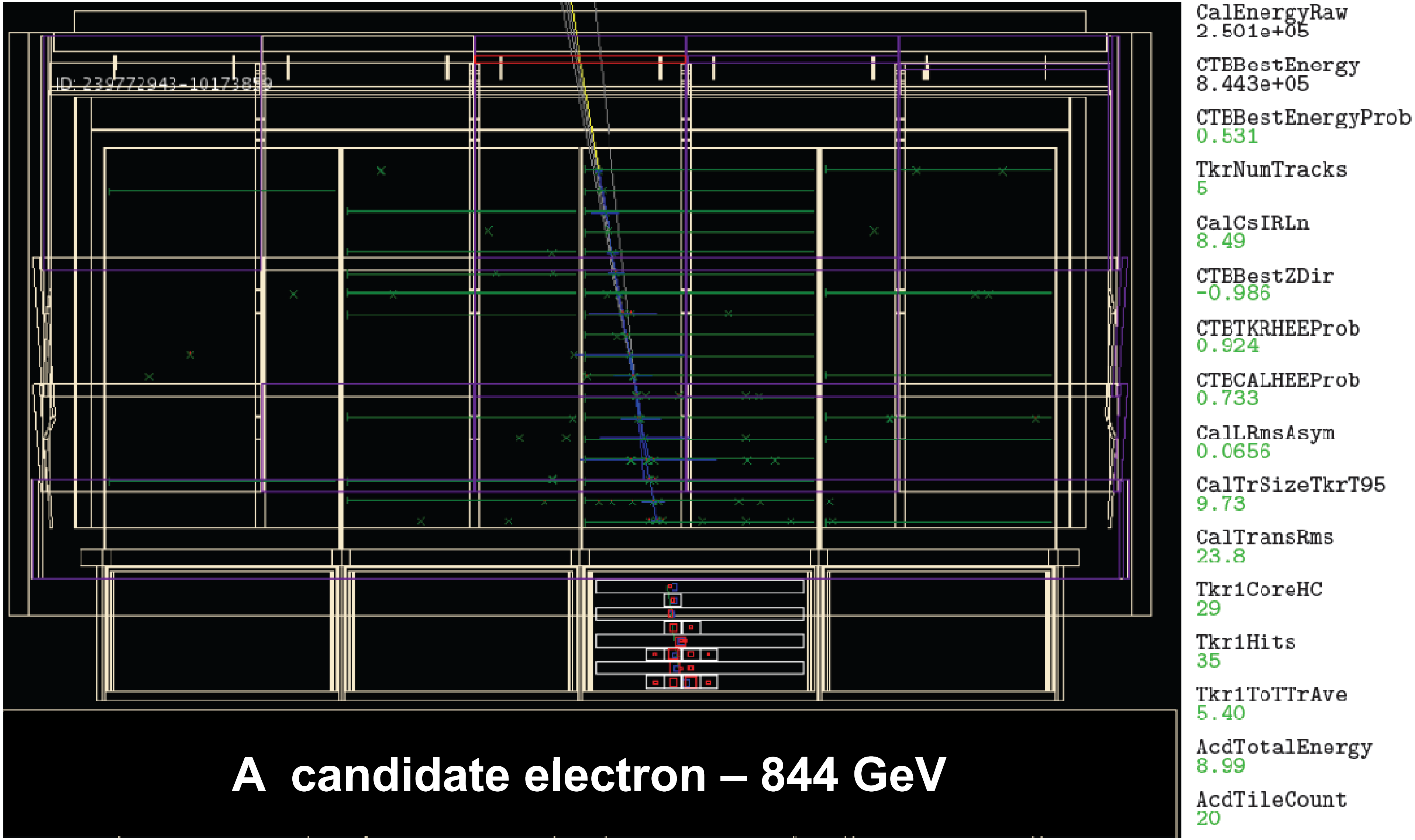
Tkr1ToTTrAve
0

AcdTotalEnergy
660.7

AcdTileCount
65

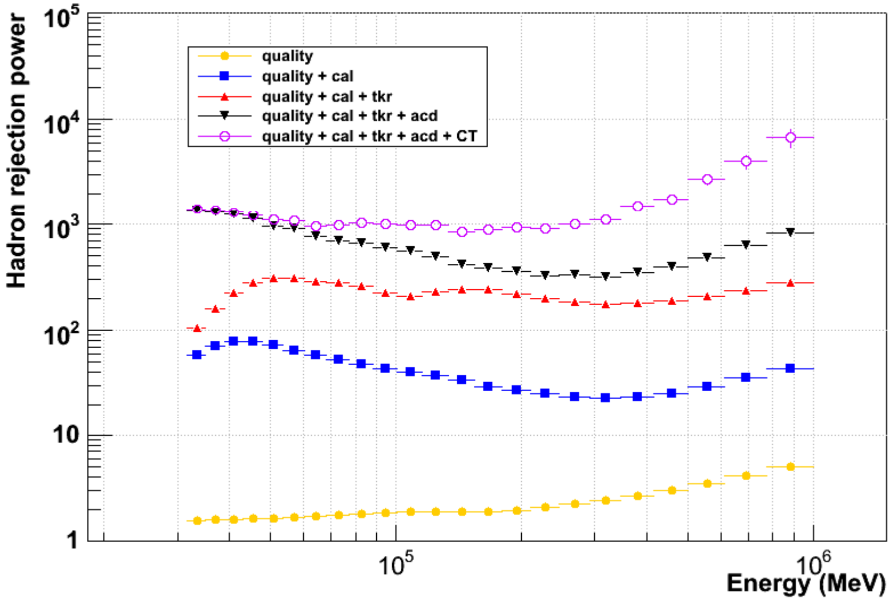
A candidate hadron event – raw energy > 800 GeV

- **ACD: large energy deposit per tile**
- **TKR: small number of extra clusters around main track, large number of clusters away from the track**
- **CAL: large shower size, low probability of good energy reconstruction**



- **ACD: few hits in conjunction with track**
- **TKR: single clean track, extra clusters around main track clusters (preshower)**
- **CAL: clean EM shower not fully contained in CAL**

LAT Electron performance



- Performance is a trade-off among:
  - electron-acceptance – hadron contamination - systematics
- Geometry factor
  - ~ 3 m^2sr (50 GeV) to ~ 1 m^2sr (1 TeV)
  - > 10x wrt previous experiments
- Rejection power: ~ 1:10^3 (20 GeV) to ~ 1:10^4 (1 TeV)
- Maximum residual contamination ~ 20% (1 TeV)
- Maximum systematic uncertainty ~ 20% (1 TeV)

GLAST tests at CERN – summer 2006

Particle	Energy
γ	0-2.5 GeV
e-	1, 5,10,20,50,100,200,280 GeV
e+	1GeV (through MMS target)
p	6, 10GeV (also through MMS), 20,100 GeV
π	20GeV
C, Xe	1, 1.5GeV/n, + Xe on target

330 configurations

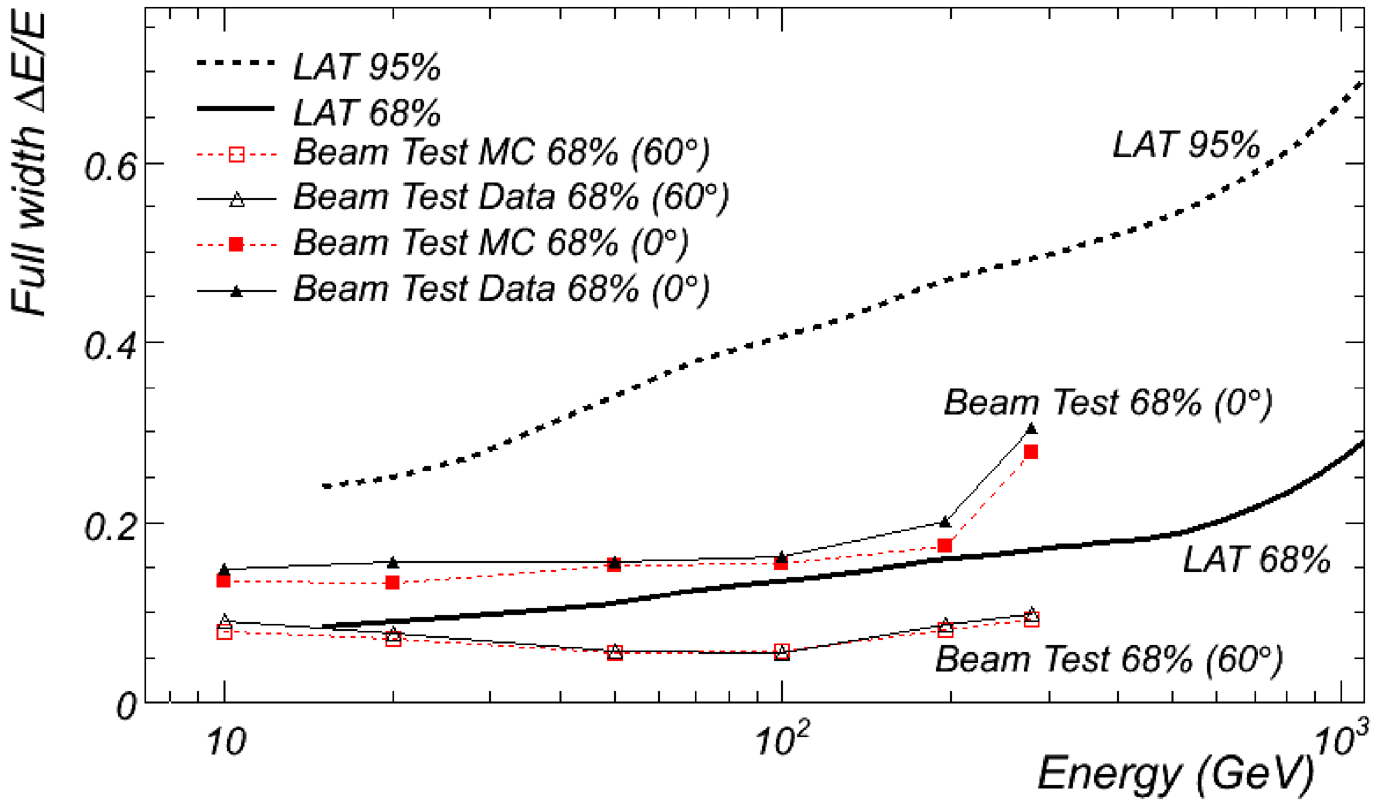
- Incoming angle
- impact point
- Rate
- CU register configurations

1800 runs

100M evts

4 weeks at PS/T9
11 days at SPS/H4
1 week at GSI
60 active people

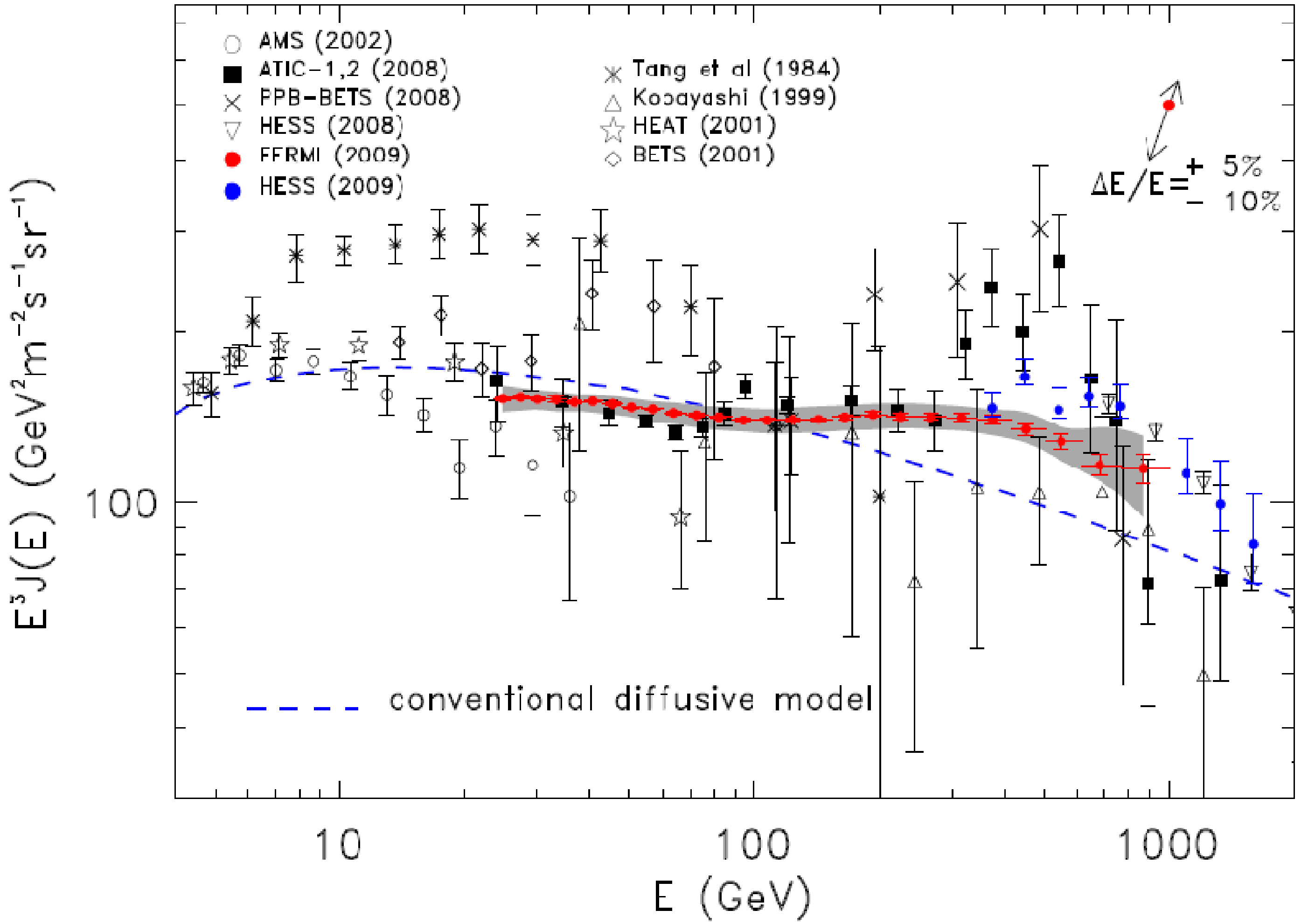
Double check your Energy resolution



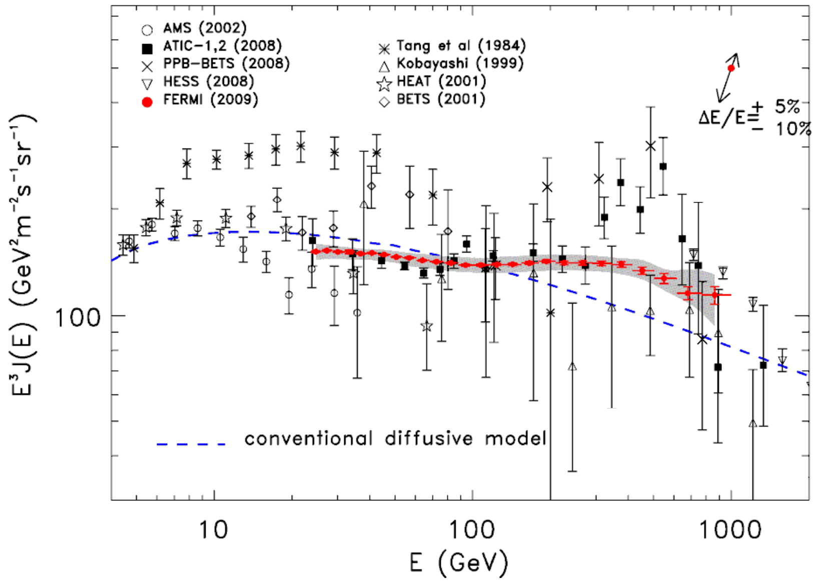
- Resolution integrated over all angles (*i.e. what we measure*)
  - Average material traversed by selected events is 12.5X0 (TKR+CAL sheer thickness + selection effects)
- Validated with BT data up to maximum available beam energies (300GeV, CERN-H4)

Selected for a Viewpoint in *Physics*
PRL **102,** 181101 (2009) PHYSICAL REVIEW LETTERS week ending 8 MAY 2009

Measurement of the Cosmic Ray $e^+ + e^-$ Spectrum from 20 GeV to 1 TeV with the Fermi Large Area Telescope



The Fermi-LAT CRE Spectrum



Energy (GeV)	GF (m^2sr)	Residual contamination	Counts
...	...	...	...
291–346	2.04	0.18	7207
346–415	1.88	0.18	4843
415–503	1.73	0.19	3036
503–615	1.54	0.20	1839
615–772	1.26	0.21	1039
772–1000	0.88	0.21	544

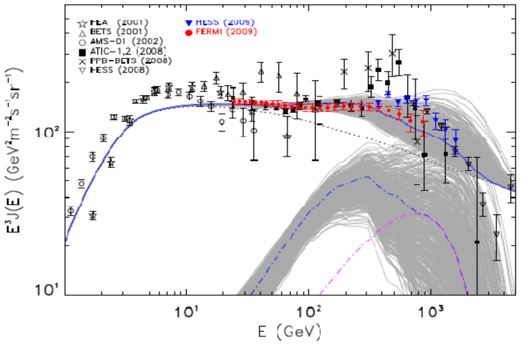
More than 400 electrons in the last energy bin 772-1000 GeV

- **High statistics 4.5M events in 6 months**
  - **systematics dominate but small wrt existing literature**
- **Not compatible with pre-Fermi diffusive model**
  - **E^{-3} versus $E^{-3.3}$**
- **No evidence of the dramatic ATIC spectral feature**
  - **Conservative statistical+systematic error allow good fit with a simple power law**

Some possible interpretations

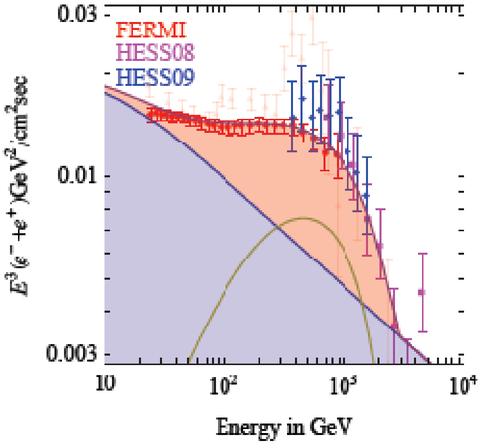
- Several papers already published to explain electron spectrum
  - Together with other observations (positron fraction, diffuse γ-ray)

Pulsars



Grasso et al. 2009

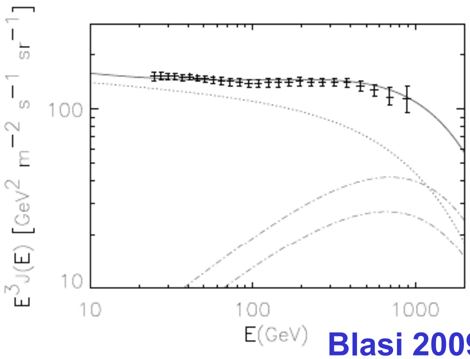
Dark Matter



Meade et al. 2009

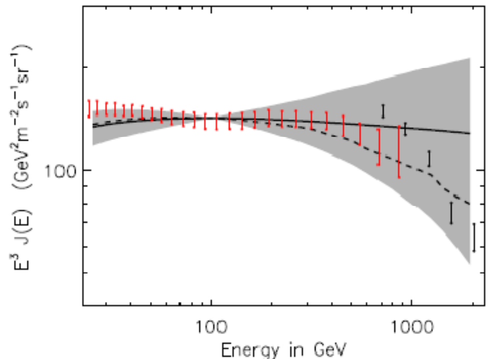
57 citations so far,
~ > 1/day

Secondary CR acc.



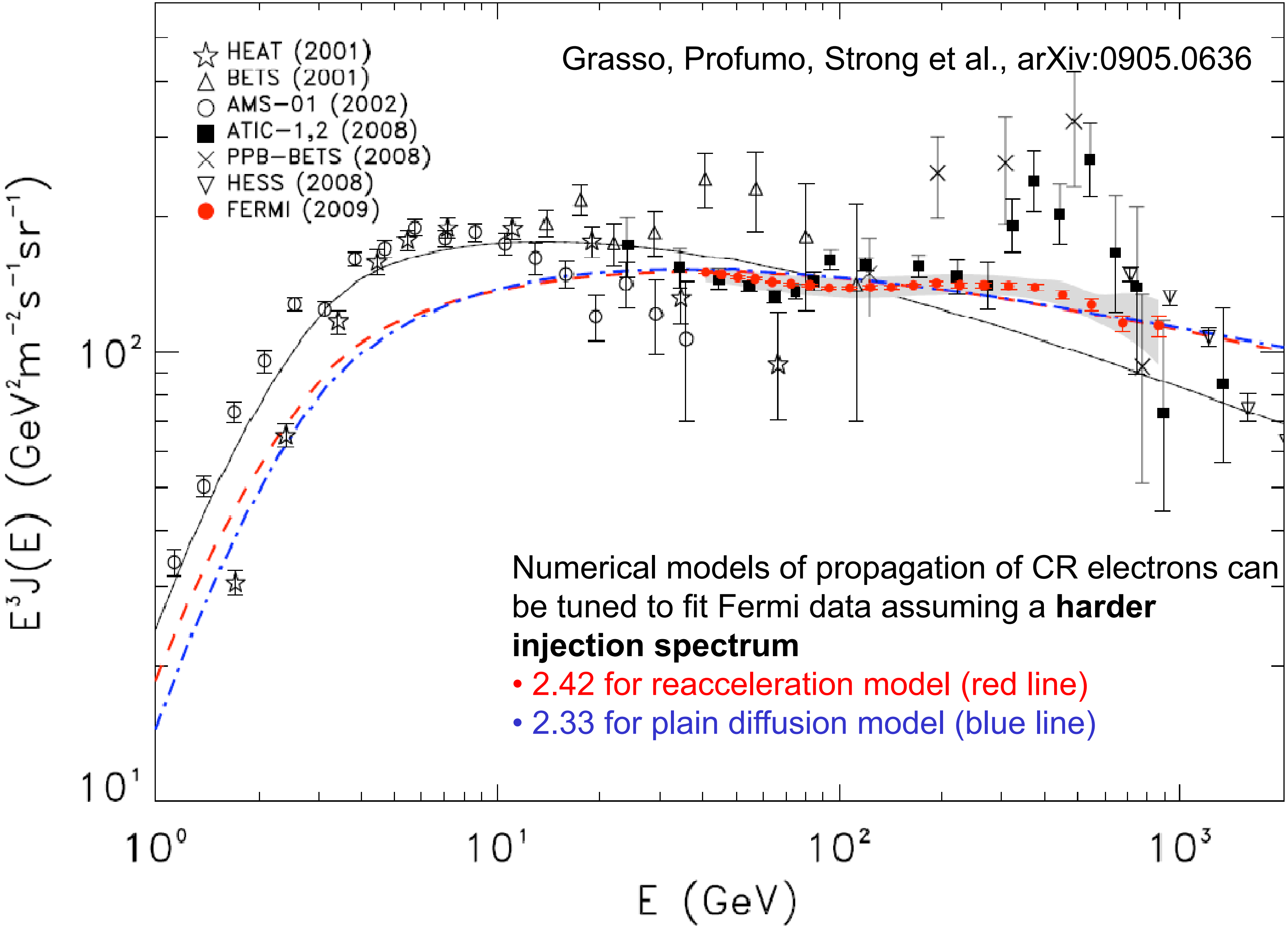
Blasi 2009

Source stocasticity



Grasso et al. 2009

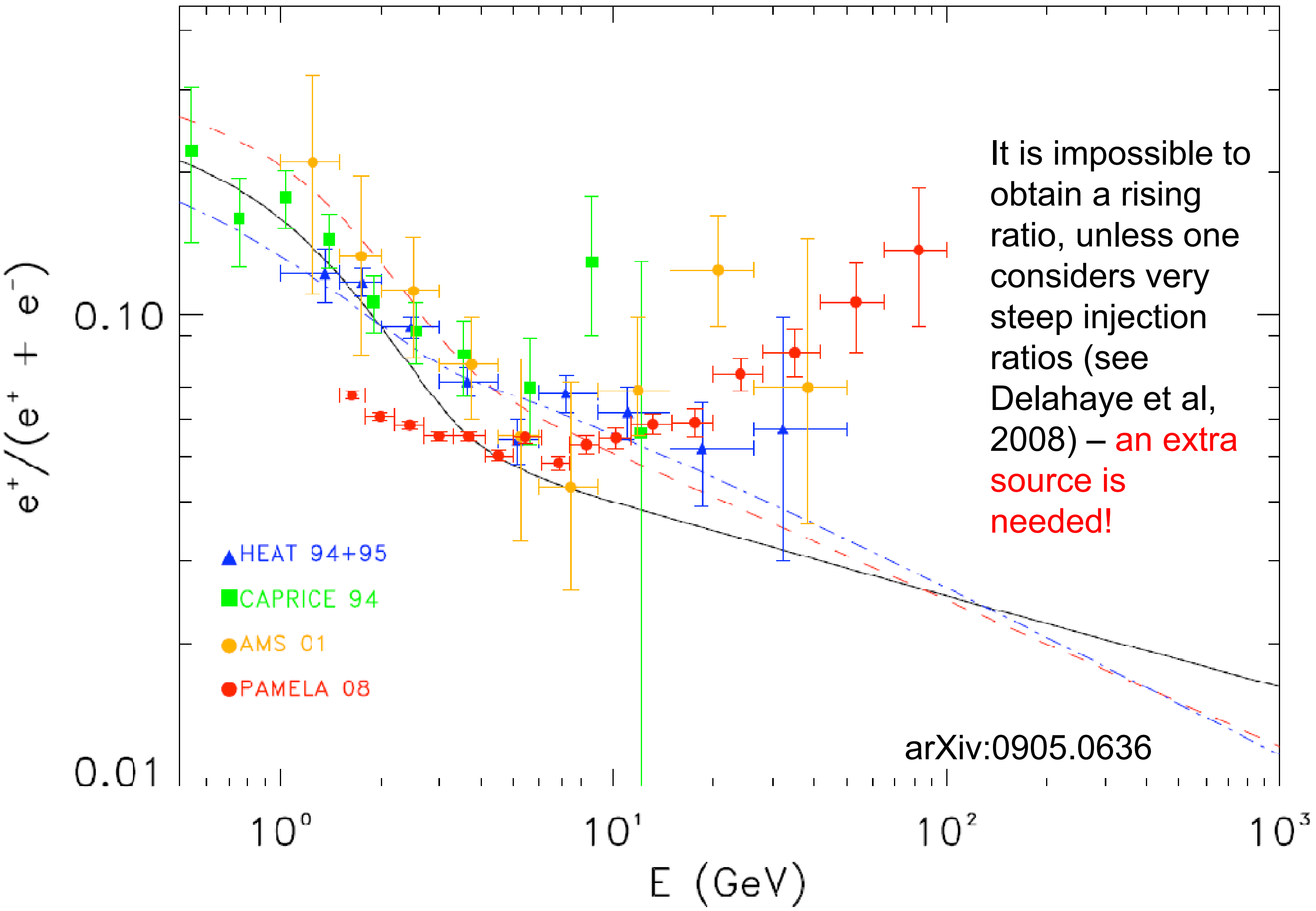
A possible "conservative" interpretation



Numerical models of propagation of CR electrons can be tuned to fit Fermi data assuming a **harder injection spectrum**

- 2.42 for reacceleration model (red line)
- 2.33 for plain diffusion model (blue line)

… does not work for Pamela data



It is impossible to obtain a rising ratio, unless one considers very steep injection ratios (see Delahaye et al, 2008) – an extra source is needed!

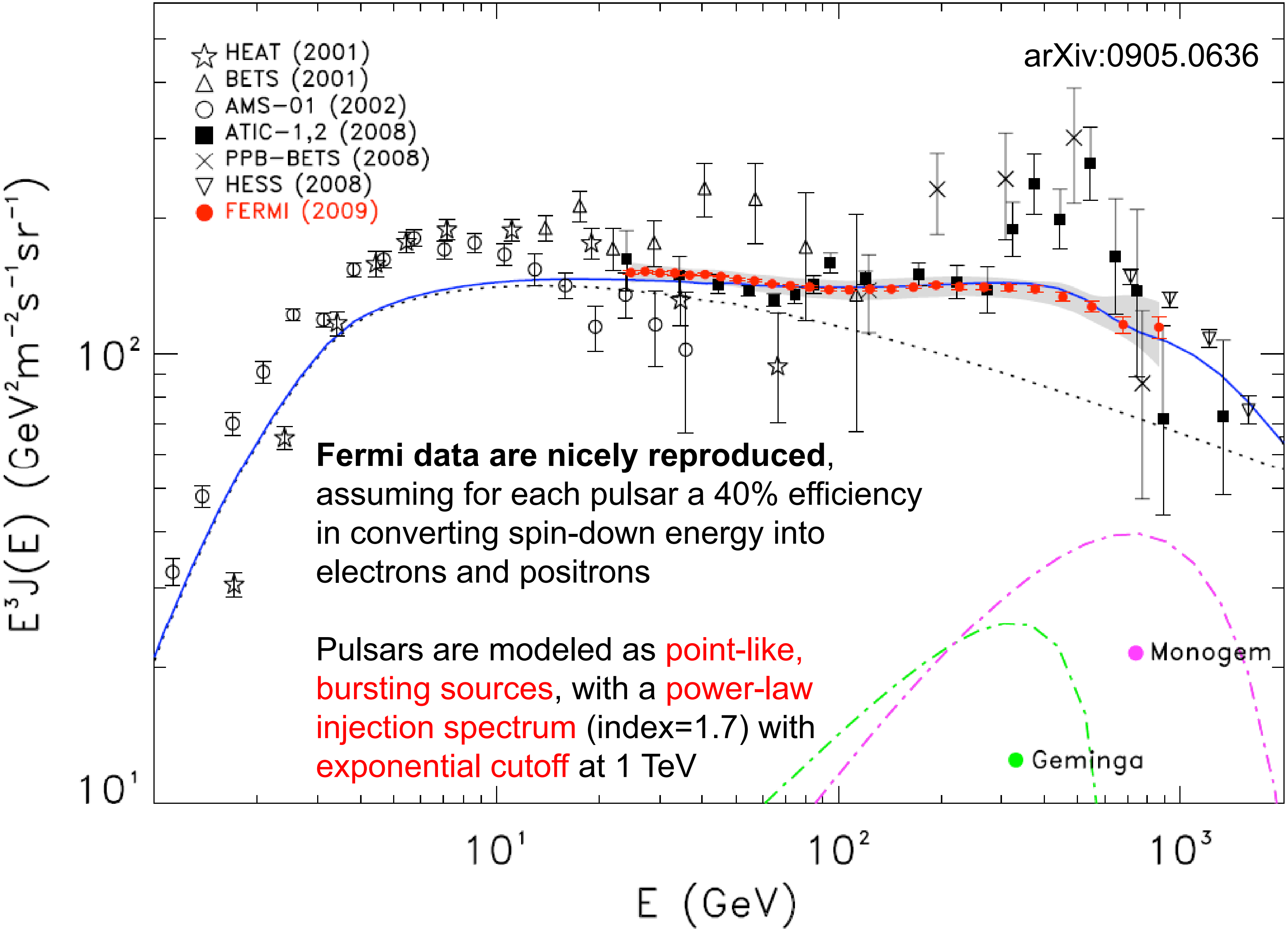
The possible role of nearby pulsars

Pulsars are candidate sources of relativistic electrons and positrons (see e.g. Shen 1970, Harding & Ramaty 1987)

- e+/e- pairs believed to be produced in the magnetosphere and re-accelerated in the wind

1. Characteristics needed to explain Fermi/Pamela excesses wrt conventional models
   - Nearby, because of synchrotron energy losses
   - Mature, because electrons remain confined in the PWN until it merges with the ISM
   - But not too old, because old electrons are already diluted in space
2. Considering distributions of pulsars from the ATNF catalog
   - With d<3kpc with age 5×10^4 yr < Y < 10^7 yr
     - Injection index, cutoff energy, e+/e- conversion efficiency, delay between pulsar birth and electron release
   - Create different possible summed contributions of all pulsars

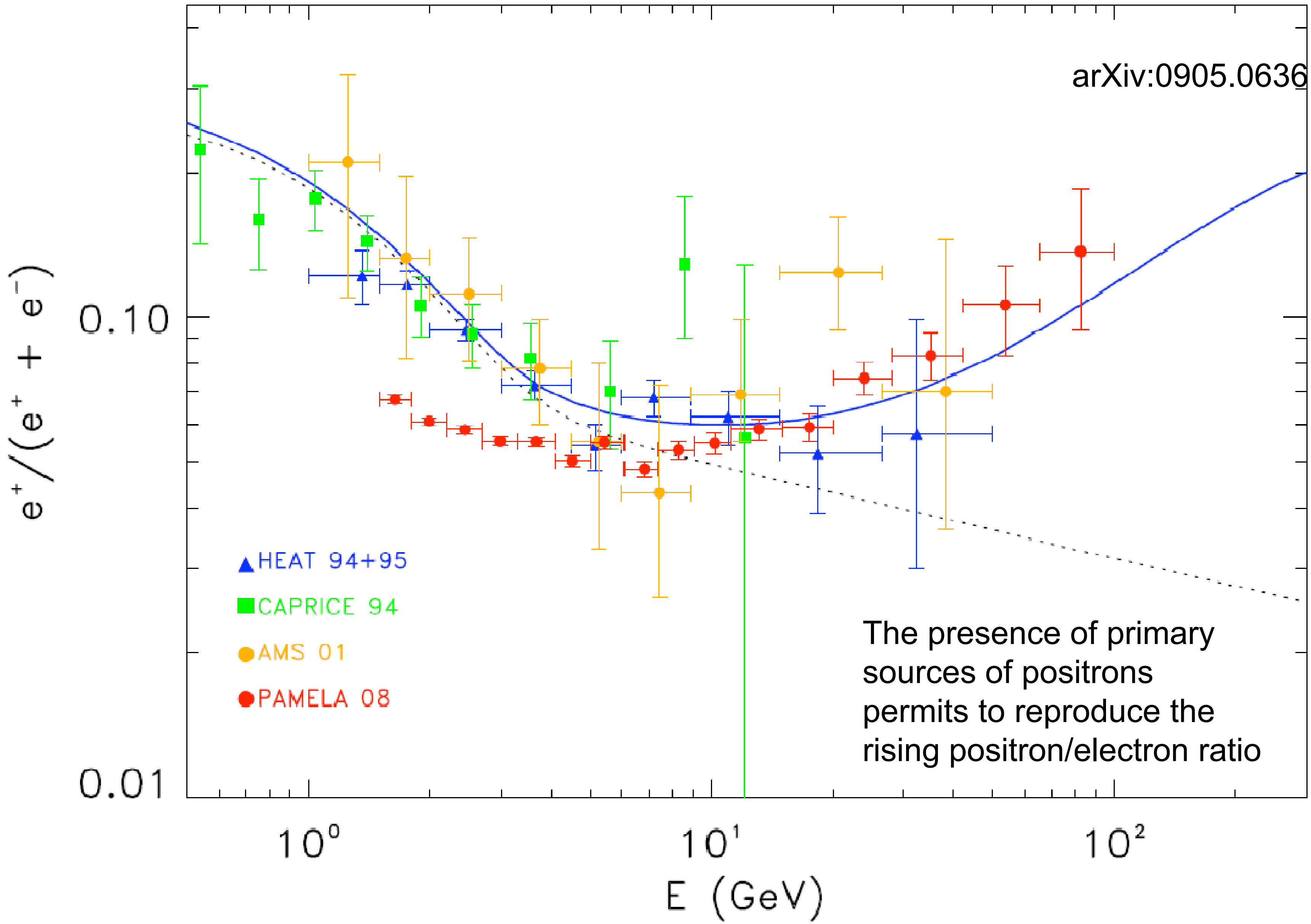
Adding candidate pulsars within 1Kpc



Fermi data are nicely reproduced, assuming for each pulsar a 40% efficiency in converting spin-down energy into electrons and positrons

Pulsars are modeled as point-like, bursting sources, with a power-law injection spectrum (index=1.7) with exponential cutoff at 1 TeV

works for Pamela too



Dark matter: the impact of the new **Fermi** CRE data

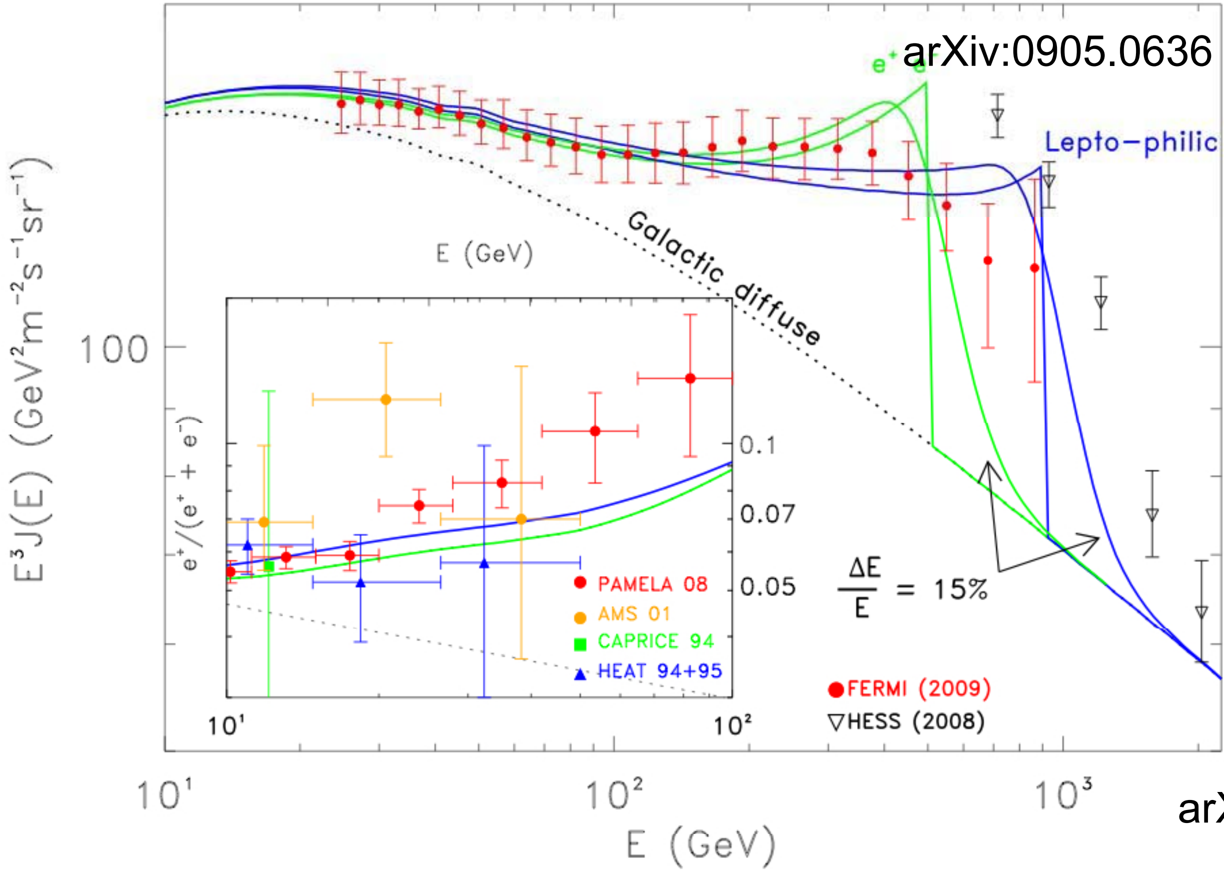
1. Much weaker rationale to postulate a **low DM mass** in the 0.3-1 TeV range ("**ATIC bump**") motivated by the CR electron+positron spectrum

2. If the Pamela positron excess is from DM annihilation or decay, Fermi CRE data set **stringent constraints** on such interpretation

3. Even neglecting Pamela, Fermi CRE data are useful to put **limits** on rates for particle **DM annihilation** or **decay**

4. We find that a **DM interpretation** to the **Pamela** positron fraction data consistent with the new **Fermi-LAT** CRE is a **viable** possibility

A possible DM interpretation

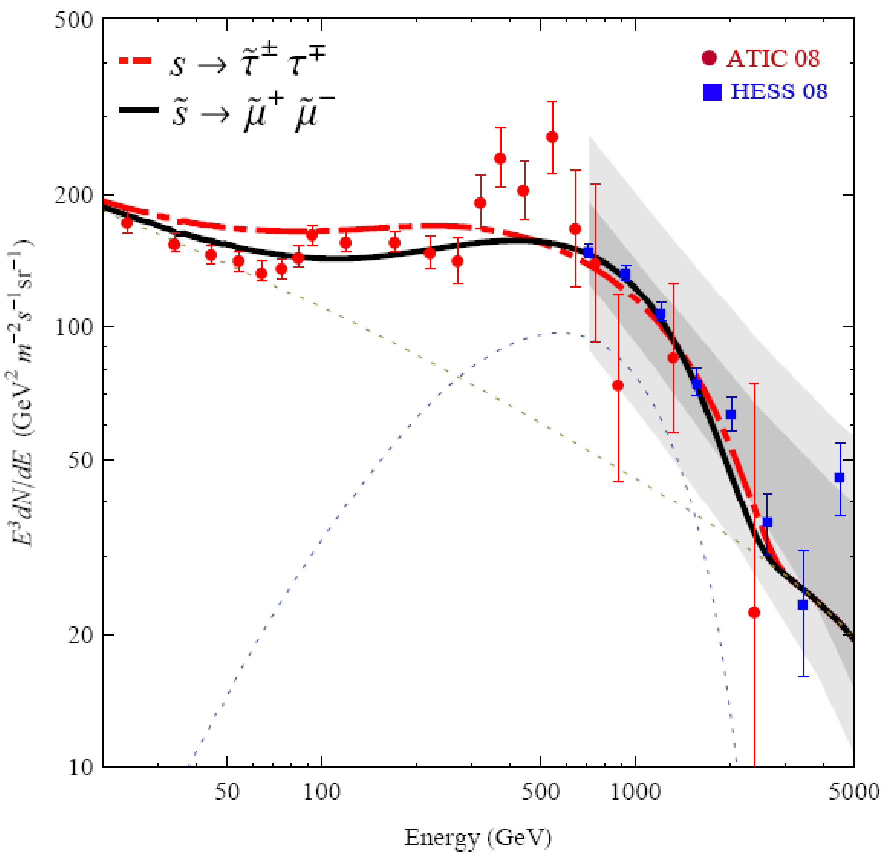


arXiv:0905.0636

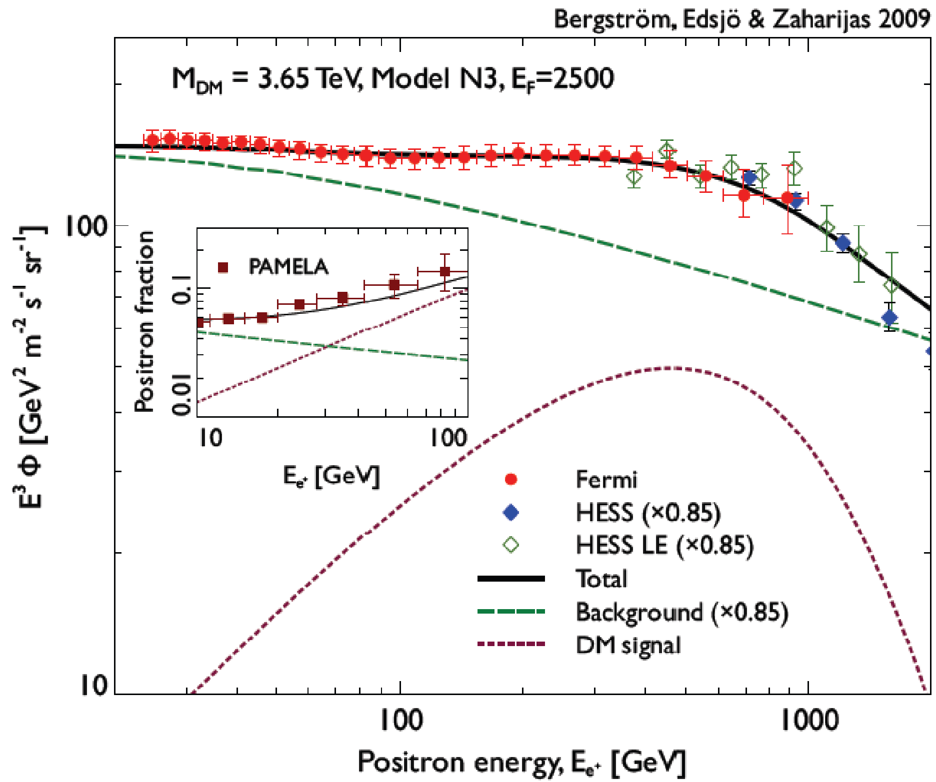
Best fit models among two classes

- **e+/e- model: DM annihilation into light gauge boson decaying into e+/e-**
- **Lepto-philic: annihilation into charged lepton species**

Dark Matter Annihilation and Decay Models

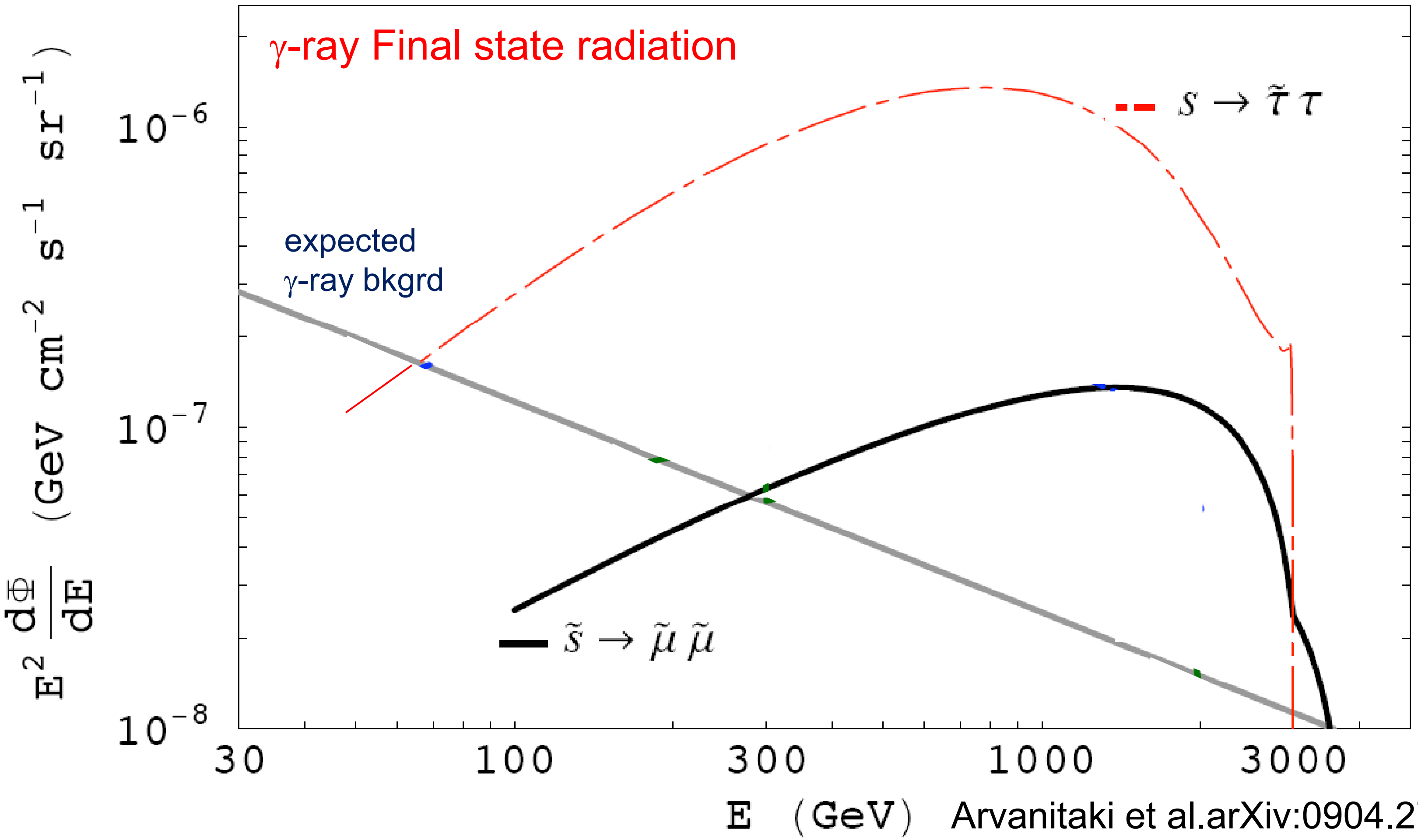


Arvanitaki et arXiv:0904.2789v2
Decaying SUSY dark matter



Bergstrom et al.arXiv:0905.0333v1
Annihilating DM

Fermi could look for signature in the diffuse gamma-ray

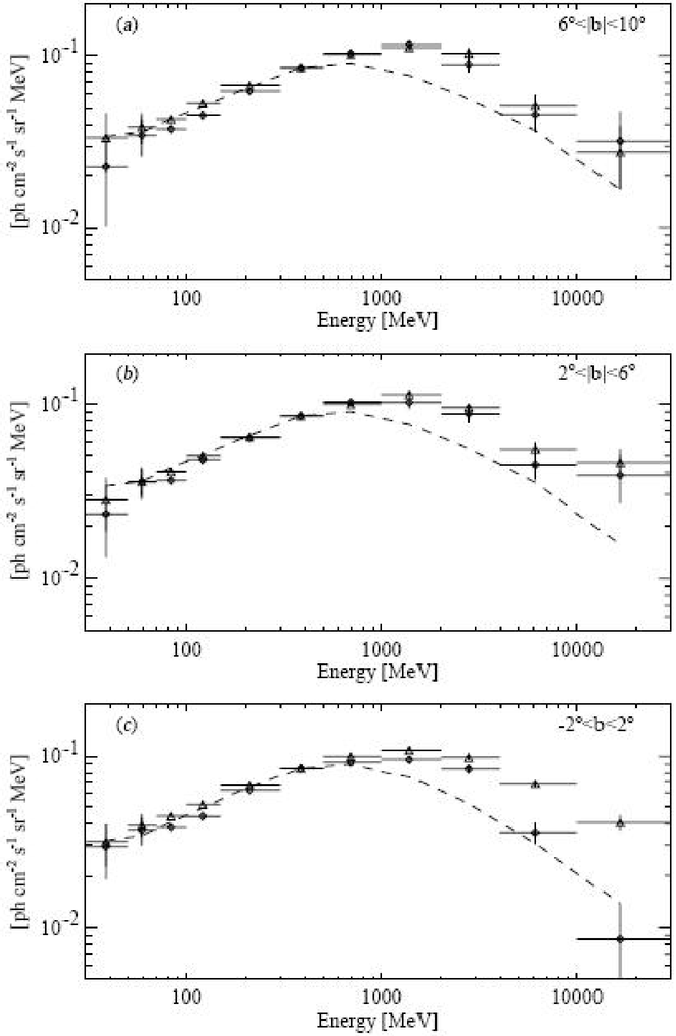


Arvanitaki et al.arXiv:0904.2789v2
Decaying SUSY dark matter

…. expect to see lots of papers about both astrophysical and DM interpretations in the near future

EGRET Legacy: GeV Excess

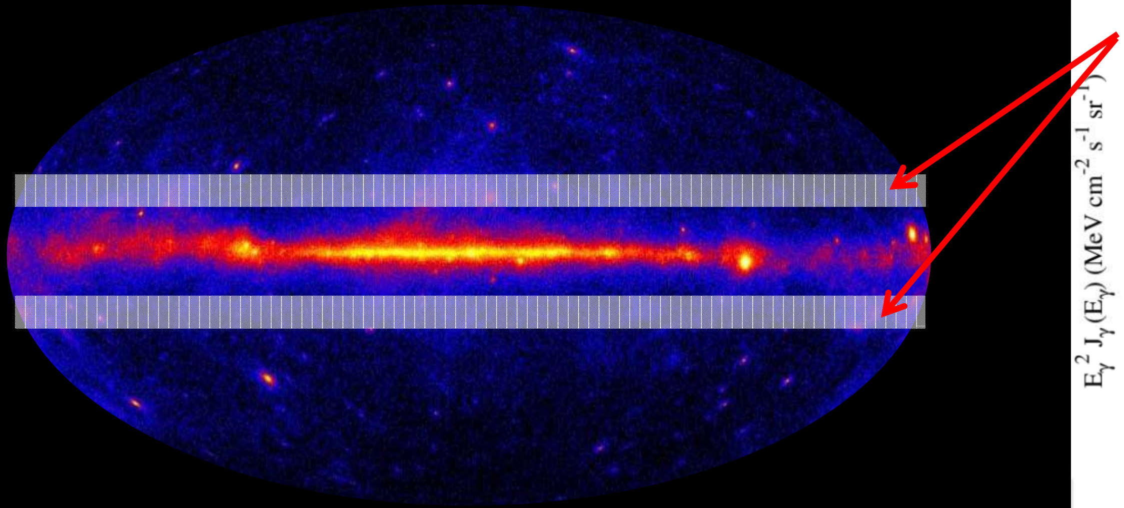
- **EGRET observations showed excess emission >1 GeV when compared with conventional model consistent with local cosmic-ray nuclei and electron spectra**
  - **Spatial variation in cosmic ray spectra?**
  - **Unresolved sources (pulsars, SNRs etc) ?**
  - **Dark matter?**
  - **Instrument calibration issue?**

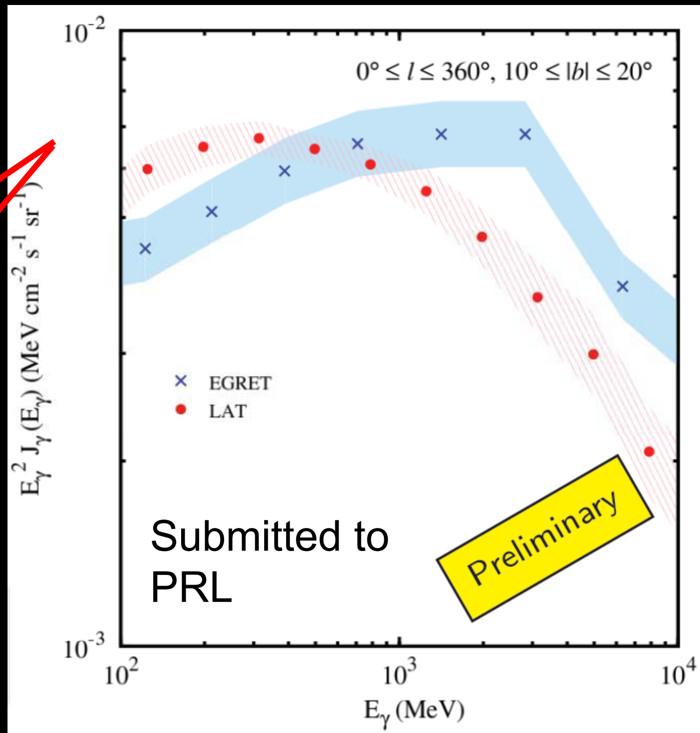


Hunter et al. 1997

The LAT view on diffuse gamma-ray emission: absence of the GeV-excess

100 MeV – 10 GeV

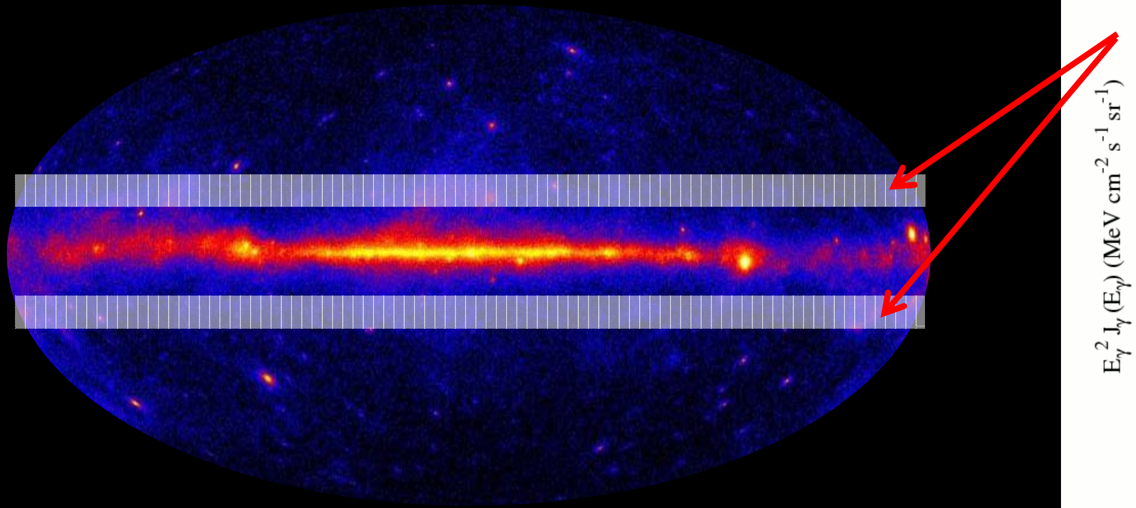


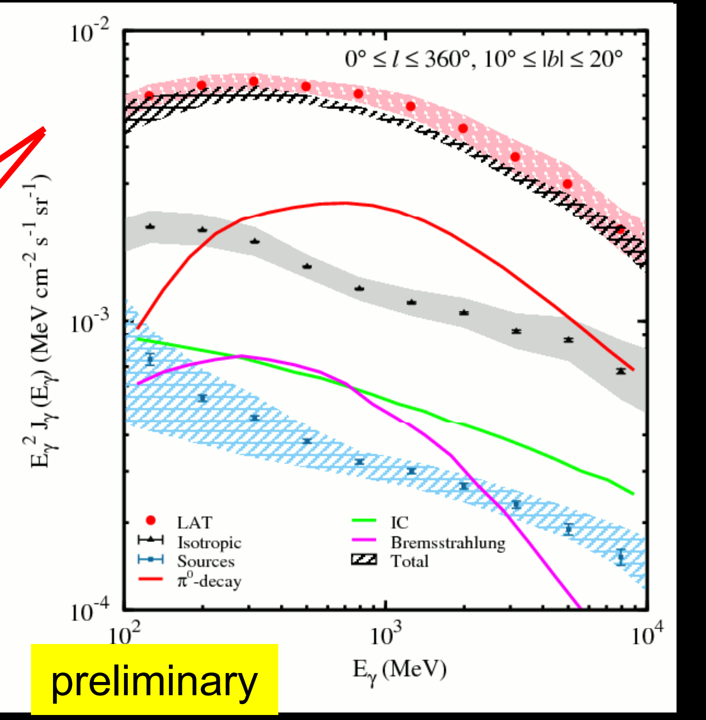


- Spectra shown for mid-latitude range → EGRET GeV excess in this region of the sky is <u>not</u> confirmed
- Sources are a minor component
- LAT errors are systematics dominated and estimated ~10%
- Work to analyse and understand diffuse emission over the entire sky and broader energy range is in progress

The LAT view on diffuse gamma-ray emission: absence of the GeV-excess

100 MeV – 10 GeV





- **Spectra shown for mid-latitude range → EGRET GeV excess in this region of the sky is not confirmed**
- **Sources are a minor component**
- **LAT errors are systematics dominated and estimated ~10%**
- **Work to analyse and understand diffuse emission over the entire sky and broader energy range is in progress**

LAT and Dark Matter searches

Dark Matter indirect searches

Self annihilation of WIMPs led to High Energy γ-rays in final state

$$\Phi_{WIMP}(E,\Psi) = J(\Psi) \times \Phi^{PP}(E)$$

Astrophysical factor

Particle physics factor

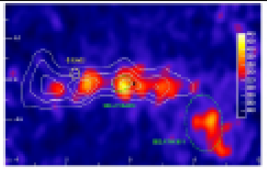
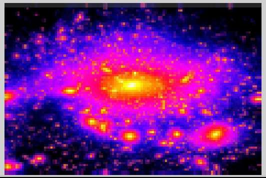
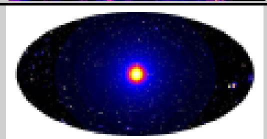
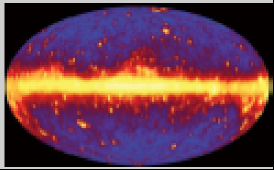
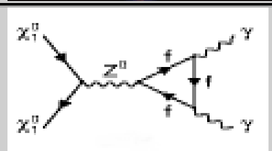
$$J(\Psi) = \int_{l.o.s} dl(\Psi)\,\rho^2(l)$$

$$\Phi^{PP}(E) = \frac{1}{2}\frac{\langle \sigma v \rangle}{m_{WIMP}^2} \sum_f \frac{dN_f}{dE} B_f$$

Particle physics factor spectrum features:

- line: « smoking gun » for DM search but loop suppressed
- continuum: differs from power-law with a cut-off at the mass, m_{WIMP}

Dark Matter Searches

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

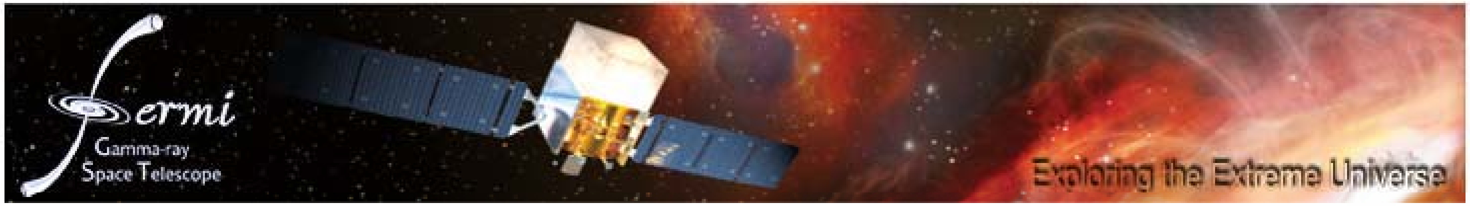
E.A. Baltz et al. JCAP07 (2008) 013, arXiv:08062911

Conclusions - I

- The Fermi Gamma-Ray Space Telescope has been performing very well and stably for the first year of operations
- Photon data will become public in august 2009
  - Join the fun at http://fermi.gsfc.nasa.gov/ssc/
- Wealth of results in γ-ray astrophysics
  - ~ 50 pulsars detected, many only in γ-rays;
  - many flaring active galaxies observed
    - about half not seen by EGRET
  - 9 GRBs at high energy
    - evidence of delayed emission above 100MeV where statistics allow light curve study (4 GRBs)
    - spectra consistent with single *Band* function
    - Record-breaking constraints on minimum Lorentz boost factor and quantum gravity mass
  - No confirmation of the EGRET GeV-excess in diffuse emission

Conclusions - II

- First high statistics measurement of CR electron spectrum (20 GeV – 1 TeV)
  - not compatible with pre-Fermi conventional diffusive models
  - several interpretation of the hard spectrum possible
    - Improved diffusive model
    - local sources of different origin (significant when considering Pamela positron fraction results)
      - Nearby pulsars
      - Dark Matter
- Future observations from the Fermi-LAT will help finding the right answer
  - gamma-ray from PSR and diffuse emission
  - improved statistics, improved systematics and anisotropies in electron arrival directions



Summary of Fermi LAT science publications

29 June 2009

Category I and II papers in refereed journals

Journal	Published	Accepted	Total
Astronomy and Astrophysics	1	-	1
Astroparticle Physics	-	1	1
Astrophysical Journal	6	4	10
Astrophysical Journal Letters	3	-	3
Astrophysical Journal Supplement	1	-	1
Journal of Cosmology and Astroparticle Physics	1	-	1
Physical Review Letters	1	-	1
Science	2	2	4
Total	15	7	22

Papers submitted to journals: 7
Ready to submit: 2

Rapid publications:
Astronomers' telegrams: 35
GCN circulars: 12

http://www-glast.stanford.edu/cgi-bin/pubpub