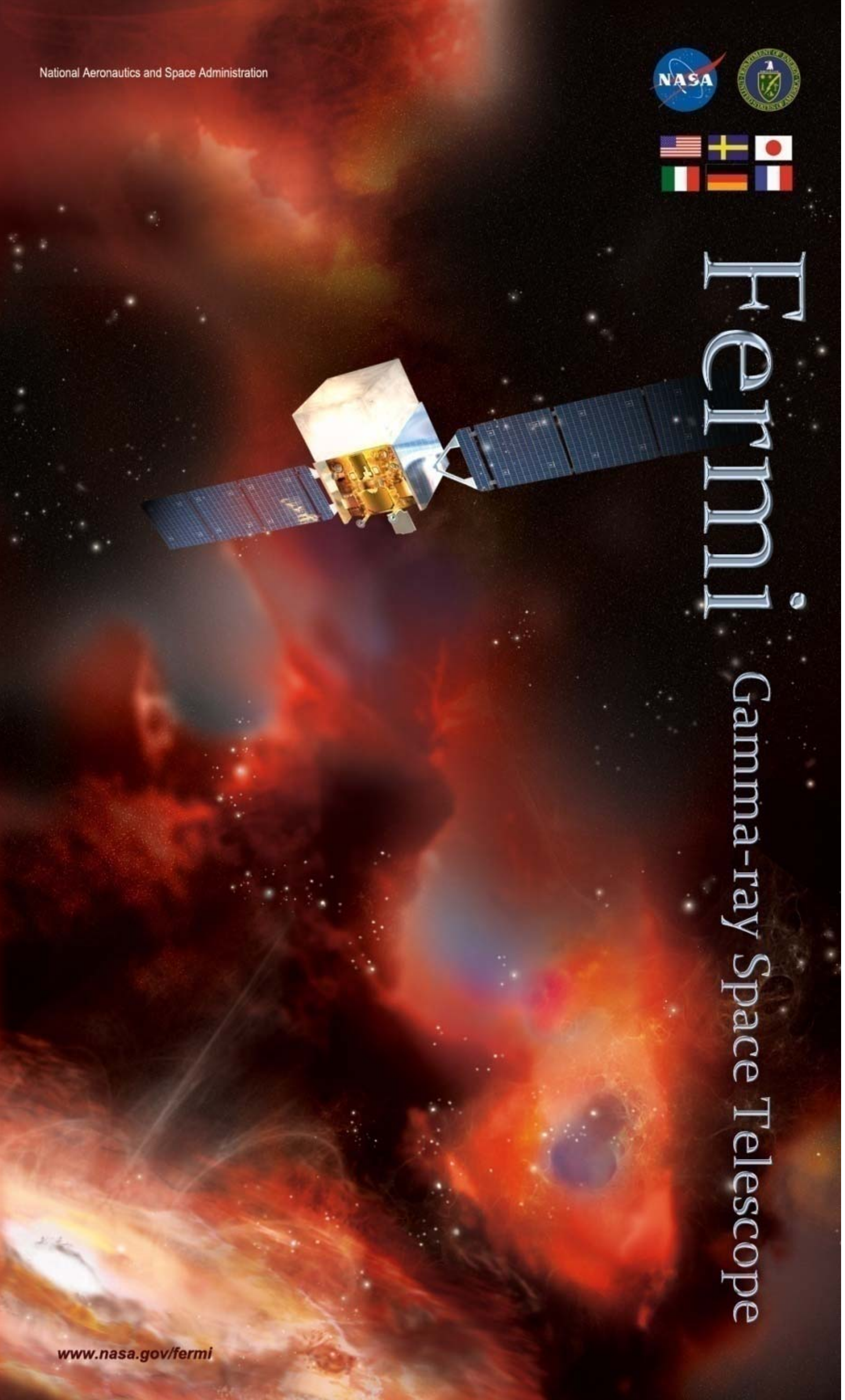


Science from the first 10 months of observations from the Fermi Large Area Telescope

Luca Latronico (INFN-Pisa)
luca.latronico@pi.infn.it

on behalf of the Fermi LAT Collaboration

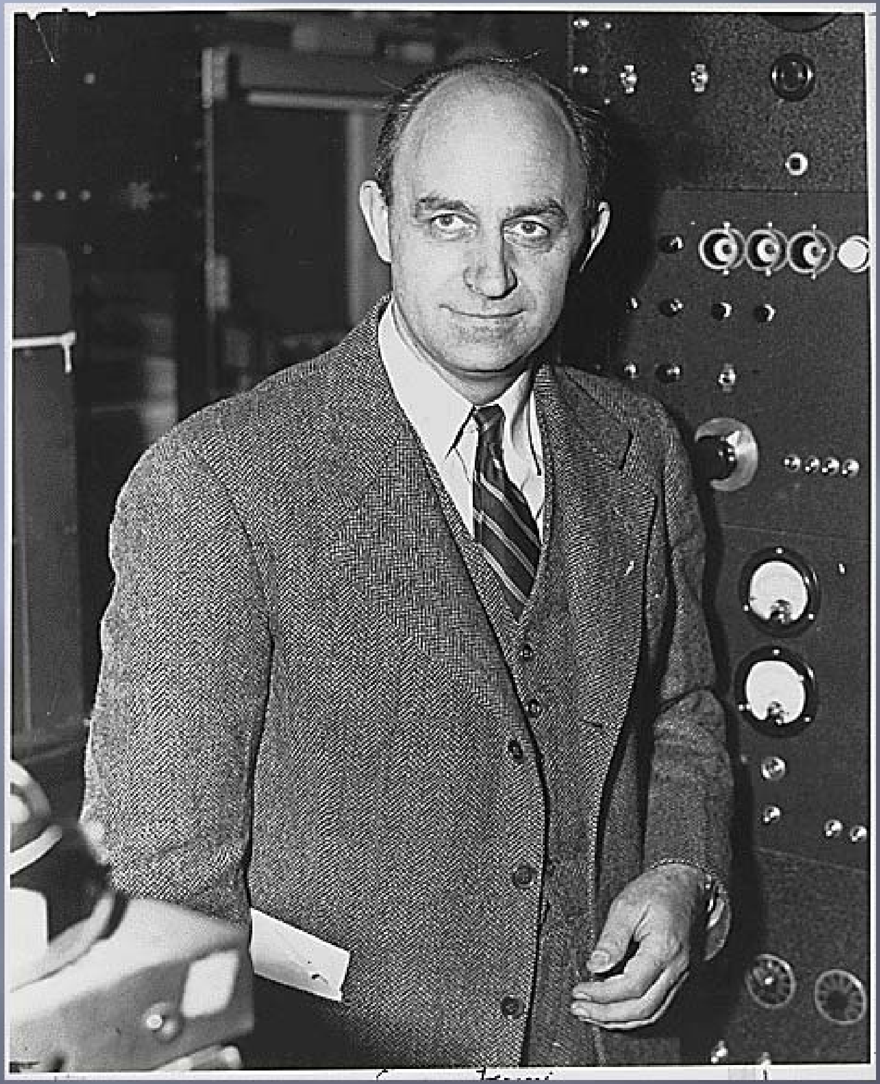
June 18 2009 - CERN

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.

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. "

THE UNIVERSITY OF CHICAGO
CHICAGO 37 · ILLINOIS
INSTITUTE FOR NUCLEAR STUDIES

March 12, 1949

Professor G. Cocconi
Cornell University
Laboratory of Nuclear Studies
Ithaca, New York

Dear Cocconi:

Excuse my answering in English your letter, since by doing so I can dictate to my secretary. I have been very much interested by your statement that you have evidence of the existence of large showers up to 10^{17} eV.

The reason why, according to the theory on the origin of cosmic rays that I have proposed, no electrons should be found, is that I postulate the existence throughout the interstellar space of a magnetic field with an intensity of about $10^{-5} - 10^{-6}$ gauss. If this assumption is correct, the radiation loss for a fast electron is quite large and prevents it from acquiring a sizeable energy. This mechanism of energy loss by electrons is much more efficient in removing fast electrons than the mechanism of the inverse Compton effects discussed by Feenberg and Primakoff. On the other hand, the existence of this last effect is much less hypothetic because all that is needed to produce it is the existence of the stellar light in the space traversed by the cosmic rays during their life. I have not read the article of Feenberg and Primakoff with particularly great attention, but as far as I can see, their conclusions seem to me to be sound.

You probably know that Teller recently has maintained that the cosmic radiation may be of solar origin and may be held within the limits of the planetary system by some suitable kind of magnetic field. Even if this hypothesis is correct, one could hardly expect to find electrons of high energy in the cosmic radiation. Probably the main reason to eliminate them is the same inverse Compton effect considered by Feenberg and Primakoff, which becomes much stronger because the particles are supposed to travel in the vicinity of the sun and are exposed, therefore, to a much stronger radiation than they would be in the interstellar space.

For all these reasons, it seems to me highly improbable that electrons of as high energy as you mention could be found in the cosmic radiation. On the other hand, all these arguments should not be over estimated, and an experimental check on them, if possible, is certainly worth while.

I ~~am sending~~ will send to you a copy of my manuscript, as soon as reprints are available.

Very sincerely yours,

Enrico Fermi

Enrico Fermi

EF:al
encl.

symmetrybreaking
extra dimensions of particle physics
A joint Fermilab/SLAC publication

Happy birthday, Fermi Gamma-ray Space Telescope

June 11, 2009 | 12:56 pm

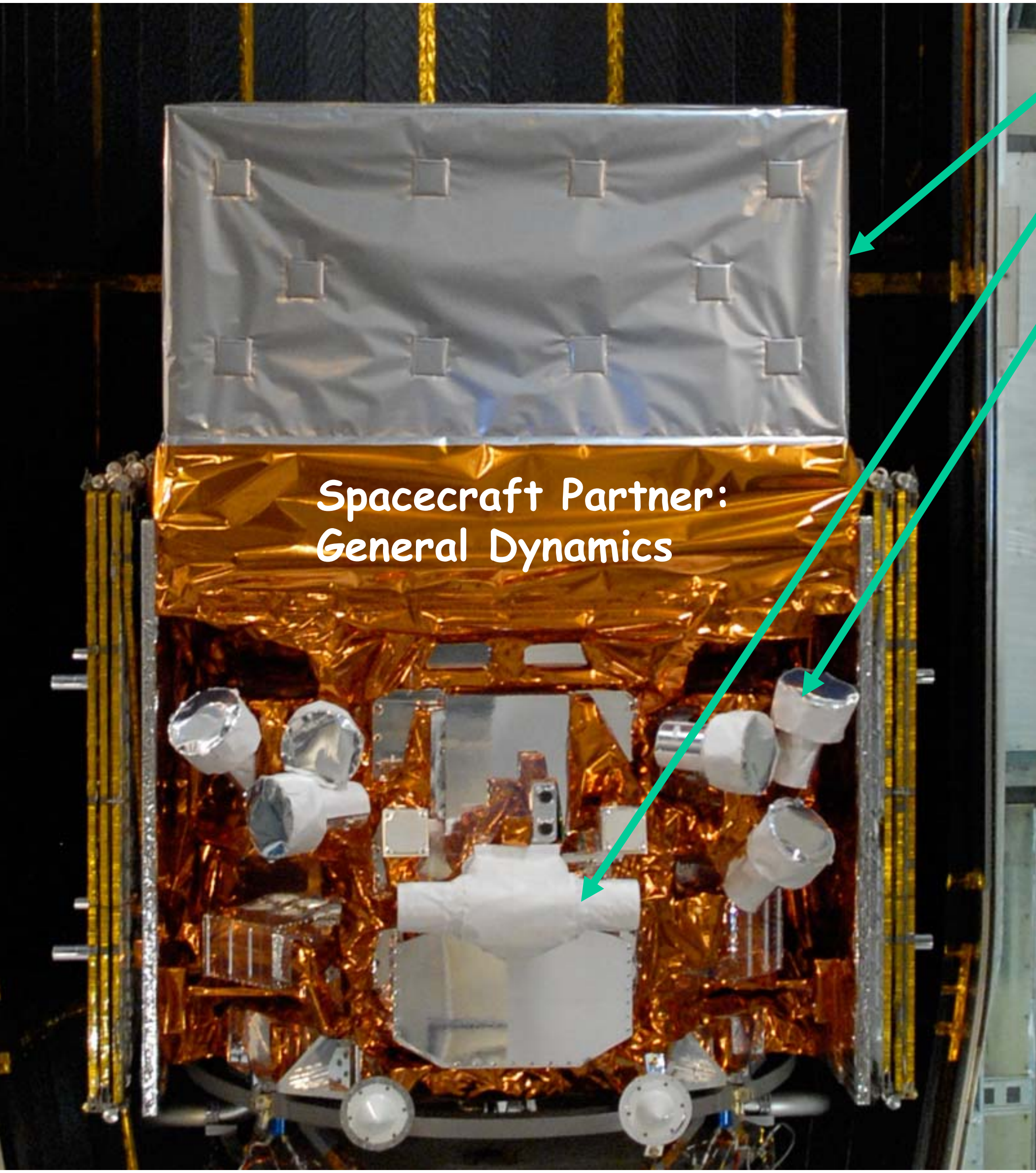
Today marks one year since the Fermi Gamma-ray Space Telescope was launched into orbit. Since then, the telescope has discovered a whole new set of pulsars, gained a new view of cosmic jets, seen the most extreme gamma-ray blasts ever, created new sky maps in gamma-rays, shown that blazars are more complex 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!

The Fermi gamma-ray observatory

The Gamma-ray Observatory



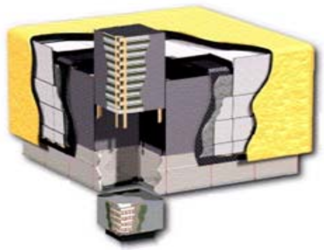
Large AreaTelescope (LAT)
20 MeV - >300 GeV

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, >7 decades!**
  - **including largely unexplored band 10-100 GeV**
- **Very small deadtime, <1us absolute timing accuracy**
- **Large leap in all key capabilities**
- **Great discovery potential**

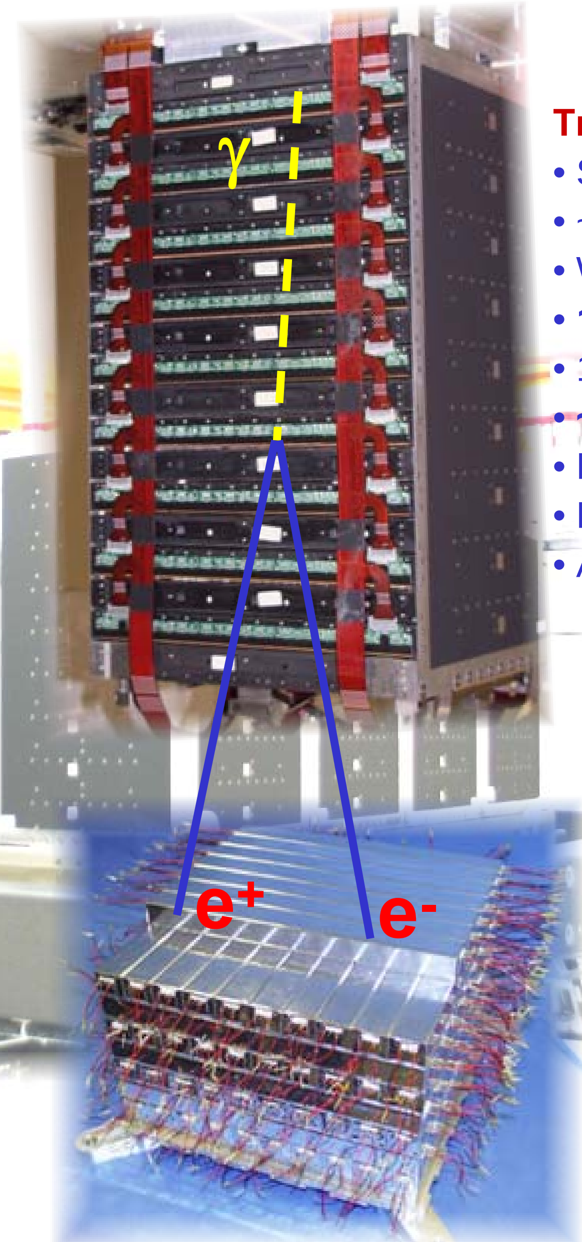
Overview of the Large Area Telescope



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)

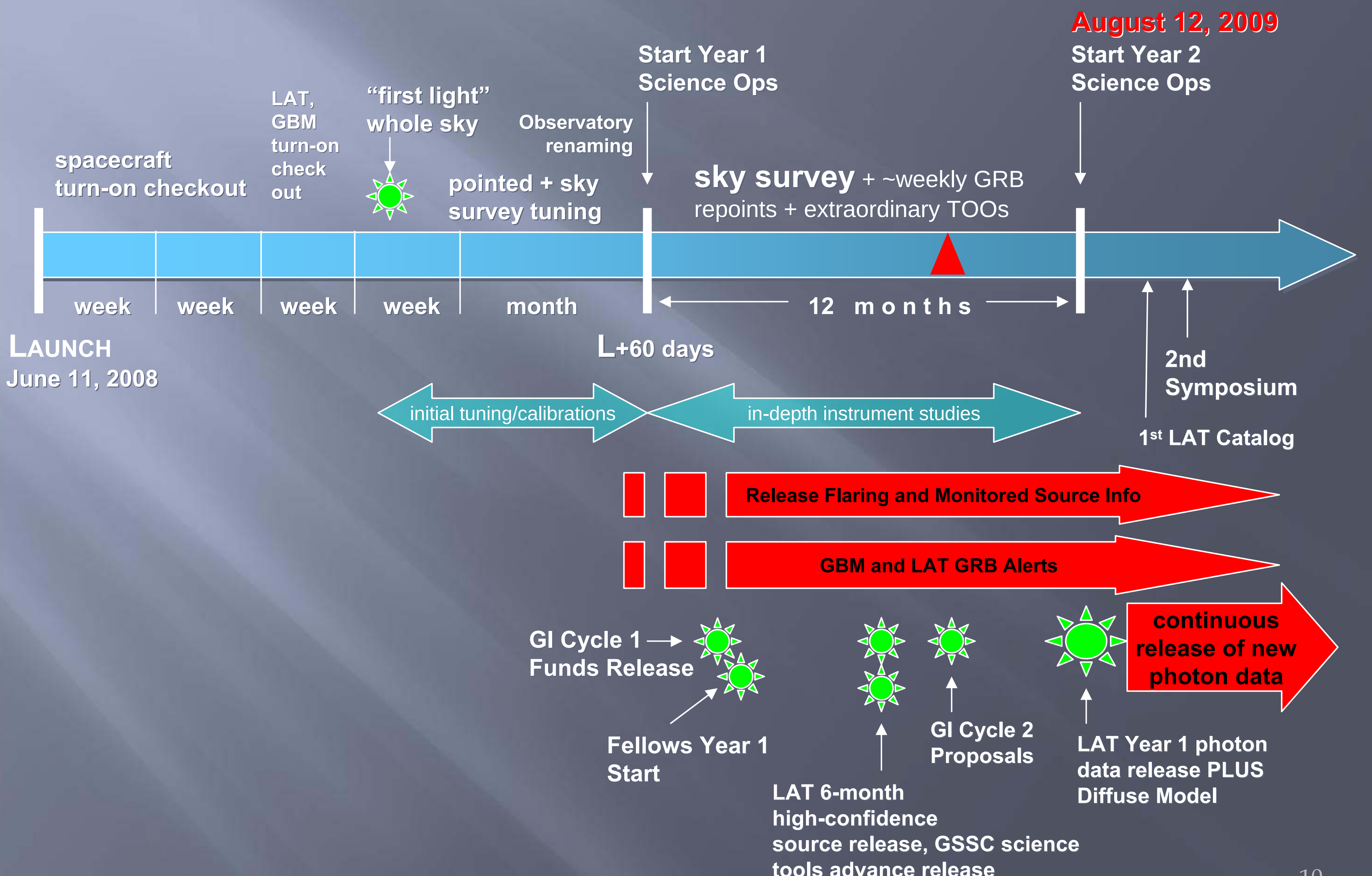
- **France**
  - CNRS/IN2P3, CEA/Saclay
- **Italy**
  - INFN, ASI, INAF
- **Japan**
  - Hiroshima University
  - ISAS/JAXA
  - RIKEN
  - Tokyo Institute of Technology
- **Sweden**
  - Royal Institute of Technology (KTH)
  - Stockholm University
- **United States**
  - Stanford University (SLAC and HEPL/Physics)
  - 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

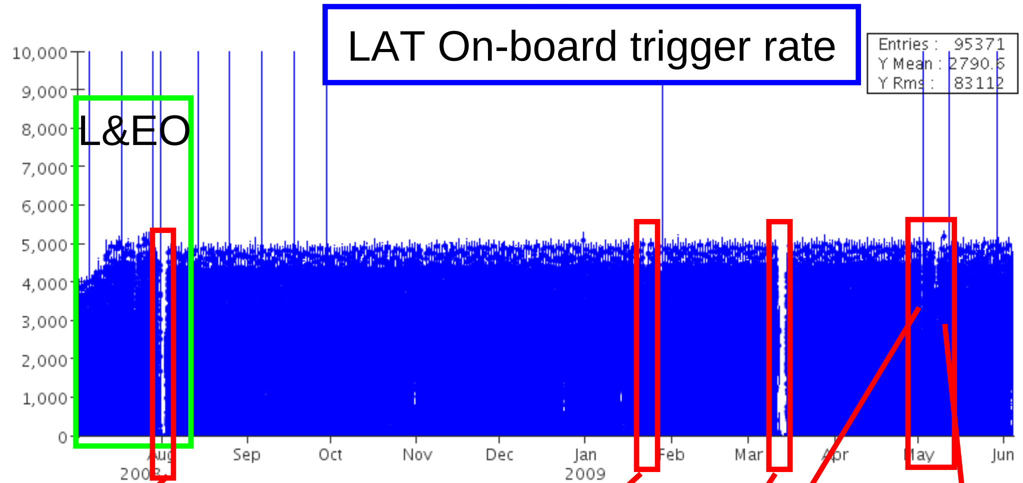
CEA/Saclay	ASI
IN2P3/CNRS	INFN
MEXT	K. A. Wallenberg Foundation
KEK	Swedish Research Council
JAXA	Swedish National Space Board

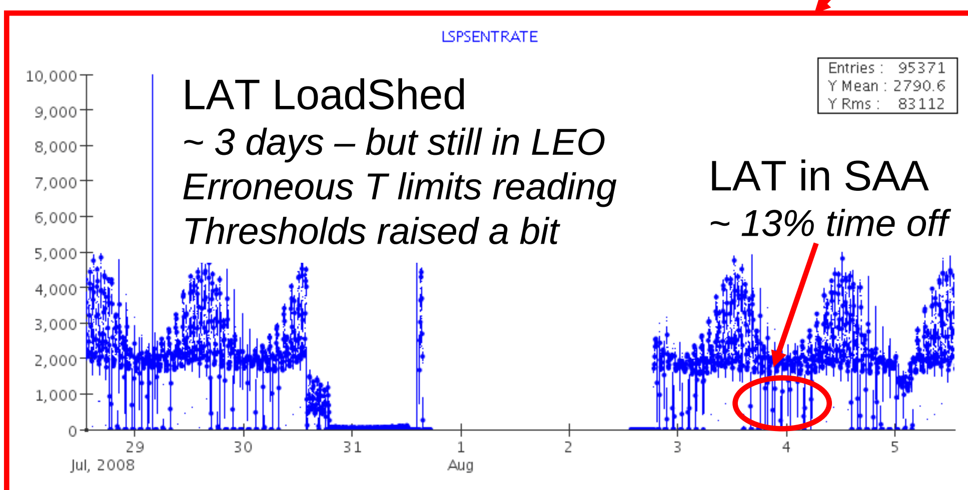
Year 1 Science Operations Timeline Overview



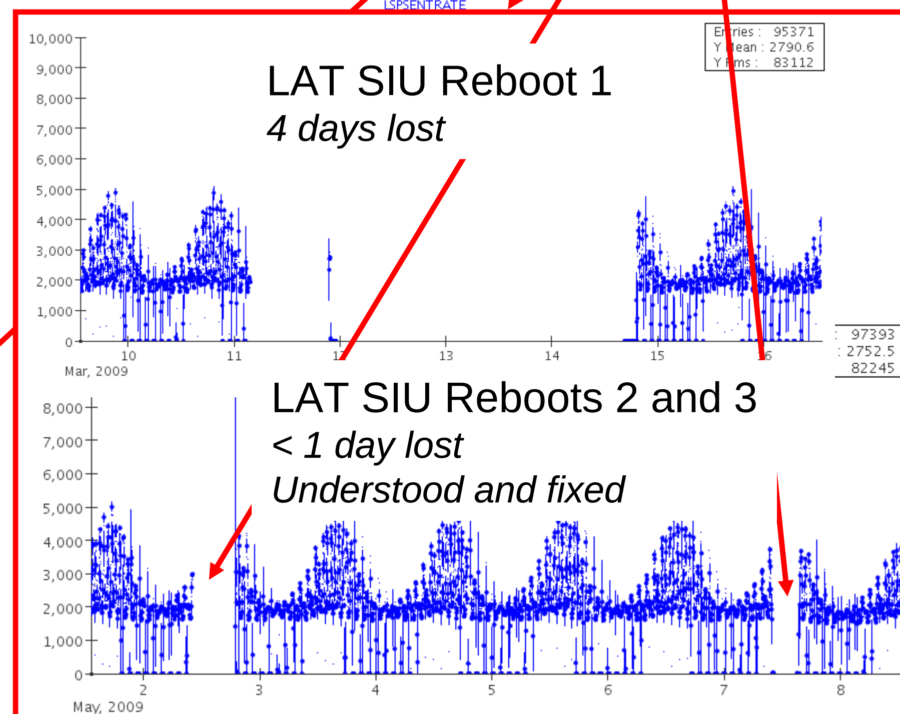
June 11, 2008

LAT Data Monitoring at the ISOC



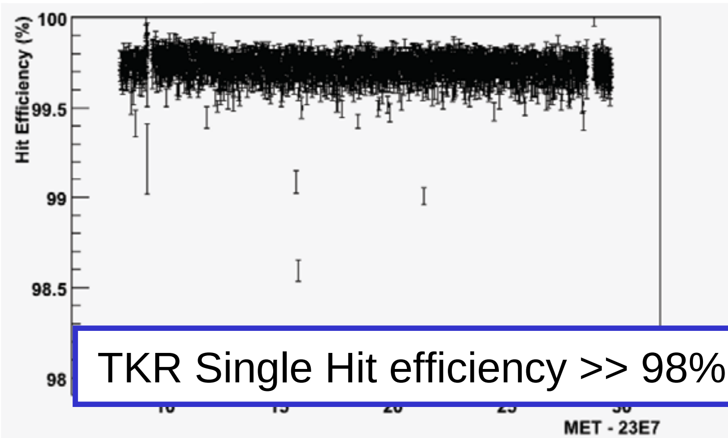


FSW upload within few hours

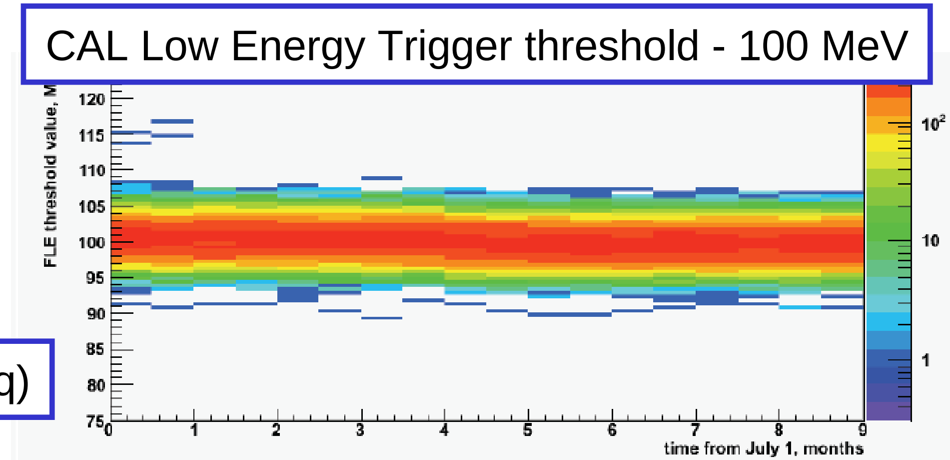


→ LAT active for ~ *85%* of the time (SAA)

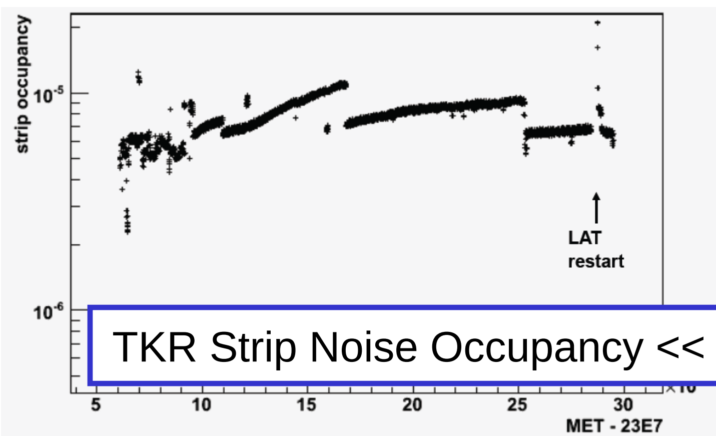
The LAT subsystems stability



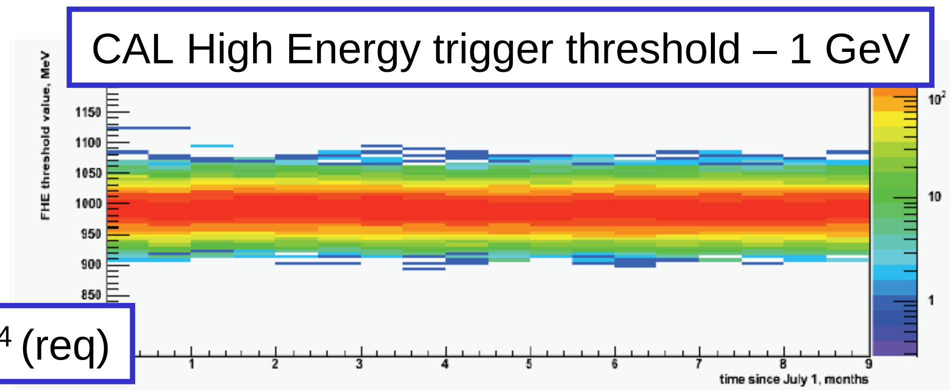
TKR Single Hit efficiency >> 98% (req)



CAL Low Energy Trigger threshold - 100 MeV



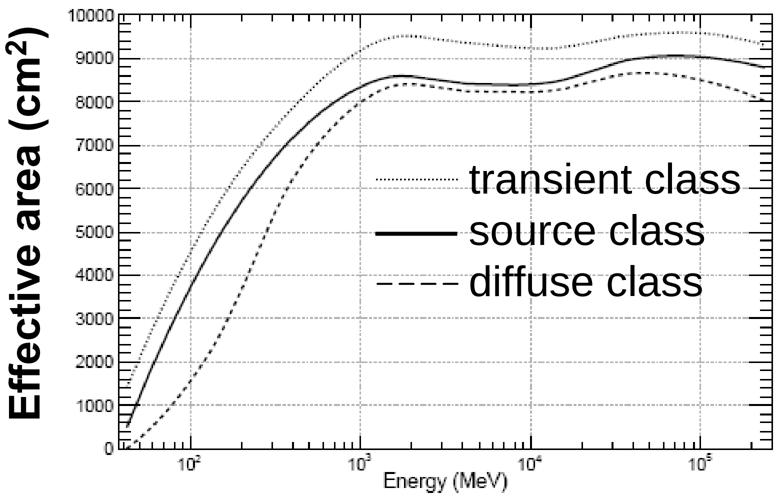
TKR Strip Noise Occupancy << 10^{-4} (req)

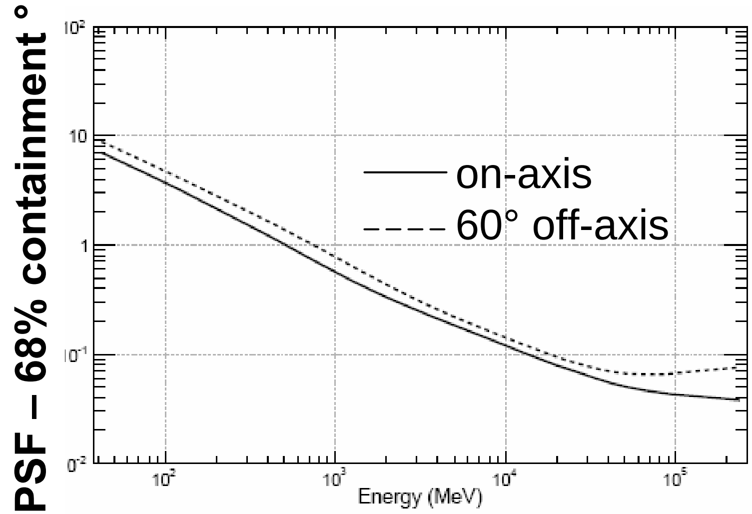


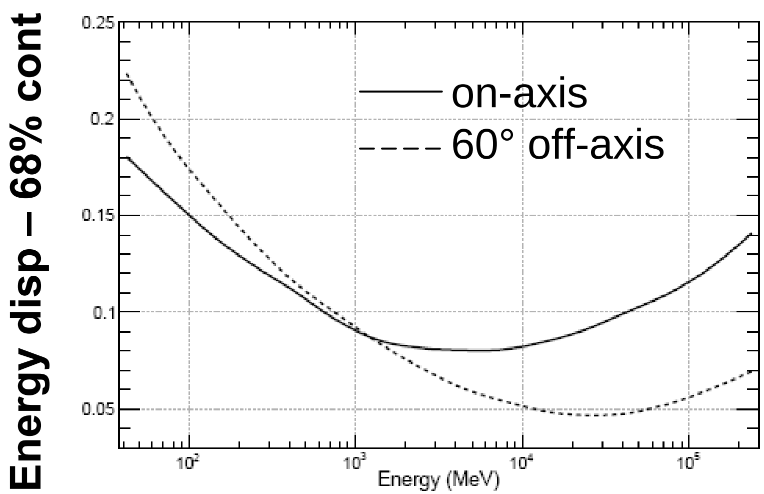
CAL High Energy trigger threshold – 1 GeV

Data Processing: 11B evts processed - 160M photon candidates

Instrument Response Functions





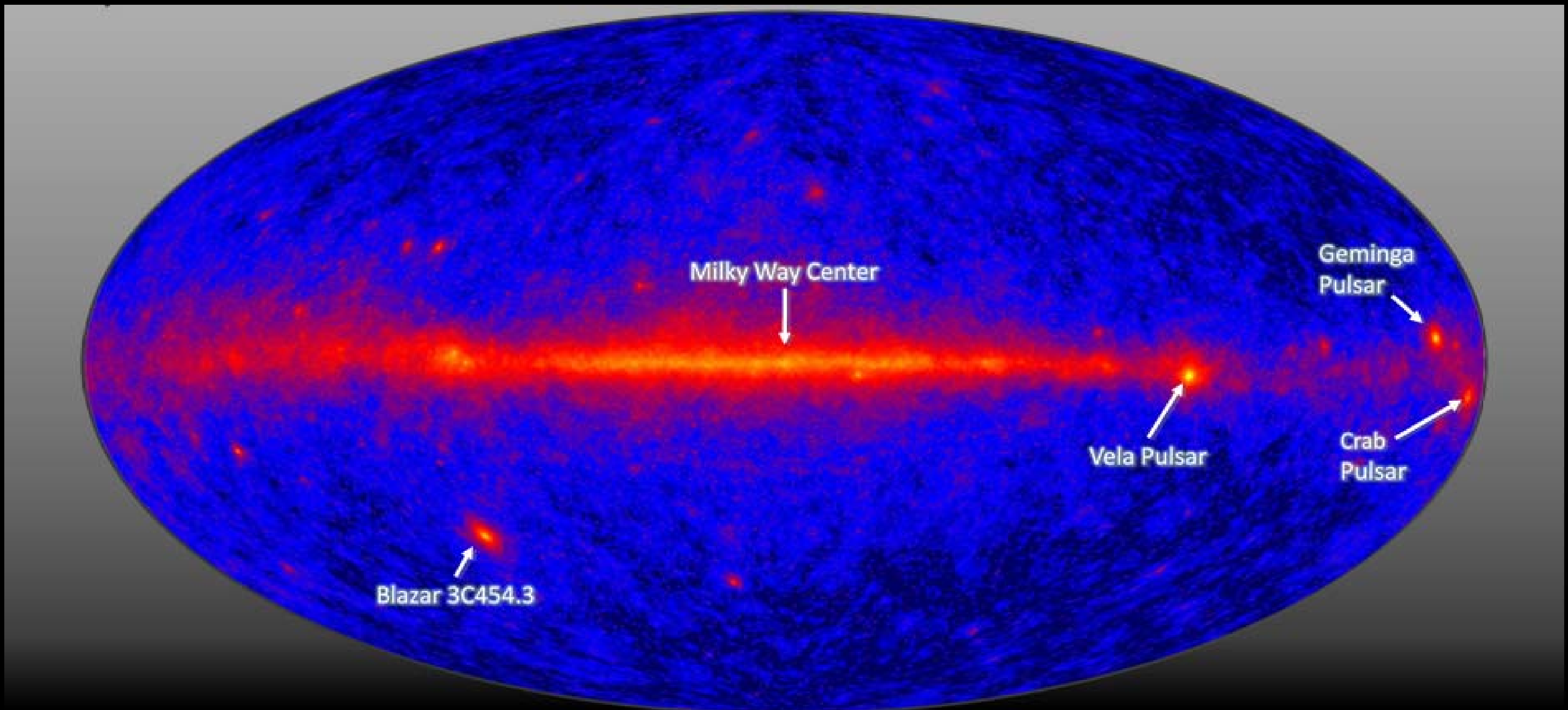


The Large Area Telescope on the Fermi Gamma-ray Space Telescope
Atwood, W. B. et al. 2009, ApJ, 697, 1071 doi: [10.1088/0004-637X/697/2/1071]

Post-launch performance tuning on-going

➢ IRF update for public data release + future updates

Fermi LAT Science Highlights

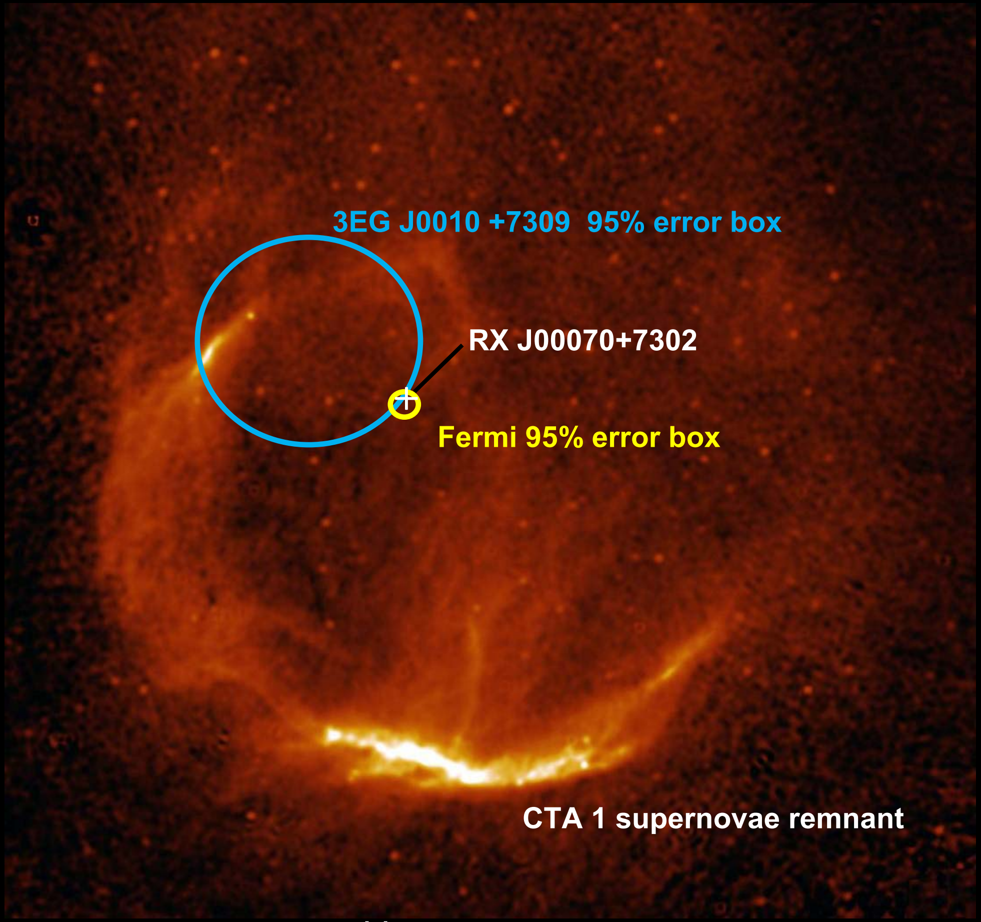


First-Light Sky map: initial 4 days of sky survey
has already achieved EGRET 1 yr source sensitivity

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

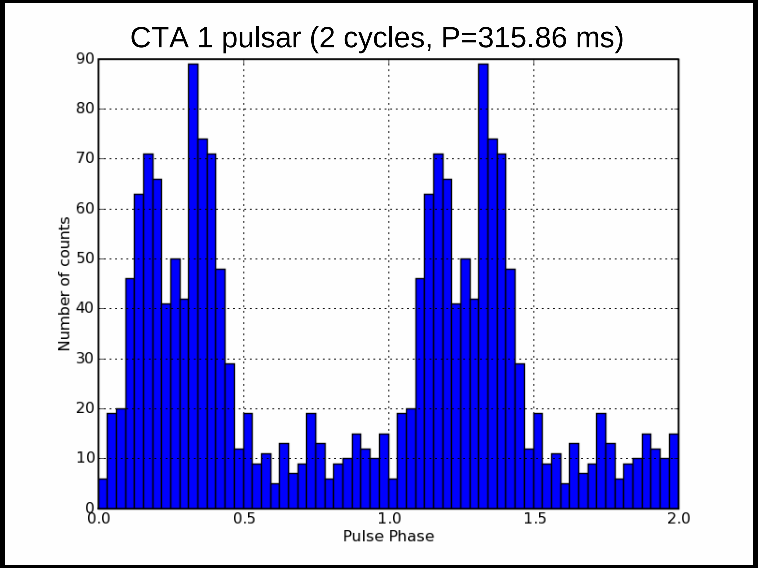
http://www.nasa.gov/fermi

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

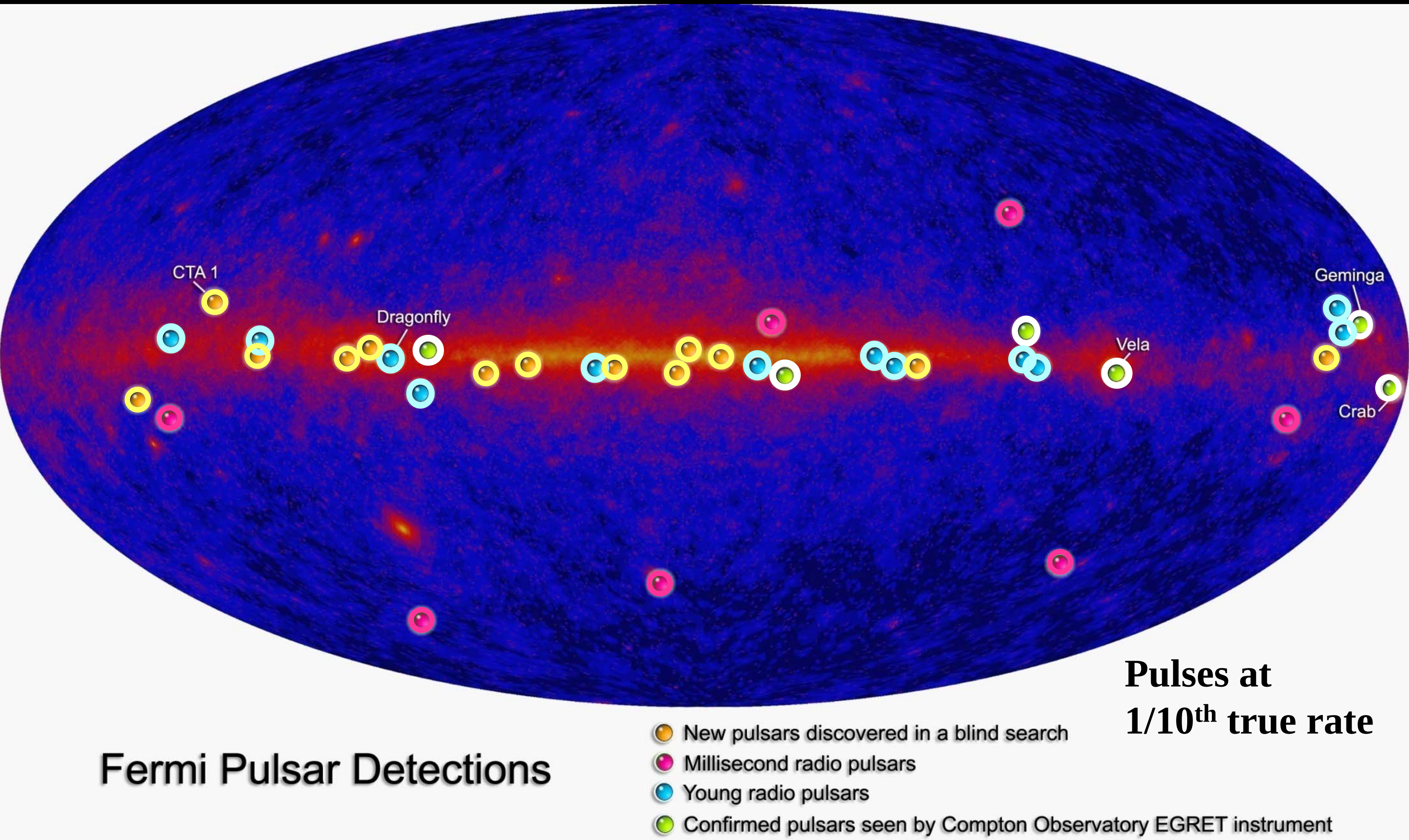
- spin-down luminosity ~10^{36} erg s^{-1}, sufficient to supply the PWN with magnetic fields and energetic electrons.

- exhibits all characteristics of a young high-energy pulsar (characteristic age ~1.4 x 10^4 yr), which powers a synchrotron pulsar wind nebula embedded in a larger SNR.

Fermi Unveils Dozen New Pulsars

6-1-2009

The Fermi Space Telescope has discovered 12 new gamma-ray-only pulsars and detected pulses from 18 others.

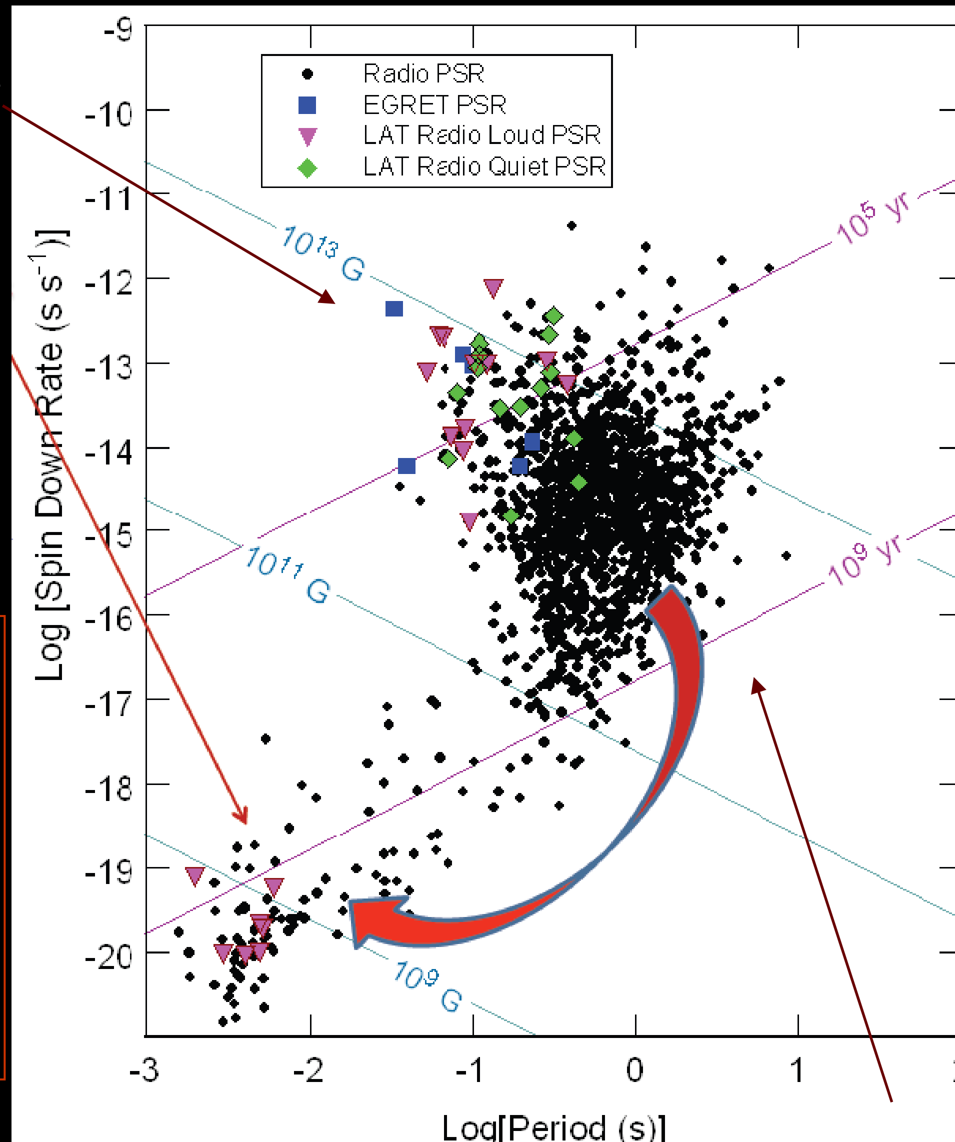


Pulses at 1/10th true rate

Spin-down power Edot = 4π²IPdot/P³.

newborn pulsars
(The EGRET pulsars are here)

“Recycled”, or
millisecond pulsars



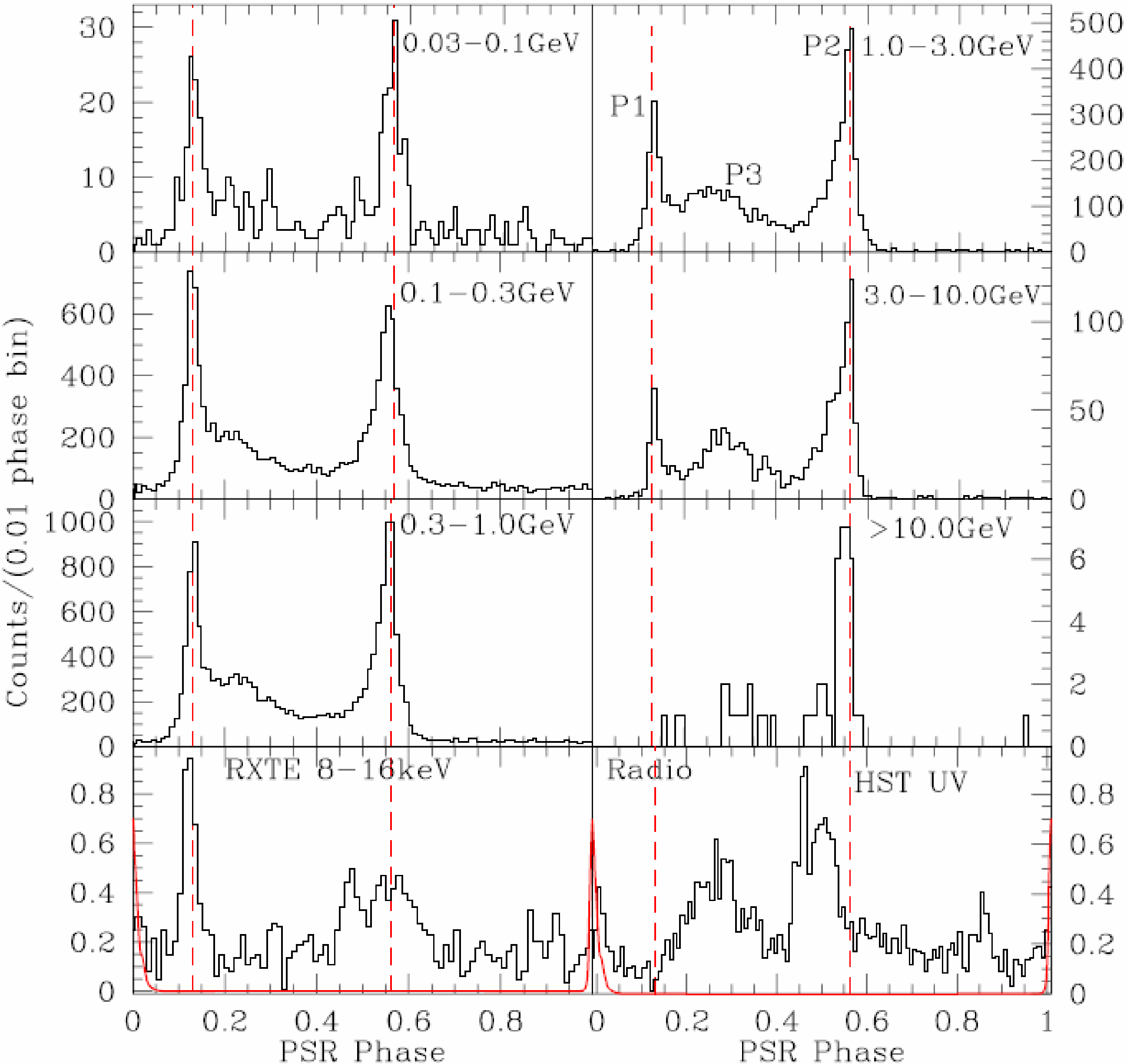
Fermi so far:
~21 young radio pulsars
~16 new young pulsars (radio quiet?)
~ 8 MSPs

~45 gamma pulsars in all

Increasing as ~ √Time

In middle age, they become invisible, but can accrete a binary companion’s spin, to live again.

Vela Light curve evolution with energy

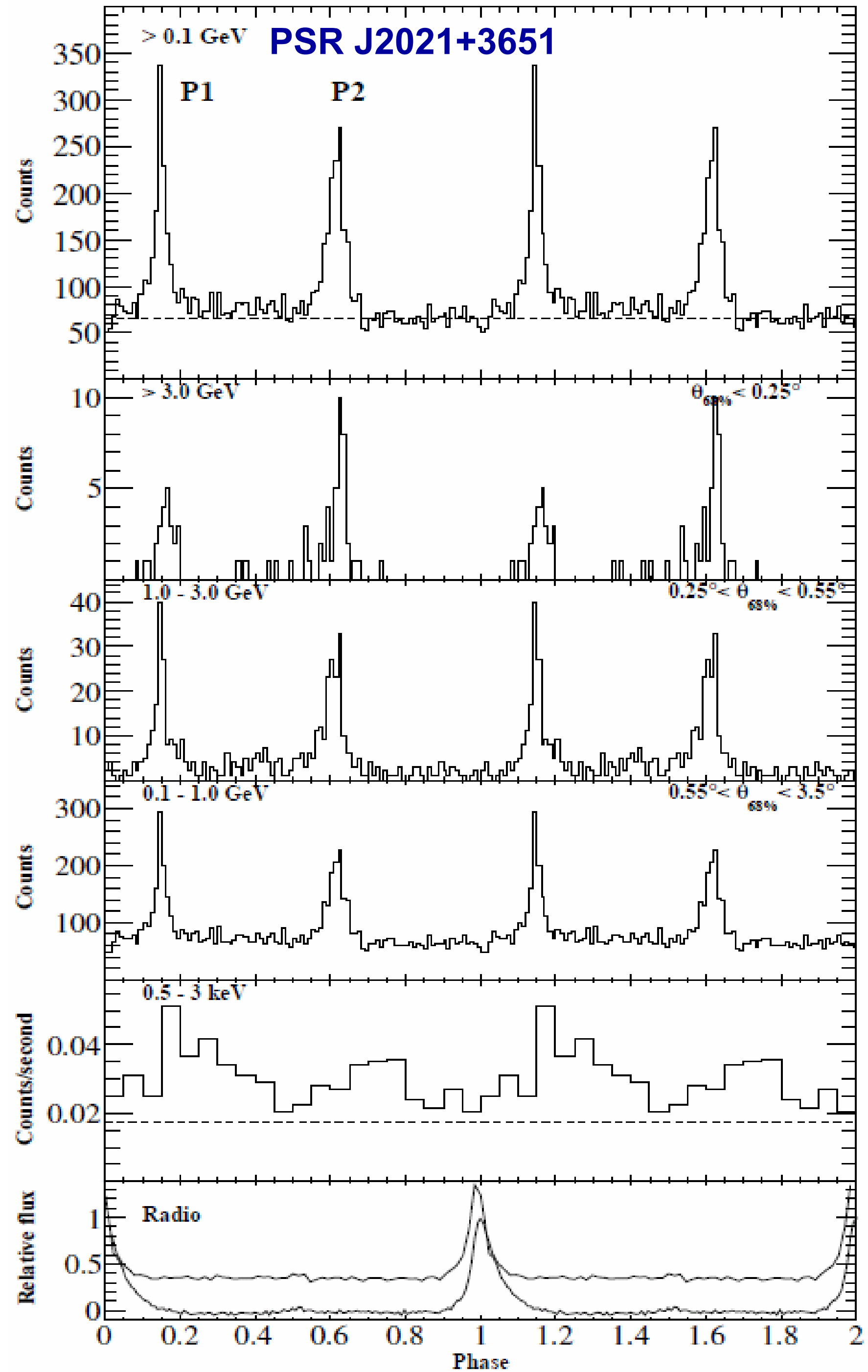


Large LAT energy window puts Vela pulsar in multiwavelength context !

→ UV peak possibly connected to high energy IC emission in P3

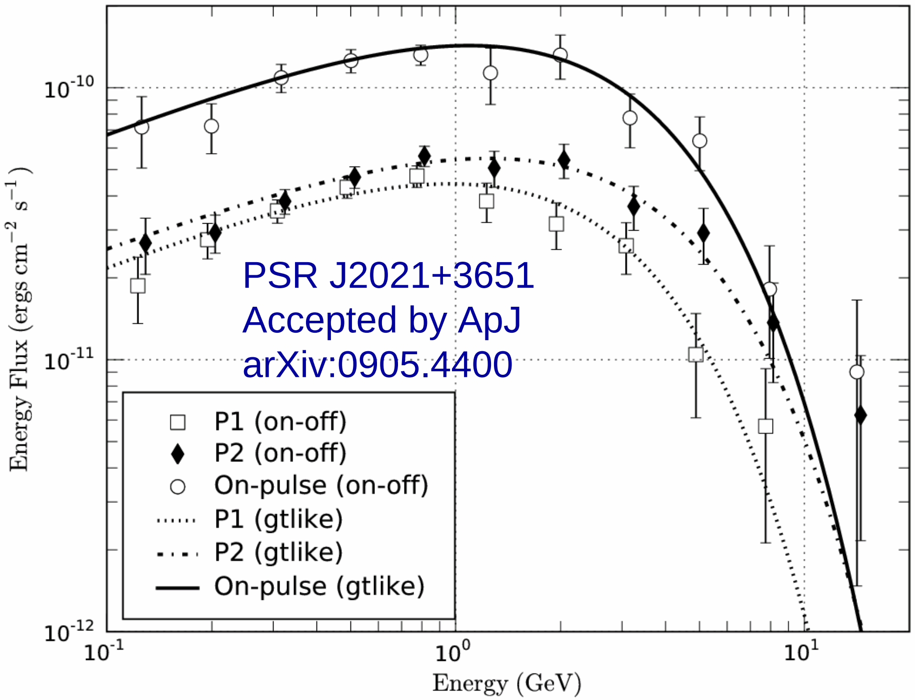
LAT Light curves

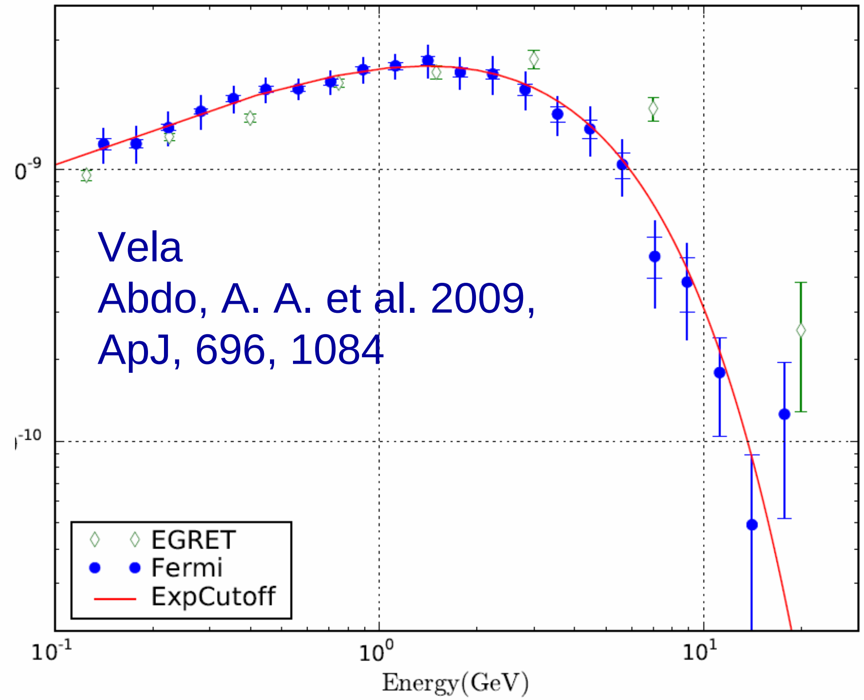
- No significant change in gamma peak location or shape with energy.
- Excellent timing allows absolute phase comparisons: beam origins in the magnetosphere.
- Re-analzyed Chandra continous clocking light curve (Hessels et al. 2004):
  - appears roughly aligned with gamma peaks



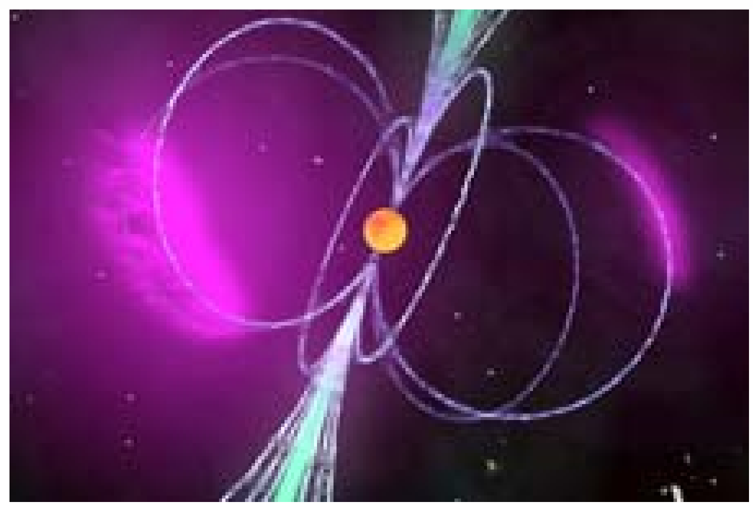
Accepted by ApJ
arXiv:0905.4400

Spectral measurements and emission models



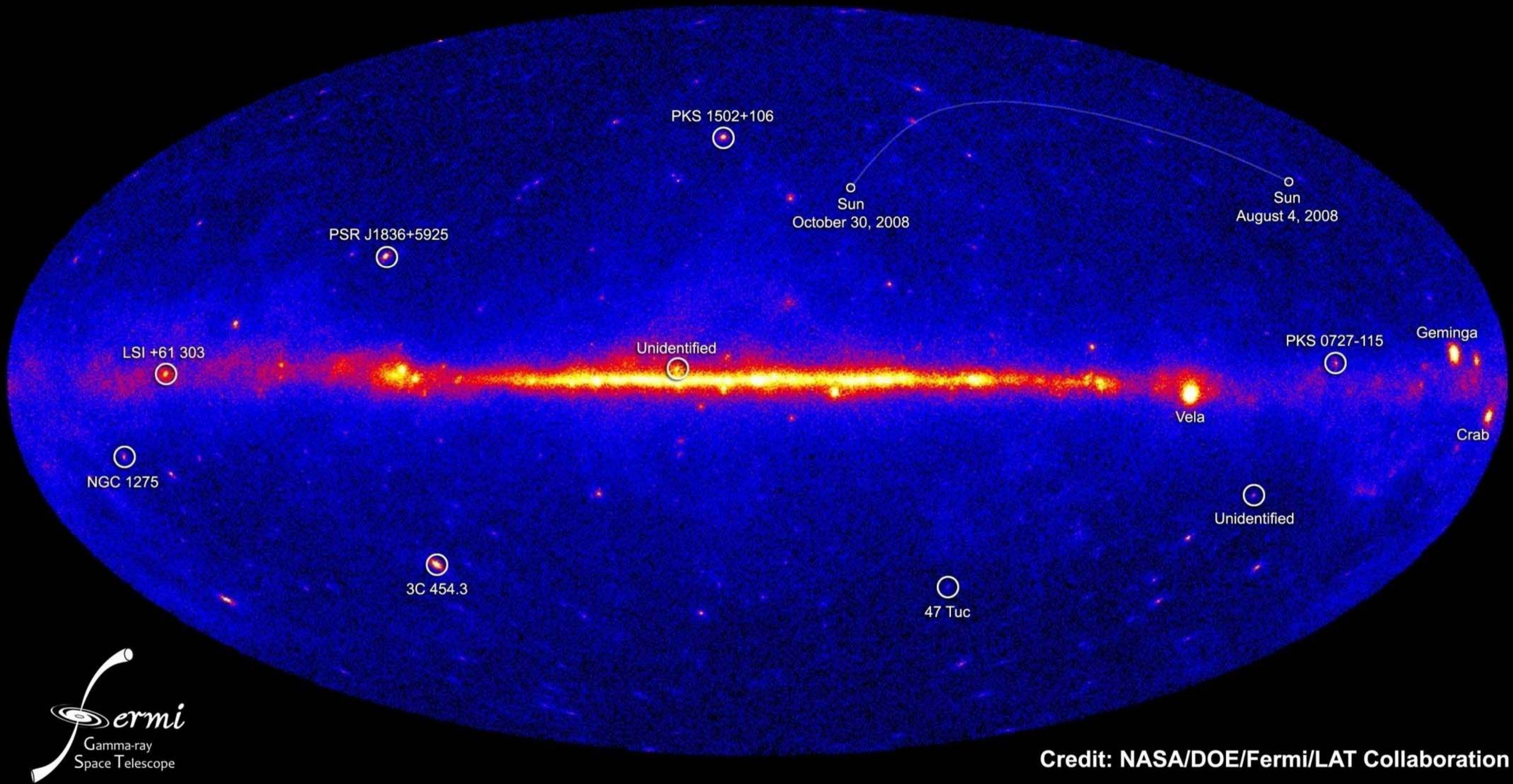


- Evidence of γ-ray emission in the outer magnetopshere due to absence of super-exponential cutoff
  - Radio and γ-ray fan beams separated
  - γ-ray only PSRs



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

11-3-2009

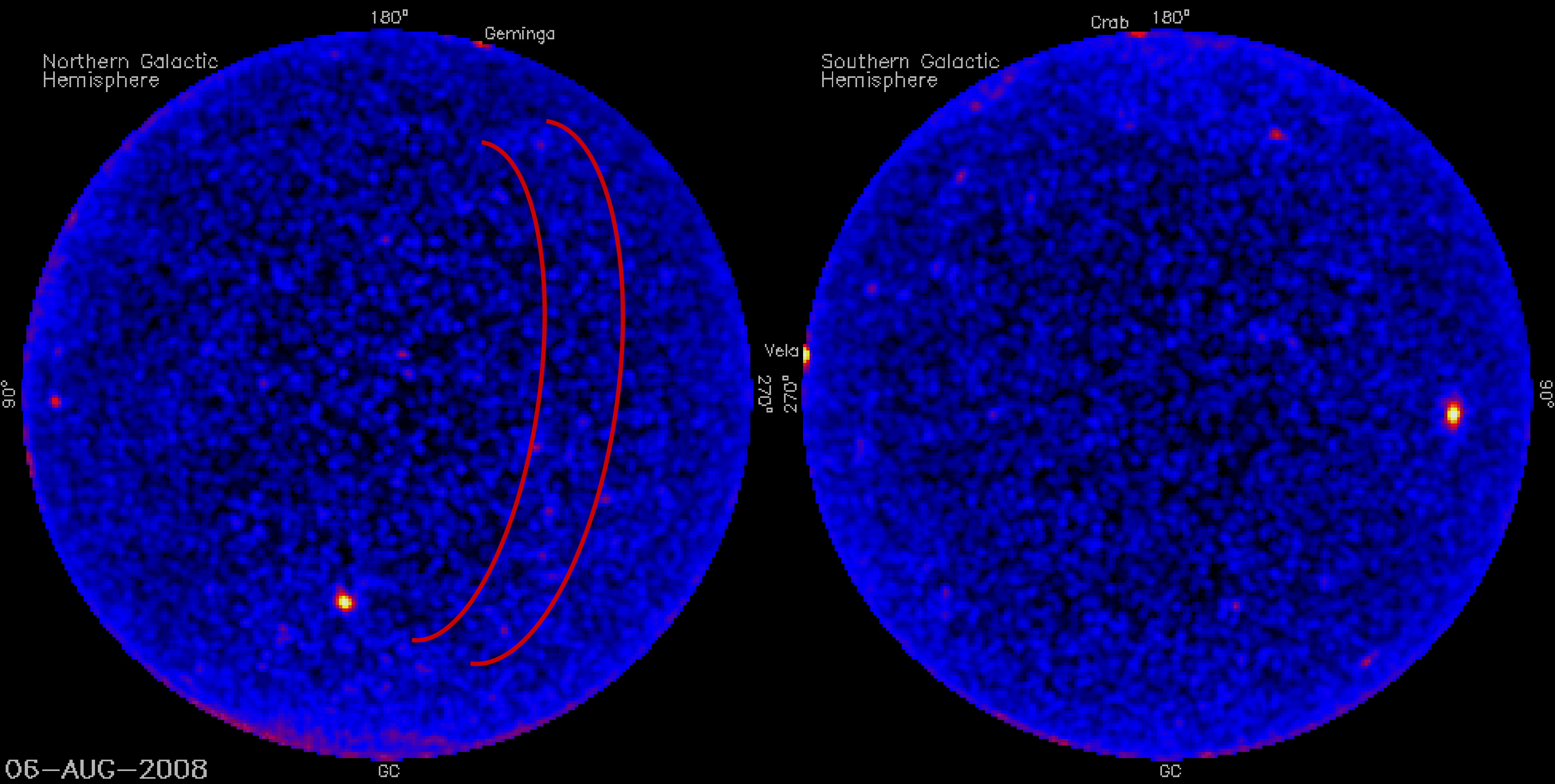


Credit: NASA/DOE/Fermi/LAT Collaboration

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

Animation of 3 months data set

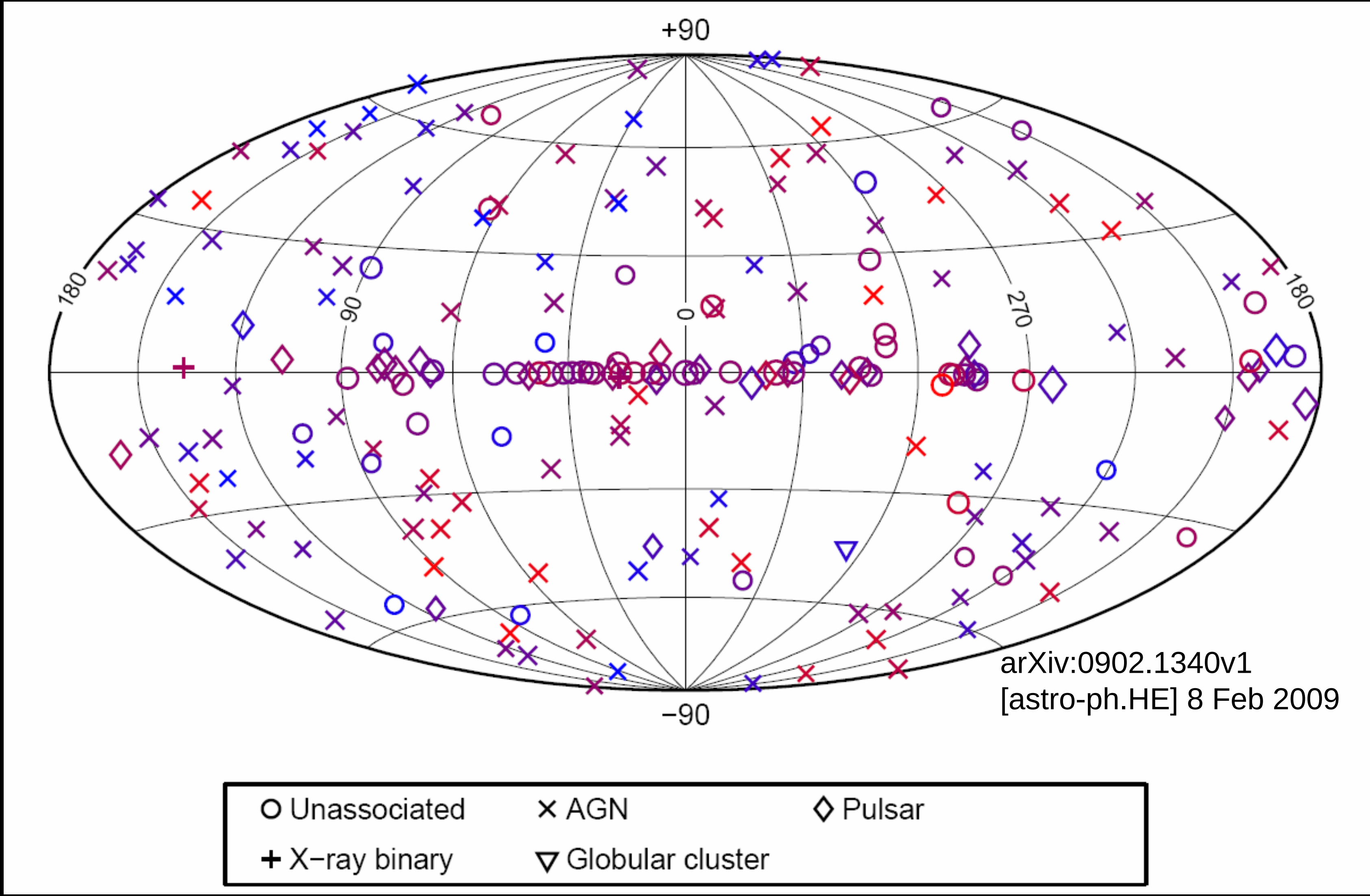


- 87 days starting with August 4 - 1 frame per day
- *Northern* (left) and *Southern* (right) hemispheres in orthographic proj.

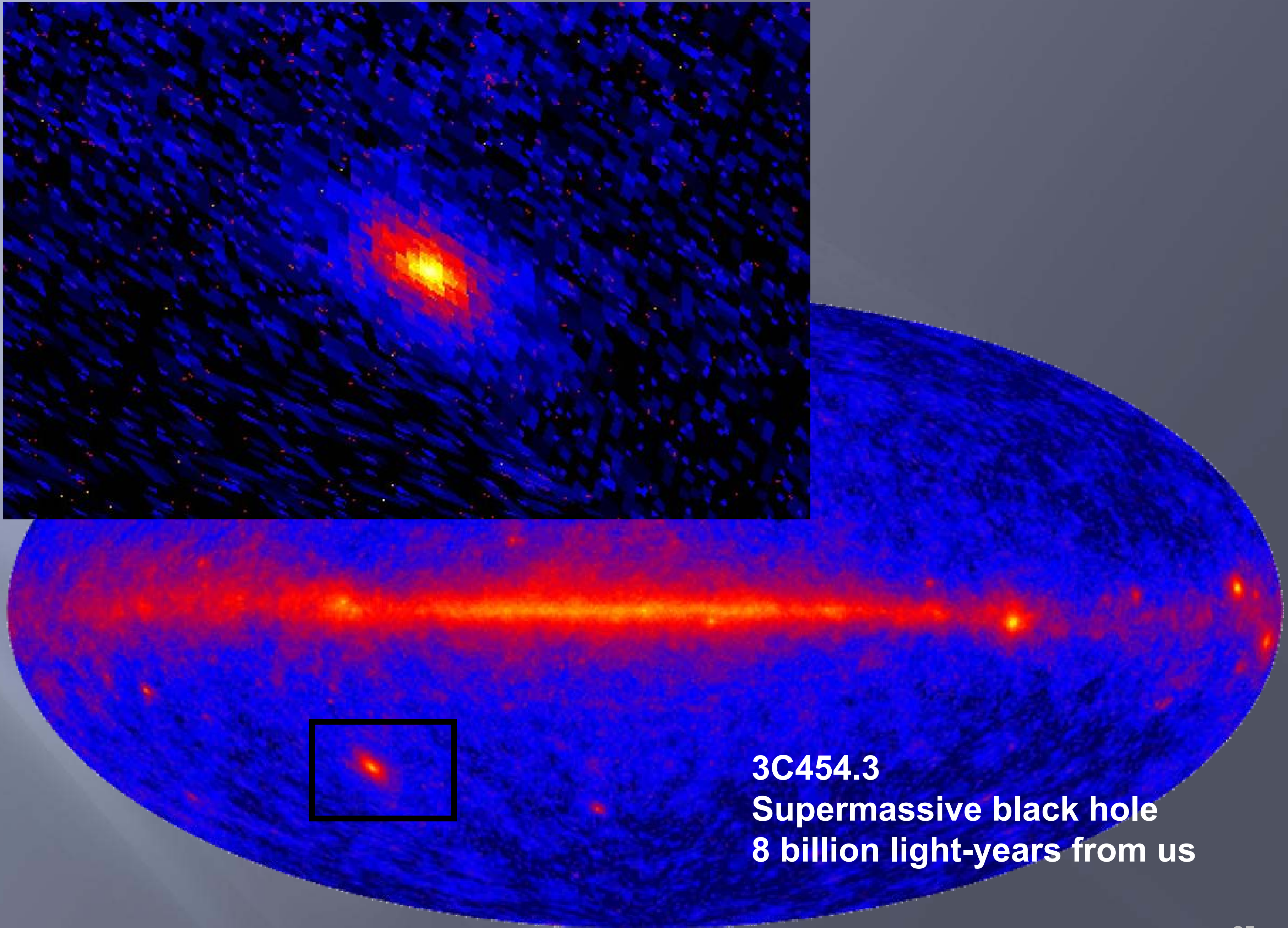
Credit: J. Ballet

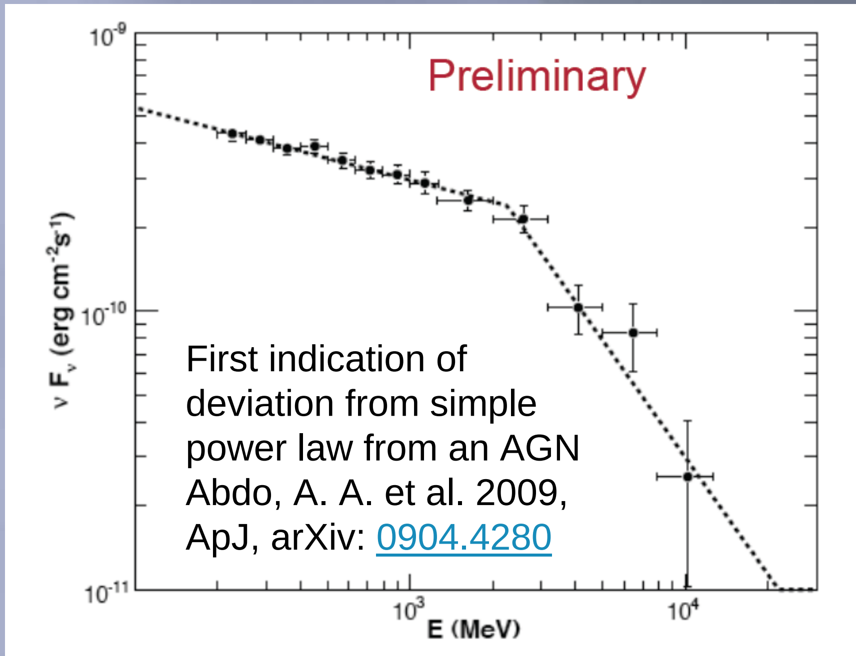
LAT High Confidence Bright Source list

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

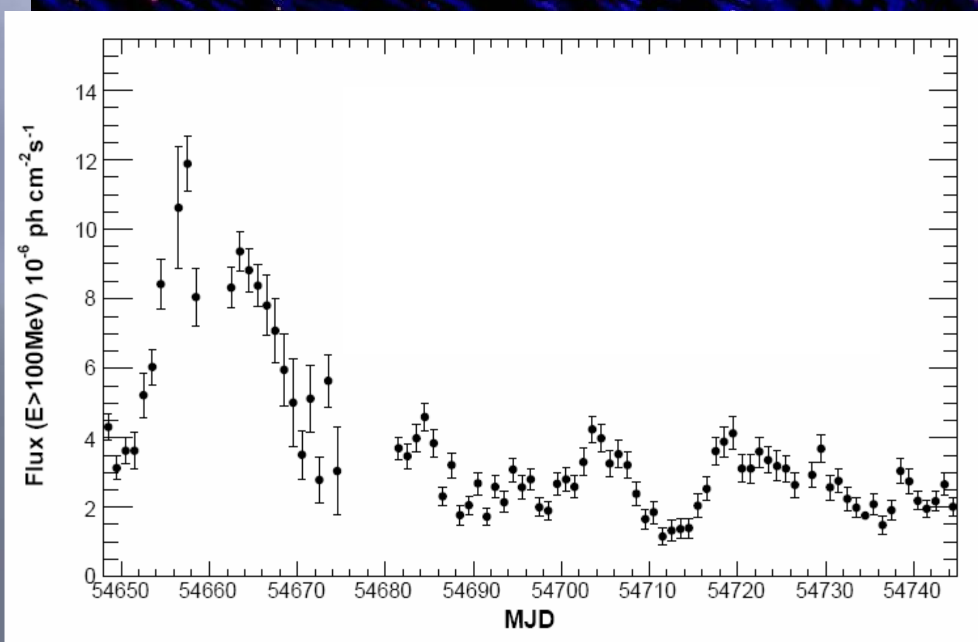


arXiv:0902.1340v1
[astro-ph.HE] 8 Feb 2009


3C454.3
Supermassive black hole
8 billion light-years from us



First indication of deviation from simple power law from an AGN
Abdo, A. A. et al. 2009, ApJ, arXiv: [0904.4280](0904.4280)



GLAST-LAT detection of extraordinary gamma-ray activity in 3C 454.3

ATel #1628; G. Tosti (Univ/INFN-Perugia) , J. Chiang (SLAC), B. Lott (CENBG/Bordeaux), E. do Couto e Silva (SLAC), J. E. Grove (NRL/Washington), J. G. Thayer (SLAC) on behalf of the GLAST Large Area Telescope Collaboration
on ***24 Jul 2008; 14:25 UT***
Password Certification: Gino Tosti (tosti@pg.infn.it)

Subjects: Gamma Ray, >GeV, AGN, Quasars

The Large Area Telescope (LAT), one of two instruments on the Gamma-ray Large Area Space Telescope (GLAST) (launched June 11, 2008), which is still in its post-launch commissioning and checkout phase has been monitoring extraordinarily high flux from the gamma-ray blazar 3C 454.3 since June 28, 2008. This confirms the bright state of the source reported by AGILE (see ATel #1592) and by the optical-to-radio observers of the GASP-WEBT Project (ATel #1625).

3C 454.3 has been detected on time scales of hours with high significance (> 5 sigma) by the LAT Automatic Science Processing (ASP) pipeline and the daily light curve (E>100 MeV) indicates that the source flux has increased from the initial measurements on June 28. Although in-flight calibration is still ongoing, preliminary analysis indicates that in the period July 10-21, 2008 the source has been in a very high state with a flux (E>100MeV) that is well above all previously published values reported by both EGRET (Hartman et al. 1999, ApJS, 123,79) and AGILE (see e.g. ATel #1592 and Vercellone et al. 2008, ApJ,676,L13).

Because GLAST will continue with calibration activities, regular monitoring of this source cannot be pursued. Monitoring by the LAT is expected to resume in early August. In consideration of the ongoing activity of this source we strongly encourage multiwavelength observations of 3C 454.3.

The GLAST LAT is a pair conversion telescope designed to cover the energy band from 20 MeV to greater than 300 GeV. It is the product of an international collaboration between NASA and DOE in the U.S. and many scientific institutions across France, Italy, Japan and Sweden.

3C454.3
Supermassive black hole
8 billion light-years from us

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

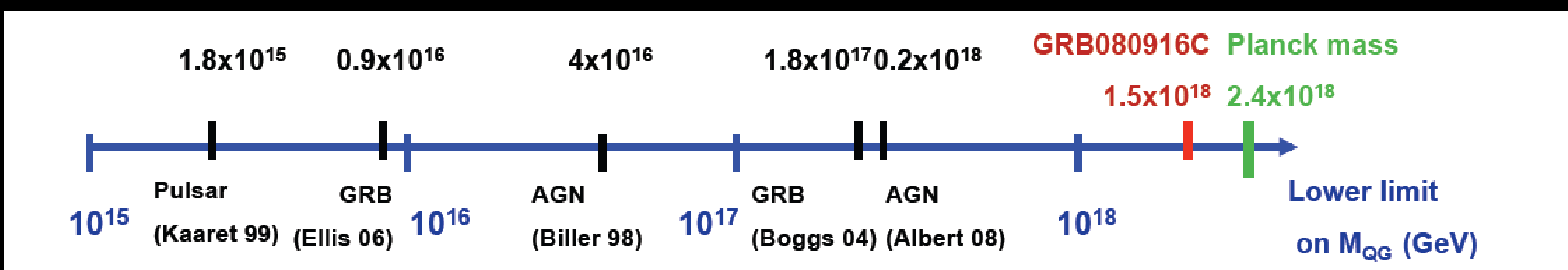
GRB080916C

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)



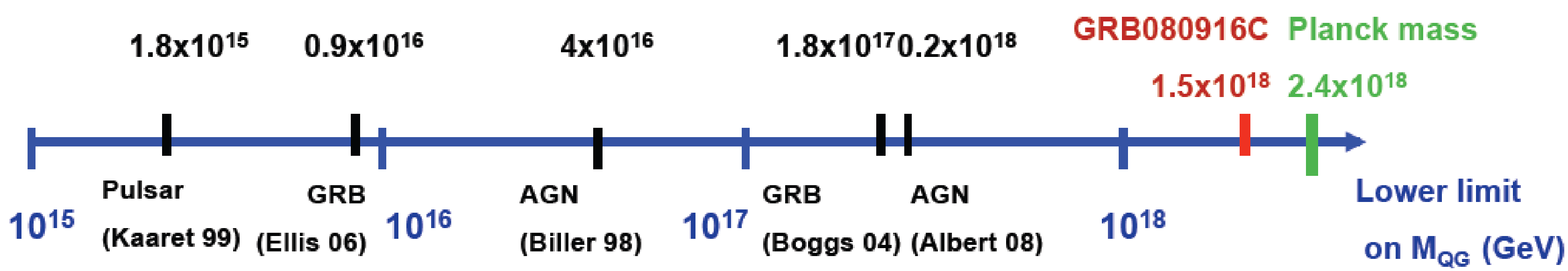
Fermi sets a new constraint on the QG energy scale

- 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)

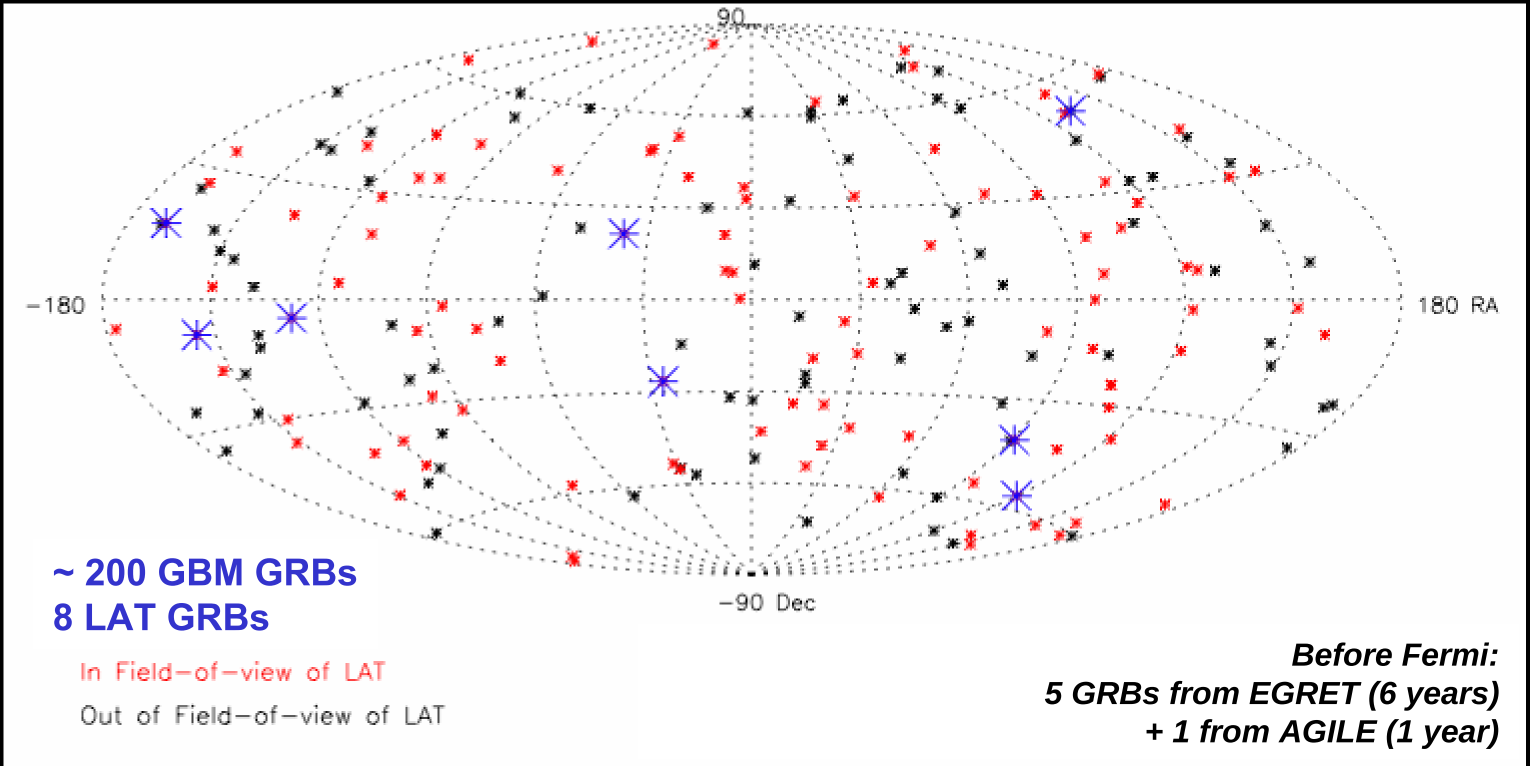
$$\Delta t = \frac{(1+n)}{2H_0}\frac{E_h^n - E_l^n}{(M_{QG,n}c^2)^n}\int_0^z \frac{(1+z')^n}{\sqrt{\Omega_m(1+z')^3+\Omega_\Lambda}}\,dz'$$

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

➢ a conservative lower limit: $M_{QG,1} > (1.50 \pm 0.20)\times10^{18}$ GeV/c^2

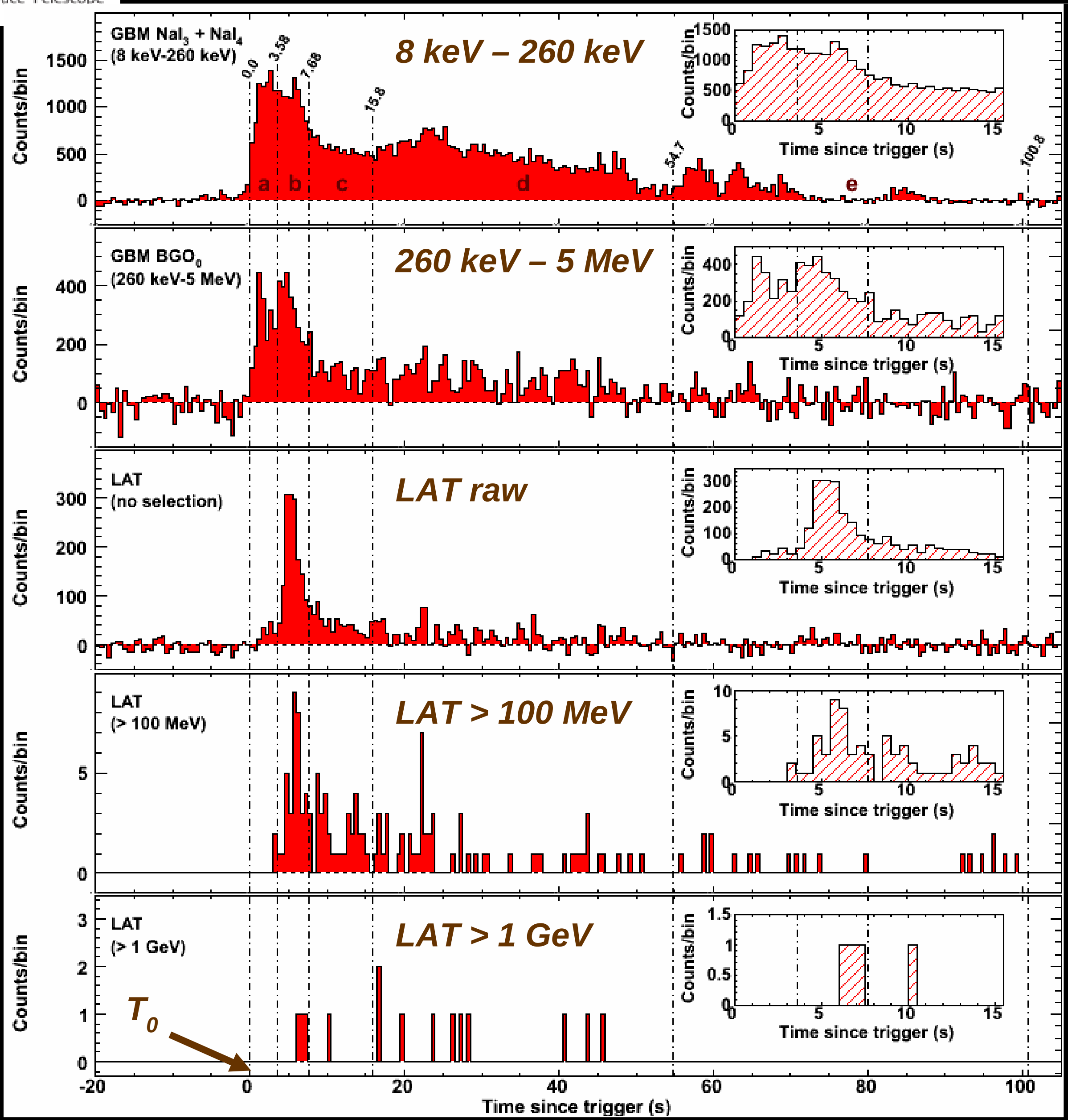


Fermi GRBs as of 090510



- **GRB 080825C:** >10 evts at > 100MeV
- **GRB 080916C:** >145 (14) evts at > 100 MeV (1GeV)), very strong, z=4.35
- **GRB 081024B:** 1st short detected above GeV
- **GRB 081215A:** outside LAT FOV, seen in raw count increase
- **GRB 090217:** several seconds after GBM trigger
- **GRB 090323:** extended emission up to 2Ks – ARR, z=3.6
- **GRB 090328:** highest energy photons at 100s seconds after GBM trigger – ARR, z=0.736
- **GRB 090510:** – short, intense, hard, 1st LAT GCN notice, z=0.9

GRB 080916C - LAT and GBM light curves



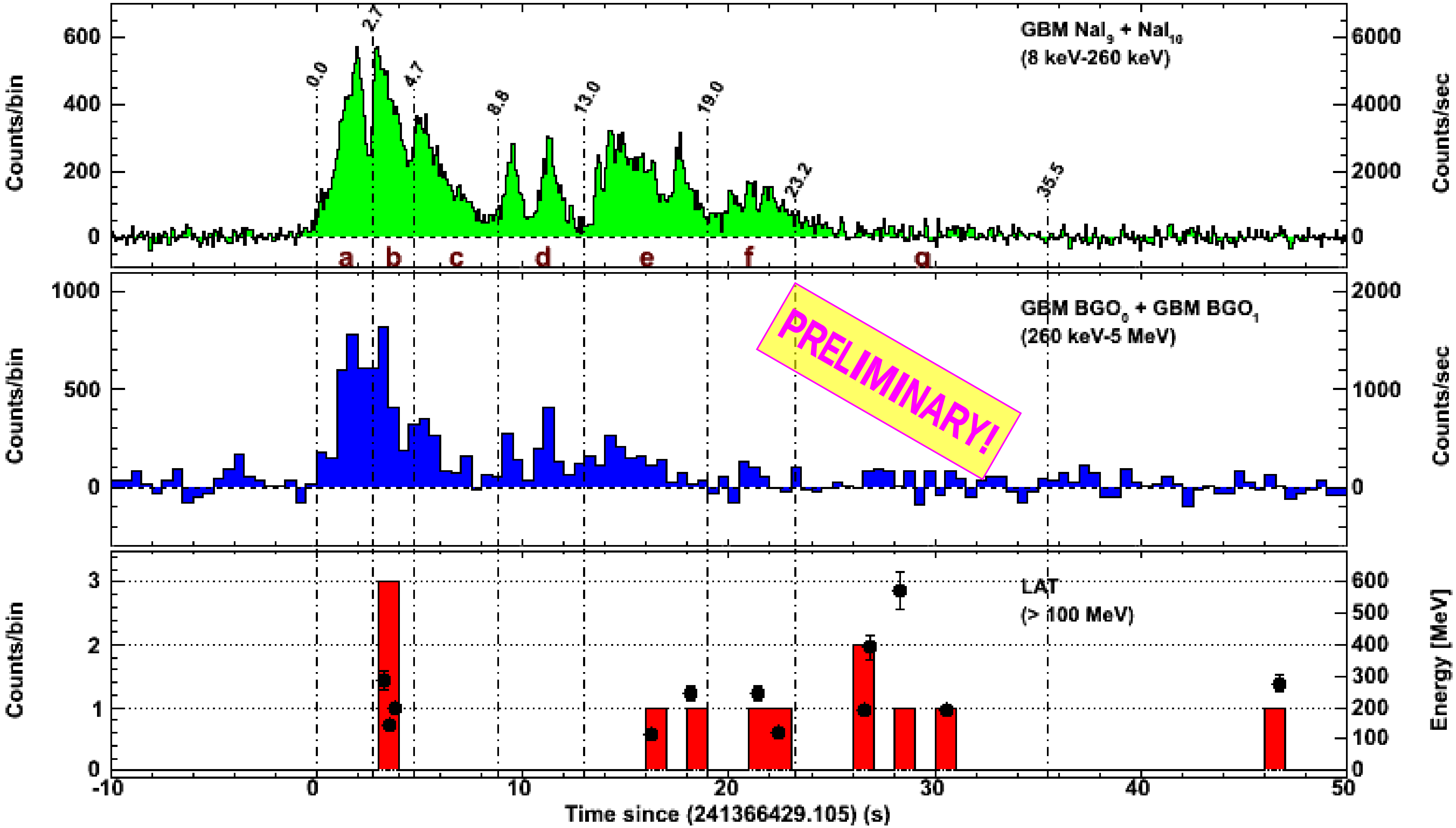
- For the first time, can study time structure > tens of MeV, 14 events above 1 GeV
- First low-energy GBM peak is not observed at LAT energies
- z = 4.35 +/0.15

- 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

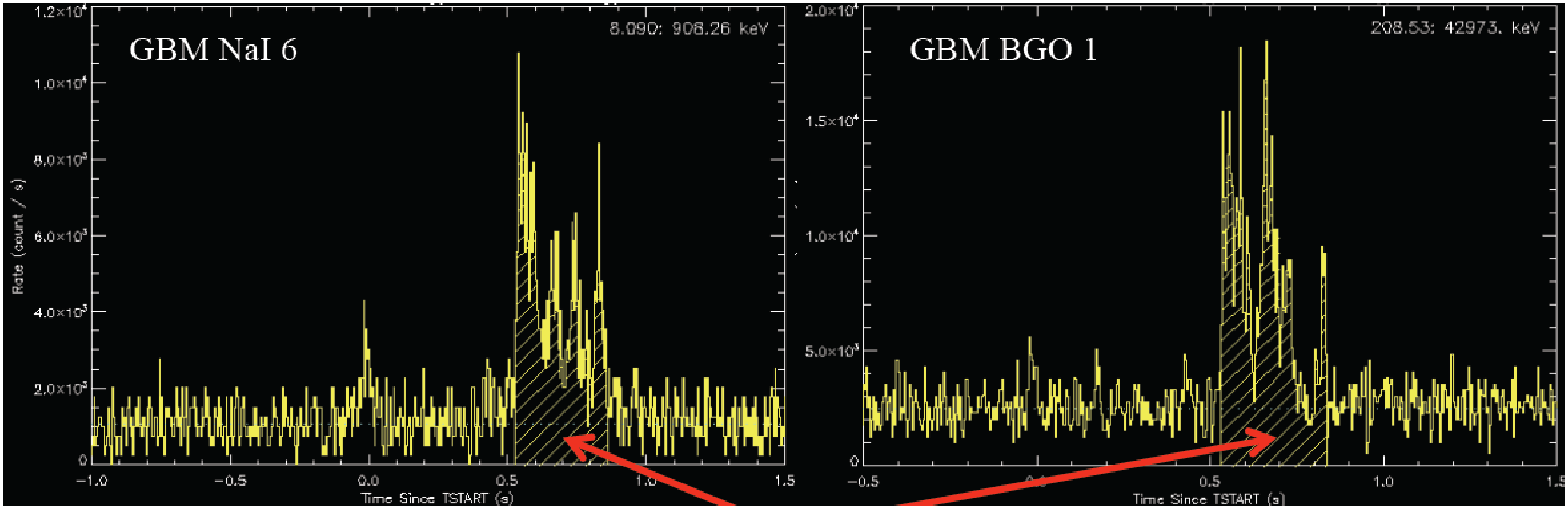
Science Express, 19 Feb 2009, pg 1

GRB 080825C

- First LAT events are detected in coincidence with the 2nd GBM peak
- Highest energy event is detected when GBM low energy emission is very weak



GRB090510 – The last promising event



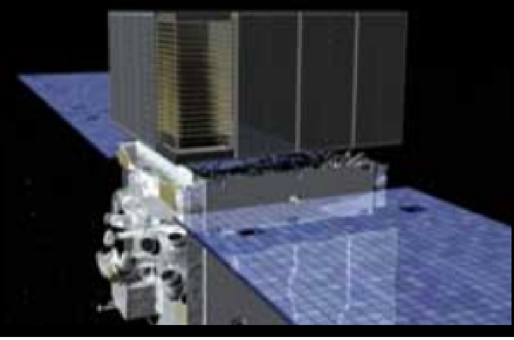
E_{peak} = 4.4 +/- 0.4 MeV, $E_{peak,rest}$ = 8.4 +/- 0.8 MeV

α = -0.80 +/- 0.03, β = -2.6 +/- 0.3

- **Bright short/hard GRB at z 0.9 with (GCN 9350)**
  - **1st second: >50 events above 100 MeV, >10 above 1 GeV**
  - **1st minute: >150 events above 100 MeV, >20 above 1 GeV**

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

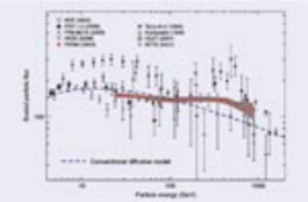
May 4, 2009

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?

+ Enlarge Image

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 claim. Researchers working with NASA's orbiting Fermi Gamma-ray Space

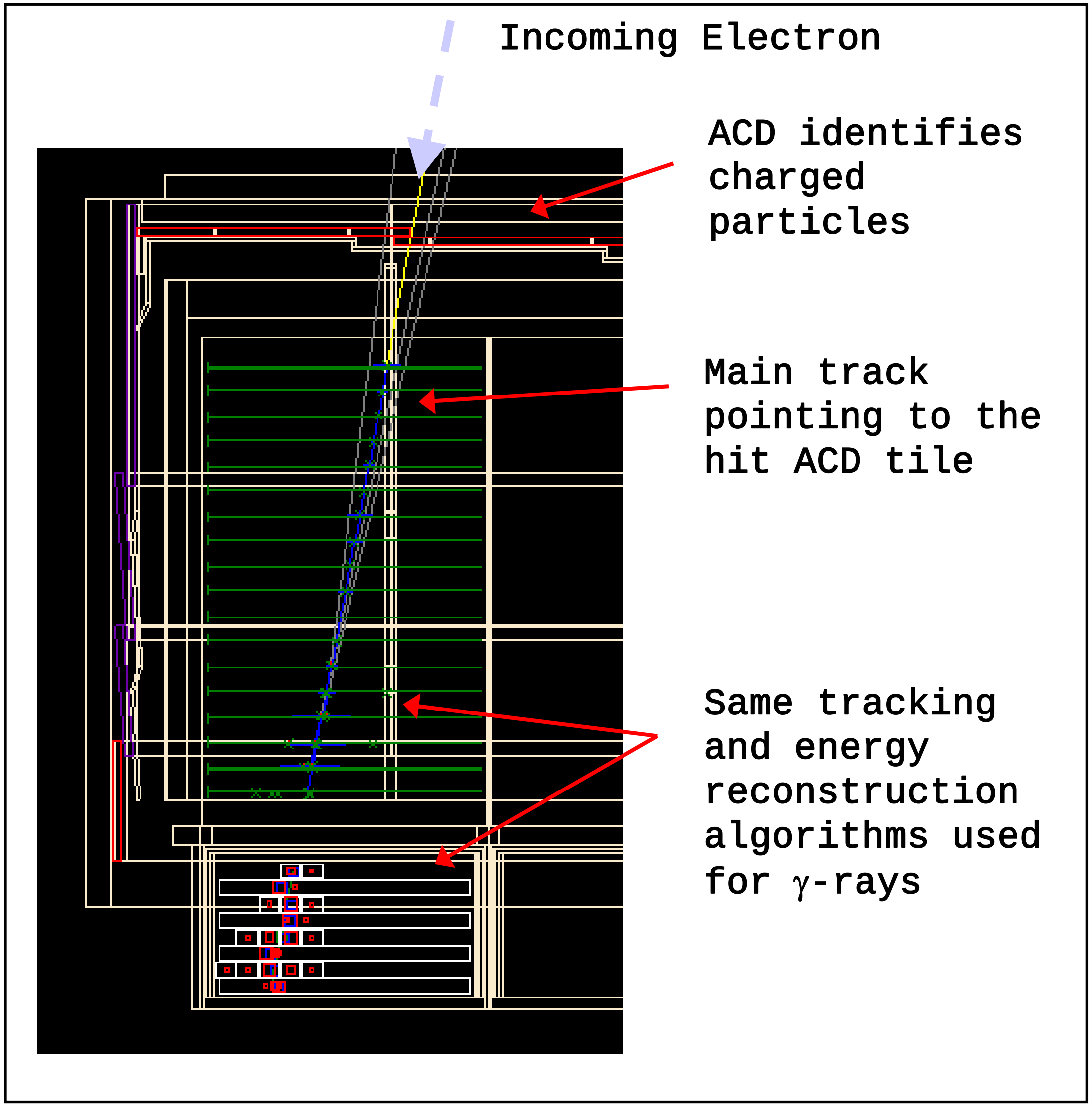
How the LAT detects electrons

Trigger and downlink

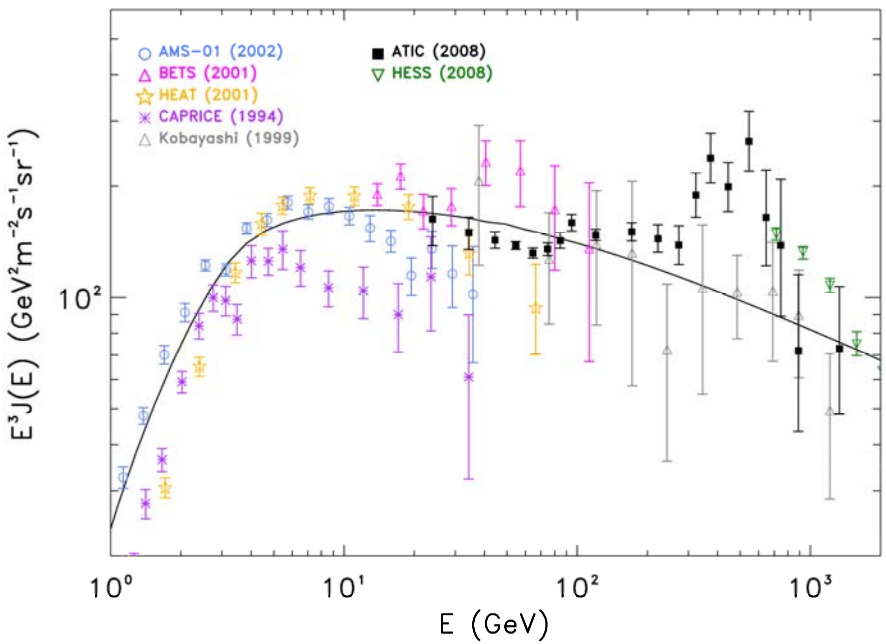
- Very versatile and configurable
  - Triggering on ~ all particles that cross the LAT
    - Including electrons
- On board filtering to fit bandwidth
  - Remove many charged particles
  - Keeps all events with more than 20 GeV in the CAL

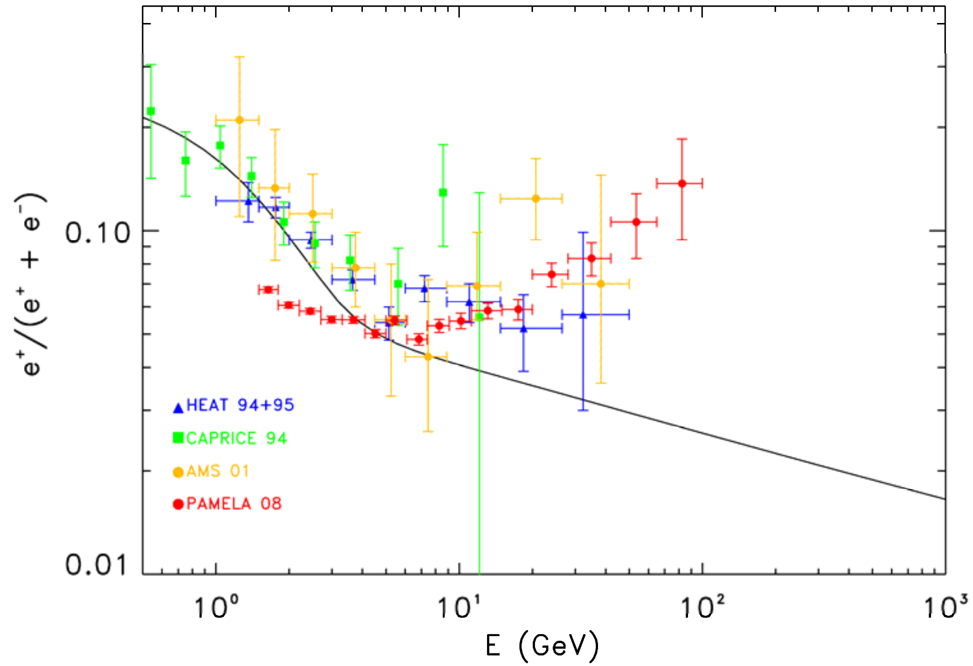
Electron identification

- 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

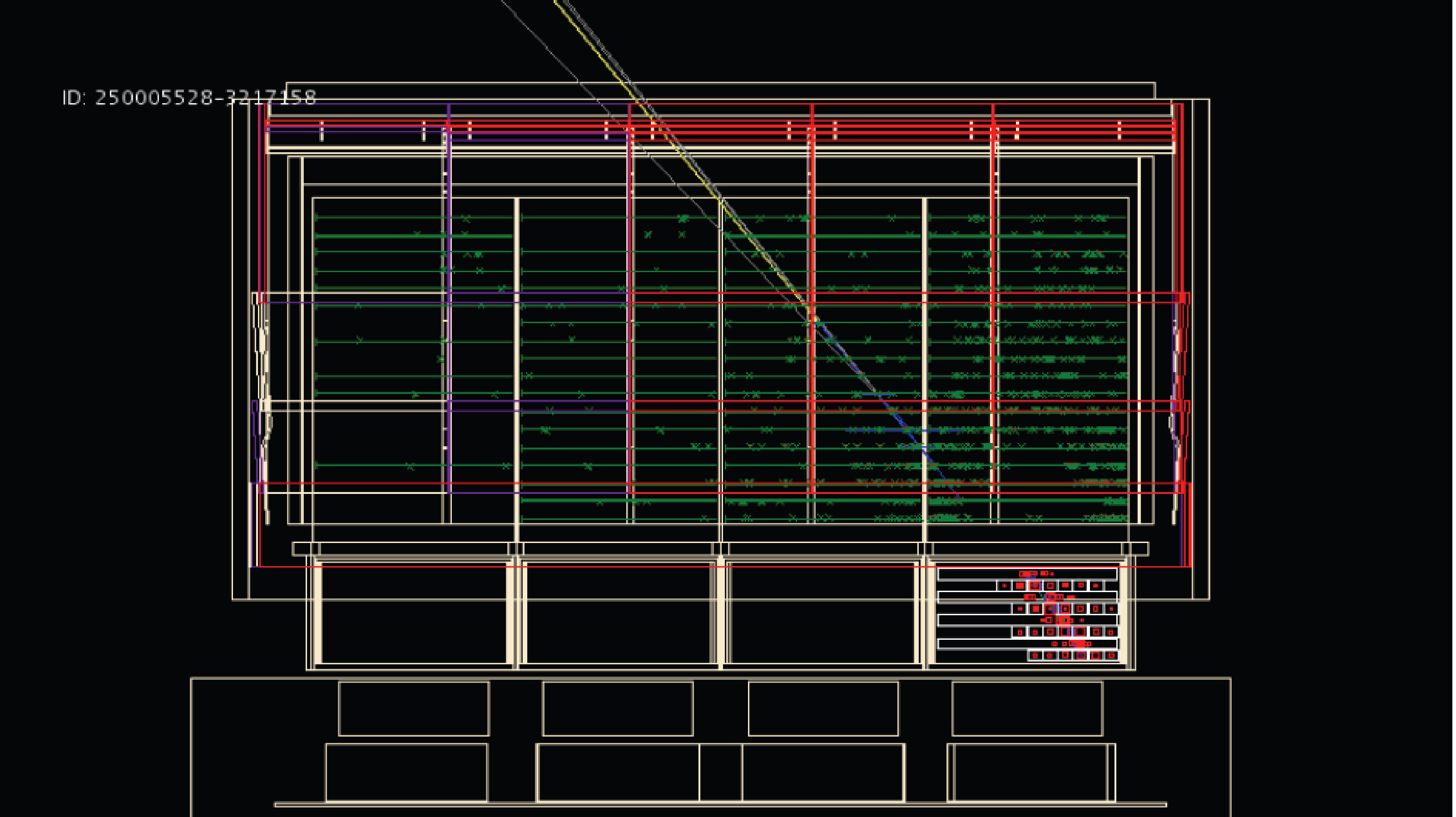




- Spectral features in the ($e^+ + e^-$) spectrum
  - possible excess around 600 GeV reported by ATIC and PPB-BETS
  - spectral cutoff measured by H.E.S.S. around 1 TeV
- Pamela reports an increase in the positron fraction

- 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

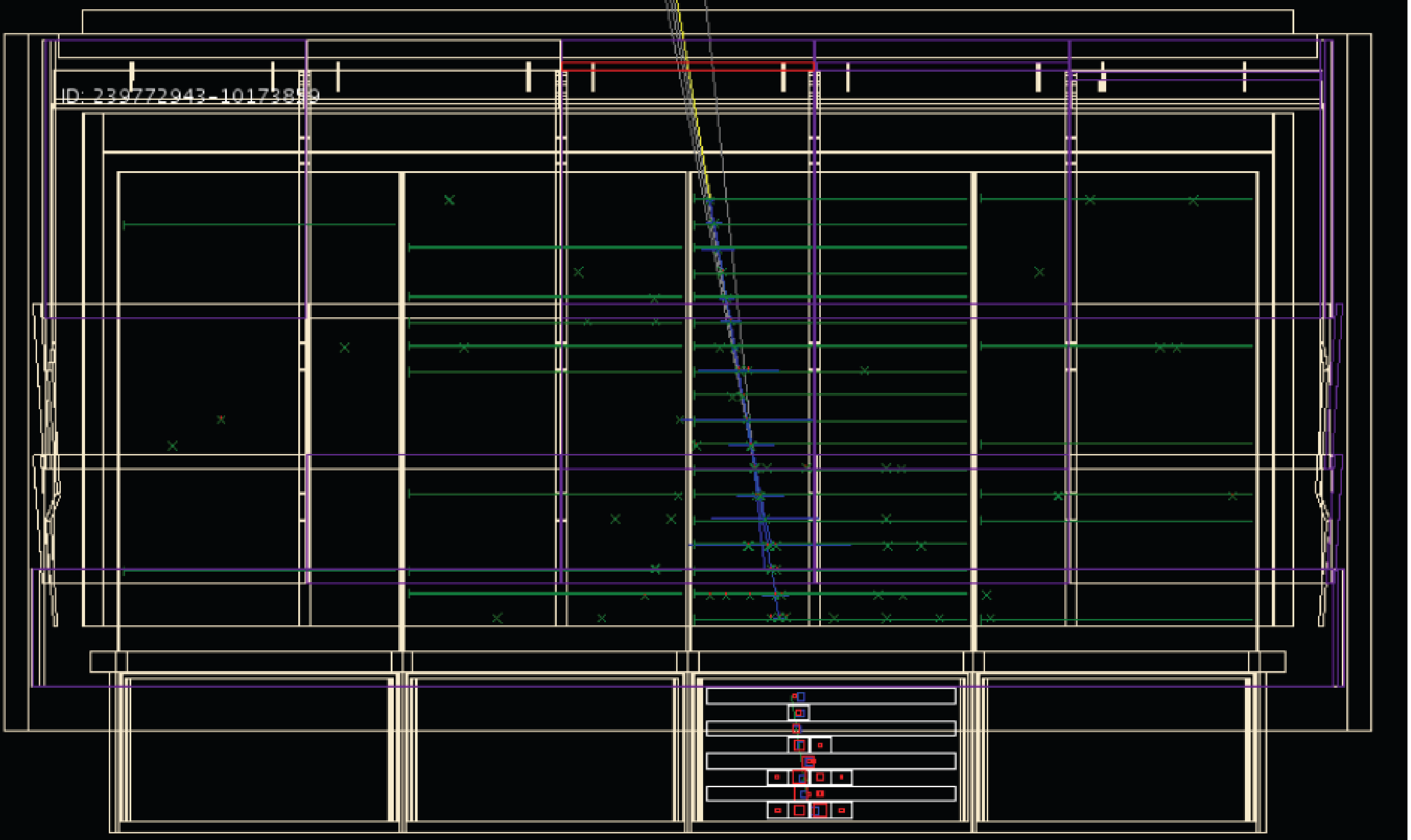
Tkr1ToTTrAve
0

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



A candidate electron – 844 GeV

CalEnergyRaw
2.501e+05

CTBBestEnergy
8.443e+05

CTBBestEnergyProb
0.531

TkrNumTracks
5

CalCsIRLn
8.49

CTBBestZDir
-0.986

CTBTKRHEEProb
0.924

CTBCALHEEProb
0.733

CalLRmsAsym
0.0656

CalTrSizeTkrT95
9.73

CalTransRms
23.8

Tkr1CoreHC
29

Tkr1Hits
35

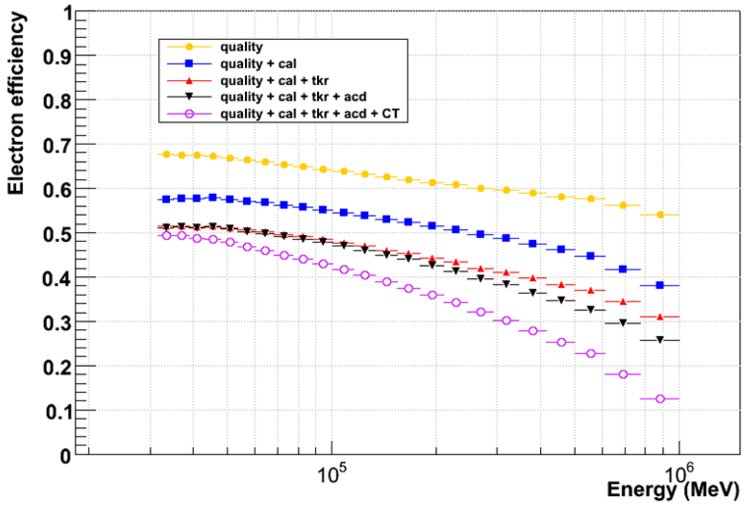
Tkr1ToTTrAve
5.40

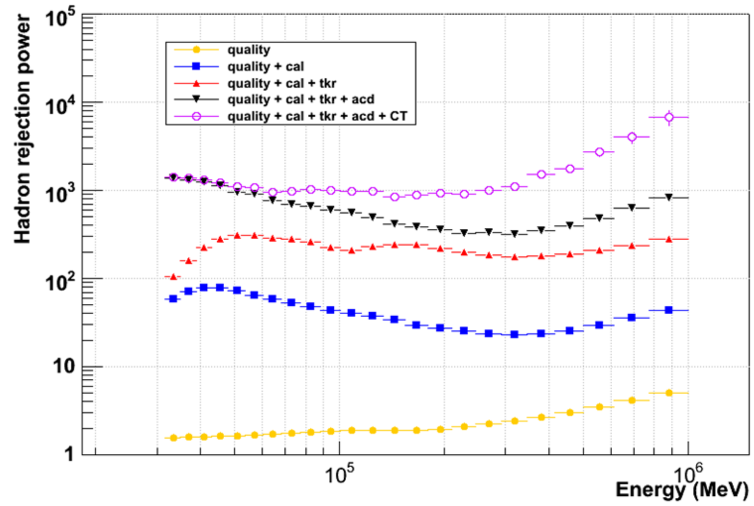
AcdTotalEnergy
8.99

AcdTileCount
20

- **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**

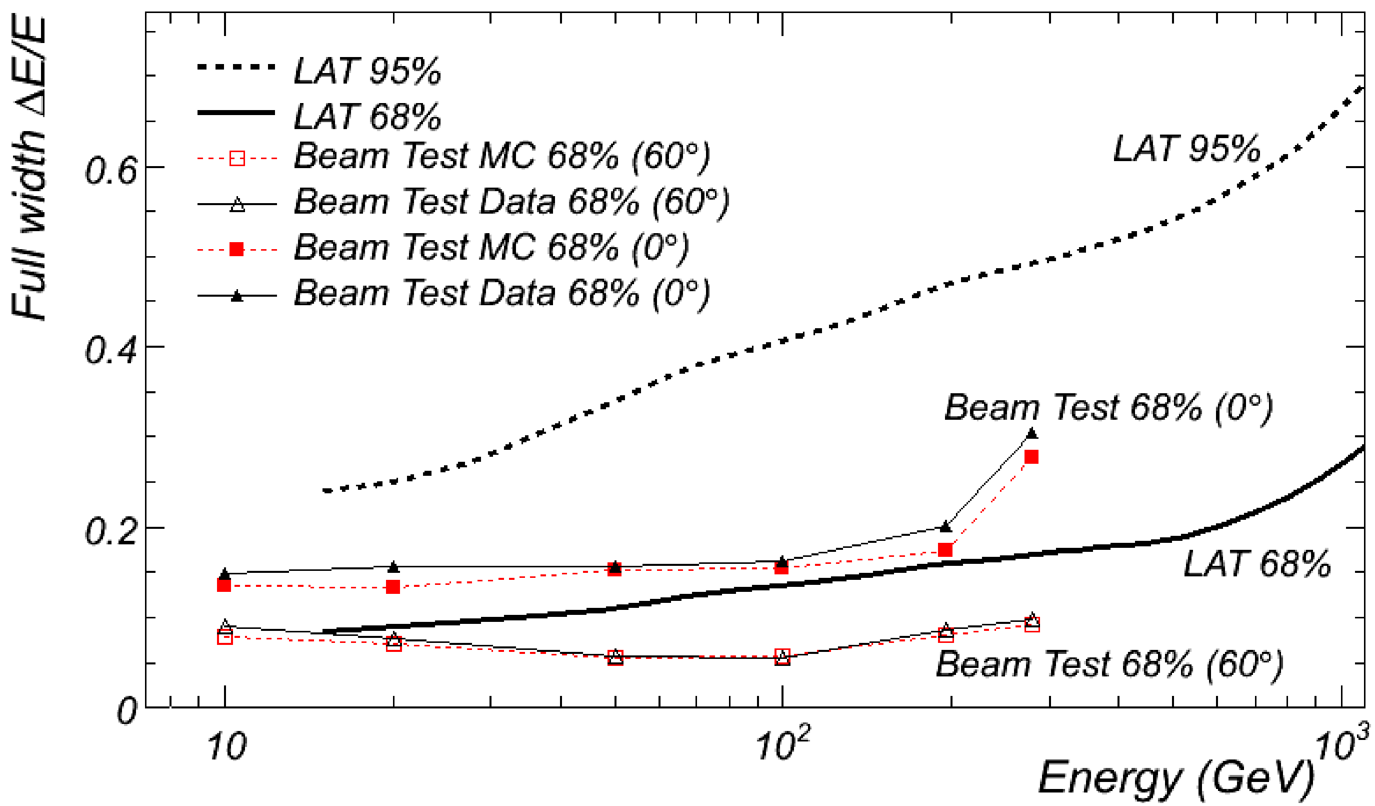
LAT Electron performance





- 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)

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)**

GLAST lands 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

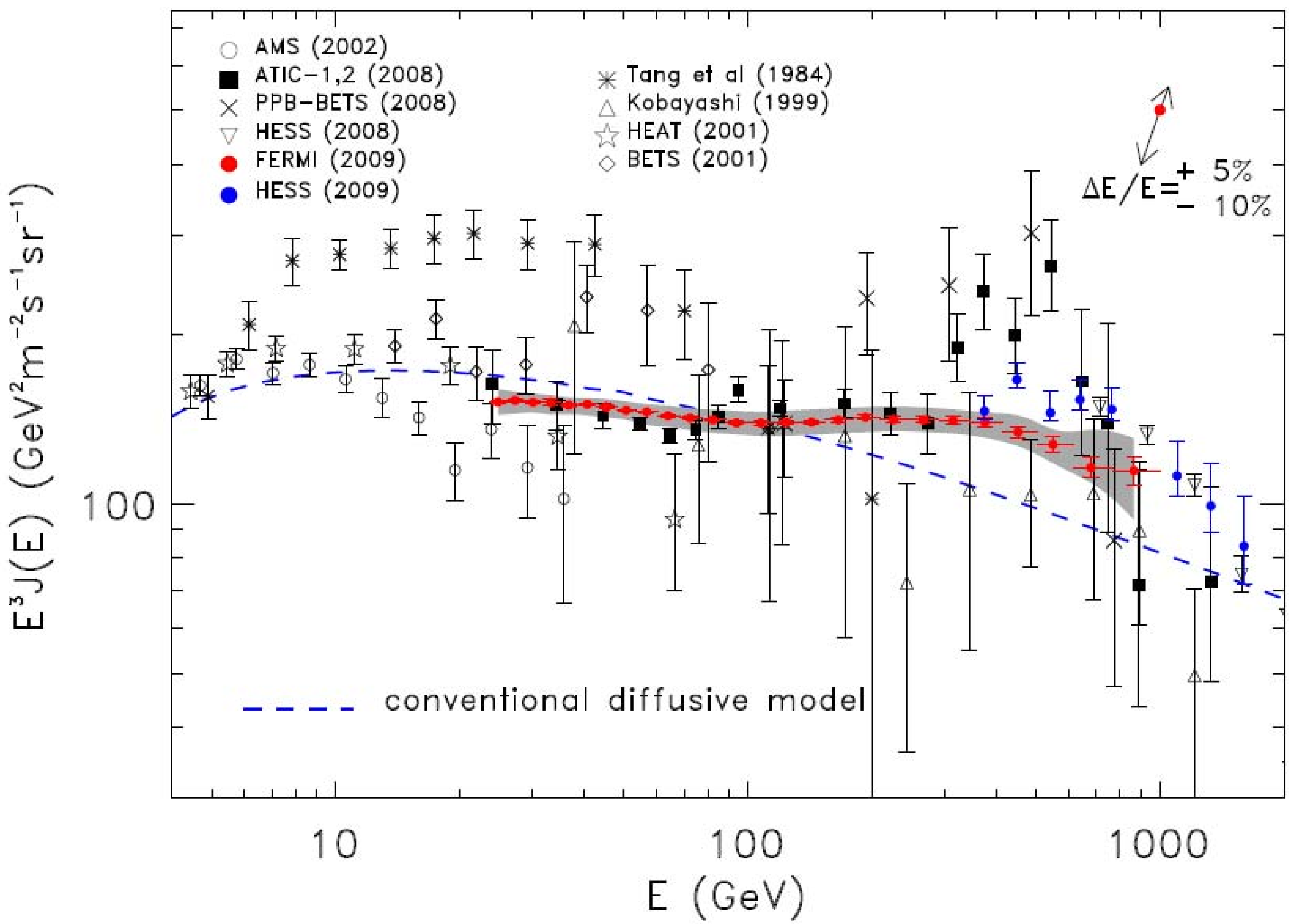
PRL 102, 181101 (2009)

Selected for a Viewpoint in *Physics*

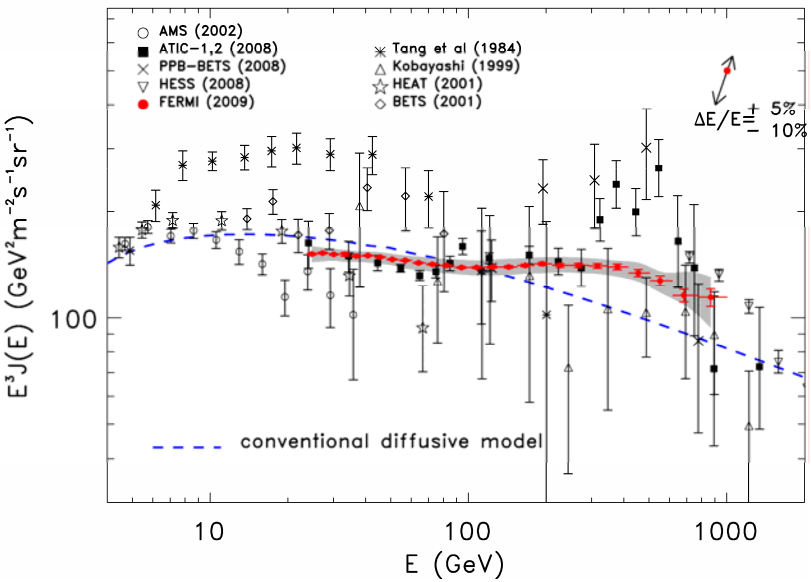
PHYSICAL REVIEW LETTERS

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

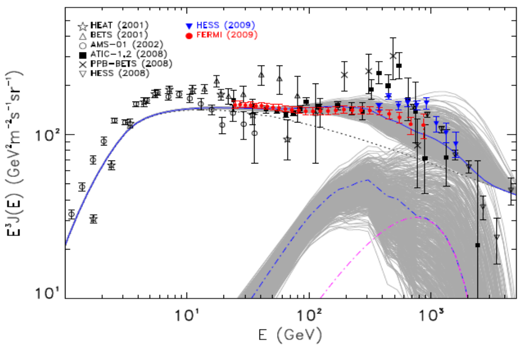
More than 400 electrons in the last energy bin 772-1000 GeV

- **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

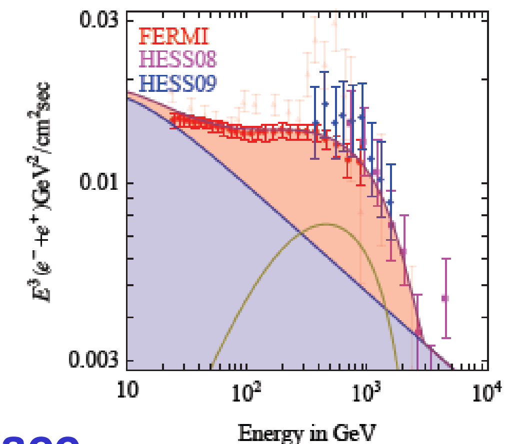
- Several papers already published to explain electron spectrum
  - Together with other observations (positron fraction, diffuse γ-ray)

Pulsars



Grasso et al. 2009

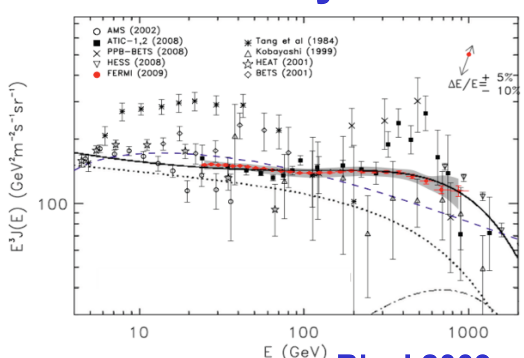
Dark Matter



Strumia et al. 2009

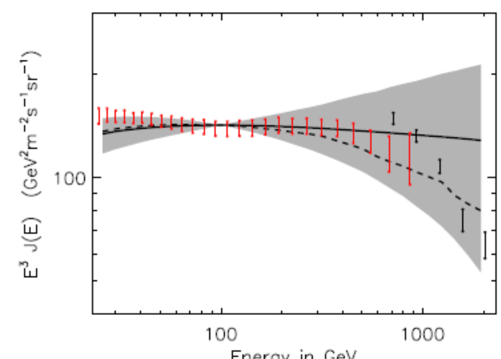
57 citations so far,
~ > 1/day

Secondary CR acc.



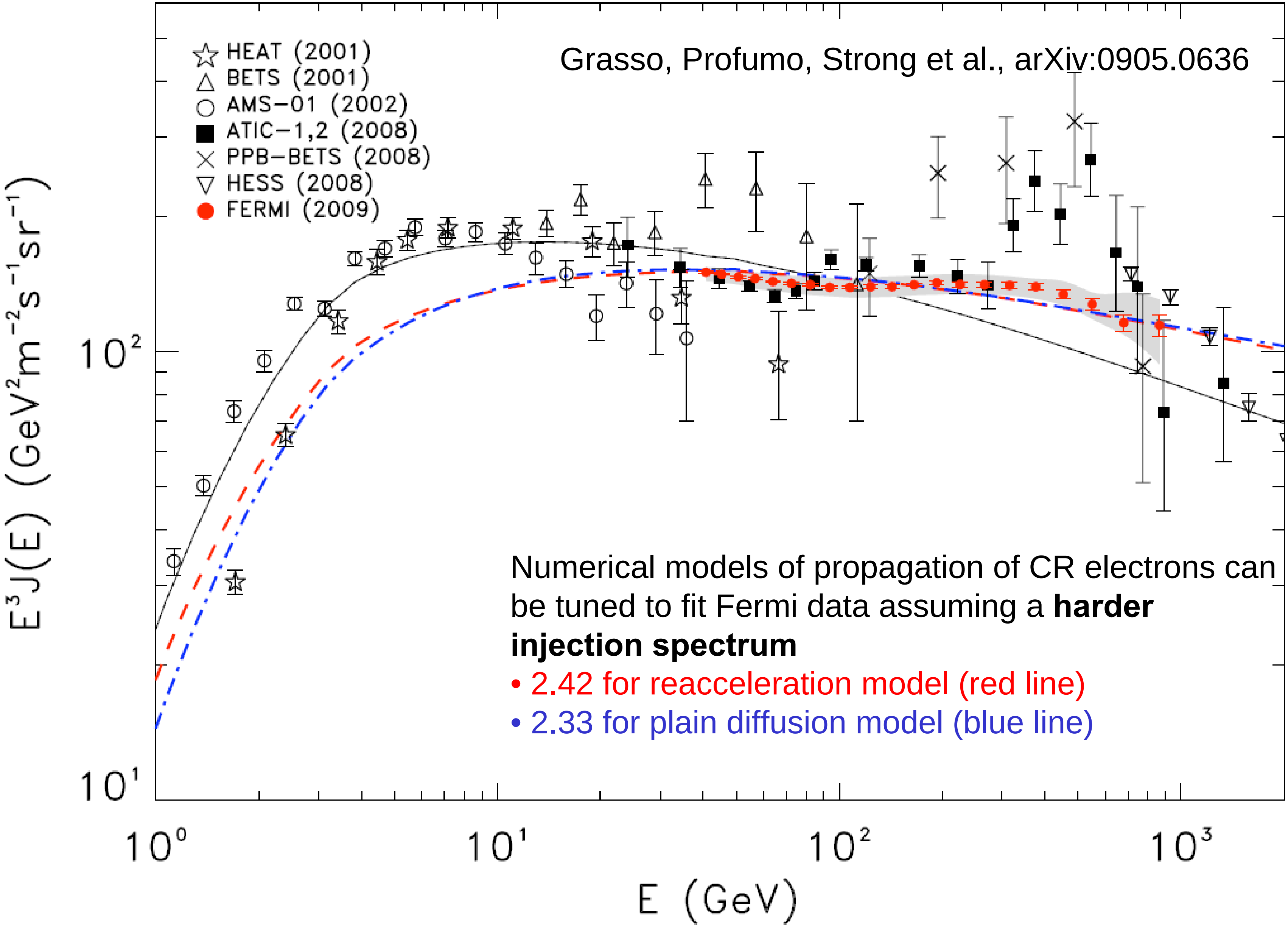
Blasi 2009

Source stocasticity



Grasso et al. 2009

A possible “conservative” interpretation

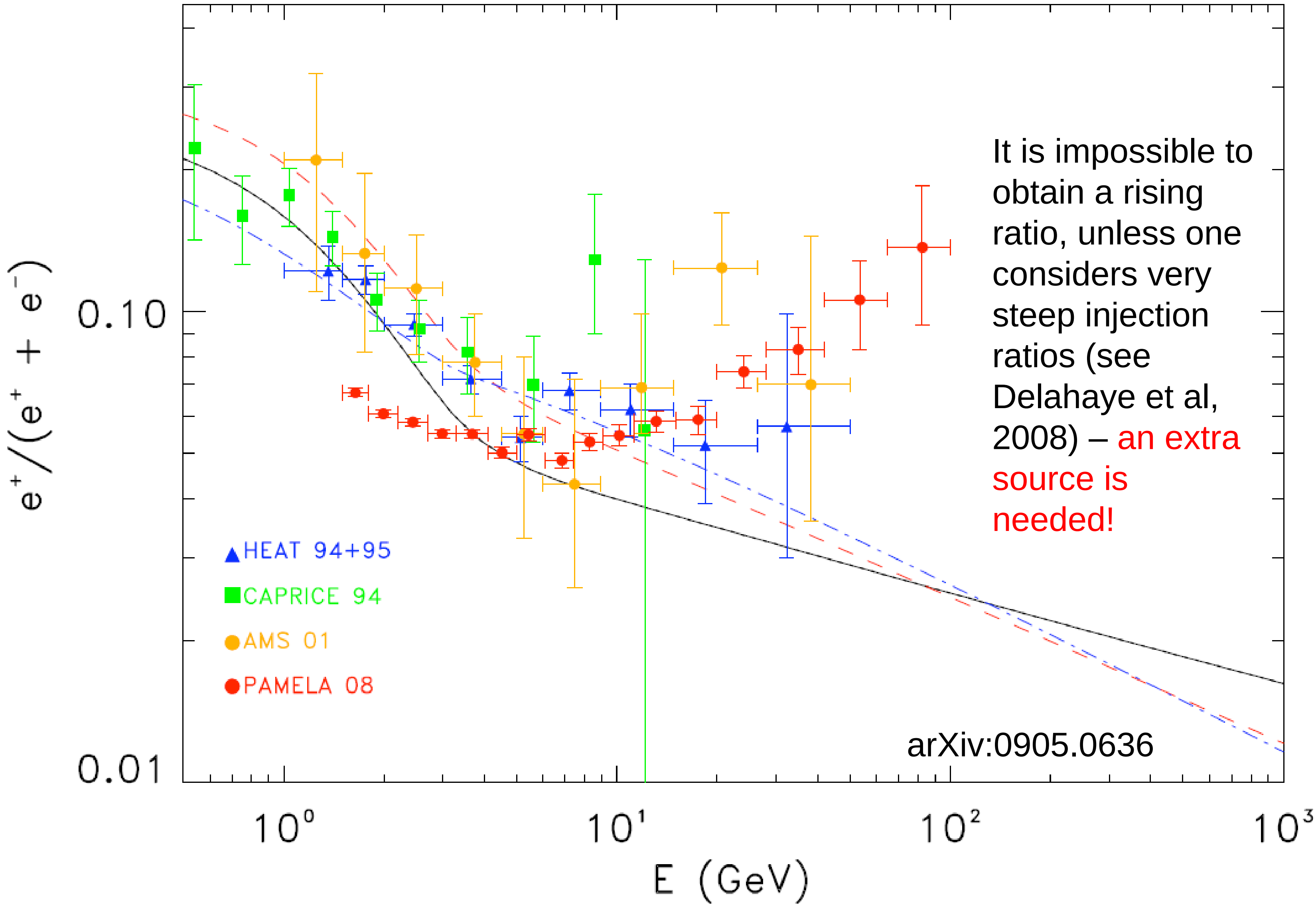


Grasso, Profumo, Strong et al., arXiv:0905.0636

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!

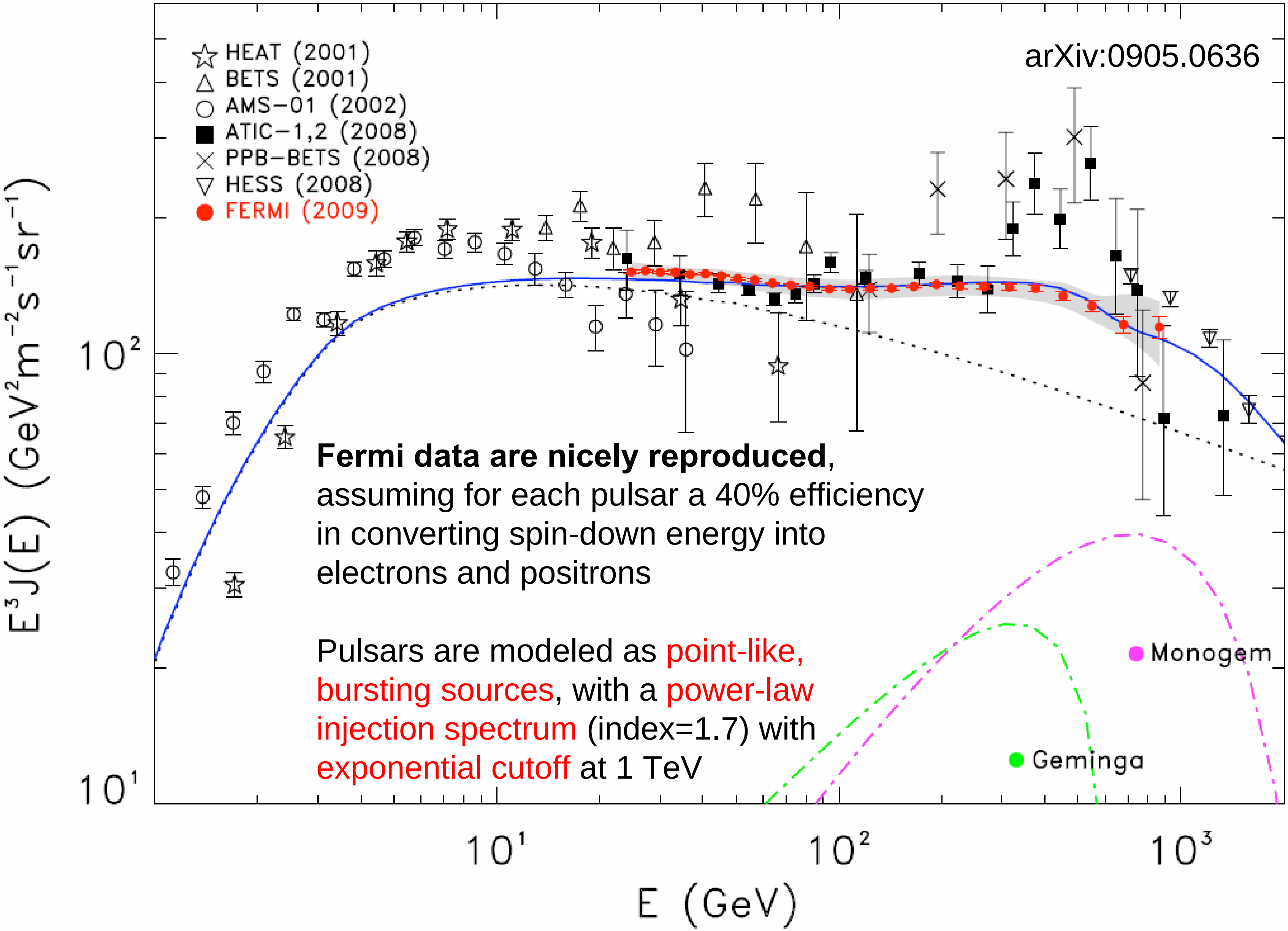
The possible role of nearby pulsars

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

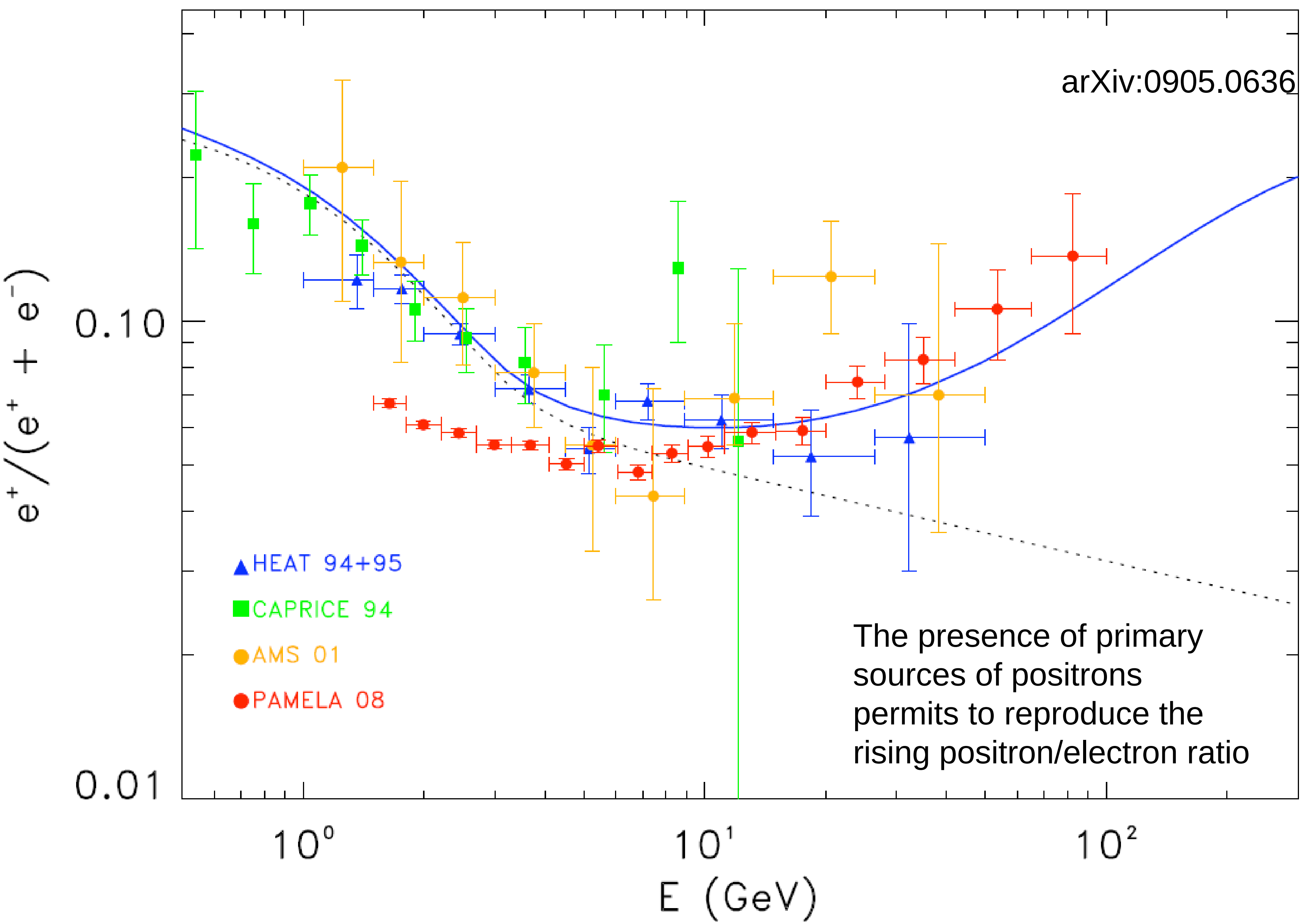
Adding candidate pulsars within 1Kpc



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

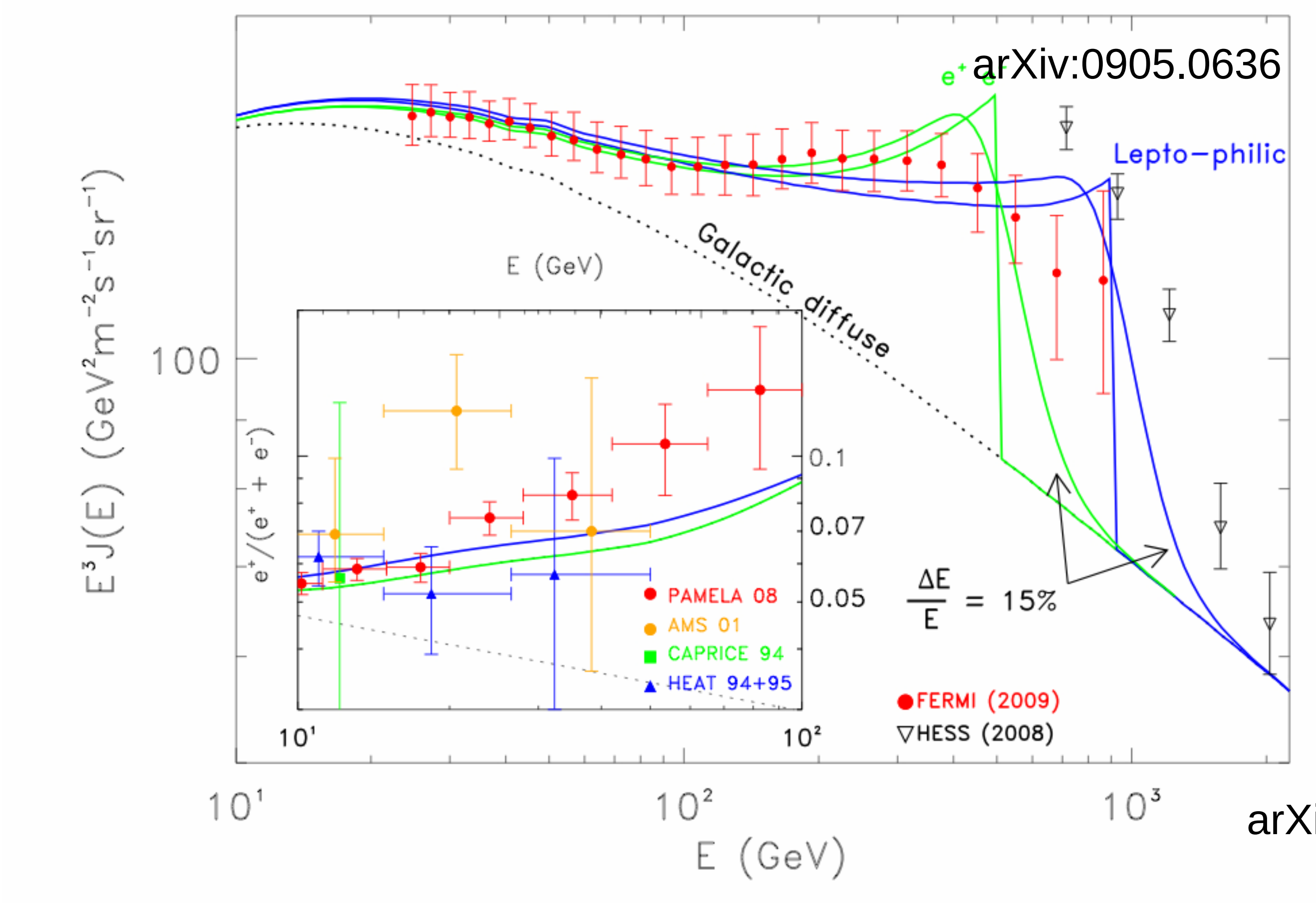
1. Much weaker rationale to postulate a **low DM mass** in the 0.3-1 TeV range ("**ATIC bump**") motivated by the CR electron+positron spectrum

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

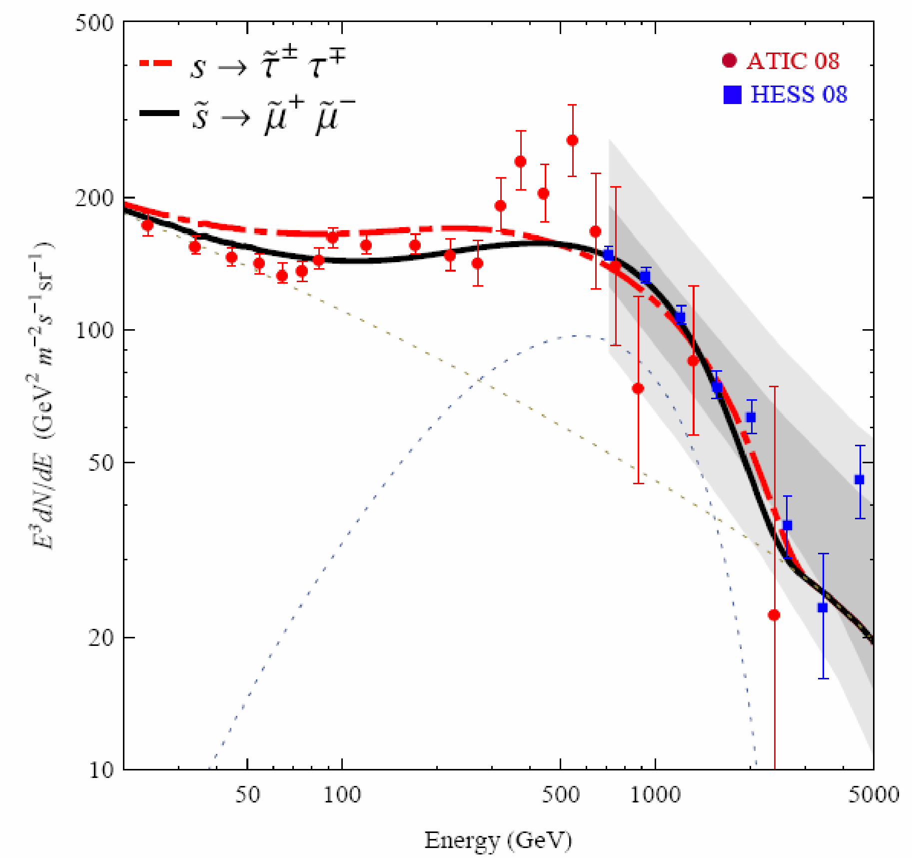


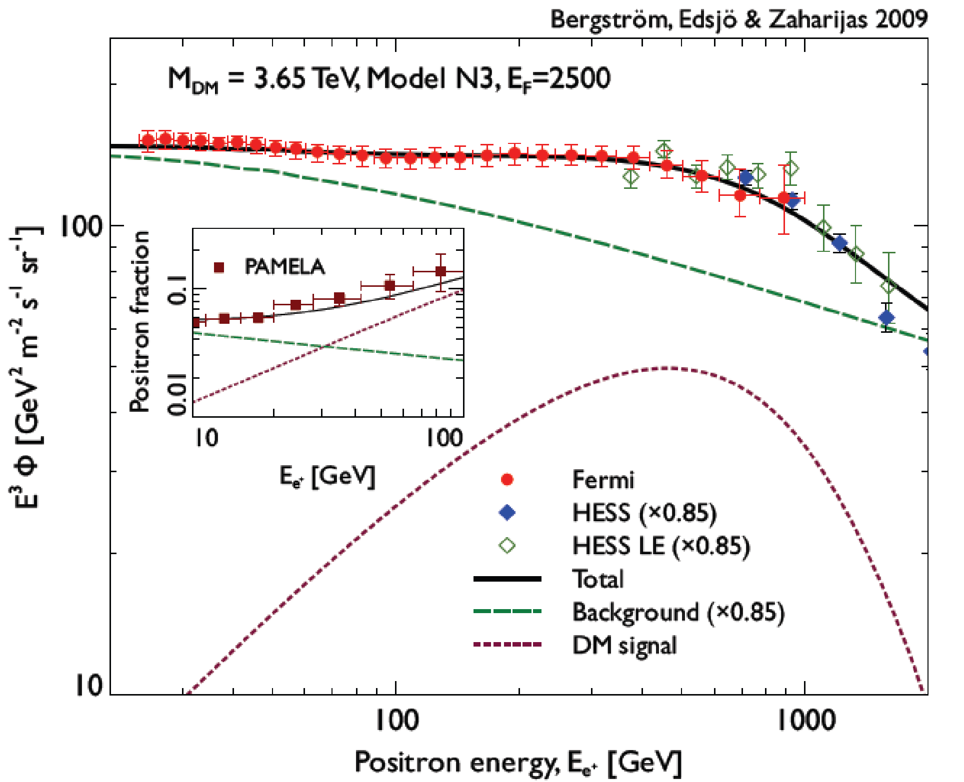
arXiv:0905.0636

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

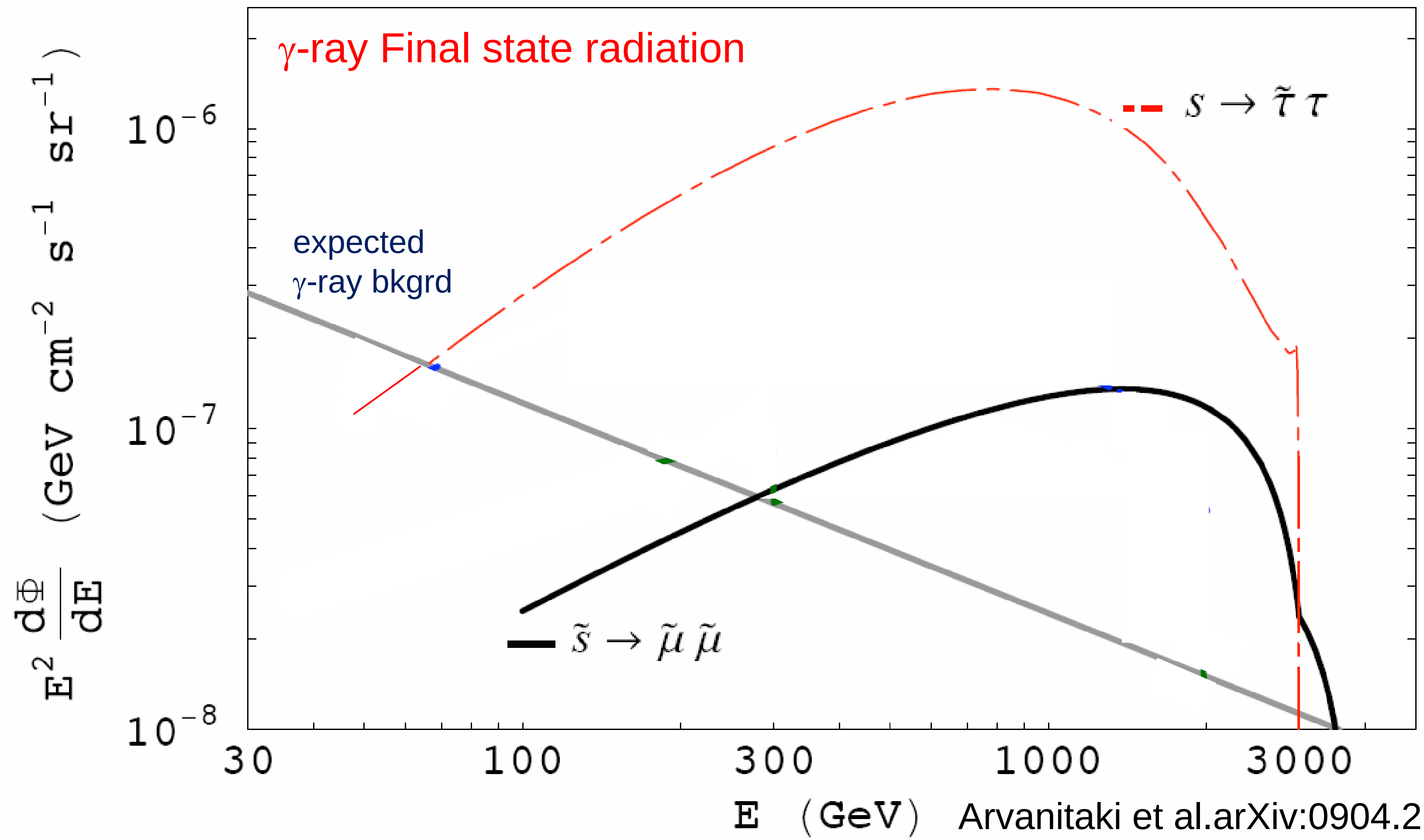




Arvanitaki et arXiv:0904.2789v1
Decaying SUSY dark matter

Bergstrom et al.arXiv:0905.0333v1
Annihilating DM

Fermi could look for signature in the diffuse gamma-ray

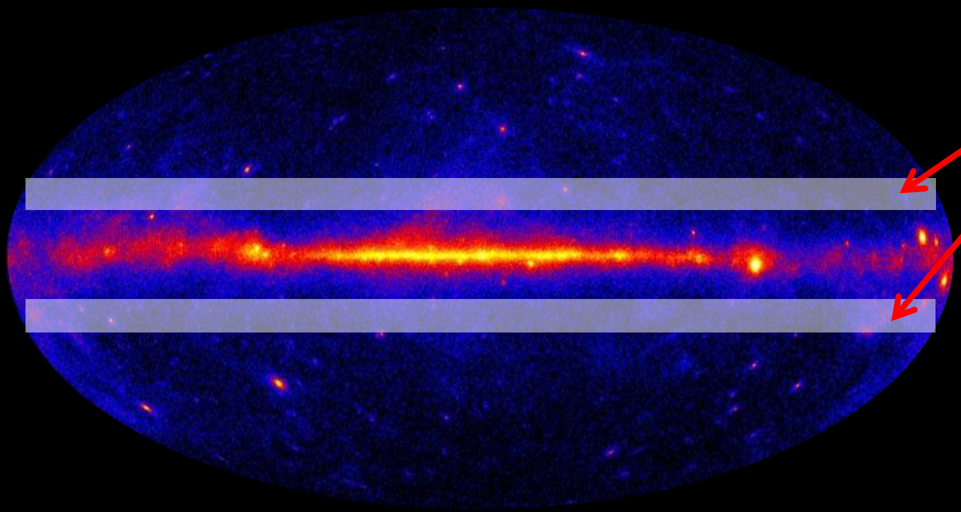


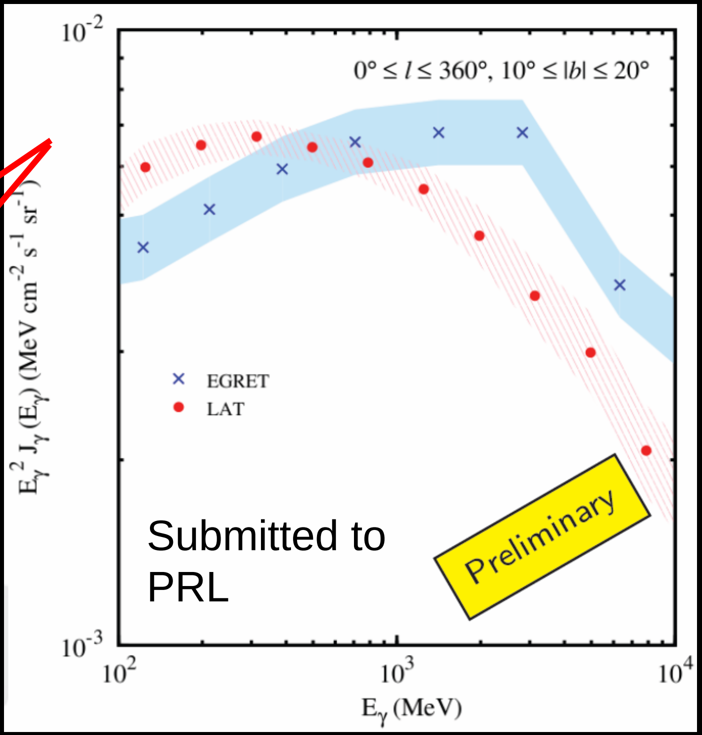
Arvanitaki et al.arXiv:0904.2789v1
Decaying SUSY dark matter

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

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

100 MeV – 10 GeV

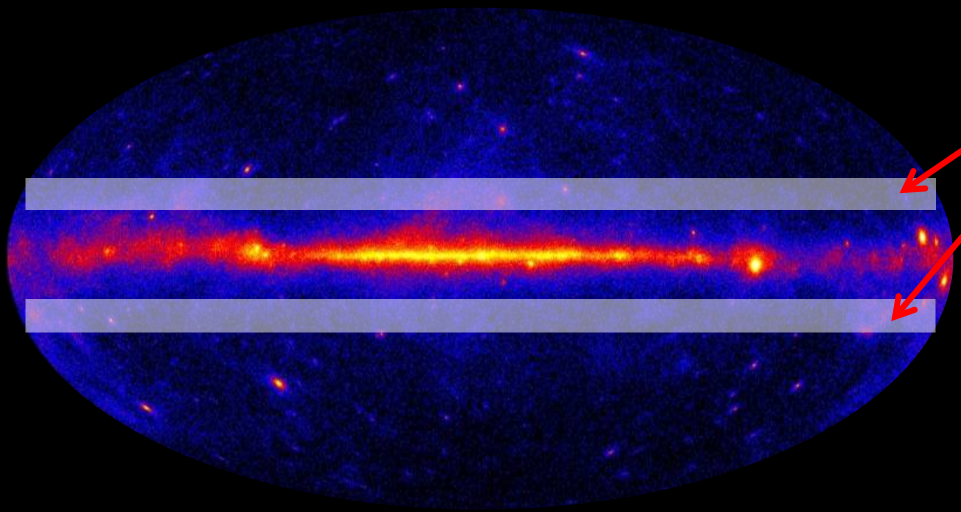


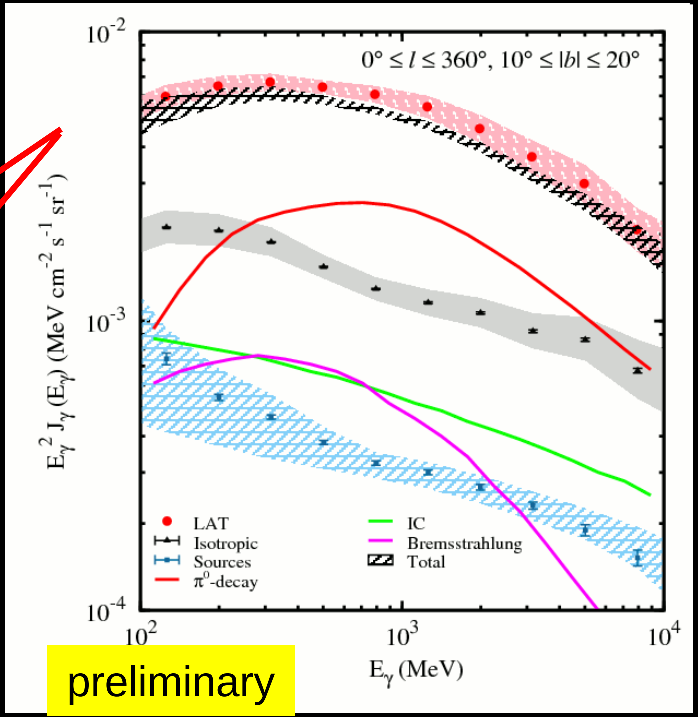


- Spectra shown for mid-latitude range → EGRET GeV excess in this region of the sky is not confirmed
- Sources are a minor component
- LAT errors are systematics dominated and estimated ~10%
- Work to analyse and understand diffuse emission over the entire sky and broader energy range is in progress

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

100 MeV – 10 GeV





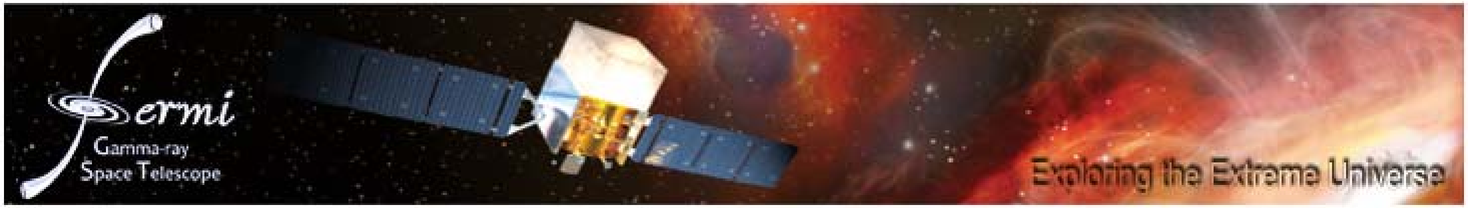
- **Spectra shown for mid-latitude range → EGRET GeV excess in this region of the sky is not confirmed**
- **Sources are a minor component**
- **LAT errors are systematics dominated and estimated ~10%**
- **Work to analyse and understand diffuse emission over the entire sky and broader energy range is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

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
  - 8 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

18 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	5	5	10
Astrophysical Journal Letters	2	1	3
Astrophysical Journal Supplement	1	-	1
Journal of Cosmology and Astroparticle Physics	1	-	1
Physical Review Letters	1	-	1
Science	2	1	3
Total	13	8	21

Papers submitted to journals: 6
Ready to submit: 1

Rapid publications:
Astronomers' telegrams: 34
GCN circulars: 11

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