The first year of the *Fermi* Large Area Telescope: a new light on the high-energy Universe

Luigi Tibaldo

luigi.tibaldo@pd.infn.it

INFN – Sezione di Padova
Dip. di Fisica "G. Galilei", Università di Padova
IRFU/SAp, CEA Saclay

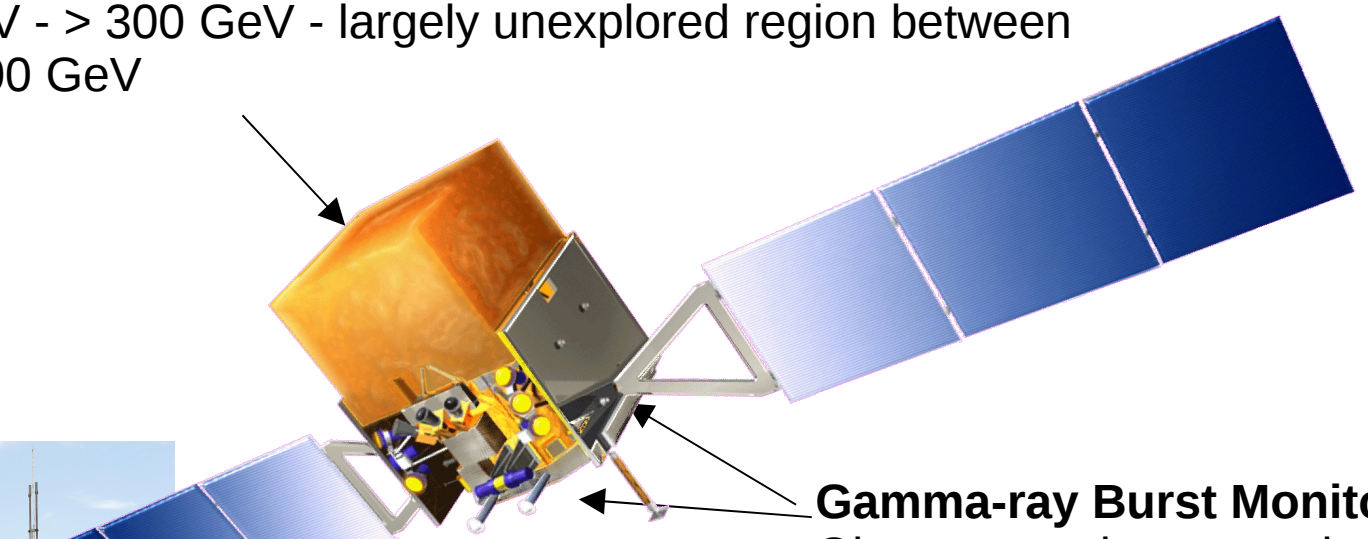
on behalf of the *Fermi* LAT Collaboration

16th July 2009

The *Fermi* Large Area Telescope

The *Fermi* observatory

Large Area Telescope (LAT)
Observes 20% of the sky at any instant, entire sky every 3 hrs
20 MeV - > 300 GeV - largely unexplored region between 10 - 100 GeV



Gamma-ray Burst Monitor (GBM)
Observes entire unocculted sky
Detects transients from 8 keV - 40 MeV

Launched from Cape Canaveral Air Station on 11 June 2008.

Orbit: 565 km, 26.5°.

Large Area Telescope

Overall LAT Design:

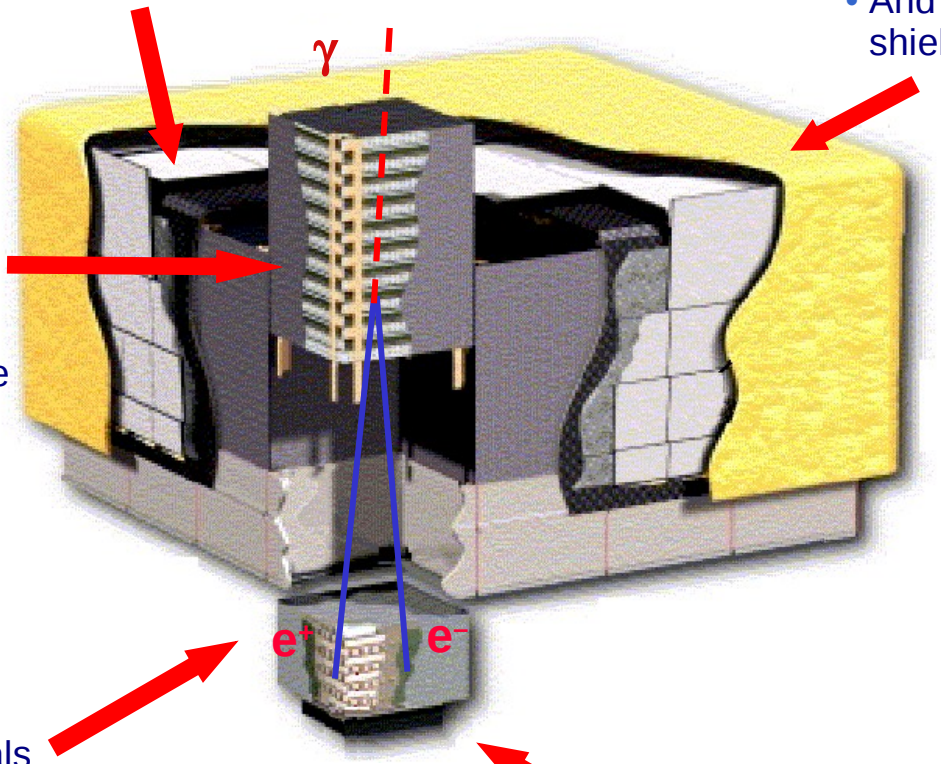
- 4x4 array of identical towers
- 3000 kg, 650 W (allocation)
- 1.8 m × 1.8 m × 1.0 m
- 20 MeV – >300 GeV

Anticoincidence Detector:

- 89 scintillator tiles
- First step in reduction of large charged cosmic ray background
- Segmentation reduces self veto at high energy

Thermal Blanket:

- And micro-meteorite shield



Precision Si-strip Tracker:

Measures incident gamma direction

18 XY tracking planes. 228 μm pitch. High efficiency. Good position resolution

12 x 0.03 X_0 front end => reduce multiple scattering.

4 x 0.18 X_0 back-end => increase sensitivity >1GeV

Hodoscopic CsI Calorimeter:

- Segmented array of 1536 CsI(Tl) crystals
- 8.5 X_0: shower max contained <100 GeV
- Measures the incident gamma energy
- Rejects cosmic ray backgrounds

Electronics System:

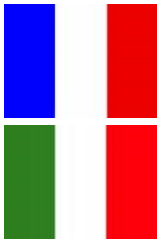
- Includes flexible, highly-efficient, multi-level trigger

The *Fermi* LAT collaboration

Principal Investigator:
Peter Michelson (Stanford University)

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

construction managed by
SLAC National Accelerator Laboratory



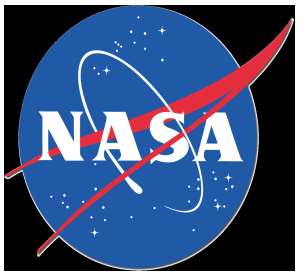
France
- IN2P3, CEA-Saclay

Italy
- INFN, ASI, INAF

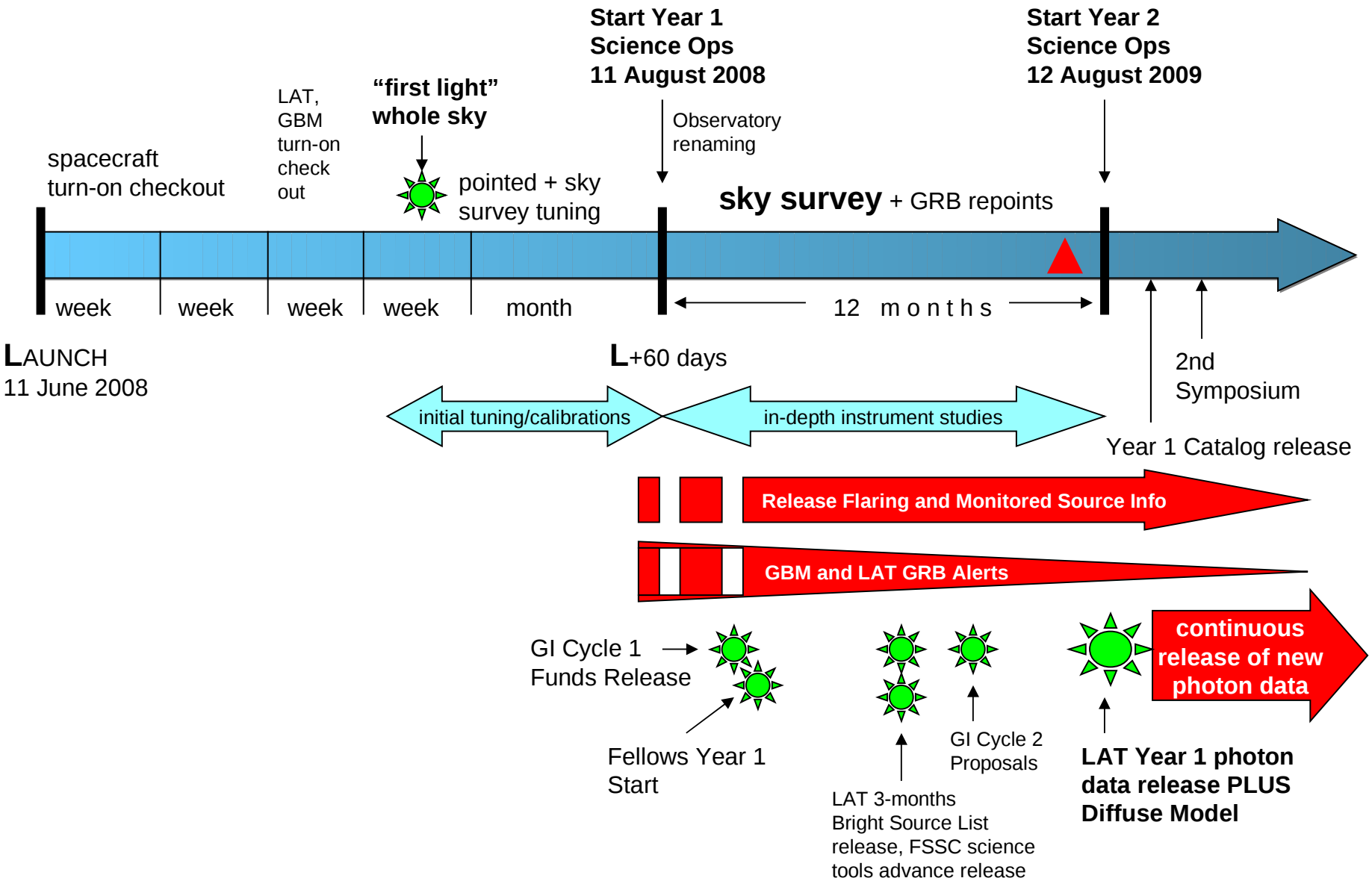
Japan
- Hiroshima University
- ISAS/JAXA
- RIKEN
- Tokyo Institute of Technology

Sweden
- Royal Institute of Technology (KTH)
- Stockholm University

United States
- Stanford University (SLAC and HEPL/Physics)
- University of California at Santa Cruz - Santa Cruz Institute for Particle Physics
- Goddard Space Flight Center
- Naval Research Laboratory
- Sonoma State University
- Ohio State University
- University of Washington

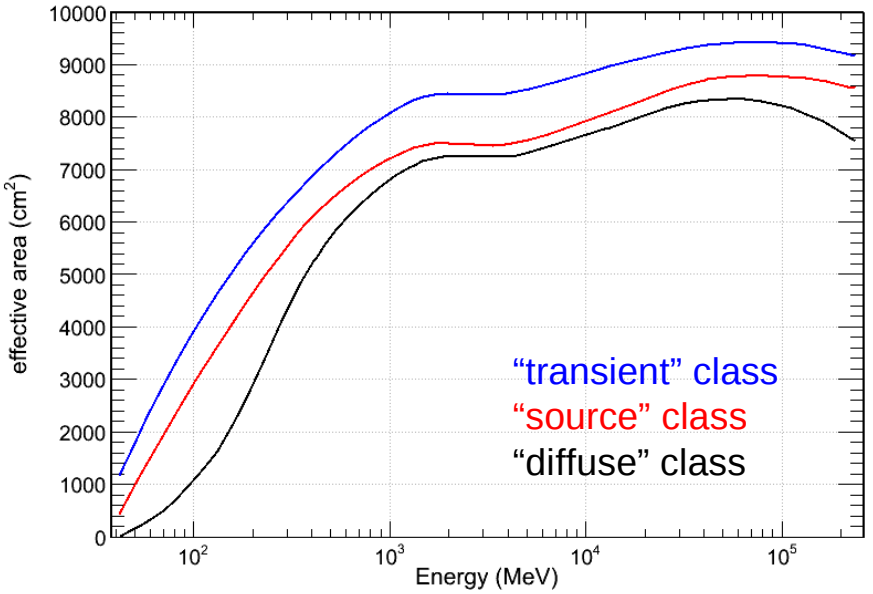


Timeline

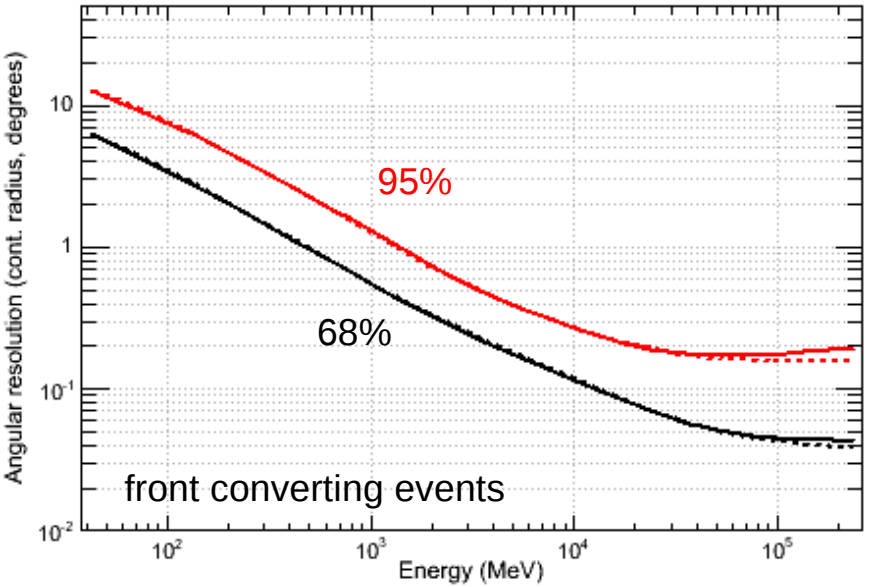

Start Year 1
Science Ops
11 August 2008
Start Year 2
Science Ops
12 August 2009
LAT,
GBM
turn-on
check
out
"first light"
whole sky
Observatory
renaming
spacecraft
turn-on checkout
pointed + sky
survey tuning
sky survey + GRB repoints
week
week
week
week
month
12 months
LAUNCH
11 June 2008
L+60 days
2nd
Symposium
initial tuning/calibrations
in-depth instrument studies
Year 1 Catalog release
Release Flaring and Monitored Source Info
GBM and LAT GRB Alerts
GI Cycle 1
Funds Release
continuous
release of new
photon data
Fellows Year 1
Start
GI Cycle 2
Proposals
LAT 3-months
Bright Source List
release, FSSC science
tools advance release
LAT Year 1 photon
data release PLUS
Diffuse Model

LAT performance

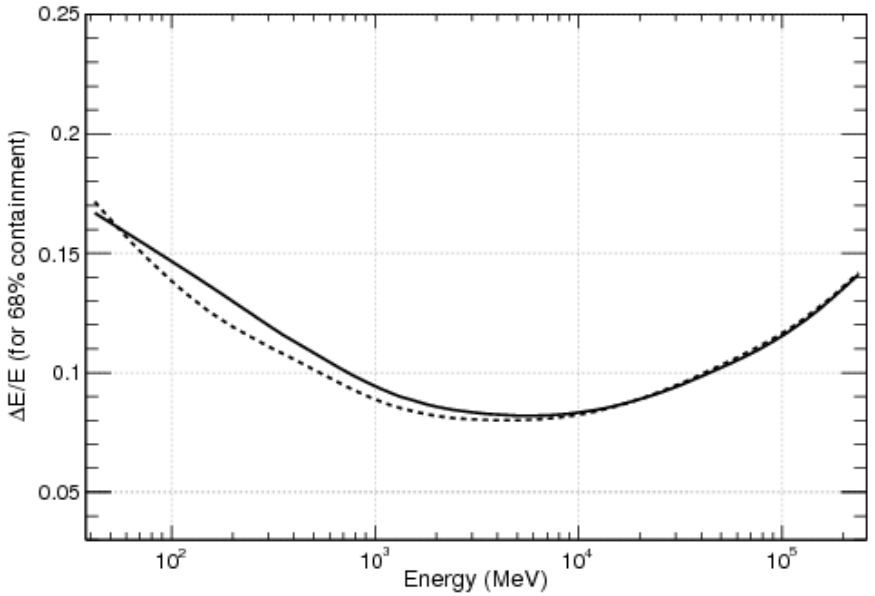
EFFECTIVE AREA



ANGULAR RESOLUTION



ENERGY DISPERSION



All plots are shown for normal incident events.

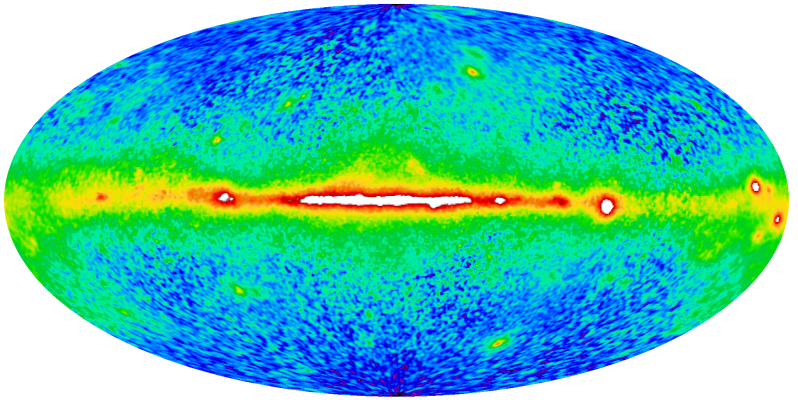
Post-launch performance:

- inflight calibration
- loss of efficiency due to pile-up events

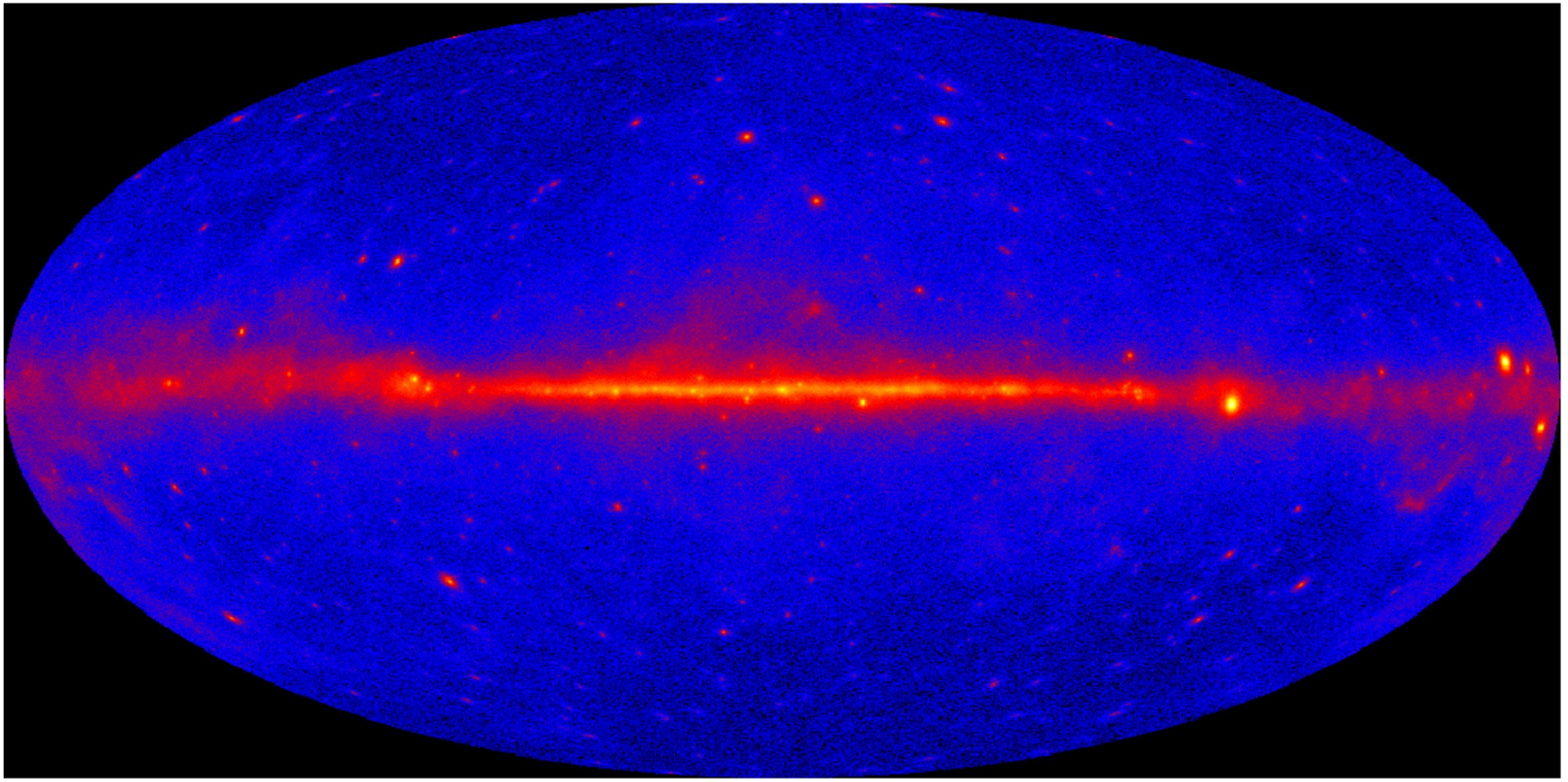
Highlights of Fermi gamma-ray Science

A fresh glimpse at the gamma-ray sky

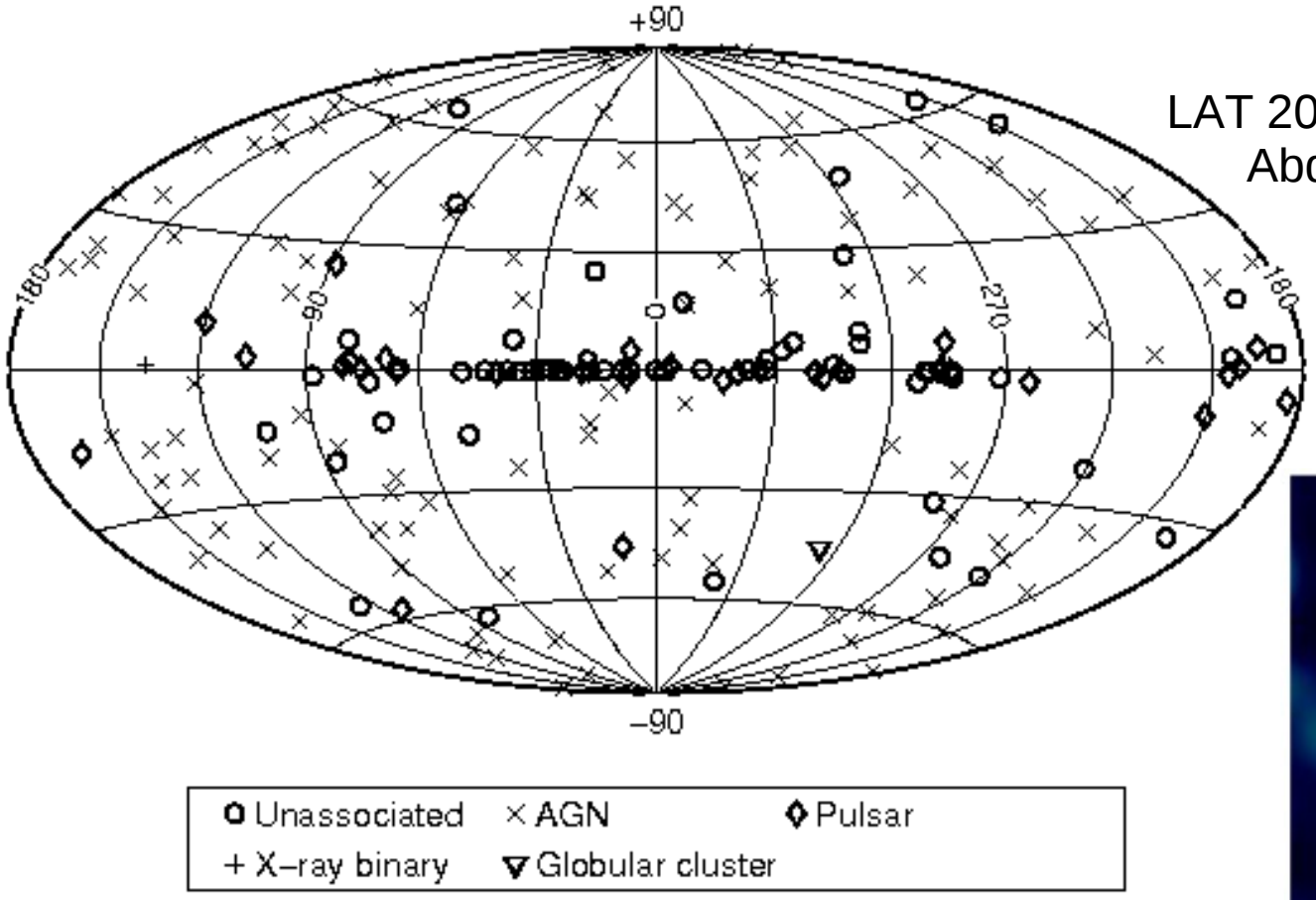
EGRET, 5 years (> 100 MeV)



LAT, 9 months (> 200 MeV)

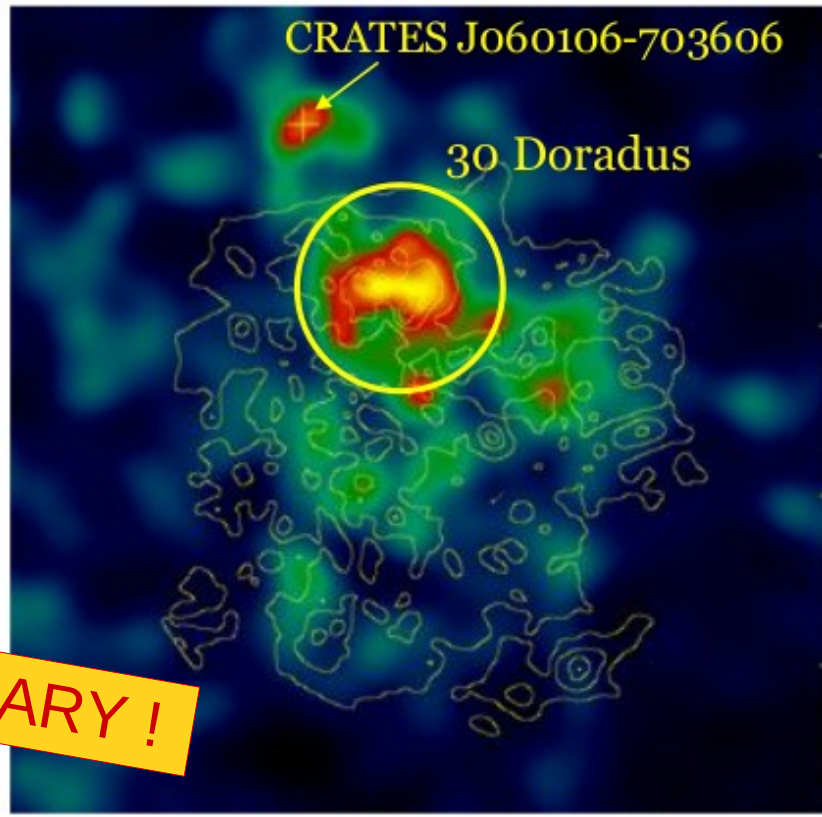


Resolving the gamma-ray sky



LAT 205 sources > 10σ in 3 months
Abdo et al. 2009 ApJS 183 46A

LMC: for the first time external Galaxy resolved in gamma-rays



PRELIMINARY !

Active Galactic Nuclei:

- 42 Bl Lac
- 58 FSRQ
- 2 radiogalaxies
- 1 Seyfert 1
- ...

Monitoring the high-energy Universe

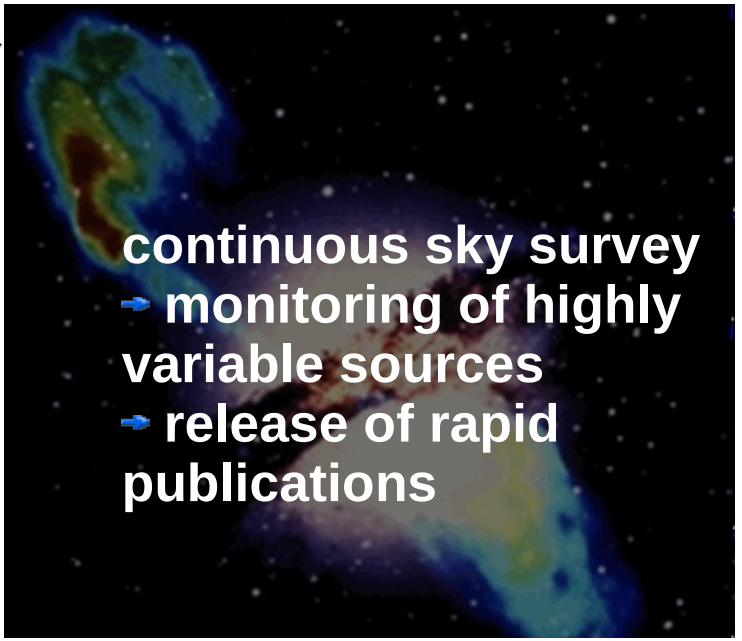
Fermi LAT detection of increasing gamma-ray activity of blazar PKS 0454-234

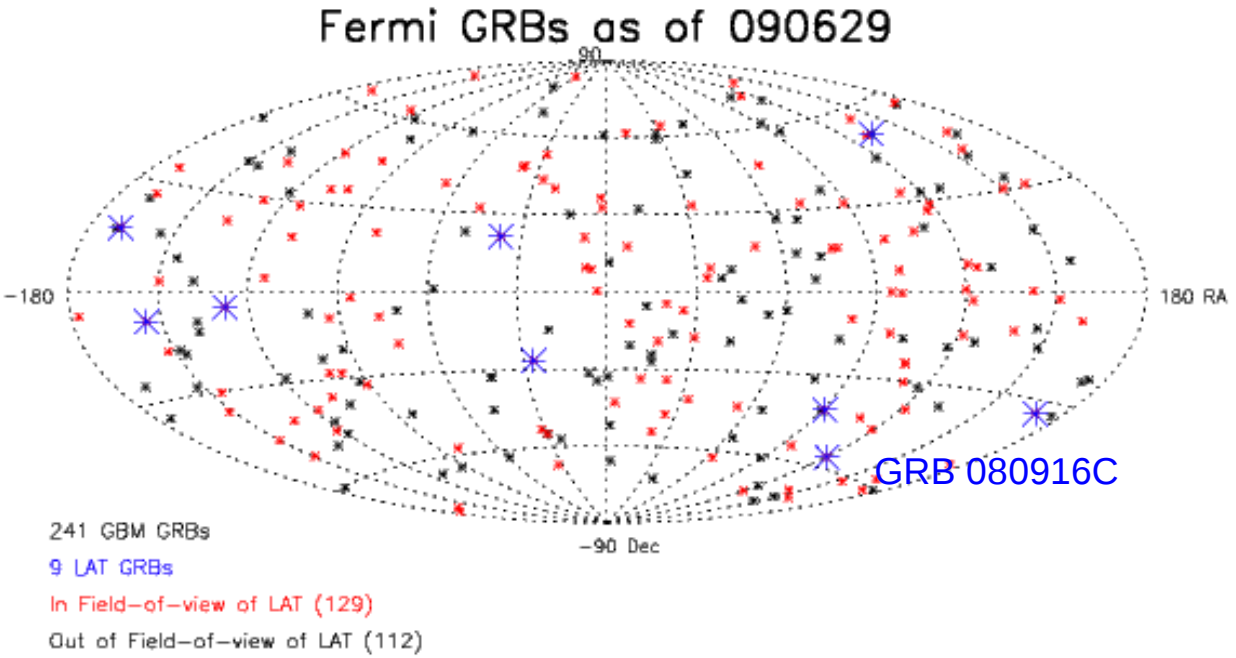
ATel #1898; *E. Cavazzuti (ASI Science Data Center), E. Hays (NASA/GSFC); on behalf of the Fermi Large Area Telescope Collaboration*
on ***12 Jan 2009; 8:18 UT***
Distributed as an Instant Email Notice (Request for Observations)
Password Certification: Gino Tosti (tosti@pg.infn.it)

Subjects: Gamma Ray, >GeV, AGN, Quasars, Transients

The Large Area Telescope (LAT), one of two instruments on the Fermi Gamma-ray Space Telescope (formerly GLAST, launched June 11, 2008), has observed a continuous and increasing trend in the gamma-ray flux from a source positionally consistent with the blazar PKS 0454-234 (Position J2000.0: RA:04h57m03.2s, Dec:-23d24m52s, Johnston, K. J et al., 1995, AJ, 110,880J, redshift 1.003, M. Stickel et al., 1989A&AS, 80, 103S). PKS 0454-234 is a flat-spectrum radio source the EGRET gamma-ray source 3EG J0456-233 123, 79H).

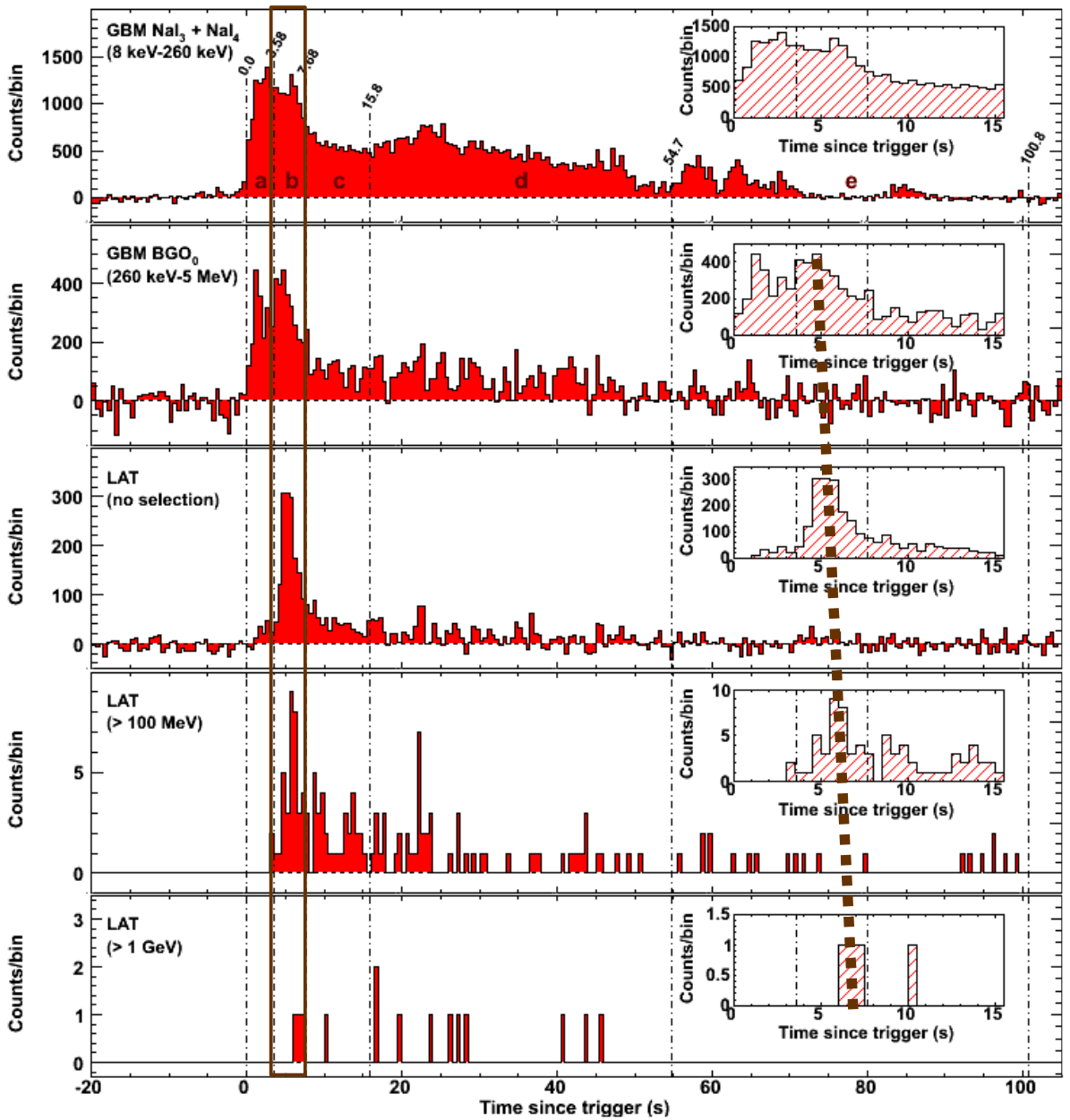
Preliminary analysis indicates that the source gamma-ray flux (E>100MeV) on January 11, 2 photons cm-2 s-1. This is the highest daily-ave this source since launch. The Fermi light curv rapid flares, up to (2.83 +/- 0.59) x10-6 photo be monitored.





GRBs: the most violent phenomena in the Universe

GRB 080916C



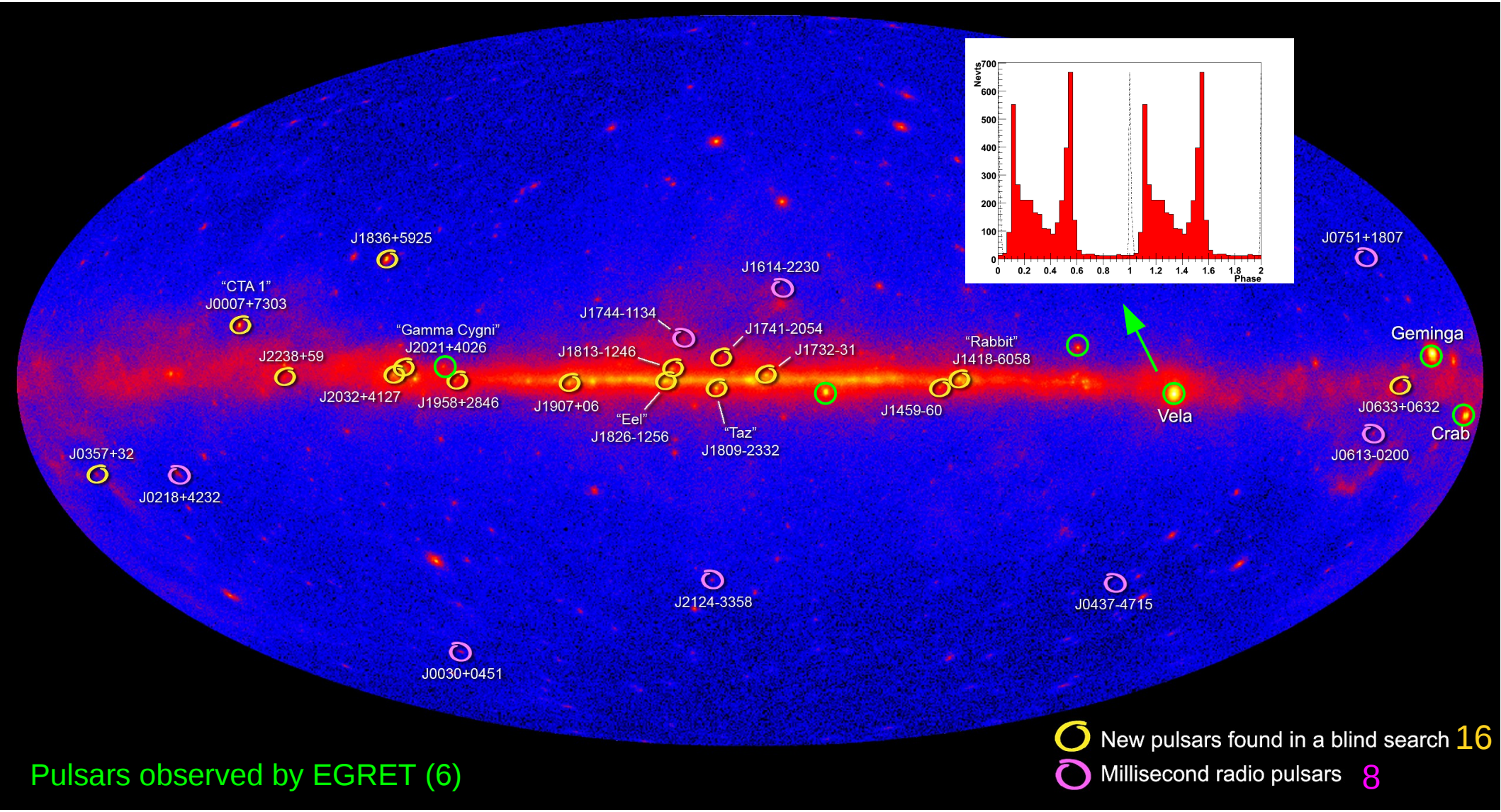
Abdo et al., 2009 Science 323 1688

$z = 4.35 \pm 0.15$ (GROND)

145 events > 100 MeV
14 events > 1 GeV

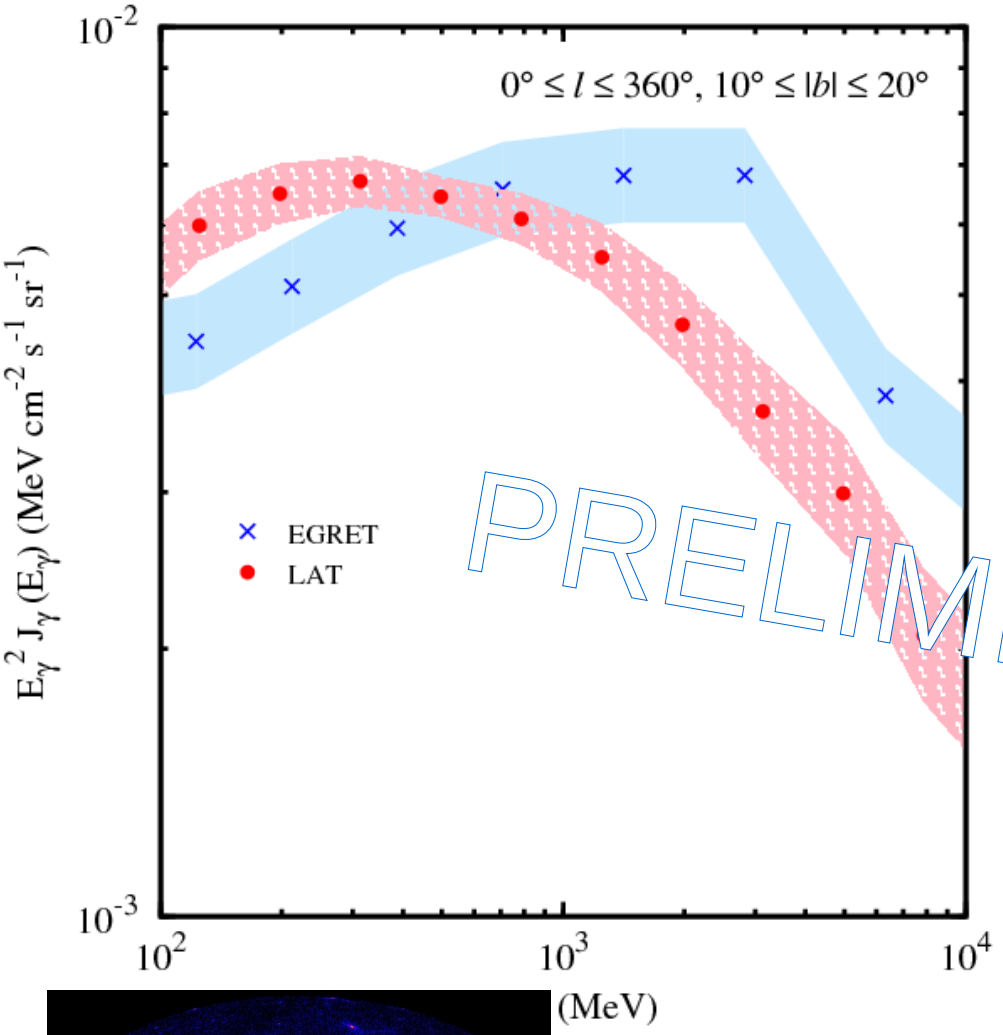
$M_{QG} > 1.3 \cdot 10^{18}$ GeV/c^2

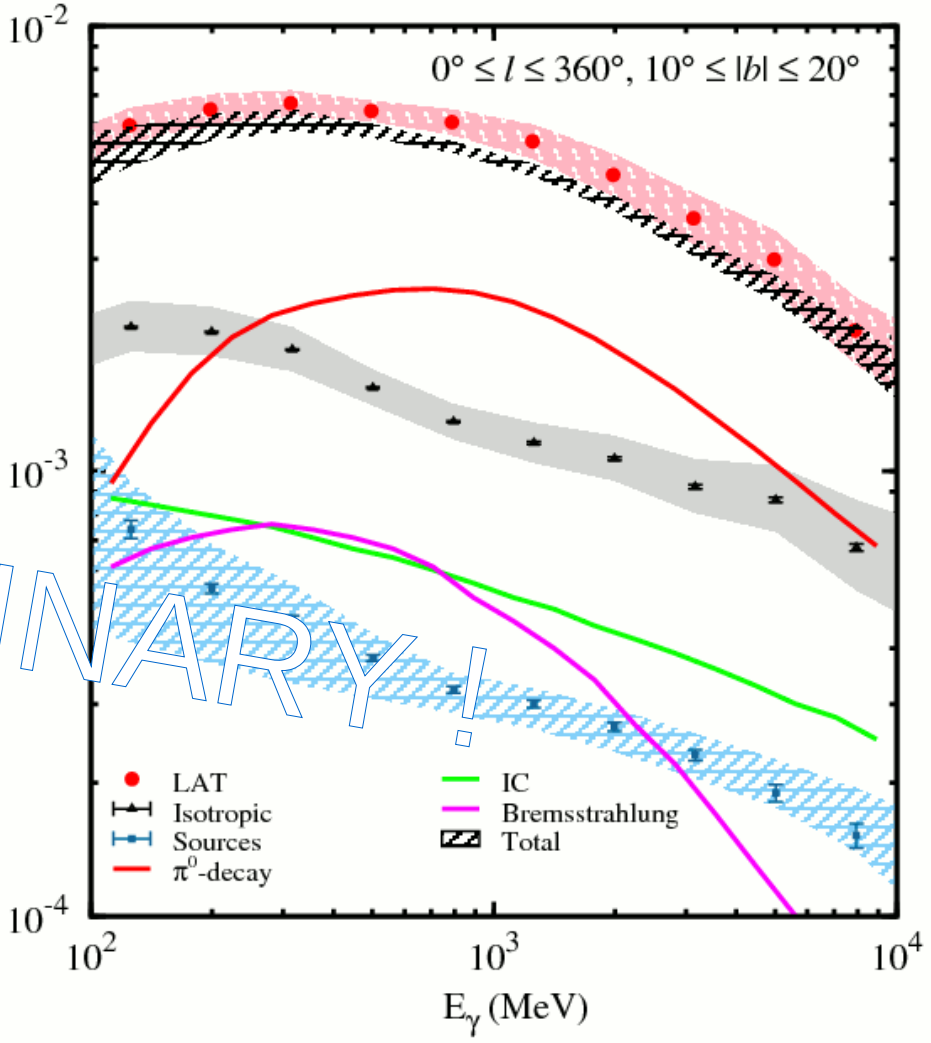
The pulsing gamma-ray sky



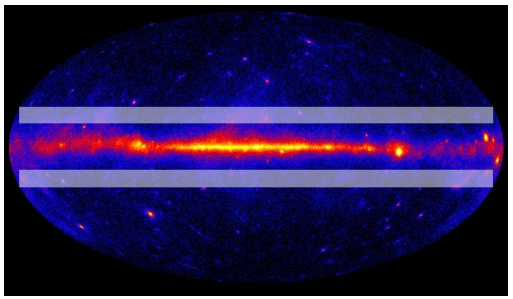
+ normal radio pulsars for the first time observed in gamma-rays (15)
Abdo et al., 2 July 2009, Science express, 10.1126/science.1175558 & 10.1126/science.1176113

Diffuse emission: intermediate latitudes



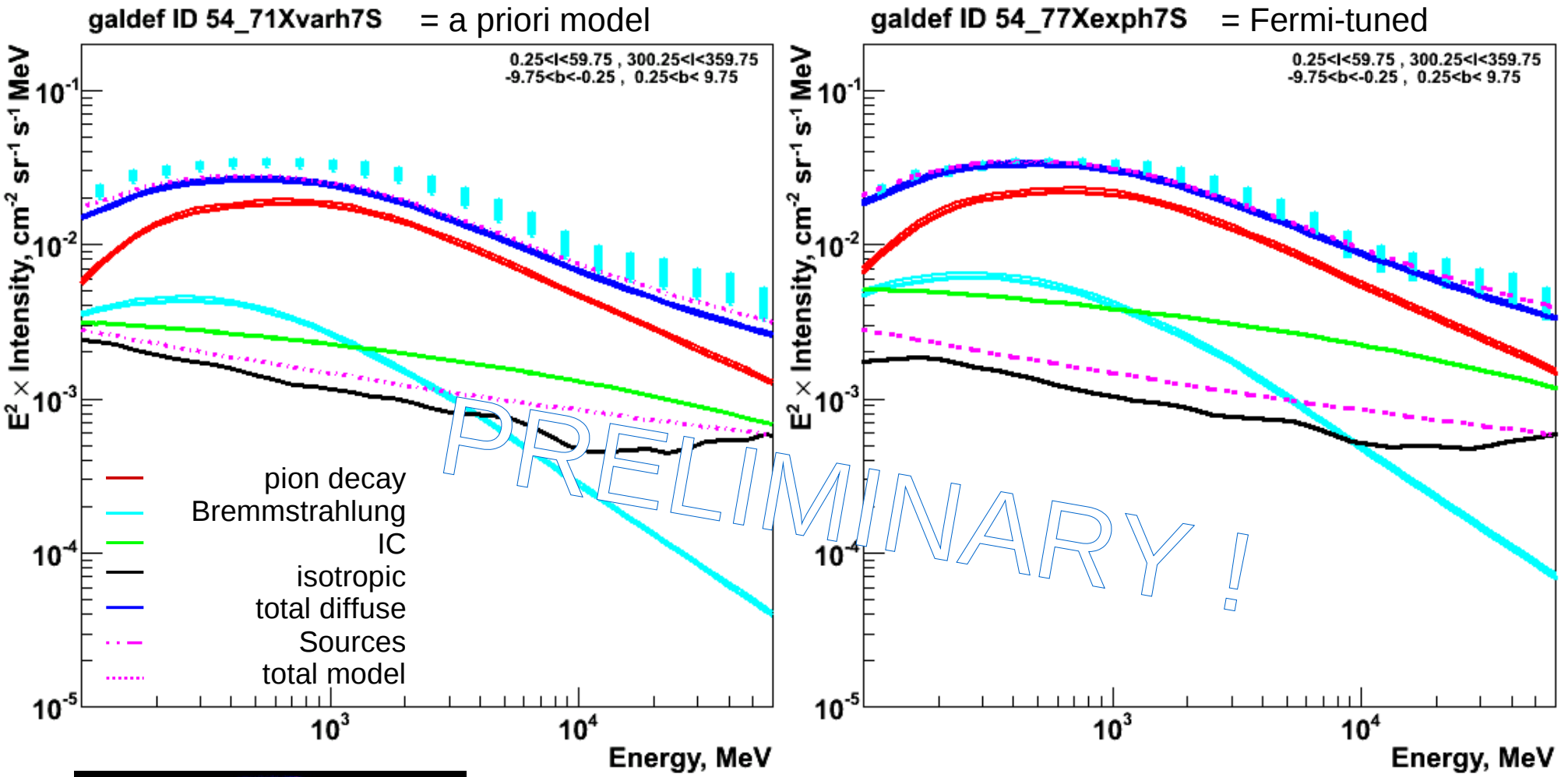


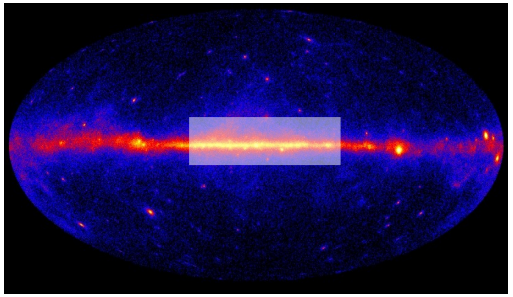
PRELIMINARY!



Gamma-ray emission from local interstellar medium explicable on the basis of directly measured CRs.

Diffuse emission: inner Galaxy



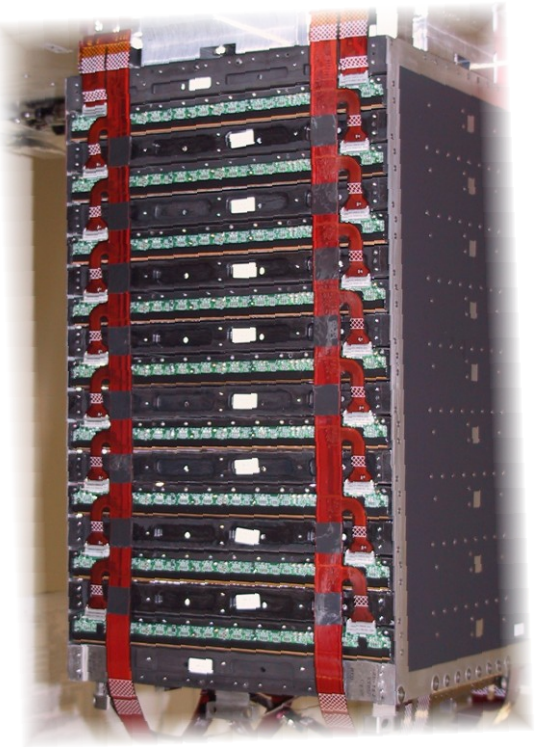


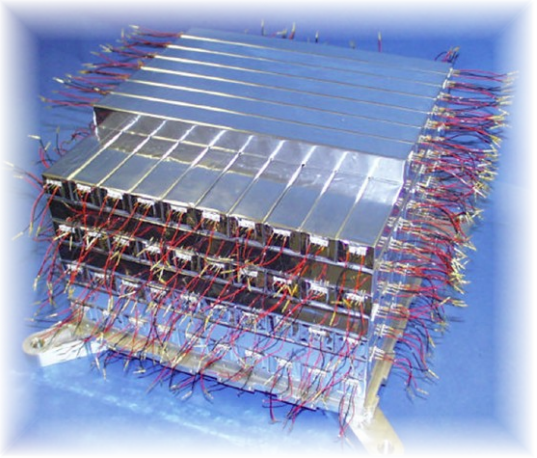
Fermi-tuning:
- protons increased by 15%
- IC component scaled by ~2 ???
- calibration of molecular masses from early Fermi results

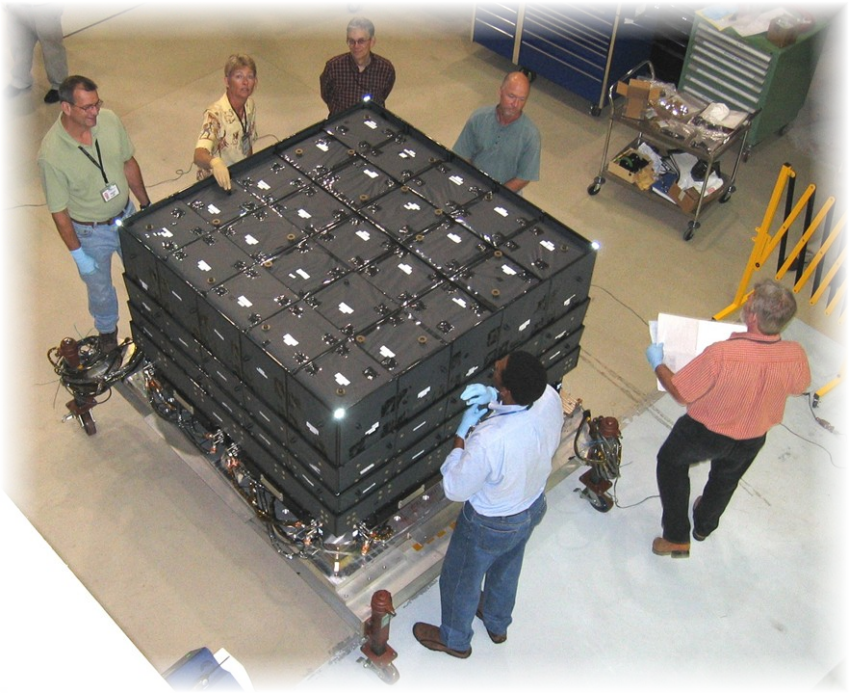
Cosmic-ray electrons

The LAT as electron detector

High efficiency:
- large field of view (20% of sky at any instant)
- 85% duty cycle
- all events > 20 GeV in calorimeter downlinked at Earth







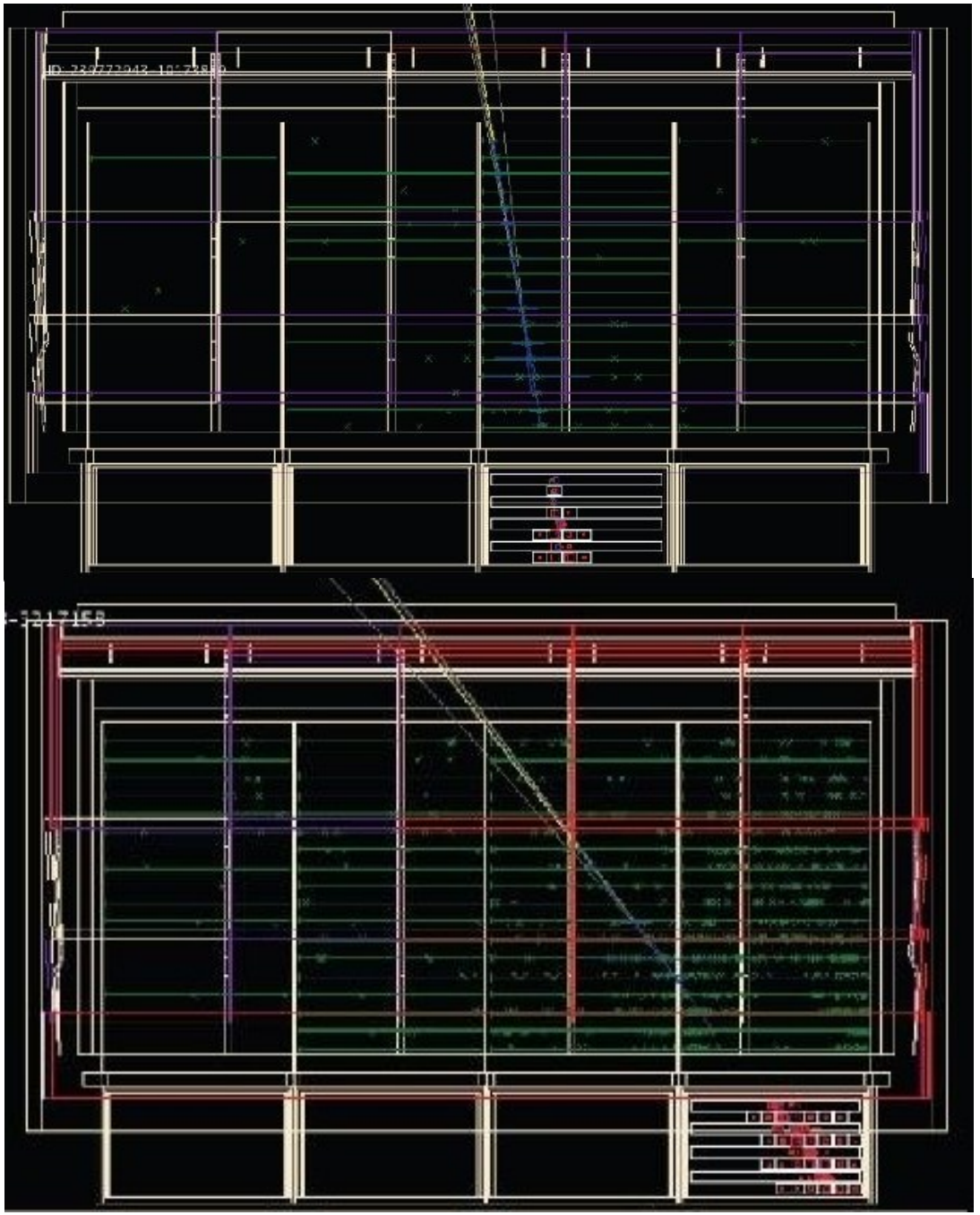
no charge separation

➡ **$e = e^+ + e^-$**

hermetic segmented ACD + granular TKR and CAL

➡ **separation e-γ-had**

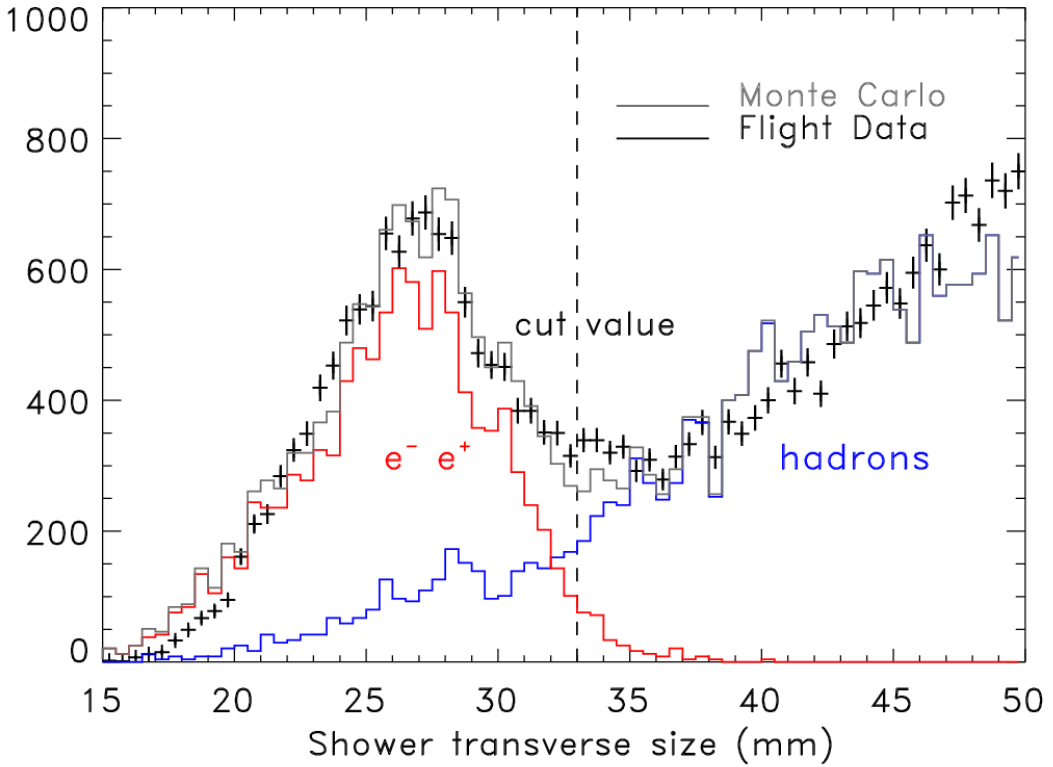
Electron-hadron separation



Candidate electron event :
- ACD few hits in conjunction with track
- TKR extra clusters around main track
- CAL clean EM shower

Candidate hadron event :
- ACD large energy per tile
- TKR many clusters away from main track
- CAL large shower size

Electron analysis



Tradeoff between:

- acceptance
- systematics
- purity

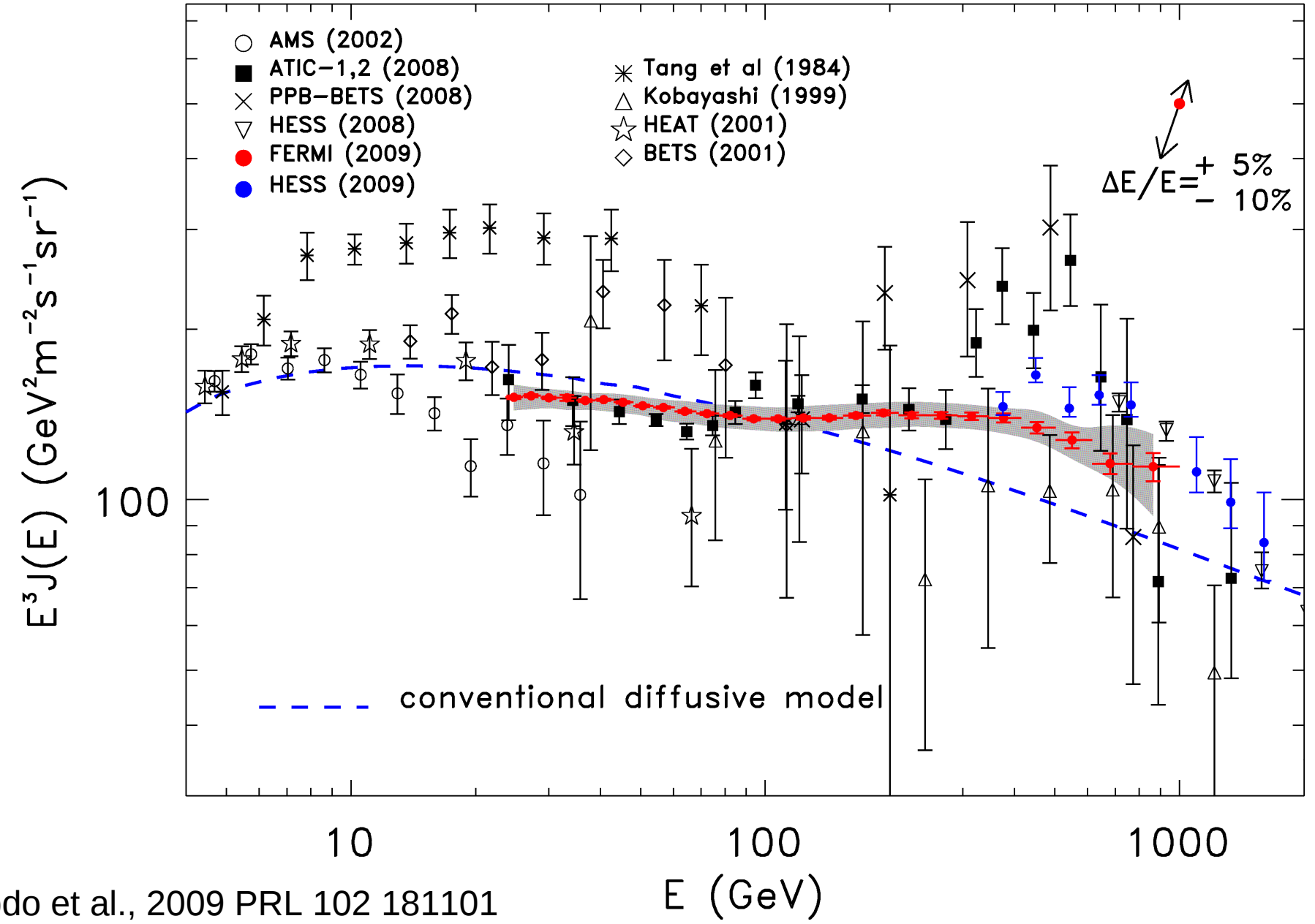
Steps:

- fail ACD vetoes for γ
- shower development variables
- selection boosted using Classification Trees

Optimized in the multi-GeV energy range:

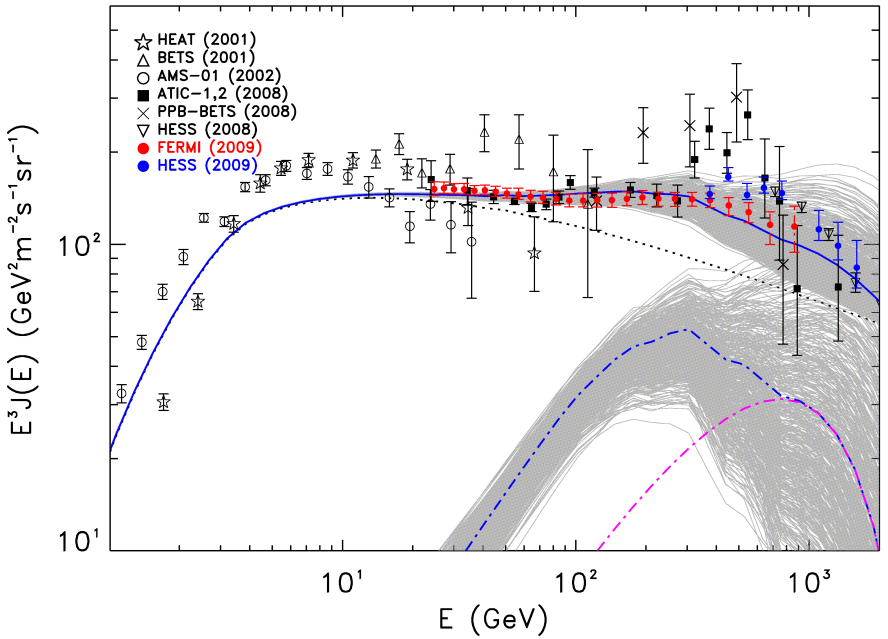
- geometry factor: ~ 3 m^2 sr (50 GeV) → 1 m^2 sr (1 TeV)
- systematics: ~20% (1 TeV)
- purity: contamination ~20% (1 TeV)

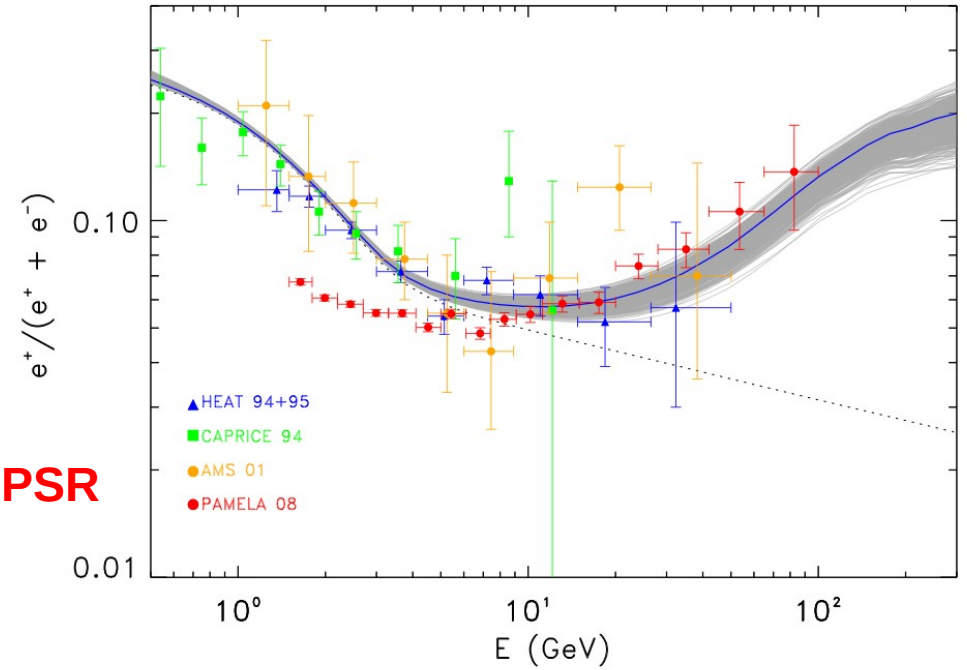
Electron spectrum

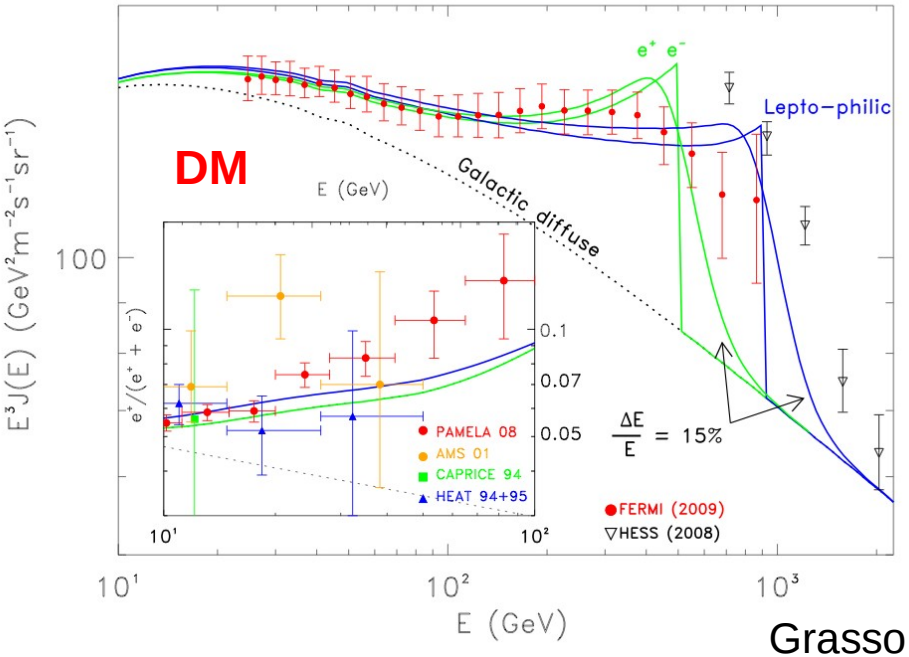


Abdo et al., 2009 PRL 102 181101

Possible Interpretations







LAT will help solving the puzzle:

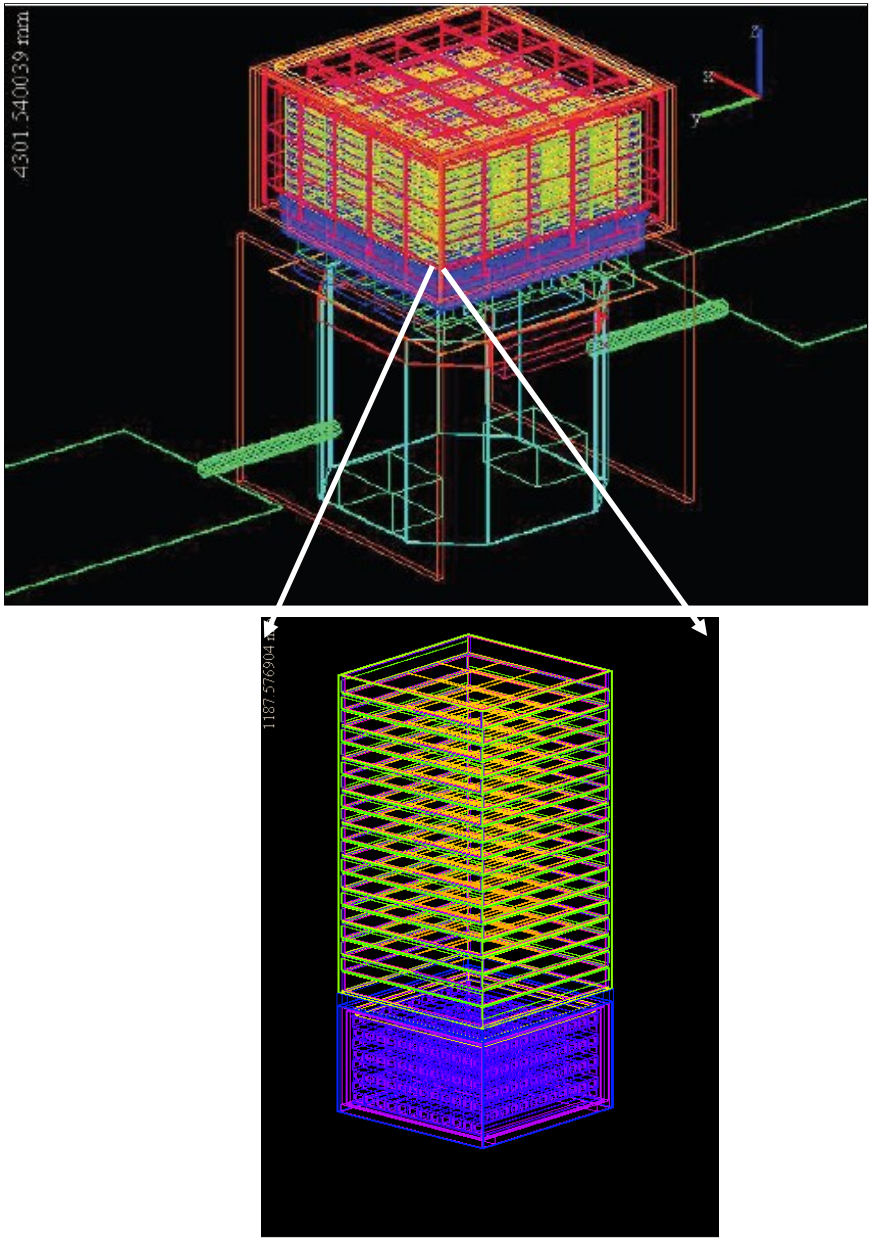
- anisotropies in CR e
- PSR populations
- diffuse gamma-ray emission
- DM gamma-ray signals

Grasso et al., accepted by Astropart. Phys. arXiv:0905.0636

Back-up slides:
why are we confident in our results?

MC simulations

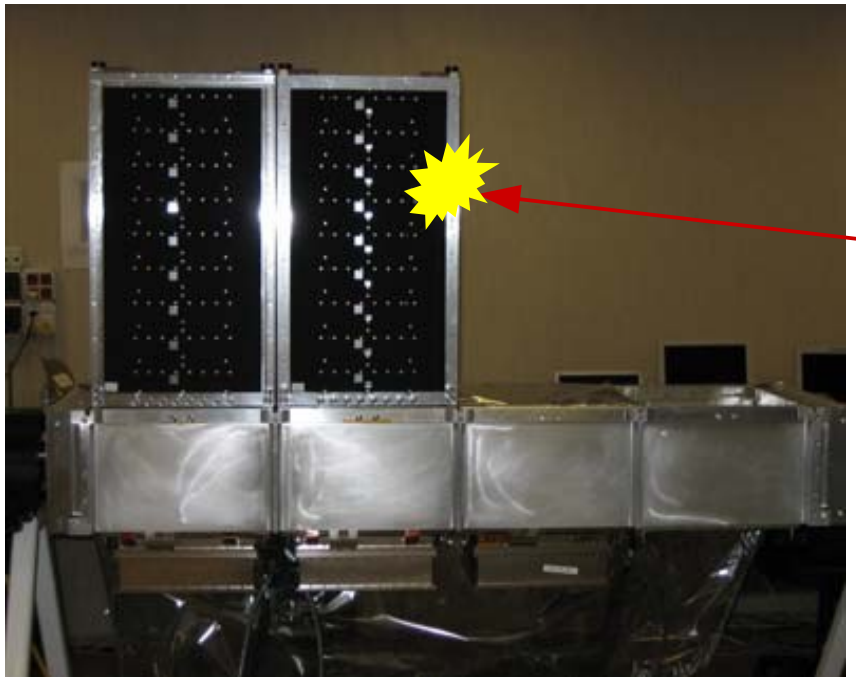
- Accurate detector model
  - more than 4500 physical volumes
- Simulation suite GEANT4-based
  - EM: LAT-debugged routines for multiple scattering and Landau-Pomeranchuck-Migdal effect
  - HAD: Bertini (E < 20 GeV) QGSP (E > 20 GeV)
- Now: uses inflight calibrations



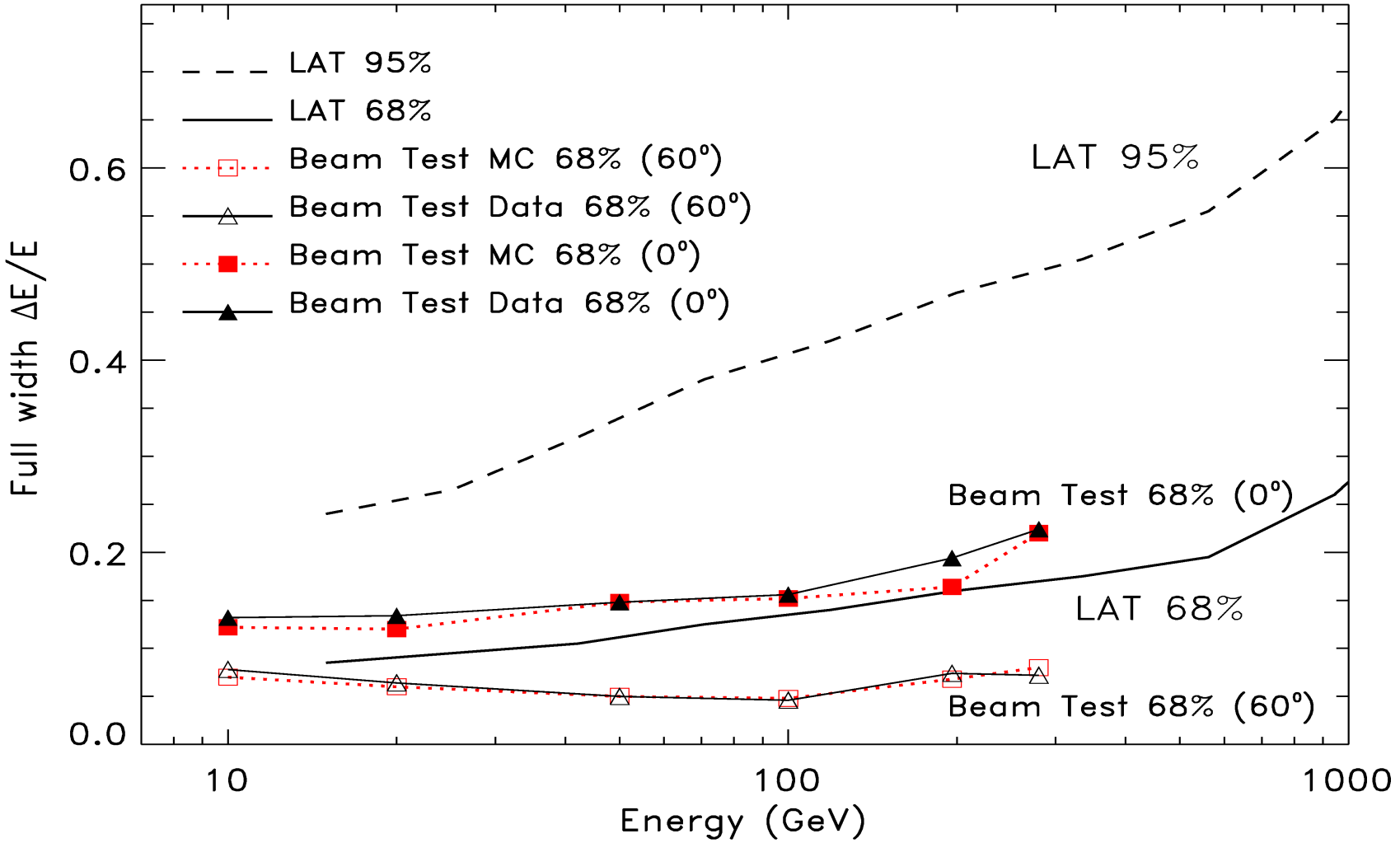
Beam Test

4 weeks at CERN-PS/T9
  26/7/06-23/8/06
11 days at CERN-SPS/H4
  4-15/9/06
1 week at GSI
  14-21/11/06
60 active people

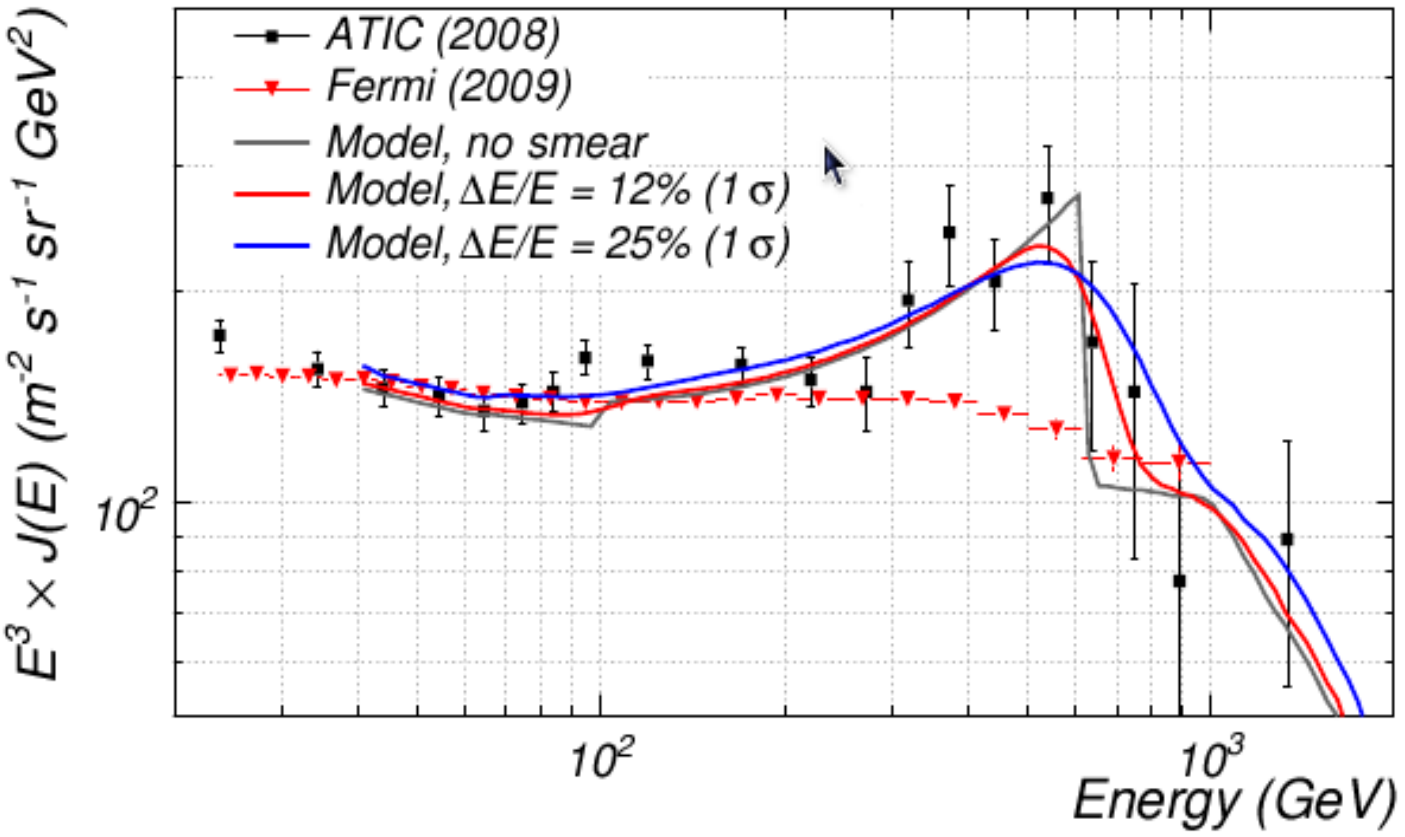
Particle	Energy
γ	0 - 2.5 GeV
e^-	1, 5, 10, 20, 50, 100, 200, 280 GeV
e^+	1 GeV (through MMS target)
p	6, 10 GeV (also through MMS), 20, 100 GeV
π	20 GeV
C, Xe	1, 1.5 GeV/n, + Xe on target



Double-checking the energy resolution

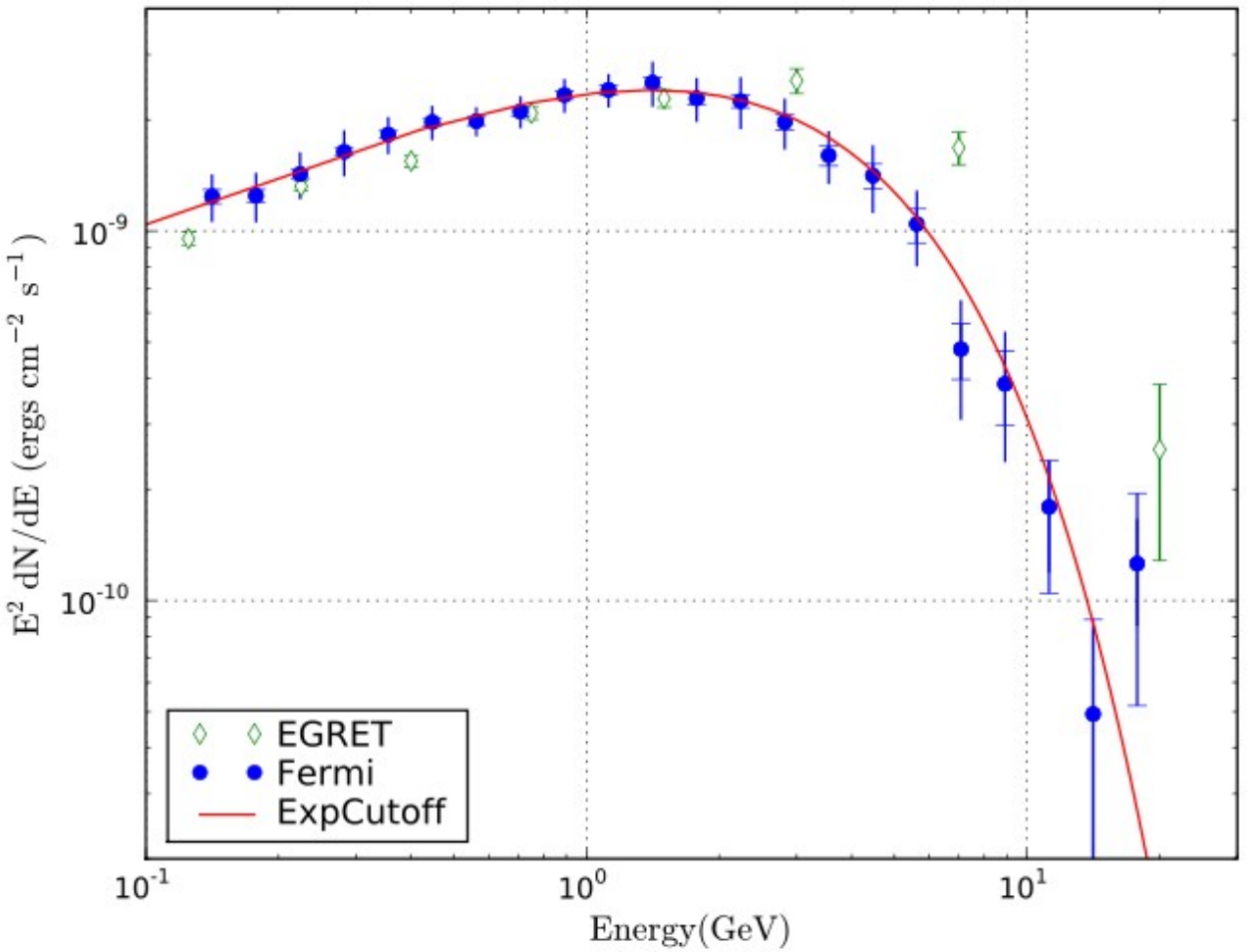


Would the LAT be able to see the ATIC bump?



Back up:
further results

Vela spectrum



Upper limits on dSph

NAME	Flux (>100 MeV) UL 95% (10^{-9} cm^{-2} s^{-1})
Segue 1	1.83
Ursa Major 2	4.60
Segue 2	2.13
Willman 1	2.12
Coma Berenices	0.97
Ursa Minor	0.72
Sculptor	4.79
Draco	1.16
Sextans	1.33
Fornax	1.67

PRELIMINARY !

Dwarf spheroidal Galaxies:

- dark matter dominated (high M/L)
- many close to our Galaxy
- free of gamma emission (low content of gas and dust)

No significant signal! UL, 9 months of data, spectral index = -2.

Isotropic gamma-ray emission