The prolonged Fermi mission

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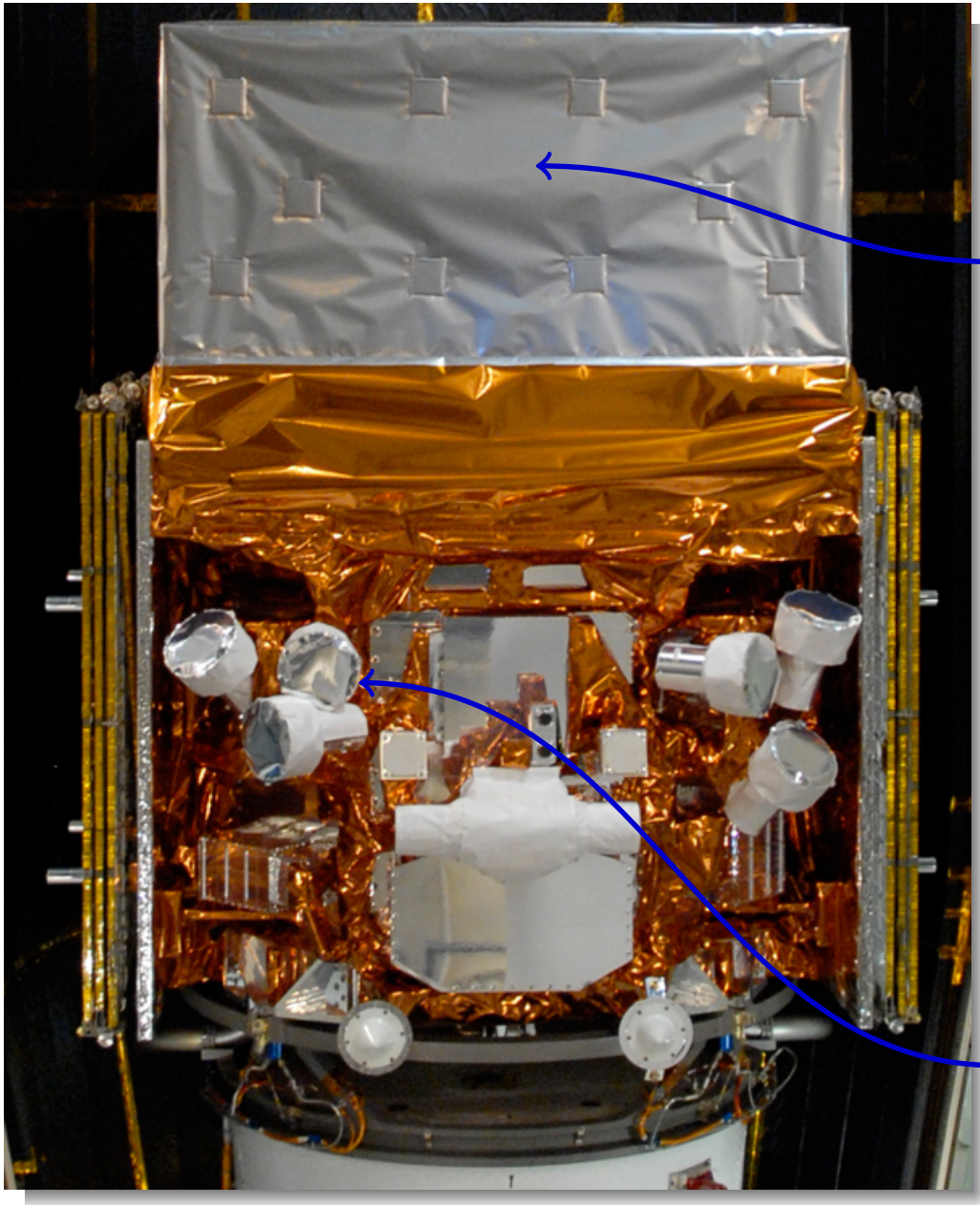
on behalf of the Fermi LAT collaboration

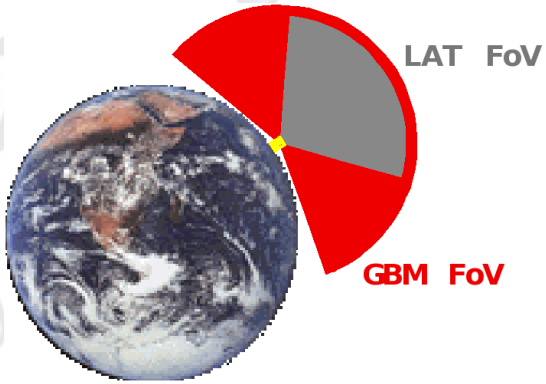
9th AGILE workshop
Frascati, April 16–17 2012

The Fermi observatory



Large Area Telescope (LAT)

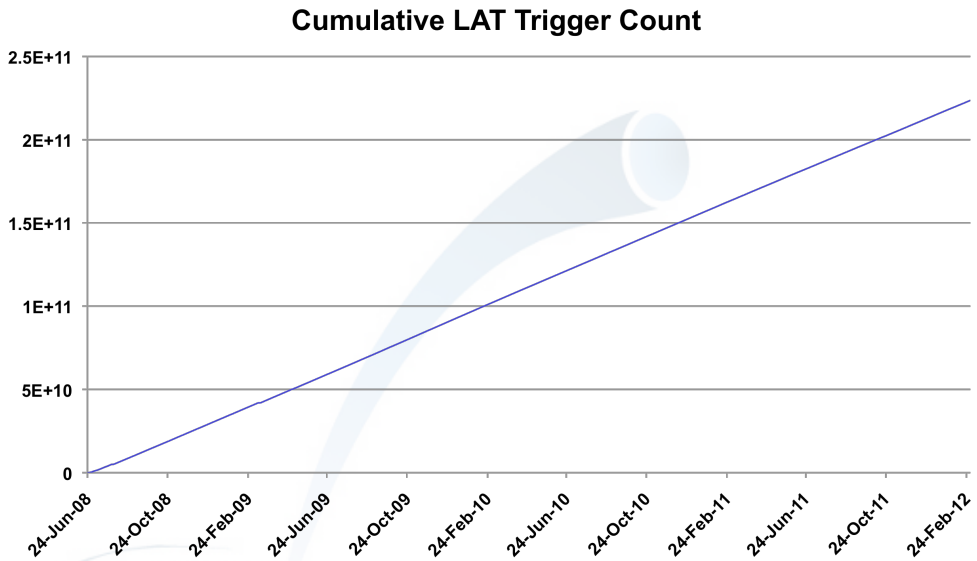
- Pair conversion telescope.
- Energy range: 20 MeV–> 300 GeV
- Large field of view ($\approx$ 2.4 sr): 20% of the sky at any time, all parts of the sky for 30 minutes every 3 hours.
- Long observation time: 5 years minimum lifetime, 10 years planned, 85% duty cycle.



Gamma-ray Burst Monitor (GBM)

- 12 NaI and 2 BGO detectors.
- Energy range: 8 keV–40 MeV.

Spacecraft/instrument status at $\sim$ L + 4



- Event statistics (as of yesterday):
  - $\sim$ 230 B triggers in orbit
  - 45,769,690,466 events down-linked to ground
  - 684,154,051 γ-ray candidates made public
- All subsystem working properly, no performance degradation
  - 0.06% of the TKR strips masked (out of 884,736)
  - One readout on one CAL crystal (out of 1536) failed, using redundant
- More than 99% up-time collecting science data (out of the SAA)
  - Including detector calibrations/hardware issues

2012 NASA Senior Review

- Fermi planned as a 10-year mission with a *5-year prime phase*
  - Prime phase ending in August 2013.
- NASA considers Mission extensions through *Senior Review* process every two years
  - All operating missions in (or about to begin) their extended phase participate.
  - SR committee evaluates the anticipated science productivity of each mission over the next four years, focusing on the next two years.
- The first Fermi SR just finished
  - http://science.nasa.gov/astrophysics/2012-senior-review/

"The SRC recommends funding at the desired level of augmentation to provide for full operations through FY14. We recommend an extension through 2016[1] *with a review in 2014."*

[1] 2016 is the horizon as far as the 2012 SR, so this is not the same as recommending that the mission *ends* at that point.

Path forward for the extended mission

(i) Continue doing what we've been doing:

- deeper exposure;
- more statistics;
- increasing fraction of pointed (target of opposrtunity and planned) observations.

(ii) Improve on what we've been doing in the prime phase and maximize the scientific reach of the observatory:

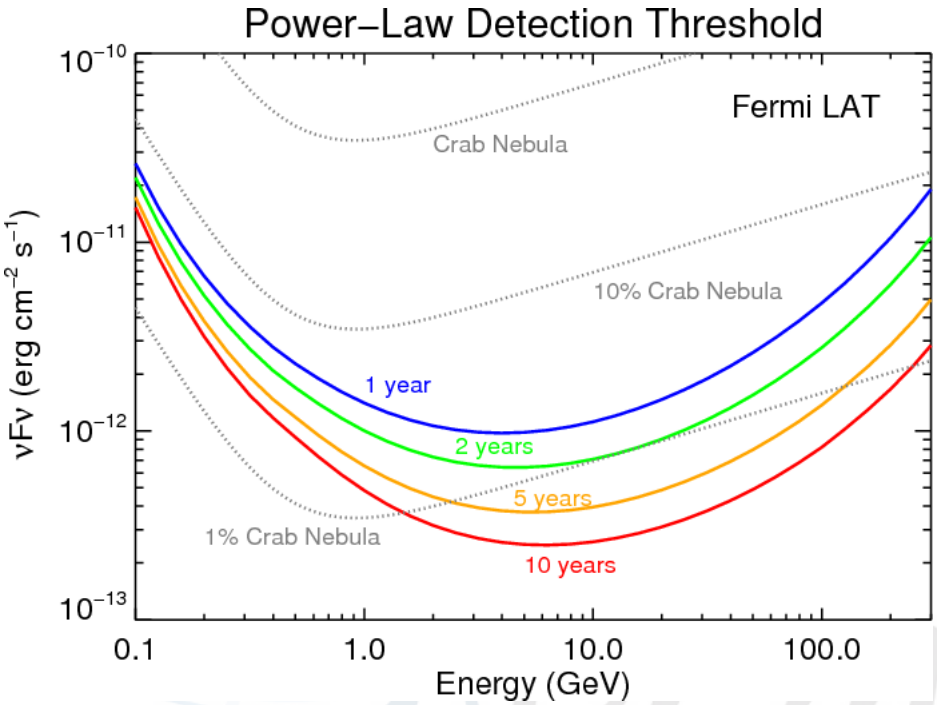
- better understanding of the instrument (reduce systematic uncertainties);
- better calibrations;
- event reconstruction improvements (better PSF, larger energy range);
- event selection improvements (larger effective area, less background);
- analysis improvements (e.g., LLE);
- operational improvements (new instrument configurations);
- external inputs (e.g., pulsar timing solutions, inputs to the DGE modeling. . .);

- This presentation mainly devoted to (ii)
  - (i.e., not a review of the Fermi science highlights).

Power law source detection threshold

—Low energy

Bkg. dominated
$\propto \sqrt{t}$

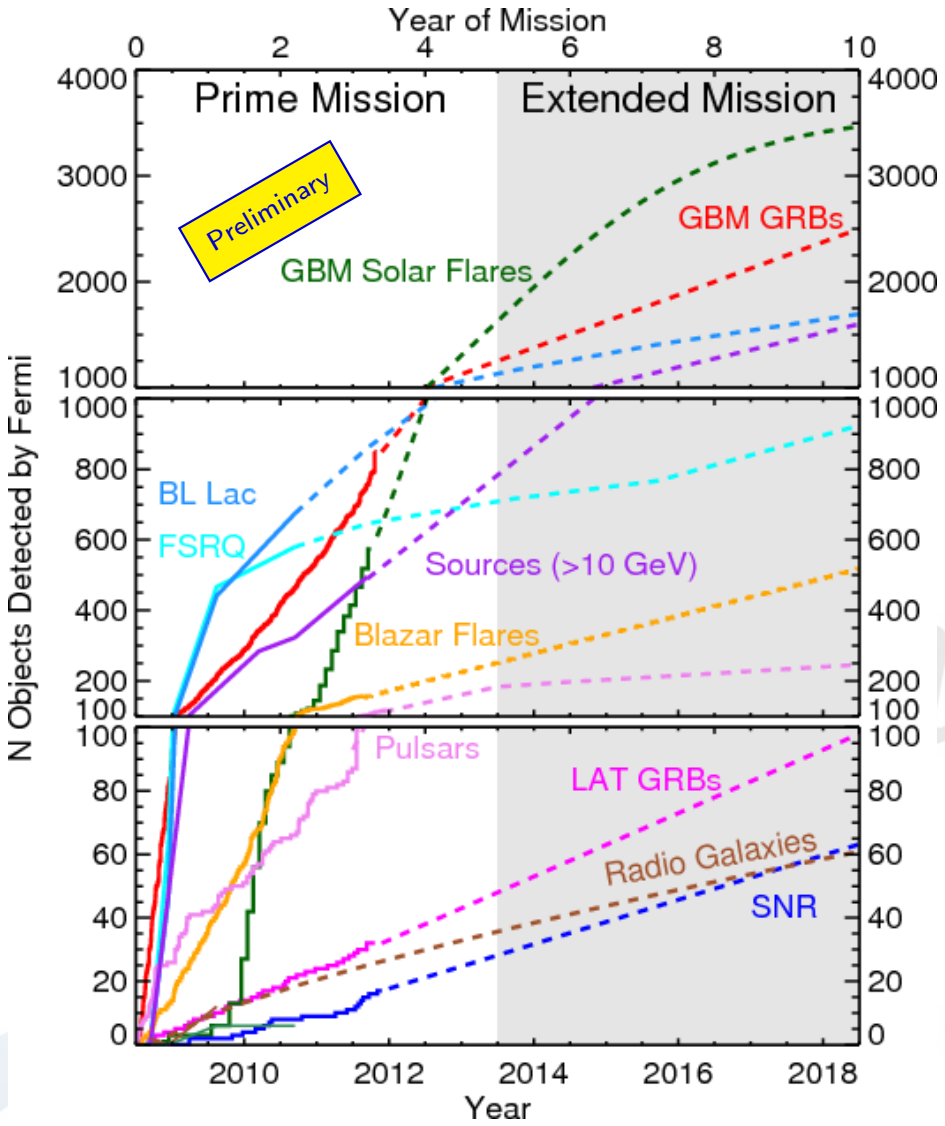


—High energy

Photon counting
nearly $\propto t$

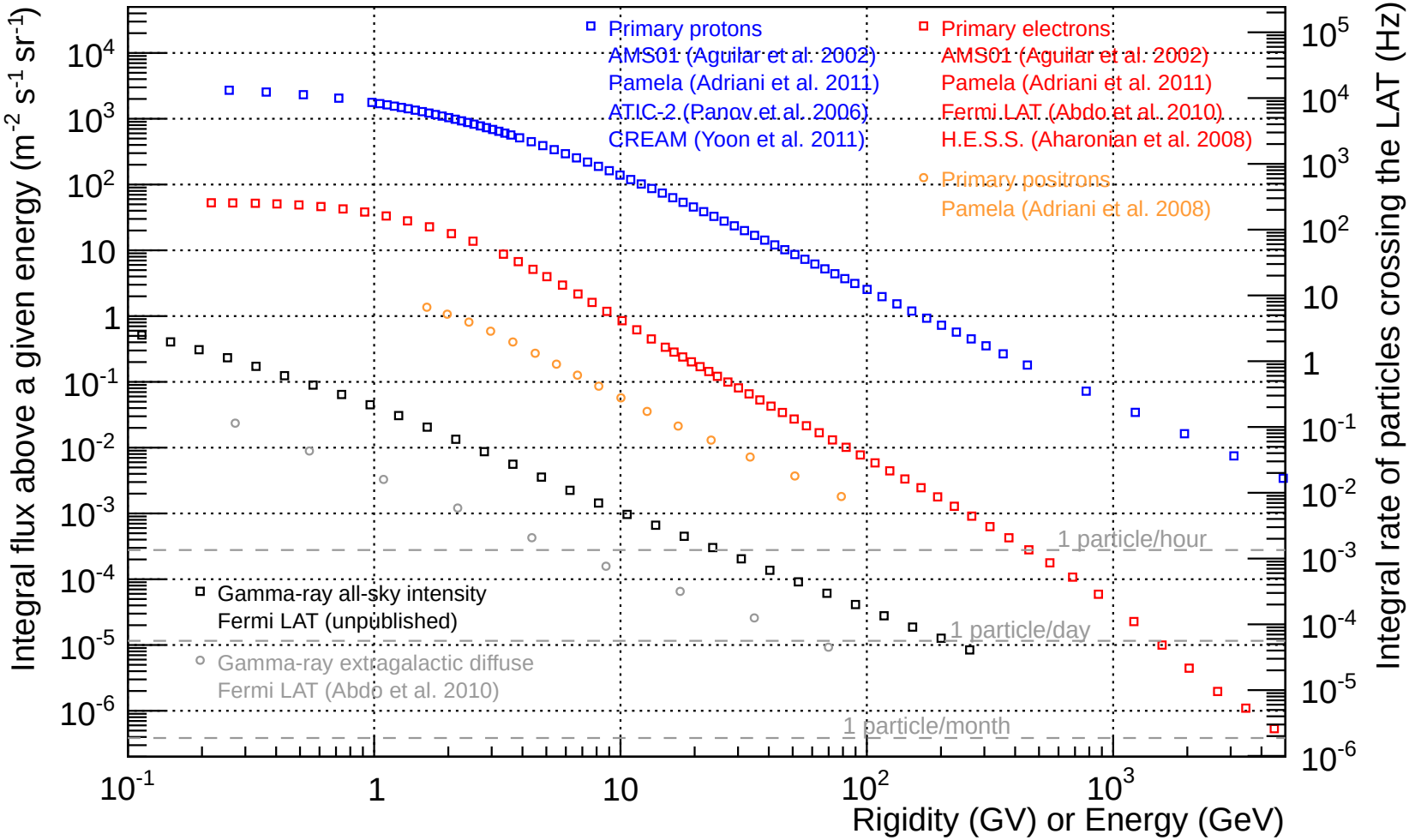
- Envelope of the minimum detectable power-law spectra over the full band, varying the spectral index
  - (i.e, not a *differential sensitivity plot*)
- Accounts for uncertainties in the background and source density
  - `P7SOURCE_V6 IRFs`, bkg. and exposure weighted over $|b| > 10$
- High-energy limiting sensitivity comes from photon counting statistics (rather than the background)
  - Increase nearly linear with time, rather than $\sqrt{t}$

Projected number of sources per class



- Beating the $\sqrt{t}$ for many classes already (e.g., transients)

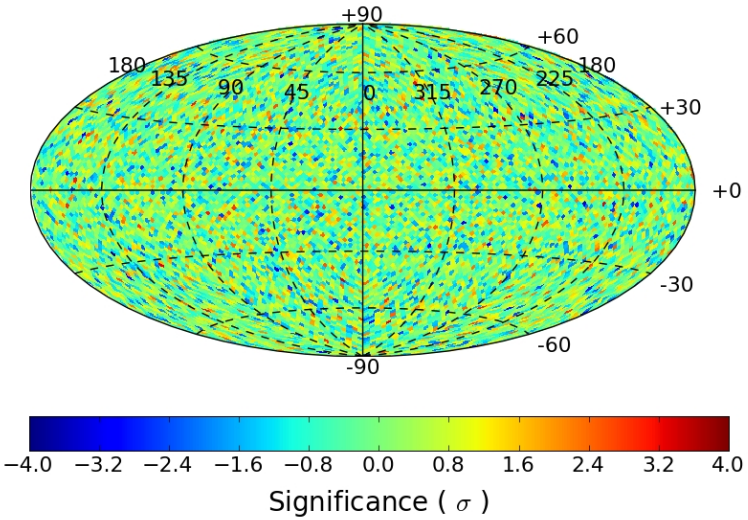
Statistics matter at high energy

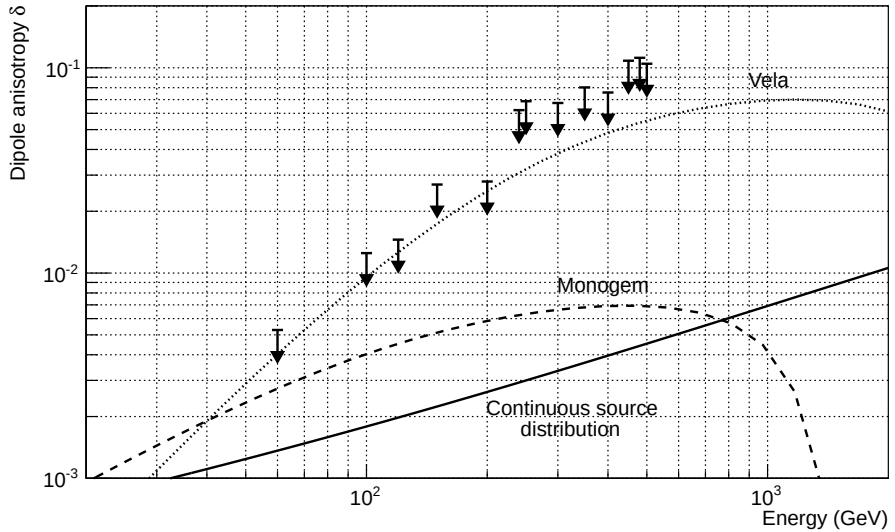


- Both for point source and diffuse studies
  - (e.g., $\sim$ 1 EGB γ-ray per week above 100 GeV)

One example: CRE anisotropies

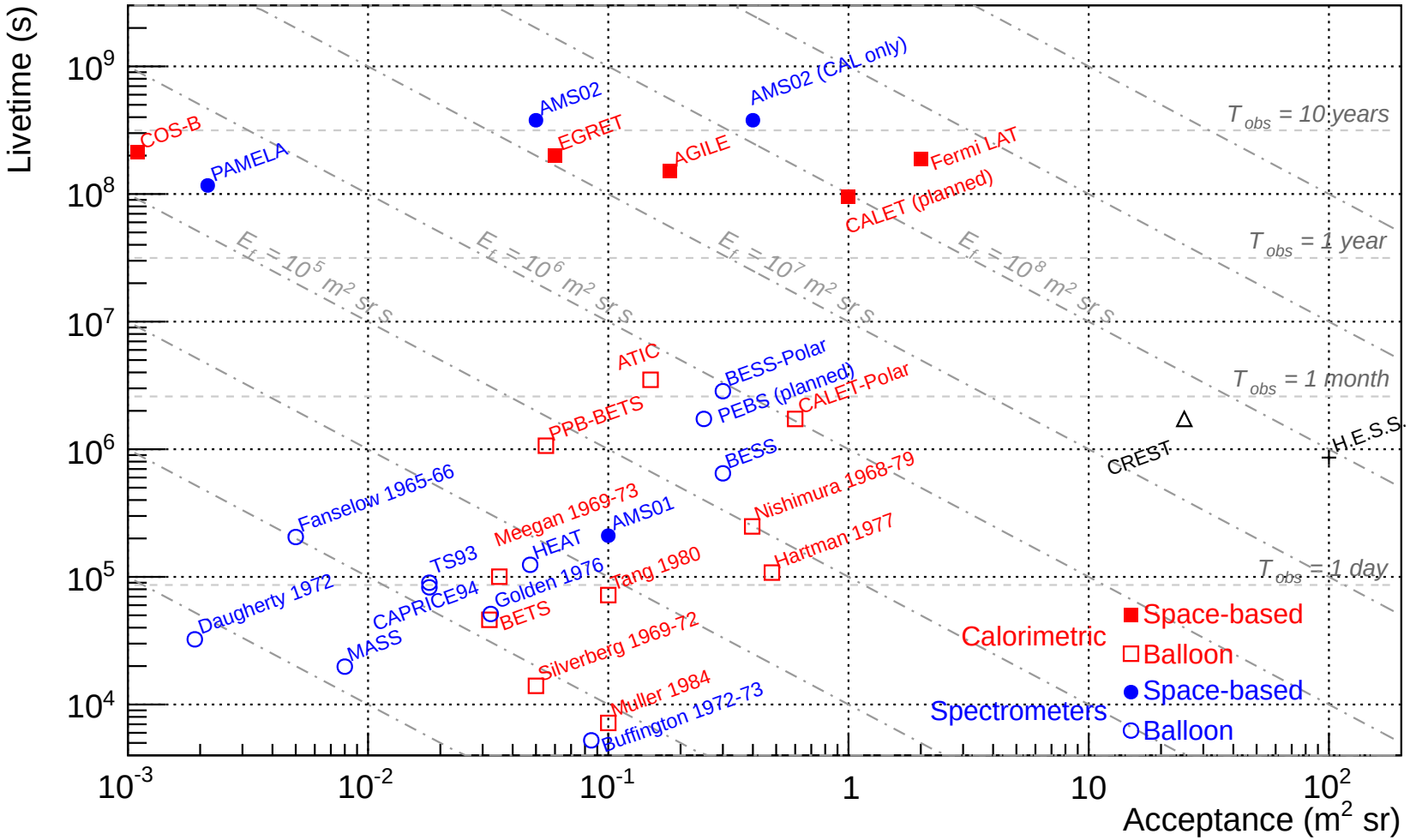
Abdo et al., Phys. Rev. D 82, 092003 (2010)



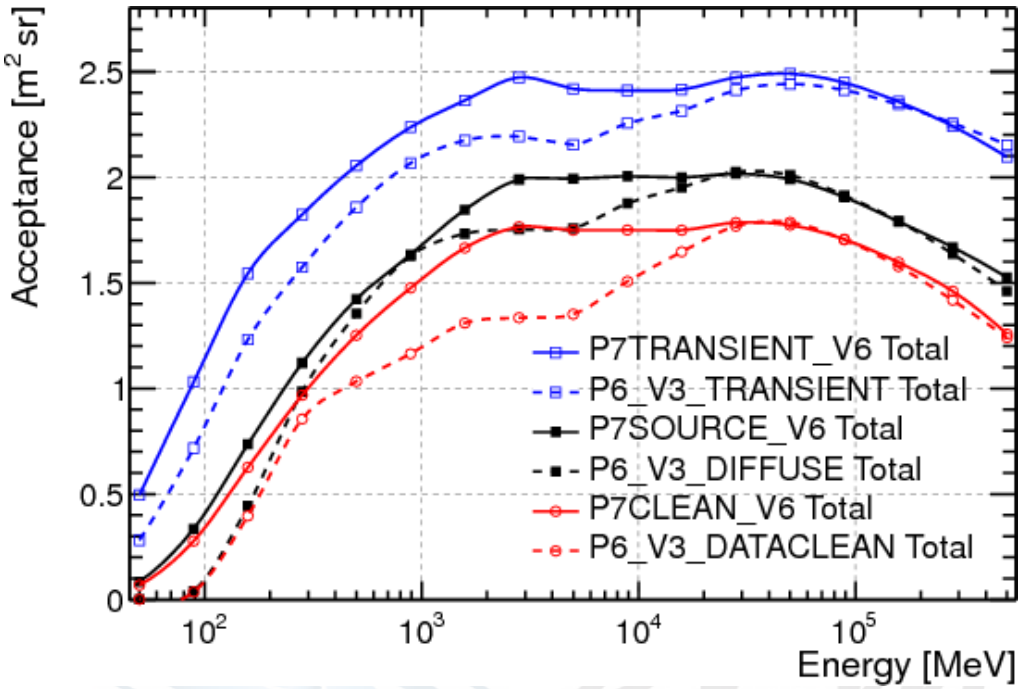


- Fermi offers a unique opportunity for the measurement of possible CRE anisotropies
  - Key factors: large exposure and large field of view
- Most stringent upper limits to date based on one year of data
  - More than 1.6 M CRE candidates above 60 GeV
- Limits are comparable to the level of anisotropy expected in realistic models
  - Can potentially expect to detect a signal in 8–10 years

Direct CR measurements: the LAT in context



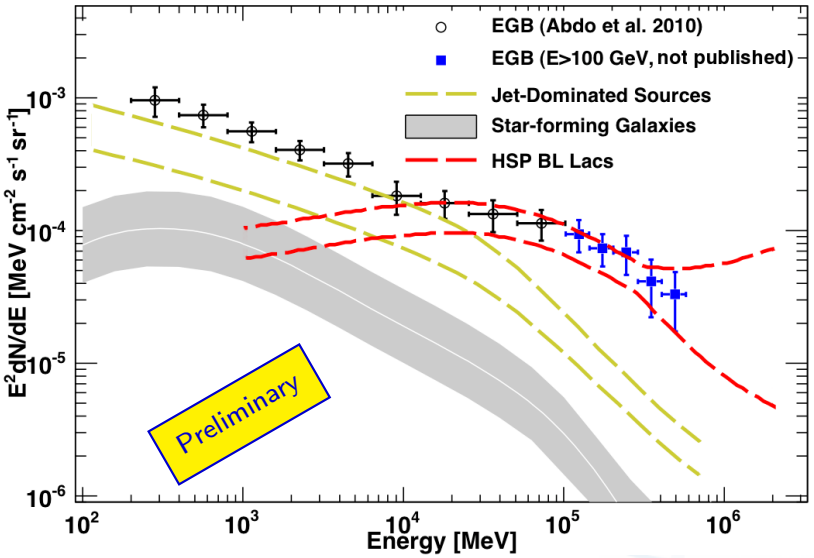
Improvements in the event selection

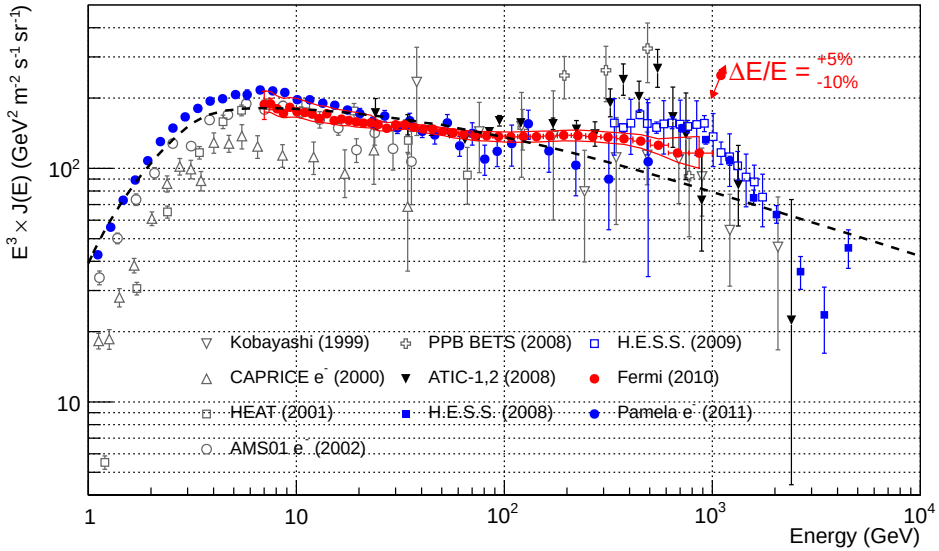


- Continuous effort by the LAT collaboration to make public the advances in the understanding of the detector
- First new event classification since launch (Pass 7) released in August 2011
  - Greater and more uniform acceptance
  - Significant enhancement at low energy (below $\sim$ 100 MeV)
- End-to-end reworking of the event reconstruction, analysis and classification (Pass 8) ongoing
  - Larger effective area, better bkg rejection, extended energy range

Extending observations to higher energies

Abdo et al., Phys. Rev. Lett., 104, 101101 (2010), Phys. Rev. D 82, 092004 (2010)



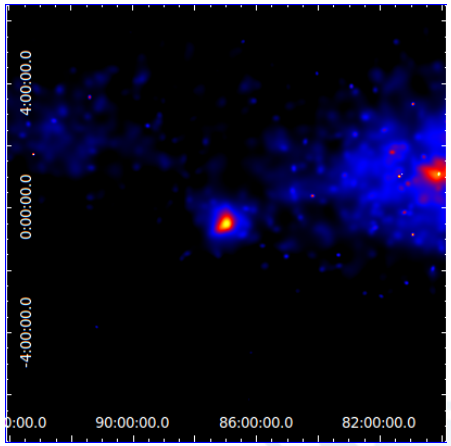


- Energy reconstruction extensively re-written
  - Compensate for the saturation in the calorimeter above ~ 70 GeV per crystal
- Extend the measurement of the isotropic diffuse emission to the highest possible energies
- Extend the CRE spectrum into the multi-TeV band
- Extend the measurement of the spectrum of the Earth limb

Two ideas under development

—TKR reconstruction

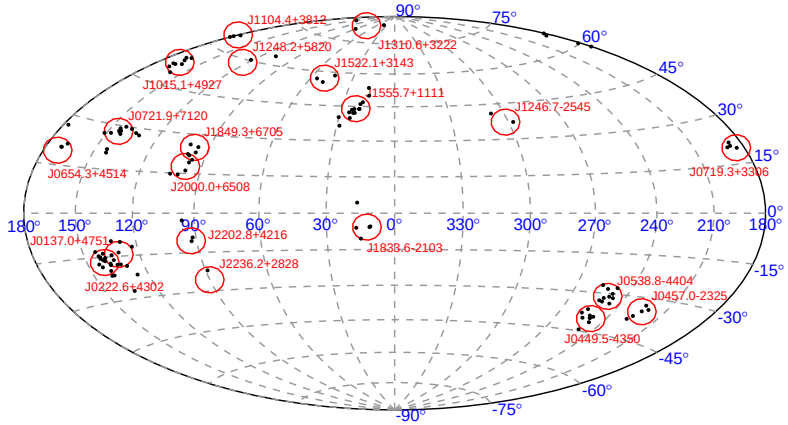
(B. Wells, 219th AAS, Austin)



- Use event-by-event errors
  - as opposed to an *average* PSF parametrization
- Project covariant error ellipse into the sky
- Aim at improving the angular resolution by using all the available information

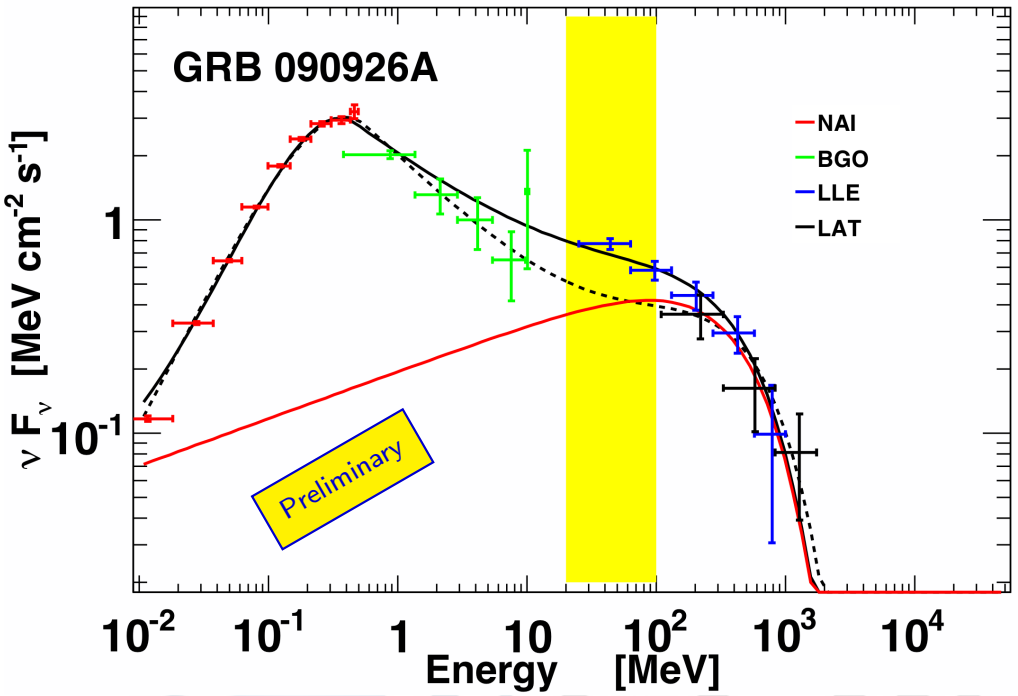
—CAL reconstruction

(L. Baldini et al., Fermi symposium 2011)



- The CAL has some imaging capability
  - at the level of $\sim 1^\circ$ above ~ 10 GeV
- Use the CAL as a *standalone* instrument
- Substantial increase of effective area at high energy

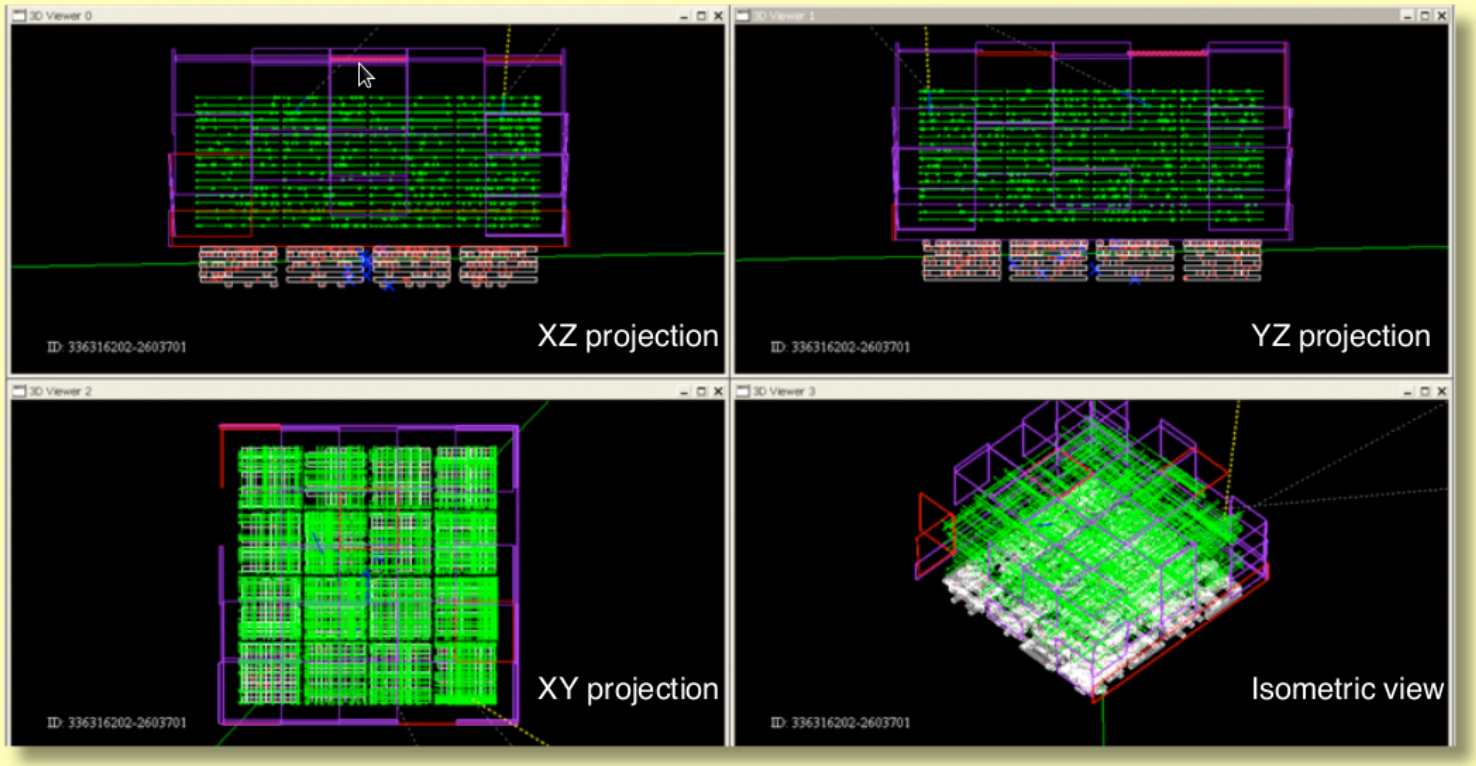
LAT Low-Energy analysis



- Applying the standard likelihood analysis below $\sim$ 100 MeV proved to be more challenging than anticipated
  - Steeply falling effective area and poor energy resolution
- LLE can fill the gap between the GBM and the LAT (30–100 MeV) for short transients (e.g., GRBs, solar flares)
- Use a loose event selection and statistically subtract the background
  - (i.e., not an event-by-event analysis)
- Release of LLE data/analysis tools coming soon

Terrestrial Gamma-ray Flashes with the LAT

E. Grove, 219th AAS, Austin

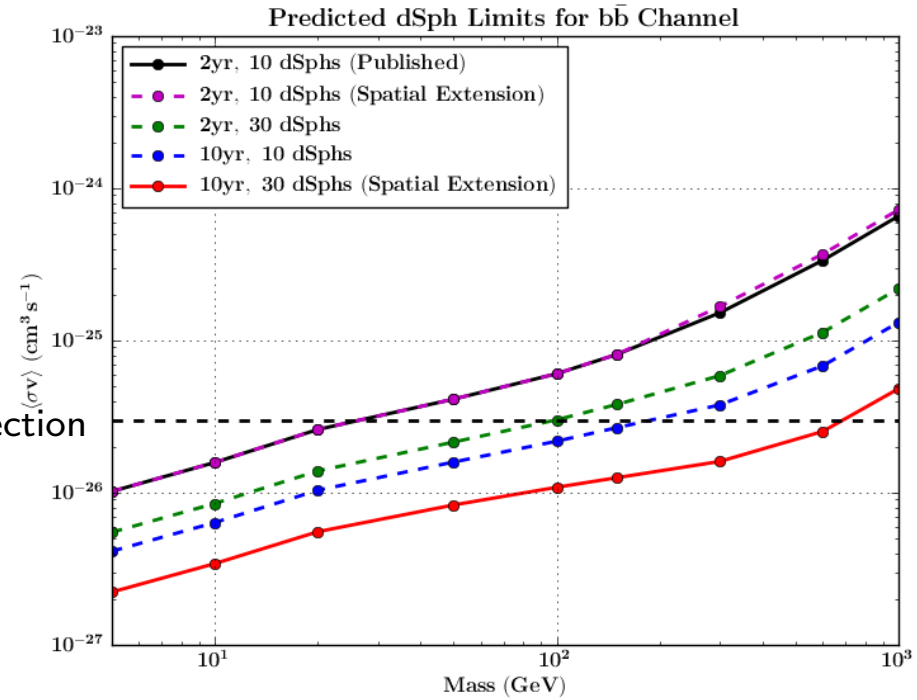


Near peak of TGF, LAT sees ~500 photons in ~5 μs integration time, assuming typical RREA spectrum. Total energy deposited in calorimeter = 2030 MeV, distributed among ~500 photons.

- Hard to reconstruct individual photons...
- ...but can address interesting questions:
  - Energy fluence in the ~ 5 μs elx integration time
  - Average rate of γ-rays between successive readouts
  - Energy endpoint of the spectrum

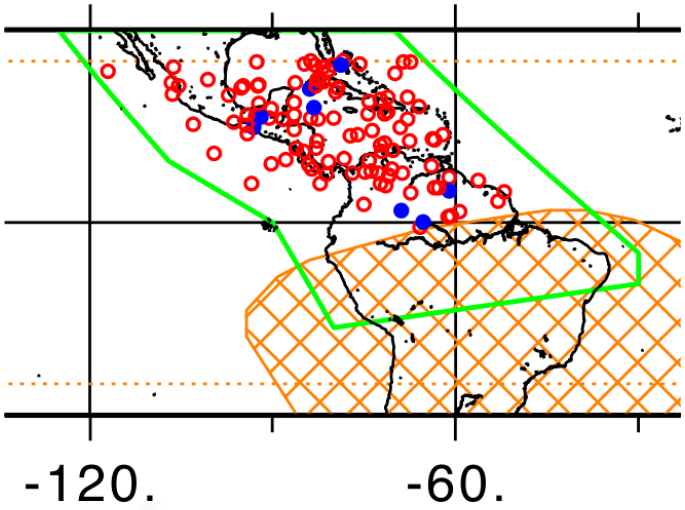
Prospects for indirect Dark Matter searches

Thermal relic cross section



- dSph are the cleanest target for DM searches w/ Fermi
- Current limits on WIMP annihilation cross-section using dSph are the most constraining; they'll improve with improved statistics
  - as $1/\sqrt{t}$ in the bkg-dominated region, as $\sim 1/t$ at high energy
- Optical surveys will discover more dSphs
  - Current dSphs come from SDSS covering about 1/4 of the sky
  - DES and PanSTARRS are ramping up
- Potential for stringent contraints on WIMP models

Operational improvements



- GBM continuous Time-Tagged Event (TTE) data
  - One order of magnitude increase in TGF detection rate
  - (16 ms trigger accumulation time sub-optimal for TGFs)
- LAT engineering runs taking place to optimize the TKR readout configuration
  - Improve high-energy direction reconstruction
- "Compton trigger" configuration under discussion
  - Increase low-energy (< 20 MeV) sensitivity

Conclusions

- Fermi prime phase (5 years) ending in August 2013
  - The observatory is performing extremely well, both from the operational and the scientific standpoint
- 2012 Senior Review committee recommends extending the mission through 2016 (pending review in 2014)
- Benefits of the extended mission well beyond the expectation from a deeper exposure
- Significant effort of the LAT collaboration to maximize the scientific reach of the observatory at all levels
- Fermi is really a scientific facility for the astrophysical community
  - Parallel effort to make the improvements available to the community at large as soon as practically possible