LAT Report

FUG Meeting
January 14, 2013

S. Ritz
on behalf of P.F. Michelson and the LAT Collaboration

see http://www-glast.stanford.edu/
and links therein

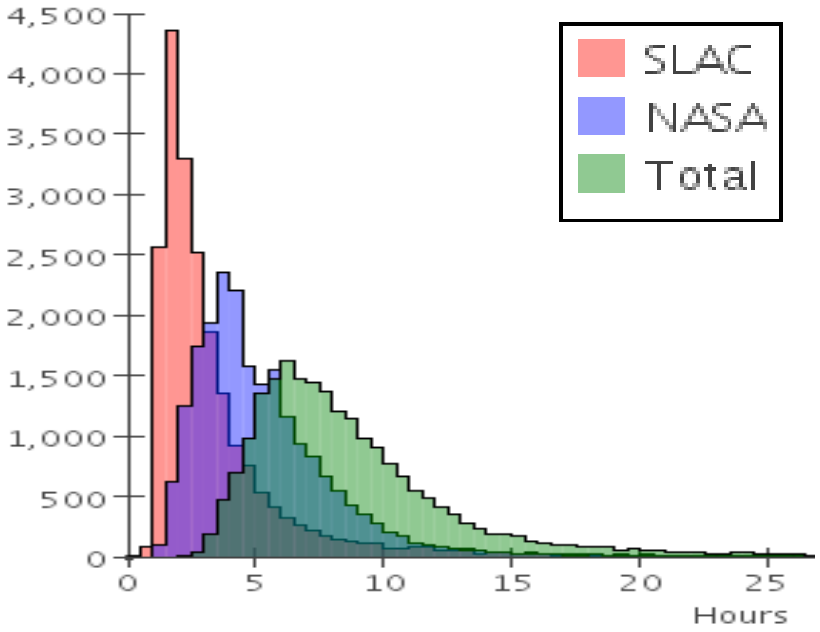
- The LAT continues to operate with > 99.5% uptime for science (excluding SAA, etc.) with no degradations in science performance.

- The international Fermi LAT Collaboration continues to provide excellent coverage for all LAT instrument operations and data processing/analysis needs
  - good coverage in all areas due to multitasking by many collaboration members
  - collaboration actively engaged in improving instrument performance (*e.g.*, Pass 8 is a key focus; well underway)
  - key commitments from DOE and SLAC reaffirmed by recent DOE review of operating experiments (28 September 2012); NASA and international partners have also reaffirmed commitments for extended operations phase

ISOC Science Data Processing

- **Since the start of the science mission**
  - >275 billion triggers of the LAT (since Sept)
  - >50 billion event readouts down-linked to the ISOC
    - 1.5 billion events classified as photons (>225M src class) processed and delivered to the Fermi Science Support Center for public release
    - >500 CPU-years of Level 1 processing at SLAC (10 CPU-yrs/month)
    - 1.5 PB of output data files
    - Data reprocessed multiple times
- **Science Data Monitoring**
  - 120,000 quantities monitored
  - 4238 quantities with alarm limits
- **Automated science processing (ASP) results regularly sent to FSSC.**
  - Blind searches for flaring sources, flux/ spectral monitoring, search for prompt/ afterglow emission from all GRB triggers within LAT FoV, transients searches,…
  - Also supports Collaboration's Flare Advocate and Burst Advocate tasks

Data Processing Times at NASA and SLAC



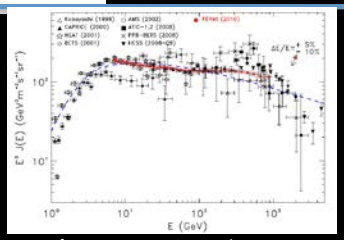
Recent Noteworthy Events

- 2012-10-04 20:54:06 - Disk failure on glastlnx11 (ISOC FASTCopy input node)
  - switched to glastlnx06 until glastlnx11 is repaired
- 2012-10-07 19:42:53 (run 371331776) - Checksum errors affecting ~100 events from EPU0
  - Appears to have been a temporary issue; primary theory is a temporarily stuck bit in one of the non-ECC memories, due to cosmic ray hit. Documented for NASA in SOAR 314.
- 2012-10-19 - B3-1-0 upload/activation error
    - LAT went 87 minutes without taking data (in SAA season), due to slow, non-turbo recovery
    - A small temperature excursion while thermal control was not running
- 2012-10-25 9:30 to 16:30 – Fermi computing outage at SLAC
  - Several critical Fermi servers moved to high-availability racks having generator power backup
- 2012-12-17 12:35:47 – Activation of new TKR hot strip mask
  - 14 strips added (~500 of 880,000 !)
- Trunc64 engineering test runs, including 2012-12-18 04:22 – 05:57 – one orbit using FSW B3-1-2
  - SSR usage is ~1% to 2% greater for trunc64 run over nominal – as expected!
- 2012-12-19 10:16 – 14:50 - Trigger timing calibrations scheduled in the weekly ATS. These calibrations were requested by the Calibration and Analysis Methods science group.
  - Treq_TkrCal_Gamma : 10:16:17 – 11:26:11 UTC
  - Treq_TkrCal_Mip : 11:56:37 - 13:05:15 UTC
  - Treq_TkrAcd : 13:36:22 - 14:49:36 UTC
- Following the trigger timing calibrations: incorrect LAT data collection from 2012-12-19 15:15:52 to 2012-12-20 02:07:46 UTC
  - Onboard filter was left in the configuration used by the last of the Treq timing runs. Unfortunately, this configuration did not include the GAMMA filter, so the data collected are of little use.
  - Problem seen in LAT data rate at the ISOC and fixed by PROC by FOT
  - Lessons learned under discussion

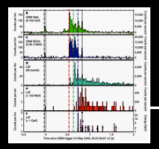
Plans

- On-going mission support and data processing activities, plus….
- Transition to using new "Trunc64" TKR readout buffering is being studied
  - Removal of TKR layer readout buffer limits, to improve the LAT PSF, bkgd rejection, and possibly Aeff
  - On-board limits may be applied in offline processing, if useful
- Pass 8 development, implementation and transition
  - Test processing
  - Then reprocess and redeliver entire mission dataset with Pass 8
  - Expecting the transition to general LAT Collaboration validation in 2013-14 timeframe

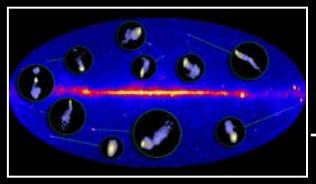
Expanding Classes of Fermi-LAT Sources



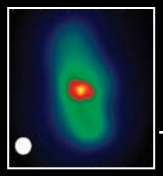
e^+e^- spectrum



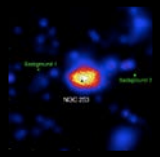
GRBs



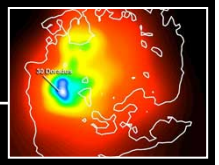
Blazars (782)



Radio Galaxies (12)

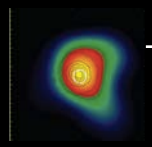


Starburst Galaxies (4)



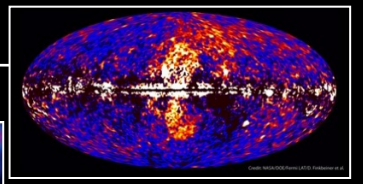
LMC & SMC

Extragalactic

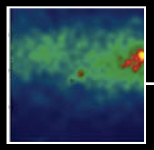


Globular Clusters (11)

Fermi Bubbles

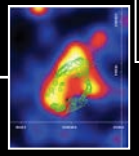


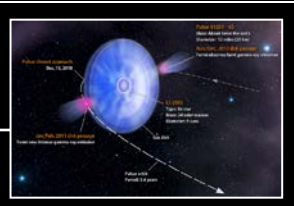
Galactic



Nova (1)

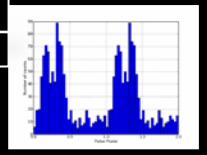
SNR & PWN (68)



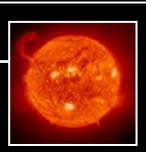


γ-ray binaries (6)

Pulsars: young & millisecond (MSP) (117+)



Sun: flares & CR interactions



Local

Terrestrial Gamma-ray Flashes

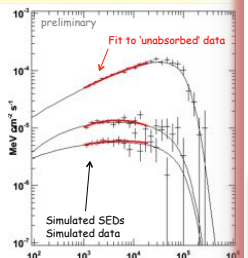
Unidentified Sources (~600/1873)

~110 LAT Fermi Symposium Contributions

Analysis Procedure

We look for the collective deviation of the spectra of blazars from their intrinsic spectra

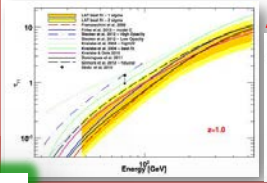
- We use 46months of P7V6 1-500 GeV data
- We define 3 redshift bins with 50 sources each:
  - z= 0-0.2, 0.2-0.5, 0.5 -1.6
- All BL Lacs are modeled with a *LogParabola* spectrum
- We perform a combined fit where:
  - The spectra of all sources are fit independently
  - The spectra of all sources are modified by a common $e^{-b\cdot\tau(E,z)}$ term
- We evaluate 2 cases:
  1. Null hypothesis b=0 : there is no EBL
  2. Null hypothesis b=1 : the model predictions are correct



$$F(E)_{absorbed} = F(E)_{int\,rinsic} \cdot e^{-b\cdot\tau_{mod.el}}$$

Composite Likelihood Results: 2

- A significant steepening in the blazars' spectra is detected
- This is consistent with that expected by a 'minimal' EBL:
  - i.e. EBL at the level of galaxy counts
  - 4 models rejected above 3sigma
- All the non-rejected models yield a significance of detection of 5.6-5.9 σ
- The level of EBL is 3-4 times lower than our previous UL (Abdo+10, ApJ 723, 1082)



Ackermann+12

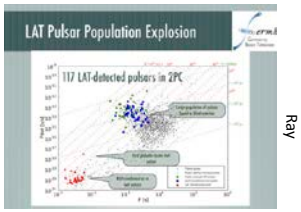
EBL Detection Significance

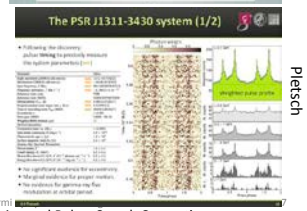
Model Rejection Significance

Model	Ref.	Significance of b=0 Rejection	b²	Significance of b=1 Rejection
Stecker et al. (2006) – fast evolution	(23)	4.6	0.10±0.02	17.1
Stecker et al. (2006) – baseline	(23)	4.6	0.12±0.03	15.1
Kneiske et al. (2004) – high UV	(22)	5.1	0.37±0.08	5.9
Kneiske et al. (2004) – best fit	(22)	5.8	0.53±0.12	5.2
Gilmore et al. (2012) – fiducial	(27)	5.6	0.67±0.14	1.9
Primack et al. (2005)	(56)	5.5	0.77±0.15	1.2
Dominguez et al. (2011)	(23)	5.9	1.02±0.23	1.1
Finke et al. (2010) – model C	(24)	5.8	0.86±0.23	1.0
Franceschini et al. (2008)	(7)	5.9	1.02±0.23	0.9
Gilmore et al. (2012) – fixed	(27)	5.8	1.02±0.22	0.7
Kneiske & Dole (2010)	(26)	5.7	0.90±0.19	0.6
Gilmore et al. (2009) – fiducial	(2)	5.8	0.99±0.22	0.6

Pulsars

- Number is still increasing rapidly – projecting >200 soon
  - Increase since 3rd FS has been on all fronts: radio monitoring & follow-up* and blind searches, with spectacular MSP increase
- **First blind search MSP** announced this week: Pletsch et al. found PSR J1311-3430
  - Optical observations (Romani 2012) constrained the search *somewhat*
  - Most compact MSP known & M_{pulsar} >2.1 M_{sun} (Romani et al.)

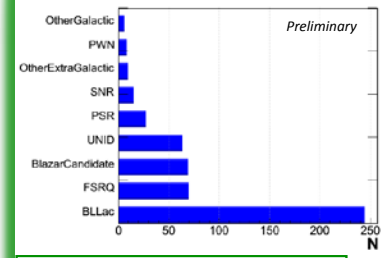




Summary 4th International Fermi

Ongoing successful MW collaboration with Pulsar Timing and Pulsar Search Consortia

514 sources in the 1FHL catalog



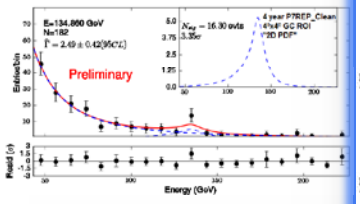
6	(1%)	
8	(2%)	
10	(2%)	
15	(3%)	
27	(5%)	
64	(12%)	
69	(13%)	
70	(14%)	
245	(47%)	

AGN (mostly BL Lacs) dominate the Fermi-LAT sky above 10 GeV (394 objects→ 76%)

12.5% of the sources remain unassociated

Line-like Feature near 135 GeV

- **Our blind search does not find globally significant feature near 135 GeV**
  - Reprocessing shifts feature from 130 GeV to 135 GeV
  - Most significant fit was in R0, 2.23σ local (<0.5σ global)
- **Much interest after detection of line-like feature localized in the galactic center at 130 GeV**
  - See C. Weniger JCAP 1208 (2012) 007 arXiv:1204.2797
- 4.01σ (local) 1D fit at 130 GeV with 4 year unreprocessed data
  - Look in 4°x4° GC ROI
  - Use 1D PDF (no use of P_E)
- 3.73σ (local) 1D fit at 135 GeV with 4 year reprocessed data
  - Look in 4°x4° GC ROI
  - Use 1D PDF (no use of P_E)
- **3.35σ (local) 2D fit at 135 GeV with 4 year reprocessed data**
  - Look in 4°x4° GC ROI
  - Use 2D PDF
    - P_E in data → feature is slightly narrower than expected
  - <2σ global

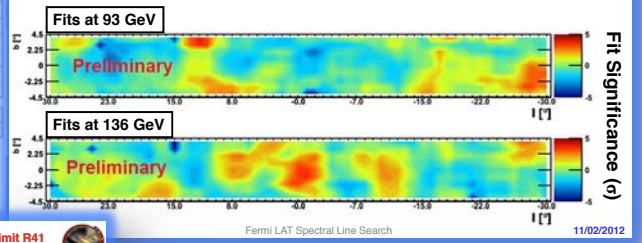


Note: Fit in 4°x4° GC ROI
Not one of our a priori ROIs

10 Fermi LAT Spectral Line

Spatial Morphology of Features in Galactic Plane

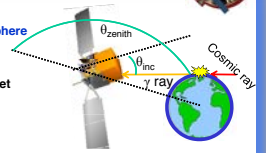
- **Fit in 4°x4° ROIs along the galactic plane in 1° steps**
  - Fit with "1D PDF"
    - To find where the counts are coming from
- **Find excess near ~135 GeV near GC**
  - But find similar features at other energies along the GP
  - Some indication the 135 feature not smooth, but 2-3 smaller "hot spots"
  - Excess near 135 GeV is one of the largest and near GC, but is not otherwise unique
  - See talk by E. Charles for more details

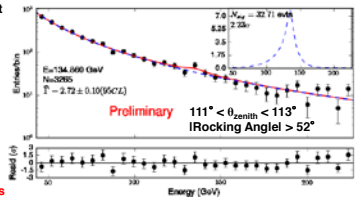


Fermi LAT Spectral Line Search 11/02/2012

135 GeV in the Earth Limb spectrum

- **Earth Limb is a bright gamma-ray source**
  - From cosmic-ray interactions in the atmosphere
    - Expected to be a smooth power-law
  - Can be used to study instrumental effects
- **Have made changes to increase our Limb dataset**
  - Pole-pointed observations each week
  - Extended "targets of opportunity" (ToOs)
    - Trace limb while target is occulted
- **Line-like feature in the limb at 135 GeV**
  - Appears when LAT is pointing at the Limb
    - IRockAnglel > 52°
  - Surprising since limb should be smooth
  - On-going systematic studies have found interesting results
    - See talk by E. Bloom
    - See talk by E. Charles

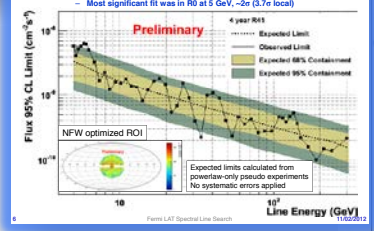




12 Fermi LAT Spectral Line Search 11/02/2012

Spectral Line 95% CL Flux Upper Limit R41

- No globally significant lines found
  - Most significant fit was in R0 at 5 GeV, ~2σ (3.7σ local)



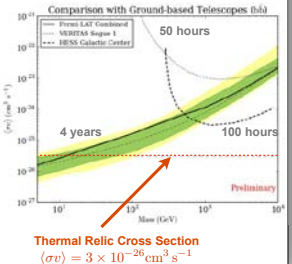
Fermi LAT Spectral Line Search 11/02/2012

4 examples:

- EBL
- Pulsars
- 1FHL
- DM search updates: line searches and dSph

Conclusions

- 4 years of Pass 7 data yields higher limits than 2 years of Pass 6 data; however, the two are statistically consistent with predictions.
- Change in the Fermi-LAT dwarf limits are due to statistical fluctuations in the event classification.
- Still no evidence for a dark matter signal from these objects.
- Immediate improvements are expected from updated diffuse and point source background models.
- Eventual improvements are expected from instrument performance (Pass 8).

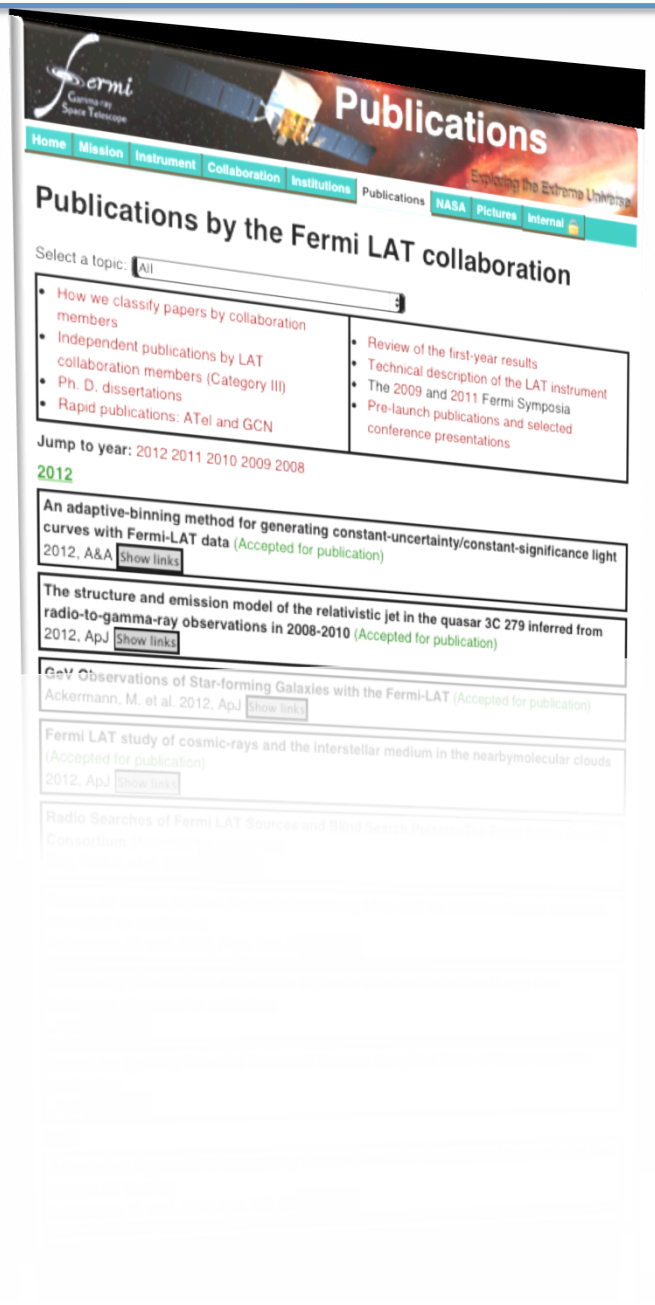


Thermal Relic Cross Section

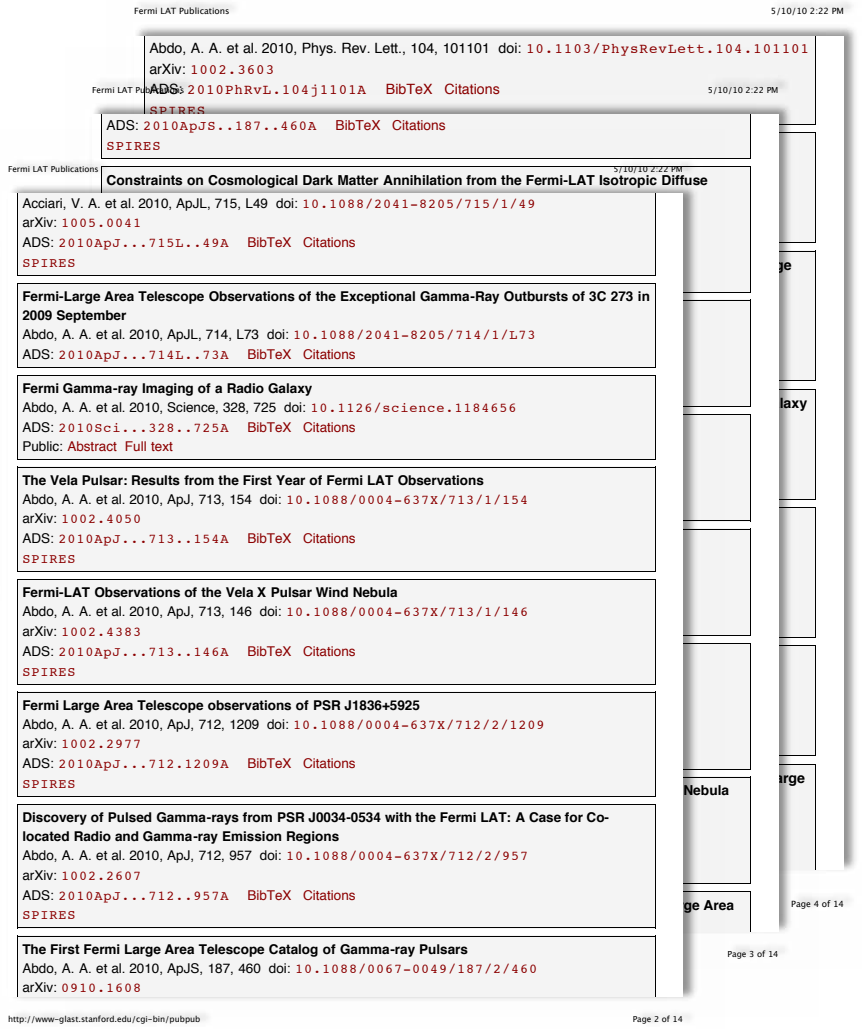
$\langle\sigma v\rangle = 3\times10^{-26}\mathrm{cm}^3\,\mathrm{s}^{-1}$

Alex Drlica-Wagner | 4th Fermi Symposium 11

>220 LAT Team papers out…



ADS: LAT 2nd Catalog most highly cited paper of 2012 in Astronomy

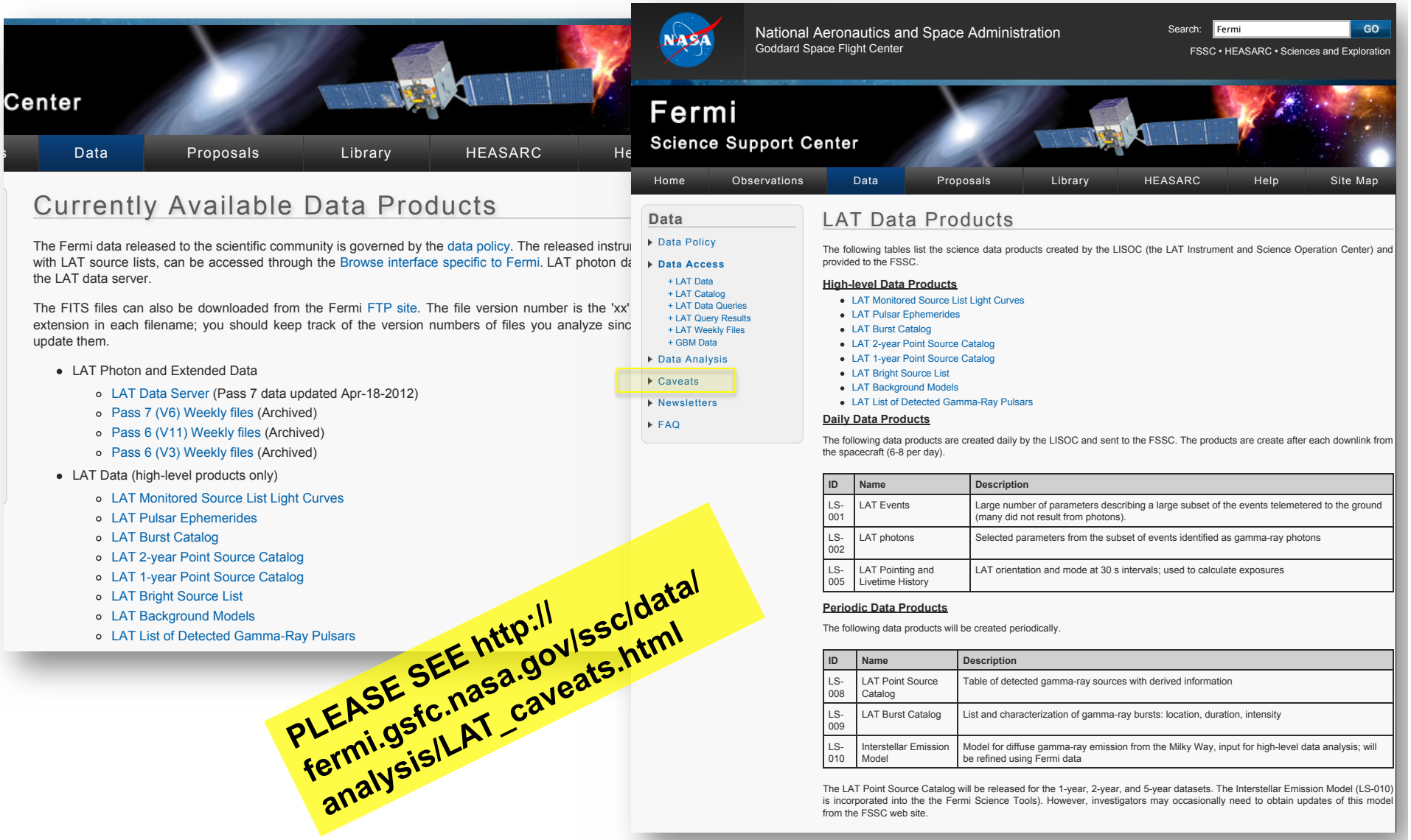


…with many more in the pipeline…and many hundreds more using public LAT data.

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

LAT Data Products @ FSSC

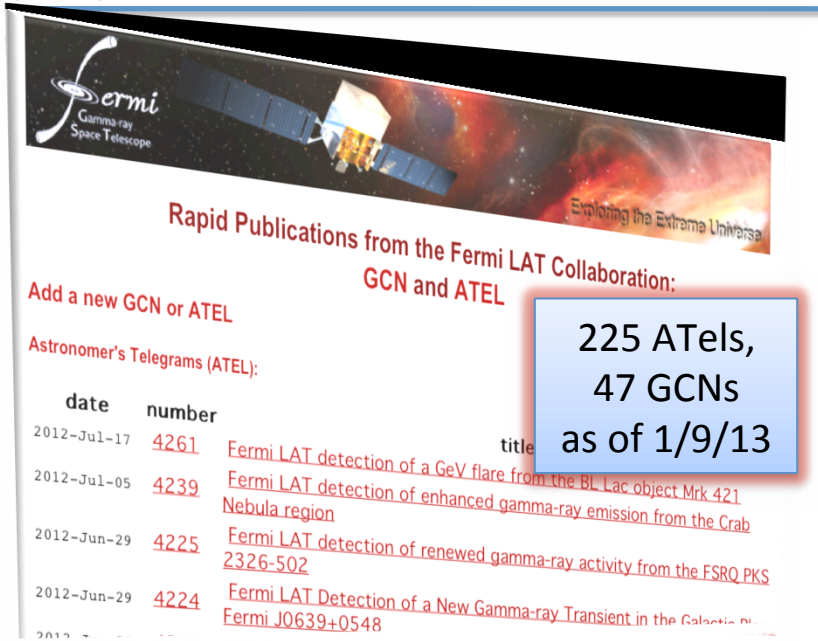
http://fermi.gsfc.nasa.gov/ssc/data/access/lat/



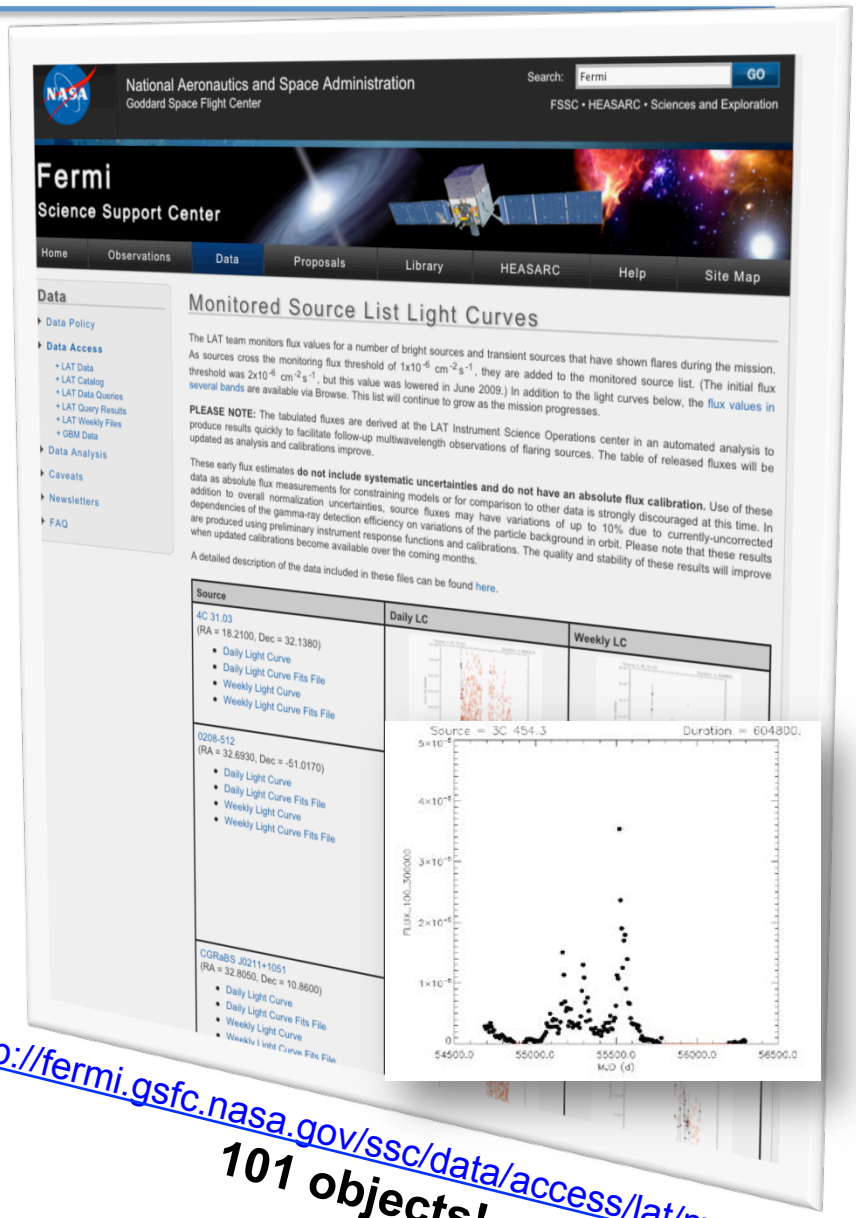
LAT Data Summary

- level-1 processed LAT "photon" data, including calibrations, updates and reprocessing
  - Pass7, Pass7-reprocessed, **Pass8**
- flux histories of monitored sources
- LLE (**L**AT **L**ow **E**nergy) data
  - a new data product. See previous FUG meeting presentation.
- with the FSSC, support & updates of LAT analysis tools
- Catalogs, including
  - LAT source catalogs: 1FGL (2009), **2FGL** (2012),.. and updates to diffuse bkgrd model in support of user source analysis
  - LAT AGN catalogs: bright AGN source list (2009), 1st catalog (2010), 2nd catalog (2011), 1st HE Catalog (1FHL) in preparation
  - LAT pulsar catalogs: 1st catalog (2010), 2nd catalog in internal review
  - LAT GRB catalog: 1st catalog in final collaboration review

Transients & Flaring Sources



225 ATels,
47 GCNs
as of 1/9/13



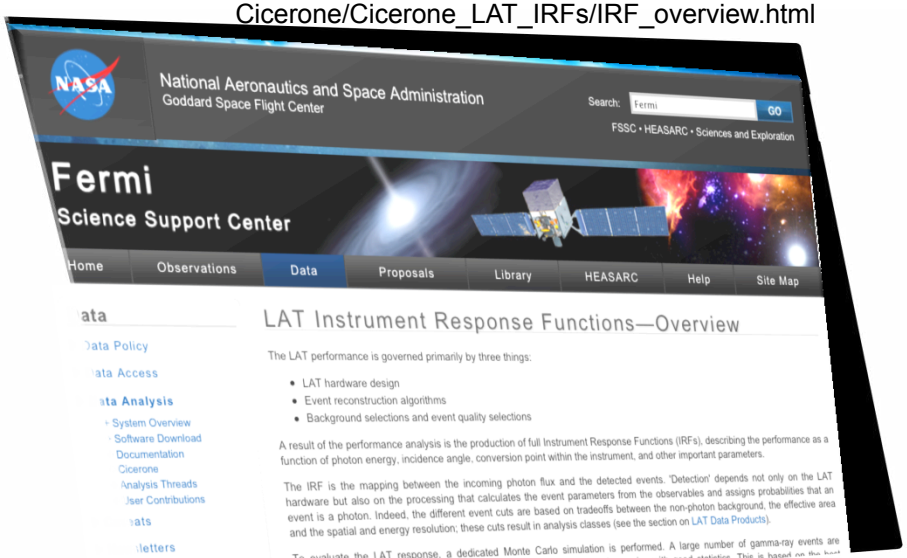
http://fermi.gsfc.nasa.gov/ssc/data/access/lat/msl_lc/

101 objects!

Also see http://fermisky.blogspot.com/

LAT Photon Data

http://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Cicerone/Cicerone_LAT_IRFs/IRF_overview.html



direction of each event, and calculating myriad quantities with are used by the selection algorithms to separate photons from cosmic ray backgrounds. This is a much longer term project and will eventually be released as "Pass 8" of the event selection.

The main features of P7 IRFs are:

- Improved effective area and/or lower background contamination relative to P6. As the "Pass 7" analysis was designed using flight data, the instrument team was able to improve the photon/cosmic ray separation. In general the selections were tuned to give roughly the same background contamination rates as for "Pass 6" analysis while gaining in effective area, particularly at lower energies (below 300 MeV).
- Inclusion of second order effects released in P6_V11: azimuthal- and livetime-dependence of effective area are also included in "Pass 7"
- As in the P6_V11 IRFs the point spread function derived by fitting the width of bright point sources. This was done because the point spread function derived from Monte Carlo was observed to be an incorrect description of the LAT performance at high energies.
- The Pass 7 event selections are based only on quantities that have been shown to be well modeled in the Monte Carlo simulations. Therefore the associated IRFs do not require any flight based correction of the type that was applied in making the P6_V11_DIFFUSE IRFs.

Recommendations for the appropriate selection and IRF set to be used within an analysis are provided in the data preparation section of the Cicerone. The tables below give the association between the Pass 7 IRF sets and the photon properties as provided in the LAT photon data.

P7 IRF name	Event Class (evclass)	Conversion Type	Description
P7ULTRACLEAN_V6	4	0+1	Highest quality and lowest background selection - somewhat overconservative, this entails a significant loss of effective area. Recommneded mainly to use as a cross check that observed features are not due to cosmic-ray contamination
P7ULTRACLEAN_V6::FRONT	4	0	Front converting events
P7ULTRACLEAN_V6::BACK	4	1	Back converting events
P7CLEAN_V6	3	0+1	Very high quality and low background selection - recommended for analyses that integrate large regions of the sky. Reduces non-photon spectral features to very low levels.
P7CLEAN_V6::FRONT	3	0	Front converting events
P7CLEAN_V6::BACK	3	1	Back converting events
P7SOURCE_V6	2	0+1	High quality selection - recommended for most analysis
P7SOURCE_V6::FRONT	2	0	Front converting events
P7SOURCE_V6::BACK	2	1	Back converting events
P7SOURCE_V6MC	2	0+1	Monte Carlo PSF - for studies of short term (<1 month) variability
P7SOURCE_V6MC::FRONT	2	0	Front converting events
P7SOURCE_V6MC::BACK	2	1	Back converting events
P7TRANSIENT_V6	0	0+1	Lower quality selection - used for certain transient or timing analysis
P7TRANSIENT_V6::FRONT	0	0	Front converting events
P7TRANSIENT_V6::BACK	0	1	Back converting events

Additional Information

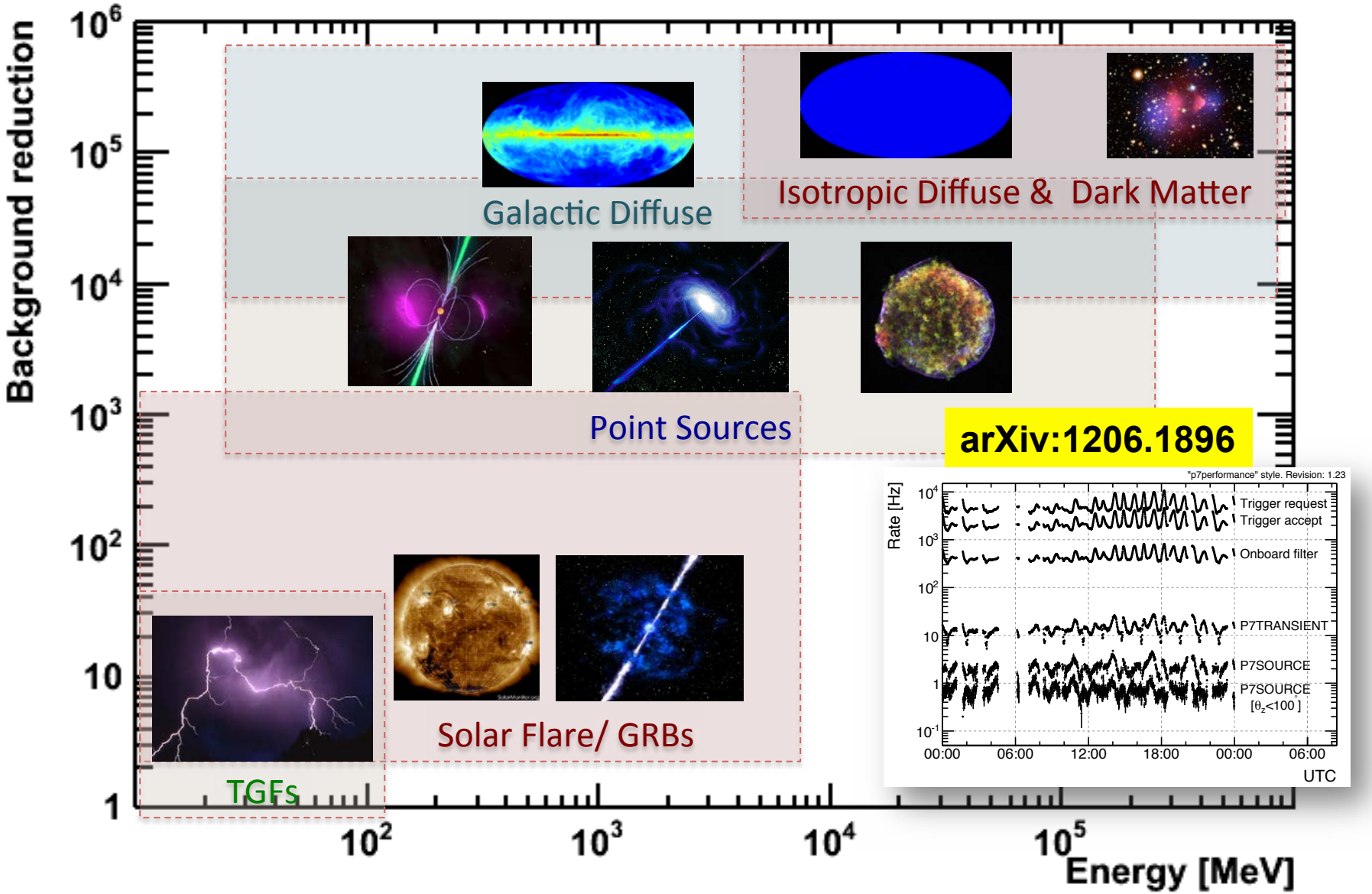
Detailed descriptions of the LAT instrument, event analysis, and performance can be found in the following:

- LAT Performance Page: http://www-glast.slac.stanford.edu/software/IS/glast_lat_performance.htm.
- Pass 7 Performance Paper: The Fermi Large Area Telescope On Orbit: Event Classification, Instrument Response Functions, and Calibration, Ackermann, M. et al., 2012, ArXiV e-print: 1206.1896.
- The Large Area Telescope on the Fermi Gamma-Ray Space Telescope Mission, Atwood, W. B. et. al., ApJ, 2009, 695, 1071.
- The on-orbit calibration of the Fermi Large Area Telescope, Abdo, A. A., et al. 2009, Astroparticle Physics, 32, 193

The IRFs shown here are based on updated simulations of the instrument that take into account effects measured in flight that were not considered in pre-launch performance estimates. Recent information regarding the results of post-launch testing which led to this formulation can be found in the following documentation:

- Post-launch performance of the Fermi Large Area Telescope, R. Rando, 31st ICRC Conference Proceedings, Lodz, Poland, 2009.

Huge Dynamic Ranges

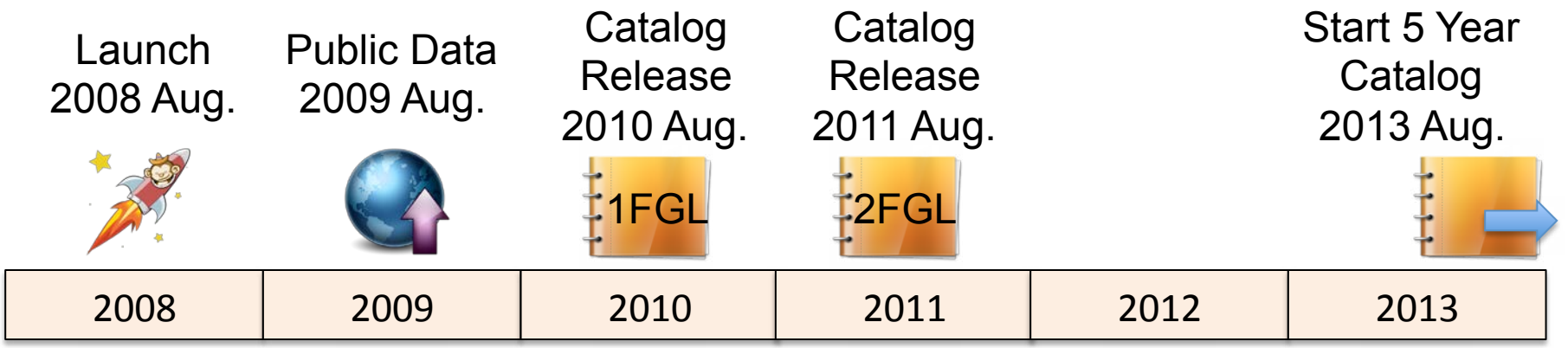


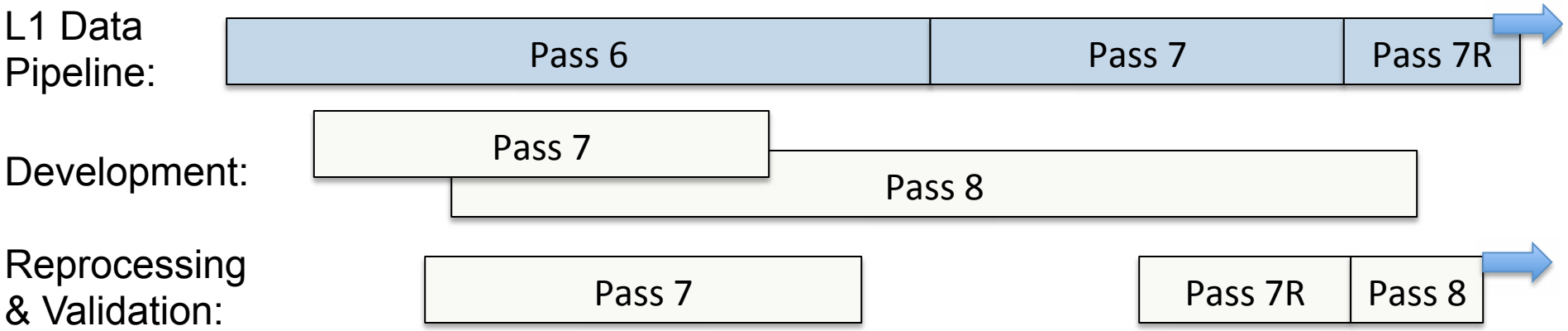
Evolution, Improvements

- Event reconstruction and choices of event selection "knobs" all determine instrument performance. For stability, standard event class definitions established with IRFs.
- Data were released with Pass 6.
  - Some known issues, described in Caveats on FSSC site and in LAT papers, addressed with patch to IRFs.
  - Pass 7 and Pass 8 address the remaining issues.
- Pass 7 released
    - Improved standard photon classes. **Used in 2nd Catalog.**
    - Event analysis taking into account "ghost" events
  - Ongoing: reprocessing Pass 7 using updated calibrations. Main improvement: PSF @ high energies.
- Exciting progress on Pass 8, expected to be the ultimate version.

LAT Data Releases

…PLUS tools, diffuse models, transients/monitored sources, LLE…

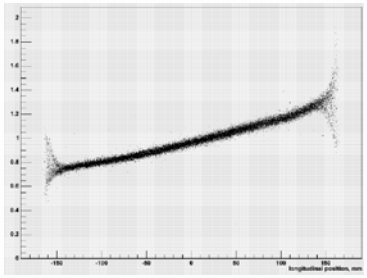




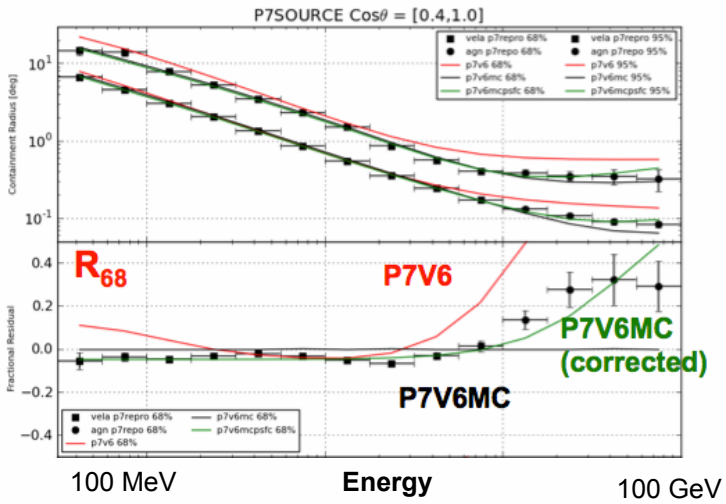
Pass 6: Pre-launch Event Reconstruction and Classification
Pass 7: Event Classification Re-optimized Using Flight Data
Pass 7R: Pass 7 Reprocessed with Improved Calibrations
Pass 8: Event Reconstruction and Classification Major Upgrades

P7REP Data Reprocessing

Light Asymmetry



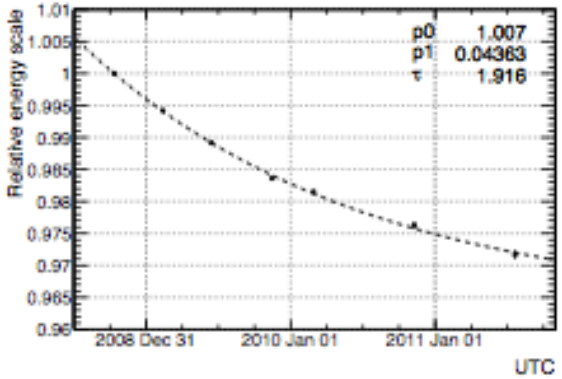
Motivation: use improved calibration of CAL light-yield light asymmetry. Original calibrations had not been updated since launch.



CAL position contributes to event direction estimate. P7REP PSF is much improved at high energies and much closer to Monte Carlo than P7.

P7REP in-flight PSF starts with Monte Carlo PSF and re-fits scaling as a function of energy to AGN and Pulsar control samples.

MIP light yield v. Time



Updated calibrations also correct for ~1% year expected (and measured) decrease in CAL light-yield.

This change in light-yield directly effects that LAT energy estimation.

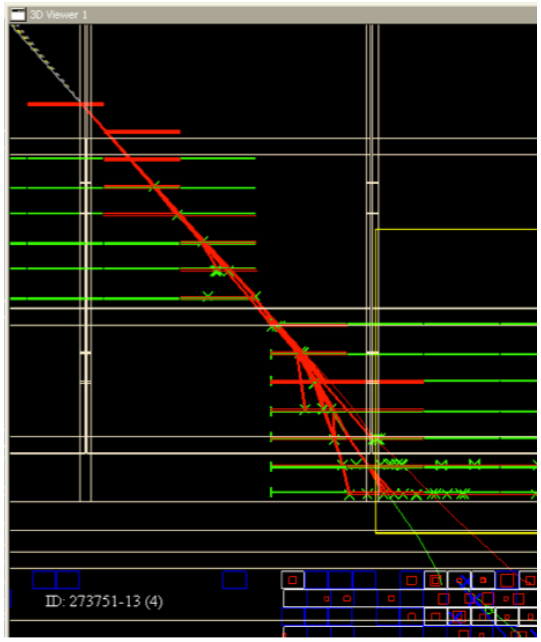
Public Release of P7REP Data

- Data have been reprocessed up to late 2012
- IRFs are available for all event classes
  - SOURCE, CLEAN and ULTRACLEAN classes use in-flight PSF
- Diffuse emission models (both Galactic and isotropic) were fit to data
  - Energy shift in P7REP data requires updated diffuse models
- Cosmic-ray leakage is absorbed into isotropic diffuse model
  - Requires updated model for each event class

- **Current Status:**
  - LAT collaboration is redoing parts of Point Source catalog analysis to validate diffuse emission models
  - Data transfer to FSSC, documentation, etc… being done in parallel
- **Expect public release of data in March timeframe**
  - Update live processing pipeline to provide seamless transition between reprocessed data and newly acquired data

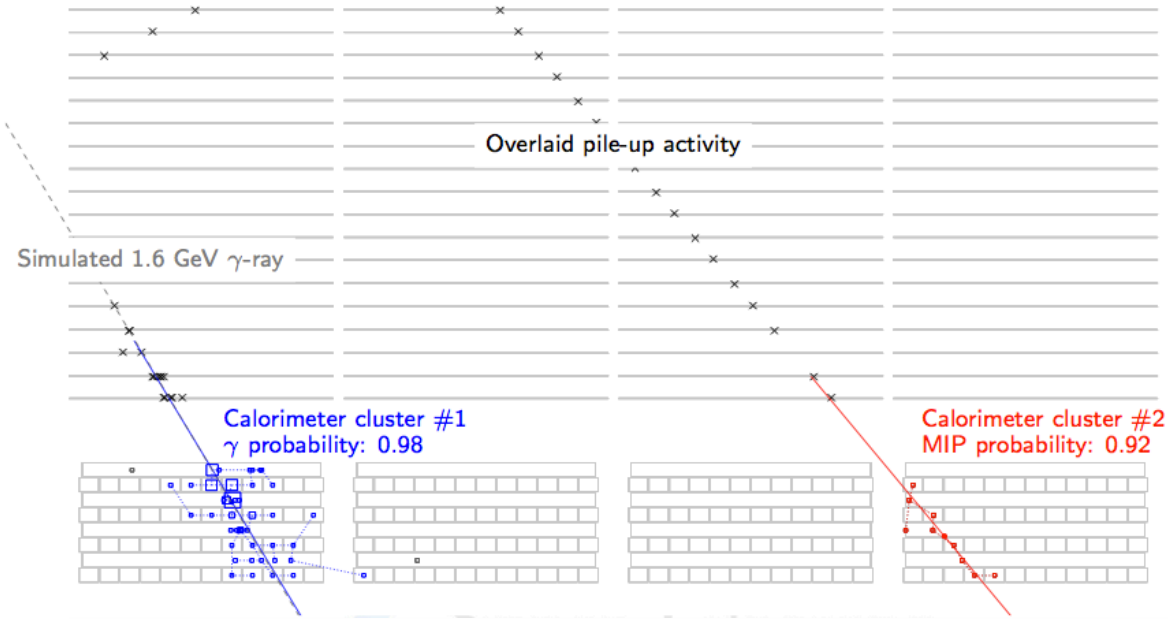
Pass 8 Synopsis

The two really MAJOR changes



Tree-based Tracking

(better model for EM shower)



Calorimeter Cluster & Cluster Classification

Also: cosmic ray track finder, handling of buffer overflows, improved cluster errors, removing ghost hits, improved track-fitting, vertex energy weighting, TKR-CAL matching, CAL-only events, improved GEANT modeling, updated simulation of CAL light yield, development of validation samples,…

Science analyses developed *along with* Pass8 => there may be some interim results. Main goal: release Pass8 data with 5-year catalog (w/updated diffuse model) based on Pass8.

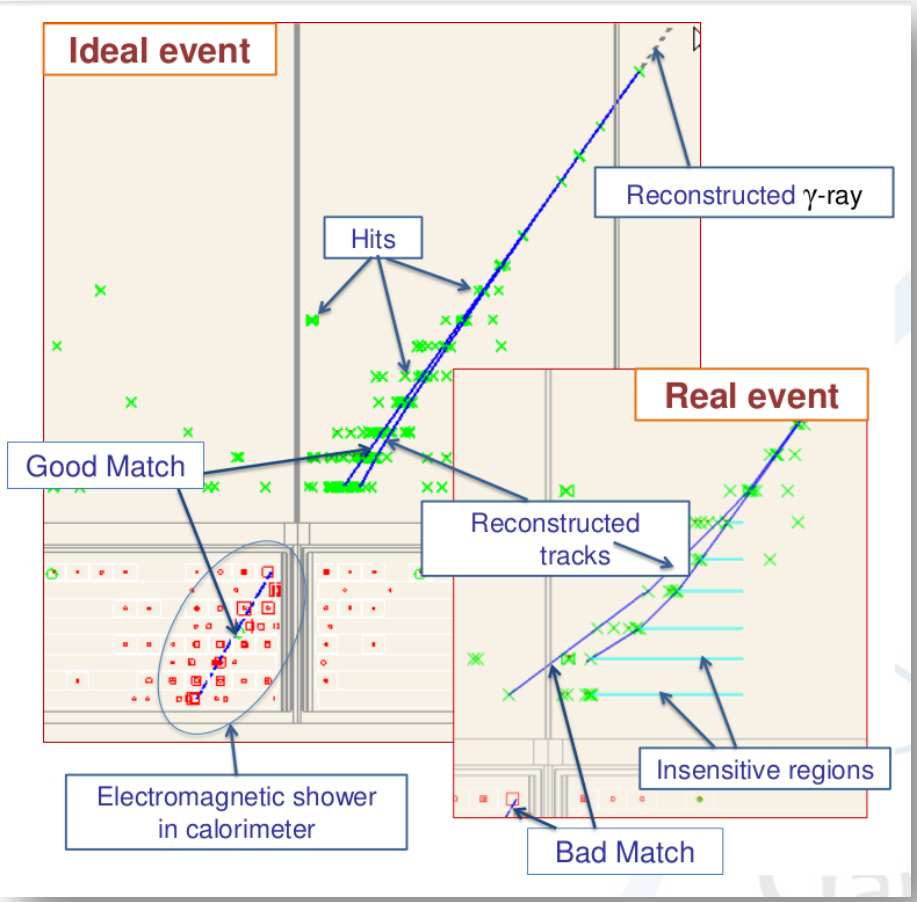
Pass8 event reanalysis

- first comprehensive (and most significant) event level reanalysis since launch. Development underway for past 3 years; will be implemented in 2013.

- involves all area of event analysis
  - Event reconstruction;
  - Overall event structure;
  - Energy analysis;
  - PSF analysis;
  - Background rejection

- will be implemented for the LAT 5-year catalog analysis and readied for release at time of 5-year catalog release (i.e. ~ end of 2014)

Trunc64: TKR truncations and tracking



arXiv:1201.1068

Hardware limitation to the number of TKR hits that can be read out (there are 880,000!)

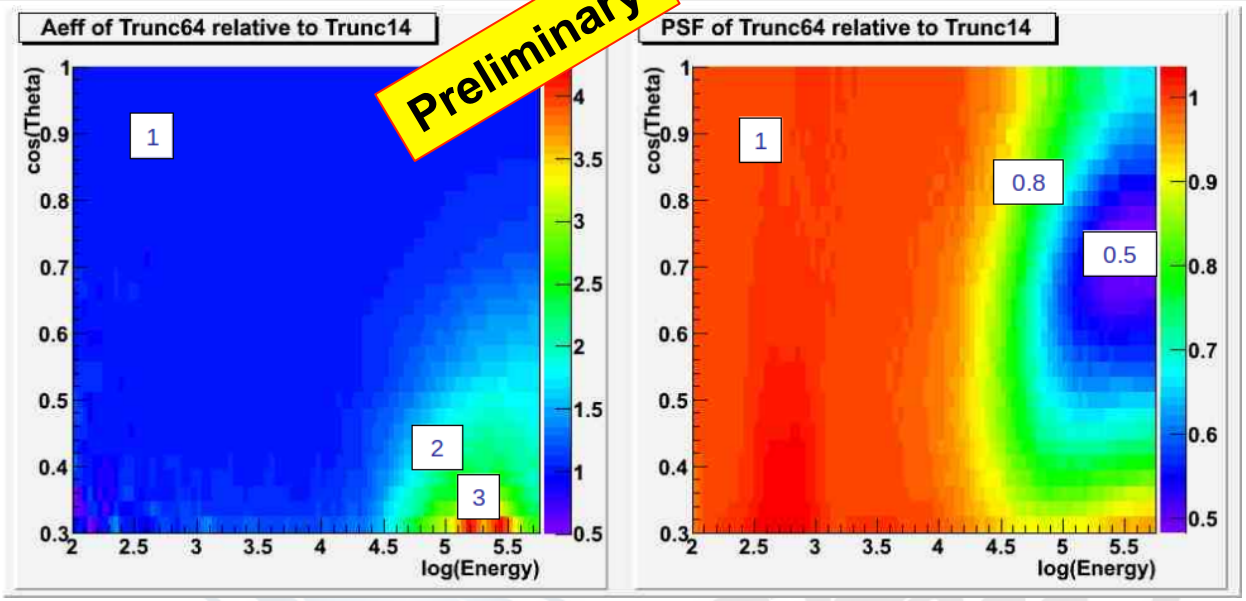
- usually there is no impact, but large (HE) events can be truncated.
- Read out is geographically configurable for setting limits on the number of hits read out.

- In the current configuration, up to 14 hits per half plane are read out.
  - as the HE shower develops, we can lose hits.
  - Impact is not huge, but PASS 8 and other developments show we can do better.

Configurable by design

Loss of hits can pull track away from true direction, potentially worsening PSF and TKR-CAL matching (important for background rejection).

Trunc64: TKR truncations and tracking



- Factor of ~ 10 reduction in the number of events affected by truncations (from $\sim 10\%$ to $\sim 1\%$).
- Substantial improvement in the PSF above ~ 10 GeV.
- Improvement in the effective area at high-energy and large angle:
  - Direct consequence of reducing the fraction of badly misreconstructed events.
- Strong motivation for pursuing this development.
  - And better sooner than later: can't get the hits back once the data have been acquired.

Caveats: see FSSC discussion

Summary

- LAT continues to perform well; plans in place for science performance upgrades.
- Science reach of LAT remains high, particularly discovery space at high energy.
- key commitments from LAT partners (NASA, DOE, international) for extended operations phase.
- feedback and new ideas welcome!

LAT Collaboration

- 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 Washington

PI: Peter Michelson
(Stanford)

~400 Scientific Members (including 97 Affiliated Scientists, plus 71 Postdocs and 123 Students)

Cooperation between NASA and DOE, with key international contributions from France, Italy, Japan and Sweden.

Project managed at SLAC.

Discussion