Welcome

Fermi Data Analysis Workshop

Chris Shrader,
Fermi Science support Center
NASA/GSFC

Workshop Objectives

- Today we'll cover *Fermi* analysis basics:
  - Data content, selection cuts, caveats
  - Analysis methodologies, synopsis of tools
    - ML method→ point source analysis
    - Light curve & pulsar analysis
- Emphasis on hands on analysis
  - roving support staff
- Feedback & discussion
- Tomorrow: **GI Program, information for proposers**

Agenda, Staff

9:00 - 9:30	Registration, Setup	
9:30 - 9:35	Workshop Welcome	Chris Shrader
9:35 - 9:50	Fermi Instruments and Data Acquisition	Chris Shrader
9:50 - 10:00	Data Usage Caveats	Chris Shrader
10:00 - 10:15	Data Access and Exploration	Robin Corbet
10:15 - 10:35	Hands on Session 1	All
10:35 - 10:45	Generating Source Models Using the LAT Catalog	Robin Corbet
10:45 - 10:55	Handling Livetime and Exposure Calculations	Jeremy Perkins
10:55 - 11:15	Unbinned Likelihood Analysis	Jeremy Perkins
11:15 - 12:00	Hands on Session 2	All
12:00 - 13:00	Lunch Break	
13:00 - 13:30	Generating Light Curves	Robin Corbet
13:30 - 14:00	Hands on Session 3	All
14:00 - 14:20	Binned Likelihood Analysis	Jeremy Perkins
15:00 - 15:40	Hands on Session 4	All
15:40 - 16:00	Using Python to Streamline Analysis	Jeremy Perkins
16:00 - 16:25	Hands on Session 5	All
16:25 - 16:30	Summary, Feedback	All

Prerequisites

- Science Tools Installation – hopefully done prior, but we can help as needed
  - Workshop web page is useful resource
- Sample datasets on workshop web page
  - Can substitute alternative data selections, but be cognizant of run-time, S/N issues
- Access to Fermi SSC web site
  - Data analysis documentation sets
    - Threads, Cicerone, Reference ('fhelp') docs

A Few Fermi Analysis Basics

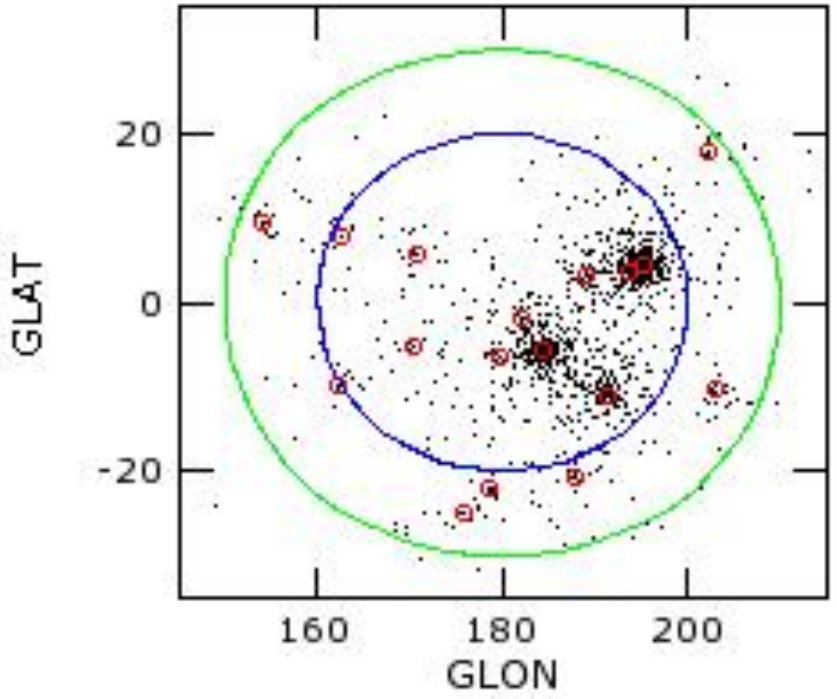
What's different about Fermi data analysis?

- Structured sky backgrounds
- Energy-dependent point spread function
- Instrument response function(s) IRFs
  - Multiple dependencies: instrument design, event reconstruction, background & quality selections
- Wide field of view, continuously variable aspect

Energy Dependent PSF

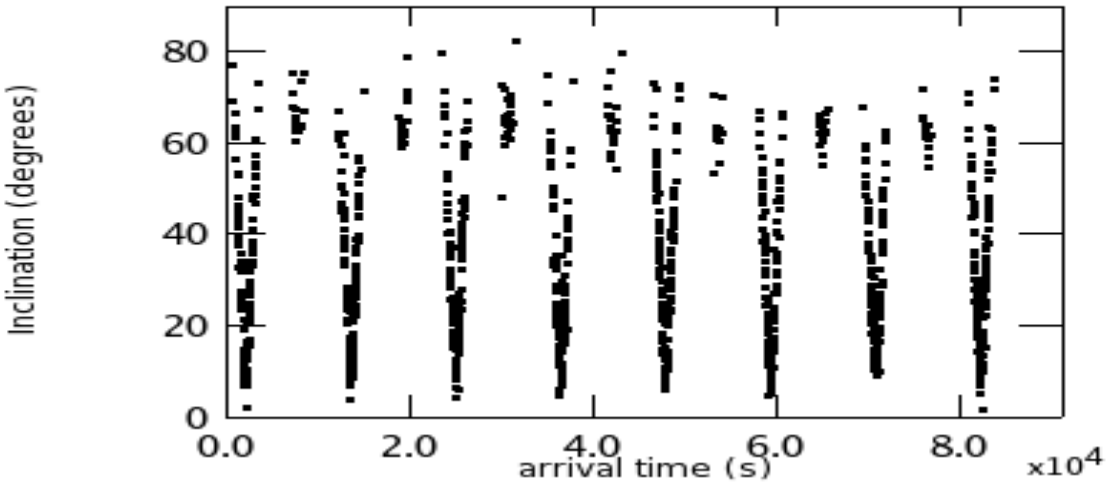
- **Sources must be fit simultaneously.**
  - Broad and energy-dependent PSFs: $\sigma_{68} < 3.5^{\circ}$ for 100 MeV (on axis) and $< 0.1^{\circ}$ for 10 GeV
  - Emission from nearby point sources overlap.
  - Intrinsic source spectrum affects the degree of source confusion.
  - "Source region" must be significantly larger than the "region-of-interest" (ROI).

- Anticenter region:



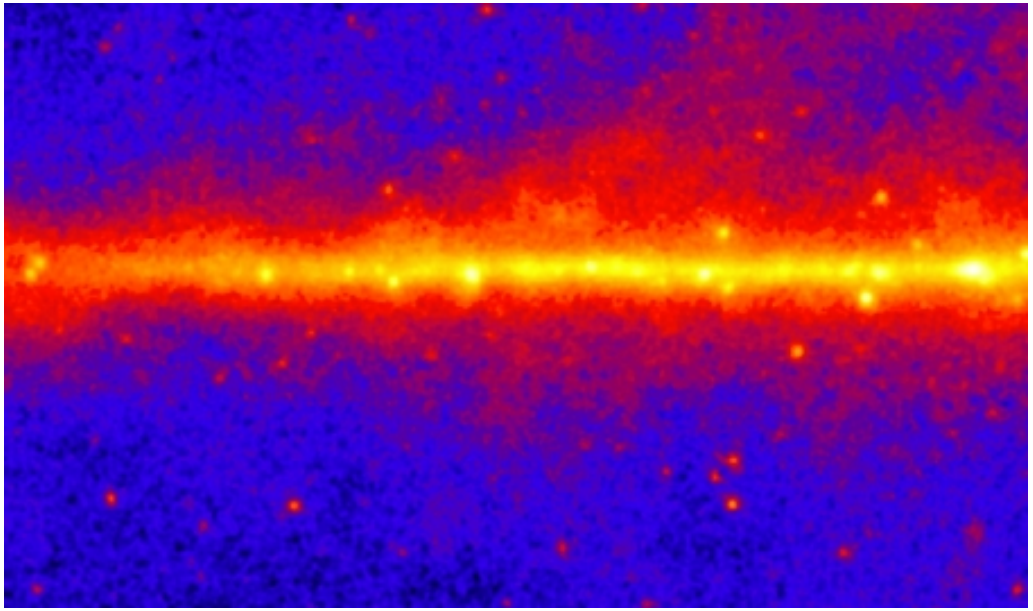
Continuously Varying Aspect

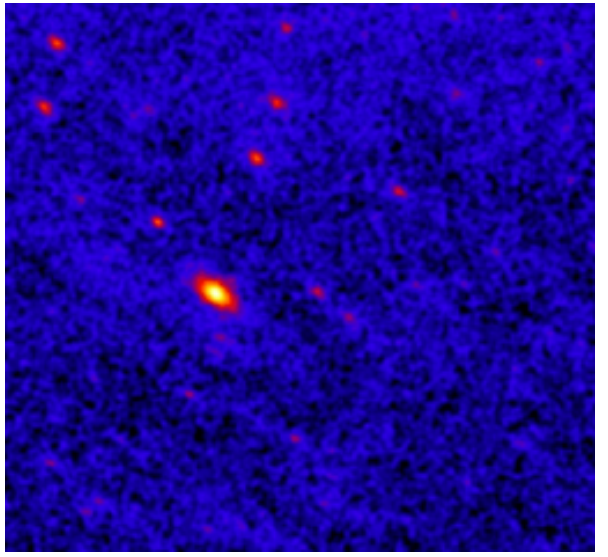
- Each event effectively has its own response function:
  - Large FOV, ~ 2.4 sr
  - Strong variation of response as a function of photon incident angle, $A_{eff} \propto \cos\theta$
  - Scanning mode of operation: 90 min orbit ⇒ continuous aspect changes of 4°/min.



Diffuse Emission

- Emission results from cosmic ray interactions with interstellar gas.
- Models rely on HI & CO observations for the gas distribution
- These observations reveal structures on angular scales similar to the PSF
- Also, extragalactic (ie full-sky isotropic) background



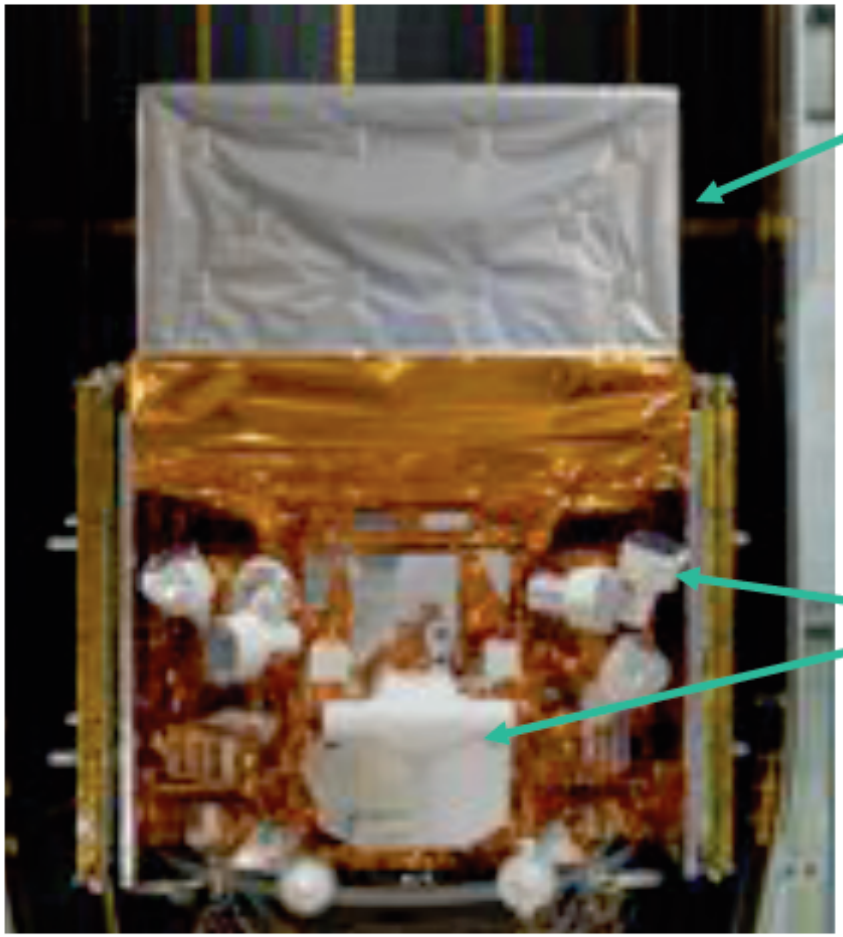


Useful Information

- Web URLS:
  - http://fermi.gsfc.nasa.gov/workshops/2010_nyu/
  - Workshop web site
  - http://fermi.gsfc.nasa.gov/ssc/
  - FSSC home
  - http://fermi.gsfc.nasa.gov/ssc/data/access/
  - Data access
  - http://fermi.gsfc.nasa.gov/ssc/data/analysis/
  - Data analysis page
  - http://fermi.gsfc.nasa.gov/cgi-bin/ssc/faq/glastfaq.cgi
  - FAQs

Quick Overview: Fermi Instruments & Data acquistion

Fermi instruments



Large Area Telescope (LAT):

- 20 MeV - >300 GeV (including unexplored region 10-100 GeV)
- 2.4 sr FoV (scans entire sky every ~3hrs)

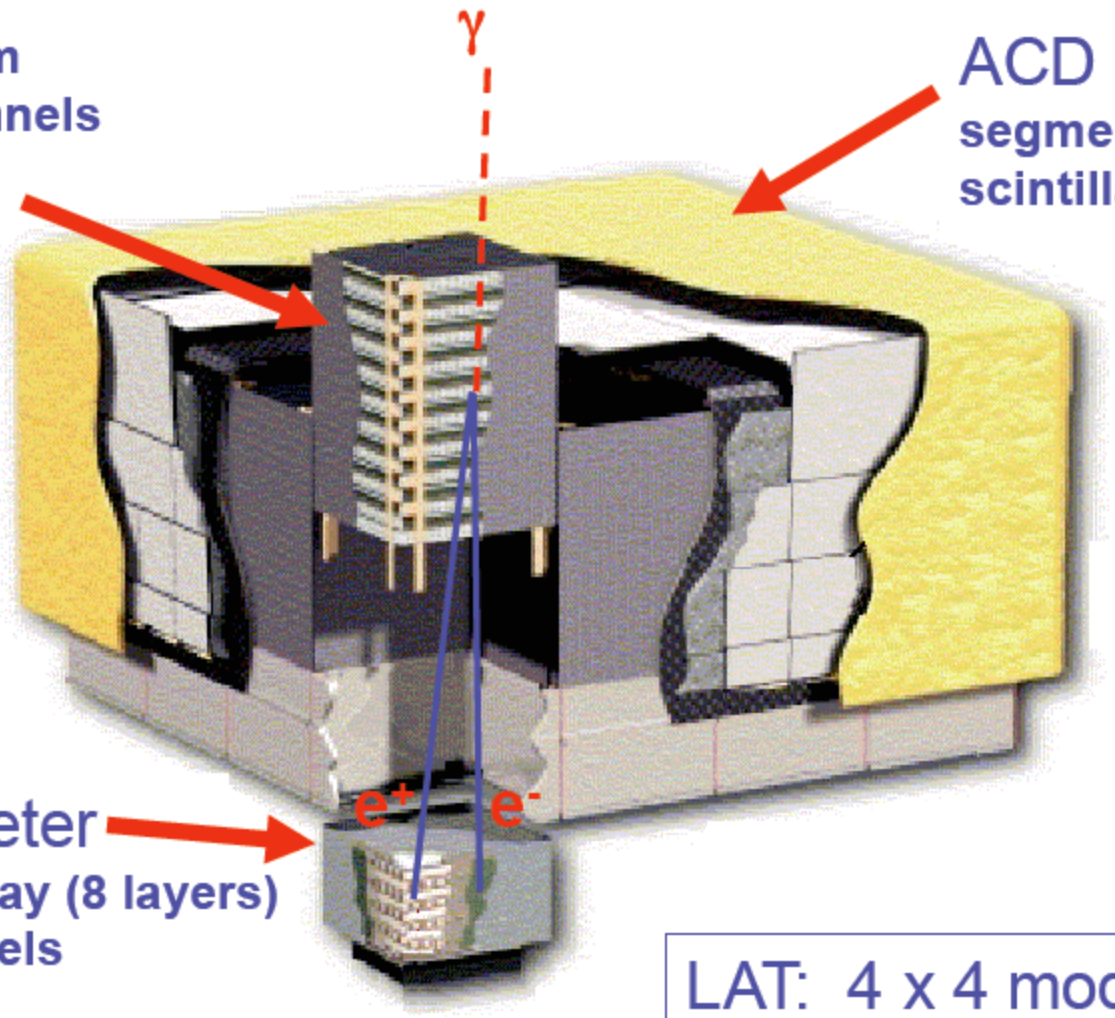
Gamma-ray Burst Monitor (GBM)

- 8 keV - 40 MeV
- views entire unocculted sky

- **Large leap in all key capabilities, transforming our knowledge of the gamma-ray universe. Great discovery potential.**

The Large Area Telescope

Si Tracker
pitch = 228 μm
8.8 x 10^5 channels
18 planes

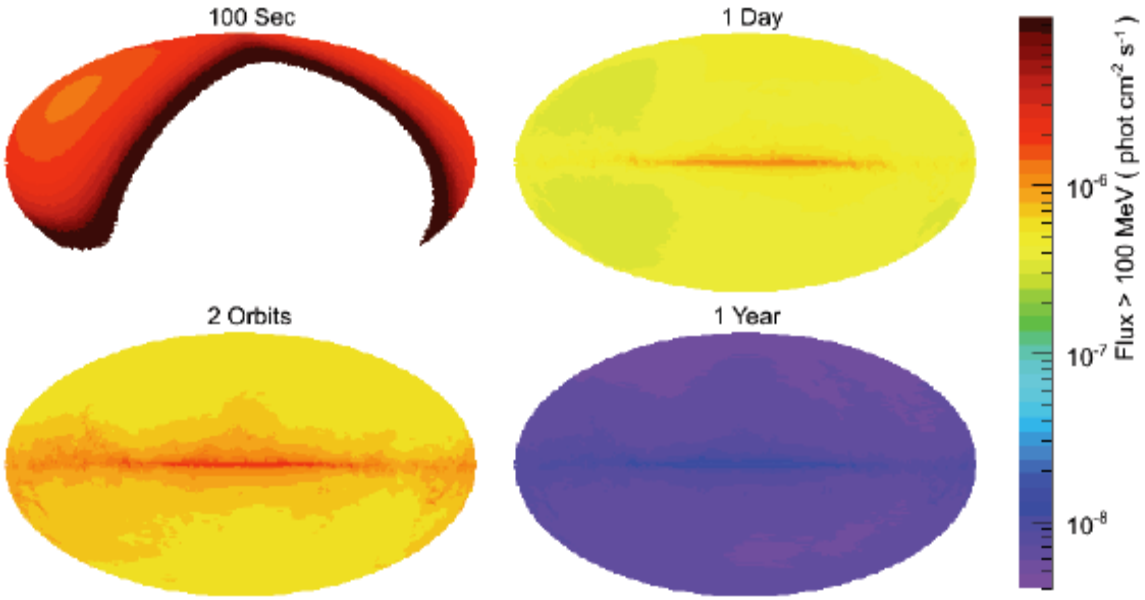


ACD
segmented scintillator tiles

CsI Calorimeter
hodoscopic array (8 layers)
6.1 x 10^3 channels

LAT: 4 x 4 modular array
3000 kg, 650 W
20 MeV – 300 GeV

Operations and observing modes



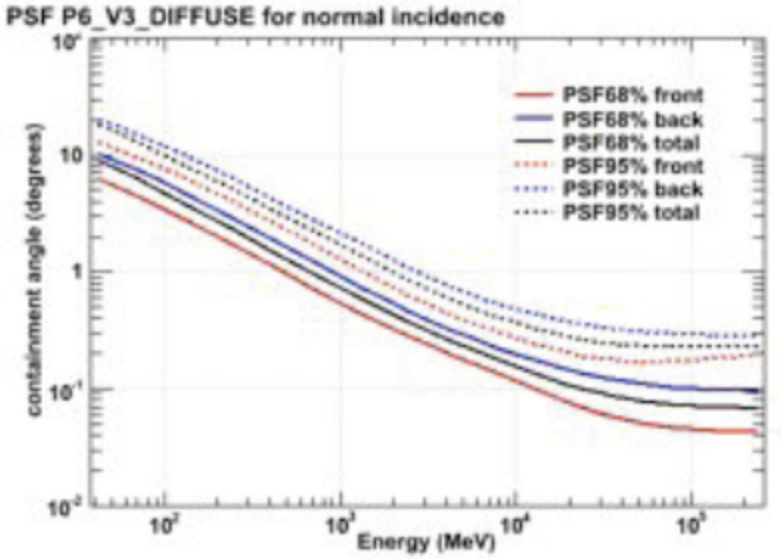
LAT sensitivity on 4 different timescales:

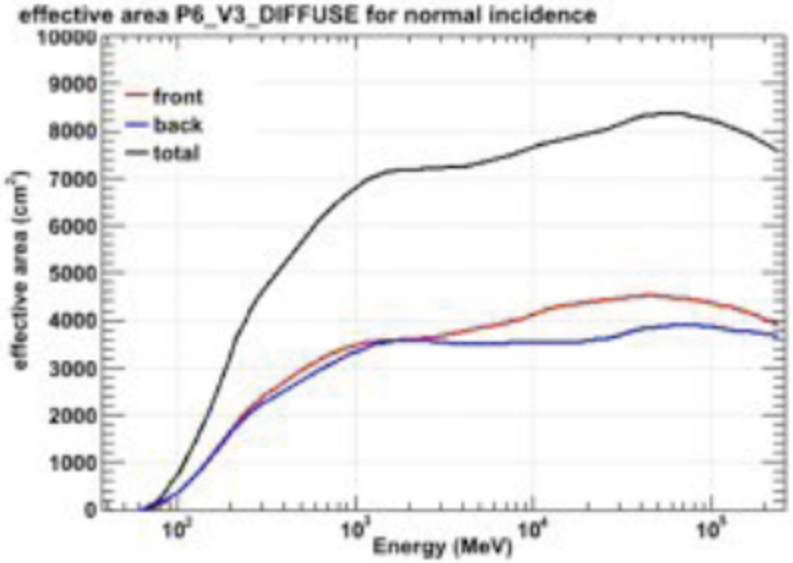
100 s, 2 orbits (2x96 mins), 1 day and 1 year

- **Almost all observations in survey mode - the LAT observes the entire sky every two orbits (~3 hours), each point on the sky receives ~30 mins exposure during this time.**
  - **35 deg rocking angle to September 2, *50 deg after***
- **39 ARRs as of March 10 2010**
  - **5 hour pointed mode observations in response to bright GBM detected GRB**
- **LAT Calibrations (13 hours), Engineering (5 days)**
  - **Very high ontime!**

LAT Performance

- **Current response functions: Pass 6 V3**
  - updated post-launch to include on-orbit, rate-dependent inefficiency
- **Point spread function**
  - Very energy dependent
  - Little variation over FOV
- **Effective Area**
  - Peak >8000 cm^2 on-axis
  - Increases rapidly above 100 MeV
  - Plateaus above ~1 GeV
- **Energy dispersion**
  - $\Delta E/E<0.15$ (68% containment)
  - Small compared to energy range



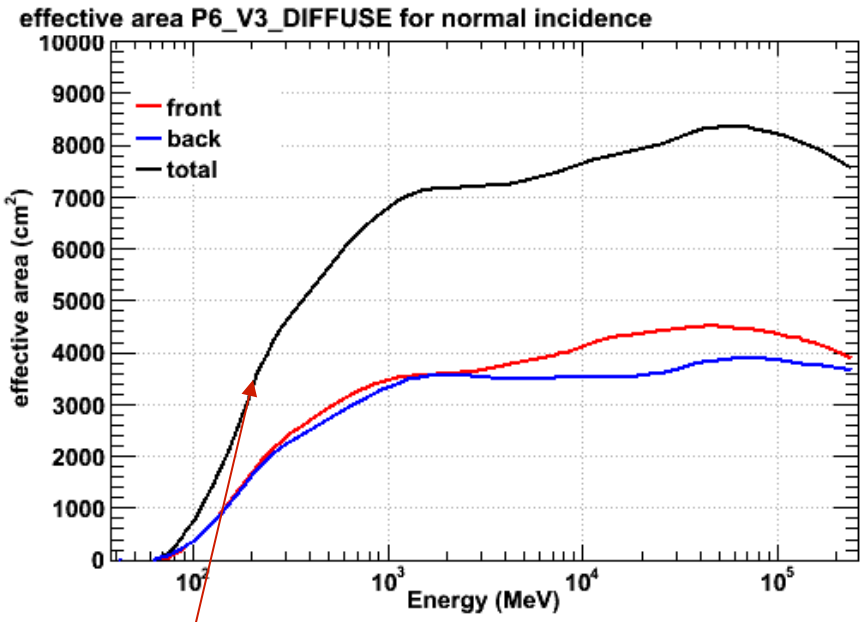


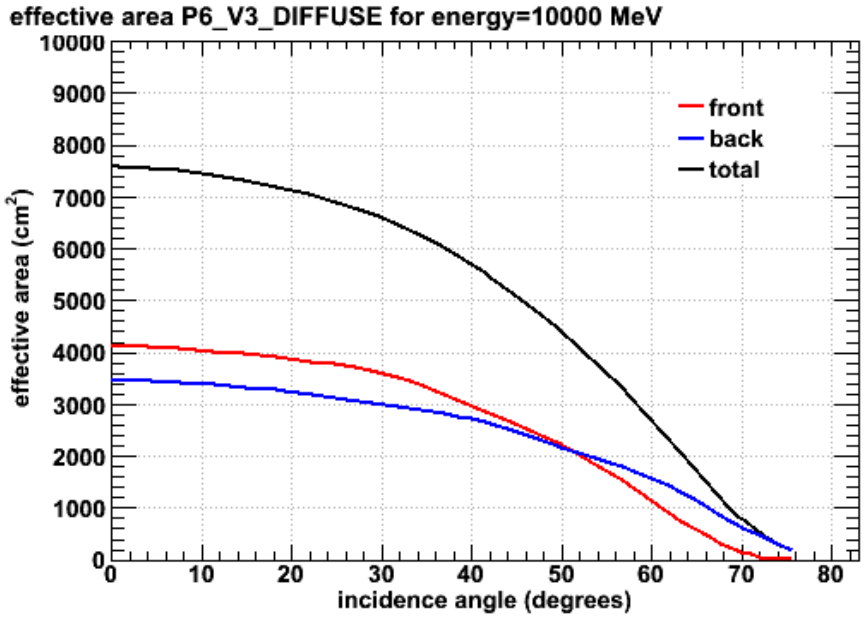
<http://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Cicerone/Cicerone_LAT_IRFs/>

Data Usage Caveats

Event Selection: Instrument Response

- Use Events >100 MeV for spectral analysis
  - To avoid spurious features due to rapidly changing effective area with energy and because of residual uncertainty in the instrument response.

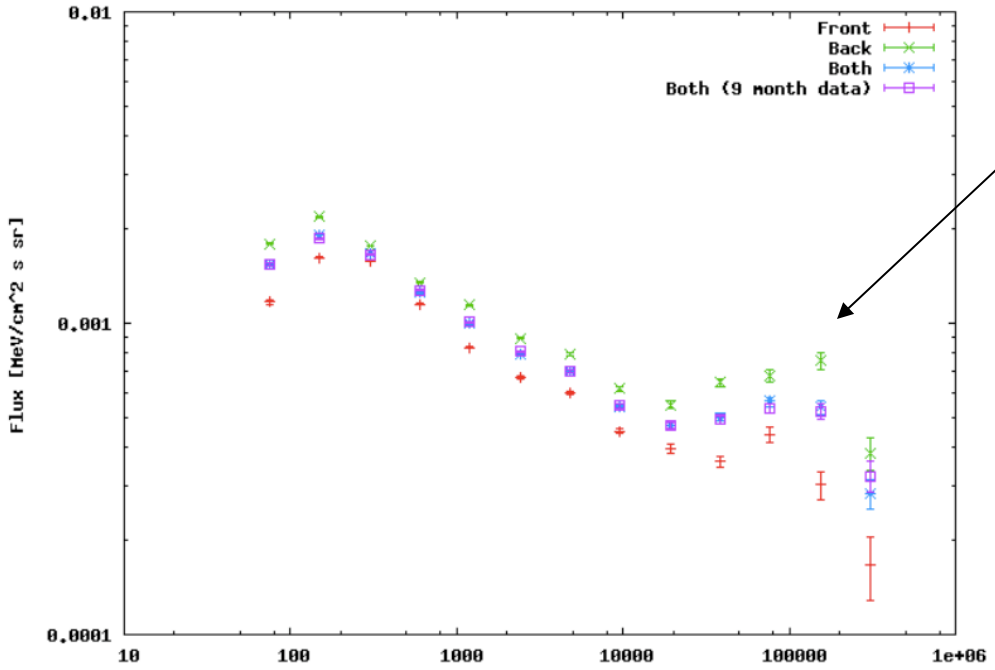




Small uncertainty in energy scale results in relatively large systematic error in final result.

Event Selection: Event Class

- Use "Diffuse" class for diffuse, extended, and point source analysis. (evclsmin=3, evclsmax=4). **NOTE - this applies to P6 IRFs; future recommended selections might change.**
  - Other event classes have higher charged-particle background contamination and may result in spurious spectral features.



Residual cosmic-ray (charged particle) background.

Spectral templates are provided for the **diffuse class** event selection that allow you to account for the presence of residual cosmic-ray backgrounds in your model fits.

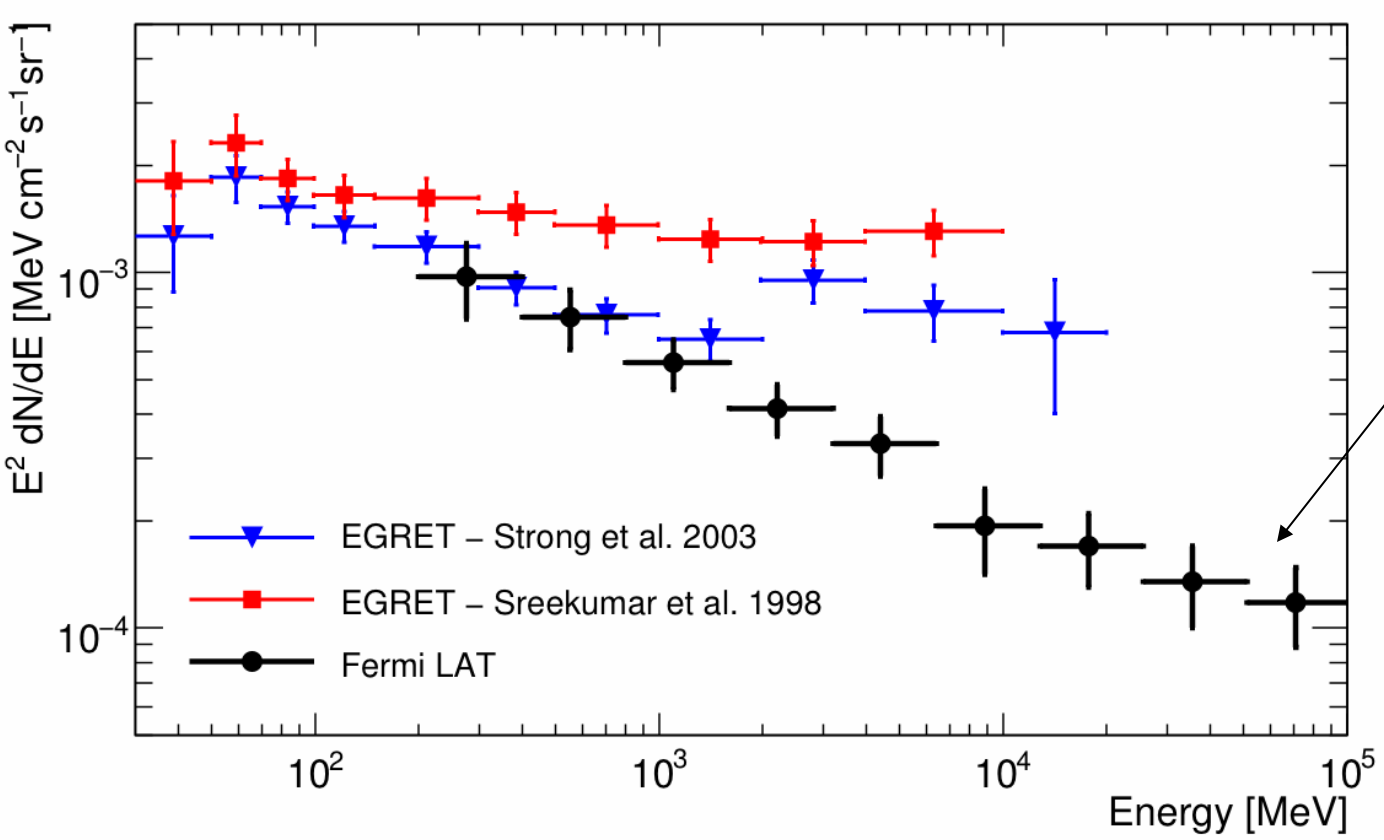
Event Selection

Event Selection Recommendations (P6_V3)

Analysis Type	Minimum Energy (emin)	Maximum Energy (emax)	Max Zenith Angle (zmax)	Minimum Event Elass (evclsmin)	Maximum Event Elass (evclsmax)	IRF Name
Galactic Point Source Analysis	100 (MeV)	-	105 (degrees)	3	4	P6_V3_DIFFUSE
Off-plane Point Source Analysis	100 (MeV)	-	105 (degrees)	3	4	P6_V3_DIFFUSE
Transient Spectral Analysis (<200s)	100 (MeV)	-	105 (degrees)	1	4	P6_V3_TRANSIENT
Galactic Diffuse Analysis	100 (MeV)	100000 (MeV)	105 (degrees)	3 or 4*	4	P6_V3_DIFFUSE or P6_V3_DATACLEAN
Extra-Galactic Diffuse Analysis	100 (MeV)	100000 (MeV)	105 (degrees)	4	4	P6_V3_DATACLEAN

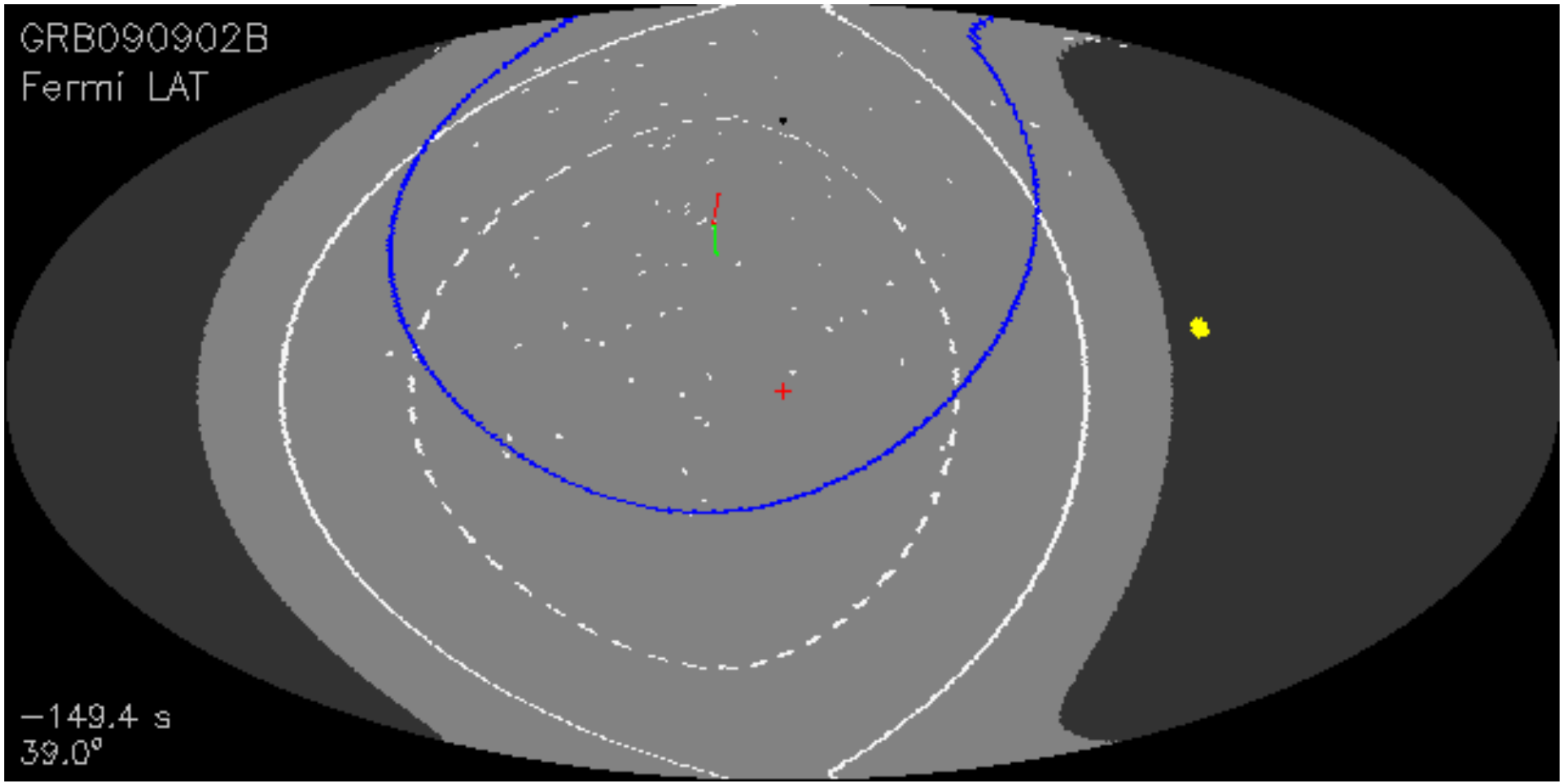
* It is appropriate to use class 3 events for studies of bright diffuse sources up to 20 GeV. For studies of faint diffuse sources and studies that go beyond 20 GeV it is preferable to use only class 4 events so as to minimize the non-photon background contamination.

Isotropic γ-Ray Spectrum (for comparison)



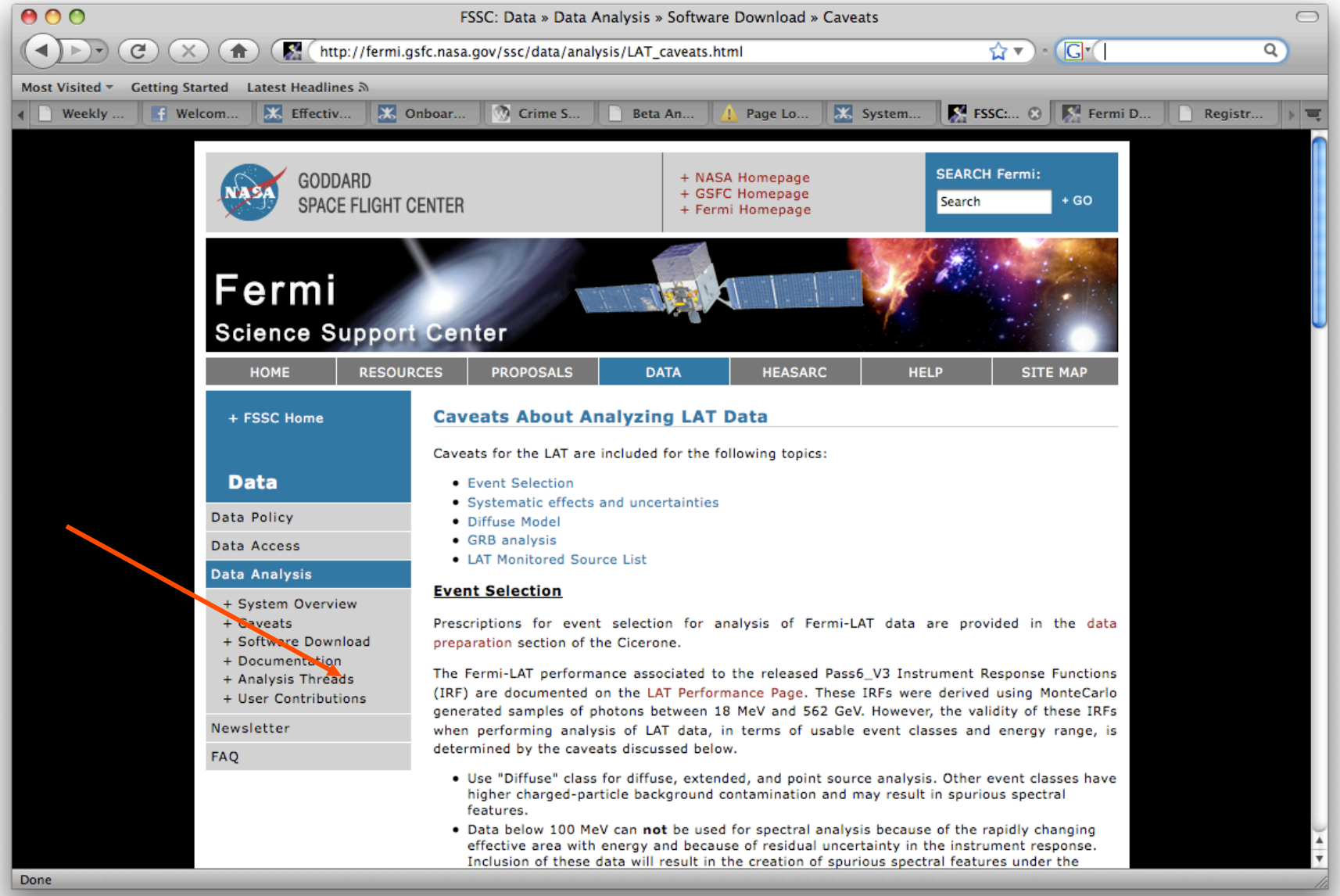
No peak at high energies

The Earth is Bright!



- Exclude all periods where the edge of your region of interest comes within 8 deg of the Earths limb (zenith angle of 105 deg)

Caveats Documentation



Let's get started …

Cycle-4 Timeline

- NRA: Fermi Amendment posted on NSPIRES 10/22/2010
- RPS for Fermi Cycle 4 opening soon
- Proposals due January 21, 2011
- Peer review early April
- Stage-I selections in subsequent ~2-3 weeks
- Stage-II ~1 month subsequent
- Fund FY11 portion by July 2011

23