



# Welcome



# Fermi Data Analysis Workshop

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# 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: **Science topics, GI Program information**

# 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	Liz Hays
9:50 - 10:00	Data Usage Caveats	Liz Hays
10:00 - 10:15	Data Access and Exploration	Dave Davis
10:15 - 10:35	Hands on Session 1	All
10:35 - 10:45	Generating Source Models Using the LAT Catalog	Dave Davis
10:45 - 10:55	Handling Livetime and Exposure Calculations	Liz Hays
10:55 - 11:15	Unbinned Likelihood Analysis	Dave Davis
11:15 - 12:00	Hands on Session 2	All
12:00 - 13:00	Lunch Break	
13:00 - 13:30	Generating Light Curves	Chris Shrader
13:30 - 14:00	Hands on Session 3	All
14:00 - 14:20	Binned Likelihood Analysis	Dave Davis
15:00 - 15:40	Hands on Session 4	All
15:40 - 16:00	Using Python to Streamline Analysis	Liz Hays
16:00 - 16:25	Hands on Session 5	All
16:25 - 16:30	Summary, Feedback	All

# Prerequisites



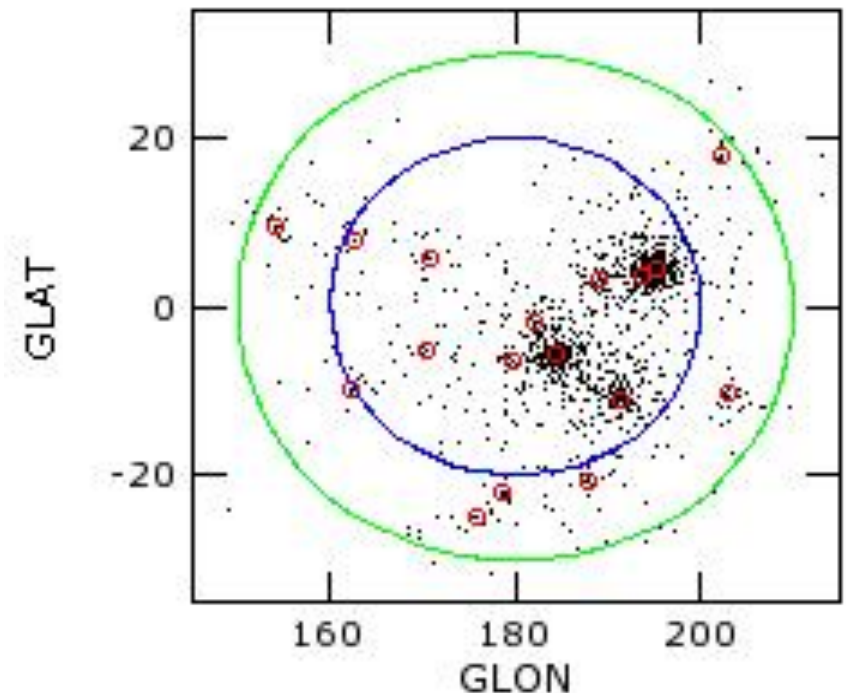
- Science Tools Installation – hopefully done prior, but we can help as needed
  - Workshop web page is useful resource
- Sample datasets on workshop web page
  - Can substitute alternative data selections, but be cognizant of run-time, S/N issues
- Access to Fermi SSC web site
  - Data analysis documentation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

## ***What's different about Fermi data analysis?***

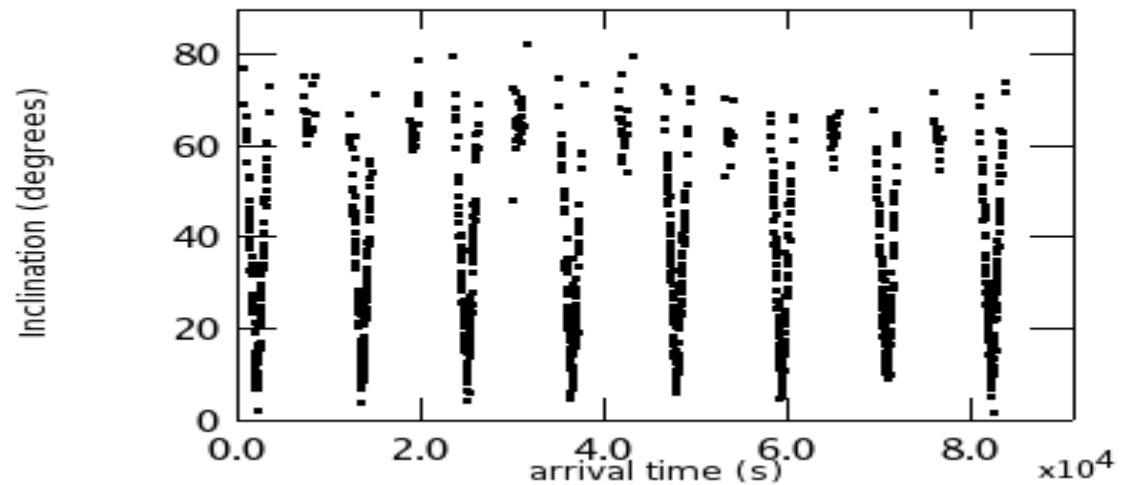
- Structured sky backgrounds
- Energy-dependent point spread function
- Instrument response function(s) IRFs
  - Multiple dependencies: instrument design, event reconstruction, background & quality selections
- Wide field of view, continuously variable aspect

- 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:



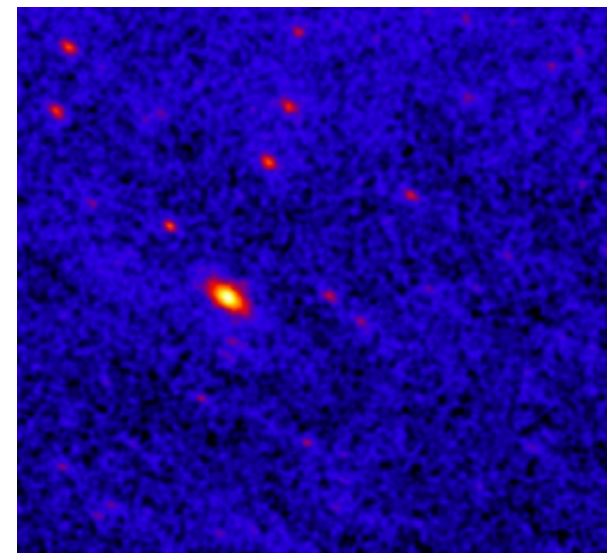
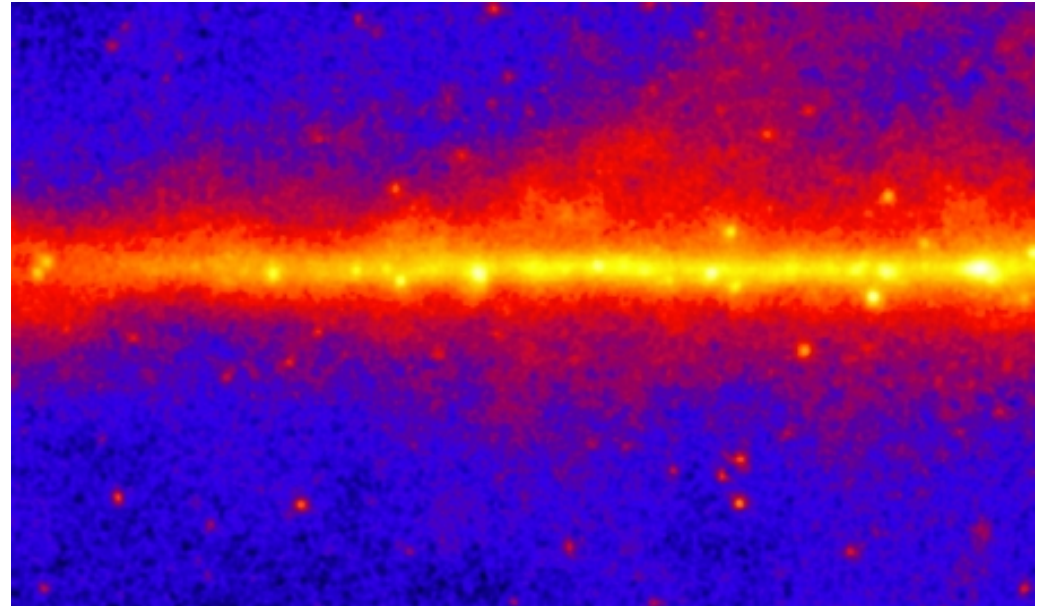
- Each event effectively has its own response function:
  - Large FOV,  $\sim 2.4$  sr
  - Strong variation of response as a function of photon incident angle,  $A_{\text{eff}} \propto \cos \theta$
  - Scanning mode of operation: 90 min orbit  $\Rightarrow$  continuous aspect changes of  $4^\circ/\text{min}$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



# 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





- Web URLs:

- [http://fermi.gsfc.nasa.gov/workshops/2010\\_nyu/](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

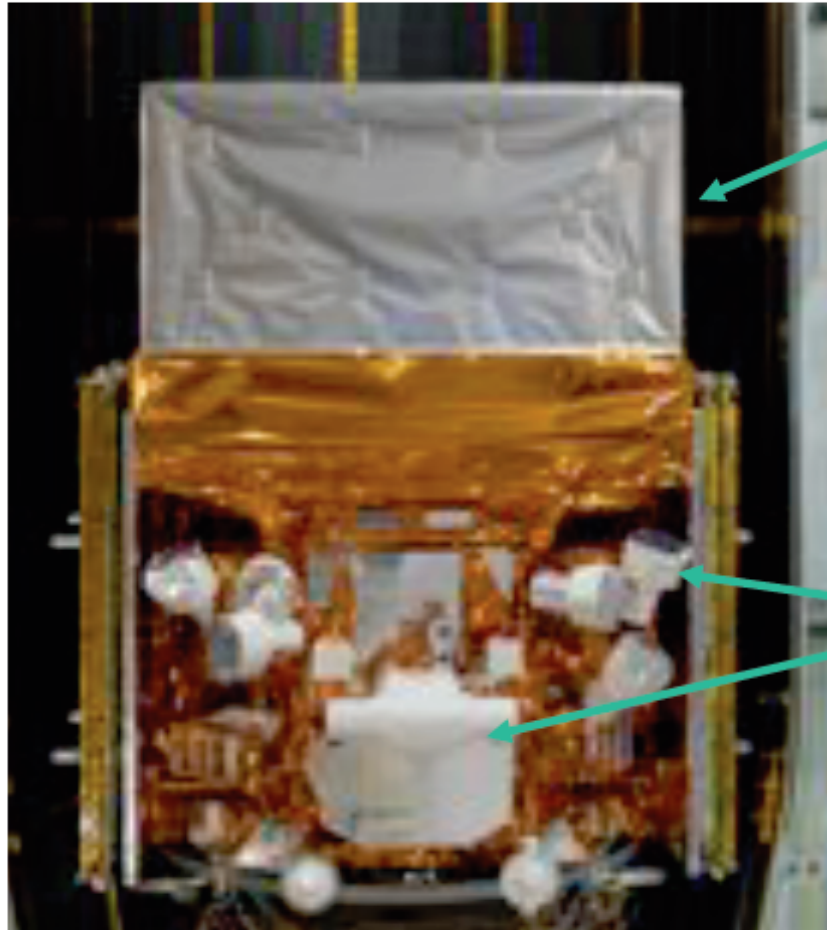
- <http://fermi.gsfc.nasa.gov/cgi-bin/ssc/faq/glastfaq.cgi>

- FAQs



# Quick Overview: Fermi Instruments & Data acquisition

## 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

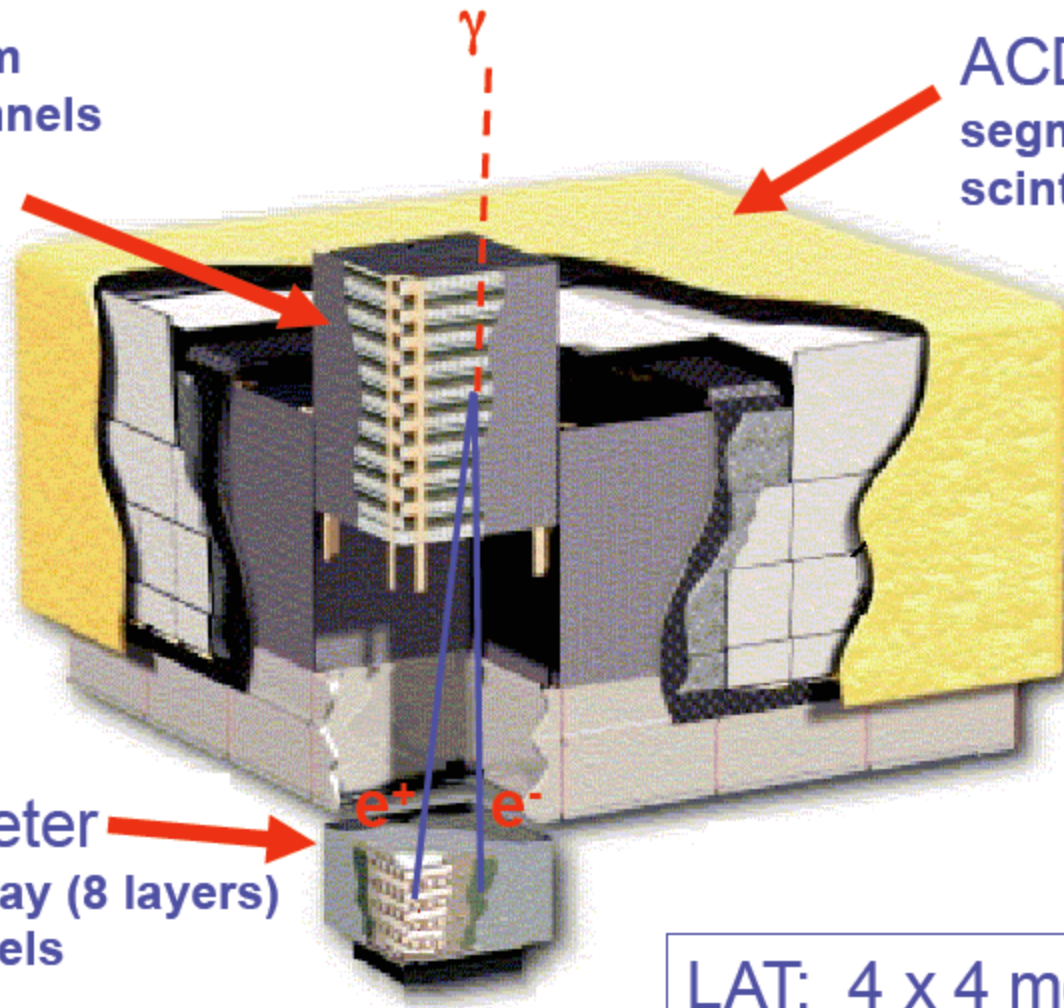
- Large leap in all key capabilities, transforming our knowledge of the gamma-ray universe. Great discovery potential.

# The Large Area Telescope

## Si Tracker

pitch = 228  $\mu\text{m}$   
 $8.8 \times 10^5$  channels  
18 planes

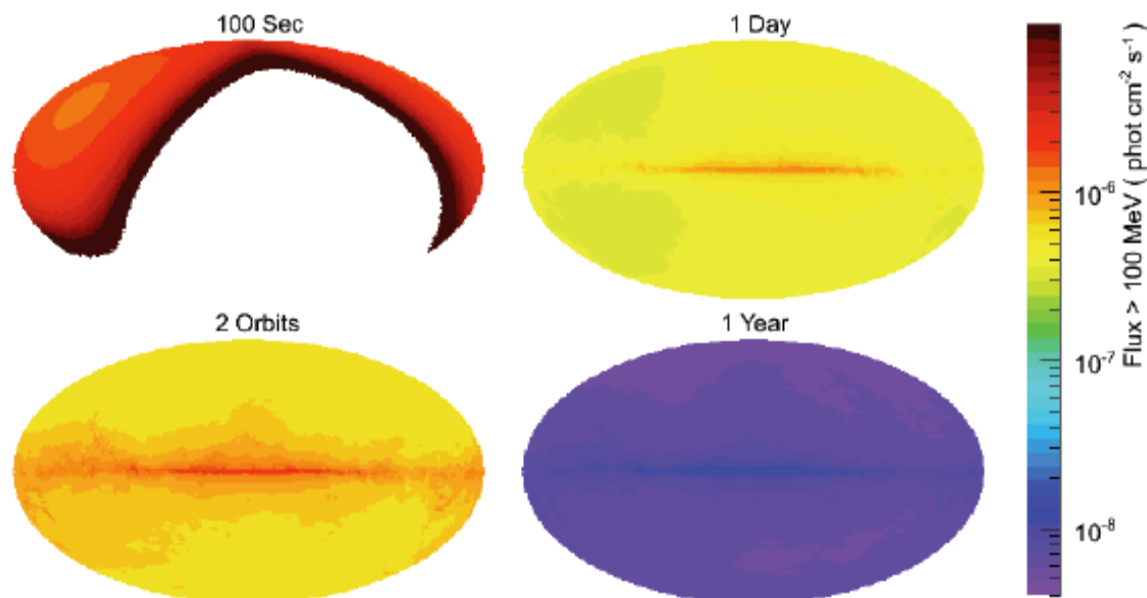
ACD  
segmented  
scintillator tiles



CsI Calorimeter  
hadronic array (8 layers)  
 $6.1 \times 10^3$  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:**

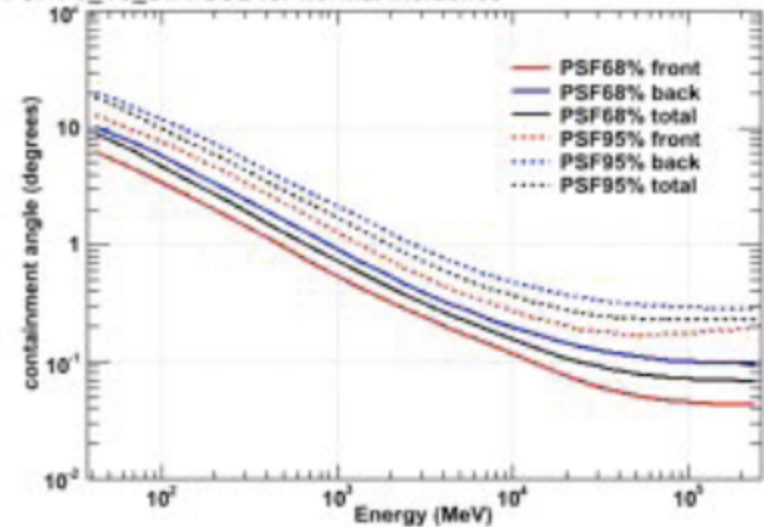
**100 s, 2 orbits (2x96 mins), 1 day and 1 year**

- **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 ARRAs 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!**

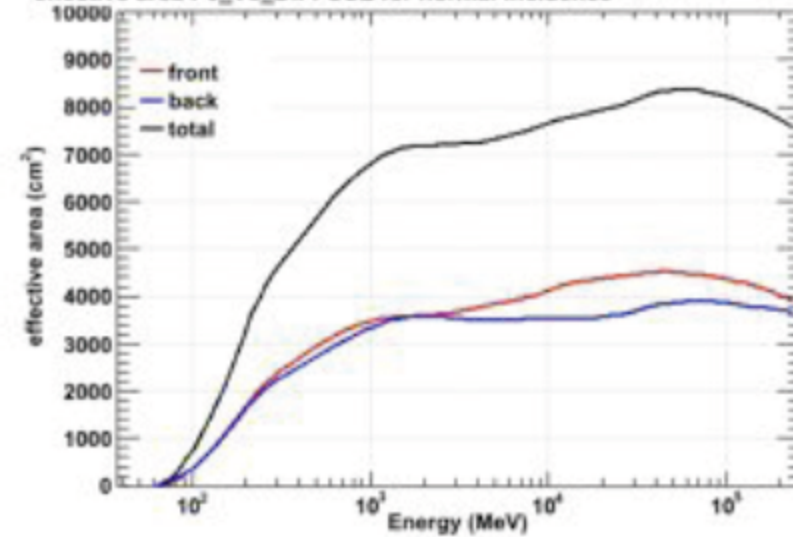
# LAT Performance

- **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<sup>2</sup> 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

PSF P6\_V3\_DIFFUSE for normal incidence



effective area P6\_V3\_DIFFUSE for normal incidence





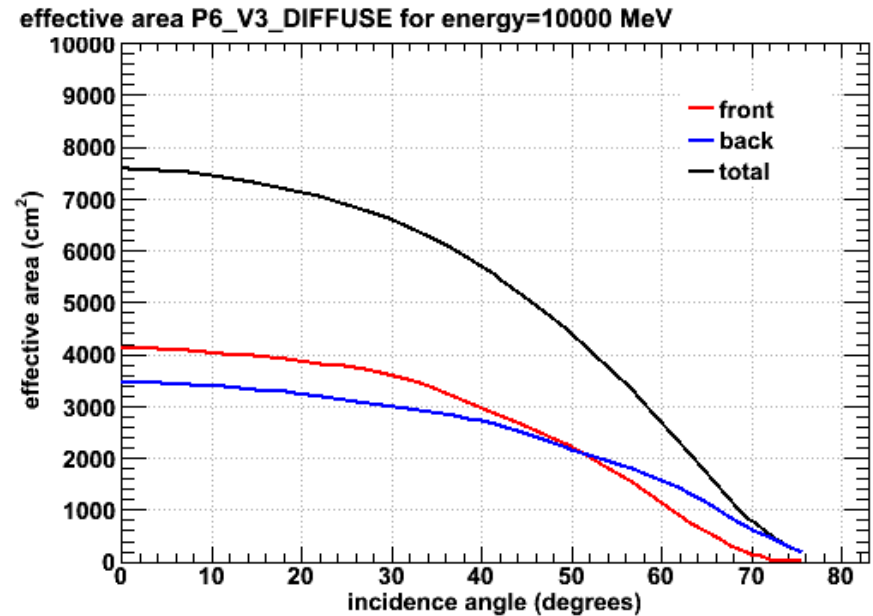
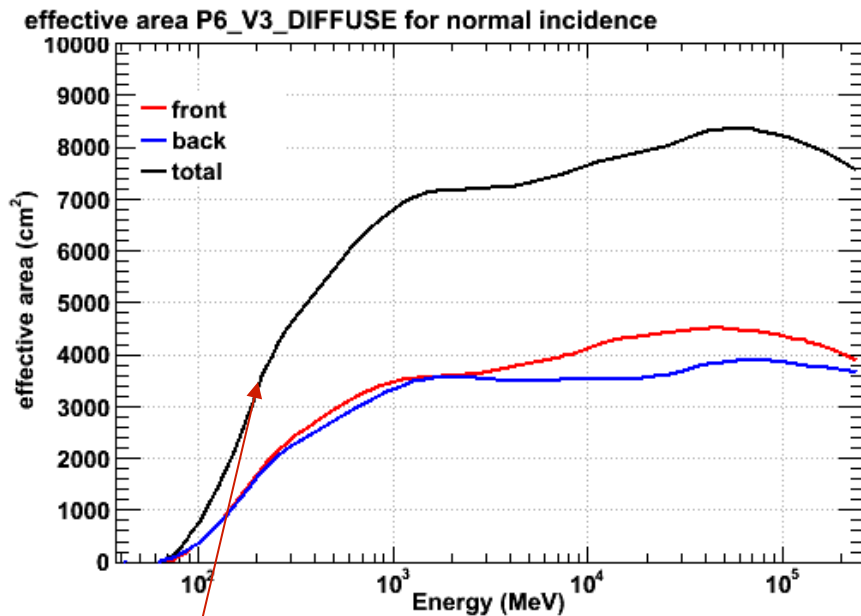
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# Data Usage Caveats

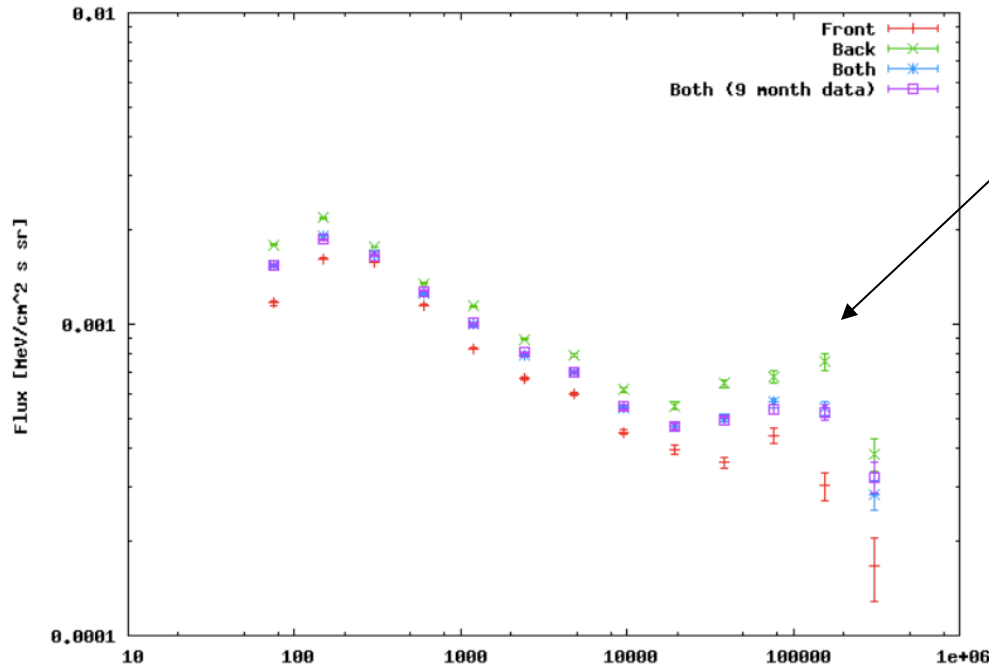
- Use Events  $>100$  MeV for spectral analysis
  - To avoid spurious features due to rapidly changing effective area with energy and because of residual uncertainty in the instrument response.



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



- 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.

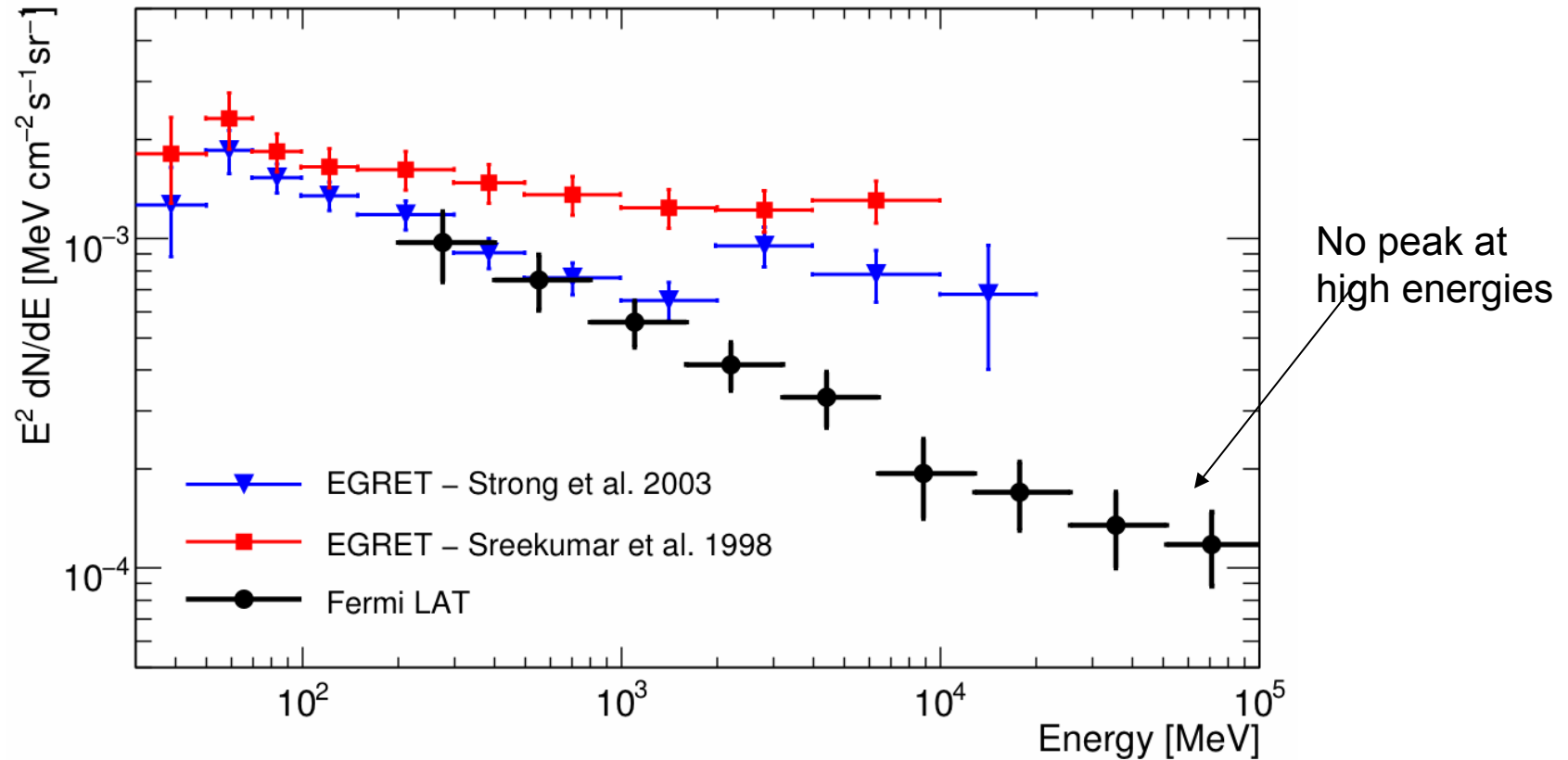
# Event Selection



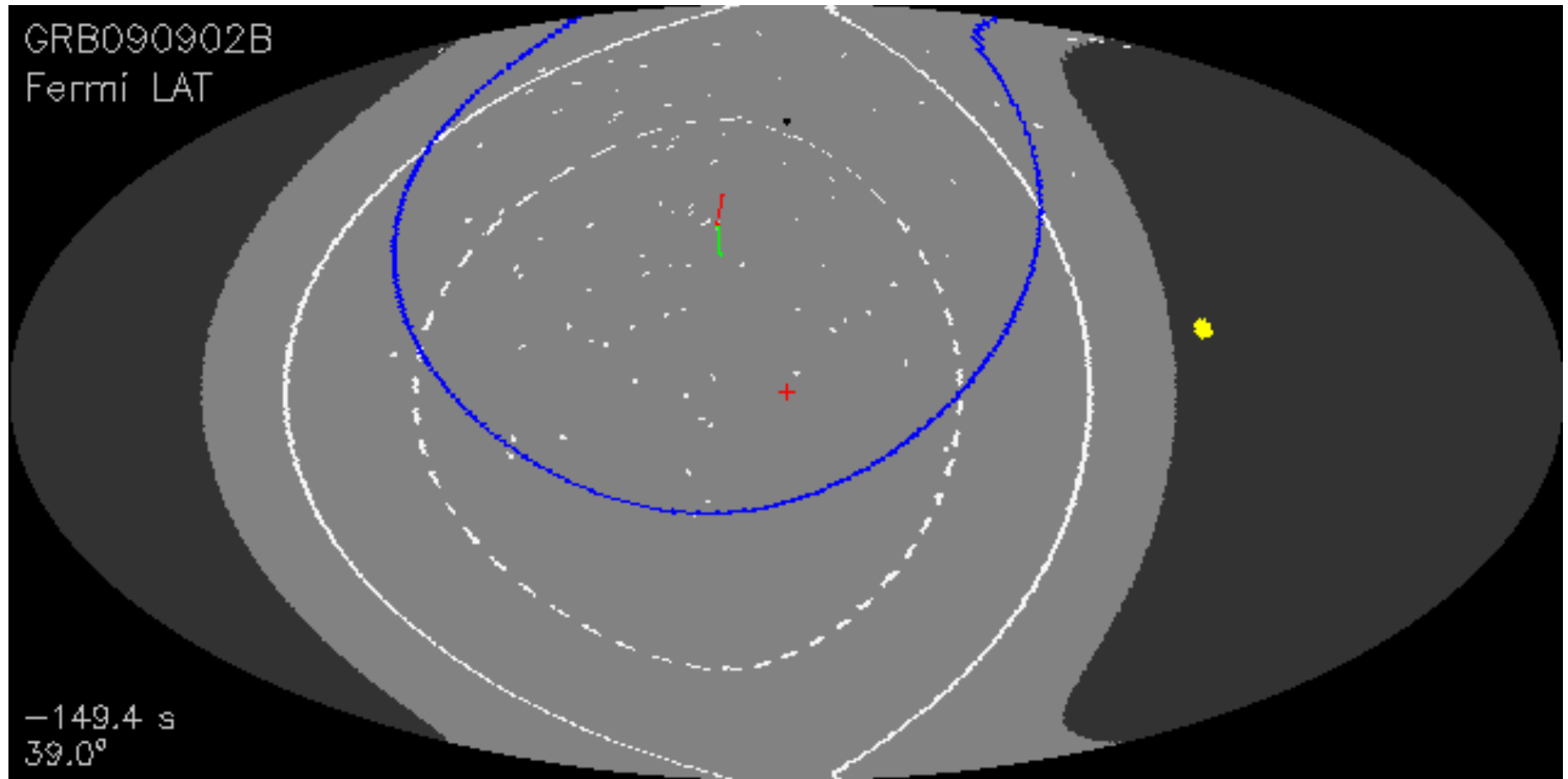
## Event Selection Recommendations (P6\_V3)

Analysis Type	Minimum Energy (emin)	Maximum Energy (emax)	Max Zenith Angle (zmax)	Minimum Event Class (evclsmin)	Maximum Event Class (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

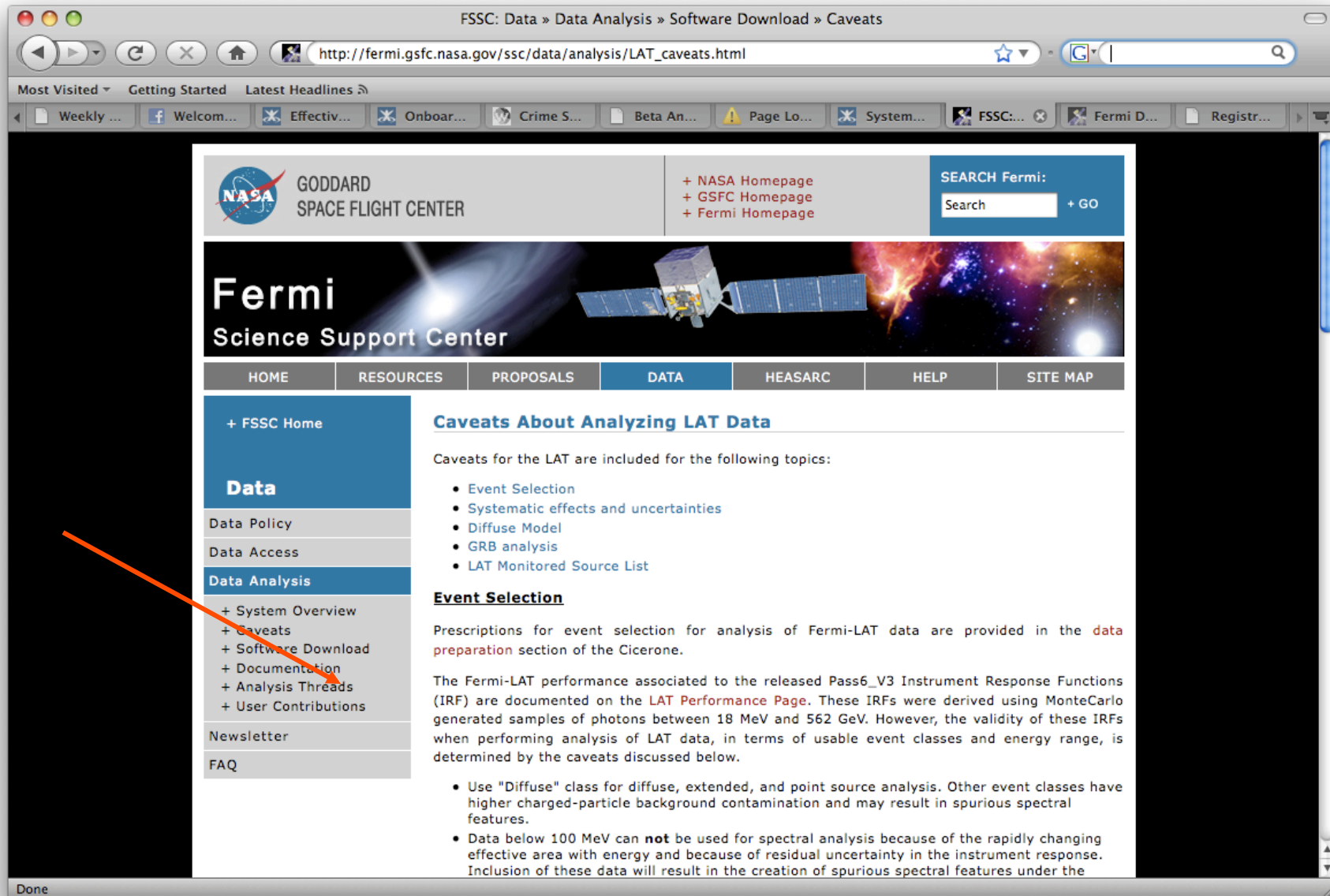
\* It is appropriate to use class 3 events for studies of bright diffuse sources up to 20 GeV. For studies of faint diffuse sources and studies that go beyond 20 GeV it is preferable to use only class 4 events so as to minimize the non-photon background contamination.



# The Earth is Bright!



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



FSSC: Data » Data Analysis » Software Download » Caveats

http://fermi.gsfc.nasa.gov/ssc/data/analysis/LAT\_caveats.html

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+ Analysis Threads  
+ User Contributions

Newsletter  
FAQ

### Caveats About Analyzing LAT Data

Caveats for the LAT are included for the following topics:

- Event Selection
- Systematic effects and uncertainties
- Diffuse Model
- GRB analysis
- LAT Monitored Source List

**Event Selection**

Prescriptions for event selection for analysis of Fermi-LAT data are provided in the [data preparation](#) section of the Cicerone.

The Fermi-LAT performance associated to the released Pass6\_V3 Instrument Response Functions (IRF) are documented on the [LAT Performance Page](#). These IRFs were derived using MonteCarlo generated samples of photons between 18 MeV and 562 GeV. However, the validity of these IRFs when performing analysis of LAT data, in terms of usable event classes and energy range, is determined by the caveats discussed below.

- Use "Diffuse" class for diffuse, extended, and point source analysis. Other event classes have higher charged-particle background contamination and may result in spurious spectral features.
- Data below 100 MeV can **not** be used for spectral analysis because of the rapidly changing effective area with energy and because of residual uncertainty in the instrument response. Inclusion of these data will result in the creation of spurious spectral features under the



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# 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

# Day 2 Agenda



9:00 - 9:30	Coffee, Conversation	
9:30 - 10:00	Welcome & Fermi Science Overview	Liz Hays
10:00 - 10:30	Why Finding Nearby Neutron Stars Could Help LIGO	Keith Riles
10:30 - 10:45	Introduction to the Fermi GI Program	Chris Shrader
10:45 - 11:00	Break	
11:00 - 11:40	Probing the Physics of Gamma-Ray Blazars with Radio Band Observations	Margo Aller
11:40 - 12:10	Measurement of Cosmic-Ray TeV Electrons	Michael Schubnell
12:10 - 13:10	Lunch Break	
13:10 - 13:40	Finding needles in haystacks - Uncovering GRB $\gamma$ -rays in the Fermi/LAT detector	Carl Akerlof
13:40 - 14:10	Early time ROTSE observations of GRB afterglows	Shashi Pandey
14:10 - 14:35	Attendee Research Presentations	All
14:35 - 14:50	GI Program Updates, Changes, & New Multi-wavelength Opportunities	Chris Shrader
14:50 - 15:00	Questions, Discussions, Snacks	
15:00	Adjourn	