Fermi Large Area Telescope:

Long Term Public Analysis

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on behalf of the Fermi LAT collaboration

The Fermi mission

Two instruments :

The Large Area Telescope (LAT) : High Energy Gamma-ray Astrophysics

The Gamma-ray Burst Monitor (GBM) : focuses on GRBs and transients

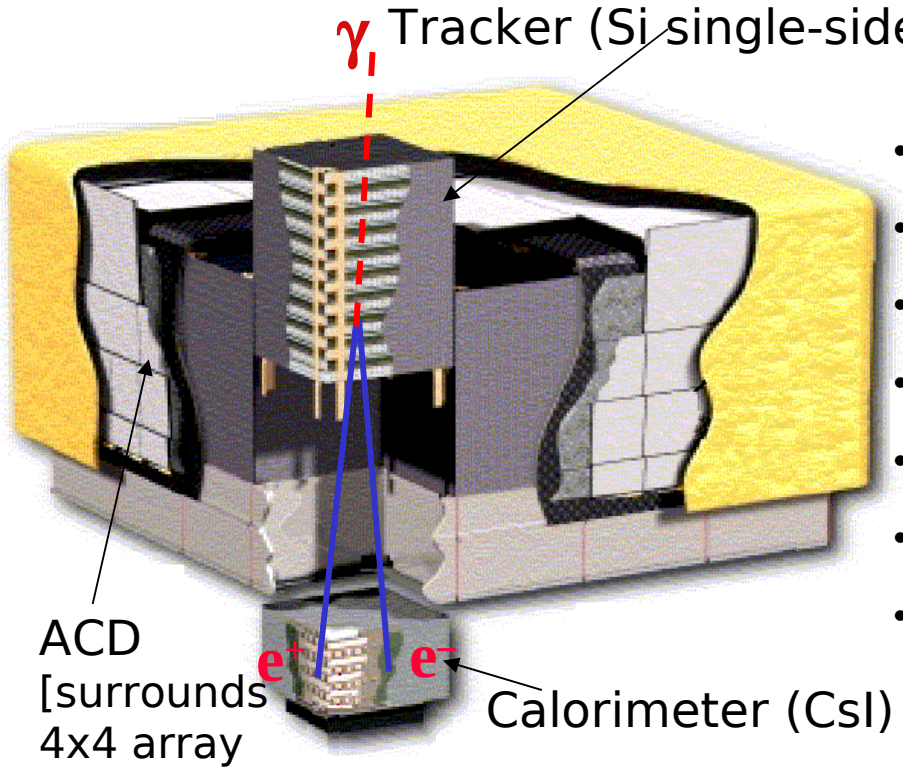
Launched 11 June 2008 – LAT activated 25 June

Nominal Science observations started on 4 August 2008

THIS TALK FOCUSES ON THE LAT PIPELINES

The Large Area Telescope (LAT)

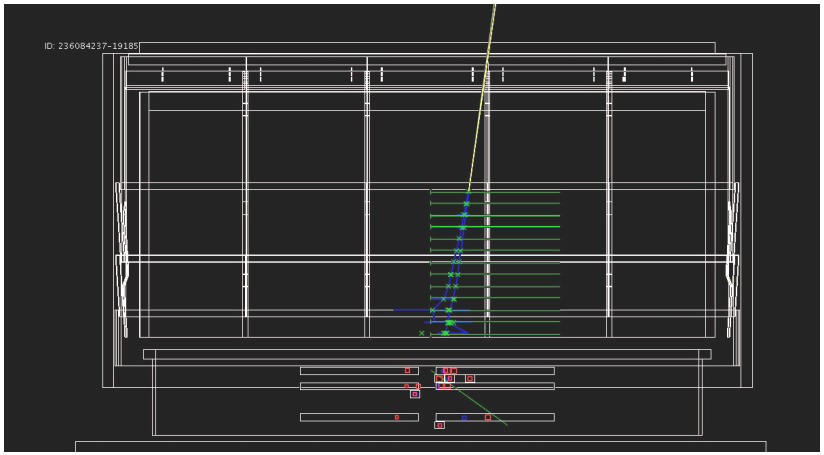
- **A HEP instrument for Astrophysics!**
  - **Built and operated by a mixed HEP/Astro collaboration**
  - **Managed at SLAC, Stanford University.**

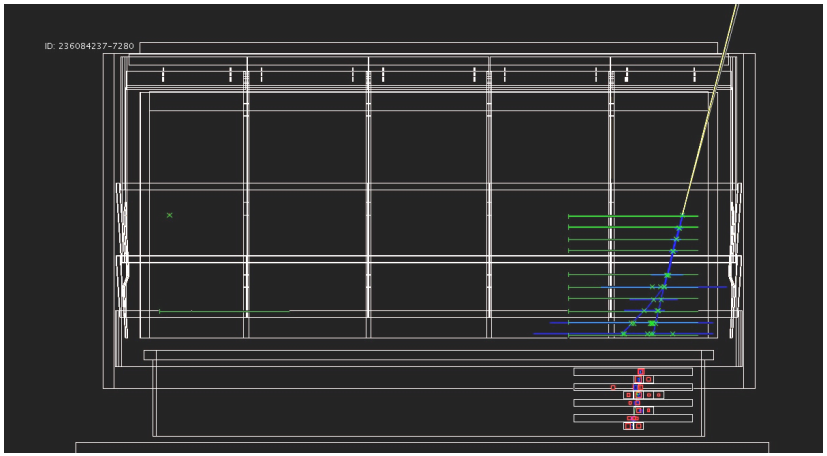


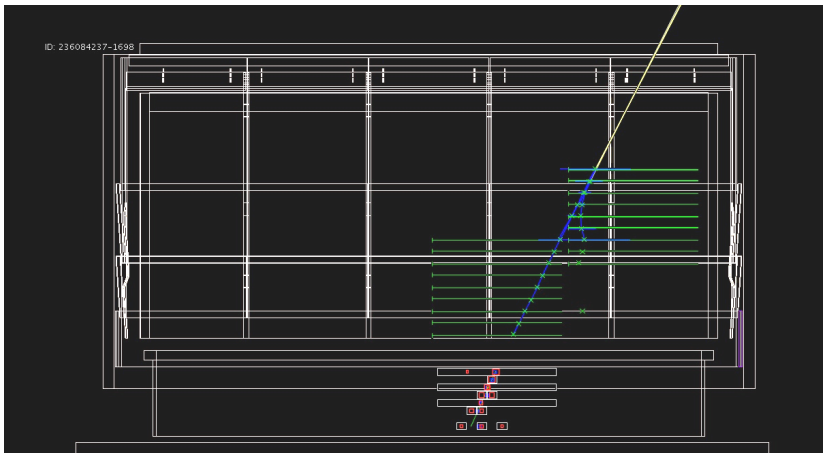
- energy range : 20 MeV to >300 GeV
- field of view : ~2.4 sr (at 1GeV)
- effective area : >1 GeV is ~8000 cm^2 on axis
- single event PSF : 0.6° (1 GeV, normal incid., thin)
- Energy resolution : <15% at energies >100 MeV
- LAT observes the entire sky every ~3 h (2 orbits)
- Trigger rate : ~2.2 kHz (averaged, excluding SAA)

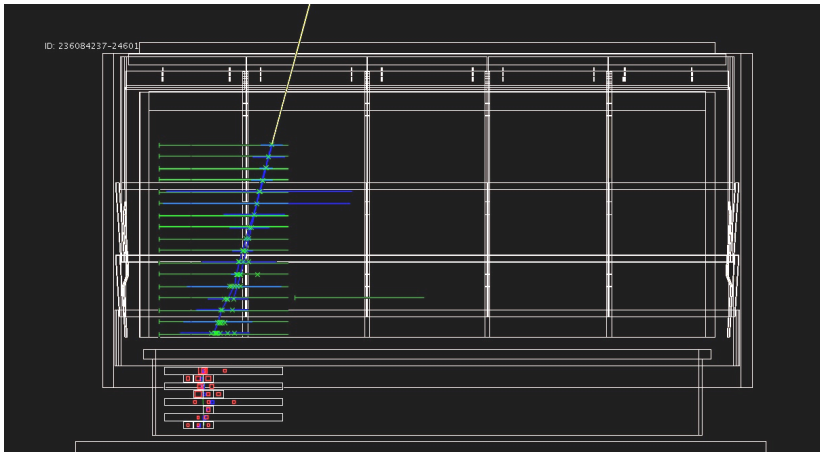
"gamma filter" rate (candidate gamma rays sent to the ground) : ~400 Hz (averaged over many orbits)

In Orbit: Single Events in the LAT









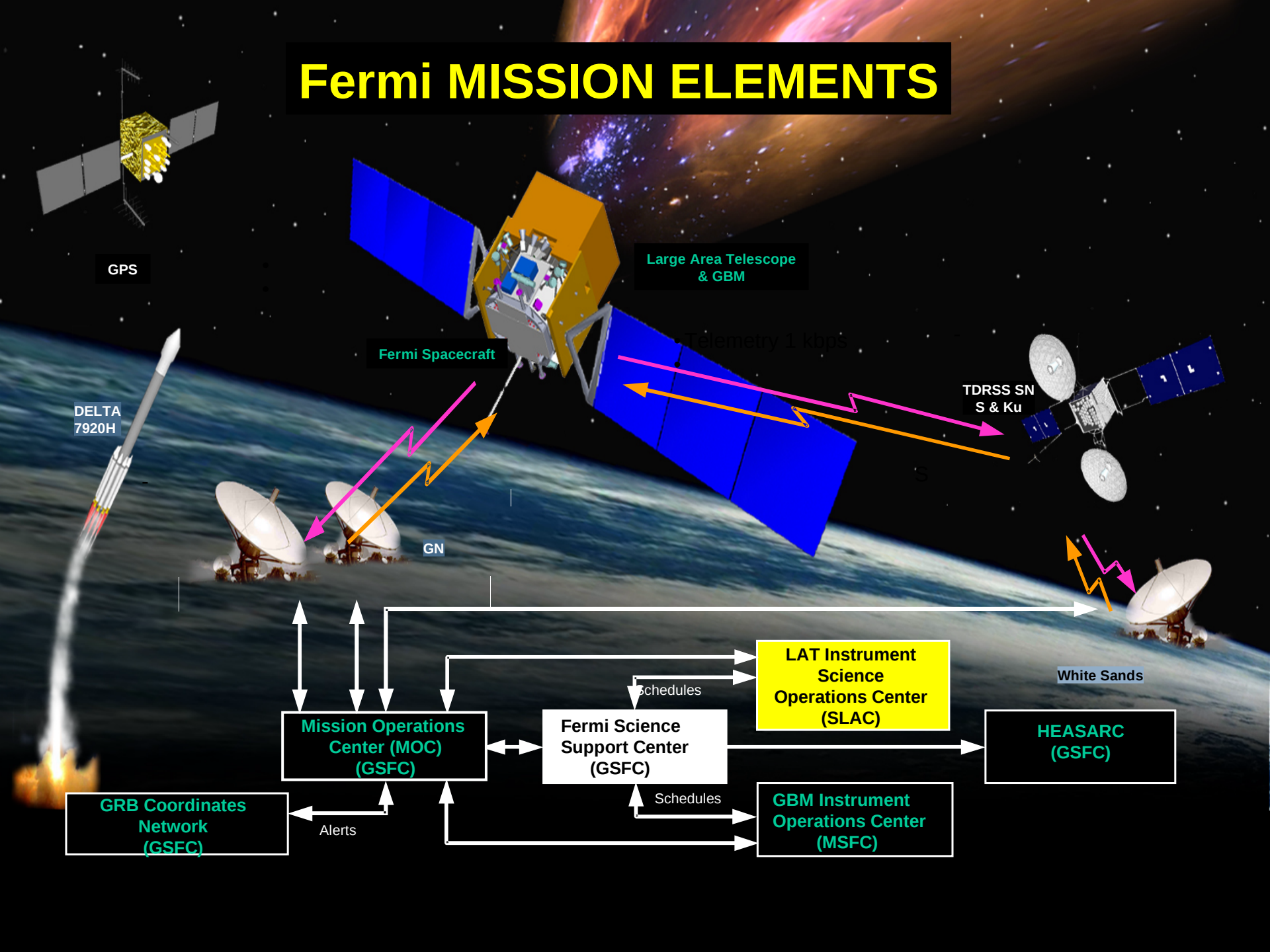
The green crosses show the detected positions of the charged particles, the blue lines show the reconstructed track trajectories, and the yellow lines shows the candidate gamma-ray estimated direction. The red crosses show the detected energy depositions in the calorimeter.

0.25 CPU sec/event to reconstruct: downlink 500 Hz
Each event independent of others

Science Accomplishments in a Nutshell

- **Mapping and measuring the entire GeV sky at a unprecedented angular and energy resolution and statistical accuracy**
  - **Detected >40 pulsars, including all the EGRET ones and several radio quiet ones**
- **Detected over 1000 sources**
  - **First year catalogue in preparation**
  - **Bright source list of ~100 sources published 6 months ago**
- **Mapped the diffuse Galactic emission and measured its spectrum**
- **Measured the cosmic-ray electron spectrum**
- **Discovered flares from several AGN reported in ATels**
- **Detected the binary LSI+61 303, the LMC, and >10 GRBs already**
- **Detected the moon and the quiet sun (and earth)**
- **Measured the light-curve and spectrum of the Vela pulsar**
- **Detected two Galactic plane transients**

Fermi MISSION ELEMENTS

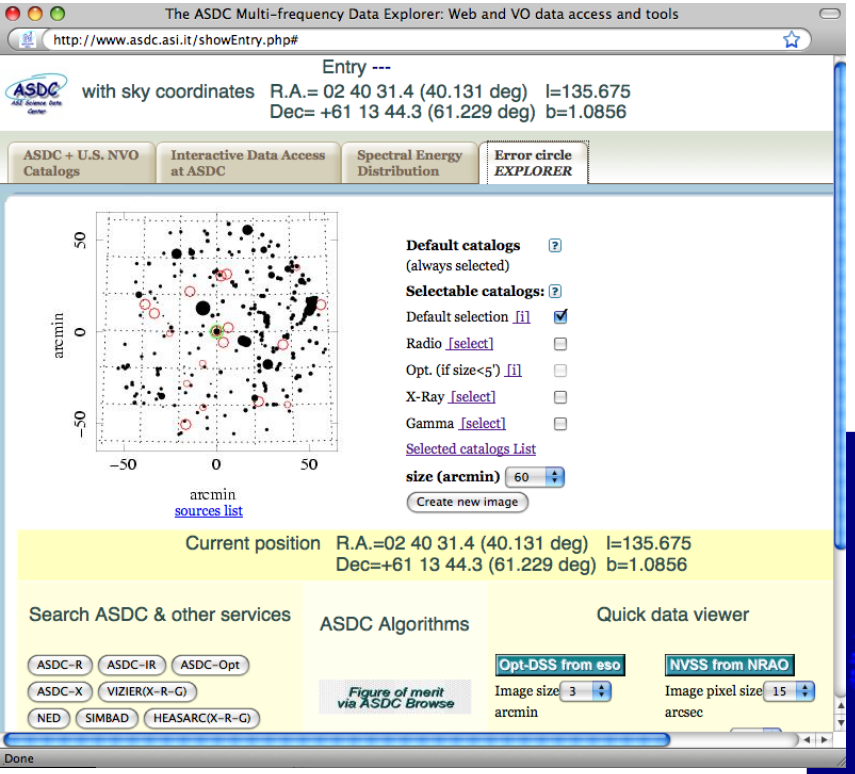


Data Processing Flow

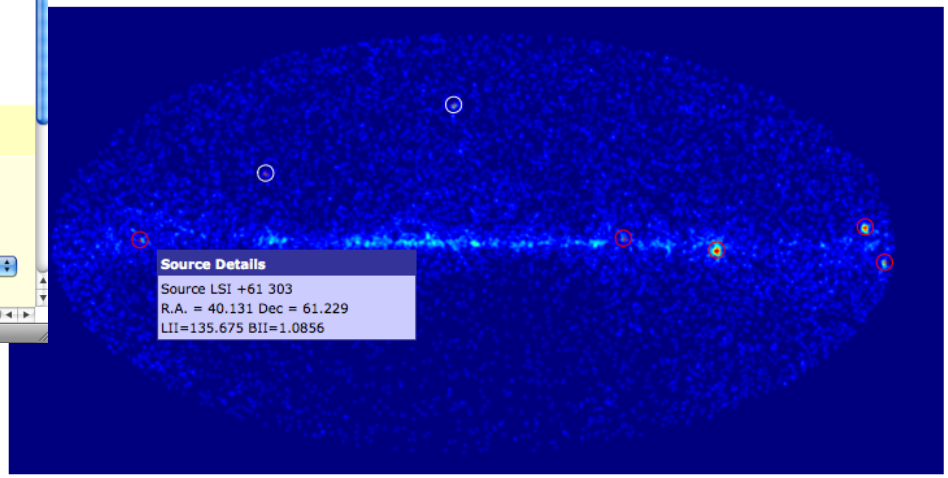
- Downlink from Goddard Space Flight Center (FASTCopy) ~8/day
  - 15 GB total daily
- Half-pipe
  - Automatic response to downlink
  - Decode & repackage incoming data
  - Trigger Level 1 Processing
- Level 1 Processing
  - Full event reconstruction: factor ~x50 expansion on raw data! 750 GB/day
  - Monitoring plots for Instrument Science Operations Center (> several 100s)
  - Transfer science summary files to Goddard Science Support Center - 200 MB/day
  - Trigger ASP
- ASP (Automated Science Processing)
  - GRB and Flare detection
  - Spectral analysis
- RSP (Routine Science Processing)
  - Automated Science Group processing
- Final science analyses

+ annual bulk reprocessing
+ simulations

Automated Science Processing



- Run every 6 hours and daily
- Track 23 public sources: get from FSSC
- Search for Flares
- Refine onboard GRB analysis
- Blind search for GRBs
- Connects to ASI Science Data Center for MWL correlation



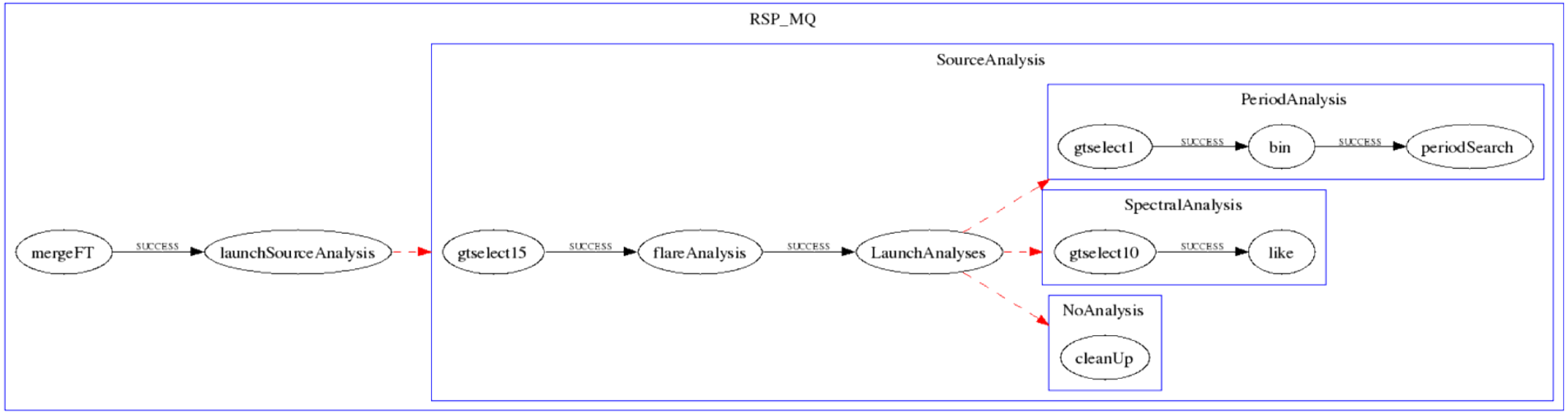
Start Time: 30/Oct/2008 18:00:00 - Stop Time: 31/Oct/2008 00:00:00

Detections

Source Name	ASDC Tools	RA	DEC	l	b	Flux	Flare Test Type	Flare Type Value	Tentative Associations (1 degree)
ASPJ124300-621500	ASDC Tools	190.75	-62.25	301.9498	0.6057	1.560E-6 +/- 3.970E-7	Chi2	14	J1245-6238
ASPJ150146+112224	ASDC Tools	225.4409	11.3734	12.072	55.6009	1.310E-6 +/- 2.870E-7	Chi2	0	J150339+104836

RSP – ongoing Growth Industry

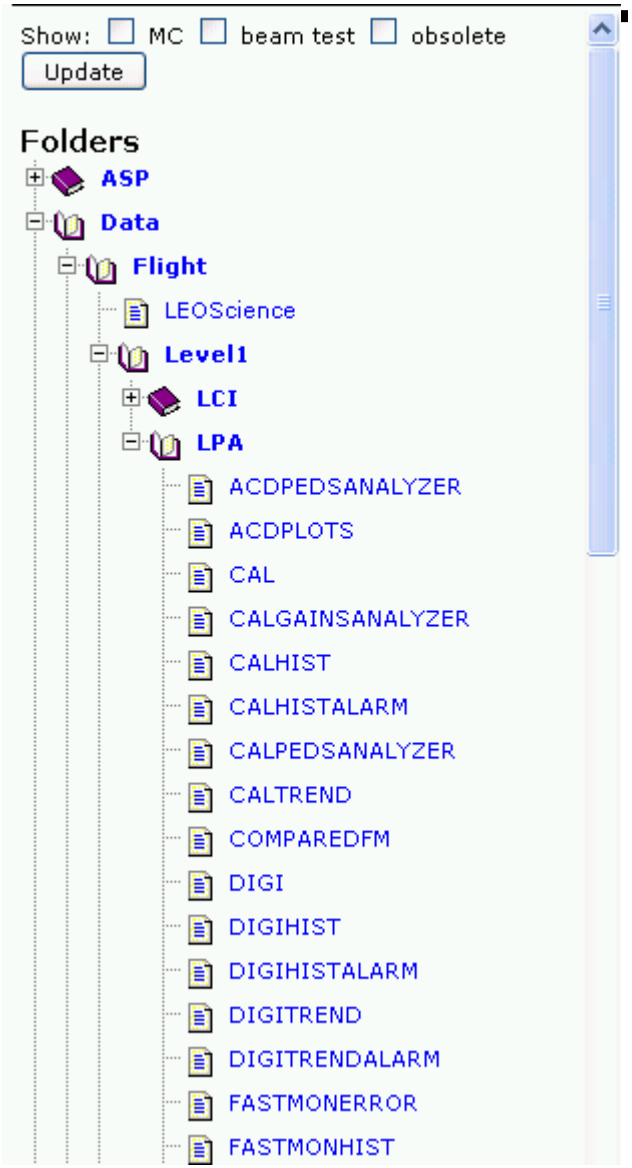
- Leverage Pipeline to support Science Groups' needs
  - Automated spectral fitting and light curve creation
  - Pulsar implemented already
  - Binaries, GRB, AGN in progress
- Should be flexible to span times between ASP and catalogue
  - Run weekly in most cases
  - Also handle reprocessed data



Principal Computing Resources

- SLAC compute farm (Fermi allocation)
  - 1200 CPUs in batch farm running LSF (+ peak loads of >2000)
  - 600TB disk = 100 TB NFS + 500 TB xroot – 32 TB Raid 10 Sun thumpers (to be replaced by thors)
  - 350 TB tapes in silo (HPSS)
    - Making transition to higher density tapes
    - Storage model strategy is to keep latest versions of data on disk; all else on tape.
- Lyon compute farm (CCIN2P3, France)
  - 600 CPUs in batch farm running BQS
  - few TB disk allocated for all Fermi uses (transfer generated files to SLAC)
  - seamlessly used by pipeline from SLAC
  - Currently used only for Monte Carlo
- Ongoing effort to also distribute simulation tasks on the grid (EGEE) : Existing VO with 10 active nodes which ran Fermi simulations successfully

Data Storage and Catalog



Folder /Data/Flight/Level1/LPA

Output from Level 1 processing of on-orbit data Edit description

Name	Type	Files	Events	Size	Created (UTC)	Links
RECON	Group	1931	3,803,647,787	52.7 TB	25-Jun-2008 16:43:00	Files
CAL	Group	1954	3,790,237,100	13.3 TB	25-Jun-2008 16:35:11	Files
SVAC	Group	1953	3,848,209,867	9.0 TB	25-Jun-2008 16:29:03	Files
DIGI	Group	1954	3,855,037,479	8.0 TB	25-Jun-2008 15:22:31	Files
FASTMONTUPLE	Group	1954	0	3.7 TB	25-Jun-2008 15:34:54	Files
MERIT	Group	1954	3,852,358,312	2.9 TB	25-Jun-2008 16:25:29	Files
GCR	Group	1954	3,852,208,291	92.6 GB	25-Jun-2008 16:32:57	Files
FASTMONTREND	Group	1954	0	58.9 GB	25-Jun-2008 15:57:51	Files
LS1	Group	1954	69,293,586	50.7 GB	25-Jun-2008 16:29:02	Files
DIGITREND	Group	1954	0	45.8 GB	25-Jun-2008 15:25:58	Files
MAGIC7HP	Group	1732	0	37.2 GB	08-Jul-2008 18:20:31	Files
CALHIST	Group	1954	0	26.4 GB	25-Jun-2008 15:32:55	Files
TKRANALYSIS	Group	1953	0	23.8 GB	25-Jun-2008 16:40:49	Files
RECONTREND	Group	1954	0	23.7 GB	25-Jun-2008 16:39:44	Files
RECONHIST	Group	1953	0	16.4 GB	25-Jun-2008 16:42:37	Files
LS3	Group	1954	0	14.7 GB	25-Jun-2008 16:29:02	Files
MAGIC7	Group	250	0	7.4 GB	25-Jun-2008 15:13:53	Files

- Data reside in xroot (some NFS, and some, temporarily, in AFS)
- Catalogue gives file location and user-supplied metadata

Accessing the Data

ROOT

Raw, Recon

Mini-summary
All events

FITS
Micro-summary
Photon list

Access via web: use pipeline/parallel batch

Apply arbitrary cuts on mini – get mini; raw,recon out

Analysis of details, event displays

+ Line mode interface

Access via web: use pipeline/parallel batch

Optimized for direction, energy, time cuts

Apply cuts on micro– get micro; (To Come: raw, recon, mini out)

+ Line mode interface

FSSC Data Server: Access via web

Optimized for direction, energy, time cuts

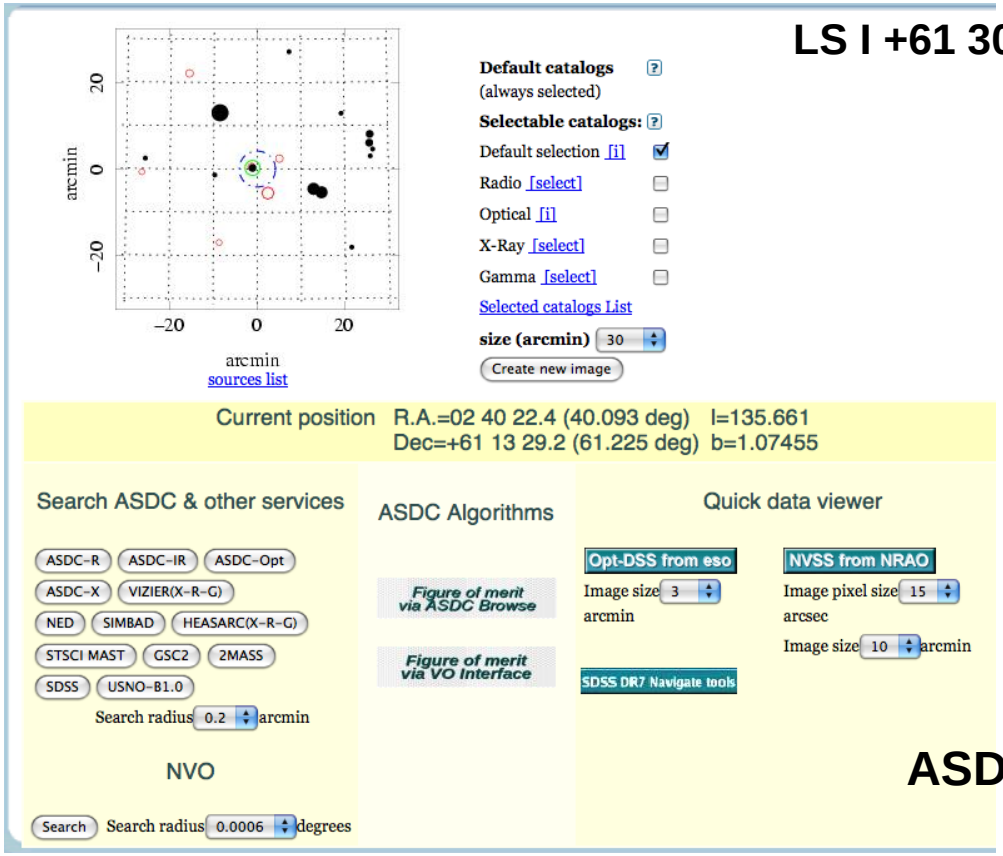
Apply cuts on micro– get micro

Pointing/Livetime history vital, distributed as well

NASA Astro Culture on Facilities

- **telescopes are "facilities" :**
  - **driven by user groups with scheduled observations**
  - **not the property of the instrument teams**
  - **community organises multi-wavelength campaigns**

TeV telescopes are the exception so far: more like HEP experiments



ASDC

The collaboration is expected to deliver ~ the same dataset that it would use in private, and an up-to-date version of the Science Analysis Software Toolkit (based on on planned features)

The FSSC : portal for the user community

- Manages High-Level Science data only

GODDARD SPACE FLIGHT CENTER

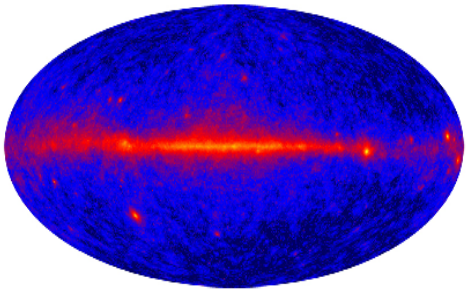
+ NASA Homepage
+ GSFC Homepage
+ Fermi Homepage

SEARCH Fermi: Search + GO

Fermi Science Support Center

HOME | RESOURCES | PROPOSALS | DATA | HEASARC | HELP | SITE MAP

The Fermi Science Support Center (FSSC) runs the guest investigator program, creates and maintains the mission time line, provides analysis tools for the scientific community, and archives and serves the Fermi data. This web site is the portal to Fermi for all guest investigators.



This all-sky view from Fermi reveals bright emission in the plane of the Milky Way (center), bright pulsars and super-massive black holes.
Credit: NASA/DOE/International LAT Team

Look into the "Resources" section for finding schedules, publications, useful links etc. The "Proposals" section is where you will be able to find the relevant information and tools to prepare and submit proposals for guest investigator projects. At "Data" you will be able to access the Fermi databases and find the software to analyse them. Address all questions and requests to the helpdesk in "Help".

Quicklist

- 2009 Fermi Symposium
- 11th COSPAR Capacity-Building Workshop
- GLAST Fellowship Program
- Fermi Guest Investigator Program
- Fermi Sky Blog

News

December 3, 2009
Data Analysis Workshop Series
The FSSC will be hosting a series hands-on data analysis workshop anyone interested in getting starte with Fermi data analysis. A discus of the Fermi GI program will follow session. The current workshop schedule is:

- Stanford University (Dec 8)
- Fermilab (Dec 17)
- AAS Meeting in DC (Jan 7)
- Boston University (Jan 11)

Refer to the appropriate workshop's site for more details.

November 2, 2009
NASA's Fermi Telescope Detects Gamma-Ray From "Star Factories" in Other Galaxies
Nearby galaxies undergoing a furious pace of star formation also emit lots of gamma rays, say astronomers using NASA's Fermi Gamma-ray Space Telescope. Two so-called "starburst" galaxies, plus a satellite of our own Milky Way galaxy, represent a new category of gamma-ray-emitting objects detected both by Fermi and ground-based observatories.

GODDARD SPACE FLIGHT CENTER

+ NASA Homepage
+ GSFC Homepage
+ Fermi Homepage

SEARCH Fermi: Search + GO

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+ FSSC Home

Data

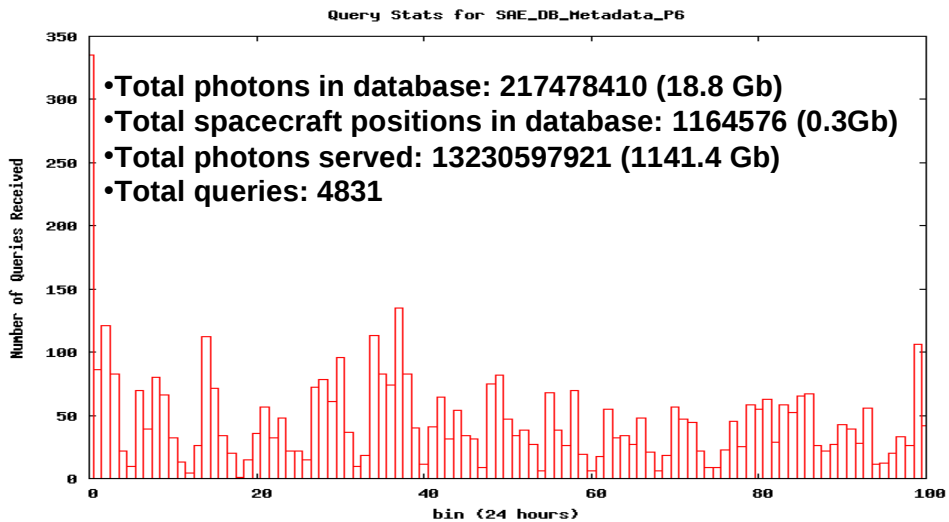
- Data Policy
- Data Access
- Data Analysis
- Newsletter
- FAQ

Fermi Data

This is the portal to the Fermi data and the software to analyze them. Before the data or software are released, they are described here.

- Data Access - the Fermi science data
- Data Analysis - the software to analyze Fermi data
- Data Policy - a summary of the policies governing the release of Fermi science data

As a resource for cycle-2 proposers, the Fermi LAT consortium, through an agreement with NASA, has provided a LAT Bright Source List



- Total photons in database: 217478410 (18.8 Gb)
- Total spacecraft positions in database: 1164576 (0.3Gb)
- Total photons served: 13230597921 (1141.4 Gb)
- Total queries: 4831

NASA Archives

NASA's HEASARC: Observatories

ACTIVE MISSIONS | PAST MISSIONS | UPCOMING MISSIONS | COMPARISON OF MISSION CAPABILITIES

ACTIVE MISSIONS
- AGILE
- Chandra
- Fermi (formerly GLAST)
- INTEGRAL
- Rossi XTE
- Suzaku
- Swift
- XMM-Newton

PAST MISSIONS

ANS	ARIEL V
ASCA	BBXRT
BeppoSAX	CGRO
COPERNICUS	COS-B
DXS	EINSTEIN
EUVE	EXOSAT
GINGA	GRANAT
HAKUCHO	HEAO-1
HEAO-3	HETE-2
OSO-7	OSO-8
ROSAT	SAS-2
SAS-3	TENMA
UHURU	VELA 5B

High Energy Astrophysics Observatories

These Web pages describe all the high energy astronomy observatories, or "missions," ever launched. The links to the left are dedicated to the most notable past and present X-ray and gamma-ray astronomy missions. The pages include

- a mission overview,
- technical information on the instrumentation,
- a bibliography and
- a gallery of images.

They also contain a description of the available data if they are present in the HEASARC archive. Information on other satellites carrying either an X-ray or a gamma-ray telescope is available on the All Missions pages.

Upcoming Missions
- ASTROSAT
- MAXI

Other Resources
- All Missions (info & images)
- All Missions by Time
- All Missions by Energy
- Comparison of Mission Capabilities
- Future Missions
- Images, Spectra, and Light Curves

Latest News

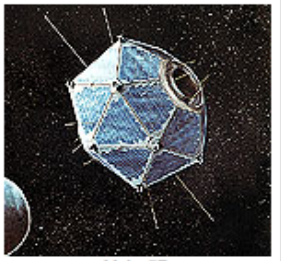
- GLAST

launched June 11, 2008

- GLAST renamed to Fermi Gamma-ray Space Telescope (Aug 26, 2008)

More News

Spacecraft Image of the Week



Vela 5B
DoD/AEC mission
May 1969 - June 1979

http://heasarc.gsfc.nasa.gov/

High Level Analysis

- Output of a telescope (for "event" data) is:
  - Location on sky, time, energy, quality
  - Very simple output ntuple!
    - Implemented in Root and FITS
    - Where instrument and celestial analysis overlap
  - Public data makes sense in astrophysics
    - NEED data from multiple missions to understand celestial sources
- NASA mandates that all its space missions use FITS as a data format
  - In use for 25+ years
  - Format fully documented and files self documenting
    - File headers are an integral part of the format
    - Interface library supplied for popular languages
  - And that the data be made public
    - LAT negotiated one year hiatus on doing this. All existing & ongoing data went public on August 25.
  - Funds a Science Support Center to interface to the public
    - Instrument teams not asked to do this
    - 10+ FTEs for Fermi (LAT+GBM)
    - Charter is to support the Fermi data "forever"

More NASA Mandates

- NASA-funded missions required to create a Project Data Management Plan prior to launch to cover the life of the mission
  - Specify data format details
    - Down to tuple column names
    - Under configuration control
  - Responsibilities across the Mission ground elements
- For high energy astrophysics, NASA further mandates their OGIP standards
  - FTOOLS are a notable example
    - Utilities do almost any manipulation you can think of
  - Adhere to the IRAF parameter file interface
- Agreement with NASA that a specified set of high level analysis tools would be jointly developed by the instrument teams and the FSSC to be used by both the team and the wider scientific community.

Is FITS All Rosy?

- Nothing is.... 
- No structures/objects in the files (think ROOT....)
  - Images or tables (BIN ok, and good compression also)
- The analysis model that goes with it is atomic operations with files used as the messengers
  - Linked together with scripts (called pipelines)
  - Designed for interactive use
    - Not made for (parallel) batch processing
    - Very easy to step on the parameters files
- OTOH, FITS headers are nice
  - Intrinsic to the files : all tools respect the header
  - Carries processing history etc etc
  - Killer App? : very mature astrophysical libraries available
    - crucial WCS conversion/display capabilities

Remaining Possible Issues

- **Long-term support of code and systems**

- **Dealing with up to 250 TB data per year**
  - **Large fileservers mean big exposure to a failure**
  - **Data spread across many servers**
  - **Tape backup?**
  - **Multiple versions – annual reprocessings?**
- **Scaling of databases**
  - **Thinning/truncating trending data**
  - **“hot” expansion of db disk space**
- **Maximising uptime**
  - **Goal is to not miss flares on 12 hour time scales**
  - **For 10 years!**

Summary

- **LAT is an amalgam of HEP (Root) and Astro (FITS)**
- **NASA worries about public data and long term analysis capability**
  - **We are riding their coat-tails**
  - **We have no plan for the Root data and assume at end of mission that it more or less dies**
  - **A price is paid in terms of functionality**
- **Our data have gone public in August 2008**
  - **2009 Fermi Symposium showed that the community is already active in looking at the data**
  - **For the collaboration, strong but healthy tension between scientific return in a competitive world, and bringing further improvements to the data (reconstruction, calibration, etc...)**