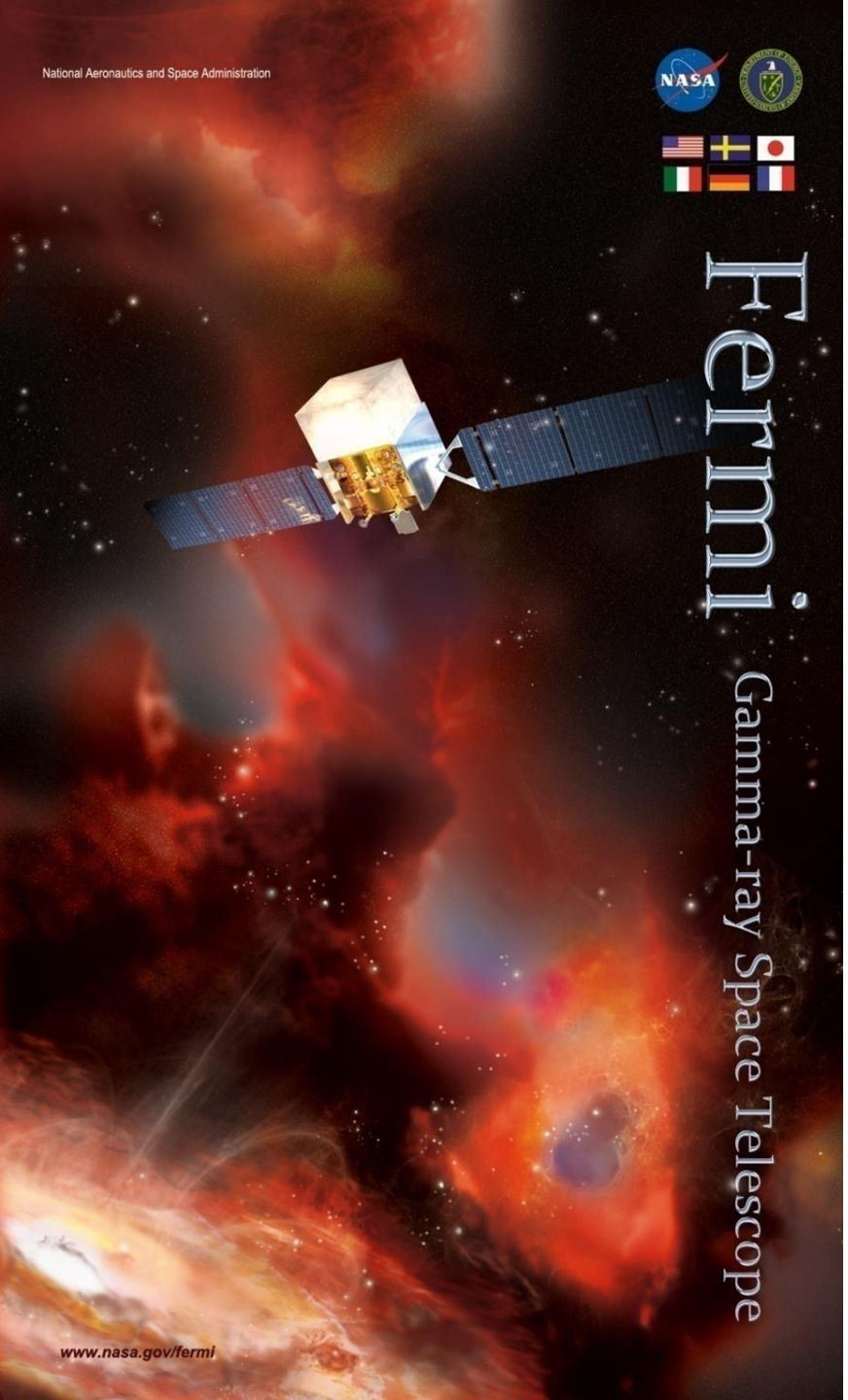

Fermi Gamma-ray Space Telescope

Fermipy hands-on

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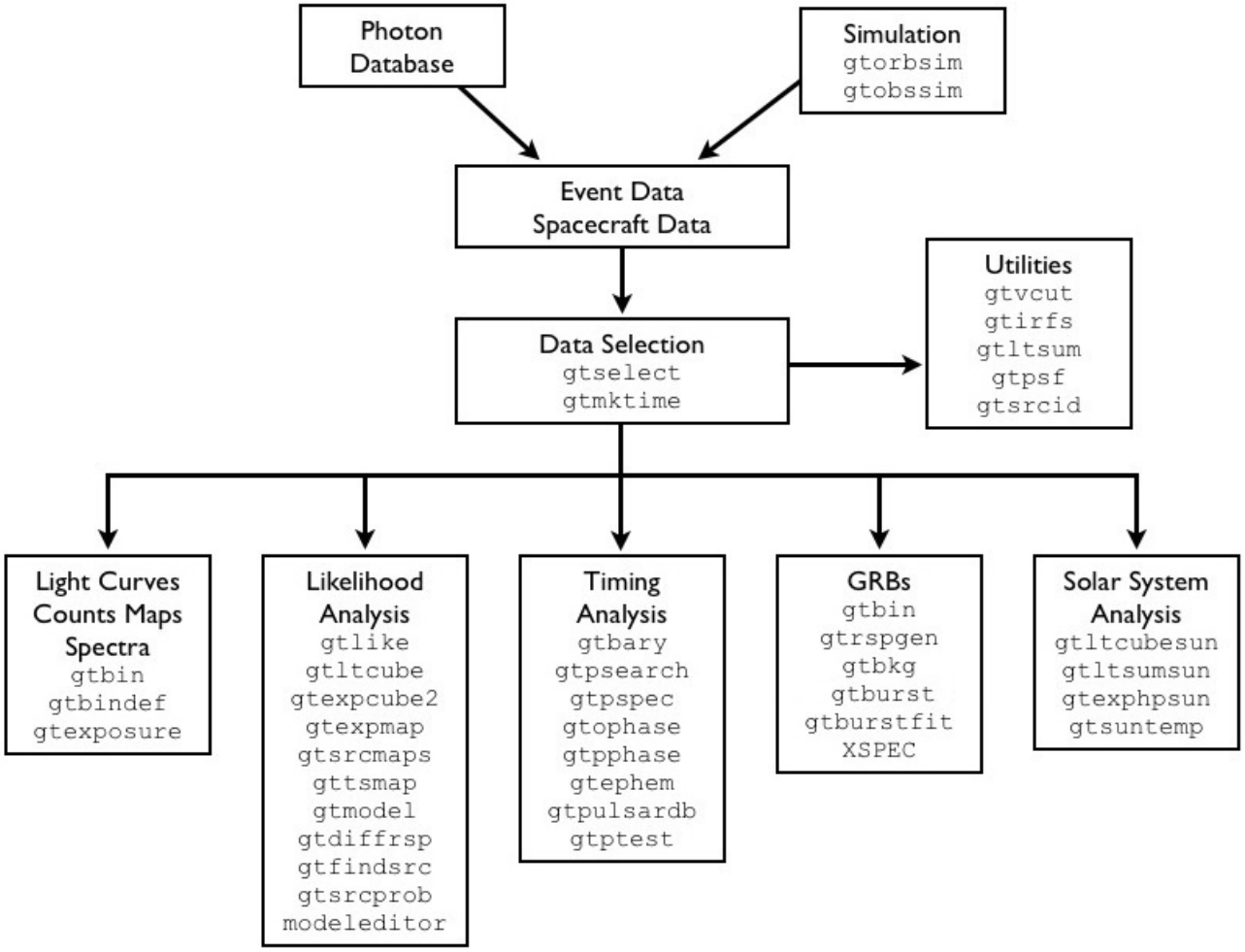
What is fermipy?

The Fermipy package is built on the pyLikelihood interface of the Fermi Science Tools and provides a set of high-level tools for performing common analysis tasks:

- Data and model preparation with the gttools (gtselect, gtmktime, etc.).
- Extracting a spectral energy distribution (SED) of a source.
- Generating TS and residual maps for a region of interest.
- Finding new source candidates.
- Localizing a source or fitting its spatial extension.
- Estimating sensitivity (also of extended sources)
- Phased analysis
- Light curves

https://fermipy.readthedocs.io/en/latest/index.html

What are the FermiTools?



https://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/overview.html

Why do we use Fermipy?

- It is flexible and (relatively) fast.
- It can work on a simple notebook but we use it also for our publications (with week long processes on the farm).
- It can handle easily the generation of intermediate files saving the hassle to the student/researcher.
- It allows us to use complex analysis techniques as the summed likelihood really easily.

Can we use Fermipy for all the Fermi-LAT analysis?

- Fermipy is based on the BinnedAnalysis method.
- This is the analysis method for most of the LAT sources except GRBs and solar flares. Those kind of sources have a duration of ~minutes/hours.
- Fermipy is not able to perform now UnbinnedAnalysis
- Other tools are available for this kind of analysis, see N. Omodei presentations.

https://fermi.gsfc.nasa.gov/ssc/data/analysis/scitools/likelihood_tutorial.html

How do I get them? (1 of 2)

- Before installing fermipy you need to install the FermiTools (known before as ScienceTools).
- It is really easy and fast using conda:

  conda create -n fermi -c conda-forge/label/cf201901 -c fermi fermitools

  conda activate fermi

- The instruction are here:

  https://github.com/fermi-lat/Fermitools-conda/wiki/Installation-Instructions

- you can check if some tools are working just writing:

  gtirfs

  this will show you all the instrument response functions available for the analysis.

How do I get them? (2 of 2)

- After activating the fermi environment you can easily install fermipy:

  conda config --append channels conda-forge

  conda install fermipy

- The full instructions are here:

  https://fermipy.readthedocs.io/en/latest/install.html

Check the version you have

- Check the version with:

(fermi) [fdepalma@dhcp122 ~]$ ***conda list fermi***

 # packages in environment at /home/fdepalma/anaconda2/envs/fermi:

#

# Name	*Version*	*Build*	*Channel*
fermipy	*0.17.4*	*py27_0*	*conda-forge*
fermitools	*1.0.7*	*py27h39e3cac_0*	*fermi*
fermitools-data	*0.17*	*0*	*fermi*

- You might need to downgrade the version you have on the VM with this command:

  conda install -c conda-forge/label/cf201901 -c fermi fermitools=1.0.2

Fermi-LAT data

- They are stored in FITS format (as seen in L. Tibaldo presentations)
- There are 2 kind of fits data:
  - ft1 data contains the informations related to the observed photons. They can be “photons” or “extended” class. The first are the data for the standard analysis, the latter is for analysis of transient sources.
  - ft2 data contains the informations related to the satellite. They can have a 30s or 1s binning.

The data are freely available from the FSSC web page:

https://fermi.gsfc.nasa.gov/ssc/data/access/

Available Data Products

Data

- Data Policy
- **Data Access**
  - + LAT Data
  - + LAT Catalog
  - + LAT Data Queries
  - + LAT Query Results
  - + LAT Weekly Files
  - + GBM Data
- Data Analysis
- Caveats
- Newsletters
- FAQ

Currently Available Data Products

The Fermi data released to the scientific community is governed by the data policy. The released instrument data for the GBM, along with LAT source lists, can be accessed through the Browse interface specific to Fermi. LAT photon data can be accessed through the LAT data server.

The FITS files can also be downloaded from the Fermi FTP site. The file version number is the 'xx' in the characters before the extension in each filename; you should keep track of the version numbers of files you analyze since the instrument teams may update them.

Note that the LAT and GBM data are accompanied by caveats about their use.

- LAT Photon and Extended Data
  - LAT Data Server (updated with P8R3 data 26-Nov-2018)
  - LAT Low-Energy (LLE) Data (Browse table)
  - Products available on the FTP Site (current processing version of the data).
    - Weekly Photon Files
    - Weekly Spacecraft Files
    - Mission Long Spacecraft File
    - Weekly 1-second Spacecraft Files
    - Filtered Weekly Photon Files with Diffuse Response Columns
  - Previous processing versions available on the FTP site
    - Pass 8 (P8R2) Weekly Files
    - Pass 7 (V6d) Weekly Files
    - Pass 7 (V6) Weekly Files
    - Pass 6 (V11) Weekly Files
    - Pass 6 (V3) Weekly Files
  - ASDC data server (external)
- LAT catalogs and associated products (high-level products only)
  - LAT Point Source Catalog
    - LAT 8-year Point Source Catalog (4FGL)
    - Preliminary LAT 8-year Source List (FL8Y)
    - LAT 4-year Point Source Catalog (3FGL)
    - LAT 2-year Point Source Catalog (2FGL)
    - LAT 1-year Point Source Catalog (1FGL)
    - LAT 3-month Bright Source List (0FGL)
  - Aperture Photometry Light Curves
    - Aperture Photometry Light Curves for LAT 4-year Catalog Sources (Updated Weekly)
    - Flaring Sources in the LAT 4-year Aperture Photometry Light Curves (Updated Weekly)
    - Aperture Photometry Light Curves for the LAT 2-year Point Source Catalog
    - Flaring Sources in the LAT 2-year Aperture Photometry Lightcurves
  - LAT High Energy Source Catalog
    - LAT Third High Energy Source Catalog (3FHL)

Photon Classification

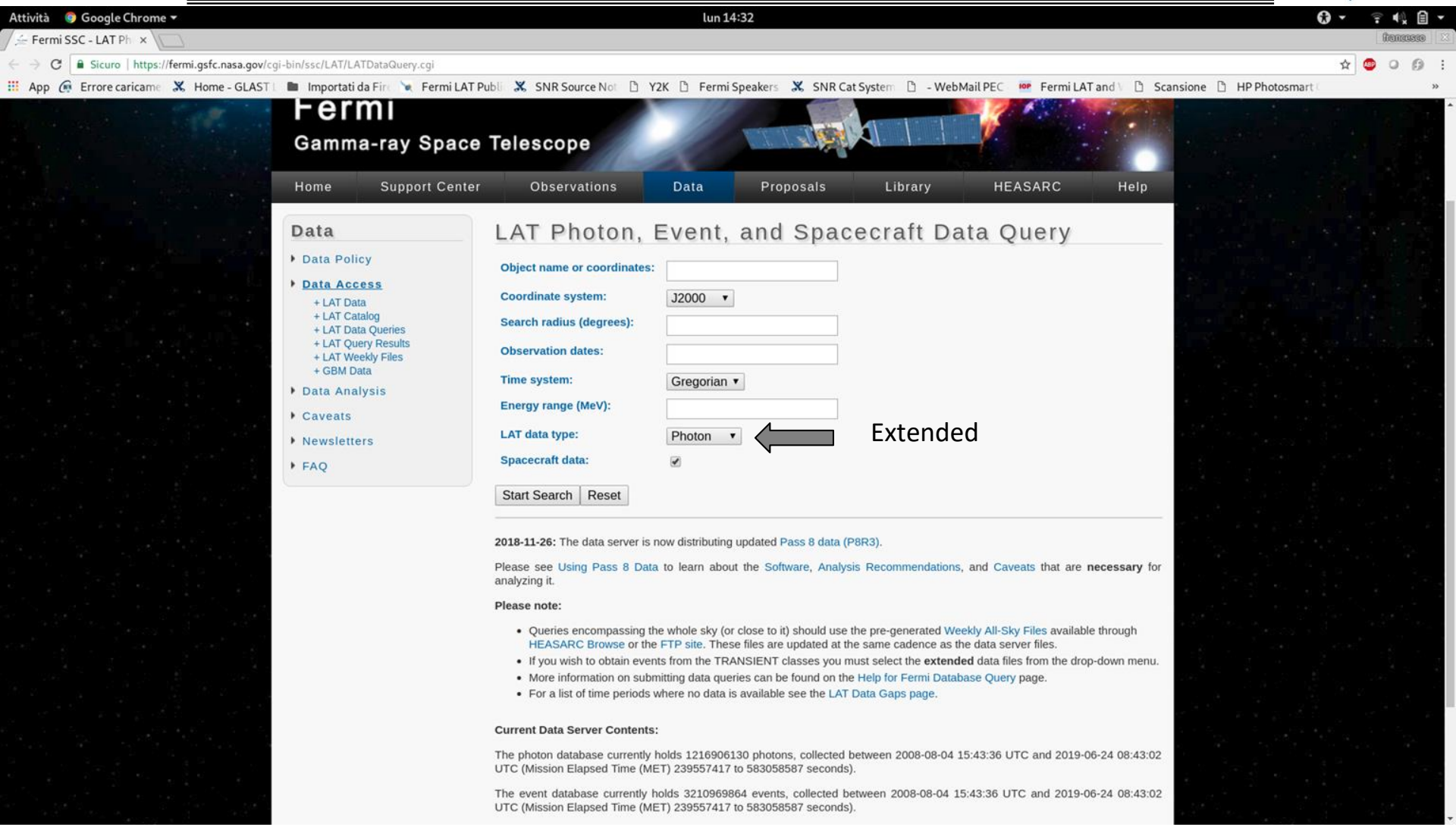
Standard Hierarchy for LAT Event Classes				
Event Class	**evclass**	**Photon File**	**Extended File**	**Description**
P8R3_TRANSIENT020	16		X	Transient event class with background rate equal to two times the A10 IGRB reference spectrum.
P8R3_TRANSIENT010	64		X	Transient event class with background rate equal to one times the A10 IGRB reference spectrum.
P8R3_SOURCE	128	X	X	This event class has a residual background rate that is comparable to P7REP_SOURCE. This is the recommended class for most analyses and provides good sensitivity for analysis of point sources and moderately extended sources.
P8R3_CLEAN	256	X	X	This class is identical to SOURCE below 3 GeV. Above 3 GeV it has a 1.3-2 times lower background rate than SOURCE and is slightly more sensitive to hard spectrum sources at high galactic latitudes.
P8R3_ULTRACLEAN	512	X	X	This class has a background rate very similar to ULTRACLEANVETO.
P8R3_ULTRACLEANVETO	1024	X	X	This is the cleanest Pass 8 event class. Its background rate is 15-20% lower than the background rate of SOURCE class below 10 GeV, and 50% lower at 200 GeV. This class is recommended to check for CR-induced systematics as well as for studies of diffuse emission that require low levels of CR contamination.
P8R3_SOURCEVETO	2048	X	X	This class has the same background rate than the SOURCE class background rate up to 10 GeV but, above 50 GeV, its background rate is the same as the ULTRACLEANVETO one while having 15% more acceptance.
Extended Hierarchy				
Event Class	**evclass**	**Photon File**	**Extended File**	**Description**
P8R3_TRANSIENT020E	8		X	Extended version of the P8R3_TRANSIENT020 event class with a less restrictive fiducial cut on projected track length through the Calorimeter.
P8R3_TRANSIENT010E	32		X	Extended version of the P8R3_TRANSIENT010 event class with a less restrictive fiducial cut on projected track length through the Calorimeter.
NON-ACD Hierarchy				
Event Class	**evclass**	**Photon File**	**Extended File**	**Description**
P8R3_TRANSIENT015S	65536		X	Transient event class designed for analysis of prompt solar flares in which pileup activity may be present. This class has a background rate equal to 1.5 times the A10 reference spectrum.

Partition types:

P8R3 Event Type Name	Event Type Partition	Event Type Value (evtype)
FRONT	Conversion Type	1
BACK	Conversion Type	2
PSF0	PSF	4
PSF1	PSF	8
PSF2	PSF	16
PSF3	PSF	32
EDISP0	EDISP	64
EDISP1	EDISP	128
EDISP2	EDISP	256
EDISP3	EDISP	512

https://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Cicerone/Cicerone_Data/LAT_DP.html#PhotonClassification
https://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Cicerone/Cicerone_LAT_IRFs/IRF_overview.html

Data Query


Attività
Google Chrome
lun 14:32
Fermi SSC - LAT Ph
Sicuro | https://fermi.gsfc.nasa.gov/cgi-bin/ssc/LAT/LATDataQuery.cgi
Fermi
Gamma-ray Space Telescope
Home
Support Center
Observations
Data
Proposals
Library
HEASARC
Help
Data
Data Policy
Data Access
+ LAT Data
+ LAT Catalog
+ LAT Data Queries
+ LAT Query Results
+ LAT Weekly Files
+ GBM Data
Data Analysis
Caveats
Newsletters
FAQ
LAT Photon, Event, and Spacecraft Data Query
Object name or coordinates:
Coordinate system:
J2000
Search radius (degrees):
Observation dates:
Time system:
Gregorian
Energy range (MeV):
LAT data type:
Photon
Spacecraft data:
Start Search
Reset
Extended
2018-11-26: The data server is now distributing updated Pass 8 data (P8R3).
Please see Using Pass 8 Data to learn about the Software, Analysis Recommendations, and Caveats that are necessary for analyzing it.
Please note:
Queries encompassing the whole sky (or close to it) should use the pre-generated Weekly All-Sky Files available through HEASARC Browse or the FTP site. These files are updated at the same cadence as the data server files.
If you wish to obtain events from the TRANSIENT classes you must select the extended data files from the drop-down menu.
More information on submitting data queries can be found on the Help for Fermi Database Query page.
For a list of time periods where no data is available see the LAT Data Gaps page.
Current Data Server Contents:
The photon database currently holds 1216906130 photons, collected between 2008-08-04 15:43:36 UTC and 2019-06-24 08:43:02 UTC (Mission Elapsed Time (MET) 239557417 to 583058587 seconds).
The event database currently holds 3210969864 events, collected between 2008-08-04 15:43:36 UTC and 2019-06-24 08:43:02 UTC (Mission Elapsed Time (MET) 239557417 to 583058587 seconds).

Backgrounds

- For the analysis of a source you should identify and model out the background events.
- We have two main kind of background:
  - point and extended sources that are in catalogs (3FGL,4FGL, etc. see Regina's Talk)
  - "diffuse" background: interstellar emission model (in fits file) and a residual isotropic template (in a txt file).
- For the usual FermiTools analysis the user should provide an xml file with the starting characteristics of all the sources in the Region of Interest, fermipy is able to create a model at runtime easily.
- Fermipy is able to find new sources, this might be needed if your setup is different from the one used in the catalog development.

Background

- Catalogs:
  - 3FGL, 4 years of data, https://fermi.gsfc.nasa.gov/ssc/data/access/lat/4yr_catalog/
  - 4FGL, 8 years of data, https://fermi.gsfc.nasa.gov/ssc/data/access/lat/8yr_catalog/
- "Diffuse" models:

  https://fermi.gsfc.nasa.gov/ssc/data/access/lat/BackgroundModels.html

N.B. I had to change the interstellar emission models in some tutorials to the latest version since the previous version was not readily available in the VM

Background selection

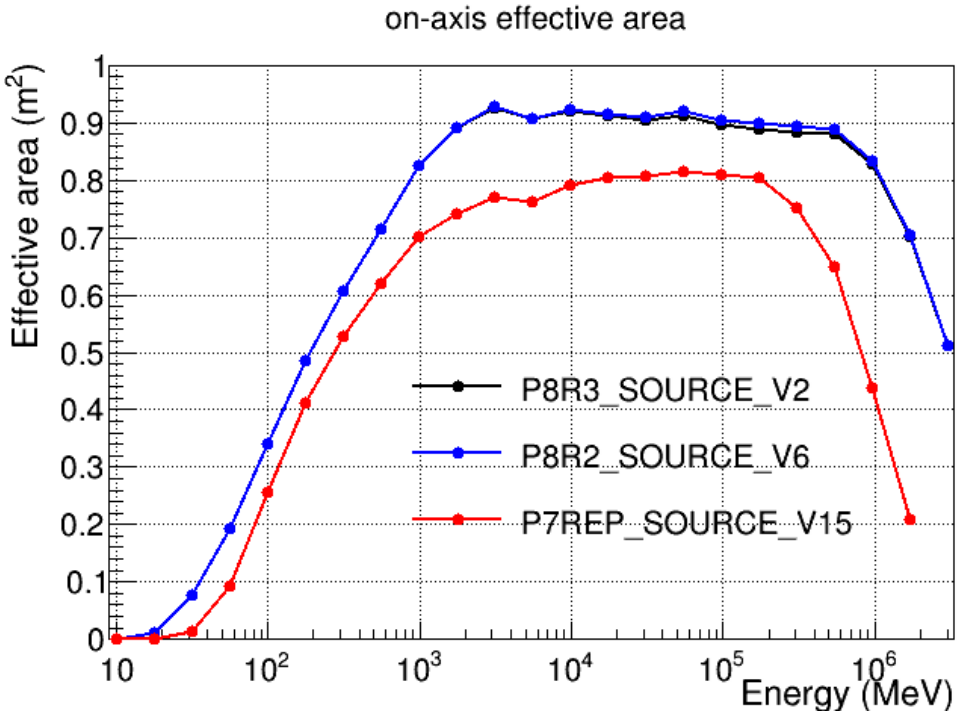
Interstellar emission model developed for the 4FGL

Galactic interstellar emission model	Event Selection/ IRF Name	Isotropic spectral template
gll_iem_v07.fits (see below for P8R3 usage notes)	Pass 8 Source (front+back, allPSF, allEDISP) P8R3_SOURCE_V2	iso_P8R3_SOURCE_V2_v1.txt
	Pass 8 Source (front only) P8R3_SOURCE_V2::FRONT	iso_P8R3_SOURCE_V2_FRONT_v1.txt
	Pass 8 Source (back only) P8R3_SOURCE_V2::BACK	iso_P8R3_SOURCE_V2_BACK_v1.txt
	Pass 8 Clean (front+back, allPSF, allEDISP) P8R3_CLEAN_V2	iso_P8R3_CLEAN_V2_v1.txt
	Pass 8 Clean (PSF0) P8R3_CLEAN_V2::PSF0	iso_P8R3_CLEAN_V2_PSF0_v1.txt
	Pass 8 Clean (PSF1) P8R3_CLEAN_V2::PSF1	iso_P8R3_CLEAN_V2_PSF1_v1.txt
	Pass 8 Clean (PSF2) P8R3_CLEAN_V2::PSF2	iso_P8R3_CLEAN_V2_PSF2_v1.txt
	Pass 8 Clean (PSF3) P8R3_CLEAN_V2::PSF3	iso_P8R3_CLEAN_V2_PSF3_v1.txt
	Pass 8 Ultraclean (front+back, allPSF, allEDISP) P8R3_ULTRACLEAN_V2	iso_P8R3_ULTRACLEAN_V2_v1.txt
	Pass 8 Ultraclean (EDISP0) P8R3_ULTRACLEAN_V2::EDISP0	iso_P8R3_ULTRACLEAN_V2_EDISP0_v1.txt
	Pass 8 Ultraclean (EDISP1) P8R3_ULTRACLEAN_V2::EDISP1	iso_P8R3_ULTRACLEAN_V2_EDISP1_v1.txt
	Pass 8 Ultraclean (EDISP2) P8R3_ULTRACLEAN_V2::EDISP2	iso_P8R3_ULTRACLEAN_V2_EDISP2_v1.txt
	Pass 8 Ultraclean (EDISP3) P8R3_ULTRACLEAN_V2::EDISP3	iso_P8R3_ULTRACLEAN_V2_EDISP3_v1.txt
	Pass 8 Ultracleanveto (front+back, allPSF, allEDISP) P8R3_ULTRACLEANVETO_V2	iso_P8R3_ULTRACLEANVETO_V2_v1.txt
	Pass 8 Sourceveto (front+back, allPSF, allEDISP) P8R3_SOURCEVETO_V2	iso_P8R3_SOURCEVETO_V2_v1.txt

Isotropic model to be chosen in function of the selected photon class

Instrument Response Function versions

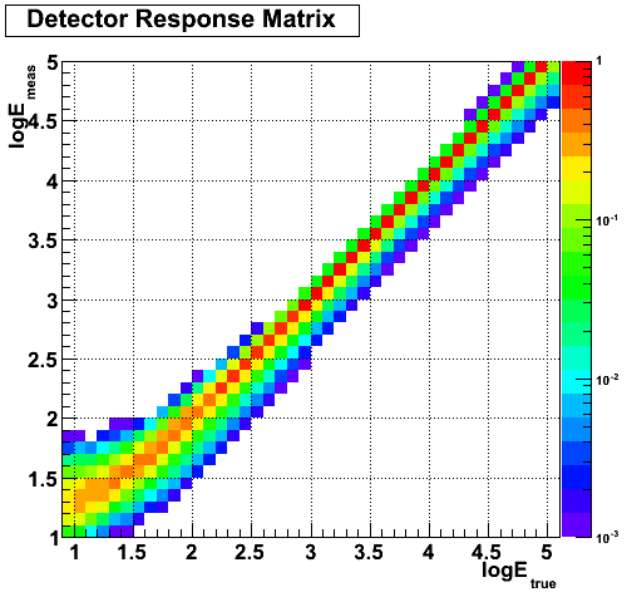
The latest IRFs version is P8r3, it has just some minor improvement over P8r2. Pass 8 was a major change from the previous P7 version of our data.



http://www.slac.stanford.edu/exp/glast/groups/canda/lat_Performance.htm

Energy dispersion

The LAT does not measure the energy of the photons with infinite precision. The finite energy resolution of the LAT called the energy dispersion has been characterized by the LAT team and this information is part of the IRFs.



https://fermi.gsfc.nasa.gov/ssc/data/analysis/documentation/Pass8_edisp_usage.html

Tutorials

In today tutorial we should see:

- a standard point source analysis
- an extended source analysis
- Ttwo phased analysis (Geminga and Vela)
- the variable flux of an AGN in coincidence of the neutrino event
- upperlimits on the dark matter annihilation.

Some of those are adapted from fermipy-extra:

https://github.com/fermiPy/fermipy-extra

Troubleshooting

In the VM is possible that you get some errors related to the extended sources models downloaded with the conda installation method.

You can redownload the extended models from the web pages and substitute that to the one that are in the VM

https://fermi.gsfc.nasa.gov/ssc/data/access/lat/8yr_catalog/

or

https://fermi.gsfc.nasa.gov/ssc/data/access/lat/4yr_catalog/

Jupyter hup

We will run the notebooks on a jupyter hub on RECAS servers (Bari)

https://www.recas-bari.it/index.php/it/