Analysis of the Impulsive Phase of Solar Flares with Pass 8 data

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on behalf of the Fermi collaboration

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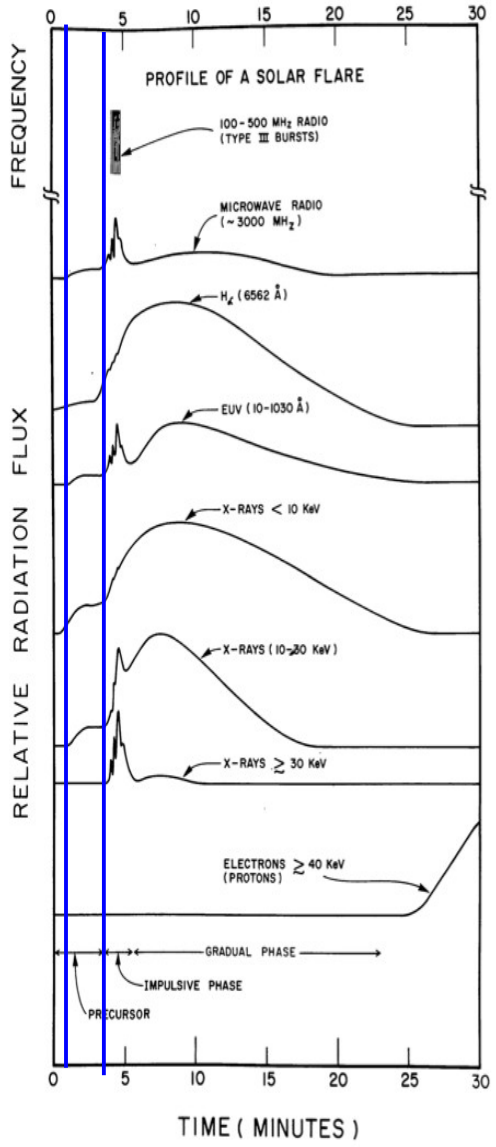
Outline

- Introduction
  - The Impulsive phase of Solar Flares
  - Studying this phase with the LAT
    - The LLE technique
- Pass 8
  - Brief description
  - The importance of Pass 8 for Solar Flares
- Data Analysis
  - Light-curves
  - Spectra
    - Using Pass 8 LLE and PASS 8 TRANSIENT event classes
- Prospects and Conclusions

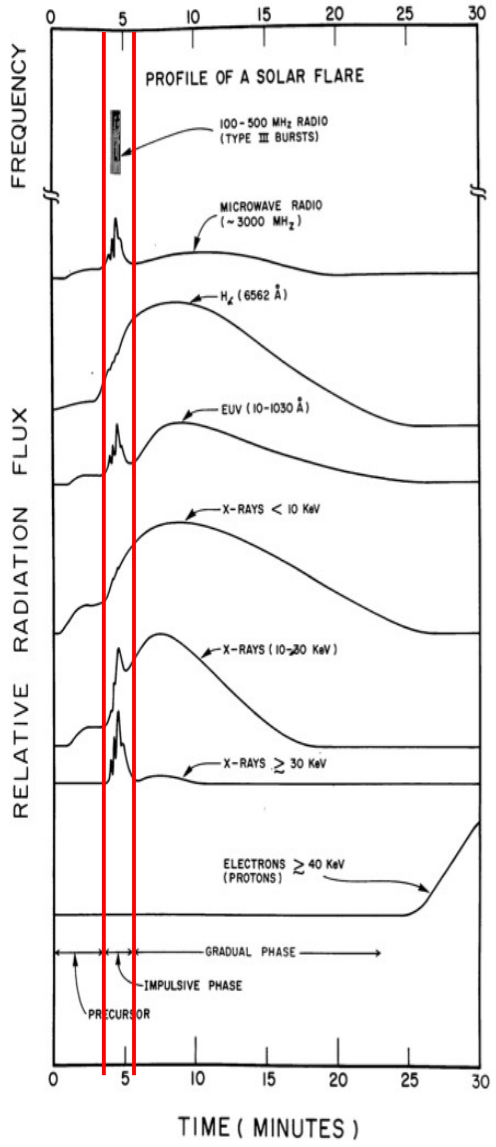
The Impulsive Phase of Solar Flares



- **Different Phases of Solar Flares in X and gamma-ray bands**
  - **Precursor**
  - **Impulsive**
  - **Gradual**
  - **Extended**

Priest (1981)

The Impulsive Phase of Solar Flares



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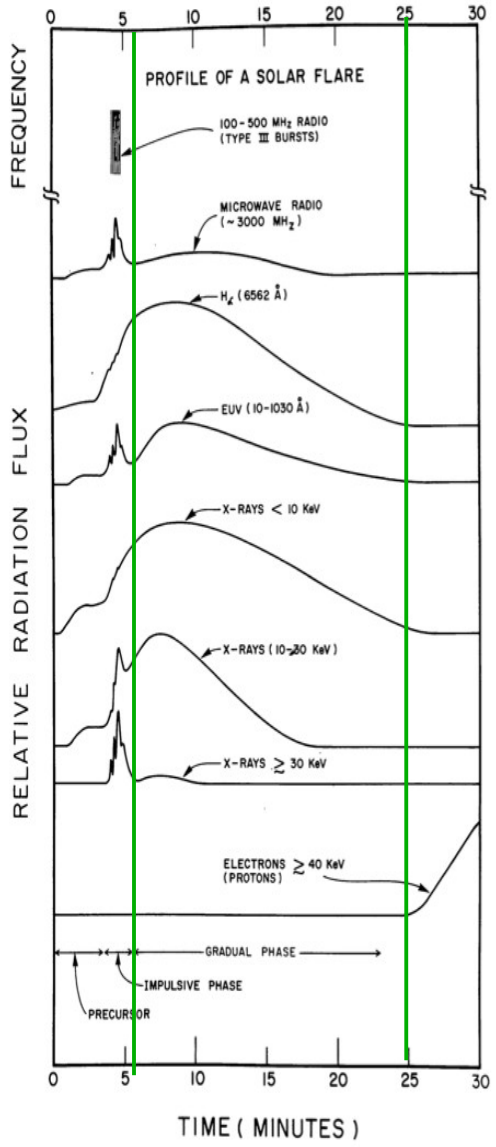

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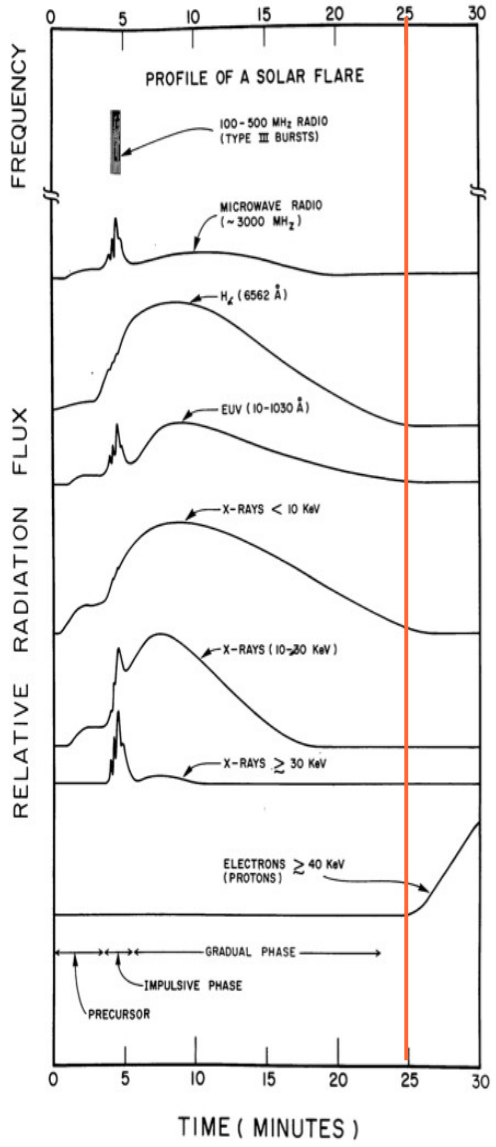

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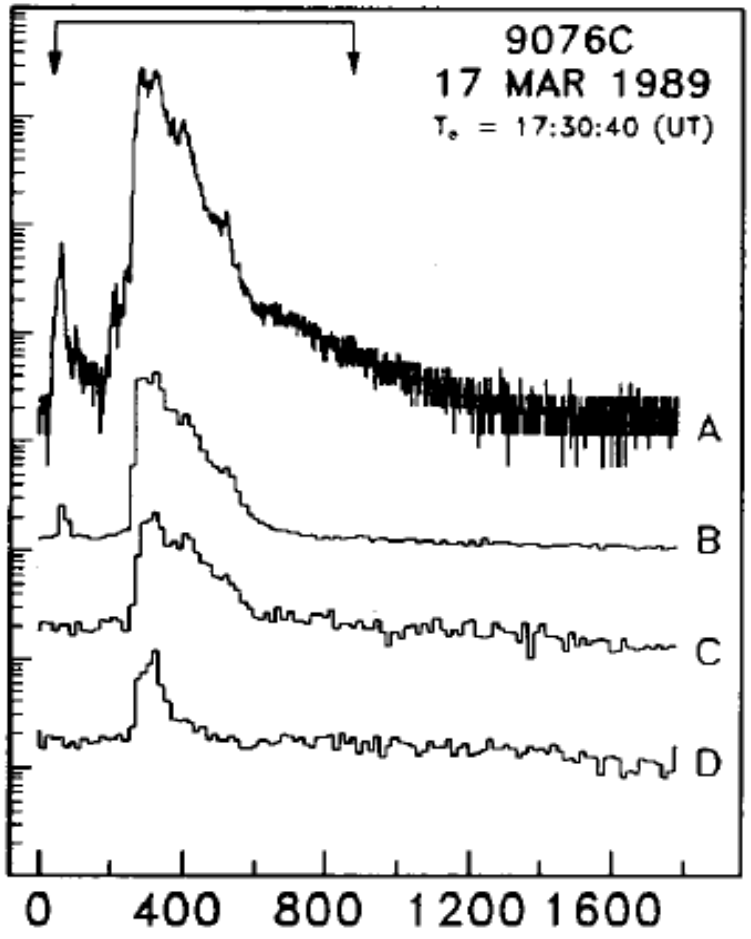
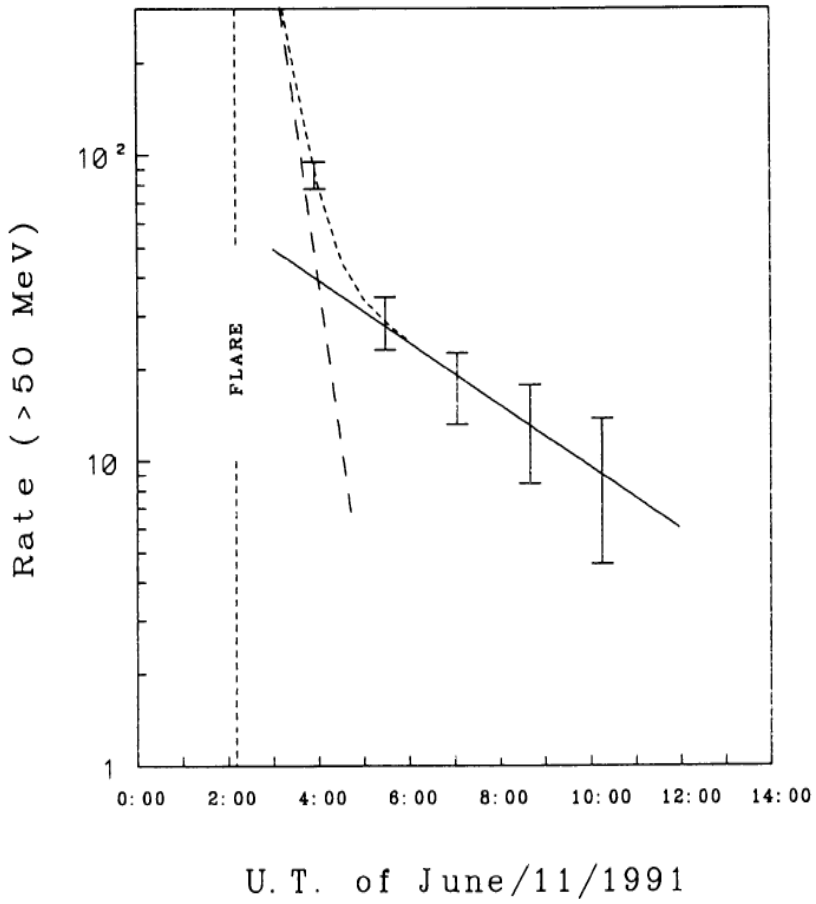
Impulsive Phase of Solar Flares in Gamma-rays

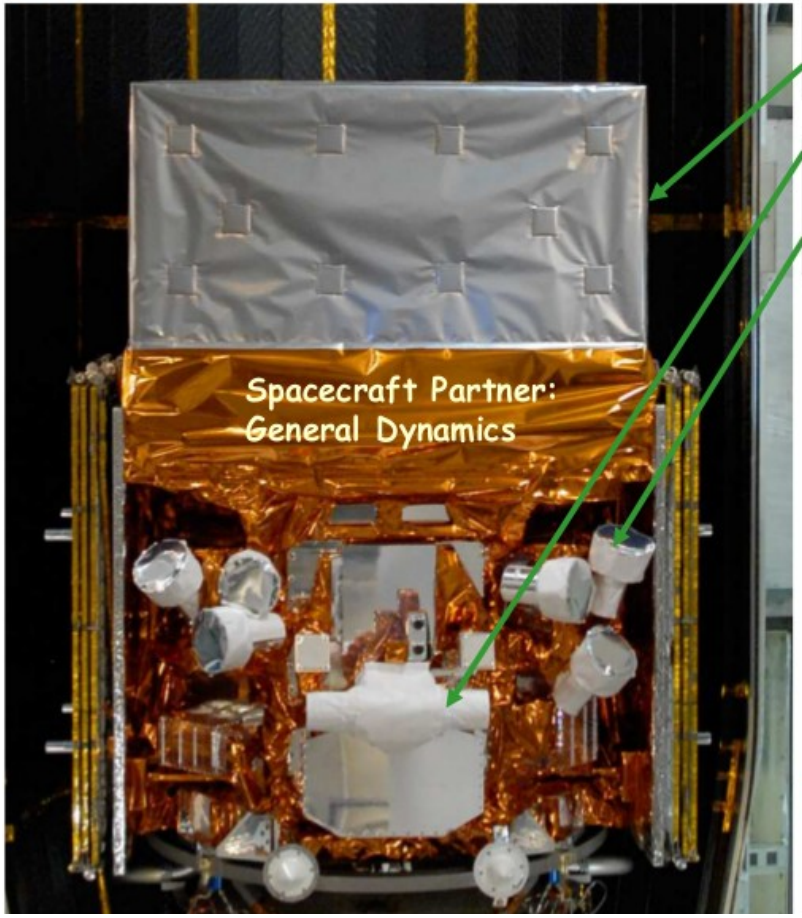


SMM Atlas of Solar Flares
(Vestrand et al. 1999) Up to 25 MeV

EGRET detection of June 11, 1991 Solar Flare
(Kanbach et al 1993)



The Fermi observatory



Large AreaTelescope (LAT)
20 MeV - >300 GeV

Gamma-ray Burst Monitor (GBM)
NaI and BGO Detectors
8 keV - 30 MeV

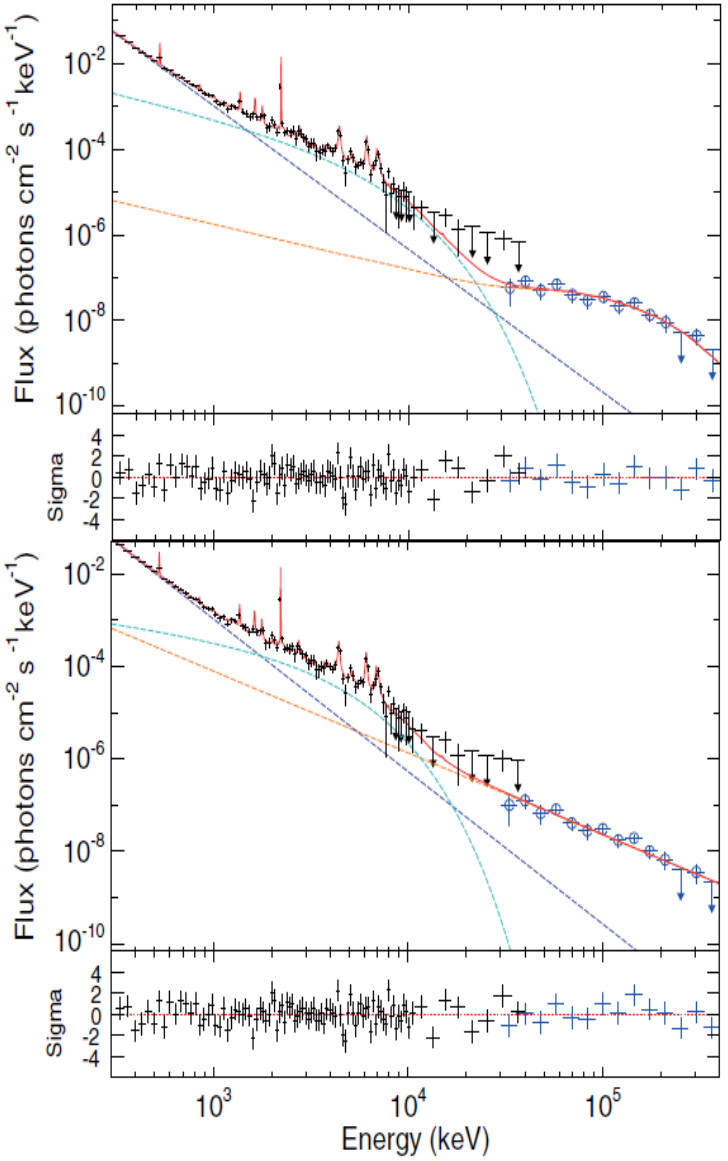
KEY FEATURES

- **Huge field of view**
  - –LAT: 20% of the sky at any instant; in sky survey mode, expose all parts of sky for ~30 minutes every 3 hours. GBM: whole unocculted sky at any time.
- Huge energy range, including largely unexplored band 10 GeV - 100 GeV. **Total of >7 energy decades!**
- Large leap in all key capabilities. Great discovery potential.

- **Perfect observatory to study transients events like solar flares!**
- **See N. Omodei poster *Monitoring the Sun with the LAT* (11.02)**

Fermi observation of Solar Flares

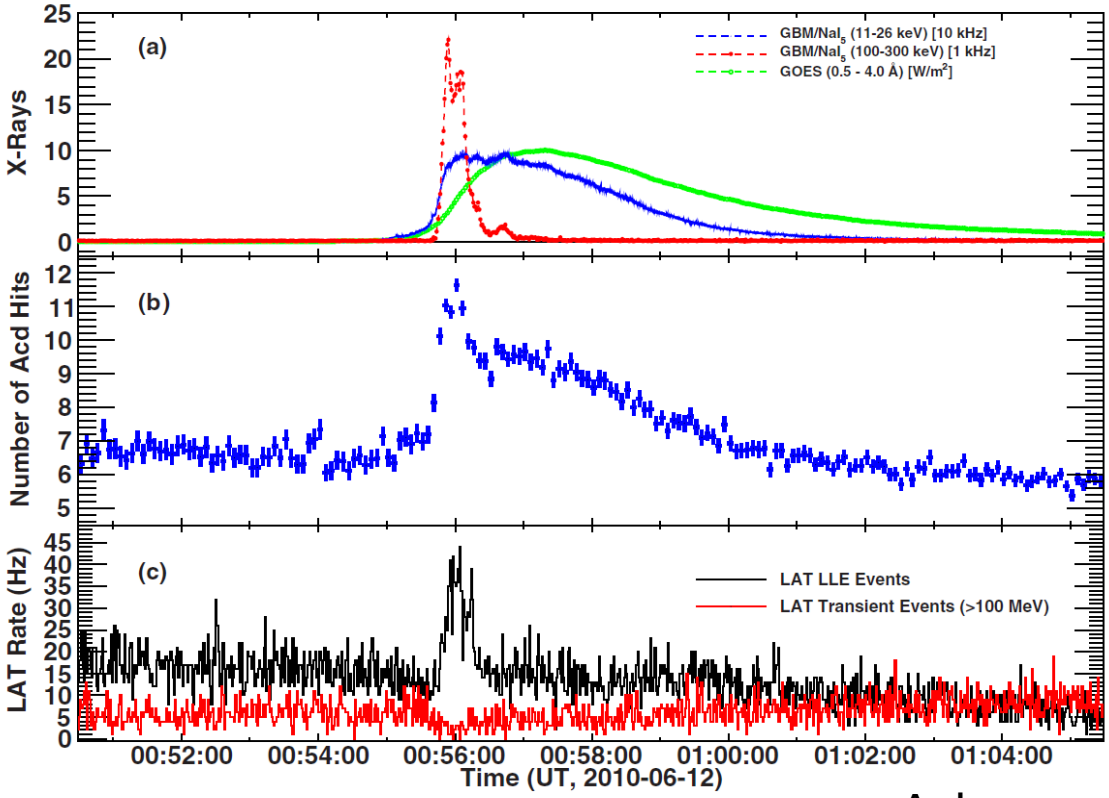
- **GBM and LAT joint spectral analysis of June 12, 2010 SFR**
  - **Electron bremstrahlung for E<1MeV**
  - **Ions/protons lines**
- **Spectral analysis > 30 MeV**
  - **Pion decay component or HE bremsstrahlung component**



Ackermann et al. (2012)

The LAT Low Energy Technique

- **Intense X-ray flux during the impulsive phase: pile-up in the ACD causes some suppression of the standard LAT event rate.**
- **Recover the signal with looser selection technique**
  - **LAT Low Energy events (LLE)**



Ackermann et al. (2012)

The LAT Low Energy Technique

Browse this table...

FERMILLE - Fermi LAT Low-Energy Events Catalog

HEASARC Archive

Overview

LAT Low-Energy events (LLE) are automatically produced for each GBM GRB in the GBM Trigger Catalog if the GBM GRB has a position within 90 degrees of the LAT boresight. LLE data are generated for a given position in the sky (RA, DEC) and for a given interval of time (T0, T1) corresponding to the GBM Burst.

The standard LLE selection applied to the downloaded events is the following:

(FswGamState==0 && TkrNumTracks>0 && (GltEngine==6 || GltEngine==7) && EvtEnergyCorr > 0) && (FT1ZenithTheta<90.0) && (FT1Theta<=90.0) && $(((\cos(FT1Dec*0.0174533)*(FT1Ra - (RA)))^2 + (FT1Dec - (DEC))^2) < PSF(EvtEnergyCorr, Theta)$

where

* FswGamState is the status of the Flight Sofware Gamma filter. We require that the event is a gamma-ray (FswGamState==0).
* TkrNumTracks is the number of tracks in the tracker. We require that there is at least one track. This requires the event to have a reconstructed direction.
* GltEngine is the status of the Global LAT Trigger. We require that GltEngine equals 6 or 7, which corresponds to taking all the events that trigger in the tracker TKR but did not have a region of interest (ROI) associated (GltEngine 7) or all the events that pass the CalHI (at least 1 GeV in one crystal).
* EvtEnergyCorr is the best estimation of the reconstructed energy, especially at low energy.
* Theta is the reconstructed source direction (Theta) with respect the LAT boresight.
* PSF(EvtEnergyCorr, Theta) represents the functional form of the containment radius of the Point Spread Function (PSF) of the LAT.

The exact cut used to select the events is saved in the keyword LLECUT in the primary header of each LLE file. If the GBM catalog position of the burst is updated (due to a refined localization from LAT or Swift or from subsequent on ground analysis), the LLE data are automatically updated and new versions of the LLE files are produced. In some cases, LLE data are manually generated (using a better localization which may or may not have been used in the GBM Trigger Catalog). For each updated position, the version of the corresponding LLE files increases by one.

There are six FITS files provided for each entry: the LLE event file, the time-binned spectrum (CSPEC) file, the CSPEC response (RSP) file, and the extracted burst spectrum (the PHA-I file) for the entire duration of the burst, an LLE event file with same time cut as the RSP and PHA-I files, and a LAT pointing and livetime history file.

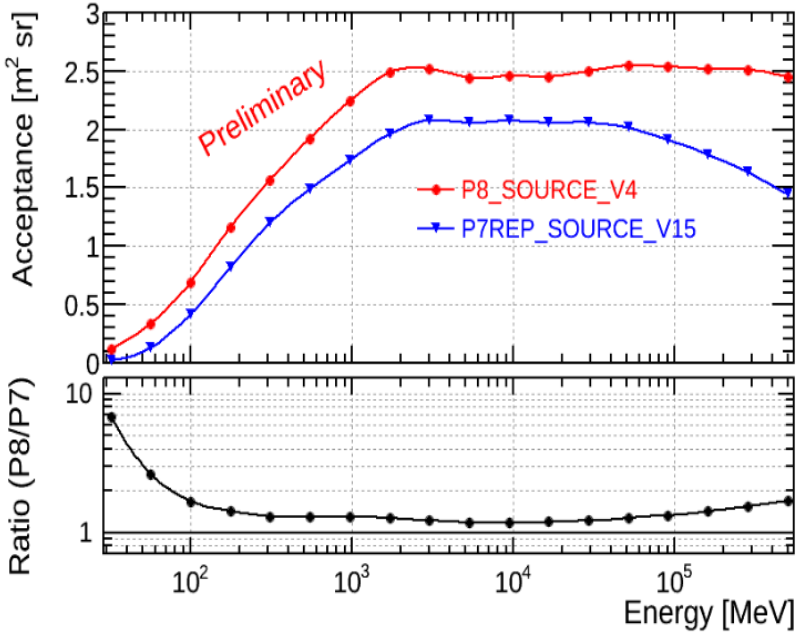
Data available for GRB and Solar Flares on the HEASARC archive:
http://heasarc.gsfc.nasa.gov/W3Browse/fermi/fermille.html

Pass 8 LAT data

- **Event analysis is periodically updated : Pass 7 REP is the current analysis distributed to the community**

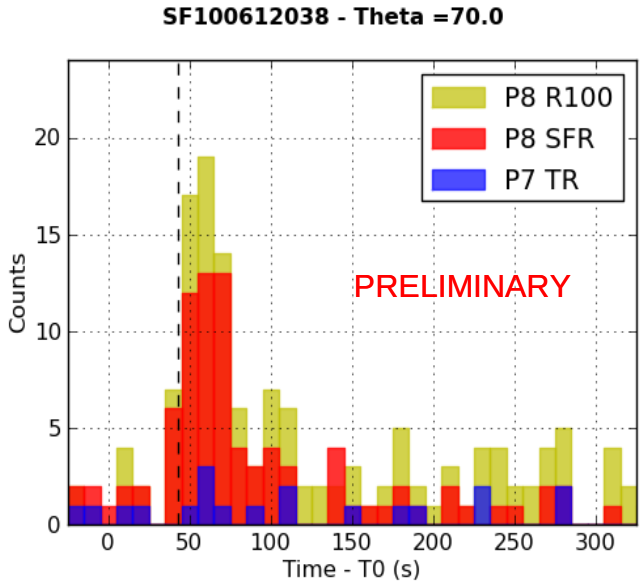
..as fully described yesterday in P. Bruel talk..

- **Pass 8 is a new analysis of LAT data after an extensive review of all the recon algorithms**
- **Performance improvements:**
  - **Larger acceptance**
  - **Better PSF**
  - **Wider energy range**
  - **Better control of systematic uncertainties**
- **Effectively a “new" LAT**

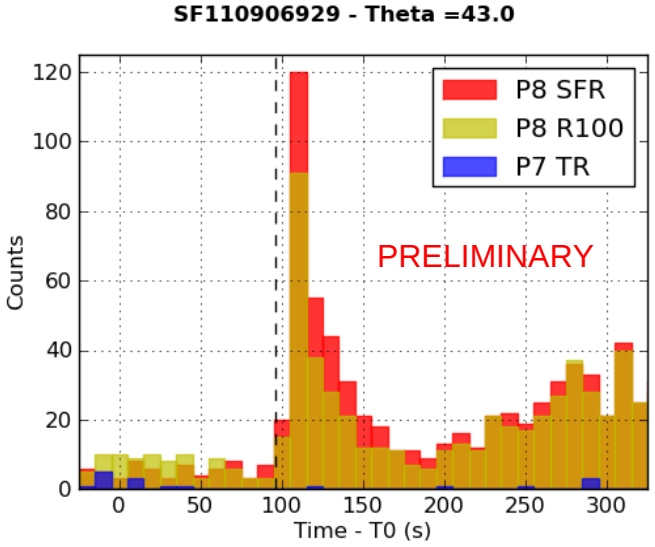


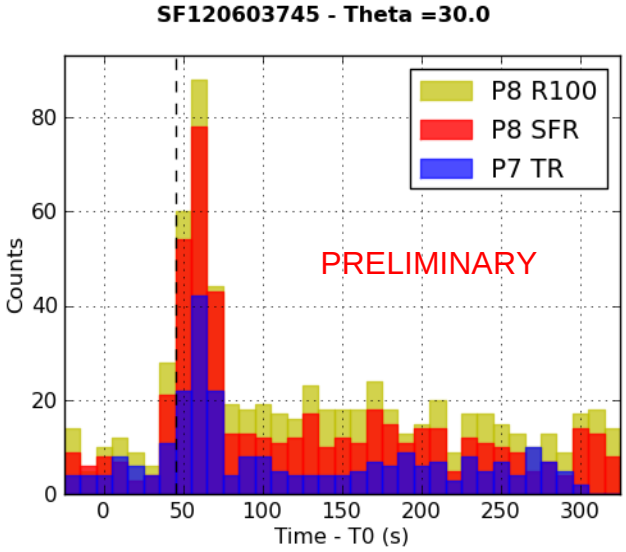
- **Development of SFR dedicated classes (with better treatment of ACD pileup)**

Pass 8 Analysis of Solar Flares (Using TRANSIENT & Solar Flare Classes)



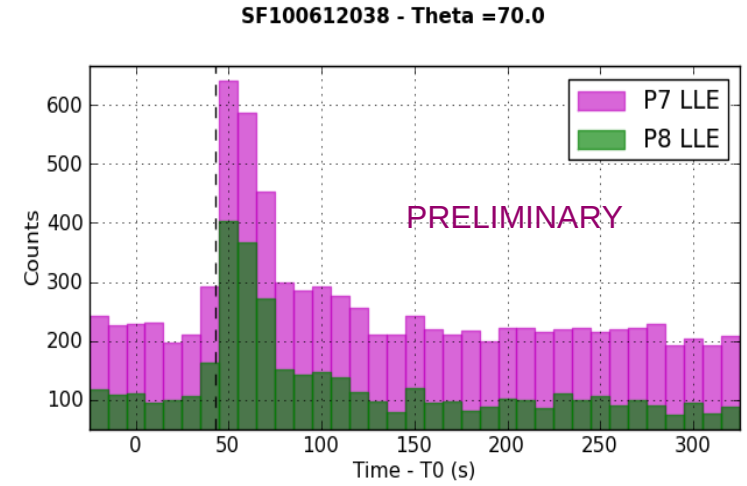
- **R100: Loosest Pass 8 Transient class**
- **SFR: Pass 8 class dedicated to Solar Flare analysis**

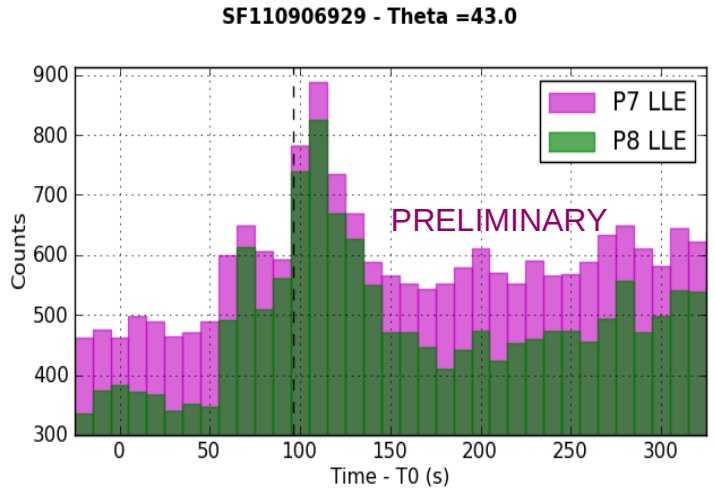




Pass 8 improvements on LLE

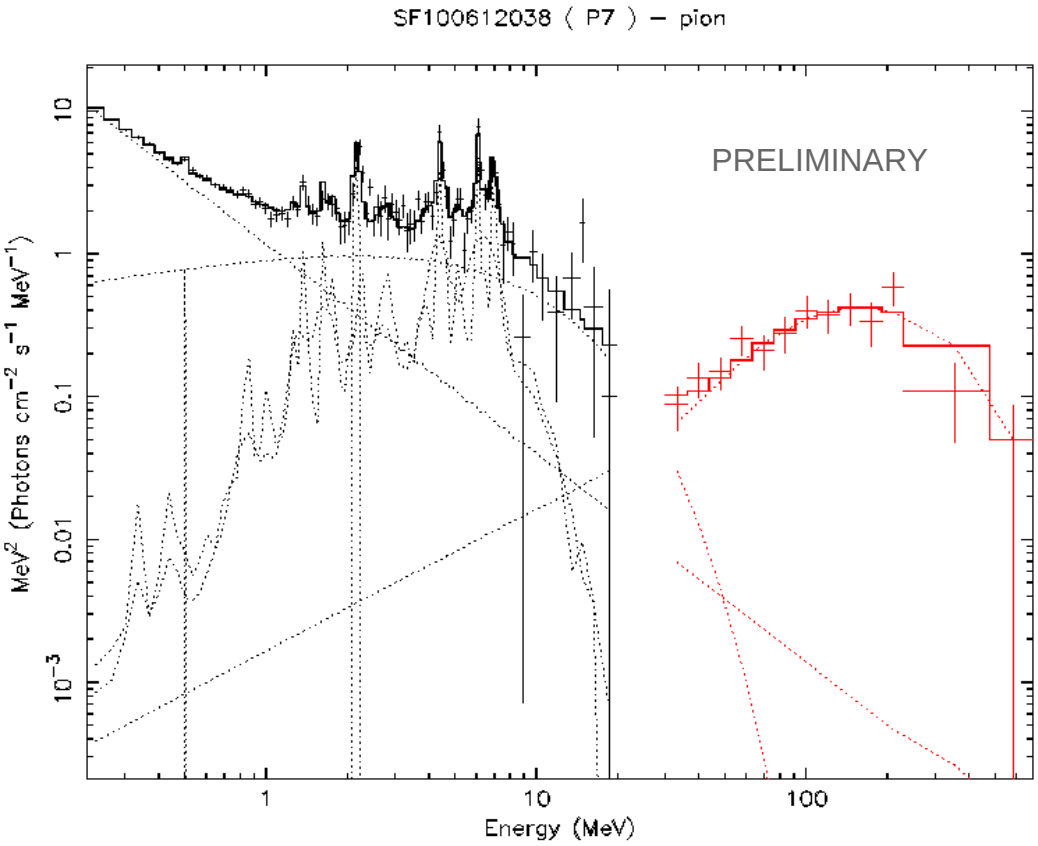
- **New cuts on ACD variables improve the LLE Signal to Noise Ratio**





Spectral Analysis of Impulsive Phase

- **For many solar flares spectral analysis was allowed only using P7 LLE selection**

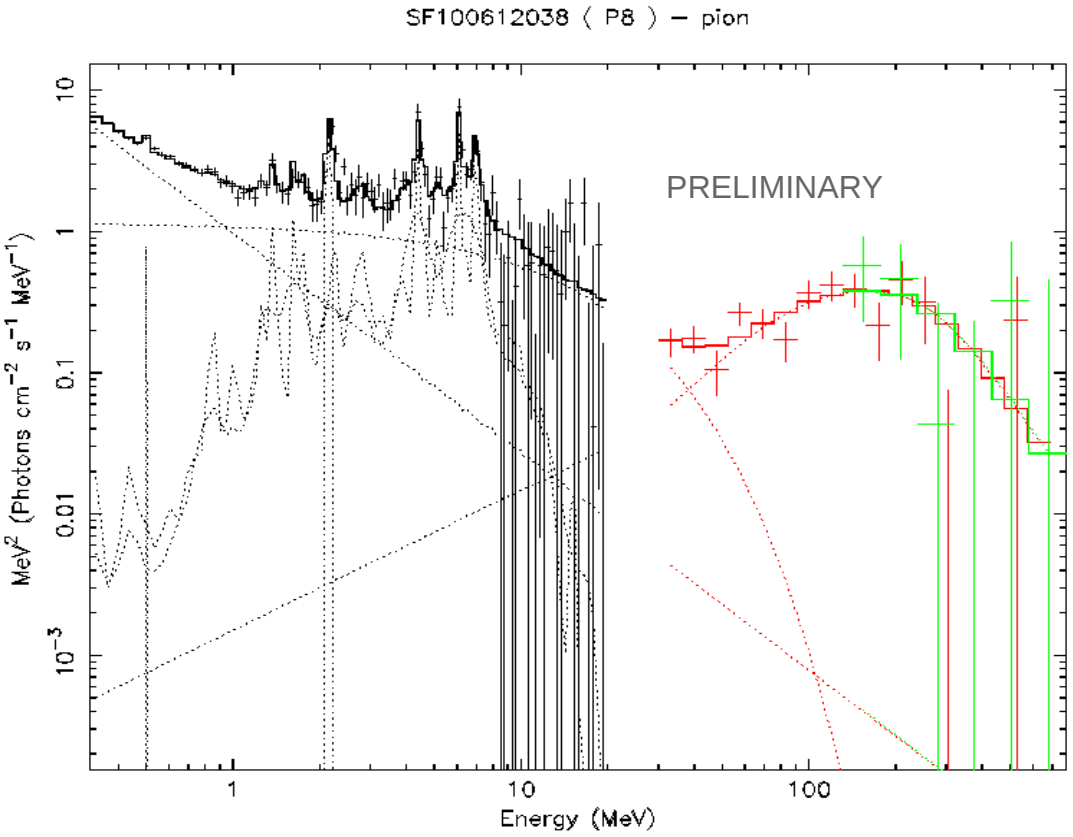


Parameter			Value
Powerlaw 1	PhoIndex		3.46 +/- 0.04
Pegpwrlw 2	PhoIndex		1.69 +/- 0.08
highecut		keV	7085.04 +/- 592.374
gaussian	LineE	keV	2200.0
gaussian	norm		0.109 +/- 0.02
gaussian	LineE	keV	511.0
gaussian	norm		0.10 +/- 0.3
PiontemplateS			6.0 +/- 0.2

BGO, P7 LLE

Spectral Analysis of Impulsive Phase (SF100612038)

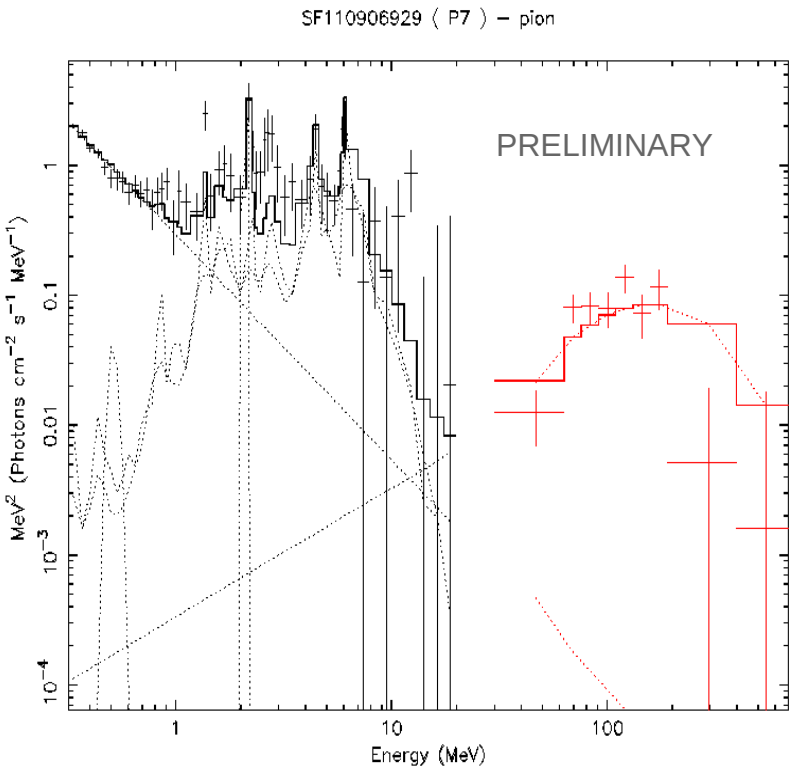
- **Impulsive Spectral Analysis could be done also using Pass 8 Standard Classes**



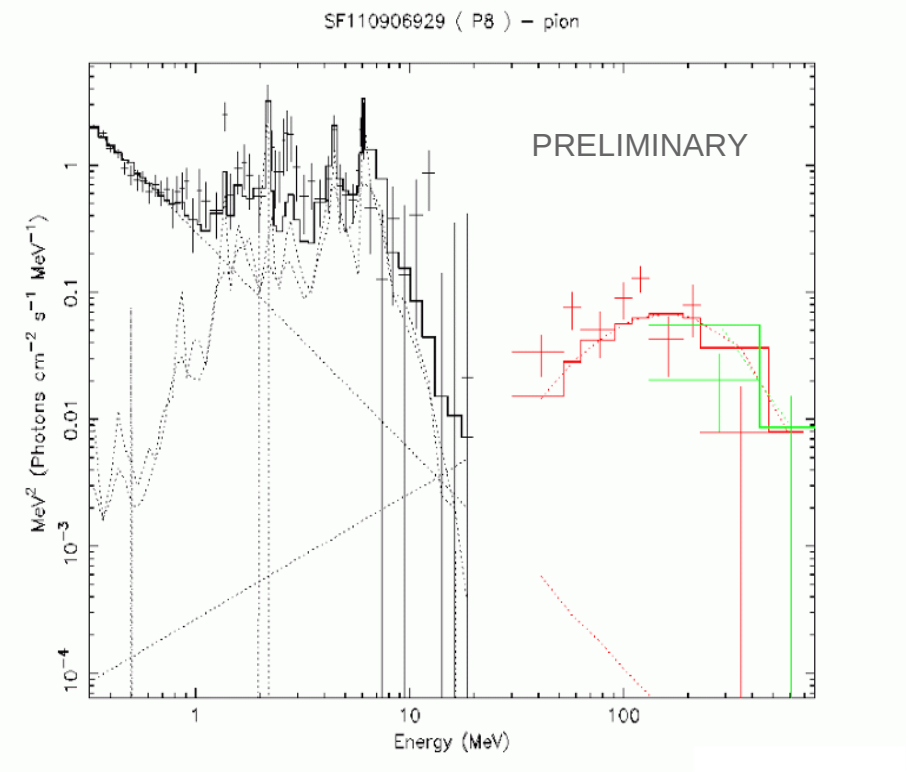
Parameter			Value
Powerlaw 1	PhoIndex		3.5 +/- 0.1
Pegpwrlw 2	PhoIndex		2.0 +/- 0.3
highecut		keV	1.39E+04 +/- 0.30E+04
gaussian	LineE	keV	2200.0
gaussian	norm		0.109 +/- 0.02
gaussian	LineE	keV	511.0
gaussian	norm		0.10 +/- 0.03
piontemplateS			6.0 +/- 1.9

BGO, P8 LLE, P8 R100

Spectral Analysis of impulsive phase (SF110906929)

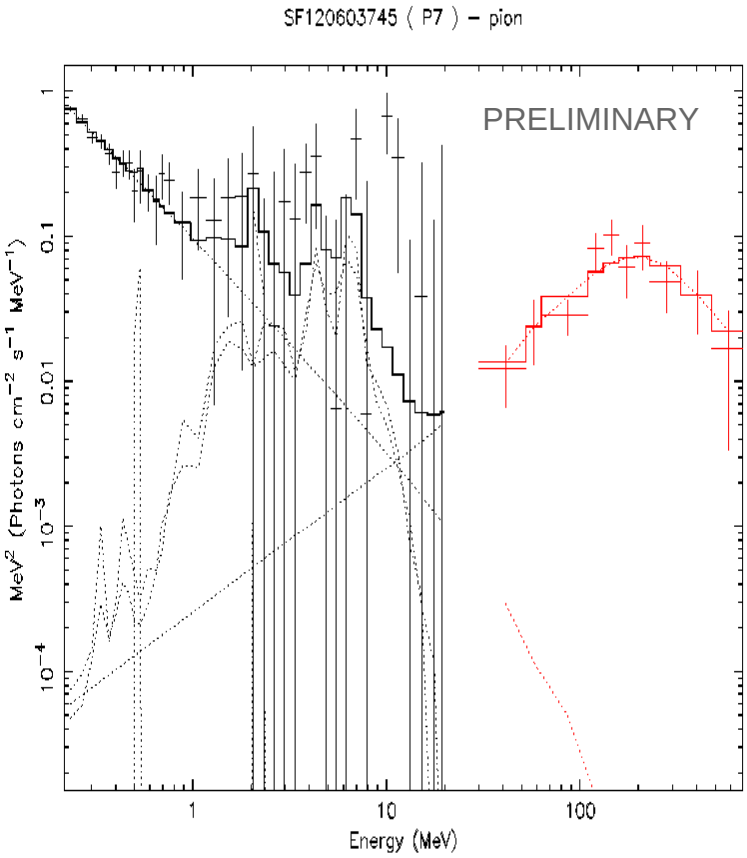


BGO, P7 LLE

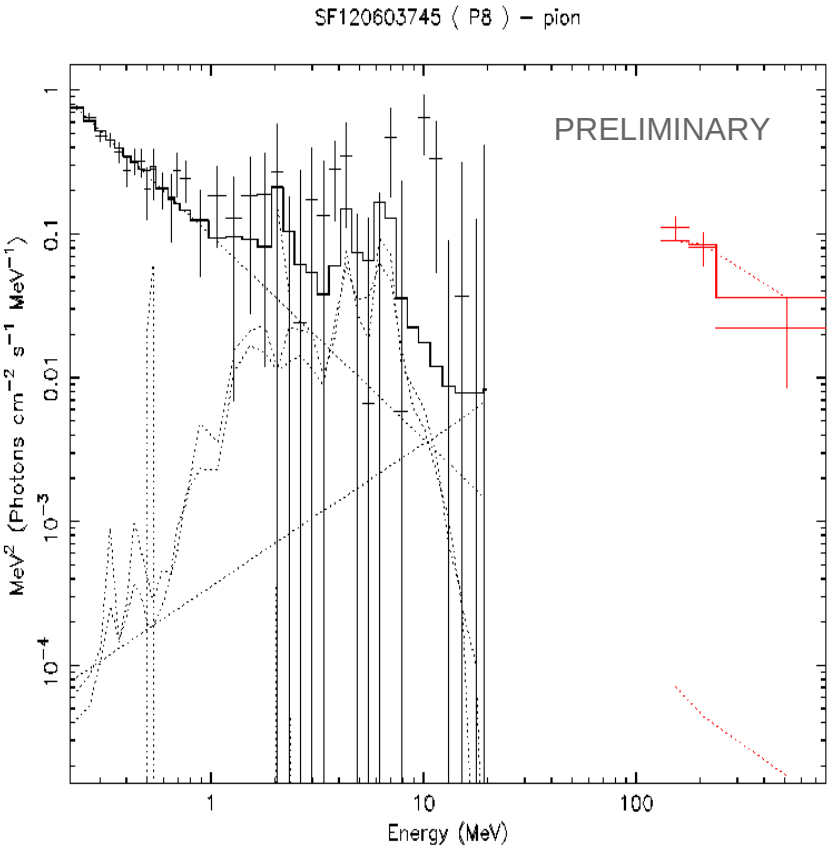


BGO, P8 LLE, P8 R100

Spectral Analysis of impulsive phase (SF120603929)



BGO, P7 LLE



BGO, P8 R100

Conclusions and Future Steps

- **Preliminary results are in agreement with Pass 7 but with larger Signal to Noise Ratio**
- **Pass 8 allows to study the Impulsive Phase of Solar Flares with Standard selections**
- **Pass 8 improves the selection of LLE data**
- **A dedicated Pass 8 Solar Flare Event selection is in development**
- **The study of GBM-BGO bright Solar Flares will allow to constrain better the emission processes**
- **Validation at Low Energy (<100 MeV) is on-going**
- **Pass8 Improvements will allow to better study the low energy gamma-ray part of the spectrum.**

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ありがとう！