Performance of the Fermi-LAT Low-Energy Event Selection

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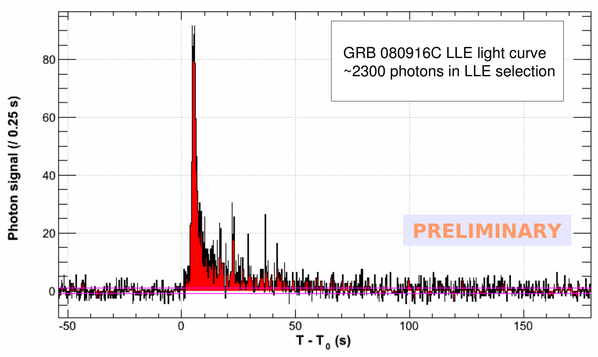
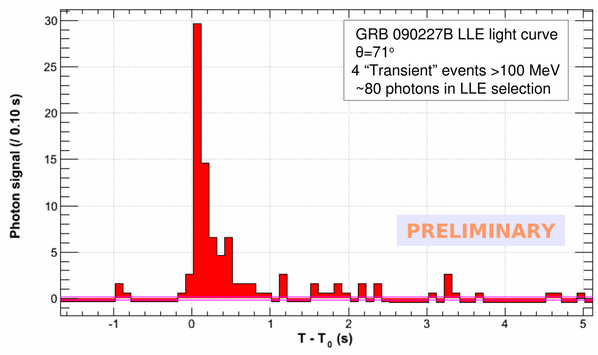
Summary: *Whereas standard science analyses with the Fermi Large Area Telescope (LAT) are restricted to well-reconstructed events, the LLE (LAT Low Energy) event selection is based on relaxed criteria which offer a much higher effective area below 100 MeV. As this new event selection also increases the background levels, it can be used in case of impulsive celestial sources such as the prompt emission of Gamma-Ray Bursts (GRBs) which provide high signal-to-noise ratios. The LLE data have been publicly released for 23 GRBs (and 5 Solar Flares) so far. They will allow any scientist interested in the LAT observations of GRBs to better study their temporal and spectral properties, especially for GRBs with faint emission above 100 MeV and/or observed at inclinations larger than 65 deg in the LAT field of view. In the following, we present a validation study of the Monte-Carlo simulations which are used to derive the LLE Instrument Response Functions (effective area, energy resolution and Point Spread Function), with particular emphasis on the estimation of the associated systematic uncertainties which are relevant for GRB spectral reconstruction based on LLE data.*

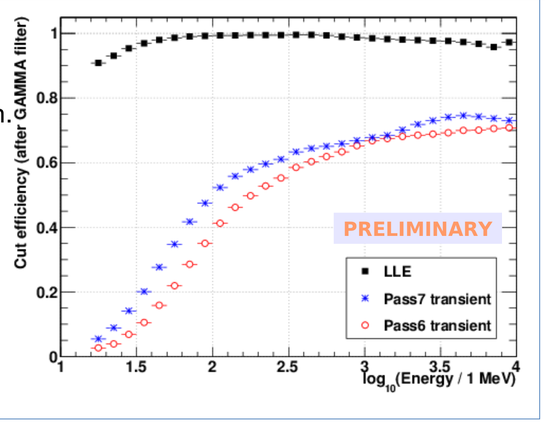
The LLE Event Selection and Effective Area

- Most GRBs are detected by means of the standard event selection (Pass6 or Pass7 Transient-class events) and analysis technique (unbinned maximum likelihood above 100 MeV).
- Some other GRBs are too weak, too soft, or at a too high off-axis angle (θ>70°) to be significantly detected.





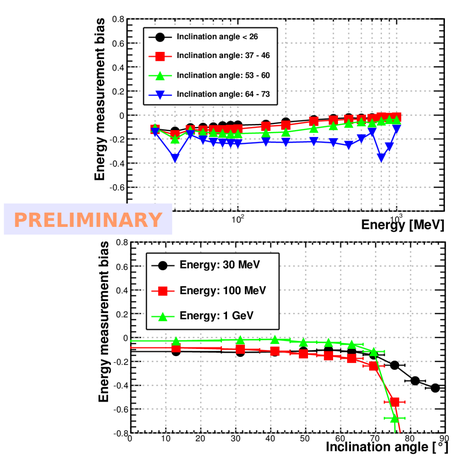
- We introduced the LLE event class, corresponding to relaxed selection criteria.
  - Keeps all events passing the onboard GAMMA filter, with a track found in the tracker by the full reconstruction.
  - Significantly higher effective area below 100 MeV and at larger off-axis angles: efficiency 14 times (resp. 7 times) larger for LLE than for Pass6 (resp. Pass7) at 30 MeV on axis.

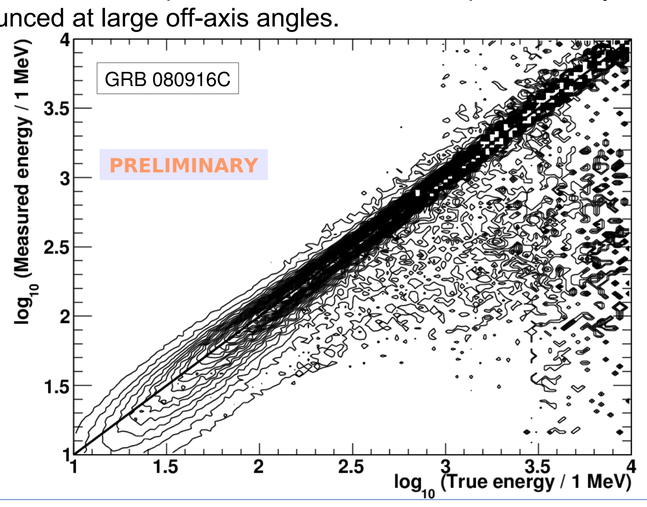


- Despite a higher background, it provides the needed statistics to study the temporal and spectral properties of GRBs and Solar Flares at tens of MeV energies in the LAT.

Event Reconstruction and Response Matrix

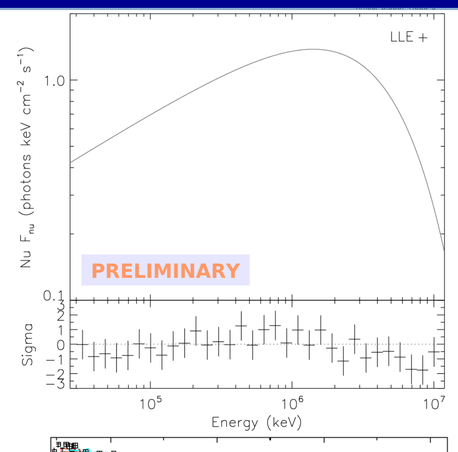
- The estimate of an LLE event's energy estimate is the sum of the raw energy deposited in the calorimeter (corrected for losses between modules) and of the energy deposited in the tracker (TKR).
  - Negligible bias and an energy resolution of ~50% (resp. 10%) at 30 MeV (resp. 100 MeV) up to an off-axis angle θ~70°.
- The estimatte of an LLE event's direction comes from the requirement of a track found in the TKR
  - The LLE Point Spread Function (PSF) is typically twice as wide as for Transient-class events.
- The energy redistribution is mapped in the Detector Response Matrix used in the spectral analysis.
  - Non diagonal component more pronounced at large off-axis angles.



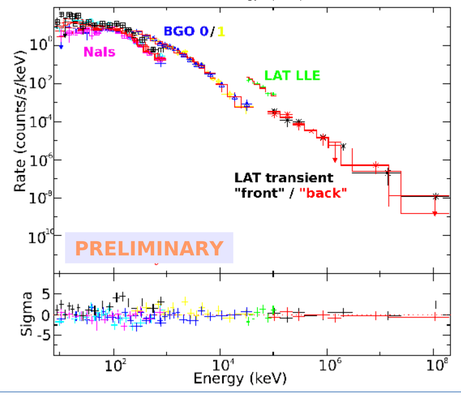


Spectral Analysis Using LLE Data

- Spectral reconstruction of the Vela pulsar spectrum above 30 MeV is consistent with results using the standard analysis technique.
- Only observed difference is a 10% lower flux using LLE data.



- The LLE selection allows to recover the prompt emission from GRBs from 30 MeV to 100 MeV, filling the energy gap between the Gamma-Ray Burst Monitor (8 keV – 40 MeV) and the LAT standard event selection.
- Fit of GRB 090510 spectrum with a Band function with an additional power-law component.
  - Statistical significance of the extra power law increased from 5.6σ to 9σ with LLE data in the fit.

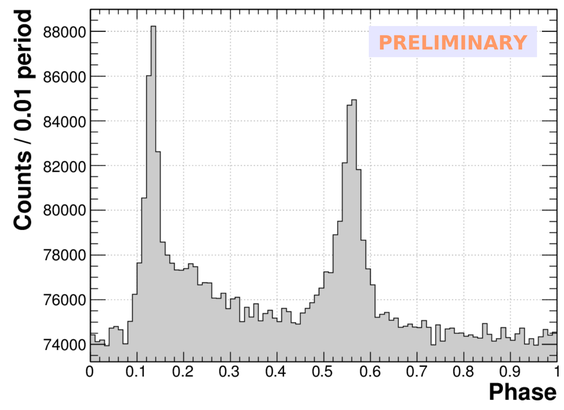


Validation of LLE Instrument Response Functions

- Discrepancies between the real instrument's response and the Monte-Carlo (MC) simulation used to build the DRM can cause systematic errors in the spectral fits.
- Evaluation of systematic uncertainties in LLE effective area and PSF at various event energies, source off-axis angles and background levels.
  - Using 2 years of observations of the Vela pulsar.
  - Comparing efficiencies of the successive selection cuts applied when building the DRM.

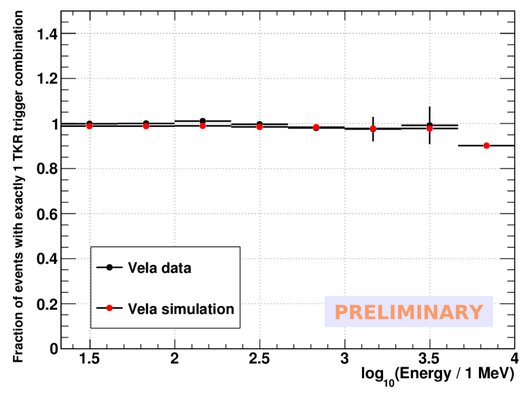
THE VELA PULSAR AS CALIBRATION SOURCE

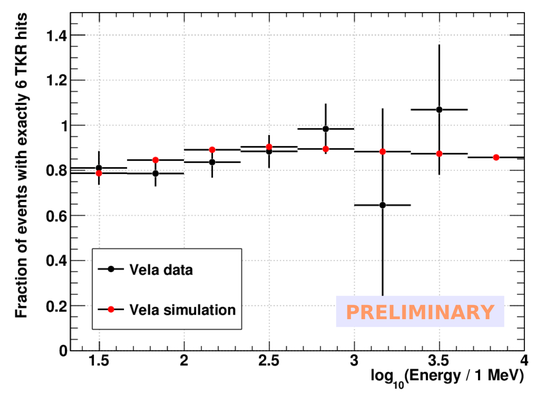
- Bright and clean source of photons.
- A gamma-ray signal which can be temporally isolated from the background via pulse folding.
- Vela phasogram obtained from LLE events contained in an energy-dependent region of interest equal to the 68% of the PSF containment, and for θ<30°.



TRACKER TRIGGER AND TRACK FINDING

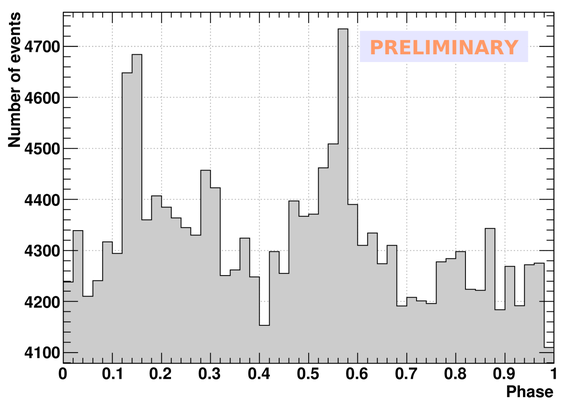
MC / data comparison of TKR efficiency (fraction of LLE events with exactly one "3 TKR bi-layers in a row", main trigger) and track finding (fraction of LLE events with 6 TKR hits, minimum needed to make a track).

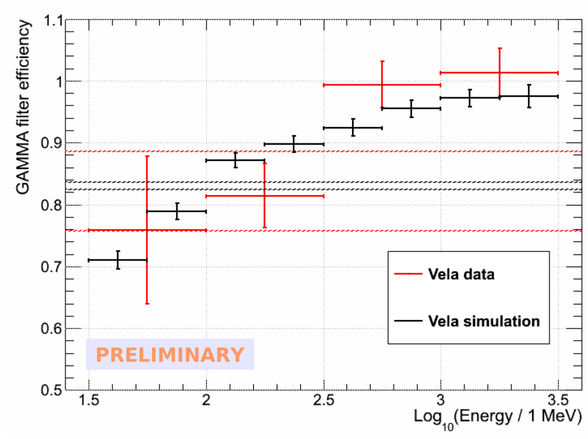




ONBOARD GAMMA FILTER

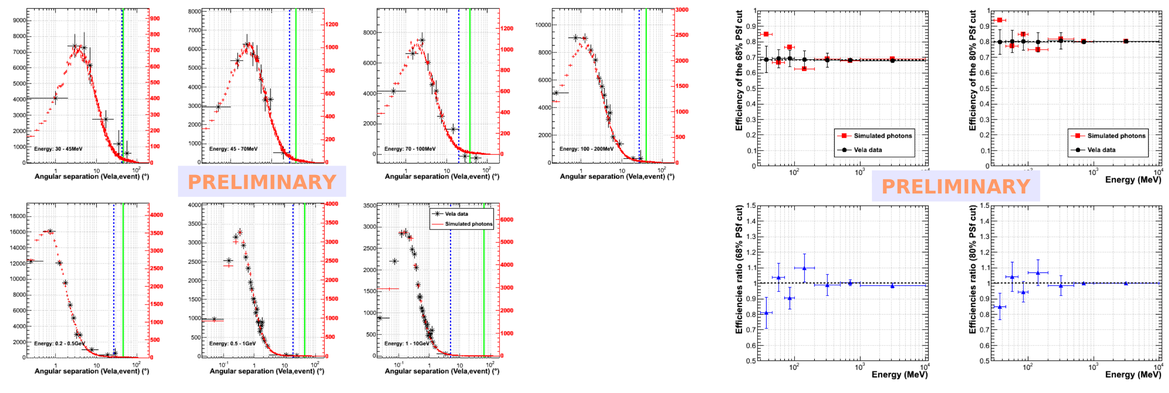
MC / data comparison of GAMMA filter efficiency using the DGN filter which provides an unbiased sample of events as seen onboard.





POINT-SPREAD FUNCTION AND SPATIAL SELECTION

MC / data comparison of LLE PSF in different bins of energy (all events with θ<40°, from 30 MeV to 10 GeV): green lines = 95% containment radius of MC PSF, blue lines = explored radius.



Conclusions

- Spectral reconstruction with LLE data is validated.
  - Systematic uncertainties are reasonable (typically <20% globally) and under control.
- LLE data for GRBs and Solar Flares is public at the Fermi Science Support Center.
  - All GRBs with >4σ in LLE event selection, observed at θ<90°.
  - Release of past GRBs with GCN notice + any new GRB (almost immediately).
  - Data products: data (± 1000s around trigger time) and responses, quick look plots.