Recovering LAT transients' signal below 100 MeV

"LAT Low-Energy" performance and validation

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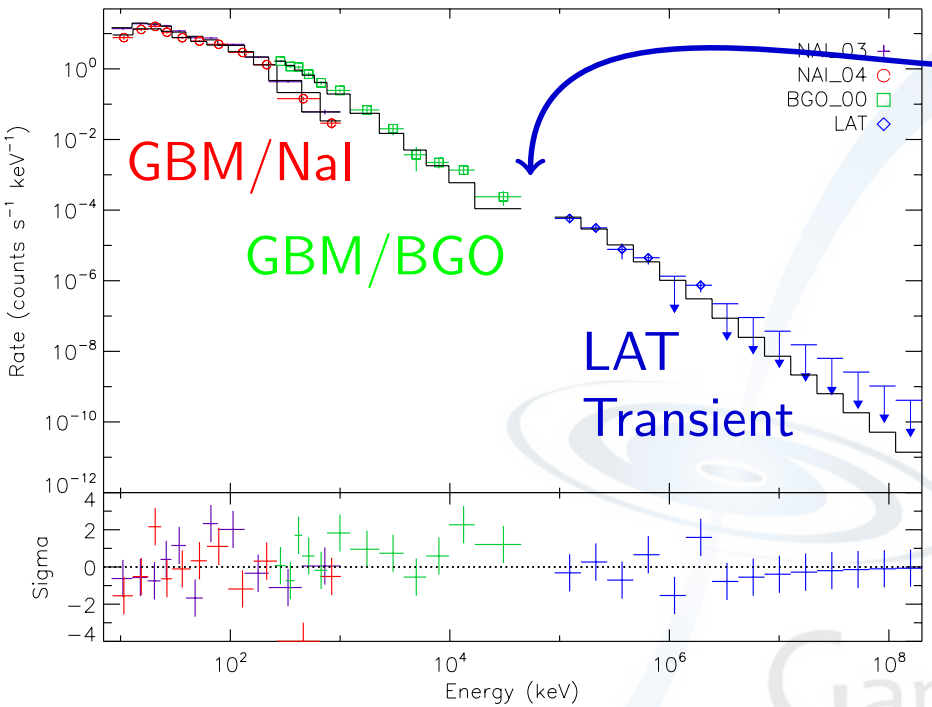
on behalf of the *Fermi* LAT & GBM collaborations

Roma, May 10th 2011

Motivation



Standard GRB analysis

- GBM: 8keV – 40MeV
- LAT Transient class: >100MeV

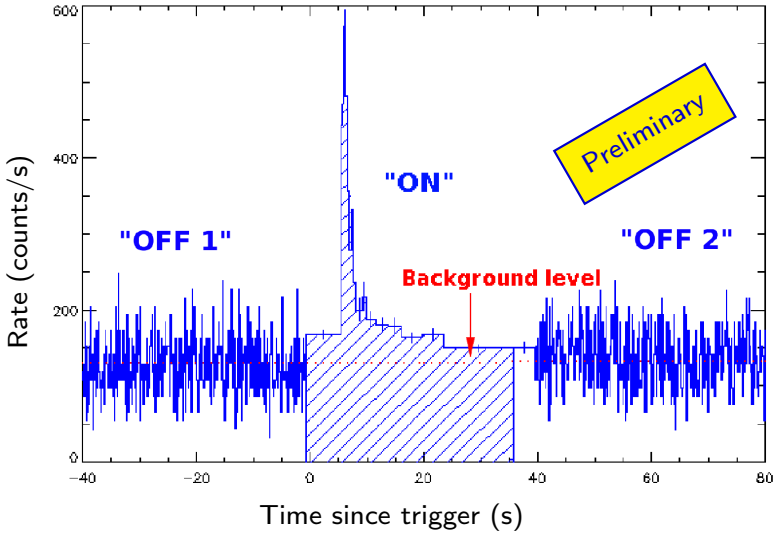
→ energy gap: 40 – 100MeV

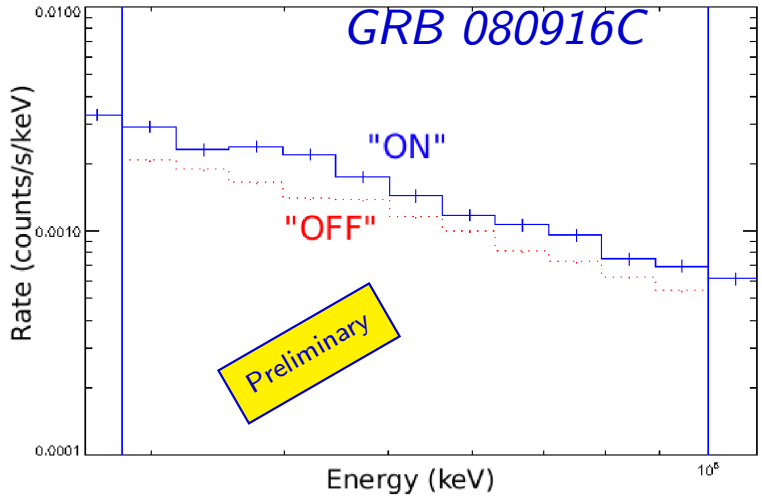
Loosened LAT data selection

- higher statistics, especially <100 MeV
- fill in the energy gap
- better constraints on spectra and models

(GRB 080916C count spectrum: A.Abdo et al, Science 323:1688 (2009))

Analysis technique

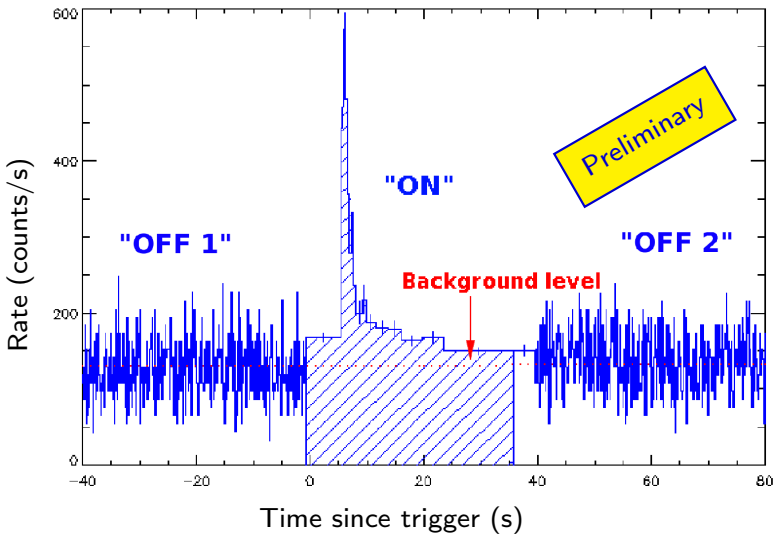


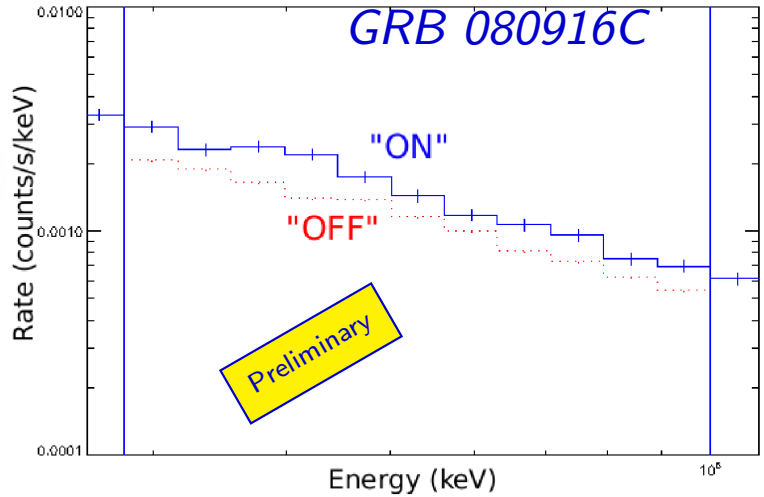


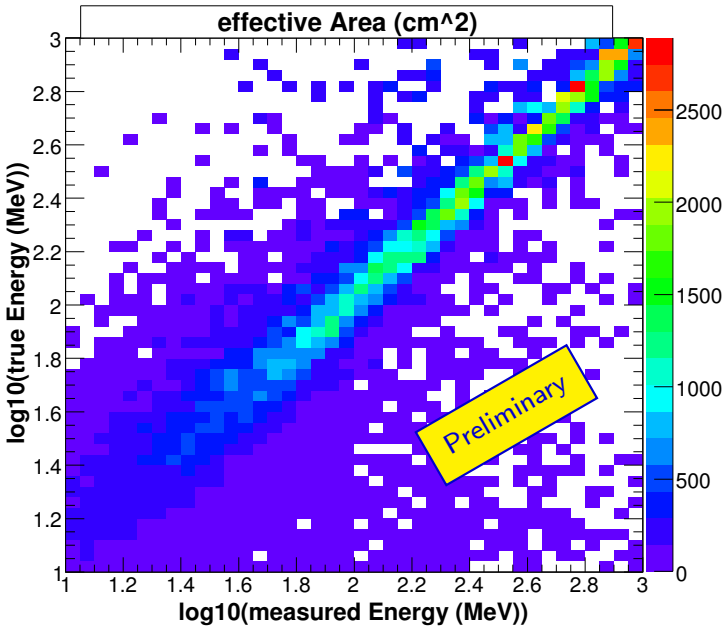
1. Background subtraction

- ON and OFF regions
- OFF: fit background rate vs. time in each energy bin
- ON: extrapolated bkg rate gets subtracted

Analysis technique







2. Detector Response Matrix (DRM)

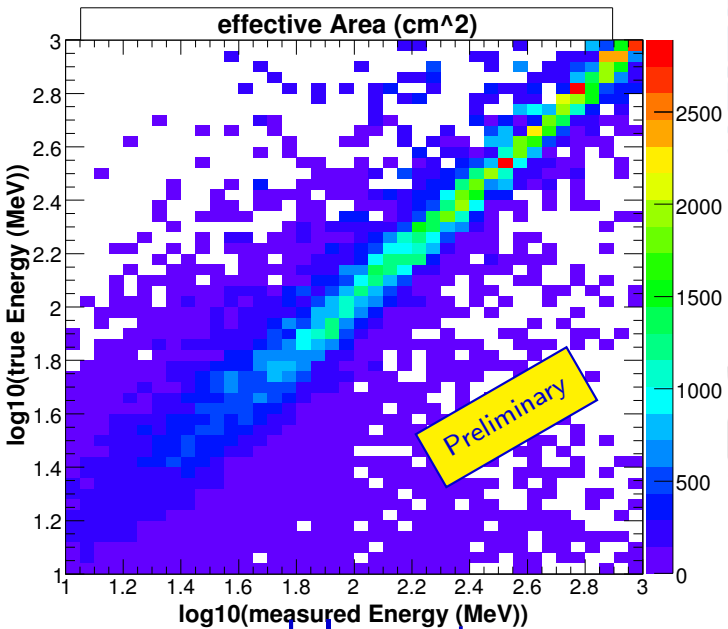
Full simulation of Monte-Carlo photons

- point source, power-law spectrum
- same pointing history as GRB
- DRM: efficiency convolved by the energy redistribution

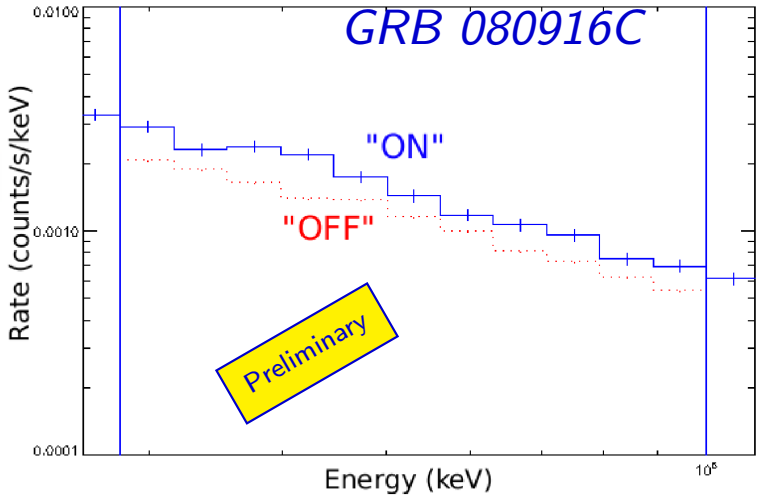
Analysis technique

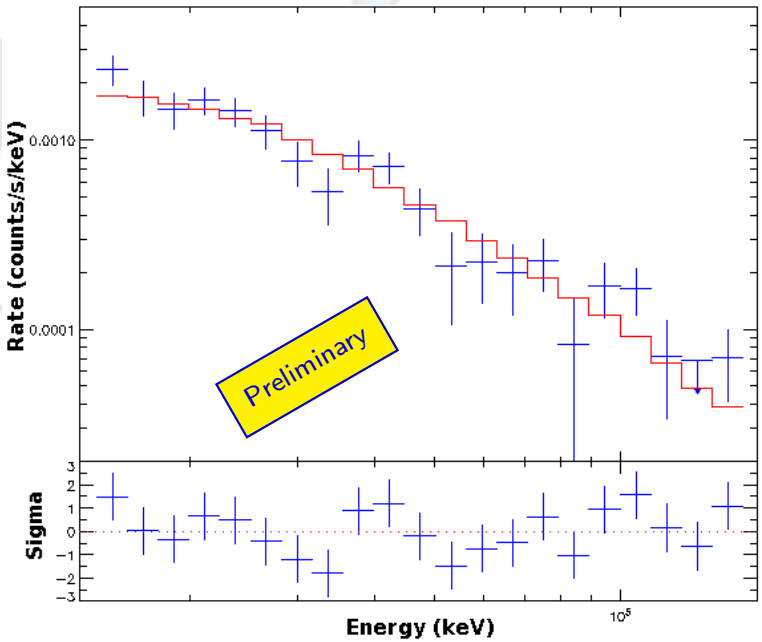
3. Fit

forward-folding technique:
model convolved by the DRM
vs. observed rates



× model spectrum





Performance and validation studies

Instrument's Response Functions

- Acceptance
- Energy redistribution
- Point Spread Function (PSF)

Systematic errors in spectral analyses

- successive cuts efficiencies: data vs MC
- construction of the response matrix (self consistency)
- minimization method: not new $\Rightarrow$ already tested

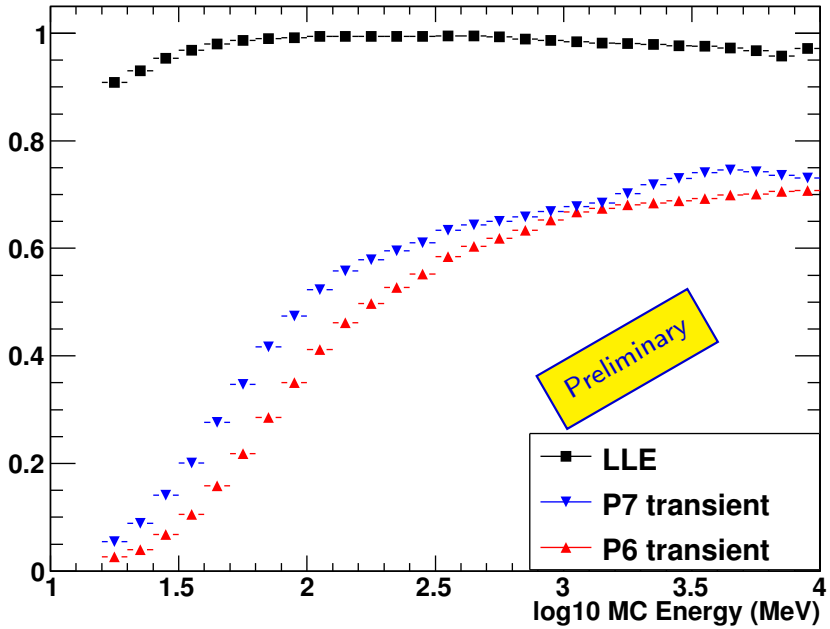
Cut defintion & acceptance

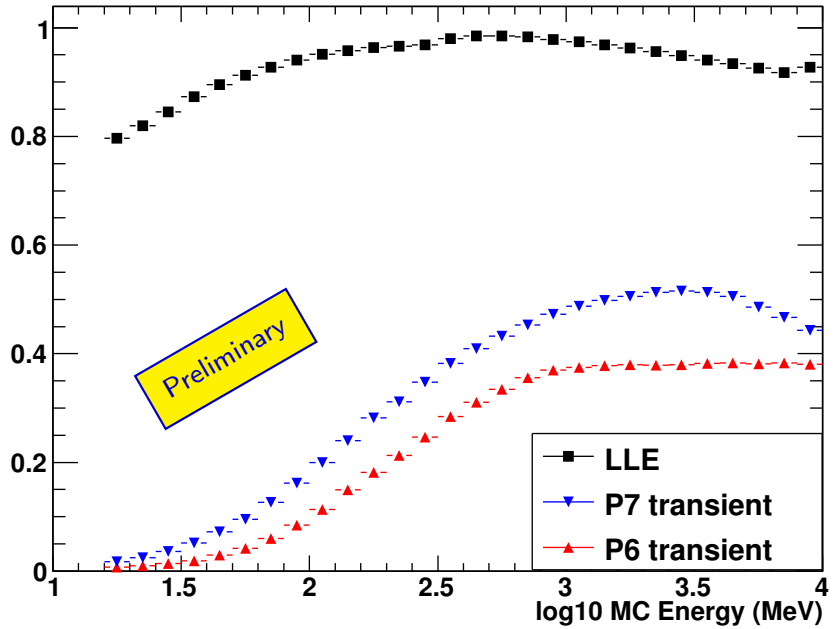
Define a minimal event selection: "LAT Low Energy" (LLE)

- on-board photon filter
- at least one track found
- +conditions on on-board trigger

LLE efficiency / On-board filter efficiency, vs. E, MC photons:

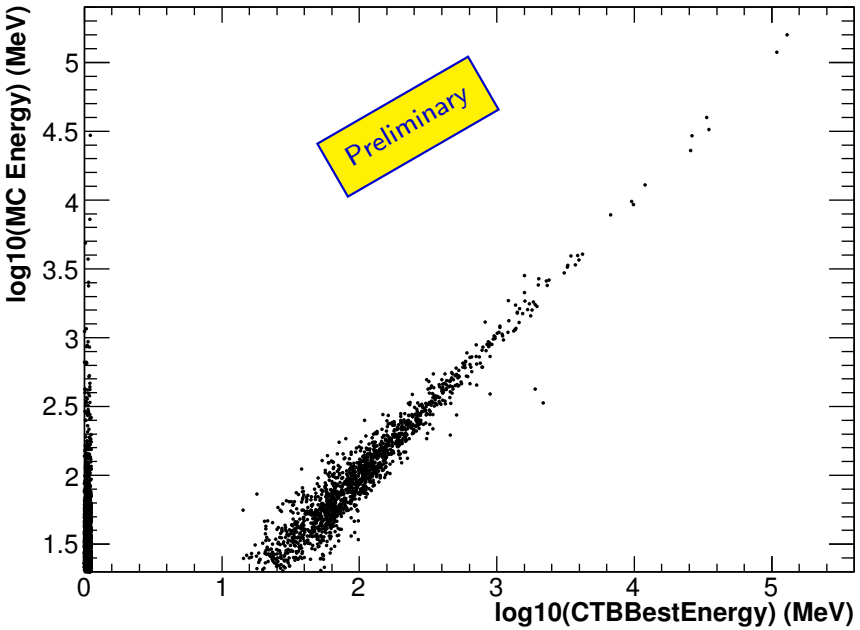
$0° < \theta < 30°$ $60° < \theta < 80°$



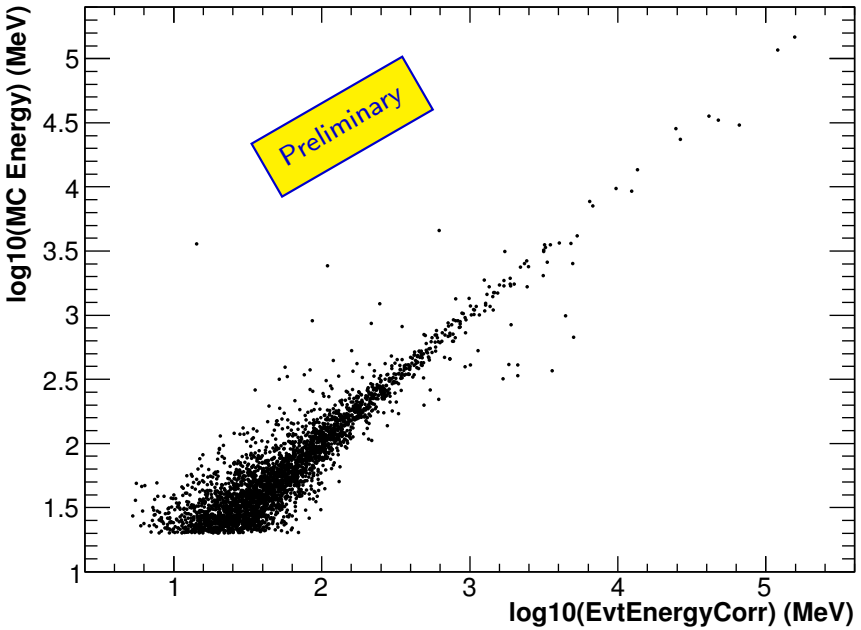


Energy estimator

Usual estimator:



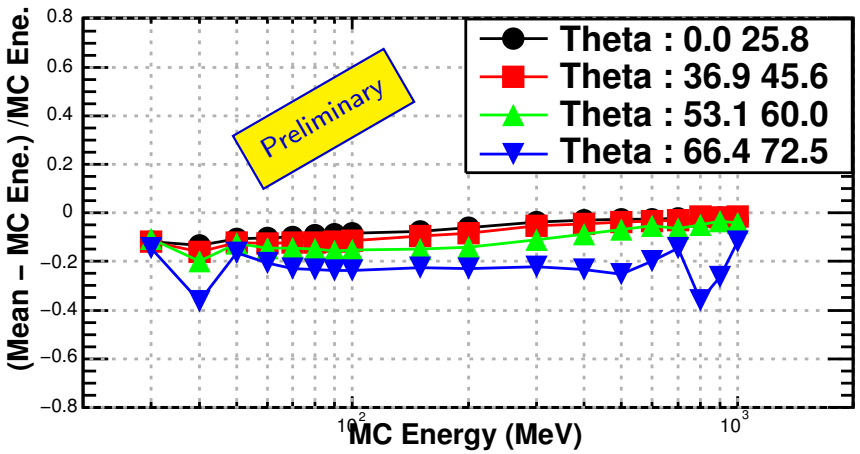
LLE estimator:

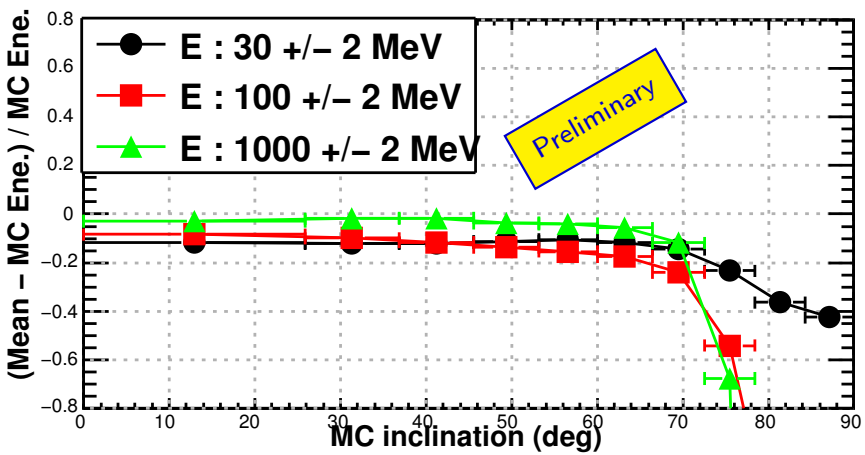


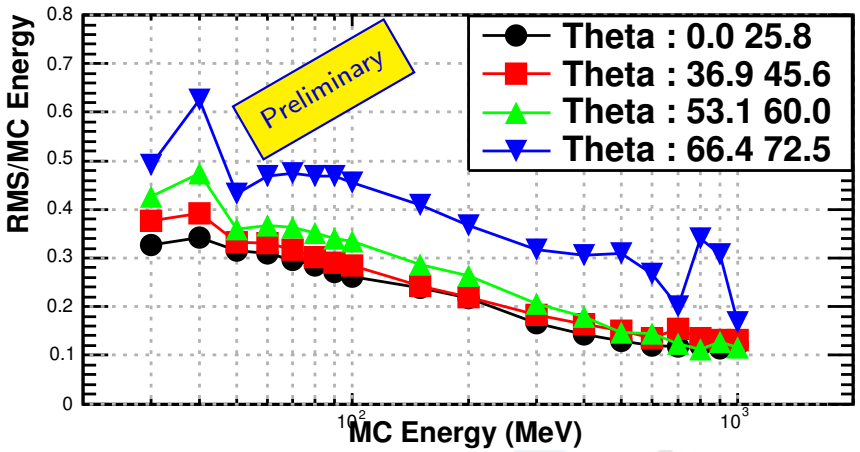
Energy measurement

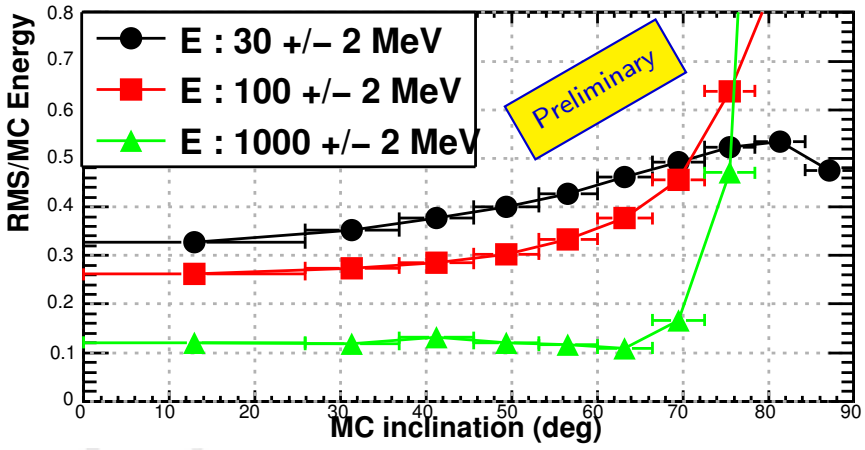
- allowed by "one track" criterion
- some low quality LLE events have no "best energy" found (E=0 on the left plot)
- estimator for LLE: counting hits in the tracker (+ calorimeter energy for events >80MeV)

Energy: biases and resolution









- low biases, reasonable resolution ($\sim 2\times$ usual analysis)
- very-inclined high-energy events can not reach the calorimeter

Point Spread Function

Direction measurement

- allowed by "one track" criterion
- implies a PSF definition
- allows to define a spatial selection (Region of Interest, ROI)

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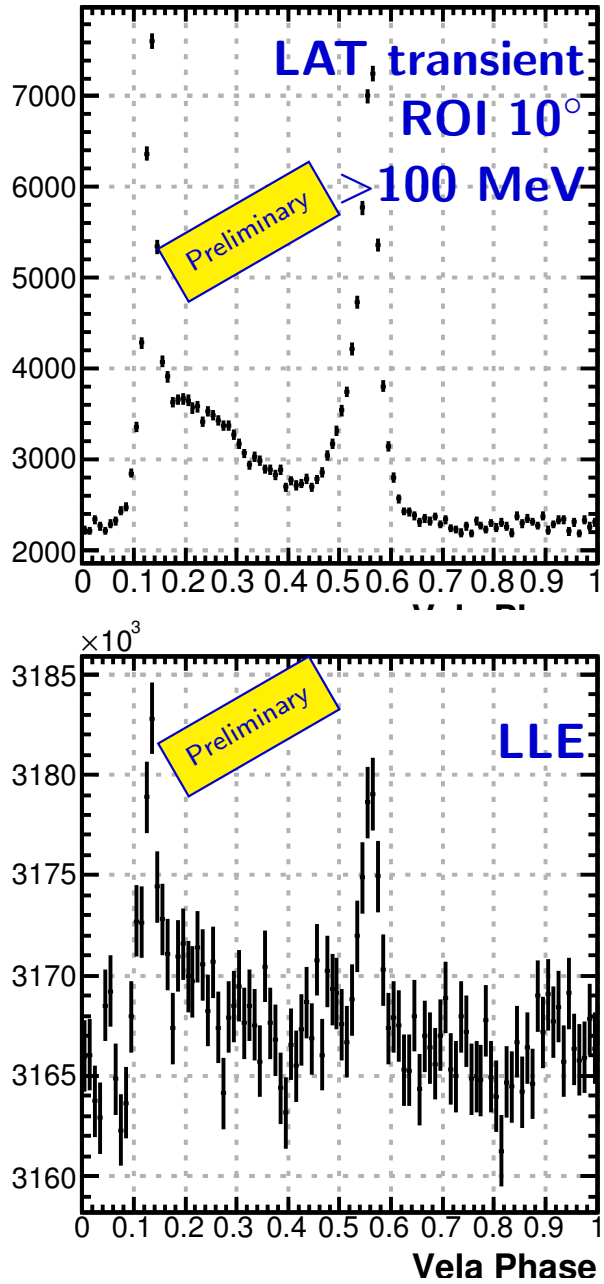
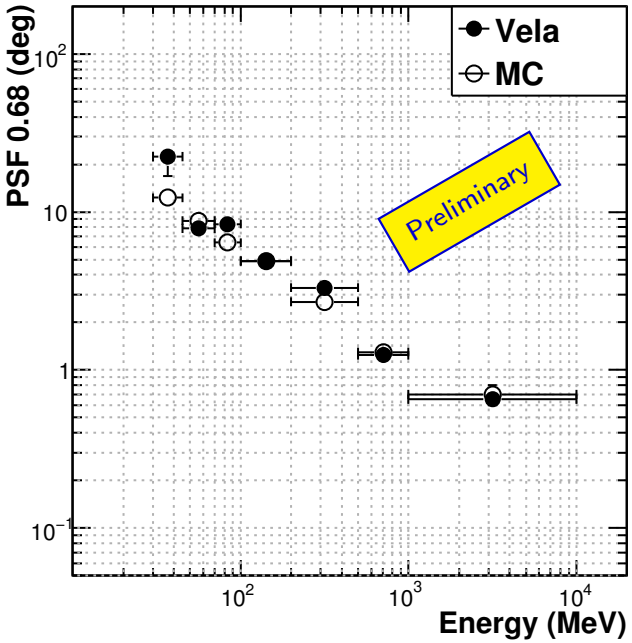
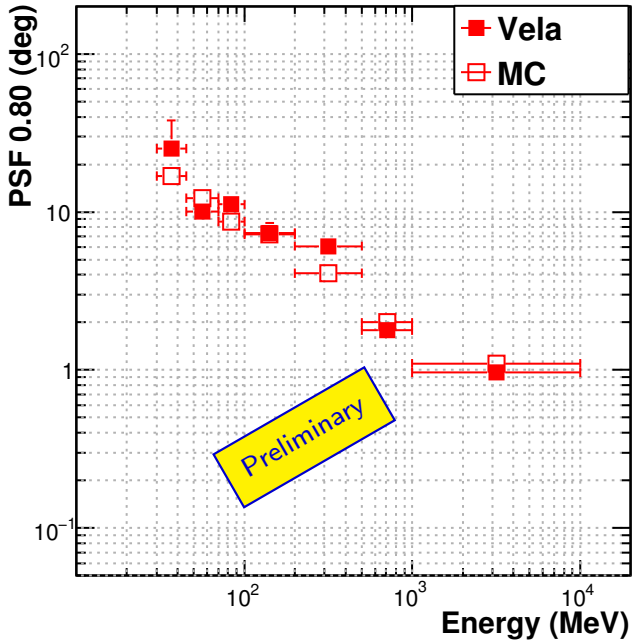
Validation study:

- bright source of sky photons
  $\Rightarrow$ Vela: brightest LAT pulsar, location and spectrum well known
- pulsar $\neq$ transient: "ON" and "OFF" phase intervals
  "ON" = 2 peaks + bridge, "OFF" = (0.7 – 1.0)
- data: Vela pulsed signal, bkg-subtracted
- vs. MC photons, same spectral shape as the pulsar



PSF VALIDATION RESULTS





$(0 < \theta < 40^\circ)$

- observation and MC in good agreement
- PSF $\searrow$ over E, $\nearrow$ over inclination
- FRONT vs BACK: no significant difference found

Systematic errors in spectral analyses

Two main sources of systematic errors.

1. (Our knowledge of the) instrument's reponse

i.e. how well do our MC reproduce the successive cuts's actual efficiencies:

- on-board trigger
- on-board photon filter
- LLE cut: "one track" criterion
- PSF-based spatial selection (ROI)

Method:

- two photon samples: MC photons and Vela bkg-subtracted pulsed emission
- compute cut's efficiency (or equivalent) for both samples $\rightarrow$ ratio
- statistical uncertainty on ratio yields the systematic error

2. The reconstruction method

- construction of the response matrix (check self consistency)
- minimization method: already tested

Trigger efficiency

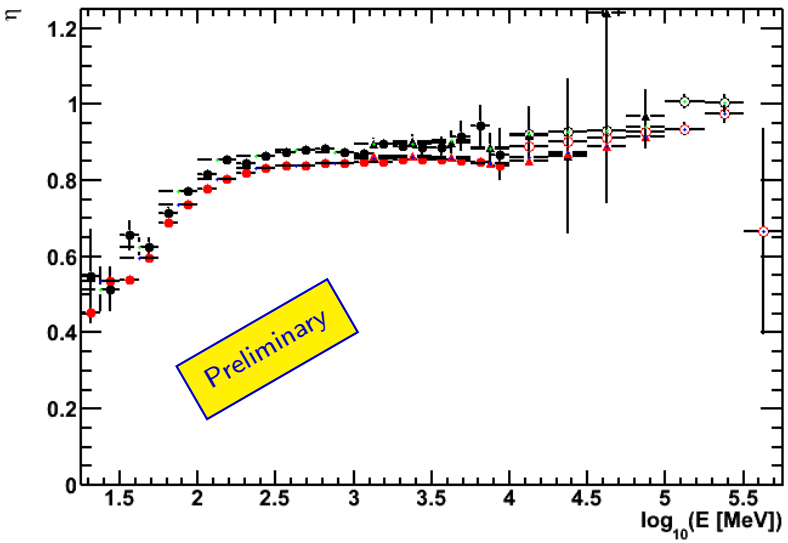
Tracker trigger

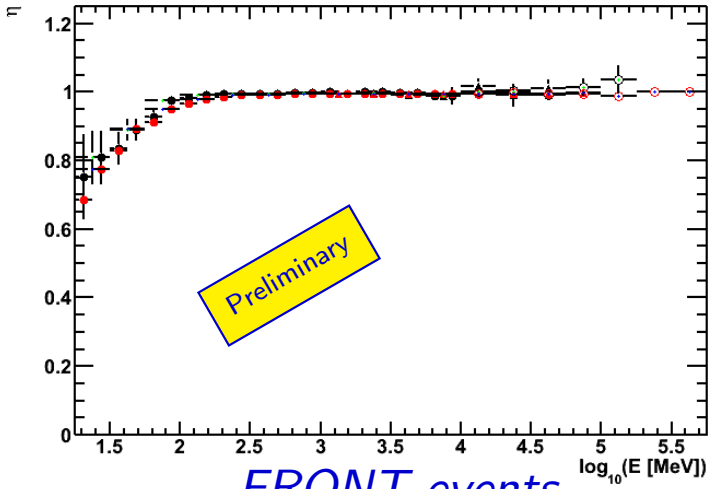
- aka "3-in-a-row": primary trigger for most LLE events
- On-board trigger: efficiency not easily measurable (no "reference")

$\Rightarrow$ Fraction of LLE events "on the border" (have exactly 3 hits in a row)

- MC and data agree within 15%
- Geometry effect: 2%

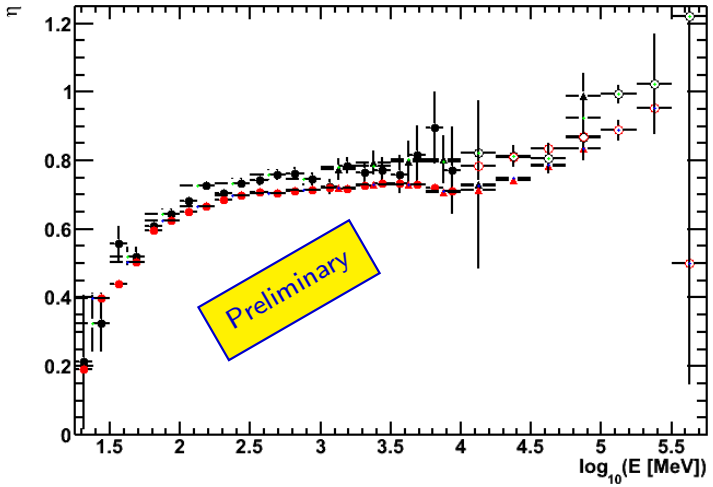
all events





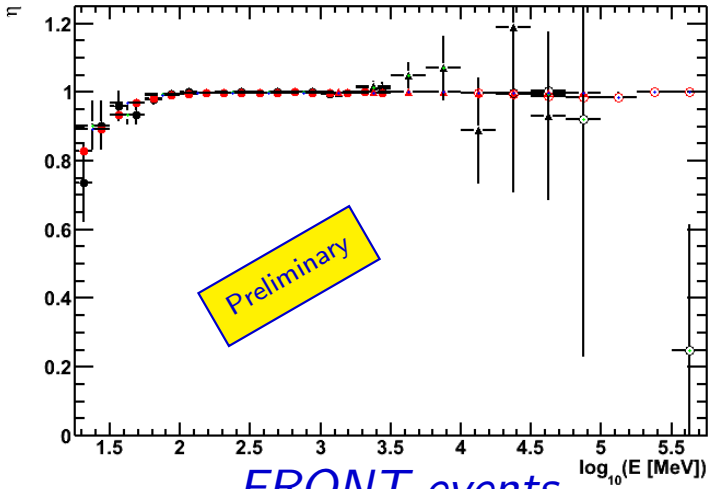
FRONT events

BACK events



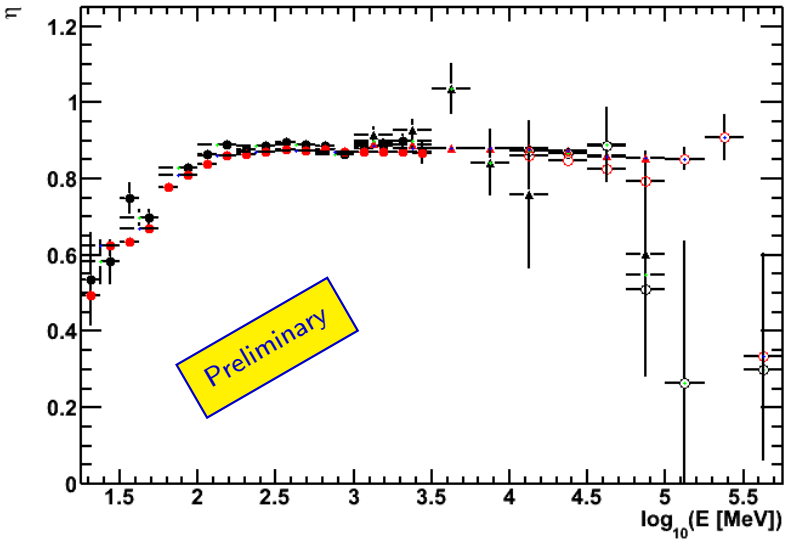
The "one-track" criterion

- Primary cut in the LLE selection
- Same method as for the TKR trigger: fraction of LLE events with minimal nb. hits for defining a Track
- MC and data agree within 15%

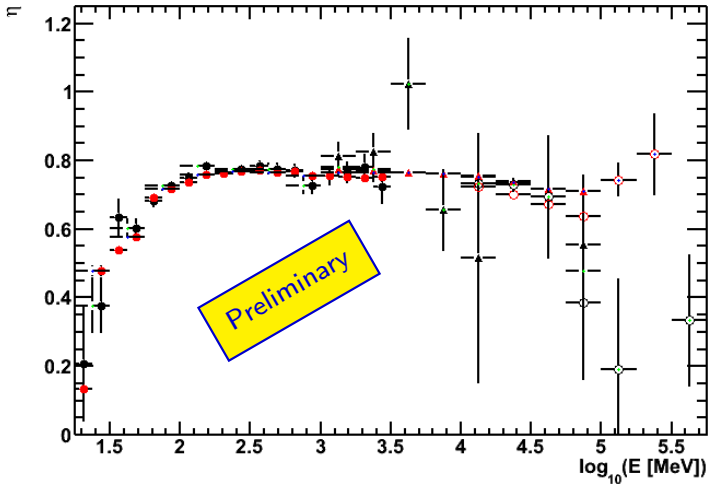


FRONT events

all events



BACK events

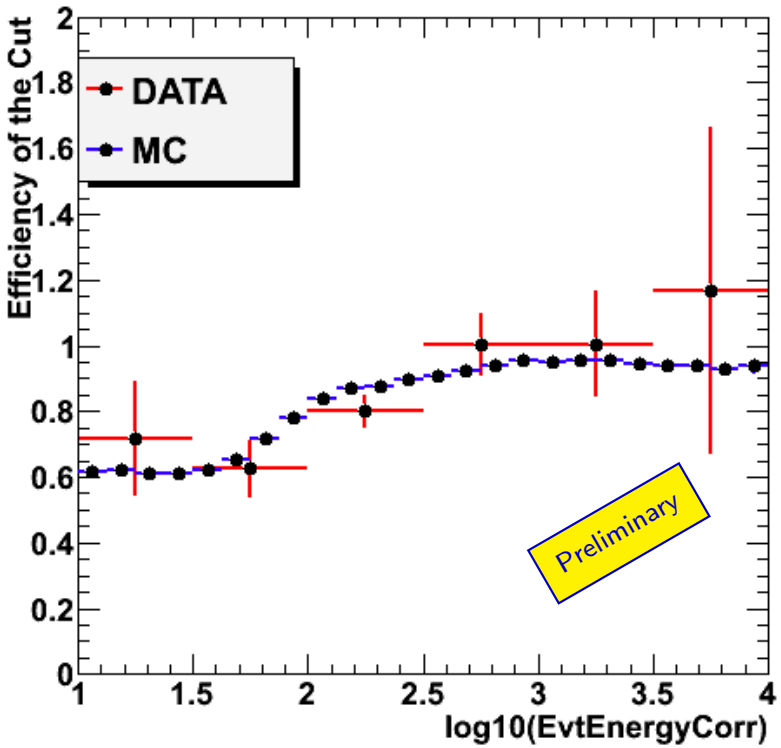


On-board photon filter

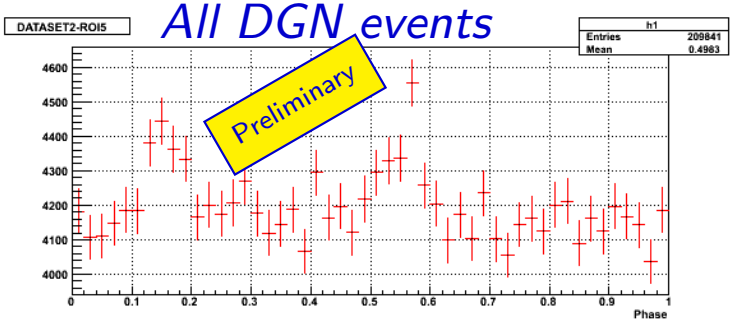
On-board "diagnostic" filter (DGN)

- unbiased sample of all LAT triggers
- allows measurement of an on-board cut efficiency
- low statistics: needs a RoI cut to identify Vela pulses

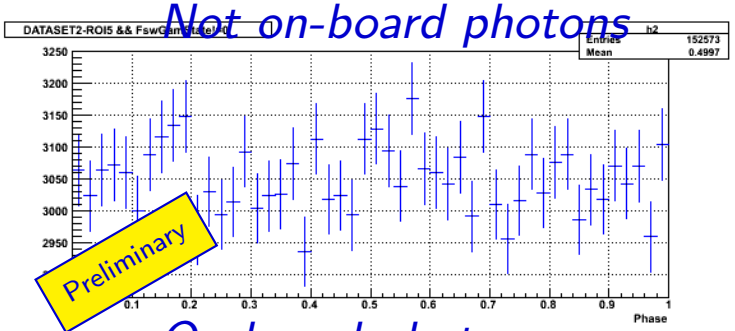
On-board photon filter efficiency



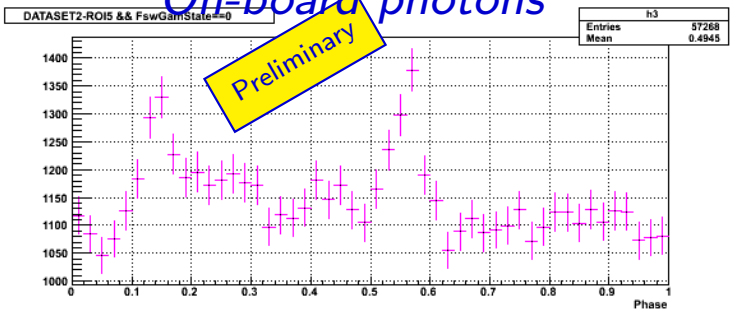
All DGN events



Not on-board photons



On-board photons



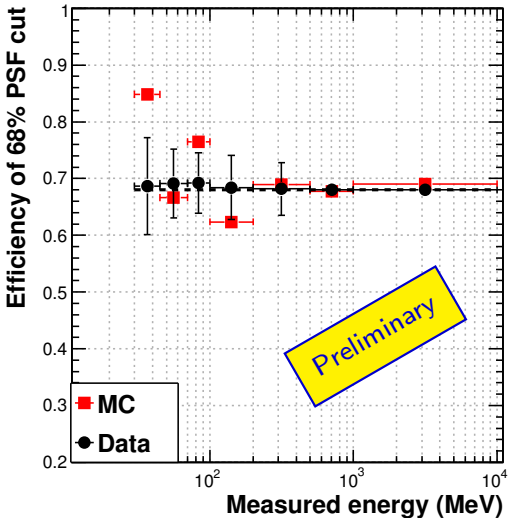
MC and data agree within:

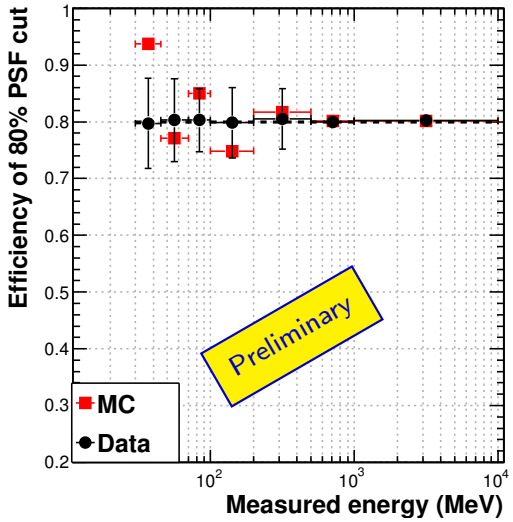
- 11% for a 5°ROI
- 20% <100MeV, 8% >100MeV

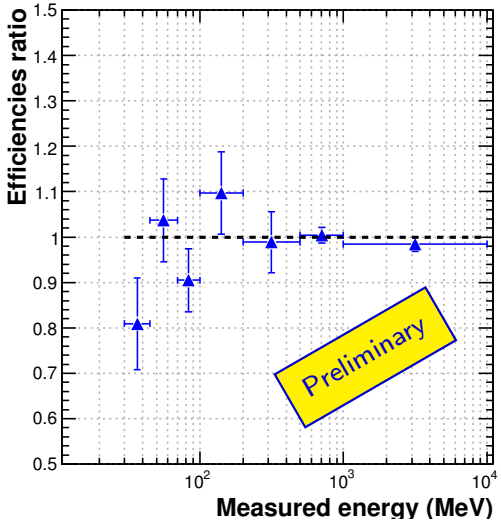
PSF-based RoI

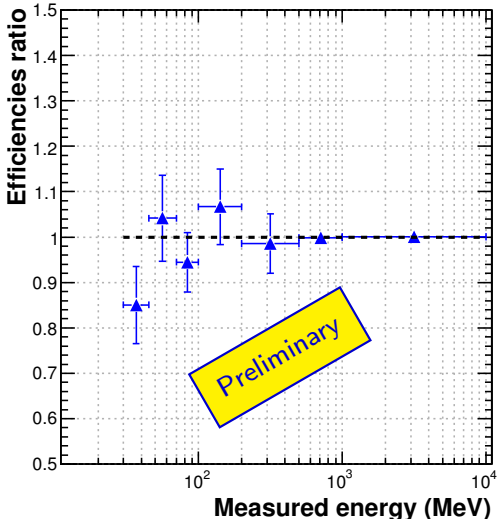
- Energy-dependent cut: 68% or 80% "explored PSF"
- 68% PSF: <30% <100 MeV, <10% >200 MeV
- 80% PSF: lower errors
- conservative values (statistics-limited)

(all events in $0 < \theta < 40^\circ$ *)*

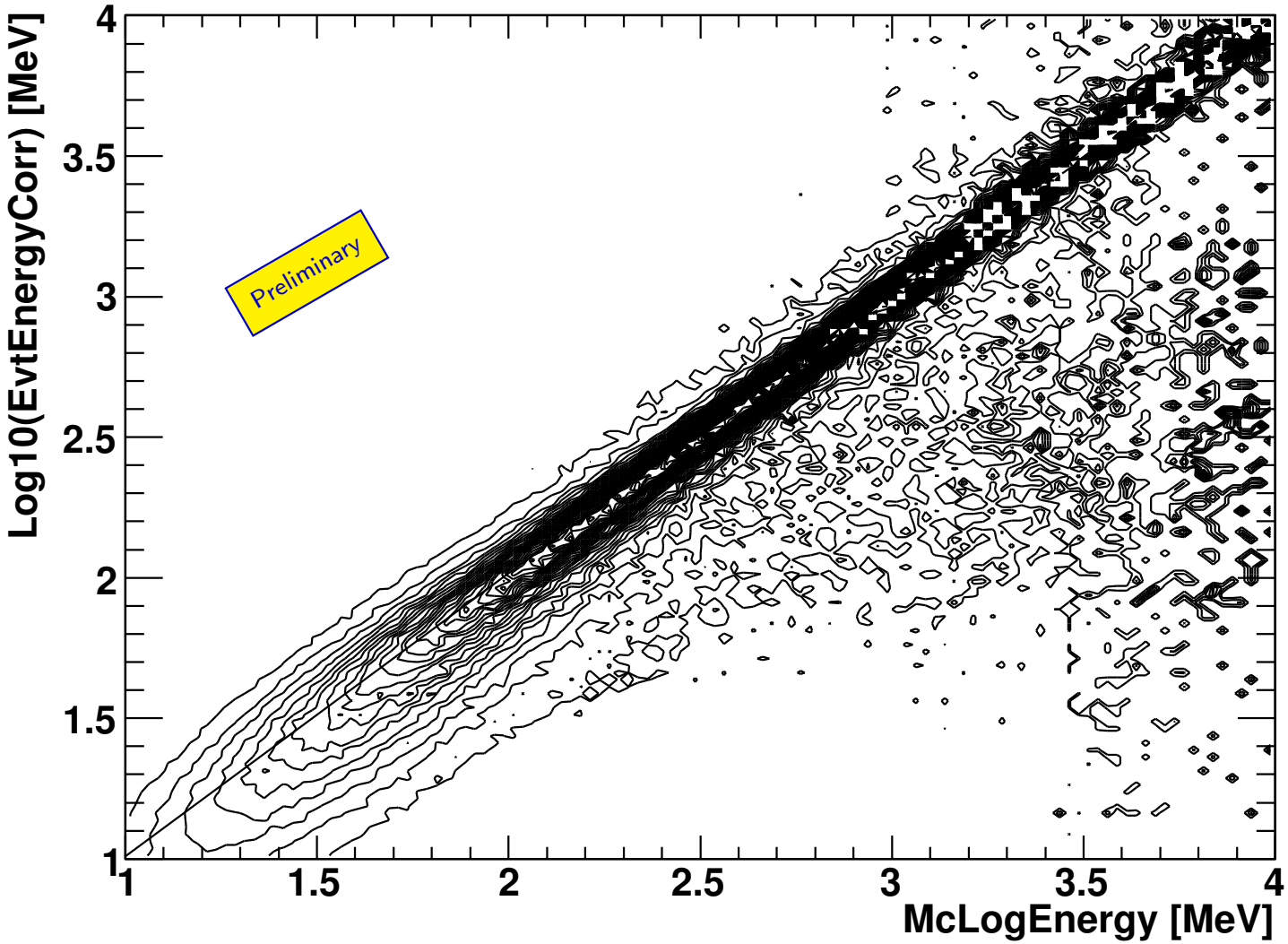






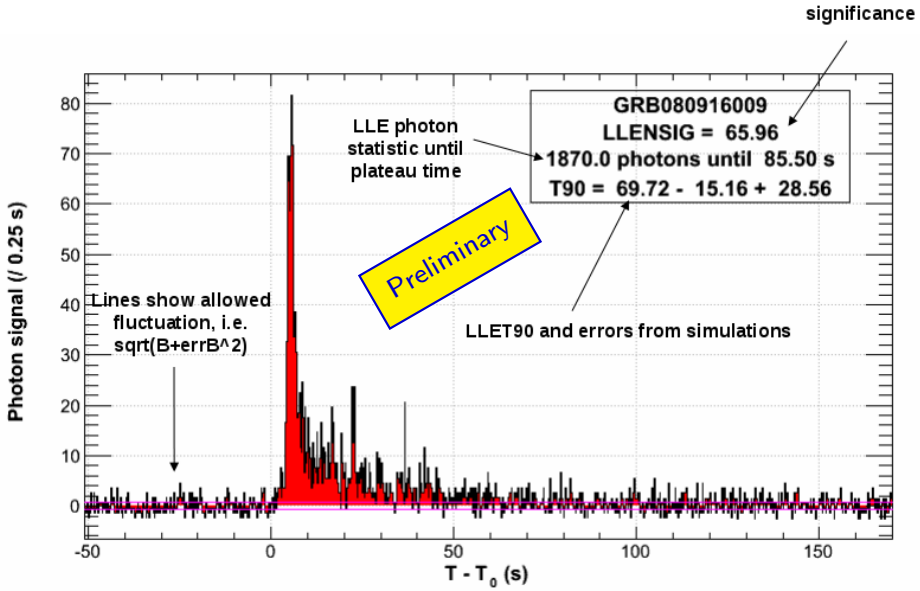


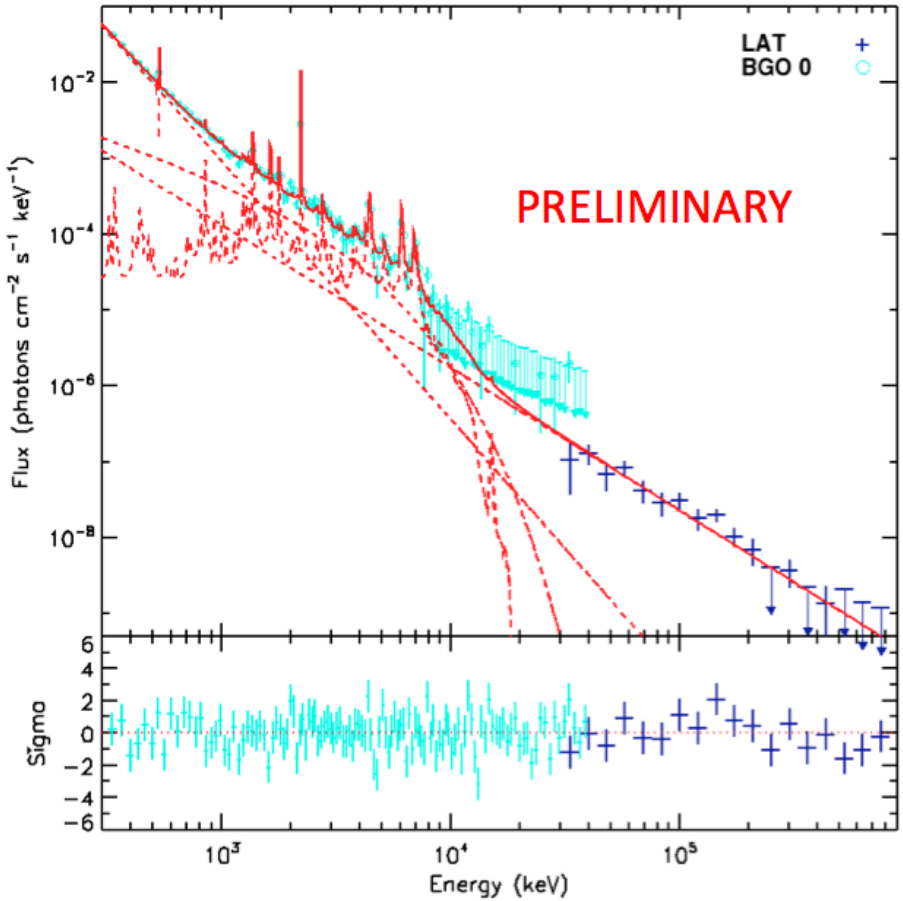
Response matrix



GRB 080916C LLE response matrix ($\theta \simeq 50^\circ$)

GRB & transients' studies





- more detections
- temporal properties

- GRB, Solar Flares, etc.
- spectra better constrained

See poster GRB S2.N23, 35 (F.Piron et al)

See poster SolarSystem S2.N2, 155 (N.Omodei et al)

Summary

The alternative LLE data selection shows good performance:

- high acceptance at all energies and angles
- low energy biases and resolution ($\sim$2$\times$ standard analysis)
- well-defined point spread function ($\sim$ standard analysis at 100MeV)
- good agreement between our MC and real instrument response

Ongoing/upcoming: more analyses of GBM-LAT transients

- more detections
- spectral analyses down to 30MeV in the LAT
- quantitative light curve studies

Take a look to posters GRB S2.N23 (35) and SolarSystem S2.N2 (155)

LLE data public release:

- target date: Fall 2011 – Winter 2012
- triggered data around GRB and SF with response matrix

THANK YOU !