New Fermi-LAT event reconstruction reveals more high-energy gamma rays from GRBs

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Summary: **Based on the experience gained during the first phase of the mission, the Fermi-LAT collaboration has undertaken a radical revision of the event level analysis. This revision affects the entire analysis scheme, from the Monte Carlo simulations to event reconstruction and background rejection. Although still under development, we can effectively benchmark the new event reconstruction in the special case of the prompt phase of bright Gamma-Ray Bursts (GRBs), where the signal to noise is large enough that loose selection cuts are sufficient to identify gamma-rays associated with the source. Using the new tracker reconstruction and calorimeter clustering algorithms, we have re-analyzed ten GRBs previously detected by the LAT for which an x-ray/optical follow-up was possible and found four new photons with energies greater than 10 GeV in addition to the six previously known. Among these four is a $\sim$28 GeV photon from GRB 080916C, which has a redshift of 4.35, thus making it the highest intrinsic energy ($\sim$147 GeV) detected from a GRB. We present here the salient aspects of the new event reconstruction and discuss the scientific implications of these new high energy photons, such as constraining some extragalactic background light (EBL) models, the prompt emission mechanism and the bulk Lorentz factor of the emitting region.**

Data selection

We concentrate on the 10 GRBs detected by the LAT with an x-ray/optical follow up $\rightarrow$ redshift measurement, very accurate positioning

- E $>$ 10 GeV where PSF flattens out to asymptotic value
- Remove obvious charged-particle events via ACD track-tile association
- Use events for which best track extrapolates to more than 4 X_0 of active material in CAL
- ROI set to 95% acceptance average PSF

Expect $\sim$0.1 background events in a 90 s time window with this selection

Spectral analysis

Complete Pass8 event level analysis not yet available

- Simulate GRBs with gtobssim using best fitted value for spectral index
- Normalize output with observed Pass7 `SOURCE` counts above 100 MeV
- Compute probability of observing the new photons

Probabilities suggest that these events are statistically consistent with photon spectrum derived with Pass7 (see tab. 1)

- Variation on probabilities due to time evolution of spectral index estimated to be less than 10%

Event reconstruction (Pass7 vs Pass8)

- Anti-Coincidence detector (ACD) (see Baldini, Poster)
  - ▷ *Pass7*: absolute distances between tracks and ACD hits
  - ▷ *Pass8*: Propagate covariance matrix, measure distances in units of sigma
- Tracker (TKR) (see Baldini, Poster)
  - ▷ *Pass7*: Pattern recognition seeded by CAL
  - ▷ *Pass8*: New pattern recognition decoupled from CAL
    - ○ Global approach, conversion point seen as preshower process
- Calorimeter (CAL) (see Sgrò, Poster)
  - ▷ *Pass7*: All crystal hits grouped together
  - ▷ *Pass8*: Clustering algorithm and multivariate classification (fig. 1)

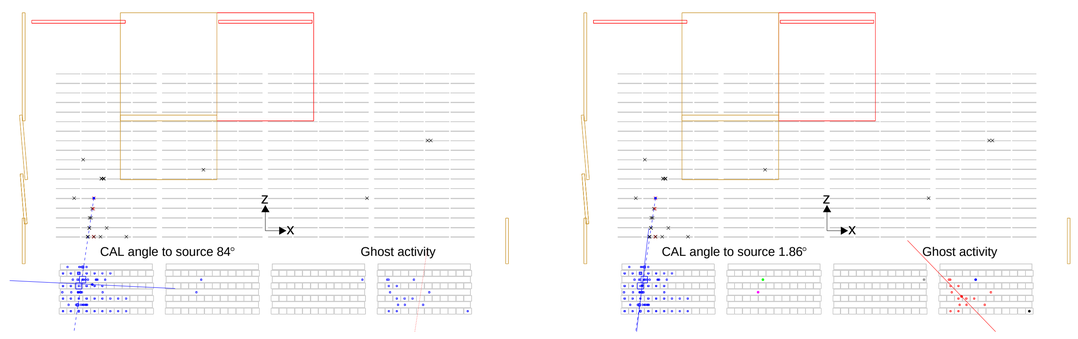

Figure 1: *14 GeV photon from GRB090902B in the LAT (x–z orthogonal projection), reconstructed with Pass7 (right panel) with Pass8 (left panel). Event recovered thanks to the new CAL clustering algorithm.*

Results

	GRB 080916C	GRB 090902B	GRB 090902B	GRB 100414A
Energy [GeV]	27.5	14.0	17.9	28.5
T_0 [s]	40.509	14.166	26.168	33.365
redshift	4.35	1.82	1.82	1.37
Conversion type	Back	Back	Back	Front
TKR angle to source [°]	0.07	0.15	0.12	0.25
CAL angle to source [°]	0.93	1.86	4.99	2.97
ACD dist metric	340	10000	10000	9368
CAL gamma prob	1.000	0.991	1.000	0.906
TKR Silicon veto	13	23	4	5
Notes on Pass7	No tracks	Bad CAL direction	No tracks	Mistracked
BKG prob	7.2×10^{-6}	5.3×10^{-5}	6.5×10^{-6}	1.1×10^{-4}
Prob of observing events	0.748	0.103	0.140	0.976

Table 1: *Basic event topology information of the four new photons.*

- 4 new photons with E>10 GeV in addition to 6 previously detected
- All well within core PSF (see fig. 2)
- Topology of these events is highly gamma-like (see tab. 1)
- Low probability of being BKG based on Monte Carlo simulations and event topology (see tab. 1)

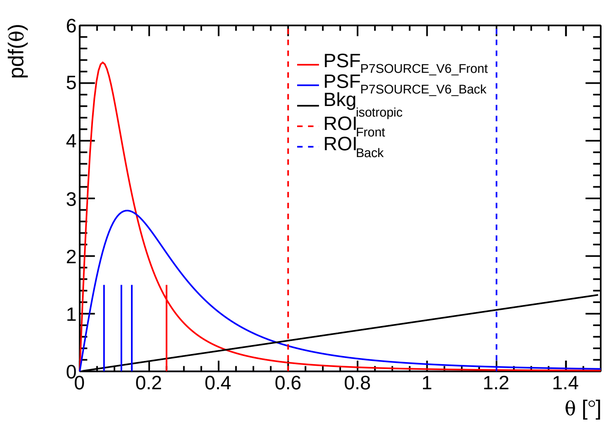

Figure 2: *Angular distance to source position for 4 new photons represented by solid vertical lines.*

Scientific interpretation

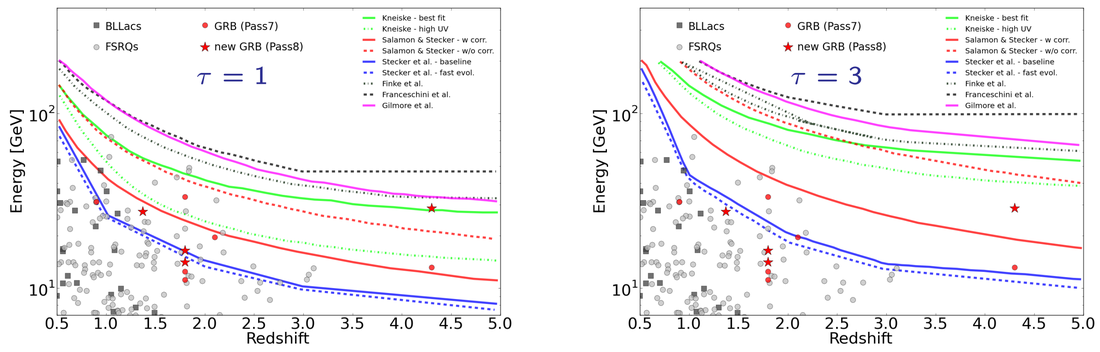

Figure 3: *Predictions of optical depth from various EBL models. The four new photons are represented by the red stars.*

- Synchrotron radiation challenged
  - ▷ Under certain assumptions, Γ factor can be as high as several 1000's ($\Gamma > 5000$ for GRB 080916C and $\Gamma > 2300$ for GRB 100414A)
  - ▷ See however, Kumar et al. 2012
- Tighter constrains on the Extragalactic Background Light (EBL)
  - ▷ GRB 080916C photon (z = 4.35) most constraining so far (fig. 3)
- Lorentz invariance violation (LIV)
  - ▷ Constraints on linear LIV from 27.5 GeV photon from GRB 080916C 11% weaker than 13 GeV photon