Prospects for the Detection of GRBs by HAWC

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Abstract

Fermi LAT has shown that GRBs produce photons in the range 10 – 94 GeV (126 GeV redshift corrected for GRB 130427A). Limited detector size constrains the sensitivity of space borne instruments at the highest energies. Ground based instruments can extend observations from 30 GeV to 300 GeV. Higher energy observations of GRBs would enable better modeling of the GRBs themselves, it would allow us to probe the extragalactic background light and would constrain Lorentz invariance violation. We show here that air shower array HAWC, currently under construction, will be mostly sensitive to the prompt phase of short GRBs and that it can have a rate for detecting GRBs as high a 1.65 GRBs/year.

Observations of GRBs above 10 GeV

Fermi LAT has shown that GRBs produce photons in the range 10 – 94 GeV. The high-energy spectrum is not well described by the Band function, instead all high S/N GRBs in Fermi LAT require an additional hard power law and/or a high energy cutoff [1]. Both long and short GRB show this behavior.

When an additional power law is present short GRBs have a high-energy spectral index of -1.6 [1,2], while for long GRBs it has a typical value of -2 [1].

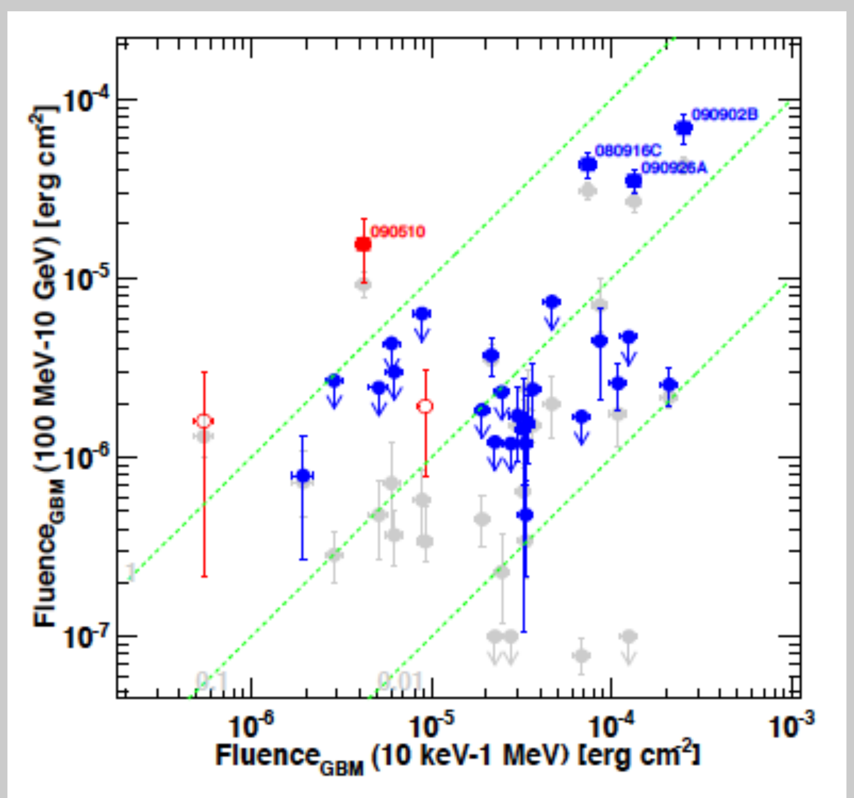

Fig. 1. Taken from [1]. Fluence measure by GBM and LAT during GBM's T90. The diagonal lines represent 100%, 10% and 1% ratio. Red (blue) markers are short (long) GRBs.

The >100 MeV emission is longer and delayed with respect to the 10 keV – 10 MeV emission. But during GBM's T90, the fluence in LAT has been found to be correlated with the fluence in GBM. For short GRBs, the LAT fluence can exceed 100% the GBM fluence, and for long GRBs, the LAT fluence is ≈10% the GBM fluence.

Modeling the >10 GeV emission

We model the high energy emission of GRBs as an additional power law of index -1.6 (-2) for short (long) GRBs. We include EBL attenuation [5]. We assume that the 100 MeV – 10 GeV fluence is correlated to the GBM measured fluence by a factor of 100% (10%) for short (long) GRBs. We have parameterized the GBM fluence distribution [6]. We have also parameterized the short and long redshift distribution.

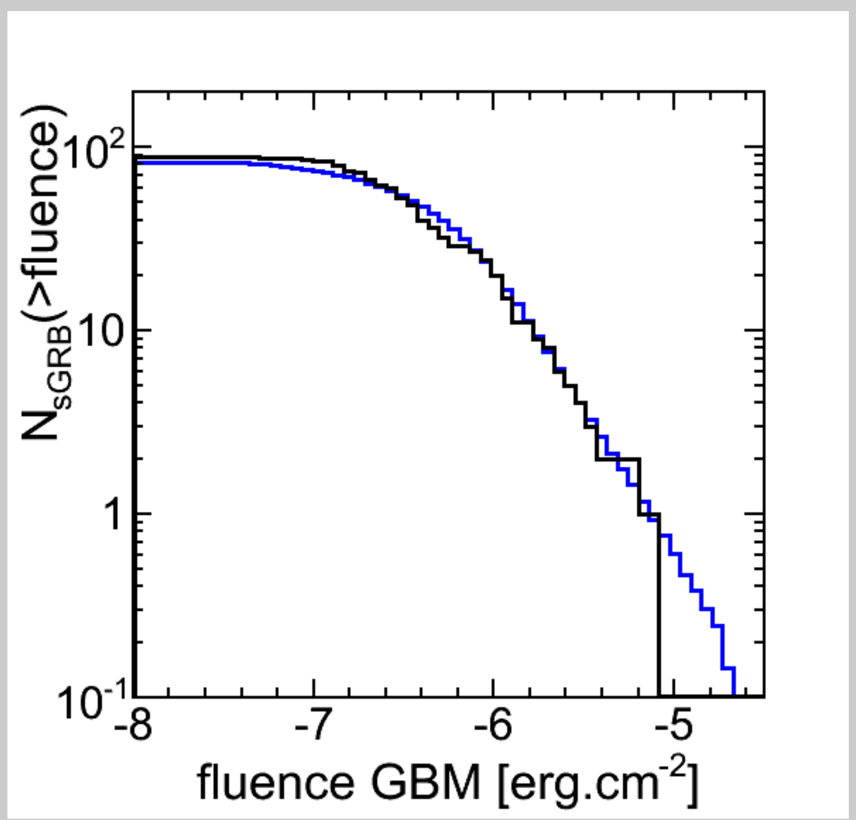

Fig. 4. GBM Fluence distribution for short GRBs. Black: GBM Catalog. Blue: Simulation

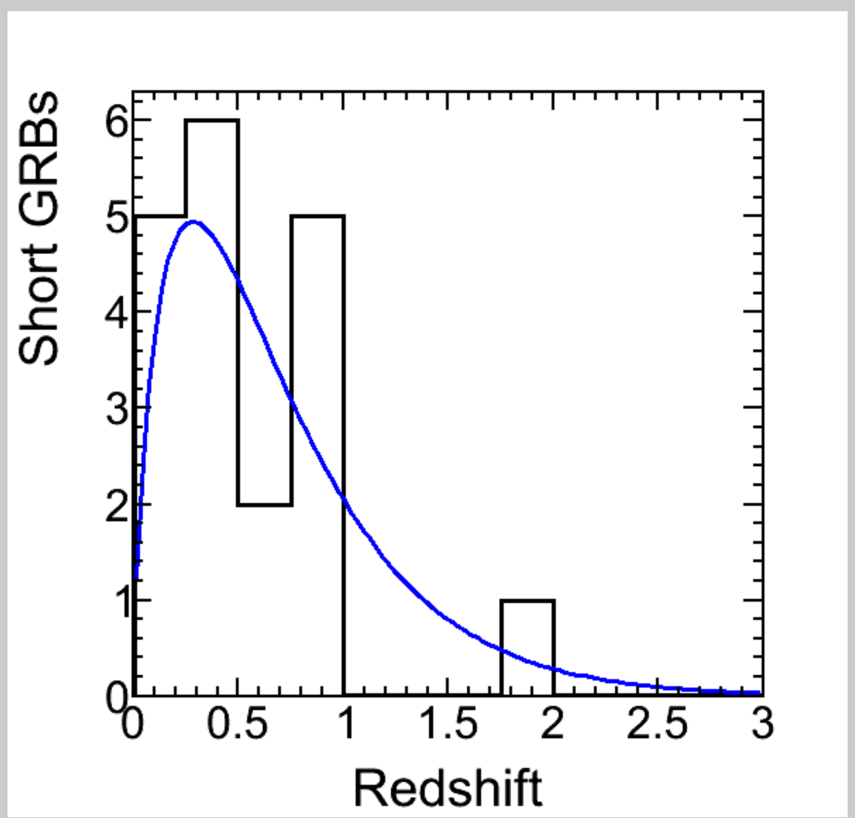

Fig. 5. Redshift for short GRBs. Black: GBM Catalog. Blue: Fitted function

HAWC Sensitivity to GRBs

Because space borne instruments have a limited size and because spectra fall with energy, extending observations to higher energies will required ground based observations. A previous study found that CTA may have a GRB detection rate as high as 0.5 – 2.0 GRBs/year, with most of the sensitivity derived from the afterglow phase of long GRBs [3]. We used the published effective area and background rates for HAWC [4], to calculate the expected GRB rate in HAWC. HAWC is an air shower array under construction in Mexico. HAWC will operate with 2 data acquisition systems with sensitivity to GRBs, the main DAQ and the scaler DAQ.

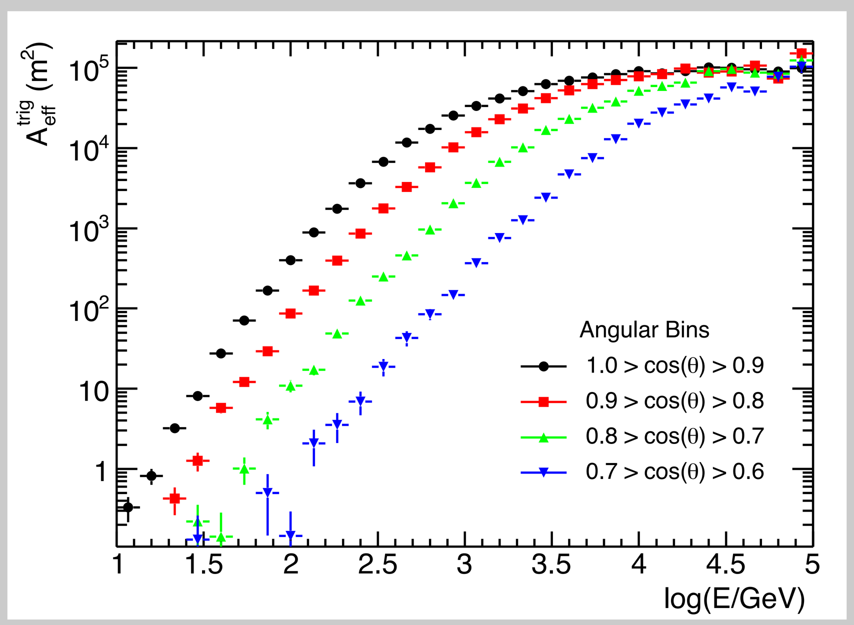

Fig. 2. Taken from [4]. HAWC effective area for the main DAQ with a threshold of Nhit≥30 as a function of energy and zenith angle.

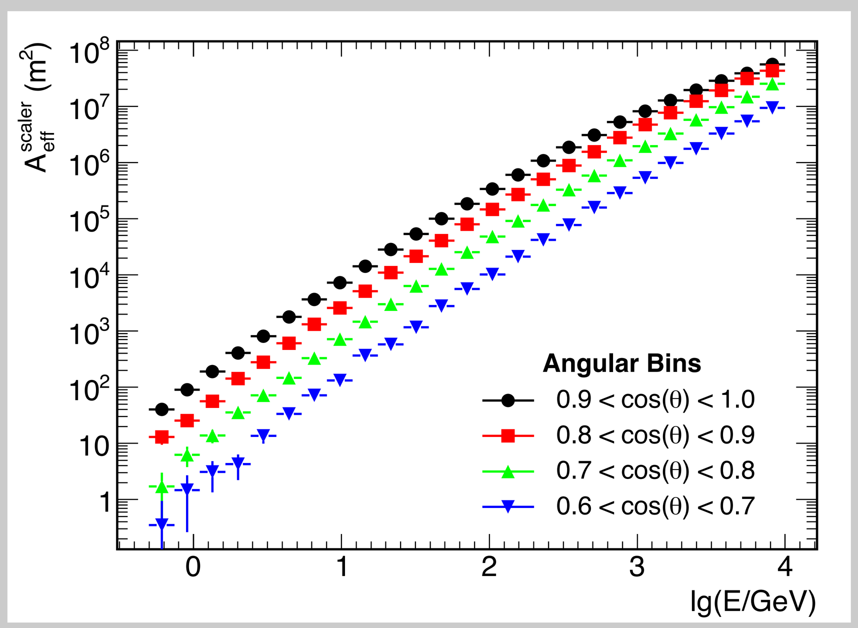

Fig. 3. Taken from [4]. Effective area for the scaler DAQ as a function of energy and zenith angle. Since the signal for scalers are individual PMT hits, the effective area has been weighted with the number of hits per air shower.

The simulation published by the HAWC collaboration [4] corresponds to an older configuration of the detector that does not include a central 10" PMT in each HAWC tank. Thus the calculations presented here underestimate the maximum GRB rate.

GRB detection rate in HAWC

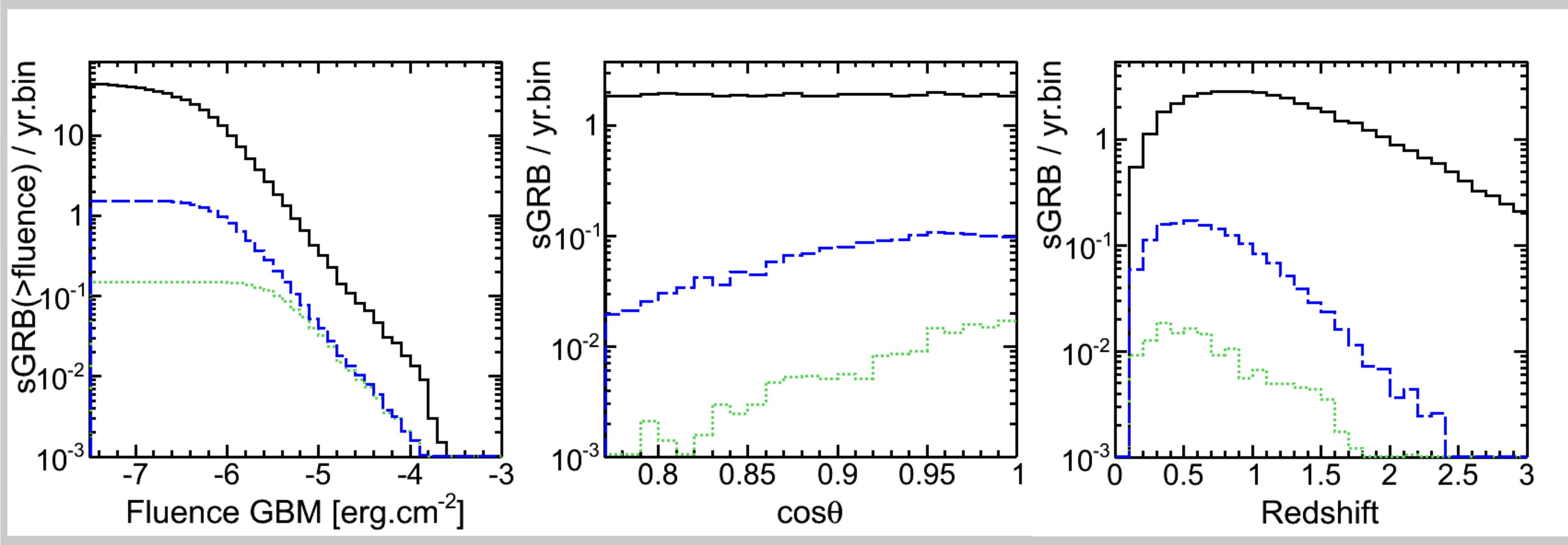

Fig. 6. Short GRB rate in Fermi GBM (black), HAWC with the main DAQ (blue) and scalers (green).

Cutoff	Main - short GRB/yr	Scaler - short GRB/yr	Main - long GRB /yr
N/A	1.4	0.15	0.25
500	1.3	0.12	0.22
400	1.2	0.11	0.20
300	0.97	0.10	0.15
200	0.54	0.07	0.08
150	0.27	0.05	0.04
125	0.07	0.02	0.01

Table 1: GRB rates in HAWC. With no cutoff, the total GRB rate is 1.65 GRBs/year. Universal cutoffs in the GRB frame can reduce this rate.

GRB detection rate in LAT above 10 GeV

We have used the same model to verify that the predicted rate of GRB in Fermi LAT. We predict 1.2 long GRBs/year above 10 GeV and 0.26 short GRBs/year in Fermi LAT. In the three year catalog there are 5 long GRBs and one short GRB above 10 GeV. We conclude that our model is a reasonable description of the 10 GeV rate.

References
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[3] "IACT observations of gamma-ray bursts: prospects for the Cherenkov Telescope Array" R.C. Gilmore et al., arXiv:1201.0010
[4] "On the sensitivity of the HAWC observatory to Gamma Ray Bursts" A.U. Abeysekara et al. (HAWC collaboration), Astropart. Phys. 35, 641-650 (2012)
[5] "GeV gamma-ray attenuation and the high-redshift UV background" R.C. Gilmore et al., MNRAS, 399, 1694-1708 (2009)
[6] "The Fermi GBM Gamma-Ray Burst Catalog: The First Two Years" W. Paciesas, et al., arXiv:1201.3099

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