Search for GeV Emission from Gamma-Ray Bursts Using Milagro Scaler Data

David A. Williams for the Milagro Collaboration

Abstract: Milagro is a wide field (2°) high duty cycle 898 photomultiplier tubes (PMTs) ground based water Cherenkov detector built to observe extensive air showers produced by high energy particles interacting in the Earth’s atmosphere. Milagro records extensive air showers in the energy range 100 GeV to 100 TeV, as well as the counting rates of the individual photomultiplier tubes in the detector. The individual tube counting rates can be used to detect transient emission above ~1 GeV. We have used the counting rate (scaler) data to search for high energy emission from a sample of about one hundred gamma-ray bursts (GRB) detected since the beginning of 2000 by BATSE, BeppoSax, HETE-2, INTEGRAL, Swift, or the IPN. No evidence for emission from any of the bursts has been found, and we present fluence upper limits from these bursts.

The Milagro Detector:

- Located in New Mexico at 2363 m above sea level
- ~60 m x 60 m light-tight, water-filled pond + outriggers
- 898 photomultiplier tubes (PMTs) detect Cherenkov light from energy particles interacting in the Earth’s atmosphere

The Scaler Data Acquisition System:

- The single hit rates of all of the PMTs at two different thresholds (a low threshold of ~0.25 photoelectrons and a high threshold of ~4 photoelectrons) are recorded once a second by a CAMAC data acquisition system
- To reduce the number of scalers needed to record the rates, tubes are combined into groups of 8 or 16, and the logical “or” of hits from the individual tubes in the group is recorded. In this analysis, we use the low threshold hits in the PMTs in the Milagro top layer. Those PMTs in groups of 8 that nearest neighbors are in different groups.

Exclusion of Noisy Channels:

- The RMS of the rate for each PMT group is calculated over the 11 day interval around each burst. The events are removed in three steps, with the signal to noise of the sum are excluded from the analysis for that burst, yielding a “cleaned” rate from the remaining groups.

Correction for Pressure and Temperature:

- The pressure and temperature change the profile of the atmospheric overburden. Linear corrections for temperature and pressure which minimize the overall RMS of the rate (while keeping the average rate unchanged) are calculated for the 11 day interval around each burst.

The GRB Fluence Limits:

- The effective area of the Milagro scalers for gamma rays is calculated using the standard Milagro simulation as described in [1], including accounting for any PMTs excluded at the cleaning step. We assume a power law energy spectrum \( \phi(E) \sim E^{-\gamma} \) absorbed by collisions with the extragalactic background light according to the model of [2], as shown in Figure 7. For bursts with measured or tentative redshifts, we report limits using EBL absorption for that redshift. For the remaining bursts, we calculate limits for 4 possible redshifts: 0.1, 0.5, 1.0 and 2.0. The preliminary fluence limits between 5 and 50 GeV for the unabsorbed power law spectrum are given in Table 1 and 2. For bursts with redshifts >3, we need a more complete model of the EBL absorption below 10 GeV to obtain meaningful limits. The limits are generally compared to those obtained by this method for other bursts by the Abdo et al. [3] group and to the sensitivity expected using this method at Auger [4].

References: