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Status and Results of the Search for Gamma-Ray Bursts above 1 TeV with the HEGRA Experiment

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Abstract

An overview on the status and results of the search for gamma-ray bursts (GRBs) with the HEGRA air shower detector is presented. HEGRA is a multi-component system for the study of cosmic rays in the energy range from 500 GeV to 10 PeV. Emission associated with GRBs registered by instruments on board of satellites has been searched in coincidence, preceding and following the trigger. An independent all-sky search for high energy GRBs has also been performed. Up to summer 1998 no convincing evidence for a GRB detection has been found. Results updated to summer 1999 will be presented at the conference.

1 Introduction:

There are strong motivations for the search of TeV emission from GRBs, which can be summarized as follows. There are models which predict or at least allow TeV emission (Meszaros, 1994; Halzen, 1991); EGRET has detected GeV emission from 5 GRBs without a hint for a spectral cutoff (Hurley, 1994); it has been suggested that a population of bursters with very hard spectra may exist and be invisible to the instruments now in space (Piran, 1995; see also Kommers, 1997); some tentative positive evidence has been recently found (Plunkett, 1995; Amenomori, 1996; Padilla, 1998). A positive detection would constrain models in two senses: the emission mechanism (see above) and the distance.

2 The HEGRA experiment:

The cosmic ray detector complex HEGRA is located at the observatory Roque de los Muchachos on the Canary island La Palma (28.8° N, 17.9° W, 2200 m a.s.l.). It is a hybrid detector system for the registration of extended air showers (EAS) initiated by neutral and charged cosmic rays in the energy range from 500 GeV to 10 PeV. The following detectors are spread over an area of 200 m x 200 m (see Barrio, 1998 for further details):

2.1 The Array of Imaging Atmospheric Cherenkov Telescopes: A system of 6 imaging atmospheric Cherenkov telescopes is used for the observation of gamma-ray sources above 500 GeV. The system consists of one prototype with an energy threshold of 1 TeV plus 5 telescopes designed for stereoscopic observation of showers initiated by photons above 500 GeV. The field of view of each telescope is around 4° and the duty cycle is 10%.

2.1.1 The GCN alert: If HEGRA receives a GCN warning when observation with telescopes is possible, then a follow-up of the GRB position is done provided it is visible and the 1σ error box is less than 1.5°.

2.2 The AIROBICC Array: AIROBICC is the name of an array of 97 wide angle Cherenkov counters. Each counter consists of a 20 cm diameter photo-multiplier viewing a 30° half-angle cone of the night sky and sampling the Cherenkov light disk produced in EAS initiated by a primary of energy above 15 TeV. Its mean angular resolution is 0.3° and has the same duty cycle as the telescopes (Karle, 1995).

2.3 The Scintillator Array: An array of 243 scintillator counters of 1 m^2 is used to continuously register the electro-magnetic component of EAS above 20 TeV with a mean angular resolution of 0.9° (Krawczynski, 1996).

3 Searches and Results:

Data recorded with different HEGRA components from 1991 to 1998 have been used in the search for GRBs. The searches can be classified as satellite dependent or independent.

3.1 Satellite dependent searches:

In this case we can distinguish between tracking and untracking searches.

3.1.1 Tracking searches:

The telescopes from the HEGRA collaboration have tracked 8 GRBs up to summer 1998. Observations began between 10 minutes and 24 hours after the GCN alert. In three cases (GRBs 950401, 960425 and 960528) the area scanned did not contain the true burst positions (received a couple of days after the initial notices). In other three cases (GRBs 970925, 970926 and 971029) the scanned area contained only 8-20% of the final uncertainty region and no signal was found. The analysis of the data for the remaining two bursts (GRBs 980519 and 980527) is in progress.

3.1.2 Untracking searches:

The wide field of view of the HEGRA arrays facilitates coincident observations of about 25 GRBs per year with the scintillator and about 3 per year with AIROBICC. Up to now more than 130 GRBs (from 1991 to 1997) detected by satellites have been searched for TeV emission using data recorded by the HEGRA arrays. Detailed descriptions of the searches can be found in Matheis (1994), Padilla (1998), Krawczynski (1999). The searches focus on the exploration of the solid angle region of possible GRB arrival directions on different time scales (from seconds to hours). TeV emission from the GRB is searched in coincidence, preceding and following the trigger given by the satellite. No convincing evidence for emission has been found and therefore flux upper limits are given. These limits range between 10^{-11} and 10^{-8} cm^{-2} s^{-1} for the integral flux above 15 TeV depending on the particular GRB. It is worth to mention that for three bursts (GRBs 950403, 951102 and 960529) the HEGRA limits on the observed number of GRB photons lie significantly below the direct extrapolation of the keV/MeV spectra. See Krawczynski (1999) for details.

Another interesting result of the search for GRB counterparts appeared in the search for the WATCH GRB 920925c. An excess with a chance probability $<10^{-4}$ was found nearly coincident with the WATCH trigger but significantly deviated from the position given by WATCH and IPN. See Padilla (1998) for details.

3.2 Satellite independent searches:

The data set of HEGRA has also been searched for emission coming from hypothetical GRBs not detected by satellites. Therefore an all-sky search has been carried out using data from several years. The searches are based on different time scales, from one second to one hour. Detailed descriptions of the searches can be found in Funk (1995), Padilla (1998). No convincing evidence for emission has been found and therefore flux upper limits for short time emission in the HEGRA data are given. These limits range between 10^{-9} and 10^{-8} cm^{-2} s^{-1} for the integral flux above 15 TeV depending on the time scale. The absence of TeV GRBs of very short duration (less than about 1 second) allows to set an upper limit on the density of evaporating primordial black holes. See Funk (1995) for details.

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