OG 2.2.10

STATUS AND RESULTS OF THE SEARCH FOR GAMMA-RAY BURSTS ABOVE 1 TEV WITH THE HEGRA EXPERIMENT

L. Padilla[1,a], B. Funk[2], H. Krawczynski[3], V. Fonseca[1], and the HEGRA Collaboration

[1] *Facultad de Ciencias Físicas, Universidad Complutense, E-28040 Madrid, Spain*
[2] *Dept. of Physics, University of Wuppertal, D-42097 Wuppertal, Germany*
[3] *II Inst. fuer Experimentalphysik, Universitaet Hamburg, D-22761 Hamburg, Germany*

[a] *e-mail: padilla@eucmdx.gae.ucm.es*

INTRODUCTION

This poster focuses on the **latest and main results** of the HEGRA Collaboration in the search for gamma-ray bursts (GRBs) at TeV energies. For a summary of all the searches see Padilla et al. (1997b) and for details see Matheis (1994), Padilla et al. (1995), Funk et al. (1995), Padilla et al. (1997a), Padilla et al. (1997c), Krawczynski et al. (1997) and Funk et al. (1997).

The search presented in this work has been carried out with the **AIROBICC detector**. It is an array of 77 wide angle Cherenkov counters, each one viewing 1 sr of the night sky with a 20 cm diameter photomultiplier. It occupies about 40000 m^2 at the HEGRA site (Observatory Roque de los Muchachos of the IAC, La Palma, Canary Islands, 28.8° N, 17.9° W, 2200 m a.s.l.). AIROBICC samples the Cherenkov light disk produced by the particles of extended air-showers initiated by primaries of **energy above 11 TeV** (vertical incidence). The mean **angular resolution** for the event selection used in this work **is 0.6°** and the **duty cycle is 10%**. See OG 10.3.36 and Karle et al. (1995) for details.

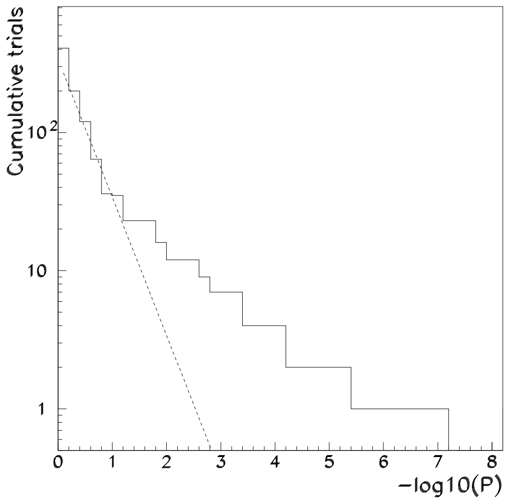

Fig. 1: Cumulative trials vs. probability in the search for emission in coincidence with WATCH GRB 920925c. The dashed line shows the expected behavior. A significative deviation can be seen.

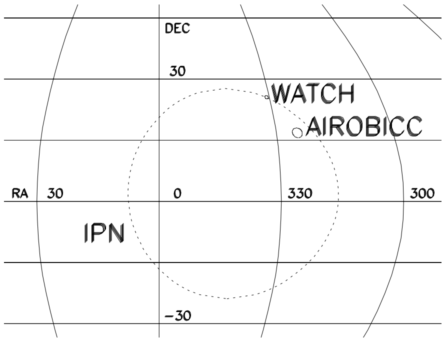

Fig. 2: Map which shows the arrival direction of GRB 920925c as determined by WATCH (3σ radius of 0.4°) and by the IPN ring (3σ width of 0.2°). Also shown is the position of the excess observed with the AIROBICC detector (3σ radius $\sim$ 1.0°).

SEARCH METHOD

We use a binned search (in time and in space) to look for transient signals. We define an **ON window** or signal window and an **OFF window** or background window where events are counted for a certain time interval. The search strategy considers each event as being **in the middle** of a burst, so for every single event in the data sample we take a pair of ON-OFF windows whose time interval is centered at the time of the event. The ON window is a circle of 0.7° centered at the position of the event and the OFF window is an annulus of 1.5° and 10.0° radii concentric to the ON window. There is always one event inside the ON window and to reduce this bias it is excluded (not counted). The sizes of both windows have been chosen such that they maximize the signal to noise ratio and minimize systematic errors (Padilla et al., 1997a). We use time intervals with lengths of **10 seconds, 1 minute and 4 minutes**, which cover the usual long duration GRBs.

Applying the search procedure to the data sample we obtain a chance probability for every pair of ON-OFF windows (Alexandreas et al., 1993):

$$P(\geq N_{ON} \mid N_{OFF}) = 1 - \sum_{n_{ON}=0}^{N_{ON}-1} \frac{\alpha^{N_{ON}}}{(1+\alpha)^{n_{ON}+N_{OFF}+1}} \frac{(n_{ON}+N_{OFF})!}{n_{ON}!\, N_{OFF}!}$$

where N_{ON} and N_{OFF} are the number of events in the ON and OFF windows respectively and α is the ON/OFF solid angle ratio. For a random distribution of events a cumulative histogram of -$\log_{10}P$ for all the windows should approximately follow a straight line with slope of -1 and which cuts the Y-axis at the height of the total number of trials. A GRB would therefore appear as a deviation from the line whose significance can be calculated knowing that every bin follows approximately a binomial distribution.

RESULTS

The search method was applied to the data recorded in the first year of operation of AIROBICC, **from March 1992 to March 1993**, and the results were presented in the past 24th ICRC (Rome 1995). We looked for transient TeV emission in a all sky-search basis with negative results. Flux upper limits were given. We also looked for TeV emission from one BATSE burst which was completely included in the data sample. The result was also negative and therefore a flux upper limit was given. Later on we received the first catalog of WATCH bursts, one of which was completely included in the data sample. The search for TeV emission from that burst (**WATCH GRB 920925c**) reveals a remarkable excess, see Figure 1, nearly in time coincidence with the WATCH trigger but **9° away** from its nominal position, see Figure 2.

The search interval with the smallest chance probability received **10 events in 4 minutes while only 0.93 were expected**, this corresponds to a **probability of** $\mathbf{7.7{\cdot}10^{-8}}$ **or** 5.4σ. The interval is centered at $\alpha = \mathbf{324.6°}$, $\delta = \mathbf{16.8°}$ **(J2000) and UT = 22:45:21**. After correcting with a **trial factor** due to the search of several bursts in different time scales, the **final probability** for that excess is $\mathbf{3.7{\cdot}10^{-3}}$ **or 99.6% confidence level** (conservative estimate). The mean **integral flux** over the 4 minutes interval **above 16 TeV is** $(\mathbf{3} \pm \mathbf{1}){\cdot}10^{-10}$ $\mathbf{cm^{-2}\ s^{-1}}$.

We have exhaustively searched for errors in our data which could explain the discrepancy with the other localizations of this burst, but none was found. On the other hand the WATCH and IPN teams have also checked their data but again no errors were found. However it is interesting to mention that if we use the time of detection of AIROBICC to compute the IPN ring then this **new** IPN ring is compatible with the AIROBICC localization and not with WATCH. This may suggest a timing error in the WATCH data, however such an error was not found. See Padilla et al. (1997a) and Padilla et al. (1997c) for further details.

LATEST RESULTS

Data recorded with AIROBICC **from October 1994 to October 1996** have been analyzed searching for short time emission independent of the detectors in space. The search has been performed in three time scales, **10 seconds, 1 minute and 4 minutes**. The results are shown in Figure 3. **No significative excesses are seen**. The small excess seen in the 1 minute time scale has a chance probability of $\sim$90% to be a background fluctuation. Upper limits with **90% confidence level** on the **integral flux** of hypothetical GRBs included in this data set are given in Table 1.

The data sample completely covered the **BATSE GRB 950624b** and therefore we searched for TeV emission from its location estimation (**intersection** of BATSE error circle and IPN ring, see Figure 5). The result is shown in Figure 4. A remarkable excess is seen in the 4 minutes time interval search, where **9 events are found while only 1.3 are expected**. This corresponds to a **probability of 8.0$\cdot 10^{-6}$ or 4.4σ**. The excess is centered at $\alpha = \mathbf{285.5^\circ}$, $\delta = \mathbf{38.0^\circ}$ **(J2000) and UT = 03:30:41**. After correcting with a **trial factor** due to the search of the bursts previously mentioned, the excess is only marginal. The mean **integral flux** over the 4 minutes interval **above 16 TeV is (2 $\pm$ 1)$\cdot 10^{-10}$ cm^{-2} s^{-1}**.

Table 1: *90% confidence level upper limits on the integral flux of any hypothetical GRB occurred in the data recorded with AIROBICC from October 1994 to October 1996. They are tabulated depending on the time window and the declination band. Uncertainties are $\sim$ 50%.*

Time scale	10 sec	1 min	4 min
$F_{UL}(E > 16\text{TeV})$ (cm^{-2} s^{-1}) ($9^\circ < \delta < 49^\circ$)	$2.0\cdot 10^{-8}$	$2.0\cdot 10^{-8}$	$1.6\cdot 10^{-8}$
$F_{UL}(E > 25\text{TeV})$ (cm^{-2} s^{-1}) ($-6^\circ < \delta < 9^\circ$, $49^\circ < \delta < 64^\circ$)	$1.6\cdot 10^{-8}$	$1.1\cdot 10^{-8}$	$1.1\cdot 10^{-8}$

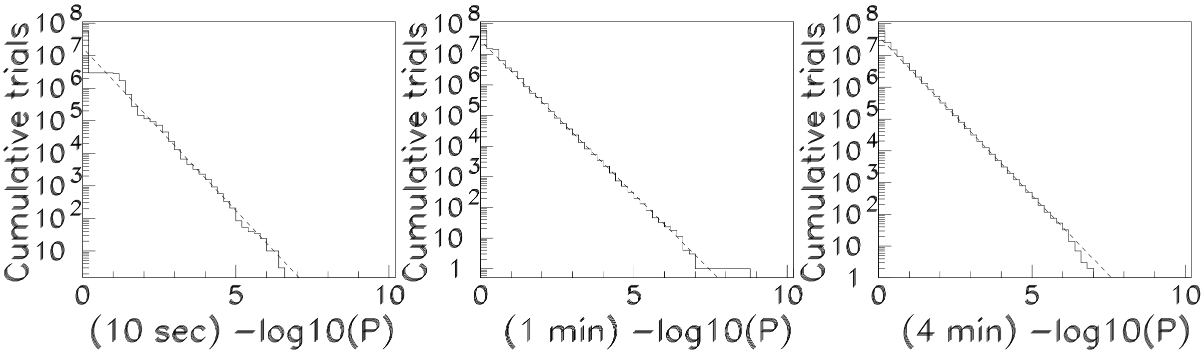

Fig. 3: Cumulative trials vs. probability in the satellite independent GRB search with AIROBICC in the data recorded from October 1994 to October 1996. The time scale is indicated in brackets. Continuous line represents real data and dashed line represents the expectation. Deviations are not significant (see text).

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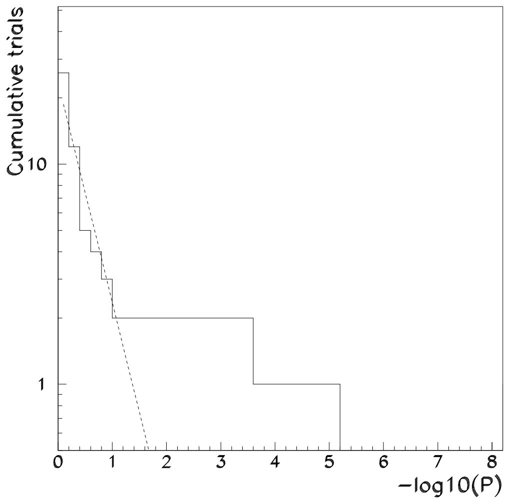

Fig. 4: Cumulative trials vs. probability in the search for emission in coincidence with BATSE GRB 950624b. The dashed line shows the expected behavior. A significative deviation can be seen.

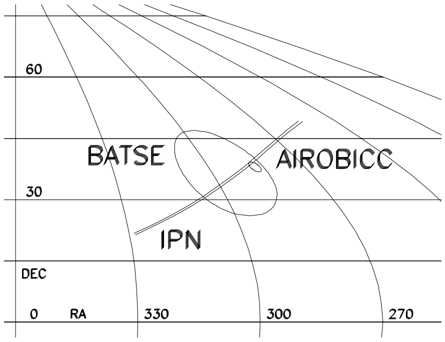

Fig. 5: Map which shows the arrival direction of GRB 950624b as determined by BATSE (3σ radius of 10.5°) and by the IPN ring (3σ width of 0.3°). Also shown is the position of the excess observed with the AIROBICC detector (3σ radius $\sim$ 1.0°).