An Improved Search for Gamma Radiation from Cosmic Point Sources Using a γ/Hadron Separation Procedure on the AIROBICC 92/93 data

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Abstract

The HEGRA collaboration has searched for gamma-ray emission from potential cosmic point sources above 65 TeV with the wide angle Cherenkov detector **AIROBICC** which is a part of the HEGRA cosmic ray detector complex on La Palma. The threshold of the studied sample is much higher than the pure trigger threshold of AIROBICC because a good reconstruction of the shower parameters is needed to allow for gamma/hadron separation [1], which has not yet been done. The analysis procedure is described and results will be presented at the conference.

1 Introduction

The search for cosmic point sources in the VHE and UHE range has been one of the main goals of the ground-based cosmic ray detectors since the late seventies. The atmospheric Cherenkov telescope technique has yielded several positive detections during the last years up to 4 TeV, while the scintillation arrays have been unable to find any convincing signal. This is due not only to their higher threshold (usually above 40 TeV [2]), but also to their limited angular resolution (of the order of 1 degree) and the lack of any γ/hadron separation procedure. Wide Angle Cherenkov Arrays (WACAs), in combination with scintillation arrays allow for additional information on energy and shower development high up in the atmosphere, thus they can provide γ/hadron separation criteria. The newly developed wide angle Cherenkov array AIROBICC is placed 2200 m above sea level in the Canary island La Palma as a part of the HEGRA experiment. For a detailed description of AIROBICC and the other components of the HEGRA experiment, see [3].

[1] see V.Fonseca: Contribution to this conference

2 The Data Sample

The data sample analyzed in the present paper was recorded during the 'run-in' phase of AIROBICC between March 1992 and March 1993. The number of showers for which the analysis procedure was able to find at least the incident direction of the primary was about $2.2 \cdot 10^7$ (approximately 60 % of all the recorded events). The details of the shower reconstruction method can be found in ref. [4]. Then we applied a series of quality cuts to the data, namely:

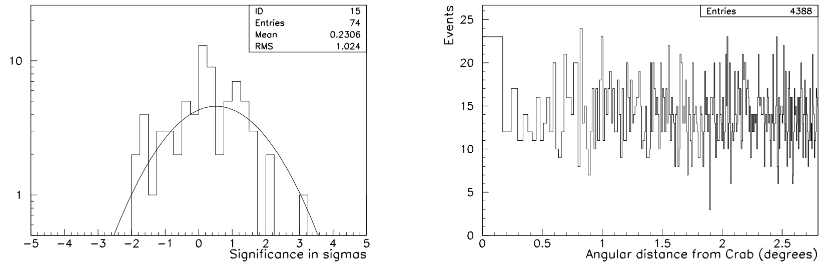
1. A 'bad weather' cut by rejecting the nights in which the mean value of the reconstructed light radius (distance from shower axis at which the Cherenkov light density drops by a factor **e**) was below 60 m [5].
2. The shower core must be at least 5 meters inside the array boundaries.
3. The reduced χ^2 of a cone fit to the Cherenkov light front must be smaller than 2.
4. A light front cone slope between 0 and 30 mrad.
5. A light radius between 25 and 140 m.
6. A successful NKG-fit to the distribution of particles measured by the scintillator array.
7. A particle front cone slope between 0 and 70 mrad (Scintillator array).

Around 20 % of the events fulfilled these conditions. A rough estimate of the energy threshold of this sample can be done through comparison of the event rate and the known all particle cosmic ray flux [6]. It turns out to be around 40 TeV (zenith angle dependent) for γ's. A further cut on L_{90} (Cherenkov light density at 90 m distance from core) is advisable if the LES method for γ/hadron separation is to be applied [1]. Here we chose $L_{90} >$ 15000 photons/m^2. This increases the photon threshold up to around 65 TeV.

3 Analysis of the data

From the mean number of fired AIROBICC huts (above 30) of the events which satisfy the above conditions we estimate [7] the angular resolution to be 0.15 degrees for the reduced sample. The most probable pointing error of AIROBICC is about -0.1 degrees in dec and about -0.1 degrees in RA (the latter depending on the declination of the source). This has been inferred from the analysis of the events simultaneously recorded by AIROBICC, the Cherenkov telescope and the Scintillator array [6]. This pointing error has been corrected for this search. The optimal source region radius is $1.1 \cdot \sigma$ if the background is Gaussian distributed. This leads to a circular ON region of 0.17

degrees radius around the source. To estimate the background, a ring-shaped OFF region with inner and outer radii of 0.5 and 2.4 degrees respectively (corresponding to a solid angle 190 times larger than that of the ON region) was chosen. A total of 74 candidate sources (including those in the EGRET and COS-B catalogues) were studied. In Table 1 a list of the event numbers in the ON and OFF regions as well as the significances (following [8]) of the observed excesses is given. The distribution of the significances of the observed excesses can be seen in fig. 1a. Figure 1b shows the distribution of the events around the Crab Nebula. All the bins in this histogram cover the same solid angle ($2.8 \cdot 10^{-5}$ sr), corresponding the first bin to the defined ON region.



(a) Significances distribution

(b) Events around Crab

Figure 1: *No gamma/hadron separation.*

Table 1: Events statistics and significances for some sources. No γ/hadron separation.

Source	N_{Source}	$<N_{BG}>$	$S[\sigma]$
Crab Nebula	23	14.2	+2.14
Cygnus X-3	12	11.7	+0.08
Cygnus X-1	16	12.3	+0.99
Hercules X-1	14	10.3	+1.07
Geminga	13	14.5	-0.39
AM Her	20	8.8	+3.23
Mrk-421	11	8.9	+0.67
Mrk-501	8	10.0	-0.64

4 Gamma/hadron separation

The gamma/hadron separation we intend to apply to the described data sample is the LES method described in [1]. This method has already been used in the search for isotropic gamma radiation of cosmological origin [5] on a data sample from four selected nights with optimal weather conditions. The problem one faces when applying the LES cut to a larger data set is to account for the changes in the absorption of the Cherenkov light in the atmosphere (due to the presence of dust and water vapor) from night to night. Besides, the data were taken during the first year of operation of AIROBICC, when things were still not completely stable (for example, the gains of the detectors).

The cut on the mean value of the light radius along each night (mentioned above) rejects the bad nights in terms of differential (i.e., height-dependent) absorption (9 nights in the described sample), but does not reject nights in which the total atmospheric absorption is too high. A cut on the ratio N_s/L_{90} (being N_s the reconstructed number of e^+e^- at the ground level obtained from a NKG fit) can be used for this purpose (as in [5]), but, in this case, and in order not to run out of statistics it is better to introduce a correction factor to normalize all the mean N_s/L_{90} values to those of a few selected 'good' nights. Work is in progress in this direction and results will be presented at the conference.

References

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