The Wide Angle Air Cherenkov Detector AIROBICC at La Palma

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Abstract

The present status of the wide angle air-Cherenkov detector AIROBICC located at the HEGRA experiment (La Palma, Canary islands, Spain) is presented. The AIROBICC detector is designed to perform studies on VHE/UHE γ-ray astronomy and on the chemical composition of the cosmic rays based on its excellent angular resolution and low energy threshold. Future developments are oriented to considerably lower the energy threshold and to improve the γ/hadron separation.

1 Introduction

The identificacion of the sources of cosmic radiation has been since long an unresolved question in Astrophysics and Cosmology. Due to the considerable progress in detector performance new questions from the field of high energy particle physics above current accelerator energies have also emerged. The detection of γ-radiation with counters, either on-board of satellites (highest detectable energy 30 GeV) or with Cherenkov ground-based detectors has been proven to be successful (lowest energy threshold 250 - 500 GeV for Cherenkov telescopes, 20 TeV for AIROBICC). γ-ray Astronomy with ground based techniques takes advantage of the calorimetric effect of the atmosphere when struck by high-energy cosmic particles. The detection concept of the AIROBICC detector is based on the sampling of the Cherenkov light disk of the shower front at ground level with bare low-gain photomultipliers (PMs) looking into the moonless night sky. The shower direction is determined with high precision from the individual timing signals and the energy of the primary particle is deduced from the measurement of the lateral Cherenkov-light distribution.

2 Detector

The AIROBICC (**Air** shower **O**bservation **B**y angle **I**ntegrating **C**erenkov **C**ounters) array in its original design [1] consists of 49 detector stations regularly distributed on an equidistant rectangular grid of 7x7 huts (30 m grid spacing) at the HEGRA site (35000 m^2, 28.8^o N, 17.9^o W, 2240 m a.s.l.). At present, 28 new huts are being installed, 16 of them forming a denser region in the middle of the array and 12 huts arranged in a new row and a new column. Further extensions are in preparation (2 more rows with 7 counters each).

Since beginning of operation in spring 1992 [2] several major hardware improvements occurred resulting in a $\sim$ 22 Hz trigger rate with the initial configuration. The trigger requires that one of the following coincidence conditions is fulfilled: 1) $\geq$6 AIROBICC huts fired within 200 nsec, 2) $\geq$14 scintillator huts fired within 150 nsec, 3) a trigger signal from the Cherenkov telescopes. The improvements were:

1) Improved high voltage power supply. The HT for the PM is produced locally inside each hut with a 21 stage cascade circuit specially designed by Matsusada. This generator has a stability of 0.0005% on short time scales and a temperature stability of 0.01%/C^o. 2) In Autumn 1993, the original data acquisition system based on CAMAC electronics was replaced by commercial Fastbus modules. We use modified Kinetic F432 12 bit TDC (64 channels, full range 600 ns) for timing with 150 psec least count and Le Croy 1882f charge sensitive ADCs (96 channels, full range 159 pC). The modules are read out with a Kinetic F800 Fastbus controller operating under OS/9. Time and charge calibrations are done periodically every 20 min by sending 200 pulses to the LED pulsers located above each PM. Linearity of the TDC modules is checked at the same time using a calibrated Phillips Scientific 7120 module in the time range 50-600 ns. 3) The original pre-amplifiers had a large output swing (about 8 V) and a non-linear response being therefore currently replaced. 4) In winter when temperature drops below 3^o and humidity is $\geq$ 60%, ice and water accumulate at the plexiglas cover protecting the upper part of the hut. To avoid it, a thin wire resistive heating system has been installed below the plastic cover, which also has to be periodically cleaned against dust accumulation. In fig. 1 a sectional drawing of a single hut is shown. A metal box which opens at night by a remotely controlled motor contains the entire Cherenkov light detector. The opening of the huts is controlled automatically

by three safety controllers: a night sky light sensor, a humidity detector and a clock programmed for the sun/moon down/up rise time. Another clock switches on the HT for the PM's. After the fastbus change the dead time for the readout of the events triggered either by AIROBICC, the scintillation array or the telescopes was 25%. The 150 m coaxial cables as well as the aluminized mylar of the Winston cones did not suffer significant changes during the running period of the AIROBICC array. The main parameters of an AIROBICC hut are:

- a six stage hemispherical PM (20 cm ϕ, EMI D668 KB5, gain: (6-9)x10^3, detection limit 2800 photons/m^2) specially designed for these measurements, - a light collecting cone (Winston cone, 40 cm ϕ), - a glass filter (Schott BG1, 2mm thickness, 300-480 nm transmission range) to restrict the measured night sky background of 3.3 x 10^{12} photon/(m^2.sec.sr) by a factor 2.5, - a yellow LED for time calibration and - a protecting plexiglass cover with the heating system. The anode current of the PMs over two years dropped by 20% to the present mean anode current of 20 μA. The angular acceptance is 1 sterad and the max observable zenith angle is 45°. A complete description of the array and its performance can be found in [1], [2].

Figure 1: Detector hut Figure 2: Angular resolution

3 Performance

During the first period of operation of AIROBICC (May 92 - March 93) the observation time was 821 hours which corresponds to 60% of the maximum available dark night time and an uptime of 15%. A sample of 2.4x10^7 showers was collected. After the change to Fastbus electronics a total of about 10^8

showers have been recorded. The detector performance was investigated with a sample of showers taken in two nights of March 1993 under good atmospheric conditions passing the standard cuts. From this analysis it is proven that a cone fit is a very good approximation to the shape of the shower front within 140 m and that there is no dependence of the timing precision on the pulse height. The fitted cone slope is 18.0 ± 0.5 mrad which is in good agreement with MC calculations. The energy threshold is 10-15 TeV for γ and 25-30 TeV for hadrons. Figure 2 shows the angular resolution of AIROBICC ($\sigma(63\%)$) as a function of the number of fired huts [3], which falls below 0.1^o for events with more than 25 fired huts.

Up to now there is no known source to test the pointing accuracy of the AIROBICC array. Therefore a comparison of reconstructed events taken simultaneously with AIROBICC and either the scintillation array or the telescopes is done. The comparison with the scintillation array shows an angular deviation of $(0.14 \pm 0.02)^o$ in the direction North-North-East (210 ± 20^o) and comparison with data taken with the first HEGRA Cherenkov telescope shows a difference in orientation of $(0.18 \pm 0.1)^o$ in the direction East-North-East (245^o). The estimated mean orientation error of AIROBICC is 0.09^o.

Physics results as well as detailed MC studies on γ/hadron separation and chemical composition using different methods, are presented in various contributions to this conference [5]. Already from the first 10 month period of operation it was possible to get a first direct isotropic γ limit in the 60 TeV energy range [4] and to determine flux limits of potential γ sources [6].

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