Nuclear Physics B (Proc. Suppl.) 16 (1990) 493–494
North-Holland

THE EAS-TOP ARRAY AT GRAN SASSO: RESULTS OF THE ELECTROMAGNETIC DETECTOR

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The detector of the e.m. component of Extensive Air Showers of the EAS-TOP array at Gran Sasso has been in operation for part of 1988 and 1989. We present the results obtained at primary energy $E_\gamma \approx 150$ TeV in the study of the candidate sources observable in the northern emisphere. The observations of Cygnus X-3 during the radio burst of June '89 are discussed.

1. THE ARRAY

EAS-TOP [1] is a detector of the e.m. (EMD), hadron and low energy muon (MHD) components of Extensive Air Showers, located on the top of the underground Gran Sasso Laboratory [2] in central Italy. The main aims of the array (operating in the energy range $E_o = 3\ 10^{13} - 10^{16}$ eV) are:

a - to measure in coincidence with the underground detectors for studies of the cosmic rays primary composition around the knee of the energy spectrum ($E_o \approx 3\ 10^{15}$ eV), and of nucleus-nucleus interactions at high energies;

b - to measure as an autonomous EAS array in the fields of VHE-UHE γ-ray astronomy, cosmic rays anisotropies and studies of primaries.

EMD (see fig. 1) consists of 29 modules 10m^2 each of scintillator detectors spread over an area $\approx 10^5$ m^2. MHD is a calorimeter $\approx$ 1000 gr/cm^2 thick (lead+iron), seen by streamer tubes operating in limited streamer mode for μ-tracking, and quasi proportional mode for hadron calorimetry. The core of the array is located at 2005 m a.s.l. (latitude: 42° 27' North, longitude: 13° 34' East), 27.5° with respect to the vertical of the Gran Sasso underground laboratory, the corresponding depth being 3100 m.w.e. and the muon energy threshold $E_\mu^{th} = 1.7$ TeV.

All scintillators (16 per module) of the e.m. detector are equipped with two PMs operating respectively in high gain mode for timing and low gain mode for particle density measurements. The array is organized into two subarrays of four modules (A,B,C,D and AA,BB,CC,X), and ten subarrays of seven (or six) modules interconnected each other. Triggering conditions and measurements (2 ADCs + 1 TDC per module) are performed in the central room. The subarrays operate in independent mode: in the present configuration any full coincidence of the modules of the subarray triggers the data acquisition of the whole apparatus. The absolute arrival time of the events is measured with 100 µs accuracy by means of a quartz oscillator syncronized by the national radio network signals.

11 modules of EMD have been operating during part of 1988 and 22 since the beginning of 1989, all scintillators being equipped with a single photomultiplier operating in high gain mode (i.e. for timing measurements, and therefore saturating in amplitude at $n_p \approx 150$ particles).

The arrival directions[3] are obtained by measuring the times of flight between different detectors (separation 20<d<80m).

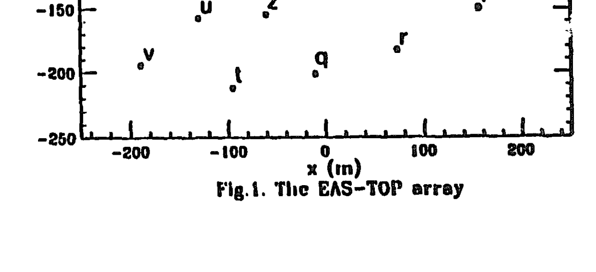

Fig.1. The EAS-TOP array

The discrimination is performed in double threshold mode (triggering threshold $E_{th} \approx 0.3$ p/module ≈ 3 MeV energy loss, timing threshold E_t at the level of the first photoelectron). The electronic resolution is $\Delta t_e = 0.5$ ns, the measured detector resolution is $\Delta t_d = 1.4$ ns. The angular resolution is obtained for each subarray by splitting its detectors into two parts, (for instance E,G,H,L and F,H,I,M) and by comparing the two measured arrival directions. For events having the core inside the array, 70% of such differences are enclosed inside an error box with $\sigma_{\Delta\psi}<1.2°$. From statistics, when all seven detectors are used together, the error in the arrival direction is $\sigma_\psi = \sigma_{\Delta\psi}/2$: i.e $\sigma_\psi \approx 0.6°$.

First results on the temporal characteristics of EAS, on the events recorded in coincidence with the deep underground muon detectors, and on the stability of the array and the search for point sources are presented in refs. 4, 5, 6.

2. SEARCH FOR UHE γ-RAY SOURCES

Data are analyzed by using sky cells of dimension $\Delta\delta=\pm1.5°$ in declination and $\Delta\alpha=\Delta\delta/\cos\delta$ in right ascension. The threshold energy (i.e. the energy for which the detection efficiency exceeds 50%), for sources culminating at zenith as Cygnus X-3, is E_o=150 TeV, slightly higher for sources culminating at greater zenithal distance. The number of counts in the bin centered on the source (ON) is compared with the average number of counts (<OFF>) from six bins located at the same declination but shifted of $\pm2K\Delta\alpha$ in right ascension (K=1,3). Only events having the core inside the array with zenith angle $\theta<30°$ are used, and days of operation in which all seven cells are observed from their rising to setting.

The sources analyzed are: Crab Nebula, Cygnus X-3, Hercules X-1, Geminga, PSR1953+29, 4U0115+63, PSR1937+214, M31 and the Galactic Plane. No significant excess is observed from any of them: the upper limit to the D.C. flux (95% c.l.) obtained in 85 days of operation is e.g. for Cygnus X-3: $I_\gamma(\geq150$ TeV$) < 2\ 10^{-13}$ cm^{-2} s^{-1} (for a discussion of previous data see T.C. Weekes [7]). Since we operate with fixed effective area (A_{eff}=3.4 10^8 cm^2 in this run) all fluxes are calculated following the direct expression $I=N_{counts}/(A_{eff}T_{eff})$.

3. CYGNUS X-3: THE RADIO BURST OF JUNE 1989

A radio burst [8] has been reported from Cygnus X-3 during 1989, starting on June 1st and reaching maximum intensity on June 2nd.

The daily distribution of the source number of counts (ON-<OFF>) shows, on June 1st, in coincidence with the beginning of the radio burst, a 2 s.d. excess (54 events from source against 40 average background). From the 4.8^h light curve relative to the same day, we see that the excess is concentrated in an interval between the X-ray phases 0.4 and 0.6 (in particular an excess of 6 events against 1 of background is observed in 7.2 minutes interval near phase 0.55 at 3^h UT). The overall probability for the event to be due to statistical fluctuations is ≈ 1%, and therefore worthwhile to be searched in other observations; the γ-ray flux would correspond to $I_\gamma(>150$ TeV$)\approx 2\ 10^{-12}$ cm^{-2} s^{-1}.

We want to remark that the characteristics of the observation (excess occurring at the beginning of radio burst, concentrated in a short interval of the phase diagram) is quite similar to the one reported by the Plateau Rosa array at the beginning of the radio burst of October 1985 [9].

4. CONCLUSIONS

During 85 days of operation in the spring 1989 we have obtained upper limits to the emission of candidate VHE-UHE γ-ray sources $I_\gamma(>150$ TeV$) < 2\ 10^{-13}$ cm^{-2} s^{-1}. This value in the case of Cygnus X-3 and Crab Nebula is of the order of the fluxes previously reported. Of course the source activity could be variable and some indications of sporadic emission (although with not high statistical significance) can be found during the radio bursts of October 1985 and June 1989.

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