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The ETscope Ground Array for the ULTRA Experiment

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Abstract

The ETscope detector designed for the ULTRA experiment is a small array made of 7 particle detection stations. Operating simultaneously with an optical telescope it detects the Extensive Air Showers in coincidence with the Čerenkov light, diffused by the impact on the ground. The main goal of the detector is the characterization of the impinging shower by the measurement of size and arrival direction. These informations, together with the UV light measurement and an accurate MC simulation, will allow the determination of the diffusing features of the ground. Since it must be placed on different surfaces including sea, it has been optimized as portable, floating and waterproof detector. First test has been performed during October 2002 at Mont-Cenis in the Alps region, at the France-Italy border. Detector performances and preliminary results will be discussed here.

1. The ETscope Detector

The ETscope array of the ULTRA project [1] was located at Mont-Cenis site (1970 meters a.s.l, 45.3 North, 6.9 East) at an equivalent atmospheric depth of 805 g/cm^2. In the used configuration 3 stations were placed at vertexes of a triangle, each one 23 m from the central fourth station (see fig. 2.). Each station includes a plastic NE102A scintillator 80×80 cm^2 wide and 4 cm thick seen by two photomultipliers XP3462. They are contained in a pyramidal shape box made with thin stainless steel, coated with white diffusing paint and placed in a 1 m^3 PVC container. A standard NIM and CAMAC electronics, controlled by a PC under LabView software, is used for data read-out. PMT calibration and gain stability are obtained through the measurement of single muon spectra from which the Vertical Equivalent Muon charge (VEM) is defined. Therefore the measured analog signal of each station converted in VEM units gives the particle density yield. A 3-fold, 150 ns coincidence between 3 external stations is required to trigger the DAQ. The hardware trigger threshold is set to 0.3 VEM/module and the dynamic range allows to measure particle densities up to 40 VEM.

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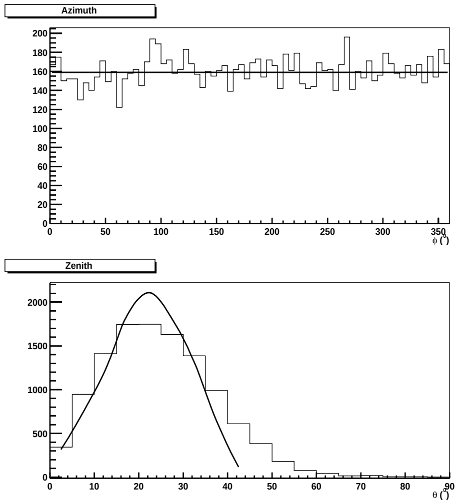

Fig. 1. ϕ and θ distributions compared with expectations.

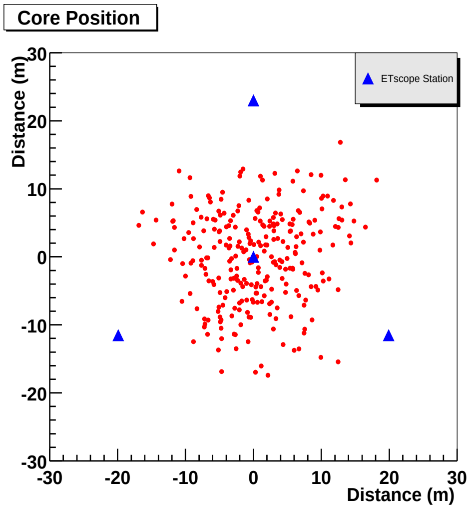

Fig. 2. Reconstructed core positions and ETScope array configuration.

2. Data Analysis and Results

During Mont Cenis test a total of 11616 events have been recorded with a mean counting rate $\bar{f} = 0.134$ Hz. For each of them the shower arrival direction is obtained and for the subset with the core located inside the array (internal events) the impact point has been reconstructed.

2.1. Arrival direction reconstruction

The reconstruction of the arrival direction is performed by triangulation using the time of flight technique. The t_0 time, i.e. the time offset due to different electronic and cables delaies, normalized to the central station, has been measured and introduced into the calculation. Due to the small dimensions of the ETscope array compared to the lateral extension of the shower, a plane shower front is assumed; 99.4% of shower arrival directions are reconstructed. Distributions of ϕ and θ parameters are shown in fig. 1.; θ distribution is compared with the expected one obtained through a preliminary simulation using the CORSIKA code [3]. The obtained azimuthal isotropy demonstrates both the detection homogeneity and the good estimate of t_0 value.

2.2. Core position and shower size determination

Since the UV light detector field of view will be limited to the array dimensions, we are interested only to internal events, that represent 10.2% of the whole data set. As first step, to optimize the reconstruction efficiency, only strong internal events have been considered requiring:

$$\delta S_{4i} = (S_4 - \sqrt{S_4}) - (S_i + \sqrt{S_i}) > 0, \;\; S_i > 1 \quad i = 1, 2, 3 \qquad (1)$$

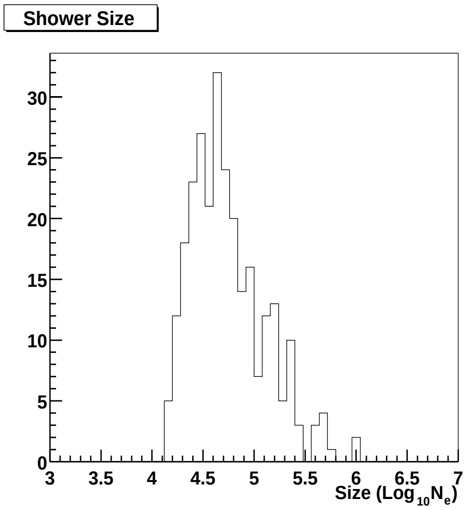

Fig. 3. Size spectrum for strong internal events.

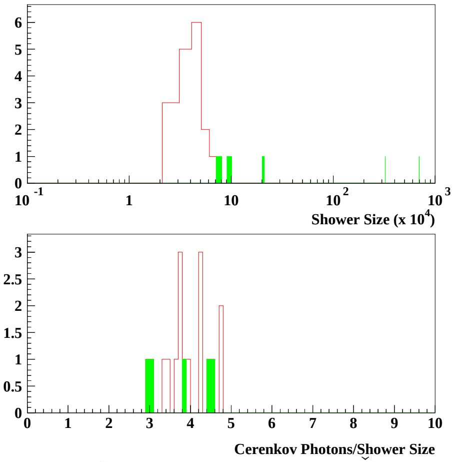

Fig. 4. Size variations and Čerenkov / Shower size ratio, see detail in the text.

where S_i is the number of particles recorded by each module. The condition $\delta S_{4i} > 0$, where the index 4 points to the central station of the array, forces the selection of internal events: 349 events are selected corresponding to 3.0% of the whole sample. Due to the limited number of sampling points in our detector, the *Circle Algorithm* [2] has been applied to determine the core location before fitting the experimental particle densities with the expected NKG* lateral distribution function. With this technique, leaving the shower size N_e and the age s in the NKG function as free parameters of the minimization process, 272 events, i.e. the 77% of the strong internal subset have been properly reconstructed. Fig. 2. shows the reconstructed core positions while in figure 3. the N_e size spectrum is presented.

3. Monte Carlo Simulations

Detector performances and reliability of the reconstruction algorithm have been tested through a Montecarlo simulation using the CORSIKA code [3] with the QGSJET model [4] for hadronic interactions. EAS produced by primary protons have been generated for fixed primary energies ranging from 10^5 to 10^7 GeV and zenith angles $\theta = 0^0, 20^0$. Two different observation levels h$=0, 2000$ m a.s.l. have been considered in order to check detector response in different conditions, i.e. at sea or mountain side. For each shower the core position is randomly extracted over a convenient sampling area A centered on the ETscope detector and the expected particle densities $\rho_i^{'}$ are obtained. The same trigger threshold and conditions are included as in experimental data requiring $S_i > 0.3$ VEM for the 3 vertexes stations and the effective area is calculated for different

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[*] $\rho_{NKG}(r) \propto N_e(\frac{r}{r_0})^{s-2}(1+\frac{r}{r_0})^{s-4.5}$, where $r_0 = 100$m is the Molière radius, N_e the shower size and s the associated age.

detector configurations as a function of the primary energy. For the used layout the effective area saturates at 690 m^2 (for internal events) with 80% efficiency at $E = 3 \cdot 10^5$ GeV. The shower size and core location resolutions have been calculated analyzing the simulated data with the same reconstruction algorithm and comparing the obtained core position and size with the MC inputs. The resulting shower size and core location resolutions are respectively: $\Delta N_e/N_e =$ 20% and $\delta r = 0.6$ m for $E > 3 \cdot 10^5$ GeV for internal and vertical events at $h = 2000$ m a.s.l. The effective area has been checked calculating the trigger rate in a narrow angular window ($\theta < 10^0$); the obtained vale $f = 0.011 \pm 0.003$ Hz is very close to the experimental rate $f = 0.015$ Hz.

3.1. Shower size and Čerenkov light correlation

Another important point is the correlation between the number of detected Čerenkov photons and the shower size detected at ground. This is of crucial importance due to the large shower to shower fluctuations at a given energy and angle. The same MC simulation has been used to study the variations of the ratio -Čerenkov Photons/ Shower Size- for vertical protons at 2000 m a.s.l.. Fig. 4. (top) shows the shower size for primaries of fixed energy 3×10^{14} eV (open histogram) and higher energies up to 10^{16} eV (solid); on the same plot (bottom) the ratio between Čerenkov photons and particle density is shown for the same events. Even if the particle density varies by an important factor ($\gtrsim$ 100%) for fixed energy, the ratio remains the same (within 25 %) for all energies. Moreover the fluctuations of particle density at fixed zenith angle decrease with energy, giving smaller expected fluctuations at higher primary energies.

4. Conclusions

A small ground array has been built to detect air showers in coincidence with an optical telescope within the ULTRA project. The first test experiment allowed to fix the characteristics of the array, collect, analyse and interpret the data. The next point will be to see a Čerenkov correlated signal and then start to characterize different surfaces at sea level.

References

[1] Catalano O. et al. 2002, ULTRA Technical Report, EUSO-SEA-REP001.
[2] Catalano O. 1997, IFCAI-Palermo Internal Report.
[3] Heck D. et al. 1998, Karlsruhe Report FZKA 6019.
[4] Kalmykov N.N et al. 1997, Nucl. Phys. B (Proc. Suppl.) 17, 52B.