

CLUE: CERENKOV LIGHT ULTRAVIOLET EXPERIMENT. PRELIMINARY RESULTS AND FUTURE PLANS

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1. INTRODUCTION.

The results of the test of a prototype apparatus aimed to detect the ultraviolet Cerenkov light in the wavelength range 1900-2300 Å are presented. The detection of the Cerenkov light emitted by the charged secondaries from a cosmic ray atmospheric shower is a well known technique (1). To reduce the background light from stars or moon (2) we propose the use of a photosensitive gas proportional chamber of the type developed for Ring Imaging Cerenkov (RICH) detectors (3) used in high energy accelerator physics, placed in the focal plane of a parabolic mirror (Fig.1). These chambers respond only to UV light around 2100 Å, a shorter wavelength than solar blind PMT (4) and, due to the Ozone layer in the high atmosphere, completely opaque at these wavelengths (5), the apparatus does not detect UV light coming from outside the atmosphere.

2. DESCRIPTION OF THE APPARATUS

The detector is a square gas proportional chamber (MWPC) with a 21*21 cm² sensitive area and a quartz front window (Fig. 2). The gas used was an ethane/isobutane 4:1 mixture saturated at 30°C temperature with TMAE (tetrakis [dimethylamino] ethylene) which is the photosensitive material. The gas avalanches from photoelectrons are detected via charge induction in the back cathode plane which consists of 16*16 square conductive pads. The signals, after a low-noise preamplifier, were analyzed with 2282 Lecroy ADC's in a CAMAC data acquisition system. A sum signal (OR), used for triggering purposes, was also taken from the anode wire plane. On the chamber side opposite the quartz window, a plastic scintillator counter of the same area 21*21 cm² was used to detect charged particles traversing the chamber. The mirror, of 1.5 m diameter and .64 m focal length, was aluminized. The measured reflectivity at 2000 Å wavelength was 75%. The measurement were taken with the apparatus placed near the extended atmospheric shower array EAS-TOP (6) at Campo Imperatore (Gran Sasso) 1800 m above sea level (Fig.3). For our testing purposes we used only 4 of their sheds 16 meter distant from one another named A, B, C and D. Fourfold coincidences among the sheds were used as a trigger defining a cosmic ray extended shower. The data were taken during nights in Summer 1989.

3. MEASUREMENTS AND RESULTS

The quantum efficiency through quartz of TMAE as a function of the wavelength is presented in Fig.4a. The distribution of the Cerenkov light as a function of λ and the spectrum of night sky light are shown in Fig.5b. It may be remarked that in principle no background should be present in the detector.

To evaluate the performance of this photosensitive chamber several tests were made in the laboratory with a hydrogen lamp. Fig.5 shows the results of the pulse height analysis of hit pads. With 6 UV photons entering on the chamber the Poisson-Furry fit on the measured distribution of Fig.5, gives 1.8 photoelectrons produced in the chamber. Fig.6 shows a typical event as seen on the on line computer during normal data taking at the Gran Sasso.

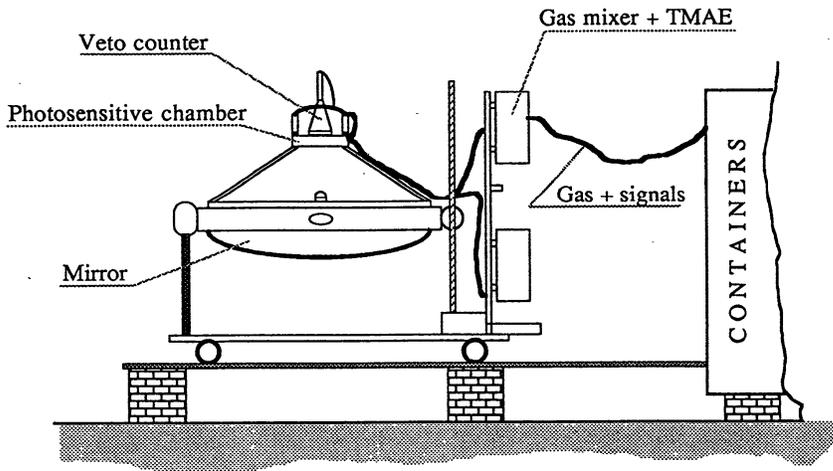


Figure 1 - Mechanical layout of the mirror and equatorial mount

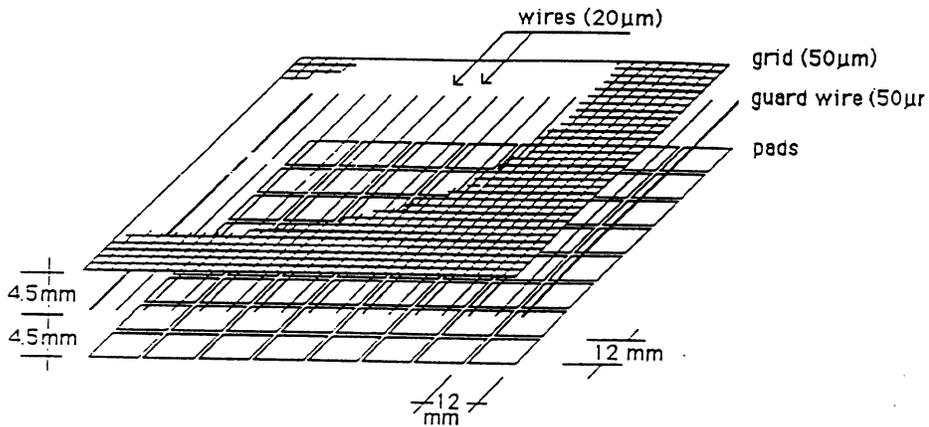


Figure 2 - Basic geometry of the chamber and schematic layout of the electrodes

In order to evaluate the capability of our system to detect the Cerenkov light shower we made two runs:

In the first one we asked our apparatus to have only charged particles through the chamber. So we obscured the quartz window of the chamber and we used the fourfold coincidence EAS-TOP (A,B,C and D sheds) in coincidence also with the scintillation counter above the chamber. In the second one we ran in the normal way in order to have only Cerenkov light in the chamber. In this case the scintillation counter above the chamber was used as veto for charged particles through the chamber. Figs.7a and 7b show the results of these two runs. Q_{tot} is the total charge induced on the pads in one event and N_{ch} is the number of pads.

The two plots are quite different. Charged particles give high signals in a small number of pads; on the contrary, Cerenkov light is more diffuse, as in Fig.4. The events in the

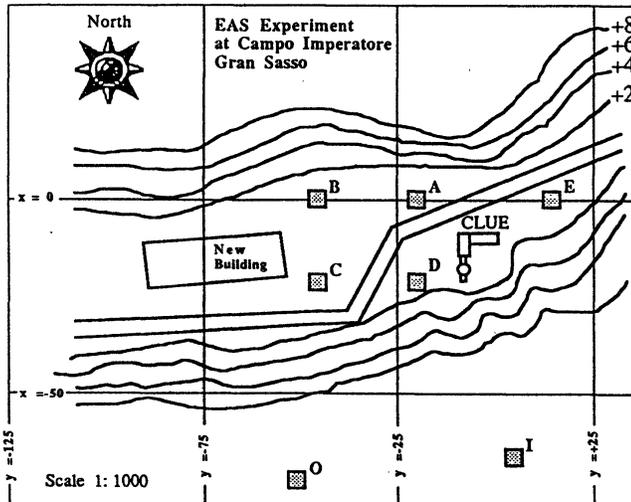


Figure 3 - EAS - TOP Experiment

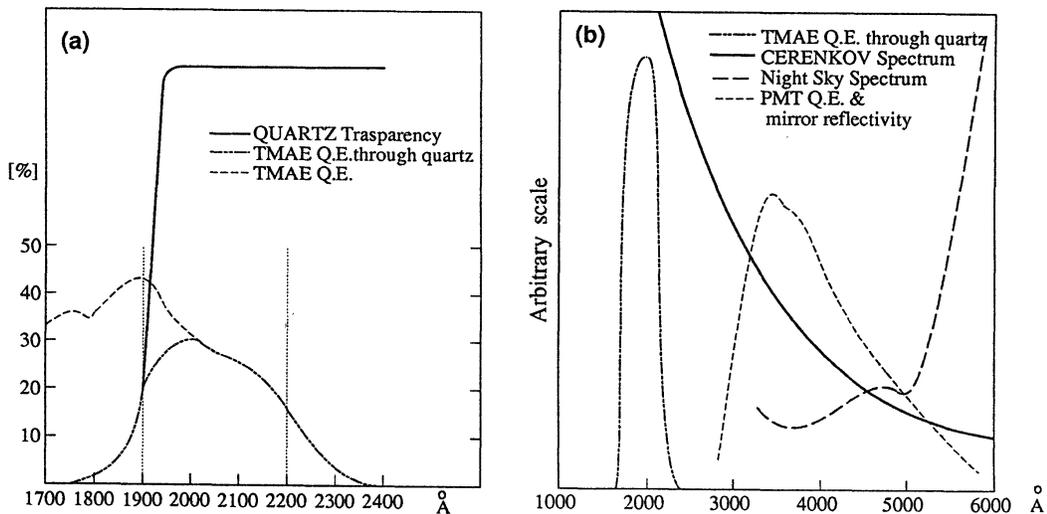


Figure 4

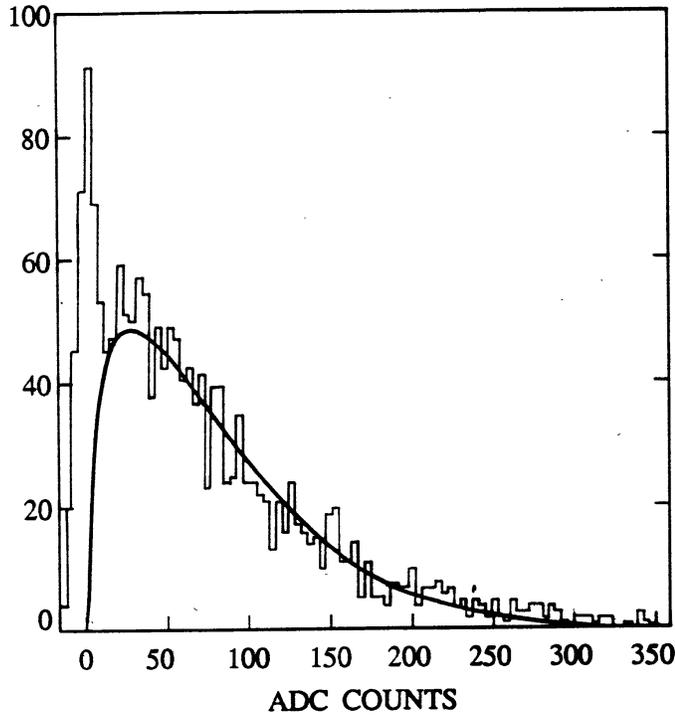


Figure 5 - Pulse height analysis of hit pads in a lamp run

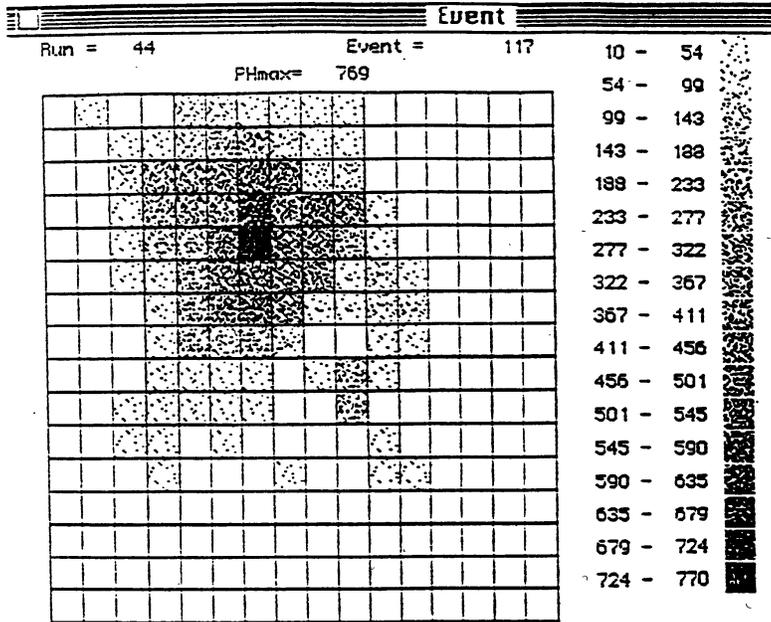


Figure 6 - A typical shower event as shown in the on line analysis

upper region of Fig.7b come from charged events not rejected by the veto. In fact the scintillator did not overlap perfectly the chamber. We can conclude that it is easy to distinguish between charged and light events. Putting a simple cut, such as cut1 on Fig.7b, the contamination may be reduced to a few percent.

The relative timing between the four EAS-TOP sheds can be used to find the shower direction. Using this standard method we expect large errors because there are only four counters and the threshold in the counters was low. Events with a large spread on the front of the shower dominate. Moreover a reasonable estimate for the angular resolution can be obtained from TOF analysis. The time difference $T_A - T_B$ versus $T_D - T_C$ of the four EAS-TOP shed counters for shower events are plotted in Fig.8a. These time differences should be the same. The length of the pattern in the scatter plot gives a

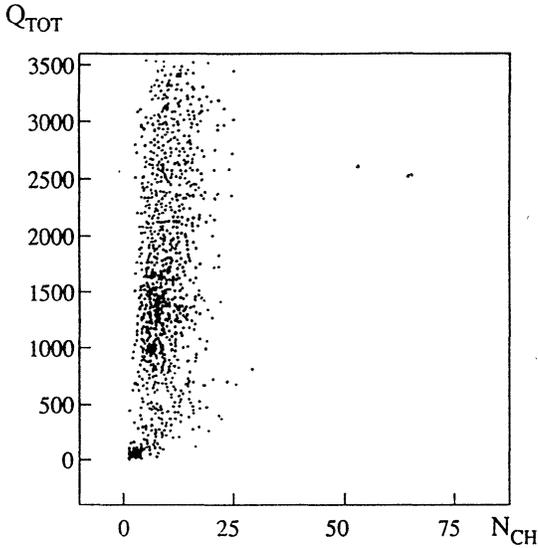


Figure 7a - Total charge in the pads versus the number of pads for charged particles through the chamber.

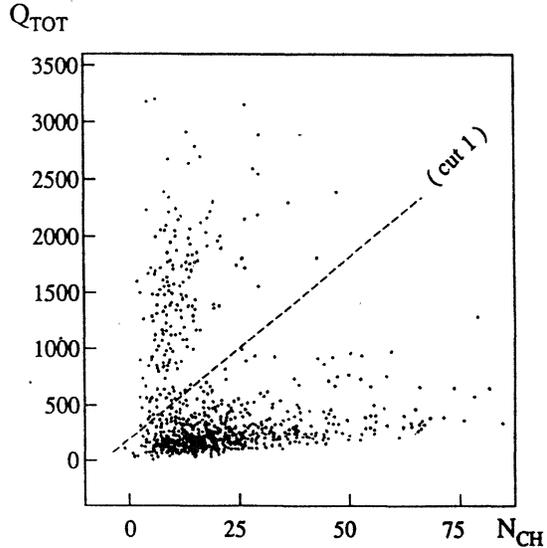


Figure 7b - Total charge in the pads versus the number of pads for Cerenkov light shower events.

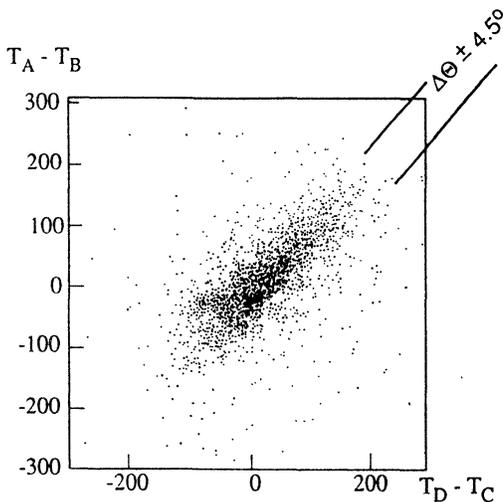


Figure 8a - Time of flight analysis for EAS-TOP events

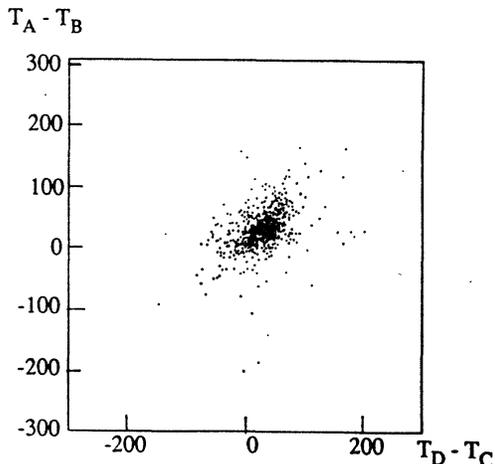


Figure 8b - Time of flight analysis for EAS-TOP events and with the chamber in coincidence.

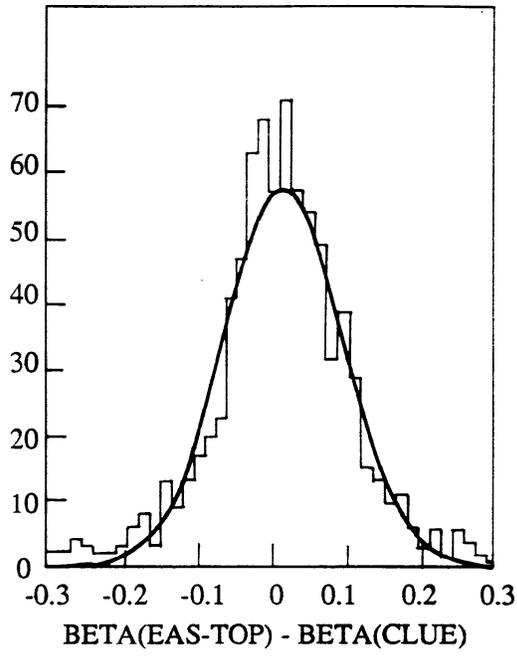


Figure 9 - Difference between the projected shower direction angles measured with TOF and with the CLUE apparatus

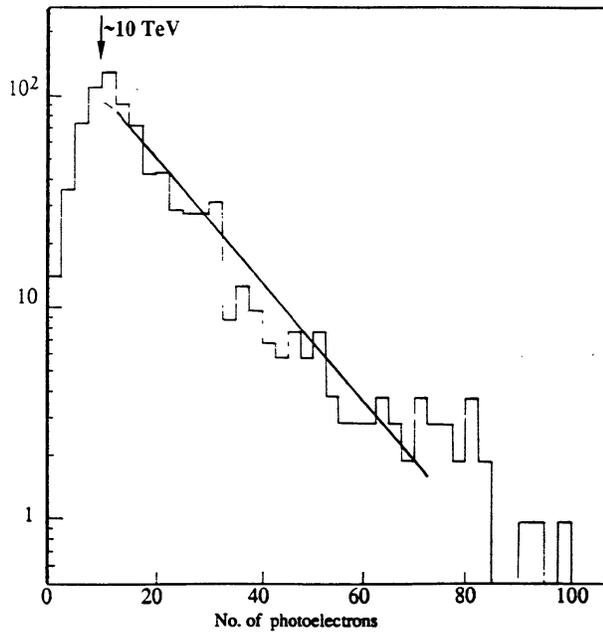


Figure 10 - Frequency distribution of photoelectrons for shower events.

measure of the angular acceptance of the coincidence of the four sheds and the width gives the errors in the shower direction. If we select the events with Cerenkov light trigger we obtain the plot in Fig.8b. These events fall in a much smaller region. In this way we get an angular acceptance of $\pm 45^\circ$ for the four EAS-TOP counter and $\pm 8^\circ$ for our detector as foreseen. We find an error in the determination of the shower direction of $\pm 4.5^\circ$ (77 mrad).

A completely independent measure of the shower direction is given by our Cerenkov detector. In fact a point in our focal plane, where the chamber is placed, corresponds to the light coming from a definite direction. So, from the centre of gravity of the Cerenkov light intensity, one may deduce the direction of the shower. Plotting the differences of the angles measured with these two methods (Fig.9) we get:

$$\langle \beta_{\text{EAS-TOP}} - \beta_{\text{CLUE}} \rangle = 0.017 \pm 0.003 \text{ rad}; \quad \text{RMS} = 0.0795 \pm 0.003 \text{ rad}$$

It is evident that the error introduced by the Cerenkov detector is smaller and negligible with respect to the EAS-TOP determination. It should be remarked that we worked in this test with one mirror only. Fig.10 shows the frequency distribution of photoelectrons for shower events triggered by EAS-TOP. If we assume that the energy threshold in this condition was 10 TeV our detector could work, at the 2 photon level, with a threshold of the order of 1 TeV or less.

4. FUTURE PLANS

We are now designing a cosmic ray telescope based on the experience gained with this prototype. It will consist of 64 units arranged in a matrix with a pitch in the order of 50 m. Aim of the collaboration is to build and operate for physics experiments a system that would allow observation of cosmic ray showers, in particular γ -initiated shower, with high sensitivity and good angular precision. The main task of the experiment is the study of the localized sources and variable stars that are visible from a tropical location and in particular of those near the centre of Galaxy. For this, the site foreseen for our telescope would be in a tropical location and at an altitude of 4000 m a.s.l. in order to reduce the UV absorption.

The main parameters proposed are:

Coverage	$2 \cdot 10^5 \text{ m}^2$
Duty-Cycle	60%
Threshold	<1 TeV
Angular resolution	3 mrad
Angular acceptance	$\pm 5^\circ$
Mirror diameter	1.5 m.
Focal length	1.5 m
Cost	4 M\$ in 3 Years

5. CONCLUSIONS

We have shown the feasibility of an experiment based on the detection of the Cerenkov light produced by cosmic ray atmospheric showers, with TMAE photosensitive gas proportional chamber. These detectors, even in prototype form, have given no particular problem, being capable to work in the open air in a rather severe environment with strong winds, large thermal excursions and humidity changes. We are at present designing a cosmic ray telescope with a large number of detectors. The possibility of working with the moon present in the sky and perhaps even in full daylight, with low background, combined with the good angular resolution achievable with such a high granularity detector, should give a significant improvement to the field of Cerenkov light gamma ray astronomy.

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DISCUSSION:

G. AURIEMMA: What are the characteristics of the light collector ?

L. PERUZZO: The search light parabolic mirror is alluminized on front face. Its diameter is 1.5 m and its focal length is 0.64 m.