The ULTRA Experiment: a Supporting Activity for the Euso Project

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Abstract

The ULTRA experiment [4] has been designed in the framework of the EUSO project to measure the reflected/diffused signal produced by the EAS impacting on the Earth surface. EUSO will detect the EECRs measuring the fluorescent light produced by the interaction with the Earth atmosphere. With this method, the particle track can be measured together with its relative depth, but not its absolute position. Čerenkov light associated to the EAS is emitted in a narrow cone and hits the Earth surface, being partially absorbed and partially diffused. This signal will give an absolute reference for the track, allowing the measurement of the shower maximum and making also easier the separation between neutrino and hadronic showers. Moreover, Čerenkov light can give an independent estimation of the shower energy if the reflectivity of the shower impinging surface is known. The ULTRA detector includes a UV optical device to collect the Čerenkov light diffused by various surfaces and an array of scintillators to detect, in coincidence, cosmic ray showers. First tests have been done last October in Mont-Cenis (France, 1970 m a.s.l.); next measurement campaign is scheduled for June 2003.

1. Introduction

The primary purpose of the EUSO [7] (Extreme Universe Space Observatory) experiment is to detect, with high statistics, Extreme Energy Cosmic Rays (EECR) and neutrinos. EUSO will look downwards to the Earth atmo-

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sphere, from an altitude of about 400 km, imaging the fluorescent ultraviolet (UV) faint traces produced by the charged secondary particles of Extensive Air Showers (EAS) developing through the atmosphere. Showers are accompanied by Čerenkov light that is reflectively back scattered by the Earth surface and will be also detected. In the EUSO context, several experiments have been identified as propaedeutic experimental supporting activities. Atmospheric background measurements have been performed at mountain altitude, looking at the nocturnal sky, and by balloon borne experiments, providing over ground and over sea background radiance profiles [3]. Laboratory measurements of fluorescence yield at low energy (22 KeV) have been performed using the x-ray facilities located in Palermo, Italy, [2] while the measurement at higher energies is presently under discussion. The study of the transmission features in the atmosphere and the reflection/diffusion over land and clouds of the light associated to EAS are other crucial subjects for EUSO, and are covered by the ULTRA (Uv Light Transmission and Reflection in the Atmosphere) experiment, that will provide quantitative measurements of the diffused signal produced by the EAS impacting on the Earth surface. A scintillator array and an UV light detector will operate simultaneously to detect EAS in coincidence with the UV light. Finally the atmospheric transmission properties will also be investigated using the UV light detector and a laser emitter.

2. Fluorescence and Čerenkov light production

Fluorescence light is produced by the EAS electrons moving through the atmosphere and exciting metastable energy levels in its atoms and molecules. After a short relaxation time, they return to the ground state, emitting photons that in air extend from infrared to UV, with peaks at wavelenghts from 330 to 450 nm. The UV yield is of the order of 4 photons per meter of electron track and is emitted isotropically and proportional to the shower size at any given depth in the atmosphere. The EUSO detector will measure the ionization as a function of the slant depth X in the atmosphere for each shower, together with its trajectory. The electrons in the EAS generate also a rather big amount of Čerenkov light, which is highly beamed in the forward direction. This light builds up with the shower front and lands on the Earth surface, or on the clouds, where is partially absorbed and partially reflectively diffused. EUSO will detect the diffused Čerenkov photons using them as a signature of the impact point of the shower front on the surface. This signal, together with auxiliary altimeter informations, will allow the measurement of X_{max} with a precision of few tens of g/cm^2, making possible the study of the primary chemical composition shower by shower, and the separation between high penetrating neutrinos and quick interacting hadrons. Moreover, Čerenkov light can be used as an independent estimation of the shower energy, if the reflectivity of the shower landing surface

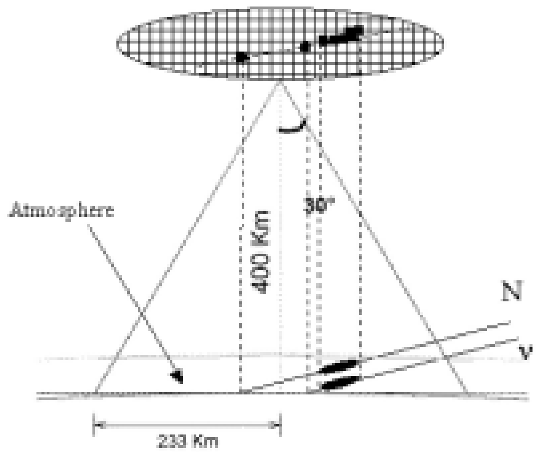

Fig. 1. Neutrino shower and hadronic shower as imaged by the EUSO focal surface detector. Note as the Čerenkov signature permits to resolve high penetrating neutrino from quick interacting primary hadron.

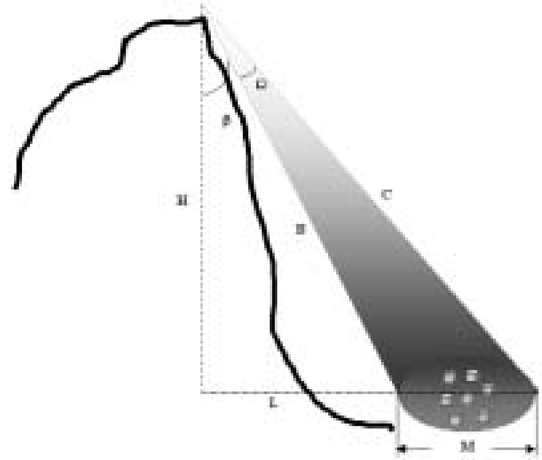

Fig. 2. Sketch of a typical configuration for the detection of the Čerenkov light diffused by EAS. The gray ellipse represents the coincidence area shared by the UVscope and ETscope array.

is known. Fig. 1 shows a sketch of the reported geometry.

The detection of EAS through the Čerenkov light reflected by snow was first proposed by A.E. Chudakov [6] in 1972 and performed in some sites since 1983; only snowed surfaces were used without any measurement of the related electro-magnetic component.

3. The detector

The ULTRA apparatus is a hybrid system consisting of an UV optical detection unit, the UVscope, and an array of scintillators, the ETscope (EAS Telescope). The UVscope is used to detect the diffused Čerenkov UV light from EAS that are detected in coincidence by the ETscope array. Data taking and synchronization between UVscope and ETscope is performed by radio-link using wireless technology and GPS devices [1]. A laser system is used to characterize the atmosphere in the measurement of Čerenkov diffused light and as an indispensable tool for the determination of the reflection coefficient of clouds. The main objective of the ULTRA experiment is the detection of the Čerenkov light associated with EAS, measuring the average reflection coefficient of different surfaces (grass-covered, trees-covered and iced land, desert and water-sea) as a function of the shower axis inclination. Meteor observation in UV light can also be made from the same location of ULTRA, employing the same basic instrumentation.

The validation and calibration of the UV yield is obtained with contextual observation in the optical range. The ULTRA apparatus operates in open field environment, and requires a suitable site allowing a convenient geometrical setup. Moreover, low light pollution and clear moonless nights are required to disentangle Čerenkov light pulses from night sky background. Observations in different locations will obviously be needed to achieve these goals. As first site we have chosen the Mont-Cenis lake (1970 m a.s.l., France), where a measurement campaign has started in October, 2002 [5]. Fig. 2 shows a favorable geometry for running the experiment. The UVscope is placed on the top of a hill whereas the ETscope array is located on the valley. The field of view of the UVscope is chosen to cover the overall scintillator array; a laser is used for continuous monitoring of the atmosphere transmission during the running periods.

4. Conclusions and Schedule

The ULTRA activity is expected to investigate the possibility of detecting the Čerenkov signal from space for the EUSO experiment.

Nevertheless this measurement makes sense by itself, due to the general lack of data in this field. Moreover the UVscope at the same location, sharing people and logistics, can be used for meteor measurement, giving valuable informations in a field poorly covered by present experiments. Our first evaluations show that the ULTRA detector can accurately measure with full efficiency and reconstruct the relevant parameters of EAS with $E > 10^{16}$ eV. Few events per hour are expected above this energy threshold, but ~ 100 events, fully reconstructed, for each experimental setup are enough for the experiment purposes. Next measurements are scheduled for June 2003 at Mont-Cenis with an ETscope array of 5 detectors placed on ground; a test above water is foreseen immediatly after. The results on the detection of the first Čerenkov signals in coincidence with EAS will be hopefully presented at the Conference.

5. References

1. Assis P. et al. "A PCI based data acquisition system for ground array detectors with wireless synchronization through GPS", these proceedings
2. Biondo B. et al. 1998, AIP Conference Proceedings No 433, 361
3. Catalano O. et al. 2002, Nucl. Instr. Meth. A, 480/2-3, 547
4. Catalano O. et al. 2002, ULTRA Technical Report, EUSO-SEA-REP001
5. Chauvin J. et al. "The ETscope Ground Array for the ULTRA Experiment", these proceedings
6. Chudakov A.E. 1972, Proc. Symp. On Cosmic Rays, Yakutsk, 69
7. Scarsi L. 2001, Il Nuovo Cimento C, 24/4-5, 471