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EUSO– Extreme Universe Space Observatory: Ground Data Handling and Outreach.

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Abstract. The Extreme Universe Space Observatory *EUSO* is the first experiment from space devoted to the investigation of the Extreme Energy Cosmic Ray radiation. *EUSO* will observe the track of fluorescence UV light induced by the Extensive Air Showers developed in the atmosphere by the incoming radiation. The main instrument consists of a UV telescope with large collecting area and wide field of view, a high-segmented focal detector, and a sophisticated on-board image processing acting as a trigger. *EUSO* has been approved by the European Space Agency for a Phase A study concerning its accommodation as external payload on the International Space Station, with a goal for flight in 2008.

1 Introduction

The flux of cosmic radiation reaching the Earth falls rapidly with energy, decreasing by a factor 50 to 100 for each decade of increasing energy. The "knee" of the spectrum, just above 10^{15} eV, is roughly the highest energy at which direct measurement of the cosmic radiation by instruments is feasible. Above this energy, measurements are made by observation of the cascades (Extensive Air Shower, EAS) of particles that result from the interaction of a high-energy cosmic ray with the Earth's atmosphere.

Historically, for more than 40 years after the discovery of EAS, they were studied by arrays of detectors (e.g. scintillators, Čerenkov detectors) deployed on the ground over many square kilometers. In effect, the atmosphere was used as a calorimeter in which the signal was detected at only one depth. The first of these ground arrays, the Volcano Ranch 8 km^2 array, reported an event with energy 10^{20} eV (Linsley, 1962), while the Haverah Park array (Lawrence et al., 1991) operating for 20 years observed 4 events with energy in excess of 10^{20} eV. The largest currently operating ground array, AGASA, covers 100 km^2 and has reported 8 events with energy above 10^{20} eV. (Hayashida et al., 2000).

A different approach to use of the atmosphere as a calorimeter exploits the fact that charged particles passing through nitrogen will excite fluorescence emission in the near ultraviolet (UV). Optical observation of the trajectory of an air shower through the atmosphere then allows reconstruction of the trajectory and determination of the full cascade development. To date, the only instruments to implement this technique are the Fly's Eye (Baltrusaitus et al., 1985) and its successor HiRes. The Fly's Eye has reported the highest energy cosmic ray event observed to date, with an energy of 3×10^{20} eV (Bird et al., 1995).

Based on the present data, the flux of cosmic radiation above 10^{20} eV is about one per square kilometer per century. Fewer than 20 such events have been reported in the literature. These facts set the scale of exposure that new instruments must achieve. The HiRes fluorescence detector has an effective aperture of 1000 km^2 sr, while the Pierre Auger Observatory (Pryke, 1998) under construction will have an aperture of 7000 km^2 sr for the ground array and about 700 km^2 sr for its fluorescence detector component.

In spite of the big efforts lavished in the last 40 years, no more than a handful of Extreme Energy Cosmic Ray (EECR) events have been reported by the ground-based experiments: a solution is provided by observing the UV induced fluorescence from space, which allows exploiting a more bigger acceptance area with respect to the ground-based observatory.

EUSO is the first experiment from space devoted to the investigation of the EECR radiation.

EUSO will observe the fluorescence and Čerenkov signals by looking downwards at the dark Earth's atmosphere from space with a 60° field of view (FOV).

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The light will be imaged by a large Fresnel lens optics system onto a finely segmented focal surface detector. The segmentation and the time resolution will allow the reconstruction of the arrival direction with a precision up to a small fraction of a degree and shower energy better than 20%. The main objective of *EUSO* is to obtain a detailed description of the Cosmic ray spectrum above 3×10^{19} eV together with a map of the arrival direction; *EUSO* is expected to detect up to a thousand EECR events per year (depending on the spectral index of the energy spectrum) with energies $>10^{20}$ eV, and to open a window to the high energy neutrino Universe.

EUSO, approved by the European Space Agency for a Phase A study, will be accommodated as external payload on the International Space Station, with a goal for flight in 2008. A detailed presentation of the *EUSO* scientific rationale and objectives (Scarsi et al., 2001) and of some specific items is given elsewhere in these Proceedings.

2 Method of Operation

EECR particles interact with the Earth atmosphere giving rise to propagating EAS accompanied by the emission of UV fluorescence induced in Nitrogen by the secondary charged particles, and by a diffuse Čerenkov signal (reflected from top of clouds, land, or sea), as result of a complex relativistic cascade process.

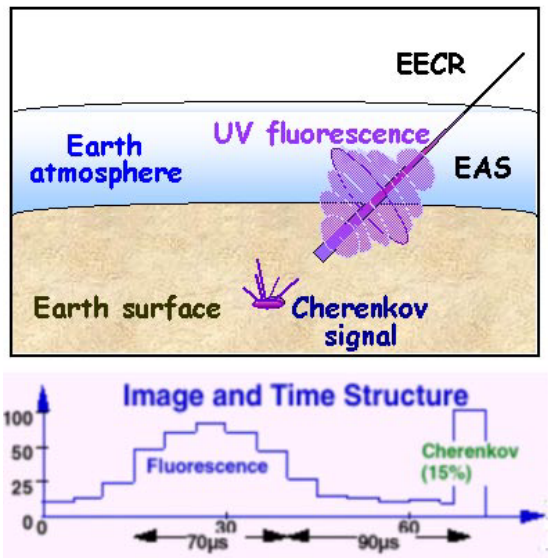

Fig.1. Time profile of the emitted UV light from an EAS.

Viewed at some instant from a distance, an EAS appears as a relatively small disc-shaped luminous object. When it is viewed continuously, the object moves on a straight path with the speed of light. As it does so, the disc luminosity changes from so faint to be undetectable, up to a maximum followed by a gradual fading (Linsley 2000).

The interaction medium is the entire Earth atmosphere and the main interaction region is within 30 km from the sea level (Fig.2); the upper level regions however have an important role too, mainly for what concerns background and atmospheric phenomena (Giarrusso et al.,2001; Kostadinov et al., 2001; Maccarone & Mineo, 2001).

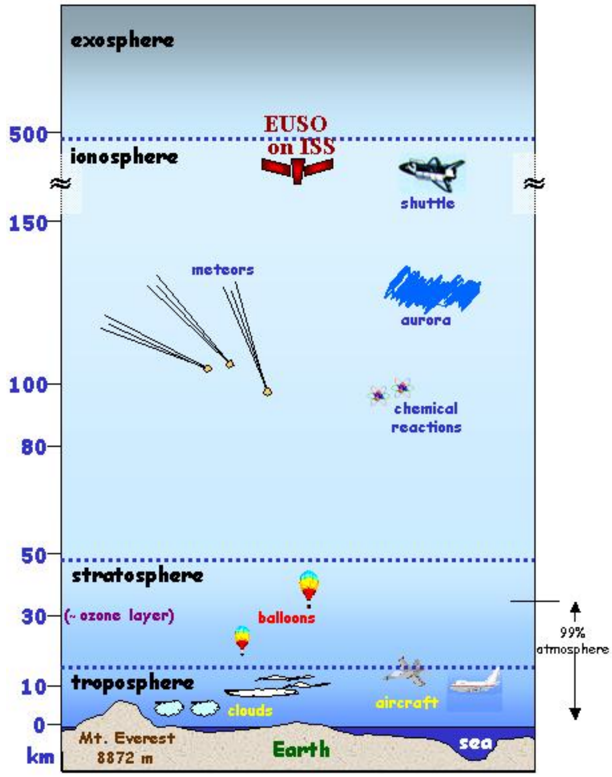

Fig.2. The various regions of the Earth atmosphere.

The fluorescence technique adopted in *EUSO* images the shower in the atmosphere onto a camera of fast photon detectors (Ameri et al., 2001). This method works best during clear moonless nights, and allows the measurement of the longitudinal development of the shower leading to a rather reliable calorimetric energy measurement. The arrival direction is determined in *EUSO* by a precise timing, at the nanosecond level (Catalano, 2001). The shower curve, specifically the height of the shower maximum, depends on the primary particle and, therefore, gives an indication about the nature of the Primary. Showers initiated after the traversal of a very deep layer of atmosphere indicate an origin by neutrinos (see Fig.3) because the neutrino-air nuclei interaction cross-section is several orders of magnitude lower than the cross section for hadrons or photons.

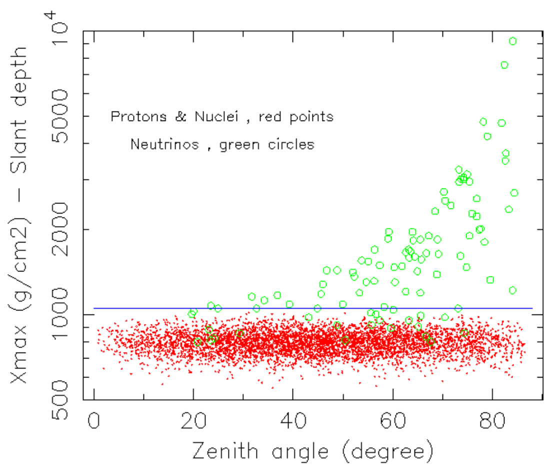

Fig.3. Shower depth distribution from Monte Carlo simulations.

3 EUSO on ISS

To comply with the *EUSO* objectives and expectations, and taking into account the faint fluorescence signal, the telescope will be composed by: an optics system with large collecting areas and wide equivalent field of view, a focal plane detector with high sensitivity in the 300-400 nm UV range and fast resolving time (of the order of few nanoseconds), a trigger and read-out electronics capable to handle hundreds of thousands channels and comprehensive of a dedicated onboard track recorder acting as a trigger. All these parts will be assembled together in an envelope, as schematically shown in Fig.4.

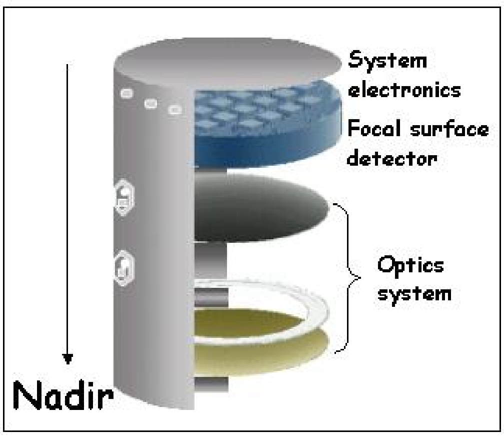

Fig.4. Scheme of the *EUSO* main telescope.

The requirement of an "in situ / real time" knowledge of the properties of the atmosphere at the EAS occurrence (presence and nature of clouds, atmosphere transparency) to correct for systematic errors in the measurement of the EAS parameters is fulfilled by a "Lidar sounding" carried out with appropriate instrumentation on *EUSO*.

The telescope will then be accommodated on the ISS as external payload of the European Columbus module. Fig.5 shows an artist view of the *EUSO* accommodation on ISS.

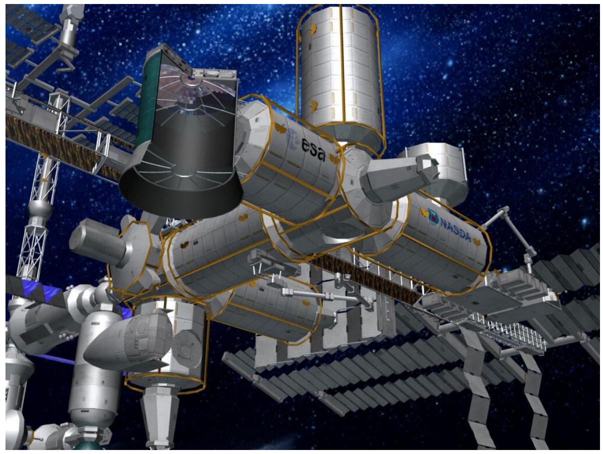

Fig.5. Artist impression of *EUSO* (split view) on the ISS.

4 EUSO operations

EUSO will be accommodated on the ISS as a fixed Nadir pointing observatory. Just after the accommodation phase, there will be a period of Commissioning and Science Verification phase during which the scientific performance of *EUSO* will be assessed and the instruments calibrated. The remainder of the operational lifetime will be in the Routine phase.

Two main operational modes are foreseeable, namely "observing" and "protection". In the "observing mode" *EUSO* will observe the Earth atmosphere during night time. During the orbital periods affected by the Sun, or when the light intensity is above acceptable limits, the *EUSO* aperture will be closed to protect its focal surface detector ("protection mode").

Telemetry from *EUSO* will be received at the Ground Station, forwarded to the *EUSO* Operations and Science Data Centre, and made available to the scientific community in accordance with the ESA-EUSO rules.

Since the main scientific goals require the establishment of a complete and homogeneous database of EECR events, the data rights will be defined for a proper period following the end of scientific operations. At the end of this proprietary period, the *EUSO* products will be made public to the scientific community. Products will include *EUSO* scientific data, ISS relevant housekeeping, and other ancillary information.

5 Conclusions

The detection of Extreme Energy Cosmic Rays and Neutrinos is the challenge of the future generation experiments in Astroparticle Physics.

EUSO, the first mission devoted to the EECR investigation from space, represents the non conventional way to look beyond at the Extreme Universe using the largest available detector for the extraterrestrial energetic radiation, as represented by the Earth atmosphere.

EUSO will record data both from EECR events and from phenomena intrinsic to the atmosphere, or induced by the flux of meteoroids incoming from space: for this aspect *EUSO* is an interesting example of multi-disciplinarity in a space mission.

EUSO it is expected to detect of the order of 10^3/year EECRs with $E>10^{20}$ eV, and to open a window into the High Energy Neutrino Astronomy.

EUSO, as an astroparticle space observatory, is unique in its class.

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References

Ameri, M., et al., 27th ICRC, Hamburg, Germany, 2001
Baltrusaitis, R.M., et al., 1985, *NIM A 311, 338*
Bird, D.J., et al., 1993, *Phys.Rev.Lett. 71, 71*
Catalano, O., 27th ICRC, Hamburg, Germany, 2001
Hayashida, N., et al., 2000, astro-ph/0008102
Lawrence, M.A., et a., 1991, *J.Phys.G: Nucl.Part.Phys. 17, 773*
Linsley, J., 1962, *Phys. Rev. Lett. 10, 146*
Linsley, J., 2000, http://www.ifcai.pa.cnr.it/~EUSO/pages/linsley1.html
Maccarone, M.C. and Mineo, T., 27th ICRC, Hamburg, 2001
Pryke, C., 1998, *AIP Conf. Proc. No. 433, 312*
Scarsi, L., et al., 27th ICRC, Hamburg, Germany, 2001