EUSO
Extreme Universe Space Observatory

A. Thea(a)(d), D. Horns(c), P. Liebing(a), K. Mannheim(b), D. Mazin(a), R. Mirzoyan(a), N. Otte(a), A. Santangelo(c), M. Teshima(a) on behalf of EUSO collaboration

(a) Max-Planck-Institut für Physik, Föhringer Ring 6, 80805 München, Germany
(b) University of Wuerzburg, Germany
(c) University of Tuebingen, Germany
(d) University of Genova, Department of Physics, Genova, Italy

The EUSO Mission

The "Extreme Universe Space Observatory–EUSO" is an ESA led international mission to be flown on-board the Columbus module on the International Space Station (Fig. 1). EUSO will investigate the nature and origin of Extreme Energy Cosmic Rays (EECRs) while opening a new window to the Universe: the High Energy Neutrino Astronomy.

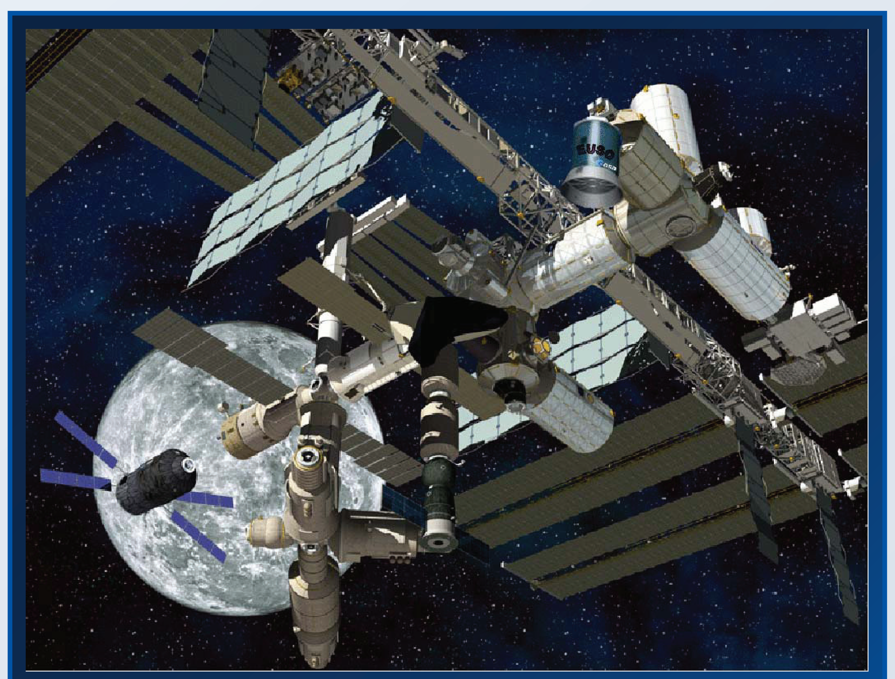


Fig. 1- EUSO on the ISS: an area of ~2×10^5 km^2 is continuosly monitored at night-time. The ISS covers the latitude range ±51° at speed of 7 km/s.

EECRs are charged particles, photons, neutrinos, with E > 5×10^{19} eV, the conventional energy of the Greisen Zatsepin and Kuzmin (GZK) effect, i.e. the photopion production on CMB photons.

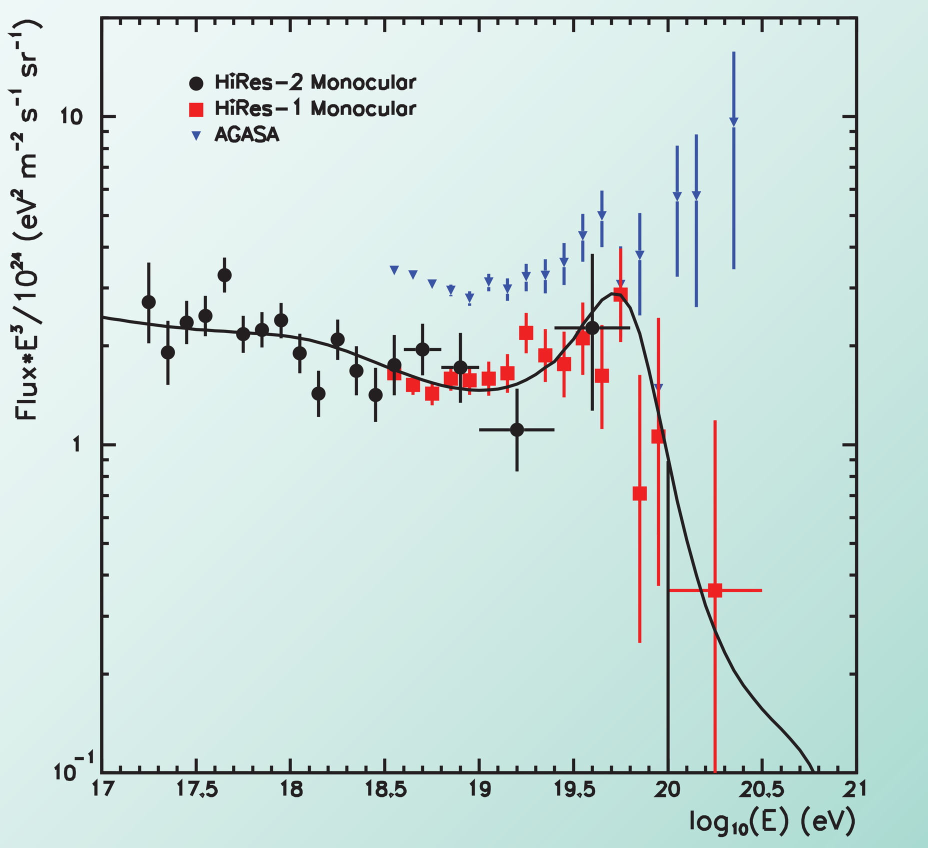


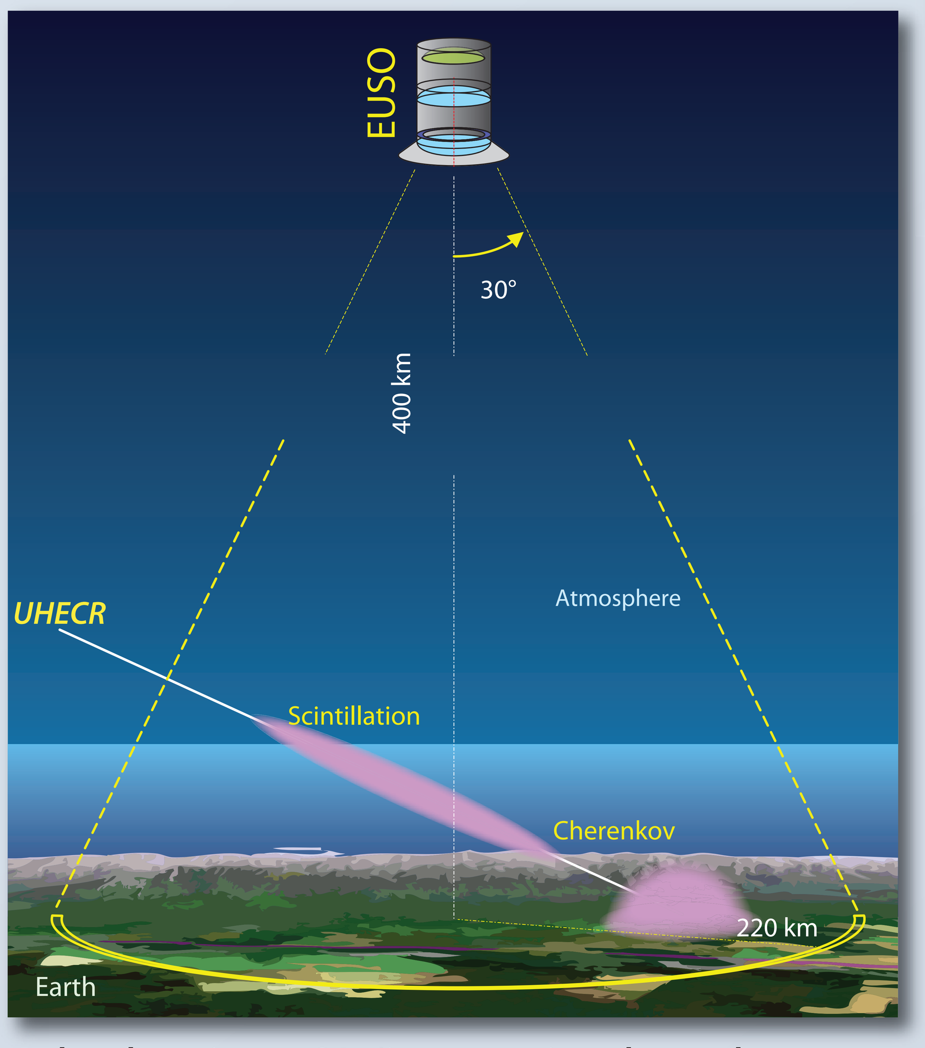
Fig. 2- EECRs flux as measured by the HiRes detectors [Abu-Zayyad et al., 2002], and the AGASA experiment [Takeda et al., 2002].

Due to GKZ, EE nucleons dramatically loose energy while propagating setting a distance limit of ~100 Mpsec. Though the existence of such EECR events is well established, there is strong disagreement between the flux and the spectrum of EECR as measured by the AGASA, which reports a Super-GZK extension of the spectrum, and the HiRes experiments, whose data are consistent with the GZK hypothesis (Fig. 2). Low statistics and systematic errors may, however, affect both experiments.

EUSO will measure the primary energy, arrival direction and composition of EECRs, using a target volume far greater than is possible from the ground. Such data will shed light on the origin of EECRs, on the sources that are producing them, on the propagation environment from the source to the Earth, and, possibly, on the particle physics mechanisms at energies well beyond the ones achievable in man-made accelerators.

The Observational Approach

EUSO will pioneer the measurement of EECR-induced Extensive Air Showers (EAS) from space (Fig. 3).



A hadronic EECR (interaction length ≈ 40 g cm^{-2} at E = 10^{20} eV) penetrating the Earth's atmosphere generates an EAS of secondary particles: the number of these secondary particles, (N> 10^{11} at the Shower maximum) is proportional to the energy of the primary event. Fig. 4 shows the expected EAS longitudinal profile, as a function of the traversed depth in atmosphere. The total energy carried by the charged secondary particles (≈ 0.5%) is converted into fluorescence photons through the excitation of the air N2 molecules. A highly beamed Cherenkov radiation is generated as well by the ultra-relativistic particles in the EAS and partly scattered by the atmosphere itself.

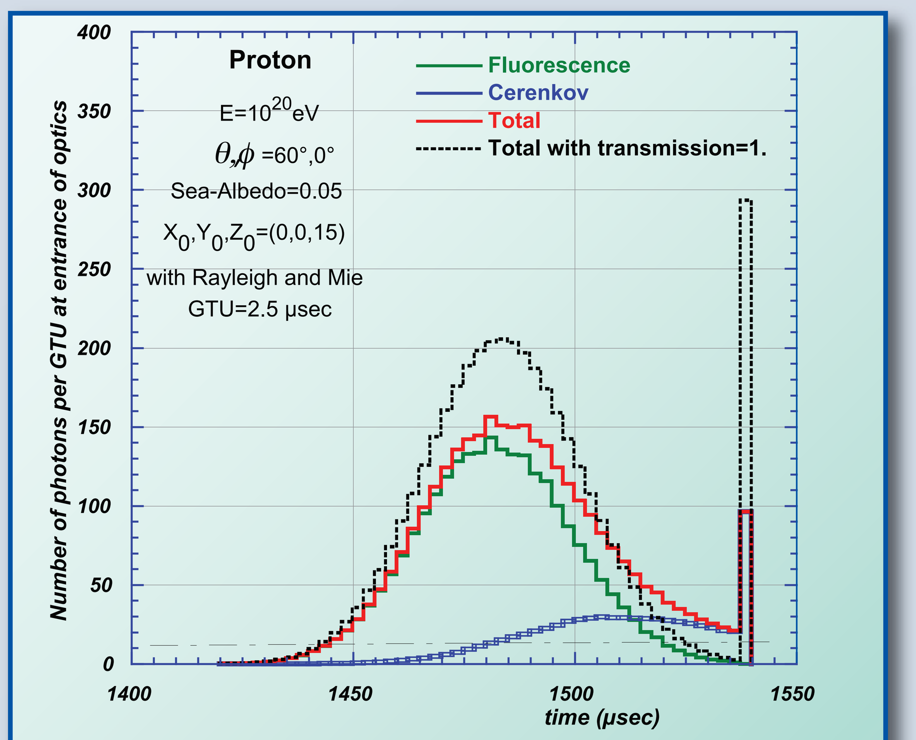


Fig. 4- Time profile of photons. The green curve shows the fluorescence photons and the blue line the diffused Čerenkov photons. The peak is the reflection of the Čerenkov photons by the sea albedo (or a cloud!).

For each shower, EUSO will measure the (330-400 nm) fluorescence track as a function of the slant depth X, in the atmosphere, and the diffusely reflected Cherenkov light, signature of the impact point of the shower front on the land, sea or cloud surface.

The EUSO Instrument

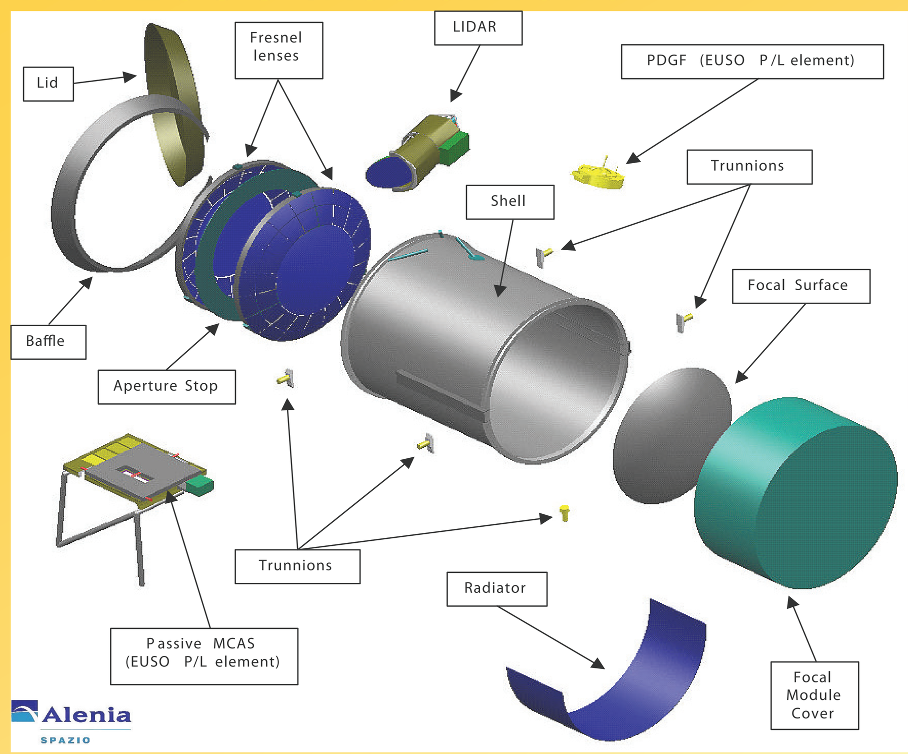


Fig. 5- Exploded view of the EUSO Instrument.

The EUSO Instrument consists of a EECR/n UV Telescope assisted by an Atmosphere Sounding Device (AS), a three wavelength LIDAR in the actual baseline. The LIDAR will provide information about the clouds location and the atmospheric transmission and attenuation of the UV fluorescence and Cherenkov light of the EAS.

The EECR/n Telescope is basically a fast, high-granularity, large-aperture and large Field-of-View digital camera, working in the near-UV wavelength range (330 nm ÷ 400 nm) with single photon counting capability.

A double Fresnel lenses module, (polychromatic, UV-PMMA-000, 2.5 m external diameter, f/1.00) is the baseline optics for EUSO. The front surface of the first lens and back surface of the second lens have micro-grating structures on them for chromatic aberration correction.

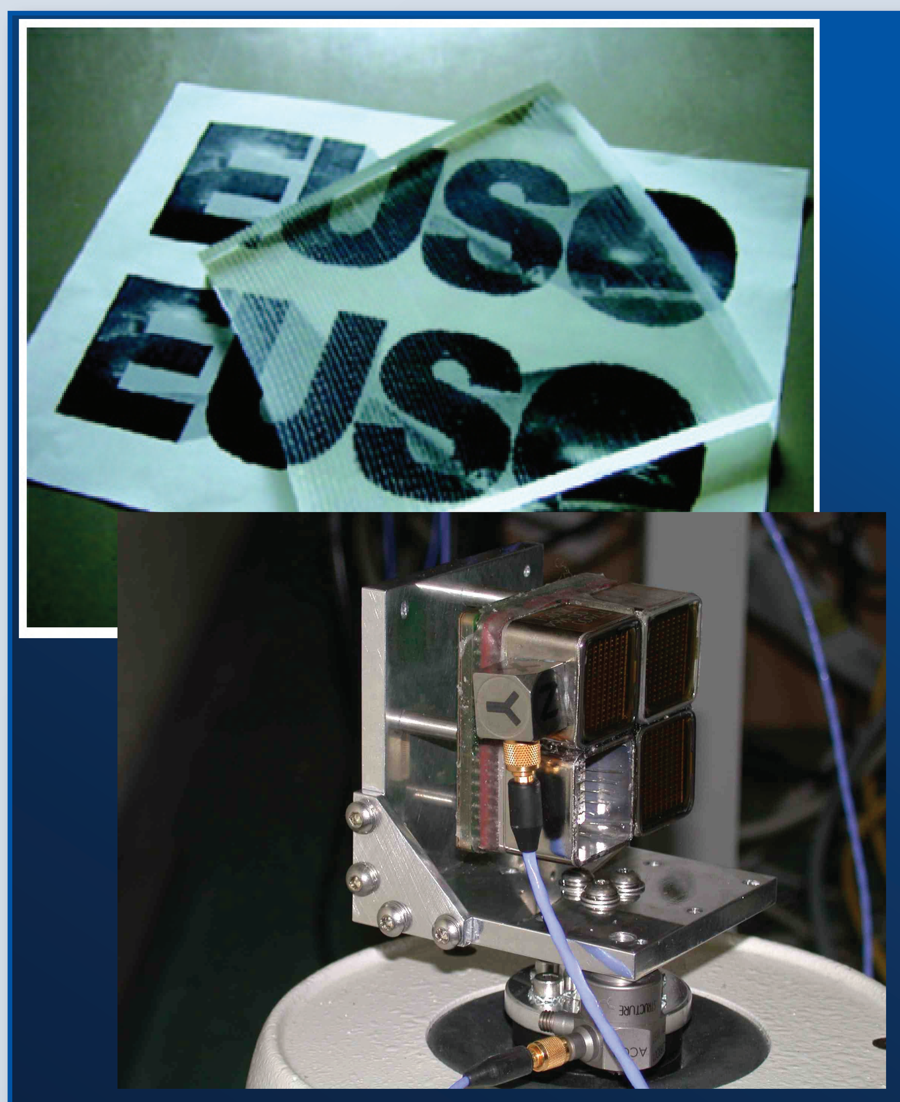


Fig. 6- Upper panel) Moulded petal segment of the Optics. Lower panel) The elementary cell of PD on the vibrating table test set-up

The baseline design of the Photo Detector (PD) is a closely packed mosaic of MAPMT, R8900-03-M36, with a bialkali photocathode deposited on the UV-glass entrance window. The MAPMT features single-photon counting capability with fast response and high gain. The PD is made of independent modules installed on a single supporting structure.

Expected Results

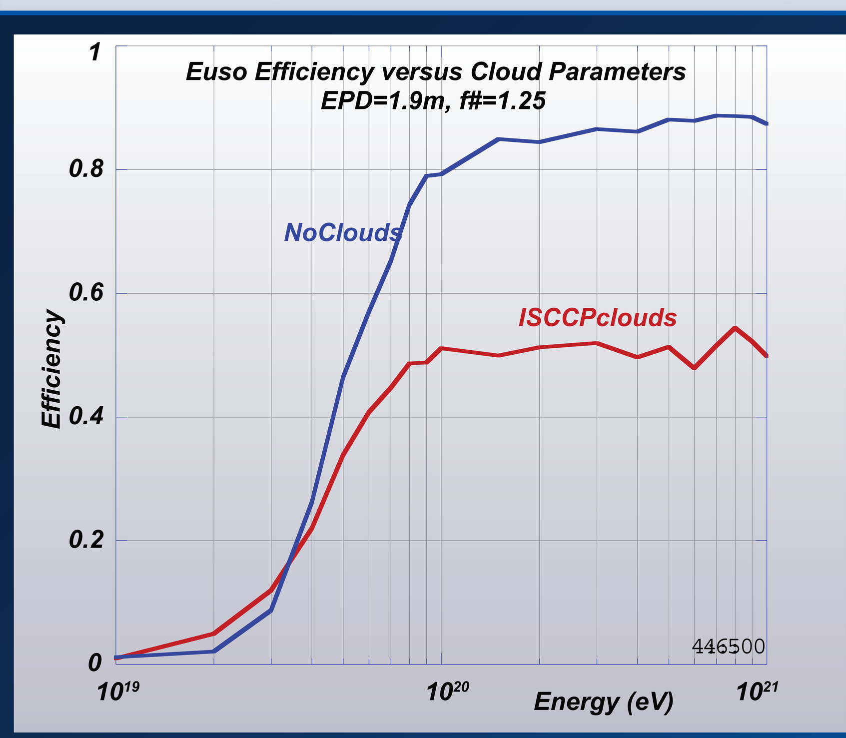


Fig. 7- EUSO efficiency, assuming the present, conservative, baseline

In Fig. 7, we show the EUSO efficiency in clear sky and cloudy conditions for the present baseline configuration. The expected duty cycle of the Mission is around 25%. EUSO will be operated night-time. Expected Lifetime is 3 years

In the case of Super-GZK, about 3.000 showers are expected to be observed above 10^{20} eV; 8.000 for E< 10^{20} eV. For the GZK case, the number of events observed for energies above 10^{20} eV is still ~ 500, with ~ 6.000 / 7.000 for E < 10^{20} eV. This implies that the GZK decrease can be precisely measured as well as the GZK recovery.

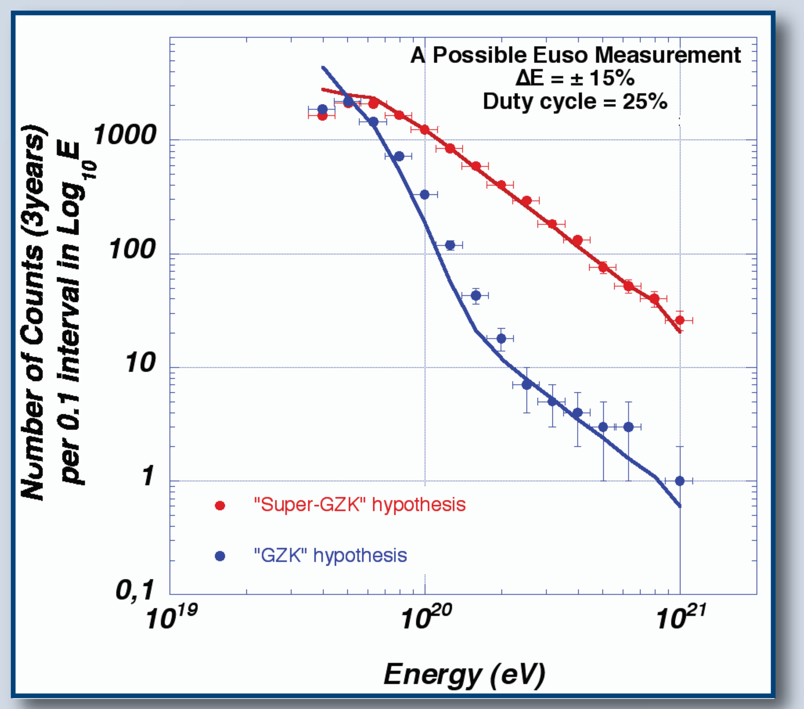


Fig. 8- EUSO expected spectrum for the Super-GZK and GZK hypothesis.

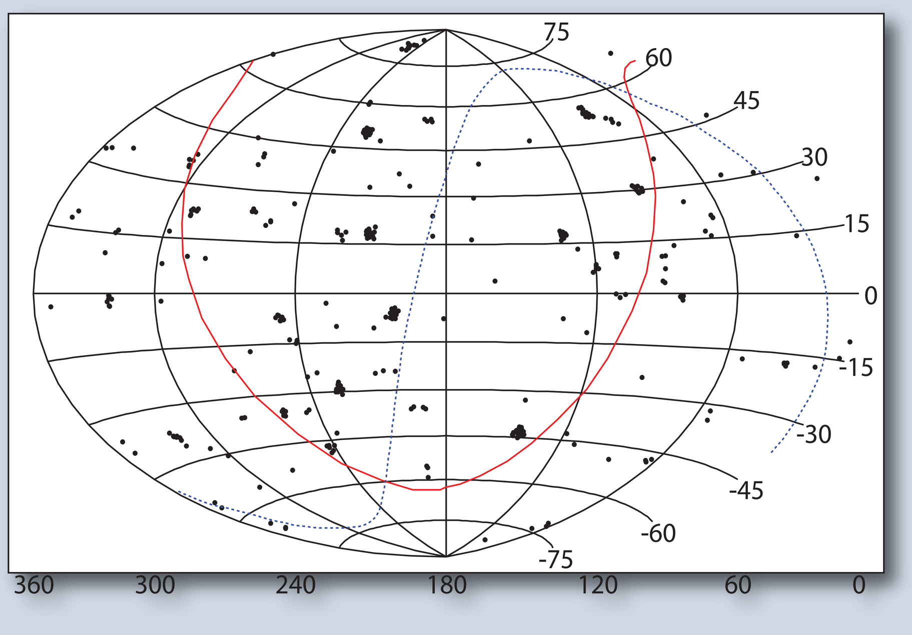


Fig. 9- EUSO expected sky map after three years of observation.

Several EECR point sources, with multiplicity up to ~ 70, will be observed by EUSO even if the GZK hypothesis is correct (Blasi & De Marco, 2003).

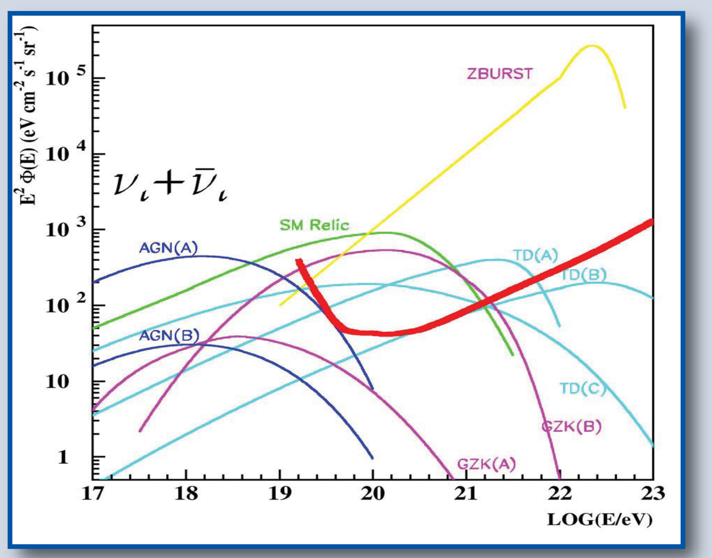


Fig. 10- Depending on the models from a few to tens of neutrinos can be observed by EUSO. More details can be found in Bottai et al.. (2003)

References

Abu-Zayyad T., et al. (HiRes Collaboration), 2002, e-print astro-ph/0208243; e-print astro-ph/0208301
Blasi P. & De Marco D., 2003, submitted to Astroparticle Phys., also ICRC-03
Takeda M., et al., 2002, astro-ph/0209422, 13 Nov. 2002
S. Bottai, F. Becattini, L. Haroyan EUSO-SIM-REP-003-1, "Neutrino induced showers in EUSO"