Downward Neutrino Induced EAS With EUSO Detector

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Abstract

We show the capability of the EUSO detector in the separation of neutrino induced EAS from the expected signals induced by protons. The results of simulations of neutrino induced showers in the atmosphere and the response of the detector to such signal are presented.

1. Introduction

The EUSO project [1,2] aims to detect from the space the fluorescence and the ground-reflected cherenkov light emitted by extreme high energy air showers. The experiment will be accommodated on the International Space Station (ISS) at $\approx 430 km$ of altitude. With a field of view (FOV) of 60^o will be able to monitor from the space an atmospheric mass $M \approx 2 \cdot 10^{18} g$ with an energy threshold close to $10^{19} eV$. Such enormous amount of target mass will offer the unique opportunity to detect cosmic neutrino events at extreme high energy ($E \geq 3 - 5 \cdot 10^{19} eV$). A complete detector and physics goals description of EUSO project are presented in other contributions to this conference.

2. EAS and detector simulation

Electron, muon and tau neutrinos interact through deep inelastic scattering with the nucleons of the atmosphere, generating an electromagnetic plus a hadronic detectable shower in case of ν_e charged current (CC) interaction and only a hadronic detectable shower in all the other cases (the probability to detect muon bursts and tau double bang is not treated here). The produced showers will be detected and reconstructed using signals coming from the fluorescence light emitted isotropically along the shower, from the cherenkov light diffusely reflected from the ground and from cherenkov light backscattered in the atmosphere. The reflected cherenkov light information will be used to accurately reconstruct the depth of the shower. The simulation [3] of shower formation and development, fluorescence and cherenkov light generation and transmission and detector response has been performed here using UNISIM simulation package. UNISIM [4] is an hybrid shower simulator where the use of both full montecarlo and shower

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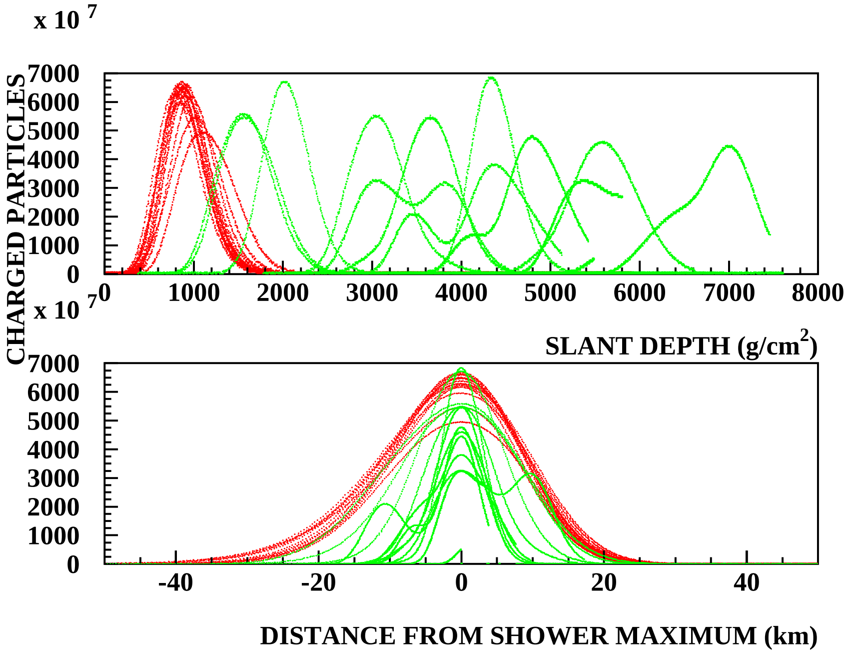

Fig. 1. In the upper graphs is shown a sample of shower longitudinal profiles for ν_e CC (green profiles) interactions and protons (red profiles). The zenith angle is $\theta_{zen} = 80^o$ and the energy $E_{protons} = E_\nu = 3 \cdot 10^{20}$ eV. In the lower graphs the profiles in space of the same showers are shown.

parametrization allows a fast simulation of shower development taking into account the fluctuations induced by the first interactions. The UNISIM package includes the LPM effect for electromagnetic interactions and it is able to simulate neutrino interactions inside the target mass seen by the detector. CC and NC differential cross sections used in the simulation for neutrino interactions have been calculated [5] in the framework of QCD improved parton model. For the relevant effect of LPM on neutrino showers see [4].

3. Results from simulation

Figure 1 shows a sample of simulated almost horizontal showers for protons and neutrinos. Due to the weakness of neutrino cross sections the neutrino flux is not significantly attenuated while traversing the atmosphere (even at the extreme high energy and for horizontal directions). As a result the probability distribution for the altitude of neutrino interactions inside the atmosphere follow the density profile of the atmosphere itself. Hence the main difference between proton-nuclei-photon showers and neutrino showers are the atmospheric density and slant depth of the environment where the shower take place. Low altitude

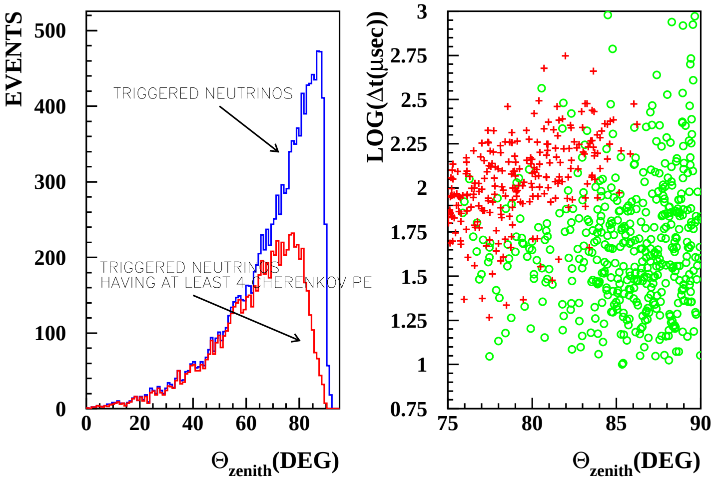

Fig. 2. Figure on left panel shows the angular distribution of neutrino triggered showers with a detectable reflected cherenkov peak. Figure on right panel shows the distribution of signal duration in the detector for showers which does not produce any detectable reflected cherenkov peak. 3 years statistics for protons without GZK cutoff and arbitrary statistics for neutrino showers in the range $10^{19}eV \leq E_\nu \leq 10^{21}eV$ with E_ν^{-1} spectrum.

neutrino showers will be in principle shorter than high altitude shower due to different atmospheric density (fig 1). In ref [4] the slant depth of neutrino showers is compared with those of detected proton showers by EUSO. The selection in the value of $Xmax$ (slant depth of shower maximum) is in principle a very efficient method to discriminate neutrinos respect to protons. Once the shower direction has been reconstructed the arrival time of the Cherenkov reflected light will give a very precise signature of the depth of the shower. For almost horizontal showers the probability to detect the Cherenkov light reflected on ground surfaces (fig 2) is however not very high. Such low altitude very inclined showers can be discriminated from protons looking at the different space development of the shower itself. Simply using the duration of the registered signal in the detector is possible to discriminate proton-neutrino showers for the cases where no cherenkov light is detected (fig 2). Better results are expected from more sophisticated shape analysis which are in progress.

4. Effective acceptance for neutrino detection in atmosphere

It is useful to characterize the detector performance in terms of target mass for neutrinos. We simulate neutrino interactions using an isotropic angular distribution over $0^o \leq \theta_{zenith} \leq 90^o$ inside the EUSO FOV ($2 \cdot 10^{18} g$ of atmosphere)

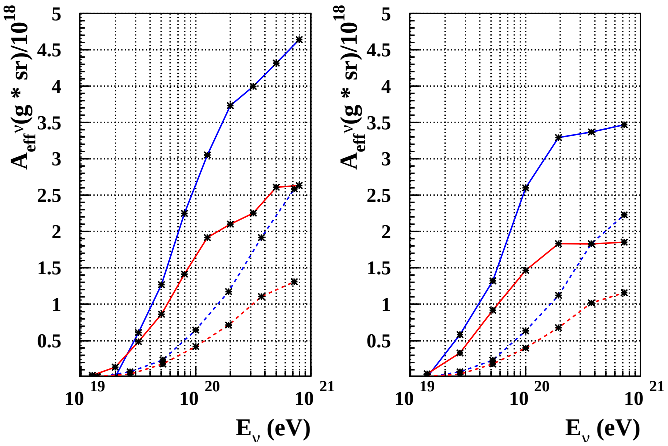

Fig. 3. Effective neutrino acceptance $A^{\nu}_{eff}(g \cdot sr)/10^{18}$ with clear sky (blue lines) and with distribution of clouds frequency and altitude expected from ISS trajectory [6] (red lines). Continuos lines are for CC interactions while dotted lines are for NC interactions. Left panel use events selected with trigger condition and $Xmax \geq 1400\, g/cm^2$, right panel add also the selection for the visibility of shower maximum ($Xmax$ above clouds or ground).

and the expected altitude distribution of first interactions. Then the effective neutrino acceptance $A^{\nu}_{eff}(g \cdot sr)$ for an isotropic flux can be calculated as : $A^{\nu}_{eff}(g \cdot sr) = \frac{triggered\ \ events}{generated\ \ events} \cdot 2 \cdot 10^{18} \cdot 2\pi\, (g \cdot sr)$, and the event rate R_{ν} for an isotropic neutrino flux $\frac{d\Phi}{dE}$ and η duty cycle is $R_{\nu} = \int \frac{d\Phi}{dE} \cdot A^{\nu}_{eff} \cdot N_A \cdot \sigma \cdot \eta\, dE$, where σ is the ν cross section (CC or NC) and N_A the Avogadro number. The results for A^{ν}_{eff} are shown in fig 3. The detection efficiency, averaged over the isotropic angular distribution, is always well below unity because a significant part of neutrinos, apart from the almost horizontals where such ratio approach unity at higher energies, interact so close to the ground that the shower has not enough space to properly develops inside the atmosphere.

5. References

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