



Cosmic ray and neutrino physics with space detectors

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Abstract: Simulations of ultra high-energy showers that may be generated by different primary particles and observed with space detectors are performed. A special driver is developed which enables us to treat neutrino as a primary particle in the framework of the traditional codes (AIRES, CORSIKA). Possibilities of the TUS detector employment for ultra high-energy neutrino studies are discussed.

Introduction

The TUS (Tracking Ultra-violet Set up) mission [1] is now planned for operation at the Small Space Apparatus (SSA) separated from the main Foton-4 satellite, due to be launched in 2009-2010. SSA is a new platform being designed for operation with space instruments having mass 50-100 Kg, power consumption of 60-100 Wt at the orbits of 500-400 km height. The TUS project was planned as a step-by-step progress in space instrumentation with the first step (already achieved, see [2]) of checking the photo receiver sensor operation in space and getting data on the near UV atmosphere background radiation. The second step is the operation in space of the pilot fluorescence imaging detector with the mirror area of about 2 m² and photo receiver of 256 pixels. In the final TUS-M detector the mirror area has to be 10 m² and number of pixels of about 5000. At extreme energies $E > 5 \times 10^{19}$ eV the near UV fluorescence signal from the EAS particle disc is high enough to be observed from space, by the detector comprising a moderate size light collectors (2-3 m in diameter). At moderate height orbits the detector (400-500 km) and large collection area (10 m²) will have the advantage of low energy threshold, which is important for developing the ultra high-energy neutrino astronomy.

At the orbit height 500 km, in the range of zenith angles $\theta > 50^\circ$ for duty cycle 20% (and in the range of $\theta < 50^\circ$ for duty cycle 10%) the TUS geometrical factor is 1000 km² sr per year and expected rate of particles with energy threshold $E = 50$ EeV is 16 per year for the case of no GZK cut-off and 8 particles per year for a GZK cut-off. Longer than 3 years operation is also important for search of the neutrino induced EAS. A long operation of the TUS detector is possible if the SSA starting orbit will have more than 500 km height.

For a cut-off, at extreme energies $E > 5 \times 10^{19}$ eV, neutrinos will become very important instrument for astronomy:

- They can travel always as primaries
- They have no deviation due to magnetic field.
- They have no important interaction close or inside the source.

Another important matter of study is neutrino oscillation and stability as well as neutrino masses.

Atmosphere is transparent for vertical neutrinos, but harder fluxes of neutrinos as predicted for "Top-Dawn" mechanisms could generate a few young, deep, inclined showers from all neutrino flavours per year which are possible to detect with fluorescence detectors from space. Tau neu-

trinos (coming from neutrino oscillations) skimming the Earth, can produce an emerging tau generating a visible shower [3]. The large interaction length of γ_τ in rock ($\sim 500\text{km}$) allows the above mechanism for generation of up-going showers with enough electromagnetic particles to be detected by Fluorescence telescopes from Earth and Space.

In this work simulations of ultra high-energy showers that may be generated by different primary particles and observed with space detectors are performed. A special driver is developed which enables us to deal with neutrino as a primary particle in the framework of the traditional codes (AIRES, CORSIKA). Possibilities of the TUS detector employment for ultra high-energy neutrino studies are discussed.

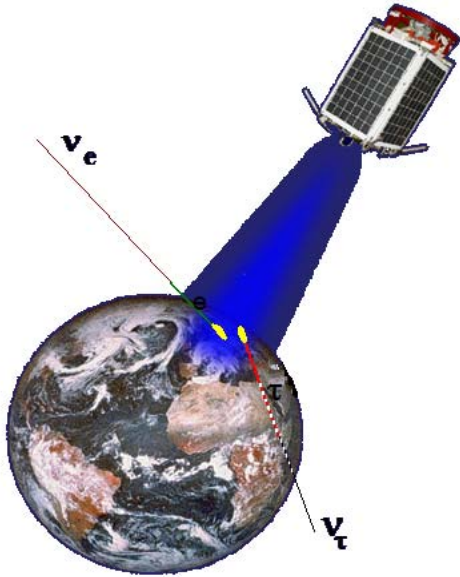


Figure 1: Very inclined Down-going electron neutrinos interacting through charged current interaction and ν_τ skimming the Earth.

Simulations

Two well-known Programs, which simulate cosmic rays in Cosmic Ray Physics, are AIRES [4] and CORSIKA [5], both of them based in the

Monte Carlo code. Although it there is the possibility of choosing the high-energy interaction method in the two mentioned Simulation-programs both of them do not consider neutrinos as primary particles.

With AIRES it is possible to perform a simulation of an initial neutrino by injecting protons at a low altitude and with a fraction of the initial neutrino energy. The simulation of an event with a neutrino as a primary particle by using CORSIKA requires the program HERWIG [6], which generates events of high-energy processes, in particular for detailed simulation of Parton QCD. Such program is used just to take into account the initial interaction of the neutrino, for the subsequent interactions the Program CORSIKA is used.

In applying AIRES and CORSIKA we have used the hadronic interaction model QGSJET. Finally, we would like to point out that by applying CORSIKA we have chosen the option of a curved atmosphere.

Results and Conclusions

As a first step, we study inclined showers for events generated by ν_e in order to compare them with those generated by protons. Further, we compare the longitudinal profile (cross section) for ν_e y ν_μ looking for the possibility of detecting such events with the TUS.

In our simulated events, we have chosen protons, electron neutrinos and antineutrinos, and muon neutrinos and antineutrinos as primary particles, with an energy of 10^{19}eV and thinning level of 10^{-5} , zenithal inclination of 70 degrees and the azimuthal angle varying from 0 to 360 degrees. Further, we have fixed the interaction-height at 7.5 km, this as an estimation of the interaction-depth of the primary particle with the atmospheric nuclei.

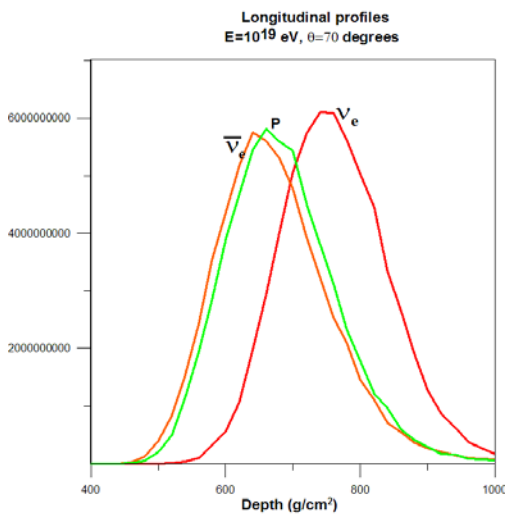


Figure 2: Longitudinal profile for electron neutrinos with an energy of 10^{19} eV and zenithal inclination of 70 degrees. We have fixed the interaction-height at 7.5 km

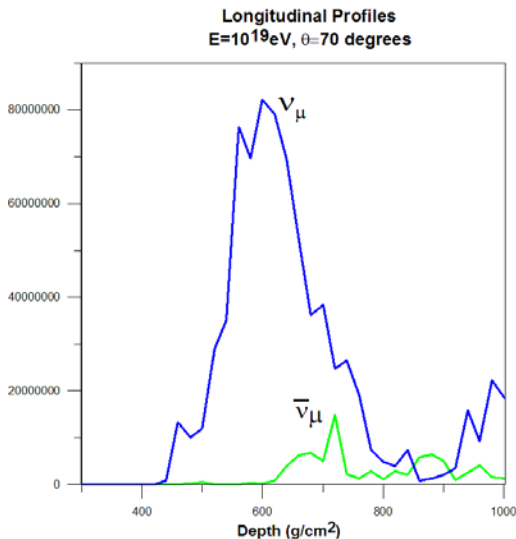


Figure 3: Longitudinal profile for muon neutrinos

In the case of muon neutrino, the number of secondary particles decrease. Then the possibility to be detected for fluorescence telescopes seems to be no realistic.

Future work will include simulations of Up-going neutrinos and horizontal neutrinos interacting by charged or neutral currents. The effect of atmosphere variations, ocean water and topography will be also taken into account. Finally we will simulate the response of the TUS detector to those showers.

References

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