Experimental Studies of the East-West Effect of the Muon Charge Ratio at Energies Relevant to the Atmospheric Neutrino Anomaly

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The atmospheric flux of muons originating from the decay of charged pions and kaons, produced by cosmic ray interactions in the atmosphere, is nearly isotropic. Nevertheless at lower muon energies it is influenced by the Earth's magnetic field as well as by a magnetic rigidity cut-off of the primary cosmic rays penetrating the Earth's atmosphere from the cosmos. Since the muon production is associated with the production of atmospheric neutrinos, a detailed understanding of the asymmetries of the fluxes of positive and negative muons is indispensable for doing reliable calculations of the atmospheric neutrino flux. A quantity rather sensitive to effects of the geomagnetic field on the muon fluxes is the charge ratio of positive and negative muons and its directional dependence.
For experimental observations of these effects, in particular of the asymmetry in the muon charge ratio for muons from the East and West directions (East-West effect) a dedicated rotatable device: WILLI has been installed in the laboratory of IFIN-HH Bucharest (44°26' N latitude, 26°04' longitude, vertical cut-off rigidity 5.6 GV). Methodically the measurements are based on observations of the life time of the muons, stopped in absorber layers of the detector. The life time is different for positive and negative muons: positive muons decay with a lifetime of 2.2 μs, while the negative muons are captured in the atomic orbits, leading to a smaller lifetime depending on the stopping material. The uncertainities in the detector efficiency and the geometry, are identical for positive and negative muons, so that systematic errors of magnetic spectrometer measurements can be minimized. The experimental apparatus is a detector telescope mounted on a rotatable frame. The telescope consists of a stack of 16 active modules, each of an area of 90x90 cm^2 (the first two being the trigger layers), formed by a plastic scintillator layer (3 cm thickness) and an aluminum support (1.2 cm thickness), working as stopper. The telescope is surrounded by four lateral anticoincidence counters.
Investigations of the zenithal and azimuthal dependence of the muon charge ratio R have been started with measurements performed in the East and West direction at a mean zenith angle of 35°. The data have been analysed for 3 partitions of the detector, corresponding to 3 different ranges of muon incident energy.
The results show a pronounced East-West effect in the low energy range. The azimuthal anisotropy: $A_\mu = (R_W - R_E)/(R_W + R_E)$, (with R_W and R_E being the values of the muon charge ratio measured in the West and East direction) has been found to be 0.26 in the momentum range of 0.3-0.4 GeV/c. The observed asymmetry effects can be analysed by realistic (3 - dimensional) Monte Carlo simulations and compared with the neutrino flux asymmetry found by Super-Kamiokande.