International Workshop on High Energy Earth Science:
Muon and Neutrino Radiography
(June 26-27, 2008, Tokyo, JAPAN)

Atmospheric Neutrinos

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In a recent paper Gonzalez-Garcia et al. [1] describe how atmospheric neutrinos might be used to study the density profile of the Earth, and in particular to probe the core-mantle transition region. The transition would show up in a large, deep detector (such as IceCube or Km3Net) as a deficit of vertically upward moving neutrino-induced muons of high energy relative to muons at larger angles produced by neutrinos that passed only through the less dense mantle. The neutrino cross section increases with energy, so that neutrinos with energy less than a few TeV are not much absorbed by the Earth. Ideally, one needs to select neutrinos with sufficiently high energy to be significantly absorbed when passing through the diameter of the Earth but not to so high as to be strongly absorbed when passing only through the mantle. This is accomplished in Ref. [1] by choosing muons with more than 10 TeV (or more than 30 TeV) at the detector to provide a lower limit on the neutrino energy. The upper limit on the neutrino energy is provided automatically by the steepness of the atmospheric neutrino spectrum at high energy. The core subtends an angle of approximately 30 degrees relative to the nadir, so the deficit is expected in the most vertical of six bins of equal solid angle, $-1 < \cos(\theta) < -0.83$.

In order to realize the measurement proposed in Ref. [1], it is essential to understand the intrinsic dependence on zenith angle of the neutrino beam at production in the atmosphere. In this talk I will review the physics of atmospheric neutrino production with particular attention to its intrinsic angular dependence. At 10 TeV, for example, the most vertical bin is approximately 25% lower than the next bin of $\cos(\theta)$ [2], which is comparable to the size of the core-mantle transition effect [1]. The largest source of uncertainty in the relevant energy range is the fraction of K-mesons contributing to the neutrino flux because such neutrinos have a different angular dependence than those from decay of pions. A recent measurement of atmospheric muons in the MINOS far detector [3] provides data than may reduce this uncertainty. Production of charmed hadrons, which decay promptly, also contribute to the uncertainty in the angular dependence of high energy neutrinos [4]. I will assess the present level of uncertainty from these effects.

References

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[3] MINOS Collaboration, Measurement of the Atmospheric Muon Charge Ratio at TeV Energies, arXiv: 0705.3815.

[4] Berghaus, P., Montaruli, T., Ranft, J., Charm Production in DPMJET, arXiv:0712.3089 *JCAP* (to appear).