Reaching the EeV frontier in neutrino-nucleon cross sections in upcoming neutrino telescopes

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Neutrinos have always been harbingers of new insight into fundamental physics. Neutrino interactions with matter, though feeble, are of great importance for particle and astroparticle physics. We make the first detailed forecast of our near-future capability to measure the neutrino-nucleon cross section ($\sigma_{\nu N}$) in the EeV energy regime with the next generation of neutrino telescopes, in particular, in the largest planned in-ice neutrino radio telescope, the radio component of IceCube-Gen2.

Ultra-high-energy neutrinos (UHEν), with EeV-scale energies, have been long predicted, but have not yet been discovered, on account of their low predicted flux. The *cosmogenic neutrinos* produced in the scattering of ultra-high-energy cosmic rays (UHECRs) on the cosmic microwave background (CMB) are a low, but guaranteed to exist flux of UHE neutrinos that could help reveal the origin of cosmic rays. In addition, there might a higher flux of UHE *astrophysical neutrinos*, produced directly inside UHECR sources (galaxy, clusters, pulsars, AGNs, GRBs, etc.). Beyond their role as tracers of UHECRs sources, these UHEν may probe the Standard Model at energies otherwise unreachable, including testing its many proposed high-energy extensions.

In this study we extract information about the cross section from the Earth attenuation, and predict the sensitivity to this quantity of future detectors in the next decade.

We use NuPropEarth as a neutrino propagation tool and take into consideration the following:

- Present our results for 3 benchmark scenario: cosmogenic, astrophysical, and IceCube extrapolated flux.
- Consider the most updated theoretical prediction of the neutrino-nucleon deep inelastic scattering cross section.
- Propagation of neutrinos per flavor.
- Event rate prediction using effective volumes and resolution function.
- Implement a Bayesian analysis using an unbinned Poissonian likelihood to obtain our credible intervals.

From our results we conclude:

- Neutrino-nucleon cross section is possible in the next generation of neutrino telescopes.
- For the standard model case we expect around 2 events for the cosmogenic flux, and above 100 for the astrophysical source flux in 10 years
- Deviations of the standard model cross section can be measured with a precision of $< 20\%$ for astrophysical flux, and $\sim 200\%$ for cosmogenic flux.
- We have computed the sensitivity to measuring the cross section using a sophisticated end-to-end computation framework base on the state-of-the-art tools, which can be easily apply for any other ultra-high-energy neutrino flux prediction.