Ultra-High Energy Neutrino-Nucleon Scattering

Ernest M. Henley^a and W-Y. P. Hwang^b

^aDepartment of Physics, and Institute for Nuclear Theory,
University of Washington, Seattle, WA 98195, USA

^bDepartment of Physics, National Taiwan University, Taipei, Taiwan RC

For ultra high energy neutrinos, does the deep inelastic cross section for the scattering from nucleons grow so fast that the unitarity limit is reached?

Deep inelastic cross sections from nucleons at ultra-high energies are dominated by the gluons in the nucleon. It is known from HERA data for electron scattering that the structure functions, e.g., F_2 , increases as the momentum fraction x decreases. The gluon density gets to be very high at small Feynman x . It is then to be expected that the partons interact with each other and this effect will lead to Glauber-type shadowing and to saturation of F_2 and of the neutrino-nucleon cross section. The saturation scale has been parameterized by Golec-Biernat and Wüsthoff[1]. A semi-phenomenological analysis has shown that the $q\bar{q}$ color dipole formalism can be used and explains saturation at very small x . We use the color glass condensate and the quenched or screened version of Bartels et al.[1]. DGLAP evolution is used. The differential neutrino-nucleon cross section can be written in terms of the structure functions F_1 and F_2 [2] (F_3 does not contribute at small x).

Our results for F_2 at $Q^2 = M_W^2$ can be summarized as follows: It rises from 10 at $x = 10^{-3}$ to 36 at $x = 10^{-5}$ and to 145 at $x = 10^{-7}$. By contrast, that obtained by Kutak and Kwieciński[3] rises more sharply for small x for both their screened and unscreened BFKL/DGLAP evolution. Our total cross section for deep inelastic scattering with two contributing flavors ($d \leftrightarrow u, s \leftrightarrow c$) is given in the Table below.

Energy (GeV)	Cross Section (cm^2)
10^6	1.2×10^{-33}
10^8	7.9×10^{-33}
10^{10}	3.3×10^{-32}
10^{12}	1.2×10^{-31}

Our result is approximately twice that of ref.[3] with screening and thus somewhat larger than theirs without screening. Our cross section is somewhat larger than that of Gandhi et al.[4] at $10^6 GeV$, but grows more slowly with energy and agrees with theirs at $10^{12} GeV$. They do not consider saturation.

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REFERENCES

1. See e.g., K. Golec-Biernat and M. Wüsthoff, Phys. Rev **D60** (1999), 114023; J. Bartels, K. Golec-Biernat, and H. Kowalski, Phys. Rev. **D66** (2002), 014001
2. J. Jalilian-Marian, Phys. Rev **68** (2003), 054005
3. K. Kutak and J. Kwieciński, Eur. Phys. J. **C29** (2003), 521
4. R. Gandhi, C. Quigg, M.H. Reno, and I. Sarcevic, Phys. Rev **D58** (1998), 093009.