Quasi elastic sacttering of neutrino with nuclei

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Introduction

The neutrinos in the energy range between 1 to 3 GeV can interact with matter by many processes such as quasi elastic scattering (QES), interaction via Resonance Production (RES) and Deep Inelastic Scattering (DIS) [1]. There is also coherent pion production process in neutrino nucleus scattering [2]. In this article, we calculate the neutrino nucleon charged current QES cross section using Llewellyn Smith model [3]. For the case of the nuclei, the Fermi gas model has been used with proposed Pauli suppression factor. Calculations have been made for CCQES differential and total cross sections for the case of $\nu_\mu - n$ and $\nu_\mu -^{12} C$ scattering and are compared with the experimental data with the aim of obtaining appropriate value of the axial mass.

Neutrino interaction with matter

The CCQES process is given by

$$\nu_\mu + n \to \mu^- + p.$$

The differential cross section for the charged current neutrino nucleus quasi elastic scattering is given by

$$\frac{d\sigma^{nucleus}(E_\nu)}{dQ^2} = \frac{2V}{(A-Z)(2\pi)^3}\int_0^\infty 2\pi k_n^2 dk_n$$
$$d(\cos\theta)\ f(\vec{k_n})\ S(\nu-\nu_{min})\frac{d\sigma^{free}(E_\nu^{\rm eff},\vec{k_n})}{dQ^2}.$$

Here $E_\nu^{\rm eff} = E_\nu(E_n - k_n\cos\theta)/M_n$, $E_n = \sqrt{k_n^2+M_n^2}$. The fermi distribution function $f(\vec{k_n})$ is defined as

$$f(\vec{k_n}) = \frac{1}{1+\exp(\frac{k_n-k_F}{a})},\ a = 0.020\ \text{GeV}.$$

The Pauli suppression factor $S(\nu - \nu_{min})$ is defined as

$$S(\nu-\nu_{min}) = \frac{1}{1+\exp(-\frac{\nu-\nu_{min}}{a})},$$
$$\nu_{min} = \sqrt{k_F^2+M_p^2} - \sqrt{k_n^2+M_p^2} + E_B\ .$$

Here k_F is the Fermi momentum, k_n is the neutron momentum, M_n is the mass of neutron, E_ν is the neutrino energy, ν is the energy transfer from neutrino to muon and Q^2 is the momentum transfer from neutrino to the muon.

Results and Discussions

Figure 1 shows the differential cross section $d\sigma/dQ^2$ per neutron for the neutrino-carbon CCQES QES as a function of Q^2 at different values of axial mass. In the upper panel, The calculations correspond to an average neutrino energy $< E_\nu > = 0.788$ GeV are compared with the data recorded by the MiniBooNE10 experiment. The calculations with M_A= 1.05, 1.12 and 1.23 GeV are compatible with the data. In the lower panal, the calculations are at an average neutrino energy $< E_\nu > = 2$ GeV. The calculations with M_A= 0.979 and 1.05 GeV are compatible with the data.

Figure 2 (upper panel) shows the total cross section σ for the neutrino - neutron CCQES as a function of E_ν. The value of σ increases with the increase in the value of axial mass M_A. The calculations are compared with the data recorded by various experiments. The calculations with M_A= 0.979, 1.05 and 1.12 GeV are compatible with the data. The calculations

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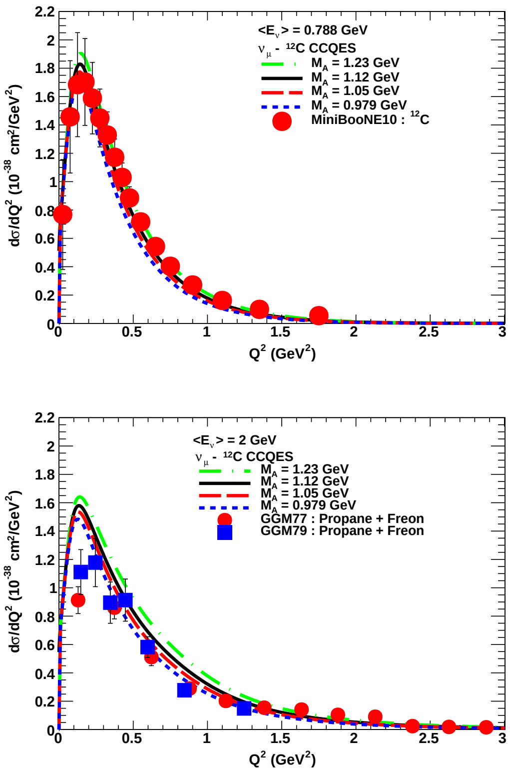

FIG. 1: $d\sigma/dQ^2$ per neutron for $\nu -^{12} C$ CCQES as a function of Q^2 at an average neutrino energy $< E_\nu > = 0.788$ GeV (upper panel) and 2 GeV (lower panel).

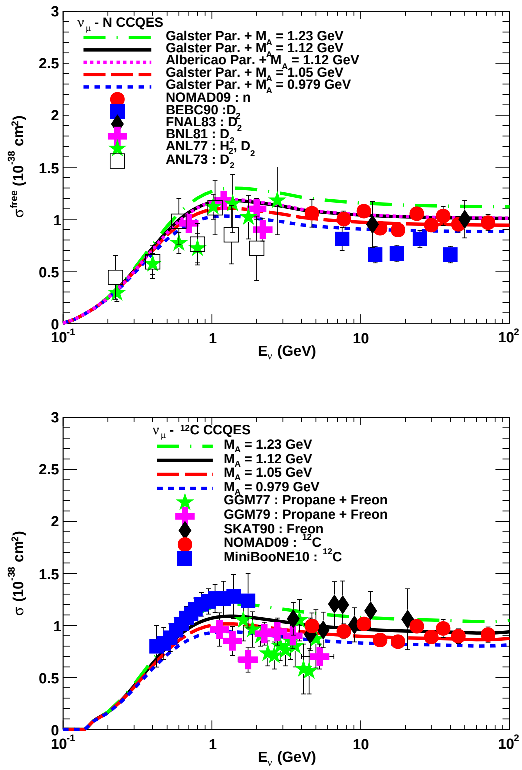

FIG. 2: σ for $\nu - n$ (upper panel) and per neutron $\nu -^{12} C$ (lower panel) CCQES as a function of E_ν for different values of the axial mass compared with the data.

of σ with $M_A = 1.23$ GeV overestimate all the experimental data. Figure 2 (lower panel) shows the total cross section σ per neutron for the neutrino-carbon CCQES scattering. The calculations with the value of $M_A = 1.23$ GeV describes the MiniBooNE data but it overestimates the other experimental data. The calculations with M_A= 1.05 and 1.12 GeV are compatible with data. References can be found in Ref.[4].

Conclusion

The calculations for CCQES total and differential cross sections for the $\nu_\mu - n$ and $\nu_\mu -^{12} C$ scattering are compared with the data for different values of the axial mass. The calculations give excellent description of the differential cross section data. The nuclear effects are found to be 10 % even at higher neutrino energy above 1 GeV. The calculations with axial mass 1.05 and 1.12 give good description of most of the experimental data.

References

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