Neutrino interactions with nuclei

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Abstract

We present a model for neutrino-nucleus scattering in the energy region relevant for present and forthcoming neutrino oscillation experiments. The model is based on the RPA treatment of the nuclear responses in the quasi elastic and delta region. It includes also in a phenomenological way nucleon knock-out. It aims at the description in an unique framework of several final state channels i.e. quasi elastic one, incoherent and coherent one pion production and two or several nucleon knock-out. It allows an easy comparison of different nuclei.

I. Formalism

Neutrino-nucleus cross section

$$\frac{\partial^2\sigma}{\partial\Omega\,\partial k'} = \frac{G_F^2\,\cos^2\theta_c\,(\mathbf{k'})^2}{2\,\pi^2}\,\cos^2\frac{\theta}{2}\,\Bigg[G_E^2\,(\frac{q_\mu^2}{\mathbf{q^2}})^2\,R_\tau^{NN} + G_A^2\,\frac{(M_\Delta - M)^2}{2\,\mathbf{q^2}}\,R_{\sigma\tau(L)}^{N\Delta} + G_A^2\,\frac{(M_\Delta - M)^2}{\mathbf{q^2}}R_{\sigma\tau(L)}^{\Delta\Delta} + \left(G_M^2\,\frac{\omega^2}{\mathbf{q^2}} + G_A^2\right)\left(-\frac{q_\mu^2}{\mathbf{q^2}} + 2\tan^2\frac{\theta}{2}\right)\left(R_{\sigma\tau(T)}^{NN} + 2R_{\sigma\tau(T)}^{N\Delta} + R_{\sigma\tau(T)}^{\Delta\Delta}\right) \pm 2G_AG_M\frac{k+k'}{M}\tan^2\frac{\theta}{2}\left(R_{\sigma\tau(T)}^{NN} + 2R_{\sigma\tau(T)}^{N\Delta} + R_{\sigma\tau(T)}^{\Delta\Delta}\right)\Bigg]$$

Response function $R(\omega,q) = -\frac{1}{\pi}\,\mathrm{Im}(\Pi(\omega,q,q))$

Bare Resp: sum of the following partial components

1. NN : quasi-elastic (Lindhard function),
2. NN : *2p-2h*,
3. $N\Delta$ and $3'$ ΔN : *2p-2h*,
4. $\Delta\Delta$: $\pi\,N$,
5. $\Delta\Delta$: *2p-2h*,
6. $\Delta\Delta$: *3p-3h*.

RPA $\mathrm{Im}\Pi = |1 + \Pi\,V|^2\,\mathrm{Im}\Pi^0 + |\Pi|^2\,\mathrm{Im}V$

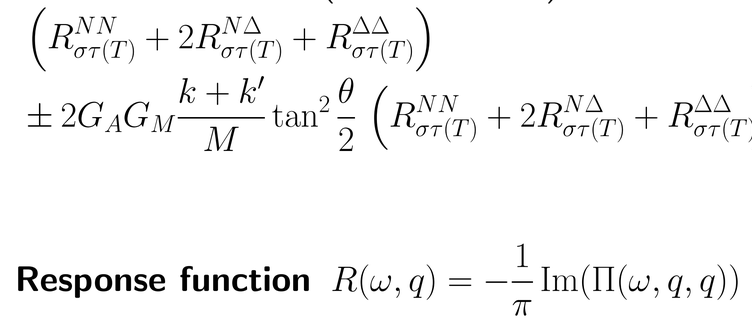

Figure 1: Graphic representation of the partial RPA response functions. (a)-(d): incoherent partial response functions. (e): coherent partial response function.

Test: pion-nucleus scattering

II. Quasi Elastic and multi- nucleon channels

Dominated by R_T

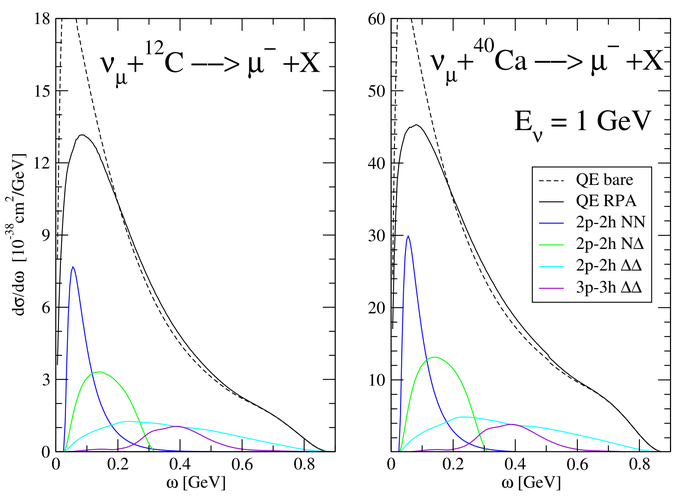

Figure 2: Differential CC ν_μ – ^{12}C and ^{40}Ca cross section versus the energy transfer.

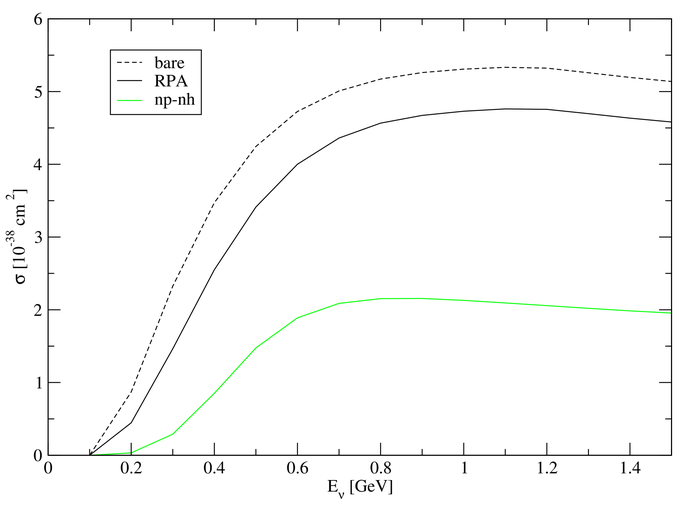

Figure 3: CC ν_μ – ^{12}C total cross section versus the neutrino energy.

III. Incoherent pion emission

Figure 4: Differential and total cross section for the ν_μ induced incoherent CC 1 π^+ production process in ^{12}C .

IV. Coherent pion emission

Dominated by R_L

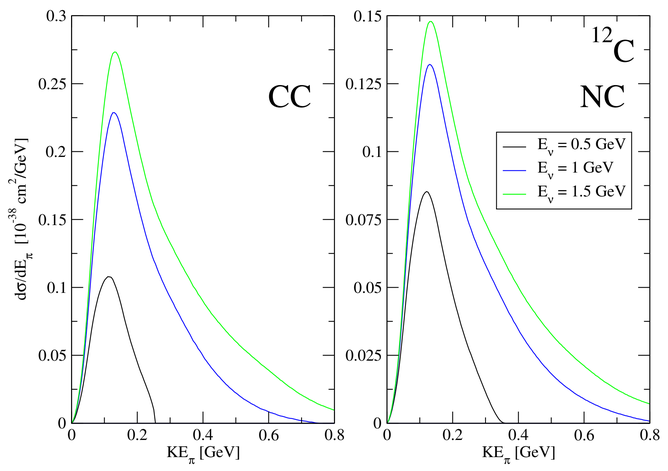

Figure 5: Differential cross section versus pion kinetic energy.

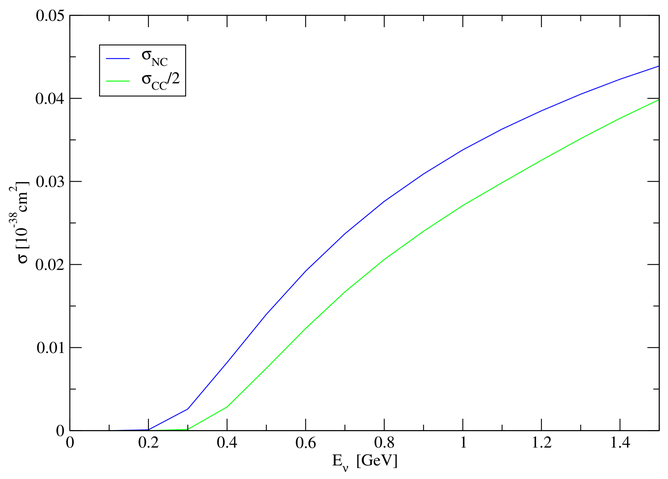

Figure 6: Total cross section for ν_μ induced coherent CC and NC one pion production process in ^{12}C.

V. Comparison with data