ON THE POSSIBILITY OF OBSERVING NEUTRINO INTERACTIONS INVOLVING COLLECTIVE EXCITATION OF THE NUCLEUS

Introduction

Recently several authors \(^1\), \(^2\), \(^3\) have considered the process

\[ \nu + {}^{12}\text{C} \rightarrow \mu^- + {}^{12}\text{N}_{\text{gi.dipol}}^{\text{dipol}} \]  

(1)

The so-called "giant dipole resonance" is a collective vibration of the whole nucleus with an excitation energy of the order of 20 MeV. This resonance has been observed in low energy photonuclear interactions. It decays by the emission of low energy protons and neutrons. Uberall \(^2\) has shown that excitation of the giant dipole resonance (1) should dominate the corresponding ground-state to ground-state transition by a factor of about 50. Apart from its fundamental interest this reaction could be important as a means of determining high-energy neutrino fluxes. For neutrino energies above 400 MeV the cross-section for reaction (1) should be constant at a value determined almost entirely by the nuclear electromagnetic form factor. The use of reaction (1) instead of the direct reaction

\[ \nu + n \rightarrow \mu^- + p \]  

(2)

at low four-momentum transfer \((q^2)\) would avoid the considerable uncertainty involved in independent particle models of the nucleus \((see Lovseth \(^4\))\). It is interesting, therefore, to see to what extent reaction (1) could be observed in present or planned neutrino experiments.

Calculations

We have compared the cross-section for reaction (1) as calculated by Kelly \(^3\) with that for the direct reaction (2) at a neutrino
energy of 500 MeV. In the calculation of reaction (2) we have used a degenerate Fermi-gas model for the nucleus with Fermi momentum equal to 267 MeV/c and we have taken vector and axial vector form-factors of the dipole type:

\[ F = \frac{1}{\left(1 + \frac{q^2}{M^2}\right)^2} \quad M = 0.84 \text{ GeV/c}^2 \]

In Fig. 1 are shown the differential cross-sections for both reactions per carbon nucleus. The total cross-section for giant dipole resonance excitation is equal to 5.5% of that for the direct reaction. At 1 GeV this proportion would fall to 4.3% and remain constant at higher energies.

Discussion

As can be seen from Fig. 1 the giant dipole resonance excitation is comparable to the direct process for small angles of muon emission. It is clear that inclusion of reaction (1) is necessary to describe the low-q^2 behaviour of the cross-section for muon production. However, the shape of the combined cross-section is not strikingly different from that of the direct process alone and therefore an unambiguous identification of reaction (1) is difficult. In principle one should be able to use the characteristics of the emitted proton in order to improve the distinction between processes (1) and (2). Protons from the de-excitation of the giant dipole resonance are emitted isotropically with energies below about 10 MeV. However, in the region of interest the protons from reaction (2) have also energies of the same order and it is doubtful that at these low energies a clear distinction can be made between "direct" and "evaporation" protons.

In order to investigate the regions of very low q^2 a certain precision is needed on the measurement of the muon angles. This precision will increase with the momentum of the muon and it can be
seen that the requirement is that the error on the muon angle be less than \( \sim 2.5^\circ/(\text{GeV/c}) \). Angular measurements with this precision are easily obtainable both in the CERN-HLBC and in Gargamelle.

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References

3. F.J. Kelly - NOLTR, 66-221.
4. J. Løysøth - CERN/TH/861
Fig 1