Further Studies of Transverse Enhancement in Quasielastic Electron Scattering

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In a previous communication we reported on a parametrization of the observed enhancement in the transverse electron quasielastic (QE) response function for nucleons bound in carbon as a function of the square of the four momentum transfer ($Q^2$) in terms of a correction to the magnetic form factors of bound nucleons. That parametrization was used to predict the overall magnitude and $Q^2$ dependence of the cross section for neutrino quasielastic scattering on nuclear targets. In this paper, we extend the study to include parametrizations of both the $Q^2$ as well as the energy transfer ($\nu$) dependence of the transverse enhancement. These parametrization can be used to give a more complete two dimensional description of the neutrino quasielastic scattering process on nuclear targets, which is essential for precision studies of mass splittings and mixing angles in neutrino oscillation experiments.

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1 Introduction

In a previous communication[11] we reported on a parametrization of the observed enhancement in the transverse electron quasielastic (QE) response function for nucleons bound in carbon as a function of the square of the four momentum transfer ($Q^2$) in terms of a correction to the magnetic form factors of bound nucleons. In this paper, we provide additional details about both the $Q^2$ as well as the energy transfer ($\nu$) dependence of the transverse enhancement.

2 The method

In our previous paper, we used a fit to existing electron scattering differential cross sections on nuclei, including preliminary data from the JUPITER collaboration[2] (Jefferson lab experiment E04-001). The fit [3] (developed by P. Bosted and V. Mamyan) provides a description of inclusive electron scattering differential cross sections on a range of nuclei with $A > 2$. It is an extension of fits to the free proton [4] and deuteron [6] cross sections. The fit is utilized for calculations of the radiative corrections for the JUPITER analysis [3]. Experiment E04-001 was designed to measure separated longitudinal and transverse structure functions for a range of nuclear targets. The measurements of the vector structure functions cover both the quasi-elastic and resonance regions.

A brief description of the fit is given in [3]. Additional details are presented in our previous paper[2]. The inclusive fit is a sum of four components:

- The longitudinal QE contribution calculated for independent nucleons (smeared by Fermi motion in carbon).
- The transverse QE contribution calculated for independent nucleons (smeared by Fermi motion in carbon).
- The contribution of inelastic pion production processes (smeared by Fermi motion in carbon).
- A transverse excess (TE) contribution (determined by the fit). The transverse enhancement contribution is a modified Gaussian, with amplitude, width and peak position which are allowed to vary in the fit.

The QE model used in the Bosted-Mamyan fit is the super-scaling model[5] of Sick, Donnelly, and Maieron. In this paper we report on an updated analysis in which we have modified the functional form for the transverse enhancement to better fit the electron scattering data.

Figure 1 shows examples of two fits to preliminary electron scattering differential cross sections for a carbon target. The top panels show the contributions from the
Figure 1: Examples of two fits to preliminary electron scattering differential cross sections for carbon target. The top panels shows the contributions from the independent nucleon quasi elastic process (in red) as a function of the final state invariant mass $W^2$. The contribution from inelastic pion production processes is shown in green. The bottom panels shows the residual of the data minus the sum of QE and pion production processes. The fit to the residual, which is the transverse excess (TE) contribution, is shown as the dashed blue line.

We extract the integrated transverse enhancement ratio as a function of $Q^2$ by integrating the various contributions to the fit up to $W^2 = 1.5 \, GeV^2$. Here

$$R_T = \frac{QE_{transverse} + TE}{QE_{transverse}}$$

We also extract the peak positions (in $\nu$) and RMS width (in $\nu$) of both the QE and transverse enhancement contributions.
Figure 2: Left panel: The ratio ($R_T$) of the integrated transverse quasielastic response function for Carbon 12 to the integrated transverse response function for the independent nucleon model as a function of $Q^2$. Middle panel: The RMS width (in $\nu$) for the transverse enhancement component as compared to the RMS width of quasielastic scattering from independent nucleons as a function of $Q^2$. Right panel: The shift in the peak position (in $\nu$) of the transverse enhancement with respect to the peak position for quasielastic scattering from independent nucleons as a function of $Q^2$.

### 3 Results

The left panel of Fig. 2 shows the ratio ($R_T$) of the integrated transverse quasielastic response function for Carbon 12 to the integrated transverse response function for the independent nucleon model as a function of $Q^2$. The ratio can be parametrized as $R_T = 1 + AQ^2 e^{-Q^2/B}$, with $A=5.19$ GeV$^{-2}$ and $B=0.376$ GeV$^2$.

The middle panel of Fig. 2 shows the RMS width (in $\nu$) for the transverse enhancement component as compared to the RMS width of quasielastic scattering from independent nucleons as a function of $Q^2$. The RMS width of the TE contribution is about 0.115 GeV. This is to be compared to the RMS width for QE scattering from nucleons which (as expected) increases with $Q^2$. The RMS width for QE scattering from independent nucleons (in $\nu$) can be represented by the function $RMS_{QE} = Cq_3$ Here, the RMS width is in GeV, $C=0.174$ and $q_3 = \sqrt{Q^2(1 + Q^2/4M^2)}$ is the
magnitude of the 3-momentum transfer to the nucleon in GeV.

The right panel of Fig. 2 shows the shift in the peak position (in $\nu$) of the transverse enhancement with respect to the peak position for QE scattering from independent nucleons as a function of $Q^2$. The shift in the peak position of the transverse enhancement contribution appears to be independent of $Q^2$. On average, the tE contribution is shifted by 0.045 GeV towards higher $\nu$. This is expected if the TE contribution originates from a two nucleon process.

References

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