Two-body currents in inclusive electron scattering

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The longitudinal and transverse structure functions are calculated for inclusive electron scattering from ^{12}C and ^{40}Ca in the quasielastic and dip region. The microscopic model presented here incorporates two-body currents derived from one-pion exchange and intermediate Δ excitation. The reaction mechanism involves both one-nucleon and two-nucleon knockout processes. It is demonstrated that, even for quasielastic kinematics, two-body currents give a substantial contribution to the transverse structure function. Furthermore, the observed excess of transverse strength in the dip region between the quasielastic and delta peak can be partially ascribed to direct two-nucleon knockout following photoabsorption on a two-body current.

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I. INTRODUCTION

During the last decade much experimental effort has been put into the separation of the longitudinal (R_L) and transverse (R_T) structure functions for inclusive (e,e') scattering from a number of nuclei [1–5]. Whereas the quasifree (e,e') cross section could be reasonably well described in the impulse approximation (IA) within a simple Fermi gas model (FGM) [6], an accurate and simultaneous description of the total cross section *and* separated structure functions needs more sophisticated theoretical models.

In the *quasielastic* (QE) *peak*, the transverse to longitudinal ratio of the response functions and the quenching of the longitudinal response function cannot be simultaneously reproduced within the FGM. Whereas the R_T data are reasonably well described, the longitudinal structure function is systematically overestimated. Over the years, different modifications to the FGM were suggested. The longitudinal response function was shown to be sensitive to various nuclear properties as there are medium modified nucleon properties [7], final-state interactions (FSI's), random phase approximation (RPA) correlations [8,9], and relativistic effects [10,11]. All these mechanisms are found to reduce the longitudinal strength, thereby improving the agreement with the data. Most of the aforementioned corrections, however, affect the transverse structure function in the same way, worsening the agreement with the data. As several many-body effects have been demonstrated to modify the absolute (e,e') response functions in the QE region and the different approaches do not agree in their relative importance, an accurate description of the R_T/R_L ratio represents one of the major challenges to any theoretical approach. Another motivation for studying the R_T/R_L ratio in more detail is provided by the findings of a y-scaling analysis of quasielastic scattering data [12]. The predicted scaling behavior of the longitudinal and transverse strength is violated throughout the QE region, pointing towards other reaction mechanisms which are not incorporated in the adopted nucleon-only approach. Most studies dealing with the effect of many-body properties have one common feature: They start from the picture that the virtual photon couples with the individual nucleons in the nucleus. As such, the nuclear current is taken to be a one-body operator (impulse approximation). However, it has been demonstrated [13–18] that even in the QE regime two-body mesonic currents (MEC's) can induce considerable corrections to the transverse structure function. In this context, Blunden and Butler [15] pointed out that in the QE region the one-nucleon knockout contribution related to MEC's should be estimated as about 10% of the total strength. Similar conclusions were drawn by Carlson and Schiavilla [13] for light nuclei. The results of their microscopic calculation demonstrated the essential role of virtual pion exchange in the description of the quasielastic ^{4}He(e,e') data.

In the *dip region* between the QE peak and the Δ peak an excess of transverse strength is observed experimentally [2]. For moderate values of the momentum transfer, pion electroproduction is estimated to be small in the high-energy tail of the QE peak and is unlikely to account for the missing strength [2]. Over the years, the observed strength has been mainly attributed to two-nucleon emission processes. A number of calculations have accounted for these two-nucleon knockout processes, incorporating two-body currents within the FGM [2,17,19]. It has been demonstrated that part of the strength in the dip region originates from two-particle knockout processes after photoabsorption on these two-body currents.

In this paper we focus on inclusive electron scattering from medium-light nuclei at the quasielastic peak and in the dip region and report on a fully microscopic nonrelativistic calculation based on the continuum RPA model. Because of the numerical complexity of these calculations, some restrictions have been respected in the model. Most of them seem to be justified within the aim of the present paper. We summarize the different ingredients and limitations of our model:

(i) In the energy region under consideration, the inclusive (e,e') strength is assumed to originate solely from one- and two-body knockout processes. As such, the nuclear charge-current four-vector is assumed to be the sum of a one- and two-body part related to one-pion exchange and intermediate Δ excitation. Real pion electroproduction is not incorporated in our approach.

(ii) At the quasielastic peak, our model goes beyond the direct nucleon knockout approach and incorporates RPA type of nucleon correlations within a continuum RPA formalism. Damping effects due to higher-order excitations of the n-particle–n-hole (np-nh) type ($n \geq 2$) are taken into account in a phenomenological way by introducing a complex self-energy.

(iii) No short-range correlation (SRC) corrections to the wave functions are implemented in the model.

(iv) The model does not include any relativistic correction. Negative-energy contributions tend to suppress both the longitudinal and the transverse structure function to the same degree [10].

This paper is organized as follows. The different aspects of the theoretical model are outlined in Sec. II. The results for inclusive electron scattering from ^{12}C and ^{40}Ca are presented in Sec. III. Some conclusions are drawn in Sec. IV.

II. MODEL

In the one-photon exchange approximation the (e,e') cross section reads as

$$\frac{d^3\sigma}{dE_f d\Omega_{E_f}}(e,e') = \sigma_M \left\{ \left(\frac{q_\mu^2}{\vec{q}^{\,2}}\right)^2 R_L(\vec{q},\omega) + \left(\tan^2(\theta_e/2) - \frac{q_\mu^2}{2\vec{q}^{\,2}}\right) R_T(\vec{q},\omega) \right\} \quad , \tag{1}$$

where $q_\mu(\omega,\vec{q})$ is the four-momentum transferred to the nucleus and σ_M is the Mott cross section for scattering from a point particle: $\sigma_M = \frac{\alpha^2 \cos^2(\theta_e/2)}{4E_i^2 \sin^4(\theta_e/2)}$. All information concerning the electromagnetic structure of the nucleus that can be derived from (e,e') reactions is contained in the longitudinal R_L and transverse R_T structure functions. Both structure functions are related to the matrix elements of the nuclear electromagnetic charge-current operator $(\rho,\vec{J})$ in the following way:

$$R_L(\vec{q},\omega) = \sum_n \mid \langle n \mid \rho(\vec{q}) \mid 0 \rangle \mid^2 \delta(\omega - E_n + E_0) \quad , \tag{2}$$

$$R_T(\vec{q},\omega) = \sum_n \left\{ \mid \langle n \mid J_{+1}(\vec{q}) \mid 0 \rangle \mid^2 + \mid \langle n \mid J_{-1}(\vec{q}) \mid 0 \rangle \mid^2 \right\} \delta(\omega - E_n + E_0) \quad . \tag{3}$$

The sum over n extends over all final nuclear states $\mid n \rangle$ with excitation energies $(E_n - E_0)$ relative to the groundstate energy E_0 of the target nucleus $\mid 0 \rangle$ $(J^\pi = 0^+)$. In our approach, the sum over all final states includes one- and two-body knockout processes. To be more specific, we assume the inclusive (e,e') strength to be mainly originating from $(e,e'N)$ and $(e,e'2N)$ processes, i.e.,

$$\frac{d^3\sigma(e,e')}{dE_f d\Omega_{E_f}} = \sum_N \int d\Omega_N dT_N \frac{d^6\sigma(e,e'N)}{dE_f d\Omega_{E_f} d\Omega_N dT_N} + \sum_{N,N'} \int d\Omega_N d\Omega_{N'} dT_N dT_{N'} \frac{d^9\sigma(e,e'NN')}{dE_f d\Omega_{E_f} d\Omega_N dT_N d\Omega_{N'} dT_{N'}} \quad . \tag{4}$$

In this expression N and N' stand for all occupied proton and neutron single-particle (SP) states of the A-particle nucleus. In order to estimate the contribution from these processes to the inclusive cross sections, the above expression involves an integration over the solid angles and energies of the outgoing particles. The kinetic energy of the outgoing nucleon(s) is fixed by the energy conservation relation $\omega = E_x^{A-1} + S_N + T_N + T_{A-1}$ for one-body knockout and $\omega = E_x^{A-2} + S_{2N} + T_N + T_{N'} + T_{A-2}$ for two-body knockout. The excitation energy of the residual nucleus and the one-nucleon separation energy are denoted by E_x and S_N. In line with our model assumptions, the structure functions consist of a one- and two-nucleon knockout part, i.e., $R(\vec{q},\omega) \equiv R^{[1]}(\vec{q},\omega) + R^{[2]}(\vec{q},\omega)$.

The wave function for one escaping particle and a residual $(A-1)$ nucleus [Fig. 1(a)] is evaluated in the continuum RPA formalism as described in Ref. [20]. The RPA formalism involves a partial-wave expansion of the final state in terms of linear combinations of particle-hole and hole-particle excitations out of a correlated A particle ground state. Bound and continuum single-particle states are eigenstates of the Hartree-Fock (HF) mean-field potential obtained with an effective interaction of the Skyrme type (SKE2) [21]. In this way, the bound and the continuum state wave functions remain orthogonal. In terms of the FSI's a continuum RPA calculation is equivalent with a coupled-channels calculation in which one-proton and one-neutron emission from the different shells is implemented.

By analogy with the one-nucleon emission picture, the wave function for two escaping particles and a $(A-2)$ residual nucleus is obtained by performing a double partial-wave expansion in terms of 2p-2h states [22]. The wave functions for the two-particle (2p) continuum states are evaluated in the same HF mean-field potential as for the one-body emission case. In this way, we arrive at a consistent description of the one- and two-nucleon knockout cross sections. It should be stressed, however, that in the two-nucleon knockout calculation a direct knockout reaction mechanism is assumed and no channel couplings are implemented.

In the present approach, the $(e,e'N)$ and $(e,e'2N)$ reaction mechanism encompasses one-nucleon and two-nucleon knockout following photoabsorption on a one-body and two-body current. As such, the nuclear current consists of a one-body part determined by the convection and magnetization current and a two-body part related to one-pion exchange. The two-body current is taken from a nonrelativistic reduction of the lowest-order Feynman diagrams with one exchanged pion and intermediate delta excitation. We adopt pseudovector coupling of the pion to the nucleon. This procedure gives rise to the seagull terms, the pion-in-flight term, and terms with a $\Delta(1232)$ excitation in the intermediate state. To lowest order, the nuclear charge operator is not affected by two-body contributions. Consequently, within our model assumptions all longitudinal strength originates from photoabsorption on a one-body operator. The adopted two-body charge-current four-vector is taken from Ref. [23] and reads

$$\begin{aligned}\rho^{(2)}(\vec{q};\vec{q}_1\vec{q}_2) &= 0,\\ \vec{J}^{(2)}(\vec{q};\vec{q}_1\vec{q}_2) &= \vec{J}^{(2)}_{\rm seag}(\vec{q};\vec{q}_1\vec{q}_2) + \vec{J}^{(2)}_{\rm pion}(\vec{q};\vec{q}_1\vec{q}_2) + \vec{J}^{(2)}_{\rm delta}(\vec{q};\vec{q}_1\vec{q}_2),\end{aligned} \tag{5}$$

with

$$\begin{aligned}\vec{J}^{(2)}_{\rm seag}(\vec{q};\vec{q}_1\vec{q}_2) &= -ie\left(\frac{f_{\pi NN}}{m_\pi}\right)^2 F_{\gamma N}(q)(\vec{\tau}_1\times\vec{\tau}_2)^3\left\{\frac{\vec{\sigma}_1(\vec{\sigma}_2\cdot\vec{q}_2)}{\vec{q}_2^{\,2}+m_\pi^2} - \frac{\vec{\sigma}_2(\vec{\sigma}_1\cdot\vec{q}_1)}{\vec{q}_1^{\,2}+m_\pi^2}\right\},\\ \vec{J}^{(2)}_{\rm pion}(\vec{q};\vec{q}_1\vec{q}_2) &= ie\left(\frac{f_{\pi NN}}{m_\pi}\right)^2 F_{\gamma\pi}(q)(\vec{\tau}_1\times\vec{\tau}_2)^3\frac{(\vec{\sigma}_1\cdot\vec{q}_1)(\vec{\sigma}_2\cdot\vec{q}_2)}{(\vec{q}_1^{\,2}+m_\pi^2)(\vec{q}_2^{\,2}+m_\pi^2)}(\vec{q}_1-\vec{q}_2),\\ \vec{J}^{(2)}_{\rm delta}(\vec{q};\vec{q}_1\vec{q}_2) &= i\frac{f_{\gamma N\Delta}f_{\pi N\Delta}f_{\pi NN}}{9m_\pi^3}\left(\frac{1}{M_\Delta - M_N - \omega - \frac{i}{2}\Gamma_\Delta(\omega)} + \frac{1}{M_\Delta - M_N + \omega}\right)F_{\gamma\Delta}(q)\\ &\quad\times\left\{4\frac{(\vec{\sigma}_2\cdot\vec{q}_2)}{\vec{q}_2^{\,2}+m_\pi^2}\vec{q}_2\tau_2^3 - (\vec{\tau}_1\times\vec{\tau}_2)^3\left(\frac{\vec{\sigma}_2\cdot\vec{q}_2}{\vec{q}_2^{\,2}+m_\pi^2}(\vec{\sigma}_1\times\vec{q}_2)\right) + [1\longleftrightarrow 2]\right\}\times\vec{q}.\end{aligned}$$

The following coupling constants are adopted: $\frac{f^2_{\pi NN}}{4\pi} = 0.079$, $\frac{f^2_{\pi N\Delta}}{4\pi} = 0.37$, and $f^2_{\gamma N\Delta} = 0.014$. In the evaluation of the Δ current an energy-dependent decay width

$$\Gamma_\Delta(\omega) = \frac{8f^2_{\pi NN}}{12\pi}\frac{(\omega^2-m_\pi^2)^{3/2}}{m_\pi^2}\frac{M_\Delta - M_N}{\omega} \tag{6}$$

has been introduced [24].

To account for the composite structure of the different vertices, the two-body nuclear current is modified by electromagnetic and hadronic form factors. For the γN form factor ($F_{\gamma N}$) we use the common dipole form [25]. The pion form factor $F_{\gamma\pi}$ is extracted from the vector dominance model [26]. It should be stressed that the use of two different parametrizations for the pion and nucleon form factor violates current conservation. An alternative choice that preserves current conservation would be replacing the pion form factor with the nucleon form factor. Since for the energy-momentum region considered here both form factors differ at most 20%, either of both choices will not appreciably affect the results. A similar conclusion was drawn by Amaro *et al.* [18] in a recent paper on the role of meson-exchange currents in quasielastic electron scattering from complex nuclei. In addition, in Ref. [27] we have shown that the calculated contribution from MEC's to the quasielastic $(e,e'p)$ structure functions is rather insensitive to the choice of the pion form factor. The delta current is divergenceless and can be multiplied with an arbitrary form factor $F_{\gamma\Delta}$. As is commonly done, we assume $F_{\gamma\Delta} = F_{\gamma N}$ in all calculations presented here. The short-range corrections to the πNN and $\pi N\Delta$ vertices are implemented in a phenomenological way by introducing hadronic form factors. These form factors are usually parametrized in momentum space as $(\Lambda_\pi^2 - m_\pi^2)/(\Lambda_\pi^2 + \vec{p}^{\,2})$ with Λ_π a scale parameter for the high-momentum cutoff. Standard values of Λ_π lie in the range 800–1250 MeV. All results presented in this paper are derived with Λ_π set equal to 1200 MeV. This value is suggested by recent parametrizations of the Bonn potential [28].

The one-nucleon knockout channels can be fed by both the one- and two-body parts of the nuclear current. In Figs. 1(a) and 1(b) we depict the diagrams that are included in our model for one-nucleon emission. The nuclear charge-current is expanded in terms of the Coulomb $M^{\rm Coul}_{JM}(q)$, electric $T^{\rm el}_{JM}(q)$, and magnetic $T^{\rm mag}_{JM}(q)$ transi-

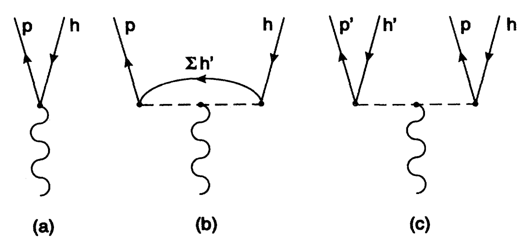

FIG. 1. Diagrams considered in the $(e,e'N)$ cross section: (a) impulse approximation, (b) one-pion exchange contribution. Two-body knockout following photoabsorption on a two-body current is depicted by diagrams of the type (c). For the two-body current contributions only pion-in-flight diagrams are displayed.

tion operators. In combination with the adopted partial-wave expansion for the one-body knockout wave function, the calculation of the $(e,e'N)$ cross section is then reduced to evaluating matrix elements of the type

$$\langle [p(\epsilon_p lj)h^{-1}]; J\omega \parallel M_J^{\mathrm{Coul}(1)}(q) \parallel 0^+ \rangle \ , \qquad (7)$$

$$\langle [p(\epsilon_p lj)h^{-1}]; J\omega \parallel T_J^{\mathrm{el,mag}(1)}(q) + T_J^{\mathrm{el,mag}(2)}(q) \parallel 0^+ \rangle \ . \qquad (8)$$

In this expression $M_J^{\mathrm{Coul}(1)}$, $T_J^{\mathrm{el,mag}(1)}$ refer to the one-body and $T_J^{\mathrm{el,mag}(2)}$ to the two-body part of the transition operator. The residual nucleus is considered to remain in a pure hole state h relative to the ground state of the target nucleus. The continuum state $p(\epsilon_p lj)$ satisfies $\epsilon_p = \omega - \mid \epsilon_h \mid > 0$, where ϵ_h is the hole single-particle energy as derived from a HF calculation. The two-body part of the transition operators is handled without any further approximation and involves two active nucleons in the absorption process [Fig. 1(b)]. Hence, the evaluation of the two-body current part in the matrix element (8) is reduced to

$$\langle [p(\epsilon_p lj)h^{-1}]; J\omega \parallel T_J^{\mathrm{el,mag}(2)}(q) \parallel 0^+ \rangle = \sum_{h' J_1 J_2} \sqrt{2J_1+1}\sqrt{2J_2+1}(-1)^{j_h - j_{h'} - J - J_2} \times \left\{ \begin{matrix} j_h & j_{h'} & J_1 \\ J_2 & J & j \end{matrix} \right\} \langle (hh'); J_1 \parallel T_J^{\mathrm{el,mag}(2)}(q) \parallel (ph'); J_2 \rangle_{as} \ , \qquad (9)$$

where the sum over h' extends over all occupied SP states in the target nucleus. The antisymmetrized two-body matrix elements with the pionic currents can be found in Ref. [22].

In the foregoing discussion only diagrams of the type depicted in Figs. 1 (a) and 1(b) are incorporated in the one-body emission model. The coupling of 1p-1h excitations to 2p-2h and higher-order excitations is not considered. However, it has been demonstrated in Ref. [29] that damping effects resulting from these higher-order contributions can be partially taken into account in a phenomenological approach by introducing a complex self-energy for the p-h state $\Sigma(\omega) = \Delta(\omega) + i\Gamma(\omega)/2$. The one-body response is then derived using a folding procedure, i.e.,

$$R^{[1]}(\vec{q},\omega) \longrightarrow \int_0^\infty dE R^{[1]}(\vec{q},E)\rho(E,\omega) \ . \qquad (10)$$

The spreading function $\rho(E,\omega)$ is expressed as a function of the real and imaginary parts of the p-h self-energy:

$$\rho(E,\omega) = \frac{(1/2\pi)\Gamma(\omega)}{[E-\omega-\Delta(\omega)]^2 + [\Gamma(\omega)/2]^2} \ . \qquad (11)$$

For the p-h spreading width Γ and energy shift Δ, we consider the same conventions and expressions as in Ref. [29].

In contrast with the one-nucleon knockout process to which both one- and two- body absorption mechanisms contribute, two-nucleon emission can only take place through photoabsorption on a two-body current within our model . In Fig. 1(c) one of the considered diagrams is depicted. The residual $(A-2)$ nucleus is a pure 2h state $\mid (hh')^{-1}; J_R M_R \rangle$ with respect to the ground state of the target nucleus. We have to evaluate matrix elements of the two-body transition operators of the following type:

$$\langle \left[(hh')^{-1} J_R; (p(\epsilon_p lj), p'(\epsilon_{p'} l'j'))J_1 \right]; J\omega \parallel T_J^{\mathrm{el,mag}(2)}(q) \parallel 0^+ \rangle. \qquad (12)$$

The continuum particle states $p(\epsilon_p lj)$ and $p'(\epsilon_{p'} l'j')$ satisfy $\epsilon_p + \epsilon_{p'} = \omega - \mid \epsilon_h \mid - \mid \epsilon_{h'} \mid > 0$.

III. RESULTS FOR ^{12}C(e,e′) AND ^{40}Ca(e,e′)

In this paper we concentrate on inclusive electron scattering from ^{12}C and ^{40}Ca. We performed calculations for several values of the momentum transfer, i.e., for ^{12}C(e,e'), $q = 400$ MeV/c , $q = 550$ MeV/c), and for ^{40}Ca(e,e'), $q = 370$ MeV/c. The theoretical predictions for the two structure functions of ^{12}C(e,e') are displayed in Figs. 2 and 3 and are compared with the results of a Rosenbluth separation from Barreau *et al.* [2]. The calculations for ^{40}Ca(e,e') are confronted with two different sets of data [1,3] and are depicted in Fig. 4. In the analysis of the experiments outlined in Refs. [1], [2], and [3], all data have been corrected for Coulomb distortion effects adopting the effective momentum approximation (EMA).

In particular, for the longitudinal ^{40}Ca(e,e') structure function at $q = 370$ MeV/c we observe a severe mismatch between the MIT and Saclay data. According to Ref. [3] this inconsistency originates from an error in the initial data taken with one of the two experimental setups and the discrepancy does not lie in the adopted Rosenbluth separation procedure. Further experimental investigation is highly needed to settle the inconsistency between both data sets.

First, in comparison with the Saclay data, it turns out that the qualitative behavior of the calculations is similar for both nuclei at different momentum transfers. The results of the IA calculations are shown as dashed lines in Figs. 2–4. These IA calculations encompass one-nucleon emission after photoabsorption on a one-body current and include the effect of 1p-1h RPA correlations and additional spreading corrections. At the quasielastic peak, the Saclay longitudinal structure functions for both target nuclei are clearly overestimated by the one-body knockout picture whereas for the transverse structure function the impulse approximation slightly underestimates the experimental results. Consequently, this is reflected in an inadequate description of the ratio R_T/R_L as obtained from the Saclay data. On the other hand, at the quasielastic peak, the MIT data for the ^{40}Ca(e,e') reaction seem to be reasonably reproduced in this nucleon-only picture and any further extension of the theoretical approach risks worsening the agreement reached. In the dip region, however, the IA is inadequate to reproduce the measured transverse strength for all data sets.

Inclusion of two-body currents in the model affects this picture in a drastic way. From Eq. (7) it is clear that the longitudinal structure function remains unaffected by the two-body part in the nuclear current. On the other hand, mesonic currents contribute substantially to the one-nucleon knockout transverse cross section. This enhancement is relatively more important for the smallest momentum transfers (q = 400 MeV/c for ^{12}C, q = 370 MeV/c for ^{40}Ca) considered here. In comparison with the Saclay data, after including two-body currents the calculations overestimate the measured longitudinal and transverse strengths to the same degree. We want to stress here that, given the complexity of the calculations when including two-body nuclear currents, we did not attempt to account for additional many-body effects, like SRC [30,31] and relativistic effects [10,15]. All these corrections tend to reduce both response functions to a more or less similar degree, thus leaving the transverse to longitudinal ratio almost unaffected.

The ^{40}Ca(e,e') data as measured in MIT-Bates exhibit a totally different behavior compared to the corresponding Saclay values. It is clear from Fig. 4 that at the quasielastic peak the measured R_T/R_L ratio is not in favor of two-body currents.

In the past, the impact of two-body currents on the (e,e') structure functions was mostly investigated within the FGM. Only recently have microscopic calculations that account for one-pion exchange currents become available. We compared our results with the theoretical predictions by Carlson and Schiavilla [13] for the ^{4}He(e,e') reaction and with a calculation similar in nature to ours of Amaro *et al.* [18] [^{12}C(e,e') and ^{40}Ca(e,e')]. For the latter the effect of pion-exchange currents and the Δ current on the quasielastic transverse structure function was investigated in a shell model framework which involves 1p-1h and 2p-2h nuclear final

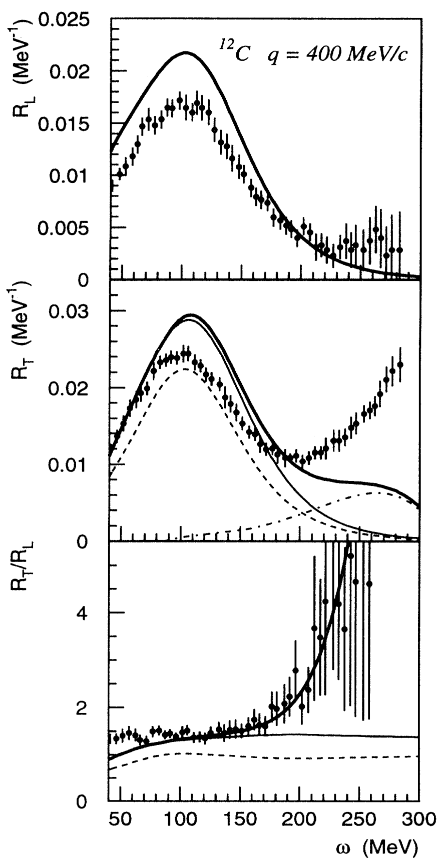

FIG. 2. The separated structure functions and transverse to longitudinal ratio (R_T/R_L) for ^{12}C(e,e') at q = 400 MeV/c. The solid line and dashed line are the calculated one-nucleon knockout contribution with and without inclusion of the two-body currents. The dash-dotted curve corresponds to two-nucleon knockout and the thick solid line to the total cross section. The data are taken from Ref. [2] (Saclay).

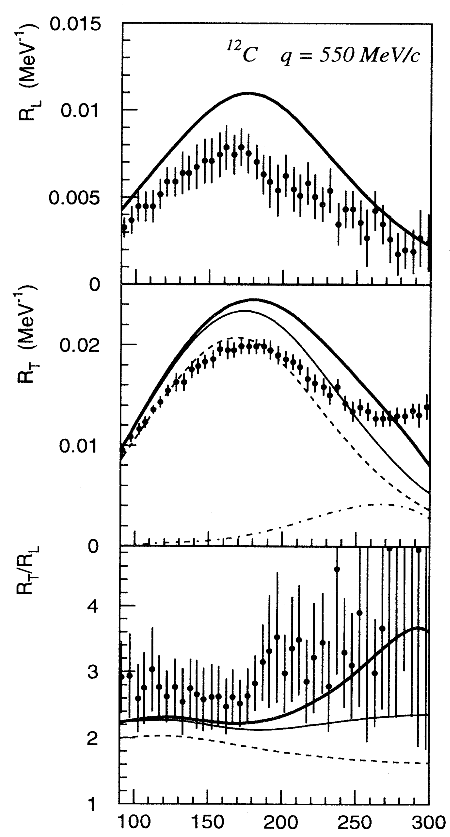

FIG. 3. Same as Fig. 2 but for ^{12}C(e,e') at q = 550 MeV/c.

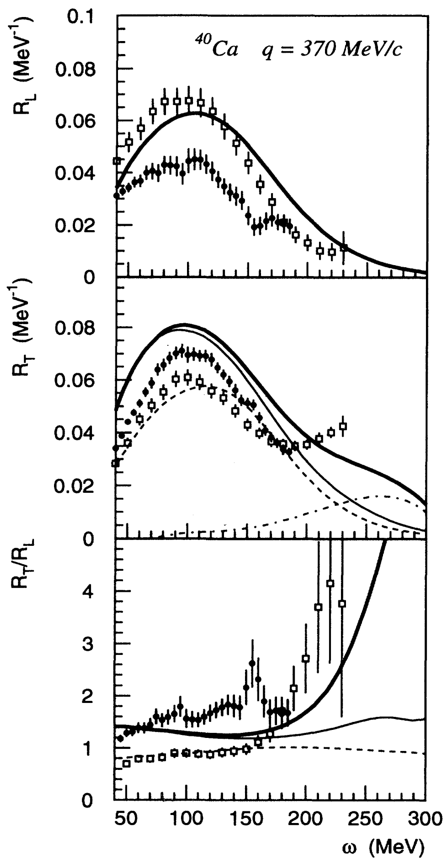

FIG. 4. Same line conventions as Fig. 2 but for ^{40}Ca(e,e') at $q = 370$ MeV/c. The data are taken from Ref. [1] (Saclay) (dots) and Ref. [3] (Bates) (squares).

states. The impact of two-body currents on the transverse (e,e') structure function in the QE peak was found to be very different for these two approaches. In line with our results concerning the relative importance of MEC's, virtual pion exchange was established to be a significant source of transverse ^{4}He(e,e') strength. On the contrary, Amaro *et al.* found that the contribution of two-body currents to the one-nucleon knockout channel in ^{12}C(e,e') and ^{40}Ca(e,e') is negligible. They attribute this small effect of two-body currents to the lack of SRC's in their nuclear wave functions. Notwithstanding the fact that SRC's are also neglected in our model, we find that a considerable amount of transverse strength at the quasielastic peak can be ascribed to the MEC's. Explicit inclusion of the SRC effects is expected to have a reducing effect on the strength produced by the meson-exchange currents. In Ref. [32] it was shown that this reduction is relatively small and of the order of 10%.

Two-particle knockout comes into play beyond $\omega = 100$ MeV. From Figs. 2–4 it is clear that part of the transverse strength in the dip region can be ascribed to two-nucleon emission processes following electro-induced photoabsorption on the mesonic currents. The q dependence for the calculated $2N$ knockout strength is similar to the one observed for the mesonic contribution to the one-body knockout strength. The two-nucleon knockout strength decreases with increasing momentum transfer. Despite the large experimental error bars for the transverse to longitudinal ratio in the dip region, our model seems to describe reasonably well the ω dependence of R_T/R_L. This is clear evidence for the importance of including two-particle knockout when describing the inclusive cross section in the dip region. In contrast with the results for the one-nucleon knockout channel, our model predictions for the two-nucleon knockout contribution to the transverse structure functions are consistent with those of Amaro *et al.* [18].

It has to be emphasized that our main focus in this study was on the quasielastic and dip region of the inclusive (e,e') spectrum. As mentioned before, real pion electroproduction is neglected in our model. Consequently we fail in describing the high-ω side of the measured transverse strength which is expected to be mainly originating from these processes [17].

IV. CONCLUSIONS

The longitudinal and transverse ^{12}C(e,e') and ^{40}Ca(e,e') response functions have been evaluated in a nonrelativistic HF+RPA model including one- and two-body nuclear currents. The main goal of this paper was to estimate the impact of two-body currents on the inclusive electron scattering structure functions. The calculations suggest that even in the QE region the two-body currents can induce an extra (20–30%) of strength into the transverse channel. In the dip region, two-nucleon knockout is found to gain in relative importance and the two-body currents are predicted to fill in a large fraction of the missing strength between the IA results and the data. Therefore, we conclude that, given the degree of importance, two-body currents play an essential role in any model that aims at a complete description of inclusive electron scattering from complex nuclei.

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