ON THE SHIFT OF THE TRANSVERSE RESPONSE FUNCTION IN ^{2}H(e, e′) REACTION

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The experimental data on inclusive electron scattering by deuteron nuclei are analyzed. The transfer momentum dependence is obtained for the transverse response function maxima position shift relatively to the point, corresponding to elastic eN-scattering over a significant range $1.43 \leq q \leq 3.24$ fm^{-1}. The results are compared with the experimental data obtained in other laboratories.

Introduction

Recently, the quasifree ^{2}H(e,e′) cross sections measured at the MIT-Bates Linear Accelerator Center [1] were analyzed by us [2], and the transferred momentum dependence was derived for the shift (ε) of a quasifree peak (QFP) maximum position relatively to the eN elastic scattering peak. This investigation (only the spectra for the forward scattering angle $\theta = 60°$ were used) has shown that ε is not a constant value and monotonically changes from $\sim$ 0.9 to 2.9 MeV with increase in the transferred momentum in the interval $1.39 - 2.73$ fm^{-1}. Under these kinematical conditions, the longitudinal and transverse contributions to the total quasifree cross section (see the text below) tend to be equal.

The energy position of maxima in the transverse response functions of ^{2}H nucleus was studied in [3]. The experiment has been carried out at the Kharkiv Electron Linear 300-MeV Accelerator. It was shown that the shift value smoothly decreases from plus 0.8 to minus 0.65 MeV with the transferred momentum increasing from 1 to 1.5 fm^{-1}. Experimental results radically changed the concept that the shift can be associated with the "average" nucleon separation energy that must be supplied to knock the nucleon out of the nucleus.

It should be stressed that the transverse response functions can be used to investigate [1, 4, 5] the importance of the meson currents, the exchange and nonlocal character of NN interaction, the core polarization effects, the nature of nucleon resonances as they appear in the nuclear medium. So, it is interesting to know all the specific experimental features of the transverse response functions in detail, their mass number and momentum transfer dependences, and, of course, their physical interpretation. At the same time, various theoretical approaches predict a rather large difference in the location of the transverse response functions for different nuclei [4, 5].

The data presented here on single-arm inelastic electron scattering by deuterons represent a part of the series of analyses of the continuum inclusive electron scattering performed on light- and medium-weight nuclei [2—7]. We have analyzed the transverse response functions which were derived from the ^{2}H(e,e′) reaction [1] for the back scattering angle $\theta = 134.5°$ by means of a Rosenbluth-type analysis of the inclusive cross sections in the momentum transfer region $1.43 \leq q \leq 3.24$ fm^{-1}.

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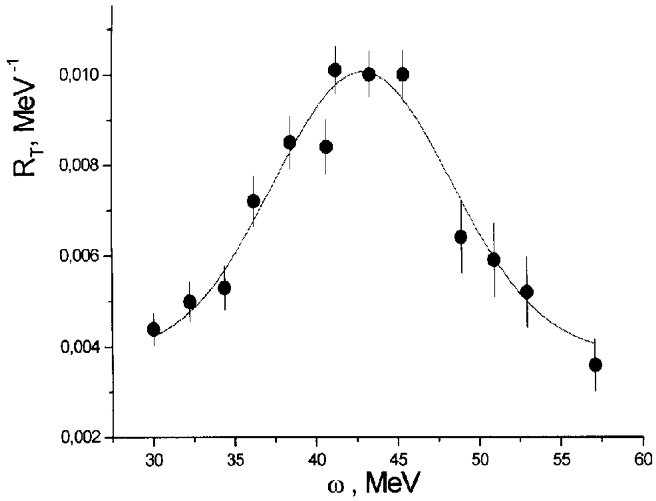

Fig. 1. Transverse response function versus the energy loss for $E = 174.3$ MeV and $\theta = 134.5°$. The solid curve is the fitting by the Gauss function

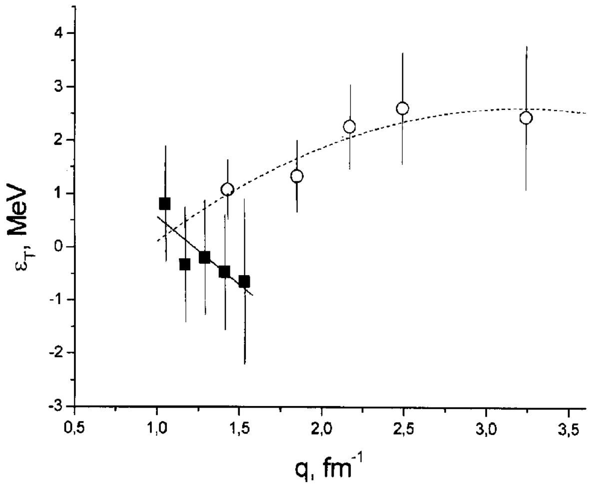

Fig. 2. Difference between the observed location of the maxima of transverse response functions of ^{2}H and those for a free nucleon peak. Open circles (solid squares) are the present result (data from [3]). The straight line (dashed curve) is a linear (polynomial) fitting to the corresponding experimental points

Data Analysis and Results

As is known (see, for example, [1]), if the Lorentz covariance, parity invariance, and current conservation are assumed, the (e, e′) cross section depends on only two response functions: the longitudinal R_L and transverse R_T ones. When using unpolarized targets and electrons, the response functions depend on two independent variables: $q = |\mathbf{q}|$ and the scattered electron energy loss ω. The inclusive double differential cross section may be written in the following form:

$$d^2\sigma/d\omega d\Omega = \sigma_{\rm M}[q_\mu^4/q^4 R_L(q,\omega)+$$

$$+\{q_\mu^2/2q^2 + {\rm tg}^2\,\theta/2\}R_T(q,\omega)], \qquad (1)$$

where $\sigma_{\rm M}$ — Mott cross section, q_μ^2 — squared transferred 4-momentum.

In accordance to Eq. (1), the differential cross section contains a mixture of the longitudinal (L) and transverse (T) contributions, and the QFP maximum position is determined by the sum of the L- and T-parts of the cross sections.

Kinematical conditions and results of analysis (N — number of experimental points used in the fitting, and χ^2 stands for the χ^2/degree of freedom)

N	E, MeV	θ, degree	N	χ^2	q, fm^{-1}	ε, MeV
1	174.3	134.5	13	0.99	1.43	1.1 ± 0.7
2	233.1	134.5	12	1.15	1.85	1.3 ± 0.8
3	278.5	134.5	12	0.90	2.16	2.3 ± 0.9
4	327.7	134.5	12	0.94	2.49	2.6 ± 1.2
5	444.2	134.5	9	0.99	3.24	2.4 ± 1.5

To study the difference between the observed locations of the maxima of the transverse response functions of ^{2}H and those for a free nucleon peak, we have processed the data given in [1]. In the kinematics under study, only the transverse response functions have been used for the present analysis. The data are taken at the initial energies E = 174.3, 233.1, 278.5, 327.7, and 444.2 MeV and at a scattering angle of 134.5° . The transferred 3-momentum at the maxima of the response functions varied from 1.43 to 3.24 fm^{-1}. Each spectrum represents a slice through the response surface along one of the kinematical curves of a measurement at 134.5° [1]. As an example, the transverse response function for ^{2}H nucleus for the initial energy $E = 174.3$ MeV together with the results of fitting are displayed in Fig. 1.

The difference between of the transverse response function maximum position for a deuteron relatively to the point corresponding to the free eN-kinematics is determined as

$$\varepsilon_T = \omega_{\rm max} - \omega_{eN}, \qquad (2)$$

where $\omega_{\rm max}$ is the transverse response function maximum energy loss and ω_{eN} denotes the energy loss corresponding to the scattering by free nucleons at rest.

The response function maximum position $\omega_{\rm max}$ and its error have been determined by fitting the Gaussian with the mean square method to experimental points in the vicinity of a maximum. The final values for the quantities delivered directly from the data are listed in Table and demonstrated in Fig. 2 (open circles).

One can see that the shift value (for a given set of experimental data) trends to be sensitive to the kinematical conditions of measurements. The $\varepsilon_T(q)$-dependence for ^{2}H nucleus at a back angle of 134.5° demonstrates a smooth rise of the shift with increasing the transferred momentum. We recall that an analogous situation takes place for the QFP shift $\varepsilon(q)$ both at a forward angle of 60° for ^{2}H [2] and nuclei heavier than a deuteron [4, 6, 7]. Then the dependence under study indicates the saturation in the interval of transferred momenta 2.2—3.24 fm^{-1}, which can be directly related to the binding energy of nucleons equal to 2.22 MeV.

The results of our analysis presented in Fig. 2 (open circles) were compared with experimental data [3] (solid squares).

The comparison indicates that there are discrepancies both in the momentum transfer behavior and absolute values of the shift. Four of five experimental points from [3] are below zero. It means that the maxima of the response functions are at a lower energy loss than ω_{eN}. The basic tendency of the shift behavior for a deuteron [3] is displayed in Fig. 2 by the linear fit line. At the same time, our results show that the maxima of the R_T-region peaks are above that for a free nucleon and shift to a higher energy loss as q increases. Unfortunately, the (e, e′) cross section statistical errors at back angles (in both cases) are rather large, and the errors on the extraction of the transverse response functions are quite large as well.

Conclusions

The experimental data at the back scattering angle $\theta = 134.5°$ are analyzed and the transfer momentum dependence $\varepsilon_T(q)$ is obtained for the maxima position shift of transverse response functions for a deuteron nucleus relatively to the energy corresponding to elastic eN-scattering in the wide kinematical interval $1.43 - 3.24$ fm^{-1}.

The maxima of transverse response functions are found to be systematically shifted to the higher energy loss compared with the location of the eN-scattering peaks. The $\varepsilon_T(q)$-dependence for ^{2}H nucleus shows a smooth rise of the shift value with increase in the momentum transfer in the range $\sim 1.43 - 2.5$ fm^{-1}, as it takes place both for the QFP shift at a forward angle of 60° and nuclei heavier than a deuteron. At the same time, the final results indicate a tend to the saturation at large transferred momenta. This saturation can be explained by the binding energy of nucleons equal to 2.22 MeV. The present data are in disagreement with results which were obtained earlier [3] in the interval of transferred momenta $\sim 1 - 1.5$ fm^{-1}.

The existing body of experimental data is rather small to make a more detailed investigation possible. Hence, it is desirable to extend the kinematical region of systematic experimental investigations, extract the longitudinal and transverse response functions with better accuracy, and include the corresponding theoretical analysis using modern realistic nucleon-nucleon potentials.

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ПРО ЗСУВ ПОПЕРЕЧНОЇ ФУНКЦІЇ ВІДГУКУ
В РЕАКЦІЇ ^{2}H(e, e′)

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Р е з ю м е

Проаналізовано експериментальні дані з інклюзивного розсіяння електронів на ядрі дейтерію в області квазівільного піка. Отримано залежність зсуву розміщення максимуму поперечної функції відгуку відносно точки, яка відповідає кінематиці пружного eN-розсіяння, від переданого 3-імпульсу в інтервалі $1,43 \leq q \leq 3,24$ фм$^{-1}$.