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THE INFLUENCE OF SHORT-RANGE CORRELATIONS ON NUCLEON EMISSION IN ELECTRON SCATTERING BY NUCLEI

A. MAŁECKI
Instytut Fizyki Jądrowej, Kraków, Poland
and
P. PICCHI
Laboratori Nazionali del CNEN, Frascati, Italy

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The nucleon emission induced by high-energy electrons is analysed in three experimental situations: electron-proton coincidence and single detection of electron or proton. The coincidence and proton detection experiments are recommended as sensible tools for studying the nuclear correlations.

The repulsive interaction acting at short distances among nucleons results in the lowering of density in the centre of the nucleus and introduces high-momentum components into the single-particle wave functions. The first effect may be observed in elastic electron scattering where, as shown by many authors [1, 2], the correlations produce a diffraction pattern of the cross-section for large momentum transfers. The second effect may be displayed in deep inelastic electron scattering since the correlation tail in the momentum distribution is expected [3, 4] to affect significantly the probability of nucleon emission. The purpose of our work is to elucidate the prospects of this way of study of nucleon-nucleon correlations.

We assumed that the inelastic scattering is dominated by single-nucleon emission. Using impulse approximation, we computed cross-sections corresponding to the three experimental arrangements:

i) detection of the emitted nucleon in coincidence with the scattered electron,

ii) detection of the emitted nucleon only,

iii) detection of the scattered electron only.

In the impulse approximation the nuclear structure is represented by the momentum distribution $W(p)$ of nucleons in the ground state. We calculated $W(p)$ as the Fourier transform of the inverted form factor:

$$W(p) = \frac{1}{2\pi^2} \int_0^\infty d\rho\, \rho^2 j_0(p\rho)\, F(\rho), \tag{1}$$

$$F(\rho) = \frac{1}{A} \langle \Psi(\dots p_j \dots) | \sum_{j=1}^{A} e^{i\varrho \cdot p_j} | \Psi(\dots p_j \dots) \rangle \quad (1)$$

where $\Psi(\dots p_j \dots)$ is the nuclear wave function in the momentum representation.

We described the short-range correlations by means of unitary operators [5, 2]. Extracting the leading term of two-particle correlations one has:

$$F(\rho) = \frac{1}{A} [\sum_{\alpha\beta} \langle \alpha\beta | u^\dagger(1,2)\, e^{i\varrho \cdot p_1} u(1,2) | \alpha\beta - \beta\alpha \rangle$$
$$- (A-2) \sum_{\alpha} \langle \alpha | e^{i\varrho \cdot p_1} | \alpha \rangle] \exp\left(\frac{\alpha^2 \rho^2}{4A}\right) \tag{2}$$

where one sums over occupied single-particle states. The last factor in eq. (2) is the centre-of-mass correction evaluated in the basis of harmonic-oscillator wave functions with the energy parameter α.

The oscillator model, which is well justified for light nuclei, allows a handy separation of the relative and c.m. motions of two particles. The correlation operators applied in our calculations act on the radial wave functions of the relative motion in the following way:

$$u(1,2) R_{nl}(p) = \tag{3}$$

$$\sqrt{\tfrac{2}{\pi}} (-i)^l \int_0^\infty dr\; r^2 j_l(pr) R_{nl}(r) \left[\frac{g^2 + (M_{nl} - 1) g}{M_{nl}} \right]^{1/2}$$

with coefficients M_{nl} determined by the norma-

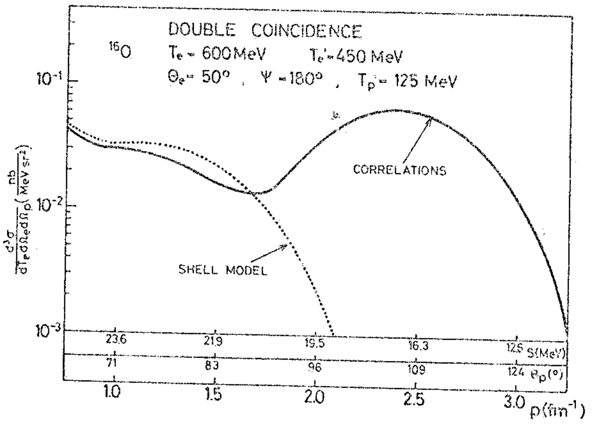

Fig.1. The double coincidence cross-section in the coplanar (Ψ = 180°) experiment with the fixed energy of the emitted proton T_p' (±3 MeV). Only the lowest scale, which displays the initial momentum p of the proton, is linear. The other two show the angle of emission (measured with respect to the electron beam) Θ_p and the energy S left for the separation of the nucleon. The oscillator parameter is α = 119 MeV and the correlation factor is assumed in the form $g(s) = 1-\exp[-\beta^2(s^2-c^2)]$ with [2] c = 0.54 fm, β = 0.64 fm^{-1}. The spectra of the separation energy are taken from ref.[7].

zation [6]; $g(r)$, being the function of the mutual distance $s = \sqrt{2}\,r$ of a nucleon pair, is supposed to vanish within a repulsive core of radius c, whereafter it rapidly rises up to unity. The correlations (3) then satisfy the healing condition.

The correlated cross-sections are compared with the predictions of the shell model in figs. 1-3. We present there our results for the ^{16}O nucleus. In all the three cases there is a domain where the correlations lead to a remarkable increase of the cross-section. In the electron detection experiment (fig. 3) a distinct correlation effect occurs only at large energy transfers (c.f.ref. [6]). The interpretation of the data in this region may be seriously obscured by the presence of meson production. However, the double coincidence arrangement, as the example of fig. 1 shows, is free of this inconvenience. The same is true of the nucleon detection case where the energy transfer $\omega = T_p' + S + T_{A-1}$, T_{A-1} being the recoil energy of the residual nucleus, may be kept below the meson threshold without blurring the correlation effect. The advantage of the proton detection over the electron detection experiment, which seems to have been somewhat overlooked in the past, stems from the fact of large nucleon mass. Thus a nucleon with kinetic energy of 125 MeV has a momentum four times greater; such a nucleon, in order to be allowed into the domain of large emission angles, had to be very fast inside the nucleus.

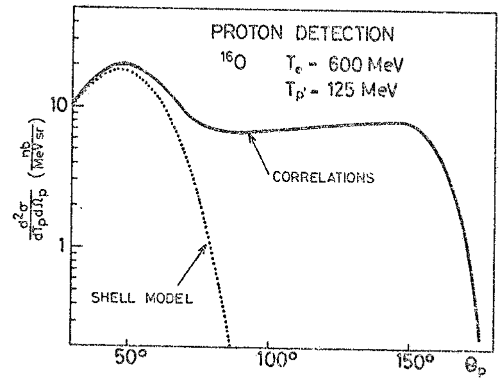

Fig.2. The proton detection cross-section in the function of emission angle. The nuclear parameters are the same as in fig. 1.

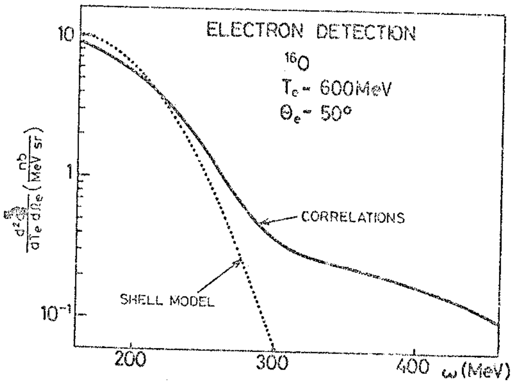

Fig.3. The electron detection cross-section in the function of electron energy loss. The nuclear parameters are the same as in fig.1.

The impulse approximation does not take into account the distortion of the wave function of the ejected nucleon and neglects the indirect mechanism of the emission. The final state interaction will only reduce [7] the cross-sections but the effect of short-range correlations remains unchanged. The indirect process also results, due to its interference with the knock-out emission, in the reduction [8] of the cross-section. This reduction will be more pronounced in the presence of the correlations since the indirect amplitude is proportional to the Fourier transform of the single-particle wave function. The effect should not, however, exceed ten per cent for the ^{16}O nucleus and will be partly compensated by the emission of more than one nucleon, which can occur only for the system of correlated nucleons [4].

The correlation effects discussed here are, of course, model dependent. This necessitates a coherent interpretation of various processes on the same target. The nuclear parameters used in our calculations were obtained from the fits to elastic scattering data [2]. It would be very desirable to check them by means of inelastic experiments.

In conclusion, we recommend the double coincidence and proton detection experiments as sensible tools for studying the nuclear correlations at short distances. The proposed measurements should be feasible with the present experimental technique. The double coincidence arrangement allows a clearer-cut interpretation of the data , but the single detection experiment offers a much greater cross-section. In both cases a characteristic plateau of the cross-section might constitute a decisive test of the correlations.

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