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Soumis à Few-Body Systems Suppl.

High missing-momentum components in ^4He studied with the $(e, e'p)$ reaction

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1 Introduction

The nucleon-nucleon (NN) interaction in the nuclear medium is of fundamental importance for the description of nuclear properties. In particular its short-range part is still poorly known. High-momentum components of the nuclear wave function are sensitive to short range correlations (SRC). Measurement of high momenta will therefore yield information on the NN-interaction at short internucleon distances [1]. Because of the availability of realistic calculations of the wave function of few-body systems, a light nucleus is preferred for such a study. Since the effects of short range correlations are expected to be enhanced in dense nuclei we choose for ^4He .

The $(e, e'p)$ reaction is suited to study high-momentum components, since in this way both the initial momentum and removal energy of the ejected proton can be determined. Calculations indicate that the high-momentum components are correlated with high removal energies [2]. In this kinematical domain the

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reaction is sensitive to both the central part and the tensor part of the interaction, while the ${}^4\text{He}(e, e'p){}^3\text{H}$ reaction is sensitive to its central part only. For this reason we have chosen to determine the proton momentum distribution of ${}^4\text{He}$ not only for high removal energies, but also for the channel in which the (A-1) system remains a triton.

2 Experimental Setup

The experiment has been performed at the electron scattering facility of NIKHEF with the extracted electron beam from the Amsterdam Pulse Stretcher (AmPS) [3]. As a target we used a cryogenic (15 K) high-pressure (4 MPa) ${}^4\text{He}$ gas target. The electrons were detected in the QDQ high-resolution magnetic spectrometer.

Protons were detected in the highly-segmented HADRON-4 scintillator detector (see ref. [4] for prototype). At the nominal distance of 80 cm from the target, the detector has an angular acceptance of $\pm 21^\circ$, both in-plane and out-of-plane, resulting in a solid angle of 500 msr. The angular resolution is 1° and 2° for in-plane and out-of-plane, respectively. The total thickness of the scintillator material is 18 cm, which in combination with a 5.2 mm lead-absorber, results in a proton energy acceptance of 67-195 MeV.

The coincidence timing resolution, after applying all corrections, is 0.8 ns FWHM. The energy resolution determined with the ${}^1\text{H}(e, e'p)$ reaction is 3.3 MeV (FWHM) for a proton energy of 122 MeV. This corresponds to 2.7 %, a value that turns out to be reasonably constant over the total energy acceptance.

3 Kinematics

The quantities missing momentum ($\mathbf{p}_m$) and missing energy (E_m) are defined in the following way:

$$\mathbf{p}_m = \mathbf{q} - \mathbf{p}' \quad (1)$$

$$E_m = \omega - T_{p'} - T_{A-1} \quad (2)$$

in which $\mathbf{q}$ and ω are the momentum and energy transferred by the virtual photon, respectively. $\mathbf{p}'$ is the momentum and $T_{p'}$ the kinetic energy of the knocked out proton and T_{A-1} the kinetic energy of the residual A-1 system. In the Plane Wave Impulse Approximation $\mathbf{p}_m$ can be identified with the recoil momentum $\mathbf{p}_{A-1}$ and is equal in size and opposite in direction to the initial proton momentum. T_{A-1} can be calculated from the measured quantities.

For the present experiment we used an electron beam with an energy of 525 MeV and a duty factor of 50%. The scattered electron was detected at an angle of 49.6° . Since multi-nucleon processes are expected to be important in the dip region, between the quasi-elastic peak and the delta resonance region, we chose the energy transfer correspondingly: $\omega = 215$ MeV, leading to a momentum transfer of 400 MeV/c. The resulting virtual photon polarization ε was 0.63. At this fixed electron kinematics we used four settings of HADRON-4, covering a range of 8° to 101° for the angle between $\mathbf{q}$ and $\mathbf{p}'$.

4 Results

The kinematical settings mentioned in the previous section result in a coverage of the (E_m, p_m) plane up to 700 MeV/c in p_m and 150 MeV in E_m . Because of a dependence of the E_m -acceptance on p_m , the cutoff of the acceptance shifts to lower E_m when p_m increases. In Fig.1 the E_m spectra for various values of p_m are shown. The data shown are preliminary, but the results are not ex-

Figure 1. Preliminary six-fold differential cross section as a function of missing energy for 4 p_m intervals of 20 MeV/c wide. The arrows indicate where the centroid of the continuum is expected according to the 'scattering on a pair' model.

pected to change by more than 10 %. Radiative unfolding has been applied. The missing-energy resolution turns out to be 6 MeV at the highest proton energy, which corresponds to the lowest missing momentum. The peak around 19.8 MeV corresponds to the ${}^4\text{He}(e, e'p){}^3\text{H}$ channel, i.e. the reaction in which the $(A-1)$ system remains in its ground state. The thresholds for the ${}^4\text{He}(e, e'p)dn$ and the ${}^4\text{He}(e, e'p)ppn$ reactions are 26.1 and 28.3 MeV, respectively. This means that above 28.3 MeV both reactions, which are experimentally indistinguishable, play a role. This part of the E_m -spectrum will be referred to as the 'continuum'. From the figure it can be seen that the strength of the two-body breakup channel decreases rapidly with increasing p_m , whereas the strength in the continuum decreases less fast.

If a model is assumed in which the reaction takes place on a nucleon pair

with the other two nucleons as spectators, the undetected nucleon of the pair takes the recoil energy. The missing energy of such a process is:

$$E_m = E_{thr} - T_{A-1} + (\sqrt{p_m^2 + M_N^2} - M_N) \quad (3)$$

The center of mass motion of the pair will cause a broadening of the peak. The arrows in the figure indicate where the centroid is expected to show up.

To obtain the five-fold differential cross section, we integrated the two-body breakup peak for different values of p_m , by fitting the spectrum with a gaussian and a three-parameter function for the continuum. The result is shown in Fig. 2. From the figure it can be seen that the data do not show any

Figure 2. Preliminary five-fold differential cross section for the ${}^4\text{He}(e, e'p){}^3\text{H}$ reaction channel. The curves are calculations by Laget. The dotted curve is the PWIA prediction, the dashed curve includes rescattering and 2-body MEC, the solid curve also 3-body effects [5].

structure: between 200 and 700 MeV/c the data can almost be described by an exponential curve. The curves in the figure are the results of calculations by Laget who uses a diagrammatic expansion of the cross section [5]. The ${}^4\text{He}$ wave function results from a variational calculation with the Urbana-V14 potential [6]. The minimum in the PWIA prediction is washed out when FSI and MEC are taken into account, but contrary to the data, still a change of slope can be seen at $p_m=450$ MeV/c in the full calculation. The data extend in a region where 3-body effects become important, but because of the discrepancy with the calculation between 250 and 450 MeV/c, the importance of 3-nucleon effects can not be quantified.

Dedicated calculations have also been performed by Laget for the continuum, the results of which are shown in Fig. 3. The spectra shown in this figure are six-fold differential cross sections for two values of the angle, γ_{pq} , between

Figure 3. Preliminary six-fold differential cross section for two values of the angle between p' and q , 30° (top) and 79° (bottom). The curves are the full calculations by Laget.

q and p' . The arrows indicate where the bump is expected according to the 'scattering on a pair model' (Eq.3). From the upper figure it can be concluded that the shape of the full calculation disagrees with that of the data, but that the strength at the peak of the calculation, which has the same position as in the naive 'scattering on a pair' model, is of roughly the right size. Apparently at higher missing energy other processes play a dominant role. In the lower figure it can be seen that both the shape and the strength of the data are well reproduced and that the position of the peak of the calculation agrees with the prediction of the model mentioned above. Hence it can be concluded that scattering on a pair is the dominant process at this value of γ_{pq} .

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