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Study of the ground-state wave function of ^{6}He via the ^{6}He(p, t)α transfer reaction

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Abstract. We have measured the ^{6}He(p, t)α transfer reaction in inverse kinematics at 25 MeV/nucleon. The data were compared to DWBA calculations in order to extract the spectroscopic amplitudes for $\alpha + 2$n and t + t configurations in the ground state of ^{6}He.

PACS. 24.50.+g Direct reactions – 25.60.Je Transfer reactions – 24.10.Eq Coupled-channel and distorted-wave models – 21.10.Jx Spectroscopic factors

1 Motivation

The ^{6}He nucleus is now currently used as one of the benchmark nuclei to study the halo phenomenon and 3-body correlations [1], especially because the alpha-core can very well be represented as inert. However, in order to have a complete and detailed description of the ^{6}He wave function, the question arises whether the only contributions are the cigar and di-neutron configurations, where only ^{4}He and 2n clusters intervene, or if some t + t clustering is also present. In the case of the ^{6}Li nucleus, it was shown that it was possible to have considerable α + d and ^{3}He + t clustering at the same time, and the importance of both configurations was studied by analyzing angular distributions of the ^{6}Li(p, ^{3}He)^{4}He reactions [2].

2 Experiment

Following the same ideas, we measured recently at GANIL the complete angular distribution for the ^{6}He(p, t)^{4}He with the SPEG spectrometer [3] and the MUST array [4], with a special emphasis on the most forward and backward angles which could not be measured in a previous experiment performed at JINR Dubna [5]. The 25 A MeV ^{6}He secondary beam was produced by fragmentation of a 60 A MeV ^{13}C beam on a 1040 mg/cm^2 thick carbon target. After selection with magnetic dipoles and an achromatic Al degrader, it was transported to the SPEG reaction chamber where it impinged on a $(CH_2)_3$ target, 18 mg/cm^2 thick. The average intensity of the secondary beam was $1.1 \cdot 10^5$ pps, with only one contaminant, ^{9}Be, at the level of 1%. Due to the large emittance of the secondary beam, the incident angle and the position on the target of the incoming nuclei were monitored event by event by two low pressure drift chambers. The most forward and backward angles of the angular distribution for the ^{6}He(p, t)^{4}He reaction were measured in the SPEG spectrometer by detecting respectively the high-energy ^{4}He and the high-energy triton at forward laboratory angles. The particles were identified in the focal plane by the energy loss measured in an ionization chamber and the residual energy measured in plastic scintillators. The momentum and the scattering angle after the

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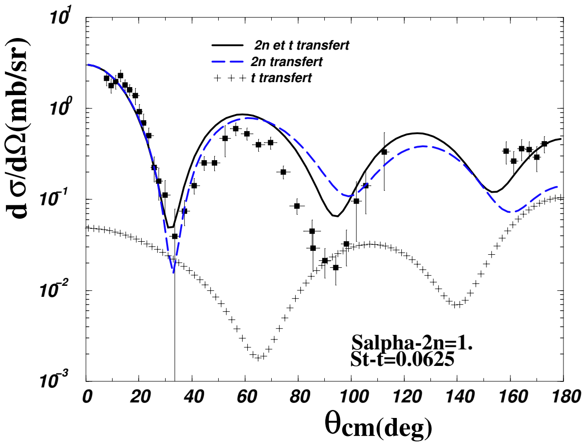

Fig. 1. Experimental angular distribution measured in the present work for the $^6\mathrm{He(p,t)}^4\mathrm{He}$ reaction, compared to DWBA calculations (see text for details).

target were obtained by track reconstruction of the trajectory as determined by two drift chambers located near the focal plane of the spectrometer. For center-of-mass angles between 20 and 110 degrees, the ^{4}He and triton from $^6\mathrm{He(p,t)}^4\mathrm{He}$ reaction were detected in coincidence by the eight telescopes of the MUST detector array. Each of these telecopes is composed of a 300 μm double-sided silicon strip detector backed by a Si(Li) and a CsI crystal which all give an energy measurement. These detectors were separated in two groups of four arranged in squared geometry on each side of the beam, one covering an angular range between 6 and 24 degrees, and the other one between 20 and 38 degrees with respect to the beam direction. The angular coverage in the vertical direction was 9 degrees. The angular distribution is presented in fig. 1. To extract differential cross-sections, data were corrected for the geometrical efficiency of the detection in SPEG or MUST. This efficiency was determined through a Monte Carlo simulation whose ingredients are the detector geometry, their experimental angular and energy resolutions, the position and width of the beam on the target. The error on the MUST detection efficiency deduced from the Monte Carlo simulation is estimated to 5%. The absolute normalisation for the transfer reaction was obtained from the elastic scattering which was measured in the same experiment with the SPEG spectrometer. Indeed elastic-scattering calculations for the system $^6\mathrm{He} + {}^{12}\mathrm{C}$ using different potentials showed that the angular distribution at forward angles is dominated by Coulomb scattering and is rather insensitive to the potential used. Therefore the absolute normalisation of the data was obtained from the measured cross-section on the first maximum of the $^6\mathrm{He}(^{12}\mathrm{C},{}^{12}\mathrm{C})^6\mathrm{He}$ angular distribution. The uncertainty on the absolute normalisation is of the order of 10%. The same normalisation was applied to the transfer data measured with the SPEG spectrometer. In the overlap domain between 19 degrees c.m. and 27 degrees c.m. where the transfer data were obtained with both SPEG and MUST, the agreement was good.

3 Analysis of the data

We have performed DWBA calculations including both 2n and t transfer. In the entrance channel, the coupling to the continuum of ^{6}He was taken into account via an effective dynamical potential derived by an iterative inversion method [6,7]. A special care was taken in the choice of the exit channel potential. Indeed no data exist for $\alpha + \mathrm{t}$ elastic scattering in the energy range considered presently. Therefore we used elastic scattering data for the system $\alpha + {}^3\mathrm{He}$ [8] to obtain the potential for the exit channel. Several potentials were considered. First, the process of one neutron transfer, which is not distinguishable experimentally from elastic scattering, was explicitely taken into account in a DWBA analysis of the $^3\mathrm{He}(\alpha,\alpha)^3\mathrm{He}$ reaction. However, the calculations performed for the $^6\mathrm{He(p,t)}^4\mathrm{He}$ reaction with the exit potential obtained with this procedure did not allow to reproduce simultaneously the forward and backward angles of the experimental angular distribution. Secondly, we used the potential B obtained in ref. [9] which was fitted, within a simple optical model approach, on the complete differential cross-section of the $^3\mathrm{He}(\alpha,\alpha)^3\mathrm{He}$ elastic scattering at $E_{\mathrm{cm}} = 28.7\,\mathrm{MeV}$ [10]. This potential gave the best simultaneous description of both $\alpha + {}^3\mathrm{He}$ elastic scattering and $^6\mathrm{He(p,t)}^4\mathrm{He}$ reaction. The data are compared to the DWBA calculation in fig. 1. The dashed line corresponds to the DWBA calculation where only the 2n transfer is taken into account, with a spectroscopic amplitude equal to 1. The crosses correspond to the triton transfer with a spectroscopic amplitude equal to 0.25. The solid line corresponds to the coherent sum of both processes with these values of their spectroscopic amplitudes. From this analysis, the value of the spectroscopic factor extracted for the $\mathrm{t} + \mathrm{t}$ configuration is between 0.06 and 0.09, which is much less than predicted by shell model or microscopic three-body cluster model [11,12]. However, it is important to include it in order to reproduce simultaneously the forward and backward angles of the angular distribution. It should be noted that the present result does not include several effects that could modify this conclusion. For example the sequential transfer of 2 neutrons or of one proton and 2 neutrons (in the case of the triton transfer) was not considered and is presently under study. Also an attempt to include transfer from the continuum states in a full Coupled Reaction Channel calculation did not give satisfactory results in the present stage of the analysis. Finally the exit channel potential should be investigated more deeply, since it was shown to strongly influence the angular distribution. This will be the subject of a forthcoming publication [13].

References

1. M. Zhukov *et al.*, Phys. Rep. **231**, 151 (1993).
2. M.F. Werby *et al.*, Phys. Rev. C **8**, 106 (1973).
3. L. Bianchi *et al.*, Nucl. Instrum. Methods A **276**, 509 (1989).
4. Y. Blumenfeld *et al.*, Nucl. Instrum. Methods A **421**, 471 (1999).

5. R. Wolski *et al.*, Phys. Lett. B **467**, 8 (1999).
6. S.G. Cooper *et al.*, Nucl. Phys. A **677**, 187 (2000).
7. R.S. Mackintosh *et al.*, Phys. Rev. C **67**, 034607 (2003).
8. O.F. Nemets *et al.*, Yad. Fiz. **42**, 809 (1985).
9. K. Rusek *et al.*, Phys. Rev. C **64**, 044602 (2001).
10. P. Schwandt *et al.*, Phys. Lett. B **30**, 30 (1969).
11. Yu.F. Smirnov, Phys. Rev. C **15**, 84 (1977).
12. K. Arai *et al.*, Phys. Rev. C **59**, 1432 (1999).
13. L. Giot *et al.*, submitted to Phys. Rev. C.