Study on few-body aspects of nuclear reactions in the alpha-induced break-up of deuterons at low energy

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Introduction and Aim

A very powerful testing ground for studying few-body characteristics of nuclear reactions is expected to be the alpha-deuteron system [1,2] because of the very high binding energy of the alpha particle. In comparison to nucleon-deuteron sysem (N+(p+n)), alpha-deuteron system (α+(p+n)) is rather richer in the sense, for the later, several resonances like $^5He_{g.s.}$ and ^{5}Lig.s. are expected to reign over the allowed phase space if the kinematics is chosen so judiciously. At low energies, several quasi two-body processes like α-n, α-p, n-p final state interactions (FSIs) and quasi-free scatterings (QFSs) have the better chance to overlap with one another and in that case, it is the rigorous Faddev theory (FT) which is expected to be best suited to describe the experimentally measured spectra of three-body correlation cross-sections. However, the same (FT) is seen to deviate strikingly in describing a large amount of existing low energy d(α,αp)n data around 12 MeV. Two important points which are rather prominent in the existing fits [1] are the discrepancies involving reproduction of peak heights as well as peak positions. In some cases, the calculated spectra as a whole are seen to suffer a very large shift with respect to the experimental ones. This is also seen even for the angular combinations where neither α–p FSI nor QFS are present in the observed phase space. Strong n-p FSIs are also rather at safe distances from the α-n FSI regions for these cases. Our aim in the present work is to investigate on, especially, these spectra, in the light of single level R-matrix theory (RM), to find whether only α-n FSI could better reproduce the experimental distribution in the region of interest. It is also our aim to search for possible three-body force (3BF) effects [2], the very sensitive issue being investigated recently [3-5] with renewed interests.

Data Analysis and Discussions

We computed three-body correlation cross-sections as a function of arc length in the light of different models inherent in the single level R-matrix theory (RM), using R-matrix parameters as a = 2.9 fm, γ^2 = 6.9 MeV and E_0 = -4.3 MeV [2]. Next, we apply a simple form [2] of three-body interaction taking into consideration that three-body forces (3BF) are, in general, strongly angle dependent and that three-body interactions are likely to be favoured at low relative energies due to long time of escape from the nuclear interaction volume. We display a part of our work in the following figures [Figs 1-2] and summarize our observations as follows.

i) Taking into account characteristic angular dependence for scattering in the $P_{3/2}$ channel, so far as the shapes of the spectra are concerned, the R-matrix theoretical fits (R1 represented by dotted curves in Fig, 1a & b) are seen to be more or less comparable to the existing [1] Faddeev theoretical calculations (FT, shown by dashed curve and FT-NP: FT excluding NP FSI, shown by dashed-dotted curves in Fig. 1a &b]. Peak positions are also better reproduced.

ii) Assuming multiple processes, if any and thereby neglecting the angular dependence, the fits (R2 represented by solid curves in Fig 1 (a & b)) are seen to be rather better w.r.t. R1.

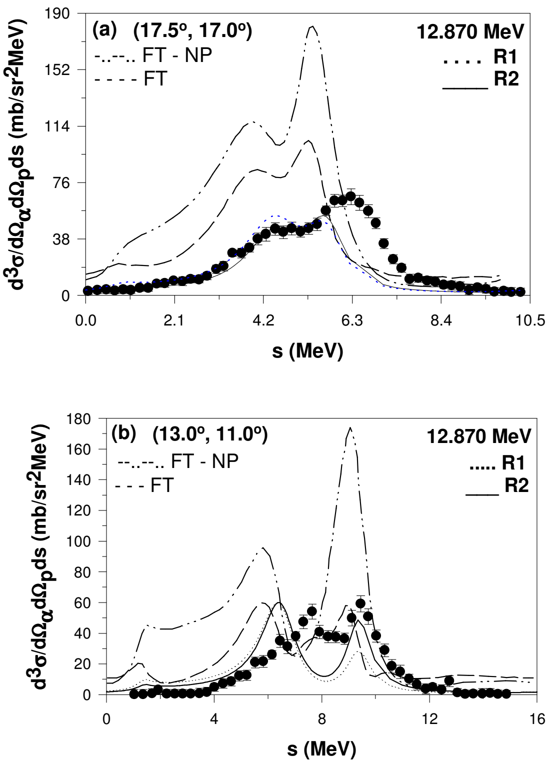

Fig. 1 Three-body correlation cross-section as a function of arc-length (S) for the reaction d(α, αp)n for incident energy and correlated pairs of angles as mentioned in the figures. R1 and R2: R-matrix theoretical calculations as mentioned in the text. FT: existing [1] Faddeev theoretical calculation and FT – NP: FT excluding np FSI.

iii) Inclusion of simple form of three-body interaction (3BF), over R2 (R2 + 3BF, shown by solid curves in Fig 2(a & b) improves largely the quality of fits.

Conclusion

Present work based on single level R-matrix theory, including a simple form of three-body interaction, though apparently provides somewhat better fits so far as the peak positions are concerned, it seems to be most important to analyze the data in the light of the recent sate-of-the-art Faddeev type calculation[6], including Coulomb interaction as well as 3BF effects, to understand the details of the reaction mechanism.

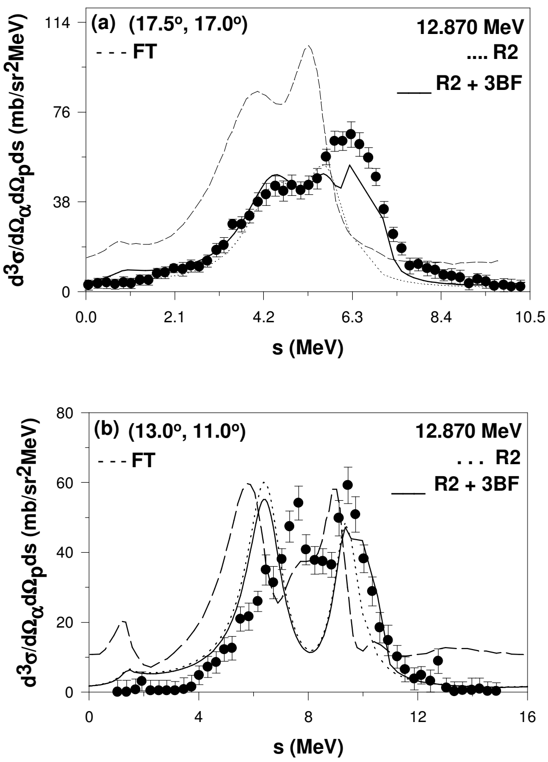

Fig. 2 Three-body correlation cross-section as a function of arc-length (S) for the reaction d(α, αp)n for incident energy and correlated pairs of angles as mentioned in the figures. R2: R-matrix theoretical calculation as mentioned in the text. R2 + 3BF: R2 + three-body force effect; FT: existing [1] Faddeev theoretical calculation.

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