An investigation on off-shell behavior of nuclear reaction in the alpha-induced break-up of deuterons at low energies

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Introduction and Aim

At low energies, α-particle could be treated as structureless boson due to its very high binding energy and thus alpha-deuteron system, next to nucleon-deuteron system, has been a very powerful testing ground in studying the few-body aspects [1-3, 7-8] of nuclear reactions. Although overall structure of the spectra of triple correlation cross-sections are best described by the rigorous Faddeev type calculations [1,3,5], there are cases of spectacular agreement as well as strong disagreement [5,6]. The aim of the present work is to investigate on the off-shell behavior of few-body nuclear reaction: α(d,αp)n as a function of incident energy by comparing the predictions from R-matrix as well as effective range theoretical calculations [2, 4] with the existing Faddeev type calculations (FT) [3]. For the purpose we choose the kinematic regions mainly governed by α-n FSI alone.

Data Analysis and Discussions

Three-body correlation cross-sections as a function of arc length were computed in the light of both single level R-matrix theory [2] and following effective range approximation [4] to FSI. The R-matrix parameters used are a=2.9fm, γ^2=6.9 MeV and E_0=-4.3 MeV corresponding to $P_{3/2}$ channel of α-n system. The effective range parameters used are those due to Arndt et al [4]. 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 fovoured at low relative energies due to long time of escape from the nuclear interaction volume, is also included to understand the detailed structure of the experimental distributions. We display a part of our work in the following figures (Figs 1a-1d) and summarize our observations as follows.

(i) R-matrix theoretical calculations, taking into account characteristic angular dependence in the $P_{3/2}$ channel (RM2, represented by solid curves in figs. 1a-1c), so far as the shapes of the spectra are concerned, reproduce the E_d=6 and 7 MeV experimentally observed distributions quite successfully. Large discrepancies between the existing Faddeev theoretical calculations [3] and the experimental data were found at these two energies. However, for E_d=8 MeV (Fig. 1c), fit due to RM2 is seen to be worse than the existing FT.

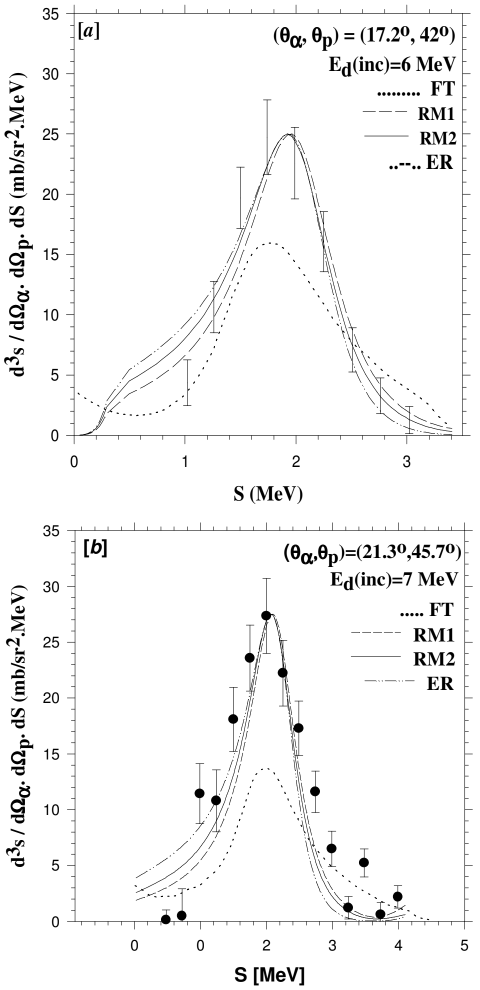
(ii) For all the incident energies studied, no significant improvement over RM2 was found by neglecting angular dependence and thereby assuming multiple processes, if any (RM1, shown by dashed curves in figs. 1a-1c).

(iii) Success or failure of effective range theoretical calculations (ER, shown by dashed-dotted curves in figs. 1a-1c) in reproducing the experimentally observed spectra seems to be more or less same as that due to RM.

(iv) Probable structure around the arc length (S) equal to 3.5 MeV in the E_d=8 MeV spectrum could not be understood by including a simple form [2] of three-body interaction (RM+3BF, shown by solid curve in fig. 1d).

Conclusion

Remarkably satisfactory fits to E_d=6 & 7 MeV experimental data, assuming two-body interaction only (RM & ER), while relatively worse (than FT) situation observed with



Figs. 1a-1b Three-body correlation cross-sections as a function of arc-length (S) for the reaction α (d, αp)n for incident energy and correlated pairs of angles as mentioned in the figures. RM1 and RM2: R-matrix theoretical calculations as mentioned in the text. ER: Effective range theoretical calculation; FT: existing [4] Faddeev theoretical calculation. Experimental data from Ref. [4].

increasing energy (E_d=8 MeV) seems to indicate increase in the off-shell contribution with increasing incident energy. Analysis based on the recent state-of-the-art three-body calculations [1], including Coulomb interaction as well as 3BF effects [7,8] would be interesting to understand the reaction mechanism over the whole energy range.

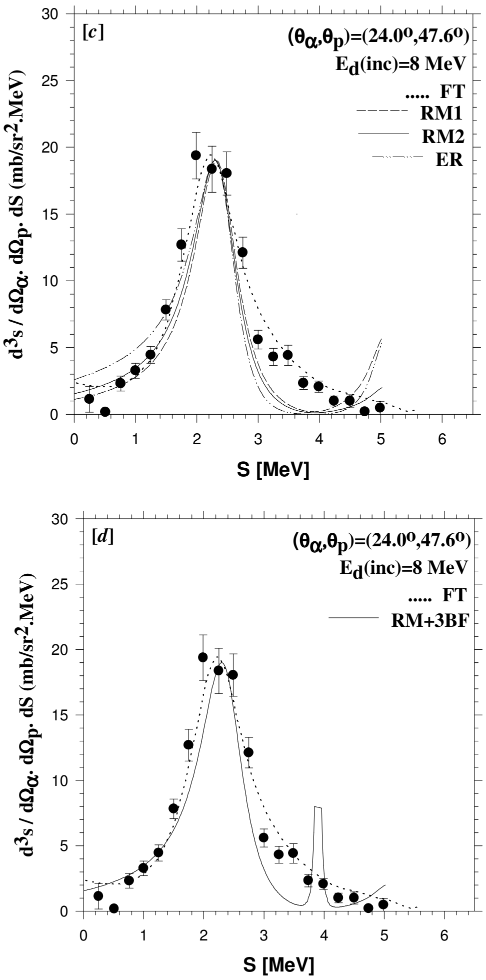


Fig. 2c. Fits are same as in Fig. 1a**. 2d:** RM + 3BF: RM2 + three-body force effect.

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