Study of few-body aspects of nuclear reactions in the break-up of deuterons by alpha-particles of 29.2 MeV

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Introduction & Aim

Alpha deuteron system, because of the very high binding energy of the alpha particle, is expected to be a very powerful testing ground in studying the off-shell behaviour involved in the underlying few-body nuclear reaction mechanism. Although overall nature of the spectra of triple correlation cross sections are best described by the rigorous Faddeev type calculations [1,2], there are cases of spectacular agreement as well as strong disagreement [2,3]. On the other hand, there are two-body calculations [4], like single level R-matrix theoretical ones, which could describe the cross-section data with different degrees of success but primarily they depend on the specially chosen kinematic regions in the allowed phase space. Two such specially chosen kinematic regions in the d(α, α p)n reaction are those due to formation of ^{5}He and ^{5}Li ground states which are manifested through the α-n and α-p final state interactions (FSI), respectively. Our aim in the present work is to understand the existing kinematically complete data [5] on the break-up of deuterons by alpha particles of 29.2 MeV, in the light of single level R-matrix theory, concentrating on the strongly favoured kinematic regions of αn FSI alone, where the existing fits [2] due to Faddeev type calculations seem to deviate significantly from the experimental distribution. Our aim is also to search for three-body force (3BF) effects [4,6,7,8] if there is any, by exploiting the kinematical configuration favouring the condition of collinearity.

Data Analysis and Discussions

We analyzed data for four correlated pairs of angles: $(\theta_\alpha, \theta_p) = (11^o, 45^o)$, $(16^o, 45^o)$, $(18^o, 45^o)$ and $(21^o, 45^o)$, all of which contain the strongly favoured kinematic regions of αn FSI. Collinearity condition is also satisfied, approximately, in addition to FSI, for the angle pairs $(21^o, 45^o)$ and $(18^o, 45^o)$, thus opening a path to search for three-body force effects [4, 6], rather directly. First, we analyze the data in the light of different models inherent in the single level R-matrix theory, using the R-matrix parameters as a = 2.9 fm, γ^2 = 6.9 MeV and E_0 = -4.3 MeV. Next, we apply a simple form [4] of three-body interaction taking into consideration that three-body forces 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 and summarize our observations as follows.

(i) Taking into account customary angular dependence for p-wave scattering, the R-matrix theoretical fits (R2, represented by dashed-dotted curves, in fig. a-c) are, in general not good; one of the FSI peaks (either at lower E_α or at higher E_α) in each of the distributions is highly, or, almost completely suppressed.

(ii) Assuming multiple processes, if any and thereby neglecting the angular dependence, the fits (R1 represented by dotted curves in fig. a-c) are indeed unable to provide satisfactory result. Here one of the FSI peaks is always over predicted.

(iii) Consideration of characteristic angular dependence for scattering in the $P_{3/2}$ channel, gives rise to much improved fit (R3, represented by solid curves in fig. a-c) w.r.t. those provided by R2; presenting in some cases, like that for $(18^o, 45^o)$, comparable or better

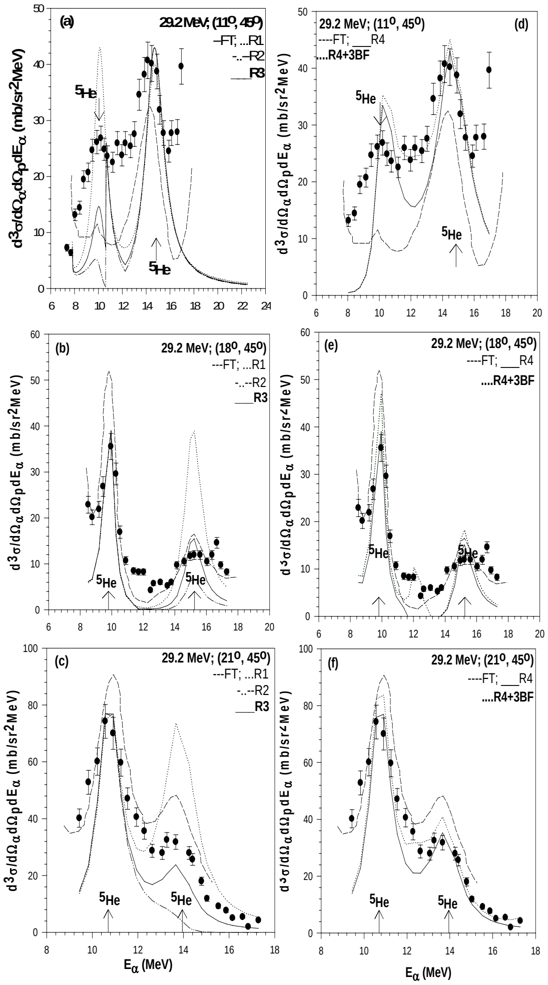

Fig.(a-f). Triple correlation cross-section as a function of scattered alpha-particle energy for the correlated pairs of angles as mentioned in the respective figure for the break-up of deuterons by alpha particles of 29.2 MeV. The symbols used for representing the theoretical curves are as mentioned in the text and the experimental data are from Ref.[5].

result with reference to existing Faddeev type calculations (FT, represented by dashed curves in the fig. a-f), so far as the relative peak heights are concerned.

(iv) Taking into account polarizations of the intermediate ^{5}He state, further improved fits (R4, represented by solid curves in fig. d-f) are achieved; valley region between two FSI peaks remain to be reproduced.

(v) Inclusion of simple form of three-body interaction (3BF) over R4, in general, yields further improved fits, at least, so far as the valley region is concerned. Prominent enhancement in the theoretical distribution is observed in the collinearity region at (18^{o}, 45^{o}).

(vi) When compared with the existing Faddeev type calculations (FT), the present analysis provides satisfactory results for some of the cases, so far as the reproduction of relative peak heights and data at valley regions are concerned.

Conclusion

From the present analysis, it is apparent that no single two-body interaction model adopted here is not at all sufficient to understand the overall structure of the data at the regions concerned. Off-shell effects seem to play significant role. It is also apparent that 3BF effects might be manifested in the region of collinearity. However, to understand the details of the reaction mechanism, it seems most important to analyze the data in the light of the recent state-of-the-art Faddeev type calculation [1], including Coulomb interaction as well as 3BF effects.

References

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