Few-body aspects in the kinematically complete cross sections of ^{4}He(d, pα) at E_d = 18 MeV

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Introduction and Aim

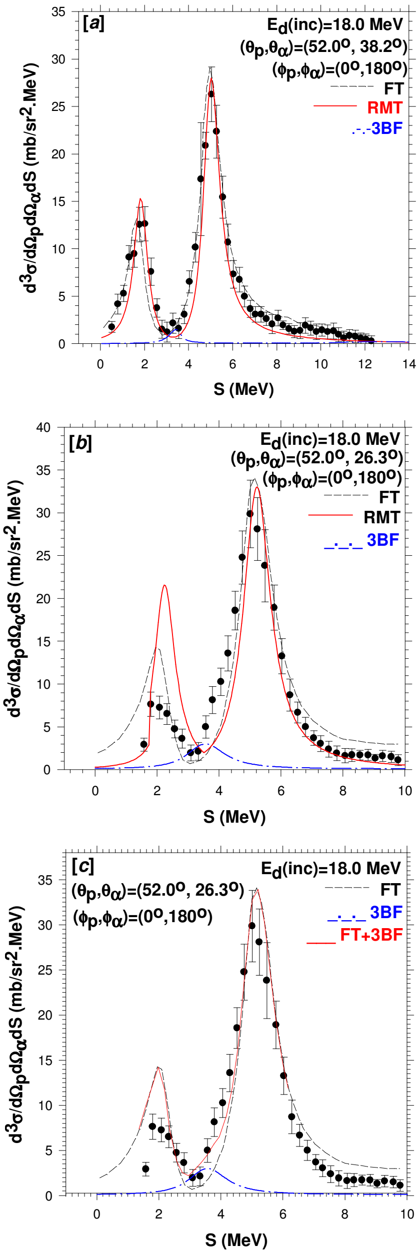
Alpha-deuteron system (next to N-d system,), due to very high binding energy of the alpha particle, presents itself as a very sensitive testing ground, for exploring the few-body characteristics of nuclear reactions [1-8]. From theoretical point of view, Faddeev type rigorous theoretical calculations (FT) are best suited for examining and explaining the experimental kinematically complete three-body correlation cross sections. However, there are cases of spectacular agreement as well as strong disagreement [4, 7] and thus calls for further investigation.. 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. One such specially chosen kinematic region in the d(α, α p)n reaction is that due to formation of ^{5}He ground state which is manifested through the α-n final state interactions (FSI). Present article is an attempt to better understand an existing set of kinematically complete experimental data [6] on the break-up of deuterons by alpha particles at E_d(inc)=18 MeV, at judiciously chosen correlated pairs of angles exhibiting sharp predominance of α-n FSI alone. There the existing fit to cross section data due to FT is found to remarkably deviate the experimental values, especially at the lower arc length region. Apart from analyzing the data in the light of single level R-matrix theory (RMT), it is also our aim to search for possible three-body force (3BF) effects [4], in the alpha-deuteron system,, the very sensitive issue being investigated recently [1-4] with renewed interests.

Data Analysis and Discussions

As the data sets under investigation are strongly dominated by the kinematically predicted α–n final state interaction (FSI) region, we first computed the three-body correlation cross sections in the light of single level R-matrix theory (RMT), following the procedure as described in Ref. [4]. The R-matrix parameters used are a=2.9 fm, γ^2= 6.9 MeV and E_0=-4.3 MeV corresponding to $P_{3/2}$ channel of α-n system. 3BF effect is then incorporated, based on a simple form [4] 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. The results of our calculations are displayed in the following figures (Figs 1a,b & c). We summarize our findings as follows.

(i) So far as the line shape of the spectrum is concerned, the fit due to RMT (represented by solid red line) at (θ_p, θ_α) = (52.0°,38.2°) (Fig. 1a) is reasonably satisfactory, and, found to provide better result, in comparison to that due to FT (dashed black line), in reproducing the right wing of the smaller peak (at lower arc length (S)).

(ii) The fit due to RMT (represented by solid red line in Fig. 1b) at (θ_p, θ_α) = (52.0°,26.3°) in reproducing shape of the larger peak (at higher arc length) is comparable to that due to FT.



Figs. 1a, b, c. Three-body correlation cross-sections as a function of arc length (s) for the reaction α(d, pα)n for incident energy and correlated pairs of angles as mentioned in the figures. RMT: R-matrix theoretical calculation; 3BF: three-body force contribution; FT: existing Faddeev type calculations [,6]. Experimental data are from ref [6].

It seems to remove the large discrepancy observed in FT in reproducing the left wing of the lower peak (at lower arc length region) but worsens the situation when relative peak heights and right wing of the smaller peak are considered.

(iii) 3BF contribution, as shown by dashed-dotted blue curves in fig. 1*a*, and 1*b* is found to be insignificant for the distribution at ($\theta_{p,}$ θ_α) = (52.0°,38.2°) (Fig. 1*a*), but it seems to be significant in the valley region between the two FSI peaks for the distribution at ($\theta_{p,}$ θ_α) = (52.0°,26.3°) (Fig. 1*b*).

(iv) Notable improvement in the reprodution of the experimental distribution is observed when 3BF contribution is incoherently added with the existing Faddeev theoretical fit (FT+3BF; shown by red solid line in Fig. 1*c*).

Conclusion

RMT, in conjunction with probable 3BF contribution, reasonably reproduces the shape of existing experimental distribution of cross section data, removing earlier observed discrepancies in some regions, leaving over/under prediction also in some other regions. however, it seems to be most important to analyse the data in the light of the recent state-of-the-art Faddeev type calculation [8], including Coulomb interaction as well as 3BF effects, for precise understanding of the problem

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