An investigation into three-body break-up of the alpha-deuteron system at low energies

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Introduction and Aim

Alpha-deuteron system, due to very high binding energy of the alpha particle, presents itself as a very sensitive testing ground, for studying the few-body characteristics of nuclear reactions. In comparison to nucleon-deuteron system (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 $^5Li_{g.s.}$ 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 Faddeev 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 significantly in describing a large amount of existing low energy d(α,αp)n data [1] with incident alpha energies in the range of 9.847 to 13.991 MeV. Two important points which are rather prominent in the existing fits are the discrepancies involving reproduction of relative heights of the peaks as well as the position of the same. In some cases, the calculated spectra as a whole seem to be shifted largely with respect to the experimental ones. This was also seen even for the angular combinations where neither α-p FSI nor QFS were present in the observed region of phase space. Strong n-p FSIs were also rather at safe distances from the α-n FSI regions for these cases. Our aim, in this note, is to investigate on, especially, these spectra to find whether only α-n FSI only could better reproduce the experimental distribution in the region of interest.

Analysis

We computed the three-body correlation cross-sections as a function of arc length using single level R-matrix theory [2,3]. 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. The results are presented by solid curves in the figures along with the existing Faddeev theoretical calculations with n-p FSI (dashed curves) and without n-p FSI (dotted curves) for comparisons.

Observations

Our observation could be summarized as below:

i) At E_α = 13.991 MeV, with (θ_α,θ_p) = (8°, 40°), the present calculation provides significantly better fit so far as the shape and positions of the peaks are concerned, including the more or less exact reproduction of the valley region between the two peaks.

ii) For the cases of (19°, 18.5°) and (19°, 20°) at E_α = 13.911 and 12.87 MeV respectively, no significant improvement is observed so far as the shapes of the spectra are concerned.

iii) At E_α = 12.87 MeV, with (θ_α, θ_p) = (19°, 35.7°), the present fit seems to be worse than the existing one with FT.

Conclusion

The present investigation based on our analysis seems not to run always in positive direction. Complicated interference mechanism among all the pair wise interactions seems to play important role. Most recent three-body calculations taking into proper account of the coulomb interactions and three-body force effects [2, 4, 5, 6] may provide better insight into the problem.

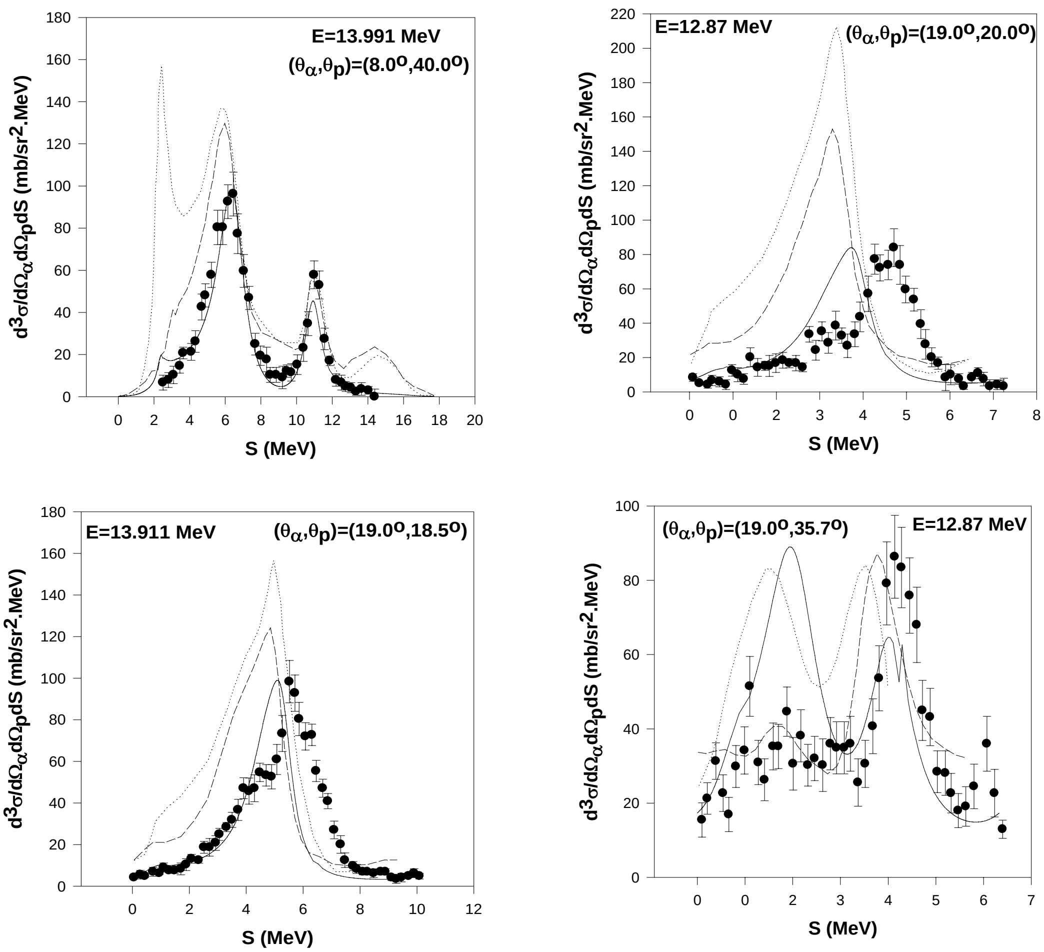

Figure: Three body correlation cross-section as a function of arc-length (S) for the reaction d(α,αp)n for incident energies and correlated pairs of angles as mentioned in the figures. The solid curve is the present calculation using R-matrix theory and dashed and dotted curves, respectively, are due to existing [1] Faddeev theoretical calculations with and without n-p FSI.

References

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