Few-body nuclear reactions at low energies – an investigation on observed anomalies

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Introduction and Aim

Few-body aspects of nuclear interaction [1-6] are expected to be best studied at sufficiently lower energies where various pair-wise interactions overlap effectively with one another in the allowed phase space in kinematically complete configuration. In this direction, next to nucleon-deuteron systems, a very powerful testing ground has been the alpha-deuteron system where the alpha particle could be treated as a structureless boson due to its very high binding energy. The aim of the present work is to examine the strong anomalies observed [4] in explaining the kinematically complete experimental observables in the light of Faddeev theoretical calculations (FT) due to Koike [4], involving alpha-induced break-up of deuterons at comparatively lower energies, ranging from E_α(inc)=11 to 18 MeV. Based, mainly, on single level R-matrix theory (RM) [3], we concentrate on two special kinematical situations where (*i*) both detectors were placed on the same side of the incoming beam and thus providing the Coulomb interaction a window to affect the differential cross section in the region close to zero α-p energy, in addition to α-n resonance as main contribution, (*ii*) kinematically predicted α-p resonance overlapped partially with the strong α-n resonance region; large discrepancies being reported [4] in both the cases.

Data Analysis and Discussions

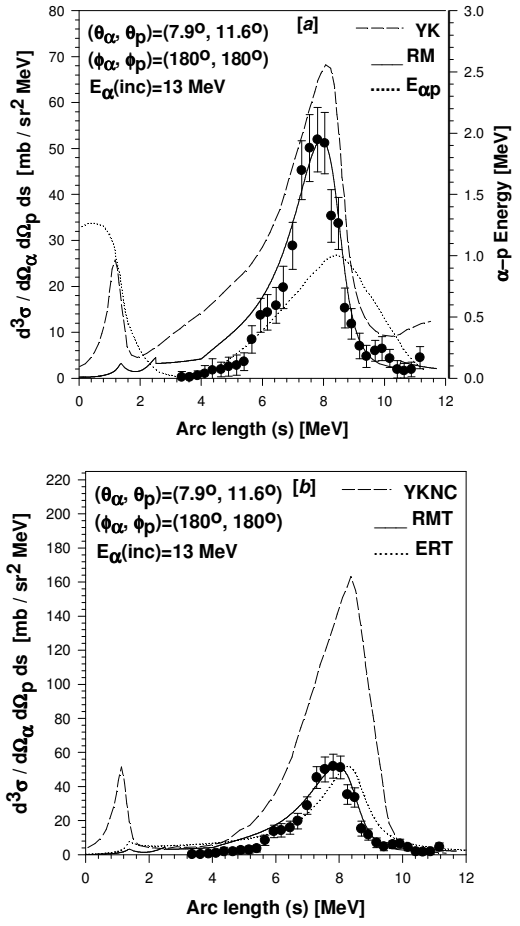
Based on single level R-matrix theory, three-body correlation cross sections were computed as a function of arc length and are displayed in figures 1a-1d. The R-matrix parameters used are a=2.9 fm, γ^2=6.9 MeV and E_0=-4.3 MeV corresponding to $P_{3/2}$ channel of α-n system. Effective range theoretical calculations were carried out for one correlated pair of angles (fig. 1b), the concerned parameters being used are those due to Arndt et al [5]. We summarize our observations as follows.

(i) The overall line shape of the experimentally observed distribution of three-body correlation cross sections at (θ_α, θ_p) = (7.9^o,11.6^o) with (φ_α,φ_p) = (180^o,180^o) and E_α(inc)=13 MeV [figs. 1a & 1b] is found to be remarkably better reproduced by the present R-matrix theoretical calculations (RM, shown by solid lines in figs 1a and 1b), in comparison to existing Faddeev type three-body calculations [4] due to Koike, both including and excluding Coulomb contribution (YK and YKNC, respectively, shown by dashed curves in figs. 1a & 1b). This is also found to be true in the region where α-p energy (shown by dotted line in fig. 1a) is close to zero.

(ii) In an aim to further improve the quality of fit in the above angular combination, calculations were also done involving three-body forces (3BF), based on a simple 3BF model as described in Ref [3]. However, inclusion of the same could bring no significant improvement in the result (not shown in the fig.).

(iii) Predictions from effective range theoretical calculations (ERT, shown by dotted line in fig. 1b) is found to be rather worse than that due to RM.

(iv) For the angular combinations (θ_α, θ_p) = (7.9^o,9.7^o) & (7.9^o,46.6^o), with E_α(inc)=13 & 15 MeV, respectively, calculations due to RM (solid lines in figs. 1c & 1d) could bring no notable improvement in the fits over those due to YK and YKNC (dashed & dotted lines, respectively).



Figs. 1a-1b: Three-body correlation cross sections as a function of arc-length (S) for the reaction d(α,αp)n at E_α(inc)=13 MeV and at the correlated pair of angles as mentioned in the figs. RM: R-matrix theoretical calculations. YK and YKNC: Existing Faddeev type theoretical calculations, including & excluding Coulomb contribution, respectively [4]. ERT: Effective range theoretical calculation. $E_{\alpha p}$: α-p relative energy. Experimental data from Ref. [4].

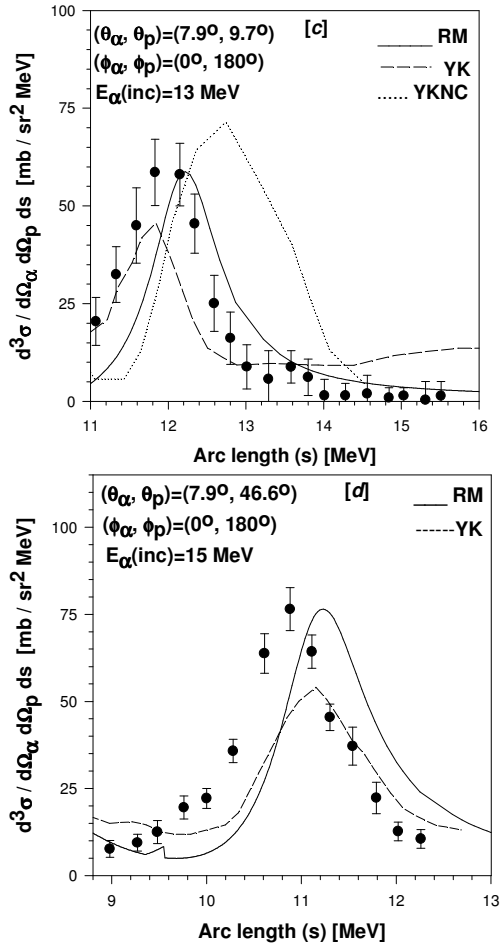


Fig. 1c-1d: Fits and experimental data: as described in Figs 1a-1b. Correlated pairs of angles as mentioned in the figs. Fig. 1c: E_α(inc)=13 MeV, Fig. 1d: E_α(inc)=15 MeV.

Conclusion

Going through details of the above results, it is apparent that interference among underlying pair-wise interactions remains to be adequately described by YK as well as YKNC.

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