Search for Three-body force contribution in the break-up of deuterons by protons

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Introduction and Aim

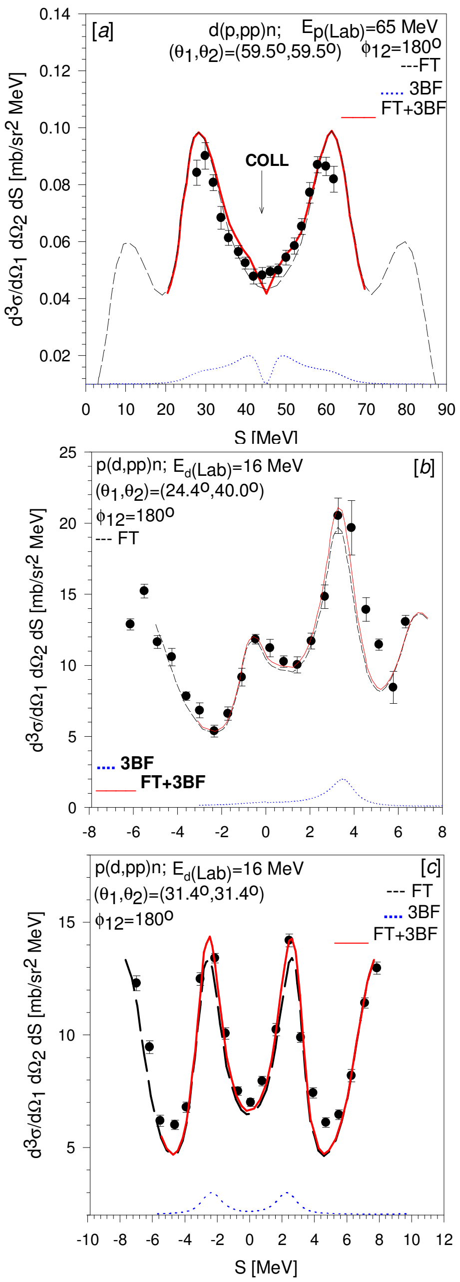
The existence and manifestation of three-body forces in few nucleon break-up experiments have been the topics of increasing interests since long ago. In this direction, the best testing table has been the nucleon-deuteron system, alpha-deuteron system being treated as the next candidate due to highly stable character of alpha particle [1-7]. With the advent of time, there have been a large collection of high precision experimental data along with highly rich different theoretical approaches like those based on Faddeev theoretical calculations. Though the overall agreement between theory and experiment is rather good, there exist certain notable discrepancies, especially at and around the collinear region in the kinematically allowed phase space, where three-body force (3BF) effects are expected to be manifested [4,7,8] quite favourably. The existing discrepancies around the collinear region point to the necessity of including new ingredient like 3BF in addition to the standard two-body inputs in the 3N calculation. The present article aims at searching the possible contribution of 3BF effects in the realization of the existing discrepancies [4-6] in the experimental distribution of three-body correlation cross sections in the proton induced break-up of deuterons at two incident energies and three chosen correlated pairs of angles.

Data Analysis and Discussions

Based on the idea that three-body forces (3BF) are, in general, strongly angle dependent and that the interaction is likely to be favoured at low relative energies due to long time of escape from the nuclear interaction volume, a simple form of 3BF calculation [7,8] which provided fairly good result for both the alpha-deuteron and nucleon deuteron systems, is also applied in the present case. Concentrating on sharp collinear region, we exploited data from the existing literature [4.5], at incident proton energies, $E_{p(lab)}$ = 65 MeV and correlated pair of angles as (θ_1, θ_2) = $(59.50^o, 59.5^o)$. Patial fulfillment of collinearty condition occurs for the data [4,6] at $E_{d(lab)}$ = 16 MeV, with correlated pairs of angles $(24.4.0^o, 40.0^o)$, and $(31.4^o, 31.4^o)$. Results of our calculations are displayed in figures 1*a*, *b* and *c*, where in each figure black dashed curve corresponds to existing [4] Faddeev type calculations (without 3BF), dotted blue curve corresponds to present 3BF calculation (in arbitrary unit), while the solid red curve represents the incoherent summation of 3BF with FT [4]. Point on the S-axis satisfying collinear condition in fig 1(a) is indicated by an arrow mark. Our observations are summarized as given below.

(i) In both the conditions: satisfying strict collinearity codition (Fig 1(a)) and meeting partial fulfillment of collinearity (Figs 1(b) and (c)), 3BF effect (blue dotted curves) seem to manifest itself leading to better reproduction (solid red curves; FT+3BF in the figures) of the shape of the experimental distribution of the three-body correlation cross sections.

(ii) At Ep=65 MeV (Fig 1(a)), the existing discrepancy between the theory and experimental distribution is found to be significantly reduced when 3BF contribution is taken care of with the existing fit (FT+3BF, red solid curve), the left wing of the right peak of the distribution is found



Figs. 1a, b, c. Three-body correlation cross-sections as a function of arc length (S) for the reactions, incident energies and correlated pairs of angles as mentioned in the figures. FT: existing Faddeev type calculations 3BF: three-body force contribution. Experimental data and theoretical FT data are as mentioned in the text.

to be fitted most, in comparison to valley region and the left peak; other regions remaining unaltered and coincide with the existing fit (FT represented by black dashed curve). This points towards the fact that the effective change is just close to the strict collinear region,.

(iii) At lower incident energy, $E_{d(Lab)}$ = 16 MeV, with (θ_1, θ_2) = (24.4°, 40.0°) and (31.4°, 31.4°), corresponding to partial fulfillment of collinear condition, 3BF effects seem to spread-up over a large region in the allowed phase space (especially, at (31.4°, 31.4°)). Here also, manifestation and extent of 3BF contribution seem to play significant role in better reproducton (FT+3BF, red solid curve fig 1(b) and (c).) of the experimental distribution.

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Conclusion

The present investigation, supplemented with the existing Faddeev type calculations (without 3BF), points toward incorporation of 3BF contributions, rather significantly, for better understanding of the experimental data, at both the higher and lower incident energies and the collinearity conditions considered. However, analyzing the data in the light of the recent state-of-the-art Faddeev type calculations [1, 9], including Coulomb interaction as well as 3BF effects, is likely to be most important for precise understanding of the problem.

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