Finite Range-DWIA Analysis of 300 MeV ^{40}Ca(p, 2p)^{39}K Reaction

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It has been known for decades that (p, 2p) reactions in the knockout energy regime (E_i=100 to 800 MeV) can provide information about the proton spectroscopic factor in various target nuclei [1-5]. One has not been able to obtain this information in an unambiguous manner. Similar to the (α,2α) anomalies, the reduced prediction of (p, 2p) reaction cross section was challenging and attempts were made in the finite-range (FR)-DWIA formalisms to fit the cross sections using parameters like bound radius and separation energy [6]. The anomaly in the case of (α,2α) reaction is finally settled by incorporating the finite-range effects in the α-α interaction [7] using repulsive core and globally attractive α-α potential at the α-α knockout vertex. A similar anomaly is presented in the FR-DWIA (p, 2p) reaction due to an improper treatment of the p-p knockout vertex in terms of the unrealistic, parameterized Love- Franey N-N interaction [8-9].

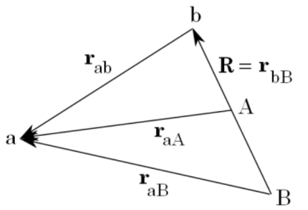

Fig.1: Vector diagram of kinematics for the knockout reaction ^{40}Ca(p, 2p)^{39}K shown as A(a, ab)B.

In the present work we incorporate the nucleon-nucleon (N-N) t-matrix [10] effective interaction derived from the Reid soft-core N-N interaction potential [11] for T=1. This formalism has *no free parameters* and the results are realistic and accurate. The vector schematic of (p, 2p) knockout kinematics is shown in Fig.1. The proper p-p t-matrix effective interaction, t(r) is required for performing the advanced calculations and for that we evaluated the p-p t-matrix of $^1P_1$, $^3S_1$, $^3D_2$, $^3D_1$, $^1S_0$, $^1D_2$, $^3P_0$, $^3P_1$, $^3P_2$ and $^3F_2$ states. Among these some have very small and some do not contribute but the largest contribution of effective interaction is obtained by $^3F_2$ which is employed in this study. From this analysis it is observed that the contribution of $^3F_2$ is not the only contribution and there must be an effective contribution beyond the $^3F_2$ due to terms like $^3D_3$, $^3G_3$, $^3F_3$, $^3F_4$, $^3H_4$ and $^1F_3$ [12]. The available literature does not describe the effect of these terms and we will incorporate these to explore the realistic situation for this (p,2p) study by using Urbana V-14 [12], and, Argonne V-14 potentials [13]. The largest contribution of t-matrix of $^3F_2$ state is represented in Fig.2.

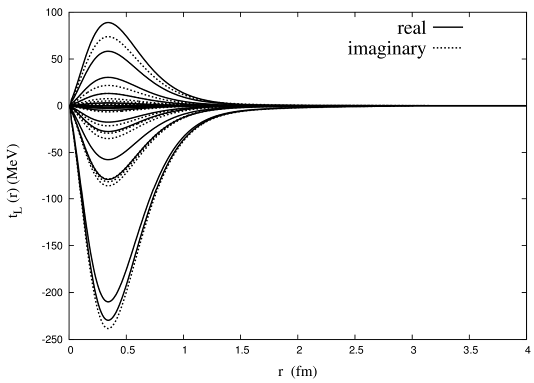

Fig.2: The t-matrix effective interaction at 300 MeV for $^3F_2$ state derived from the Reid soft-core N-N interaction potential for T=1.

The overlap functions with respect to separation ‘r’ between p-p and ‘R’ between p-^{39}K (Fig.1) is observed to be tapering down to zero at large separations which are desired. The overlap integrals bring out the required saturation characteristics of these integrals as functions of these separations. The overlap integral with respect to separation r between p-p, has shown in Fig.3.

We have used the Dirac equation based optical potentials [14] for deriving the distorted wave cross section in (p, 2p) reaction for ^{40}Ca. The obtained results are realistic and free from parameters like enhanced bound radius parameter or by equivalently reducing the separation energy as used in [6].

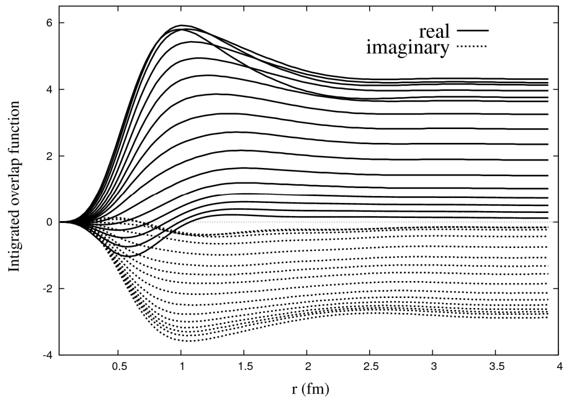

Fig.3: The overlap integral as a function of separation r between p-p.

Results of normalized finite-range theoretical and experimental cross sections for $2S_{1/2}$ state of ^{40}Ca nucleus are compared in Fig.4 for distorted wave (DW) and plain wave (PW). With this analysis the observed spectroscopic factor is of the order of 2 which is reasonable and good agreement with the $2S_{1/2}$ state of ^{40}Ca.

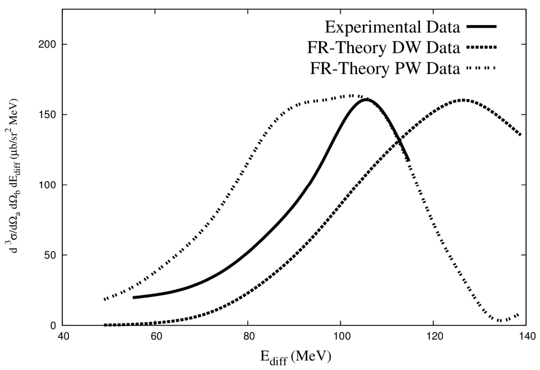

Fig.4: Shape comparison with experimental data [1] and FR-DWIA theory for ^{40}Ca(p, 2p)^{39}K reaction at 300 MeV and $(\theta_a = 30^0, \theta_b = 55^0)$ for the $2S_{1/2}$ state.

In conclusion, we have analyzed the data of ^{40}Ca(p, 2p)^{39}K reaction at 300 MeV by using the formalism based on finite-range effective p-p t-matrix interaction. Our results are satisfactory and more accurate in comparison to earlier attempts in the literature. Here we have observed that the largest contribution is by partial wave $^3F_2$ which is used. We recommend to incorporate higher partial waves $^3D_3$, $^3G_3$, $^3F_3$, $^3F_4$, $^3H_4$ and $^1F_3$ for a better FR-DWIA description.

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