Finite Range-DWIA Study of 140 MeV $^6Li(\alpha, \alpha p)^5He$ Reaction.

Arun K Jain* and B. N. Joshi

Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA

The energy sharing spectra for the 140 MeV $^6Li(\alpha, \alpha p)^5He$ reaction [1] show a pronounced asymmetry about the p_3=0 point. A Zero Range (ZR) distorted wave impulse approximation (DWIA) study could ascribe part of this asymmetry due to the product of the kinematic factor and free α-p scattering cross section. However, only the (θ_α=12.5^o. θ_p=-55.2^o) data could be explained in terms of the ZR-DWIA. The remaining two angle pairs (θ_α=12^o, θ_p=-47.5^o) and (θ_α=12.5^o, θ_p=-27^o) data had pronounced more asymmetry which could not be accounted by the ZR-DWIA treatment. Most of the ZR-DWIA anomalies could be resolved by a proper Finite Range(FR)-DWIA treatment in the past. Therefore we have analyzed the available 3-spectra on the 140 MeV $^6Li(\alpha, \alpha p)^5He$ reaction in the FR-DWIA formalism.

In the FR-DWIA formalism the triple differential cross section, $\dfrac{d^3\sigma}{d\Omega_1 d\Omega_2 dE_1}$ of the energy sharing distribution for a knockout reaction $A(\alpha_o, \alpha p)B$ is expressed in terms of a kinematic factor and the absolute square of the Finite Range transition amplitude T_{FR}:-

$$T^{L\wedge}_{FR} = \int \chi_1^{(-)*}(\vec{k}_{\alpha B}, \vec{r}_{\alpha B}) \chi_2^{(-)*}(\vec{k}_{pB}, \vec{r}_{pB})$$
$$t_{\alpha p}(\vec{r}) \chi_0^{(+)}(\vec{k}_{\alpha A}, \vec{r}_{\alpha A}) \varphi_{L\wedge}(\vec{r}_{pB}) d\vec{r}_{\alpha B} d\vec{r}_{pB}$$

with self explanatory coordinate convention and the finite range α-p t-matrix effective interaction, $t_{\alpha p}(\vec{r}_{\alpha p})$ given by,

$$t^+_{\alpha p}(E, \vec{r}_{\alpha p}) = e^{i\vec{k}_{\alpha p}\cdot\vec{r}_{\alpha p}} V(\vec{r}_{\alpha p}) \psi^{(+)}_{\alpha p}(\vec{r}_{\alpha p}) \quad (1)$$

we evaluate the FR-DWIA results using s and p state $\varphi_{L=0}$ and $\varphi_{L=1,\wedge}$ bound wave function in a r_0=1.45 fm and a=0.65 fm Woods-Saxon bound potential[2] for the $2s_{1/2}$ and $1p_{3/2}$ proton state bound with unbound ^5He in the corresponding residual state.

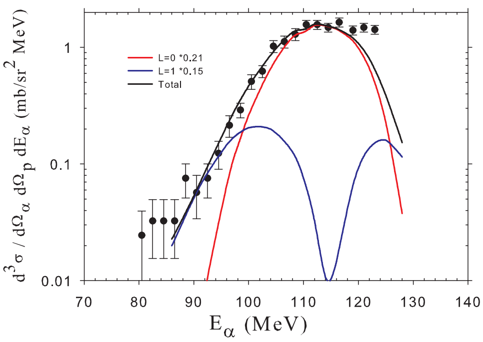

FIG. 1: 140 MeV $^6Li(\alpha, \alpha p)^5He$ reaction at θ_α/θ_p =10.0^o / =-55.2^o. Red curves are the results for ℓ=0 knockout and blue curve for the ℓ=1 with the correspoding multipliers indicating the respective spectroscopic factors. Black curve is the sum of the red and blue curves.

For generating the various proton wavefunctions we have used no spin oribit interaction. For the unbound ^5He in the final state we assumed it to be a bound state. The will dept parameters for both the $2s_{1/2}$ and $2p_{3/2}$ states we have generalized them autometically to satisfy the binding energy of p+$^5He \rightarrow {}^6Li$ (4.59 MeV the experimental value). The incident and outgoing scattering state wave functions were generated using the 166 MeV α-^6Li pots of [3] and [4] and 35 MeV p-^6Li potential of Bray *et al*[5]. For the α-p vertex generation we have used 135 MeV α-p optical potential of Thompson *et al* [6].

Using all through attractive α-p potentials of Thompson we find that the ℓ=0 and ℓ=1 bound p-^5He wave function generates

*Electronic address: arunjain@barc.gov.in

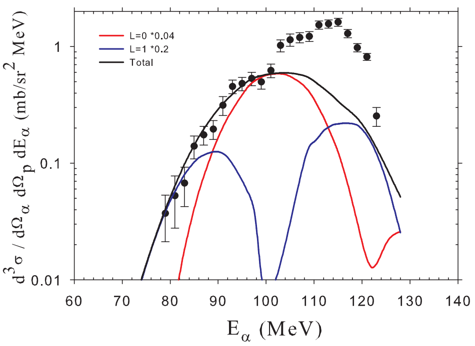

FIG. 2: 140 MeV $^6Li(\alpha,\alpha p)^5He$ reaction at θ_α/θ_p =12.0^o / =-47.5^o. Red curves are the results for ℓ=0 knockout and blue curve for the ℓ=1 with the correspoding multipliers indicating the respective spectroscopic factors. Black curve is the sum of the red and blue curves.

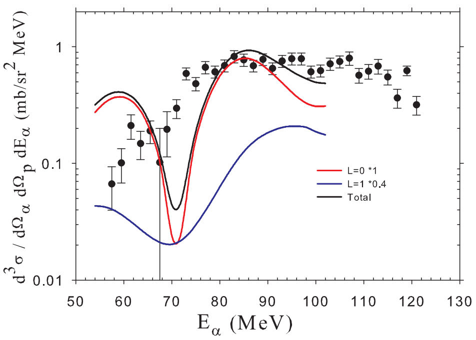

FIG. 3: 140 MeV $^6Li(\alpha,\alpha p)^5He$ reaction at θ_α/θ_p =12.5^o / =-27.0^o. Red curves are the results for ℓ=0 knockout and blue curve for the ℓ=1 with the correspoding multipliers indicating the respective spectroscopic factors. Black curve is the sum of the red and blue curves.

cross section values which are almost hundred time larger than the observed values. This could arise from repulsion caused by the antisymmetrization of the α-p scattering and bound wavefunctions. In order to take care of this factor we have removed the ℓ=0 contribution from the α-p t-matrix. This ℓ=0 removal leads to a reduction factor of about 10 in the absolute cross section values. Besides this ℓ=0 removal we have also included the antisymmetrization effect of α-nucleon (belonging to the residual nucleus in the final state) wavefunction by including enhanced repulsion and enhanced absorption for $E_{\alpha-residualnucleus}$ oprical potentials[7] . These enhanced α-residual nucleus oprical potentials are having very large reduction in $(\alpha,\alpha p)$ cross sections. The final results are presented in the Figures 1, 2 and 3 and seem to give a reasonable description of the data.

It is therefore to conclude that the fit to the $^6Li(\alpha,\alpha p)^5He$ Reaction data requires not only the finite range effects of the knockout vertex but also requires many of the Pauli exclusion principle/antisymmetrization effects of the various nucleon exchanges which are normally considered to neglected or are supposed to be taken care of by the phenomenological optical potentials.

References

[1] A. Nadasan *et al*, PRC. **19**, 2099 (1979).
[2] L. R. B. Elton and A. Swift Nucl. Phys. **94**, 52 (1967).
[3] D. Bachelier *et al*, Nucl. Phys. **A195**, 361 (1972).
[4] R. M. DeVries *et al*, Nucl. Phys. **A178**, 424 (1972).
[5] K. H. Bray *et al*, Nucl. Phys. **A189**, 35 (1972).
[6] G. Thompson *et al*, Nucl. Phys. **A142**, 576 (1970).
[7] B. N. Joshi *et al*, Prog. Theor. Exp. Phys. Lett. **2016**, 121D01 (2016).