ON THE THREE-PARTICLE INTERMEDIATE STATE CONTRIBUTIONS IN HEAVY-ION ONE-NUCLEON TRANSFER REACTIONS.

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One-nucleon transfer reactions are studied from the viewpoint of the reaction mechanism and the main theoretical relations are introduced to compute the three-particle intermediate state contributions in F.S.D. M. and the differences with D.W.B.A.

Consider the transfer reaction $b+(a+c) \rightarrow a+(b+c)$ where b and $A = a+c$ are the initial-channel particles, a and $B = b+c$ are the final-channel particles and c represents the transferred nucleons.

The experimental existence of such a phenomenon in heavy-ion interaction was known by the identification of Reynolds et al. (1). Since the nuclear scattering phenomena should not be relevant in tunnelling, this low energy process has been used in various basic problems and in particular as test for current theories of reaction mechanisms. Using approximations of the exact matrix element (2), the D.W.B.A. explains the angular distributions as well as the total cross-section behaviour on single-nucleon transfer reactions. Of course one hopes to explain the nature of the transfer mechanism in D.W.B.A. using the phenomenological approach of Feynman diagram summation method. Summing four Feynman graphs (3) with a pole mechanism, oneobtains that $T_{M.S.D.(pole)} \cong T_{D.W.B.A.}$ in which the approximation is equivalent to neglect the three-particle intermediate state contributions that appear in the M.S.D. matrix element. Otherwise, considering the new M.S.D. matrix element, connecting the sum of eight diagrams with pole and triangle-mechanisms respectively, one has that (4) $T_{M.S.D.(pole+triangle)} \cong T_{D.W.B.A.}$ if the Coulomb (A-b) and (B-a) optical potentials are assumed to hold between the core-core potentials.

In order to test the D.W.B.A., the threshold effects must be described in rigorous detail and other treatments appeared in literature with deviations by very large factors (5). Expanding into partial waves (6), one has that : $T_{M.S.D.(pole)} = \sum_l (2l+1) I_l(p_i, p_f) P_l(\hat{p}_i \cdot \hat{p}_f)$, where

$$I_l(p_i, p_f) = -\frac{\exp i(\sigma_l + \sigma'_l)}{2\pi \eta_i p_i p_f} \left[\frac{\eta_i \eta_f}{[\exp(2\pi\eta_f) - 1]\,[\exp(2\pi\eta_i) - 1]} \right]^{1/2}.$$

(1) L. H. Reynolds, D.W. Zucker, Proc. Natl. Acad. Sci., 39, (1953), 975.
(2) K. R. Greider et al. Phys. Rev., 146, (1966), 675; Adv. Theor. Phys., N. Y. (1965), 245; V. Vanzani, Lett. Nuovo Cim. 11, (1969), 706; L. D. Faddeev, Sov. Phys. YETP 12, (1961), 1014; C. Lovelace, Phys. Rev. 135B, (1964), 1225.
(3) L. D. Blokhintsev, EI. Dolinskii et al. Nucl. Phys. 40, (1963), 117.

$$\lim_{\gamma\to 0^+}\int_0^\infty dk\, Q_1(p_i,k)R_1(p_f,k) = Z(p_i,p_f)\lim_{\gamma\to 0^+} D_1(p_i,p_f,\gamma)$$

$$Q_1(p_i,k) = \mathrm{Im}\,(\exp(-i\delta_1')(ck+p_i+i\sigma_B)^{i\eta_i}(ck-p_i+i\sigma_B)^{-i\eta_i}\, F(-1,1+1,1-i\eta_i;-(ck-p_i)^2+\sigma_B^2)/4cp_ik)$$

$$R_1(p_f,k) = \mathrm{Im}\,(\exp(-i\delta_1)(k+p_f)^{i\eta_f-1}\, F(-1,1+1,1-i\eta_f;-(k-p_f)^2/4p_fk)\,(k-p_f+i\gamma)^{-i\eta_f-1}$$

Regularizing in $x=1$ $(x=k/p_f)$, one has that:

$I_1(p_i,p_f) = Z(p_i,p_f)+C_1(p_i,p_f)+E_1(p_i,p_f)+H_1(p_i,p_f)$, that have thefollowing expressions in the under-threshold and over-threshold cases respectively:

$$C_1(p_i,p_f) = \exp(\pi\eta_f)\int_0^1 dx\,(1-x)^{-1}\left[\varphi_1(\eta_f,x)R_1(\eta_i,\lambda,x) - \bar\varphi_1(\eta_i,x)\, R_1(\eta_i,\lambda,1)\right]$$

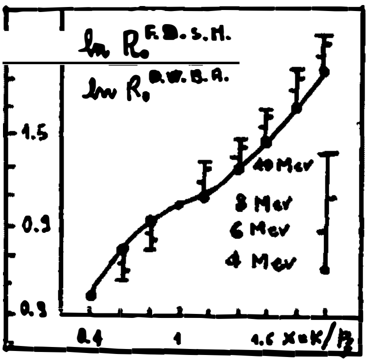
and

$$C_1(p_i,p_f) = \exp(\pi\eta_f)\int_0^{x_0} dx\,(1-x)^{-1}\left[\varphi_1(\eta_f,x)\, R_1(\eta_i,\tau,x) - \bar\varphi_1(\eta_f,x)R_1(\eta_i,\tau,1)\right].$$

$$E_1(p_i,p_f) = \int_1^2 dx\,(1-x)^{-1}\left[\varphi_1(\eta_f,x)R_1(\eta_i,\lambda,x) - \bar\varphi_1(\eta_f,x)R_1(\eta_i,\lambda,1)\right]$$

and the same expression for the over-threshold case.

$$H_1(p_i,p_f) = -\int_0^{1/2} dx\,(1-x)^{-1}\left[\varphi_1(\eta_f,x)R_1(\eta_i,\lambda,1/x)\right] + (1/\eta_f)\cos(\delta_1-\eta_f\ln 2)\,(1-\exp(\pi\eta_f))$$



with the addition of

$$\int_{x_0}^1 dx\,(1-x)^{-1}\left[\varphi_1(\eta_f,x)R_1(\eta_i,\lambda,x) - \bar\varphi_1(\eta_f,x)\, R_1(\eta_i,\lambda,1)\right]$$

in the over-threshold case.

$$\varphi_1(\eta_f,x) = (2\eta_f/(x+1))\sum_{0}^{l}{}_n \frac{(l+n)!}{(l-n)!\,n!}\prod_{m=0}^{n}(m^2+\eta_f^2)^{-1/2}\left[\frac{(x-1)^2}{4x}\right]^n \mathrm{sen}\,(\delta_l-\delta_m+\eta_f\ln(|x-1|/2(x+1)))$$

$$\bar\varphi_1(\eta_f,x) = \mathrm{sen}(\delta_1'+\eta_f\ln(|x-1|/2))$$

$$R_1(\eta_i,\lambda,x) = -\eta_i\exp(\eta_i\,\mathrm{arctg}(2\omega\lambda/(x^2-\lambda^2+\omega^2))\sum_{0}^{l}{}_r\frac{(l+r)!}{(l-r)!\,r!}\prod_{s=0}^{r}(s^2+\eta_i^2)^{-1/2}\left[\frac{(x-\lambda)^2+\omega^2}{4\lambda x}\right]^r \mathrm{sen}\,(\delta_l'-\delta_r'-\frac{\eta_i}{2}\ln(((x+\lambda)^2+\omega^2)/((x-\lambda)^2+\omega^2))).$$

$\lambda = p_i/cp_f$; $\omega^2 = (\chi_B^2+b(k^2-p_f^2)/c^2p_f^2$ and $x_0 = (1-(1/b)(\chi_B/p_f)^2)^{1/2}$; $\tau = (b/c^3)(1-(1/b)(\chi_B/p_f)^2-x^2)$, $\chi_B = 2\mu_{bc}/\varepsilon_B$.

The theoretical analysis is now able for a complete numerical computation of the differences between F.S.D.M. and D.W.B.A. The intermediate state contributions are only contained in $R_1(\eta_i,\lambda,x)$ that, in a preliminar analysis, has been computed by us for both the mechanisms.

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(6) E. I. Dolinskii, A.M.Mukhamedzhanov, Sov.Journ.Nucl.Phys.3, (1966), 180.

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