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A Study on the Existence of T_L and T_P Tensor Potentials in Elastic Scattering of Polarized Deuterons

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Earlier, the following three types have been proposed as tensor interactions between deuterons and 0^+ targets[1].

$$T_R = [\,\mathbf{s}\times\mathbf{s}\,]^{(2)}\cdot[\,\mathbf{R}\times\mathbf{R}\,]^{(2)},$$
$$T_L = [\,\mathbf{s}\times\mathbf{s}\,]^{(2)}\cdot[\,\mathbf{L}\times\mathbf{L}\,]^{(2)}, \qquad (1)$$
$$T_P = [\,\mathbf{s}\times\mathbf{s}\,]^{(2)}\cdot[\,\mathbf{P}\times\mathbf{P}\,]^{(2)}.$$

The T_R type potential can be derived by folding models which include the D-state in the deuteron ground-state wave function and has been used in analyses of polarization observables, for example tensor analyzing powers, in scattering of deuterons. Other two types of tensor interactions have been discussed[2] but their existences are not clear. In this note, we will investigate possible effects of T_L and T_P interactions by the invariant-amplitude method[3] and optical model calculations, and discuss how to examine them experimentally.

Define the scattering matrix M for deuteron elastic scattering from spin 0 targets.

$$M = \begin{pmatrix} A & B & C \\ D & E & -D \\ C & -B & A \end{pmatrix}. \qquad (2)$$

By the consideration based on the invariant-amplitude method, the following combinations of the above matrix elements turn out to be good descriptions of the effects of individual spin-dependent interactions[4].

$$U = \frac{1}{\sqrt{3}}(\,2A + E\,),$$
$$T_1 = \frac{1}{\sqrt{3}}[\,2\sqrt{2}\,C + (\,B + D\,)\cot\theta\,], \qquad (3)$$
$$T_2 = \frac{-1}{\sqrt{3}}(\,B + D\,)/\sin\theta,$$

where U, the scalar amplitude, describes effects of the central interaction and T_1 and T_2, the tensor amplitudes, describe those of the tensor interactions in their first order.

To grasp the essence of effects of T_R, T_L and T_P on T_1 and T_2, we will treat these interactions by the first-order perturbation theory, the results of which are

$$T_1 = a^{(R)} + a_0^{(L)}\cos\theta + a_2^{(L)}(3+2\cos\theta) + a^{(P)}\cos\theta$$
$$T_2 = a^{(R)} - a_0^{(L)} + a_2^{(L)} - a^{(P)}, \qquad (4)$$

where $a^{(R)}$, $a_0^{(L)}$ and $a_2^{(L)}$ and $a^{(P)}$ are the amplitudes which correspond to T_R, T_L and T_P, respectively, and are functions of the absolute magnitude of momentum transfer, θ being the scattering angle. Eqs.(4) show that T_1 is not equal to T_2, except for $\theta = 180°$, when at least one of the T_L and T_P interactions exists. Thus the difference between T_1 and T_2 will be a key to recognize the existence of such interactions.

Since T_1 and T_2 contribute to polarization observables remarkably through $T_1{*}U$ and $T_2{*}U$, we will examine $T_1{*}U$ and $T_2{*}U$ more quantitatively. Figs. 1 and 2 show $T_1{*}U/\sigma$ and $T_2{*}U/\sigma$ calculated by optical models where a reasonable set of parameters is assumed for potentials. In the figures, it is clear that both of T_L and T_P affect $T_1{*}U$ and $T_2{*}U$ considerably and, in particular, the T_L type potential makes bigger differences between $T_1{*}U$ and $T_2{*}U$ than T_P type one.

Finally, we will show the relation of $T_1{*}U$ and $T_2{*}U$ to observable quantities in the following.

$$\mathrm{Im}(T_1{}^*U)/\sigma = 2K^{22}_{10} + \frac{1}{\sqrt{2}}(K^{22}_{11} + K^{11}_{22})\cot\theta - \frac{1}{\sqrt{2}}(K^{22}_{1-1} + K^{1-1}_{22})\cot\theta, \quad (5)$$

$$\mathrm{Im}(T_2{}^*U)/\sigma = -\frac{1}{\sqrt{2}}(K^{22}_{11} + K^{11}_{22})/\sin\theta - \frac{1}{3\sqrt{2}}(K^{22}_{1-1} + K^{1-1}_{22})/\sin\theta, \quad (6)$$

$$\begin{aligned}\mathrm{Re}(T_1{}^*U)/\sigma = {} & \frac{\sqrt{2}}{9} + \frac{\sqrt{2}}{3}\cos^2\theta + \frac{\sqrt{2}}{3}(1+2\cos^2\theta)K^{10}_{10} - \frac{2\sqrt{2}}{3}K^{11}_{11}\cos^2\theta \\ & - \frac{4\sqrt{2}}{9}K^{20}_{20} + \frac{1}{3}(K^{11}_{10} + K^{10}_{11})(1+2\cos^2\theta)\cot\theta - \left(\frac{5}{9} - \frac{1}{2}\cos^2\theta\right) \\ & \times T_{20} + \frac{1}{3\sqrt{6}}(10-\cos^2\theta)T_{22} + \frac{2}{3}\sqrt{\frac{2}{3}}\sin\theta\cos\theta\, T_{21}, \quad (7)\end{aligned}$$

and

$$\begin{aligned}\mathrm{Re}(T_2{}^*U)/\sigma = {} & -\frac{1}{\sqrt{6}}\left[\left(\sqrt{\frac{3}{2}}T_{20} - T_{22}\right)\cos\theta - 2T_{21}\sin\theta\right] \\ & + \frac{1}{3}(K^{11}_{10} + K^{10}_{11})/\sin\theta, \quad (8)\end{aligned}$$

where σ is the differetial cross section, T_{2q} the tensor analyzing powers and $K^{k'q'}_{kq}$ the polarization transfer coefficients.

Measurements of the polarization observables which appear in the above equations will provide an unambiguous judge for the existences of T_L and T_P interactions. The present investigations can easily be extended to scattering of other projectiles, for example ^{7}Li, which will be given elsewhere.

References

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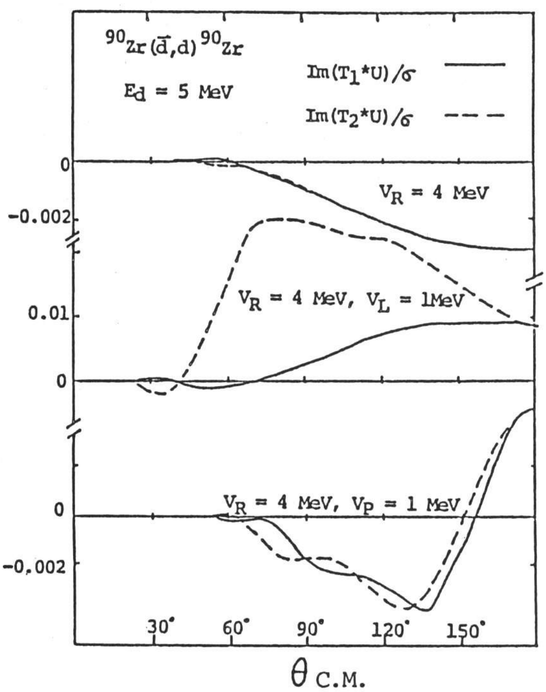

Fig. 1

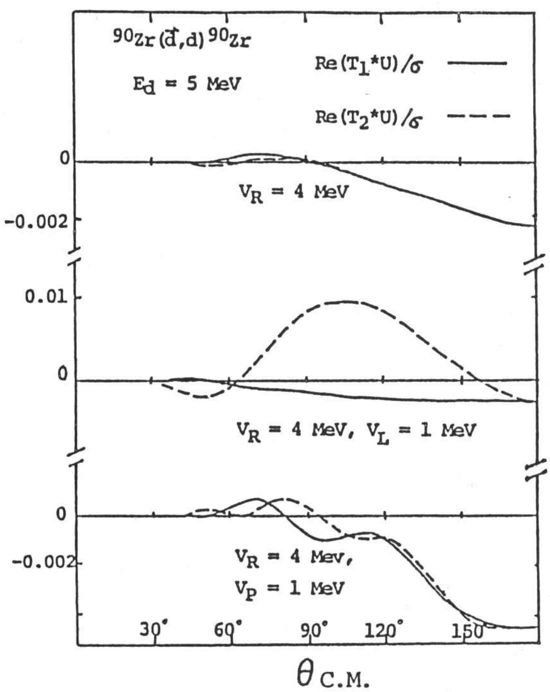

Fig. 2