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ON DEFORMED TENSOR POTENTIAL FOR INELASTIC DEUTERON SCATTERING

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Tensor analysing powers for inelastic deuteron scattering have been measured since a long time around 12 to 15 MeV [1,2]. The aim of such measurements for elastic scattering was to obtain informations on a tensor potential which comes from the interference[3] between the S and D parts u(r) and ω(r), of the deuteron in a crude folding model:

$$V_T(r_d) = f_T(r_d)T_r \qquad T_r = \frac{\sqrt{8\pi}}{3}[Y_2(\hat{r}_d)T_2]^o_o \qquad (1)$$

$$f_T(r_d) = \int \frac{18\omega(r)}{r^2\sqrt{2}}\left(u(r) - \frac{\omega(r)}{\sqrt{8}}\right)[V(r_p)+V(r_n)]P_2(\cos \widehat{r_d r})\, d\vec{r}$$

where the deuteron wave function is :

$$\varphi_d(r) = \frac{1}{r\sqrt{4\pi}}\left[u(r) + \frac{\omega(r)}{\sqrt{8}} S_{np}\right] \qquad S_{np} = 3(\vec{\sigma}_p\hat{r})\ (\vec{\sigma}_n\hat{r}) - 1 \qquad (2)$$

There is a similar term generated by the spin-orbit nucleon-nucleus potential.

There is no problem to use such a tensor potential for the excited states in coupled channels calculations. However, for transition potentials, form factors are very different if $f_T(\vec{r}_d)$[4] or $V(\vec{r}_p)$ is assumed to be deformed : in the last case the form factors of $^P[Y_L T_2]_\lambda$ for $L = \lambda\pm2,\lambda$ are different.

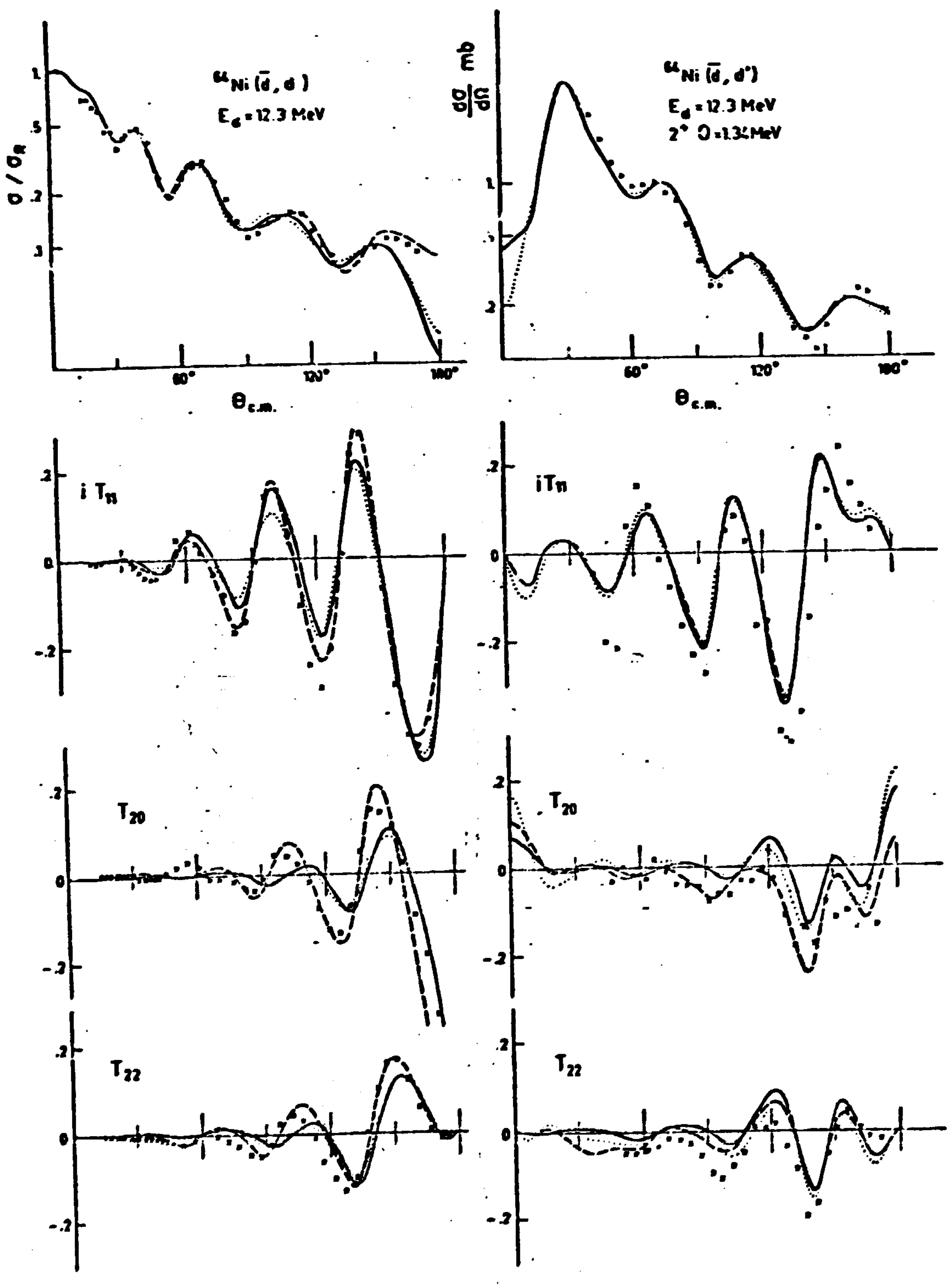
Using a nucleon nucleus potential $V_c(\vec{r}_p) + \vec{\nabla}_p V_{LS}(\vec{r}_p)\wedge \frac{\vec{\nabla}_p}{i}.\vec{\sigma}_p$, the contribution of the central potential to the folded one is :

$$V_c(\vec{R},\vec{S}) = \int \varphi_d(r)V_c(\vec{r}_p)\varphi_d(r)d\vec{r} = \frac{1}{4\pi}\int V^c(\vec{r}_p)\left\{\frac{u^2+\omega^2}{r^2} + \frac{\omega}{r^2\sqrt{2}}\left(u-\frac{\omega}{\sqrt{8}}\right)S_{np}\right\}d\vec{r} \qquad (3)$$

Using $\vec{\nabla}_p = \frac{1}{2}\vec{\nabla}_R + \vec{\nabla}_r$, the contribution of the spin-orbit potential is splitted into a spin-orbit term :

$$\begin{aligned} V_{LS}(\vec{R},\vec{S}) &= \frac{1}{2}\vec{\nabla}_R \int \varphi_d(r)V_{LS}(\vec{r}_p)\wedge i\vec{\sigma}_p\varphi_d(r)d\vec{r}.\vec{\nabla}_R \\ &= \frac{1}{8\pi}\vec{\nabla}_R\wedge i\int V_{LS}(\vec{r}_p)\frac{1}{r^2}\left\{\left(u^2-\frac{u\omega}{\sqrt{2}}+\omega^2\right)\vec{\sigma}_p + \frac{3\omega}{\sqrt{2}}\left(u-\frac{\omega}{\sqrt{2}}\right)(\sigma_n\hat{r})\hat{r} + \frac{9\omega^2}{4}(\sigma_p\hat{r})\hat{r}\right\}d\vec{r}.\vec{\nabla}_R \\ &= \frac{1}{8\pi}\vec{\nabla}_R\int V_{LS}(\vec{r}_p)\left\{\frac{1}{r^2}\left(u^2-\frac{u\omega}{\sqrt{2}}+\omega^2\right) - \int_a^r \frac{3\omega(r')}{r'^3\sqrt{2}}\left[u(r')+\frac{\omega(r')}{\sqrt{2}}\right]dr'\right\}d\vec{r}\wedge\frac{\vec{\nabla}_R}{i}.\vec{S} \end{aligned} \qquad (4)$$

and a central plus tensor potential :



^{64}Ni ($\bar{d}$, d)
E_d = 12.3 MeV
σ / σ_R
θ c.m.
60°
120°
180°
^{64}Ni ($\bar{d}$, d')
E_d = 12.3 MeV
2⁺ Q = 1.34 MeV
dσ/dΩ mb
i T11
iT11
T20
T22
.2
0
-.2

$$V'_{LS}(\vec{R},\vec{S}) = -i\int [\vec{\nabla}_r\varphi_d(r)\wedge\vec{\sigma}_p.\vec{\nabla}_r\varphi_d(r)]V_{LS}(\vec{r}_p)d\vec{r}$$
$$= \frac{1}{4\pi}\int V_{LS}(\vec{r}_p)\left\{\frac{3\omega}{r^4}[2r\omega'-\omega] + \frac{3\omega}{2r^4}[\sqrt{2}ru'-\sqrt{2}u-r\omega']S_{np}\right\}d\vec{r} \qquad (5)$$

Due to the simple expressions in r, these integrals are easily evaluated, changing $d\vec{r}$ into $d\vec{r}_p$ and $\vec{r} = 2(\vec{r}_p-\vec{R})$. The central form-factor of a transfert λ is obtained from the multipole λ of $\frac{1}{r^2}(u^2+\omega^2)$ in (3) and of $\frac{3\omega}{r^4}[2r\omega'-\omega]$ in (5). Similarly, the form-factor of $[Y_L T_2]_\lambda$ involves the multipoles of $f_1(r) = \frac{\omega}{r^4\sqrt{2}}\left(u-\frac{\omega}{\sqrt{8}}\right)$ in (3) and $f_2(r) = \frac{3\omega}{2r^4}[\sqrt{2}ru'-\sqrt{2}u-r\omega']$ in (5). The results are

$$\frac{64}{\sqrt{10\pi}}\frac{2L+1}{2\lambda+1}\langle L200|\lambda 0\rangle\int[V^\lambda(r_p)f_1(r)+V^\lambda_{LS}(r_p)f_2(r)][R^2P_\lambda(\cos\theta)$$
$$+r_p^2P_L(\cos\theta)-2Rr_pP_{\frac{L+\lambda}{2}}(\cos\theta)]r_p^2dr_pd\cos\theta \qquad L=\lambda\pm 2$$

$$\frac{64}{\sqrt{10\pi}}\langle\lambda 200|\lambda 0\rangle\int[V^\lambda(r_p)f_1(r)+V^\lambda_{LS}(r_p)f_2(r)]\Big[(R^2+r_p^2)P_\lambda(\cos\theta)$$
$$-\frac{Rr_p}{2\lambda+1}\left\{(2\lambda-1)P_{\lambda+1}+(2\lambda+3)P_{\lambda-1}\right\}\Big]r_p^2dr_pd\cos\theta \qquad L=\lambda \qquad (6)$$

To study the importance of such terms, a fit has been done with the first order vibrational model for $^{64}Ni(dd')^{64}Ni^*$, 2^+ at 1.344 MeV. The plain curve shows the best fit obtained without tensor potentials. The dashed elastic curves are an optical model fit with complex spin-orbit interaction and some tensor potential. These curves were obtained, using primarily cross-sections and elastic vector polarization in the χ^2. In the optical model, the tensor polarizations are quite well fitted as soon as the fit of the vector one is good. In coupled channel calculations the spin-orbit interaction became real but the fit of the elastic vector analyzing power cannot be maintained. The dotted curve, obtained with a tensor potential with different strengths for the elastic and inelastic channels, shows that a tensor potential cannot fill the gap between calculation and experiment. The inelastic dashed curves are obtained with deformed tensor potentiels (6) of which the strength was varied. These results show that a tensor potential for the 2^+ or a tensor transition potential, chiefly $L = 4$ can give a better fit for inelastic tensor analyzing powers. However, they show primarily the importance of central and spin-orbit terms : without a very good fit for cross-sections and vector polarizations, such a search is not conclusive.

References

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