p-p t-matrix Effective Interaction from Argonne Av18 Interaction

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Recent nuclear studies are mostly centered around loosely bound or halo nuclei [1, 2]. Exclusive measurements of knockout $(p, 2p)$ reactions, involve high energy and momentum transfers, are more sensitive to the nuclear surface and are thus best suited for these studies. A *p*-*p* *t*-matrix effective interaction has been a mandatory ingredient in all the DWIA predictions of $(p, 2p)$ reaction cross sections[3, 4]. This t-matrix has to be evaluated from an established realistic *p*-*p* interaction such as the Argonne Av18[5], so that free parameters do not spoil the predictive power. This is a realistic N-N interaction, $V_{N-N}(r)$ with repulsive core potential for energies below the pion production threshold. The basic definition of the t-matrix effective interaction can be visualized from the equation:

$$t\Phi = V\Psi. \qquad (1)$$

Where Ψ and Φ are solutions of the free *N*-*N* scattering Schrödinger equation (with proper boundary conditions) with and without the realistic *N*-*N* interaction V, respectively. The strong short-range repulsion in the realistic *N*-*N* interaction makes an ad hoc perturbative solution of this equation unreliable[6]. The Argonne Av18 interaction for a *p*-*p* system has one pion exchange terms as:

$$v^{\pi}(pp) = 0.075 v_{\pi}(m_{\pi^0}). \qquad (2)$$

$$v_{\pi}(m_{\pi^0}) = 42.0782(Y_{\mu}(r)\vec{\sigma_i}\cdot\vec{\sigma_j} + T_{\mu}(r)S_{ij}). \qquad (3)$$

Where $Y_{\mu}(r)$ and $T_{\mu}(r)$ are the usual Yukawa and Tensor functions with an exponential cutoff. The remaining intermediate and short range part is expressed as a sum of central, ℓ^2, tensor, $\vec{\ell}\cdot\vec{s}$ and $(\vec{\ell}\cdot\vec{s})^2$ terms in S. T and T_z states. The expression is quite lengthy but it is sufficient to know that there is a term of the range of two pion exchange force besides a shorter range component for each of the central, ℓ^2, tensor, etc terms. These involve a large number of parameters fitting the various scattering data.

The *N*-*N* *t*-matrix effective interaction $t(\vec{r})$ is obtained by us in a non-perturbative approach using the aforementioned Av18 realistic interaction. The main difficulty arises because of the Tensor part of the interaction. This tensor interaction does not lead to a good orbital angular momentum or ℓ value for the state. Thus we get coupled equations for each J (>0) for S=1, coupling the ℓ values, say: ℓ=0 *S*-state to the ℓ=2 *D*-state or the ℓ=1 *P*-state to the ℓ=3 *F*-state. Having solved these difficult coupled scattering states we incorporate them in Eq.1. Finally we get the following equation:

$$t^{S,T}(E,\vec{r}) = \sum_{L=0,1,2,\dots} t_L^{S,T,E}(r) P_L(\hat{r}), \qquad (4)$$

where $t_L^{S,T,E}(r)$ form the radial part of the *t*-matrix effective *N*-*N* interaction which for any state e.g. ${}^{2T+1,2S+1}\ell_J$ is spin S, isospin T, multipole L and energy E dependent. It is evident that this $t^{S,T}(E,\vec{r})$ is a multipole tensor containing terms of different orders, L. Figs.(1a and 1b) show these $T_L^{S,T,E}(r)$ results for two representative energies, E_{Lab}=150 and 50 MeV. As there are too many L- values contributing to all these states, only certain representative cases significantly contributing to the $t_L(r)$'s are presented here. From these some general observations are as follows:

1) whatever the state(S, T, ℓ) and L the $t_L^{S,T,\ell,E}(r)$ vanishes at r=0,
2) for the singlet states, S=0, the $t_L^{S,T,\ell,E}(r)$'s also vanish at r where $V_{NN}(r)$ vanishes,
3) for the triplet states, S=1, the tensor coupling sometimes allows $t_L^{S,T,\ell,E}(r)$ to vanishes at r where $V_{NN}(r)$ vanishes (e.g. L=5 case

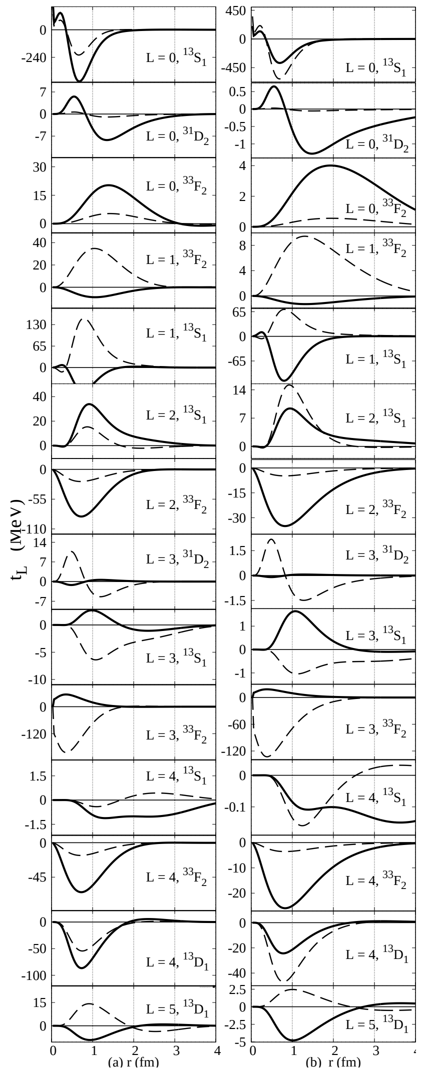

FIG. 1: Some t-matrix effective interactions plotted for $^{13}S_1$, $^{31}D_2$, $^{33}F_2$ and $^{13}D_1$ states using the Argonne Av18 N-N interaction at $E_{Lab.}$=150 MeV (left pannel) and 50 MeV (right pannel),real: solid line, imaginary: dashed line.

of $^{13}D_1$) while sometimes not (e.g. all L's for $^{13}S_1$),
4) for the lower $E_{Lab.}$ (e.g. ∼50 MeV) the $^{13}S_1$ dominates over the $^{33}F_2$ while for the higher $E_{Lab.}$ (e.g. ∼150 MeV) it is the other way,
5) as the energy E_{Lab} is decreased the $t_L(r)$'s are seen to expand as a function of r,
6) the triplet strengths of $t_L(r)$'s are in general much larger than the singlet strengths,
7) for the larger $E_{Lab.}$ the even L's have imaginary $t_L(r)$'s, smaller than the real ones while for the odd L's it is the reverse,
8) with increasing L-values the $t_L(r)$ strengths go on reducing and
9) comparing the magnitudes of $t_L(r)$'s with the phenomenological effective interactions of Love and Franey Ref([7]) one can witness the phenomenological ones to be much larger than the $t_L(r)$'s obtained by us using the Argonne Av18 realistic interactions.

Although we have achieved a major break through by evaluating the t-matrix effective interaction from the Argonne Av18 realistic n-n interaction a major task is still remaining that of incorporating it in the FR-DWIA code. This is under way but will take time because the computer program has already become quite huge.

We can conclude that our FR-DWIA formalism with these $t_L(r)$'s will have a parameter free prediction of the nucleon knockout cross sections. Moreover these calculations will also be useful to predict the (p,pn) and (n,2n) cross sections for Accelerator Driven System (ADS) reactors conceptualized for energy and neutron multiplications.
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