Separable Kernel of Nucleon-Nucleon Interaction in the Bethe-Salpeter Approach for $J = 0, 1$

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The solution for the nucleon-nucleon (NN) T matrix in the framework of the covariant Bethe-Salpeter approach for a two spin-one-half particle system with a separable kernel of interaction is analyzed. The explicit analytical connection between parameters of the separable kernel and low energy scattering parameters, deuteron binding energy and phase shifts is established. Covariant separable kernels for positive-energy partial channels with total angular momentum $J = 0$ (${}^1S_0^+$, ${}^3P_0^+$) and $J = 1$ (${}^3S_1^+ -{}^3 D_1^+$, ${}^1P_1^+$, ${}^3P_1^+$) are constructed by using obtained relations.

1. Formalism

We start with the partial-wave decomposed Bethe-Salpeter equation for the nucleon-nucleon T matrix (in the rest frame of two-nucleon system):

$$\begin{aligned} t_{L'L}(p_0', p', p_0, p; s) &= v_{L'L}(p_0', p', p_0, p; s) \\ &+ \frac{i}{4\pi^3} \sum_{L''} \int dk_0 \int k^2\, dk\, \frac{v_{L'L''}(p_0', p', k_0, k; s) t_{L''L}(k_0, k, p_0, p; s)}{(\sqrt{s}/2 - e_k + i0)^2 - k_0^2}. \end{aligned} \tag{1}$$

Here t is the partial-wave decomposed T matrix and v is the kernel of the NN interaction, $e_k = \sqrt{k^2 + m^2}$. There is only one term in the sum for the singlet (uncoupled triplet) case ($L = J$) and there are two terms for the coupled triplet case ($L = J \mp 1$). We introduced square of the total momentum $s = P^2 = (p_1 + p_2)^2$ and the relative momentum $p = (p_1 - p_2)/2$ [$p' = (p_1' - p_2')/2$] (for details, see reference [1]).

Assuming the separable form (rank I) for the partial-wave decomposed kernels of NN interactions

$$v_{L'L}(p_0', p', p_0, p; s) = \lambda g^{[L']}(p_0', p') g^{[L]}(p_0, p), \tag{2}$$

we can solve eq. (1) and write for the T matrix:

$$t_{L'L}(p_0', p', p_0, p; s) = \tau(s) g^{[L']}(p_0', p') g^{[L]}(p_0, p), \tag{3}$$

with the function $\tau(s)$ being:

$$\tau(s) = 1/(\lambda^{-1} + h(s)). \tag{4}$$

2. Calculations and results

We can now calculate internal parameters of the NN kernel by using obtained above equations to reproduce experimental values for the phase shifts (data are taken using SAID program http://gwdac.phys.gwu.edu/), deuteron energy and quadrupole moment, low-energy parameters (data are from ref. [3]).

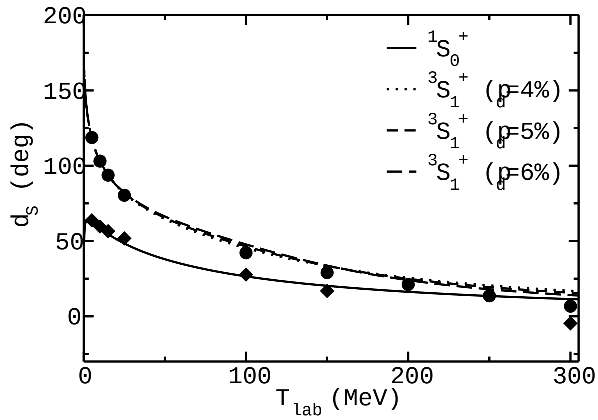

Figure 1. ${}^1S_0^+$ and ${}^3S_1^+$ channels phase shifts.

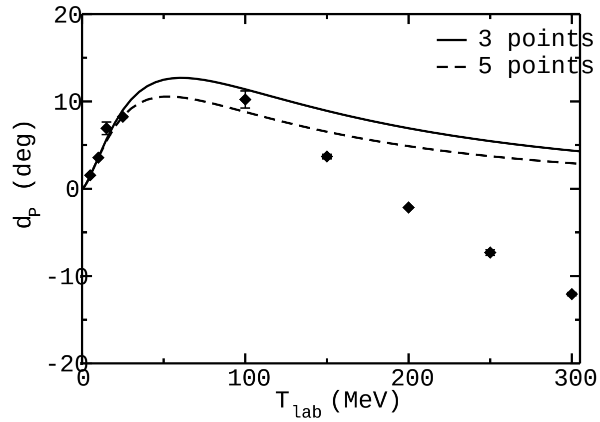

Figure 2. ${}^3P_0^+$ channel phase shifts.

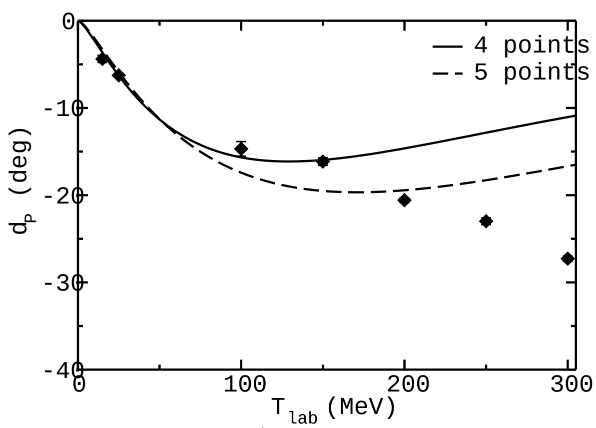

Figure 3. ${}^1P_1^+$ channel phase shifts.

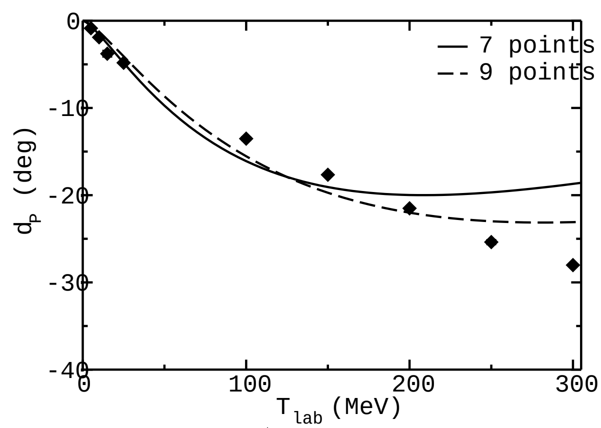

Figure 4. ${}^3P_1^+$ channel phase shifts.

REFERENCES

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