# The $pn \to d\eta$ Reaction Revisited

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The $pn \to d\eta$ reaction has been studied using meson exchange model within non-relativistic and relativistic approaches [1]. In these calculations, contributions from the exchange of $\pi$, $\rho$, $\eta$, and $\eta'$ mesons are included. The theoretical results are in reasonable agreement with the experimental numbers [2]. We intend to study this reaction using an initial state wave function containing N*(1535) resonance generated by means of coupled differential equations.

In this approach, the $\eta$ production for the $pn \to d\eta$ reaction is considered to proceed in two steps NN $\to$ NN* and NN* $\to$ d$\eta$ (see Fig. 1). The production matrix is written as,

$$\langle |T_{pn\to d\eta}|\rangle = \langle \psi_d |H^{prod}|(\psi_{pn} + \psi_{NN^*})\rangle \quad (1)$$

where, $\psi_{pn}$ and $\psi_{NN^*}$ are the NN and NN* wave functions respectively and $\psi_d$ is the deuteron wave function corresponding to the Reid soft core potential. The NN and NN* wave functions are obtained as the solutions of the coupled channel differential equations.

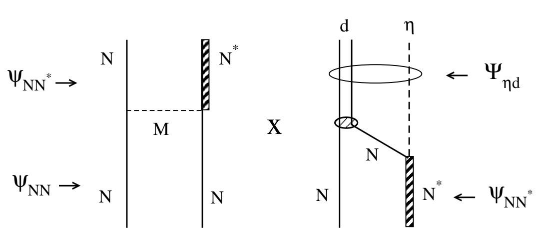


FIG. 1: The production mechanism of the $pn \to d\eta$ reaction. $M$ stands for the exchanged mesons.

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The production operator $H^{prod}$ is given as,

$$H^{prod} = \frac{f_{\eta NN^*}}{\sqrt{2E(q)}}\, e^{-i\,\vec{k_\eta}.\vec{R}}\,[e^{-i\,\vec{k_\eta}.\vec{r}/2} + e^{i\,\vec{k_\eta}.\vec{r}/2}] \quad (2)$$

where $\vec{r} = \vec{r_1} - \vec{r_2}$ and $\vec{R} = (\vec{r_1} + \vec{r_2})/2$.

The transition potential required to generate NN* wave function contains exchange of $\pi$, $\rho$, $\omega$, and $\eta$ mesons. In configuration space, transition potential for exchange of meson $M$, is written as,

$$V^M(r) = \frac{1}{(2\,\pi)^3} \int d\,\vec{q}\; V^M(q)\, e^{-i\,\vec{q}\,.\,\vec{r}} \quad (3)$$

where,

$$V^M(q) = \Gamma_{MNN}\, D_M(q)\, \Gamma_{MNN^*} \quad (4)$$

$\Gamma_{MNN}$ and $\Gamma_{MNN^*}$ are the vertex factors at $MNN$ and $MNN^*$ vertices respectively in the non-relativistic limit taken from Ref. [3]. $D_M(q)$ is the intermediate meson propagator given by

$$D_M(q) = \frac{1}{q^2 - m_M^2 + i\,\epsilon} \quad (5)$$

To obtain a proper resonance form for the production cross section, the width of N* resonance is included in the calculation of the NN* wave functions. The form of width employed in the calculations is taken from Ref. [3], given as

$$\Gamma(\mu) = \Gamma_0 \left(0.5\frac{k_\eta(\mu)}{k_\eta(m_{N^*})} + 0.4\frac{k_\pi(\mu)}{k_\pi(m_{N^*})} + 0.1\right) \quad (6)$$

with $\Gamma_0 = 150$ MeV and $m_{N^*} = 1535$ MeV.

The initial state interaction (ISI) is included through the $\psi_{pn}$ in the transition matrix. We

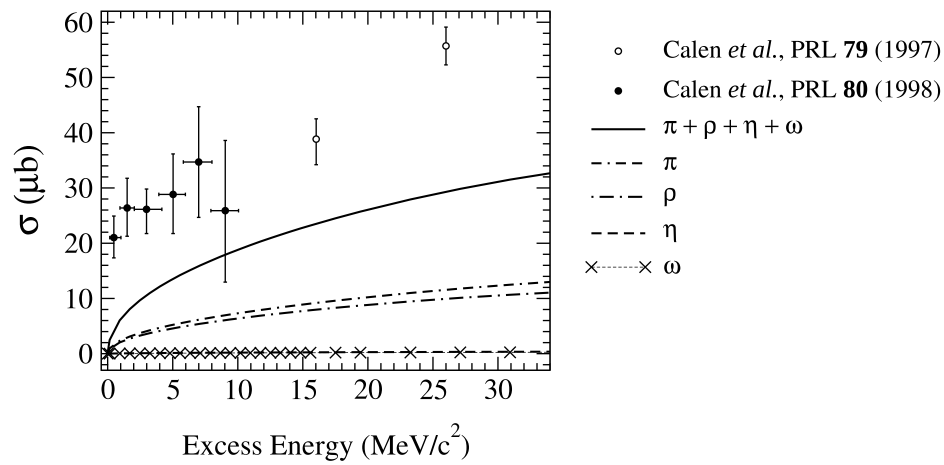


FIG. 2: Total cross section with respect to excess energy.

find that the inclusion of ISI does not show significant effect on the results.

The plane wave results of the calculations are shown in Fig. 2. Experimental points are from Ref. [2]. We see that the calculated cross sections for $p\,n \rightarrow d\,\eta$ reaction considering only one-eta and one-omega exchange transition potential are very small and almost overlap each other. Main contribution comes from one-pion and one-rho exchange transition potential. The results obtained using $p\,n \rightarrow N\,N^*$ transition potential summed over the exchange of one-pion, -rho, -eta, and -omega are far below the experimental points.

From our experience on the study of the $p\,d \rightarrow p\,d\,\eta$ reaction [4], the inclusion of the $\eta$-d final state interaction will enhance the amplitude near the threshold. The wave function of the interacting $\eta$-d in the $s$-wave can be written as,

$$\Psi_{\eta d} \;=\; j_0(k_\eta\, r) + \int \frac{d\vec{q}}{(2\pi)^3} \frac{T_{\eta d\rightarrow \eta d}\; j_0(q\,r)}{E(k_\eta)\;-\;E(q)\;+\;i\epsilon} \tag{7}$$

The $\eta$-d interaction is incorporated through half-off-shell $\eta$-d $t$-matrix, which is obtained by multiplying the on-shell $\eta$-d $t$-matrix by an off-shell extrapolation form factor $g(k', k_0)$. It is written as,

$$T_{\eta d \rightarrow \eta d} \;=\; g(k, k_0)\, T_{\eta d}(E(k_0))\, g(k', k_0) \tag{8}$$

where,

$$g(k', k_0) \;=\; \int d\vec{r}\, j_0(rk'/2)\, \psi_d^2(r)\, j_0(rk_0/2) \tag{9}$$

The on-shell $\eta$-d $t$-matrix is given by

$$T_{\eta d}(k) \;=\; -\frac{2\pi}{\mu_{\eta d}} \times \left(\frac{1}{A_{\eta d}} - ik\right)^{-1} \tag{10}$$

The calculations to include final state interactions are in progress.

## References


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