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# THE ABSORPTIVE $\rho^2$ TERMS IN THE $\eta$ OPTICAL POTENTIAL* **

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The two-nucleon absorptive optical potential for $\eta$-mesons is calculated on the basis of recent experiments of $\eta$ production in two nucleon collisions. The mesons are most likely to be absorbed on $NN$ pairs in the spin 1 state.

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The lifetime of $\eta$ mesons in nuclear matter is of importance in the search for $\eta$-nucleus quasi-bound states, performed now in Brookhaven [1] and Darmstadt [2]. The $\eta$ lifetime in a nucleus is determined essentially by the basic reaction $\eta N \to \pi N$. In addition, the two nucleon capture processes are also expected

$$\eta(NN)^0 \to NN \qquad \text{and} \qquad \eta(NN)^1 \to NN. \tag{1}$$

These reactions correspond to $\eta$ absorption on two correlated $NN$ pairs in either the spin singlet or spin triplet states, denoted by the superfixes. The rates for these two-nucleon $\eta$ capture modes have been uncertain so far. Now a phenomenological evaluation is possible as the cross sections for

$$pp \to pp\eta\,, \tag{2}$$

$$pn \to d\eta\,, \tag{3}$$

$$pn \to pn\eta \tag{4}$$

have been measured in the close to threshold region [3–7]. The first reaction allows to calculate the rate of the inverse reaction (1), when the protons are

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correlated into a spin singlet state. The second reaction gives the rate of $\eta$ absorption on a spin triplet $NN$ pair.

General, albeit approximate, relations of the scattering cross sections to the nuclear decay rates are given by the following formulas for the absorptive optical potentials $W$:

$$W^{0,1}_{NN}(r) \;=\; \rho(r)^2 \left[\tfrac{1}{2} v_{NN}\sigma\left(NN \to (NN)^{0,1}\eta\right)\right] \frac{L_1(NN)}{L_2(NN\eta))}\,, \tag{5}$$

$$W^{1}_{NN}(r) \;=\; \rho(r)^2 \left[\tfrac{1}{2} v_{NN}\sigma(pn \to d\eta)\right] \frac{L_1(NN)}{L_1(d\eta)\psi_d(0)^2}\,, \tag{6}$$

where $\sigma$ are the total cross sections at low energies, $v_{NN}$ is the relative velocity in the $NN$ system required to produce a slow $\eta$, $v_{\eta N}$ is the $\eta N$ relative velocity, $L_1, L_2$ are the phase space elements defined by $L_1(NN) = \int \frac{d\bar{p}}{(2\pi)^3}\delta[E - E_{NN}(p)]$, $L_2(NN\eta) = \int \frac{d\bar{p}d\bar{q}}{(2\pi)^6}\delta[E - E_{NN}(p) - E_\eta(q)]$ and $\psi_d(0)$ is the deuteron wave function at the origin. These relations reflect the detailed balance property of the direct and inverse processes. However, an additional assumption is made here: since the meson formation requires high ($\approx 900\,\mathrm{MeV}/c$) momentum transfer between the two nucleons by the uncertainty principle one expects short $NN$ distances to be involved. Next the deuteron is formed in a coalescent way. In this way the deuteron wave function at origin arises in Eq. (6).

Now we present some numbers. The experimental cross section $\sigma(pn \to d\eta) = 93\,\mu b$ measured in Ref. [6] at the excess energy $Q = 56$ MeV and Eq. (6) generate an absorptive potential of $W^1_{NN}(0) = 4.2$ MeV strength at the nuclear center. On the other hand, $\sigma(pp \to pp\eta) = 4.9\,\mu b$, measured at $Q = 38$ MeV [5], yields $W^0_{NN}(0) = 1.2$ MeV according to Eq. (5).

Corrections to relation (5) are necessary, since it is based on the detailed balance assumption which has clear limitations in the nuclear medium situation. Close to the meson production threshold the inverse reaction $NN \to NN\eta$ rates are strongly enhanced by final state interactions between the two nucleons. These interactions reflect the proximity either of the deuteron or the spin singlet virtual state. Such long ranged structures are not formed in the initial states of $\eta NN \to NN$ reactions inside nuclei, and a correction should be introduced into Eq. (5). It may be expressed in terms of a final state wave function $\psi_{NN}$ in the same way as it was done in Eq. (6) for the deuteron. The enhancement due to final state interactions is due to large values of $\psi_{NN}$ at short ranges as compared to the values of the incident $j_0$ wave. In order to average over the interaction range a simple model of Ref. [8] is used to describe reaction (2). It follows that an enhancement of the reaction rate due to final state $pp$ interactions amounts to a factor of 5 at $Q = 38$ MeV. The same factor reduces the spin singlet absorptive potential to an almost negligible value of $W^0_{NN}(0) = 0.2$ MeV. A consistency check for this procedure was found in the reaction (4), which has been studied recently on a deuteron target [7]. We summarize this note with the values $W^1_{NN}(0) = 4.2$ MeV and $W^0_{NN}(0) = 0.2$ MeV.

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