$NN \to N\Delta$ cross section in nuclear matter

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It has been shown in [1] within the relativistic Dirac-Brueckner approach, that the $NN \to N\Delta$ cross section is reduced at high baryon densities. In [2], however, the opposite result has been obtained. An important contribution which was missed in [2] is given by the effective nucleon and Δ resonance masses. We will show, that the introduction of the effective (Dirac) nucleon and Δ masses in the one-pion exchange model (OPEM) leads to the in-medium reduction of the $NN \to N\Delta$ cross section.

We assume that both nucleons and resonances are coupled to the scalar (vector) mean field σ (ω) by the same universal coupling constant $g_\sigma = 10.138$ ($g_\omega = 13.285$) as given by the NL1 version of the relativistic mean field model [3]. This produces the effective masses $m_N^* = m_N + g_\sigma\sigma$, $m_\Delta^* = m_\Delta + g_\sigma\sigma$ and the kinetic 4-momenta $p_N^* = p_N - g_\omega\omega$, $p_\Delta^* = p_\Delta - g_\omega\omega$, which replace the bare masses $m_N = 0.938$ GeV, $m_\Delta = 1.232$ GeV and 4-momenta p_N, p_Δ in the calculations.

For simplicity, we consider the situation when the c.m. frame of colliding nucleons coincides with the nuclear matter rest frame, i.e. $\mathbf{p}_N^* = \mathbf{p}_N$ and $\mathbf{p}_\Delta^* = \mathbf{p}_\Delta$. This gives the differential cross section:

$$\frac{d\sigma_{NN\to N\Delta}}{dM_\Delta^{*2}d\Omega} = \frac{(2m_N^*)^3 2M_\Delta^*}{64\pi^2}\overline{|T|^2}\frac{p_{N\Delta}}{p_{NN}s^*}\mathcal{A}_\Delta^*(M_\Delta^{*2}) , \quad (1)$$

where p_{NN} and $p_{N\Delta}$ are the c.m. momenta of incoming and outgoing particles respectively, $(s^*)^{1/2} = 2(p_{NN}^2 + m_N^{*2})^{1/2} = (p_{N\Delta}^2 + M_\Delta^{*2})^{1/2} + (p_{N\Delta}^2 + m_N^{*2})^{1/2}$ is the c.m. energy, $\mathcal{A}_\Delta^*(M_\Delta^{*2})$ is the in-medium spectral function of the Δ resonance and $\overline{|T|^2}$ is the in-medium matrix element squared and averaged over initial and summed over final spin projections.

The spectral function is given by the following expression:

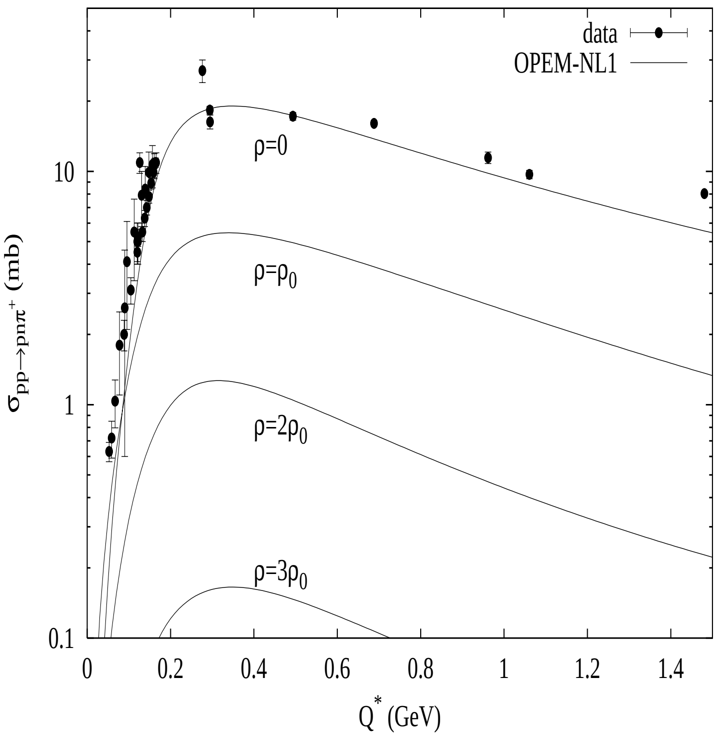
$$\mathcal{A}_\Delta^*(M_\Delta^{*2}) = \frac{1}{\pi}\frac{M_\Delta^*\Gamma^*(M_\Delta^*)}{(M_\Delta^{*2} - m_\Delta^{*2})^2 + M_\Delta^{*2}\Gamma^{*2}(M_\Delta^*)} , \quad (2)$$

where the total in-medium width $\Gamma^*(M_\Delta^*)$ is approximated as follows:

$$\Gamma^*(M_\Delta^*) = 0.08 \text{ GeV}\frac{\rho}{\rho_0} + \Gamma^{vac}(M_\Delta^* - g_\sigma\sigma) . \quad (3)$$

The first term in (3) is the spreading width [4] (ρ is the baryon density and $\rho_0 = 0.16$ fm^{-3}) and the second term is the vacuum $\Delta \to N\pi$ width neglecting for simplicity the effect of Pauli blocking on the decay nucleon.

The matrix element T was evaluated from the non-relativistic reduction of OPEM [5]. The coupling constants were $f_{\pi NN} = 1.008$ and $f_{\pi N\Delta} = 2.202$. The monopole pion off-shell form factor with the cutoff parameter $\Lambda = 0.67$ GeV was applied. We took into account the collectivity of the exchange pion and the vertex corrections due to the short-range correlations in an analogous way as in [2]. However, in addition to the ΔN^{-1} loop we also included the NN^{-1} loop. The Landau-Migdal parameters were all set to be equal to 0.6. Fig. 1 shows the cross section $\sigma_{pp\to pn\pi^+} = 10/9\,\sigma_{pp\to n\Delta^{++}}$ vs the c.m. energy $Q^* = (s^*)^{1/2} - 2m_N^* - m_\pi$ above the pion production threshold at several densities. Dots show the experimental data from [6]. The cross section quickly drops with the baryon density. This explains the phenomenological density dependent quenching-factors for the $NN \leftrightarrow N\Delta$ cross sections introduced in the BUU calculations [7] in order to describe the pion multiplicity in Au+Au collisions at 1 A GeV.



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