Hyperon resonances and K^- production at SIS

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In a recent work Hartnack, Oeschler and Aichelin [1] studied the possible importance of in-medium modified $\pi Y \to \bar{K}N$ cross sections in subthreshold K^- production at SIS. Within their scenario, which does not consider a momentum dependence of the antikaon mean field nor a proper treatment of the spectral distributions of hadrons, they observe an enhancement of the K^- yield by a factor 2 if the $\pi Y \to \bar{K}N$ cross sections are enlarged by an ad hoc factor three.

An improved microscopic understanding of the $\pi Y \to \bar{K}N$ cross sections as they may change in a nuclear environment is desirable. In Fig. 1) the results of a computation based on a self consistent chiral SU(3) dynamics [2, 3, 4] are presented. In the upper panel we show the isospin averaged $\pi\Sigma \to \bar{K}N$ and $\pi\Lambda \to \bar{K}N$ cross sections where the in-medium scattering amplitudes are used together with the antikaon spectral function defining the final-state phase space. Comparing the solid with the dashed and dotted lines one realizes a dramatic enhancement for the $\pi\Lambda$ reaction but a much more moderate enhancement for the $\pi\Sigma$ reaction. The dashed and dotted lines correspond to the situation where the sum of initial three-momenta is 0 MeV and 600 MeV respectively. To explain the source of this effect the figure shows in its lower panel the same cross sections evaluated in two different schematic ways. The dotted lines give the result obtained according to the prescription $\sqrt{s} \to \sqrt{s} - \Delta m_{\bar{K}}$ as commonly applied in transport model simulations. It is used $\Delta m_{\bar{K}} = -100$ MeV typically for the amount of attraction found for the antikaon at saturation density. The cross sections remain as small as they are in free-space. A striking enhancement is shown by the dashed lines in the lower panel. Here we use the free-space scattering amplitude and evaluate the cross section with the final state phase space determined by a reduced kaon mass of 394 MeV. As a result this cross section probes the scattering amplitudes at subthreshold energies a kinematical region where they are not directly constrained by the scattering data. Since the $\chi-$BS(3) scheme predicts considerable strength in the subthreshold amplitudes from the s-wave $\Lambda(1405)$ and p-wave $\Sigma(1385)$ resonances the former cross sections are dramatically enhanced as compared to the free-space cross sections. Comparing the lower with the upper panel demonstrates that the latter cross section, though providing a simple physical interpretation of the enhancement, do not adequately reproduce the full computation as it arises in a self consistent framework. In particular the large cross section of the $\pi\Sigma \to \bar{K}N$ reaction predicted by the free-space amplitudes is significantly reduced in the self consistent scheme. Here one should note that the s-wave and p-wave final-state phase space factors probe the antikaon spectral function in different ways. Thus, the net result is a combined effect depending on the in-medium amplitude and a projection of the antikaon spectral function that depends on the angular momentum.

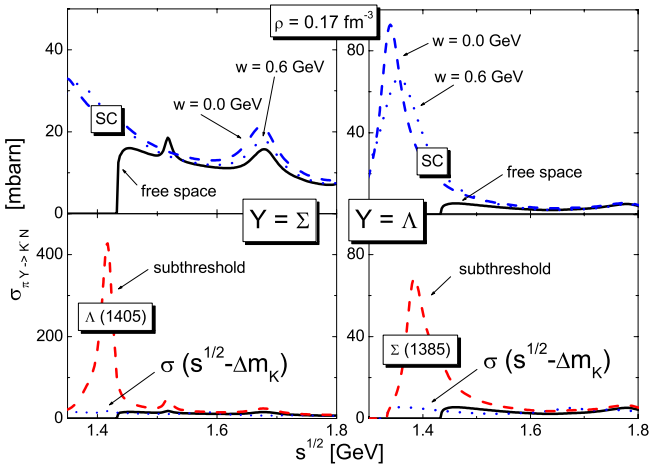

Figure 1: The upper panels show the pion induced cross sections of antikaons obtained in a self consistent many-body evaluation (dashed for $\vec{w} = 0$ MeV and dotted lines for $\vec{w} = 600$ MeV) at nuclear saturation density as compared to the free-space cross sections (full lines). The lower panels give the results of schematic evaluations. The dotted lines are the free-space cross section shifted in $\sqrt{s}$ by $\Delta m_{\bar{K}} = -100$ MeV. The dashed lines follow with computations that are based on the subthreshold free-space amplitudes as predicted by the χ-BS(3) approach together with a final state phase space evaluated with a reduced kaon mass.

The moderate enhancement for the $\pi\Sigma \to \bar{K}N$ reaction confirms the results of our previous works, in which it was pointed out that a self consistent antikaon dynamics does not generate the large enhancement factor predicted by a scheme that considers Pauli blocking only. The striking effect induced by the $\Sigma(1385)$ resonance in the $\pi\Lambda \to \bar{K}N$ reaction is novel. It is the result of our detailed analysis of the kaon and antikaon scattering data which predicts that there is a strong coupling of the $\Sigma(1385)$ resonance to the $\pi\Lambda$ and $\bar{K}N$ channels at subthreshold energies [2]. The self consistent many-body computation presented here suggests that this strong coupling persists in the nuclear medium giving rise to the large enhancement factor found for the in-medium $\pi\Lambda \to \bar{K}N$ reaction. This effect should have important consequences for the antikaon yield in nucleus-nucleus collisions at SIS energies.

References

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