Ξ Production in $\bar{K}$ Induced Reactions in a Coupled-Channel Approach

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Because of the large production rate of strange quarks in a quark-gluon plasma, enhanced production of hadrons made of strange quarks has been suggested as one possible signal for the QGP that is expected to be formed in relativistic heavy ion collisions [1]. However, strange hadrons can also be produced from the hadronic matter that dominates later stage of heavy ion collisions. In particular, the strangeness-exchange reactions between antikaons and baryons, such as $\bar{K}N \to \Lambda M$, $\bar{K}N \to \Sigma M$, $\bar{K}\Lambda \to \Xi M$, $\bar{K}\Sigma \to \Xi M$, and $\bar{K}\Xi \to \Omega M$ with M denoting either pion or eta meson, have been shown in a multiphase transport model [2] to contribute significantly to the production of multistrange baryons [3]. The cross sections for $\bar{K}N \to \Lambda\pi$ and $\bar{K}N \to \Sigma\pi$ reactions have been measured experimentally [4], while all others are unknown. In Ref. [3], these unknown cross sections are determined by assuming that they have the same transition matrix elements as that of the empirically measured reaction $\bar{K}N \to \Sigma\pi$.

For the empirically known cross sections for the reaction $\bar{K}N \to \Lambda\pi$ and $\bar{K}N \to \Sigma\pi$ there are already theoretical studies based on a coupled-channel approach [5, 6]. In these studies, a SU(3) invariant hadronic Lagrangian is used for constructing the kernel of the coupled-channel Bethe-Salpeter equation for the transition amplitudes. From these studies, it is found that the measured cross sections for these two reactions can be reproduced with appropriate form factors at the interaction vertices.

We have extended the method of Ref. [6], which includes only the on-shell part of the propagator in the Bethe-Salpeter equation but otherwise satisfies the unitarity condition for the transition amplitude, to study the following strange-exchange reactions for Σ production, i.e., $\bar{K}\Lambda \to \Xi M$, $\bar{K}\Sigma \to \Xi M$

For each strange-exchange reaction, we evaluate the lowest-order Born diagrams in the *s*, *t*, and *u* channels. Also, the Born amplitudes for the elastic channels $\bar{K}\Lambda \to \bar{K}\Lambda$, $\bar{K}\Sigma \to \bar{K}\Sigma$, and $\Xi M \to \Xi M$ are evaluated using the same interaction Lagrangians. These Born amplitudes are needed to construct the kernel for the Bethe-Salpeter equation. The coupling constants at interaction vertices are taken from the empirical values if they are known. Otherwise, they are obtained from the known ones using SU(3) relations. To take into account the fact that hadrons are composite particles made of quarks, we have also introduced form factors at the interaction vertices. The Bethe-Salpeter equation is then solved using the partial wave expansion as in Ref. [6].

In Fig. 1, we show the energy dependence of the cross sections for the reactions $\bar{K}\Lambda \to \Xi\pi$ and $\bar{K}\Lambda \to \Sigma\pi$ using a cutoff parameter $\Lambda = 1\,GeV$ in the form factors. Because these reactions are exothermic, their cross sections diverge near the threshold. For center-of-mass energies about a few hundred MeV above the threshold, the cross section is about 5 mb for $\bar{K}\Lambda \to \Xi\pi$ and 3 mb for $\bar{K}\Sigma \to \Xi\pi$. Contrary to the Born approximation, the coupled channel results are not very sensitive to the value of the cutoff parameter in the form factors. They increase by less than a factor of two when the value of the cutoff parameter is doubled.

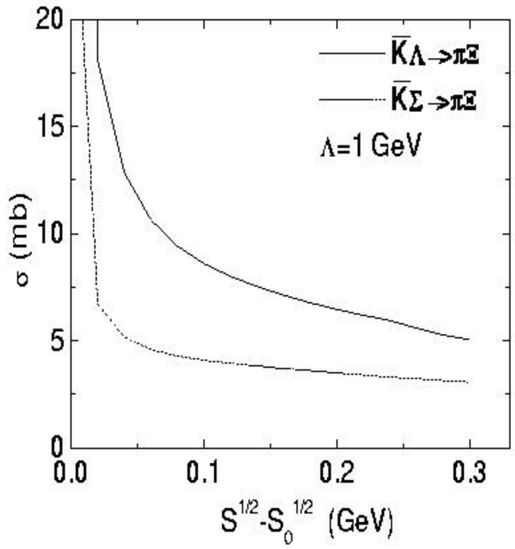

Figure 1: Cross sections for strangeness-exchange reactions $\bar{K}\Lambda \rightarrow \Xi\pi$ and $\bar{K}\Sigma \rightarrow \Xi\pi$.

The results for the reactions $\bar{K}\Lambda\Xi\eta$ and $\bar{K}\Sigma \rightarrow \Xi\eta$ using the same cutoff parameter $\Lambda = 1\,GeV$ are shown in Fig. 2. In these cases, the cross sections increase with the center-of-mass energy due to the large eta meson mass. At center-of-mass energy of a few hundred MeV above threshold, the cross section for $\bar{K}\Lambda \rightarrow \Xi\eta$ is about 4 mb, similar to that for $\bar{K}\Lambda \rightarrow \Xi\pi$, while the cross section for $\bar{K}\Lambda \rightarrow \Xi\eta$ is only about 0.5 mb, much smaller than that for $\bar{K}\Sigma \rightarrow \Xi\pi$.

The cross sections for the strangeness-exchange reactions that lead to the production of Ξ predicted by the SU(3) flavor symmetric hadronic Lagrangian are comparable to the measured strangeness-exchange reactions for Σ

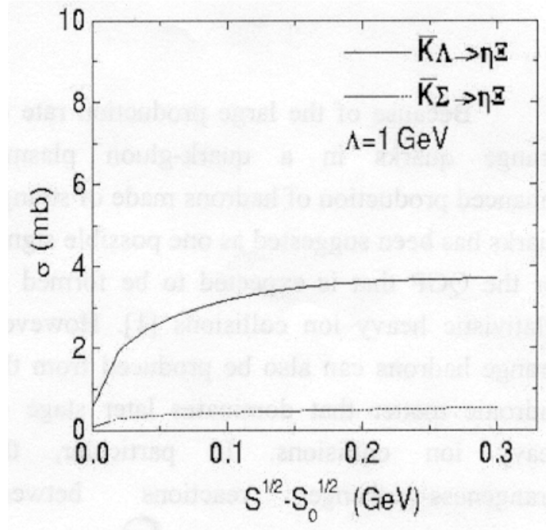

Figure 2: Cross sections for strangeness-exchange reactions $\bar{K}\Lambda \rightarrow \Xi\eta$ and $\bar{K}\Sigma \rightarrow \Xi\eta$

production. Our study thus supports the assumption used in Ref. [3] and the conclusion that strangeness-exchange reactions play an important role in the production of multistrange baryons in relativistic heavy ion collisions.

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