Production of a cascade hyperon by the $p(K^-, K^+)\Xi^-$ and $p(K^-, K^0)\Xi^0$ reactions

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Spectroscopy of hadrons is one of the key tools for studying quantum chromodynamics (QCD) in the non-perturbative regime. Lattice simulations, which provide the only *ab initio* calculations of QCD in this regime, are now able to reproduce a large part of the experimentally observed ground state hadron spectrum (see, e.g., Refs. [1]). However, only a small subset of the excited state hadron spectrum is currently amenable to lattice calculations. For the success of this endeavor, it is highly desirable to have a large amount of data on the excited state spectrum, including in particular those hadrons where the widths associated with the states are not large - so that they can be easily identified. A major advantage of investigating the double strangeness ($S = -2$) Ξ states is that they are much narrower than the N^*, Δ^*, Λ^* and Σ^* states, which reduces the overlap complications with the neighboring states.

In contrast to $S = -1$ hyperons, the Ξ states are underexplored. Out of more than twenty Ξ candidates expected in the SU(3) multiplet and at least ten such candidates predicated by the quark model calculations, only two ground state cascades, Ξ and $\Xi(1530)$, are established with near certainty. The reason is that the cross sections of $S = -2$ hyperons are relatively small. Some data on the total cross sections of the $K^-+p \rightarrow K^++\Xi^-$ and $K^-+p \rightarrow K^0+\Xi^0$ reactions that have been collected in the sixties and early seventies using the hydrogen bubble chambers are tabulated in Ref. [2].

The proper understanding of the $K^- + p \rightarrow K^+ + \Xi^-$ reaction within a rigorous model is important for several reasons. A strong program is proposed at the JPARC facility in Japan and eventually at GSI-FAIR in Germany to obtain information about the spectroscopy of $\Xi-$hypernuclei through the (K^-, K^+) reaction on nuclear targets. The $K^- + p \rightarrow K^+ + \Xi^-$ reaction is the best tool to implant a Ξ hyperon in the nucleus through the (K^-, K^+) reaction. Coupled with recent progress in lattice QCD [3], the availability of a high quality K^- beam is likely to revive interest in looking for a near stable six-quark dibaryon resonance (H) with spin-parity of 0^+, isospin 0 and $S = -2$ [4], by studying the (K^-, K^+) reaction. The amplitude for the $K^-+p \rightarrow K^++\Xi^-$ process must be known accurately in order to estimate the cross section for H production.

We have investigated the $K^- + p \rightarrow K^+ + \Xi^-$ and $K^- + p \rightarrow K^0 + \Xi^0$ reactions within a single channel effective Lagrangian model, which is similar to that developed in Ref. [5] to study the associated photoproduction of kaons off protons. In our model, contributions are included from s- and u-channel diagrams (Figs. 1(a) and 1(b), respectively), which have as intermediate states Λ and Σ hyperons together with eight of their three and four star resonances with masses up to 2.0 GeV [$\Lambda(1405)$, $\Lambda(1520)$, $\Lambda(1670)$, $\Lambda(1810)$, $\Lambda(1890)$, $\Sigma(1385)$, $\Sigma(1670)$ and $\Sigma(1750)$, which are represented by Λ^* and Σ^* in Fig. 1]. These reactions are clean examples of a process in which baryon exchange plays the dominant role and the $t-$channel meson exchanges are absent, as

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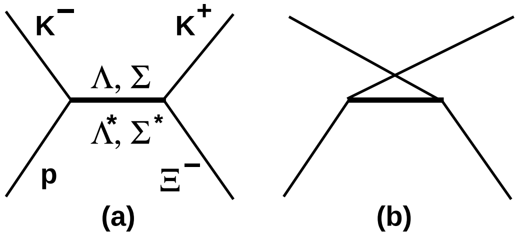

FIG. 1: Graphical representation of our model to describe $K^- + p \to K^+ + \Xi^-$ reaction.

no meson with $S = +2$ is known to exist. In past studies of these reactions, such a comprehensive investigation of the influence of so many intermediate resonance states has not been attempted.

The form of the effective Lagrangian vertices (L) involving spin-$\frac{1}{2}$ and spin-$\frac{3}{2}$ resonance intermediate states are taken from Ref. [6]. For spin-$\frac{3}{2}$ resonance vertices, we have used the gauge-invariant effective Lagrangian, which has the interesting property that the product $\gamma \cdot L = 0$. As a consequence the spin-$\frac{1}{2}$ part of the corresponding propagator becomes redundant and only the spin-$\frac{3}{2}$ part gives rise to nonvanishing matrix elements [6].

In Fig. 2, we show comparisons of our calculations with the data for the total cross sections of the $K^- + p \to K^+ + \Xi^-$ (panel a) and $K^- + p \to K^0 + \Xi^0$ (panel b) reactions for K^- beam energies (E_{K^-}) below 3.0 GeV because the resonance picture is not suitable at energies higher than this. It is clear that our model is able to reproduce the data well for both the channels within the statistical errors. We note that for the $K^- + p \to K^+ + \Xi^-$ reaction, the cross sections around the peak and the tail ($E_{K^-} \geq 2.1$ GeV) regions are dominated by the s- and u-channel contributions, respectively. This result is in contrast to the conclusions of past studies where u-channel contributions dominated this reaction everywhere.

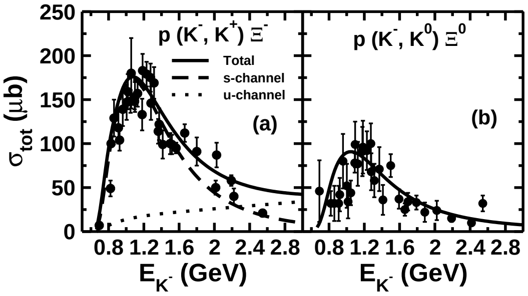

FIG. 2: Comparison of the calculated and measured total cross section for the $K^- + p \to K^+ + \Xi^-$ (a) and $K^- + p \to K^0 + \Xi^0$ (b) reactions as a function of incident K^- kinetic energy. In panel (a) the individual contributions of s- and u-channel diagrams are also shown.

An important result of our study is that total cross section of this reaction is dominated by the contributions from the $\Lambda(1520)$ state through both s- and u-channel terms. We further noted that the strong backward peaking of the K^+ differential cross sections results from the interference effects of various intermediate states in both s- and u-channel terms. This result is of vital significance as it invalidates the long standing belief that the strong backward peaking of the angular distributions in this reaction results from the u-channel dominance.

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