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Λ-Λ Interferometry in (K^-, K^+) Reactions at $P(K^-) = 1.8$ GeV/c

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Abstract. We study (K^-, K^+) reactions on nuclear targets (^{12}C and ^{9}Be) at incident K^- momentum of $P(K^-)$ =1.65 and 1.8 GeV/c by using the intranuclear cascade model combined with the correlation function technique. We compare the calculated results with two different sets of elementary meson-baryon cross sections, but we cannot find significant differences in K^+ spectra and $\Lambda\Lambda$ invariant mass spectra. The calculated $\Lambda\Lambda$ invariant mass spectrum in ^{9}Be$(K^-, K^+\Lambda\Lambda)$ reaction at $P(K^-) = 1.8$ GeV/c shows a comparable yield to that in ^{12}C target reaction.

1 Introduction

The recent measurement of $\Lambda\Lambda$ invariant mass spectrum in KEK-E224 experiment [1] has made a great impact on strangeness nuclear physics. It not only provides us of the oppotunity to search for the H dibaryon state above the $\Lambda\Lambda$ threshold, but also can be regarded as the first "$\Lambda\Lambda$ scattering" data. The measured data show two striking features concering the above two points. The first one is the enhancement just below the ΞN threshold, which might come from the ΞN bound state partially having features of the flavor singlet H dibaryon resonance. The second one is the strong enhancement at low energies, $E_{\Lambda\Lambda} = M_{\Lambda\Lambda} - 2M_\Lambda \leq 10$ MeV. At these energies, two emitted Λ particles are considered to scatter through the pairwise $\Lambda\Lambda$ final state interaction (FSI).

Recently, we have analyzed the $\Lambda\Lambda$ invariant mass spectrum data of KEK-E224 by using a combined framework of IntraNuclear Cascade (INC) model and the correlation function technique, and we have shown that the observed enhancement at low-invariant masses can be well reproduced with appropriate attractive $\Lambda\Lambda$ interactions, as shown in Fig. 1 [2]. Therefore, it would be possible to extract precise information of the $\Lambda\Lambda$ interaction, *if* precise $\Lambda\Lambda$ correlation data are available, *and* theoretical ambiguities other than the $\Lambda\Lambda$ interaction is small. In the BNL-E906 experiment, the estimated number of detected $\Lambda\Lambda$ pairs exceeds that in KEK-E224 by one to two order of magnitude [4, 5], then high quality correlation data will be available soon. Theoretically, it is required to explain various data other than $\Lambda\Lambda$ correlation based on the well-established knowledges of elementary hadron-hadron cross sections and the mean field potentials. Especially, since various two-step processes ($K^-N \to MY, MN \to K^+Y$) significantly contribute to the concidence yield of $(K^-, K^+\Lambda\Lambda)$ [6], theoretical estimates of experimentally unknown cross sections such as $\eta N \to KY$ may cause a large ambiguity. Therefore we focus our attention to the elementary meson-baryon cross sections in this work.

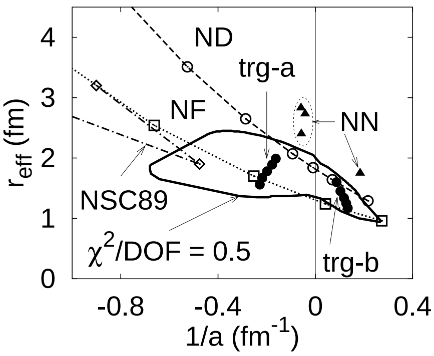

Figure 1. Extracted Λ-Λ scattering parameters [2]. Fitted two-range gaussian potentials (solid circles) are compared with Nijmegen models (open marks) [3]. Inside the thick solid line, potential with $\chi^2/\mathrm{DOF} \leq 0.5$ exists with longer gaussian range parameters in $0.6 \leq \mu_l \leq 1.0$ fm.

2 Meson-Baryon Cross Sections

Meson-baryon reactions have been extensively studied mainly in 60's and 70's, and various baryon resonances have been found. In ref. [6], experimentally unknown cross sections were estimated by using the so-called Generalized Breit-Wigner (GBW) formula [7], which assumes that the s-channel formation of these baryon resonances is dominant and that the interferences between resonances can be ingored. Phenomenologically, this prescription works reasonably well, but if we compare the cross sections in more detail, it has some defects. For example, the GBW formula gives the same cross section in $K^-p \to \pi^-\Sigma^+$ and $K^-p \to \pi^+\Sigma^-$ reactions, while the latter cross section falls much faster than the former experimentally, as shown in Fig. 2.

The reason of this difference can be easily understood by considering t- and u-channel diagram. In the case of $K^-p \to \pi^-\Sigma^+$, K^* exchange is possible, while the baryon exchange is necessary for $K^-p \to \pi^+\Sigma^-$. The baryon exchnage amplitude decrease much faster than that of meson exchange, as explained in the Regge theory [8]. The Regge theory tells us that at high energy limit,

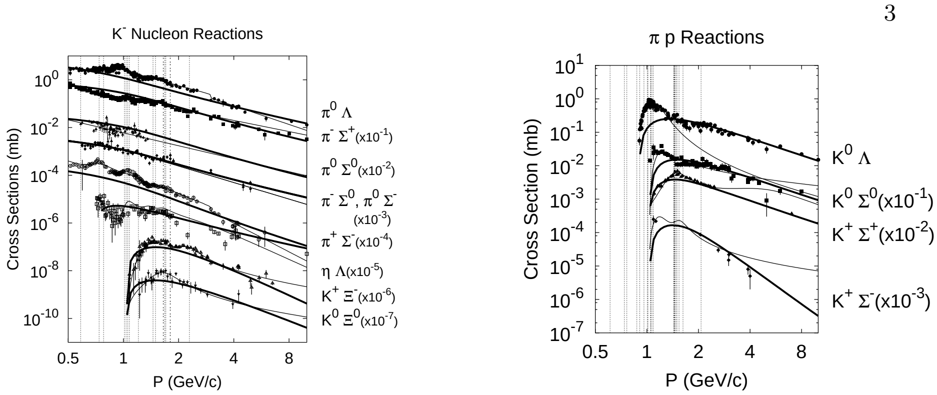

Figure 2. $K^- N$ (left panel) and $\pi^{\pm} p$ cross sections. Thin lines show the cross sections which we used in ref. [6], while thick lines show the Reggeon exchange cross sections.

the t-channel meson exchange amplitude is approximately given by $\mathcal{M}(s,t) \simeq F(t)\,(s/s_0)^{\alpha_R(t)}$ (thick lines in Fig. 2), where $J = \alpha_R(M^2) = \alpha_R(0) + \alpha'_R(0)\,M^2$ represents the angular momentum of hadron resonances in the range $M^2 > 0$.

In this work, we have adopted the meson-baryon cross section, which is dominated by the s-channel reaction at resonance region, and gragually converges to the Reggeon exchange cross section at higher energies. This treatment reproduces the data very well (energy-dependent weighted average of thin and thick lines in Fig. 2), and guarantees the high energy behavior. It should be noted that we here ignore coherence and duality [9]. However, since we are more interested in the many-body or few-body problems rather than in the hadron reaction itself, we do not go into the detailed underlying problems of hadron-hadron reacion, and proceed to the (K^-, K^+) reactions on nuclei in the next section.

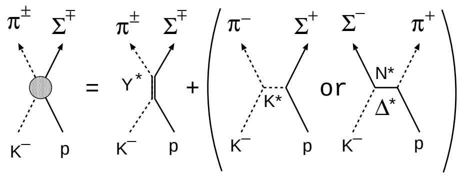

Figure 3. Diagrams which contribute to $K^- N \to \pi^{\pm} \Sigma^{\mp}$ reactions.

3 Results

We have made the INC simulation calculation for ^{12}C(K^-, K^+) $(P(K^-) = 1.65$ GeV/c, corresponding to KEK-E176 and E224 experiments) and ^{9}Be(K^-, K^+) $(P(K^-) = 1.8$ GeV/c, corresponding to BNL-E906 experiment). The number of generated events is around 10^8 for each reaction, and the mean field effects for baryons are included as the external field.

The left panel of Fig. 4 shows the calculated momentum distribution of K^+ particle, in comparison with the KEK-E176 data (^{12}C(K^-, K^+)) [10] and the BNL-E906 preliminary data (^{9}Be(K^-, K^+)) [5]. We also compare the calcu-

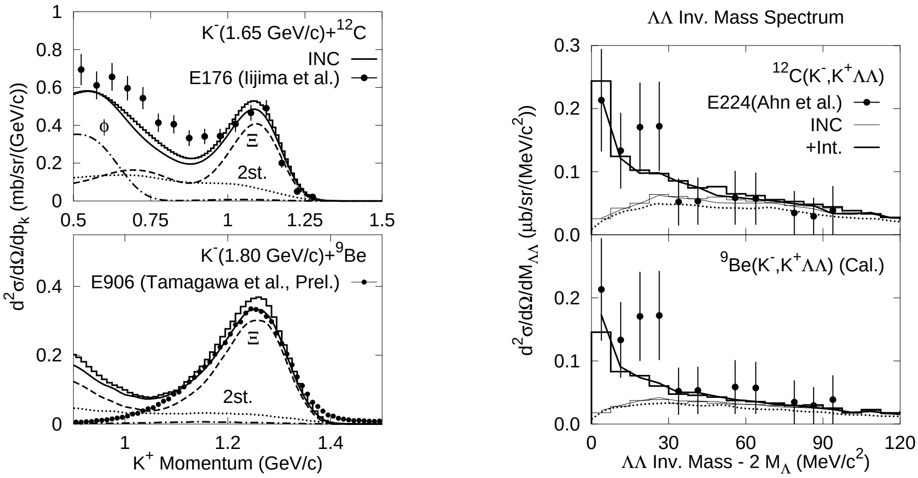

Figure 4. K^+ spectra (left panel) and $\Lambda\Lambda$ invariant mass spectra (right panel) in (K^-, K^+) reactions. Solid histograms and curves show the calculated results with elementary meson-baryon cross sections which are used in ref. [6] and those with Regge behavior (see text). Experimental data are taken from refs. [10, 5, 1]. The detector efficiency correction has not been done for E906 data yet. Thin and thick lines in the right panel show the calculated results without and with correlation effects generated by FSI between $\Lambda\Lambda$. Dotted curves show two-step contributions without FSI effects.

lated results with the elementary cross sections used in ref. [6] (solid histograms) and those explained in the previous section including the Reggeon exchange behavior (solid curves). In both of the reactions, the difference between the two calculated results are small.

In the right panel of Fig. 4, we show the calculated $\Lambda\Lambda$ invariant mass spectrum without (thin) and with (thick) the FSI correlation effects [11], in comparison with the KEK-E224 data (^{12}C(K^-, K^+) reaction). The difference caused by the elementary cross section choice (histograms and curves as in the left panel) is not large.

4 Summary

In this work, we have studied (K^-, K^+) reactions at $P(K^-) = 1.65$ and 1.8 GeV/c, and $\Lambda\Lambda$ correlation in these reactions. One of the problems to extract $\Lambda\Lambda$ interaction from the correlation is the elementary cross section ambiguity, but we have shown that, there will be no serious differences in K^+ spectra and $\Lambda\Lambda$ correlation caused by this ambiguity, if we are interested in the high momentum range of K^+ particle. This is mainly because the dominant processes to produce K^+ with high momentum are quasi-free Ξ production, $K^-N \to K\Xi$, and two-step processes with pions in the intermediate stage,

$K^-N \to \pi Y$ followed by $\pi N \to KY$, whose elementary cross sections are experimentally well known.

In ^{9}Be(K^-, K^+) reaction at $P(K^-) = 1.8$ GeV/c, the quasi-free Ξ production is dominant in high momentum region of K^+, but the two-step contributions are much more important in the coincidence yield of $(K^-, K^+\Lambda\Lambda)$ (dotted curves in Fig. 4). By using the $\Lambda\Lambda$ interaction which well reproduces the $\Lambda\Lambda$ correlation data of KEK-E224 experiment, the present model predicts the invariant mass spectrum of $\Lambda\Lambda$ for the BNL-E906 experiment as shown in the right panel of Fig. 4, which is comparable in magnitude to that in KEK-E224 data.

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