Hyperon Distribution and Correlation in (K^-, K^+) Reactions

A. Ohnishi[a], Y. Hirata[a], Y. Nara[b c], S. Shinmura[d] and Y. Akaishi[e]

[a] Division of Physics, Graduate School of Science, Hokkaido University, Sapporo 060-0810, Japan

[b] Advanced Science Research Center, Japan Atomic Energy Research Institute, Tokai, Ibaraki 319-11, Japan

[c] Physics Department, Brookhaven National Laboratory, Upton, N.Y. 11973, U.S.A.

[d] Faculty of Engineering, Gifu University, Yanagido 1-1, Gifu 501-1193, Japan

[e] Institute of Particle and Nuclear Study, High Energy Accelerator Research Organization (KEK), Oho 1-1, Tsukuba 305-0801, Japan

We analyze the hyperon momentum distribution and correlation in (K^-, K^+) reactions on ^{12}C and ^{9}Be targets. Both of K^+ and Λ momentum distributions are well reproduced with the the IntraNuclear Cascade model followed by the statistical evaporation of Λ from hyperon compound nuclei. In the momentum correlation analysis of $\Lambda\Lambda$ based on the model source functions, it is shown that strongly attractive $\Lambda\Lambda$ interaction is preferred.

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).

We have recently analyzed the $\Lambda\Lambda$ invariant mass spectrum data of KEK-E224 by using a combined framework of IntraNuclear Cascade (INC) [2] model and the correlation function technique [3,4], and we have shown that the observed enhancement at low-invariant masses can be well reproduced with appropriate attractive $\Lambda\Lambda$ interactions [5]. In order to complete this analysis, it is required to explain various data other than $\Lambda\Lambda$ correlation based on the well-established knowledges. Among them, the hyperon momentum distribution is the key quantity to address hyperon-hyperon and hyperon-nucleon momentum correlation. In this paper, we put emphasis on the understanding of Λ momentum spectra which is obtained through the re-analysis of KEK-E224 data [6].

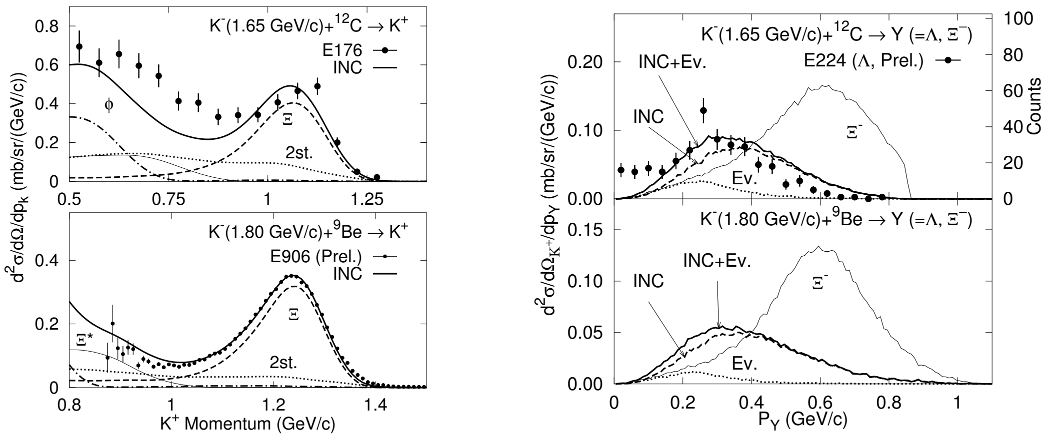

Figure 1. Calculated K^+ (left) and hyperon (right) momentum spectra in comparison with data [7,9,6]. The E906 data are still preliminary, and shown in an arbitrary unit. The detector efficiency and Λ momentum are not corrected in the Λ spectrum of KEK-E224, and it is shown in counts (right axis).

2. K^+ AND Λ SPECTRA

We have analyzed K^+ and hyperon momentum spectra and $\Lambda\Lambda$ correlations in (K^-, K^+) reactions on ^{12}C target at $P(K^-) = 1.65$ GeV/c (for KEK-E176 and E224) and ^{9}Be target at $P(K^-) = 1.8$ GeV/c (for BNL-E906). The number of generated events is around 10^8 for each reaction, and the mean field effects for baryons are included as an external field.

As shown in Fig. 1 (left panel), the coincidence of the calculated K^+ spectra and data is satisfactory, especially at high momentum region of K^+ where Λ spectra and correlations are measured. On the other hand, in the experimental Λ spectrum [6] on ^{12}C target, we find a peak at around $P_\Lambda \simeq 0.26$ GeV/c, which we cannot reproduce theoretically in INC calculation. This difference can be understood by considering the later evaporation processes of Λ. Since Λ particles feel an attractive potential from the residual nucleus, they are easily trapped and make hyperon compound nuclei. When the excitation energy is high enough to emit particles, Λ and nucleons are emitted statistically. The importance of this later statistical processes has been discussed in the context of hyperfragment formation [10], while there will be no evaporations of K^+. This Λ evarporation process from hyperon compound nuclei (dotted lines in right panel) enhances Λ distribution at low momenta, and explains the peak shift as shown in the right panel of Fig. 1.

3. INVARIANT MASS SPECTRUM OF $\Lambda\Lambda$

In Fig. 2, we show the calculated $\Lambda\Lambda$ invariant mass spectra in comparison with data [1, 9]. Although the low energy part is enhanced due to Λ evaporation compared to the pure INC results [5], it is not enough to explain the strong increase at low energies observed in data. Thus it is necessary to invoke the enhancement coming from the attractive final state interaction (FSI) between $\Lambda\Lambda$.

We have made the χ^2 fitting to the KEK-E224 ΛΛ invariant mass spectrum within the two-range gaussian (trg) form by using the correlation function formalism [3,4] based on the model source function of Λ given in INC with statistical decays. The interaction which gives the χ^2 minimum (thin-dashed lines) is found to be strongly attractive, which makes ΛΛ barely unbound, showing the virtual pole like behavior. However, since the reduced $\chi^2(=\chi^2/\mathrm{DOF})$ is much less than one (~ 0.4), the restriction to the ΛΛ interaction is not strong. For example, we also show the results with the YNG-D interaction [11] (thin-solid lines), which gives $\chi^2/\mathrm{DOF} \simeq 0.56$ and is within the allowed range. Data with higher statistics is necessary to pin down the interaction between ΛΛ.

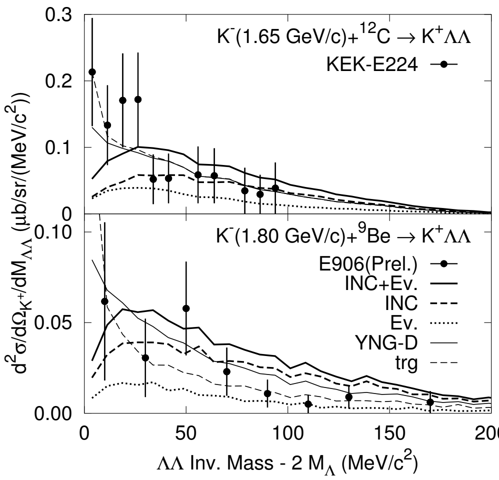

Figure 2: ΛΛ invariant mass spectra. Experimental data are taken from Refs. [1,9]. The E906-Preliminary data are still preliminary, and shown in an arbitrary unit.

4. CONCLUSION

In this paper, we have studied the hyperon momentum distribution and correlation between ΛΛ, as well as K^+ spectra, in (K^-, K^+) reactions on ^{12}C and ^{9}Be. Global understanding of K^+ and Λ momentum distribution is achieved in the IntraNuclear Cascade model followed by the Λ evaporation from hyperon compound nuclei. The correlation function analysis based on the model source function of Λ suggects that attractive ΛΛ interaction is necessary, and the best fit interaction makes ΛΛ system barely unbound. Higher statistics data is desired to determine ΛΛ interaction more precisely.

REFERENCES

1. J.K. Ahn et al. (KEK-E224 collab.), Phys. Lett. **B444** (1998), 267.
2. Y. Nara et al., Nucl. Phys. **A614** (1997), 433.
3. W. Bauer et al., Annu. Rev. Nucl. Part. Sci. **42**, 77 (1992), and references therein.
4. I. Slaus, Y. Akaishi and H. Tanaka, Phys. Rep. **173** (1989), 257.
5. A. O., Y. Hirata, Y. Nara, S. Shinmura, Y. Akaishi, Nucl. Phys. **A670** (2000), 297c.
6. J.K. Ahn (KEK-E224 collab.), private communications.
7. T. Iijima et al. (KEK-E176 collaboration), Nucl. Phys. **A546** (1992), 588.
8. T. Fukuda for BNL-E906 collab., Nucl. Phys. **A639** (1998), 355; in this proceedings.
9. T. Tamagawa (BNL-E906 collab.), private communications.
10. Y. Hirata et al., Prog. Theor. Phys. **102** (1999), 89.
11. Y. Yamamoto et al., Prog. Theor. Phys. Suppl. **117** (1992), 361.