Λ Flow and Λ-P Correlation in Au+Au collisions at AGS energies

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Abstract. Transverse and Radial flow measurements are presented for Λ hyperons along with Λ - P correlations from Au + Au collisions at AGS energies. The flow measurements are compared to those of co-produced protons. The measurements indicate that Λ hyperons flow consistently in the same direction as protons but with a smaller magnitude for all beam energies. Comparisons with RQMD calculations show that the experimentally determined Λ sideward flow is consistently larger compared to the calculated value obtained from scattering processes only. The experimental transverse flow ratio Λ/P is consistent with predictions ($\simeq 2/3$) of the quark counting rule at 2 AGeV but is found to decrease with increasing beam energy. These observations may be related to the detailed features of the Λ-nucleon potential for the nuclear densities produced. At 6 AGeV, Λp correlation functions are observed to be essentially flat [within statistical uncertainty], indicating little or no correlation between Λ's and co-produced protons. This suggests that Λ's may have a space-time emission pattern which is different from that for protons. Further evidence from radial flow measurements also indicates that 6 AGeV Λ hyperons [at mid-rapidity] do not share the same emitting source characteristics as co-produced protons.

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1. Introduction

Strange particles have long been upheld as probes for the properties of high-density nuclear matter created in relativistic heavy ion collisions. Li and Brown [1] have suggested that studies of Λ hyperon flow can provide important insights concerning the in-medium properties of these particles. Such properties are not only important to a detailed understanding of neutron star dynamics, but also to the issue of chiral symmetry restoration [2, 3, 4, 5]. Recent work by Wang and Pratt [6] has also suggested that Λp correlation functions provide a more sensitive probe [than pp correlation functions] for the space-time extent of emitting sources. Acting on these theoretical insights, the E895 Collaboration has carried out systematic measurements of Λp correlation functions and Λ flow in Au+Au collisions (2-8 AGeV) at the AGS.

2. Λ Reconstruction and Invariant Mass Spectra

Measurements were performed with the EOS Time Projection Chamber (TPC) situated in a uniform magnetic field of 3/4 T for 2 AGeV beam and 1 T for 4, 6 and 8 AGeV. The TPC provides continuous 3–D tracking and identification for charged particles with $-1 \leq Z \leq 6$ [7]. Λ particles were reconstructed from their charged particle decays; $\Lambda \longrightarrow p + \pi^-$ $\quad BR \simeq 64\%,\ c\tau \simeq 7.8$cm. Each pair of p π^- was considered and an invariant mass calculated . Thereafter, a neural network was used to separate real Λ's from combinatoric background [8, 9].

Figs.1(a)-(c) show invariant mass spectra for Λ's from 2, 4 and 6 AGeV semi central (b $\leq$ 6 fm) Au+Au collisions respectively. The distributions show relatively narrow mass peaks (FWHM $\simeq$ 6 MeV) at the characteristic value expected for the Λ hyperon $\simeq$ 1.116 GeV). The good peak to background ratio obtained establishes the feasibility of Λ flow and correlation studies with the E895 data set. Panel (d) attests to the neural network's reliability in preserving the integrity of the mass spectrum by removing combinatoric background indiscriminately across the spectrum. The $c\tau$ value obtained from the decay length distribution in panel (e) gives a further indication that the particles represented by the hatched area in panel (c) are indeed Λ particles.

3. Λ Sideward Flow

The Λ sideward flow analysis was carried out using the standard transverse momentum technique of Danielewicz and Odyniec [10]. Possible autocorrelations have been avoided by excluding daughter protons [resulting from Λ decay] from the particle sample used for reaction plane determination. Figs.2 (a)-(c) show the mean in-plane transverse momentum, $< p^x >$, vs normalized cm rapidity, $y_{Lab}/y_{cm} - 1$, for Λ's (stars) and co-produced protons (circles) at 2, 4 and 6 AGeV respectively. The $< p^x >$ values have been corrected for reaction plane dispersion [11, 12, 13]. The effect of the 9% combinatoric background on the flow has also been removed via a weighted subtraction technique. Figs.2 (a)-(c) show that Λ's flow consistently in the same direction as protons, albeit with a smaller magnitude. These results are in qualitative agreement with prior Λ flow measurements [14, 15] obtained at beam energies $\leq$ 2AGeV. However, they are in stark contrast to the anti-flow pattern [16, 8] recently observed for K_s^0 mesons at 6AGeV. It is suggested that this contrast results from differences in the kaon-nucleon and Λ-nucleon potential; namely, for the densities of interest, the kaon-nucleon potential is repulsive whereas that for Λ's is attractive.

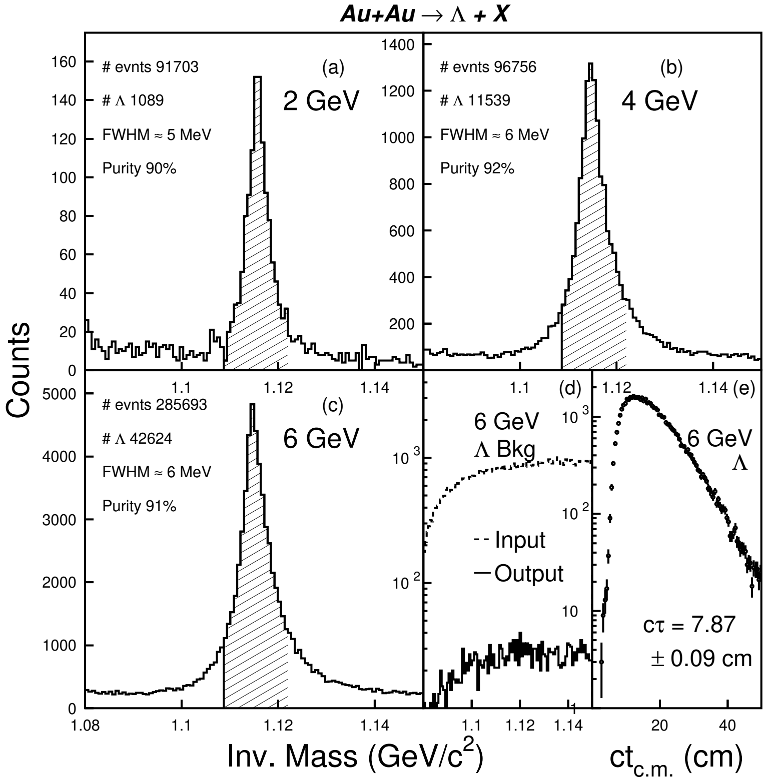

Figure 1. Invariant mass spectra for reconstructed Λs in 2, 4 and 6 AGeV semi-central collisions. The purity (indicated in the figure) is obtained by extrapolating and subtracting the combinatoric background from the hatched area in the figure. Panel (d) shows input (dashed curve) and output (solid curve) mass distributions for fake Λ's (from mixed events) before and after neural network filtering. Panel (e) shows the decay length distribution for 6 AGeV Λ's.

The flow magnitudes have been evaluated from the slopes, at mid-rapidity, in Figs.2 (a)-(c). These magnitudes are shown in Fig.3(a). They indicate that the flow decreases monotonically with beam energy. Although this decrease is expected on the basis of decreasing proton flow with beam energy, this trend of the Λ flow could also result from a weaker attractive Λ-nucleon potential as predicted by Li et al. [1].

Fig.3(b) indicates a Λ/P flow ratio of $\sim 2/3$ at 2 AGeV, which is consistent with the quark counting rule. However, there is a marked deviation from the 2/3 value at higher energies. Such a deviation could be related to the detailed features of the Λ-nucleon potential for the densities produced at 4 and 6 AGeV.

4. Λp Correlations and Radial Flow

The space-time extent of the emitting source at 6 AGeV, was evaluated from a sample of about 120,000 Λ's (80% purity) via a Λp correlation function. The correlation function was obtained from the ratio of a foreground and a background Λp K distribution, where K is half of the relative momentum between the Λ and the proton in the cm frame. The foreground distribution was constructed with Λp pairs in which

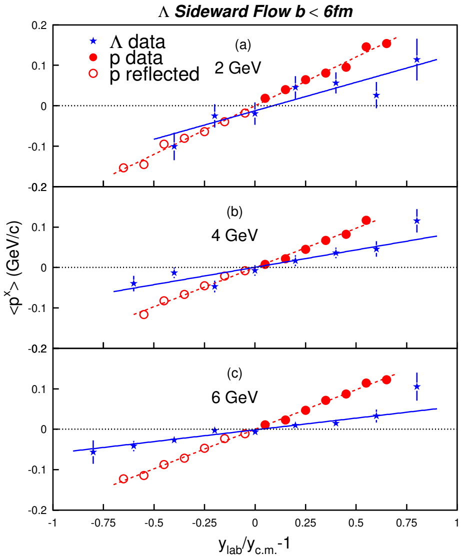

Figure 2. $< p^x >$ vs normalized cm rapidity for Λ's (stars) and protons (circles) in 2, 4 and 6 AGeV Collisions. The solid and dashed curves represent linear fits to the data.

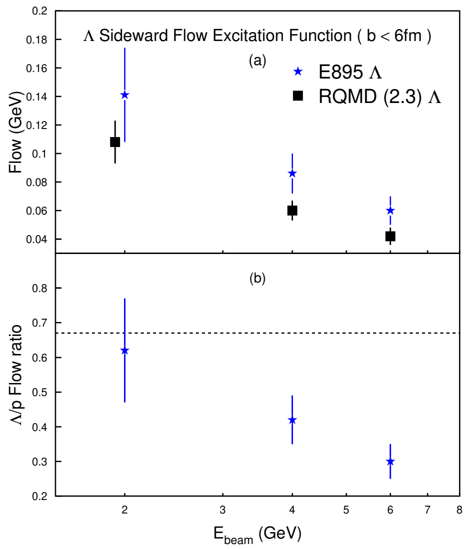

Figure 3. (a) Λ flow vs beam energy for semi-central Au+Au collisions (b) Λ/p flow ratio for same beam energy range.

both the Λ and the proton came from the same event. The background distribution was obtained by choosing Λ's and protons from different events to form Λp pairs.

The finite two-track resolution of the TPC can introduce different distortions in the foreground/background distributions. Possible bias to the correlation function resulting from such distortions, were removed by "filtering" the foreground and background distributions through a track-merging cut. That is, Λp pairs, for which the primary and daughter protons are separated by less than 6.5cm over a distance of 14cm, were removed from both foreground and background distributions [17].

Figs.4(a) and (b) show the correlation function for the opening angle (between the primary and daughter protons), γ_{pp}, and the relative momentum respectively. Although the γ_{pp} correlation function, in panel (a), suffers from losses at low γ_{pp}, the relative momentum correlation function, in panel (b), is virtually unaffected and remains essentially flat within statistical uncertainty.

Fig.4(b) suggests a rather small [or zero] magnitude for the Λp correlation function at 6 AGeV. This observation suggests a source of relatively large space-time extent. Such a space-time extent could arise if Λ's and protons have different space-time emission characteristics. Evidence for [or against] such a scenario can be obtained from a radial flow analysis following the Siemens-Rasmussen Blast Wave model [18]. Such an analysis has been performed to determine the radial flow velocity and temperature for protons, K_s^0's, and Λ's produced in the same events at 6 AGeV. We find a common flow velocity and temperature for K_s^0's and Λ's which is different from that obtained for protons. Consequently, it is suggested that V^0's (Λ's and K_s^0's) do not share the same emitting source characteristics as co-produced protons.

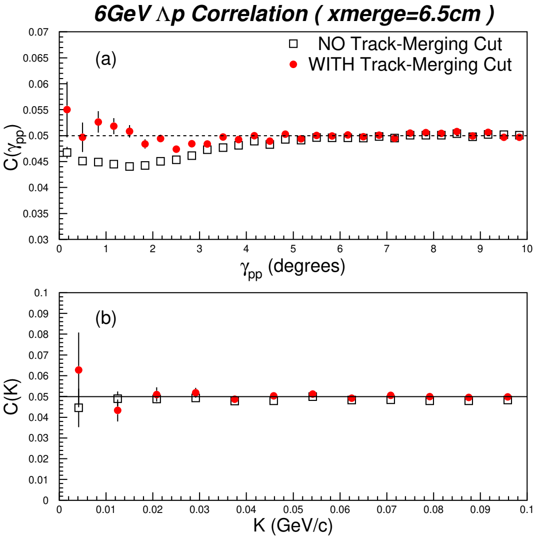

Figure 4. (a) Opening angle between primary and daughter proton, γ_{pp}, correlation function. (b) Λp relative momentum correlation function.

5. Summary

The E895 Collaboration has performed systematic measurements of Λ flow as well as Λp correlation functions in Au+Au reactions at the AGS. The Λ's are found to flow in the same direction as the protons but with smaller magnitudes. The Λ/p flow ratio is consistent with the expected value of 2/3 at 2 AGeV but found to decrease with beam energy. This decrease may very well be related to the details of the in-medium potential for Λ's. Λp correlation functions at 6 AGeV, display very small or zero correlation between co-produced Λ's and protons. Such a correlation function could result from an emitting source of large space-time extent. A radial flow analysis of the same data set points to an emitting source with common features (v and T) for Λ's and K_s^0's which are different from those for co-produced protons. This observation suggests that Λ's and protons may very well have different space-time emission characteristics.

6. References

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