Chapter 1

STRANGENESS PRODUCTION IN AU+AU COLLISIONS AT THE AGS: RECENT RESULTS FROM E917

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Abstract Strangeness production in Au+Au collisions has been measured via the yields of K^+, K^- at 6, 8 AGeV and of $\overline{\Lambda}$ at 10.8 AGeV beam kinetic energy in experiment E917. By varying the collision centrality and beam energy, a systematic search for indications of new phenomena and in-medium effects under high baryon density is undertaken.

Keywords: AGS, Strangeness, kaons, $\overline{\Lambda}$, $\overline{p}$, excitation function.

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1. INTRODUCTION

The study of strangeness production in relativistic heavy-ion collisions has been of continuing interest as strangeness is predicted to be enhanced by the formation of a quark gluon plasma (QGP)[1]. At the same time, many particle properties such as effective mass, production threshold, and absorption cross section may be sensitive to a high baryon density. Their study might reveal the influence of a many-body mean-field potential and provide a signal of chiral symmetry restoration.

Experiment E917 at the AGS measured Au+Au collisions at beam kinetic energies of 6, 8 and 10.8 AGeV in the winter of 1996/97. The Henry Higgins spectrometer, used previously in experiments E802, E859 and E866 [2], and an upgraded data acquisition system enabled the experiment to take 280×10^6 kaon-pair/$\overline{p}$ triggered events. The quality of this data set allows for a detailed study of short lived vector mesons, baryons, anti-baryons and the systematics of two particle correlations of pion, kaon and proton pairs. E917 is unique among the AGS experiments in its ability to measure a wide variety of strangeness-carrying particles including K^+, K^-, Λ, $\overline{\Lambda}$ and ϕ-mesons. The study of the excitation function of kaon production may help identify a possible phase transition, and the study of ϕ-mesons may provide a direct probe of any in-medium effect. More details on the experimental setup and trigger condition can be found in Ref. [3, 4].

This article presents a systematic study of the spectra and yield of K^+ and K^- in Au+Au collisions at beam energies of 6 and 8 AGeV combined with published E866 data [2] at 10.8 AGeV. A previously reported discrepancy in the measured $\overline{p}$ yields between AGS experiments E878 and E864 has been hypothesized to arise from an abundance of $\overline{\Lambda}$ production and different acceptances for the $\overline{p}$ daughter from $\overline{\Lambda}$ decay in the two experiments. Experiment E917 is able to make the first direct measurement of $\overline{\Lambda}$ yields, for which preliminary results are presented.

2. MEASUREMENT OF KAONS

There is significant theoretical interest in the study of kaon properties in dense nuclear matter. Qualitatively, the models suggest that K^+ mesons experience a weak repulsive potential inside the nuclear medium resulting in a slight increase in the effective mass with baryon density, whereas a strong attractive potential for K^- mesons leads to a significantly reduced effective mass in the high baryon density environment [5]. Because the ΛK^+ production channel is expected to be larger than K^-K^+ pair production at AGS energies, this scenario results in a larger K^-/K^+ yield ratio for central events near mid-rapidity, where high baryon density is expected and the K^-K^+ channel is enhanced.

The rapidity distributions of kaons were obtained from exponential fits to the transverse mass, m_t, spectra at each rapidity bin. From these fits we obtain the integrated production probability, dN/dy, per unit of rapidity and the inverse slope, T_{inv}, of these spectra. We emphasize that T_{inv} should not be interpreted as the *temperature* of the emitting source as it is well known that collective effects, such as radial expansion, can mimic high source temperatures.

The rapidity distributions, dN/dy, for K^+ and K^- emission for 0-5% central collisions are shown in Fig. 1.1 for beam energies of 6, 8 and 10.8 AGeV . The rapidity distributions are observed to be peaked at mid-rapidity and the yields increase with beam energy without substantial change in the shape of the rapidity distributions. We also find that the rapidity distributions are essentially independent of centrality.

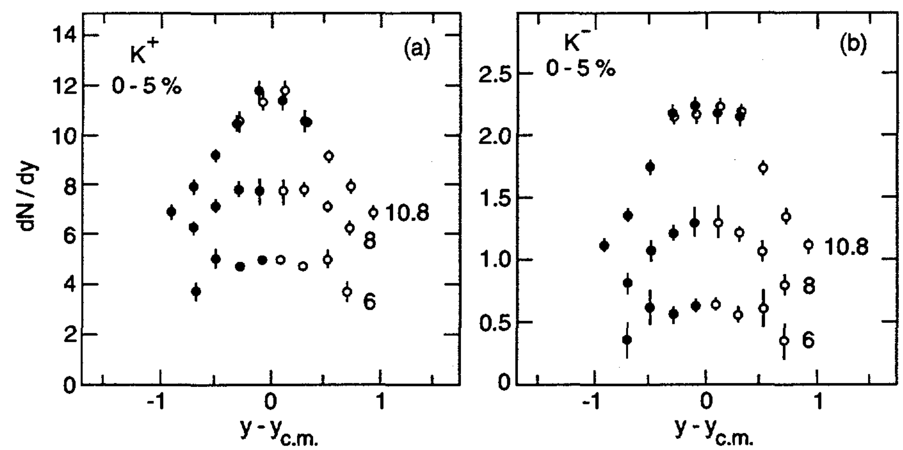

Figure 1.1 Rapidity distributions for K^+ (panel a) and K^- (panel b) for 0-5% central events are shown for beam energies of 6, 8 (E917 preliminary) and 10.8 AGeV (E866 [2]).

Since the effects of the nuclear medium have opposite sign for K^+ and K^-, the ratio of K^-/K^+ production might be a very sensitive probe for studying such effects. It was studied as a function of global parameters for the collision, such as centrality and rapidity. In Fig. 1.2(a), the K^-/K^+ ratio is shown as a function of rapidity for the 5% most central events at 6, 8, and 10.8 [2] AGeV. We observe that the ratio increases with beam energy over the rapidity range of this study and that the rapidity distribution for K^- is narrower than for K^+ , an observation that has also been made in studies of Ni+Ni collisions at SIS energies [6]. The fact that the production of K^- relative to K^+ is more abundant around mid-rapidity might be expected, because:

- the available energy for producing particles is peaked around mid-rapidity.
- the baryon density is largest around mid-rapidity and the in-medium effect enhances the production of K^- relative to that of K^+.

It is, however, difficult to disentangle the relative importance of these two effects [7].

The measurements of the K^-/K^+ -ratio at mid-rapidity is shown in Fig. 1.2(b) as a function of center-of-mass energy from SIS through AGS to SPS energies. The observed increase in the ratio with beam energy may be expected on the basis of the higher production threshold for K^-. This makes the production cross section of K^- increase faster than that of K^+ above the production threshold [7]. At SPS energy, the increase in the ratio is not as steep as that in the lower energy. This is probably caused by a near saturation in the population of the available phase space for both K^+ and K^-.

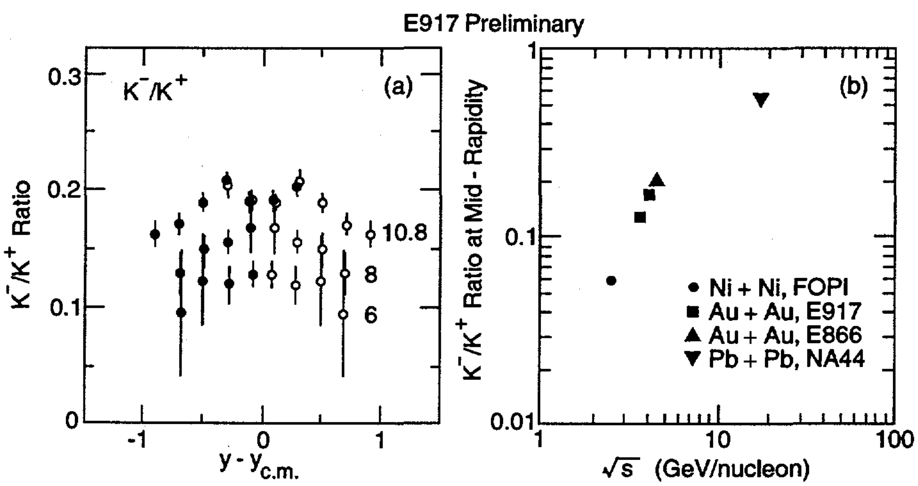

Figure 1.2 The rapidity distribution of K^-/K^+ ratio for the 0-5% central events at various beam energies (panel a) and the K^-/K^+ ratio at mid-rapidity at SIS, AGS and SPS [6, 8] (panel b).

We have also studied the centrality dependence of K^-/K^+ over a wide range of rapidities. The rapidity distribution of this ratio exhibits a very weak dependence on centrality at all three energies, similar to the observations at SIS energies [6, 9]. This weak dependence seemingly contradicts the naive expectation based on the in-medium effect. Thus, one might expect that the K^-/K^+ ratio at mid-rapidity should increase significantly towards central collisions, and that this increase should be most pronounced in the low-energy region close to the production threshold where the effect of the reduction (increase) of K^- (K^+) mass from the in-medium effect is expected to be strongest. Li and Brown have proposed [7] that a suppression of K^- production through the hyperon-feeding channel compensates for the increase in the K^-/K^+ -ratio from the in-medium effect in the central collisions. It is, however, difficult to verify this hypothesis experimentally.

The inverse slope parameter, T_{inv}, derived from the fits to the m_t-spectra is found to peak at mid-rapidity for both K^+ and K^- . There is also a slight increase in T_{inv} with beam energy, but the rapidity dependence is virtually unchanged. The difference in T_{inv} for K^+ and K^- transverse mass spectra is found to be small, although the value of T_{inv} for K^+ is about 50 MeV larger than that of K^- at the 6 AGeV beam energy.

3. MEASUREMENTS OF $\overline{\Lambda}$ AND $\overline{P}$

AGS experiment E859 has measured a large $\overline{\Lambda}/\overline{p}$ ratio of $2.9\pm0.9\pm0.5$ for Si+Au at 13.7 AGeV [10]. This ratio is unexpectedly large relative to thermal model calculations or with reference to the results for NN collisions at AGS energies [11]. In addition, experiments E864 and E878 at the AGS have measured $\overline{p}$ production in the mid-rapidity region and zero p_t for Au+Pb at 10.6 AGeV [12] and Au+Au at 10.8 AGeV [13] respectively. There is a significant discrepancy between the two experiments in the reported anti-proton production probability for central events (about a factor of 3.5), but a good agreement for the most peripheral events. Since these two experiments have different acceptances for detecting the $\overline{p}$ from $\overline{\Lambda}$ and $\overline{\Sigma}$ decay, a large production of $\overline{\Lambda}$ might reconcile the results for the two experiments. If this discrepancy is attributed entirely to this effect, a $\overline{\Lambda}/\overline{p}$ ratio of 3.5 (most probable value) or larger than 2.3 (98% confidence level) is required.

Experiment E917 measured $\overline{p}$ in the rapidity range $1.0 < y < 1.4$ and $\overline{\Lambda}$ were reconstructed from $\overline{p}\pi^+$ pairs. The signal of $\overline{\Lambda}$ is clearly seen in the invariant mass distribution shown in the Fig. 1.3. The transverse mass spectra of $\overline{p}$ and $\overline{\Lambda}$ in the rapidity range $1.0 < y < 1.4$ for the central 0-23% events are shown in Fig. 1.4. The efficiency of detecting $\overline{p}$ from $\overline{\Lambda}$ decay is close to unity in our experiment. Assuming that the decay of $\overline{\Lambda}$ is the only source of hyperon feed-down into $\overline{p}$, the yield of $\overline{p}$

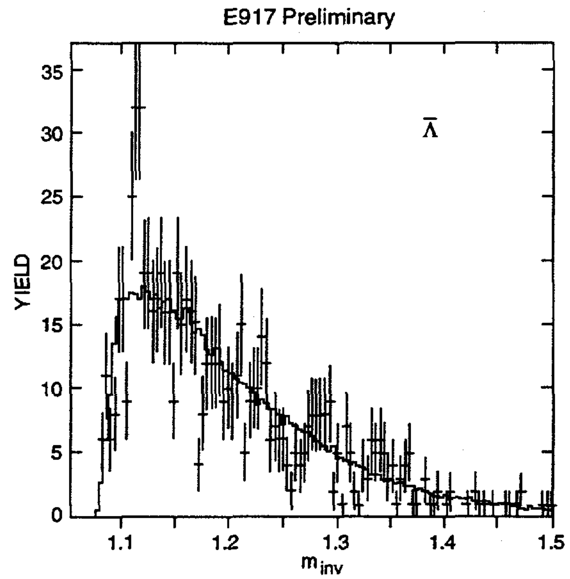

Figure 1.3 The invariant mass distribution of $\overline{\Lambda}$ reconstructed from the pair of $\overline{p}$ and π^+. The line is the fitted background from mixed events.

Table 1.1 The measurement of $\overline{p}$ and $\overline{\Lambda}$ by E917 in the rapidity interval $y = 1.0 - 1.4$.

	Minimum bias		Central events 0-23%	
Particle	dN/dy ($\times 10^{-3}$)	T_{inv} (MeV)	dN/dy ($\times 10^{-3}$)	T_{inv} (MeV)
$\overline{\Lambda}^a$	$4.3^{+1.8}_{-1.2}$	243^{+112}_{-59}	$12.9^{+5.5}_{-3.7}$	243^{+110}_{-60}
$\overline{p}_{measured}$	7.31 ± 0.17	179 ± 8	15.0 ± 0.6	196 ± 11
$\overline{p}_{direct}$	$4.6^{+0.7}_{-1.2}$		$6.8^{+2.3}_{-3.6}$	
Ratio $\overline{\Lambda}/\overline{p}_{direct}$	$0.9^{+0.9}_{-0.3}$		$1.9^{+3.8}_{-0.9}$	

[a] $dN(\overline{\Lambda})/dy = dN(\overline{\Lambda} \rightarrow \overline{p}\pi^+)/dy \,/\, 0.64$.

directly produced is $dN(\overline{p}_{\text{direct}})/dy = dN(\overline{p}_{\text{measured}})/dy - 0.64dN(\overline{\Lambda})/dy$, thereby correcting for the 64% branching ratio of the $\overline{\Lambda}$ decay into the $\overline{p}\pi^+$ channel. The rapidity yield, dN/dy, for $1.0 < y < 1.4$ and the inverse slope parameter, T_{inv}, obtained from a fit to the m_t-spectra with an exponential function, are listed in Table 1.1. Details on this analysis are available in Ref. [14].

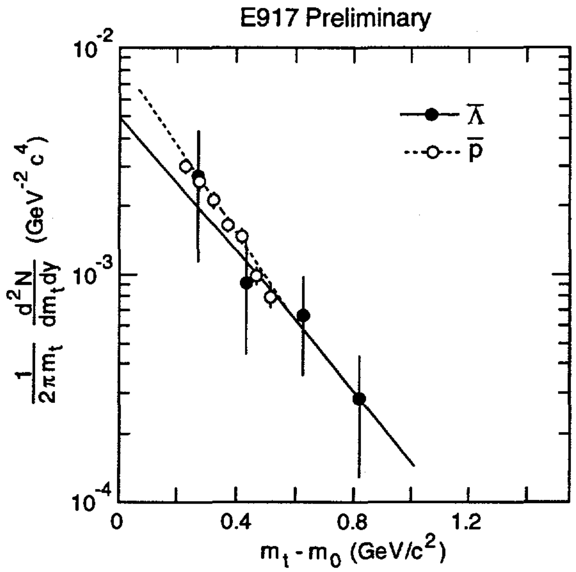

Figure 1.4 Transverse mass (m_t) spectra of $\bar{p}$ (open circles) and $\bar{\Lambda}$ (solid circles) for the 0-23% central events.

The E917 measurement of the $\bar{\Lambda}/\bar{p}$-ratio is greater than unity for the 0-23% central collisions and consistent with the E859 measurement in Si+Au system. The ratio derived from the difference between the E864 and E878 $\bar{p}$ measurements lies within the upper bound of E917 results. It should be noted, however, that there exist several differences in the experimental measurements presented here and those of E864, E878, and E859, as listed in Table 1.2. Most important are the ranges in m_t, rapidity, and centrality measured by the different experiments. More data will be analyzed in the future to compare the results from the other experiments under similar centrality and rapidity cuts.

4. SUMMARY AND OUTLOOK

A complete measurement of kaon production at 6 and 8 AGeV has been presented. No dramatic change is evident in the excitation function of kaons from 6 to 10.8 AGeV. A straightforward expectation based on the scenario of many-body in-medium effect on kaons cannot explain the observation of a weak centrality dependence of K^-/K^+ ratios with changing beam energy.

Table 1.2 The difference in experimental conditions for measuring $\overline{\Lambda}/\overline{p}$-ratio.

Exp.	Collision	E_{beam} (GeV/nucleon)	Centrality (%)	Rapidity	$m_t - m_0$ (MeV/c^2)
E859	Si+Au	13.7	0-15	$1.0 - 1.4$	> 250
E864	Au+Pb	10.6	0-10	$1.6 - 2.0$	$= 0$
E878	Au+Au	10.8	0-10	$1.4 - 2.4$	$= 0$
E917	Au+Au	10.8	0-23	$1.0 - 1.4$	> 250

The $\overline{\Lambda}/\overline{p}$ ratio was measured to be greater than unity for 0-23% central collisions. More data need to be analyzed to enable a detailed comparison with the other results.

The results presented in this talk are all very preliminary in nature. For this reason, we have not presented any comparison with, or analysis in terms of, theoretical models. These will be presented in future publications.

Acknowledgments

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