

MEASUREMENTS OF K_S^0 , Λ AND Ξ FROM Au + Au COLLISIONS AT $\sqrt{s_{NN}} = 7.7, 11.5$ AND 39 GeV IN STAR*

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We report on the measurements of K_S^0 , Λ and Ξ spectra at mid-rapidity ($|y| < 0.5$) in the most central (0–5%) Au + Au collisions at $\sqrt{s_{NN}} = 7.7, 11.5$ and 39 GeV from the STAR experiment. The extracted yields are consistent with the corresponding data from Pb + Pb collisions measured by the NA49 and CERES experiments at SPS. The Λ , $\bar{\Lambda}$, Ξ^- and $\bar{\Xi}^+$ to π ratios agree well with the predictions of the statistical hadronization model at all three energies.

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1. Introduction

The enhanced production of strange hadrons in $A + A$ with respect to $p + p$ collisions has been suggested as a signature of quark-gluon plasma (QGP) formation in these collisions [1]. Until now, strangeness has been extensively measured in many experiments at different accelerator facilities [2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18]. In these experiments, substantial strangeness enhancement has indeed been observed, especially for multi-strange hyperons. However, it is also observed that strangeness enhancement tends to increase toward lower energies. Generally, the yields of strange hadrons in nuclear collisions are close to those expected within the statistical hadron gas models using a grand canonical ensemble [19, 20, 21]. According to canonical statistical models, the strangeness enhancement in nuclear collisions is also due to canonical suppression of strangeness production in $p + p$ collisions [22]. At SPS energies, there is a significant disagreement in the strangeness measurements between NA49 and NA57 experiments [7, 8, 9].

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The precise measurement of strangeness production in heavy ion collisions at SPS energy range will certainly lead to a better understanding of strangeness enhancement/production mechanism in nuclear collisions.

During the first phase of the Beam Energy Scan (BES) program in 2010, STAR has collected high statistics Au + Au data at $\sqrt{s_{NN}} = 7.7, 11.5$ and 39 GeV, which allows high precision strangeness measurements at these energies. In STAR, strange hadrons are reconstructed with their secondary TPC tracks through the topology of their weak decay channels, $K_S^0 \rightarrow \pi^+\pi^-$, $\Lambda \rightarrow p\pi$ and charged $\Xi \rightarrow \Lambda\pi$ [14, 15]. This analysis is based on about 5, 12 and 14 million minimum bias Au + Au events at $\sqrt{s_{NN}} = 7.7, 11.5$ and 39 GeV, respectively. In this paper, we will focus on the collision energy dependence and present the strangeness data from the most central (0–5%) collisions at three BES energies.

2. Results

After correcting the raw spectra for geometrical acceptance and reconstruction efficiencies, we get the p_T spectra of K_S^0 , $\Lambda(\bar{\Lambda})$, $\Xi^-(\bar{\Xi}^+)$ at mid-rapidity ($|y| < 0.5$) for the most central Au + Au collisions (0–5%) at $\sqrt{s_{NN}} = 7.7, 11.5$ and 39 GeV, as shown in Fig. 1. The $\Lambda(\bar{\Lambda})$ spectra have been corrected for the feed-down contributions from Ξ and Ξ^0 weak decays. We assume that Ξ^0 has the same spectra as the Ξ s. The feed-down from Ω is neglected in this analysis. The percentage of the feed-down contribution in the raw $\Lambda(\bar{\Lambda})$ spectra depends on the $\Lambda(\bar{\Lambda})$ topological selection cuts, and decreases with the increase of p_T . With the current cuts, the overall feed-down contributions are 22% (31%), 18% (34%) and 14% (47%) for $\Lambda(\bar{\Lambda})$ at $\sqrt{s_{NN}} = 39, 11.5$ and 7.7 GeV, respectively.

In order to extract the total yield, the p_T spectra have to be extrapolated to the unmeasured p_T range with a function that fits to the measured data. The K_S^0 spectra can be well described with a Levy function [23], as shown in Fig. 1. The measured Λ and Ξ spectra can be extrapolated at low p_T with the Maxwell–Boltzmann function ($1/p_T d^2N/dp_T dy \propto m_T e^{-m_T/T}$) or m_T -exponential function ($1/p_T d^2N/dp_T dy \propto e^{-m_T/T}$). Figure 1 shows the corresponding Maxwell–Boltzmann function fitting curves for Λ and Ξ^- (the fitting range is $p_T < 1.6$ GeV/c for Λ and $p_T < 2.6$ GeV/c for Ξ^-). The fitting can also be done with m_T -exponential function. The difference between the extrapolations with two different fitting functions is considered as the systematic error due to the extrapolation to unmeasured p_T range. Their values are about 3% for K_S^0 , 1% for $\Lambda(\bar{\Lambda})$ and 3% for $\Xi^-(\bar{\Xi}^+)$. In fact, the main source of systematic uncertainties in the yield resides in the reconstruction efficiencies due to imperfect detector simulations. A previous

estimation shows that this uncertainty is less than 10% [16]. We take a value of 10% in this analysis.

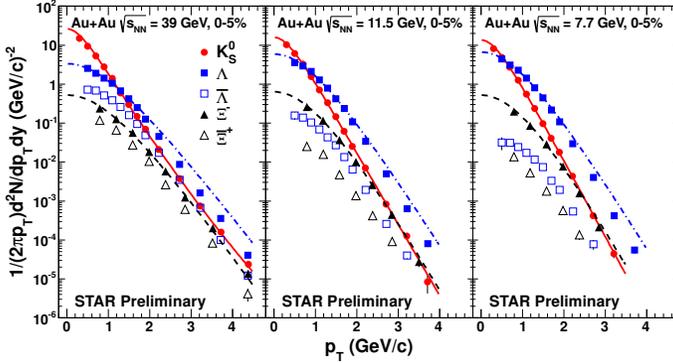


Fig. 1. Transverse momentum spectra of K_S^0 , $\Lambda(\bar{\Lambda})$, $\Xi^-(\bar{\Xi}^+)$ at $|y| < 0.5$ from the most central (0–5%) Au + Au collisions at $\sqrt{s_{NN}} = 39, 11.5$ and 7.7 GeV. The solid, dot-dashed and dashed lines are the Levy (for K_S^0) and Maxwell–Boltzmann (for Λ and Ξ^-) functions fitted to the corresponding spectra. Errors are statistical only.

Figure 2 shows the collision energy dependence of the particle yield (dN/dy) at mid-rapidity for K_S^0 , Λ , $\bar{\Lambda}$, Ξ^- and $\bar{\Xi}^+$ from the most central (0–5%) Au + Au collisions, compared to the corresponding data from NA49, NA57 and CERES, as well as the STAR data at higher energies. The NA57 and NA49 data are from the most central Pb + Pb collisions, their data have

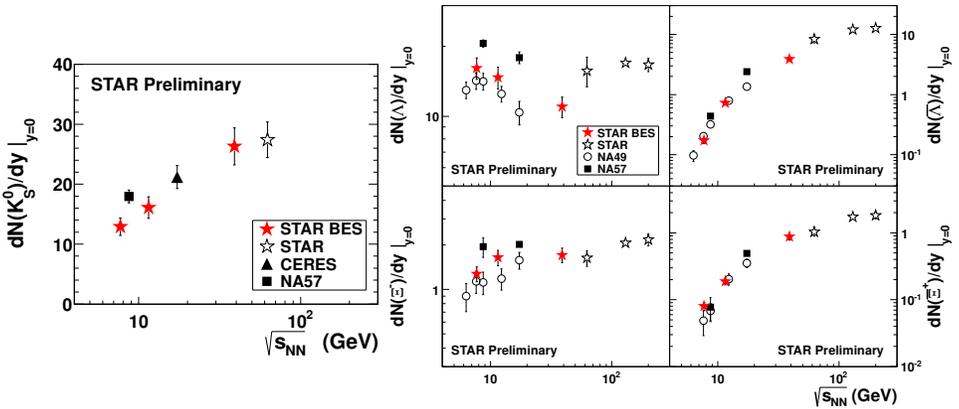


Fig. 2. The strange hadrons dN/dy at mid-rapidity in the most central Au + Au collisions as a function of $\sqrt{s_{NN}}$. There are also shown the results from STAR experiments at higher energies [12, 14, 15, 16], Pb + Pb collisions from NA57 [7] and NA49 [8], and Pb + Au collisions from CERES [10]. The rapidity ranges are $|y| < 0.5$ for STAR and NA57, $|y| < 0.4$ for NA49 $\Lambda(\bar{\Lambda})$ and $|y| < 0.5$ for NA49 $\Xi^-(\bar{\Xi}^+)$. CERES data are the extrapolated values based on the measurements at backward rapidity.

been re-scaled according to the estimated numbers of wounded nucleons, $\langle N_W \rangle$. The scale factor is $N_{\text{part}}/\langle N_W \rangle$, where N_{part} is the number of participants in the most central (0–5%) Au + Au collisions in STAR. A Monte Carlo Glauber model estimation gives $N_{\text{part}} = 337.4 \pm 2.3$, 338.4 ± 2.1 and 341.8 ± 2.3 at $\sqrt{s_{NN}} = 7.7$, 11.5 and 39 GeV. For simplicity, a N_{part} value of 338 is used in the scale factor. Figure 2 shows that STAR BES data lie in a trend with the corresponding data from higher energies, though there seems to be a non-monotonic $\sqrt{s_{NN}}$ dependence in the Λ dN/dy . While STAR BES data and NA49 data are consistent in general, the NA57 data are significantly higher except the Ξ^+ yield at $\sqrt{s_{NN}} = 8.7$ GeV. The CERES K_S^0 data seems in line with STAR BES data as well. It should be noted that the ϕ measurements in STAR BES also show consistent results with NA49 [24].

Figure 3 shows the anti-baryon to baryon ratios (\bar{B}/B) from STAR BES and in comparison to the STAR higher energies and NA49 data. It seems that STAR BES data and NA49 data are consistent with each other. The $\bar{\Xi}^+/\Xi^-$ ratio is much larger than $\bar{\Lambda}/\Lambda$ at lower energies, which agrees with the predictions of the thermal models [19, 21, 22]. In these models, $\ln(\bar{B}/B)$ is proportional to the difference between strangeness numbers of \bar{B} and B . And the coefficient of proportionality (μ_S/T) becomes more important at lower energies due to the large μ_B and the zero initial strangeness number.

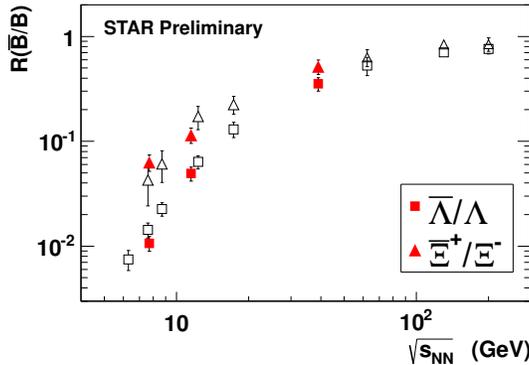


Fig. 3. The $\sqrt{s_{NN}}$, dependence of $\bar{\Lambda}/\Lambda$ and $\bar{\Xi}^+/\Xi^-$ ratios at mid-rapidity in the most central Au + Au collisions from STAR and Pb + Pb collisions from NA49. Solid symbols are STAR BES data; open symbols are STAR data at higher energies (> 62 GeV), and NA49 data at SPS energy range.

Figure 4 shows the $\sqrt{s_{NN}}$ dependence of the ratios of Λ , $\bar{\Lambda}$, Ξ^- and $\bar{\Xi}^+$ mid-rapidity dN/dy to that of pions in STAR BES, as well as the existing data from various experiments at different energies and the predictions of the hadronic transport models (UrQMD v1.3 and HSD). Although the hadronic models seem to reproduce the Λ/π data, the default UrQMD (v1.3) fails in

reproducing the Ξ^-/π and Ξ^+/π ratios due to the underpredicted Ξ yield in the model. The data is also compared with the statistical hadron gas model (SHM). This model is based on a grand canonical ensemble and it assumes chemical equilibrium. The parameters T_{ch} and μ_B in the model are obtained from a smooth parametrization of the original fitting parameters to the mid-rapidity particle ratios from heavy ion experiments at SPS and RHIC. Figure 4 shows that SHM model predictions agree well with data across the whole energy range from AGS to top RHIC energies.

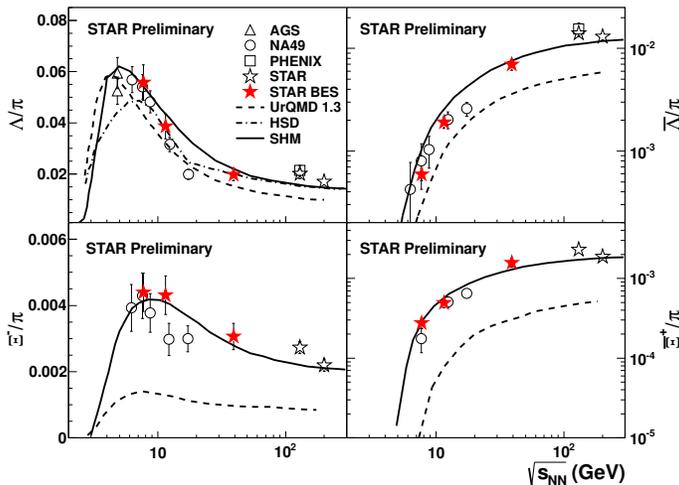


Fig. 4. The dN/dy of Λ , $\bar{\Lambda}$, Ξ^- and Ξ^+ at mid-rapidity divided by that of pions ($1.5(\pi^+ + \pi^-)$) in central Au + Au and Pb + Pb collisions as a function of $\sqrt{s_{NN}}$. The dN/dy of pions in STAR BES is taken from [25]. Also shown are AGS [2,3,5,6], NA49 [8], PHENIX [17,26] and STAR [12,14,15,27,28] data, as well as predictions from two hadronic transport models: HSD and UrQMD (v1.3) [29] and a statistical hadron gas model (SHM) [21].

3. Summary

In summary, we presented the transverse momentum spectra and dN/dy of K_S^0 , Λ and Ξ at mid-rapidity, as well as the \bar{B}/B and strange hadron to pions ratios, from central Au + Au collisions at $\sqrt{s_{NN}} = 7.7, 11.5$ and 39 GeV at RHIC. The strange hadrons dN/dy from STAR BES and the corresponding NA49 and CERES data seem consistent in general, and are much lower than the data from NA57. The \bar{B}/B ratios agree with the published energy-dependence trend. The ratios of Λ , $\bar{\Lambda}$, Ξ^- and Ξ^+ to pions at mid-rapidity are reproduced well by the statistical hadronization model.

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