Strange hadron production in small system using the STAR Detector

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Abstract. Strangeness enhancement has long been considered a signature of quark-gluon plasma formation in heavy-ion collisions. Recently, strangeness enhancement has also been observed in small systems at the Large Hadron Collider (LHC), but the underlying physics is not yet fully understood. This motivates us to study of strange hadron production in small system at Relativistic Heavy Ion Collider (RHIC). In this proceedings, we present new measurements of strange hadrons (K^0_S, $\Lambda(\bar{\Lambda})$) in d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV, collected by the STAR experiment in 2016. We will report p_T spectra, dN/dy, $\langle p_T \rangle$, nuclear modification factor and Y_{Asym} of these particles in d+Au collisions.

1 Introduction

The primary goals of high-energy heavy-ion (A–A) collisions are to create a system of deconfined quarks and gluons known as quark–gluon plasma (QGP) and to study its properties. Asymmetric small collision systems like proton-nucleus (p–A) and deuteron-nucleus (d–A) can be considered as control experiments where the formation of an extended QGP phase is not expected. These collision systems are used for baseline measurements to study the possible effects of cold nuclear matter and disentangle them from hot dense matter effects present in collisions of heavy ions. The process of generating hadrons can be affected by various factors, including alterations in parton distribution functions within nuclei, the possiblity of parton saturation, multiple scatterings, and radial flow. It is anticipated that the magnitude of these effects may vary with the rapidity of the produced particles.

Strangeness enhancement in heavy ion collisions with respect to proton-proton (p+p) collisions has been suggested as a signature of quark-gluon plasma (QGP) formation [1]. But creation of QGP in small systems is still under intense debate. Nuclear effects can be quantified using various variables such as nuclear modification factor and rapidity asymmetry. Nuclear modification factor is defined as the ratio of the yield of particle in heavy-ion collisions to its yield in p+p collisions, scaled by the number of binary nucleon-nucleon inelastic collisions [2].

$$R_{AB}(p_T) = \frac{\mathrm{Yield}_{AB}}{\langle N_{bin} \rangle \mathrm{Yield}_{pp}} \tag{1}$$

where $\langle N_{bin} \rangle$ is the average number of binary nucleon-nucleon collisions. Comparative study of particle production in forward and backward rapidity regions is done using rapidity asymmtery (Y_{Asym}) [3]. Y_{Asym} is defined as

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$$Y_{Asym}(p_T) = \frac{Y_B(p_T)}{Y_F(p_T)} \tag{2}$$

where Y_B and Y_F are particle yields in backward and forward rapidity regions, respectively. Y_{Asym} may provide unique information to help determine the relative contributions of various physics processes affecting particle production, such as multiple scattering, nuclear shadowing, recombination of thermal partons, and parton saturation.

2 Analysis Details

A successful run of d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV was carried out in 2016 at RHIC. A total of approximately 100 million good events have been selected in STAR for the reconstruction of K^0_s, $\Lambda(\bar{\Lambda})$. K^0_s, $\Lambda(\bar{\Lambda})$ are weakly decaying particles and they travel a certain distance before decaying into daughter particles ($K^0_S \to \pi^+ + \pi^-$ and $\Lambda(\bar{\Lambda}) \to p(\bar{p}) + \pi^-(\pi^+)$). Identification of daughter particles (π, K and p) is done via measuring $\langle dE/dx \rangle$ using Time Projection Chamber (TPC).

The K^0_s, $\Lambda(\bar{\Lambda})$ signals are extracted by reconstructing the invariant mass of the decay daughter pairs. The decay topology can be used for their reconstruction and to suppress the background. We have used double Gaussian and second order polynomial function to describe the signal and background invariant mass distributions. Raw yield is determined by using the bin counting method under the mass window of $M_0 \pm 3\sigma$, where M_0 is mass of K^0_S (or Λ) and σ is the fitted width. Raw yield for each p_T interval is corrected for branching ratio, acceptence and efficiency. Weak decay feed down correction from Ξ is applied to Λ.

3 Results and Discussions

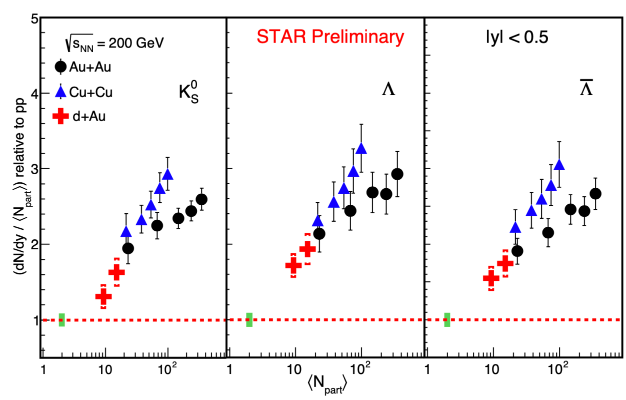

Figure 1: (dN/dy / $\langle N_{part} \rangle$) relative to p+p as a function of $\langle N_{part} \rangle$ of (K^0_s, Λ and $\bar{\Lambda}$) in d+Au, Cu+Cu and Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV at $|y| < 0.5$.

In Fig. 1, dN/dy scaled by the average number of nucleon participants ($\langle N_{part} \rangle$) for K^0_S, Λ and $\bar{\Lambda}$ as a function of $\langle N_{part} \rangle$ is d+Au collisions is shown. d+Au collisions fill the gap fill the gap between p+p collisions and peripheral Au+Au and Cu+Cu collisions [1]. The yields of K^0_s, Λ and $\bar{\Lambda}$ in d+Au collisions lie in trend with peripheral Cu+Cu and Au+Au collisions and are consistent with strangeness enhancement.

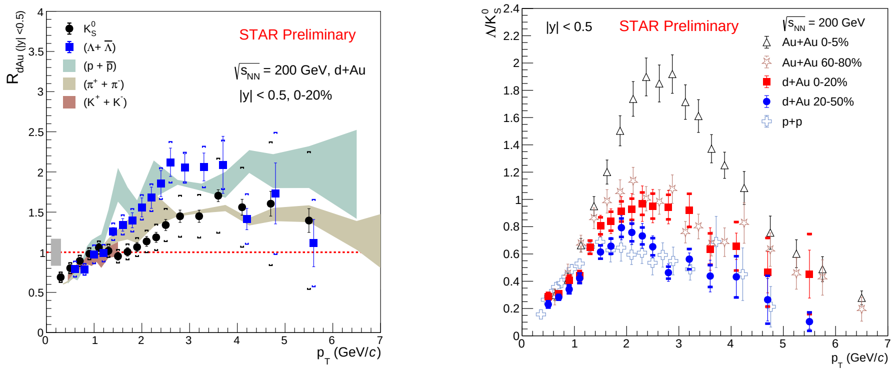

Figure 2: Nuclear modification factor (R_{dAu}) (left) for strange particles (K^0_S and Λ) in d+Au collisions and baryon to meson ratio (Λ/K^0_S) (right) in p+p, d+Au, Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

In Fig. 2 (left), nuclear modification factors for K^0_S and Λ at mid rapidity (|y| < 0.5) for d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV are shown. Cronin-like enhancement is observed at intermediate p_T (2-4 GeV/c) for K^0_s and Λ. R_{dAu} for K^0_s are consistent with charged kaons and enhancement observed is stronger for baryons (Λ, p) as compared to mesons (K^0_S, π).

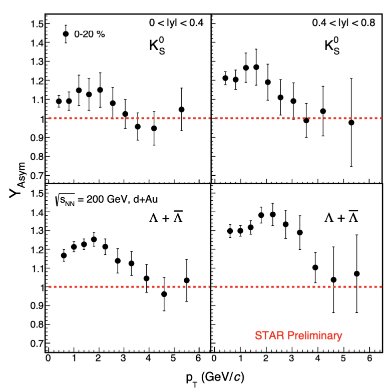

Figure 3: Rapidity asymmtery (Y_{Asym}) of strange particles (K^0_s and Λ) in d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV for 0-20% centrality.

In Fig. 2 (right), the baryon to meson ratio (Λ/K^0_S) as function of transverse momentum for d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV is shown. At intermediate p_T, baryon to meson ratio in central A+A collsions compared to that in p+p collisions at $\sqrt{s_{NN}}$ = 200 GeV can be interpreted as strange hadrons formed from parton collectivity and parton recombination. Therefore, these ratios are predicted to be sensitive to the parton dynamics of the collision system. Λ/K^0_S at intermediate p_T is larger for 0-20% central collisions as compared to that in 20-50% centrality. Similar radial flow is observed for most central d+Au collisions and Au+Au peripheral collisons.

We have also measured the transverse momentum dependence of $\mathrm{Y_{Asym}}$ for $\mathrm{K_s^0}$ and Λ in two rapidity intervals (0 < |y| < 0.4, 0.4 < |y| < 0.8) in d+Au collision at $\sqrt{s_{NN}}$ = 200 GeV. $\mathrm{Y_{Asym}}$ values deviate from unity at low $\mathrm{p_T}$ (< 3 GeV/c), suggesting the presence of a rapidity dependence in the nuclear effects. $\mathrm{Y_{Asym}}$ is consistent with unity at high $\mathrm{p_T}$, providing a hint that nuclear effects become weaker at high $\mathrm{p_T}$ as shown in Fig. 3. $\mathrm{Y_{Asym}}$ is more prominent for larger rapidity interval and it is larger for Λ as compared to that for $\mathrm{K_s^0}$.

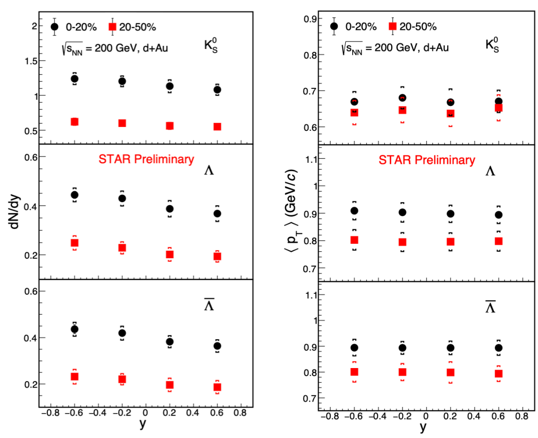

Figure 4: dN/dy (left) and $\langle p_T \rangle$ (Right) of strange particles ($\mathrm{K_S^0}$, Λ and $\bar{\Lambda}$) as a function of rapidity in d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

In Fig. 4, The integrated yield (dN/dy) and mean transverse momentum ($\langle p_T \rangle$) are calculated for different rapiditiy intervals (0 < |y| < 0.4, 0.4 < |y| < 0.8). Integrated yield (dN/dy) decreases slightly from negative to positive rapidity but mean transverse momentum ($\langle p_T \rangle$) is constant in the measured rapidity range for $\mathrm{K_s^0}$, Λ and $\bar{\Lambda}$.

4 Summary

In this contribution, we present the new measurements of strangeness production in d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV with the STAR experiment. Strangeness enhancements in d+Au collisions are observed with respect to in p+p collisions. Hint of Cronin-like enhancement is observed for 0-20% centrality for $\mathrm{K_S^0}$, Λ. In addition, $\mathrm{Y_{Asym}}$ > 1 at low p_T, indicating the presence of the nuclear effects.

References

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