Strange hadron production in Au+Au collisions at $\sqrt{s_{NN}} = 3 - 27$ GeV with UrQMD.

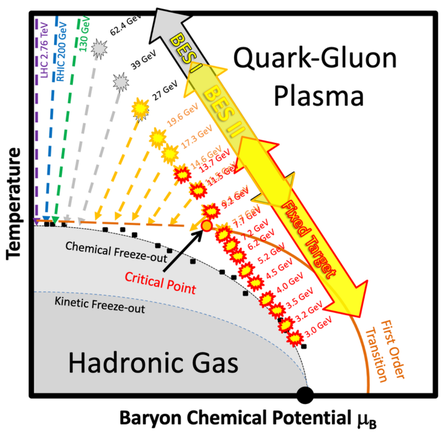
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Abstract

Strange hadrons serve as critical probes for characterizing the hot and dense nuclear matter produced in heavy-ion collisions. Their utility arises from two key factors: they provide unique insights into the QCD phase transition and possible QGP formation, and they exhibit strangeness enhancement - a phenomenon where their production is significantly higher in deconfined matter than in standard hadronic interactions. This enhancement, coupled with their sensitivity to hadronization conditions, makes them ideal observational tools.
In this work, we study the model dependence of the spectra for K^0_S, Λ, Ξ and Ω hadrons as functions of transverse momentum, rapidity and collision centrality. The analysis covers the collision energy range $\sqrt{s_{NN}} = 3-27$ GeV, which probes the dynamics of matter at the onset of deconfinement. Precise measurements of strange particle yields and their ratios in Au+Au collisions thus have the potential to deepen our understanding of the thermodynamics of hot matter and the hadronization process near the phase boundary.

Introduction



The Beam Energy Scan (BES) program searches for the QCD critical point and the onset of deconfinement by colliding heavy ions at varying energies. This maps the QCD phase diagram where a smooth crossover at low baryon chemical potential (μ_B) is expected to turn into a first-order phase transition at high μ_B. Strange hadrons are sensitive probe for these studies. Comparison between experimental data and the UrQMD transport model are crucial to extract the properties of the produced matter and identify the signatures of the critical point.

Near threshold production

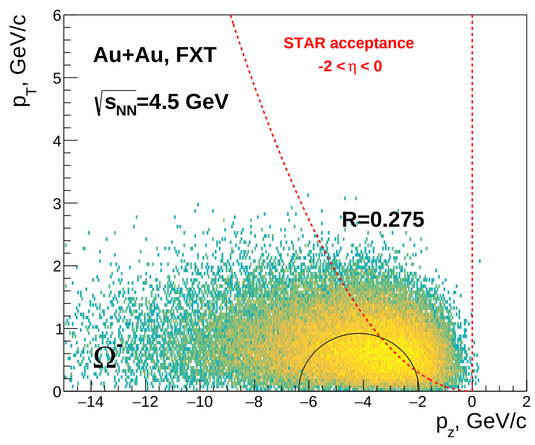


Figure 2: $\mathbf{p_T}$ versus $\mathbf{p_Z}$ distribution for Ω^- from UrQMD. Black ellipse line is a region allowed in p+p collisions.

The study of strange hadrons at collision energies close to their kinematic threshold is a unique probe into the role of multi-nucleon interactions. The fraction R shows a ratio of strange particles produced in the cumulative region and falling within STAR acceptance ($-2 < \eta < 0$) to the total yield of particles of a given type.

Reaction	E_{thresh} (GeV/c^2)
$p + p \rightarrow \mathbf{K^0_s} + p + \Sigma^+$	2.63
$p + p \rightarrow \mathbf{\Lambda} + p + K^+$	2.55
$p + p \rightarrow \mathbf{\bar{\Lambda}} + 2p + \Lambda$	4.11
$p + p \rightarrow \mathbf{\Xi^-} + p + 2K^+$	3.25
$p + p \rightarrow \mathbf{\bar{\Xi}^+} + 2p + \Xi^-$	4.52
$p + p \rightarrow \mathbf{\Omega^-} + n + 3K^+$	4.10
$p + p \rightarrow \mathbf{\bar{\Omega}^+} + 2p + \Omega^-$	5.22

p_T Spectra

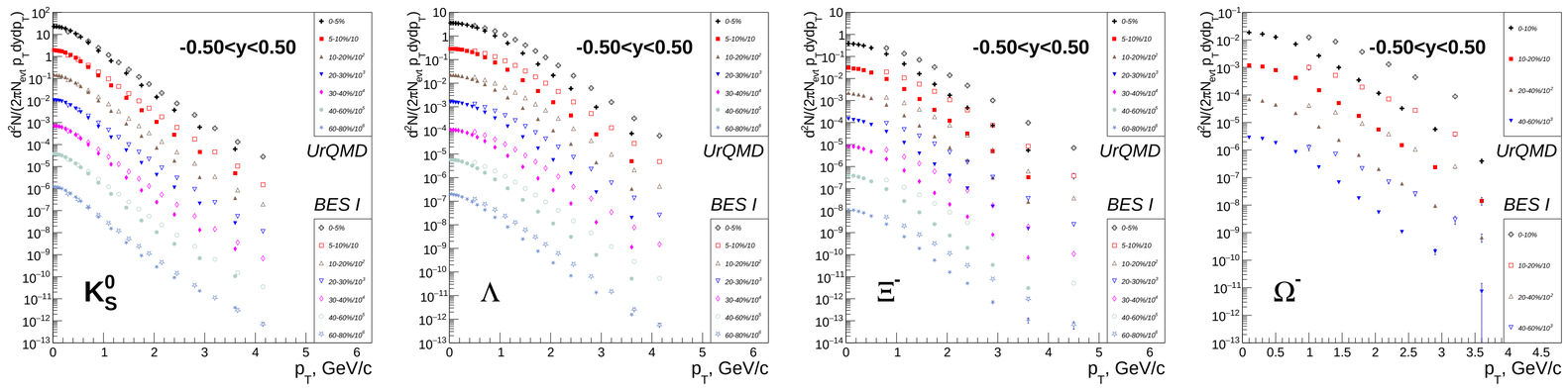
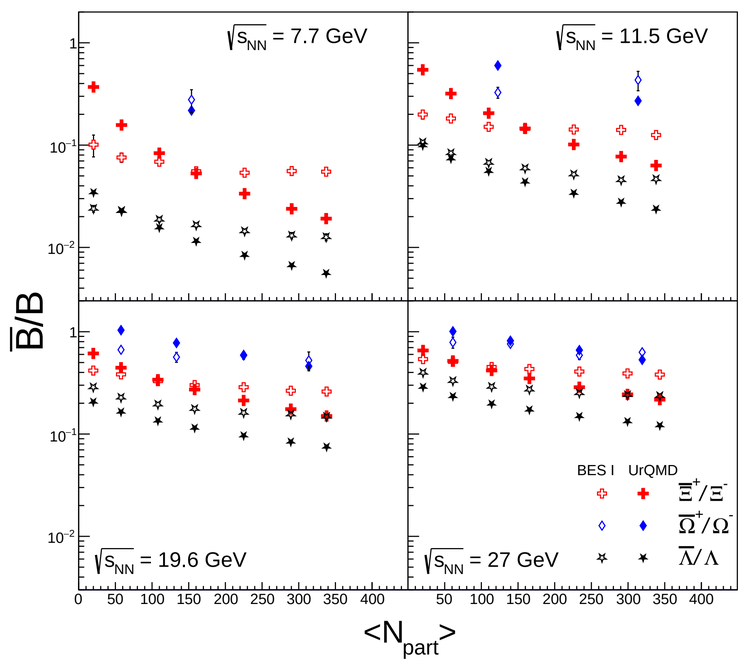


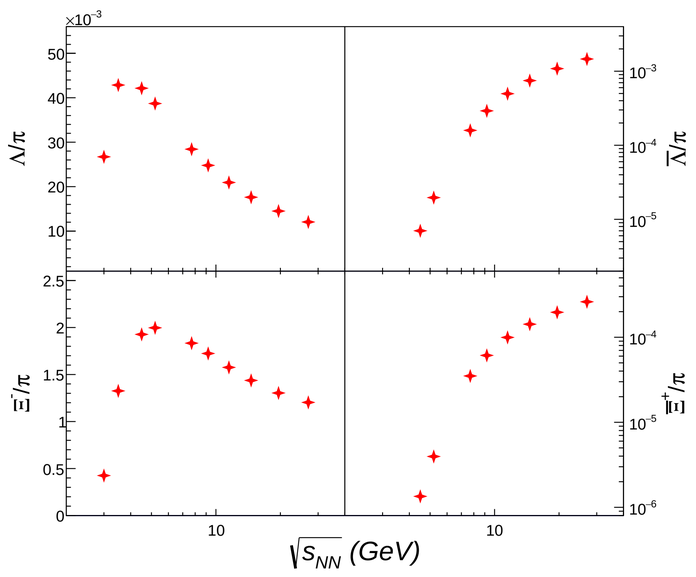
Figure 1: Transverse momentum distribution of K^0_S, Λ, Ξ^- and Ω^- for $\sqrt{s_{NN}} = 27$ GeV for $|y| < 0.5$ from UrQMD and BES I [1].

From figure 1, it can be noticed that UrQMD spectra for K^0_S demonstrate similarity to BES I data for $p_T \lesssim 1$ GeV/c. For Λ, Ξ^- and Ω^- the general trend from UrQMD is similar to BES I while the yield is suppressed for all centralities with the discrepancy increasing with strangeness content.

Particle ratios



The antibaryon-to-baryon ratios are sensitive to the net-baryon number density in the collision region and provide insights into baryon transport number. The UrQMD data show that ratios decrease from peripheral to central collisions for Λ, Ξ, Ω at $7.7 - 27$ GeV energies same as from BES I [1] data, except $\bar{\Omega}^+/\Omega^-$ ratio at 11.5 GeV where BES I shows increase trend. The UrQMD model underestimates $\bar{\Lambda}/\Lambda$ ratio for $\sqrt{s_{NN}} \geq 11.5$ GeV, for $\bar{\Xi}^+/\Xi^-$ and $\bar{\Omega}^+/\Omega^-$ UrQMD underestimates ratios for central collisions and overestimates for peripheral.



UrQMD calculations of hadron-to-pion ($1.5\,(\pi^+ + \pi^-)$) yield ratios at mid-rapidity for the to the $0 - 5\%$ centrality show monotonic growth for $\bar{\Lambda}/\pi$ and $\bar{\Xi}^+/\pi$. In contrast, the Λ/π and Ξ^-/π ratios show smooth peak at approximately 4.5 and 5.2 GeV, respectively, followed by a monotonic decrease with increasing energy. The general trend is similar to BES I [1] data while the absolute values are suppressed in the model.

Conclusions

The UrQMD model calculations were compared with a BES I data on strange hadron production in Au+Au collisions at $\sqrt{s_{NN}} = 3 - 27$ GeV. The model shows an agreement for K^0_S production while significantly underestimates the yield of strange baryons with the discrepancy increasing with strangeness content. The antibaryon-to-baryon ratios demonstrate centrality dependent discrepancies: model underestimates ratios in central and overestimates in peripheral collisions. The general trends in hadron-to-pion ratios in consistency between UrQMD and BES I while the absolute values are suppressed in the model.

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References

[1] J. Adam et al. Strange hadron production in Au + Au collisions at $\sqrt{s_{NN}} = 7.7$, 11.5, 19.6, 27, and 39 gev. *Phys. Rev. C*, 102:034909, Sep 2020.