Strangeness production in Au+Au collisions at $\sqrt{s_{NN}}$ = 27 GeV at STAR

Yue Hang Leung, *for the STAR Collaboration*
Lawrence Berkeley National Laboratory

Abstract

Strangeness production is a classic tool to study properties of the quark gluon plasma (QGP). The ratios of particle yields involving strange particles are often utilized to study various properties of nuclear matter, such as the strangeness chemical potential and the chemical freeze-out temperature. In particular, the yield ratios $N_K N_\Xi / N_\phi N_\Lambda$, $N_K N_\Omega / N_\phi N_\Xi$ are suggested in [1] to be sensitive to strange quark density fluctuations. Studying this ratio as a function of collision energy may provide a unique probe to the fluctuation of strange quark densities during the phase transition from the QGP to hadronic matter. In addition, studying the central-to-peripheral nuclear modification factor R_{CP} of strange hadrons may provide insight on strangeness production mechanisms in nuclear collisions.

In this poster, we present new measurements of mid-rapidity strange baryons $\Lambda(\bar{\Lambda}), \Xi(\bar{\Xi}), \Omega(\bar{\Omega})$ from $\sqrt{s_{NN}}$ =27 Au+Au collisions at RHIC. The large data sample taken in 2018 by STAR and the use of supervised machine learning techniques extend both the low and high p_T reach compared to previous measurements. We present the yield ratio $N_K N_\Xi / N_\phi N_\Lambda$, and discuss their physics implications.

Motivation

- Particle yields may carry information on the properties of QGP and onset of deconfinement.
- The yield ratio $N_t N_p / N_d^2$ maybe sensitive to the neutron relative density fluctuation $\Delta n = \langle(\delta n)^2\rangle / \langle n \rangle^2$ at kinetic freezeout[2].
  - Non-monotonic behavior observed in Au+Au 0-10%.
- Similarly strange quark relative density fluctuation may be probed by the ratio $N_K N_\Xi / N_\phi N_\Lambda$.
- Although such yields have been measured using BES-I data,
  - Large systematic uncertainties from low p_T extrapolation.
  - BES-II provides x10 statistics.
  - Apply supervised learning techniques to optimize significance and improve low p_T reach.

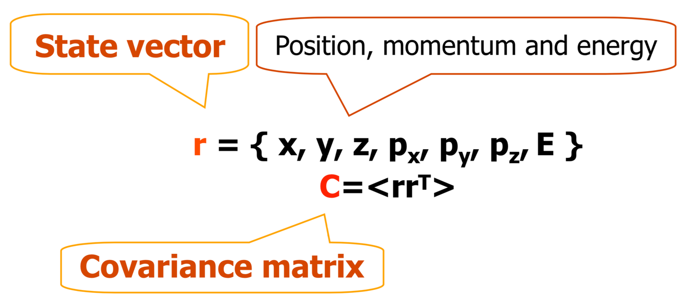
Λ, Ξ, Ω Reconstruction

- Λ, Ξ, Ω reconstructed through their hadronic decay channels.

	Decay channel	Branching ratio
$\Lambda(\bar{\Lambda})$	$p(\bar{p}) + \pi^-(\pi^+)$	63.9%
$\Xi(\bar{\Xi})$	$\Lambda(\bar{\Lambda}) + \pi^-(\pi^+)$	99.987%
$\Omega(\bar{\Omega})$	$\Lambda(\bar{\Lambda}) + K^-(K^+)$	67.8%

Particle reconstruction: KFparticle method

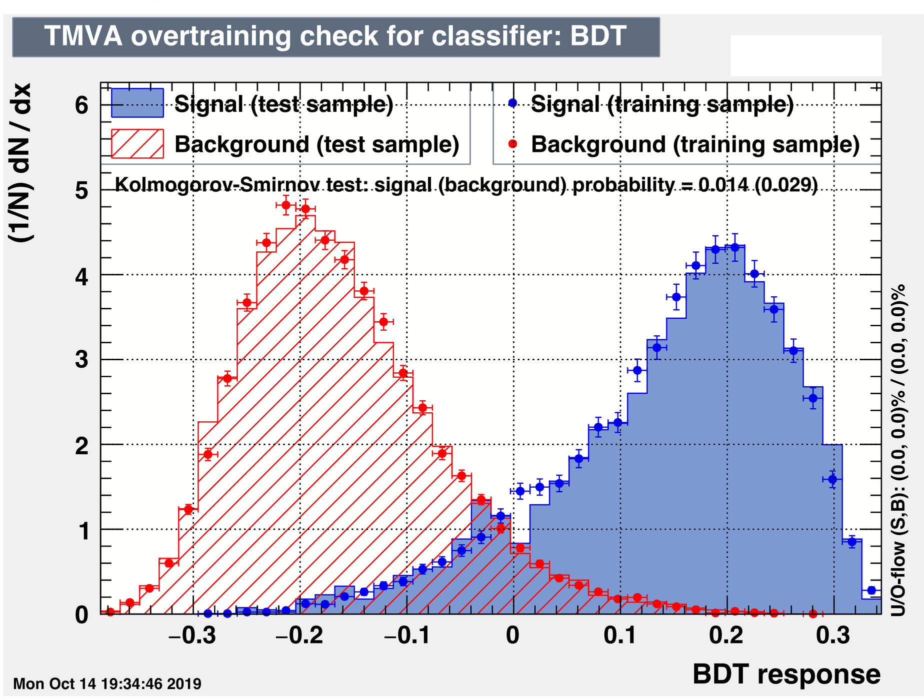
- Kalman Filter based reconstruction method; developed based on CBM, ALICE experiments [3].
- All particles (mother and daughter) described by state vectors and covariance matrices.
- Reconstruction of decay chains and computation of all physics parameters and associated uncertainties.
- Analysis cuts based on physical parameters normalized by their respective error.



Cut optimization: TMVA (Toolkit for Multivariate Data Analysis)

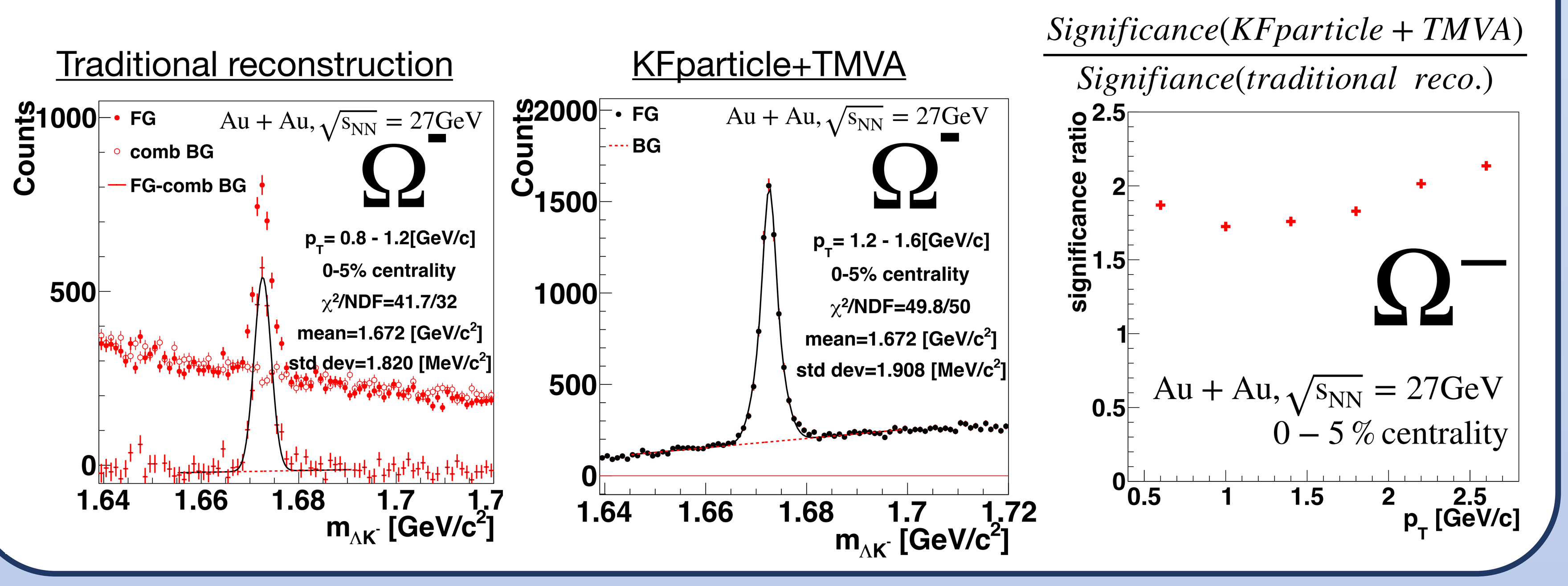
- A family of supervised learning algorithms
  - make use of training events, typically events labelled "signal" or "background".
  - Multivariate analysis that takes into account correlations between different variables.
- Training on multiple variables (decay length, DCA, etc.) based on the BDT (Boosted decision tree) method.
  - All variables simplified to a single axis (BDT response)
  - Scan BDT response cut value to optimize signal significance.

Signal: embedding simulation
Background: sideband from real data

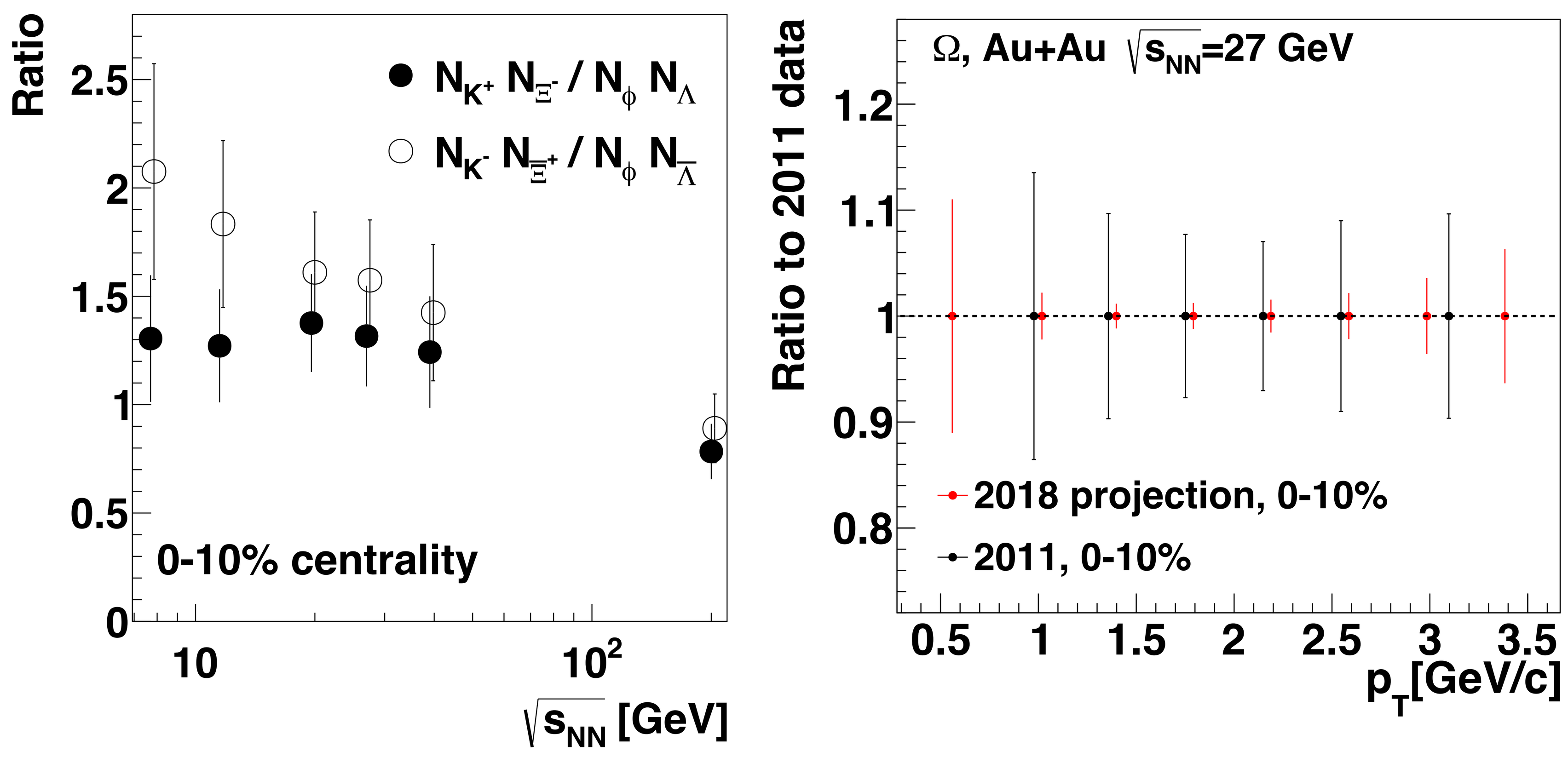


Signal extraction

- Raw counts and significance calculated within a 3 sigma mass range with the bin counting method.
- Background modeled by polynomial fitting.
- Comparing to traditional reconstruction method, the KFparticle+TMVA method increases the significance by ~40% for Λ and ~80% for Ω at 27 GeV.



Statistical projections and outlook



- Expect significantly improved statistical significance using 2018 data with new analysis methods compared to previous measurements [4].
- The ratio $N_K N_\Xi / N_\phi N_\Lambda$ for the 0-10% Au+Au collisions constructed using previous measurements shows a decreasing trend.
  - Measurements using new analysis methods and data can help reduce the uncertainty of such ratios.

Summary

- Applied TMVA-BDT method to strange particle reconstruction, achieved increase in the signal significance by ~40% for Λ and ~80% for Ω in Au+Au collisions at $\sqrt{s_{NN}}$ = 27 GeV.
- Future BES-II data at lower energies will be useful to probe potential strange quark fluctuations at the QGP to hadronic matter phase transition, and in general enhance our understanding of strangeness production mechanisms and nuclear matter.

Reference

[1] C. M. Ko, EPJ Web of Conferences 171, 03002 (2018)
[2] K.J. Sun et al., Phys. Lett. B 774, 103 (2017)
[3] M. Zyzak, "*Online selection of short-lived particles on many-core computer architectures in the CBM experiment at FAIR*", thesis, urn:nbn:de:hebis:30:3-414288
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The STAR Collaboration
https://drupal.star.bnl.gov/STAR/presentations