Energy dependence of the fluctuations of net - Λ distributions at STAR.

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Abstract

The measurement of conserved charge distributions have generated considerable interest in understanding the cumulants of conserved quantum numbers in the QCD phase diagram, in particular the behavior near a possible critical end point and hadronization near chemical freeze-out line. Net - protons have been used as a proxy for net - baryons. In this poster, we show a first measurement of the efficiency-corrected cumulant ratios (C_2/C_1, C_3/C_2) of net - Λ, which are subject to strangeness and baryon number conservation, for five beam energies ($\sqrt{s_{NN}}$ = 19.6, 27, 39, 62.4 and 200 GeV Au + Au collisions) as a function of centrality and rapidity. We compare our results to the previous STAR results, the Poisson and negative binomial expectations, as well as predictions from the UrQMD model and hadron resonance model. We deduce chemical freeze-out parameters (μ, T) and discuss the deviations of the cumulant ratios from Poisson.

1. Motivation

Several observations from lattice and thermal model calculations show different freeze-out (FO) conditions depending on the particle quark content.

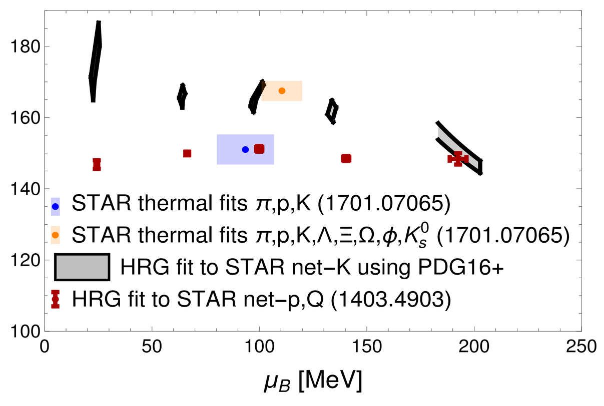


Figure 1: T and μ_B calculated at chemical freeze-out using thermal fits for different particle species.

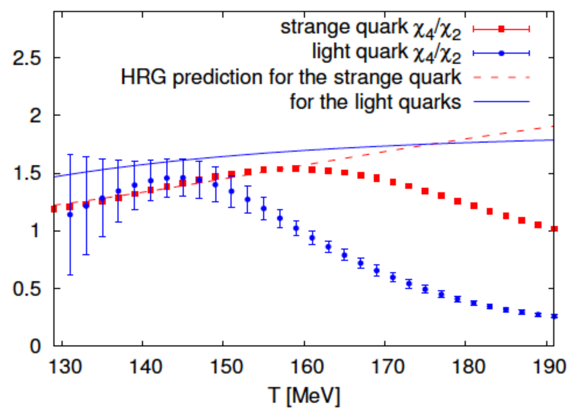


Figure 2: Comparison of χ_4/χ_2 calculated in HRG and lattice for light and strange quarks.

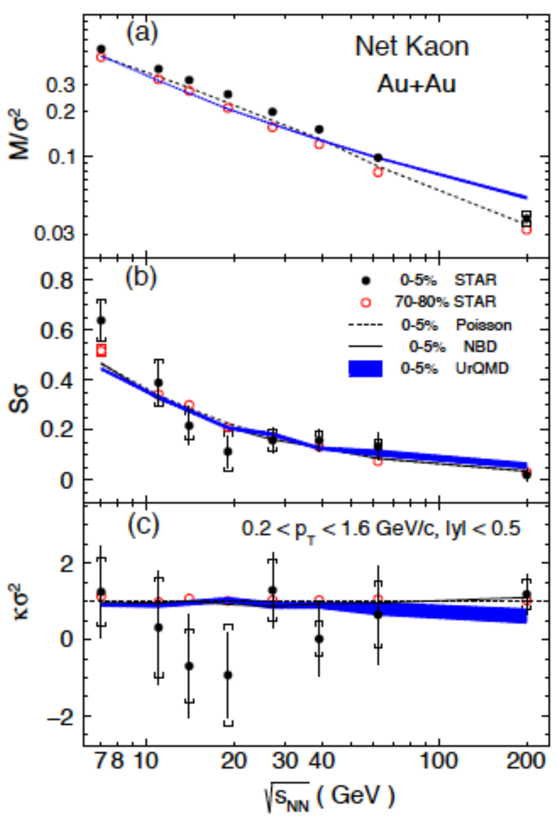


Figure 3: Energy dependence of net - kaon cumulant ratios at STAR experiment [3].

- Figures 1 [1] and 2 [2] show different FO conditions in HRG and lattice QCD calculations for different strange and non - strange particles.
- Previously, net - kaons [3] and net - protons [4] were used as proxies for net - strangeness and net - baryon number respectively and in each case FO conditions were studied.
- In order to understand FO conditions in the context of both the strangeness and the baryon number, we measure net - Λ cumulants and compare it to the theoretical predictions.

2. Method (Λ reconstruction)

Data sets:

Energy (Au + Au)	Statistics (millions)
19.6 GeV	34
27 GeV	74
39 GeV	97
62.4 GeV	54
200 GeV	320

- Λ decays into : Λ → p + π⁻, Invariant mass is calculated using relativistic kinematics.
- Protons and pions are identified by using STAR time projection chamber (TPC).
- V^0s were reconstructed via decay topology.
- Tight topological cuts were used to obtain a pure (~94%) sample of V^0s.
- Centrality: Based on the multiplicity of kaons and non - Λ daughter pions.

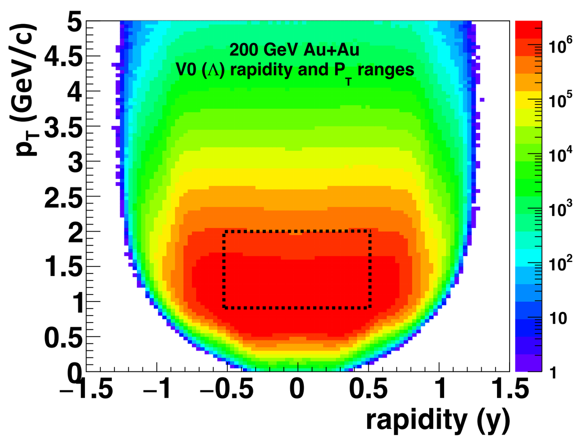
Event/track cuts:

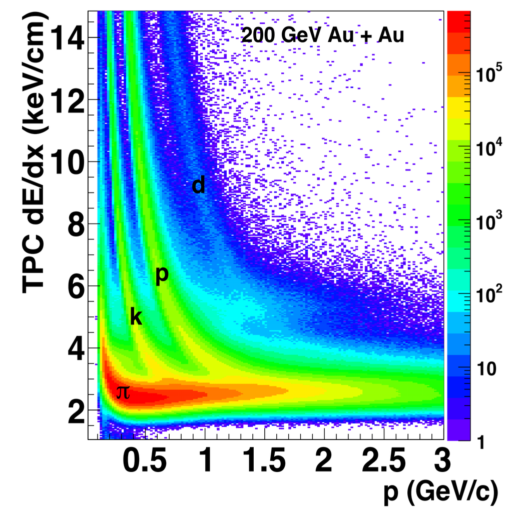
- V_z < 2 cm and $|V_r|$ < 30cm
- $|V_z - V_{z(VPD)}|$ < 3cm
- $nSigma_{proton}$ < 2 and $nSigma_{pion}$ < 2
- V^0 rapidity: |y| < 0.5
- 0.9 < p_T (V^0) (GeV/c) < 2.0

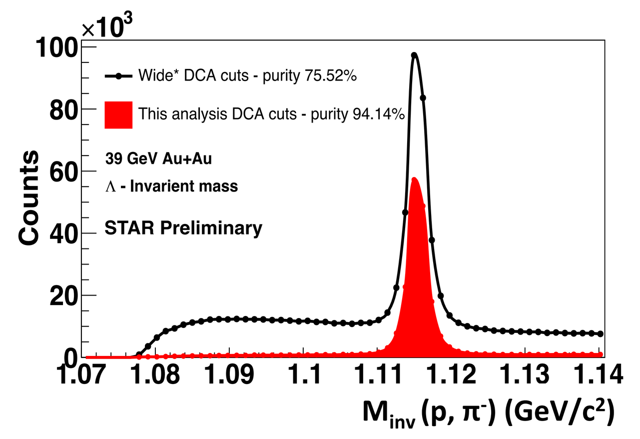
Topological cuts: (* wide topological cuts in square brackets)

- DCA of V^0 to PV < 0.5 cm [0.95 cm]
- DCA of p to PV > 0.5 cm [0.2 cm]
- DCA of π⁻ to PV > 1.5 cm [1.0 cm]
- DCA of p to π⁻ < 0.6 cm [0.9 cm]

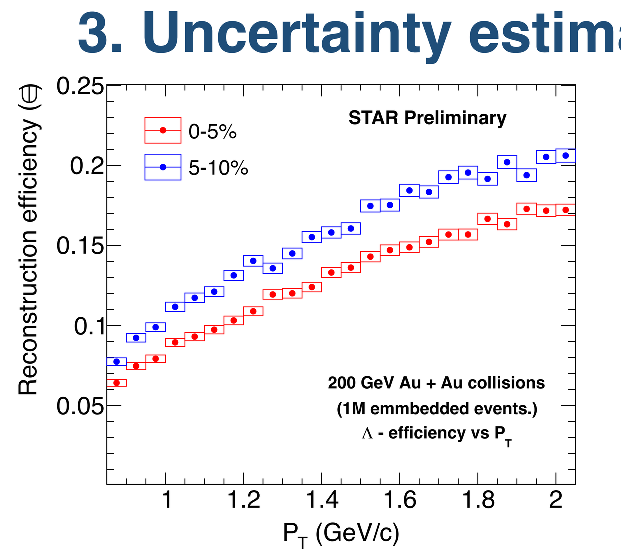
(DCA: distance of closest approach, PV: primary vertex.)







3. Uncertainty estimation, efficiency correction & baselines.



- Efficiency correction is done as explained in [6] using p_T-integrated efficiency in each centrality bin in the range 0.9 < p_T (GeV/c) < 2.0.

$$\epsilon_x = \frac{\int \epsilon_x'(p_T) f(p_T) p_T dp_T}{\int f(p_T) p_T dp_T}$$

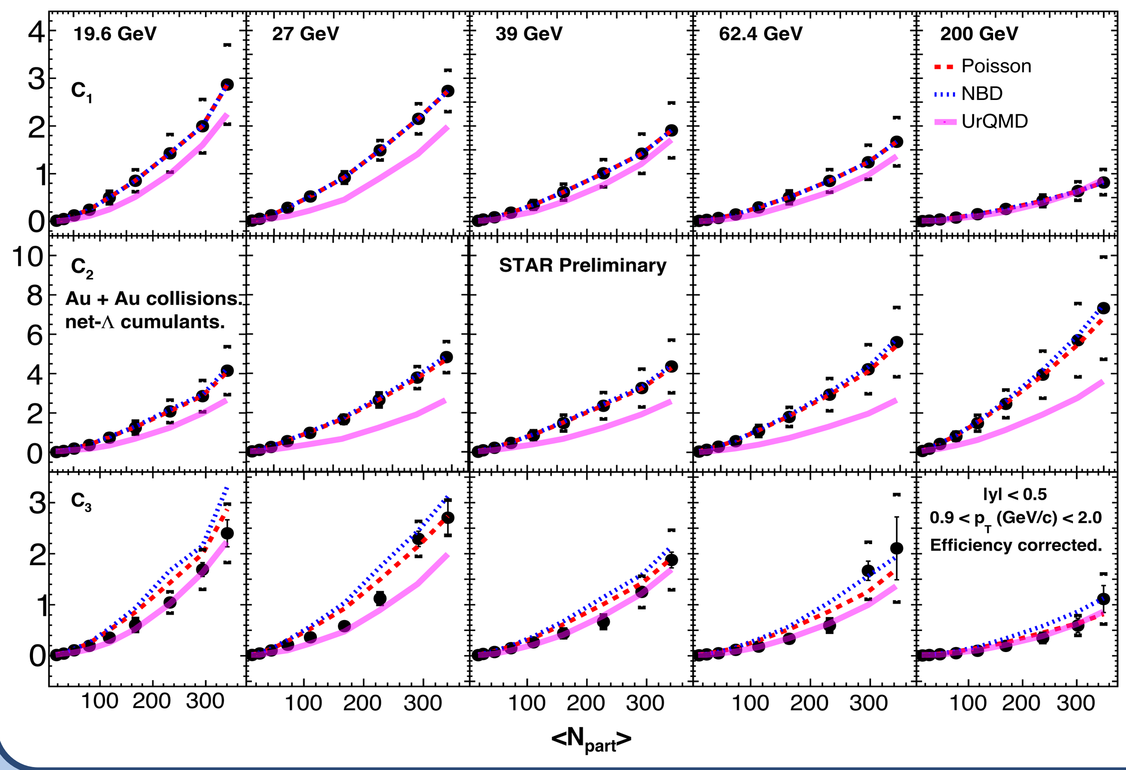
where, $f(p_T)$ is the corrected p_T spectra.

- Centrality bin width correction (CBWC) is applied.
- Statistical uncertainties are calculated using delta theorem and following error propagation as explained in [7].
- Systematic uncertainty estimation is done varying the selection criteria and including the effect of efficiency variation.

Baselines and models

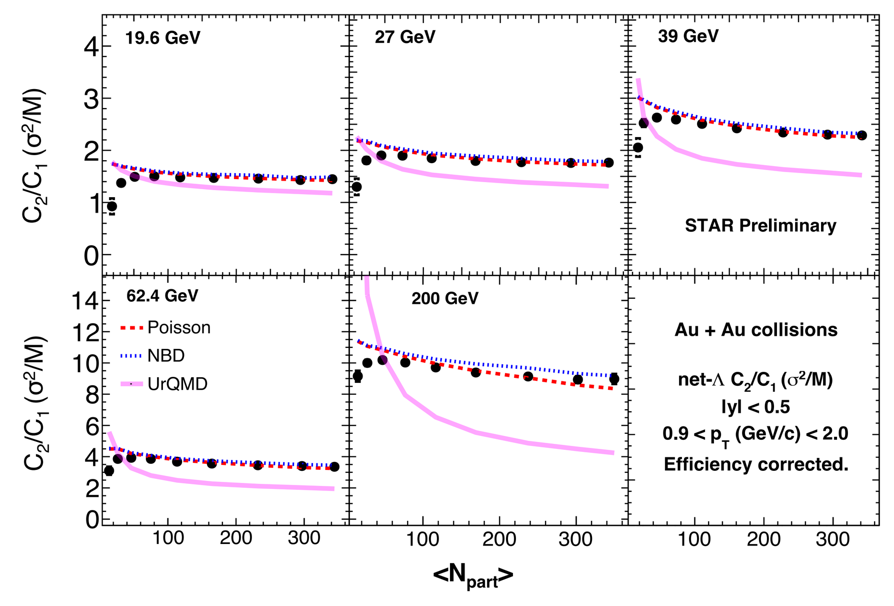
- **Poisson**: Moments as a function of positive (M^+) and negative (M^-) particle distributions.
- **Negative binomial expectation (NBD)**: Moments as a function of both the mean (M) and the variance (σ^2).
- **The ultra relativistic molecular dynamic model (UrQMD)** : For transport model predictions [5].
- **The hadron resonance gas model (HRG)** : Calculating cumulant ratios with different FO assumptions [1].

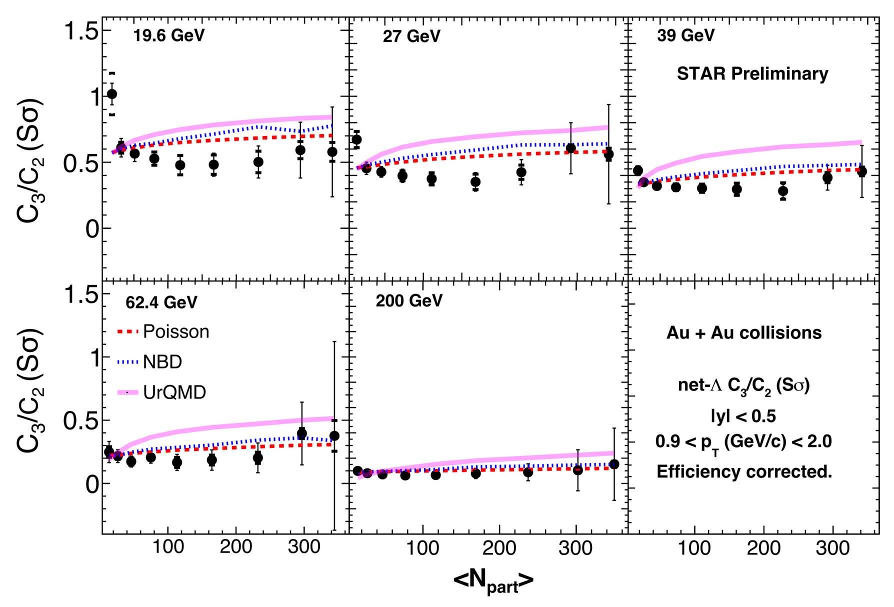
4. Results - I (Centrality dependence.)



- C_1 decreases with increasing collision energy. C_2 is larger at 62.4 and 200 GeV than for the other energies.
- Both NBD and Poisson expectations agree with data within the uncertainties. UrQMD has the largest deviations in C_2.
- Systematic uncertainties of C_2 are larger at 62.4 and 200 GeV than for the other energies. Statistical and systematic uncertainties both become larger in C_3 compared to C_1 at 62.4 and 200 GeV.
- C_1, C_2, and C_3 increase with increasing $\langle N_{part} \rangle$.

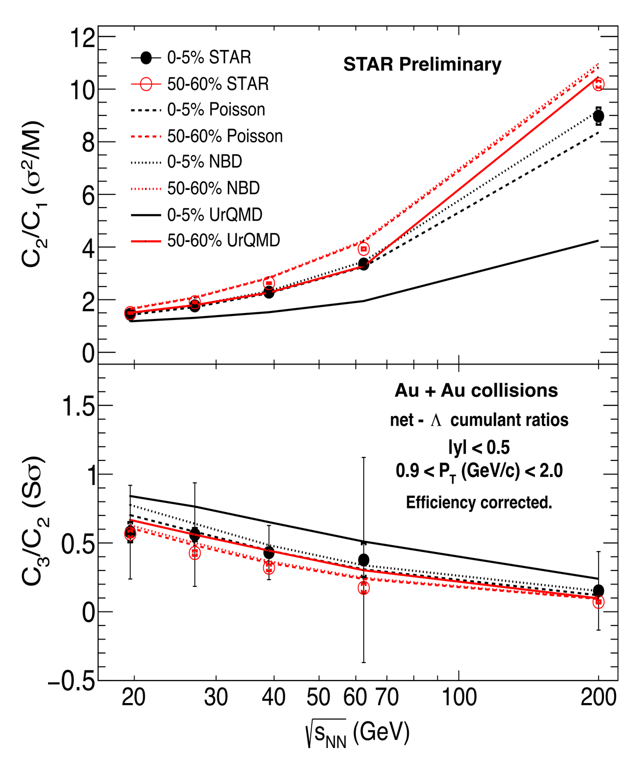
5. Results – II (Centrality dependence).

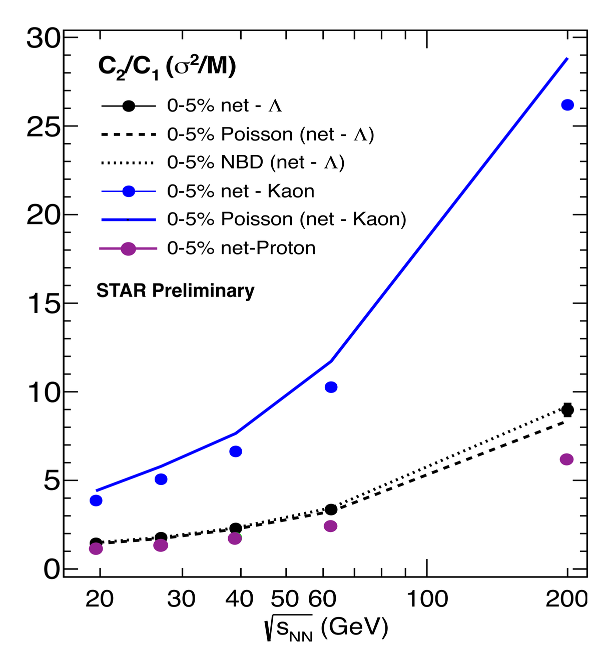


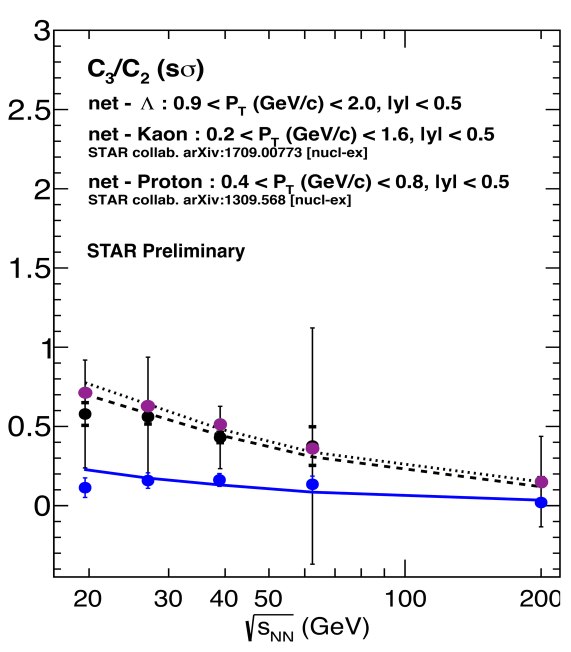


- C_2/C_1 increases with increasing collision energy which is mostly driven by C_1. Both NBD and Poisson have an agreement with data except in the most central collisions of 200 GeV. UrQMD deviates in all cases.
- For C_3/C_2, statistical uncertainties dominate and the effect is largest in the most central collisions. NBD, Poisson and UrQMD predictions are within error bars in the most central collisions.

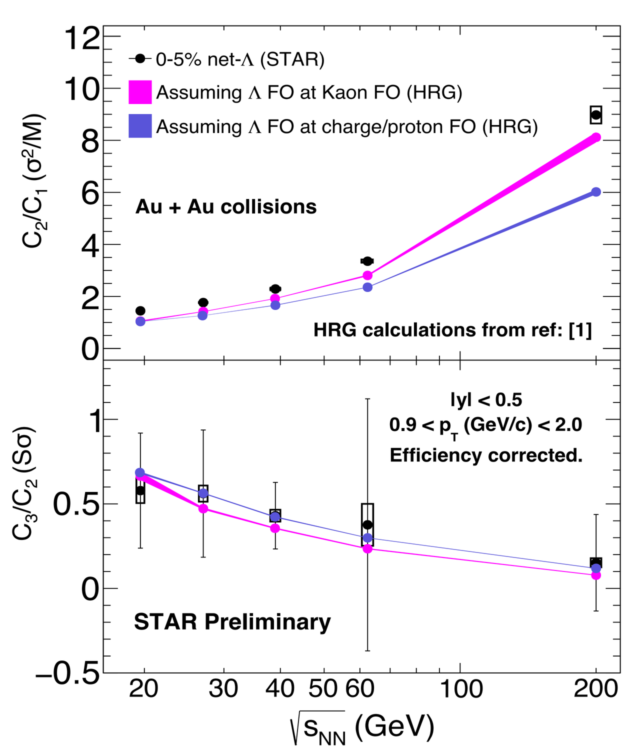
6. Results – III (Energy dependence).





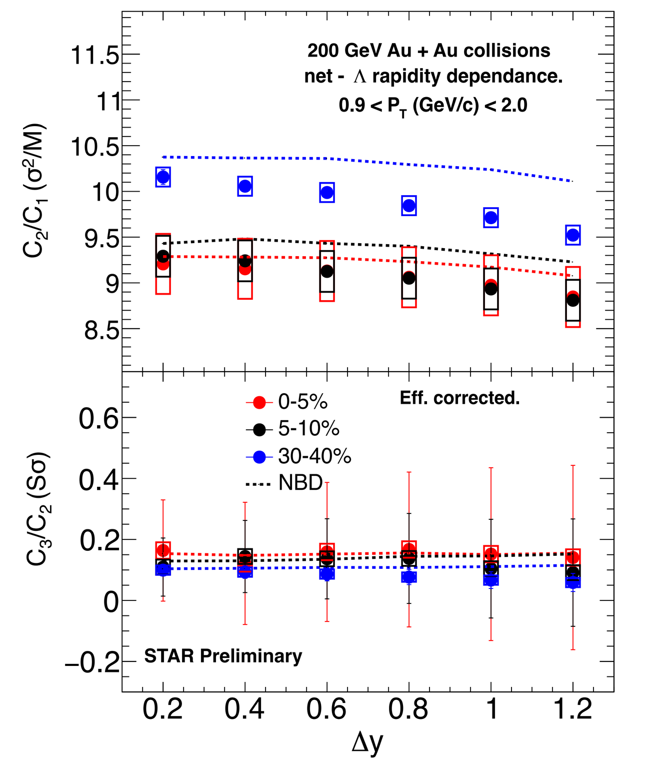


- C_2/C_1 increases with increasing collision energy. NBD expectations have better agreement with data than Poisson. UrQMD predictions deviate by large amount at 62.4 and 200 GeV.
- In the C_3/C_2, statistical uncertainties make the comparison to the baselines and UrQMD difficult.



- Experimentally measured net - Λ (C_2/C_1) is between net - kaon [3] and net - proton [4] data.
- HRG model is also used to calculate C_2/C_1 and C_3/C_2. These ratios are calculated first, by assuming Λ FO at kaon FO conditions. Secondly, assuming Λ FO at Proton FO conditions and the net - Λ (STAR) is closer to C_2/C_1 calculation that assumes net - Λ FO at kaon FO surface.
- Experimentally measured net - Λ C_2/C_1 ratio is closer to net - proton results in [4]. The HRG results [1] based on the FO surface obtained from the net - kaon are close to the measured net - Λ, C_2/C_1 ratio.

7. Results – IV (Rapidity dependence).



- Systematic uncertainties are assumed to be independent on rapidity.
- For C_2/C_1, systematic uncertainties are large in most central collisions.
- C_2/C_1 slightly decreases with increasing rapidity.
- For C_2/C_1, NBD expectations have larger deviations from data at peripheral collisions than at central ones.
- C_3/C_2 is independent of rapidity. Statistical uncertainty dominates.

8. Summary / Conclusion.

- Efficiency corrected net - Λ C_1, C_2, C_3, and C_1/C_2, C_3/C_2 are presented with Poisson, NBD and UrQMD expectations as a function of collision centrality, energy and rapidity with a comparison to net - proton [4] and net - kaon [3] data.
- Poisson expectations show slight deviations in most central collisions at 200 GeV. NBD expectations show better agreement with data.
- UrQMD expectations deviate from data mostly in C_2. This propagates to C_2/C_1 and the deviations increase as collision energy increases. C_1 and C_3 agree with UrQMD.
- **HRG model results [1] based on the assumption that the Λ freezes-out at the same surface as the kaons are closer to the experimental values for net - Λ C_2/C_1 than the results based on the proton freeze-out surface.**

References

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