Measurement of cumulants of net-proton distributions in Au+Au collisions at $\sqrt{s_{NN}}$ = 54.4 GeV at RHIC

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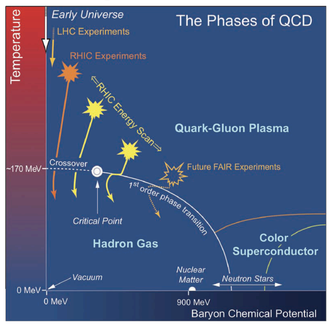
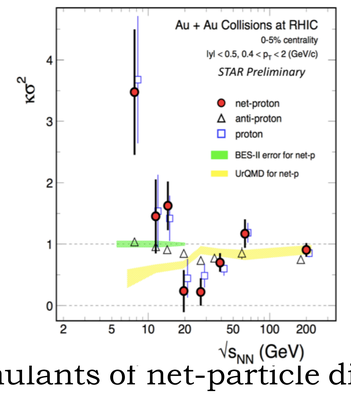
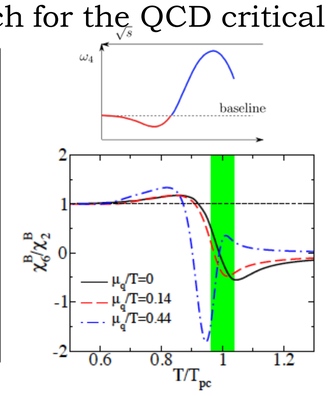
1. Motivation

❑ Study of the QCD Phase diagram and search for the QCD critical point.







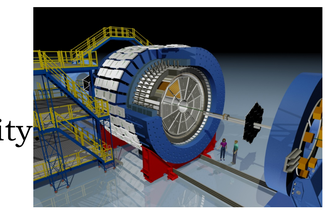
❑ Observables → Cumulants of net-particle distributions (B, Q, S)
- ➢ Related to correlation length and thermodynamic susceptibility.
- ➢ $C_6 < 0$ (net-baryon and net-charge) predicted at crossover tansition.

$$C_2 \sim \xi^2 \qquad C_4 \sim \xi^7$$

$$\kappa\sigma^2 = \frac{C_{4,q}}{C_{2,q}} = \frac{\chi_q^{(4)}}{\chi_q^{(2)}} \qquad S\sigma = \frac{C_{3,q}}{C_{2,q}} = \frac{\chi_q^{(3)}}{\chi_q^{(2)}} \qquad \frac{C_{6,q}}{C_{2,q}} = \frac{\chi_q^{(6)}}{\chi_q^{(2)}}$$

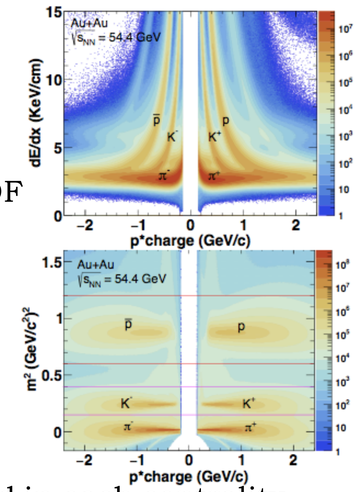
2. Analysis Techniques

❑ STAR Detector at RHIC



- ➢ Full azimuthal angle and $|\eta|<1$ coverage.
- ➢ Uniform acceptance in p_T vs rapidity at midrapidity

❑ Proton Identification
- ➢ TPC: Measures ionisation energy loss of charged tracks.
- ➢ TOF: Measures flight time of charged tracks.



- ▪ PID at lower p_T ($0.4 < p_T < 0.8$ GeV/c): TPC
- ▪ PID at higher p_T ($0.8 < p_T < 2.0$ GeV/c): TPC+TOF

❑ Centrality Definition
- ➢ Use charged particles other than protons and anti-protons to avoid self-correlation effects.

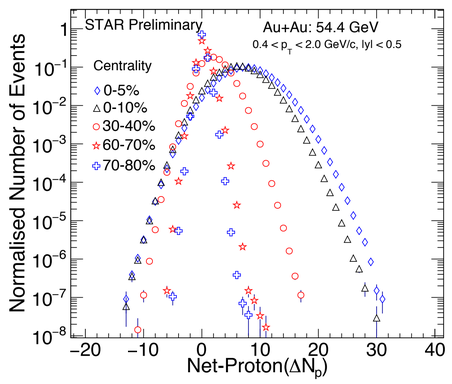
❑ Centrality Bin Width Correction
- ➢ Perform weighted average of cumulants measured in each centrality bin in a given centrality to suppress volume fluctuation effect.

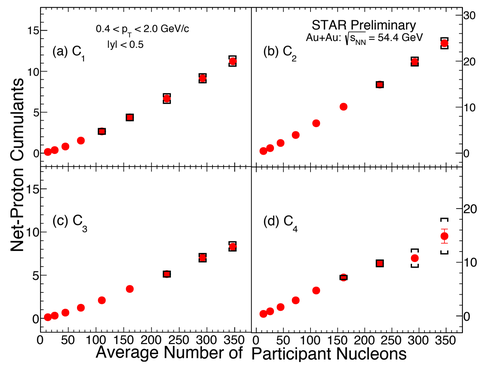
❑ Efficiency Correction
- ➢ Correct the cumulants for finite detector efficiency assuming the detector response to be binomial.

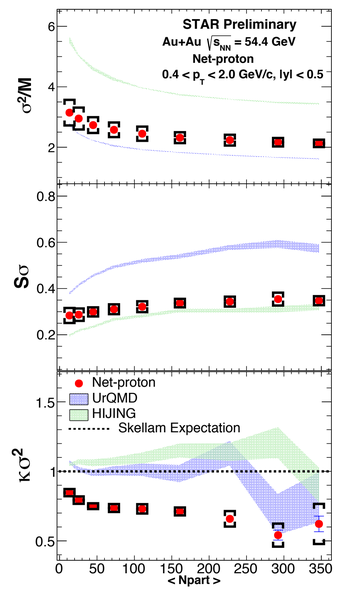
❑ Statistical And Systematic Uncertainties
- ➢ Statistical uncertainties are obtained by bootstrap method.
- ➢ Systematic uncertainties are estimated by varying PID and track selection criteria.

3. Results

❑ Event-by-Event Net-Proton Distribution for Various Collision Centralities
- ➢ From peripheral to central collisions
- ▪ Mean of net-proton distributions increases
- ▪ Width or the sigma of the distributions also increases





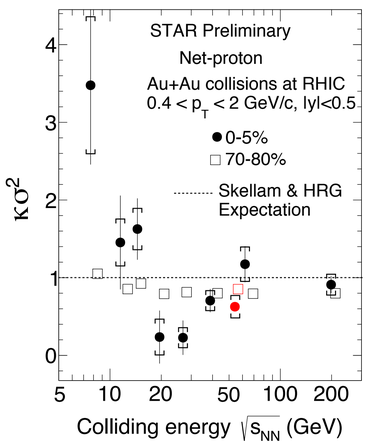


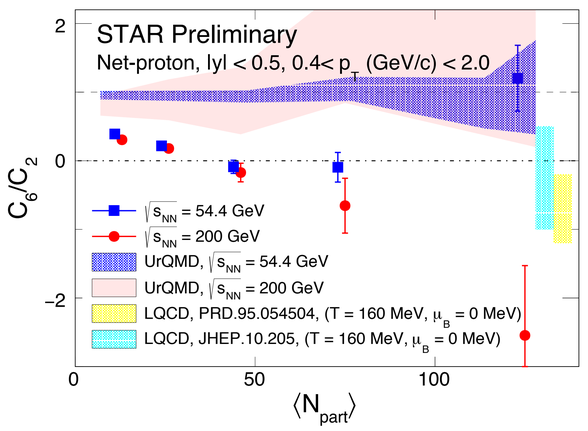
Bars and caps are statistical and systematic uncertainties respectively.

❑ Net-proton Cumulants And Cumulant Ratios
- ➢ Net-proton cumulants up to the fourth order monotonically increases with average number of participant nucleons
- ➢ C_2/C_1 decreases from peripheral to central collisions.
- ➢ C_3/C_2 and C_4/C_2 show weak dependence on centrality.
- ➢ Expectations from the UrQMD and HIJING model fail to explain the measurements.

❑ Beam Energy Dependence of the Cumulant Ratio C_4/C_2
- ➢ Non-monotonic beam energy dependence of C_4/C_2 with respect to the statistical baseline observed for most central (0-5%) collisions.
- ➢ New measurement at 54.4 GeV agrees with the trend from BES-I results.

❑ The Sixth-Order Cumulant
- ➢ For most central collisions (0-40%): $C_6/C_2 < 0$ at 200 GeV $C_6/C_2 > 0$ at 54.4 GeV.
- ➢ Measurement for C_6/C_2 at 54.4 GeV is consistent with Skellam baseline and UrQMD expectation.





4. Summary

❑ The cumulants of net-proton distributions up to the fourth order increase with average number of participant nucleons.

❑ C_2/C_1 shows a strong collision centrality dependence whereas C_3/C_2 , C_4/C_2 and C_6/C_2 have a weak collision centrality dependence.

❑ The centrality dependence of cumulant ratios is only qualitatively reproduced by the UrQMD and HIJING models. Quantitative differences exist.

❑ The C_6/C_2 of net-proton distribuions for central Au+Au collisions at 54.4 GeV is positive while that for 200 GeV, C_6/C_2 is negative (most central). The observed negative sign of C_6/C_2 at 200 GeV could be experimental evidence of crossover phase transition.

5. References

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