Probing the nature of the QCD phase transition with higher-order net-proton number fluctuation and local parton density fluctuation measurements at RHIC-STAR

Dylan Neff and Ashish Pandav
(for the STAR Collaboration)

Higher-order cumulants (C_n) of net-baryon distributions are sensitive to the nature of the QCD phase transition. Recent lattice QCD calculations [1] suggest a negative C_5/C_1 and C_6/C_2 in the crossover regime at small baryon chemical potential ($\mu_B \leq 110$ MeV). In addition, lattice QCD predicts a special ordering of cumulant ratios for systems of thermalized QGP [2]: $C_3/C_1 > C_4/C_2 > C_5/C_1 > C_6/C_2$. Both predictions can be tested in heavy-ion collision experiments by measuring higher-order cumulants of the net-proton multiplicity distributions.

In the high μ_B region of the QCD phase diagram, proton multiplicity distributions are utilized to probe characteristics of the phase transition. The variance of proton multiplicity within azimuthal subvolumes of phase space may provide insight into local parton density fluctuations. The deviation of this variance from a binomial baseline along with proton factorial cumulants over the full azimuth [3] may be observables sensitive to a possible first-order phase transition.

In this talk, we report measurements of net-proton C_5/C_1 and C_6/C_2 in Au+Au collisions with center-of-mass energies from 3 GeV to 200 GeV, where the 3 GeV data are from the fixed-target program and the other data sets are from the Beam Energy Scan program phase I at RHIC-STAR. Proton factorial cumulants and the variance of proton multiplicities in azimuthal partitions are also presented. The cumulant measurements are compared with a QCD-based FRG model, UrQMD, and HRG calculations as well as lattice QCD calculations. The AMPT and MUSIC+FIST models are used as non-critical references in the search for local density fluctuations.

References

[1] W.-j. Fu et al. *Physical Review D* 104.9 094047 (2021).

[2] A. Bazavov et al. *Physical Review D* 101.7 074502 (2020).

[3] A. Bzdak and V. Koch. *Physical Review C* 100.5 051902 (2019).