Precision Measurement of (Net-)proton Number Fluctuations in Au+Au Collisions at RHIC

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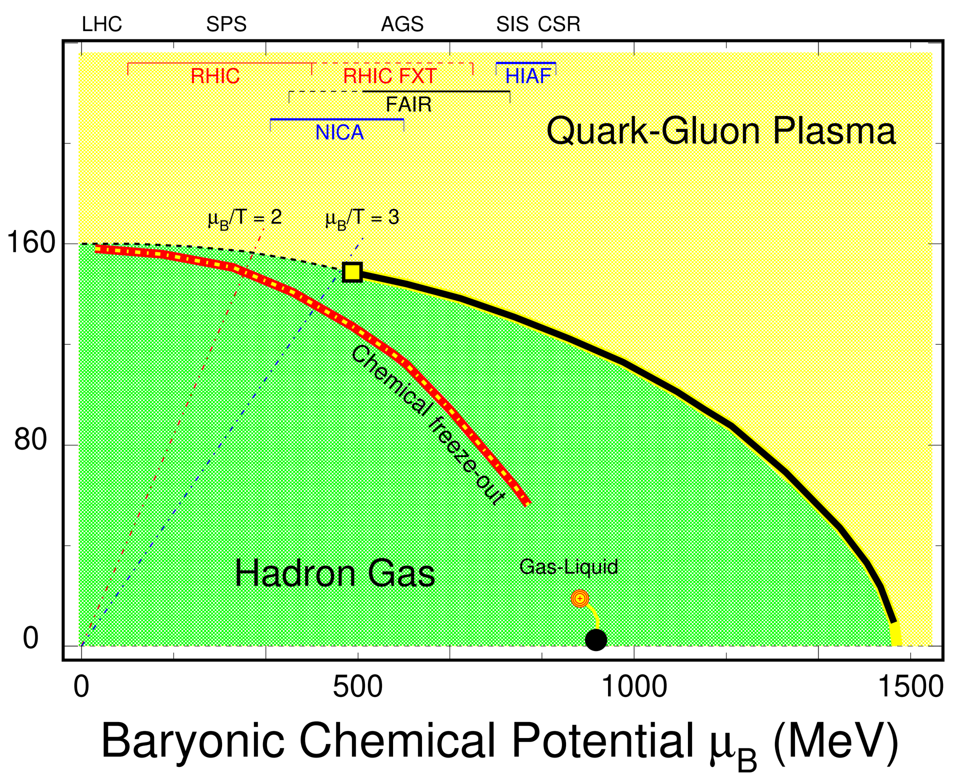
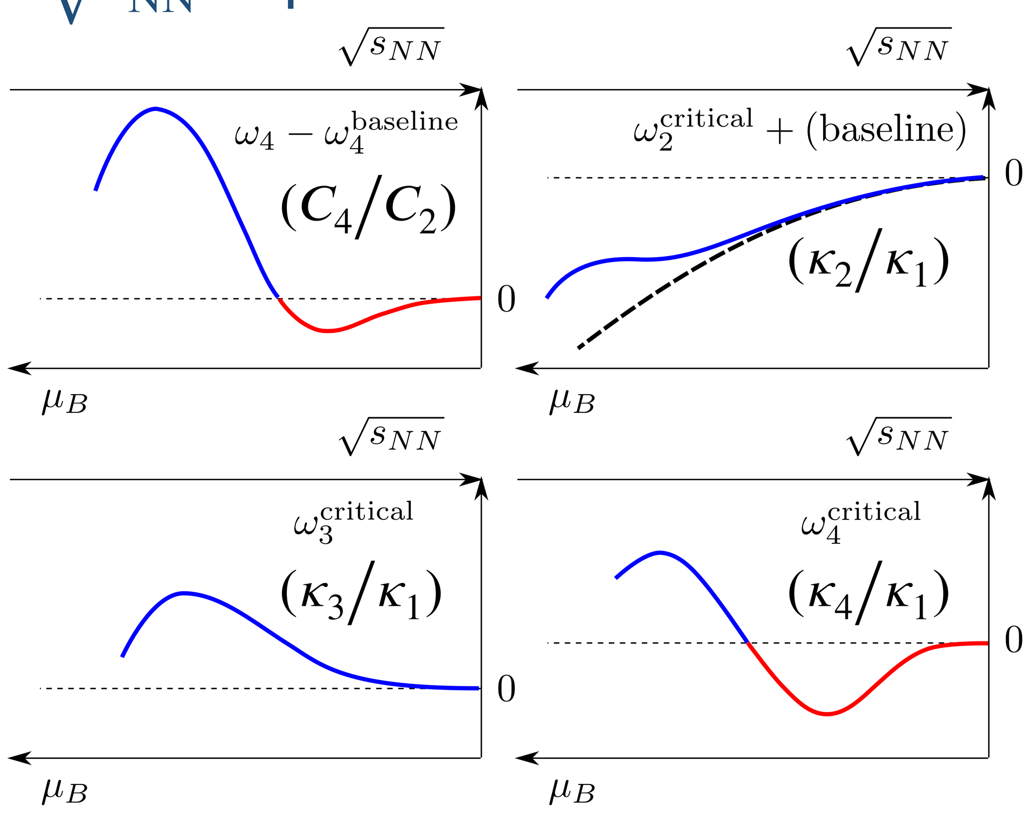
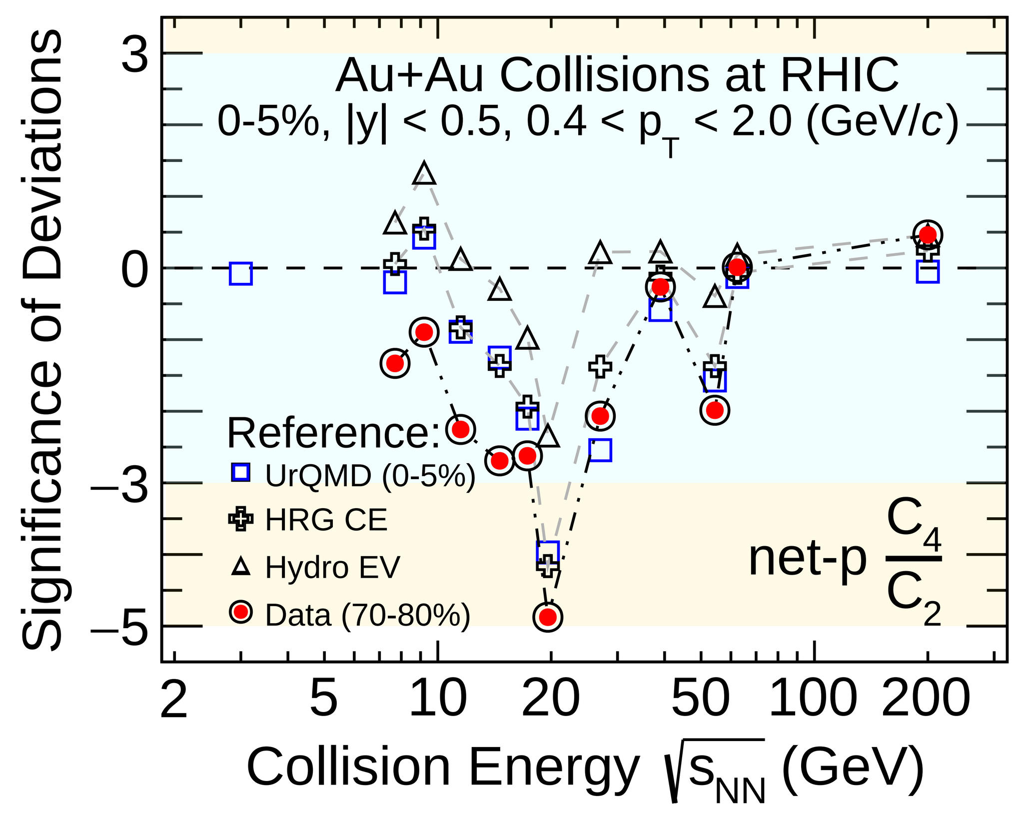
Introduction



1. QCD phase diagram [1]
   - Predicted CP terminates 1st-order boundary towards crossover
2. Observables
   - Higher-order conserved-charge fluctuations sensitive to CP [2,3]
   - N: E-by-E net-proton number (proxy for net-baryon number B)
   - Cumulants: $(\mu_n = \langle (N - \langle N \rangle)^n \rangle)$
     - $C_1 = \mu \quad = \langle N \rangle$
     - $C_2 = \sigma^2 \quad = \mu_2$
     - $C_3 = S\sigma^3 = \mu_3$
     - $C_4 = \kappa\sigma^4 = \mu_4 - 3\mu_2^2$
   - Factorial cumulants:
     - $\kappa_1 = C_1$
     - $\kappa_2 = C_2 - C_1$
     - $\kappa_3 = C_3 - 3C_2 + 2C_1$
     - $\kappa_4 = C_4 - 6C_3 + 11C_2 - 6C_1$
   - Taking C_n or κ_n ratios to cancel trivial volume dependence
3. Expectation [4,5]: non-monotonic $\sqrt{s_{NN}}$ dependence around CP



Deviations w.r.t Non-CP Refs.

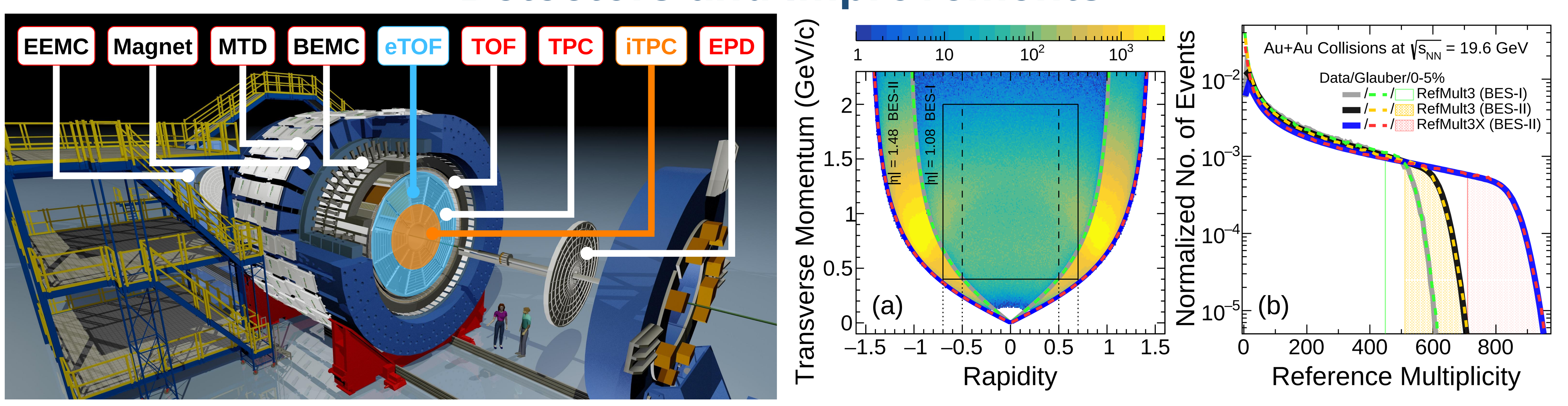


$\text{significance} = (\text{data} - \text{reference})/\sigma_{\text{total}}$

Abstract

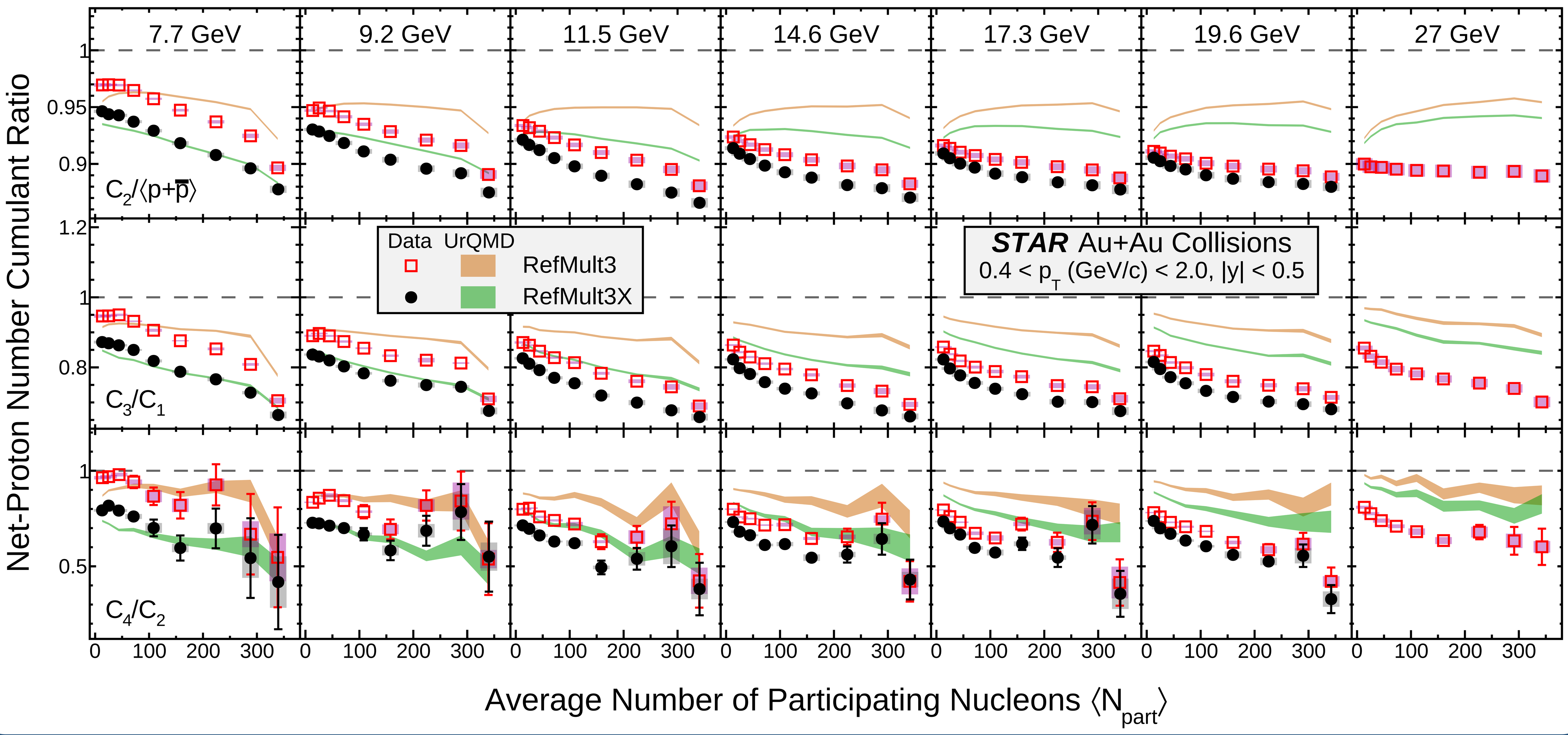
The RHIC Beam Energy Scan (BES-I 2010–2017 & BES-II 2018–2021), to map the phase diagram of strongly interacting matter, covers a wide range of collision energy $\sqrt{s_{NN}}$ = 3–200 GeV, corresponding to baryonic chemical potential μ_B = 750–25 MeV. This poster, based on arXiv:2504.00817, focuses on the precision measurement of higher-order fluctuations of (net-)proton numbers from BES-II within $\sqrt{s_{NN}}$ = 7.7–27 GeV, serving as effective probes for the QCD phase structure including the potential critical point (CP).

Detectors and Improvements

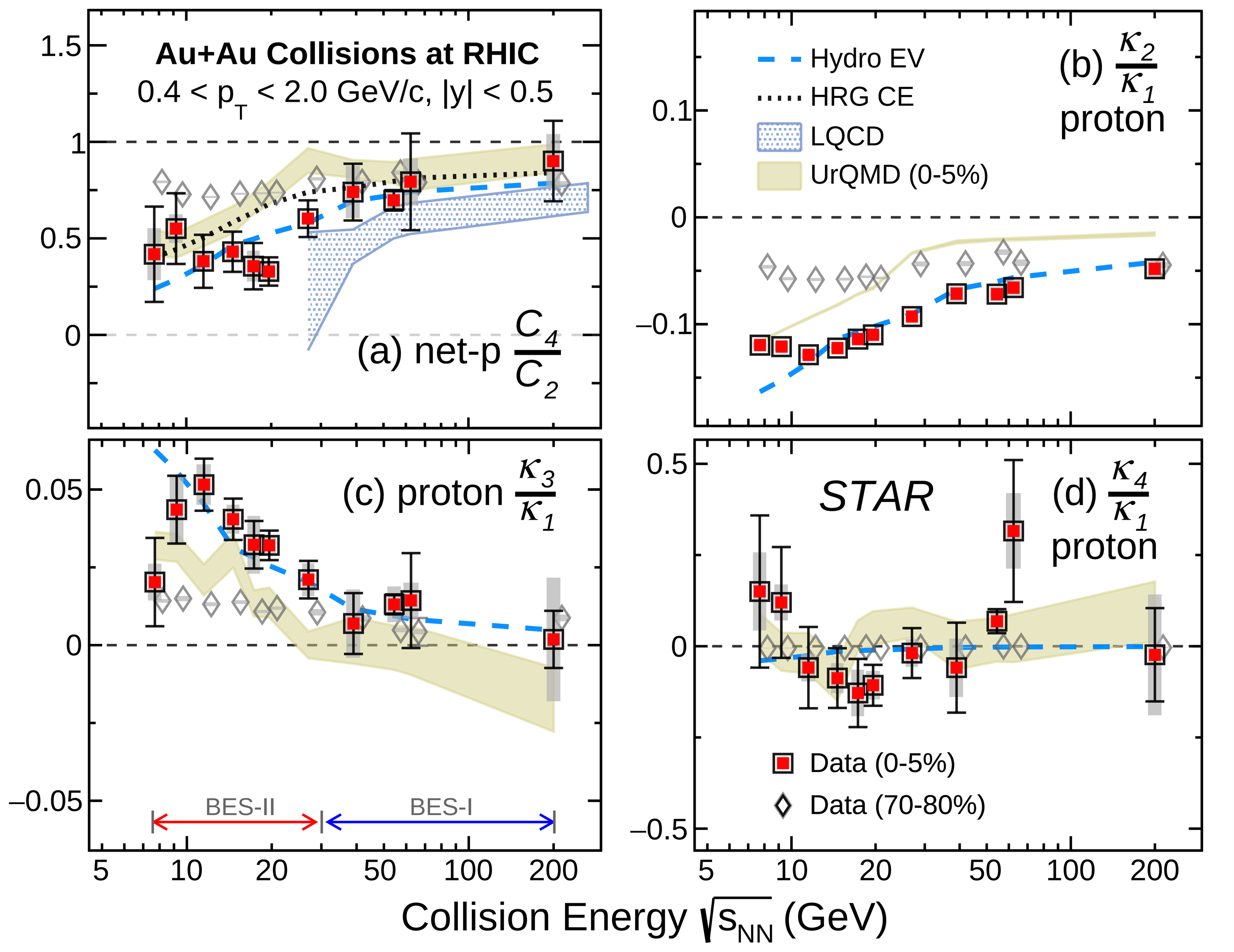


1. Inner TPC upgrade (2019+)
   - Larger acceptance and lower p_T
   - Better dE/dx resolution
2. BES-II 7.7–27 GeV. Compared to BES-I:
   - New energies: 9.2 and 17.3 GeV
   - Larger statistics: × 7–18
3. Centrality: charged-particle (excl. (anti)protons) multiplicity within $|\eta| < 1.6$ (1.0 in BES-I)
   ⇒ Better statistics, better systematics, better centrality resolution

Centrality Dependence of Net-proton Number C_n Ratios



Net-proton C_n and Proton κ_n Ratios



1. High precision in both 0–5% and 70–80%
2. Peripheral data closer to Poisson than central
   - C_4/C_2 below unity; negative κ_2, positive κ_3

Summary

1. Precision measurement in BES-II for (net-)proton number κ_n (C_n)
2. Comparison to Lattice QCD [6] and non-CP models:
   - (1) HRG CE [7]
   - (2) Hydro EV [8]
   - (3) UrQMD (0–5%) [9]
3. Max. 2–5σ deviation of central C_4/C_2 at $\sqrt{s_{NN}} \sim 20$ GeV from non-CP references (models and 70–80% data)

References

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