AMPT Model Studies of Net-Baryon Number Fluctuations in High Temperature and Density QCD Matter

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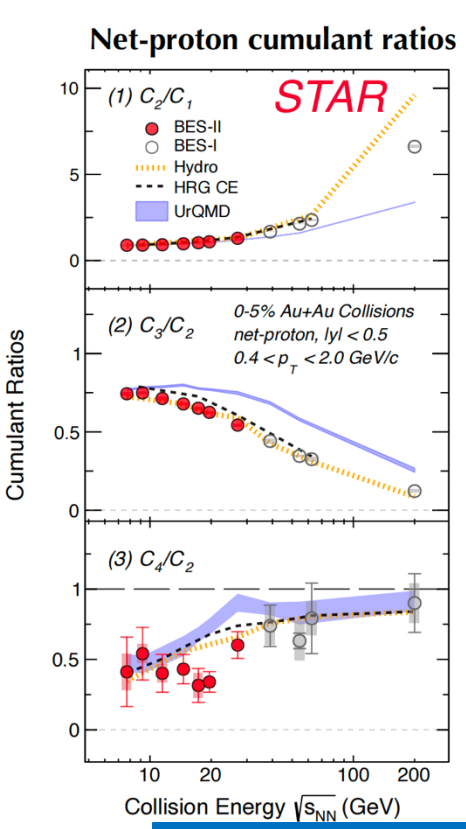
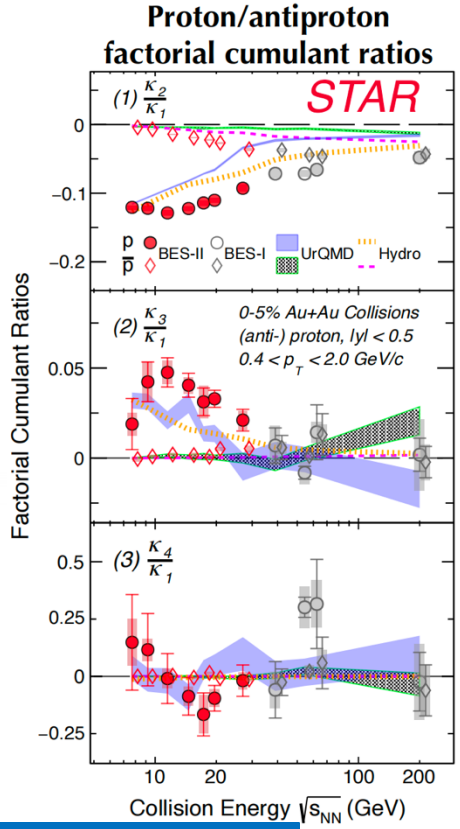
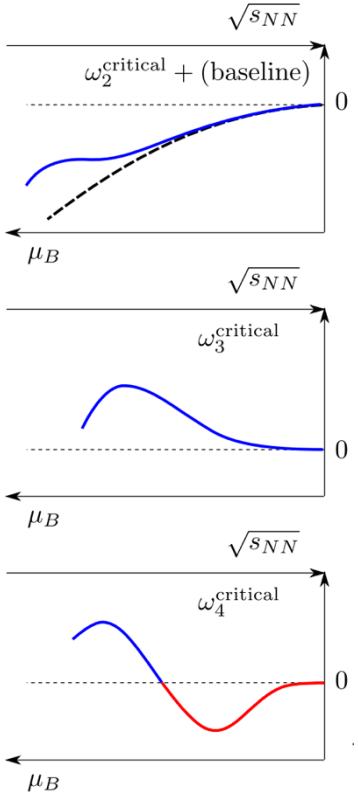
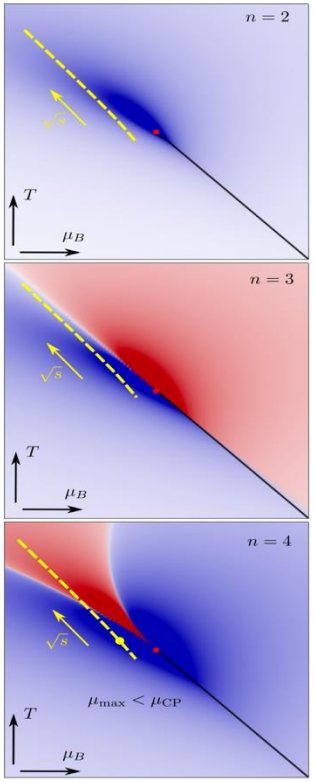
Fluctuations of Conserved Charges





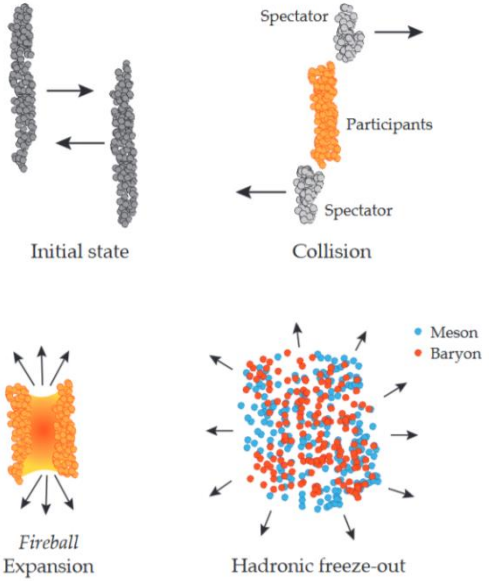




STAR:CPOD2024, SQM2024

arXiv:2410.02861

A multiphase transport model



HIJING (PDFs, nuclear shadowing):
minijet partons, excited strings, spectators

Melt to q & qbar via intermediate hadrons

ZPC (Zhang's Parton Cascade)

Partons freeze out

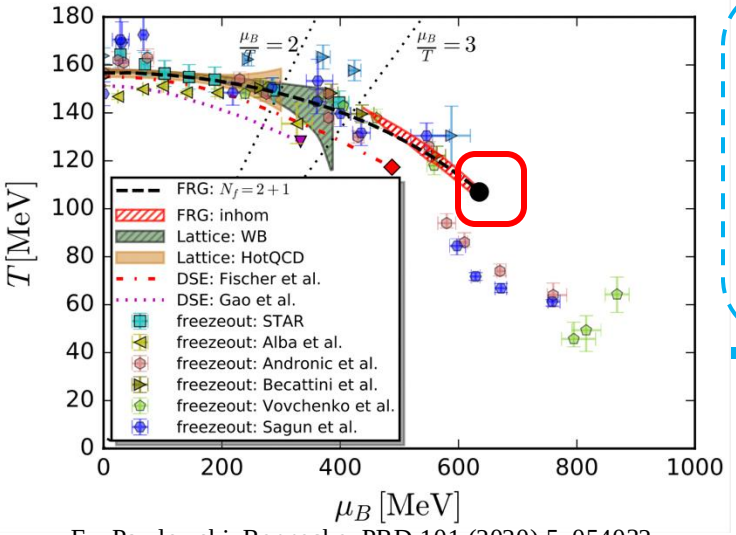
Hadronization (Quark Coalescence)

ART (A Relativistic Transport model for hadrons)

Hadrons freeze out (at a global cut-off time)
strong-decay all remaining resonances

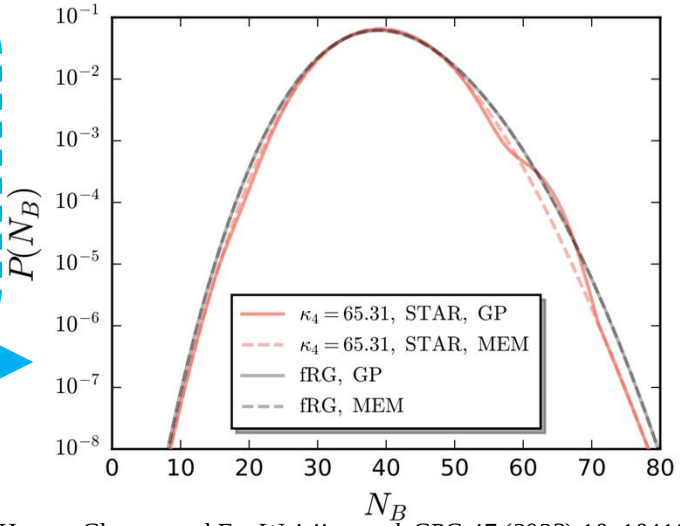
Extended AMPT model ensures the conservation of various conserved charges (including electric charge, baryon number, and strangeness) for all hadronic reaction channels during the evolution of hadronic phase

Functional Renormalization Group



Fu, Pawlowski, Rennecke ,PRD 101 (2020) 5, 054032

the net-baryon number distributions are reconstructed from the cumulants of different orders by means of the maximum entropy method

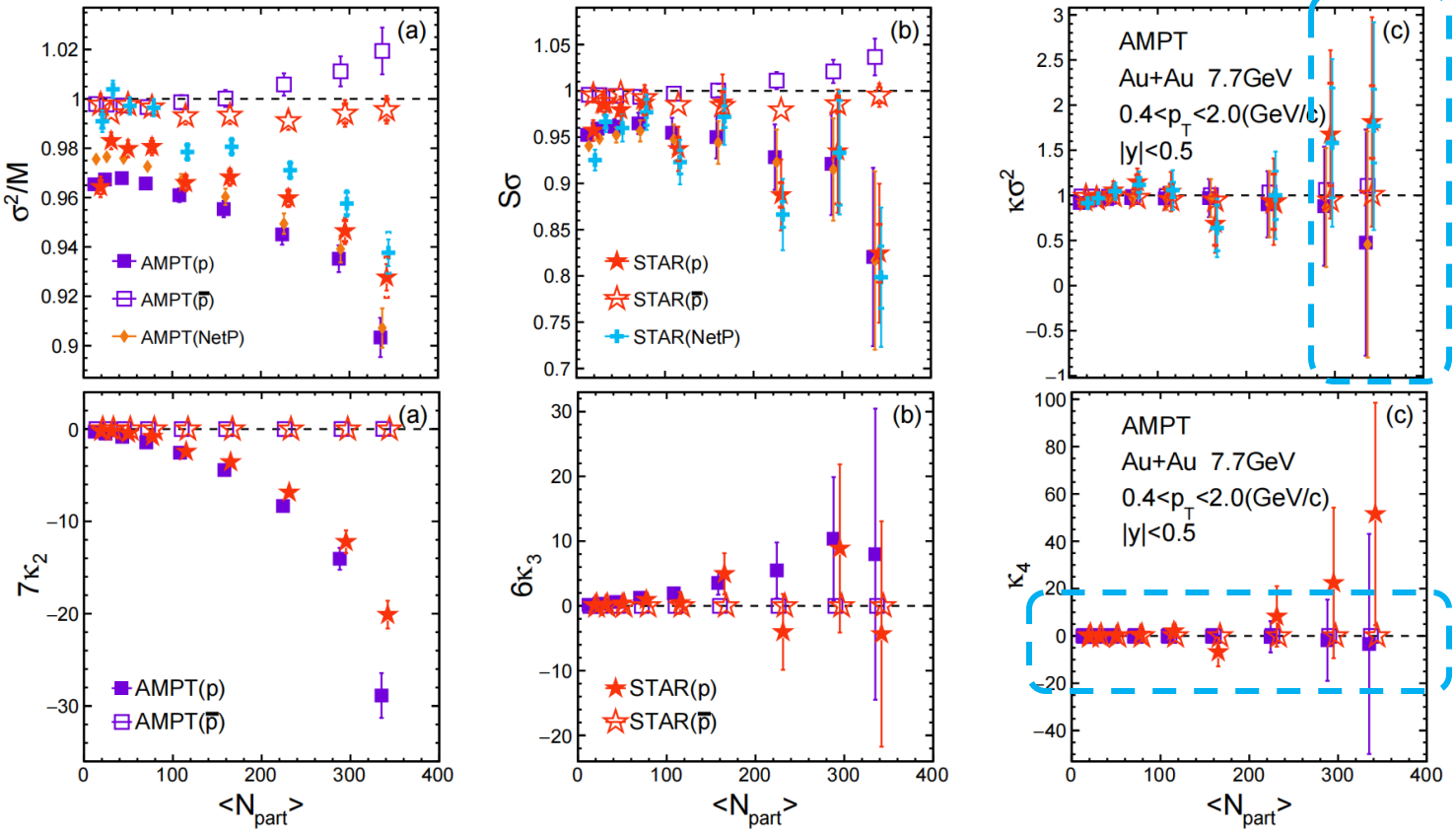


Huang, Chuang and Fu, Wei-jie, *et al.* CPC 47 (2023) 10, 104106

FRG enables the study of equations of state at both high and low baryon chemical potentials.

FRG with critical fluctuations mechanism without interactions between hadrons and decay processes

Results—— Fluctuations of Net-Proton



- In the 0-5% and 5-10% centrality bins, the AMPT results for $\kappa\sigma^2$ of net-proton are notably underestimates STAR's results.
- The four-proton correlation from AMPT is very small, consistent with zero.

Qian Chen, Guo-Liang Ma, Phys.Rev.C 106 (2022) 014907

Results—— Incorporating FRG Into AMPT Model

FRG parameter input:

baryon chemical：

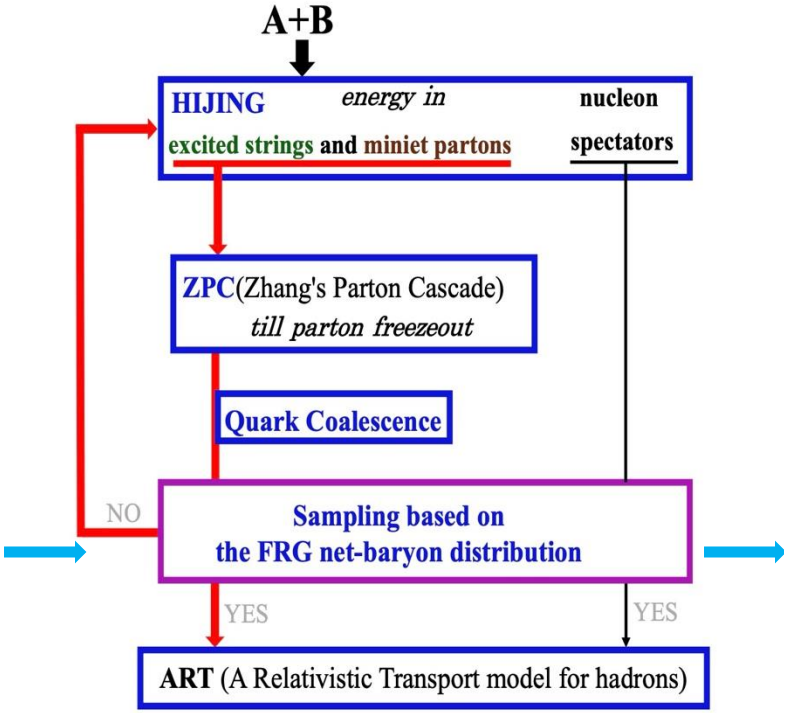
μ_B = 399 MeV;

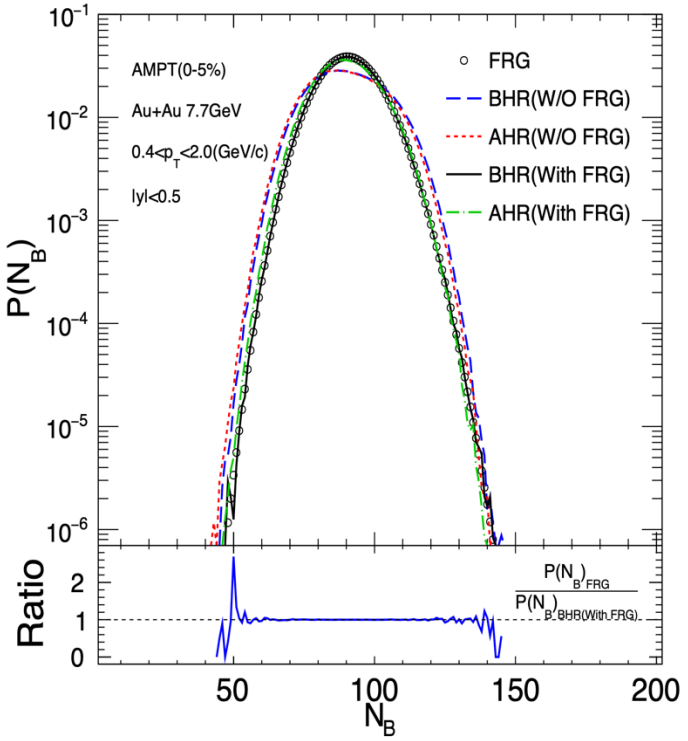
volume of the fire ball：

V = 980 fm^3;

pseudo-critical temperature：

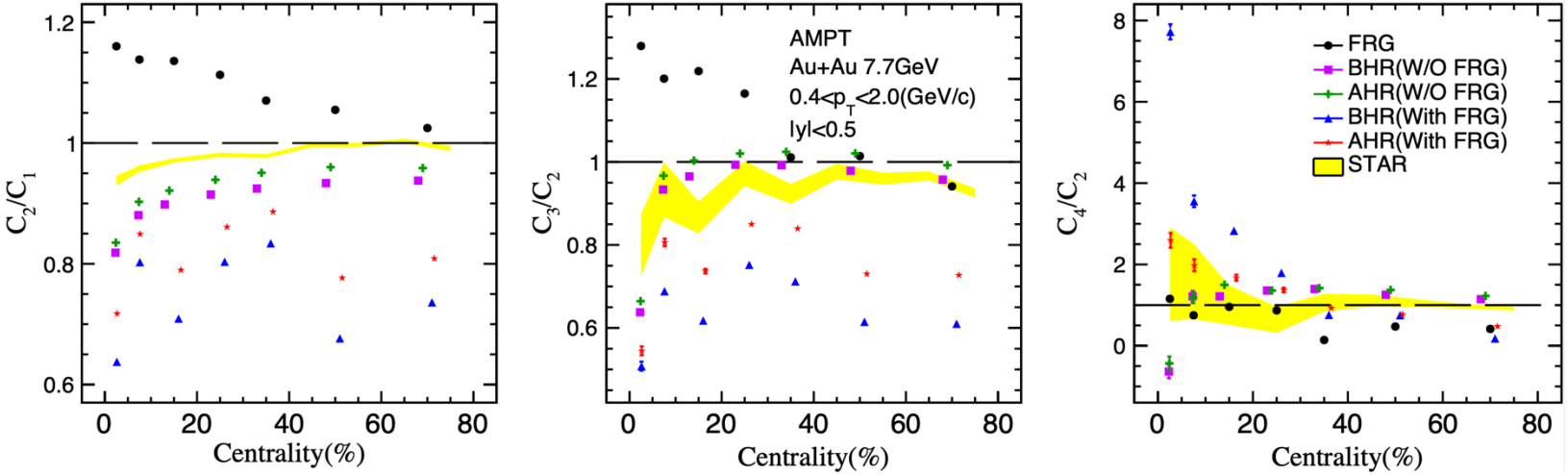
T = 139 MeV;





Qian Chen, Rui Wen, Shi Yin, Wei-jie Fu, Zi-Wei Lin, and Guo-Liang Ma. arXiv:2402.12823.

Results—— Fluctuations of Net-Baryon



- The process of hadronic rescatterings exerts a Poissonization effect on fluctuations.
- The effect of hadronic rescatterings is more significant for **critical fluctuations** than **dynamical fluctuations**.

Qian Chen, Rui Wen, Shi Yin, Wei-jie Fu, Zi-Wei Lin, and Guo-Liang Ma. arXiv:2402.12823.

Summary

- The AMPT results of cumulants, cumulant ratios, and correlation functions of proton multiplicity distributions basically describe the trend in the experimental data.
- The AMPT results are consistent with the expectation from baryon number conservation.
- The incorporation of the FRG into the AMPT model reveals that the hadronic rescatterings process affects different orders of net-baryon cumulant ratios.

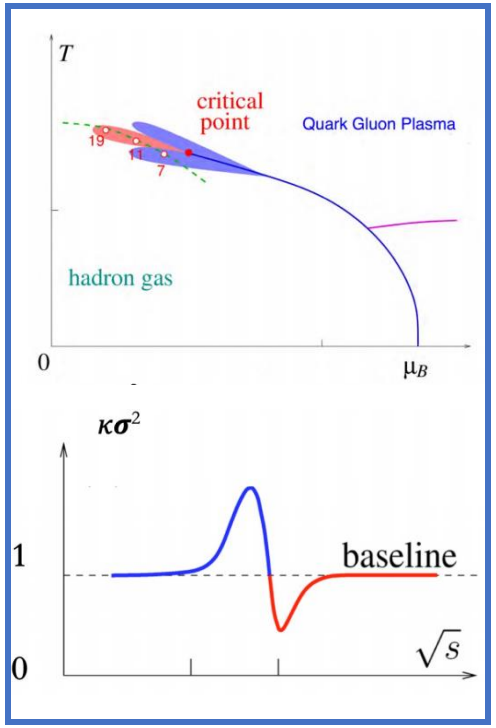
Outlook

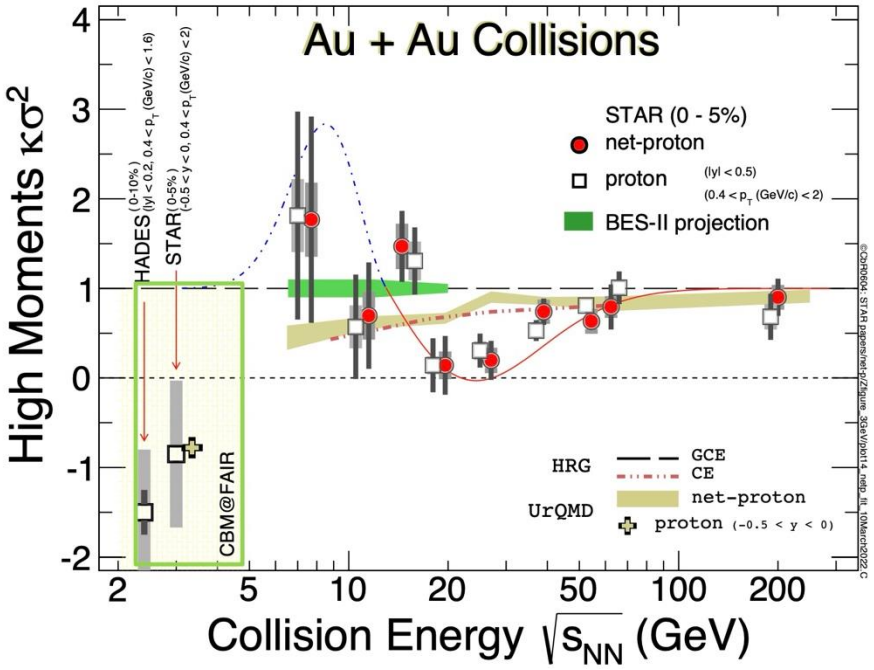
- ◆ Incorporation of critical fluctuation physics into AMPT： FRG、density fluctuations.
- ◆ nuclear thickness effects, coalescence mechanisms, different collision systems, ...

THANKS!

Back Up

Fluctuations measured by STAR





1）Non-monotonic energy dependence: **hint of entering critical region.**

2）3 GeV proton high moments data：**Hadronic interaction dominant!**

3）Energy gap between 3 and 7.7 GeV, important for **Critical Point search.**

STAR:PRL126,92301(2021)PRL128,202303(2022)HADES: PRC102, 024914(2020)

Back Up

- In the old version, only K^+ and K^- were introduced in hadron rescatterings as explicit particles, but K^0 and $\bar{K}^0$ were omitted.

- In the old version, some isospin-averaged cross sections were used, and the charge of the final state particles is chosen randomly from all possible charges, independent of the total charge of the initial state.

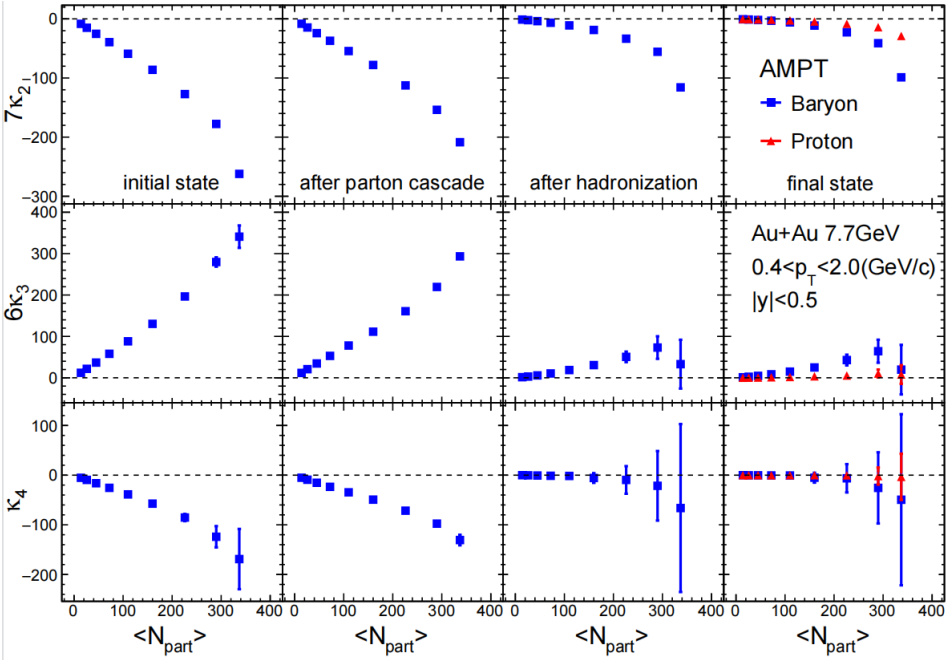
For example:

$$1)\ \pi^+ + \pi^+ \rightarrow \rho^+ + \rho^+ \quad \checkmark$$
$$2)\ \pi^+ + \pi^+ \rightarrow \rho^+ + \rho^- \quad \times$$
$$3)\ \pi^+ + \pi^+ \rightarrow \rho^- + \rho^- \quad \times$$

Back Up

Expectation of baryon number conservation:

$$P(N) = \frac{B!}{N!(B-N)!} p^N (1-p)^{(B-N)}$$



Qian Chen, Guo-Liang Ma, Phys.Rev.C 106 (2022) 014907

n-baryon correlations:

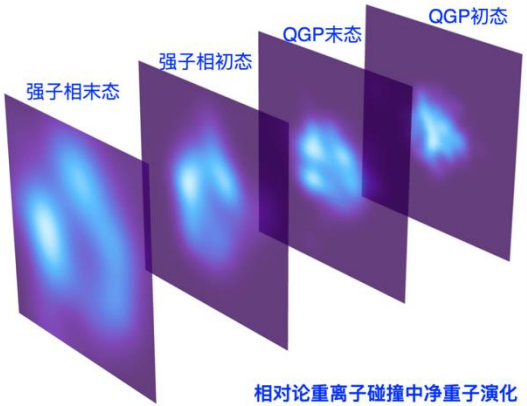
$$\kappa_1 = \langle N \rangle = pB$$

$$\kappa_2 = -\frac{\langle N \rangle^2}{B}$$

$$\kappa_3 = 2\frac{\langle N \rangle^3}{B^2}$$

$$\kappa_4 = -6\frac{\langle N \rangle^4}{B^3}$$

- Multi-baryon correlations are getting weaker with stage evolution of heavy-ion collisions



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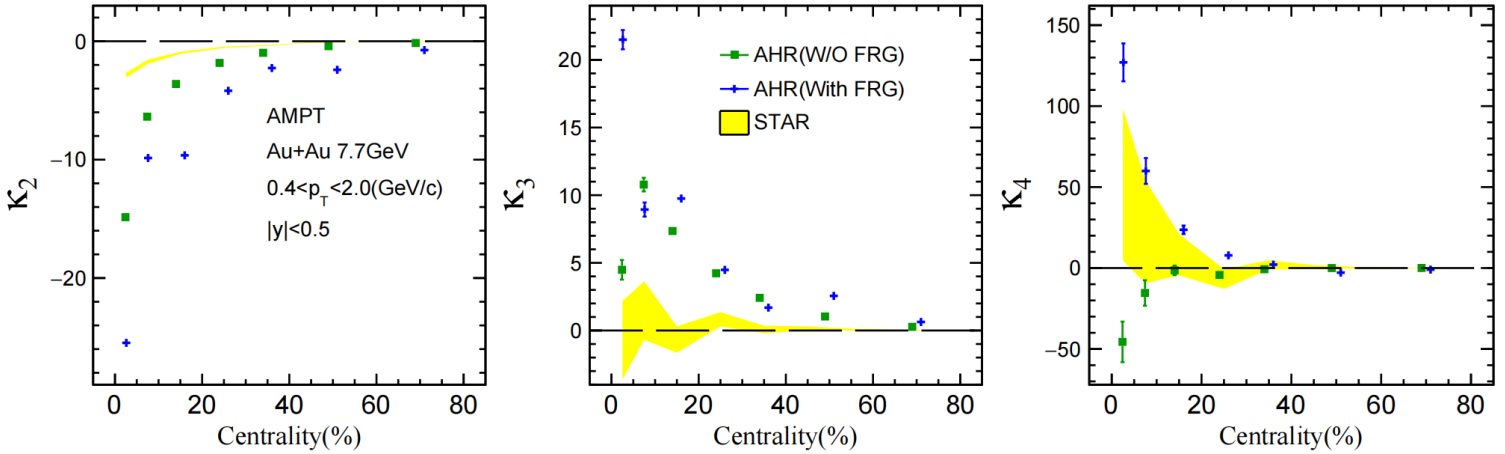

- The strengths of the correlation functions κ_2 and κ_3 in the AMPT model without the FRG sampling are smaller than those in the AMPT model with the FRG sampling.
- The correlation functions κ_4 from negative to positive, which would be more consistent with the current experimental measurement.

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