Dynamics of conserved baryon near QCD critical point within QGP profile

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Physics at High Baryon Density (PHD2024), Nov 1-4, 2024@CCNU

QCD phase diagram

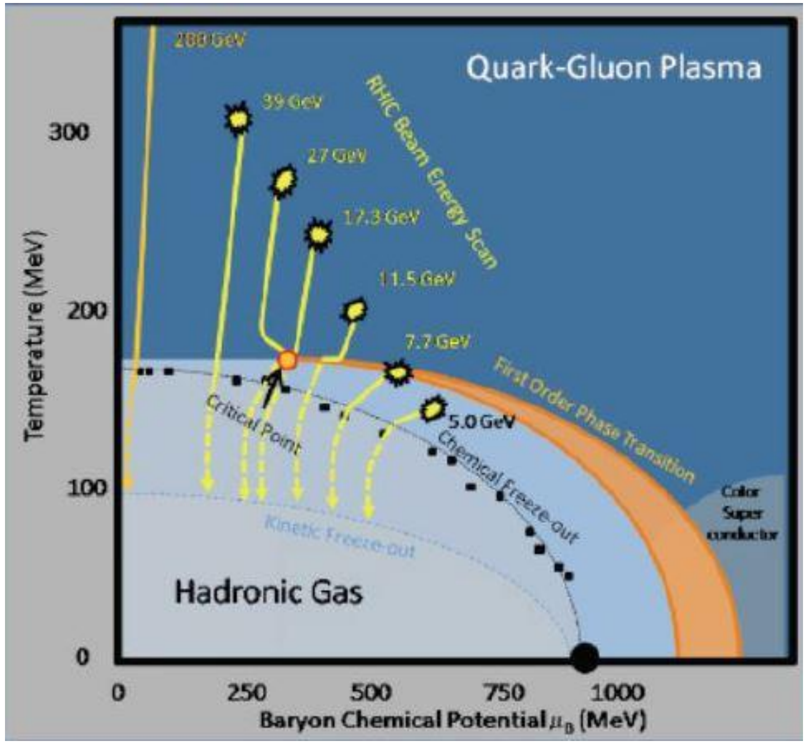
- **Lattice QCD** (small μ_B finite T):
  - Crossover
- **Effective models** (large μ_B)
  - 1st order phase transition

→ Critical point

- Lattice QCD: sign problem at large μ_B
- Effective models: parameters dependent

→ **Heavy-ion collisions :**

  - tuning $\sqrt{s_{NN}}$,mapping $T-\mu$ phase diagram: RHIC(BES),NICA,FAIR,J_PARC,HIAF….

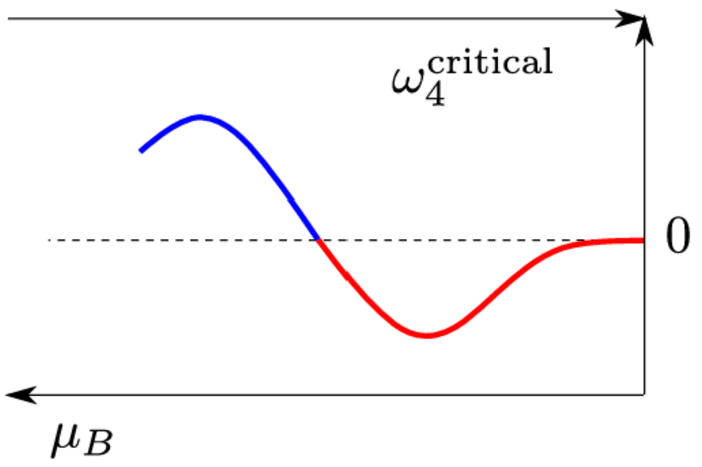


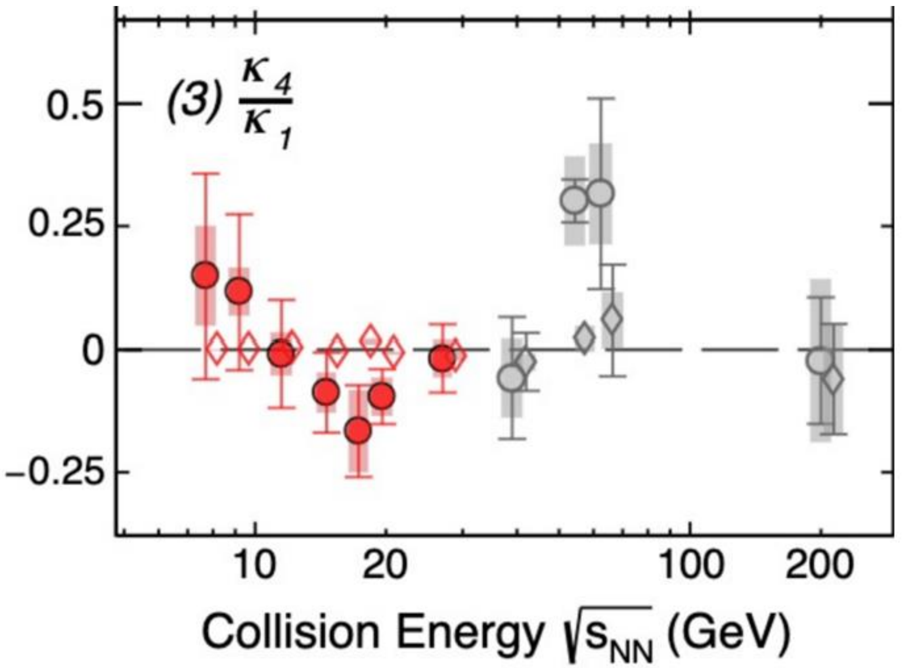
Net-proton fluctuations near critical point

- Characteristic feature of critical point:
  - long range correlation
  - large fluctuations
- **Non-monotonicity** of factorial Cumulant

$\sim$ susceptibilities $\left(\frac{\partial}{\partial \mu}\right)^n \ln Z$

$\langle(\delta N)^4\rangle$ $\sqrt{s_{NN}}$





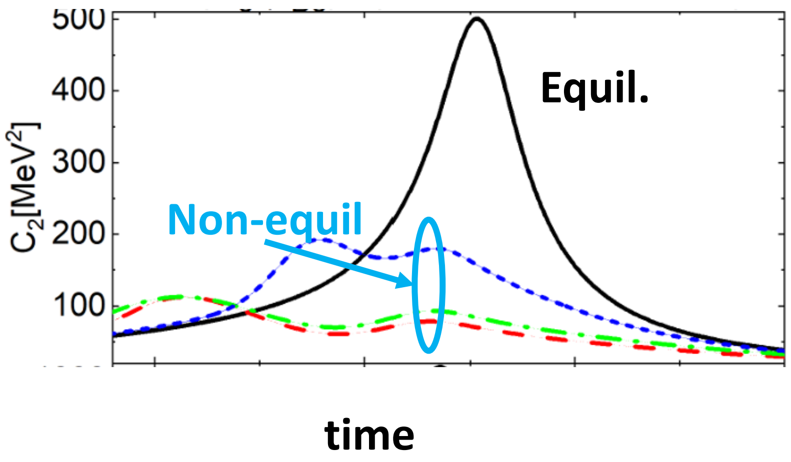
STAR, CPOD 2024

M.Stephanov, 2410.02861

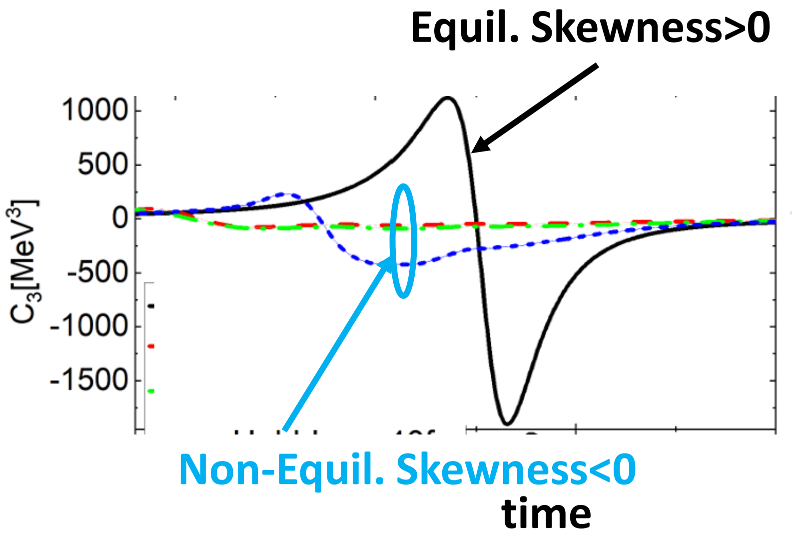
Dynamical effects modifies the critical fluctuations

Shian Tang, Shanjin Wu, Huichao Song, PRC(202

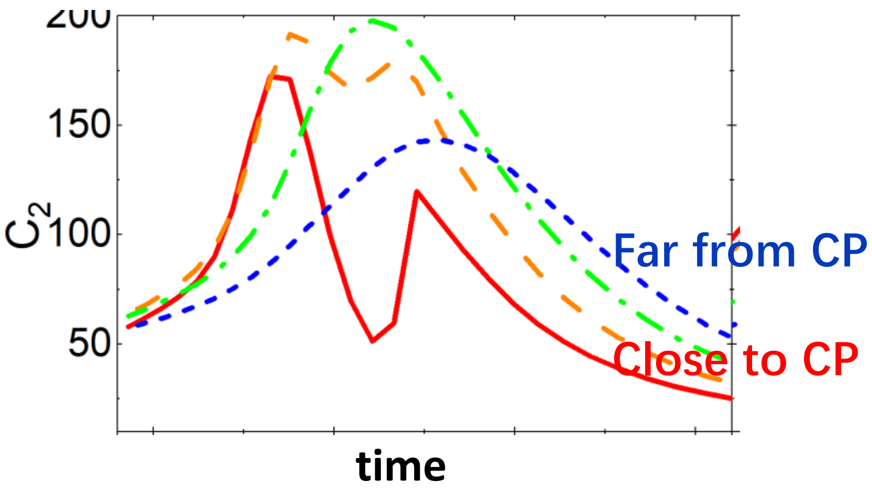
- Expanding QGP fireball => Critical Slowing down => modified critical fluctuations



Suppression of the fluctuations



Reverse the sign of skewness

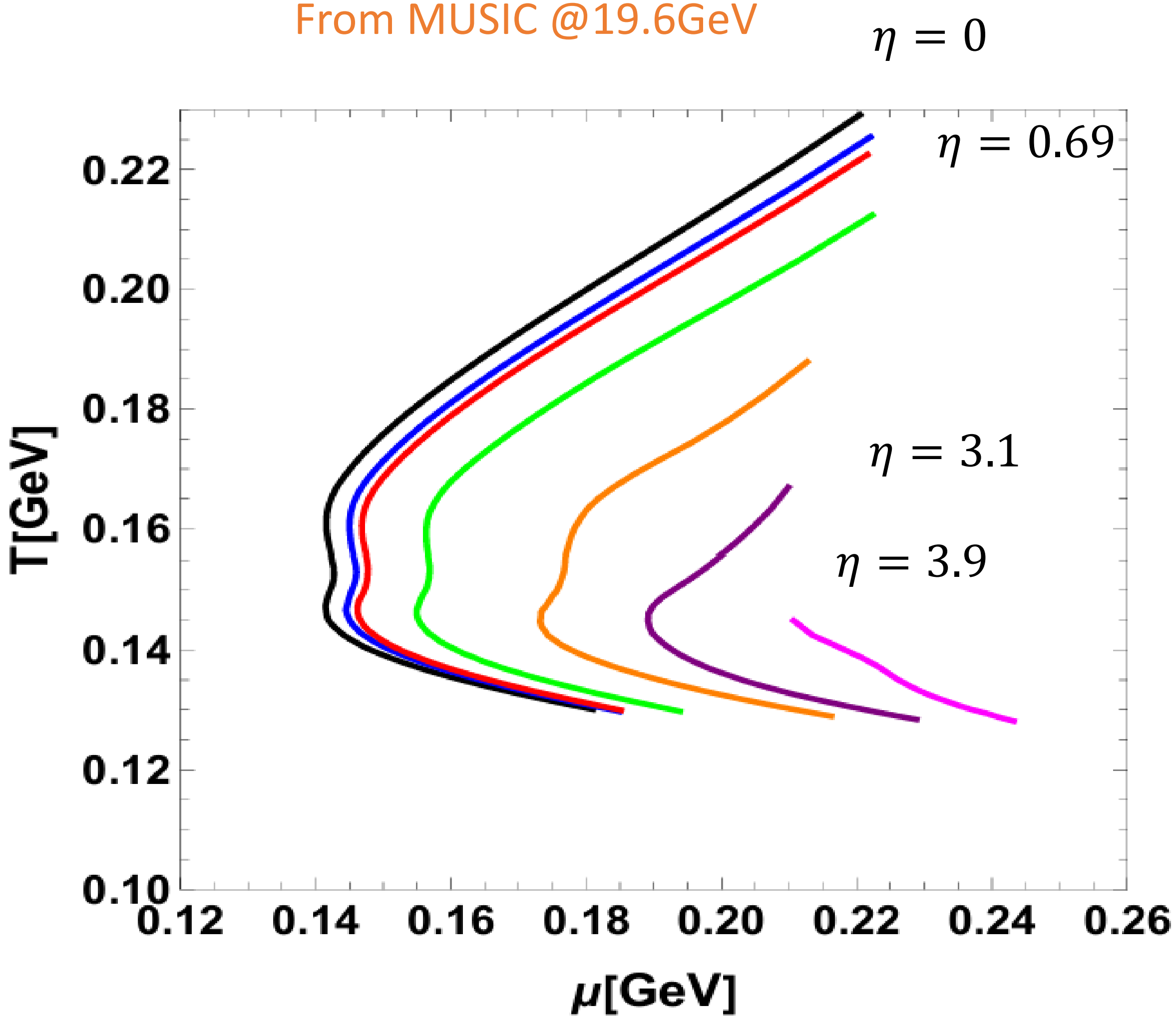


Largest $C_2 \neq$ closet to CP

Inhomogeneous QGP profile

- Different rapidity
- $\sim$ different trajectories
- $\sim$ detect different region of phase diagram
- $\sim$ different critical behavior

From MUSIC @19.6GeV

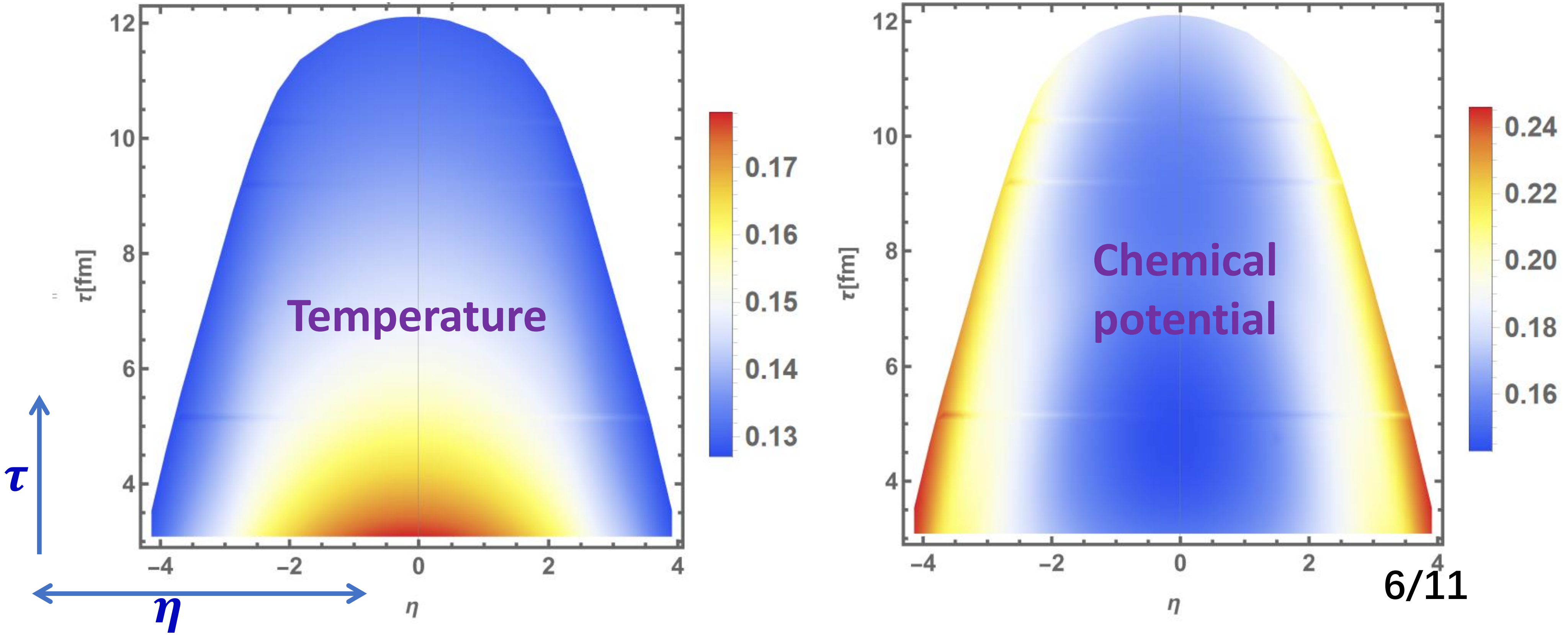


Different η in one QGP profile

Inhomogeneous T and μ profile from hydro simulation

- This talk aims to study the inhomogeneous QGP profile effects on the diffusion of net-baryon
- Hydro simulation: AMPT+MUSIC@19.6GeV

Shanjin Wu 2406.12325



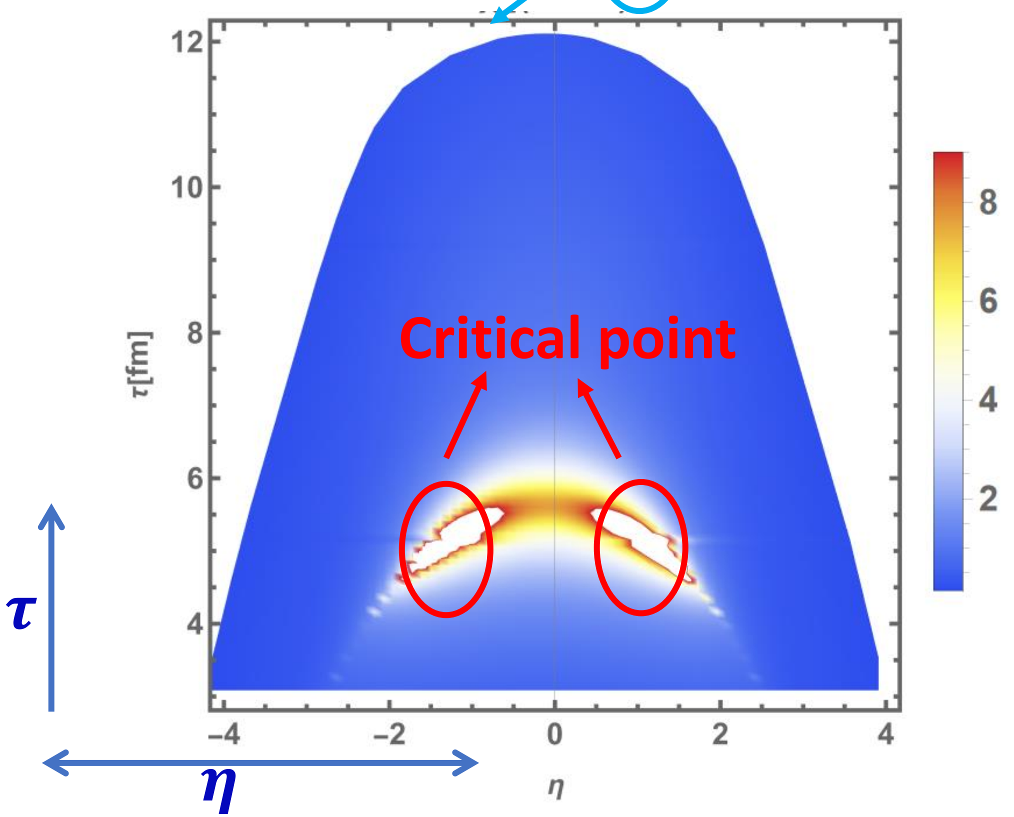
Conserved net-baryon with inhomogeneous T and μ profile

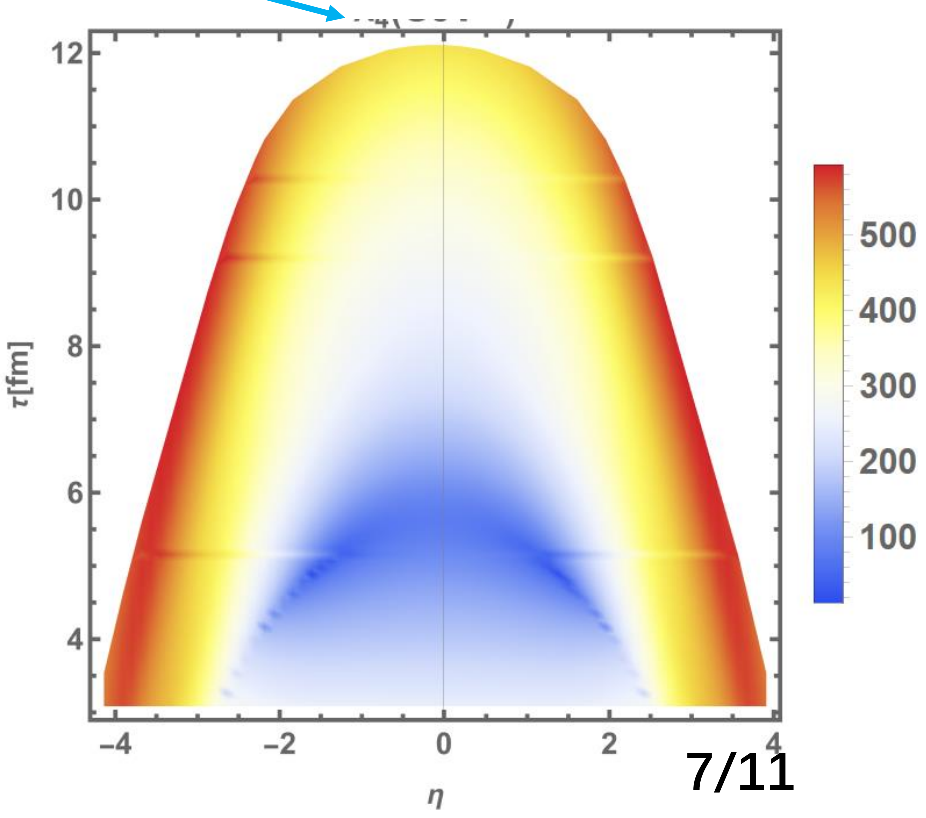
- Diffusion of conserved baryon near critical point: Shanjin Wu 2406.12325

G.Pihan et al., PRC.107.014908(2022)
Sakaida et al, PRC.95.064905(2017)

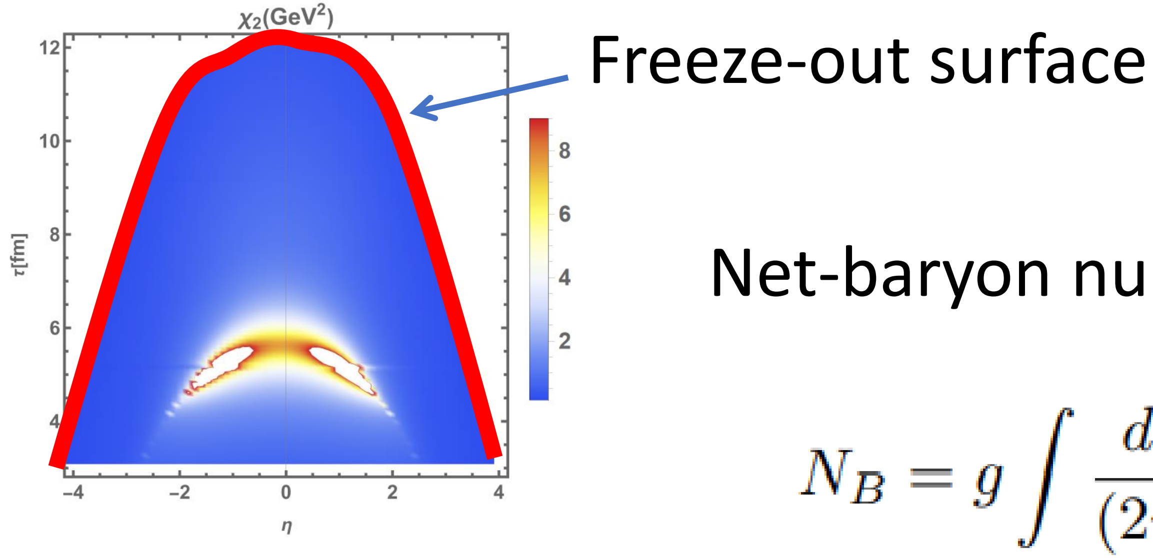
$$\partial_\tau n = \nabla^2\left(\frac{n}{\chi_2} + \lambda_3 n^2 + \lambda_4 n^3\right) + \text{noise}$$

χ_2, λ_4 from Ising model (EoS)





Conserved net-baryon fluctuations at freeze-out surface



Net-baryon number at freeze-out surface

$$N_B = g \int \frac{d^3p}{(2\pi)^3} \frac{1}{p^0} \int d\sigma_\mu p^\mu f(\boldsymbol{x}, \boldsymbol{p})$$

Net-baryon fluctuations at freeze-out surface:

$$\delta N_B \sim \int \exp\left(\frac{\mu}{T}\right) \delta\mu \sim \int exp\left(\frac{\mu}{T}\right) \delta n_B / \chi_2$$

Conserved net-baryon fluctuations at freeze-out surface

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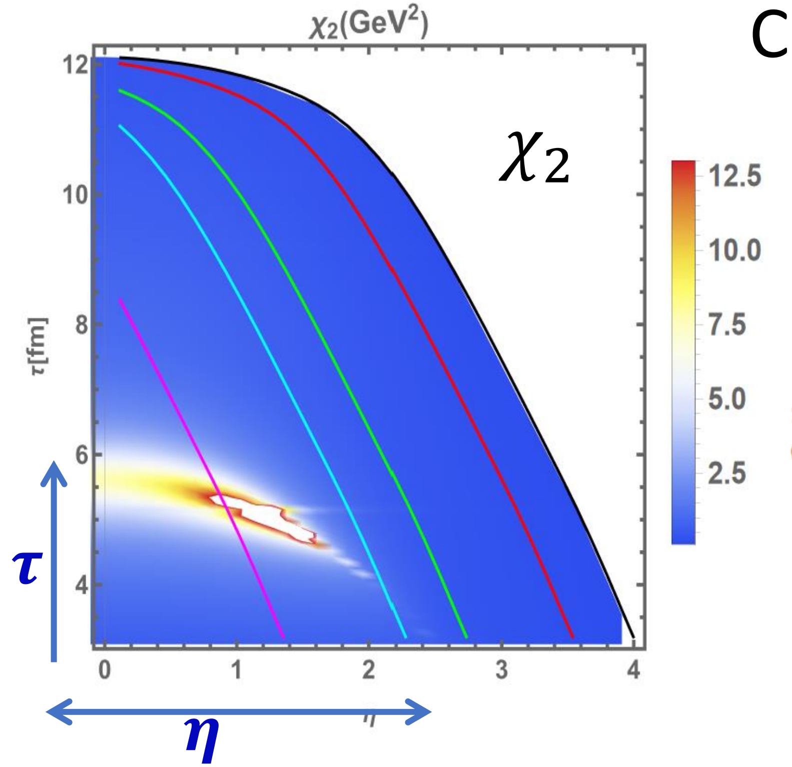
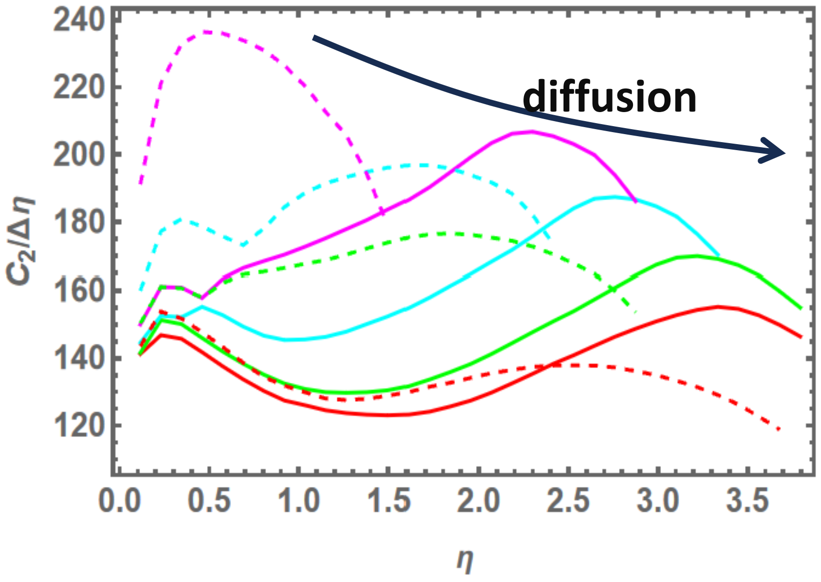
$$\delta N_B \sim \int \exp\left(\frac{\mu}{T}\right)\delta\mu \sim \int exp\left(\frac{\mu}{T}\right)\delta n_B/\chi_2 \qquad \partial_\tau n \sim \frac{1}{\tau_{relax}}\nabla^2\frac{n}{\chi_2} + \text{noise}$$

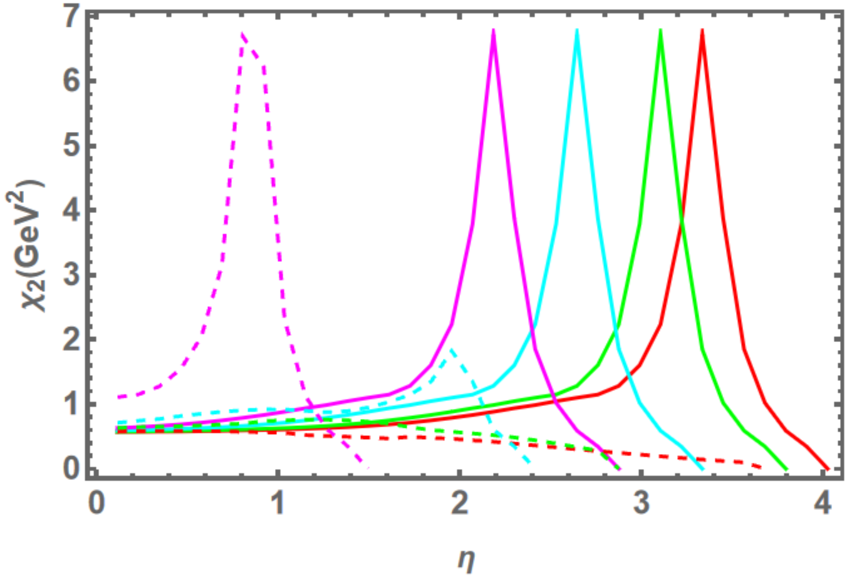


Critical slowing down: evolution of δn_B slower than χ_2

$C_2 = \langle(\delta n_B)^2\rangle$

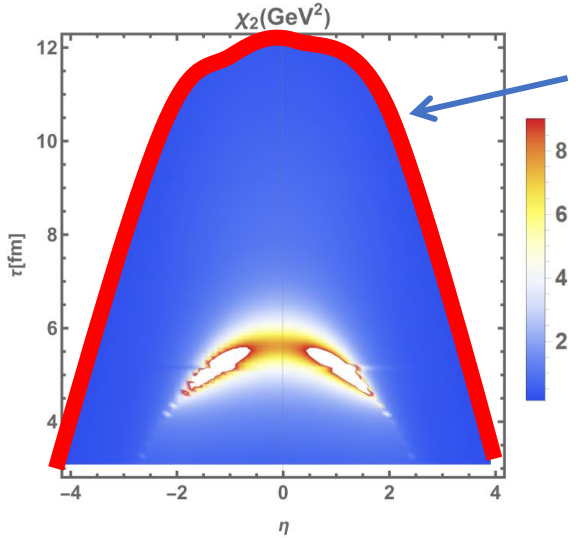


χ_2



Solid: uniform profile; Dashed: inhomogeneous profile

Conserved net-baryon fluctuations at freeze-out surface



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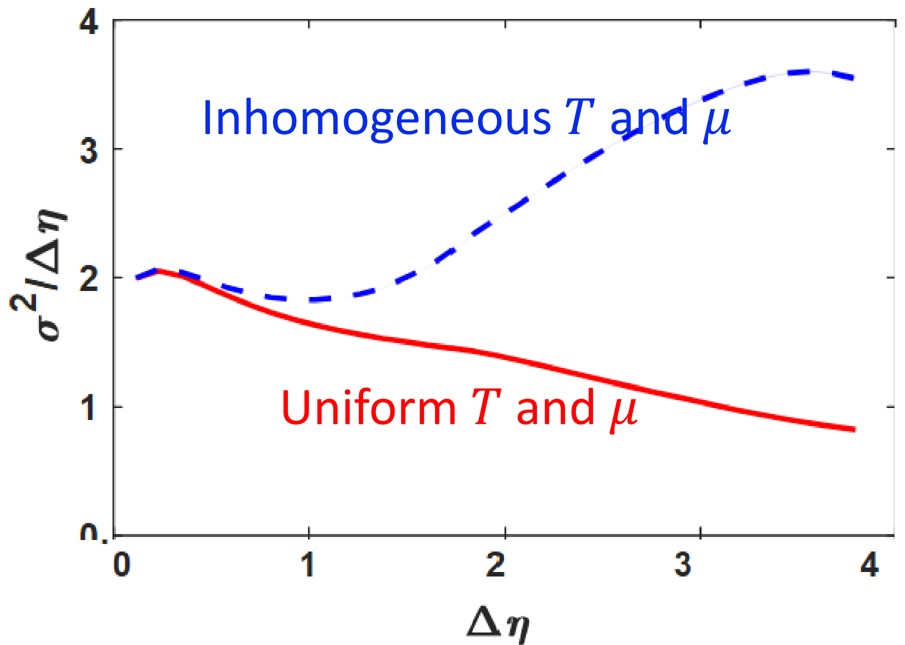
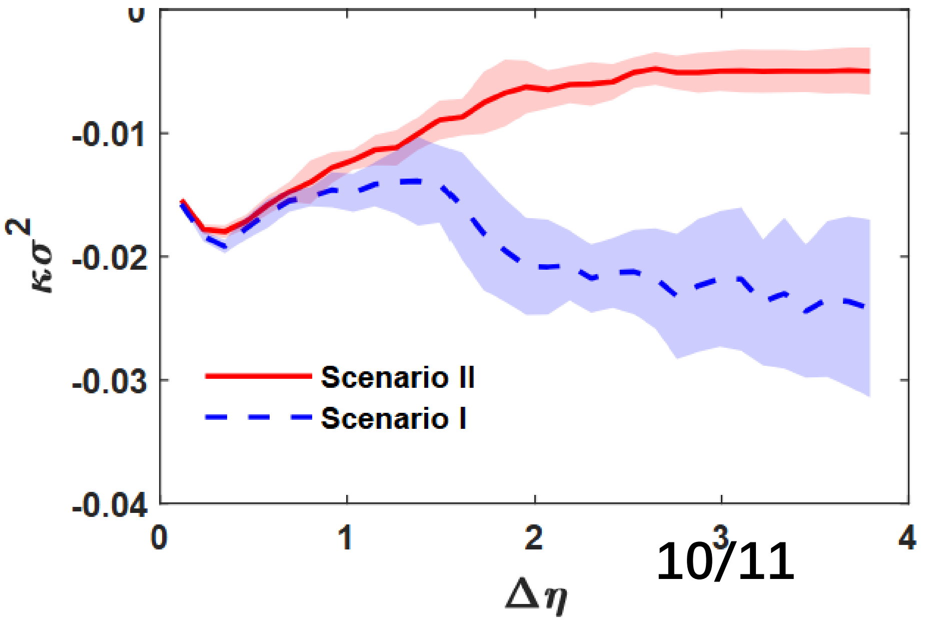
Critical slowing down effects:
cumulants at large rapidity preserves the larger fluctuations (critical effects) at early evolution history





Summary

- Dynamical modeling the QGP evolution near the QCD critical point is essential for the study of fluctuations in heavy-ion experiments;
- The diffusion of conserved net-baryon density preserves the early evolution history and behaves non-monotonically with increasing rapidity;
- Considering the inhomogeneous T and μ profile has significant effects at large rapidity.
- Non-boost invariant

Thank you!