Non-Markov effect on time evolution of conserved-charge fluctuations in heavy ion collisions

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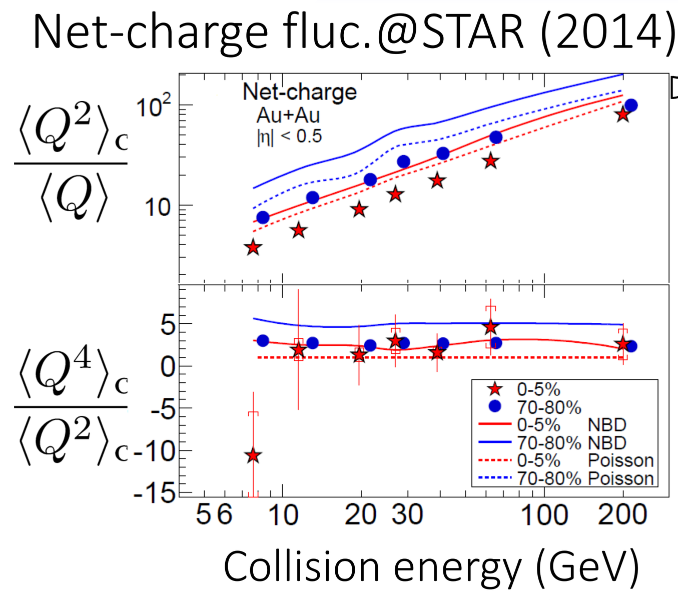
Intro

Conserved-charge fluctuations tells us much information on QGP & hot medium…

■ Conserved-charge fluctuation in HIC

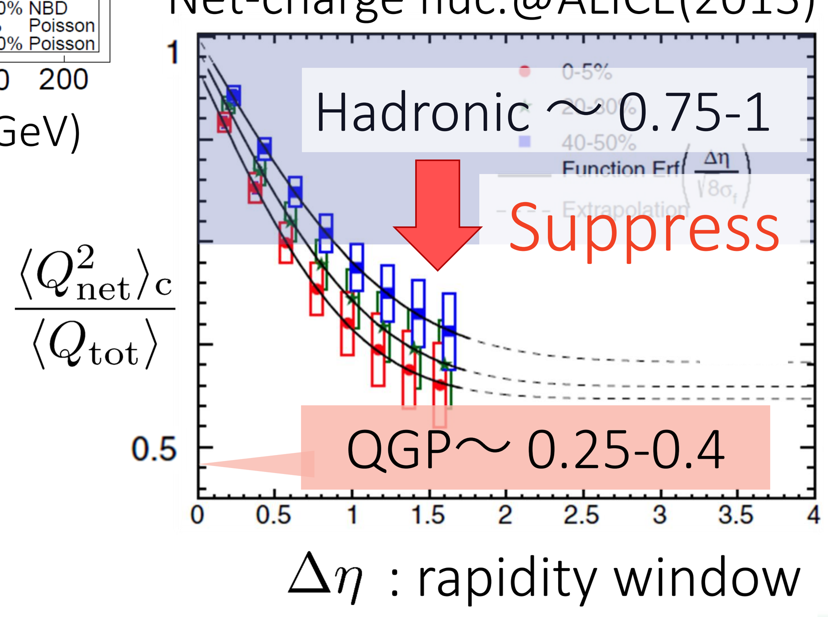
Net-charge fluc.@STAR (2014)



☞ Non-Gaussianity are also observed in HIC!
☞ much info.!

■ Why fluctuation?

Net-charge fluc.@ALICE(2013)



☞ Fluctuations are not thermal at freeze-out.

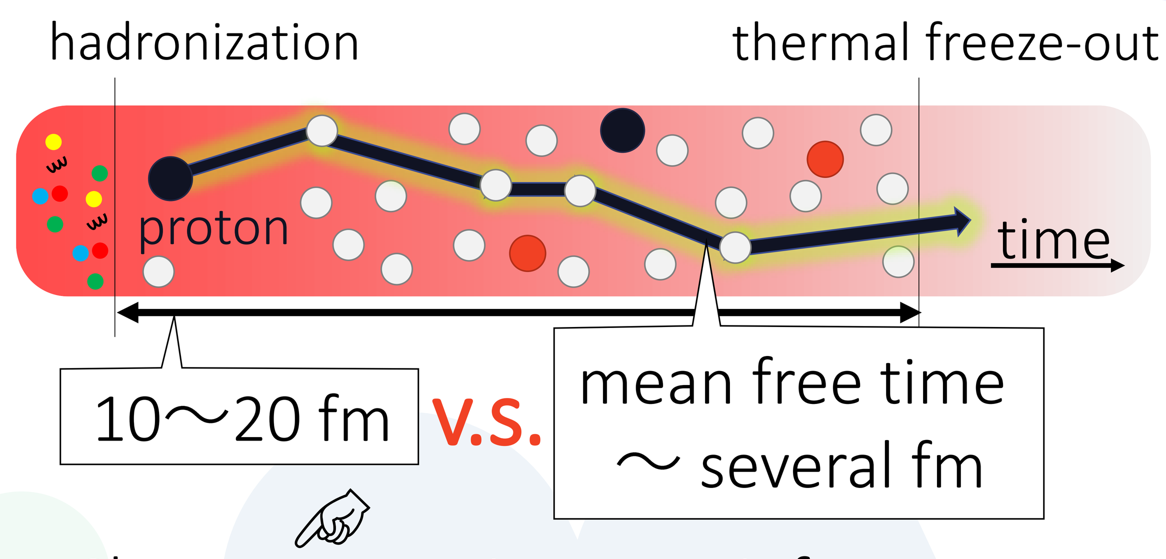
☞ Fluc. memorize info. on QGP!!

MS *et.al.*, PRC90, 064911 (2014)

↓

describe dissipation
+ compare with data
➡ extract info. on QGP

■ Time evolution of charge in HIC



Charge memorizes past info. for a non-negligible time scale.

☞ Charge diffusion in HIC = Non-Markov(NM)

Aim : Study Non-Markov effect (memory time effect)

Methods

1 ■ Stochastic eq. (SDE) for a single particle

First, focus on a single particle

v : velocity
x: position

Adopt Langevin eq. (※Markov)

$$\begin{cases} \dot{x} = v \\ \dot{v} = -\tau_m^{-1}[v + \sqrt{2D}\,\xi(\tau)] \end{cases}$$

τ_m : memory time
D : diffusion const.
$\xi(\tau)$: random force
τ : proper time
$\Delta\eta$: rapidity window

□ way1

Calculate $\langle x(\tau)\rangle_c, \langle x^2(\tau)\rangle_c$ by solving Langevin directly
(Assumption: white noise)

↓

Gaussian NM exact solution

$$P_{\rm L}(x-x_0,\tau) = \frac{1}{\sqrt{2\pi\sigma^2}}\exp\left[\frac{-(x-x_0)^2}{2\sigma^2}\right]$$

$$\sigma^2 = 2D\tau + D\tau_{\rm m}(4{\rm e}^{-\tau\tau_{\rm m}^{-1}} - 3 - {\rm e}^{-2\tau\tau_{\rm m}^{-1}})$$

Non-Markov nature

□ way2

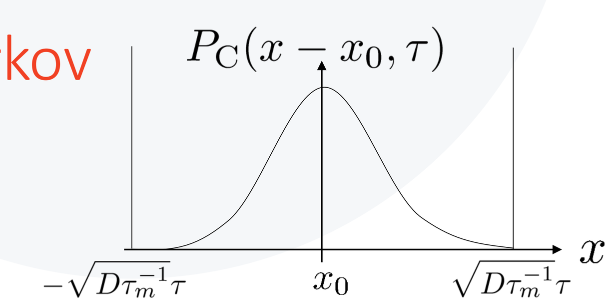
Convert to Kramers' eq.
(SDE for prob. distribution $P(x,v,\tau)$)

↓ Adiabatic elimination :
Assume $P(x,v,\tau) = P_{\rm s}(v)P(x,\tau)$

Cattaneo eq.(NM) & Solution

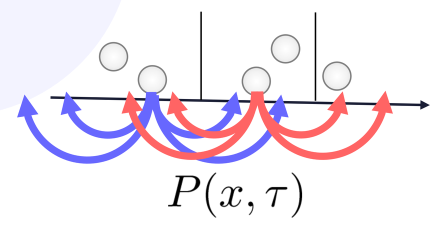
$$\tau_m\partial_\tau^2 P_{\rm C}(x,\tau) + \partial_\tau P_{\rm C}(x,\tau) = D\partial_x^2 P_{\rm C}(x,\tau)$$

Non-Markov & Causal



2 ■ Multi-particle system

Assumption: all particles obey same eq. without interaction



➡ relation between P(x,τ) & charge cumulants

$$\langle Q^2(\tau)\rangle_c = \int_{-\infty}^{\infty} dx_0 \left[\int_{-\Delta\eta/2}^{\Delta\eta/2} dx P(x-x_0,\tau) - \left\{\int_{-\Delta\eta/2}^{\Delta\eta/2} dx P(x-x_0,\tau)\right\}^2\right]$$

↑ Substitute P(x,τ) ↑

Results

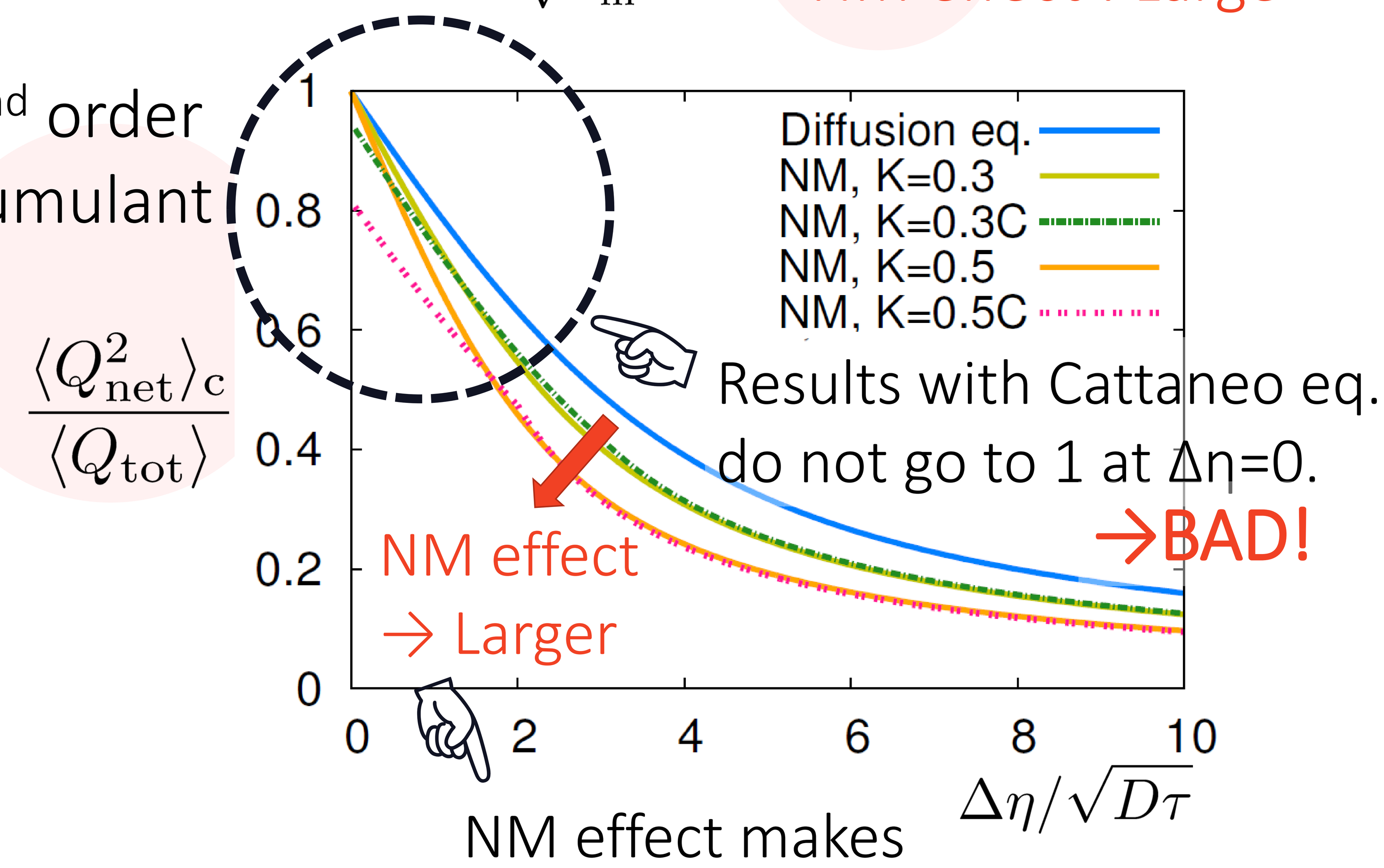
Goal

■ Fluc. with NM effect

Free para. : $K = 0.5\sqrt{\tau_m\tau^{-1}}$

K : Large ⇔ NM effect : Large

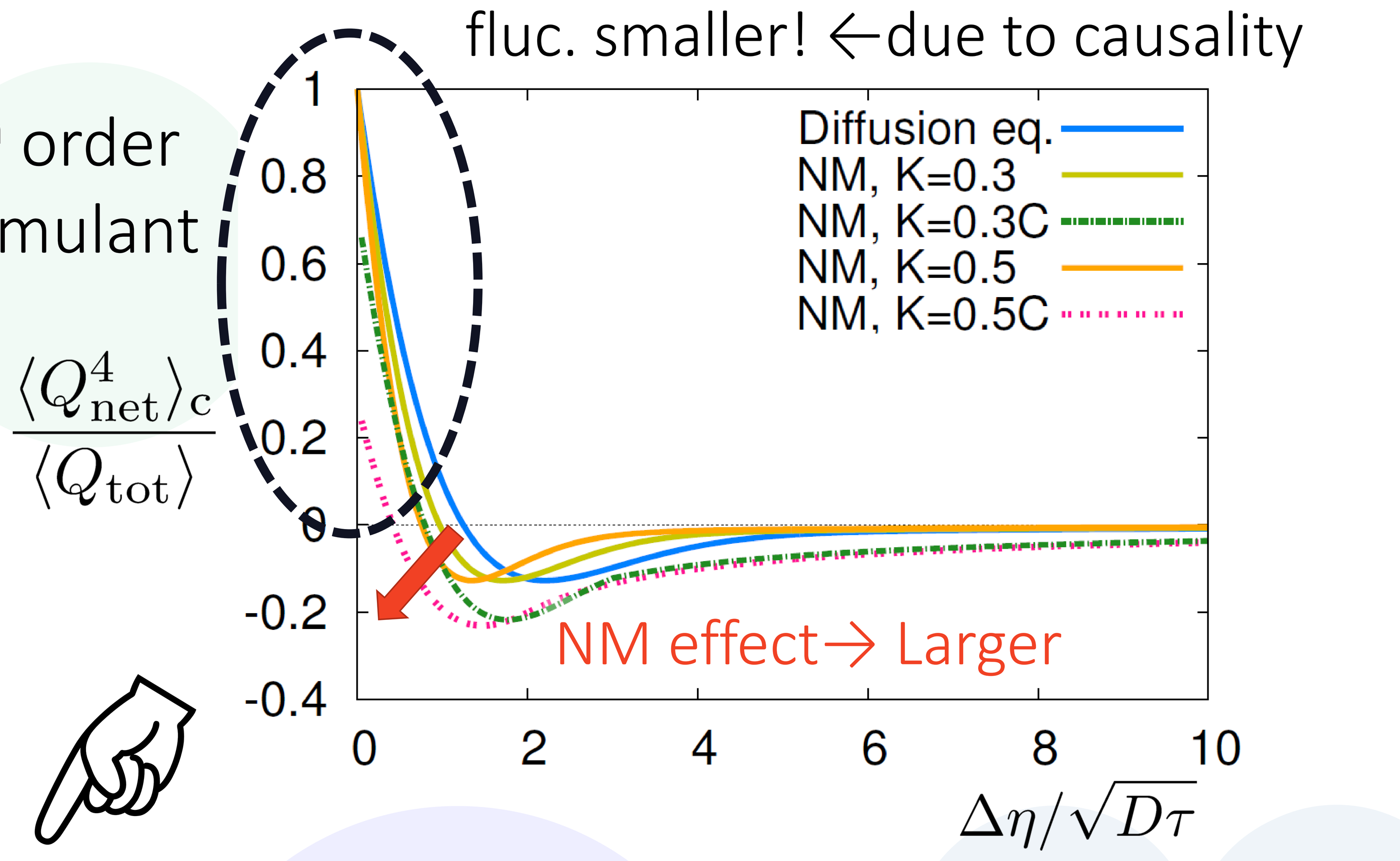
2nd order cumulant



☞ Results with Cattaneo eq. do not go to 1 at Δη=0.
→BAD!

NM effect makes fluc. smaller! ←due to causality

4th order cumulant



Result1: NM effect makes fluc. smaller! ←due to causality

Result2: Using Cattaneo eq.is risky! (Results with Cattaneo eq. do not go to 1 at Δη=0)

Summary

- ◆ We studied non-Markov effect on time evolution of higher order conserved-charge fluctuations.
- ◆ We obtained higher order charge cumulants with NM effect from the solution of Cattaneo eq. and also directly from Langevin eq..

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