Effect of the global charge conservation on the time evolution of fluctuations of conserved charges in relativistic heavy ion collisions

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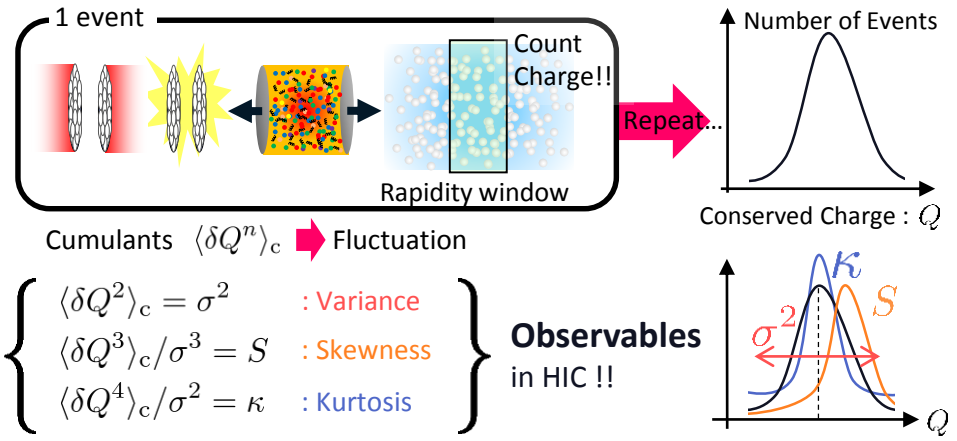
Motivation and Introduction

We want information on the properties of QGP & hot medium.

Focus on **Fluctuations of Conserved Charges (Net Electric Charge & Net Baryon Number)**

Event-by-Event Fluctuation



Cumulants $\langle \delta Q^n \rangle_c$ ➡ Fluctuation

$$\begin{cases} \langle \delta Q^2 \rangle_c = \sigma^2 & : \text{Variance} \\ \langle \delta Q^3 \rangle_c / \sigma^3 = S & : \text{Skewness} \\ \langle \delta Q^4 \rangle_c / \sigma^2 = \kappa & : \text{Kurtosis} \end{cases}$$

Observables in HIC !!

Charge Fluctuation at ALICE

2nd order Fluctuation of Net Electric Charge

$$\frac{4\langle \delta Q_{\rm ch}^{(\rm net)2} \rangle_c}{\langle Q_{\rm ch}^+ + Q_{\rm ch}^- \rangle_c}$$

($Q_{\rm ch}$: Electric Charge)

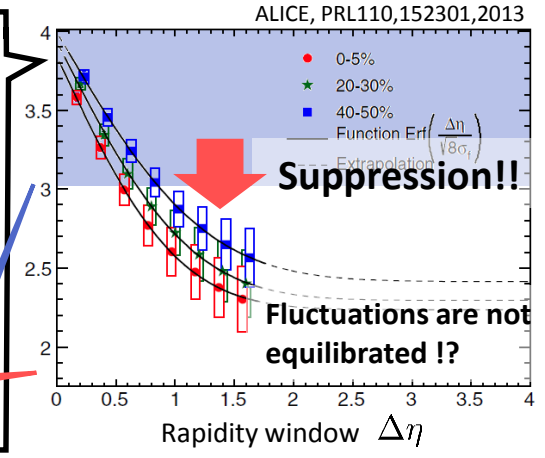
Equilibrated Value (Infinite System)

in Hadrons 3 - 4

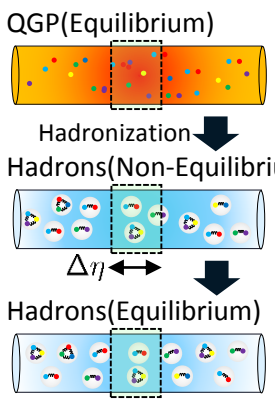
in QGP 1 - 1.5

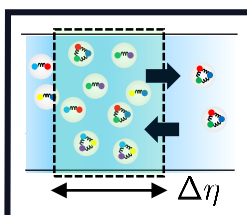
Jeon,Koch,2000

ALICE, PRL110,152301,2013



Time Evolution of Fluctuation





Conserved charges in $\Delta\eta$ Change **only through diffusion.**

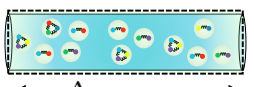
$\Delta\eta$: Large ➡ QGP ← Hard to become Equilibrium !!

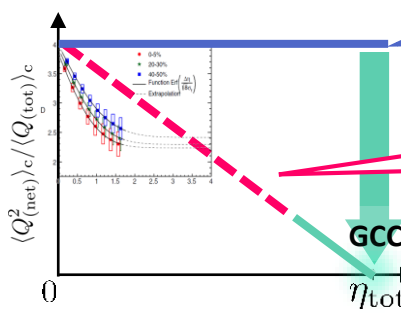
$\Delta\eta$: Small ➡ Hadronic

Asakawa,Heinz,Muller,2000

Global Charge Conservation (GCC)

If one looks at the total system, conserved charges **do not fluctuate**.





Equilibrated Value in Hadrons (Infinitely Long System)

Naïve Estimate of Effects of the GCC

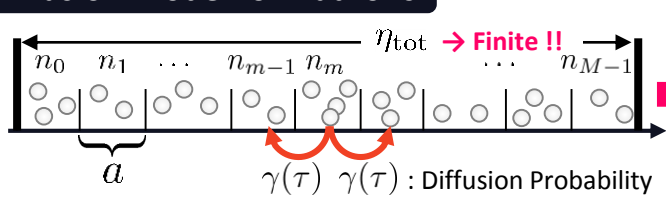
$$\langle \delta Q^2 \rangle_{\rm finite} = \langle \delta Q^2 \rangle_{\rm inf.} \times \left(1 - \frac{\Delta\eta}{\eta_{\rm tot}} \right)$$

Bleicher, Jeon, Koch, PRC62, 061902, 2000

GCC may also suppress the value of fluctuation! ➡ **Study Effects of the GCC and Implication of the Suppression!!**

Method

Diffusion Model for Hadrons



Probability Distribution $P(\mathbf{n}, \tau)$

Kitazawa *et al.*, 2014

Diffusion Master Eq.

$$\partial_\tau P(\mathbf{n},\tau) = \gamma \sum_m [(n_m+1)\{P(\mathbf{n}+\mathbf{e}_m-\mathbf{e}_{m+1},\tau) + P(\mathbf{n}+\mathbf{e}_m-\mathbf{e}_{m-1},\tau)\} - 2n_m P(\mathbf{n},\tau)]$$

+ **Boundary Condition**: Charges do not flow in/out at boundaries.

- Initial Condition : Thermal QGP Value
- Time evolution until thermal freeze-out

Time Evolution of Fluctuations of Conserved Charges $Q_{(\rm net)}(\tau)$

Solutions $\langle \delta Q_{(\rm net)} \rangle_c$, $\langle \delta Q^2_{(\rm net)} \rangle_c$ ⇔ agree Solutions of Stochastic Diffusion Eq.

$\gamma(\tau) a^2 = D(\tau)$: Diffusion Coefficient

Results (Δη Dependence of Fluctuations)

Dimensionless Parameters

$$L = \eta_{\rm tot}/d(\tau),\ T = d(\tau)/\eta_{\rm tot}$$

$$d(\tau) = \left[2\int_{\tau_0}^{\tau_{f.o}} D(\tau')\, d\tau' \right]^{1/2}$$: Diffusion Length

$\eta_{\rm tot}$: Total Rapidity Length of the Hot Medium

Without Initial Fluctuations

Interpretation of GCC Effects

$$\frac{\eta_{\rm tot}-\Delta\eta}{2} \leq d(\tau)$$

No GCC Effects at ALICE !!

With Initial Fluctuations

Summary

*Electric charge fluctuation at ALICE is affected by GCC !

*Fluctuations are not equilibrated at thermal freeze-out!

→Various Information from Δη Dependences of Fluctuations (Ex. Fluctuations in QGP, Diffusion coefficient etc…)