Effect of Hydrodynamic Fluctuations on Mixed Harmonic Cumulants at the LHC

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Introduction

Purpose

- Effect of hydrodynamic fluctuations on observables
- Relation between determination of viscosity of QGP and hydrodynamic fluctuations

Hydrodynamic Fluctuations

$$\left\langle \xi^{\mu\nu}(x)\xi^{\alpha\beta}(x')\right\rangle = 4\eta(x)T(x)\Delta^{\mu\nu\alpha\beta}\delta^{(4)}(x-x')$$

$$\left\langle \xi^{\mu\nu}(x)\right\rangle = 0$$

Hydrodynamic fluctuation is included through the noise term

Mixed Harmonic Cumulants $MHC(v_m^k, v_n^l)$

・**Property**

Sensitive to viscosity

Comparison of models

・**Example**

$$MHC\left(v_2^2, v_3^2\right) = \left\langle v_2^2 v_3^2\right\rangle - \left\langle v_2^2\right\rangle \left\langle v_3^2\right\rangle$$

$$MHC\left(v_2^2, v_4^2\right) = \left\langle v_2^2 v_4^2\right\rangle - \left\langle v_2^2\right\rangle \left\langle v_4^2\right\rangle$$

$$MHC\left(v_2^4, v_3^2\right) = \left\langle v_2^4 v_3^2\right\rangle - 4\left\langle v_2^2 v_3^2\right\rangle \left\langle v_2^2\right\rangle - \left\langle v_2^4\right\rangle \left\langle v_3^2\right\rangle + 4\left\langle v_2^2\right\rangle^2 \left\langle v_3^2\right\rangle$$

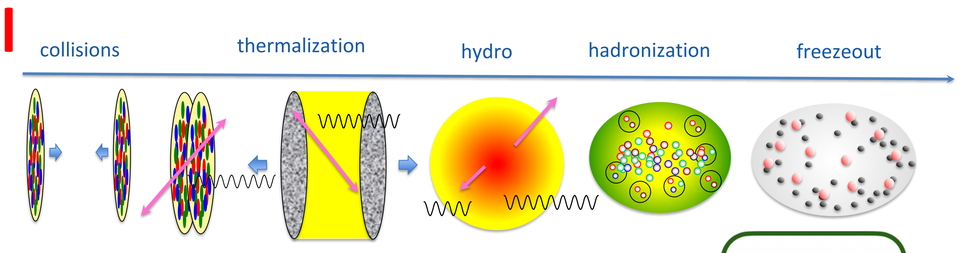
・**Normalized Mixed Harmonix Cumulant**

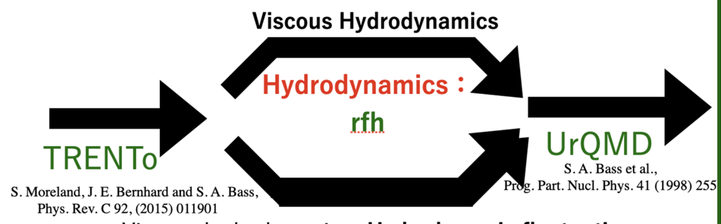
nMHC = normalized Mixed Harmonic Cumulant

Ming Li, You Zhou, Wenbin Zhao, Baochi Fu, Yawen Mou, and Huichao Song, Pays. Rev. C 104, (2021) 024903

ALICE Collaboration, Phys. Lett. B 818, (2021) 136354

Model





- **EoS**: Lattice QCD(NPA929)

  M. Bluhm, P. Alba, W. Alberico, A. Beraudo and C. Ratti, Nucl. Phys. A 929 (2014) 157

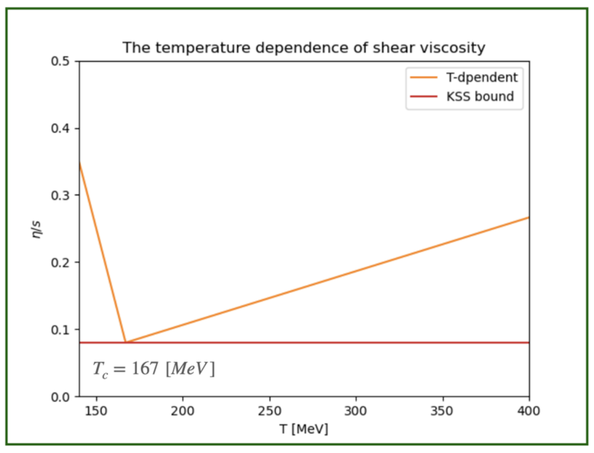
- **Hydrodynamic fluctuations**
  - Cutoff parameter

    $\lambda_\eta = 2.0, \lambda_\perp = 2.0$ [fm]

    A. Sakai, K. Murase, and T. Hirano, Phys. Lett. B 829, 137053 (2022)

- **Parameters in TRENTo**
  - $p = 0$ (IP-Glasma)
  - $n = 130$ (T-dependent), $n = 145$ (KSS bound)

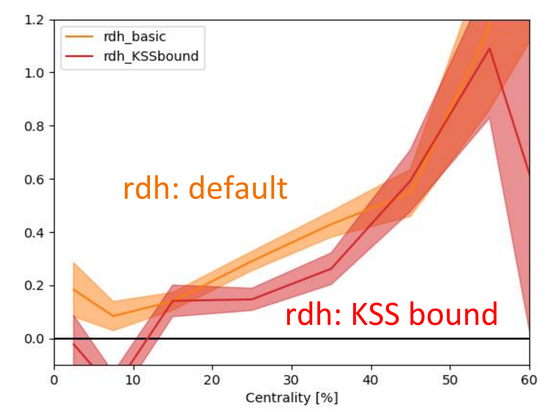
- **Viscosity**
  - ①T dependence
  - ②KSS bound



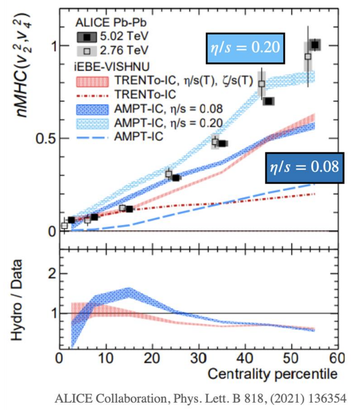
Kazuhisa Okamoto and Chiho Nonaka, Eur. Phys. J. C 77, (2017) 383

Results

$nMHC(v_2^2, v_4^2)$



M. Li, Y. Zhou, W. Zhao, B. Fu, Y. Mou, and H. Song, PRC**104** 024903 (2021)

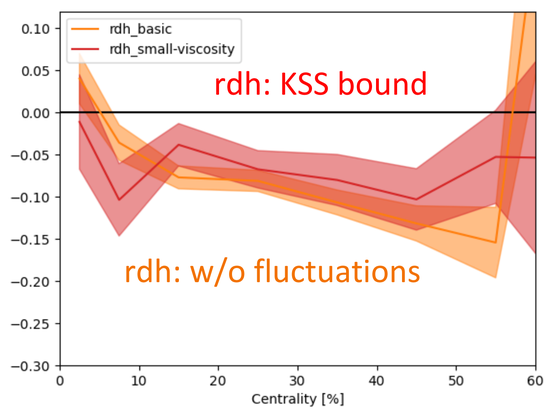


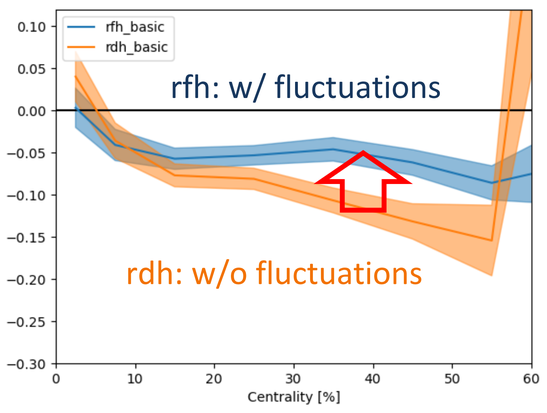
ALICE Collaboration, Phys. Lett. B 818, (2021) 136354

Viscosity dependence
Smaller viscosity → $nMHC$ decrease
Consistent with previous study

Hydrodynamic fluctuations
Decrease $nMHC$
→ Smaller viscosity

$nMHC(v_2^2, v_3^2)$

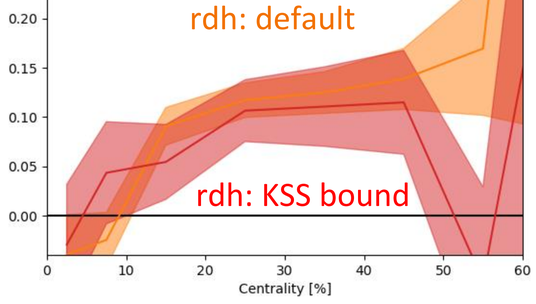


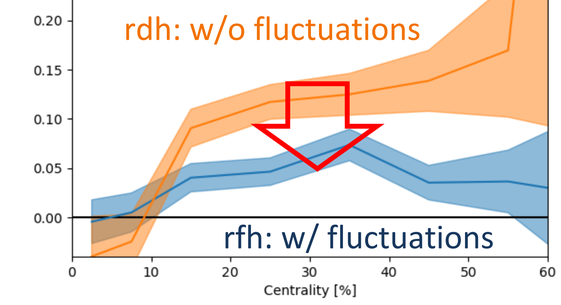


Viscosity dependence
No viscosity dependence

Hydrodynamic fluctuations
Decrease $nMHC$ magnitude

$nMHC(v_2^4, v_3^2)$





Viscosity dependence
No viscosity dependence

Hydrodynamic fluctuations
Decrease $nMHC$ magnitude

Summary

We investigated the effect of hydrodynamic fluctuations on mixed harmonic cumulant $nMHC(v_m^k, v_n^l)$

Analyzed:
$nMHC(v_2^2, v_3^2), nMHC(v_2^2, v_4^2), nMHC(v_2^4, v_3^2)$

$nMHC(v_2^2, v_3^2)$ and $nMHC(v_2^4, v_3^2)$:
No viscosity dependence
Sensitive to hydrodynamic fluctuations

Mixed harmonic cumulants $nMHC\left(v_m^k, v_n^l\right)$
Key for
→ Understanding the properties of hydrodynamic fluctuations
→ Determination of viscosity value

Hydrodynamic fluctuations play an important role in determination of viscosity

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