Flow and non-flow response in Pb-Pb, p-Pb collisions at 5.02 TeV

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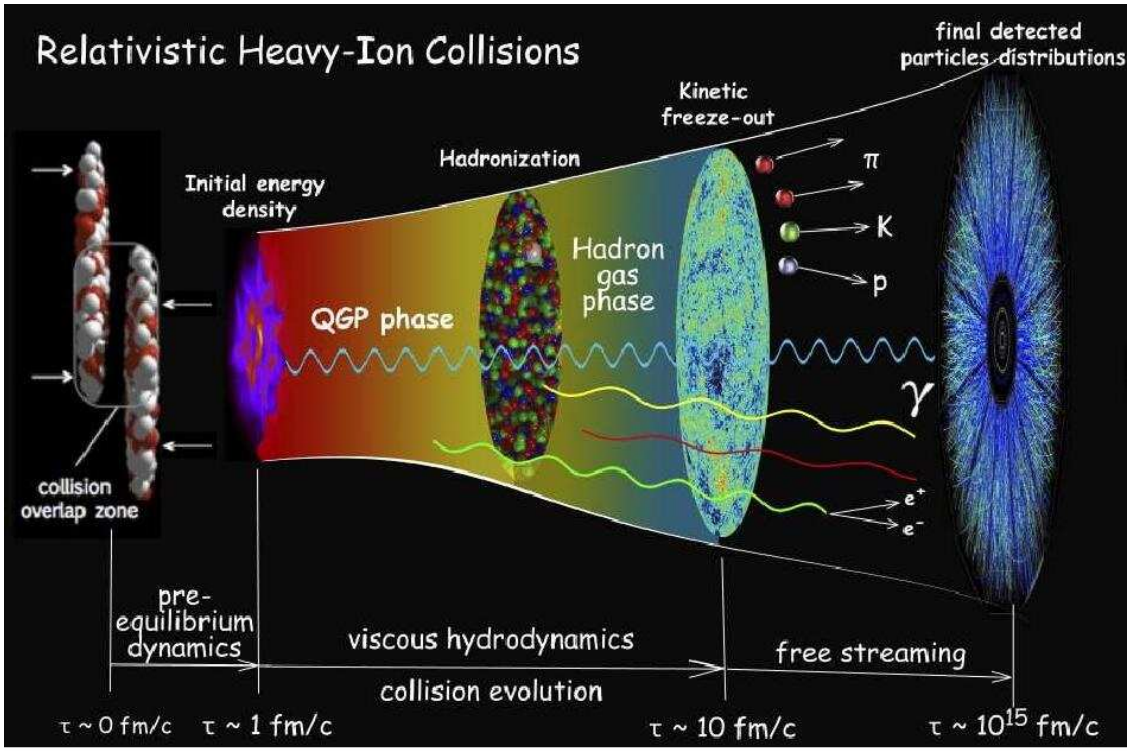
Contents

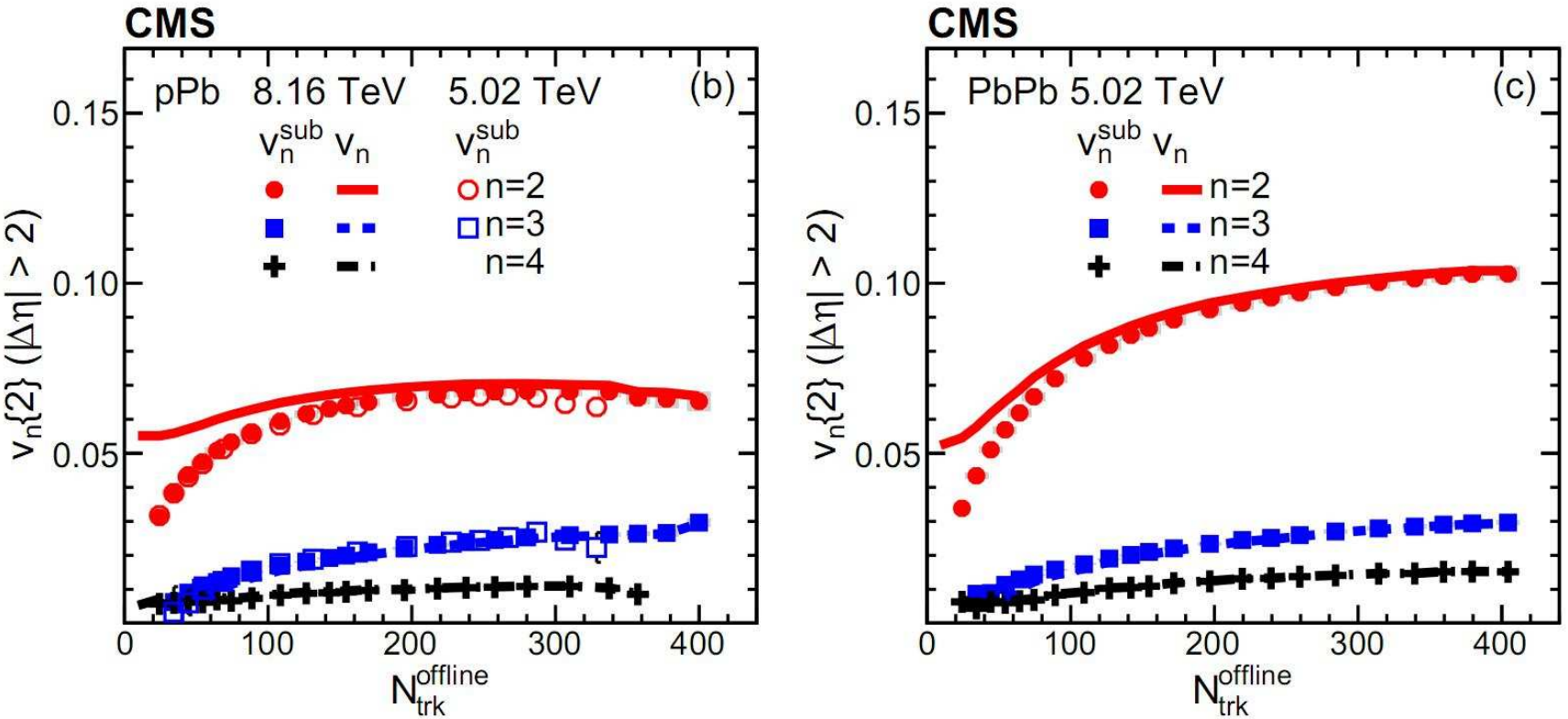
Contents

I. Introduction



1. **In heavy-ion collisions(HIC), final flow induced from initial fluctuate geometry.**
2. **However, we know little about the initial states without a directly experimental data.**

I. Introduction

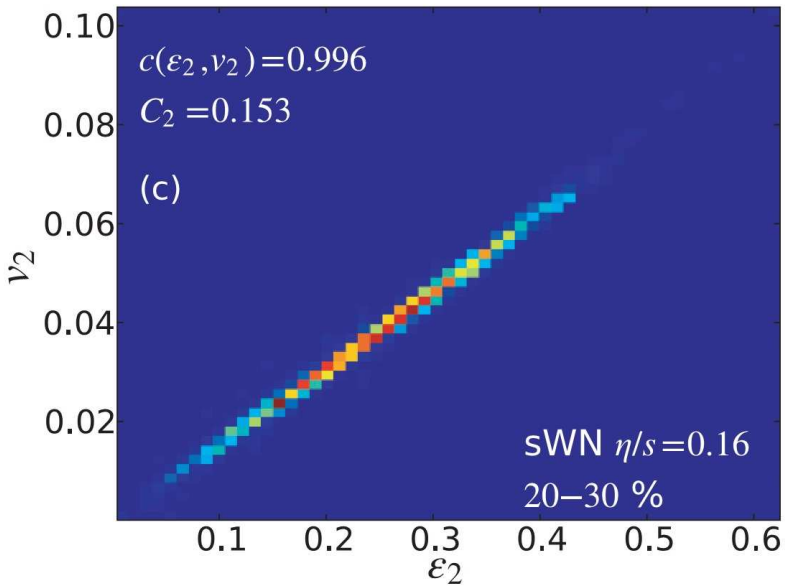


1. **Similarly multiplicity dependent v_2 for Pb-Pb and p-Pb system[1].**
2. **Initial fluctuations-driven both flow and non-flow on small system, especially for low multiplicity. How about the real flow can be seen in small system?**
   (Talks by: Q. H. Xu, J. Y. Jiang, G. L. Ma, Z. Chen, ...)

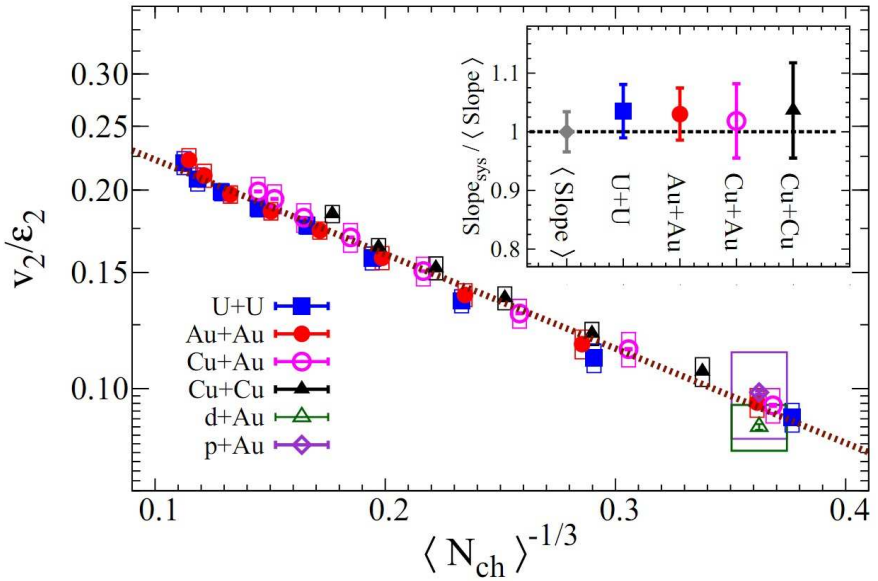
[1]. A. M. Sirunyan et al.(CMS), PRL 120,092301 (2018)

I. Introduction

H. Niemi et al., PRC 87,054901(2013)



J. Adam et al.(STAR), PRL 122,172301(2019)



1. **The v_2 are determined by linear response to ε_2 without initial fluctuations.**
2. **A linear relation, v_2/ε_2, from large system to small system. A sizable uncertainties for the pA systems at low multiplicity where estimates for residual non-flow contributions.**

Contents

II. Response theory

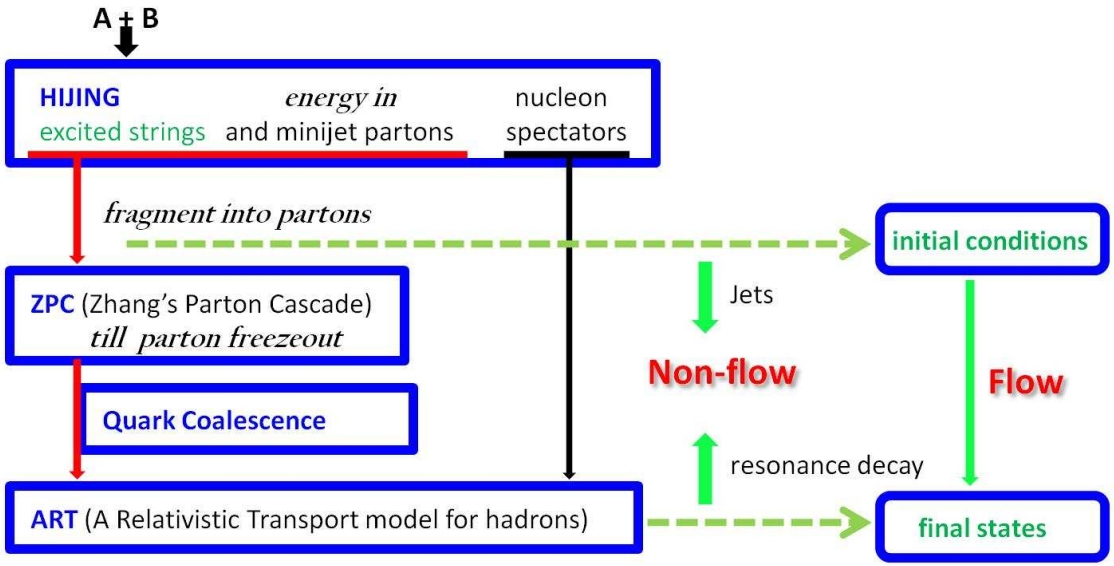


FIG. Structure of the AMPT model with string melting

AMPT is a hybrid model, which has composed of four main stages:

1. **Initial conditions: Heavy Ion Jet Interaction Generator(HIJING).**
2. **Parton cascades: ZPC, describe partons interaction as two-body elastic scattering.**
3. **Hadronizations: partons are formed into hadrons via a coalescence model.**
4. **Hadronic rescatterings: ART, included hadrons rescatterings and resonance decays.**

Z. Lin et al., PRC 72, 064901 (2005)

II. Response theory

The azimuthal distribution of particles:

$$Inital\ states: E_n \equiv \varepsilon_n e^{in\Phi_n} = -\frac{\int r^n e^{in\phi}\epsilon(r,\phi)rdrd\phi}{\int r^n \epsilon(r,\phi)rdrd\phi}. \quad (1)$$

$$Final\ \ states: V_n \equiv \upsilon_n e^{in\Psi_n} = \frac{\int e^{in\varphi}h(\varphi)d\varphi}{\int h(\varphi)d\varphi}. \quad (2)$$

where Φ_n, Ψ_n named Participant Plane and Event Plane, respectively.

A simple theory is the response relation between the initial states and final states, as[1]

$$v_n e^{in\Psi_n} = \kappa_n \varepsilon_n e^{in\Phi_n} + \kappa_n^{'}\varepsilon_n^{'} e^{in\Phi_n} + \kappa_n^{''}\varepsilon_n^{''} e^{in\Phi_n} + \cdots + \delta_n \quad (3)$$

where $\varepsilon_n^{'} = \varepsilon_2^2\varepsilon_n, \quad \varepsilon_n^{''} = \varepsilon_3^2\varepsilon_n$.

One solves of the first two order for κ_2 and κ_2' (named **USNF**):

$$\kappa_2 = \frac{\mathrm{Re}(\langle\varepsilon_2^6\rangle\langle V_2E_2^*\rangle - \langle\varepsilon_2^4\rangle\langle V_2E_2^*\varepsilon_2^2\rangle)}{\langle\varepsilon_2^6\rangle\langle\varepsilon_2^2\rangle - \langle\varepsilon_2^4\rangle^2}$$

$$\kappa_2' = \frac{\mathrm{Re}(-\langle\varepsilon_2^4\rangle\langle V_2E_2^*\rangle + \langle\varepsilon_2^2\rangle\langle V_2E_2^*|\varepsilon_2|^2\rangle)}{\langle\varepsilon_2^6\rangle\langle\varepsilon_2^2\rangle - \langle\varepsilon_2^4\rangle^2}, \quad (4)$$

[1]. **DXW**, X. Huang and L. Yan, PRC 98, 044908 (2018)

II. Response theory

To subtract the non-flow effect, one by the cumulants mothod[1]

$$v_2\{2,|\Delta\eta|\} = \kappa_2\varepsilon_2\{2\}[1+\frac{\kappa_2^{'}}{\kappa_2}\frac{\langle\varepsilon_2^4\rangle}{\langle\varepsilon_2^2\rangle}]. \quad (5)$$

$$v_2\{4\} = \kappa_2\varepsilon_2\{4\}[1+\frac{\kappa_2^{'}}{\kappa_2}\frac{2\langle\varepsilon_2^2\rangle\langle\varepsilon_2^4\rangle-\langle\varepsilon_2^6\rangle}{2\langle\varepsilon_2^2\rangle^2-\langle\varepsilon_2^4\rangle}]. \quad (6)$$

$v_2\{2\}$ is obtained from two-particle correlations using a pseudorapidity gap with $|\Delta\eta| > 1.0$. And the solution is (named **SNF**)

$$\kappa_2 = \frac{v_2\{2,|\Delta\eta|\}\cdot B - v_2\{4\}\cdot A}{\varepsilon_2\{2\}\cdot B - \varepsilon_2\{4\}\cdot A}, \quad (7)$$

$$\kappa_2^{'} = \frac{-(v_2\{2,|\Delta\eta|\}\varepsilon_2\{4\} - v_2\{4\}\varepsilon_2\{4\})}{\varepsilon_2\{2\}\cdot B - \varepsilon_2\{4\}\cdot A}. \quad (8)$$

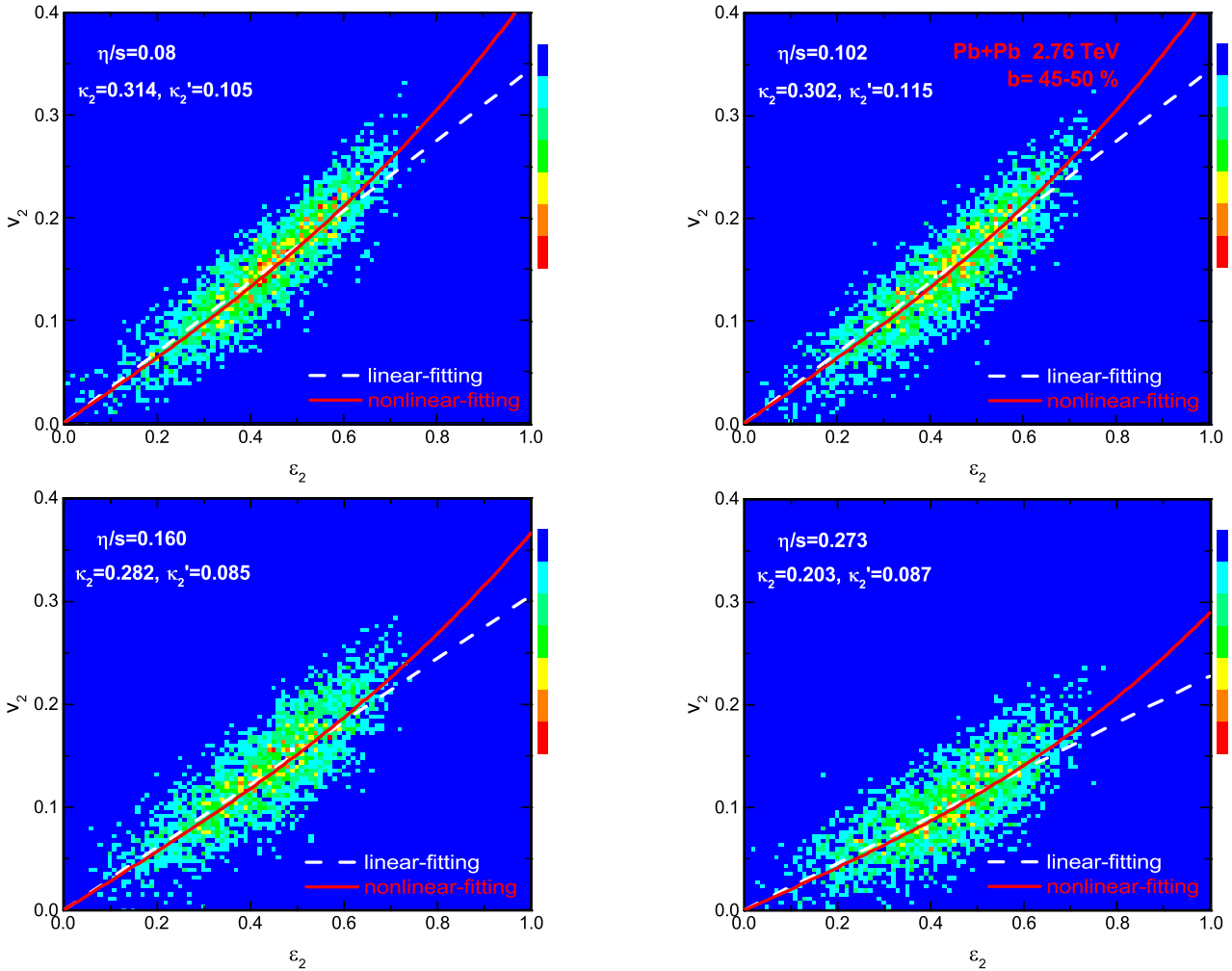
where

$$A = \frac{\langle\varepsilon_2^4\rangle}{\langle\varepsilon_2^2\rangle}\cdot\varepsilon_2\{2\}, \quad B = \frac{2\langle\varepsilon_2^2\rangle\langle\varepsilon_2^4\rangle-\langle\varepsilon_2^6\rangle}{2\langle\varepsilon_2^2\rangle^2-\langle\varepsilon_2^4\rangle}\cdot\varepsilon_2\{4\}. \quad (9)$$

[1]. **DXW**, X. Huang and L. Yan, PRC 98, 044908 (2018)

Contents

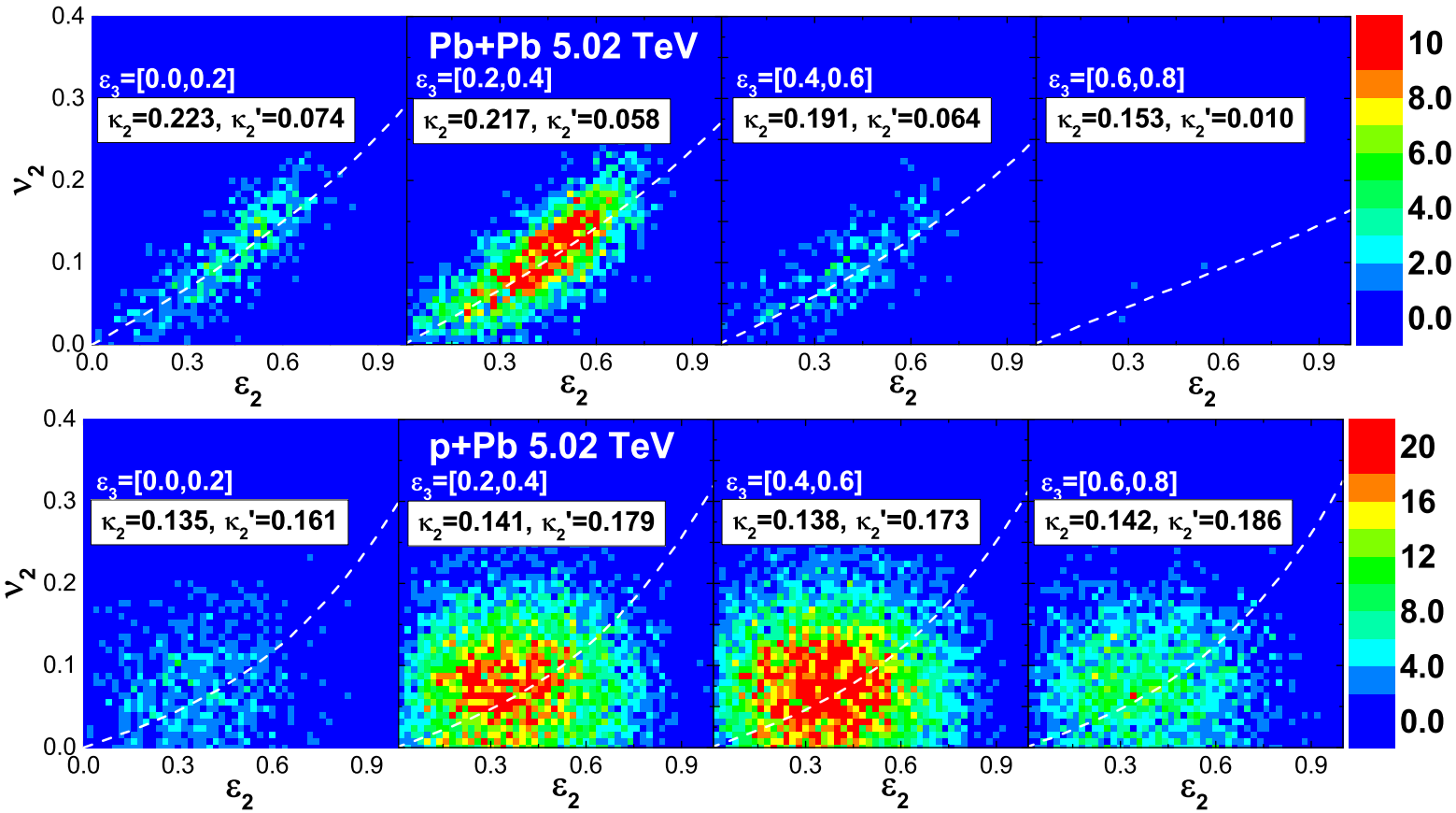
III. Flow and non-flow response: Large and small systems



DXW, X. Huang and L. Yan, PRC 98, 044908 (2018)

1. **Both κ_n and $\kappa_n^{'}$ are sensitive to the specific viscosity η/s.**

III. Flow and non-flow response: Large and small systems

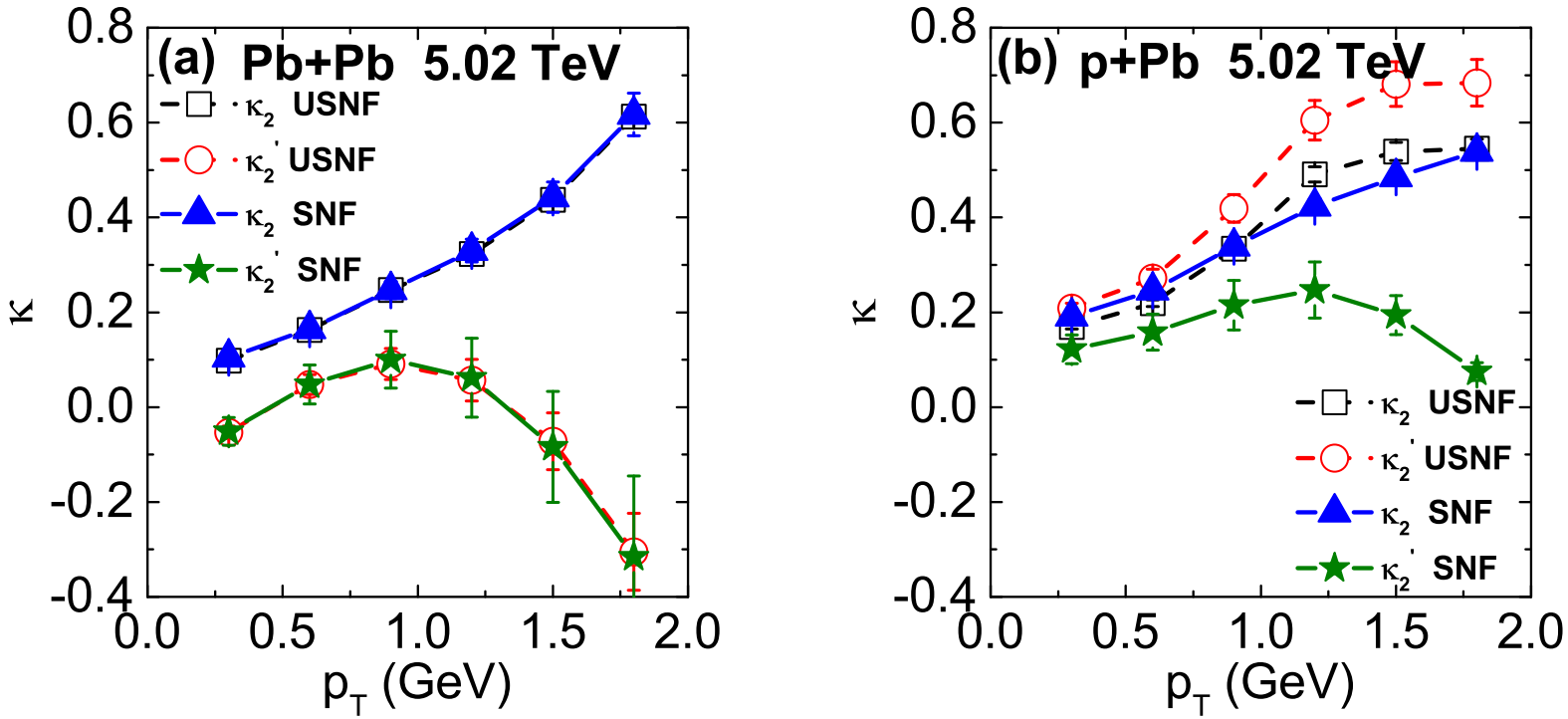


1. **Dissimilarly 2D-response distribution for Pb-Pb and p-Pb system.**
2. **A weaker Pearson correlation result observed on p-Pb system. For p-Pb system, flow is not only come from the initial geometry but also come from the medium expanding and/or hadrons cascade, similarly results seen in Ref.[1 – 2] (also calculated by AMPT).**

[1]. M. Nie, L. Yi, J. Jia and G. Ma, arXiv:1906.01422

[2]. Z. Lin, PRC 90,014904(2014)

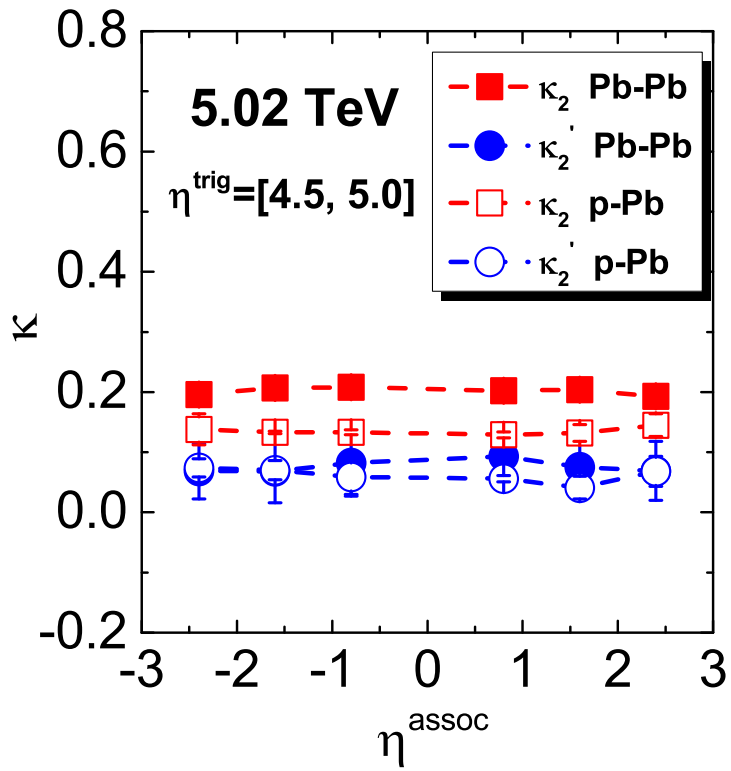
III. Flow and non-flow response: Large and small systems



1. **A non-negligible non-flow effects of response relations shown on p-Pb system, but hydrodynamic response for Pb-Pb system.**
2. **Similarly p_T dependent distribution within SNF for Pb-Pb and p-Pb system.**
3. **A specific viscosity η/s-driven response relation within both the two systems. Similarly results can be seen in STAR[1].**

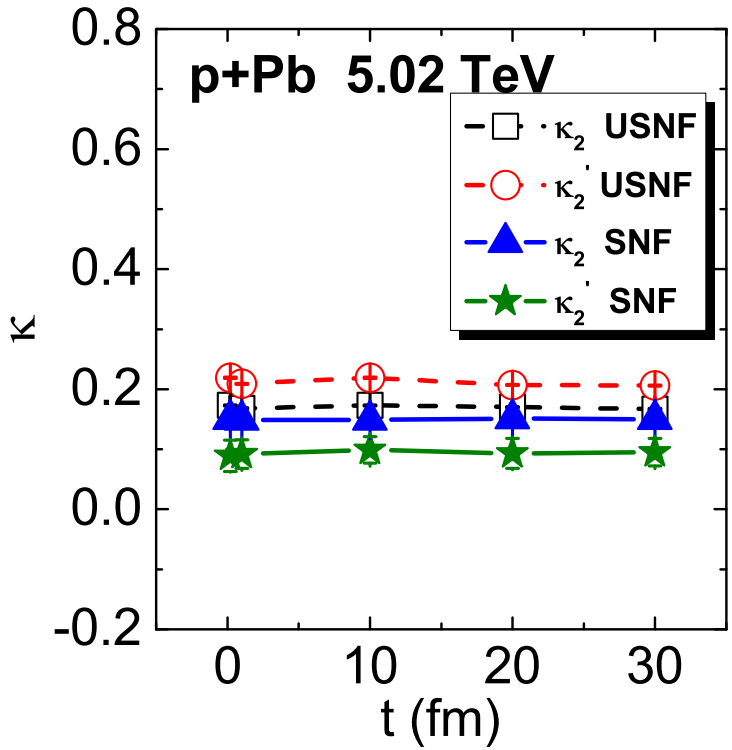
[1]. J. Adam et al.(STAR), PRL 122, 172301 (2019)

III. Flow and non-flow response: Large and small systems



1. **Similarly η dependent distribution within SNF for Pb-Pb and p-Pb system. (Talks by: L. Yan)**
2. **Similarly longitudinal dynamics, provides information on the initial states and the expanding medium for both the two systems.**

III. Flow and non-flow response: Large and small systems



1. **Response relations are not sensitive to the hadron evolution times.**
2. **A dominated contribution to response relation of non-flow effect is from the early time of the expanding medium.**

Contents

IV. Summary

1. **Dissimilarly 2D-response distribution for Pb-Pb and p-Pb system. For small system, flow is not only come from the initial fluctuate geometry but also from the medium expanding.**
2. **A non-negligible non-flow effects of response coefficients shown on p-Pb system where unlike on Pb-Pb system, and these non-flow effects mainly come from the early time of the expanding medium.**
3. **Response coefficients also dependence on p_T and η.**

Thank you!