The 9th China LHC Physics Workshop (CLHCP2023)

Recent highlights of collective flow studies at LHC-ALICE

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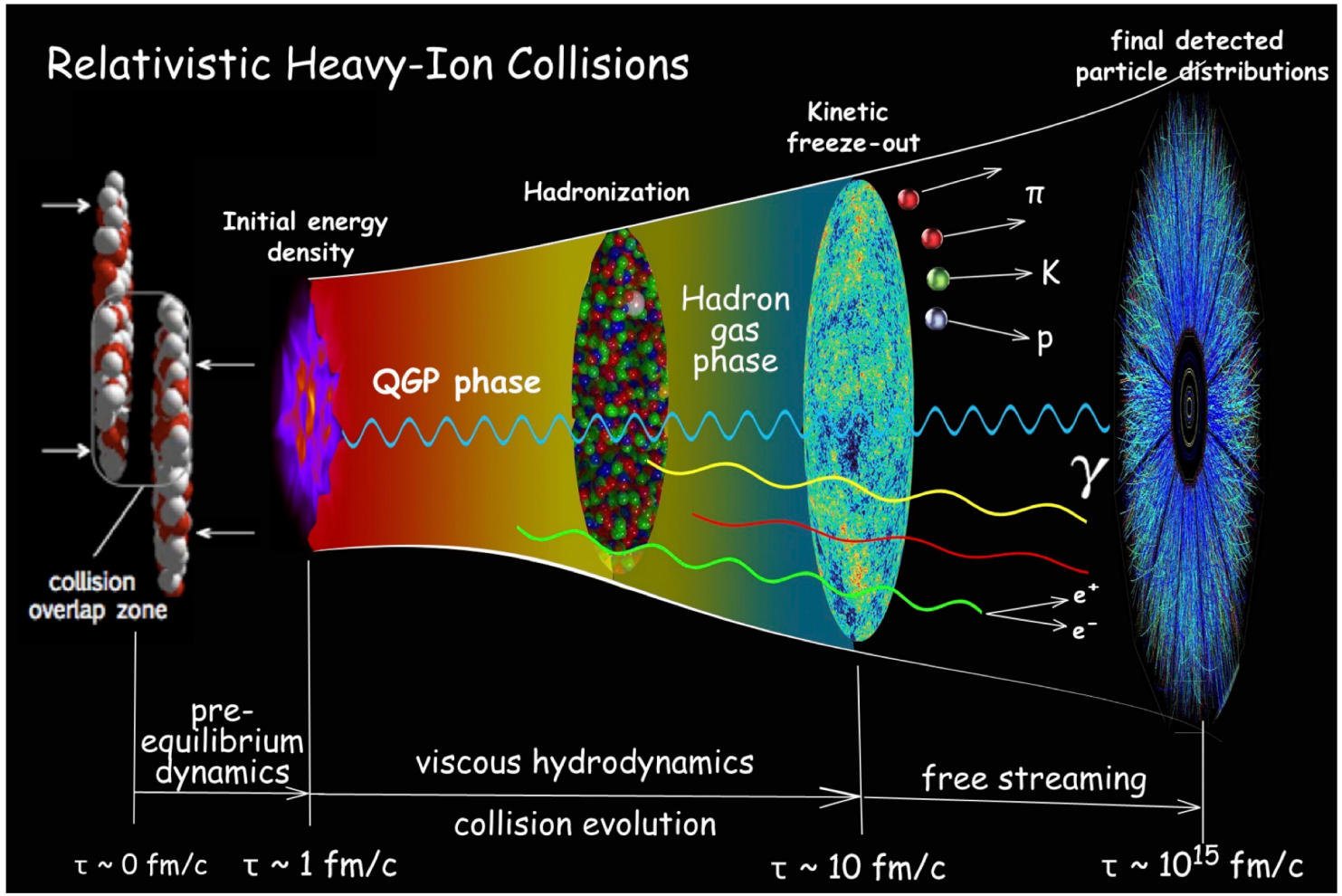
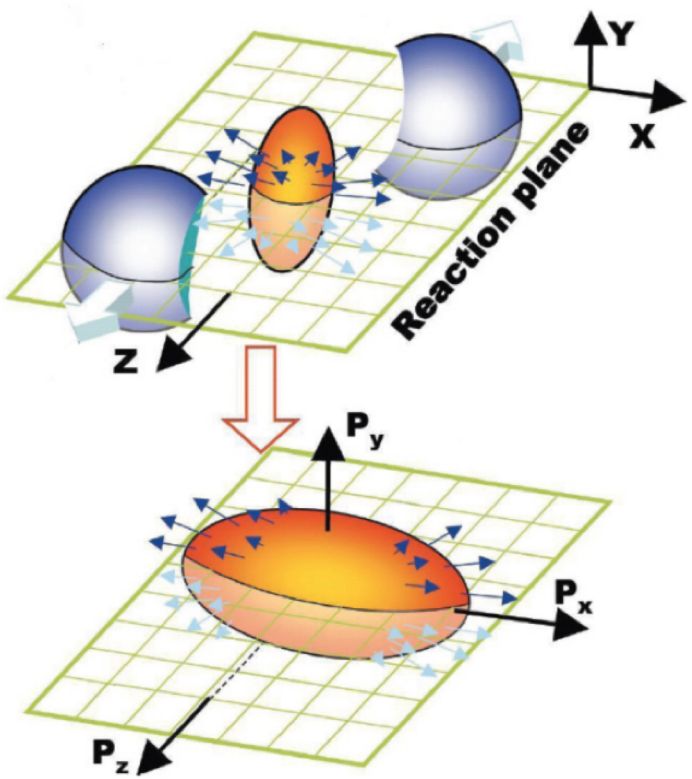
Relativistic heavy-ion collisions

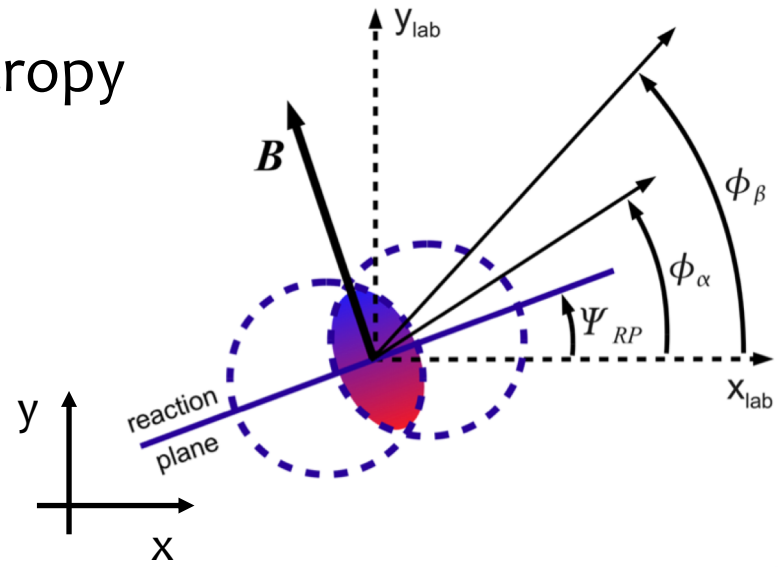


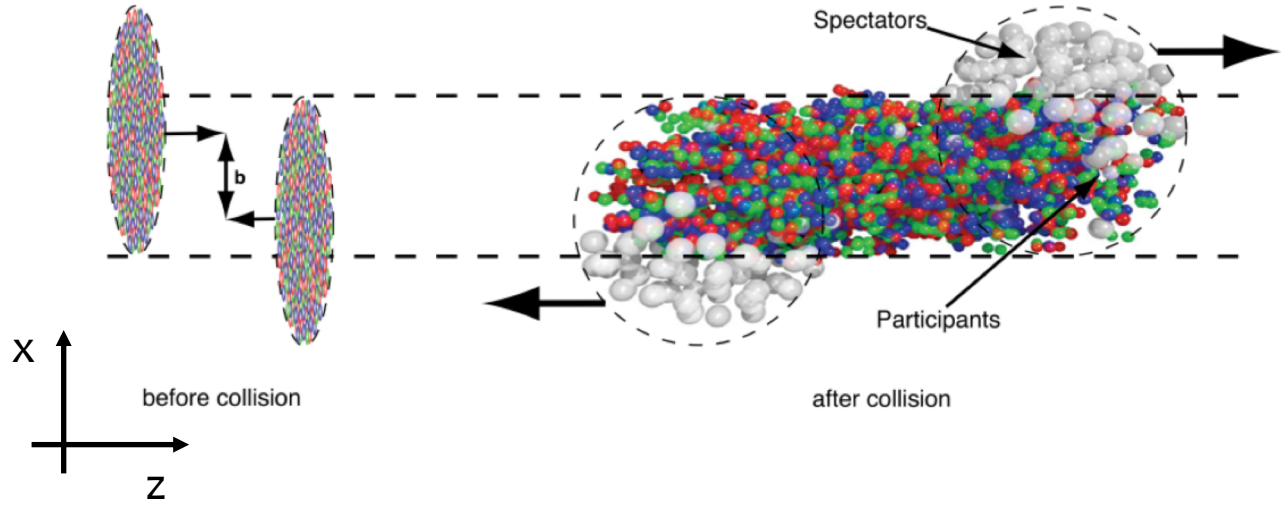
Criticality, Collectivity, Chirality

Azimuthally anisotropic emission of final state hadrons

Initial eccentricity → Final momentum anisotropy





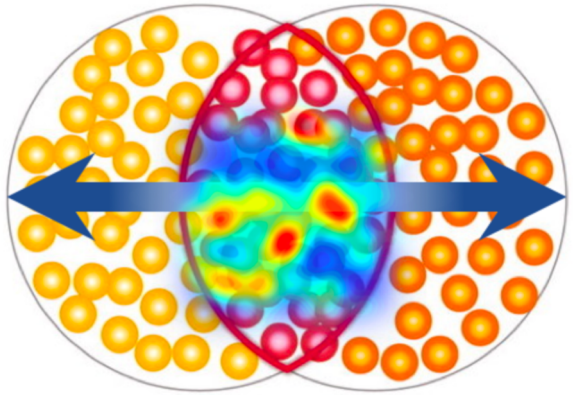


Collectivity and anisotropic flow

$$E\frac{\mathrm{d}^3N}{\mathrm{d}^3\mathbf{p}} = \frac{1}{2\pi}\frac{\mathrm{d}^2N}{p_\mathrm{t}\mathrm{d}p_\mathrm{t}\mathrm{d}y}\left(1+2\sum_{n=1}^{\infty}v_n\cos[n(\varphi-\Psi_\mathrm{RP})]\right)$$

$$v_n(p_\mathrm{t},\, y) = \langle\cos[n(\varphi-\Psi_\mathrm{RP})]\rangle$$

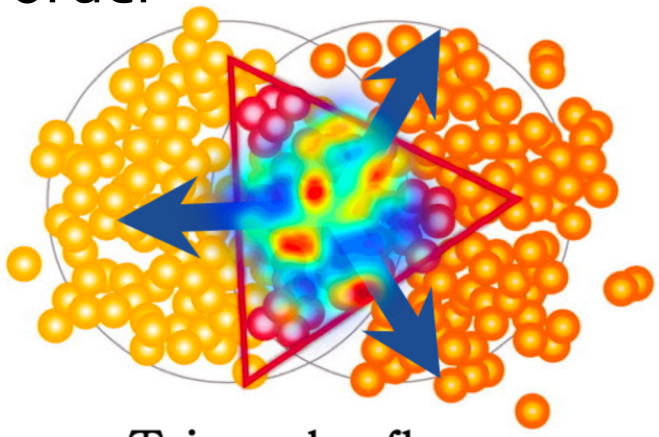
2nd order



Elliptic flow

+

3rd order



Triangular flow

+ higher order

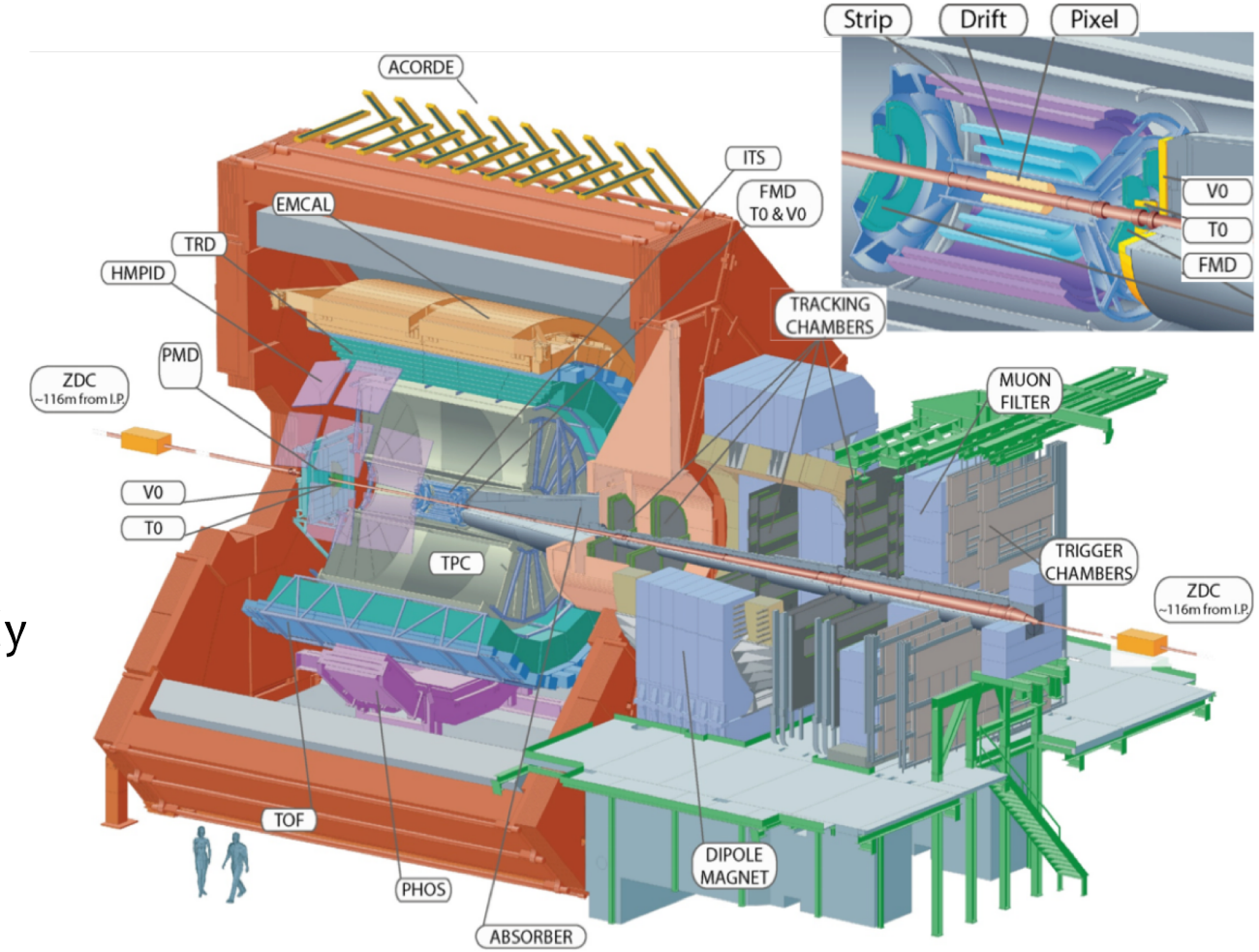
What's special in ALICE experiment?

Compared to RHIC-STAR, ALICE has

- Higher collision energies
- Higher multiplicity, smaller fluctuation

Compared to ATLAS/CMS/LHCb, ALICE has

- Dedicated configuration for the QGP study
- Good capability of particle identification

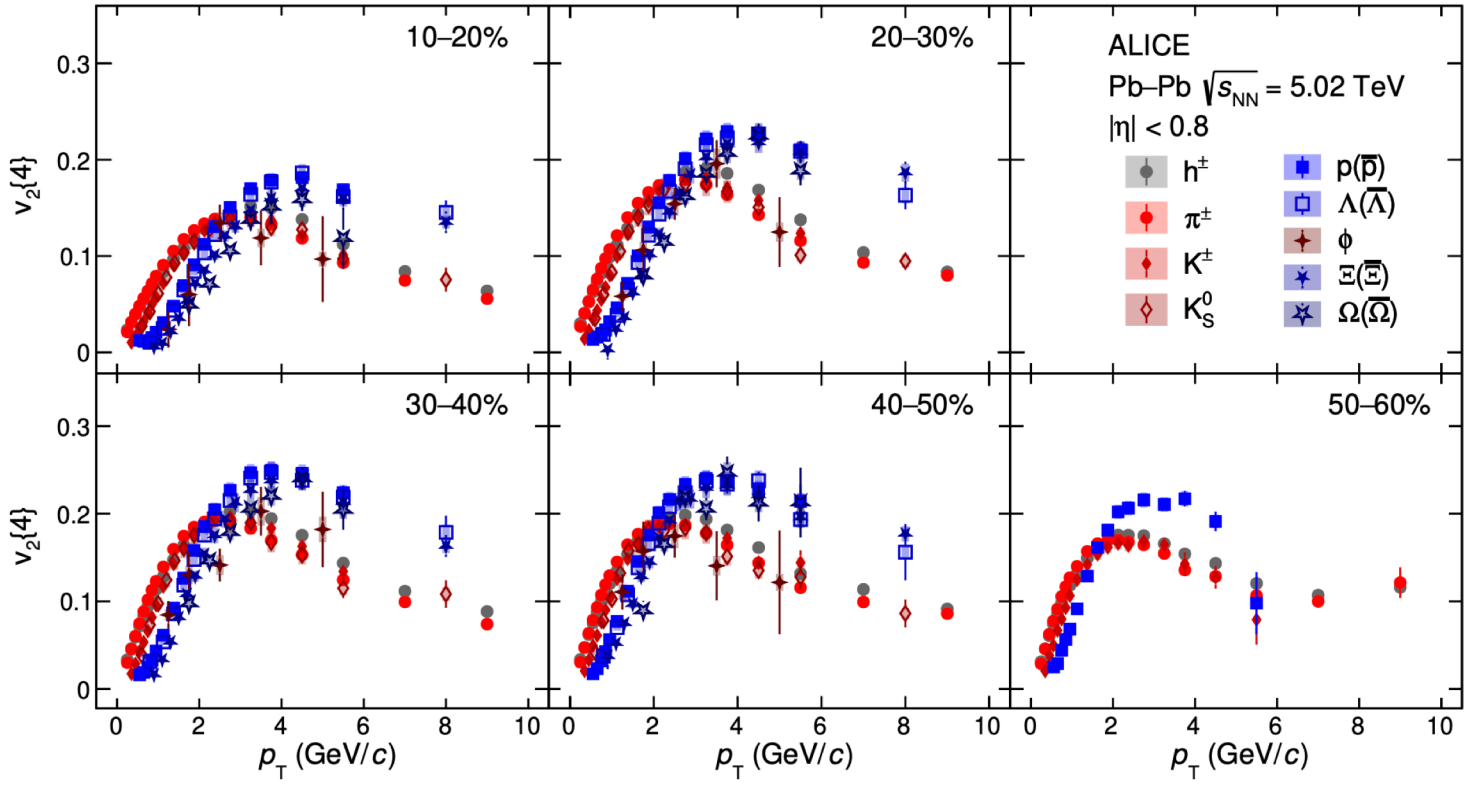


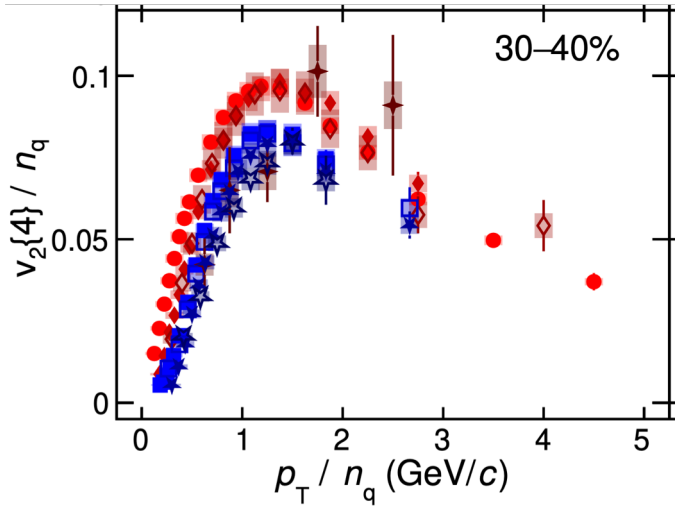
Recent highlights of the flow studies in ALICE

- Testing dynamic features and the evolution of the QGP in Pb-Pb collisions
- Probing partonic collectivity in p-Pb and pp collisions
- Imagining the nuclear structure in Pb-Pb and Xe-Xe collisions
- Search for the anomalous chiral effects in Pb-Pb collisions

Testing dynamic features and evolution of the QGP in Pb-Pb collisions

JHEP 05(2023)243

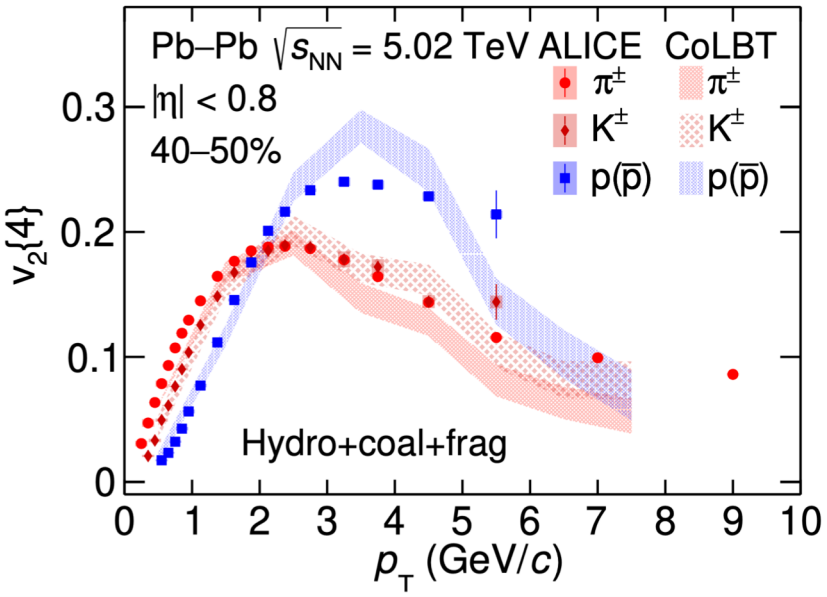


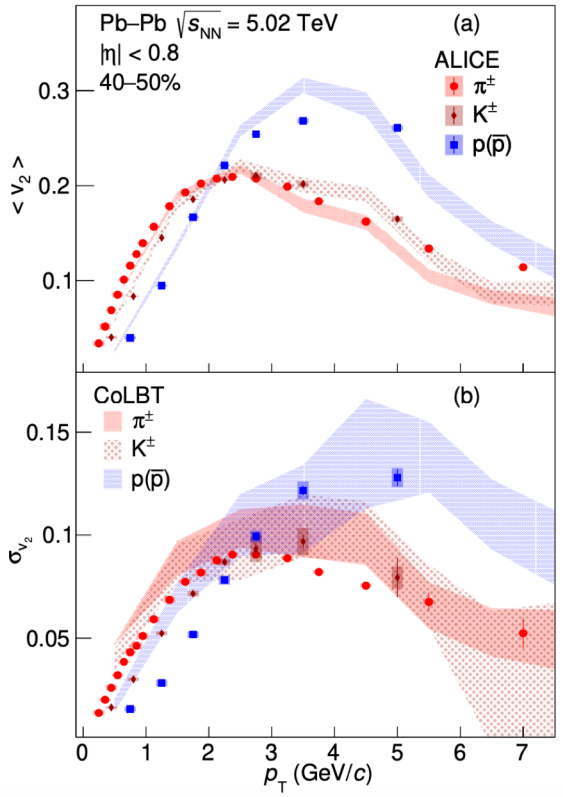


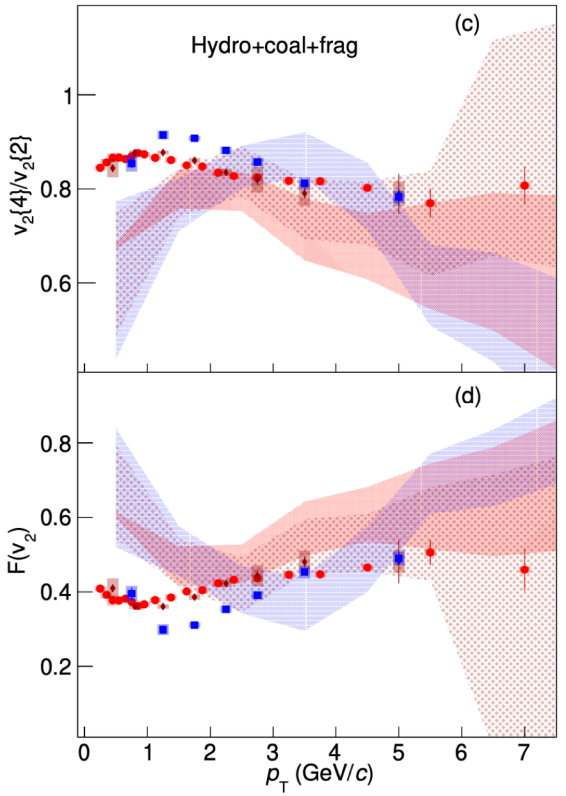
- Mass ordering and the meson–baryon grouping imply the dynamical evolution of the colliding system
- The number of constituent quarks (NCQ) scaling only holds approximately

Testing dynamic features and evolution of the QGP in Pb-Pb collisions

JHEP 05(2023)243

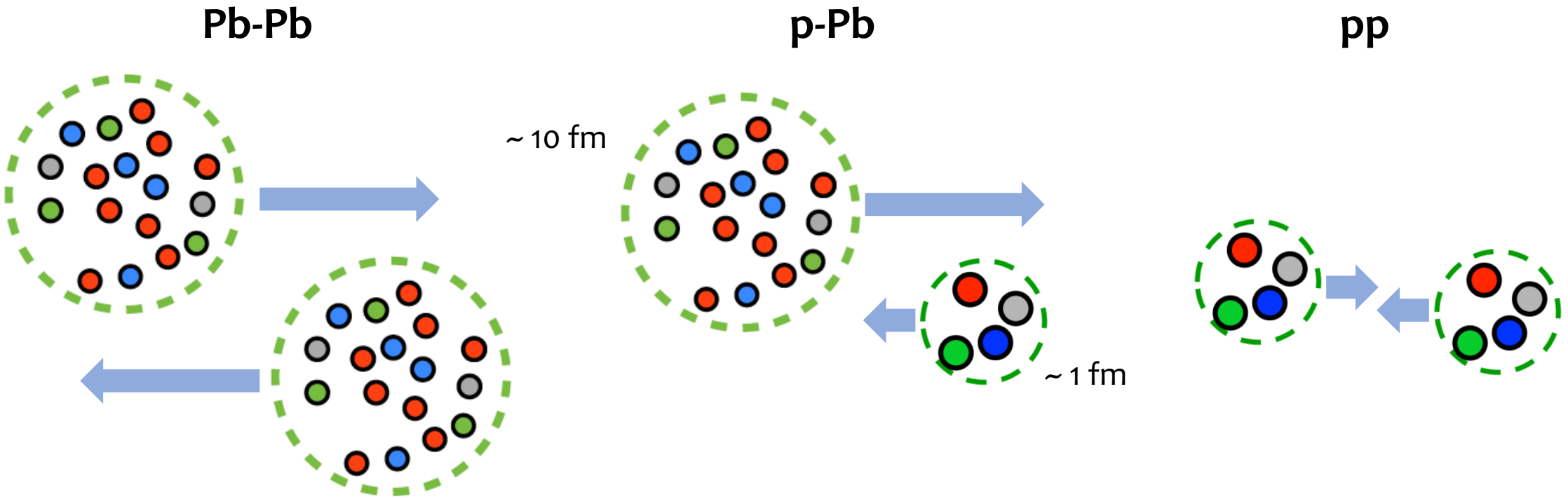






- Can be tested by the hydrodynamical expansion + hadron production through quark coalescence + jet fragmentation

Probing partonic collectivity in p-Pb and pp collisions

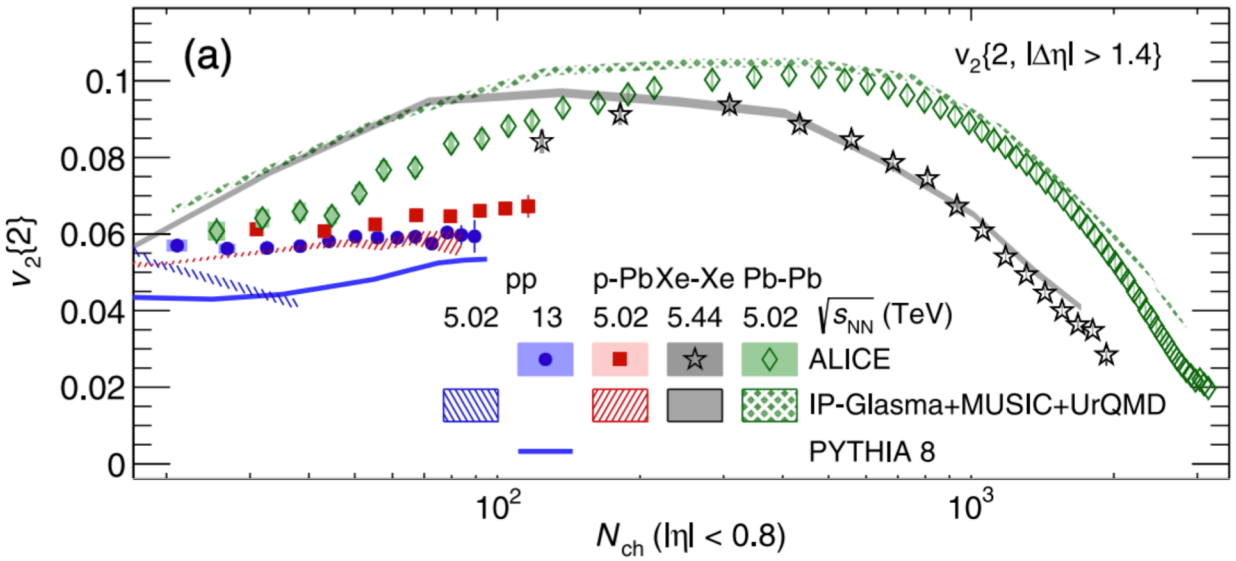


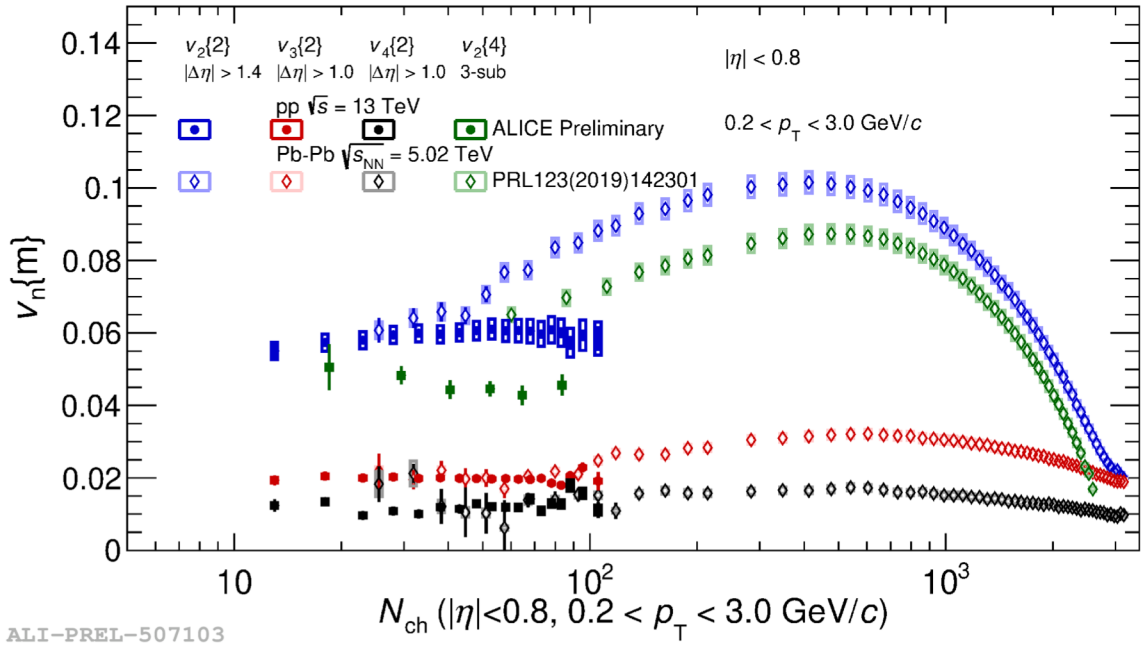
Do we expect the collectivity in small collision systems?

Probing partonic collectivity in p-Pb and pp collisions

11月17日15:15
赵明锐

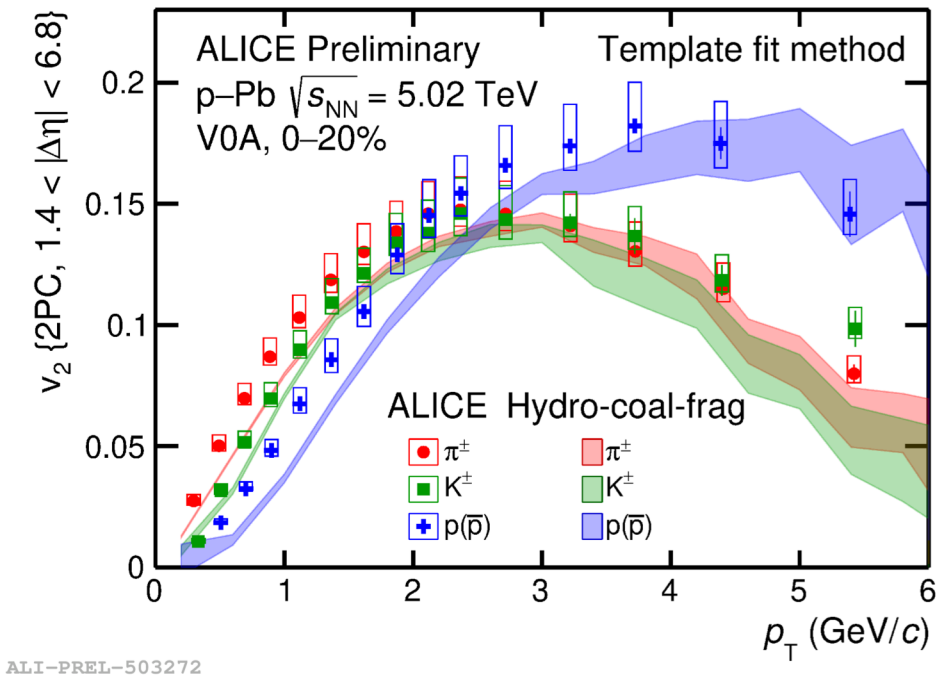
PRL 123, 142301 (2019)

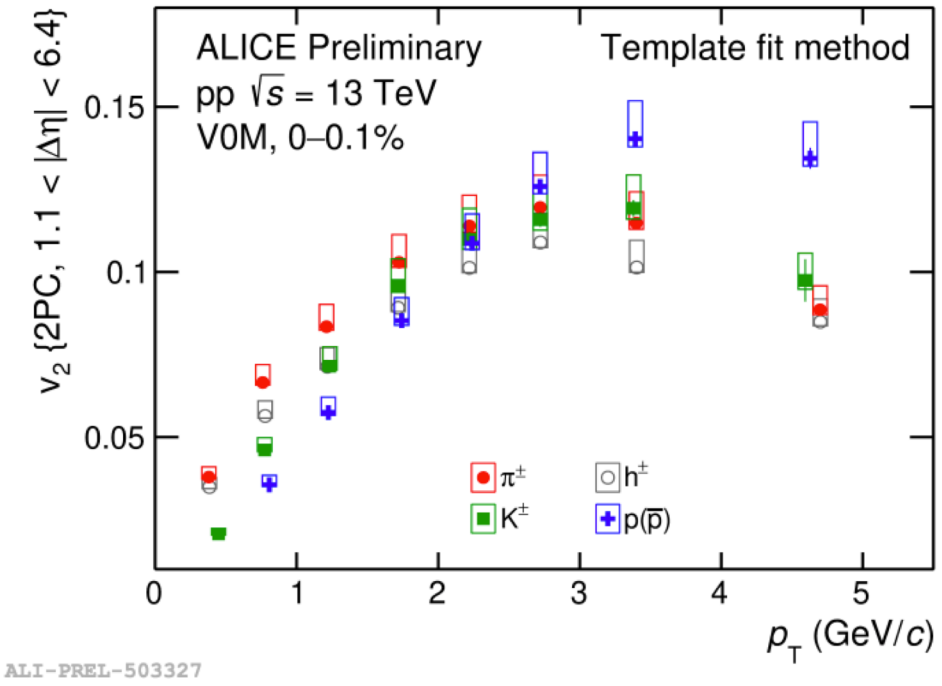




- The magnitudes of v_n in pp and p-Pb are similar as in Pb–Pb at low multiplicities

Probing partonic collectivity in p-Pb and pp collisions

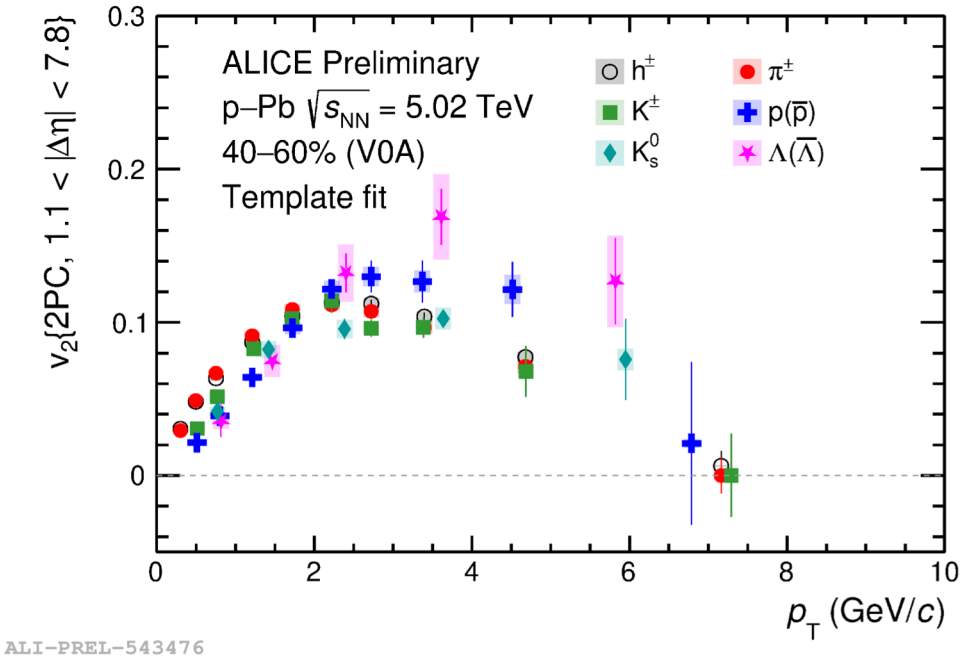


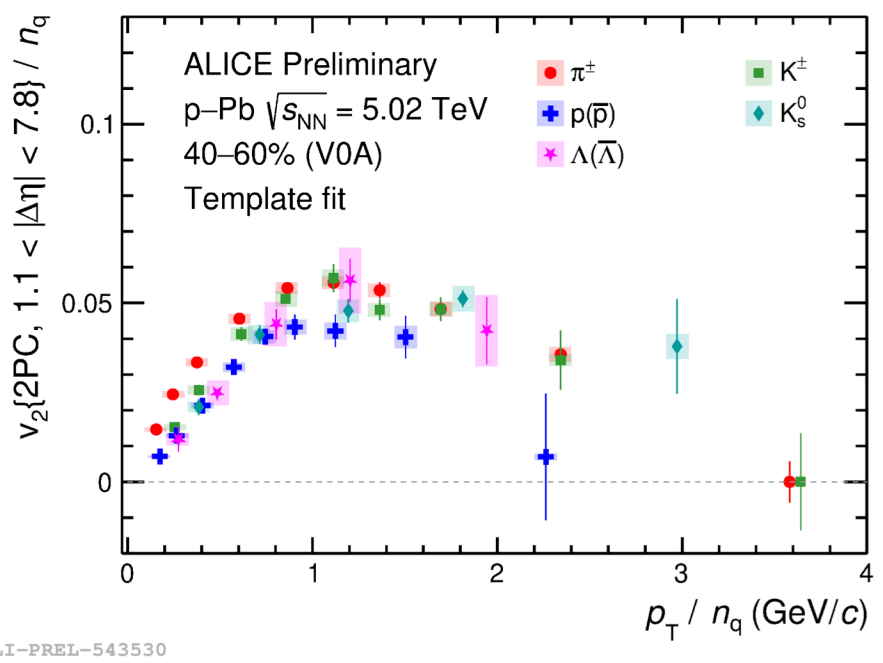


- Mass ordering and the meson–baryon grouping remain valid in p-Pb and pp collisions, indicating the partonic collectivity

Probing partonic collectivity in p-Pb and pp collisions

11月17日16:35
吴文雅





- Mass ordering and the meson–baryon grouping for all centrality
- Decrease to zero at high p_T range
- NCQ scaling barely holds
- **What is the "small" (pA, pp, ee...) and "dilute" (lower multiplicity) limit of onset of collectivity?**

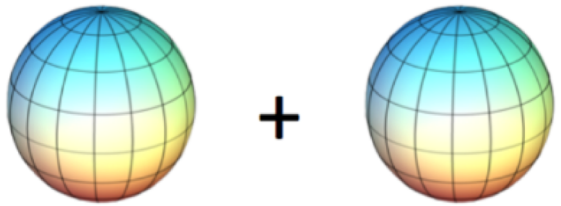
Imagining the nuclear structure in Pb-Pb and Xe-Xe collisions

nucleon density described by **Woods-Saxon profile**

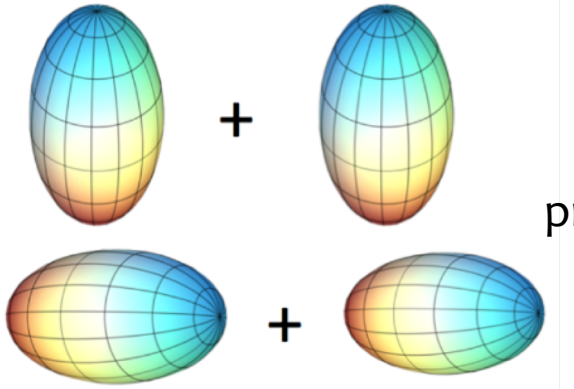
$$\rho(r,\theta,\phi) = \frac{\rho_0}{1+e^{[r-R(\theta,\phi)]/a_0}},$$

$$R(\theta,\phi) = R_0(1+\beta_2[\cos\gamma Y_{2,0} + \sin\gamma Y_{2,2}] + \beta_3 \sum_{m=-3}^{3} \alpha_{3,m} Y_{3,m} + \beta_4 \sum_{m=-4}^{4} \alpha_{4,m} Y_{4,m})$$

β_2: overall deformation parameter
a_0: diffuseness parameter
γ: triaxiality parameter

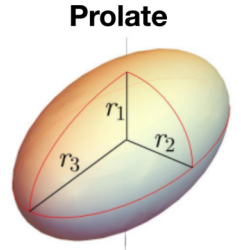


Pb-Pb

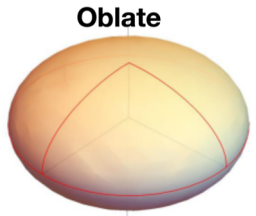


Xe-Xe

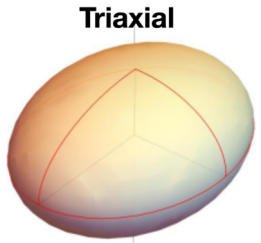
predicted to be triaxial



$r_1 = r_2 < r_3$

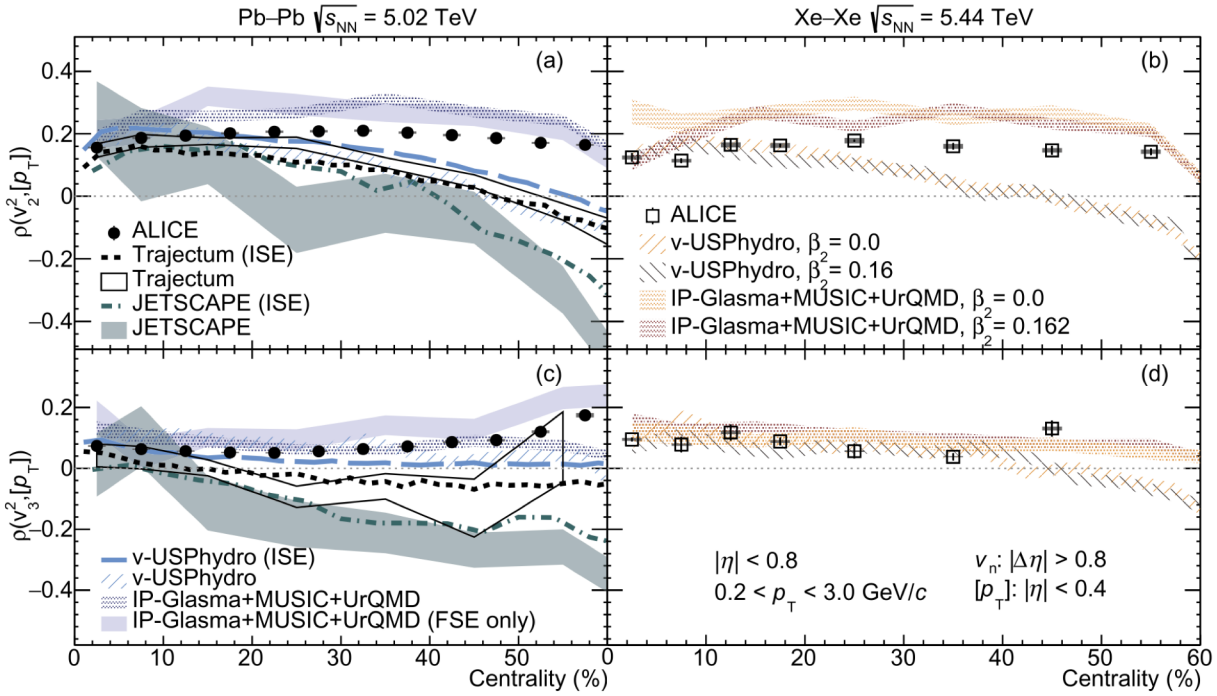


$r_1 < r_2 = r_3$



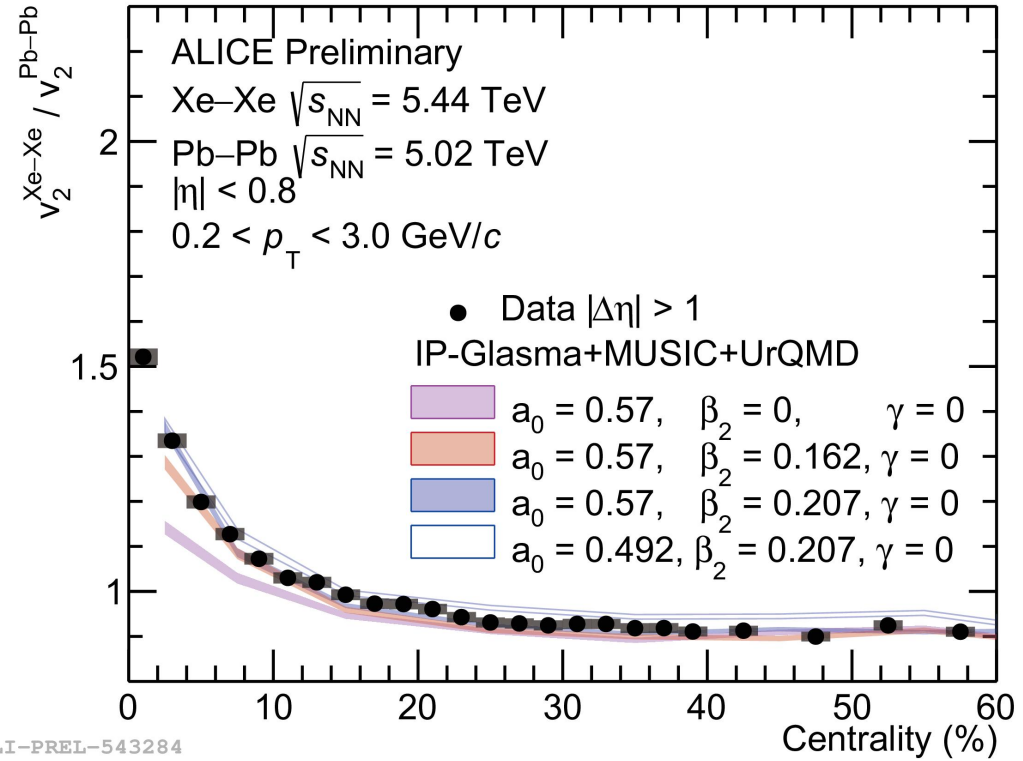
$r_1 \neq r_2 \neq r_3$

Imagining the nuclear structure in Pb-Pb and Xe-Xe collisions



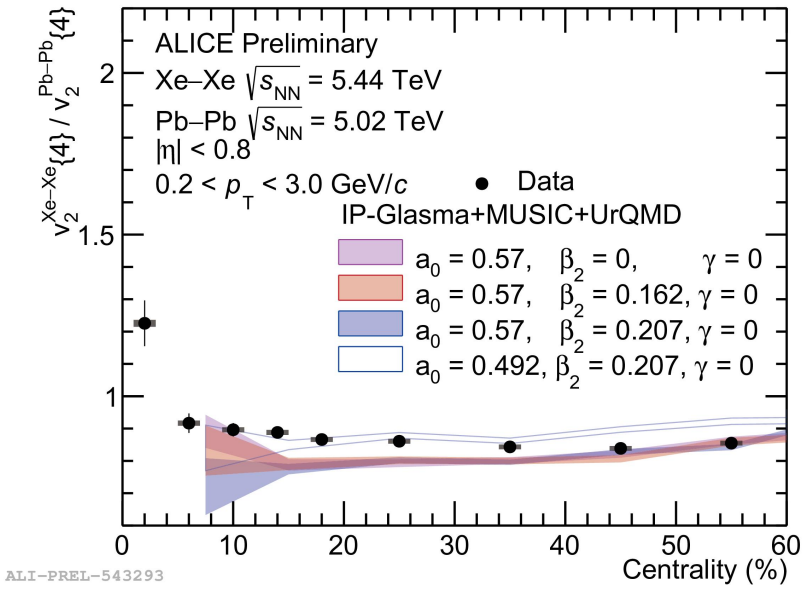
$$\rho(v_n^2,[p_T]) = \frac{\mathrm{Cov}(v_n^2,[p_T])}{\sqrt{\mathrm{Var}(v_n^2)}\sqrt{c_k}}$$

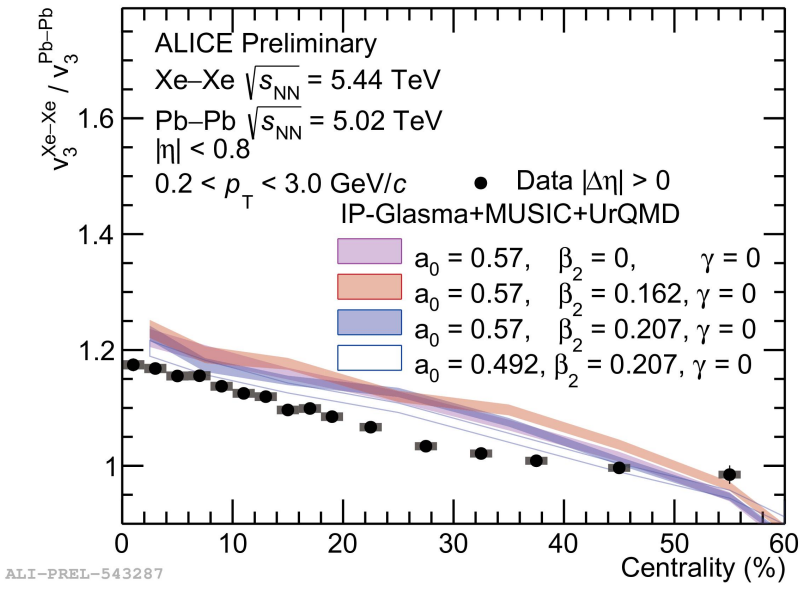
PLB 834 (2022) 137393

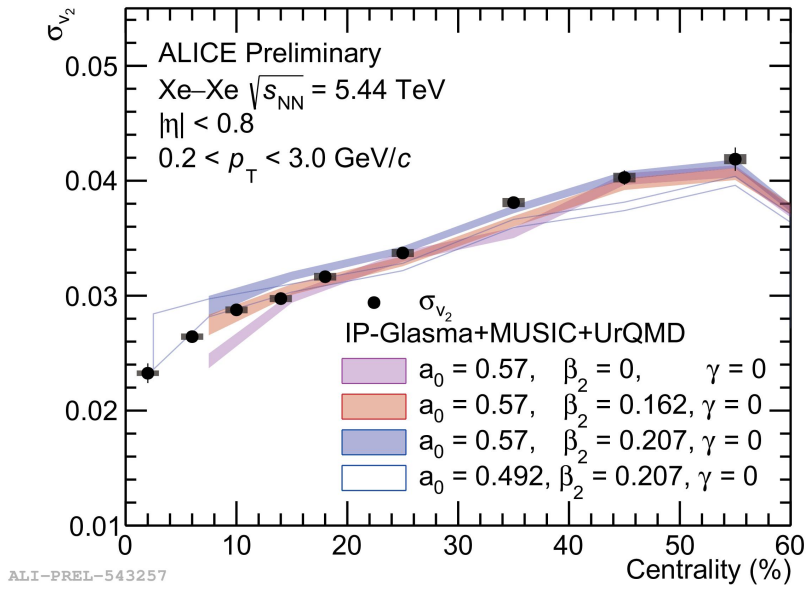


- v_2-$[p_T]$ correlation is a powerful tool to imagine the initial nuclear structure

Imagining the nuclear structure in Pb-Pb and Xe-Xe collisions



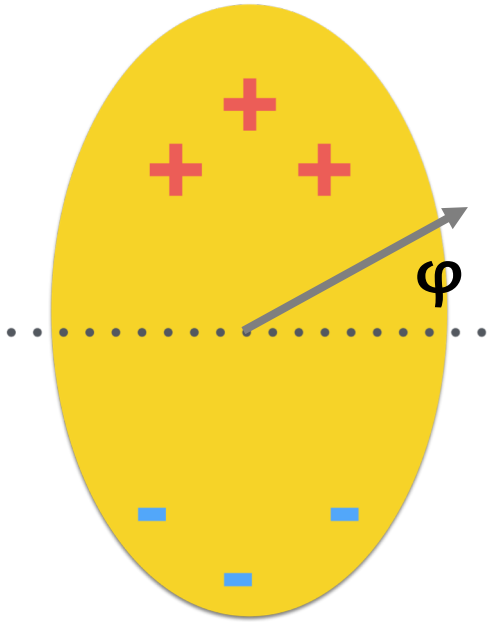




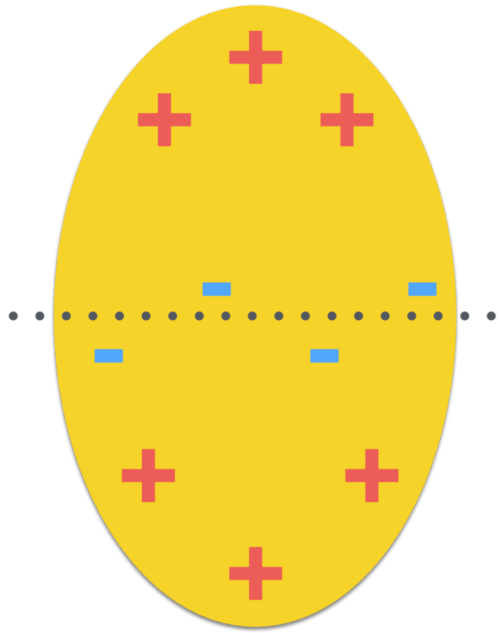
- Systematic study on the centrality dependence of various flow observables in Xe–Xe and Pb–Pb collisions, aiming at revealing the nuclear structure/initial geometry

11月18日08:30
卢志永

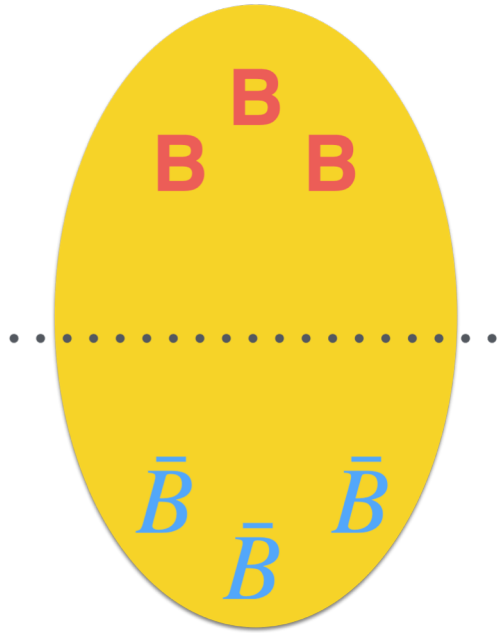
Search for the anomalous chiral effects in Pb-Pb collisions



Chiral magnetic effect
Possible effect: Out-of-plane electric dipole moment
Observables: δ, γ correlator
$\delta = \langle\cos(\varphi_\alpha - \varphi_\beta)\rangle$
$\gamma = \langle\cos(\varphi_\alpha + \varphi_\beta - 2\Psi_2)\rangle$



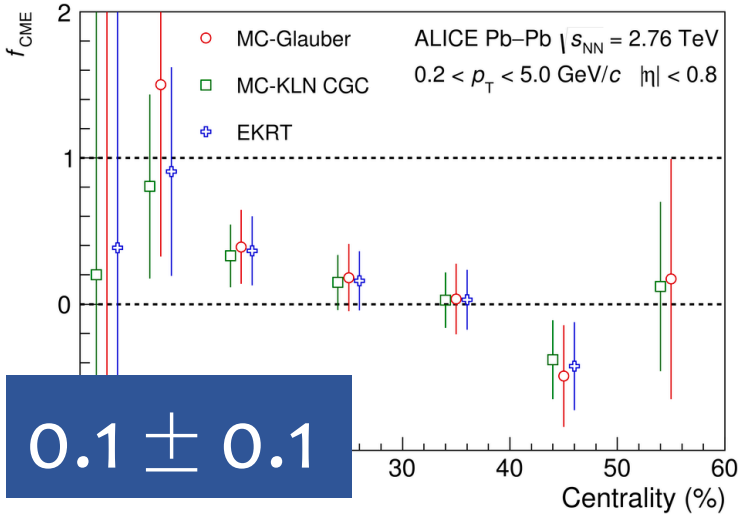
Chiral magnetic wave
Possible effect: Out-of-plane quadrupole dipole moment
Observables: Charge asymmetry dependent v_2
$\Delta v_2 = v_2^- - v_2^+ \sim rA_{ch}$
with $A_{ch} = (N^+ - N^-) / (N^+ + N^-)$



Chiral vortical effect
Possible effect: Out-of-plane baryonic dipole moment
Observables: baryon δ, γ correlator

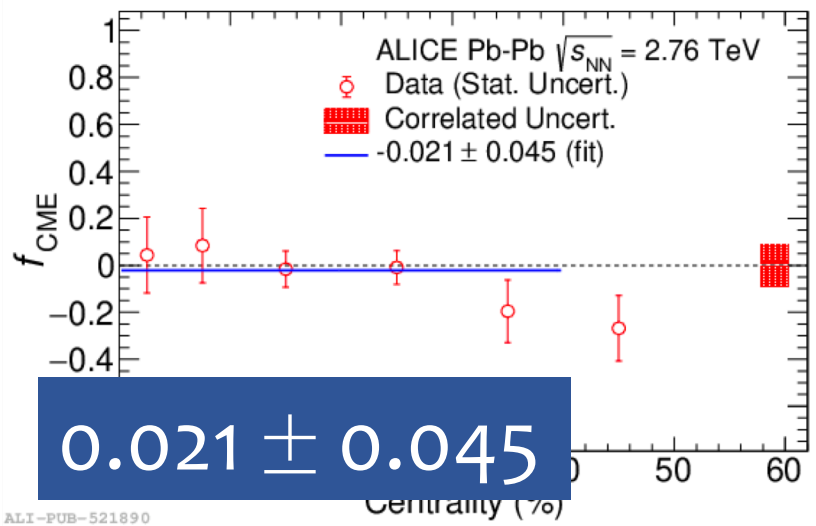
ALICE measurement of the CME

PLB 777, 151 (2018)

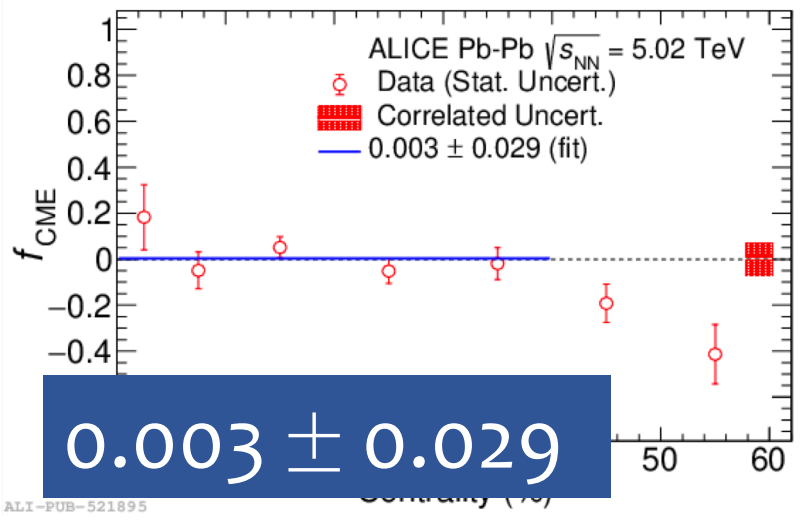


0.1 ± 0.1

JHEP 2020, 160 (2020)

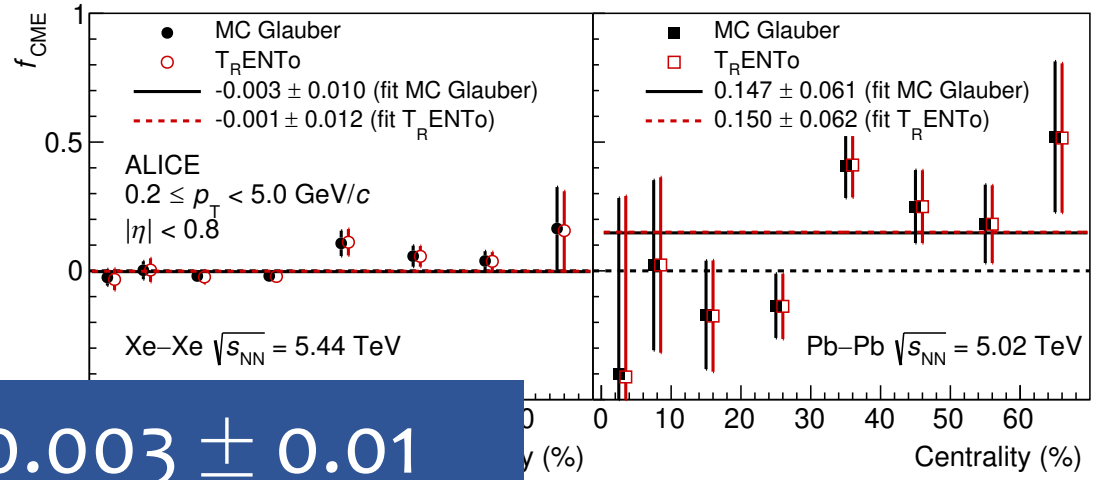


0.021 ± 0.045



0.003 ± 0.029

arXiv:2210.15383

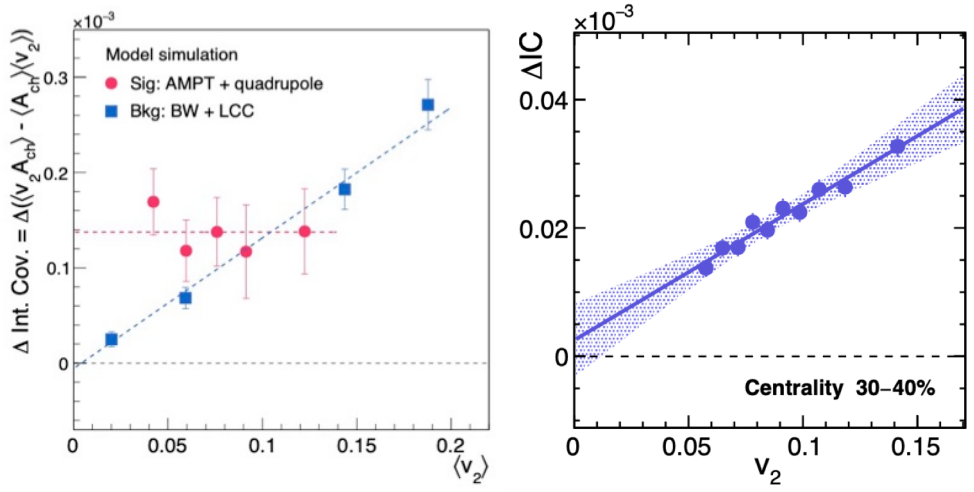


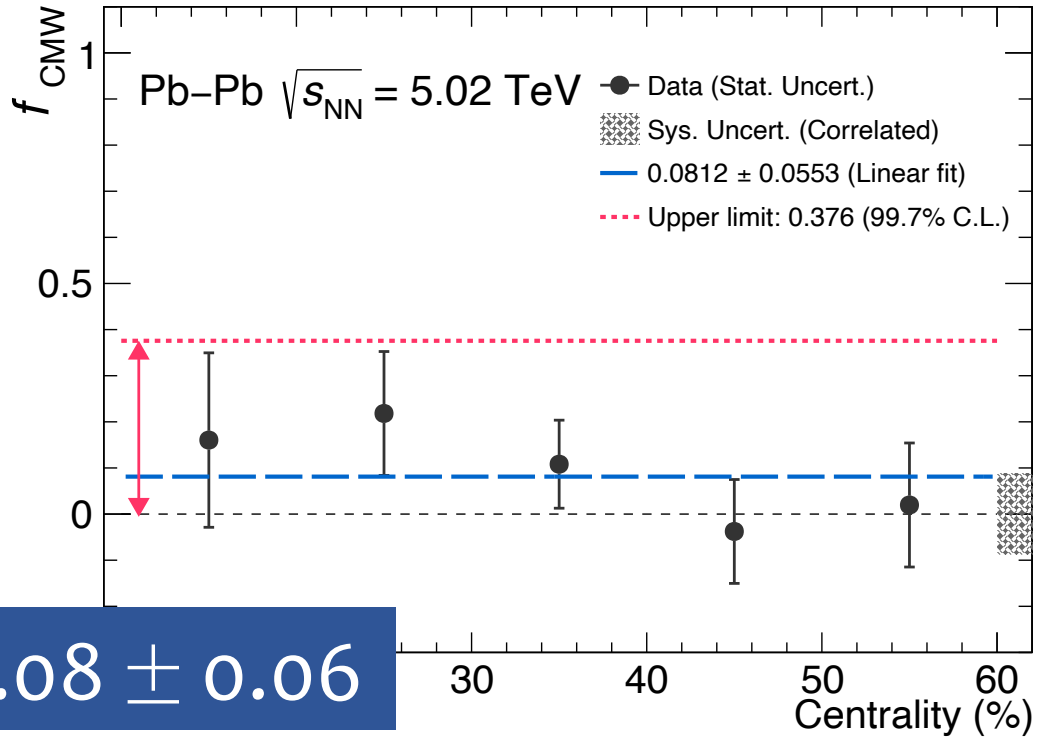
0.003 ± 0.01

- CME fractions are extracted to a high precision by various methods
- Consistent with our current knowledge: the background plays a dominant role

ALICE measurement of the CMW

arxiv: 2308.16123

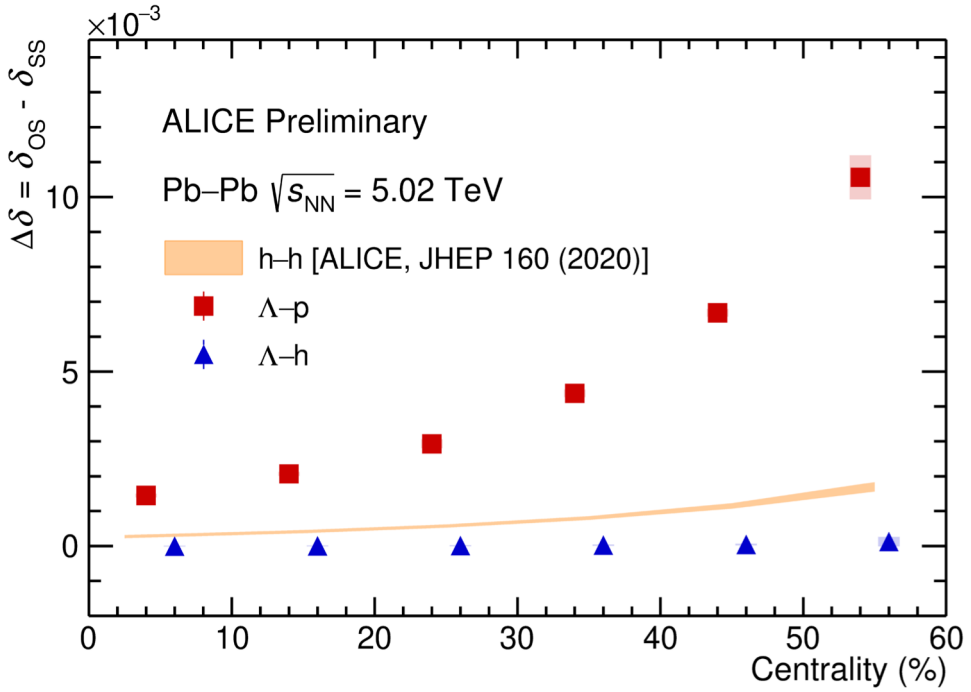


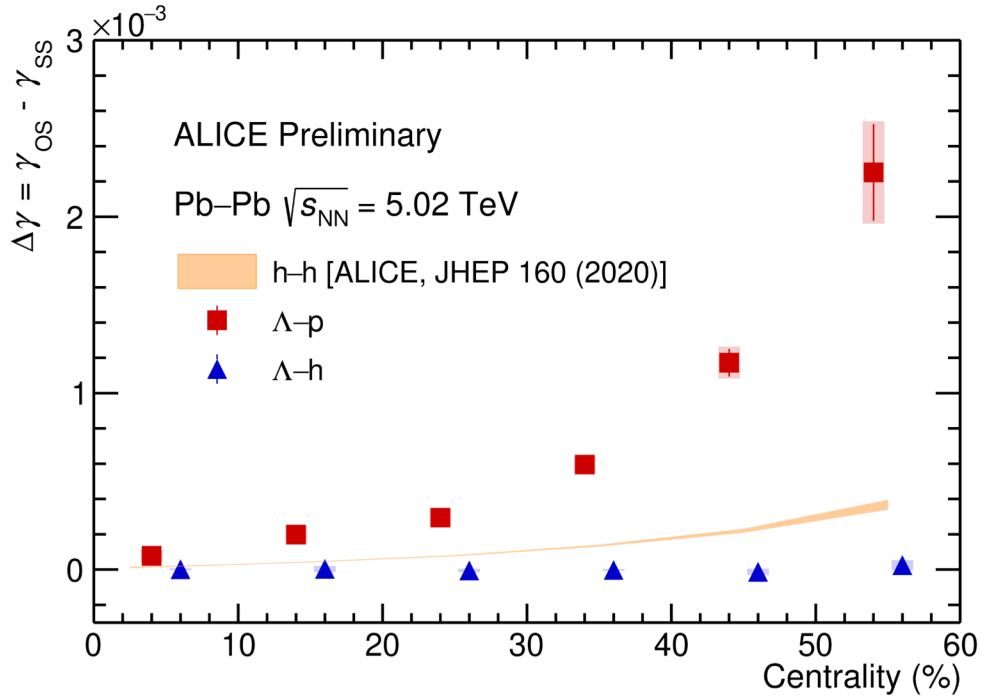


0.08 ± 0.06

- CMW fraction 0.08±0.06 is experimentally extracted for the first time

ALICE measurement of the CVE





- First measurement of CVE with ALICE
  δ and γ correlators of Λ–p show non-trivial splitting behaviors

11月17日17:05
王淳正

Summary

- Collective flow is always one of the key branches in the QGP study
- With the help of high statistics Run 3 data, we look forward to more exciting results

Thank you for your attention!