Medium anisotropy in p–O and p–C collisions at the LHC with exotic α-clustered nuclear density profiles

Based on: arXiv:2407.03823

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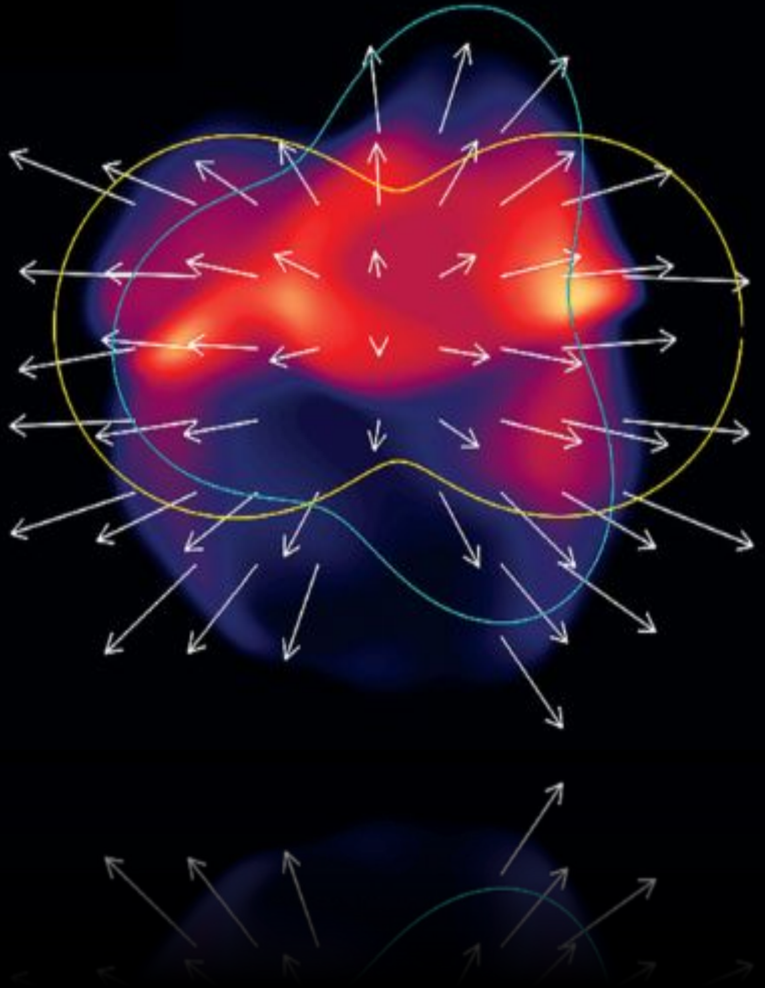
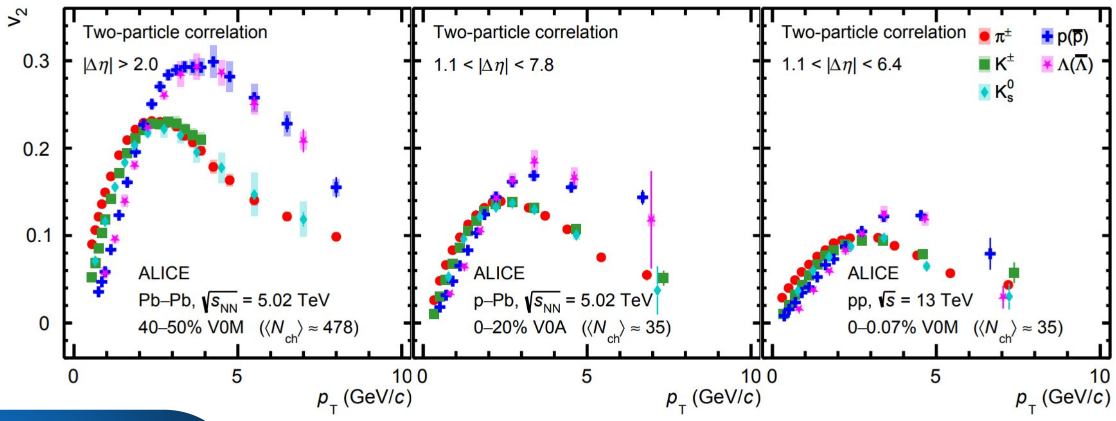
1. **Motivation**
2. α-clusters in ^{16}O and ^{12}C nuclei
3. Results
4. Summary



Motivation

- Recent observations of collectivity in high-multiplicity pp, p-Pb collisions warrant us to probe small collisions in detail

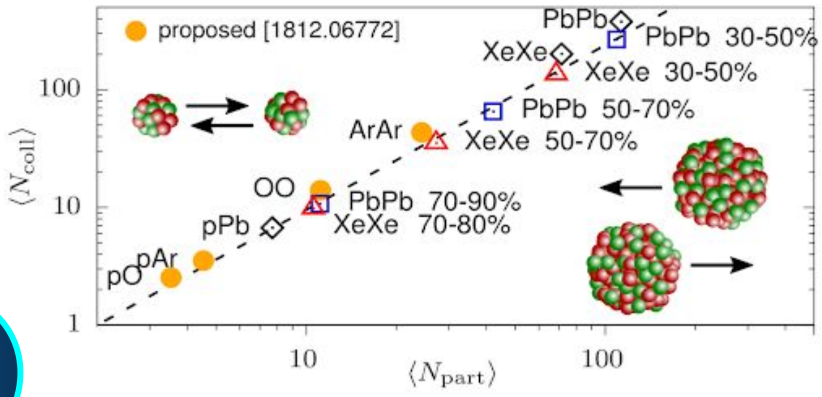
Focus :
SMALL COLLISION SYSTEMS



S. Acharya et al. [ALICE], [arXiv:2411.09323]

p-O and O-O collisions planned in Run 3 at the LHC in 2025

1. **PERFECT SYSTEM SIZE to fill multiplicity gap between pp, p-Pb and Pb-Pb**
2. **To investigate jet quenching effects & comprehend COLLECTIVE PHENOMENA in p-Pb**
3. **p-O studies help COSMIC AIR SHOWER MODELLING**
4. **Effect of initial CLUSTERED geometry in final-state azimuthal correlations**



Phys. Rev. Lett. **126**, 192301 (2021)

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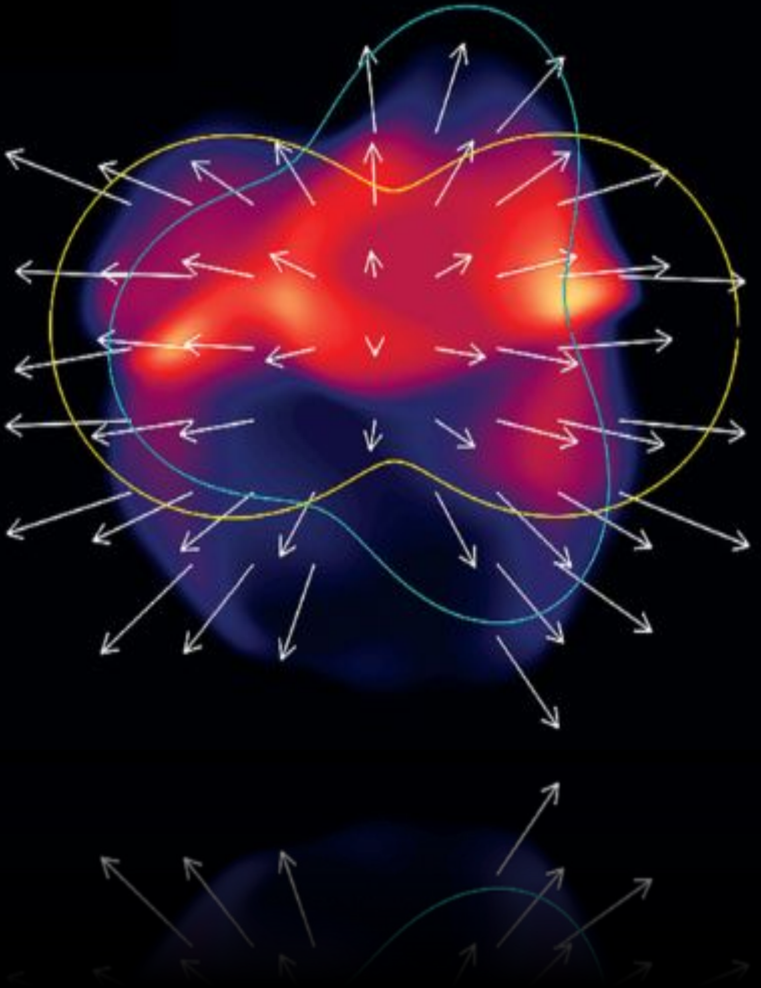
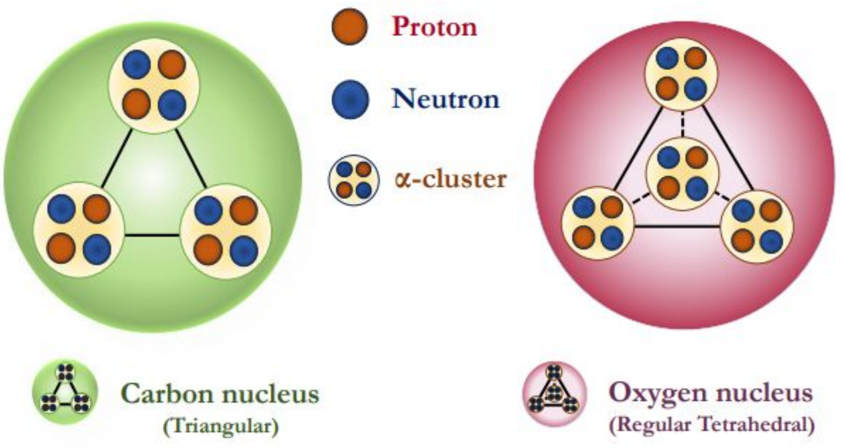


α-clusters in O and C nuclei

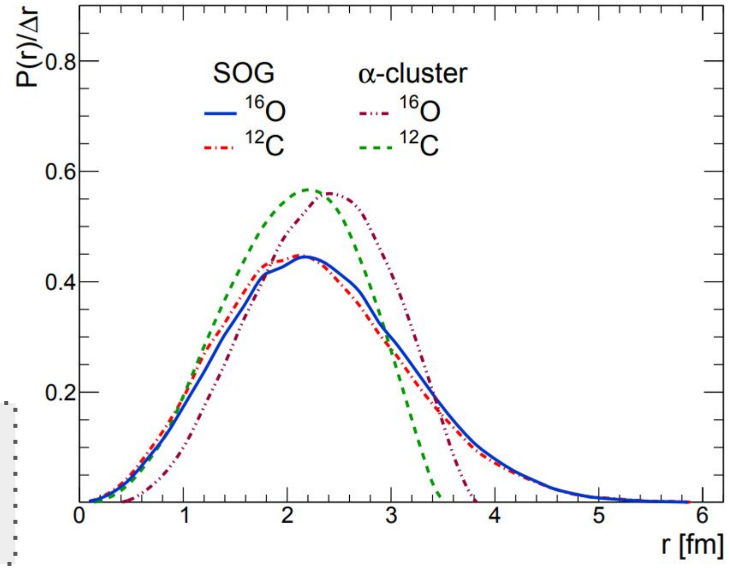


A. Menon K. R., S. Prasad, N. Mallick, and R. Sahoo, arXiv:2407.03823

SUM of GAUSSIANS

- ➢ Nuclear charge densities (NCDs) are fitted by a Sum of two Gaussians: $\rho(r) = C_1 e^{-a_1 r^2} + C_2 e^{-a_2 r^2}$
- ➢ Model-independent method via which experimental nuclear charge distributions are approximated

- ❖ ^{4}He nuclei with two protons and two neutrons is called an *α*-particle
- ❖ Light nuclei having ***4n*** nucleons can possess ***α*-clustered** nuclear structure → Ex.: ^{8}Be, ^{12}C, ^{16}O etc.
- ❖ ***α*-clustering** provides additional stability to nucleus



A. Shukla, S. Aberg and S. K. Patra, J. Phys. G: Nucl. Part. Phys. 38, 095103 (2011)

Comparative study between **clustered and unclustered** initial nuclear density profiles of colliding **^{16}O and ^{12}C** nuclei, performed using **AMPT**, for p-O and p-C collisions at $\sqrt{s_{\rm NN}} = 9.9\ TeV$

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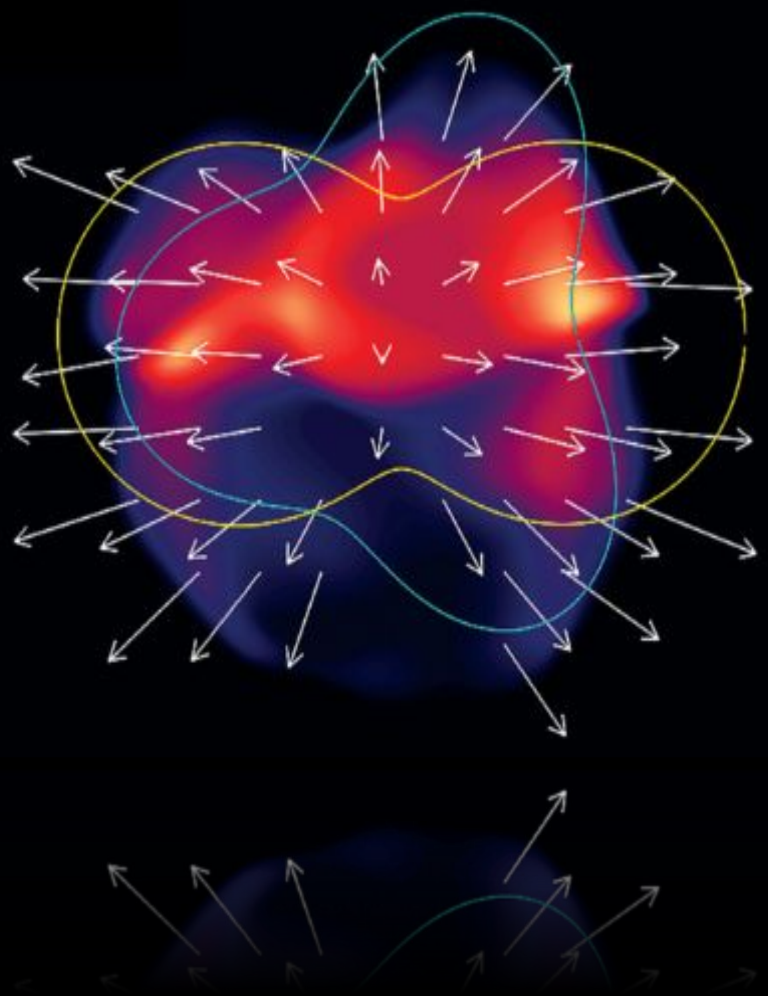
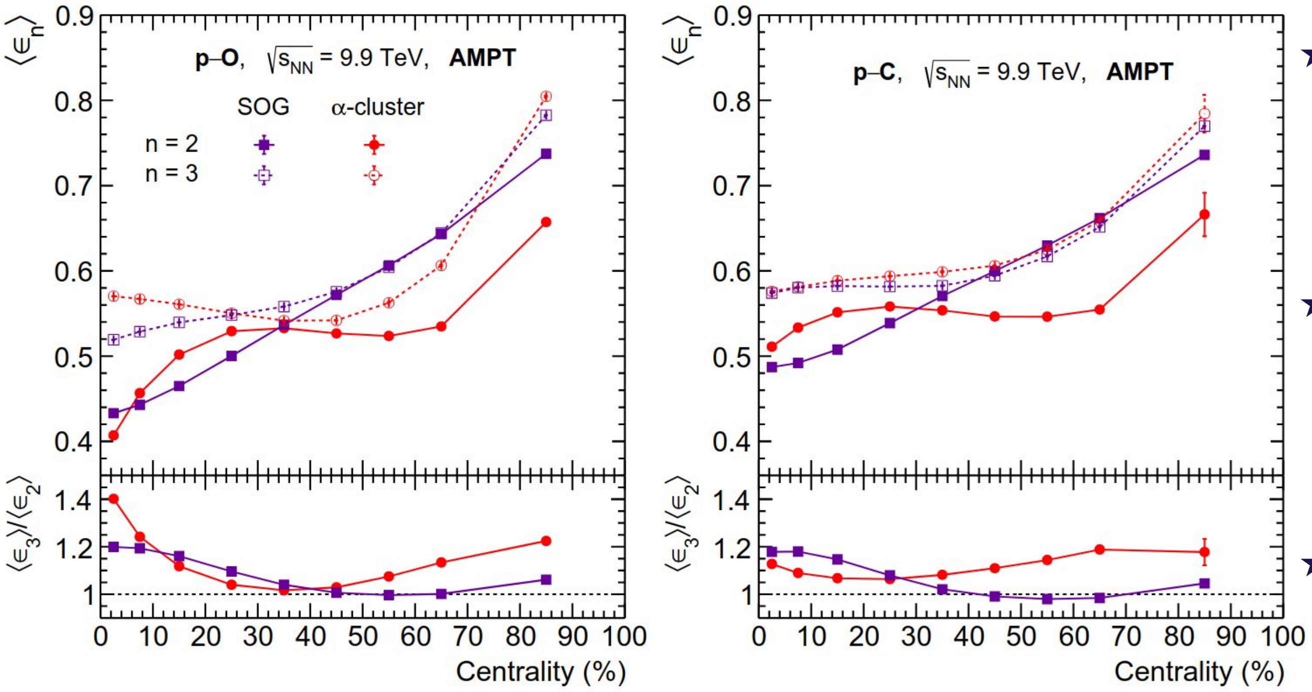


Eccentricity & Triangularity

Initial spatial anisotropies, such as, eccentricity (ϵ_2), triangularity (ϵ_3), etc., are quantified as: $\epsilon_n = \frac{\sqrt{\langle r^n \cos(n\phi_{\text{part}})\rangle^2 + \langle r^n \sin(n\phi_{\text{part}})\rangle^2}}{\langle r^n \rangle}$



A. Menon K. R., S. Prasad, N. Mallick, and R. Sahoo, *arXiv:2407.03823*

- ★ Both ϵ_2 and ϵ_3 may emerge due to density fluctuations than from geometrical asymmetry in small collision systems
- ★ Trends of $\langle\epsilon_n\rangle$ and $\langle\epsilon_3\rangle/\langle\epsilon_2\rangle$ for α-cluster profiles are closely **similar to that in O-O** collisions at $\sqrt{s_{\text{NN}}} = 7\ TeV$
- ★ **$\langle\epsilon_3\rangle/\langle\epsilon_2\rangle$ shows a sharp rise** towards most central p-O collisions (absent in p-C)

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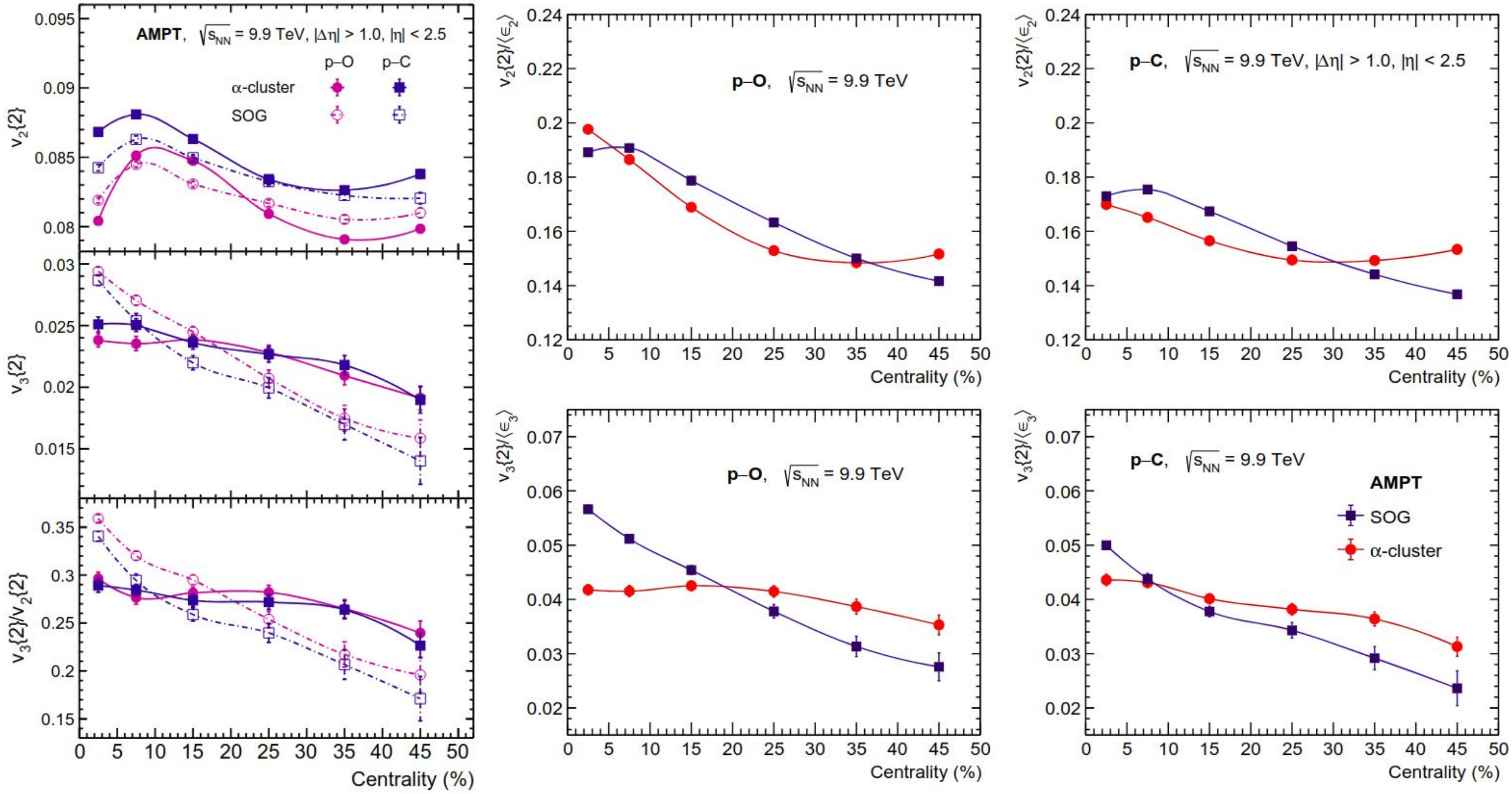
Same collision species ➡ ***Different nuclear density profiles*** ➡ ***Different initial anisotropies***

Elliptic flow and Triangular flow



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Summary

For the first time, systematic study on the effects of initial nuclear density profiles (α-cluster nuclear geometry especially) on final state flow coefficients through pO and pC collisions at the LHC energy is reported

- $\langle \epsilon_n \rangle$ shows significant dependence on collision centrality, initial nuclear geometry and collision system
- α-cluster profile maintains similar unique qualitative behavior throughout the collision systems, pC, pO and OO
- Fluctuation dominated final state $v_2\{2\}$ shows small collision centrality dependence compared to corresponding $v_3\{2\}$ $\Rightarrow$ initial geometry cannot be effectively carried to final state; coalescence picture is not effective due to small particle density in final state

A. Menon K. R., S. Prasad, N. Mallick, and R. Sahoo, *arXiv:2407.03823*

Though theorized in **low energy nuclear physics**, we look for the signs and effects of α-clustered nuclear density profile, via **the lens of high energy physics**

p-C and p-O collision simulations are performed,

keeping in mind the ongoing LHC runs and small collisions systems in mind

…WAITING FOR THE pO and OO DATA FROM THE LHC RUN 3…

Back-up

Anisotropic Flow Estimation

- In non-central collisions, **spatial asymmetry** along different directions leads to **hierarchy of pressure gradients**
- Strong pressure gradients convert **initial spatial anisotropy** to final-state azimuthal **momentum space anisotropy**
- Anisotropic transverse expansion/**anisotropic flow** is quantified via coefficients of Fourier expansion of the azimuthal distribution of final state particles: $\frac{dN}{d\phi} = \frac{1}{2\pi}\left(1 + \sum_{n=1}^{\infty} 2v_n \cos[n(\phi - \psi_n)]\right)$ *where* $v_n = \langle \cos[n(\phi - \psi_n)] \rangle$ is the **nth order anisotropic flow coefficient**
- In this study, estimation of v_n is done by **two-particle Q-cumulant method**
- Pseudorapidity gap in the sub-events helps in suppressing non-flow contributions