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Exploring nuclear structure and sub-nucleonic geometry with multi-particle correlations in Ne-Ne and OO collisions with ALICE at the LHC

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Recent LHC results have demonstrated that small collision systems can exhibit collective behavior reminiscent of that observed in heavy-ion collisions, opening a new frontier for exploring the connection between nuclear structure and collective dynamics at ultrarelativistic energies. In this talk, we present the first measurements of multi-particle cumulants (up to eight-particle) for v_2 and v_3, along with mixed-harmonic observables such as $\mathrm{NSC}(2,3)$, $\mathrm{NSC}(2,4)$, and $\mathrm{NSC}(2,3,4)$, in Ne–Ne and OO collisions at the LHC. These measurements carry unique sensitivity to the initial-state geometry and its event-by-event fluctuations, enabling direct investigation of the nuclear structure, i.e., α-cluster configurations, of ^{20}Ne and ^{16}O at the TeV energy scale for the first time.

Additionally, the correlation between anisotropic flow and mean transverse momentum, $\rho(v_n, [p_\mathrm{T}])$, has been measured for the first time in light-ion collisions, offering a direct probe of the shape-size correlations in the initial conditions. These new results exhibit novel sensitivity to the effective nucleon and sub-nucleon density widths, which play a critical role in defining the initial QCD energy density and, consequently, the emergence of collective flow. Together, these measurements provide unprecedented constraints on models of the initial state, connecting the domains of nuclear structure and QGP collectivity in small, well-defined collision systems.

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