Light-Ion Collisions at the LHC

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The Large Hadron Collider is not only a machine for discovering new particles — it is also a laboratory for creating and studying a new phase of QCD matter. When lead nuclei collide at ultrarelativistic energies, the resulting energy densities far exceed the QCD confinement scale, melting hadrons into a Quark-Gluon Plasma (QGP): a strongly coupled, nearly perfect fluid well-described by relativistic Navier-Stokes equations. Yet a fundamental question remains: how do a handful of elementary particles thermalize and form a collective medium in such a vanishingly short window of time?

Light-ion collisions probe the critical regime where nuclear structure, perturbative QCD, and quark–gluon plasma physics intersect. The first oxygen–oxygen and neon–neon runs at the LHC in July 2025 have opened a new chapter in the LHC ion program, bridging the gap between proton–proton and heavy-ion collisions in a controlled and theoretically tractable way. For a decade, experiments had found QGP-like collective flow even in proton–proton collisions, while jet quenching — the canonical signature of QGP — remained elusive in small systems. The 2025 runs have changed the picture: first results show evidence of jet quenching in systems with as few as ten participating nucleons, and collective flow measurements in oxygen–oxygen and neon–neon collisions are in good agreement with hydrodynamic predictions using ab initio nuclear structure calculations.

I will discuss what these results reveal about thermalization, collectivity, and the boundaries of the QGP phase — and what might come next in the ion program at the LHC.