

# Current Status of Hydrodynamic Modeling from $p+p$ to Heavy Ions

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In recent years, suggestive signatures of collective flow-like behavior have been observed in  $p+p$  collisions at the LHC and also in light+heavy-ion collisions. We review hydrodynamic model calculations that reasonably describe the experimentally measured  $dN_{\text{ch}}/d\eta$  and  $v_2, v_3, v_4$  at  $\eta = 0$  in collisions from Pb+Pb down to  $p+p$ . Nevertheless, it is still uncertain whether the flow-like correlations in small collisions should be ascribed the same hydrodynamic origin as in heavy+heavy-ion collisions. Resolving this problem requires knowing (1) how a proton should impart its fluctuating shape on hydrodynamic initial data (e.g.  $\varepsilon_2, \varepsilon_3$ ), and (2) in what situations hydrodynamics is justified. It turns out the entire non-hydrodynamic behavior of a system is encoded at large orders in the hydrodynamic gradient expansion, whose resummation yields a subset of microscopic system trajectories known as a hydrodynamic attractor. The behavior of trajectories near this attractor define an “off-equilibrium” version of hydrodynamics, whose applicability for small collisions is justified. This provides an answer to (2), but leaves (1), the choice of hydro initial data, as an open issue.

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