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Observations of residual bulk-fluid motion and low-mode areal-density asymmetries at peak convergence in NIF implosions through spectral measurements of DD and DT neutrons

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Hot-spot ignition planned at the National Ignition Facility (NIF) requires proper assembly of the DT fuel, as manifested by the evolution of areal density (ρR) symmetry and hot-spot ion temperature (Ti). Ideally, a spherically symmetric layer of cold and dense fuel with a ρR exceeding 1 g/cm2 surrounding a ˜5 keV lower-density hot spot is obtained at peak convergence. To reach these conditions, the implosion must be 1D in nature and efficient conversion of the implosion kinetic energy to hot-spot thermal energy must be obtained. If substantial 3D non-uniformities in the implosion exist, the conversion efficiency is degraded and significant fraction of the implosion kinetic energy, in the form of bulk-fluid motion, remains at peak convergence. Experimentally, the residual bulk-fluid motion is assessed from directional measurements of the primary DT and DD neutron spectrum. The width of the primary spectrum is characteristic of Ti as well as the variance of the bulk-fluid motion in the burning region. Energy shifts beyond Ti-induced shifts are also an indication of bulk-fluid motion. Additionally, ρR asymmetries are determined from directional yield measurements of scattered neutrons or un-scattered neutrons. In recent high-foot-implosion experiments, directional measurements of the neutron spectrum illustrate the existence of substantial bulk-fluid motion and low-mode ρR asymmetries at peak convergence, which degrade the implosion performance. The measured DT-weighed apparent Ti is also consistently higher than the apparent DD-weighed Ti, a discrepancy that increases with increasing implosion drive. From a 1D perspective, the DD yields are also too high relative to DT yields. Effects due to profiles, reactivity differences, and bulk-fluid motion partly explain these observations, but none of them appear sufficient to explain the data. The observables are most likely caused by significant ρR asymmetries (>500 mg/cm2) and substantial bulk-fluid motion of about 50-100 km/s. The hypothesis is that these observations are driven by radiation drive asymmetry, and instabilities seeded by the fill tube and thin tent holding the capsule in the Hohlraum. These issues are currently being addressed by new engineering solutions, more refined implosion modeling, and implementation of new diagnostics. This work was supported by the US DOE (contract DE-AC52-07NA27344).

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Presenter: Dr FRENJE, Johan (Massachusetts Institute of Technology)

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