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Inferring the Thermal Ion Temperature and Residual Kinetic Energy from Nuclear Measurements in Three-Dimensional Inertial Confinement Fusion.[1]

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In inertial confinement fusion implosion experiments, the presence of residual anisotropic fluid motion within the stagnating hot spot leads to significant variations in ion-temperature measurements using neutron time-of-flight (nTOF) detectors along different lines of sight (LOS). The minimum ion-temperature measurement is typically used as representative of the thermal temperature. However, in the presence of isotropic flows, even the minimum DT neutron-averaged ion temperature is well above the plasma thermal temperature. In this work, it is first shown that by using six LOS measurements, it is possible to accurately determine the true minimum DT ion temperature over 4π solid angle and therefore account for the contribution of anisotropic flows. Furthermore, using both DD and DT neutron-averaged temperature measurements, it is possible to determine the contribution of isotropic flows and infer the thermal temperature. Using multimode simulations, it is shown that large isotropic flows drive the ratio of DD to DT neutron-inferred ion temperatures well below unity and approaching the lower bound of 0.8. The minimum of DD neutron-inferred ion temperature is determined from the velocity variance analysis, accounting for the presence of isotropic flows. Being close to the real thermal temperature, the inferred DD minimum ion temperatures demonstrate a strong correlation with the experimental yields in the OMEGA implosion database. An analytical expression is also derived to explain the effect of mode 1 ion-temperature measurement asymmetry on yield degradations caused by the anisotropic flows. Furthermore, residual fluid motion in the shell leads to unconverted kinetic energy and yield degradation. An analytic theory benchmarked with 3-D simulations is developed to relate the residual kinetic energy to the yield degradation. In collaboration with: R. Betti, R. Epstein, O.M. Mannion, C.J. Forrest, J.P. Knauer, V.N. Goncharov, P.B. Radha, D. Patel, K.S. Anderson, J.A. Delettrez, M. Charissis, A. Shvydky, I.V. Igumenshchev, V. Gopalaswamy, A.R. Christopherson, Z.L. Mohamed, D. Cao, H. Aluie, and E.M. Campbell, Laboratory for Laser Energetics, U. of Rochester; R. Yan, U. of Science and Technology of China; P.-Y. Chang, National Cheng Kung U.; A. Bose, MIT; D. Shvarts, Ben Gurion U. of the Negev; J. Sanz, U. Politecnica de Madrid.

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