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Alpha Heating and Burning Plasmas in Inertial Confinement Fusion

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In inertial confinement fusion, a spherical capsule of cryogenic DT is accelerated inward at a high velocity. Near stagnation, a dense hot spot is formed where the deuterium and tritium ions begin to fuse, creating a 3.5-MeV alpha particle per reaction. These alpha particles deposit energy back into the plasma, thereby increasing the pressure, temperature, and reaction rate. This feedback process is called "alpha heating," and ignition is a direct consequence of this thermal instability. The onset of a burning-plasma regime occurs when the total alpha-particle energy produced exceeds the shell compression work. Using an analytic compressible-shell model for the implosion, it is found that the onset of the burning-plasma regime is a unique function of the neutron yield enhancement caused by alpha particles for any target, direct or indirect drive. This yield enhancement can then be inferred from experimentally measureable quantities, such as the Lawson parameter. From this analysis, the onset of a burning plasma occurs at yields exceeding 50 kJ for implosions at the National Ignition Facility.
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