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Dephasing of ion beams as the Magnetic Vortex Acceleration regime transitions into a bubble-like field structure

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The interaction of an ultra-intense laser pulse with a near critical density target can result in the formation of a plasma channel, a strong azimuthal magnetic field and moving vortices. An application of this is the generation of energetic and collimated ion beams via Magnetic Vortex Acceleration (MVA). The optimized regime of MVA is becoming experimentally accessible with new high intensity laser beamlines coming online and advances made in near critical density target fabrication. A series of three-dimensional simulations was performed to study the robustness of the acceleration mechanism with realistic experimental conditions. Of particular interest is the acceleration performance with different laser temporal contrast conditions, in some cases leading to pre-expanded target profiles prior to the arrival of the main pulse. We studied the pre-plasma effects on the structure of the accelerating fields, transitioning from MVA into a bubble-like field structure at longer pre-plasma scale lengths, and performed a detailed analysis of the ion beam properties and the efficiency of the process. Additionally, we present improved scaling laws for the MVA mechanism when the focal spot size is taken into consideration.

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