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Laser Wavefront-based Classification of successful Injection in LWFA

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We present an in-depth analysis of Laser Wakefield Acceleration (LWFA) experiments performed at the ATLAS-3000 system at CALA in Garching, achieving GeV-scale electron energies with a slit-nozzle target. Through simultaneous monitoring of laser and electron diagnostics for about 2000 shots performed at a 0.25 Hz repetition rate, we identify the laser wavefront as the primary factor influencing electron energy. Notably, fluctuations in the defocus and astigmatism coefficients exhibit strong correlation with electron energy variations, closely mirroring their dynamics that fluctuates on a timescale of minutes. This correlation enables classification of successful injection into the first plasma bubble based solely on wavefront properties, underscoring the predictive value of wavefront diagnostics for LWFA performance.
Additionally, we investigate the origin of defocus fluctuations by comparing them to temperature variations within the main amplifier crystal and other possible sources. By enhancing cooling systems and reducing crystal temperature, we could demonstrate first improvements in wavefront stability.

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