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Self-Modulation and Micro-Bunching Phase Stability Studies in AWAKE

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In the AWAKE experiment, a train of micro-bunches resonantly drives high-gradient wakefields in which electrons have been accelerated up to 2 GeV. The micro-bunches result from the 400 GeV CERN SPS proton beam self-modulating in a pre-formed plasma through a self-modulation (SM) process. Initial transverse wakefields focus and defocus the bunch at the scale of the plasma wavelength. When not seeded, the proton bunch modulates with randomly distributed phases from event to event. For a stable electron acceleration, the SM process must happen in a controlled manner. AWAKE uses a sharp relativistic ionization front to seed this process, called seeded self-modulation. For the analysis of the measurements presented here, we use a streak camera and a reference signal indicating the time-of-arrival of the ionization front on the streak camera images. We show that when not seeded, the phases of the SM with respect to the ionization front varies over the full range of 2π (i.e, no phase stability from event to event), called self-modulation instability. We demonstrate that the seeded SM leads to stable phases varying over only a small fraction of 2π. We determine the transition point between seeded and unseeded self-modulation and the corresponding seed level.

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