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Experimental Observation of Beam-Plasma Resonance Detuning due to Motion of Ions

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In this contribution we discuss experimental results that show how plasma ion motion affects a proton drive bunch train and wakefields using the AWAKE experiment. Plasma ions move due to the ponderomotive force of transverse wakefields and lead to an average ion density decrease in the region around the axis. This, in turn, leads to a shift in the local plasma frequency, resulting in a sharp decrease in the wakefield amplitude along the bunch, which we observe by measuring a clear beam tail in the experimentally obtained proton bunch density images. The same effect is also present in particle in cell simulations. We performed experiments using Helium (A=4), Argon (A=40) and Xenon (A=131) plasma and show that the observed effect scales as expected with ion mass (less for heavier ions) and wakefield amplitude (more for higher amplitudes). The results we present are important for any wakefield accelerator that is driven using long or multiple drivers. These will work best with sufficiently heavy ions to avoid their motion. Additionally, we detune a resonantly-driven beam-plasma system. This is an important validation of the idea of suppressing the beam-hose instability using ion motion, which is based on the same physics concept.

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