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Evolution of an ionized plasma column measured by proton beam self-modulation

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The AWAKE experiment at CERN is a proof-of-concept proton beam-driven plasma wakefield accelerator. The plasma source is a 10 meter-long Rubidium vapor cell ionized by a high-intensity laser pulse. The proton beam is modulated by the plasma, which results in micro-bunching at the plasma frequency and resonant excitation of the plasma wave. We measure the frequency of the micro-bunching when the laser and proton beams are coincident, and when the proton beam propagates through the plasma long after the passage of the laser pulse. The plasma density is inferred from the frequency of modulation of the proton beam. We observe a microsecond-long plateau in the plasma density, followed by a power-law decay of the density versus time. We provide a model of the plasma column evolution by considering thermal and diffusive processes as well as three-body recombination.

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