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Proton Driven Plasma Wakefield Acceleration: AWAKE at CERN - Concept, Experiment and Latest Results

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The Advanced Wakefiled Experiment (AWAKE) at CERN is a proof-of-principle experiment for the concept of a proton-driven plasma-wakefield accelerator. In AWAKE, electrons are externally injected in wakefields driven by the 400 GeV proton beam of the Super Proton Synchrotron (SPS) and accelerated over 10 meters of plasma up to energies in the GeV range.
We have shown that in plasma the initially long proton bunch is subject to the Seeded Self-Modulation (SSM) process. By self-modulation of the beam density, the proton bunch is transformed into a train of micro-bunches, which resonantly drives wakefields. Low energy electrons ($\sim$ 18 MeV) externally injected into the wakefields reached energies up to 2 GeV.
The physics of SSM, the experiments and a sample of experimental results obtained so far will be presented.
Furthermore, we show first results on the appearance of the Hosing Instability (HI), another transverse beam-plasma instability with a growth rate similar to that of the Self-Modulation Instability (SMI). The HI is caused by a small displacement of the proton bunch density distribution with respect to the bunch propagation axis. When the Self-Modulation process is not seeded, the hosing grows starting from noise and can overcome the SMI, leading to a break-up of the micro-bunch structure. In a plasma wakefield accelerator, this would drastically reduce the useful acceleration length. Even though, the HI is not a limitation for AWAKE as it mainly appears at lower plasma densities than the one optimum for acceleration, a better understanding of the physical processes is needed.

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