AWAKE: physics of self-modulation of a relativistic proton bunch in a plasma and electron acceleration results

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Relativistic proton bunches available today carry large amounts of energy (tens to hundreds of kilojoules) and can thus, in principle, drive wakefields in long plasmas, possibly leading to the acceleration of electrons to very high energies (TeVs). Since these bunches are long (6 to 12 cm), the self-modulation process is necessary to drive large amplitude wakefields ($\sim$GV/m) [1]. Experimental results obtained in the AWAKE [2] experiment highlight many of the physics aspects of the self-modulation process. They include: first observation of the self-modulation of a relativistic particle bunch in a plasma [3]; growth of the process both along the bunch and along the plasma [4]; excitation of large amplitude wakefields; transition from a self-modulation instability process to a seeded-self-modulation process with two seeding mechanisms; observation of the non-axi-symmetric hosing instability. In addition, observation of electrons exiting the plasma with up to 2 GeV energy after external injection at $\sim$19 MeV [5] demonstrates that acceleration of particles is possible in these wakefields. We will introduce plasma wakefields and the particular case of those driven by the self-modulation process. We will describe the AWAKE experimental setup and present the main physics and acceleration experimental results. We will briefly outline plans for the next experiments, as well as possible applications for the acceleration scheme.

References

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