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AWAKE - Input to the European Strategy for Particle Physics Update on behalf of the AWAKE Collaboration

The Advanced Wakefield Experiment, AWAKE, is a well-established international collaboration and aims to develop the proton-driven plasma wakefield acceleration of electron bunches to energies and qualities suitable for first particle physics applications, such as strong-field QED and fixed target experiments (~50–200 GeV). Numerical simulations show that these energies can be reached with an average accelerating gradient of ~ 1 GeV/m in a single proton-driven plasma wakefield stage. This is enabled by the high energy per particle and per bunch of the CERN SPS (~19 kJ, 400 GeV) and LHC (~120 kJ, 7 TeV) proton bunches. Bunches produced by synchrotrons are long, and AWAKE takes advantage of the self-modulation process to drive wakefields with GV/m amplitude.

By the end of 2025, all physics concepts related to self-modulation will have been experimentally established as part of the AWAKE ongoing program that started in 2016. Key achievements include: direct observation of self-modulation, stabilization and control by two seeding methods, acceleration of externally injected electrons from 19 MeV to more than 2 GeV, and sustained high wakefield amplitudes beyond self-modulation saturation using a plasma density step.

In addition to a brief summary of achievements reached so far, this document outlines the AWAKE roadmap as a demonstrator facility for producing beams with quality sufficient for first applications. The plan includes:

- Accelerating a quality-controlled electron bunch to multi-GeV energies in a 10 m plasma by 2031;
- Demonstrating scalability to even higher energies by LS4.

Synergies of the R&D performed in AWAKE that are relevant for advancing plasma wakefield acceleration in general are highlighted.

We argue that AWAKE and similar advanced accelerator R&D be strongly supported by the European Strategy for Particle Physics Update.

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