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Current Filamentation Instability of a Long Proton Bunch in Plasma

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Exciting wakefields in plasma requires focusing the driver to a transverse size smaller than the plasma skin depth [1] to avoid (transverse) filamentation of the driver. Conversely, operating with a driver of large transverse size in a plasma with high density offers the possibility to study filamentation [2]. In addition, the three phases expected with the process may be observed with a long driver [3]: filamentation in the front, followed by merging of filaments, and then by development of a shock.

The AWAKE experiment at CERN [5, 6] provides a platform for studying the self-modulation [4] and the filamentation of a long ($\sigma_z \sim$7 cm), relativistic ($\sim$400 GeV/c per particle) proton bunch in a 10-m-long plasma with electron density in the 10^{13}-10^{15} cm^{-3} range.

The overall effect of self-modulation and filamentation can be observed on time-integrated, transverse images of the bunch. Time-resolved images obtained for example with a streak camera can record the evolution of the filamentation within a thin longitudinal slice of the bunch.

Self-modulation is observed when the bunch is focused to a small transverse size ($\sigma_{r0} \cong 200\,\mu m$) at the plasma entrance [7]. Preliminary experimental results show that when the bunch is focused to a larger transverse size ($\sigma_{r0} \cong 500\,\mu m$) and the plasma operated at high density ($> 4\times10^{14}$ cm^{-3}) filamentation may occur. We will present these preliminary results, as well as plans to study filamentation with a discharge plasma source [8].

References

[1] P. Chen *et al.*, PRL 54, 693 (1985)
[2] R. Lee and M. Lampe, PRL 31, 1390 (1973), B. Allen *et al.*, PRL 109, 185007 (2012)
[3] A. Bret *et al.*, Laser and Particle Beams, 31(3), 487 (2013)
[4] N. Kumar et *al.*, PRL 104, 255003 (2010)
[5] A. Caldwell *et al.* (AWAKE Collaboration), NIM A, 829, 3 (2016)
[6] P. Muggli (AWAKE Collaboration), J. Phys.: Conf. Ser. 1596 012008 (2020)
[7] AWAKE Collaboration: PRL 122, 054802 (2019), M. Turner *et al.*, PRL 122, 054801 (2019), F. Braunmueller *et al.*, PRL 125, 264801 (2020), F. Batsch *et al.*, PRL 126, 164802 (2021), L. Verra *et al.*, PRL 129, 024802 (2022)
[8] N. Lopes *et al.*, Proceedings IPAC 2023