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Focusing of a Long Relativistic Proton Bunch in Underdense Plasma

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In this contribution we show, with experimental and numerical simulation results, that a long, relativistic proton bunch can be focused to an equilibrium transverse size, when traveling in underdense plasma. In the presence of the space-charge field of the bunch, the plasma electrons move towards the axis of propagation of the beam, generating a focusing force for the protons. We observe that the transverse size of the bunch, measured downstream of the plasma exit, decreases when increasing the plasma electrons density, until it reaches a saturation value. Moreover, the transverse size does not oscillate along the bunch, further suggesting that no transverse oscillation of the plasma electrons nor of the protons occurs, and that the plasma does not sustain wakefields. When the plasma electron density becomes comparable to the peak density of the bunch, the effect of the self-modulation instability becomes observable on the proton bunch charge distribution. This indicates the transition to collective motion of the plasma electrons and to the presence of wakefields, that can be used for high-gradient particle acceleration, as in the AWAKE experiment at CERN.

Acknowledgments

Primary authors: VERRA, Livio (CERN); Dr MUGGLI, Patric (Max-Planck Institute for Physics)

Co-authors: Dr BERGAMASCHI, Michele (Max-Planck Institute for Physics); Dr GSCHWENDTNER, Edda (CERN); Ms NECHAEVA, Tatiana (Max-Planck Institute for Physics); PUCEK, Jan (Max-Planck Institute for Physics); Dr RANC, Lucas (Max-Planck Institute for Physics); Dr ZEVI DELLA PORTA, Giovanni (Max-Planck Institute for Physics)

Presenter: VERRA, Livio (CERN)

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