Laboratory Plasma Astrophysics at CERN

C. D. Arrowsmith[1], P. Simon[2], N. Charitonidis[2], T. Hodge[3], R. A. Simpson[4], P. Bilbao[5], D. Haberberger[6], S. Iaquinta[1], R. Boni[6], H. Chen[4], T. Davenne[7], I. Efthymiopoulos[2], D. H. Froula[6], N. Lopes[5], T. Ma[4], L. O. Silva[5], V. Stergiou[2], R. M. G. M. Trines[7], J. T. Gudmundsson[8,9], B. T. Huffman[1], F. Miniati[1], B. Reville[10], S. Sarkar[1], R. Bingham[7,11], G. Gregori[1]

[1] University of Oxford, Oxford, United Kingdom

[2] European Organization for Nuclear Research (CERN), Geneva, Switzerland

[3] AWE, Reading, United Kingdom

[4] Lawrence Livermore National Laboratory, Livermore, USA

[5] GoLP/Instituto de Plasmas e Fusão Nuclear, Lisboa, Portugal

[6] University of Rochester Laboratory for Laser Energetics, Rochester, USA

[7] Rutherford Appleton Laboratory , Didcot, United Kingdom

[8] University of Iceland, Reykjavik, Iceland

[9] KTH Royal Institute of Technology, Stockholm, Sweden

[10] Max-Planck-Institut für Kernphysik, Heidelberg, Germany

[11] University of Strathclyde, Glasgow, United Kingdom

Relativistic electron-positron (pair) plasmas exhibit properties that differ from electron-ion plasmas due to their mass symmetry. They are predicted to play an important role in energetic astrophysical environments where pair-dominated outflows are expected, such as the winds from pulsars and magnetars, or the jets of Gamma-Ray Bursts. The generation and amplification of intense magnetic fields in pair plasmas, due to collisionless kinetic plasma instabilities, is commonly invoked to model the intense synchrotron emission detected from Gamma-Ray Bursts and other relativistic astrophysical sources. However, an understanding of these instabilities currently relies upon Particle-in-cell simulations that have not been benchmarked by experiments for the conditions of interest, due to the difficulty of producing electron-positron pairs in sufficiently large numbers. Experimental platforms are motivated to gain a better understanding of the microphysics, especially in regimes where instabilities

become non-linear and saturate; which is difficult to simulate in full 3-d for the large numbers of plasma periods needed for instabilities to fully-develop.

In this talk, we describe a newly developed experimental platform to study interactions of pair beams with plasma at CERN's HiRadMat facility. 10^{12}-10^{13} electron-positron pairs will be produced by irradiating a target with a nanosecond-duration bunch of 440 GeV protons. A metre-scale plasma column sustained by inductive coupling of radio-frequency power will be used to study electromagnetic beam-plasma filamentation instabilities. We will present the preliminary results of the recent experiment, and the broader potential for using ultra-high energy proton facilities as facilities for studying fundamental plasma physics and laboratory astrophysics.

UK Ministry of Defence © Crown owned copyright 2023/AWE