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Astrophysically relevant pair plasma experiments at CERN

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Relativistic electron-positron pair plasmas are expected to be found in energetic astrophysical environments, such as the winds of pulsars and magnetars, and the jets of Gamma-Ray Bursts [1-4]. Plasma instabilities associated with such pair-dominated outflows play an important role in explaining their energy dissipation and the radiative signatures we observe from these objects on Earth [5-7]. For example, the generation and amplification of intense magnetic fields in pair plasmas, due to collisionless kinetic plasma instabilities, is commonly invoked to explain the intense synchrotron emission detected from Gamma-Ray Bursts and other relativistic astrophysical sources [8]. Current-neutrality and mass equality of component species is expected to lead to significantly different instability behaviour for pair plasma jets compared with pure-electron beams and electron-ion plasmas. However, the difficulty of experimentally producing sufficient yields of electron-positron pairs has limited our understanding of pair plasma instabilities to Particle-in-cell (PIC) simulations [9]. Experiments are required to benchmark these simulations and probe regimes where instabilities have evolved to stages of non-linearity. This can take prohibitively long using full scale 3-d PIC simulations.

In this talk, we describe a newly developed experimental platform to study interactions of pair beams with plasma at CERN's HiRadMat facility [10,11]. More than 10^{13} electron-positron pairs are 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 is used to study electromagnetic beam-plasma filamentation instabilities [12]. We will present results of the first experiment of this platform, as well as the broader potential of using high-energy particle accelerator facilities for studying fundamental plasma physics and laboratory astrophysics.

References

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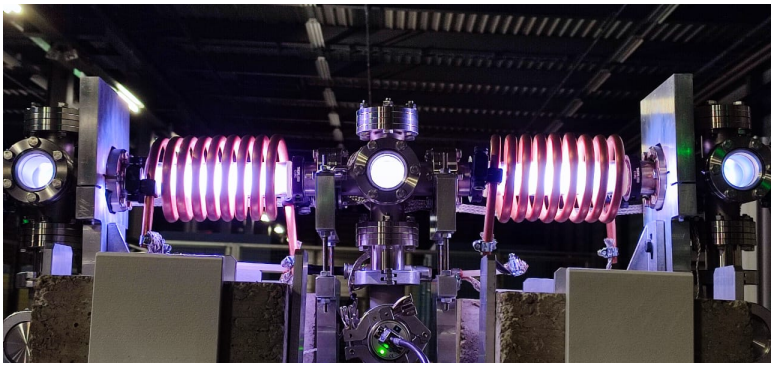

Figure 1: Photograph of a metre-scale plasma column installed at CERN to study plasma instabilities of pair beams.