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Theoretical and numerical study of the ECRIPAC accelerator concept

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This work presents a comprehensive study of the Electron Cyclotron Resonance Ion Plasma Accelerator (ECRIPAC) concept, an idea developed in the nineties for a compact, plasma-based accelerator capable of producing high-energy pulsed ion beams using robust and well-established technologies. The limited literature and absence of experimental prototypes motivate further studies on the topic.

The ECRIPAC concept is strongly intertwined with Electron Cyclotron Resonance Ion Source (ECRIS), exploiting similar physical principles for their operation and including an ECRIS as injector in its original design. The physical and technological similarities between ECRIPAC and ECRIS will be explored and discussed, reviewing the physical theory behind ECRIPAC with novel corrections to the existing literature.

Afterwards, a detailed theoretical analysis of the ion acceleration stability condition is conducted, revealing more stringent limitations than previously anticipated and examining the influence of various physical parameters on the accelerator's performance. Based on this analysis, a compact accelerator design is proposed, capable of accelerating He^{2+} ions to 9.5 MeV per nucleon within a 1.8-meter-long cavity. Finally, a Monte Carlo particle-tracking code is used to study the electron population behaviour within the proposed accelerator design. The simulation results validate the theoretical treatment of ECRIPAC and provide insights into the effects of important physical parameters on electron dynamics during operation.

Primary author: CERNUSCHI, Andrea (CNRS-LPSC, Université Grenoble Alpes)

Co-authors: GARRIGUES, Laurent (LAPLACE, Université de Toulouse, CNRS); THUILLIER, Thomas (CNRS-LPSC)

Presenter: CERNUSCHI, Andrea (CNRS-LPSC, Université Grenoble Alpes)

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