Contribution ID: **19** Type: **Poster (participant)**

Heavy-ion-driven plasma wakefield acceleration

Monday, 14 April 2025 17:10 (1h 30m)

This paper pioneers the first study on heavy-ion-driven plasma wakefield acceleration, highlighting potential of heavy ions (higher beam charge density, heavier particle mass and higher kinetic energy) to plasma-based acceleration techniques. Our investigation aims to identify an optimal regime for achieving high-amplitude wakefields excited by heavy ion beams. Among various drivers in HIAF, the Bismuth beam with an rms beam radius of 0.1 mm and an energy of 9.58 GeV/u in HIAF, due to its high beam charge intensity and energy, can rapidly develop self-modulation instability after 0.14 m, exciting a wakefield with a maximum amplitude of 6 GV/m. However, the phase slippage caused by differences in relativistic velocities limits further acceleration. By introducing a plasma density gradient, we ensure that the accelerated beam remains in the accelerating and focusing phase of the wakefield throughout the process, enabling electrons to be accelerated up to 562 MeV within 0.26 m. Then, an extremely narrow and short electron bunch is employed as a witness beam. With plasma density gradients, after propagating a distance of 0.92 m in the plasma, electrons can be accelerated from 16 MeV up to 626 MeV, resulting in an acceptable energy spread of 0.8 %.

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Session Classification: Poster Session

Track Classification: Electron acceleration