Design and Simulation of a Compact Thomson Parabola Spectrometer for Laser-Accelerated Ions and Electrons

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The development of high-intensity ultrashort laser facilities requires compact and versatile diagnostics capable of characterizing the broad energy and charge-state distributions of laser-accelerated particles. We present the design of a Thomson Parabola Spectrometer (TPS) for particle-beam diagnostics at the IPEN laser facility. The system is conceived to characterize both ion and electron beams within a single compact spectrometer, providing species, charge-state, and energy discrimination over the broad distributions expected from laser–matter interactions.

The TPS design combines electric and magnetic deflection stages with a two-aperture collimation system. Particular attention is given to the magnetic configuration and overall geometry in order to maximize dispersion while restricting the spectrometer length to approximately 20 cm. The design targets proton energies up to approximately 10 MeV and multiple charge states of light and intermediate-mass ions, including carbon and oxigen. The opposite deflection direction of electrons allows their simultaneous detection while minimizing interference with the ion traces.

The spectrometer geometry and expected response are being optimized through particle-transport simulations, including relativistic kinematics where required. Simulated proton trajectories between 2.5 and 10 MeV indicate submillimeter trace widths and sufficient spatial separation for energy reconstruction at the upper end of the investigated range. The system is also being designed for experimental calibration using well-defined monoenergetic ion beams from an electrostatic accelerator.

The resulting instrument will provide a compact and flexible diagnostic platform for quantitative characterization of laser-driven particle acceleration at IPEN and for future experiments involving different target configurations and acceleration regimes.