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Compact high-resolution multi-GeV electron spectrometer for PW-laser-driven plasma accelerators

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With the availability of petawatt lasers, the space required to generate beams of electrons to GeV-levels by laser-plasma acceleration has reduced to that of the university laboratory [1]. However, measuring these electrons in the relatively compact space of a vacuum chamber that can be supported by the typical university laboratory is challenging, as it typically requires large magnets (peak magnetic field B = 1.25T, 40s cm length) [2]. For example, a spectrometer with a magnet of ~1T extending 5 cm will yield an uncertainty 200 MeV around a 1GeV peak for an electron launch angle variation of ±4mrad.
Here we report on a compact, high-resolution electron spectrometer with a resolution of ±XXX MeV for measuring 4 GeV electrons, which uses a 1.48T magnet, made possible by using two sets of tungsten wires, each at a different propagation distance beyond the magnet. The wires, placed with ~100-micron accuracy, act as fiducials by introducing shadows on both the electron beams and their associated betatron X-rays, to determine the electron energy, source position and launch angle. The spectrometer was used to measure ~4 GeV electrons from recent TPW LWFA experiments. The results were compared with the two-screen method and showed a good agreement.
We also studied the high-energy electron shadows of tungsten wires under different electron energy, both in experiments and GEANT4 simulations. A wire is scattering less electrons when the electron energy is higher. We provided a formula summarized from a series of GEANT4 simulations as a guidance of a high energy (>10GeV) spectrometer design. And detailed error analysis for this kind of spectrometer was made, which showed its ability to measure electron spectrum with more 10 GeV energy.

[1] X. Wang et al., Nature Communications 4, 1988 (2013)
[2] K. Nakamura et al., Review of scientific instruments 79, 053301 (2008)

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