7th European Advanced Accelerator Conference

EAAC2025

Contribution ID: **682** Type: **Oral contribution**

Statistical analysis of sources of instability on electron beam quality in a laser plasma accelerator preparing for Bayesian optimization

Tuesday 23 September 2025 17:20 (20 minutes)

Laser-electron accelerators emerge as novel, compact sources of high-quality relativistic electron beams. Their extremely high peak currents make them ideal for applications in fields such as material science, healthcare, and particle physics.
Each experimental application requires unique electron parameters. Additionally, all the input parameters are interconnected, resulting in a highly complex parameter space. This increases the cost in time and resources for preparing experiments. To address this issue, we have developed a semi-automated Bayesian optimization loop that adjusts six input parameters simultaneously to achieve optimal electron beam parameters.
However, the high nonlinearity of laser wakefield acceleration poses a challenge for automated optimization, as even minor fluctuations in input parameters can lead to significant changes in electron beam properties. To quantify and mitigate the effects of these statistical fluctuations, we have compiled an extensive dataset through systematic studies of their characteristics and influence on the electron beam quality.
Alongside demonstrating an initial prototype for semi-automated Bayesian optimization, this work will enhance the understanding of the underlying sources of instability in laser-plasma acceleration experiments, which are essential for more complex machine learning experiments.

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Session Classification: PS7: Beam diagnostics, instrumentation, Machine Learning

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