Contribution ID: **38** Type: **not specified**

Accurate and confident prediction of electron beam longitudinal properties using spectral virtual diagnostics

Wednesday, 12 May 2021 17:30 (35 minutes)

Longitudinal phase space (LPS) provides a critical information about electron beam dynamics for various scientific applications. For example, it can give insight into the high-brightness X-ray radiation from a free electron laser. Existing diagnostics are invasive, and often times cannot operate at the required resolution. In this work we present a machine learning-based Virtual Diagnostic (VD) tool to accurately predict the LPS for every shot using spectral information collected non-destructively from the radiation of relativistic electron beam. We demonstrate the tool's accuracy for three different case studies with experimental or simulated data. For each case, we introduce a method to increase the confidence in the VD tool. We anticipate that spectral VD would improve the setup and understanding of experimental configurations at DOE's user facilities as well as data sorting and analysis. The spectral VD can provide confident knowledge of the longitudinal bunch properties at the next generation of high-repetition rate linear accelerators while reducing the load on data storage, readout and streaming requirements.

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Session Classification: Virtual Diagnostic