Contribution ID: **228** Contribution code: **MOP002** Type: **Poster Presentation**

Advancing accelerator virtual beam diagnostics through Latent Evolution Modeling: An integrated solution to forward, inverse, tuning, and UQ problems

Monday 11 August 2025 16:00 (2 hours)

Virtual beam diagnostics relies on computationally intensive beam dynamics simulations where high-dimensional charged particle beams evolve through the accelerator. We propose Latent Evolution Model (LEM), a hybrid machine learning framework with an autoencoder that projects high-dimensional phase spaces into lower-dimensional representations, coupled with transformers to learn temporal dynamics in the latent space. This approach provides a common foundational framework addressing multiple interconnected challenges in beam diagnostics. For *forward modeling*, a Conditional Variational Autoencoder (CVAE) encodes 15 unique projections of the 6D phase space into a latent representation, while a transformer predicts downstream latent states from upstream inputs. For *inverse problems*, we address two distinct challenges: (a) predicting upstream phase spaces from downstream observations by utilizing the pretrained CVAE with transformers trained on reversed temporal sequences, and (b) estimating RF settings from the latent space of the trained LEM using a dedicated dense neural network that maps latent representations to RF parameters. For *tuning problems*, we leverage the trained LEM and RF estimator within a Bayesian optimization framework to determine optimal RF settings that minimize beam loss. This paper summarizes our recent efforts and demonstrates how this unified approach effectively addresses these traditionally separate challenges.

Please consider my poster for contributed oral presentation

Yes

Would you like to submit this poster in student poster session on Sunday (August 10th)

No

Footnotes

Funding Agency

This work was supported by the Los Alamos National Laboratory LDRD Program Directed Research (DR) project 20220074DR

I have read and accept the Privacy Policy Statement

Yes

Author: RAUTELA, Mahindra (Los Alamos National Laboratory)

Co-author: SCHEINKER, Alexander (Los Alamos National Laboratory)

Presenter: RAUTELA, Mahindra (Los Alamos National Laboratory)

Session Classification: Monday Poster Session

Track Classification: MC6 - Beam Instrumentation, Controls, AI/ML, and Operational Aspects