Beam Condition Forecasting with Adaptive Graph Neural Networks

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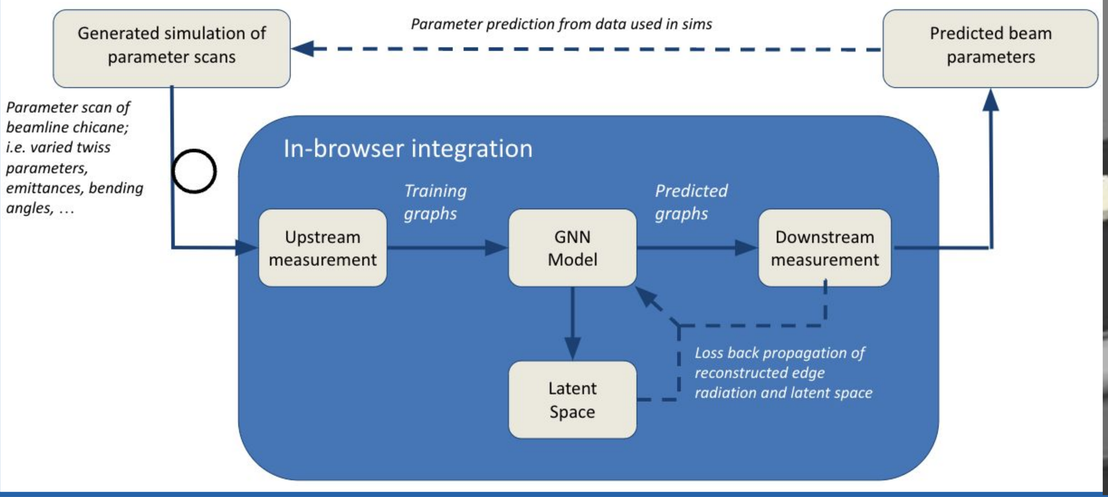
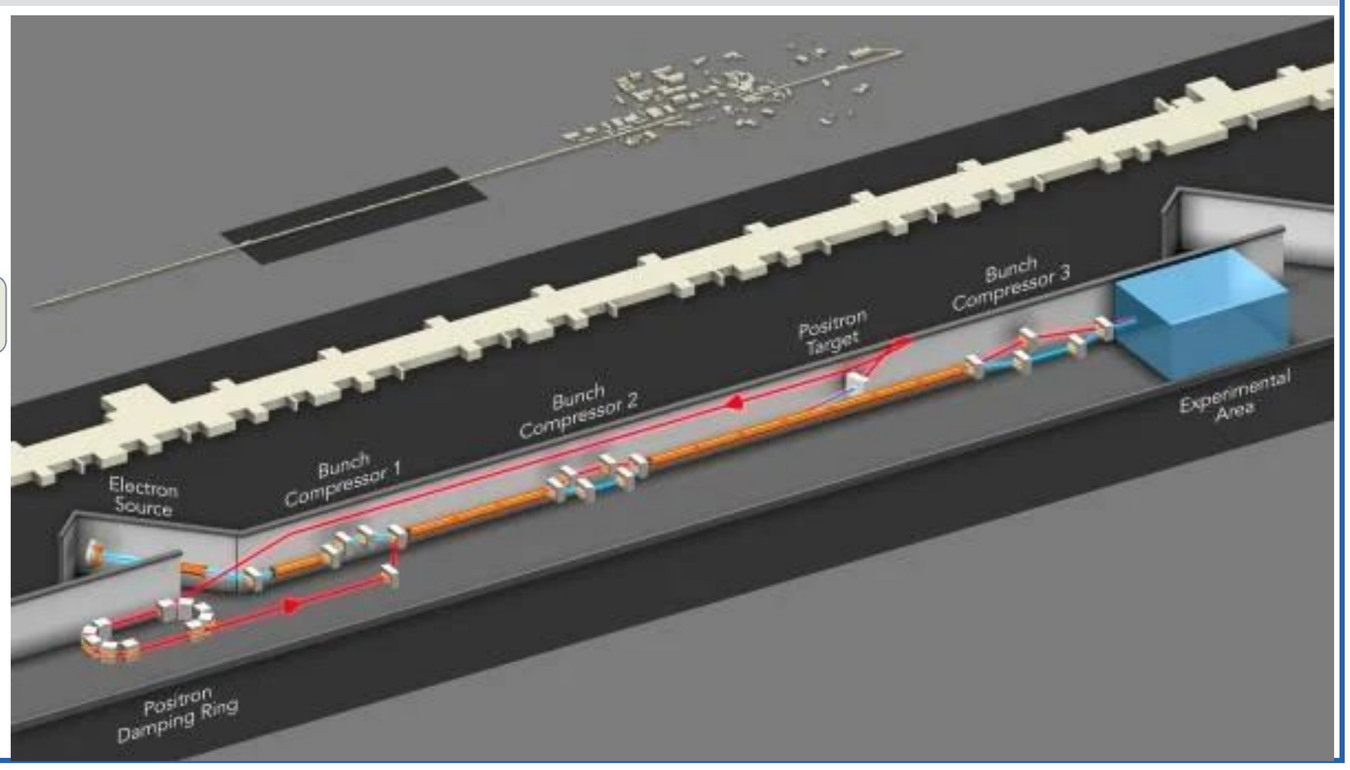
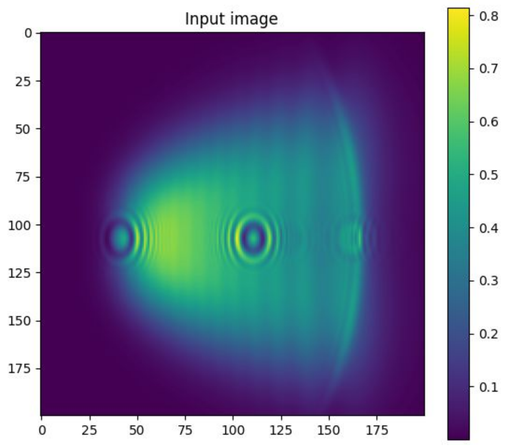
Background

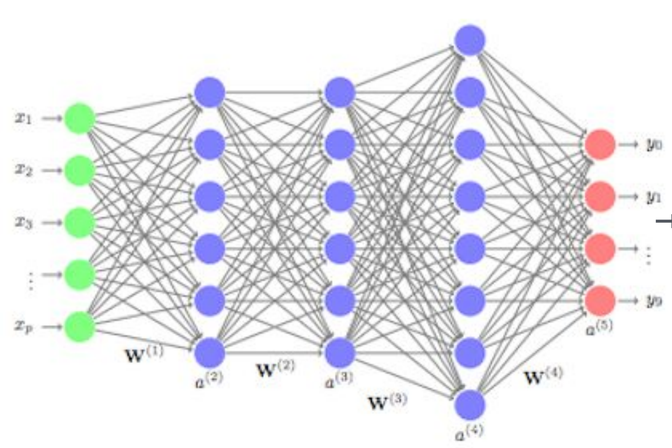
- Beam Diagnostic Measurements
  - Standard measurement techniques are destructive
  - Perturbations to the beam cause inherent uncertainties
  - Can run while the beam is operating
  - Measurements during operation improve performance



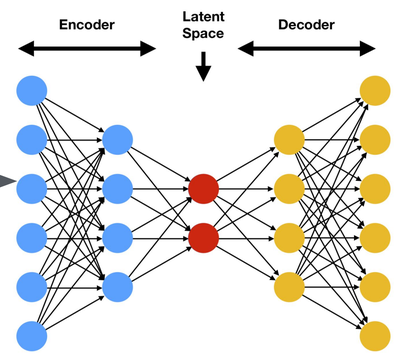


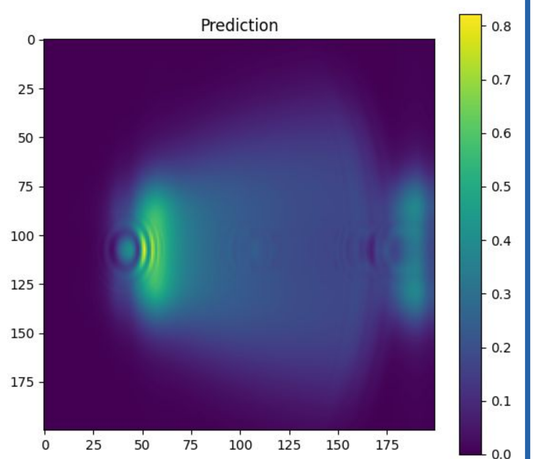
Data and Model Pipeline



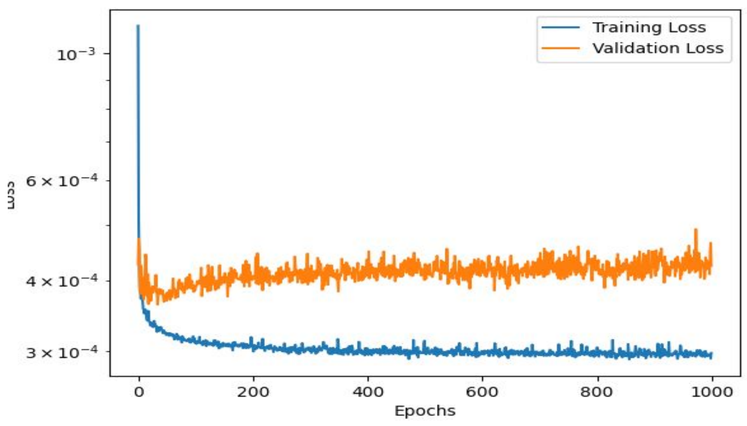


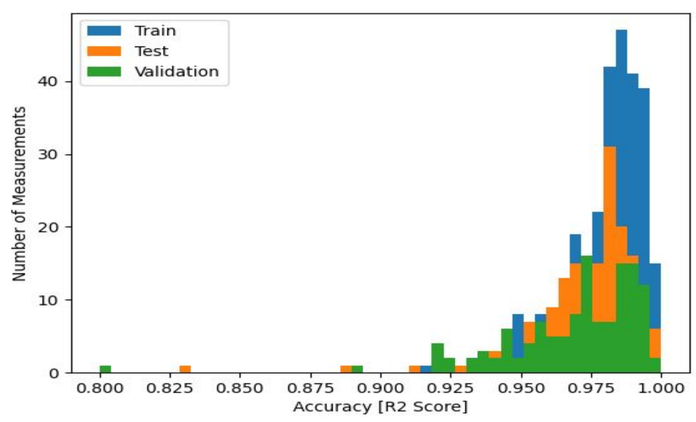
Reconstructed downstream edge radiation

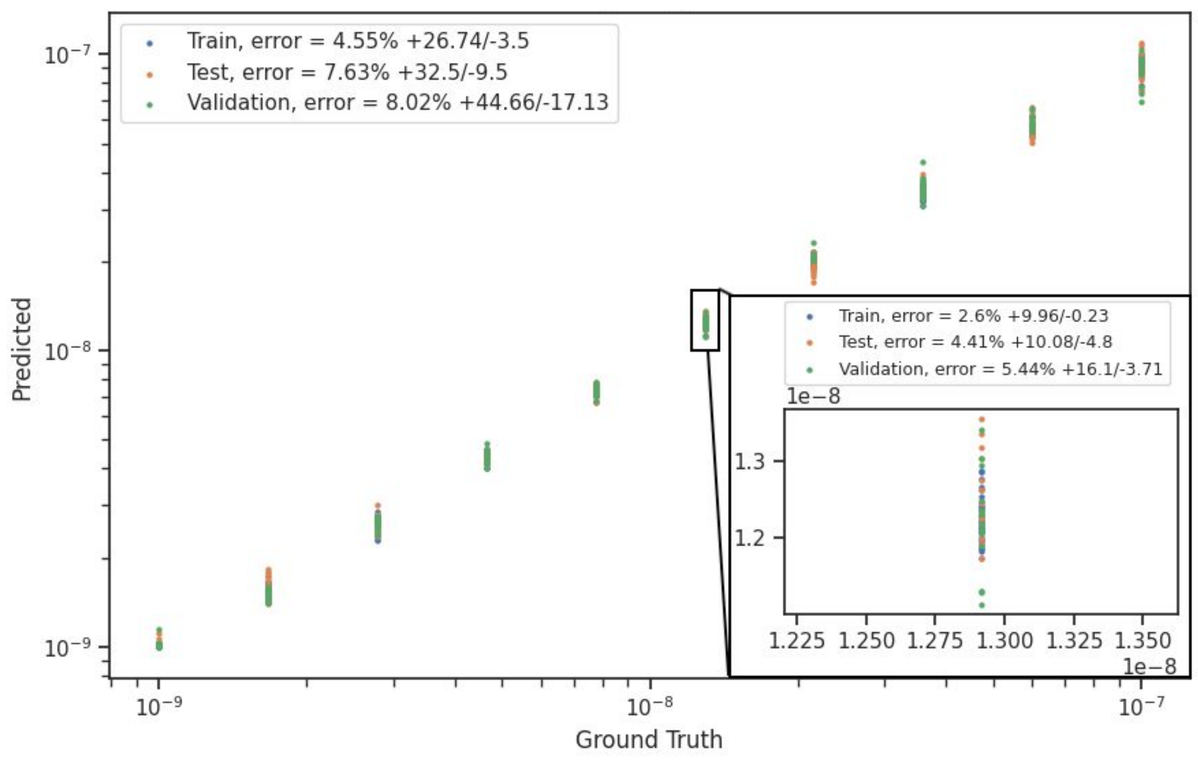




- Edge Radiation diagnostics
  - Non-destructive measurements allow for an accurate prediction
  - Measurements can be run during experiments
  - FACET-II upgraded cameras in 2023
- Edge Radiation Dependencies
  - Charged particles emit radiation due to far-field magnetic effects
  - Measuring interference between pairs of magnets in chicane
  - Variations due to magnetic field strengths, distance between magnets, and beam emittances







- Data Pipeline
  - Developed a model to use initial upstream edge radiation measurements to predict the downstream edge radiation and beam emittances and twiss parameters
  - Data processing pipeline utilizing graph image conversion and cleaning for model training
  - SRW simulation used to generate beamline parameter scans for model training
- Building the Model
  - Input graphs generated using the pixel intensities as nodes and gradients as the edge connections
  - Training graphs are dynamically cleaned based upon normalized intensities
  - Feedforward GNN for prediction of downstream edge radiation, then input into graph autoencoder for latent space prediction of beam parameters
- Model Evaluation
  - Predicted downstream radiation is approx. 97% accurate for all datasets
  - Latent space reconstruction spans 2 orders of magnitude
  - Emittance prediction is accurate with roughly a 5-10% relative error

References

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