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MACHINE LEARNING TECHNIQUES FOR BETATRON DIAGNOSTICS IN AWAKE RUN 2

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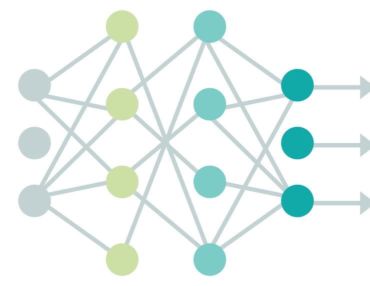
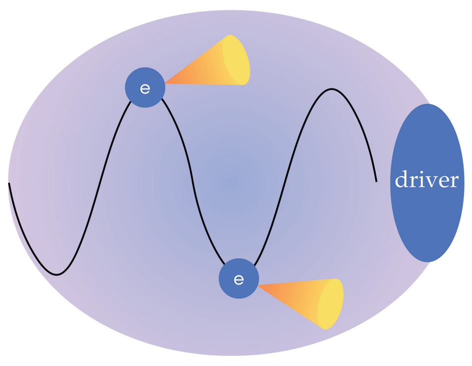
Objectives

- Explore machine learning-based betatron diagnostics to predict witness beam parameters in the context of the AWAKE experiment.
- Generate a dataset through large-scale simulations with a comprehensive parameter scan.
- Determine the radiation features to train the machine learning models.
- Validate the models and explore their applicability as diagnostics.

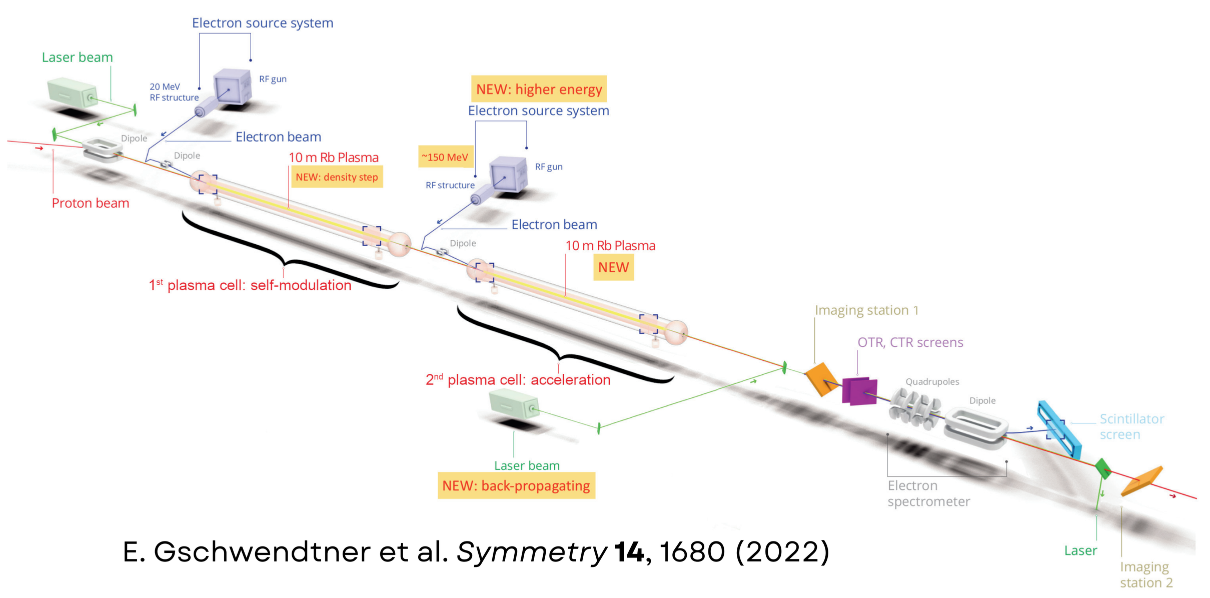


1. Introduction

- In plasma accelerators, betatron radiation is a footprint of the electron beam.
- It could potentially provide information about the beam parameters, and serve as a non-invasive diagnostics tool.



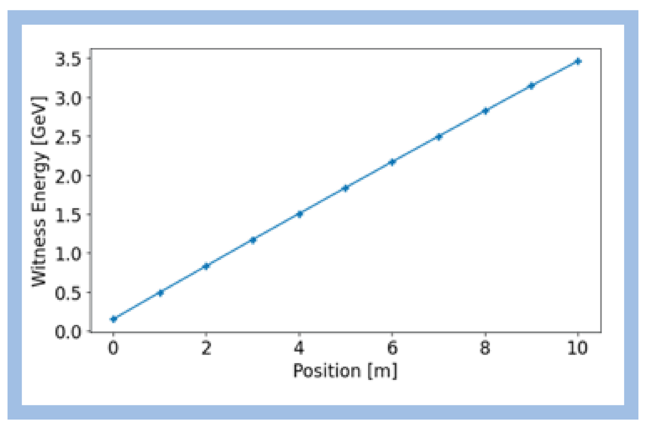
- In AWAKE Run 2 setup, witness beam is injected and accelerated in the second plasma cell.

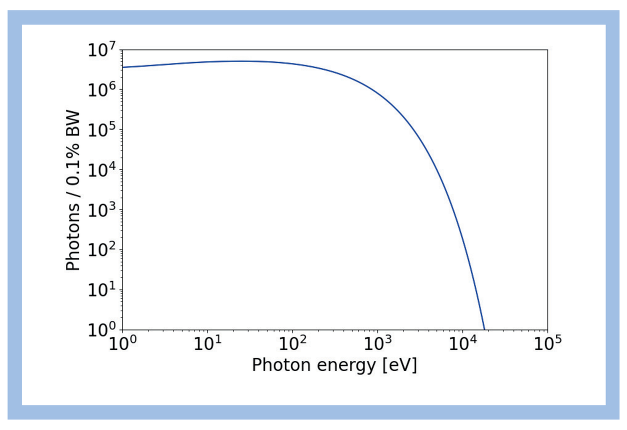


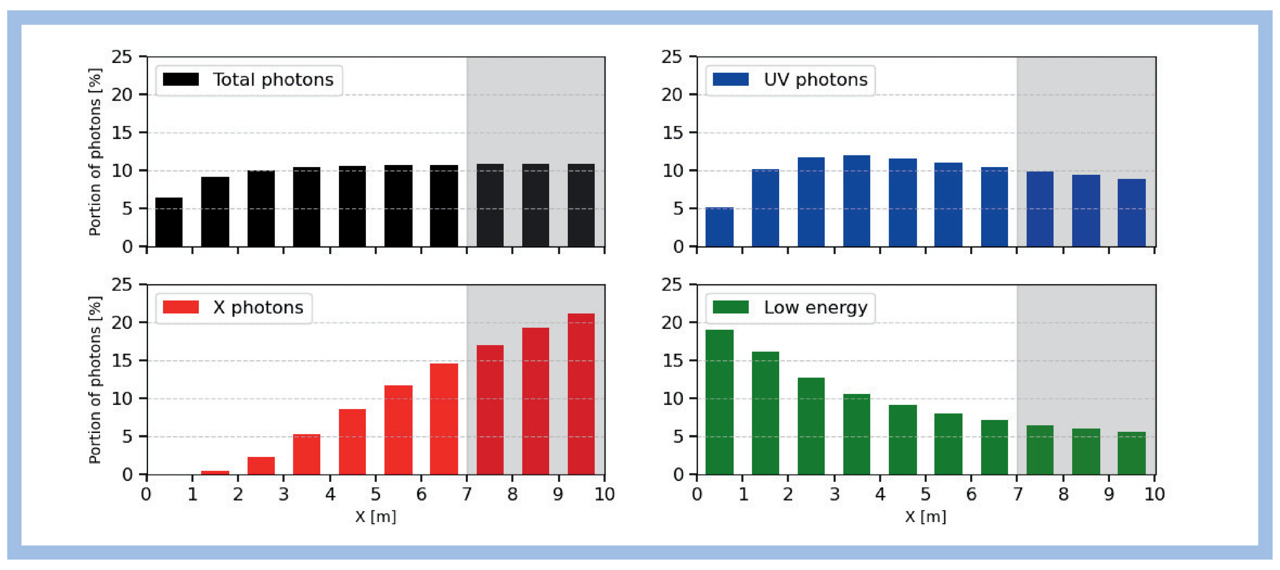
E. Gschwendtner et al. *Symmetry* **14**, 1680 (2022)

2. Betatron Radiation at AWAKE

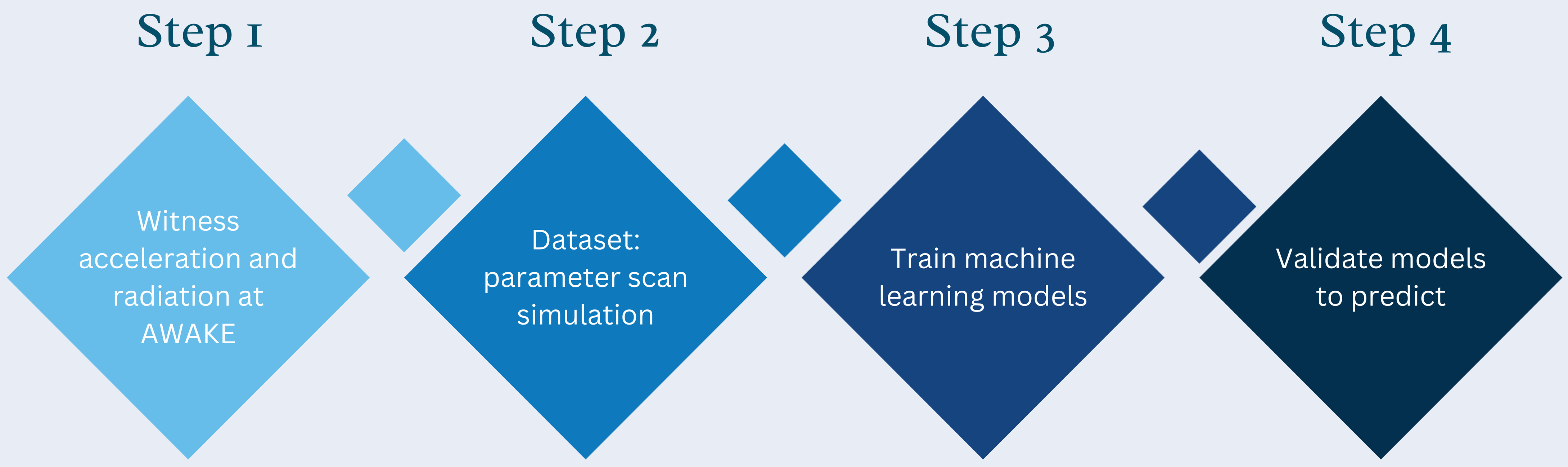
- With a simplified simulation model we explore witness beam acceleration and radiation over 10 meters plasma cell [1-3].
- QV3D simulation code has been employed.





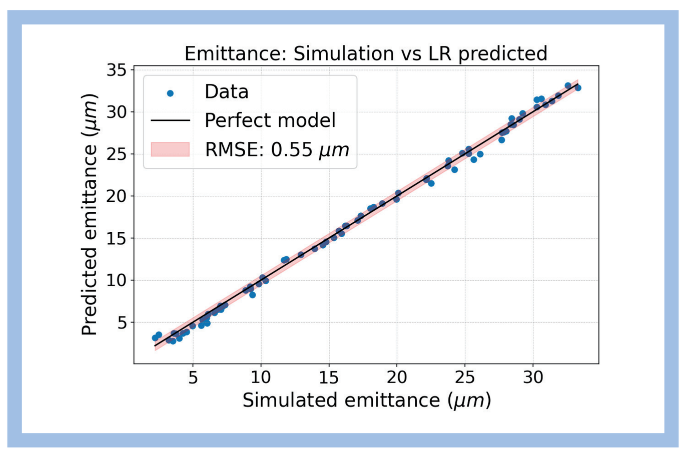


- Machine learning models [4] to predict final witness beam parameters using X-ray photon data.



3. Machine Learning Results

- Machine learning models are developed and trained using the dataset generated from simulation scans over witness initial emittance and its rms radius.



- **Linear regression** has been applied to a small dataset from plasma-matched witness beam with an emittance scan.
- Linear regression performs very poorly when the initial beam radius is varied.
- Neural network aims to capture this nonlinear behaviour.

Radiation Features

- X-ray mean radius on the screen
- X-ray percentage with respect to the total photons
- X-ray critical energy

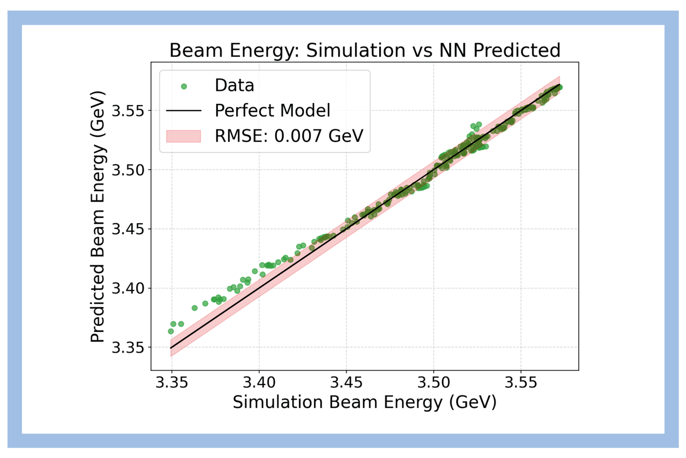
Predict Parameters

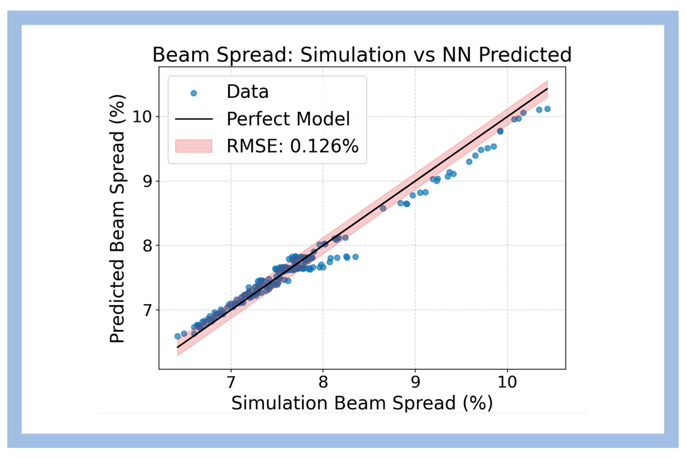
- Witness final energy
- witness energy spread
- Witness final emittance

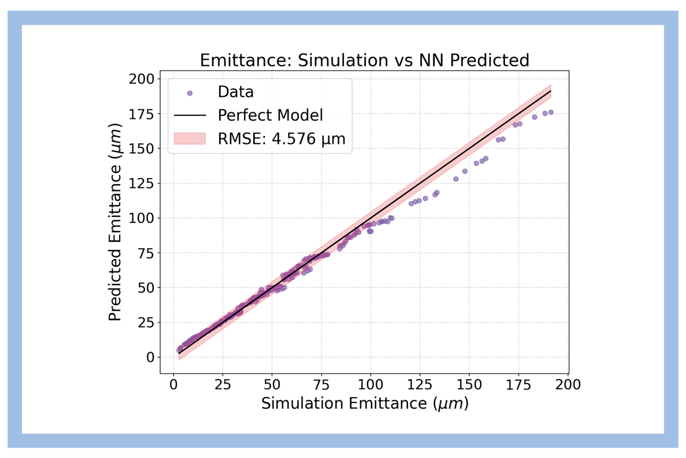
Neural Networks

- 10 hidden layers, each with 36 nodes
- leaky ReLU activation function
- Adam optimisation function

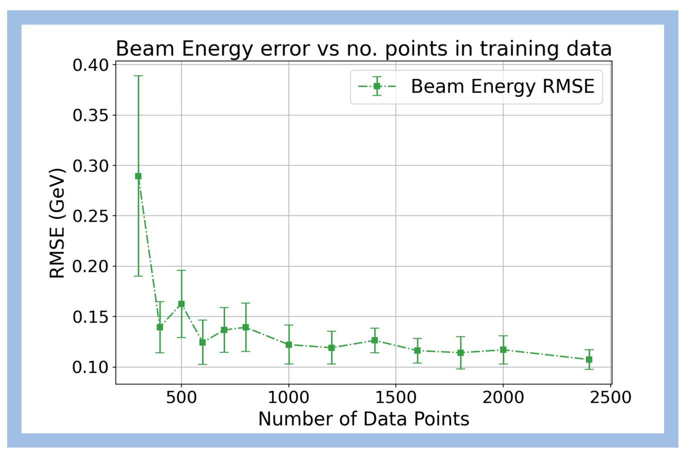
- **Neural network** predicts beam parameters to various degrees of precision.
- Dataset was split into 80% training, 10% validation and 10% test dataset.
- Results varied depending on how the test/train data was split, so an average was taken across many different random splits.

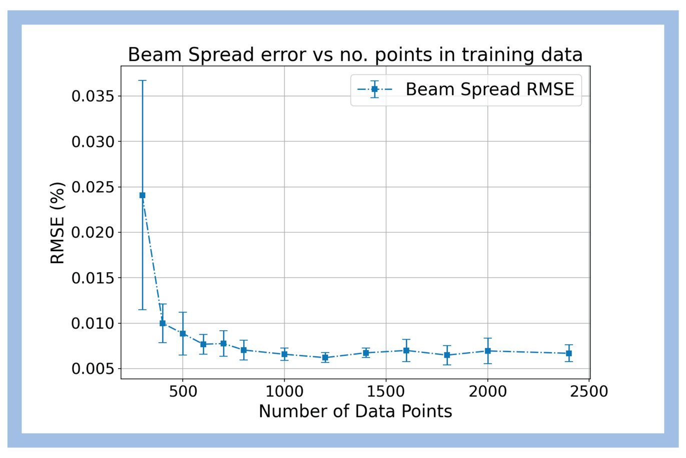


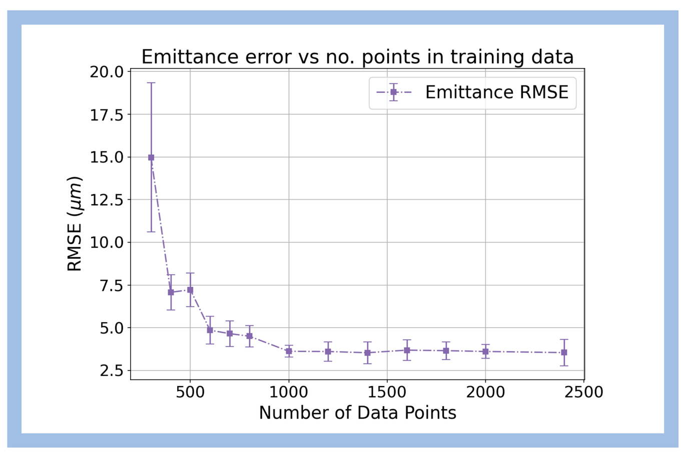




- With the current dataset generation, increasing the amount of data will not significantly enhance the neural network's predictions.







- Our current focus is on improving dataset generation and refining the model architecture.

4. Conclusion

- The results demonstrate the ability to predict several witness parameters, including emittance, energy and energy spread based on X-ray features of the betatron spectrum.
- Ongoing research is in progress to refine and optimize the machine learning models.

References

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