Virtual diagnostics for X-ray pulse characterization

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Motivation

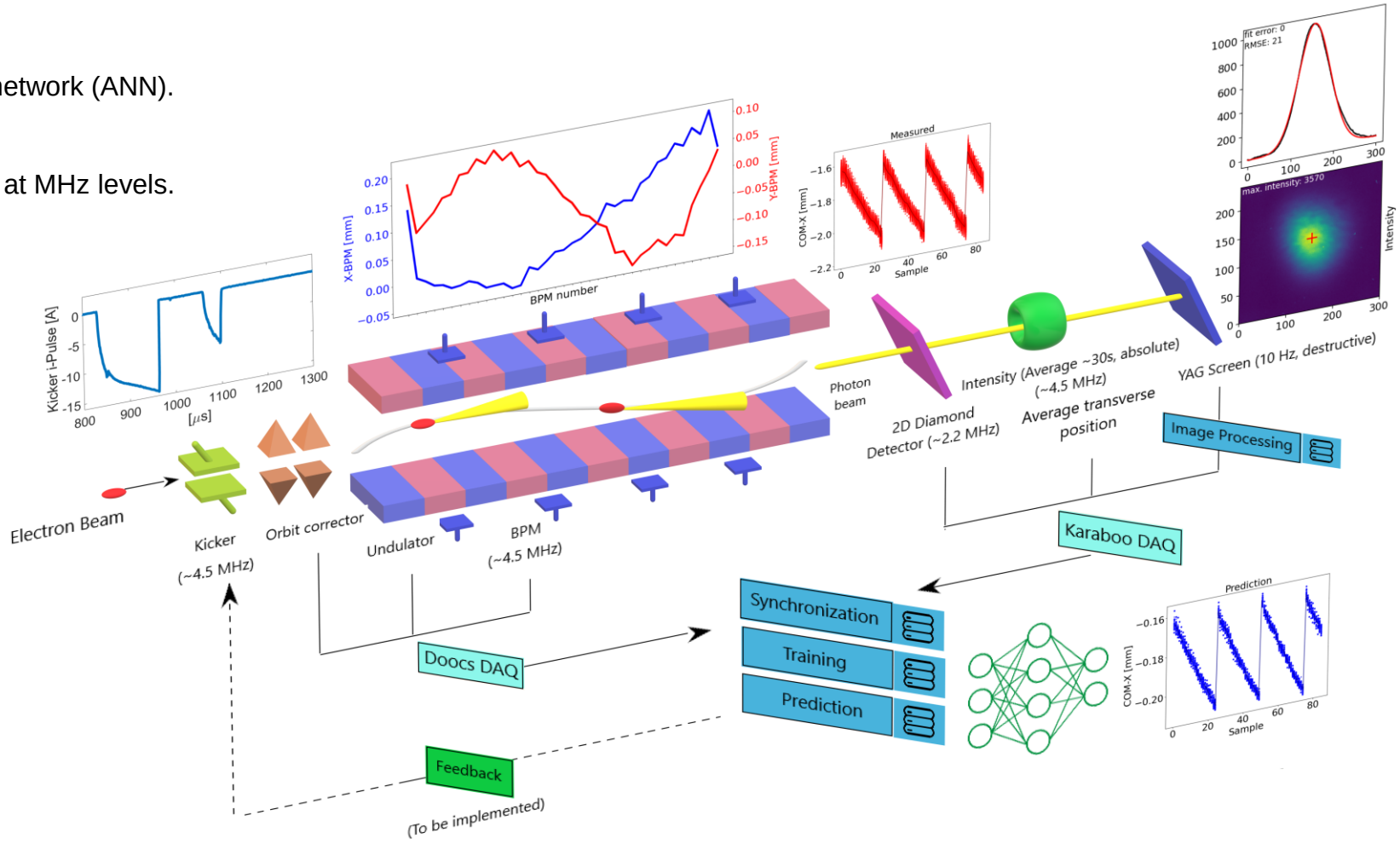
- Jitter in pointing affects intensity and sample safety.
- Conventional diagnostics are invasive and limited at high rates.
- Need for a non-invasive, high-frequency predictive model.

Goals

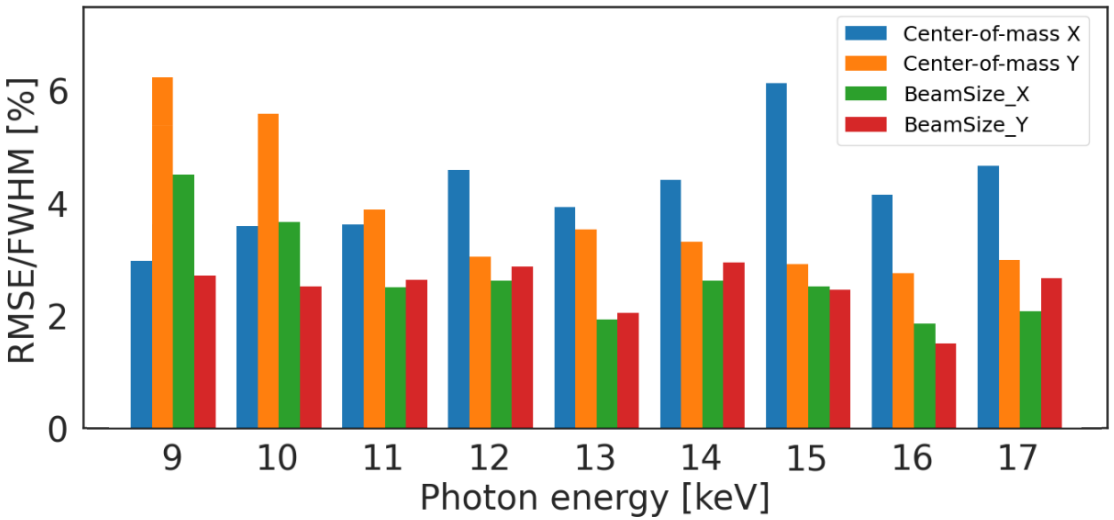
- Develop a virtual diagnostic tool for real-time pointing prediction at the European XFEL at MHz repetition rate.

Photon Pointing Prediction Framework

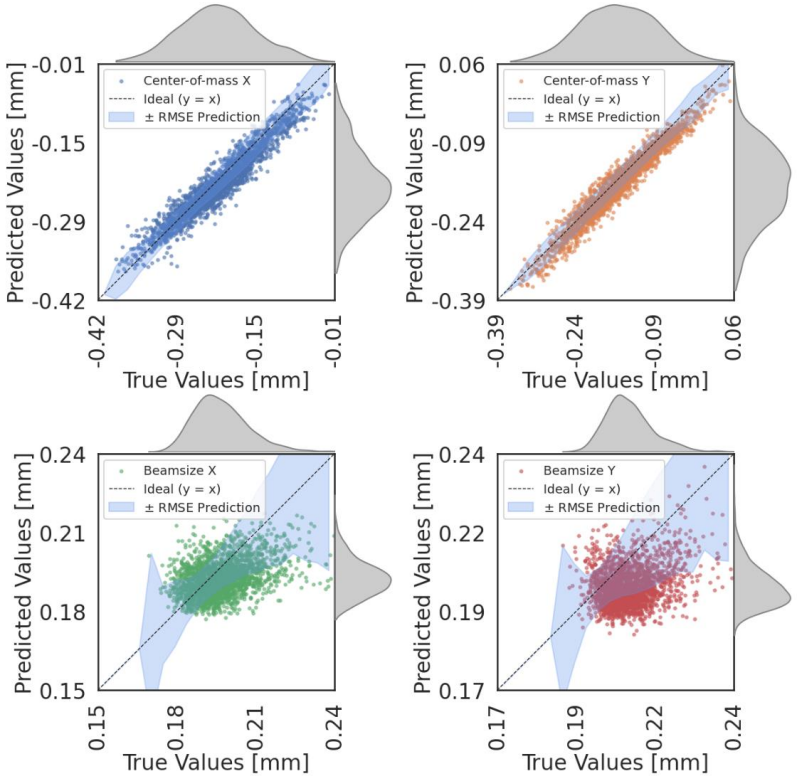
- **Model**: Feed-forward artificial neural network (ANN).
- **Inputs**: Parasitic diagnostics (BPMs).
- **Outputs**: Predicted photon properties at MHz levels.



Prediction (Single Pulse)

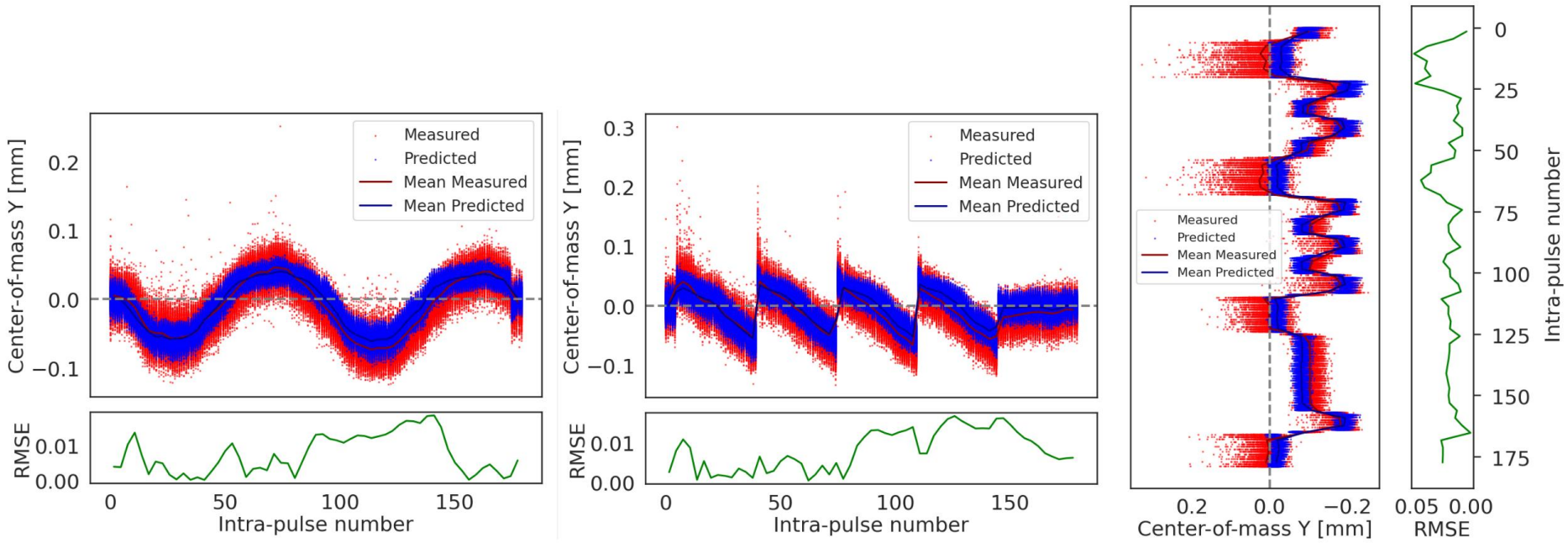


- Root-mean-square error of the predicted photon beam properties normalized by the average FWHM of the photon beam size across various photon energies, with each energy serving as the test set while others are used for training.



- 13 keV case

Prediction (Many Pulses)



- Validation with Diamond detector (17 keV, SA2)
- Intra-train X-kicks, generating distinct beam shapes
- Model ability to predict intra-train properties

Summary and Outlook

- Developed ANN-based diagnostics enable high-precision pointing prediction.
- Non-invasive solution for both hard and soft X-rays.
- Our approach enables operators to make informed decisions in real time, optimizing beam trajectories, and enhancing the efficiency of photon pulse generation without interrupting experimental operations.
- Real-time feedback and feed-forward loops with MHz kicker system.

Acknowledgments

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Thank you for your attention!