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Prediction and clustering of longitudinal phase space images and machine parameters using Neural Networks and K-means algorithm

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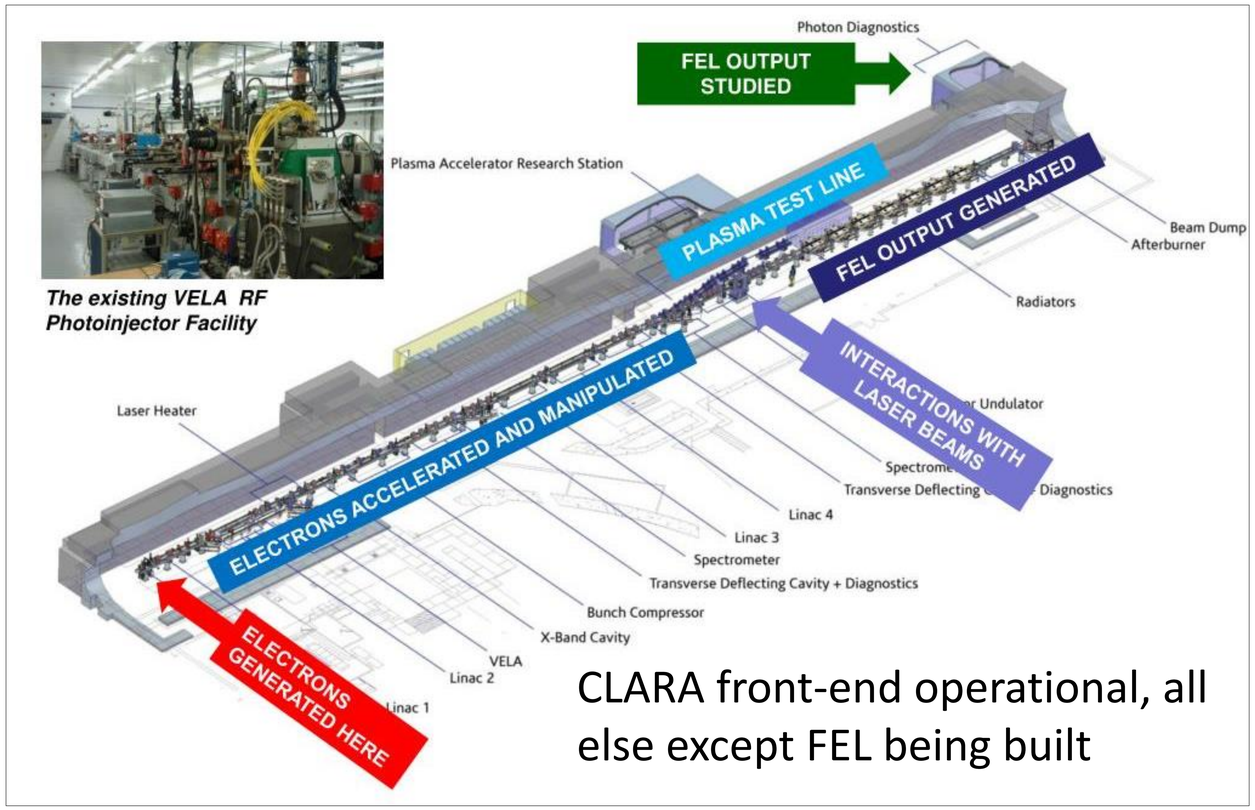
FELs & CLARA test facility

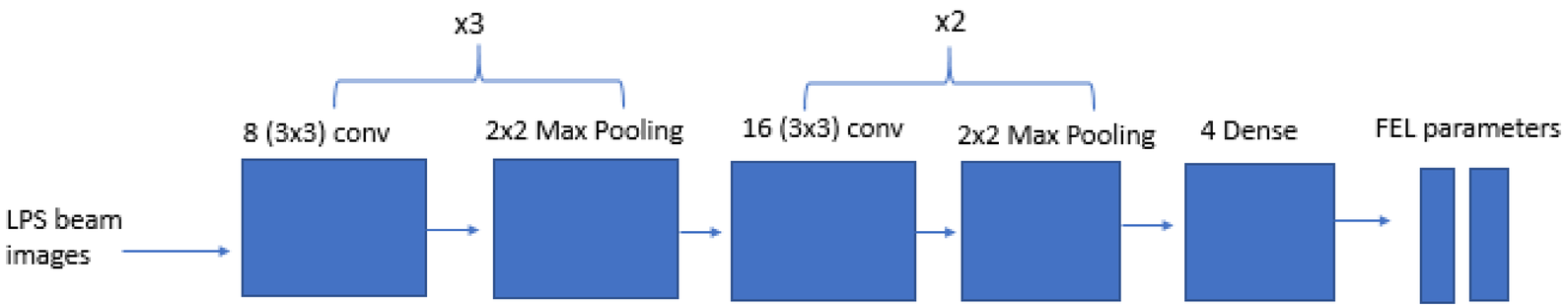
- The UK is presently assessing the case for a UK XFEL (X-ray Free-Electron Laser). In simple terms it's the next generation of x-ray source, capable of observing ultra-fast dynamics as well as structure.
- FELs are linear accelerators (single-pass) with various setups (need fast switching and optimisation)
- FELs generate huge amounts of data – ML interest from both machine and experiment sides
- CLARA is an accelerator test facility at Daresbury – broadly relevant but particularly for FELs

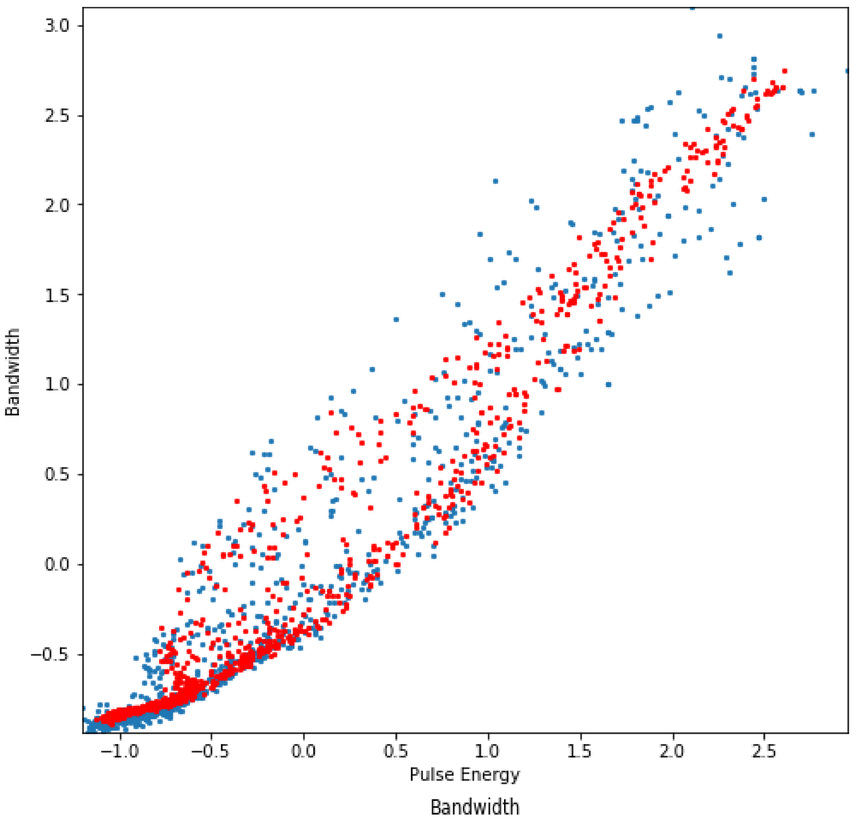


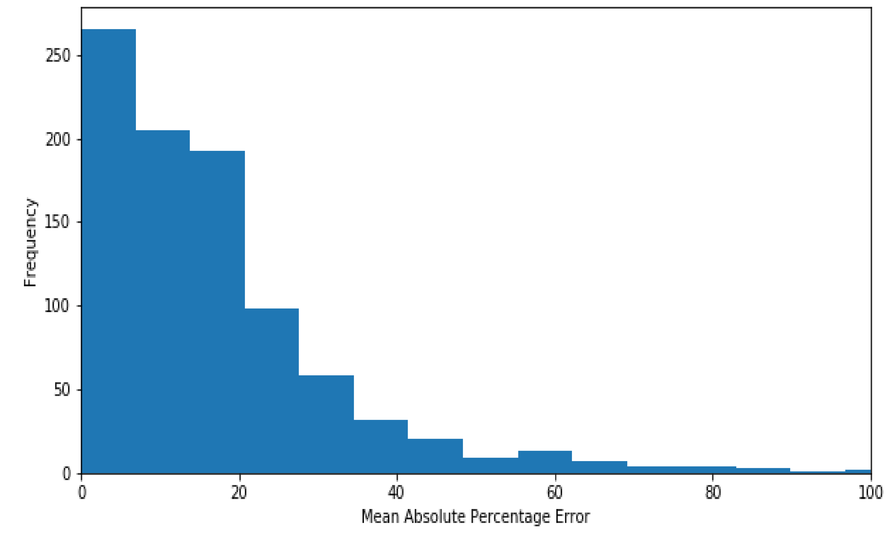
CLARA front-end operational, all else except FEL being built

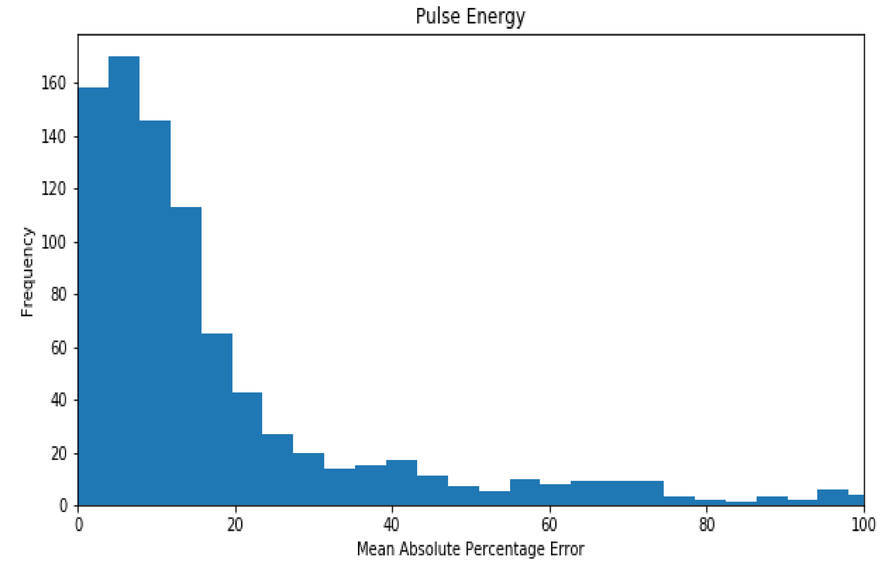
Predicting FEL Parameters

- Using 10,000 start-to-end simulation data from the accelerator and FEL, 17 machine parameters were varied and used to produce 6D bunches and FEL simulation results
- LPS images were generated (200x200 pixels, fixed screen size for all cases) and used as input to a Convolutional Neural Network (CNN), in an attempt to reproduce the FEL pulse energy and bandwidth values for future accelerator optimization
- The FEL pulse energy vs. bandwidth scatter plot shows the predicted values (red) and the corresponding true values (blue)



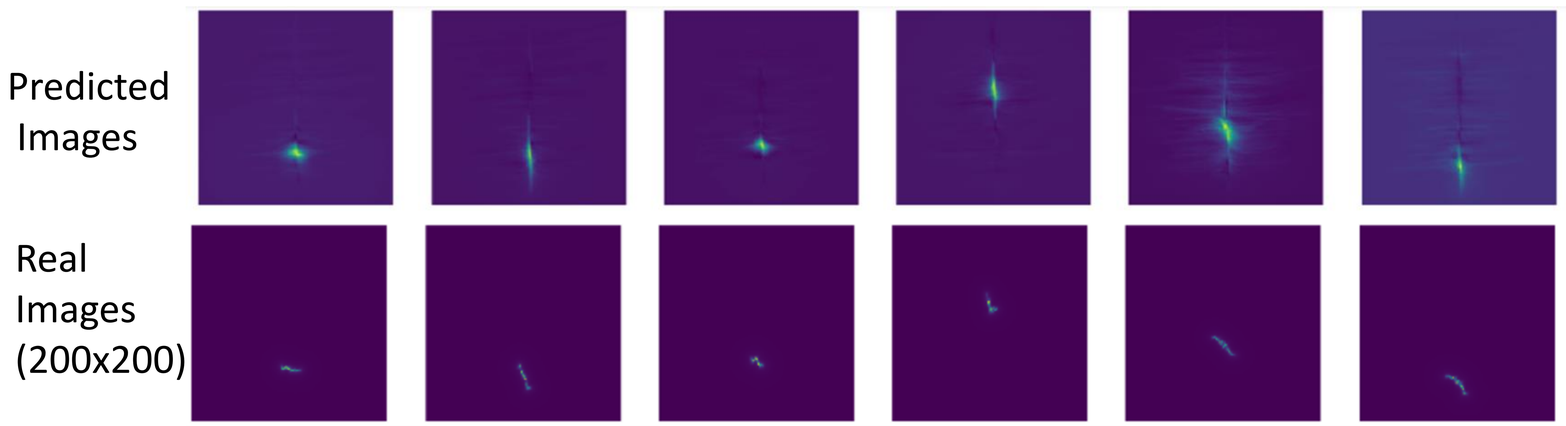




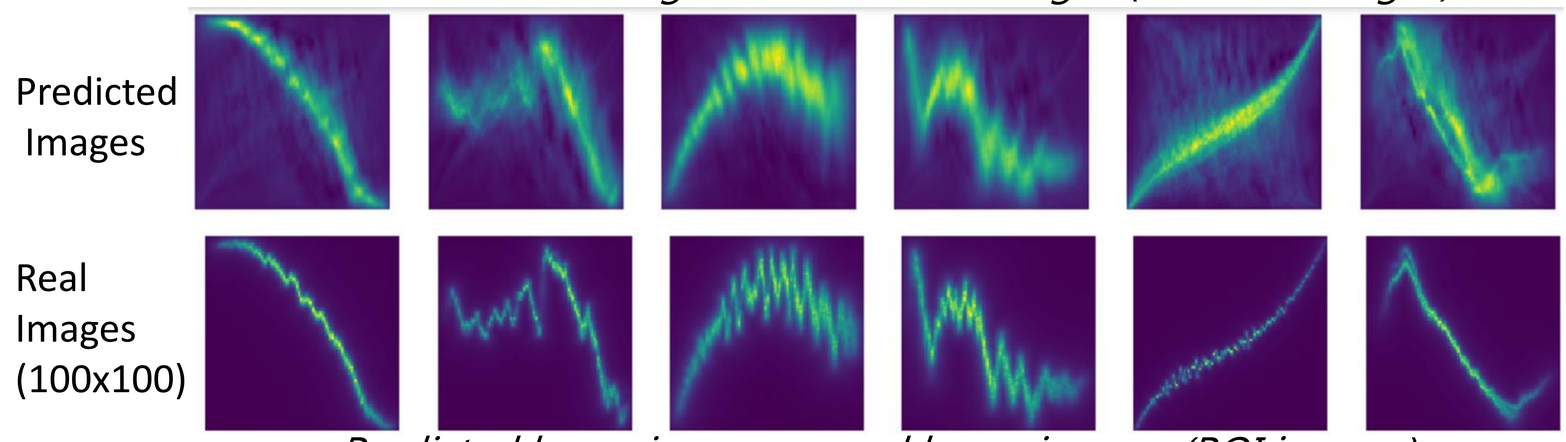


Predicting LPS Beam Images

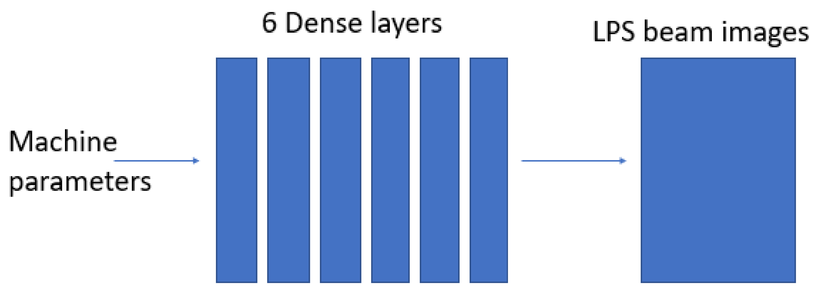
- Start-to-end simulation data from the accelerator and FEL was used to produce 2 kinds of LPS beam images
- SLAC used Neural Networks (NN) to reproduce LPS images from machine parameters
- The same NN model was used to predict the images – the model is significantly better at predicting the beam images with ROI scaling (the mean squared error was a lot lower)



Predicted beam images vs real beam images (non-ROI images)



Predicted beam images vs real beam images (ROI images)



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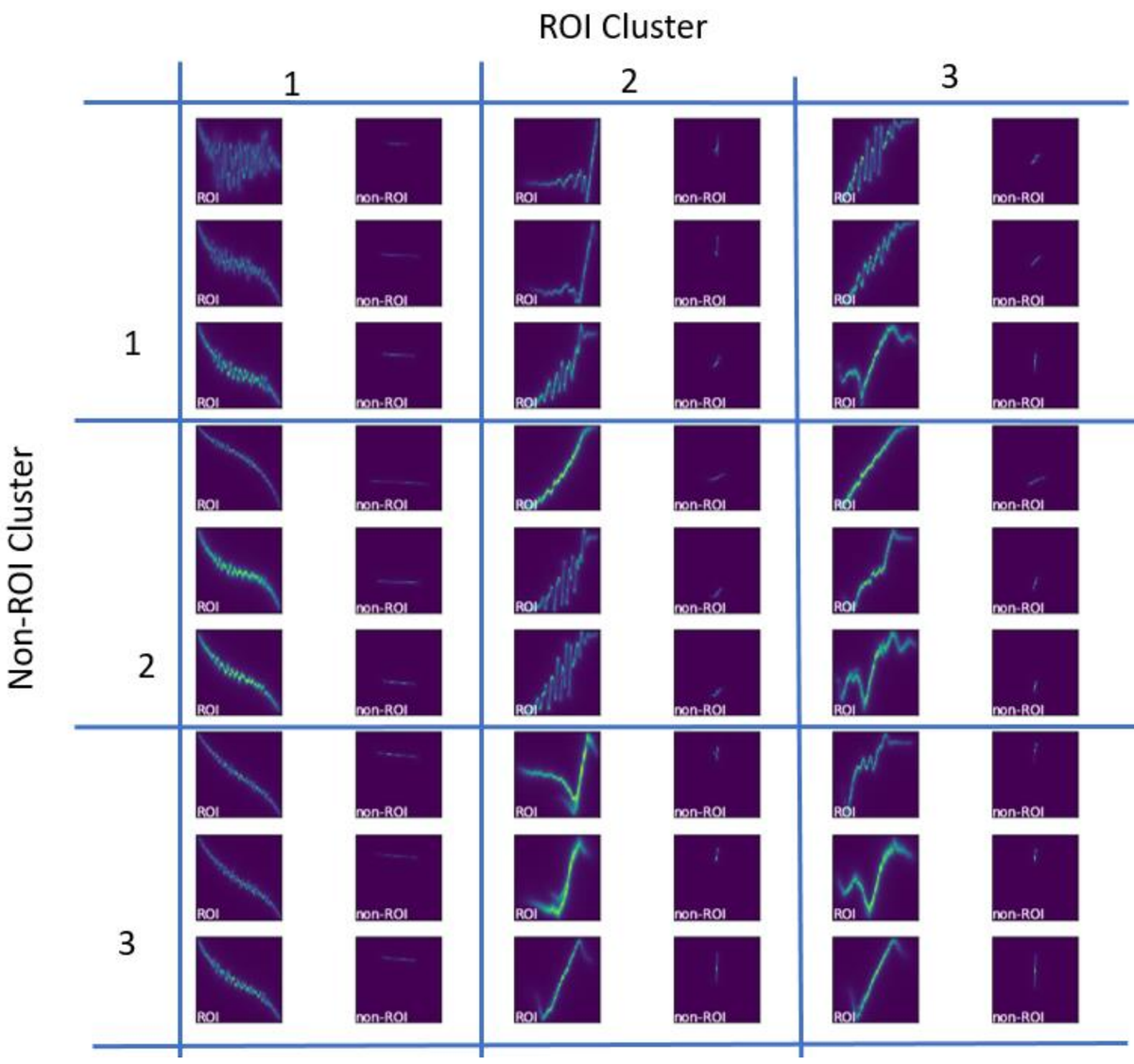
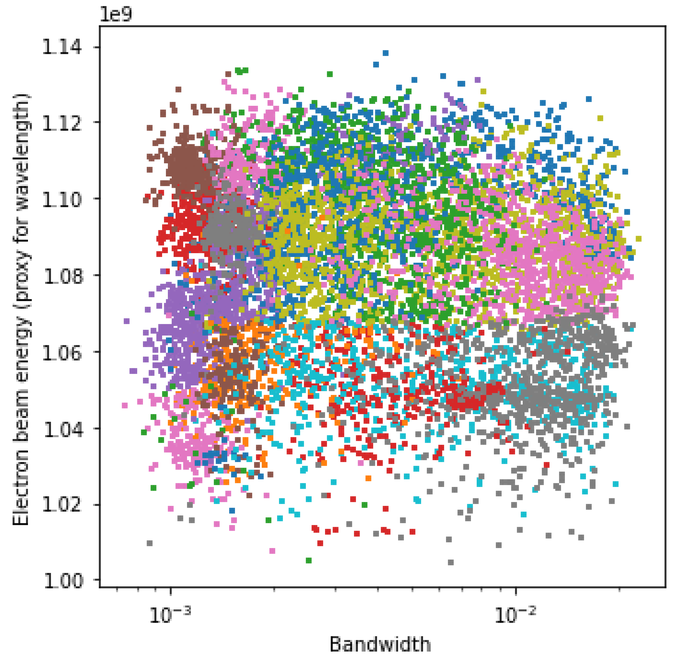
Beam Image Clusters

- PCA was applied to the beam images after which they were clustered using K-means
- 8 clusters were used for each – the images (ROI and non-ROI) were distributed well within these clusters but the model had trouble clustering the non-ROI images with smaller and less-defined shapes of the beam
- Examining the average machine parameters within each cluster showed some relationship to beam position (non-ROI images) and shape (ROI images)
- The ‘2D’ clusters were related to FEL performance metrics as shown in the scatter plot

Some common iterations in both ROI and non-ROI image clusters





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Thank you!