Machine Learning for Longitudinal Phase Space Reconstruction

Preliminary Results

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Hamburg, 6 December 2022

Structure

This Presentation

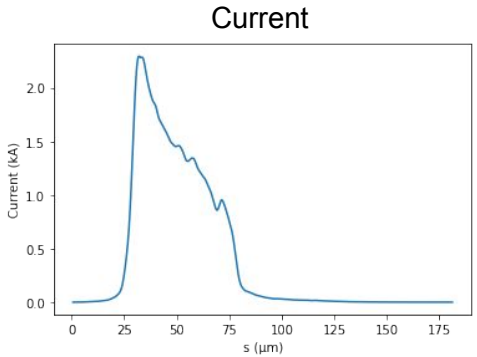
- Scalar & Spectral Virtual Diagnostics
- Intro to KNN & ANN
- Adaptive Resolution Reconstruction
- A Comparison of Methods
- Deploying to the Control Room
- Where to go from here?

Longitudinal Phase Space Inference

Initial Approach (Fixed Resolution)

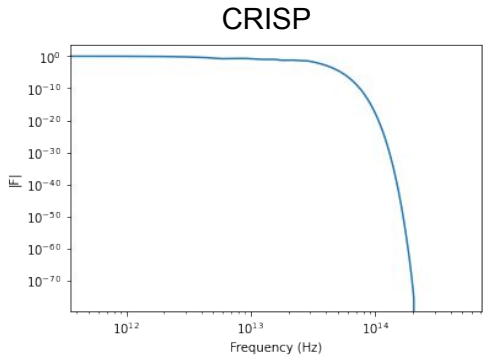
Scalar Virtual Diagnostic

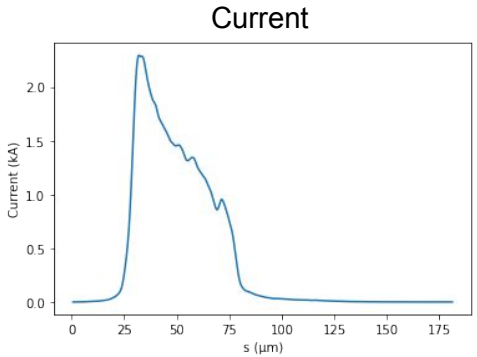
RF Parameters → Machine Learning Model → Current



Spectral Virtual Diagnostic

CRISP → Machine Learning Model → Current

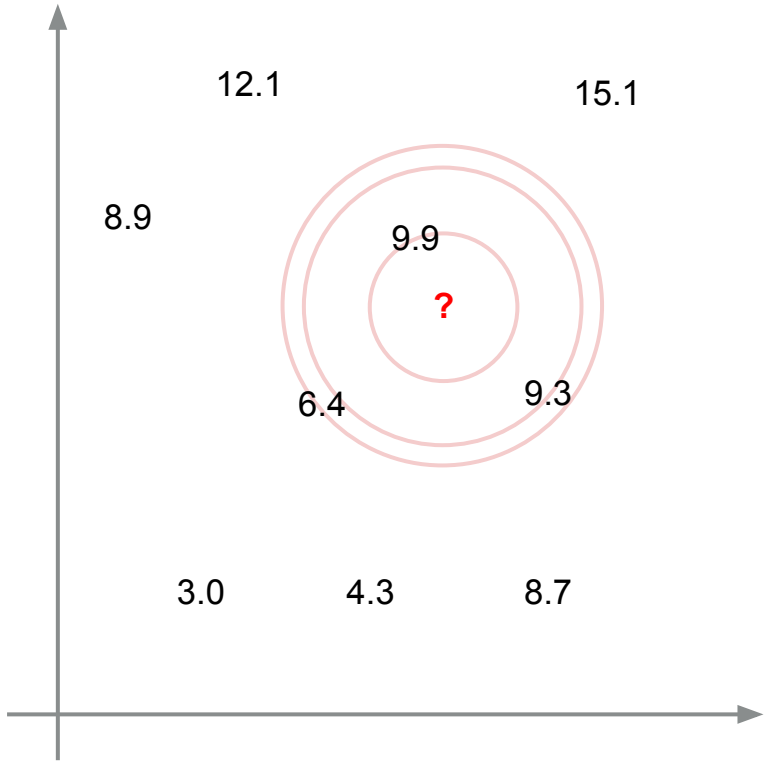




K-Nearest Neighbour (Regression)

Brief Introduction

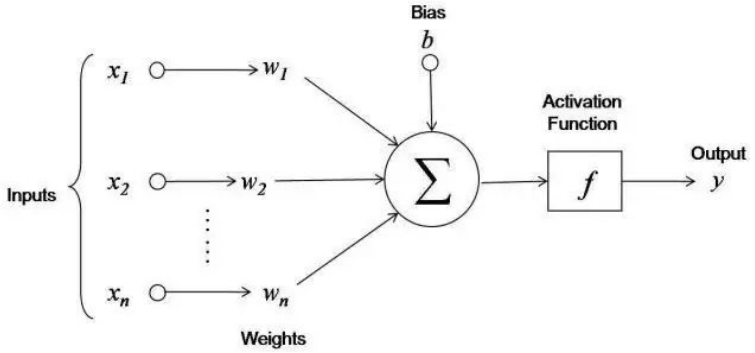
- (Weighted) mean of closest neighbours
- If *k=1*, basically a lookup in database
- How to compute distance?
- Interpolation?
- Potentially large database and expensive lookup



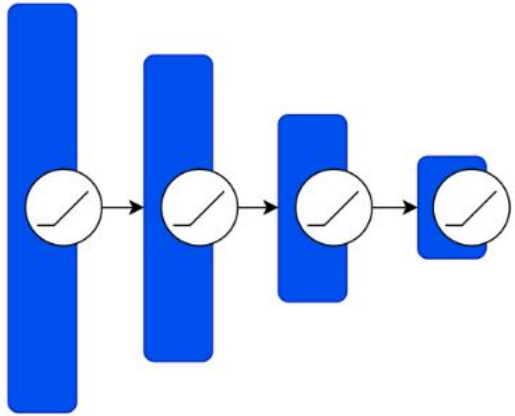
Artificial Neural Networks

Brief Introduction

- General purpose function approximator
- Trained via some kind of stochastic gradient descent on gradient of *loss function* over weights



- Basically compress the learned dataset by learning function
- Approximate “correct” interpolation
- Potentially very fast, especially on easily available dedicated hardware.

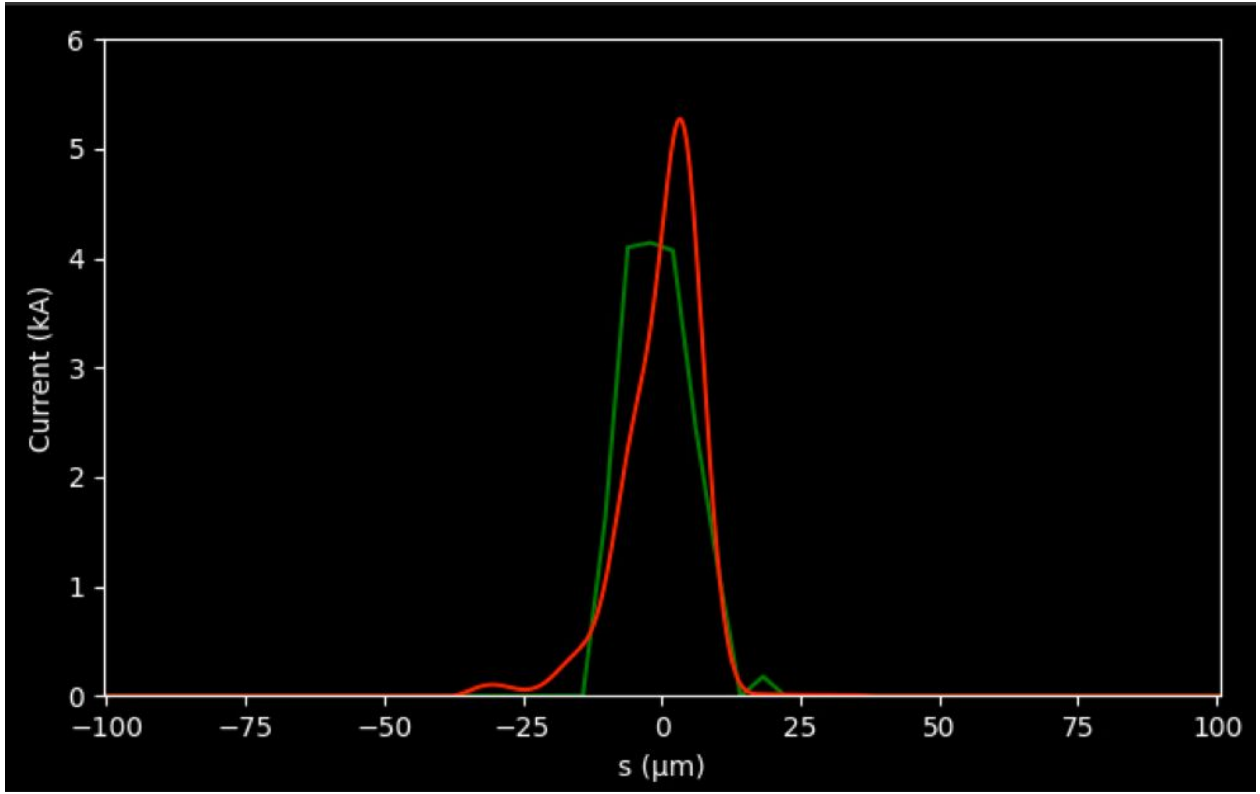


$$\mathbf{y} = \sigma\left(W\mathbf{x} + \mathbf{b}\right)$$

Fixed Sampling

The Problem

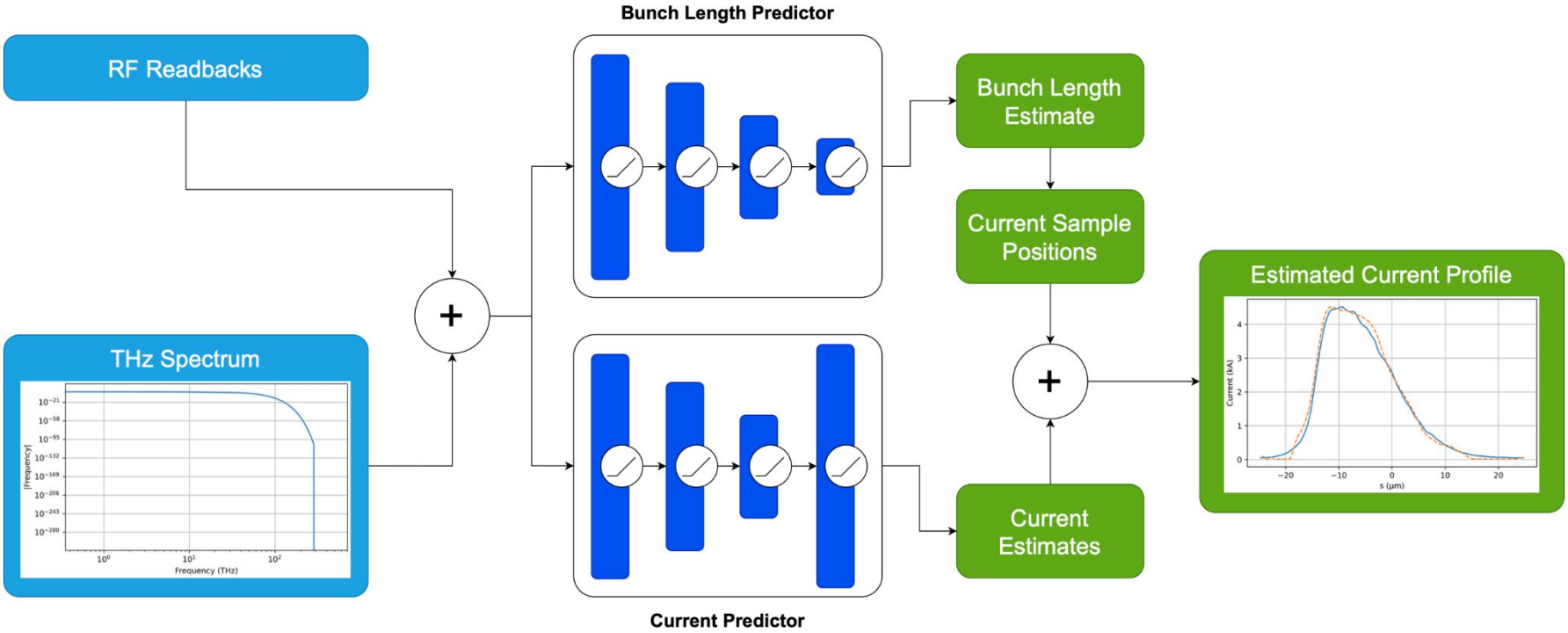
- Range covered needs to be very long for long bunches
- Number of samples needs to be infeasibly high to resolve short bunches



Improved Approach

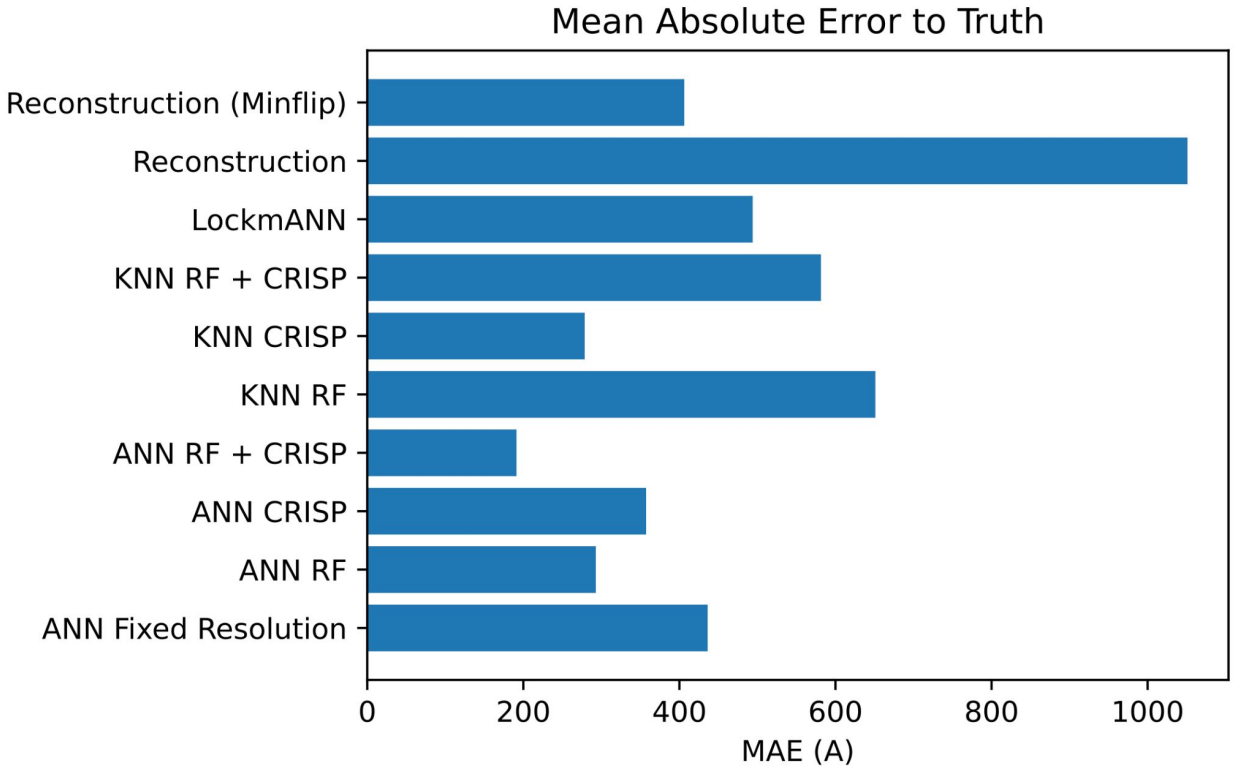
Adaptive Output Resolution

- Second ML model to predict width of bunch and determine positions of *n* longitudinal samples.



Comparison of Different Methods

ANN vs. KNN vs. Reconstruction



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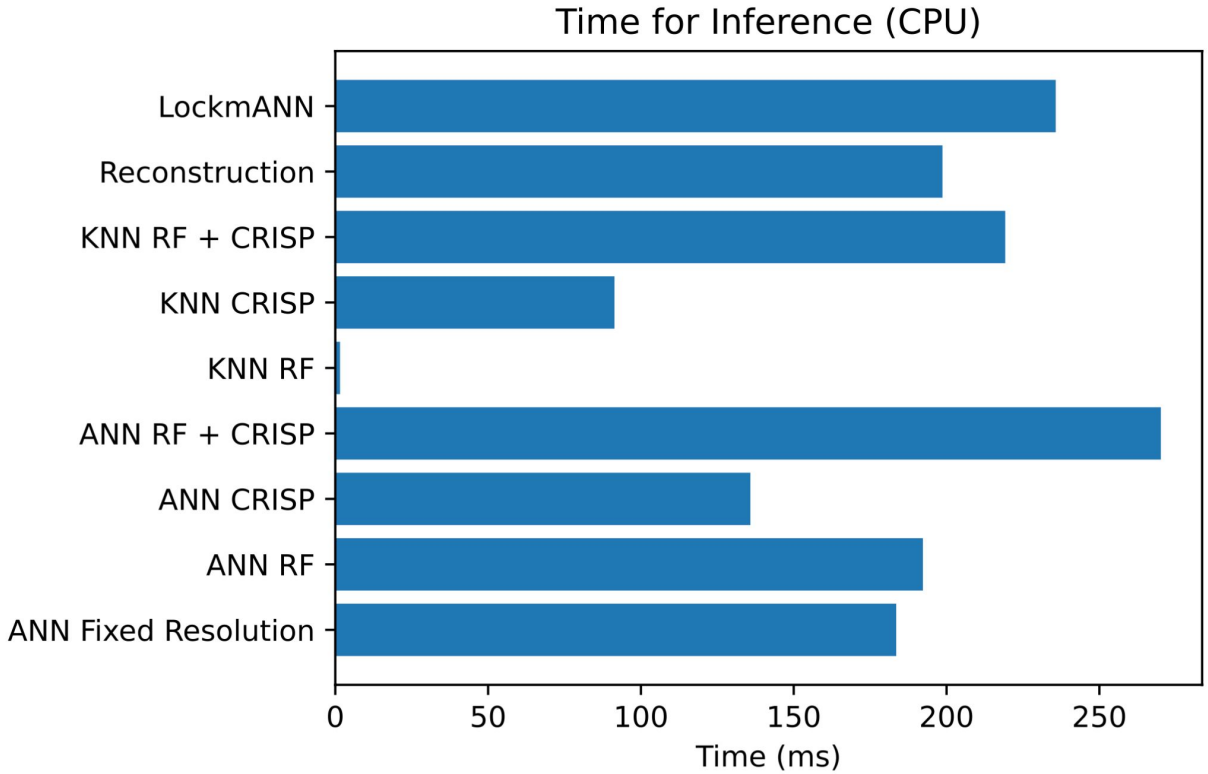

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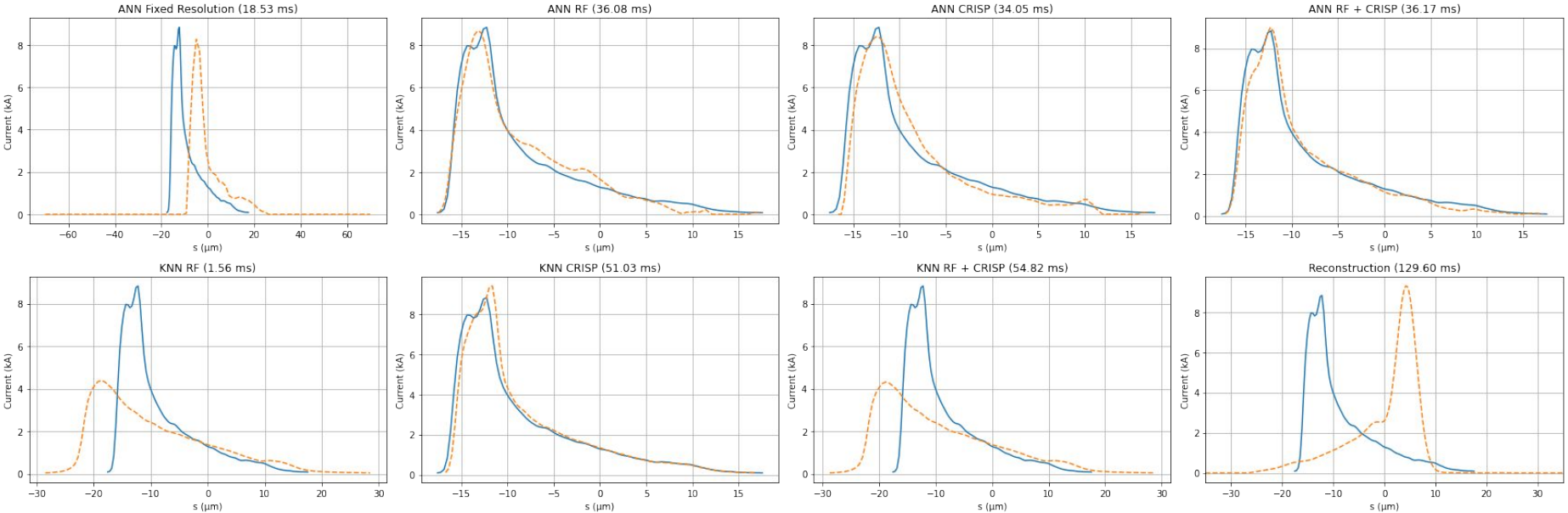
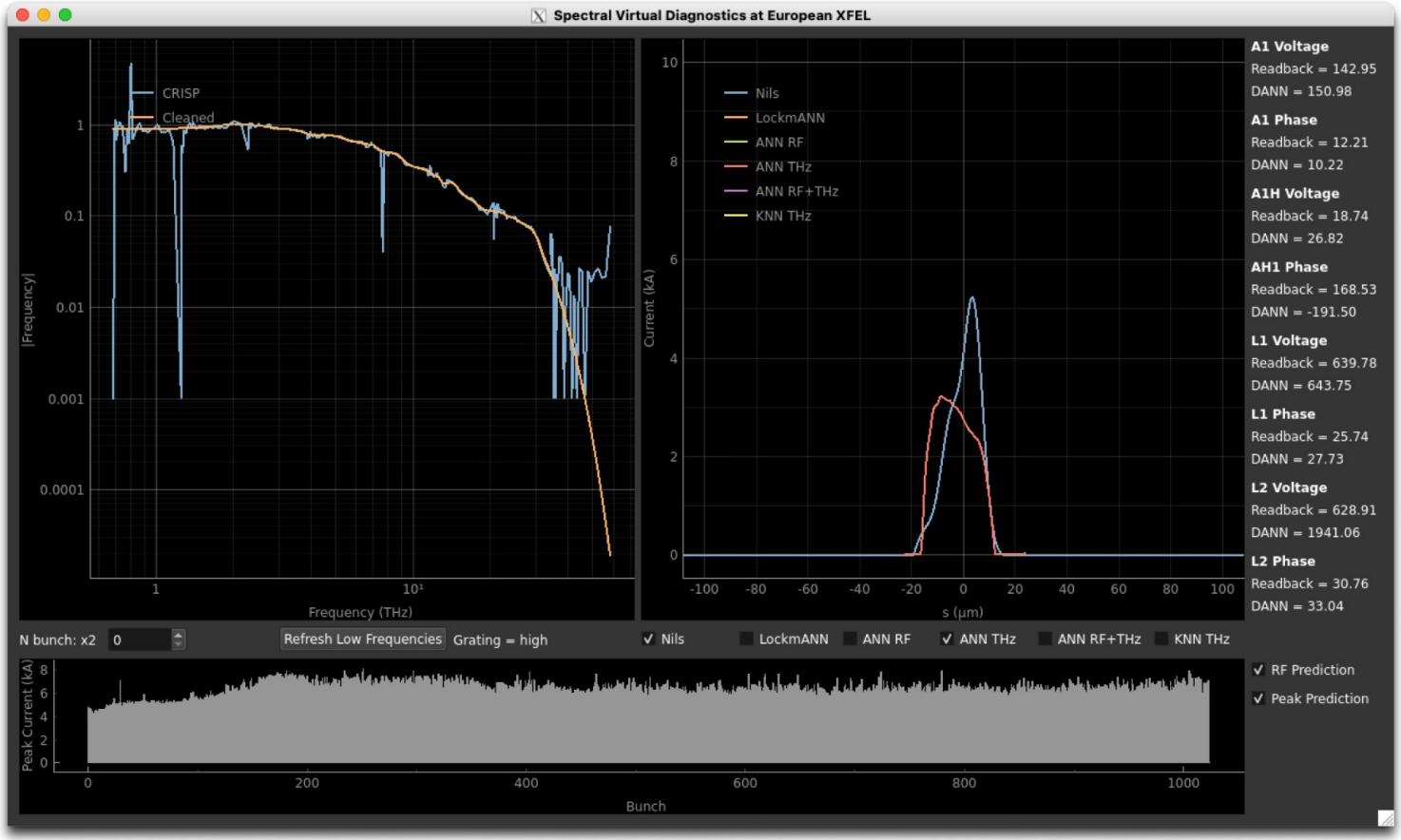
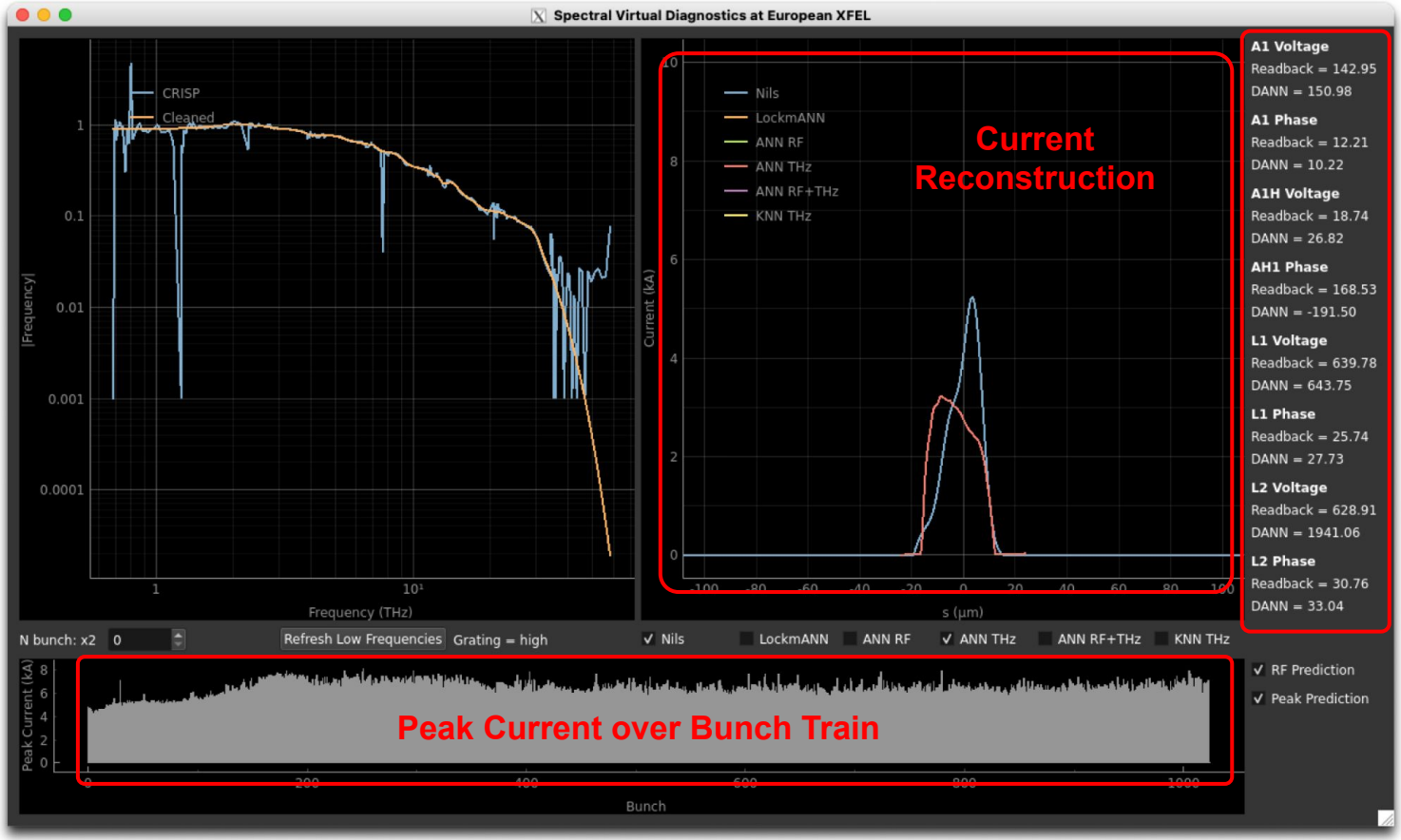


Python Application



Python Application

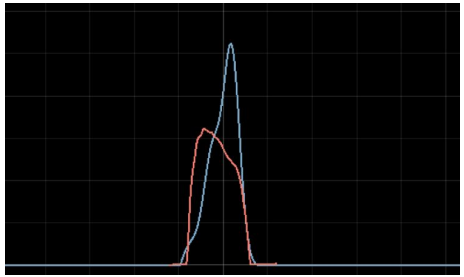


Reverse Prediction of RF Parameters

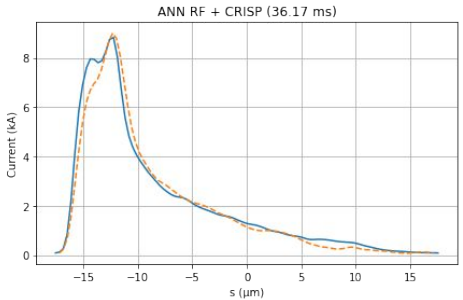
Where to go from here?

Future Work

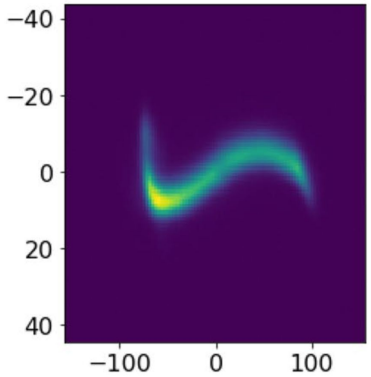
- New dataset to train for better real-world agreement



- More suitable loss function
  - Replace MSE with loss functions from image generation (e.g. perceptual loss, GAN)



- 2D LPS



- Improve model architecture?
  - Share length and current weights
  - CNN? LSTM?
- Deploy to server with better reliability (dependencies)

Thank you!

Contact

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