Uncertainty aware anomaly detection to predict errant beam pulses in the SNS accelerator

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What are you trying to do?

1) **Develop ML capabilities for time series analysis and prediction**:
   a) Develop ML models with multiple timescales to predict failure scenarios
   b) Develop ML-based models for anomaly detection, component degradation forecasting and beam component optimization
   c) Develop robust and safe model predictions with uncertainty quantificatior

2) **Demonstrate Objective (1) on the SNS accelerator and target systems**

How is it done today, and what are the limits of current practice?

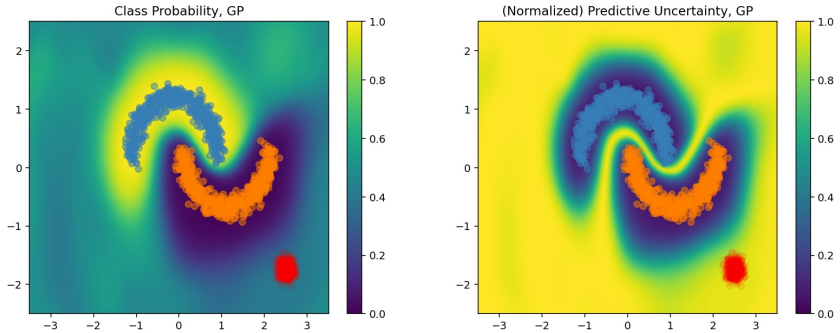
1. Collection of threshold alarms
2. Does not forecast any upcoming faults in time to be actionable

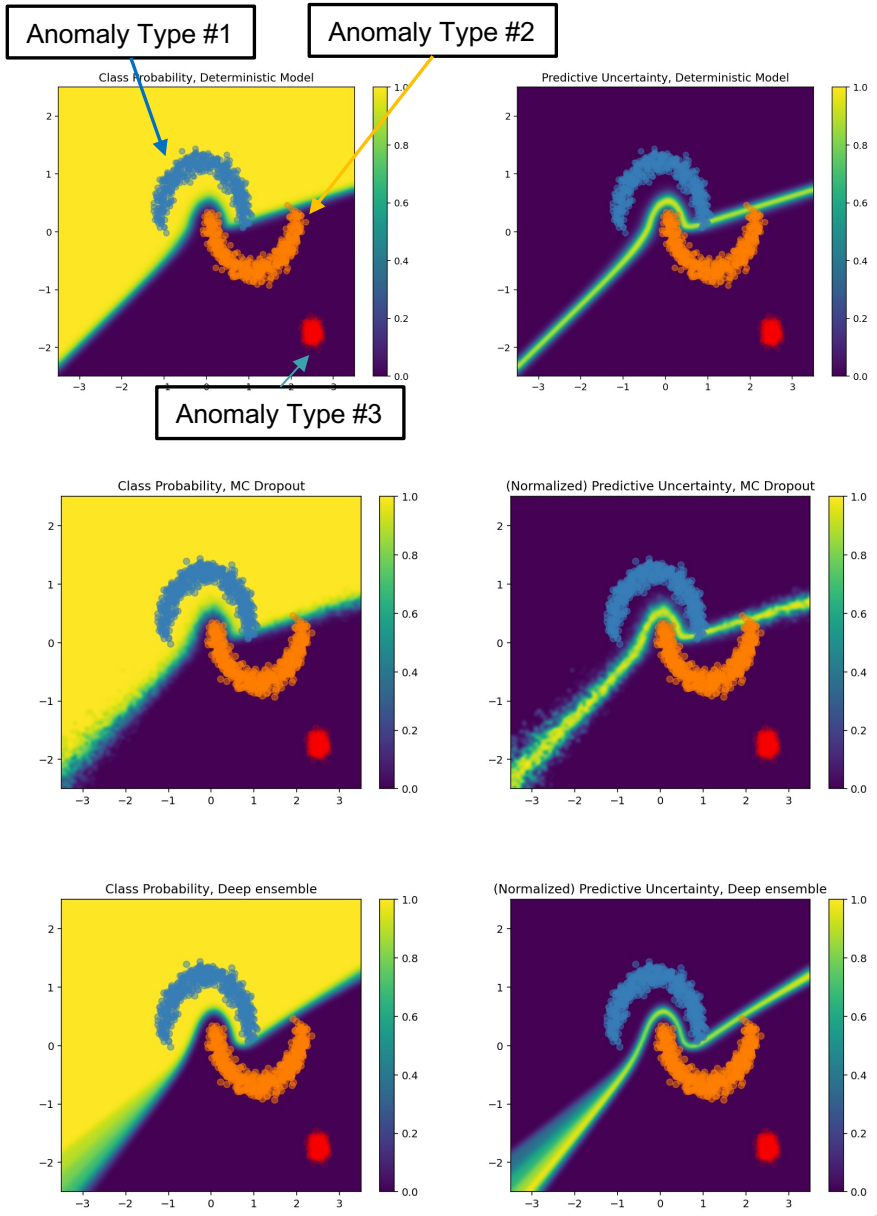
What is new in your approach and why do you think it will b successful?

- Provide a model that captures the in-domain vs. out of domain *uncertainty*

Who case?

- Directly related to the effort is SNS and BES
- Any critical for real-world applications





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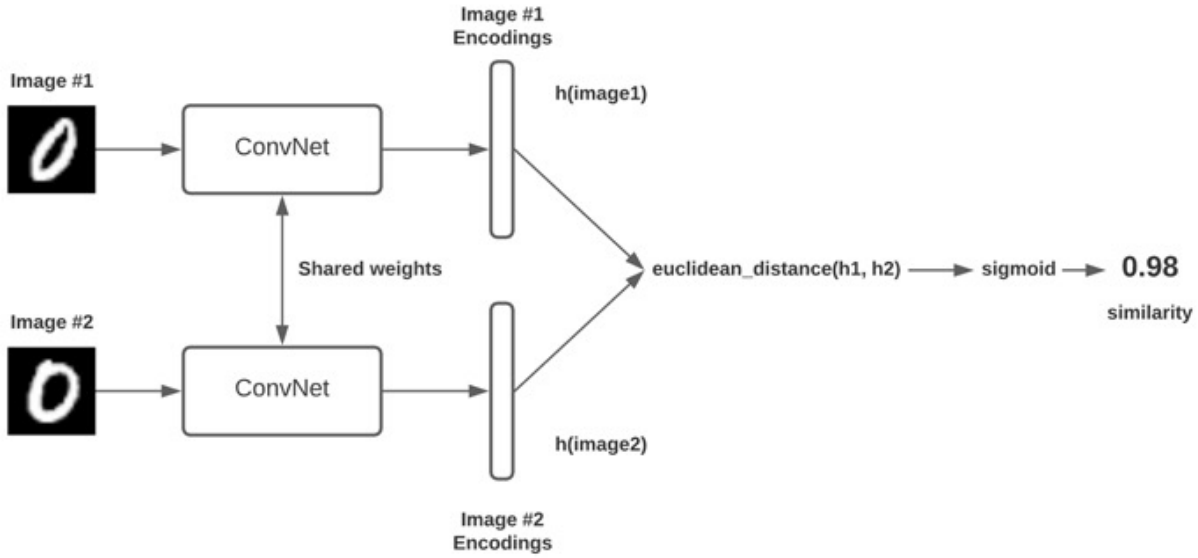
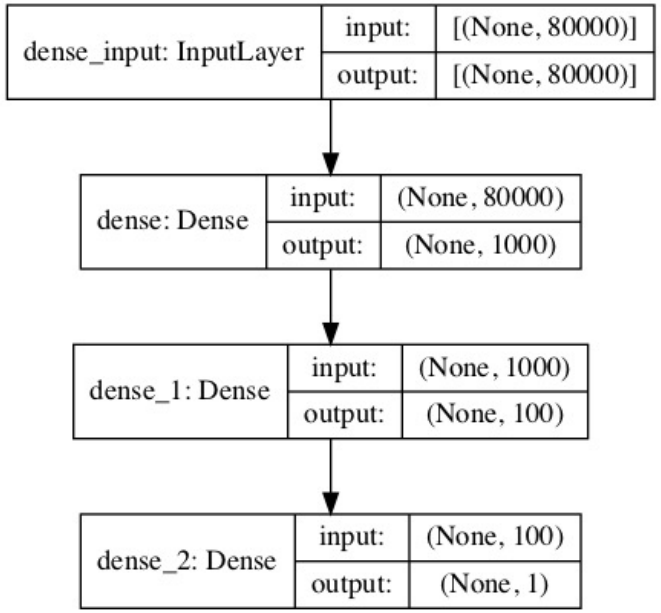
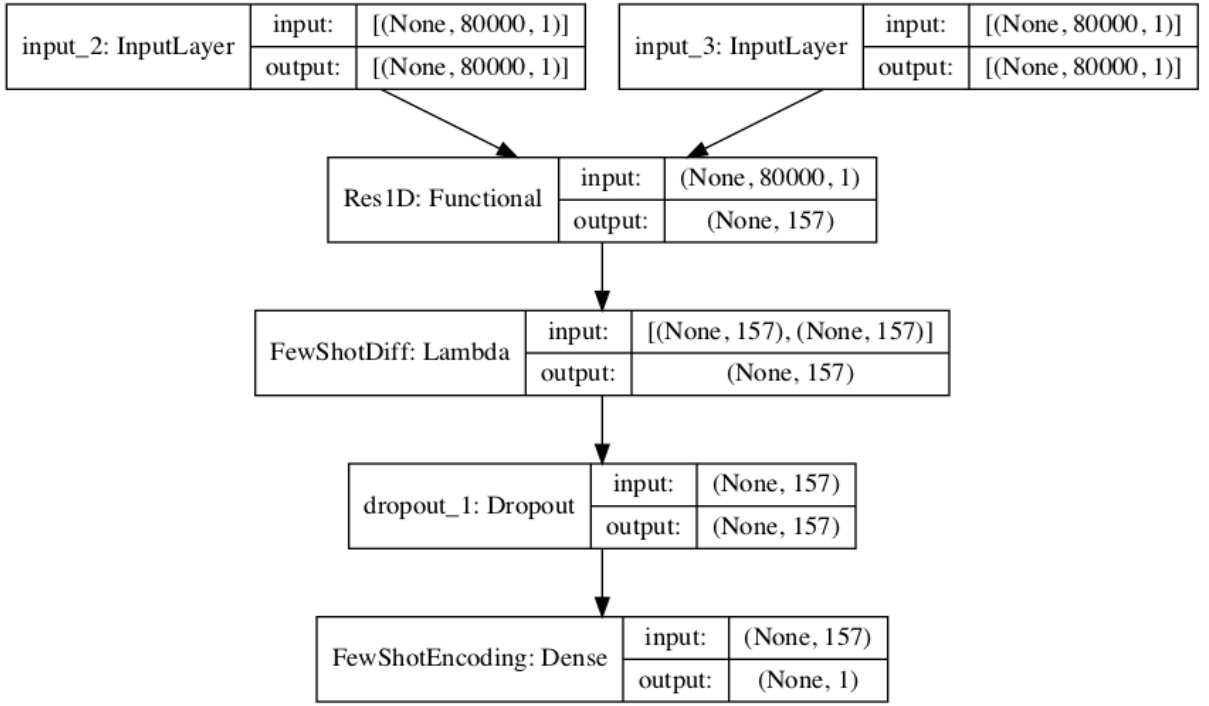
Machine Learning: Classification vs. Similarity

- We are using a Siamese model since we want to focus on the similarity between a reference pulse and the current pulse
- Siamese model does not explicitly model the classification but focuses on the similarities
- Embedding is done using a ResNetCov1D

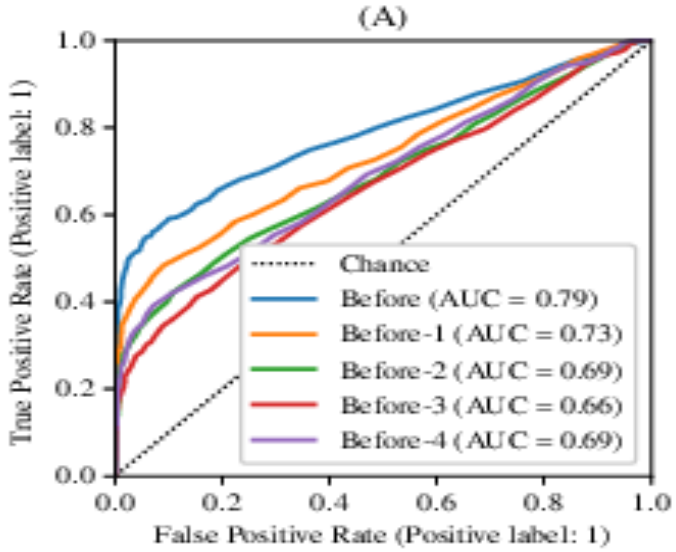


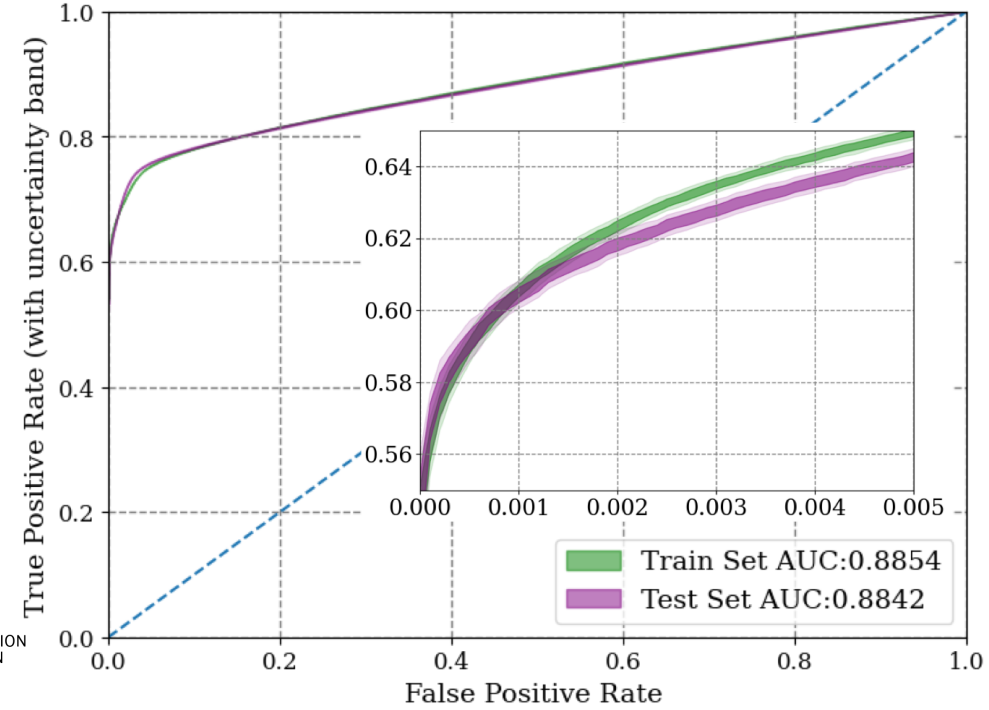


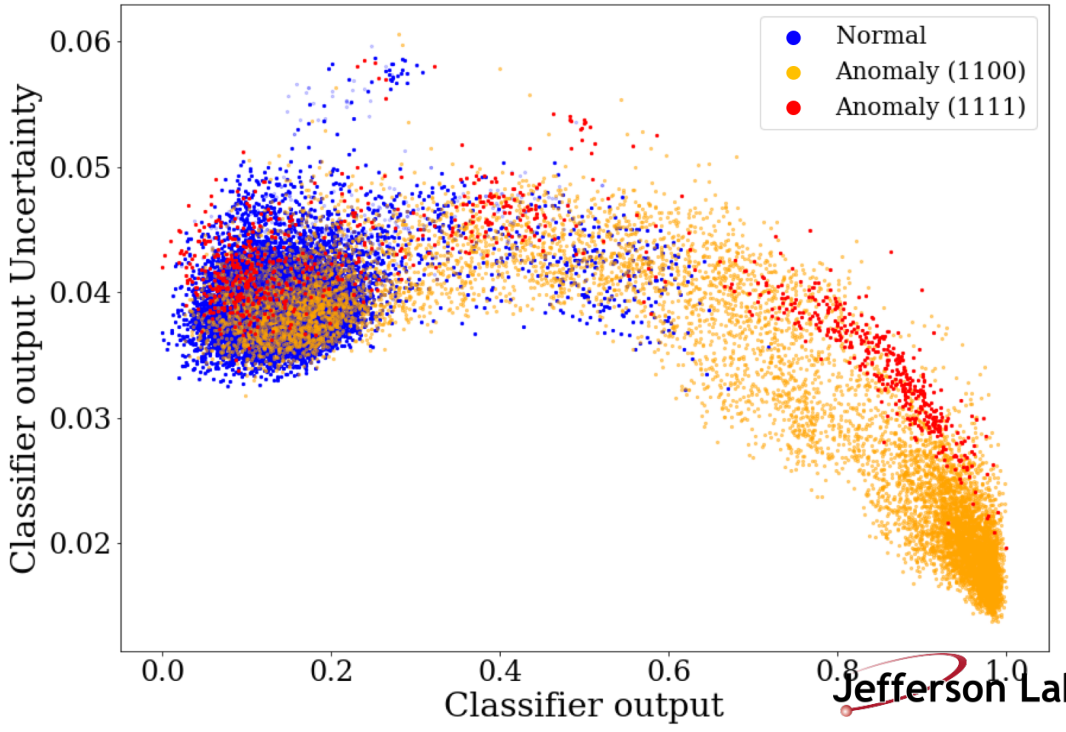


Results of the UQ-based Siamese Model

- We enhanced our Siamese model by adding GP layer providing an uncertainty estimate
- The Siamese model as ~4x better performance than the previous RF results
- The ROC curves shows nearly the same level of performance (not optimized)
- We introduced an out-of-domain anomaly, labelled 1111 (red), the UQ-based model correctly identified the anomaly and indicated high uncertainty (as expected)







Thank you

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High-power particle accelerators are complex machines with thousands of pieces of equipment that are frequently running at the cutting edge of technology. In order to improve the day-to-day operations and maximize the delivery of the science, new analytical techniques are being explored for anomaly detection, classification, and prognostications. As such, we describe the application of an uncertainty aware Machine Learning method, the Siamese neural network model, to predict upcoming errant beam pulses using the data from a single monitoring device. By predicting the upcoming failure, we can stop the accelerator before damage occurs. We describe the accelerator operation, related Machine Learning research, the prediction performance required to abort beam while maintaining operations, the monitoring device and its data, and the Siamese method and its results. These results show that the researched method can be applied to improve accelerator operations.

Keywords: accelerator, beam current, anomaly prediction, machine learning, Siamese neural network