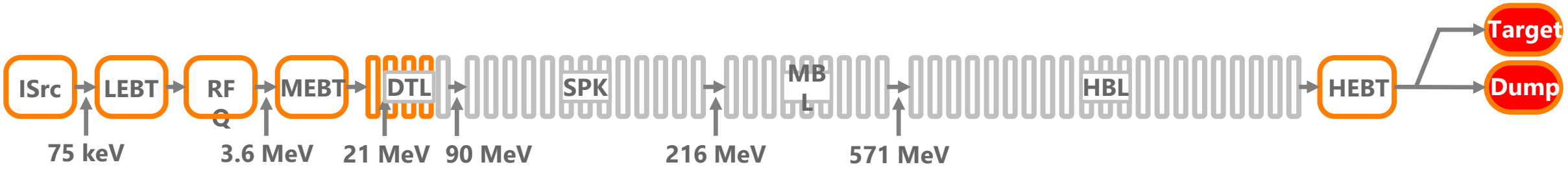
Anomaly detection at ESS

IFAST task 10.6 plus related topics

PRESENTED BY THOMAS SHEA – BEAM DIAGNOSTICS SECTION LEADER

2023-07-18

European Spallation Source Accelerator



Beam Commissioning to DTL4 – 74 MeV

Periods of RF conditioning

Beam Commissioning to Dump

Beam to Target

>95% Availability

IFAST Task 10.6

Goals: Low latency ML for Intelligent trigger; Errant pulse prediction→interlock

ongoing

Acquisition: Archive detailed instrumentation and RF waveforms – approaching PB scale

Curation: query archiver with multi-variable selection criteria – performance issues

Cleaning: time correction, saturation checks

Transformation: Dynamic time warping, spectral analysis

Clustering: version of k-means and barycenters.

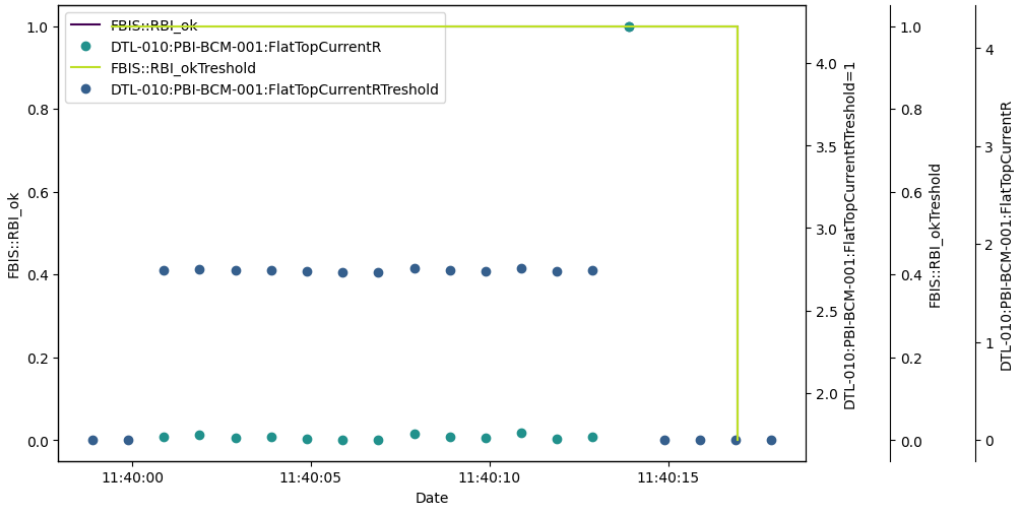
upcoming

Classification: Neural Networks…

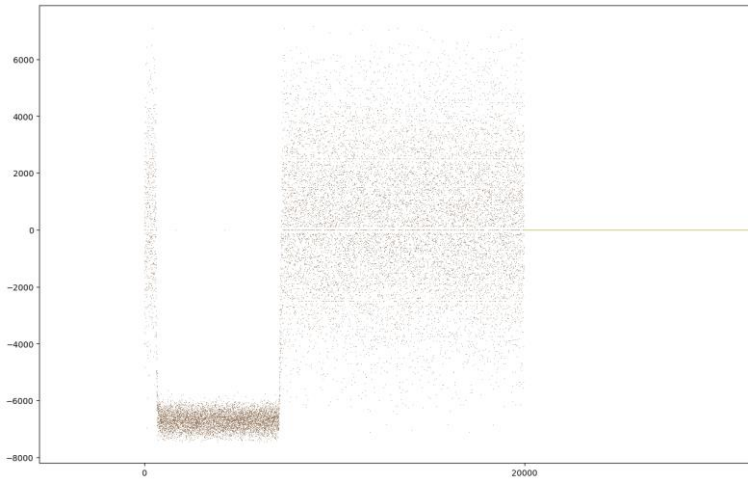
Low Latency Prediction: Random Forest (experience from ORNL), Implement on FPGA platform

Finally: Trigger acquisitions, raise alarms, mitigate damage from errant beam

Selection criteria:

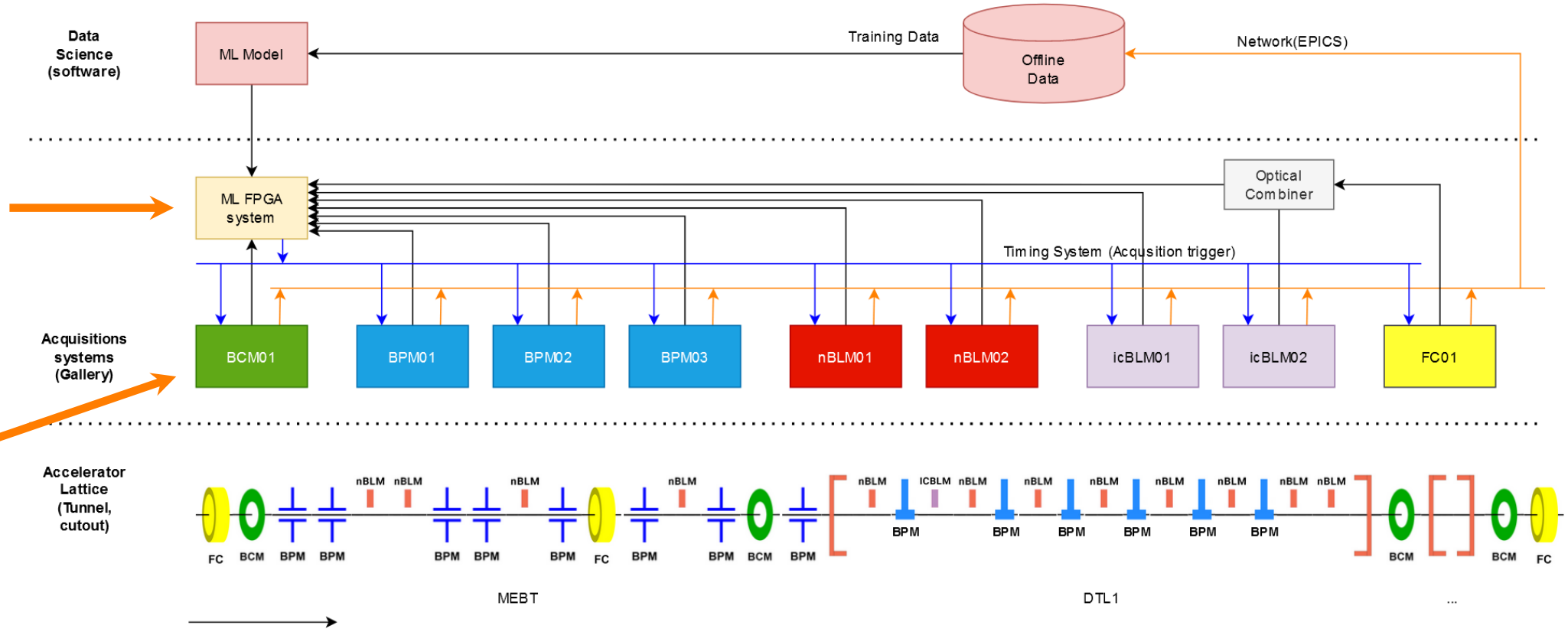


Waveforms around the time criteria is met:



Low Latency ML Prototype – ESS Normal Conducting Linac, Low Energy Section

- System covering Normal Conducting Linac (NCL)
- 2nd layer: **ML FPGA System** to detect "off normal" events and request readout via timing system (DoD extraction).
- 1st layer: **network of FPGAs** to acquire and process signal from detector channels.
- System could connect to beam interlock system (not shown).



Transverse Challenges and Topics

Proposal: Collect these and similar topics to create “Data Engineering for Accelerator RIs” task

Common data formats accommodating large structures (waveforms, images,…), aggregation results and metadata

Uniform timestamp

Resource limitations – solve by utilizing network of several institutes?

Overall data strategy:

- Quality standards (eg. raw, bronze, silver and gold)
- Curation at each stage
- Data owners, provenance
- Formats, structures (as above)

Integration of data sources – ex. kafka to broker diverse sources, uniform API to data pool, etc

Performance of archivers and other continuous logging systems:

- Ingestion
- Query

Data acquisition – triggered, buffered acquisition; trigger management; backpressure management

Data analysis environment – offline and streaming; algorithm portability from data center to edge devices.

Additional applications of interest at ESS

Virtual diagnostics, particularly longitudinal

Beam halo estimation

Beam loss and activation minimization

RF system/structure breakdown prediction

Accelerator digital twin (Beam physics section interest)

Adaptive, online learning to keep up with changing machine configuration

Image analysis from radiation degraded luminescent materials, optics, cameras

Particle discrimination and background suppression for loss measurement and halo measurement

Combination of multiple measurements to increase robustness – suppressing bias from sensitive/anamolous channels, etc

Alarm management (ongoing project)

Predictive maintenance

Fault classification:

- Automatic restart
- Operator intervention required