Klystron Fault Identification at LCLS

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Motivation

- LCLS (Linac Coherent Light Source) is frequently prone to unplanned downtime and unexpected failures that are difficult to pinpoint and correct
- Failures cause significant beam degradation or loss
- A common, high priority failure mode is klystron faults
- The 250 klystrons power the LCLS x-ray laser's accelerator

Goals

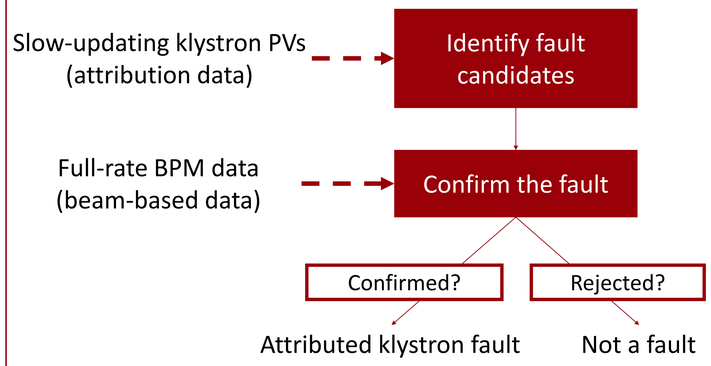
- To find klystron faults
- To attribute each fault to the correct klystron
- To classify the severity of the fault

Combining LCLS Data Sources

- We combine two sources of LCLS data
  1. Beam-based data at full 120 Hz rate
  2. Klystron health data at slow rate
- *Full-rate beam data (120 Hz)*
  - 174 beam position monitors (BPMs)
  - Each BPM measures:
    1. X (position)
    2. Y (position)
    3. TMIT (transmitted charge intensity)
- *Klystron health data (<0.2 Hz)*
  - 13 health (0/1) indicators
  - Several other raw signals

- Klystron faults affect the laser's energy, which manifests as change in position at a subset of BPMs
- Klystron faults are normally indicated by a health indicator AMM (Amplitude Mean Out of Tolerance) and its underlying signal AMPL (Amplitude)

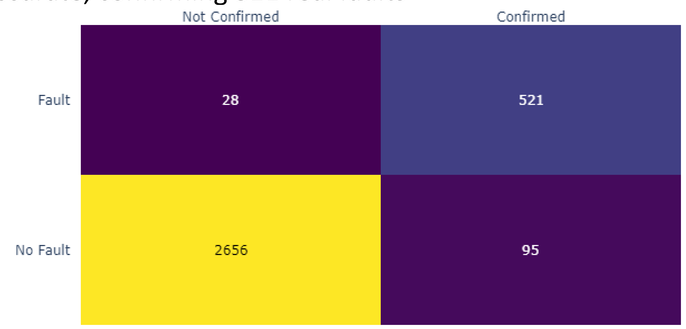
Identifying Klystron Faults



1. Identify fault candidates using AMM and AMPL signals
2. Load BSA data for subset of BPMs (i.e., dispersive bpms)
3. Get per-signal anomaly score from univariate anomaly detection algorithm Modified Spectral Residual (MSR)
4. Aggregate score across space (i.e., downstream BPMs)
5. Aggregate score across time (i.e., consecutive beam pulses)

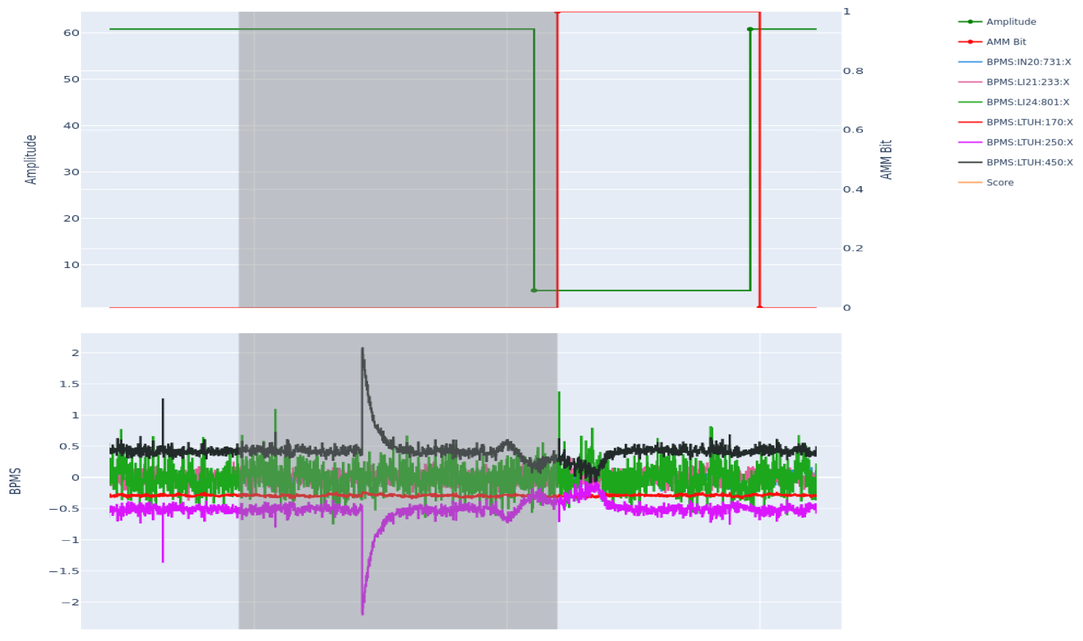
Results

- 3300 *uniquely identifiable* fault candidates from 11/2 – 12/10
- Using hand labels (Fault/No Fault), we find our method is 96.3% accurate, confirming 521 real faults



- AMPL identifies 238 faults that AMM misses
- Klystron faults can be grouped into three categories: Pulse, Sustained, and Catastrophic
- A classifier is >85% accurate in labeling a fault candidate as No, Pulse, Sustained, or Catastrophic fault

Example Fault



Conclusions

- Fully automated system to identify and confirm klystron faults
- Using beam data rejects almost all the false candidates
- Using AMPL detects significantly more klystron faults than AMM alone
- These labeled faults can be used as a supervision source for ongoing anomaly detection work

Acknowledgments

- Funding from SLAC National Accelerator Laboratory Seed Grant and HAI Seed Grant.
- Use of the Linac Coherent Light Source (LCLS), SLAC National Accelerator Laboratory, is supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences.