

Development of an Automated Beam Loss Tuning Application in a High-Power Accelerator

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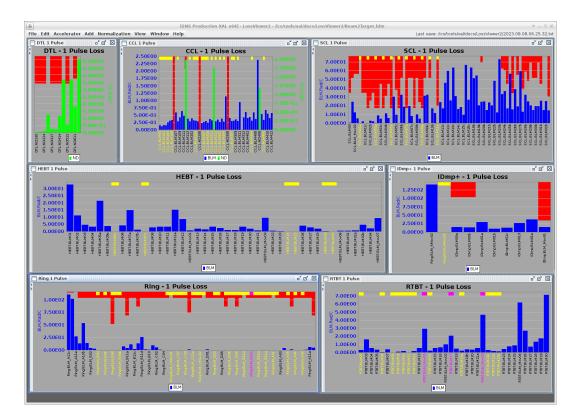
Spallation Neutron Source, Neutron Sciences Directorate

- 2.8 MW, 1.3 GeV-capable, pulsed H- linear accelerator
- Deliver 5000 neutron production (NP) hrs. to a variety of experiments at 90% availability



Motivation for Automated Beam Loss Tuning (ABLT)

- Minimize radiation exposure
- Maintain uptime through Proton Power Upgrade (PPU)
- Maintain losses due to:
 - Beam halo
 - Day-to-day variances
- Find optimum loss profile with ML



LossViewer application showing all Beam Loss Monitors



Objectives

1. Maintain and Optimize Beam Loss

- Tune like an operator first, then explore alternative methods
- Shift RF cavity phases, amplitudes, and quadrupole magnet currents
- Save knob settings & diagnostics to HDF5 file
- Maintain beam & centering on injection dump, beam size and centering on target, power on target, orbit, etc.
- Correlate loss with activation using survey data

2. Run Application during NP

- Test and verify behavior during Accelerator Physics periods
- Receive approval from SNS Accelerator Configuration Control Committee (ACCC)
- Implement safeguards for reliability
- Feed data to ML for future





Team: Operators, Accelerator Physicists, Operations mgmt.



Tools: ScanEngine (python), PyEPICS, PyQT, LossViewer, Orbit Correction, SCORE (Java)



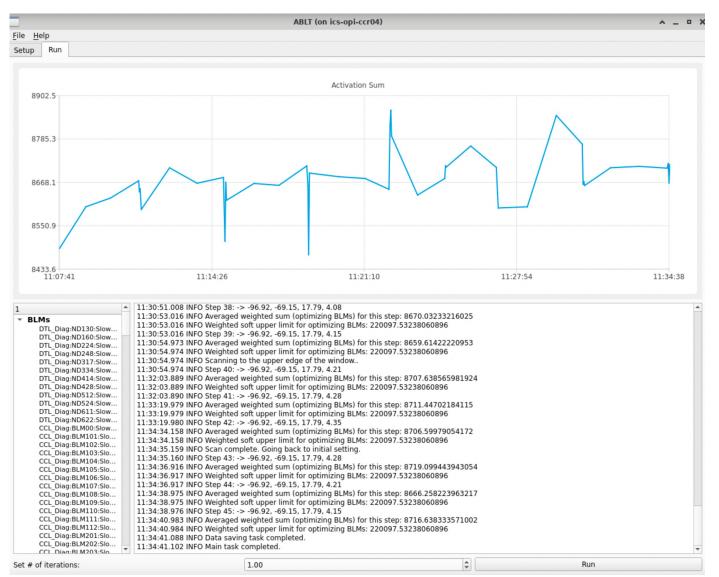
1^{s†} run cycle (Nov 2022 – Feb 2023)

"observer" script Changed phases, return to initial Changed phase, set phase to minimize activation Used data for hand-tuning (G. Gallimore)



6

User Interface



*J. Rye, PO48



2nd run cycle (June 2023 – August 2023)

Improvements

- Integrated GUI with scan
- Monitored BLM signals at every step
- Improved usability
- Implemented orbit correction, filtered blank pulses from optimization
- Added more knobs, more diagnostics

Safety / Building Trust

- Established safe windows, step sizes with experts; save as defaults
- Stopped application if violating userdefined BLM limits
- Locked to one instance of script running at one time
- Approval from ACCC to run at 60 Hz for 24 hrs; No trips!



Analyzing Knob Impact

(Max-Min)/STD between SCL BLM Losses and FC 45.0 Phase Changing Run Date: 20230608, Time: 122654 SCL FCM01a SCL FCM01b SCL BLM12b Losses (Rad/C) SCL FCM01c 44.5 SCL FCM02a SCL FCM02k SCL FCM02 SCL FCM03a SCL FCM03b 44.0 SCL FCM030 SCL FCM04 SCL FCM04k SCL FCM040 43.5 RF SCL FCM05 SCL FCM05 **Beam Loss Monitor** 43.0 4.2 4.0 4.1 4.3 4.4 CCL FCM4 Phase (Φ) CCL FCM4 0.1 0.4 0.3 0.7 0.2 0.3 0.5 0.4 0.8 0.4 0.5 0.3 0.3 04 0.6 0.3 0.1 07 0.2 SCL BINIOC BINIT SCL BLM MOVOL MOVOL SCI-BLM030 SCL BLMO3C SCL BLMOAC SCL BLMOSD SCL BLM100 SCL BLM12D SCL BLMOID SCL BLMOIC SCL BLMO2D SCL BLMOZC SCL BLMOAD SCL BLMOSC SCI BIMILE SCI-BUN MONO3 SCL BLM 13D SCL BLMOO SCL BLM12C INOSO LANOSC LANOOD LANOOC LANOID LANOIC LANOOD LAN SCLBIN

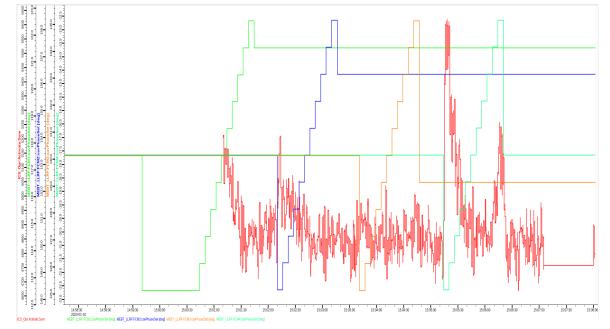
S. Thomas

SCL BLM12b Losses vs. CCL FCM4 Phase Changes Run: 20230814 AP Study Period

9

Lessons Learned (and Ongoing)

- Connect to +1000 variables reliably and predictably
- Improve ScanEngine for production
- Handle noise in BLM/activation data
- Improve usability
 - setting GUI BLM limits easily
 - pause function
 - restore old setpoints
- Survey data post-scan correlates well with our predicted activation



Est. activation (red) over the course of one scan



Future Goals

- Choice of stepping: sequential, random, 1-D or n-D, etc.
- Choice of optimization modes
- Monitor additional diagnostics on the fly
- Fine-tune data analysis methods
- Develop analysis/data visualization interface
- Establish ML infrastructure in the control room
- Analyze data from full-power test with ML



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Thank you

ありがとうございました



Additional Slides

- <u>ABLT</u>
- <u>Analysis</u>
- <u>ScanEngine</u>
- Intrabeam stripping paper: <u>here</u>



