Booster Activation

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The Problem

• Beam losses in the Booster cause activation of accelerator components which can lead to equipment failure and long down times due to the need to restrict doses to personnel.

• Since the turn on of MiniBooNE the Booster has increased its output by an order of magnitude.
  • The tunnel is hotter.
  • Equipment (particularly HV cables) failure rates has increased.
  • Personnel are accumulating higher doses

• The proton demand is not expected to go down in the foreseeable future. *(Will continue to increase.)*

• Is the situation getting out of hand? *(I don’t think so.)*

• What are we doing about it?
Activation Monitoring

- Since June 2001 we have been performing systematic radiation measurements at many locations around the ring.
  - 1 measurement at each of the 24 short straight sections
  - 2 measurements at each of the 18 RF cavities
  - 3 measurements at the injection and extraction sections
  - 2 measurements at complicated long straight sections
  - 1 measurement at each of the 8 remaining long straights
  - Several miscellaneous “hot spots”.
- This has been done during each significant shutdown period.
- Daily measurements were made during the January 2003 shutdown in order to understand cool down rates.
- Results are posted on the web:
  - (http://www-bd.fnal.gov/proton/booster/activation/)
Corrected Dose Rates at All Measurement Points
Corrected Dose Rates at RF Cavities
Dose Rates versus Time Shorts 1 to 12

MiniBooNE
Dose Rates versus Time Shorts 13 to 24

MiniBooNE
Dose Rates versus Time Longs 1 to 12

MiniBooNE
Dose Rates versus Time Longs 12 to 24
Overall Trends

[Graph showing Median Change, Average Dose, and Protons/Week trends over time with a label for MiniBooNE.]
Cool Down Data

Long time scales!
If $^{57}\text{Co}$ (282 days half life) is assumed for the long-lived term in the double exponential fit, then the second term requires a 5.6 days half life.
Controlling Activation – The Watt Meter

• The “watt meter” (B:BPL5MA) measures the beam power loss averaged over the past 5 minutes.
  • Limit is currently set to 400 watts and is generally the most restrictive limit on what the Booster can deliver.
  • Initially intended to run at 450 watts which roughly corresponds to the SNS design goal of 1 watt/meter.
• A “blunt instrument”, it does not distinguish where the losses occur.
  • Not effective against losses concentrated in sensitive locations (e.g. RF cavities).
  • Is unnecessarily restrictive when losses are concentrated in “safe” locations (e.g. collimators).
• Will need to replace it (soon) in order to get full benefit from the Booster collimators.
Controlling Activation – The BLM system

• The Booster is equipped with ~60 Beam Loss Monitors strategically located around the ring.

• Devices \((B:BLxxx0)\) associated with each BLM return the total loss recorded by the BLM, integrated over the last \(~100\) sec.

• Trip points have been established for each BLM in order to separately control losses at each BLM location.

• The problem reduces to choosing appropriate trip points.
  • But not so easy!
  • The relationship between recorded losses and measured activation is complicated ...

\[
A(T) = \left( \sum_i x_i e^{-\lambda_i T} \right) A_0 + \sum_i \int k_i BLxxx0(t) e^{-\lambda_i (T-t)} \, dt
\]
  
  Sum is over produced isotopes

• Many parameters \((x_i, \lambda_i, k_i)\) need to be determined
Choosing Trip Points – The Ad Hoc approach

• Original settings were defined as twice the BLM sums observed during a “typical” stable running period in April, 2002.
  • Don’t let the tunnel get any more than twice as hot as it was at the time.
  • Trip values varied enormously between BLM’s

• The loss pattern quickly evolved away from the original and the operators had difficulty managing losses in areas with very low trip points
  • Raised low value trip settings in regions known to have little activation

• When MiniBooNE turned on all levels were increased by 50% as agreed to by the Division Head.

• Adjustments were then made based on observed activation levels (e.g. L24 and L15 to reduce rates at RF cavities)
The Near Future

• Would like to determine more “defensible” BLM limits
  • Take a series of closely spaced (~ 1 week) activation measurements
  • Compare measurements with BLM data and try fitting to a “two isotope model”
  • If a predictive fit can be found then adjust BLM trip levels accordingly.
  • Work in progress

• Once relationship between BLM’s and activation is established we need to decide on an acceptable activation level at each location and set an appropriate trip point.