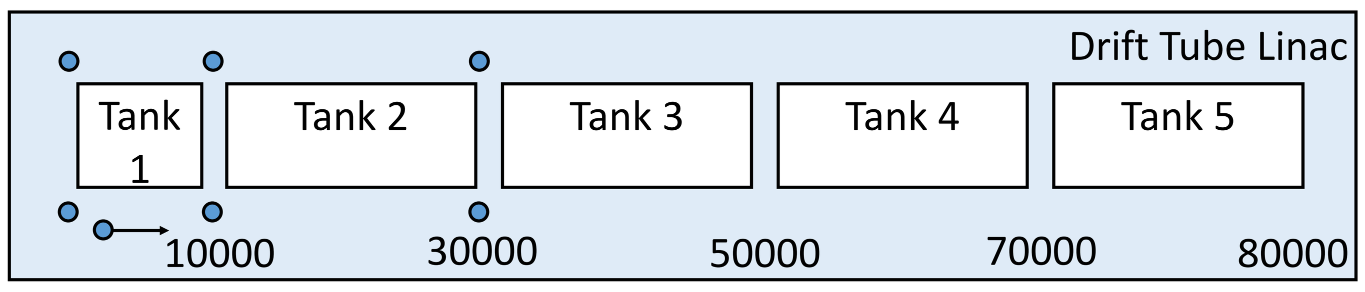
Beam Loss Assessment Through Use of Photomultiplier Tubes

Alexander Waggoner, Under Advisor Dr. Ralitsa Sharankova, Lake Land College
CCI Summer Intern

FERMILAB-POSTER-24-0201-AD-STUDENT

Background

The first machine in the Fermilab Accelerator chain, the Linac, delivers a 400 MeV proton beam. The first portion of the Fermilab Linac, the Drift Tube Linac, lacks the degree of instrumentation necessary for beam tuning. To compensate for this, photomultiplier tube (PMT's) based loss monitors were installed on either side of the first two drift tube tanks.



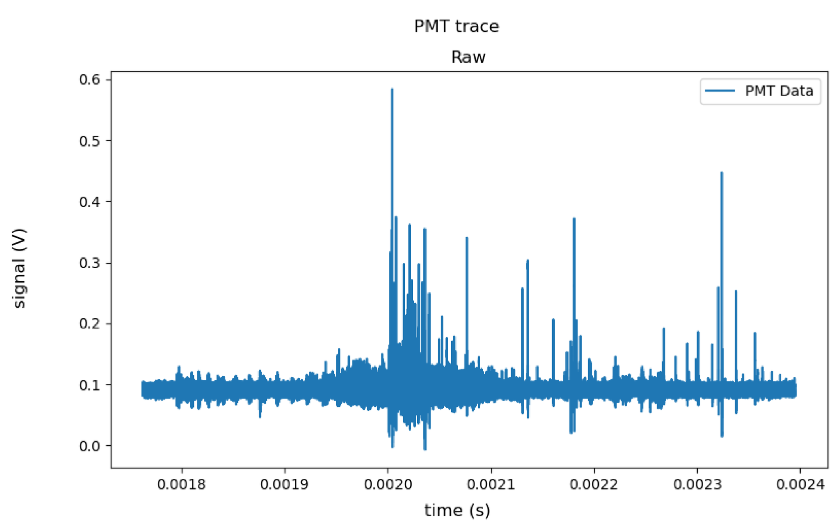
Drift Tube Linac with approximate PMT Positions

Motivation

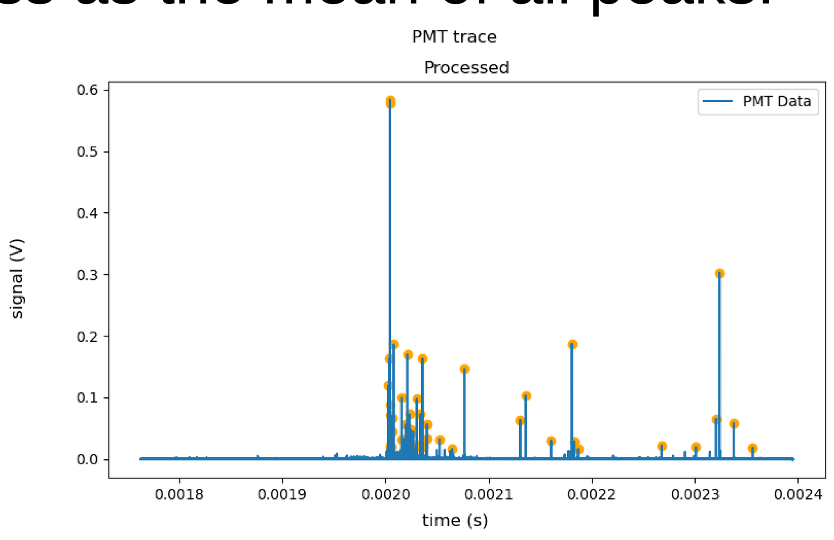
The PMT's used in the Linac are not absolutely energy calibrated. The PMT signals include 3 distributions: RF emissions, beam loss, and electronic noise. This results in a need for data processing to select for only the beam loss contribution. Noise reduction and peak finding on the PMT data allows for the PMT's to be used as operational beam loss monitors, making the study and processing of PMT signals a possible route through which to improve loss assessment in the Drift Tube Linac. One of the main goals in this is to make this operational for tuning.

Methods

The PMT component of the signal has short rise times O(5 ns), creating distinct peaks. The monitor system picks up the 201 MHz RF signal among other sources of electronic noise. Dedicated hardware exists to minimize the RF component of the noise. Other sources of noise need to be eliminated via software analysis. A method was developed to eliminate this noise based on signal strength over time. This method results in adjacent low points becoming extremely small, and adjacent high points becoming much greater proportionally, emphasizing peaks above the noise substantially. A peak-finding function within the Scipy library was used to locate the newly emphasized peaks. For the purpose of this study, a high-bandwidth oscilloscope was used to collect data waveforms. We defined a measure of beam loss as the mean of all peaks.



1200V PMT After Low Pass Filter Hardware

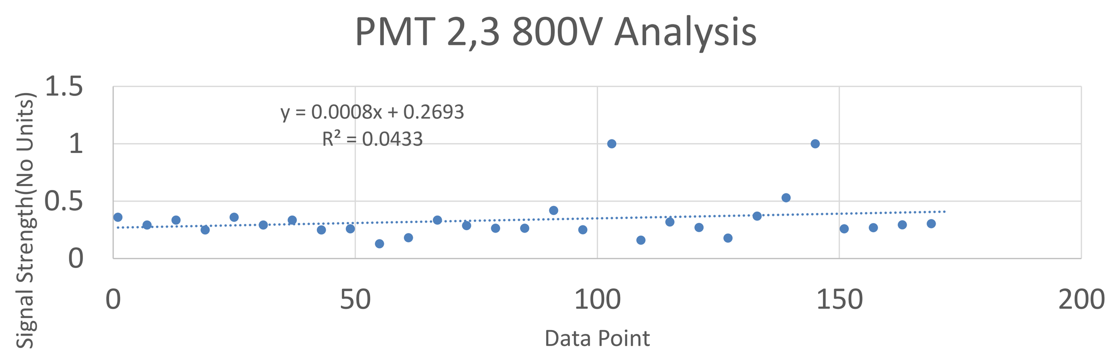


1200V PMT After Low Pass Filter Hardware Plus Software Processing

This manuscript has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics. This work was supported in part by the U.S. Department of Energy, Office of Science, Office of Workforce Development for Teachers and Scientists (WDTS) under the Community College Internship (CCI)

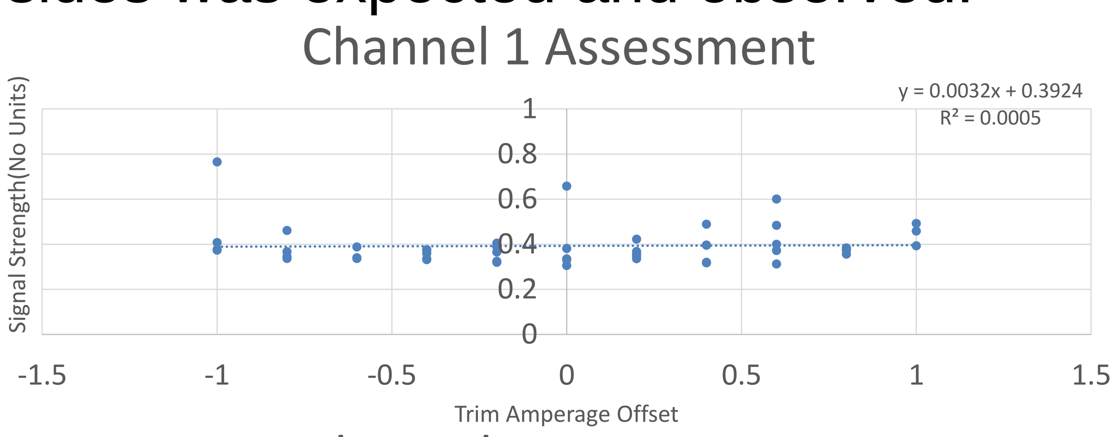
Beam Study Results

The mean of peaks in the waveform was found to be consistent over a set of parameters, meaning that this method is a reasonable and stable estimate of beam loss useful for beam condition monitoring.

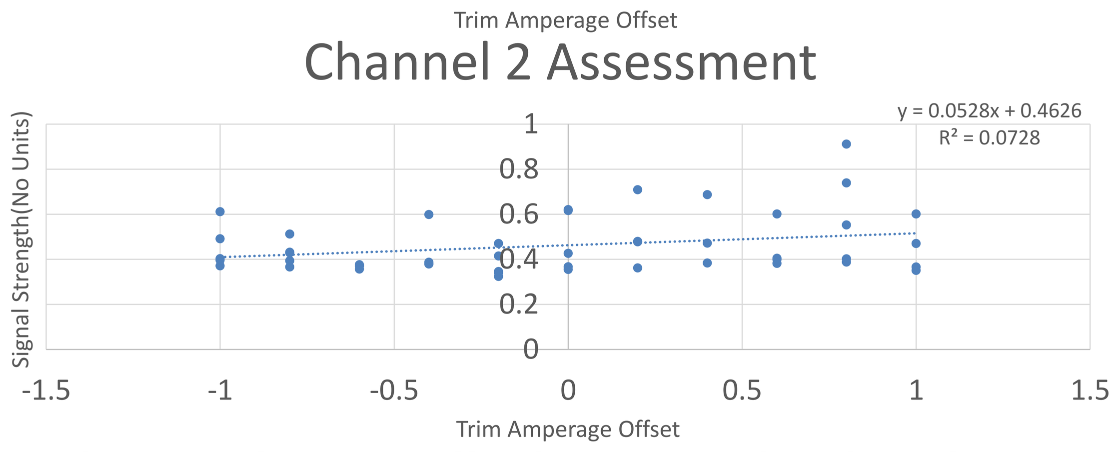


800V PMT Analysis Over Many Measurements

Current applied to a bending magnet upstream of the DTL was scanned in the range [-1,+1] A with respect to nominal with a step size of 0.2 A. Readings from each PMT were taken at each step, allowing for the assessment of trends based on the beam tilt. An increase in loss in one or both sides was expected and observed.

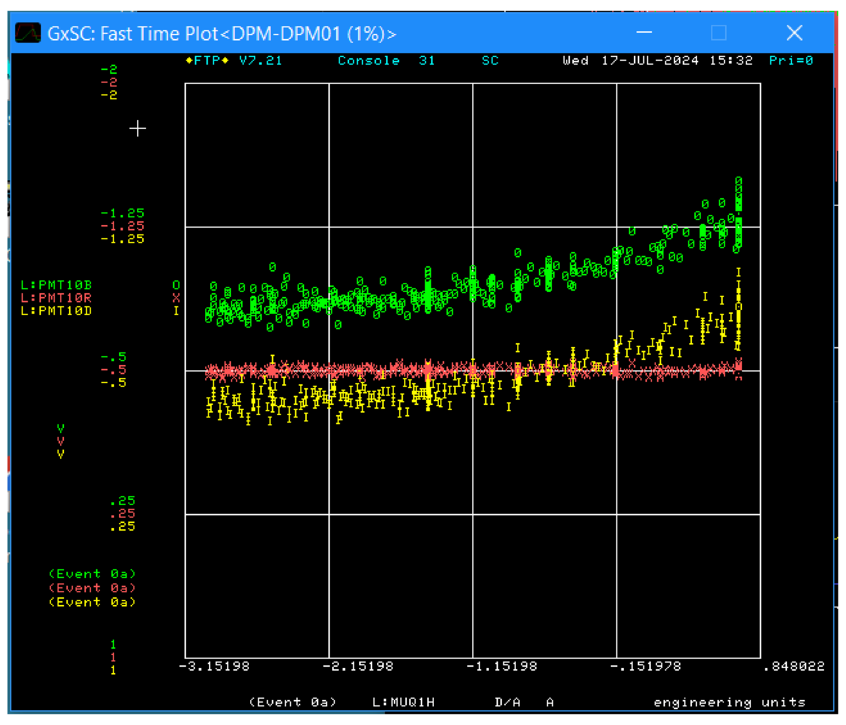


Channel 1 Assessment over range of -1 A to +1 A relative to nominal

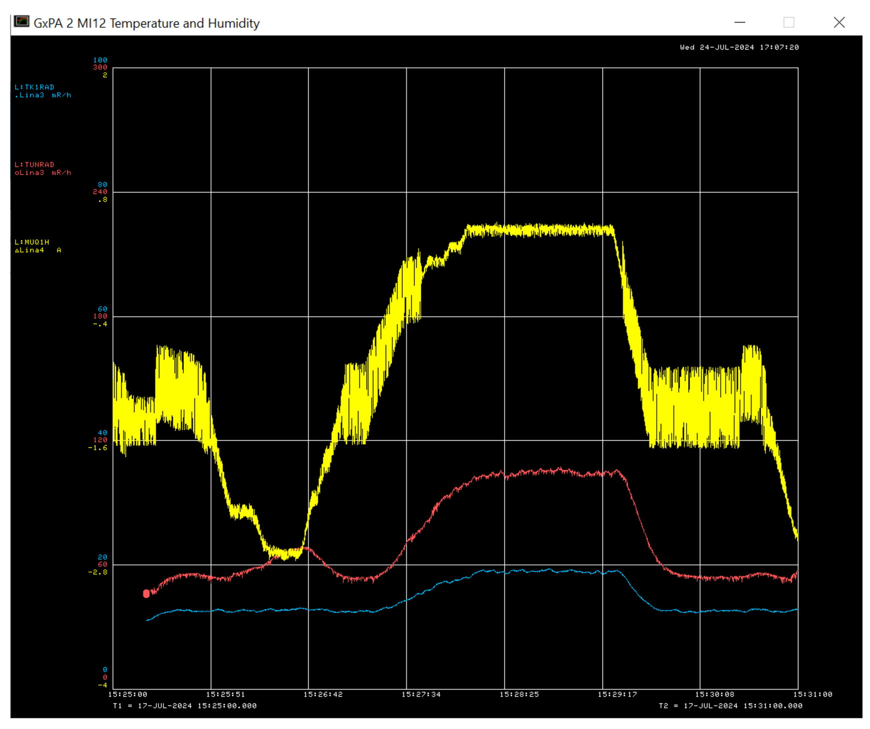


Channel 2 Assessment over range of -1 A to +1 A relative to nominal

Independent radiation monitoring instrumentation showed that this method of tilting the beam did, in fact, increase the beam loss, which is reflected in the channel 2 assessment but not the channel 1 assessment.



Baseline Radiation(Red), Radiation during beam pulse(Green), and Difference in Radiation Measured(Yellow)



Trim Current(Yellow), Radiation Monitor(Red and Blue)

Conclusion

A method for noise reduction and peak finding has been developed and implemented to produce a consistent and stable output. In comparing data with and without a signal amplifier and filtering board, it was found that the board substantially improves the difference between noise and signal. Future work includes integration with ACNET to automate input and output of data for analysis of beam loss.