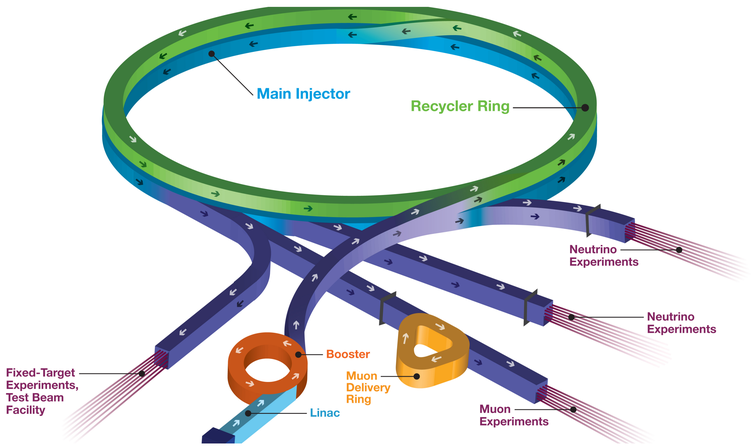
Beam Trail Tracking at Fermilab

Dennis J. Nicklaus, Linden Carmichael, Richard Neswold, Zongwei Yuan
Fermilab, Batavia, Illinois, USA

The Fermilab Accelerator Chain

The beam at Fermilab begins at the ion source and, after an initial acceleration to 750 keV by a radio-frequency quadrupole, it is accelerated to 400 MeV by the Linac (Linear accelerator). The Booster ring boosts its energy to 8 GeV. From there, the beam can go to the Recycler Ring, where multiple batches from the Booster can be "slip stacked" into higher intensity batches that are then sent to the Main Injector for acceleration from 8GeV to 120 GeV.



The Fermilab Accelerator Chain

Experiments/Targets

Our proton beams are directed to several different experiments, including:

- Short Baseline Neutrino Experiments (8 GeV from Booster)
- Long Baseline Neutrino Experiments (120 GeV)
- Neutron Therapy (Linac beam)
- Detector Technology Test Area
- Muon Experiments (Muon g-2, Mu2e)

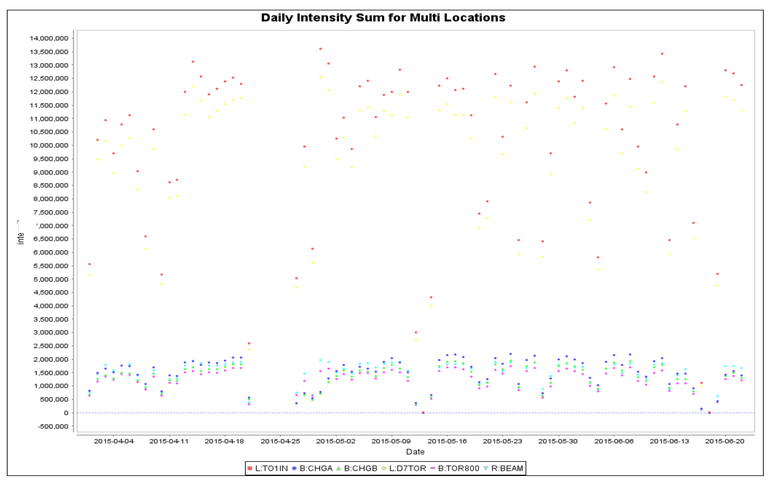
The Goal of Beam Trail Tracking

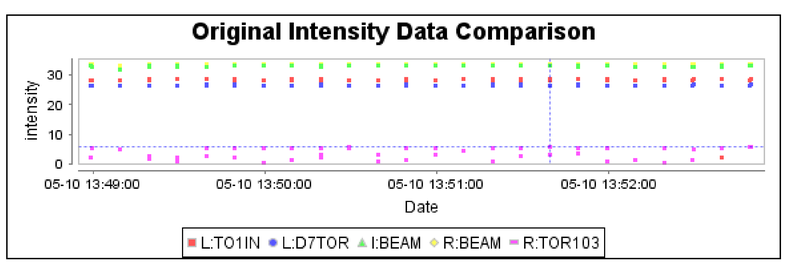
We have instrumentation to acquire intensity readings along the various paths the beams can take. We wanted to form trails of these intensity values according to the different beam destinations. We need to construct these trails in real-time as the beam is happening. With the data stored in a database, we can use it for reports and statistics about our accelerator performance. We can produce graphs that let us:

1. Report the performance in absolute terms: How much short baseline neutrino beam did we produce last week?
2. Measure accelerator efficiencies over time: How much beam loss is there on different trails as the beam goes through the chain of accelerators
3. Perform closer performance studies: Why is the third pulse of twelve on Trail 60 always different when it passes position X?

Some Plots from Our Data

The first plot shows summed intensities over many days. The second displays readings from individual instances of one trail.



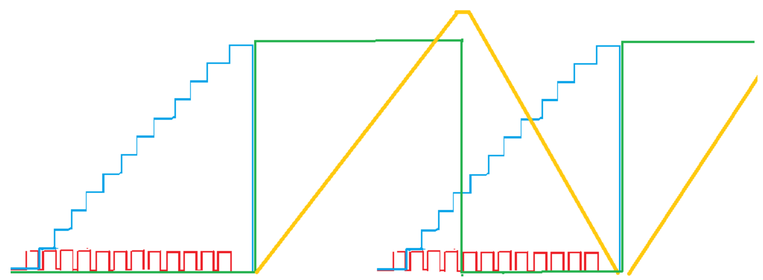


Abstract

We present a system for acquiring and sorting data from select devices depending on the destination of each particular beam pulse in the Fermilab accelerator chain. The 15 Hz beam that begins in the Fermilab ion source can be directed to a variety of additional accelerators, beam lines, beam dumps, and experiments. We have implemented a data acquisition system that senses the destination of each pulse and reads the appropriate beam intensity devices so that profiles of the beam can be stored and analysed for each type of beam trail. We envision utilizing this data long term to identify trends in the performance of the accelerators.

It's Complicated!

In addition to the variety of experiments, dumps, and targets that make up our set of beam destinations, trail collection is also complicated by the fact that some trails are made up of multiple beam pulses from the Linac, and these more complex trails can overlap. The figure below is a schematic of stacking cycles to the Main Injector. It shows how multiple booster batches are used to fill the Recycler while the Main Injector is ramping. When the ramp is finished, the stacked Recycler Beam is transferred to the Main Injector. This overlapped timing allows Fermilab to achieve record values of beam power.



Red: Booster Intensity. Blue: Recycler Intensity
Green: Main Injector Intensity. Yellow: Main Injector Energy.