Automation of Operations at Fermilab

Check lists to mouse clicks

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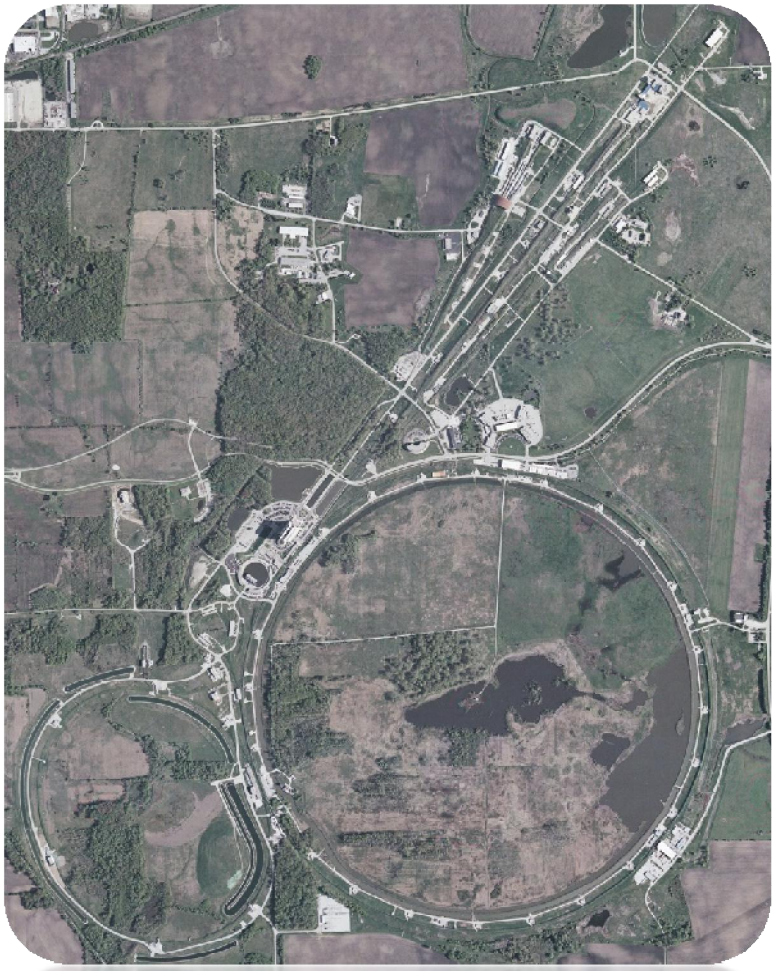
Abstract

- Implementing system automation to increase productivity, improve efficiency, ensure repeatability, and reduce errors has become essential for complex accelerator operations. This presentation will address some of the positive and negative effects of automation on operations and operators using experiences and examples from the Fermilab Operations Department.

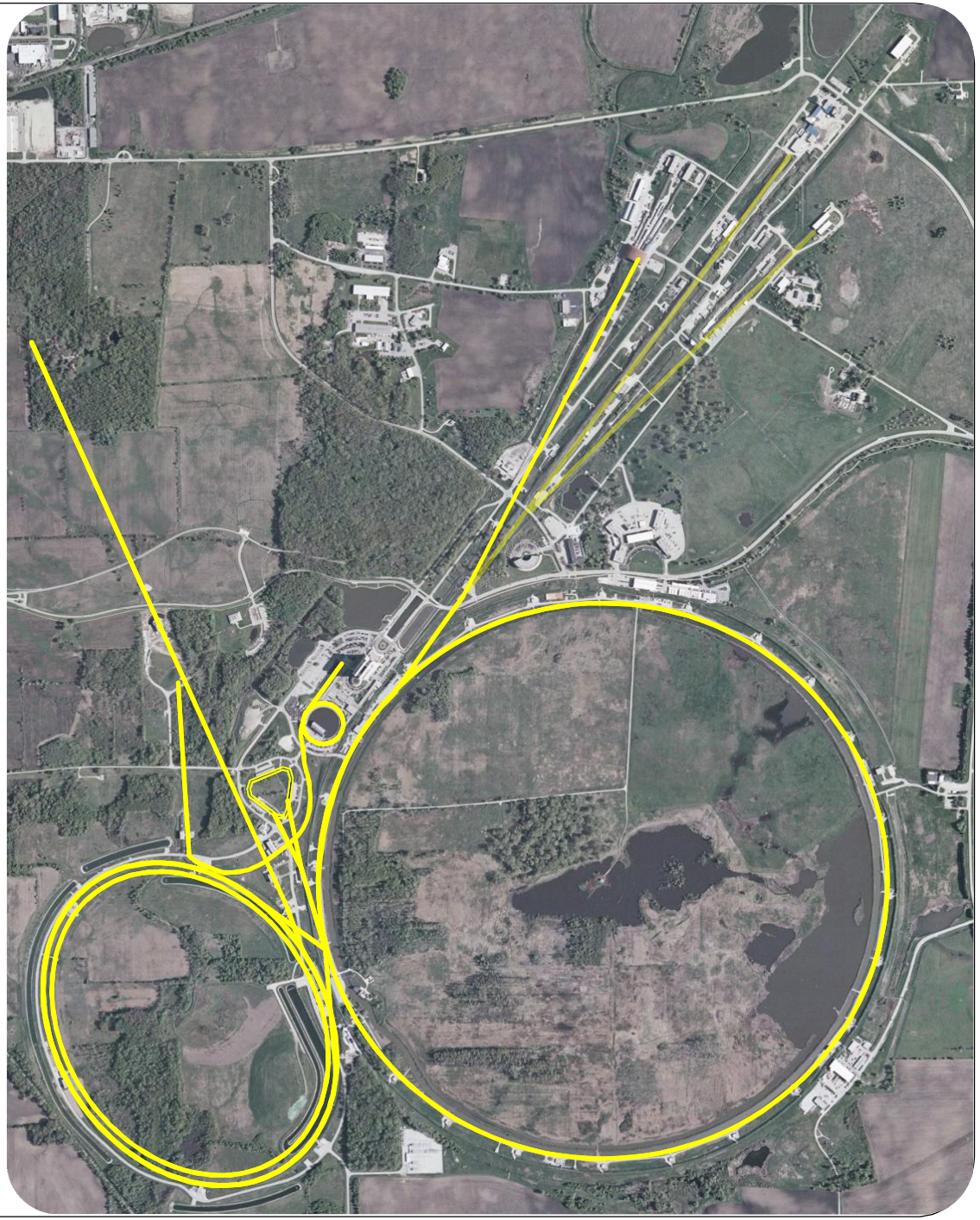
Overview

- Intro
  - Machines
  - Operational Modes
- Automation Examples
  - Accelerator Coordination
  - Collider
  - Anti-Proton
  - Neutrino Production
- Operations
  - Affects
  - Pros
  - Cons
  - Maybes
- Summary



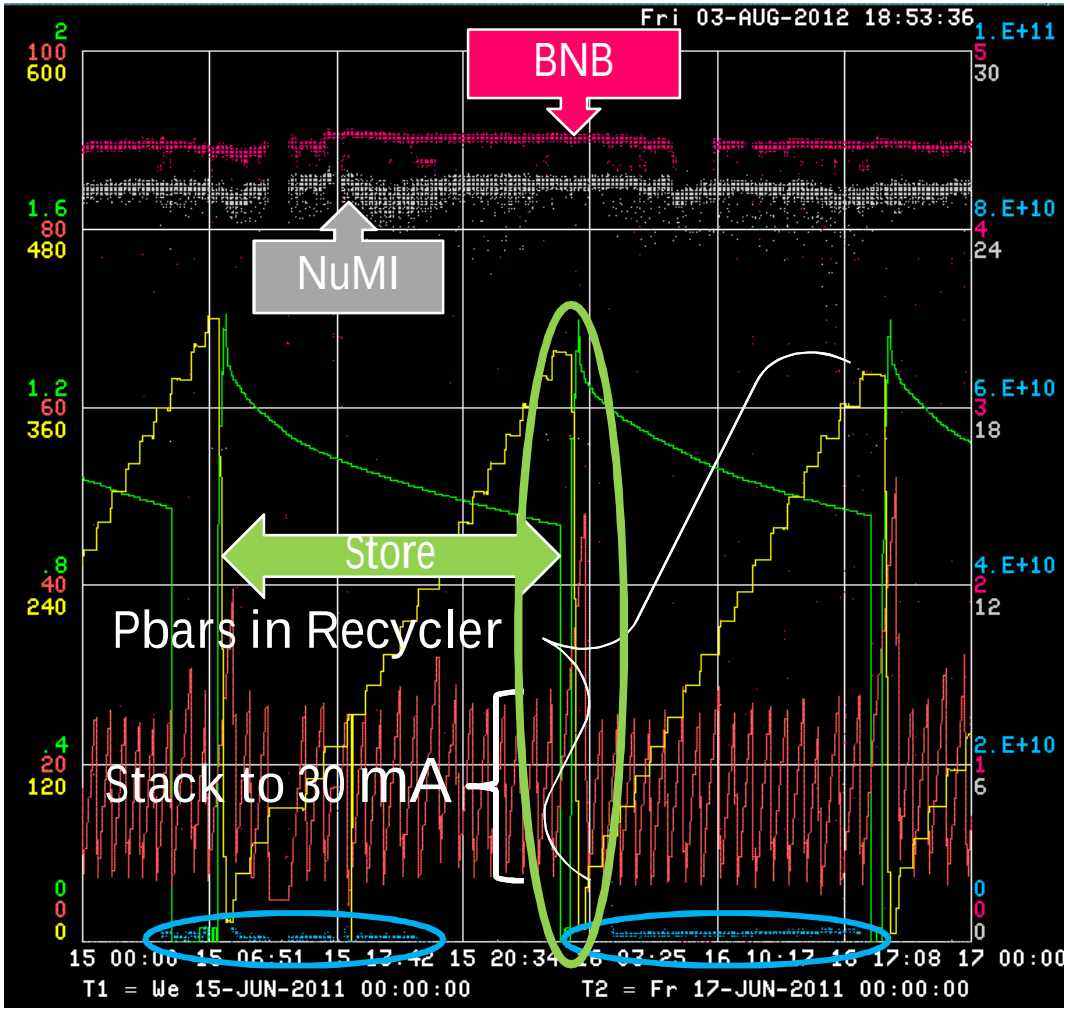
Machine Intro

- Proton Source
  - Provides 8 GeV protons
- Booster Neutrino Beamline (MiniBoone)
  - 8 GeV protons for neutrino production
- Main Injector
  - 120 GeV proton for fixed target
  - 120 GeV protons for anti-proton production
  - 120 GeV protons for neutrino production
  - 150 GeV protons and anti-protons for collider
  - 8 GeV anti-protons
- Switchyard (Fixed Target)
  - 120 GeV protons for Test Facility
- Anti-Proton Source
  - 120 GeV protons to target
  - 8 GeV anti-protons (pbars)
- NuMI beamline
  - 120 GeV protons for neutrino production
- Tevatron
  - Anti-proton on proton collider
- Recycler Ring
  - 8 GeV anti-proton storage ring



Operational Modes

- Collider Store
  - ~16 hours
- Fixed Target
  - Approx. once per minute
- Neutrino Production
  - NuMI (MINOS, MINERνA)
    - 350 kW ~0.5 Hz
  - BNB (MiniBooNE)
    - 2.5-5 Hz
- Anti-Proton Production (Stacking)
  - ~0.5 Hz rate
  - 30 mA ~ 1hr
- Anti-Proton Transfer to Recycler (Stashing)
  - 10 minutes
- Tevatron Shot Set Up
  - ~ 1 hour
- Repeat !

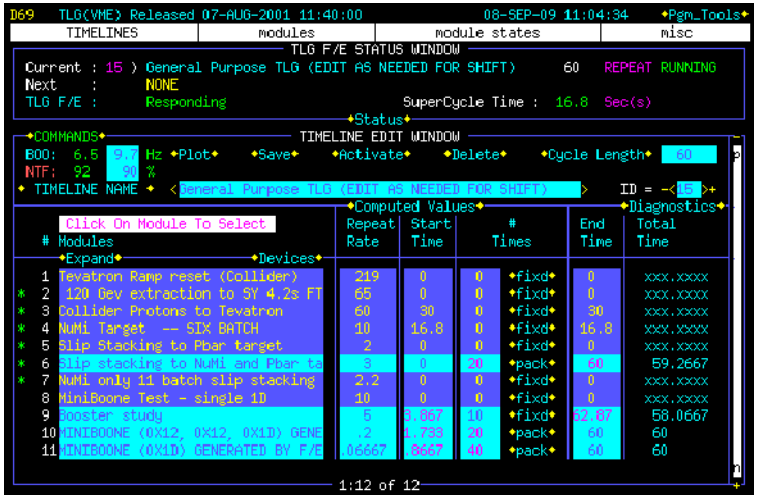


Accelerator Coordination

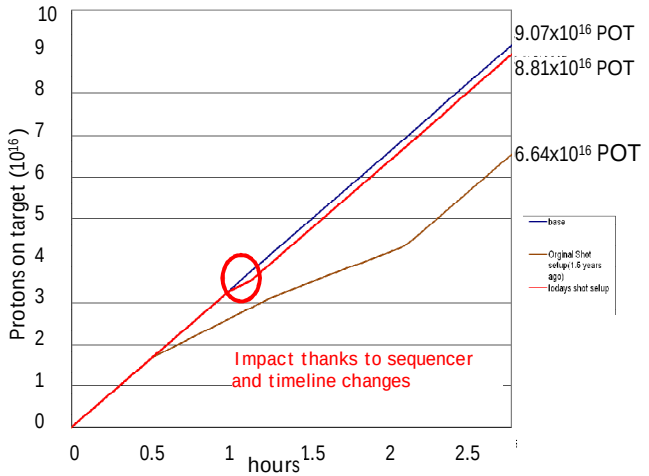
Maximize store hours, minimize shot set up time, don't waste time transitioning between operational modes, and still deliver beam for neutrinos. The first step was better coordination through automation.

Accelerator Coordination

- Timeline Generator (TLG)
  - Sets overall Accelerator Complex timing clock events (TCLK) to orchestrate beam delivery from machine to machine.
  - Timelines built with modules
    - Allows quick reconfiguration of operational modes
  - One-Shot function
    - Minimized impact of Shot Set Up and Pbar Transfers on beam delivered for NuMI and Pbar Production
  - Sequencer Loading
    - Increased efficiency of timeline transition during Shot Set Up and Pbar Transfers
- Replaced Operators building individual timelines for mode changes
  - Increased efficiency and reduced errors

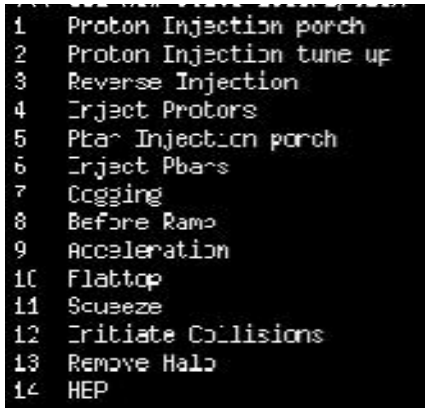


Protons on NuMI target during Tevatron shot setup

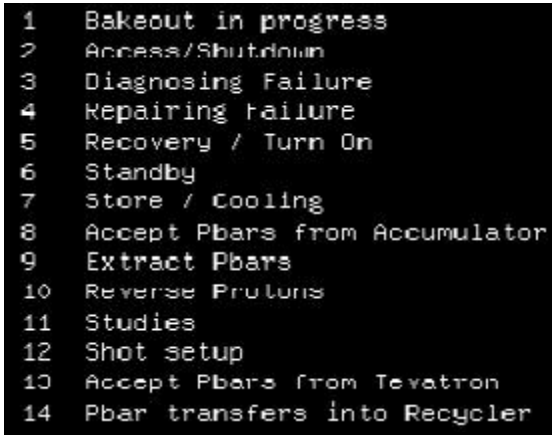


Accelerator Coordination

- State Devices
  - Provide persistent conditions, triggers and informational messages through Accelerator Control Network (ACNET) parameters
  - When a state device is set, it is reflected to the rest of the control system
    - Multicast
    - Registered listeners (Sequencers)
  - Sequencer can set state devices



Tevatron States



Recycler States

Accelerator Coordination

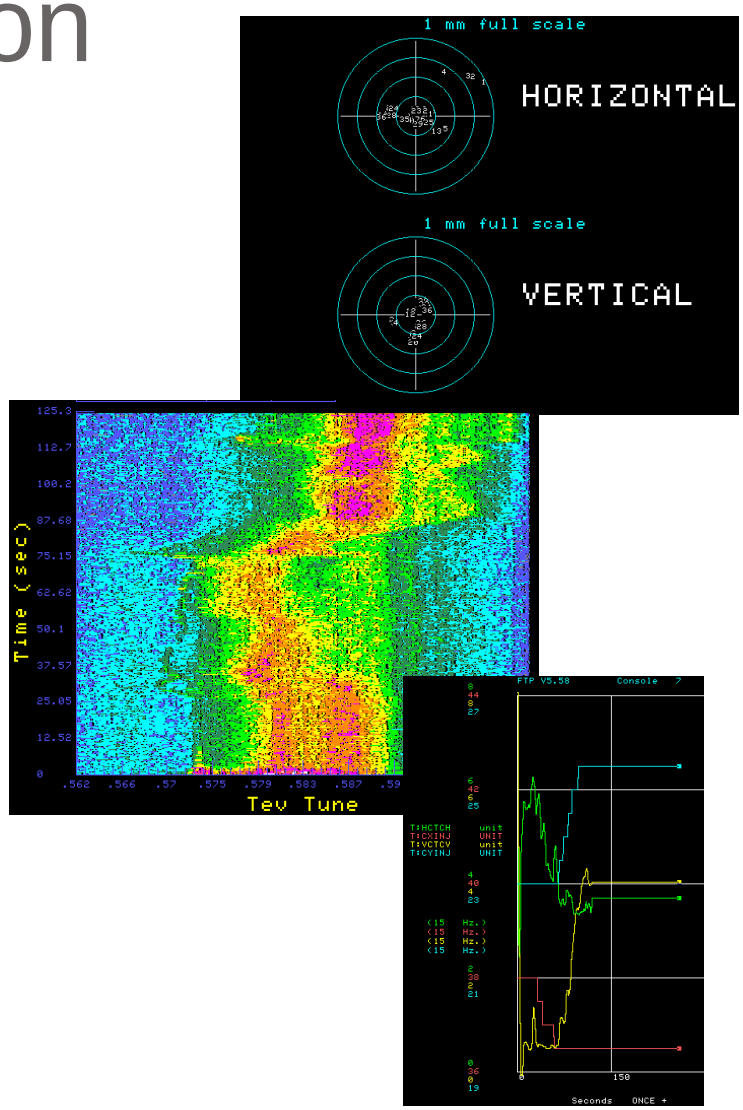
- "Smarter" Sequencer
  - Separate sequencer instances for TeV, MI, Pbar, Recycler
  - Sequencer issues high level control commands
    - Changes Timeline
    - Launch programs and scripts for complex operations (`Tev_Auto_Closure`)
  - Listens too and sets State Devices to provide synchronization
    - (`V:RRTLG`)
  - Implemented to improve efficiency of Shot Set Up and Pbar Transfers to Recycler

Collider Automation

Focus on reducing the shot set up time, and build some tools to be proactive and increase productivity.

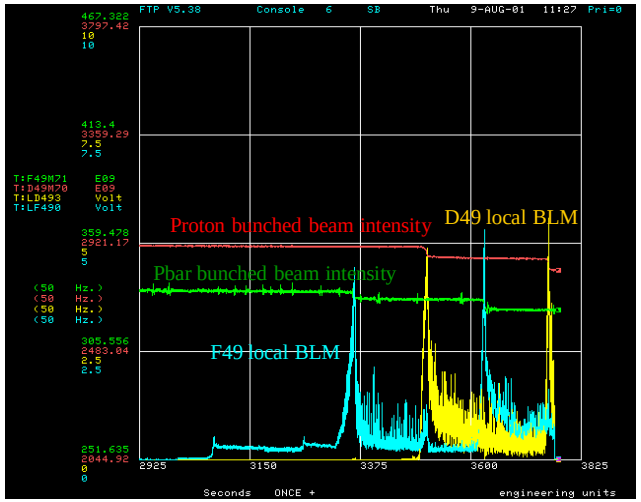
Collider Automation

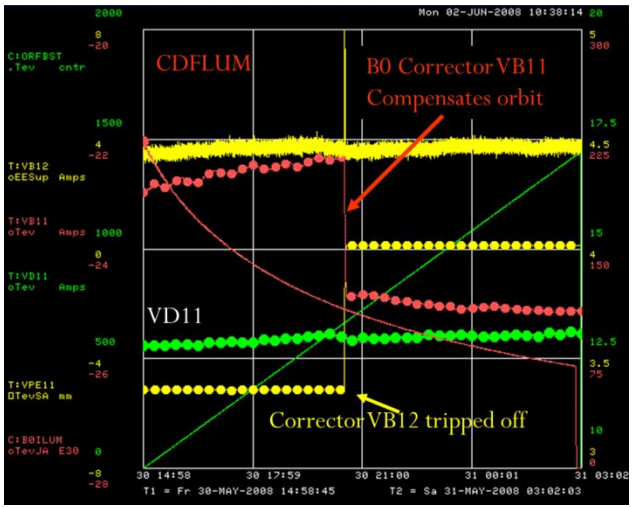
- Automated Injection Closure program
  - Forward and Reverse injection
- Tune Tracker (PPLL)
  - Provided continuous measurement of Tev tunes during tune up, ramp and squeeze
  - Monitor tune drift during the store
    - Alarmed when out of tolerance
    - Manual Correction
    - Improved response time to maintain stable tunes throughout the store
- Chromaticity Tracker
  - Auto Chromaticity Measurement Program
    - Set the chromaticities, and coupling for Tevatron Shot setup



Collider Automation

- Automated Collimators to remove halo at IP
  - Beam intensity and loss monitor feedback
  - Reduced time from 30 to 10 min.
- Orbit Stabilization Program
  - Orbit smoothed to a reference orbit file one time at lowbeta, at Int collisions and at the end of a store.
  - During a store, corrects the orbit every 30 sec.
  - Implemented to correct orbit drift due to environmental factors and corrector failures.



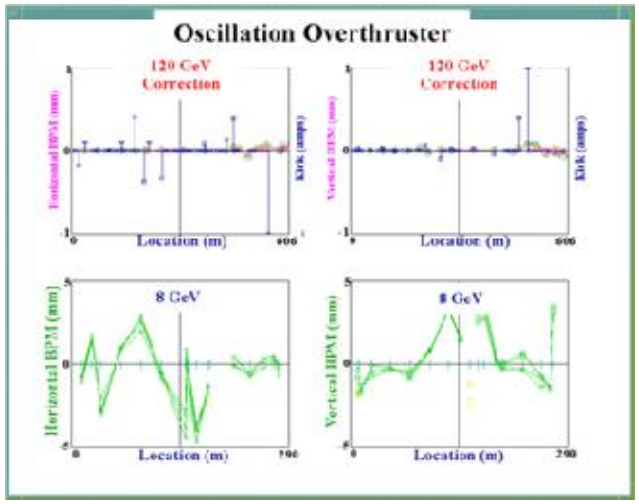


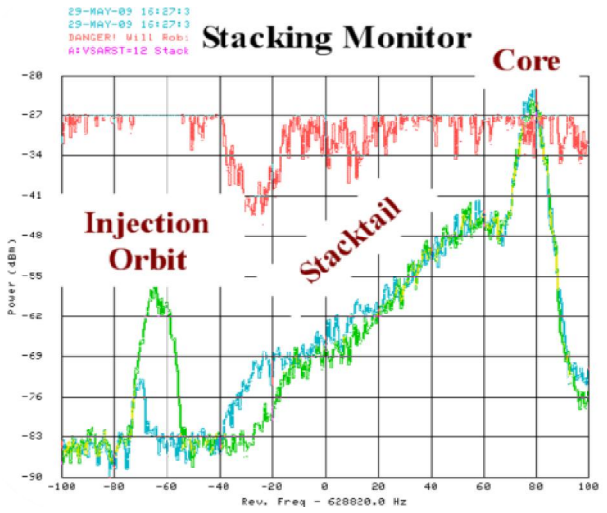
Anti-Proton Automation

Increase the repeatability and consistency of the beam conditions for the anti-protons. Normalize the results with automation.

Anti-Proton Automation

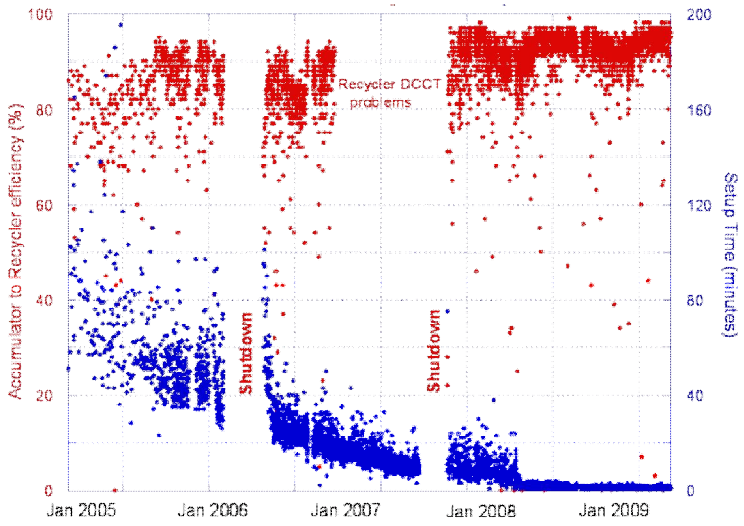
- Beam Line Tuner
  - 120 GeV proton trajectory in 3 beamlines prior to the Pbar target and 8 GeV secondary beam after the target.
    - Replaced Operators target tuning.
- Stacktail Monitor
  - Regulates stacktail momentum cooling power
- Core Babysitter
  - Core momentum cooling power regulation



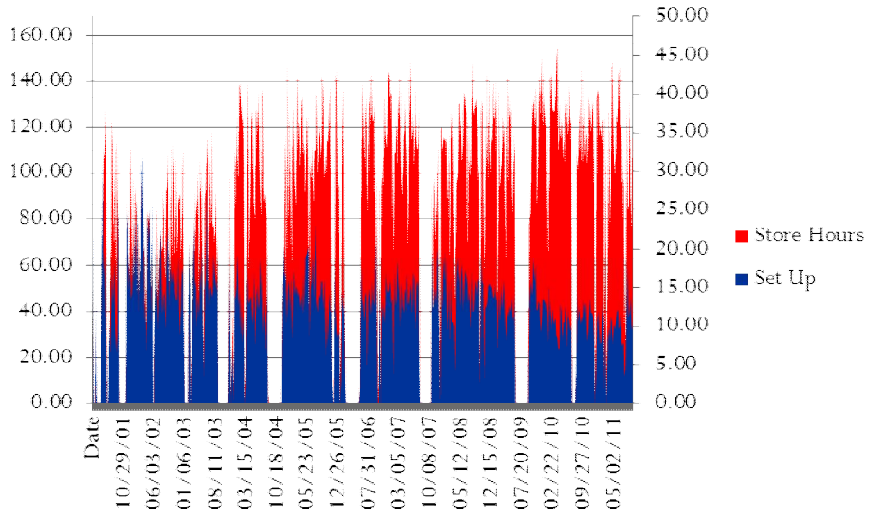


Results

Pbar Transfer



Tevatron Shot Set Up

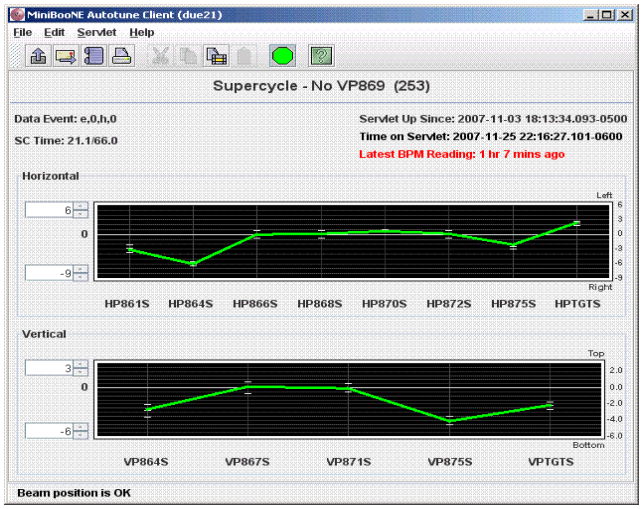


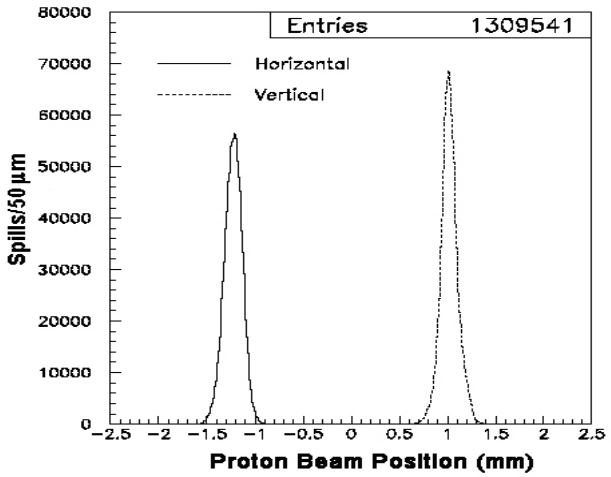
Neutrino Production

With all this collider and pbar production who has time to make neutrinos?

Neutrino Production

- Booster Neutrino Beamline Tuner (MiniBoone)
  - Target position stability
    - 2-5 Hz rate
- NuMI Beamline Tuner
  - Target position
    - 100µm rms
    - 350 kW beam power on target MINOS, MINERνA
    - 700 kW NOνA (future)



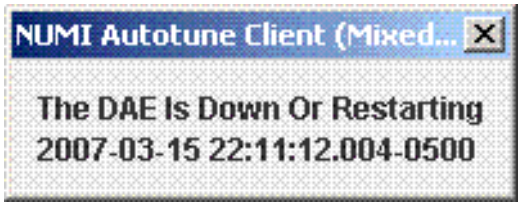


Affects on Operators/Operations

What does this button do?

Affects on Operators/Operations

- Process/System knowledge suffers.
  - Slows learning.
  - A good operator will learn it.



- Operations becomes more expert dependent.
  - First response is to call someone.
- Difficult to operate in a non-standard configuration.
  - Large pbar stack sizes.
- Requires more attention in training
  - Don't just know that it works, know how it works.

Affects on Operators/Operations

- Increase productivity.
  - Focus on areas that have no automation.
- Expands our responsibility.
- Different skills are being developed
  - More computer savvy, operators that write their own automation programs.
  - Is this just the evolution of an operator at work?

Summary

Automation when it's done correctly improves reliability, reduces human error, increases productivity, and is a necessity for complex operations. Generally the benefits outweigh the drawbacks, and with effort, attention and training Operations can nearly eliminate them.

Summary

- Automation
  - Improves reliability
  - Reduces human error
  - Increases accelerator productivity
  - Is a necessity for complex operations
- Operations / Operators
  - Will adjust and evolve

AUTOMATION

- 1: the technique of making an apparatus, a process, or a system operate automatically
- 2: the state of being operated automatically
- 3: automatically controlled operation of an apparatus, process, or system by mechanical or electronic devices that take the place of human labor

Thank You.


1985
1992
CDF
DØ
1985
PBAR
SEPT. 30, 2011
ECOOL
2005
TEVATRON
1983