Frequent Accumulator to Recycler Antiproton Transfers

Elvin Harms

DOE Review

February 24-26, 2004

Frequent Antiproton Transfers

- Introduction/Definition
- Overview of each Subproject (including progress since previous Review)
  - Beam Line Regulation
  - Software
  - Oscillation Feedback & Control
  - Diagnostics
  - Commissioning
- Implementation Steps
- Summary

Frequent Antiproton Transfers - Introduction

- Current set-up
  - ~2 hours to load the Tevatron
  - ~1 hour to set up and send pbars to the Recycler
  - Expect perfection on every transfer
- Motivation for speeding process
  - Increased stacking rates only possible by not building a core – empty the Accumulator when it 'fills up'
  - Maintain as high an average stacking rate as possible – minimal impact on stacking
- Expected set-up time
  - move from shot set up to transfer when full
  - actually, *automated* transfers as they occur on event now
  - Unstack/transfer time now ~30 seconds, driven by time to adiabatically bunch, accelerate, and extract pbars from the Accumulator

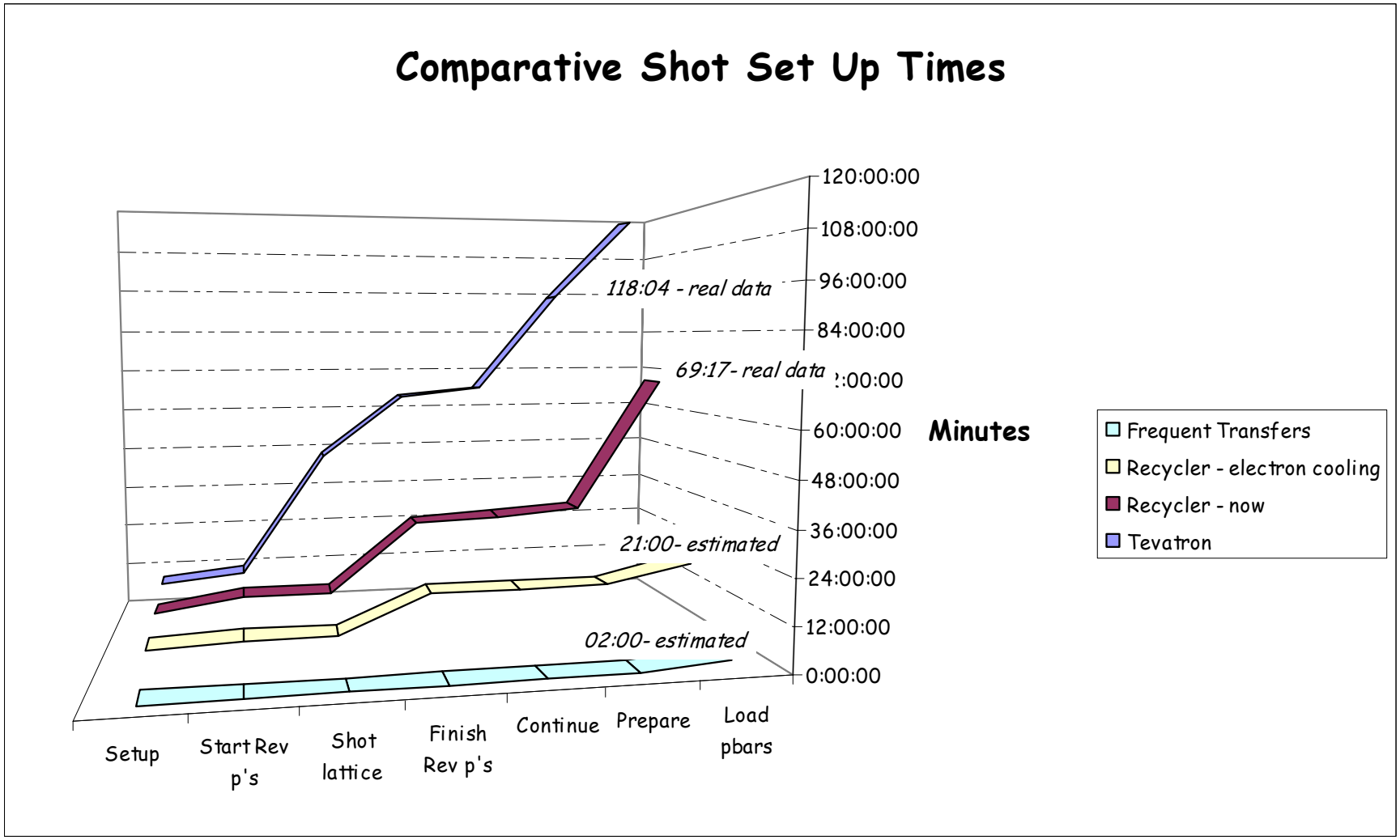
Frequent Antiproton Transfers - Introduction

- Requirements
  - Time
    - Empty stack every 30 minutes
    - Transfers of order one minute
  - Stack size
    - 40 E10 or less
  - Emittances
    - Transverse: 10π mm-mrad (95% normalized)
    - Longitudinal: 10 eV-s
    - Up to 50% dilution allowable

Frequent Antiproton Transfers - Introduction

- Differences from current scheme
  - No Main Injector tune up – *current time to accomplish*
  - No core cool-down – *current time to accomplish*
  - Beam line tune up only when transmission degrades, monitor with upgraded beam line BPM's – *current time to accomplish*
    Remain on stacking lattice – *current time to accomplish*
  - No waits to load Tevatron protons – *current time to accomplish*
  - Interrupt stacking only to transfer pbars – *35 seconds/transfer*
    - number of transfers, 1 or 2, driven by longitudinal emittance
  - Transverse emittance low because of small stack size (40 ma)
  - Reconfiguration minimized – timers, cooling gains and delays, etc. primarily driven by tune up
  - 'leaner' sequencer
  - Occasional failed transfers are acceptable
- Build on experience from Runs I & II
  - Beam line tune is reproducible
  - Unstacking process is mature and stable
- Now: manual set up, transfers on event
- Future: set up and transfers on event

Frequent Antiproton Transfers - Introduction



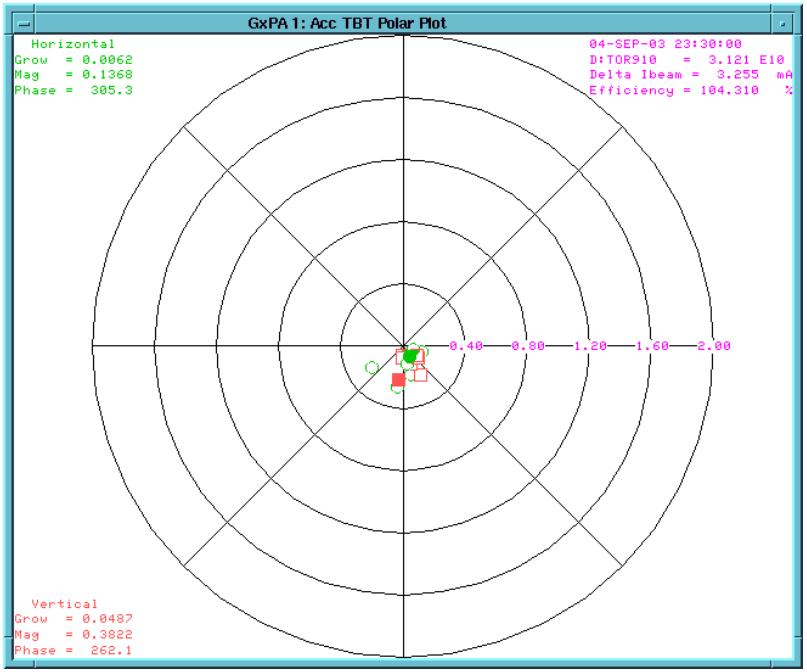
Frequent Antiproton Transfers - Introduction

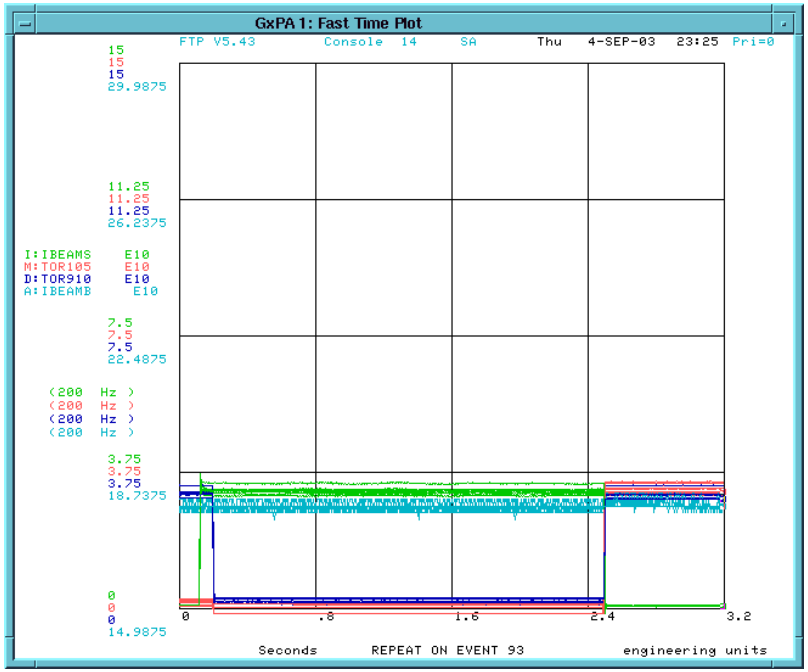
- Remaining steps from current scheme
  - Orient AP1 for 8 GeV operation
    - power supplies ramped to appropriate energies on clock events
    - Hysteresis and rest level built into ramps (now done for P1 and P2)
  - Unstack on clock event
    - As is now done on clock event (automatically) once all tuneups are complete, 'go's from all affected machines via state devices and communicated through sequencers
    - Phase displacment ramp added to move beam off stack tail

Frequent Antiproton Transfers – Beam Line Regulation

- Motivation
  - Current AP1 powering scheme – 2 sets of power supplies
  - Ramp beam line on clock events – single set of supplies
- Magnetic Field Tolerance
  - Virtually complete
- Improve regulation as necessary
  - Beam studies conducted in September
    - Reverse protons from MI to Accumulator with majority of AP1 120 GeV supplies at 8 GeV currents
    - TBT oscillations at Accumulator injection monitored
    - At least as good as with normal suite of AP1 suplpies
- Waveform generator control for AP1
  - Fermilab CAMAC 465 cards can be built to support ramping AP1 supplies
  - 15 cards needed at $800 each
  - Can be fabricated and installed in a matter of weeks
  - 2 are installed, preparations to ramp 2 supplies in progress

Frequent Antiproton Transfers – Beam Line Regulation





Proof of principle
4 September 2003

Frequent Antiproton Transfers – Software

- Support for beam line ramping
  - User friendlier 465 card application
  - Fold into current operation (with beam line tuning)
- Sequencer upgrades/other support
  - Ongoing as needed

Frequent Antiproton Transfers – Oscillation Feedback & Control

- Pbar Injection damper in MI
  - Damper operation demonstrated with protons
  - Hardware procured – reversing switches and amplifiers
    - Additional amplifiers ordered
- Quadrupole pickup in Accumulator
  - New amplifier designed and built
  - Installation planned for next access

Frequent Antiproton Transfers – Diagnostics

- Beam line BPM upgrade
  - Requirements spelled out and are being refined
  - Survey of current systems in progress
  - Resources are being identified
    - Instrumentation
    - Computing division
  - Follow on to Tevatron BPM upgrade
  - RFP for necessary 'Echotek' boards in line
- Magnetic field probes on beam line elements
  - proof of principle on an AP3 line quadrupole
  - Life testing in progress

Frequent Antiproton Transfers – BPM requirements

P1 line

Mode	Energy (GeV)	Particle	Bunch structure	Intensity	Read frequency
Reverse protons	8	protons	53 MHz up to 84 bunches	10^{11}	.1 Hz or less
Pbars to MI/RR/Tevatron	8	pbars	4 bunches of 2.5 MHz superimposed on 53 MHz	10^{10} – 10^{11}	.1 Hz or less
Stacking	120	Protons	53 MHz up to 84 bunches	10^{13}	~.5 Hz
SY120	120	Protons	slow spill 53 MHz	10^{11}	.5 – 1 sec spill
Collider protons	150	Protons	single coalesced bunch	10^{12}	

Frequent Antiproton Transfers – BPM requirements

P2 line

Mode	Energy (GeV)	Particle	Bunch structure	Intensity	Read frequency
Reverse protons	8	protons	53 MHz up to 84 bunches	10^{11}	.1 Hz or less
Pbars to MI/RR/Tevatron	8	pbars	4 bunches of 2.5 MHz superimposed on 53 MHz	10^{10} – 10^{11}	.1 Hz or less
Stacking	120	protons	53 MHz up to 84 bunches	10^{13}	~.5 Hz
SY120	P2120	protons – slow spill	53 MHz	10^{11}	.5 – 1 sec spill

Frequent Antiproton Transfers – BPM requirements

AP1 line

Mode	Energy (GeV)	Particle	Bunch structure	Intensity	Read frequency
Reverseprotons	8	protons	53 MHz up to 84 bunches	10^{11}	.1Hz or less
Pbars to MI/RR/Tevatron	8	pbars	4 bunches of 2.5 MHz superimposed on 53 MHz	10^{10} – 10^{11}	.1 Hz or less
Stacking	120	protons	53 MHz up to 84 bunches	10^{13}	~.5 Hz

Frequent Antiproton Transfers – BPM requirements

AP3 line

Mode	Energy (GeV)	Particle	Bunch structure	Intensity	Read frequency
Reverse protons	8	protons	53 MHz up to 84 bunches	10^{11}	.1Hz or less
Pbars to MI/RR/Tev atron	8	pbars	4 bunches of 2.5 MHz superimposed on 53 MHz	10^{10} – 10^{11}	.1 Hz or less

Frequent Antiproton Transfers – BPM requirements

A1 line

Mode	Energy (GeV)	Particle	Bunch structure	Intensity	Read frequency
Collider tuneup – protons from Tevatron to MI	150	protons (from Tevatron to MI)	53 MHZ up to 84 bunches single coalesced bunch	10^{10} - 10^{11}	
Pbars from MI to Tevatron	150	pbars	2.5 MHz up to 4 bunches	10^{10} - 10^{11}	.5 Hz?

Frequent Antiproton Transfers – Commissioning

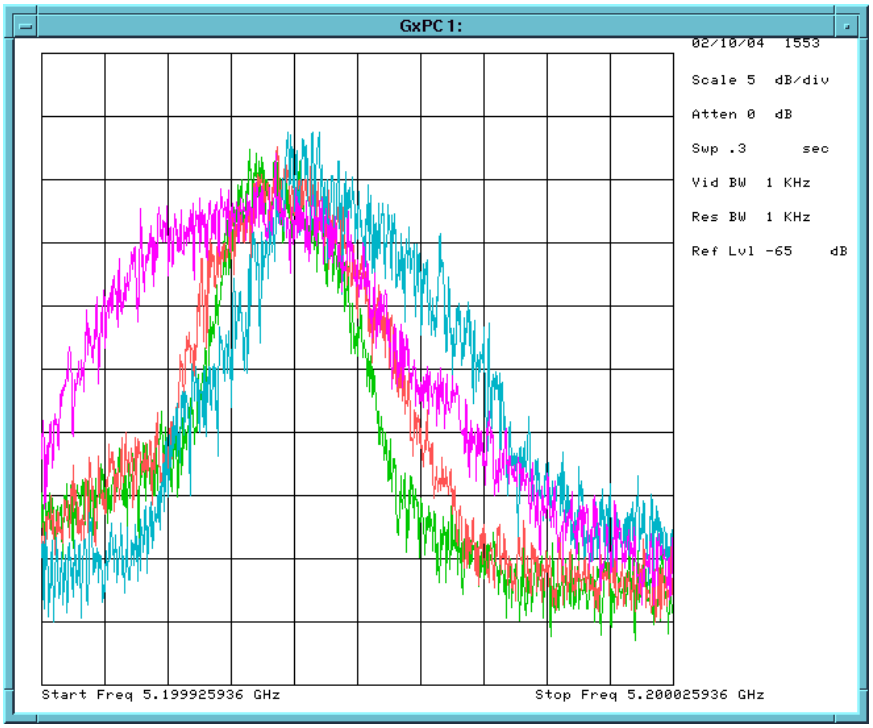
- Phased/parallel implementation
  - Implement aspects which will benefit Collider operation in the short term (pre-Recycler integration)
    - Main Injector pbar injection damper – spring '04
    - Sequencer streamlining - ongoing
    - Phase in ramped AP1 supplies – 3/04 – 9/04
  - Complete additional steps in anticipation of Recycler integration/Electron cooling/Stack Tail upgrades
    - Beam line BPM upgrade – end of CY '04
    - Software – ongoing through end of project
    - Frequent transfers – fully implemented consistent with Recycler electron cooling and Stack Tail upgrades

Frequent Antiproton Transfers – Energy Matching

- Mismatch in circumferences of machines
  - 120 GeV MI to Debuncher not optimized
  - Accumulator to MI requires frequency jump after transfer phase lock
  - 8 GeV Accumulator to Recycler requires an 'energy dip' in the MI
- New project aims to mitigate mismatches by
  - '8 GeV' defined by the Recycler
  - Allow frequency flexibility between MI and Debuncher
  - Adjust Debuncher to exploit this flexibility
  - Adjust Accumulator to remove energy dip
  - Redefine Booster extraction energy
  - Adjust transfer line 8 GeV levels
  - RF phase/frequency adjustements
    - Booster to MI
    - MI to Debuncher
    - Accumulator to MI/RR
- Technical expertise by Integration dept. (Val Lebedev et al)
- Progress to date
  - Defined in January '04
  - Scope of work in development
  - MI to Debuncher phase jump implemented this month
    - Collaborative effort with Cornell (Bill Ashmanskas)
    - Exploitation plan under development
    - Dedicated 1-shift studies period to implement – coming weeks?
    - Collaboration/MOU with Cornell begun

Frequent Antiproton Transfers – Energy Matching

Scope trace of phase jump



Intentionally moving Debuncher energy

Frequent Antiproton Transfers – Summary

- With the Recycler and electron cooling integrated into Collider operation and high stacking rates, frequent transfers will be vital
  - Unstack and transfer every 30 minutes/40 x 10^{10} stack
  - Interrupt stacking for ~ minutes
- 6-fold plan to realize automated transfers
  - Beam Line Regulation
  - Software
  - Oscillation Feedback & Control
  - Diagnostics
  - Commissioning
  - Circumference (energy) matching - NEW
- Status
  - Progress on majority of fronts