Tevatron Collimator Experience

• Introduction:
  – Tevatron Machine Parameters
  – Overview Tevatron Collimator System

• Halo Removal Performance

• Protecting Against Abort Kicker Prefires

• Collimators, Quenching and Damage
# Tevatron Machine Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Injection Energy</td>
<td>150 Gev</td>
</tr>
<tr>
<td>Flattop Energy</td>
<td>980 Gev</td>
</tr>
<tr>
<td>Number of bunches</td>
<td>36 proton &amp; 36 antiproton</td>
</tr>
<tr>
<td>Particles per bunch</td>
<td>220-260 E9 protons &amp; 30-50 E9 pbars</td>
</tr>
<tr>
<td>Total Beam Intensities at 150, 980 Gev</td>
<td>Protons 1E13, 9E12, Antiprotons 1.6 E12, 1.4E12</td>
</tr>
<tr>
<td>Orbits Types</td>
<td>Both beams in 1 vacuum pipe; Beams separated by electrostatic separators</td>
</tr>
<tr>
<td>Lowbeta steps</td>
<td>15 different lattice in 25 steps</td>
</tr>
<tr>
<td>Beta *</td>
<td>1.7m and transition to 35cm</td>
</tr>
<tr>
<td>Number of IP’s</td>
<td>2 : CDF &amp; D0</td>
</tr>
<tr>
<td>Shot setup (Fill) time</td>
<td>2 hours</td>
</tr>
<tr>
<td>Store lengths</td>
<td>~ 30 hours</td>
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</tbody>
</table>
Tevatron Collimator Overview

Motivation for Collimators for Collider II Run.

• Collider I System was:
  – Slow motion controls.
  – not a 2 stage collimator system.
  – done completely manually and took 30 min

• Collider II System desired:
  – A Halo Removal system only- To reduce losses at IP’s.
  – A new 2 stage collimation design with new “L” shaped collimators.
  – An automated system that could be initiated by Collider Sequencer software.
  – Halo removal had be complete in 5 -10 min.
Tevatron Collimator for Halo Removal

New System Build 4 new Targets and 12 new 1.5m Collimators for Halo Removal

2 Stage Collimator System

2 Stage Collimator System

Target @ ~5\sigma

Collimator @ ~6\sigma

Scattered trajectories

Proton Set 1
- D49 Tar,
- E03 & F172

Proton Set 2
- D171 Tar,
- D173 & A0

Pbar Set 1
- F49 Tar,
- F48 & D172

Pbar Set 2
- F173 Tar,
- F171 & E02

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Tevatron Shot Setup Process

- Inject 36 final protons
- Open Helix & Inject 9 Trans of 4 Pbar bunches
- Accelerate
- Goto Lowbeta
- Remove Halo
Collimator Moving Order for Halo Removal

Collimators move under 2 types of feedback:
1) Loss monitor Feedback
2) Beam intensity and Loss monitor feedback

Sequence in Time of Collimator movement for Halo Removal
Proton & Pbar Targets moving during Halo Removal

Proton bunched beam intensity

Pbar bunched beam intensity

D49 local BLM

F49 local BLM

BLM Stop Limit

Remove .5% of proton beam

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Collimator Controls Hardware

- Local Loss Monitors used for p̅bar losses
- Local Loss Monitors used for proton losses

Protons

VME based processor to conduct fast feedback
Collimator Controls Block Diagram

OAC is a Central Process that orchestrates global movement of all collimators across 4 Front Ends

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Tevatron Collimator Experience

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- **Halo Removal Performance**

- **Protecting Against Abort Kicker Prefires**

- **Collimators, Quenching and Damage**
Halo Removal Efficiency

**Halo Removal Efficiency (Protons)**

- CDF Protons
- D0 Protons

**Halo Removal Efficiency (Antiprotons)**

- CDF Antiprotons
- D0 Antiprotons

CDF Halo loss reduced ~ 10
D0 Halo loss reduced ~ 1 until Vacuum and alignment improvements

CDF Halo loss reduced ~ 20
D0 Halo loss reduced ~ 100

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Halo Removal Comments

• Success
  – New 2 stage design has proven to work with good efficiency.
  – Automation process to Halo Removal very easy and reliable

• Adapting
  – The Double scrape: Collimators stopping prematurely.
  – Alignment of Collimators; only checked 3 times a year
Halo Removal Comments - Continued

- Problems
  - Quenching while scraping - Providing a Post-Mortem account in the Collimator Front end.
  - Quenching due to automating Halo Removal.

<table>
<thead>
<tr>
<th>Date</th>
<th>Lost Store Comment</th>
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<tbody>
<tr>
<td>March 2002</td>
<td>Lost store at Halo removal due to mech stand failure</td>
</tr>
<tr>
<td>March 2002</td>
<td>Lost store at Halo removal due to mech stand failure</td>
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<tr>
<td>March 2005</td>
<td>Lost store at Halo removal due to D17 ahead of D49</td>
</tr>
<tr>
<td>March 2005</td>
<td>Lost store at Halo removal due to FE bug</td>
</tr>
<tr>
<td>March 2005</td>
<td>Lost store at Halo removal due to FE bug</td>
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</table>
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# History of Abort Kicker Prefires

<table>
<thead>
<tr>
<th>Date</th>
<th>Store #</th>
<th>kicker to prefire</th>
<th>Lattice</th>
<th>Comment</th>
<th>SVRAD0 west-inner (Rads)</th>
<th>SVRAD1 west-inner (Rads)</th>
<th>SVRAD2 east-inner (Rads)</th>
<th>SVRAD3 east-inner (Rads)</th>
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<tr>
<td>3/16/2005</td>
<td>4048</td>
<td>aak1</td>
<td>lowbeta</td>
<td>A48 and A11 in. A48 Stopped 4 bunches</td>
<td>150</td>
<td>150</td>
<td>190</td>
<td>190</td>
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<td>3/9/2005</td>
<td>4029</td>
<td>pak3</td>
<td>flattop</td>
<td>A48 and A11 not in</td>
<td>190</td>
<td>190</td>
<td>190</td>
<td>190</td>
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<tr>
<td>2/20/2005</td>
<td>3991</td>
<td>aak1</td>
<td>lowbeta</td>
<td>A46 in, resurveyed from other events</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>4/16/2004</td>
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<td>Not a store only P24 P25 No quench</td>
<td>170</td>
<td>163</td>
<td>202</td>
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<td>3401</td>
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<td>lowbeta</td>
<td>A48 in but too far from beam</td>
<td>170</td>
<td>163</td>
<td>202</td>
<td>167</td>
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<td>4/4/2004</td>
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<td>flattop</td>
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<td>0.2</td>
<td>0</td>
<td>0.4</td>
<td>0.9</td>
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<td>4/1/2004</td>
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<td>~ 100</td>
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<td>~ 80</td>
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<td>12/20/2003</td>
<td>3108</td>
<td>all</td>
<td>lowbeta</td>
<td>AO room lost power</td>
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<td>11/28/2002</td>
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<td>3/28/2001</td>
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<td>11/3/1994</td>
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<td>11/11/1994</td>
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<td>ramping</td>
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<td>flattop</td>
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<td>4/21/1994</td>
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</tr>
</tbody>
</table>

**Prefire Collimators Not installed**

**Collider Run I Prefires**

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Addition of A48 Collimator to Protect against A0 abort kicker prefires

Add .5 m Collimator at A48 to shield against prefires

A11V collimator
Already in place

A0 proton abort kickers
A0 Kicker Transient Recorder

Antiproton Abort Kickers

Proton Abort Kickers

12 bunches hitting the A0 abort block

AAK1 prefire kicks 6 bunches to CDF.
A49 Loss Paddle for Prefire 3-8-2005
Quench Data

A48U is one of the fastest quenches we have had.

Notice we did not quench A1.
Comments on Kicker Prefire and Collimators

• Tevatron did not originally design a collimator system to protect against kicker prefires.

• Once the collimator was installed, it was hard to tell if the prefired beam was hitting it.

• Once confident prefired beam hit the collimator, may need to increase length to protect downstream cold spool.

• Need a better post-mortem system to determine where all kicked bunches went.
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Collimators, Quenches and Damage

• December 5, 2003
  – First learned of a new category of quench called a “Fast Quench”
  – A Roman Pot moved into beam due to a controls error causing beam loss damaging 2 collimators and 2 spool pieces (3 correction elements)
A48 Bus Drawing – Fast Quench

Pot 3 location

A48U quenching dipoles: Looses current At .5A/msec before the abort fires
QPM Over Sample Buffer

Quenched 5 dipoles at A48; DI/Dt = .5A/msec

Development of Quench:
A48U 16msec
D48L 13.5msec
F17L 13msec
E11U 12.5 msec

Before abort

(Courtesy D. Wolff & EE Support)
July 8, 2004 – B11 Horizontal Separator Spark

Fast QPM abort would have stopped quenches in 4 other houses.

Hor orbit for F48 kick due to F4 Quench
2 msec after quench

Resulting Orbit
Due to fast quench

Estimate of Orbit growth w/ QPM Fast Abort

Fast Quench

Quench
BLM Plot from December 5 Quench

- Minimum Level to Set BLM abort level
- Fast quench could have been detected
- Dipole at d4 could have pulled abort
- Abort Kicker fired

1 frame = 2 msec

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Comments on Fast Quench

- Tevatron masks all BLM inputs during a store due to very high probability of false abort.
- Fixed the Fast Quench by QPM code; over sample and detect a large quench. Pulls abort within 2msec instead of 16msec.
- BLM upgrade is in the works to gain additional protection.
- Host of mechanisms to create fast quench
  - Separator sparks
  - Motion controlled device, Vacuum values, pots, mirrors for sync light, collimators
Comments on Fast Quench - Continued

- May 15, 2004 – Unknown cause – Damaged E03 collimator again

- With a scan found it damaged and ran 3 months with it damaged.
Summary

- Collider II Halo removal system has worked well as far as halo removal efficiency and automatic process.
- Still working on improving collimator and post-mortem system for abort kicker prefires.
- Dec 5, 2003 quench and damage was “wake up call” to rethink Tevatron beam loss protection.
- Learned details of new category of “fast quenches”.
- Implemented new QPM code to abort on detection of quench within 1-2msec, instead of 16msec. But still mask BLM during stores due to false aborts.
- Reviewed all motion controlled devices with appropriate Abort.
  - Vacuum abort upgrade done.
  - Pot motion upgrade done.
- Insufficient process for gathering systematic and automatic data for analyzing past quenches involving beam loss. Working on better record keeping of data for every quench.
- Provided input to new BLM system coming in 2005.