Tevatron Status and Recent Improvements

R. Dixon
Overview

- Overview of Fermilab Accelerator Complex
- Collider Run II Performance
  - Machine Performance
  - Luminosity Summaries
  - Performance Projections
  - Summary of Improvements and Optimizations
Total Run II Integrated Luminosity

Integrated Luminosity 5009.46 (1/pb)
Yearly Luminosity Curves

Integrated Luminosity (1/pb)

Days since October 1

Integrated Luminosity (1/pb)

- Fiscal Year 09
- Fiscal Year 08
- Fiscal Year 07
- Fiscal Year 06
- Fiscal Year 05
- Fiscal Year 04
- Fiscal Year 03
- Fiscal Year 02
- Highest
- Lowest
Typical Reliability Issues

FY08 Integrated Luminosity 1799.38 (1/pb)

Integrated Luminosity (1/pb) vs. Time (Nov-2007 to Sep-2008)

- Startup Linac
- Booster
- Tev Helix
- Tev Mag.
- Lithium Lens
- MP02 Booster Kicker

Fiscal Year 08 Integrated Luminosity
- Highest
- Lowest
Luminosity Projection Curves for Run II

Projected Integrated Luminosity in Run II (fb⁻¹) vs time

- FY08 start
- FY10 start
- Real data for FY02-FY07

Integrated Luminosity (fb⁻¹)

- 8.75 fb⁻¹
- 7.29 fb⁻¹

Highest Int. Lum
Lowest Int. Lum

ICFA October, 2008 - R. Dixon
Inputs for FY08 and FY09 – Sc. IV (optimistic1)

Assuming 21 hour long stores and 6 pbar transfer shots between stores

- Number of protons per bunch: $260, 270, 270, 270, 270, 270, 270 \times 10^9$
- Luminosity Density @ $100 \times 10^{10}$: 90.32, 92.126, ..., 92.126 $\mu$b$^{-1}$/sec
- Luminosity Density @ $300 \times 10^{10}$: 190.34, 194.147, ..., 194.147 $\mu$b$^{-1}$/sec
- Init Tevatron Lifetime @ 80 $\mu$b$^{-1}$/sec: 7.07, 7.14 hours
- Init Tevatron Lifetime @ 160 $\mu$b$^{-1}$/sec: 6.59, 6.65, ..., 6.65 hours
- HEP store hours/week: 110, 120, 120, 120, 110, 120, 120, 120 hours
- Acc-Rec Transfer Efficiency @ $0 \times 10^{10}$: 90, 92, ..., 92%
- Acc-Rec Transfer Efficiency @ $300 \times 10^{10}$: 90, 91, ..., 91%
- Acc-Rec transfer time: 0.19, 0.16, ..., 0.16 hours
- Recycler lifetime: 500 hours
- Recycler mining efficiency: 93.8%
- Peak stacking rate: 22, 25, 27, ..., $27 \times 10^{10}$/hour
- Half rate stack size: 210, 250, ..., $250 \times 10^{10}$
- Maximum stack size: 420, 500, ..., $500 \times 10^{10}$
- Timeline Utilization Factor: 80, 83, ..., 83%
- Accumulator leftover factor: 10%

With above inputs we should expect $\sim 3545 \text{ pb}^{-1}$ in 2 years
Inputs for FY08 and FY09 – Sc. IV (optimistic1)

Assuming 21 hour long stores and 6 pbar transfer shots between stores

- Number of protons per bunch: 260, 270, 270, 270, 270, 270 x 10^9
- Luminosity Density @ 100 x 10^{10}: 90.32, 92.126, ..., 92.126 \mu b^{-1}/sec
- Luminosity Density @ 300 x 10^{10}: 190.34, 194.147, ..., 194.147 \mu b^{-1}/sec
- Init Tevatron Lifetime @ 80 \mu b^{-1}/sec: 7.07, 7.14 hours
- Init Tevatron Lifetime @ 160 \mu b^{-1}/sec: 6.59, 6.65, ..., 6.65 hours
- HEP store hours/week: 110, 120, 120, 120, 110, 120, 120, 120 hours
- Acc-Rec transfer time: 0.19, 0.16, ..., 0.16 hours
- Acc-Rec transfer efficiency @ 0 x 10^{10}: 90, 92, ..., 92%
- Acc-Rec transfer efficiency @ 300 x 10^{10}: 90, 91, ..., 91%
- Recycler lifetime: 500 hours
- Recycler mining efficiency: 93.8%
- Peak stacking rate: 22, 25, 27, ..., 27 x 10^{10}/hour
- Half rate stack size: 210, 250, ..., 250 x 10^{10}
- Maximum stack size: 420, 500, ..., 500 x 10^{10}
- Timeline Utilization Factor: 80, 83, ..., 83%
- Accumulator leftover factor: 10%

With above inputs we should expect \sim 3545 pb^{-1} in 2 years
Inputs for FY08 and FY09 – Sc. IV (optimistic)

Assuming 21 hour long stores and 6 pbar transfer shots between stores

- Number of protons per bunch: 260, 270, 270, 270, 270, 270, 270 x 10^9
- Luminosity Density @ 100 x 10^{10}: 90.32, 92.126, ..., 92.126 μb^{-1}/sec
- Luminosity Density @ 300 x 10^{10}: 190.34, 194.147, ..., 194.147 μb^{-1}/sec
- Init Tevatron Lifetime @ 80 μb^{-1}/sec: 7.07, 7.07 hours
- Init Tevatron Lifetime @ 160 μb^{-1}/sec: 6.59, 6.65, ..., 6.65 hours
- HEP store hours/week: 110, 120, 120, 120, 110, 120, 120, 120 hours
- Acc-Rec Transfer Efficiency @ 0x10^{10}: 90, 92, ..., 92%
- Acc-Rec Transfer Efficiency @ 300x10^{10}: 90, 91, ..., 91%
- Acc-Rec transfer time: 0.19, 0.16, ..., 0.16 hours
- Recycler lifetime: 500 hours
- Recycler mining efficiency: 93.8%
- Peak stacking rate: 22, 25, 27, ..., 27 x 10^{10}/hour
- Half rate stack size: 210, 250, ..., 250x10^{10}
- Maximum stack size: 420, 500, ..., 500x10^{10}
- Timeline Utilization Factor: 80, 83, ..., 83%
- Accumulator leftover factor: 10%

With above inputs we should expect ~ 3545 pb^{-1} in 2 years
Average Store Hours FY08

FY Average Store Hours per week 105.80

- FY Average Store Hours per week
- 10X Average Store Hours per week
Luminosity Data

Weekly Integrated Luminosity (1/pb)

Days since October 1

Fiscal Year 08 • Fiscal Year 07 • Fiscal Year 06 • Fiscal Year 05 • Fiscal Year 04
Fiscal Year 03 • Fiscal Year 02 • Design • Base
Records During the Past Year

Stacking: $27.01 \times 10^{10}$/hour on June 3, 2008

Record Initial Luminosity:

$3.18 \times 10^{32} \text{ cm}^{-2} \text{ sec}^{-1}$ on July 5, 2008

Record Delivered Luminosity for one week:

$57.5 \text{ pb}^{-1}$ on June 30, 2008

Record Delivered Luminosity for one month:

$221 \text{ pb}^{-1}$ May 2008 (Fourth best month = 217)
Improvements

- **Reliability**
  - Overall Machine Reliability-- weaknesses continue to be found and mitigated

- **Tevatron reliability**
  - Quench Protection
  - Fewer quenches

- **Better instrumentation**
  - Beam Position Monitors all around

- **Careful alignment and realignment of the Tevatron**

- **Increased antiproton stacking rate**
  - 15 ma/hr --> 27 ma/hr peak

- **Electron cooling of antiprotons in the Recycler**
  - Single largest luminosity gain

- **Optimizing Running Conditions**
  - Improve transfer efficiencies, transfer times, shot setup times
  - Optimize store length and initial luminosities
  - Optimize beam brightness
## Store Terminations

<table>
<thead>
<tr>
<th>Year</th>
<th>Stores</th>
<th>Normal Terminations</th>
<th>% Normal Terminations</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>186</td>
<td>55</td>
<td>30%</td>
</tr>
<tr>
<td>2004</td>
<td>166</td>
<td>110</td>
<td>66%</td>
</tr>
<tr>
<td>2005</td>
<td>243</td>
<td>170</td>
<td>69%</td>
</tr>
<tr>
<td>2006</td>
<td>171</td>
<td>107</td>
<td>63%</td>
</tr>
<tr>
<td>2007</td>
<td>220</td>
<td>177</td>
<td>80%</td>
</tr>
<tr>
<td>2008</td>
<td>304</td>
<td>262</td>
<td>86%</td>
</tr>
</tbody>
</table>
Average Roll all Magnets
Optimizing Run Conditions

- **Run Coordinators**
  - Report directly to me
  - All have operations backgrounds/work closely with operations department
  - Live with machine 24 hours per day
  - Make all decisions
    - Meet with me everyone morning for guidance
    - Meet with AD machine coordinators and Experiment coordinators every morning to make a plan for the day

- **Run Coordination Support**
  - Theory support
    - Mike Syphers (Assist. Div Head)
    - APC personnel as needed
  - Shot Data Analysis Group (in Headquarters)
    - Vaia Papadimitriou
    - Mary Convery
    - Software support from Controls Department
  - Rest of the Accelerator Division as needed
2007 vs 2008 Running

Avg. Store Length = 23 hours

44 pb\(^{-1}\)

Avg. Store Length = 15 hours

56 pb\(^{-1}\)
Tune Diagram

- Resonance Lines in tune space indicate potential problem spots for operation

- Tev operation:
  - $\sim 20.59, 20.58$

width $\sim 0.025$
Lifetimes during 1st two hours

Data available thru SDA; thanks -- J. Annala

~1000 stores
Cold Pbars...

Tune Distributions

\[ \frac{\alpha_p}{\sigma_p} = \frac{1}{2} \]

previous curve, for equal sizes (for comparison)

\[ = 0.025, \text{ for 2 IR's} \]
Optimal?

Tune Distributions

Roughly equal tune spreads in both beams
--> does this optimize lumi lifetime??
Controlling the Brightness of the Beams

- Antiprotons and “jacked” by PBJ after injection into the Tevatron to increase their emittance (decrease brightness)

- Now experimenting with proton brightness
  - Better quality beam from Booster
  - More intense beam from Booster that is scraped in the Main Injector resulting in beam with smaller emittance
  - This led to record store and a number of other stores above the curves
Ongoing Improvements

- Stacking Rate
  - Equalizer to mitigate core heating ✓
  - Debuncher notch filter
  - ~12 equalizers on the Debuncher, stacktail, and core

- Improve transfer efficiencies and times ✓

- Decreasing shot setup time by loading protons 2 bunches at a time

- Orbit stabilization in the Tevatron ✓

- Controlling Antiproton brightness in the Tevatron due to improvements in the Recycler ✓
  - Antiprotons emittances are blown up slightly to improve proton lifetimes during the store

- Improving proton brightness
  - Improve beam quality coming out of Booster
  - Scraping in Main Injector

- Optimize Running Conditions
  - Store Length
  - Proton/Antiproton brightness
Run II Strategy

Maximize the delivered luminosity

Continue

- to make small improvements with short payback times
- to Optimize Running Conditions to take advantage of improvements
- to increase overall machine reliability
Summary

Collider Performance continues to improve

- Making small improvements to stacking
- Improving efficiencies, transfer times, and shot setup times
- Improving reliability
- Optimizing running modes