Tevatron Accelerator and CDF Detector

Particle Physics at High Energy Frontier

Yukawa Institute for Theoretical Physics, Kyoto University
March 17-18, 2003

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Tevatron

Fermilab Tevatron: \( R = 1 \text{ km} \), \( E_{\text{beam}} = 1 \text{ TeV} \)
Run II Upgrade

- Main Injector (150 GeV proton storage ring) replaces Main Ring: x 5
- New stochastic cooling system for antiprotons
- Permanent magnet Recycler ring for antiprotons: x 2
  - Will be integrated this summer
- Higher Energy: 900 -> 980 GeV
- Number of bunches: 6x6 (3500 ns) -> 36x36 (396 ns)
- After 2005: electron cooling etc.: x 2

Run II started in April 2001
Stable physics running established early 2002
Accelerator Complex

- P injection to MI
- AP production
  - cooling
  - accumulating
- Coalesced P bunches: MI -> Tevatron
- AP from pbar ring: MI -> Tevatron
- AP -> recycler
Tevatron Luminosity since June 2002

- 151 stores
- 170 pb\(^{-1}\) to each detector (130 pb\(^{-1}\) recorded)
- Increase in luminosity from 20e30 to 36.9e30
- Run I record of 36.9e30 broken on 7/26/2002
Beam Intensities

Number of protons
- Mostly steady

Number of antiprotons
- Increase factor of $\sim 2.5$
# Operations Status and Plan

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Current Status</th>
<th>FY03 Goal</th>
<th>Run II Goal</th>
<th>(Units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Luminosity</td>
<td>3.2e31</td>
<td>6.6e31</td>
<td>33e31</td>
<td>cm(^{-2})sec(^{-1})</td>
</tr>
<tr>
<td>Integrated Luminosity</td>
<td>6.0</td>
<td>12.0</td>
<td>70.0</td>
<td>Pb(^{-1})/week</td>
</tr>
<tr>
<td>Protons/bunch</td>
<td>170e9</td>
<td>240e9</td>
<td>270e9</td>
<td></td>
</tr>
<tr>
<td>Antiprotons/bunch</td>
<td>22e9</td>
<td>31e9</td>
<td>135e9</td>
<td></td>
</tr>
</tbody>
</table>
For Higher Luminosity

Current problems:

- Emittance growth on transfers
- Instabilities
- Aperture limitation for beam-beam separation
- Pbar coalescing, bunch length
- Reliability
- Alignment, vacuum
- ...
- Integrate Recycler into operations
Run II CDF Detector

Faster detector
Better Performance
Most components
Renewed:
- Tracking
- Calorimetry
- TOF
- Muon system
- Front-end, Trigger
- Software
CDF Tracking system

- Silicon: SVX, ISL, L00
- Drift chamber: COT (Central Outer Tracker)

\[ |\eta| < 1.0 \]
(COT, ISL, SVX)
\[ \delta p_T / p_T^2 \sim 0.1\% \]

\[ 1.0 < |\eta| < 2.0 \]
(ISL, SVX)
\[ \delta p_T / p_T^2 \sim 0.4\% \]
CDF II Silicon System

- **Layer00**
  - 1 single-sided layer
  - $1.35cm < R < 1.65cm$
  - Improve IP resolution

- **SVX II**
  - 5 double-sided layers
  - $2.5cm < R < 10.6cm$
  - 3D tracking

- **ISL**
  - 2 double-sided layers
  - $20cm < R < 28cm$
ISL Side View
Silicon Detector Status

Now operating >90% of silicon

Slow commissioning was due to:

- Optical transmission problem
- Delays in PS deliveries, and radiation-related PS failures
- Cooling trouble in the central ISL
Silicon Performance (1)

Efficiencies:

Signal to Noise > 10

Single Hit $\varepsilon > 99\%$
Silicon Performance (2)

Alignment: $d_0$ vs. $\phi$

before and after

SVX II resolution residual $\sim 11 \mu m$
COT (Central Outer Tracker)

- Small (open) cells, Maximum drift distance = 0.88cm
- Maximum drift time = 100ns
- 8 Super Layers x 12 wires = 96 points
COT Tracking

- $\sigma = 175 \, \mu m$
- Maintain Run I momentum resolution
Z Resolution

$\Delta Z$ distributions for $J/\psi \rightarrow \mu\mu$ tracks

- **COT only**
  - Nent = 46428
  - Under = 20.42
  - Over = 33.92
  - Chi2 / ndf = 833 / 197
  - $p^0 = 0.992 \pm 0.093$
  - $p^1 = 0.0004225 \pm 0.00519$
  - $p^2 = 0.797 \pm 0.004408$

- **High quality SVX tracks**
  - Nent = 4914
  - Under = 12.33
  - Over = 13.85
  - Chi2 / ndf = 181.1 / 134
  - $p^0 = 477.4 \pm 3.986$
  - $p^1 = -0.0002965 \pm 0.0002571$
  - $p^2 = 0.01441 \pm 0.0002629$
Calorimeters

Endwall Calorimeter

New Plug Calorimeter
Plug Upgrade Calorimeter

- Scintillator + WLS with lead(EM)/steel(Hadron)
- Fast and hermetic (1.1 < |\(\eta| < 3.6|)
- Segmentation: \(\Delta\phi = 15^\circ, 7.5^\circ, \Delta\eta = 0.1 \sim 0.6\)
Muon Detector Upgrade

- Increase eta and phi coverage,
- Higher rate capabilities
- Better trigger shielding

CDF total muon coverage increases by about 50%
TOF Detector

TOF resolution : 110ps
(getting close to design 100ps)

Tag Kaons in $\phi \rightarrow KK$
Run II Trigger System

- **Level 1** (5.5 µs latency)
  - Hardware Trigger
  - 50 kHz accept rate
- **Level 2** (asynchronous)
  - Nominal 20µs decision time
  - Mostly hardware trigger
  - 300 Hz accept rate (→ 1kHz)
- **Level 3**
  - Linux boxes
- “Deadtimeless”

~75Hz, 20MB/s
XFT (eXtremely Fast Tracker)

- Track trigger in Level 1
- High efficiency / purity
- $\Delta P_T/P_T^2 = 1.65\%$
- Angular resolution = 5.1 mrad

Better than design

1.5 GeV
4 GeV
8 GeV
SVT (Silicon Vertex Trigger)

- Level 2 trigger using SVX hits and tracks from XFT trigger
- look for large $d_0$ in 2D
- $d_0$ resolution: $\sigma = 48 \mu m$ incl. $\sim 33 \mu m$ beamspot

![SVT Impact Parameter distribution](image)

![Mass spectrum](image)
Run IIb Upgrade Plan

- SVX replacement
  - Single-sided
  - Rad-hard
- Central preshower detector
  - scintillator-based
- TDCs for COT
- Level 3 trigger
Summary

- Significant luminosity improvement
  - Still need to continue progress
- CDF detector performing well
- Early physics results are ready to present