The Run IIb CDF Detector Upgrade Project

Patrick T. Lukens
Fermilab
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CDF for Run IIb

- As in Run I, CDF’s strength lies in its tracking system
  - Good momentum precision, lepton ID
  - Good vertex precision – b hadron identification

- Operating conditions for Run IIb:
  - Maximum instantaneous luminosity of $4-5 \times 10^{32} \text{cm}^{-2} \text{s}^{-1}$.
  - Integrated luminosity of as much as 15 fb$^{-1}$.

- CDF’s capabilities must be retained in these conditions
Run IIa silicon system

- Radiation damage tests and rate measurements allow us to predict the lifetime of the SVXII.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Lifetime (fb⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>7.4</td>
</tr>
<tr>
<td>0</td>
<td>4.3</td>
</tr>
<tr>
<td>1</td>
<td>8.5</td>
</tr>
<tr>
<td>2</td>
<td>10.7</td>
</tr>
<tr>
<td>3</td>
<td>23</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
</tr>
</tbody>
</table>

- We are forced to replace the inner layers.

Silicon detector end view
The instantaneous luminosity of run IIb produces:

- Occupancy problems - fake triggers and overlapping events
  - An issue for the preshower and track trigger
- Data collection rate problems - handling the data volume/rate
  - Impacts the data acquisition
  - Exceeds the readout capacity of our TDCs
The CDF Run IIb Project replaces key elements needed for maintenance of the high $P_T$ program.

To maintain CDF as a viable Higgs search experiment for Run IIb we will:

- Replace the Silicon Detector
- Upgrade the Calorimeter
- Upgrade the Data Acquisition and Trigger system

This program was approved by the Physics Advisory Committee.

- June, 2002 meeting
SVX Replacement

- The inner six layers of the silicon system are tightly coupled mechanically.
  - Disassembly would be time consuming and very risky.
  - Many parts are obsolete.
- This motivates a complete replacement with a new detector
  - ISL is retained, inner portion (SVX II) will be replaced.
  - Requires roll out of the central detector

ISL Space Frame
The replacement detector is being designed to be simple, and should be relatively quick to build.

- Based on single sided detectors
- Readout chip is common with D0, manufactured in a standard process.
- One structure is used for most of the detector
- Compatible with existing systems
  - Data acquisition
  - Cooling
Run IIb silicon system

- All inners layers will be replaced.
- New detector is designed for quick construction
- A basic module - the “stave” will be built
- This structure will populate most of the detector volume
- This gives the advantage of fewer different parts than the current detector
Silicon Detector - Run IIb

- Single sided sensors will be used for Run IIb.
  - Production readiness review was held in Feb.
  - Sensors have been ordered
- Axial and small angle stereo layers will be joined in a single structure – this is used for layers 1-5.
- Layer 0 (innermost) will be axial only, and a different structure.

Stave layout

Mini Portcard
Hybrids
Chips
Axial Sensors
Stereo Sensors
SVX4 chip

- 1st full prototype
  - submitted - April ’02
    - received June ‘02
  - Tested at LBL and FNAL
  - No major problems found
  - Corrections for bow and channel to channel variation – fixed in new chip
  - Yield looks very good, ~85%
  - Radiation tests showed no problems

- Next Submission is in progress
  - Could be the final version
Module

- Ten modules fully assembled
- Hybrids work with No problems!
- Module tests at LBL in progress, FNAL (FCC) with full DAQ

Noise with 0, 1, and 2 sensors connected to the readout
Tests are being done at LBL and FNAL.

Full DAQ and deadtimeless operation are being tested.
● Preshower expected to suffer high occupancy and aging effects in Run IIB.
  ➢ Gas chamber system – most replaced for run II
  ➢ Occupies inner surface of central calorimeter
● Expected to provide 5-10% Jet Energy Resolution improvement, part of the 20-30% needed improvement for the Higgs search.

Central Calorimeter extracted for maintenance
Preshower Progress

- Replacement Preshower uses scintillator tiles
- Optical fiber readout with 16 channel phototubes
  - Same phototube and light collection used in the endplug calorimeter
  - Not a new technology – reuses existing electronics.
- Full-scale mechanical prototypes built at ANL.

Detector mockup and Fiber routing scheme at MSU
Prototype tests at ANL, Pisa, Rockefeller for uniformity and light yield.

Uniform Response better than 10%
Meets the spec

12 photoelectrons/MIP
Meets the spec
Electromagnetic Timing

- Electromagnetic timing needed to reject photon backgrounds from cosmic rays, in new physics searches such as SUSY.

- Timing system will take electromagnetic calorimeter signals to TDCs
  - Dynode signals taken from the endplug cal.
  - Anode signals go to a splitter in the central cal.

- Working testbench and vertical slice test shows system works as designed.

- Working prototypes of all components in hand

- Signal splitting has no degradation of the energy measurements
The DAQ/Trigger upgrades planned are driven exclusively by the Run IIb trigger and data acquisition needs to carry out our high-$p_T$ physics program.

Our current level of understanding is based upon:

- Run IIa data: $\mathcal{L} \leq 2 \times 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$, $\sim 1$ interaction per crossing
- Run I data: $\mathcal{L} \sim 2 \times 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$, $\sim 2$ interactions per crossing

We are extrapolating to Run IIb:

- $\mathcal{L} = 2 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ w/396ns bunch spacing ($\sim 5$ int/beamX)
- $\mathcal{L} = 5 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ w/132ns bunch spacing ($\sim 5$ int/beamX)
- Due to significant uncertainties in extrapolation, and a desire to be prepared for success, we have evaluated our system for: $\mathcal{L} = 4 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ w/396ns bunch spacing ($\sim 10$ int/beamX)
Trigger Strategy

- Focus on Higgs & high $p_T$ searches
  - Know that triggers needed for these modes will allow for many beyond Standard Model searches

- General requirements:
  - High $p_T$ electrons and muons
    - Associated $WH/ZH$ modes, also $t \to Wb$
  - Missing $E_T$ triggers
    - $ZH$ with $Z \to \nu \nu$, modes with taus
  - $b$-jet triggers
    - $H \to bb$, $b$-jets tagged by displaced tracks
  - Calibration triggers
    - $Z \to bb$, $J/\psi \to \mu^+ \mu^-$, photons
Data Acquisition

- Our current data acquisition is specified to operate at a level 2 trigger accept rate of 300 Hz.
- The Run IIb high $P_T$ program requires at least 750 Hz capability.
- Upgrades are needed to
  - Event builder switch – collects data from many sources, forms an event, and moves it to the level 3 computers
  - Time to digital converters – TDCs used for the COT have an inherent readout limit at about 300 Hz.
Triggers

- The high event occupancy for Run IIb drives up the rate of fake triggers in the tracking system
  - Fast track trigger (XFT) requires upgrading
- The duration of the run motivates the need for maintenance of processors that will become obsolete, and uneconomical to maintain
  - Level 2 decision crate
  - Level 3 processors (PCs)
    - High occupancy will also drives a need for greater processing power
Trigger/DAQ Upgrades for Run IIb

**General considerations:**

- upgrades “targeted” to specific needs
  - e.g. COT TDCs replaced, but remaining COT readout (ASDQ, repeaters) unmodified
- retain existing infrastructure
  - cables, crates unchanged
  - I/O protocols, timings retained
  - upstream/downstream components unchanged
- upgrades plug compatible with existing components
  - take advantage of knowledge & experience
  - will aid in commissioning
Schedules

- The silicon detector sets the critical path for the project.
- A base estimate schedule has been written, which the Level 2 managers feel accurately reflects the length of time it will take to build the detector.
- Explicit contingency tasks have then been included in this base schedule.
- Base end date is 31 May, 2006
  - This contains 39 weeks of schedule contingency (~30%).
Installation

- The project does not include installation of the detector components in its scope.
  - Project completion is decoupled from Tevatron operations.
  - In this strategy, project completion can be independent of Run IIa operations.
- However, we will manage the installation activities.
  - Resource loaded schedule will be maintained for it.
- We currently plan a 34 week shutdown for the silicon replacement.
  - Installations for preshower and the various cabling tasks occur within that period.
## Installation Milestones

<table>
<thead>
<tr>
<th>Task</th>
<th>Date Completed</th>
<th>Lead/Lag (weeks)</th>
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<tbody>
<tr>
<td>Drop Interlocks, Access to Collision Hall</td>
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<tr>
<td>Central Detector Ready to Roll Out</td>
<td>5/17/2006</td>
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<td>Install Silicon Interlock Hardware</td>
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<td>Silicon Detector Ready for Installation</td>
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<td>Silicon Ready for Power</td>
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<tr>
<td>Ready for Collisions</td>
<td>11/29/2006</td>
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</table>
Foreign Contributions

- Japan
  - Sensors and analog cables for silicon layer 0
  - Phototubes and bases for the calorimeter
- Italy
  - Chip engineering, power supplies for silicon
  - ASDs, fibers, scintillator for calorimeter
- Taiwan
  - SVX4 chip manufacture
- Discussion are underway with Korea and Canada for contributions to silicon.
## Funding Required

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<th>Cost (AY $K)</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>Totals</th>
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<td>$9,841</td>
<td>$11,333</td>
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<td>$30,383</td>
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### Funding (AY $K)

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<tr>
<th></th>
<th>2002</th>
<th>2003</th>
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<td>$9,841</td>
<td>$8,544</td>
<td>$1,113</td>
<td>$30,383</td>
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- Costs include G&A and Contingency
- All costs/funds are in AY $K
Project Status

- In addition to the PAC, the CDF Run Ilb Detector Upgrade Project has been reviewed by:
  - Director’s Cost and Schedule Review – Apr. and Aug, 2002 (E. Temple)
  - Baseline Readiness Review – Sep., 2002 (D. Lehman)
  - External Independent Review – Nov., 2002 (Jupiter Corp.)

- Critical Decisions 1, 2, and 3a were granted in Dec, 2002 by the Office of Science
  - Completed by AEP signoff in Feb, 2003
Project Status

- CD-3a allows us to spend equipment money for project construction through FY 2003.
- Several significant procurements have been placed, or are close
  - Second SVX4 readout chip submitted
  - Silicon Sensors for the outer layers
  - Preproduction Hybrids for the outer layers
  - First batch of photomultipliers for the preshower detector
- The project is moving ahead with construction.
We have developed a well focused program to upgrade CDF for the Run IIb era. This project will maintain the high $P_T$ physics program, and enable CDF to continue as a Higgs search experiment until the LHC era begins. The project has been extensively reviewed. The technical choices, cost, and schedule have been endorsed by a variety of reviewers. Construction has begun.