Status of CDF Tracking

Steve Nahn
Yale University/CDF
CDF Run II Tracking

- **Subject Matter**
  - Session: “R&D on Future”
  - Abstract: “Current CDF Silicon”
  - Title: “CDF Tracking”

- Hardware of CDF Tracking with emphasis on Silicon and lessons learned

- **CDF Run II Motivations**
  - Find b quarks for top, Higgs, CKM, Exotica, …
  - Maintain pT resolution for EW…
  - Increase coverage

- **Talk Roadmap**
  - Tour of CDFII Silicon and Commissioning
  - Si Performance
  - Glance at Wire Chamber
  - Trigger Innovations
  - Physics
8 Layers, 704 ladders, 722432 Channels

- SVXII: 5 Double Sided Layers
  - 3 $90^\circ$, 2 $1.2^\circ$, $2.5 < r < 10.6$ cm, $l = 90$ cm
  - 360 ladders, 405505 Channels
  - 3D tracking, Displaced Track L2 trigger

- ISL: 2 Double Sided Layers
  - $1.2^\circ$ $r =$ 20, 28 cm, $l =$ 1.9 m!
  - 296 ladders, 303104 Channels
  - Hits out to $|\eta| = 2$

- Layer 00 (L00): 1 Single Sided Layer
  - 48 ladders, 13824 Channels
  - Improves IP resolution
Construction Pictures
Si DAQ (common)

- **SVX3D Chip**
  - 128 Ch x 46 Capacitor Ring
  - “Deadtimeless”-Acquires during Readout
  - Features: Common Noise suppression, Sparsification…

- **Portcards**
  - Control: 1⇒5 Fanout
  - Data: Electrical ⇒ Optical

- **Custom VME DAQ and PS**

- **Cooling, Interlocks, Radiation Protection, etc**
Silicon Integration and Installation

L00 Into SVXII

SVXII into ISL

Final Assembly

Installation

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Silicon Commissioning Issues

- **Vendors**
  - Delay, failure of PS

- **Realistic Testing**
  - ISL blocked cooling
  - L00 noise issues
  - Optical problems

Get to operating conditions ASAP

- **Beam**
  - Chip Damage
  - VME PS failure

Characterize failure modes before Installation

- **Currently 90%/80% and stable**
Performance of Silicon (1)

- **Signal to Noise > 10**

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

- SVXII Alignment
  - $d_0$ vs. $\phi$ before and after

- SVXII 2 Strip Resolution
  - Deconvolute pointing resolution
    - residual $\sim 11 \, \mu m$
  - Track by track pull has $\sigma = 1$
CDF Central Outer Tracker

- More Hits on tracks
  - $5 \times$ Run I sense wires
  - $2 \times$ Run I Stereo layers
- Uniform Drift Field
- Maintain Run I momentum resolution

Resolution = 175 $\mu$m

\[
Fit = p_0 e^{p_1 x} + p_2 x + \frac{x^2}{p_4}
\]

$p_0 = 1.966 \times 10^5$
$p_1 = -35.16$
$p_2 = 4.25 \times 10^5$
$p_3 = -0.009 \times 10^4$
$p_4 = 0.0175$

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Trigger Innovations

- **COT Tracking at L1**
  - Feeds CAL, Muon, and Two-Track triggers

- **Secondary Vertex Trigger**
  - Combines Silicon Hits with L1 tracks, looks for large $d_0$ in 2D
Calibration from Physics

- $J/\psi$

- $Z_s$, $W_s$

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$ct = 458 \pm 10 \pm 11 \mu m$

COT: $\frac{\sigma_p}{p_i^2} < 0.13\%$
B Physics from CDFII

\[ M(\psi(2S)) = 3686 \pm 0.54 \text{ MeV}/c^2 \]
\[ M(B^0) = 5279.8 \pm 1.9 \pm 1.4 \text{ MeV}/c^2 \]
\[ M(\psi(2S)) = 3686 \pm 0.54 \text{ MeV}/c^2 \]
Summary

- **CDF Run II tracking performing well**
  - Si detector is producing clusters and tracks
  - Trigger innovations enhancing physics content of data
  - CDF tracking-based results being presented at ICHEP2002

- **Light at the End of the Tunnel...**
  - Exiting Commissioning phase, entering Maintenance
  - Getting to the small and subtle problems is progress
  - Lessons learned about vendor dependencies, realistic testing, and probing failure modes while not entombed

- **Still fair amount of work yet to do**
  - Most of the remaining problems are the hard ones…
  - New things appear from time to time
Support Slides Follow this one
Charge correlation (ISL)
All detector types peak at roughly the same timing!

(n- & p-side responses different here due to timing problem in FIB sequence, later fixed.)
Unable to cool central part of ISL:

- Solid blockage experienced
- Appears at Al elbows (glue blockage seen with boroscope)
- Laser successfully remove glue 10/12 lines so far, finish in Oct 2002.
Optical Problems

- **Largest single source of problems**
- **Time consuming to fix (requires Access)**
  - Light Level too low: Increase voltage
    - *Caviat: voltage shared by 5 ladders x 9 bits*
  - Light Level too high: Introduce attenuation
    - *Caviat: Attenuation shared by 9 bits*
  - Light level OK: Bad connectivity of TX
- **Solutions at the RX side are being implemented**
Beam Incidents

- During Oct 01 Shutdown, found new failure mode consistent with Analog power not getting to a chip on a ladder
  - Suspected thermal cycles mechanically breaking connection, or perhaps anomalous high current states blowing bonds

- March 30, 2002 Beam incident damages 6 single chips on 6 different ladders in a similar fashion
  - Saw high currents on other voltage lines etc
  - Suspect high DOSE RATE causes failure

- Test beam tests failed to reproduce the symptoms
  - Fell back to “Only the strong survive”
  - Required new interlocks on Beam and tighter constraints on beam conditions for safe operation
Connecting the full detector

Intensive pre-testing of cables, power supplies, optical components, cooling and interlocks took place before connection of the real detector... nonetheless:

Connecting the full detector took 7 weeks, 24 hrs/day, 4 people at a time!
### CDF Run IIa Silicon

<table>
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<tr>
<td>00</td>
<td>1.35/1.62</td>
<td>25</td>
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<tr>
<td>0</td>
<td>2.5/3.0</td>
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<td>90</td>
<td>141</td>
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<td>1.2</td>
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<tr>
<td>5 Forward</td>
<td>19.7/20.2</td>
<td>112</td>
<td>1.2</td>
<td>112</td>
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<tr>
<td>5 Central</td>
<td>22.6/23.1</td>
<td>112</td>
<td>1.2</td>
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<tr>
<td>6 Forward</td>
<td>28.6/29.0</td>
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<td>1.2</td>
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### Summary Table

<table>
<thead>
<tr>
<th>CDF</th>
<th>Layer 00</th>
<th>SVX II</th>
<th>ISL</th>
<th>Totals</th>
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<td>1</td>
<td>5</td>
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<tr>
<td>Length</td>
<td>0.9 m</td>
<td>0.9 m</td>
<td>1.9 m</td>
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<td>Channels</td>
<td>13824</td>
<td>405504</td>
<td>303104</td>
<td>722432</td>
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<td>Modules</td>
<td>48 SS</td>
<td>360 DS</td>
<td>296 DS</td>
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<td>Readout Length</td>
<td>14.8 cm</td>
<td>14.5 cm</td>
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<td>Inner Radius</td>
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<td>Power</td>
<td>~100 W</td>
<td>1.4 kW</td>
<td>1.0 kW</td>
<td>2.5 kW</td>
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</table>
Z Resolution

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

\begin{itemize}
  \item COT JPs\i tracks
    \begin{itemize}
      \item Nout6sigma/Notot: 0.03
      \item Noutbox/Notot: 0.00
      \item Sigma1: 0.7970 cm
    \end{itemize}
  \item Preliminary

  \begin{itemize}
  \item OIZ with 3 more Z Hits
    \begin{itemize}
      \item Nout6sigma/Notot: 0.05
      \item Noutbox/Notot: 0.01
      \item Sigma1: 0.0144 cm
    \end{itemize}
  \item Preliminary
  \end{itemize}
\end{itemize}

COT only

High quality SVX tracks

Data taken from Aug to Oct 2001
$J/\psi$ mass window: $3.08 \pm 0.05$ GeV
Sidebands: (2.88, 3.00) and (3.16, 3.28) GeV
SVX3D ASIC

- 128 input channels
- Designed to operate with 132 or 396 ns beam crossing rate
- ENC = 700 + 53 electrons/pF
- 46 cell analog pipeline
- Buffers up to 4 events
- 8-bit Wilkinson ADC, digital readout
- Deadtimeless operation
- On-chip sparsification and common mode noise suppression
- Fabricated in the Honeywell 0.8μm radiation hard process
Dynamic Common Mode Suppression works as designed

There is common mode noise on the strips, and DPS suppresses it efficiently.

Long range charge correlations: $L_2(\phi \text{-side})$

Common mode noise...

...goes away w/ DPS (emulation)

Q on corresponding Strip from LH sideband

Q on strip from RH sideband

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Measurement of Radiation Dose

- May – Oct 2001 running
- Collision dominated, but losses still present
- Measurements found radial and z dependence of dose
- Radial dependence fit to $1/R^\alpha$ scaling
- Result: $\alpha(z) = 1.5 - 2.0$
- Run IIa lifetime estimates assumed $\alpha = 1.7 \pm 30\%$ (OK)

Large number of TLDs used

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