Status and Performance of the CDF Run II Silicon Detector

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on behalf of

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CDF Collaboration

The Sixth International "Hiroshima" Symposium on the Development and Application of Semiconductor Tracking Detectors

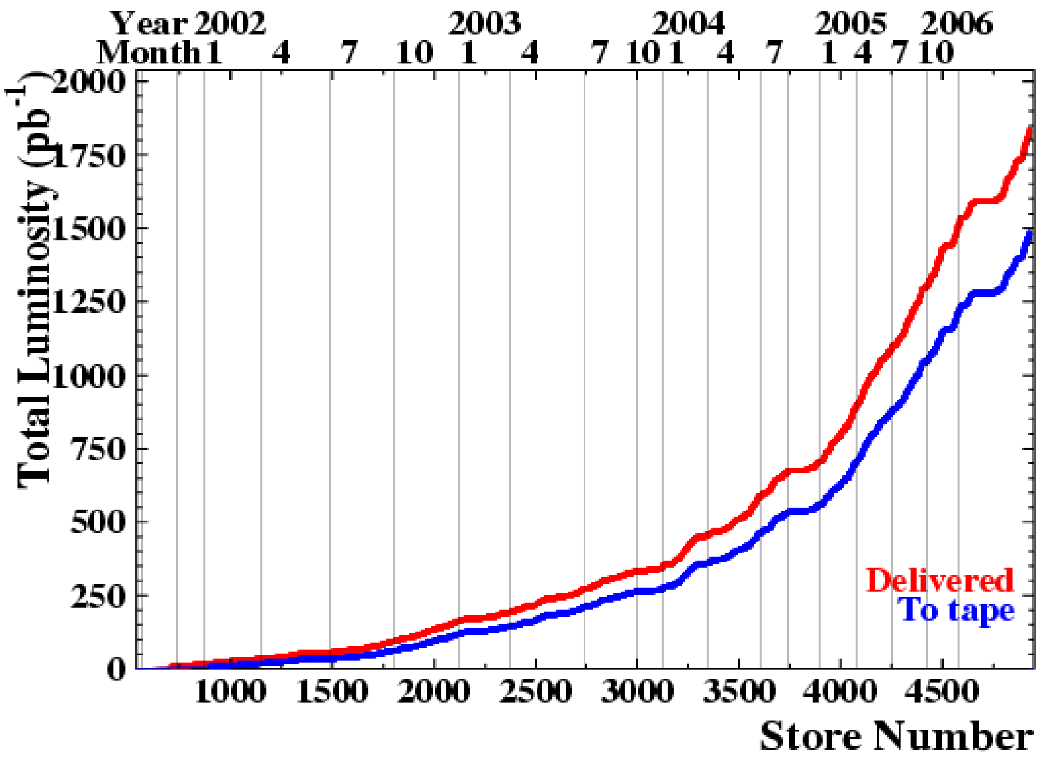
September 11-15, 2006

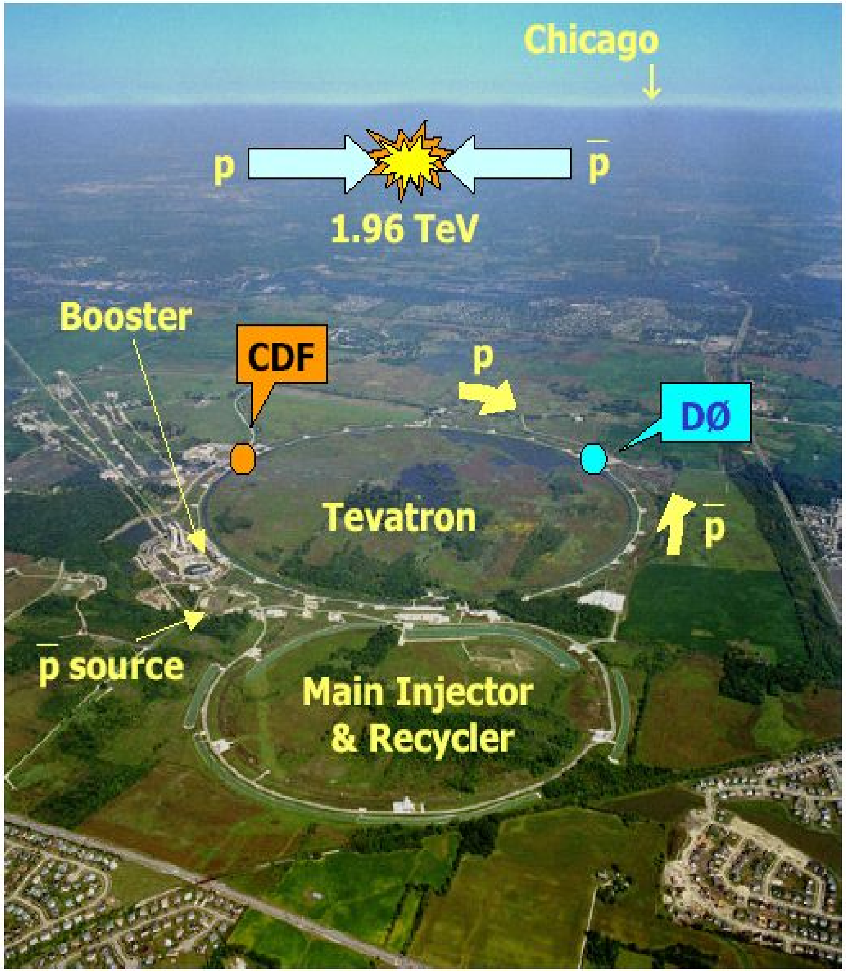
Outline

- Introduction
- Commissioning
- Operational Experience
- Status of Detector
- Detector Longevity
- Summary

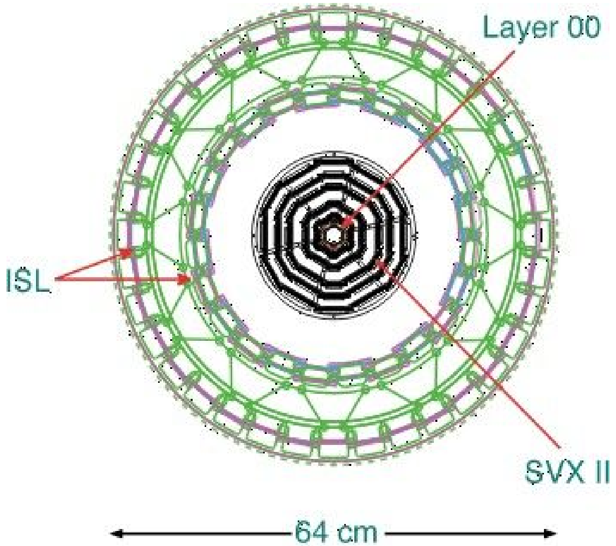
Tevatron

- Initial luminosity $2 * 10^{32} cm^{-2} s^{-1}$
- 36*36 bunches, bunch spacing 396 ns
- Delivered luminosity 1.9 fb^{-1}
  (1.5 fb^{-1} on tape)



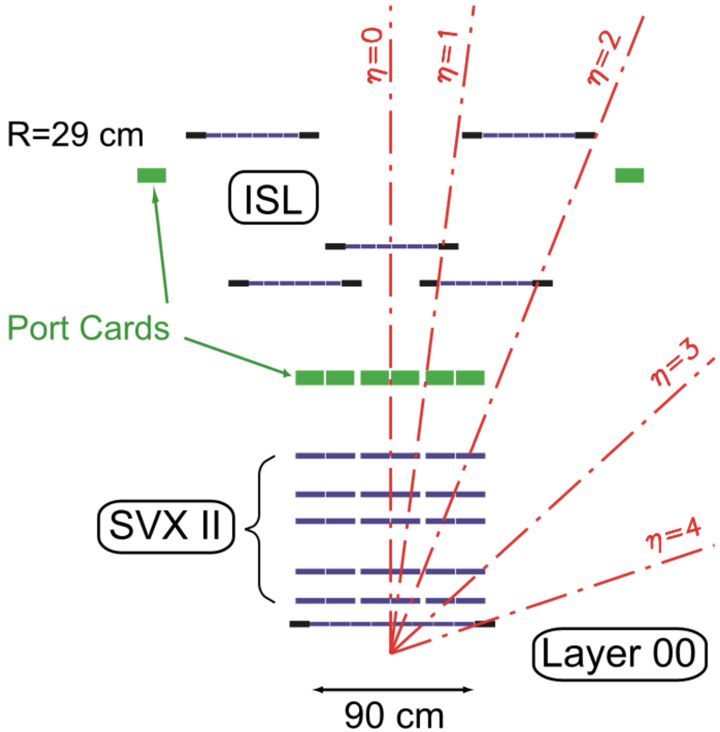


CDF Silicon Detector



Run II Silicon

- *7-8 silicon layers*
- *722,432 channels/ 704 ladders/ 5644 chips*
- *largest operating silicon detector in HEP*



Consist of three sub-detectors

- *SVX II*
- *ISL*
- *L00*

Detector is inaccessible until the end of Tevatron Run II

Importance for Physics

Silicon tracking needed for

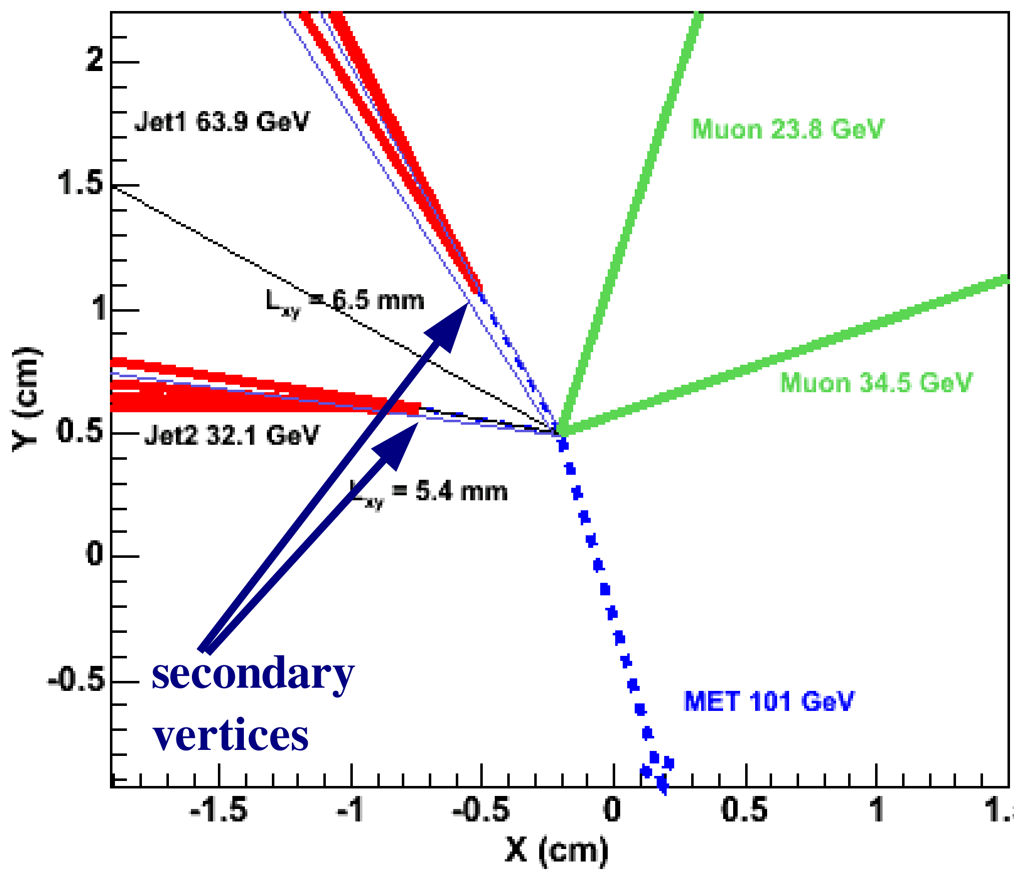
- Precision tracking
- Identification of primary and secondary vertices

CDF silicon has had significant contribution to, for example

- Recent B_s mixing result
- Top quark mass and properties

Example: dileptonic $t\bar{t}$ event

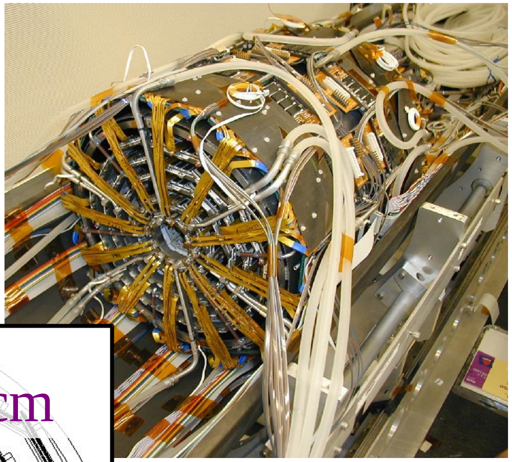
- **Two jets b-tagged by finding secondary vertices**

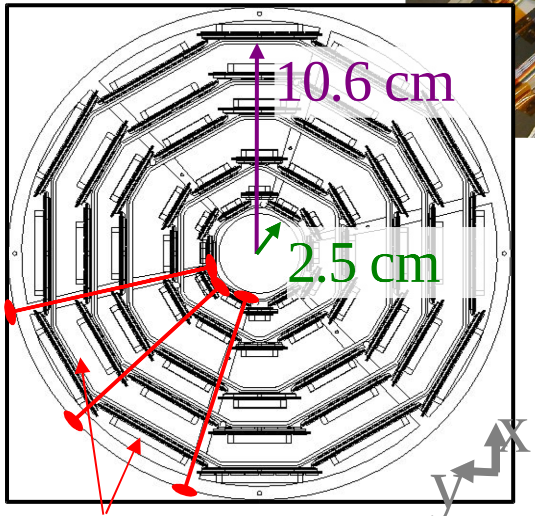


SVX II

SVX II is the core of CDF Silicon Detector

- Five double-sided layers
  - *layers 0,1,3 with axial & 90° rZ strips*
  - *layers 2,4 with axial & 1.2° stereo strips*
- Strip pitch from 60 μm to 140 μm
- Highly symmetric in φ and z
- Used in Silicon Vertex Trigger (SVT) at Level 2
  - *tight alignment constraints, fast parallel readout*
- Basic building block called ladder
  - *microstrip sensors*
  - *SVX3D readout chips*





Note wedge symmetry

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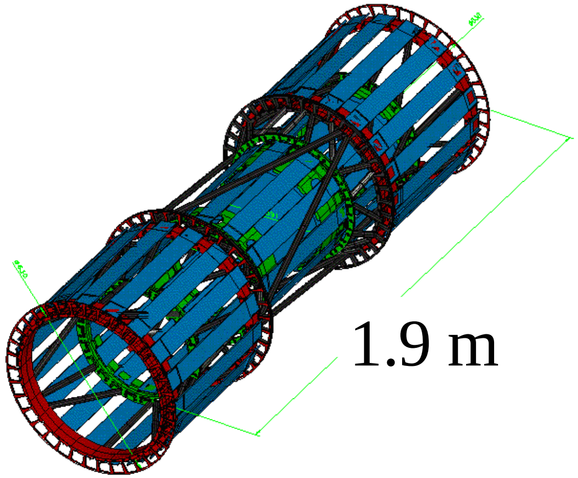
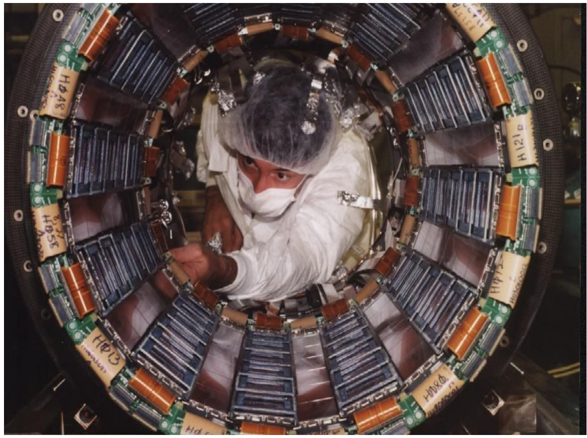
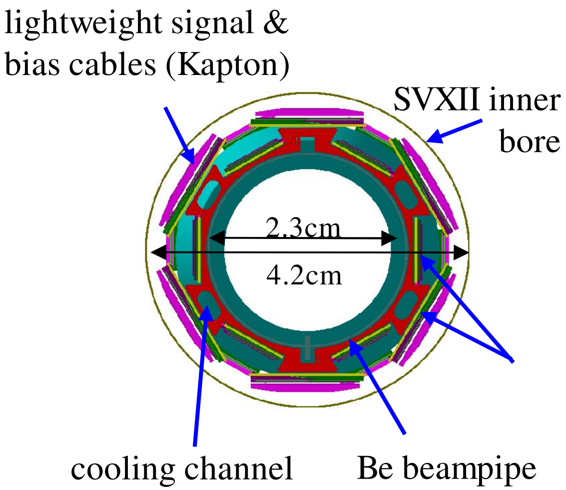
ISL and L00



Intermediate Silicon Layers (ISL)

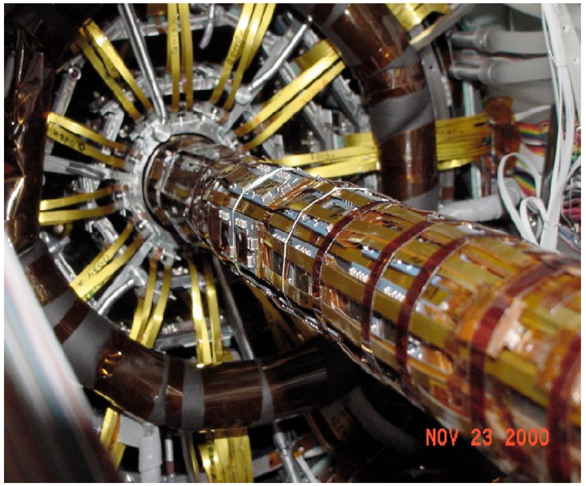
- One double-sided central layer
  - *link tracks from drift chamber to SVX II*
- Two double-sided forward layers
  - *silicon tracking in forward regions up to pseudorapidities of η=2*
- Strip pitch 112 μm





Layer 00 (L00)

- Single-sided layer mounted on beampipe
  - *precision position measurement before scattering in inactive material*
- Strip pitch 25 μm



Infrastructure – A Complex System

DAQ

- VME based
- 135 VME boards in 17 crates

CAEN power supplies

- high voltage to bias silicon sensors
- low voltage to power electronics
- 114 modules in 16 crates

Interconnectors

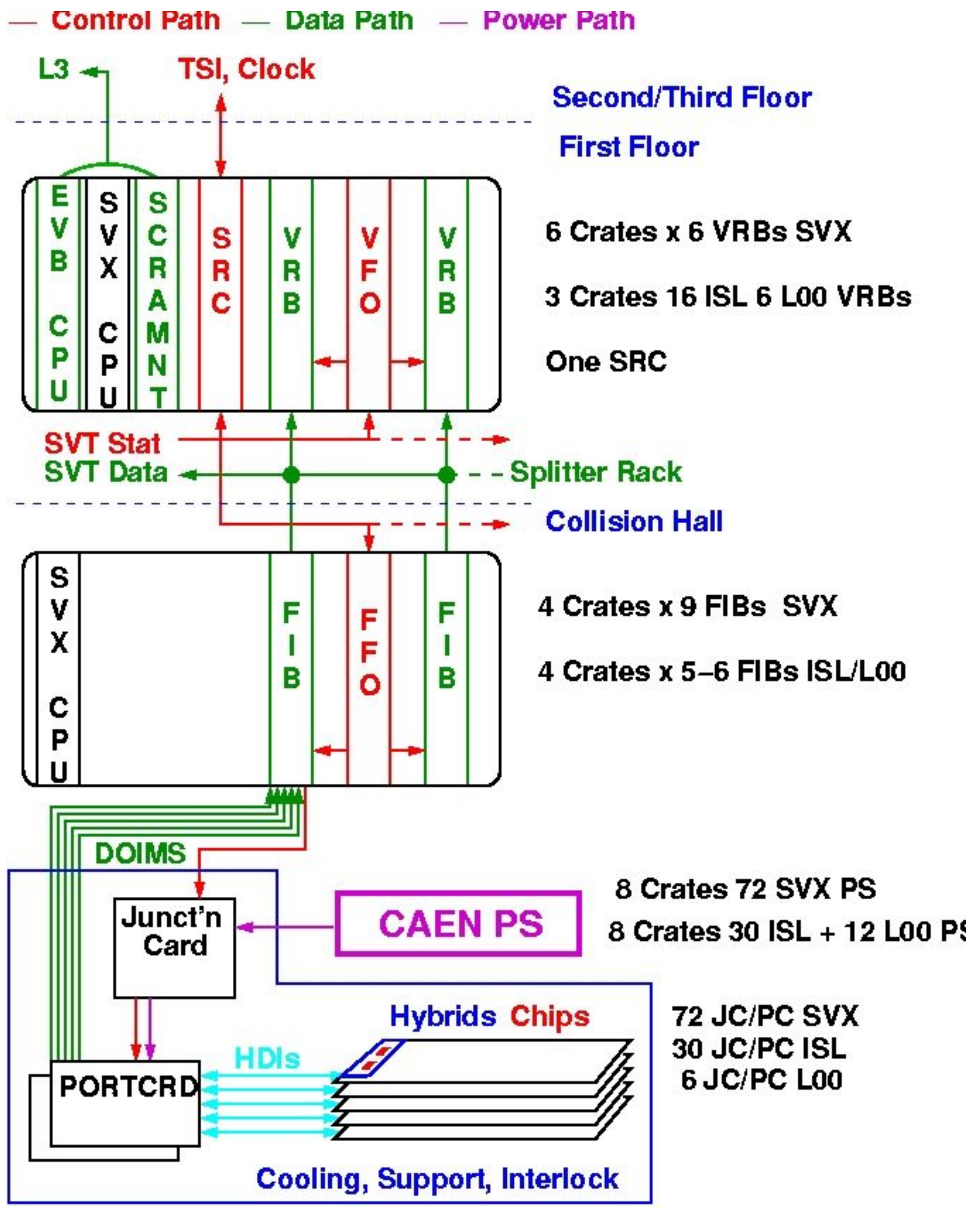
- 216 port and junction cards

Cooling and interlock system

- SVX II cooled to -10 °C
- ISL cooled to +6 °C

Cables

- ~1000 cables in total

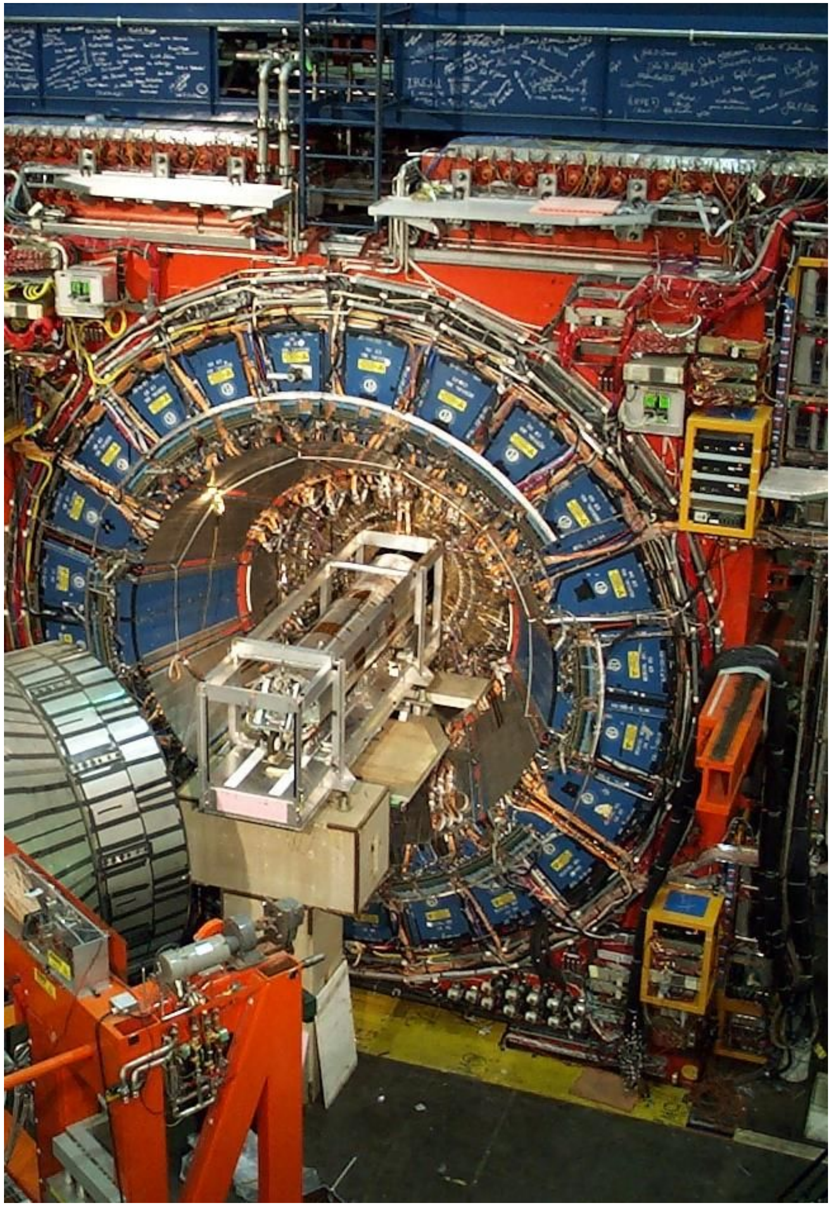


Commissioning

Lengthy commissioning period of 1.5 years:

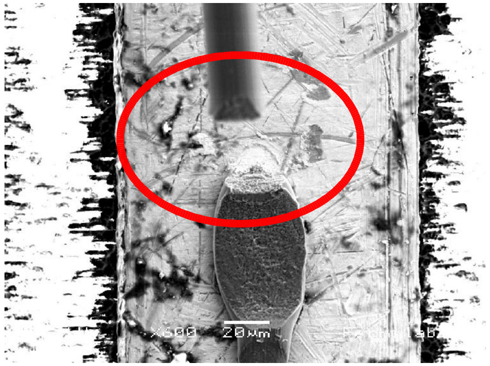
- Large and complex system
- Several initial problems
  - *blocked ISL cooling lines*
  - *wirebond resonance problems*
  - *failed power supplies on L00*
  - *noise pickup on L00*
- All of the problems have been addressed

- For more information, see
  - *B.Brau, Operational Experience from the CDF Run 2 Silicon Tracker, proceedings for STD5*

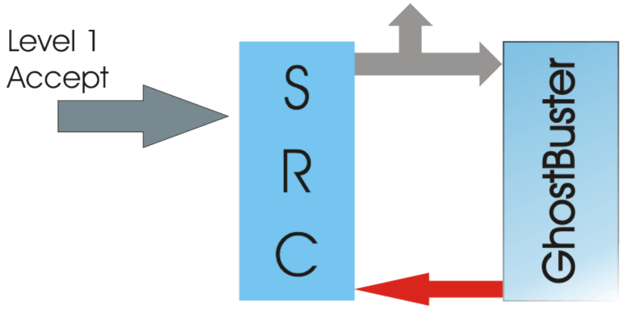


Wirebond Resonances

- **Observed loss of data and power to Z sides of ladders**
  - *found to correlate with high trigger rates*
- **Failure due to wirebond resonances**
  - *wires orthogonal to magnetic field*
  - *wires feel Lorentz force during readout*
  - *if frequency is right, wires resonate and they can break*



- **VME board introduced to prevent resonances**
  - *board measures $\Delta(\Delta t)$ between readout commands*
  - *if $\Delta(\Delta t)$ smaller than programmed value, counter incremented*
  - *if counter reaches threshold, DAQ stopped*
- **No new failures after installation of the board**



Operating CDF Silicon Detector

- Accessing silicon sensors is impossible
  - *maintaining high level of performance is a significant challenge*
- Power supplies and part of DAQ boards are in collision hall
- Daily operations require 5 FTEs from post-docs and graduate students
  - *keep detector running*
  - *recover from incidents*
- 2 people always on-call

Beam Incidents

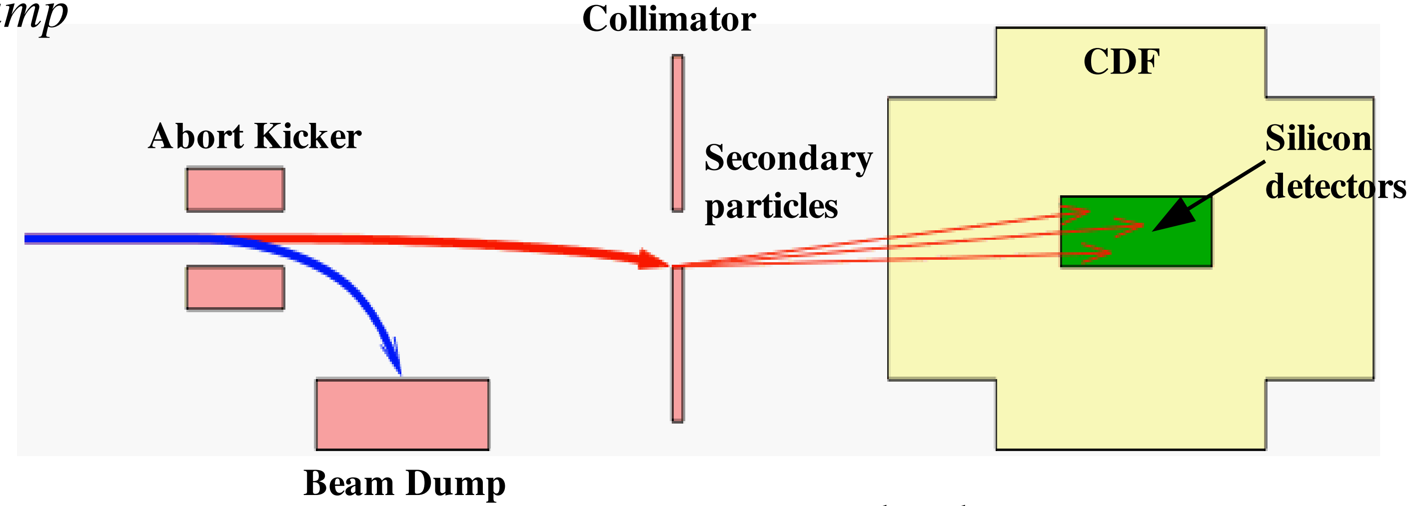
- 1 TeV beam has a lot of energy
  - *can cut through solid steel*

Quenches

- Unstable beam can quench Tevatron's superconducting magnets

Kicker prefire

- 1 (out of 5) abort-kicker tube fires at random time
  - *1 abort-kicker insufficient to kick beam into abort dump*



Beam Incidents and Silicon

Silicon detector very close to 1 TeV beam

- Sensitive to abnormal and unstable beam conditions
- Large amount of charge deposit in the chips may cause loss of communication to the analog part of the SVX chips
  - *often problems disappear within days*
  - *but previous problems can reappear or become worse*
  - *a few of ladders shown unrecoverable problems*

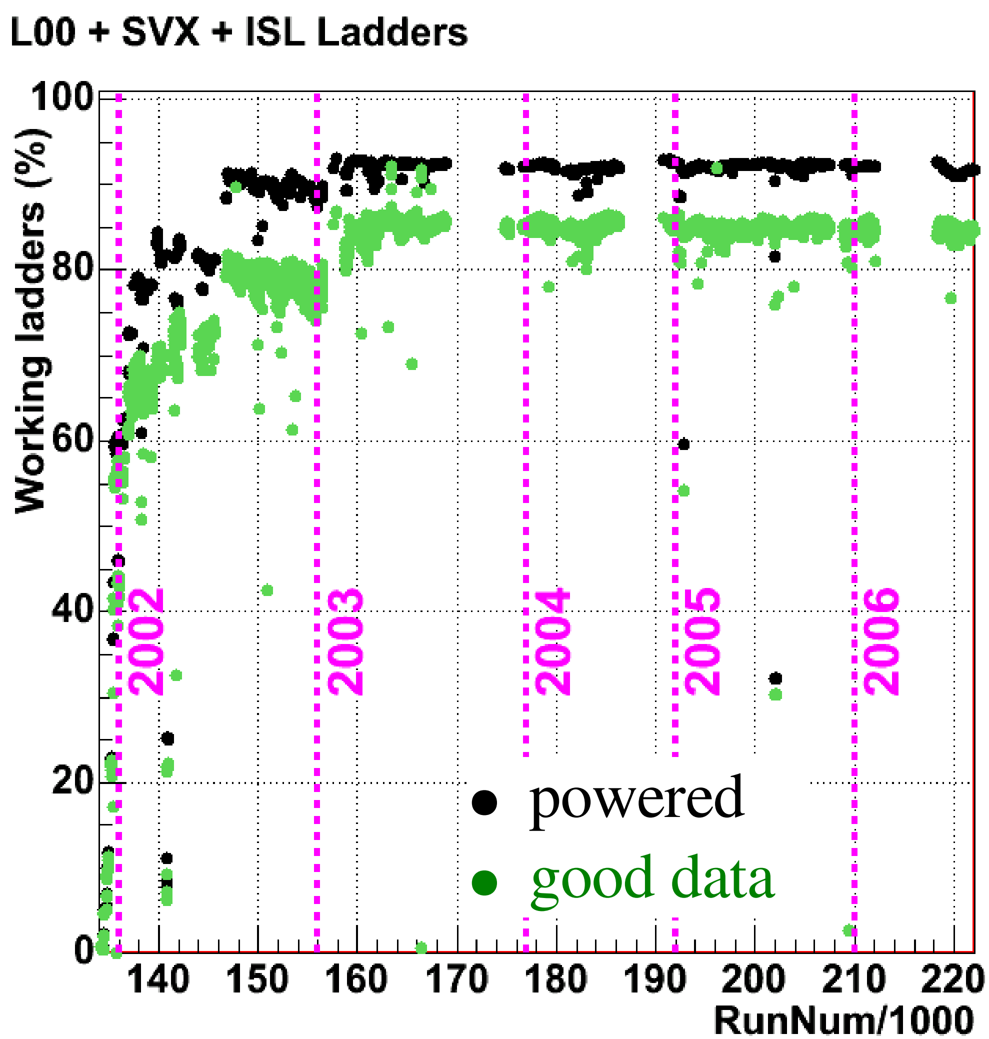
How to mitigate effects of incidents?

- Monitor beam conditions
- Beam collimator in front of CDF
- BLM abort system
- Novel diamond system being commissioned
- We work closely with Accelerator Division to improve situation

Status of Detector

- 92% of ladders powered
- 85% of ladders return good data
  - good = error rate <1%

Detector	Total	Powered	Good
L00	48	98%	96%
SVX II	360	92%	84%
ISL	148	91%	82%



- Silicon Vertex Trigger
  - *requires good data from 4 out of 5 ladders/wedge of SVX II*
  - *coverage 96%*
  - *important not to lose more ladders*

Longevity of Silicon

CDF silicon detectors must perform reliably and efficiently until the end of experiment in 2009 (5-8 fb^{-1})

- Silicon sensors main concern:

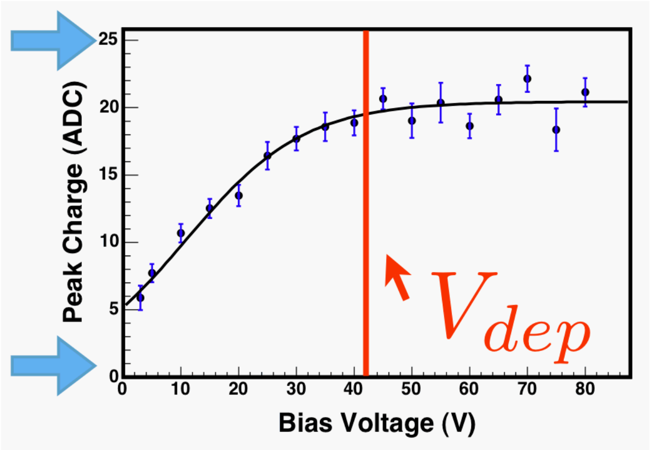
1. Ability to fully deplete silicon ladders
   - *depletion voltage evolves under long-term irradiation*
   - *our detector has AC-coupled sensors which limit bias voltage*
2. Signal-to-noise (S/N) ratio good enough for SVT and b-tagging
   - *irradiation increases bias current and capacitive noise*
   - *signal decreases, the reason not understood*

Bias Voltage

Bias voltage can be measured with two methods:

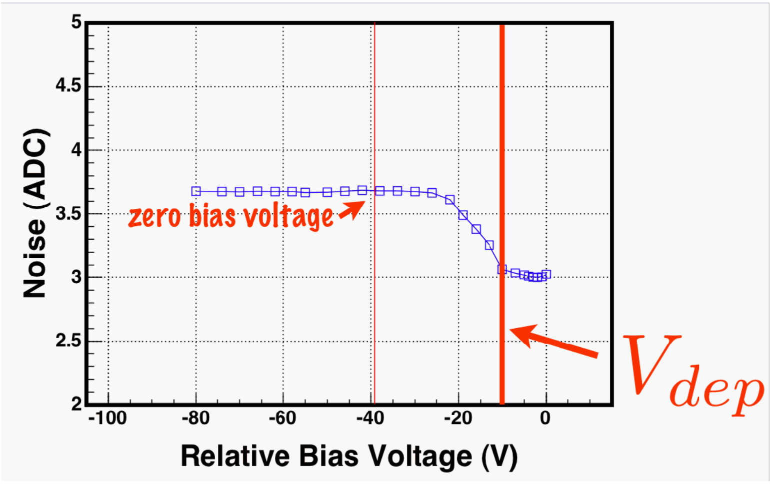
Method 1: Signal vs. Bias

- Requires beam
- Vary bias voltage and watch the collected charge
- Determine V_{dep} as 95% amplitude of sigmoid fit



Method 2: Noise vs. Bias

- Beam not required
- Vary bias voltage and watch the average noise
- Assume the detector is fully depleted when noise is minimum
- Does not work for L00 (single-sided sensors)



Two methods give similar results

Depletion Voltage

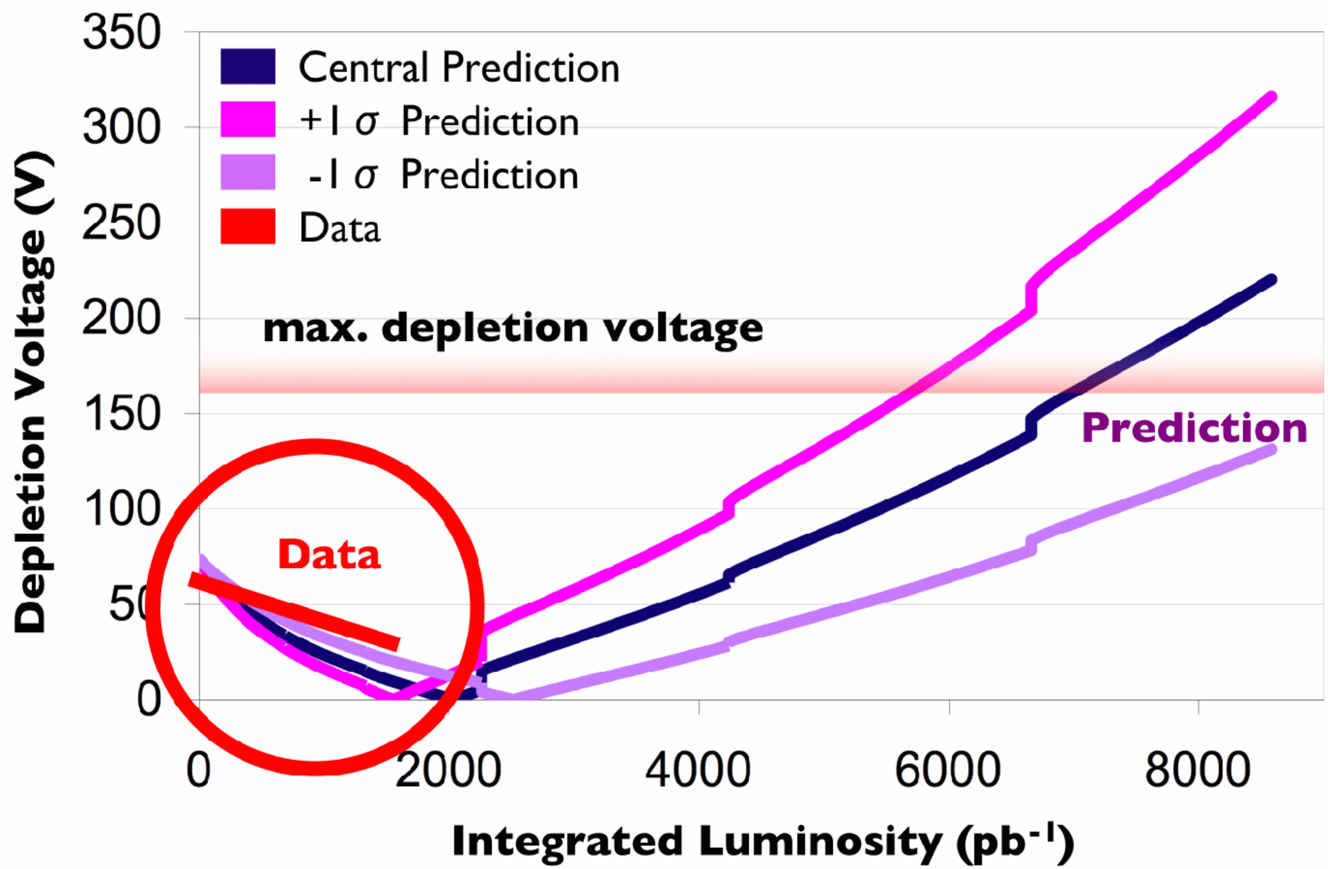
Innermost layers experience largest amount of radiation

- L00: radiation hard, single-sided
- SVX L0: first layer not to be fully depleted due to radiation damage

- We seem to follow optimistic prediction

Ability to deplete silicon sensors not a limiting factor

Innermost layer of SVX



Prediction: S. Worm, "Lifetime of the CDF Run II Silicon," VERTEX 2003

Signal-to-Noise Ratio

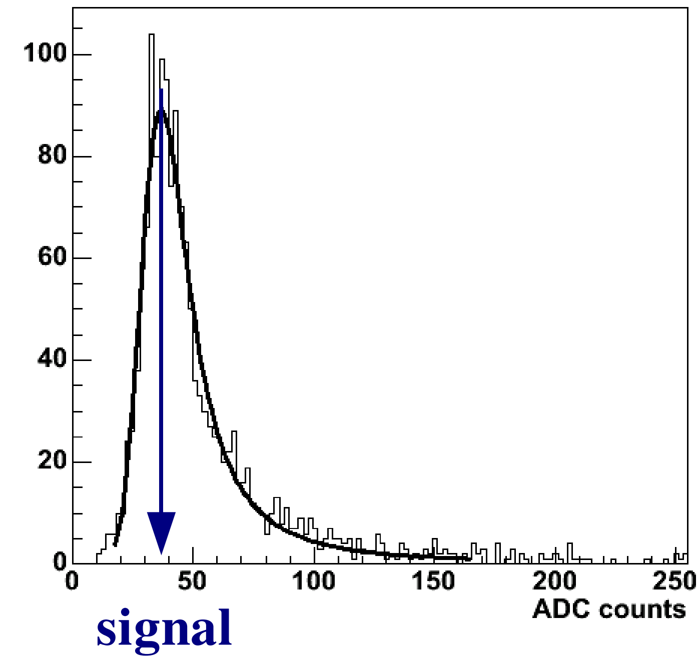
Signal-to-noise ratio studied in dimuon J/ψ events:

- Signal: charge of a cluster
- Noise: average strip noise in a cluster
- Charge path length corrected

SVX II after **1.7 fb^{-1}** delivered luminosity

- RΦ S/N = 9.5:1 - 12:1
- Z S/N = 9.5:1 - 12:1

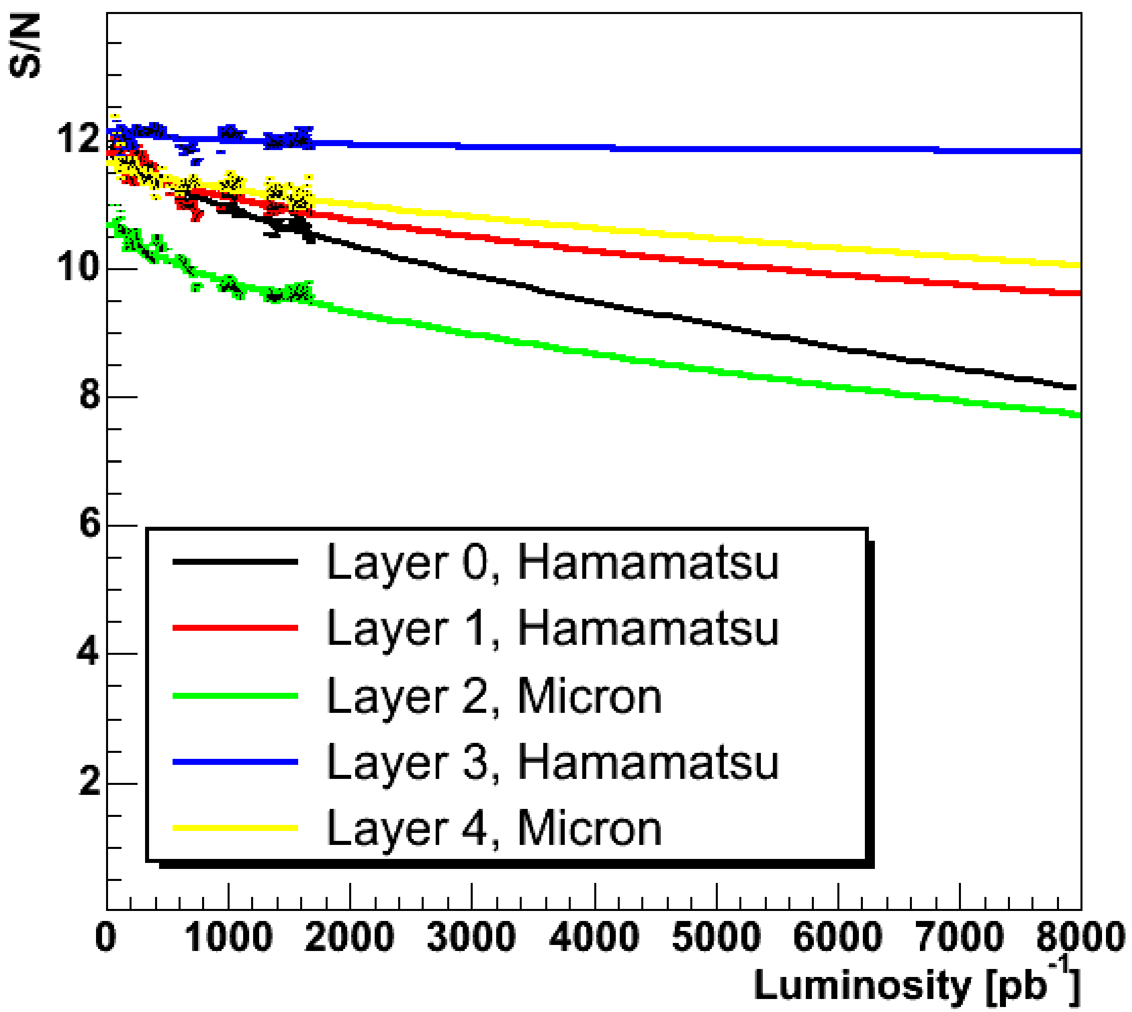
Cluster charge distribution



Signal-to-Noise ratio

- Empirical model for S/N predictions
  - *linear decrease in signal*
  - *sqrt increase in noise*
- Benchmarks for S/N
  - *SVT predicted to start losing efficiency at S/N<8*
  - *Run I: top quark discovery with S/N = 3*

There is no evidence S/N won't be good enough until the end of Run II



How to make silicon last longer

We have taken several actions to make silicon last longer:

- SVX cooling temperature reduced from -6 °C to -10 °C
  - *reduction of noise, mitigation of reverse annealing*
- Silicon detector volume thermally isolated
  - *minimize thermal cycles of silicon detectors*
  - *volume flushed with nitrogen: avoid condensation*

We monitor the status of detector, and prevent accidents:

- Measure depletion voltage in bias scans and measure S/N
- Monitor beam conditions and take fast action if there is high risk for beam incidents

Summary

- The CDF silicon detector is a large and complex system that continues to operate well
  - *success comes at the cost of considerable effort*
- The detector will be operating for 3 more years
  - *significant contribution to most of CDF physics results*
- There is no evidence the CDF silicon detector will not survive until the end of Run II
- We are working hard to ensure our detector performs at a consistently high level throughout Run II