The Run IIb CDF Detector Upgrade Project

Patrick T. Lukens

Fermilab

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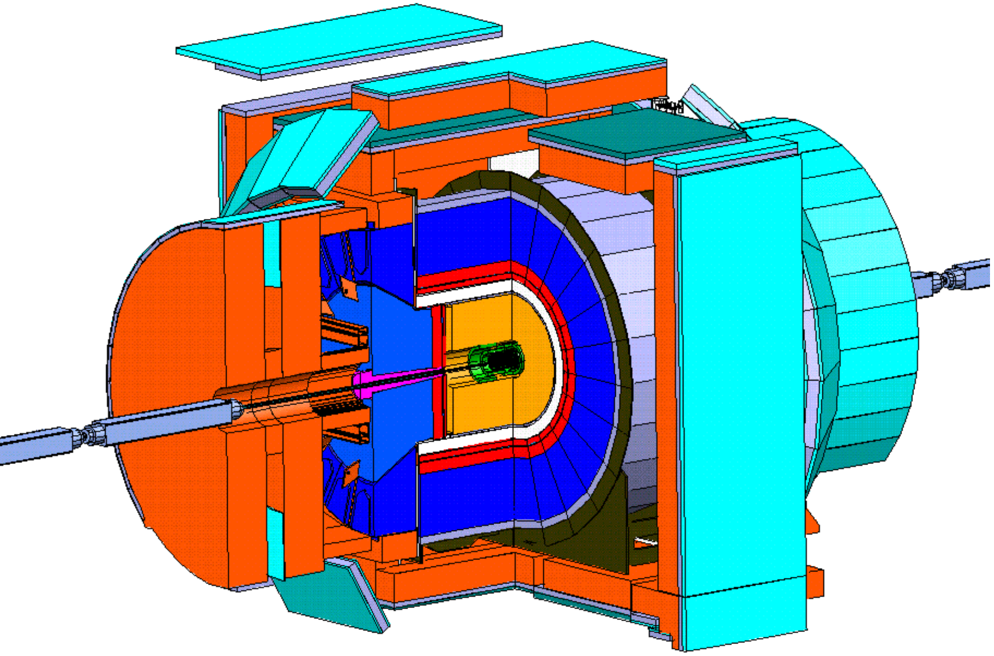
CDF for Run IIb



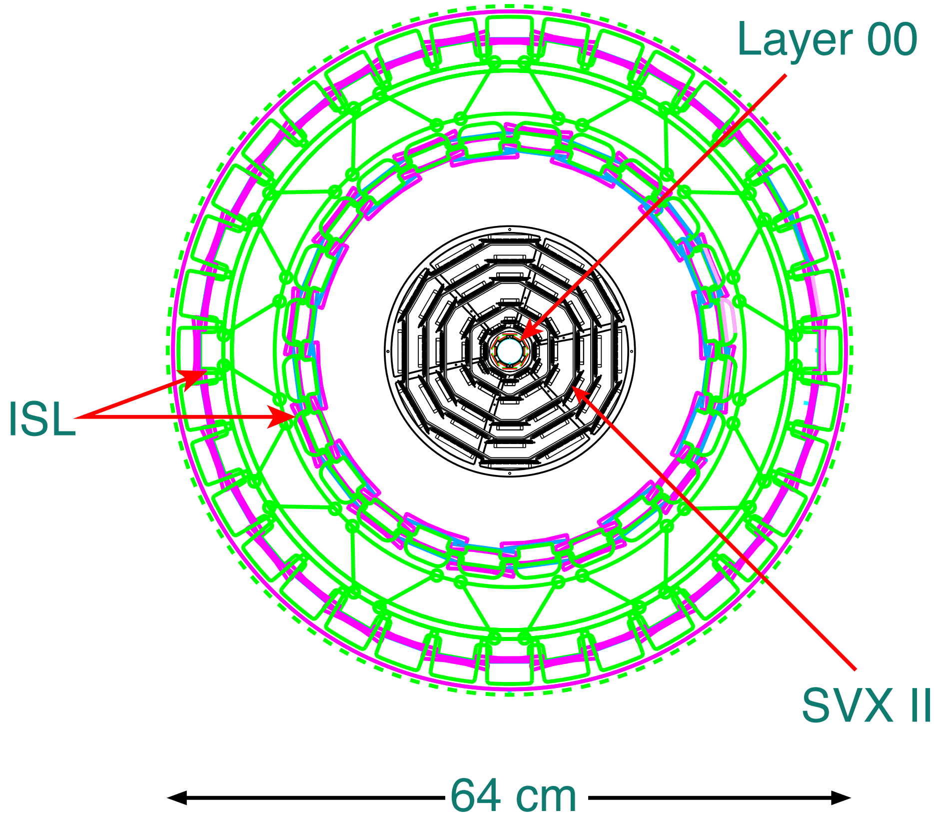
- As in Run I, CDF's strength lies in its tracking system
  - Good momentum precision, lepton ID
  - Good vertex precision – b hadron identification
- Operating conditions for Run IIb:
  - Maximum instantaneous luminosity of $4\text{-}5\times10^{32}\,cm^{-2}s^{-1}$.
  - Integrated luminosity of as much 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.

Layer	Lifetime (fb^{-1})
00	7.4
0	4.3
1	8.5
2	10.7
3	23
4	14

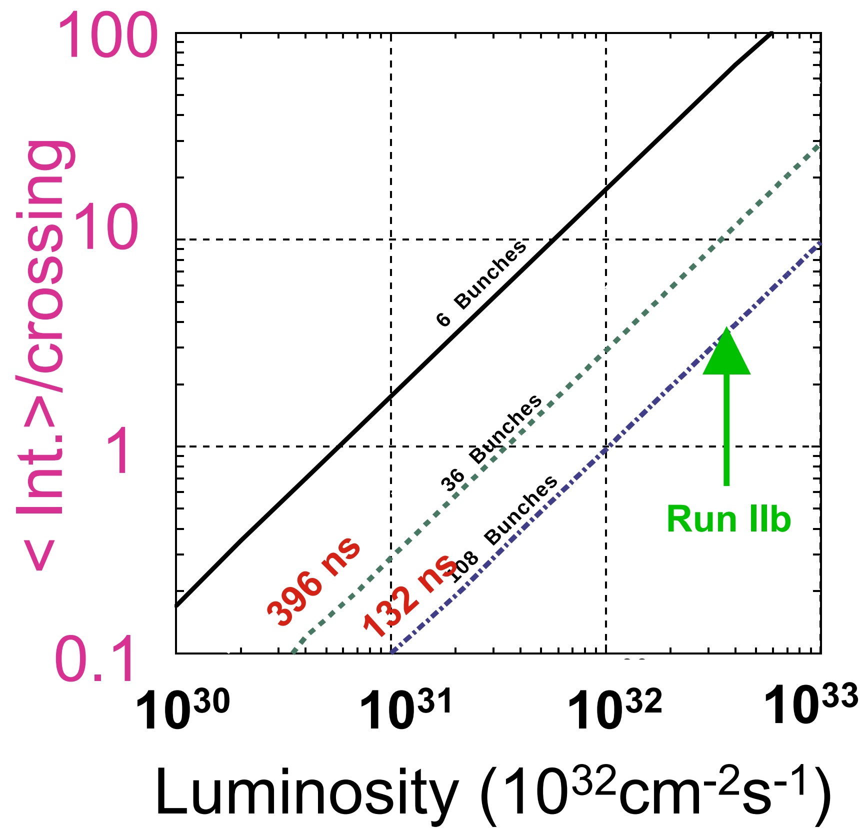
- We are forced to replace the inner layers.



Silicon detector end view

Instantaneous Luminosity

- 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

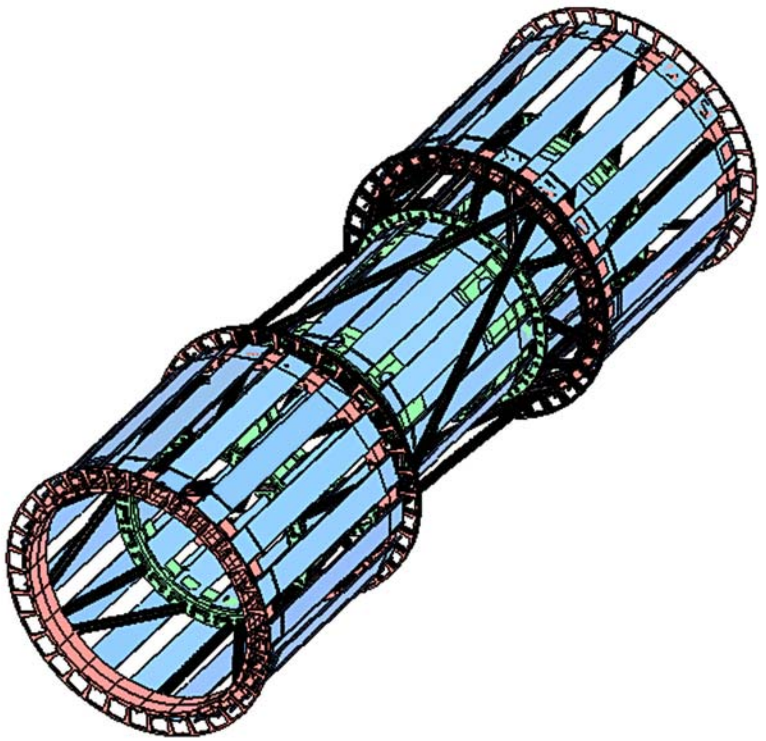


CDF's Run IIb Projects

- 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



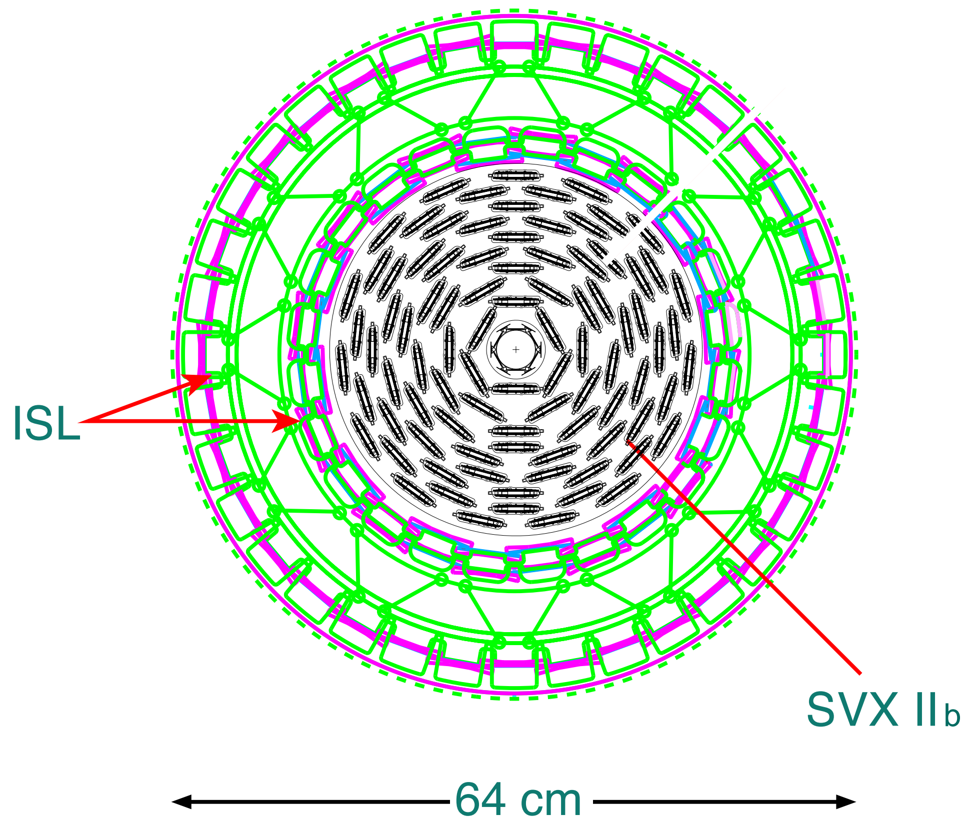
ISL Space Frame

SVX Replacement

- 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

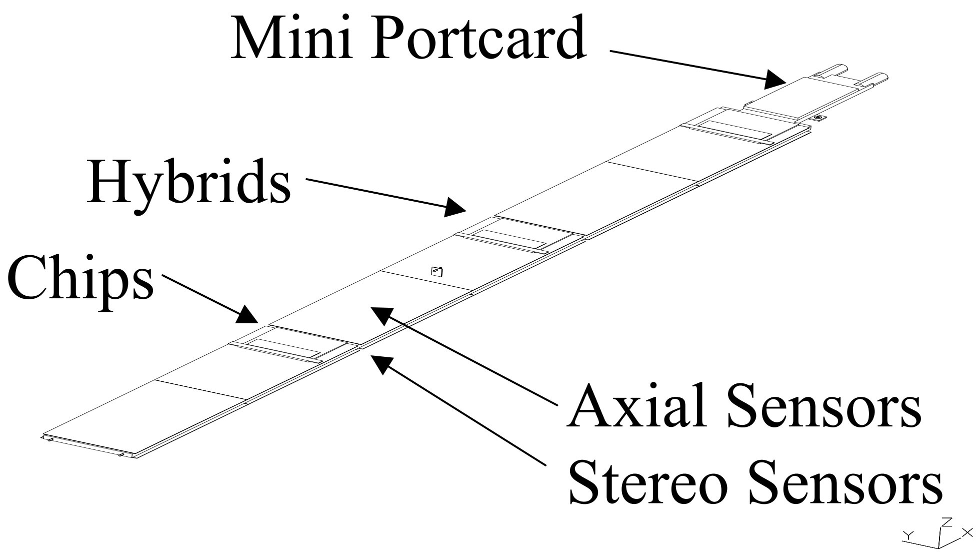
- All inners layers will be replaced.
- New detector is designed for quick construction
- A basic module - the “stave” will be built
- This structure will populate most of the detector volume
- This gives the advantage of fewer different parts than the current detector



Silicon detector end view

Silicon Detector - Run IIb

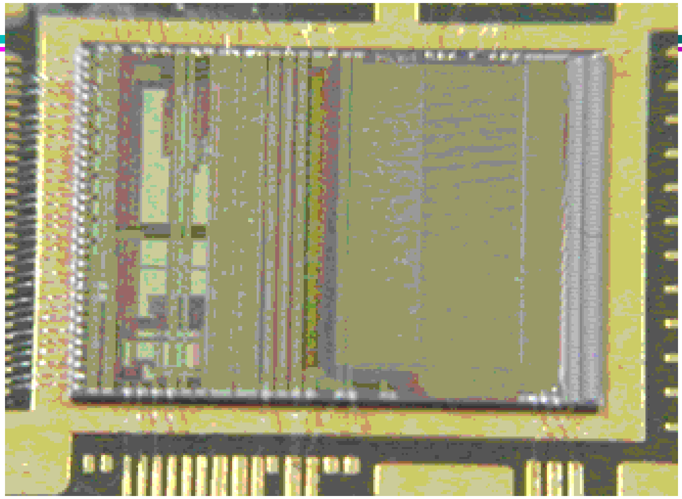
- Single sided sensors will be used for Run IIb.
  - Production readiness review was held in Feb.
  - Sensors have been ordered
- Axial and small angle stereo layers will be joined in a single structure – this is used for layers 1-5.
- Layer 0 (innermost) will be axial only, and a different structure.

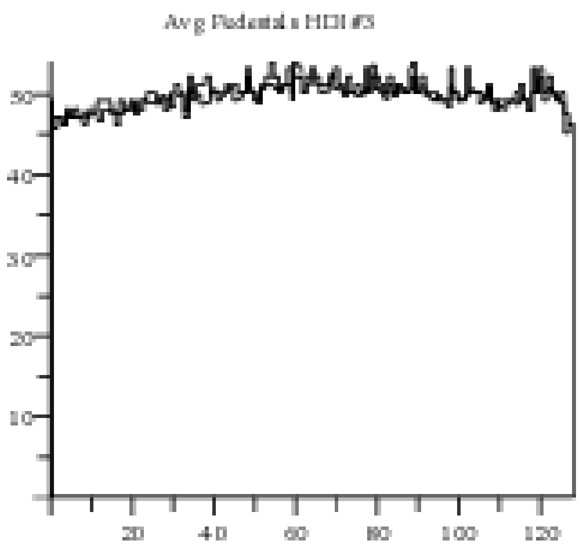


- Stave layout

SVX4 chip

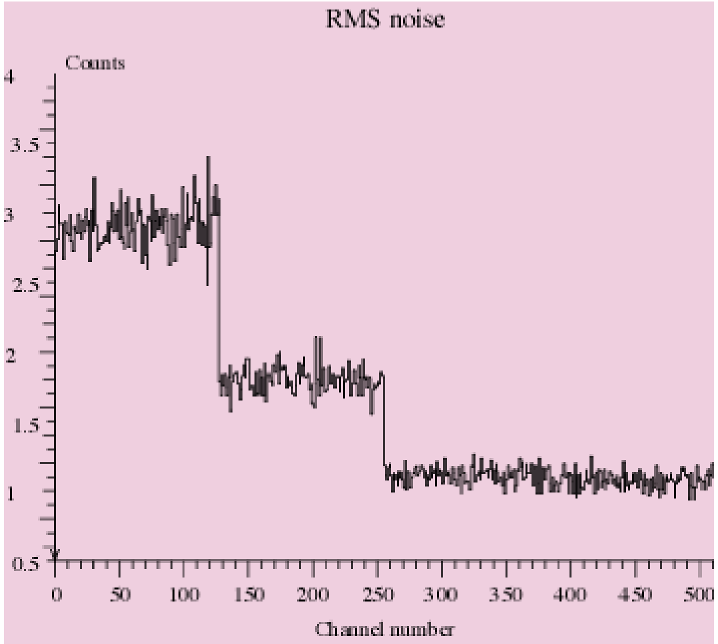
- 1st full prototype
  - submitted - April ’02 received June ‘02
  - Tested at LBL and FNAL
  - No major problems found
  - Corrections for bow and channel to channel variation – fixed in new chip
  - Yield looks very good, ~85%
  - Radiation tests showed no problems
- Next Submission is in progress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

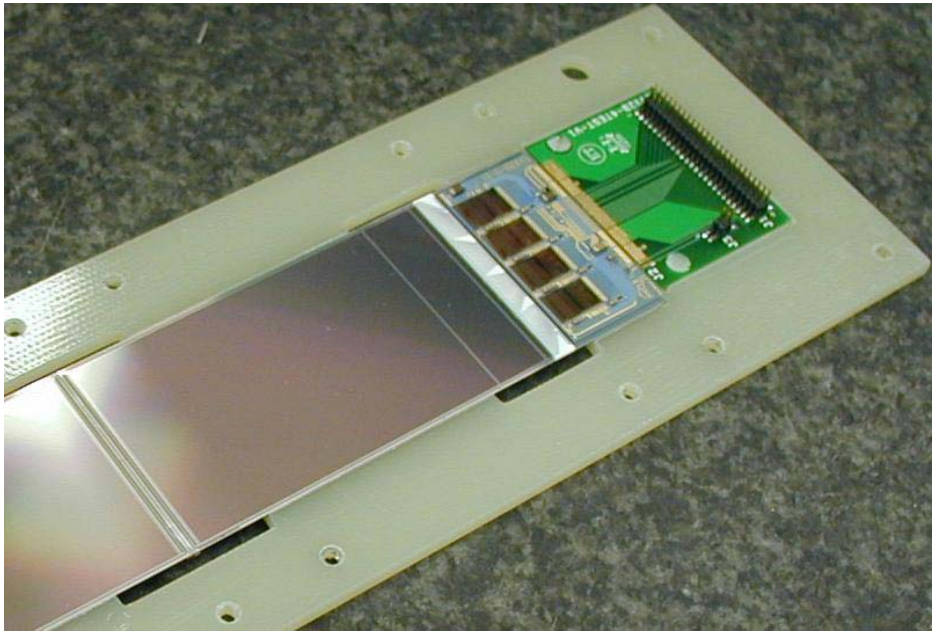




Module

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

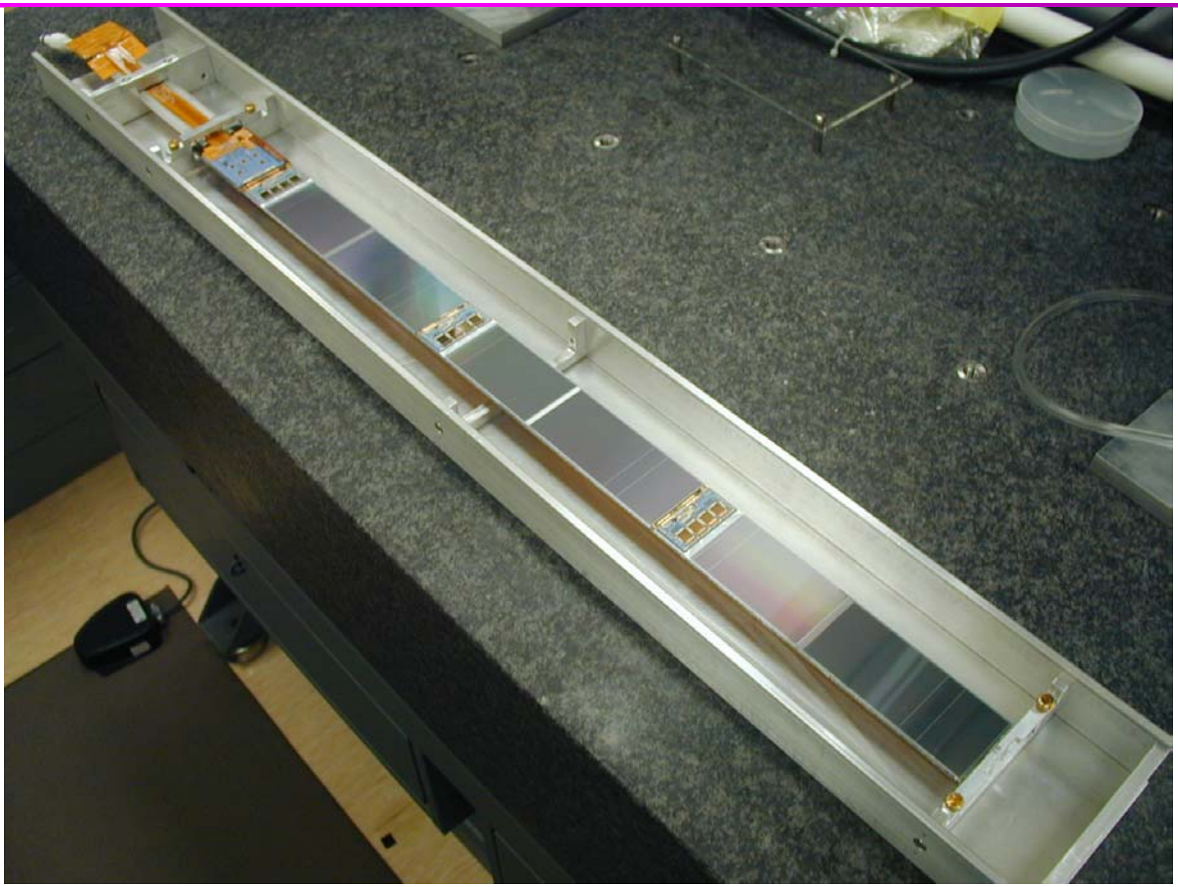




← Noise with 0, 1, and 2 sensors connected to the readout

Electrical Stave Testing

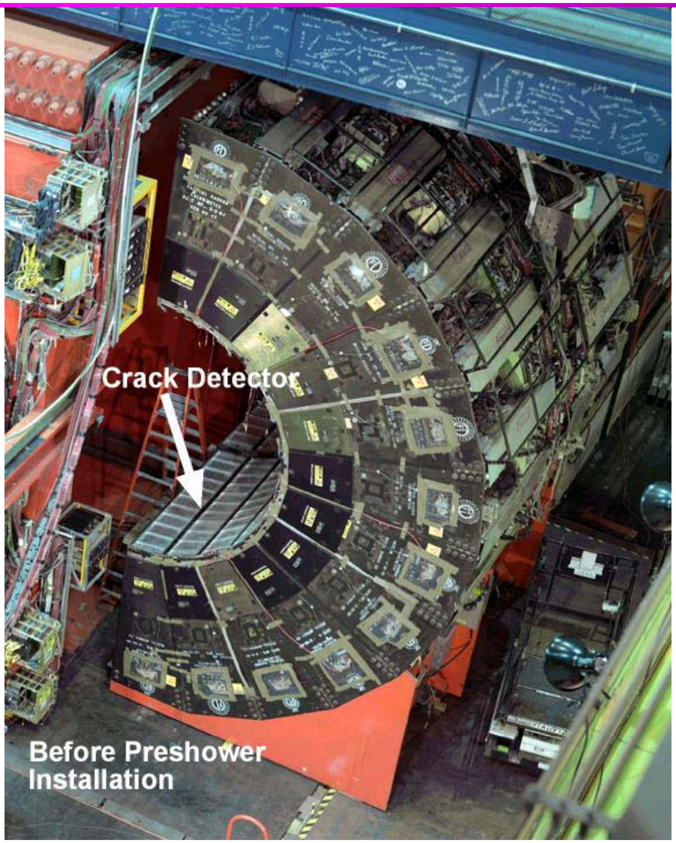
- Tests are begin done at LBL and FNAL
- Full DAQ and deadtimeless operation are being tested.



Electrical Stave Prototype

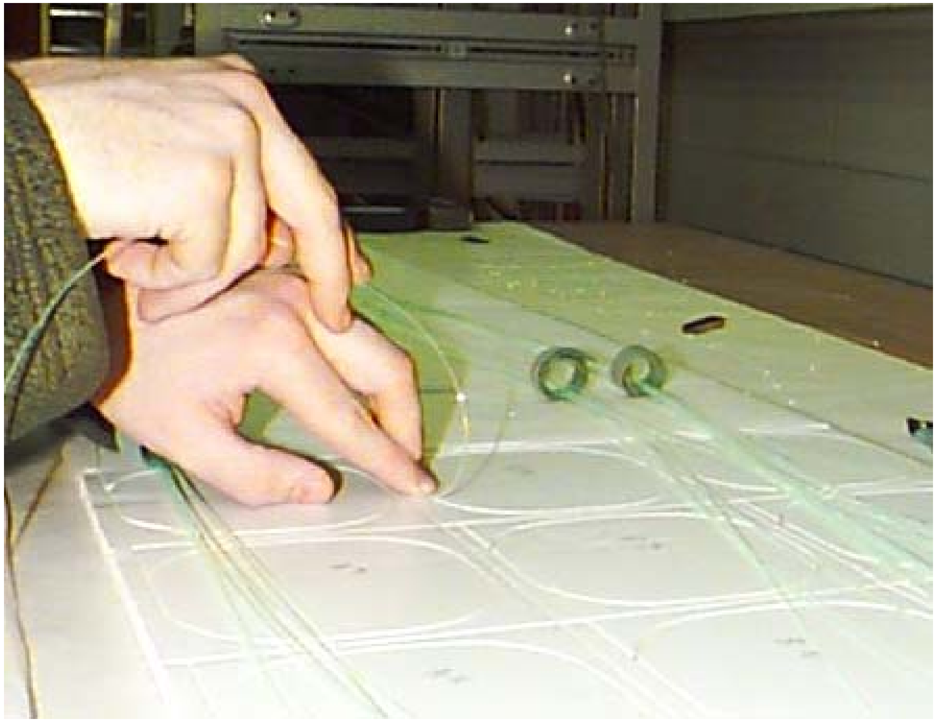
Preshower/Crack Detectors

- 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 improve jet energy resolution, part of the 20-30% needed improvement for the Higgs search.



Central Calorimeter extracted for maintenance

Preshower Progress



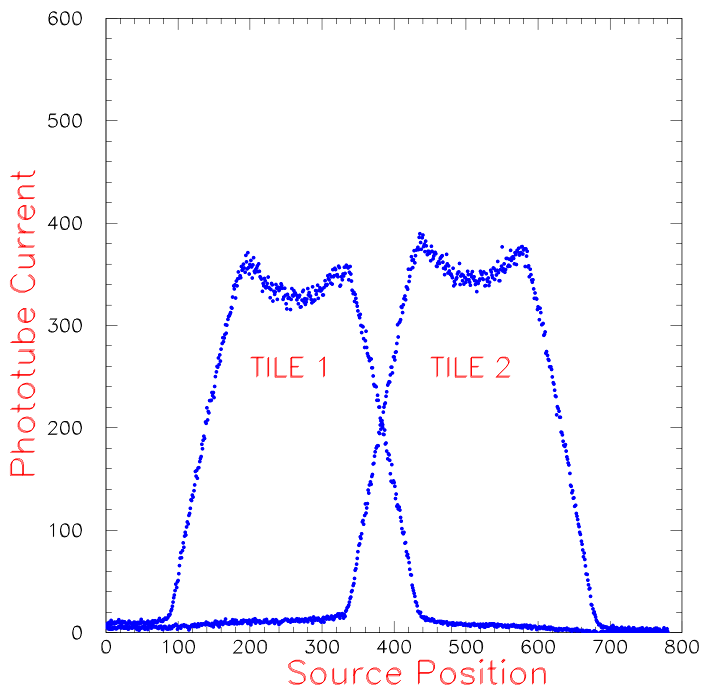
Detector mockup and Fiber routing scheme at MSU

- 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.

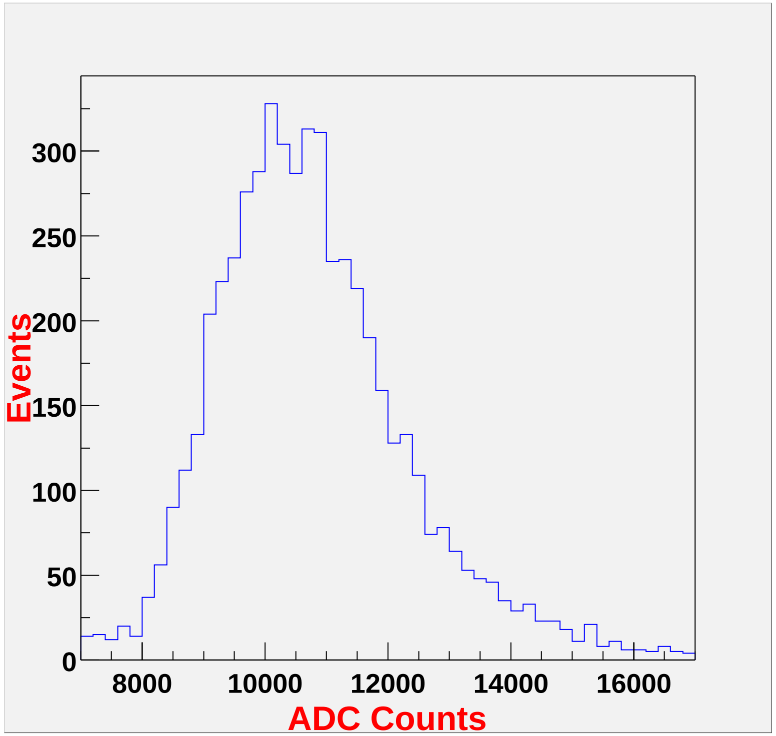
Preshower/Crack Progress

Prototype tests at ANL, Pisa, Rockefeller for uniformity and light yield.

Uniform Response better than 10%
Meets the spec

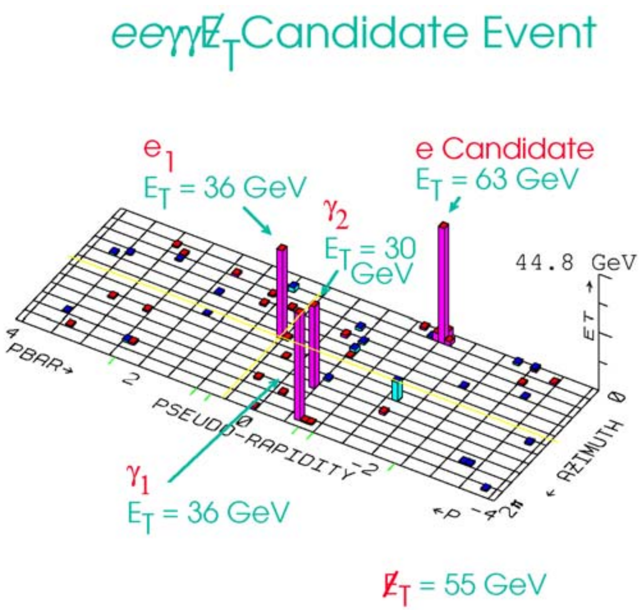


12 photoelectrons/MIP
Meets the spec



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

Trigger and Data Acquisition Motivation

- 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: $\mathcal{L} \leq 2 \times 10^{31}$ cm^{-2} s^{-1}, ~1 interaction per crossing**
  - **Run I data: $\mathcal{L}$ ~2×10^{31} cm^{-2} s^{-1}, ~2 interactions per crossing**
- We are extrapolating to Run IIb
  - **$\mathcal{L} = 2 \times 10^{32}$ cm^{-2} s^{-1} w/396ns bunch spacing (~5 int/beamX)**
  - **$\mathcal{L} = 5 \times 10^{32}$ cm^{-2} s^{-1} w/132ns bunch spacing (~5 int/beamX)**
  - **Due to significant uncertainties in extrapolation, and a desire to be prepared for success, we have evaluated our system for: $\mathcal{L} = 4 \times 10^{32}$ cm^{-2} s^{-1} w/396ns bunch spacing (~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 $t \rightarrow Wb$
  - Missing E_T triggers
    - *ZH* with $Z \rightarrow \nu\bar{\nu}$, modes with taus
  - *b*-jet triggers
    - $H \rightarrow b\bar{b}$, *b*-jets tagged by displaced tracks
  - Calibration triggers
    - $Z \rightarrow b\bar{b}$, $J/\psi \rightarrow \mu^+\mu^-$, 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.

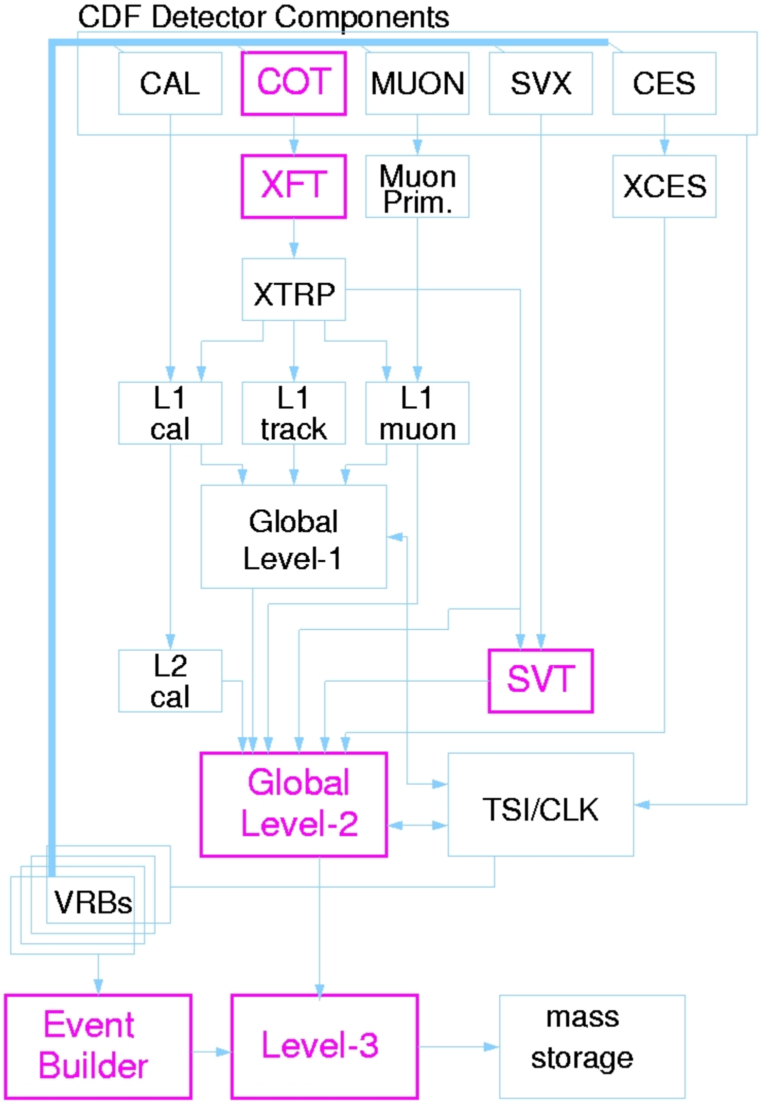
Triggers

- 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

Task	Date Completed	Lead/Lag (weeks)
Drop Interlocks, Access to Collision Hall	4/12/2006	-7
Central Detector Ready to Roll Out	5/17/2006	-2
Install Silicon Interlock Haardware	5/10/2006	-3
Silicon Detector Required at Si. Facility	5/31/2006	-
Silicon Detector Ready for Installation	7/26/2006	8
Central Detector Ready to Roll In	8/16/2006	11
Central Detector Moved	8/23/2006	12
Silicon Ready for Power	9/6/2006	14
Ready for Collisions	11/29/2006	26

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

Cost (AY $K)	2002	2003	2004	2005	2006	Totals
Silicon	$ -	$ 2,865	$ 7,226	$ 7,165	$ 877	$ 18,134
Calorimeter	$ -	$ 785	$ 521	$ 16	$ -	$ 1,322
DAQ/Trigger	$ -	$ 749	$ 1,407	$ 3,635	$ -	$ 5,791
Administration	$ -	$ 420	$ 505	$ 516	$ 236	$ 1,677
Total Equ. Cost	$ -	$ 4,818	$ 9,659	$ 11,333	$ 1,113	$ 26,923
R&D Cost	$ 1,802	$ 1,477	$ 182	$ -	$ -	$ 3,460
Total Project Cos	$ 1,802	$ 6,295	$ 9,841	$ 11,333	$ 1,113	$ 30,383
Funding (AY $K)						
DOE - Equip. Tot	$ 3,500	$ 3,469	8,396	8,509	1,113	$ 24,987
DOE - R&D	$ 1,670	$ 480	$ -	$ -	$ -	$ 2,150
Japan	$ 235	$ 867	$ 1,081	$ 10	$ -	$ 2,193
Italy	$ 65	$ 351	$ 261	$ -	$ -	$ 676
University base	$ 24	$ 225	$ 103	$ 26	$ -	$ 377
Total Funding	$ 5,494	$ 5,392	$ 9,841	$ 8,544	$ 1,113	$ 30,383

- Costs include G&A and Contingency
- All costs/funds are in AY $K

Project Status

- In addition to the PAC, the CDF Run IIb Detector Upgrade Project has been reviewed by
  - Technical Review – Dec, 2001 (J. Pilcher)
  - 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.

Summary

- 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.