The Run IIb CDF Detector Project

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Fermilab

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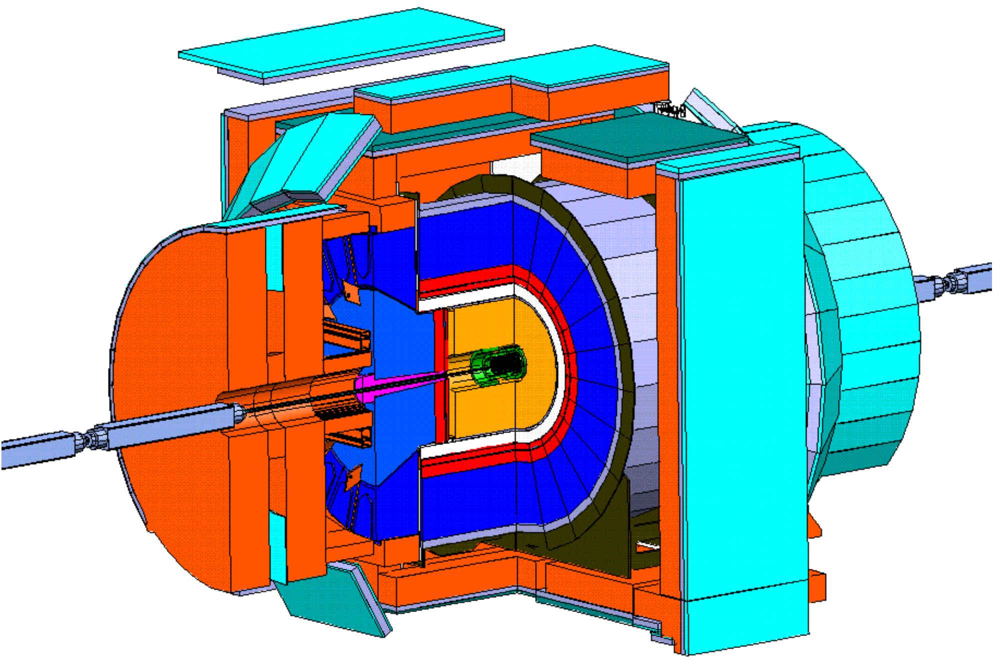
CDF for Run II



- The current detector was designed/built based on Run IIa specifications:
  - Maximum instantaneous luminosity of $2 \times 10^{32} cm^{-2} s^{-1}$.
  - Integrated luminosity of 2 fb^{-1}.
  - Operation with 396 ns and 132 ns bunch spacing.
- As in Run I, CDF's strength lies in its tracking system
  - Good momentum precision
  - Good vertex precision – b hadron identification

The Run IIb Specifications

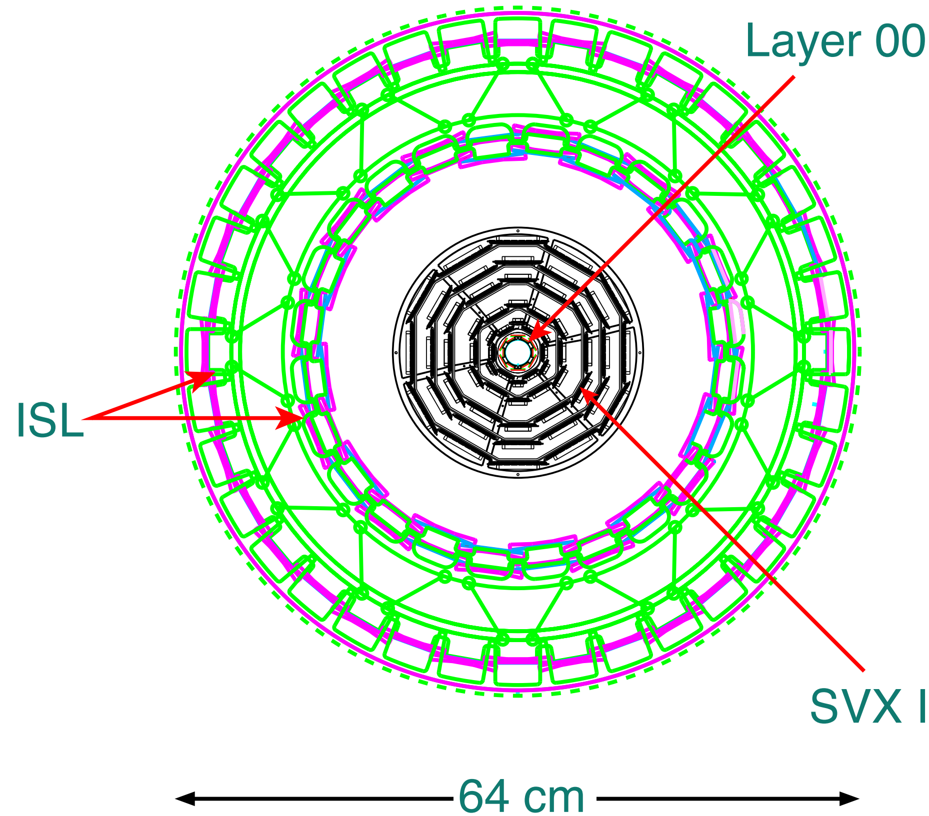
- Operating conditions for Run IIb:
  - Maximum instantaneous luminosity of $4\text{-}5\times10^{32}cm^{-2}s^{-1}$.
  - Integrated luminosity of as much as 15 fb^{-1}.
- Not all portions of the detector can operate effectively in these conditions
  - Integrated luminosity results in radiation damage of the tracking system.
  - Instantaneous luminosity results in high occupancy events and requires increase data acquisition bandwidth.
- The Run IIb project consists of replacements for key elements needed for the Higgs search and maintenance of the high P_T program.

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

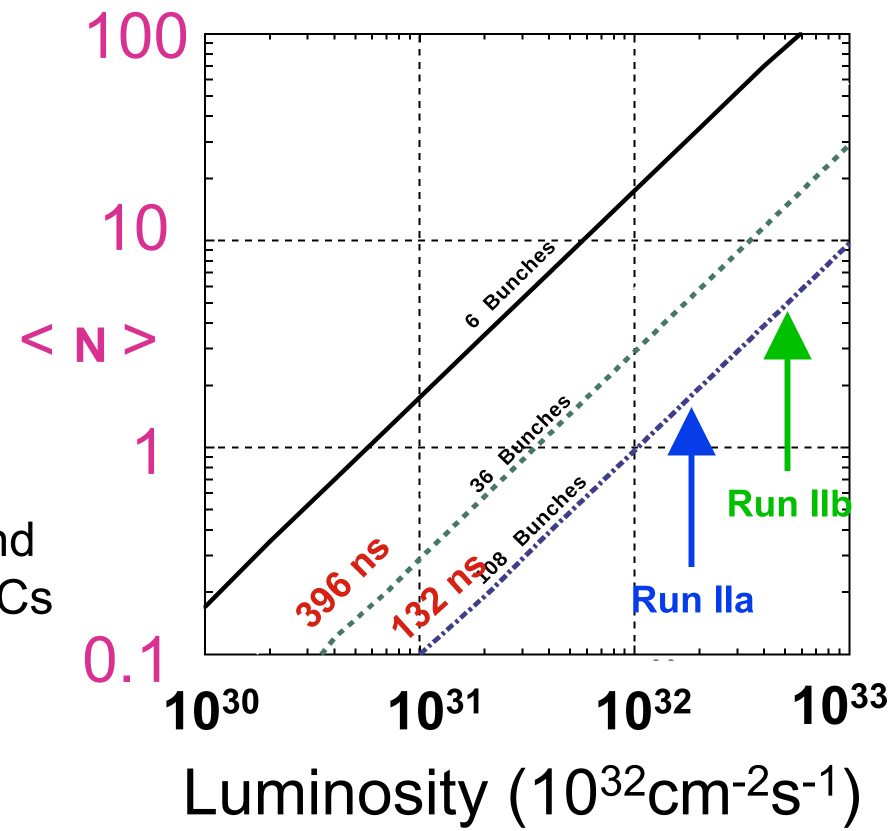
- We are forced to replace the inner layers.



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, and exceeds the capacity of our TDCs

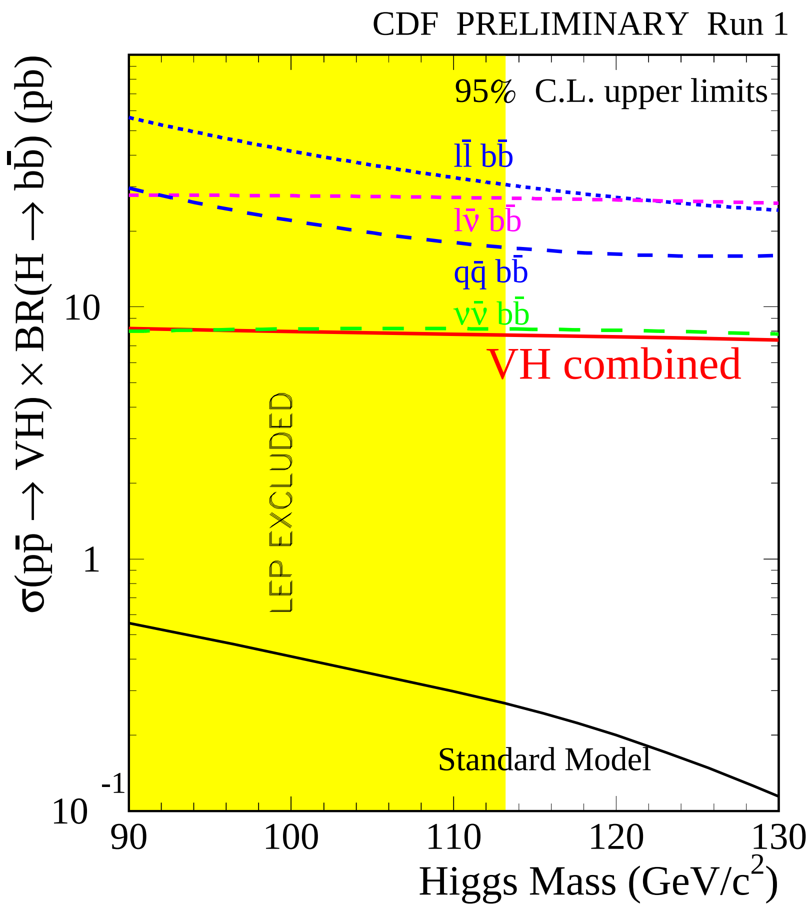


CDF's Run IIb Projects

- We have developed a program of upgrades to the current system that is required to maintain CDF as a viable Higgs search experiment for Run IIb:
  - Replacement Silicon Detector
  - Upgrades to the Calorimeter
  - Upgrades to the Data Acquisition and Trigger system
- This program has been presented to the Physics Advisory Committee and received its approval.

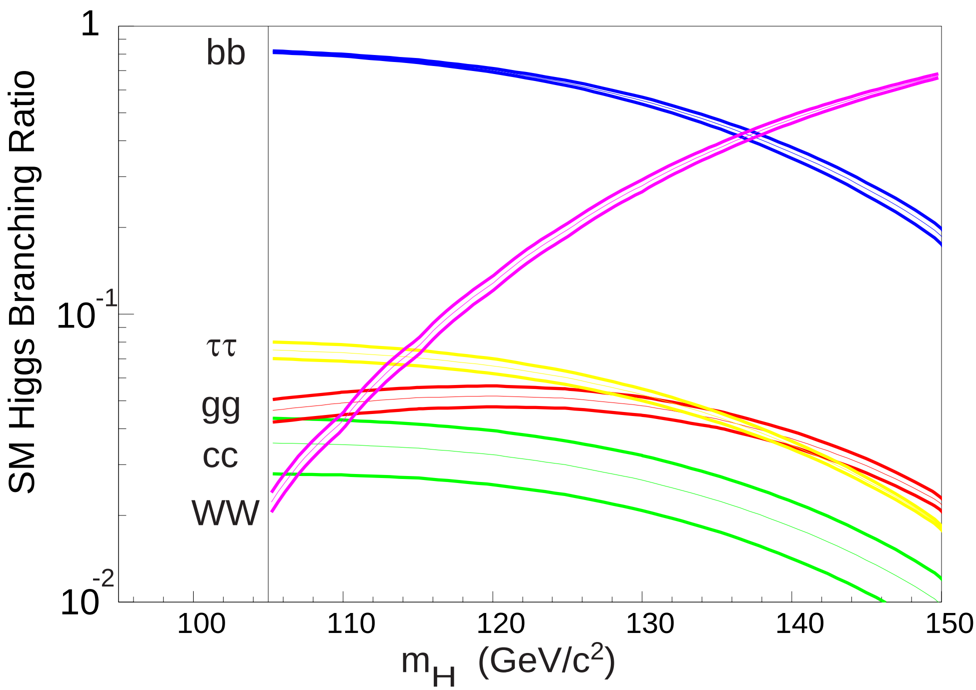
Higgs searches in Run I

- Standard Model Higgs
  $p\bar{p} \rightarrow VH$
  - Lepton + jets (≥ 1 *b* tag)
  - Missing E_T + jets (2 *b* tags)
  - Multijets (2 *b* tags)
- All channels require the ability to tag jets containing *b* quarks.



b tagging

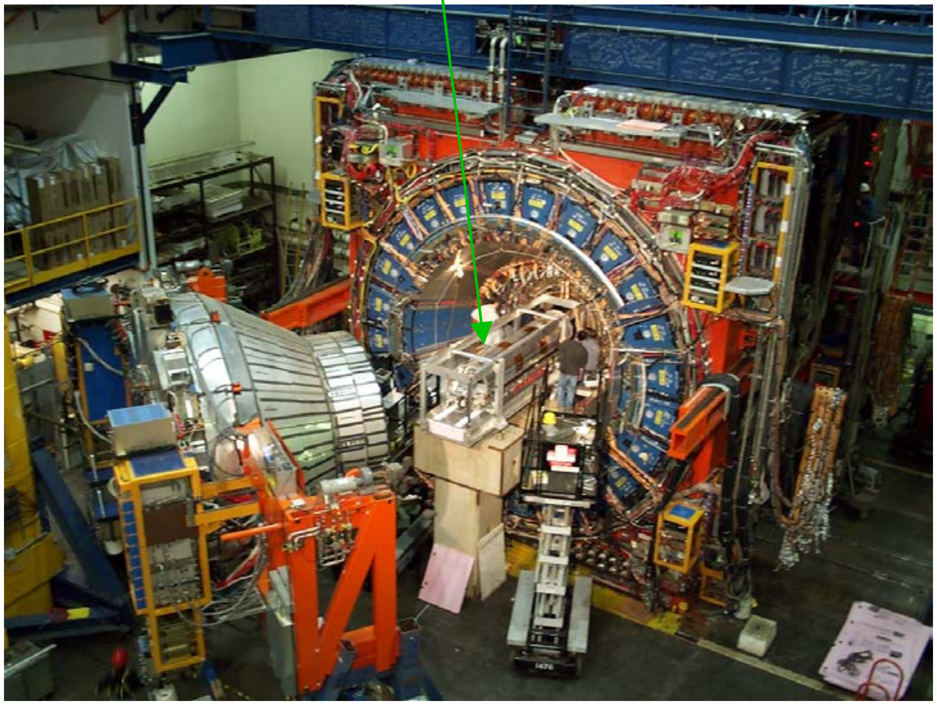
- Why is tracking important?
  - *bb* jets is the dominant branching ratio for a Standard model Higgs below 135 Gev/c^2.
- Tagging of *b* jets requires a precision vertex detector.
- This capability must be maintained for the Higgs searches of Run IIb.



Silicon Replacement Constraints

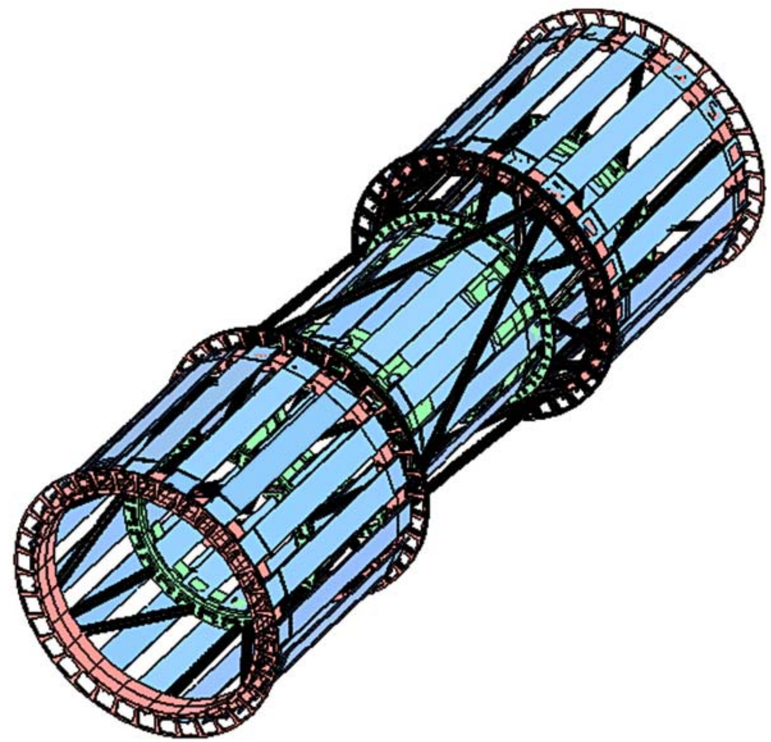
- Silicon detector removal
  - Space constraints require removal of the central detector from the collision hall
  - This requires 14 weeks.
  - Entire ISL/SVXII system must be taken to silicon facility for disassembly.
- A rapid reinstallation is needed to keep the down time to a minimum.

ISL and SVXII positioned for installation (Jan. 2001)



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.
  - Also tight connection with the beampipe.
- This motivates a complete replacement with a new detector
  - ISL is retained, but inner portion (SVX II) will be replaced.



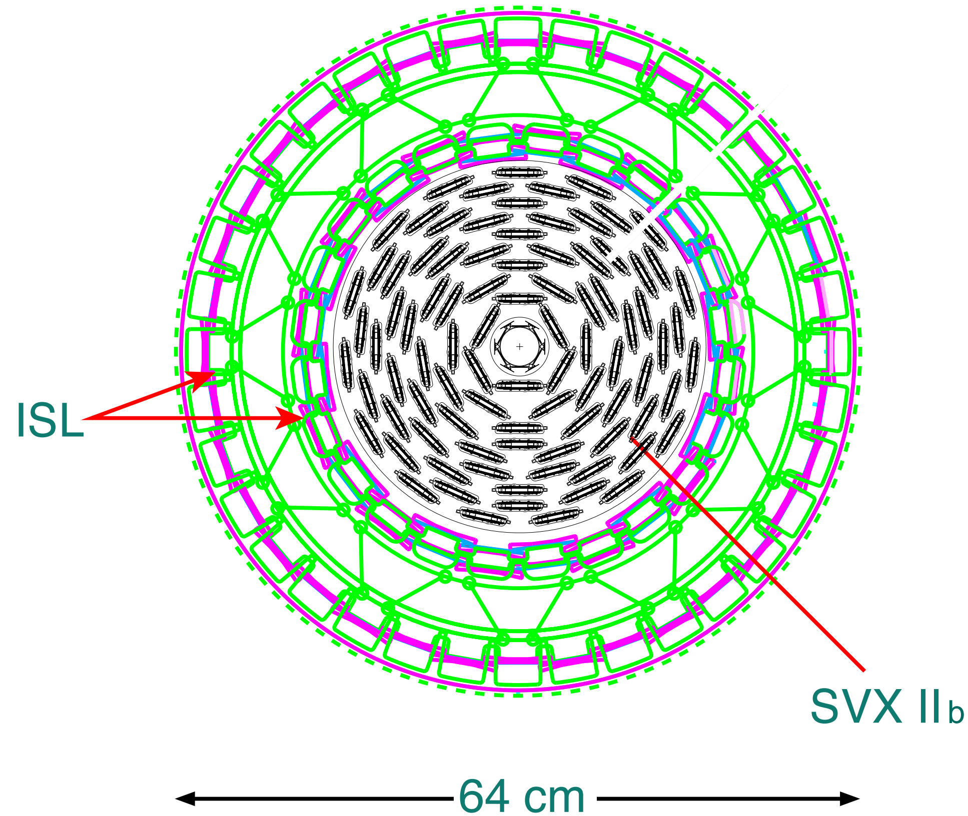
ISL Space Frame

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

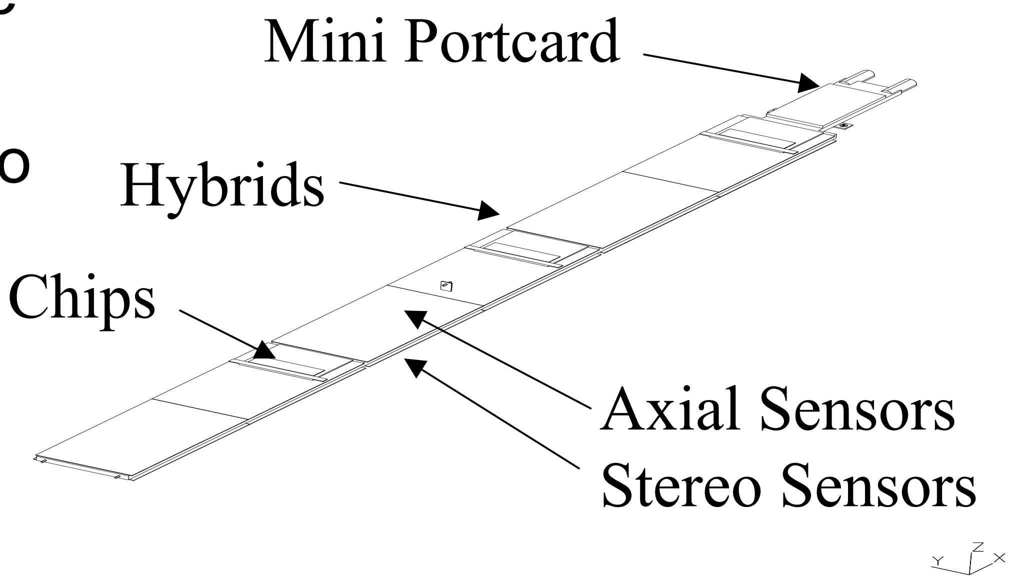
- All inners layers will be replaced.
- New detector is designed for quick construction
- A basic module - the “stave” will be built
- This structure will populate most of the detector volume
- This gives the advantage of fewer different parts than the current detector



Silicon detector end view

Silicon Detector - Run IIb

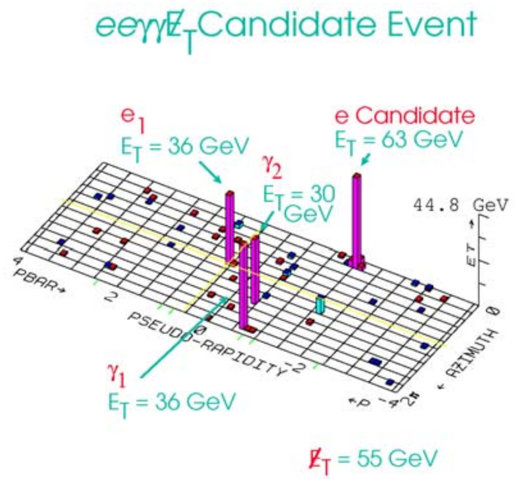
- Single sided sensors will be used for Run IIb.
- Axial and small angle stereo layers will be joined in a single structure – this is used for layers 1-5.
- Layer 0 (innermost) will be axial only, and a different structure.



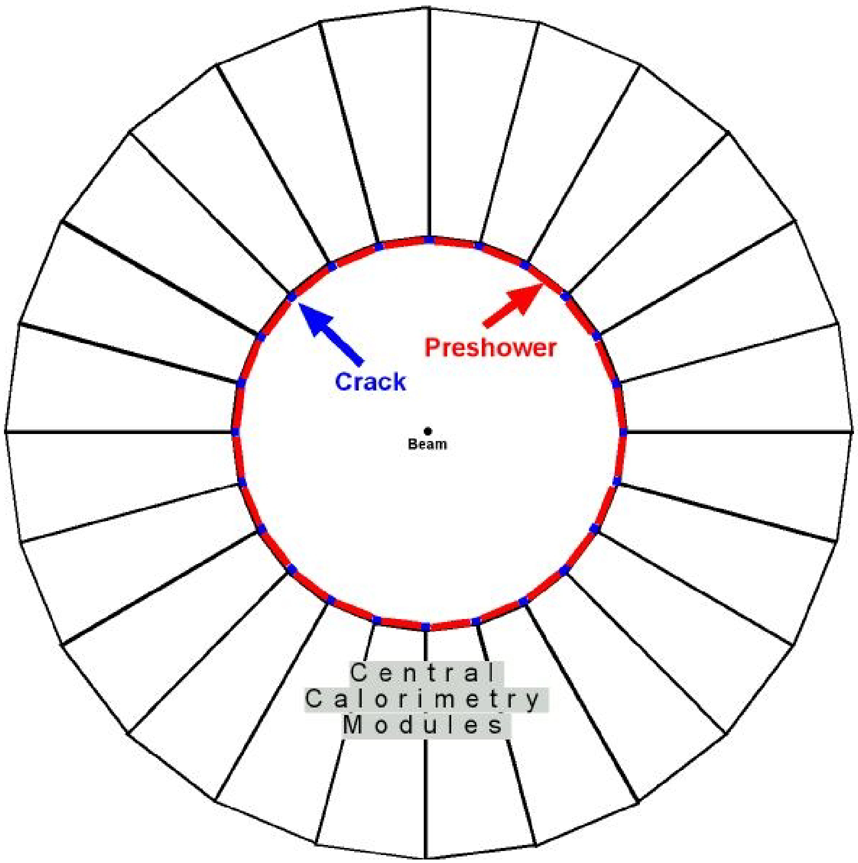
- Stave layout

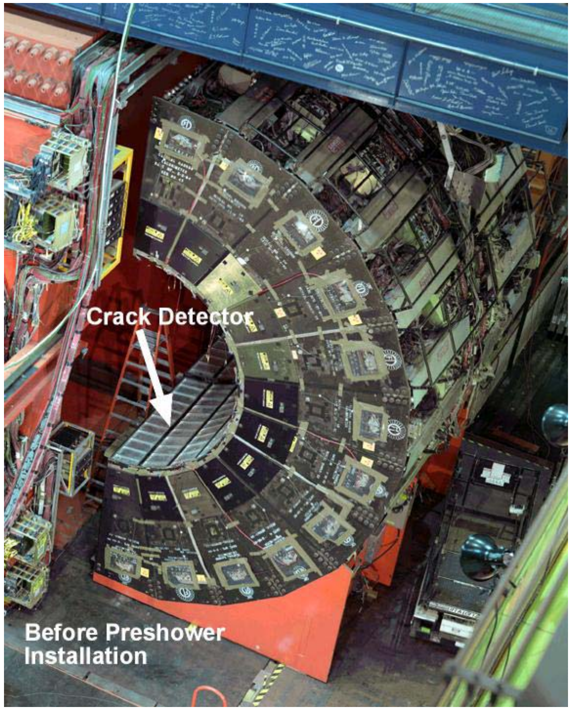
Calorimetry Upgrade Motivation

- Maintain capabilities of current Preshower detector, used in over 100 papers.
- Preshower expected to suffer high occupancy and aging effects in Run IIB.
- Preshower and Crack detectors expected to provide 5-10% Jet Energy Resolution improvement, part of the 20-30% needed improvement for the Higgs search.
- Electromagnetic timing needed to reject photon backgrounds from cosmic rays, in new physics searches such as SUSY.



Preshower/Crack Detectors





Calorimeter Upgrades

- The new preshower will replace the existing CPR.
- One of the last pieces of gas calorimetry (most replaced for Run IIa)
  - Replacement uses scintillator
  - Optical fiber readout, with 16 channel phototubes
    - Not a new technology for CDF
    - Same tube/light collection used in the endplug calorimeter.

A CPR2 prototype

Trigger and Data Acquisition Motivation

- The DAQ/Trigger upgrades presented here are driven exclusively by our 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: L $\leq$ 2x10^{31} cm^{-2} s^{-1}, ~1 interaction per crossing**
  - **Run I data: L ~2x10^{31} cm^{-2} s^{-1}, ~2 interactions per crossing**

- We are extrapolating to Run IIb
  - **L = 2x10^{32} cm^{-2} s^{-1} w/396ns bunch spacing (~5 int/beamX)**
  - **L = 5x10^{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: L = 4x10^{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

Summary of Run IIb specifications

- Level 1 Accept rate: >25kHz (spec 50kHz)
  - deadtimeless
- Level 2 Accept rate: 750 Hz $\rightarrow$bursts to 1.1kHz
  - L2 processing deadtime < 5%
  - readout deadtime (on L2A) < 5%
- Level 3 Accept rate: 85Hz
  - Event builder rate: 400MB/s
  - Output data rate: 40MB/s

- Reminder: trigger & bandwidth rates estimated based upon Run IIa, significant underestimate possible (assumes linear growth in fake contribution)

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.

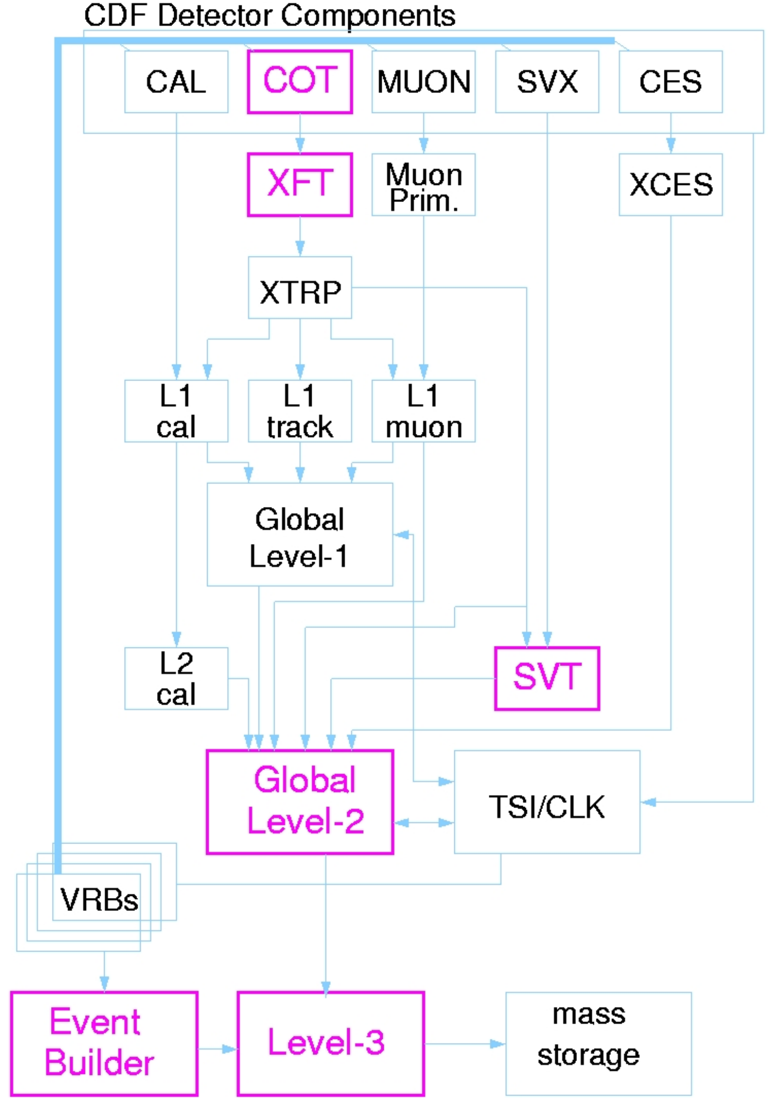
Triggers

- 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

<u>*General considerations:*</u>

- 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



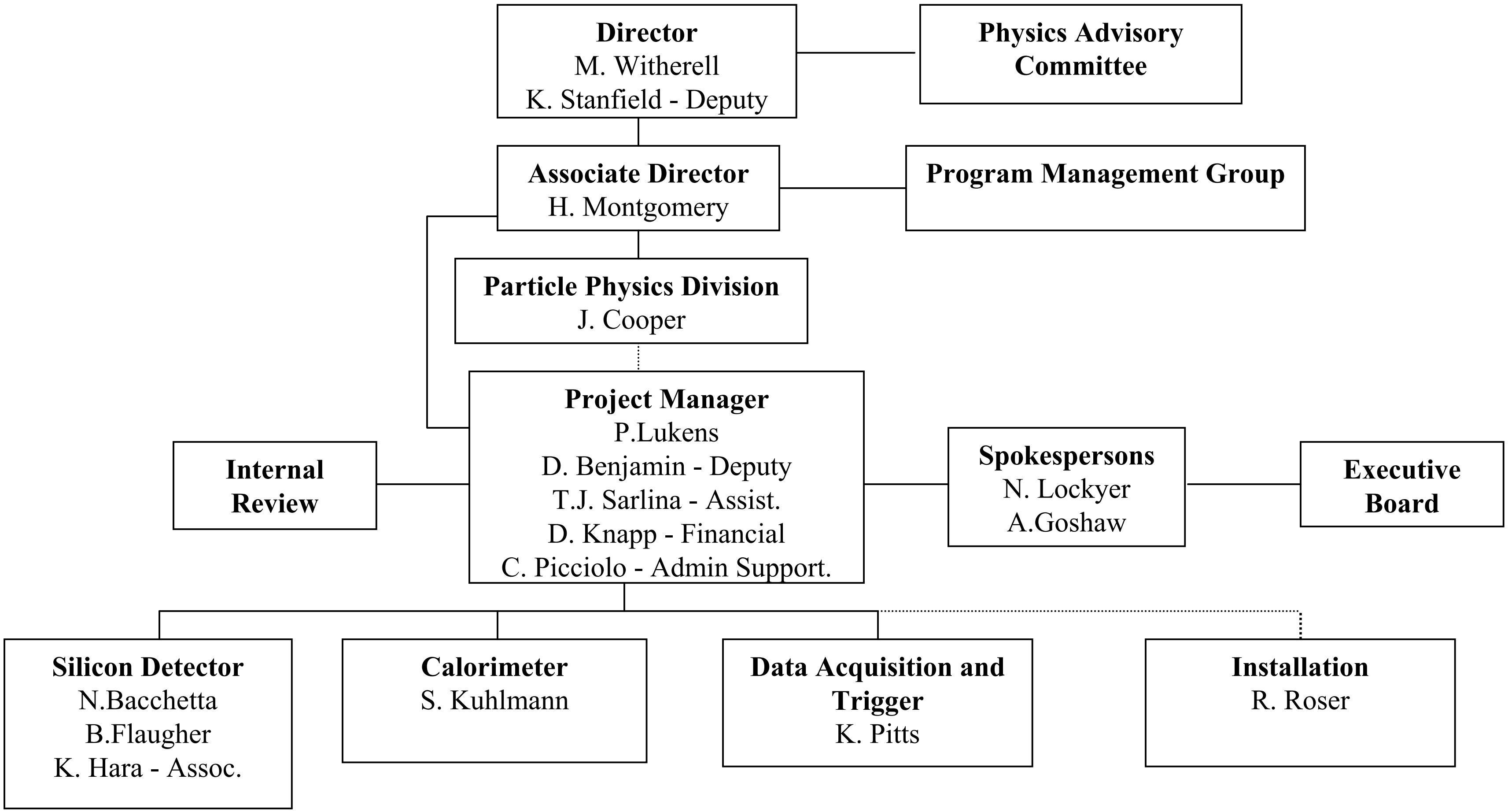
Installation

- 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

Run IIb Organization



CDF's Run IIb Team

- Project Management –
  - Project Manager
    - Pat Lukens – Fermilab
  - Deputy Project Manager
    - Doug Benjamin – Duke Univ.
  - Assistant Project Manager
    - T.J. Sarlina – Fermilab
  - Budget Analyst
    - Dale Knapp - Fermilab
- Subproject Management
  - Silicon Detector
    - Nicola Bacchetta – Padova
    - Brenna Flaugher – Fermilab
    - K. Hara – Tsukuba Univ.
  - Calorimeter Upgrades
    - Steve Kuhlmann – Argonne
  - Data Acquisition and Trigger
    - Kevin Pitts – Univ. of Illinois

Resource Loaded Schedules

- Resource loaded schedules have been created for each subproject.
- All M&S, R&D, and labor costs have been derived from the schedules.
- Labor rates originate from Particle Physics Division
  - Special category created for Silicon Facility labor
- Some labor is contained in M&S costs
  - Silicon work at LBL
  - Preshower construction at Argonne

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 44 weeks of schedule contingency (~30%).

Cost Contingency

- Our cost contingency is calculated for the lowest level tasks in the schedules.
- Guidelines are as follows:

Description	Level
Item is Complete	0%
Purchase order has been placed	10%
Engineering estimate, based on vendor information	30%
Labor, based on possible overtime use	40%
Physicist estimate, based on conceptual design	50%
Estimate based on experience	100%

Risk Analysis

- Risk is minimized in the basic design of the subprojects in every way possible
  - Reuse of familiar technologies and techniques
  - Conservatism in the designs - no aggressive performance specifications
  - Ample cost and schedule allocated - contingency added where appropriate.
- Analysis of risk to the current plan has been performed along the lines of a formalism described in the Project Management Body of Knowledge.

Risk Analysis

- Two factors are estimated in the risk analysis
  - Impact factor - severity of impact of an item's substandard performance on the project (cost overrun, schedule slip, technical performance, etc.)
  - Probability of occurrence - the likelihood that substandard performance will occur
- The product of these gives a risk factor.
- Mitigation is considered for items with a high risk factor (> 0.15).

Risk Analysis

- The impact table is adapted to reflect meaningful situations with respect to the subprojects.
- Risk analyses are performed by the Level 2 managers
  - An separate analysis of our riskiest project (silicon) has also been written by the Run IIa silicon manager.
- High risk items are mitigated
  - Cost or schedule contingency
  - Alternative strategies (additional vendors, preproduction pieces, etc.).

Cost Estimates

- Currently, all cost estimates are obtained by extracting the resource loaded schedule information into a spreadsheet.
- Indirect costs and escalation are then applied to obtain total cost estimates.

Fiscal Year	2002	2003	2004	2005	2006
Escalation	1	1.023	1.052	1.08	1.108
SWF Inflation	1.000	1.040	1.082	1.125	1.170

Project Tracking

- The Cobra financial package will provide a more precise estimator for total costs
  - Indirect charges, labor rates, handled better
  - Timing changes handled correctly (i.e., purchase slips into another year and indirects are adjusted)
- Most importantly, it also takes input from the general ledger for comparison to our schedules.
- This is the tool which will be used to calculate earned value, for tracking the project progress.
  - Currently used by NUMI for their tracking.

Tracking Status

- We have successfully loaded the silicon detector schedule (our largest by far) into Cobra.
  - Sample reports are available
- Other schedules will follow soon.
  - Technical issues for incorporating schedules are understood.
- Interface with the general ledger is in progress.

Total Cost by Subproject

	2002	2003	2004	2005	2006	Contingency	Totals
Silicon	$ 1,317	$ 2,894	$ 5,229	$ 5,150	$ 623	5,341	$ 20,555
Calorimeter	$ 66	$ 612	$ 389	$ 12	$ -	348	$ 1,427
DAQ/Trigger	$ 36	$ 711	$ 1,130	$ 2,803	$ -	1,742	$ 6,422
Administration	$ 205	$ 385	$ 388	$ 397	$ 182	422	$ 1,979
Total	$ 1,625	$ 4,601	$ 7,137	$ 8,363	$ 805	$ 7,853	$ 30,383

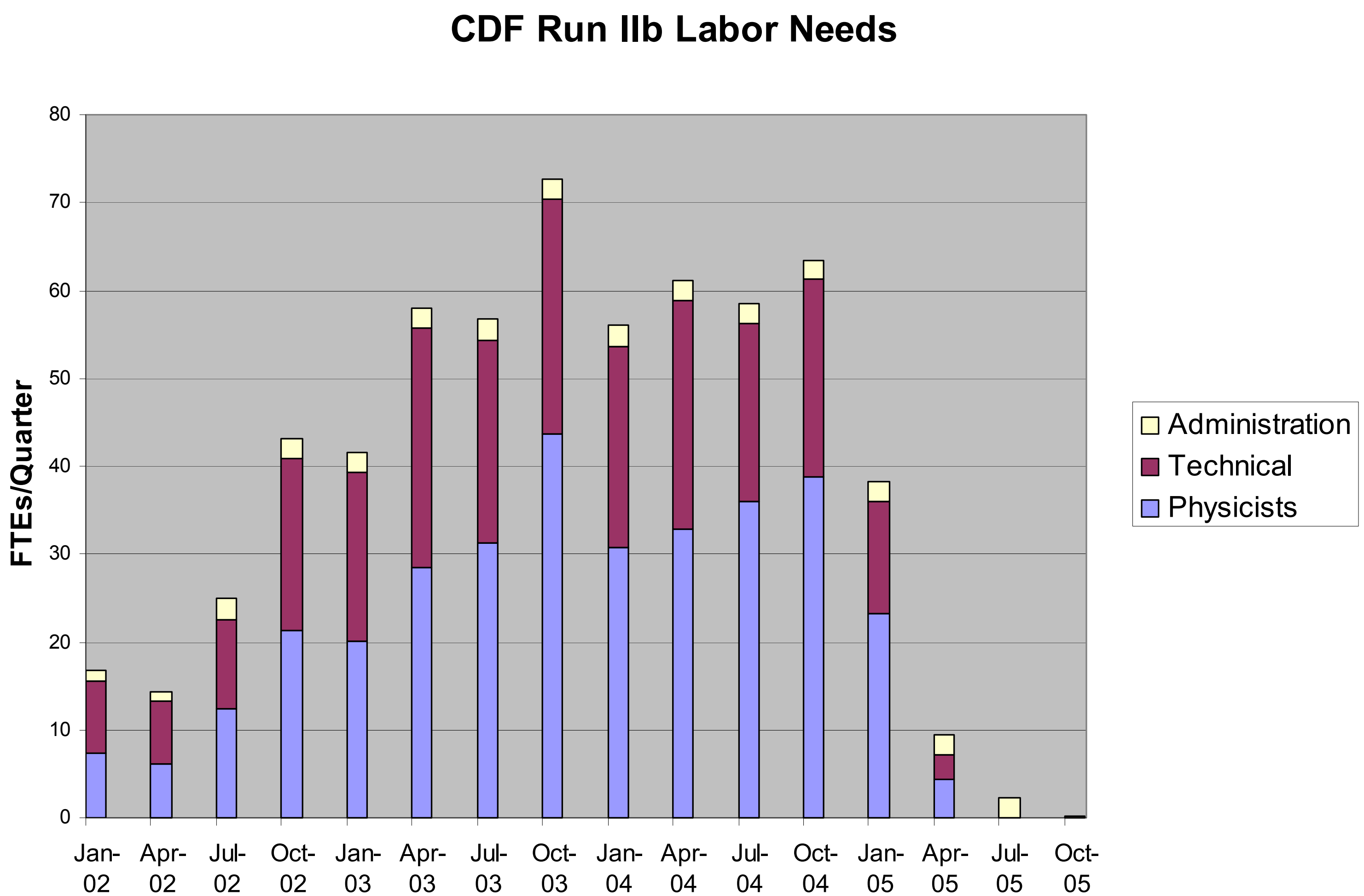
Total costs (with G&A) in AY $K

- Our overall contingency is 35%.
- Additional resources are required in the form of contributed labor.
  - Physicists are not considered part of the project cost.
  - This labor is included in the schedules.

Foreign Contributions

- Substantial foreign funding is anticipated
- 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
- Discussion are underway with Taiwan, Korea, and Canada for contributions to silicon.

Labor Required



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

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 window of opportunity for Run IIb requires the detector upgrades to begin soon.

Conclusion

- The CDF collaboration has a strong history of supporting the experiment, and has made good use of the data.
  - Recent Spokesmen's poll indicated ample scientific manpower will be available for the project.
- We are fully committed to proceeding with the Run IIb CDF detector project, and we are eager to get going.