Tevatron Detector Upgrades

Contents

- Upgrade History
- The Detectors in Run IIa
- Tevatron Scenarios and Running Conditions
- CDF and D0 Upgrades
- Maximizing Physics
- Conclusions

This will not have WBS numbers/L1,2,3 managers and cost/schedule information …

Upgrades Past

- Tevatron Run II was originally planned for 2 fb^{-1}
- TeV2000 and TeV33 studies indicated an extended physics reach and substantial Higgs discovery potential for Tevatron experiments
- Luminosity goals increased to ~15 fb^{-1}
  - Silicon detectors designed in the early 90s will not survive beyond 4-5 fb^{-1}
  - Trigger and DAQ systems inadequate to the high rates and multiple interaction backgrounds
- Run IIb Upgrades approved in ~2002

Upgrade Past II

- Tevatron luminosity ramped up *slowly*
- Various reviews indicated that initial Run IIb accelerator goals were unrealistic
- Winter 2002-2003 decision to drop 132ns running
  - Findley report - Detectors should survive increased <interactions> - luminosity leveling will help
- Summer 2003 Lehmann - new accelerator goal 5-8 fb^{-1}
- September 2003 – Run2b silicon replacements cancelled
  - D0 proposes Layer 0 – approved Oct 2003
  - Trigger and DAQ and some detector upgrades retained

Luminosity Projections

Accelerator draft plan:
Peak luminosities

Peak to date ~7.63E31

~2.8e32 peak
~8.6 fb^{-1}
integrated

~1.6e32 peak
~4.5 fb^{-1}
integrated

Peak Luminosity (x10^{30}cm^{-2}sec^{-1})

300
250
200
150
100
50
0

3 4 5 6 7 8 9 10

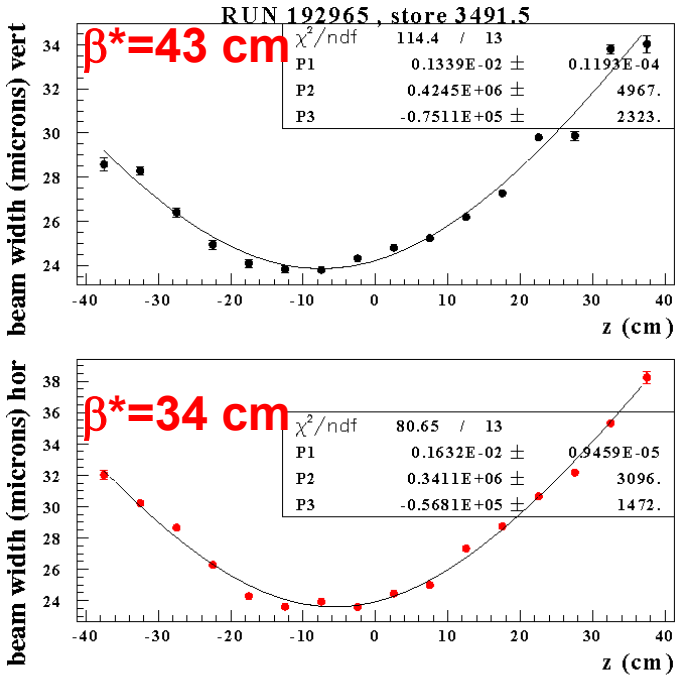
Start of Fiscal Year

Tevatron experiments must survive 10 years with
10 to 20x current integrated luminosity

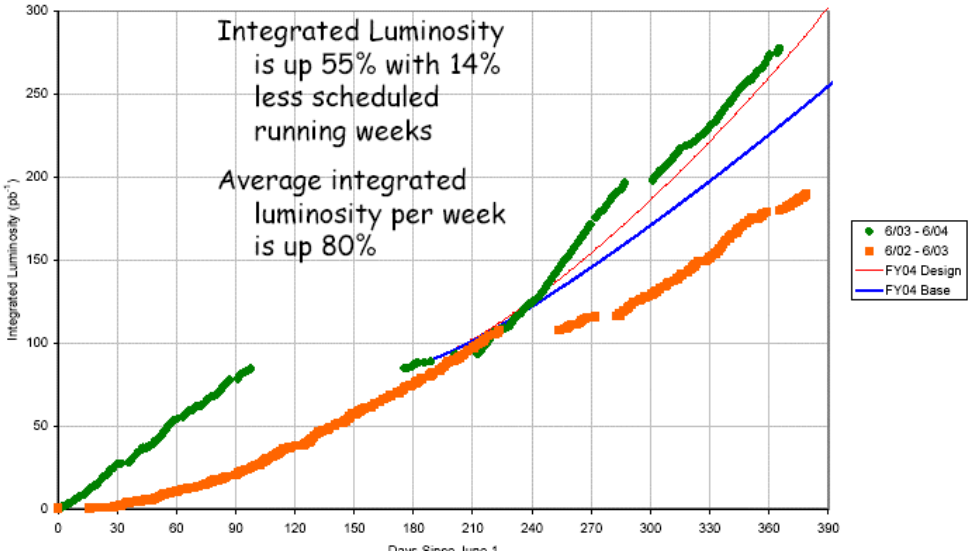
Tevatron Performance

The Tevatron is now performing well

- **Expect to achieve "design" integrated luminosity goals this year**
- **Improvements in running conditions/accelerator parameters**
- **Experiments are planning for initial luminosities of 100×10^{30} by this summer's shutdown**
- **Branch point - electron cooling in the recycler being installed this fall**



Improved optics ~ 2 weeks



Ronald Lipton HCP 2004

The Detectors in Run IIa

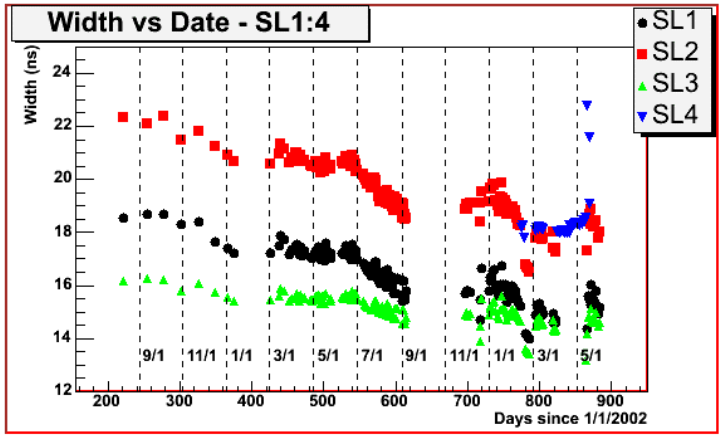
The Run2a Detectors are extremely complex

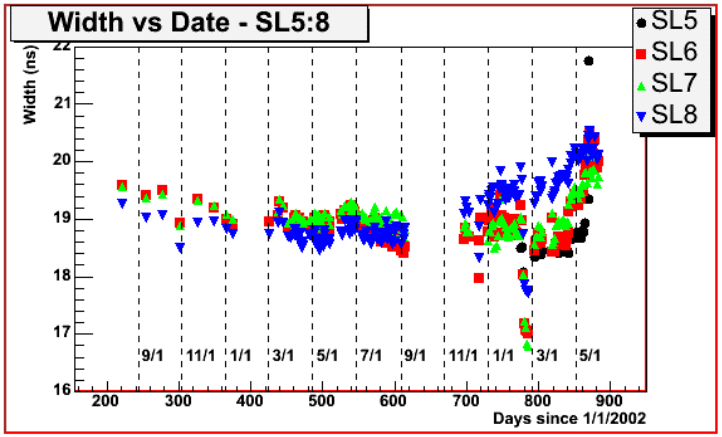
- **Commissioning took ~1.5 years**
- **Huge overhead**
  - **C++**
  - **Databases, control systems, online monitoring**
  - **Firmware debugging …**
- **Complex trigger and DAQ – interactions among subsystems**
- ***Many detector problems were hidden behind poor initial Tevatron performance - upgrades must be commissioned efficiently***

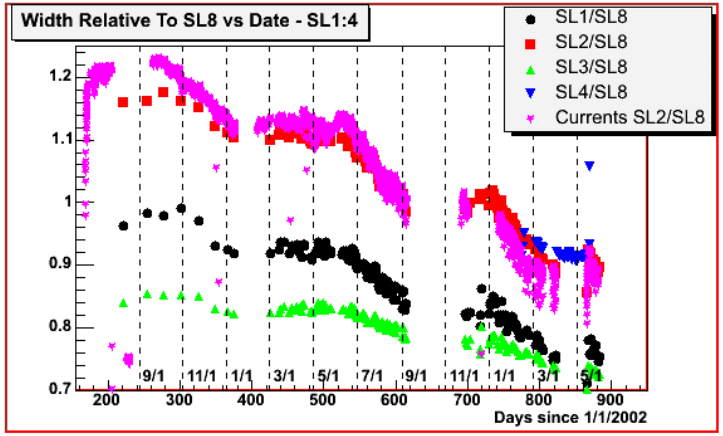
The Detectors in Run IIa

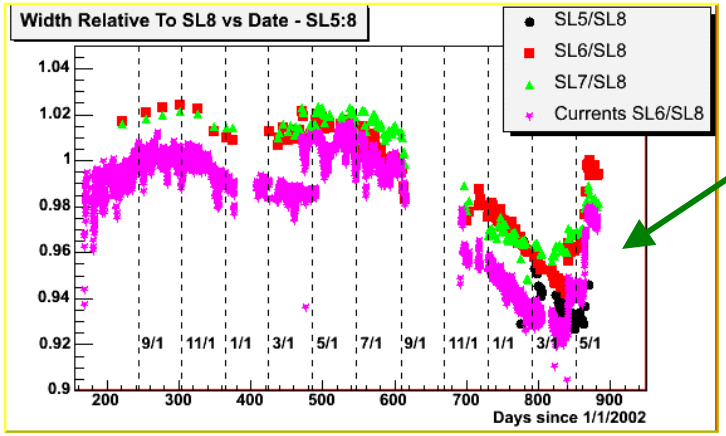
Detectors are now working well – as demonstrated by the physics results at this conference but …

- Both experiments have had trouble achieving their L1 accept goals
- Both experiments have had problems with their tracking detectors
  - CDF with radiation damage in the COT and beam loss related damage to the silicon
  - D0 with noisy sensors and unreliable SVX II readout
- Occupancy-related trigger rate issues at high luminosity are problems for both experiments
- Upgrades address some (but not all) of these issues



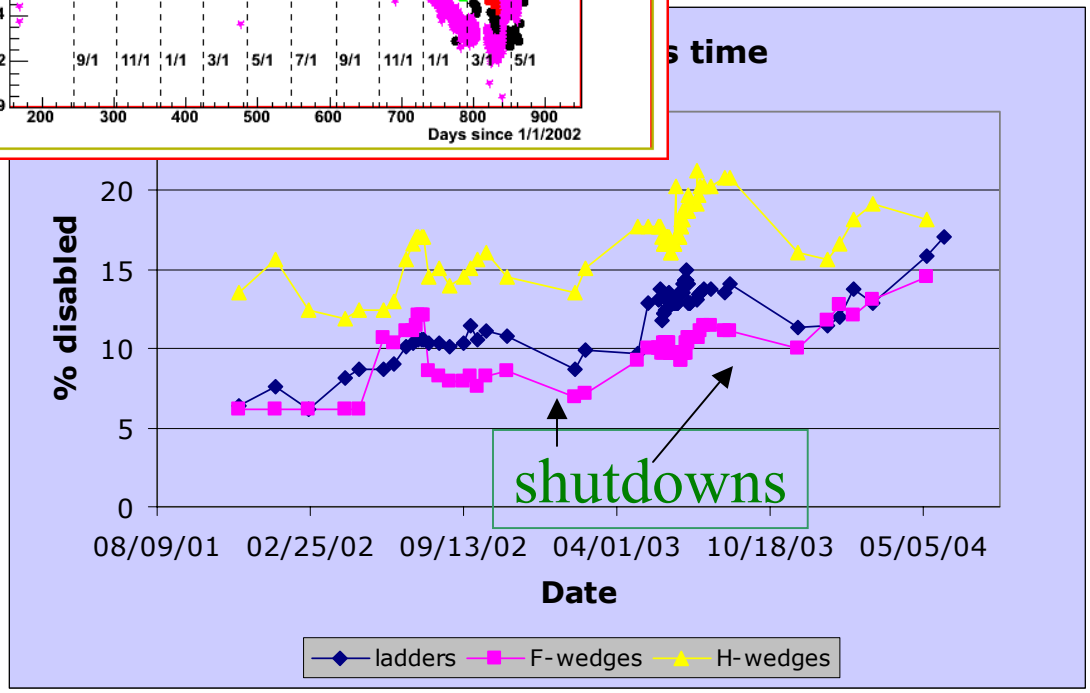






Pulse widths and ratios vs time for the CDF COT

COT gas recirculation



D0 disabled silicon devices vs time since 8/9/2001

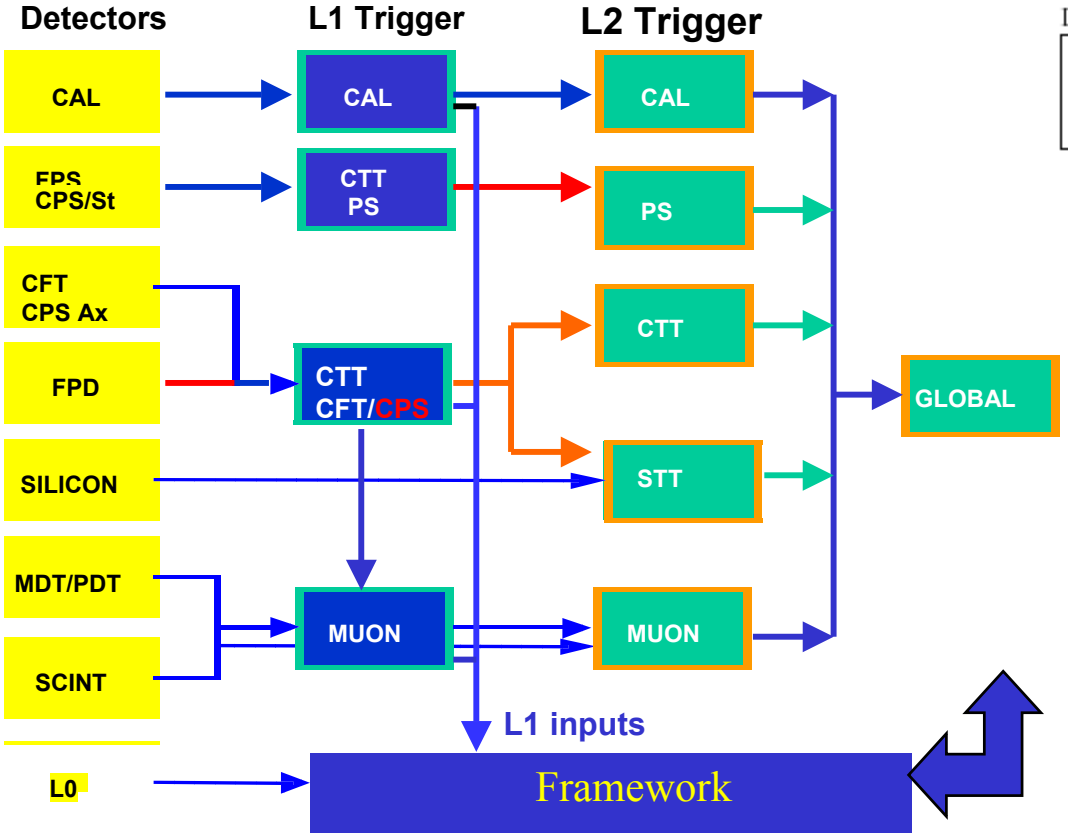
CDF and D0 Upgrades

Goals

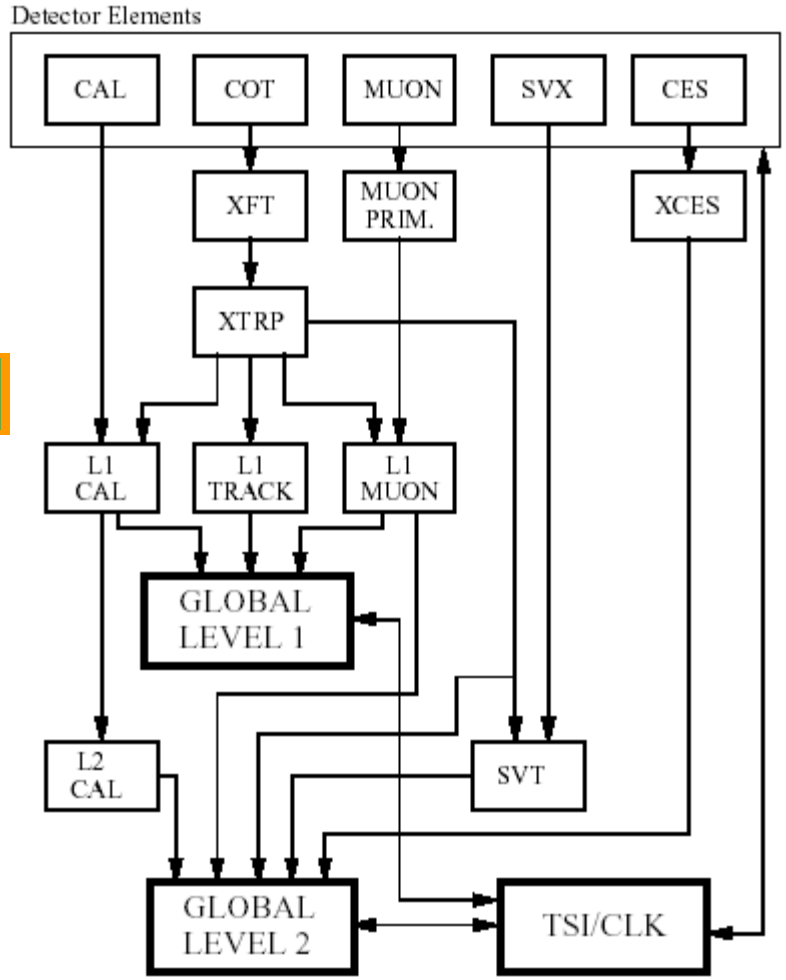
- Survive in a high luminosity environment until 200Lhc
  - Trigger upgrades
- Improve detector performance
  - CDF Calorimeter upgrades
  - D0 AFE (fiber tracker readout) replacement
  - D0 Layer 0
- Maximize Physics

Trigger Schemes

D0 Trigger



CDF Trigger



Trigger Upgrades

Trigger Rates				
	D0 Now	D0 RunIIb	CDF Now	CDF Run IIb
L1	1500	2500	25000	25000
L2	850	1000	300	750
L3	50	50-150	50	85

- **Trigger schemes are similar but differences are striking**
  - **CDF L1 trigger bandwidth allows for SVT B triggers …**
  - **CDF "deadtimeless" at L1, D0 incurs SVX2 deadtime**
  - **L2 rejection important for CDF, must be done at L1 for D0**
- **L1 is not yet a limiting factor for D0 – i.e. single muons are 70% pure at L1 – can be raised to 2500 Hz with firmware modifications**

Trigger Upgrades

- **Both experiments will suffer from increased occupancy in high Luminosity 396 ns running**
  - **Higher tracking fake rates, reduced resolution, larger data loads**
- **Significantly affects tracking triggers**
  - **Attack by better hit resolution (both D0 and CDF)**

From Finley report

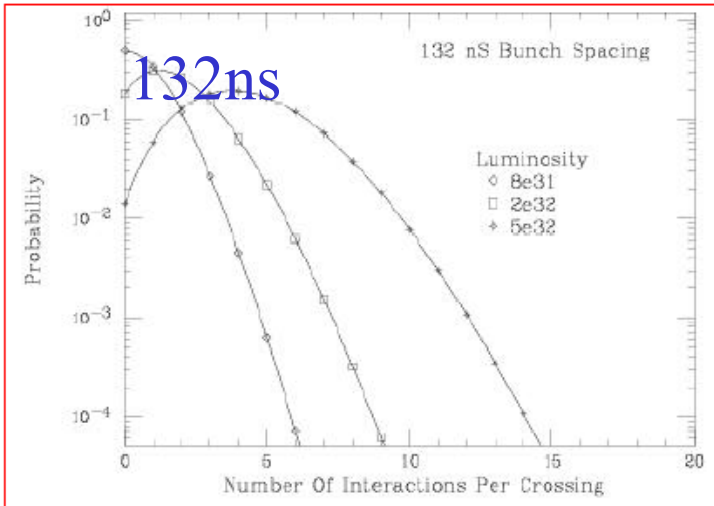


Figure 1. Number of Interactions per bunch crossing for L = 8×10^{31}, 2×10^{32}, and 5×10^{32} cm^{-2} s^{-2}, with 132 nsec operation.

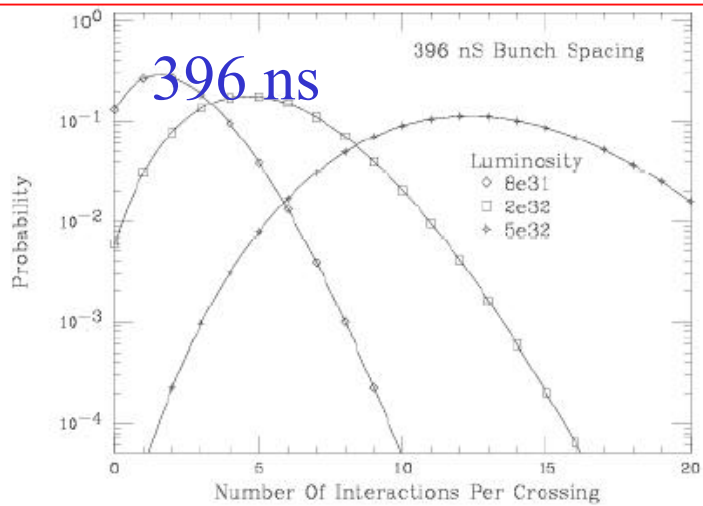


Figure 2. Number of Interactions per bunch crossing for L = 8×10^{31}, 2×10^{32}, and 5×10^{32} cm^{-2} s^{-2}, with 396 nsec operation.

CDF Upgrades

Trigger

- Central Outer Tracker TDC Upgrade
  - Allow faster L2 readout, provide better timing to XFT
- XFT (tracking trigger) upgrade
  - Improve resolution, add stereo information
- Replace Level 2 DEC Alphas with commodity processor
- Replace Event Builder ATM switch with gigabit ethernet

Detector

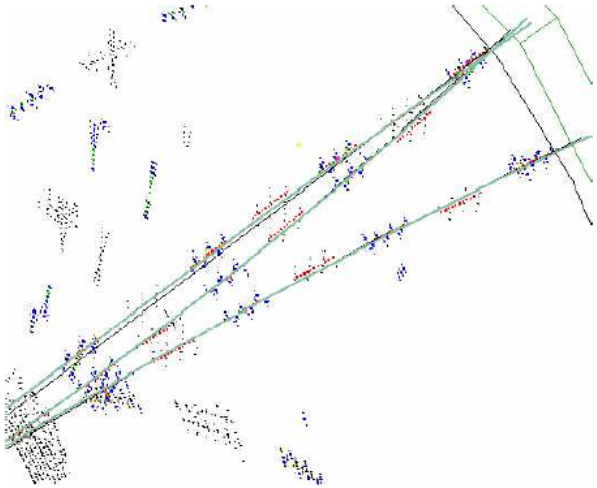
- Central crack/preshower
  - Replace gas chambers with scintillator
- EM timing
  - Add timing to EM cal readout – reject cosmics

Track Triggers - CDF

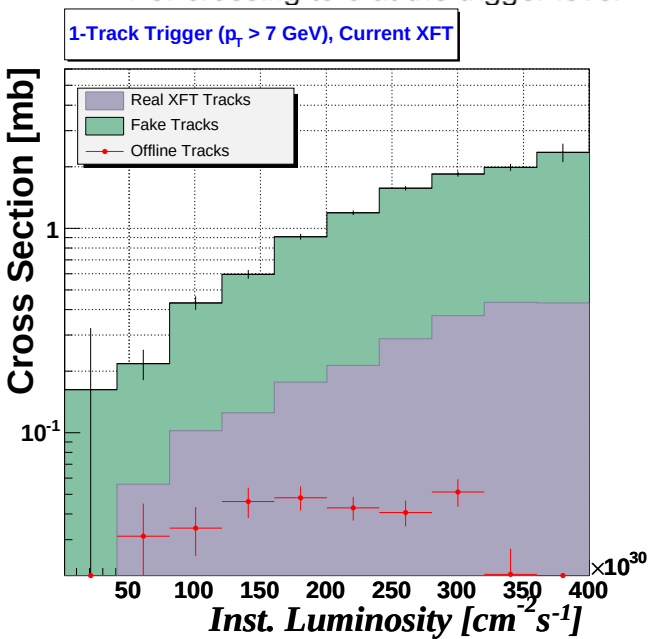
XFT – Uses coarse COT hit timing information for track finding. High occupancy in 396 ns running at high luminosity will

- Degrade momentum resolution
- Degrade ϕ_0 resolution
- Increase Fake rate

- Improve hit timing resolution (x3)
- Include stereo information – Z pointing
- This will improve hit resolution and provide more flexibility for alternate algorithms



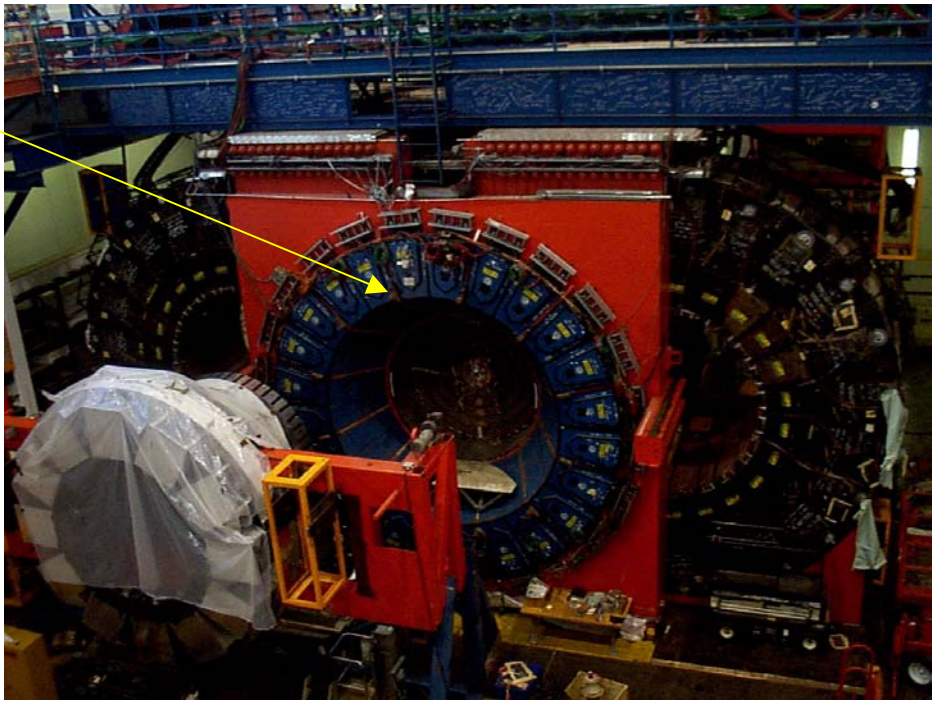
CDF will go from 2 time bins
Per crossing to 6 at the trigger level

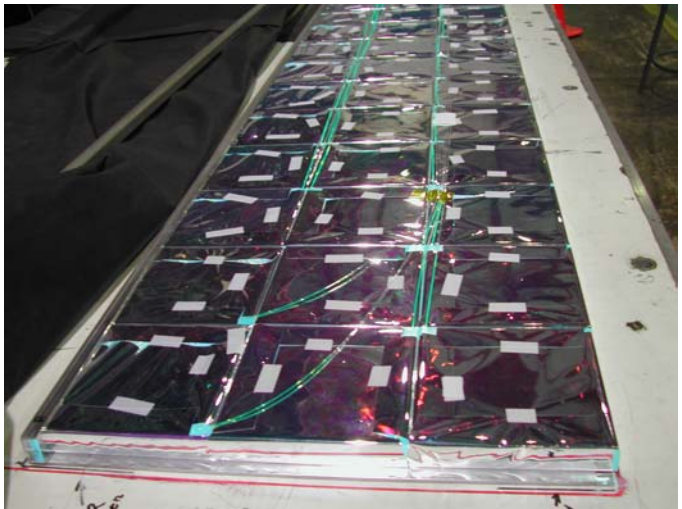


CDF Calorimeter Upgrades

Preshower/Crack detectors CPR
- Important for electron/photon ID
- Replace gas detectors with scintillator/wavelenght shifter technology (plug calorimeter)
- Reuse Run2a electronics

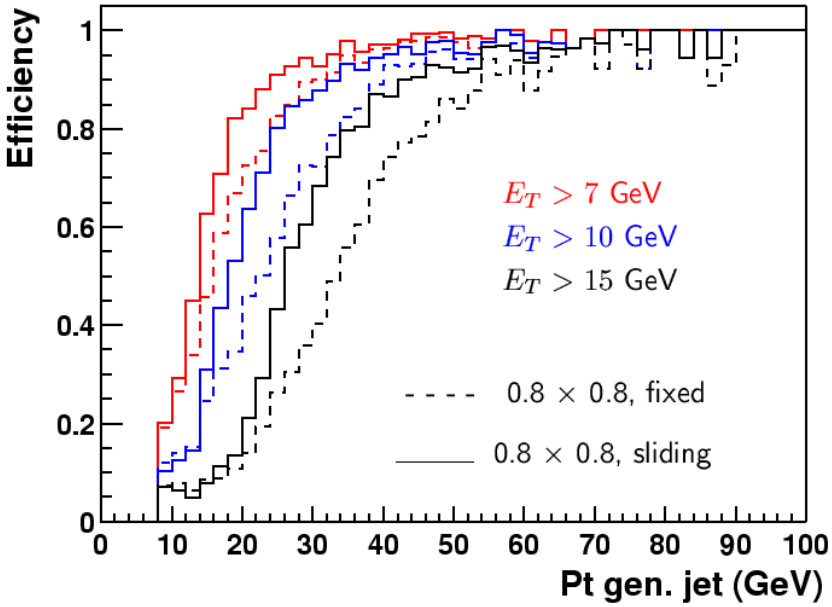
EM Timing
- Based on hadronic section electronics
- Reject cosmics – tag good electrons – nail rare decays signals

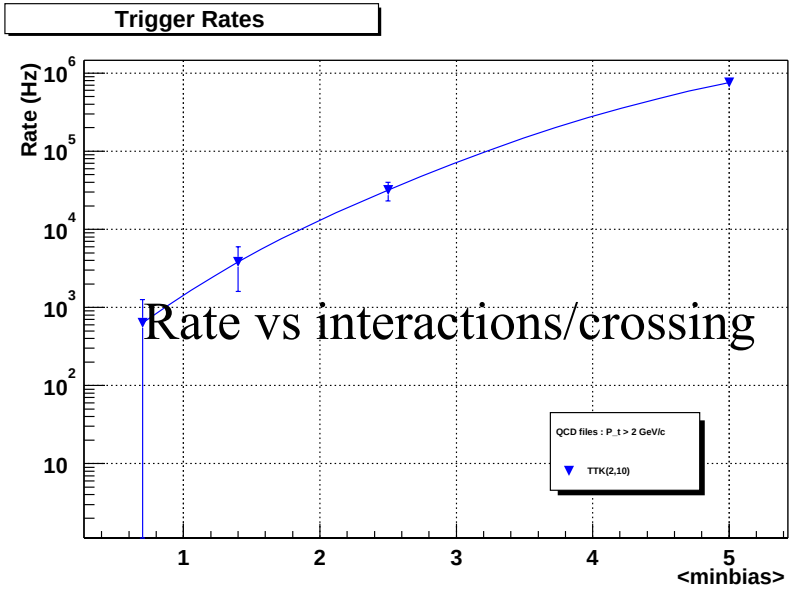




D0 Trigger Upgrades

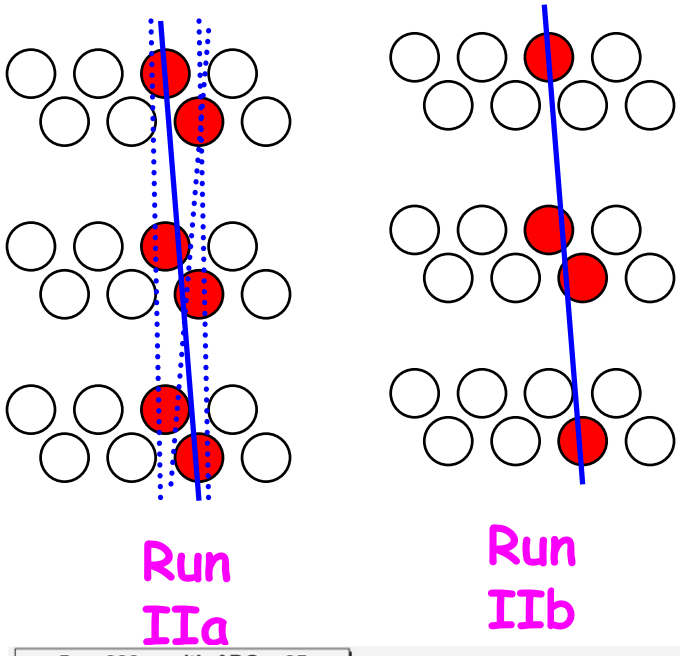
- Calorimeter trigger upgrade
  - Digital filtering/sliding windows
  - sharpens turn-on trigger thresholds
  - more topological cuts
  - Calorimeter track-match
    - fake EM rejection
    - tau trigger
- L1 tracking trigger upgrade (CTT)
  - improved tracking rejection especially at higher occupancies
- Level 2
  - L2 Processor upgrades for more complex algorithms
  - Silicon Track Trigger expansion to accommodate L0, add processing

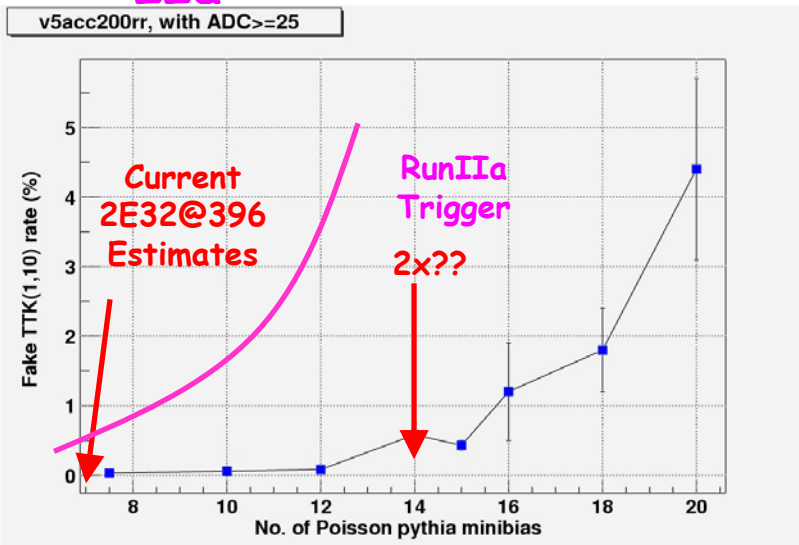




Track Triggers – D0

- D0 Run2a Central Track Trigger
  - Uses fiber doublets
  - Requires 8 of 8 hits
  - Implemented in FPGA
- CTT Upgrade
  - Use fiber singlet hits – reduce combinatorics use more equations
  - Larger FPGA – flexibility in algorithms (n of m) and pt bins

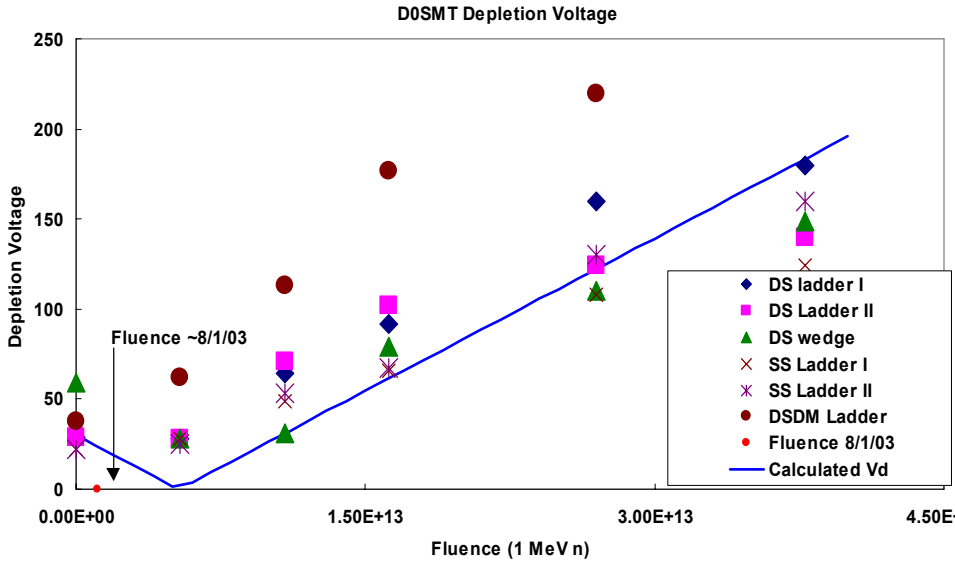




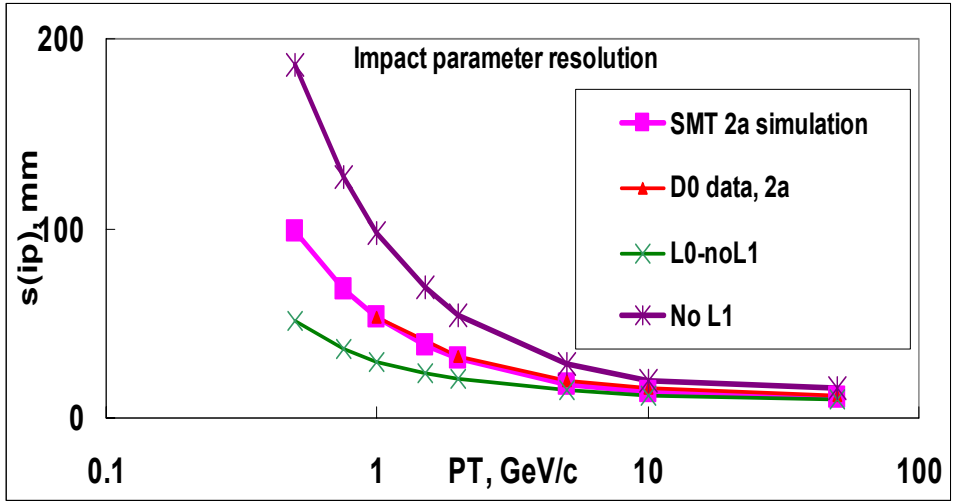
- Rate of fake high-p_T tracks vs. Luminosity

D0 Layer 0 Silicon Detector

After cancellation of the Run2b silicon upgrades D0 Studied the possibility of installing a new detector *inside* the current SMT

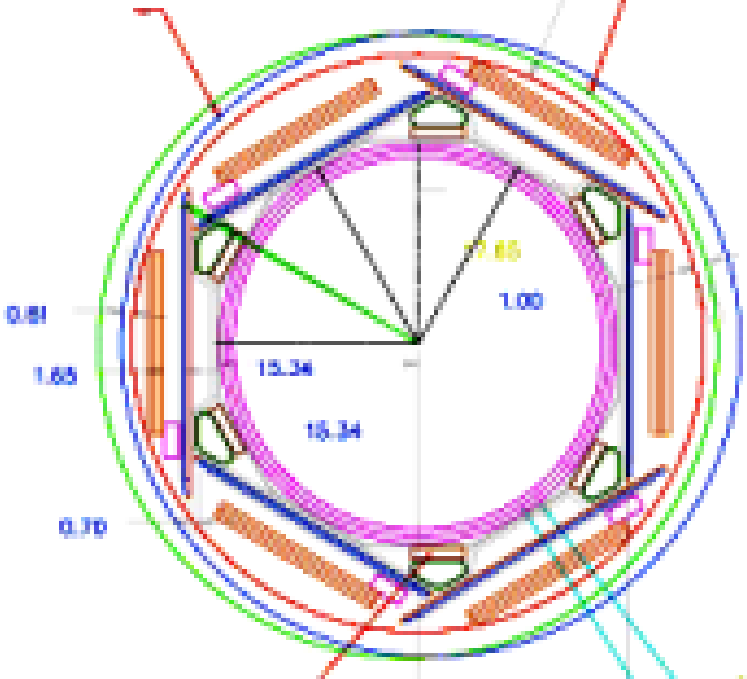


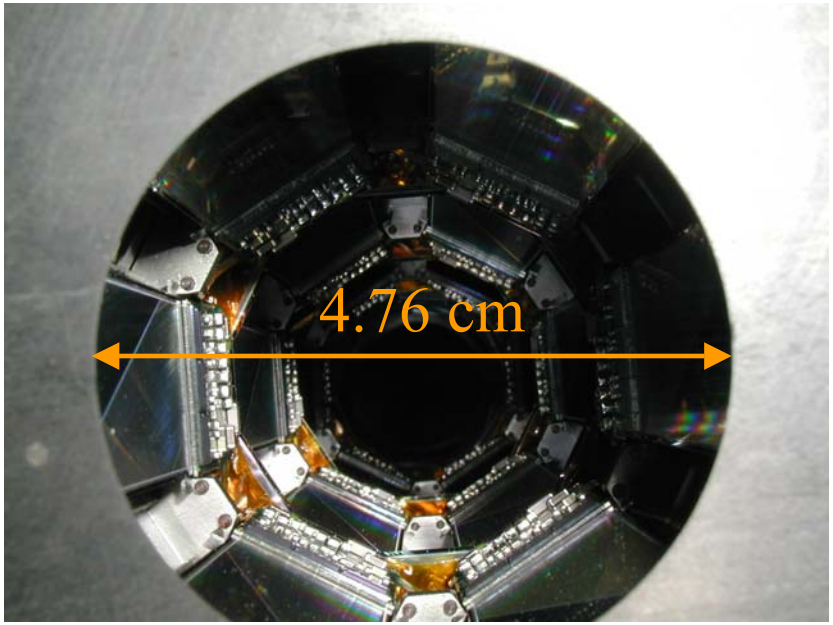
- **Retain B ID, tracking, and vertexing if layer 1 fails due to radiation damage**
- **Improve impact parameter resolution- analog cables move hybrids out of volume**
- **Use Run2b R&D (and funding)**



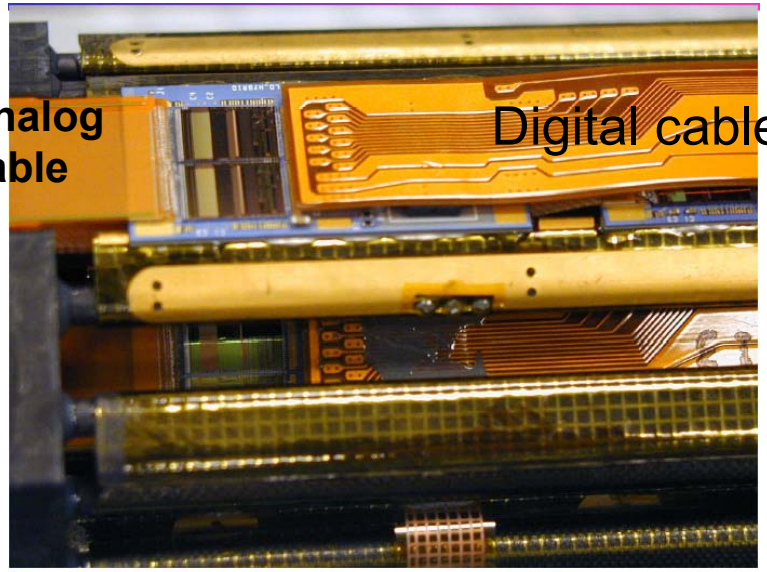
D0 Layer 0

- Mechanical and electrical design constrained by available space (will it fit?)
- Avoid coherent and random noise problems induced by ~30 cm analog cables and ground loops with integration of ground/support design
- Use Run2b project SVX4, support structure, beam pipe
- On track for installation summer of '05

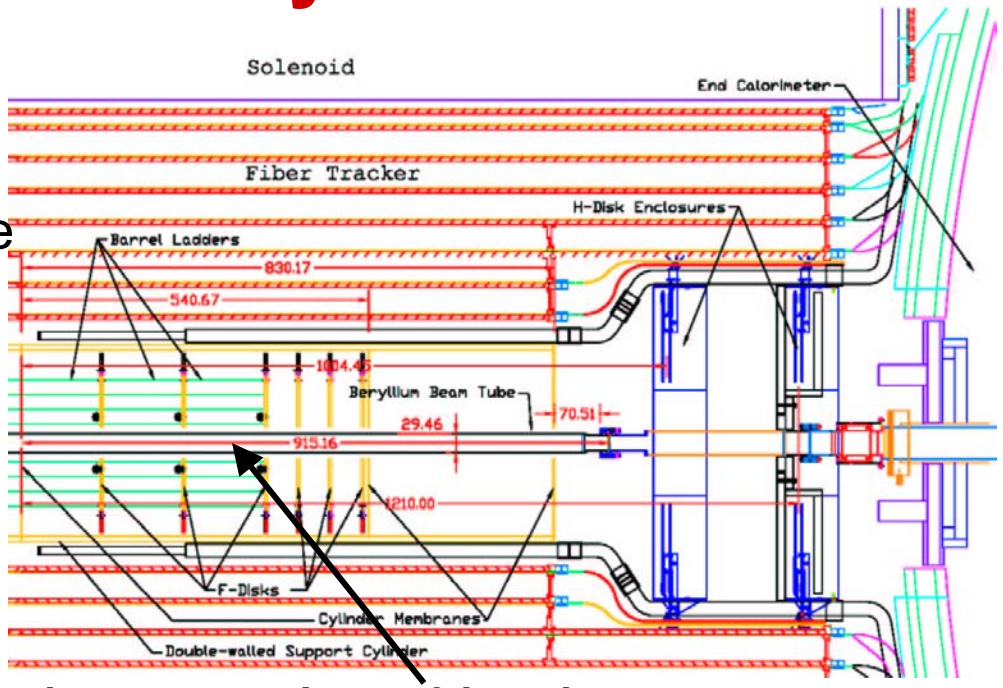




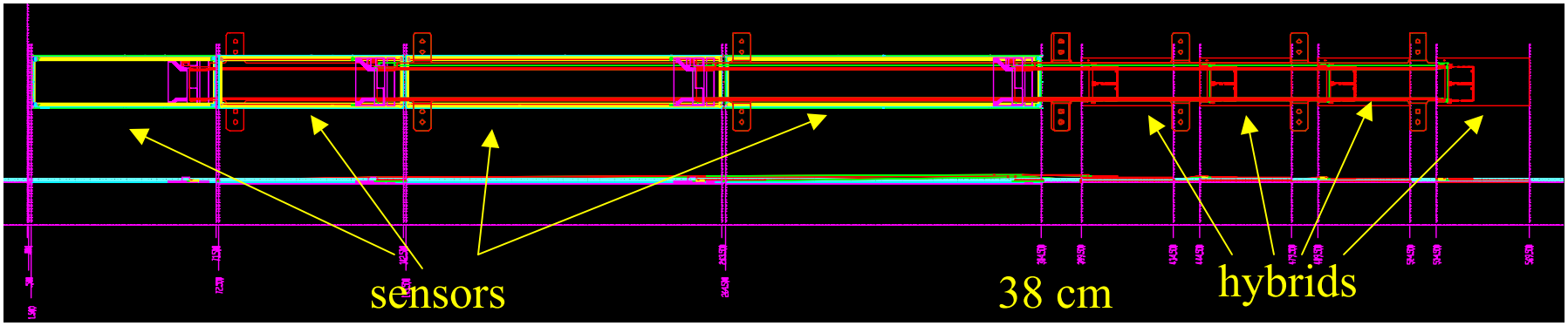
D0 Layer 0



Hybrid region with co-cured kapton circuit



Layer 0 location



Layout of one detector half facet

Maximizing Physics

- The aim of both experiments is to maximized integrated luminosity before LHC turn-on
- Need to integrate upgrades seamlessly
- Formal upgrades will merge into "operations"
  - CDF silicon lifetime committee
  - D0 trigger rate improvements
  - DAQ improvements with faster processors
- Repairs when needed
  - D0 will refurbish outer silicon disks during L0 installation
  - CDF COT gas recycling

Conclusions

- The D0 and CDF detectors will be *the* discovery experiments until LHC turn-on
- Current upgrades should maintain viability of the experiments through Run II
- Upgrade installation is expected during the Summer 2004 and 2005 shutdowns
  - Last chance for major changes
- Beyond that time experiments will need to balance necessary improvements and maintenance with the need for stable running as manpower shifts to LHC