STATUS OF PREPARATIONS FOR TEVATRON COLLIDER RUN II: MAIN INJECTOR/TEVATRON, CDF, AND D0

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I. Collider Run IB (1993-96) Performance

II. Run II Goals

III. Accelerator Status

IV. Detector Status

V. Longer Term Prospects

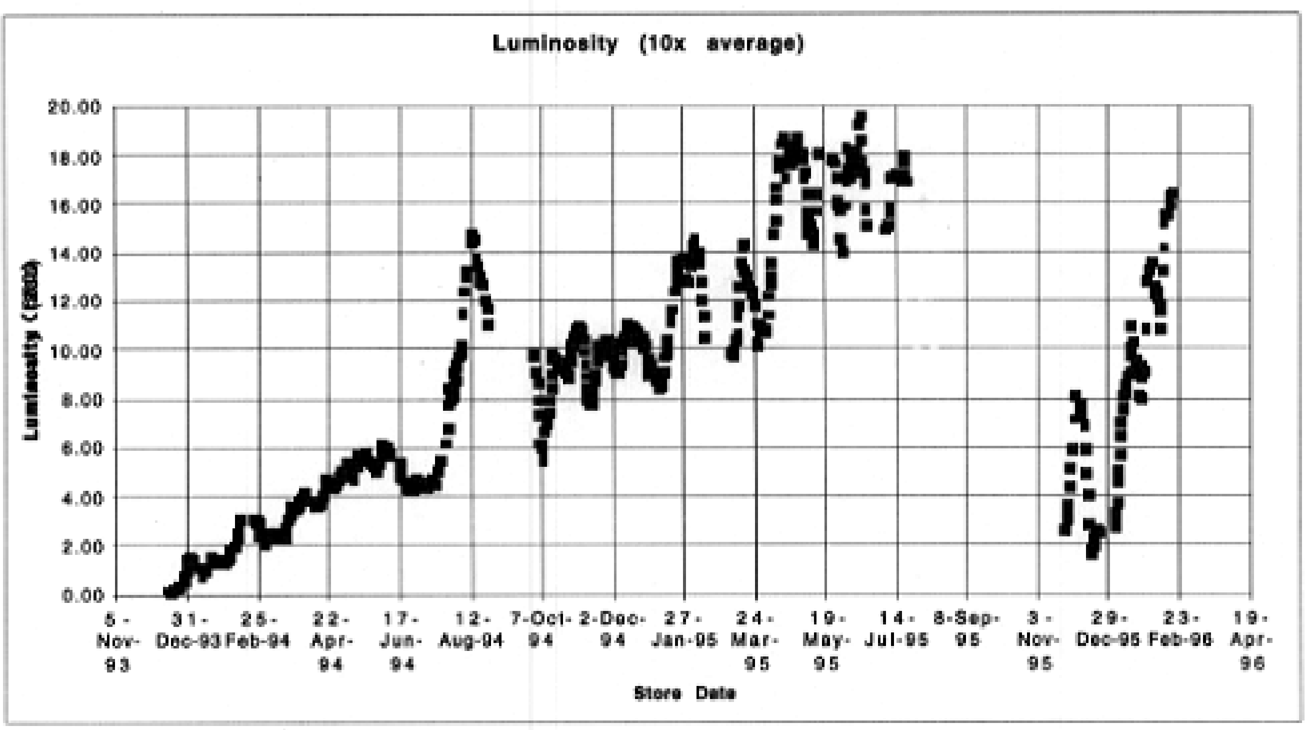
COLLIDER RUN IB PERFORMANCE

The last Tevatron Collider Run was completed over the period 1993-96. An integrated luminosity of approximately 150 pb^{-1} was delivered to each detector @ E_{cm} = 1800 GeV

- Delivered luminosity = 2 pb^{-1}/week (end of run)
- Typical initial luminosity = 1.6×10^{31} $cm^{-2}sec^{-1}$ (end of run)

Record initial luminosity = 2.5×10^{31} $cm^{-2}sec^{-1}$

Record monthly integrated luminosity = 18 pb^{-1}



Collider Performance Limitations

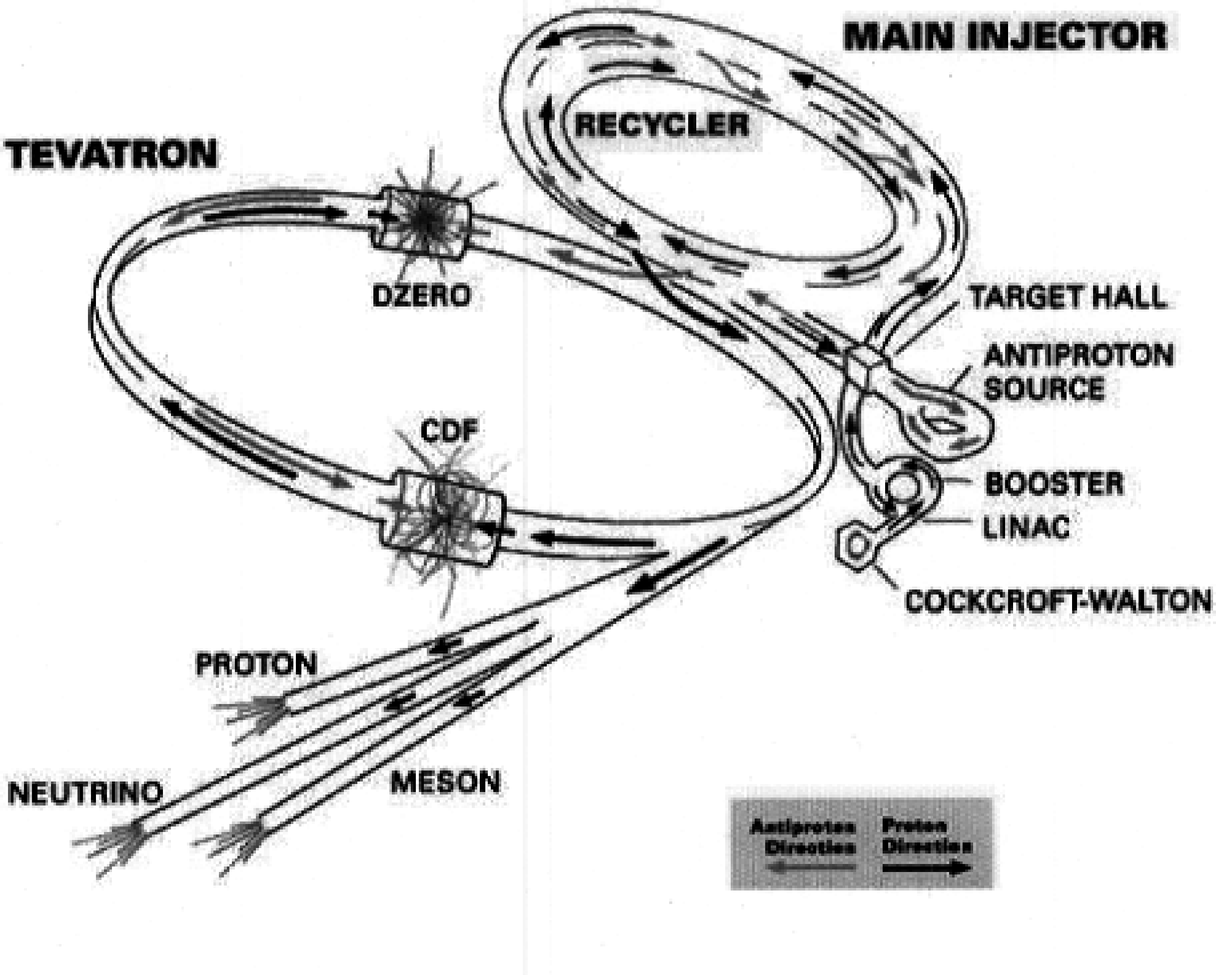
Under current operating conditions, the most important factor influencing Tevatron luminosity performance is the total number of antiprotons in the ring, $BN_{\bar{p}}$. The second most important factor is the proton phase space density, N_p/ε_p.

-> Beam-beam interaction precludes a large increase in N_p/ε_p.

For Run II the Fermilab complex will be required to support:

- More protons in collision
- Many more antiprotons in collision
- A significant increase in the antiproton stacking rate
- A capability for recovering antiprotons at the end of stores

Fermilab's
ACCELERATOR CHAIN



The **Main Injector** is designed to support:

- a three-fold increase in the antiproton production rate.
- good antiproton transmission efficiency from the Recycler to Tevatron.
- a modest increase in coalesced proton bunch intensity.

The **Recycler** is designed to:

- relieve the Antiproton Source of responsibility for maintaining high stacking rate at high stacks
- double the effective stacking rate via antiproton recovery
- provide a platform for further performance enhancements

The **Antiproton Source** is being reconfigured to:

- Achieve a factor of three increase in the achievable antiproton production rate.
- Accommodate future improvements leading to an additional factor of four increase in performance.

The **Tevatron** has been reconfigured to:

- Accommodate 36 bunch operations.
- Achieve collider operations at 2000 GeV in the center-of-mass.

RUN II GOALS

The Fermilab Tevatron is the highest energy collider operating in the world today. The aim of upgrade projects currently nearing completion is to exploit the capabilities of the Tevatron to the fullest extent possible while it retains this unique position.

Collider Performance Goals

The initial Run II goal is to deliver an integrated luminosity of >2 fb^{-1} by about the end of 2002.

⇒ *Run II Luminosity Goal*: >8-20x$10^{31}cm^{-2}sec^{-1}$

RUN	IB	II (36 × 36)	II (140×121)	
Protons/bunch	2.3x10^{11}	2.7x10^{11}	2.7x10^{11}	
Pbars/bunch	5.5x10^{10}	3.0 x10^{10}	3.0 x10^{10}	
Total Pbars	3.3x10^{11}	1.1x10^{12}	3.6x10^{12}	
Pbar Production Rate	6.0x10^{10}	2.0x10^{11}	2.0x10^{11}	pbar/hour
Proton emittance	23π	20π	20π	mm-mr
Pbar emittance	13π	15π	15π	mm-mr
β*	0.35	0.35	0.35	m
Energy	900	1000	1000	GeV
Bunches	6	36	121	
Bunch length (rms)	0.60	0.37	0.37	m
Crossing Angle	0	0	126	μrad
Typical Luminosity	1.6x10^{31}	8.6x10^{31}	16.1x10^{31}	$cm^{-2}sec^{-1}$
Integrated Luminosity	3.2	17.3	32.5	pb^{-1}/week
Bunch Spacing	~3500	396	132	nsec
Interactions/crossing	2.5	2.3	1.3	
(@ 50 mb)				

CDF-D0 Physics Goals

QCD

- Precision measurements using W, Z, Photon in association with jets
- High E_t jet production:
  - proton structure functions at high x and Q^2
  - search for di-jet resonances and deviations from QCD at distance scales < 10^{-17} cm

Bottom Physics

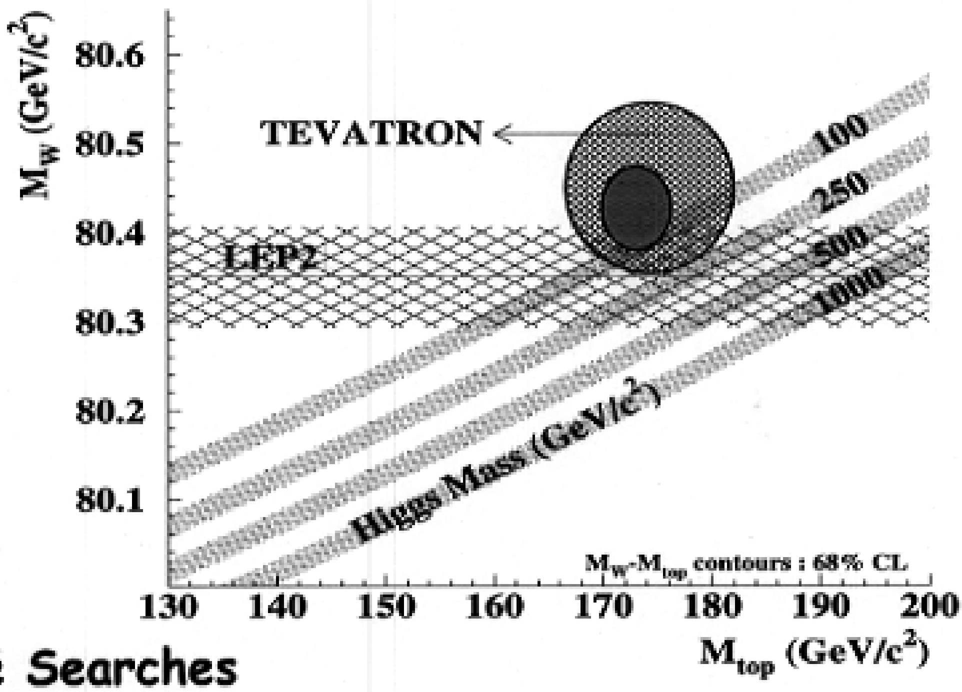
- sin 2β, Δsin 2β < 0.08
- B_s Mixing, x_s -> 60
- CP Violation in B_s, $B_s \rightarrow J/\psi\ \phi$
- sin 2α , sin 2γ might be feasible
- Rare Decays
- High Mass States Accessible! (B_c, Λ_b)

Top Physics

- top production: σ_{tt}, P_t^{top}, resonance searches, spin correlations, single top (σ, V_{tb})
- top decay: branching ratios, W helicity, V_{tb}, rare decay modes

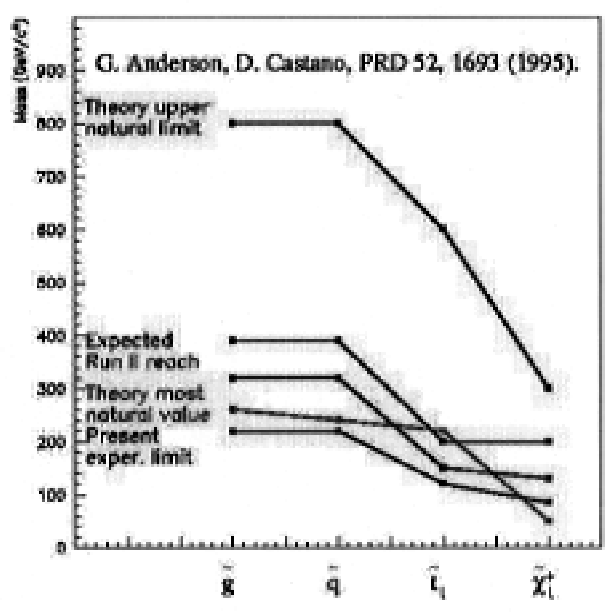
Electroweak

- *Gauge Couplings, W-boson width*
- W-boson mass, uncertainty ~ 40 MeV
- Top-quark mass, uncertainty ~ 2 GeV



Particle Searches

- Gauge Bosons:
  - 1 TeV -Direct
  - 6 TeV -Indirect
- Leptoquarks:
  - Technicolor >500 GeV
- SUSY squarks, gluinos:
  - 300-400 GeV
- SUSY Gauginos:
  - 150-250 GeV

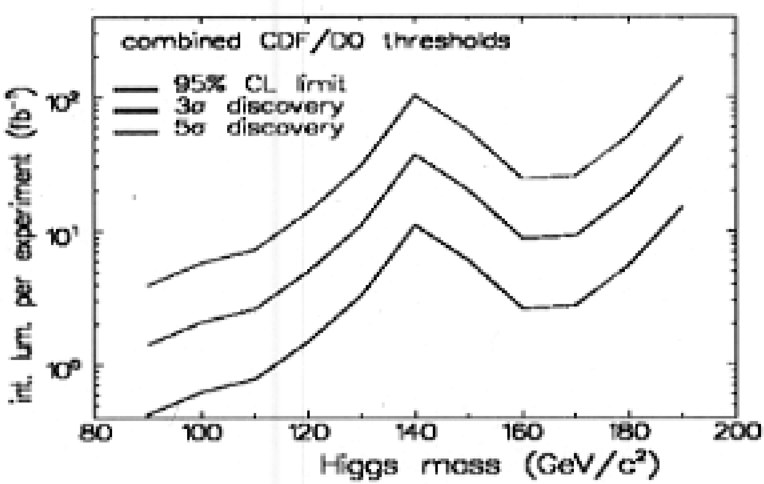


The Higgs

Possible reach of CDF/D0 for Higgs search based on assumptions listed below:

Combined channel thresholds

→ Gaussian approximation in combination
→ 30% better $m_{b\bar{b}}$ resolution than Run 1
→ Run 2 acceptance ×1.3 NN improvement
→ 10% systematic error on background
→ all except $\ell^{\pm}\ell^{\pm}jj$



ACCELERATOR STATUS

Main Injector

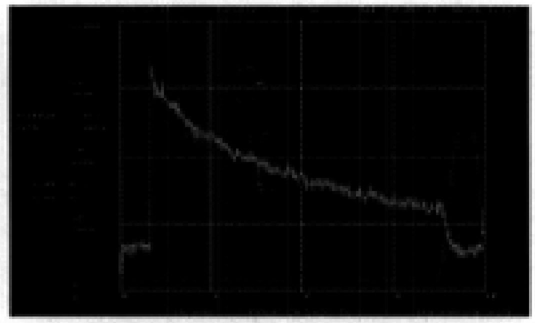
The Main Injector was completed and commissioned in May, 1999. It is currently operating in support of the Tevatron fixed target run. Current performance:

- Up to 2×10^{13} protons accelerated in 6 batches to 120 GeV
- ~3×10^{12} protons to 120 GeV every 2.5 seconds (antiproton production)

Recycler

The Recyler achieved circulating beam on May 18, 1999—and became the first ever permanent-magnet-based storage ring.

- Lifetime is limited by vacuum, aperture, and magnetic interference from the Main Injector.



- Vacuum bakeout, completion of magnetic shielding and corrector installation scheduled for October-November.
- Stochastic cooling installation scheduled for April '00.

Antiproton Source

The antiproton accumulator has been recommissioned with upgraded (higher bandwidth) stochastic cooling systems. The Debuncher 4-8 GHz cooling systems are still under construction and will be installed in the winter of 99-00.

Tevatron

The Tevatron has been reconfigured to support:

- ~2 TeV collider operations
- 36x36 bunch operations. (140x121 ultimately)
- A new injection area

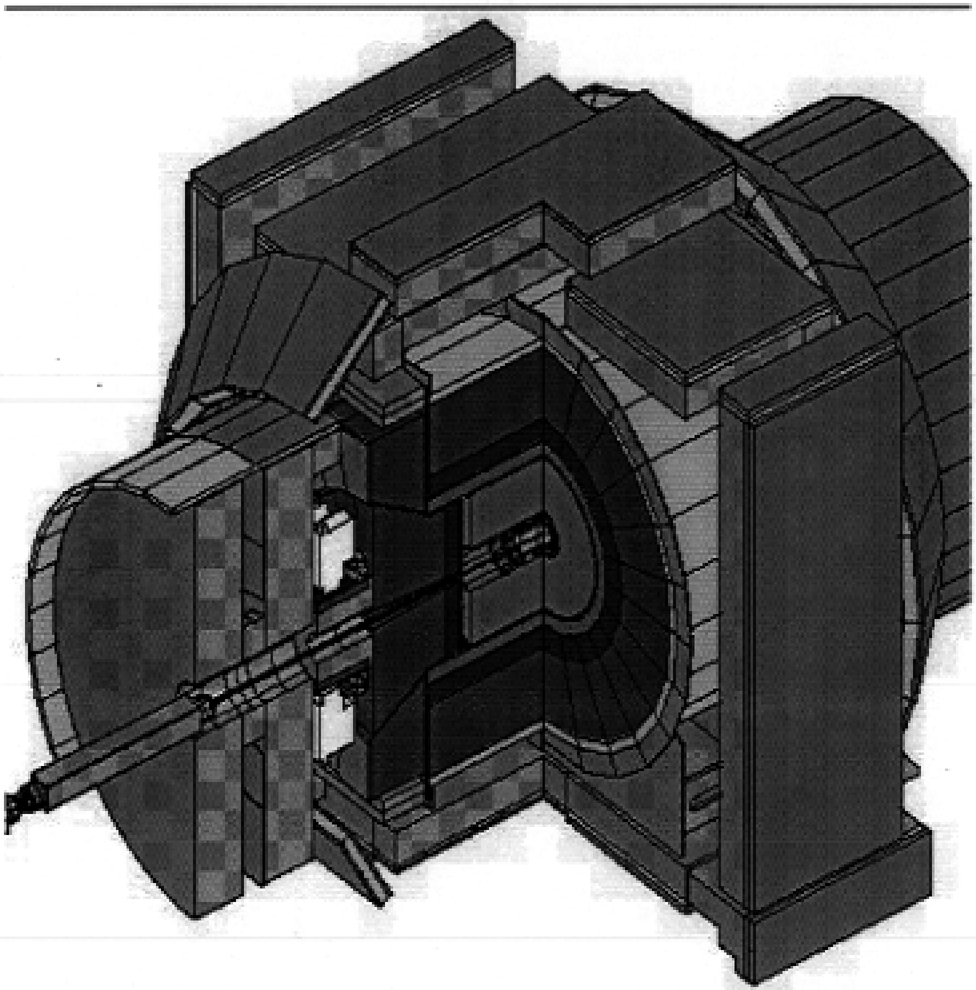
Schedule

The Tevatron is currently running in 800 GeV fixed target mode. We expect to end the fixed target run at the end of January 2000. At that time the B-0 and D-0 straight sections be reconfigured for collider operations.

- Collider engineering run to start ~May 1, 2000
- Collider commissioning run will start when first detector(s) are ready to roll onto the beamline. (Summer/fall 2000)
- Run II will begin when the detectors in the complete configurations are on the collider beamline. (Winter 00-01).

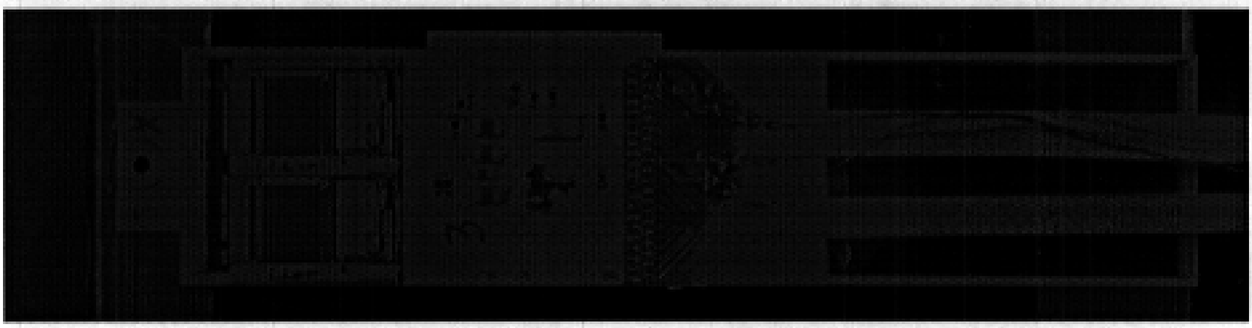
CDF UPGRADES
New Detector Systems

CDF II Detector cross section



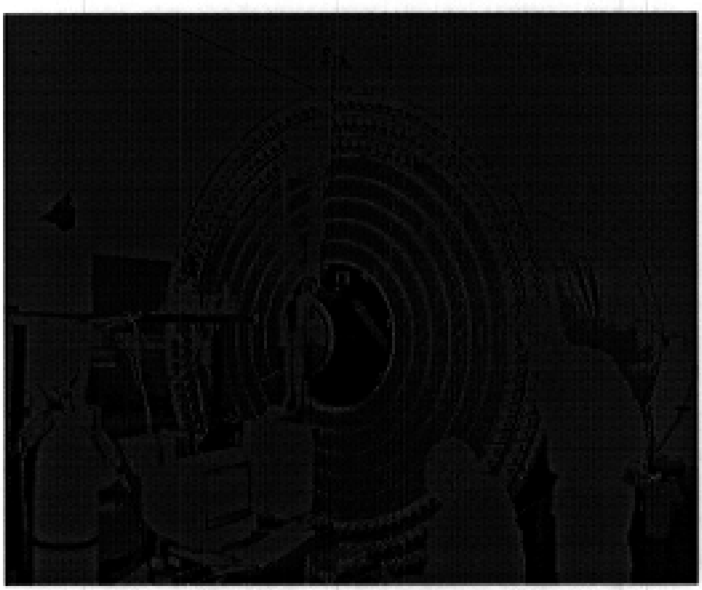
- Tracking
  - ➢ Silicon Vertex Detector
  - ➢ Intermediate Silicon Layers
  - ➢ Central Outer Tracker
- Endplug Calorimeter
- Front-end Electronics
- Trigger (pipelined)
- DAQ system
- Muon systems
- Infrastructure
- Off-line software

CDF Upgrade Progress - Tracking Detectors



- **Silicon detectors:** Ladder production is beginning.
- **"SVX3"** custom monolithic chips digitize and acquire data at the same time.
- Readout electronics -mostly delivered.
- New **Silicon Vertex Tracker** - custom electronics to find tracks w/ large impact parameters in the trigger (Level 2).

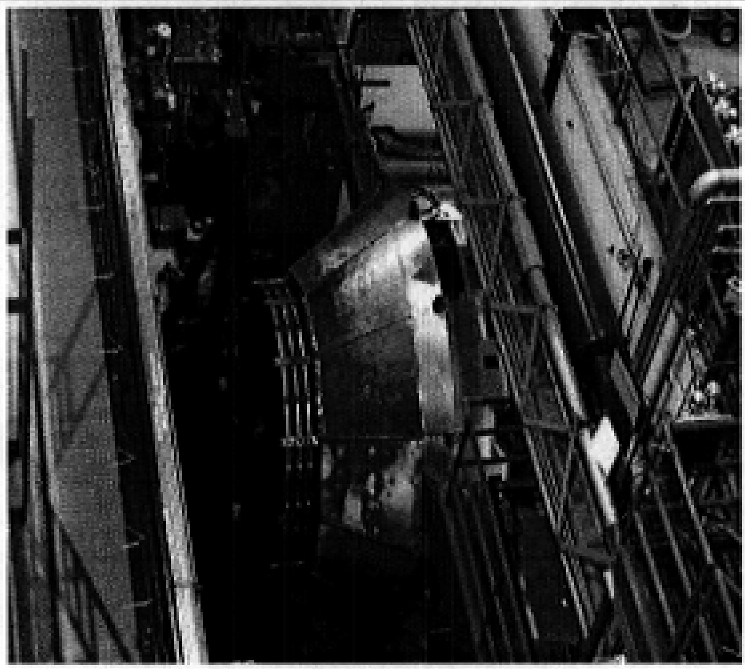
Central Outer Tracker

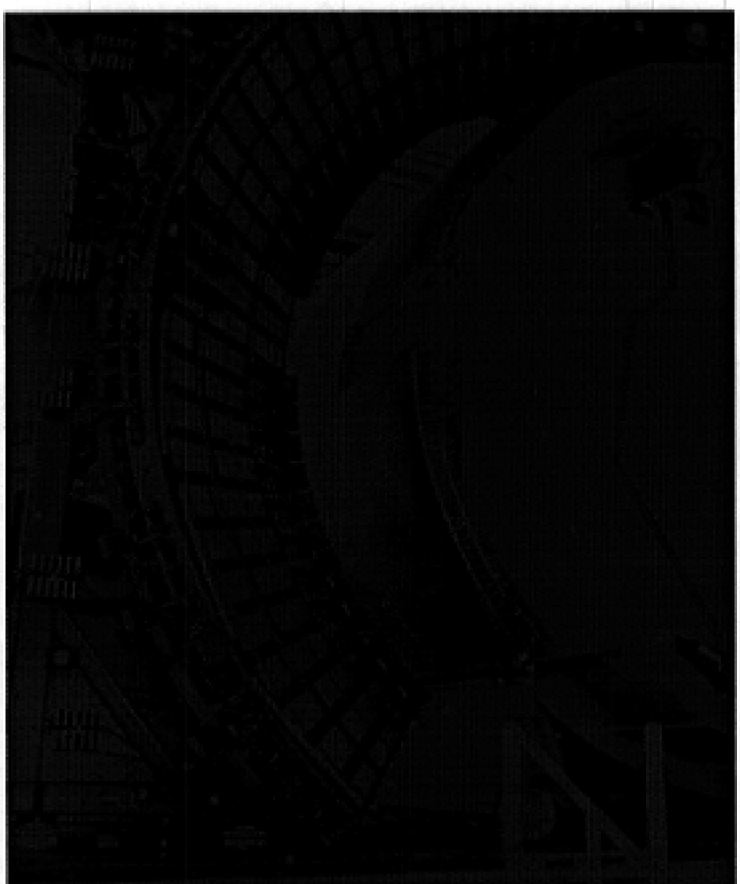


- Consists of wire planes and field sheets between two precision endplates.
- Wire planes and field sheets all installed.
    - ➢ Now doing final QC.
- Next - gas seal, then HV installation and testing.
- Chamber will be read out with new custom TDCs.
- New trigger system includes COT track finding at Level 1.

CDF Upgrade Progress - Calorimeters and Muon Detectors

- New scintillating tile/fiber endplug calorimeters.
  - ➢ Construction complete; testing w/ sources.
- Central and plug calorimeters read out with new custom electronics - in production.
- New Trigger system for shorter bunch spacing.



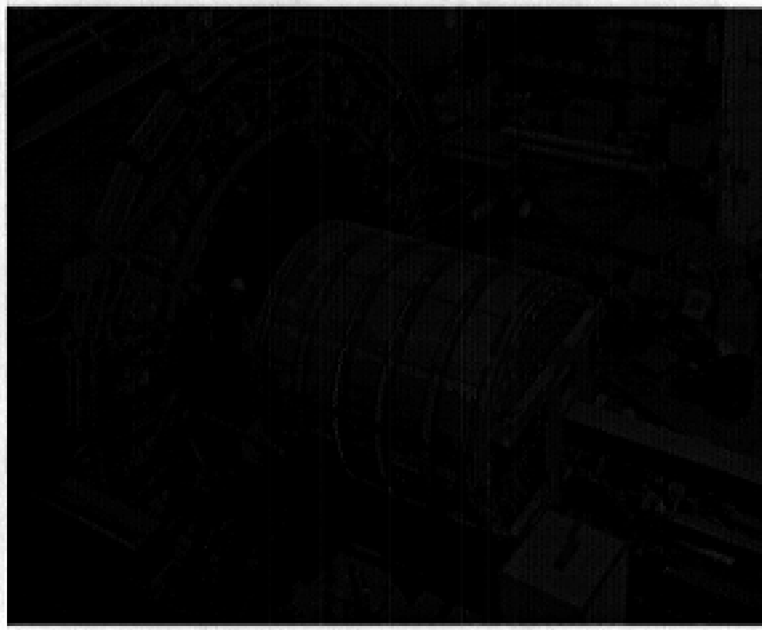


- New muon steel shielding is finished.
- Intermediate muon chambers are complete.
- New scintillators will be installed for triggering.
- Muon detectors will be read out with new TDCs (like outer tracker).
  - ➢ TDCs are in production.

CDF Upgrade
Infrastructure and Schedule

Infrastructure

- Have removed old detectors. →
- Lots of work on power distribution, cooling, gas system, etc.
- Commisioning solenoid.
- Building new luminosity monitor.

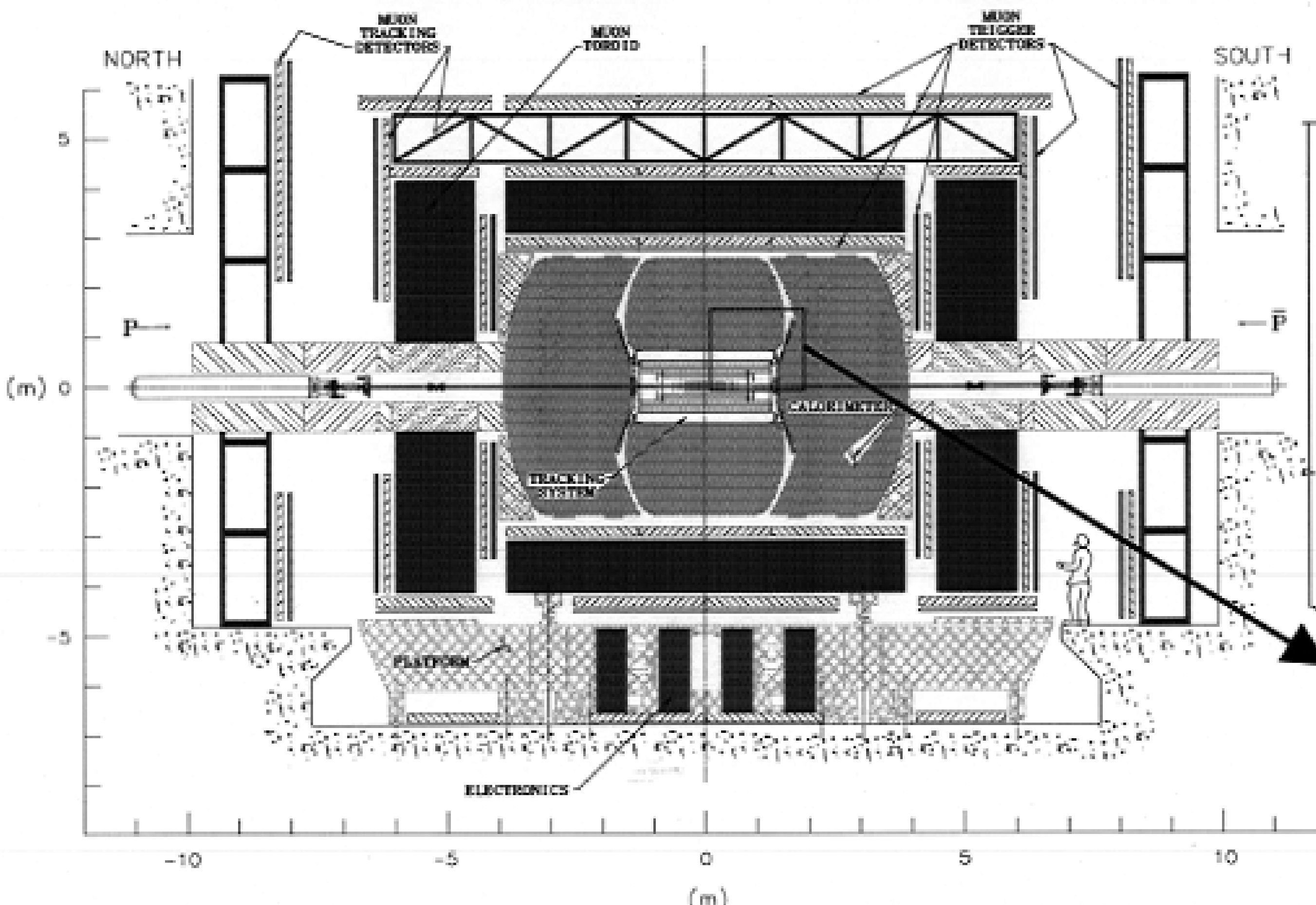


Schedule

- Calorimeters operational by ~ Jan, 2000.
- Central outer tracker complete ~ Feb, 2000.
- Most of electronics and trigger installed by Spring, 2000.
- Ready for commissioning with beam without full silicon system by Summer, 2000.
- Silicon detectors complete ~ Fall, 2000.
- Full detector ready for data ~ early 2001.

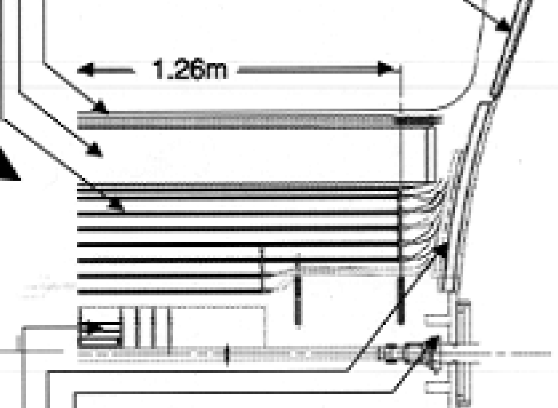
DØ

UPGRADE



New Systems

- Fiber Tracker
- 2T Super conducting Solenoid
- Central Preshower
- Intercryostat Detector



- Luminosity Monitor
- Forward Preshower
- Silicon Tracker

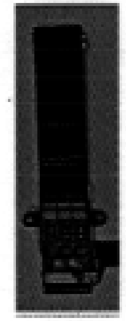
- Shielding
- Central Muon Scintillators
- Forward Muon Tracking
- Forward Muon Trigger Pixels

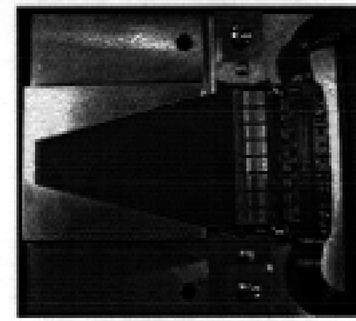
- Calorimeter Electronics
- 3 Level Trigger & DAQ
- Online System
- Offline Computing

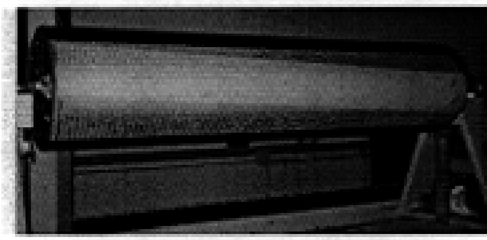
DØ Upgrade Status

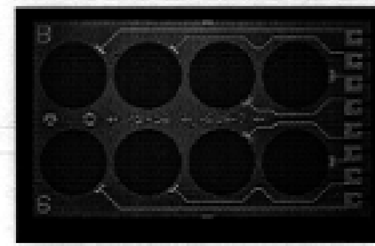
- **Silicon**
  - 800k ch: barrels & disks, SVXII readout
  - Detector production well along
  - Detector assembly starting
- **Fiber**
  - 80k fibers w/ VLPC readout on 8 cylinders
  - Produced first cylinder with ribbons
- **Solenoid**
  - 2T superconducting
  - Installed and tested
- **Preshowers**
  - Scintillator extrusions, WLS, VLPC
  - Central: complete & installed
  - Forward: in production

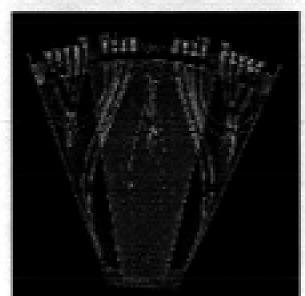

Si Barrel bulkhead w/ ladders & flex cable

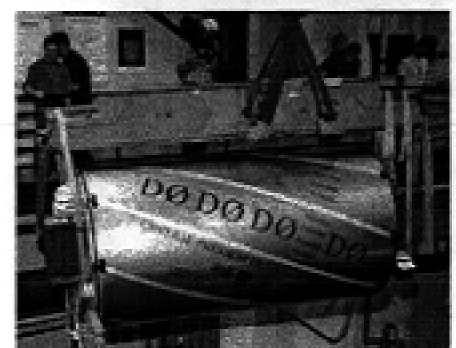

Si barrel ladder


Double sided Si disk wedge


Fiber cylinder w/ ribbons


8ch VLPC readout chip


Forward Preshower Module

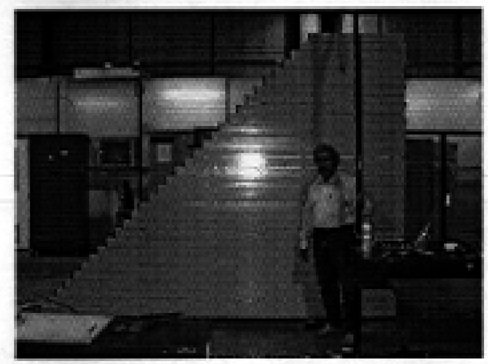


Solenoid with central preshower being intalled

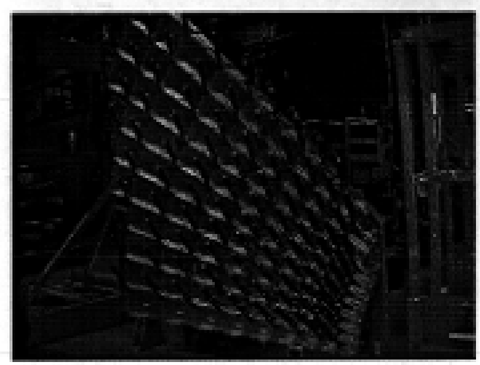
DØ Upgrade Status

- **Calorimeter Electronics & ICD**
  - 60k ch preamp & shaper, scint tiles for ICD
  - Production started
- **Muon System**
  - Central scint tiles installed
  - Forward scint pixels fabricated, modules being assembled
  - Forward mini-drift tube fabrication well along, module assembly begun
- **Trigger & DAQ**
  - 3 level trigger
  - Production in many systems
- **Online**
  - First systems purchased, central muon readout
  - Software being written

Central Muon Scintillator tiles Installed in D0



Forward Muon tracking system mini drift tube octant



Forward Muon Trigger detector – Scintillator pixel w/ PMT readout

DØ Schedule & Milestones

- Solenoid & CPS installed 9/98
- Muon central installed Summer 99
- Fiber Tracker assembly complete Spring 00
- Calorimeter electronics fabricated Summer 00
- Muon Forward tigger pixels installed Summer 00
- Muon Forward tracking MDT planes installed Summer 00
- Silicon Tracker assembly complete Fall 00
- Remove shield wall for roll in late Fall 00
- Rolled in and hooked up Early 01

LONGER TERM PROSPECTS

The initial Run II goal is achievement of a luminosity of $\sim 1\times10^{32}$ $cm^{-2}sec^{-1}$, with 2 fb^{-1} delivered to each detector by the end of 2002. Further performance enhancements would be based upon:

- Improved antiproton availability
  - Electron cooling
  - Slip-stacking
  - Liquid lithium lens
  - Aperture improvements
- Controlling the antiproton (long-range) beam-beam interaction.
  - Electron beam compensation

R&D projects aimed at these areas are currently underway.

The expectation is that luminosity could rise into the mid-to-upper 10^{32} $cm^{-2}sec^{-1}$ with these improvements.

Possible Accumulation of Luminosity in the pre-LHC Era

2001	Main Injector and Recycler	0.6 fb^{-1}
2002	Initiate antiproton recycling	1.2 fb^{-1}
2003	6 month shutdown to install e-cool, 132 nsec, and other intensity improvements	0.8 fb^{-1}
2004	Achieve 2×10^{32} $cm^{-2}sec^{-1}$	2.0 fb^{-1}
2005	Achieve 3.5×10^{32} $cm^{-2}sec^{-1}$	3.5 fb^{-1}
2006	Achieve 5×10^{32} $cm^{-2}sec^{-1}$ 6 month shutdown to install C-0.	2.3 fb^{-1}
2007	Achieve 5×10^{32} $cm^{-2}sec^{-1}$ Initiate Kaon program	3.8 fb^{-1}
TOTAL		**~15 fb^{-1}**

SUMMARY

The Fermilab complex is being readied for the start of Collider Run II.

- Significant improvements to the accelerator complex have been completed including:
  - The Main Injector and Recycler Ring
  - Upgrades to the antiproton source stochastic cooling systems
  - Reconfiguration of the Tevatron to support 36 bunch operations

  →Tevatron collider changeover will be initiated in the winter of 2000, with a collider engineering run scheduled to start in spring 2000.
- Significant upgrades to the collider detectors are underway to capitalize fully on improved Tevatron collider performance:
  - A detector commissioning run, without silicon, is scheduled for fall 2000.
  - Startup of Run II with both completed detectors is expected in late winter/early spring 2001.

⇒We expect to be able to deliver approximately 2 fb^{-1} of integrated luminosity to each detector by the end of 2002, with the potential for 15 fb^{-1} by the start of LHC operations.

Fermilab is currently uniquely positioned to make discoveries that could reshape our understanding of the physical world. We look forward to capitalizing on this opportunity during the pre-LHC era.