The DØ Upgrade
where we are and where we're going

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Abstract

The upgraded DØ detector for Run II at the Fermilab Tevatron is described. Its expected performance is compared to that observed in the Run I detector. With an eye toward the March 20001 start date for the Tevatron, the status of the project is also summarized. Finally, studies of the changes to the Run II detector necessary for it to continue to function effectively for integrated luminosities beyond the 2 fb^{-1} baseline are mentioned.

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1 Introduction

The DØ experiment at the Fermilab Tevatron has produced a rich array of physics results [1] using data taken from 1992-1996. During this period, referred to as "Run I", DØ collected more than 120 pb^{-1} of $p\bar{p}$ collision data at $\sqrt{s} = 1.8$ TeV. A similarly impressive performance was also recorded by the CDF experiment. Not content to rest on its laurels, however, Fermilab has embarked on a major upgrade of the Tevatron [2]. This involves the replacement of the Main Ring, used to inject particles into the Tevatron collider, with the Main Injector and the construction of a new antiproton storage ring, the Recycler. The results of these improvements will be to raise the $p\bar{p}$ center-of-mass energy to 1.96 TeV and to increase the instantaneous luminosity delivered by the machine by a factor of nearly 20 from the largest peak luminosities of Run I.

Both DØ and CDF are also making major changes to their experiments to deal with these higher luminosities and to take advantage of the physics opportunities presented by an anticipated data set more than a factor of 20 larger than what is currently available.

The upgraded DØ detector being built for "Run II" will be described in this paper and its predicted performance will be compared to that observed in Run I. I will also briefly touch upon the status of our preparations for the beginning of Run II, scheduled to start in March of 2001. More details on the DØ upgrade and its current status are available from the collaboration web page [3]. Projections for B-physics at DØ in Run II are presented in [4].

2 The DØ Upgrade

The DØ detector in Run II [5] will be significantly different from that used in Run I [6]. The excellent calorimetry and nearly hermetic detection capabilities for electrons, photons, muons and jets in Run I will be retained or improved, but the charged particle tracking system will be completely changed. This involves adding a solenoid magnet producing a 2.0 T axial field surrounding precise scintillating fiber and silicon micro-strip detectors. Additionally, the trigger and data acquisition systems have been completely redesigned. Using the new detector, the physics capabilities [5] (especially in the area of b-quarks) will be dramatically enhanced. A schematic of the DØ detector for Run II is shown in Fig. 1. A comparison between some of the major accelerator and detector performance parameters in Run I and Run II is given in Table 1.

2.1 Tracking

Changes to the DØ tracking system are at the heart of the Run II upgrade. The old drift chambers and TRD are being replaced by a state of the art tracking system composed of a silicon micro-vertex tracker (SMT), a scintillating fiber tracker (CFT), a superconducting solenoid magnet and preshower detectors in the central (CPS) and forward (FPS) regions to aid in electron and photon identification. A diagram of this tracking system is shown in Fig. 2.

Of particular importance in the design of the tracking system was the fact that the Tevatron beam in Run II will have a spread in the longitudinal direction of $\sim$25 cm. This requires long tracking detectors to decrease the loss in acceptance for events with a primary interaction far from the nominal center of the detector.

The DØ SMT consists of 3.0 m^2 of silicon sensors of three basic types. Double-sided Barrel detectors, making axial and $90°$ or $2°$ stereo measurements, are arranged in four cylindrical "layers" in the central region at radii from 2.7 cm to 9.4 cm about the beam pipe. Six, four-layer barrels are used with a total length of 76 cm. The acceptance of the silicon system is extended into the forward direction using wedge-shaped F-disks and H-disks arranged in 14 wheels about the beam pipe and reaching to $\pm$120 cm from the detector center. This allows DØ to identify charged particles to $|\eta|<3.0$. In total, the SMT contains 793k channels, all of which are read out using SVX IIe chips, containing 128 channels of preamplification, a 32-stage analog pipeline and an 8-bit ADC with sparse readout.

The CFT serves as the main tracking chamber in DØ. It has 77k, 830 μm diameter, scintillating fibers arranged in eight concentric cylinders from radii of 20 cm to 51 cm. Each cylinder has a staggered double layer of fibers (to ensure full coverage) along the beam direction and a + or $-3°$ stereo double layer. Light from the fibers is read out using visible light photon counters, devices derived from solid state photomultipliers. The resulting signals are pipelined and digitized using the SVX IIe chip.

The 2.8 m long superconducting solenoid was installed inside of the calorimeter and reached 2.0 T in September of 1998. It has been extensively operated and its field mapped since then.

The preshower detectors are located directly outside of the solenoid in the barrel region and along the forward calorimeter cryostat wall. They are made of ∼24k scintillating strips with a triangular profile and are read using the same electronics as the CFT.

2.2 Calorimetry

The Uranium – Liquid Argon calorimeter used in Run I has been retained for Run II because of its excellent characteristics. The readout electronics for the calorimeter, however, have been completely redesigned to deal with the shorter beam crossing time in Run II.

2.3 Muon System

The Run II muon system improves upon that used in Run I in several ways. The basic structure of one super-layer of chambers inside a toroid magnet and two super-layers outside in both the central and forward regions is retained. But triggering is significantly enhanced by increasing the coverage of highly segmented scintillators such that muons hit at least one layer in more than 90% of the acceptance. Additionally, the proportional drift tubes in the central region have been completely revamped and those in the forward region have been replaced by new mini-drift tubes.

2.4 Trigger

To cope with data arriving at 7.5 MHz and to take advantage of the enhanced capabilities of the DØ detector, the trigger system has been completely redesigned in three levels. Level 1 uses custom-built hardware to find tracks (with P_T>1.5 GeV) in the CFT/PS, energy clusters and global missing energy in the calorimeter and muon tracks (with P_T>1.5 GeV) in the muon system. At level 2, preprocessors, built around a custom VME board containing an Alpha CPU, refine level 1 information from all subsystems and, in some cases, add data with more accurate calibrations. The preprocessors' output is sent to a global level 2 Alpha processor, which correlates their information and produces "physics objects" such as electrons, muons, taus and jets, from which level 2 decisions are made. The level 3 trigger consists of a farm of PCs that perform a simplified event reconstruction using data from all subsystems. Offline-like algorithms can be run on this farm allowing very sophisticated triggers to be formed.

2.5 Installation and Status

With all mechanical elements of the upgraded detector in hand the concentration of the collaboration has turned to installation and commissioning in the assembly hall. This is a complicated problem with severe constraints in both space and time. As of November, however, most detector elements are in place, with the final half of the SMT slated to be inserted in early December. Some of the readout electronics is still in production, however, this should not prevent the detector from rolling into the collision hall by mid February, in time for the start of Run II in March.

3 Beyond Run II

The original goal for Run II integrated luminosity was 2 fb^{-1}. Recent work, particularly by the Fermilab Higgs Working Group [7], has indicated that the Higgs sensitivity of CDF and DØ can be extended to $\sim$180 GeV with an order of magnitude more data. In order to achieve this new goal the Tevatron luminosity has to be boosted a factor of 2.5 over that expected for Run IIa. The increased radiation dose associated with this higher luminosity is expected to damage the inner layers of the DØ SMT and may cause pattern recognition problems in the inner CFT layers. The DØ collaboration is currently studying options to maintain, or even improve, tracking and trigger performance under the Run IIb conditions. Possibilities include partial or full replacement of the current SMT with more radiation hard sensors and the addition of extra layers of silicon close to the beam pipe, to improve impact parameter resolution, and at large radius, to aid in pattern recognition for track finding.

4 Conclusions

The DØ experiment is poised to begin a new epoch of data-taking in Run II with significantly enhanced capabilities. As the March 1, 2001 start date approaches we are busily installing the upgraded detector. With the exception of some electronics, all the components of the detector are in hand and we anticipate being ready when first collisions arrive.

Looking beyond the first few years of Run II, we are working out the changes necessary to the detector to allow us to collect 15 fb^{-1} of data or more. Clearly, DØ will be an exciting place to be for many years to come!

5 Acknowledgments

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References

[1] See `http://www-d0.fnal.gov/public/d0_physics_v2.html` for a list of DØ physics results.

[2] See `http://www-bd.fnal.gov/lug/` for details.

[3] `http://www-d0.fnal.gov/`.

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[7] M. Carena, J.S.Conway, H.E. Haber and J.D. Hobbs, "*Report of the Higgs Working Group of the Tevatron Run 2 SUSY/Higgs Workshop*", Fermilab-Conf-00/279-T, `hep-ph/0010338` (2000).

	Run I	Run II
Tevatron		
E_{CM} [GeV]	1.8	1.96
Collision Interval [ns]	3500	396 $\rightarrow$ 132
Luminosity [$\times 10^{32}$ cm^{-2}s^{-1}]	0.16	2.0 $\rightarrow$ 5.0(Run2b)
Integrated Lumi [fb^{-1}]	0.125	2 $\rightarrow$ >15(Run2b)
Tracking		
Magnetic Field [T]	—	2.0
$\mid \eta \mid$ Coverage	<3.0	< 3.0(Si), <1.7(CFT)
Radial Extent [cm]	3.7–75	2.7–9.4(Si), 20–51(CFT)
Hit Resolution [μm]	50–200	10(Si), 100(CFT)
$\delta P_T/P_T$[%]	—	$2 \oplus 0.2P_T$
Impact Param Res [μm]	—	$13 \oplus 37/P_T$
Calorimetry		
$\mid \eta \mid$ Coverage	<4.0	
Granularity	$\Delta\eta \times \Delta\phi = 0.1\times0.1$	
Energy Res (EM) [%]	$14/\sqrt{E} \oplus <1\%$	
Energy Res (Had) [%]	$50/\sqrt{E}$	
Energy Res (Jet) [%]	$80/\sqrt{E}$	
Muon System		
$\mid \eta \mid$ Coverage	<3.3	< 2.0
$\delta P/P$ [%]	$18(P-2)/P \oplus 0.3P$	$2 \oplus 0.2$ (tracking)
Trigger		
Event Rate [kHz]	300	7500
L1 Accept Rate [kHz]	0.15	10
L2 Accept Rate [kHz]	—	1
L3 Accept Rate [Hz]	4	50
Track Trig Min P_T [GeV]	—	1.5
Muon Trig Min P_T [GeV]	3	1.5
Electron Trig Rejection		$\times$3–5 better(CPS)

Table 1: A comparison of the expected performance of the DØ detector in Run II with Run I measurements.

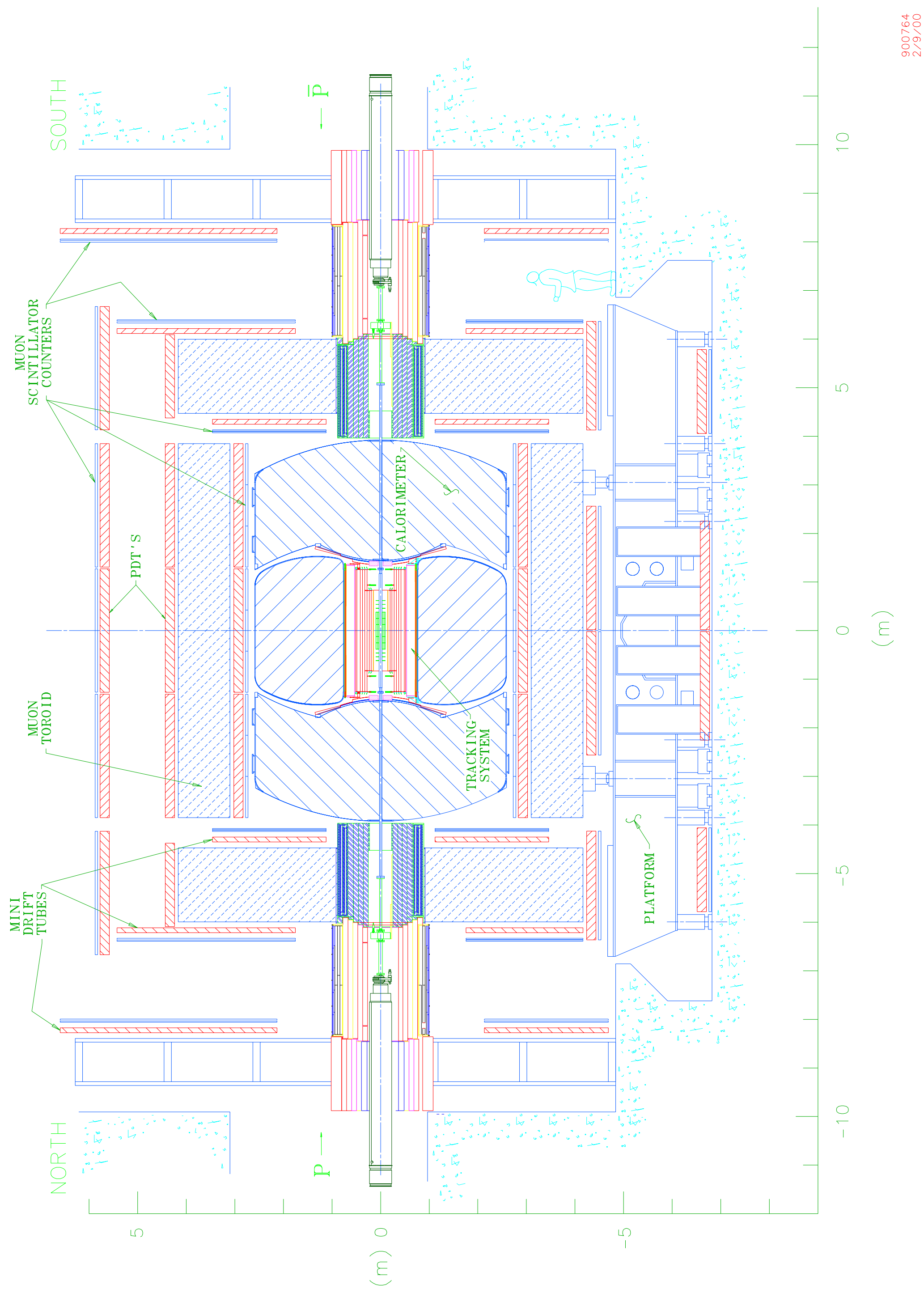

Figure 1: The DØ detector in Run II.

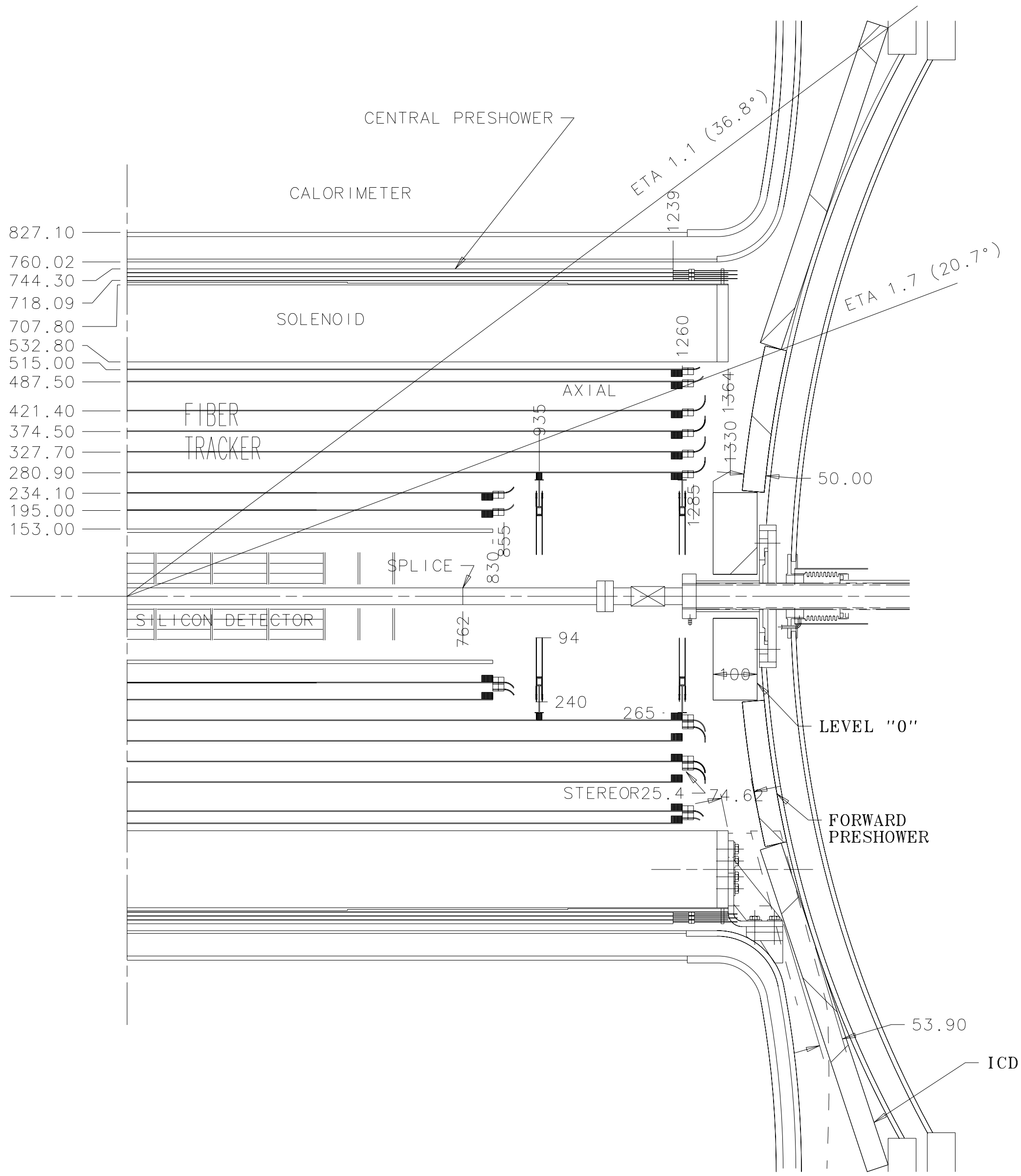

Figure 2: The DØ tracking system in Run II.