1707: The DØ Detector Upgrade at Fermilab

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Abstract. The DØ detector at the Fermilab Tevatron is undergoing a major upgrade to prepare for data taking in the Main Injector era with luminosities reaching 2×10^{32} cm^{-2} s^{-1}. The upgrade includes a new central tracking array, new muon detector components, and electronic upgrades to many subsystems. The DØ upgraded detector will be operational for Run II in early 2000.

1 Overview of the Upgrade

The DØ upgrade at the Fermilab Tevatron is designed to operate in the high luminosity environment of the upgraded Tevatron, where the instantaneous luminosity will reach 2×10^{32} cm^{-2} s^{-1} and the minimum time between bunch crossings will be reduced initially from the present 3.5 μs to 396 ns, and then to 132 ns. The upgrade builds on the strengths of DØ, including nearly complete solid angle calorimetric and muon detection, while enhancing tracking and triggering capabilities. [1] A major element of the upgrade is the replacement of the inner tracking system with a silicon vertex detector and a scintillating fiber tracker inside a two Tesla superconducting solenoid. The new tracking system will improve secondary vertex finding and allow momentum measurements for charged hadrons up to pseudorapitidity ≈ 3. Between the solenoid and the inner radius of the central calorimeter cryostat is a preshower detector with wavelength shifter readout. In the forward region, a preshower detector is installed on the faces of the end calorimeter cryostats. The preshower detectors and the fiber tracker use a visible light photon counter readout. The improved muon system includes scintillator trigger detectors over the full pseudorapidity region to handle the higher event rates, and replaces the forward proportional drift tubes with mini-drift tubes. Electronic upgrades are needed because of the smaller bunch spacing and to provide pipelining of the various signals from the new tracking, calorimeter, and muon front-end electronics. More extensive triggering, together with a new trigger control system, is planned to help contain the raw event rates. The DØ upgrade detector is shown in Fig. 1, and details of the new tracking system are shown in Fig. 2.

2 The Silicon Vertex Detector

The 840,000 channel silicon vertex detector [2] will provide high resolution position measurements of charged particle tracks within a radius of 2.5 to 10 cm from the beam line and up to $\eta \approx 3$. Many of the design features of the

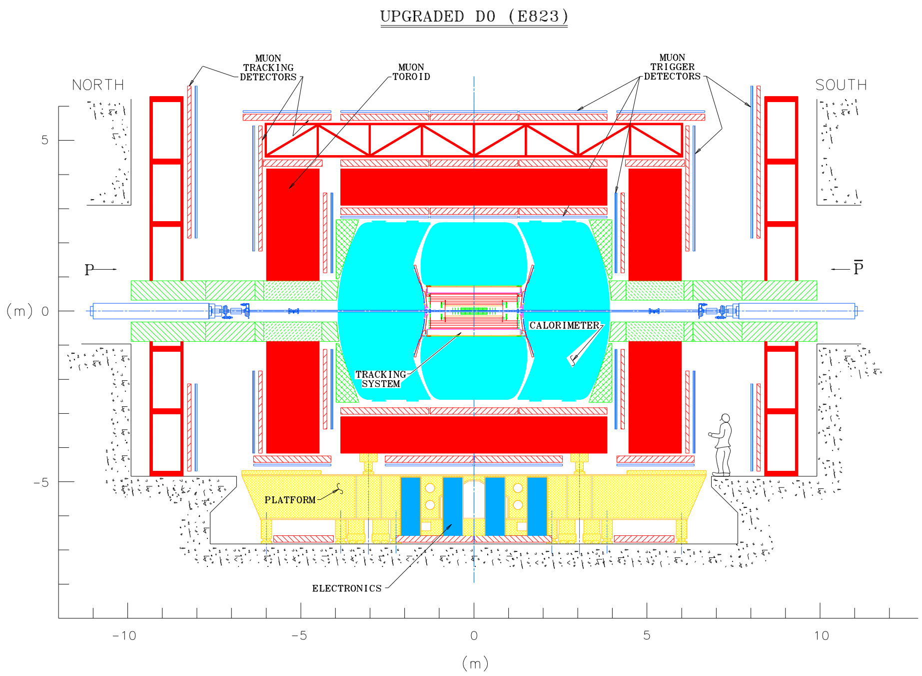

Fig. 1. The DØ Upgrade Detector.

vertex detector are influenced by the expected performance of the upgraded Tevatron. For instance, the increased luminosity requires that the silicon operate after receiving a total radiation dose of about 1 Mrad, corresponding to an integrated luminosity of about 2 fb^{-1}. The radiation hardness of the silicon has been tested, and we have demonstrated that this lifetime can be achieved at an operating temperature of about 10° C[3].

The Tevatron interaction region will have $\sigma_z \sim 25$ cm which makes it difficult to deploy detectors such that the tracks are generally perpendicular to the detector surfaces for all η. This has motivated a barrel/disk hybrid geometric design. The silicon detector is constructed from six modules, each having four layers of silicon oriented parallel to the beam axis (barrels) and one layer of silicon oriented perpendicular to the beam axis (disks). Each barrel/disk module is 12 cm in length so that the six modules extend to $|z| \sim 36$ cm. Barrels 1 through 4 are located at nominal radii of 2.77, 4.61, 6.83, and 9.16 cm, respectively. Barrels 2 and 4 are constructed from double sided AC-coupled silicon devices with 2° stereo angle strips. Barrels 1 and 3 are constructed from double sided AC-coupled devices with 90° stereo strips on the inner four modules and single sided AC-coupled axial strips on the outer two modules. At the end of each module, the disks extend from a radius of 2.57 to 9.96 cm and consist of double sided AC-coupled silicon with $\pm 15°$ stereo strips. At each end of the barrel/disk array a series of 3 more identical disks are added to enhance the tracking in the forward region. Finally, two larger disks are located at $z = \pm 110$ cm and $z = \pm 120$ cm with a radius between 9.5 and 26 cm to allow tracking in the large η region. These disks are composed of two single sided AC-coupled silicon devices, placed back to back with strips set at an angle of $\pm 7.5°$. The single point resolution for the silicon detectors has been shown to be $< 10\,\mu$m.

Electronic readout will be done using the 128 channel SVX II readout chip developed by Fermilab and Lawrence Berkeley Laboratory. Each channel contains a charge sensitive preamp, 32 stages of analog pipeline delay, an 8 bit analog to digital converter, and sparse data readout. The SVX II chip has been tested is fully functional.

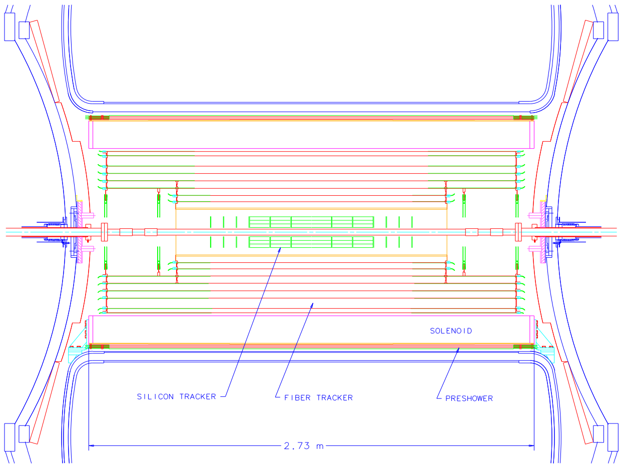

Fig. 2. The DØ tracking system.

3 The Scintillating Fiber Tracker

The central fiber tracker (CFT) surrounds the silicon vertex detector and provides a momentum measurement, a first level trigger, and full track reconstruction for a pseudorapidity range up to $|\eta| = 1.7$. The detector consists of 77,000 scintillating fibers mounted on eight concentric cylinders at radii from 20 to 52 cm. Each of the eight cylinders has two layers of 835 μm diameter multiclad fibers oriented axially, and two layers oriented at small angle stereo, either $\pm 2°$. The inner (outer) two (six) cylinders have fiber length of 1.6 (2.5)

m. The fibers are mated to 8-11 m multiclad clear fiber waveguides which conduct the light to photodetectors situated under the central calorimeter. Each fiber will be precisely located to $< 40\,\mu$m to allow for efficient tracking and triggering.

The photodetectors must be capable of detecting single photons with high efficiency at high rates and with large gain. We will make use, for the first time in a high energy physics experiment, of a large number (77,000) of visible light photon counters (VLPC's). VLPC's are impurity band conduction devices derived from solid state photomultipliers. Test results indicate they can detect single photons with quantum efficiencies up to 80% and gains $> 10^4$. The VLPC's operate at a temperature of 6-12° K with a bias voltage of 6-10 V. They can operate at rates of at least 10 MHz, and $> 40 \times 10^6$ photoelectrons/sec.

A cosmic ray test stand consisting of 3000 fiber channels arranged in doublet layers, each with two rows of scinitillating fibers, has been constructed to test the resolution and efficiency of the CFT. Test results confirm that single point resolutions for doublet layers are $\approx 100\,\mu$m with hit efficiencies of 99.5%.

4 Conclusion

The physics potential of the new tracking system has been partially determined by conducting Monte Carlo studies to test the b tagging efficiency in $t\bar{t}$ events. We find that secondary vertices can be reconstructed with a resolution of $\sim 10\,\mu$m. Preliminary results indicate that events having three or more tracks with normalized impact parameter > 2.5 are tagged as b quark events with 64% efficiency. Backgrounds from other events are estimated to be $< 5\%$.

The DØ detector upgrade consisting of a new tracking system, an improved muon detection system, new triggers, and upgraded electronics, is on schedule to be completed for data taking in early 2000 when the Main Injector is operational at Fermilab. These improvements will allow us to operate in the high luminosity environment of the upgraded Tevatron and will enhance the already excellent physics potential of the DØ detector.

References

[1] "The DØ Upgrade: The Detector and Its Physics," DØ Collaboration, Fermilab Pub-96/357-E, (1996), Also available on the WWW at http://higgs.physics/lsa/umich.edu/dzero/d0doc96/d0doc.html.

[2] "DØ Silicon Tracker Technical Design Report," DØ Collaboration, DØ Note 2169, July 1, 1994.

[3] "Summary of Results on Prototype Single-sided Silicon Microstrips for the D0 Barrel Tracker," DØ Note 2812, unpublished, 1995, "Effects of Radiation on the D0 Silicon Tracker," DØ Note 2679, unpublished, 1995.