Fermi National Accelerator Laboratory

FERMILAB-Conf-96/137

New Technologies in the D0 Central Tracker Upgrade

D. Lincoln

For the D0 Collaboration

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

University of Michigan
Ann Arbor, Michigan 48109

June 1996

Presented at the *VIth International Conference of Nuclear Physics on Instrumentation for Experiments at e+ e- Colliders*, Budker Institute of Nuclear Physics, Novosibirsk, Russia, February 29-March 6, 1996

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CHO3000 with the United States Department of Energy

Disclaimer

FERMILAB-Conf-96/137

New Technologies in the DØ Central Tracker Upgrade

D. Lincoln

University of Michigan, Ann Arbor, Michigan 48109, USA

(for the DØ Collaboration)

The DØ collaboration has undertaken an aggressive upgrade of its central tracking system. The existing tracker will be completely removed and replaced by a two Tesla superconducting solenoidal magnet, an 837 000 channel silicon vertex system, an 80 000 channel scintillating fiber tracker, followed by a 7 680 channel central preshower detector and a 16 000 channel forward preshower detector. In this paper we shall discuss all of the subsystems of the DØ central tracker upgrade, but will emphasize those aspects which involve new technology: radiation hard scintillating fiber, VLPC's and extruded scintillating strips.

The DØ collaboration has just finished its first data-taking run. Rather than being simply an 'engineering run', this run was enormously successful, culminating in the discovery of the top quark [1]. Using the knowledge thus gained, the DØ collaboration has embarked on an aggressive upgrade [2] necessary to exploit the increased luminosity ($\mathcal{L} = 2 \times 10^{32}$ cm^{-2}s^{-1}) to be delivered by Fermilab's new Main Injector. Both the Main Injector and the DØ upgrade will be finished in early 1999. One of the largest projects of the upgrade is the replacement of the entire current central tracker by a two Tesla superconducting solenoid, an 837 000 channel silicon vertex detector, an 80 000 channel fiber tracker, a 7 680 channel central preshower detector and a 16 000 channel forward preshower detector. In this paper, we briefly discuss all of the central tracker subsystems, but concentrate on those aspects of the upgrade which involve new technology.

The silicon vertex detector consists of a hybrid barrel and disk system, covering the range $|\eta| < 3$ [3]. The barrel consists of four layers, two of axial strips only and two of both axial and stereo ($\pm 2°$). There are 12 small-diameter (9 cm), double-sided, disks with a stereo angle of ($\pm 30°$) and 4 large-diameter (26 cm) disks for high η momentum reconstruction with a stereo angle of $\pm 15°$. This disk/barrel configuration is optimized for the extended luminous region

Preprint submitted to Elsevier Preprint *17 June 1996*

($\pm 30 - 40$) cm at the Tevatron. The strip pitch is 50 μm for axial strips and 62.5 μm for the stereo strips, and the detector will yield a position resolution of ~ 10 μm. The silicon tracker is shown in fig. 1.

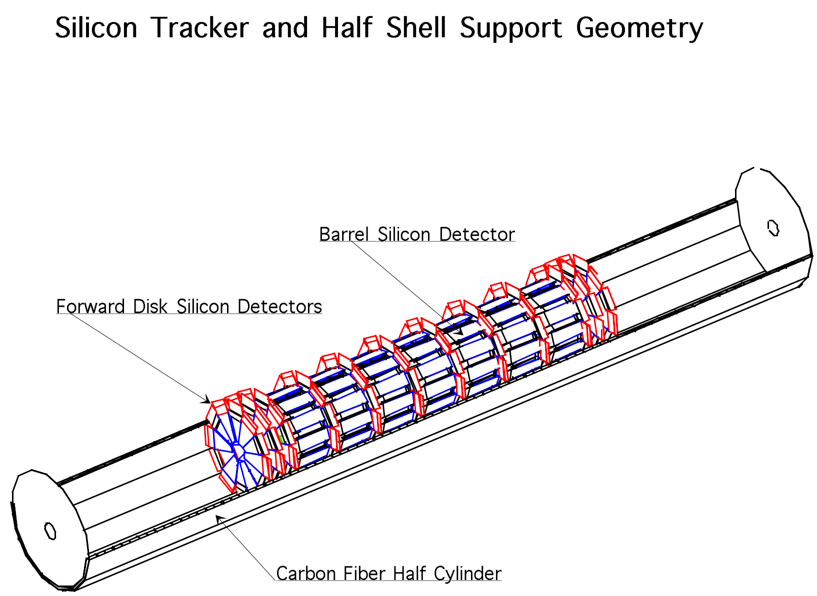

Fig. 1. A diagram of the silicon tracker with the support structure shown.

The scintillator fiber tracker consists of 80 000 fibers arranged on 8 carbon fiber cylinders with radii in the range of 20-50 cm. There are 8 layers of fibers parallel to the beam axis and 4 layers each of fibers with a $\pm 2^\circ$ stereo angle. Each fiber is commercially available multiclad Kuraray [4] fiber with dimensions 830 μm in diameter and $\gtrsim 2$ m long. Multiclad fiber consists of a core with index of refraction 1.59, surrounded by concentric layers of cladding with indices of refraction 1.49 and 1.42 respectively. Due to the increased trapping fraction, the use of multiclad fiber increases the light yield by 70% over conventional single-clad fiber. Each fiber is doped with p-terphenyl and 3HF [5] at a concentration of 1% and 1500 ppm by weight. The fluor 3HF is novel in that it shifts directly from ultraviolet to green rather than the more conventional blue and thus is more radiation resistant.

These fibers will be formed into ribbons which will be attached to carbon fiber cylinders. Tests of ribbons of this type have [6] demonstrated a position resolution of 100 μm and a light yield of 10 photoelectrons per minimum ionizing particle. The fiber technical R&D is now complete and current effort is concerned with mechanical issues.

The photodetectors (Visible Light Photon Counters, or VLPC's) are solid state devices developed jointly by the DØ collaboration and Rockwell International [7]. The details of the principle of the devices operation are given in [8], but broadly they can be thought of as avalanche photodiodes. In order to attain the desired performance, the VLPCs must be operated at temperatures in the range 6-12 K and voltages in the range 6-8 V. The R&D of these devices in ongoing, but in version 4 (HISTE-IV) of these devices a quantum efficiency of 65% for green light, a gain of 15 000 and a dark noise of 200 kHz has been achieved [8] (the dark noise is the count rate above a threshold of half a photoelectron). Figures 2 and 3 show the gain and noise of version 5 (HISTE-V) as a function of both temperature and bias voltage. (Note that the difference between HISTE-IV and HISTE-V is mostly in the concentration of donor atoms.) One can see that while the gain of the device increases as either temperature or voltage is increased, so does the noise. In addition, the high rate capability of VLPC's improves as the temperature increases, due to the increased mobility of the mobile positive charges (the 'holes'). The work to explore the performance space of the VLPC is continuing, but current results suggest that one can achieve a quantum efficiency of $> 80\%$ and an intrinsic gain $\geq 50\ 000$ with acceptable noise and rate characteristics.

The preshower detector consists of extruded strips of plastic scintillator with wavelength-shifting (WLS) fiber placed within a hole along the axis of the strip. The strips are made from polystyrene, doped with the same fluorescent compounds as Bicron [9] BC-404. The fibers are commercially available, Kuraray 835 μm multiclad Y11 [10] fiber, doped to a concentration of 250 ppm. The strips are prepared in an unconventional way. Standard polystyrene pellets are compounded with the scintillating fluors, resulting in pellets of scintillator. These pellets are then heated and the result is extruded in long strips with an axial hole. This extrusion is done by an commercial vendor using the same technology by which one makes hoses and tubing. One can make essentially any cross-section and arbitrarily long strips.

DØ has chosen to make strips of triangular cross section. These strips are formed into cylindrical layers as shown in fig 4. Three layers are used, the inner being strips parallel to the beams and the outer two layers having a stereo angle of approximately $\pm 20^\circ$. Test results of strips similar to these are given in ref. [11]. For strips on the order of one meter long, with WLS fibers silvered at one end and an eight meter long clear fiber connecting the WLS fibers and the VLPCs, one is able to achieve 4.0 photoelectrons per millimeter of scintillator traversed (for a minimum ionizing particle (MIP)). Since the DØ

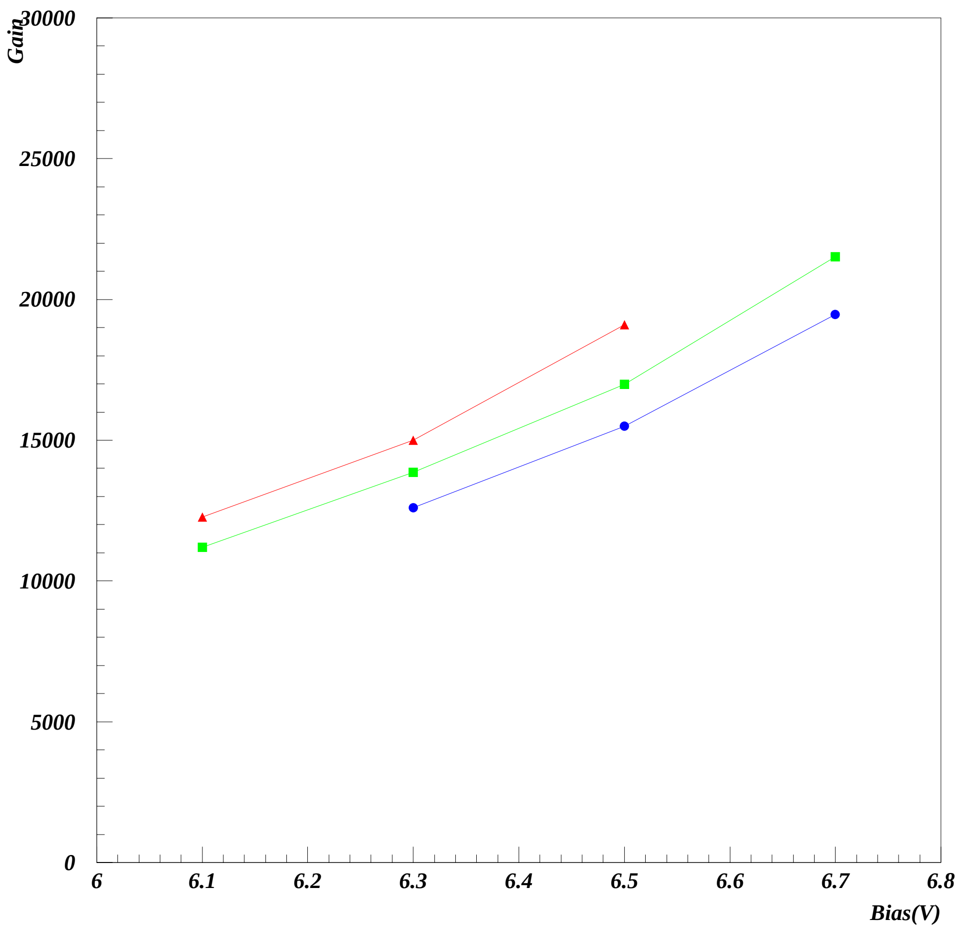

Fig. 2. The gain of a typical VLPC as a function of both bias voltage and temperature. Each set of points represent a different temperature: circles 6.0 K, squares 6.5 K, and triangles 7.0 K.

preshower detector will consist of layers of scintillator approximately 6 mm thick, this detector will be essentially 100% efficient in detecting MIPs. In addition, due to the shape of strips within a layer, one is able to use the ratio of signals in adjacent strips to determine the position a particle crosses the detector to a precision of 6% of the base of the triangle. For the DØ detector, with a base of approximately 7 mm, we expect to attain a MIP position resolution of 450 μm. The position resolution of a test module is shown in fig. 5. In this test module, the triangle base was 9 mm and the measured position resolution was 560 μm. Monte Carlo studies suggest that the location of a 10 GeV electron can be determined with a position resolution $\sim$ 1 mm. The success of this program of R&D has led to the adoption of the same technology for the forward preshower detector [12] which will give the DØ detector good

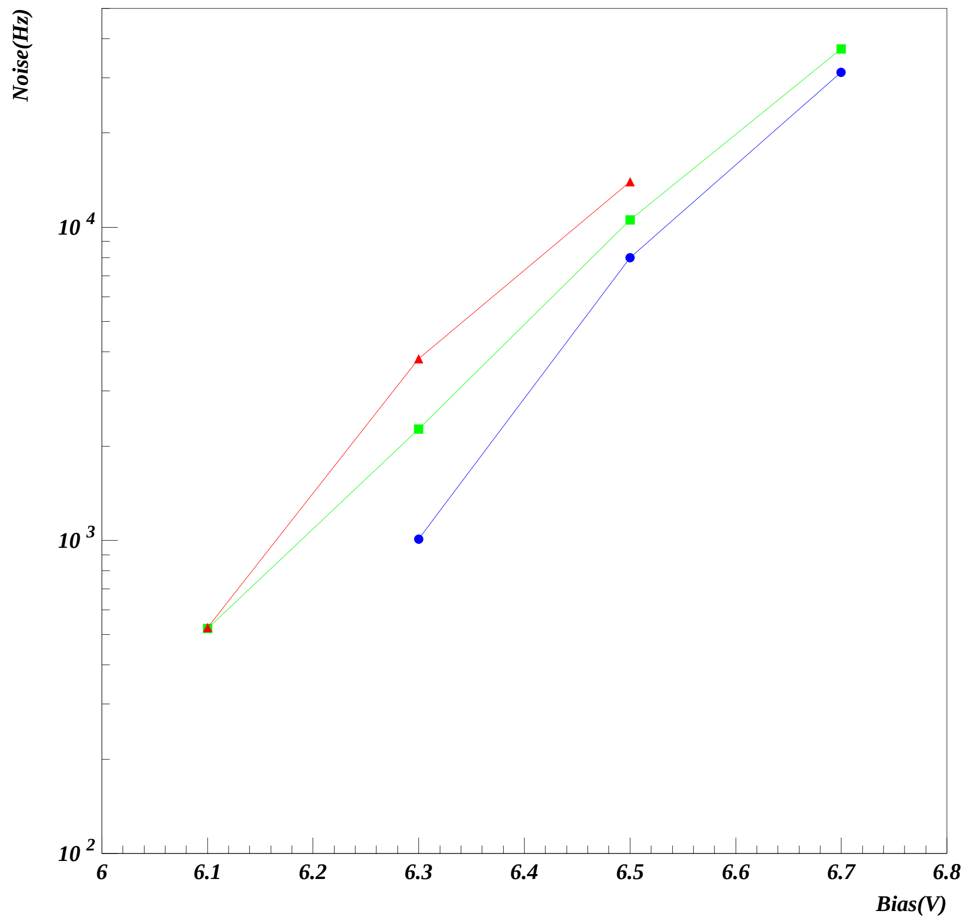

Fig. 3. The noise rate of a typical VLPC as a function of both bias voltage and temperature. Each set of points represent a different temperature: circles 6.0 K, squares 6.5 K, and triangles 7.0 K.

electron identification in the region $(1.4 < |\eta| < 2.6)$.

In this paper we have outlined our plans for the DØ central tracker upgrade. Throughout the course of our R&D efforts, we have explored novel technologies that are required to get the desired performance. With this upgrade we expect to achieve many important physics goals, including exploring top quark branching fractions, measuring the W boson mass to 50 MeV, and further investigating SUSY and other possible new phenomena.

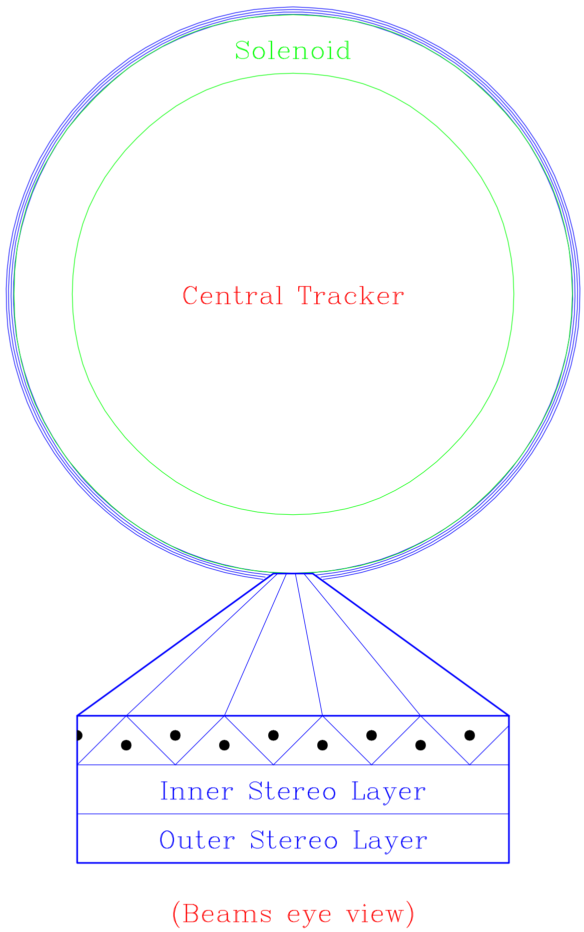

Fig. 4. An endview of parts of the DØ central tracker with the structure of the preshower detector highlighted.

Acknowledgement

We thank the Fermilab Accelerator, Computing, and Research Divisions, and the support staffs at the collaborating institutions for their contributions to the success of this work. We also acknowledge the support of the U.S. Department of Energy, the U.S. National Science Foundation, the Commissariat à L'Energie Atomique in France, the Ministry for Atomic Energy and the Ministry of Science and Technology Policy in Russia, CNPq in Brazil, the Departments of Atomic Energy and Science and Education in India, Colciencias in Colombia, CONACyT in Mexico, the Ministry of Education, Research Foundation and KOSEF in Korea and the A.P. Sloan Foundation.

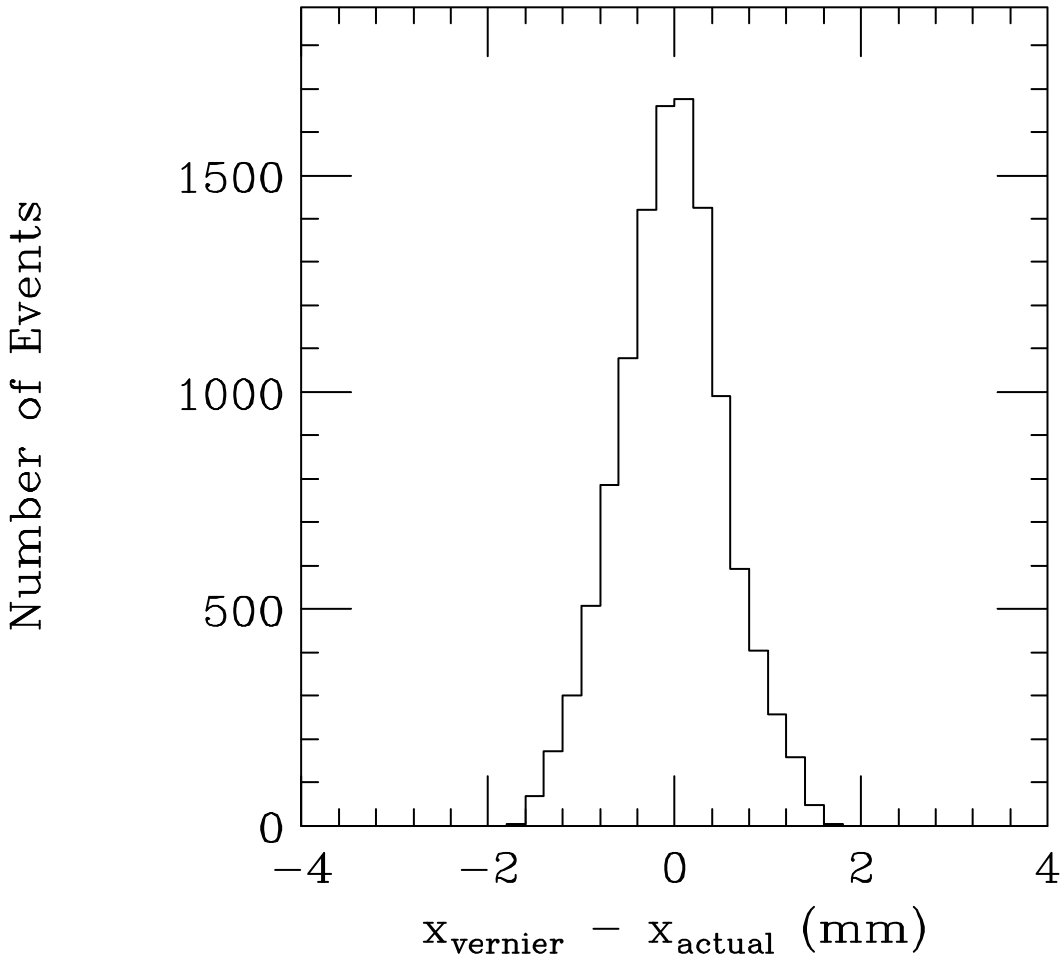

Fig. 5. The distribution of position measured by using the light yield in adjacent strips compared to an accurate external tracker. The base of the triangles in this test was 9 mm and a position resolution of 560 μm was achieved. Since the resolution is directly proportional to the triangle length of the triangle base, in the final detector we will achieve a MIP resolution of 450 μm.

References

[1] S. Abachi et al., Phys. Rev. Lett. 74 (1995) 2632; F. Abe et al., Phys. Rev. Lett. 74 (1995) 2626.

[2] M.R. Wayne (for the DØ Collaboration), Nucl. Instrum. Meth. A, 351 (1994) 77; A. Bross (for the DØ Collaboration), Nucl. Phys. (Proc. Suppl.) B 44 (1995) 12.

[3] A. P. Heinson (for the DØ Collaboration), 1992 DPF Conference Proceedings, (1731-1733).

[4] Kuraray Intl., 200 Park Ave, New York, NY 10166, USA. Tel. +1 (212) 986-2230.

[5] A. Pla-Dalmau, A.D. Bross, and C.W. Spangler, FERMILAB-Pub-93/038, Submitted to Journal of the Chemical Society Perkin Transactions 2; A.D. Bross, A. Pla-Dalmau and C.W. Spangler, Nucl. Instr. and Meth. A 325 (1993) 168; A.D. Bross et al., Nucl. Instr. and Meth. A 307 (1991) 35; A.D. Bross and A. Pla-Dalmau, Nucl. Instr. and Meth. A 327 (1993) 337.

[6] D. Adams et al., FERMILAB-Conf-94/312-E, Published in the 1994 DPF Conference Proceedings, p. 1869-1872; DØ Fiber Tracking Group, Nucl. Phys. B (Proc. Suppl.) 44 (1995) 332; M. Wayne, *Performance of a Large Scale Scintillating Fiber Tracker using VLPC Readout*, to be published in IEEE Trans. Nucl. Sci.

[7] Rockwell International Science Center, 3370 Miraloma Avenue, Anaheim, CA 92803.

[8] D. Adams et al., FERMILAB-Conf-94/318-E, published in the 1994 DPF Conference Proceedings p. 1873-1876; M. Atac et al., Nucl. Instr. and Meth. A 314 (1992) 56; M.D. Petroff and M.G. Stapelblock, IEEE Trans. Nucl. Sci. **NS-36** (1989) 158; M.D. Petroff and M. Atac, ibid., p. 163; G.B. Turner et al., in the Proceedings to SCIFI 93, World Scientific, River Edge, NJ (ed. A. Bross, R. Ruchti and M. Wayne), p. 613; M.G. Stapelbroek and M.D. Petroff, ibid., p. 621.

[9] Bicron Corporation, 12345 Kinsman Road, Newbury, OH, 44065-9677, USA. Tel. +1 (216) 564-2251.

[10] A. Pla-Dalmau, G.W. Foster and G. Zhang, Volume 1, FERMILAB-TM-1873, December 1993; A. Pla-Dalmau, G.W. Foster and G. Zhang, FERMILAB-TM-1875, December 1993.

[11] M. Adams et al., Nucl. Instr. and Meth. A **366** (1995) 263; M. Adams et al., *A New Detector Technique Using Triangular Scintillating Strips to Measure the Position of Minimum Ionizing Particles*, FERMILAB Pub-95/285-E, (1995), to be published in Nucl. Instr. and Meth. A.

[12] DØ Collaboration, FERMILAB-FN-641, Apr 1996.