CHAPTER 9

INTERACTION REGIONS AND EXPERIMENTAL FACILITIES

9.1 EXPERIMENTAL AREAS

9.1.1 BO Experimental Area. A general-purpose detector is being designed and constructed by the Colliding Detector Facility Department, CDF. The desire to measure antiproton-proton collisions and available technology both demand a large, massive and complicated apparatus. The BO Colliding Beam Experimental Area has been designed to handle the assembly, installation, operation and maintenance of such a detector.

The project includes the following:

BO Collision Hall an underground structure that will replace approximately 100 ft of the Main Accelerator enclosure, and will contain the experimental physics detectors and both the accelerator and Energy Saver beam components. On the outside wall (away from the accelerator center) will be a large door and movable shield wall that will provide acess to the Assembly Hall.

BO Transition and Equipment Bypass Enclosure an underground structure that connects the Collision Hall to the existing Main Accelerator enclosures, and provides a passage for personnel, utilities, and magnet-moving vehicles around the BO Collision Hall.

BO Assembly Hall a large pit at the elevation of the Collision Hall and adjoining to the shield door passage, with a service floor at grade level, all covered by a highbay building with an overhead crane. The various experimental physics detectors will be assembled, tested and serviced in this hall prior to placement in the BO Collision Hall.

BO Site Development hardstands, access roads, drainage facilities, relocation of utilities, extension of services and temporary earth retaining structures for construction sequencing and adjacent road and building protection.

BO Primary Power 13.8 kV feeders, substations and switchgear for extending primary power to the BO Experimental Area and into the BO Assembly Hall.

The BO Collision Hall connects with and becomes a part of the Main Accelerator and Energy Saver enclosures. All systems, services and utilities are designed for compatibility with these systems. Access to the BO Assembly Hall will be from the adjacent Road D near the Industrial Buildings.

At the time of writing, construction of the BO area is almost complete.

9.1.2 DO Experimental Area. This experimental area is still in the process of definition and conceptual design.

9.2 BO Low Beta Design[1]

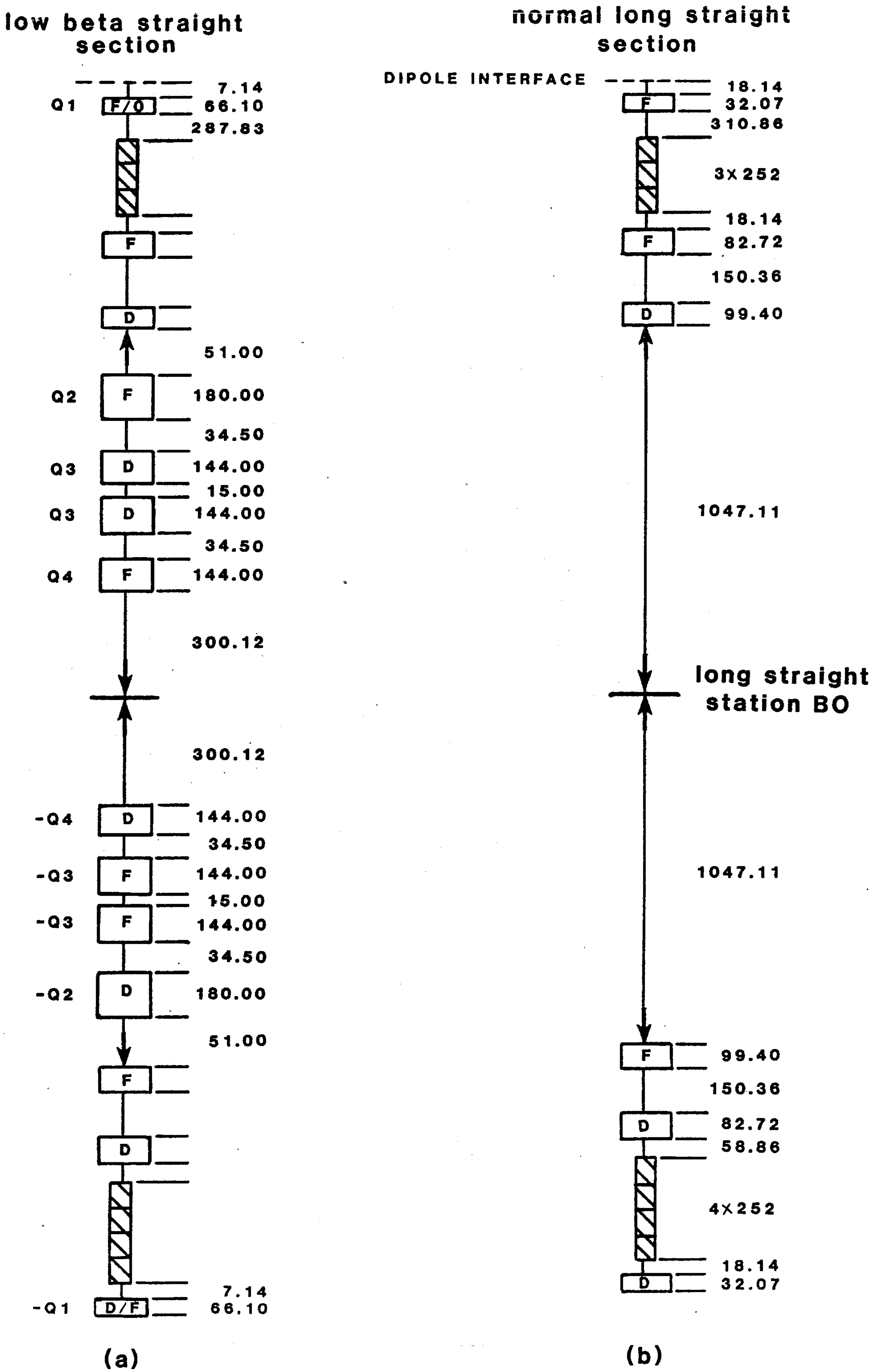
9.2.1 Lattice Design. As discussed in Chapter 6, the $\bar{p}$ and p bunches are placed at equal spacings around the circumference of the Tevatron, arranged so that one of their crossings occurs in the BO long straight section, the location of the Collider Detector Facility. There will also be crossings in the DO long straight section, the second colliding-beam experimental area, at present in a primordial state of design.

The luminosity can be enhanced for given beam currents by focusing the beams down to narrow waists at the collision point, using extra quadrupoles on either side of the collision point. These quadrupoles give a decrease in the amplitude function β and the low β gives the narrow waist.

It is desirable for our purposes to achieve a minimum β value of 1 meter. Given the Tevatron lattice and dimensions, it is possible to achieve this minimum with a design that utilizes quadrupoles having gradients of 25 kG/in. and requires replacement of a single normal-cell quadrupole on either side of BO, at A48 and B12, by longer quadrupoles. The design uses four separately powered quadrupole buses and either can be adiabatically varied from the normal $\beta^* = 72$ m configuration to $\beta^* = 1$ m, while causing very little betatron mismatch or manipulation outside the interaction region except for correction-quadrupole changes to preserve the overall tunes and sextupole changes to maintain the desired chromaticity.

A layout of the 25 kG/in. low-beta insertion is shown in Fig. 9-1. It requires the replacement of the 32 in. quadrupoles at A48 and B12 with separately powered 66 in. quadrupoles and the addition of two 180 in. quadrupoles and 6 144 in. quadrupoles within the long straight section. These ten quadrupoles are powered anti-symmetrically on four separate circuits and must reach a maximum gradient of 25.5 kG/in. at 1 TeV. In order to keep maximum luminosity point close to the Tevatron BO location, the quadrupoles at A48 and B12 must be pushed as far upstream as possible. To do this, the normal dipole interface-to-quadrupole magnetic length has been reduced from 18.137 in. to 7.137 in. by changing the upstream bellows and moving the beam detector to the downstream end of the quadrupoles. This motion puts the maximum luminosity point 0.9 in. downstream of the Tevatron BO for the final low beta of 1 m.

9.2.2 Transition to Low Beta. For normal fixed-target operation, Q1 must run at approximately 10 kG/in. and Q2, Q3, and Q4 must all be off. By contrast, in the low-beta configuration, all the quadrupoles must be on and running quite hard. The problem is to find a method of connecting these



low beta straight section
7.14
Q1
F/O
66.10
287.83
F
D
51.00
Q2
F
180.00
34.50
Q3
D
144.00
15.00
Q3
D
144.00
34.50
Q4
F
144.00
300.12
300.12
-Q4
D
144.00
34.50
-Q3
F
144.00
15.00
-Q3
F
144.00
34.50
-Q2
D
180.00
51.00
F
D
7.14
-Q1
D/F
66.10
(a)
normal long straight section
DIPOLE INTERFACE
18.14
F
32.07
310.86
3x252
18.14
F
82.72
150.36
D
99.40
1047.11
long straight station BO
1047.11
F
99.40
150.36
D
82.72
58.86
4x252
18.14
D
32.07
(b)

Figure 9-1

two solutions in a stepwise continuous manner while maintaining the overall tune of the Tevatron. This is by no means a simple straightforward process. The two solutions are in fact quite different and probably cannot be connected without disturbing the normal lattice functions outside the insertion region. A method has been found, however, that does not greatly disturb the rest of the ring. This sequence takes the lattice from a retuned fixed mode to a low beta of 1 m.

In all this sequence, the Tevatron has been retuned to 19.585 in each plane. For particle-antiparticle collisions it is desirable to be above the half integer and the value of 0.585 centers the tune in a region free of all resonances of order lower than 11th. The correction quadrupoles consist of two families, QFC and QDC, located next to the correponding quadrupoles, QF or QD, at all stations 13 through 47. These corrections have a range of approximately ±2 kG/in. at 50 amps. QFC has ranges from +0.4 kG/in. to -0.9 kG/in. QDC is given by

$$QDC = 0.0457 - QFC \text{ (kG/in.)}$$

In this turn-on sequence, there is some disturbance to the lattice functions outside the insertion region, for three distinct reasons:

1. The "off" solution and the "low-beta" solution are, in fact, quite different. It is doubtful that they can be connected without allowing some mismatch.

2. The initial sequence, in steps of less than 1/3 kG/in., was not a very smooth curve. Some amount of mismatch was allowed in order to produce smoother curves.

3. It was found that a higher luminosity can be achieved in the "1 meter low-beta" by introducing some mismatch. This is because the long straight sections are not exactly antisymmetric; one side has more dipole edge focusing than the other, while the low beta quads of necessity are symmetric.

The amount of disturbance to the normal lattice, however, is quite small and should cause no problem since this turn-on will not start until high energy where the beam is very small.

9.3 Hardware Modifications

9.3.1 Magnets. Special quadrupoles have been designed and are being built for the B0 interaction region. These magnets use special cable with 20 micron filaments and a copper-to-superconductor ratio of 1.3 (as opposed to 8 microns and a ratio of 1.8). This cable has a short sample limit of 5250A at 6.5T. The new quadrupole has added turns to reach higher fields.

There are many new features of the new design. The strength of the coil collars has been carefully considered, as has quench protection. A smaller cross section is being considered to give less interference with the Collider Detector. Because the special quads are powered separately from the regular Superconducting Ring magnets, the regular excitation currents are bypassed through the quads in a notch at the outside of the coil collar.

The beam monitor and correction magnet at B12 have been redesigned in a special package and relocated downstream of the special quad. Dipole fields will arise from quad misalignment. Even though shimming will be done, misalignments in the high-β regions adjacent to the low-β interaction region can give large orbit distortions and trim dipoles are being designed for correction.

9.3.2 Power Supplies and Bus. Four separate power supplies and associated circuits will be needed for the 1-m β^* design. The supplies will be modified Tevatron holding supplies capable of providing up to 6000 A. The supplies will be located in an annex to the B0 service building and the power will be transported to the magnets via water-cooled copper bus (total length of 4 circuits is 2700 ft). For a current of 6000 A, the power consumed by the bus is 770 kW. Power will enter the magnets through lead boxes constructed especially to fit the 15 in. space provided for them.

9.3.3 Refrigeration. Liquid-He refrigeration needs are as follows: quadrupoles (50 W), four pairs of 5-kA leads at 10 W each (40 W + 56 l/hr), two turnaround boxes at 10 W each (20 W), two feed boxes (45 W) and U tubes (5 W), for a total of 160 W plus 60 liters per hour. This refrigeration need can be met initially by the A4(C4) and B1(D1) satellite refrigeration systems. Later, it may be desirable to provide stand-alone refrigeration, and it would certainly be needed if operation at 1.8 K is desired. The 60 liters per hour of liquid He will come from the Central Helium Liquifier through the A4 and B1 refrigerator and magnet systems. The estimated LN_2 requirement is 250 W. Refrigeration estimates for the interaction-region detector magnets are not included here, because it is expected that those needs will be satisfied by separate refrigeration.

9.3.4 Vacuum. Pressure in the interaction region straight section should not exceed 10^{-9} Torr. This means the warm vacuum pipe through the detector plus a transition piece on either side will require special preparation (possible bakeout). The transition pieces will contain isolation valves and ion pumps, as well as the connections to turbomolecular and roughing pumps.

9.4 D0 Low-Beta Design

At this time, the D0 low-beta region is still being designed.

References

1. D.E. Johnson, Tevatron B0 Low Beta Tuning Report, Fermilab Report TM-1106, May 1982 (unpublished).