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BOOSTER LENGTH STORAGE RING DESIGN FOR ANTIPROTON COOLING

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In order to match an electron-cooling scheme with $\bar{p}$ production at Fermilab, it is necessary to do the cooling in a storage ring with the same circumference as the booster. In addition, one wants to be able to do the cooling on a large percentage of the circumference, approximately 15-25%. Finally, it is desirable to be able to use as much of the present proton storage ring as possible. An initial design of such a storage ring is presented below. It incorporates the present ring's curved sections and power supplies, unmodified, has a total of 100 meters of electron beam, and utilizes as few additional quadrupoles and power supplies possible, consistent with the above requirements.

The present electron cooling ring is built in a racetrack design, with two, tightly-packed curved sections connected by relatively short straight sections, one of which is to be used for the initial cooling tests.[1] It consists of 24, four-foot dipoles, and 32, two-foot quadrupoles connected to nine separate power supplies. It has a circumference of some 135 meters. In order to bring it to booster size, approximately 340 meters more need to be added. The most straightforward way to accomplish this is to cut the present ring at the end of the curved sections, and simply trombone the

the design to the desired length. This can be done by leaving the south end of the ring in its present location, moving the north end next to the linac annex, and connecting the two with very long straight sections.

The design presented cuts the present ring between the #6 dipoles and the #6 quadrupoles - i.e., B16, Q16, B26, Q26, etc, and leaves the curved sections completely unchanged. Thus the power supplies, tuning parameters, and lattice functions of the curved sections do not change at all. For simplicity, all of the electron cooling has been put into one straight section, although it may be more desirable to cool on both sides in order to achieve super-periodicity. This, however, would require considerably more quadrupoles, as well as an additional electron gun system.

The design presented bridges the straight section without the electron beam with a simple FODO channel, using four quadrupoles at each end to match into the curved lattice. The other side is somewhat more difficult due to the defocussing effect of the electron beam, as well as the required $\bar{p}$ beam size in the cooling region. The design chosen has ten cooling sections, each containing a 10 m, 13 amp electron beam, separated by a quadrupole triplet, and the complete straight section is connected to the curved lattice with a triplet at each end. Plots of the lattice for the two halves are shown in Figs. 1 and 2. Note that in Fig. 2, only two electron beams and one triplet are shown for simplicity, while, in actuality, the beam-triplet configuration is repeated nine times. This design requires a total of 36 additional 2-foot quadrupoles, and 6 additional quadrupole power supplies. Various parameters for the ring are listed below.

Expanded Cooling Ring Parameters

Number of dipoles	24
dipole effective length	1.3125 m
dipole field (200 MeV)	4.29149 kG
Number of quadrupoles	68
quadrupole effective length	0.6767 m

Curved Section

Drift length (D0)		1.9455 m
Drift length (D1)		0.3789
Drift length (0)		0.8340
Quadrupole gradient	Q0	6.6759 kG/m
	Q1	-13.1961
	Q2	13.1961
	Q3	-15.8528
	Q4	15.8528
	Q5	-17.3551
Quarter arc (C)		(D0)Q0(D1)B(0)Q1(0)B(0)Q2 (0)B(0)Q3(0)B(0)Q4(0)B(0) Q5(0)B

Straight section without e^- beam

Matching section

Drift length	(DW1)	3.000 m
	(DW2)	1.0000
	(DW3)	5.0000
	(DW4)	3.0000

Quadrupole gradients	QW1	13.1810 kG/m
	QW2	-11.5192
	QW3	1.3739
	QW4	-2.0626
Structure (TW)	(DW1)QW1(DW2)QW2(DW3)QW3(DW4)QW4	

FODO Section

Drift length (DW)	19.7062 m	
Quadrupole gradients	QF	2.2336 kG/m
	QD	-2.1659
Structure (FODO)	QF(DW)QD(DW)	

Half Ring Structure (W)

(C)TW(DW)FODO(FODO)FODO(QF)DW($\overline{TW}$)$\overline{C}$

Straight section with electron beam

Matching section

Drift length	(DE1)	0.9343 m
	(DE2)	1.3221
	(DE3)	0.6956
Quadrupole gradients	QE1	-11.5223 kG/m
	QE2	19.7050
	QE3	-14.9517
Structure (TE)	(DE1)QE1(DE2)QE2(DE3)QE3	

Beam Section

Drift length	(DE)	2.2784 m
	(D)	1.0000
Quadrupole gradients	QTF	8.8190 kG/m
	QTD	-4.6017

Electron beam (Beam)	10.02 m
	13 Amp
Beam Structure (EB)	(DE)Beam(DE)
Triplet Structure (TRP)	QTD(D)QTF(D)QTD

Half Ring Structure (E)

(C)TE(EB)TRP(EB)TRP(EB)TRP(EB)TRP(EB)TRP(EB)
TRP(EB)TRP(EB)TRP(EB)TRP(EB)$\overline{\text{TE}}$($\overline{\text{C}}$)

Entire Ring (E) (W)

	Total length	474.2027 m
Tunes:(*)	Q_x	5.47
	Q_y	7.23

Beam parameters in cooling region

$$\beta_x = \beta_y \text{ (center)} = 30.0 \text{ m}$$

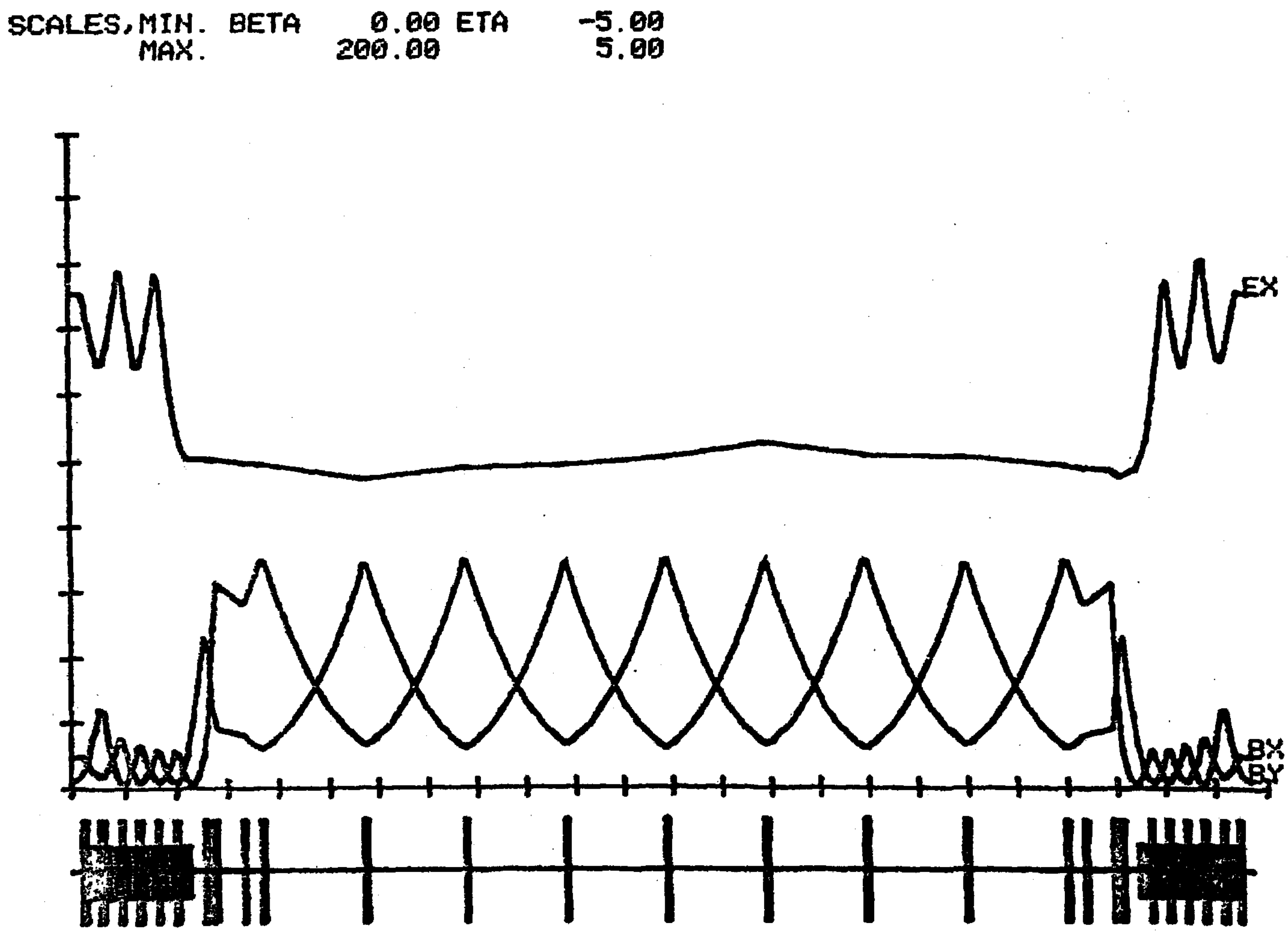
$$\beta_x = \beta_y \text{ (ends)} = 34.2 \text{ m}$$

$$\eta_x \simeq 0.2 \text{ m}$$

*N.B. Tunes have not been optimized, but are easily changeable.

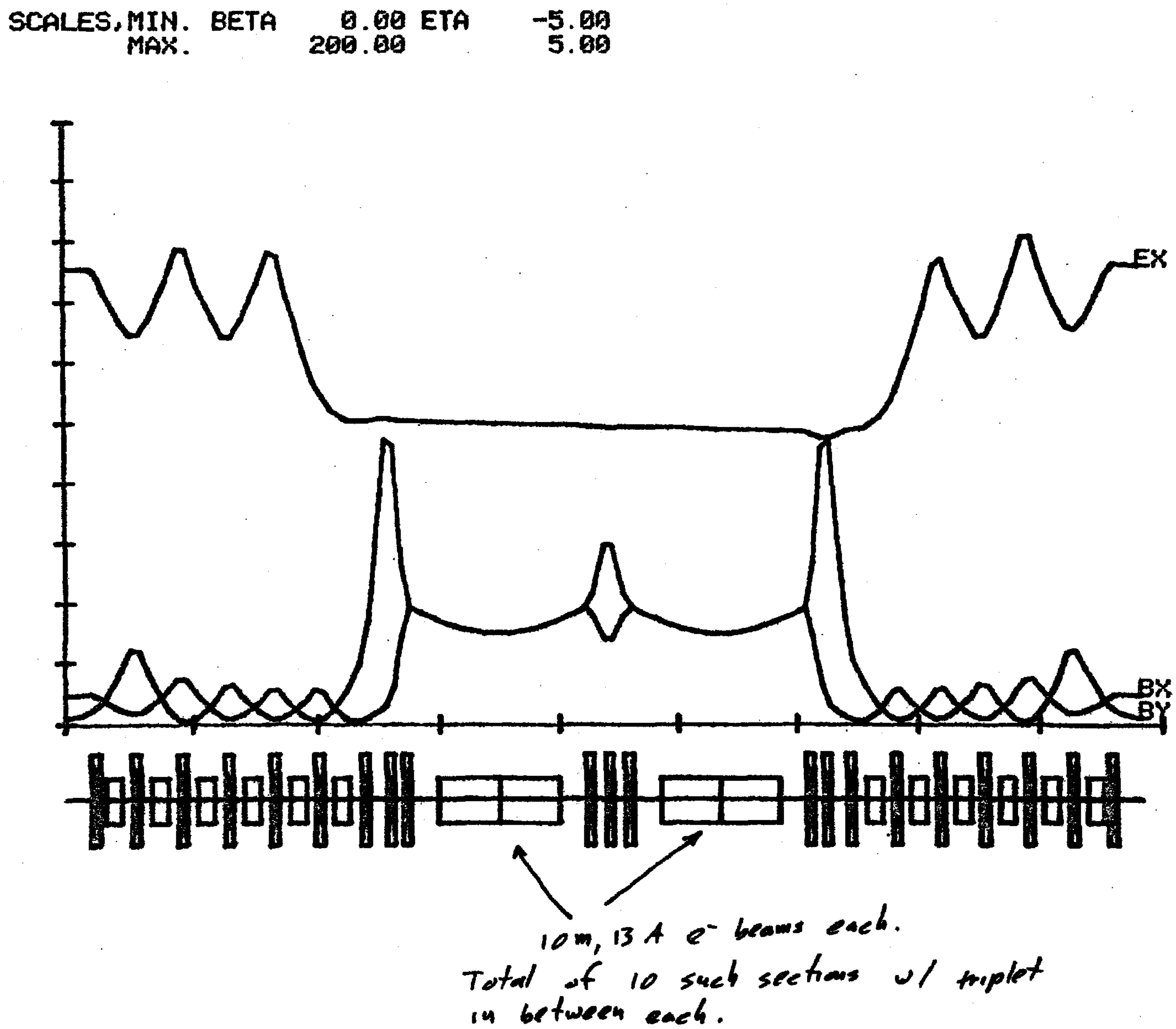
Reference

1. "Fermilab Electron Cooling Experiment Design Report", August 1978



Expanded cooling ring, west half

Figure 1



Expanded Cooling Ring, east half. P-bar's.

Figure 2