CHAPTER 11

BEAM - TRANSPORT LINES

11.1 120-GeV Proton Transport From F17 to Target (Line AP-1)

The extraction energy for the protons to be used for antiproton production was 80 GeV in an earlier design. It was decided to raise this energy to 120 GeV in order to increase antiproton production. The earliest choice for a 120-GeV extracted beam was to upgrade the then-existing 80-GeV line, which extended 1000 ft from F17 to F25 within the Main Ring tunnel. Although this design satisfied most of the project requirements, it possessed a number of undesireable features. Its estimated power consumption of 2 MW would place a heavy burden on the cperating cost of the Antiproton Source. The elements of the 80-GeV line were placed immediately above the Main Ring magnets, below which the Energy Saver magnets have now been installed. As a consequence, difficult operational problems would be encountered wherever work had to be performed on the Main Ring or the Energy Saver. It was necessary to dismantle the 80-GeV beam in many locations in order to install the Energy Saver. The location of the original $\bar{p}$ hall, which is very close to F25, limited the ability to vary the proton targeting. The 80-GeV line had been put in the Main Ring tunnel because the 400-GeV operating schedule in 1977 and 1978 did not allow the several-month interruption that was believed to be needed to modify the Main Ring tunnel at F18 in order to build a more flexible beam. This constraint is no longer relevant. For these reasons, a more efficient and flexible beam design was developed.

The design of the 120-GeV proton transport line was based on the following requirements:

(i) It must leave the Main Ring tunnel as close as possible to location F18.

(ii) The target elevation is to be 7.0 ft above Main Ring beam height.

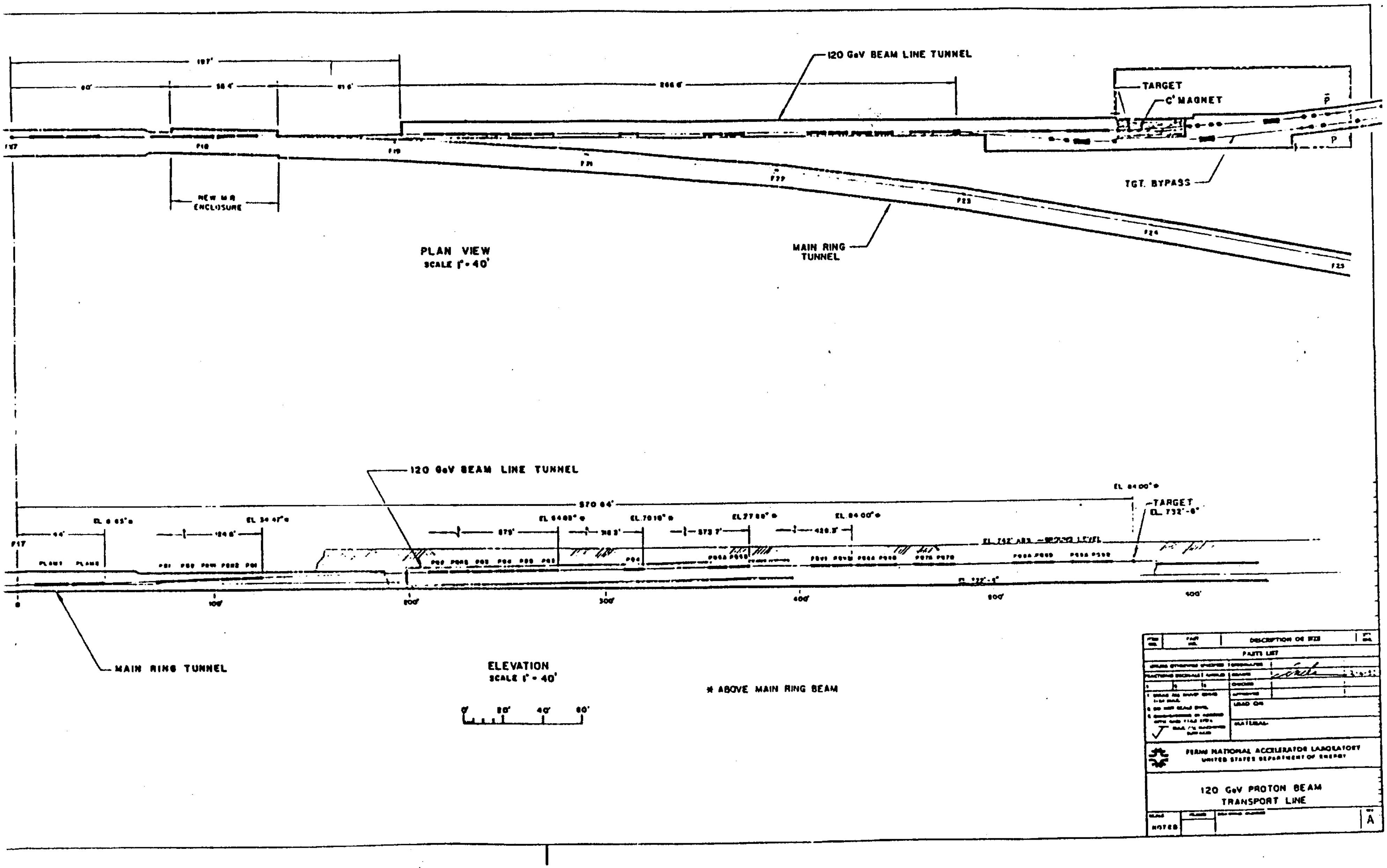
(iii) It must transport a 120-GeV proton beam with a momentum spread of ±0.2%.

(iv) It must be possible to bypass the target and collection system in the reverse direction.

(v) It must transport the 8.9-GeV/c cooled antiproton beam with an emittance of 2.0π mm-mrad.

(vi) It must produce a round proton beam spot at the target which can be varied from 0.2 mm to 0.8 mm rms.

(vii) It must have zero dispersion at the target.



120 GeV BEAM LINE TUNNEL
TARGET
C' MAGNET
TGT. BYPASS
NEW MR ENCLOSURE
PLAN VIEW
SCALE 1" = 40'
MAIN RING TUNNEL
120 GeV BEAM LINE TUNNEL
TARGET
MAIN RING TUNNEL
ELEVATION
SCALE 1" = 40'
* ABOVE MAIN RING BEAM
0' 20' 40' 60'
0 100' 200' 300' 400' 500' 600'
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
120 GeV PROTON BEAM
TRANSPORT LINE
A

Figure 11-1

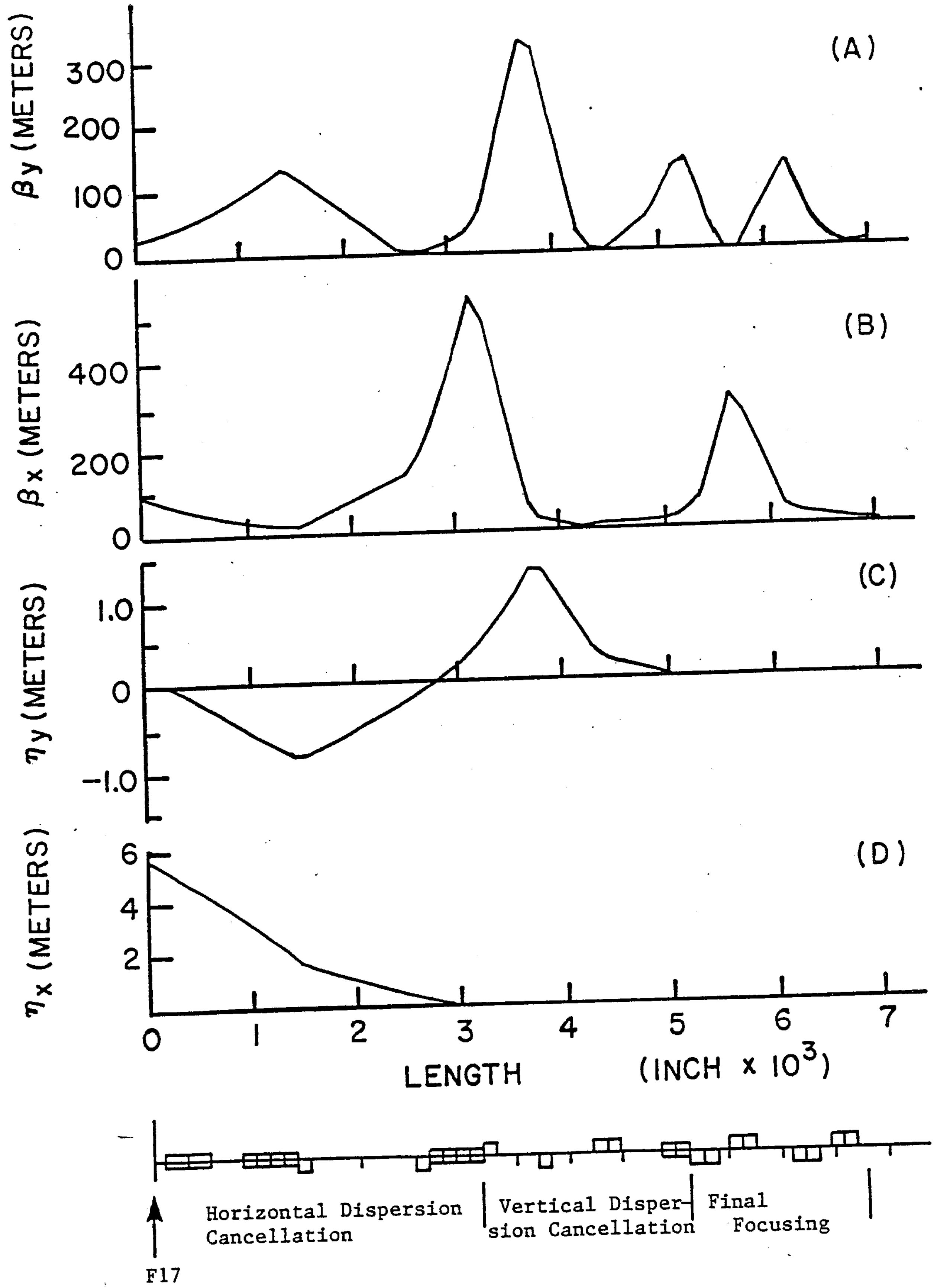


Figure 11-2 Twiss parameters β_y, β_x and dispersion functions η_y, η_x through the 120 GeV beam transport system.

(viii) The power consumption must remain below 500 kW.

A layout of the beam is shown in Fig. 11-1 and its parameters are tabulated in Table 11-I. In Fig. 11-2 we show the behavior of the monoenergetic β_y, β_x, η_y, and η_x through the system from extraction to the target. The beam consists of 10 EPB dipoles excited to a field of 13 kG or less and 14-3Q120 quadrupoles excited to a field gradient of 4.75 kG/in. or less. Three of the dipoles, indicated by (R), are rotated by 45° to achieve the necessary vertical and horizontal bends with the minimum number of magnets. The Main Ring tunnel must be widened over a distance of roughly 18 m in order to accommodate the four EPB dipoles and one 3Q120. The length of the beam is 174 m, of which 41 m is located in the Main Ring tunnel. The remainder of the beam elements are located in a new 115-m long enclosure. The new enclosure and the Main Ring tunnel are connected by an 18-m long pipe.

A 4.5° bending magnet, which bends the reverse antiproton beam to the left, is placed within the final focus section between PQ7B and PQ8A in order to allow the target and antiproton collection lens to be bypassed whenever cooled antiprotons are transported back to F17. The total power consumption of the beam is estimated to be less than 390 kW. In Table 11-II the gradients of the four final focusing quadrupoles, which obtain the required range of beam sizes, are listed.

TABLE 11-I 120-GEV TRANSPORT ELEMENTS

NEW BEAM TRANSPORT MAIN RING TO TARGET
AP-1

31 August 84 D. E. Johnson

120 GEV PROTONS KINETIC

X, Y, Z SITE COORDINATES
COORDINATES GIVEN AT EACH END OF ELEMENT
MAIN RING STATION AO AT X=0.0, Y=0.0

NAME	EFF. LENGTH (IN)	FIELD (KG-KG/M)	X (FT)	Y (FT)	Z (FT)
MAIN RING			1010.4910	-2446.2350	725.5000
drift	76.70		1005.7696	-2441.9266	725.5000
P-LAMBERTSON 1	162.00	8.58	995.8012	-2432.8232	725.5587
drift	15.00		994.8785	-2431.9799	725.5699
P-LAMBERTSON 2	162.00	8.58	984.9146	-2422.8730	725.7464
drift	18.00		983.8075	-2421.8609	725.7726
P-CMAG 1	119.40	10.21	976.5261	-2415.2063	725.9826
drift	21.00		975.2347	-2414.0257	726.0266
P-CMAG 2	118.40	10.21	967.9548	-2407.3720	726.3117
drift	162.00		957.9951	-2398.2693	726.7530
PB1	120.00	12.79	950.5852	-2391.5623	727.0801
drift	12.00		949.8410	-2390.8953	727.1125
PB2	120.00	12.79	942.3664	-2384.2602	727.4396
drift	12.00		941.6158	-2383.6002	727.4721
PBR1	120.00	12.79	934.0862	-2377.0264	727.7651
drift	12.00		933.3307	-2376.3716	727.7907
PBR2	120.00	12.79	925.7549	-2369.8480	728.0151
drift	12.00		924.9950	-2369.1982	728.0341
PQ1	120.00	-65.87	917.3963	-2362.7004	728.2241
drift	1012.99		853.2512	-2307.8471	729.8271

NAME	EFF. LENGTH (IN)	FIELD (KG-KG/M)	X (FT)	Y (FT)	Z (FT)
PQ2	120.00	-48.50	845.6526	-2301.3489	730.0190
drift	12.00		844.8925	-2300.6993	730.0381
PBR3	120.00	12.42	637.3152	-2294.1757	730.1952
drift	12.00		836.5595	-2293.5208	730.2077
PB3	120.00	12.42	829.0343	-2286.9364	730.3314
drift	16.17		829.0241	-2286.0443	730.3481
PB4	120.00	12.42	820.5611	-2279.3897	730.4721
drift	16.17		819.5596	-2278.4882	730.4888
PB5	120.00	12.42	812.1589	-2271.7639	730.6129
drift	16.17		811.1660	-2270.8529	730.6296
PQ3	120.00	120.93	803.7972	-2264.0941	730.7536
drift	400.00		779.2345	-2241.5638	731.1670
PQ4	120.00	-159.61	771.8656	-2234.8045	731.2910
drift	400.00		747.3031	-2212.2744	731.7044
PQ5A	120.00	183.05	739.9341	-2205.5154	731.8284
drift	12.00		739.1972	-2204.8394	731.8409
PQ5B	120.00	183.05	731.8284	-2198.0806	731.9649
drift	391.63		707.7797	-2176.0217	732.3698
PBV1	120.00	8.21	700.4104	-2169.2624	732.4629
drift	12.00		699.6735	-2168.5864	732.4688
PBV2	120.00	8.21	692.3044	-2161.8269	732.5000
drift	24.00		690.8306	-2160.4749	732.5000
PQ6A	120.00	-114.28	683.4611	-2153.7154	
drift	12.00		682.7242	-2153.0394	
PQ6B	120.00	-114.28	675.3549	-2146.2797	
drift	100.00		669.2138	-2140.6466	
PQ7A	120.00	102.73	661.8443	-2133.8871	
drift	12.00		661.1073	-2133.2111	
PQ7B	120.00	102.73	653.7380	-2126.4514	
drift	350.00		632.2439	-2106.7359	
PQ8A	120.00	-123.78	624.8746	-2099.9762	
drift	12.00		624.1376	-2099.3002	
PQ8B	120.00	-123.78	616.7686	-2092.5407	
drift	100.00		610.6273	-2086.9078	
PQ9A	120.00	92.66	603.2580	-2080.1480	
drift	12.00		602.5211	-2079.4720	
PQ9B	120.00	92.66	595.1517	-2072.7123	
drift	150.00		585.9399	-2064.2629	
TARGET			585.9399	-2064.2629	732.5000

11.17.20.UCLP, DD, TB10, 0.136KLNS. ** END OF LISTING **

TABLE 11-II GRADIENT OF FINAL FOCUSING QUADRUPOLES AS A FUNCTION OF BEAM SIZE AT THE TARGET, IN T/m.
(MAXIMUM GRADIENT 18T/m)

QUADRUPOLES

β^*(m)	σ(mm)	PQ6A/B	PQ7A/B	PQ8A/B	PQ9A/B
1.17	0.20	-13.2	+10.3	-12.1	+13.2
4.69	0.40	-11.4	+10.3	-12.4	+ 9.3
18.75	0.79	-10.3	+ 9.7	- 9.8	+ 2.0

11.2 8-GeV Antiproton Transport to Debuncher (Line AP-2)

The antiproton transport line is shown symbolically in Fig. 11-3. This beam line can transport an 8-GeV beam with 20π mm-mrad transverse emittance and $|\Delta p/p| > 4.0\%$. The match to the Debuncher is accomplished with an integrated efficiency of 80% over the 4.0% passband in $\Delta p/p$.

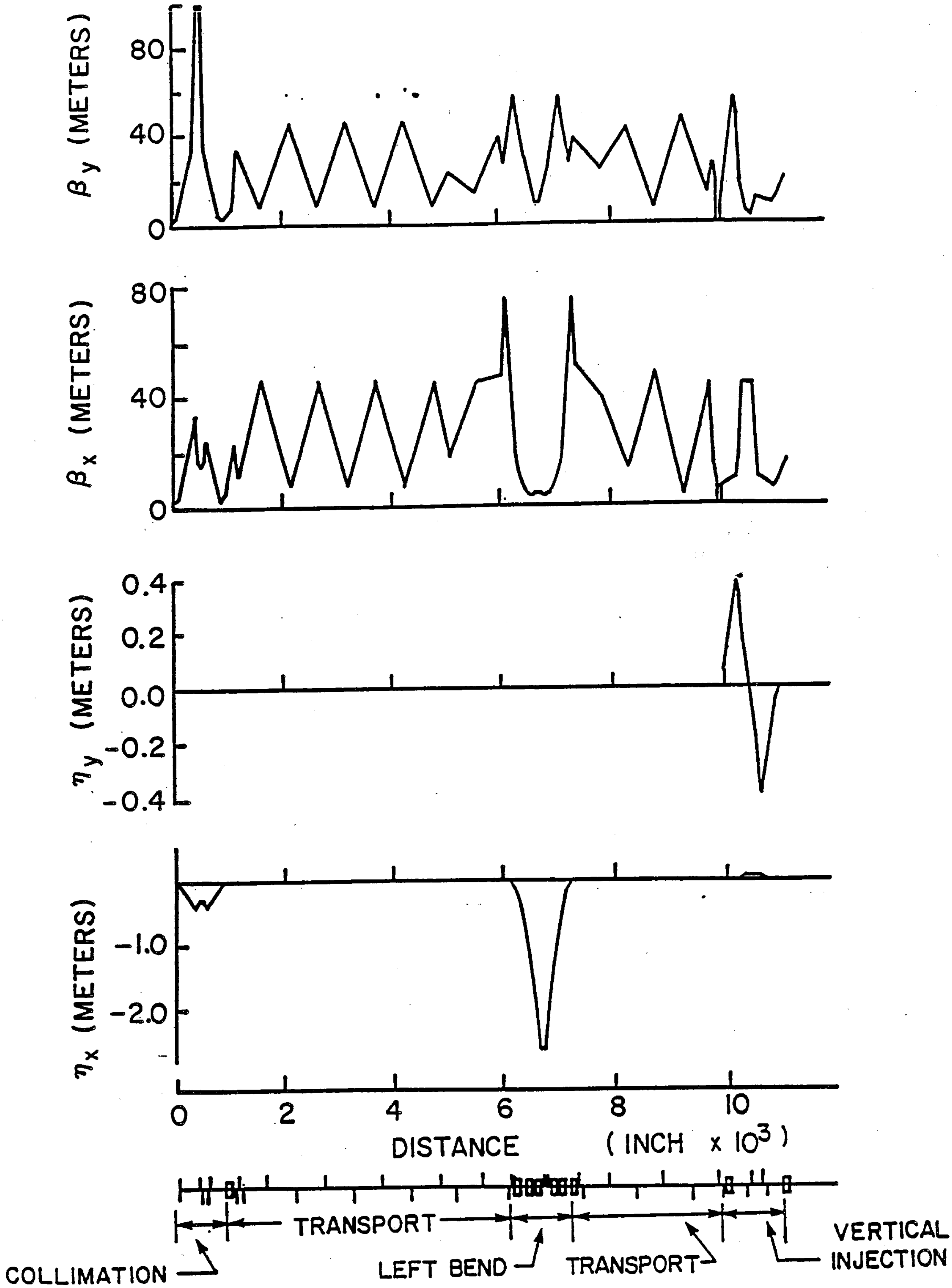


Figure 11-3 The antiproton transport line to the Debuncher monoenergetic envelope functions β_y, β_x and dispersion functions η_y, η_x.

Independent controls for emittance definition in both x and y planes and $\Delta p/p$ selection are possible using collimators. The detailed design can be found in Reference 9.

The "source" for the beam line is the center of the 5.0 cm $\bar{p}$ production target. For the purpose of the transport calculations we have assumed a circular spot and a β^* of 2.25 cm. The lithium lens collector then performs point to parallel optics for negatives with a momentum of 8.9-GeV/c (8-GeV $\bar{p}$). The beam line consists of five basic sections: (i) cleanup, (ii) long transport, (iii) left bend, (iv) long transport, and (v) injector. Section (i) uses a pulsed C magnet to bend the 8-GeV $\bar{p}$ 3° left, and two quadrupole doublets and another 3° bend left in order to complete the achromatic transformation. Charge, central momentum and vertical emittance ε_y are selected within this section using collimators. The long transport sections (ii) and (iv) consist of 90° FODO quadrupole cells and matching quadrupole lenses. The periodic structure has a cell length of 88.81 ft. with β_{max}/β_{min}=45.93m/7.98m. The left bend (iii) which deflects the antiproton by 36.53°, consists using of six dipoles. Horizontal emittance (ε_x) selection is performed at the entrance and exit of this section where β_x is nearly 80 m. The fine $\Delta p/p$ selection is performed in the center of the left bend section where β_x^o = 5.0 m and a maximum in the dispersion η_x^* = 2.62 m is obtained. The first-order momentum resolving power is 1.31 for $\varepsilon_x = 20\pi$ mm-mrad and $\Delta p/p$ = 1.0% and 2.62 for $\varepsilon_x = 5\pi$ mm-mrad. The injector (v) is an achromatic vertical translation ending at the downstream end of the 2.1 m long current septum. The beam is deflected downward by 48 inches using 3.62° bends.

The components for the beam line are listed in Table 11-V.

TABLE 11-III BEAM TRANSPORT TARGET TO DEBUNCHER

BEND AND QUAD CENTERS FOR AP2 INJECTION LINE
IN FEET WITH AO AT (O.,O.)

A. J. LENNOX 7-17-84

CALCULATED FROM D JOHNSON'S TRANSPORT OUTPUT WHICH GIVES COORDINATES DEFINING INCOMING AND OUTGOING RAYS FOR EACH MAGNET. FOR BENDS CALCULATED THE INTERSECTION OF THE RAYS. ALSO PROJECTED TO THE BENDPOINT FROM BOTH UPSTREAM AND DOWNSTREAM ENDS. ANSWER GIVEN HERE IS THE AVERAGE OF THE PROJECTIONS, WHICH GENERALLY AGREES WITH THE INTERSECTION CALCULATION TO WITHIN ONE MIL.

FOR QUADS FOUND THE MIDPOINT BETWEEN THE POINTS DEFINING THE MAGNETIC EDGES OF THE MAGNET.

DEVICE	X(FEET)	Y(FEET)	ELEVATION(FEET)
LITH	585.3961	-2063.7639	732.5000
CMAG	582.3137	-2060.9358	732.5000
IQ1	562.0705	-2044.2266	732.5000
IQ2	558.7672	-2041.4999	732.5000
IQ3	553.1373	-2036.8529	732.5000
IQ4	549.8339	-2034.1263	732.5000
IB1	529.5908	-2017.4171	732.5000

DEVICE	X(FEET)	Y(FEET)	ELEVATION(FEET)
IQ5	515.9906	-2007.3399	732.5000
IQ6	511.5648	-2004.0605	732.5000
IQ7	482.3402	-1982.4062	732.5000
IQ8	447.1932	-1956.3636	732.5000
IQ9	412.0462	-1930.3211	732.5000
IQ10	376.8991	-1904.2785	732.5000
IQ11	341.7521	-1878.2359	732.5000
IQ12	306.6051	-1852.1933	732.5000
IQ13	271.4581	-1826.1507	732.5000
IQ14	251.4719	-1811.3417	732.5000
IQ15	199.9270	-1773.1489	732.5000
IQ16	186.9132	-1763.5062	732.5000
IQ17	184.0553	-1761.3886	732.5000
IB2	178.0788	-1756.9602	732.5000
IQ18	170.3371	-1752.4096	732.5000
IB3	162.5955	-1747.8590	732.5000
IB4	151.4725	-1742.8232	732.5000
IQ19	142.9373	-1740.0056	732.5000
IQ20	136.5429	-1737.8947	732.5000
IB5	128.0077	-1735.0771	732.5000
IB6	116.0727	-1732.5012	732.5000
IQ21	107.1433	-1731.5486	732.5000
IB7	98.2139	-1730.5959	732.5000
IQ22	90.7756	-1730.5958	732.5000
IQ23	84.5753	-1730.5958	732.5000
IQ24	53.4534	-1730.5956	732.5000
IQ25	23.9291	-1730.5955	732.5000
IQ26	-17.3335	-1730.5952	732.5000
IQ27	-60.7370	-1730.5950	732.5000
IQ28	-90.6750	-1730.5948	732.5000
IQ29	-145.0596	-1730.5945	732.5000
IQ30	-148.7762	-1730.5945	732.5000
IBV1	-159.0362	-1730.5944	732.5000
IQ31	-181.0835	-1730.5943	731.0734
IQ32	-189.8568	-1730.5942	730.5057
IQ33	-195.9009	-1730.5942	730.1146
D4Q5	-214.7902	-1730.5941	728.8924
SEPT	-222.6742	-1730.5940	728.3822

15.09.34.UCLP, GG, T810, 0.115KLNS. ** END OF LISTING **

Fig. 11-3 shows the evolution of the monoenergetic β_y and β_x envelope functions and the beam dispersions η_y and η_x through the transport line from the target to the downstream end of the injection kicker. Figure 11-4 shows beam envelopes through the line.

11.3 Debuncher to Accumulator Transfer (Line D to A)

The beam transfer between the Debuncher and the Accumulator is a horizontal transfer taking place in the 10 straight section. Extraction

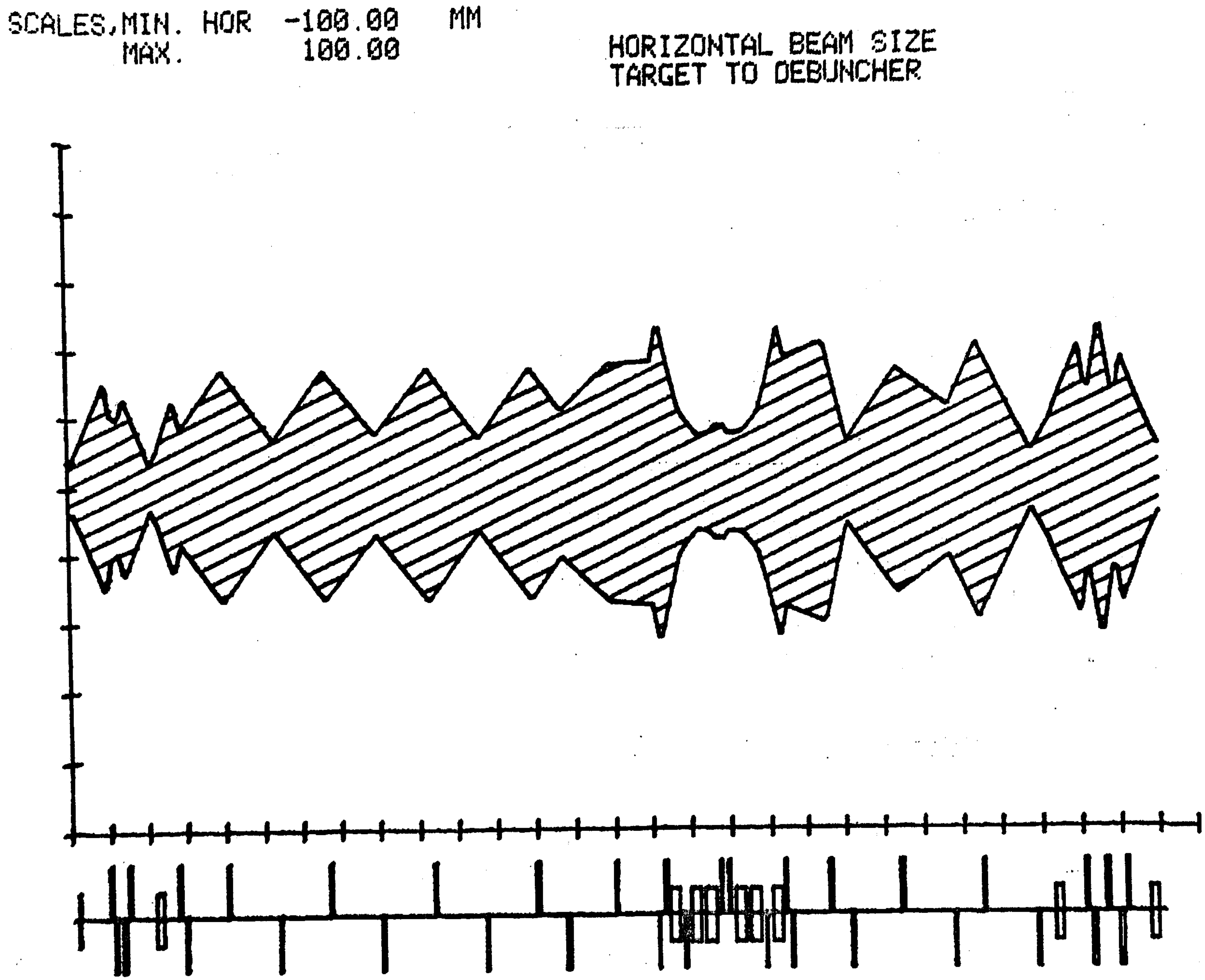

SCALES,MIN. HOR -100.00 MM
MAX. 100.00
HORIZONTAL BEAM SIZE
TARGET TO DEBUNCHER

Figure 11-4a

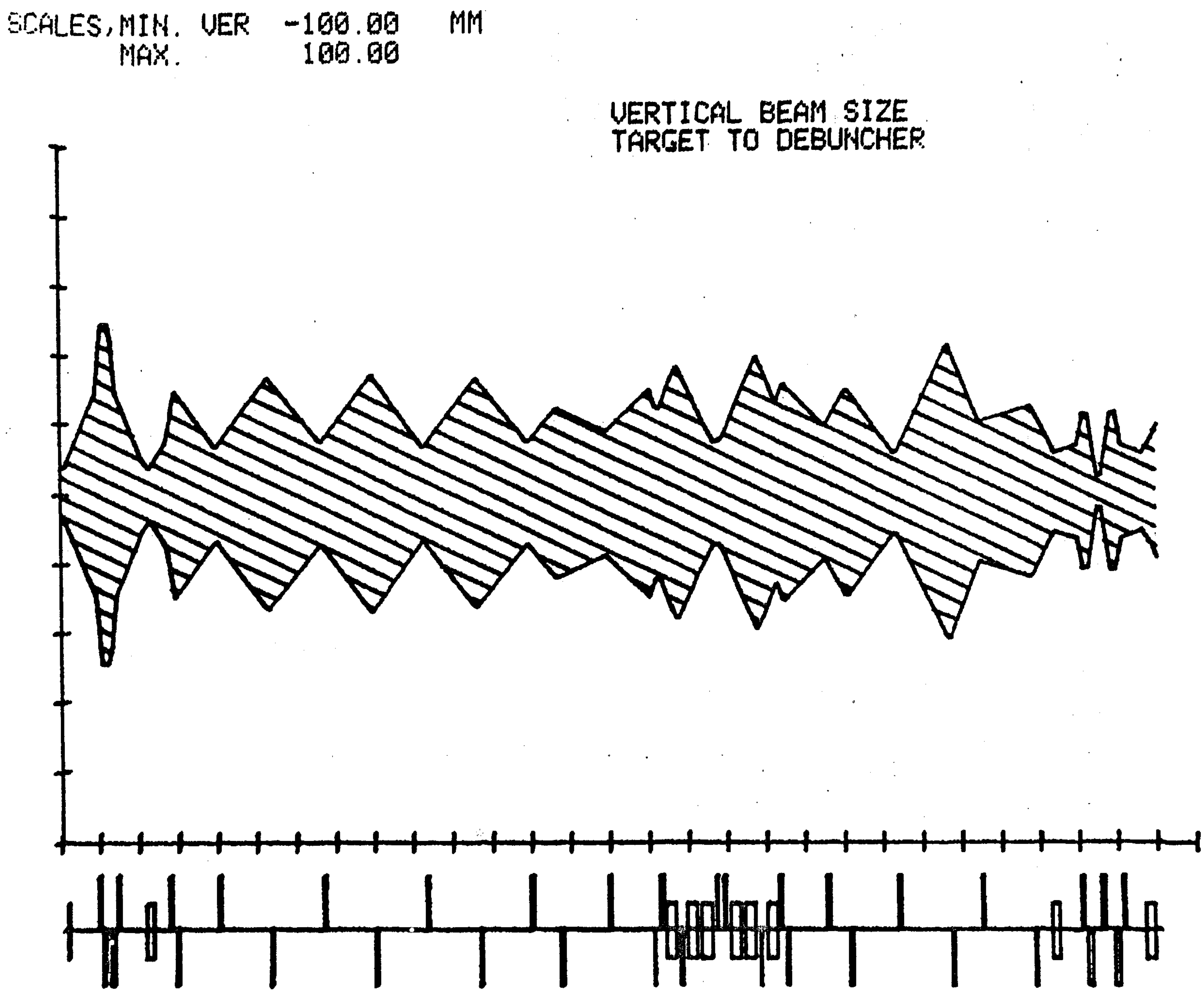
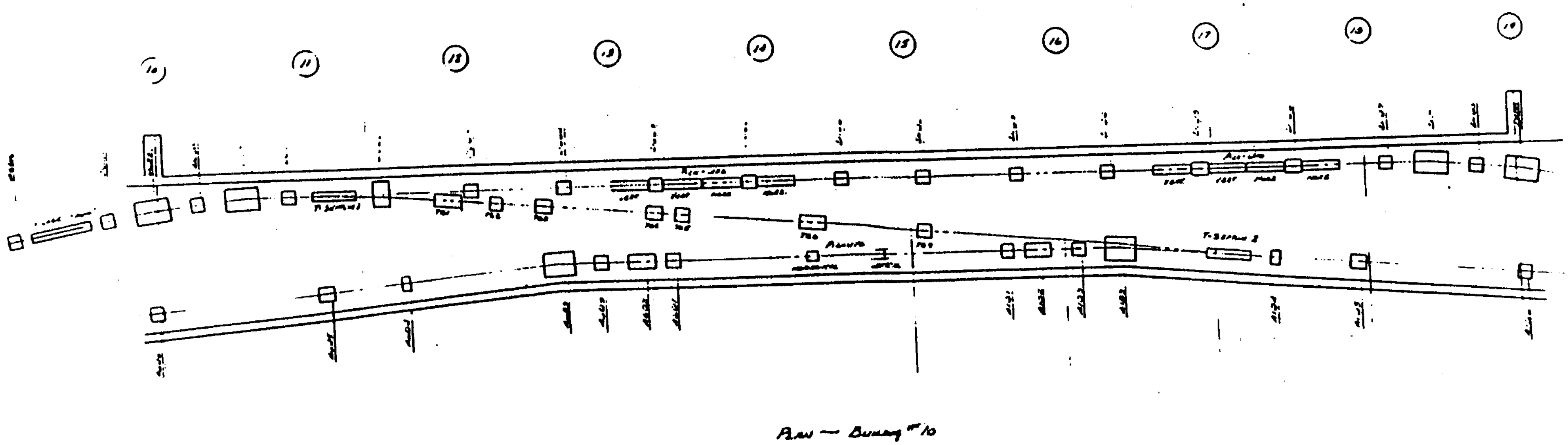
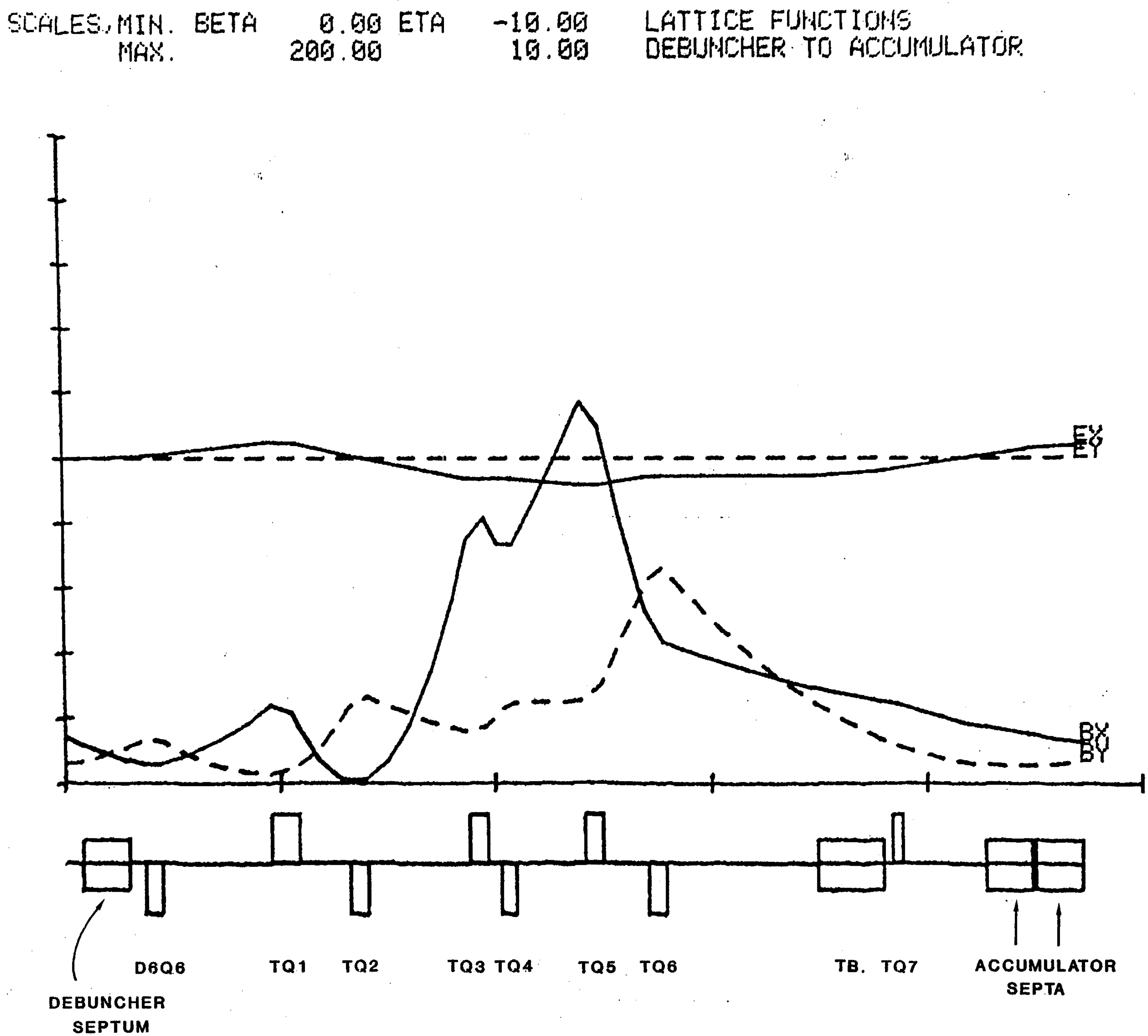

SCALES,MIN. VER -100.00 MM
MAX. 100.00
VERTICAL BEAM SIZE
TARGET TO DEBUNCHER

Figure 11-4b



Beam Transfer From Debuncher To Accumulator

Figure 11-5



SCALES, MIN. BETA 0.00 ETA -10.00
MAX. 200.00 10.00
LATTICE FUNCTIONS
DEBUNCHER TO ACCUMULATOR
EX
EY
BX
BY
D6Q6
TQ1
TQ2
TQ3 TQ4
TQ5
TQ6
TB. TQ7
ACCUMULATOR SEPTA
DEBUNCHER SEPTUM

Figure 11-6

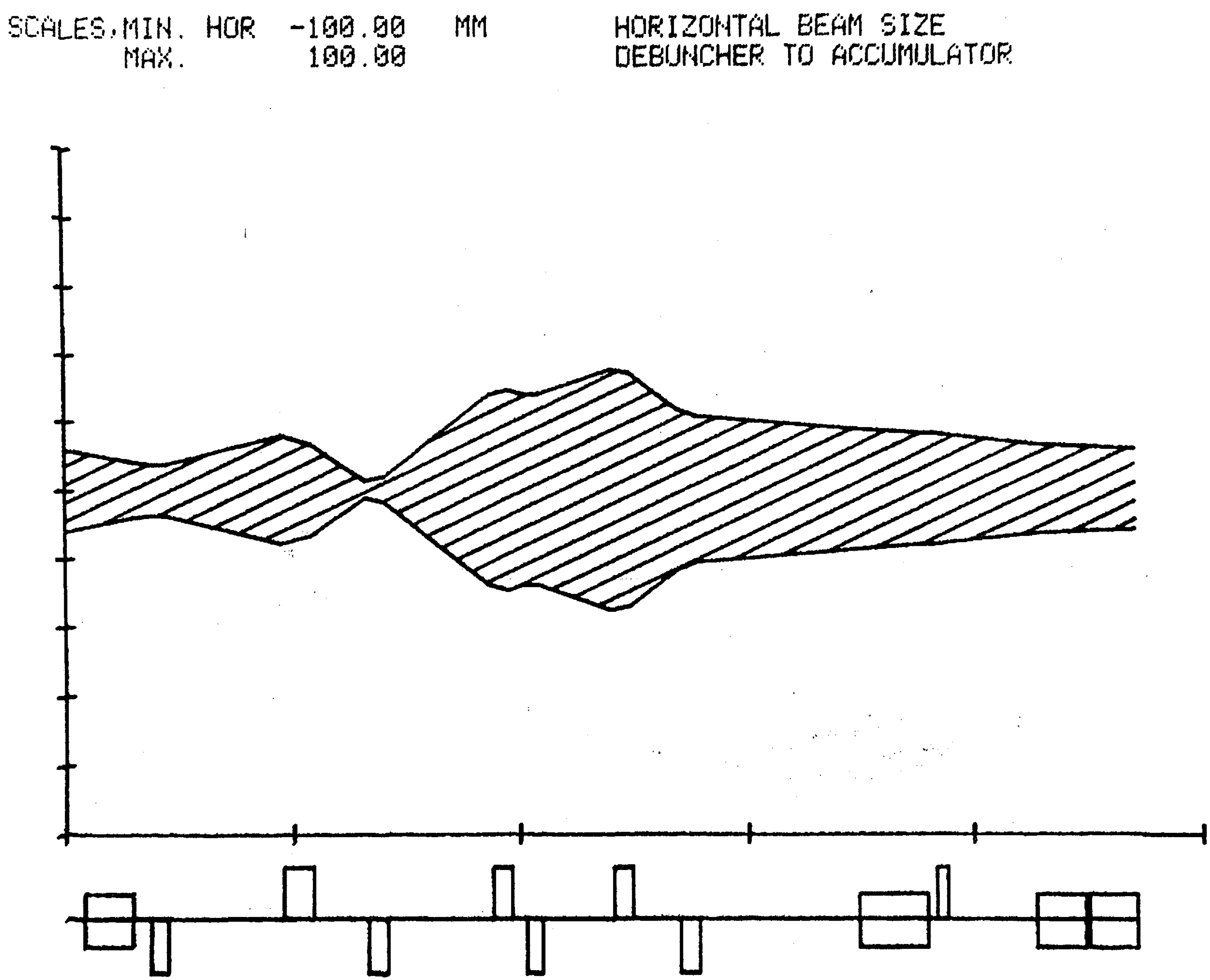

SCALES,MIN. HOR -100.00 MM
MAX. 100.00
HORIZONTAL BEAM SIZE
DEBUNCHER TO ACCUMULATOR

Figure 11-7a

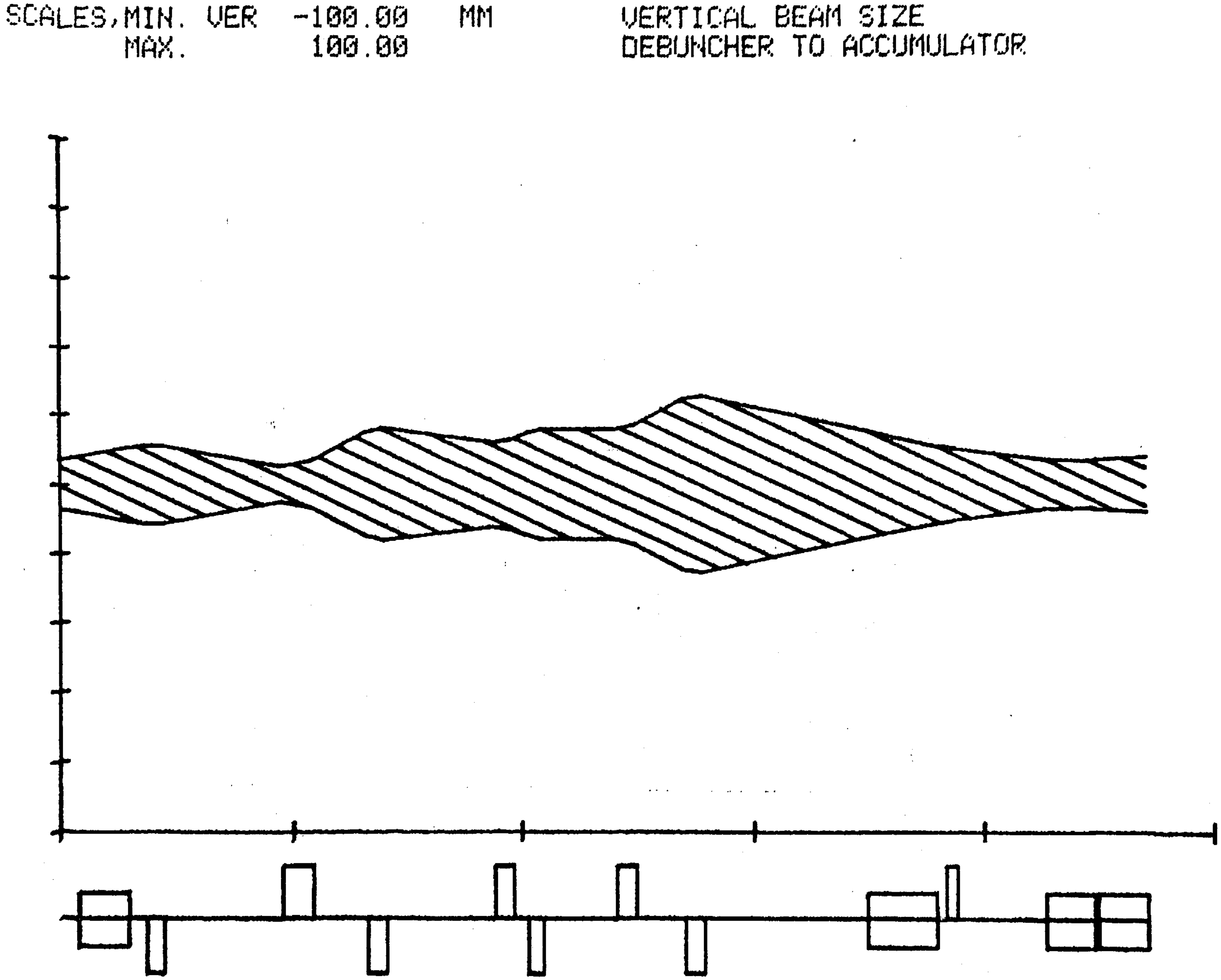

SCALES,MIN. VER -100.00 MM
MAX. 100.00
VERTICAL BEAM SIZE
DEBUNCHER TO ACCUMULATOR

Fig 11-

from the Debuncher is accomplished with a kicker and a septum magnet, as shown in Fig. 11-5. The quadrupole after the septum magnet, QD3, has a large aperture to accommodate both the circulating and the extracted beam. This quad kicks the beam further to the inside of the ring toward the Accumulator. The horizontal displacement of the extracted beam from the magnet axis is 5 in. After extraction, the beam is transported to the Accumulator with no further bending through a string of 6 quadrupoles. At the Accumulator, the beam is injected onto a path displaced from the central momentum by $\Delta p/p$=+0.775% with a 12-kG 7 ft long pulsed septum placed between A1B3 and A1S3. Finally the beam is kicked onto the proper orbit in the Accumulator with a 500-G, 7 ft long shutter kicker placed in the A20 straight section. A plot of the lattice functions of the transfer line is shown in Fig. 11-6 and the elements are listed in Table 11-IV. Figure 11-7 shows beam envelopes through the line.

TABLE 11-IV BEAM TRANSFER, DEBUNCHER TO ACCUMULATOR

Element	Name	Length (m)	Field
Debuncher kicker		3.0480	459.32 G
Septum	TS1	2.1336	7.03 kG
Drift		0.3099	
Debuncher Quad	D6Q6	0.4140	-96.24 kG/m
Drift		5.1272	
Quad	TQ1	1.3120	70.12 kG/m
Drift		2.1527	
Quad	TQ2	0.8280	-90.68 kG/m
Drift		4.4904	
Quad	TQ3	0.8280	90.68 kG/m
Drift		0.5818	
Quad	TQ4	0.7010	-90.68 kG/m
Drift		5.2097	
Quad	TQ5	1.3120	70.12 kG/m
Drift		3.5860	
Quad	TQ6	0.8280	-90.68 kG/m
Drift		4.8706	
Quad	TQ7	0.7010	94.22 kG/m
Drift		5.8240	
Septum	TS2	2.1336	11.72 kG
Accumulator Kicker		2.1336	515.56 G

11.4 Accumulator to Main Ring Transport (Line AP-3)

Two separate downward bends of 50 mrad each eventually restores the extracted beam to target height (Δz=48.0 in.). Then the beam is taken through four modules consisting of: (i) long transport, (ii) left bend, (iii) long transport, and (iv) target bypass. Following this, the beam rejoins the 120-GeV proton line just downstream of quadrupole PQ7B and is reverse-injected into the Main Ring at F17. The orbit parameters are identical for 120-GeV protons and 8-GeV antiprotons at this point.

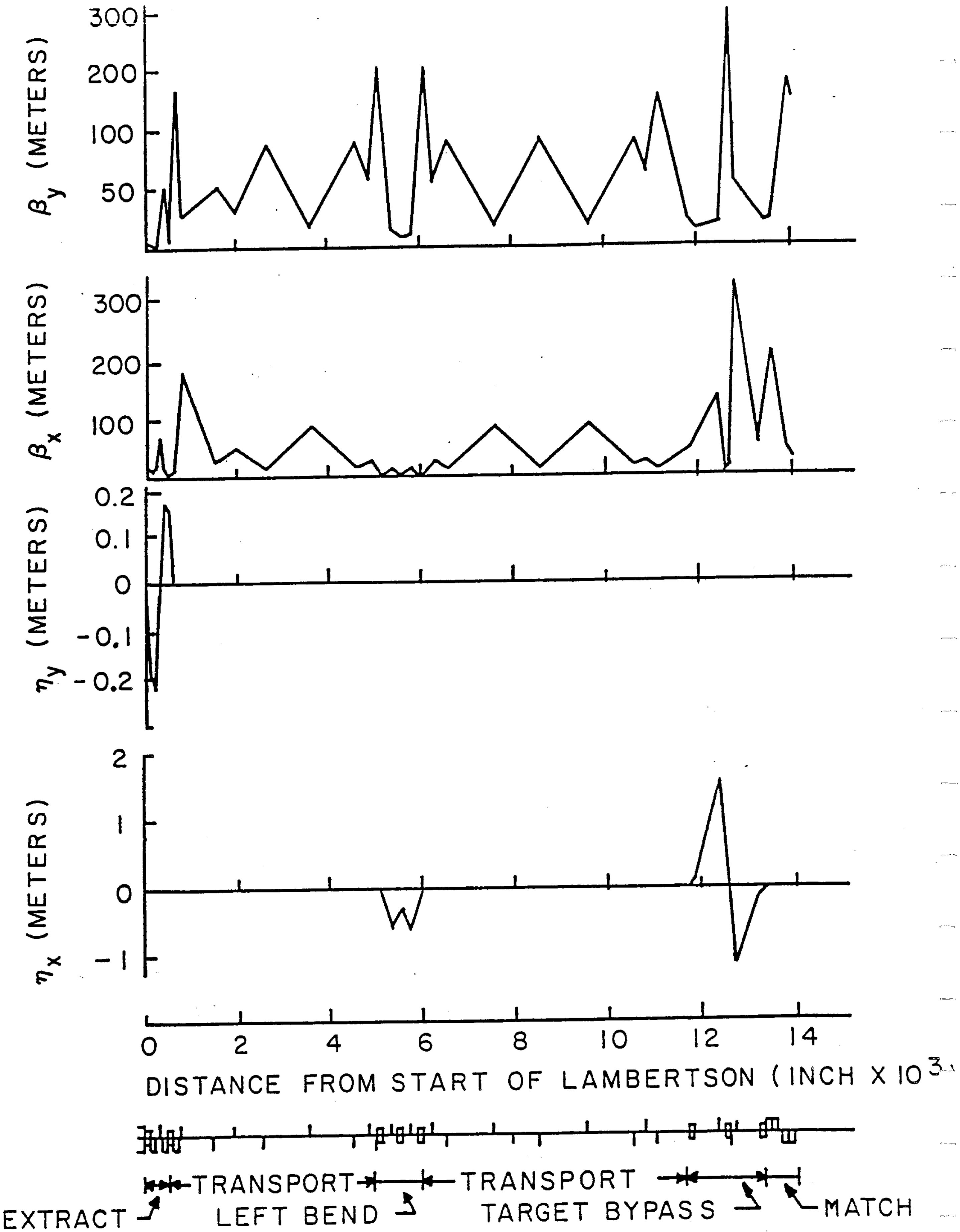


Figure 11-8 Beam functions β_y, β_x and dispersion functions η_y, η_x for the antiproton beam transport from the Accumulator to the 120 GeV proton transport line.

The long transport (iii) parallels the long transport carrying the hot $\bar{p}$ to the Debuncher. The target bypass is an achromatic transport using three dipoles and three quadrupoles. Figure 11-8 shows the behavior of the monoenergetic β_y, β_x, η_y, and η_x functions through the extraction system, starting at the Lambertson and ending at the downstream end of EB6. Figure 11-9 shows beam envelopes through the line.

Table 11-V lists the antiproton transport line elements from the Accumulator to the match point in the proton extraction line (EB6).

TABLE 11-V BEAM TRANSPORT ACCUMULATOR TO TARGET BYPASS

BEND AND QUAD CENTERS FOR AP3 EXTRACTION LINE
IN FEET WITH A0 AT (0.,0.)

A LENNOX 7-17-84

CALCULATED FROM D JOHNSON'S TRANSPORT OUTPUT WHICH GIVES COORDINATES DEFINING INCOMING AND OUTGOING RAYS FOR EACH MAGNET. FOR BENDS CALCULATED THE INTERSECTION OF THE RAYS. ALSO PROJECTED TO BENDPOINT FROM BOTH UPSTREAM AND DOWNSTREAM ENDS. BENDPOINTS GIVEN HERE ARE THE AVERAGES OF THE PROJECTIONS WHICH NORMALLY AGREE WITH THE INTERSECTION CALCULATION WITHIN 1 MIL.
FOR QUADS FOUND THE MIDPOINT BETWEEN THE POINTS DELIMITING THE EFFECTIVE LENGTHS.

DEVICE	X(FEET)	Y(FEET)	ELEVATION(FEET)
LAMB	-121.6827	-1344.1093	728.5000
CMAG	-116.7765	-1351.1117	729.1230
EQ1	-109.1432	-1362.0059	730.4588
EBV1	-105.9929	-1366.5021	731.0101
EQ2	-101.8382	-1372.4317	731.3727
EQ3A	-97.3078	-1378.8976	731.7681
EQ3B	-95.1778	-1381.9376	731.9541
EQ4	-92.3343	-1385.9959	732.2022
EBV2	-88.9229	-1390.8647	732.5000
EQ5	-85.2979	-1396.0383	732.5000
EQ6	-82.9022	-1399.4575	732.5000
TRIM	-80.4490	-1402.9586	732.5000
EQ7	-57.9644	-1435.1434	732.5000
EQ8	-33.9041	-1469.5837	732.5000
EQ9	-.4771	-1517.4316	732.5000
EQ10	16.9957	-1542.4423	732.5000
EQ11	54.8459	-1596.6217	732.5000
EQ12	82.2884	-1635.9033	732.5000
EQ13	110.7951	-1676.7082	732.5000
EQ14	122.4967	-1693.4580	732.5000
EB1	126.2317	-1698.8043	732.5000
EQ15	135.2586	-1709.1464	732.5000
EB2	149.5821	-1725.5569	732.5000
EQ16	162.8483	-1737.8019	732.5000
EB3	173.4980	-1747.6318	732.5000
EQ17	178.7384	-1751.5139	732.5000
EQ18	191.0764	-1760.6539	732.5000
EQ19	218.5475	-1781.0044	732.5000

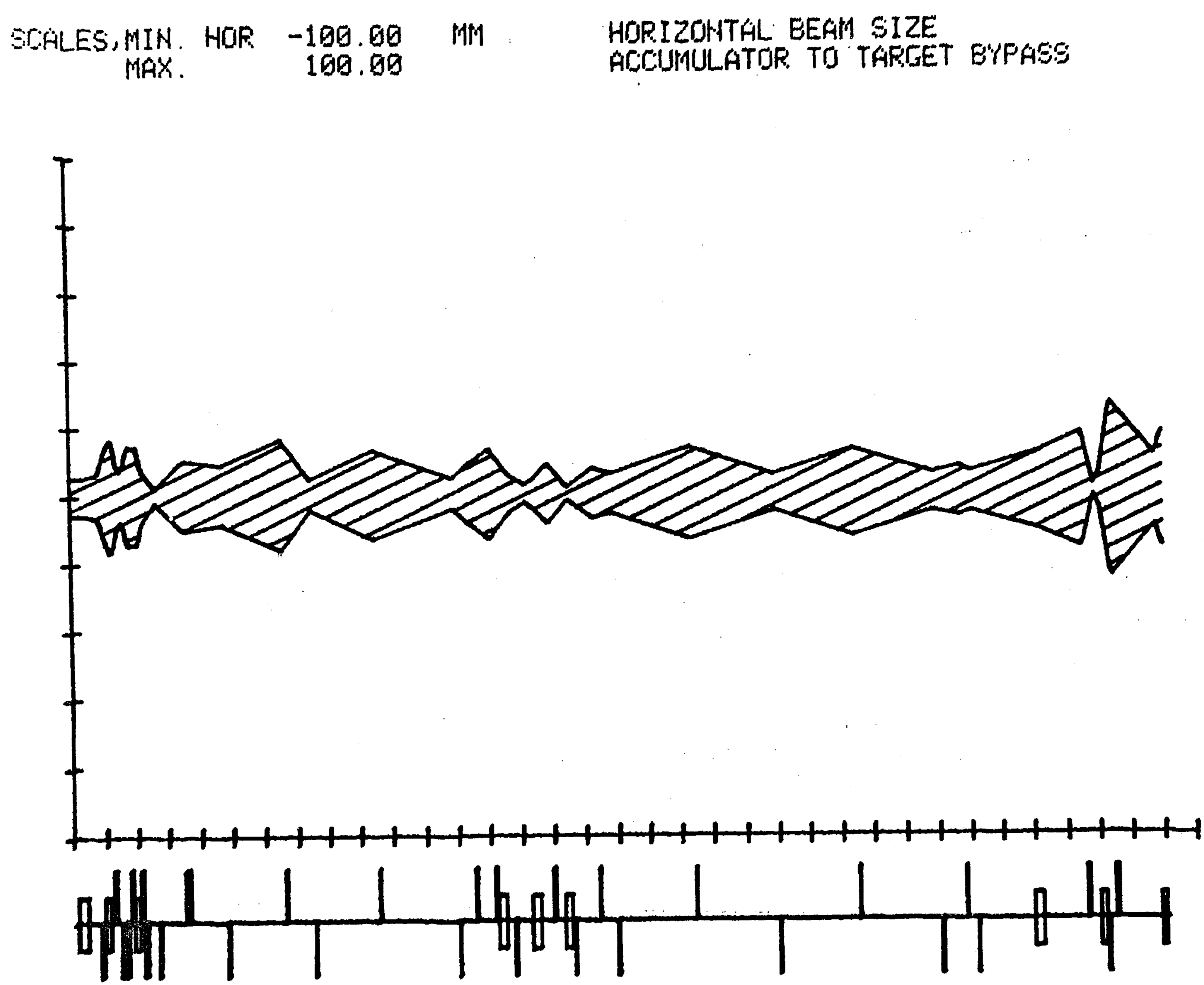

SCALES,MIN. HOR -100.00 MM
MAX. 100.00
HORIZONTAL BEAM SIZE
ACCUMULATOR TO TARGET BYPASS

Figure 11-9a

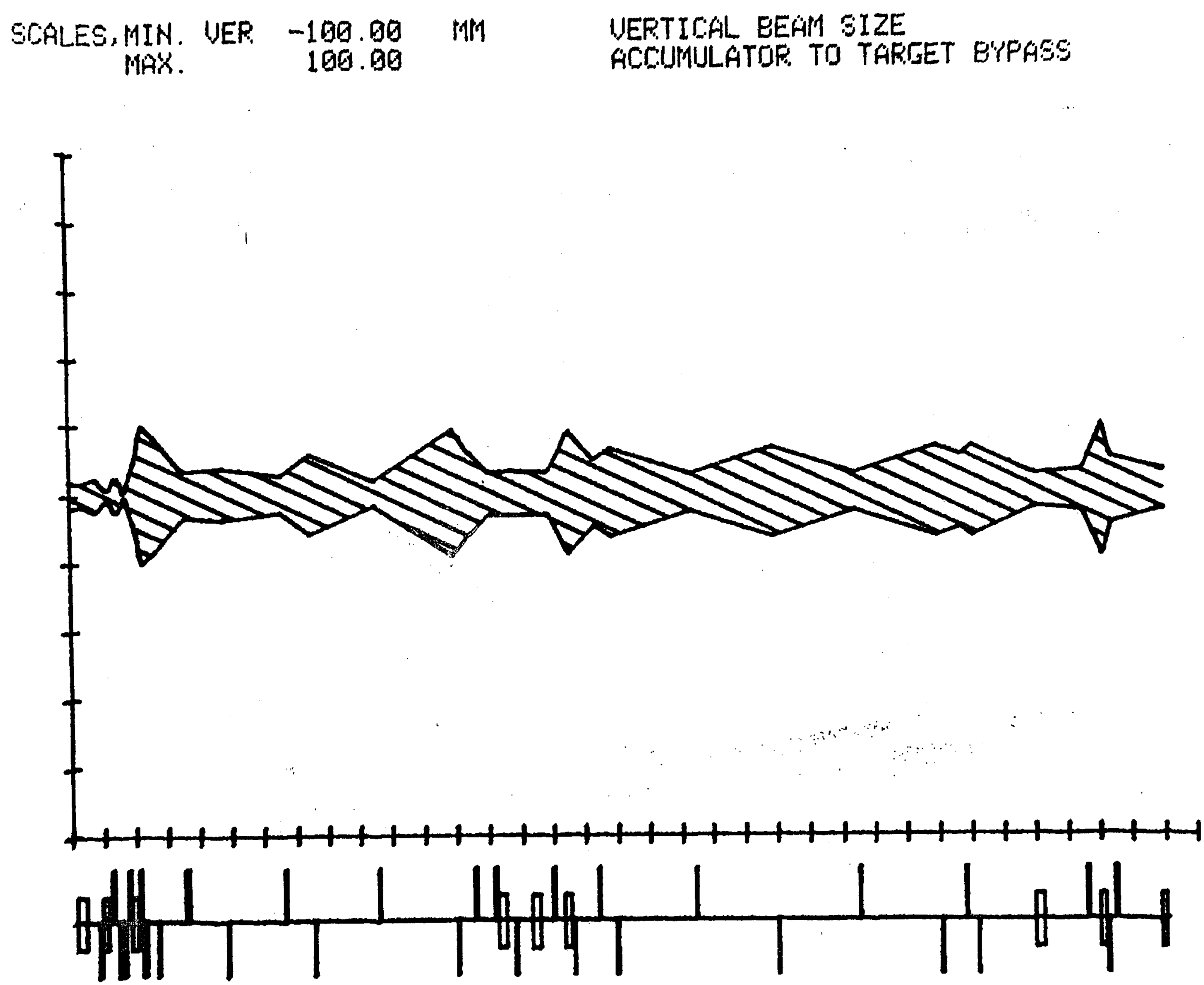

SCALES,MIN. VER -100.00 MM
MAX. 100.00
VERTICAL BEAM SIZE
ACCUMULATOR TO TARGET BYPASS

Figure 11-9b

DEVICE	X(FEET)	Y(FEET)	ELEVATION(FEET)
EQ20	279.6268	-1826.2518	732.5000
EQ21	346.6145	-1875.8761	732.5000
EQ22	413.6021	-1925.5003	732.5000
EQ23	480.5898	-1975.1246	732.5000
EQ24	500.7278	-1990.0427	732.5000
EQ25	510.0000	-1996.9116	732.5000
EB4	560.4502	-2034.2850	732.5000
EQ26	597.1626	-2067.9670	732.5000
EB5	607.9111	-2077.8283	732.5000
EQ27	612.0593	-2082.2827	732.5000
EQ28	617.3697	-2087.9850	732.5000
EB6	650.1344	-2123.1679	732.5000
PQ7B	657.4153	-2129.8478	732.5000
PQ7A	665.5208	-2137.2843	732.5000
PQ6B	679.0300	-2149.6784	732.5000
PQ6A	687.1355	-2157.1149	732.5000

15.09.55.UCLP, GG, TB10, 0.113KLNS. ** END OF LISTING **

11.5 Booster Test Beam Line (Line AP-4)

This section describes the beam line connecting the Booster to the Debuncher Ring. The 8-GeV kinetic energy beam is extracted vertically from the Booster with a kicker and a pulsed septum at Booster long straight 3. At 1.5 ft above the Booster beam height, the extracted beam is bent down by 10 mrad to level, taken out of the Booster enclosure and focused down to a 6 mm spot on a Be target. With a set of vertical dipoles, the targeting angle is varied from 10 mrad to 50 mrad down. The target is followed by a dump and collimator set at a level that collects secondary 8-GeV protons. The variable targeting angle allows the intensity of the secondary to vary from 10^7 to 10^{11} per Booster batch. The beam is bent up and transported to the Debuncher at the same elevation as the other beam lines. Finally, the beam is bent down and injected vertically into the Debuncher with a Lambertson magnet at station D23 in a manner similar to the antiproton injection line.

Lattice functions for this line are shown in Figs. 11-9 and 11-10 and the line is described in Table 11-VI.

TABLE 11-VI XYZ COORDINATES OF BOOSTER TO DEBUNCHER LINE

(Coordinates given at end of element (toward Debuncher) Main Ring Station A0 at X=0.0, Y=0.0)

NAME	LENGTH (IN)	FIELD (KG-KG/M)	X (FT)	Y (FT)	Z (FT)
BOOSTER LONG STRAIGHT 3			-488.791	-689.897	726.500
B-SEPTUM	84.00	7.28	-485.293	-695.956	726.683
BQ1	32.60	-142.28	-474.283	-715.026	727.836

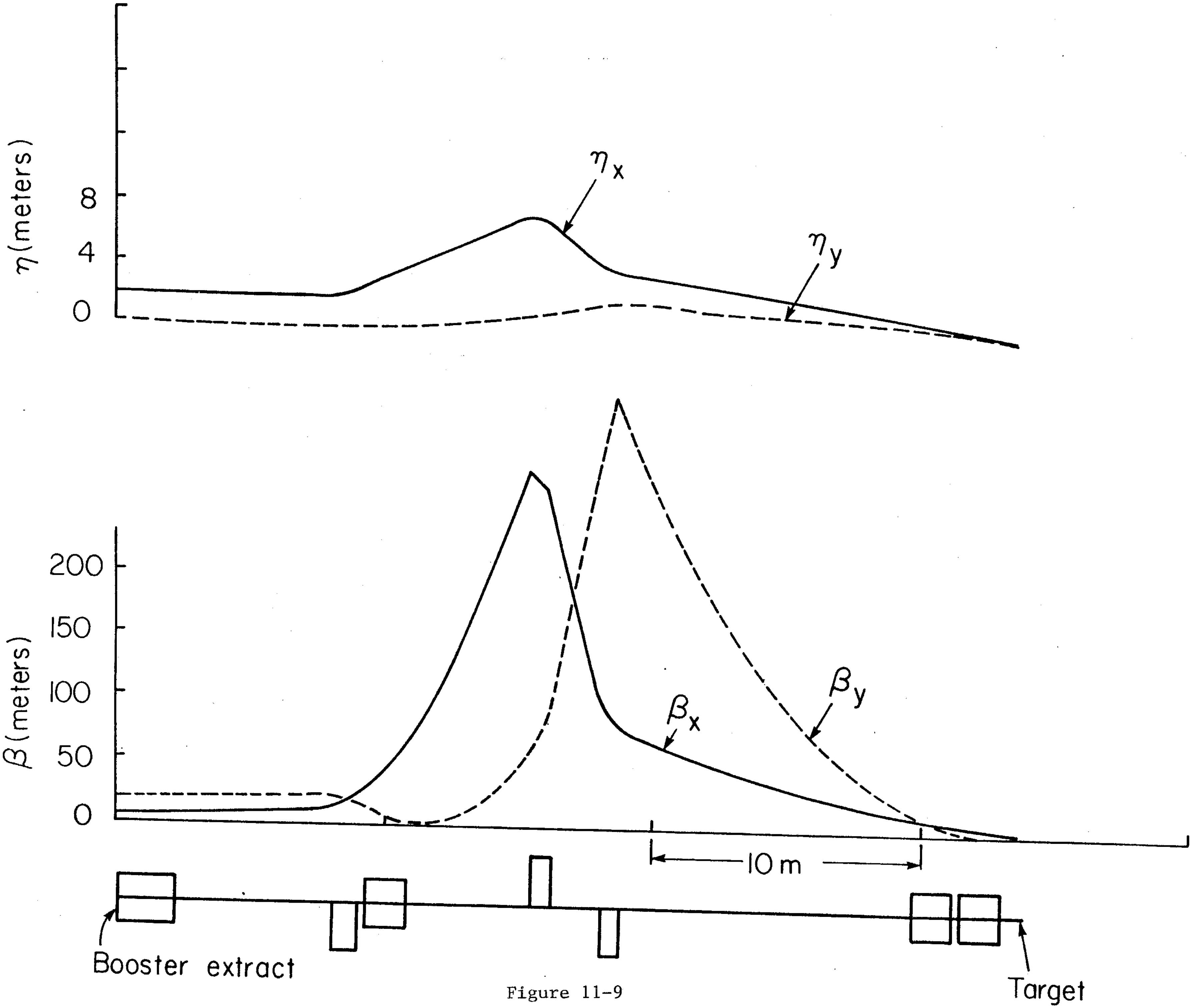

η(meters)
8
4
0
η_x
η_y
β(meters)
200
150
100
50
0
β_x
β_y
10 m
Booster extract
Target

Figure 11-9

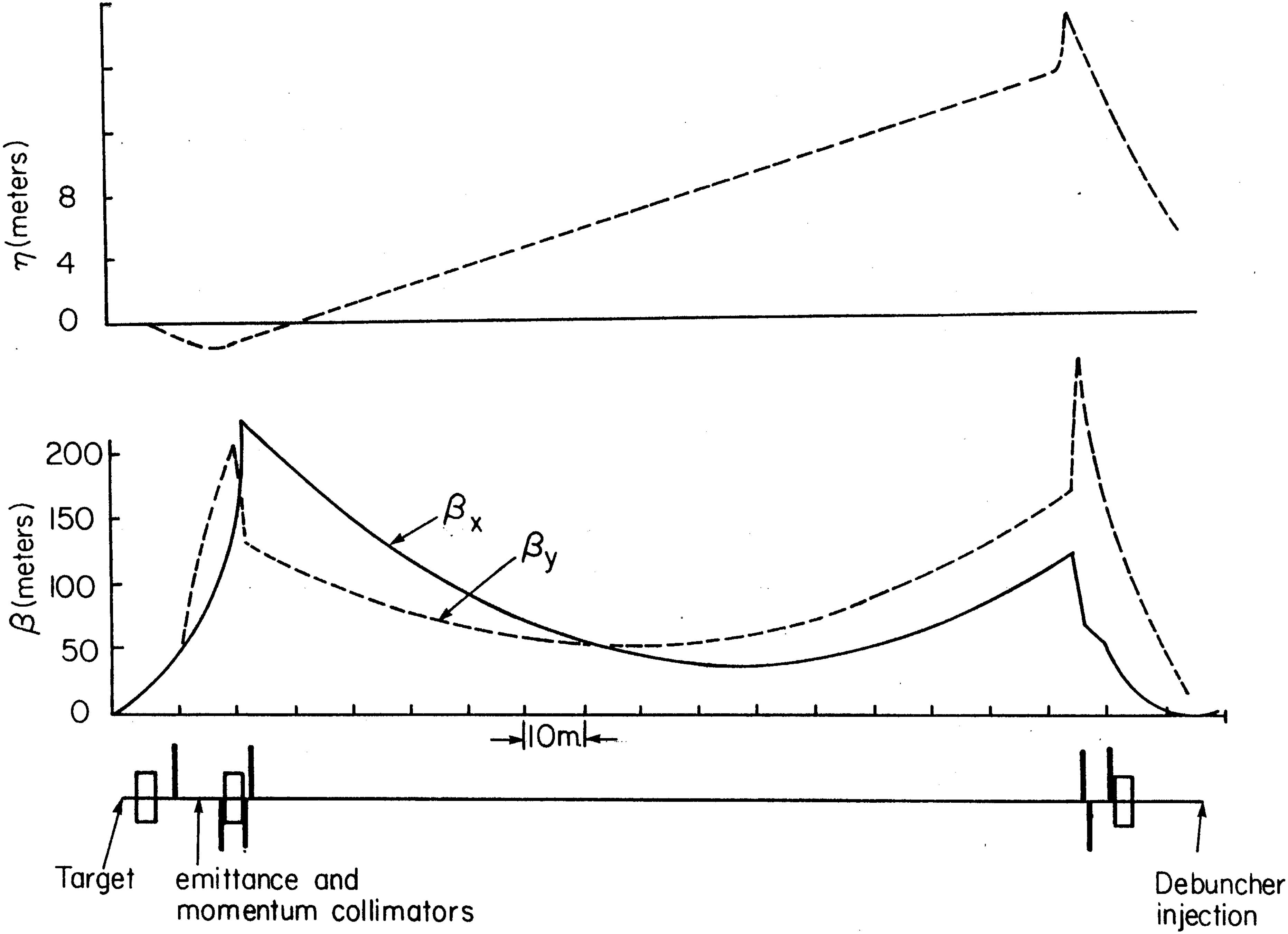

η (meters)
8
4
0
β (meters)
200
150
100
50
0
β_x
β_y
10m
Target
emittance and
momentum collimators
Debuncher
injection

Figure 11-10

BB1	60.00	-12.14	-471.284	-720.220	728.000
BQ2	25.20	142.28	-462.365	-735.669	727.818
BQ3	25.20	-142.28	-458.148	-742.972	727.734
BB2	60.00	10.00	-437.700	-778.389	727.326
BB3	60.00	-10.00	-434.784	-783.440	727.267
TARGET			-433.534	-785.605	727.242
COLLIMATOR					
BEND UP .573 DEG; BEND LEFT .363 DEG.					
DUMP					
BB4	120.00	10.49	-411.872	-822.582	727.781
BQ4	18.00	25.84	-405.669	-833.169	729.110
BQ5	18.00	-20.53	-392.859	-855.035	731.854
BB5	120.00	-10.49	-387.312	-864.504	732.500
BQ6	18.00	-152.02	-386.048	-866.661	732.500
BQ7	18.00	154.12	-384.279	-869.681	732.500
BEAM PIPE					
BQ8	27.60	118.61	-146.351	-1275.813	732.500
BQ9	27.60	-129.92	-144.683	-1278.660	732.500
BQ10	18.00	24.91	-139.302	-1287.844	732.500
BB6	120.00	-6.31	-133.075	-1298.473	732.176
MID D2Q5		90.60	-107.183	-1342.670	728.847
DEBUNCHER RING					728.500

11.6 Beam-Line Vacuum Systems

The vacuum in the 5 beam lines is required to be comparable in quality to that of the Debuncher (1×10^{-8}). It is planned to use SEM grid profile monitors in the beam lines. There are 3 lines that connect directly with the Accumulator ring: AP-4, D to A, and AP-3. The first two lines have thin windows to isolate their vacuum system from the Accumulator vacuum system. The AP-3 line uses differential pumping to isolate the Accumulator vacuum from the almost 1000 times worse vacuum in the Main Ring.