national accelerator laboratory

TM-556
9000

FERMILAB MEDICAL FACILITY: BEAM TRANSPORT LINE

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A design for the beam transport line for the linac medical facility is presented. This design has been calculated using MAGIC[1] for a 66-MeV proton beam extracted between tanks 4 and 5 of the linac using two bending dipoles and seven quadrupoles. The original design criteria were to have an achromatic bend and to have the spot size at the target be as small as possible. One consideration was that the quadrupole gradients are limited to 160-170 kG/m. It was found impossible to make the entire line dispersionless with these quadrupoles and still remain within the beam pipe. The beam line was therefore designed to have zero dispersion at the target. The spot size at the target, 6 mm in both planes, was as small as possible consistent with the limits on the quadrupole gradients, and also with the available number of power supplies.

These calculations were done assuming a matched 18π mm-mrad emittance at the end of linac tank 4. Effects of dispersion and momentum shift in the linac, as well as quadrupole fluctuations have been examined and found to cause no disastrous dilution of the beam.

Reference

1. M.J. Lee, W.W. Lee and L.C. Teng, "Magnet Insertion Code (MAGIC)", 1973 PEP Summer Study

Name	Length (in)	Field(kG) gradient (kG/m)	Betatron Size ε = 18 π mm-mr				Dispersion Size $\Delta p/p$ = 0.4%	
			x-in(mm)	x-out(mm)	y-in(mm)	y-out(mm)	x-in(mm)	x-out(mm)
Drift	4.5							
B1	24.012	19.847	9.577	11.898	12.735	4.911	0.0	1.134
Drift	10.0							
Q1	6.0	113.5	13.396	12.880	4.241	6.477	2.262	2.669
Drift	13.0							
Q2	6.0	-83.6	8.833	7.880	13.957	16.317	2.934	3.301
Drift	1.0							
B2	15.567	16.870	7.853	8.258	16.500	16.804	3.405	5.367
Drift	25.5							
Q3	6.0	74.6	11.650	11.866	13.329	13.585	9.497	9.765
Drift	28.0							
Q4	6.0	-61.4	9.982	10.487	19.780	19.971	7.695	7.707
Drift	19.5							
Q5	6.0	85.6	14.693	14.848	16.811	17.279	9.224	8.922
Drift	15.5							
Q6	6.0	-159.0	12.219	13.195	22.214	20.703	6.171	6.030
Drift	10.5							
Q7	6.0	159.0	18.407	18.492	12.213	9.130	7.384	7.007
Drift	27.846							
Target			6.000	6.000			0.0	

LEAST SQUARE F= 0.1496719E-12

	ITEM	IVAR	CHAR. VALUE	LENGTH
	DRFT 0	0	0.1143000E+00	0.1143
B1	QUAD 2	0	-0.9223460E+00	0.0000
B1	BEND 1	0	0.1661676E+01	0.6099
B1	QUAD 2	0	-0.9223460E+00	0.0000
	DRFT 0	0	0.2540000E+00	0.2540
	QUAD 2	0	0.9505610E+01	0.1524
	DRFT 0	0	0.3302000E+00	0.3302
	QUAD 2	0	-0.7000000E+01	0.1524
	DRFT 0	0	0.2540000E-01	0.0254
B2	QUAD 2	0	-0.4050070E+00	0.0000
B2	BEND 1	0	0.1412431E+01	0.3954
B2	QUAD 2	0	-0.4050070E+00	0.0000
	DRFT 0	0	0.6477000E+00	0.6477
	QUAD 2	1	0.6250586E+01	0.1524
	DRFT 0	0	0.7112000E+00	0.7112
	QUAD 2	1	-0.5141899E+01	0.1524
	DRFT 0	0	0.4953000E+00	0.4953
	QUAD 2	1	0.7168375E+01	0.1524
	DRFT 0	0	0.3937000E+00	0.3937
	QUAD 2	1	-0.1331269E+02	0.1524
	DRFT 0	0	0.2667000E+00	0.2667
	QUAD 2	1	0.1331269E+02	0.1524
	DRFT 0	0	0.7073000E+00	0.7073

TOTAL LENGTH= 6.0179 TOTAL ITEMS= 23

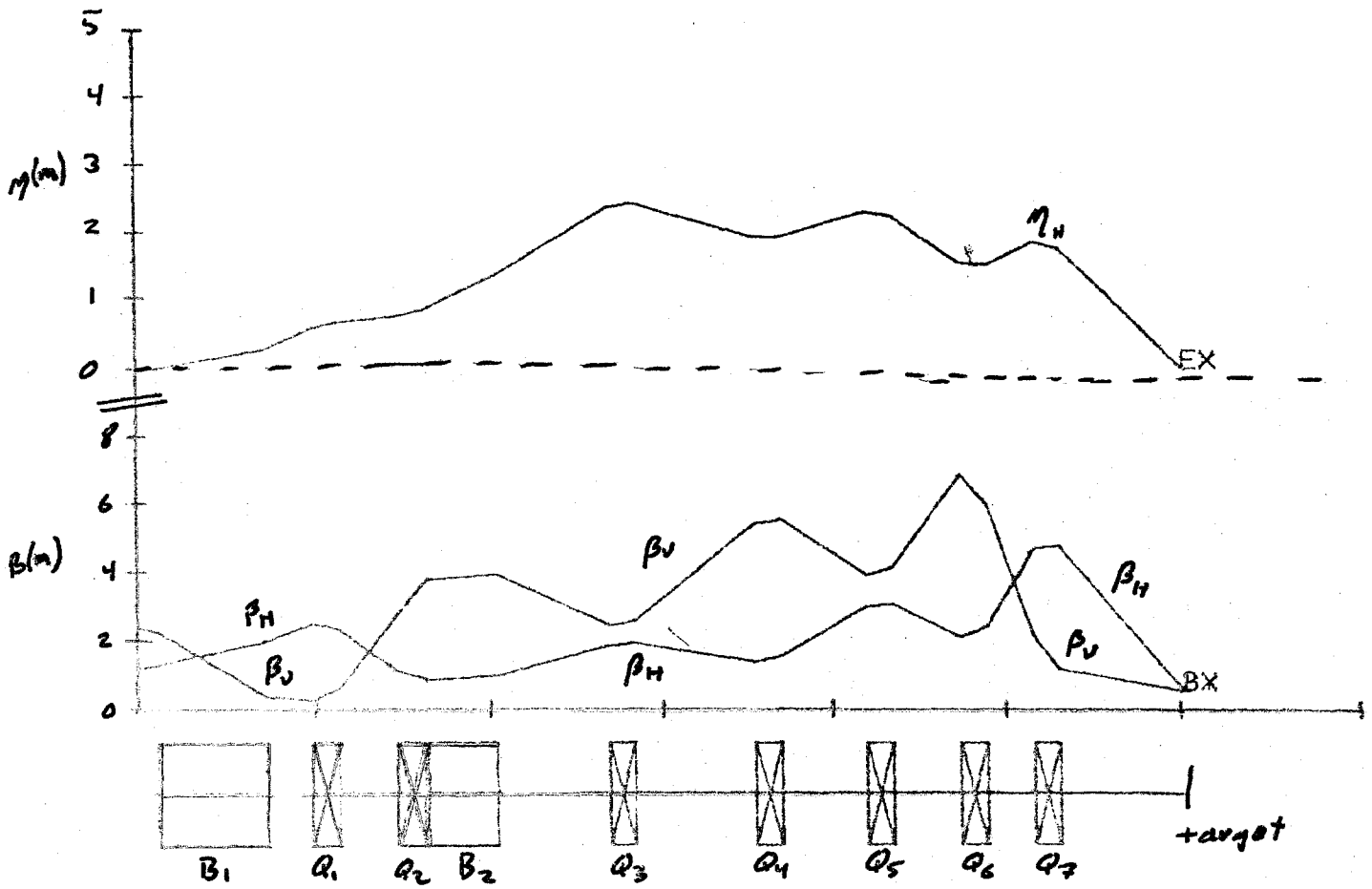
MATRIX ELEMENTS

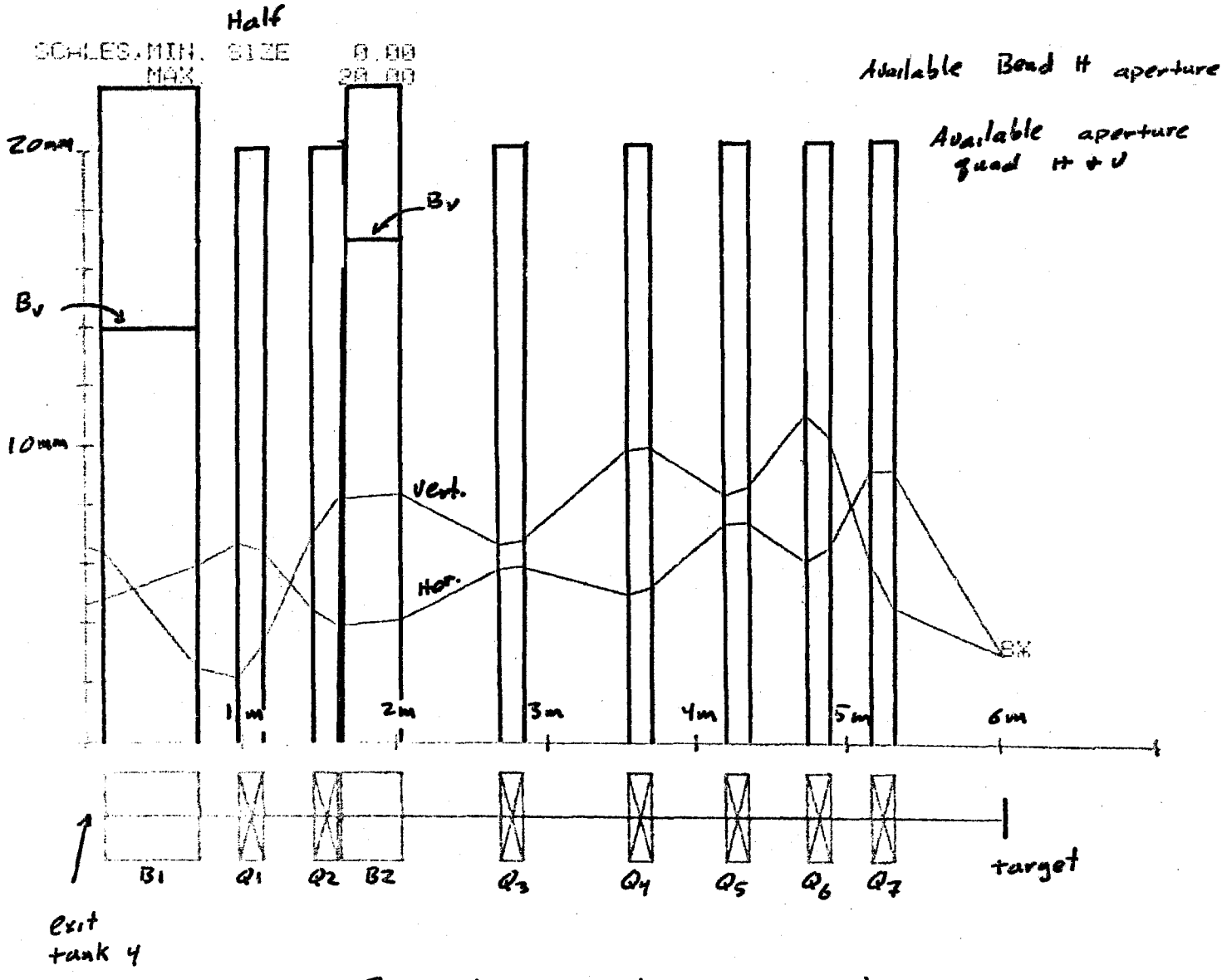
X11	X12	X13	-0.4543141E+00	-0.3853971E+00	-0.1043081E-06
X21	X22	X23	0.2139618E+01	-0.3860713E+00	-0.2476810E+01
Y11	Y12	Y13	-0.2382048E+00	-0.1083859E+01	0.0000000E+00
Y21	Y22	Y23	0.8432187E+00	-0.3613254E+00	0.0000000E+00

	ITEM	BETA	ALPHA	ETA	ETAP	PSI	
	BEGN	1.1858000	-0.3318260	0.0000000	0.0000000	0.0000000	X
		2.3980500	0.6707780	0.0000000	0.0000000	0.0000000	Y
	DRFT	1.2738860	-0.4388301	0.0000000	0.0000000	5.3361233	X
		2.2526094	0.6016683	0.0000000	0.0000000	2.8188502	Y
	QUAD	1.2738860	-1.6137937	0.0000000	0.0000000	5.3361233	X
		2.2526094	2.6793535	0.0000000	0.0000000	2.8188502	Y
B1	BEND	1.9663221	0.8966791	0.2834904	0.8486650	24.1623380	X
		0.3349383	0.4648849	0.0000000	0.0000000	47.4190431	Y
	QUAD	1.9663221	-0.9169502	0.2834904	1.1101413	24.1623380	X
		0.3349383	0.7738140	0.0000000	0.0000000	47.4190431	Y
	DRFT	2.4925303	-1.1547356	0.5654663	1.1101413	30.7505298	X
		0.2498002	-0.4386247	0.0000000	0.0000000	108.8356920	Y
	QUAD	2.3041545	2.2934656	0.6672145	0.2004789	34.2637410	X
		0.5826555	-1.9038786	0.0000000	0.0000000	133.3128510	Y
	DRFT	1.0835553	1.3980798	0.7334126	0.2004789	46.3260717	X
		2.7054048	-4.5247990	0.0000000	0.0000000	148.5609700	Y
	QUAD	0.8624681	0.1304026	0.8252316	1.0227760	55.6464262	X
		3.6979222	-1.6309574	0.0000000	0.0000000	151.2484150	Y
	DRFT	0.8566044	0.1004514	0.8511593	1.0227760	57.3398199	X
		3.7814133	-1.6560971	0.0000000	0.0000000	151.6375980	Y
	QUAD	0.8566044	-0.2464794	0.8511593	1.3655015	57.3398199	X
		3.7814133	-0.1245982	0.0000000	0.0000000	151.6375980	Y
B2	BEND	0.9472138	0.0416556	1.3416956	1.0528862	81.9531708	X
		3.9219321	-0.2307856	0.0000000	0.0000000	157.5307580	Y

QUAD	0.9472138	-0.3419727	1.3416956	1.5942823	81.9531708	X
	3.9219321	1.3576243	0.0000000	0.0000000	157.5307580	Y
DRFT	1.8848935	-1.1057342	2.3743123	1.5942823	110.9484350	X
	2.4673867	0.8880843	0.0000000	0.0000000	169.5483360	Y
QUAD	1.9556739	0.6639915	2.4411746	-0.7274646	115.3915940	X
	2.5632723	-1.5474090	0.0000000	0.0000000	173.1073420	Y
DRFT	1.3838755	0.1399996	1.9238018	-0.7274646	141.0058250	X
	5.4341316	-2.4892327	0.0000000	0.0000000	184.0927470	Y
QUAD	1.5274817	-1.1195136	1.9267386	0.7663886	147.1436160	X
	5.5398800	1.8231908	0.0000000	0.0000000	185.6528990	Y
DRFT	2.9983661	-1.8501702	2.3063309	0.7663886	160.5254670	X
	3.9253077	1.4365959	0.0000000	0.0000000	191.7500080	Y
QUAD	3.0620545	1.4557216	2.2305718	-1.7467698	163.3290500	X
	4.1469564	-2.9708162	0.0000000	0.0000000	193.9753670	Y
DRFT	2.0737079	1.0546838	1.5428686	-1.7467698	172.3176210	X
	6.8534315	-3.9036443	0.0000000	0.0000000	198.2104780	Y
QUAD	2.4180094	-3.5420632	1.5074638	1.2702292	176.4246810	X
	5.9528488	9.1909931	0.0000000	0.0000000	199.5082910	Y
DRFT	4.7058253	-5.0361743	1.8462339	1.2702292	180.9594190	X
	2.0716817	5.3615644	0.0000000	0.0000000	203.8638120	Y
QUAD	4.7495682	4.7793583	1.7518478	-2.4768102	182.7129560	X
	1.1578296	1.2404893	0.0000000	0.0000000	209.8075160	Y
DRFT	0.5000001	1.2287967	-0.0000001	-2.4768102	210.0341090	X
	0.5000003	-0.3104324	0.0000000	0.0000000	278.1801030	Y

SCALES MIN BETA 0.00 ETA -5.00
MAX 20.00 5.00





Beam ½ size, (ϵ = 18π mm-mr)