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A TEVATRON PROTON TRANSPORT FOR THE NEUTRINO AREA

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The dichromatic neutrino beam will be twice as long at Tevatron energies and will not fit into the neutrino target tube.[1] An easy way to accommodate this new beam is to build a new targeting area upstream of neuhall, where soil radioactivity will not overly hinder construction. This report describes a proton transport system for this new targeting area as well as the transport for the horn and triplet beams that will be housed in the old target tube. Also described in this report is a transport system to a new hadron area that will be used for calibration beams and beam dump experiments in the Tevatron era.

An overview of the modified neutrino area is given in Figure 1. The crosshatched area in G2 and the area between G3 and Neuhall are the extensions to the existing enclosures anticipated for the Tevatron era. The G2 extension was originally proposed to house a major bend for the new muon beam which is not shown in the figure. This same extension, however, will also house a set of switching magnets that will switch the proton beams between the neutrino targeting stations and the transport system to the new hadron area. The new targeting station is shown in the G3 extension; The area upstream of the target will house the targeting magnets for the dichromatic beam; The area downstream of the target and into Neuhall will house the dichromatic beam. A targeting station is also shown in the target tube that will house horn and triplet beams in about the same way that it now does at 400 GeV.

The specifications for the new targeting area are given by a set of spacial coordinates, constraining the beam's postion and orientation at several points in the Neutrino Area. Such coordinates are listed in Table I for the Doubler energy neutrino beams, and for a proton transport to an additional targeting area for a new set of hadron beams. The targeting coordinates for the neutrino beams are determined by the requirement that the final neutrino beam be centered in the decay pipe. The beam transport to the hadron areas must not interfere with beam elements in the neutrino lines - and is displaced far to the east to avoid any interference. The bend points in enclosure G2 are chosen to match with the existing Switchyard transport system into the neutrino area.

The constraints given in Table I determine a unique set of beam trajectories between enclosure G2 and the new target area, and these are shown graphically in Figure 2. Operationally, only one of the neutrino beams will run at any one time, and a change between horn, dichromatic and triplet trains would be made between these running periods. The hadron transport line, however, would share the beam with the neutrino line: The bends in enclosure G2 would switch the slow or fast spill into the neutrino or hadron transport line with a switching time of .5 sec at 1 TeV and .2 sec at 400 GeV.

The hadron transport system in further constrained to lie outside of the existing target tube, to pass outside of the expansion port, and to pass within enclosure 100 (to locate magnets within this existing enclosure).

The coordinates of the beam at there locations are given in Table II. The beam line is shown graphically in Figure 1 and satifies all of the constraints specified in Table II.

The physical location of beam elements in a Neutrino area coordinates system is given in Table III, IV and V for the transport to the new hadron area, the dichromatic beam and the target tube respectively. The corresponding beam optics are given in Figure 3, 4 and 5. The optics were designed to match into the existing proton transport at G2, to allow the beam to fit within the apertures of the beam magnets and to form a small spot at the targets. Also, beam elements that must be intercharged to accommodate a change between horn, dichromatic or triplet trains will be located on bedplates and can be moved with the Neuhall transport and rail system. All of the elements in the transport to the hadron area, however, are fixed and will be mounted on permanent stands.

In this design a special problem arose with regard to the orientation of the switching magnets in G2. The transport to the dichromatic beam requires substantial vertical and horizontal bends in this enclosure. Also, the transport to the hadron area requires a large horizontal bend. A string of bending magnets that would meet these requirements would have to have a 3" gap between pole tips. However, magnets of such size tend to have a high inductance and are not suitable as fast switching magnets. In addition, their transverse size would make it impossible to fit them into the enclosure: EPB dipoles are the only magnets that will fit into the space above muon beam bending magnets.

To solve this problem, we rotated the dipoles so that the three downstream bends (HG2) lie in the plane defined by the two beam lines - the transport to the dichromatic beam and the transport to the hadron area. HG2 is then used to switch the proton beam between the two beam lines. The two upstream bends (VG2) are not used as switching magnets, but lie perpendicular to the switching plane, and bend the beam into this plane.

This solution is illustrated in Figure 6 for a coordinate system defined by the vertical and horizontal bending angles y' and x'. The transport to the dichromatic beam requires bends of 2.78 mrad vertically and 1.77 mrad horizontally. The transport to the new hadron area requires a 4.16 mrad bend horizontally. By rotating the dipoles through 25.07^{o} we transform these bends into a 1.76 mrad bend by VG2 and a switch by HG2 between 2.78 mrad and 3.77 mrad. Because, in this configuration only HG2 is used to do the switching, the beams fit within the 1.5" gap of the EPB dipoles. This problem does not arise when we transport beam to the target tube, because no ends are required in G2 for this transport system. HG2 then only switches the beam by 4.16 mrad to go to hadron area, and zero mrad to go to the target tube.

The designs given in this report constitute another pass toward a Tevatron transport system.[2] It is used mainly to demonstrate the feasibility of the new targeting area in conjunction with the new hadron transport system. It also serves the function of helping to determine the size of the new enclosures, and the means of moving magnets within them. The ultimate transport system that might be used in the Tevatron era might well use superconducting magnets or magnets of a different design. In the extreme, physics perogatives might change so that a different set of beams might be required. However, this report demonstrates the eminent feasibility of the upstream targeting station and the switching station in enclosure G2.

References:

1. TM 841, L. Stutte

2. TM 729, J.A. Appel and J.C. McCarthy
TM796, R. Evans and T. Kirk

TABLE I

Coordinate Specification
for
Proton Transport to Nu-Hall

	Z	X	Y	X'	Y'
Doublet Dichromatic(TM841)	3018.75'	0.83'	744.81'	6.42mr	5.77mr
Target Tube Focus		-.67	745	0	0
Hadron Beam	3000	<-3.	NS	NS	NS
SY Transport in G2	2291.5	-0.562	736.215	0.11	10.084

TABLE II

Coordinate Specification
for
Transport to New Hadron Area

	Z	X	Y	X'	Y'
Neutrino Targetting Area	3000	<-3.	NS	NS	NS
Nu-Hall	3304	NS	745	NS	0
Nu-Hall	3445	-5.25	745	NS	0
Enclosure 100	4850	12.333	745	NS	0

All coordinates are given in Neutrino Lab system.
NS refers to coordinates not specified.

TABLE III

Beam Elements for Proton Transport to the New Hadron Area

Magnet Type	z (ft.)	x (ft.)	y (ft.)	B/G Kg/Kg/in	Name	φ rotation	Peak Power KW	I amp
3Q120	2227.5	-0.568	735.57	-4.4849	Q120-1*		12.1	95
3Q120	2238.5	-0.567	735.68	-4.4849	Q120-2*		12.1	95
3Q120	2269.5	-0.563	735.99	4.8812	Q121-1*		14.3	103.5
3Q120	2280.5	-0.562	736.10	4.8812	Q121-2*		14.3	103.5
5-1.5-120	2291.5	-0.561	736.22	Variable †	VG2-1*	Variable	32.9	~1370
5-15.-120	2302.5	-0.562	736.33	"	VG2-2*	"	32.9	~1370
5-1.5-120	2313.5	-0.567	736.46	"	HG2-1*	"	21.5	~1106
5-1.5-120	2324.5	-0.581	736.58	"	HG2-2*	"	21.5	~1106
5-1.5-120	2335.5	-0.607	736.70	"	HG2-3*	"	21.5	~1106
4-4-30	2346.5	-0.646	736.81	.9866	HTG2*			
4-4-30	2350.	-0.660	736.85	1.0455	VTG2-1*	90°		
4-4-30	2353.5	-0.675	736.88	1.0455	VTG2-2*	90°		
4-2-240	2868	-2.747	742.05	15.336	7VG3	90°	112.5	3970
4-2-240	3241.1	-4.250	744.78	13.329	7BN	81.8667	85	3451
4-2-420	3262.1	-4.338	744.90	13.329	7BN	81.8667	85	3451
4-2-240	3283.1	-4.434	744.98	13.329	7BN	81.8667	85	3451
3Q120	3315.1	-4.592	745.	5.240	7FN		16.5	111
3Q120	3395.1	-4.997	745.	-4.885	7DN		14.3	104
4-2-240					7W00-1		122	~4142
4-2-240					7W00-2		122	~4142
							Sum = 825 KW	

* These magnets are the same in Table III, IV, and V.

† The operating currents and the rotations of these magnets depends on whether the dichromatic, horn or triplet beam is operating the NØ line.

TABLE IV
BEAM ELEMENTS FOR PROTON TRANSPORT TO
DOUBLET DICHROMATIC BEAM

MAGNET TYPE	Z (ft)	X (ft)	Y (ft)	B/G Kg/Kg/in	NAME	Ø ROUTINE	PEAK POWER KW	I amp
3Q120	2227.5	-0.568	735.57	3.0188	Q120-1*		5.47	64
3Q120	2238.5	-0.567	735.68	3.0188	Q120-1*		5.47	64
3Q120	2269.5	-0.563	735.99	2.533	Q121-1*		3.85	54
3Q120	2280.5	-0.562	736.10	2.533	Q121-2*		3.85	54
5-1.5-120	2291.5	-0.561	736.22	9.6452	VG2-1*	-64.93°	14.54	911
5-1.5-120	2302.5	-0.562	736.33	9.6452	VG2-2*	-64.93°	14.54	911
5-1.5-120	2313.5	-0.567	736.46	10.1444	HG2-1*	-154.93°	16.08	959
5-1.5-120	2324.5	-0.569	736.58	10.1444	HG2-2*	-154.93°	16.08	959
5-1.5-120	2335.5	-0.562	736.72	10.1444	HG2-3*	-154.93°	16.08	959
4-4-30	2346.5	-0.545	736.86	1.3859	HTG2*			
4-4-30	2350	-0.539	736.91	1.2669	VTG2-1*	90°		
4-4-30	2353.5	-0.532	736.95	1.2669	VTG2-2*	90°		
3Q84	2866.1	.449	743.57	4.6264	FG3-1		51.2	3373
3Q84	2874.1	.464	743.68	4.6264	FG3-2		51.2	3373
3Q84	2882.1	.479	743.78	4.6264	FG3-3		51.2	3373
4-2-240	2890.1	.495	743.88	15.6429	VG3-1	90°	117	4050
4-2-240	2911.1	.535	744.12	15.6429	VG3-2	90°	117	4050
4-2-120	2932.1	.575	744.30	15.6429	VG3-3	90°	58.5	4050
3Q84	2943.1	.596	744.37	5.606	DG3-1		75.2	4087
3Q84	2951.1	.611	744.42	5.606	DG3-2		75.2	4087
3Q84	2959.1	.627	744.47	5.606	DG3-3		75.2	4087
3Q84	2967.1	.642	744.51	5.606	DG3-4		75.2	4087
3Q84	2975.1	.657	744.56	5.606	DG3-5		75.2	4087
4-2-120	2983.1	.673	744.60	16.441	HG3-1		64.7	4257
4-2-120	2994.1	.703	744.67	16.441	HG3-2		64.7	4257
4-2-120	3005.1	.749	744.73	16.441	HG3-3		64.7	4257
TARGET	3018.86	.83	744.81					

Sum = 1.11MW

* These magnets are the same in Table III, IV and V.

TABLE V

Beam Elements for Proton Transport to Target Tube

Magnet Type	z (ft.)	x (ft.)	y (ft.)	B/G Kg/Kg/in	Name	φ rotation	Peak Power KW	I amp
3Q120	2227.5	-0.568	735.57	-2.9317	Q120-1*		5.2	62
3Q120	2238.5	-0.567	735.68	-2.9317	Q120-2*		5.2	62
3Q120	2269.5	-0.563	735.99	2.3923	Q121-1*		3.5	51
3Q120	2280.5	-0.562	736.10	2.3923	Q121-2*		3.5	51
5-1.5-120	2324.5	-0.558	736.55	3.0618	HG2*			
3Q120	2978.7	-0.667	743.15	2.7704	FG3		4.6	59
5-1.5-120	2989.7	-0.669	743.26	1.8618	HG3		1.5	289
4-2-120	3125.9	-0.67	744.63	15.766	V140-1	90°	119	4082
4-2-240	3136.9	-0.67	744.73	15.766	V140-2	90°	119	4082
4-2-240	3157.9	-0.67	744.88	15.766	V140-3	90°	119	4082
4-2-240	3178.9	-0.67	744.97	15.766	V140-4	90°	119	4082
3Q120	3333.6	-0.67	745.	-5.0	DN-1		15	106
3Q120	3345.0	-0.67	745.	-5.0	DN-2		15	106
3Q120	3356.6	-0.67	745.	-5.0	DN-3		15	106
3Q120	3381.6	-0.67	745.	5.0	FN-1		15	106
3Q120	3393.1	-0.67	745.	5.0	FN-2		15	106
3Q120	3404.6	-0.67	745.	5.0	FN-3		15	106
target	3484.1	-0.67	745.					
						Sum =	590KW	

These magnets are the same in Table III, IV and V.

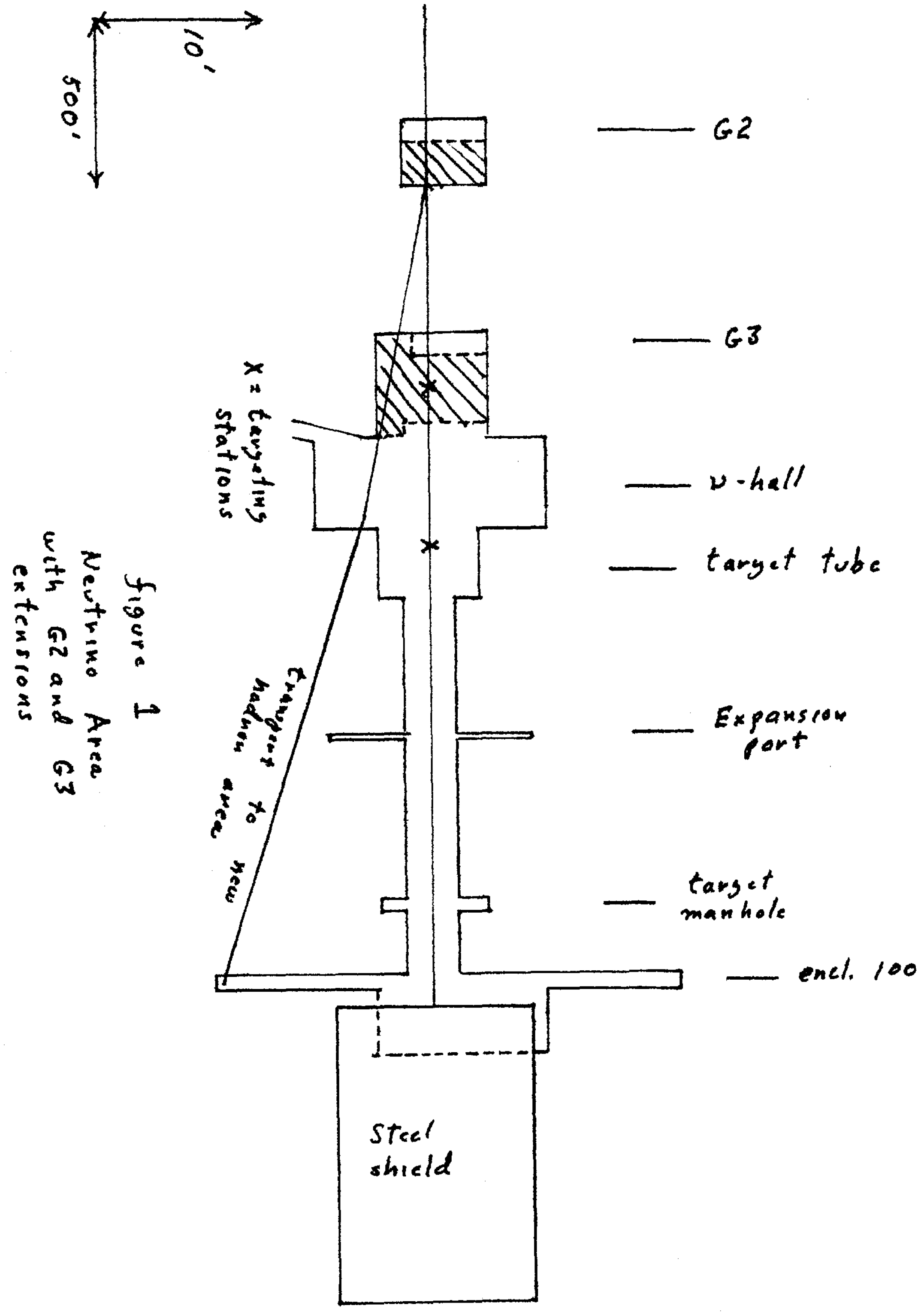

Figure 1
Neutrino Area with G2 and G3 extensions

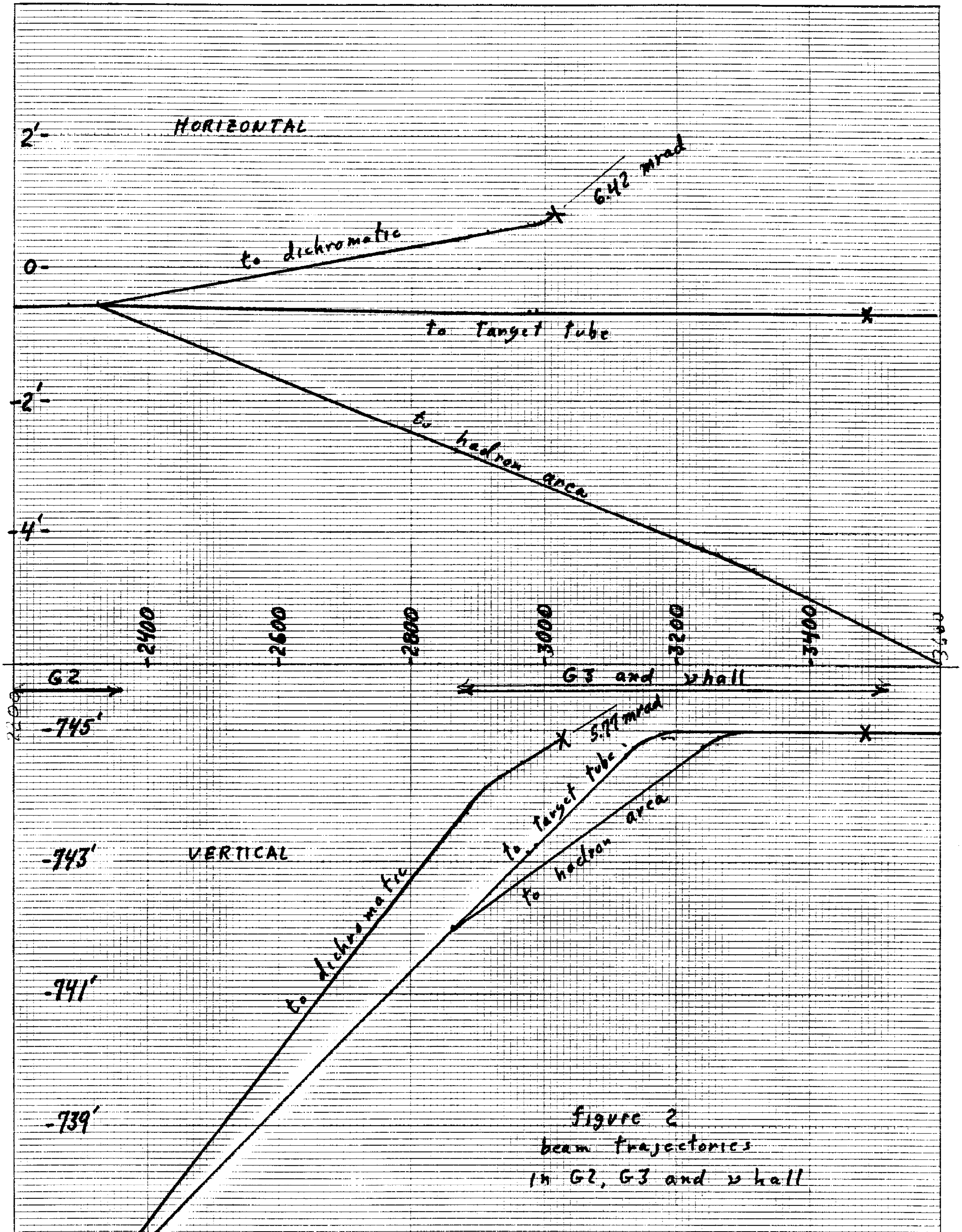

figure 2
beam trajectories
in G2, G3 and ν hall

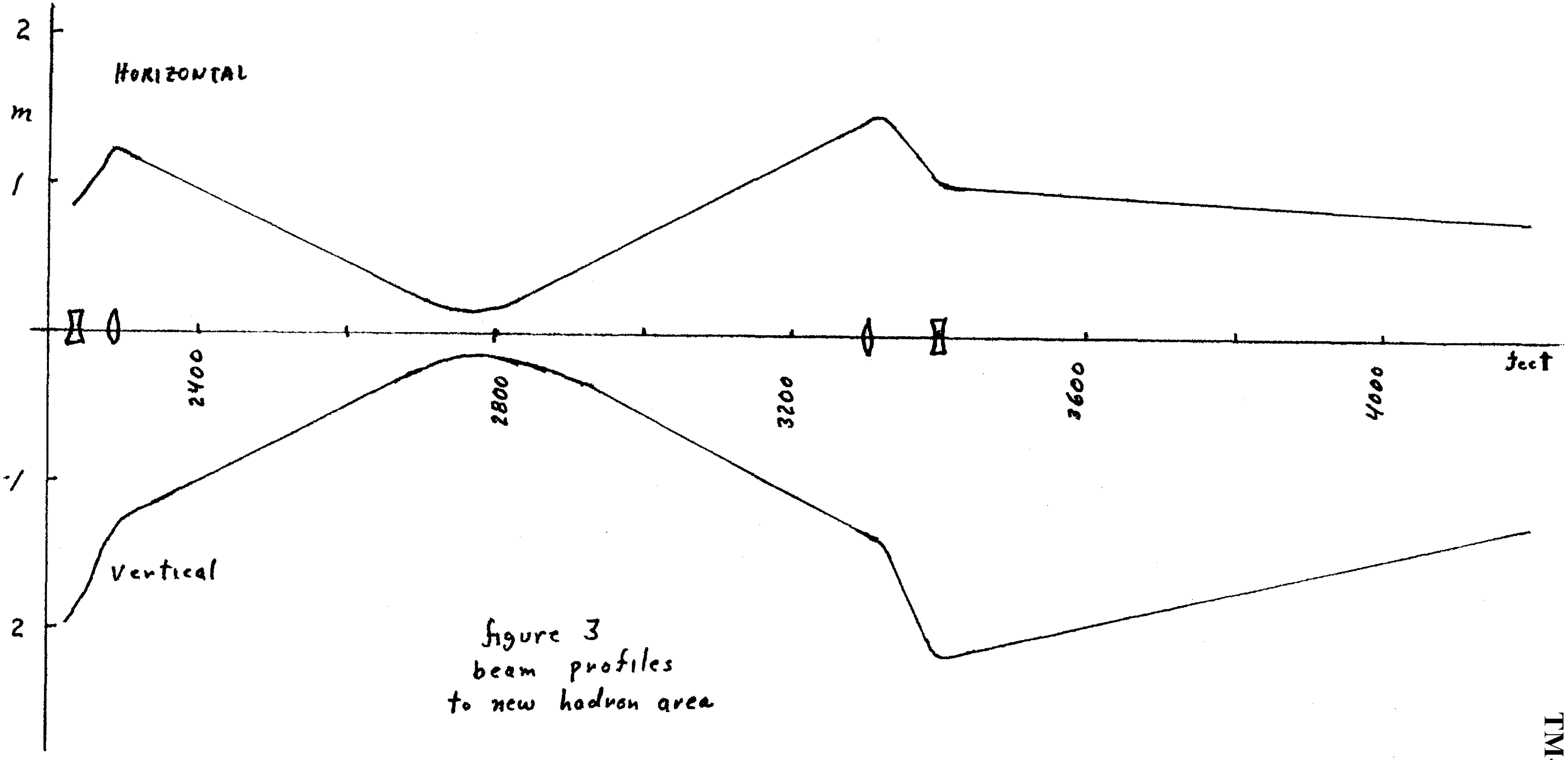

figure 3
beam profiles
to new hadron area

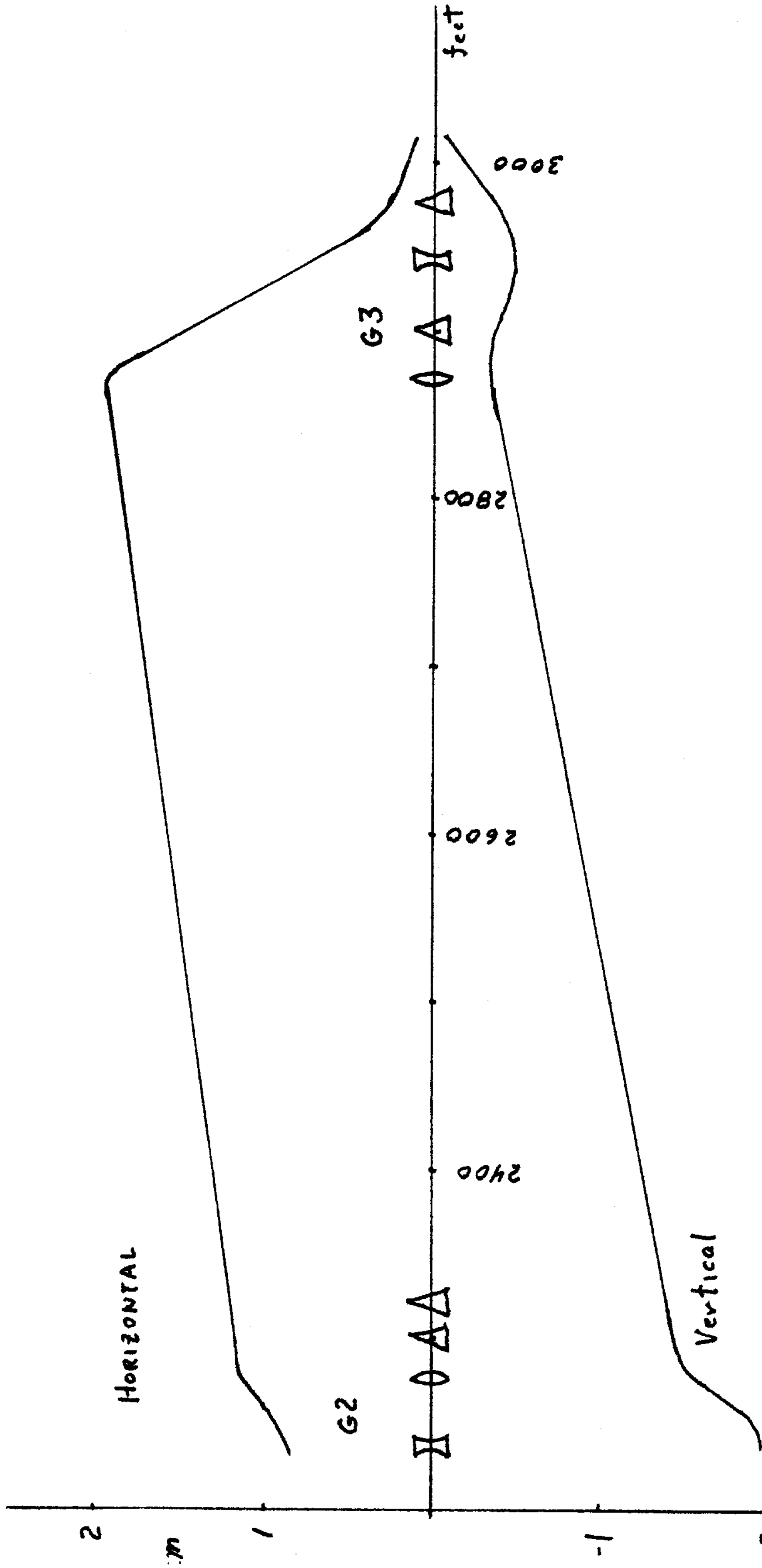

figure 4
beam profiles
to dichromatic train

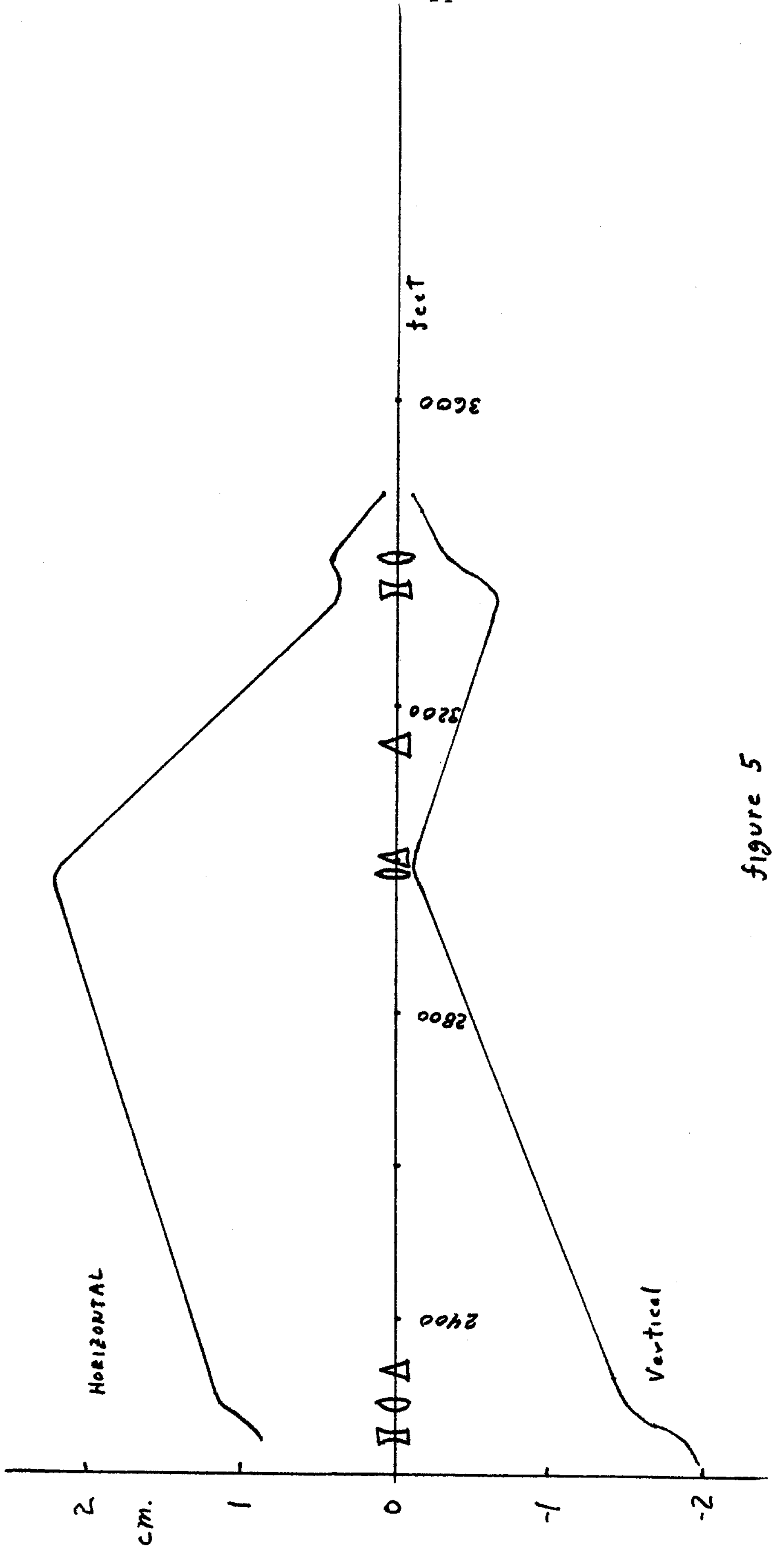

figure 5
beam profiles
to target tube

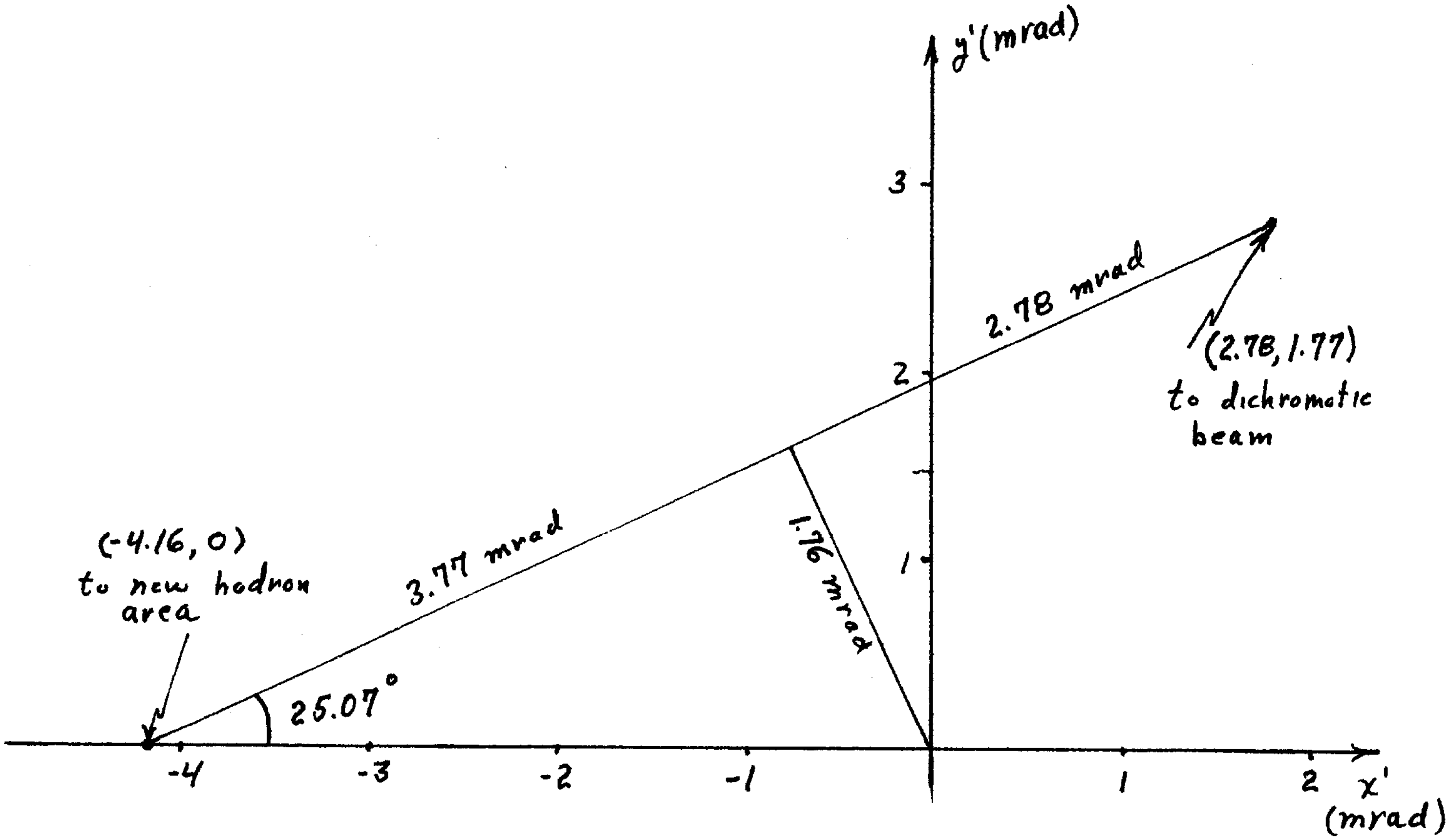

figure 6
G2 bend angles