4. BEAM DUMP / MUON SWEEPING

The Beam Dump System is made up of the Primary Beam Dump and its associated shielding, the Muon Sweeping System and the Radioactive Water (RAW) Cooling System.

4.1 Beam Dump System—Overview

4.1.1 System Function and Location

The Beam Dump System:

· stops the primary beam
· sweeps charged particles out of the neutral secondary channel
· sweeps muons away from the detector and personnel
· keeps muons below grade level, eliminating the issue of muons at the site boundary
· provides shielding to control residual radiation levels and
· provides ground water protection.

The components of the Beam Dump System are:

· Target Sweeping Magnet - NM2S1
· Primary Beam Dump - NM2BD
· E8/Hyperon Magnet - NM2S2
· Mu-Sweep II - NM2S3
· Target Pile Shielding
· Radioactive Water Cooling System—RAW water system

With the exception of steel to provide muon "ranging" buried between the NM2 and NM3 enclosures, the Beam Dump System is entirely in NM2.

The NM2 enclosure is made up of 3 principle sections: an upstream section which houses the components of the Primary Beam, a larger, "hall-like" section which houses the components of the Beam Dump System, and a downstream section which houses components of the Secondary Beam. The hall is referred to as the KTeV Target Hall. See Section 2 for a description of the Primary Beam and Section 5 for a description of the Secondary Beam. Plan and elevation views of the KTeV Target Hall and its associated components are found in Figures 4.1.1 and 4.1.2, respectively.

Not all beamline components in the KTeV Target Hall are addressed in this section. The target, the lead and beryllium absorbers, and the primary collimator are described in the section on the Secondary Beam.

4.1.2 Component Function and Location

Target Sweeping Magnet—NM2S1

The Target Sweeping Magnet is the first element following the target, and like the target, is located inside the steel shielding of the Target Pile. The label NM2S1 indicates that it is the first sweeping magnet in the NM2 enclosure. This magnet provides early horizontal sweeping and early absorption of charged secondaries.

NM2S1 also fulfills a limited radiation safety role as a fixed-hole or "shadow" collimator. The magnet steel geometrically shadows the aperture of the beam dump, eliminating any primary beam "line-of-sight" through the dump aperture. This is independent of beam displacement at the target.

Because NM2S1 sweeps horizontally, the desired vertical placement of the primary beam spot on the beam dump depends only on the vertical angle of the beam at the target. Therefore no current interlock is required for NM2S1.

Primary Beam Dump

The Primary Beam Dump is also in the Target Pile and is downstream of the Target Sweeping Magnet (see Figure 4.1.1). The beam dump stops the primary beam. Under normal operating conditions the primary beam interacts in the front face of the dump below the aperture . However under certain conditions it is possible for the beam to dump inside the aperture. This issue is addressed in Section 3.

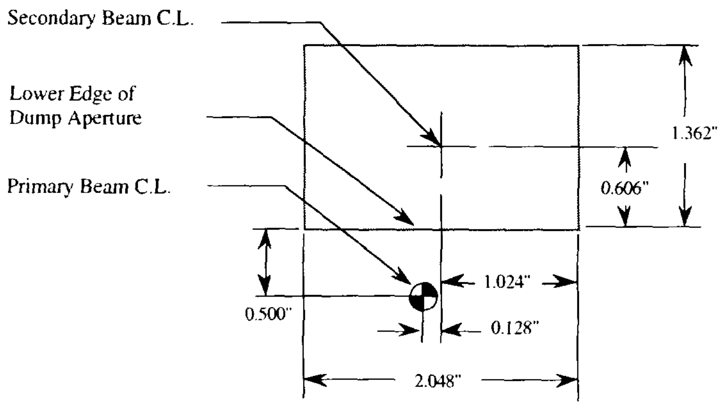

Figure 4.1.3
Primary Beam Position at Upstream Face of Primary Beam Dump
(Minimum incoming beam angle of -4 mradians is assumed for calculation.)
(Units are inches.)

E8/Hyperon Magnet—NM2S2

This magnet has been used elsewhere at Fermilab and is often referred to as the E8 Magnet or the Hyperon Magnet. Its correct designation for KTeV is NM2S2, indicating that it is the second sweeping magnet in the NM2 enclosure. NM2S2 is located immediately downstream of the Target Pile after the Primary Beam Dump.

NM2S2 separates prompt and decay muons from the target and dump into two muon "plumes" horizontally separated by sign. These plumes are directed to either side of the neutral centerline resulting in a lower muon rate at the detector. The complete Muon Sweeping System is described in Section 4.4.

In addition, because of the large cross-section of NM2S2, few muons see a magnetic field component that sweeps them above grade level. As a result, the muon plumes remain below grade and muon rates above grade and at the site boundary are well below limits (see Section 4.4.1).

NM2S2 is also part of the radiation safety system providing backup sweeping and bulk shielding should the primary beam be lost within the aperture of the beam dump.

Mu-Sweep II—NM2S3

Mu-Sweep II is the third and most downstream magnet in the Beam Dump System. During design the "II" identified it as the second conceptual design iteration of the magnet. The current, correct designation, NM2S3, identifies it as the third sweeping magnet in NM2. All three sweeping magnets in NM2 have the same sign magnetic field, sweeping positives to the west.

NM2S3 has two principle functions. First, it contributes to the horizontal separation of the muon plumes away from the detector. See Section 4.4 for expected muon rates. Secondly, it provides cleanup sweeping in the neutral channel due to its location downstream of the lead and beryllium absorbers and the primary collimator.

Target Pile Shielding

The Target, the Target Sweeping Magnet, and the Beam Dump must have sufficient radiation shielding to allow beam-off access into NM2 for routine maintenance, repairs or measurements after primary beam has been delivered to the area. Also sufficient shielding must be present to provide radiation protection for groundwater during beam-on operation.

The required radiation protection is provided by approximately 900 tons of steel shielding which surrounds the elements of the target pile. The radial thickness of the steel is set by satisfying the groundwater requirements (see Section 6.8.2). The resulting steel thickness more then satisfies the 100 mr/hr at 1 foot residual activity limit at any accessible part of the Target Pile (see Section 6.9).

Cooling

A closed loop, water system is used to provide cooling for the Target Sweeping Magnet, its collimator inserts and the dump. This closed loop system is referred to as the RAW (Radioactive Water) cooling system.

The standard Research Division, LCW (Low Conductivity Water) system is used to provide cooling for components in the Target Hall that will not be activated with primary beam. The target (see Section 5) does not require water cooling.

4.1.3 Apertures

The apertures through the Target Sweeping Magnet, the Primary Beam Dump and the Hyperon Magnet were sized, where possible, to be 0.250 inches greater then the exclusion line limits proposed in the memo "Design Considerations for the KTeV Target Pile", January 24, 1993. This exclusion line (shown in the following figure) is designed so there is no direct line of sight through the collimator to material upstream of the primary collimator. This insures scattering from the apertures upstream of the primary collimator do not enter the apparatus. The dimensions of the exclusion area decrease vertically and increase horizontally with increasing distance downstream of the target.

The following figures show the aperture size, the exclusion lines (which define the "exclusion area"), and the size of the neutral beam envelope for the Beam Dump System elements that are upstream of the primary collimator. The apertures of these elements were sized in each plane according to the largest dimension of the exclusion area in each element.

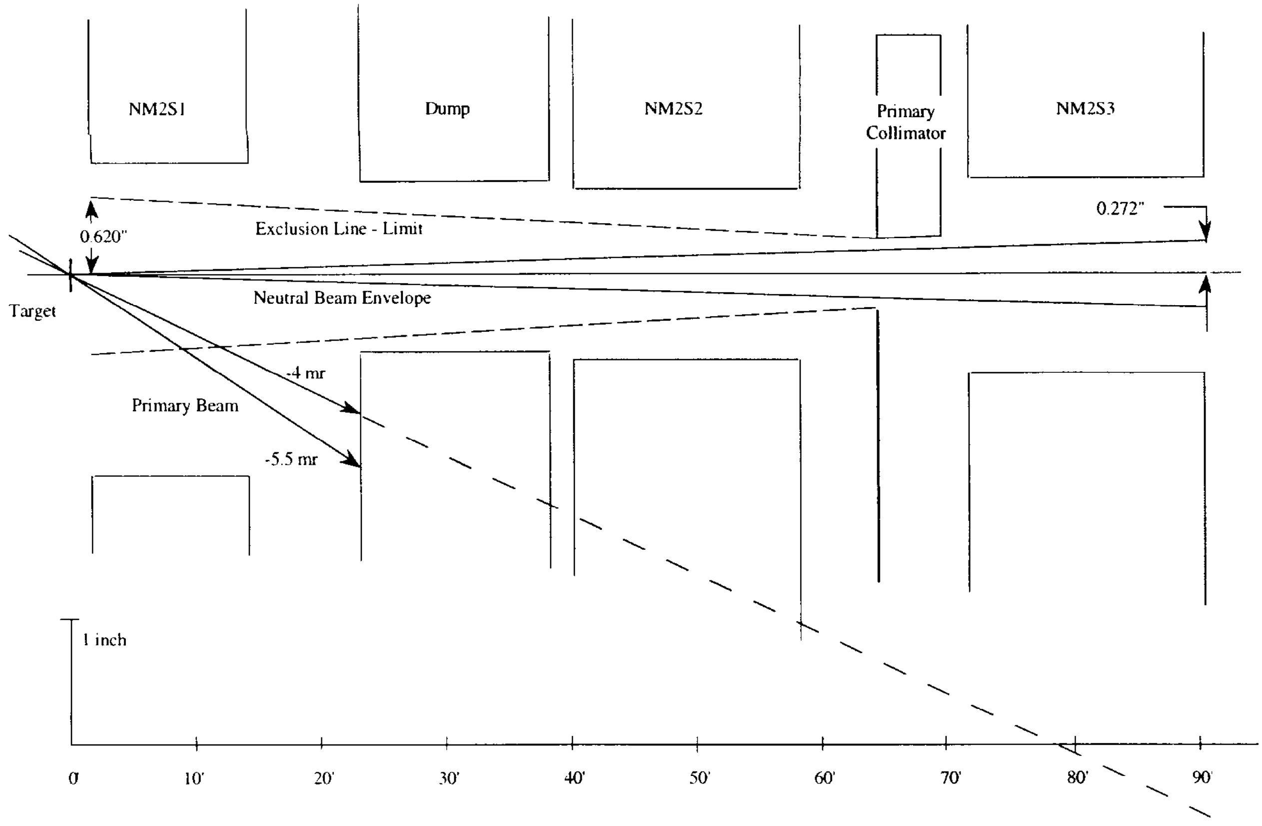

Figure 4.1.4
Apertures with Exclusion Lines through the KTeV Target Hall Elevation View

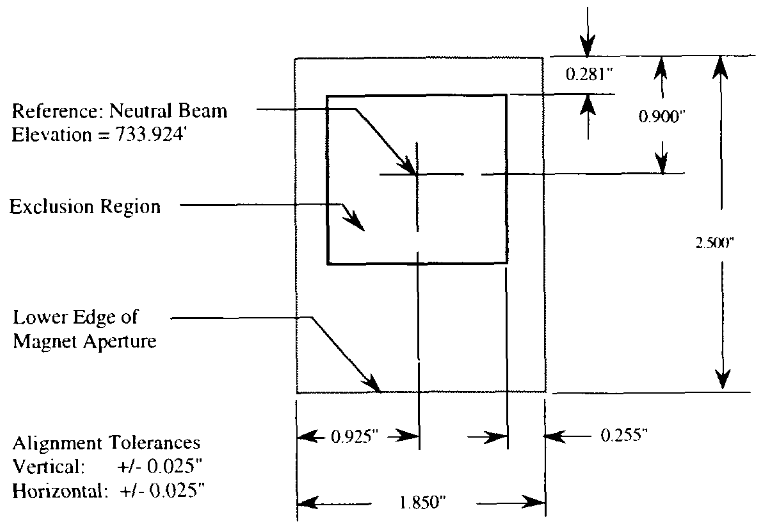

Figure 4.1.5
NM2S1 Aperture, Exclusion Area and Installation Tolerance
(Units are inches)

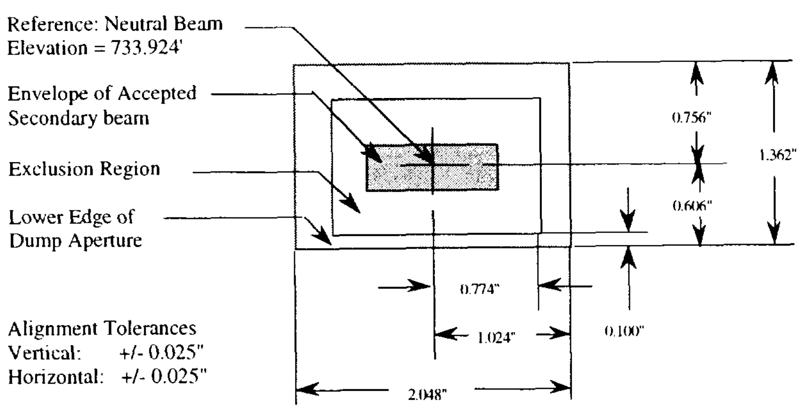

Figure 4.1.6
Primary Beam Dump Aperture, Exclusion Area and Installation Tolerance
(Units are inches)

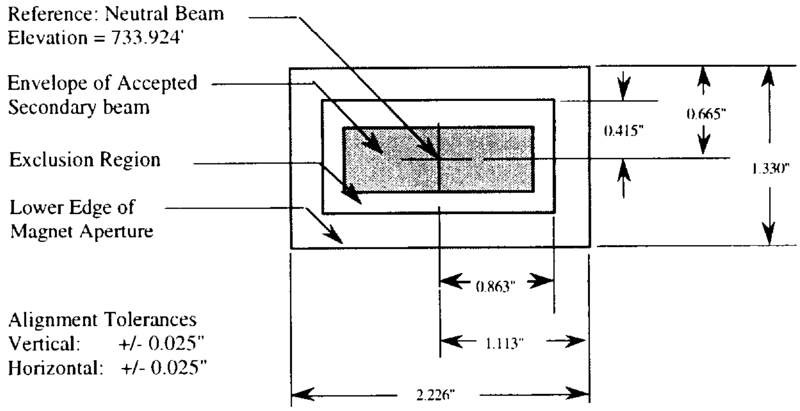

Figure 4.1.7
Hyperon Magnet Aperture, Exclusion Area and Installation Tolerance
(Units are inches)

4.2 Design and Installation

A list of common design requirements incorporated into the Beam Dump System follows:

- Provide vertical adjustment to account for settling.
- Provide access to all elements to permit alignment measurements.
- Design to use the Target Hall crane.
- No secondary beamline collimation will occur inside the target pile or elements that cannot be remotely adjusted.
- Where possible, apertures will be 0.25 inches larger than the exclusion line limits defined.
- Design should allow straightforward replacement with available spares.

4.2.1 Target Sweeping Magnet—NM2S1

NM2S1 is a modified version of the standard, Research Division, Target Dump Magnet, also referred to as an Eartly Dump Magnet. To accommodate the possible range of primary beam angles, positions and sizes, the "nominal" vertical aperture of the magnet is increased from 1.125 inches to 2.500 inches. This reduces the maximum magnetic field of the magnet from 20 kG to 9 kG. The expected operating field of NM2S1 is 5 kG.

To provide early absorption of pions, high density spacers made of brass or copper are inserted in the horizontal plane of the magnet aperture. These spacers define the horizontal aperture width of 1.850 inches and are pinned into place against the pole tips. The spacers are cooled with water from the RAW system. Figure 4.2.1 shows an engineering drawing of the modified magnet.

NM2S1 and its support structure will be pre-assembled and pre-aligned in the shop. This assembly will then be installed on the centerline of the neutral beam in the open Target Pile. Self-centering pins in the magnet support allow the alignment to be preserved should there be any need to exchange the magnet in the future.

Standard alignment fixtures are permanently attached to the east side of the magnet and are fiducialized to the aperture centerline both horizontally and vertically. These fixtures and the adjustable jacks that support the magnet are accessible through "ports" in the east side of the shield pile. The jacks will allow ±1 inch height adjustments to the magnet after installation.

Because the magnet position will be stable in the horizontal direction and the magnet aperture has been oversized 0.5" (±0.25") in the horizontal (and vertical) plane (with respect to the exclusion lines), no remote, external "post-installation" horizontal adjustment has been provided. Any further horizontal adjustment after installation will require opening the target pile.

4.2.2 Primary Beam Dump—NM2BD

The primary beam dump is a water cooled copper block, 15 feet long x 8 inches wide x 10 inches high, clad in two bands of steel, each 3 inches thick. The "inner" steel band runs the entire 15 foot length of the copper dump and the "outer" band is 7.5 feet long centered lengthwise on the dump. The resulting "stagger" in the steel bands is mirrored by an equivalent "stagger" in the steel shielding of the target pile dump cavity. This eliminates any "straight through" line-of-sight to the upstream end of the dump. Centering the outer band keeps the loading symmetric when handling the dump. Figure 4.1.1 shows how this package fits in the Target Pile steel shielding.

Figure 4.2.2 shows the dump design in more detail. There are 4 independent water loops through the copper. These water loops use a common manifold connected to the RAW water supply. The water manifold will be on the downstream end of the dump where it will be accessible for service.

Alignment fixturing is permanently attached to the east side and the downstream face of the dump. The alignment fixtures are fiducialized to the centerline of the aperture. A port is available through the Target Pile to access the upstream alignment fixture. The downstream fixtures are visible at the downstream face of the Target Pile.

Like the target sweeping magnet, the dump is supported on jack stands that are accessible through ports in the east side of the Target Pile. These stands allow a ±1 inch vertical adjustment in the height of the dump to correct for any settling in the Target Pile that may occur.

The dump is installed and aligned in the same way as the Target Sweeping Magnet. That is, the dump and its support structure will be pre-assembled and pre-aligned in the shop and installed as a single assembly.

Because the beam dump position will be stable in the horizontal direction and the dump aperture has been oversized 0.5" (±0.25") in the horizontal plane (with respect to the exclusion lines), no remote, external "post-installation" horizontal adjustment has been provided. Any further horizontal adjustment after installation will require opening the target pile.

4.2.3 E8/Hyperon Magnet—NM2S2

The Channel

Studies using POISSON[22] and CASIMU[23] (see Section 4.4.2) led to the pole tip and channel design shown below. Steel is used to extend the NM2S2 pole tips and copper spacers define the aperture in the horizontal bend plane. The copper provides mechanical support and becomes part of an extended beam dump should the primary beam be dumped inside the Primary Beam Dump aperture as described in Section 3.1.1.

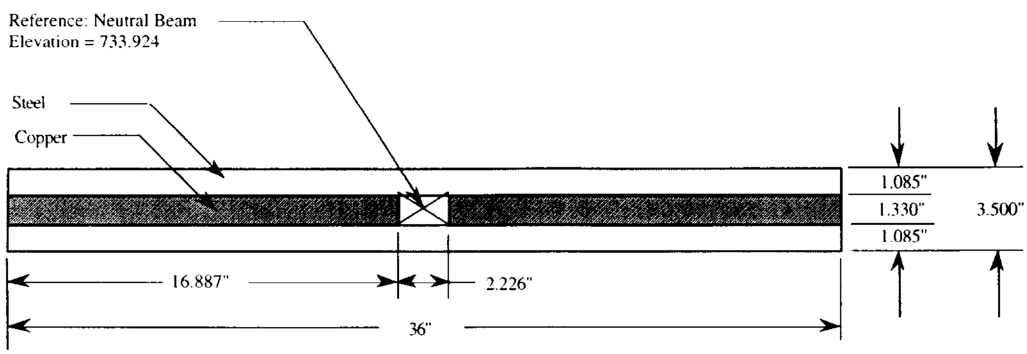

Figure 4.2.3
Hyperon Magnet Channel

Because beam could be dumped at the end of the Primary Beam Dump (Section 3.1.1), water cooling is provided for the Hyperon Magnet Channel (which is immediately downstream of the dump). (These water cooling paths are not shown in Figure 4.2.3). Cooling water is supplied by the RAW water system. The magnet coils are cooled with LCW. At full current, the field across the pole tips is expected to be 23 kG.

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[22]POISSON is a generic name for a set of codes that solve the generalized Poisson Equation for magnets; see Los Alamos Accelerator Code Group, Reference Manual for the POISSON/SUPERFISH Group of Codes, LA-UR-87-126 (January, 1987)

[23]CASIMU is a modified versino of the hadronic cascade program CASIM; see A. Van Ginneken, Fermilab Report FN-272 (1975)

Support Structure

The support stand for NM2S2 is designed to allow position adjustments horizontally and vertically as small as 1 mil. Vertical adjustments are made by temporarily lifting the I-beam (and magnet) on jacks, installing or removing shim stock of the right thickness between the vertical columns and the supporting I-beam, then replacing the I-beam on the shimmed column.

The support columns sit on brass plates that allow horizontal adjustments to be made by jacking against fixed stops. See Figure 4.2.4 for a conceptual engineering drawing of NM2S2 and its support structure.

The Hyperon Magnet steel and coils are available for NM2S2. The steel requires some clean-up from long outdoor exposure as well as preparatory work to accept the support structure.

The magnet and its supports will be pre-assembled in the Meson Assembly Building, partially dismantled for shipping, then re-assembled in the NM2 Hall (after completion of the Target Pile).

4.2.4 Mu-sweep II—NM2S3

NM2S3 is a new magnet, not yet constructed. See Figure 4.2.5 for a conceptual engineering design. The coils are designed. Most of the required steel is available on-site including Maryland Cyclotron Steel left over from the spectrometer magnet construction. The magnet will be assembled in the KTeV Target Hall on a support structure that will permit both vertical and horizontal adjustment.

This is a "C-Type" magnet with the return yoke displaced to the west, outside of the westward going muon plume. The magnet poles give an additional kick to the muon plumes, further separating them horizontally away from the detector. The magnet is 19 feet long with a magnetic field of 19.3 kG. The coils will be water cooled with LCW.

To accommodate the installation of Mu-Sweep II, the cable tray and LCW on the west wall of the downstream end of the Target Hall will need to be either modified or raised. The cable tray will need to be temporarily removed during the magnet installation.

4.2.5 Target Pile Shielding

The Target Pile houses in beam order, the Target and Target Drive, the Target Sweeping Magnet and the Primary Beam Dump.

The steel shielding of the target pile, starts 8.2 feet downstream of the beginning of the KTeV Target Hall and extends 41.3 feet to the end of the Primary Beam Dump. See Figure 4.1.1.

Requirements for groundwater radiation protection set the outer dimensions of the steel shield. These dimensions require approximately 44 inches of steel below the beam centerline and 60 inches radially to the sides and top. See Figure 4.2.6. The program CASIM[24] was used to establish the amount of steel necessary for groundwater protection. This analysis is described in Section 4.3.2.

The target is recessed 3.0 feet downstream of the beginning of the Target Pile in an re-entrant cavity. Cabling for the target mover, instrumentation cabling (e.g., SWIC and klixons) and the RAW water cooling loop for the target magnet inserts are routed through the upstream, re-entrant cavity of the Target Pile. Klixon cabling for the dump is routed through the downstream face of the target pile.

The bus that provides power and RAW cooling for NM2S1 are brought through vertical ports in the top of the steel shielding that are located at the west, downstream end of the magnet. Access "ports" are also provided horizontally through the steel for alignment and jack adjustment. These ports are normally plugged and are opened only when alignment

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[24]A. Van Ginnekin, CASIM, Program to Simulate Transport of Hadronic Cascades in Bulk Matter, Fermilab Report FN-272 (1975)

measurements or vertical adjustments to the target magnet or the dump need to be made. The alignment and adjustment ports are made of 2" diameter tubing that fits through rectangular flame cut holes in the steel plates. The gaps between the tubing and the steel plates are filled with steel stock.

The new target pile has been designed using steel pieces from the existing MC6 and NM2 target piles. The residual activity and contamination levels within these piles will determine the success of this plan. Handling, grinding, and flame cutting limitations on radioactive steel will determine whether and how any given piece from MC or NM is used in the new pile. An attempt to identify alternative sources of steel is underway.

As currently configured, the NM2 target pile does not match KTeV's requirements and will be entirely removed. And although pieces of the current pile are intended to be re-used for KteV, there is insufficient space in the NM2 enclosure to allow simultaneous staging and construction.

Staging areas will be developed in the Meson Area and as close to NM2 as the KTeV Experimental Hall construction will allow, to handle the the removal of the MC6 and NM2 target piles. Radiation and dimensional measurements of each piece will be made to determine the disposition of each piece as it is removed from its existing target pile. Cutting will be done either in the staging areas or the Target Service Building depending on the radiation class of the steel. Unused steel will be sent to the railhead.

A steel stacking plan, referencing MC6 and NM2 Target Pile design drawings has been developed. Figure 4.2.7 shows two views of the new KTeV Target Pile steel plate stacking plan. Additional drawings, not included here, show each of the steel layers in detail. Each steel plate has a number painted on it which identifies its original source and its location in the original pile. Five digit numbers identify the steel as coming from MC, two digit numbers identify the steel as coming from the old NM2 Target Pile.

Both the KTeV Target Hall and the MC6 target piles have existing 20 ton crane coverage. This, along with "drop hatch" access limitations in NM2 determine the maximum size of any piece to be handled in NM2.

Because space is not available in the upstream section of NM2 to store spare magnets, a wedge shaped piece of the target pile may be removed to allow the passage of a 20 foot B2 magnet (See Figure 4.1.1). This wedge shaped piece is normally in place and can be removed by the crane if necessary. See Figure 4.1.1.

4.2.6 Cooling

Radioactive Water Cooling System (RAW)

The RAW cooling system will provide cooling for the NM2S1, its inserts and the Beam Dump. It will be located downstream of NM2S3 and the absorbers, against the west wall (see Figure 4.1.1). This area is under crane coverage and personnel access will be by ladder over NM2S3.

These elements represent a total thermal load of approximately 55 kW, which is slightly below the 60 kW capability of the existing system in NM2. ICW (Industrial cooling water) can be supplied to add another 20 to 30 kW of cooling to the RAW system if necessary. RAW piping along the west wall of the Target Hall is available to be used with minimal modifications.

Low Conductivity Water (LCW)

In the KTeV Target Hall, LCW is required by NM2S2 and NM2S3. While these elements and the components of the primary beam can be supplied at the limit of the existing LCW system, the addition of the secondary beam LCW requirements exceeds the 300 gpm flow rate of the current 4" header. The header size will be increased to 6" enabling the 570 gpm flow rate required by KTeV however the existing piping within NM2 will not require any significant modification. See Table 7.2 for flow requirements.

4.3 Installation

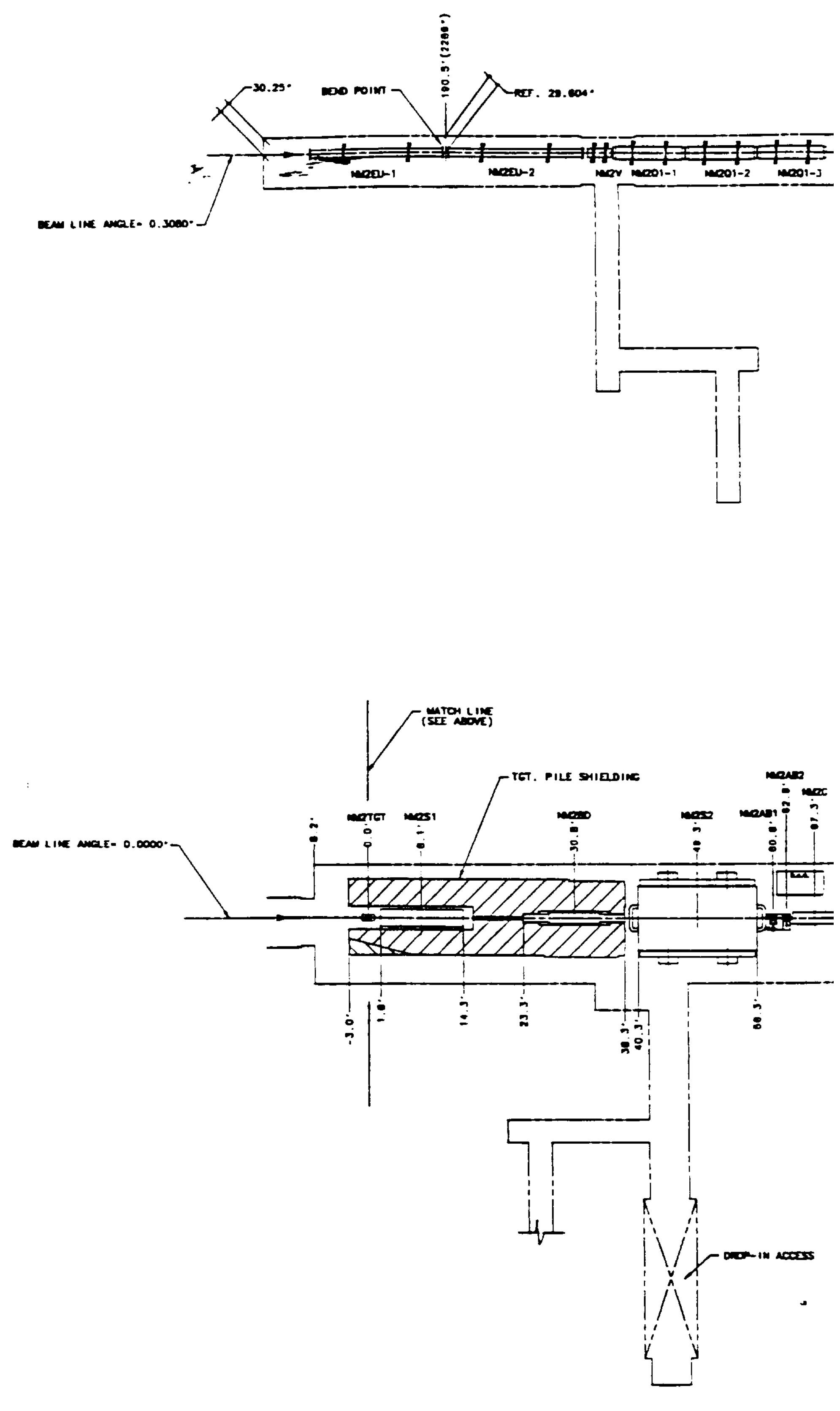
The NM2 components will be installed in the following order:

- Primary beam magnets and beam pipe in the NM2 upstream extension
- Secondary beam elements and beam pipe in the NM2 downstream extension
- The Target Pile Steel and
  - The Target Sweeping Magnet
  - The Primary Beam Dump
- The Hyperon Magnet
- Mu-Sweep II
- RAW cooling system
- Target, SWICs, Absorbers and Primary Collimator.

Since NM2S2 effectively blocks the access way to large pieces, pre-staging of the NM2S3 steel in NM2 after the target pile installation but before the NM2S2 installation will be required. Space is available in the downstream NM2 section for pre-staging NM2S3.

Handling and staging plans are being developed to account for post-installation staging that might be required during repairs or access to the target pile. Sufficient space is available in the NM2 enclosure to accommodate this. Figure 4.2.8 shows an open Target Pile and indicates which steel plates (dashed lines) must be removed to replace the Target Sweeping Magnet. The fixture which helps to preserve alignment by guiding the magnet onto its already aligned stand can also be seen.

Figure numbers mentioned in this section follow next.



PLAN VIEW OF THE NM2 ENCLOSU

The KTeV Target Hall starts at -8.2' and e

The KTeV target is at 0.0'.

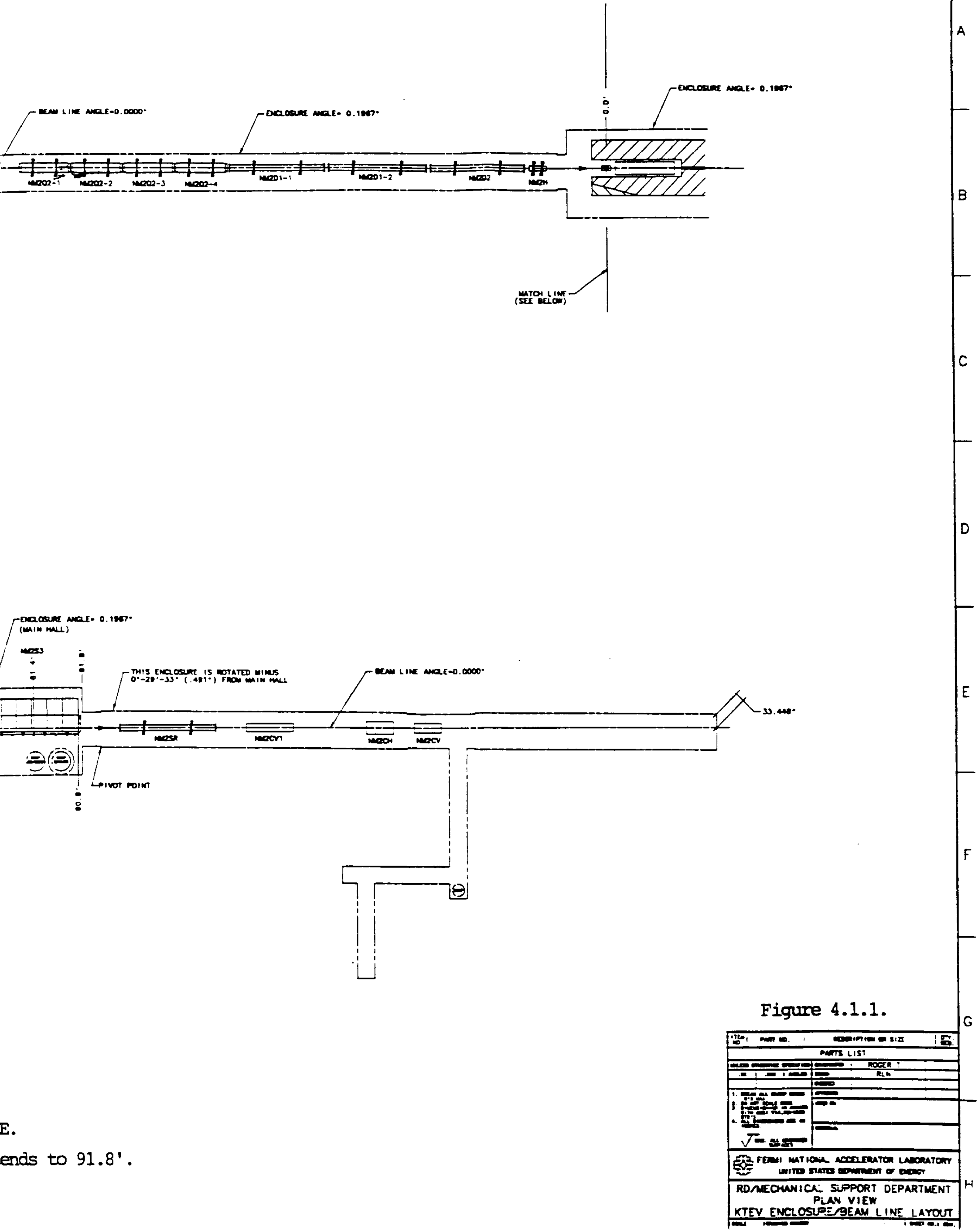
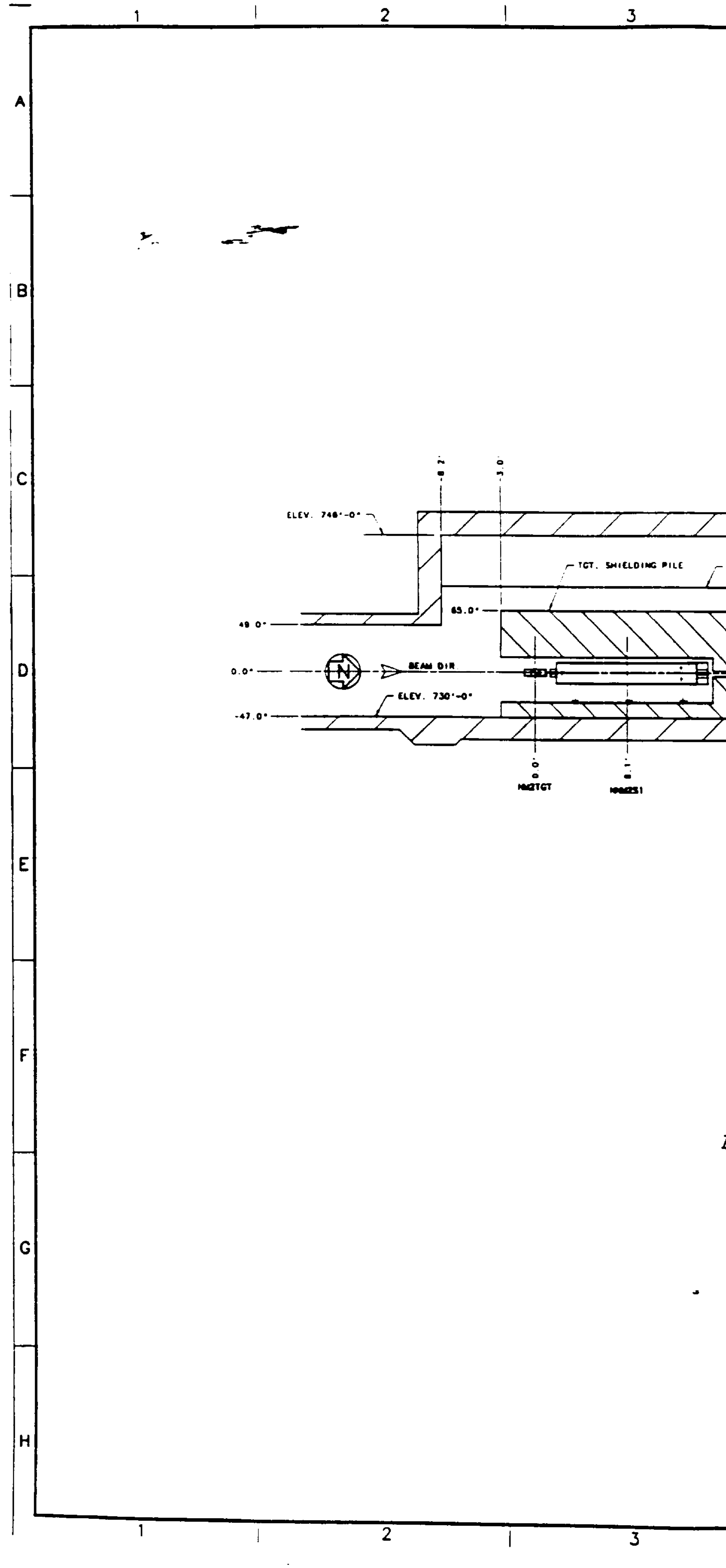
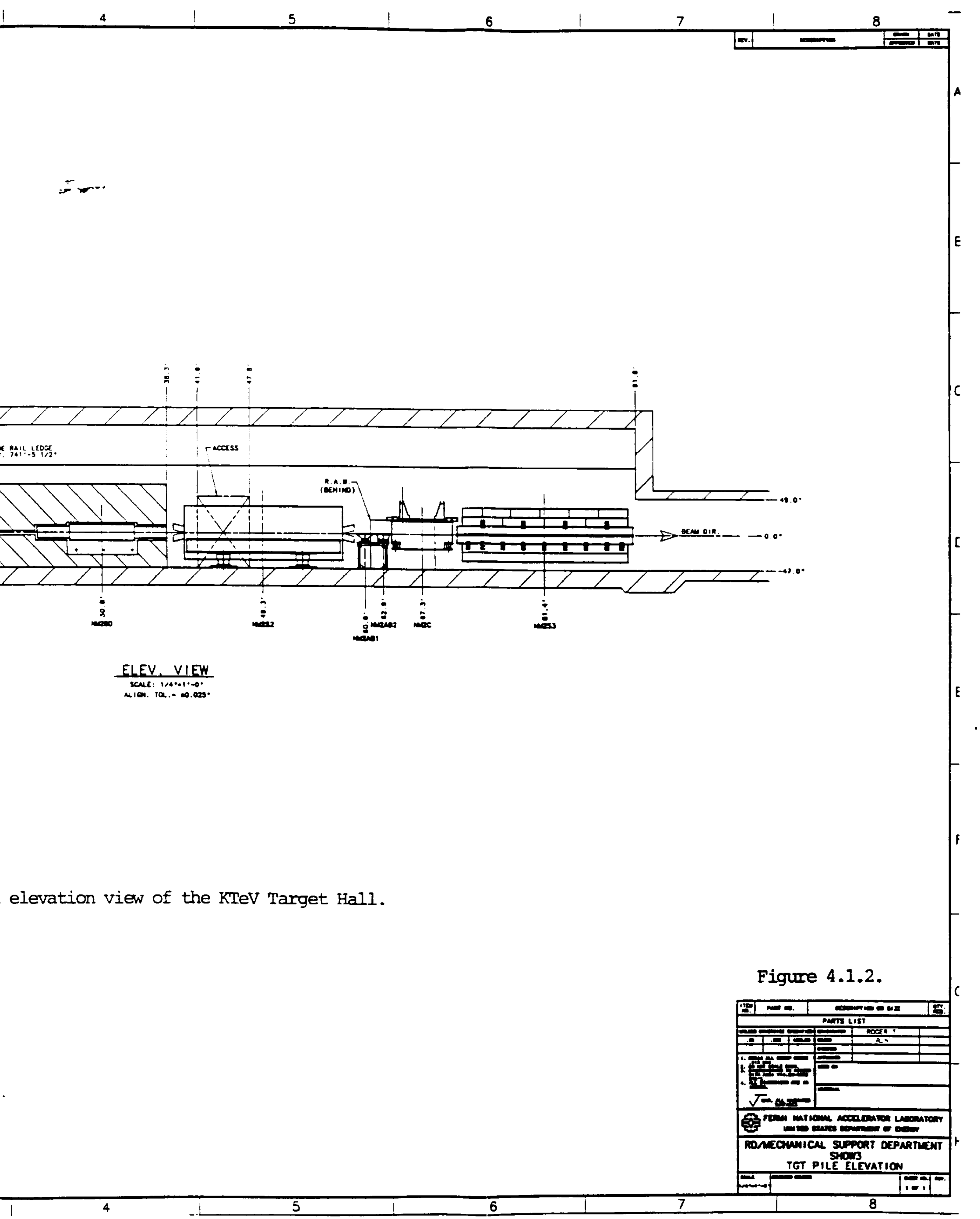


Figure 4.1.1.

E.

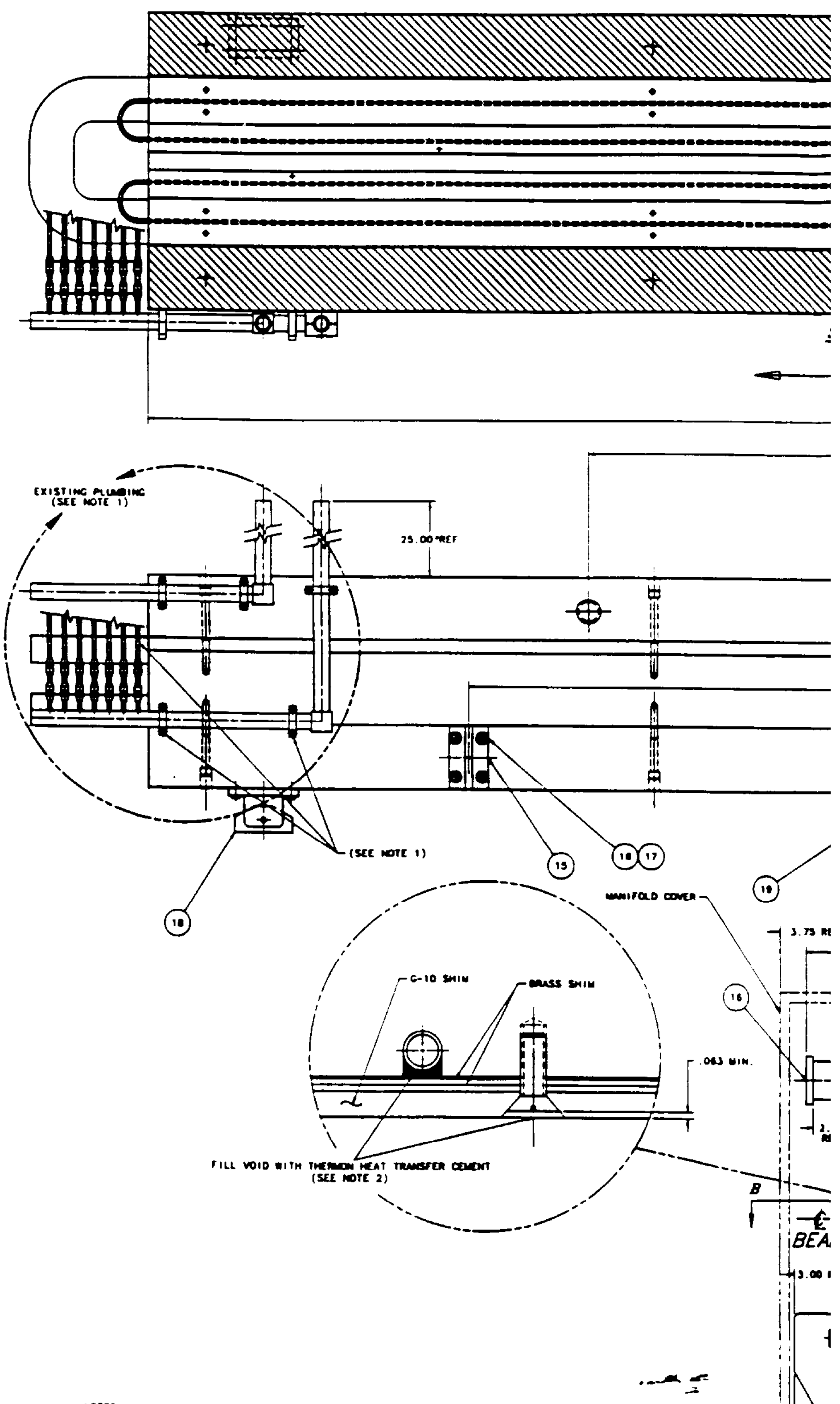
ends to 91.8'.


ELEV. 748'-0"
TGT. SHIELDING PILE
65.0"
49.0"
0.0"
BEAM DIR
ELEV. 730'-0"
-47.0"
-8.2'
-3.0'
0.0'
NM2TGT
8.1'



elevation view of the KTeV Target Hall.

Figure 4.1.2.



NOTES:

1. TO REASSEMBLE COIL PLUMBING AFTER MAGNET IS REASSEMBLED LONGER LENGTHS OF TUBING ARE NEEDED (BENT TO SUIT). NEW TAPPED HOLES FOR MANIFOLD CLAMPS ARE ALSO NEEDED.
2. USE THERMON HEAT TRANSFER CEMENT (STANDARD GRADE THERMON).
3. COPPER TUBING TO BE CONTINUOUS (NO JOINTS). ALLOW ENOUGH TUBING LENGTH TO MAKE CONNECTIONS.
4. POLE PIECE TO BRASS INSERT (ITEM 2) TO BE TIGHT. COIL TO BRASS INSERT (ITEM 2) TO BE SNUG. THIS IS TO BE ACHIEVED BY SHIMMING.

TARGET SWEEPING MAGNET

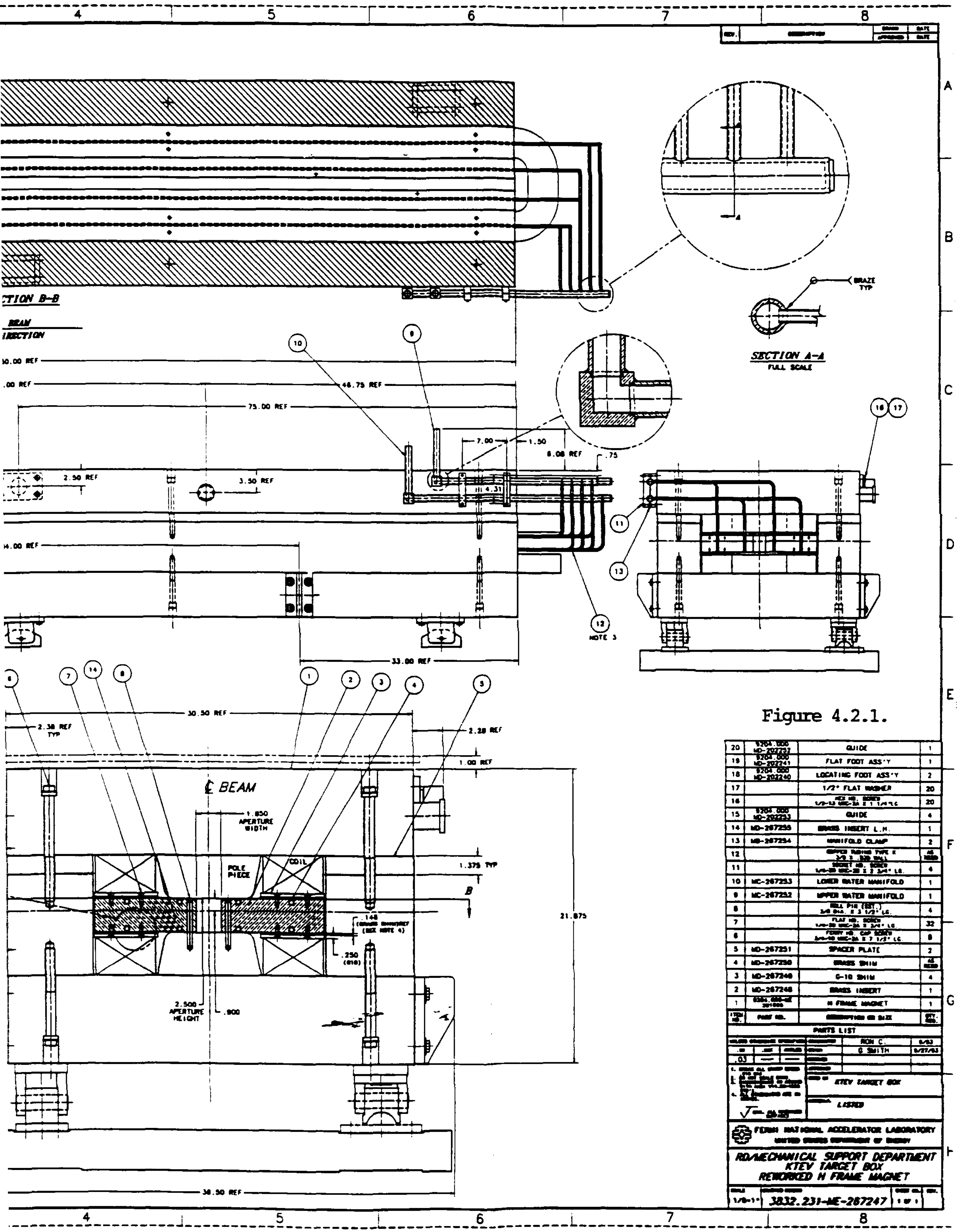
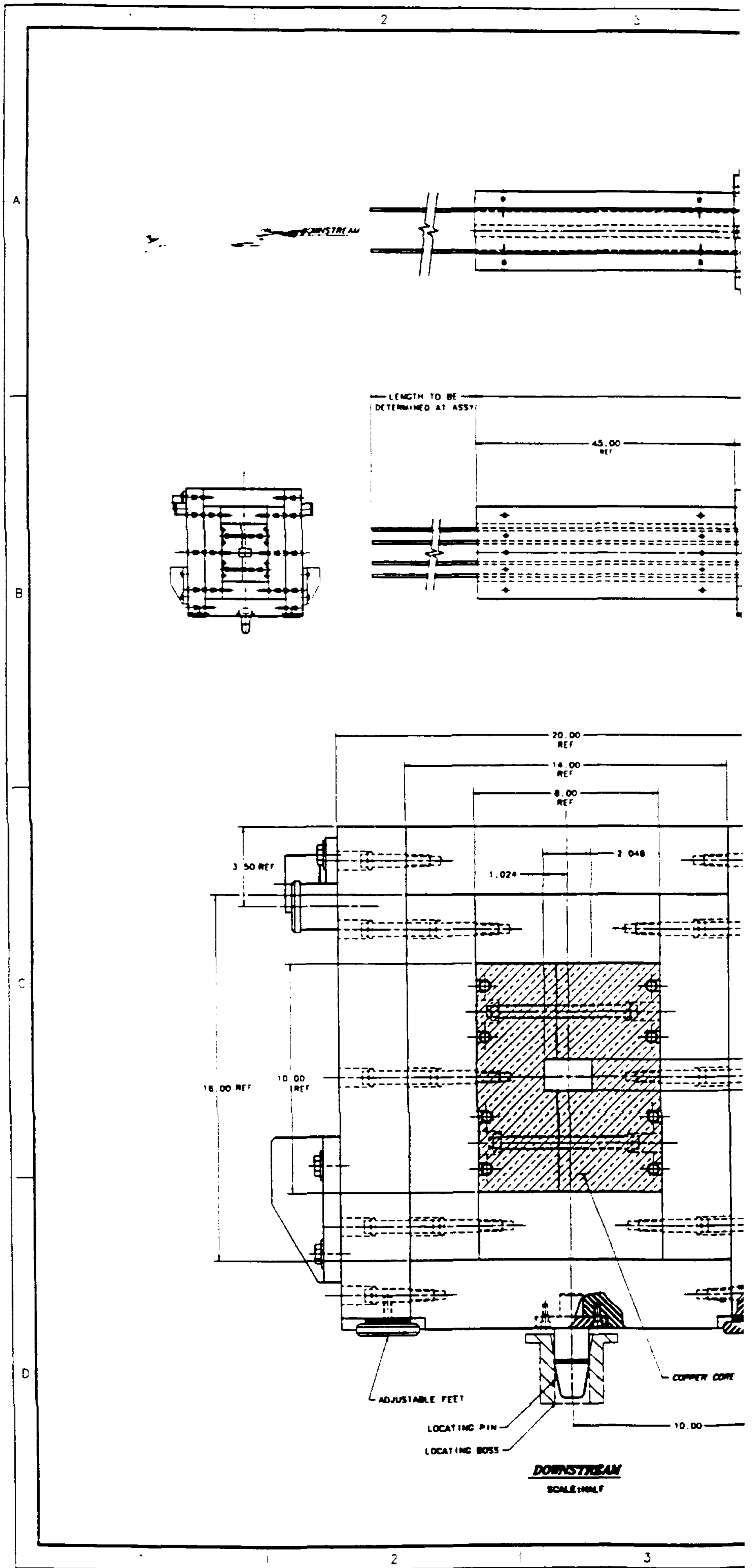


Figure 4.2.1.

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
20	9204.000 MD-202237	GUIDE	1
19	9204.000 MD-202241	FLAT FOOT ASS'Y	1
18	9204.000 MD-202240	LOCATING FOOT ASS'Y	2
17		1/2" FLAT WASHER	20
16		HEX HD. SCREW 1/2-13 UNC-2A X 1 1/4" LG	20
15	9204.000 MD-202233	GUIDE	4
14	MD-287255	BRASS INSERT L.H.	1
13	MD-287254	MANIFOLD CLAMP	2
12		COPPER TUBING TYPE K 3/8 X .035 WALL	AS REQD
11		SOCKET HD. SCREW [illegible] X 2 3/4" LG.	4
10	MC-287253	LOWER WATER MANIFOLD	1
9	MC-287252	UPPER WATER MANIFOLD	1
8		DOWEL PIN (SST.) 3/8 DIA. X 3 1/2" LG.	4
7		FLAT HD. SCREW [illegible] X 3/4" LG.	32
6		[illegible] HD. CAP SCREW [illegible] X 7 1/2" LG.	8
5	MD-287251	SPACER PLATE	2
4	MD-287250	BRASS SHIM	AS REQD
3	MD-287249	G-10 SHIM	4
2	MD-287248	BRASS INSERT	1
1	[illegible]	H FRAME MAGNET	1

PARTS LIST



2
3
A
B
C
D
DOWNSTREAM
LENGTH TO BE DETERMINED AT ASSY
45.00 REF
20.00 REF
14.00 REF
8.00 REF
2.048
1.024
3.50 REF
10.00 REF
16.00 REF
COPPER CORE
ADJUSTABLE FEET
LOCATING PIN
LOCATING BOSS
10.00
DOWNSTREAM
SCALE:HALF

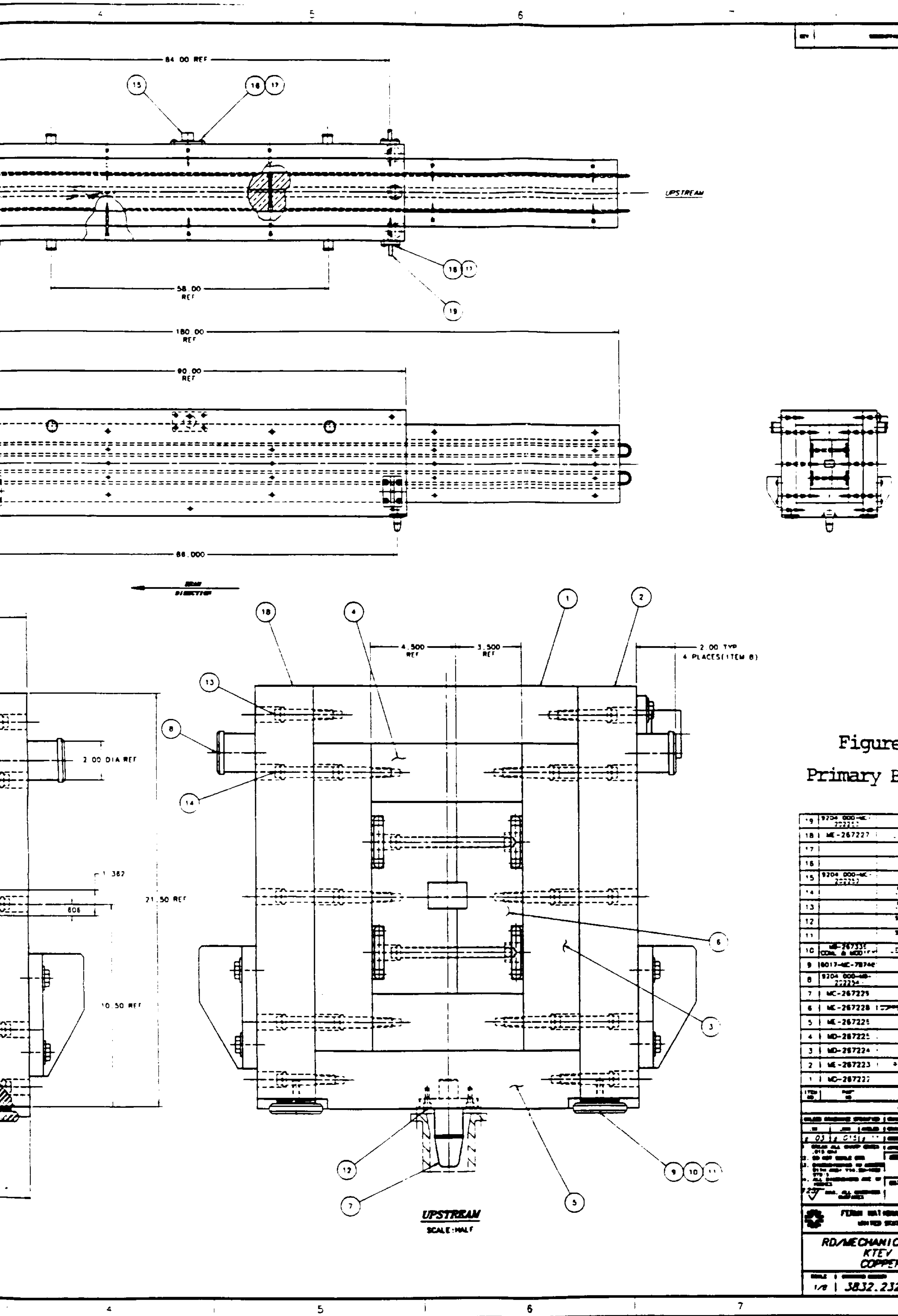


Figure 4.2.2.
Primary Beam Dump

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
19	9204 000-ME-222212	GUIDE	4
18	ME-267227	- SIDE OUTER PLATE	1
17		1/2" FLAT WASHER	20
16		HEX HD SCREW GRADE 5 1/2 UNC-2A X 1 1/2"LG	20
15	9204 000-ME-222252	GUIDE	1
14		FERRY HD CAP SCREW PLAIN 1/2-13 UNC-2A X 5 1/2"LG	12
13		FERRY HD CAP SCREW PLAIN 1/2-13 UNC-2A X 2 1/2"LG	36
12		SOCKET HD CAP SCREW,PLAIN 1/4-20 UNC-2A X 3/4"LG	8
11		SOCKET HD CAP SCREW,PLAIN 3/8-16 UNC-2A X 1"LG	4
10	MB-267335 CONL & MOD	LEVELING SPACER WASHER	AS REQ'D
9	8017-MC-78740	LEVELING PAD	4
8	9204 000-MB-222254	LIFTING PIN	4
7	MC-267229	LOCATING PIN	2
6	ME-267228	COPPER COOLING CORE SUB-ASSY	1
5	ME-267225	LOWER OUTER PLATE	1
4	MD-267225	UPPER INNER PLATE	2
3	MD-267224	SIDE INNER PLATE	2
2	ME-267223	+ - SIDE OUTER PLATE	1
1	MC-267222	UPPER OUTER PLATE	1

PARTS LIST

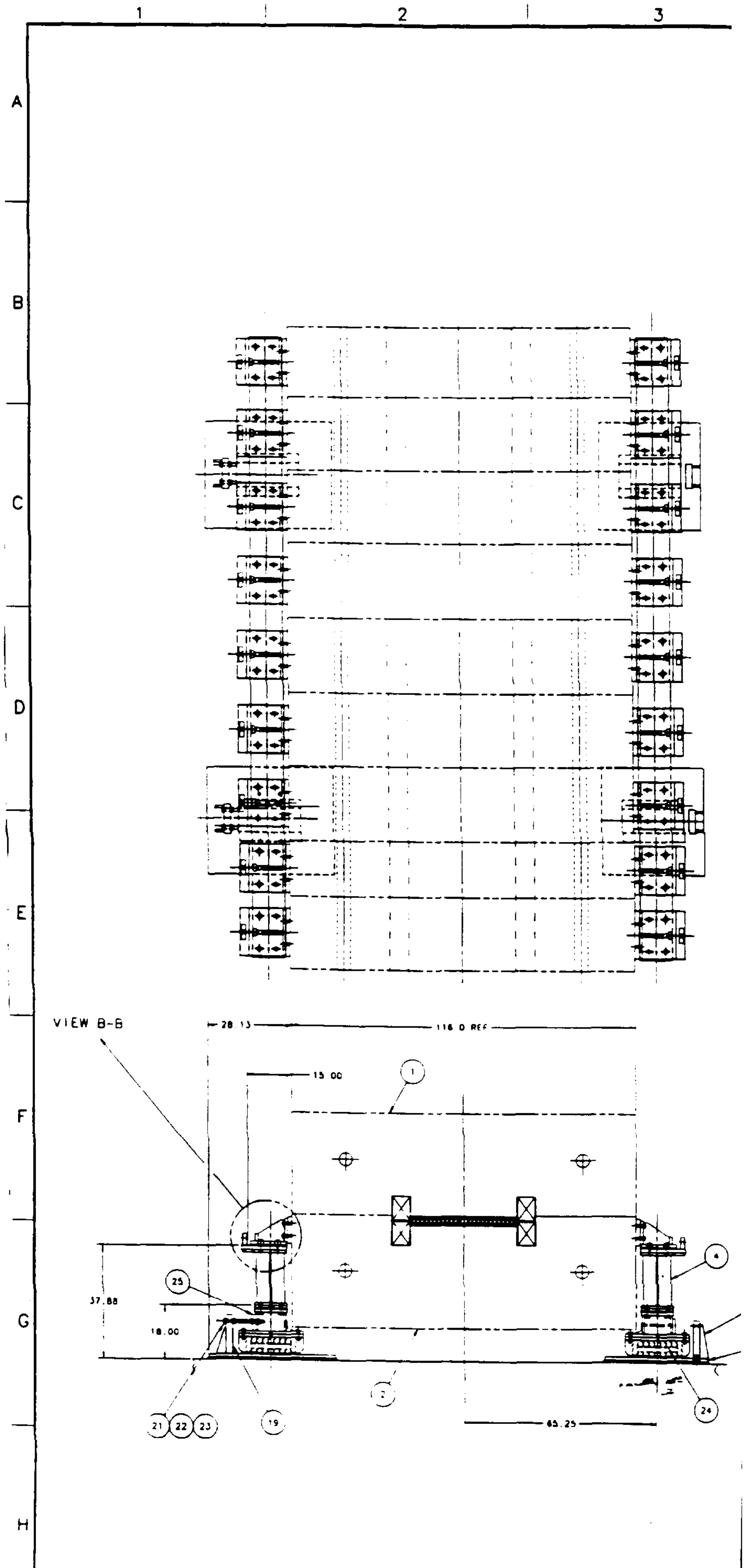
R CURRIER 10/93
C SMITH 10/28/93

MATERIAL: SEE PART LIST

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

RD/MECHANICAL SUPPORT DEPT.
KTEV TARGET BOX
COPPER BEAM DUMP

SCALE 1/8 | DRAWING NUMBER 3832.232-ME-267221 | SHEET NO. 1 OF 1



NM2S2 (old E8/Hyperon magnet) and support struc

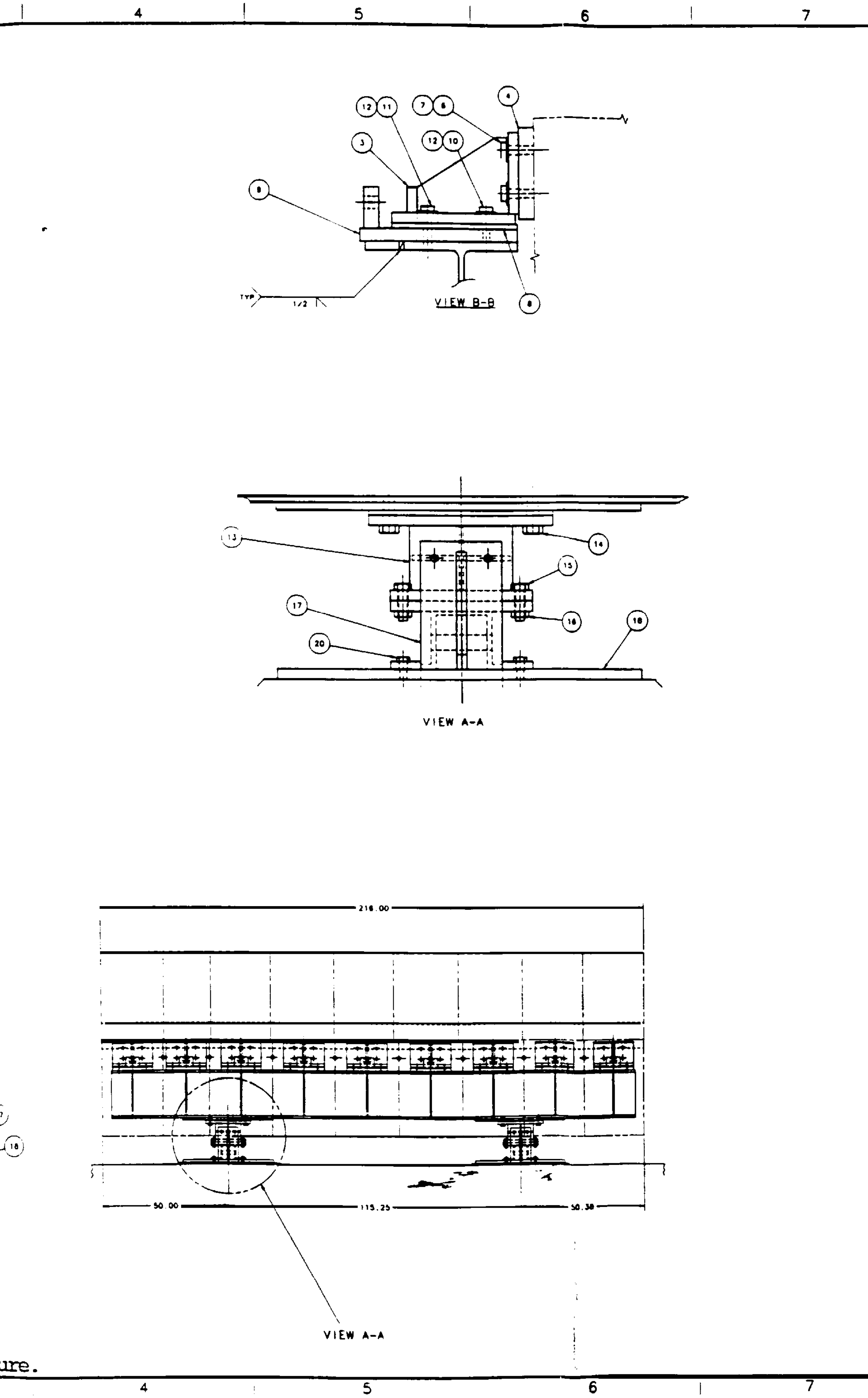


Figure 4.2.4.

ITEM NO	PART NO	DESCRIPTION OR SIZE	QTY REQ
25	ME-267245	UPRIGHT SUPPORT	2
24	COML	ROLLER BEARING	4
23	COML	[illegible]	
22	COML	[illegible]	4
21	COML	[illegible]	4
20	COML	[illegible]	2
19	MD-267155	ROLLER PLATE	2
18	MD-267156	ROLLER PLATE	2
17	MC-267157	ROLLER PLATE BLOCK	2
16	COML	[illegible]	24
15	COML	[illegible]	24
14	COML	[illegible]	16
13	ME-267151	UPRIGHT SUPPORT	2
12	COML	[illegible]	72
11	COML	[illegible]	36
10	COML	[illegible]	36
9	ME-267147	I-BEAM UPPER PAD	18
8	MC-267210	SUPPORT BRACKET SHIM	48 [illegible]
7	COML	[illegible]	36
6	COML	[illegible]	36
5	ME-267145	I-BEAM ASS'Y	2
4	MC-267150	SUPPORT BRACKET BACK PLATE	18
3	MD-267148	SUPPORT BRACKET	18
2		HYPERON MAGNET-LOWER PART	1
1		HYPERON MAGNET- UPPER PART	1

PARTS LIST

DRAWN [illegible] 5/4/94
[illegible] R MARTINC 5/4/94

SEE ABOVE

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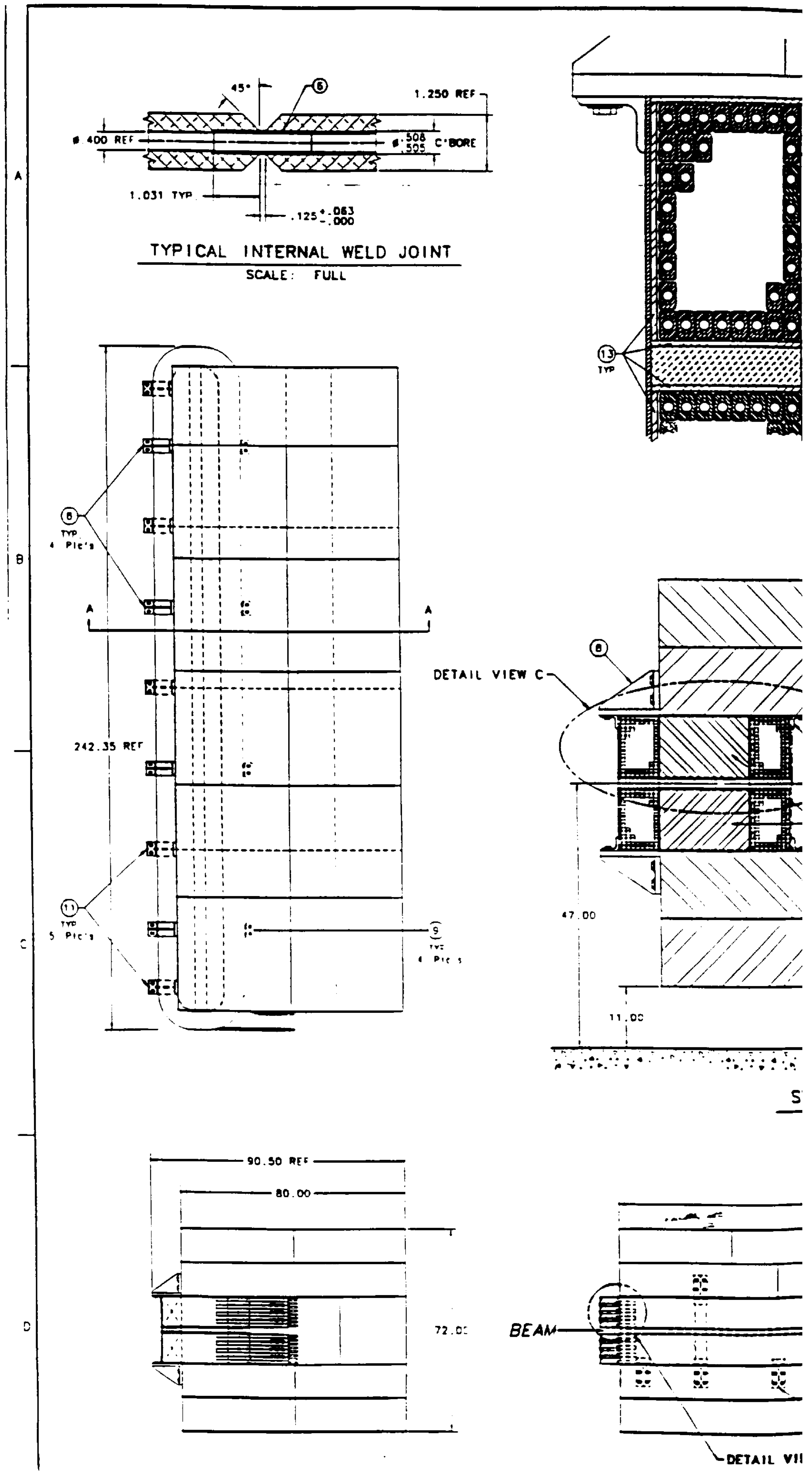
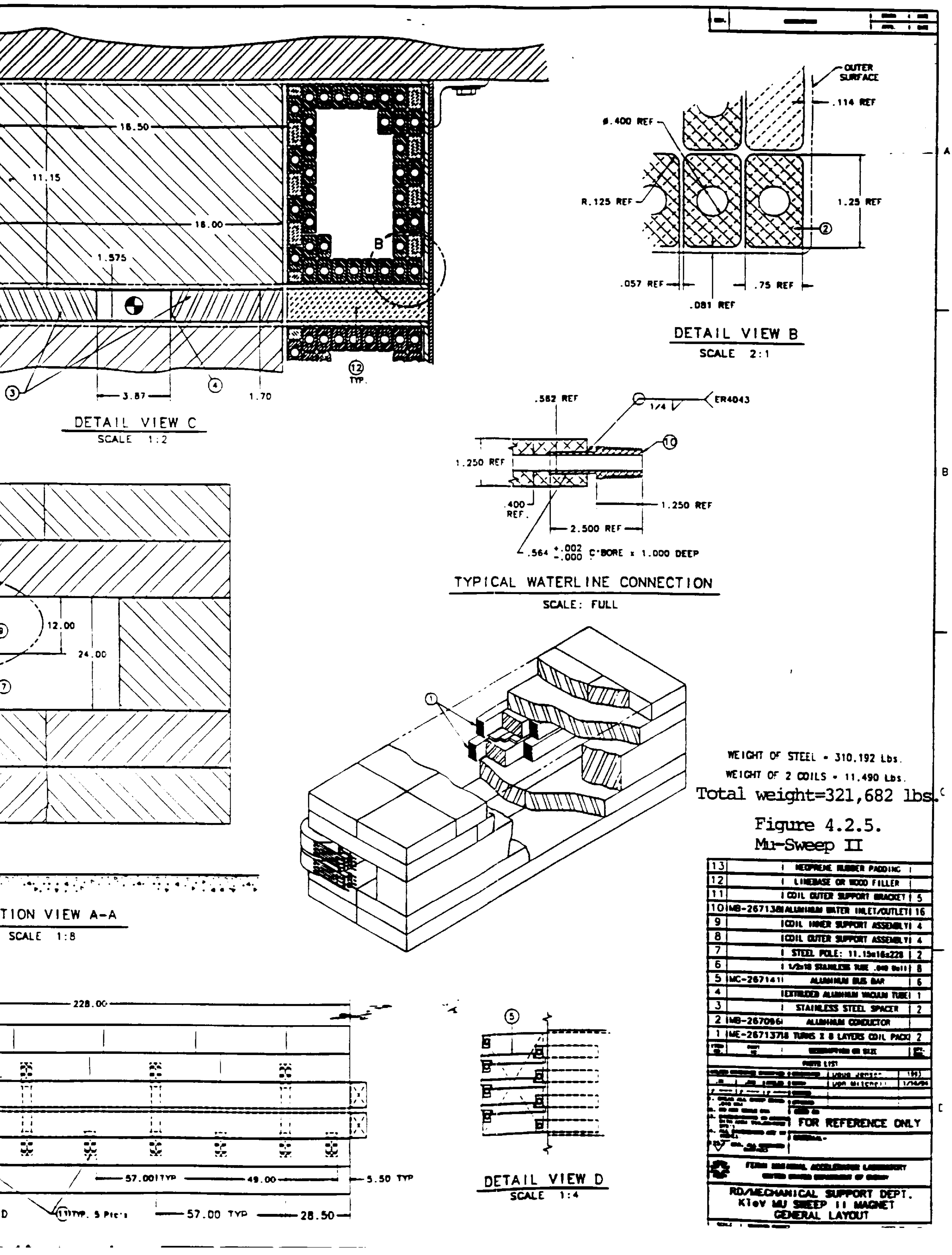
UNITED STATES DEPARTMENT OF ENERGY

RD/MECHANICAL SUPPORT DEPT.
KTEV/HYPERON MAGNET SUPPORT SYSTEM
ASSEMBLY

SCALE 1/16 | 3832.233-ME-267454

ure.


45°
6
1.250 REF
⌀ .400 REF
⌀ .508/.505 C'BORE
1.031 TYP
.125 +.063/-.000
TYPICAL INTERNAL WELD JOINT
SCALE: FULL
13
TYP
8
TYP
4 Plc's
A
A
DETAIL VIEW C
8
242.35 REF
11
TYP
5 Plc's
9
TYP
4 Plc's
47.00
11.00
90.50 REF
80.00
72.00
BEAM
DETAIL VI
A
B
C
D



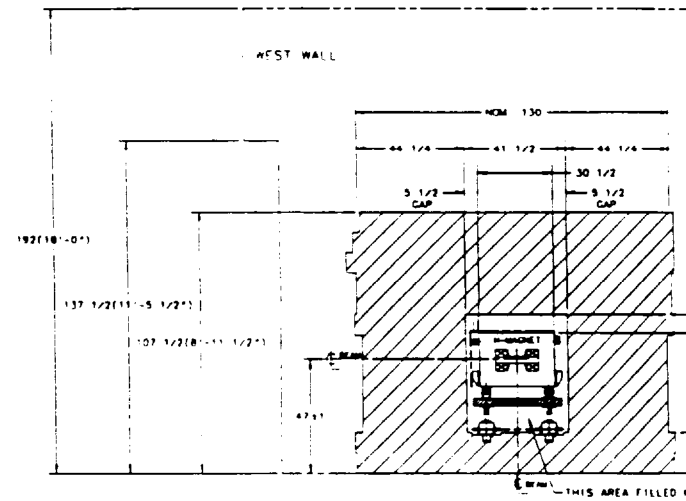
13		NEOPRENE RUBBER PADDING	
12		LINEBASE OR WOOD FILLER	
11		COIL OUTER SUPPORT BRACKET	5
10	MB-267138	ALUMINUM WATER INLET/OUTLET	16
9		COIL INNER SUPPORT ASSEMBLY	4
8		COIL OUTER SUPPORT ASSEMBLY	4
7		STEEL POLE: 11.15x18x228	2
6		1/2x18 STAINLESS TUBE .049 Wall	8
5	MC-267141	ALUMINUM BUS BAR	6
4		EXTRUDED ALUMINUM VACUUM TUBE	1
3		STAINLESS STEEL SPACER	2
2	MB-267086	ALUMINUM CONDUCTOR	
1	ME-267137	18 TURNS X 8 LAYERS COIL PACK	2

WEIGHT OF STEEL = 310,192 Lbs.

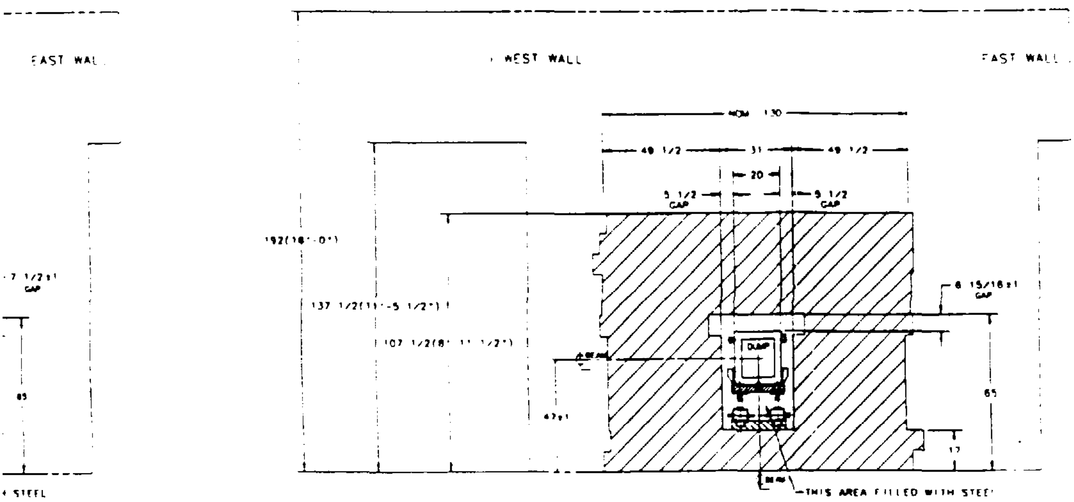
WEIGHT OF 2 COILS = 11,490 Lbs.

Total weight=321,682 lbs.

Figure 4.2.5.
Mu-Sweep II



TYP SECTION THRU H-MAGNET



TYP. SECTION THRU DUMP

Figure 4.2.6.

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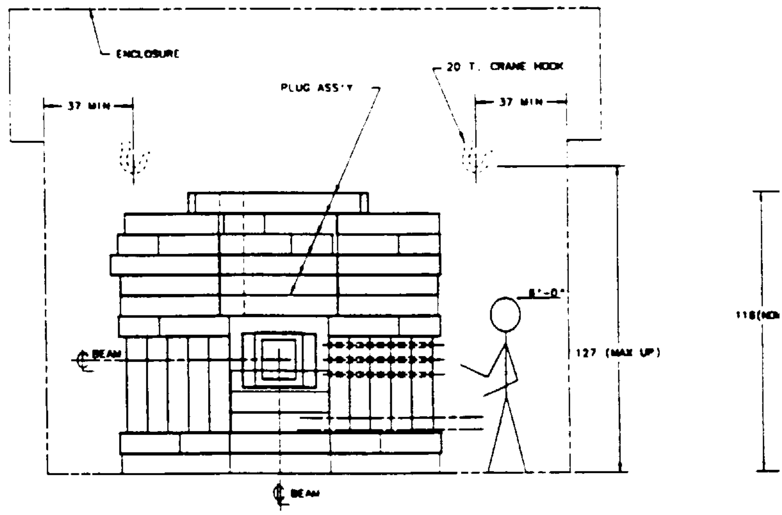
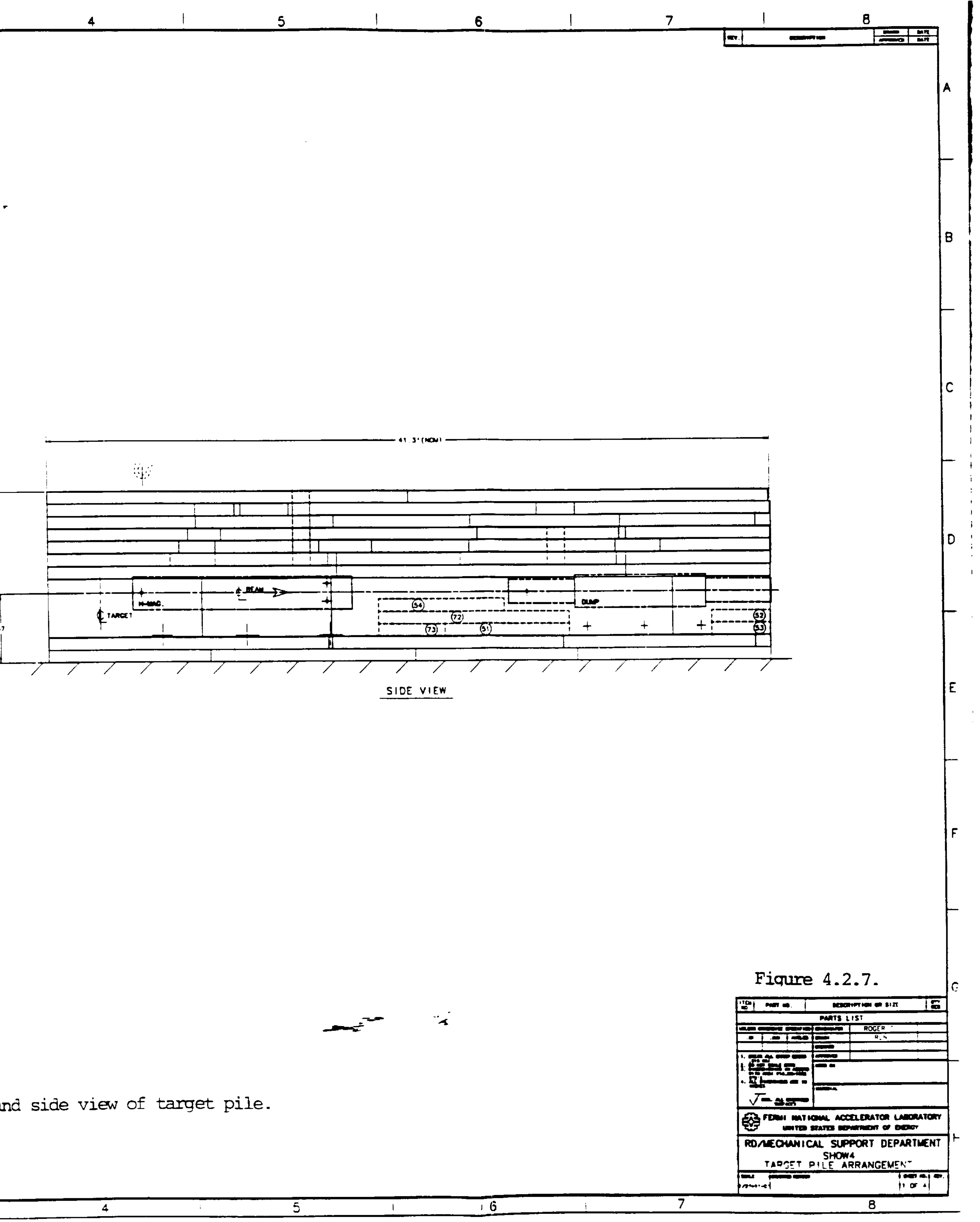
UNITED STATES DEPARTMENT OF ENERGY

RD/MECHANICAL SUPPORT DEPARTMENT
SHOW5
TGT. PILE END VIEW/ELEVATION

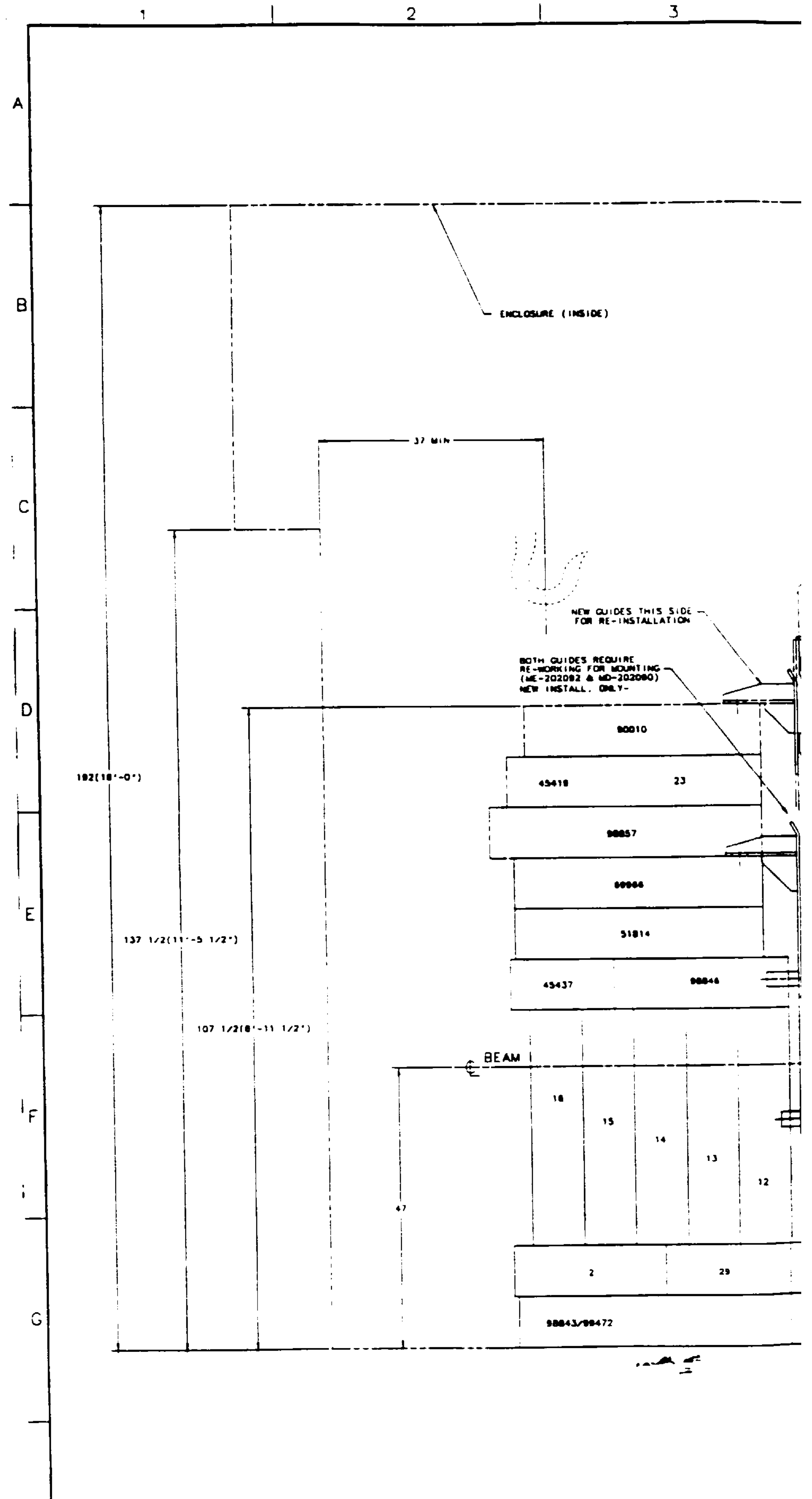


U.S. END VIEW

Front



...nd side view of target pile.



Cross-section of target pile showing target sweepinc
The dump is installed in a similar wav.

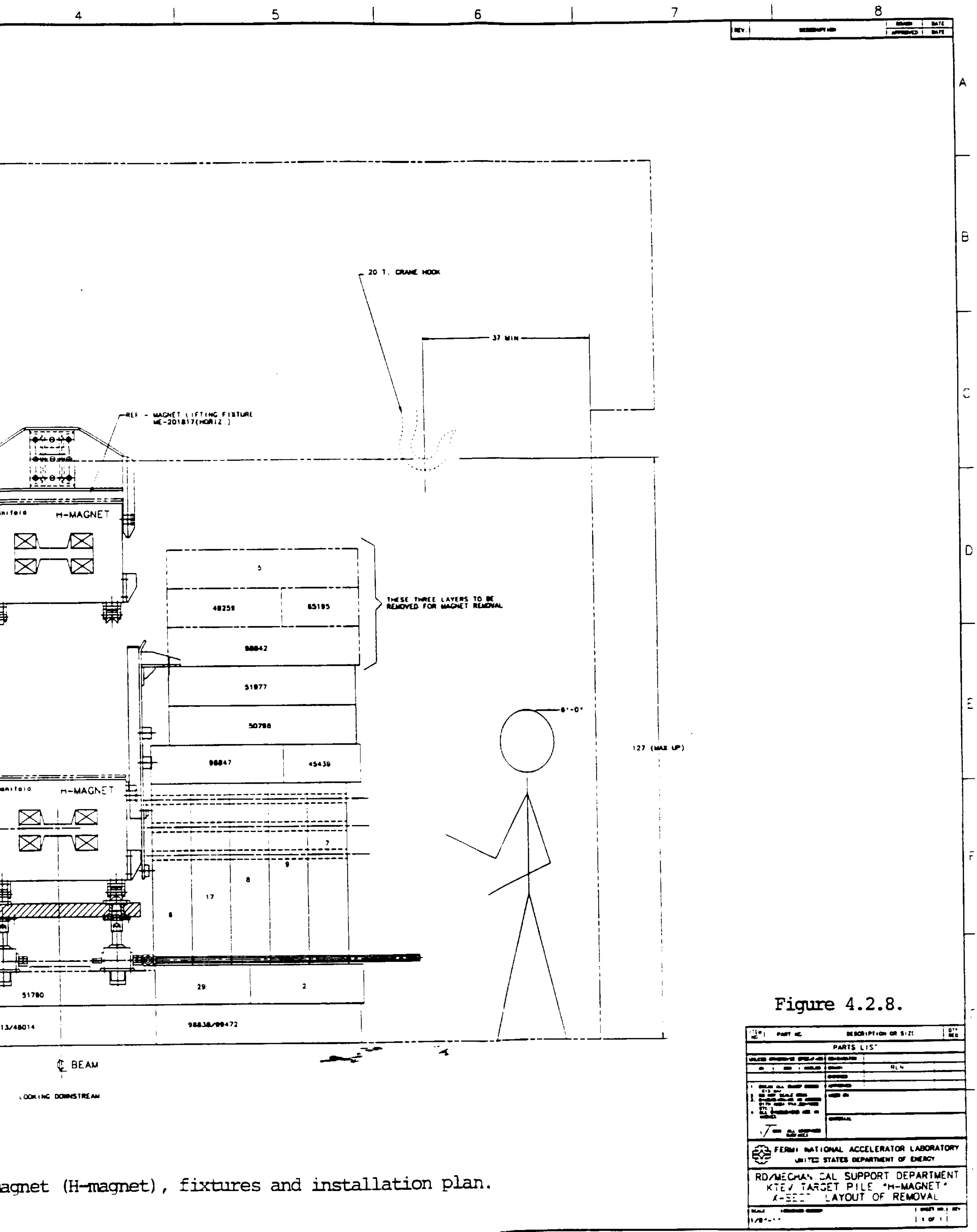


Figure 4.2.8.

RD/MECHANICAL SUPPORT DEPARTMENT
KTEV TARGET PILE "H-MAGNET"
X-SECT LAYOUT OF REMOVAL

...agnet (H-magnet), fixtures and installation plan.

4.4 Muon Sweeping System

4.3.1 Design Criteria

Table 4.4.1. summarizes the design criteria for muons:

Table 4.4.1.
Summary of Design Criteria

Detector	100 kHz	(See footnote [25])
Counting House	0.25 mrem/hr	(See footnote [26])
Site Boundary	10 mrem/yr	(See footnote [27])

In this section, 900GeV/c protons are always assumed. An incident rate of $5.0x10^{12}$ protons per pulse (ppp) with a 20s spill time is assumed for detector-rate calculations. For hourly dose rates, $5.0X10^{12}$ ppp and 60 pulses per hour are assumed. For yearly rates, an annual integrated rate of $2.0X10^{18}$ protons is assumed.

For the purpose of this section, the detector is taken to be a 4m high by 4m wide area, centered on the neutral beam, located 185m downstream of the target center. This is slightly larger than the size of the muon veto NM4MU3.[28]

The counting house is taken to extend from 21.8m east of neutral beam center to 10.8m east of neutral beam center. The floor is 5m above neutral beam center and the ceiling is 9m above neutral beam center. Refer to Figure 4.4.1.

The site boundary is located 3.6km from the target. Since the neutral beam remains approximately 15 feet below grade level for 1.8km—an adequate

[25] G. Bock, et al., *Technical Requirements for the KTeV Experimental Facility*, Version 2.0, Page 13

[26] Fermi Lab Radiological Control Manual

[27] Ibid

[28] G. Bock, et al., *Technical Requirements for the KTeV Experimental Facility*, Version 2.0, Page 13.

distance to range-out a majority of the muons—the earth's curvature is not explicitly included.

4.3.2 Quality Assurance

The program CASIMU[29] was used to predict dose/rates due to muons produced from interactions with the target and dump. "Physics sources" of muons, e.g. K_L decays, are not accounted for in this model. CASIMU allows the user to specify an arbitrary geometry and incident beam. Muon production and transport is then simulated. Materials are described by their atomic number, atomic mass, density, interaction length, radiation length, elastic cross-section, and ionization potential. Material geometry is specified via the subroutine HITOR. Magnetic fields may also be incorporated into the code via the subroutine FIELD.

CASIMU is a weighted monte-carlo which simulates muon production and transport. Muons are produced by simulating charged pion decay, charged kaon decay, electromagnetic cascades, and prompt production. The muons are then transported through matter where energy loss and scattering are modeled.

CASIMU Benchmarks

The production spectrum used in CASIMU was compared to data from E595 taken from the thesis of Jack L. Ritchie. E595 was an instrumented iron beam dump designed to measure muon production from 350 GeV protons, 278 GeV pions incident. Figure 4.4.2. compares CASIMU predictions to the E595 data. As can be seen, the two are in excellent agreement.

The spatial distribution and absolute rate from CASIMU was benchmarked by Selcuk Cihangir against muon fluxes measured in the E613

29 Op. Cit., CASIMU, A. Van Ginnekin

beam dump experiment. The results, shown in the KAMI Conceptual Design Report, indicate good agreement within a factor of two. [30]

Geometry Validation

Several programs have been written to validate the geometry and magnetic fields used to model the muon sweeping system. Two programs, GVAL and OUTLINE, are used to validate the geometry used in CASIMU. Both programs call the geometry subroutine HITOR. These programs validate the geometry in complimentary manners.

In GVAL, cross-sections of the geometry are specified and the user indicates the material in which he is interested. GVAL searches the area of interest and produces a figure with the pertinent material indicated by dots. Refer to Figure 4.4.3. Note that the location of boundaries is limited by the granularity of the picture.

OUTLINE reads the input deck and draws the outline of each object. Refer to Figure 4.4.4. The principle difference between GVAL and OUTLINE is that OUTLINE draws the object boundaries regardless of material, whereas GVAL indicates the location of one material at a time.

By checking the same cross-sections with both GVAL and OUTLINE, both the material types and boundaries may be checked.

Magnetic Field

The program BVAL is used to validate the magnetic fields. BVAL allows the user to plot the magnetic field components along any axis by calling the CASIMU subroutine FIELD for the appropriate coordinates. Figure 4.4.5. illustrates the Y (vertical) component of the magnetic field as a function of lateral displacement through NM2S2.

---

30 K. Arisaka, et. al., *Conceptual Design Report: Kaons at the Main Injector*, Fermilab Report FN-568, (June 1991)

The magnetic fields used in the model were generated using the CERN package POISSON which consists of programs to calculate magnetic fields (POISCR), to plot isocontours (TRIPCR) and determine forces. POISCR allows the user to generate a field map of the magnet modeled. This field map may be dumped as raw data for further use (for example, by the program TRIPCR).

The CASIMU subroutine FIELD was modified to read POISSON generated field maps. This allowed subroutines to be called which could interpolate the magnetic field at any point. These subroutines were lifted directly from POISCR. Thus the same program which did the initial field calculation also did the field interpolation.

Because POISCR is a two dimensional program, Z (parallel to neutral beam) components of the magnetic field are not accounted for. However, fringe fields are expected to be small compared to the total field.

4.3.3 System geometry

Because of the short secondary beam length (~86m from target to defining collimator), the muon sweeping system is designed as an integral part of the target pile.

Sweeping System

The sweeping system consists of three magnets as listed in Table 4.4.2. Refer to figure 4.4.4 for layout.

Table 4.4.2.
Muon Sweeping System

Name	Length [m]	Field [kG]	Field Integral [kGm]
NM2S1	3.81	5	19
NM2S2	5.49	24	131
NM2S3	5.79	21	122
TOTAL:	15.5	NA	273

NM2S1 imparts a lateral kick to prompt muons and pions which may decay before reaching the dump. NM2S2 (located after the beam dump) is a wide pole-tip magnet (91.4cm) which imparts a large (4.25GeV/c) lateral kick to the remaining muons. Furthermore, the field density in the return yoke is about one half that of the pole-tip, lessening problems of wrong direction sweeping. NM2S3 (Figure 4.4.6.) is a new magnet with a large pole-tip (40cm) and a single wide (60cm) return leg located far (110cm) from the center of the pole. This combination provides for small wrong direction sweeping and large transverse kick (3.8GeV/c).

Although the return yokes of the sweeping magnets are far from neutral beam center and the field densities are low compared to the central field, low energy muons can reach the return yokes and be swept back toward the detector. This source may be minimized by the addition of passive shielding.

Passive Shielding

A careful analysis of the model shows that the muons with a momentum of approximately 10 GeV/c or less are being swept back toward the detector.[31] Because low energy (10 GeV) muons lose energy at about 1

[31] T. Kobilarcik and S. Childress, *Muon Shielding Requirements for KTeV*, KTeV Internal Note, April 2, 1993.

GeV per meter of iron, a 10m long block of iron will reduce the rate from these "return-yoke" muons. When an 8' high by 8' wide by 10m long block of iron, located between NM2 and NM3, was added to the model, the muon rates decreased significantly. (This decrease is addressed quantitatively in Section 4.4.4).

4.3.4 Rate projections

The program CASIMU was used to calculate muon rates at the detector, counting house, and site boundary.

Experimental Rates

Figure 4.4.7. summarizes the projected muon rate at the detector for six runs of CASIMU. Each run used a different random number seed, and used 10,000 primaries on target. Averaging the six runs yields a rate of 99±23 kHz. Recall that for the purpose of this calculation, the detector is taken to be a four meter by four meter area centered on the neutral beam, located 185m downstream of the target.

Figure 4.4.8. shows the muon distribution in the detector plane (note this is plotted on a logarithmic scale). Each bin is 50cm wide and four meters tall. Each bin is centered vertically on the neutral beam. The distribution is uniform within the detector, and rises sharply beyond it.

Passive Iron Filter

Without this shielding, the rate in the detector is 330±85 kHz. This is the result of 5 runs, with 50,000 primaries on target.

Sweeper Efficiency

Figure 4.4.9. shows the muon distribution with NM2S3 off. Although very close to beam center the rate is comparable to that with NM2S3 on, the

distribution rises much more sharply. The rate in the detector is 1044±53 kHz—the rate increases by an order of magnitude.

Environmental Rates

Figure 4.4.10. shows the muon dose at 146m from the target. Figure 4.4.11. shows the muon dose 185m from the target. This region is of interest because dose in the counting house is predicted. In both figures, each bin is 3' by 3'. Referring to Figure 4.4.11., the peak dose is 0.16 mrem/hr. However, averaging over the adjoining eight bins yields an average dose of 0.05 mrem/hr., well below the allowed limit. This calculation is based on 12 runs of 10,000 primaries each, each run having a different seed.

Figure 4.4.12. shows the dose at the site boundary. Each bin is five meters by five meters. Ground level is indicated. Note that with the exception of two spikes, the dose remains well below 1 mrem per 10^{18} protons. As the two spikes are surrounded by empty bins, and their error bars are comparable to their magnitude, these significance of these spikes is negligible.

4.3.5 Conclusion

In conclusion, a muon sweeping system is designed which satisfies both experimental constraints and environmental constraints.

Table 4.4.3. summarizes the results.

Table 4.4.3.
Summary of Results

REGION	RATE	NUMBER OF PRIMARIES
Counting House	0.05 mrem/hr	120,000
Detector	100 kHz	60,000
Site Boundary	<<10 mrem/yr	60,000
"Physics Sources"	200 kHz (E799-II)	(see Sect 1.3.2)

Cross Section of KTeV Experimental Hall

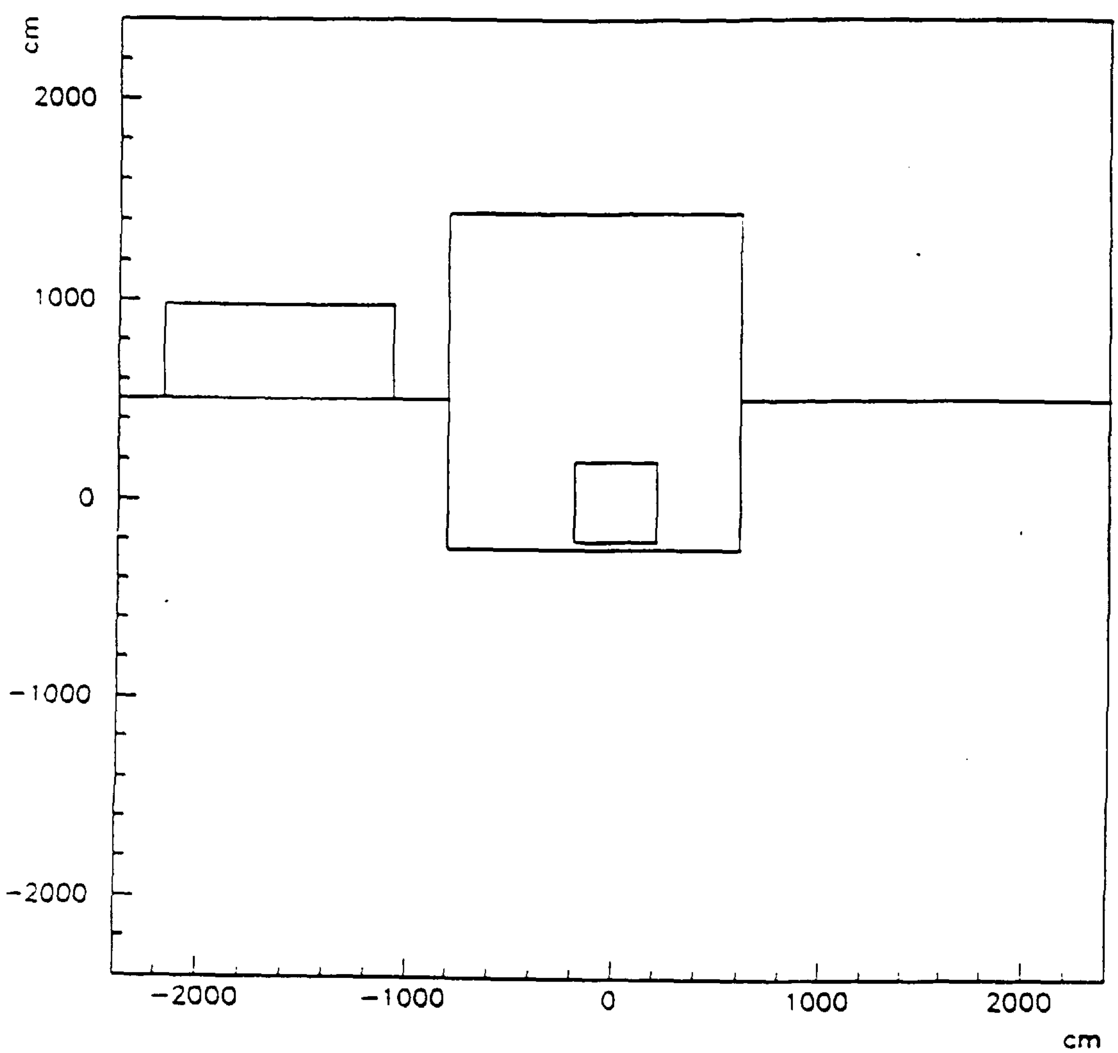


FIGURE 4.4.1.

Comparison of E595 and CASIMU

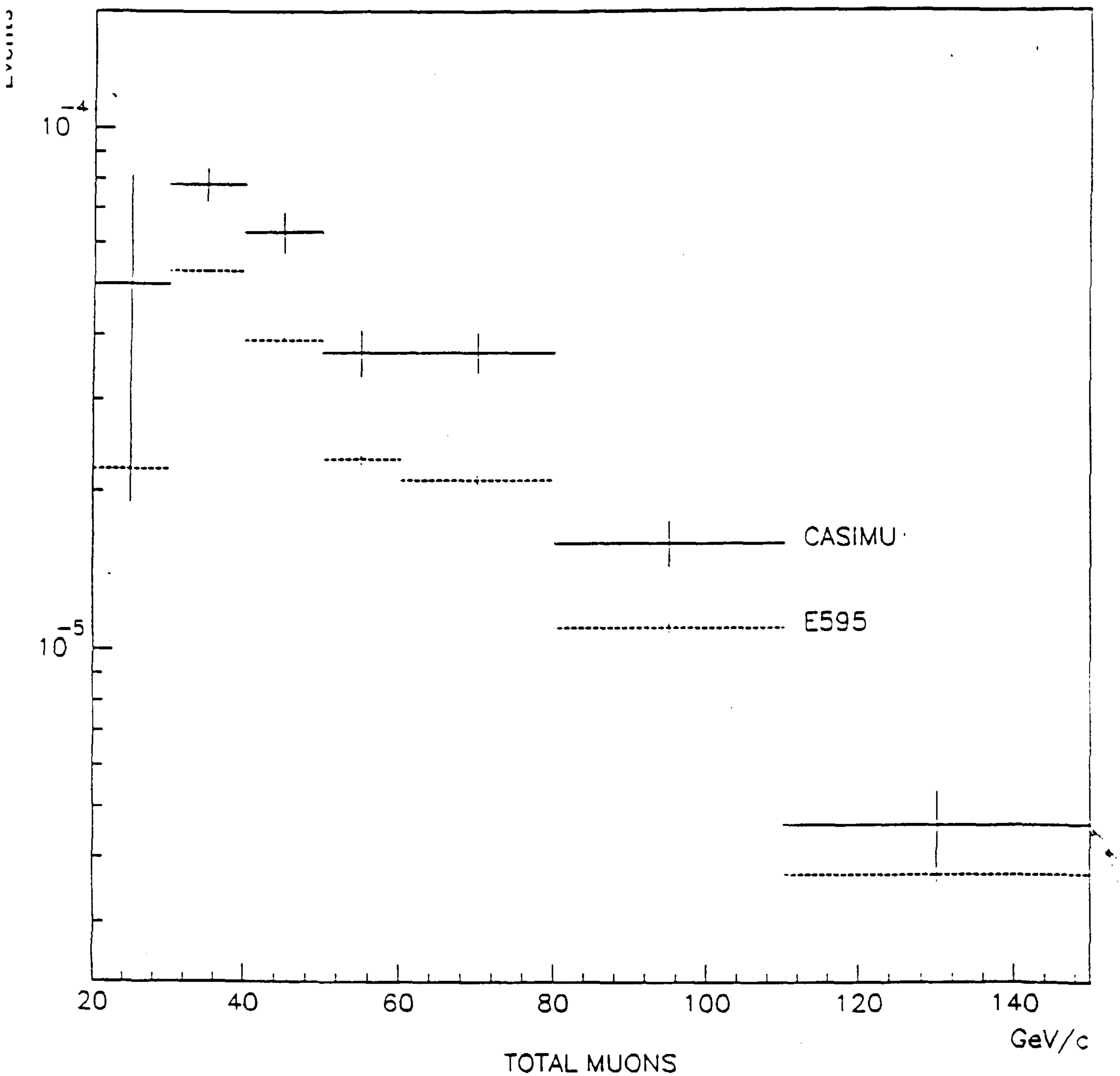


FIGURE 4.4.2.

Cross Section of Secondary Beamline Using GVAL

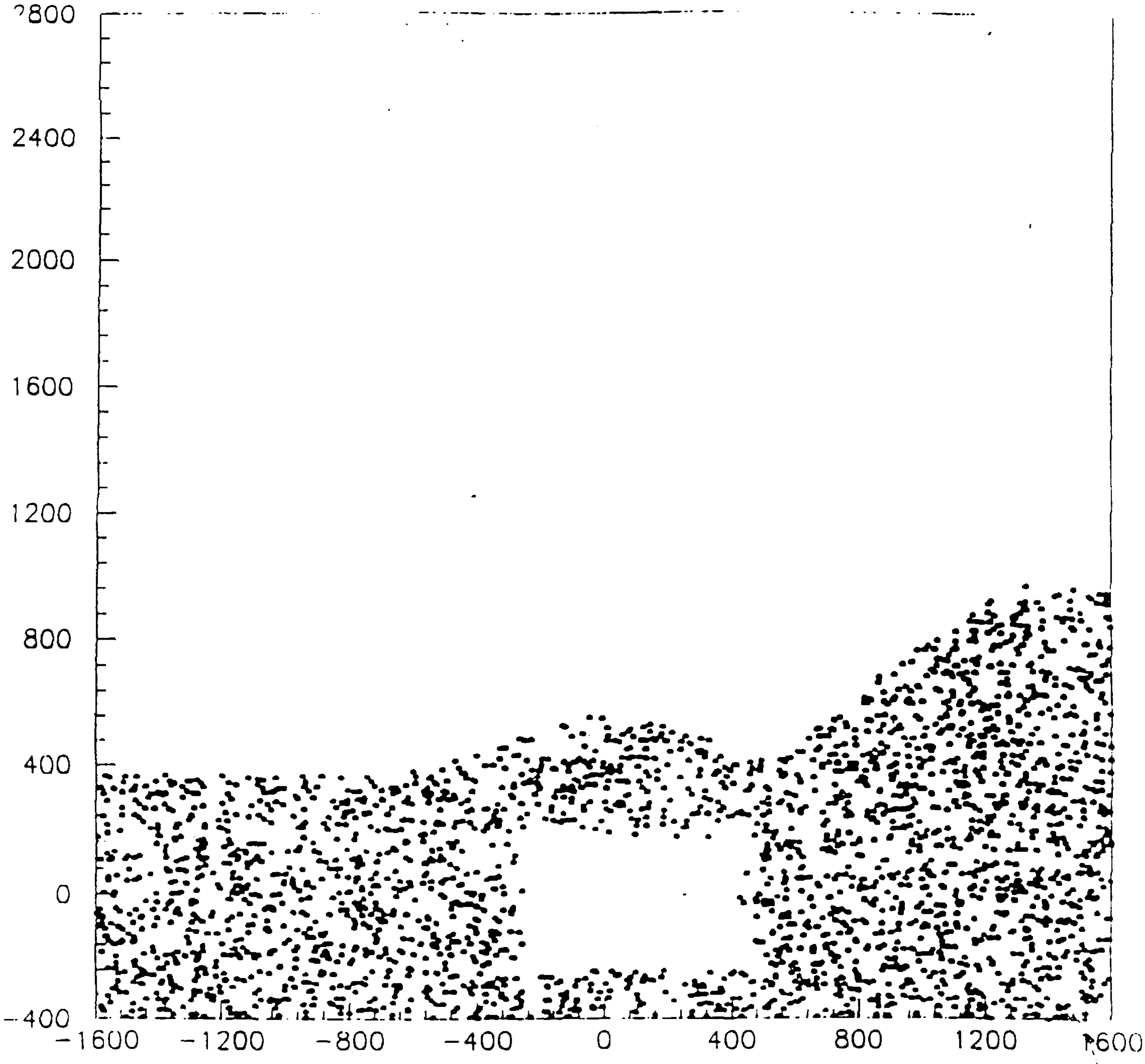


FIGURE 4.4.3

XY Sect. at Z = 9500.0 cm

Plan View of KTeV Target Hall using OUTLINE

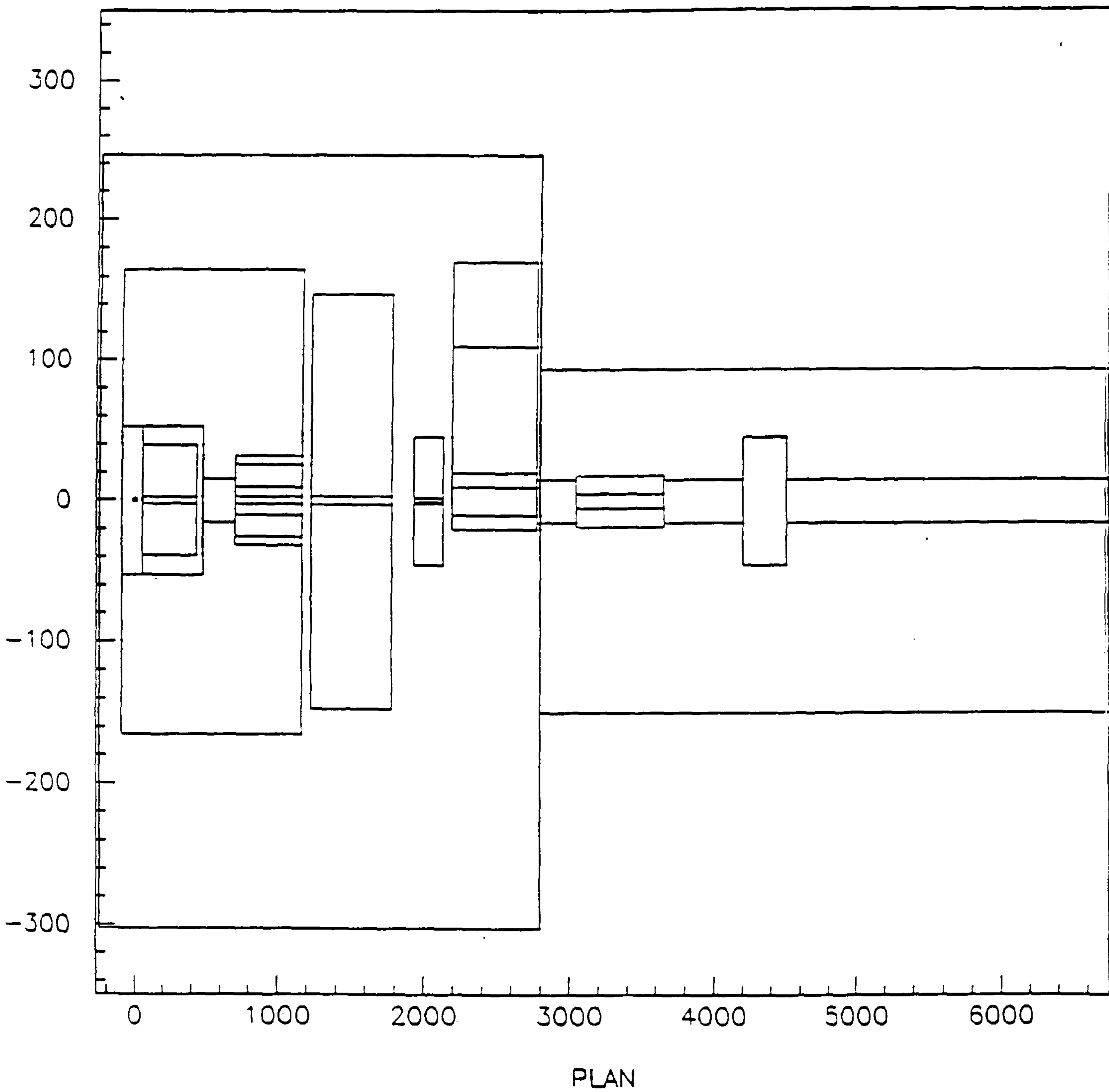


FIGURE 4.4.4.

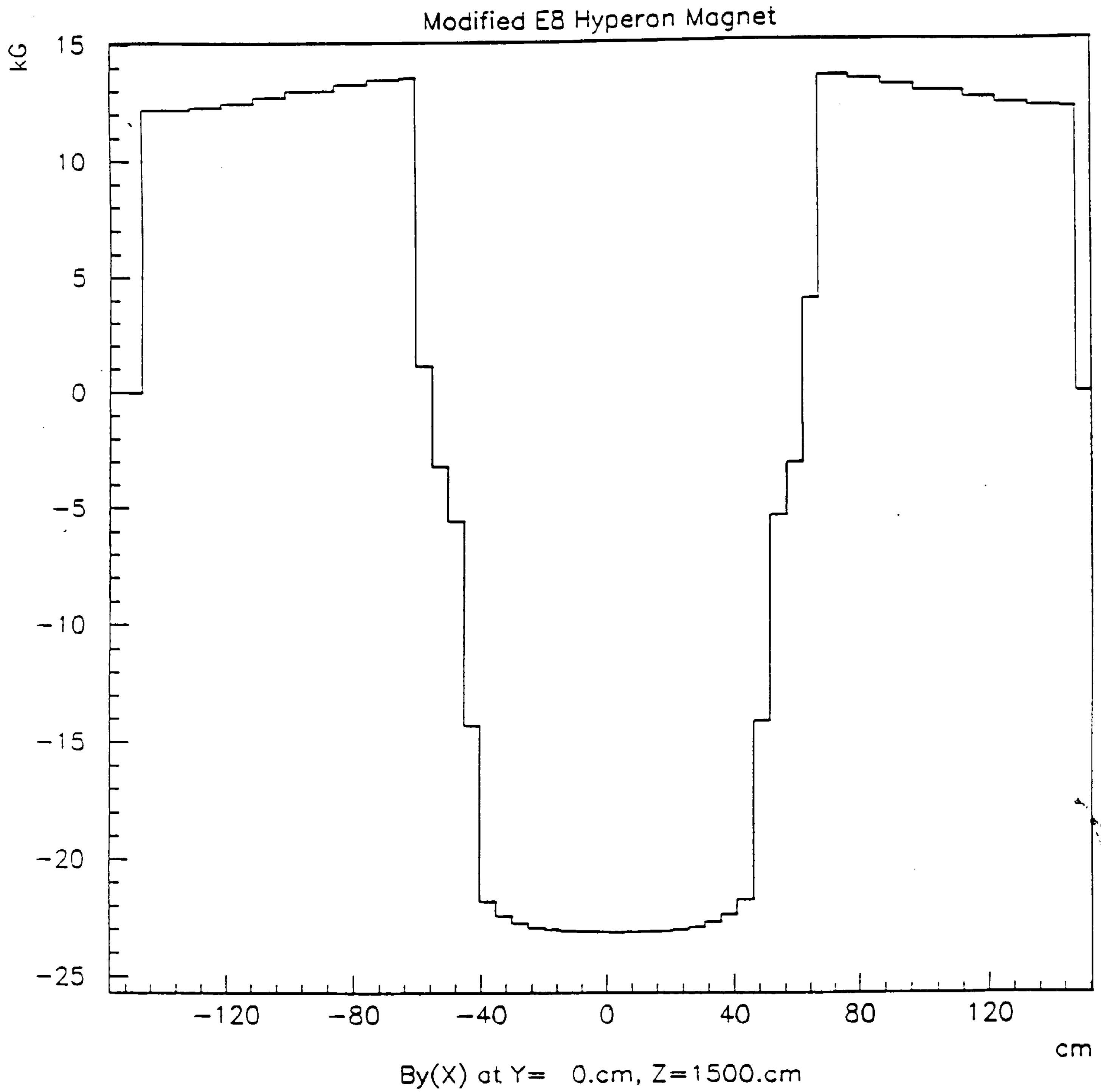
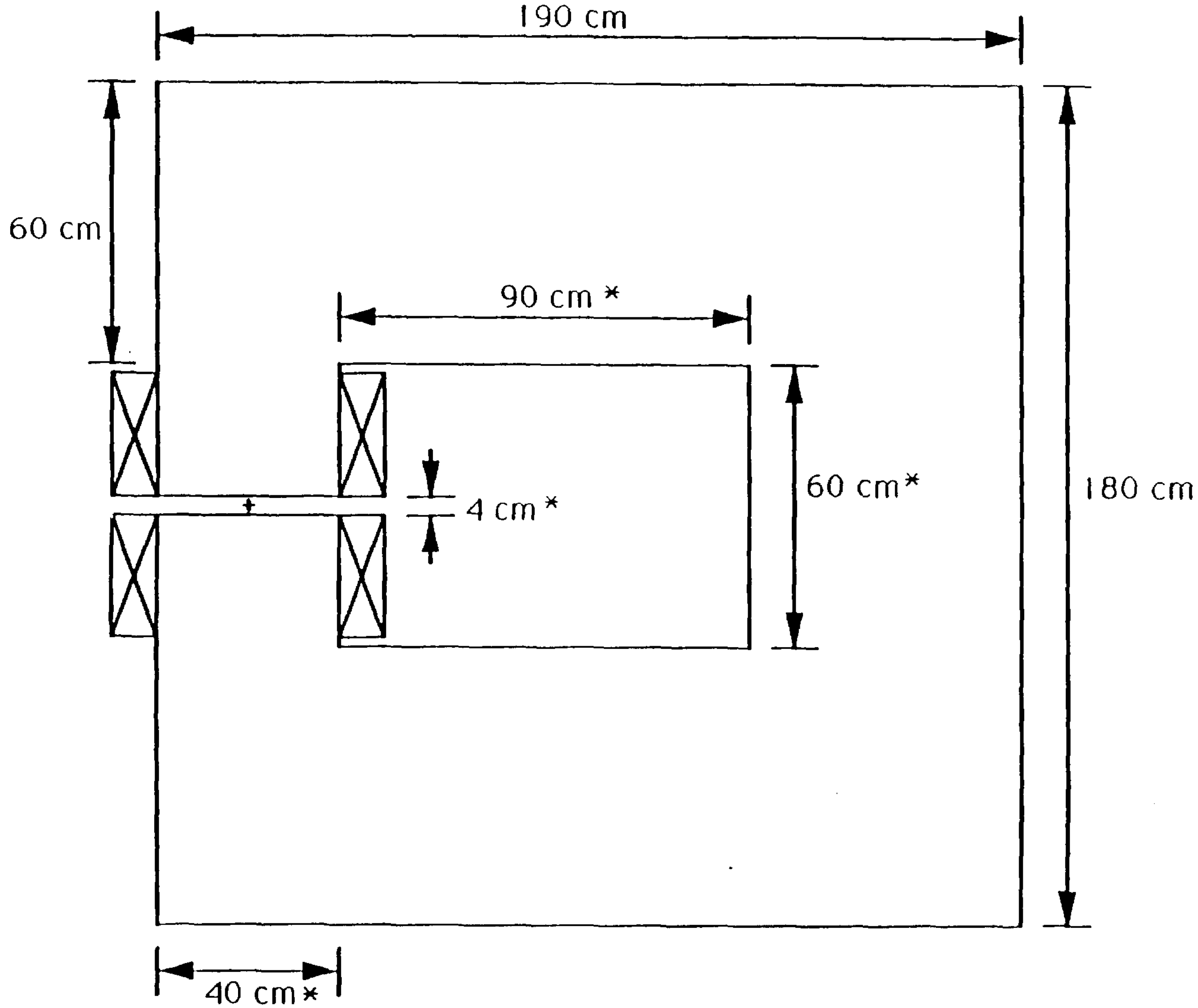

Modified E8 Hyperon Magnet
kG
15
10
5
0
-5
-10
-15
-20
-25
-120
-80
-40
0
40
80
120
cm
By(X) at Y= 0.cm, Z=1500.cm

FIGURE 4.4.5.

Conceptual Design of NM2S3



NM2S3 version 2
coils are conceptual only
length: 580 cm
mass: 130730 kg or 144 tons
* indicates non-negotiable

FIGURE 4.4.6.

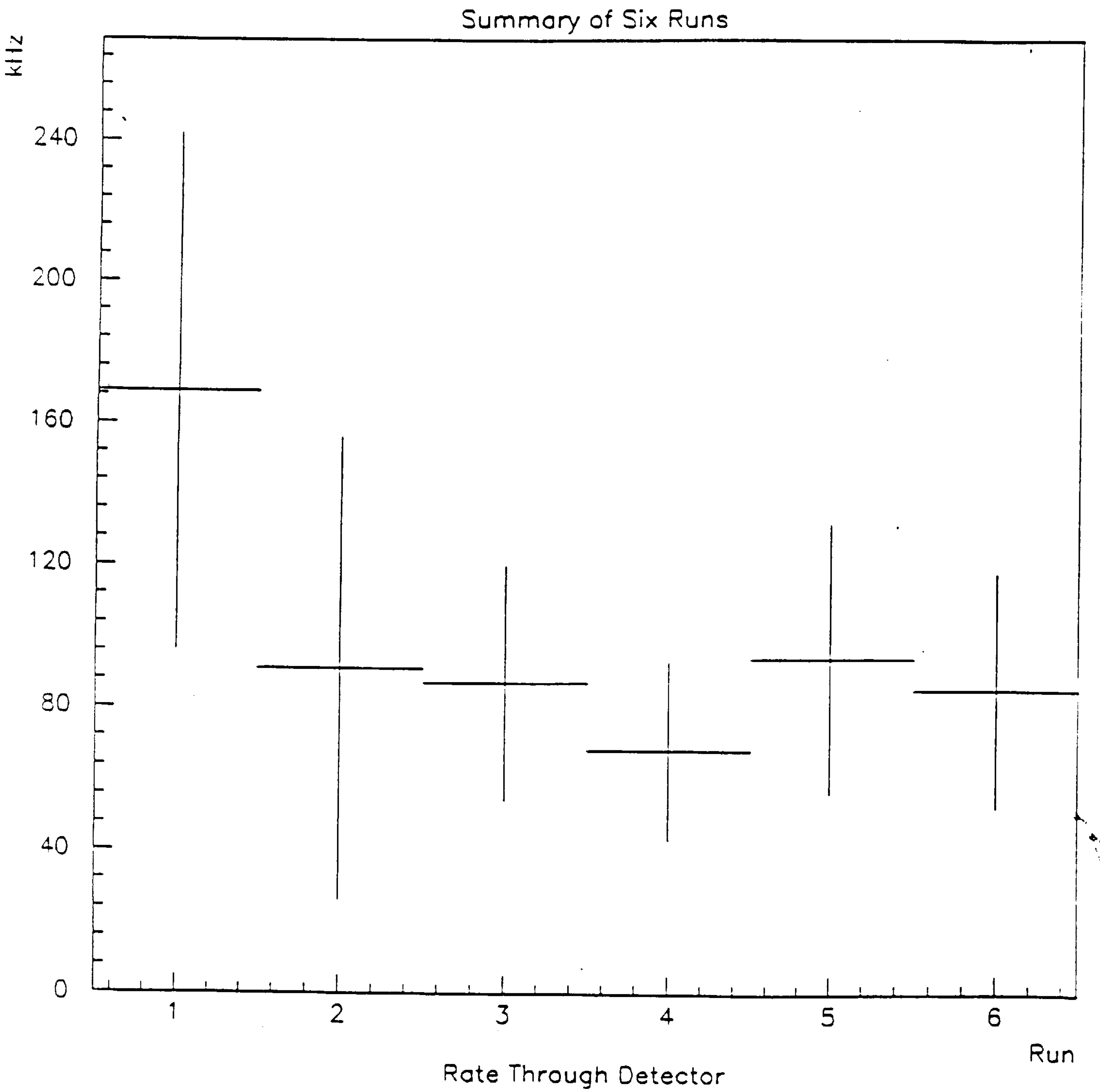
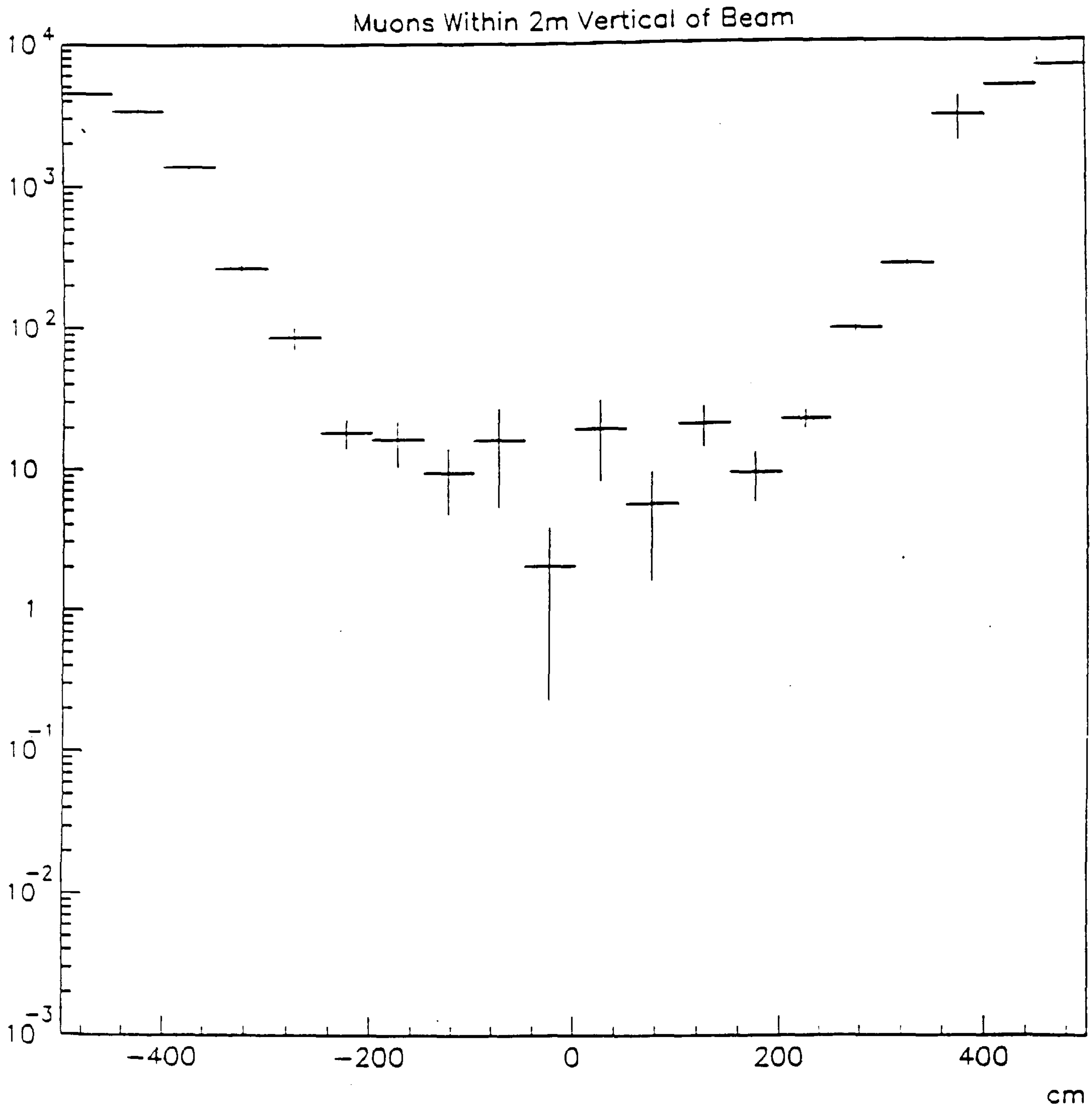

Summary of Six Runs
kHz
240
200
160
120
80
40
0
1
2
3
4
5
6
Run
Rate Through Detector

FIGURE 4.4.7.



All Muons

FIGURE 4.4.8.

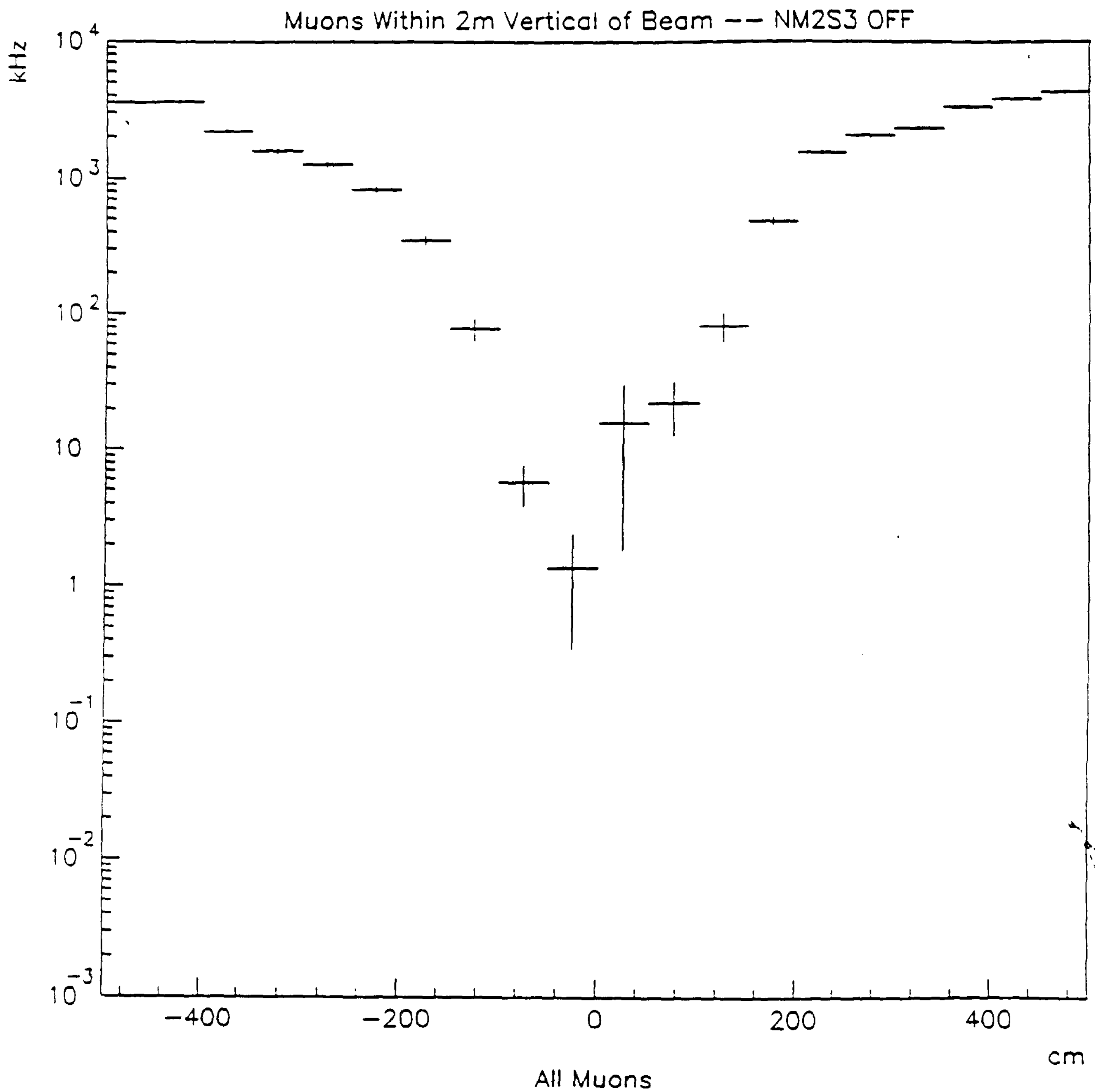

Muons Within 2m Vertical of Beam -- NM2S3 OFF
kHz
10^4
10^3
10^2
10
1
10^-1
10^-2
10^-3
-400
-200
0
200
400
cm
All Muons

FIGURE 4.4.9.

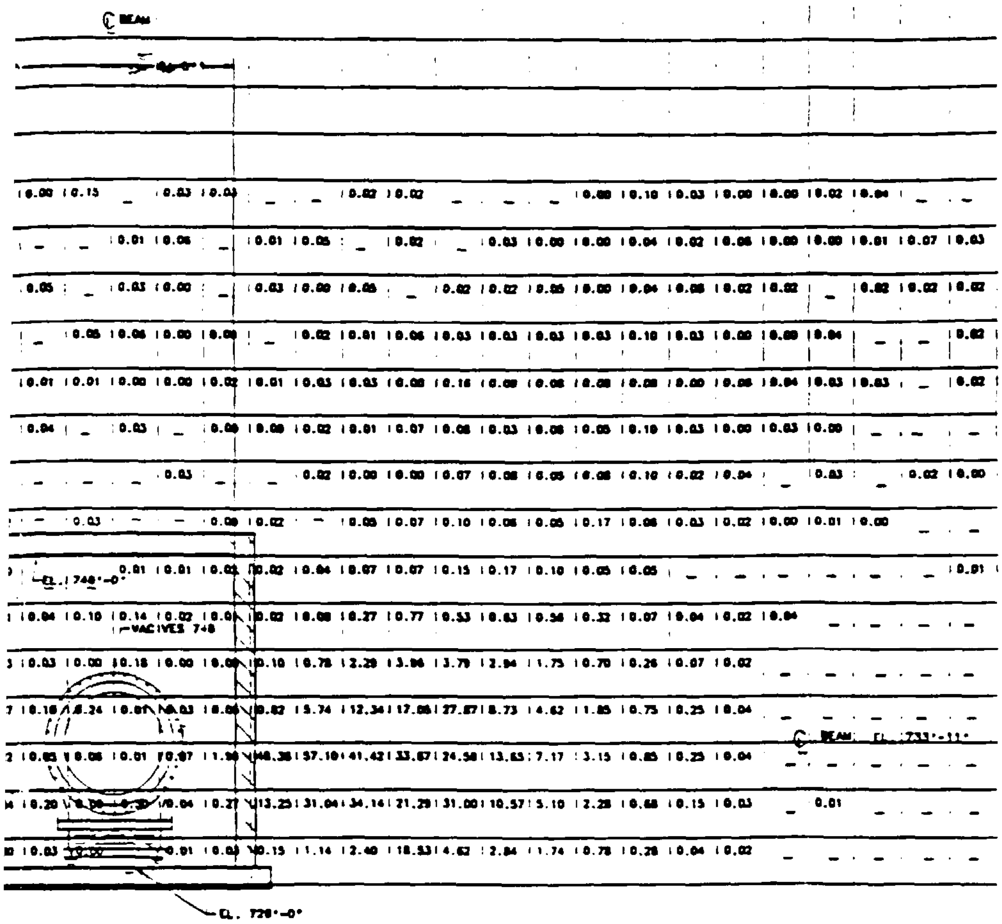
DOSE FROM MUONS PRODUCED IN TAR

—	—	—	—	0.01	—	—	0.00	—	—	0.03	0.05	0.00	0.08	—	0.07	—
0.03	0.00	—	0.00	0.13	0.03	0.03	0.00	0.06	0.59	0.14	0.00	0.05	0.00	0.01	0.00	—
0.00	0.00	0.00	0.00	0.12	0.02	0.02	0.02	0.03	0.08	0.04	—	0.00	0.05	—	0.03	—
—	0.08	0.10	0.04	0.05	0.00	0.00	0.10	—	0.04	0.06	—	0.04	—	0.01	0.10	—
—	—	0.06	0.01	0.00	0.03	0.05	0.03	0.01	0.01	0.05	0.09	0.06	0.03	0.04	0.00	0.10
0.01	0.05	0.00	0.09	0.07	0.14	0.12	0.04	0.08	0.07	0.01	0.07	0.00	0.09	0.02	0.01	0.00
0.01	0.06	—	0.02	0.05	0.02	0.10	0.03	0.08	0.06	0.05	0.09	0.06	0.04	0.01	—	—
—	—	0.01	0.00	0.01	0.04	0.04	0.04	0.03	0.10	0.16	0.12	0.09	0.06	0.02	0.02	—
—	—	—	0.02	—	0.03	0.01	0.04	0.06	0.07	0.06	0.17	0.16	0.07	0.04	0.06	0.01
—	—	—	0.02	—	—	0.01	0.07	0.19	0.25	0.73	0.88	0.63	0.31	0.18	[illegible]12	0.04
—	—	—	—	—	—	0.02	0.18	0.42	1.28	2.20	2.80	3.33	2.35	1.16	[illegible]44	0.04
—	—	—	0.01	—	0.03	0.02	0.24	0.88	3.30	7.45	10.80	12.82	26.80	10.17	7.86	1.17
—	0.01	—	—	0.00	0.01	0.03	0.35	1.51	4.86	11.89	19.31	37.30	31.78	33.81	[illegible].31	30.76
—	—	—	—	—	—	0.08	0.33	1.25	4.52	9.87	28.46	31.48	32.84	26.43	[illegible]7.20	0.63
—	—	—	—	—	—	0.08	0.17	0.83	1.38	3.57	4.70	5.76	3.80	2.34	[illegible]77	0.11

CROSS SEC

DOSE ANI

T/DUMP SYSTEM ASSUMING 5E12ppp 900 GeV



ON AT Z = 146M (478.997')

ERROR IN mREM/HOUR

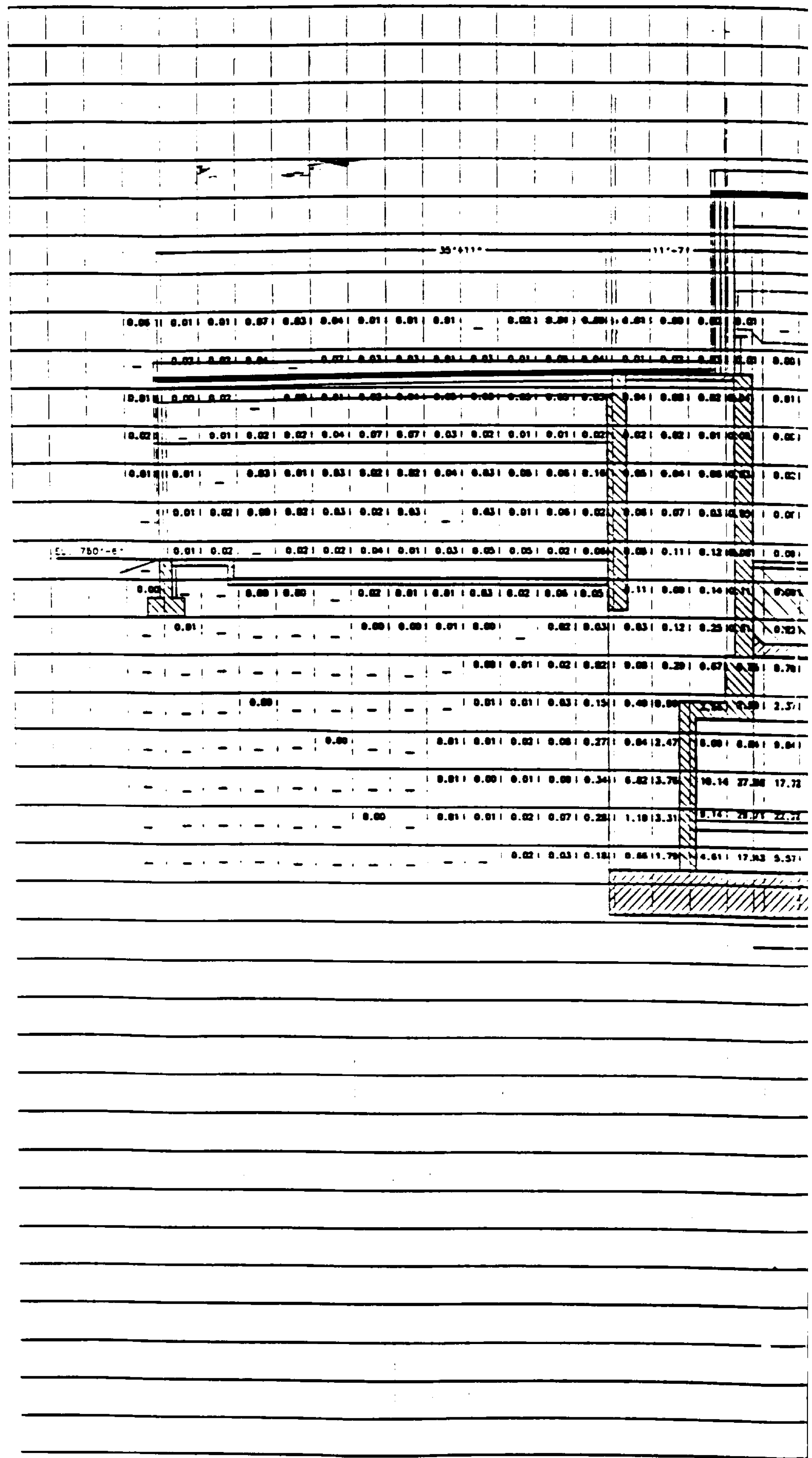
FIGURE 4.4.10.

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

RD/MECHANICAL SUPPORT DEPT.
KTeV EXPERIMENTAL HALL - MUON DC
CROSS SECTION AT Z-146M (478.997

3832.200-ME-257106

DOSE FROM MUONS I



ODUCED IN TARGET/DUMP SYSTEM ASSUMING 5E12 ppp 900 GeV

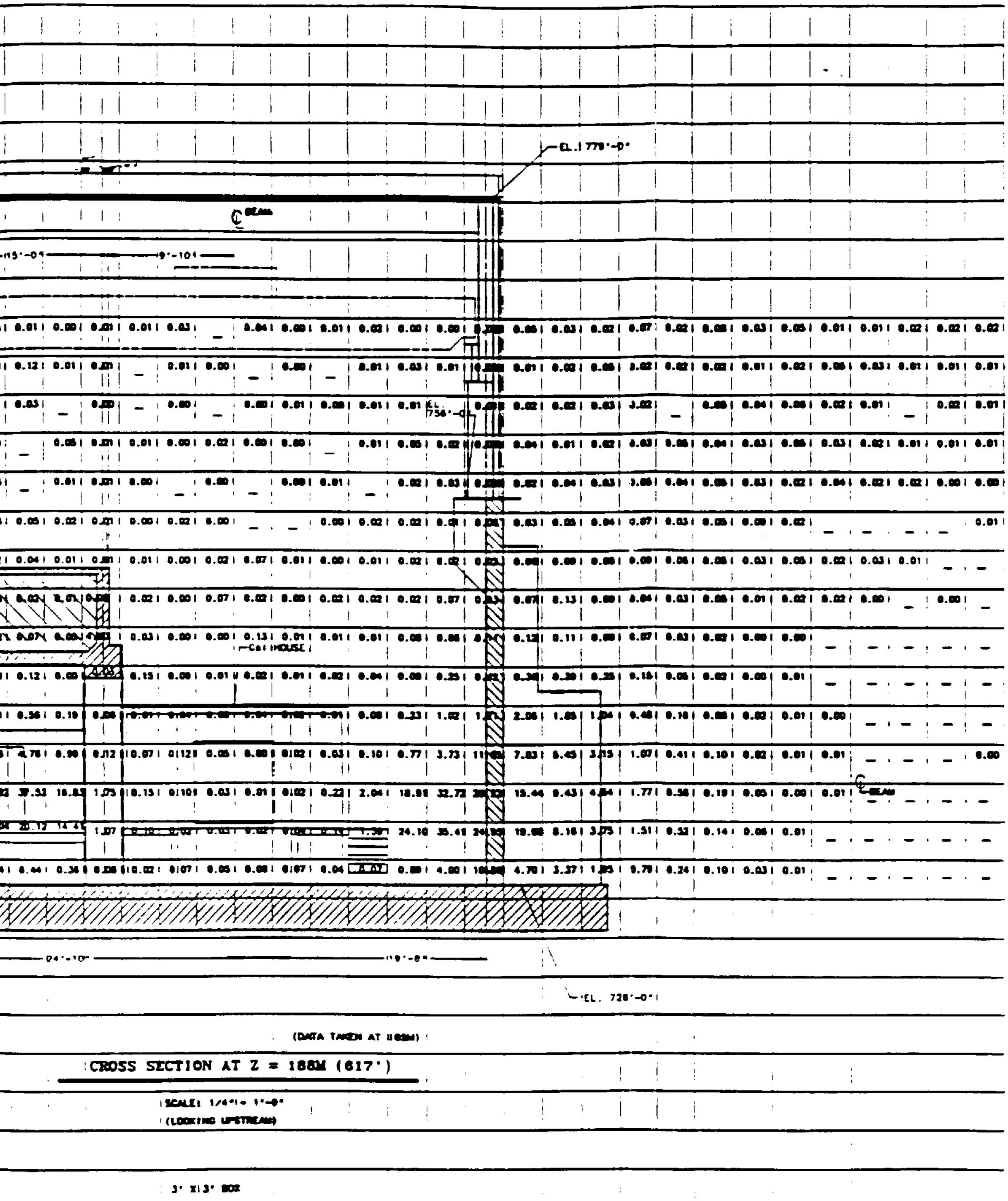


FIGURE 4.4.11.

DOSE AND ERROR IN mREM/HOUR

PARTS LIST

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

RD/MECHANICAL SUPPORT DEPT.
KTeV EXPERIMENTAL HALL - MUON DOSE
CROSS SECTION AT Z = 188M (617')

3832.200-ME-267105

Muon Dose per 1E18 Protons at Site Boundary

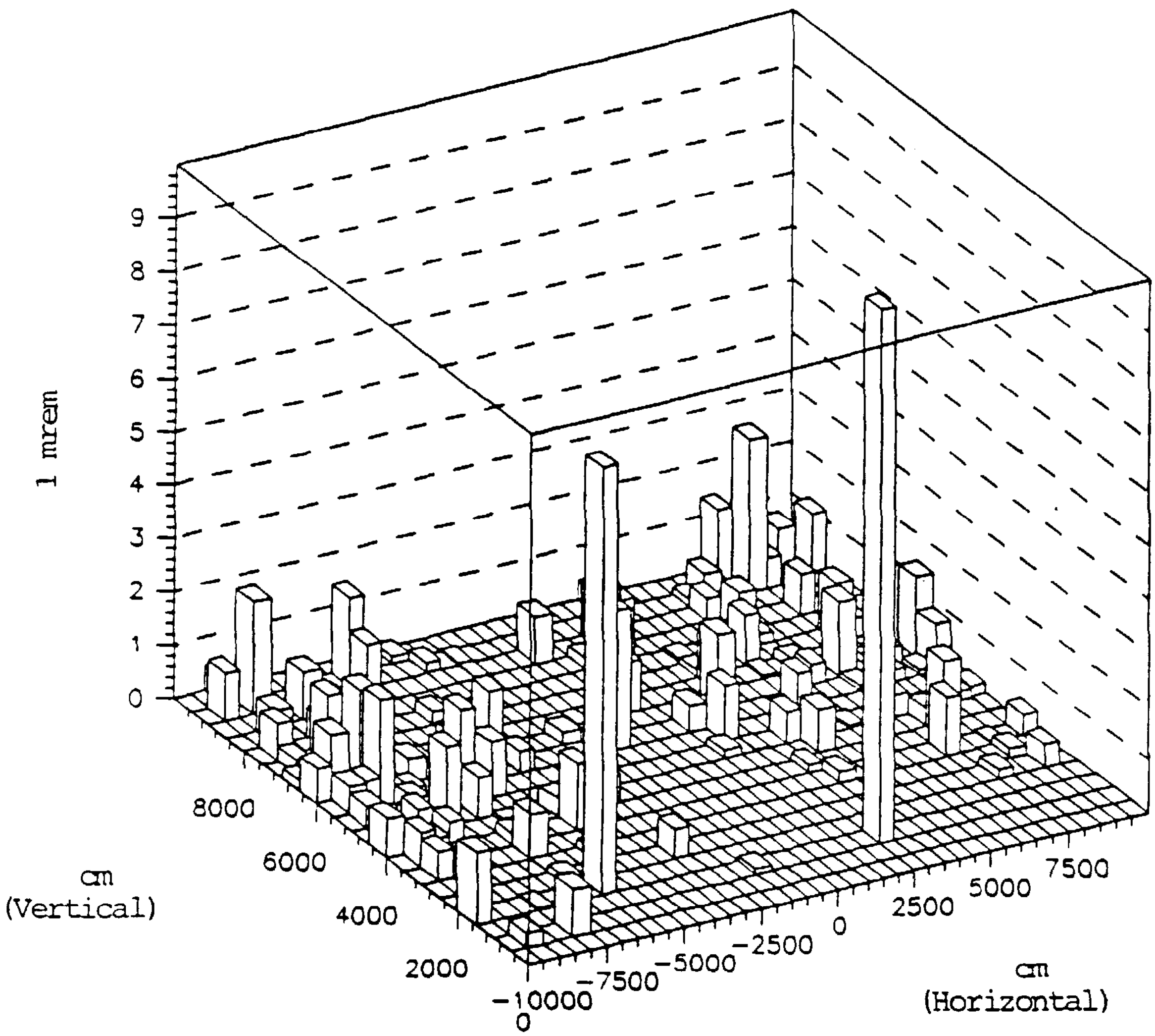


FIGURE 4.4.12.