Fermilab

TM-729
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NEW MUON LABORATORY

Part I: Switchyard

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1. Introduction

This technical memo describes a series of modifications to the Switchyard which will provide a new primary 1 TeV proton beam to the Neutrino Enclosure 99 (Neuhall) region. In accord with Neutrino Department planning for a new Muon facility, the proton beam is located approximately ten-feet below ground level and arrives approximately 20-feet east of the present beam line at Neuhall (at about 25 mr with respect to that beam). To the extent that it is easy, the present capabilities of the N0 and N7 beam lines are maintained. The design is consistent with both 400 and 1000 GeV operation. All apertures are sized for 400 GeV operation and all field strengths are sized for 1 TeV operation.

Three schemes have been considered. They can be characterized by the locations of the three central elements in any schemes; 1) the electrostatic septa, 2) the Lambertson magnets; and 3) the superconducting bend magnets. The three schemes are delineated in Table I. The advantages and disadvantages of each of the schemes have been considered and listed in Table II.

This memo concentrates on scheme 2. It is sketched in Figure 1. The optics have been worked out for the second scheme and are presented in Figures 2a. and 2b. Here, the beam is brought to a sharp focus at a new muon target location. There is no need for focusing enclosures between G2 and the new target hall unless losses associated with upstream splitting, etc. create too high a radiation problem in the target hall.

2. Beam Line: Strength of Elements

The design of the beam line has assumed parameters as they exist in presently available devices. Thus, the splitting electrostatic septa have 2-cm gaps and are capable of 100-kv operation. This provides 0.03 mr opening angle between the two 1-TeV beams per ten-foot module. The Lambertson magnets (Type II) are capable of 8 kgauss in the gap, providing a deflection of 0.75 mr at 1 TeV. Superconducting magnets are assumed for horizontal bends and some vertical bends. These are capable of 30 kgauss and 2.7 mr per ten-foot module. The quadrupole magnets may be superconducting in any final design. However, quadrupole magnets are assumed to be conventional here. The doublets are spaced so that a single ten foot conventional module serves for each member of the doublet. Furthermore, the quadrupoles are placed without interrupting any cryogenic string of magnets. This avoids extra heat leaks in warm to cold transitions. All trim magnets (MVT's and MHT's) are conventional magnets. Similarly, pulsed trim magnets (PVT's and PHT's) are of the present design.

3. Beam Line: Placement and Number of Components

The placement and number of elements in each design were arrived at by the following criteria.

1. Separation of the two beams must be 0.475" at the entrance to a Lambertson string.
2. Separation of the two beams must be > 9.0" where one beam is in a standard beam pipe next to the other beam in an EPB quadrupole magnet.
3. Vertical and horizontal superconducting bend elements were selected to have the same currents. Matching of the 10 mr total vertical bend in the muon line was then obtained with the number and strength of the vertically bending Lambertson magnets. This particular requirement may be overzealous. Separate cryogenic leads to the vertical and horizontal bend magnet strings adds tuning ease and removes the need for two trim magnets. (Using the same currents involves the same tuning complications as rotating a string of magnets to do horizontal and vertical bends together.)

The specific locations of elements is listed in Table III. The added tunneling required for the elements themselves is as follows:

1. Extension downstream of G1 by 40 feet.
2. New region labeled G1.5 of 70 feet.
3. Extension upstream of G2 manhole by 45 feet.
4. Extension downstream of G2 manhole by 85 feet of standard tunnel - offset by 1 ½ feet from G2 to allow for the horizontal bend.

The details of access to these added tunnel sections is left for future design consideration. Many attractive features may be included in a single construction program when the full 1 TeV Switchyard plans are included.

4. Beam Line: Optics

In the preliminary design an attempt was made to keep beam sizes reasonably small at 400 GeV and still allow the use of conventional guads for 1 TeV. The constraints were a large horizontal size at G1 for the electrostatic split, and a parallel beam out of G2 for the long drift to the target area. The examples (Figures 2a and 2b)show the beam envelope using present 400 GeV parameters. In this scheme the target is located at 5000 feet from AØ. Very similar results are obtained if the target is moved 1000 feet upstream, as the beam is essentially parallel. Table IV shows the initial parameters and the quad currents used. The quads prior to MQ103 were untouched as they are part of other existing lines. The currents listed are for 400 GeV operation. The quadrupole magnet locations are given in Table III.

TABLE I

Three Schemes for New Muon Beam Line

Scheme #	Central Location of Electrostatic Septa	Length of Electrostatic Septa	Central Location of Lambertson Magnet	Length of Lambertson Magnet	Location and Strength of Remaining Vertical and Horizontal Bends
1	"The Notch" 1325'	40'	G1 Enclosure 1675'	20'	8.5 mr vertical and 25.5 mr horizontal at G2 Manhole
2	G1 Enclosure 1700'	50'	New Tunnel Between G1 and G2 2000'	60'	5.5 mr vertical and 24.75 mr horizontal at G2 Manhole
3	G1 Enclosure 1680'	30'	G2 Manhole	110'	25 mr horizontal at G2 Manhole

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TABLE II

Advantages and Disadvantages of Three Schemes

1. Scheme 1:

   A. Advantages

      1.) Minimizes number of septum and magnet elements.

      2.) Minimizes the length of full cross-section tunnel required.

   B. Disadvantages

      1.) Requires digging in the Notch region which cannot proceed while Meson beam line is operational (some possibilities exist to minimize digging by making special narrow devices to fit 12" x 24" region between Enclosure C and the Notch. This digging will close Road D between Road A and the Switchyard Service Building.

      2.) Requires special access to G2 region for cryogenic fluids and, possibly, long magnets.

      3.) Contains least flexibility in terms of maintaining "enhanced" (pinged) beam for Bubble Chamber and slow beam splitting.

      4.) Possible need for modifications to existing equipment to minimize digging in Notch region.

2. Scheme 2:

   A. Advantages

      1.) No new design devices required.

      2.) Potentially most flexible design.

      3.) Modest number of septum and magnet elements.

TABLE II (Cont'd.)

4.) Potential for tie-up of Enclosures C, E, G1, and G2 for common cryogenic and magnet servicing.

5.) Continuous operation of Proton and Meson Laboratory experiments during Neutrino Lab construction.

B. Disadvantages

1.) Longest section of tunnel construction (and consequent cost) to take advantage of flexibility, etc.

3. Scheme 3:

A. Advantages

1.) Starts construction as far downstream as possible.

2.) Uses minimal drift lengths.

B. Disadvantages

1.) Requires the most magnet components.

2.) Requires new design Lambertson magnets.

3.) Requires special access to G2 for long magnets and cryogenic services (from Enclosure C or Enclosure E).

Table III

Components and Center Locations for Scheme 2

			Feet
1.	PHT104	Horizontal Pulsed Bump Magnet	1330
2.	MHT104	Horizontal Splitting Bump Magnet	1335
3.	MQ110	Existing Quadrupole Magnet	1655
4.	PHT111	Horizontal Pulsed Bump Magnet	1660
5.	MHT111	Horizontal Splitting and Angle Bump Magnet	1664
6.	MUSEPT	Electrostatic Septa Modules (5)	1700
7.	MHT112	Horizontal Angle Bump and Trim Magnet	1736
8.	MVT112	Vertical Trim Magnet	1740
9.	MQ112	Existing Quadrupole Magnet	1748
10.	MH116	Horizontal Trim Magnet	1955
11.	MV116	Vertical Trim Magnet	1961
12.	MV116	Lambertson Magnet Modules (6)	2000
13.	MQ120	Existing Quadrupole Magnet	2172
14.	MHT120	Existing Horizontal Trim Magnet	2180
15.	COLL	Existing Collimator from G1	2190
16.	MVT120	Existing Vertical Trim Magnet	2195
17.	MQ121	Existing Quadrupole Magnet	2222
18.	SV122	Vertical Bend Magnets (Superconducting)	2240
19.	SH122	Horizontal Bend Magnets (Superconducting)	2305

TABLE IV

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49                  BEAM LINE OPTICS PROGRAM
  NEUTRINO   MESON   PROTON  1 *2  3  LIST

  QUAD CURRENTS                 XBETA =100
MQ90    74.8 OFN-4   -36        XALPHA= .43
MQ91   -75.05OFT1    -36        XEMIT = .14
MQ100   60.75OFT2     26        YBETA = 72.
MQ101  -60.75ODT      26        YALPHA= .7
MQ103    5.85                   YEMIT =    .08
MQ110  -20.5                        X =        MM
MQ111   20.6                        XP= .05    MR
MQ120  -30.3                        Y =        MM
MQ121   25.55                       YP= .05    MR
OFN-1      0                    ENERGY=  400 G
OFN-2     30
ODN-1     30
ODN-2     30
ODN-3    -36
OFN-3    -36
ENVELOPE  HOR VER Z1=           Z2=5000   FT
RAY TRACE HOR VER Z1=           Z2=5000   FT
ELIPSE    HOR VER Z1=           Z2=5000   FT

 611 CURSOR  Z=      FT    X=      MM
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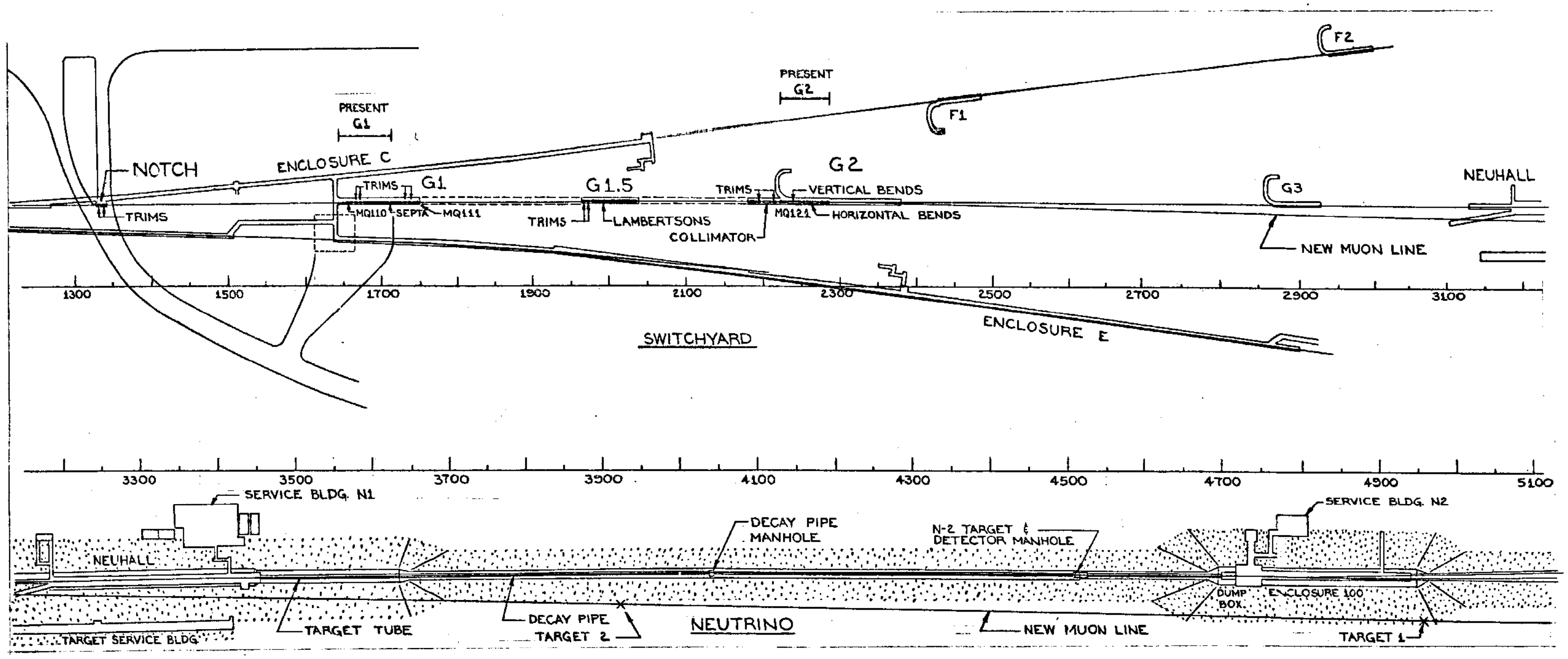
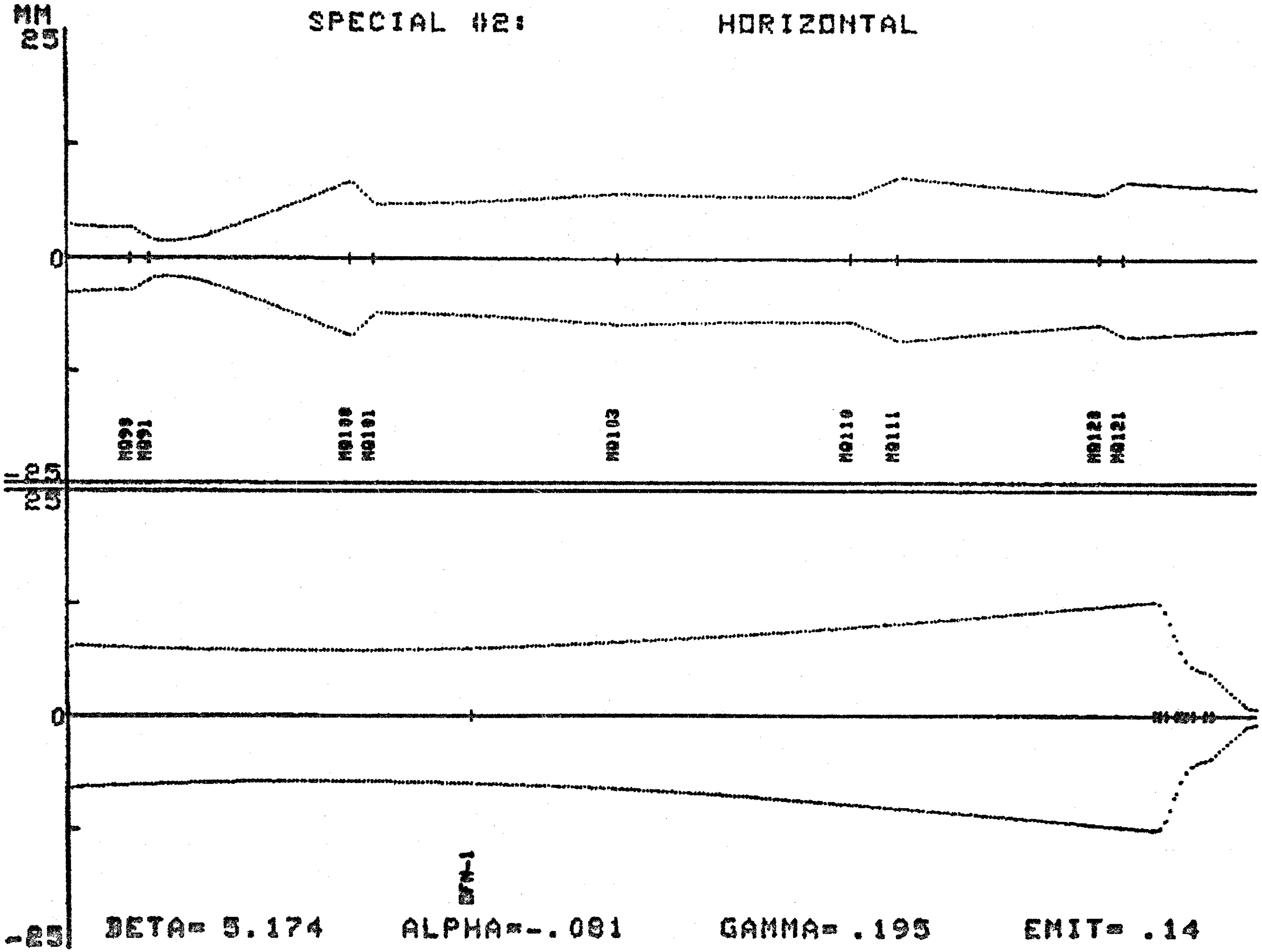

PRESENT
G1
PRESENT
G2
F2
F1
NOTCH
ENCLOSURE C
TRIMS
G1
G1.5
TRIMS
G2
VERTICAL BENDS
G3
NEUHALL
TRIMS
MQ110
SEPTA
MQ111
TRIMS
LAMBERTSONS
COLLIMATOR
MQ121
HORIZONTAL BENDS
NEW MUON LINE
1300
1500
1700
1900
2100
2300
2500
2700
2900
3100
SWITCHYARD
ENCLOSURE E
3300
3500
3700
3900
4100
4300
4500
4700
4900
5100
SERVICE BLDG. N1
DECAY PIPE
MANHOLE
N-2 TARGET &
DETECTOR MANHOLE
SERVICE BLDG. N2
NEUHALL
DUMP
BOX
ENCLOSURE 100
TARGET SERVICE BLDG
TARGET TUBE
DECAY PIPE
TARGET 2
NEUTRINO
NEW MUON LINE
TARGET 1

Fig. 1



SPECIAL #2: HORIZONTAL
MM
25
0
-25
MQ90
MQ91
MQ100
MQ101
MQ103
MQ110
MQ111
MQ120
MQ121
BFN-1
BETA= 5.174
ALPHA=-.081
GAMMA= .195
EMIT= .14

FIGURE 2a

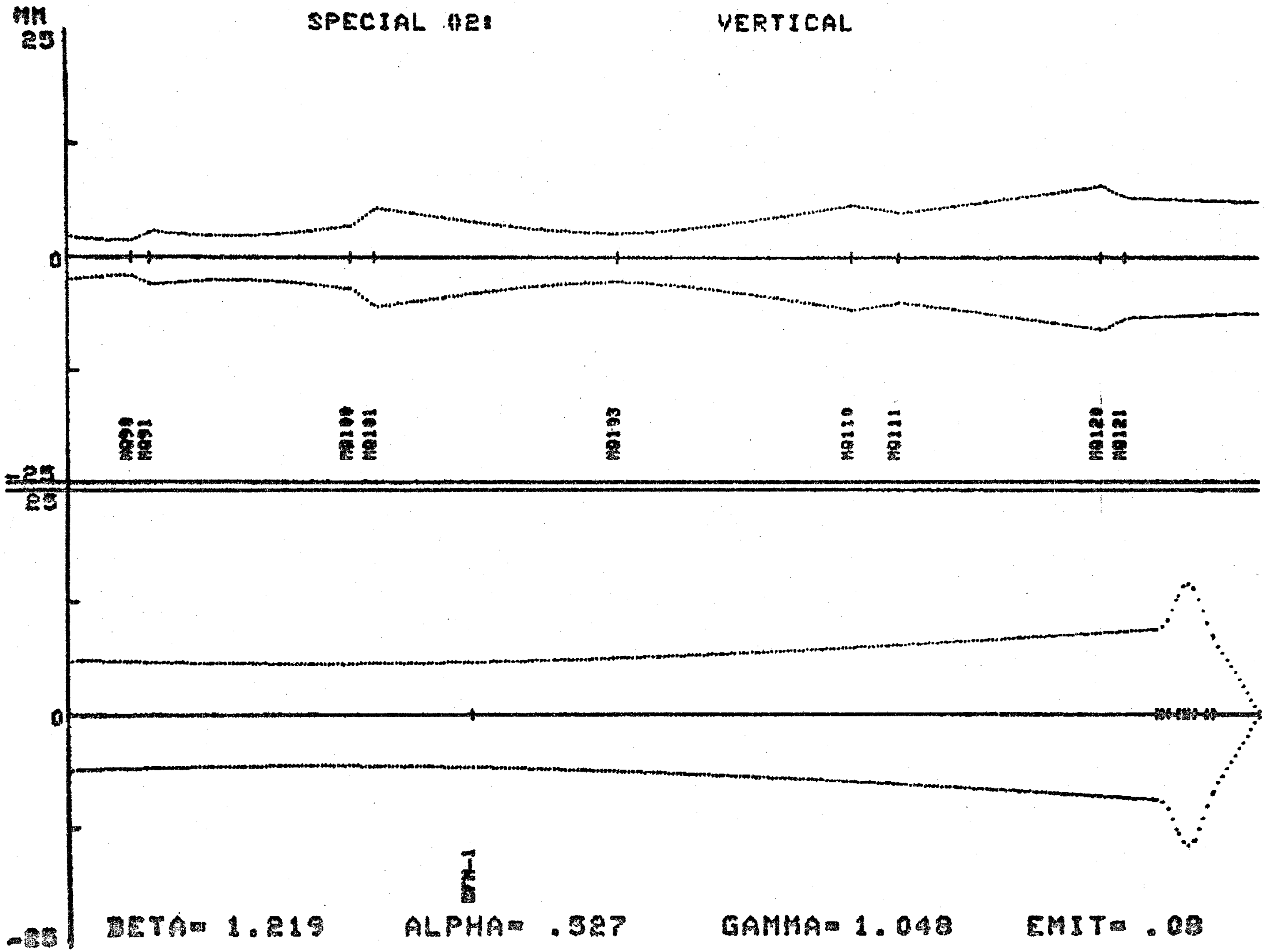

MM
25
SPECIAL 02:
VERTICAL
0
-25
25
0
-25
BETA= 1.219
ALPHA= .327
GAMMA= 1.048
EMIT= .08

FIGURE 2b