

## BEAM OPTICS FOR THE SLOW BEAM EXTENSION

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As presently planned, the SEB extension to the new East Experimental Building Addition (EEBA) will be a straight through extension of the present "R" beam to a target station (heretofore known as target "C") at grid coordinates<sup>1</sup> N15000.000", E14385.343". The target center is then 5929.767" from the SEB fiducial at the center of AGS straight section F13, taken here as the source point for beam optics calculations. The source emittances used are from recent data taken just prior to the 1969 shutdown.<sup>2</sup> For the horizontal emittance (87% contour), I use the ellipse parameters at F13

$$\begin{aligned}\alpha_H &= -2.8896 \\ \beta_H &= 1086.95 \text{ inches} \\ \epsilon_H &= .0618 \text{ inch-mrad}\end{aligned}\tag{1}$$

which pertain for data obtained without simultaneous G10 targeting. (The horizontal emittance is essentially unaffected by internal targeting.<sup>2</sup>) I assume that the larger horizontal (and vertical) beam spots observed<sup>2</sup> for data time-averaged over the entire SEB spill duration can be corrected

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1. H.N. Brown, private communication (Sept. 1969).

2. L.N. Blumberg, M.Q. Barton, J.D. Fox, J.W. Glenn and L.E. Repeta, "Emittance Measurements in the AGS Slow External Beam," BNL Accel. Dept. Int. Rep. AGS DIV 69-12 (1969).

either by eliminating the source of the instability or by adjustment of the existing beam position servo. For vertical emittance at F13 the ellipse parameters are taken as

$$\begin{aligned}\alpha_V &= .9911 \\ \beta_V &= 147.02 \text{ inches} \\ \epsilon_V &= .0684 \text{ inch-mrad}\end{aligned}\tag{2}$$

corresponding to data obtained with 50% of the circulating beam interacting at G10. This emittance is nearly twice as large as the value pertaining without internal targeting.

Considerations pertaining to the optical design are:

(A) It is desirable to retain the existing quadrupoles RQ1 (N3Q36) and RQ2 (8Q48) in their present positions.

(B) The beam envelope should have a horizontal maximum near the anticipated locations of future beam splitters--one just downstream of the existing steel beam stop in the old East Experimental Building (EEB) to provide a future second target in the EEBA building, and another near the present RD1-RD2 magnets to provide simultaneous targeting in EEB and EEBA. Horizontal beam size of  $\sim 1.5''$  seems reasonable with present splitter designs<sup>3</sup> to limit losses to  $\lesssim 1\%$ , and vertical size of  $\lesssim .5''$  is consistent with required septum thickness and field<sup>4</sup>.

(C) Existing quadrupole designs should be used if possible, preferably the old 8Q16 Cosmotron quads which are available<sup>5</sup> and less in demand for experimental physics use than other 8" quads.<sup>6</sup> The gradient of the 8Q16 should not exceed 1.75 kG/in for optimum match to existing power supplies.<sup>6</sup>

3. L.N. Blumberg, "Energy Deposition in Cryogenic Splitter Magnet," BNL

Accel. Dept. Int. Rep. AGS DIV 69-7 (1969), Designs B and D.

4. H. Hsieh, private communication (1969).

5. W.G. Walker, private communication (1969).

6. J.R. Sanford, private communication (1969).

(D) The beam envelope calculated for the 87% contour should not exceed 50% of the vacuum pipe aperture. A 6" diameter pipe has been specified for the SEB extension.

(E) The vertical divergence of the beam spot at target C should be about  $\pm 2.5$  mrad and the vertical size about  $\pm .025''^1$ ; the horizontal divergence should not exceed the vertical but the horizontal size can be larger, say  $\sim .1''$ .

(F) Sufficient reserve capability should be provided in the quadrupoles to operate the beam at  $P \approx 33$  GeV/c,  $\sim 10\%$  higher momentum than we presently achieve for the SEB. Design momentum is taken here as 29 GeV/c.

R. Warkentien pointed out that the simplest configuration to satisfy condition (B) is a horizontally converging lens (HC) at each splitter location and a vertically converging element (VC) between. Clearly, RQ2 must be the HC lens near the upstream splitter. Lens RQ1 must then be horizontally diverging (HD) with the present SEB emittance to increase the horizontal size to 1.5" as required at RQ2. J.D. Fox subsequently determined that conditions (C), (D) and (F) require two vertically converging 8Q16's (RQ3 and RQ4) between the splitter points. The position of the HC quadrupole (RQ5) at the downstream splitter is then fixed by the splitter design<sup>3</sup> and the desirability of locating the quad between the thin and thick septum of the splitter, thus assuring that a horizontally diverging beam impinges on this element. In the present note the position of the downstream quads RQ7 and RQ8 were varied to satisfy condition (E) and the position and strength<sup>7</sup> of matching quad RQ6 was determined to attain equal horizontal and vertical filling of RQ7, RQ8. The final geometry and beam conditions are given in Table I and the resulting beam envelopes using Eqs. 1 and 2 as sources are plotted in Fig. 1. The vertical envelope at RQ4 slightly exceeds the 50% filling

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7. J.D. Fox points out that with a slight modification of beam size at the splitters and a tolerable increase in gradient of RQ3, the strength required of RQ6 is reduced and an 8Q16 could suffice here.

criterion; this can be corrected by slightly increasing the strength of RQ3 without violating condition (F). The constraint that  $RQ3 = RQ4 = RQ5$  used in the computer calculation is arbitrary. Likewise, the slight over-filling of RQ7 and RQ8 can be corrected by increasing RQ5. For the immediate future condition (C) on the maximum gradients of the 8Q16's can be relaxed since they will be operated from 450 KW supplies<sup>8</sup> which can easily supply the 1000 A maximum current (2.3 kG/in maximum gradient) rating. The beam ellipses at target C are plotted in Fig. 2. The spot sizes and angular divergence satisfy condition (E).

In Fig. 2, the envelopes corresponding to emittances for no simultaneous internal targeting are plotted. The vertical source ellipse is then<sup>2</sup>

$$\begin{aligned}\alpha_V &= .9873 \\ \beta_V &= 145.55 \text{ inches} \\ e_V &= .0367 \text{ inch-mrad}\end{aligned}\tag{3}$$

Also of interest is the response of the optical system of Table I to the  $\sim \pm .5\%$  momentum variation in the SEB. In Fig. 4 A, the trajectory of the .5% off momentum central ray is plotted. The horizontal coordinates at the C target change very little, i.e.,  $\Delta X = .004''$ ,  $\Delta X' = .8 \text{ mrad}$ . However, the beam excursion in RQ7 of  $\sim .6''$  is excessive in view of the horizontal filling of RQ7 in Fig. 1. The momentum shift is easily corrected by the ferrite steering magnet; the response of the central ray to a .1 mrad steering magnet bend is plotted in Fig. 4 B and shows a coordinate displacement at target C of  $\Delta X = .012''$ ,  $\Delta X' = 1.2 \text{ mrad}$ . Since the steering magnet has a capability<sup>9</sup> of  $\approx \pm 1 \text{ mrad}$ , we can easily correct for position misalignment at target C with the present location of the steering magnet.

Finally, an additional desirable feature of the optics is that we do

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8. G. Ryan, private communication (1969).

9. A.V. Soukas, private communication (1968).

not have a  $180^\circ$  rotation of the phase ellipse between splitter #1 and #2. A  $\pi$  phase shift would give maximum sensitivity of the horizontal extent of the beam at splitter #2 to the ratio of the split at splitter #1.<sup>10</sup> To illustrate this point, the ellipses of the present solution at the two splitter positions are shown in Fig. 5. If the septum of the upstream splitter is oriented as shown (passing nearly through points 7 and 19), then the image of the septum at splitter #2 is sufficiently tilted so that the beam transmitted to splitter #2 ( $\approx 25\%$  in example shown) will have a horizontal size of  $\approx 75\%$  of the maximum attainable value. Similarly, for a 50-50 split at #1, the size of the transmitted beam at splitter #2 is  $\approx 95\%$  of the maximum.

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10. D. Berley, private communication (1969).

TABLE I

## GEOMETRY FOR SEB EXTENSION

<u>Component</u>	<u>Polarity</u>	<u>Lens Type</u>	<u>Length (inches)</u>	<u>Distance From F13 (inches)</u>
Drift 1			217.25	217.25
RQ1	VC	N3Q36	37.5	254.75
Drift 2			150.55	405.3
RQ2	HC	8Q48	51.5	456.8
Drift 3			627.7	1084.5
RQ3	VC	8Q16	20.0	1104.5
Drift 4			1418	2523
RQ4	VC	8Q16	20.0	2543
Drift 5			1517	4060
RQ5	HC	8Q16	20.0	4080
Drift 6			550.5	4630.5
RQ6	VC	8Q32 *	36.0	4666.5
Drift 7			741.4	5407.9
RQ7	HC	N3Q36	37.5	5445.4
Drift 8			56.0	5501.4
RQ8	VC	N3Q36	37.5	5538.9
Drift 9			390.9	5929.8

\* See footnote 7

## LOCATION OF CENTER OF QUADRUPOLES

<u>Lens</u>	<u>Distance From F13 (inches)</u>
RQ1	236
RQ2	431
RQ3	1094.5
RQ4	2533
RQ5	4070
RQ6	4648.5
RQ7	5426.65
RQ8	5520.15



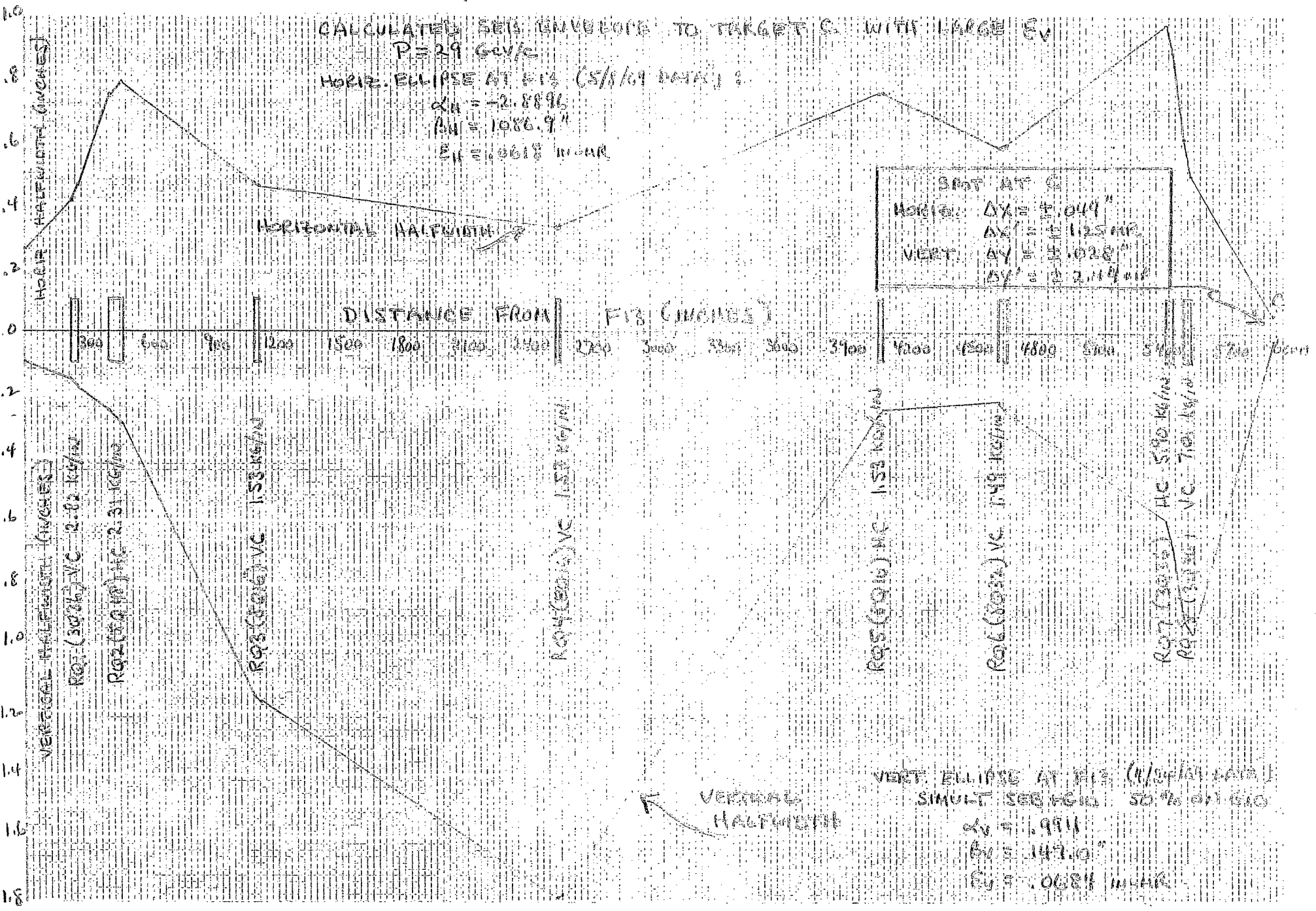
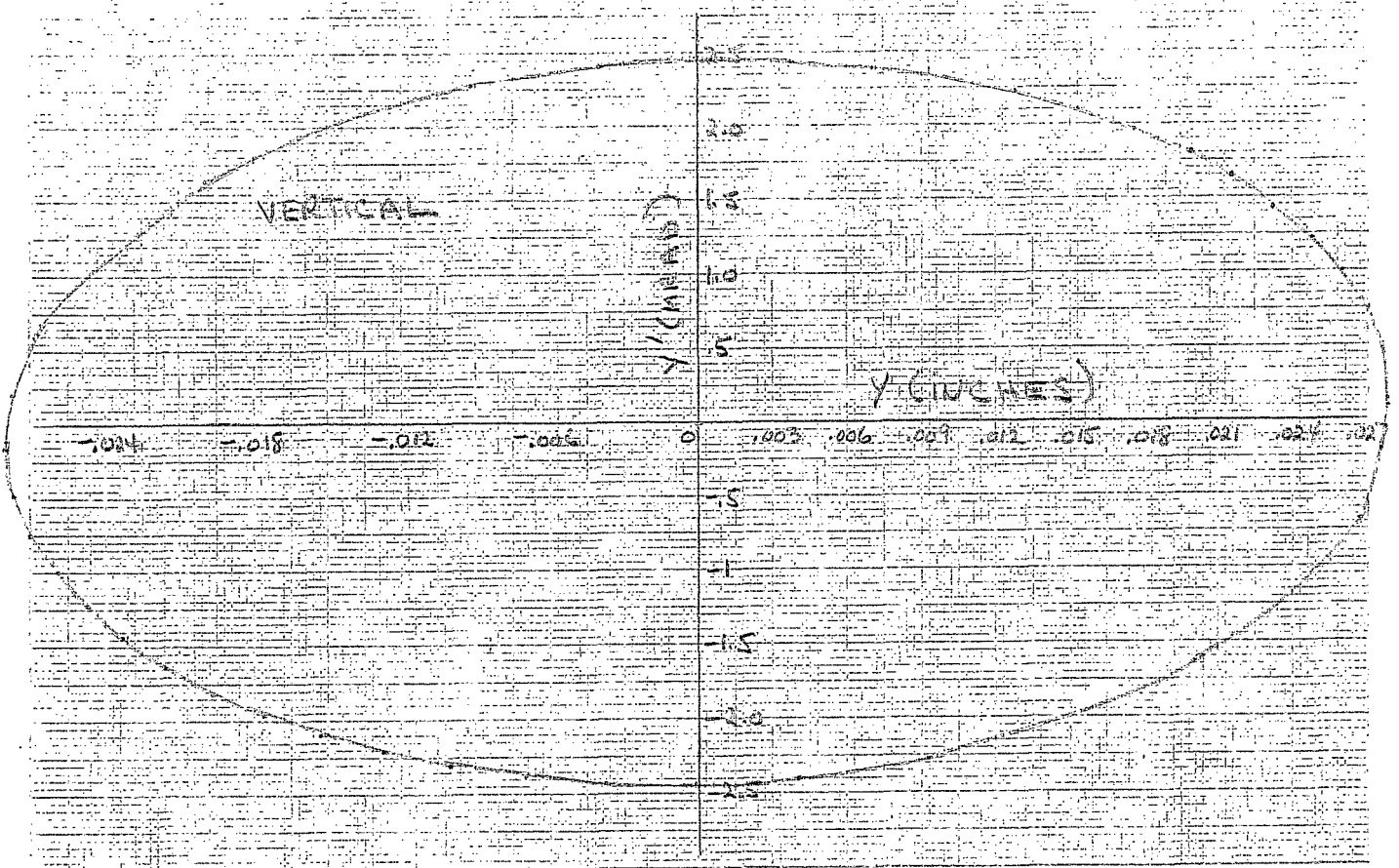
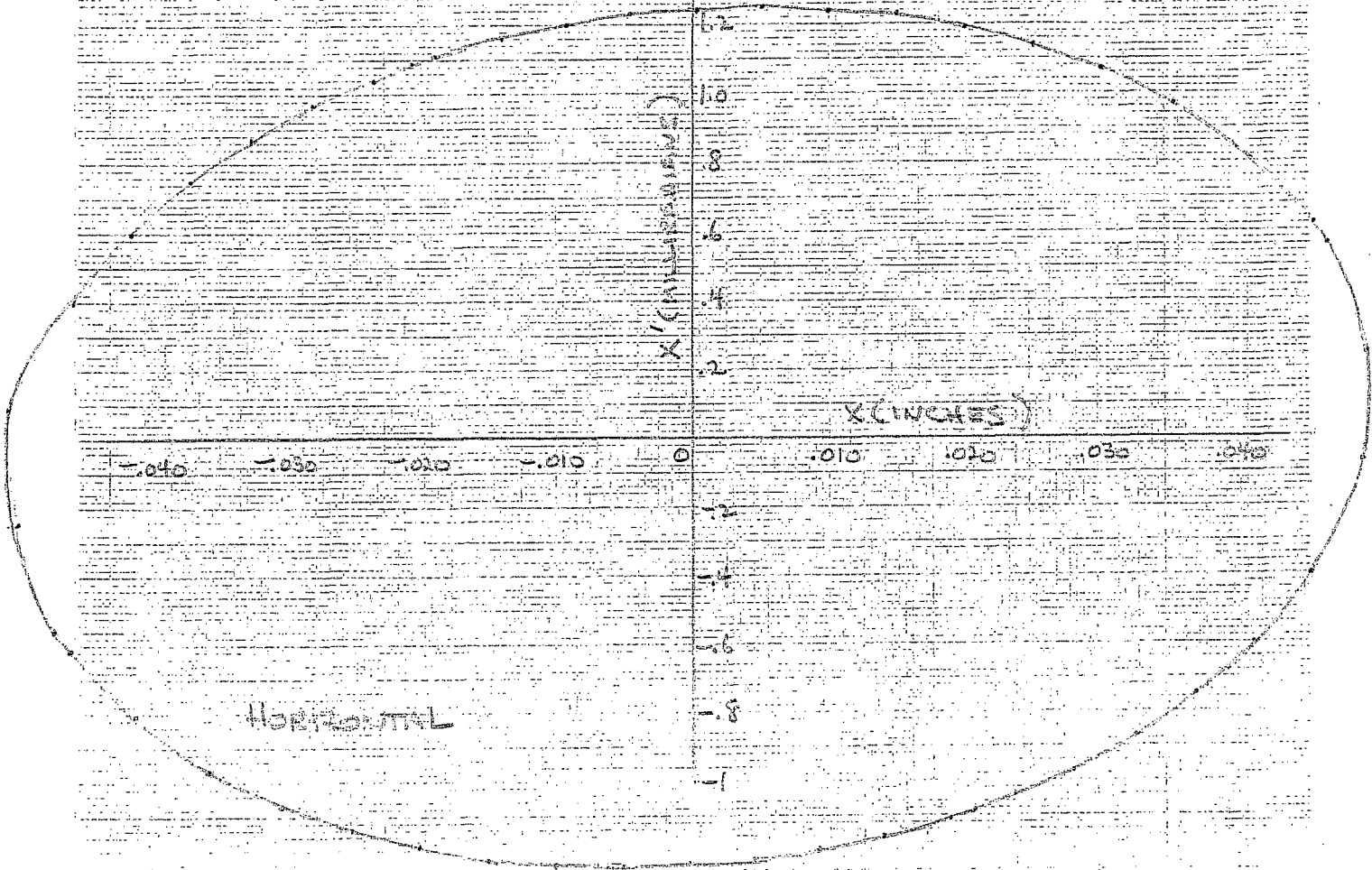
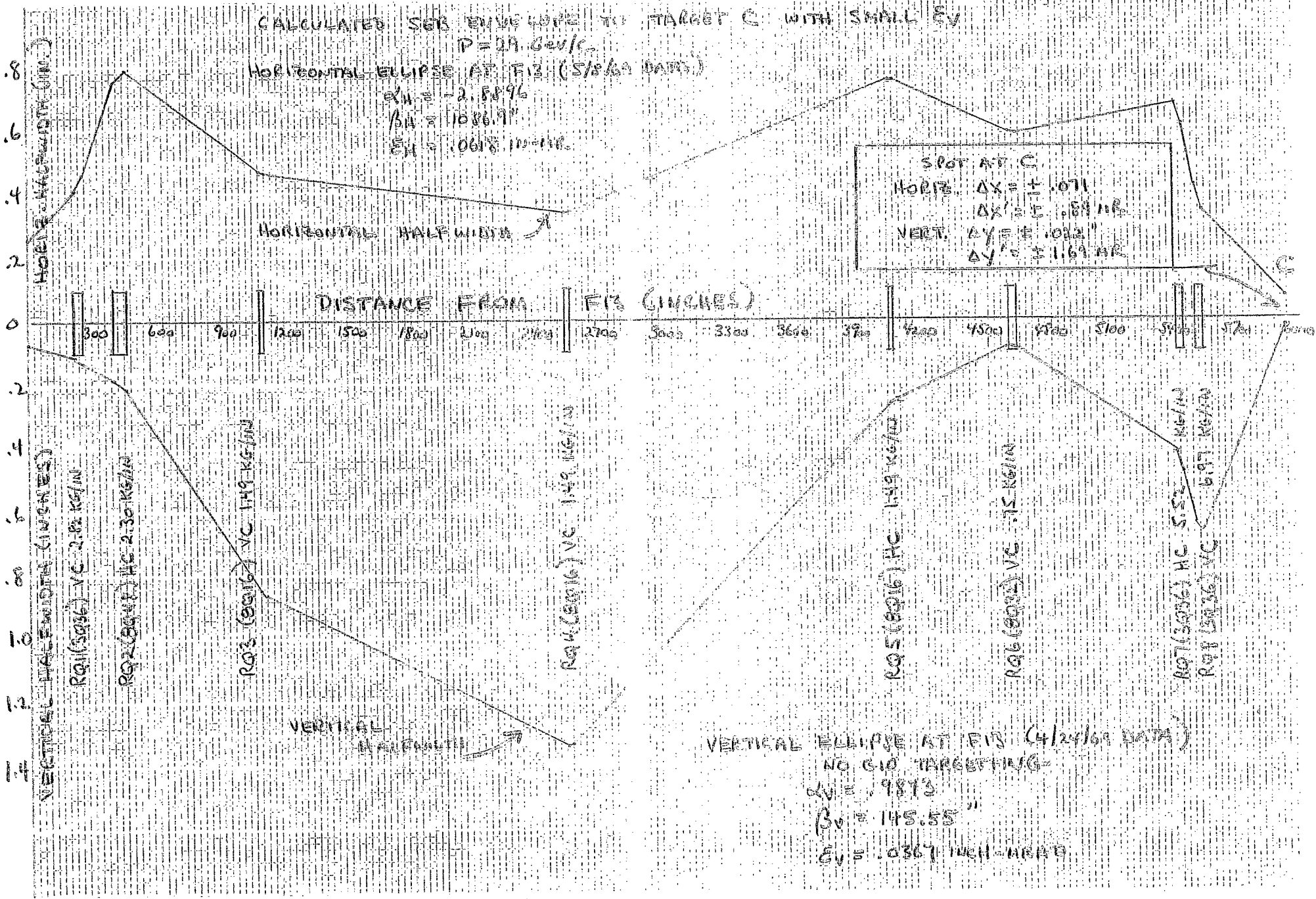


Fig. 1

# EXPECTED HORIZONTAL AND VERTICAL ELLIPSES AT TARGET C



Case 62 10/3/69



10000 1000

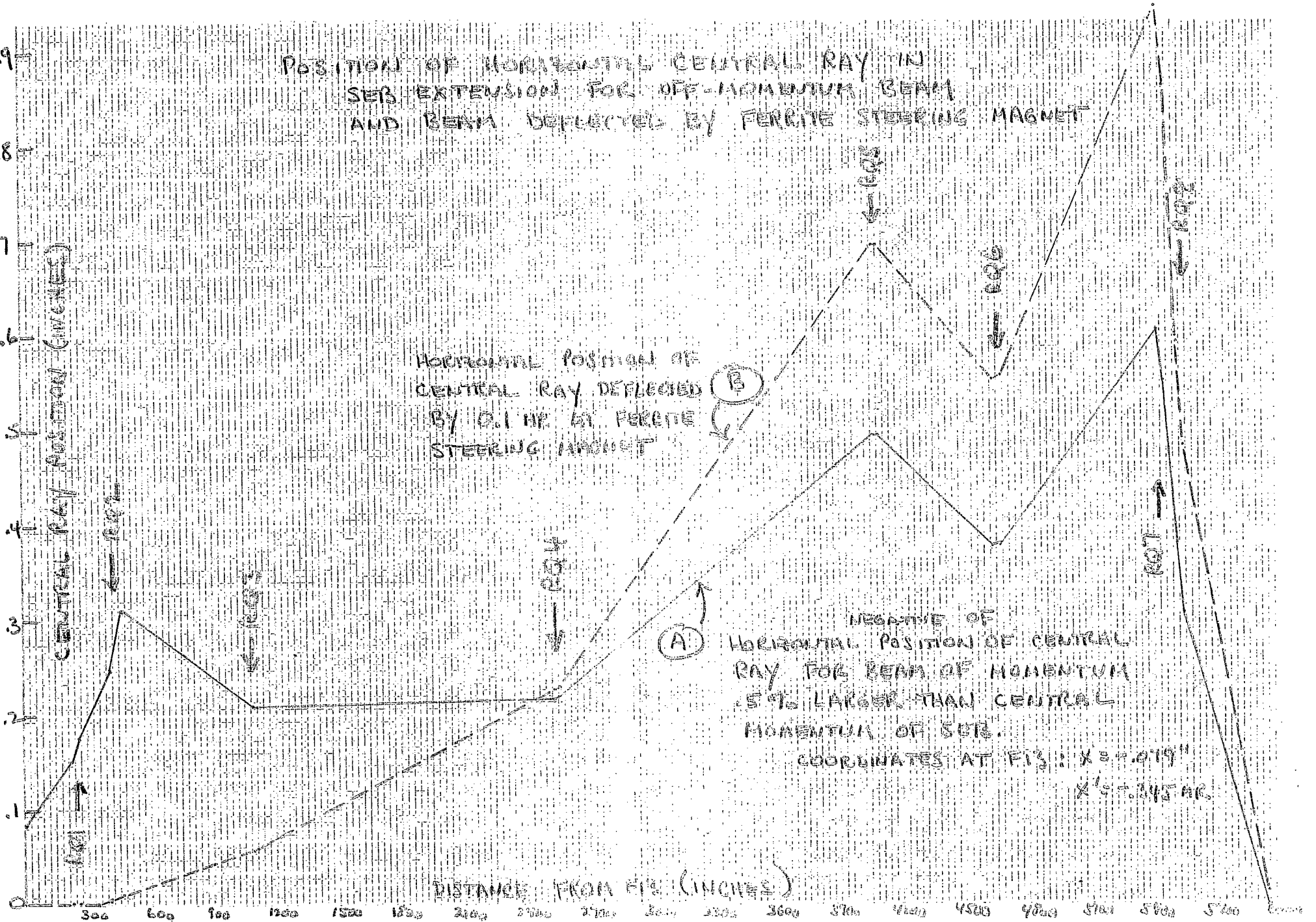


Fig. 4

HORIZONTAL PHASE SPACE  
 ELLIPSE AT SPLITTER  
 #1 AND #2

