FERMI NATIONAL ACCELERATOR LABORATORY

TM-723
6035.000

COMPARISON OF EMITTANCES AND LOSSES IN THE PROTON LINE AT 100,200,400 GEV

by

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April 15, 1977

I. The accelerator advertizes the capability of running at two different energies during one machine cycle (i.e. the so called front porch, flat-top mode). Since this configuration is a relative scarcity during a years time, approximately 8 weeks during 1976, it seems reasonable to ask oneself if adequate analysis has been performed on this type of operation. Thus the province of this report is a brief study of the front porch mode as it effects the proton line in switchyard from MQ300 to SC400 in the proton east target area. The questions being asked are:

i) How do the horizontal emittances, ε_x, at 100-200-400 GeV compare?

ii) How does the 100-200 GeV beam size (i.e. FWHM) compare with the 400 GeV?

iii) How do the 100 and 200 GeV losses compare with the 400 GeV values?

To answer these questions a parasitic beam study was performed during the 100-200 GeV run between 9/16-9/20/76. Hard copies and photographs of the SWIC displays and loss monitor readouts formed the bulk of the data for this report. Analysis of the data resulted in the following: a) Figure 1 and 2 show the graphs of the vertical and horizontal beam size (i.e. FWHM) respectively. b) A plot of loss monitor readouts at crucial points in the proton beam line is shown in Figure 3. c) The results of Figure 2 plus additional analysis produced Figure 4 which is a graph of horizontal emittance, ε_x, vs. beam energy.

II. This report is a comparative study and as such it can only uncover trends or differences in the specified system variables. It is hoped however, that this and other similar documents will support a more rigerous analysis, thus increasing our knowledge of the "Proton Line" transport system. In this view I decided to write down, in a semi formal manner, the following functional description of the problem.

Horizontal emittance $\equiv \epsilon_x \equiv f(E,D_f,T,V,X)$

where

$E \equiv$ Beam Energy

$D_f \equiv$ Beam Quality

$T \equiv$ SY-Split

$V \equiv$ Vacuum

$I \equiv$ Intensity

$X \equiv$ Unknown

To answer question (i) it is helpful to know: (2)

$$\left.\frac{\partial \epsilon_x}{\partial E}\right|_{D_f,T,V,X} \equiv \Delta\epsilon_x$$

at various points on the proton line.

One could describe the losses, L_m, in similar fashion:

$$L_m \equiv g(E,F_w,D_f,T,V,X \quad (3)$$

where

$F_w \equiv$ FWHM and the other variables are defined in equation 1. A likely attempt at answering question (iii) is to calculate:

$$\Delta L_m = \left.\frac{\partial L_m}{\partial E}\right|_{F_w,D_f,T,V,X} \quad (4)$$

If one can satisfy the boundary conditions imposed by equations 2 and 4 (i.e. keeping all beam transport system variables constant except energy) then graphing ϵ_x vs. F_w and L_m vs. E could determine $\Delta\epsilon_x$ and ΔL_m.

III. Data for this report was selected such that it meets the previously mentioned constraints as nearly as experimentally possible. However, a few brief comments concerning the data collection are still in order.

1) All FWHM values between SCMH300 and SC312 were calculated using the SWIC profile program on the MCR X530, developed in part by Rod Gerig.

2) All FWHM values between SC319 and SC400 where calculated by hand using pictures of the SWIC displayed on the scopes. The method used for hand calculation is described by T. Murphy in T.M. -454 (065).

3) SWIC and loss monitor data in Tables 2,3, and 4 respectively, were all taken within 1 hour of each other. For practical purposes loss monitor and SWIC data points correspond to the same beam pulse.

4) Normal tune conditions existed. (i.e. tuned to minimize total Losses).

5) The beam split conditions during data taking were as follows:

100 GeV	(9/19/76)
P-West	3.0E10
P-Center	1.0E10
P-East	5.0E10
Meson	Ø
N-Ø	Ø

200 GeV	(9/19/76)
M.R.	1.7E13
P-West	5.0E16
P-Center	1.0E16
P-East	4.8E12
N-Ø (Fast)	5.0E12
N-Ø (Slow)	2.0E12
N-7	3.0E10
Meson	2.5E12

400 GeV	(11/11/76)
M.R.	1.7E13
P-West	2.0E10
P-Center	1.0E10
P-East	3.0E12
N-Ø (Fast)	Ø
N-Ø (Slow)	1.1E13
N-7	2.0E11
Meson	2.4E12

DEVICE	FWHM-V (mm)	DATE	COMMENTS	FWHM-H (mm)	DATE	COMMENTS
SCMQ300	4.0	10/22(0055)		8.0	10/23(0055)	H.G.
	5.0	10/26(0230)		1.0	10/11(0400)	
	4.0	11/11(0400)		1.1	11/11(0400)	
AVERAGE	4.3±.5mm			1.0±.5		
SCMQ302	?			11.0		H.G. OFF
	?			82.0		H.G. OFF
	3.0			6.8		
AVERAGE	2.0±.5mm			7.0±.5		
SCMQ302	5.0			3.0		
	5.0			4.0		
	4.0			4.0		
AVERAGE	4.7±.5mm			3.3±.5		
SCMQ305	3.0			6.0		
	5.0			6.0		
	2.0			8.0		
AVERAGE	2.7±.5mm			7.0±.5		
SCMH400	3.0			16.0		
	3.0			16.0		
	3.0			16.0		
AVERAGE	3.0±.5mm			16.0±.5		
SCMQ310	5.0			20.0		
	5.0			20.0		
	6.0			48.0		
AVERAGE	5.3±.5mm			20.0±.5		
SCESEP E	7.0			15.0		
				15.0		
	7.0			16.0		
AVERAGE	&.0 ±1mm			15.3 ±.5		
SCMV310E	4.0			13.0		
	3.0			14.0		
	4.0			17.0		
AVERAGE	3.0 ±1mm			15.0 ±.5		
SC319/320		10/23				
	7.0 ±1	11/20(1730)	319E	13.0 ±2	11/30(1730)	319E
	6.5 ±1	11/20	320E	10.0 ±2	11/20(1730)	320E
SC323	6.0 ±1	11/20(1730)		1.1 ±.5	11/20(1730)	
SC400	14.0 ±2	11/20		22.0 ±2mm	11/20	

TABLE #1

200 GeV

DEVICE	FWHM-V (mm)	DATE	COMMENTS	FWHM (mm)	DATE	COMMENTS
SCMQ300	5.0	9/19(1800)		6.0	9/19(1800)	
	6.0	9/19(1100)		2.0	9/19(1100)	
	6.0	9/17(1000)		2.0	9/17(1000)	
AVERAGE	5.7±.5			3.3±.5		
SCMQ302	2.0	9/19		8.0	9/19	
	4.0	9/19				
	4.0	9/17		8.0	9/17	
AVERAGE	3.5±.5			8.0±.5		
SCMQ303	6.0	9/19		4.0	9/19	
	4.0	9/19		4.0	9/19	
	4.0	9/17		4.0	9/17	
AVERAGE	4.7			4.0±.5		
SCMQ305	5.0	9/19		6.0	9/19	
	5.0	9/19		6.0	9/19	
	5.0	9/17		6.0	9/17	
AVERAGE	5.0±.5			6.0±.5		
SCMH300	7.0	9/19		13.0	9/19	
	7.0	9/19		13.0	9/19	
	7.0	9/17		14.0	9/17	
AVERAGE	7.0±.5			13.3±.5		
SCMQ300	5.0	9/19		19.0	9/19	
	9.0	9/19		19.0	9/19	
	8.0	9/17		19.0	9/17	
AVERAGE	7.3±.5			18.3±.5		
SCESEP	7.0	9/19		12.0	9/19	
	11.0	9/19		14.0	9/19	
	10.0	9/17		13.0	9/17	
AVERAGE	9.3±.5			13.0±.5		
SCMV310E	6.0	9/19		12.0	9/19	
	6.0	9/19		13.0	9/19	
	6.0	9/17		13.0	9/17	
AVERAGE	6.0			12.9		
SC319/320	9.0±5mm	9/19(1800)		10.0±3mm	9/19	
SC323	10.0±1mm	9/19(1800)		10.0±1mm	9/19	
SC400	22.0±2mm	9/19(1800)		36.0±2mm	9/19	

TABLE #2

100 GeV

DEVICE	FWHM-V (mm)	COMMENTS	FWHM-H (mm)	COMMENTS
SCMQ302	6.0±.5	9/19(1800)	13.0±.5	19/19(1800)
SCMQ302	3.0±.5		11.0±.5	
SCMQ303	9.0±.5		7.0±.5	
SCMQ305	8.0±.5		10.0±.5	
SCMQ400	6.0±.5		21.0±.5	
SCMQ310	8.0±.5		35.0±.5	
SCESEP	9.0±.5		20.0±.5	
SEMV310E	8.0±.5		21.0±.5	
SC319/320E	15.0±.5		15.0±1.0	
SC323	15.0±1.0		15.0±1.0	
SC400	30.0±2.0		40.0±2.0	

TABLE #3

LOSS DATA

DEVICE	LM(A/D)t 400 GeV	LM(A/D)A 100/200 GeV
DTLM	0.40	0.25
LQ303	0.10	0.10
LHT305	0.05	0.10
ETLM	2.50	2.10
LESEM	1.80	1.00
LQ310	7.50	3.80
LESE10C	7.80	3.00
LESE11C	2.00	1.50
LHT310	2.10	2.50
LVT312	0.30	0.40
HTLM	2.40	2.20
L320	5.20	4.60
L404	5.40	6.30

t All 400 GeV Loss Data Was Taken On 11/11/76.

A All 100/200 GeV Loss Data Was Taken on 9/19/76.

TABLE #4

IV. In order to calculate $\Delta\varepsilon$ one starts with the FWHM of the beam at several SWIC locations along the line and errors are calculated using the resolution of the SWIC as the best possible case. Then a least-square fitting program is run to calculate emittances. One limitation of the program is the necessity of a waste between the start and stop points. If no waster exists when the program gives indeterminate results. Since we are concerned primarily with emittances in the Proton-East target areas the following SWIC's were chosen:

A) SC312 (1mm/wire)
B) SC319E (mm/wire)
C) SC400 (1mm/wire)

Figures 1 and 2 show a horizontal waste between SWIC 312 and 400 but none in the vertical plane. Thus, this analysis will include only horizontal emittance calculations.

The calculation of ΔL was hindered by the fact that the front porch and flattop loss monitor data can not be seperated (i.e., it is a summation of both 100 and 200 GeV values). Thus the calculation of L_m vs. E is not available at this time. However, a plot of losses vs. position along the proton beam line for 400 GeV and the sum of 100 plus 200 GeV losses is shown in Figure 4. Normalized losses were not used because the total intensity for the 400 and 200 + 100 GeV data is approximately equal as shown in Section III., Paragraph 5.

V. The results of this study allowed the following answers to the opening questions:

i) The plot in Figure 4 shows that the horizontal beam emittance in the P-East line does not have a linear energy dependence.

ii) 100-200 GeV beam sizes, on the average, are larger than the 400 GeV values. However it should be noted that Figures 1 and 2 show a different beam envelope pattern for 100 GeV as it does for 200 and 400 GeV. Presumably this difference is due to loss minimization tuning.

iii) Figure 4 shows that the losses at 400 GeV are similar to the combined 100 plus 200 GeV losses.

During the writing of this report another front porch run was made and thus a future T.M. comparing emittances and losses at 100, 200, 300, and 400 GeV is in the works.

Comparison of Horizontal FWHM

at 100-200-400 Gev.

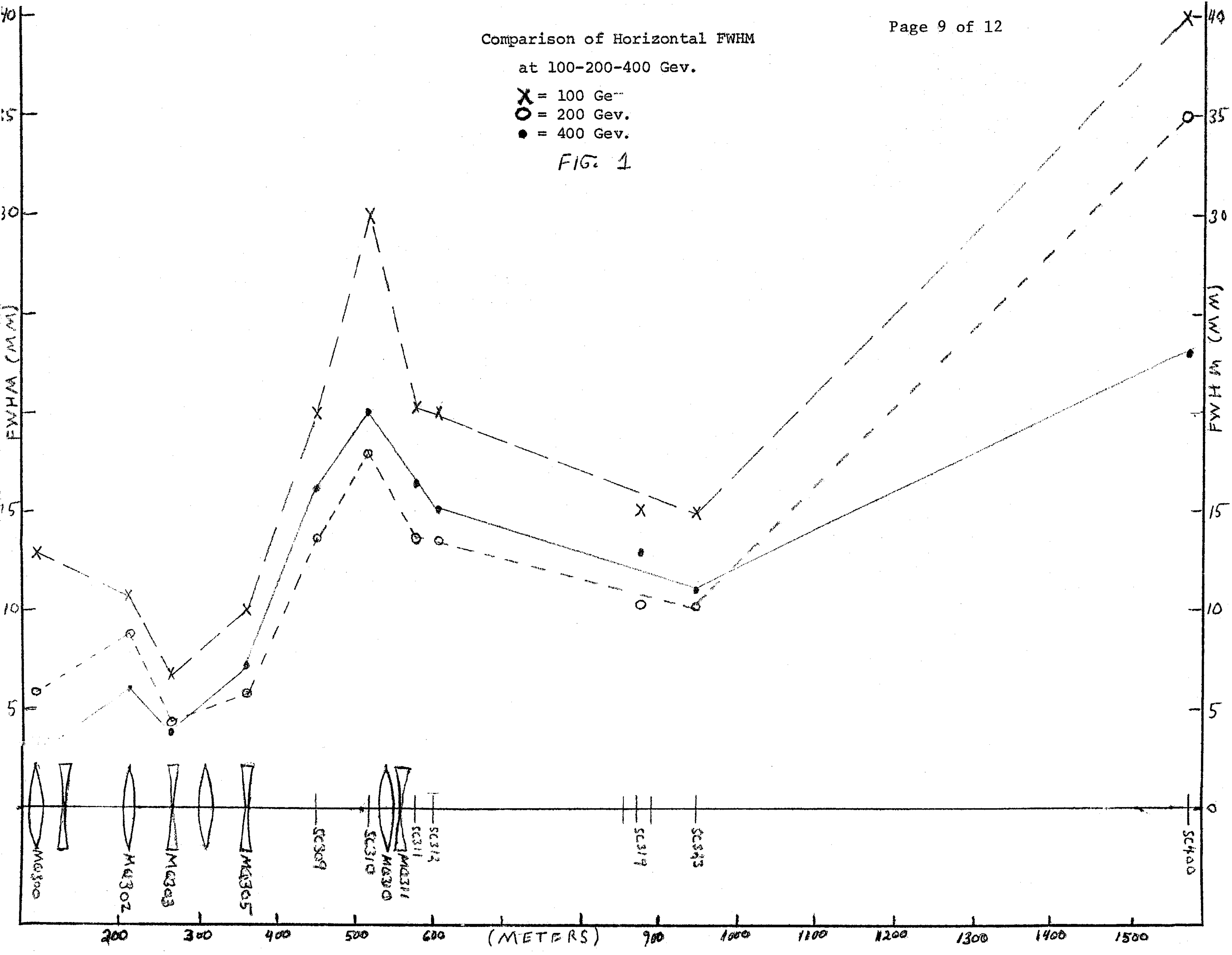


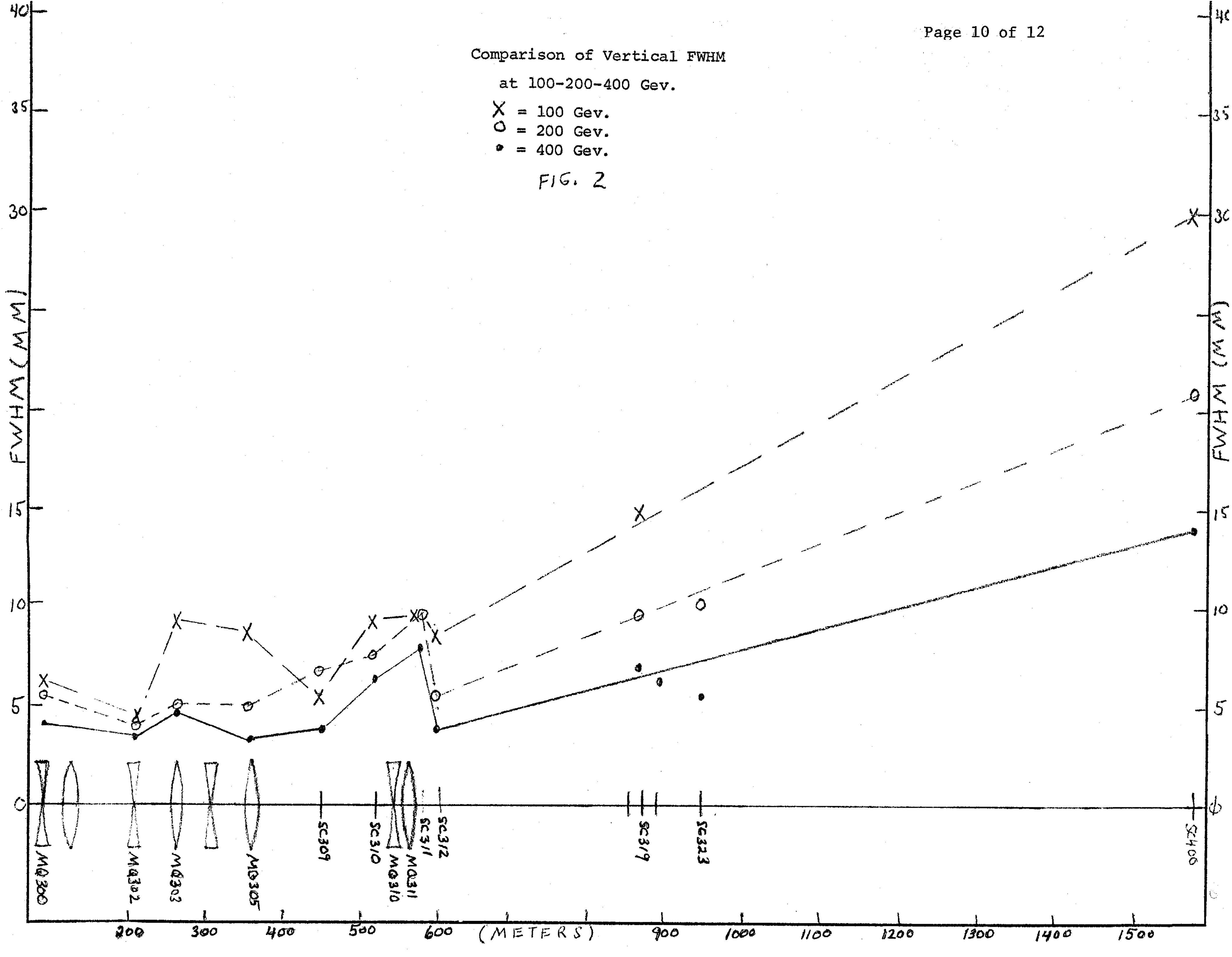
FIG. 1

Comparison of Vertical FWHM

at 100-200-400 Gev.

X = 100 Gev.
O = 200 Gev.
• = 400 Gev.

FIG. 2



COMPARISON OF LOSSES

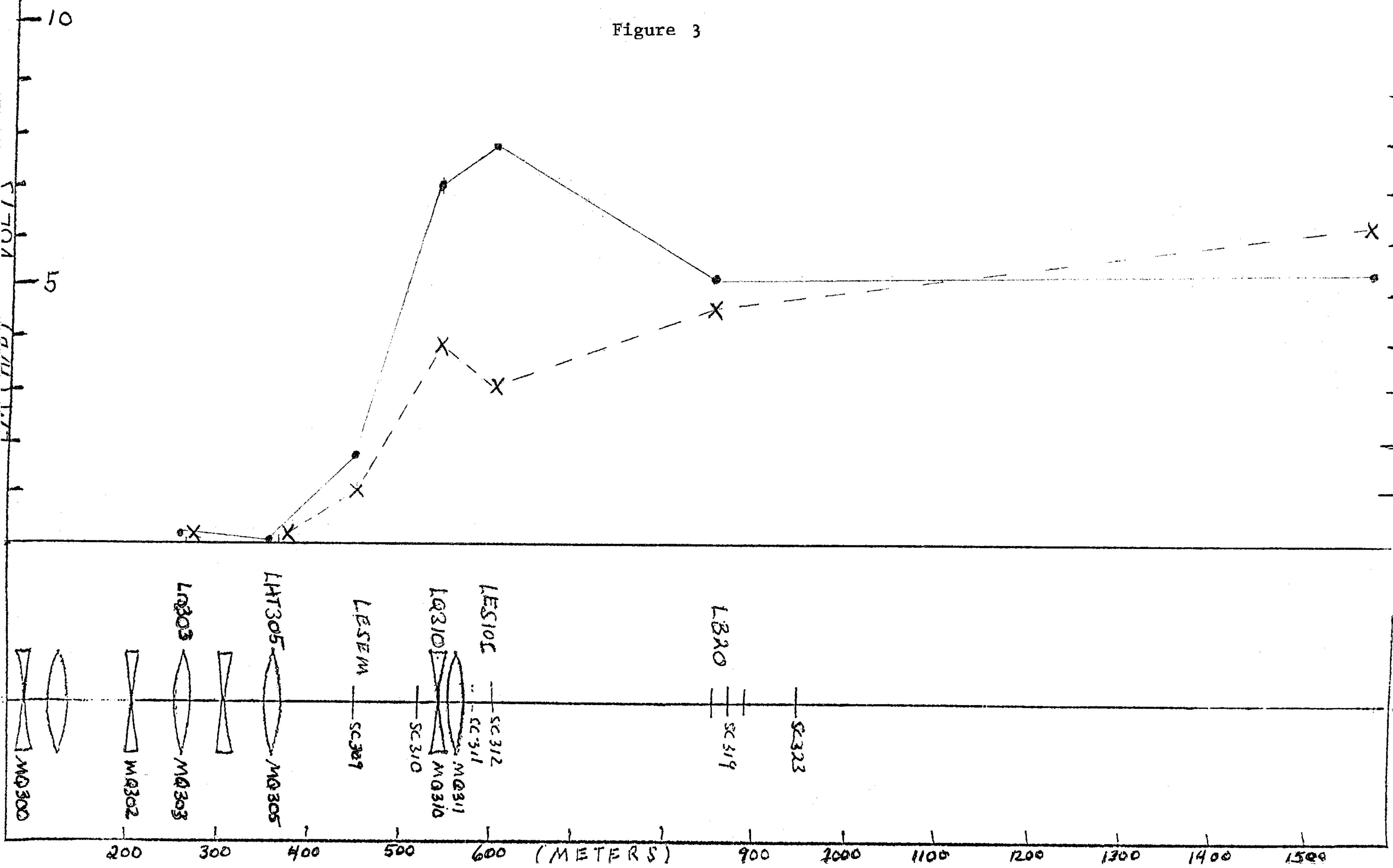
at

100-200-400 GeV

•≡400 GeV

X≡100 + 200 GeV

Figure 3



ε_x VS. BEAM ENERGY

Figure 4