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How to operate Beam 5A

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Introduction

Beam 5A is a one-stage electrostatically separated beam which provides useful fluxes of $\pi^{\pm}$, $K^{\pm}$, $p^{\pm}$ for counter physics in the momentum range from about 1.0 to 3.1 GeV/c ($\bar{p}$ down to 750 MeV/c). In the region around 2 GeV/c, the ratio of kaons or antiprotons to pions and muons is about 1:1, and becomes less as the momentum is raised or lowered. The purpose of this report is very briefly to summarize the extensive operating experience with this beam,[1] and to provide future users with the operating procedures and beam element settings for the beam. Original design considerations are to be found in an unpublished report by B. Barish and T.F. Kycia.[2]

Beam Layout and General Design

The beam layout is shown in Fig. 1, and the major beam characteristics are summarized in Table I. The beam component positions and polarities are shown in Table II.

The intensity of the circulating proton beam striking the internal G-10 target is monitored by two scintillation counter telescopes viewing the target at 90° and 30°. The rough calibrations are 750 90° monitor counts/10^{12} proton striking G-10, and 11,000 30° monitor counts/10^{12}. The 90° monitor is under the control of the Main Control Room through the EAO Target Desk.

The first optical elements in the beam are a quadrupole triplet Q_1,Q_2, and Q_3. This triplet produces a nearly parallel beam horizontally and vertically in the beam separators. Following the triplet, the bending magnet D1 both selects the momentum and deflects the beam away from the AGS. This magnet is usually set to define the beam momentum.

Following D1 is a fixed 8" x 4" collimator which limits the acceptance of the beam. Next, there are two electrostatic separators with a common high voltage and deflecting coil settings. A quadrupole doublet is used to bring the beam to a horizontal focus at the high and low momentum collimators straddling the sextupole and to a vertical focus at the mass slit. The sextupole minimizes vertical chromatic aberrations at the mass slit. The final three quadrupoles are normally used as an asymmetric triplet to produce as small an image as possible at the experiment.

Ray traces for the horizontal and vertical planes are shown in Fig. 2 for typical operating conditions.

The momentum slits are lead and hevimet bricks which are inside the vacuum box. Displacement of ± 0.8 inches from the beam center line correspond to a momentum bite of ± 2%. The opening of the mass slit is determined by shims placed between the hevimet blocks. A normal opening for 2 GeV/c is 0.125", but smaller openings may be useful for better separation at the highest momentum. For the lower (particularly $\bar{p}$) momentum, it may be useful to lower the separator HV in order to reduce the size of the vertical image due to dispersion from the separators and to open the mass slit to allow a larger image to pass through it. For 750 MeV/c $\bar{p}$'s, a mass slit opening of 0.375" for the separators at 300KV was found to be necessary.

Beam Tuning

The absolute momentum calibration of the beam is given by the D1 magnet and the momentum slits, and then the elements are fine tuned about their nominal values to optimize the flux and/or the particle separation. The calibration curve for D1 along with a variety of measurements are given in Fig. 3. As can be seen from the curve, the various measurements are in agreement to within ± 1%.[3]

In Table III, the magnet and separator settings for a number of representative momenta are given for the beam in its present configuration. These are given in terms of MV on the DVM and counts from the separator. The magnets are controlled by helipots, and shunts are read by an ungrounded digital voltmeter. The HV as set by the separator group is given by a train of pulses where 10KC corresponds to 100KV.

Assuming that the elements have been set at their nominal values, and a Čerenkov counter has been set to detect the desired particles, the first step in tuning is to do a quick sweep of the separator magnet. If peaks of about the width shown in Fig. 4 are seen, then the beam has been set up correctly and one can proceed to the fine tuning. The main purpose of the fine tuning is to produce as small an image as possible at the mass slit. If the peaks are much broader, then all of the magnet settings should be rechecked, the status of the gate valves at the end of the separator checked with the separator operator (also see the indicator light in the trailer), and finally, confirm the quadrupole polarities with EAO. The quadrupole polarities can be checked by varying the currents to see if the settings correspond to a maximum in flux. Also check the condition and position of the G-10 target with Main Control. Taking polaroid pictures at the mass slit for a series of D1 settings is also a very useful diagnostic tool.

Fine tuning is usually done in the following sequence.

1. Adjust D_3 to steer beam along beam axis.
2. Fine tune beam separator for maximum intensity through mass slit.
3. Adjust Q5 for maximum intensity.
4. Adjust Q8 for good beam spot at focus.
5. Adjust Čerenkov counter pressure or carriage setting for optimum separation and/or flux.
6. Adjust sextupole for best flux and separation.

An iteration of these steps may be required if especially delicate tuning is desired.

Particle Fluxes and Separations

Approximate kaon and antiproton fluxes per 10^{12} on G-10 target with a momentum bite of $\pm$ 1% as measured by a number of experimenters are given in Fig. 5.[3,4] Since these measurements are dependent on the particular experimental configuration, they may easily vary by as much as $\pm$ 20%. The maximum fluxes are about four times this since the maximum intensity on G-10 target is limited to 1.5×10^{12} protons/pulse, and the maximum momentum bite is $\pm$ 2.5%. Pion fluxes exceed 10^6/pulse over much of the range, and care must be taken not to exceed the limits set by Health Physics. In Fig. 6, a very rough guide to the ratio of unwanted to wanted particles is given. The curves represent an eyeball average to various measurements. A very large component (> 50%) of the background is muons from pion decays. These ratios are given within the nominal beam spot size. There is a comparable number of particles outside of this spot in the beam "halo".

Čerenkov Counters

There are usually two differential Čerenkov counters available for use in this beam. A liquid cell counter for particles with momentum less than 2.5 GeV/c,[5] and a high pressure gas counter for particles with momenta greater than 1.5 GeV/c.[6]

Acknowledgments

I would like to thank D. Lazarus and D. Michael for supplying many of the values and graphs contained in this report.

B1 Distribution

TABLE I

Beam 5A - Medium Energy Partially Separated Beam

Particles	$K^{\pm}$, $\bar{p}$	
Useful momentum range	$K^{\pm}$	1.0 → 3.1 GeV/c
	$\bar{p}$	.7 → 3.1 GeV/c
Momentum bite	≤ ± 2.5%	
Target location	G-10, internal, multiple transversal	
Target material	Boron carbide	
Target size	.02-in. high, .04-in. wide, .64-in. long at 10^{o} to the circulating beam	
Production angle	10^{o}	
Solid angle	0.47 msr	
Length	1788-in.	
Beam spot	~ 1-in. wide x 0.5-in. high	
Separators	2 electrostatic separators, 4" separation 500 KV	

TABLE II

Beam Elements

Element	Effective Length	Size, Diam. or W x H	Polarity*
Free Space (FS)	140.6"		Positive Beam
Q1	27.5	7.5"	B
FS**	14.0		
Q2	36.0	7.5"	A
FS	9.3		
Q3	36.0	7.5	B
FS	7.1		
D1	35.0	3^{o} bend	B
FS	21.0		
Collimator		8" x 4"	
FS	27.3		
BS1	200.0	H=4"	
FS	51.0		
BS2	200.0		
FS	32.4		
Q4	35.2	11.5"	A
FS	7.8		
Q5	35.2	11.5	B
FS	172.6		
HMC***			
FS	52.0		
SEXTUPOLE	26.5		
FS	60.0		
LMC***			
FS	214.0		
Mass Slit			
FS	16.5		
D2	43.0	8^{o} bend	B
FS	13.1		
Q6	34.8	7.5"	A
FS	11.2		
Q7	34.8	7.5"	B
FS	11.2		
Q8	34.8	7.5"	A
FS to target	199.0		

TABLE 2 (continued)

*	'A' polarity for quadrupoles for positive beam is horizontally focussing. 'A' polarity for positive beam in dipoles bends to left looking downstream.
**	FS = Free Space
***	HMC and LMC refer to the High momentum and Low momentum collimators

TABLE III

TABLE III

Initial Magnet Settings Scaled from 2.1 GeV/c. All values in MV

Beam Momentum GeV/c	0.5	1.0	1.5	2.0	2.5	3.0
Q1	11.72	23.45	35.17	46.90	58.62	70.34
Q2	12.01	24.02	36.03	48.04	60.05	72.06
Q3	4.77	9.54	14.33	19.09	23.86	28.63
D1	14.17	28.34	42.51	56.69	70.86	85.03
Q4	8.86	17.73	26.59	35.46	44.32	53.19
Q5	8.84	17.70	26.54	35.39	44.24	53.09
D2	9.41	18.83	28.24	37.64	47.07	56.49
Q6	14.35	28.70	43.06	57.41	71.76	86.11
Q7	14.96	29.91	44.87	59.83	74.79	89.74
Q8	6.45	12.90	19.36	25.81	32.26	38.71
BS (π) at 500 KV	46.5	46.5	46.5	46.5	46.5	46.5

References

1. The following is a partial list of representative experiments performed in this beam:

   a. σ Total, R.L. Cool, et.al. Phys. Rev. D 1887-1917 (1970).
   b. $K^{\pm}$ Lifetime, F. Lobkowicz, et.al., Phys. Rev. Letters 548, 17 (1966).
   c. $\bar{p}p \rightarrow e^{+}e^{-}$, B. Barish, et.al., Phys. Rev. Letters 720, 17 (1966).
   d. Ξ^{-} Magnetic Moment, R.L. Cool, et.al., Phys. Rev. D, 10, 792 (1974).
   e. $K^{+}p$ Backward Elastic Scattering, A.S. Carroll, et.al., Phys. Rev. Letters 21, 17 (1968).

2. B. Barish and T.F. Kycia, A Partially Separated Antiproton and K-Meson Beam of High Intensity, (unpublished) (1967).

3. L. Guerriero, et.al, Brown University (unpublished).
   Internal Report #122 (1972).
   Experiment #607 - Yale University/BNL - D. Lazarus.
   Private Communication.

4. S.K. Tewksbury - Thesis - University of Rochester (unpublished) (1969, K^{+}.
   C.A. Smith - Thesis - University of Rochester (unpublished) 1970 K^{-}.
   H.W. Nicholson - Thesis - California Institute of Technology (unpublished) 1971 $\bar{p}$.

5. B.A. Leontic and J. Teiger, BNL 50031 (T-447) 1966.

6. J.D. Tyson - Thesis - Yale University, p. 49-56 (unpublished), 1967.

Figure Captions

Fig. 1. Beam layout as of 1975.

Fig. 2. a) Horizontal ray trace Beam 5A.

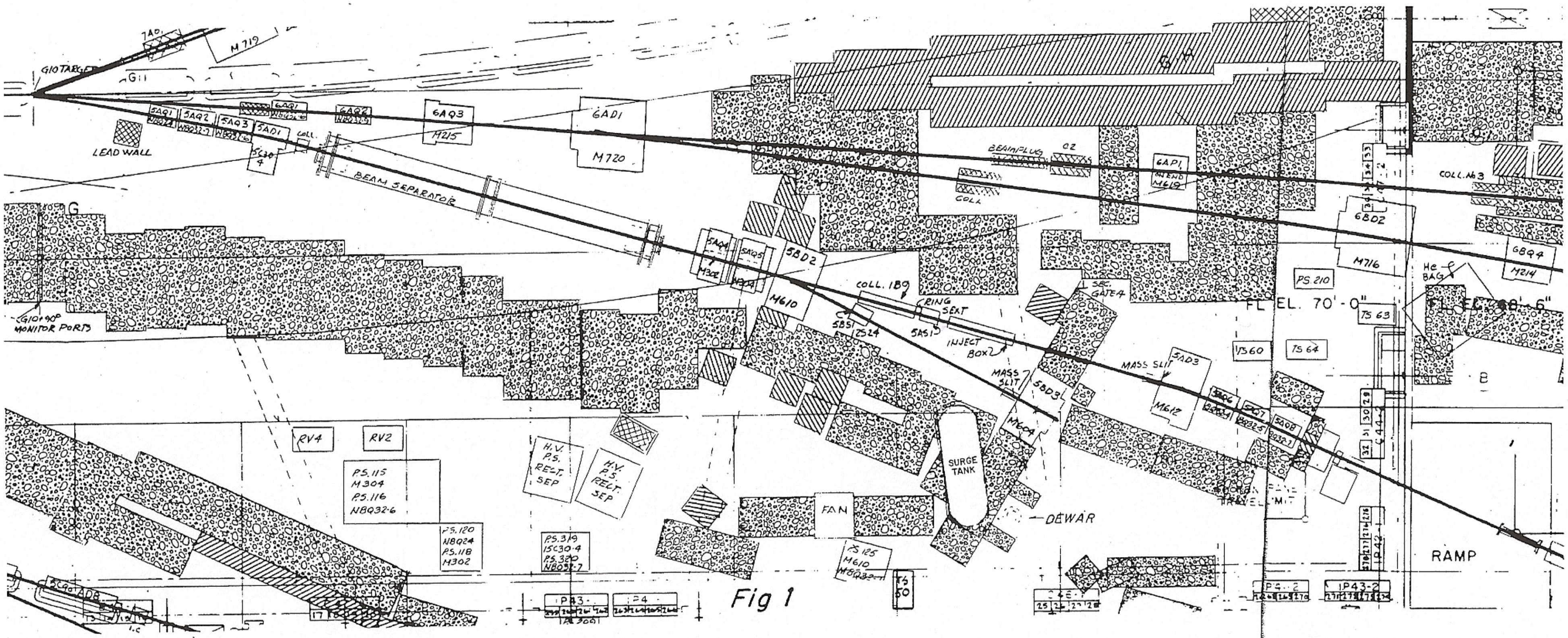
b) Vertical ray trace Beam 5A.

Fig. 3. D1 magnet, 15C30 magnet momentum calibration.

Fig. 4. Separator sweeps in Beam 5. Curve marked S is the total beam flux and that marked SČ includes the Čerenkov requirement.

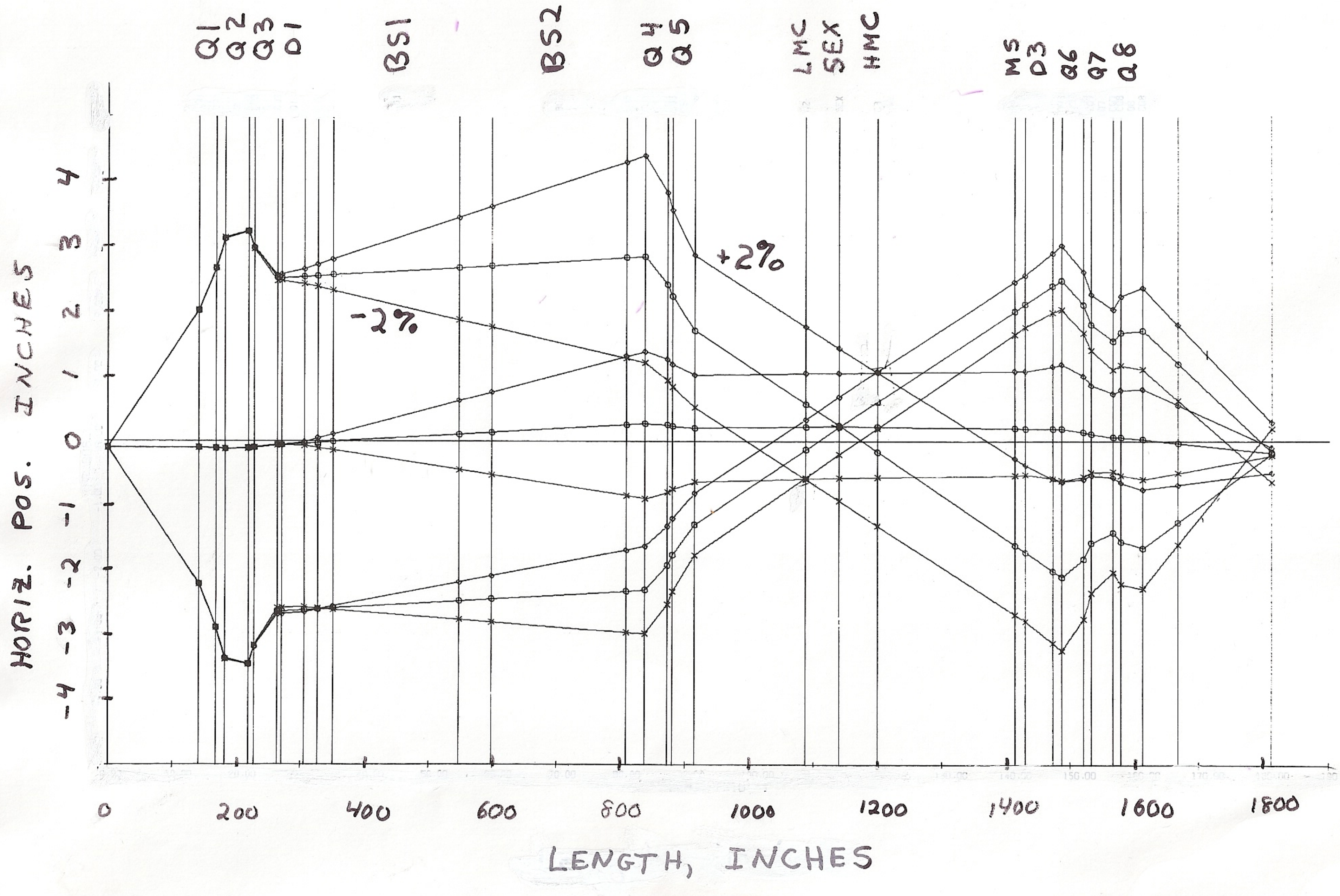
Fig. 5. Particle fluxes at final focus as a function of momentum. Smooth curves are "eyeball" fits to the data from Ref. 3 and 4.

Fig. 6. Ratio of π's to wanted particles from Ref. 3 and 4.



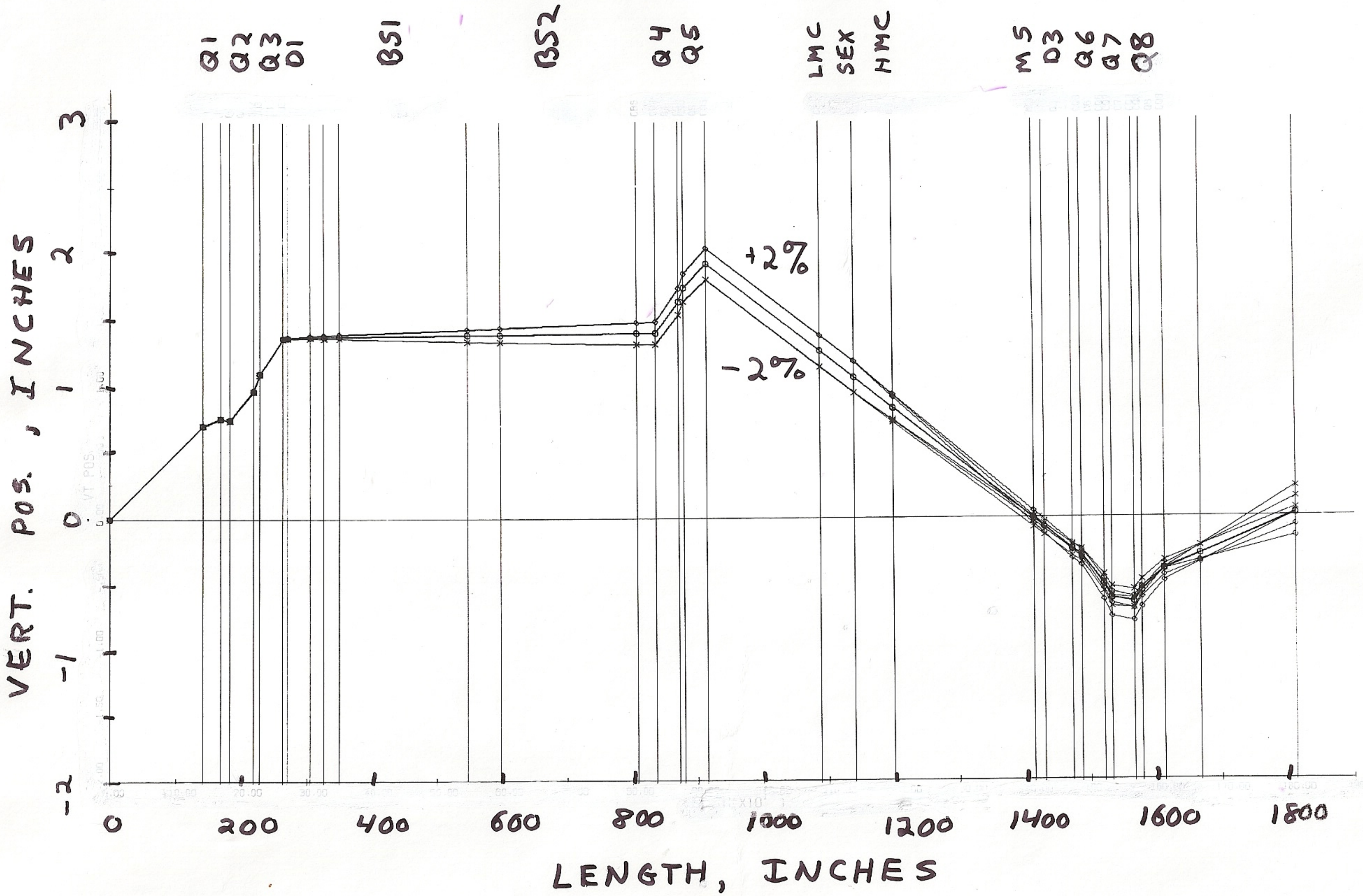
G10 TARGET
G11
M719
LEAD WALL
5AQ1
5AQ2
5AQ3
5AD1
6AQ3
M215
6AD1
M720
BEAM SEPARATOR
G10 90° MONITOR PORTS
5BD2
M610
COLL. 189
RING SEAT
INJECT BOX 2
MASS SLIT
5BD3
M604
5AD3
M612
SURGE TANK
DEWAR
FAN
RV4
RV2
P.S. 115
M304
P.S. 116
NBQ32-6
P.S. 120
NBQ24
P.S. 118
M302
H.V. P.S. RECT. SEP
P.S. 319
P.S. 125
M610
BEAMPLUG
COLL
6AP1
M619
6BD2
M716
PS 210
TS 63
TS 64
TS 60
FL. EL. 70'-0"
COLL. No 3
6BQ4
M214
He BAG
SEC. GATE 4
RAMP
IP43
P4
IP43-2
IP42
B
G

Fig 1



Q1
Q2
Q3
D1
BS1
BS2
Q4
Q5
LMC
SEX
HMC
MS
D3
Q6
Q7
Q8
+2%
-2%
HORIZ. POS. INCHES
-4 -3 -2 -1 0 1 2 3 4
0
200
400
600
800
1000
1200
1400
1600
1800
LENGTH, INCHES

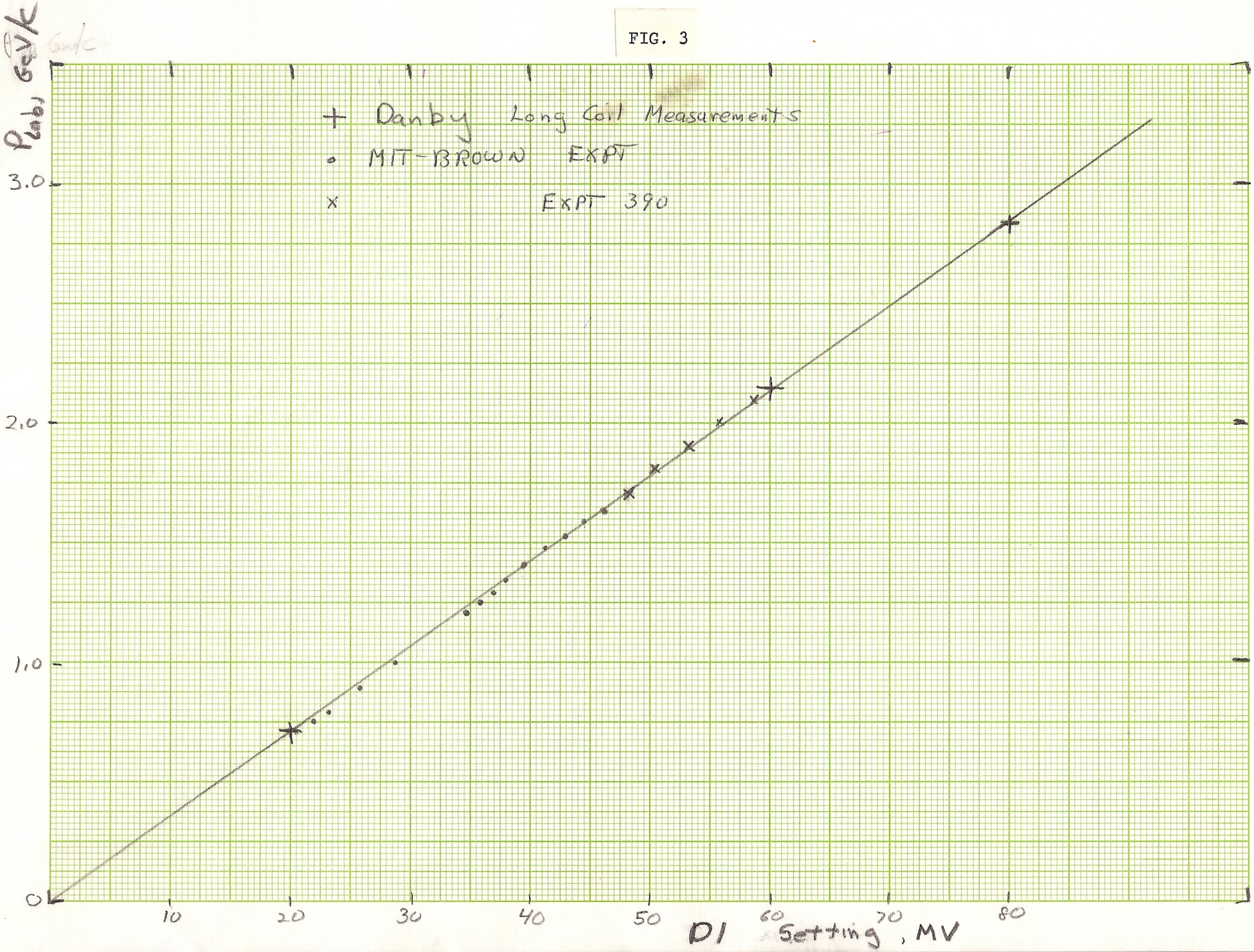
FIG. 2a

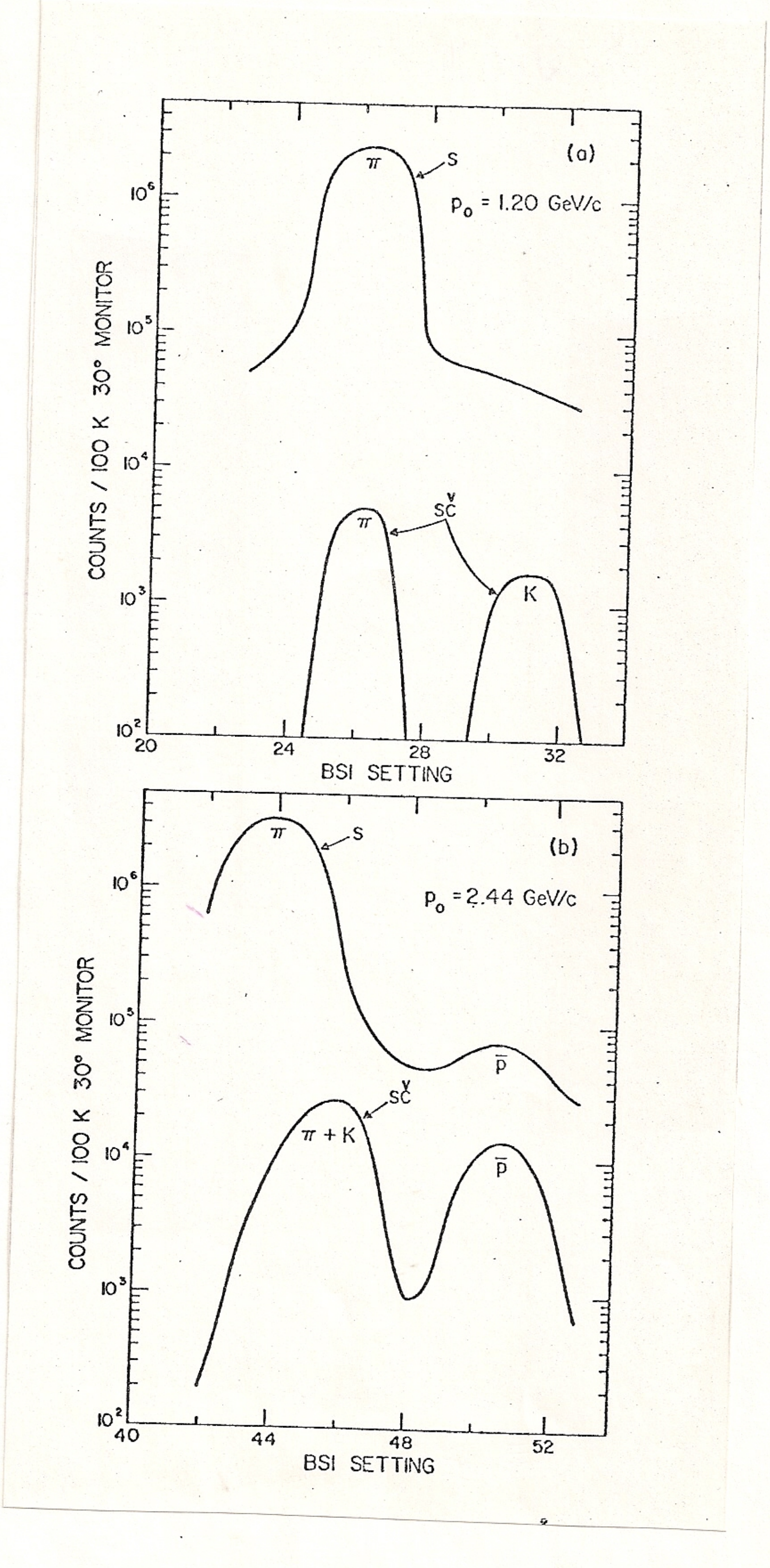


Q1
Q2
Q3
D1
BS1
BS2
Q4
Q5
LMC
SEX
HMC
M5
D3
Q6
Q7
Q8
+2%
-2%
VERT. POS., INCHES
3
2
1
0
-1
-2
0
200
400
600
800
1000
1200
1400
1600
1800
LENGTH, INCHES

FIG. 2b

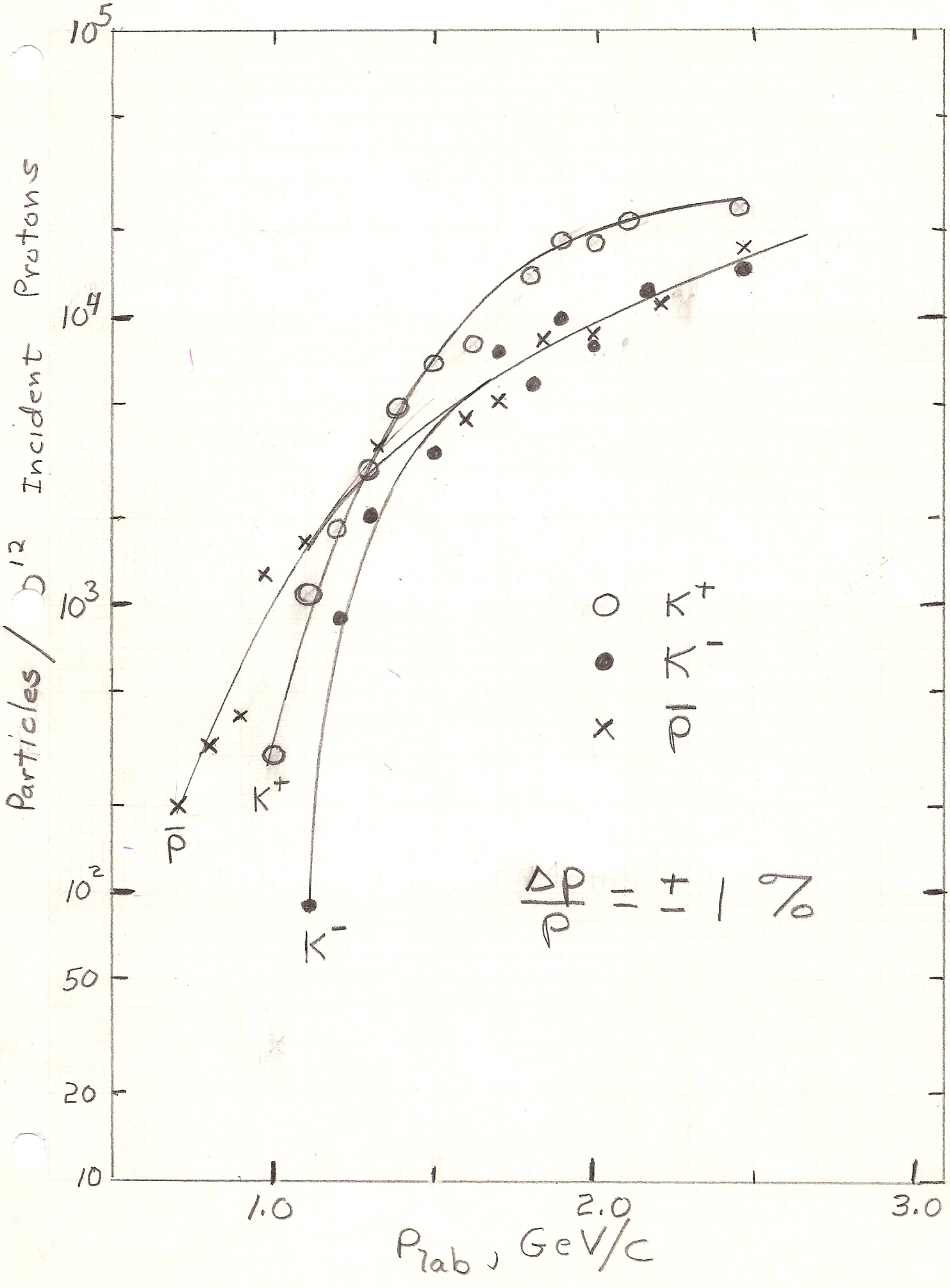
FIG. 3


+ Danby Long Coil Measurements
• MIT-BROWN EXPT
× EXPT 390
P_{Lab}, GeV/c
3.0
2.0
1.0
0
10
20
30
40
50
60
70
80
DI Setting, MV



(a)
π
S
P_o = 1.20 GeV/c
$\check{S}C$
π
K
COUNTS / 100 K 30° MONITOR
BSI SETTING
(b)
π
S
P_o = 2.44 GeV/c
$\bar{p}$
$\check{S}C$
π + K
$\bar{p}$
COUNTS / 100 K 30° MONITOR
BSI SETTING

FIG. 4



Particles / 10¹² Incident Protons
10⁵
10⁴
10³
10²
50
20
10
1.0
2.0
3.0
P_lab , GeV/c
○ K⁺
● K⁻
× p̄
K⁺
K⁻
p̄
Δp/p = ± 1 %

FIG. 5

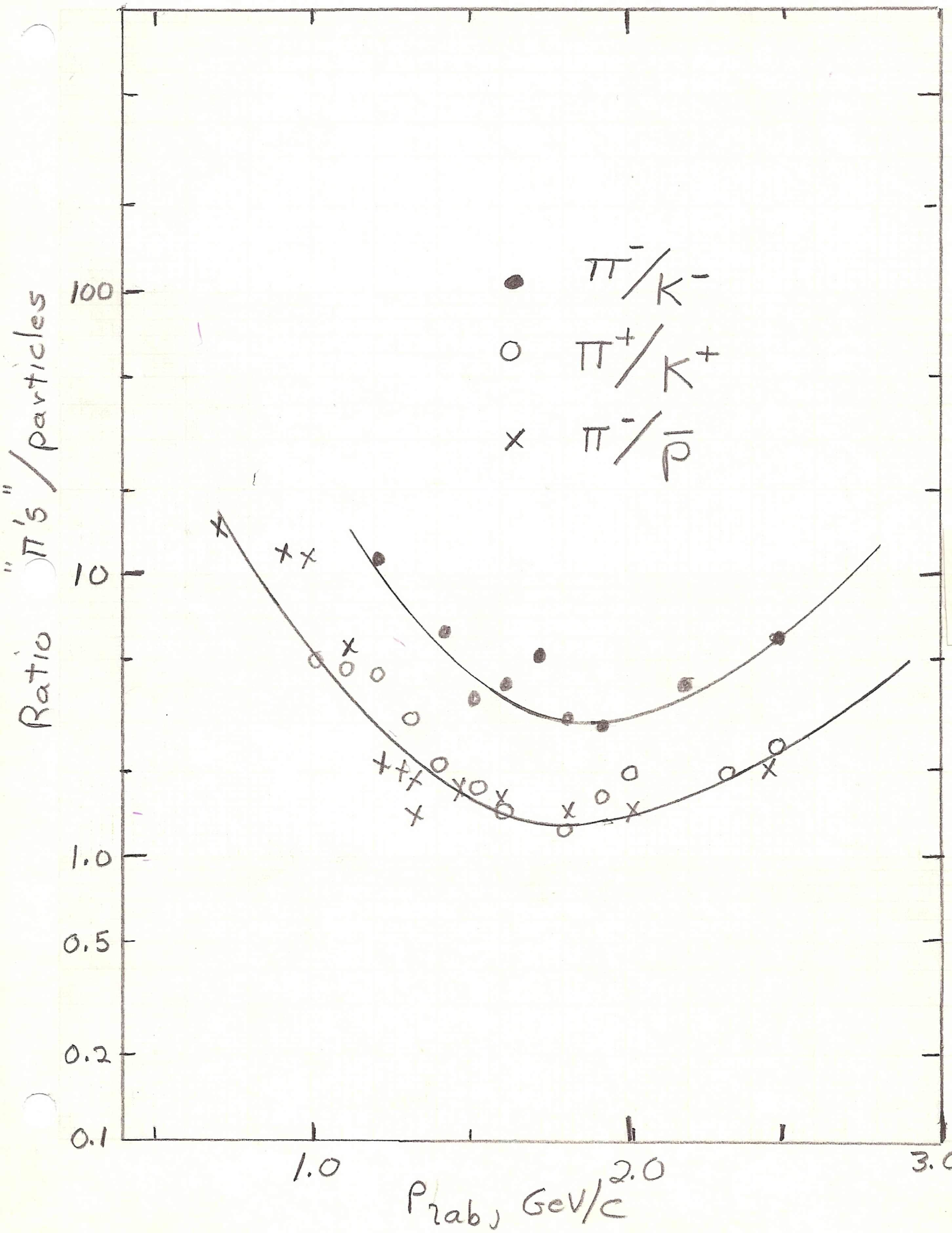

π^-/K^-
π^+/K^+
$\pi^-/\bar{p}$
Ratio "π's"/particles
100
10
1.0
0.5
0.2
0.1
1.0
2.0
3.0
P_{lab}, GeV/c

FIG. 6