Title
Summary of the Research Progress Meeting

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SUMMARY OF THE RESEARCH PROGRESS MEETING

March 17, 1949

H. P. Kramer

Berkeley, California

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INFORMATION DIVISION
Radiation Laboratory
Univ. of California
Berkeley, California

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The Shape of the Synchrotron Beam. M. Martin.

Experiments have been carried out to locate the center line of the x-ray beam and to determine its intensity about this line. The method which was used is due to W. Powell who had previously aligned the cloud chamber with the beam by means of it.

Fig. 1 shows a number of lead encased electroscopes that are placed in a row obliquely across the probable line of the beam. The electroscopes are exposed for some time, readings are taken, and the variation of intensity with lateral distance is plotted and interpolated for the maximum in order to locate the center of the beam. These measurements were made at 18 ft and 36 ft from the machine. The two points of maximum intensity which are located in this way determine the center line of the beam.

Vertical and horizontal measurements indicate that the beam is isotropic in the neighborhood of the center line. It is seen however from Figs. 2, 3, 4, and 5 that the beam spreads with distance from the machine. At 18 ft from the target, the spread between points of half-maximum intensity is 2 inches. At 36-1/2 ft, it has increased to about 6 inches.

It was thought that the spread in the beam is due to the production of secondary x-rays of lower energy. In order to test this hypothesis, the crystal electroscopes were covered with an additional 1/6 inch of lead to filter out any possible secondary rays which might contribute to the beam spread. With this arrangement it was found that the distance between points of half-maximum intensity was reduced to 3-1/2 inch at 36-1/2 ft, from the previous value of 6 inches. (Fig. 6)

E. McMillan advanced the hypothesis that part of the beam spread is attributable to the scattering of photons. He furthermore, reported on the background of scattered x-rays that was also recorded with electroscopes. At point (A) of Fig. 1, the intensity is about 1/500 of that of the maximum in the beam. In a vertical plane through the beam, the background is symmetrical. In the median plane, on the other hand, the backgound is higher to the North of the beam because the geometrical configuration of the machine favors scattering in that direction. The general radiation survey will be extended to all points around the periphery of the synchrotron so that the entire radiation from the machine may be accounted for.

The Synchrotron Current. W. Panofsky.

An attempt has been made to determine the absolute measure of the x-ray flux in the synchrotron beam in order to calculate from the results of these measurements the current of electrons that produces the beam.

It was thought to be a well warranted assumption that for the 350 mev electron beam in the synchrotron, the only consequential mechanism for the conversion of its energy is the release of bremsstrahlung in the target.

The first step in determining the number of electrons that are instrumental in creating the x-ray beam is to calculate the number of quanta that are carried in the beam. Fig. 7 shows a graph of the product of the cross section for the production of bremsstrahlung σ and the energy k. This graph has an almost rectangular shape and therefore the total energy that is carried in the beam, $E = N_{\sigma}\int \sigma_k dk$, may be well approximated by the expression $E = N_o E_o \sigma_k k$ where E_o is the energy of an electron that impinges on the target, E_o = 350 mev and N_o is the number of electrons that strike the target. E/E_0, it is seen from the graph, is almost a constant. The significance of this quantity is that it represents the number of quanta that would be contained in the beam if each quantum carried energy E_0. The number of quanta of energy k that are released by an electron is precisely the quantity σ_k. The total number of quanta in the beam is therefore $N=\int \sigma_k dk = {}^E/Eo\int \frac{1}{k}\,dk$. If the integration is carried out between the limits of observed energies in the beam, k_1 and k_2, the following expression for the number of quanta is arrived at:

$$N = \frac{E}{Eo} \log\ {}^{k_2}/k_1.$$

A reasonable assumption as to the average number of quanta created by an electron in its passage through the target will then enable one to estimate the number of electrons that interact with the target to produce the x-ray beam. N was determined experimentally by measuring E with an ionization chamber that is diagrammed in Fig. 8. The total charge is collected on a low leakage condenser and discharged at the end of a run. One thus has a measure of the total ionization produced which in turn enables one to form an idea of the total energy carried by the beam.

It was also of interest to predict the number of pairs produced by the x-ray beam. Two ionization chambers such as that shown in Fig. 8 were placed 18 feet apart and various materials of variable thickness were placed between them. Fig. 9 shows the ratio of the ionization produced in the second ionization chamber to that produced in the first, after a correction has been made to account for the decrease in intensity with the inverse square of the distance. The slope of the graph represents the cross section for pair production, i.e. the number of pairs produced by the beam in unit thickness of material, Pb in this instance.

The total number of expected pairs is given by

$$N_p = N_V X\ n_V x \int \sigma_p \sigma_k dk$$

where N_V is the number of atoms in unit volume of the synchrotron target and X its thickness; n_v the number of atoms in unit volume of the target in which the pairs are produced and x its thickness; and σ_p and σ_k are the cross sections for pair production and for the production of quanta of x-ray. The integrand is plotted in Fig. 10. In order to compute the quantity N_p the integrand was evaluated graphically.

In conjunction with the total ionization measurements that have been described an absolute calibration of the Zeus meter that had previously been used to indicate the intensity of the beam was possible.

The results of measurements and calculations based on the assumption of a 1R reading on the Zeus meter are summarized as follows:

1. The average current striking the target is 1.8×10^{-12} amp.

2. The number of electrons that produce a beam of 1 R as measured on the Zeus meter 4.0×10^{10}.

3. The total circulating beam of electrons is 2.3×10^{-5} amp.

4. The injection current calculated on the basis of 1/2 μ sec inacceptance time is 1.0×10^{-6} amp.

5. The number of quanta in the beam/R is 6.6×10^9.

6. The charge in the orbit/pulse is 3×10^6 e.

It is of interest to note that the "catching efficiency", the ratio of electrons produced in the injector to the number of electrons accepted into a stable orbit is only 1/5000. Furthermore, it has been calculated that no more than 1/6 of the circulating beam serves to produce the x-ray beam. The remaining 5/6 of energy in the electron beam is free to be dispersed in the form of irregular x-ray spray.

Spallation Yields of Copper with Full Energy Protons. R. Batzel.

Spallation is the process whereby a target nucleus is converted into a number of other nuclei by reactions that are initiated through bombardment with accelerated particles.

A copper foil was exposed to full energy (about 350 mev) protons in the 184-inch cyclotron. After the bombardment, the foil was dissolved in concentrated H_2NO_3 and this solution was then examined for spallation products. Special techniques are necessary for the chemical analysis of the minute quantities of spallation products that are produced from an initially small target. Since the quantities are so small, any loss from handling, such as by adsorption, which may ordinarily be neglected, represents a significant fraction of the spallation yield. If, however, a radioactively inert carrier is added to the solution, its losses will be in the same proportion as those of the isotope to be analyzed, and thus the proportion of radioactive isotope to inert isotope is preserved in the carrier extract and from this measurement, the yield of spallation product is calculated very simply.

The extracted fractions were placed in counters and their activities were recorded and resolved. The yields are set down in the table as fractions of the yield of Cu^{61} which was arbitrarily given the value 1.

No definite correlation can at present be made between the data obtained from deuteron bombardment and those recently found for protons. The trend of the tables seems to be the same except at the extreme ends.

It is planned to determine the yields from recoil protons from copper on Al that is sandwiched between two copper foils.

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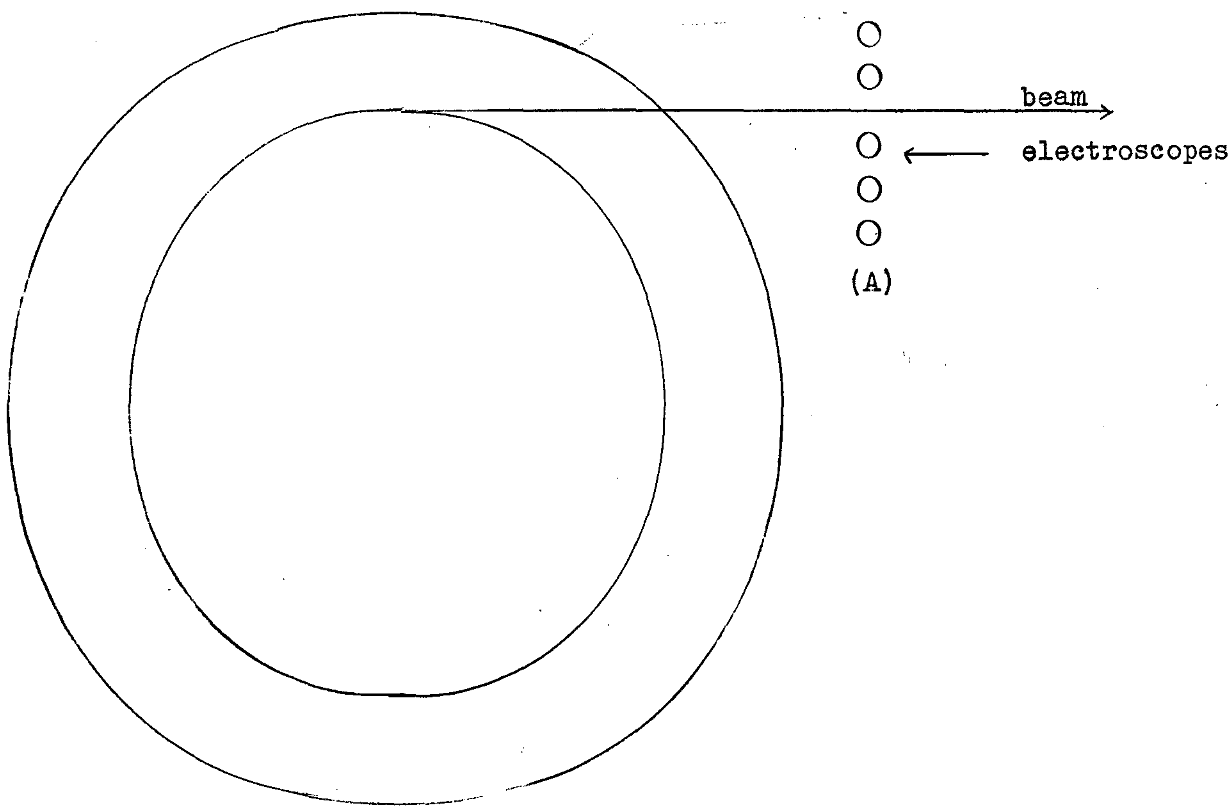
Table of Yields

Isotope	Bombardment by Protons (350 Mev)	Bombardment by Deuterons (190 Mev)
Zn	.14	.06
Zn	.12	.05
Cu	1.00	1.00
Cu	.64	.63
Ni	.05	.03
Co	.36	.23
Co	.15	.07
Fe	.12	.07
Fe	.025	.006
Mn	.09	.04
Cr	.08	.05
Cr	.07	.01
Cl	.016	.0005
P	.009	.00005



Location of the X-ray Beam with Crystal
Electroscopes

Fig. 1

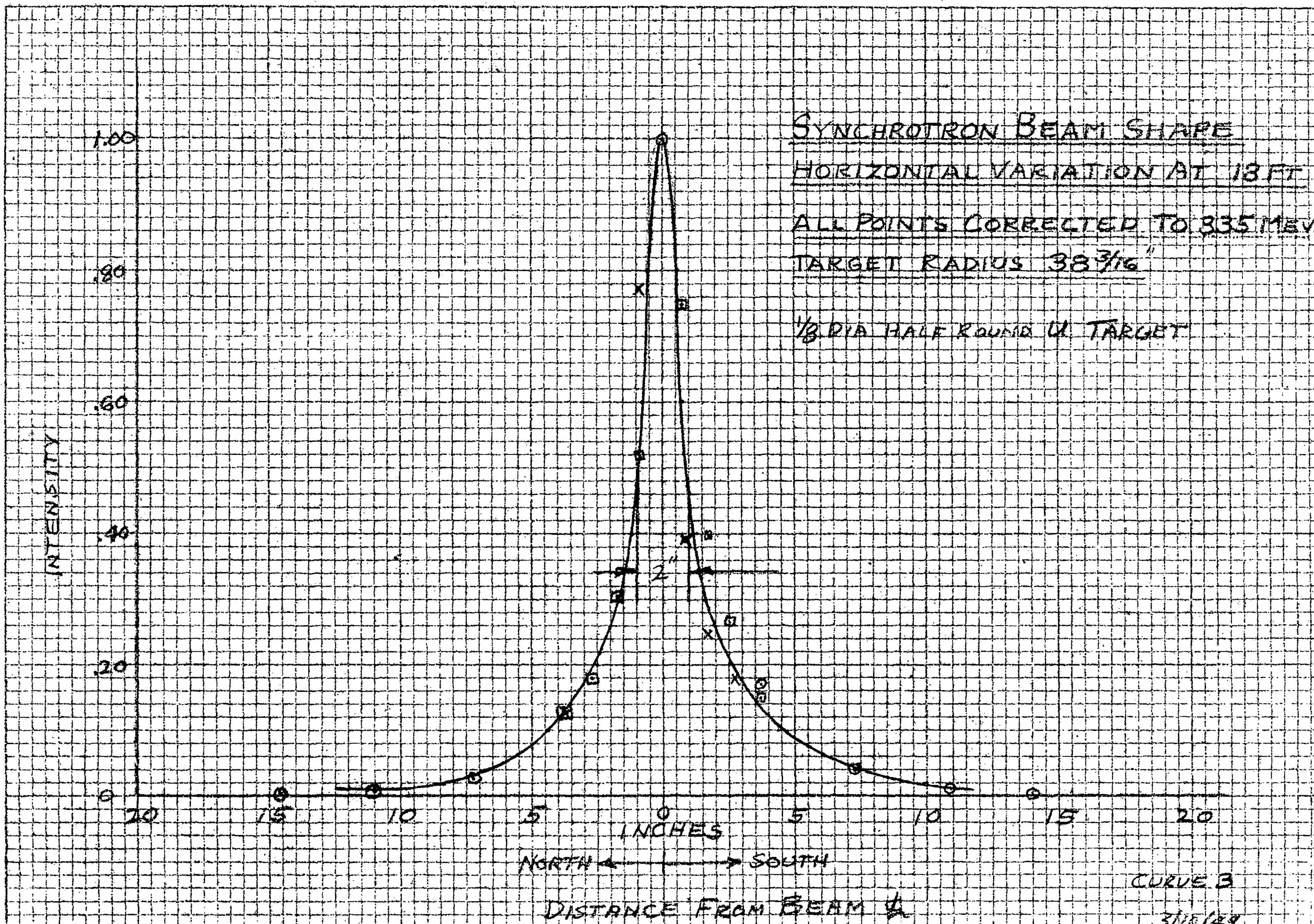

SYNCHROTRON BEAM SHAPE
HORIZONTAL VARIATION AT 13 FT
ALL POINTS CORRECTED TO 335 MEV
TARGET RADIUS 38 3/16"
1/8 DIA HALF ROUND W TARGET
INTENSITY
1.00
.80
.60
.40
.20
0
20
15
10
5
0
5
10
15
20
2"
INCHES
NORTH
SOUTH
DISTANCE FROM BEAM ℄
CURVE 3
3/15/49

FIG. 2

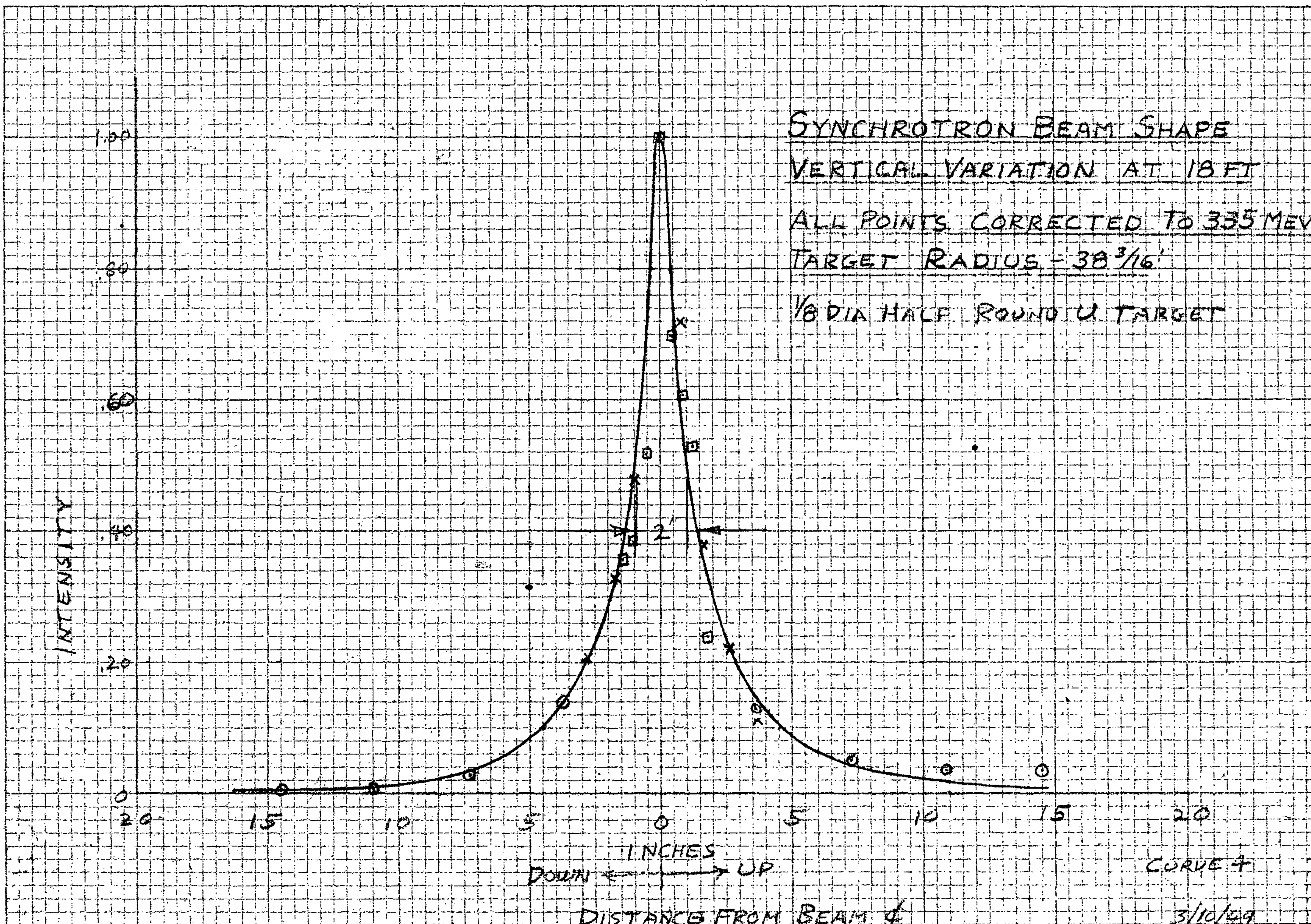

SYNCHROTRON BEAM SHAPE
VERTICAL VARIATION AT 18 FT
ALL POINTS CORRECTED TO 335 MEV
TARGET RADIUS - 38 3/16'
1/8 DIA HALF ROUND U TARGET
INTENSITY
1.00
.80
.60
.40
.20
0
20
15
10
5
0
5
10
15
20
2'
INCHES
DOWN ← → UP
DISTANCE FROM BEAM ℄
CURVE 4
3/10/49
Martin

FIG. 3

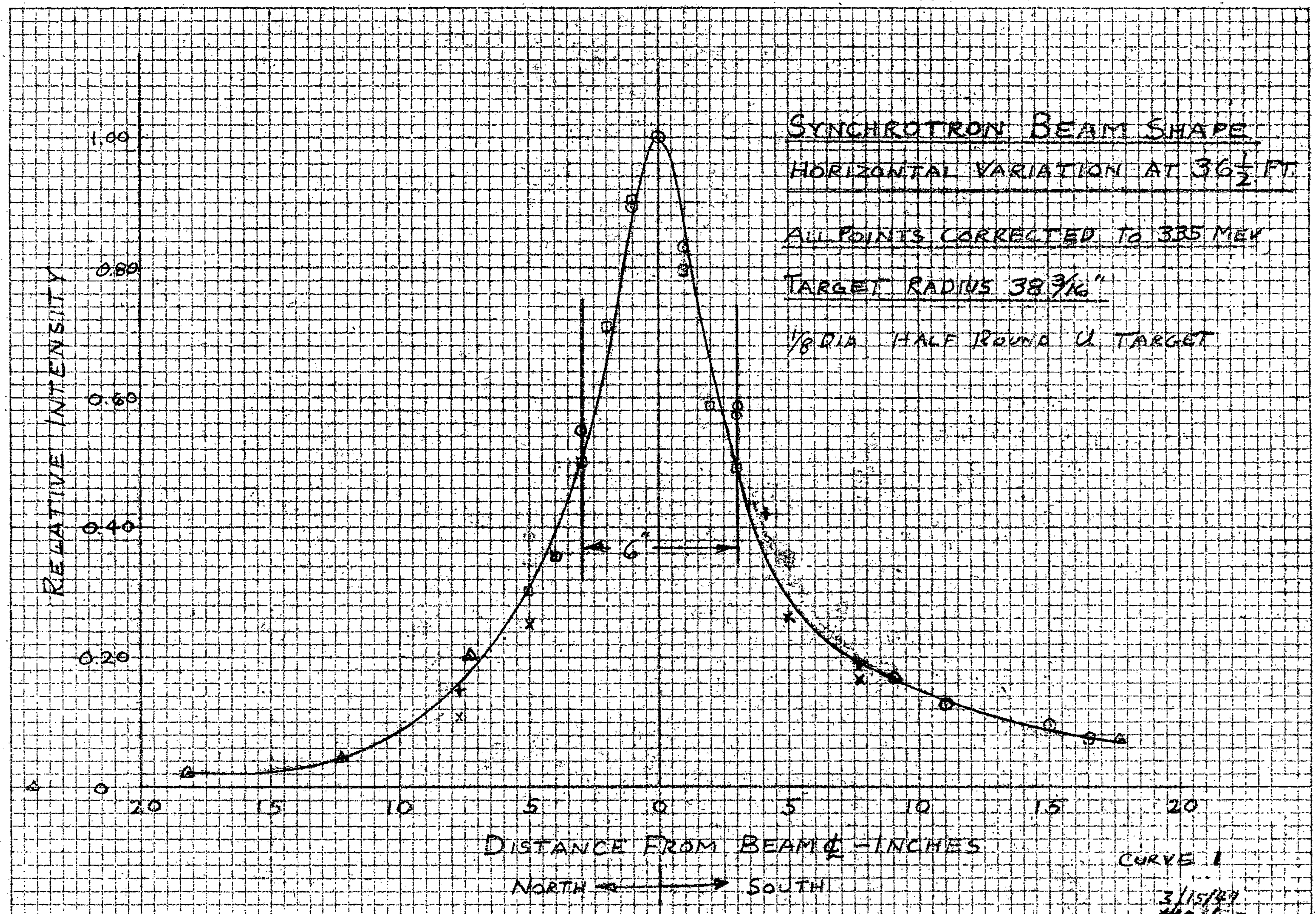

SYNCHROTRON BEAM SHAPE
HORIZONTAL VARIATION AT $36\frac{1}{2}$ FT.
ALL POINTS CORRECTED TO 335 MEV
TARGET RADIUS $38\frac{3}{16}$"
1/8 DIA HALF ROUND U TARGET
RELATIVE INTENSITY
1.00
0.80
0.60
0.40
0.20
0
6"
20
15
10
5
0
5
10
15
20
DISTANCE FROM BEAM ℄ - INCHES
NORTH
SOUTH
CURVE 1
3/15/49

FIG. 4

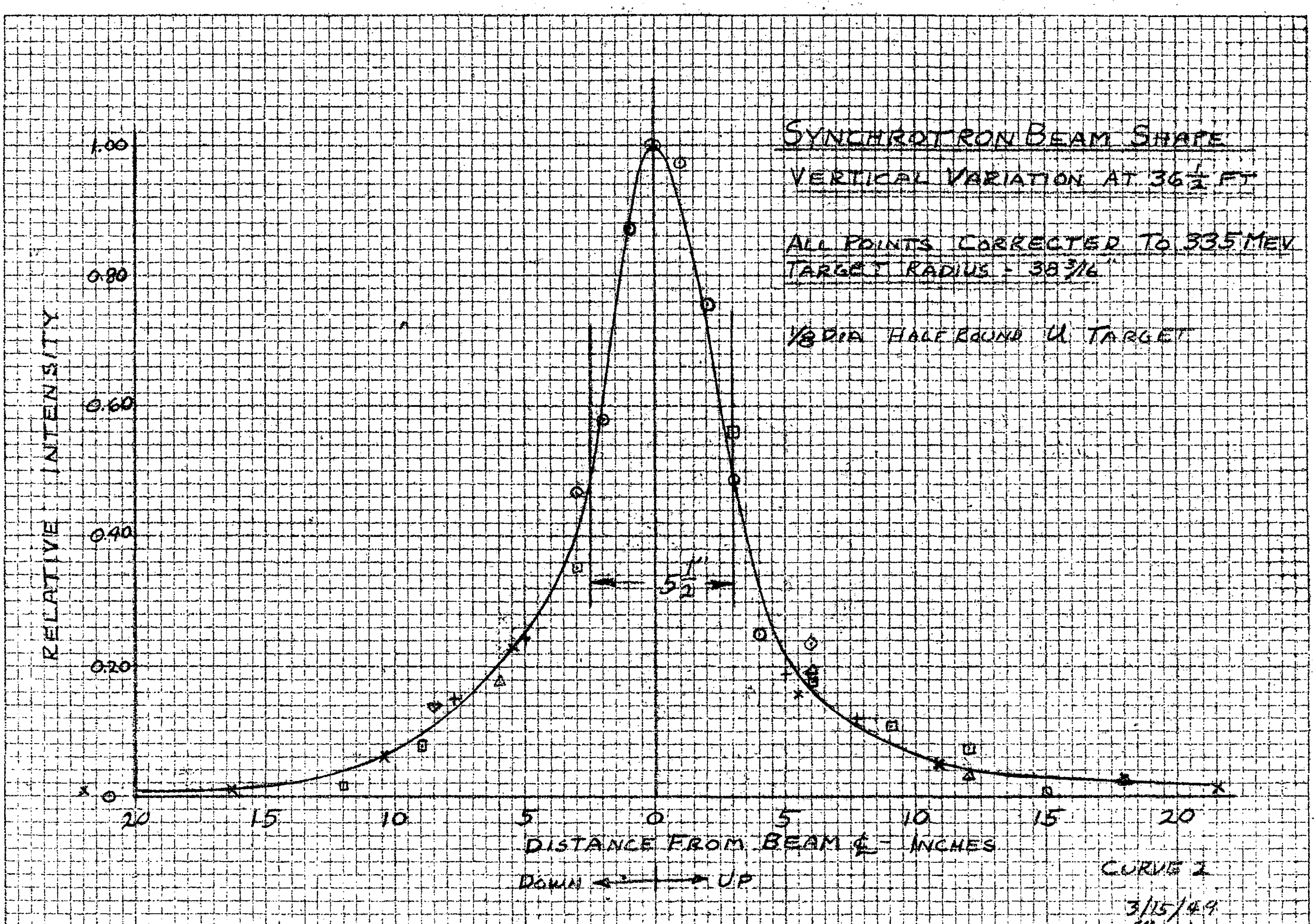

SYNCHROTRON BEAM SHAPE
VERTICAL VARIATION AT 36 1/2 FT
ALL POINTS CORRECTED TO 335 MEV
TARGET RADIUS - 38 3/16"
1/8 DIA HALF ROUND U TARGET
1.00
0.80
0.60
0.40
0.20
RELATIVE INTENSITY
5 1/2"
20
15
10
5
0
5
10
15
20
DISTANCE FROM BEAM ℄ - INCHES
DOWN ← → UP
CURVE 1
3/15/49

FIG. 5

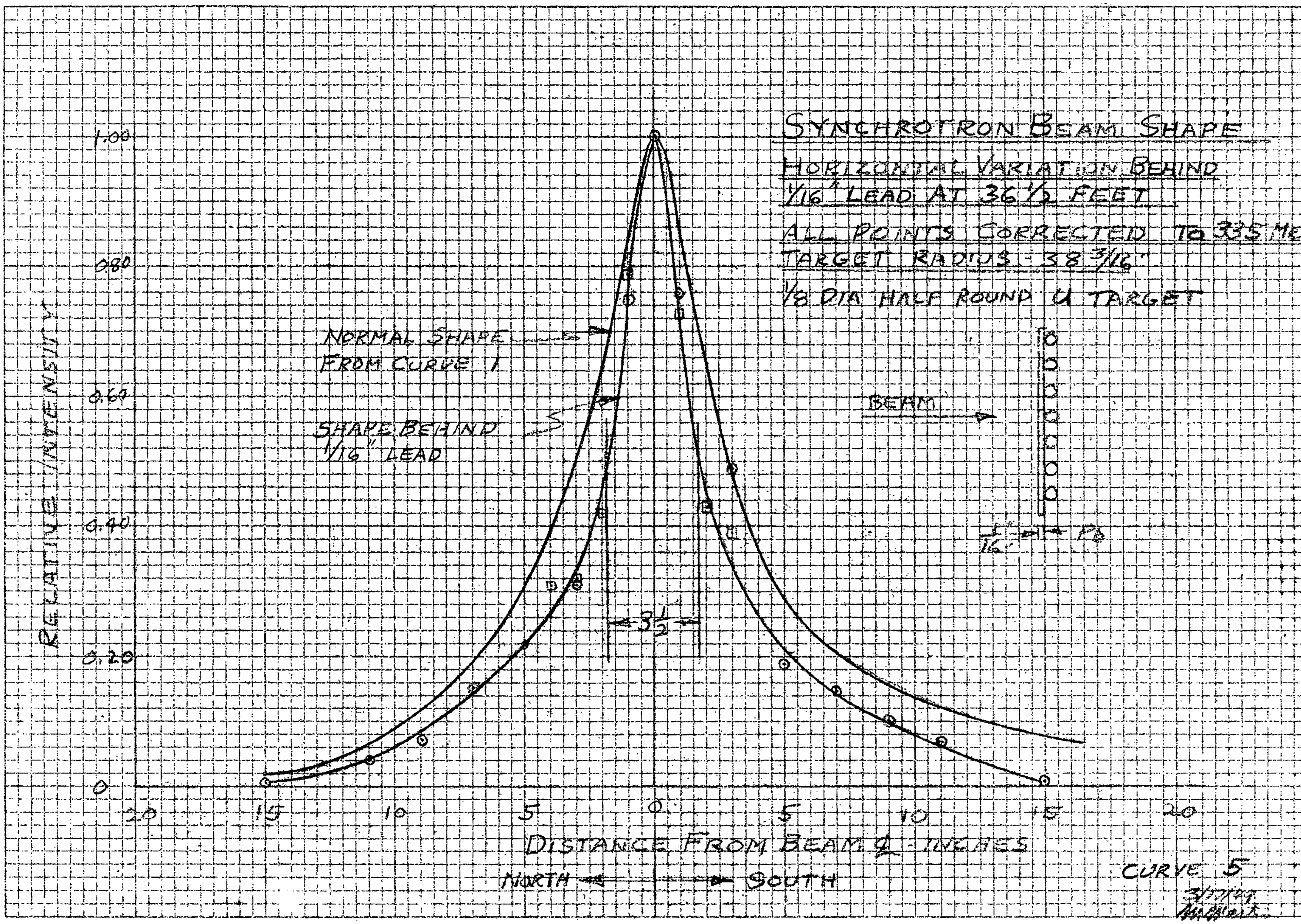

SYNCHROTRON BEAM SHAPE
HORIZONTAL VARIATION BEHIND
1/16" LEAD AT 36 1/2 FEET
ALL POINTS CORRECTED TO 335 MEV
TARGET RADIUS - 38 3/16"
1/8 DIA HALF ROUND U TARGET
BEAM
1/16" Pb
NORMAL SHAPE
FROM CURVE 1
SHAPE BEHIND
1/16" LEAD
3 1/2
RELATIVE INTENSITY
1.00
0.80
0.60
0.40
0.20
0
20
15
10
5
0
5
10
15
20
DISTANCE FROM BEAM ℄ - INCHES
NORTH
SOUTH
CURVE 5
3/17/49

FIG. 6

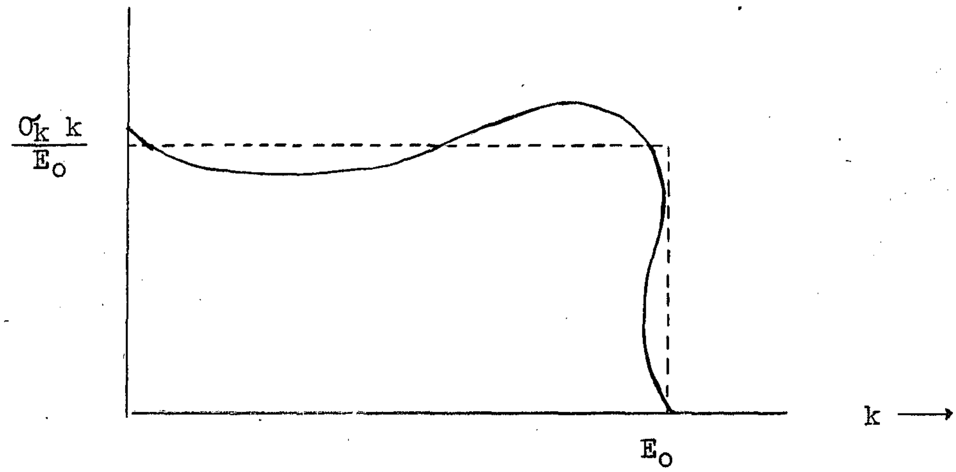
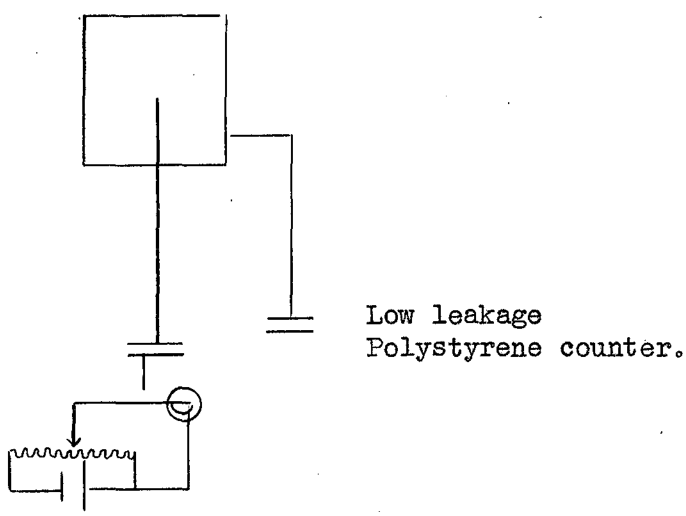
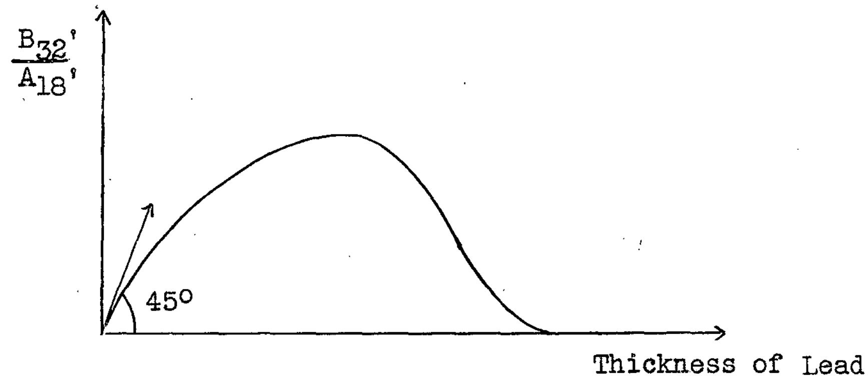


Fig. 7



Total Ionization Chamber

Fig. 8



Measure of the Cross Section for Pair Production

Fig. 9

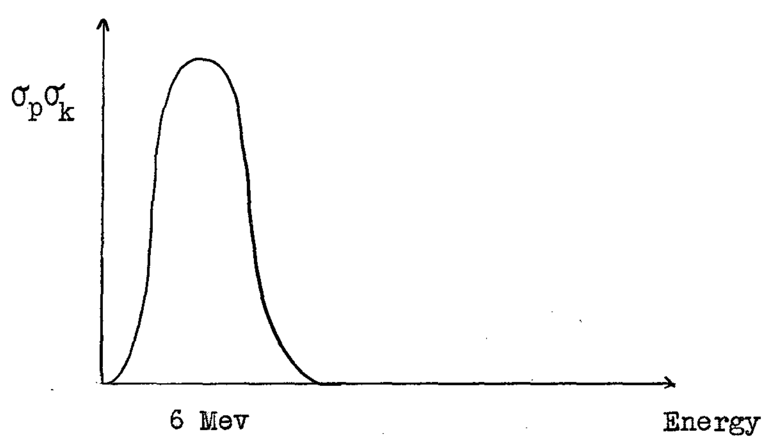


Fig. 10