AD/RHIC/RD–33

RHIC PROJECT

Brookhaven National Laboratory

Preliminary Study of Energy Deposition Downstream of the Internal Dump

A. J. Stevens

January 1992

Preliminary Study of Energy Deposition Downstream of the Internal Dump

A.J. Stevens

I. Introduction

Energy deposition in magnets downstream of the internal dump was previously studied as a part of a preliminary conceptual design of the internal dump.[1] However, the calculations reported in Reference 1 were performed for an abort system design in which the dump was located upstream of the crossing point. In that design, the nearest downstream magnet (Q3) was approximately 40m from the dump - a distance which was large enough to insure that a high margin of safety existed against quenching downstream magnets.

Recently, a lattice review committee, chaired by Alex Chao, endorsed the idea that the internal dump should be located downstream of the crossing point in order that the nuclear cascade initiated in the dump by an abort be directed away from detectors. One implication of this recommendation is that the location of the internal dump, as now envisaged, is only about 8m upstream of the nearest superconducting magnet (Q4). The purpose of the study reported here is to evaluate the energy deposition in the coil of this magnet as a part of the feasibility study of this new location for the dump.

II. Description of the Calculations

A sketch of the dump region is shown in Fig. 1. The most notable difference between this sketch and the previous approximation of the dump[1] is that the dump considered here is much longer. This change is based on the results of a series of calculations[2], done at the request of H. Foelsche, which revealed that "punch through" could be a significant source of radiation emerging from the relatively short dump of reference 1.

With this exception, the approximation of materials is quite similar to those made previously. The dump is composed of a thin titanium window followed by a carbon region (with density of 2.2 g/cc), and then iron. The carbon region extends to a transverse radius of 8 cm. and to Z of 1.5m. The beam pipe is assumed to be titanium in the region of the dump (for $Z < 4.3$m) and steel[3] thereafter. The coil region in Q4 is approximated by reduced density (6 g/cc) Fe and the magnetic field is assumed to have gradient 5.576 KG/cm within the 4 cm. aperture and is ignored in the coil and yoke regions.

The beam is incident on the dump face at a specific "Y" value (direction of the kick) and with a 2 cm. spread in the other transverse ("X") coordinate. This spread corresponds to the total "sweep" width[4] during beam abort. This geometry is illustrated in Fig. 2 which shows a symmetric sweep in the X coordinate which was assumed in the calculations reported here. In fact, the sweep will begin at X=0 and proceed in only one direction which implies an average displacement from the dump aperture greater than assumed here. The angles with respect to the beam axis are taken to have the values dY/dZ = Y/20m, dX/dZ = 0[5], and the internal divergence of the beam is ignored.

Energy deposition calculations were performed using the hadron cascade Monte Carlo program CASIM.[6] Most calculations assumed incident 250 GeV/c protons which are believed to represent the worst case. The dump kicker will achieve a Y displacement on the dump face of 3.6 cm. (ΔY=2.2 cm. from the aperture) for the central orbit with beam "tails" extending as far as +/- 0.5 cm. on either side of this value[4] (including 95% of the beam). For this reason, calculations were made for 3 Y values; 3.1cm., 3.6 cm., and 4.1 cm. In order to reduce computer time, the cascade was terminated for hadrons of less than 20 GeV emerging from interactions of the primary beam particle, and transport was terminated if any transverse radius exceeding 10 cm. was encountered.[7]

In order to compare Au at 100 GeV/u with incident 250 GeV/c protons, runs were also made with 100 GeV/c protons and neutrons. In the next section results are reported for these runs normalized by the relation (97*"p" + 118*"n")/197 where "p" and "n" correspond to energy deposition values obtained from the incident protons and neutrons respectively. This crude approximation for forward energy emerging from Au interactions in the dump must be verified when a better approximation of heavy ion interactions becomes available.[8]

III. Results

Most of the energy deposition in the coil region is electromagnetic resulting from π^0 creation in interactions close to or in the coil. These "local" interactions are initiated by hadrons whose "parents" were themselves typically third, fourth, or fifth generation products of the initial interaction. Fig. 3 illustrates a typical example where a third generation pi+ escapes into the dump aperture and interacts in the vacuum pipe near Q4. This example is from one of the 250 GeV/c incident proton runs at Y = 3.1 cm. Such "histories" were examined (printed) for each primary proton which resulted in greater than 0.5 GeV being deposited in the coil. Fig. 4 shows the momentum spectrum for the Y=3.1 runs, weighted by the energy deposited in the coil, for secondaries in the printed histories whose trajectories crossed the plane at Z=4.3m with a transverse (R) coordinate less than the 1.4

cm. aperture. The events in this plot, which number 276 out of the 2,000,000 primaries generated, represent approximately 70% of the energy deposition in the coil.

To examine the spacial dependence of energy deposition, the Q4 coil was segmented into 4 bins in the Z coordinate, 3 in R, and 4 in azimuth. No R dependence was observed in this geometry so that an average over the 3 R bins was always used. Both longitudinal (Z) and azimuthal (phi) dependence were observed. The former is caused by the magnetic field of Q4 and the latter by the inherent asymmetry of the source. As illustrated by the event sketched in Fig. 3, the "down" (negative Y) azimuthal quarter is the azimuthal "hot spot."

Fig. 5 shows the energy deposition density in the coil averaged over R and phi as a function of Z for the 3 values of incident transverse displacement which were considered. The error bars in this figure correspond to the rms deviation of 5 computer runs, each with 400,000 250 GeV/c primary protons. The enhancement at the beginning of the coil corresponds to the relatively low momentum (Fig.4) charged secondaries being drawn into the coil by the magnetic field.

Fig. 6 shows the energy deposition density "hot-spot" (first Z bin and "down" azimuth) as a function of the incident transverse beam displacement. Also shown in Figs. 5 and 6 is the approximate fast-loss quench threshold[9] assuming that the design intensity, 5.7 X 10^{12} 250 GeV/c protons, are dumped. Fig.7 shows the results for 100 GeV/c incident nucleons, as discussed in the preceding section, corresponding to Fig. 6. In this case, the design intensity limit corresponds to 197 X 5.7 X 10^{10} nucleons.

IV. Discussion

The results of the calculations reported here indicate that approximately an order of magnitude safety exists against quenching the nearest magnet in a geometry which aborts the beams downstream of the crossing point. However, as mentioned above, such a conclusion is subject to verification by more refined approximations of heavy ion interactions when those become available. It should be noted that additional measures to reduce the radiation burden on the Q4 coil are possible but have not been explored. These include (a) the possibility of a protective "collar" in front of Q4 which intrudes into the aperture and shadows the coil, (b) a stronger kicker to achieve greater transverse displacement on the face of the dump, and (c) magnitizing the steel of the dump (which might require compensation).

References/Footnotes

1. A.J. Stevens, "RHIC Internal Beam Dump; Preliminary Conceptual Design", AD/RHIC-43 (1988).

2. Memorandum from A.J. Stevens to H. Foelsche dated 8/1/1991.

3. The beam pipe downstream of the dump shown in Fig. 1 is twice the normal beam pipe thickness. This size was selected to reduce the probability of "stepping over" the pipe during transport. The density was reduced to half the normal value to compensate for this approximation.

4. H. Foelsche, private communication. Other parameters assumed herein, e.g., the dump aperture at R=1.4 cm., are also preliminary results of beam abort system performance studies currently in progress.

5. The kicker was assumed to be 20m upstream of the entrance face of the dump.

6. A. Van Ginneken, "CASIM. Program to Simulate Hadronic Cascades in Bulk Matter", Fermilab FN-272 (1975).

7. A completely unbiased calculation was performed with R extending to the yoke radius (13 cm.) for the smallest Y value with somewhat reduced statistical precision. No difference was observed between this calculation and the results presented in section III.

8. The current approximation of heavy ion interactions in CASIM does not adequately describe the interaction of massive ions with light (e.g., carbon) nuclei. A new version is currently being developed by A. Van Ginneken which will incorporate the physics of heavy ion event generators such as HIJET.

9. R. Dixon, N.V. Mokhov, and A. Van Ginneken, "Beam Induced Quench Study of Tevatron Dipoles", Fermilab FN-327 (1980).

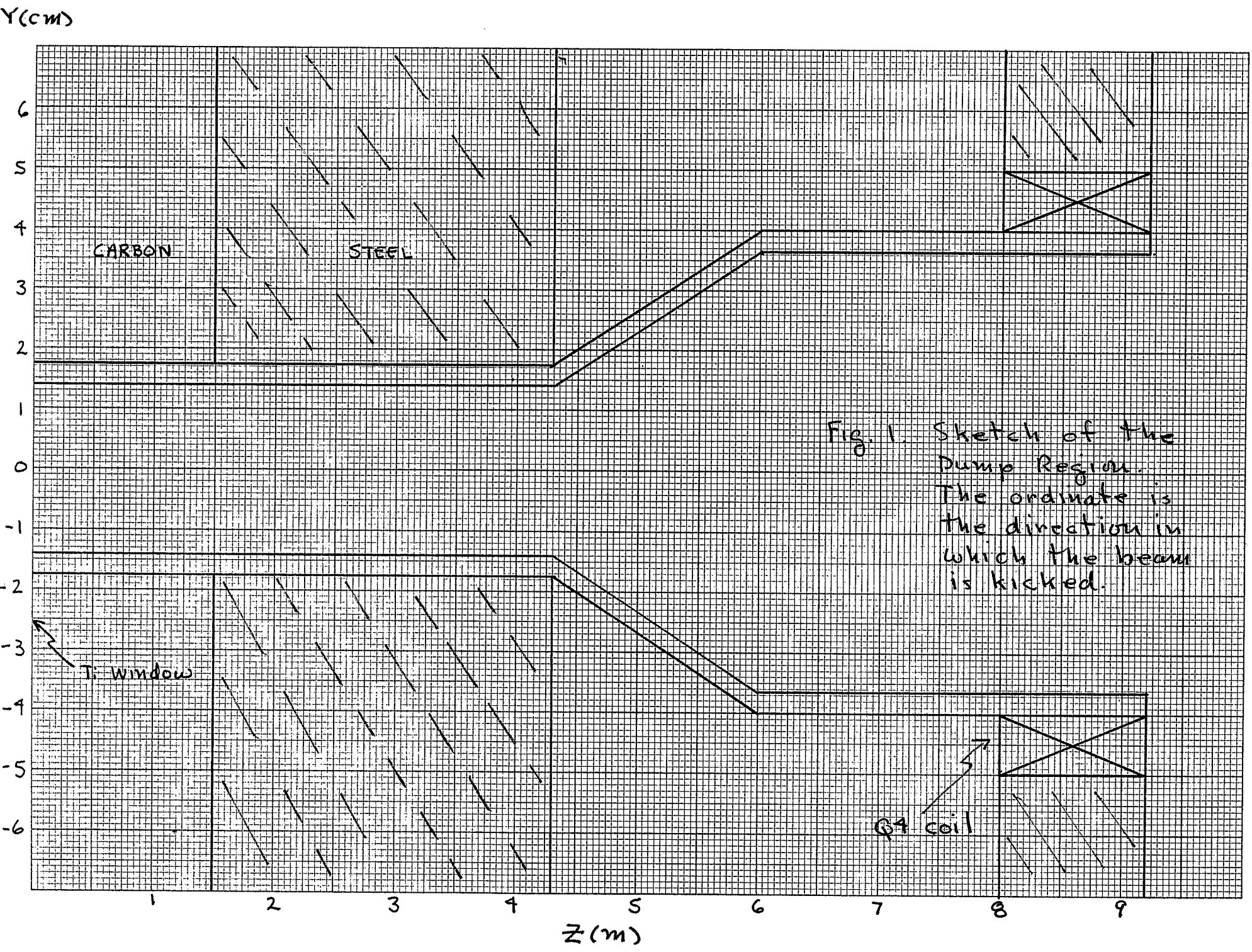

Fig. 1. Sketch of the Dump Region. The ordinate is the direction in which the beam is kicked.

GRAPH PAPER ® GRAPHIC CONTROLS CORPORATION Buffalo, New York Printed in U.S.A.
SQUARE 10 X 10 TO THE HALF INCH AS-0813-60

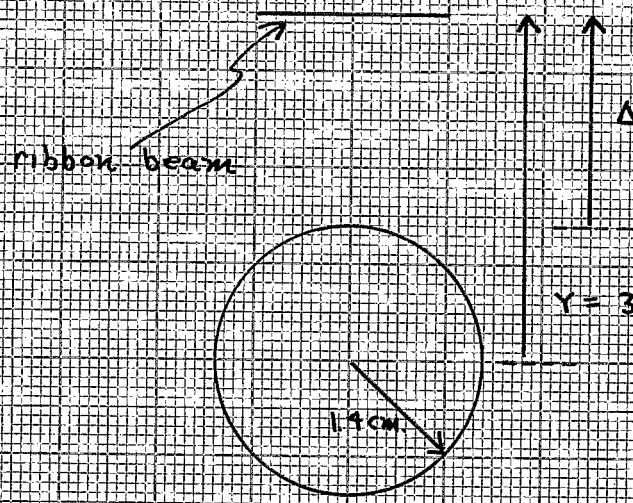

Fig. 2. Sketch of a ribbon beam kicked in the Y direction on the dump face. The X spread is created by a sweeper. The Y value shown is the nominal position of the central orbit.

SQUARE 10 X 10 TO THE HALF INCH AS-0013-60
© GRAPHIC CONTROLS CORPORATION GRAPH PAPER
Buffalo, New York Printed in U.S.A.

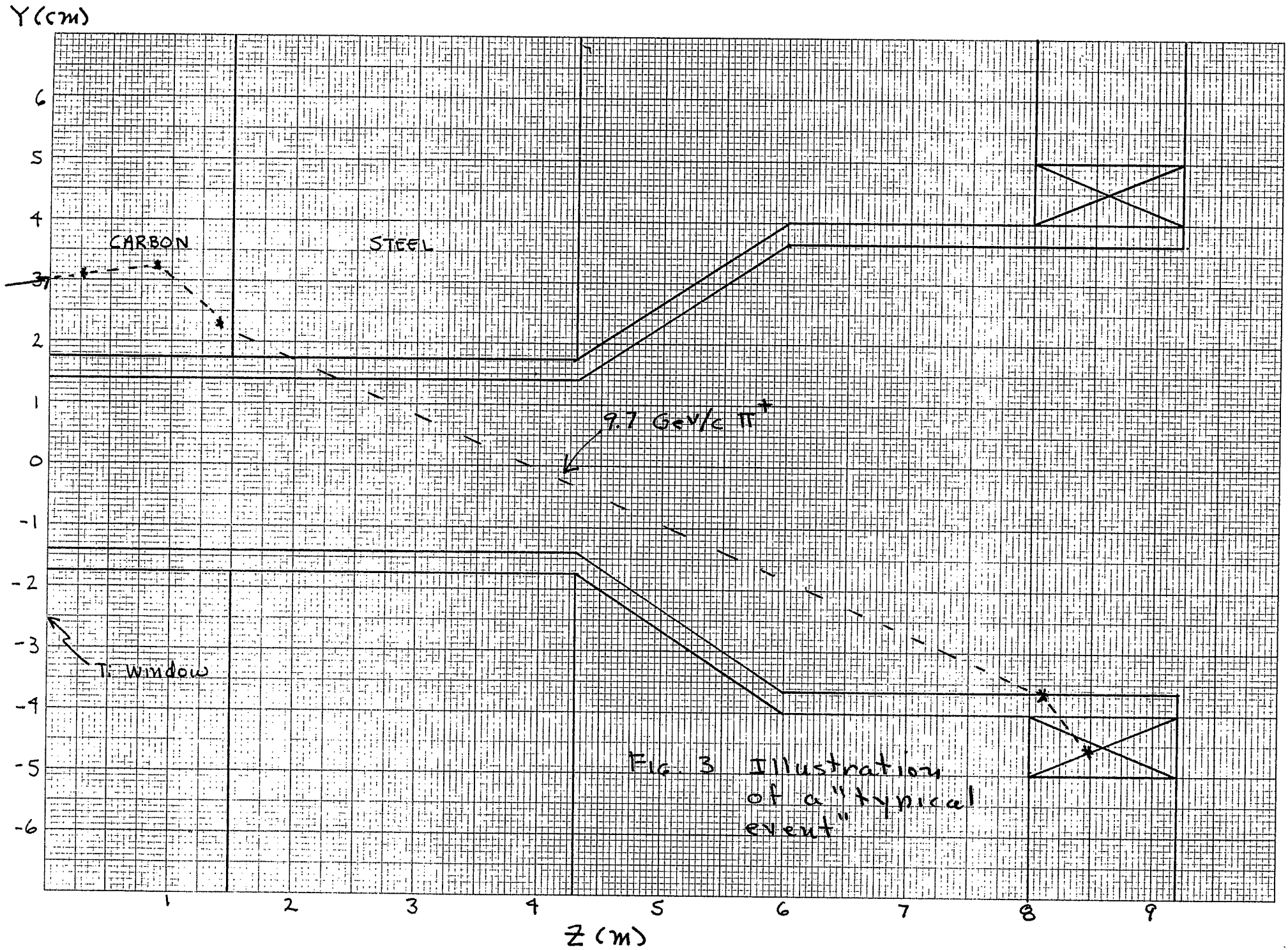

Fig. 3 Illustration of a "typical event"

GRAPH PAPER © GRAPHIC CONTROLS CORPORATION
Buffalo New York Printed in U S A
SQUARE 10 X 10 TO THE HALF INCH 45-8913-60

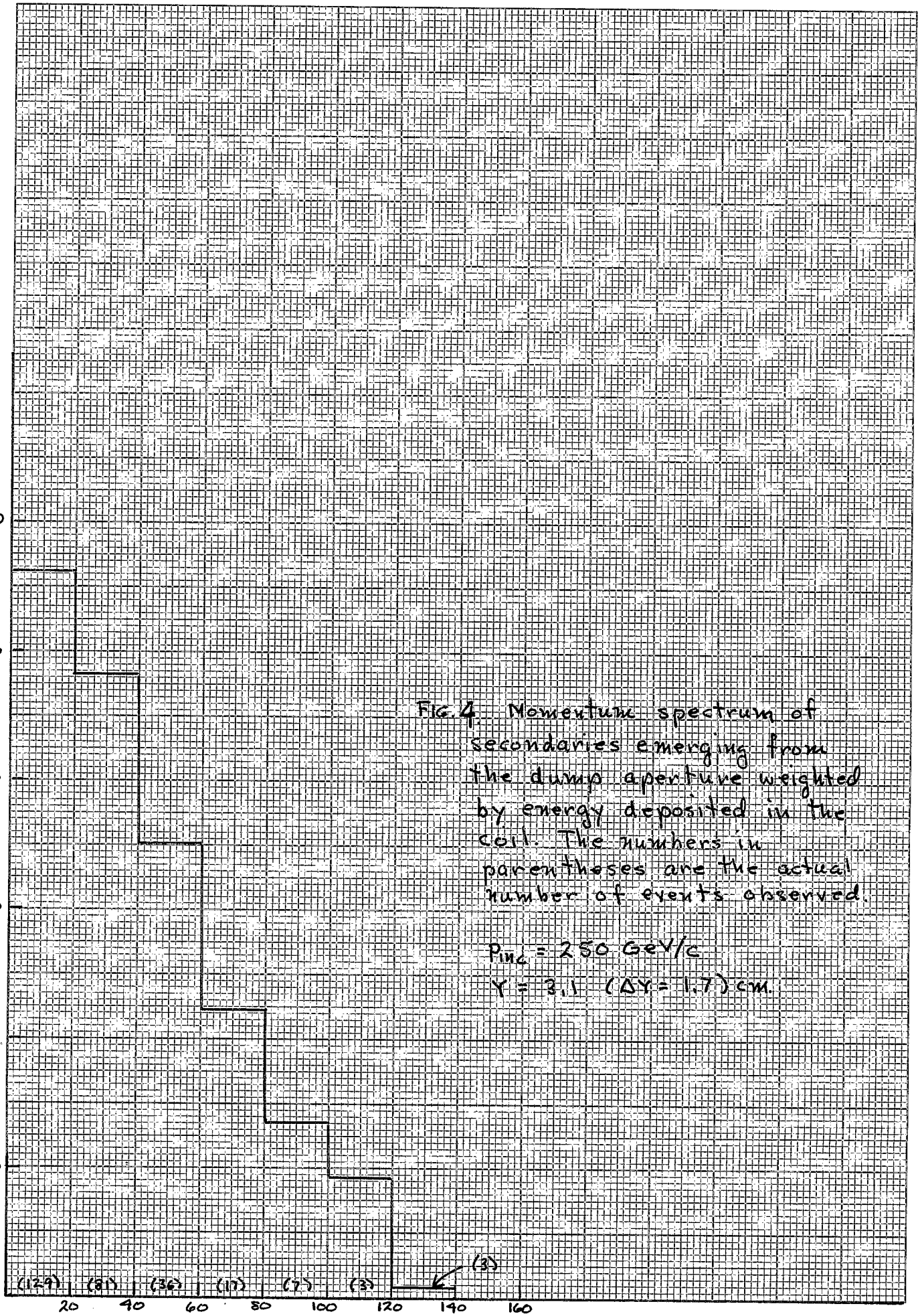

FIG. 4. Momentum spectrum of secondaries emerging from the dump aperture weighted by energy deposited in the coil. The numbers in parentheses are the actual number of events observed.

P_{INC} = 250 GeV/c

Y = 3.1 (ΔY = 1.7) cm.

SQUARE 10 X 10 TO THE HALF INCH AS-0013-60
GRAPHIC CONTROLS CORPORATION Buffalo, New York Printed in U.S.A.
GRAPH PAPER

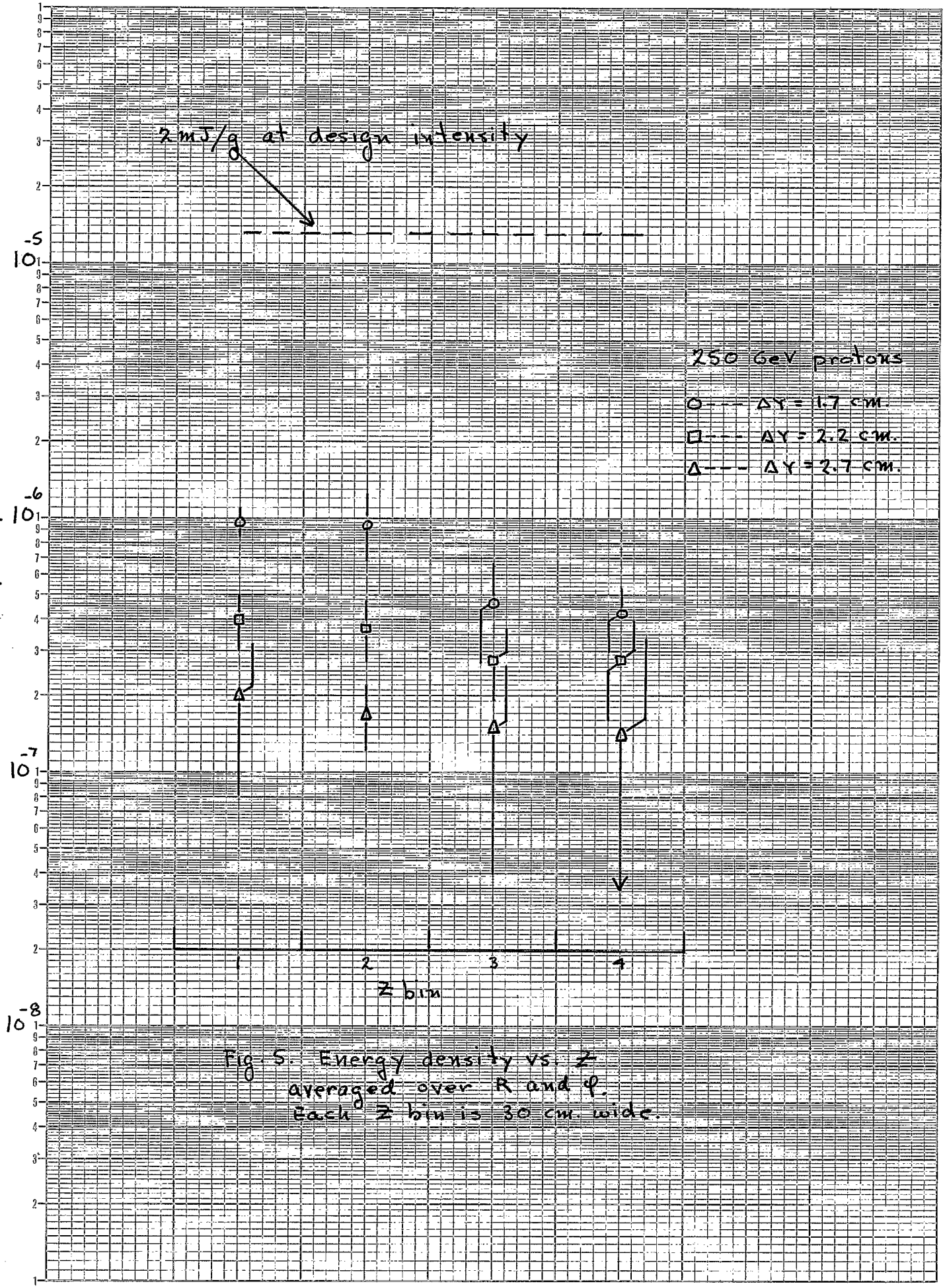

Fig. 5. Energy density vs. Z averaged over R and φ. Each Z bin is 30 cm wide.

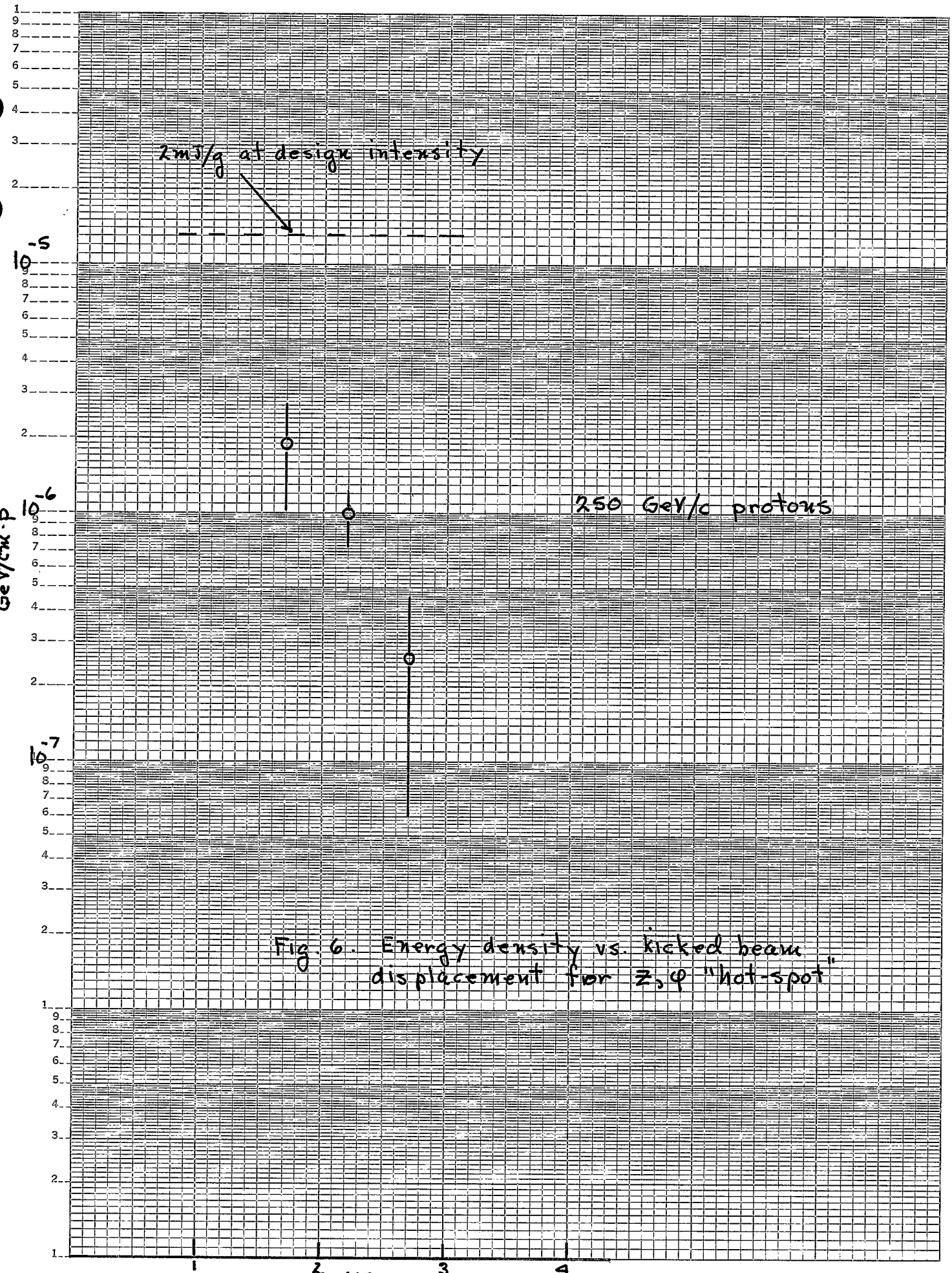

Fig. 6. Energy density vs. kicked beam displacement for Z, φ "hot-spot"

46 6210
SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

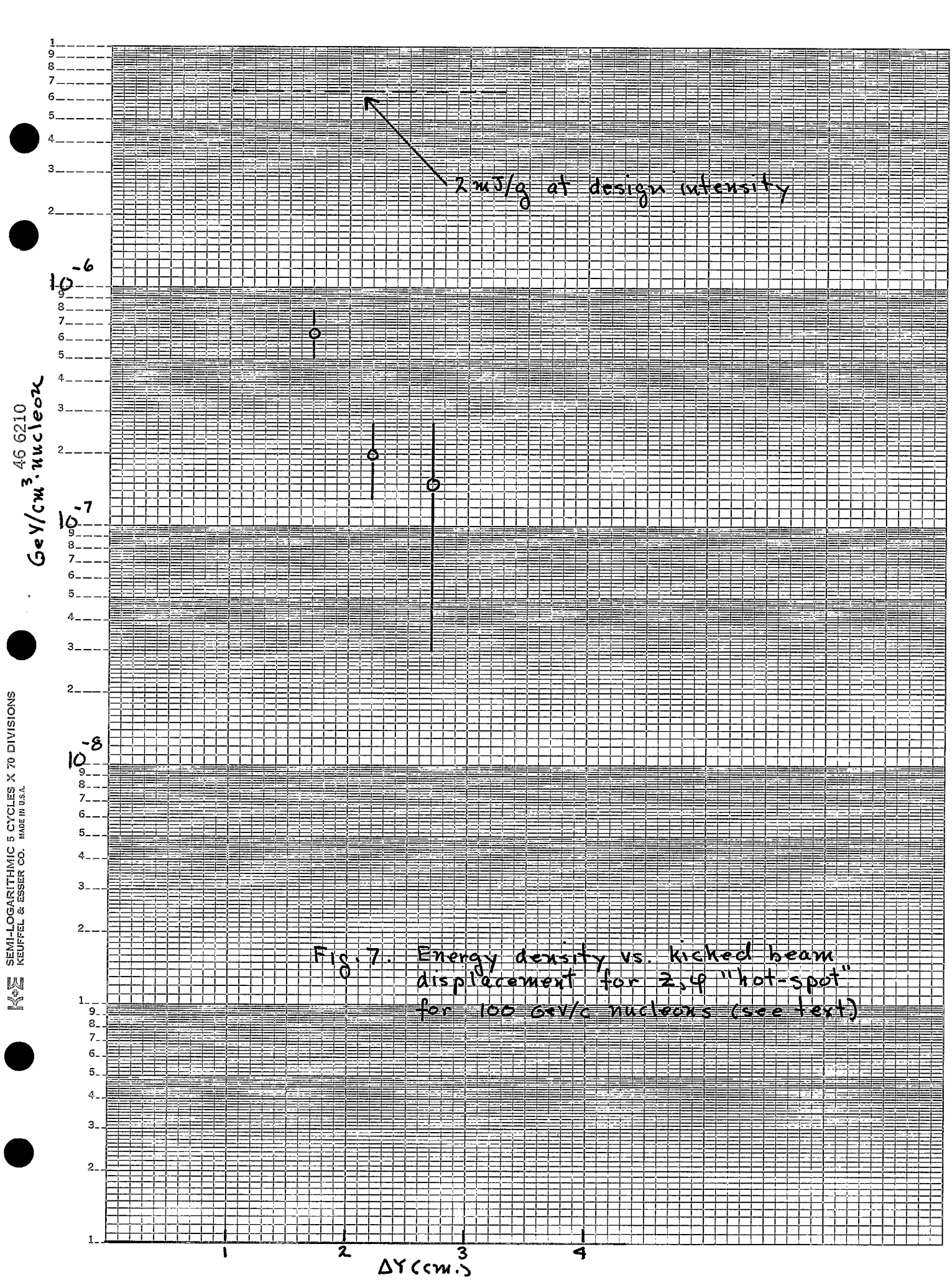

Fig. 7. Energy density vs. kicked beam displacement for 2.4 "hot-spot" for 100 GeV/c nucleons (see text)

46 6210
SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.