Fermi National Accelerator Laboratory

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Scintillating Fiber Ribbon - Tungsten Calorimeter

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Abstract

We describe an ultra-high density scintillating fiber and tungsten calorimeter used as an active beam-dump for electrons. Data showing the calorimeter response to electrons with momenta between 50 and 350 GeV/c are presented.

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1 Introduction

Experiment 774 at Fermilab is an electron beam-dump experiment that is searching for neutral, short-lived particles that couple to the electron. The sensitivity of such a search to short lifetimes is determined by the energy of the beam and the length of the dump, in particular the shorter the dump, the more sensitive the experiment. In order to minimize the length of the dump, tungsten was chosen as the absorber and scintillating fiber ribbon as the sampling medium.

A new scintillator [1] developed in the scintillating fiber program at Fermilab was used in the dump calorimeter. This scintillator was fabricated at Fermilab and drawn into fiber ribbons commercially. [2]

2 Scintillation Fiber Ribbons

The scintillator used in the calorimeter consisted of a polystyrene base doped with 2-(2'-Hydroxyphenyl)benzothiazole (HBT) at a concentration of 1 % by weight. This molecule exhibits an intra-molecular proton transfer upon excitation [3]; thus there is essentially no overlap between the emission and absorption spectra of this compound, (Figure 1). Since this single dopant couples directly to the intrinsic fluorescence of the polystyrene, we have referred to this type of scintillator as an intrinsic IPT scintillator. The light yield from this scintillator is approximately 1/3 that of NE 110 and has a decay time of 3-4 nsec.

Fibers were drawn from square preforms consisting of a core of HBT scintillator and a cladding of PMMA (acrylic). The scintillator core was clad with the acrylic at the facilities at the Washington University, St. Louis. [4] The cladding thickness was approximately 4 % of the core diameter. Fibers were then drawn from the clad preform to a cross section of 200 X 200 microns and wound around a drum in a continuous helix. The fibers were then glued together with a vinyl adhesive to form ribbons, (Figure 2). The attenuation length for this fiber was measured using an UV excitation source and a silicon photodiode. A typical attenuation curve is shown in figure 3.

3 The calorimeter

The dump calorimeter was comprised of two sections. The upstream section consisted of thirty-two 10 cm. X 10 cm. X 3 mm. thick tungsten plates (28 radiation lengths) interspersed with the fiber ribbons. Figure 4 shows a picture of the front section along with one of the fiber ribbons. This section of the calorimeter had a mean density of 17.5 grams/cc and a sampling fraction of 0.5 %. It was readout by a 4 X 4 array of Hamamatsu R1450 PMT's (figure 5). The fibers and plates were oriented transverse to the beam; thus the 16 PMT's gave a longitudinal and transverse measurement of the electron shower profile. The back section used eleven 10 cm X 18 cm. X 10 mm thick plates (32 radiation lengths) readout by a single 3" Hamamatsu R2238 PMT. The final assembly (without the R2238) is shown in figure 6.

4 Calibration Run and Results

A brief calibration run was performed using the wide band electron beam [5] at Fermilab. Electrons with momenta between 50 and 350 GeV/c were used in this study. The dump calorimeter energy calibration from these runs is shown in figure 7. A typical shower profile in the 16 channels of the front section is shown in figure 8. Due to the nature of the wide band beam, we were unable to reduce the momentum spread of the beam below 6% and thus could not measure the energy resolution of the calorimeter. Figure 9 shows the dump calorimeter energy sum for the 275 GeV/c run. The width is consistent with the expected momentum spread of the beam. The measured signal sum from the calorimeter was consistent with the expected photon yield based on the beam energy, sampling fraction, and the intrinsic light yield of the HBT scintillator. At 275 GeV/c 98 % of the shower energy is contained in the front section of the calorimeter.

5 Conclusions

We have operated an ultra-high density scintillating fiber and tungsten electron beam dump calorimeter at momenta up to 350 GeV/c. The sampling medium of 200 micron scintillating fiber has allowed for an extremely compact design. The response linearity is excellent over the entire test range of 50 to 350 GeV/c.

We thank the departments of the Fermilab Research Division and the Fermilab Physics Section for their help in the construction of the apparatus.

We should also like to acknowledge the co-operation of the E-687 experiment, the designers and primary users of the wide-band photon beam, and the help of Robert Binns and John Epstein of the Washington University in fabricating the fiber preforms. This research was supported by the U.S. Department of Energy.

References

[1] A.D. Bross, Fermilab Technical Memo **TM-1587**.

[2] Fiber Optics Research Development Corporation, Santa Barbara, California.

[3] D.L. Williams and A. Heller, *Journal of Physical Chemistry*, Vol. **74**, No. 26 (1970) 4473.

[4] W.R. Binns, J.J. Connell, P.F. Dowkontt, J.W. Epstein, M.H. Israel, and J. Klarmann, *Nucl. Inst. and Methods*, **A251** (1986) 402.

[5] J. Butler et. al., Fermilab Technical Memo **TM-963**, April, 1980.

Figure Captions

Figure 1. Absorption and Fluorescence spectra of HBT in polystryene. Concentration equals 1 %, optical path length equals 1.2 cm.

Figure 2. Cross sectional diagram of fiber ribbon.

Figure 3. Attenuation curve for typical ribbon, UV excitation, $\lambda_{ex} = 313$ nm.

Figure 4. Front section of the calorimeter. A single fiber ribbon is also shown for comparison.

Figure 5. Front section of the calorimeter with PMT's mounted.

Figure 6. Final Assembly showing front and back sections and the PMT divider chain electronics for front section.

Figure 7. Calorimeter energy calibration, p = 50 to 350 GeV/c.

Figure 8. Lego plot of 275 GeV/c electron shower energy deposition in the front section of the calorimeter.

Figure 9. Calorimeter energy sum for the 275 GeV/c run.

Figure 1

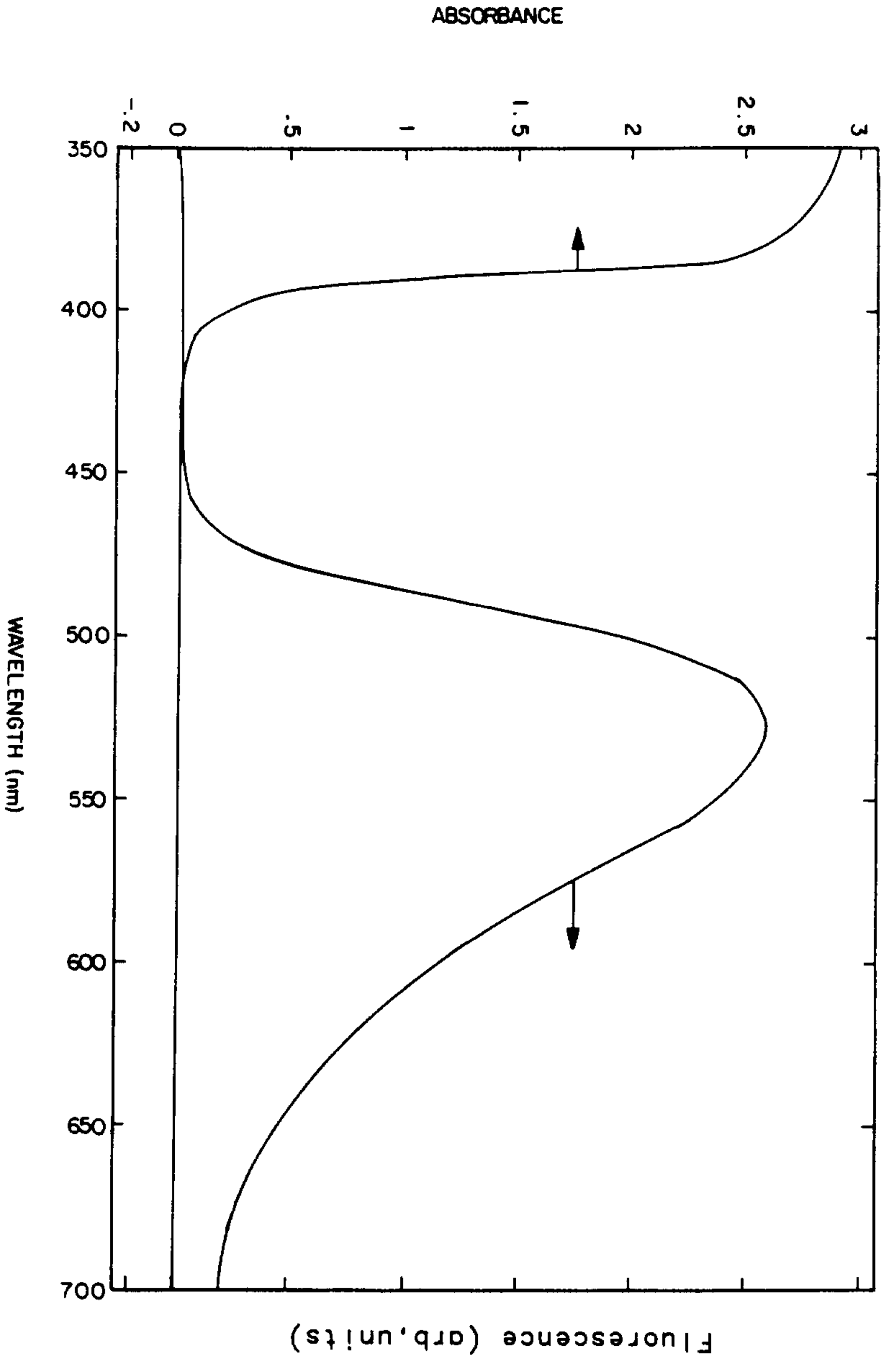

ABSORBANCE
-.2
0
.5
1
1.5
2
2.5
3
350
400
450
500
550
600
650
700
WAVELENGTH (nm)
Fluorescence (arb,units)

Figure 2

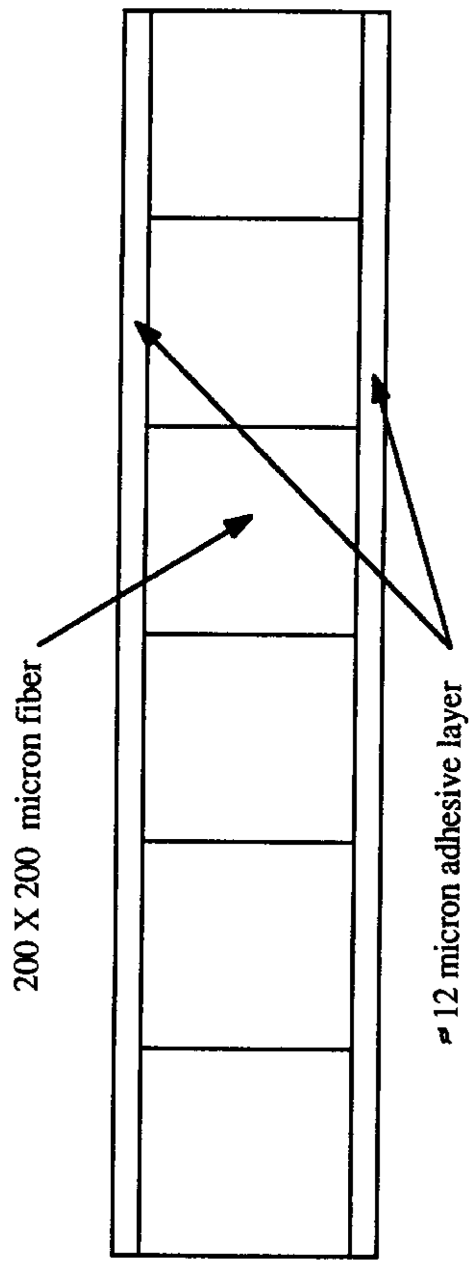
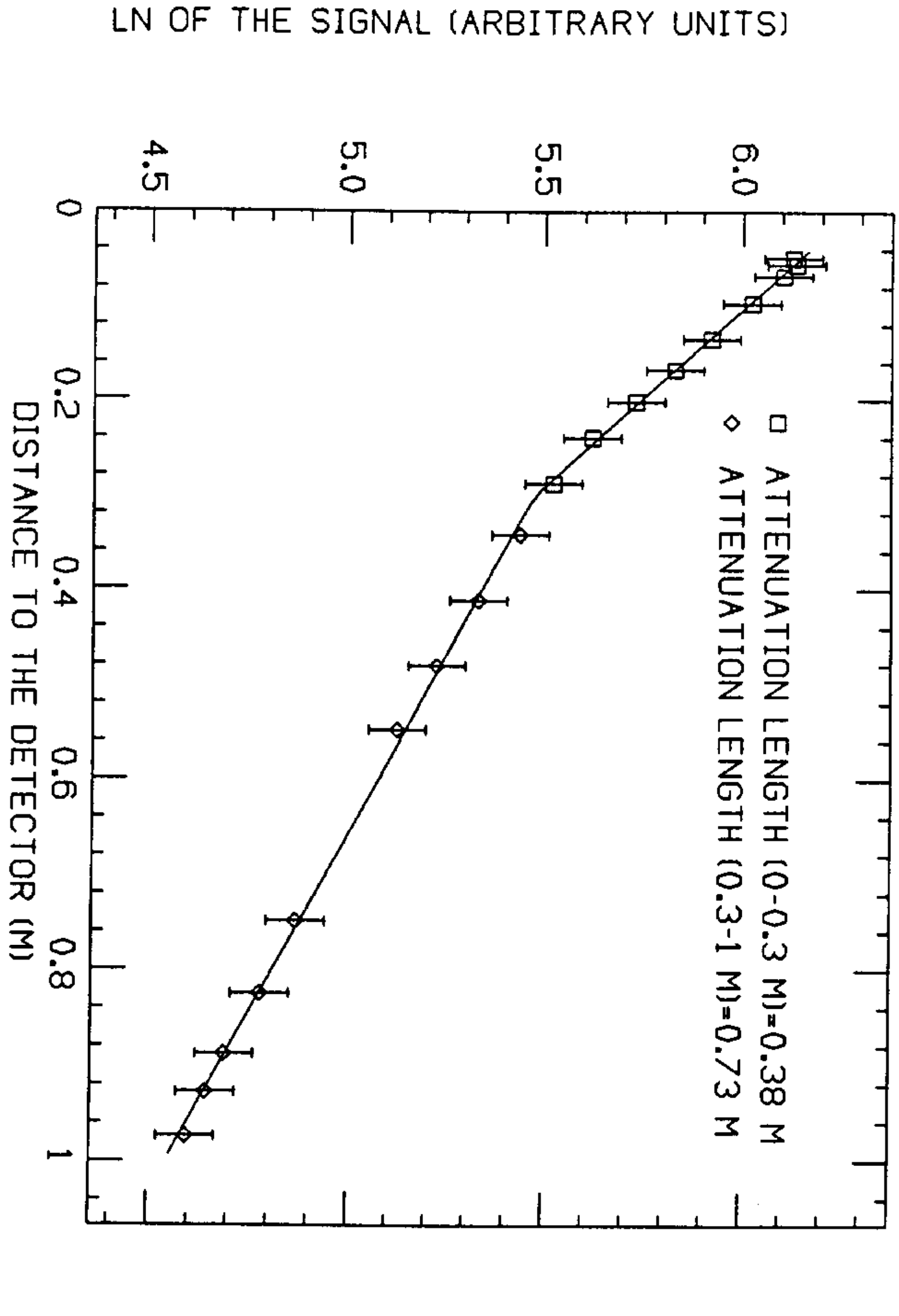


Figure 3



LN OF THE SIGNAL (ARBITRARY UNITS)
4.5
5.0
5.5
6.0
0
0.2
0.4
0.6
0.8
1
DISTANCE TO THE DETECTOR (M)
ATTENUATION LENGTH (0-0.3 M)=0.38 M
ATTENUATION LENGTH (0.3-1 M)=0.73 M

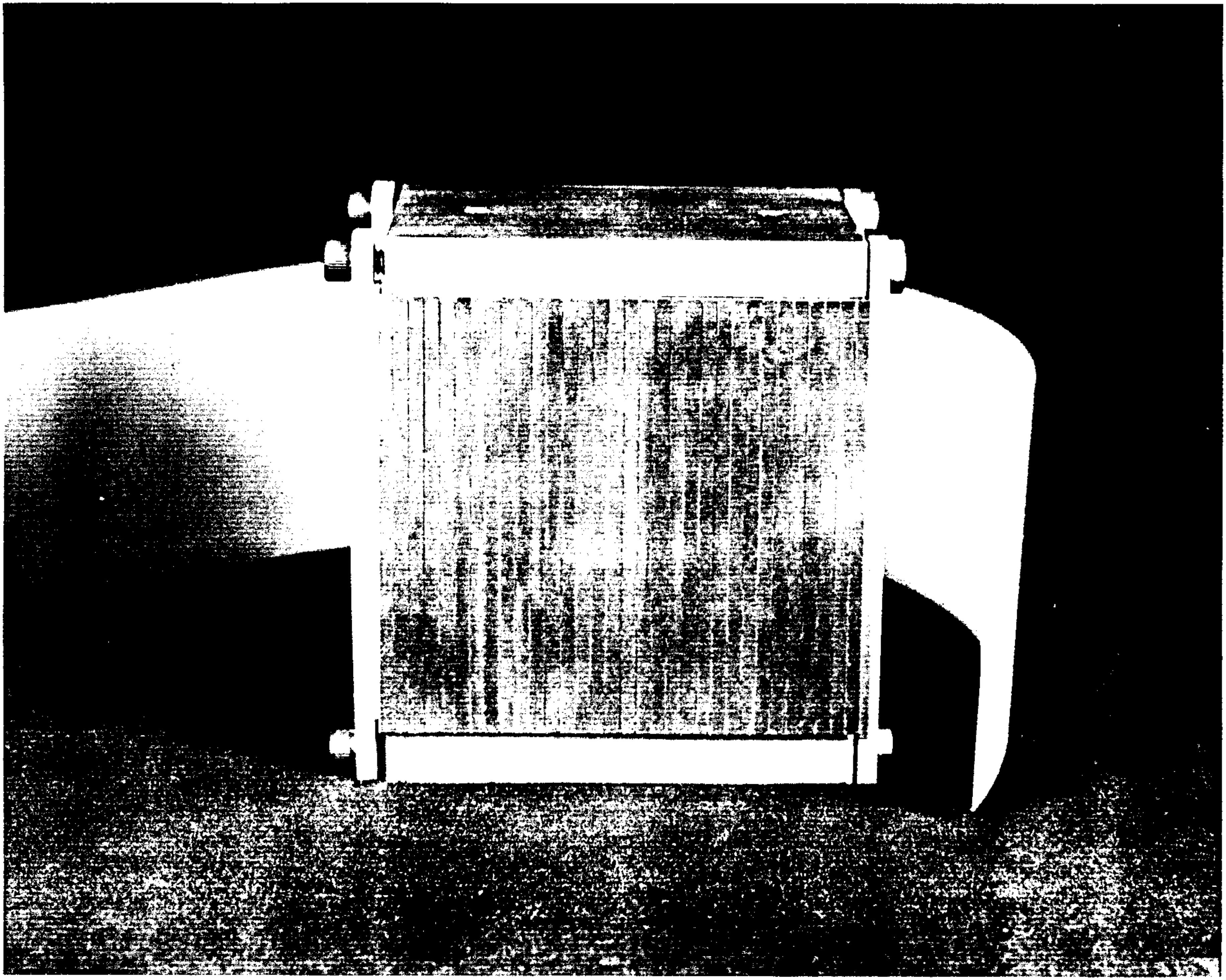


Figure 4

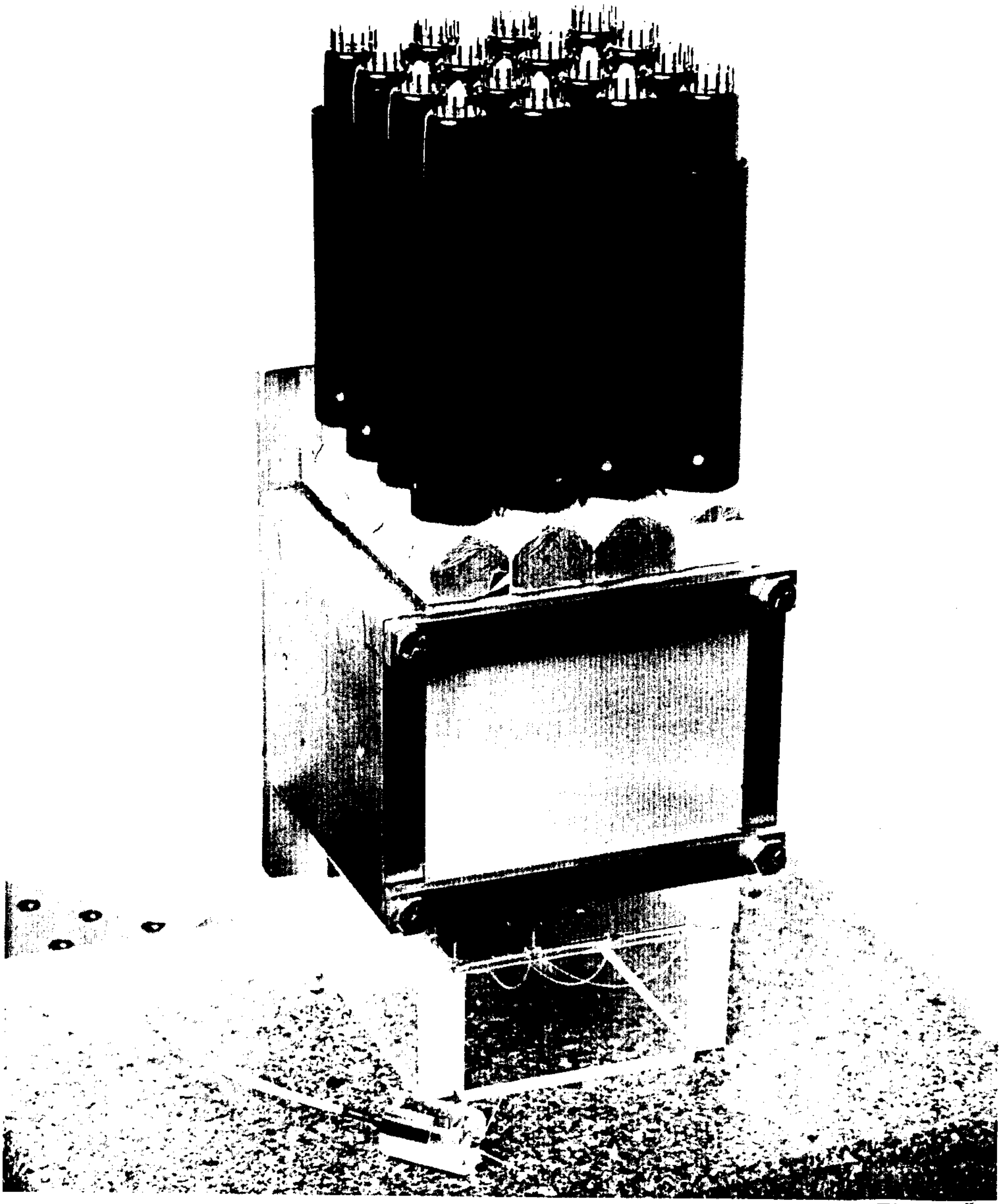


Figure 5

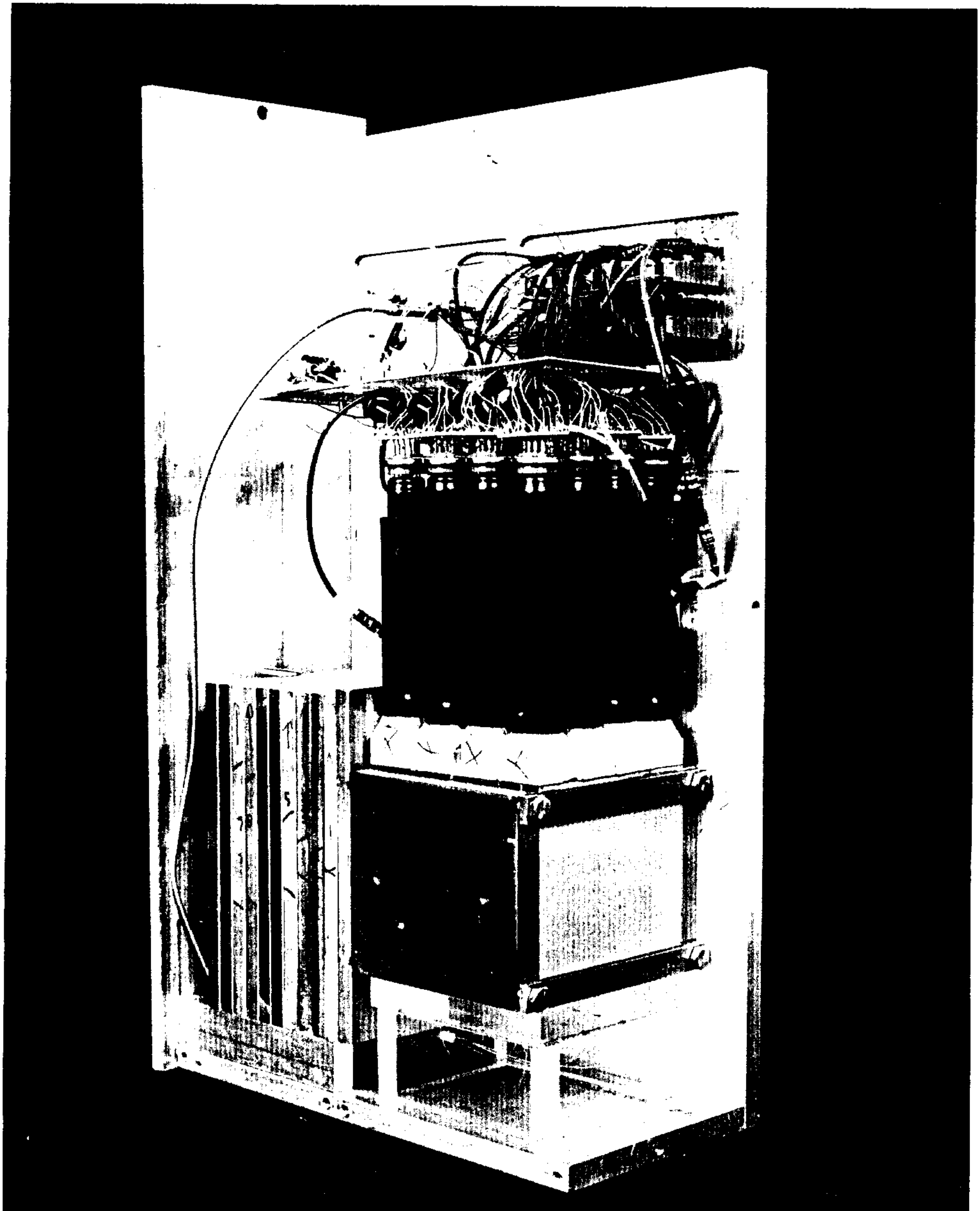


Figure 6

Figure 7

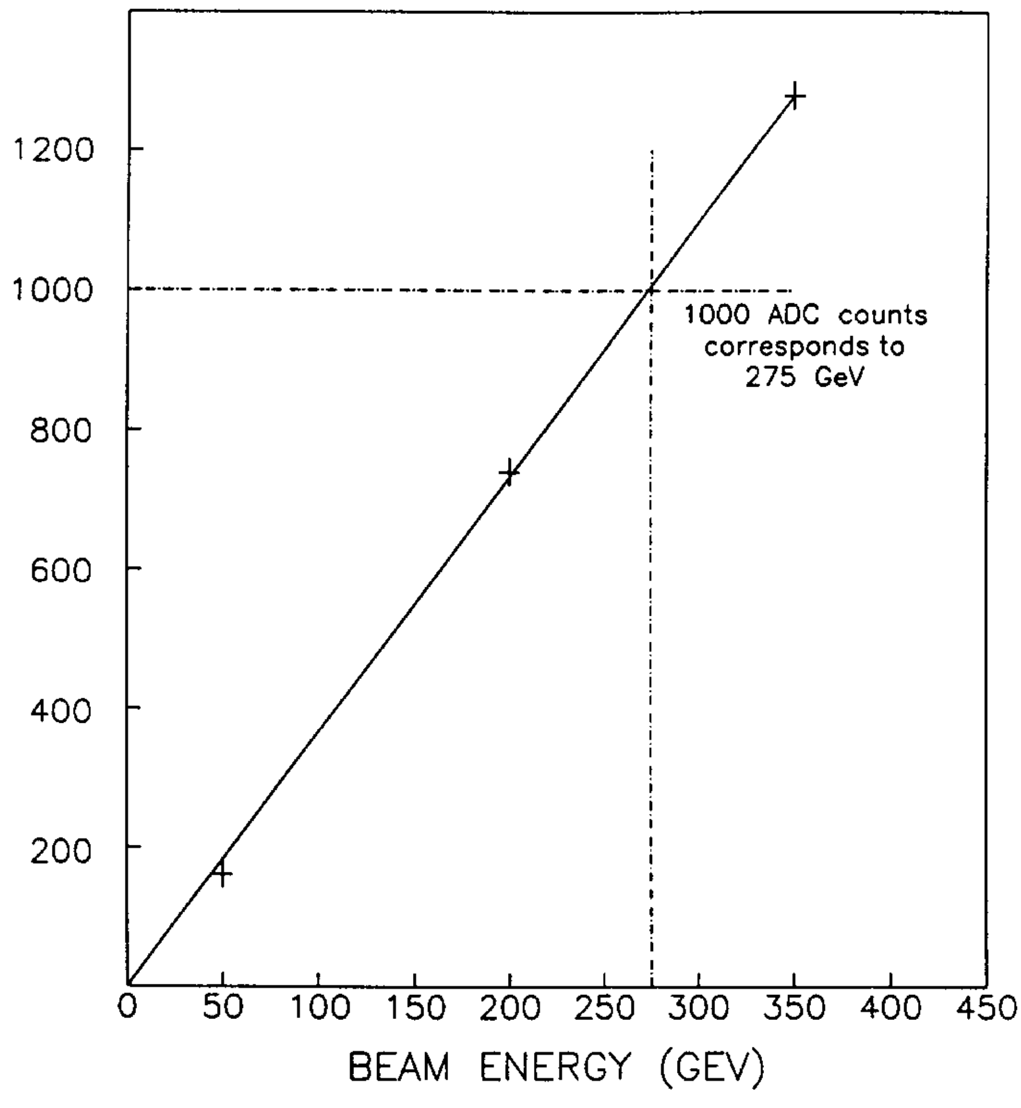
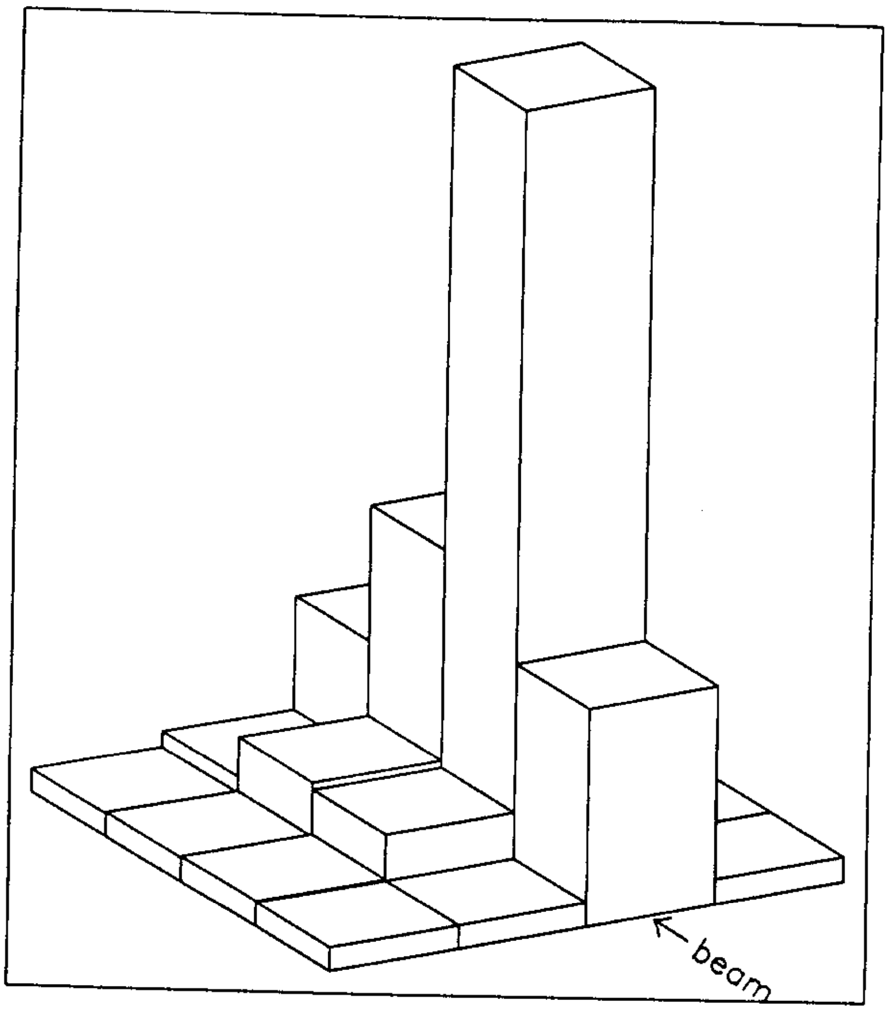

1200
1000
800
600
400
200
0
50
100
150
200
250
300
350
400
450
BEAM ENERGY (GEV)
1000 ADC counts
corresponds to
275 GeV

Figure 8



TARGET CAL

Figure 9