ANL-7196
Particle Accelerators and
High-Voltage Machines
(TID-4500)
AEC Research and
Development Report

CFSTI PRICES

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

H.C. \$ 1.00; MN .50

MEASUREMENT OF BEAM PROFILES
WITH THERMOLUMINESCENT DOSIMETERS

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April 1966

Operated by The University of Chicago
under
Contract W-31-109-eng-38
with the
U. S. Atomic Energy Commission

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ABSTRACT

Thermoluminescent dosimeters have been used to determine the profile of the 12.5-BeV external beam of the Zero Gradient Synchrotron at Argonne National Laboratory. The total number of particles in the beam, the distribution of particles, and the shape of the beam were determined.

The results are in excellent agreement with results obtained by other techniques used for determination of beam profiles. Using only one accelerator pulse, a beam of comparable size with intensity up to 10^{12} particles per pulse and as low as 10^6 particles per pulse could be analyzed.

INTRODUCTION

A beam profilometer, employing thermoluminescent dosimeters, has been used to give a quantitative and qualitative representation of the focus of the 12.5-BeV external proton beam at the Argonne National Laboratory's Zero Gradient Synchrotron.

Thermoluminescent dosimeters have been widely used for measuring personnel radiation exposures, material and equipment exposures, and environmental radiation levels. They are useful because they are small and of simple construction. They have a wide range of linear dose response and are dose-rate independent to at least 1.7×10^6 rads/hr.¹

PROCEDURE

The thermoluminescent dosimeters consist of polyethylene capsules filled with thermoluminescent powder (LiF-Mn), which can be excited by radiation and de-excited by heating. The thermoluminescent powder used was Harshaw Chemical Co. type TLD-100, which consists of 93% ^7LiF and 7% ^6LiF . These crystals have metastable energy levels to which electrons are raised during exposure to radiation. When heated, the electrons return to their ground states, emitting light. This light is measured with a photomultiplier-scalar counting system. The amount of light is directly

proportional to the quantity of radiation to which the powder is exposed. The dosimeters are linear for radiation doses from 10 millirads to 10^5 rads. (Ref. 2)

Fig. 1. Beam Profilometer

The beam profilometer consists of a 10-by-10 matrix of dosimeters constructed by drilling holes the size of the capsules in an aluminum block (see Fig. 1). Letters were used to denote horizontal positions, and numbers for vertical positions. Center-to-center spacing was 250 mils. The block was carefully machined so the edges could be accurately positioned. All available capsules were placed in the holes.

The profilometer was placed at a focus of the external proton beam of the Zero Gradient Synchrotron for 100 machine pulses. Because of radiation hazards, the beam was kept below 10^{10} protons/pulse. Previous ionization-chamber studies and radiographic analyses have indicated typical intensities from 2 to 4×10^9 protons/pulse. (Ref. 3)

EXPERIMENTAL RESULTS

Doses were read on a commercial thermoluminescent-dosimeter readout. Measurements were in the middle range of the instrument. Counts are shown in their relative positions in Fig. 2. Sufficient phosphor

Fig. 2
Dosimeter Reading
Distribution

	A	B	C	D	E	F	G	H	I	J
1			600	1377	6079	19000	3418	1301		
			+	+	+	+	+	+		
2			927	2030	13428	78000	8789	1962		
			+	+	+	+	+	+		
3			921	2200	21631	243650	14379	2744		
			+	+	+	+	+	+		
4	246	455	961	2130	16829	146200	11830	2418	976	466
	+	+	+	+	+	+	+	+	+	+
5	238	451	730	1464	7391	47072	4886	1440	721	377
	+	+	+	+	+	+	+	+	+	+
6	178	304	504	889	3235	3680	1819	828	484	272
	+	+	+	+	+	+	+	+	+	+
7	140	198	320	478	1072	941	776	462	318	222
	+	+	+	+	+	+	+	+	+	+
8			217	270	393	437	406	290		
			+	+	+	+	+	+		
9			139	164	184	222	210	164		
			+	+	+	+	+	+		
10			107	111	124	132	122			
			+	+	+	+	+			

was placed in each capsule for three readings of about 30 mg/reading. The counts shown are averages of several readings. Initial measurements showed that the three readings of phosphor from one capsule increased successively. Powder was always poured from the same end of the capsules. This indicated a higher radiation intensity at the back end than at the front. (The increase was about 20%.) When subsequent capsules were shaken to mix the powder before readings, the count was the same. The spread in counts was then about 5%. The counts were normalized to dose in rads by exposing the dosimeters to a calibrated Co^{60} source. Using standard conversion factors, the dose was converted to particle flux. It was assumed that scattering from the aluminum was negligible. The physical size of the phosphor in the capsules was a circle 125 mils in diameter. The readings represent an average flux over the area of the phosphor.

The horizontal distribution of intensity as a function of vertical position and the vertical distribution of intensity as a function of horizontal position were obtained by plotting the counts and are shown in Figs. 3 and 4, respectively. These curves were then used to map the intensity with

Fig. 3. Horizontal Intensity Distribution (in Counts) Plotted as a Function of Horizontal Positions (Letters) for Various Vertical Positions (Numbers)

Fig. 4. Vertical Intensity Distribution (in Counts) Plotted as a Function of Vertical Positions (Numbers) for Various Horizontal Positions (Letters)

isorad lines and produce the beam intensity profile of Fig. 5, where lines of equal intensity have been plotted on a physical layout of the profilometer. In Fig. 5, the solid lines represent regions in which readings were available; the dashed lines are from extrapolations into regions in which there were no dosimeters. The central intensity is about 250,000 counts. The beam size at 10^5 counts is 225 mils wide by 550 mils high and encloses approximately one-third of the protons. Figure 5 can be compared with Fig. 6, which is a photograph of the same beam obtained by using X-ray film placed in the proton beam.

Fig. 5. Beam Intensity Profile

Fig. 6. Photograph of the Beam

To obtain the total number of protons in the beam, the intensity was assumed to be constant over a 125-mil square centered on each dosimeter. Extrapolations were used to estimate the intensity between dosimeters. The vertical and horizontal distributions were used to extrapolate to regions where there were no dosimeters. These counts were summed over various ranges of intensities. The range from 100 to 1000 counts contributed less than 5% to the total. It was assumed that the region with intensities of less than 100 counts would give negligible contribution to the total. The fraction of the protons in the beam in intensity regions greater than a given number of counts (the abscissa) are plotted against intensity in counts in Fig. 7. Figures 5, 6, and 7 can be used to map the physical distribution of the particles in the beam.

Fig. 7
Proton Beam Distribution

The sum of counts was $2.85 \times 10^6 \pm 5\%$. Each contribution to the sum was over an area of about 0.1 cm^2 . The calibration of the dosimeters was 2.45×10^5 counts, which equals 1.3×10^4 rads. One rad is approximately equal to 3×10^7 minimum ionizing charged particles per cm^2 in LiF. The total number, n , of protons in the beam is given by

$$n = 2.85 \times 10^6 \pm 5\% \text{ counts} \times \frac{1.3 \times 10^4 \text{ rads}}{2.45 \times 10^5 \text{ counts}} \times 3 \times 10^7 \frac{\text{protons}}{\text{cm}^2\text{-rad}} \times 0.1 \text{ cm}^2$$

$$= 4.64 \times 10^{11} \pm 5\% \text{ protons.}$$

This is an excellent agreement with previous results and indicates that the technique is valuable for both quantitative and qualitative measurements of beam profiles.

DISCUSSION

The filling, exposure, readout, and analysis were completed in about 4 days. As a result of advances in technique and some simple modifications in the readout instrument, the entire procedure could now be

completed in about 2 man days. With only one machine pulse, it would be possible to analyze a beam of comparable size with intensity up to 10^{12} particles per pulse and as low as 10^6 particles per pulse. By using smaller dosimeters with closer spacing, the resolution could be considerably improved. Lower-density material and different profilometer construction could be used to minimize the effect of scattering.

ACKNOWLEDGMENT

We would like to thank Dr. Thomas A. Romanowski for the photograph of the proton beam (Fig. 6).

REFERENCES

1. M. J. Marrone and F. H. Attix, Health Physics 10, 431 (1964).
2. J. R. Cameron, D. Zimmerman, G. Kenney, R. Buch, R. Bland, and R. Grant, Health Physics 10, 25 (1964).
3. T. A. Romanowski, Argonne National Laboratory, private communication.