Particle Accelerators
1976, Vol. 7, pp. 119–121

RADIATION LEVELS IN THE FERMILAB MAIN RING ENCLOSURE DURING ACCELERATOR OPERATION

J. H. McCRARY and D. D. YOVANOVITCH

Fermi National Accelerator Laboratory, Batavia, Illinois 60510, USA

(*Received January 19, 1976; in final form March 18, 1976*)

Film badges have been used to measure the "beam-on" radiation levels in a 45° segment of the Fermilab Main Ring. This segment contains regions where proton losses from the primary beam are both high and low. A comparison is made between the beam-on radiation intensity and the residual radioactivity measured with the beam off. A quantitative description is given of the decrease in radiation intensity with position downstream from a high loss point.

INTRODUCTION

The intensity of the radiation from residual radioactivity within the Fermilab main ring enclosure is routinely and periodically measured. The self-propelled survey vehicle[1] used to make these measurements provides a strip chart record showing the radiation intensity plotted logarithmically as a function of distance. The lower graph in Figure 1 is a reproduction of a portion of a radiation survey strip chart which was made on November 7, 1974 in "D sector" of the main ring. The Fermilab main ring is divided into six sectors of equal length which are designated by the letters A through F (see Figure 1 in the preceding paper[2]).

Injection and extraction take place in the upstream end of A sector. In the upstream end of D sector (diametrically opposite injection and extraction) is the beam abort device. D sector was selected as the site for the beam-on radiation intensity measurements because of the proton beam abort device and because of a relatively isolated proton loss point located approximately 800 feet downstream from the abort target. The residual radioactivity from these two loss points are the major features of the beam-off graph shown in Figure 1. The abort target is essentially a series of beam stops located radially outward onto which a small amount of beam (1 or 2%) is dumped at the end of slow spill extraction. Most of the protons lost at this point have the maximum energy (300 GeV). No details are available concerning the other loss point.

The purposes of these measurements were: (1) to obtain an estimate of the radiation level in the main ring during accelerator operation, (2) to correlate beam-on radiation levels with beam-off residual radioactivity, and (3) to determine the relative radiation intensity as a function of position downstream from a proton loss point.

PROCEDURE

On November 8, 1974, one-hundred film badges* were exposed in the D sector of the Fermilab main ring during $10\frac{1}{4}$ hours of accelerator operation at 300 GeV. The radiation survey strip chart shown in Figure 1 was made at 0940 on November 7, 1974. The proton beam had been turned off the preceding midnight. Shortly before noon on November 7 the film badges were attached to the cable tray which runs parallel with and approximately 3 feet above the beam line. The 100 badges were placed at 25-foot intervals beginning 150 feet upstream from the abort target. At each badge position the ambient radiation level from residual radioactivity was checked with a Geiger counter. These ambient radiation levels were found to be essentially identical with those measured by the survey vehicle. The slight difference between the geometries of the film badge measurements and the survey vehicle measurements is thus negligible. Proton acceleration began in the main ring at 2330 hours on November 7 and continued until 0945 on

* Landauer holders, each containing one packet of Kodak Type 2 β, γ film and one packet of Kodak Neutron Monitoring film Type A.

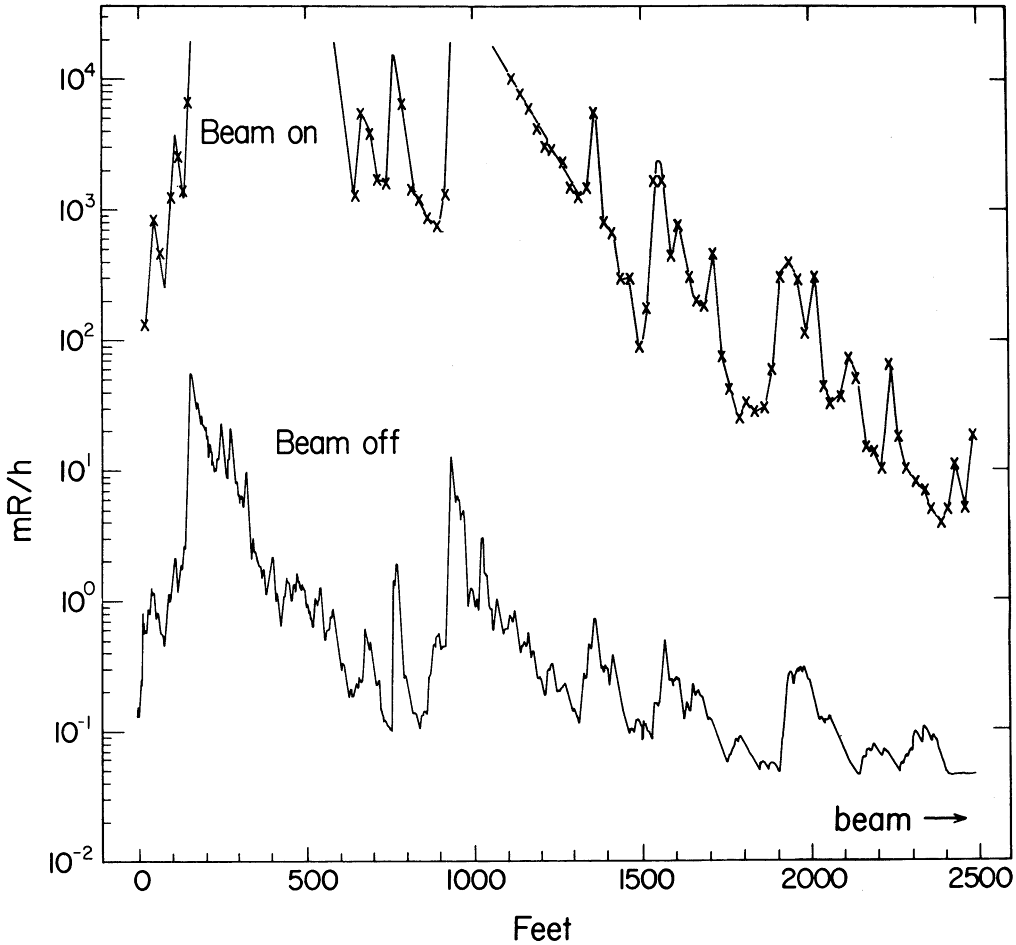

FIGURE 1 Plots of ambient radiation intensity in mR/h and of beam-on β, γ dose rate in mrem/h vs film badge position. Each x represents a single film badge reading.

November 8 at which time the badges were retrieved. During this $10\frac{1}{4}$-hour exposure period approximately 2×10^{16} protons were accelerated in the main ring. Of the order of 5×10^{14} of these protons were lost in the abort device. The mean intensity in the main ring beam was 5×10^{12} protons per pulse.

RESULTS

The results from the β, γ films are shown in the upper graph of Figure 1. The film badge doses were divided by the exposure time, and this mean dose rate (mrem/h) is plotted in the figure. The film badge processor did not report doses greater than 100 rem (10^4 mrem/h) of β, γ. Beam-on data in the vicinity of the two large peaks was thus lost due to the saturation of the film caused by the long exposure. The most important characteristic of Figure 1 is the similarity in the shapes of the two graphs. This is considered to be a remarkable result in view of the complexity of the nuclear reactions, cascades, and decays which lead to the emission of both the prompt and the delayed radiations. The beam-on radiation levels exceed the ambient levels by two to four decades. This factor is larger ($\sim 10^4$) at the high loss points and lower in the less radioactive portions of the accelerator.

Figure 2 is a plot of the fast neutron dose rate vs position. These data were obtained by the film processor by counting proton recoil tracks in the relatively thick neutron film emulsion. An effective quality factor of 10 was used in obtaining the neutron dose. Neutron films which received more than 4 rem of β, γ radiation were fogged to such

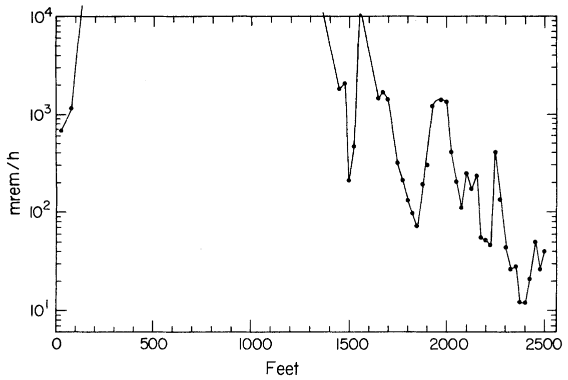

FIGURE 2 Plot of beam-on fast neutron dose rate in mrem/h vs film badge position.

an extent that their tracks could not be discerned. Thus most of the neutron film data were lost. A comparison of the data shown in Figures 1 and 2 indicated, however, that the fast neutron dose rate is three to five times greater than the β, γ dose rate in the lower loss portions of the main ring.

It has been noted that the radiation intensity at positions downstream from a proton loss point decreases exponentially with the distance from the loss point.[3] Both Figures 1 and 2 exhibit this behavior downstream from the major loss points. Over distances of 500 feet the radiation intensity can be described by the equation:

$$I/I_0 = \exp(-mx)$$

where I/I_0 is the decrease in radiation intensity over the distance x. The slope (m) of the curves in Figure 1 is nearly the same for both beam-on and beam-off conditions. It was found empirically to be 0.010 ft^{-1}. The radiation intensity thus decreases by a factor of two in 69 ft.

CONCLUSIONS

The following conclusions were made as a result of these measurements:

1) Radiation levels in the Fermilab main ring enclosure with beam-on range from a few mR/h to perhaps 10^3 R/h at high loss points.

2) The beam-on β, γ intensity is higher than the ambient radiation levels by a factor of $\sim 10^4$ in the high loss regions and by a factor of 10^2 to 10^3 in low loss segments of the main ring.

3) The fast neutron intensity exceeds that of the beam-on β, γ radiation by a factor of 3 to 5.

4) The beam-on radiation pattern closely resembles that of the residual radioactivity even over distances as short as 10 meters. Large variations in the residual radioactivity along the accelerator beam line replicate the actual radiation field during beam-on operation.

5) The loss pattern is stable and prevails over long periods (months); otherwise the beam-on and beam-off results would not be so strongly correlated. The ambient activity is related to the long-term history of accelerator operation.

6) Downstream from a loss point the radiation intensity decreases exponentially with distance with a half-length of 69 ft.

REFERENCES

1. R. E. Shafer and D. D. Jovanovic, *IEEE Trans. Nucl. Sci.*, **NS-20**, No. 3, 499 (1973).
2. J. H. McCrary and H. H. Casebolt, Jr., *Particle Accelerators*, **7**, 111 (1976).
3. J. Ranft, *Particle Accelerators*, **3**, 129 (1972).