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Response of the Booster Loss Monitor System for Beam Dumps at Various Intensities and Energies

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Subject: RESPONSE OF THE BOOSTER LOSS MONITOR SYSTEM FOR BEAM DUMPS AT VARIOUS INTENSITIES AND ENERGIES

Summary

A brief study of the total "counts" registered in the Booster loss monitor system as a result of various beam dumps demonstrated an apparent linear response against intensity, and an apparent quadratic response against kinetic energy. The response for various loss "geometries" was not investigated in this study. Two other situations, from past measurements, are mentioned in the conclusions.

Introduction

The "calibration" of the response of the Booster loss monitor system to the energy, intensity, and distribution of beam loss would significantly increase the information content of the numbers produced by the loss monitor system. The expectation that the observed counts will depend strongly on the "geometry"--the (unknown) details of the equilibrium orbit at the time and place of loss--making the extraction of fundamental relations difficult has lowered the priority for this work. Nevertheless, if such relations were known, they would be very useful in quantifying losses, and indeed at the extraction point a calibration has been done. The present study is a first pass (no study of the geometry) for the ring loss monitors.

Procedure

The accelerating Booster beam was aborted by turning off the ring rf ("early turn off" switch) at one of three times in the cycle, just after injection, midway, and slightly before extraction (all have positive $\dot{B}$). The response of the loss monitor system (set to "low" gain) to this dump was measured by positioning an integrating "window" for the acquisition system starting at dump time, and extending for 30 ms. The integral over this window is the data. For each of these energies, the intensity of the beam in the Booster was varied by changing the number of turns injected into the Booster from the Linac using the chopper program. The intensity at the abort time was measured using the normalized current transformer analog signal. No attempt was made to change the "natural" loss pattern at these three times, which is localized near the D6 dump "inside" limiting aperture. Intensity was sufficiently reduced for each energy to yield at least one run with no monitors in saturation.

Results

Table I shows a summary of the data from the three most active loss monitor channels, D6, D7, (which look at the D6 dump) and E6 (which appears to catch significant beam at low energy) for the different situations investigated.

The data is plotted in Figure 1. It appears that, for a given geometry, the response of a particular monitor is nearly proportional to the beam intensity. It is also clear that the loss distribution among these three monitors is strongly energy, or time in cycle, dependent.

Figure 2 shows the spatial distribution at the three energies for intensities chosen so that in each case all monitors are out of saturation. There was no significant response in the sectors of the Booster ring not shown. This data is reduced in Table II. The sum of counts over the entire ring is given, along with intensity and kinetic energy. The sum, normalized for intensity, is also shown. This data, plotted against kinetic energy is shown in Figure 3, with an ad hoc quadratic "fit" (to the origin and the lowest point) superimposed.

Conclusions

For this particular set of data, an extremely simple relation among beam intensity (I) in protons, beam kinetic energy (KE) in GeV and loss monitor sum (L) in counts exists, namely,

$$I = (2.61 \times 10^7)\ (L)/(KE)^2.$$

Since this data involved only a particular loss pattern and very few monitors, its value is limited but interesting because it is simple. Two other response measurements are known to me. One was in LTB. For a dump into the carbon studies block in LTB back in April, 1991, the standard monitors in the line (LTB 071 and LTB 083) gave 444 counts for a (200 MeV) beam of 2.3×10^{11} protons or 5.2×10^{11}/1000 counts. A "steering" loss in the same region gave 2091 counts for 9.4×10^{11} or 4.5×10^{11}/1000 counts. The ring loss formula predicts (for a very different geometry) 6.5×10^{11}/ 1000 counts. The other measurement was near the F6 septum at Booster extraction. The results there were (1.0-1.4) $\times 10^{10}$/1000 counts over the downstream half of the F sector for fast and low dumps into the septum. The formula predicts 1.8×10^{10}/1000 counts. "Next time", we should investigate other loss patterns.

TABLE I					
INTENSITY PROTONS ($x 10^{12}$)	FIELD (Gauss)	K. ENERGY (GeV)	D6 COUNTS	D7 COUNTS	E6 COUNTS
3.0	1584	0.207	1200	1450	900
2.1			875	1100	650
1.5			600	740	450
0.8			300	370	200
1.3	2510	0.448	2048	2048	1700
0.7			1350	2048	800
0.3			600	1100	350
0.3	4260	1.032	2048	2048	275
0.15			1475	2048	130
0.09			850	1900	100
0.04			325	850	25

TABLE II			
INTENSITY PROTONS ($x 10^{12}$)	K. ENERGY (GeV)	L.M. SUM COUNTS	L.M. SUM/INT. (COUNTS/PROTONS) ($x 10^{-9}$)
2.1	0.207	3215	1.53
0.3	0.448	2565	8.55
0.09	1.032	3420	38.0

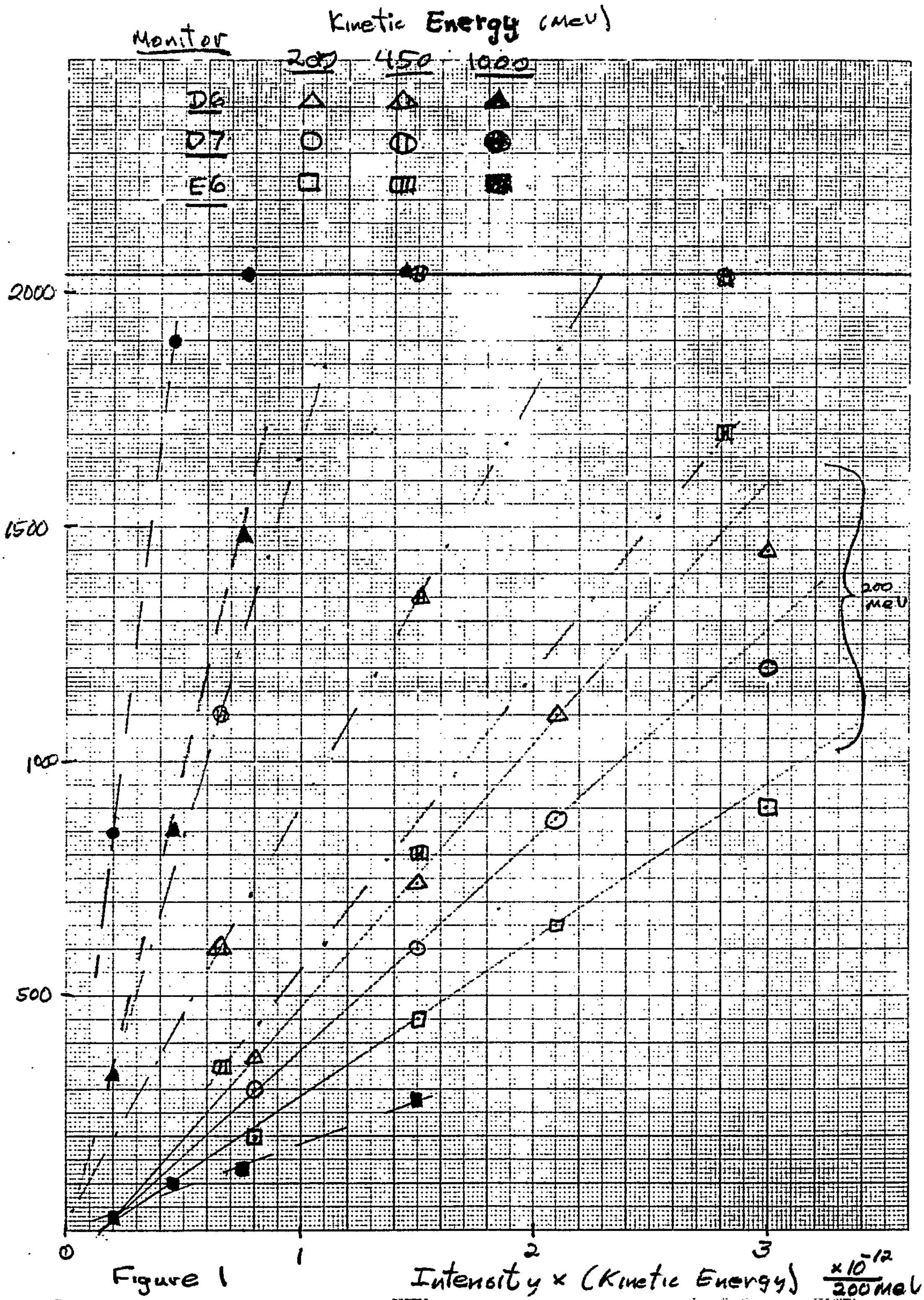
Kinetic Energy (MeV)
Monitor
200
450
1000
D6
D7
E6
2000
1500
1000
500
0
1
2
3
200 MeV
Intensity × (Kinetic Energy) $\frac{\times 10^{-12}}{200\,\text{MeV}}$

Figure 1

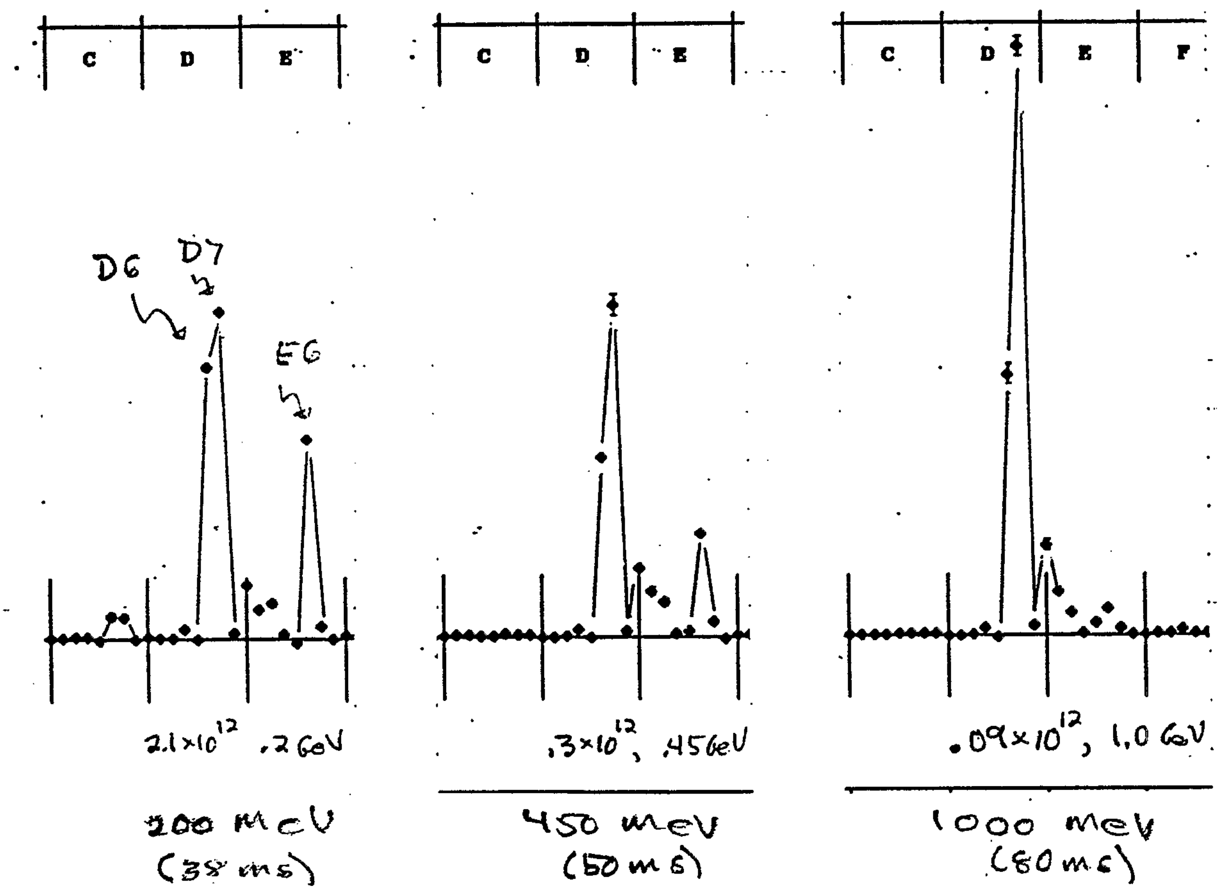

Figure 2   Loss Patterns at RF OFF

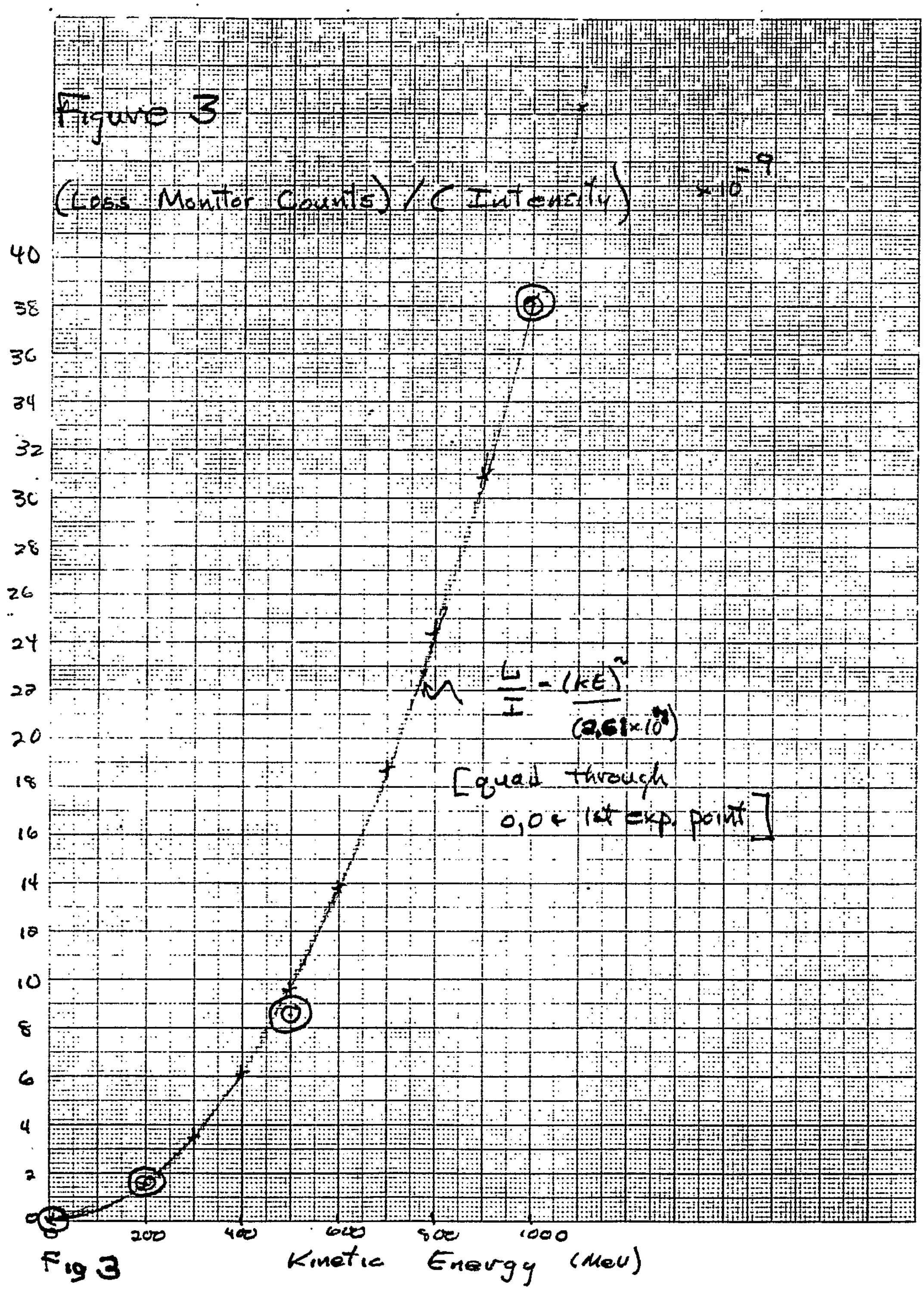
Figure 3
(Loss Monitor Counts) / (Intensity) ×10^-9
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
200
400
600
800
1000
L/I = (KE)^2 / (2.61×10^)
[quad through
0,0 + 1st exp. point]
Kinetic Energy (MeV)

Fig 3