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THE AGS BEAM LOSS MONITORING SYSTEM

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Summary

The usefulness of a beam loss monitoring system in diverse aspects of accelerator operation is documented with a variety of examples.

Introduction

The AGS Radiation Monitoring System, previously described[1,2], is reviewed here with a block diagram (Figure 1) and a list of detector characteristics (table 1). Figure 2 shows the detector and the transmitted pulse. The schematic of the accelerator complex (Figure 3) shows the extent of the application, every significant segment is monitored.

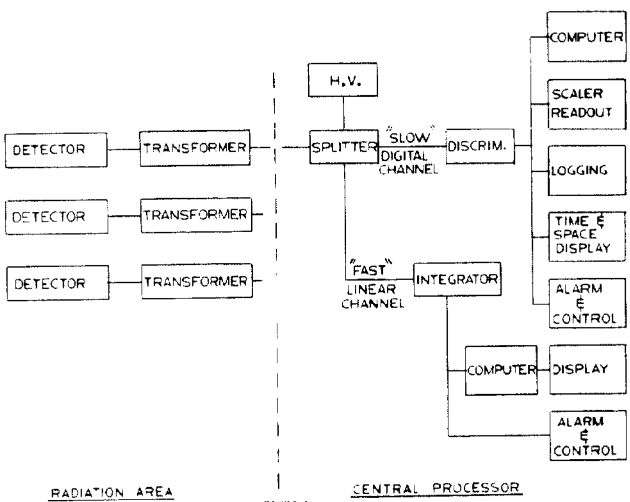


Figure 1

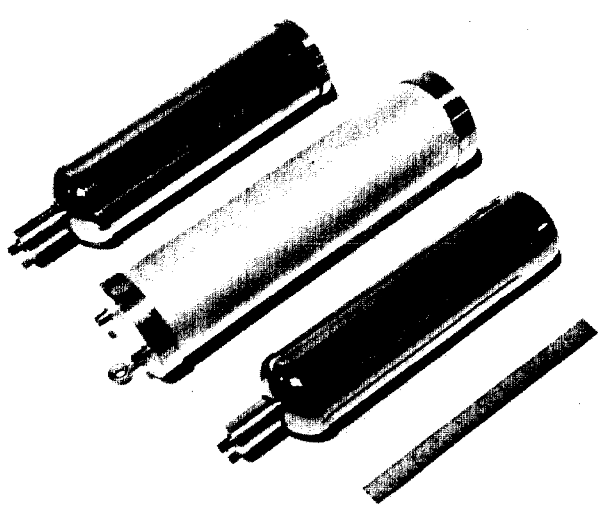
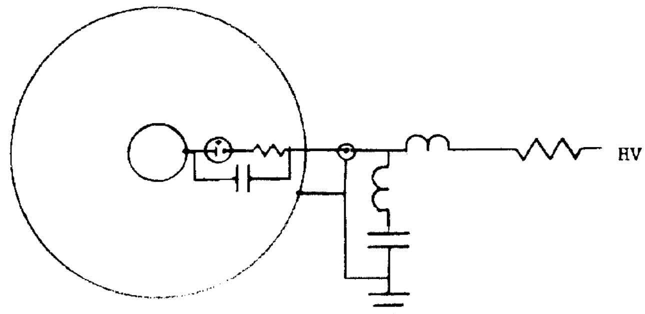


Figure 2a



IPDIC   MATCHING TRANSFORMER

INTEGRATING PULSE DISCHARGE ION CHAMBER
CYLINDRICAL IONIZATION CHAMBER

~ 1000 cm^3 Argon at 10 atmospheres
.030" Chrome Plated Steel Walls

PULSE CHARACTERISTICS

1 Volt, 1 Microsecond into 1000 ohms
Pulse Pair Resolution 15-100 Microseconds

RADIATION EFFECTS

Sensitivity - Nominally 1 pulse = 1 mrad
Life > 10^9 pulses
Radiation Damage - Functions After > 10^8 Rads

Table I

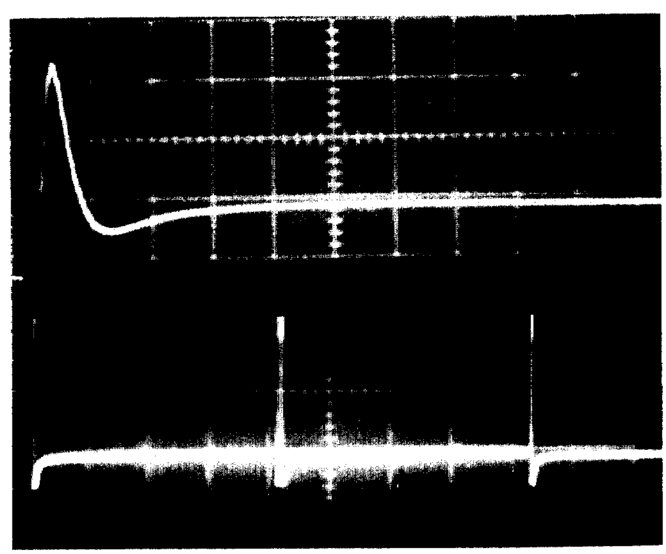


Figure 2b
IPDIC PULSES - upper trace - 2 microsec/cm 1V/cm
lower trace - 50 microsec/cm 1V/cm

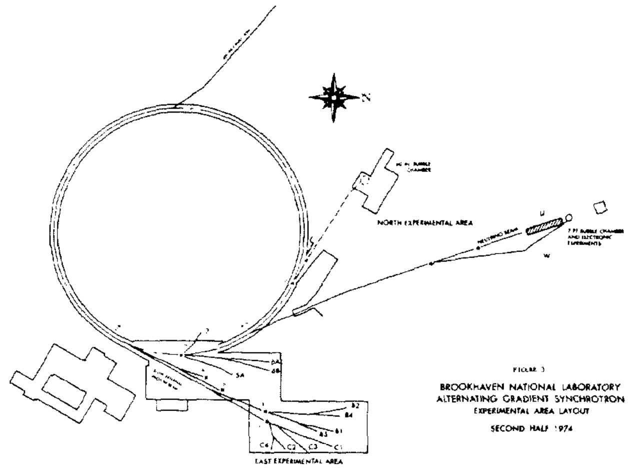


Figure 3

Applications

The system was principally developed to detect large beam losses which would result in high radiation levels and damage to the accelerator. However, as an extensive source of information about machine operation, it has been used increasingly in roles other than protection. The initial portion, the ring system, employing only display, is described in Figure 4, with the output format shown in Figure 5.

The section capitalizing on the linear mode of operation in the detection of very short radiation pulses, (less than a millisecond) the Fast Extracted Beam System, is described in Figure 6. A typical display, (Figure 7) generated by computer, is used to monitor and tune the beam line. Beams characterized by slow extraction and losses distributed over hundreds of milliseconds are scanned by a subsystem employing the digital mode of operation (Figure 8). Displays, showing the time distribution of losses, used for tuning and monitoring, are shown in Figures 9 and 10. The Linac portion (Figure 11) has a dedicated digital display for qualitative overview of injector performance, and an instantaneous shutdown function on the linear circuitry for protection purposes. (Figure 12)

FIGURE 4 AGS RING SYSTEM

Protons Accelerated from 0.2 - 33 Gev

Intensity - 10^{13} protons/pulse

Repetition Rate - 15-60 pulses/minute

Beam Extraction - Internal Target, Slow Extraction } Duration ~ 1 sec.

Fast Extraction - Duration - Microseconds

Monitoring

48 Detectors, symmetrically located around ring (55 foot intervals)

1 Target Monitor

Dedicated display of digital signals

Scaler display of some units

The 48 vertical columns are a linear representation of the ring detectors in their spatial sequence. The lamps display the amplitude of counts accumulated by the scaler for that detector. Each column is composed of 16 lamps, representing 2^0 (1) at the bottom, to 2^{15} (32, 768) at the top. The uppermost lamps turns on those below it when activated, so the bar grows vertically, without blinking. The data can be continuously displayed, in which case the time and spatial distribution for each accelerator pulse appears. Optional choices of reset, sampling interval, strobing, permit alternative formats such as integrating over many pulses, or viewing the loss distribution during a particular portion of the accelerator cycle.

Figure 5
Dynamic Lamp Display of Ring Ion Distribution

FIGURE 6 FAST EXTRACTED BEAM SYSTEM

Extraction of Full Energy Protons for Bubble Chambers

Intensity - 10^{13} protons/pulse

Pulse - Twelve 20 nanosecond bunches extracted in ~ 2 microseconds

Monitoring

22 - Two terminal detectors distributed along beam line with emphasis on critical locations

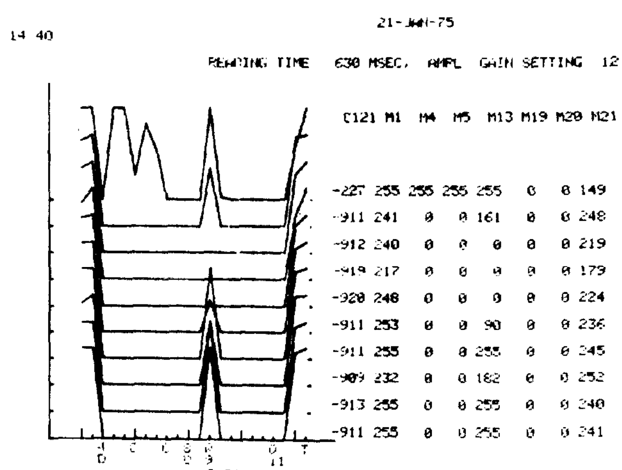
Linear signals integrated each pulse
- a) tested by alarm discriminators for beam shutdown

and

- b) transmitted to computer for generation of display

Figure 7.

SPATIAL DISTRIBUTION OF LOSSES IN THE FAST EXTRACTED BEAM



Abscissa - Distance along beam line
Ordinate - Amplitude of loss in detectors, baseline offset for successive scans

Digital readout of selected detectors, defined by column headings, corresponding to plot at left.

FIGURE 8 SLOW EXTRACTED BEAM SYSTEM

Extraction of Full Energy Protons for Electronic Detectors

Intensity - 10^{13} protons/pulse

Pulse - hundreds of milliseconds

Monitoring

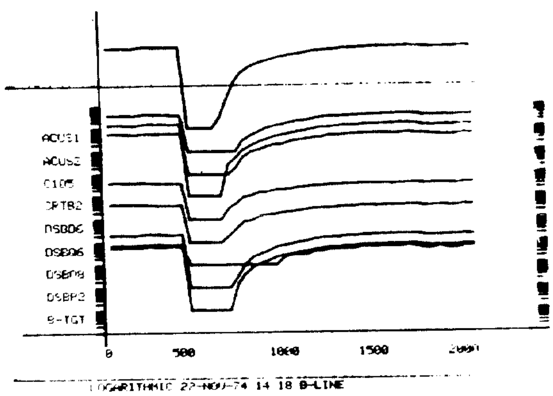
22 detectors distributed along beam line and spurs with emphasis on critical locations and targets

Digital signals transmitted to
1. dedicated display with alarm and shut-down options
2. computer for processing, generation of displays

Figure 9.

COMPUTER GENERATED DISPLAY

TIME DISTRIBUTION OF LOSSES IN THE SLOW BEAM



LOGARITHMIC 22-NOV-74 14 18 B-LINE

ENTER INTERVAL(MSEC),LINE #

Explanation

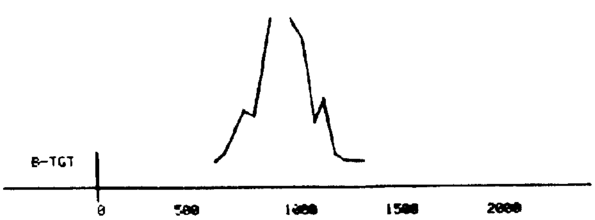
Abscissa: Time in msec
Ordinate: Log. of Amplitude (ionization current)

Marks along left, right edge are log scales of each scan.

TIME SCANS OF DETECTORS AT NINE LOCATIONS ALONG SEB-B LINE

Reset occurs (500 msec) before spill begins (700 msec)

Fig.10. Time Distribution of Beam Loss at Slow Beam Target



ABSCISSA - Time (msec)
ORDINATE - Loss Amplitude (Logarithmic scale)

NOTE: Gap in peak is printing error

START TIME = 600 STOP TIME = 1500
LOGARITHMIC 14-FEB-75 13 12 LINE

ENTER START,STOP TIMES,LINE OR UNIT NAME

BEAM

Protons accelerated to 200 MeV intensity - 10^{14} protons / pulse
Pulse length - 200 microseconds
Repetition rate - 10 pulses/second

MONITORING SYSTEM

32 detectors distributed along Linac, AGS Transport Line, Experimental Beam Line
Lamp display in control room, shutdown system on linear outputs of 8 detectors. Beam turned off within 10 microseconds of detection of excessive loss.

Figure 11
Linac System

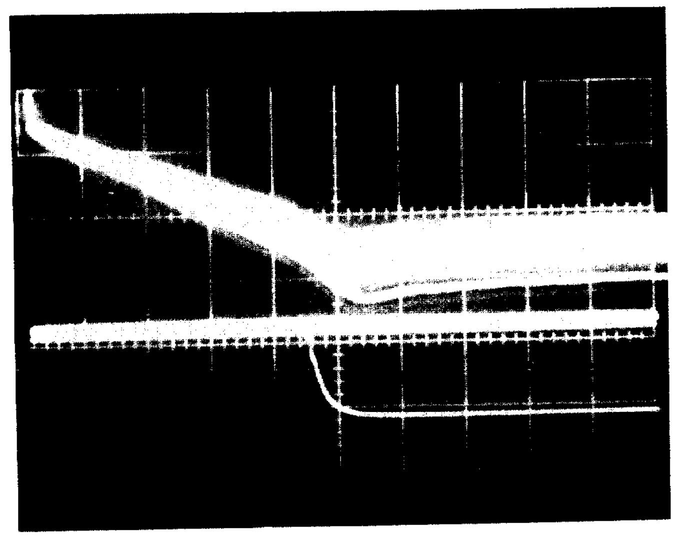


Figure 12
Linac Shutdown

Upper Trace - Integrated loss, several pulses 10 mv/cm

Lower Trace - Alarm signal, normally 10 V, went to 0 V on largest amplitude signal above

FUTURE APPLICATIONS

Now that the various techniques of data handling by computer have been demonstrated, it is appropriate to investigate the use of pattern recognition for diagnosis and automatic control. It is clear that the detection of secondary radiation, produced by primary beam losses, is a very sensitive technique which can be more powerfully employed in accelerator operation. This then implies that detector characteristics and performance must be better known.

Acknowledgments

The programming producing the computer generated displays was done by J. Claus, initially, and R. Witkover.

References

1. Levine, G.S., Second International Conference on Accelerator Dosimetry and Experience, Stanford, 1969, pp. 817-822.
2. Levine, G.S., Bennett, G. W., IEEE Trans. Nucl. Sci., NS-18, No. 3, 1971, pp. 734-735.