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.

IPDIC

MATCHING
TRANSFORMER

INTEGRATING PULSE DISCHARGE ION CHAMBER
CYLINDRICAL IONIZATION CHAMBER

~ 1000 cm³ 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 > 10⁹ pulses
Radiation Damage - Functions After > 10⁸ Rads

Table I

Figure 1

Figure 2a

Figure 2b

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

MASTER

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 } Duration
Slow Extraction } ~ 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 2^7 (1) at the bottom, to 2^{15} (32, 768) at the top. The uppermost lamps turn 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

Abcissa - 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 shutdown options
  2. computer for processing, generation of displays

FIGURE 9

THE SCANS OF DETECTORS AT NINE LOCATIONS ALONG SLOW-B LINE
Beam covers (500 msec) before spill begins (700 msec)

FIGURE 10 - TIME DISTRIBUTION OF BEAM LOSS AT SLOW BEAM TARGET

START TIME = 000 STOP TIME = 1000
LOGARITHMIC 10-100-100 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

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References

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