Global Beam Loss Monitoring Using Long Ionisation Chambers at ISIS.

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Abstract

A description is given of the global beam loss monitoring system at ISIS, the high intensity pulsed neutron source at the Rutherford Appleton Laboratory. The system has proved to be an important machine tuning and protection diagnostic, and has enabled a regime of 'hands-on' maintenance to continue, with operational mean proton currents in excess of 180 μA.

1 INTRODUCTION

ISIS is now the most intense pulsed neutron source for condensed matter materials research in the world. Operational from December 1984, the fast cycling (50 Hz) proton synchrotron is now running close to its design intensity (200μA), and routinely delivers mean proton currents in excess of 180 μA to a tantalum or depleted uranium target.

Calculations, performed during the machine design phase, indicated that operational beam loss would need to be carefully minimised, on a machine wide (global) basis, if the required regime of 'hands-on' maintenance was to be supported. A further requirement was that total beam loss (under fault conditions) should result in a beam trip within one machine pulse, if catastrophic damage to machine components was to be prevented.

A global beam loss monitoring system, using long argon filled ionisation chambers of the Brookhaven [1] type, was considered to be most able to provide the required uniform (and stable) sensitivity per unit beamline length, dynamic range, spatial and temporal resolution, and long term reliability.

2 DESCRIPTION

2.1 System Overview

The ISIS beam loss monitoring system is composed of three subsystems. This division is dictated by differences in the time dependent nature of beam loss in three distinct machine areas. These are: the 70 MeV H^- linac and transport line; the 800 MeV proton synchrotron; and the 800 MeV proton transport line. A plan view of the global system is shown in Fig. 1. Beam loss in each area is sensed by a linear array of argon filled long ionisation chambers, made from 3 - 4 m lengths of large diameter coaxial cable, and situated 2 - 3 m from the beam axis.

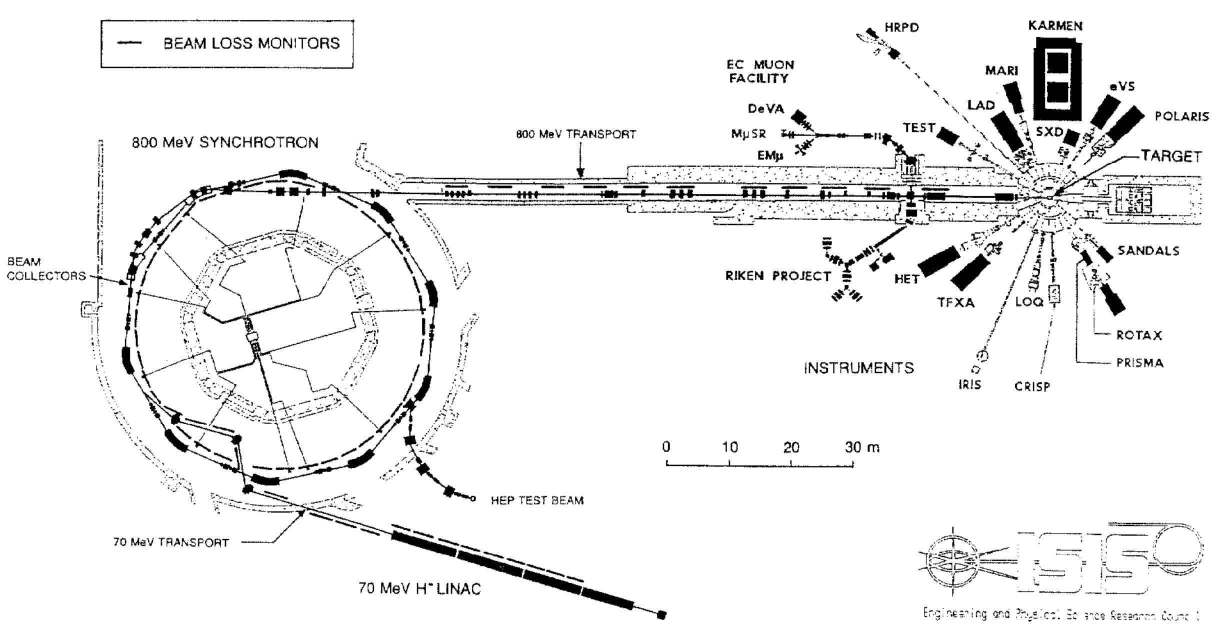

Figure 1: Plan view of ISIS.

2.2 Beam loss detection process

Mis-directed beam particles (H^- or p) undergo p - n type interactions with the nuclei of machine components (eg. vacuum vessel) to produce forward directed cascade neutrons and isotropically emitted evaporation spectrum neutrons. The latter, after a short flight in air, interact with nuclei in the ionisation chamber wall, to produce the 'knock-on' protons responsible for generating ion-electron pairs in the argon gas, that fills the chamber volume. The ion-electron pairs, separated by the field (10 - 20 V/mm) due to an externally applied bias potential, give the chamber an ideal current source characteristic. Argon filled chambers are used in preference to the simpler air filled option [3], to take advantage of their faster (electron collection) response time, and better saturation characteristics [4,5]. The chambers have good spatial resolution, resulting from the local detection of isotropically emitted neutrons, and, due to their length, do not suffer from the $\frac{1}{r^2}$ dependency shown by point-like radiation detectors.

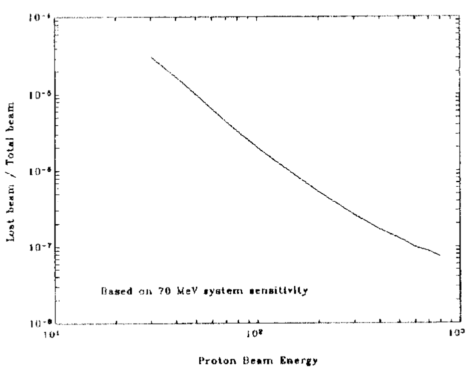

Figure 2: Lower limit of detection.

Ionisation chamber sensitivity to beam loss has been shown to increase rapidly with beam energy in the range 37 - 200 MeV [1], being determined by the neutron yield per incident proton, interacting with a medium atomic number target nucleus [6]. Fig. 2 shows the lower limit of detection for beam loss, as a function of energy, for the ISIS 70 MeV system.

2.3 70 MeV Linac and Transport System.

The distribution of beam loss monitors (BLM's) in the 70 MeV linac and transport area is shown in Fig. 1. These large diameter (~32 mm), 4 m long monitors have a volume of 2.9 litres, and are pressurised with argon. The monitors, head-amplifiers, cables and gas lines are installed in continuous lengths of protective steel conduit, mounted 2 - 3 m from the beam axis. A cross-section of the standard coaxial termination is shown in Fig. 3. The important features of the signal conditioning and data acquisition system are shown in Fig. 4. A close coupled, low noise, wideband (<.1 Hz - 20kHz) head amplifier boosts the low current (10^{-7} - 10^{-10} A), monitor signal and outputs a high level, low impedance differential analogue signal to a

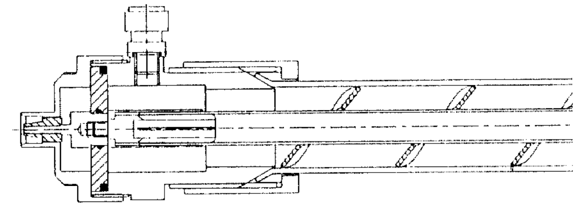

Figure 3: Cross section of BLM (70 MeV system).

remote post-amplifier and data acquisition system. The switched, high voltage bias circuit delivers a ~2 ms charge pulse to the head-amplifier input coupling capacitor during the linac 'dead-time', with a ~0.2 Hz p.r.f. This simple circuit enables a single, low power, supply, to provide very low noise high voltage bias to a distributed set of remote head-amplifiers via a single cable. The high open circuit leakage resistance (>10^{10} Ω) of the high voltage switch, combined with the 0.01 μF input capacitor give an input time constant of T ~ 100 s, in effect providing a ~ d.c. low frequency cutoff, for this a.c. coupled configuration.

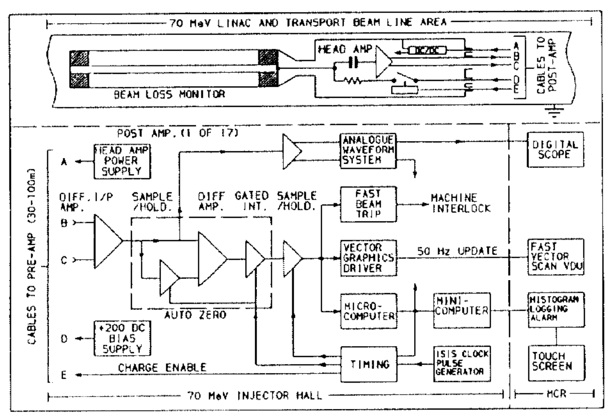

Figure 4: 70 MeV system schematic

Beam loss signals from the linac tank area have a pulsed X-ray background component. These (interfering) flat top pulses, together with head-amplifier zero offset, are rejected by the gated auto-zero circuit in the post-amplifier. As a result, zero drift in the gated integrator is very low.

Analogue signals are output to the analogue waveform system (AWS) and can be selected for display in the main control room (MCR). Loss signals, integrated over the 300 μs linac pulse, update a dedicated vector graphics display in the MCR on a pulse by pulse basis. These signals are also output to a beam interlock unit, and to a data acquisition system that performs a long term logging function.

2.4 800 MeV Synchrotron System

The distribution of BLM's in the synchrotron is shown in Fig. 1. The monitors are 3 m long, 16 mm in diameter, and have an active volume of 0.6 litres. They are mounted 2 - 3m from the beam axis in free-standing lengths of protective steel conduit, linked in groups of four per super-

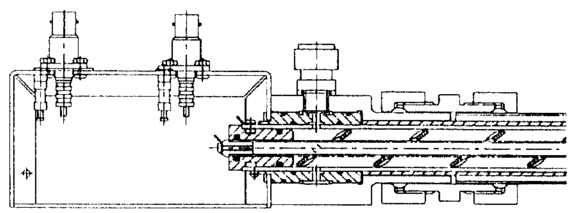

Figure 5: Cross section of BLM (800 MeV system).

period. The necessary degree of radiation hardness, and a dc - 20 kHz frequency response, have been achieved using triaxially configured monitors coupled to remote (~30m) head amplifiers with low capacitance cable. The increasing chamber sensitivity as a function of lost beam energy in the 70 - 800 MeV range (see Fig. 2), and a double-screened installation, help to maintain a good signal to noise ratio. A cross section of the synchrotron BLM is shown in Fig. 5. The important features of the signal conditioning and data acquisition system are shown in Fig. 6. In addi-

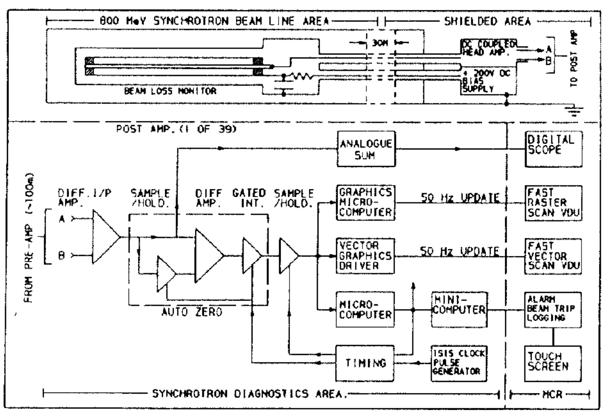

Figure 6: 800 MeV synchrotron system schematic

tion to the facilities provided by the 70 MeV system, this system has two useful tools that aid in minimising beam loss during the 10 ms acceleration cycle. These are; a fast (RISC) microcomputer-controlled display showing beam loss in four preselected time bins, and an analogue sum signal showing total beam loss, in the time domain, on a digitising oscilloscope in the MCR.

2.5 800 MeV Transport System

The distribution of BLM's in this area is shown in Fig.1. The monitors are 4 m long versions of the synchrotron type. Head amplifier time constants have been optimised, to take advantage of the short pulse nature (<1μs) of the extracted beam pulse. Data is output to a dedicated vector graphics display and to a microcomputer with beam interlock and logging functions.

3 OPERATIONAL EXPERIENCE

The global BLM system has proved to be a powerful machine tuning and protection diagnostic. The system plays an important part in ensuring that; operational loss is restricted, almost entirely to 70 - 80 MeV beam, lost during injection (~2%) and trapping (~10%); and that this loss is localised at graphite beam collectors in one superperiod. Dose rates measured 0.5 m from the collectors are typically ~40 mSv/hr, and maintenance in this area requires the use of local shielding and specialised handling methods. Fine tuning techniques, using wideband analogue beam loss signals, have been developed for minimising loss during beam transport, injection, trapping, acceleration and at extraction.

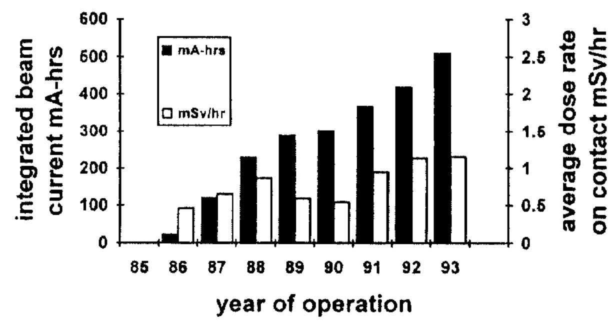

Figure 7: Operational data

Fig. 7 shows yearly totals of beam on target, and also average contact dose rates (excluding loss on collectors) for the synchrotron at the start of the annual shutdown. The data suggests that the regime of 'hands-on' maintenance will continue to be supported with mean beam to target currents in the 180 - 200 μA range.

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