SPALLATION NEUTRON SOURCE RING DIAGNOSTICS*

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Abstract

Brookhaven is providing the Ring and Transfer Lines Beam Diagnostics for the Spallation Neutron Source (SNS), to be installed at Oak Ridge National Laboratory. The customary diagnostics that will be present include Beam Position Monitors (BPM), Ionization Profile Monitors (IPM), Beam Loss Monitors (BLM), Beam Current Monitors (BCM), Coherent Tune Measurement, and Wire Scanners. An overview of these systems is presented, along with brief discussions of SNS-specific problems that must be addressed, including unprecedented beam power, large dynamic range, a stringent loss budget, space charge, beam halo, and electron cloud. We also present an overview of systems more specifically tailored to address these problems, including Beam-in-Gap measurement and cleaning, two types of incoherent tune measurement, halo monitor, and video monitors for stripping foils and the electron catcher.

OVERVIEW

An overall description of the SNS project and status is available in these proceedings[1], as well as an update on the Ring and Transfer Lines[2]. Additional background information on SNS diagnostics is available in earlier conference[3] and Beam Instrumentation Workshop[4,5] proceedings. An overall layout of SNS Diagnostics is shown in Figure 1.

The SNS Diagnostics team is taking full advantage of the cost and performance advantages offered by the ubiquitous PC platform. With a few exceptions, a typical SNS diagnostic is a rack-mount PC running embedded Windows 2000 or XP, with control of data acquisition and accomplishment of data analysis handled by LabVIEW[6]. Each PC also runs EPICS IOC core, so the PCs appear to be Input-Output Controllers to the EPICS Control System. Whenever possible standard off-the-shelf PCI analog front end/digitizer boards have been used. In the more demanding applications (BPM, BCM, IPM, tune systems) a custom PCI board is used. Timing signals are

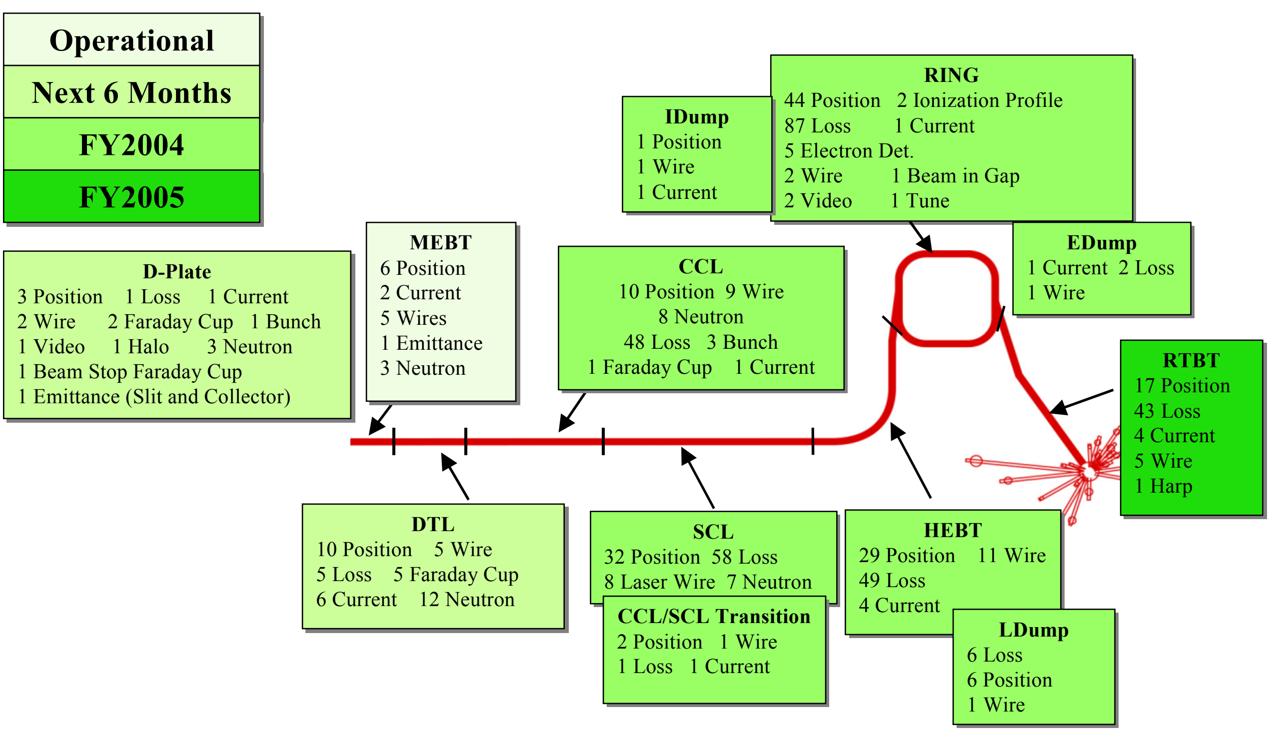

Fig. 1. (color) Layout of the diagnostics in the SNS facility, color-coded to indicate the staged installation dates.

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decoded by a standard SNS timing module embedded in a PCI-interfaced FPGA. For systems using the custom PCI AFE/digitizer boards, this gate array is the PCI interface, and also offers the possibility of fast pre-processing.

BEAM POSITION MONITORS

Dual plane 50ohm 250mm long stripline electrodes are located at all quadrupoles. The transfer line striplines are shorted to take advantage of the superior mechanical accuracy offered by that construction. The Ring striplines are open to permit biasing for electron clearing. Apertures vary from 12cm in HEBT to 36cm in the downstream portion of RTBT.

Verification of signal path and calibration of electronics will be accomplished via S21 measurements. Beam-based offset determination (BBOD) will be employed to find BPM electrical centers relative to quad magnetic centers[7]. Log-ratio processing in combination with BBOD opens the possibility of further calibration of the electronics. All Ring and RTBT electronics will be dual-band, with both baseband and 402.5MHz processing.

IONIZATION PROFILE MONITOR

The SNS IPM is an improved version of the IPMs installed[8] in the RHIC ring. Modifications were necessary due to rf coupling to the beam, susceptibility to beam loss, and interference from electrons.

To deal with rf coupling, the microchannel plates were moved outside the beam image-current path and 100dB of rf shielding was added.

Beam loss can cause particle showers to pass through the micro-channel plate and the collector board, generating large background signals. Again, moving all components outside the aperture minimized this problem.

Interference from electrons is handled by extending the IPM's electric and magnetic fields beyond the active volume to prevent electrons created outside from entering. Additionally, the beam pipe in the ring is TiN-coated to suppress electron creation. Finally, the IPM's strong electric field will prevent electron multipacting.

The modified RHIC IPM was tested by scraping beam upstream on the beam pipe wall. As shown in Fig. 2, the profile using the improved IPM is much cleaner than the profile measurement using the unmodified unit.

BEAM LOSS MONITORS

The high average beam power requires that uncontrolled losses be kept very low to allow machine maintenance. The BLM system is designed to detect an uncontrolled loss of 1 part in 10^4 at 1 MW over the full ring and provide a signal to inhibit further injection. Ion chambers (IC) will be used as the detectors to provide the interlock function and multi-turn loss data. Several photo-multipliers will provide observation of losses within the bunch. The ICs will be at each quadrupole, the collimators, and key injection and extraction loss points.

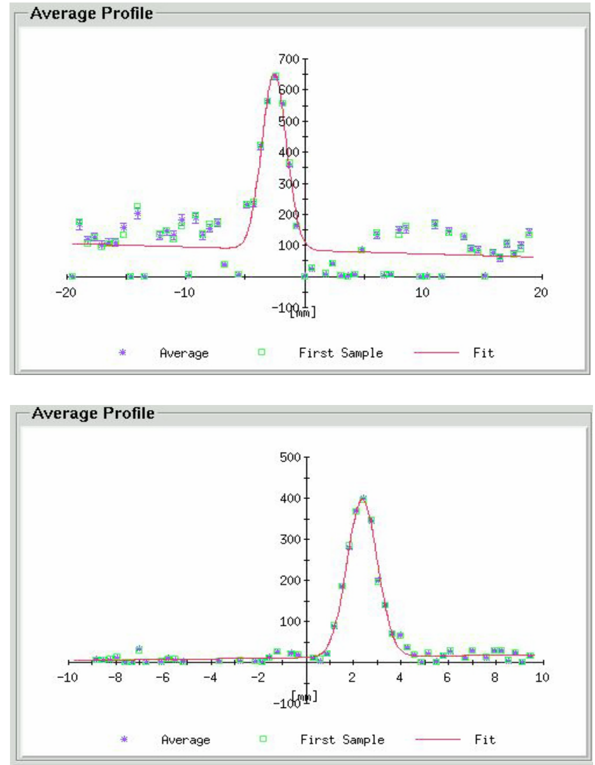

Fig. 2. (color) RHIC IPM measurements before (top) and after (bottom) modifications.

Several movable units may be placed at local hot-spots, for a total of 70 channels.

A new design IC has been developed for the SNS[9], resulting in significantly faster ion transit times and higher dose rate capability. Nominal sensitivity is 70 nC/rad. The system is designed to handle a 10^4 dynamic range. Each BLM signal will be acquired by an individual channel of a 24-bit ADC sampling at 100 KS/sec[10].

The fast BLMs consist of bare photomultipliers, eliminating the problems of radiation darkening and disposal of mixed wastes. Unit-to-unit variation and radiation effects on the window of the tube will require periodic re-calibration and individual HV power supplies. The signals will be integrated over the bunch length and read through digitizer channels of a multi-channel fast digitizer to observe losses within the bunch.

BEAM CURRENT MONITOR

The BCM system is designed to handle the $2x10^{14}$ circulating protons required for a 2MW beam. Peak current can reach 100A, and care must be taken to prevent transformer core saturation. To achieve 1% accuracy and 0.1% resolution, droop is specified to be less than 0.1% during the 1msec accumulation period, requiring a decay time constant of about 1 second. Rise time is specified at 50ns. A Bergoz® current transformer with rise time <1ns and droop of 0.1%/μs is used. Software[11] compensates for transformer droop and provides the 1 second time constant. The signal is processed by a switched gain amplifier followed by a 7MHz Gaussian Filter. A 5-pole

17MHz Chebyshev filter provides anti-aliasing before digitization at 68MS/s. Charge is calculated for each turn as well as the macro-pulse total. A 100MHz BW output goes to a fast digitizer capable of capturing the edge information.

INCOHERENT TUNE

Incoherent tune will be determined by both dipole and quadrupole beam transfer function measurements. Both systems will employ resonant kickers and pickups. Kicker control and data acquisition and analysis will be accomplished with modified BPM electronics. The objective of the BTF systems is to map the tune footprint, which is large in the SNS Ring as a result of chromaticity and space charge tune depression. Both systems will be similar to an existing system in RHIC[12].

BIG/HALO MONITOR

Gap beam will be vertically kicked onto the collimators for the last 60 to 100 turns of the accumulation cycle by 4.5m long 50 ohm striplines driven by 7KV pulsers, and observed with a gated FBLM. Kick strength and number was determined utilizing particle-in-cell tracking code[13]. Scrapers for BIG tuning and halo observation will be installed adjacent to the IPMs. Kicker control and data acquisition and analysis will be accomplished with modified BPM electronics.

COHERENT TUNE

The BIG/Halo kicker will also be utilized in the coherent tune system. Position signals will come from a dedicated BPM. Kicker control and data acquisition and analysis will be accomplished with independent modified BPM electronics. Both FFT and fit algorithms will be employed. In addition to this independent system, the capability to calculate tune using all ring BPMs will be a part of the Orbit software.

WIRE SCANNERS

The wire scanner mechanisms and electronics are provided by LANL, and are described in detail in ref [14[

VIDEO FOIL MONITOR

Normal operating temperature of the primary stripping foil will be ~2000K, permitting use of a vacuum tube radiation hard video camera, located in a cubby near the injection region. This camera will also be used to confirm the position of the primary foil and monitor its integrity. A second similar camera will be similarly installed to monitor beam profiles at the secondary stripping foil when a phosphor screen is positioned in the beam path. During tuning, a similar phosphor screen can be positioned at the primary stripping foil location. The position and angle of the injected beam can be measured, and beam profile data can be obtained. A third system will monitor the electron catcher, which is located just below the primary injection stripping foil. Each system will have a multi-position neutral density filter assembly mounted between camera and lens to avoid saturation. The analog video signals will be processed using the NI-PCI-1409 Image Acquisition board, and live video will be available via the network using a video-to-Ethernet converter.

FAST DAQ SYSTEMS

Fast signals from the BLM, BCM, and electron detector systems will be processed by ‘PC scopes’, utilizing standard commercially available PCI-based digitizers.

CONCLUSION

A full complement of sophisticated diagnostics systems is essential to provide the information needed to commission and operate the SNS. The challenge of integrating these systems and bringing them on-line with limited manpower is being met by utilizing commonality between systems, in both the inter- and intra-laboratory arenas.

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