SNS BLM SYSTEM EVOLUTION: DETECTORS, ELECTRONICS, AND SOFTWARE

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Abstract

Spallation Neutron Source (SNS) is a high-intensity hadron beam facility; so the Beam Loss Monitor (BLM) system is a crucial part of Machine Protection System and an important tool for beam tuning. This paper presents the current status of installed detectors and experimental data obtained during SNS operations. We compare several different types of BLMs and show advantages and disadvantages of each type. The electronic parts obsolescence became an issue since the original electronics was designed around 10 years ago. The first test of our next generation BLM system is expected to be completed by summer 2009. The new system will contribute to significant noise reduction and will follow a modular concept of Smart Device to achieve a higher degree of reliability and maintainability.

PRESENT BLM SYSTEM

The SNS Beam Loss Monitor (BLM) system consists of 362 radiation detectors measuring secondary radiation due to beam loss. The BLMs are used as MPS device to shutdown the beam if the integral loss is above threshold. This MPS system is software and timing independent which makes it very reliable. The BLMs are distributed along the whole SNS machine. Since the beam parameters are different in different parts of the machine (2.5MeV injected in linac and 1GeV hitting the target) the nature of losses is very different. In addition to energy spread, the H-/proton beam pulse duration varies from 1 ms in linac to less than 1 uS in RTBT.

Detectors

SNS uses ionization chambers (IC) as its main BLM device because of their simple design and immunity to radiation damage. In addition to ICs we use several type of PMT-based detectors. The neutron detectors (ND) are neutron-sensitive detectors that are useful in low energy part of the linac where ICs lack sensitivity. Also the NDs can be used for measuring the residual radiation due to their gamma-sensitivity.

The detectors are distributed more or less uniformly along the machine. By default ICs are located near quads and NDs are placed in the middle of DTL tanks and SCL cryo-modules. The distance to the beam line varies from 5 cm to 1 m.

The BLM system is also used as a beam tuning diagnostic device (the same detectors are playing two roles) and have to combine reliability for MPS and flexibility for beam diagnostics.

The ICs are not fast enough to provide the macro-pulse structure to physicists so the PMTs can be used for such diagnostics purposes.

Table 1: BLM Distribution in Linac

Area	IC	ND	PMT
DTL	11	12	6
CCL	50	8	6
SCL	76	23	
HEBT, LDmp, IDmp	59		
Ring	71		
RTBT	40		

All photo multiplier tube devices can greatly (~100 times) adjust their sensitivity by changing HV bias [1]. The ion chambers are sensitive to "local" losses (that occur within proximity of detector) while neutron detectors are good at detecting losses occurred meters away from the detector itself [1]. This makes NDs hard to interpret but more reliable for MPS purposes. Solely relying on ICs can lead to hiding of losses instead of eliminating them because the tuning process sometime moves the loss to a place where it is not seen by the IC.

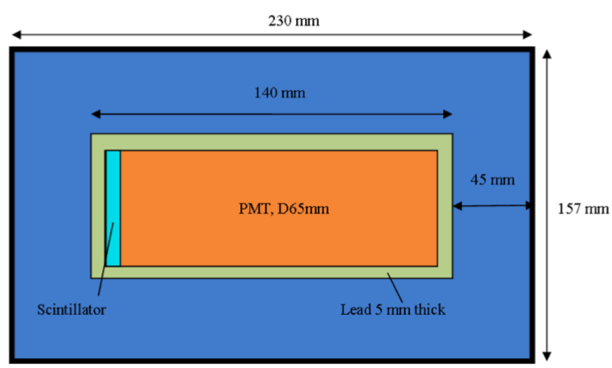

Figure 1: Neutron Detector is a 230x157x150mm box. PMT is inside x-ray shielding (lead) and is surrounded by polyethylene neutron moderator.

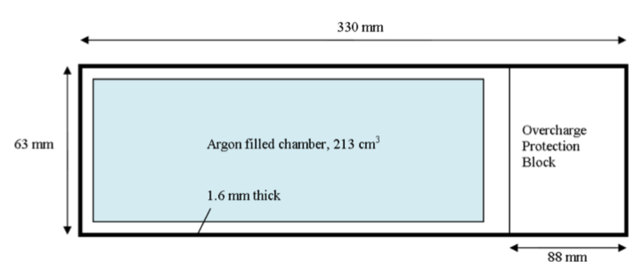

Figure 2: IC has cylindrical shape of 330 mm length and 63 mm diameter. The protection block contains RC chain and neon bulb that would discharge the detector if the signal line was disconnected for a long time while under HV and high losses.

Table 3: BLM Parameters

Parameter	**IC**	**ND**	**PMT**
Type	Ion chamber	Neutron sensitive plastic scintillator + PMT	Plastics scintillator +PMT
Detector medium	Argon, 113 cm^3	Polyethylene moderator, ZnS(Ag) scintillator	EJ-208 scintillator
Typical HV, V	-1000	-700	-700
Response time	~2µS	~50µS	10nS
Typical sensitivity	70nC/Rad	80 pC/n/cm^2	2mA/R/hr
Primary sensitivity	gamma	Neutron	gamma
Connectors	Sig (BNC), HV in (SHV), HV out (for daisy chain)	Sig (BNC), HV in (SHV), Test(BNC)	Sig (BNC), HV in (SHV), Test(BNC)

Front End Electronics and MPS

The BLM system was initially designed by BNL [2] for ion chamber type of detectors.

All three types of detectors are effectively current sources and are interfaced to the same front end electronics that features transconductance amplifier with jumper-settable gains (620, 6.2E3, 62E3 [Ohm]). The amplified signal is split between MPS circuit (leaky integrator to integrate the total loss), "view" circuit (used to observe the waveform) where the "fast" signal leaves the AFE and goes to a VME ADC card where it is sampled at 100kS/s (signal BW is 35 kHz) and slow signal that is smoothed (BW 1kHz); it also goes to separate ADC channel.

The system can shutdown current macropulse within 10uS after the integrated value exceeds threshold. The HV bias is shared by several (usually four) ICs that are daisy-chained in accelerator tunnel. The HV is supplied by VME HV module.

In addition to integrated loss software MPS monitors detector health: gain settings, HV bias settings and read back and HV bias current (that will detect cable problems in HV circuit). Software-based integration over a longer period of time is used to limit residual activation of the tunnel

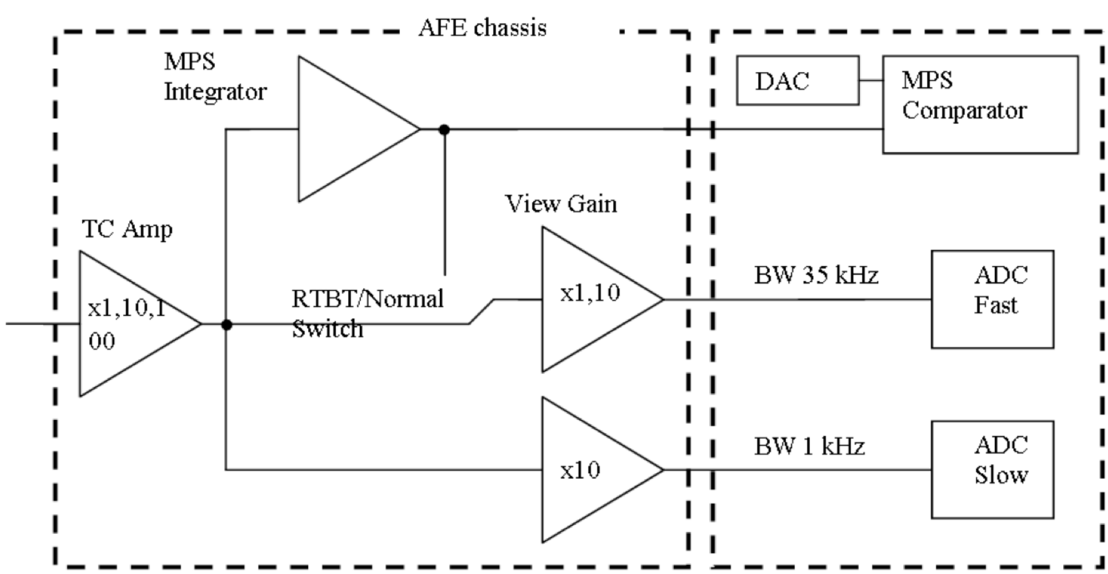

Figure 3: AFE –MPS diagram.

The gain setting of the AFE is controlled and monitored by a VMIC VMIVME2510 64-bit digital IO module. The Machine Protection System (MPS) interface module compares AFE MPS loss to an MPS trip level and outputs result to a separate MPS chassis. The MPS trip levels are set with the outputs of two Hytec8402 Industry Pack (IP)

DAC cards (16 channels of 16-bit DAC each) residing on a GreenSpring VIPC616 IP Carrier board. There is a direct communication link from the Motorola MVME-5110 CPU board to the MPS Chassis through the PMCSPAN card attached to CPU board. Two ICS110B ADC cards read the AFE outputs of the fast loss and slow loss signals. Each ICS110B card has 32 independent 24-bit Sigma-Delta ADCs. The MVME-5110 features a 500MHz MPC7410 microprocessor, 512MB ECC SDRAM.

High-Level Console Software

While BLM system uses EPICS as the control system, it also is incorporated in XAL[3] framework. The Lossviewer2 is an application for monitoring losses in Control Room. Main features of Lossviewer2:

- Bar plot showing losses (shows integral loss, loss limits, allows different types of normalization)
- Waterfall plot displays ten minutes history of losses.
- Weighted sum plot shows a history of losses in several detectors

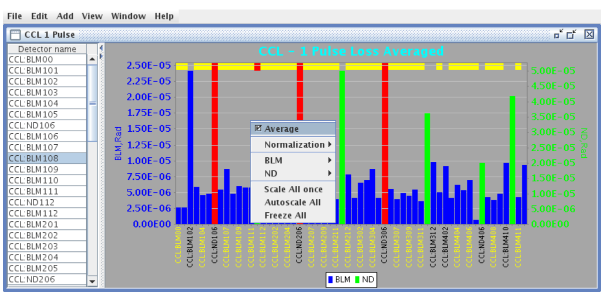

Figure 4: Loss viewer XAL app.

All losses have been tracked since January 1, 2007 in Oracle database (one minute integral of all detectors). Web interface is used to access the data.

FUTURE BLM SYSTEM

The current BLM system has following shortcomings:

- electronic parts obsolescence;
- being a highly centralized system (1 ADC card controls up to 16 detectors) – the failure of VME crate leads to machine downtime, since large number of detectors are not protecting the machine;
- detectors are sensitive to x-ray radiation being emitted by RF cavities. The software algorithms fight this problem but make the MPS part software dependent; and
- the electronics are relatively slow (100kS/s) which makes it impossible to separate mini-pulses of SNS beam structure.

Chassis Design

The new system uses custom made 4U chassis to host analog part of electronics. One chassis contains 12 units. Every unit is self-consistent and incorporates:

- HV bias source;
- Analog Front End electronics; and
- digital controller (equipped with AVR micro-controller). It handles communication with IOC, HV settings and AFE settings

RS-485 based bus sits in chassis backplane. The RS-485 is converted to USB for IOC connection. Several chassis can be daisy-chained to use 1 IOC.

Dual Input Amplifier Design

Since noise is a serious issue in several areas of the machine (especially RTBT where the noise is induced by high current beam flying by) the amplifier has two inputs: signal line and reference line. The reference line is subtracted from signal line. In noise suppression mode, the reference line is an unterminated wire following the same path as signal cable. Alternatively it can subtract signals coming from different detectors (this allows eliminate sensitivity to cavity x-rays). The fader chip allows performing such subtraction with different coefficients 0.0-1.0. The PGA is used to control amplification gains. In addition to that, the input could be set to high (for PMT-based detector) or low (ICs) impedance.

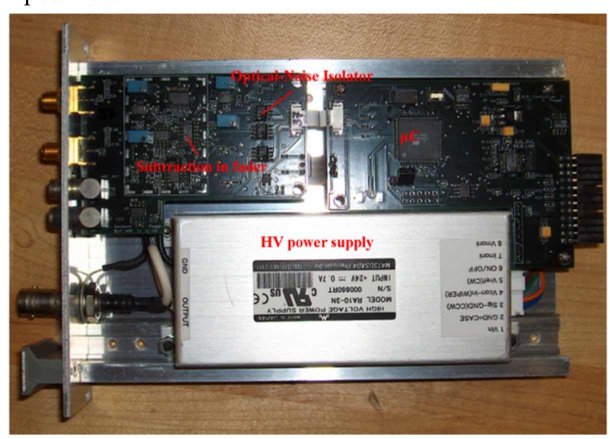

Figure 5: Dual input amplifier module.

The MPS integrator repeats the MPS functionality of current VME-based system.

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