NSLS-II Injector System Diagnostics

D. Padrazo, O. Singh, I. Pinayev, R. Flliler, T. Shafton, B. Kosciuk, R. Meier, Y. Hu

Brookhaven National Laboratory, Upton, NY 11973, USA

Abstract. The NSLS-II Injector System Diagnostics will provide instrumentation in the LINAC, Booster, Transfer Lines and Beam Dumps for measuring key beam parameters. These instruments will be adequate in providing staged commissioning of NSLS-II injectors, as well as allowing sufficient beam diagnostics for tune-up and top-up operations. This paper will summarize the status of the NSLS-II injector system diagnostics, and will focus on those intended for implementation in the transfer lines. Including the LTB and BSR.

INTRODUCTION

The NSLS-II is a state of the art 3GeV synchrotron light source being developed at Brookhaven National Laboratory. The injection system will consist of a 200 MeV LINAC, a 3 GeV booster synchrotron, and associated transfer lines. The instrumentation in the LINAC will provide sufficient beam diagnostics to determine bunch charge, length, transverse size, position, and beam losses. The LTB and BSR will include key instruments to be used for beam commissioning and tune-up, particularly the beam dumps and those diagnostics elements within the booster vault. Measurements of beam charge, bunch train, bunch charge, energy jitter, emittance, and energy spread, can be achieved. Booster diagnostics will provide measurements for orbit correction, injection matching and transverse profile. In addition, elements are provided to measure beam current, bunch train pattern, tune and chromaticity measurements. This paper will detail the implementation of these diagnostics components for the NSLS-II Injector System.

LINAC DIAGNOSTICS

A turn-key procurement, the NSLS-II LINAC is specified to have an output energy of 200MeV, energy spread of 0.5%, bunch length of 20ps, and normalized emmittance of 55 mm-mmrad. The LINAC will be capable of operating in single bunch mode with a charge of up to 0.5nC, or in multibunch mode with a bunch train of 80 to 150 bunches, separated by 2ns with a charge per train of 22nC. The LINAC will have a 100kV electron gun with thermionic cathode, sub-harmonic pre-buncher, 3 GHz pre-buncher, 3GHz buncher, and a 3 GHz acceleration section. LINAC diagnostics will consist of a Wall Current Monitor (WCM) after the gun, and another before the buncher. There will be a WCM, FLAG, and Beam Position Monitor (BPM) before each LINAC tank. This will provide sufficient diagnostics to determine bunch charge, length, transverse size, and position. The WCMs will also provide a measure of the beam losses in the LINAC. Refer to the Diagnostics Table of Elements and the Plan View of Injector as shown in Table 1 and Figure 2 respectively.

TABLE 1 DIAGNOSTICS –LINAC / GUN

System	Qty	Monitor Type	Abbrev	Measured Beam Parameter
Electron Source (Gun)	2	Wall Current Monitor	WCM	Intensity, Longitudinal Beam Characteristics
LINAC	3	Fluorescent Screens	FLAGS	Position, Transverse Profile
	3	Wall Current Monitor	WCM	Bunch Charge Intensity, Beam Loss
	3	Beam Position Monitor	BPM	Beam Position

BOOSTER DIAGNOSTICS

A turn-key procurement, the NSLS-II BOOSTER is a 158m combined function for magnet synchrotron with an extraction energy of 3 GeV for top-up injection. The beam emittance will be damped below 50 nm-rad, with train up to 150 bunches. The bunch length will be 15 ps, and an energy spread of 0.08% when fully damped. The expected total charge out of the booster is estimated to be 10 nC when the LINAC operates in multi-bunch mode. The booster diagnostics are chosen for commissioning and robust operation. The booster will have 24 BPMs placed at strategic points in the ring to allow for robust orbit correction. Six Flags will be located in the booster for commissioning, injection matching and transverse profile measurements. Beam current will be measured with a DCCT. An FCT will monitor the bunch train pattern. A pair of Stripline Kickers will be available for tune and chromaticity measurements, also serving in a beam cleaner system. Synchrotron light will also be used in conjunction with a streak camera to measure the bunch length. The Diagnostics Table of Elements and the Preliminary layout of the Booster is shown in Table 2 and Figure 2 respectively.

TABLE 2 DIAGNOSTIC- BOOSTER

System	Qty	Monitor Type	Abbrev	Measured Beam Parameter
Booster	1	DC Current Transformer	DCCT	Beam Current
	1	Fast Current Tfmrs	FCT	Bunch Charge
	6	Fluorescent Screens	FLAGS	Intensity, Beam Shape & Position
	1	Strip Line Detector	SLD	Tune Measurement System
	1	Strip Line Detector	SLD	Bunch Cleaner
	24	Beam Position Monitor	BPM	Beam Position, Orbit
	1	Streak Camera	OBSC	Bunch Length
	1	FireWire Camera	FWC	Beam Position, Profile

FIGURE 1– ENERGY SLIT (ES) FOR LTB TRANSPORT LINE

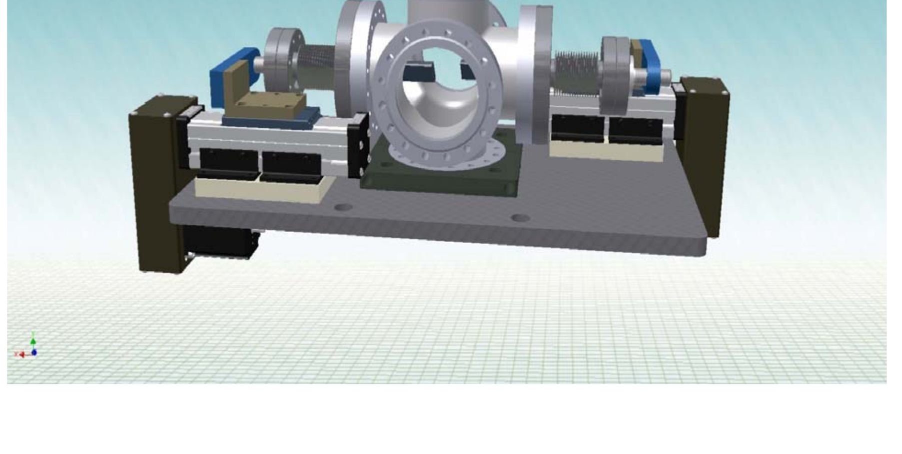


FIGURE 2– INJECTOR SYSTEM

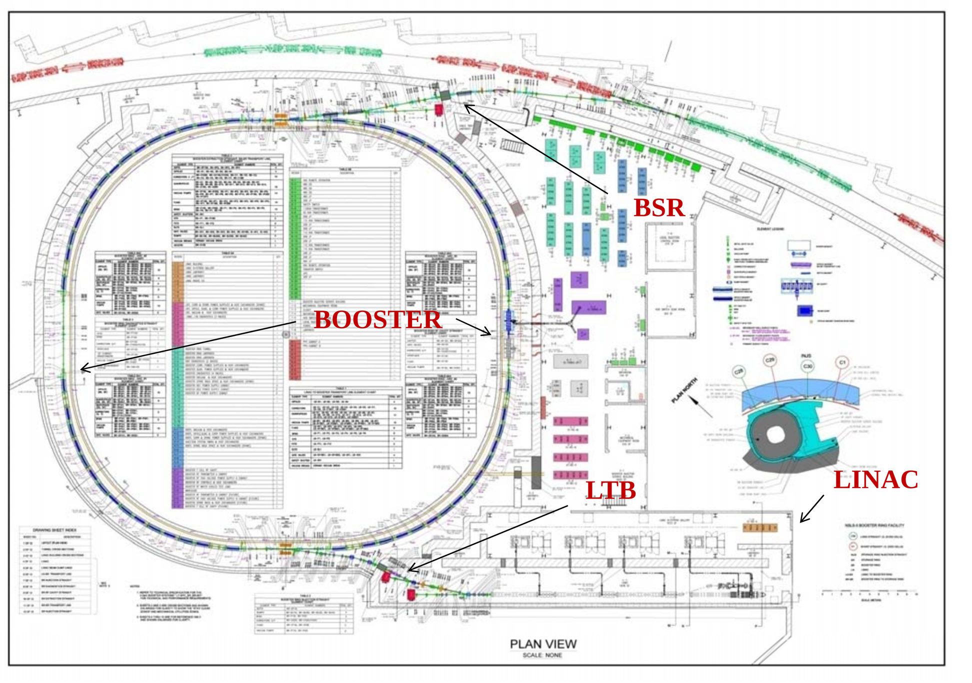
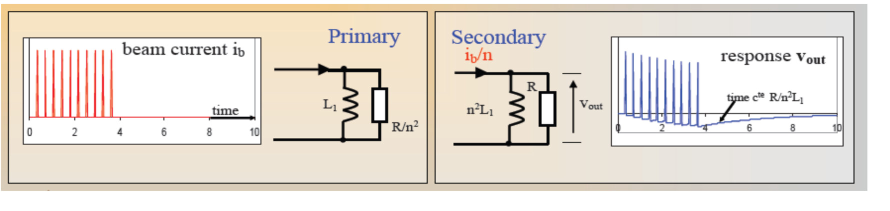
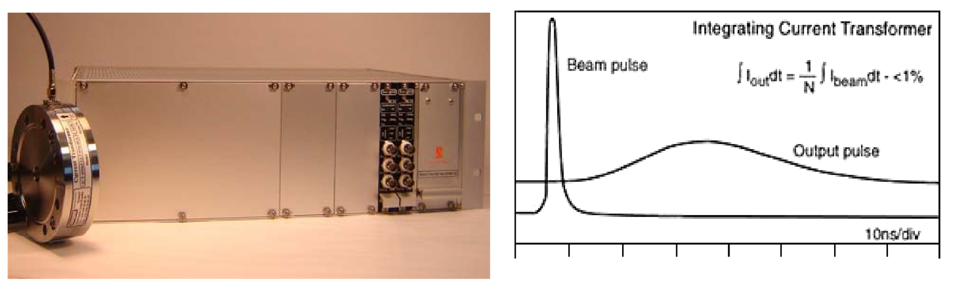


FIGURE 3– FAST CURRENT TRANSFORMER (FCT)



Bergoz Fast Current Transformers (FCT) will be used for fill pattern monitoring. The Bergoz FCT will be directly mounted on the beam chamber with a ceramic break and RF shielding, and will provide electrical signal proportional to the charge of individual bunches. It has 1.75 GHz bandwidth with a 200 psec rise time. Fast ADC sampling (>1GS/s) of the FCT output voltage will make charge distribution available to the control system. The information obtained will be used in the top-off algorithm.

FIGURE 4– INTEGRATING CURRENT TRANSFORMER (FCT)



The ICT/BCM will provide a multiply time integral output, and is proportional to the beam pulse charge irrespective of the bunch width or bunch frequency spectrum. For NSLS-II Linac injection, with the maximum 150 bunches (500MHz RF), the bunch train to be integrated and measured is 298ns long. It will pass through the ICT and the ICT output will be a 368ns long signal with rise-time of about 20ns, fall-time of about 30ns and a flat top (if the 150 bunches are evenly charged). Bergoz BCM is comprised of a chassis and module. It has a bipolar voltage output that is directly proportional to the total beam charge. BCM electronics are made in various versions. The BCM-IHR-E (Integrate-Hold-Reset) module has been selected to measure single pulse or bunch trains up to 5us long .

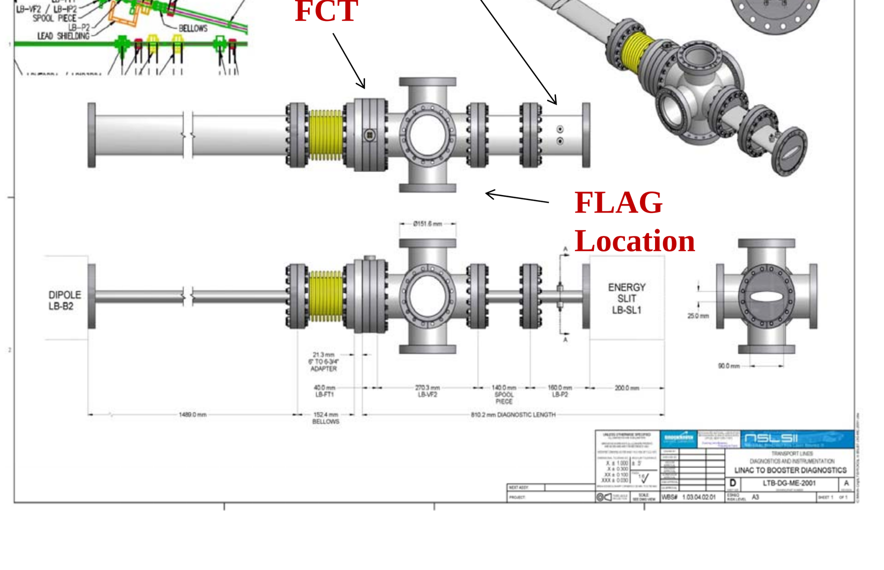
CONTROLS INTERFACE FOR DIAGNOSTICS

Diagnostics controls can also be considered as data acquisition (DAQ) rather than device control. Diagnostics control subsystem will conform to NSLS-II control system standards. It will be EPICS-based and the preferred operating systems for IOCs are RTEMS (Real-Time Executive for Multiprocessor Systems) and Linux. For VME-based controls, the CPU board will be standardized as Motorola MVME3100. Whenever possible, diagnostics controls will utilize commercial off-the-shelf hardware to reduce cost as well to achieve better reliability. Although NSLS-II Linac and Booster are turn-key solutions provided by vendors, the intention is to standardize the diagnostics controls for the whole machine. Each type of beam monitor requires electronics (device controller) to process its output signal. The proposed electronics for the above groups and associated EPICS IOC platform are listed in Table 3.

TABLE 3 CONTROLS ELECTRONICS AND IOC PLATFORM

Beam Monitor	Controls Electronics	EPICS IOC platform
WCM & FCT	Acqiris Digitizer DC252 (10-bit, 4-8GS/s)	CompactPCI/RTEMS
DCCT & ICT	1) Hytec 8002 carrier board 2) Hytec IP-ADC-8401(8-channel, 16-bit, 100KHz) 3) Agilent 3458 DVM (8.5-digit, 18-bit at 2KS/s) 4) GPIB-to-Ethernet converter	VME/RTEMS
BPM	1) I-tech Libera Brilliance (Baseline) 2) In-House development custom electronics	Embedded Linux IOC
Gigabit-Ethernet Cameras	Motorola MVME 3100 (CPU)	VME/RTEMS
Stepper-motor-based	1) Pro-dex OMS MAXv-8000 2) Hytec MDS-8	VME/RTEMS
Instrument controls	Windows-based network/spectrum analyzer	X86/Windows
Digital I/O and DAC	1) Hytec 8001 carrier board included digital TTL I/O 2) Allen-Bradley compactLogix for 24V digital output 3) Hytec IP-DAC-8402 (16-channel, 16-bit)	VME/RTEMS

FIGURE 5– LTB INTEGRATION MODEL FOR FCT, ICT, BPM-PUE



LINAC TO BOOSTER (LTB) TRANSPORT LINE DIAGNOSTICS

The layout of the LTB transport line is shown in Figure 2. It consists of 3 sections, a LINAC to achromatic section, an achromatic, and a matching section into the booster. In addition, there are two beam dumps located in the LINAC vault that will be used for commissioning, tune-up and diagnostics. Table 4 shows the available diagnostics in the LTB. There are Flags at the start of the LTB, after the Energy Slit, and prior to booster injection that will be used for commissioning. There is an Integrating Current Transformer (ICT) and a Fast Current Transformer (FCT) to measure the beam charge and bunch train at each end of the LTB. An Energy Slit will be placed at the maximum dispersion location in the achromat, to remove any low energy particles. Six BPMs are placed through the LTB. The first is located at the end of the LINAC. One exists after the Energy Slit for online energy jitter measurement. Four BPMs are in the matching section for matching into the booster. There is also a Safety Shutter placed before the exit of the LINAC vault that will allow safe operation of the LINAC independent of the status of the booster. The beam dumps are equipped with Flags, including three Flags in the "straight ahead" beam dump for emittance measurement. The second beam dump will have sufficient dispersion to perform an energy spread and energy jitter measurement. Incorporated into each beam dump will be the design of a Faraday Cup which will also act as a beam stop and will measure gross charge per train, capturing the entire charge of the electron beam and it's shower for all dumps.

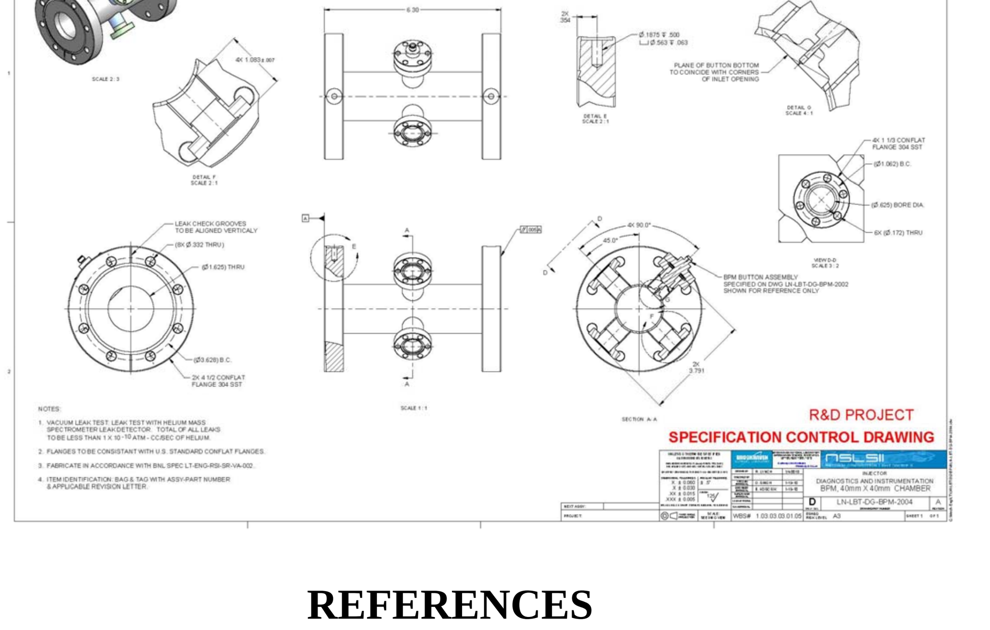
TABLE 4 – DIAGNOSTICS -TRANSPORT LINES

Monitor Type	Qty. (LtB)	Qty. (BSR)	Resolution	Measured Beam Parameter
Screens(OTR+YAG)	9	10	10/30 µm	Energy Spread, Electron Beam Size, Position
Fast Current Tfmrs	2	2	~0.6pC/bunch	Fill Pattern, Bunch Charge
Energy Slit	1	1	NA	Beam Energy Spread
Integrating Current Tfmrs	2	2	~10 pC/train	Injected Bunch Charge, Injection Efficiency
Beam Position Monitor (40mm x 90mm Beam Pipe)	1		30 µm	Beam Position
Beam Position Monitor (40mm Beam Pipe)	5	8	30 µm	Beam Position
Faraday cup	2	1		Bunch charge

BOOSTER TO STORAGE RING (BSR) TRANSPORT LINE DIAGNOSTICS

Extraction form the booster is performed with a four bump scheme. A kicker imparts a 5 mrad angle, which is then followed by thin pulsed septum, and a large DC septum into the BSR line. The BSR line consists of 3 main sections, the booster extraction, an achromatic transport, and the matching section. There is also a beam dump located in the booster vault for commissioning and tune up. The Diagnostics Table of Elements and the Preliminary layout of the BSR is shown in Table 4 and Figure 2 respectively. The BSR line has nine Flags. Two Flags are placed before the first dipole to commission booster extraction. Three Flags are in the achromat section for emittance measurements. Three Flags are in the matching section for injection matching. Last Flag is prior to the beam dump to allow for energy spread measurements. There is an FCT in the booster extraction section and near the injection point to measure the bunch train distribution. There is an ICT near injection point to measure the bunch charge. Eight BPMs are placed in the transport line. Two BPMs are in the booster extraction section, three are in the achromat, and remainder are in the matching section. There is an Energy Slit near the maximum dispersion region to limit the energy spread entering the storage ring. A Safety Shutter near the exit of the booster vault will allow operation of the booster independent of the storage ring. The booster beam dump is equipped with a Flag for energy spread measurements. It also has an ICT for bunch charge measurements. The beam dump will be used for booster commissioning and tune-up, allowing for characterization of the booster independent of the storage ring status. Incorporated into the beam dump will be the design of a Faraday Cup which will also act as a beam stop and will measure gross charge per train, capturing the entire charge of the electron beam and it's shower.

FIGURE 6– BPM-PUE CHAMBER ASSEMBLY FOR LTB (40 mm)



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