NSLS-II NEXT BEAMLINE 12-ID COMMISSIONING PLAN

OCTOBER 26, 2016

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REV. 1

NSLS-II NEXT BEAMLINE 12-ID COMMISSIONING PLAN

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REVISION HISTORY

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1	First Issue	October 26, 2016

Acronyms

13DOF	13 Degree of Freedom
BDM	Bounce Down Mirror
BNL	Brookhaven National Laboratory
CRLs	Compound Refractive Lenses
EPS	Equipment Protection System
ESH	Environment, Safety and Health
ESR	Experiment Safety Review
FE	Front End
FLUKA	Fluktuierende Kaskade (Monte Carlo simulation software)
GI	Grazing Incidence
GV	Gate Valve
ID	Insertion Device
IRR	Instrument Readiness Review
mA	milli-Ampere
MAXS	Medium-angle X-ray Scattering
NEXT	NSLS-II Experimental Tools Project
NSLS-II	National Synchrotron Light Source II
PASS	Proposal, Allocation, Safety and Scheduling
PPS	Personnel Protection System
PSD	Photon Science Division
RGA	Residual Gas Analyzer
SAF	Safety Approval Form
SAXS	Small-angle X-ray Scattering
SMI	Soft Matter Interfaces
TCP	Technical Commissioning Plan
WAXS	Wide-angle X-ray Scattering
XBPM	X-ray Beam Position Monitor

Table of Contents

Acronyms ii

1. INTRODUCTION 1

2. SHIELDING 1

3. BEAMLINE COMMISSIONING 1

3.1 Radiation Survey Commissioning 2

3.2 Technical Commissioning 2

3.3 Scientific Commissioning 2

4. COMMISSIONING ACTIVITY APPROVAL 3

5. END STATION EQUIPMENT ADDITIONS 3

6. END OF COMMISSIONING; TRANSITION TO OPERATIONS 4

7. SMI BEAMLINE TECHNICAL COMMISSIONING PLAN 5

7.1 SMI Beamline Subsystem Definition 5

7.2 SMI Beamline Commissioning Without Beam 6

7.3 SMI Beamline Commissioning With Beam 7

7.3.1 Pre-beam Commissioning Activities 7

7.3.2 First-beam Extraction and Radiation Surveys 8

7.3.3 Beamline Optics Commissioning & Transition to Operation Condition 11

7.3.4 Experimental Station and Data Acquisition Commissioning 14

8 REFERENCES 20

Appendix A: SMI Beamline Component Layout 21

1. INTRODUCTION

This plan outlines the actions needed to commission the NSLS-II NEXT 12-ID (Soft Matter Interfaces, SMI) Beamline from the accelerator enclosure ratchet wall to the endstation. Once the readiness process is complete and authorization to begin commissioning the beamline is received, the technical commissioning will proceed, initially hand in hand with a radiation safety commissioning, until the beamline is deemed to be radiation safe in standard x-ray operations. In the latter stages of technical commissioning, the main optical elements of the beamline are optimized for User Operations, and finally the end-stations are also commissioned. There are several processes established to manage the risks associated with this task, which are outlined below.

The scope of this plan includes managing specific commissioning activities for the beamline, reviewing requirements for equipment not needed for commissioning, but planned for operations, and the basis for transitioning to operations. Technical commissioning of the FEs and IDs is managed separately from the beamline.

2. SHIELDING

Ray tracing and computer modeling (FLUKA) indicate that 12-ID is shielded for the maximum planned stored electron beam current of 500 mA. The primary Gas Bremsstrahlung ray traces have been completed in accordance with *Synchrotron and Bremsstrahlung Ray Trace Procedure* (PS-C-XFD-PRC-008) and *Insertion Device Front End Ray Tracing Procedure* (PS-C-ASD-PRC-147) and top-off safety analyzed, resulting in one Bremsstrahlung collimator and a Bremsstrahlung stop within the 12-ID-A hutch. Two Secondary Gas Bremsstrahlung shields were designed following NSLS-II guidelines. The scattering of Bremsstrahlung has been modeled using FLUKA, which showed that the secondary shields are adequate at 500 mA beam current. The summary of these simulations including the simulation of the monochromatic beam containment in beam transport and endstation enclosures are provided in *12-ID SMI Beamline Radiation Shielding Analysis* (Tech Note #228).

3. BEAMLINE COMMISSIONING

The commissioning of the SMI beamline and its transition to operations begins with the IRR. This will be followed by the first two phases of the Technical Commissioning Plan (TCP) in which the electron beam current is gradually increased while monitoring equipment safety. The TCP is conducted in parallel with Radiation Survey Commissioning, which monitors radiation safety as the ring current is increased. When the beamline equipment has been demonstrated to be capable of safely operating during standard x-ray operations, there is a final comprehensive radiation survey. The TCP then moves on to a new phase, in which all the key optical components such as the monochromator and mirrors are commissioned in detail in order to determine optimal operating parameters. In a final phase of the TCP, the endstations are commissioned. Scientific commissioning will then follow, with the

participation of expert users, to verify that the beamline meets the design performance goals and to build up endstation and beamline parameters and configurations that optimize beamline performance for routine user operations.

3.1 Radiation Survey Commissioning

A comprehensive *SMI Beamline (12-ID) Radiation Survey Procedure* (NSLSII-12ID-PRC-001) was developed in accordance with *NSLS-II Beamlines Radiation Safety Commissioning Plan* (PS-C-XFD-PRC-004), which guides the steps needed to control radiological hazards. It includes specific hold points to manage identified radiation risks and maintain commissioning within an approved envelope. The Radiation Survey Procedure requires participation and coordination between Beamline, Operations, Radiological Control, and ESH Staff. It identifies specific radiation scatter points along the beamline and provides instruction for mechanical manipulation of the optics to allow for a comprehensive radiological survey along the beamline. Execution of the Radiation Survey Procedure, along with the evaluation of the data collected, will be used as a basis by the PSD Director and ESH Manager to approve commissioning activities at an electron beam current of up to 3 times the electron beam current measured during the survey. Approval of commissioning of the beamline at a higher electron beam current requires re-execution of the Radiation Survey Procedure. The maximum current allowed during commissioning is indicated on the Caution Tag that is applied by Operations Staff to the beamline enable key. Enabling the beamline at a higher current requires re-execution of the full Radiation Survey Procedure and re-approval by the PSD Director and ESH Manager.

3.2 Technical Commissioning

The Technical Commissioning Plan (TCP), described in Section 7 below, documents in some detail the sequence of activities planned to safely commission the beamline. The TCP starts with lowest ring current, and gradually increases ring current until it is at the value for standard operations. At the completion of TCP, all major beamline components will be ready to use, and parameters that optimize their performance will be documented.

3.3 Scientific Commissioning

The SMI beamline will have two experimental endstations. Enclosure 12-ID-B allows diagnostic work such as measurement of primary focus of the x-ray beam and will eventually be dedicated to an independent outboard branch line in the canted sector 12-ID. No installed instrumentation is commissioned in 12-ID-B in the scope of the NEXT Project or this TCP. Enclosure 12-ID-C will enable grazing incidence small-angle and wide-angle x-ray scattering (GI-SAXS/WAXS) experiments. 12-ID-C instrumentation is installed in the scope of the NEXT Project. A scientific commissioning plan will be developed while the technical commissioning takes place. The goal of the scientific commissioning will be to define the beamline parameters and configurations needed for the anticipated scientific program, and the process to bring the complete beamline into routine operations for users.

4. COMMISSIONING ACTIVITY APPROVAL

Work planning needed for safe and efficient commissioning, requires a commissioning SAF and is performed in accordance with *Experiment Safety Review* (PS-C-ESH-PRC-039). This process drives definition of scope, identification of hazards and controls, and review and approval requirements for all commissioning activities. A commissioning SAF describing the commissioning tasks to be undertaken by the commissioning team will be submitted. This form will include the equipment and materials that will be used, the personnel authorized to participate in the commissioning and any controls that will be placed on the beamline (such as a current limit). This form will be submitted to the ESH Manager and PSD Director for approval. This commissioning activity approval process authorizes the commissioning team for a specific task or tasks (such as performing a radiation survey) thereby enforcing a step-by-step and HOLD point approach to commissioning. Most commissioning tasks are expected to take approximately one week to complete, though some may be longer. All commissioning activities will be reviewed on a weekly basis to determine if a new commissioning SAF is needed. This allows for flexibility in the commissioning process, but at the same time ensures that during commissioning the work is periodically reviewed and that the necessary controls are placed on the commissioning activities.

An approved commissioning SAF is required for the beamline to be enabled. Beamline enable is managed in accordance with *Enabling Beamlines for Operations* (PS-C-XFD-PRC-003). This procedure defines the process for enabling the beamline safety shutter and for giving control of that shutter to the Beamline Staff. The process requires participation and coordination between Beamline, Operations, and ESH Staff. A checklist is employed to assure systems are ready (PPS and safety system configuration control) and that staff is prepared to begin.

5. END STATION EQUIPMENT ADDITIONS

Experimental modules will be added to the end station as commissioning moves from technical to scientific, and the focus is shifted to optimizing the photon beam and preparing end station instrumentation for the expected scientific program. All equipment will be added in accordance with the *NSLS-II Process Description: Review Process for Facility Additions and Modifications* (PS-C-CMD-PLN-001), which provides a process for determining the type and extent of reviews warranted.

The end station equipment additions for the beamline have been evaluated and it has been determined that the addition of this equipment will not constitute a sufficient modification of the beamline instrument, and therefore will not require an IRR. These additions will be reviewed through the BNL ESR process, in accordance with *Experiment Safety Review* (PS-C-ESH-PRC-039). This system allows for the treatment of the end stations as experiment areas and provides an electronic mechanism to gather the information needed to define and review equipment and materials in that area. The BNL ESR system contains fields for entry of the equipment and materials to be used, task analyses, control requirement definition, and for ESH review and approval. This approach will be documented in a

Tailored Review Plan in accordance with the *NSLS-II Process Description: Review Process for Facility Additions and Modifications* (PS-C-CMD-PLN-001).

The ESRs will be posted at the end station so that they are readily available and provide an ESH envelope of the allowed equipment and activities in the area. This system is used in experiment spaces throughout BNL. Annual review and approval is required, but any change also triggers a system update with an approval requirement. This system will assure careful management of equipment additions and will be correlated with the ESR process planned for the management of User activities.

6. END OF COMMISSIONING; TRANSITION TO OPERATIONS

Commissioning ends when the beamline has shown, through the execution of procedures and surveys, that it meets the NSLS-II Shielding Policy, that radiation leakage or scatter is controlled to as low as reasonably achievable, that the photon beam is ready for data collection, and that the necessary authorizations for beginning operations have been obtained. Prior to the beamlines commencing User Operations, the process outlined in *Beamline User Readiness (*PS-C-XFD-PRC-030) will be completed.

The safety of ongoing beamline operations will be managed with the *Experiment Safety Review* (PS-C-ESH-PRC-039) process, which will control materials, equipment, and tasks at the end station areas through the use of the BNL electronic ESR system. A Cognizant Space Manager is assigned to the area and has responsibility to assure that the system is current and accurate. This system provides a valuable envelope for the resources and allows operations at each location.

Individual experiments will be managed with the electronic SAF section of PASS; a system for Proposal, Allocation, Safety, and Scheduling for User science. The SAF will allow collection of information specific to each experiment and will be reviewed by NSLS-II Staff to determine what hazards are outside the safety envelope established. The SAF will provide the mechanism for definition of scope, analysis of hazards, establishment of controls, and collection of feedback for each experiment. Users must identify the materials and equipment they wish to bring along with a task analysis describing how those items will be used. An iterative review between the User, Beamline, and ESH Staff results in a final approval with definition of requirements.

The SAF process combined with the BNL ESR safety envelope provides the basis needed to assure ongoing control of beamline operation and changes. No additional readiness reviews are expected for the 12-ID at this time.

7. SMI BEAMLINE TECHNICAL COMMISSIONING PLAN

7.1 SMI Beamline Subsystem Definition

Refer to Appendix A, SMI Beamline Component Layout, for context.

12-ID-A

a. Differential Pumping Assembly:
   - First and second ion pump crosses, with RGA at first cross downstream of ratchet wall GV-2
   - Water-cooled Fixed Aperture Mask (FAM) and PPS Aperture
   - GB Collimator

b. White Beam Slits (WB Slits) + slit photocurrent diagnostic

c. White Beam Stop

d. Gaseous Bremsstrahlung Stop (GB Stop)

e. Double Crystal Monochromator (DCM), fixed exit Si(111), 25mm bounce-up

f. X-ray Beam Position Monitor 1 (XBPM1), instrumented diamond, thin window for tender x-rays, *NEXT Project scope, ESR to be submitted after IRR approval*

g. Horizontal Focusing Mirror (HFM), bimorph, reflects inboard, incorporating horizontal monochromatic beam slits (H slits) before the mirror and a stripe photocurrent diagnostic

h. Vertical Focusing Mirror (VFM), bimorph, reflects up, incorporating vertical monochromatic beam slits (V slits) before the mirror. Vessel contains an RGA

i. Vertical Deflection Mirror (VDM), flat, reflects down, in same vacuum vessel following VFM

j. X-ray Beam Position Monitor 2 (XBPM2), instrumented diamond, thin window for tender x-rays

k. Photon Shutter (PSH) for monochromatic beam

12-ID-B-1

l. X-ray Beam Position Monitor 3 (XBPM3), instrumented diamond, thin window for tender x-rays

m. Secondary Source Aperture (SSA) + slit photocurrent diagnostic

12-ID-B

n. Removable Shielded Beampipe, incorporates PPS interlocks to detect configuration and enable shutter logic for access to 12-ID-B while taking beam in 12-ID-C

o. Removable Beam Stop Block, incorporates PPS interlocks to detect configuration and enable shutter logic for access to 12-ID-C while taking beam in 12-ID-B. A Be Window terminates the upstream part of the vacuum line when the Beam Stop Block is in use.

12-ID-C

p. Installed beam transport from upstream includes ion pump crosses and reserves space for future beam conditioning elements.

q. CRL Transfocator, provides microfocus. Lenses can be extracted entirely from the beam

r. WAXS Assembly:

- Sample Vacuum Chamber, equipped with EPX dry turbo pump
- WAXS Goniometer, arc stage for Wide Angle Detector motion
- Pilatus 300K-W detector, *NEXT Project scope, ESR to be submitted after IRR approval*
- Vacuum Sample Stages, 13 degree of freedom (13DOF) hexapod based sample positioner
- Bounce Down Mirror (BDM), coated silicon for grazing incidence onto liquids

s. SAXS Assembly: *NEXT Project scope, ESR to be submitted after IRR approval*

- SAXS Beam Chamber, equipped with EPX dry turbo pump
- Beam Stop Assembly, small stops to block direct beam on SAXS detector, equipped with diode and photocurrent diagnostics
- Detector XYZ Mechanics
- Pilatus 1M detector

t. Rayonix MAXS (Medium Angle) detector supplied by CFN Partner (not shown in layout)

7.2 SMI Beamline Commissioning Without Beam

The majority of these tasks will be accomplished prior to IRR, and documented in executed travelers.

a. Vacuum Systems: all pumps, gauges, and valves functional with readouts in EPS system

b. White Beam Components package:

1. Motors, temperature sensors, and other signals functioning for WB Slits and DCM
2. Cryo-Cooler test and DCM cold test
3. PPS and EPS utilities and systems including PPS Aperture manifold tested and ready
4. Camera viewing phosphor plates on WB Stop
5. EPICS functionality of DCM geometry / energy code installed / tested
6. Verify the functionality of the CSS screens

c. H-V Mirror and SSA package

1. Motors, temperature sensors, and other signals functional for slits and mirrors
2. Bimorph mirror high voltage controller interfaced and tested

d. Photon Shutter interfaced and tested

e. CRL Transfocator interfaced and tested

f. WAXS Assembly:

1. Sample Vacuum Chamber vacuum tests
2. WAXS Goniometer interfaced and tested
3. Pilatus 300K-W interfaced and tested, including utilities, triggers, and data servers
4. Bounce Down Mirror controller tested, incorporated into EPICS
5. Sample Vacuum Stages tested, incorporated into EPICS
6. Cable management complete

g. SAXS Assembly:

1. SAXS Beam Chamber installed and surveyed
2. SAXS detector XYZ mechanics installed and tested
3. Pilatus 1M interfaced and tested, including utilities, triggers, and data servers
4. Beam stop assembly tested, signals incorporated into EPICS as detectors
5. Cable management complete

h. Data Acquisition

1. Motor scan and scaler setup and test
2. Area detector EPICS setup and test
3. Verify scripting capabilities and high-level control GUIs

7.3 SMI Beamline Commissioning With Beam

7.3.1 Pre-beam Commissioning Activities

The in-vacuum undulator (IVU) source has been installed at 12-ID and has been commissioned by the Accelerator Division during February-September 2016.

Prior to the beamline commissioning activities, the following prerequisites shall be satisfied:

- IRR completed and pre-start findings closed
- PPS and EPS functional
- Accelerator operating at current determined by the accelerator division
- IVU source and front end commissioned

- Front end slits controllable by beamline control system, slit-current reading functional
- Cameras connected and working to align beam with respect to visualization screens
- Beamline control environment with basic capabilities (including motor control and scanning) and basic graphics and user interface available
- For a given commissioning-with-beam activity, relevant commissioning-without-beam activities are completed

7.3.2 First-beam Extraction and Radiation Surveys

Initial activities are carried out in support of the SMI Radiation Survey Procedure (NSLSII-12ID-PRC-001), which is organized as follows:

I. **GB Radiation Survey**

a. Integrity of enclosure 12-ID-A, GB on fixed components

b. GB on movable components (WB Slits, DCM)

II. **White Beam Radiation Survey**

a. Integrity of enclosure 12-ID-A, white beam on fixed components (FAM, WB Stop)

b. White beam on movable components (WB Slits, DCM)

III. **Monochromatic Beam Radiation Survey**

a. Integrity of enclosure 12-ID-A and transport pipe

b. Integrity of enclosures 12-ID-B-1 and 12-ID-C:
Configuration: Removable Shielded Beam Pipe installed

c. Monochromatic beam on SSA

d. Monochromatic beam in 12-ID-B:
Configuration: Be Window and Beam Stop Block installed

Part I, GB Radiation Survey, requires the IVU gap to be open and all FE and FOE slits wide open to maximize GB on FOE components. First light will be established at a storage ring current of 2mA and diagnostics used to confirm that the beam is conducted to the WB Stop in the FOE. When acceptable vacuum and thermal performance is confirmed, this condition will be re-established for successively higher storage ring currents, to a target of 100 mA. Carrying out the Comprehensive Radiation Survey at 100 mA will enable SMI to take beam at all operating currents up to 3× the current surveyed, or a ring current of 300 mA.

A typical shift will include the following tasks:

- Establish the desired storage ring current and prepare FE with slits open, IVU gap open
- Prepare FOE with WB Slits open, DCM rotated near 0°, Mirrors extracted, PSH closed
- Open FE shutter and monitor beam position, component temperatures, and vacuum in the FOE

- Insert movable FOE white beam components (WB Slits, DCM Bragg rotation)
- Document performance
- Insert FOE mirrors and slits into mono beam
- Document performance

Part II, White Beam Radiation Survey, requires the IVU gap to be *closed to minimum permissible* and all FE and FOE slits wide open to maximize white beam on FOE components. The first shifts with IVU gap closed will be established at a storage ring current of 2mA, working with Accelerator Division staff to determine appropriate starting conditions for the IVU. Diagnostics will be used to confirm that the beam is conducted to the WB Stop in the FOE. When acceptable vacuum and thermal performance is confirmed, this condition will be re-established for successively higher storage ring currents, to a target of 100 mA. A typical shift will have the same steps itemized above.

Figure 1 gives the relationship between IVU gap setting and photon energy (established from bench measurements). The minimum gap setting at 12-ID is 6.1mm, K_{max} = 2.05. At K_{max}, the maximum power available from the undulator at 500mA must be restricted by the WB Slits to an acceptance of 40µrad × 40µrad when the DCM Bragg angle is greater than 33° (3.6 keV). This corresponds to a power density on the DCM first crystal of 28 W/mm^2. At lower storage ring currents, the power can be scaled to provide a table of safe WB Slit apertures dependent on the ring current and the Bragg angle. Staff will refer to this information, provided below as Table 1, to choose the appropriate working range for the DCM for the commissioning shift. At larger IVU gaps, the table will also be utilized, to maintain acceptably low power density. For ring current ≤ 80mA, wide open WB slits are always safe.

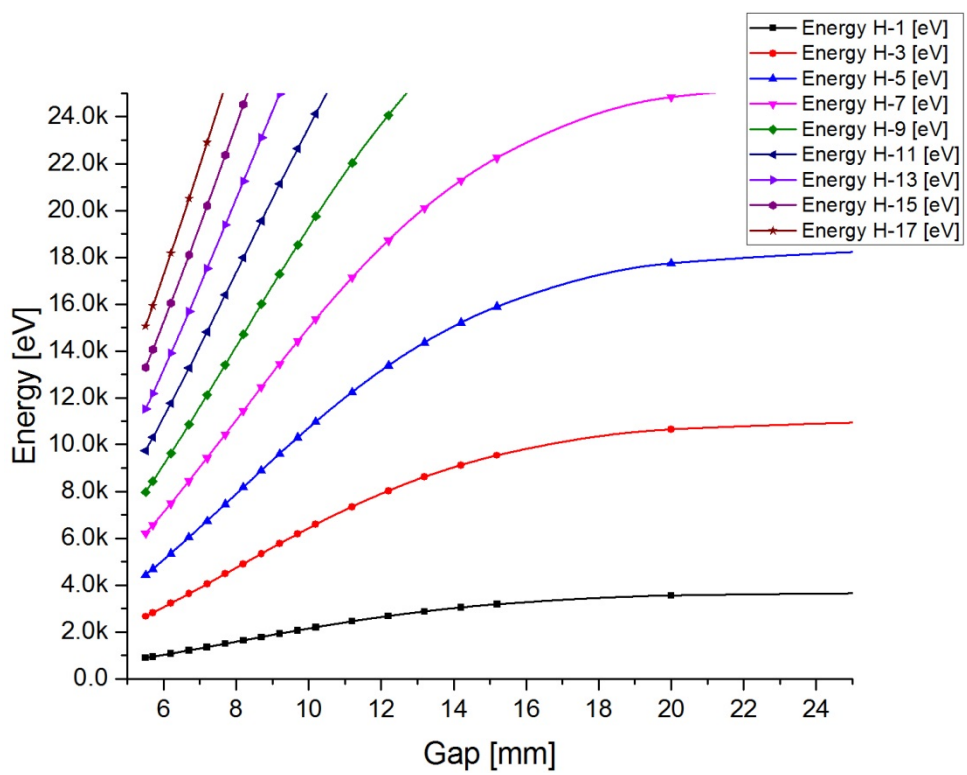

Figure 1. Photon energy versus gap setting for the 23mm period IVU installed at 12-ID.

Table 1. WB Slit X and Y aperture setting to maintain power density < 30 W/mm^2 on the DCM first crystal, for selected energies with IVU at minimum gap. Gray lines are disallowed conditions. The maximum aperture shown is 100µrad × 100µrad, the FAM acceptance (WB Slits wide open).

Energy (keV)	Ring Current (mA)	Aperture X (µrad)	Aperture Y (µrad)	Bragg Angle (deg)	Power Density
20.4	500	100	100	5.56	30.69
20.4	450	100	100	5.56	27.62
20.4	500	80	80	5.56	19.64
10.8	500	100	100	10.54	57.97
10.8	250	100	100	10.54	28.98
10.8	500	80	80	10.54	37.10
10.8	400	80	80	10.54	29.68
10.8	500	60	60	10.54	20.87
8.4	500	100	100	13.6	74.53
8.4	200	100	100	13.6	29.81
8.4	500	80	80	13.6	47.70
8.4	300	80	80	13.6	28.62
8.4	500	60	60	13.6	26.83
6	500	100	100	19.23	104.34
6	130	100	100	19.23	27.13
6	500	80	80	19.23	66.78
6	200	80	80	19.23	26.71
6	500	60	60	19.23	37.56
6	350	60	60	19.23	26.29
6	500	40	40	19.23	16.69
4.8	500	100	100	24.31	130.43
4.8	100	100	100	24.31	26.09
4.8	500	80	80	24.31	83.47
4.8	180	80	80	24.31	30.05
4.8	500	60	60	24.31	46.95
4.8	300	60	60	24.31	28.17
4.8	500	40	40	24.31	20.87
3.6	500	100	100	33.29	173.90
3.6	80	100	100	33.29	27.82
3.6	500	80	80	33.29	111.30
3.6	120	80	80	33.29	26.71
3.6	500	60	60	33.29	62.60
3.6	200	60	60	33.29	25.04
3.6	500	40	40	33.29	27.82

Part III of the Comprehensive Radiation Survey Plan, the Monochromatic Beam Radiation Survey, requires that beam be conducted into the two endstations. Proper alignment of the DCM and H-V Mirrors degrees of freedom is necessary. Establishing the Part III scenarios is required for two important goals: Measurement of the SMI Key Performance Parameters with beam (defined in the NEXT Project); and beginning the more quantitative phase of Technical Commissioning that requires calibration and user operability of all beamline components.

At each storage ring current step, SMI commissioning with mono beam into 12-ID-B or -C will be undertaken, and optics will be aligned as well as the diagnostics allow at low beam intensities. An approximate schedule of priorities is shown in Table 2. By completing the Comprehensive Radiation Survey at 100 mA SMI will enable further Technical Commissioning during Operations at 300 mA.

Table 2. Priorities for the beam conditioning phase of commissioning that leads to the Comprehensive Radiation Survey at 100 mA storage ring current.

Scenario	***2 mA***	***5 mA***	***10 mA***	***20 mA***	***50 mA***	***100 mA***
Part I – GB	1	2	3	3	5	6
Part II – WB	1	2	3	4	5	6
Part III – mono		2		4		*final*

7.3.3 Beamline Optics Commissioning & Transition to Operation Condition

7.3.3.1 Goals of Beamline Optics Commissioning

The goal is to achieve calibration, control, and understanding of beamline optics operation, energy selection, beamline alignment procedure, and optimizations for different experimental configurations. To the maximum extent possible, alignment procedures shall be documented and automated.

7.3.3.2 Introducing beam into the Photon Delivery System

a. Criteria for alignment of WB Slits:
    1. In standard usage the SMI WB Slits will be maintained at 40μrad × 40μrad once the calibration is established.
    2. WB Slits have a gap-scan mechanism. An open gap will be scanned in the beam using photocurrent signals to determine the center.
    3. Gap motor will be scanned to find the fully closed position.
    4. Gap will be driven to 2.7mm × 2.7mm and left fixed with drive current off.
    5. Subsequent alignments may adjust the scan position only.

b. Criteria for alignment of the DCM:
    1. DCM Bragg theta has a precalibrated air bearing servomotor drive that can be homed to its limits and encoders at any time. For safety, home with the FE shutter closed.
    2. DCM EPICS code is programmed with appropriate starting positions for 2nd crystal.
    3. By extracting the HFM and inserting the Fluorescent screen, mono beam can be visualized in the FOE.
    4. DCM 2nd crystal degrees of freedom can be tuned coarsely with screen visualization.
    5. DCM 2nd crystal and IVU-DCM relationship can be tuned finely with quantitative measurements using XBPM1

c. Criteria for calibration of the XBPMs:
   1. The XBPM diamond has six pads (dual quad), photocurrent detection by electrometer.
   2. The XBPM will have been calibrated previously with synchrotron x-rays.
   3. The XBPM has XY motions and a clear through-hole region. Scan XBPM X,Y and monitor signals.
   4. Using an XBPM pad as a knife edge, measure mono beam size in X and Y.
   5. Using XBPM scan axes, calibrate quad signal using the measured beam size.
   6. XBPMs can now be used to monitor intensity and beam position.

Introducing stable beam into the photon delivery system at different energies requires further familiarity with IVU, DCM, and XBPM. A more detailed outline is given in Table 3.

Table 3. Outline of commissioning tasks for white beam, DCM, and XBPM1 in hard x-ray range.

Activity	***Desired Steps***
White beam	Start with gap closed to minimum Start with DCM theta = 5° Monitor P/T and beam when shutter opens Adjust WBslits, monitor current Steer beam to slit center if known Monitor DCM temperatures If gap started open, close while monitor DCM T Drive DCM to finite angle, 8-10 keV matching IVU gap Close FE XY slits while monitor all T. Want to stop after T drops on FAM, but before any beam change is noticeable. *Completion: The relevant systems can be observed and controlled, and the heat load is not problematic.*
shifts:	2
DCM – general	Start at 10.8 keV (IVU gap closed) (Radius similar 10-20keV) Tune theta, gap, 2nd xtal for this IVU position Drive DCM to IVU harmonics at fixed gap. Tune and gather information for lookup tables. Confirm acceptable vacuum and cooling with E change Repeat the above for 24 keV and document Repeat the above for 8 keV, 12 keV, 16 keV *Completion: Confidence that we can drive to the desired energy, knowledge of whether it has to be tuned, easy to find documentation (ideally, automated in readable code)*
shifts:	6
DCM – feedback + stability	10.8 keV: Measurements of DCM stability with feedback off. May take ~3 shifts simply for the study. XBPM1 stability measurement XBPM1 spatial calibration Test driving DCM piezo while measuring at XBPM1 Implement simple proportional feedback to XBPM1 Analyze whether it is necessary to make feedback fancier

	24 keV, feedback off: test stability with lower heat load, finer Darwin width on crystals Test high energy feedback operation Spot check feedback at 8, 12, 16 keV
shifts:	10
	Completion: Confidence in the implemented feedback. DCM can be driven to target and left unattended. DCM will not get lost in space if beam is lost.

7.3.3.3 Commissioning the H-V Mirrors

a. Criteria for alignment of H-V Mirrors:
   1. Each mirror can be fully inserted/extracted. Stripe change axis keeps mirror within the beam path. Pitch axis limits were documented by Survey during installation, so after a homing procedure the nominal pitch can be recovered independently from the beam.
   2. Bimorph mirrors have a documented (measured) nominal radius of curvature with voltage off.
   3. Initial beam steering can be done with disregard for focus.
   4. Bimorph voltage matrices are documented from metrology. However, focus depends on curvature of DCM 1st crystal with heat load, which at low energies is estimated only by FEA and must be optimized during commissioning.
   5. Each mirror has four stripes to be characterized.
   6. Nominal incidence angle of each mirror is 0.18° for hard x-rays.

b. Diagnostics useful for beam steering by mirrors:
   1. Fluorescent screen inserted after HFM will simultaneously view unreflected and reflected beam, allowing insertion and pitch positions to be verified.
   2. HFM Pt stripe has photocurrent lead to measure absorbed intensity and enable DCM tuning.
   3. XBPM2 is located after the VFM and VDM.
   4. Both mirror vessels have gap-scan slits before the mirrors.
   5. XBPM3 is located after the mirrors in the upstream part of 12-ID-B-1.

The basic mirror steering requires insertion of a mirror, approximate alignment, finding the beam and refinement of the mirror position, then proceeding to the next mirror. Optimal use of the mirrors at different energies is dependent on DCM heat load and only some of the conceivable operating conditions can be documented during Technical Commissioning. It is necessary during Technical Commissioning to establish an efficient procedure so that new energies encountered during user experiments can be optimized in preparation for their beamtime. Table 4 outlines the top priorities to reach a stopping point with optimization of the mirror system.

Since this process conducts beam to the SSA in 12-ID-B-1, the SSA slit gap and position alignment and calibration will also be accomplished, with a process similar to that of the WB Slits discussed above. At this point, beam can be utilized either in 12-ID-B or 12-ID-C, for the purposes described in Table 4. With reliable beam in the end-stations, photon delivery system commissioning is complete. (Note that the CRL transfocator aperture also requires alignment for beam to 12-ID-C sample.)

Table 4. Outline of commissioning tasks for H-V Mirror system.

Activity		***Desired Steps***
Mirrors – basic		10.8 keV: mirror insertion, detection of reflected and unreflected beam on diagnostics in FOE XBPM2 stability measurement and calibration HFM slit combing to assess profile at zero voltage piezos to nominal voltage for low divergence HFM slit combing at nominal piezo voltage open shutter to hutches: look for beam at GISAXS XBPM3 stability measurement and calibration steer beam using HFM and measure at XBPM3 steer beam using VFM/VDM and measure at XBPM3 Explore gap/offset for VFM/VDM angle min and max Verify vacuum, slit currents, temperatures, etc with beam in B-1 and C focus/defocus mirrors and study XBPM2,3 signals test stability of beam in C on all stripe changes at 0.18°
	shifts:	10 *Completion: Beam is steered to endstation. KPPs can be achieved and documented.*
Mirrors – focus		10.8 keV: measure focus: GISAXS, low divergence mode: beam in C Align C hutch slits Optimize focus at 10.8 keV Energy steps: 12, 16, 20, 24 keV: measure focus explore HFM stripe current at 0.18°, 10.8-24 keV quantify intensity of reflection from each stripe Characterize effect of SSA on beam profile Configuration change: beam in B 10.8 keV: measure focus in B for microfocus mode Optimize focus at 10.8 keV Energy steps: 12, 16, 20, 24 keV: measure focus Characterize effect of SSA on beam profile
	shifts:	12 *Completion: Confidence in operation with good quality beam in 10.8-24 keV range*

7.3.4 Experimental Station and Data Acquisition Commissioning

The essential priority at SMI is to Commission SAXS measurements. Every other technical capability is a variation on SAXS, as follows:

- SAXS: beam scatters from sample into Pilatus 1M in vacuum, low divergence beam
- Time resolved SAXS: fast 1M frame acquisition while sample variable changes
- GI-SAXS: sample oriented to grazing incidence in beam
- SAXS/WAXS: with simultaneous acquisition by the Pilatus 300K-W
- Microbeam SAXS/WAXS: incorporation of CRL micro-focusing
- Tender X-ray SAXS/WAXS: extend energy range to 2.1-4.5 keV for resonant experiments
- Liquid Interfaces: development of appropriate sample handling for liquids in beam

Every extension of SAXS requires the same starting point of beam at the sample position in 12-ID-C. The following sections give some information and outlines regarding the endstation equipment that provides the required capabilities. Our goal is an adequate rather than exhaustive exploration of the many degrees of freedom, and the plan will be customized based on results obtained.

7.3.4.1 Sample positioning

a. The sample positioner is a 13DOF system with double hexapod and rotation stage. An EPICS like command set has been implemented and for best usage needs to be incorporated into a channel access framework.

b. Stages have built in calibration and homing capabilities.

c. Commissioning requires measurement of the system stability and reproducibility without beam using an interferometer system. This implies a measurement of the vibration conditions at SMI.

d. Thermocouples will be used to measure heating of the hexapod motors with realistic duty cycle.

7.3.4.2 SAXS Detector: Pilatus 1M, XYZ mechanics, and beam stop assembly

a. During bench testing without beam, the basic documented features of the detector have been established in air.

b. Tests of the detector in vacuum, implementing EPS controls of the sensor voltage, are prerequisite for usage in the beam.

c. Basic setup of the beam stop assembly to protect the detector is prerequisite for usage in the beam.

d. The 1M will be installed at fixed position and used to measure standard powders, ~10-20 keV.

e. Mechanical test of XYZ motion in air without beam is prerequisite for motions in vacuum and with beam.

f. Detector Z will be driven to minimum and maximum sample-detector distances to establish limits and explore accessible q range for selected hard x-ray energies.

g. Detector XY will be driven to minimum and maximum values to establish limits and explore accessible q range

h. Beam Stop motions will be refined and impact on minimum q range documented.

7.3.4.3 WAXS and MAXS Detectors: Pilatus 300K-W and Rayonix CCD from CFN Partner User

The WAXS detector, housed in the Sample Vacuum Chamber, has a similar but simpler set of commissioning requirements: similar data acquisition, two degrees of freedom on its motion, and no beam stop.

The MAXS detector being supplied to SMI by CFN Partners will be installed outside of NEXT scope and requires some mechanical design for support and vacuum interfacing. Once in place, this CCD detector also requires data acquisition commissioning. Table 5 outlines sample and detector tasks.

Table 5. Outline of commissioning tasks for sample positioner and detectors

Activity	***Desired Steps***
Sample Positioning	Hexapod reproducibility in beam – 13 DOF
shifts:	2
Pilatus 1M – basic	Functional, 10.8 keV @ 8m, low div.: detects x-rays
	Powder pattern tests
	Beamstop alignment
	Characterize clean beam
	Explore threshold settings
	Test 500Hz acquisition
	Test data streaming, visualization and retrieval
	Document beam intensity conversions with different types of measurements
shifts:	8
Pilatus 1M – energy	Repeat tests: 8,12,16,20,24 keV
	Document thresholds and efficiencies
	Test attenuator box and refine – needed for next activities
	SAXS pattern calibration – test with different E
shifts:	4
Beamstop refinement and XYZ mechanics	Stability and usability of photocurrent measurements – test the 3 beamstops
	Automatic lineup routines – develop and test.
	Long Z scan – linearity, run-out. Calibrate a SAXS pattern at different Z and parameterize, 1.6 to 8 m.
	Implement and test a lookup table for SAXS Z
	SAXS XY test: fidelity, compensation tables
	SAXS XY test: SAXS images, calibrations
shifts:	6
GIWAXS – Pilatus 300K-W	Functional, 10.8 keV @ 8m, low div.: detects x-rays
	Powder pattern tests
	Characterize clean beam
	Explore threshold settings
	Test 500Hz acquisition
	Test data streaming, visualization and retrieval
	Document beam intensity conversions with different types of measurements
	Y/theta mechanics calibration
shifts:	8
GIWAXS – Rayonix	Functional, 10.8 keV @ 8m, low div.: detects x-rays
	Powder pattern tests
	Characterize clean beam
	Explore threshold settings
	Test data streaming, visualization and retrieval
	Document beam intensity conversions with different types of measurements
shifts:	6

7.3.4.4 Micro-Focus with CRL Transfocator

The CRL system is located ~ 1.5m upstream of the sample position.

a. The system has five degrees of freedom for positioning, and 12 lens actuators which can be completely extracted, and also can be scanned with high resolution into the beam.
b. There is a differential pumping aperture tube and a set of scatter guard slits between the CRLs and the sample chamber.
c. Vacuum has been maintained in the differential pumping aperture volume with an ion pump. A prerequisite for user operations is to determine how easily vacuum in this volume is recovered when the sample chamber is opened.

Hardware commissioning involves insertion of the lenses, alignment of the assembly, and confirmation of transmitted beam to the sample and detectors.

Characterization involves measurements of the beam size using edge scans, diagnostics, and detectors in the WAXS and SAXS vessels.

Documentation requires validation of equations and lookup tables that are used to determine settings for a desired focus.

Finally, making the best use of the microbeam to map a sample requires development of fly scanning capability. See Table 6.

Table 6. Outline of the high priority tasks for Micro-Focus Commissioning.

Activity		***Desired Steps***
Microfocus at 10.8 keV		Microfocus in B already characterized for 10.8-24 keV. Set up this configuration at 10.8 keV
		Detect beam at GISAXS position, CRLs out
		Scan and align each CRL cartridge
		Move lens/TF to nominal for microfocus
		Measure beam focus
		Document behavior of XBPMs – they need recalibration with every change of beam size!
		Improve with TF positioning
		Scan mirror slits and look for issues
		Investigate algorithms / methods for optimizing mirrors
		Iterate until focus cannot be improved
		Completion: 2.5µm V × 26µm H
	shifts	6
Microfocus 12-24 keV		As above. Document. Populate lookup tables and other code as needed.
		Completion: nominal performance
	shifts	8

Microfocus: Sample positioning		
		Basic – stability of beam and hexapod stages Basic – reproducibility of beam and stages Advanced – centering of rotations, other run-out Step scans with microbeam *Completion: beam can be utilized for experiments without running off sample or going out of calibration*
	shifts	8
Detection with microbeam: SAXS		Characterize the divergence: 10.8 keV Characterize the divergence: 12-24 keV Test powder patterns and explore combination of detector frames with step scans Assess relevance of oversampling Document any changes to response of beamstops *Completion: implications for GU, documentation of findings*
	shifts	8
Detection with microbeam: WAXS		as above for MAXS detector, 10.8-24 keV Pilatus 300K-W: characterize patterns, 10.8-24 keV Pilatus 300K-W: oversampling and resolution, 10.8 keV Pilatus 300K-W: oversampling and resolution, 12-24 keV
	shifts	24
Fly scanning: SAXS or WAXS		tasks tbd – hardware test tasks tbd – controls tasks tbd – detectors tasks tbd – hexapods (very difficult) *Completion: can do a fly-scan with the WAXS goniometer and make sensible use of the Pilatus 300K-W frames acquired. Everything else is tbd*
	shifts	8

7.3.4.5 Tender X-ray Capabilities

Development of capabilities from 2.1-4.5 keV invokes special considerations:

a. Large DCM Bragg angle significantly increases heat load and 1st crystal curvature. All differences between measured and expected curvature will require investigation of optimal mirror focus.

b. For best reflectivity, the mirrors have B_4C coated stripes that are considered experimental by experts in the field. These need to be characterized.

c. Reduction of harmonics by increasing VFM/VDM reflection angles is specified.

Because of the heat on the optics it is possible that much of the photon delivery commissioning steps need to be revisited for the tender x-rays. See Table 7.

Table 7. Outline of the high priority tasks for Tender X-ray Commissioning

Activity	***Desired Steps***
Tender X-rays: DCM	Open IVU gap corresponding to 2.1 keV; scan DCM down from ~ 10keV with stops at each harmonic. At each stop, find the energy with DCM theta and optimize 2nd crystal orientation. Document DCM lookup table. Close gap partway towards fully closed and repeat, to lowest useful harmonic. Fully close gap and repeat, down to 3rd harmonic. Confirm reasonable performance of XBPMs as we work. Beam size will change and XBPM calibration must be determined and documented. *Completion: Confidence that we can drive to the desired energy, knowledge of whether it has to be tuned, easy to find documentation (ideally, automated in readable code)*
shifts:	6
Tender X-rays: Mirrors	Drive to B4C stripes and 0.35° Prepare for low divergence mode Drive DCM and mirrors to 2.1 keV and measure focus Optimize focus at GISAXS Test and improve energy scan Repeat focus measurement and optimization 3.6 keV Repeat at other two resonant energies
shifts:	4
Tender X-rays: Harmonic rejection	Spend a couple shifts making up experiments that measure how much leakage there could be, perhaps by comparing VFM/VDM angles at fixed energy and perhaps by driving DCM to different harmonics
shifts:	2
Tender X-rays: Detectors	Test and characterize Pilatus 1M and beam stops in low divergence mode, noting beam size and divergence, 4 resonant energies Test and characterize Pilatus 300K-W and WAXS goniometer in low divergence mode, noting beam size and divergence, 4 resonant energies
shifts:	4
Tender X-rays: Sample stages	Assess stability and carry out test experiments
shifts:	2
Tender X-rays: microfocus	Work for 6 shifts and assess progress
shifts:	6

7.3.4.6 Liquid Interfaces

More detailed planning is required than is possible at this time due to the engineering and safety evaluations required to implement liquid surfaces into a windowless beamline (or to implement new x-ray windows).

8 REFERENCES

1. NSLSII-12ID-PRC-001, *SMI Beamline (12-ID) Radiation Survey Procedure*
2. PS-C-ASD-PRC-147, *Insertion Device Front End Ray Tracing Procedure*
3. PS-C-CMD-PLN-001, *NSLS-II Process Description: Review Process for Facility Additions and Modifications*
4. PS-C-ESH-PRC-039, *Experiment Safety Review*
5. PS-C-XFD-PRC-003, *Enabling Beamlines for Operations*
6. PS-C-XFD-PRC-004, *NSLS-II Beamlines Radiation Safety Commissioning Plan*
7. PS-C-XFD-PRC-008, *Synchrotron and Bremsstrahlung Ray Trace Procedure*
8. PS-C-XFD-PRC-030, *Beamline User Readiness*
9. Tech Note #228, *12-ID SMI Beamline Radiation Shielding Analysis*

9 APPENDICES

Appendix A, *SMI Beamline Component Layout*

Appendix A: SMI Beamline Component Layout

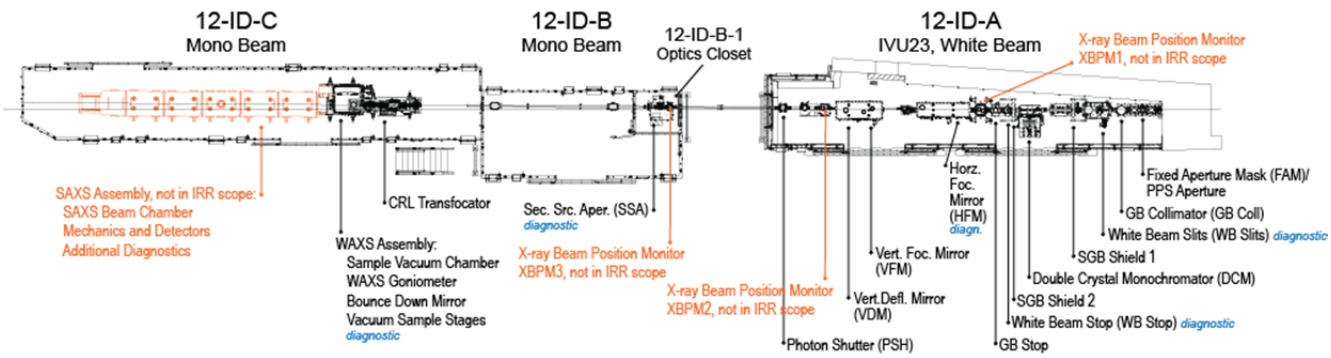

Figure A1. SMI Beamline, Sector 12-ID. Enclosure 12-ID-A: FOE (White Beam). Enclosure 12-ID-B-1: Optics closet. Enclosure 12-ID-B: Diagnostics / Future outboard branch. Enclosure 12-ID-C: GI-SAXS/WAXS experimental station. SAXS Assembly and X-ray Beam Position Monitors depicted in orange are to be constructed within NEXT scope, and will be installed on an ESR following IRR approval.

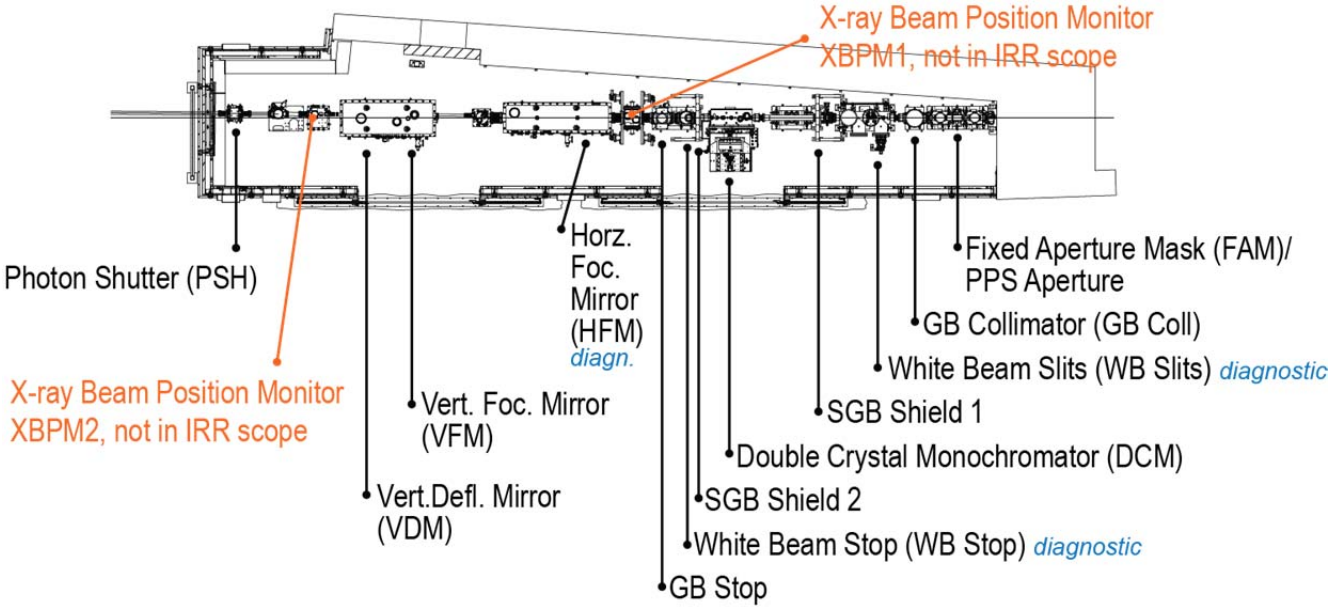

Figure A2. Enclosure 12-ID-A showing principal optical components. Components that incorporate beam diagnostics are labeled in blue. The XBPM diagnostics will be installed upon approval of an ESR to be submitted shortly following IRR approval.

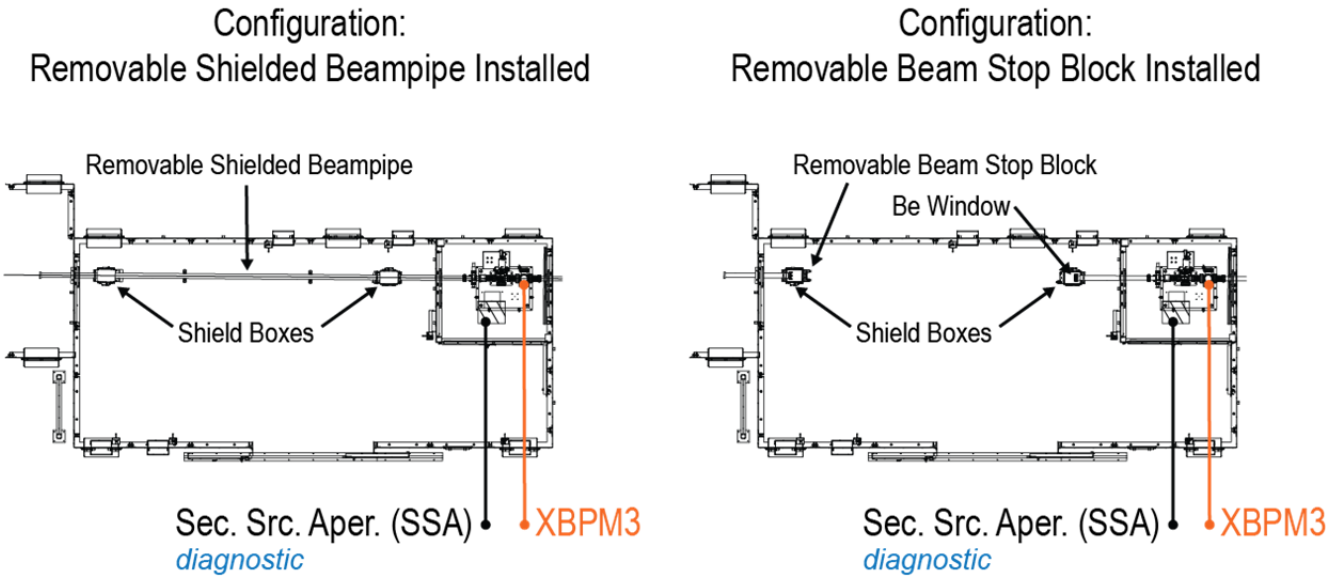

Figure A3. Enclosures 12-ID-B and 12-ID-B-1. The optics closet 12-ID-B-1 contains one principal component that incorporates beam diagnostics. 12-ID-B is shown in two configurations. Left: Removable Shielded Beampipe conducts beam to 12-ID-C for experiments. Right: The Removable Beam Stop Block and Be Window are installed to enable diagnostic measurements in 12-ID-B.

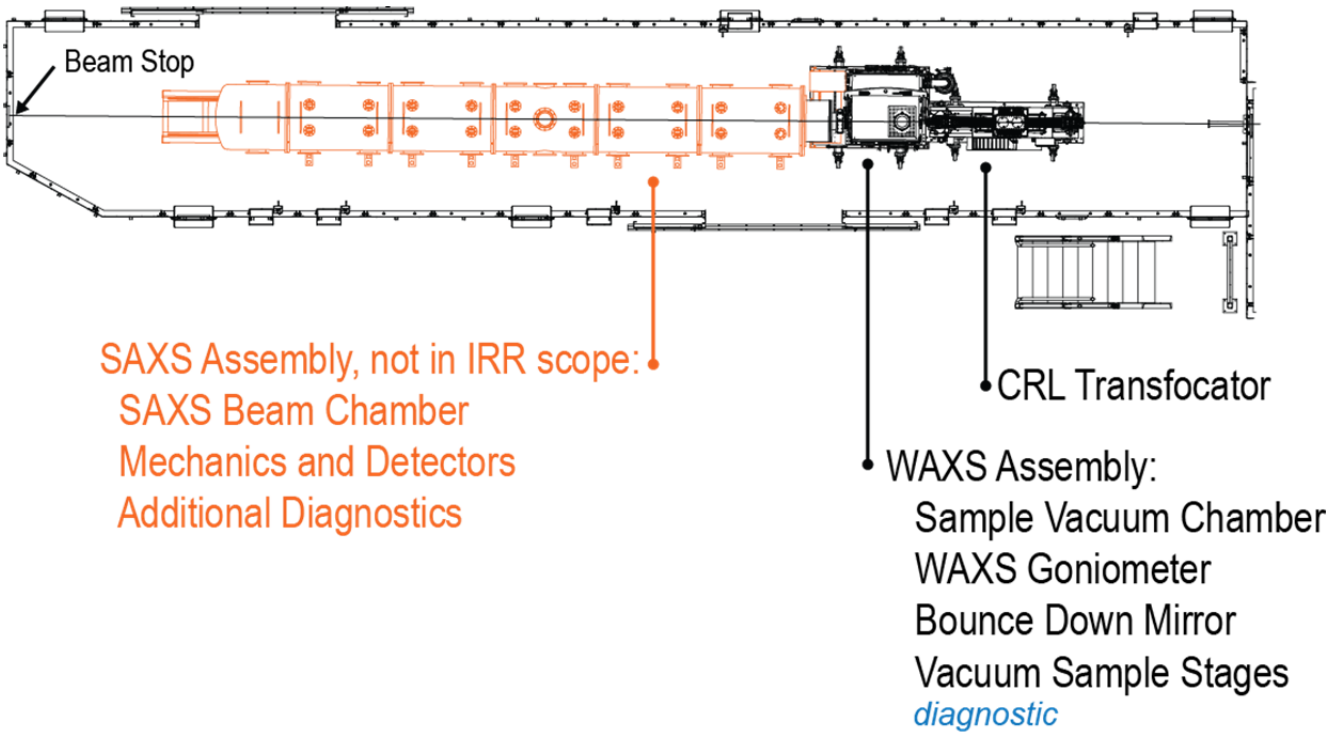

Figure A4. Enclosure 12-ID-C contains the CRL microfocus and GI-SAXS/WAXS assemblies.