NYX Beamline 19-ID
Instrument Readiness Overview

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Instrument Readiness Review November 8-9, 2016

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On behalf of NYSBC Beamline Development Team & BNL IRR Readiness Team

Outline

The Path to CRS → "Rocky Road" to CRS

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- Overview

  IRR Scope, Functional Description, Commissioning

Instrument Readiness Review Procedure PS-C-ESH-PRC-001

- Pillar I: Documentation:

  RSI, Front Ray Trace, Beamline Ray Trace, FLUKA Simulations, RSC Review, RADIATION SURVEY PROCEDURE

- Pillar II: Hardware

  Radiation Containment, Photon Delivery, EPS, Diagnostics

- Pillar III: Personnel

  Beamline Team & Training

IRR Scope

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IRR scope includes:

- Radiation containment & shielding components
- Enclosures 19-ID-A, 19-ID-C & 19-ID-D
- Photon Delivery System
- EPS
- PPS
- Hazard identification and mitigation
- Utilities

IRR scope exclusions:

- Beam Diagnostics (XBPMs, Energy Analyzer)
- Microdiffractometer
- Robotic sample changer
- Pixel Array Detector

Self-identified Pre & Post start Findings

Pre-start findings ”safety significance”:

Documentation incomplete

1. Some drawings are not formally released (includes some safety critical components), just awaiting final signatures / release (deadline: 14th Nov).
2. DRs needed for discrepancies of z-location of several Radiation Shielding components (deadline 14th Nov).

Post-start findings ”no safety significance”:

1. Beam Diagnostic Hardware

   Will be implemented as required for optimization.

Beamline Overview

What is different about NYX?

1) Asymmetric Canting in Low-β Straight
2) 17m White Beam Transport
3) Acceptance Angle of monochromator is matched to ID

19-ID-NYX Overview

- Beamline layout
- Canted Low-β straight section layout
- 19-ID SR Sources
- ID Spectral Flux
- SR power distribution

NYX Microdiffraction Beamline Port 19-ID NSLS-II

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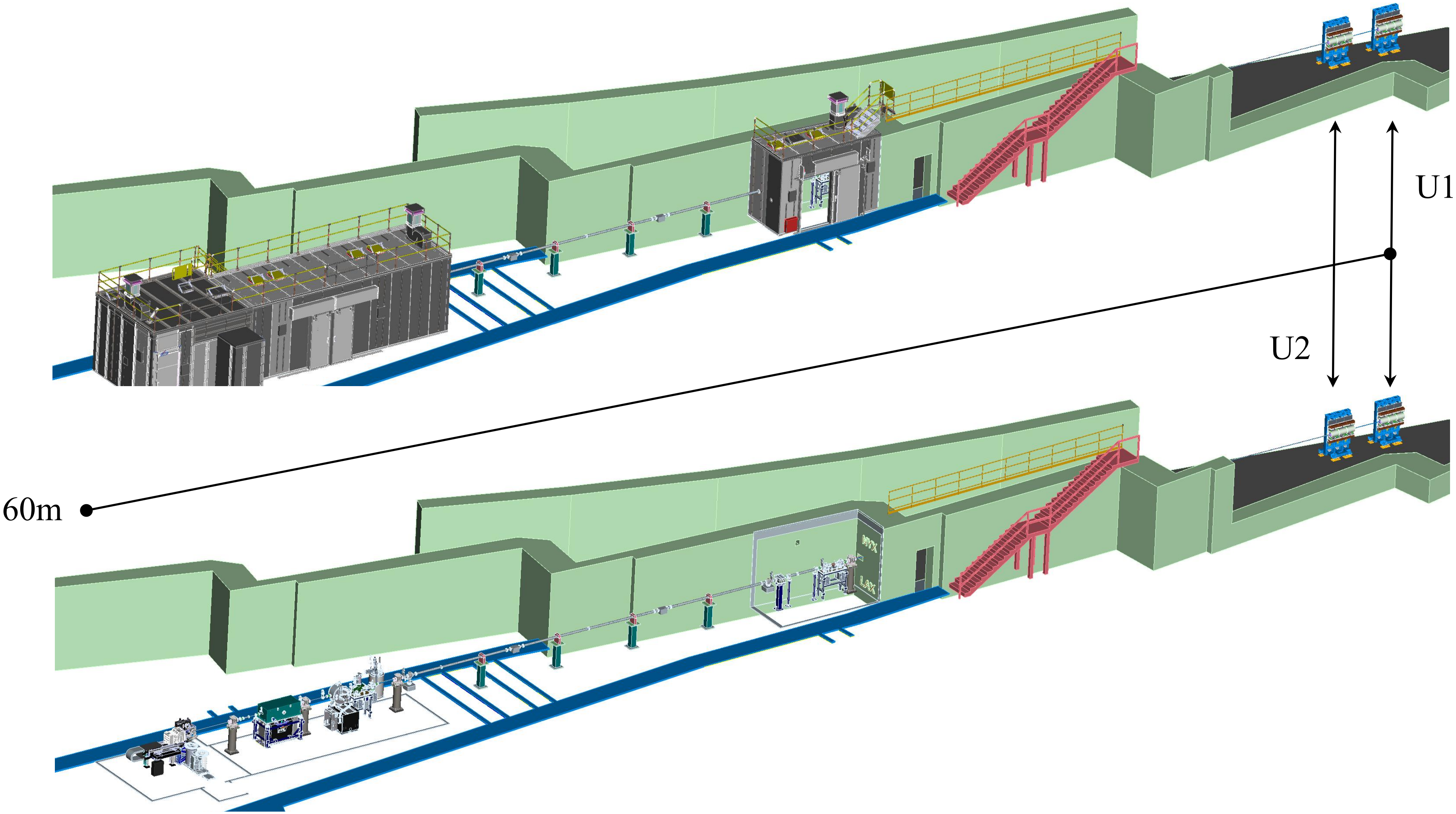

Optimized Low Beta straight section (Future Scope)

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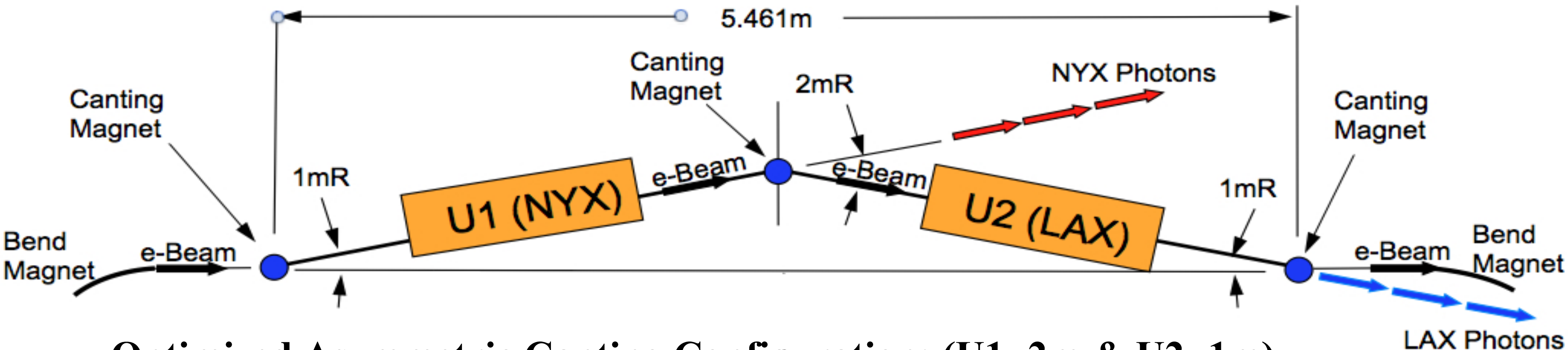
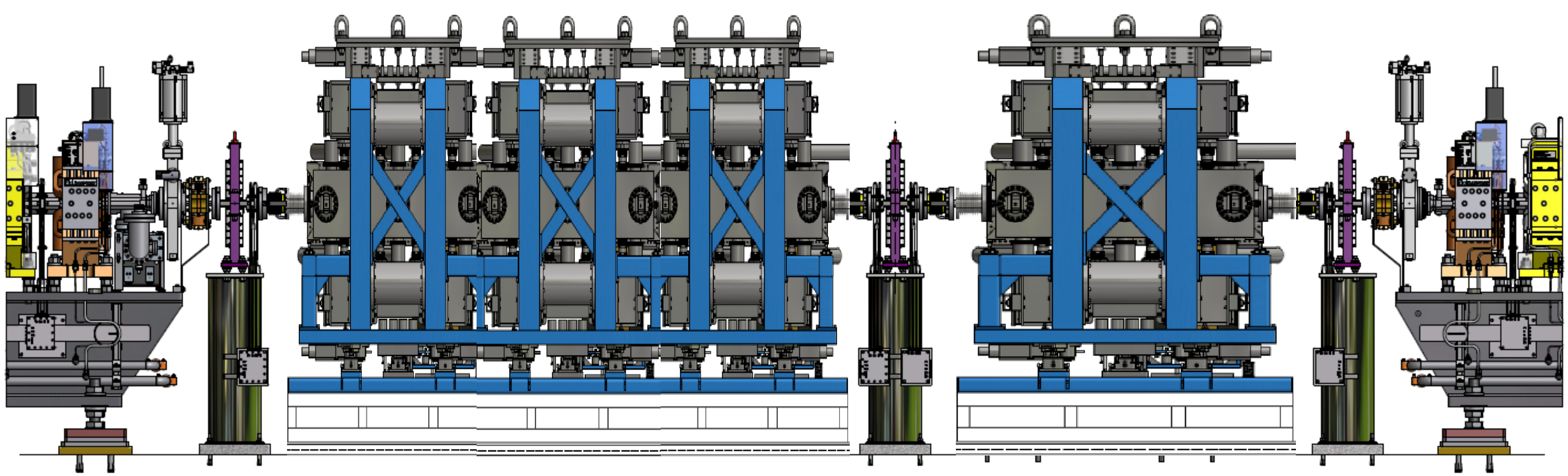
Typical Symmetric Canting Configuration with 2 IVUs:



Optimized Asymmetric Canting Configuration: (U1=2m & U2=1m)



Fully built out straight consistent with RSI (2 meter SAGU & 1 meter LAX)

Optimized IVU Energy Coverage

Companions U1 (NYX) & U2 (LAX)

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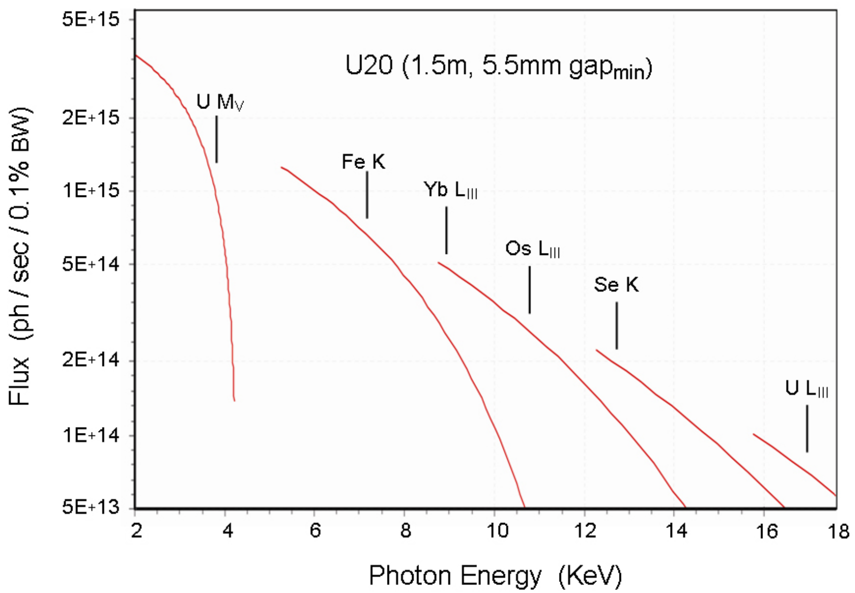
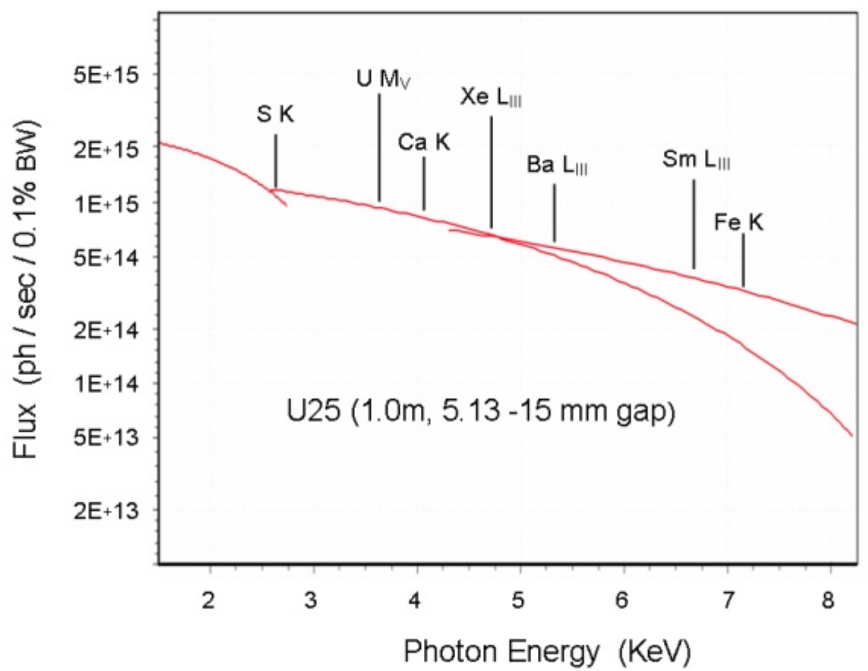


← U1 Tuning Curve Optimized for NYX

4 – 17.5 keV

U2 Tuning Curve Optimized for LAX →

2.1 -5 keV



NYX Startup with X25 in 2m Asymmetric Straight Section

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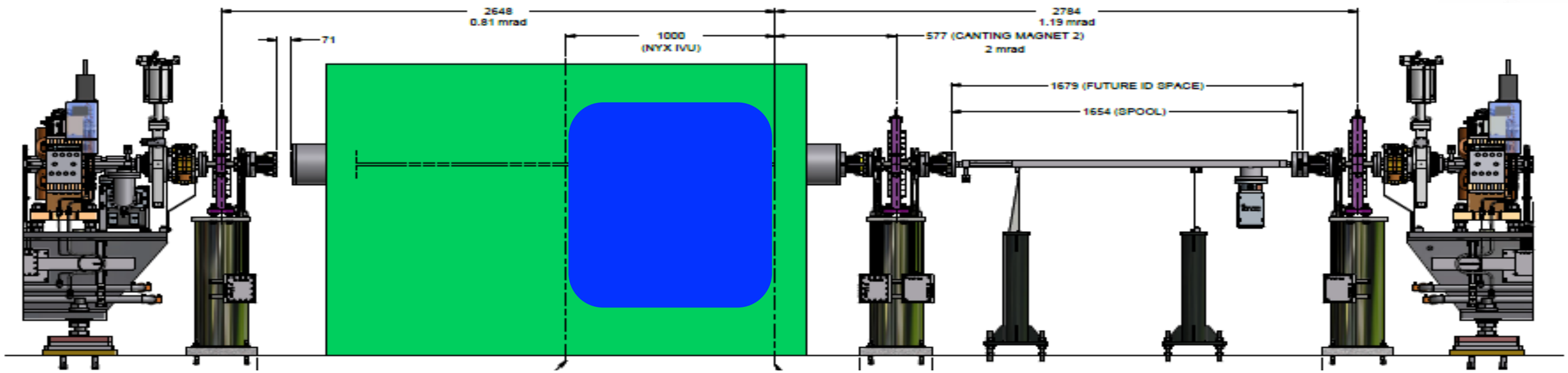
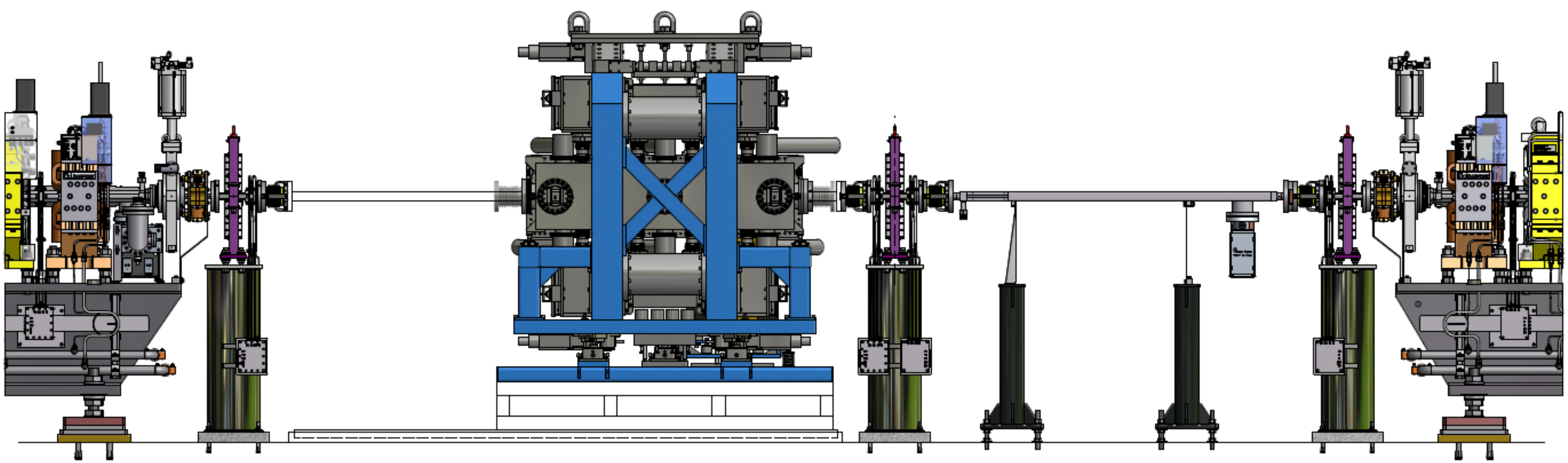


X25 magnetic length in blue SAGU envelope in green



Asymmetric Straight is universal for both X25 & SAGU

X25 & SAGU Comparison to "Standard" IVU (1.5m x 20mm)

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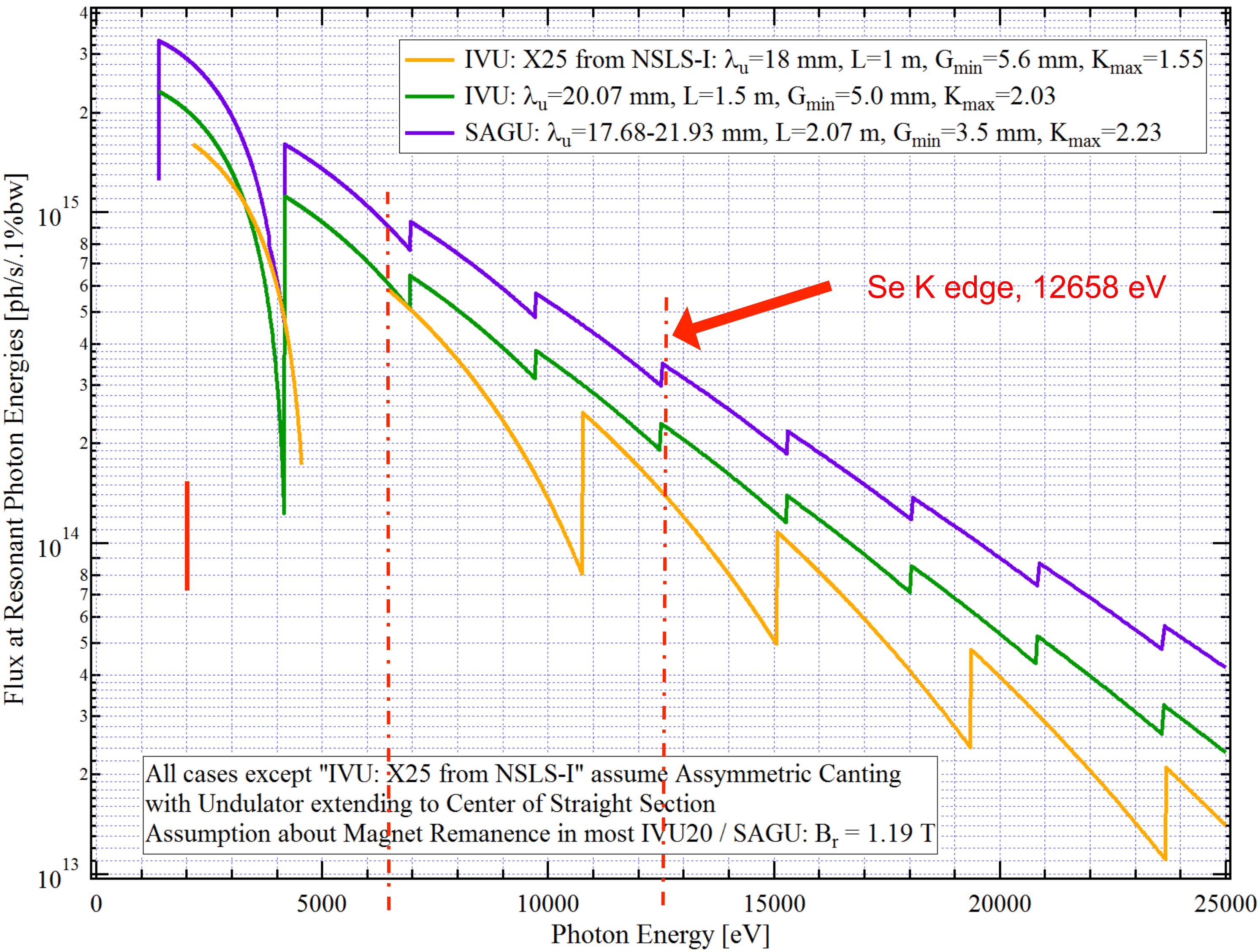

Ref. flux=2.2 x 10^{14} ph/s/0.1%BW @ 12658eV

Estimates provided by Oleg Tchoubar

All 19-ID Beamline Components are Designed for Combined Power of Fully Built-out Straight with SAGU & LAX IVU as Listed in RSI

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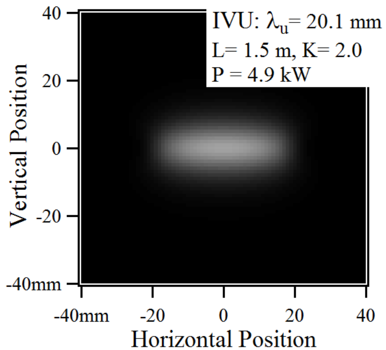
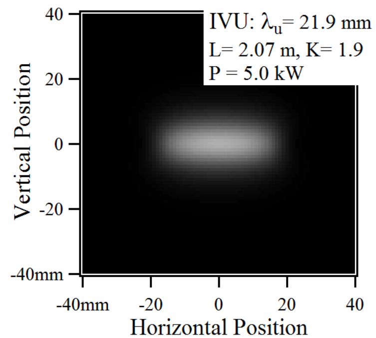
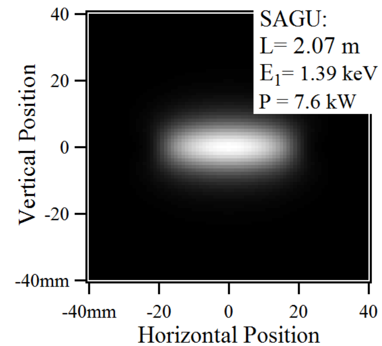
At Mono

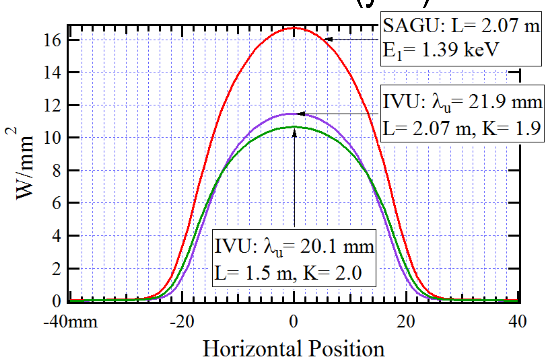
~56 m from Undulator



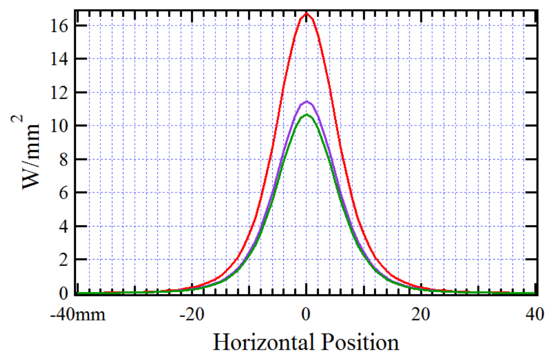




Horizontal Cuts (y=0)

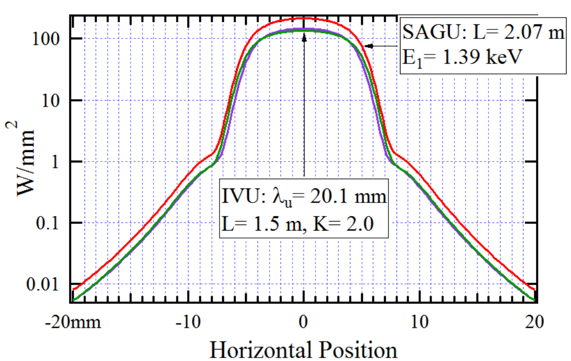


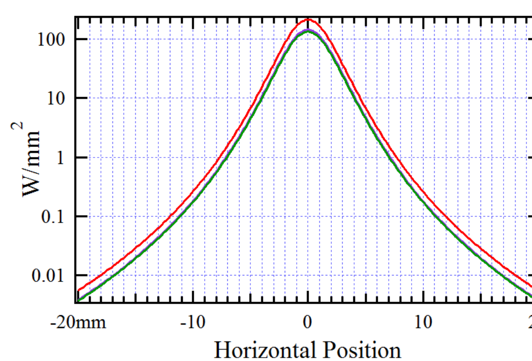
Vertical Cuts (x=0)



At Front-End

~16 m from Undulator Center





Pillar I

Documentation

1) *PA-C-XFD-RSI-NYX-001*
2) *SR-FE-IVU19-1001revB*
3) *S3052 NYSCB ray trace rev 17*
4) *19-ID NYX Beamline Radiation Shielding Analysis*
5) *19ID (NYX) Top-Off Radiation Safety Analysis*
6) NSLSII-19ID-PRC-001

19-ID Insertion Devices (RSI)

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INSERTION DEVICES FOR 19-ID BEAMLINES

Table 3.1: Insertion devices for 19-ID beamlines.

Beamline	NYX	LAX
Type	X25 IVU (SAGU) *4	IVU
Length	1.09 (2.07) m *5	~1 m
Usable photon energy range	6.5 (1.4) – ~20 keV	~3 – 7 keV
Canted	Y (asymmetric)	
Canting angle	2.0 mrad NYX: ~0.81 mrad outwards ring LAX: ~1.19 mrad towards ring	
Period	18 (17.7 – 21.9) mm	~25 mm, TBD
Minimum magnetic gap *1	5.6 (3.5 – 6.3) mm	~6.6 mm
Peak magnetic field	0.95 (~0.98 – 1.43) T	~0.94 T
K_{eff} *2	1.55 (~1.90 – 2.23)	~2.2
Power total	2.43 (~7.6) kW	~2.5 kW
On-axis power density	22.6 (~55) kW/mr²	~16.3 kW/mr²
Straight section type	Short (low beta)	
Lowered horiz. beta desired	N/A	N/A
Device center from lattice centerline	U/S 0.545 (~1.035) m	D/S ~1.68 m
Fan angle *3 (mrad H)	0.75/1.36 (0.91/1.50)	~0.97/~1.57
Fan angle *3 (mrad V)	0.80/1.26 (0.82/1.30)	~0.83/~1.32
Gap scanning and other requirements	Gap scanning speed 30 eV/sec or greater, over usable photon energy range.(?)	

10.1 kW combined

Front End Ray Trace

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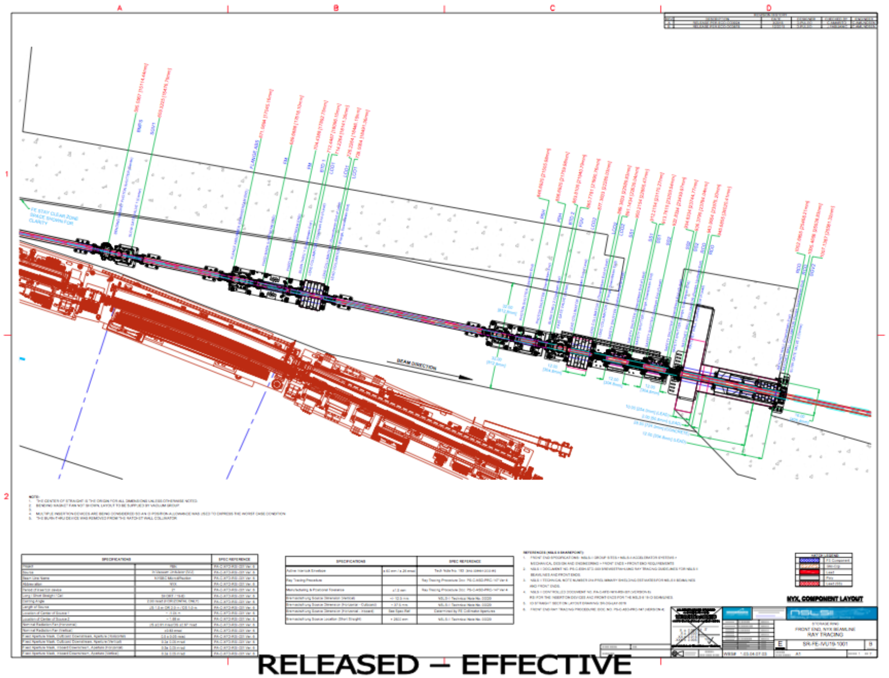

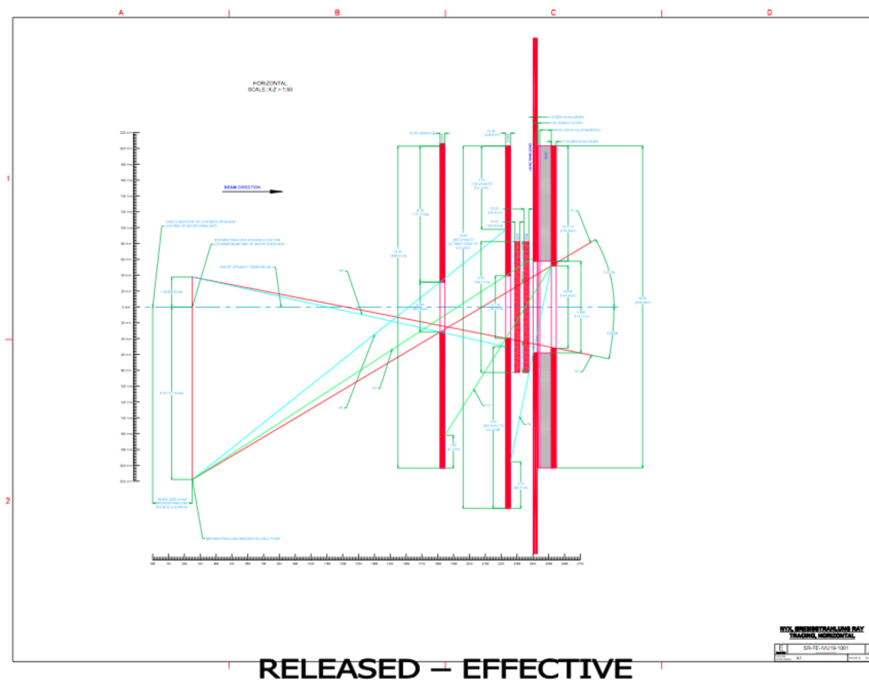

First Optical Enclosure (FOE) shielding requirements are dominated by the scattering of the primary bremsstrahlung and not the synchrotron beam.

Beamline Ray Trace

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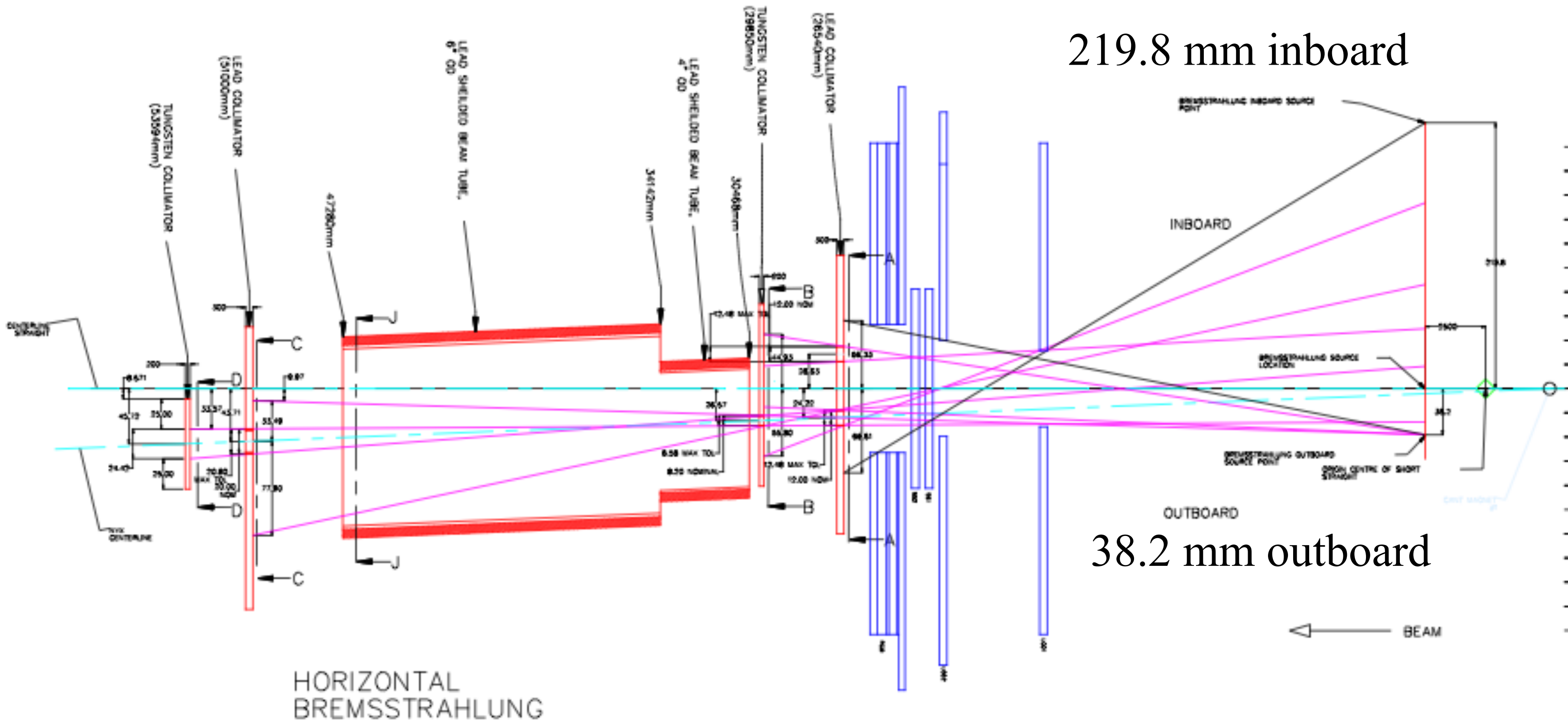

Horizontal Bremsstrahlung

Primary Shielding for Synchrotron Radiation (SR) & Gas Bremsstrahlung (GB)

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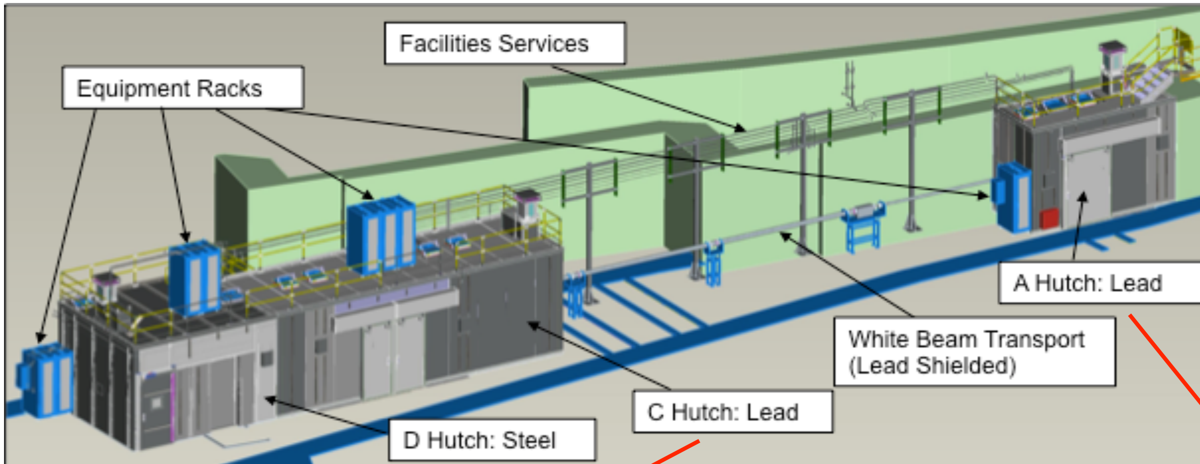
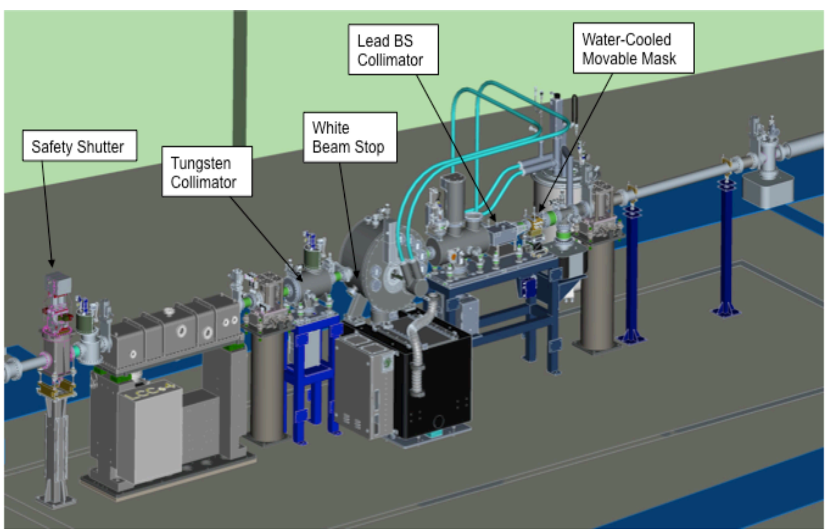
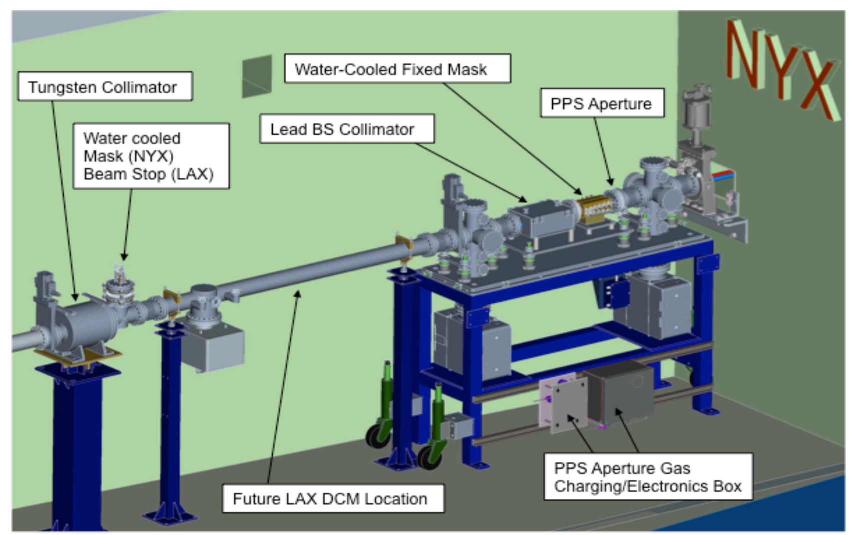


19-ID-C components



19-ID-A components



Secondary (Scattered) Gas Bremsstrahlung (SGB) Shielding Geometry

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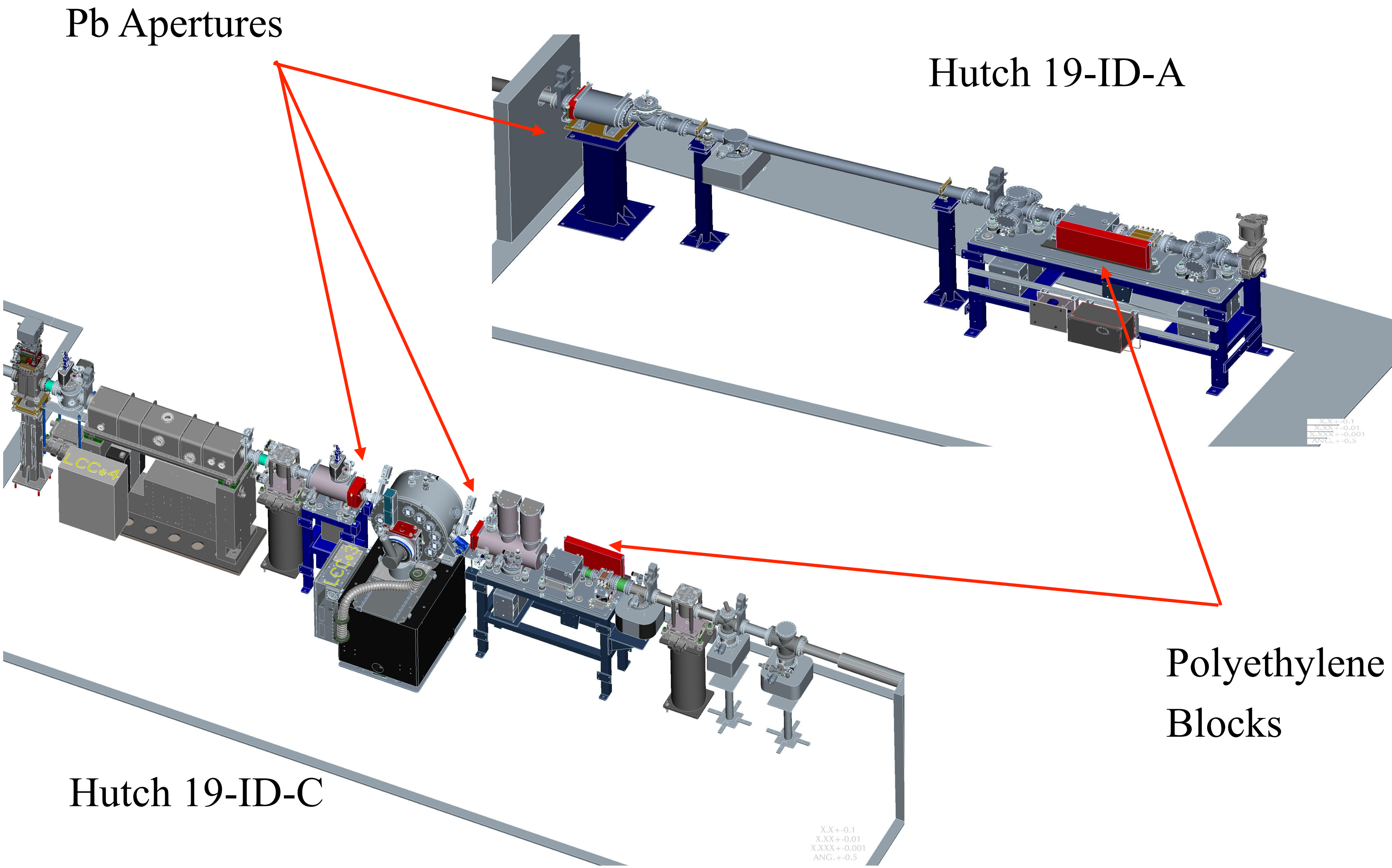

Gas Bremsstrahlung (GB) FLUKA Simulations

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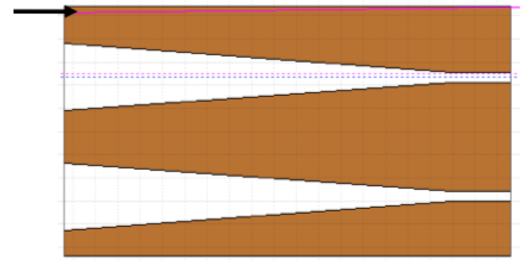
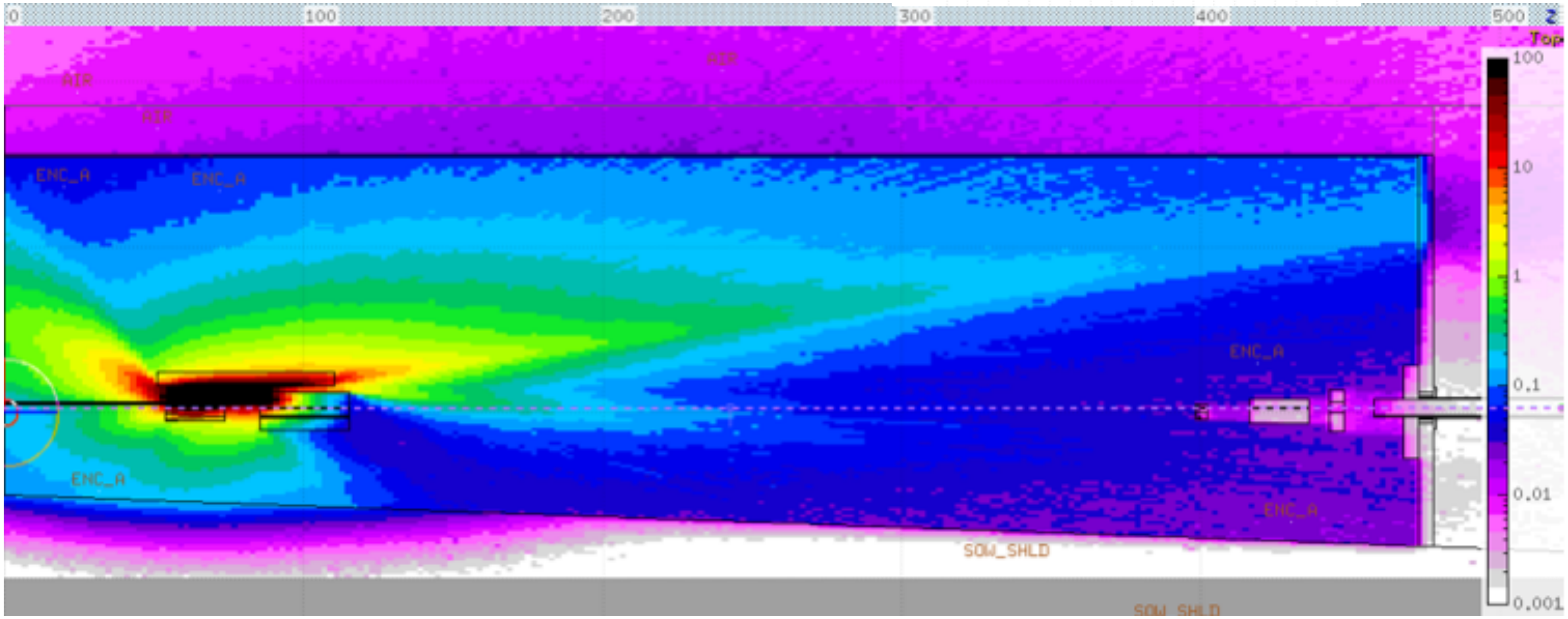
Case 3.1 (d) simulation:

The GB source was placed just upstream of the front face of the dual aperture FM1 in hutch 19-ID-A.





GB in the forward direction resulting in maximum dose rates of approximately 0.15 mrem/h on contact with the downstream wall of FOE. The polyethylene block reduces the SGB in the outboard direction keeping the maximum dose rate below 0.05 mrem/h at 1 ft away from the lateral wall of FOE.

White Beam Transport Shielding Geometry

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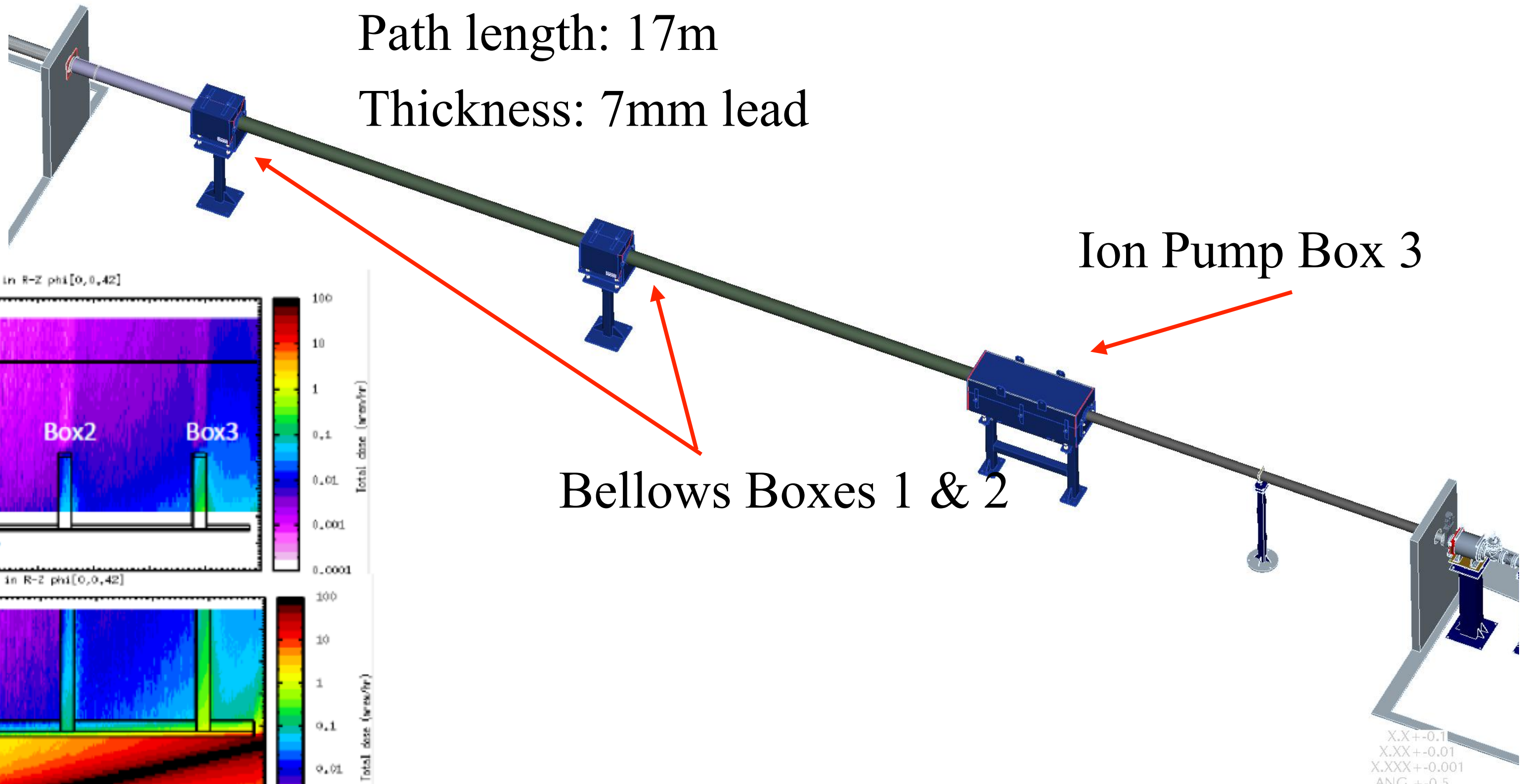

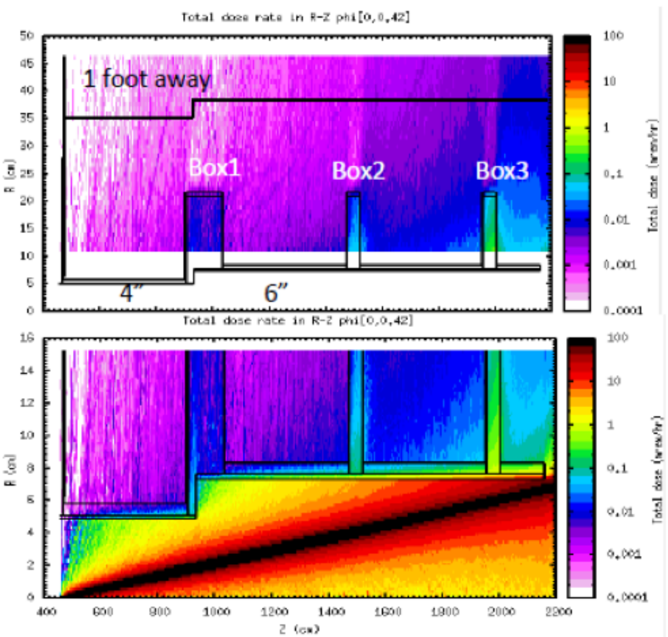

The dose distribution 1 ft away from the beam pipes shown above are well below the 0.05mrem/h allowable limit.

Gas Bremsstrahlung (GB) FLUKA Simulations

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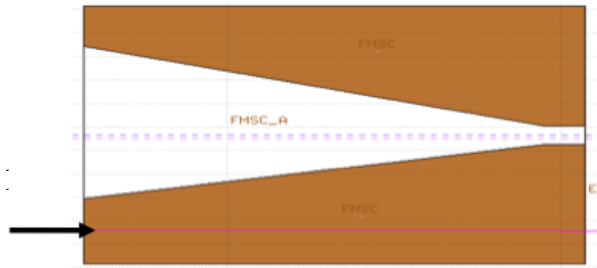
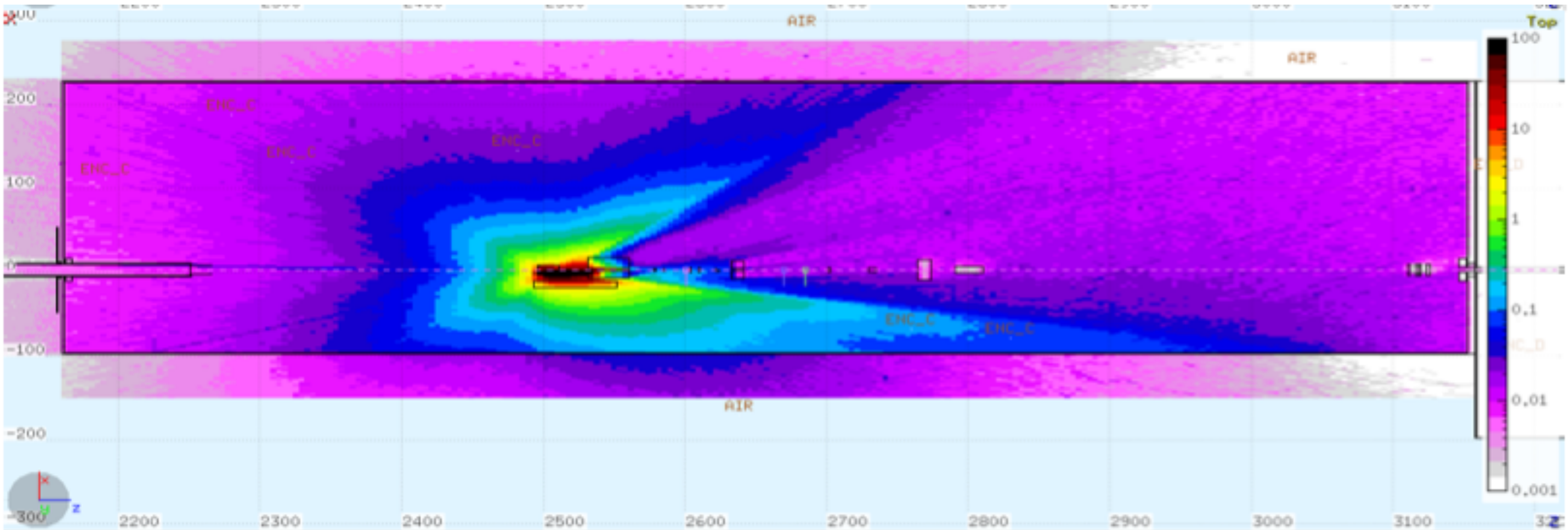
Case 3.3 (b) simulation:

The GB source was placed at the middle point of the inboard front face of the FM3 in hutch 19-ID-C.



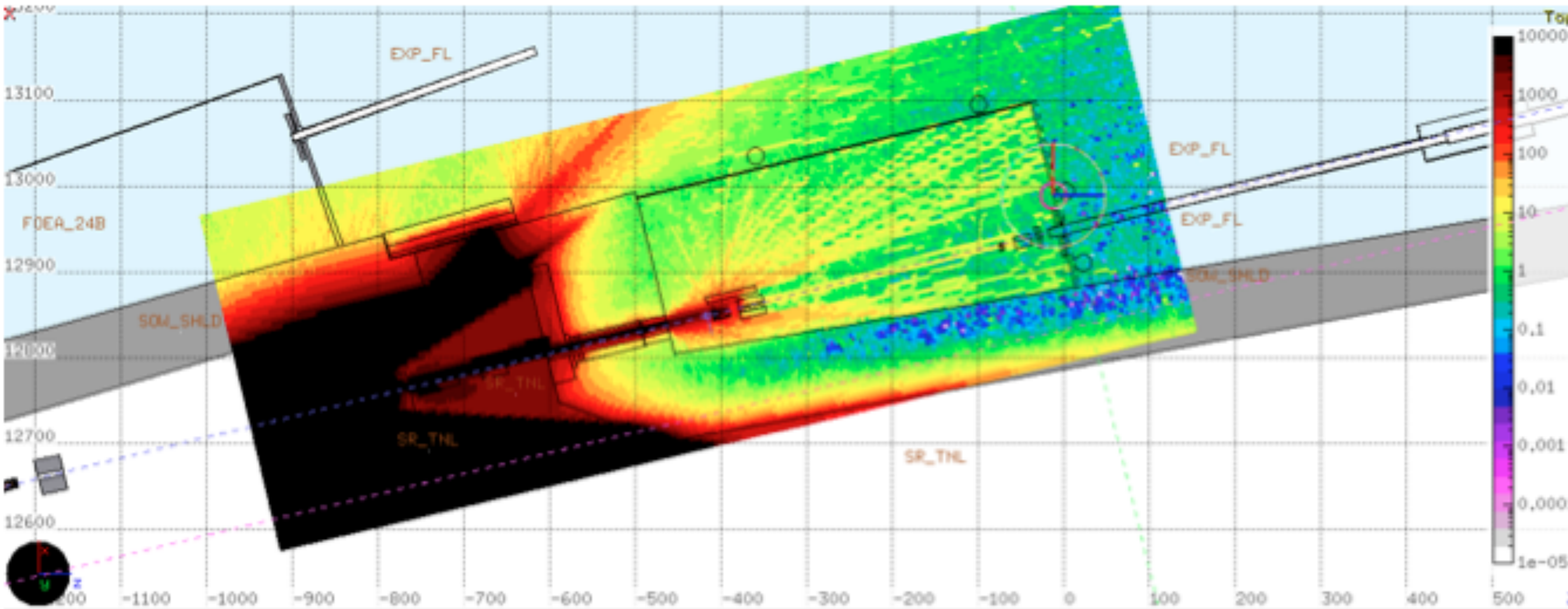


The GB in the forward direction resulting in maximum dose rate below 0.05 mrem/h at 1 ft away from the downstream wall in 19-ID-C-Hutch. The polyethylene block reduces the SGB in the inboard direction keeping the maximum dose rate below 0.05 mrem/h at 1 ft away from the inboard wall.

Results for Top-Off FLUKA Simulations

Case 1: i_i simulation:

Accidental electron beam (45nC) is injected downstream of the horizontal aperture on the inboard side of the FM1 and directed toward the front face of LCO2 at 5 mm from the inboard side of the horizontal aperture.



Dose distributions (mrem/h) in the FE and FOE.

Total dose rates on the roof, sidewall and the downstream wall of the FOE were plotted and found to be below 100 mrem/h.

Summary of FLUKA Shielding Validation

- At NSLS-II the First Optical Enclosure (FOE) shielding requirements are dominated by the scattering of the primary bremsstrahlung and not the synchrotron beam. For the FLUKA simulations the GB beam is normalized at 17µW incident power. This value corresponds to the estimated bremsstrahlung power generated by a 500mA electron beam of 3GeV, assuming that the vacuum in the 15.5 m long straight sections is better than 10E-9 Torr.

- The dose rate1 ft away from the white beam transport pipe is below the 0.05mrem/h allowable limit.

- 19-ID-NYX beamline components that intercept the primary GB beam were selected as scattering targets in the FLUKA simulations and the shielding geometry for 22 cases were evaluated.
  - For all cases the total dose rates on the roof, side wall, and downstream and upstream walls of C-Hutch were all below 0.05 mrem/h at 1 ft away.
  - The total dose rates on the downstream wall of the FOE were below 0.5 mrem/h for all cases.

- *19-ID NYX Top-off Radiation safety Analysis* considers 4 cases for the top-off abnormal beam losses.
  - None of the cases studied resulted in radiation dose rates at the exterior of the FOE greater than 100 mrem/hr.

References:

1. 19-ID NYX Beamline Radiation Shielding Analysis, X. Yang and M. Benmerrouche

2. *19ID (NYX) Top-off radiation safety analysis,* M. Benmerrouche, X. Yang, R. Fliller and Y. Li.

19-ID-NYX Radiation Survey Procedure

Excludes Front-End (Executed Independently)

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NSLS-II 19ID-PRC-001

Comprehensive radiation survey (CRS) at 100mA; will enable NYX to operate with ring current ≤ 300mA.

- GB Radiation Survey: IVU gap open:
  - Integrity 19-ID-A, GB on fixed components
  - White beam transport
  - 19-ID-C GB on movable components (WB Slits, DCM 1st crystal & WBS)
  - 19-ID-D, beamline shutter open & closed.
- Synchrotron Radiation (SR) Survey: IVU gap closed
  - 19-ID-A, white beam on fixed & movable components
  - 19-ID-C white beam on fixed & movable components
- Monochromatic Beam Surveys:
  - 19-ID-C with 1^{st} crystal in nominal configuration.
  - 19-ID-D with 1^{st} crystal in nominal Configuration with beam delivered to screen #4 and IC

PRE-CRS "FIRST LIGHT"

NYX will be enabled to operate with low ring current that is gradually increased current steps (e.g. 3mA, 9mA, 27mA and 81mA).

- The actual current ramp rate for vacuum conditioning will be determine by observation of the evolution of vacuum to EPS avoid trips.
- The temperature of the primary heat loads will be observed as current is increased.
- While equilibrium conditions in vacuum and temperature evolve the SR beam will be propagated through the Photon Delivery System to facilitated the steps outlined in the Radiation Survey Procedure.

Pillar II

Hardware

- Simplified Optical Configuration
- Photon Delivery & Endstation Components
- Component & Power Map
- FEA & Thermal Management
- DCM SR Bandpass
- EPS
- PPS Components

Simplified Optical Configuration for NYX

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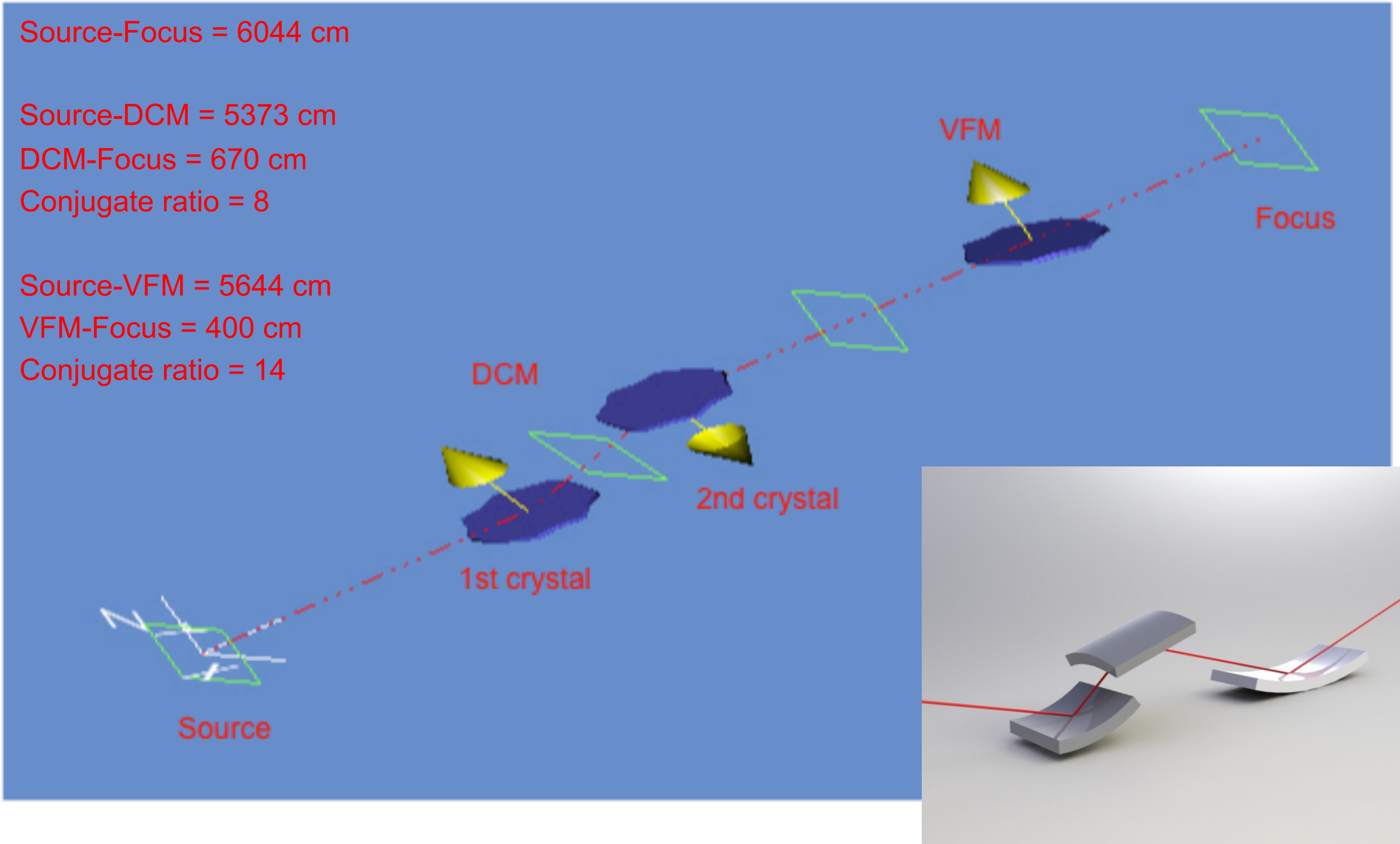

19-ID-NYX PHOTON DELIVERY COMPONENTS

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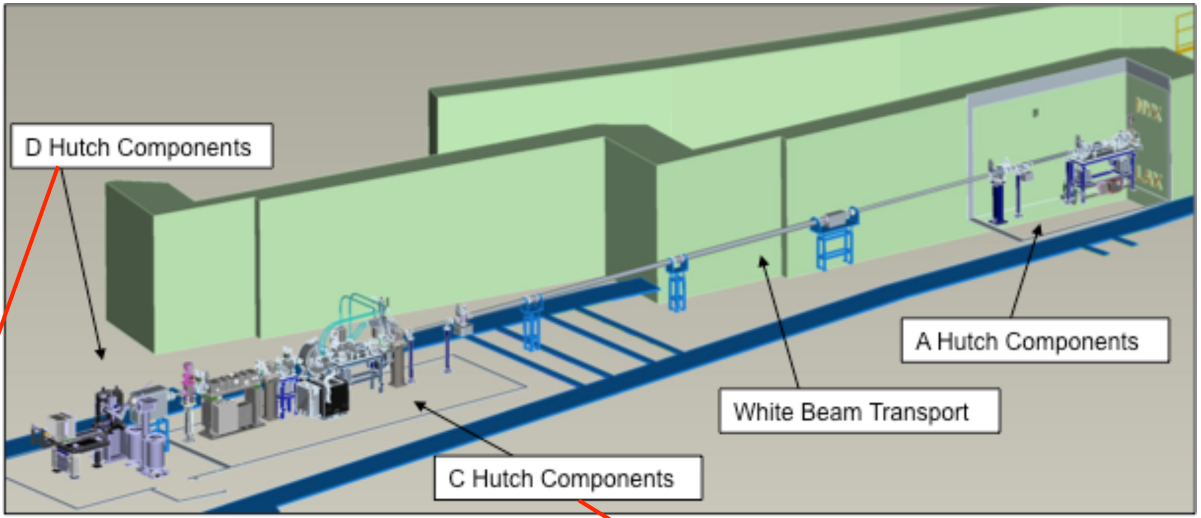

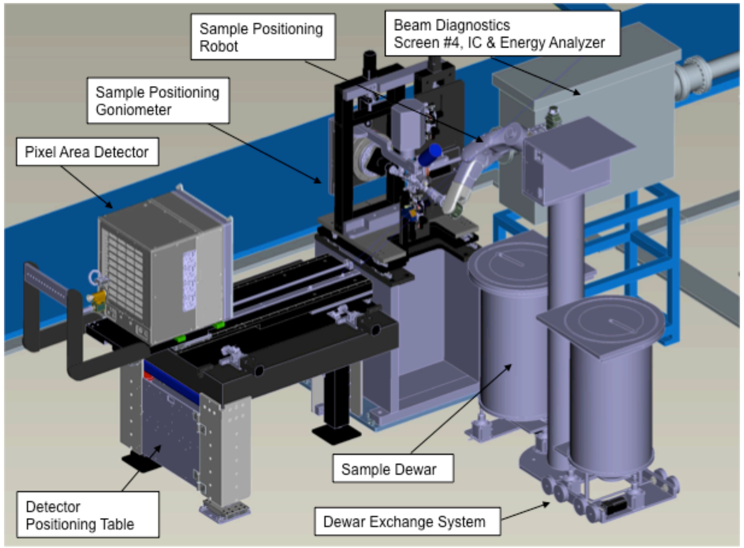

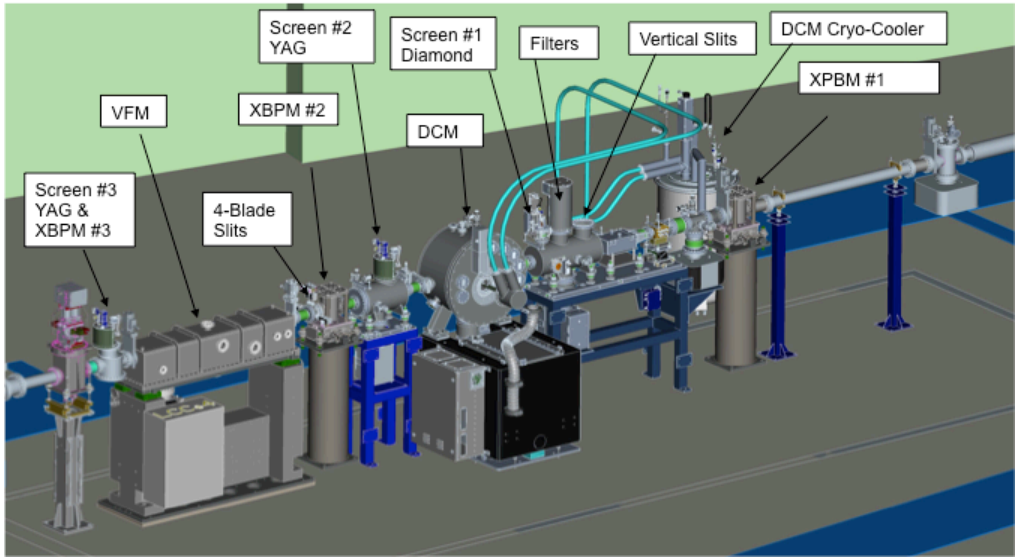

Layout of the 19-ID-NYX beamline components

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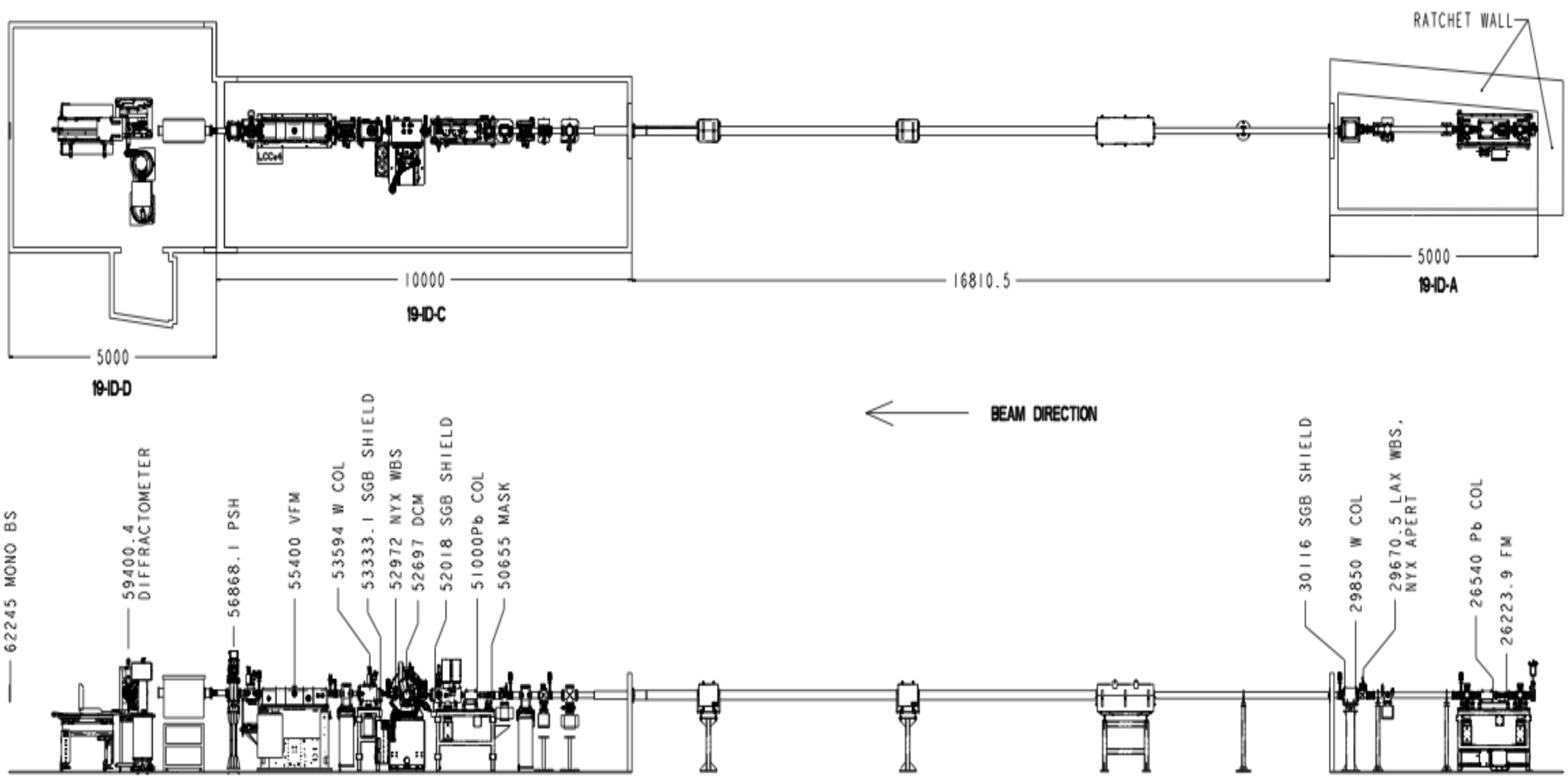

Component & Power Map

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19-ID Component Map

Position	Beamline Component	Acceptance Angle	Combined Power Upstream	Combined Power Downstream	Power Absorbed
mm		*mrad²*	*kW*	*kW*	*kW*
-545	Center of Source IVU				
0	Center of Straight				
17893	Fixed Mask-Front End (water cooled) NYX	0.142			
17893	Fixed Mask-Front End (water cooled) LAX	0.122	10.100	9.590	0.510
------------------------	Ratchet Wall				
26224	Fixed Mask (water cooled) NYX	0.013			
26224	Fixed Mask (water cooled) LAX	0.013	9.590	0.908	8.682
26540	Lead Collimator				
29670	NYX Fixed Mask & LAX Beamstop (water cooled)	0.016	0.908	0.700	0.208
29850	Tungsten Collimator				
30116	Lead Shield (SGBS-1)				
------------------------	Downstream Hutch Wall 19-ID-A				
	White Beam Transport				
------------------------	Upstream Hutch Wall 19-ID-C				
49840	XBPM #1 DN160				
50655	Movable Mask (water cooled) on ± 1mm Center	0.012	0.700	0.659	0.042
51000	BS Collimator (Lead)				
51465	Vertical Slit-upper (water cooled)				
51535	Vertical Slit-lower (water cooled)				
51711	Filters # 1-4 (water cooled)		0.659	0.350	0.309
51782	Filters # 5-8 (water cooled)		0.350	0.350	0.000
51919	Screen #1 Diamond (water cooled) DN63				
52018	Lead Shield (SGBS-2)				
52697	DCM (cryo-cooled)	0.012	0.350	3.498E-05	0.350
52972	White Beam Stop (water cooled)				
53333	Lead Shield (SGBS-3)				
53550	Screen #2 (YAG) DN160				
53594	Tungsten Collimator				
54152	XBPM #2 DN160				
54283	4-Jaw Slits				
55400	VFM				
56414	XBPM #3 DN160				
56461	Screen #3 (YAG) DN160				
56868	Photon Shutter				
------------------------	Downstream Hutch Wall 19-ID-C				
57413	Beryllium Window #1				
57818	Energy Analyzer				
58068	Ion Chamber				
58318	Screen #4 (Phosphor)				
58838	Beryllium Window #2				
59400	Microdiffractometer (goniometer)				
60400	Pixel Array Detector				
62245	Beam Stop - Downstream Wall				
------------------------	Downstream Hutch Wall 19-ID-D				

Worst Case Scenario Heat Load FM1

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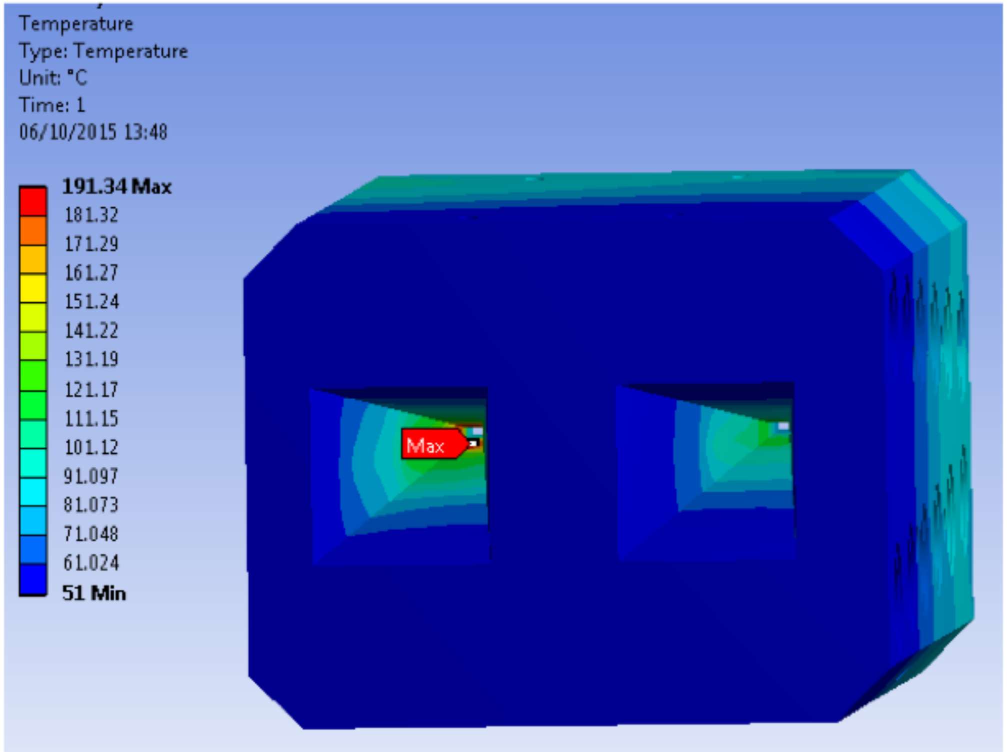

Aperture size is 4.3 mm (H) × 2.2 mm (V) and limits the maximum combined downstream power to ~908 watts.

When Glidcop mask @ 26224 mm absorbs 9820 W, the maximum temperature reached by the mask is 191.34℃. This is well below the maximum temperature <300℃ design criteria for Glidcop AL-15.

Component	Nominal Flow rate [l/min]	Minimum Flow rate [l/min]
Glidcop Fixed Double aperture mask	6	4
Copper White beams stop and aperture	4	3
Copper Moveable mask	3	2
Glidcop White beam stop	3	2

DCM 1st Cryo-cooled Crystal Bender Design Criteria

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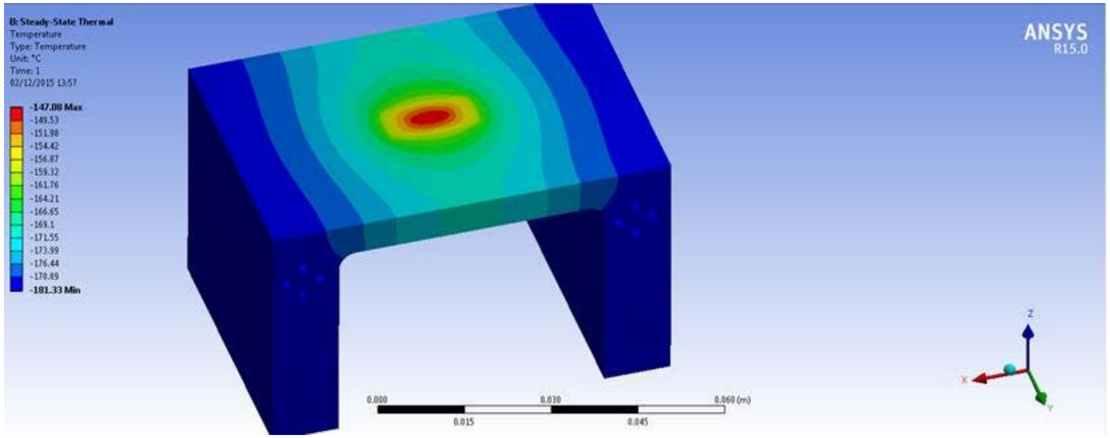


FMB-Oxford FEA:

incident power: 336 watts

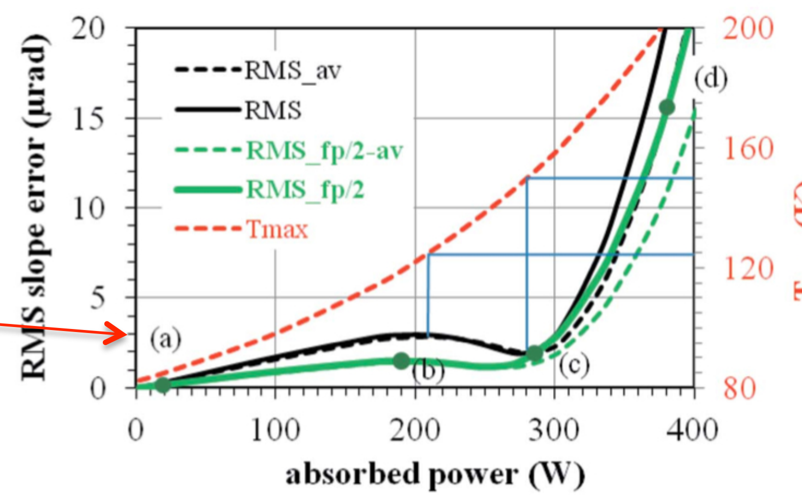
T_{min} = -181°C (92°K)

T_{max} = -148°C (125°K)

Zhang, L., Sánchez del Río, M., Monaco, G., Detlefs, C., Roth, T., Chumakov, A. I., & Glatzel, P. (2013). **Thermal deformation of cryogenically cooled silicon crystals under intense X-ray beams: measurement and finite-element predictions of the surface shape.** *Journal of Synchrotron Radiation, 20(Pt 4), 567–580.*

Local maximum thermal contraction at 125°K results in a concave shape with radius ≈ 200m

3μrad slope error degrades ΔE/E 5% (6.276E-5)



Monochromator SR Bandpass

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ASC Si(111) Monochromator Parameters at Selected Relevant Energies (SAGU)

Energy (eV) harmonic #	Source $2\sigma'_x{}^{overall}$ (μrad)	Si(111) Darwin Width α=0 (μrad)	Si(111) Darwin Width α=6° (μrad)	Energy Resolution Si(111), α=0 flat (ΔE/E)	Energy Resolution Si(111), α=0 flat (ΔE)	Energy Resolution Si(111), α=6° bent (ΔE/E)	Energy Resolution Si(111), α=6° bent (ΔE)	Flux (ph/s/0.1%)
4000 H1	53	77.47	64.26	1.65×10^{-4}	0.66	1.130×10^{-4}	0.45	1.0×10^{15}
12658 H7	43	21.00	9.46	3.05×10^{-4}	3.86	5.983×10^{-5}	0.76	3.5×10^{14}
17500 H9	35	15.14	2.98	3.35×10^{-4}	5.87	2.617×10^{-5}	0.46	1.7×10^{14}

Si(111) high order reflections (3^{rd},5^{th},7^{th} harmonics) @ Theta = 6.487 deg.

17,500 eV (111) Darwin Width=1.47E-5 rad, source 3.5E-6

52,500 eV (333) Darwin Width=1.02E-6 rad

87,500 eV (555) Darwin Width=2.13E-7 rad

122,500 eV (777) Darwin Width=6.62E-8 rad

Equipment Protection System (EPS)

19-ID Vacuum

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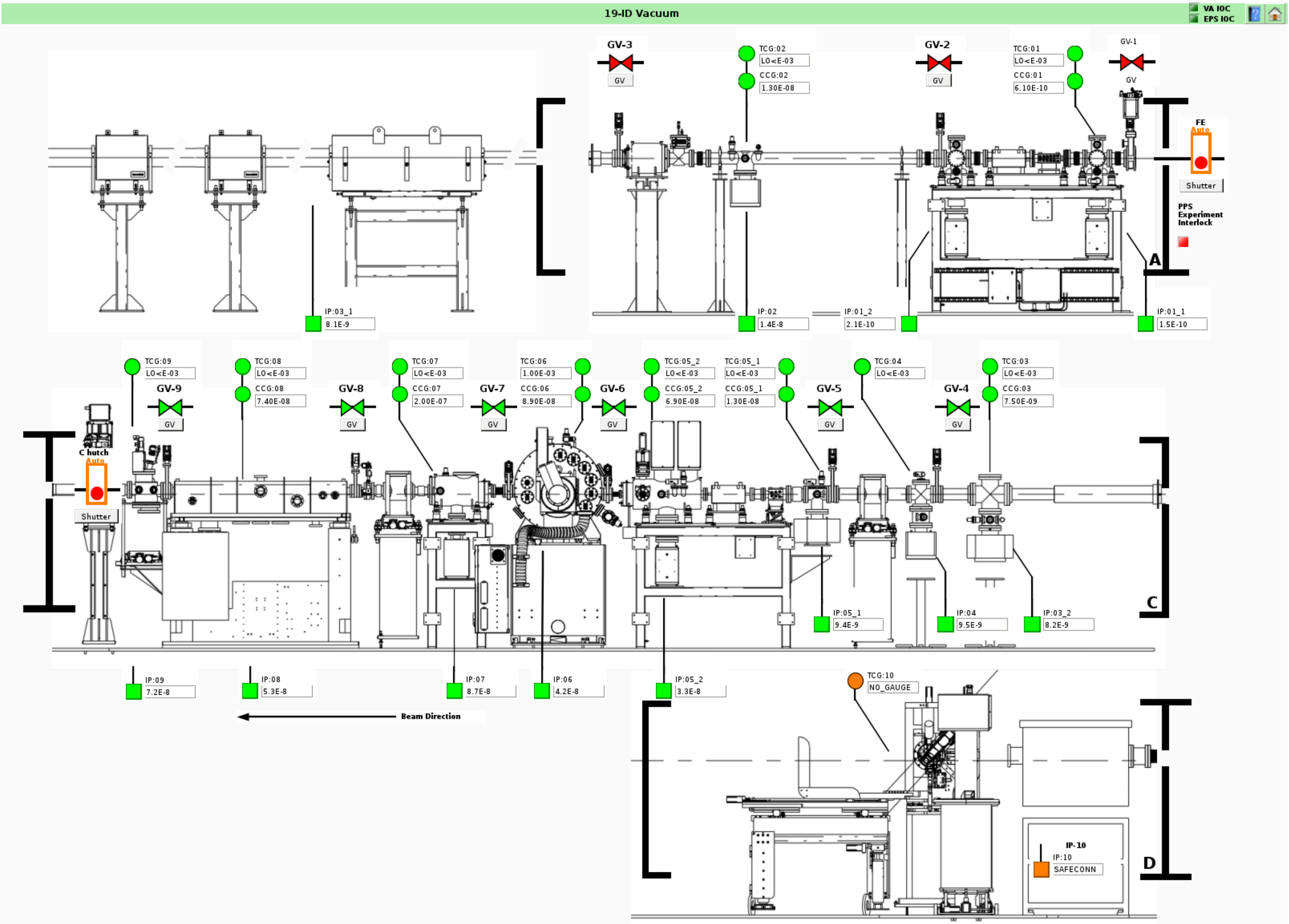
Control System Studio (CSS) Screen



Equipment Protection System (EPS)

19-ID Thermal Management

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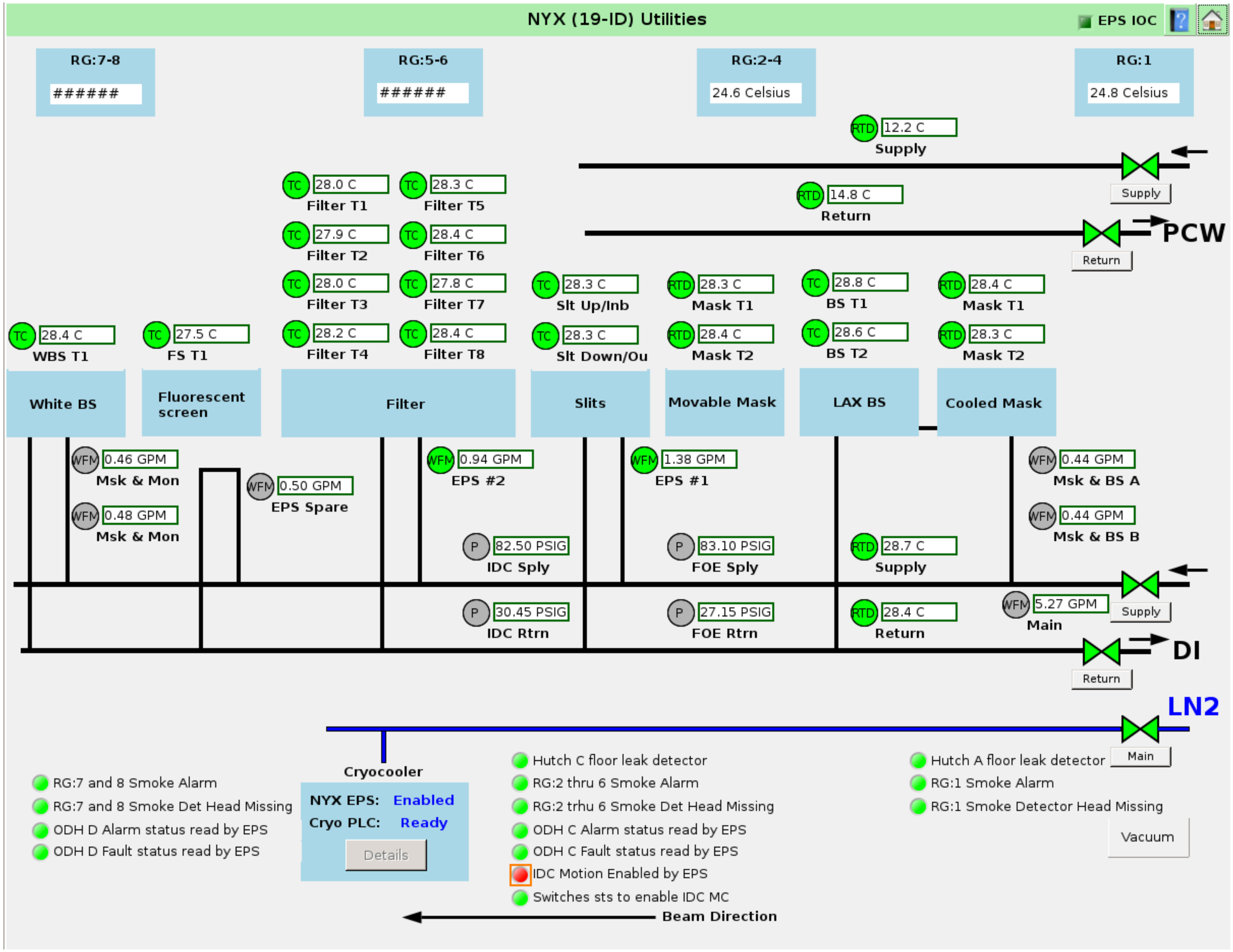
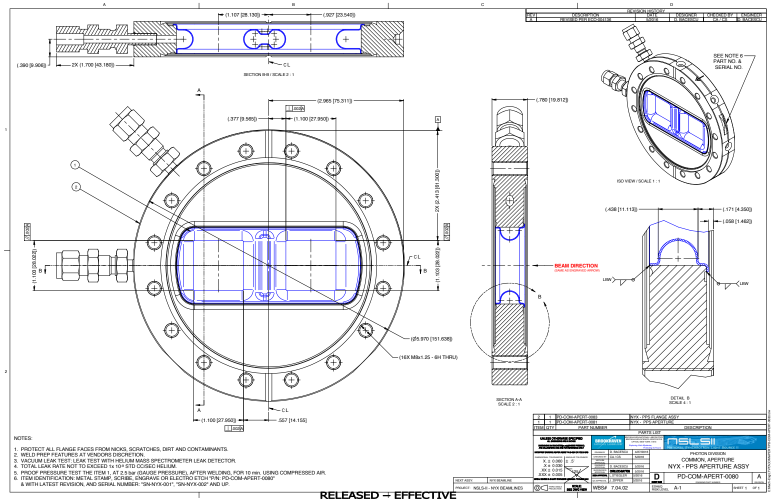
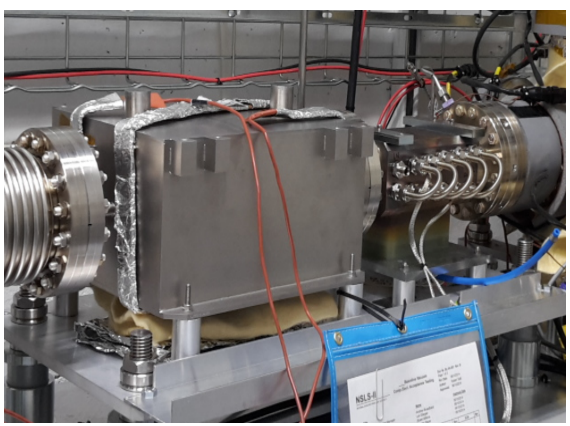
Control System Studio (CSS) Screen

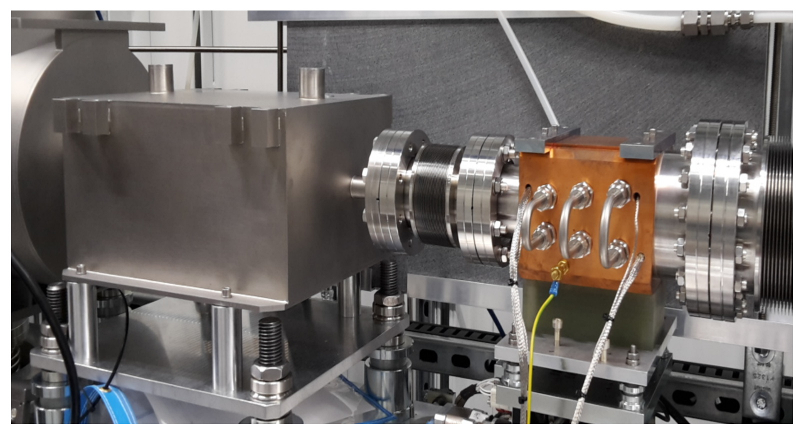


PPS Components



PPS Aperture located before FM1.
27.950 mm (H) × 28.022 mm (V)





Examples of radiation safety components under configuration control. (Left) Pb collimator & water cooled-mask in the 19-ID-A hutch. (Right) Pb collimator & water-cooled mask in the 19-ID-C hutch.

Hazard Identification and Mitigation

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Radiation Hazard:

Containment & Shielding provided.

Area Radiation Monitor (ARM) installed.

Oxygen Deficiency Hazard:

Oxygen sensor installed on 19_ID to monitor potential oxygen deficiency.

- Lead shielding painted.
- Beryllium windows documented.
- Burst discs install on vessels containing cooling loops.
- Electrical bonding according to NEC.

Pillar III

Personnel & Training

NYX Beamline Staff

Lead Beamline Scientist

Joseph Lidestri

Authorized Beamline Staff

Doug Holmes	Mechanical Engineer
Seetharaman Jayaraman	Beamline Scientist
Randy Abramowitz	Engineering Technologist

Supporting Beamline Staff

Xiaochun Yang	Software Engineer
Dave Cook	Controls Engineer

"Sufficient staff training to commission beamline"

Bruce Lein (SHSD) as of 11/8/16 (Caveat – Never Ends)

Summary

NYSBC

- 19-ID hardware and personnel is ready for 1st Light documentation will be closed out Nov14

- Endstation installation is complete however is not part of the IRR. Activities associated with the endstation will proceed in accordance with Experiment Safety Review (PS-C-ESH-PRC-039).

- Commissioning Sequence:
  1) Initial Radiation Survey Nov 26 & 27 (4-12 shifts)
  2) CRS as early as Nov 27
  3) Post-CRS Commissioning

  (Photon Delivery Optimization, Endstation Commissioning with SR, Scientific Commissioning)