NSLS-II Front Ends

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Front End Discussion Overview

- Purpose of the Front End
- Typical location and layout configurations
- Beam Fans - synchrotron (nominal and interlocked)
- Components for managing the synchrotron fan power and NSLS-II innovative designs
- Credited control components
- Beam Fans - synchrotron maximum and bremsstrahlung radiation
- Components for managing the bremsstrahlung fan radiation and innovative Designs

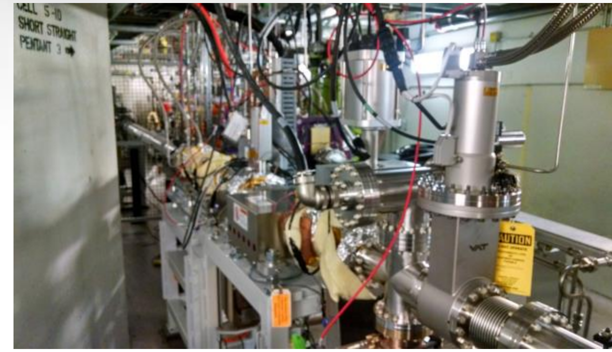
Purpose of Front End

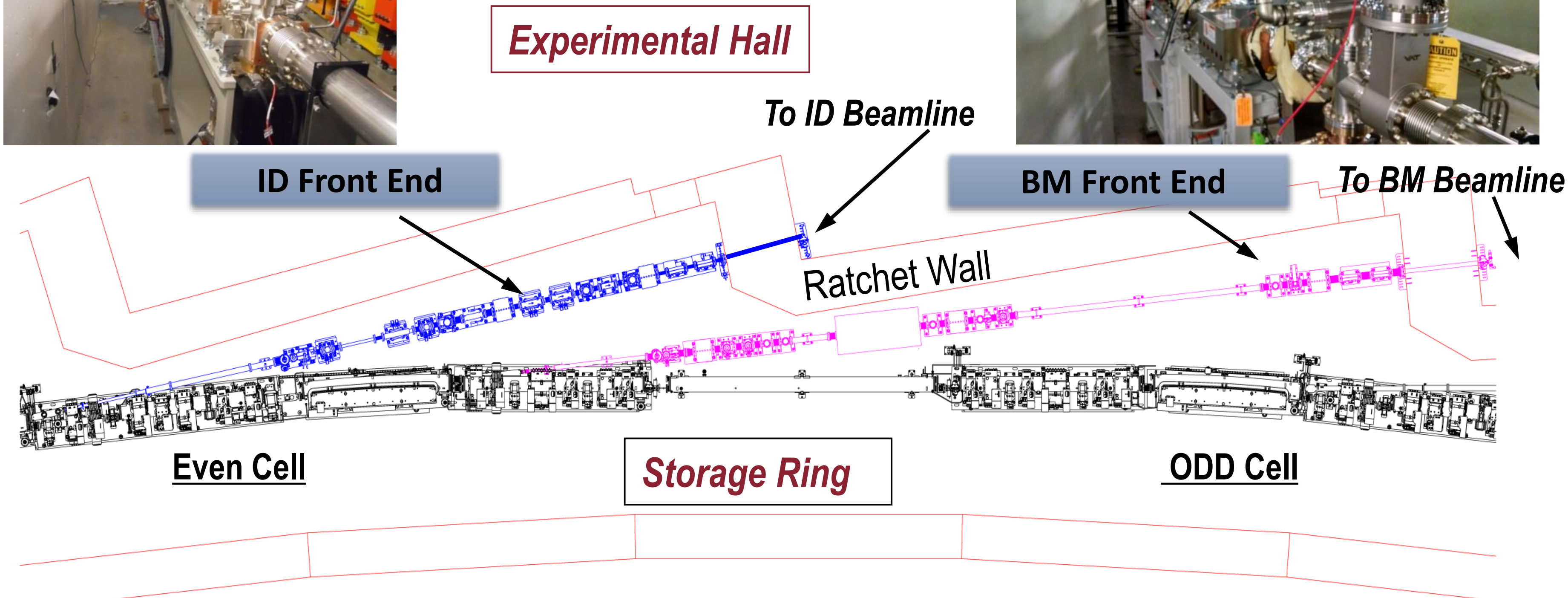
- Transports the beam, from the Insertion Device source, through the ratchet wall, and delivers it to the First Optical Enclosure.

- Controls the sizes of both the synchrotron and bremsstrahlung radiation fans, by collimating beam and absorbing power.

- Ensures safety of personnel for entrance into the FOE - safely blocks beam from the Storage Ring with shutters, which absorbs the full power of beam and attenuates the Bremsstrahlung (braking radiation).

Typical Location

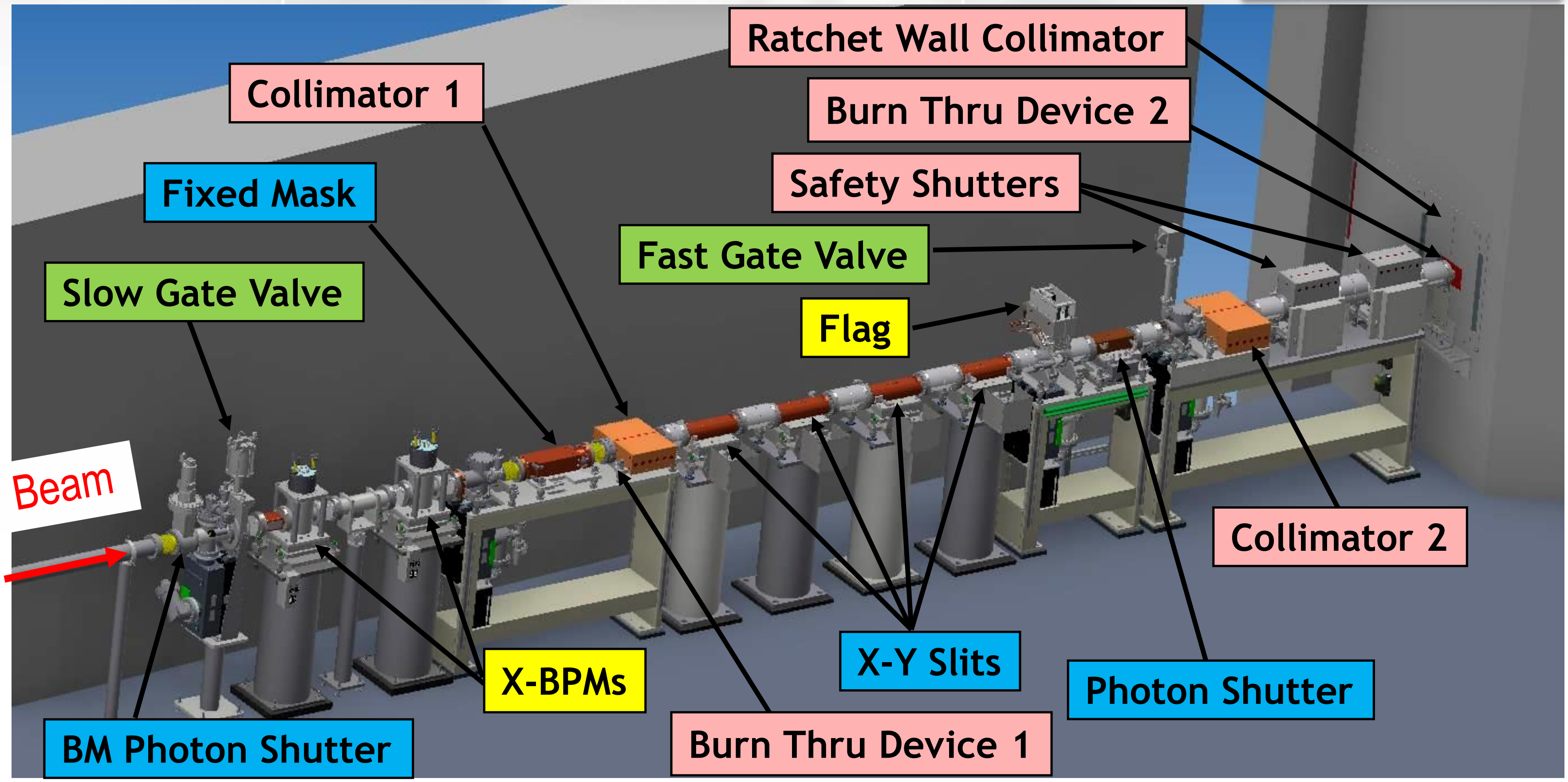




- Insertion Device & Bending Magnet front ends have different configurations, but the component design methods are similar.
- ID FE's manage fans from higher powered Insertion Devices, with total power up to 61 kW.
- BM FE's manage lower power (0.4 kW), but nominal fan angle can be as large as 3 mrad.

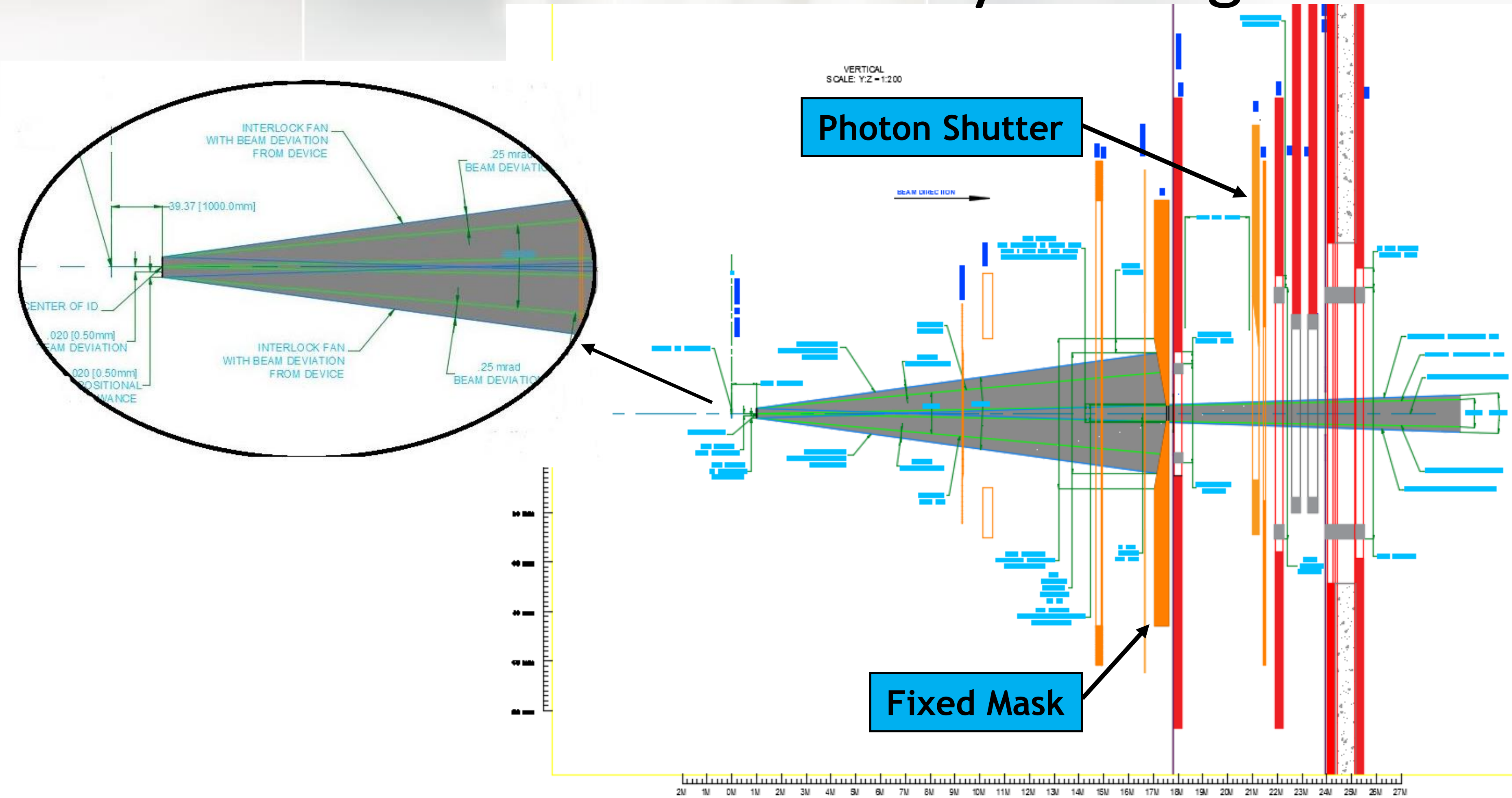
Typical Configuration

ID Front End



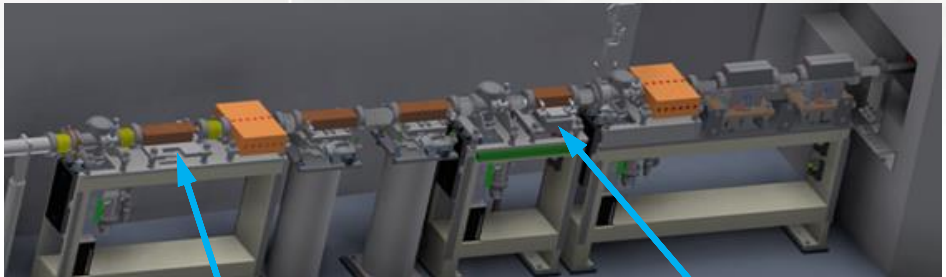
- Water-cooled components, accept and manage the synchrotron fan power.
- Radiation components absorb ionized atoms and attenuate the radiation fields to safe levels.
- Downstream components, including photon and safety shutters, block full power of synchrotron fan and limit bremsstrahlung radiation to acceptable dose rates in the FOE.

Interlocked Beam Fans - Ray Tracing



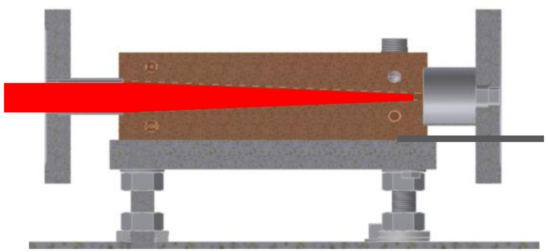
- Nominal and Interlocked Fans – geometry enables sizing of apertures and walls of components.
- Power absorbing, water-cooled devices are designed to survive this fan.

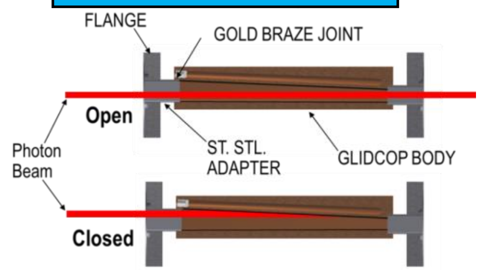
Fixed Mask and Photon Shutter Design



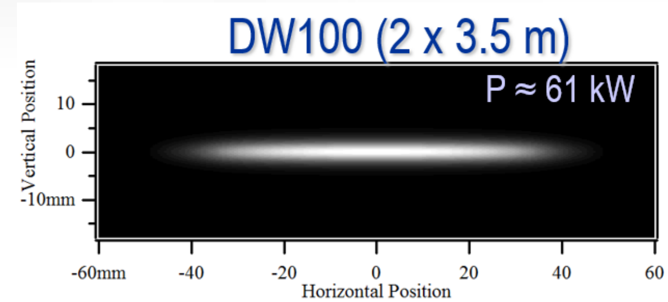
Fixed Mask

Photon Shutter





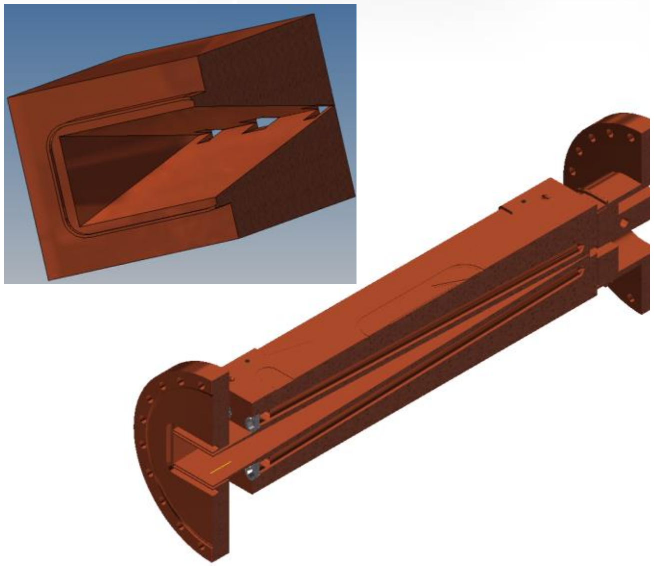
Power Density Distribution at Mask

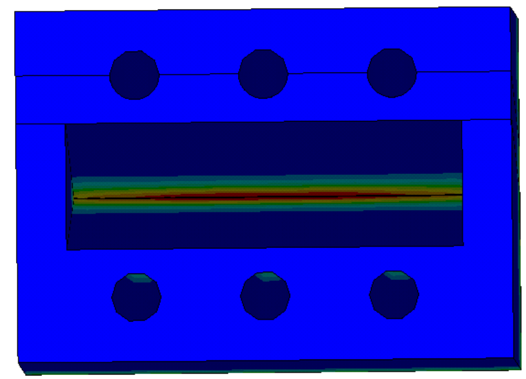


ID	Damping Wiggler100 (XPD)	
Total Power (kW)	61	
Peak Angular Power Density (kW/mrad^2)	55.5	
Components	Fixed Mask	Photon Shutter
Location (m)	20.19	22.88
Fixed Mask Exit Aperture (mrad)	1.10(h) X 0.15(v)	
P_Absorbed (kW)	52	9
Peak Power Density (W/mm^2)	136	107
Horizontal Taper Angle (°)	4	
Vertical Taper Angle (°)	2	3
Peak Temperature (°)	331	268
Peak von Misses Stress (MPa)		424

- The photon beam is intercepted by water-cooled inclined surfaces. Water flow rate is interlocked within the Equipment Protection System (EPS).
- The fixed mask shadows the vacuum chambers of the downstream collimators and safety shutters for *beam deviations controlled by the active interlock (part of EPS).*
- Photon shutter is used to stop the photon beam in order to protect the uncooled safety shutters.

Fixed Mask for HEX Beamline Front End

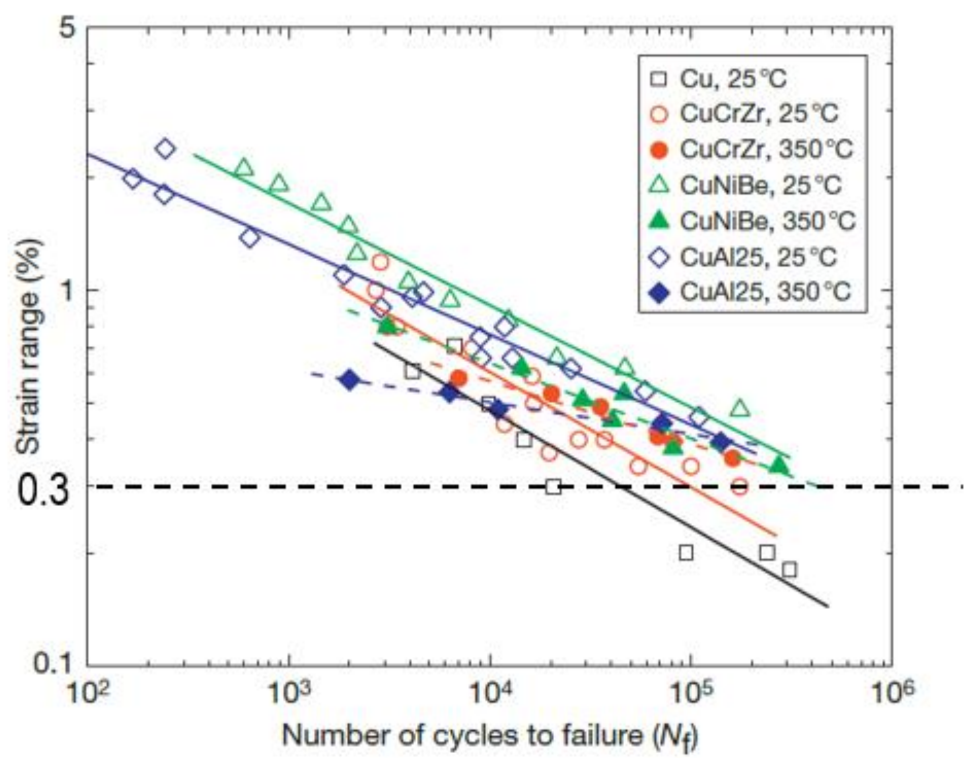




- The fixed mask splits the main X-ray beam into three User beams.
- The new design concept (beam is intercepted only by top and bottom water-cooled surfaces) allows 3 closely-spaced apertures.
- X-rays escaping through the wire gap is intercepted by a downstream water-cooled flange.
- A mask of this design is also installed in the SST Beamline Front End.

CuCrZr for HHL Components – Innovative Design

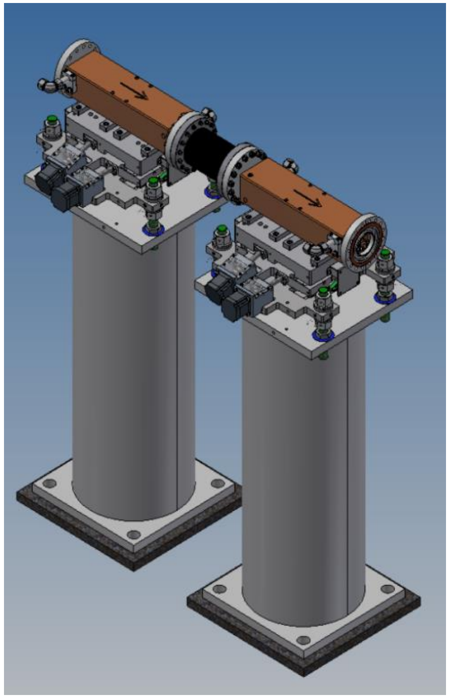
- CuCrZr is widely available in all sizes from many suppliers and is considerably less expensive than Glidcop.
- CuCrZr can be welded thus eliminating high-temperature brazing, which is less reliable and adds ~ 14 weeks to the fabrication schedule.
- Cyclic fatigue life of CuCrZr is comparable to that of Glidcop.
- Design Specification → Temperature rise of < 300 ºC → strain range of 0.3% → fatigue life > 100,000 cycles (30,000 cycles are expected during 30 years of operation).



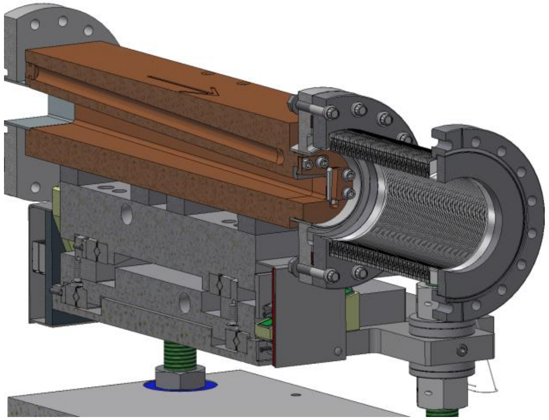
Ref: Li M. and Zinkle S. J. (2012) Physical and Mechanical Properties of Copper and Copper alloys, Comprehensive Nuclear Materials, Vol. 4, pp 667-690

Slit Assemblies

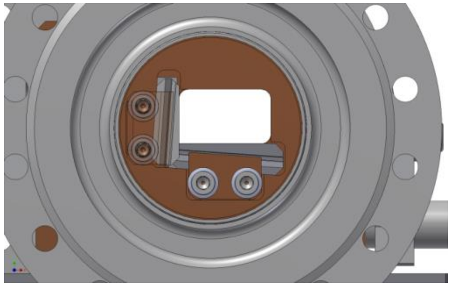
Slits Assemblies



Slit Cross-Section

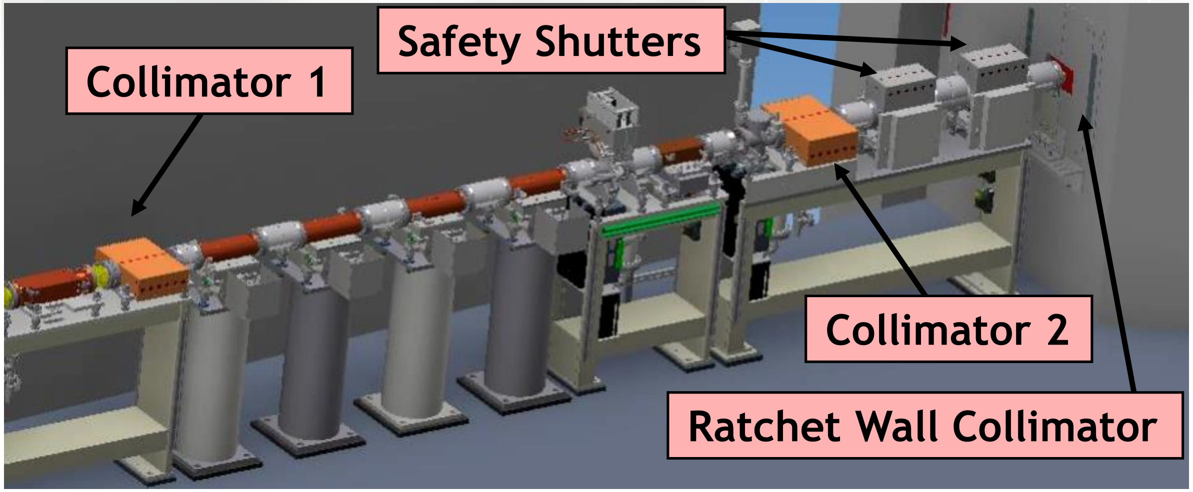


Downstream End



- A pair of slits allows the user the adjust the size of the photon beam.
- The beam is intercepted on water-cooled inclined surfaces. Water-flow is interlocked in EPS.

Credited Controls

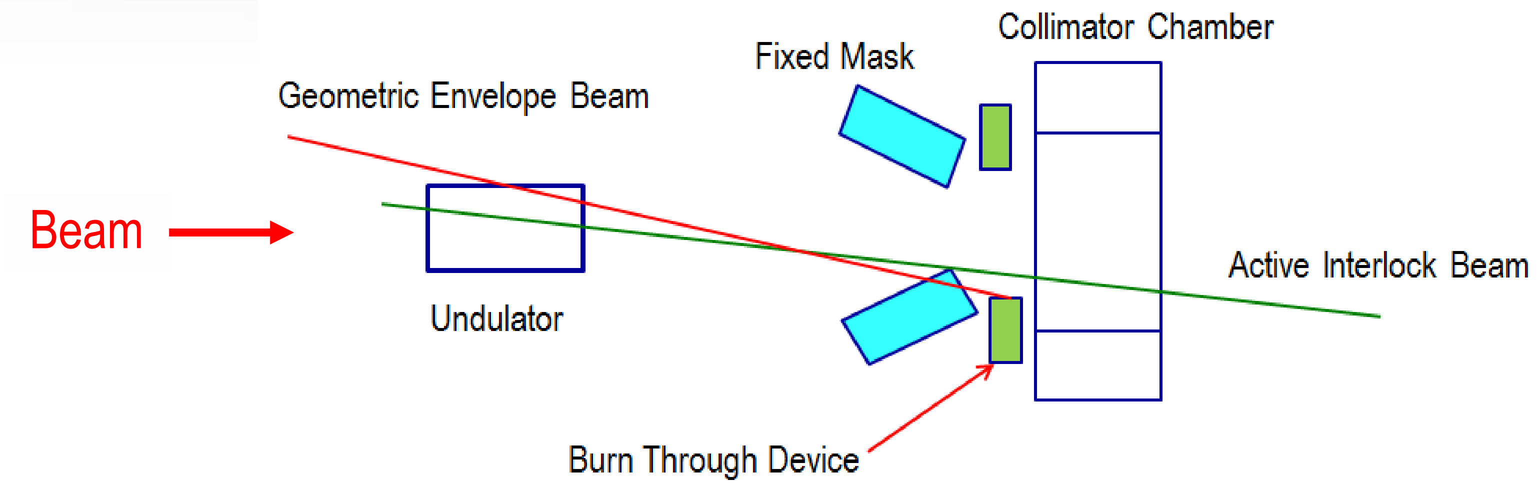


Credited Controls in a Front End:

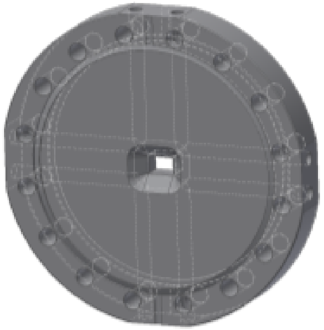
- Lead Collimator – 1
- Lead Collimator – 2
- Dual Safety Shutters
- Ratchet Wall Collimator

The credited controls are passively protected from the un-interlocked photon beam by completely passive devices (burn-through disks, displaced bellows).

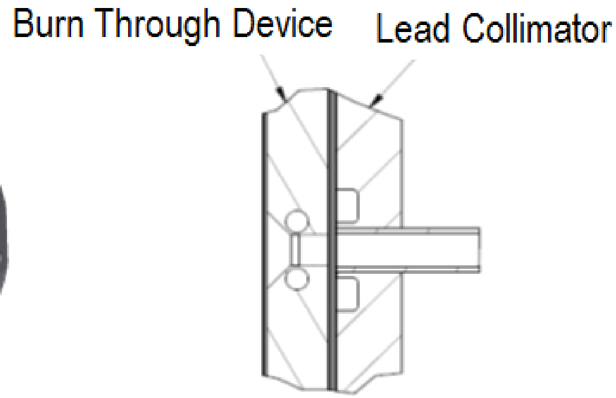
Burn Through Device – Innovative Design



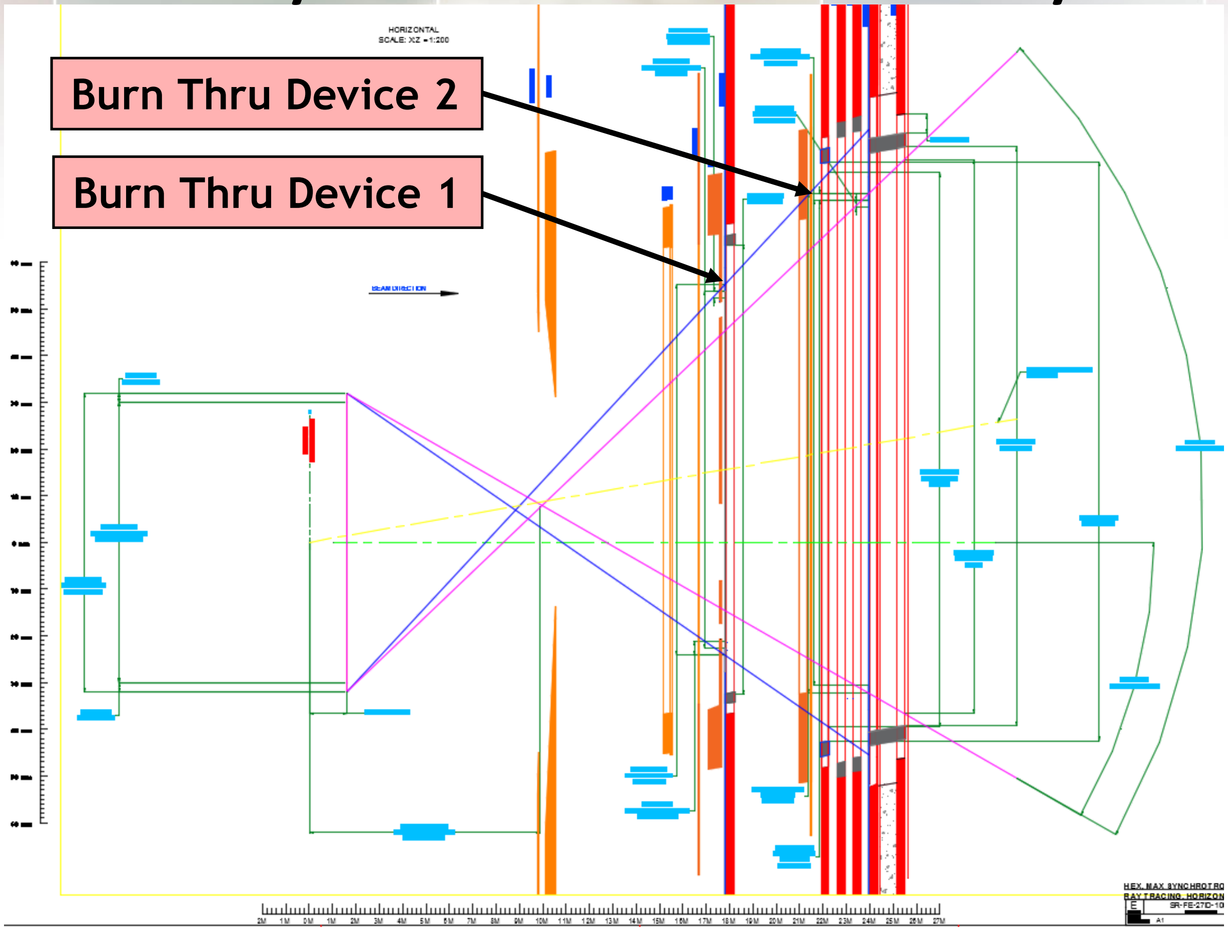
The burn-through device shadows the collimator chamber from the “geometric envelope” photon beam. The photon beam melts the burn-through device thin wall, causing a vacuum leak, which leads to electron beam being dumped in the storage ring.



Burn Through Device

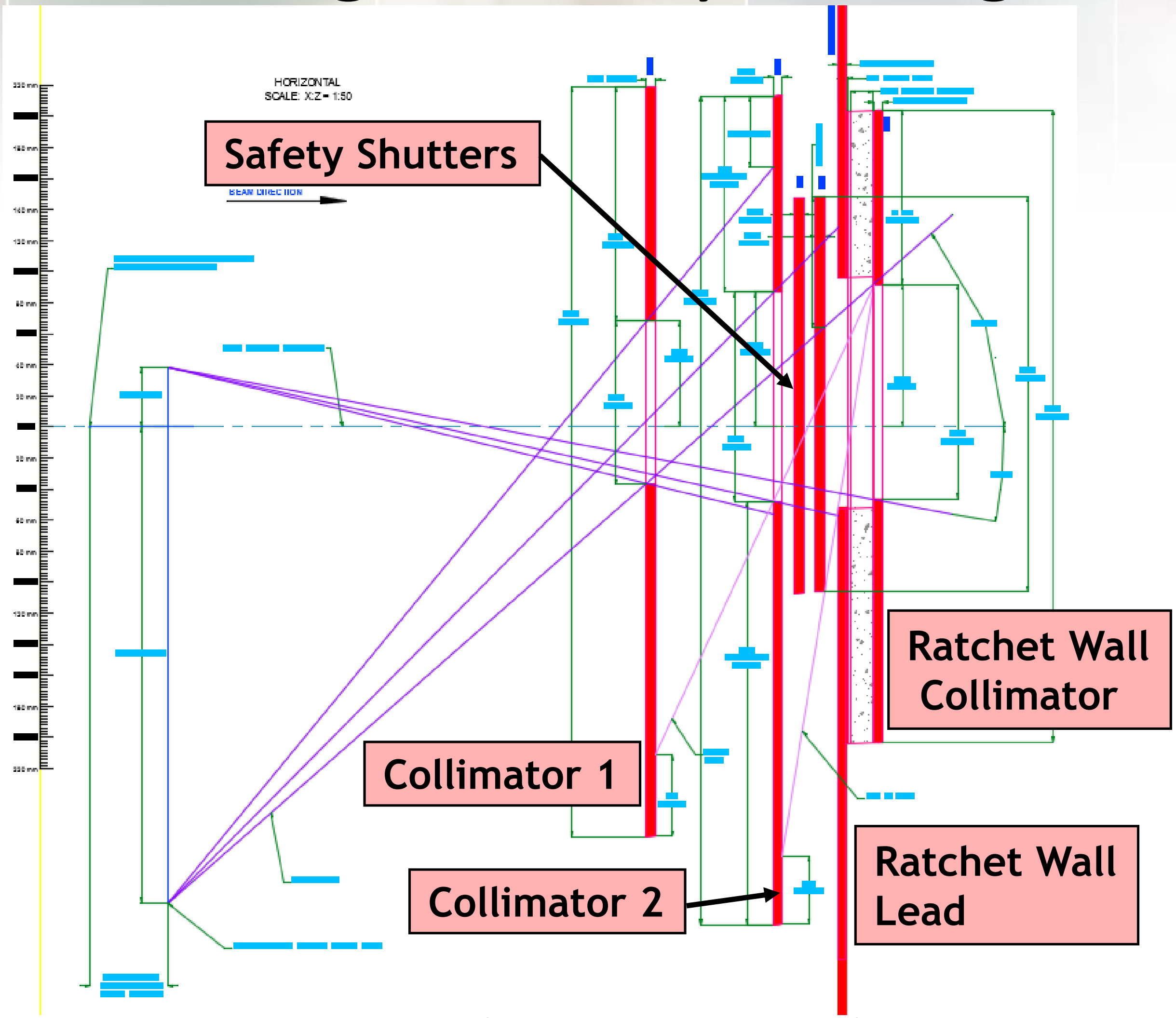


Maximum Synchrotron Fan - Ray Tracing



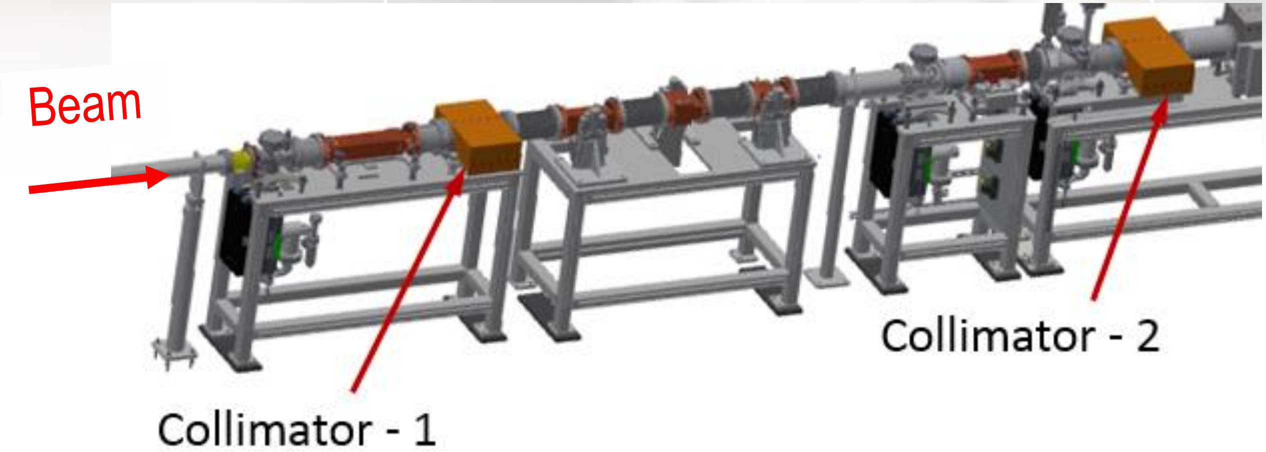
- For Personnel Protection Safety (PPS), a Maximum Fan is drawn. This enables the design of the Burn Thru Device aperture, should the Interlock and Equipment Protection System (EPS) control systems fail. A geometric envelope for the source is used to simulate the most conservative condition for the location and size of the beam source. This and the "Burn Thru" apertures define the geometry of this fan.
- The Lead Collimator and Safety Shutter vacuum tubes are sized to clear this Maximum Fan.

Bremsstrahlung Fan - Ray Tracing



- The Lead Shield apertures are dependent of the tube sizes, given from Max Fan. These Lead apertures are then included on Bremsstrahlung ray trace.
- The lead brick size and apertures are determined from this ray trace.

Lead Collimators 1 and 2

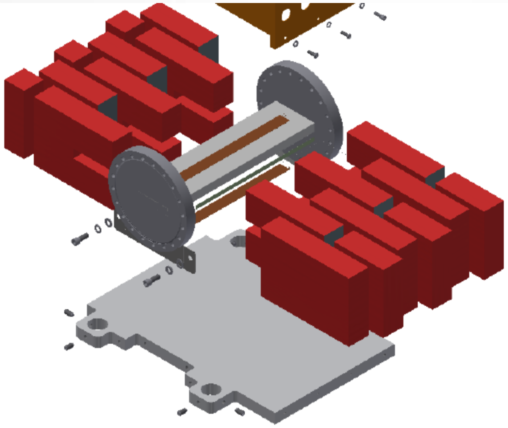


- A lead collimator consists of a stainless steel vacuum tube encased by overlapping lead bricks.

- Lead collimators (with Ratchet Wall Collimator) trim the Bremsstrahlung fan exiting to the beamlines.

- The dimensions of the lead bricks were determined using the guideline documents provided by the NSLS-II ESH group.

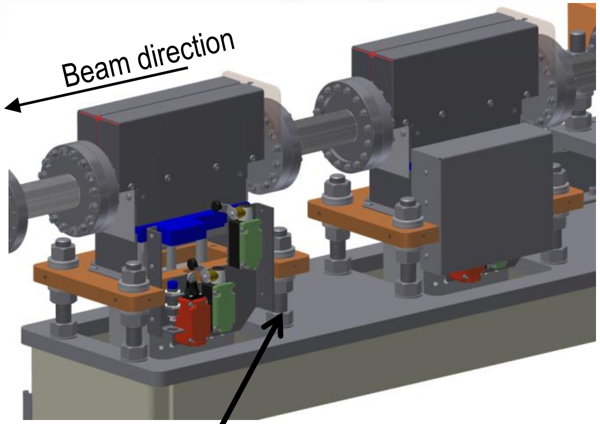
- The vacuum tube is protected by the fixed mask (normal operation), and the burn through device (fault condition).

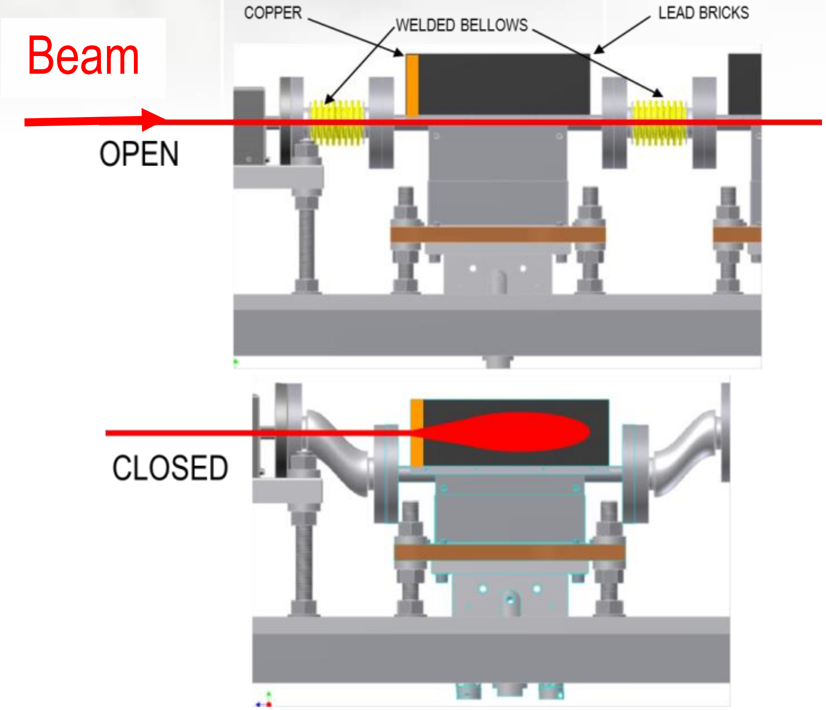


Lead Stacking Details

With Lead Cover

Safety Shutters

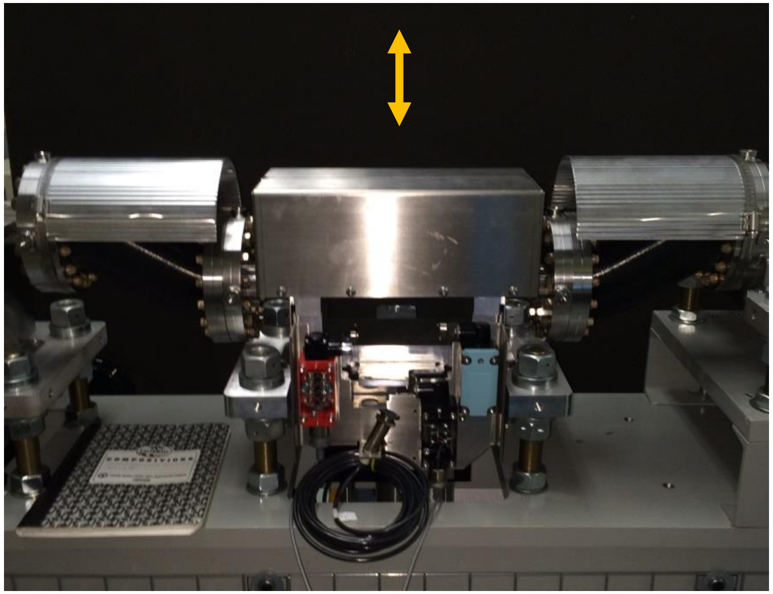




- The safety shutters block the bremsstrahlung radiation from exiting through the RCO chamber opening.
- Two safety shutters are provided (safety redundancy requirement).
- The shutters are actuated by air thrusters that lowers the lead blocks into the beam path.

Testing – Fatigue Life of Bellows and Switches

Photon Sciences Directorate, Brookhaven National Laboratory			
Doc No. **PS-C-ASD-PRC-152**	Author: **G. Dacos**	Effective Date: **01April2014** Review Frequency: **3 yrs**	Version **1**
Title: **Procedure for Evaluation of Safety Shutter System Performance**			**Technical**



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Attachment A

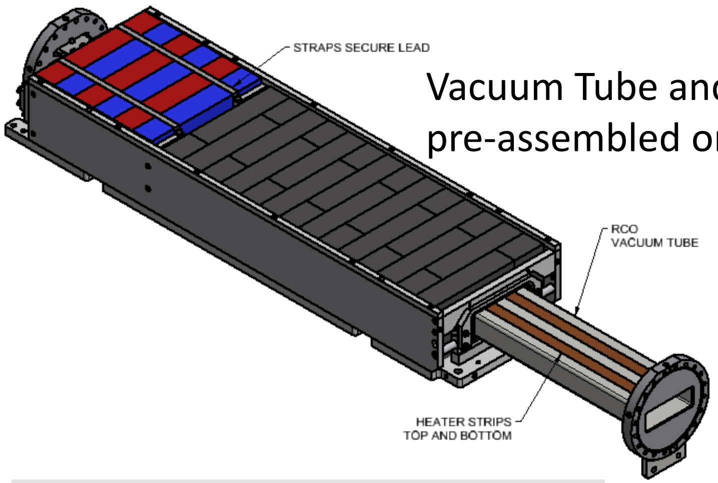
Cycle Test Log Sheet

Number of cycles	Frequency (cycles per hour)	Initial Vacuum Pressure	Current Vacuum Pressure	Date	Initials	Comments/Observations
0	25	2.4E-7	2.4E-7	5/5/14	[illegible]	TRIP SET POINT @ 4.4E-7
3320			6.8E-8	5/5/14	[illegible]	
40,982			7.3E-8	5/8/14	[illegible]	
44,534			8E-8	5/10/14	[illegible]	SLIGHT PRESSURE CHANGES
54,600			1.1E-7	5/12/14	[illegible]	DUE TO TEMP CHANGES*
106,265			1.2E-7	5/15/14	[illegible]	
171,775			9.5E-8	5/20/14	[illegible]	STOPPED FOR A FEW DAY
213,300			1.5E-7	6/1/14	[illegible]	RESTART
374 000			1.7E-7	6/4/14	[illegible]	
1,078,802			9.2E-8	6/15/14	[illegible]	STOP TEST

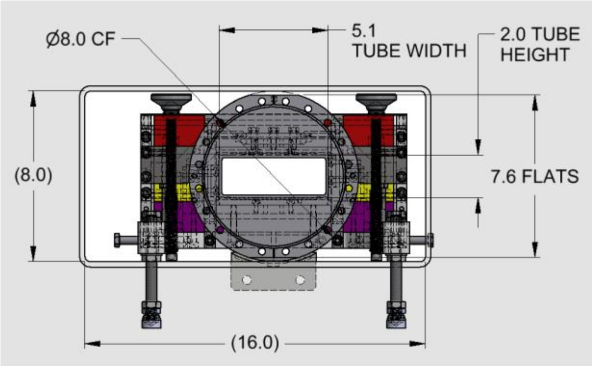
- Cycle Testing of Bellows and Safety Switches. The bellows was specified for and tested to 1,000,000 cycles of lateral displacement.
- The innovative bellows application allows for out of vacuum shielding of Bremsstrahlung, and it also serves as a passive failure device that will protect lead of Shutters.

Ratchet Wall Collimator

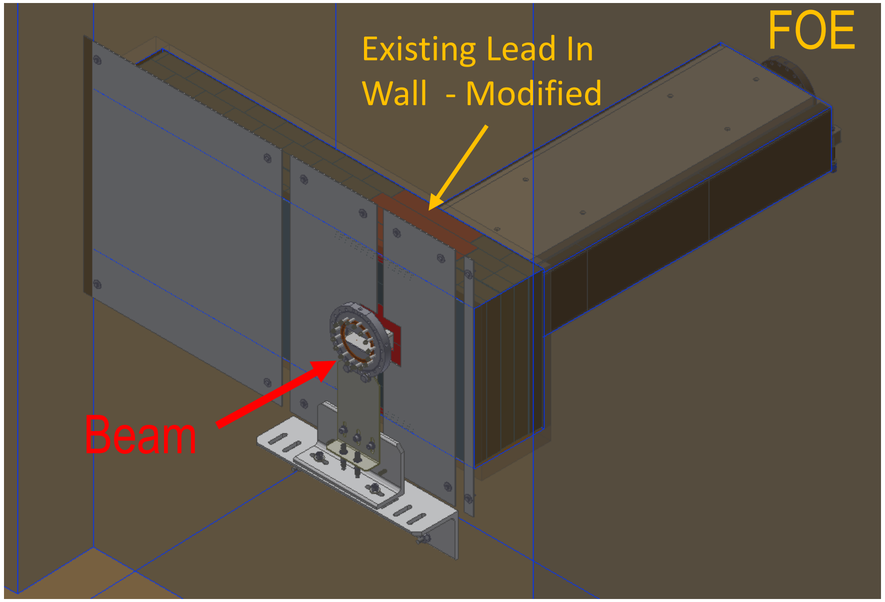
- The RCO Shielding materials trim and attenuate the Bremsstrahlung radiation fields to acceptable dose rate levels.
- Burn Thru 2 mounts on the upstream flange of RCO to provide full passive protection to the RCO lead.



Vacuum Tube and Shielding Materials are pre-assembled on a chassis.



Flats machined on CF Flange, to clear wall sleeve



Installed in downstream Ratchet Wall

Current Status

- Since 2014, 22 Front Ends, 16 ID type and 6 BM type, have been installed. All have met all functional requirements and are performing quite reliably.

- Designs for HEX (High-energy Engineering X-ray Scattering and Imaging) are 85% complete. Testing of new slit assemblies will start next month.

- As-built documents, procedures and travelers are available for all the front ends.

Engineering and Technical Team

- Engineering and Design
    - Sushil Sharma, Mechanical Engineering Advisor
    - Bill Wahl, Mechanical Group Leader
    - Chris Amundsen, Project Engineer
    - Mark Breitfeller, Project Engineer
    - John Fabijanic, Designer
    - John Tuozzolo, Designer
- Production Support
    - Frank DePaola
- Technical Support
    - Front End Assembly - Frank Lincoln
    - Vacuum Group – Charles Hetzel, et al
    - Tech Group – Bob Scheuerer, et al
    - Survey Group – Chenghao Yu, et al
    - Electrical Group – G. Ganetis, et al
    - Diagnostic Group – Danny Padrazo, et al
    - Controls Group – Qinfu Tang, et al
    - Installation Coordination – G. Fries, L. Doom

Special Thanks to Sushil Sharma – Champion of Engineers