Bending Magnet and 3-Pole Wiggler Frontend Design

Prepared by: Muhammad Aftab Hussain

October, 2014

MEDSI 2014
Mechanical Engineering Design of Synchrotron Radiation Equipment and Instrumentation

NSLS-II
NATIONAL SYNCHROTRON LIGHT SOURCE II

BROOKHAVEN NATIONAL LABORATORY

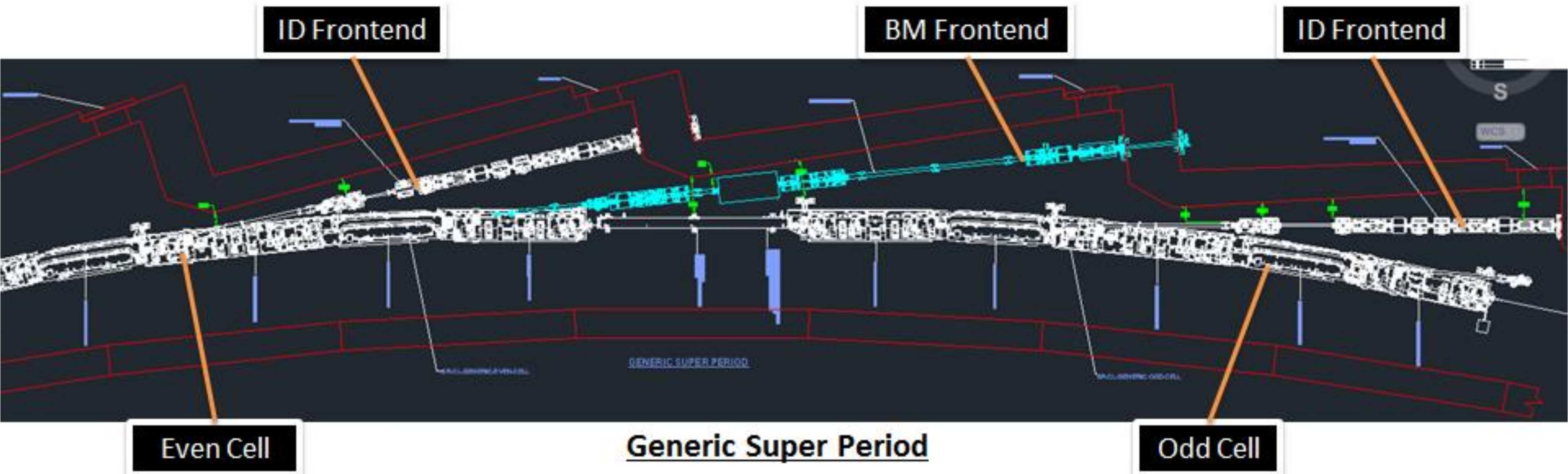
Outline

- Introduction
- Frontend Configuration & Interfaces
- Frontend Overall Design Approach and Challenges
- Frontend Components Design
- Summary and Conclusion

Introduction

Frontend serves the following purpose:

- ❑ It transports the required synchrotron radiation from the source to the first optics enclosure.
- ❑ It protects the storage ring vacuum.
- ❑ It removes the undesired heat from the synchrotron beam.
- ❑ It collimates the Bremsstrahlung radiation to a safe level.

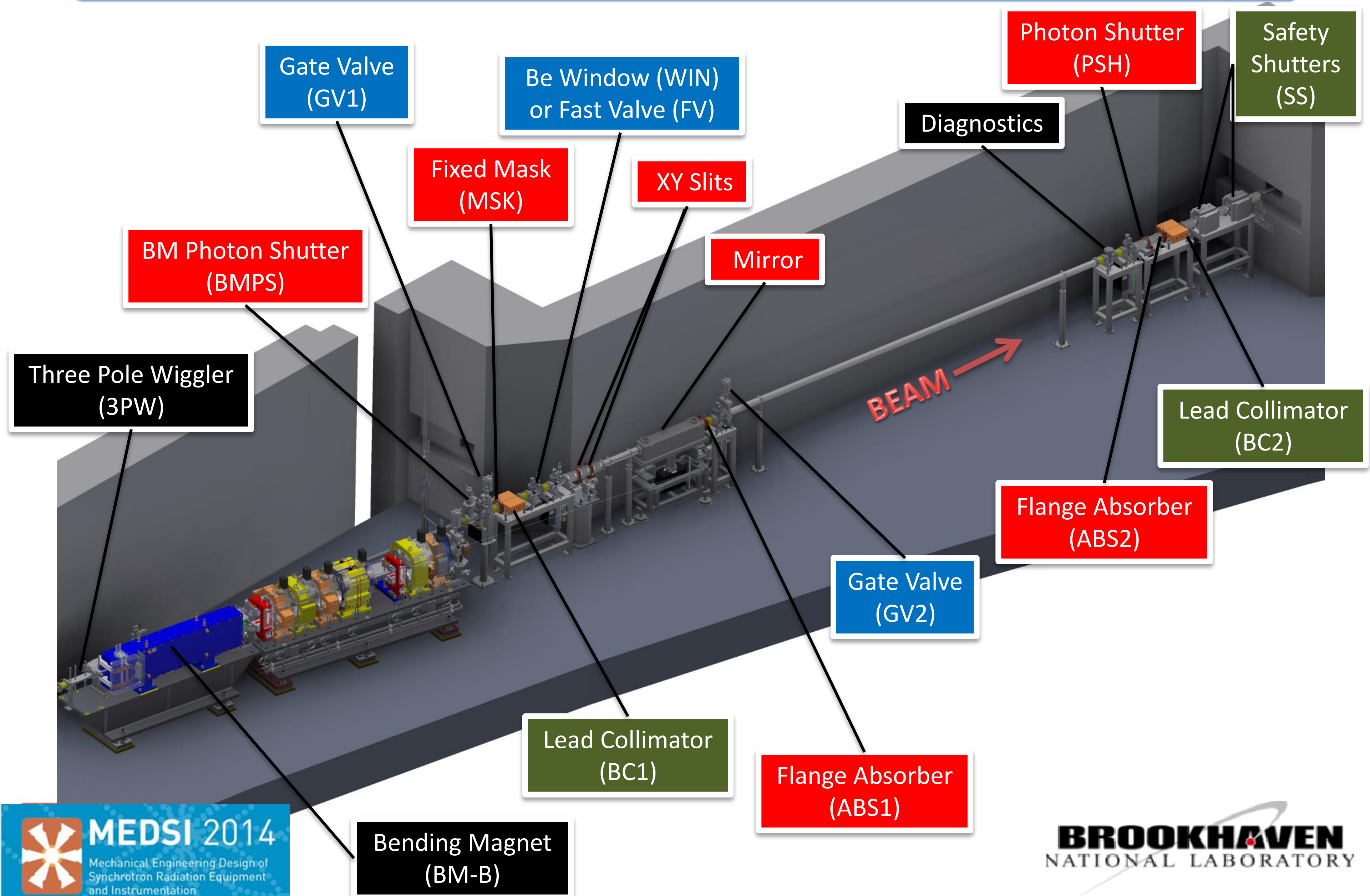


Beamline Source Parameters

Sources for the NSLS-II BM port beamlines:

- ***Source Type:*** *3PW and BM*
- ***Nominal magnetic field at source location:*** *3PW (1.2 T) & BM (0.40 T)*
- ***Usable photon energy range:*** *1-31 keV*
- ***Maximum fan power (500mA current):*** *3PW (250 W) & BM (69 W)*
- ***Maximum Power Density:*** *3PW (365 W/mrad^2) & BM (115 W/mrad^2)*
- ***Beamline Horizontal Acceptance Fan:*** *0.2-3 mrad*
- ***Beamline Vertical Acceptance Fan:*** *0.15-0.6 mrad*

Frontend Configuration & Interfaces



Frontend Overall Design Approach & Challenges

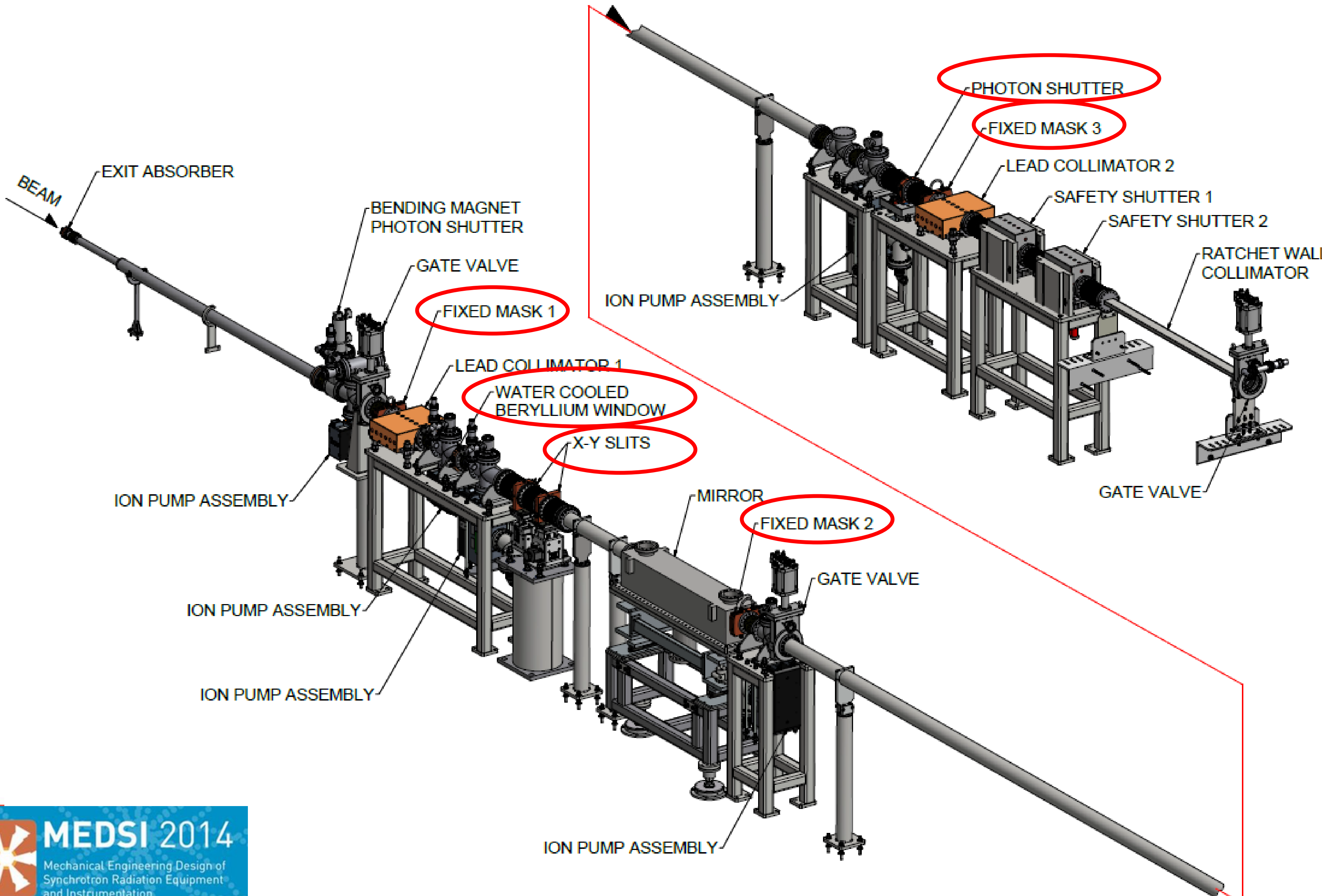
Challenges

- ❑ Full passive protection to the frontend components.
- ❑ Geometric Envelope as opposed to Active Interlock Envelope for full passive protection.

Design Approach

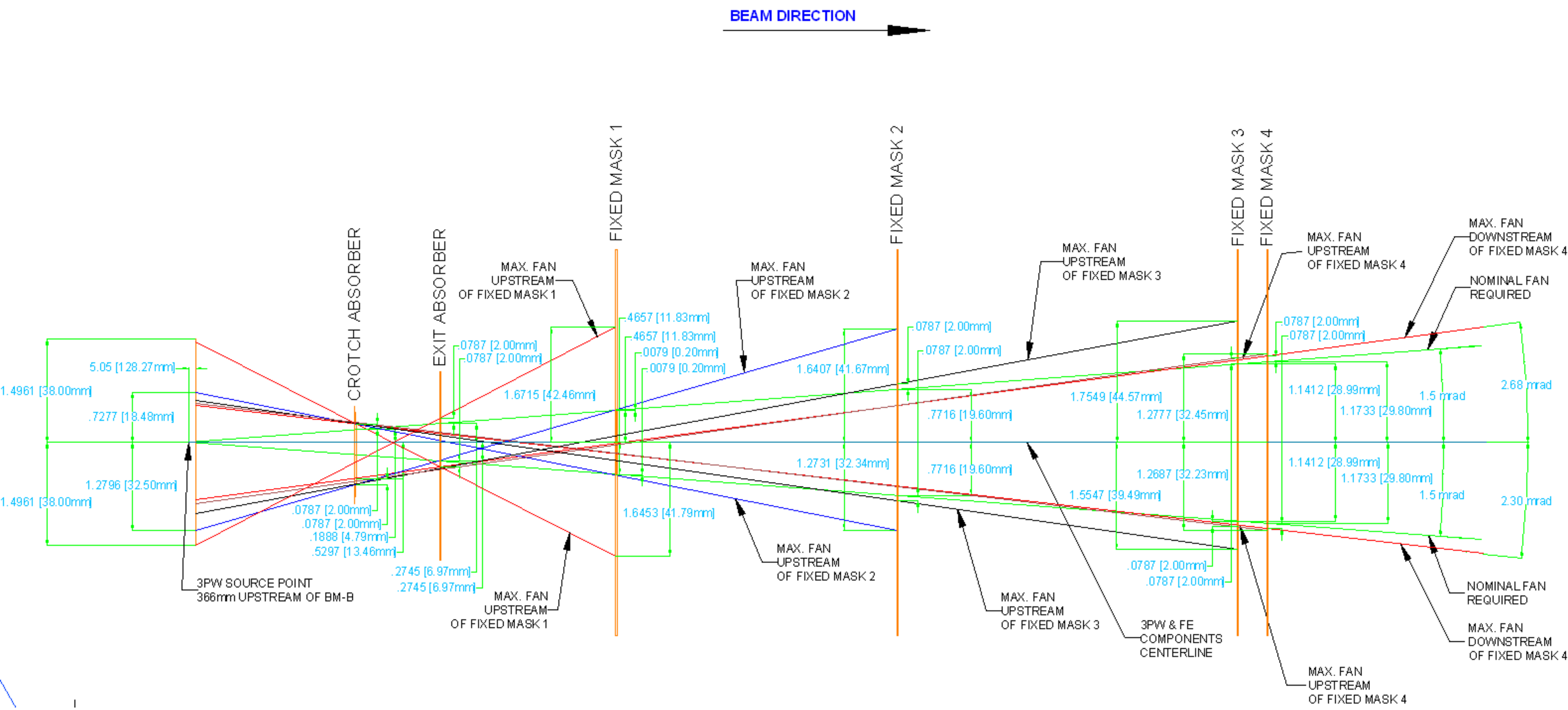
- ❑ Ray tracing to locate and size the components.
- ❑ Multiple flange absorbers for the progressive trimming of synchrotron beam.
- ❑ Fixed mask and flange absorbers are double sided conflate flanges. (BNL Patent Pending)
- ❑ Glidcop AL-15 and Copper Chromium Zirconium as a flange material.

Frontend Configuration



Frontend Ray Tracing

Horizontal Synchrotron Ray Tracing



Glidcop VS Cu-Cr-Zr

Material Properties

- *Thermal Conductivity (RT):*
  Glidcop Al25, Al15: 344 - 365 W/(m.K)
  Cu-Cr-Zr: 314 - 335 W/(m.K)
- *Elastic Modulus:*
  Glidcop Al15, Al25: 130 GPa
  Cu-Cr-Zr: 123 GPa
- *0.2 % Yield Strength, (RT, Cold Worked):*
  Glidcop Al15, Al25: 470 - 580 MPa
  Cu-Cr-Zr: 350 - 550 Mpa
- *Coefficient of Thermal Expansion:*
  Glidcop Al15, Al25: 16.6 µm/K
  Cu-Cr-Zr: 17.0 µm/K

- *Cu-Cr-Zr (C18150) is 1/4th the price of Glidcop AL-15.*
- *Cu-Cr-Zr is readily available in different forms and sizes from many suppliers.*
- *Cu-Cr-Zr loses its strength rapidly if exposed to sustained temperatures > 500°C*
- *Glidcop is the choice if brazing is required.*

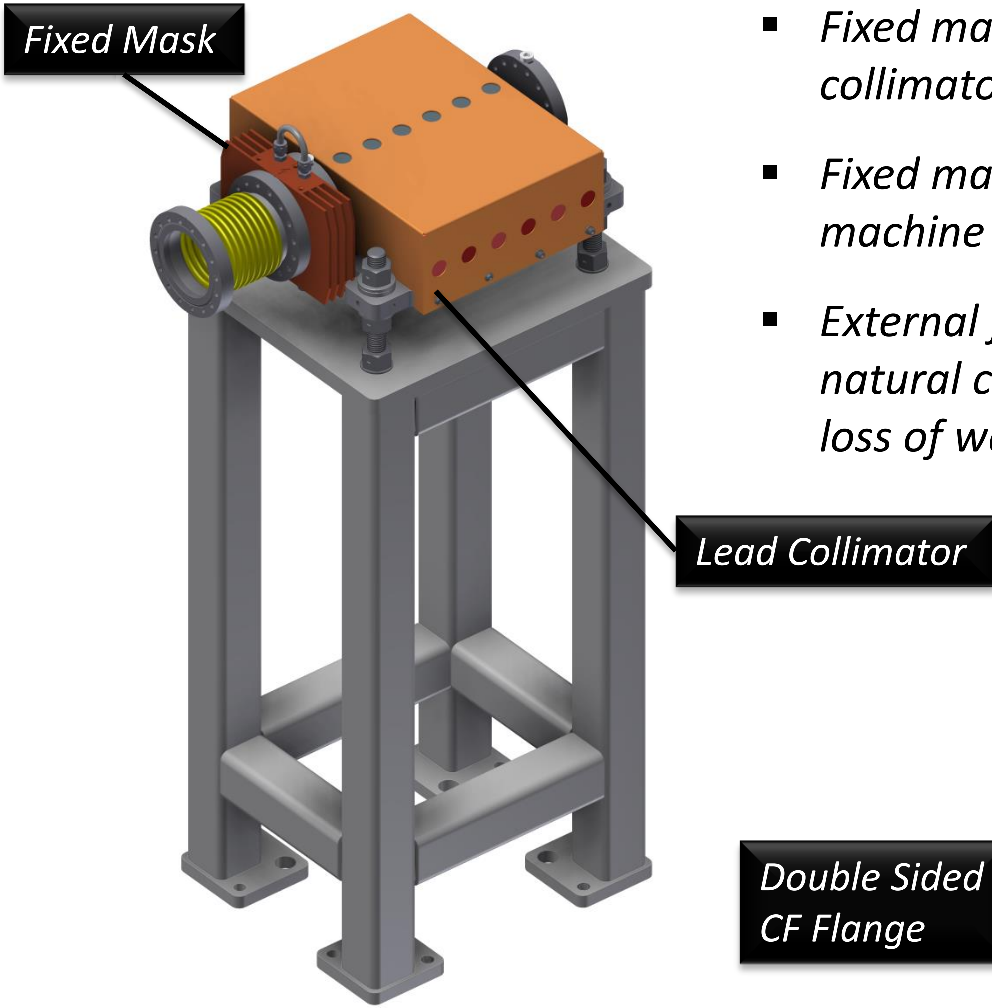
Ref: Li M. and Zinkle S. J. (2012) Physical and Mechanical Properties of Copper and Copper alloys, Comprehensive Nuclear Materials, Vol. 4, pp 667-690

(Tests on Cu-Cr-Zr Conflate Flanges and Flare Fitting Connections)

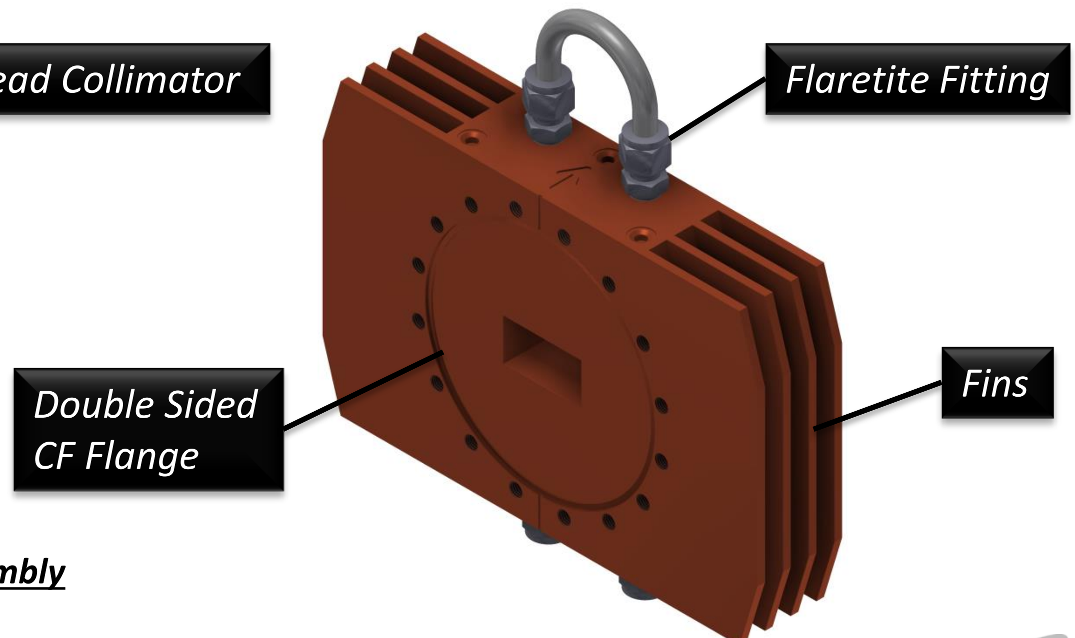
Ref: Sushil Sharma, et al. " A Novel Design of High Power Masks & Slits", MEDSI2014

Fixed Mask / Flange Absorber Design

- *Fixed mask defines the beam size and shadow collimator aperture.*
- *Fixed mask is water cooled and interlocked to the machine EPS.*
- *External fins are added to fixed mask to provide natural convection and equipment protection from loss of water flow.*



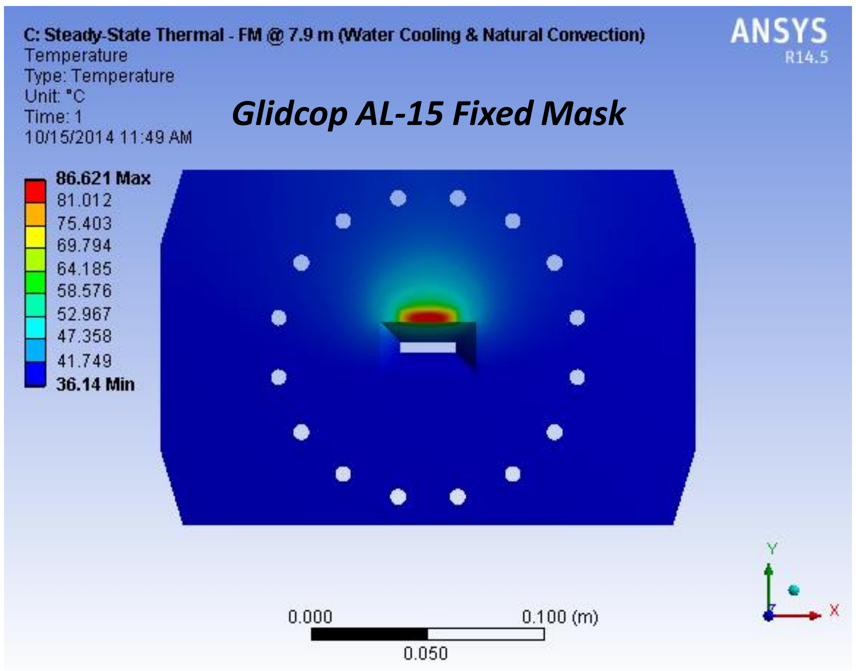
Fixed Mask /Lead Collimator (BC1) Assembly



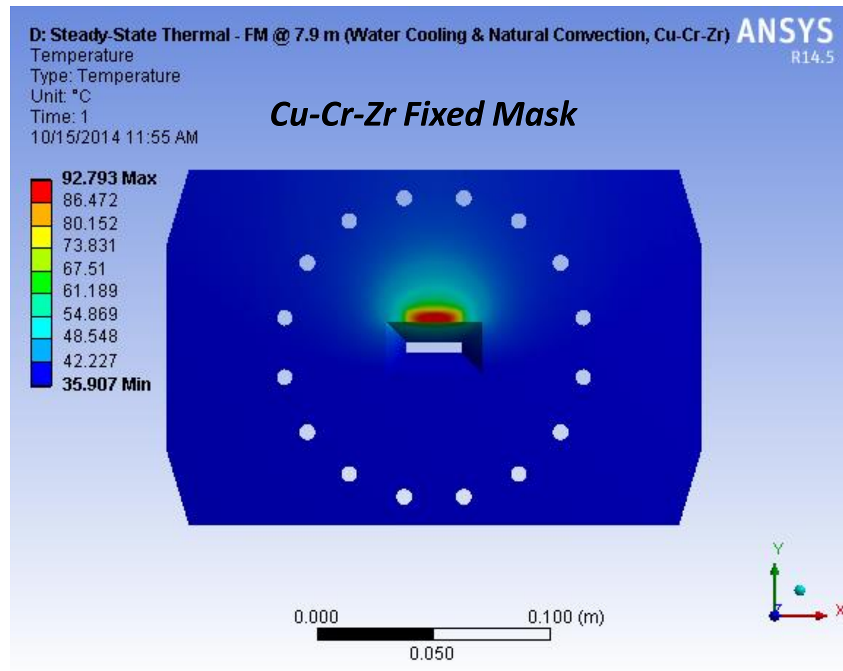
Fixed Mask Thermal Analysis

Analysis Parameters

- Distance from Source ~ 7.9m
- Total Power (3PW & BM) = 319 W
- Assumed heat transfer coefficient of 10 $W/m^2.K$ for natural convection.
- Assumed film coefficient of 0.4 $W/cm^2.°C$ for a flow rate of 1GPM in Ø0.375” cooling channel.



Temperature Contour Plot, Tmax ~ 87°C

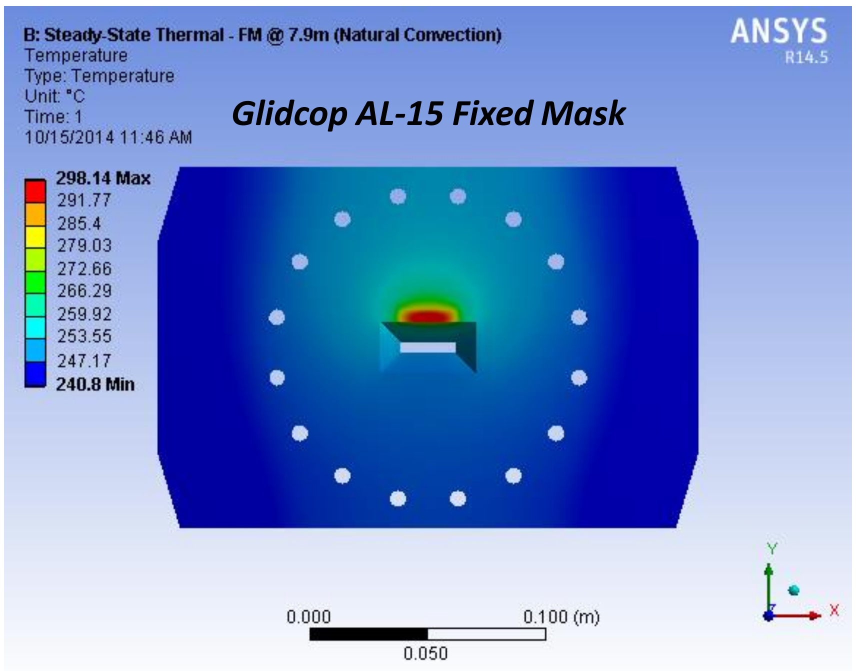


Temperature Contour Plot, Tmax ~ 93°C

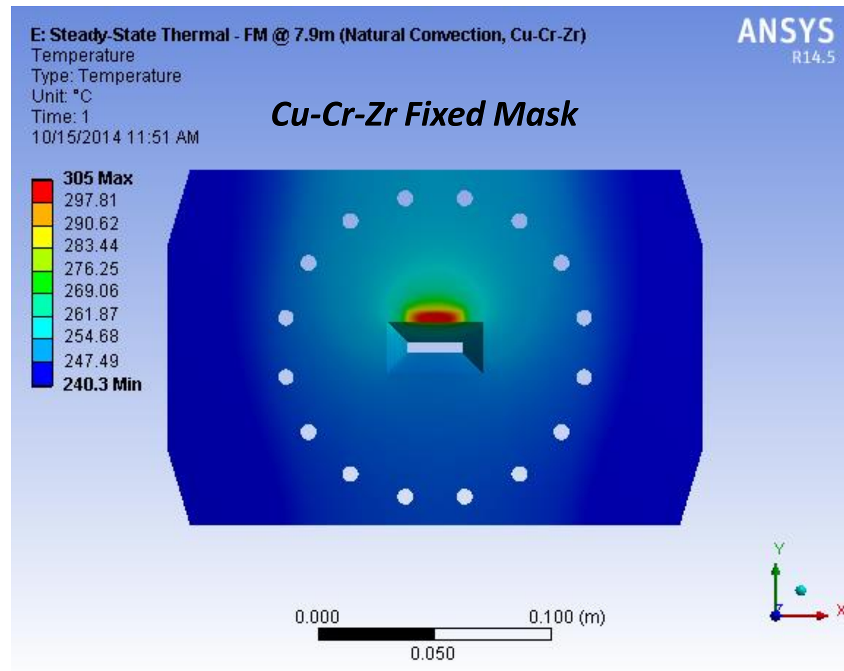
Fixed Mask Thermal Analysis (Natural Convection Only)

Analysis Parameters

- Distance from Source ~ 7.9m
- Total Power (3PW & BM) = 319 W
- Assumed heat transfer coefficient of 10 W/m².K for natural convection.
- Typically the heat transfer coefficient value for natural convection ranges from 5-25 W/m².K



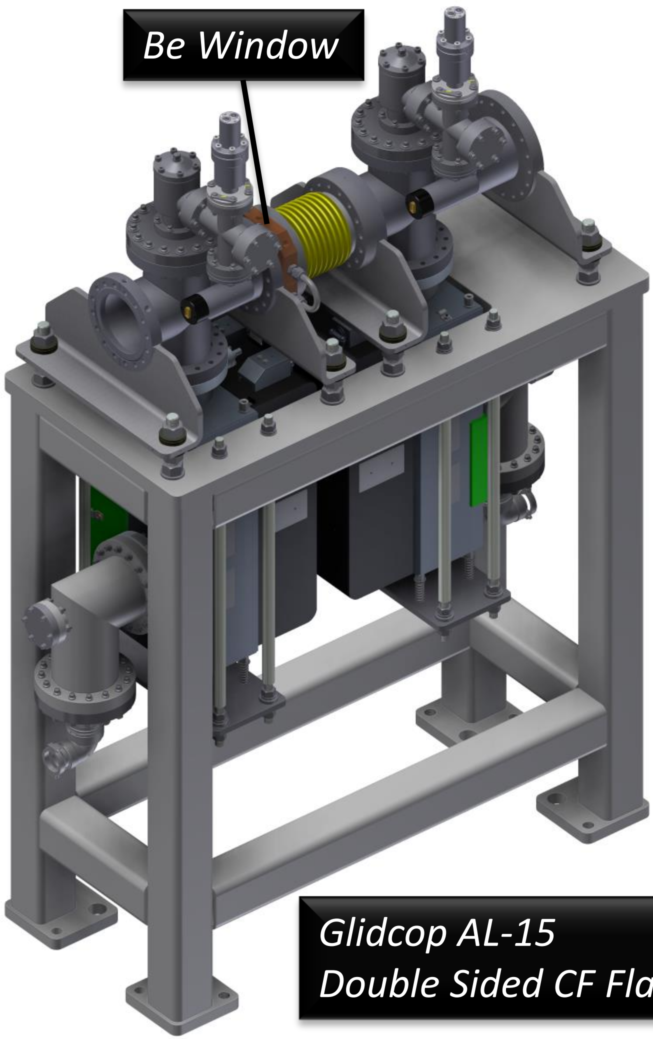
Temperature Contour Plot, Tmax ~ 298°C



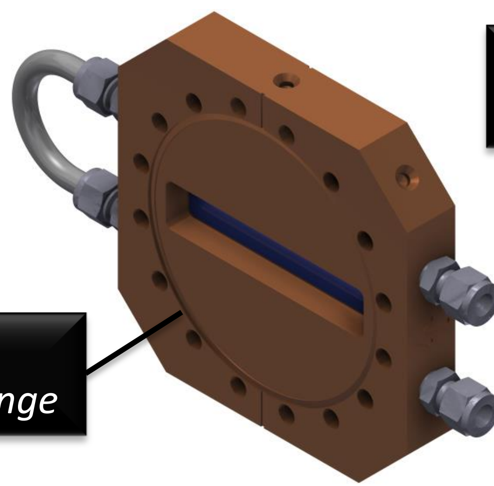
Temperature Contour Plot, Tmax ~ 305°C

Beryllium Window Design

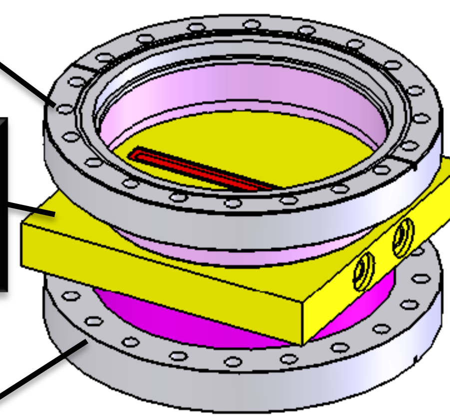
- *Water cooled Be Window.*
- *Provide isolation to storage ring vacuum from beamline vacuum.*
- *Window thickness (250 μm).*
- *Window aperture (10mm x 92mm).*
- *Polished to RA < 100 nm RMS on both sides.*
- *Diffusion bonded assembly bakeable to 450°C.*
- *Capable of sustaining > 2.4 bar pressure differential.*



Be Window/Ion Pump Assembly

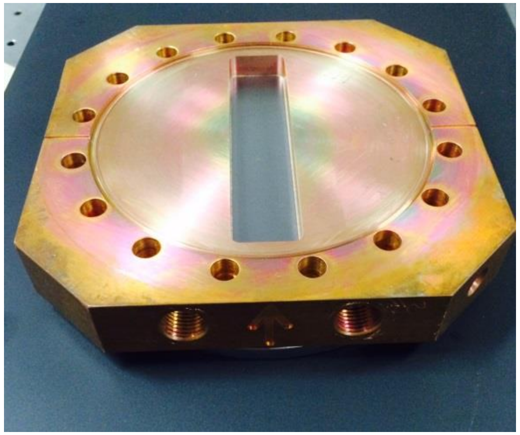


New Design

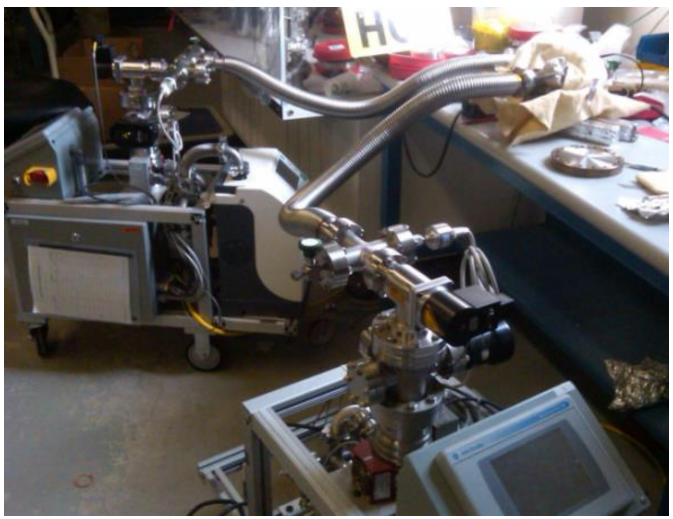


Traditional Design

Be Window Test Results



Prototype Be Window



Test Setup

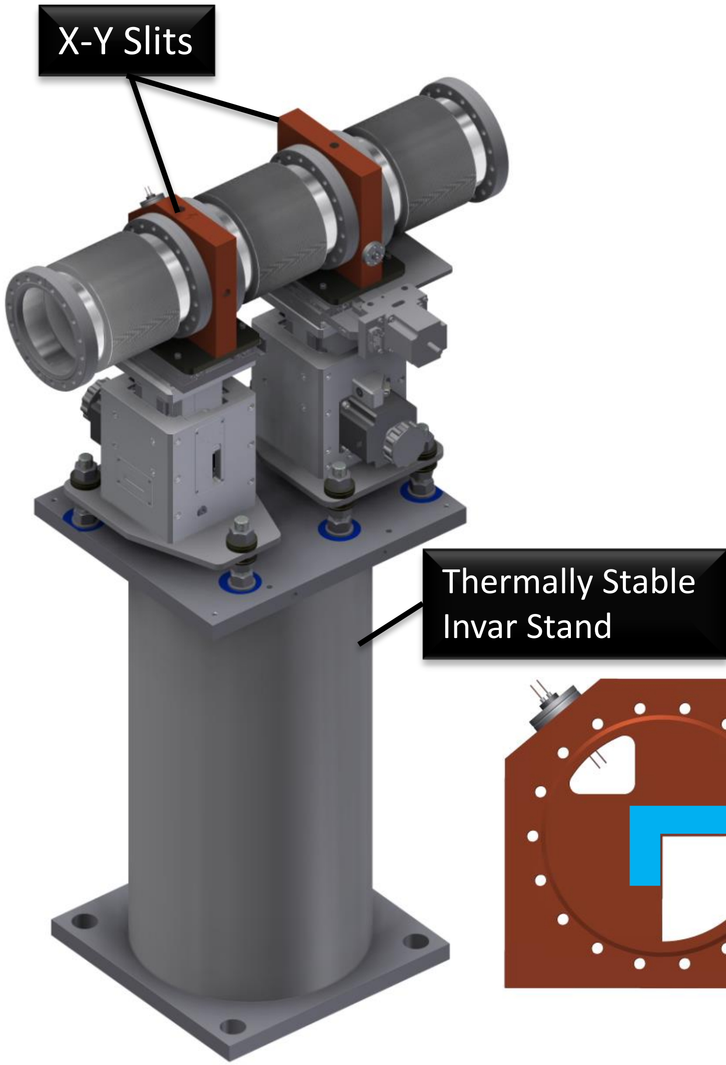
- *Leak check before and after the diffusion bonding at room temperature.*
- *Leak check and pressure test was performed after repeated thermal cycling up to 150°C.*
- *Pressure test was performed to check the window strength.*

NSLS-II NexGen Beamline Front-End Beryllium Window Leak and Pressure Tests

E. Hu (5-29-2014)

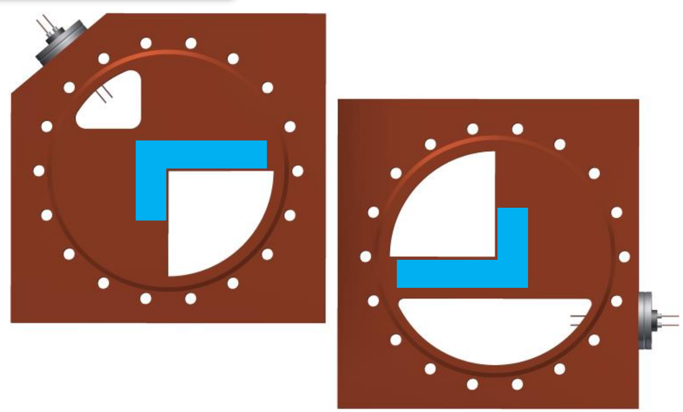
Be-Window Leak Check and Pressure Test	Valve-1 /Valve-2	Pressure-1/Pressure -2	Leak at Be-window or knife edge (side 1 or 2)
(2 identical independent sets at both sides of Be)	(open or close)	(mTorr vs 1.5 atm)	< 2E-10 (Torr-Liter/sec)
Leak/P-test at Room Temp using helium			
pump side-1 to LV, feed He to side-2 (1.5 atm)	open / close	mTorr / 1.5 atm	$< 2 \times 10^{-10}$
pump side-2 to LV, feed He to side-1 (1.5 atm)	close / open	1.5 atm / mTorr	$< 2 \times 10^{-10}$
(temperature rise at rate of 50-deg C per hour)			
Leak/P-test at 70-deg C using helium			
pump side-1 to LV, feed He to side-2 (1.5 atm)	open / close	mTorr / 1.5 atm	$< 2 \times 10^{-10}$
pump side-2 to LV, feed He to side-1 (1.5 atm)	close / open	1.5 atm / mTorr	$< 2 \times 10^{-10}$
(temperature rise at rate of 50-deg C per hour)			
Leak/P-test at 120-deg C using helium			
pump side-1 to LV, feed He to side-2 (1.5 atm)	open / close	mTorr / 1.5 atm	$< 2 \times 10^{-10}$
pump side-2 to LV, feed He to side-1 (1.5 atm)	close / open	1.5 atm / mTorr	$< 2 \times 10^{-10}$

X-Y Slits Design

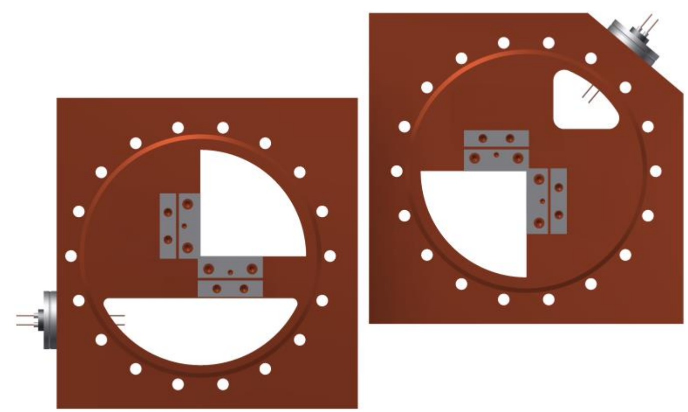


X-Y Slits Assembly

- *Water cooled , normal incidence design.*
- *Allow full independent adjustment of all four blades.*
- *Maximum Opening (50 mm H x 10 mm V)*
- *Minimum Aperture Size (-10 mm, fully closed, overlapped)*
- *Allow selection of any part of the beam.*
- *Position Resolution < 1 µm*
- *Aperture Stability (1 µm or better over any 24-hour period)*
- *Repeatability (5µm)*
- *Beam intensity monitoring.*

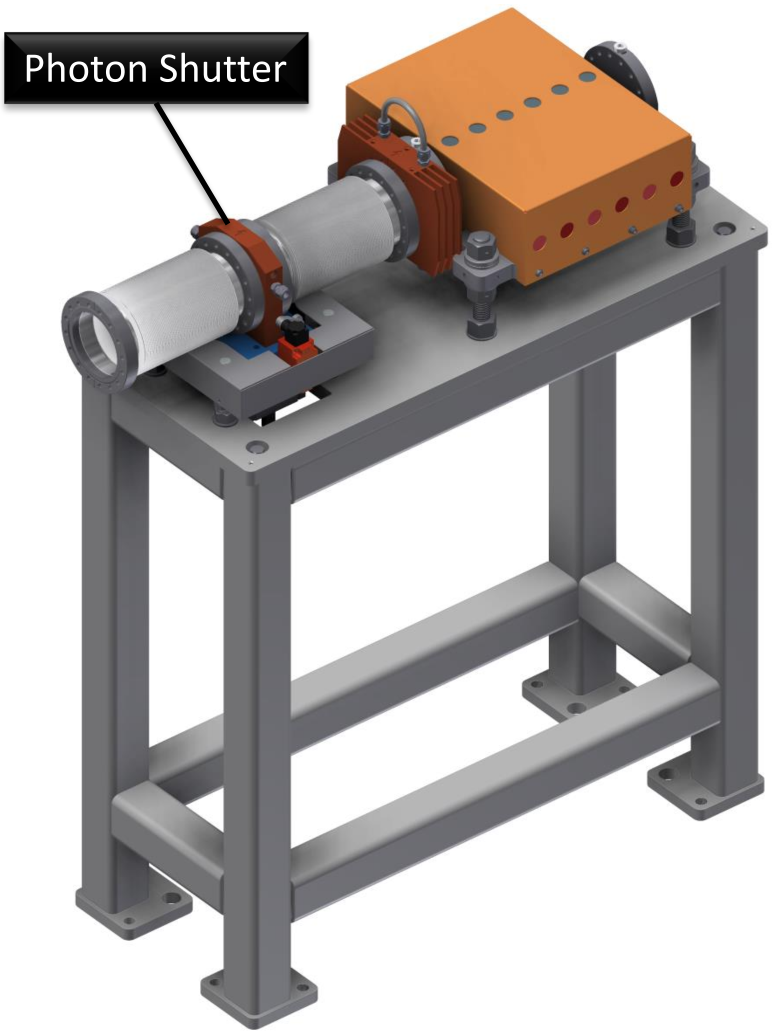


Front View



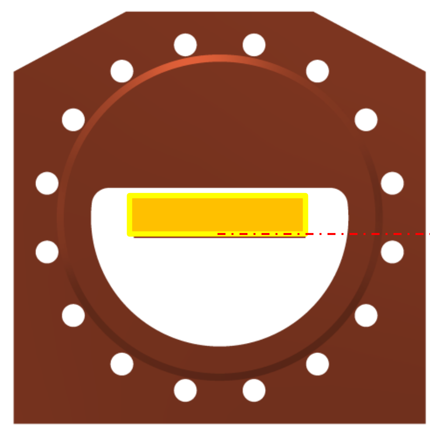
Back View

Photon Shutter Design

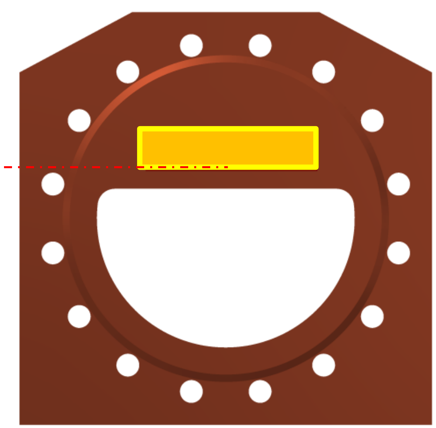


Photon Shutter/Bremsstrahlung Collimator Assembly

- *Water cooled , normal incidence design.*
- *Stops synchrotron beam whenever safety shutters are closed.*
- *Integrated into the machine PPS.*



Photon Shutter
Open Position



Photon Shutter
Closed Position

Summary & Conclusion

- *Full passive protection.*
  - Any beam deviation is acceptable for frontend components.
  - Progressive trimming of fan using flange absorbers.
  - Flange absorbers shadow lead collimators.
  - Components protection in absence of water flow by natural convection.

- *Cost effective design.*
  - No welding or brazing required for mask, slits, absorbers & photon shutter.
  - Cu-Cr-Zr is 1/4th the price of Glidcop AL-15.
  - Cu-Cr-Zr is available in different forms (bars, sheets & plates) and sizes.
  - Standardized components for mass production.

- Glidcop AL-15 double sided CF flange is needed for Be window.

- Design work in progress for five NSLS-II BM port beamlines
  - Two frontends will be installed in 2015.

Acknowledgement

- Dick Hseuh
- Eugene Hu
- Frank DePaola
- Frank Lincoln
- John Tuozzolo
- Jeff Keister
- Paul Northrup
- Sushil Sharma

Thank you for your attention!