MEETING REPORT	Report No. TR-391-003-12	
MEETING DESCRIPTION: CXI Instrument Team Leader Meeting		
WBS: 1.3 Coherent X-ray Imaging		
Organized By:	Sébastien Boutet	
Report Prepared By:	Sébastien Boutet	**Date:** 17 October 2008
Attendees/Lab :	Henry Chapman John Miao Janos Hajdu (via phone) Sébastien Boutet Tom Fornek	
Distribution:		
Attachments:	☐Slides ☐Other ☐Calculations ☐Other	

Report on proposed modifications to CXI beamline
CXI Team Leaders meeting
October 19, 2008

Henry Chapman
John Miao
Janos Hajdu

1- Discussion of the current CXI status

The first part of the meeting was spent discussing the latest design of every CXI component. Images of the 3D designs were shown and discussed at length. The team leaders were very pleased with the current designs and no major issue were identified.

2- Discussion of the XCS plans to move the large offset monochromator

The plans for XCS to move the large offset monochromator to the end of the XRT were discussed. Also, the plans for XCS to add a channel-cut monochromator which would use the direct beam line was discussed. This has the effect for CXI of shortening the length of the beamline from 250 m to a total of roughly 20 m, the length of hutch 5. The team leaders expressed concern that this may be restrictive for future upgrades. Since then, CXI agreed with XCS to move the large offset mono back 10 meters to allow CXI to install some components at the end of the XRT. This will allow sufficient space for current devices and future upgrades in the XRT.

XCS also plans on using the channel-cut monochromator in the early stages on the main beam line, before the large offset monochromator is available. This implies that CXI will also have access to the channel-cut and possibly the split-and-delay unit. The team leaders agree that this increased capability outweighs the loss of space in the XRT.

There was a concern that with XCS using the direct beamline, it would greatly increase the switchover time between XCS and CXI. It is critical that the XCS design allows for rapid changes to let the beam pass to the CXI station so that CXI can take the beam rapidly when it is available. There is a concern that more beamtime will be given to XCS versus CXI due to the time and effort that may be required to swap the XCS configurations. Slow reconfiguration of the XCS beamline should not be allowed to prevent beam from being used in the CXI hutch.

3- Discussion of the new CXI layout

A new layout for CXI was proposed to the team leaders. In this layout, the focal planes of the 2 KB mirrors are separated instead of being the same. This was found to have many advantages including better protection of the mirror vacuum from contamination, bringing the multiple CXI beams closer together and allowing for 2 experiments to be run in series. The team leaders are in agreement that this is a proper way to design the instrument.

4- Scope Addition/ Reduction Priorities

The priorities for scope addition and reduction were discussed. The priority list for additions is

1. Cryo-goniometer
2. Second Full Detector
3. Populating the Inside of the 0.1 micron Sample Chamber
4. Pump Laser System
5. Wavefront Sensor with a fast Direct Detection Detector
6. X-ray Focusing Lenses

The team leaders feel that no scope reduction is justifiable. The possibility of installing the 0.1 micron KB System on operations money was discussed as a way to save money for the LUSI project if necessary.

Coherent X-ray Imaging Instrument

Team Leaders Meeting

October 17, 2008

LUSI Status Update

- Project Status
- Directorate Reorganization
- Budget
- Schedule

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LUSI Major Accomplishments March-October

- Decision to include all LUSI scope (including XCS) in a single CD-2 made in April
- Completed a working Baseline in April and began status reporting
- Exercised the change control process May-July
  - Included updated XCS cost & schedule
  - Included XCS large offset monochromator
- Completed CD-2 Lehman Review in August
- Completed post-CD-2 responses to recommendations – ESAAB scheduled for Oct 22.

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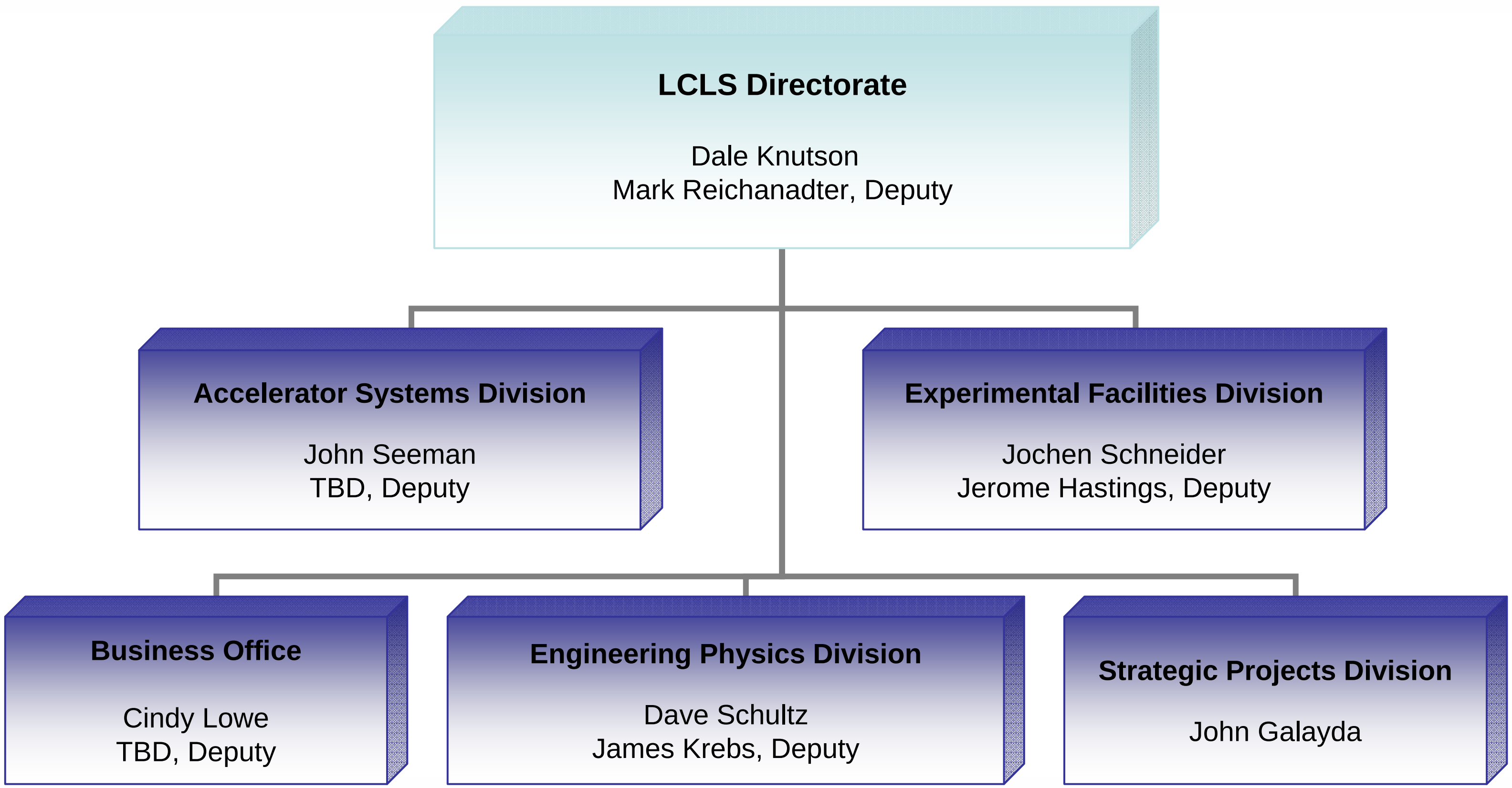
LCLS Directorate Organization



LUSI Incorporated into LCLS Directorate

LCLS STRATEGIC PROJECTS DIVISION

LCLS Strategic Projects Division
John Galayda – Division Director

Michael Scharfenstein – ES&H
Darren Marsh – QA
Helen O'Donnell – Administrative Support

LCLS Construction Project
John Galayda – Project Director
Mark Reichanadter – Deputy Project Director
Jess Albino – Associate Project Director for Civil Cinstruction

LUSI MIE Project
Tom Fornek – Project Manager
TBD – Deputy Project Manager

LUSI uses LCLS Directorate Services (ES&H, QA, PMCS, Finance)

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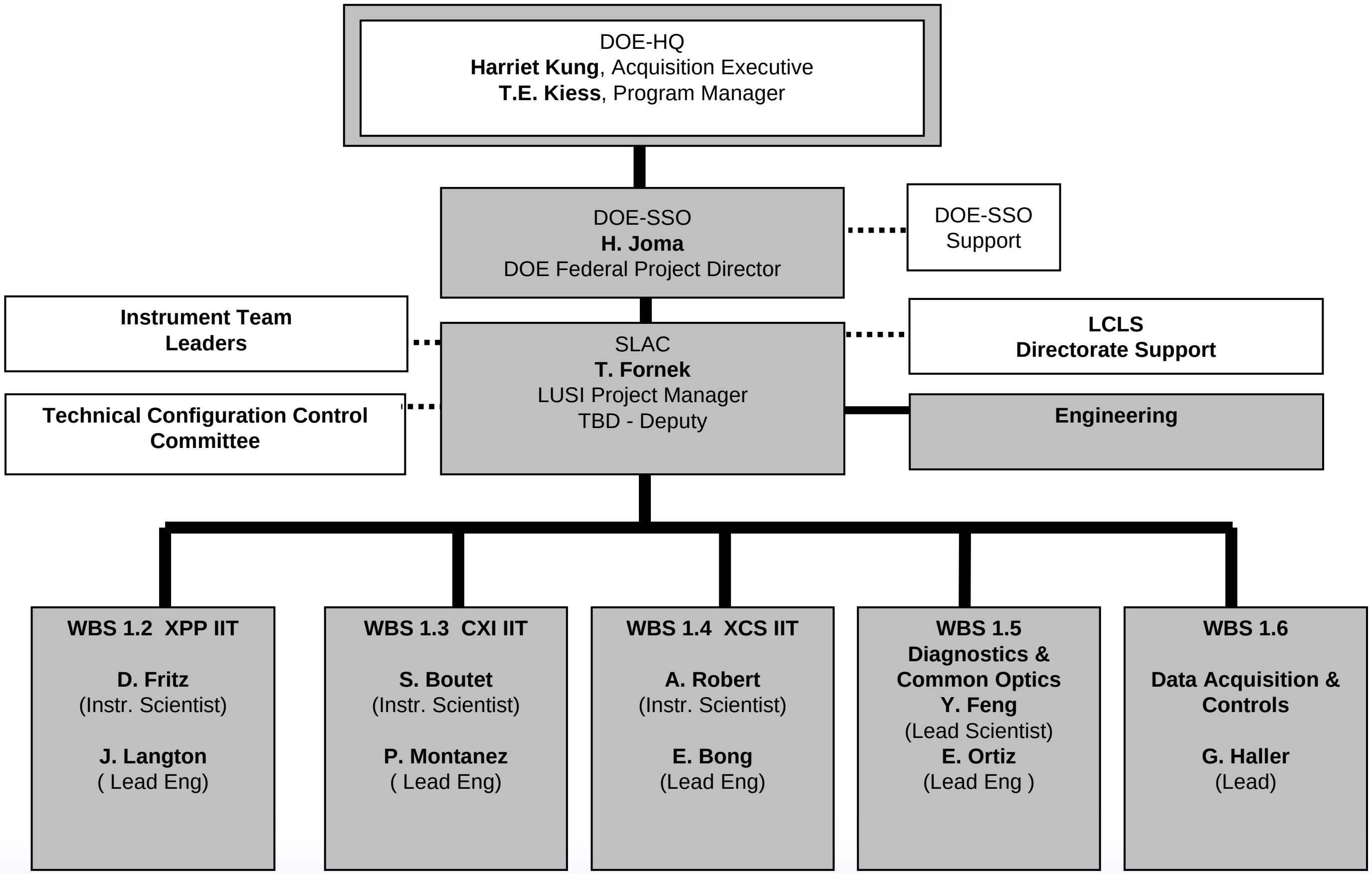
LUSI integrated Project team



LUSI Cost Baseline[1]

WBS	Description	CD-2 Est. ($M)
1.1	Project Management	5.5
1.2	X-ray Pump Probe (w/BNL)	5.9
1.3	Coherent X-ray Imaging	9.5
1.4	X-ray Correlation Spectroscopy (w/BNL)	7.7
1.5	Diagnostics & Common Optics	6.4
1.6	Controls & Data Acquisition	7.1
	Contingency	13.0
2.0	Other Project Costs	4.9
LUSI Total Project Costs		60.0

Note 1 – Pending DOE Approval

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LUSI Funding Profile ($M)

	Prior Yrs	FY07	FY08	FY09	FY10	FY11	FY12	Total
TEC		0.50	6.00	15.00	15.00	13.50	5.10	55.10
OPC	3.40	1.50						4.90
Total	3.40	2.00	6.00	15.00	15.00	13.50	5.10	60.00

	Q1	Q2	Q3	Q4
Planned	1.5	1.5	6	6
Expected	5.5		4.5+	

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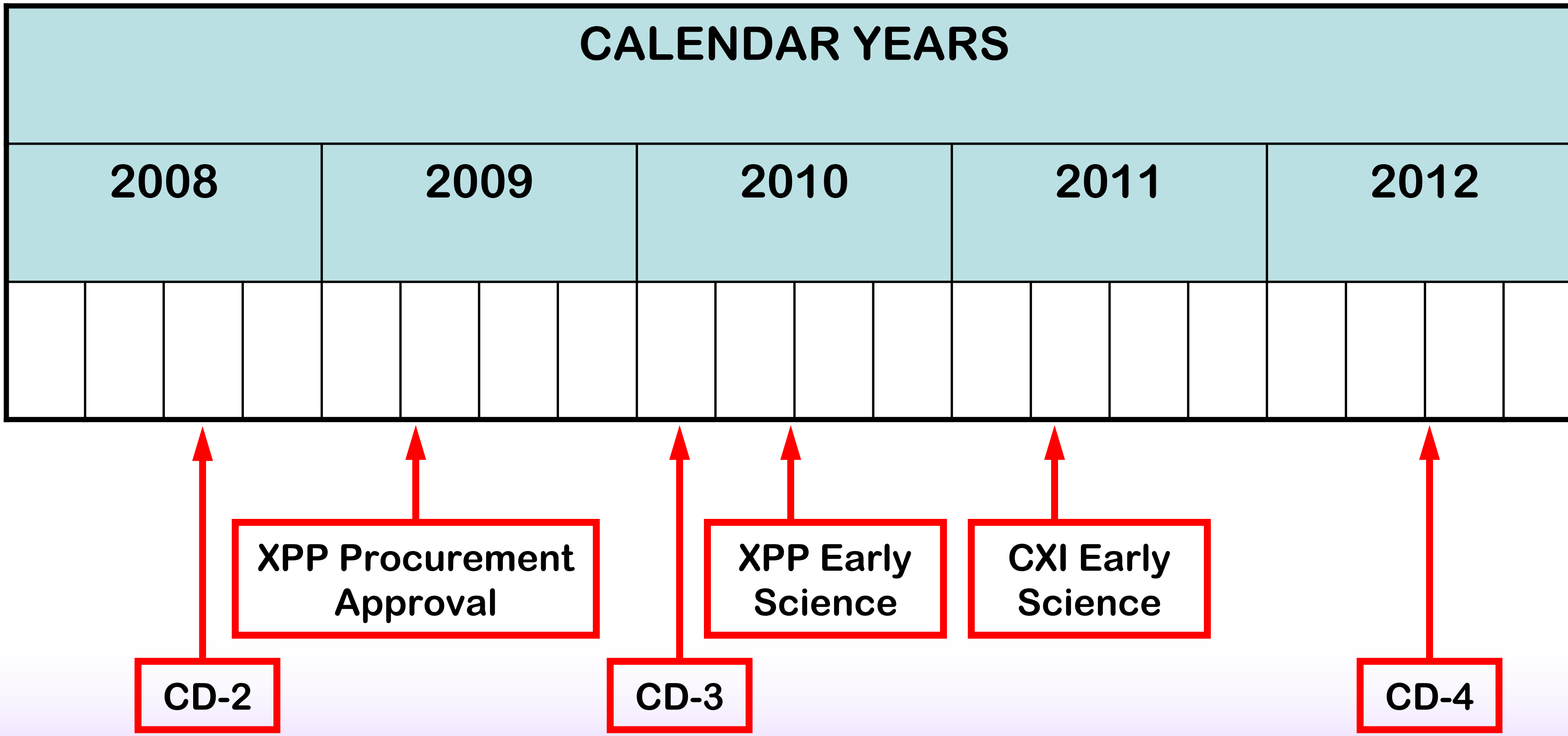
LUSI Schedule Baseline



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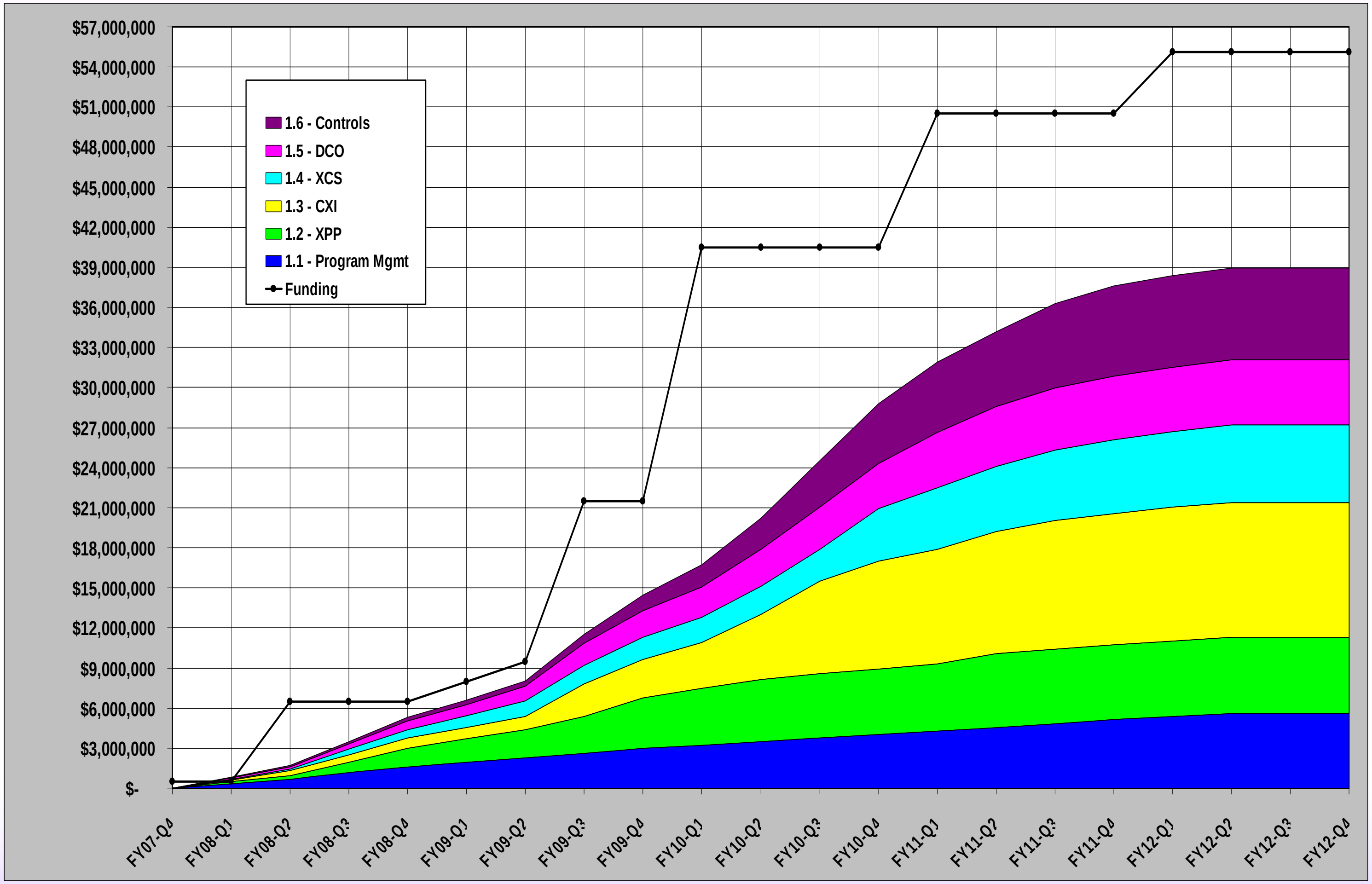
BA Plan & BCWS to Fit BA Profile



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CXI Major Accomplishments

- Added 1 micron sample chamber to reduce project risk
- Conducted LUSI's first advance procurement technical review
  - CXI 1 micron mirror system - October 8
- Developed one micron K-B mirror system mechanical support system concept
- Provided hutch 4 specification input to LCLS Conventional Facilities for FEH hutch design
- Cornell detector system progressing well
  - Support system design developed
- Satellite Workshop held Friday, October 17
  - " Application of Coherent X-rays at the LCLS"

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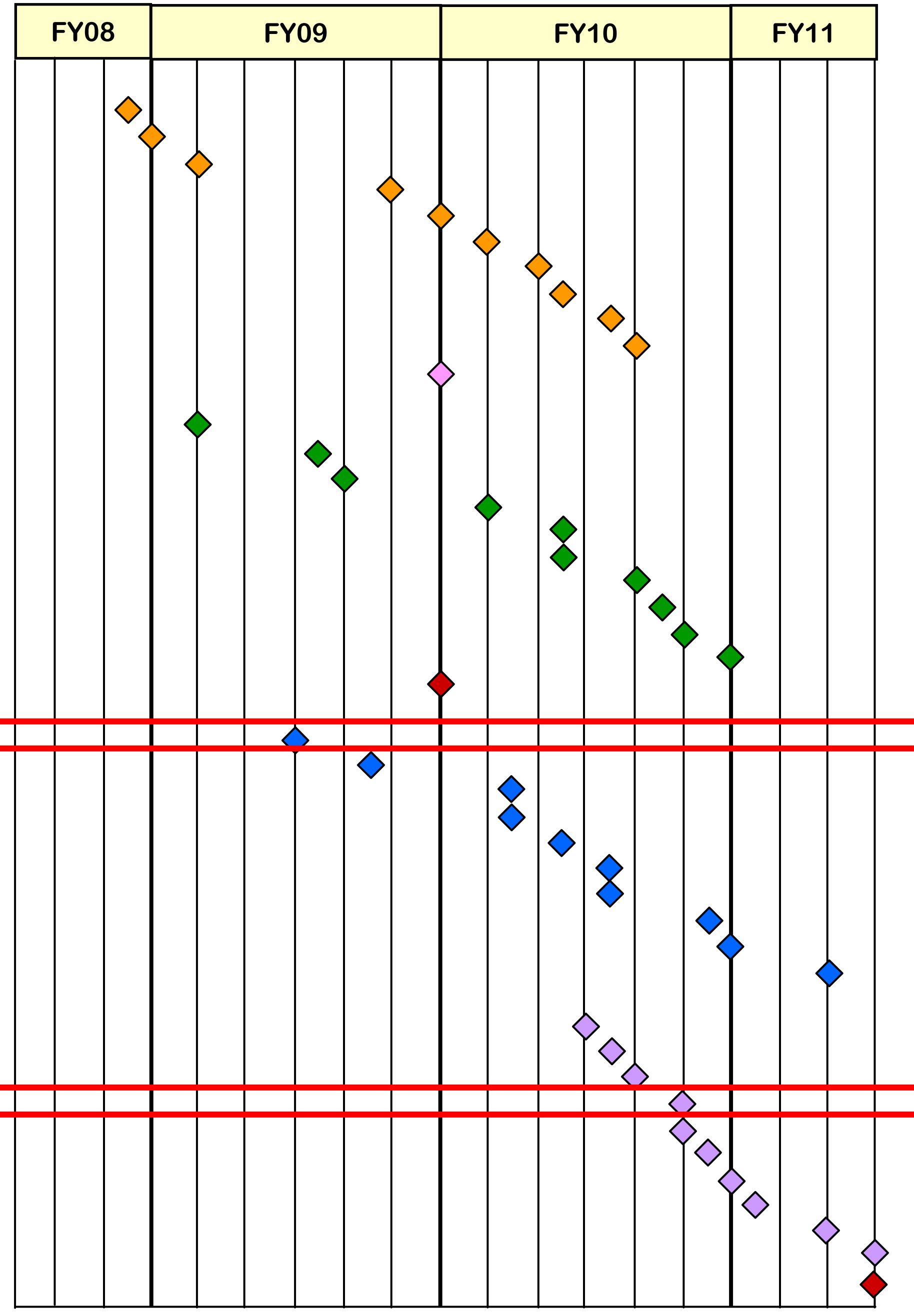
- Preliminary Design Reviews
  - Detector Stage – September 2008
  - Reference Laser – October 2008
  - 1 micron Sample Chamber – December 2008
  - Particle Injector – August 2009
  - 1 micron KB System – October 2009
  - 1 micron Instrument Stand – December 2009
  - 0.1 micron KB System – February 2010
  - 0.1 micron Sample Chamber – March 2010
  - 0.1 micron Instrument Stand – May 2010
  - Ion TOF – June 2010
- Final Instrument Design Review – October 2009
- Final Design Reviews
  - Reference Laser – December 2008
  - Detector Stage – May 2009
  - 1 micron Sample Chamber – June 2009
  - Particle Injector – December 2009
  - 1 micron KB System – March 2010
  - 1 micron Instrument Stand – March 2010
  - 0.1 micron KB System – June 2010
  - Ion TOF – July 2010
  - 0.1 micron Instrument Stand – August 2010
  - 0.1 micron Sample Chamber – October 2010
- Project Ready for CD-3 - October 2009
- Award PO
  - 1 micron KB System – April 2009
  - 0.1 micron KB System – July 2009
  - 1 micron Sample Chamber – January 2010
  - Detector Stage – January 2010
  - Reference Laser – March 2010
  - 1 micron Precision Instrument Stand – May 2010
  - Particle Injector – May 2010
  - Ion TOF – September 2010
  - 0.1 micron Precision Instrument Stand – October 2010
  - 0.1 micron Sample Chamber – February 2011
- Receive
  - 1 micron Sample Chamber – April 2010
  - Reference Laser – May 2010
  - Detector Stage – June 2010
  - 1 micron KB System – August 2010
  - Reference Laser – August 2010
  - 1 micron Precision Instrument Stand – September 2010
  - Ion TOF – October 2010
  - 0.1 micron KB System – November 2010
  - 0.1 micron Precision Instrument Stand – February 2011
  - 0.1 micron Sample Chamber – April 2011
- Project Ready for CD-4 - April 2011



All dates are early finish

CXI Design Updates

- Far Experimental Hall Design
- Component Designs

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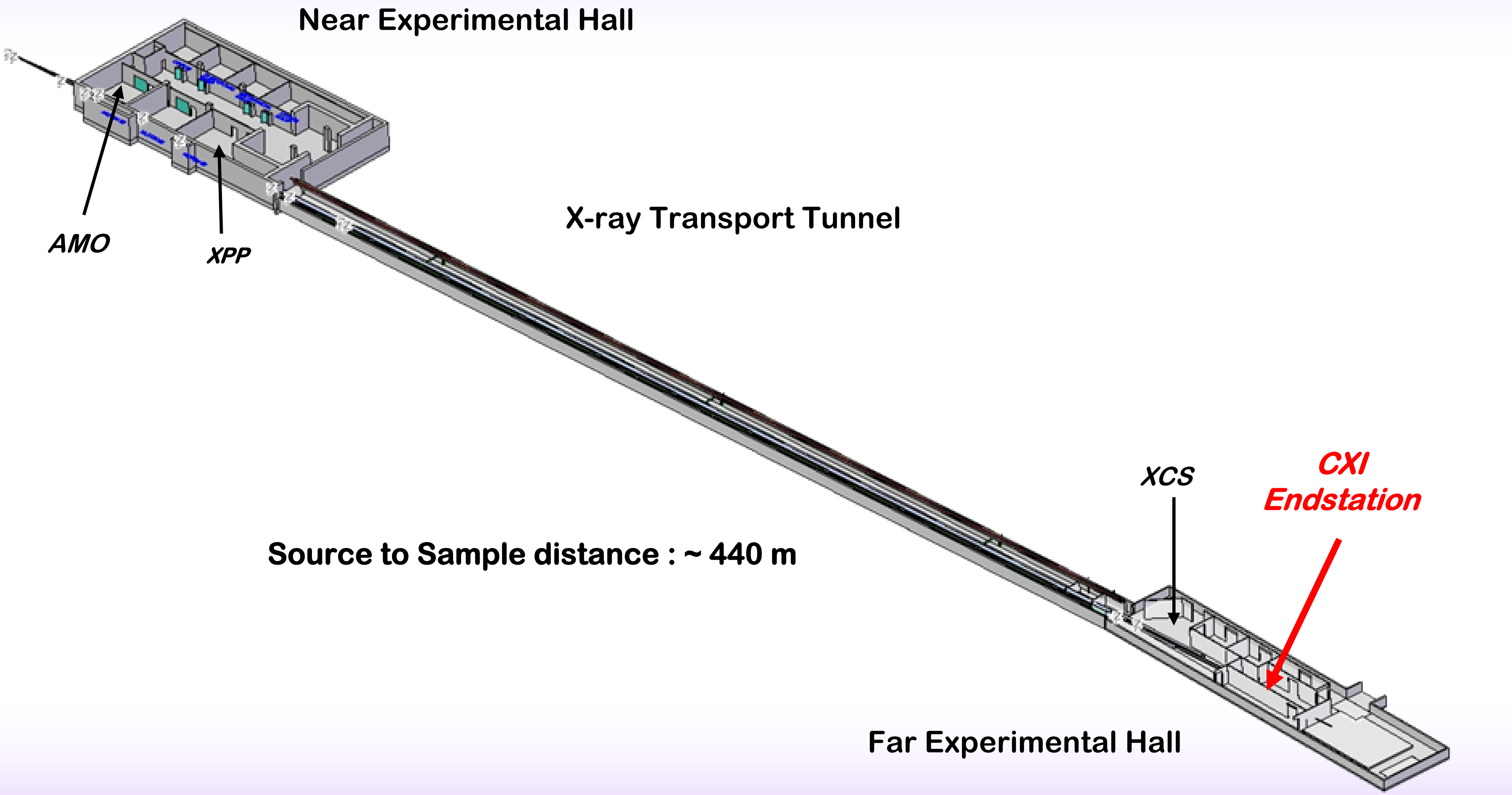
CXI Instrument Location



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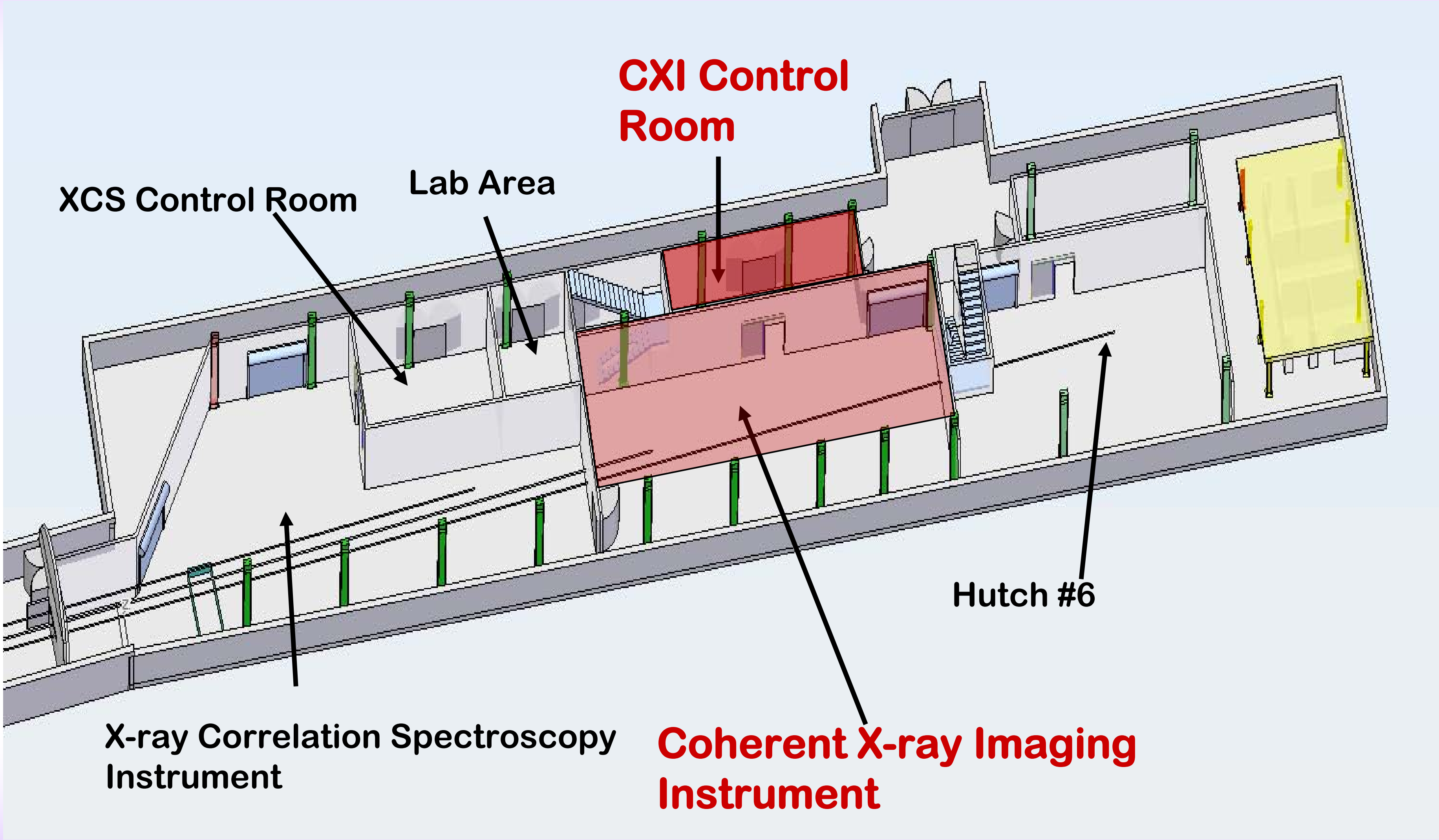
Far Experimental Hall



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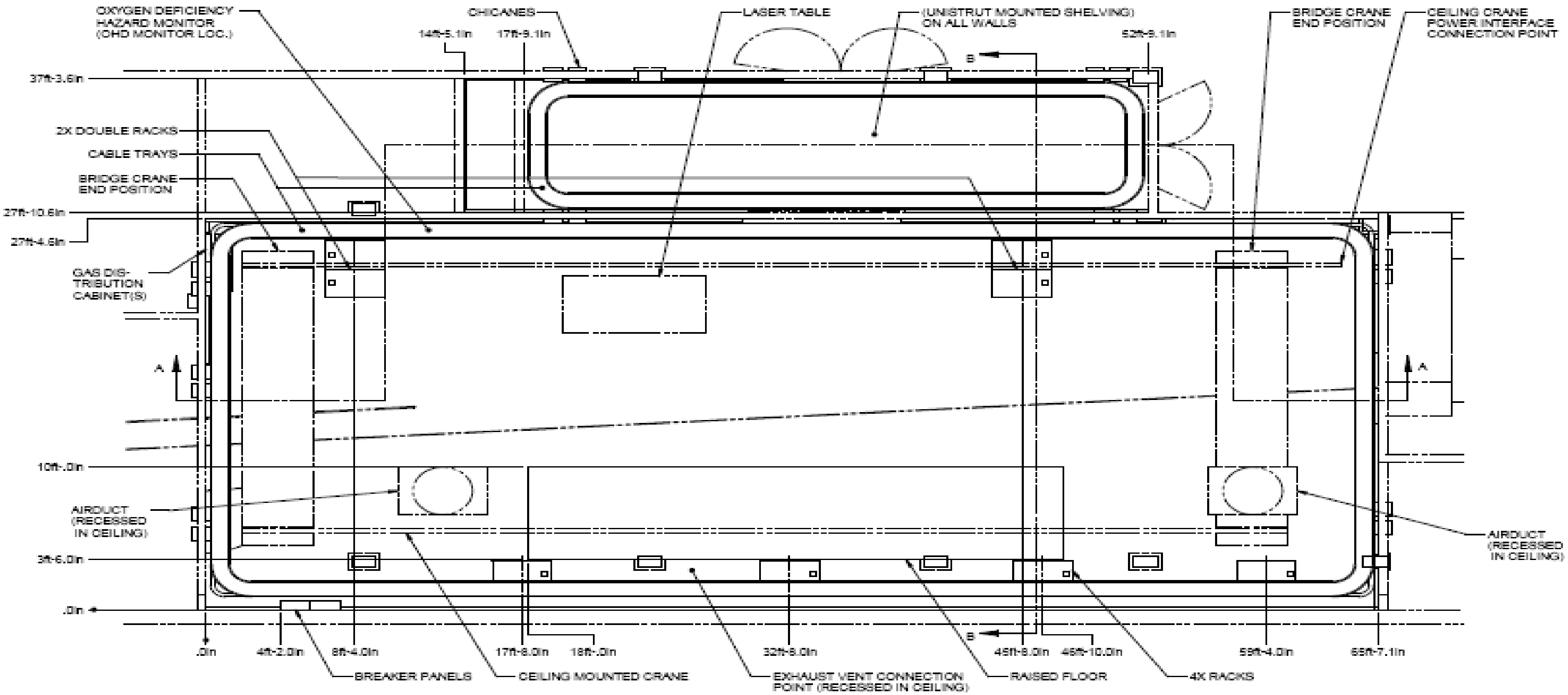
FEH Hutch 5



- Dimensions
  - Hutch
    - 20 x 8.35 m
  - Control Room
    - 10.67 m x 2.87 m

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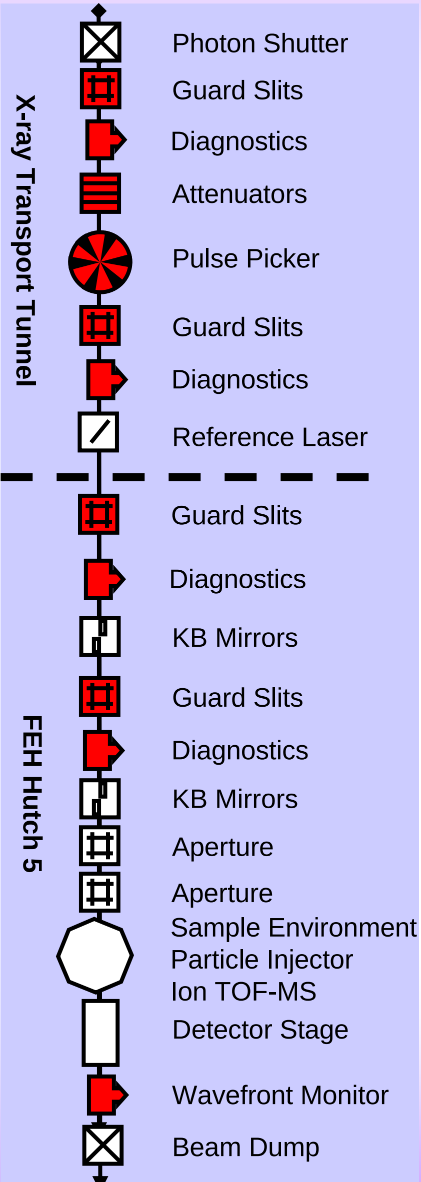
CXI Components



Requirement	Device
Remove X-ray beam halo	X-ray Guard Slits/Apertues
Tailor X-ray intensity	Attenuators
Tailor X-ray repetition rate	Pulse Picker
Characterize X-ray pulse intensity	Intensity Monitor
Characterize X-ray spatial profile	Profile Monitor
Characterize X-ray pulse intensity before the sample on every shot	Non-destructive Intensity Monitor
Characterize X-ray focus	Wavefront Monitor
Align experiment without X-ray beam	Reference Laser
Maximize X-ray flux on sample Tailor focal spot size to the sample	Focusing optics 1 micron Kirkpatrick-Baez Mirrors 0.1 micron Kirkpatrick-Baez Mirrors
Minimize air scatter and background Position sample and final apertures	Sample environment
Position sample environment	Instrument Stand
Deliver single particles to the X-ray beam in the gas phase	Particle Injector
Measure X-ray scattering pattern	2D X-ray Detector (Utilizing the LCLS Detector)
Position X-ray area detector	Detector Stage
Analysis of sample fragments after Coulomb explosion	Ion Time-of-Flight

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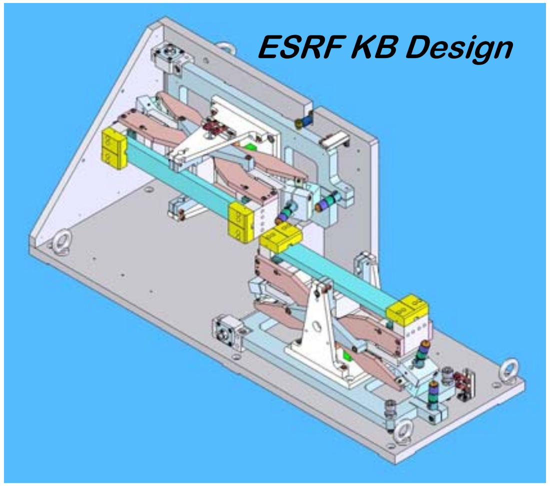
KB Mirrors

- CXI 0.1µm KB system
  - 0.1µm spot size for samples less than 50nm in size
  - State of the art focusing optic
  - A few potential vendors identified
    - Osaka U/JTEC – actively pursuing and pushing the technology
    - WinlightX
    - Zeiss
    - Accel
  - Pre-figured mirrors are the chosen solution
  - Physics Requirements Document (PRD) released June 2008
  - Vendor Preliminary Design Review (PDR) scheduled for November 2009
  - Overall system PDR scheduled for February 2010
  - ~$1,400K



- CXI 1µm KB system
  - 1µm spot size for samples between 50nm and 1µm
  - Technology is proven
    - Mimura et al., Review of Scientific Instruments 79, 083104 (2008)
  - Pre-figured mirrors are the chosen solution
  - PRD released June 2008
  - Engineering Specifications Document (ESD)/ Technical Specification completed
  - Draft of ESD sent to multiple vendors for Request for Information (RFI):
    - Engineering feasibility study
    - Budgetary Inquiries
  - Vendor PDR scheduled for August 2009
  - Overall system PDR scheduled for October 2009
  - ~$1,390K ($970,000 in long lead procurement – April 2009)

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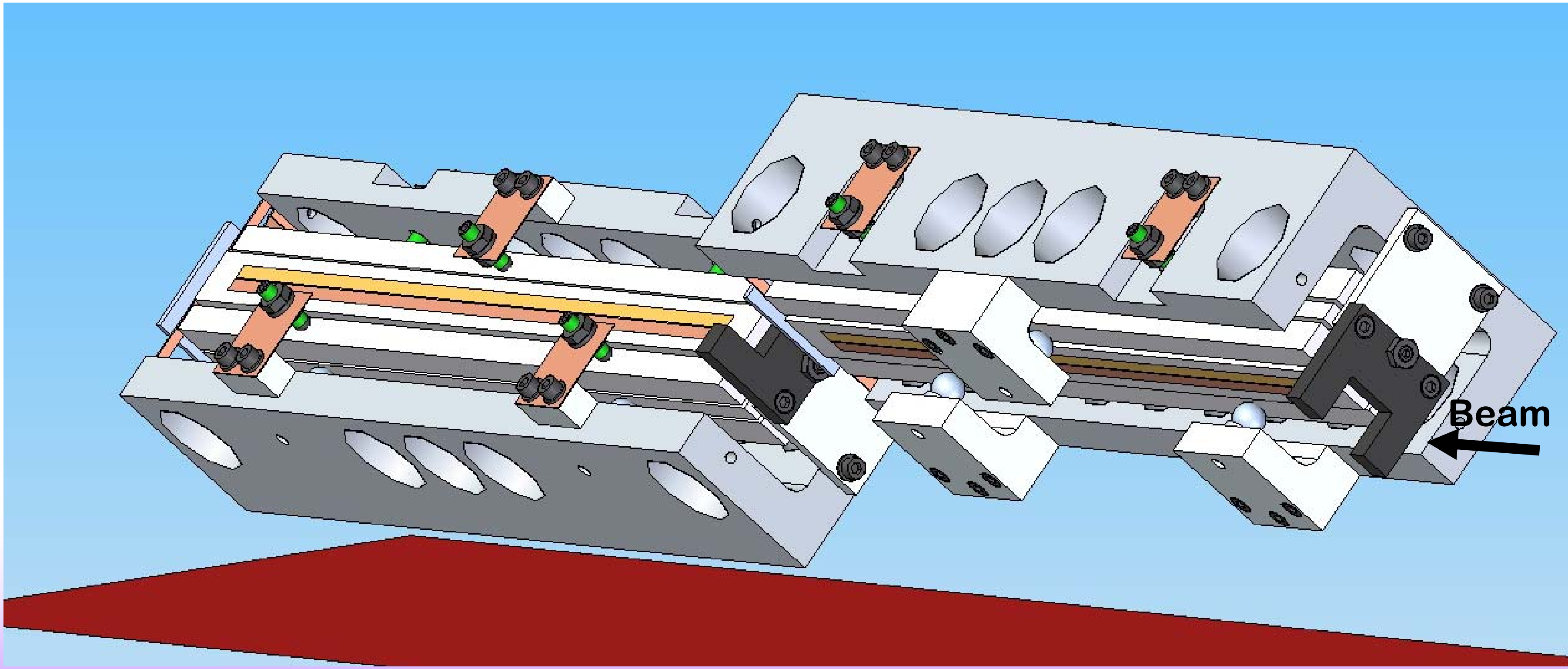
Kirkpatrick-Baez Mirrors

- High reflectivity (>75%) over 2-11 keV range
- Highly polished
  - Preserve the coherence properties of the beam
- Resistant to radiation damage
  - Coated with SiC
- Mirror length = 350 mm
  - Accepts the full beam
- 3.4 mrad incidence angle
- Ultra-high vacuum (<10^{-9} Torr)
- Rotated by 45 degrees
  - Deflect the beam in the horizontal plane only



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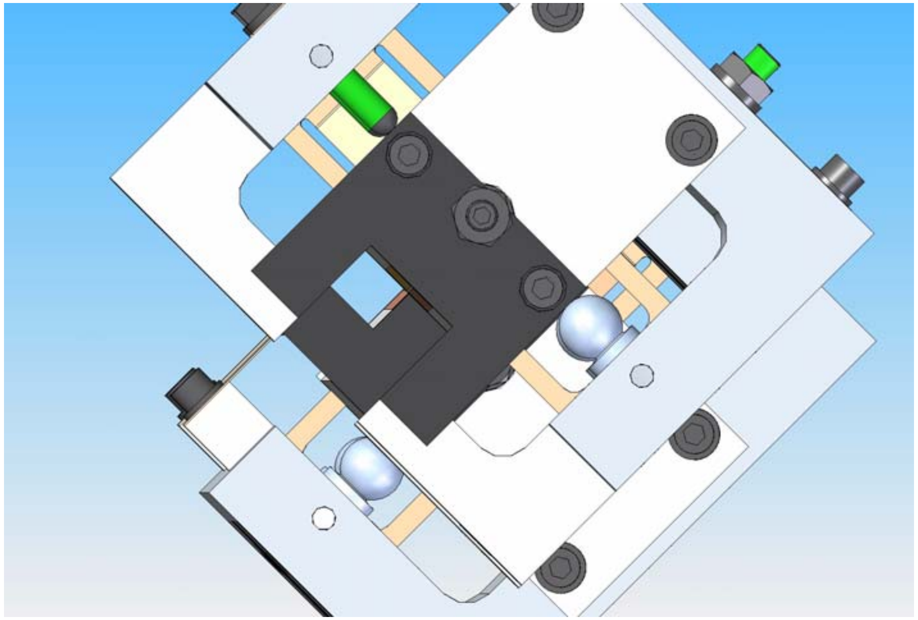
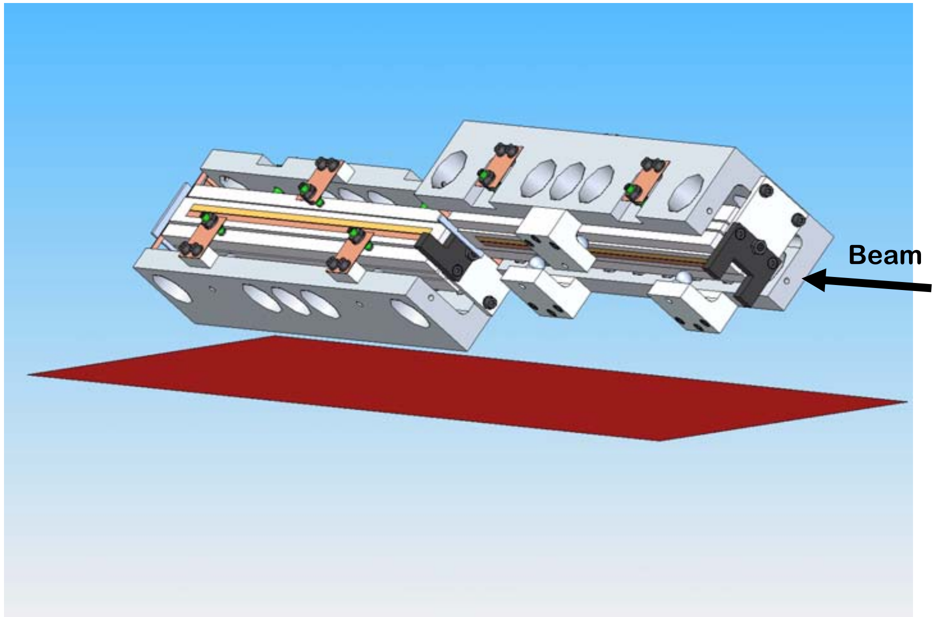
Orientation (45 degrees)





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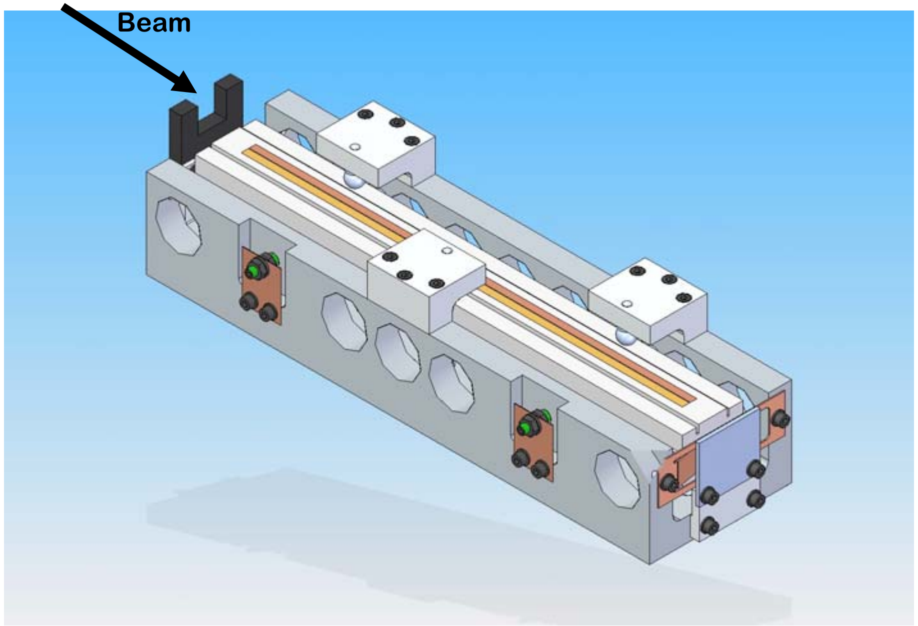
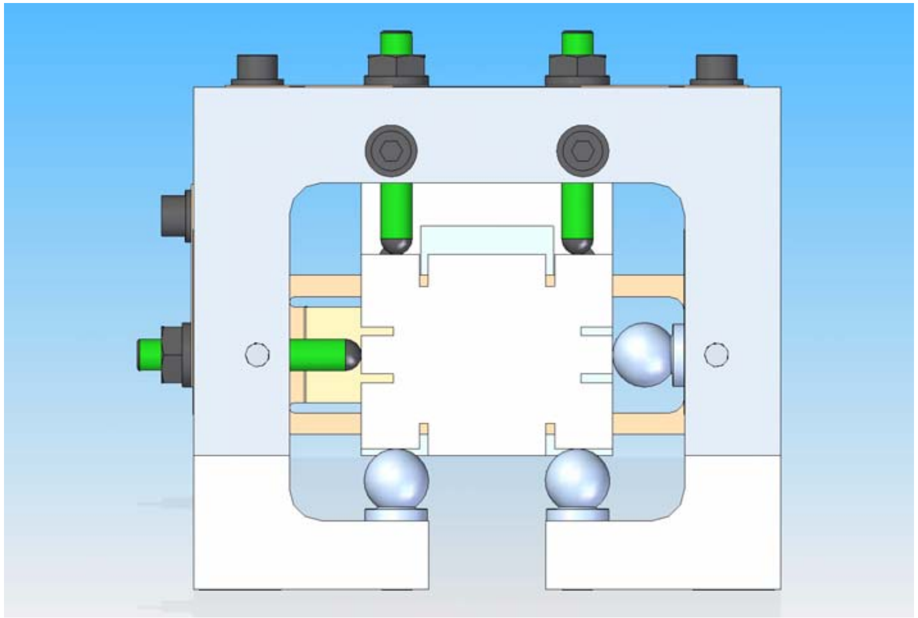
KB Mounting





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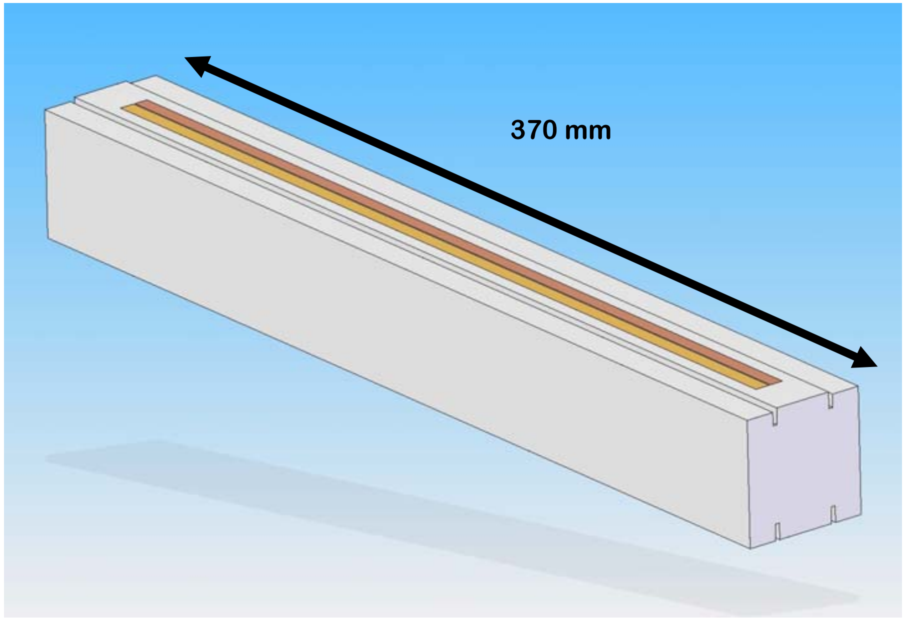

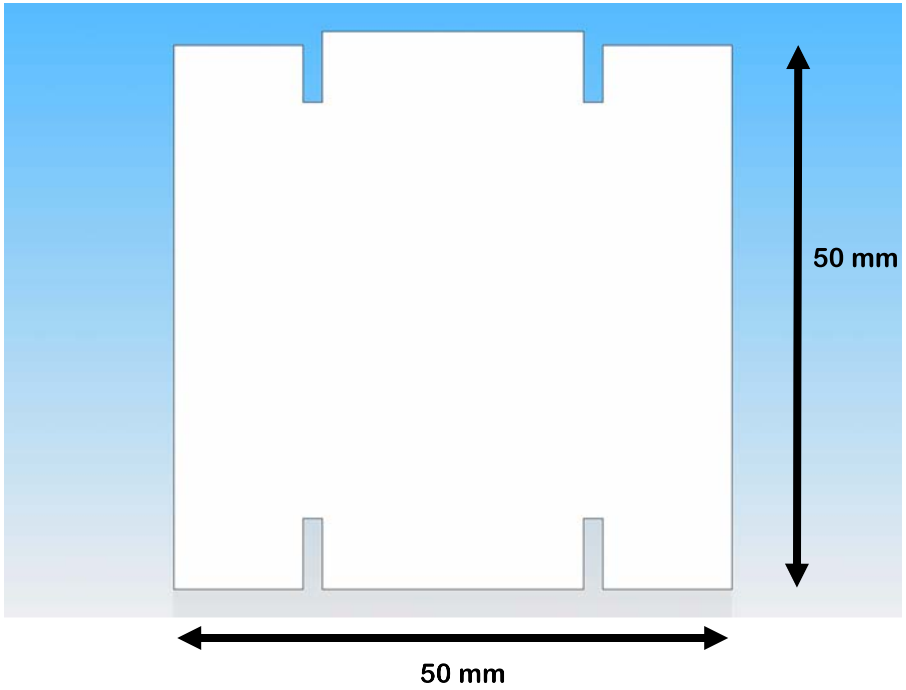

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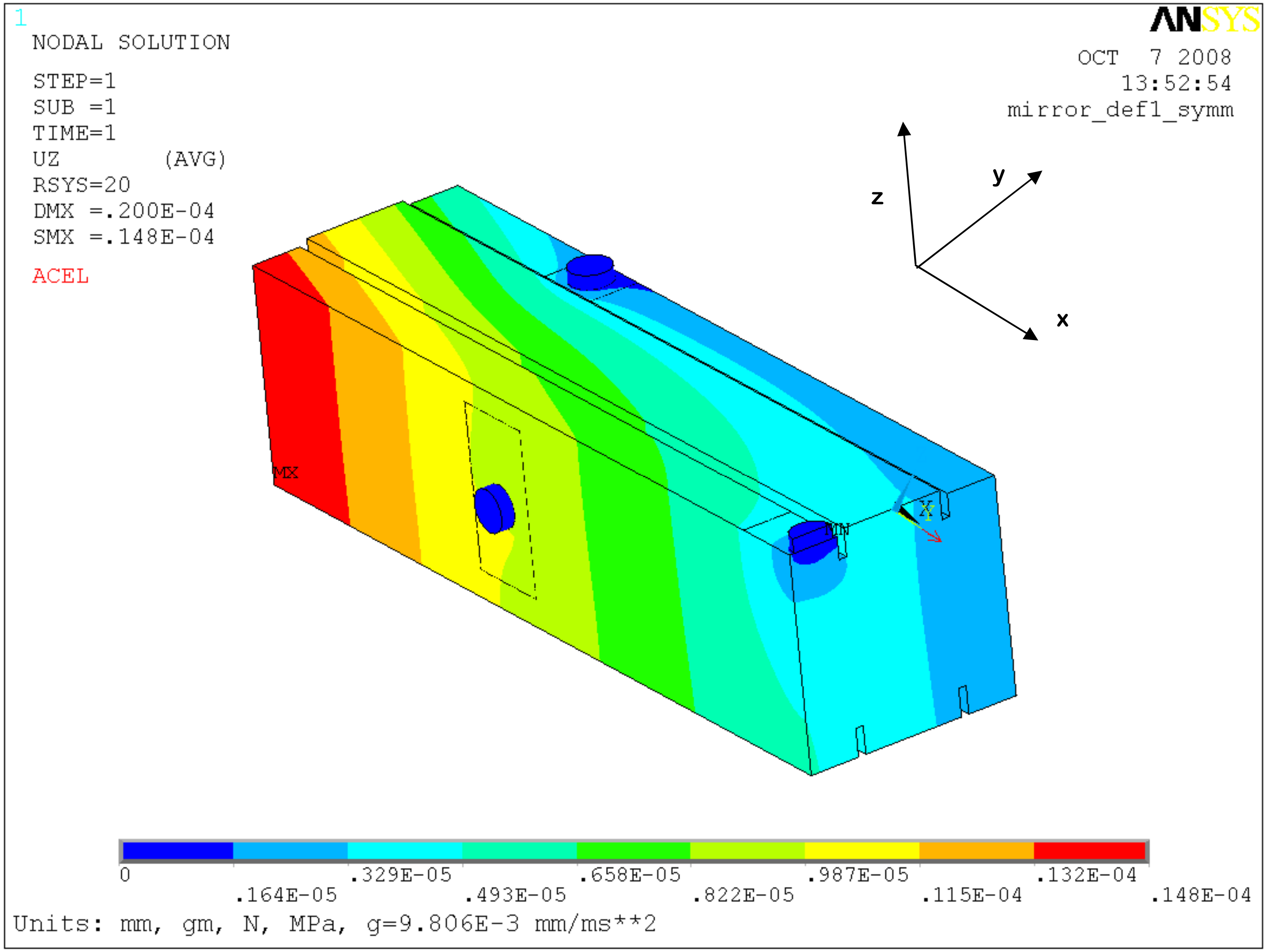
ANSYS Analysis



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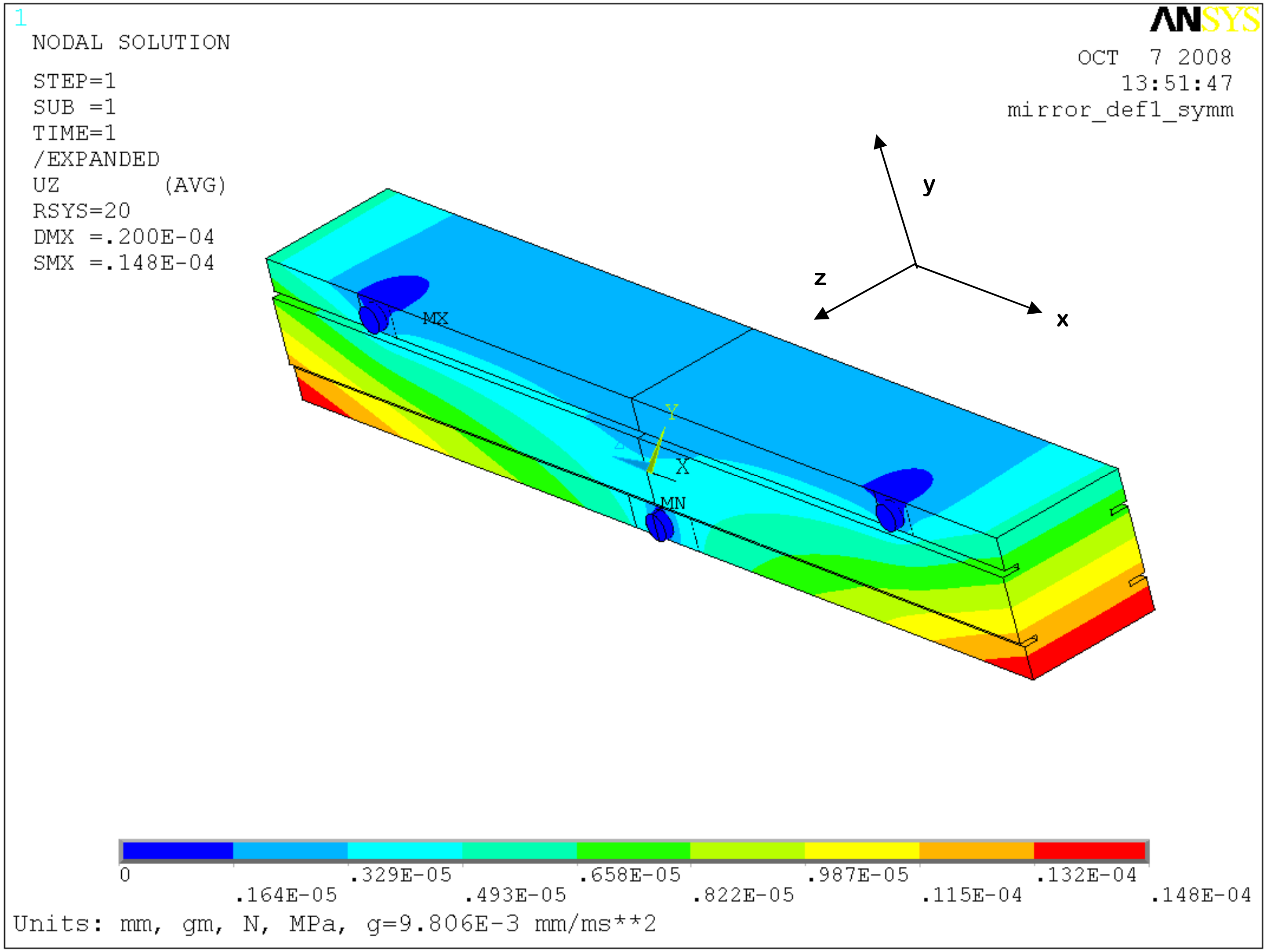

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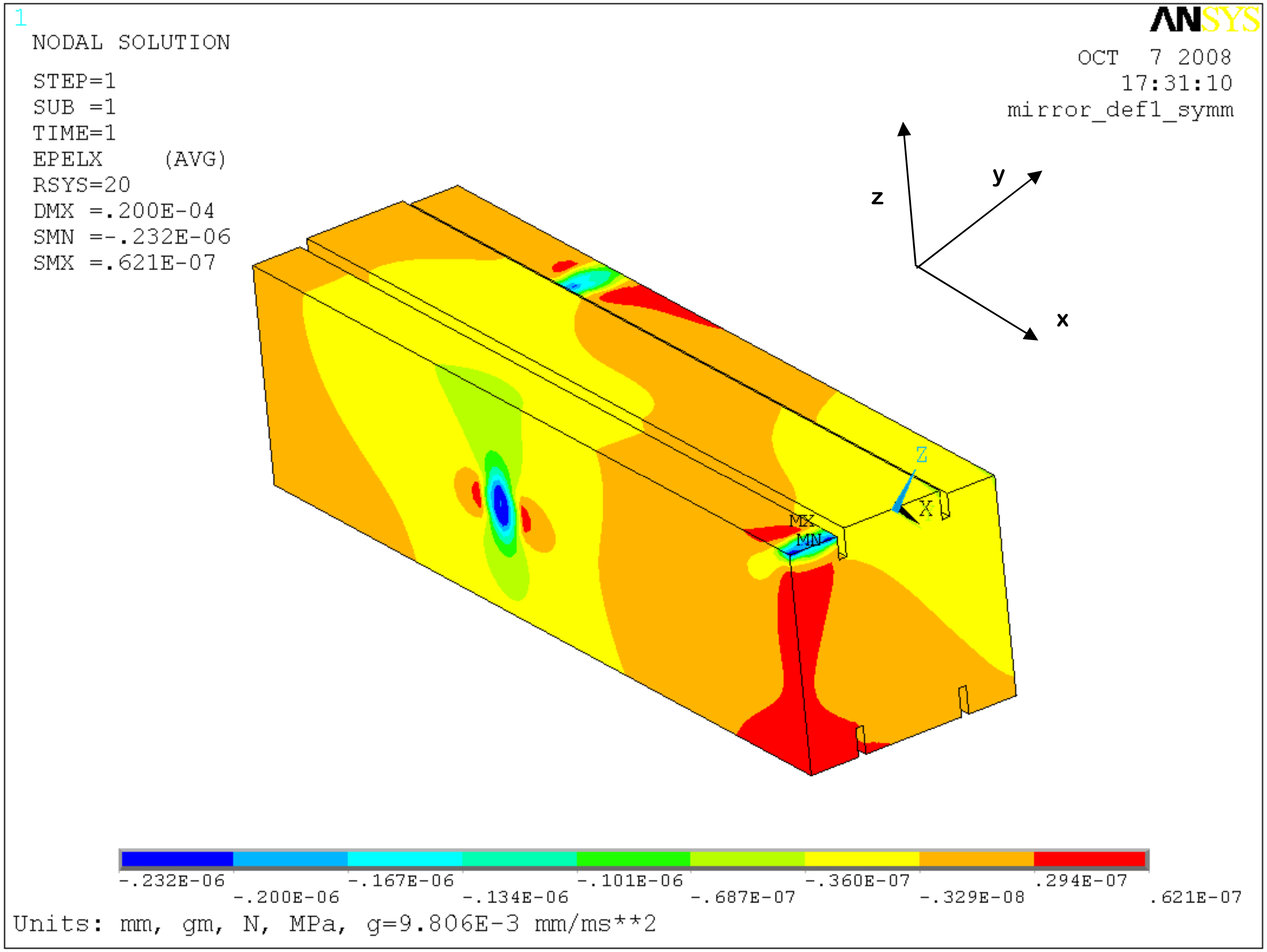

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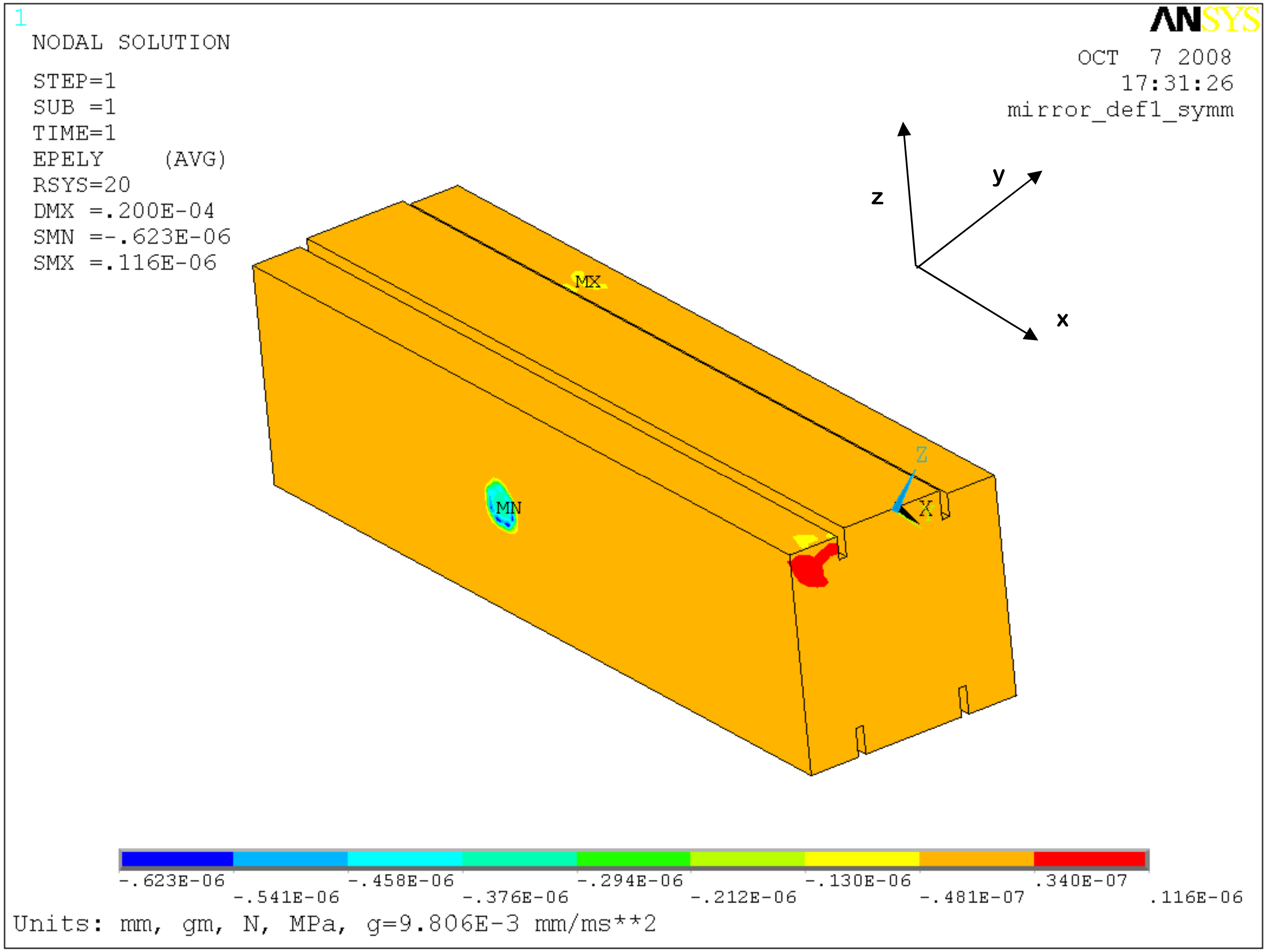
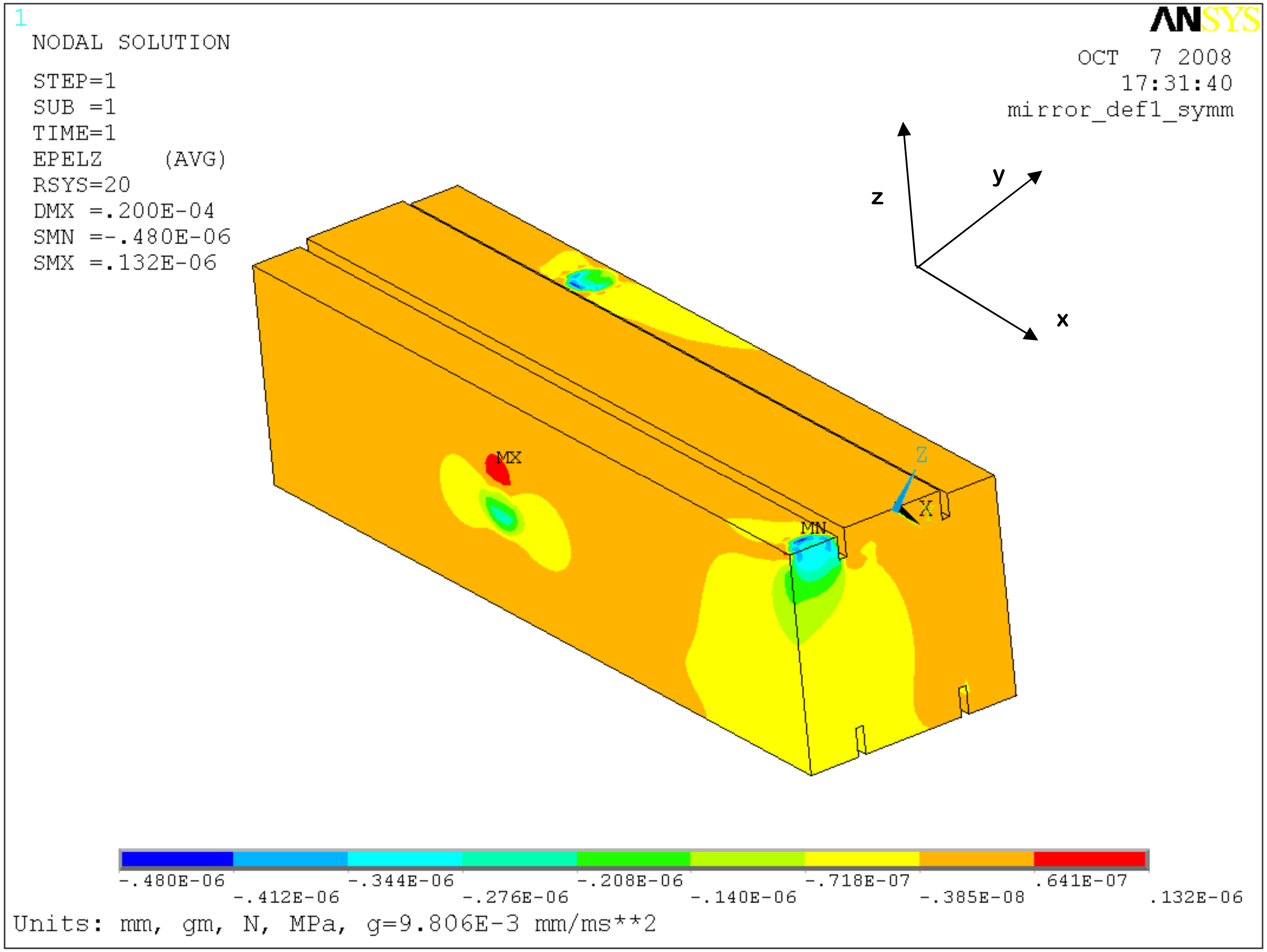


ANSYS Analysis



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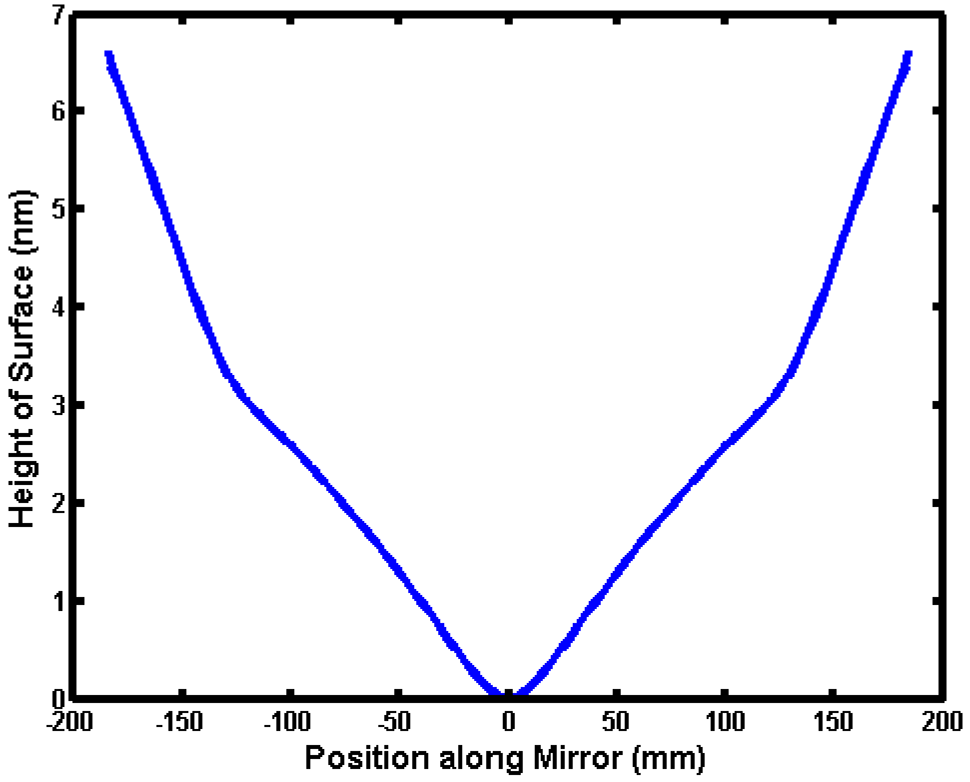
Surface displacement



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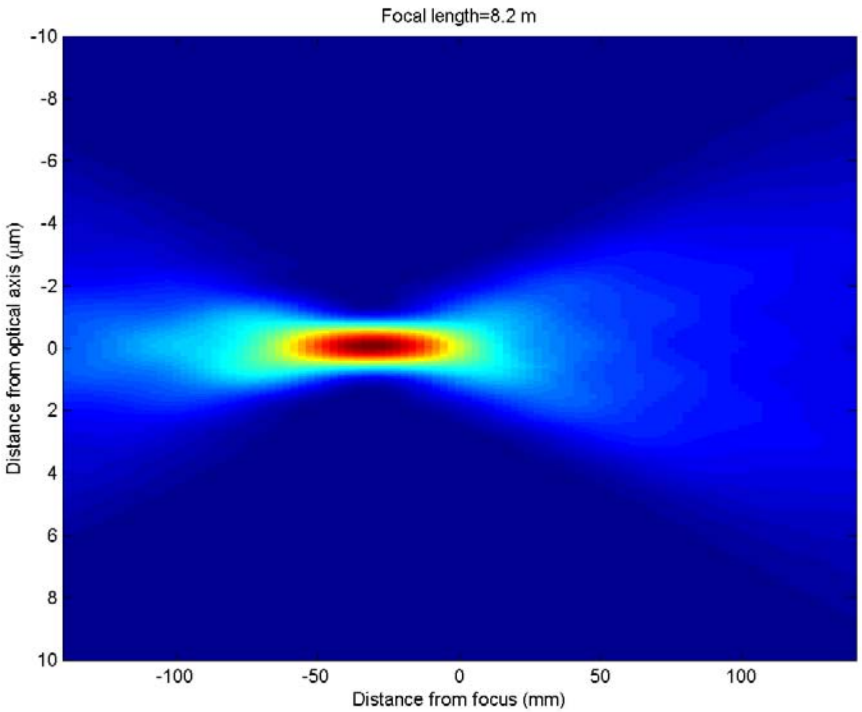
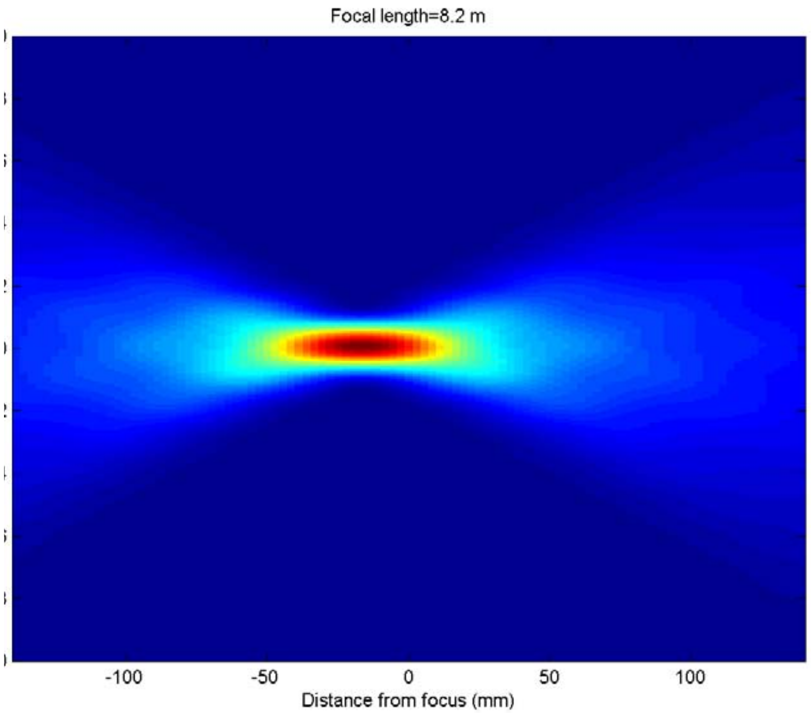
Wavefront Simulations

With Distortions



Without Distortions



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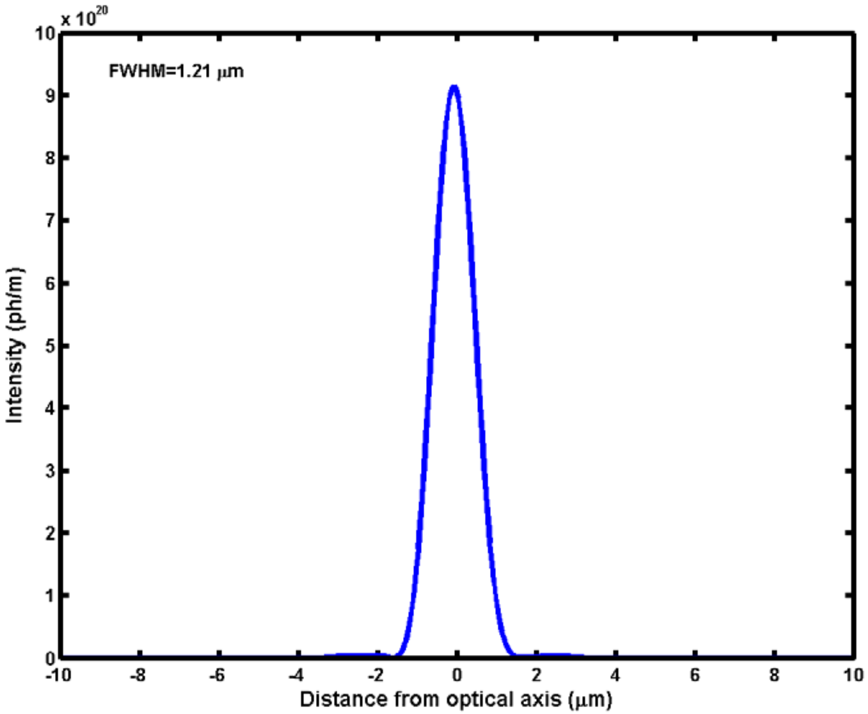
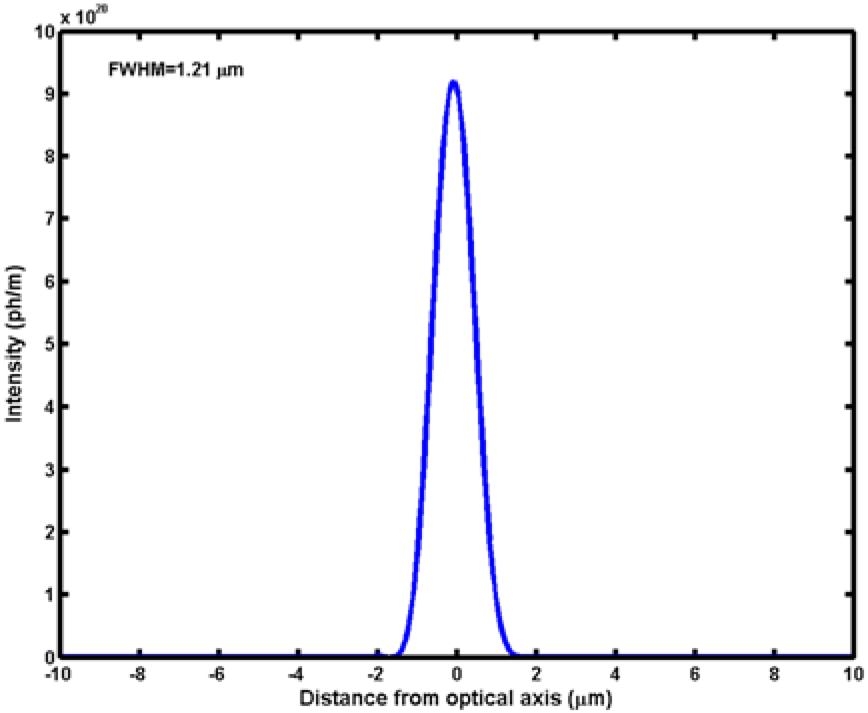
Wavefront Simulations

With Distortions



Without Distortions



- Gravity distortions only add small shoulders to the beam and shorten

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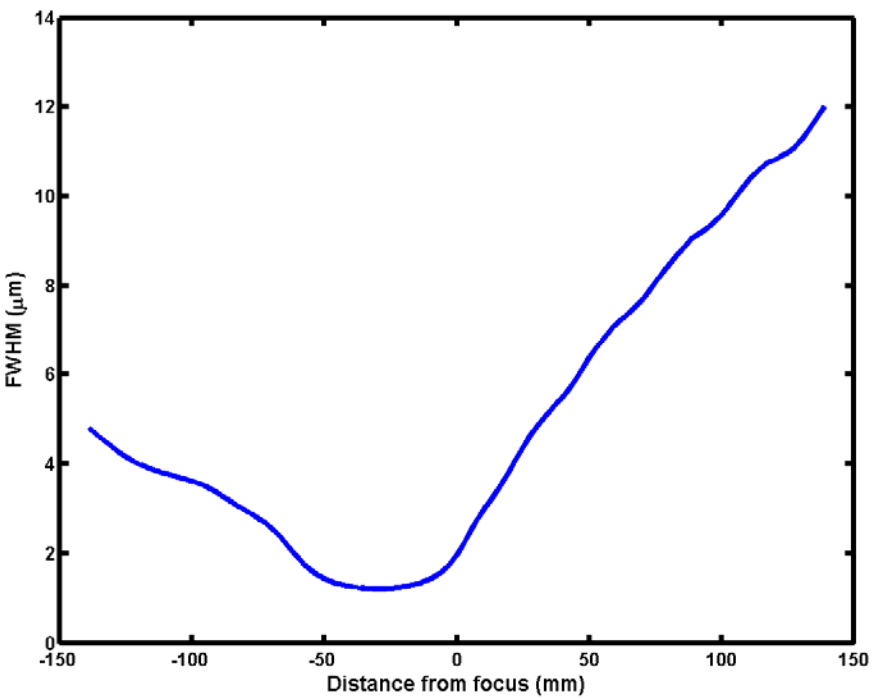
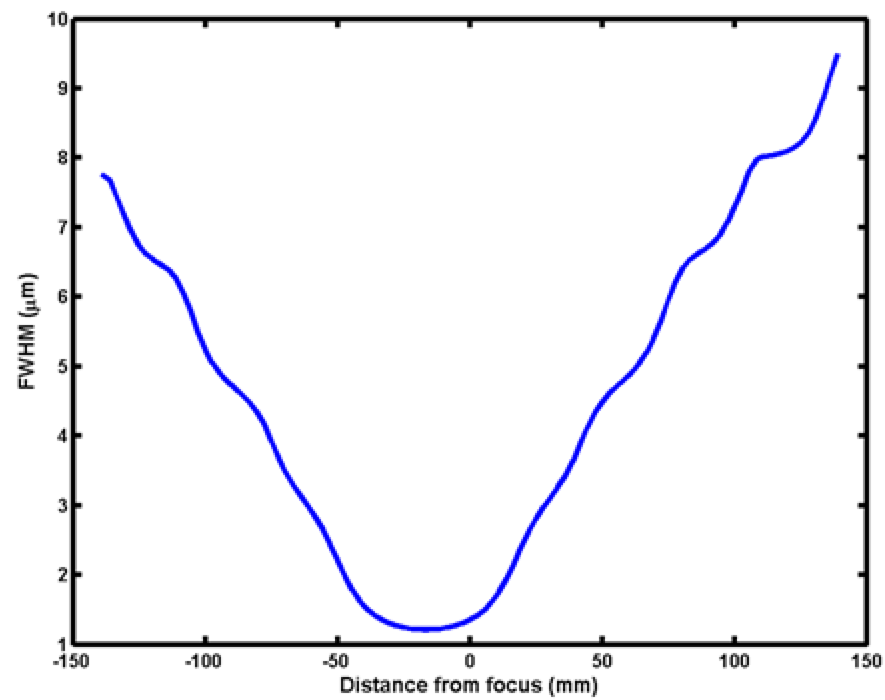
Wavefront Simulations

With Distortions



Without Distortions



- **Focal length of mirror is reduced by 0.2 % due to gravitational distortions**

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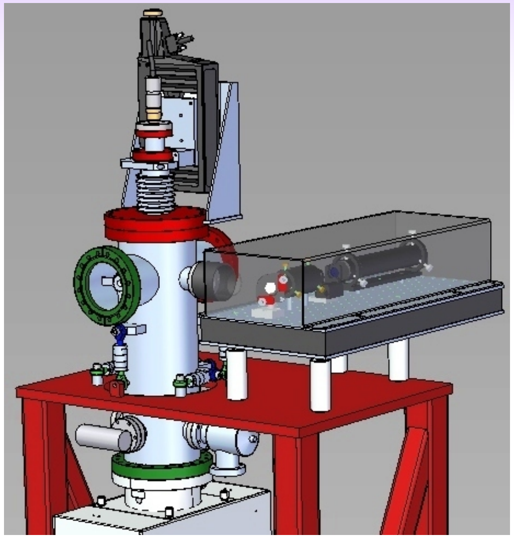
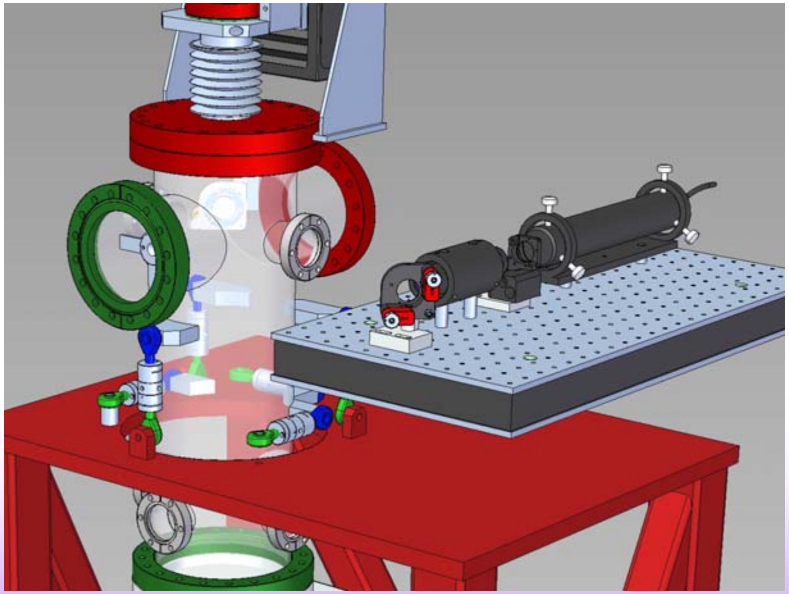
Engineering/Design Status (4)

- **CXI Reference Laser**
  - **Used to align components without requiring FEL beam**
  - **Pointing stability critical**
    - If laser is installed in the tunnel (50 m away)
  - **Preliminary design nearly complete**
  - **Detailed engineering analysis ongoing to ensure pointing stability**
  - **PRD released June 2008**
  - **ESD draft completed (in review)**
  - **PDR scheduled for October 2008**
  - **~$115K**





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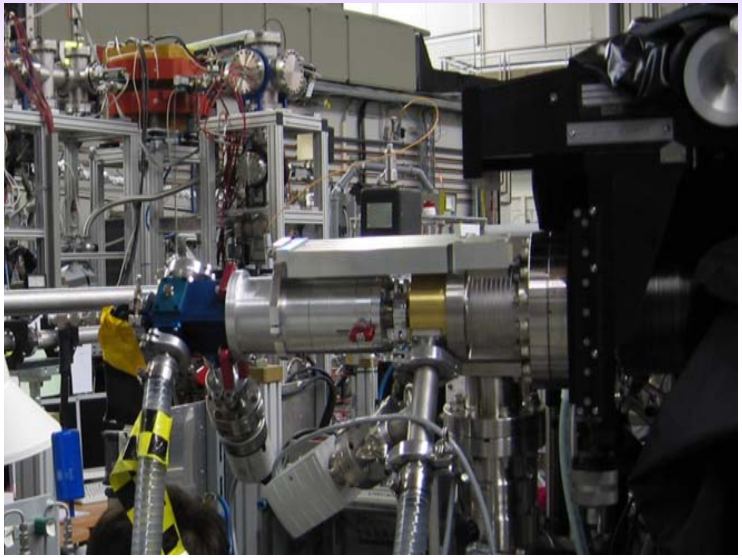
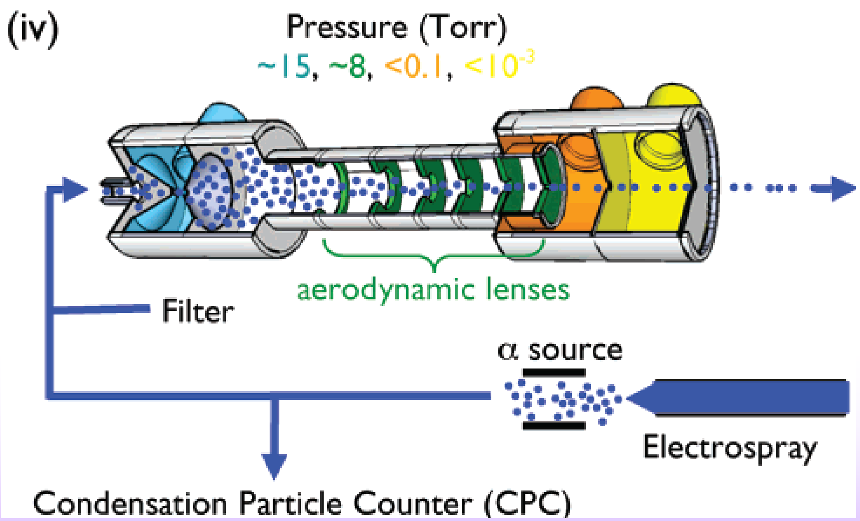
Engineering/Design Status (5)





- Particle Injector
  - Injector design exists from LLNL
  - LUSI project will advance the design
  - Recently hired LLNL physicist who was primarily responsible for the design, fabrication and testing of the injector
  - Work on the injector scheduled to begin July 2008
  - PRD draft exists
  - PDR scheduled for August 2009
  - ~$1,005K
  - Plan to revive the LLNL MOU
    - Greatly reduced funding for LLNL
      - $500K total over 3.5 years
    - Should reduce the SLAC engineering effort to partially offset MOU cost
  - LLNL will
    - Provide existing injector drawings
    - Move injector prototype to SLAC
    - Provide support for design, fabrication, assembly, testing and installation
    - Access to aerodynamic lens software

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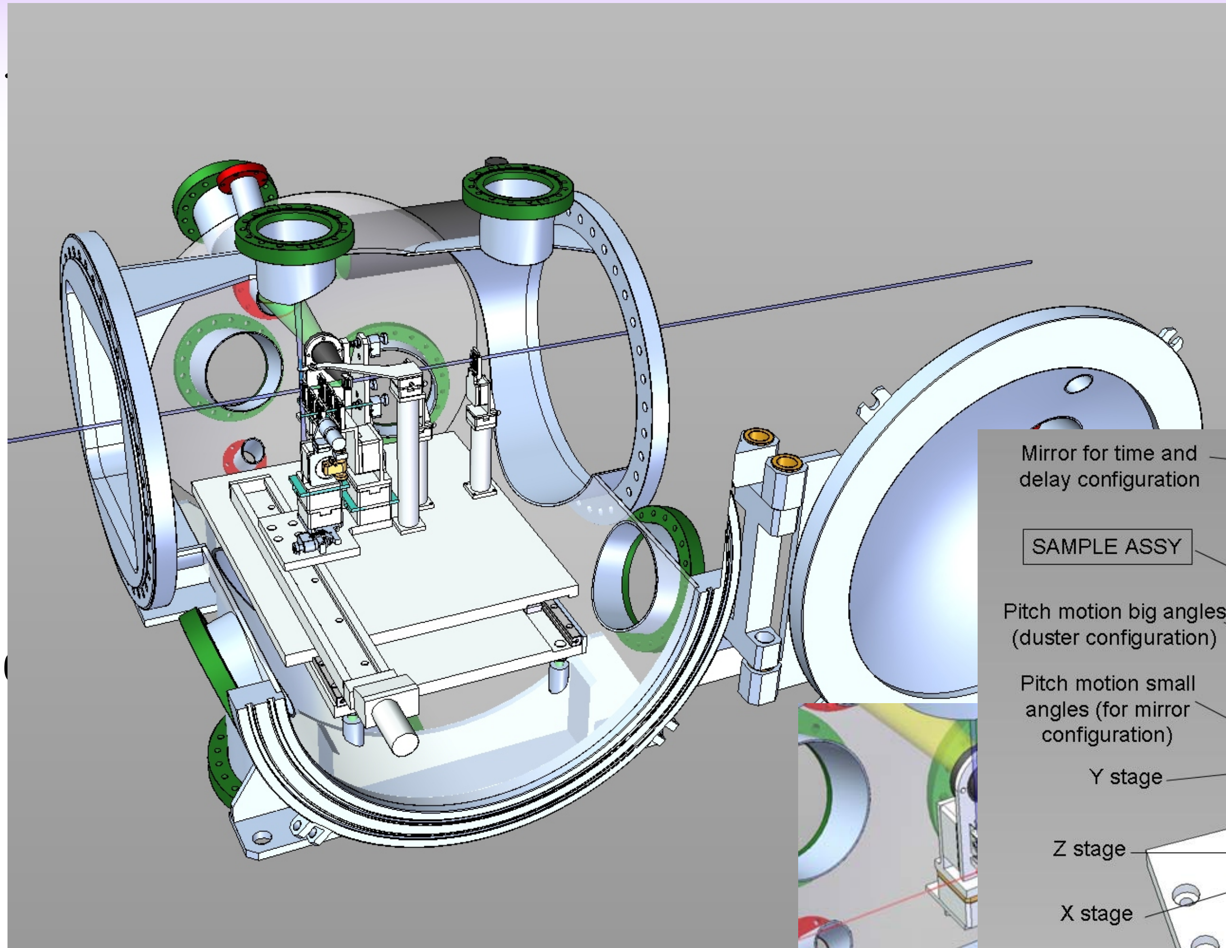
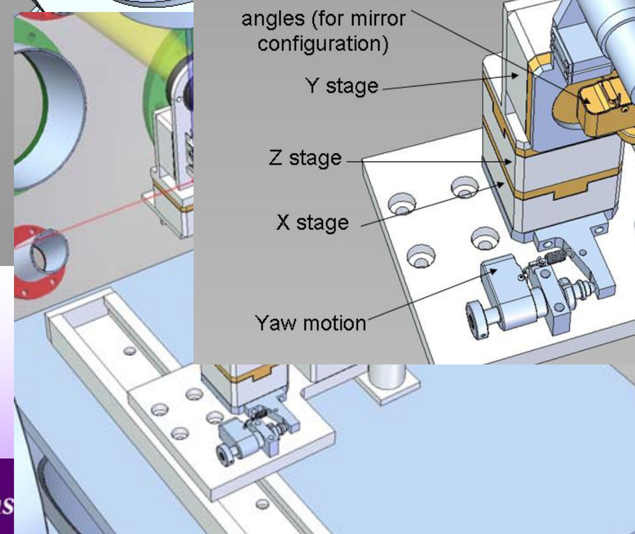
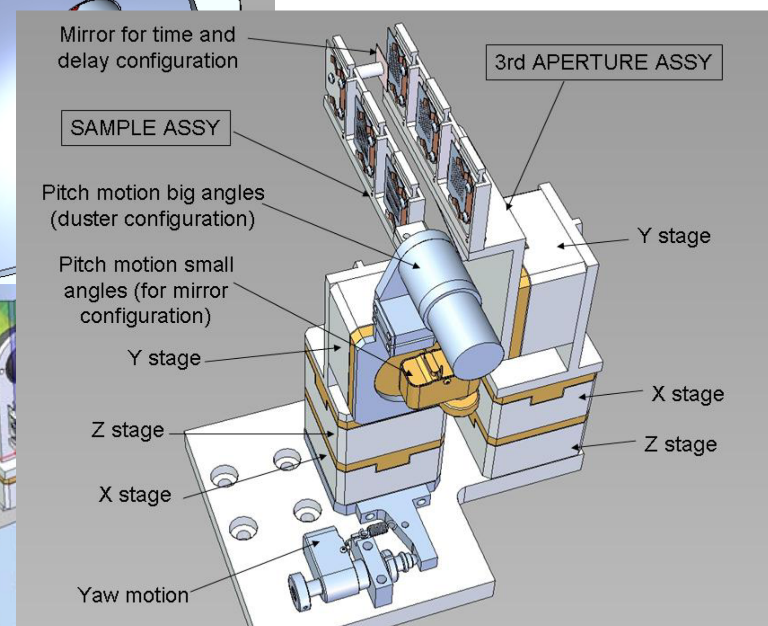
- **CXI**

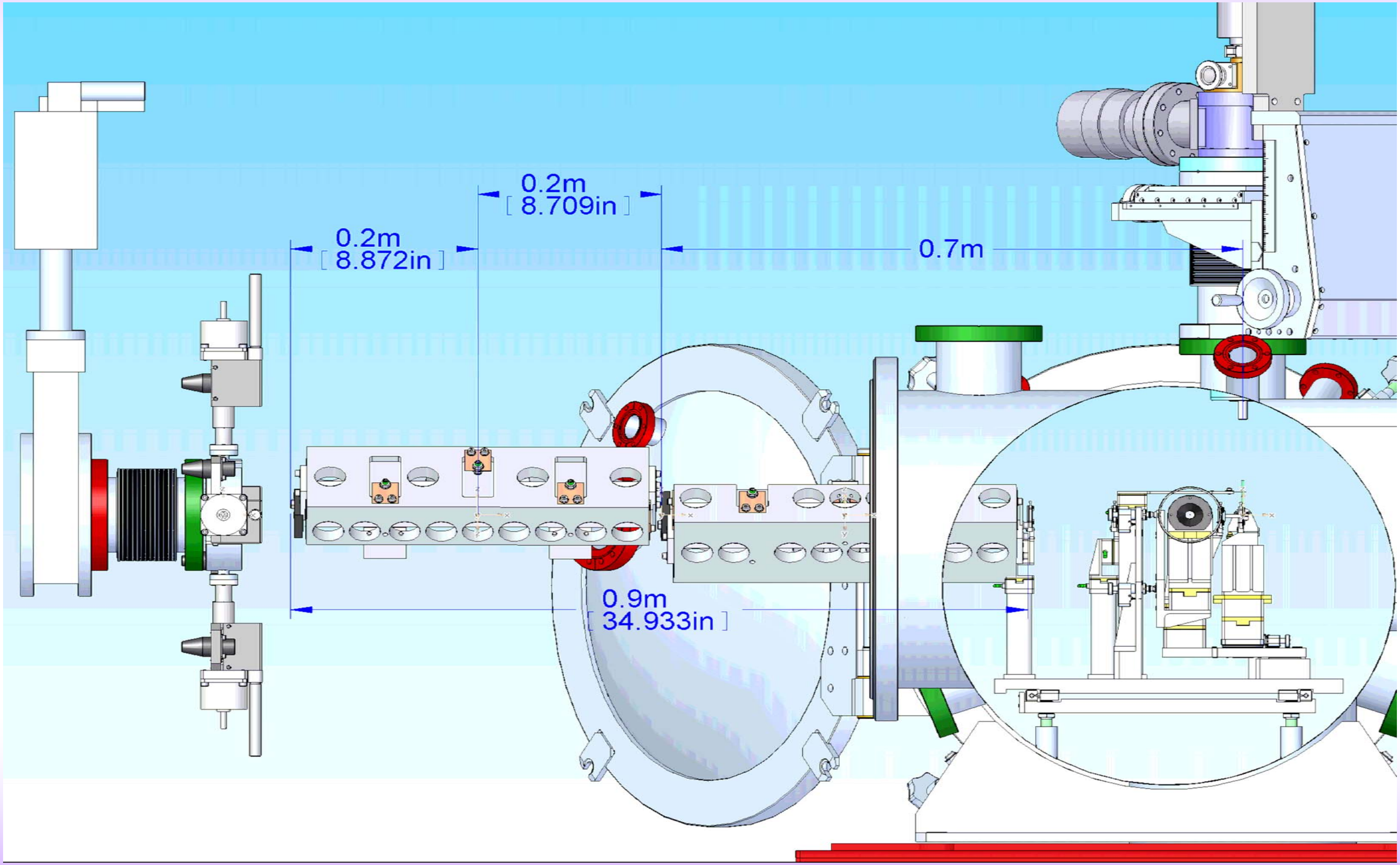




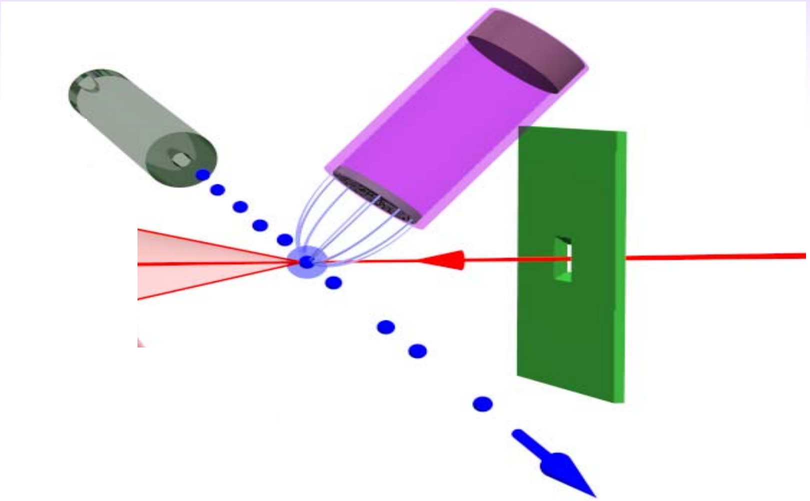


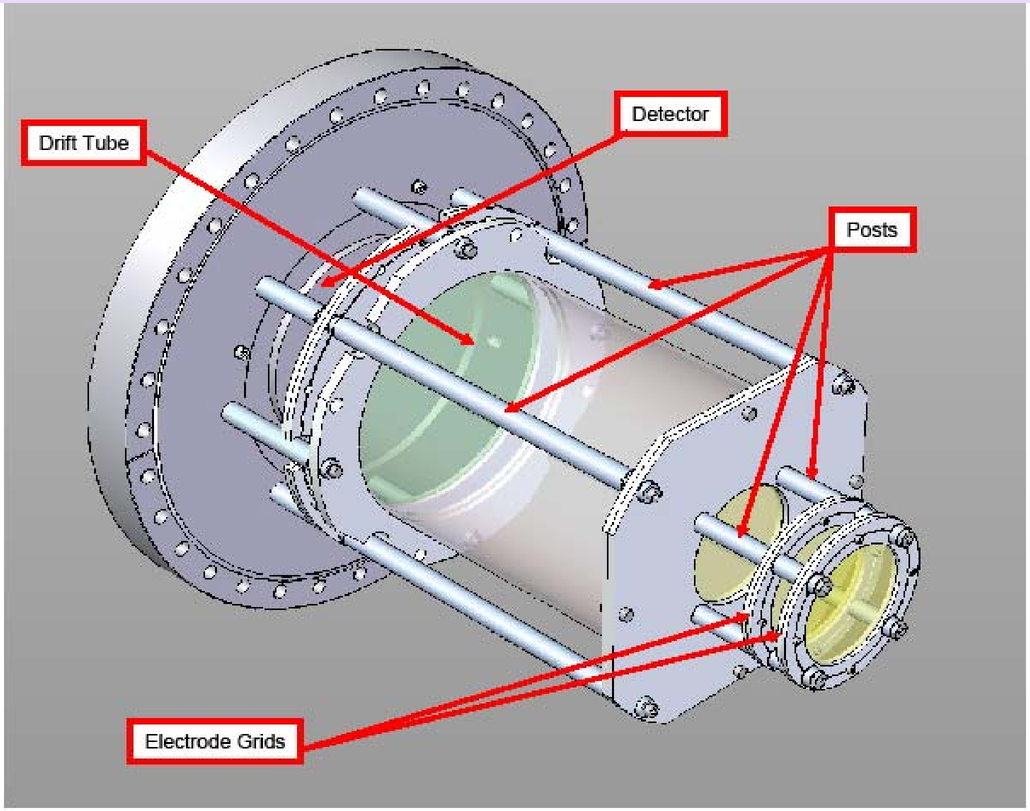
  - **Injector and ITOF**
    - **PRD released July 2008**
    - **ESD draft completed (in review)**
    - **PDR scheduled for March 2010**
    - **~$500K**

0.1 micron KB and Sample Chamber



Ion Time-of-Flight





- Design will be a scaled down version of the AMO TOF
- Draft PRD complete

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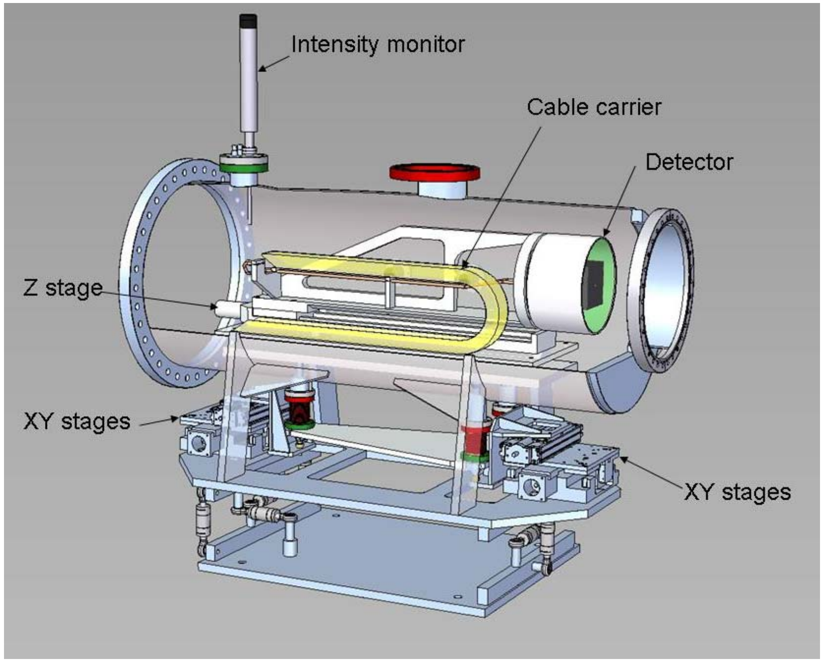
Engineering/Design Status (8)

- Detector Stage
  - Centers the detector on the beam and positions it in “Z” relative to the interaction point
  - Concept completed
  - Analysis required to ensure detector stability
  - Design waiting
    detector packaging details
  - PRD released
  - ESD draft completed (in review)
  - PDR scheduled for September 2008
  - ~$325K



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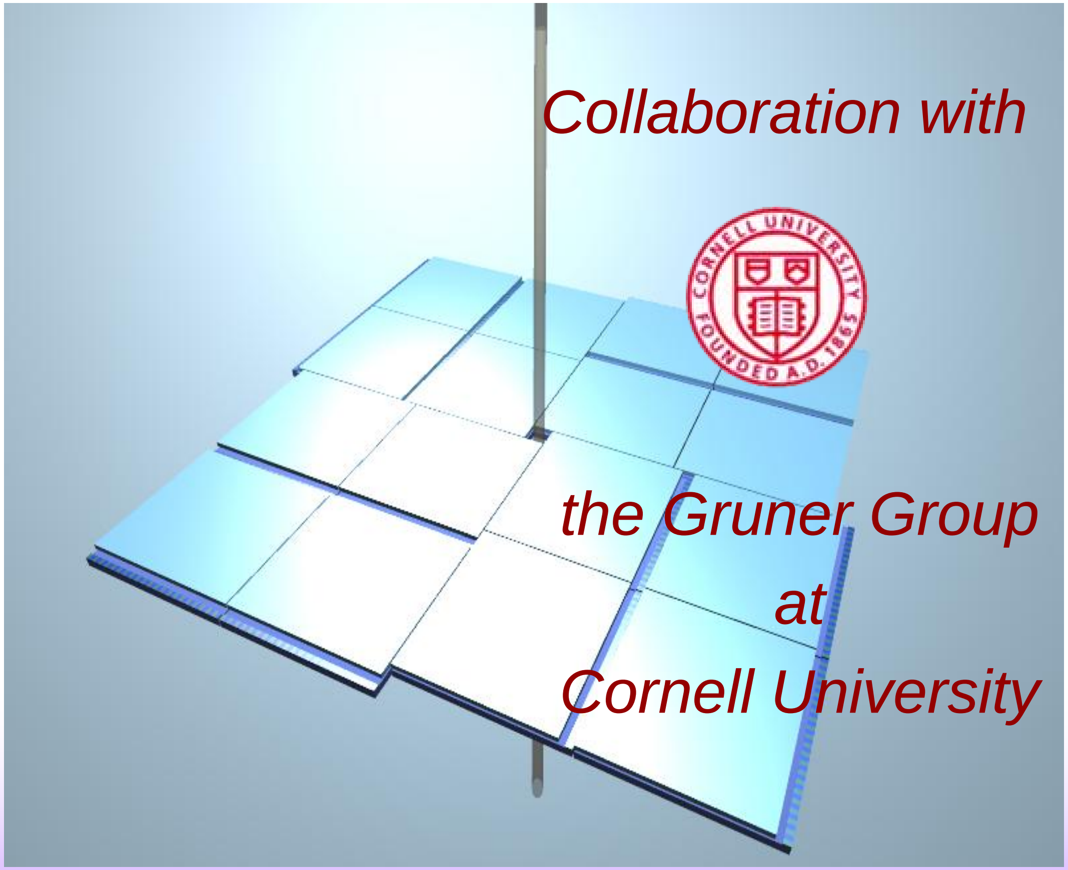
CXI Detector

- **2D Pixel Array Detector**
  - **High resistivity Silicon (500 μm) for direct x-ray conversion.**
  - **Reverse biased for full depletion.**
  - **Bump-bonding connection to CMOS ASIC.**

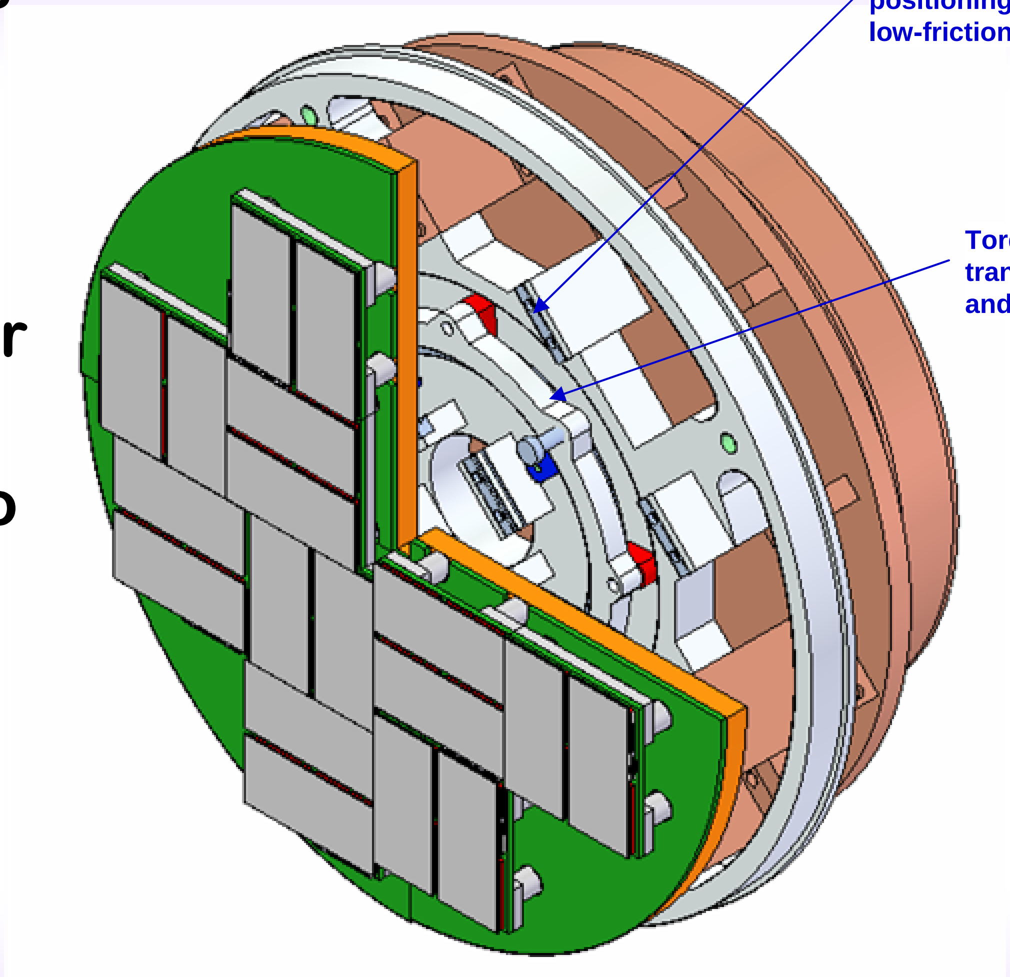
- **<1 photon readout noise**
- **110x110 μm^2 pixels**
- **760x760 pixels**
- **10^3 dynamic range**
- **120 Hz readout**

- **Tiled detector, permits variable ‘hole’ size**



CXI Detector

- Modular design
  - Allows for addition of tiles in the future
- Initial detector
  - 8 modules
- Expandable to 64 modules
- Variable hole size



Martin Nordby & Matthew Swift

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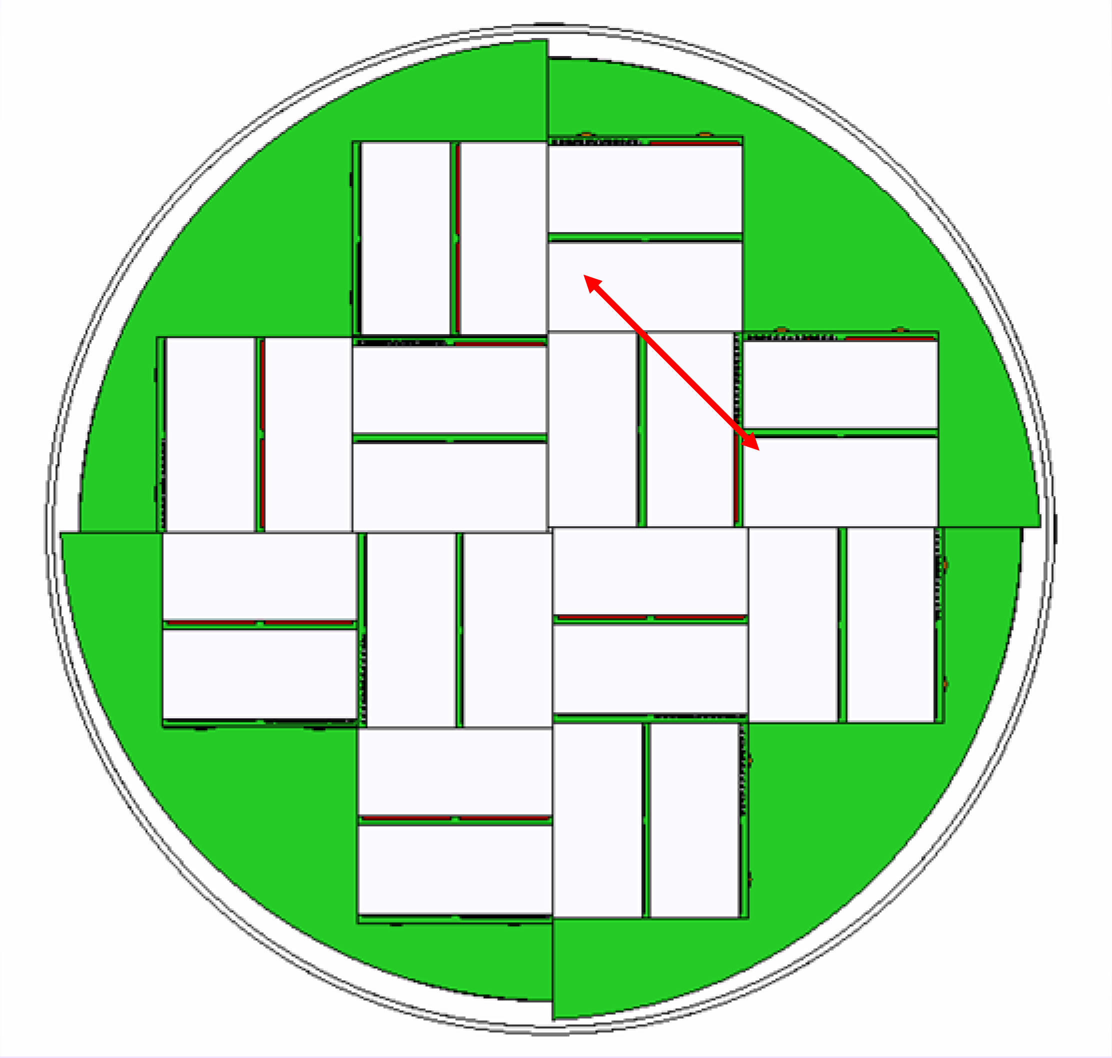
Front View—1 mm Aperture



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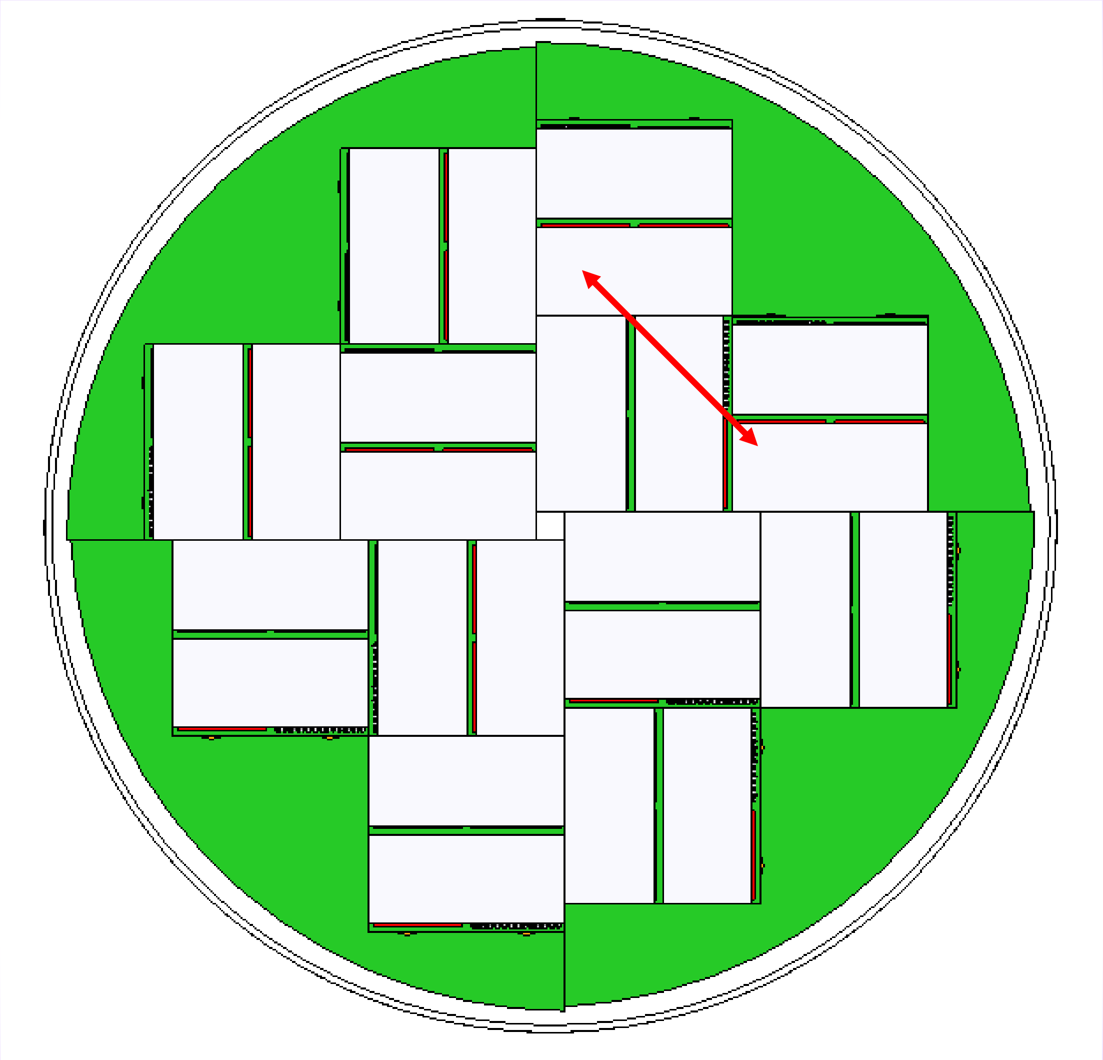
Front View—6 mm Aperture



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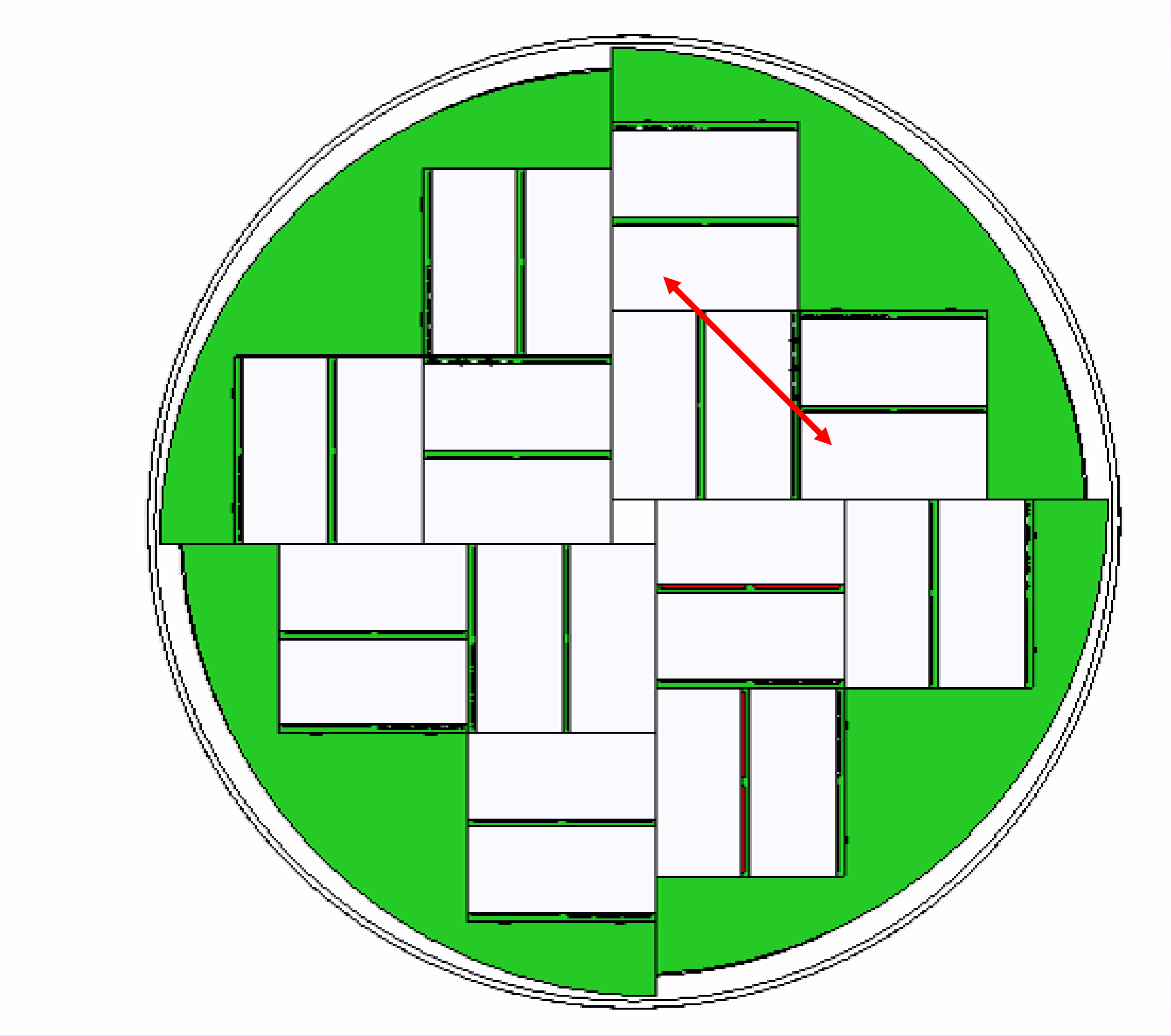
Front View—10 mm Aperture



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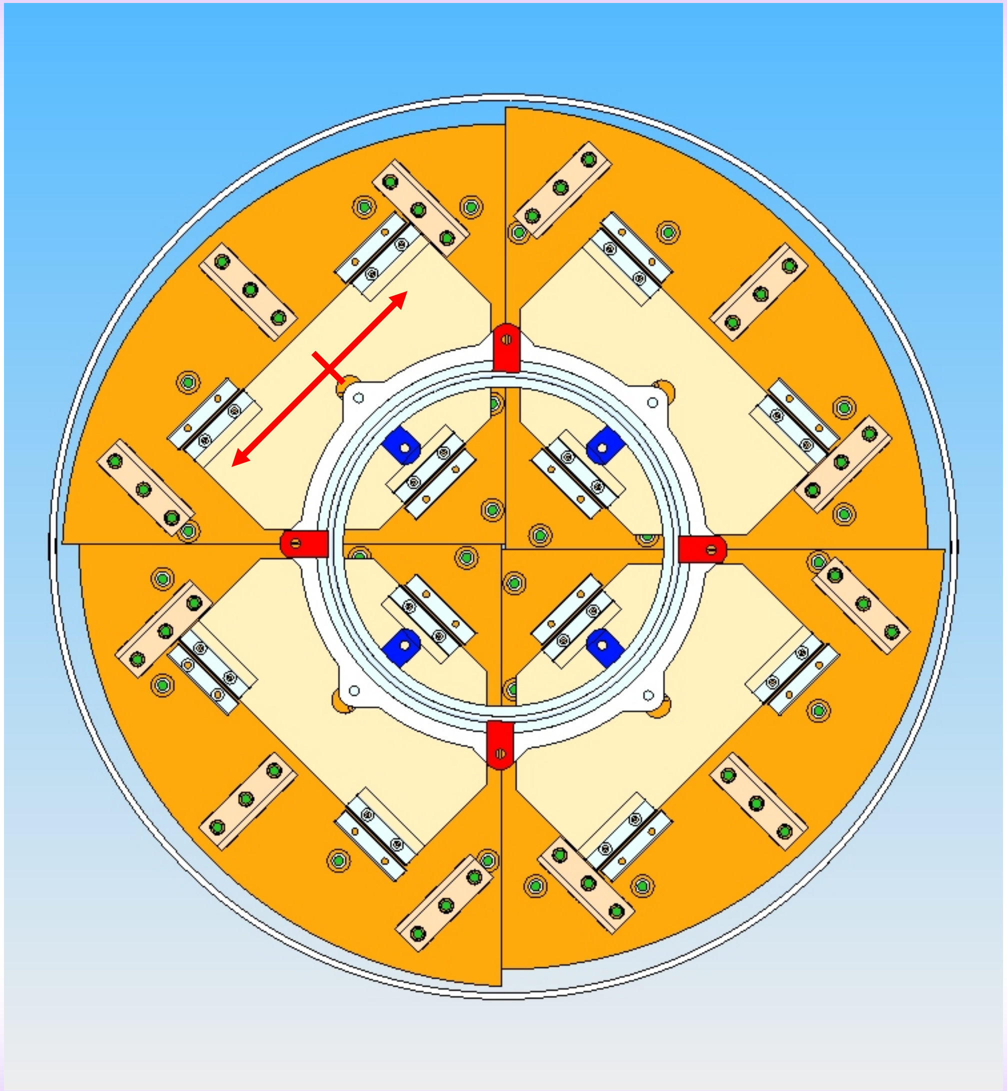
Back View with Base Plate Removed—1 mm Aperture



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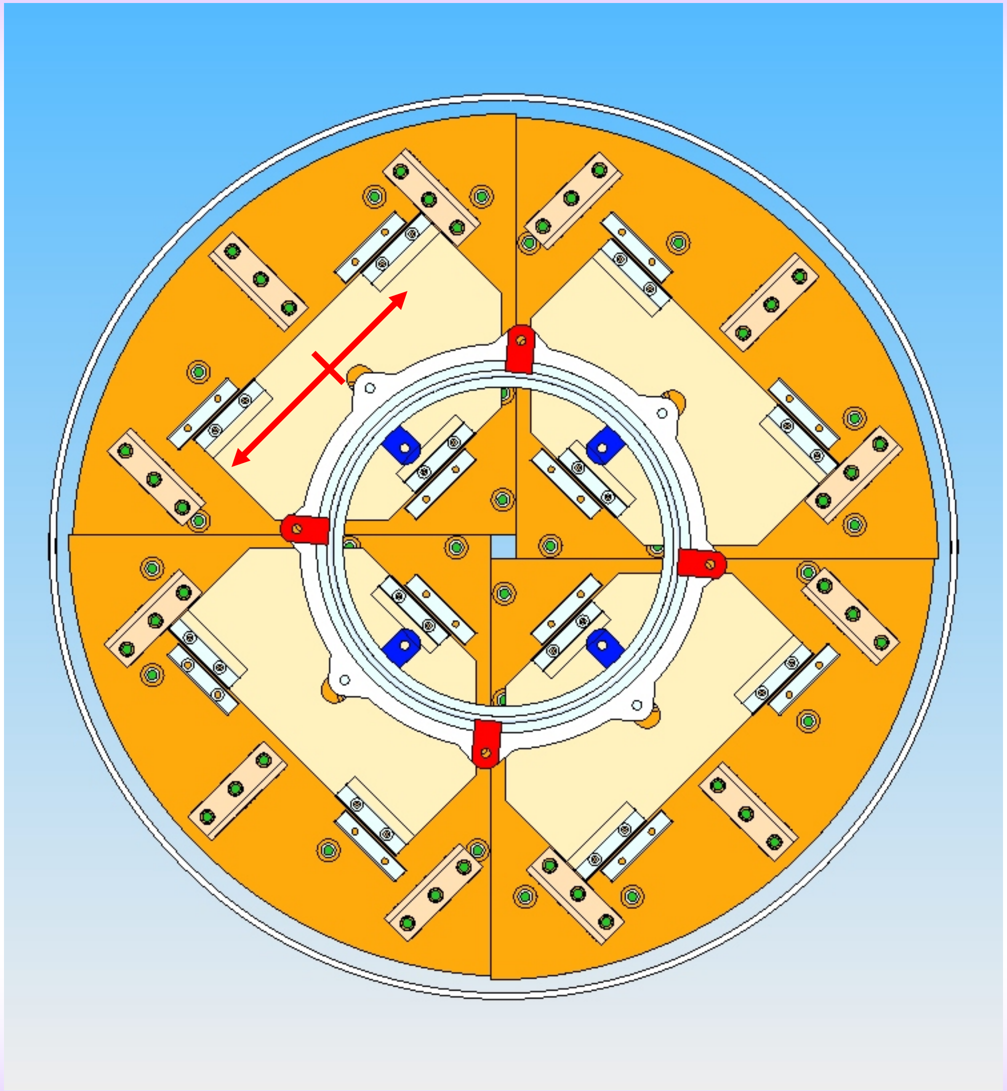
Back View with Base Plate Removed—6 mm Aperture



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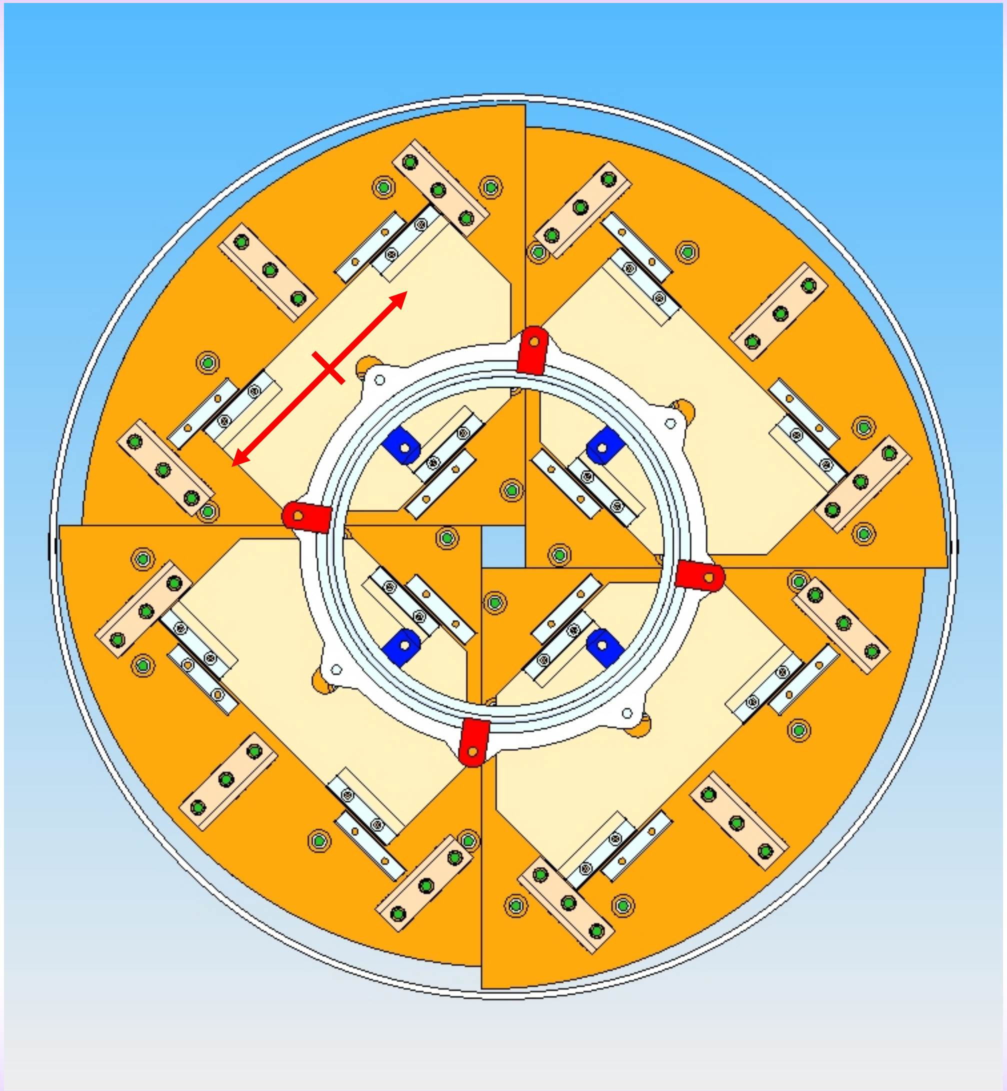
Back View with Base Plate Removed—10 mm Aperture



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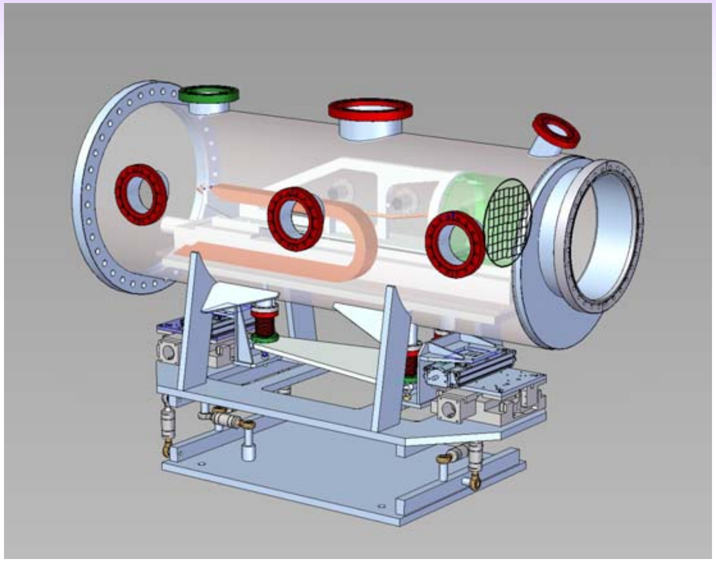
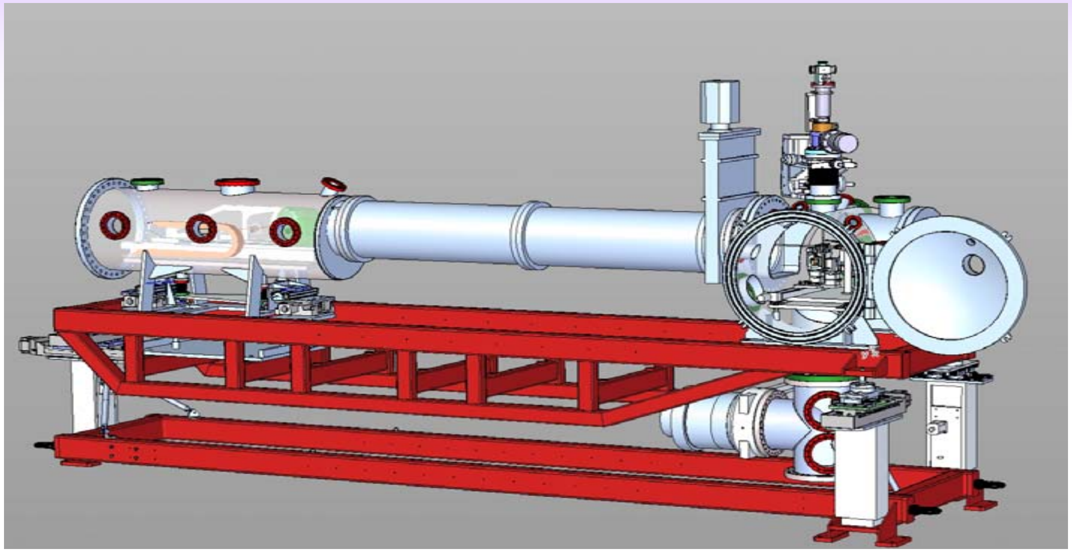
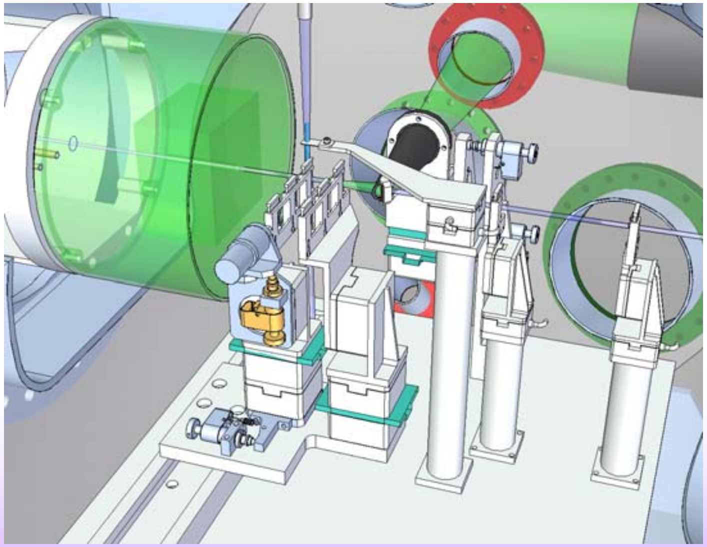
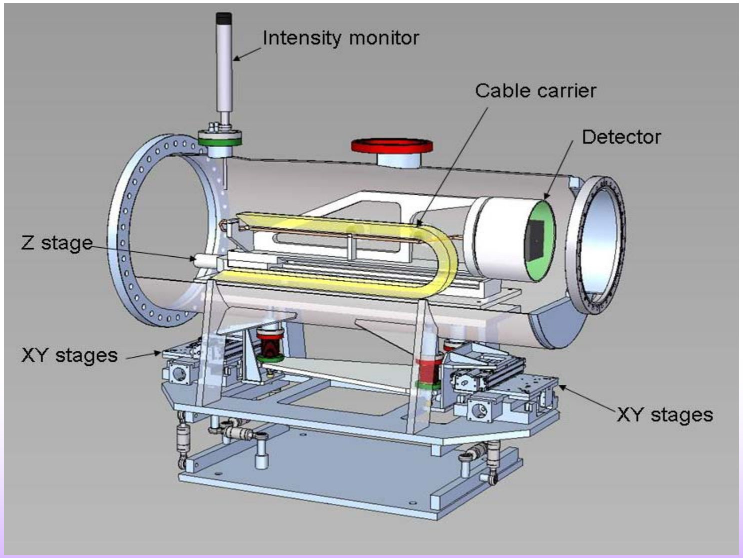
Detector Stage









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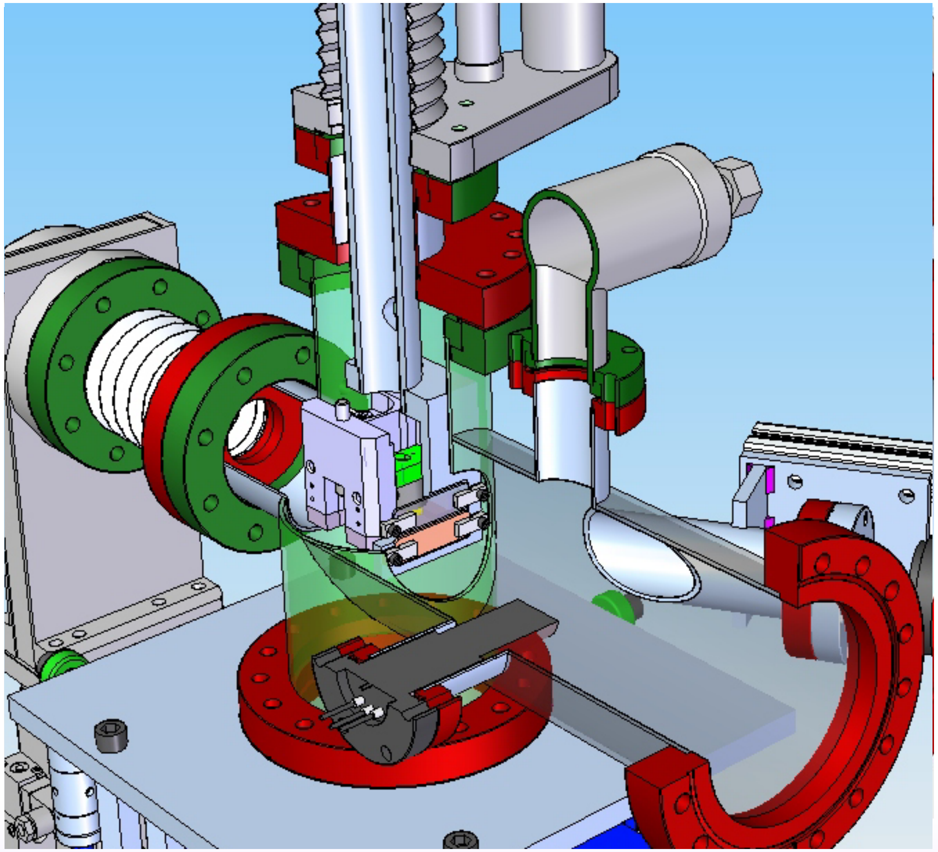
Common Optics

- Slits
  - Withstand full LCLS FEL flux
  - Remove the halo around the focused beam
- Attenuators
  - Minimize wavefront distortion
  - Withstand full FEL flux
  - 10^8 attenuation at 8.3 keV
  - At least 3 steps per decade
- Pulse Picker
  - < 3 ms switching time
  - Reduce rep rate < 10 Hz operation
  - Single pulse selection



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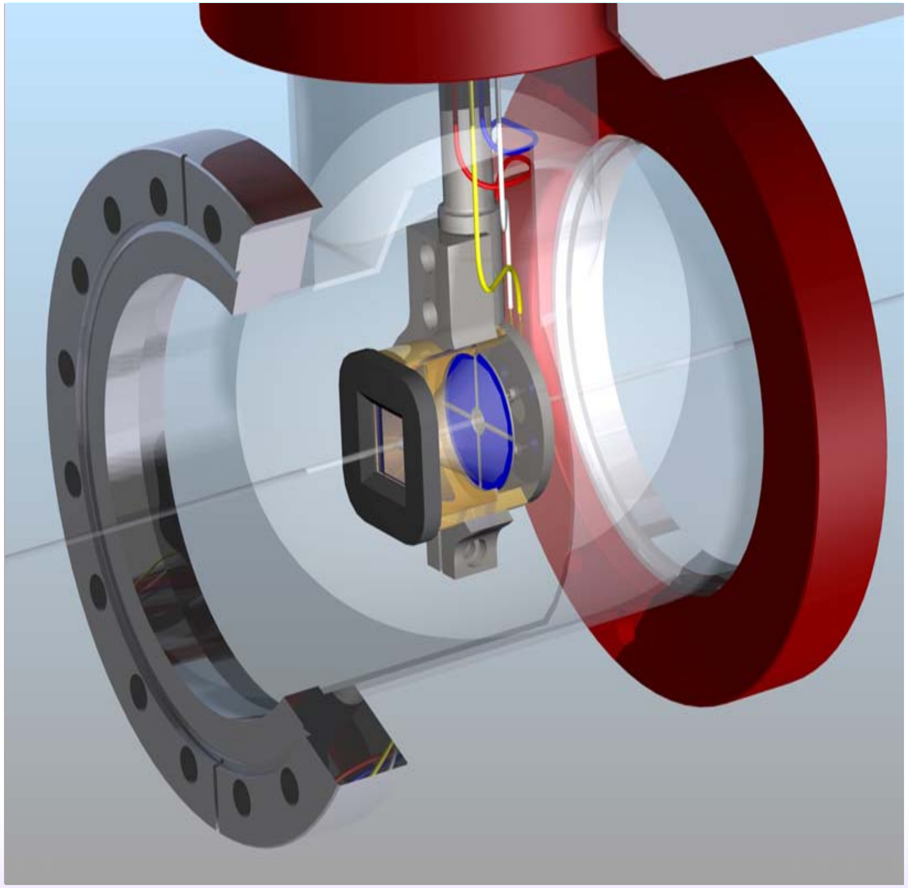
Diagnostics

- Pop-in Profile Monitor
  - Measure the spatial profile of the beam
  - Retractable
  - YAG screen with optical camera
- Pop-in Intensity Monitor
  - Measure the intensity of the beam
  - Retractable
  - Photodiode
- Intensity-Position Monitor
  - Measure the intensity and the position of the beam without destroying the beam
  - This Beryllium foil
    - High transmission
  - Backscattering detected with multiple diodes
  - Relative intensity of diodes gives the beam position
  - Retractable if desired



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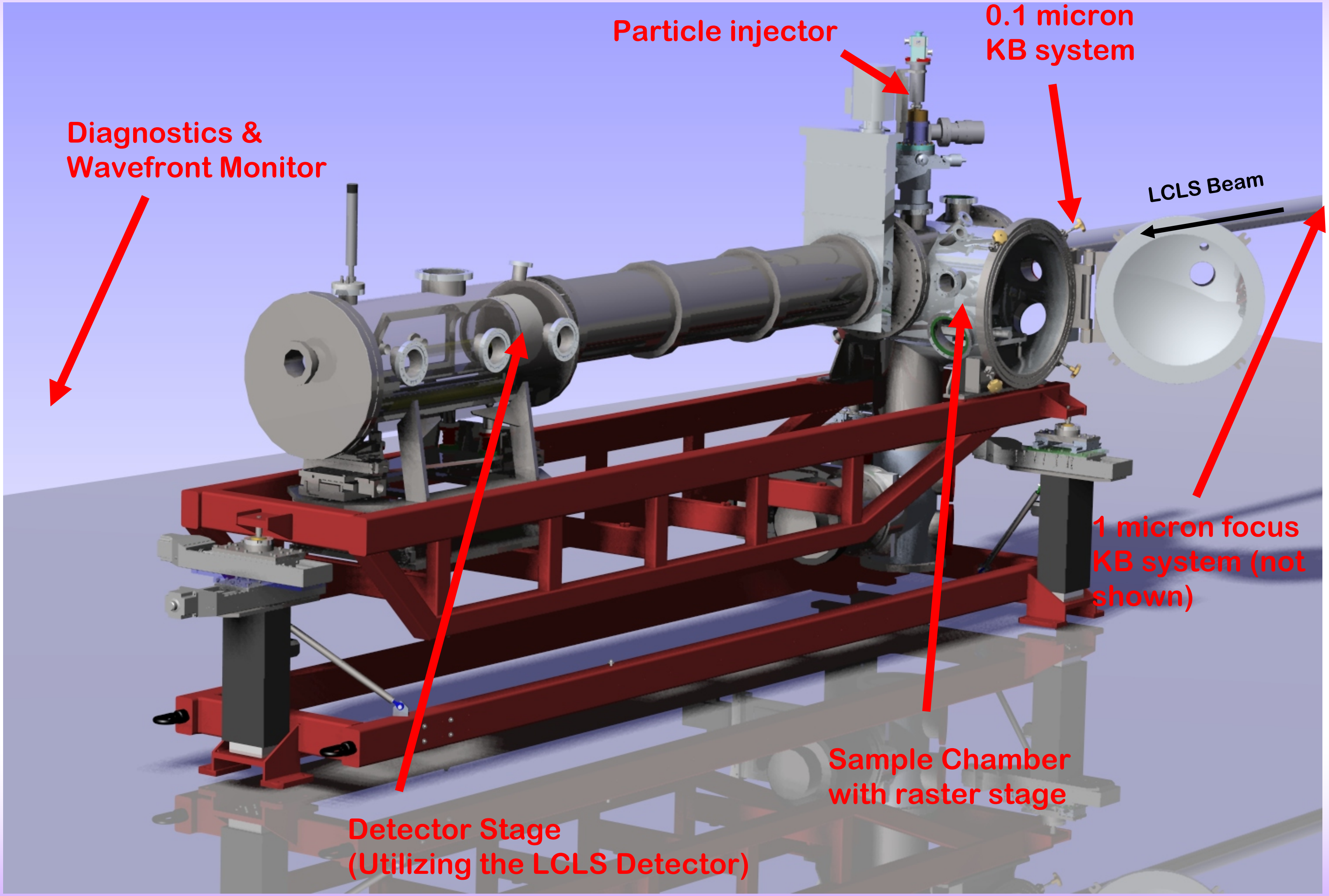
CXI Instrument Design



Engineering/Design Status (12)

- 6 month "look-ahead" at Level 4/5 Milestones
  - ESDs released
    - CXI Detector Stage – Sept 08
    - CXI Reference Laser – Sept 08
    - CXI 1.0µm KB System – Sept 08
    - CXI 1.0µm Precision Instrument Stand – Sept 08
    - CXI 1.0µm Sample Chamber – Oct 08
    - CXI 0.1µm KB System – Oct 08
  - PRDs released
    - CXI Injector – Jan 09
  - Preliminary Design Reviews
    - CXI Detector Stage – Sept 08
    - CXI Reference Laser – Oct 08
    - CXI Vacuum Equipment – Nov 08
    - CXI 1.0µm Sample Chamber – Dec 08
  - Final Design Reviews
    - CXI Reference Laser – Dec 08
    - Vacuum System Equipment – Jan 09
    - Cornell Detector Packaging (Participate in) – Feb 09
  - Vendor Related
    - Release CXI KB Systems RFP – Jan 09
    - Receive CXI KB Systems Vendor Proposals – Feb 09
  - Far Experimental Hall Hutches
    - FEH H5 Preliminary Layout – Sept 08
      - LCLS 30%, 60%, 90% hutch drawing review – Sept 08, Oct 08 and Jan 09
      - LCLS FEH FDR – Jan 09

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Current Plans for XCS Monochromator

- Large offset mono at entrance of tunnel
  - > 200 meters upstream of CXI
  - The beamline is dedicated to CXI only for ~240 meters
    - Tons of space to put stuff in the tunnel

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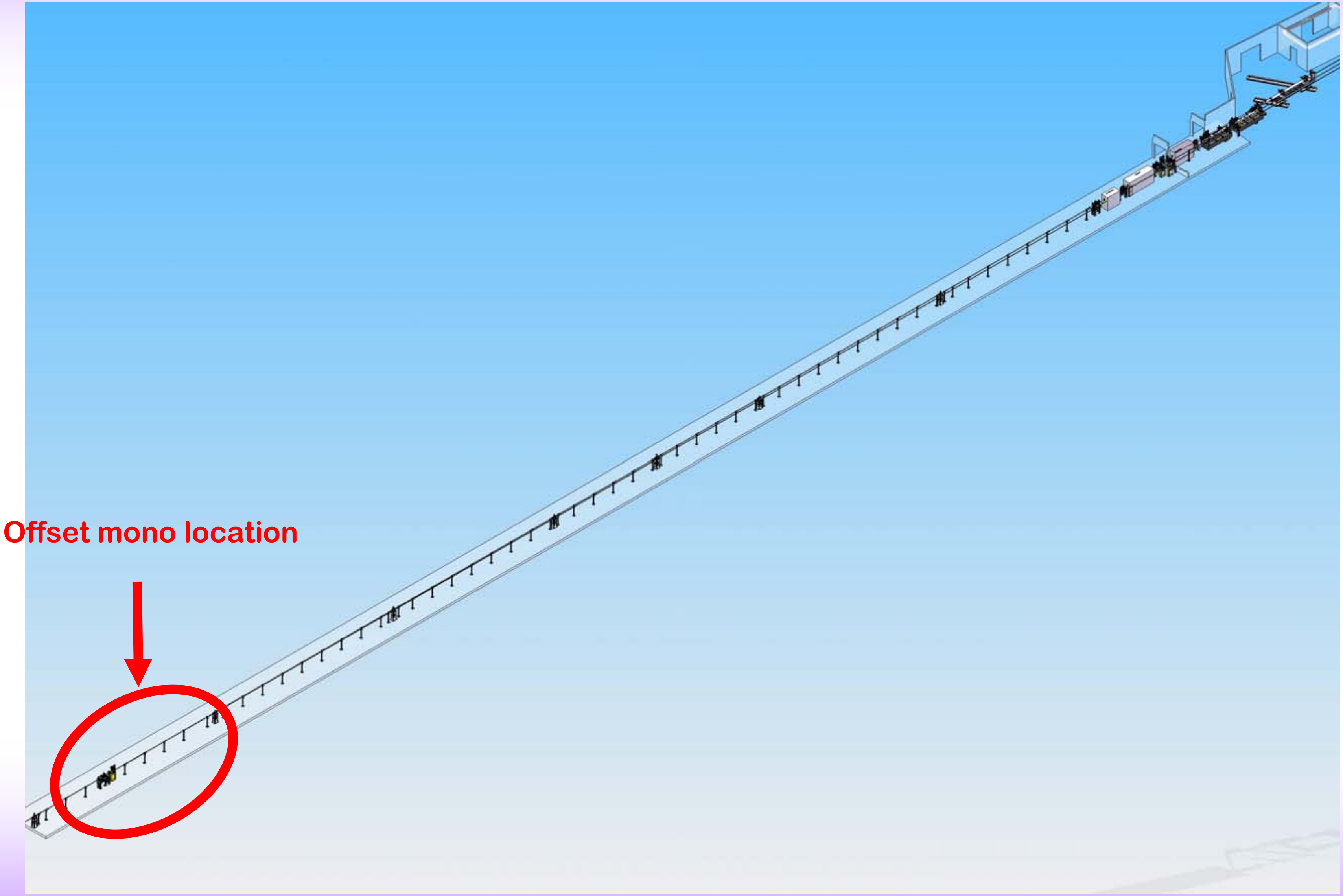
Current XCS Mono Location



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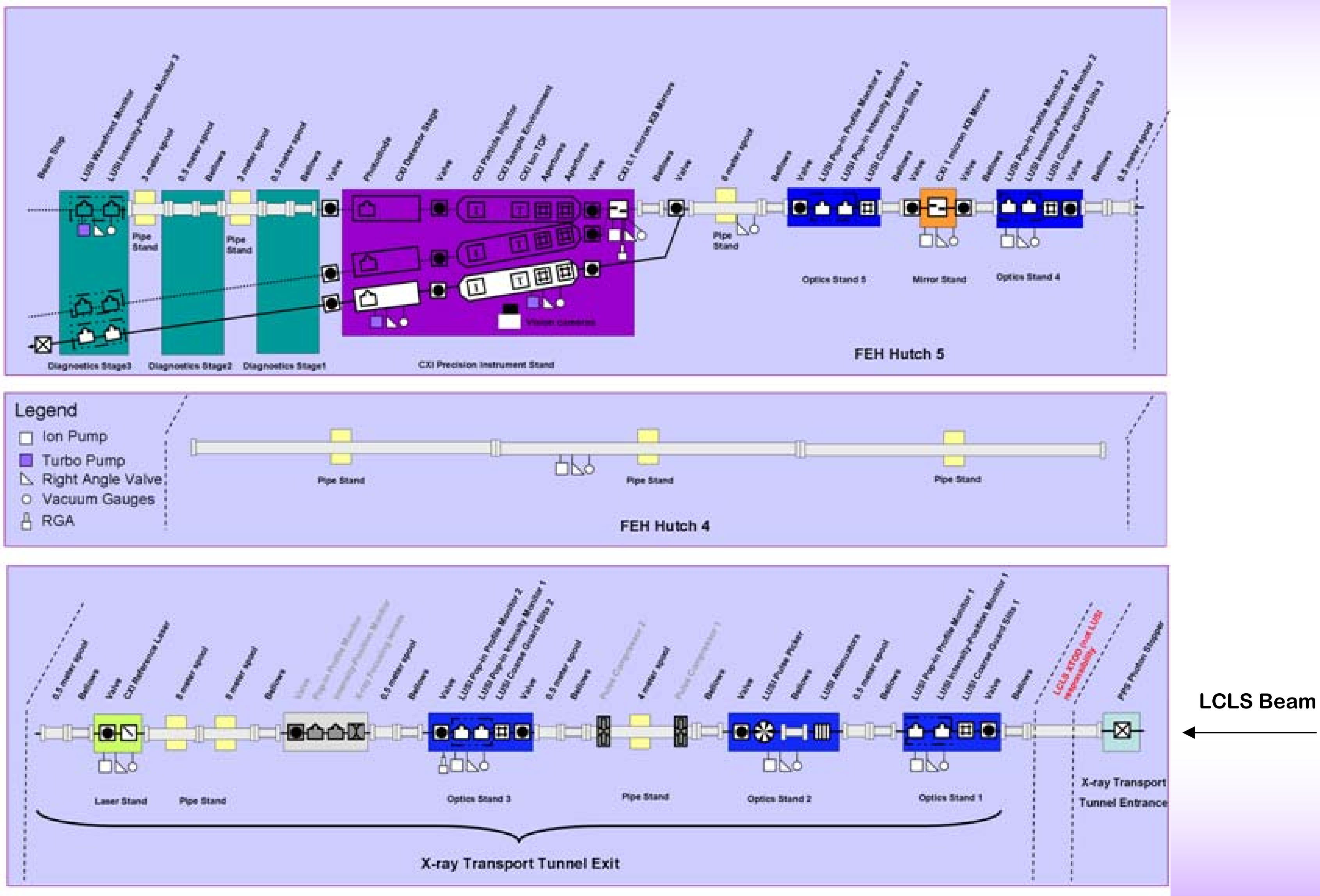
Current CXI Instrument Layout



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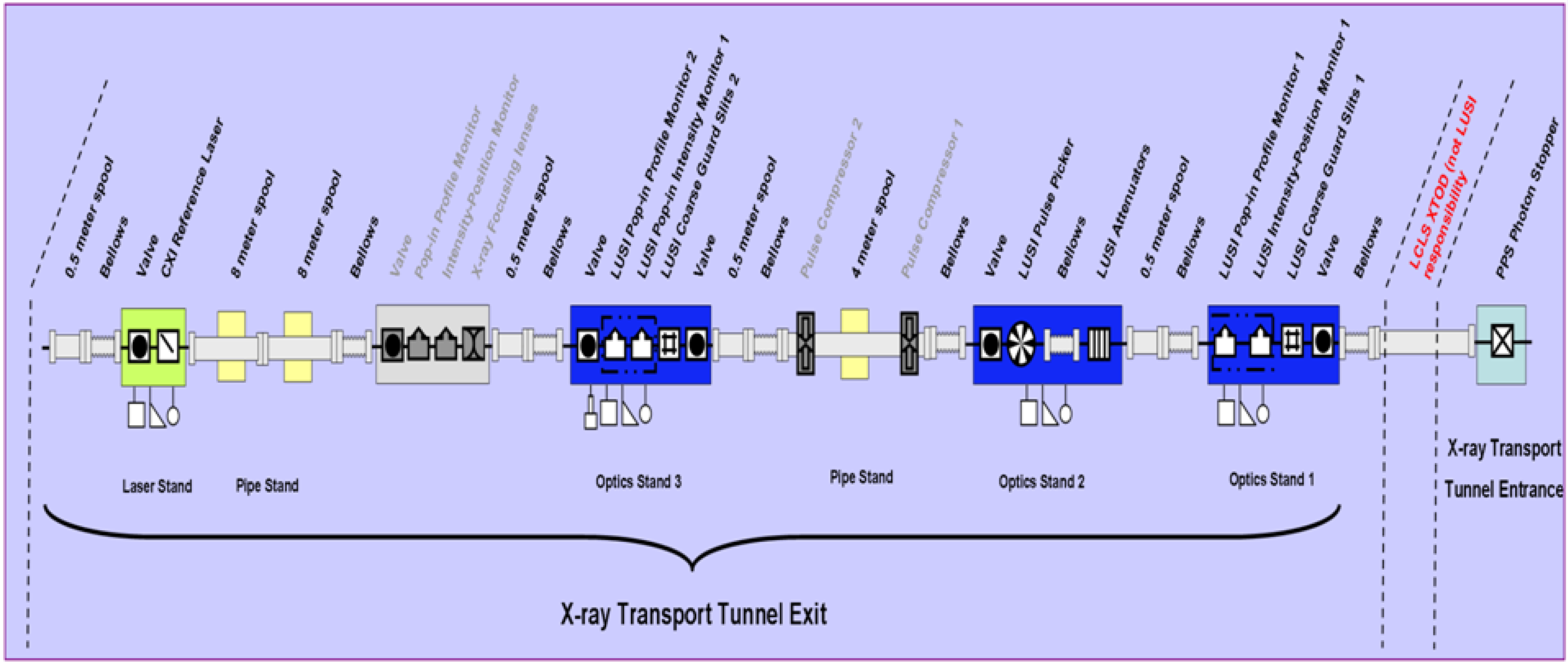
Current CXI Instrument Layout (X-ray Transport Tunnel)



- Optics near the tunnel exit
  - Slits
  - Diagnostics
    - Pop-in Profile Monitors (Beam viewers)
    - Pop-in Intensity monitors
    - Intensity-Position Monitors (Non-destructive intensity monitors)
  - Attenuators
  - Pulse Picker
  - Reference Laser

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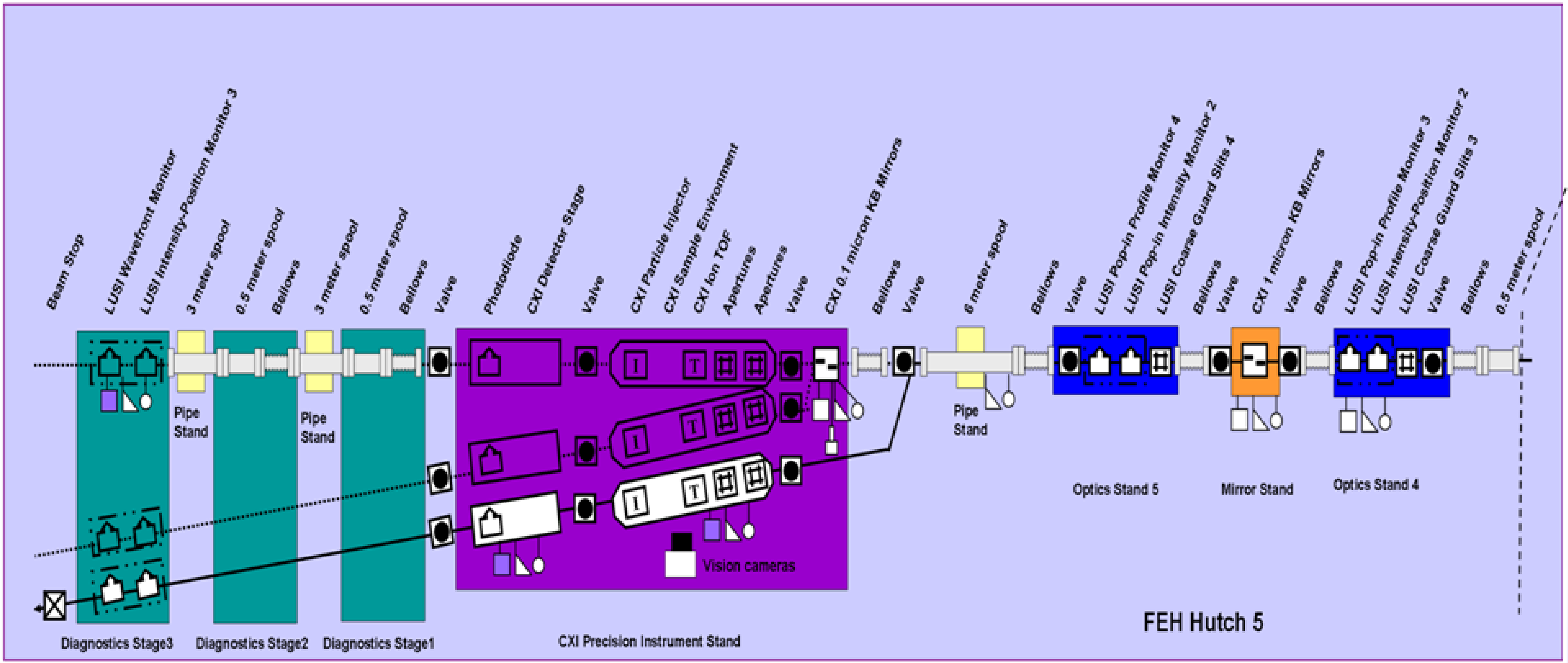
Current CXI Instrument Layout (FEH Hutch #5)

- 2 KB systems to produce 1000 and 100 nm focus
  - Each KB deflects the beam and the sample chamber must move with the beam
  - 3 beam locations
- Precision Instrument Stand holds the Sample Chamber, the Detector Stage and the 0.1 micron KB system
- 10 meters of space behind sample chamber
  - Wavefront Monitor to characterize the focus
    - Used as a second detector for low q data
- Diagnostics
- Slits



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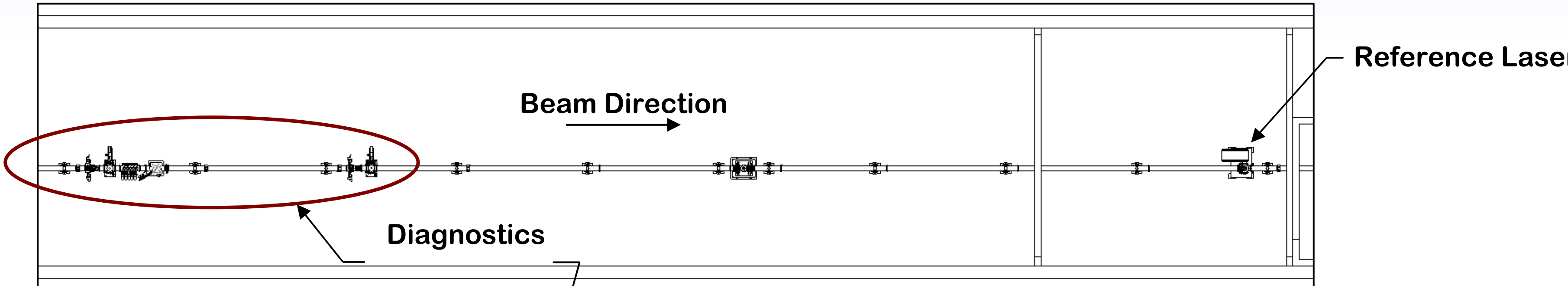
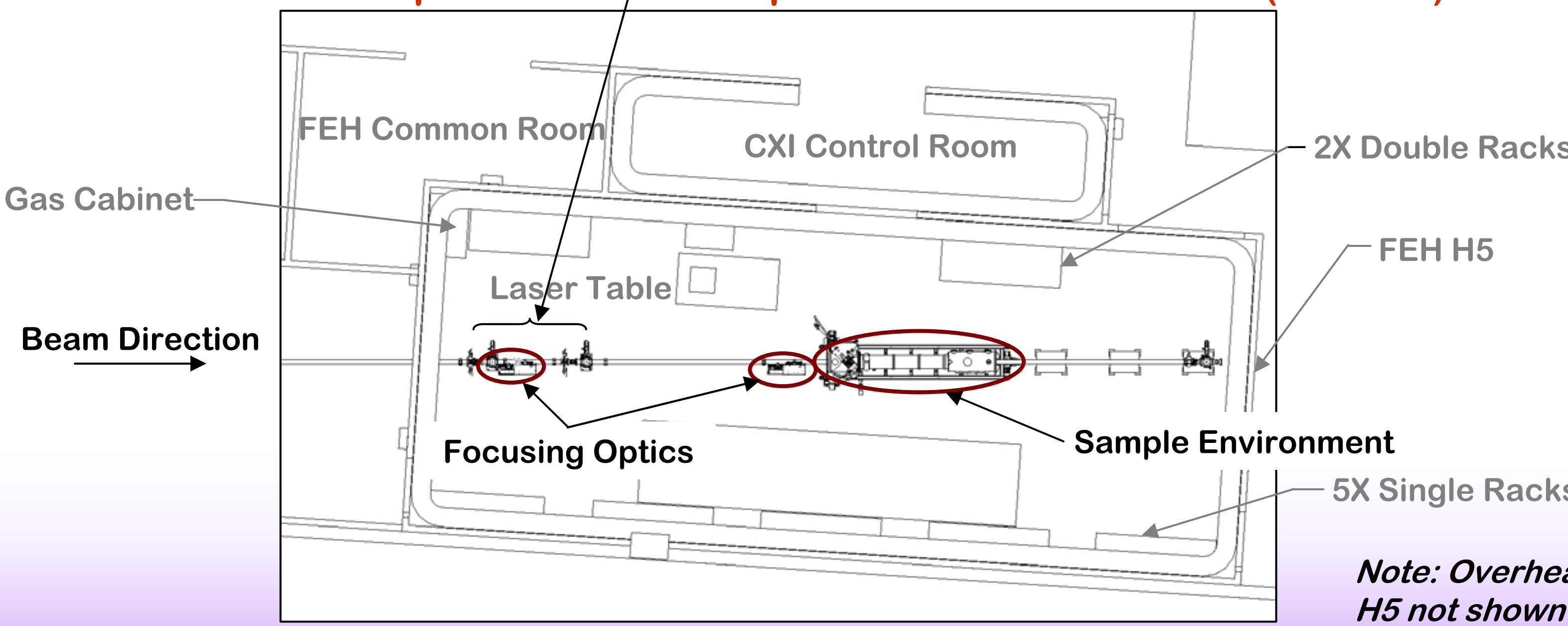
Current Instrument Configuration

CXI Components in the X-ray Transport Tunnel (XRT)



CXI Components in Far Experimental Hall Hutch 5 (FEH H5)



Note: Overhead crane in H5 not shown for clarity

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New Plans for XCS Monochromator

- Move the large offset mono to the end of the tunnel
  - Relaxes the stability requirements
  - Saves 200 m of vacuum beamline
- Add a second mono (channel-cut) before the large offset mono
  - Can be ready earlier
    - XCS is operational earlier
  - Cheap
  - Very small offset
  - Easy alignment

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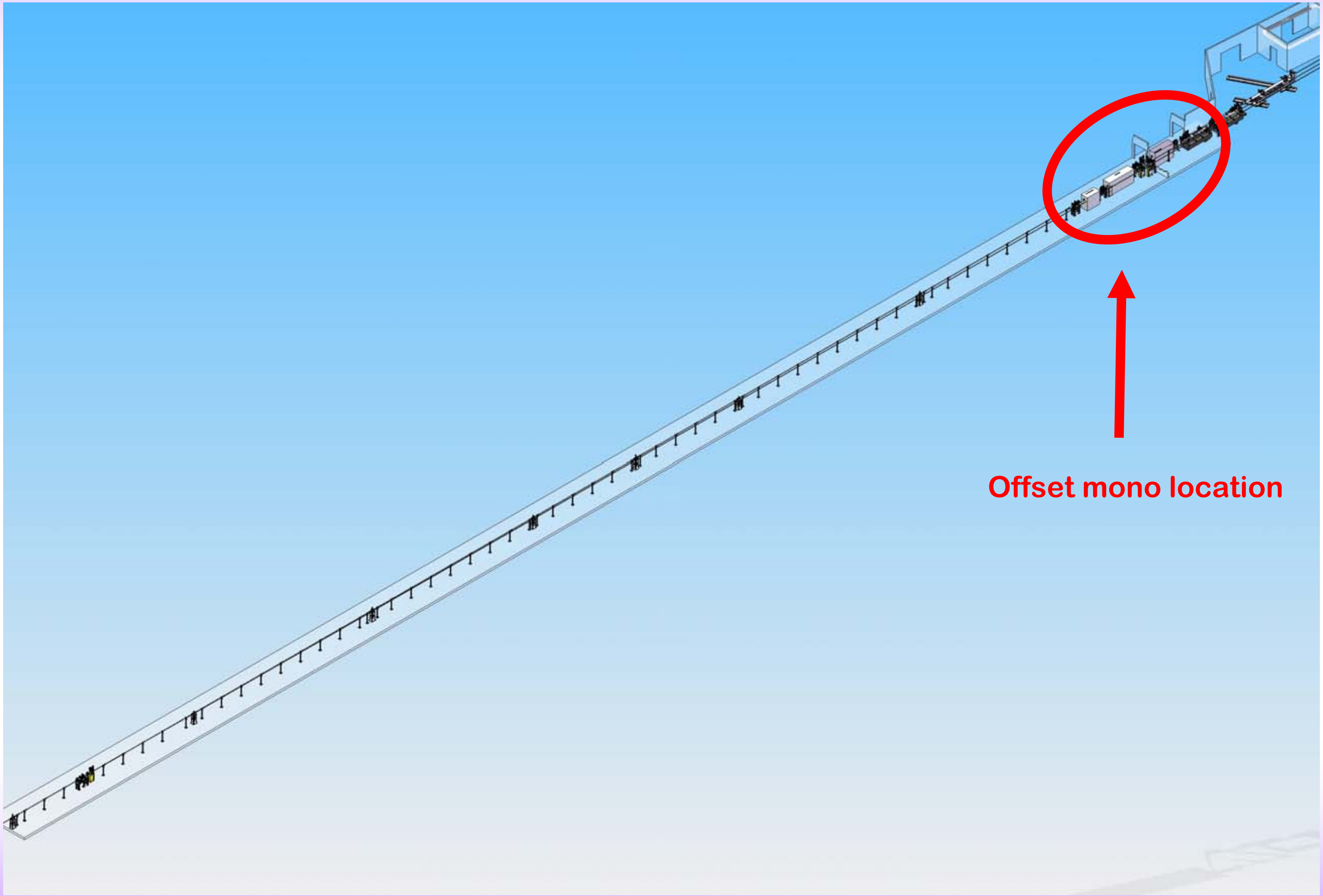
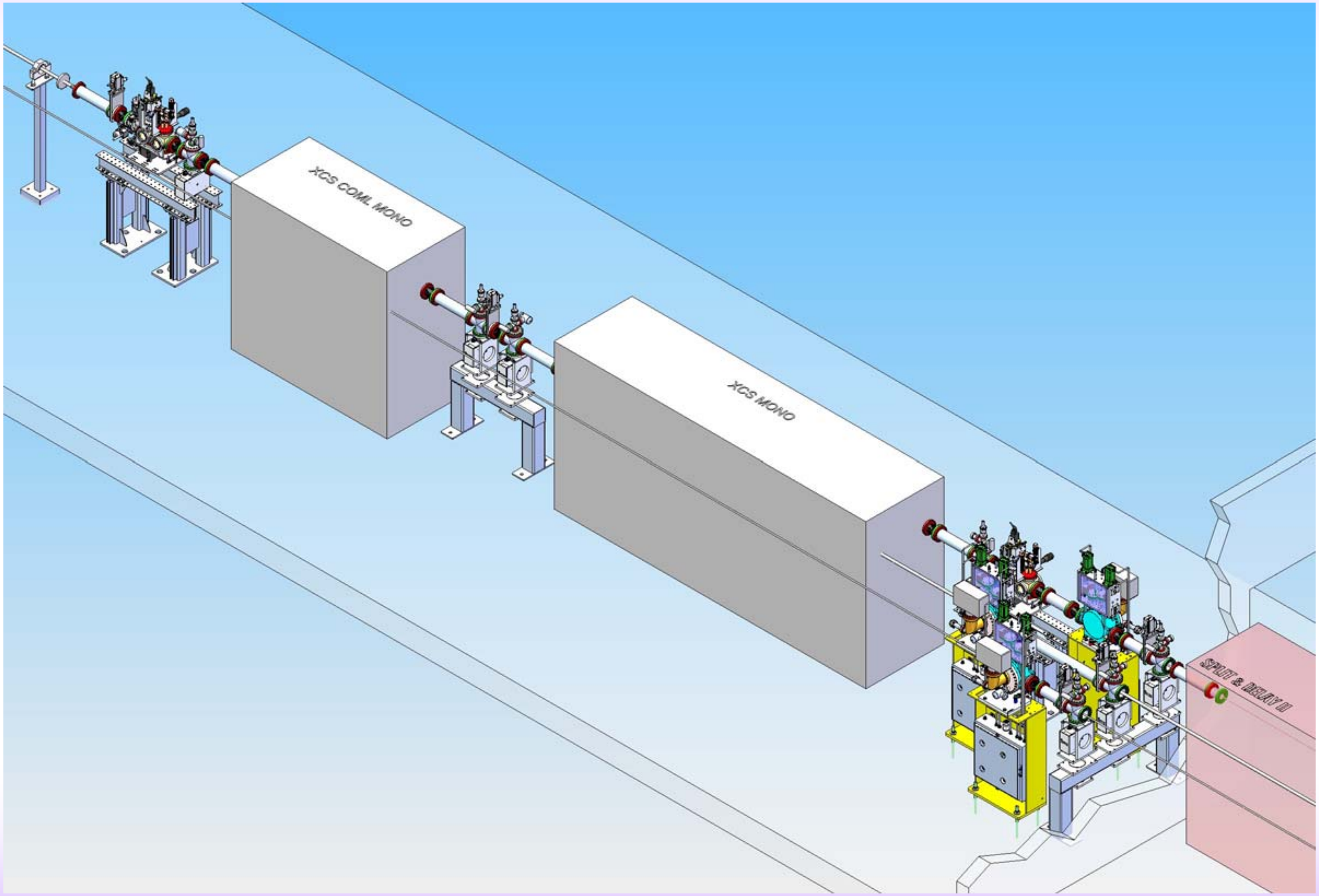
Proposed XCS Mono Location



Two XCS Monos



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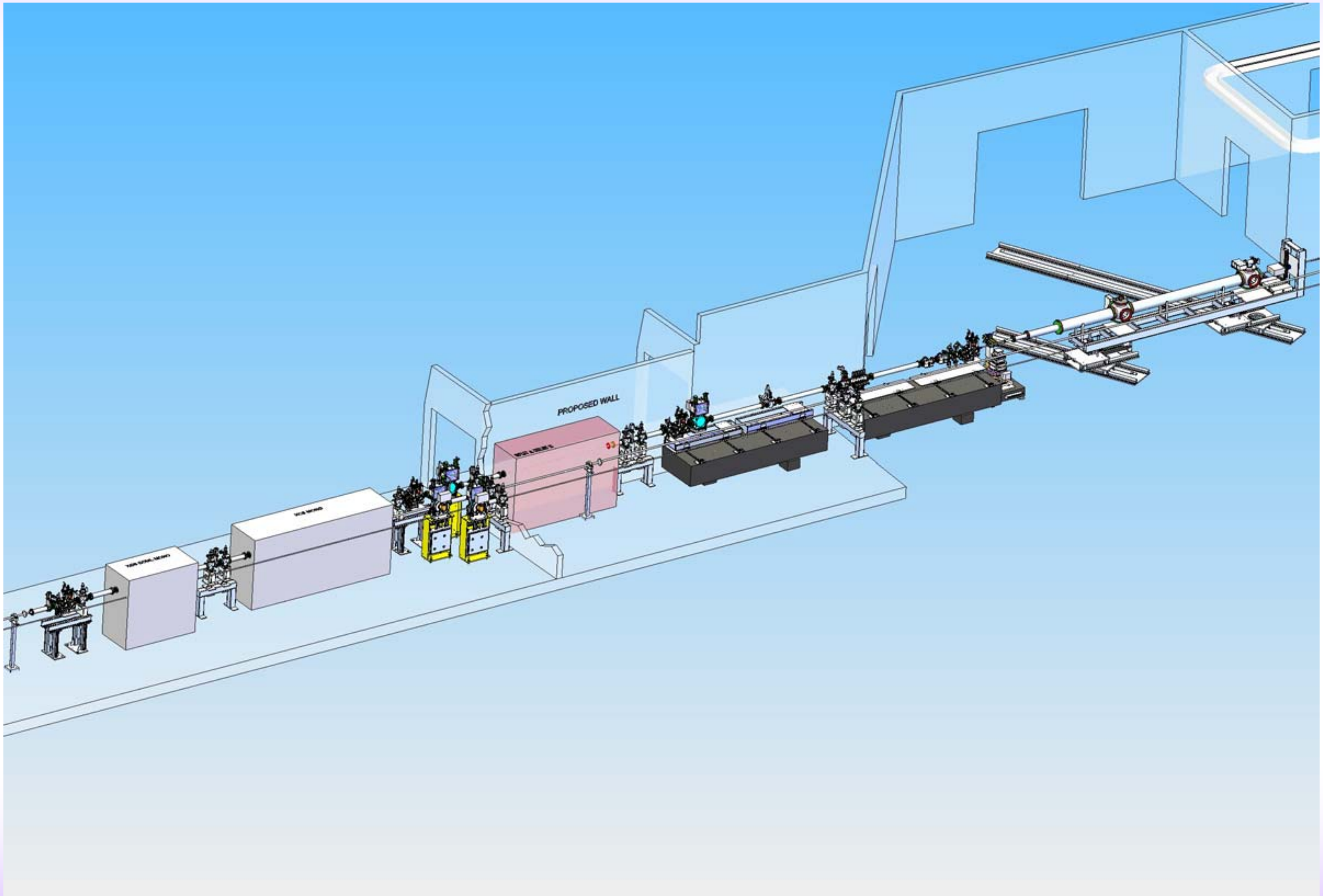
XCS Components at exit of the tunnel



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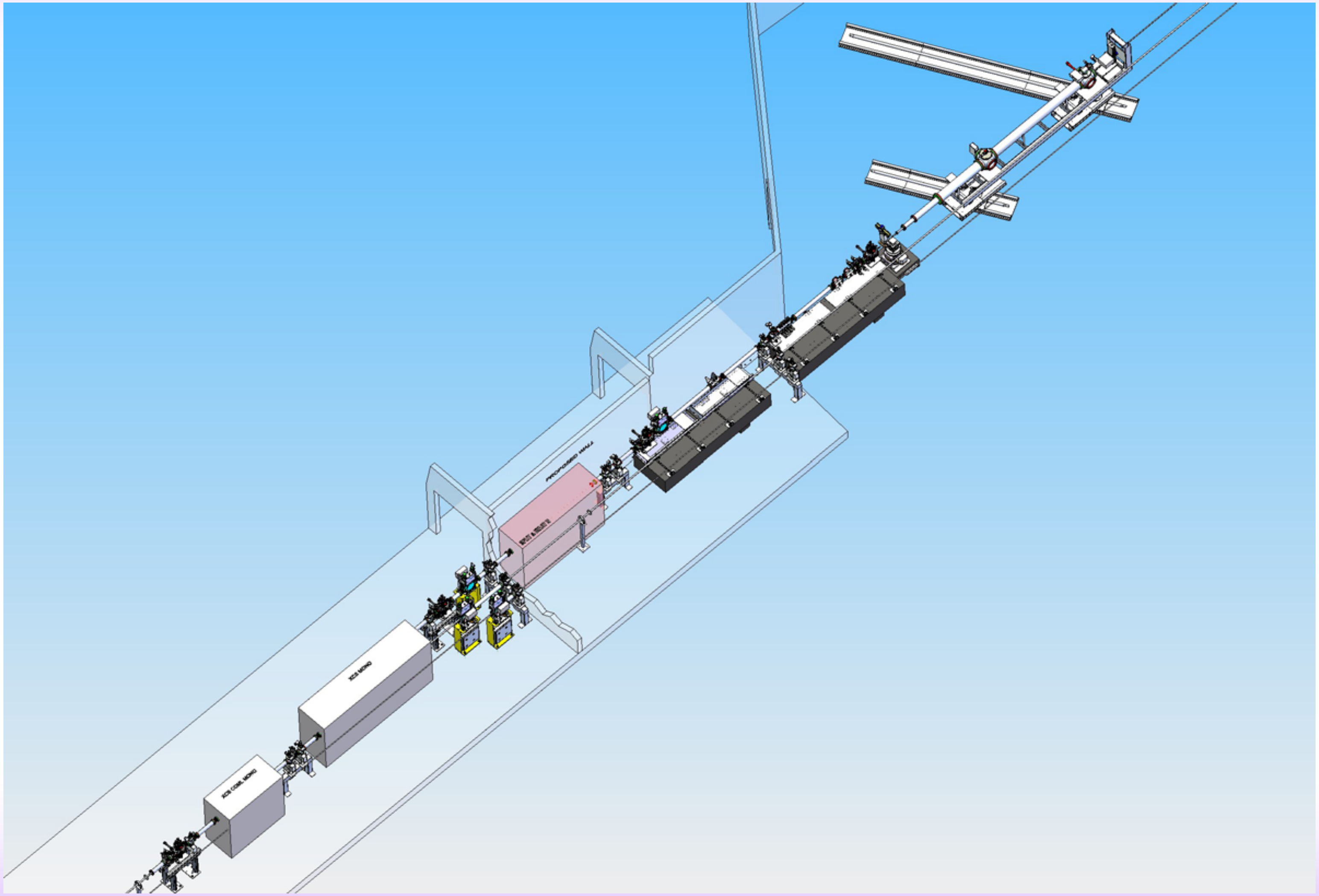
XCS Components at exit of the tunnel



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Impacts of XCS Changes on CXI

- Disadvantages
  - All dedicated CXI components have to be inside the hutch
    - Beamline got much shorter and there less space available
    - All optics that were in the tunnel move to the hutch
      - Will loss 2-3 meters for wavefront sensing
  - May take longer to switch between XCS and CXI for certain XCS configurations
- Advantages
  - We get a channel-cut monochromator for free
    - Since XCS will have one on the direct beam line
  - We get access to the split-and-delay for free
    - It will move from the channel-cut mono line to the large offset mono line
      - CXI is on the same line as the channel-cut line
  - We may be able to use the mono to shorten the pulses
    - With loss of intensity
  - We can always put CXI devices in the tunnel but they would be shared with XCS and not useable during beam-sharing

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New Proposed CXI Layout

- Problems
  - Everything must go inside the hutch
  - Need to make sure KB mirror vacuum is never contaminated by Sample Chamber
    - Big concern for 0.1 micron KB due to short focal length
  - Long arm from KB to back of the hutch complicates beamline mechanics
  - How do we get 10 micron focus without lenses in the tunnel?
  - We are building 2 sample chambers anyway, so how can we keep both instead of throwing 1 away?
- Solutions
  - Bunch optics and diagnostics and combine some of them to reduce length of devices inside the hutch
  - Put both sample chambers in series and have each KB system focus at different planes
    - Put KB1 system first and focus past the KB0.1 system
    - Allows differential pumping to protect mirrors and also the possibility to place a very thin (< 1 micron) window (removable) downstream of the KB0.1 system
      - Allows high pressure (>10^{-5} torr) experiments
  - Place Be lenses between the 2 sample chambers to refocus the 100 nm beam into the second sample chamber
    - Could get larger focus and also collimated "unfocused" beam in second chamber
  - All beams are on the same axis and only slightly (<20 mm) offset from each other
    - Simplifies the mechanics

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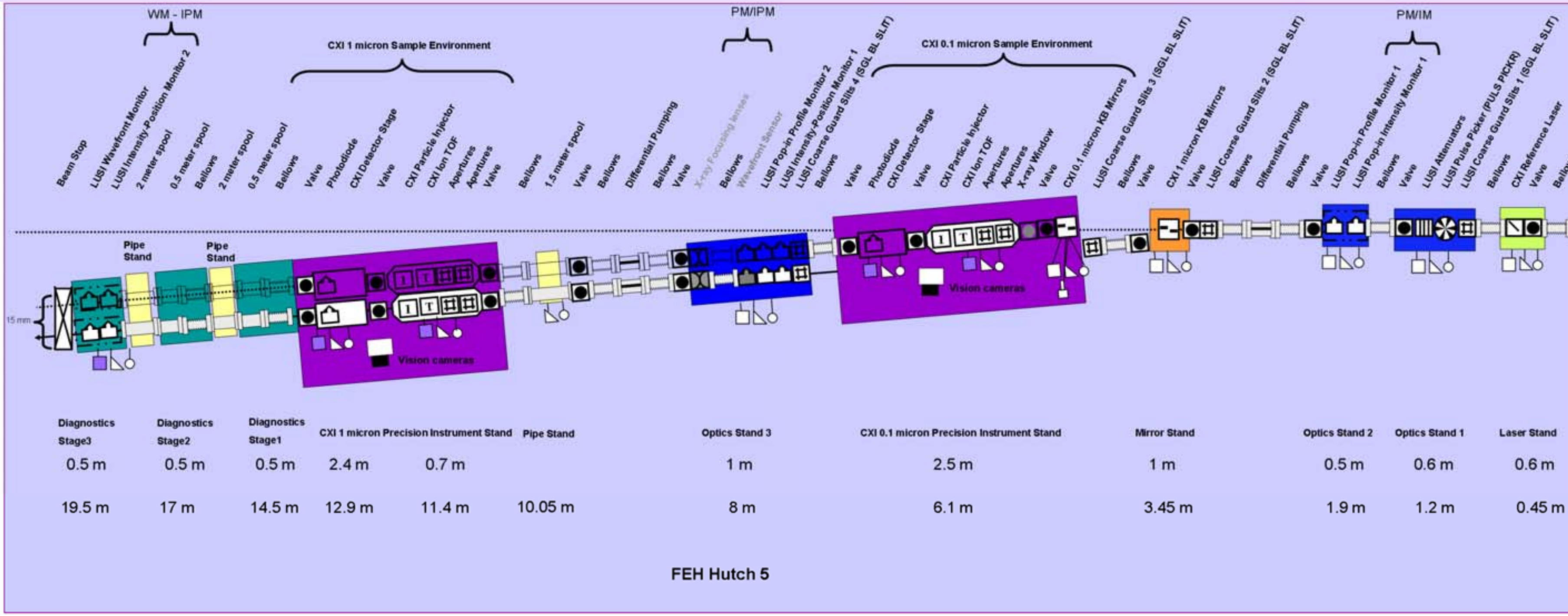
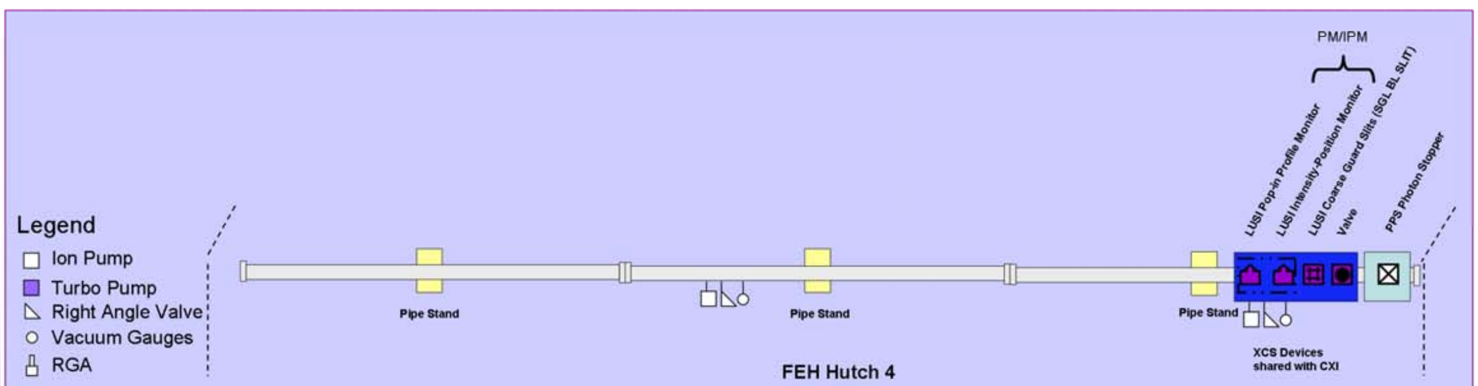
New Proposed CXI Layout





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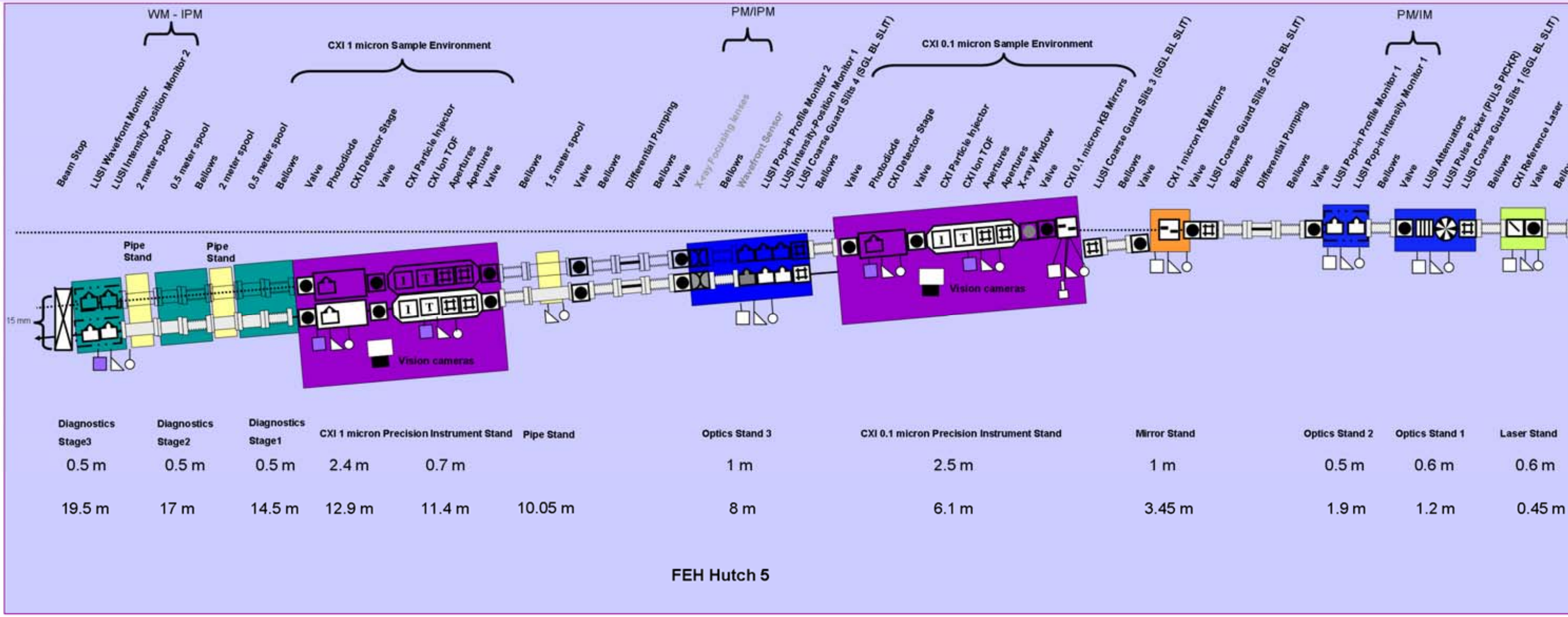
New Proposed CXI Layout



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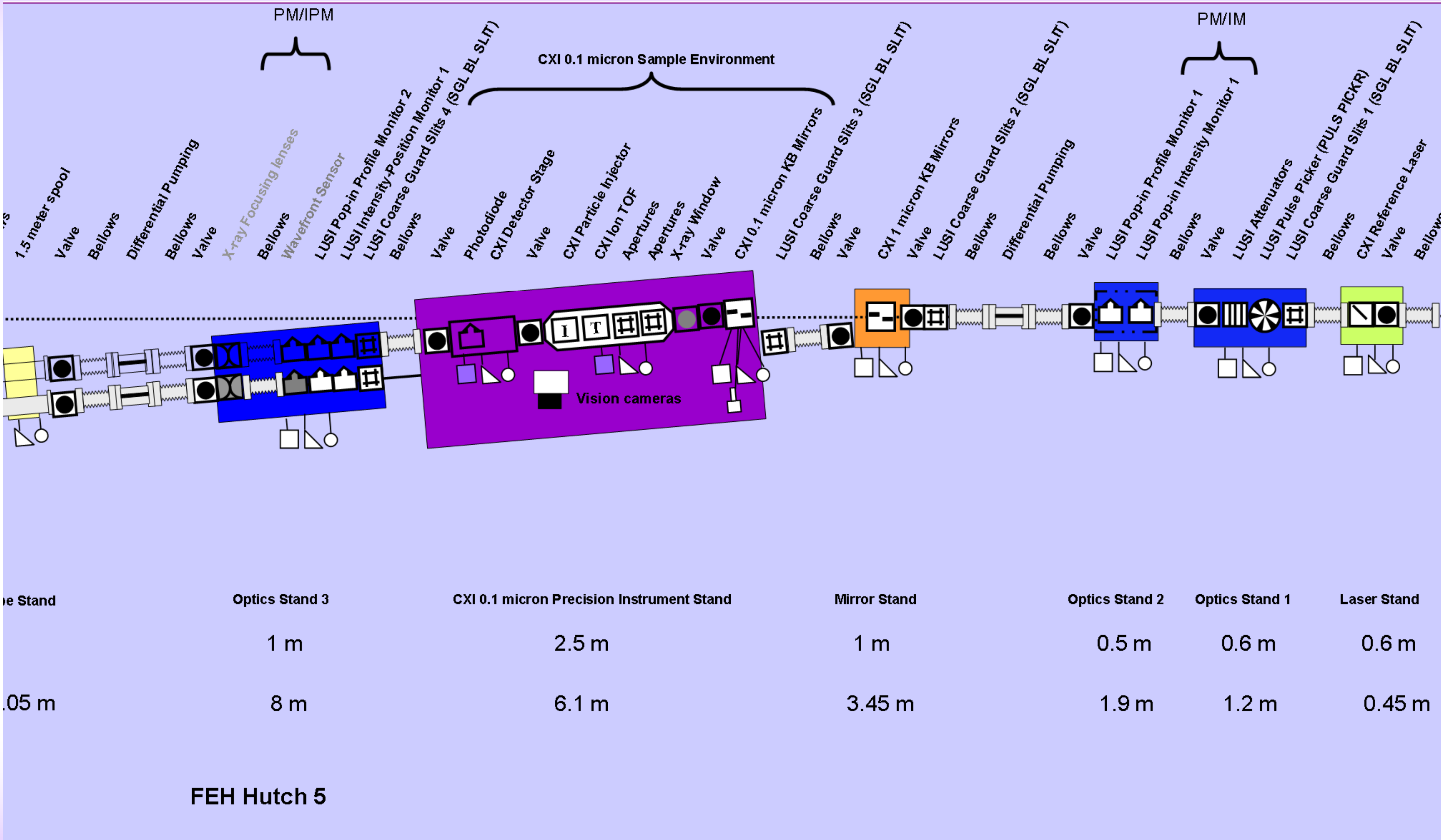

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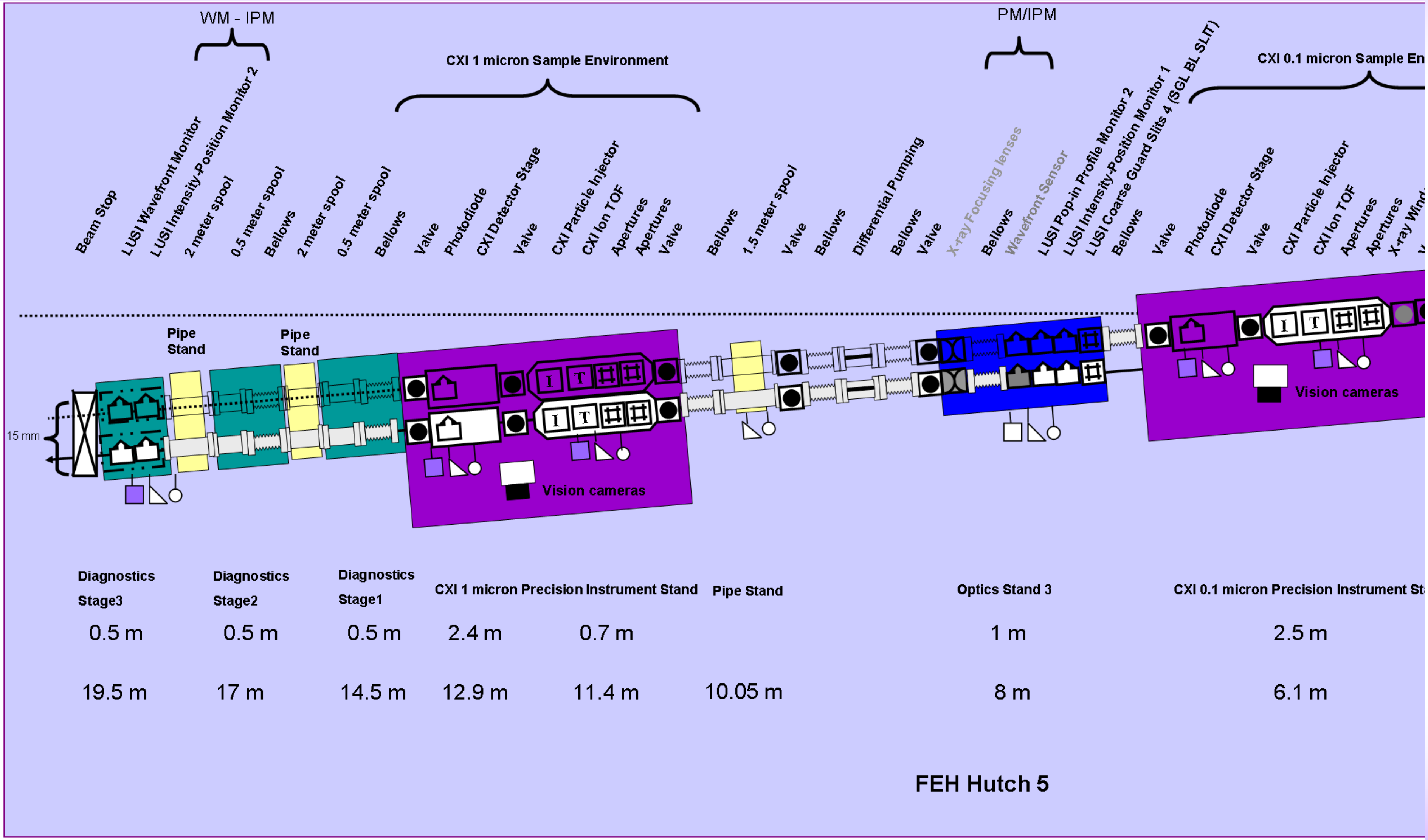

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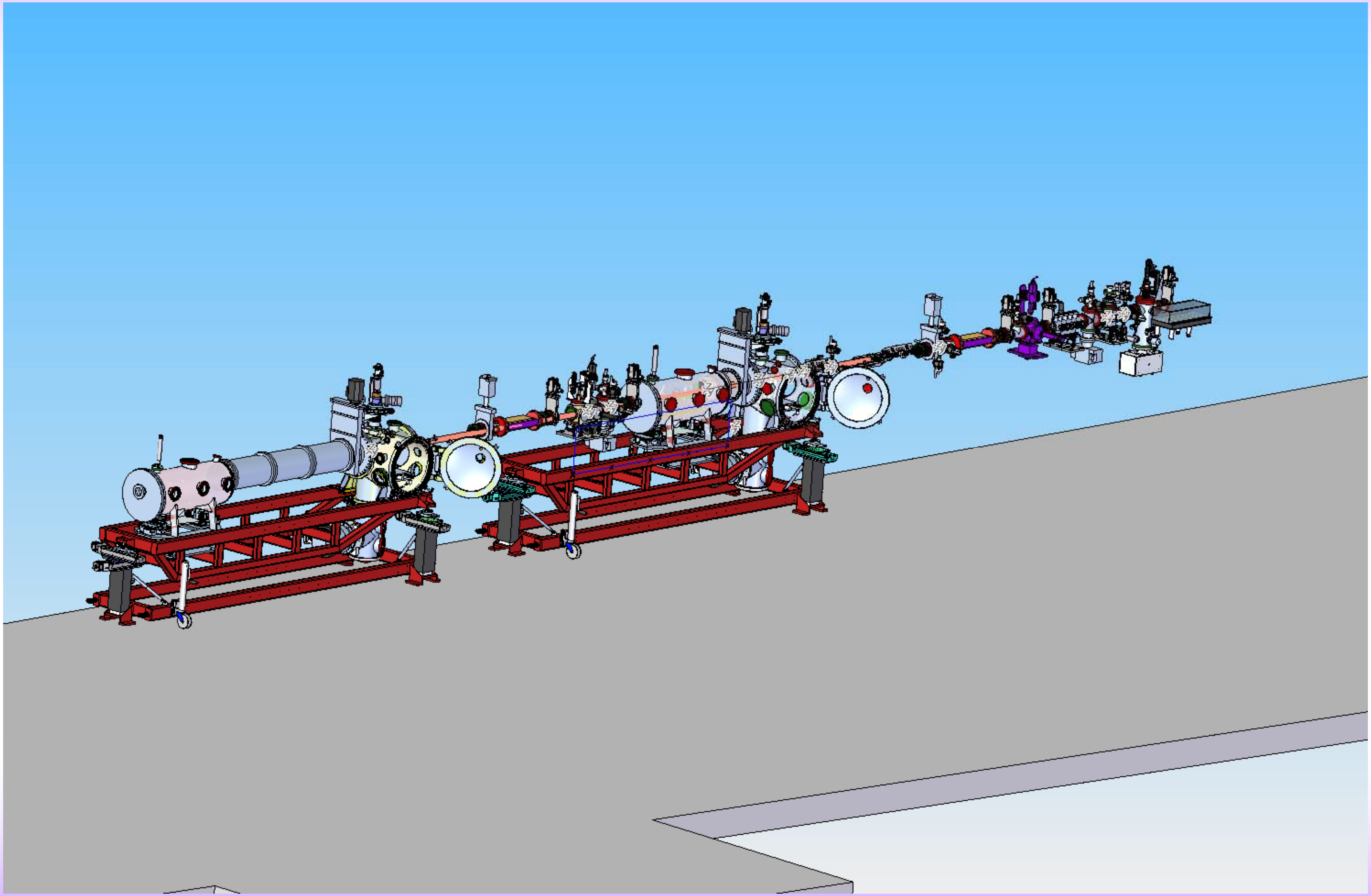

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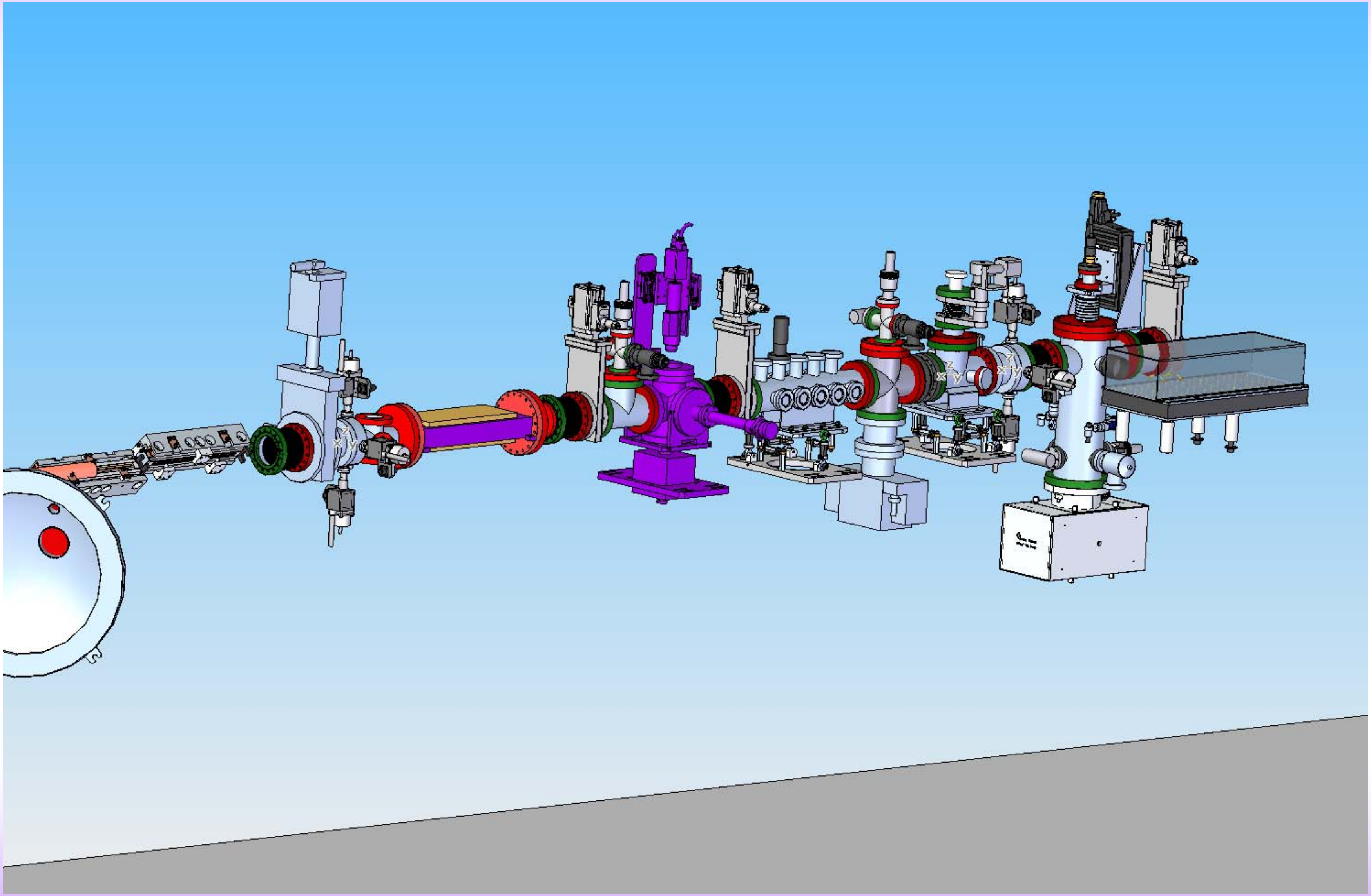

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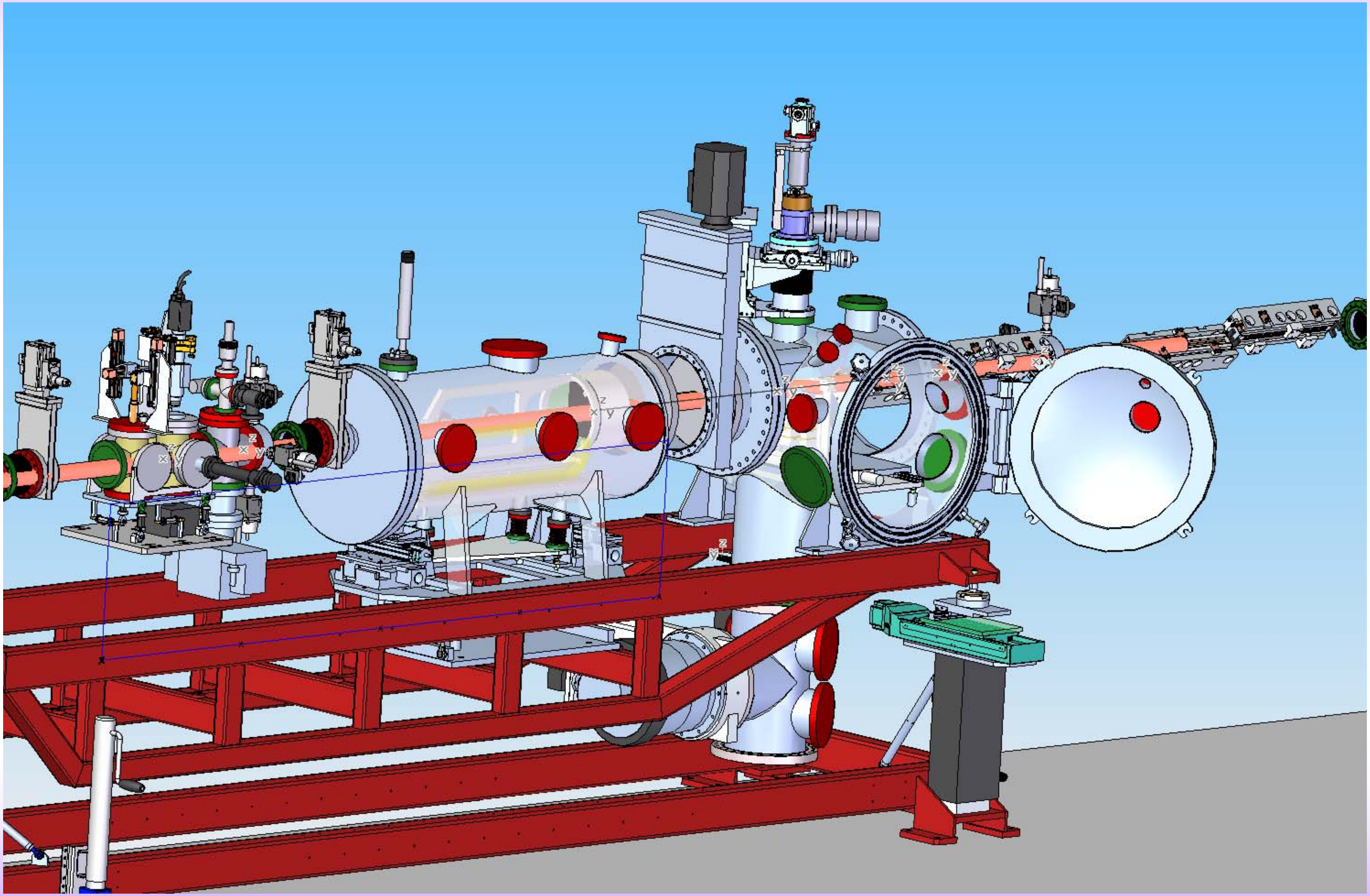

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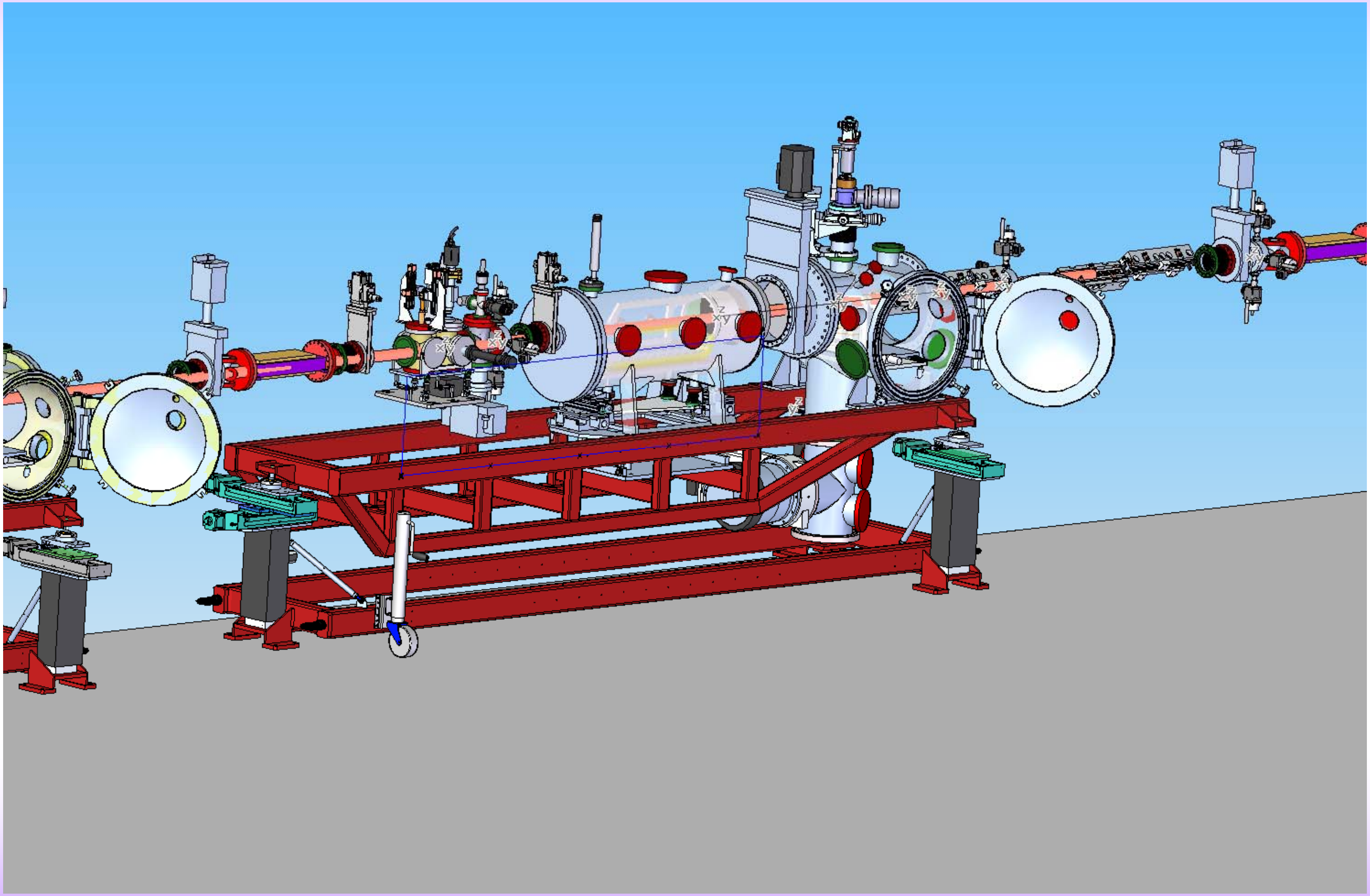

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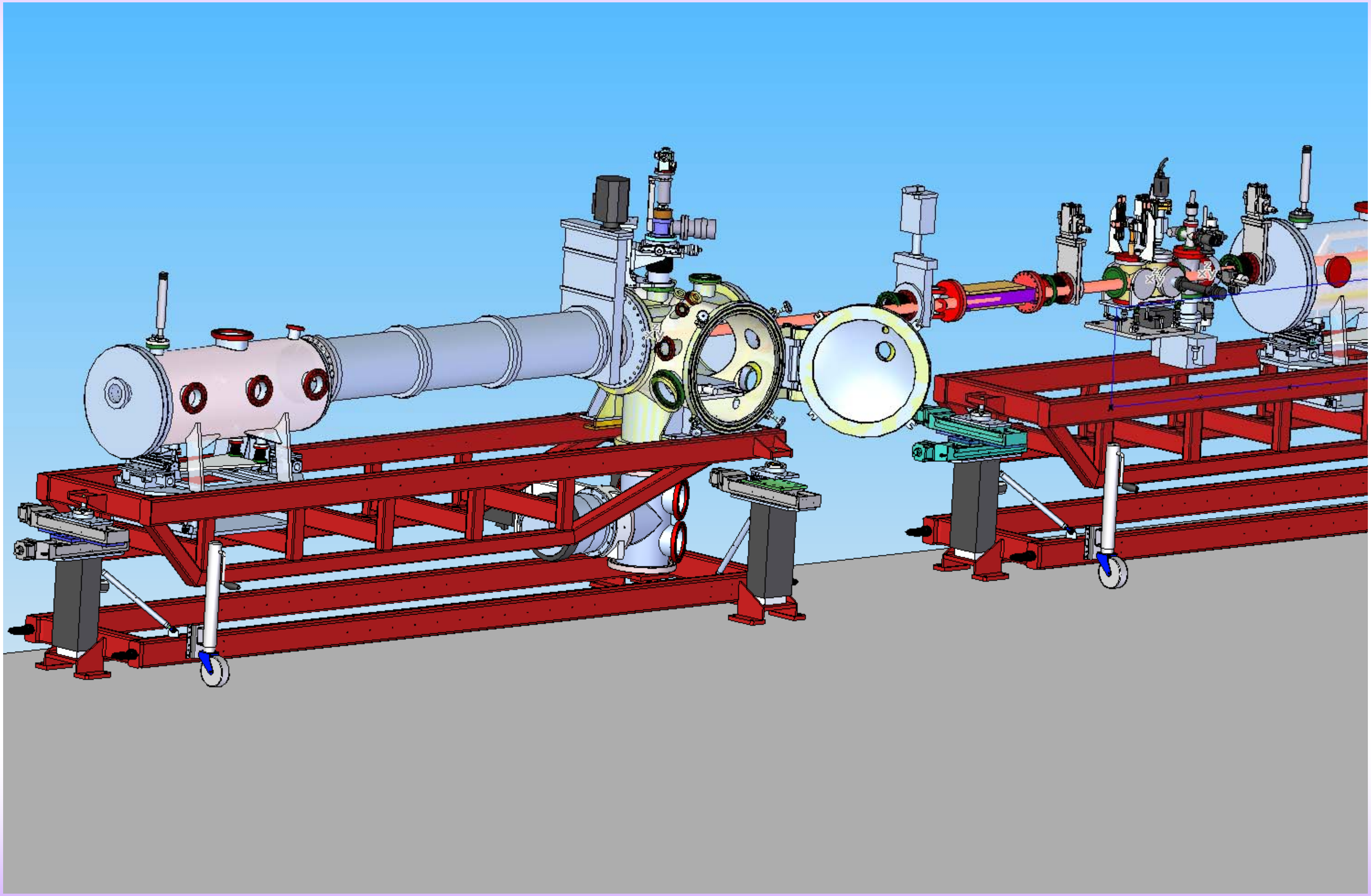

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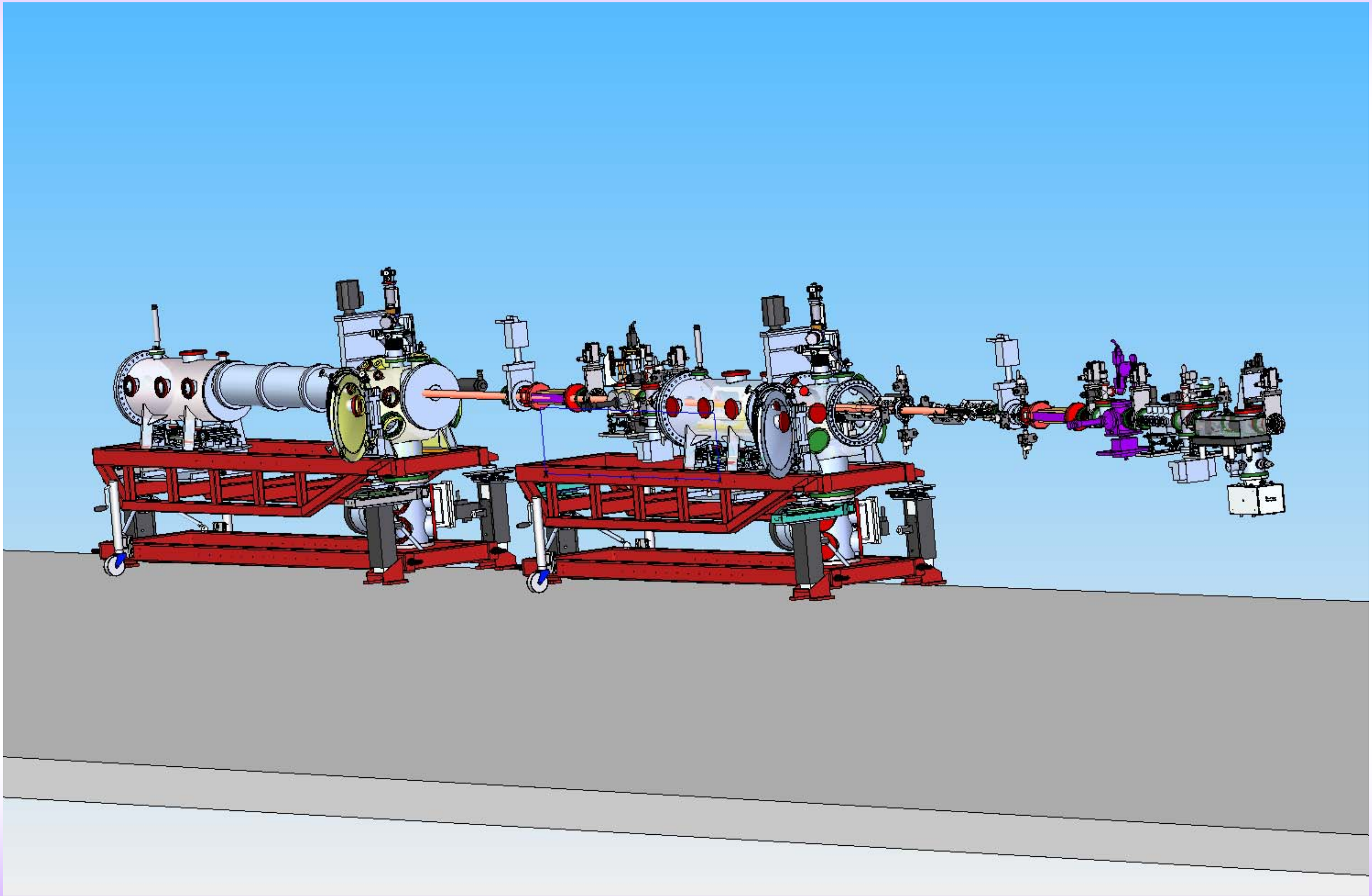

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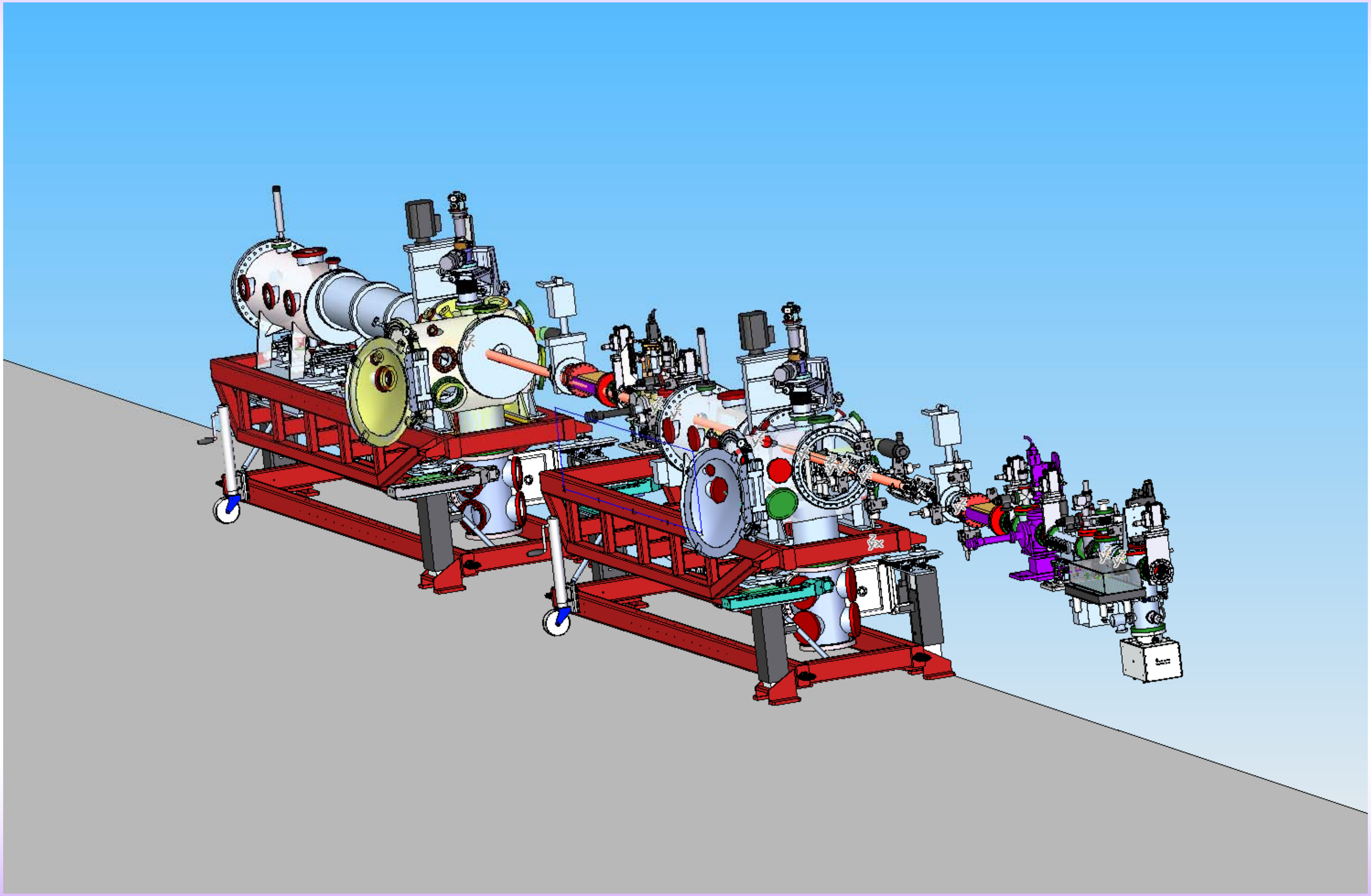

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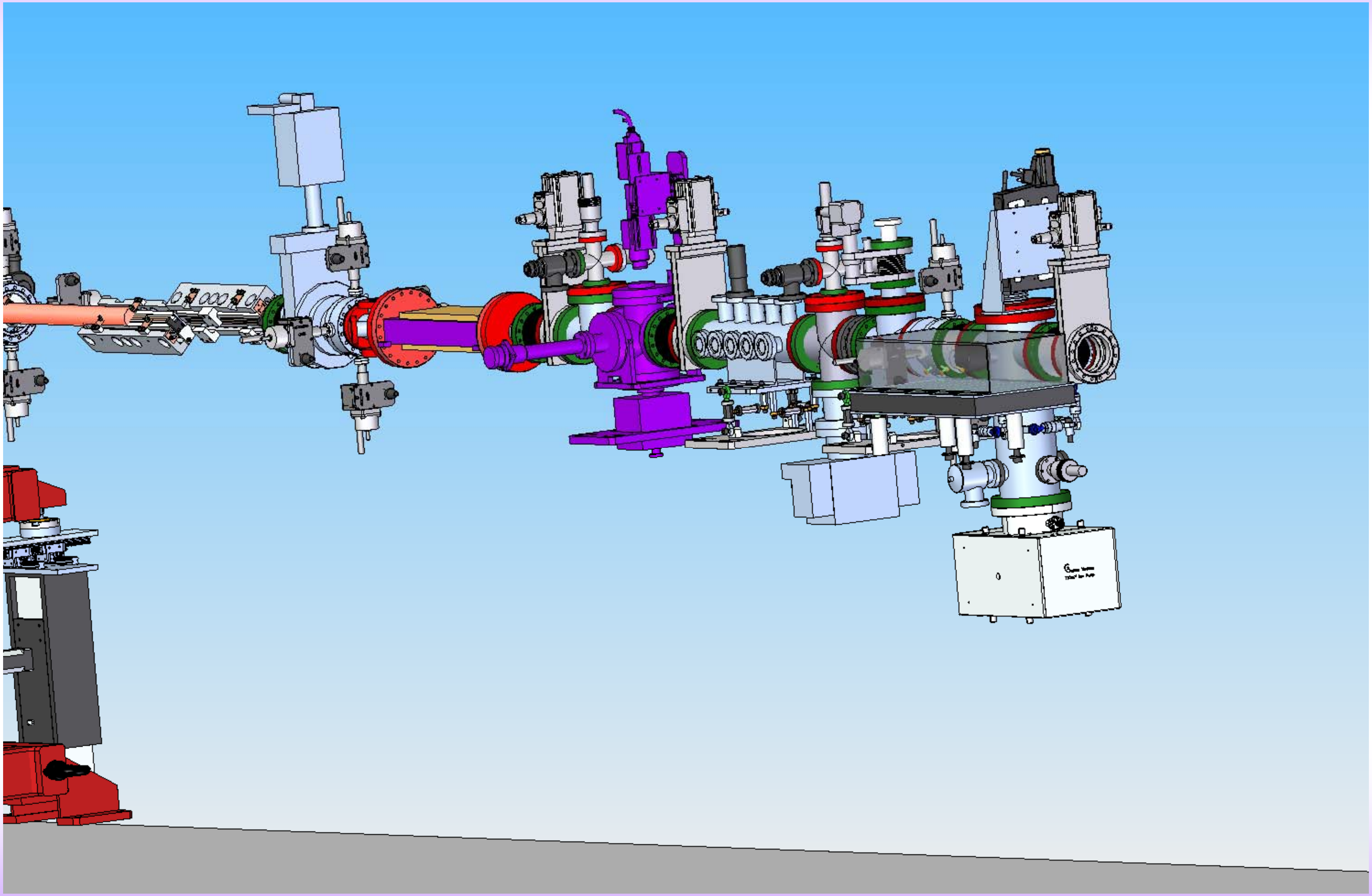

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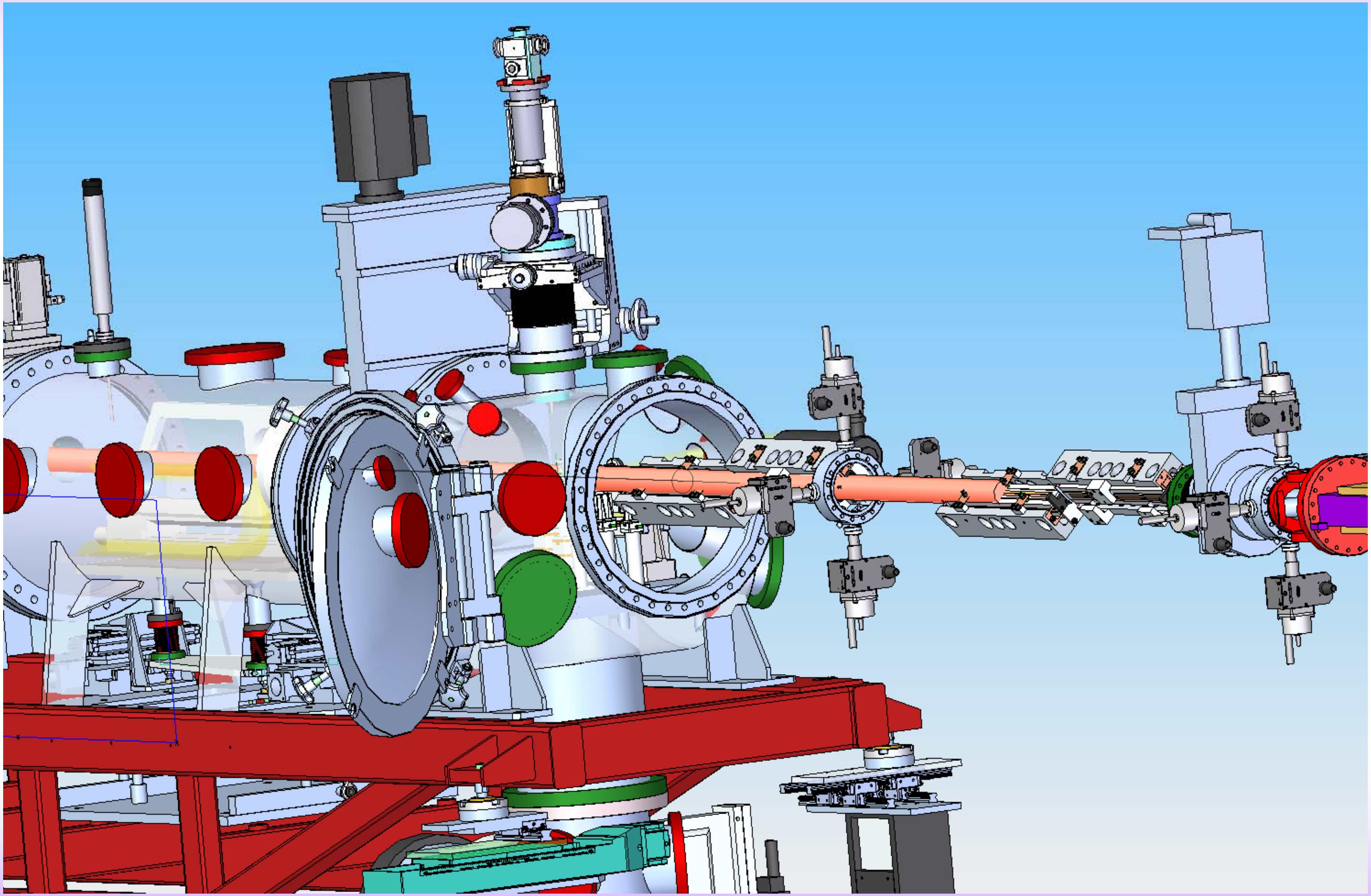

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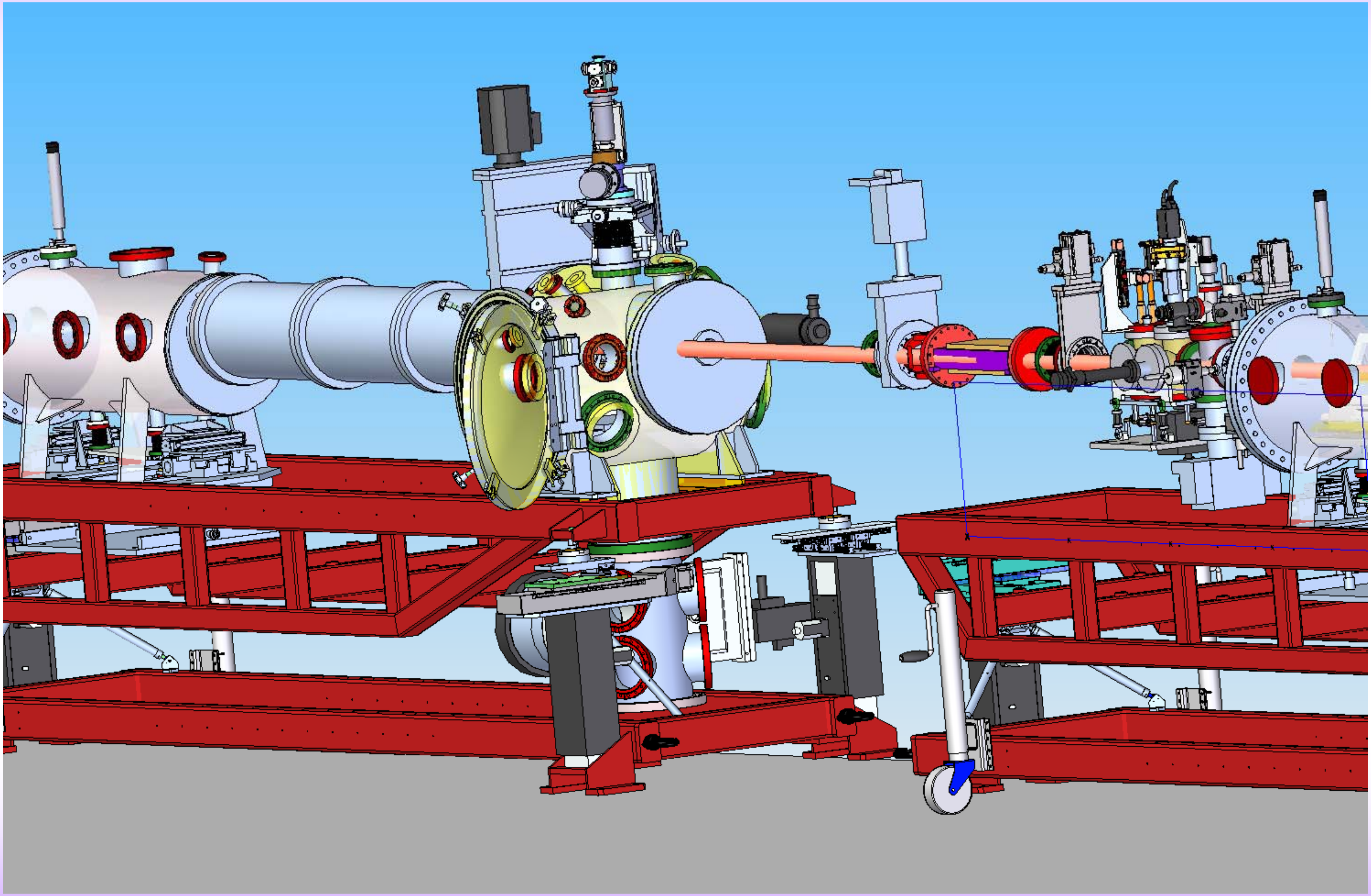

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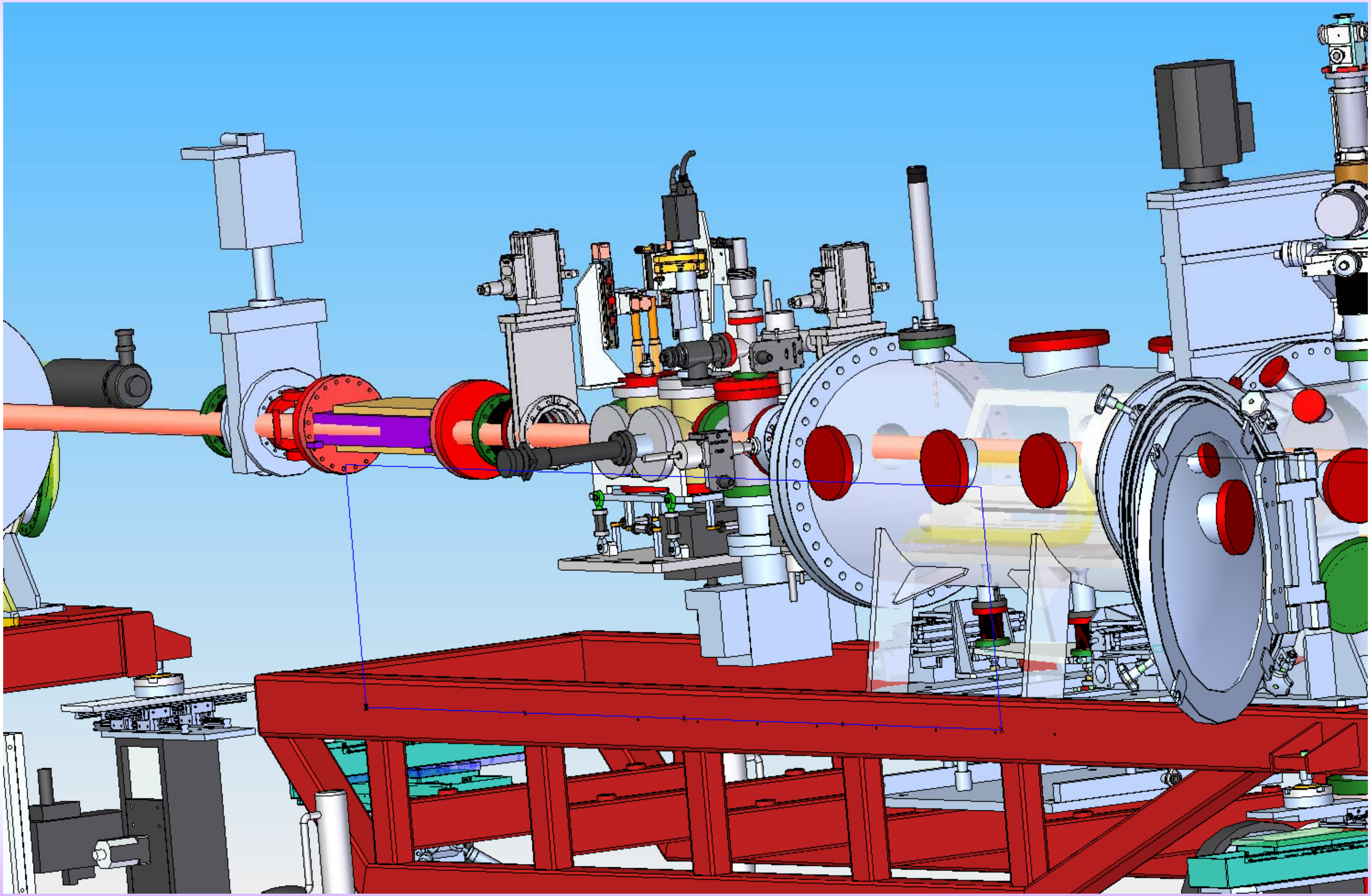

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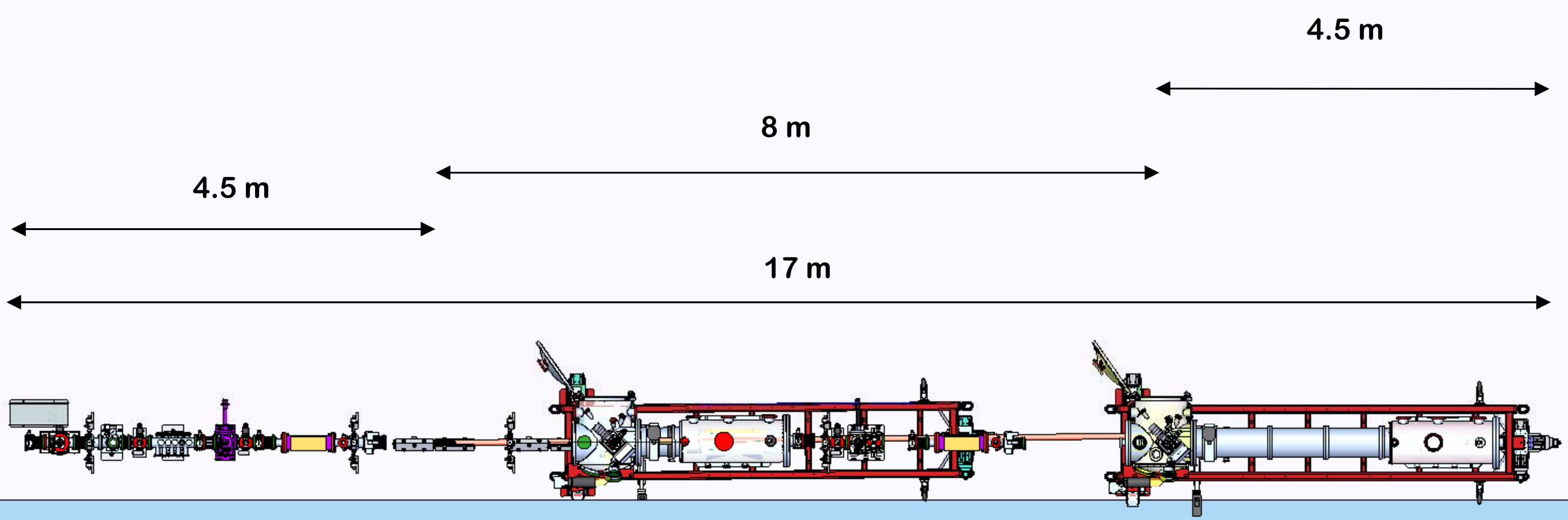
Dimensions



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CXI Scope Additions Priority

- Cheap
  - Wavefront Sensor
    - Fast direct detection detector
  - Imaging ion TOF
  - Be lenses (for larger focus)
  - Second set of chamber inner parts
  - Electron TOF
- Expensive
  - Cryo-goniometer
  - Laser System
  - Pulse Compressor
  - Second Detector

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CXI Scope Reduction Priority

- Install the 0.1 micron KB on LCLS installation
- 0.1 micron KB System
  - 0.1 micron Sample Chamber and Stand

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