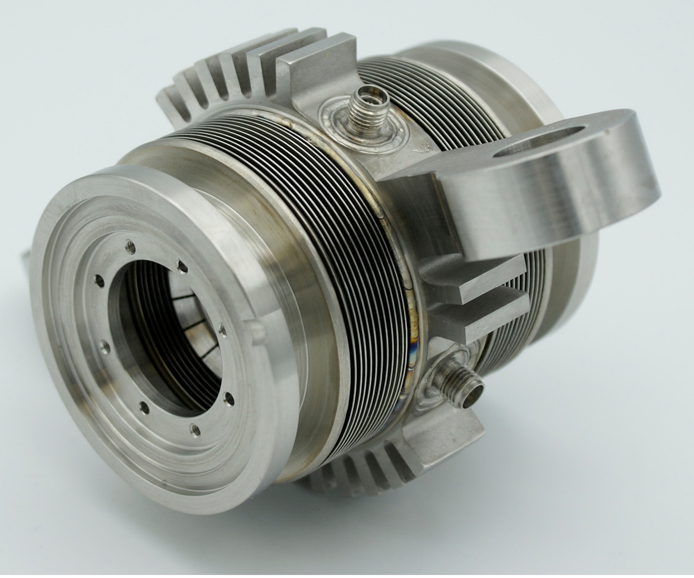
Argonne NATIONAL LABORATORY

Final Design of the APS-Upgrade Storage Ring Vacuum System



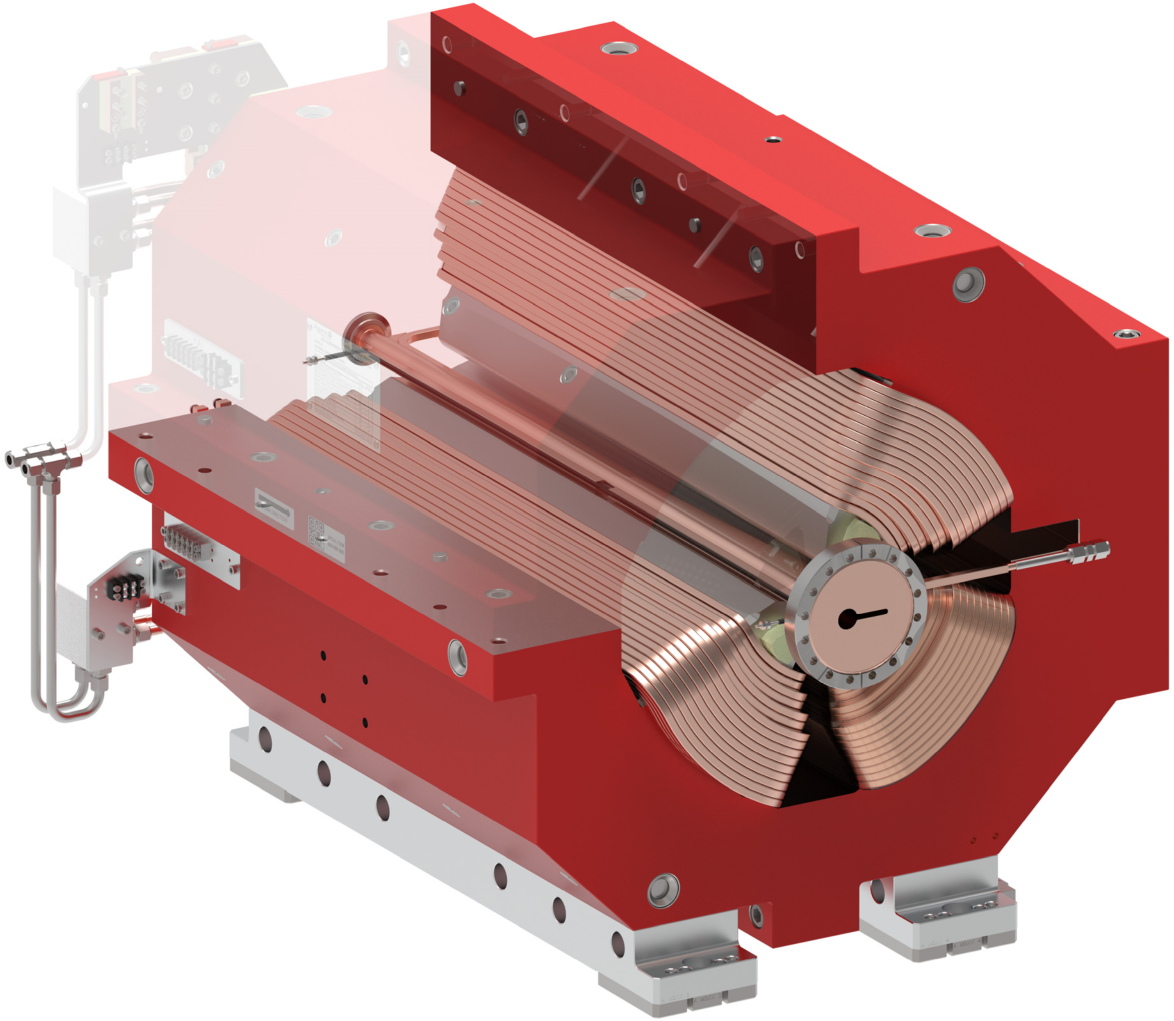
Jason Carter
Lead Vacuum Engineer, APS-U Storage Ring Vacuum System Design Group
Advanced Photon Source
Argonne National Laboratory, Lemont, IL

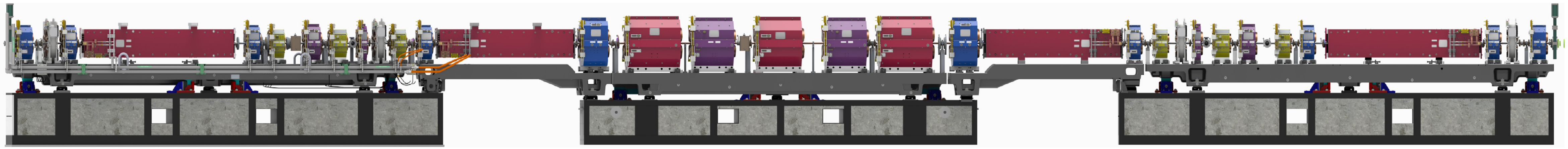
NAPAC 2019 Lansing, MI
September 3, 2019

NAPAC2019
NORTH AMERICAN PARTICLE ACCELERATOR CONFERENCE

Agenda

- APS-U overview
- Interfaces & design challenges
- CAD modeling
- Design of vacuum components
- Future work

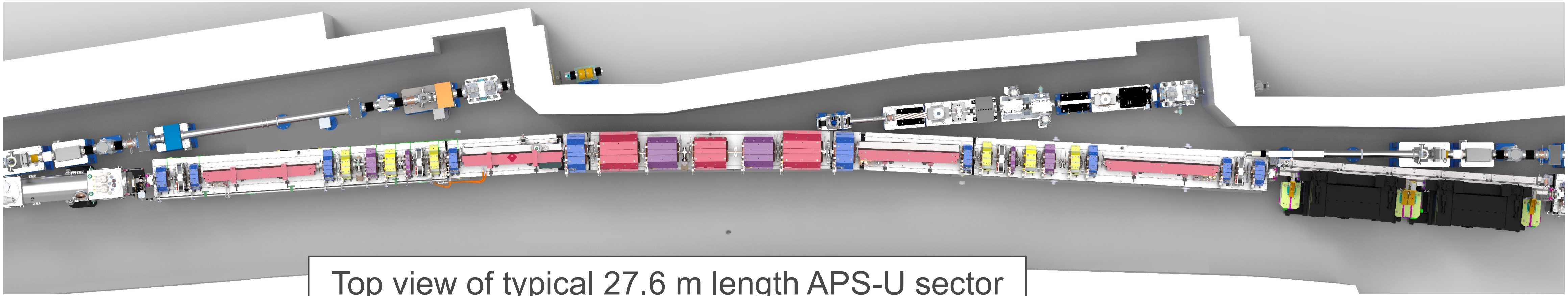




APS Upgrade Project - Overview

- Advanced Photon Source (Operating since 1995)
  - 7 GeV, 100 mA synchrotron light source
  - 1104 m circumference
- APS Upgrade (Operations 2025)
  - 6 GeV, 200 mA retrofit
  - Optimized for brightness above 4 keV
  - Exceeds capabilities of today’s storage rings by 2 to 3 orders of magnitude in brightness, coherent flux, and nano-focused flux
  - Deliver 5000 hrs / year of beam to users at 95% availability
  - Powers entire beamline suit for APS’s >5000 users per year

Advanced Photon Source (APS), Argonne National Laboratory, Lemont, IL

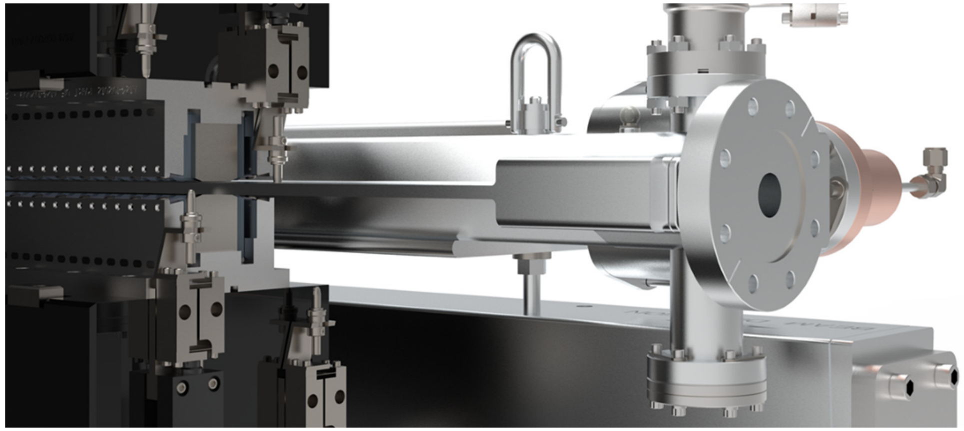


Top view of typical 27.6 m length APS-U sector

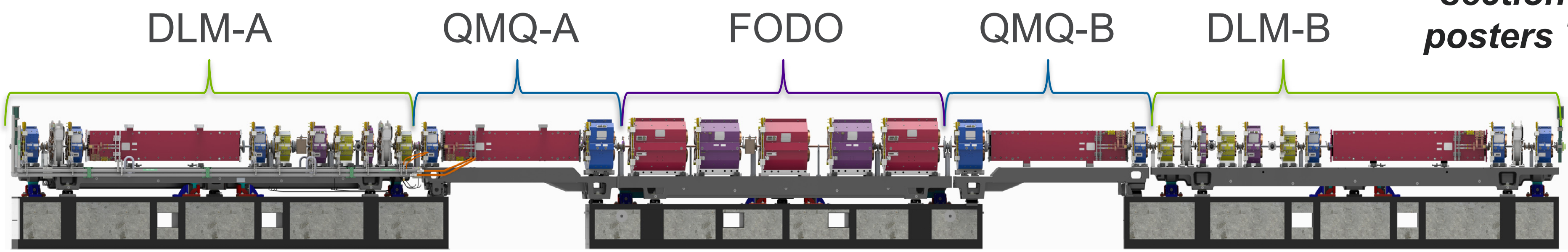
Argonne NATIONAL LABORATORY

APS-U Storage Ring - Overview

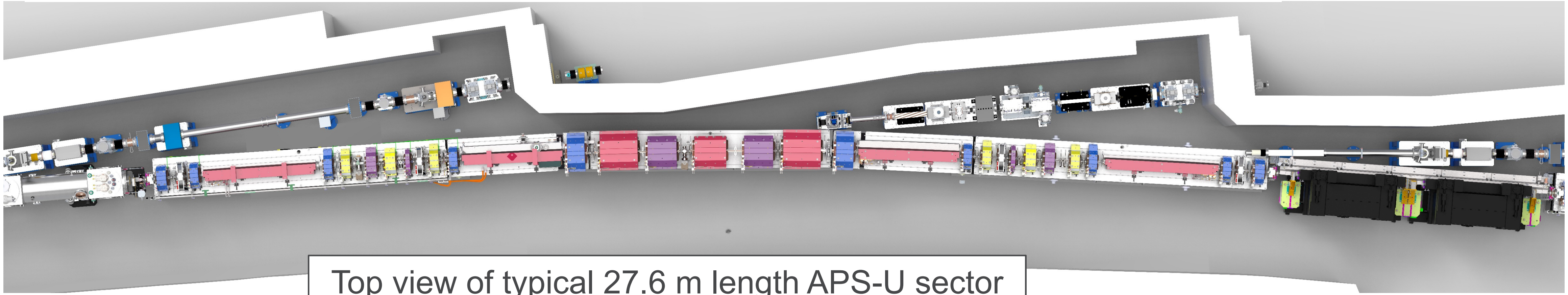
- 40 sectors in the storage ring, each 27.6 m in length
- Sectors consist of arcs + straight section
  - Arcs divided in 5x modules per sector
  - Modules each assembled during pre-installation phase
  - Assembled modules brought into tunnel during 1-year installation/dark time



For information on straight section vacuum design see posters TUPLS02 & TUPLS03



Aisle-side view of arcs only

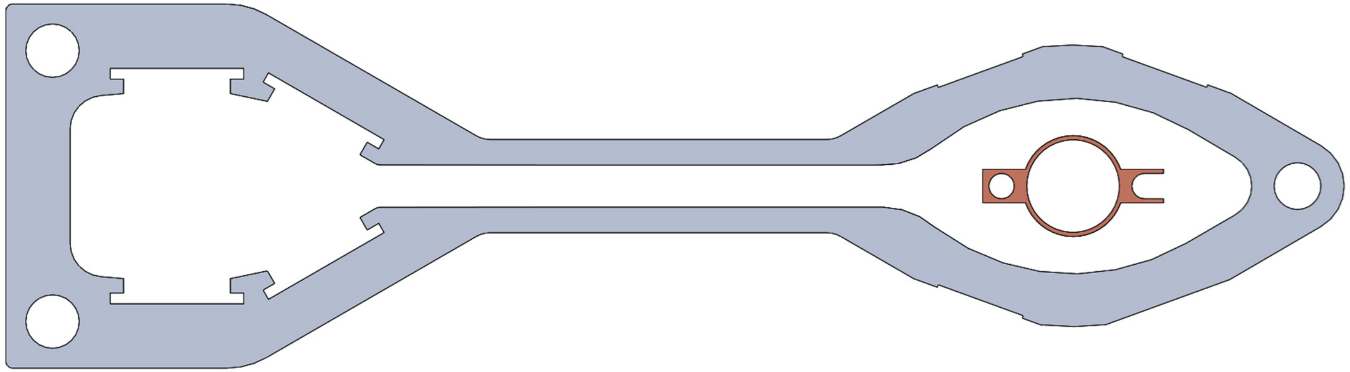


Top view of typical 27.6 m length APS-U sector

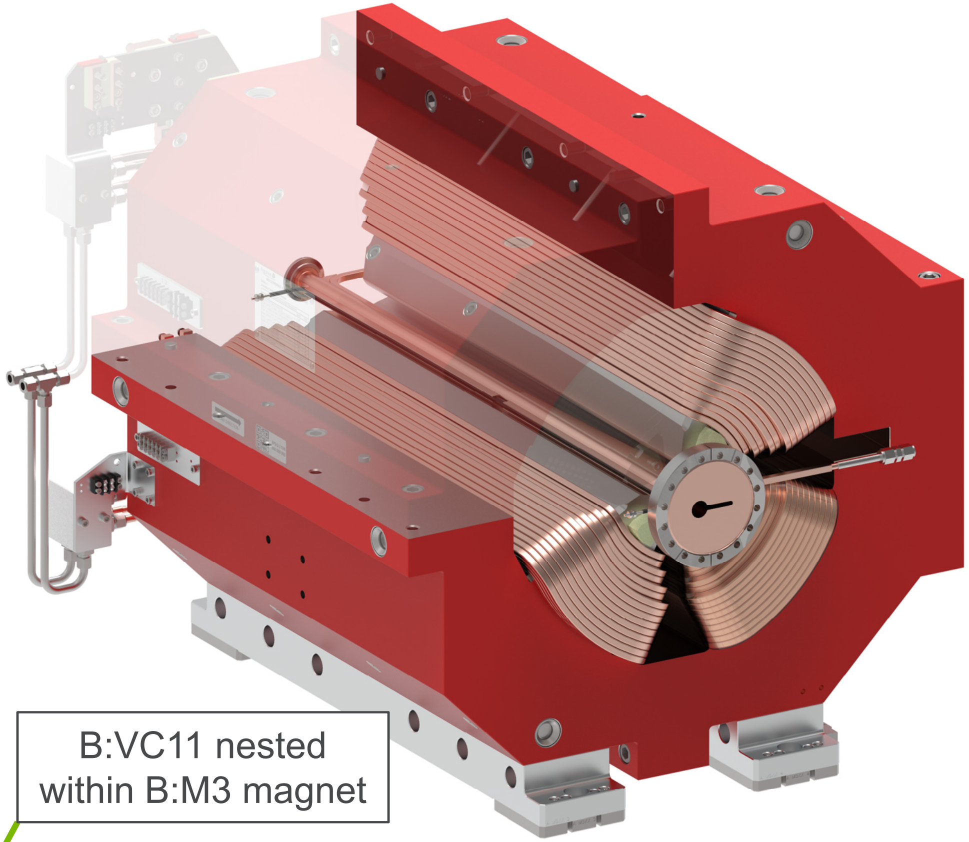
Argonne NATIONAL LABORATORY

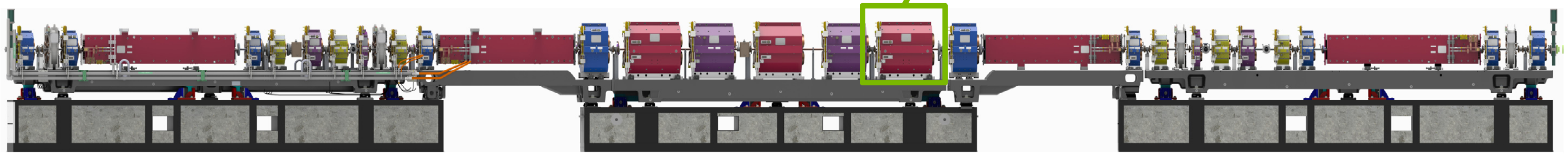
APS U Storage Ring Vacuum System - Overview

- 22 mm nominal vacuum chamber aperture
- Hybrid use of common pumping elements
  - NEG-coated tubes across 40% of the ring
  - 9x discrete ion pump / NEG cartridge combos
  - NEG strips across 2 m long chambers with antechambers
- Quick conditioning for good beam lifetimes
  - 2 nTorr @ 200 mA by 1000 A*hrs conditioning (1E-11 Torr/mA)



Existing APS storage ring chamber compared to new 22 mm ID APS-U style chamber

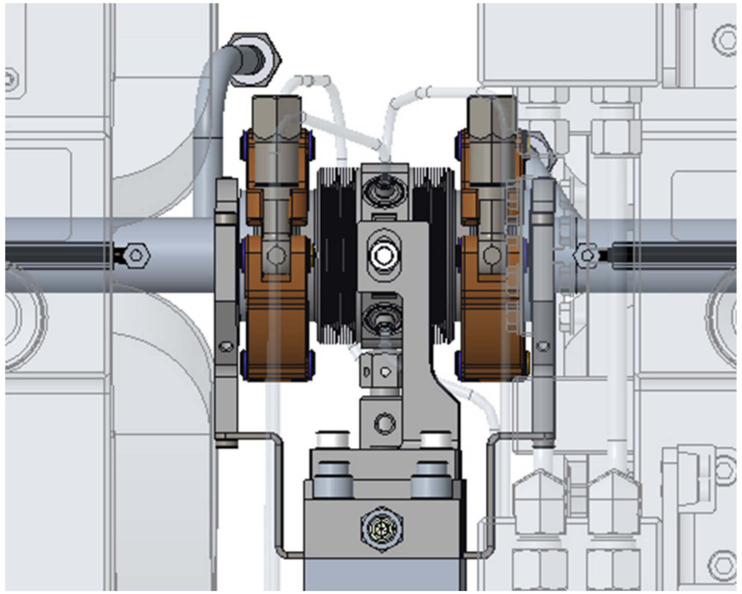




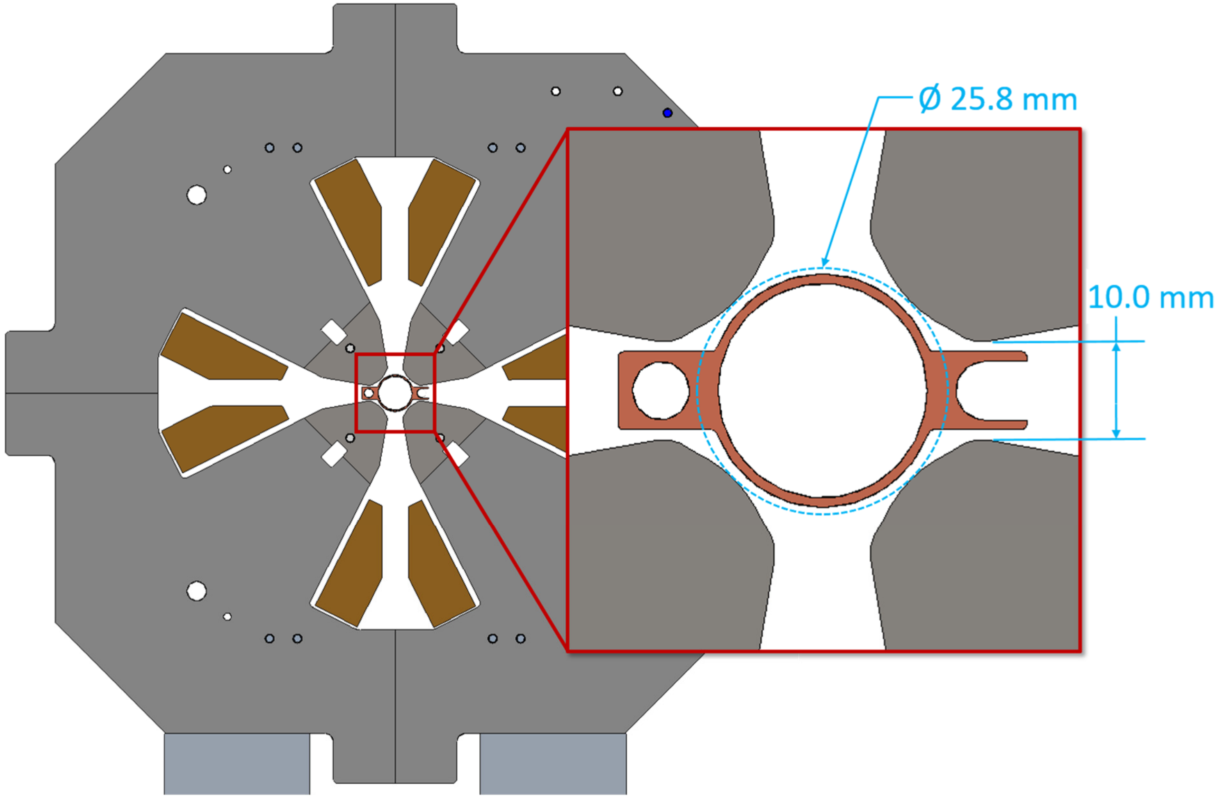
See poster TUPLS11 on all NEG-coated Copper Vacuum Chambers

Interfaces & Design Challenges

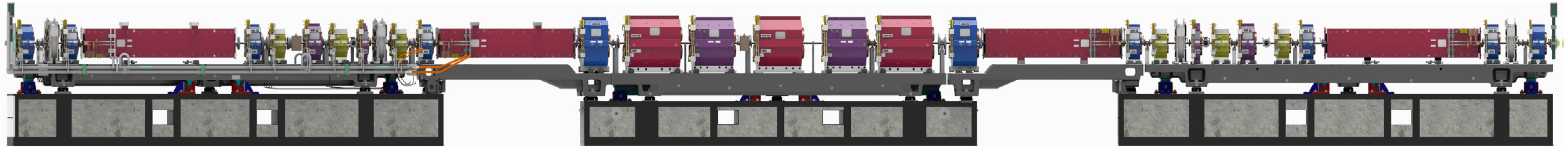
- Chambers typically connect to a standalone Beam Position Monitor (BPM) and compact chamber support
- BPMs accessible through installation gaps as small as 125 mm
- QCF chain clamps for majority of joints
- 0.5 – 1.0 mm clearance between magnet poles



Chambers connected to 70 mm flange-to-flange BPM and support



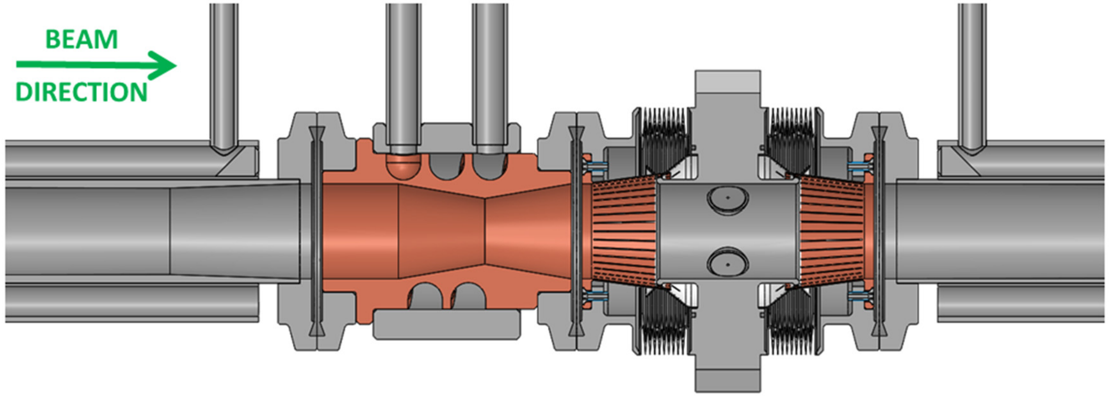
Typical narrow magnet-to-vacuum chamber gaps



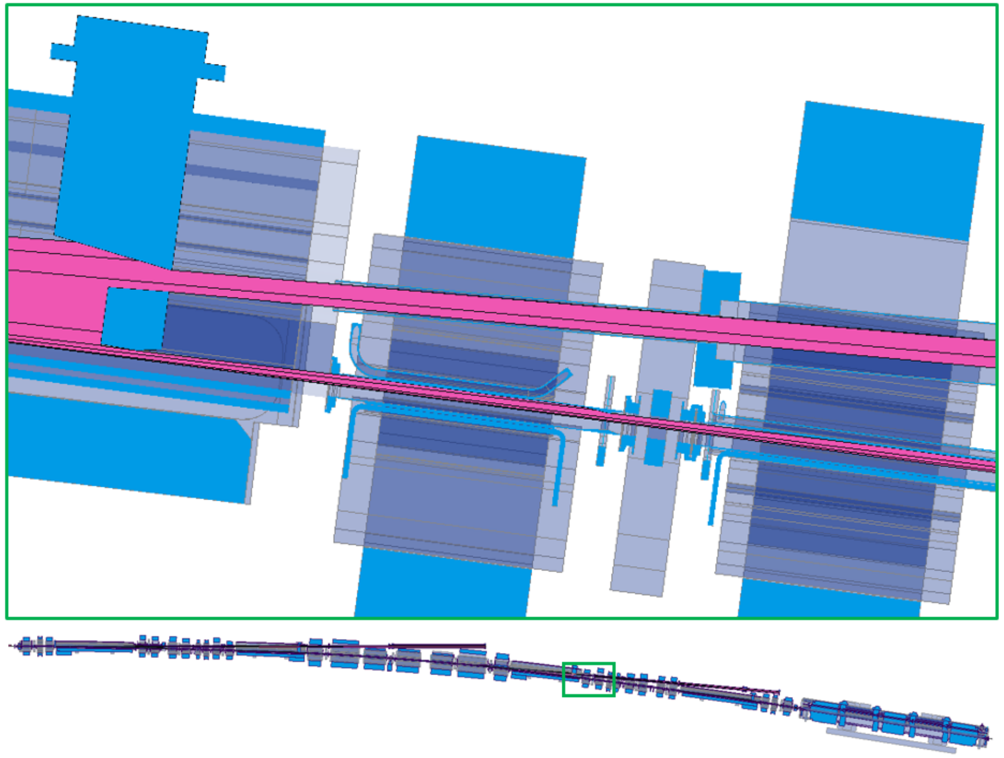
Argonne NATIONAL LABORATORY

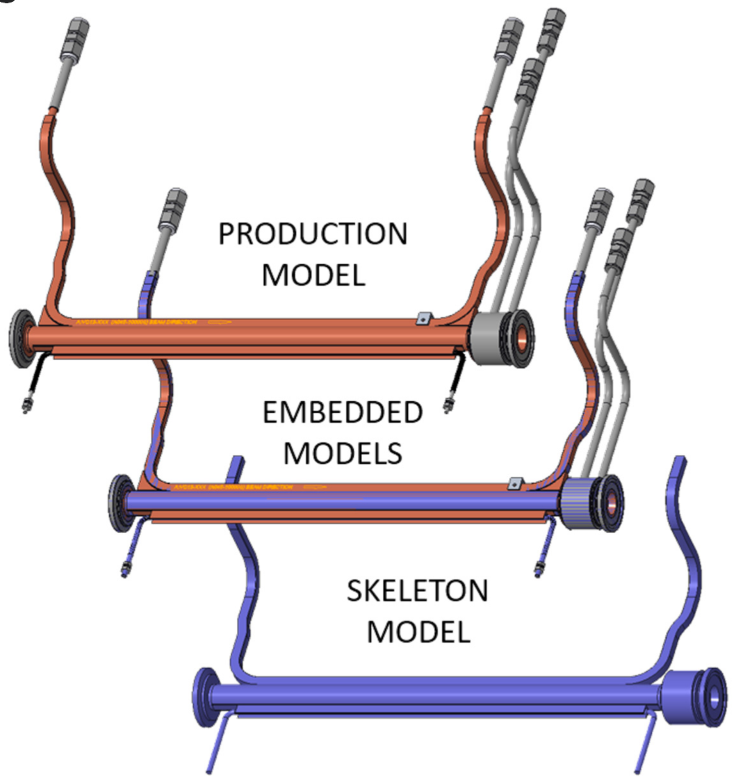
Vacuum System CAD modeling

- Production models built off ‘skeleton’ CAD framework
- Skeletons define interconnected lengths and locations of all components
- Simplified models capture core details, embedded within production model details
- Subtle system-level adjustments easier to implement, communicate across groups
- Full sector ray trace off of 29 unique dipole arcs
- Robust shadowing designed across all BPMs, flange joints, and extraction chambers



Typical ‘in-line’ absorber shadowing BPM



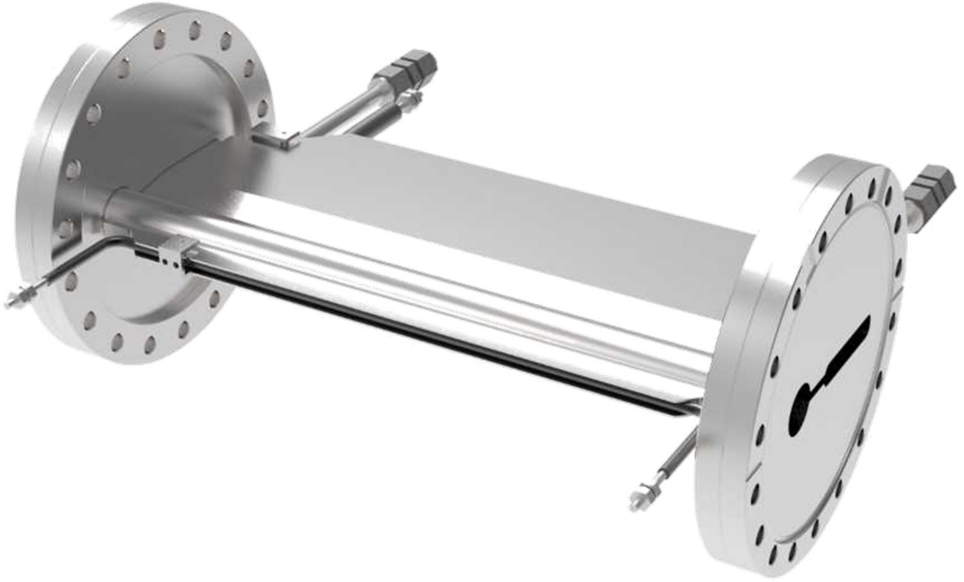


Ray tracing (pink) off of crotch absorber using simplified skeleton geometry (blue)

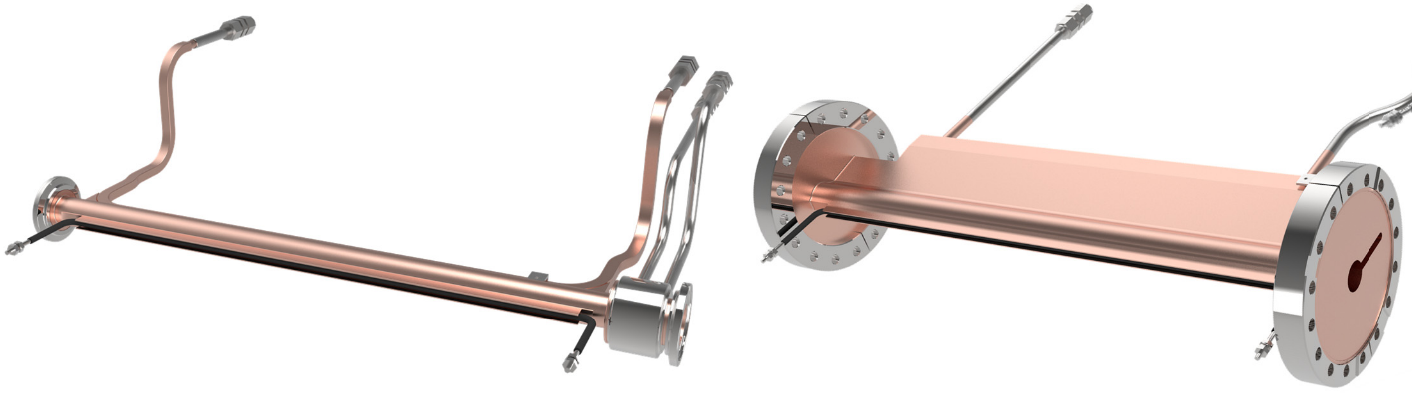
Argonne NATIONAL LABORATORY

Design of Vacuum Components

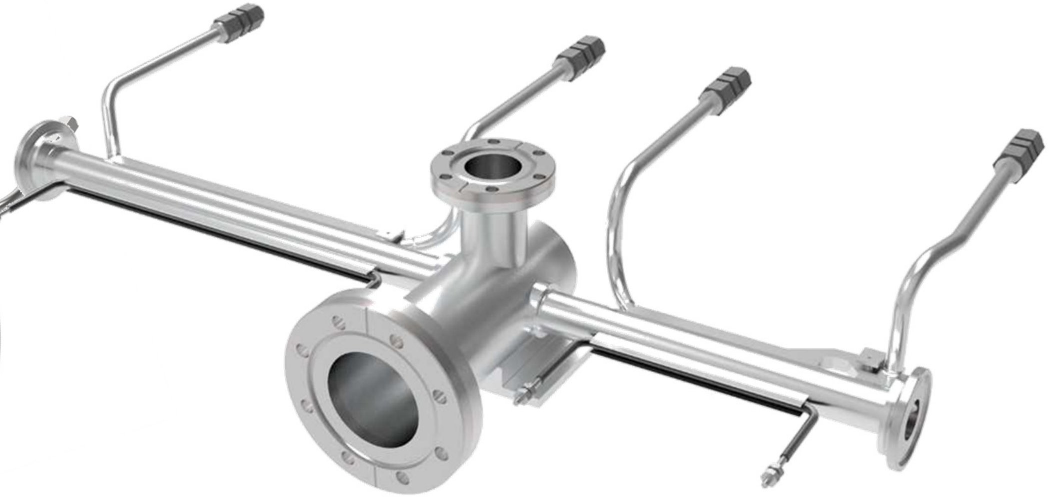
- 41 vacuum chambers per sector
  - 19 NEG-coated vacuum chambers 0.3 – 1.7 m lengths
  - 4 L-bend chambers w/ antechambers 2.0 – 2.2 m lengths
  - 2 keyhole, 2 crosses, 14 BPMs 0.1 – 0.4 m lengths
- Variety of chamber materials
  - Copper/GlidCop/CuCrZr for 600 – 1000 W/m distributed loads
  - Aluminum up to 160 W/m distributed loads
  - L-bend chambers from long aluminum extrusions
  - Inconel chambers passing through corrector magnets
- Electric bakeout via tube heaters



See poster TUPLS12 on SST Keyhole Vacuum Chambers



See poster TUPLS11 on NEG-coated Copper Vacuum Chambers

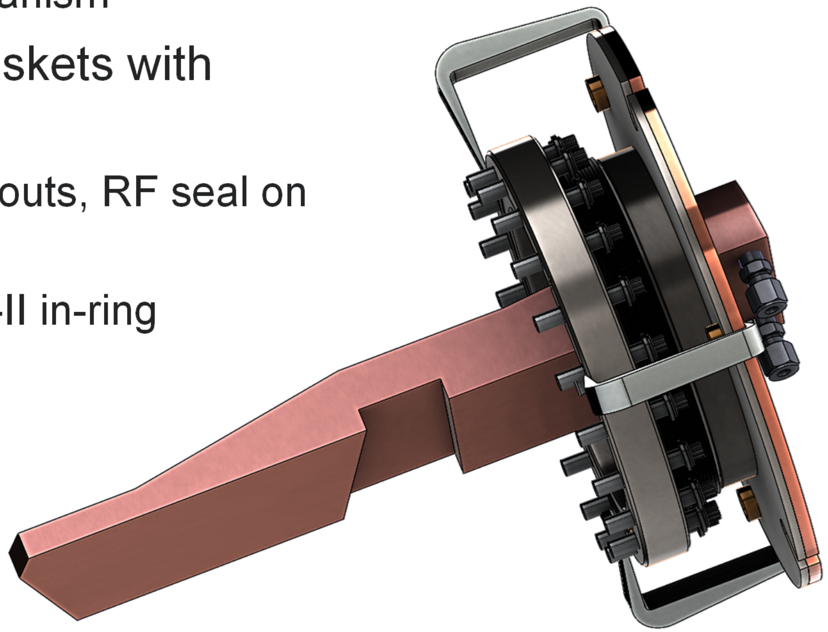


See poster TUPLS12 on NEG-coated Aluminum Vacuum Chambers

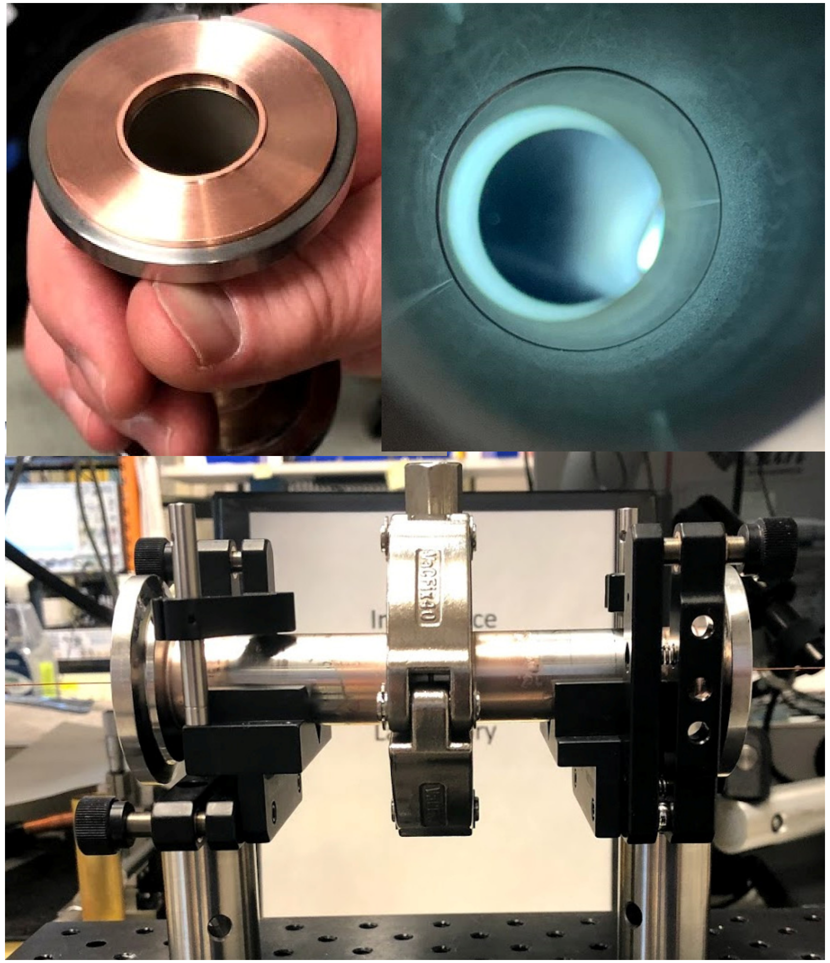
Argonne NATIONAL LABORATORY

Design of Vacuum Components

- High heat load photon absorbers
  - Crotch with 3.4 kW heat load at 200 mA
  - CuCrZr for high strength, lower cost than GlidCop
  - Bellows-based alignment mechanism
- Single-piece custom copper gaskets with RF-sealing internal lip
  - Tested for vacuum across bakeouts, RF seal on stretched-wire Goubau line
  - Performed well in recent NSLS-II in-ring tests with follow-up APS in-ring tests at the end of this month (see next slide)



APS-U crotch-style photon absorber with bellows for precision alignment



Single piece RF-sealing gasket tested for vacuum and on stretched-wire Goubau line

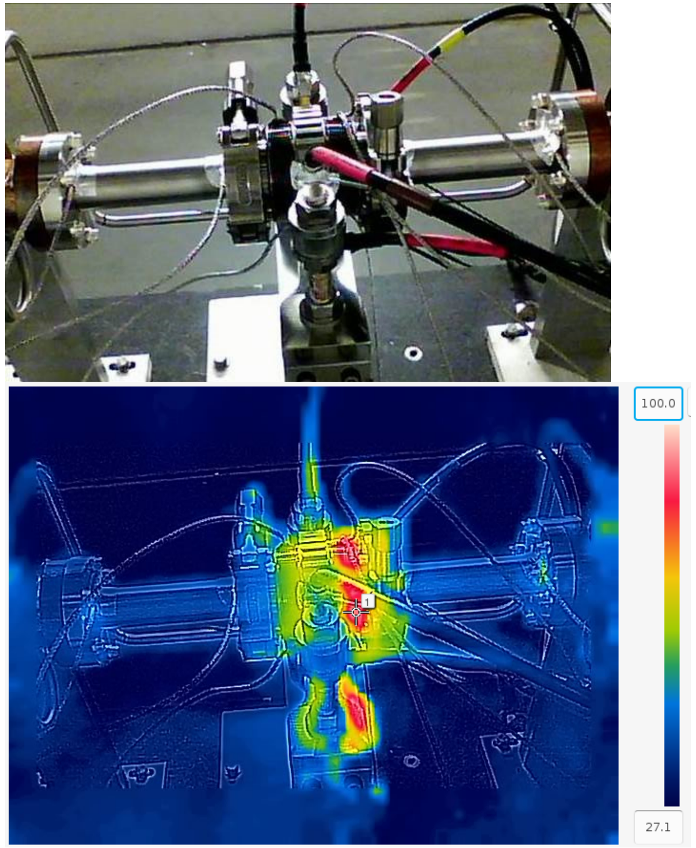
5 discrete photon absorbers per sector

Argonne NATIONAL LABORATORY

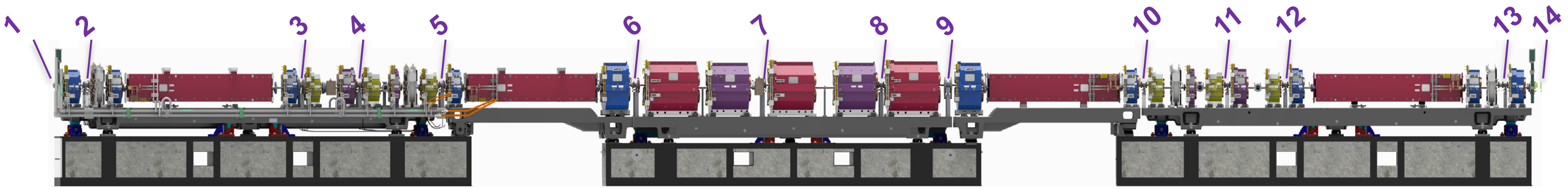
Design of Vacuum Components

- August 2019 NSLS-II in-ring tests of APS-U BPM prototype
  - Prototype with BPM feedthroughs and bellows welded to central housing, internal coatings, detachable RF fingers
  - In-ring test stopped at 100 mA where unit was hot due to unrestrained RF fingers slipping out of contact
  - Follow-up APS in-ring test to be installed September 2019
- Lessons learned:
  - Careful QA of BPM feedthroughs
  - Finalizing bellows restraints
  - Improving design of weld joints
  - Coating process is dirty and best earlier in manufacturing

APS-U BPM prototype



NSLS-II in-ring setup (top) and infrared image (bottom)



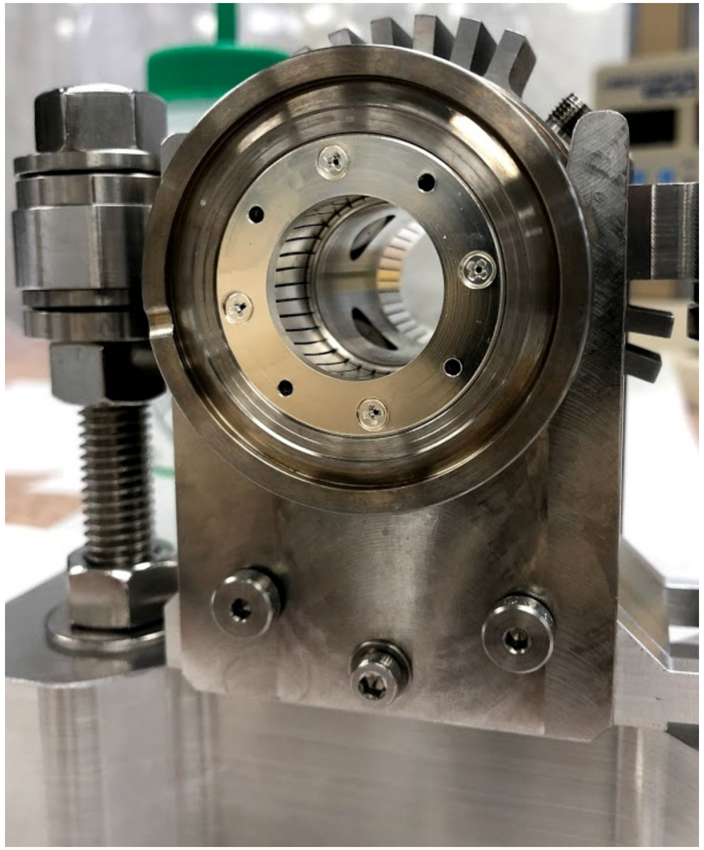
14 BPMs per sector

Argonne NATIONAL LABORATORY

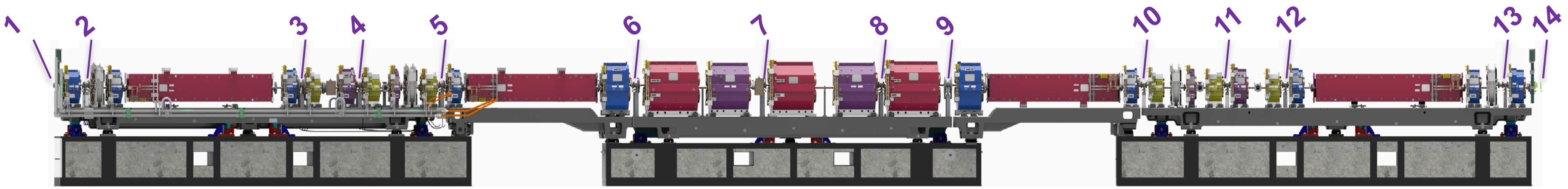
Design of Vacuum Components

- August 2019 NSLS-II in-ring tests of APS-U BPM prototype
  - Prototype with BPM feedthroughs and bellows welded to central housing, internal coatings, detachable RF fingers
  - In-ring test stopped at 100 mA where unit was hot due to unrestrained RF fingers slipping out of contact
  - Follow-up late September 2019 APS in-ring test
- Lessons learned:
  - Careful QA of BPM feedthroughs
  - Finalizing bellows restraints
  - Improving design of weld joints
  - Coating process is dirty and best earlier in manufacturing

APS-U BPM prototype



RF fingers installed w/ additional restraints for APS in-ring test

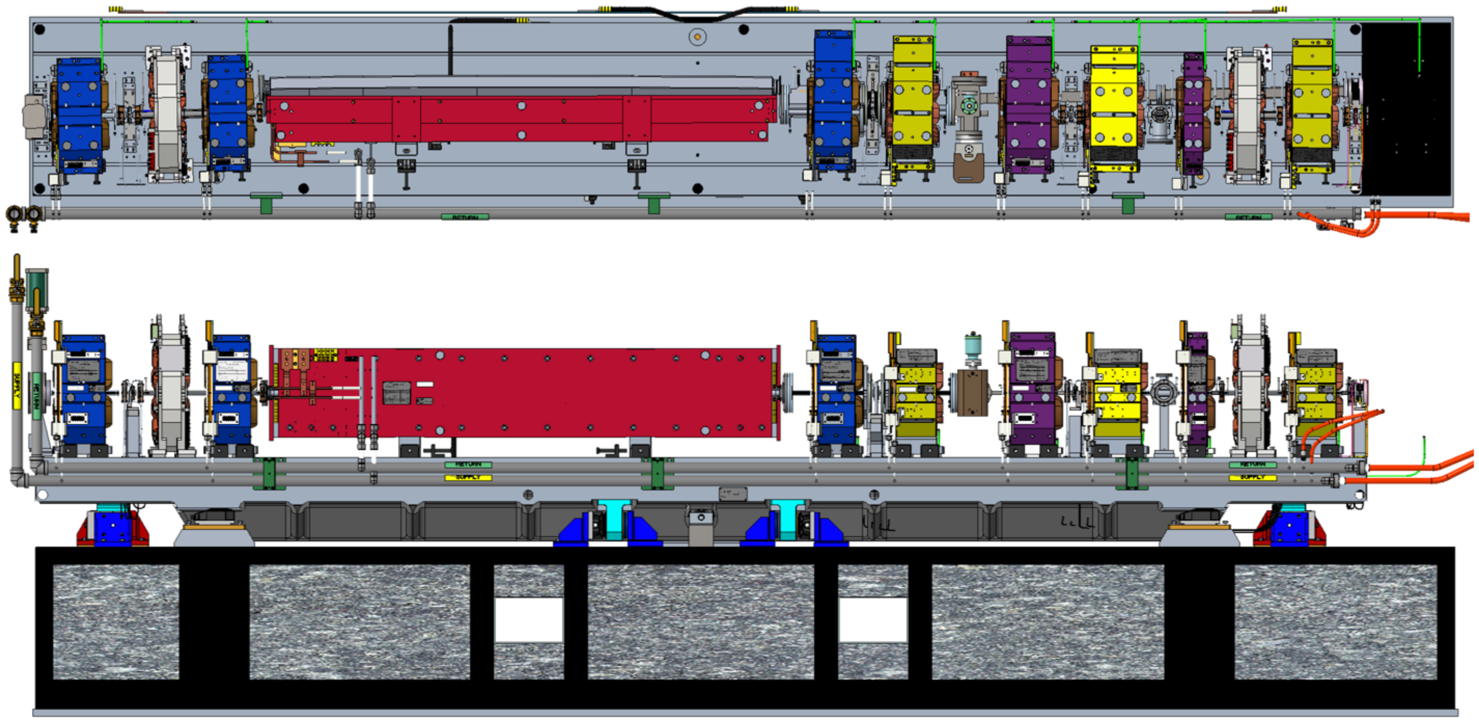


14 BPMs per sector

Argonne NATIONAL LABORATORY

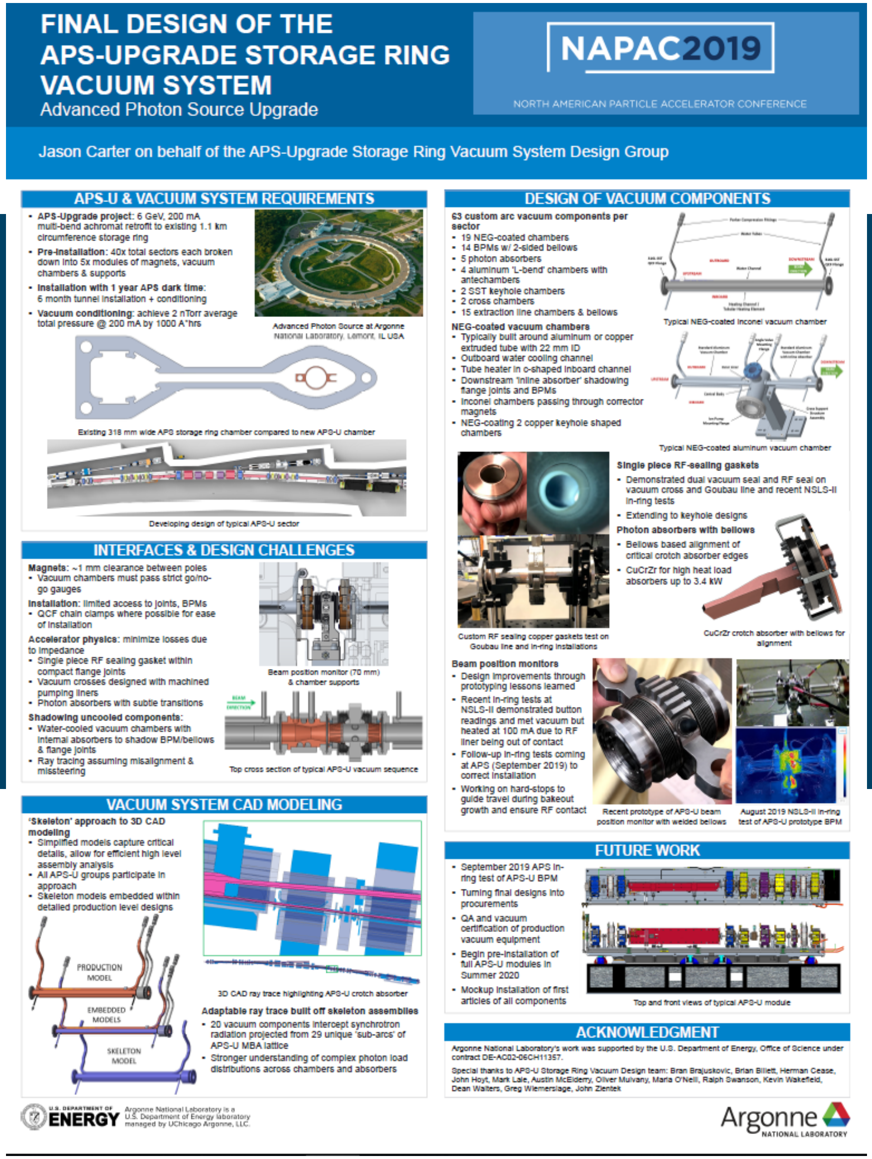
Conclusions and future work

- Future work
  - APS in-ring test of BPM prototype at the end of this month (September 2019)
  - Turning final designs into procurements
  - Contracts have been awarded for keyhole chambers and some NEG-coated vacuum chambers
  - Extensive QA and vacuum certification of components
  - Begin pre-installation of APS-U modules in Summer 2020 and tunnel installation of modules in 2022
  - Continue towards operations ~2025



Top and aisle-side views of DLM-A module

Questions?



*For questions or more info on this topic visit my poster **WEPLM10** on Wednesday

Additionally, this Tuesday afternoon please see:

TUPLS11 – NEG-coated copper chambers

TUPLS12 – NEG coated aluminum chambers &

TUPLS02/TUPLS03 on APS-U straight section vacuum