PROGRESS ON THE FINAL DESIGN OF THE APS-UPGRADE STORAGE RING VACUUM SYSTEM

MEDSI PARIS 2018
MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION

Jason Carter (CAM, APS-U Storage Ring Vacuum System) on behalf of the APS-Upgrade Storage Ring Vacuum System Design Group

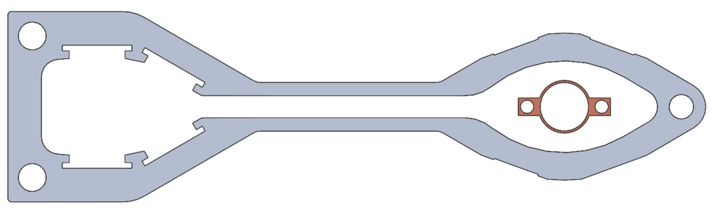
APS-U VACUUM SYSTEM REQUIREMENTS

- **APS-Upgrade**: 6 GeV, 200 mA, 1.1 km circum. optimized for brightness > 4 keV
- **Scope**: Design of vacuum components for 40x sector arcs & 5x 'Zone F' straight sections
- **Installation**: 1 year APS downtime = 6-7 months install + commissioning
- **Conditioning**: 2 nTorr avg pressure @ 200 mA by 1000 A*hrs (1E-11 nTorr/mA)

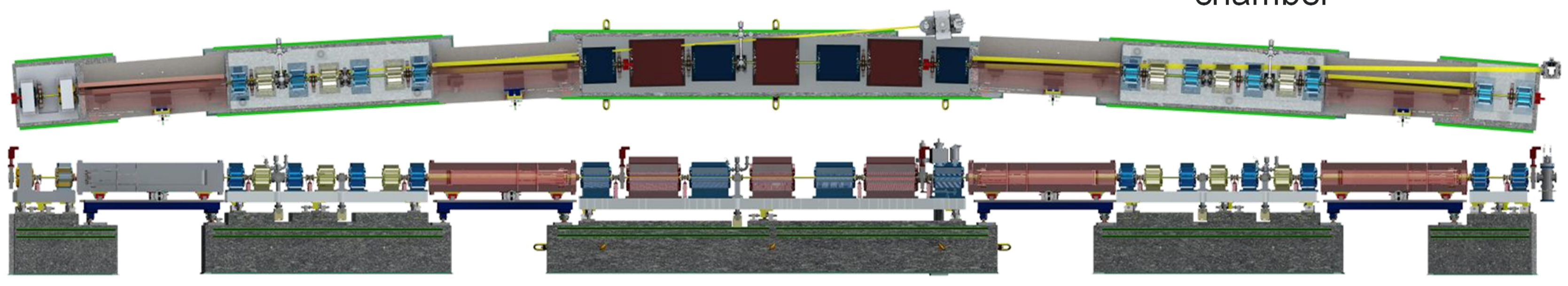
Advanced Photon Source at Argonne National Laboratory, Lemont, IL USA

Standard arc vacuum components

- 27x custom vacuum chambers: 17x round & NEG coated, 2x keyhole, 4x L-bends w/ antechambers, 2x crosses
- 14x BPMs, 6x photon absorbers, 3x gauges, 2x gate valves, photon extraction chambers
- 13x NEG cartridge pumps, 9x ion pumps
- 11.2 m of total 22.1 m length NEG coated



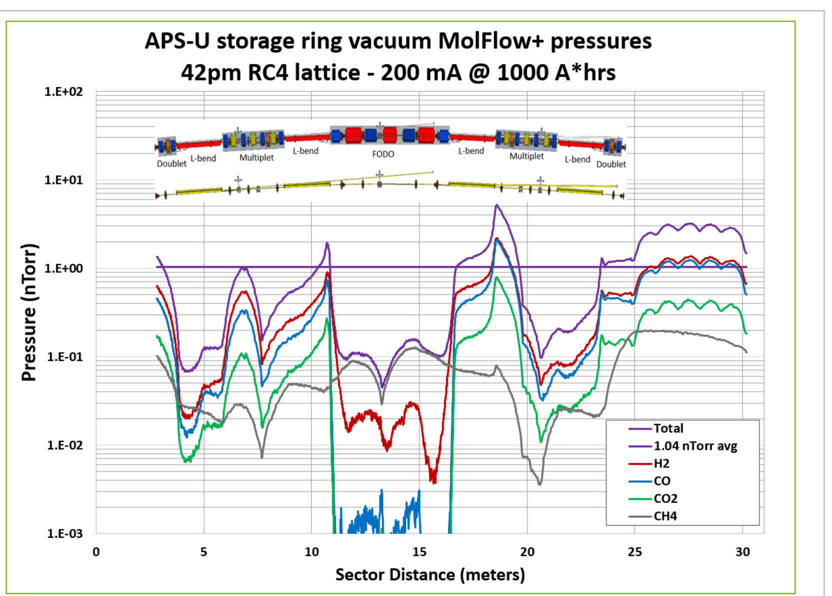
Existing APS storage ring chamber compared to new 22 mm ID APS-U chamber



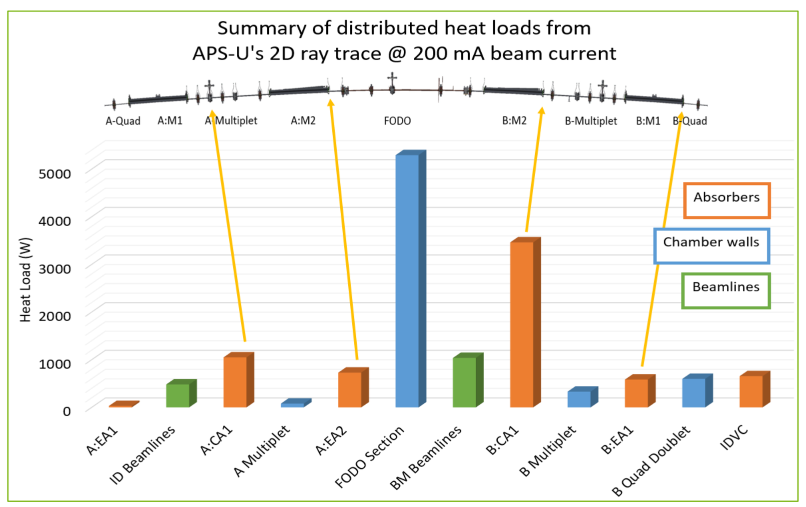
One 22 meter length sector of APS-U storage ring (excluding straight section)

VACUUM SYSTEM ANALYSIS

- **Vacuum pressure analysis**:
- Low pressures across lengths w/ distributed pumping or NEG coatings
- High pressures across uncoated conductance limited apertures
- 1D and 3D analyses predict we'll beat conditioning target. Extra margin helps w/ unknowns elsewhere in storage ring
- Analysis informed decision to increase NEG coating scope, reduce pressure bumps across small round tubes
- **Ray tracing and thermal management**: High heat loads in FODO section (~ 1 kW/meter), B-side crotch absorber (3.4 kW), and B-Quad Doublet (~700 W/m)
- Numerical analysis of missteered ray tracing helped inform +/- 0.5 mm BPLD limits at full 200 mA current, protect uncooled narrow extrusion chamber apertures



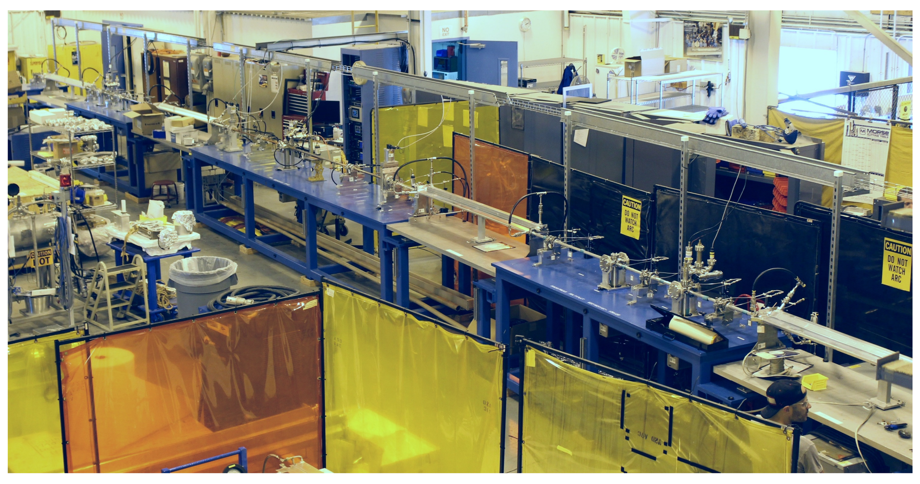
Full length sector pressure profile



Ray tracing summary

VACUUM R&D

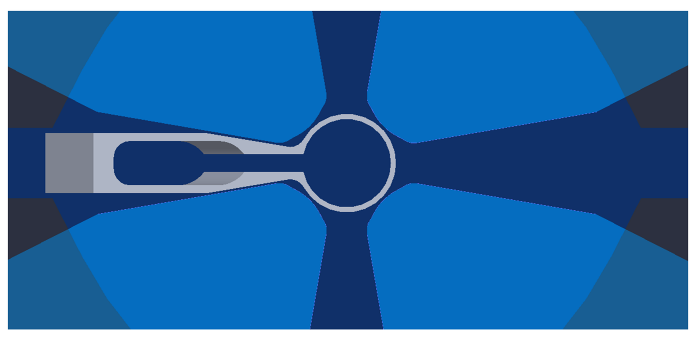
- **Sector Mockup**: Built one standard sector of storage ring vacuum components, assembled in Fall 2017
- **R&D results**: Mixed system NEG coating activation, BPMs isolated from turbulent water flow vibrations
- **Coming R&D**: static vacuum pressures compared to MolFlow models, new BPM assembly to be tested in APS storage ring



APS-U storage ring vacuum system sector mockup

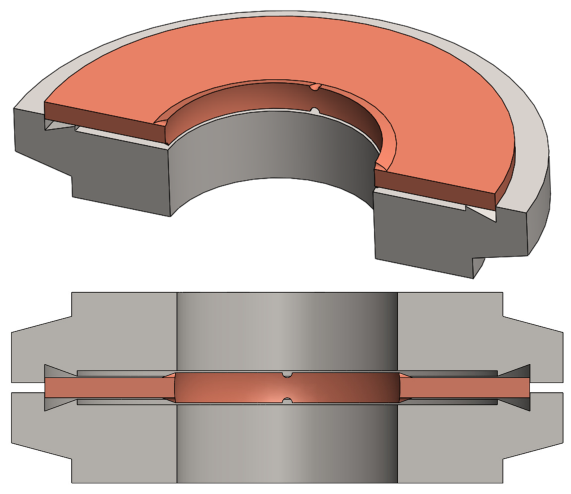
INTERFACES

- **Magnets**: ~50-150 mm width access for installation/maintenance, ~1 mm to pole tips
- **Beam physics**: Minimize impedance losses with Rf seals, tapered photon absorbers
- **Internal to vacuum**: Absorber tips protect uncooled flange joints, BPMs, and gate valves



Cross section of keyhole chamber within quadrupole magnet

Mockup of compact BPM between two quadrupole magnets

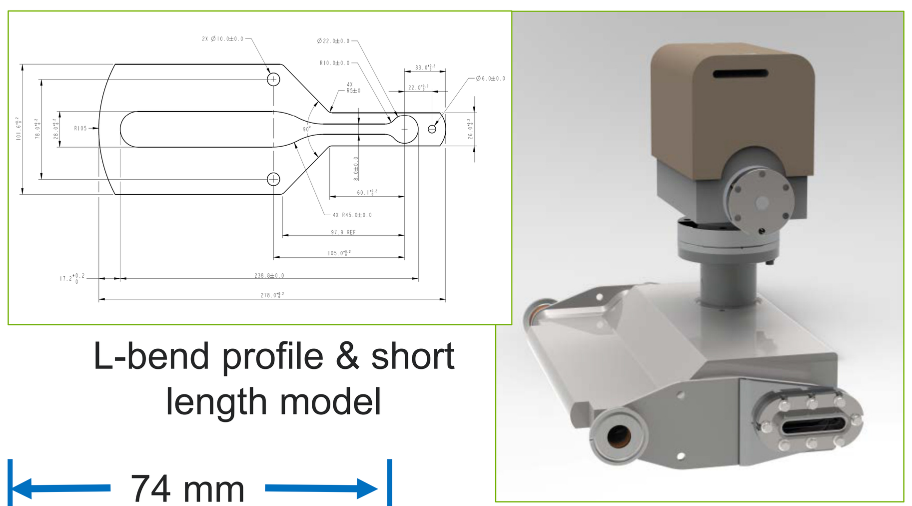


Cross section of single piece rf-sealing gasket design

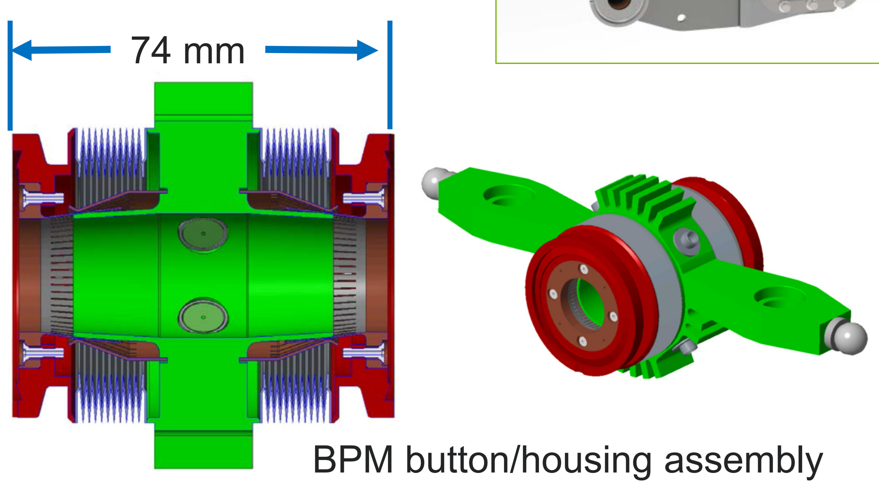
FINAL DESIGN OF VACUUM COMPONENTS

- Vacuum chamber materials on beam path:
  - 55% Aluminum (L-bends, rounds chambers)
  - 27% OFE (Round FODO chambers)
  - 9% 316 SST (BPMs, Gate Valves, Keyhole chambers)
  - 9% Inconel (Fast corrector chambers)
- 5x photon absorbers
  - Max load 3.4 kW @ 200 mA on B-Crotch
  - Mount inside L-bend chambers or cross
  - Either GlidCop or monolithic CuCrZr
- BPMs: both buttons and bellows/fingers welded to central housing to isolate chamber motion
- L-bends (bent, extruded aluminum)
  - Many interfaces: flange connections to e-beam chambers, extraction chambers, photon absorbers, ion pumps

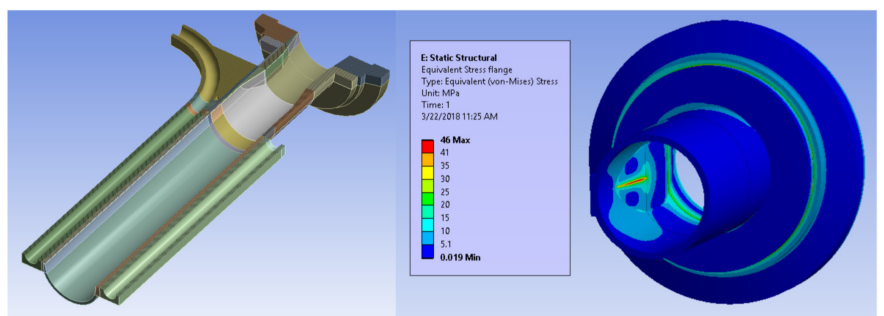
Renderings of vacuum chamber designs: Aluminum style vacuum chamber (top) Aluminum style pumping cross with vented liner (middle) Copper style vacuum chamber (bottom)



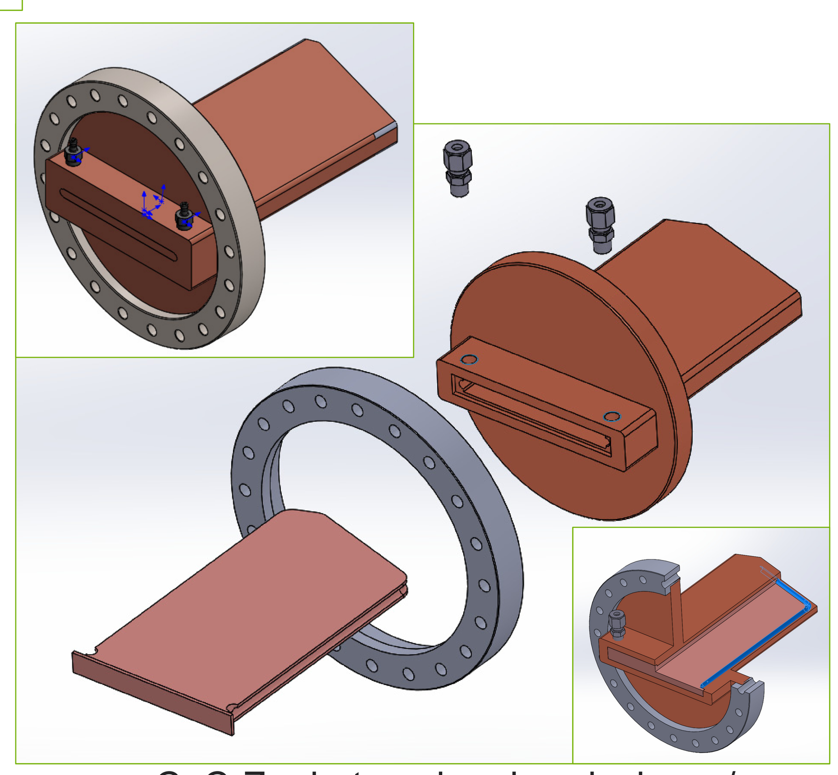
L-bend profile & short length model



BPM button/housing assembly



Peak thermal stresses typically along narrow stripe (~200 microns tall) on water cooled inline absorber face



CuCrZr photon absorber design w/ press fit cooling channels

FUTURE WORK

- **Complete R&D** by September 2018
- **Final design** of arc vacuum components, extraction lines, Zone F straight sections, collimators and beam dumps
- **Design challenges**: Keyhole BPMs, develop and test a robust, compact rf-seal design for standard and keyhole flange joints
- **Production**: manufacture components both standard and custom 'build-to-print' 2019-2022
- **Assembly**: Pre-assemble modules of vacuum components w/ magnets, girders, and more 2021-2022
- **Installation**: Remove existing storage ring and then assemble new modules 2022-2023

ACKNOWLEDGEMENTS

Argonne National Laboratory's work was supported by the U.S. Department of Energy, Office of Science under contract DE-AC02-06CH11357

Special thanks to (and many more):

- Engineering: Bran Brajuskovic, Greg Wiemerslage, Austin McElderry, Dean Walters, John Zientek & John Hoyt (AES-MOM), John Noonan, Herman Cease
- Physics: Ryan Lindberg, Medani Sangroula, Uli Wienands
- Design: Maria O'Neill, Brian Billett, Mark Lale, Kevin Wakefield, Ralph Swanson