APS-Upgrade Storage Ring Vacuum System Design

APS Upgrade Accelerator Vacuum Group

October 15, 2014

Outline

- APS Upgrade
- APS-Upgrade Vacuum System Design
- Ray tracing
- Vacuum chamber design
- Vacuum pressure simulations
- R&D plans for a vacuum chamber sector mockup

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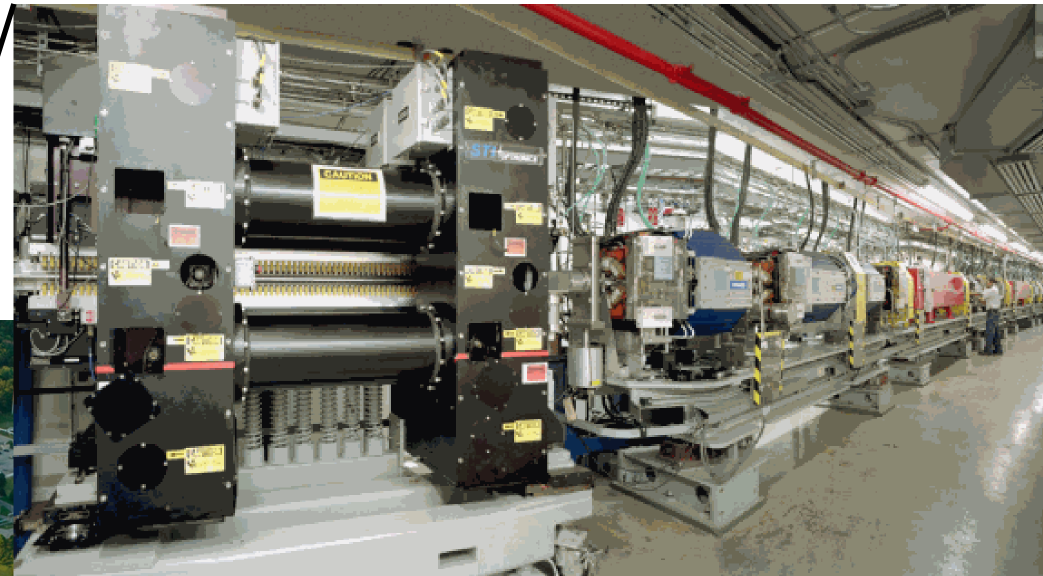
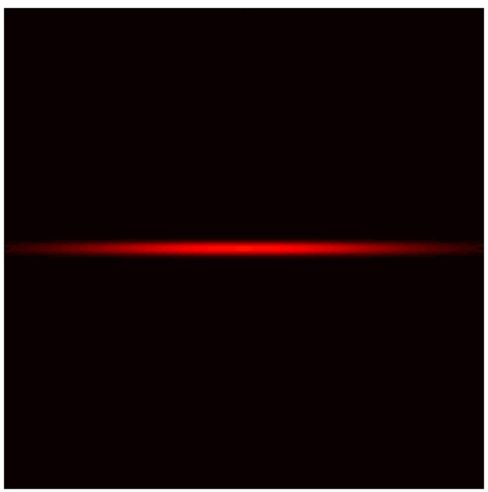


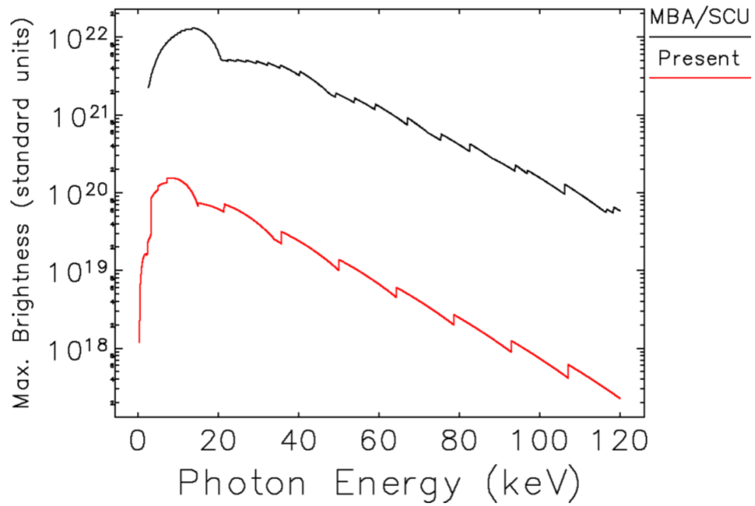
The Upgrade is evaluating a completely new DLSR (Diffraction Limited Storage Ring) magnet lattice and vacuum system

APS Upgrade Vacuum System - Scope

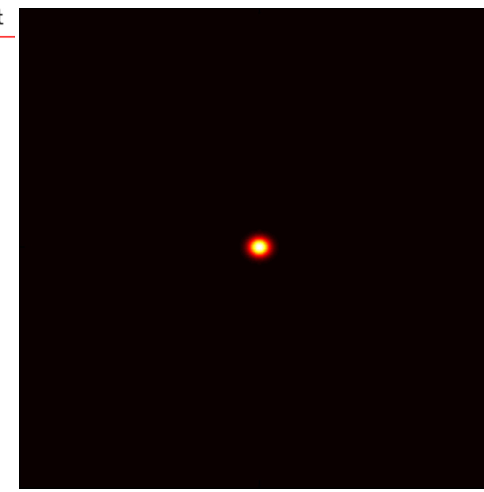
- APS Upgrade Multi Bend Achromat Magnet Lattice
  - 1104 meters circumference
  - 40 sectors, each sector is the same lattice
    - 35 sectors have both an ID and BM photon source
    - 5,000 scientists per year



Comparison inspired by C. Steier



Dramatically enhance the performance of the APS as a hard x-ray source



1 mm

Particle Beam Profiles

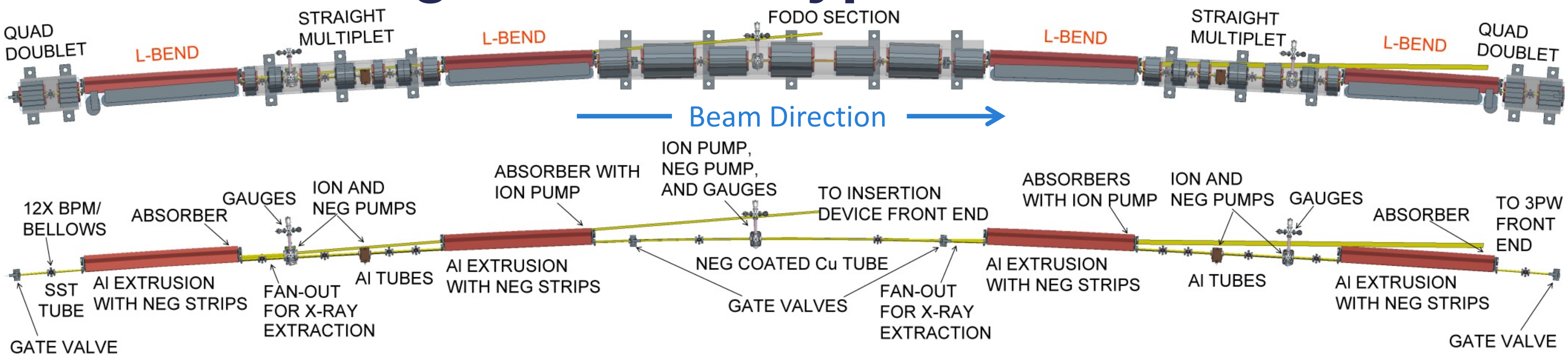
Preliminary APS MBA fill patterns

- Total beam current is expected to be 200 mA at 6 GeV
- Fill patterns with 48 to 324 bunches will be possible
- Various timing patterns should be possible with up to 4.2 mA/bunch
- Parameters subject to change

6 GeV

Total current	I	200	200	mA
Number of bunches	N_b	48	324	
Bunch current	I_b	4.2	0.6	mA
Bunch rate	f_b	13	88	MHz
Rms bunch duration	σ_t	70	18	ps

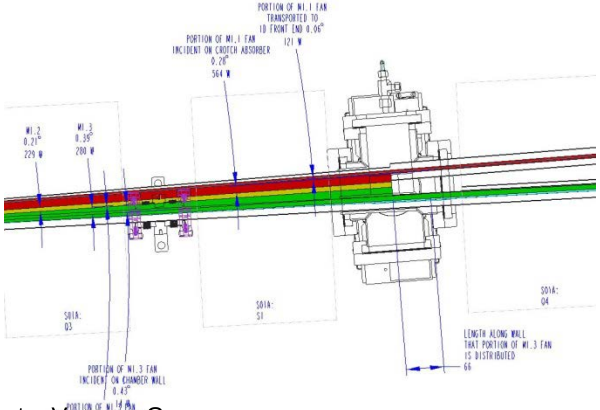
Basic Design Scheme, typical sector

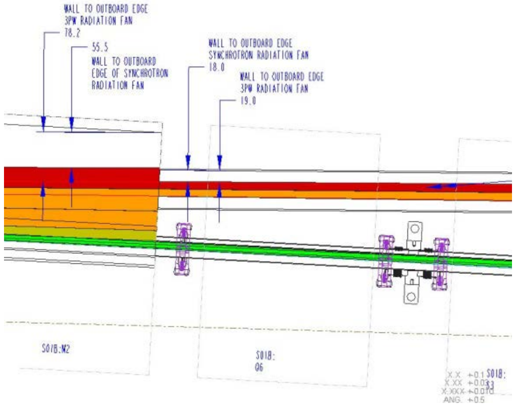


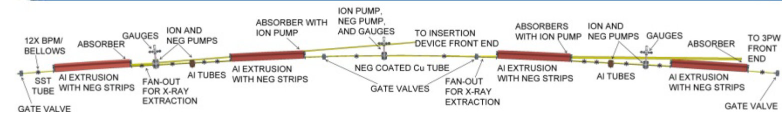
- **27 Beam chambers**
- **Vacuum pumps:** 7 Discrete active pumps, NEG strips in L-Bend ante-chambers, NEG coating in FODO section between gate valves.
- **Quad doublet:** Chamber is a simple spool. Magnets incorporate fast correctors.
- **L-bend:** Magnet is C-shaped, we can use APS-style Al extrusions with antechambers.
- **Multiplet:** Space is tight except for two ~250 mm gaps between adjacent magnet per section. There is also a light synchrotron heat load (~100 W/m). Simple spools with water cooling are used except where x-ray extraction requires a wider “key-hole” geometry.
- **FODO:** Distributed absorber, and cooling. Average thermal load (~1–1.5 W/mm). Required thermal performance suggests high-strength Cu chambers.
- **ID Chambers**: Aluminum extrusions, ante chambers, NEG strips, design by ID group. May be a long-term interest in small diameter chambers -6 mm round.

Synchrotron Radiation Ray Trace: Heat Loads

- Ray traces initial performed with CAD program and analytically.
- Total thermal load due to radiation per sector is 11.2 kW
- Bending magnet radiation power is concentrated in the center (FODO) section and at the ends (close to the ID beam), distributed power in FODO section is 4.5 kW.
  - Glidcop in-line absorbers needed in FODO section to shadow downstream flanges and bellows.
  - Maximum power density on the FODO section chamber wall is ~20 W / mm^2.
  - Maximum power density on an in-line absorber is ~50 W/mm^2.
- In addition we need BM crotch absorbers. These discrete absorbers will receive 2.2 kW of power and will be located in the antechambers of L-bend chambers.







Vacuum chamber design

- Example chamber design for high thermal loads.
  - 6 FODO chambers per sector, chambers between 500-1600mm length
  - Radiation load is 1-1.5 W/mm length or ~11 W/mm^2
  - Straight and bent chambers: 3/6 chambers have a curvature
  - Current plan is 4/6 chambers NEG coated (central 4 chambers)
  - OFS copper and or Glidcop stubs at each end,
  - Joining methods: brazing or welding TBD
  - CF/QCF flanges
  - Inner Diameter: 22mm, 2 chambers have key hole geometry for photon extraction.

Thermo-Mechanical design of the FODO module Vacuum Chambers for MBA Storage Ring at the APS. B. Brajuskovic

Vacuum design and implementation

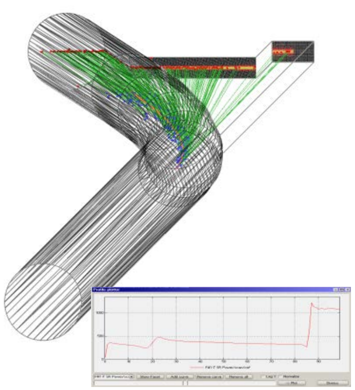
- Vacuum design and implementation.
  - 3-D Vacuum simulations
    - Parameterized Solid model for Design
  - Flange tests and evaluation of flange to chamber bonding techniques
  - Sector mockup
    - Fabrication of a sectors worth of vacuum components for testing
      - Quad doublet, stainless steel chamber
      - Multiplet chambers, extruded aluminum with water channel
      - L-Bend chambers with waters channels and ante-chamber for NEG strips
      - FODO chambers, NEG coated copper
      - BPM assemblies, supports, photon extraction to front ends
      - Assembly and testing procedures

    - Impedance bench measurements
    - Impedance measurement with beam – NEG coated ID chamber

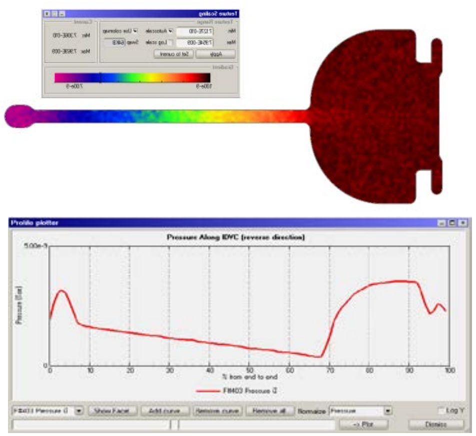
Vacuum design and implementation

3-D Vacuum simulations to develop sector pressure profiles

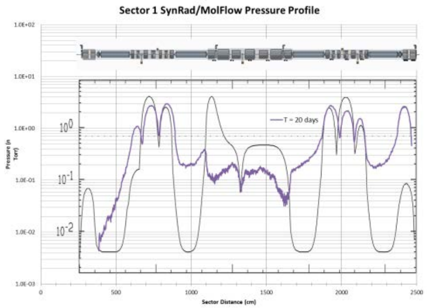
- Working with SynRad and MolFlow+ from CERN.
  - Developing detailed 3-D simulations for the entire sector.
  - Parameterized CAD model is used to define the chamber and absorber geometries.
  - SynRad generates power loads at absorbers and chamber walls.
  - MolFlow used for pressure analysis at absorbers and the entire sector.



Power deposited on Absorber



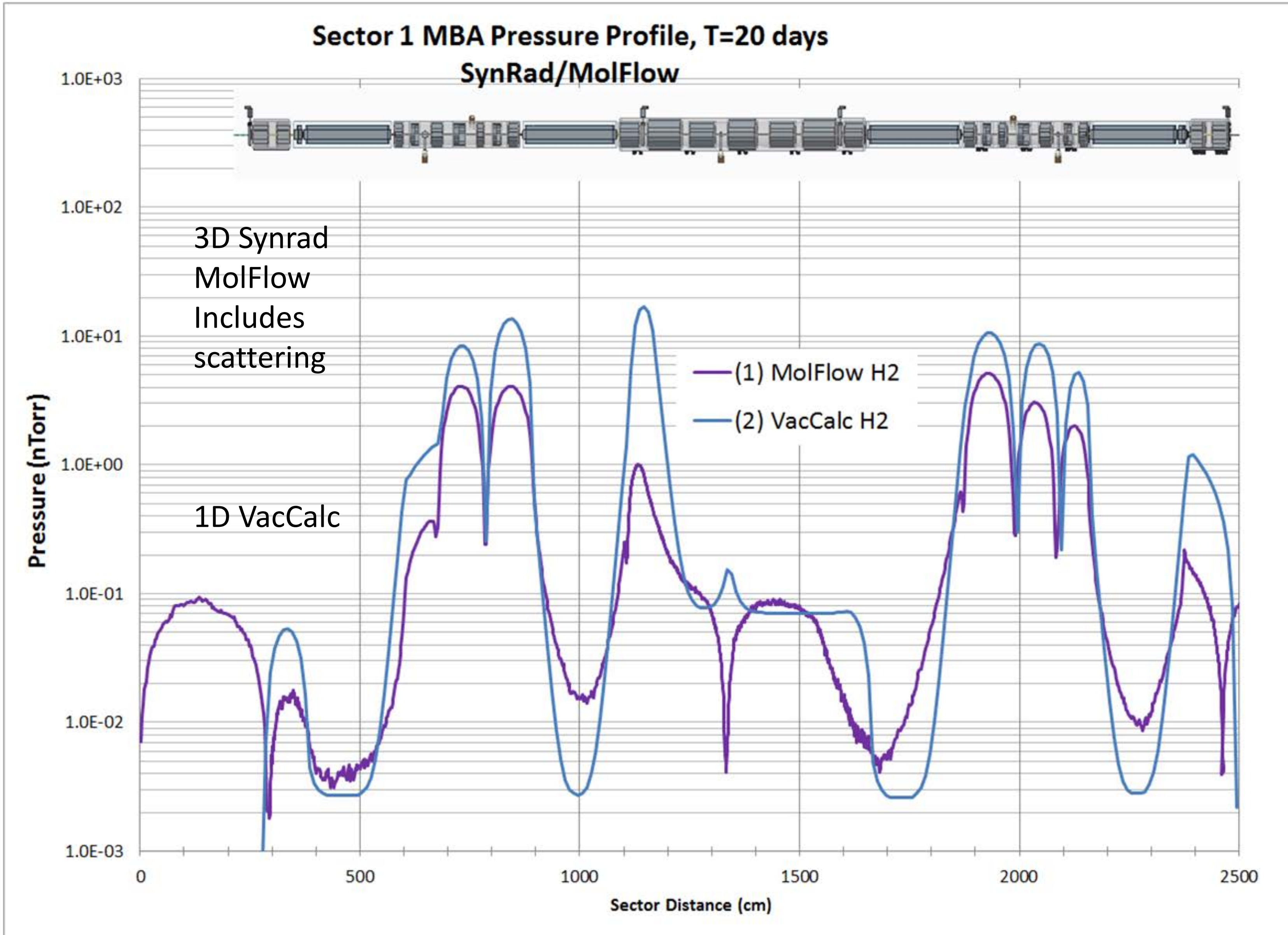
ID chamber Pressure



Sector pressure profile

Vacuum pressure profile with 3-D simulation tool

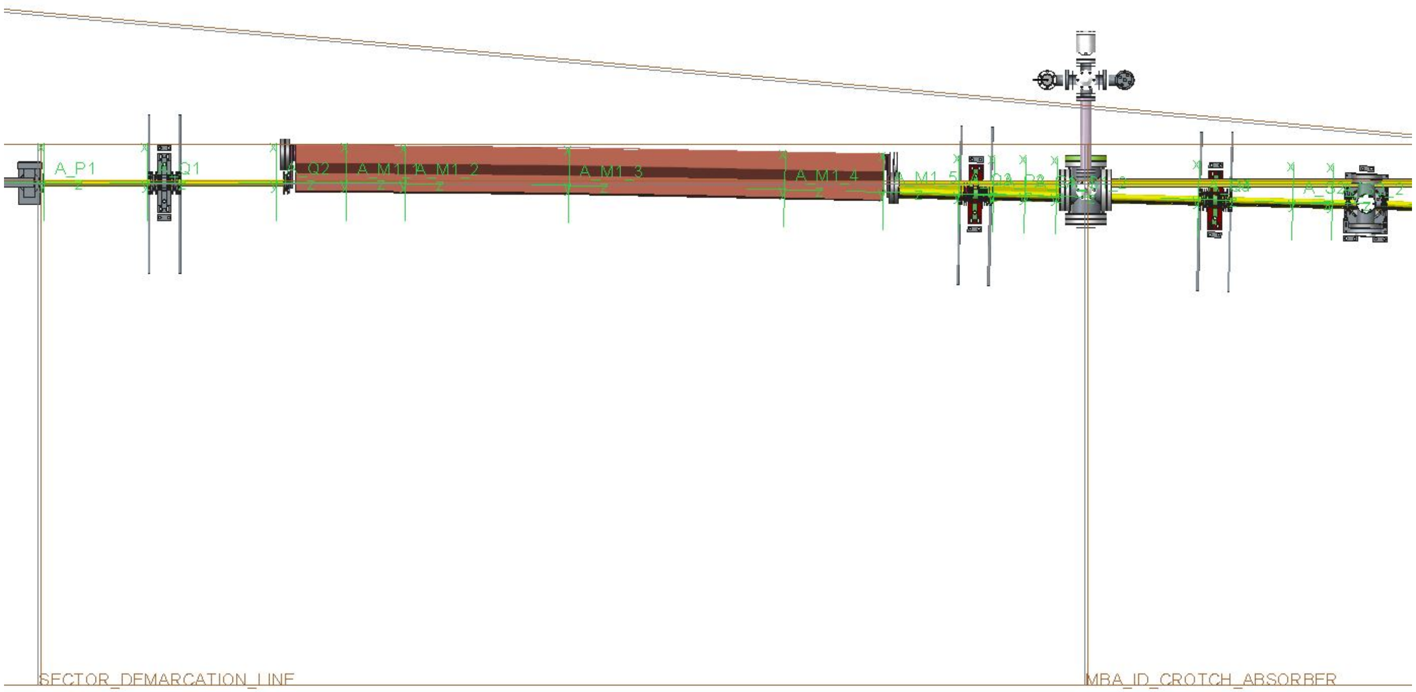
Nano Torr



After 20 days less than 1 nTorr

Vacuum design and implementation

- Parameterized solid model design.
  - Parameterized Solid model for Design

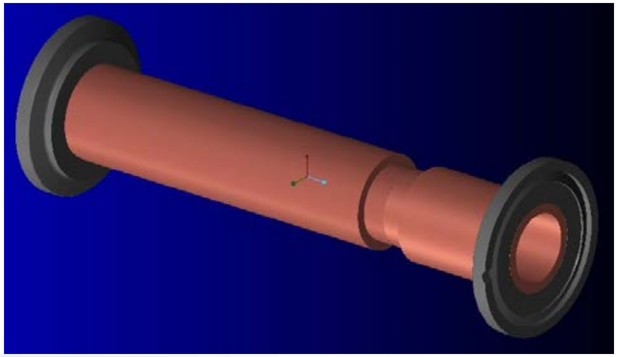


Leveraging Parametric Computer-Aided Design (CAD) for Efficient Optimization of a Storage Ring Vacuum System Design for the APS Upgrade (19109)

Vacuum design and implementation

- Flange tests and flange to chamber bonding techniques.
  - Chamber material to Stainless Steel 316L Flange bonding techniques.

Qty	Flange Ends	Tube 1	Tube 2	Tube-Tube Bond	Tube-Flange Bond(s)
10	Single	SST 316L	NA	NA	TIG
10	Double	OFE Cu	Glidcop Al-15	E-beam	E-beam/E-beam
10	Double	OFE Cu	Glidcop Al-15	TIG	Braze/Braze
5	Double	OFE Cu	NA	NA	Laser/Laser
5	Double	Glidcop	NA	NA	Laser/Laser
5	Double	Al 2219	NA	NA	Friction/Friction
5	Double	Bi-metal Al 2219 –SST316L	Bi-metal Al 2219 –SST316L	TIG (Al to Al)	TIG/TIG (SST to SST)



Vacuum design and implementation

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