Argonne NATIONAL LABORATORY

Conceptual Design
MBA Vacuum System Overview

Herman Cease

APS Upgrade Accelerator Vacuum Group

October 15, 2014

U.S. DEPARTMENT OF ENERGY

Outline

- APS-U Accelerator Vacuum System
- Vacuum chambers in the 40 arc sections
- Ray tracing
- Vacuum pressure simulations
- Installation plans
- R&D plans for a vacuum chamber sector mockup

APS-U Accelerator Vacuum System:
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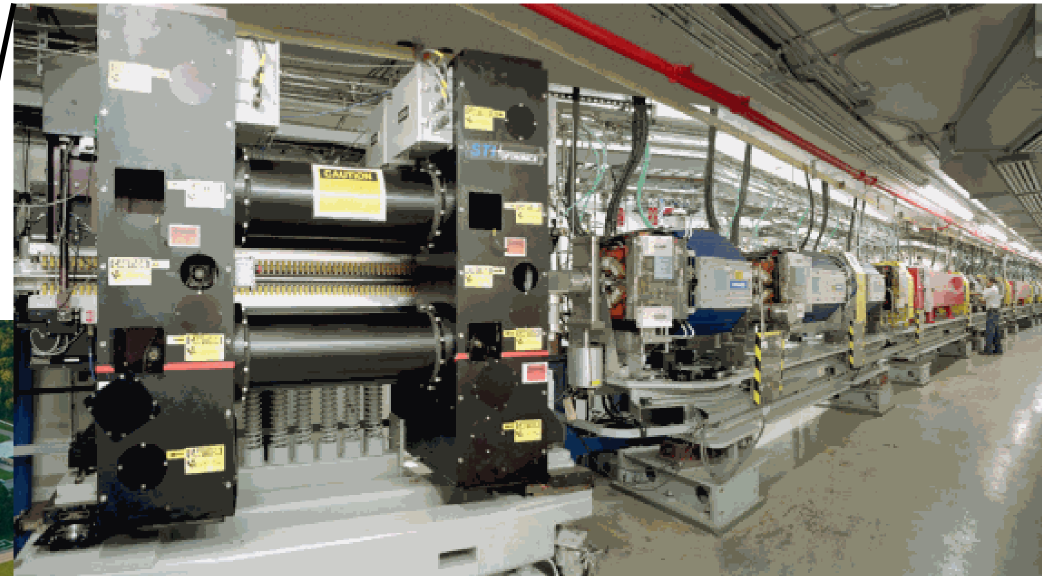
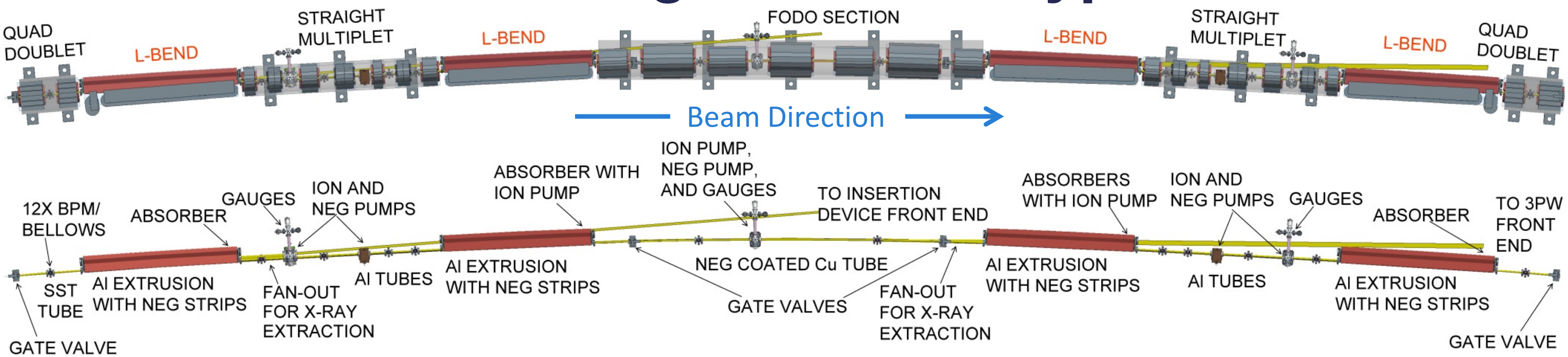
Operations: MOMs group



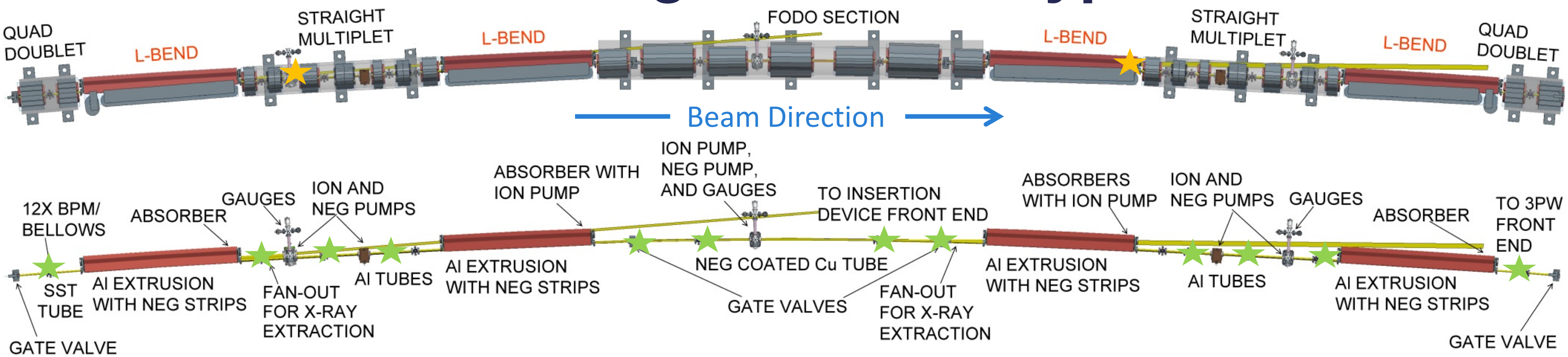
The Upgrade is evaluating a completely new DLSR magnet lattice and vacuum system

MBA Vacuum Design Scheme, typical sector

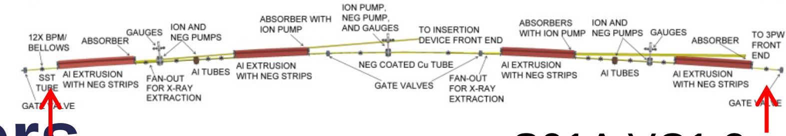


- **28 Beam chambers:**
- **Vacuum pumps:** 7 Discrete active pumps, NEG strips in L-Bend ante-chambers, NEG coating in FODO section between gate valves.
- **Quad doublet:** Chamber is a simple spool. Magnets incorporate fast correctors.
- **L-bend:** Magnet is C-shaped, we can use APS-style Al extrusions 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. 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.

MBA Vacuum Design Scheme, typical sector

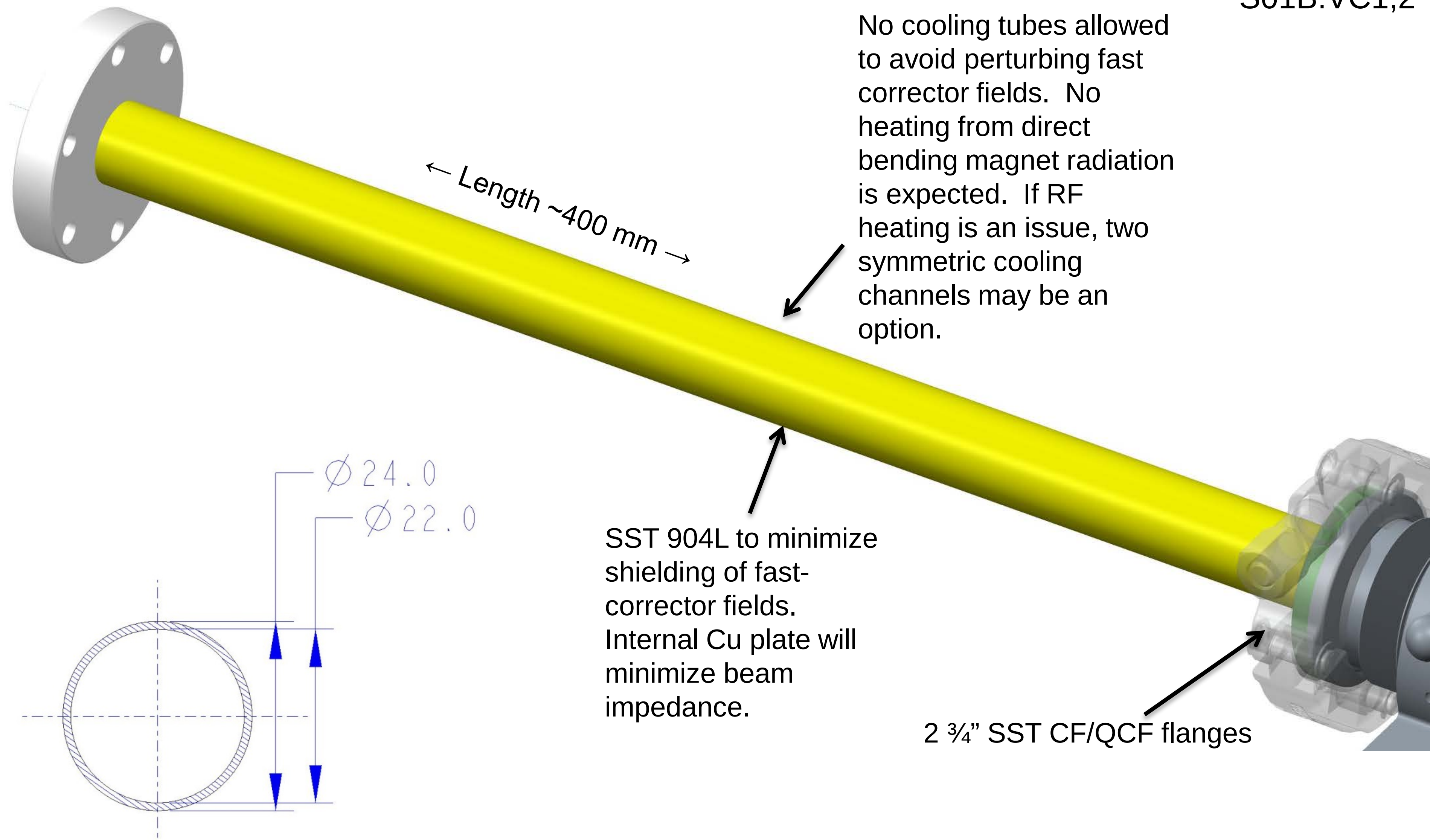


- Vacuum System:
  - Arc Chambers and photon extraction chambers,
  - Pumping and gaging,
  - ★ Crotch Absorbers,
  - ★ BPMs: 12 per arc section,
  - Interfaces,
  - Vacuum design of ID straight chambers,
    - Design of the chamber is done in the ID group.
  - Transition chambers for
    - beam injection, extraction, RF cavities.



Quad Doublet Vacuum Chambers

S01A:VC1,2
S01B:VC1,2

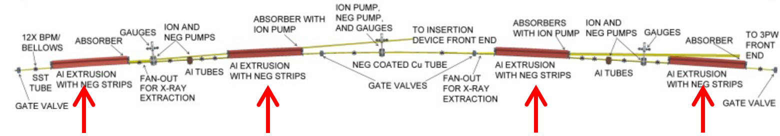


No cooling tubes allowed to avoid perturbing fast corrector fields. No heating from direct bending magnet radiation is expected. If RF heating is an issue, two symmetric cooling channels may be an option.

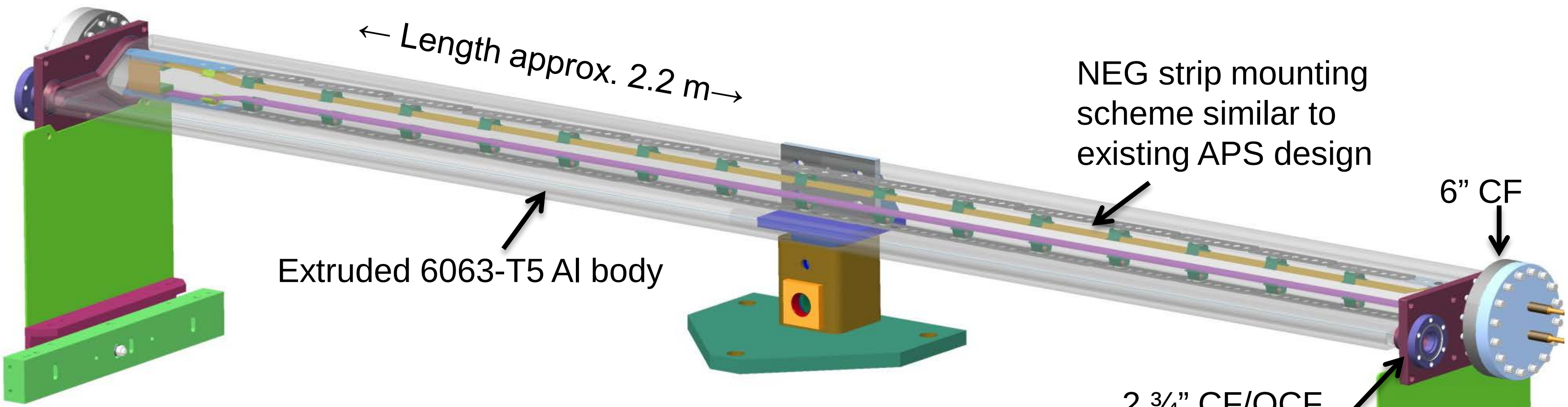
SST 904L to minimize shielding of fast-corrector fields. Internal Cu plate will minimize beam impedance.

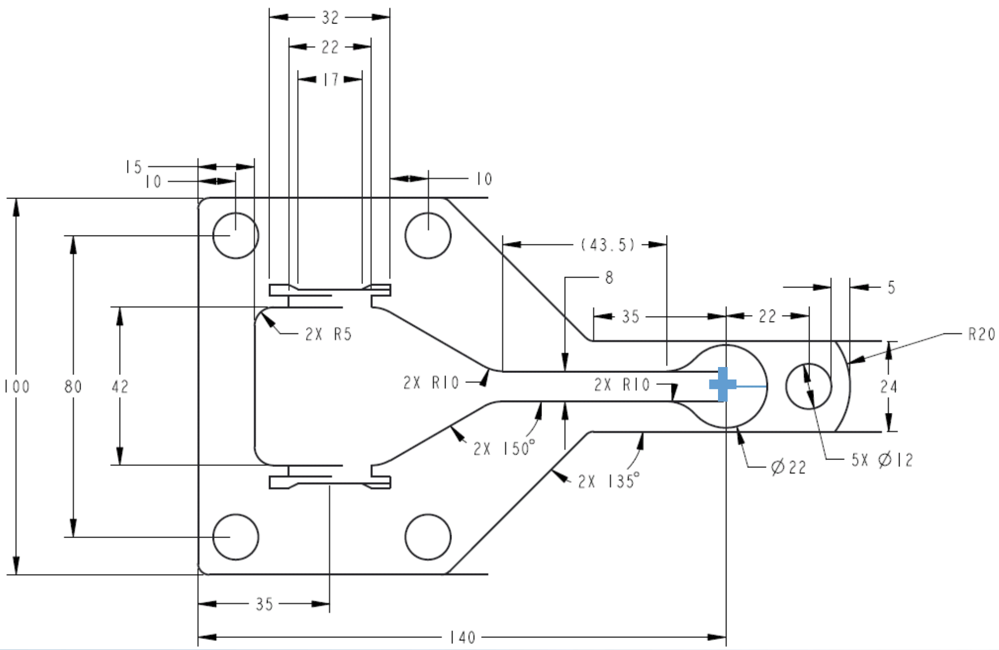
2 ¾” SST CF/QCF flanges

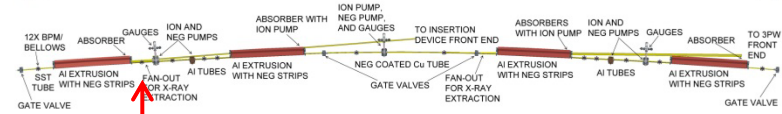
L-Bend Vacuum Chambers



S01A:VC3,11
S01B:VC3,11

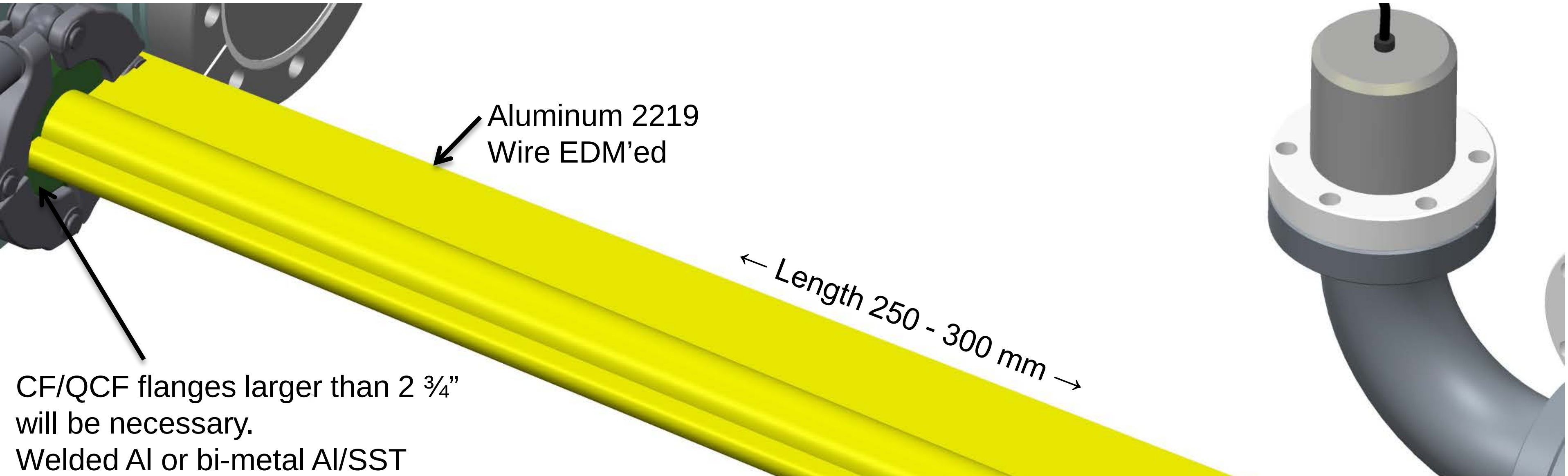




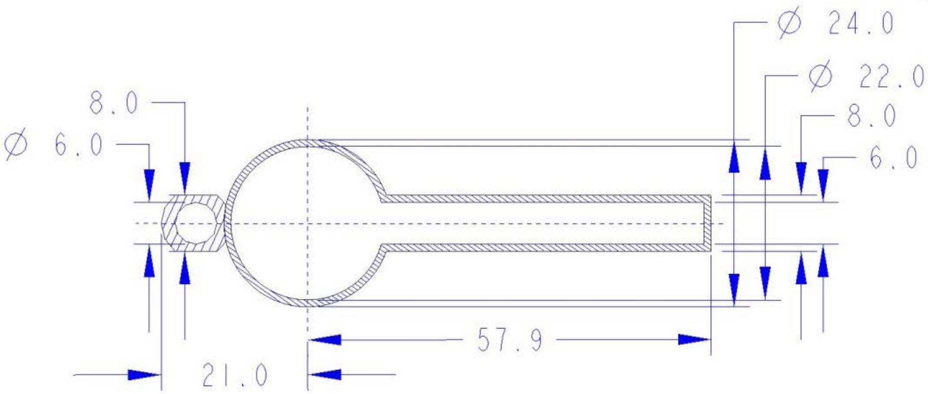


ID X-ray Beam Extraction Chambers

S01A:VC4,5



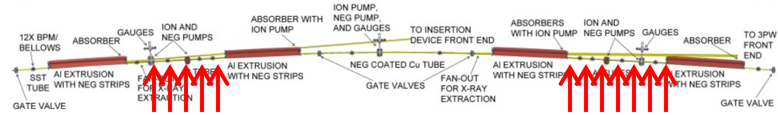
CF/QCF flanges larger than 2 ¾" will be necessary.
Welded Al or bi-metal Al/SST



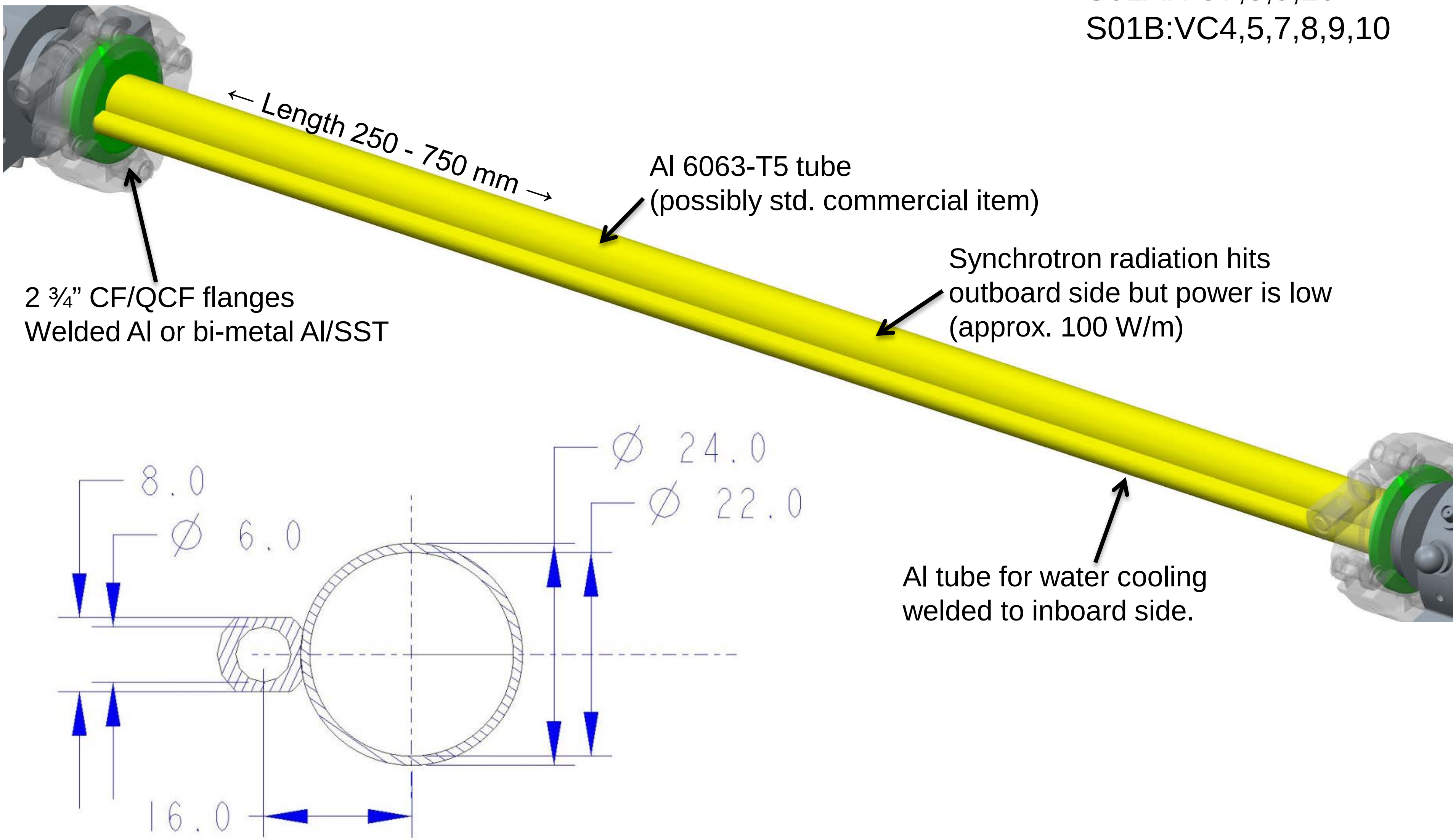
Height on x-ray beam side must be increased by 3 mm. A "bowtie"-like shape will result.

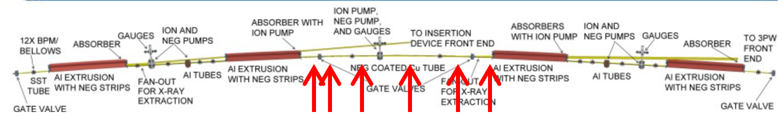
Water cooling channel on inboard side either welded on or EDM'ed along with body. These chambers receive no direct heating from synchrotron radiation.

Multiplet Vacuum Chambers



S01A:VC7,8,9,10
S01B:VC4,5,7,8,9,10





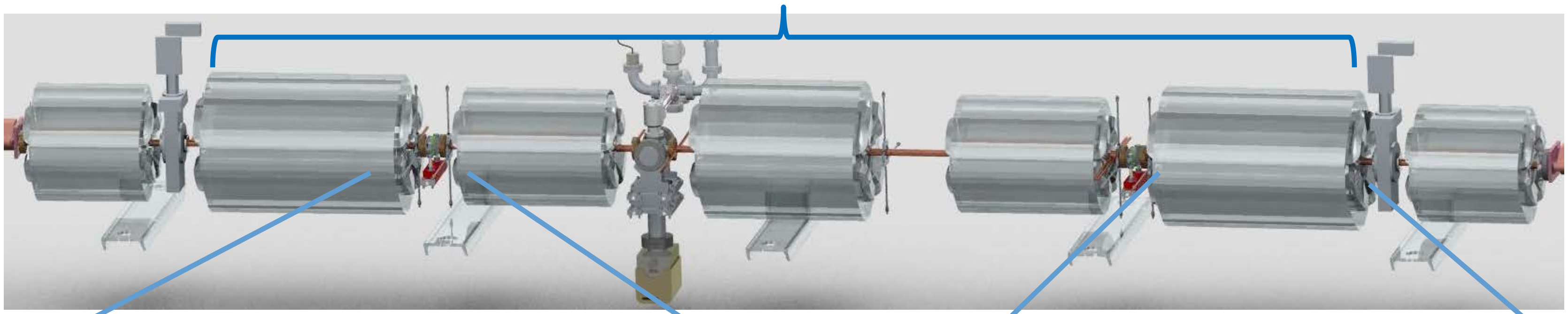
FODO Chambers

6 FODO chambers per sector, chambers between 500-1600mm length

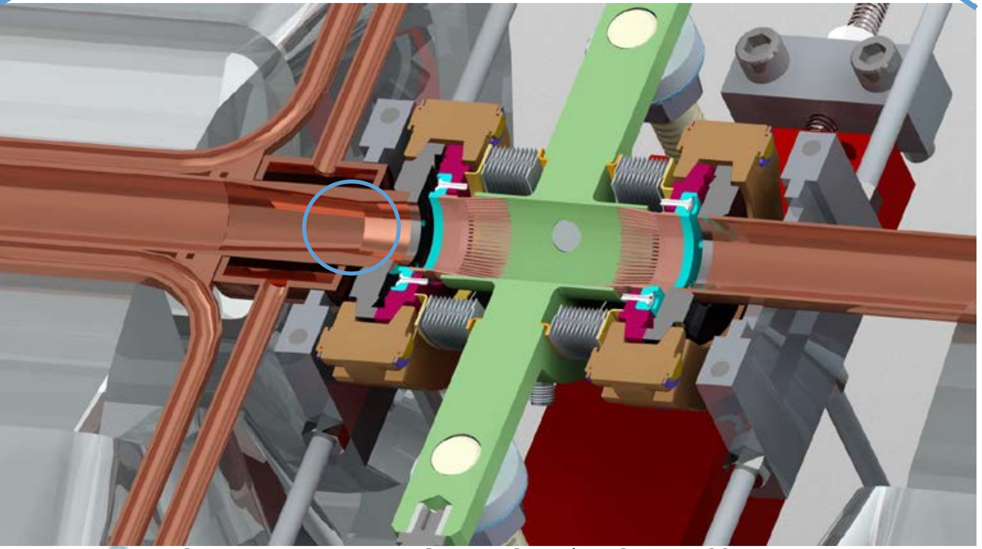
Water cooled Copper chambers:

Radiation thermal load is 1-1.5 W/mm length or ~11 W/mm^2

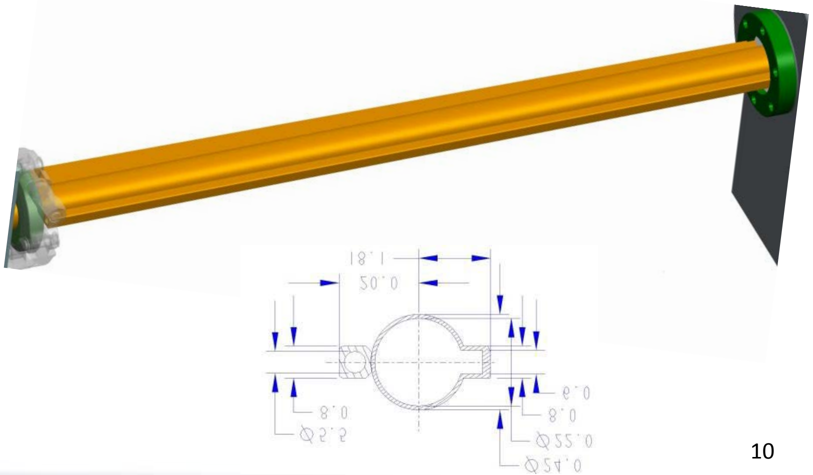
NEG Coated between Gate Valves

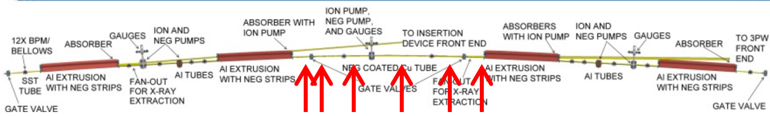


Flange Absorber shields downstream elements



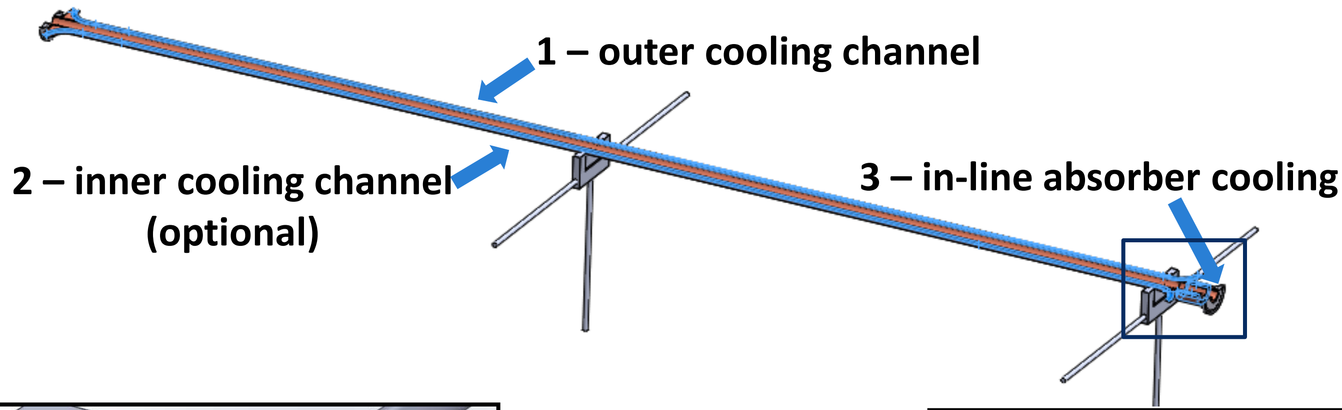
Downstream Chambers include photon extraction slot for BM line

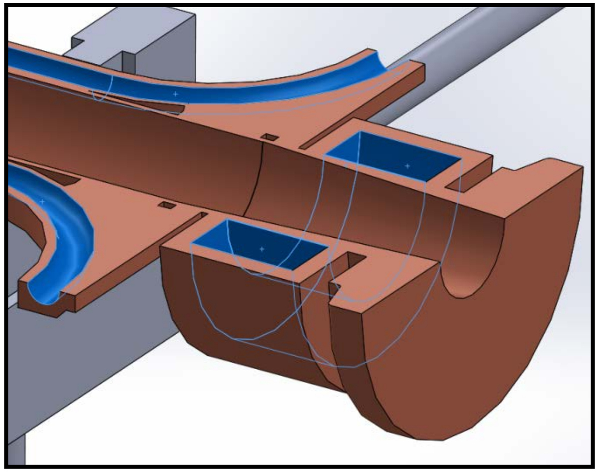


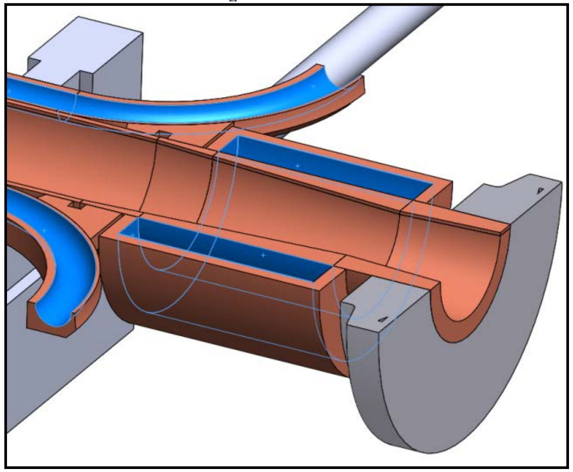


FODO Chambers

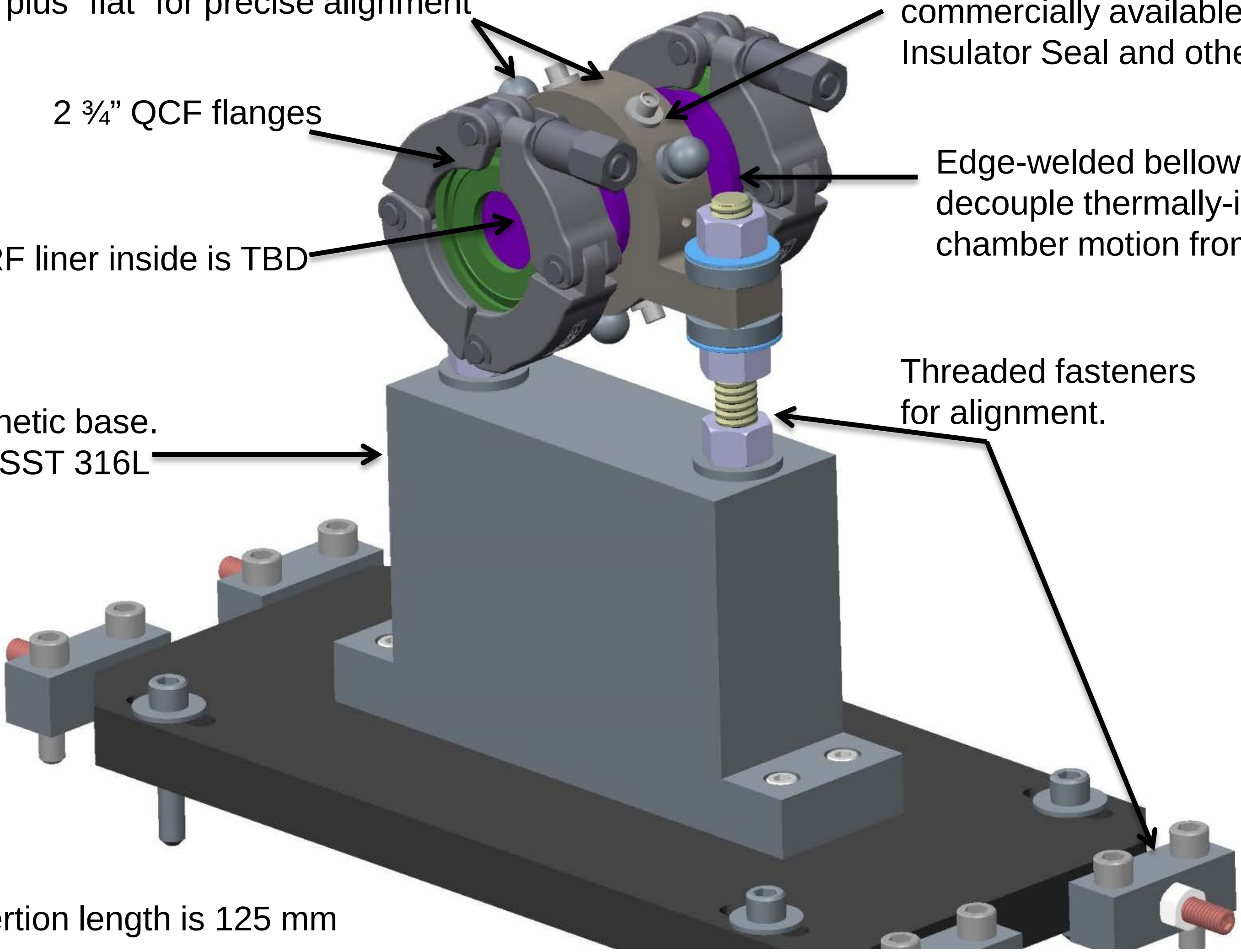
- Optimizing for thermal cooling and minimizing impedance.
- Cooling system of VC18 is envisioned to have of two (might be reduced to one) longitudinal cooling channels and a separate cooling circuit for in-line absorber





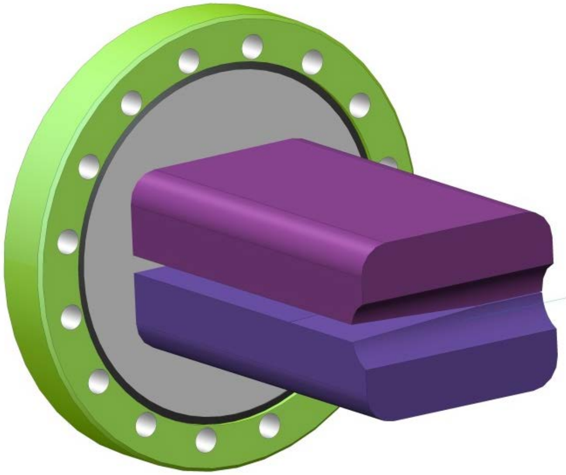


Integrated BPM / Bellows Assemblies

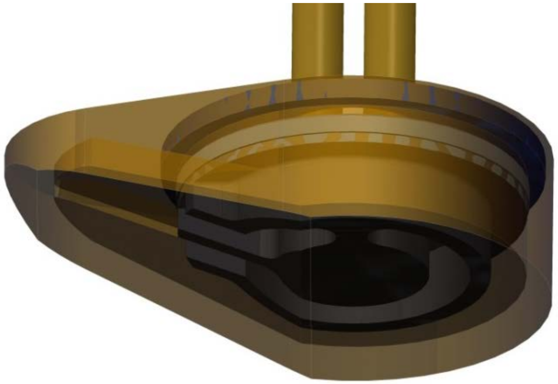


Estimated insertion length is 125 mm

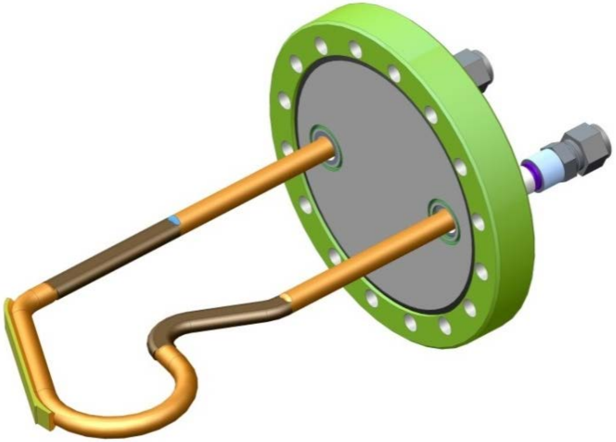
Synchrotron Radiation Ray Trace: Absorbers



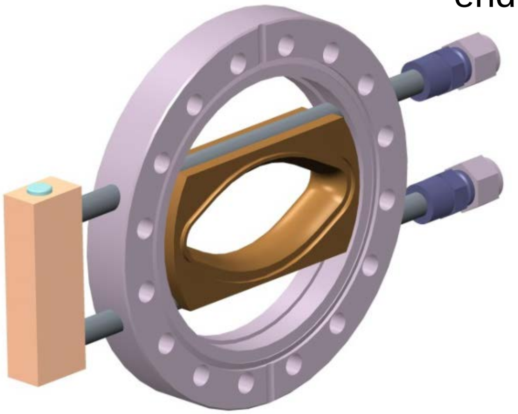
MAX-IV crotch absorber for the ID beam extraction crotch: S01A:CA1



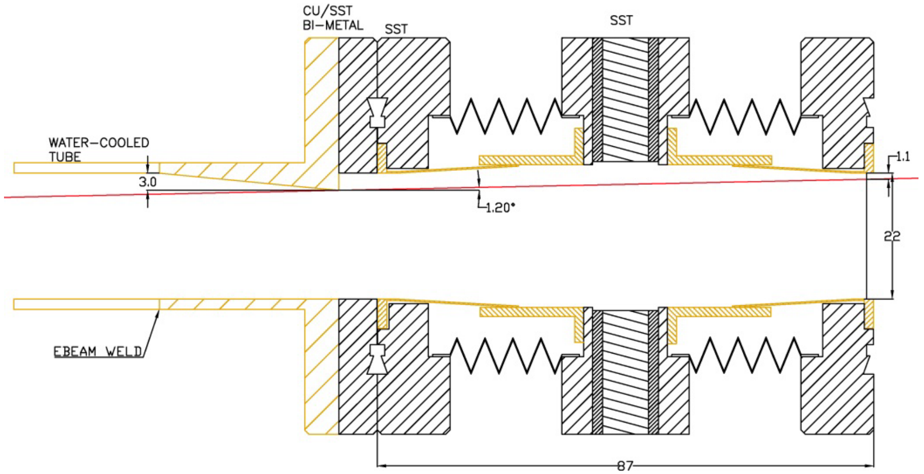
APS end absorber for the 3PW extraction crotch: S01B:CA1 and end absorber: S01A:EA2



APS boot absorber for the end absorbers on L-bend chambers: S01A:EA1, S01B:EA1, S01B:EA2



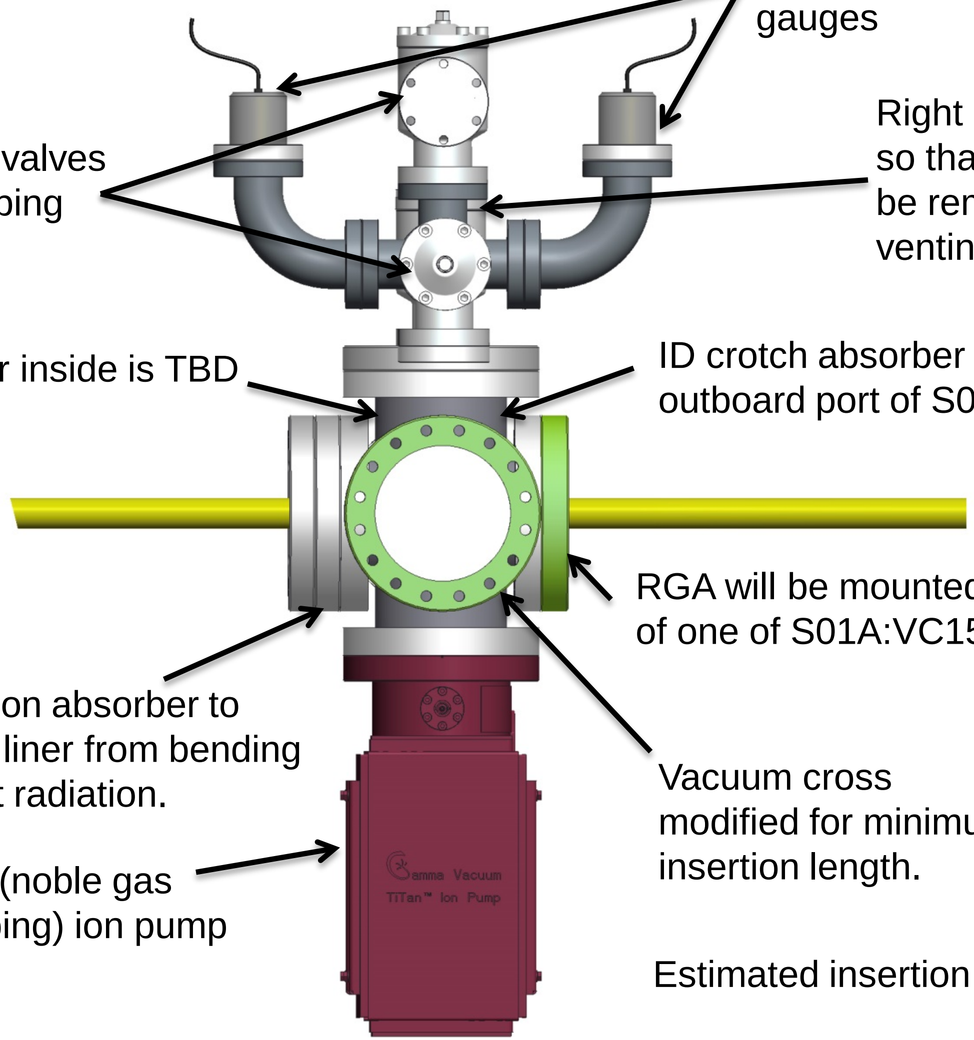
APS transition absorber for use upstream of shielded gate valves and pump-out liners: S01A:TA1,2 S01B:TA1,2



MAX-IV inspired bellows absorber

Ion Pump, and Gauge Insertion

S01A:VC6,15
S01B:VC6



Cold cathode and thermocouple gauges

2X right angle valves for rough pumping and purge

Right angle valve (back) so that entire tree can be removed without venting chambers

RF liner inside is TBD

ID crotch absorber will be mounted in outboard port of S01A:VC6

RGA will be mounted in outboard port of one of S01A:VC15 OR S01B:VC6

Transition absorber to protect liner from bending magnet radiation.

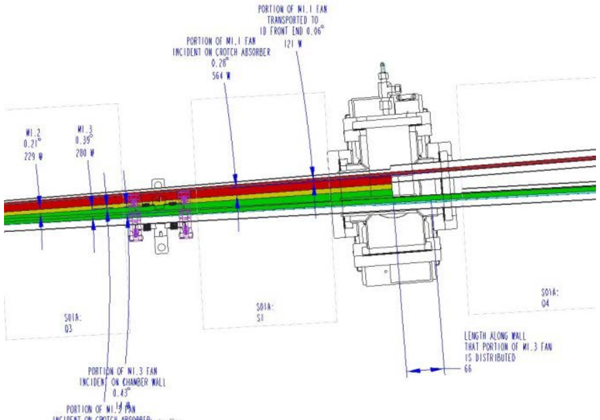
Vacuum cross modified for minimum insertion length.

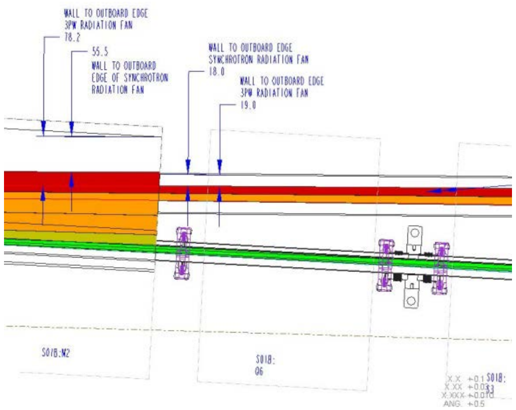
Ta/Ti (noble gas pumping) ion pump

Estimated insertion length is 250 mm

Synchrotron Radiation Ray Trace: Heat Loads

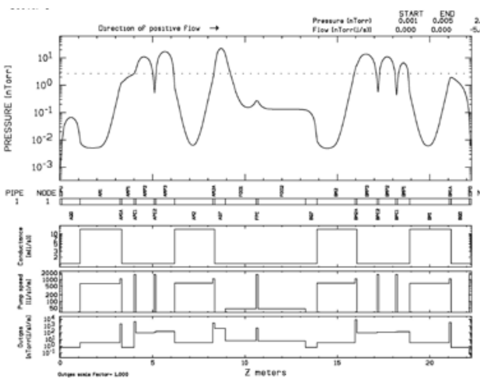
- Ray traces initial performed with CAD program and analytically.
- Total thermal load due to radiation per sector is 11.2 kW
- Bending magnet radiation power is concentrated in the center (FODO) section and at the ends (close to the ID beam), distributed power is 4kW.
- Glidcop lip absorbers needed in FODO section to shadow downstream flanges and bellows.
- Maximum power density on the FODO section chamber wall is ~11 W / mm^2.
- Maximum power density on an absorber is ~50 W/mm^2.
- BM crotch absorber is 2.2kW, discrete absorber located in L-bend chamber – antechamber.



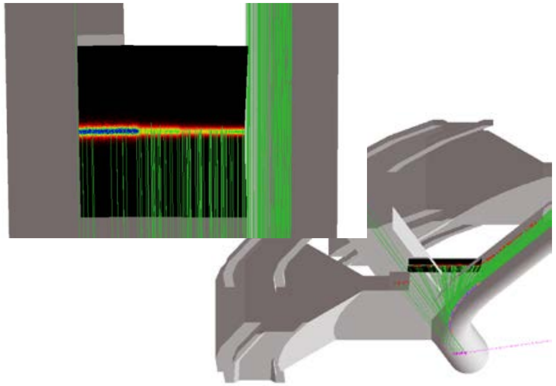


Overview & Status: Vacuum Analysis

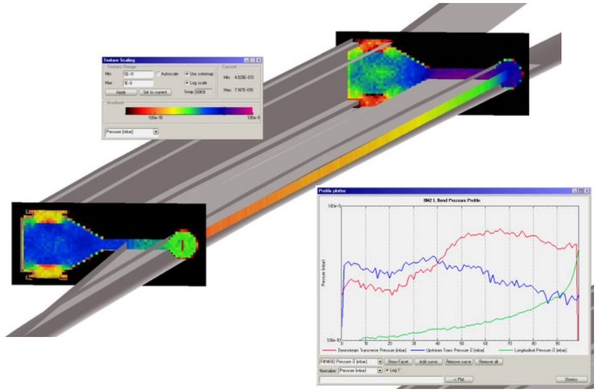
- Initially 1-D analytical calculations.
  - Has many limitations, but is a good first pass to compare initial designs. Using VacCalc.
- Working with SynRad and MolFlow+.
  - Utilizes a parameterized 3-D CAD model for the sector geometry.
  - Developing detailed 3-D simulations for the entire sector.
  - Can be used as a ray tracing tool and for steering conditions.
  - Includes power at absorbers and chamber walls.
  - Pressure analysis at absorbers and the entire sector.



Sector pressure profile
1-D Analysis VacCalc

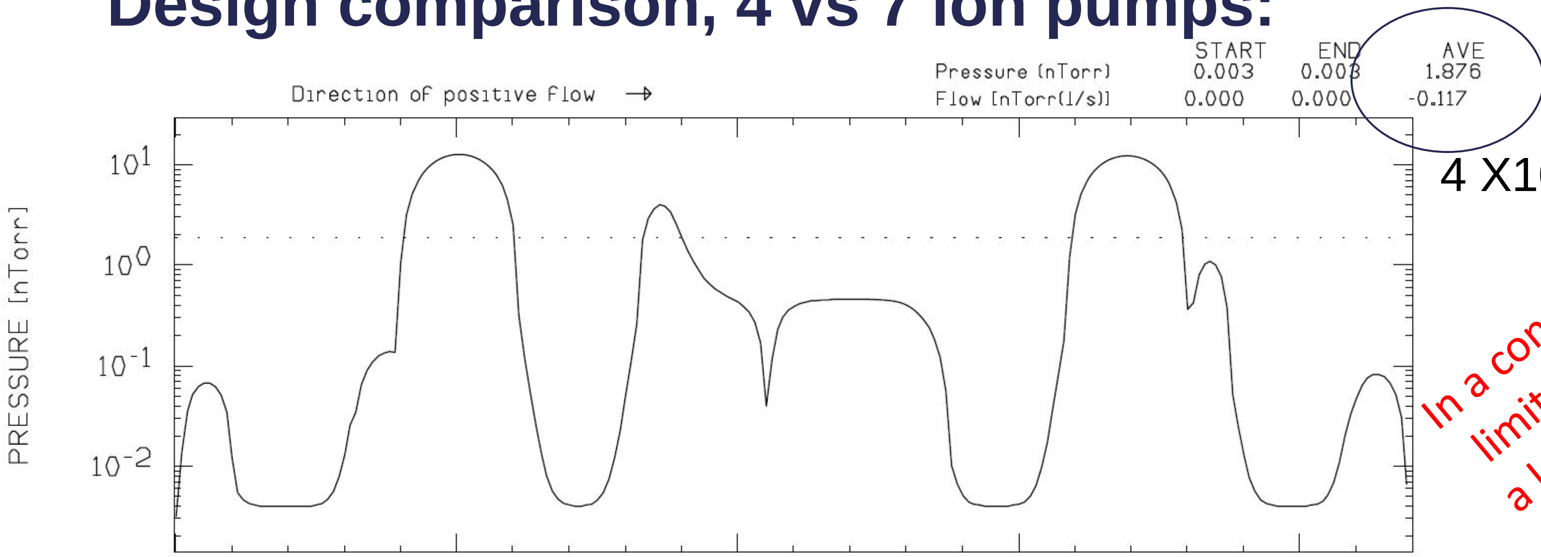


Power deposited on L-Bend Absorber
3-D Analysis SynRad



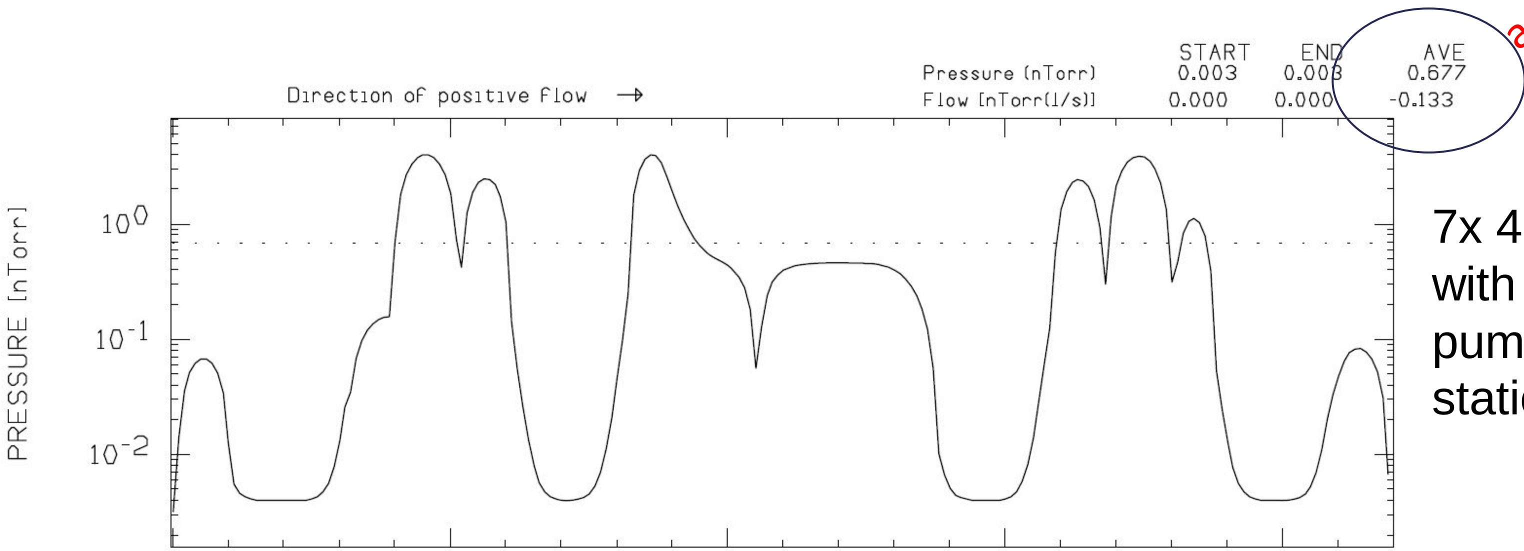
L-Bend chamber Pressure
3-D Analysis MolFlow

Design comparison, 4 vs 7 ion pumps:

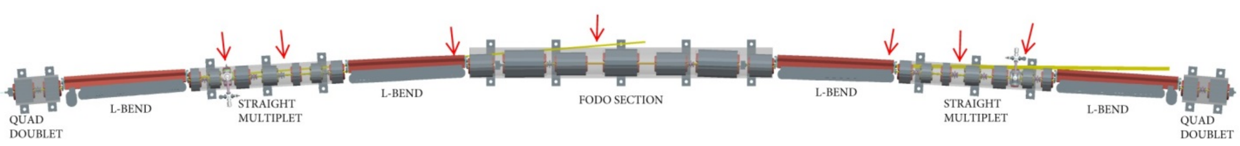


4 X100 L/s pumps

In a conductance limited system, a larger number of small pumps are more efficient than a few large pumps.

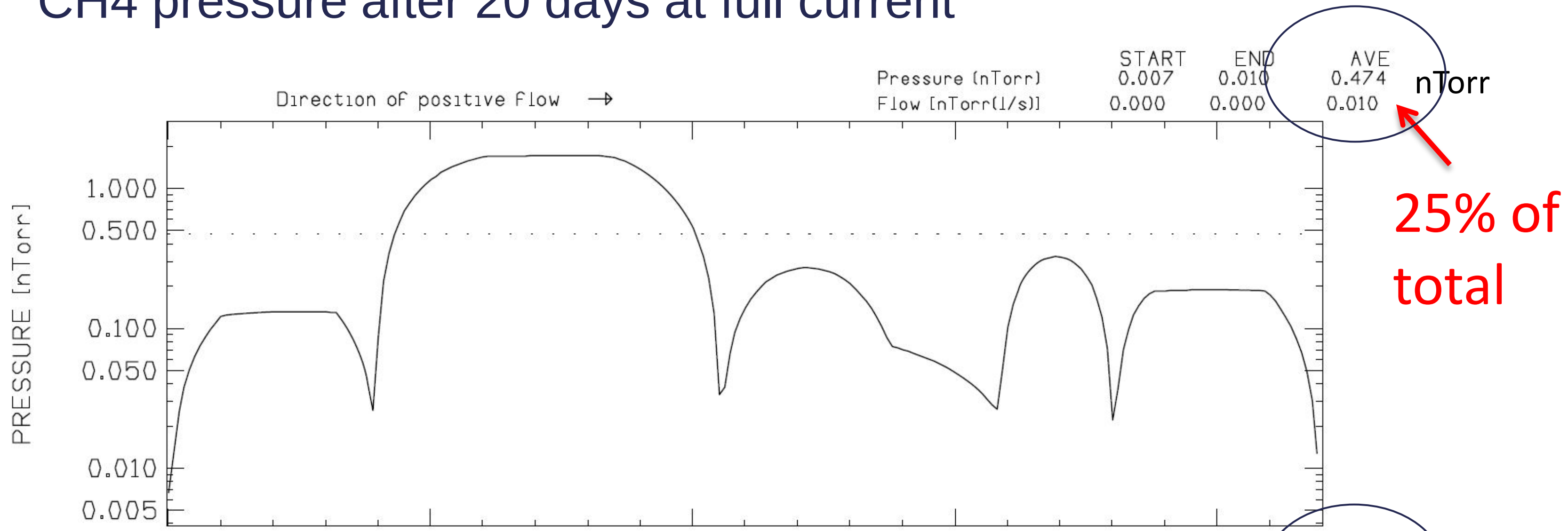


7x 45 L/s pumps with cartridge pumps at cross stations

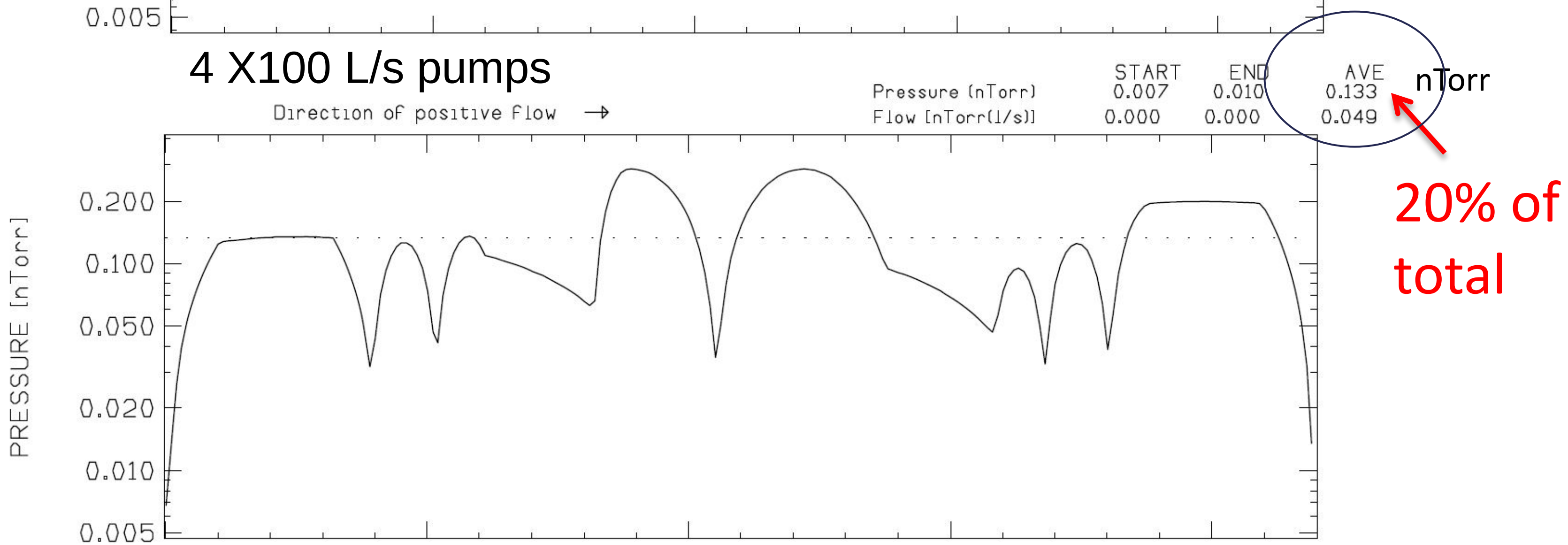


Design comparison, CH4 pressure:

CH4 pressure after 20 days at full current



4 X100 L/s pumps



7x 45 L/s pumps with cartridge pumps at cross stations

SynRad: Ray tracing and synchrotron radiation

- SynRad Development.
  - – Utilizes a parameterized 3-D CAD model for the sector geometry.
  - – Determines beam thermal profile both vertical and longitudinal on chamber walls and absorbers.
  - – Simulates Photon Stimulated Desorption.
  - –Can be used as a ray tracing tool and for steering conditions.

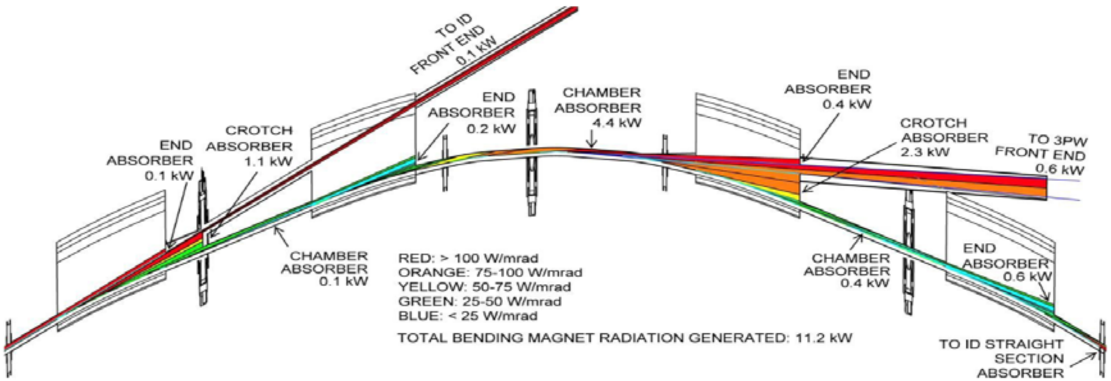
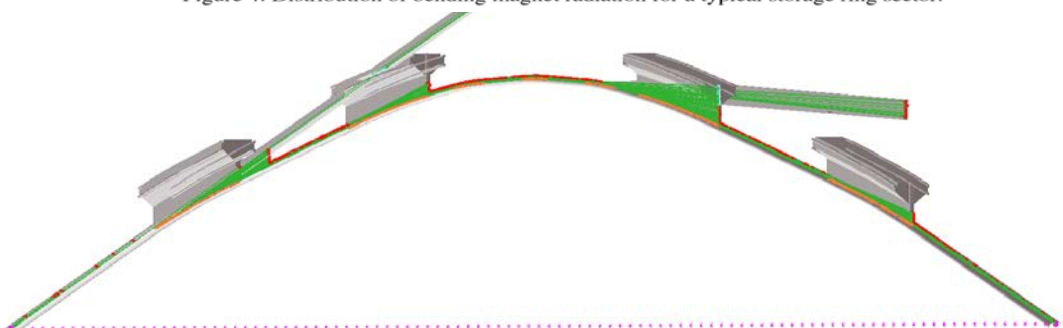


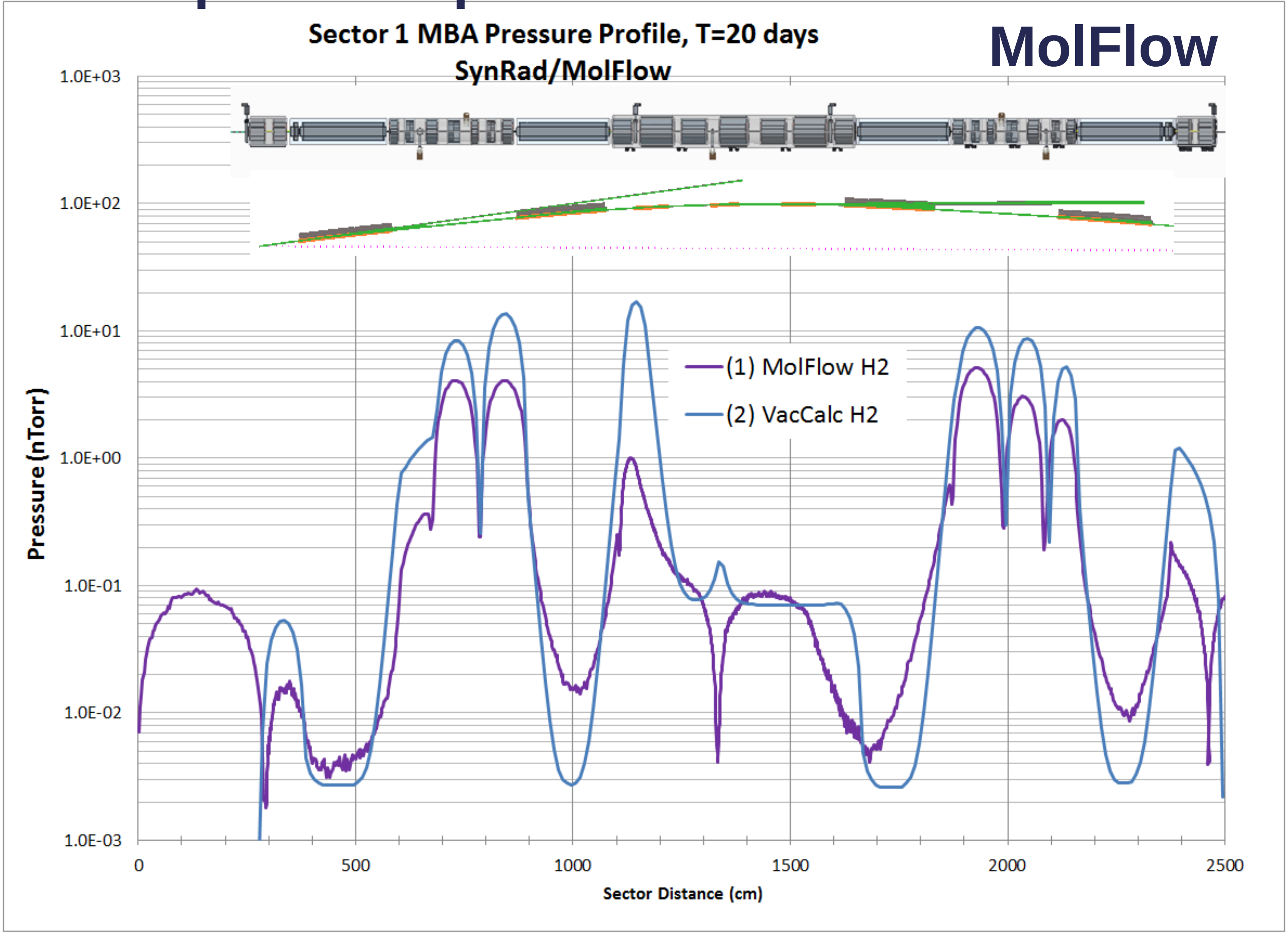
Figure 4: Distribution of bending magnet radiation for a typical storage ring sector.



Sections	Ray trace power (W)	SynRad Power (W)	Difference (W)	% diff
ID front end	141	140	-1	-1%
AM1	121	127	6	5%
A Crotch	1073	1075	2	0%
Multiplet 1	112	115	3	3%
AM2	244	250	6	2%
AQ7	174	183	9	5%
FODO wall	4295	4329	34	1%
BM2	368	281	-87	-24%
BM front end	612	591	-21	-3%
B Crotch	2327	2387	60	3%
Multiplet 2	382	372	-10	-3%
BM1	195	205	10	5%
Walls + straight	1143	1124	-19	-2%
TOTAL	**11187**	**11179**	**-8**	**0%**

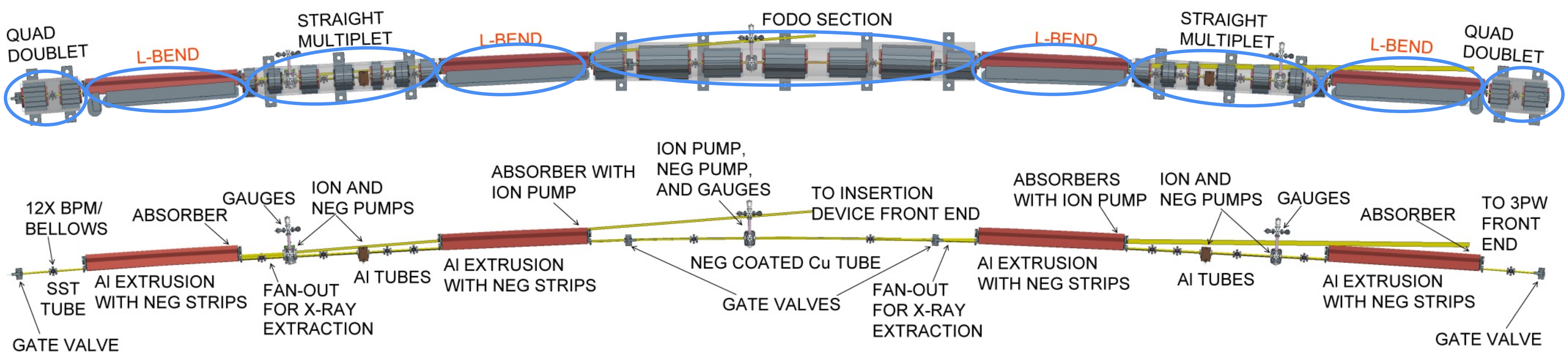
Vacuum pressure profile with 3-D simulation tool

MolFlow



Removal, Installation, function tests with beam

- 1 year total duration
- Vacuum chambers pre-installed on girders.
- Integrated and pre-aligned with magnets.
- Chamber assemblies same length as girder.
- 9 integrated support, magnet, vacuum assemblies installed in the tunnel per each arc section.
- ~3 months allocated for closing the vacuum system.



Overview & Status Risks and R&D plan

- Vacuum System Risk List.
  - Vacuum pressure requirement exceeded
    - Consequence is operating at less beam current
  - Installation duration exceeded
    - Delayed integrated testing.
  - Impedance budget exceeded
    - Consequence is operating at less bunch current
  - Temperature of component is higher than expected

- Vacuum System R&D Plan.
  - Sector mockup
    - Fabrication, cooling methods, alignment, stability, installation procedures,
  - Vacuum pressure on the sector mockup
    - Pressure can be measured across the sector with simulated loads at absorbers.
  - Impedance measurements
    - Stretched wire testing of components
    - NEG coating measurements

Summary

- Vacuum system design drivers:
  - Magnet bore diameters are small
    - Limited Space for ante-chambers and NEG strips.
    - Ex-situ activation of NEG coated chambers.
  - Installation time requires minimizing bake out and activation durations.
    - The number of NEG coated chambers requiring ex-situ activation are minimized.
    - NEG coated chambers are isolated with gate valves, allowing installation under vacuum.
- Vacuum System Design developments:
  - Parameterized CAD model
  - Synchrotron radiation power loads on chamber walls and absorbers modelled analytically and with 3-D simulations.
  - Vacuum pressure across the sector modelled with 1-D and 3-D simulations tools.
  - Chamber fabrication techniques
    - High heat load in FODO section, requires specialized flange absorbers
    - Vacuum flange and vacuum flange to chamber material bonding techniques are being evaluated.
- Vacuum system conceptual design of arc chambers is developed.

Backup Slides

Integrated Assemblies

Vacuum components integrated inside the assembly.

Chamber assembly with utility pigtails mounted in lower half.

Top half closes the unit.