DISCRETE PHOTON ABSORBERS FOR THE APS-UPGRADE STORAGE RING VACUUM SYSTEM

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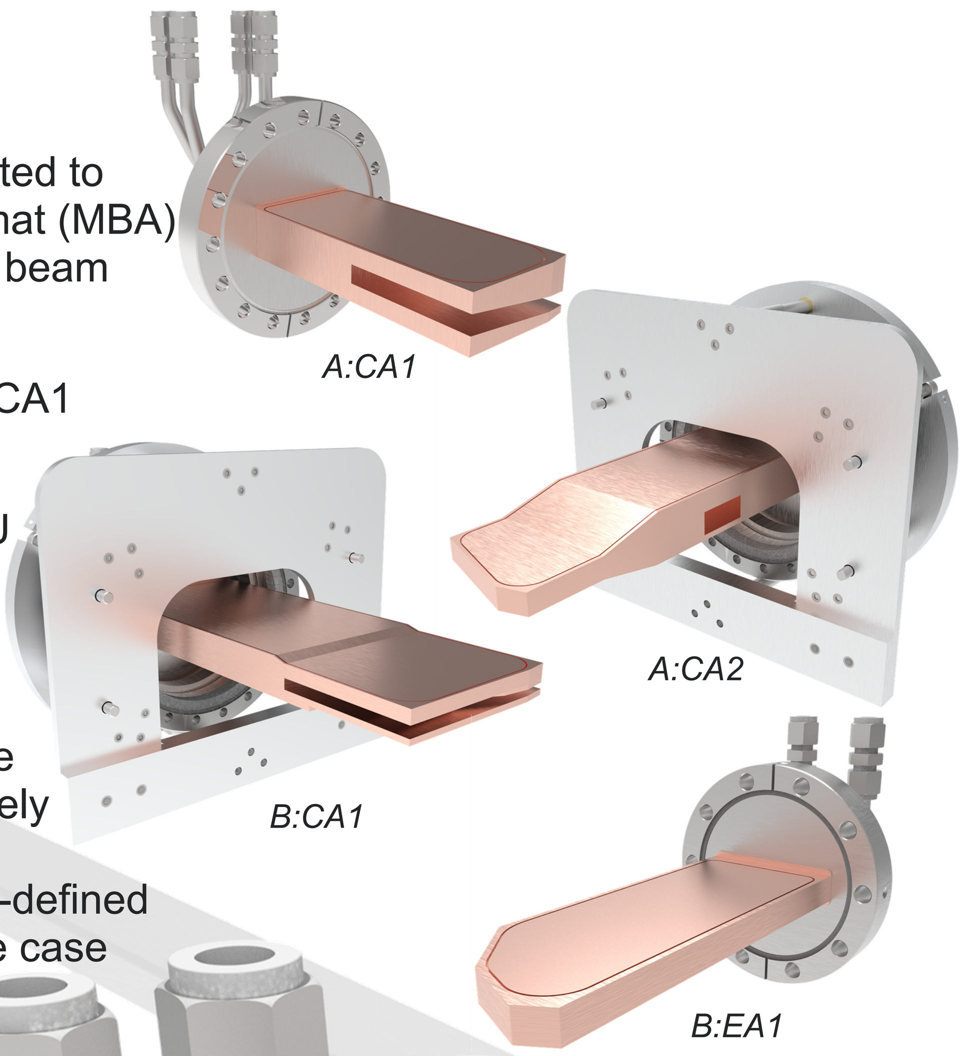
OVERVIEW

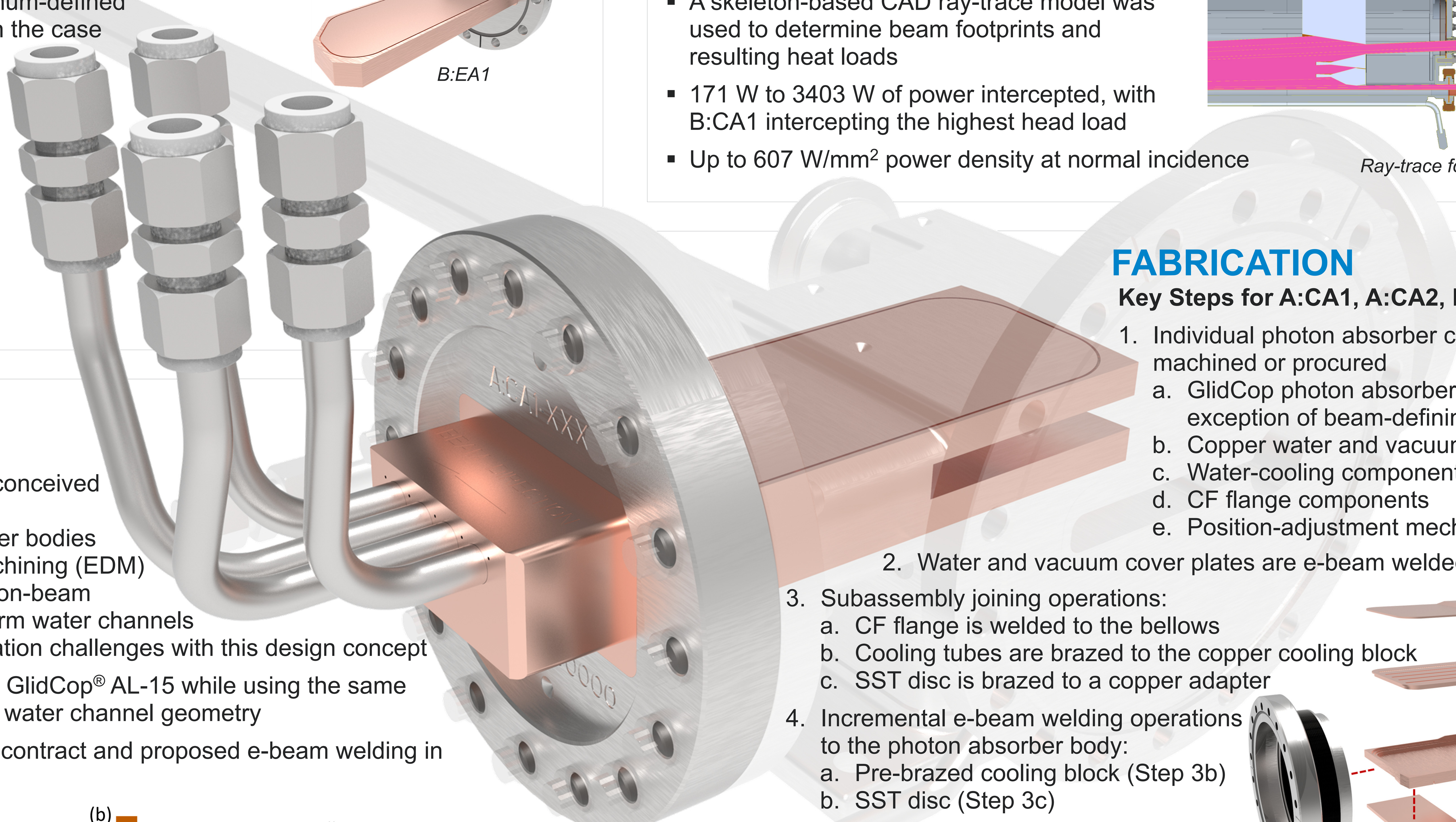
APS-Upgrade (APS-U) Storage Ring

- 40 sectors, 1.1-km circumference, retrofitted to the current APS with a multi-bend achromat (MBA) lattice that will produce a 6-GeV, 200-mA beam

Discrete Photon Absorbers

- 3x Crotch Absorbers: A:CA1, A:CA2 & B:CA1
- 1x End Absorber: B:EA1
- 1x Inline Absorber: B:FA1 (see the APS-U NEG-coated copper vacuum chambers)
- GlidCop® AL-15 construction
- Key Design Requirements:
  - Protect neighboring components in the storage ring vacuum system while safely handling heat loads
  - Permit photon extraction via minimum-defined vertical and horizontal apertures in the case of the crotch absorbers
  - Seamlessly integrate into the storage ring vacuum system

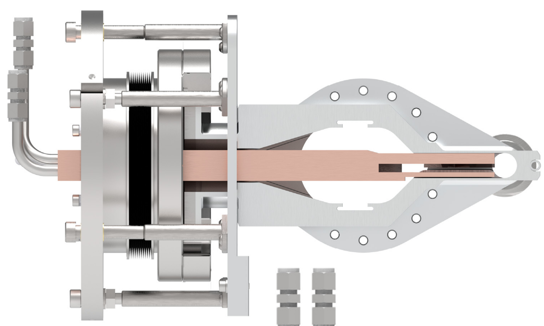




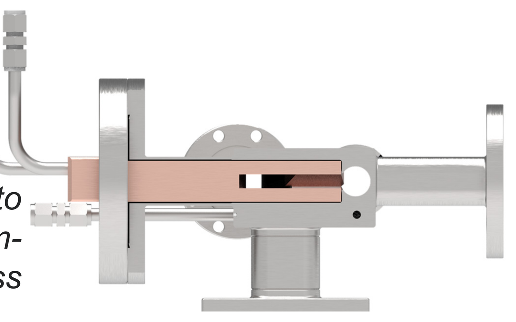
DESIGN CONSTRAINTS

Primary Interfaces

- The tight confines of the storage ring vacuum system led to very strict spatial limitations
- A:CA2, B:CA1 & B:EA1 mount to stretch-formed, aluminum extrusion-based L-bend vacuum chambers
- A:CA1 mounts to the A:VC6 stainless steel vacuum cross
- B:FA1 is a 60-mm vacuum chamber and also shadows downstream components
- Accelerator Physics
  - Gaps of 1 mm to 1.25 mm were included between the vacuum chambers and photon absorbers by the electron beam
  - Geometry of beam-intercepting faces was also negotiated with accelerator physics



B:CA1 mounted to the B:M2 L-bend vacuum chamber

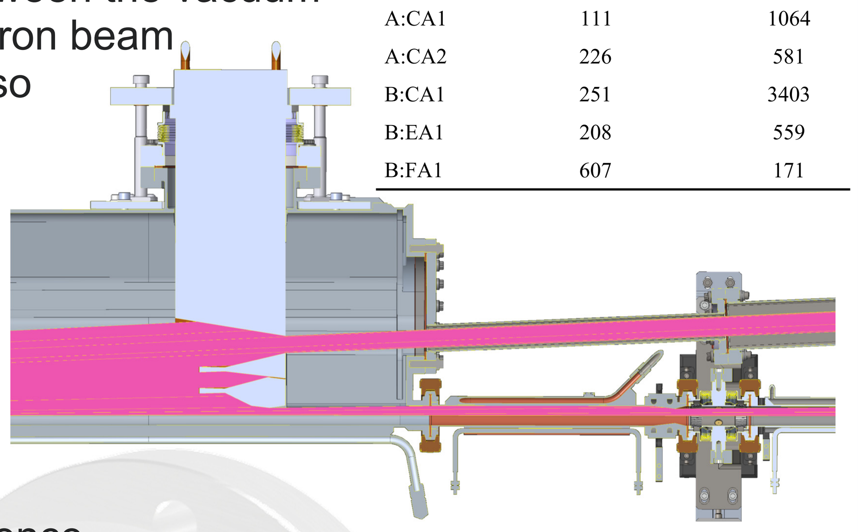


A:CA1 mounted to the A:VC6 vacuum-pumping cross

Photon Absorber	Normal Power Density (W/mm^2)	Total Power (W)
A:CA1	111	1064
A:CA2	226	581
B:CA1	251	3403
B:EA1	208	559
B:FA1	607	171

Ray-Tracing

- A skeleton-based CAD ray-trace model was used to determine beam footprints and resulting heat loads
- 171 W to 3403 W of power intercepted, with B:CA1 intercepting the highest head load
- Up to 607 W/mm^2 power density at normal incidence



Ray-trace for B:CA1

FINAL DESIGN

Material Selection

- All photon absorbers were originally conceived as monoblock CuCrZr designs
  - A "pocket" is formed in the absorber bodies via sinker electrical discharge machining (EDM)
  - An "insert" is machined and electron-beam (e-beam) welded to the body to form water channels
  - Vendors relayed significant fabrication challenges with this design concept
- The designs were changed to brazed GlidCop® AL-15 while using the same outer geometry, with slightly modified water channel geometry
- A reputable vendor was awarded the contract and proposed e-beam welding in place of brazing

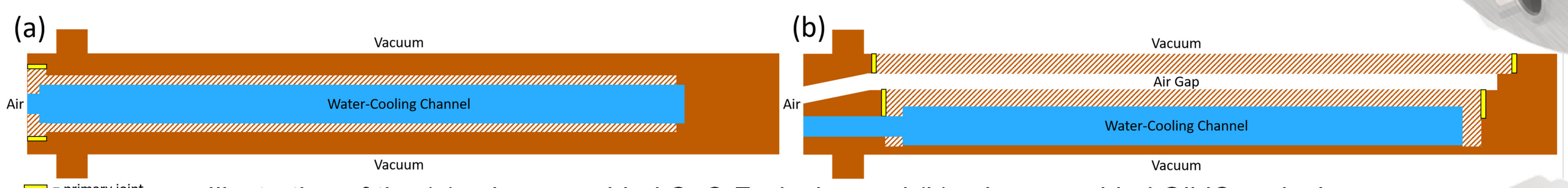
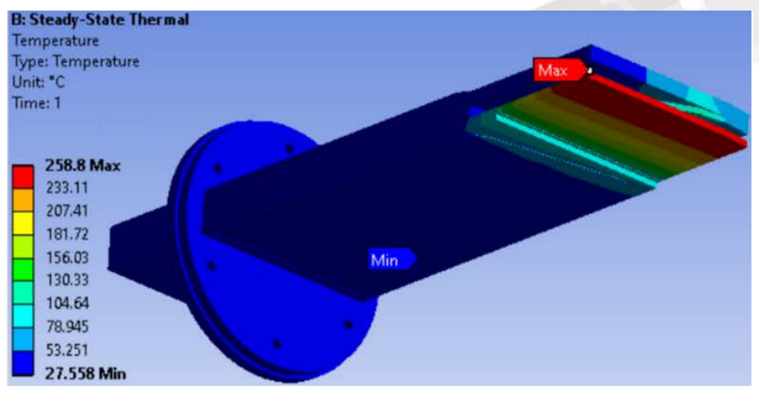


Illustration of the (a) e-beam welded CuCrZr design and (b) e-beam welded GlidCop design

Finite Element Analysis

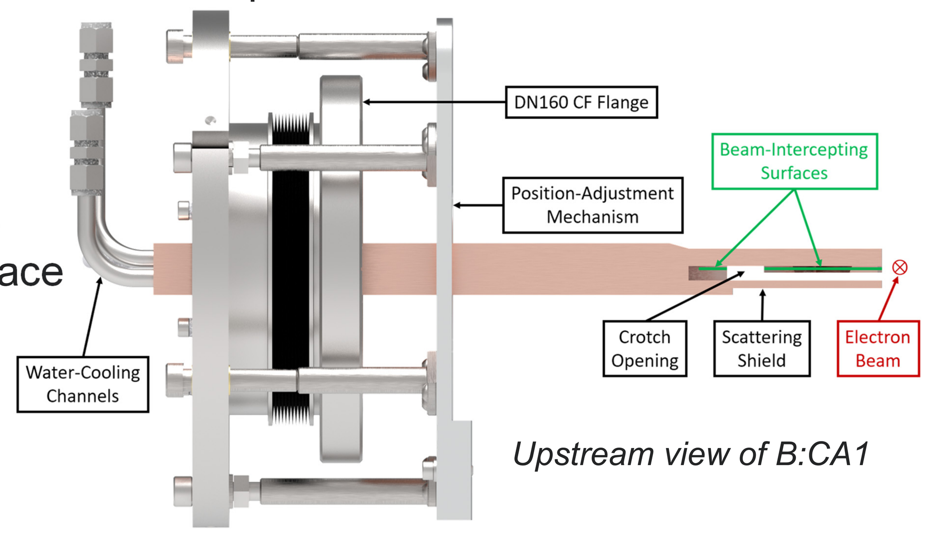
- FEA was extensively utilized to optimize each design
- Thermal-structural analysis: high stresses primarily from beam interception and water pressure during machine operation
- Modal analysis: to ensure that the vibrational characteristics of the designs do not impact the electron beam and beam-defining edges



B:CA1 thermal analysis results assuming a scattered heat load

Primary Design Features

- Beam-intercepting surfaces to shadow downstream components
- CF flange(s) to form a vacuum seal
- Crotch opening for the crotch absorbers to permit photon extraction to front ends
- Position-adjustment mechanism to achieve the precise alignment dictated by the ray-trace
- Scattering shield to intercept scattered power, similar to ESRF photon absorbers
- Water-cooling channels with unique shapes to dissipate heat in strict spaces

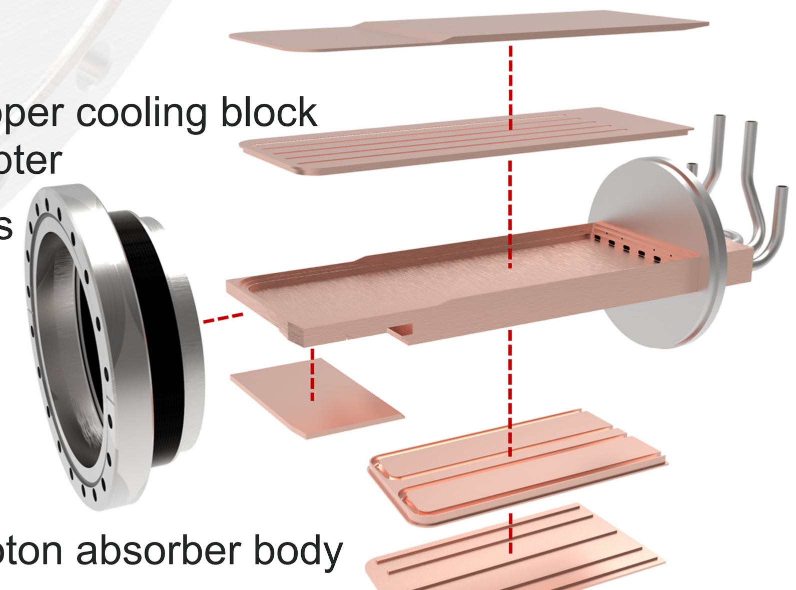


Upstream view of B:CA1

FABRICATION

Key Steps for A:CA1, A:CA2, B:CA1 & B:EA1

1. Individual photon absorber components will be machined or procured
   a. GlidCop photon absorber bodies (with the exception of beam-defining edges)
   b. Copper water and vacuum cover plates
   c. Water-cooling components
   d. CF flange components
   e. Position-adjustment mechanism components
2. Water and vacuum cover plates are e-beam welded to the GlidCop body
3. Subassembly joining operations:
   a. CF flange is welded to the bellows
   b. Cooling tubes are brazed to the copper cooling block
   c. SST disc is brazed to a copper adapter
4. Incremental e-beam welding operations to the photon absorber body:
   a. Pre-brazed cooling block (Step 3b)
   b. SST disc (Step 3c)
5. The beam-defining edges are machined via conventional machining and EDM
6. The scattering shield is e-beam welded to the photon absorber body (if necessary)
7. The bellows-flange assembly (Step 3a) is TIG welded to the SST disc (Step 4b)
8. The position-adjustment mechanism and water fittings are assembled to the absorber

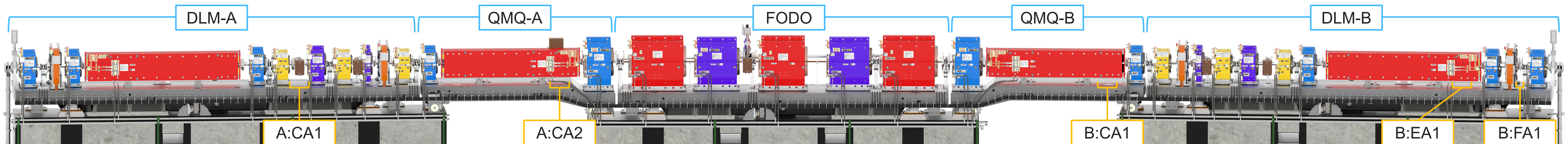


Quality Assurance (QA)

- Critical e-beam welded samples are being fabricated to qualify first articles and production
- Photon absorbers will undergo standard vacuum component QA processing:
  - Dimensional evaluation
  - Vacuum and hydrostatic leak testing
  - Ultra-high vacuum (UHV) cleaning
  - Bake-out & residual gas analysis (RGA) scan
- Comprehensive QA reports will be provided for all photon absorbers
- All photon absorbers will arrive installation-ready with potential further on-site testing

CONCLUSION

Following an intensive and well-scrutinized design process, the procurement of the discrete photon absorbers is underway with first articles expected in late 2021. Next steps include continued fabrication followed by testing and quality assurance steps, assembly onto the respective magnet modules, and finally, installation into the storage ring tunnel during the APS dark period.



Standard APS-U Sector Arc

*Courtesy of Josh Downey

U.S. DEPARTMENT OF ENERGY

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