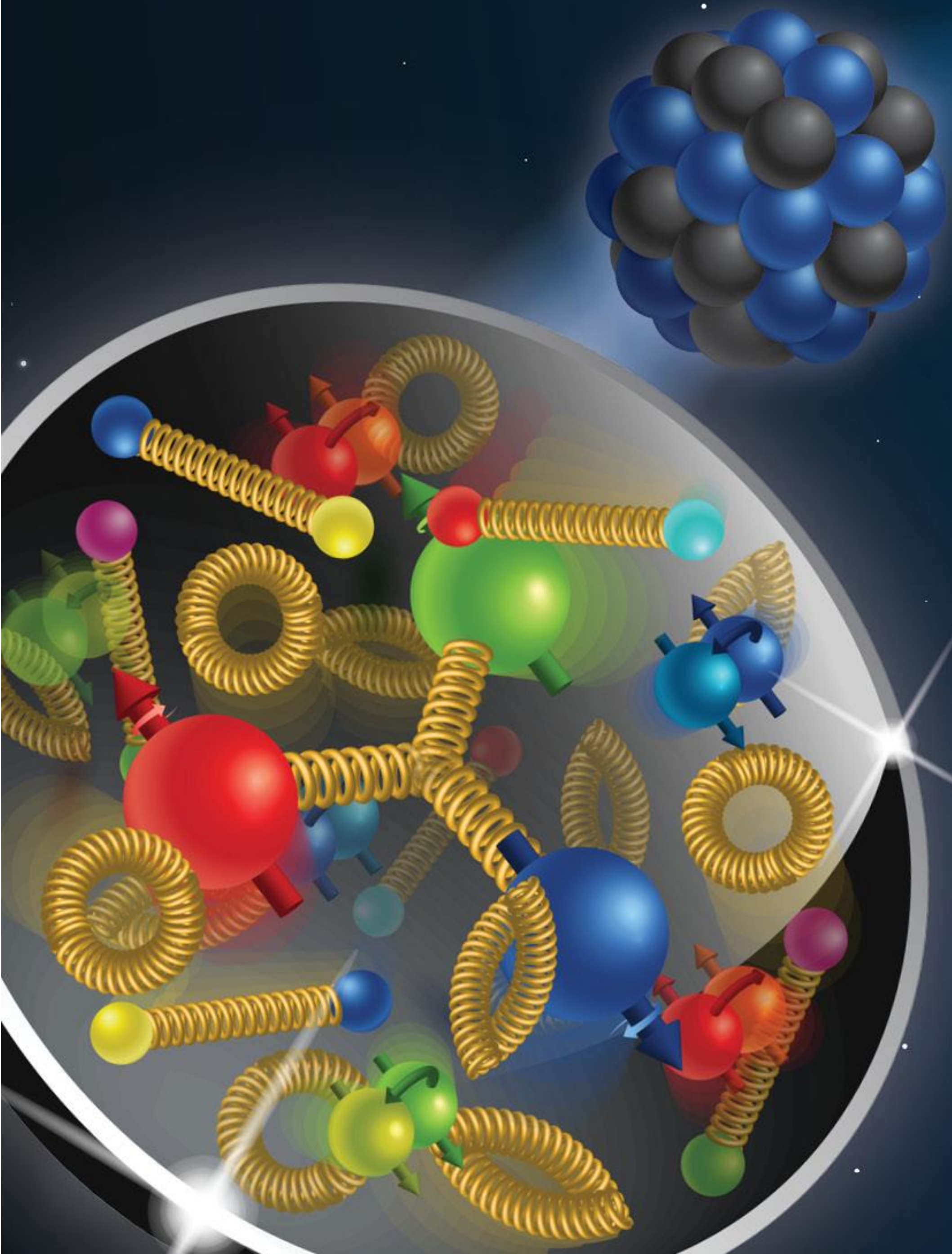


Vacuum Systems of EIC

eeFACT2022 Workshop

Charles Hetzel on behalf of the team

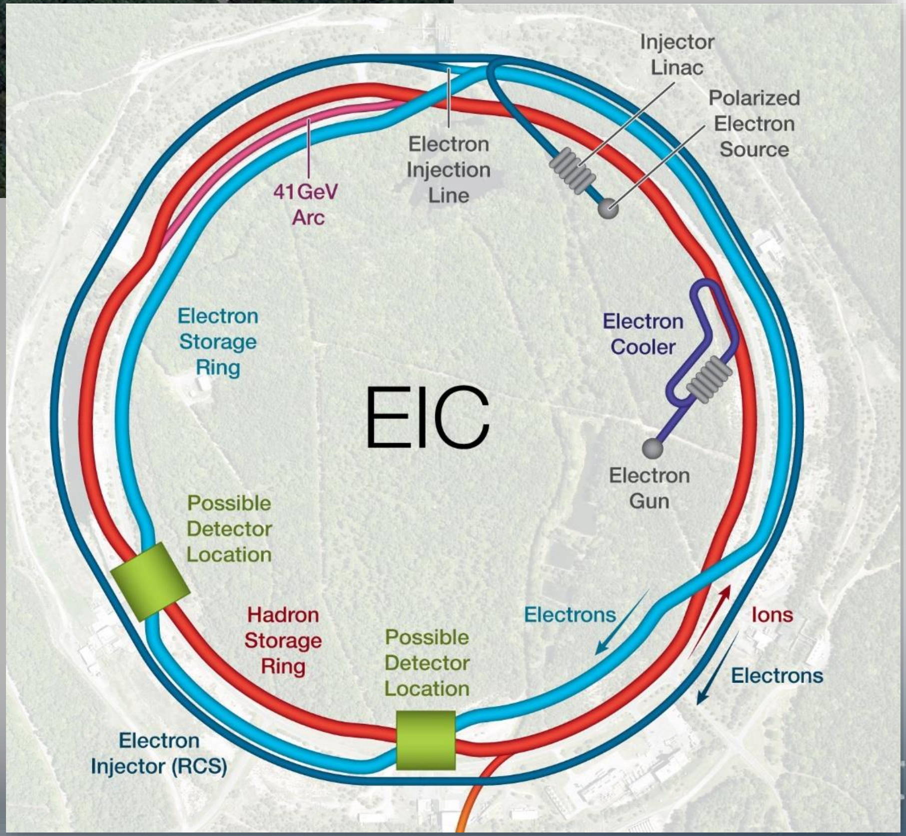
September 15, 2022

Electron-Ion Collider

BROOKHAVEN NATIONAL LABORATORY
Jefferson Lab
U.S. DEPARTMENT OF ENERGY | Office of Science

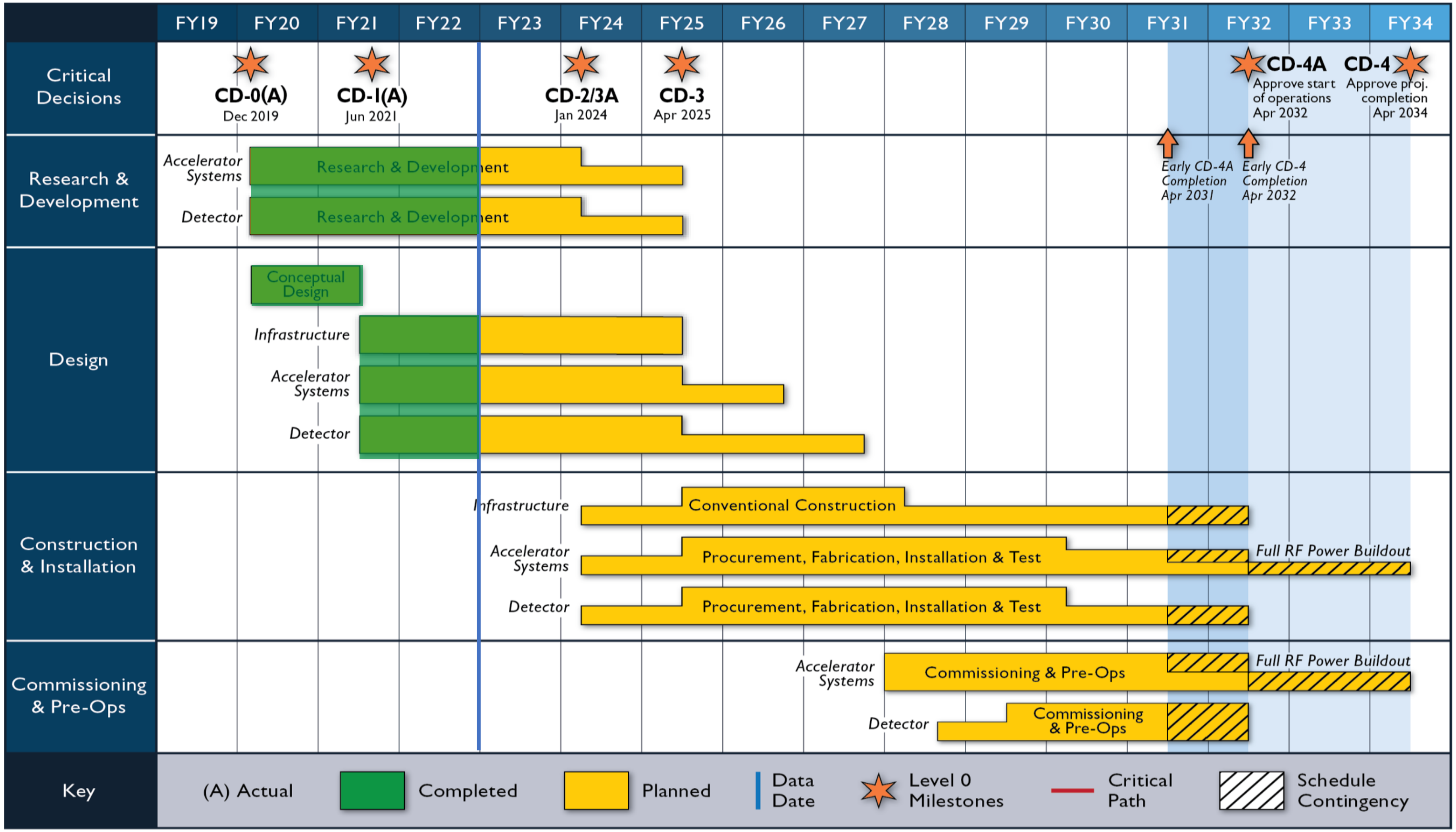
Outline

- Timeline
- ESR Vacuum System
  - Integrate photon absorber
  - Chamber flanges
  - RF bellows
  - Chamber design concepts
- HSR Vacuum System
  - Actively cooled beam screen
  - RF bellows/BPM module
  - EIC interconnect



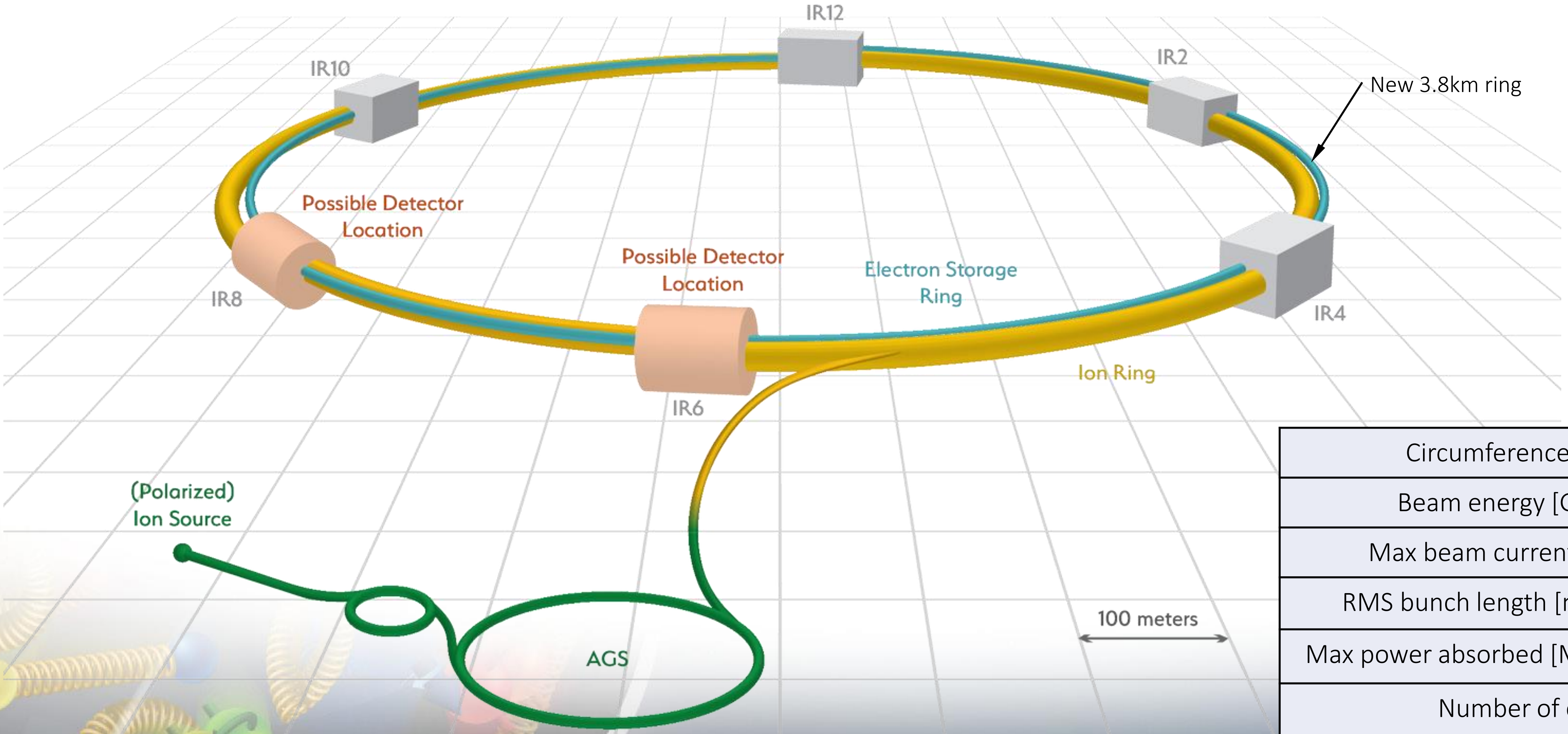
Electron-Ion Collider

EIC High Level Schedule



Electron-Ion Collider

Electron Storage Ring

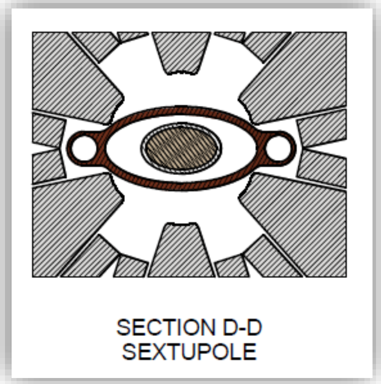


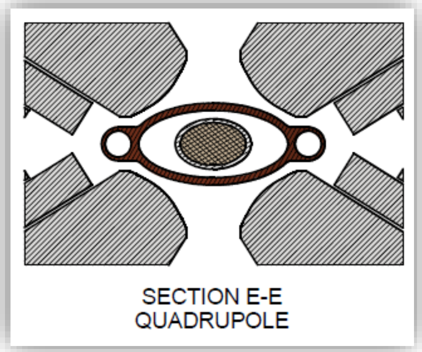
Circumference [m]	3833.94
Beam energy [GeV]	5, 10, 18
Max beam current [A]	2.5
RMS bunch length [mm]	~7
Max power absorbed [MW]	10
Number of cells	96

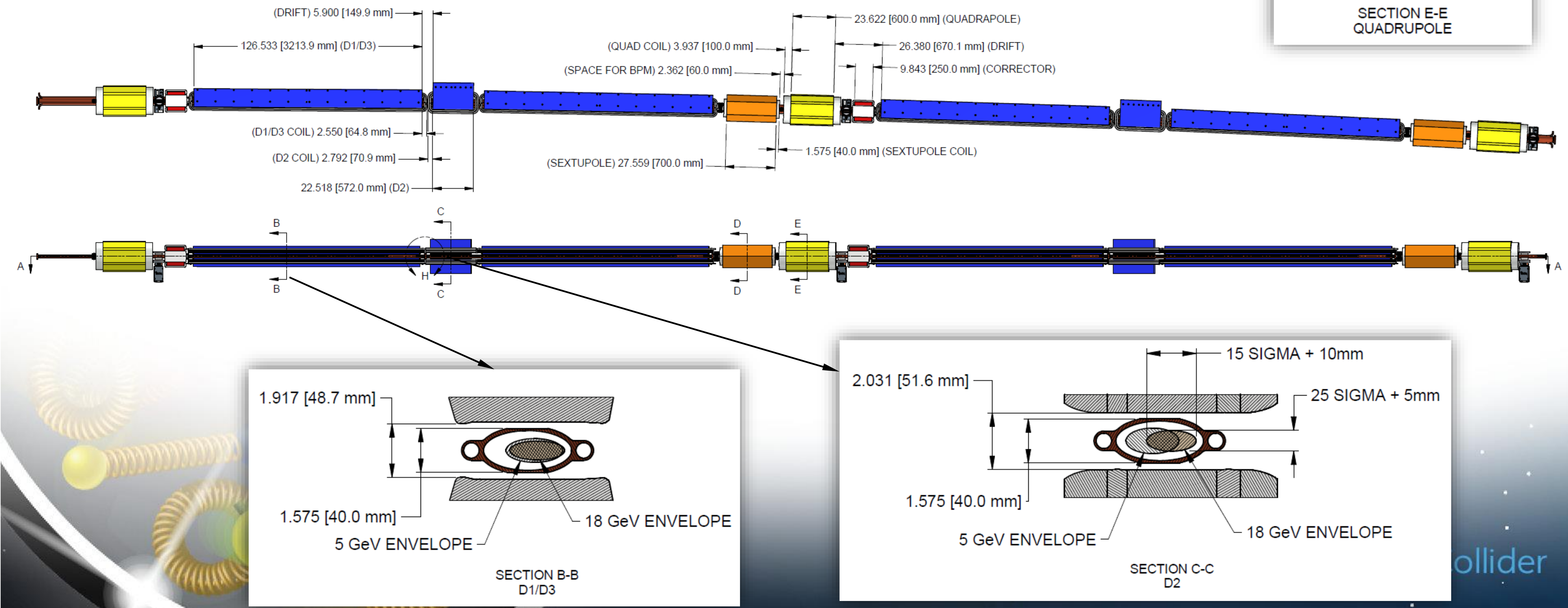
ESR Arc Layout

$15\sigma_x/25\sigma_y$ + 10/5mm for orbit distortion

Reverse bends required for 5GeV operations

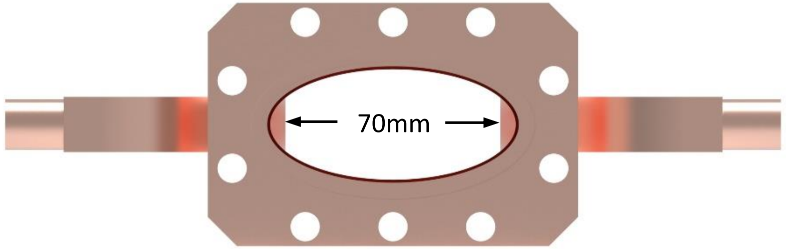


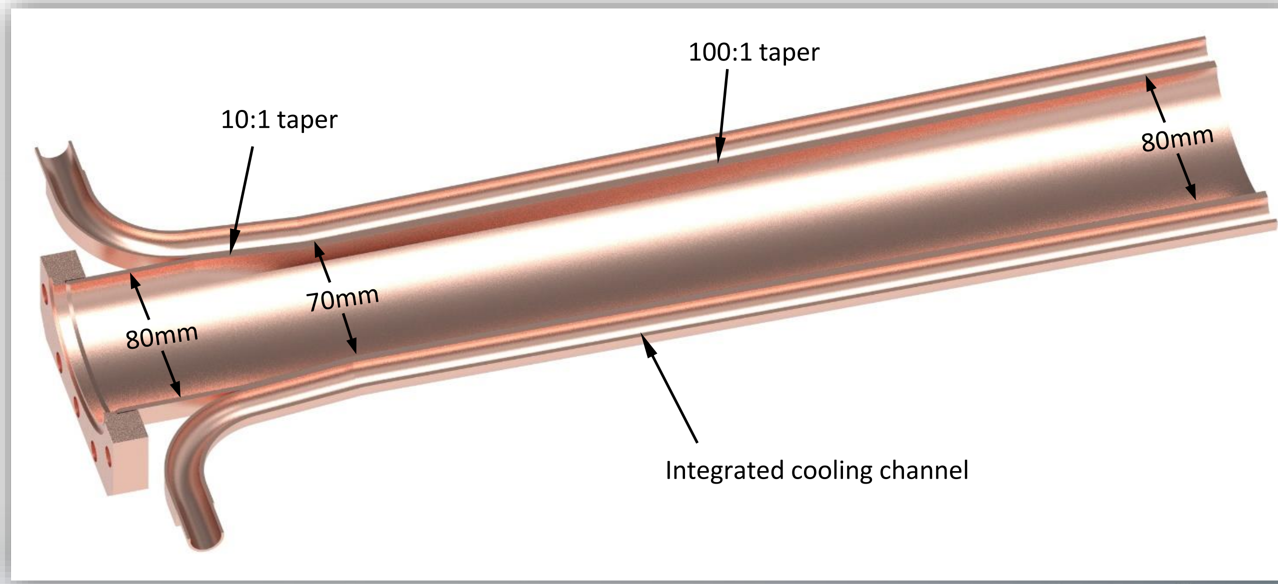




Integrated Photon Absorber

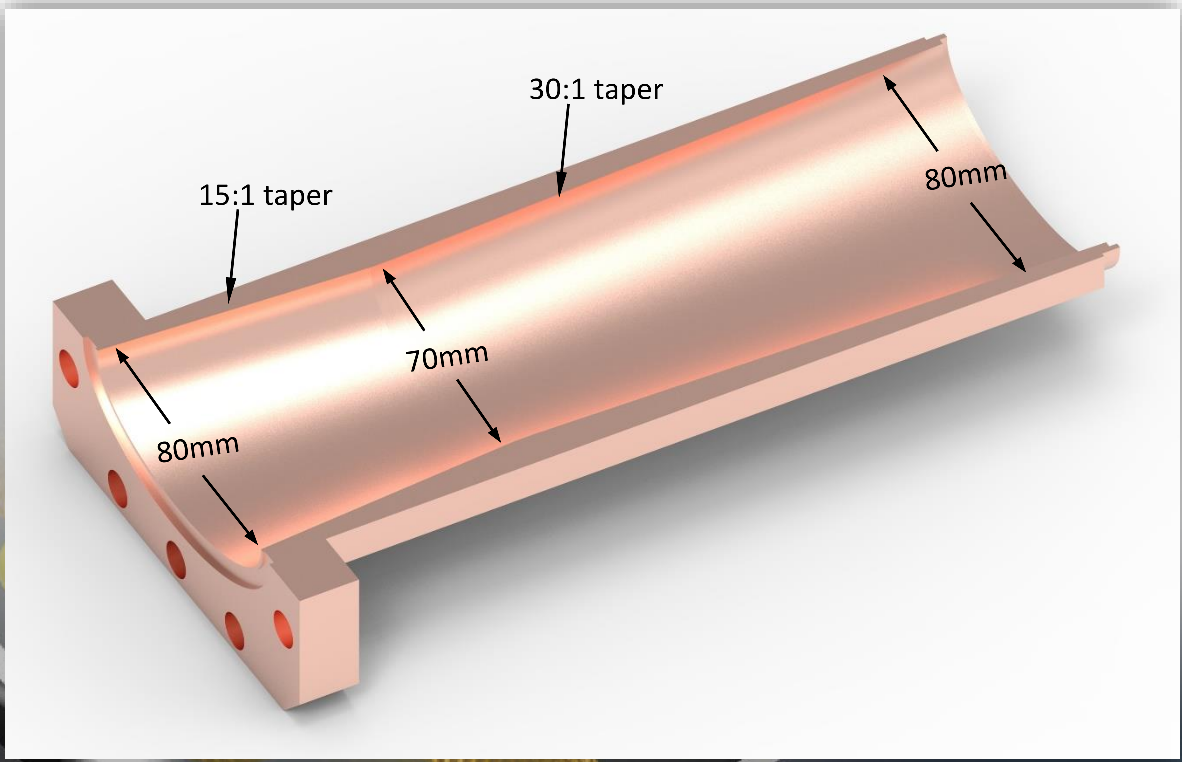
- Mechanical deformation to profile
- Shallow tapers
  - 100:1 on forward side, 10:1 on rear side
- Single layer between heat and cooling water
- Some distortion to vertical profile expected
- Tooling development required

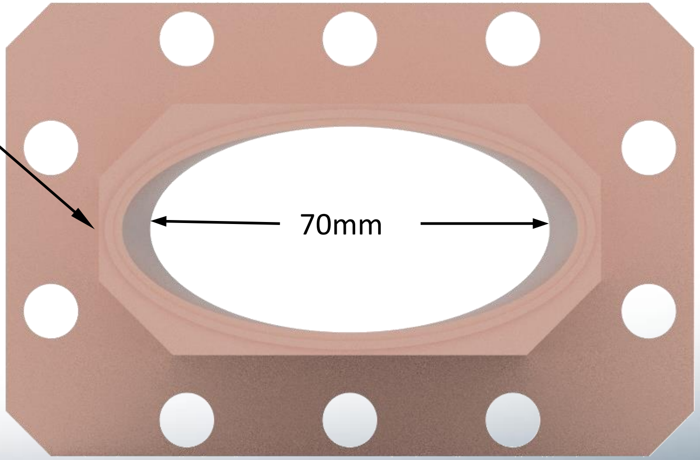




Alternative Exit Absorber Concept

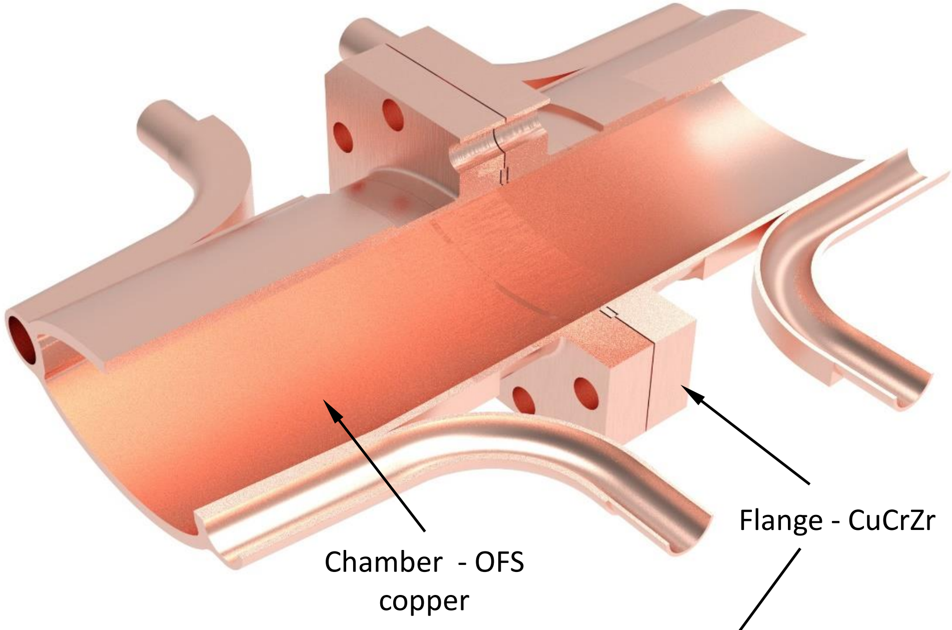
- Better control over aperture
  - Wire EDM profile
- Still one weld to extrusion
- Cooling line e-beam welded

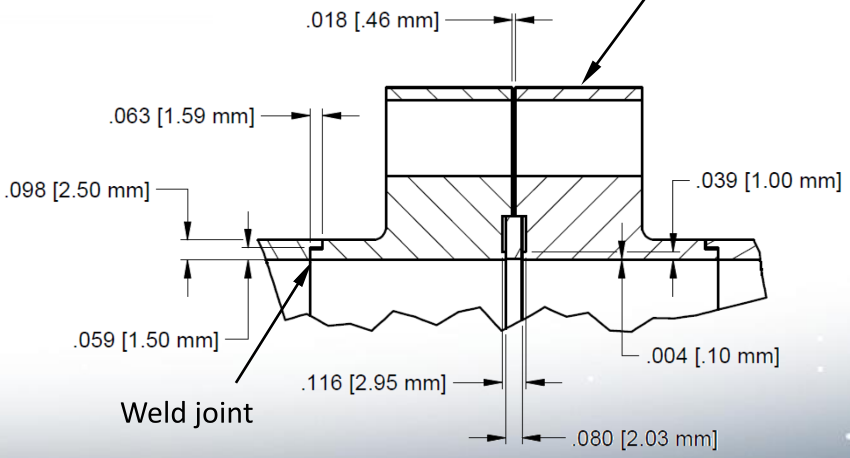


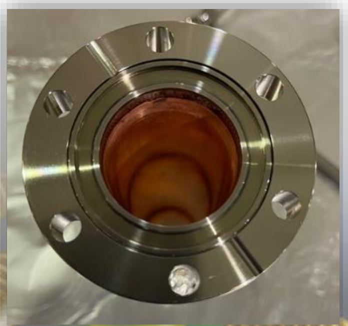


Chamber Flange

- Flanges welded to extrusions
  - Retain hardness of seal surface (R_B = 65 min)
  - ¼ hard copper gaskets (R_B = 25 max)
- Oversized bolt holes
- Common flange geometry
- Final gasket dimension to be developed
  - 'Bulging' of material into beam channel



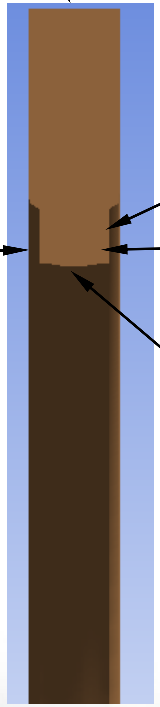




J. Bellon

Incursion Into Beam Channel

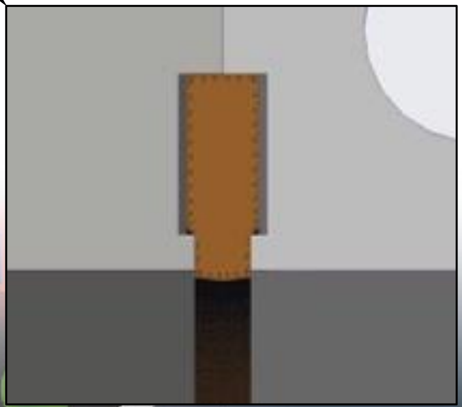
Fixed in radial direction
Free in axial direction

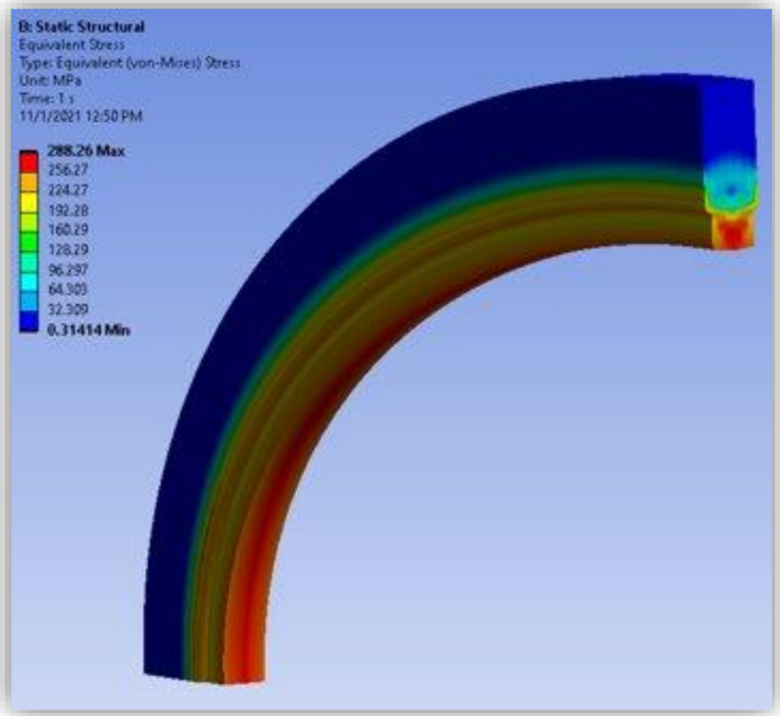


Fixed in normal direction

Axial compression 0.46mm

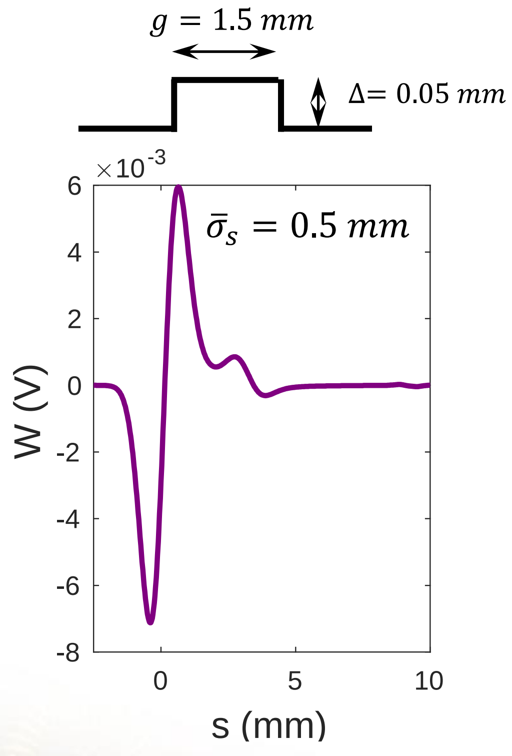
Gasket protrudes
0.28mm



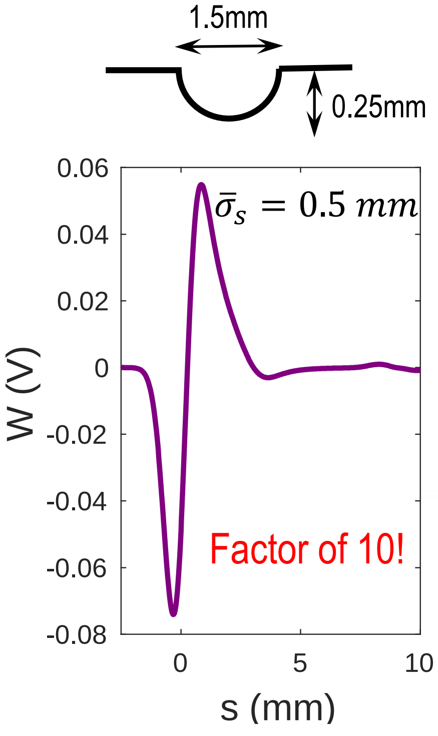


A. Blednykh

Incursion Into Beam Channel

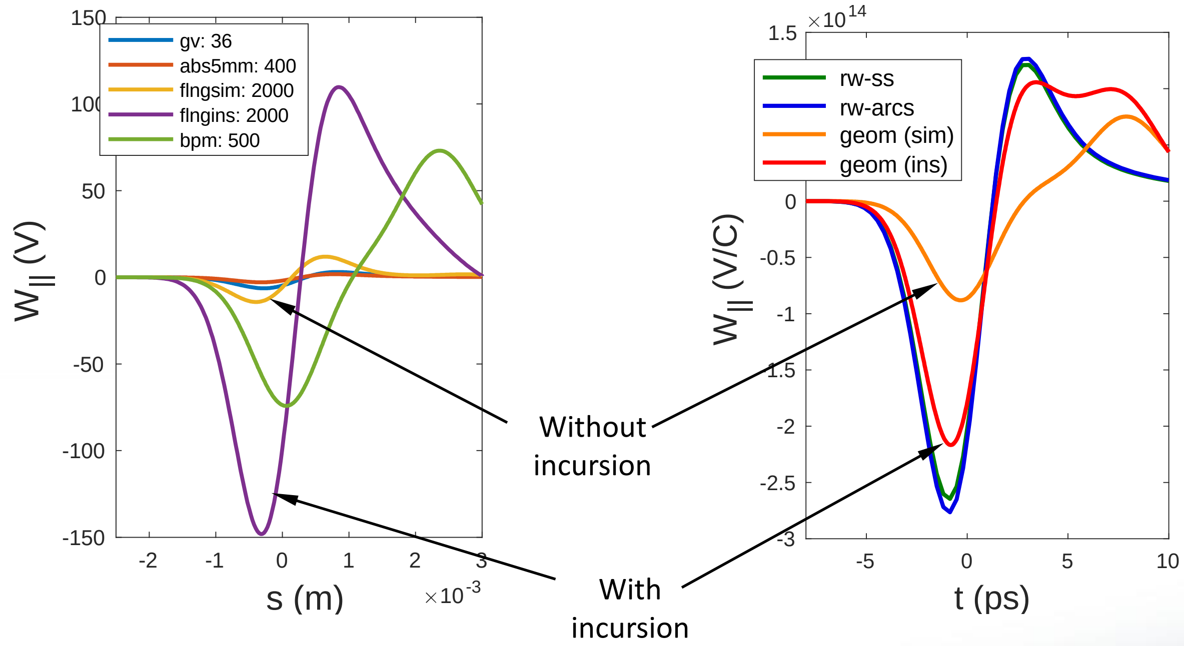


$k_{loss} = 5.9\ \mu V/pC\ (\sigma = 7mm)$



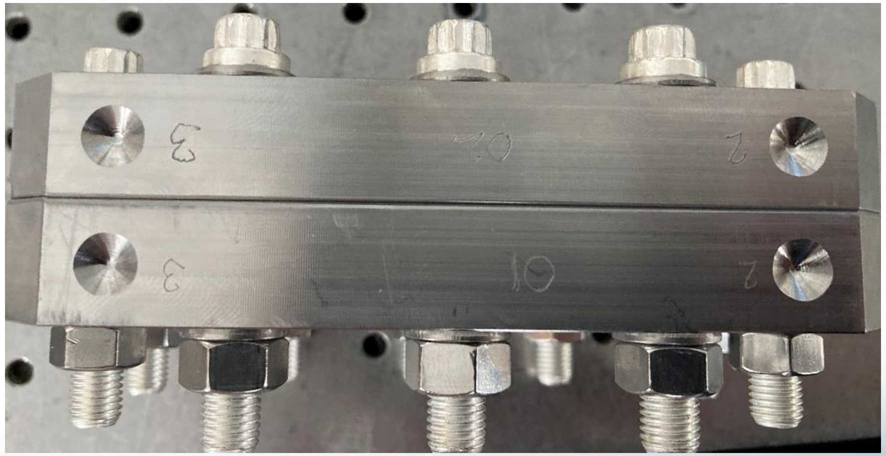
$k_{loss} = 12\ \mu V/pC\ (\sigma = 7mm)$

Longitudinal wakefield

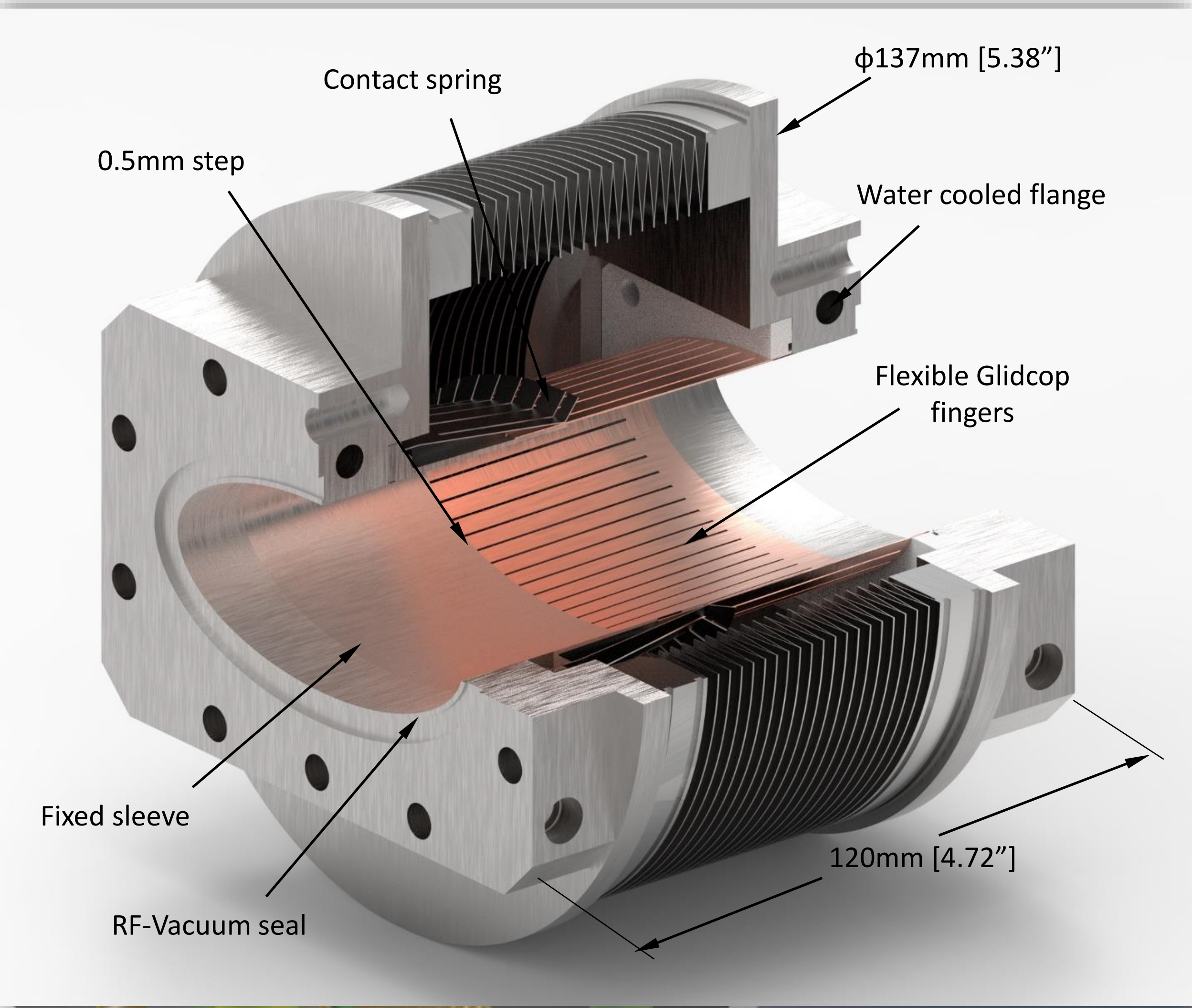


Longitudinal short-range wakefield for a 0.5mm bunch length

Gasket Test

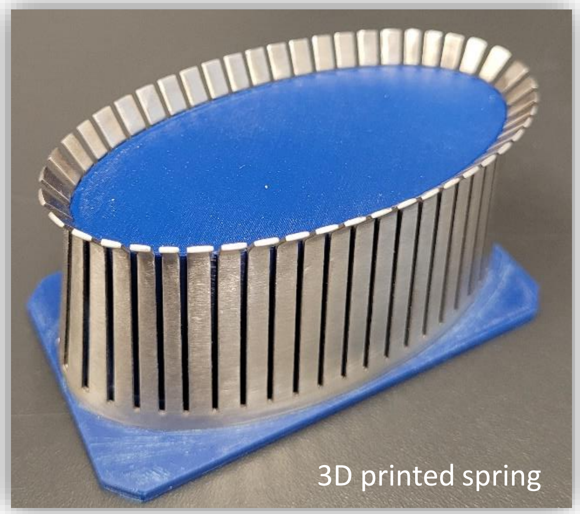


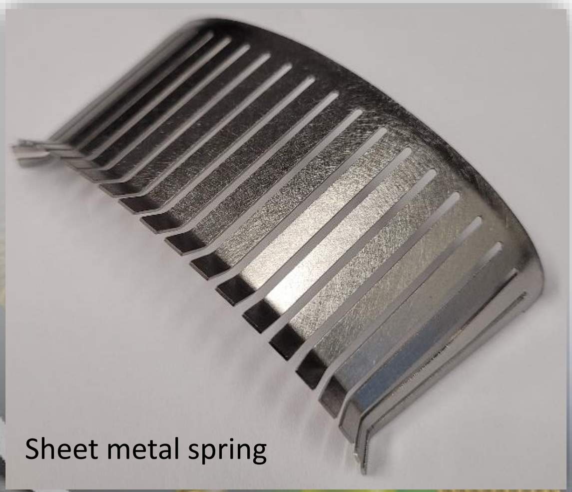
ESR RF Shielded Bellows Requirements



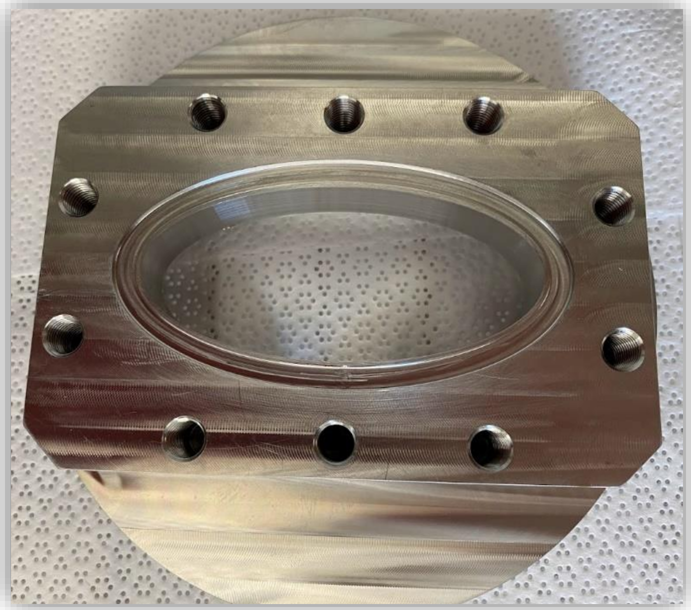
- Combination RF-Vacuum seal
- 30W beam induced heating
- Compact footprint
- Stroke Req: -25/+10mm
  - Cell length variation: +/-5mm
  - Compression: -15mm
  - Extension: +3mm
  - Chamber length: +/-2mm
  - Alignment: +/-1mm
- Radial offset: +/-2mm
- Angular offset: +/-0.5° [8.7mrad]

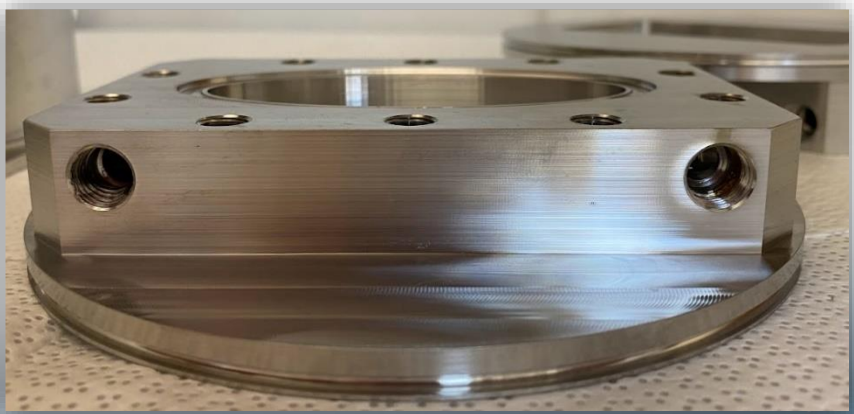
Bellows Prototype Parts


3D printed spring

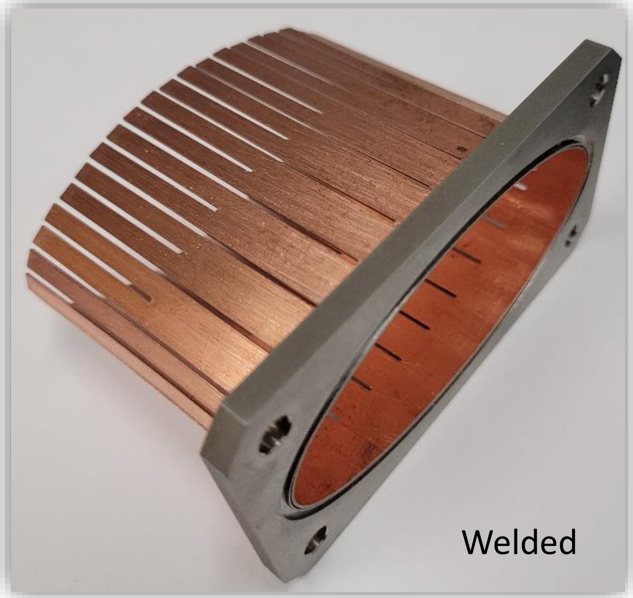

Sheet metal spring

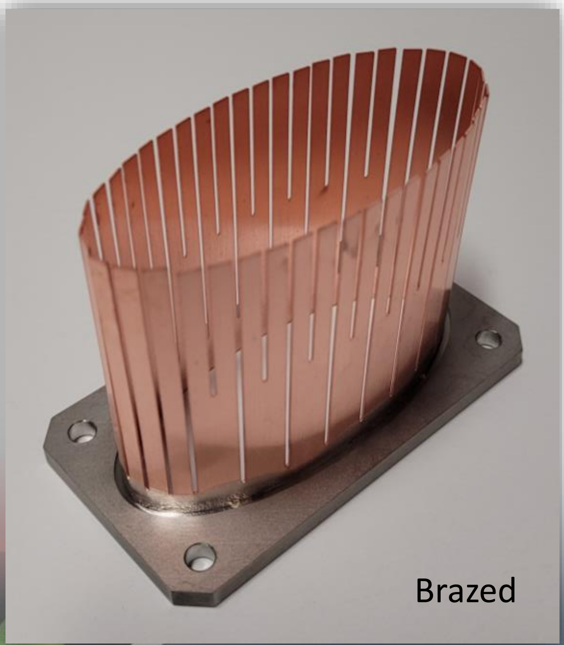

Fixed sleeves


Complete flanges with water cooling

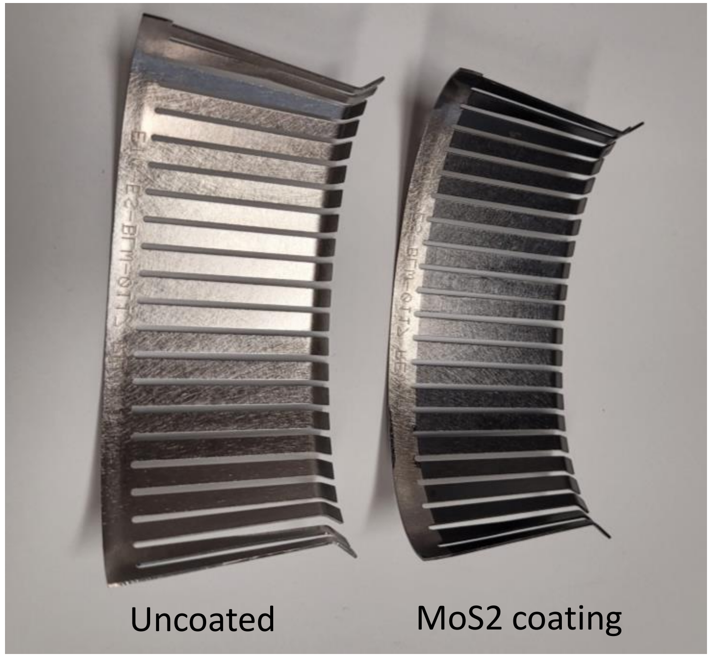


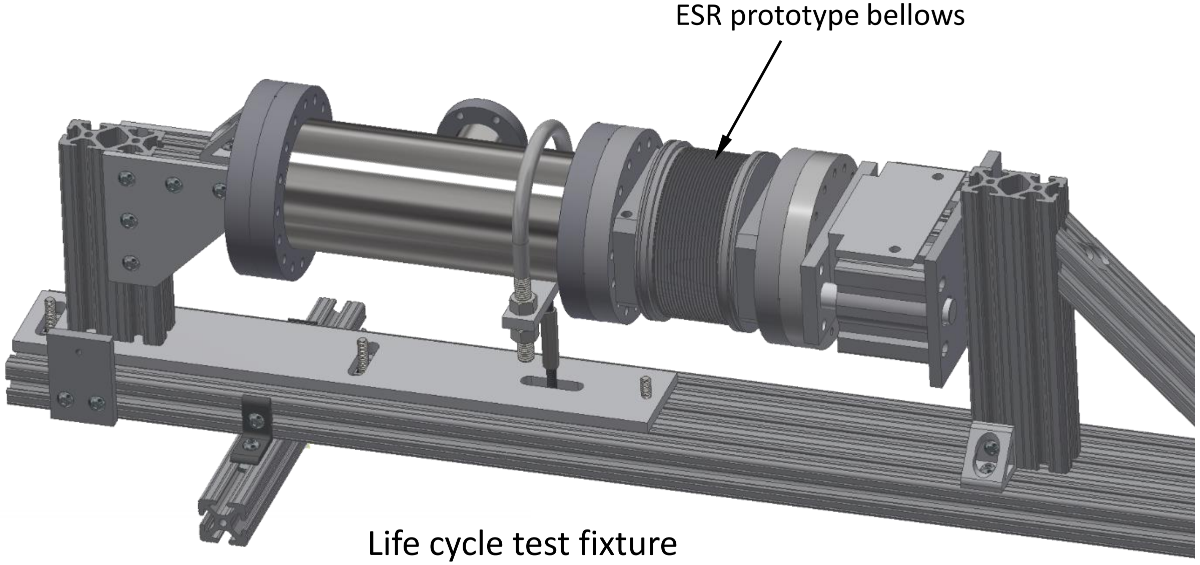
Bellows Prototype Parts





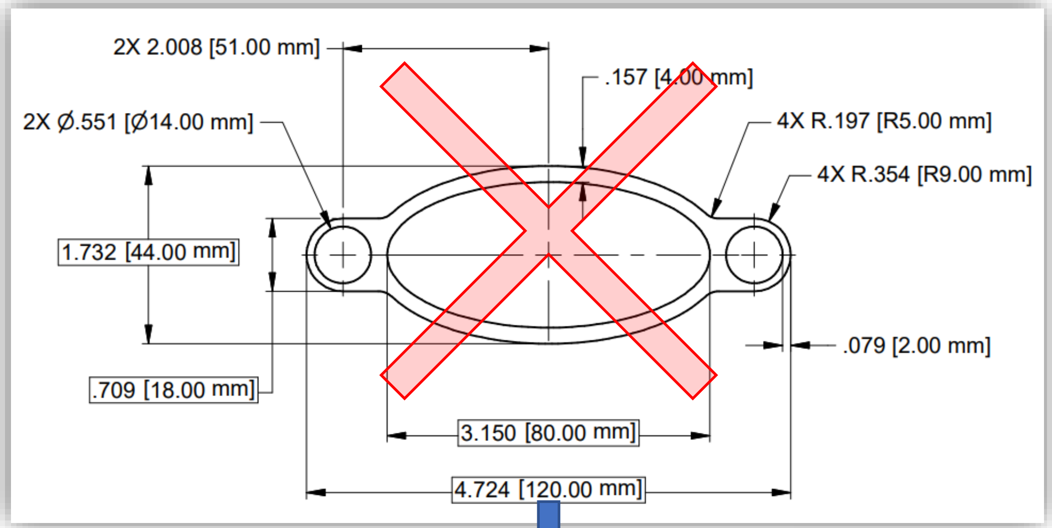
Bellows Prototype Parts - Coatings

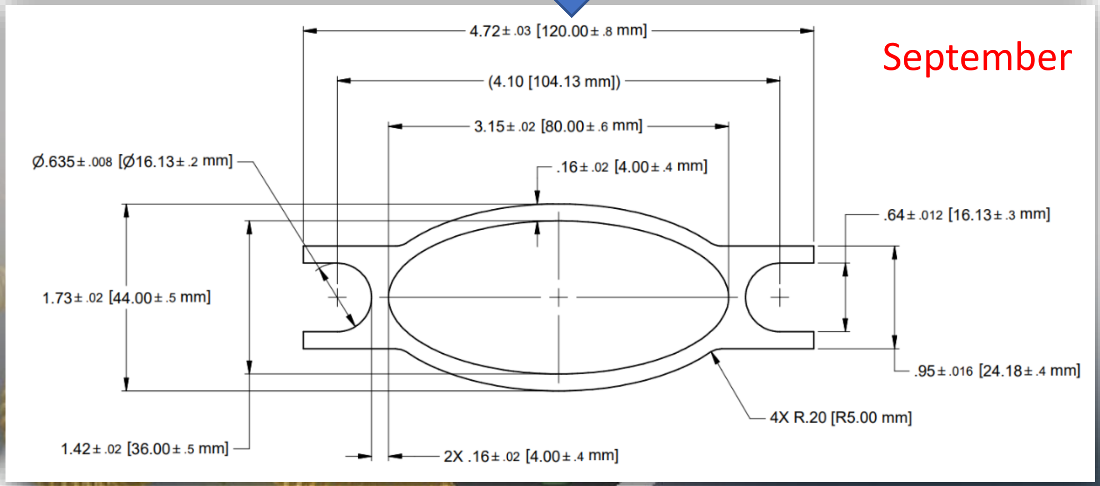


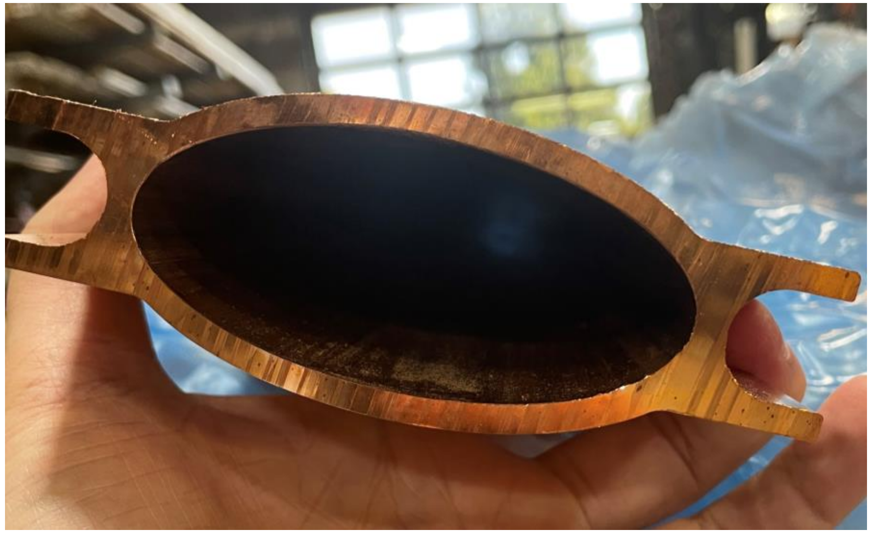


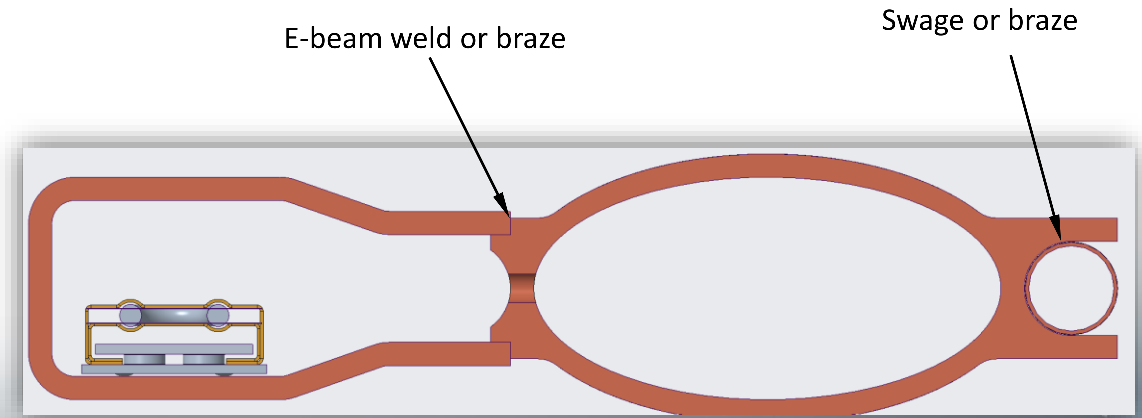
- Silver plated sleeves also in hand
- Silver plating plus heavy metal ion implanting
  - Copper and Tungsten
- Life cycle testing planned in coming weeks

ESR Chamber Profile

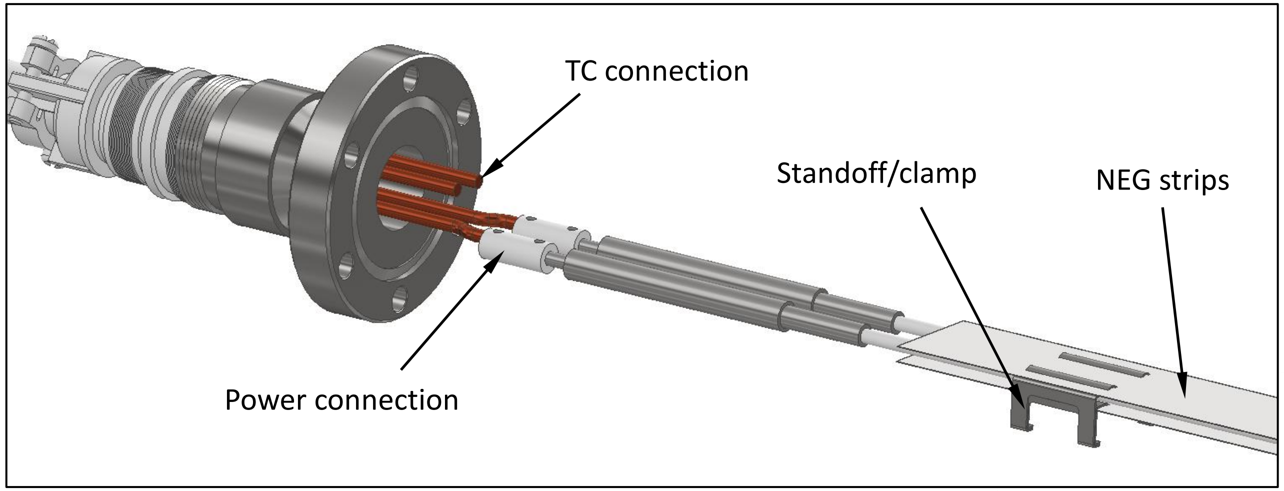


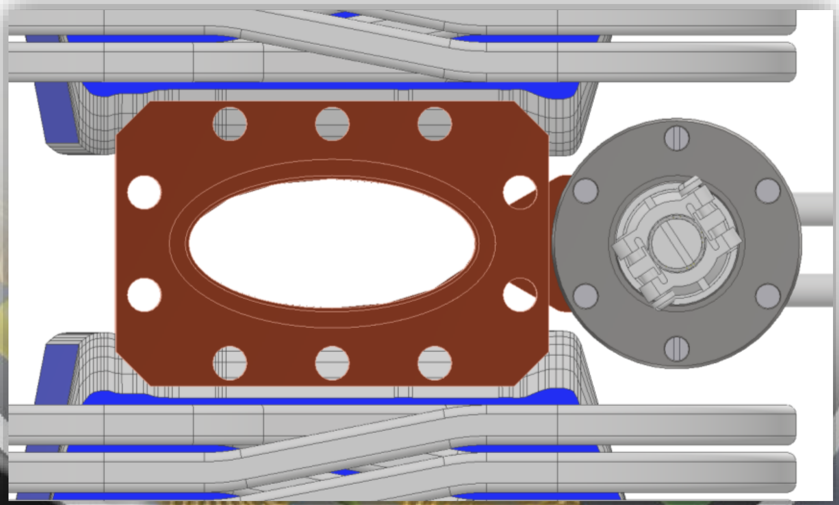


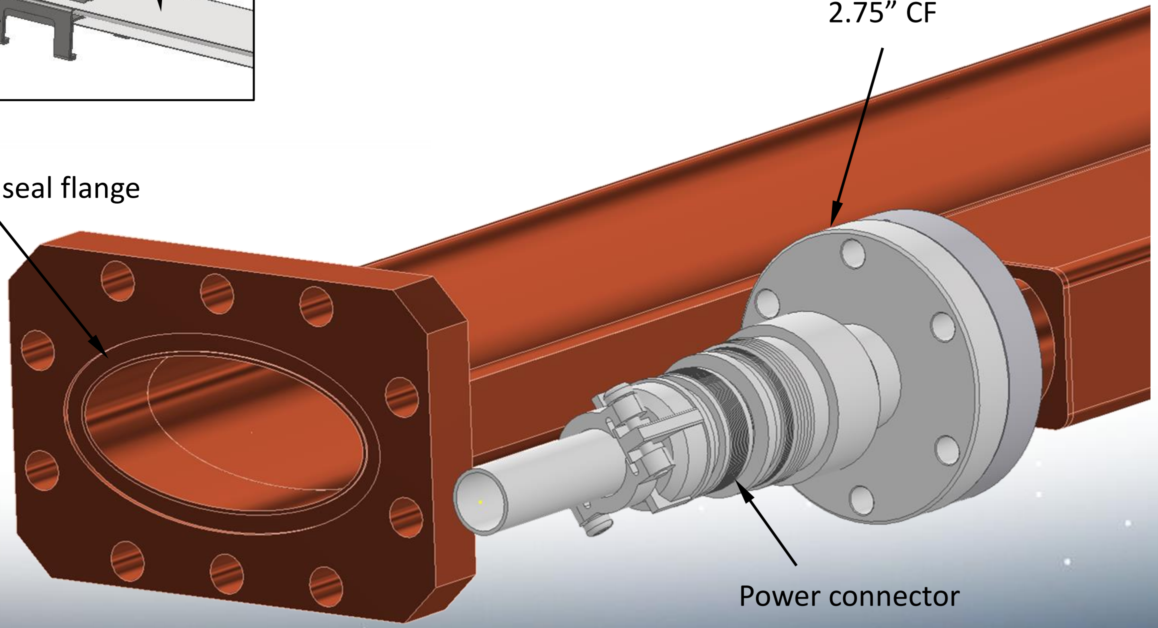




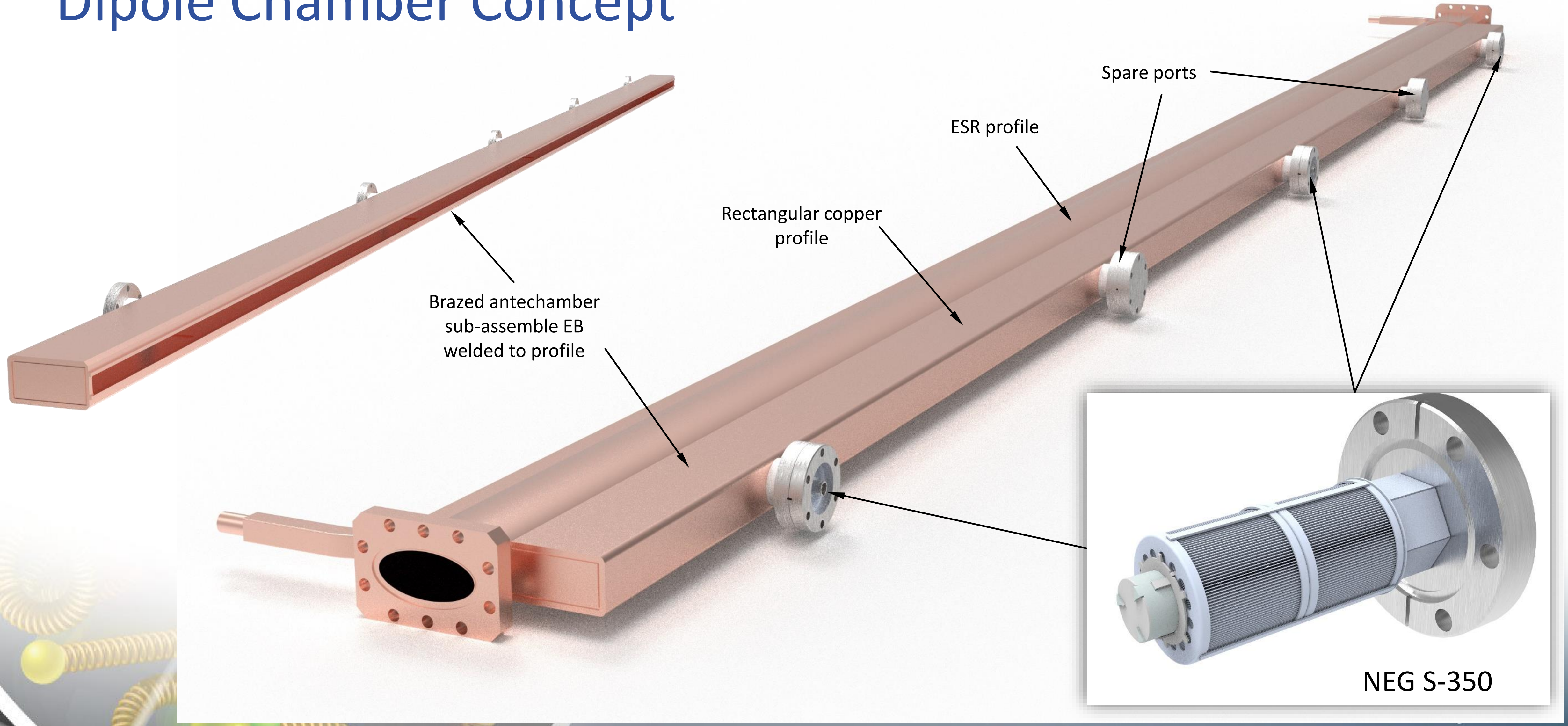
NEG Pump Concept – Resistive Wire Heater



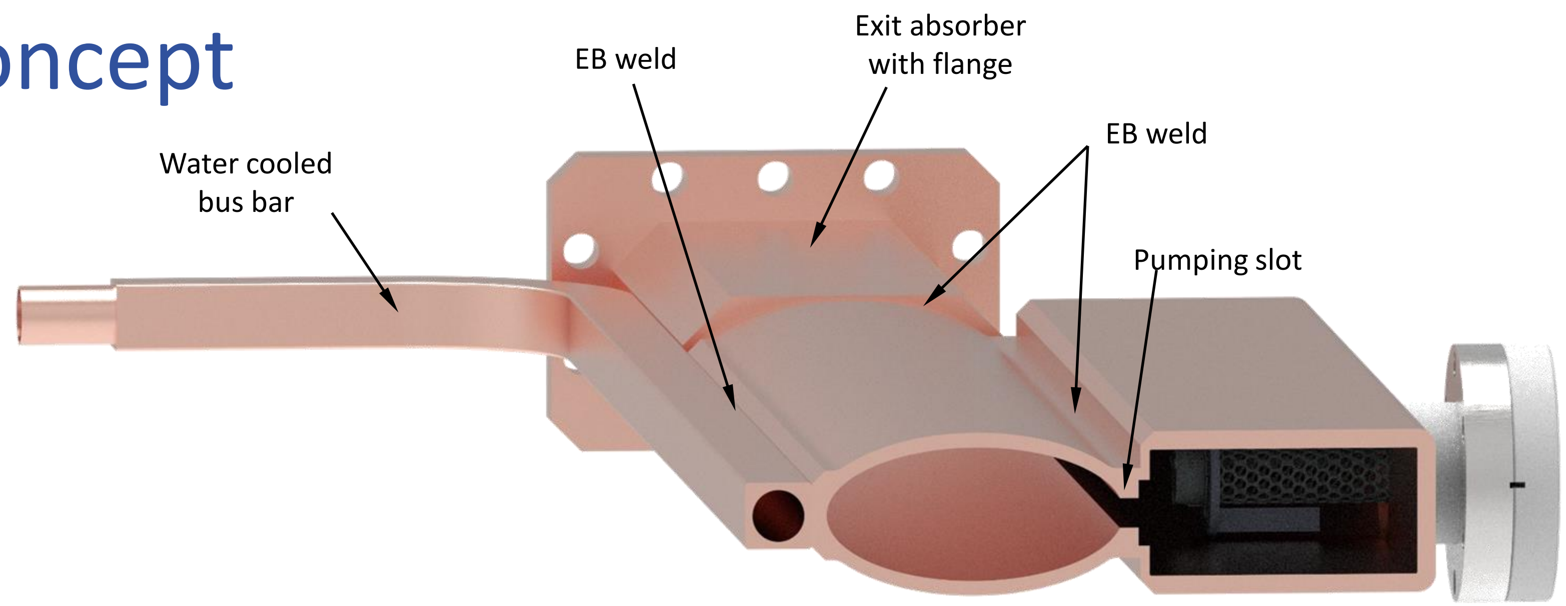


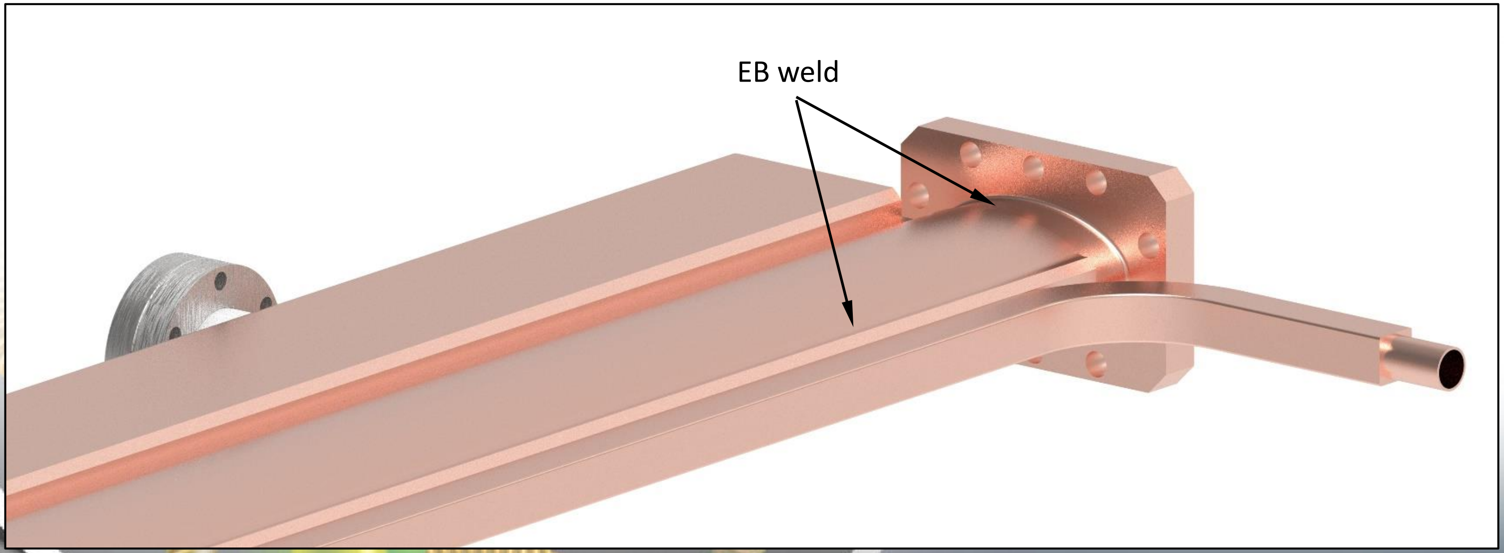


Dipole Chamber Concept



Dipole Chamber Concept



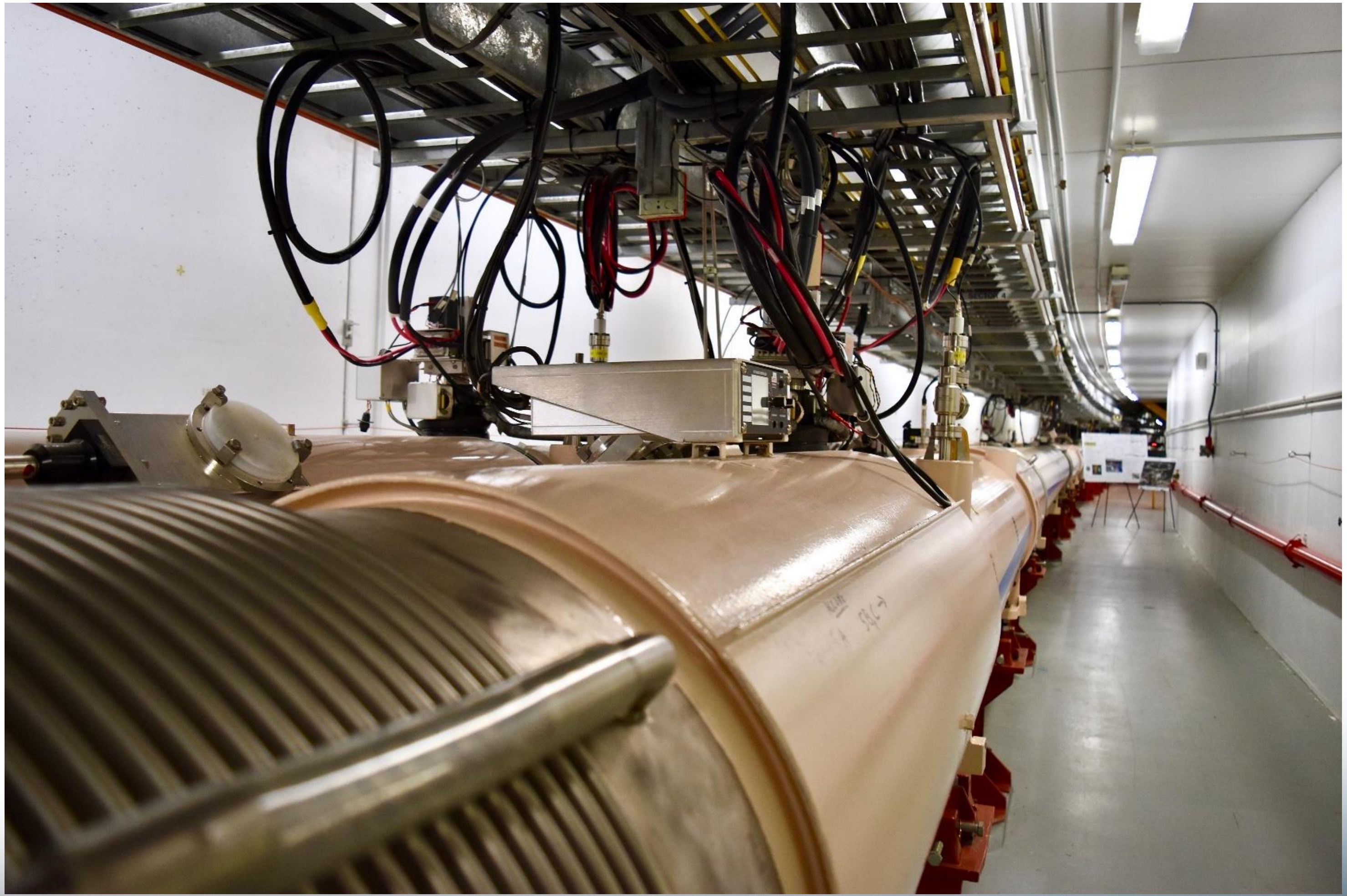


Summary and Next Steps - ESR

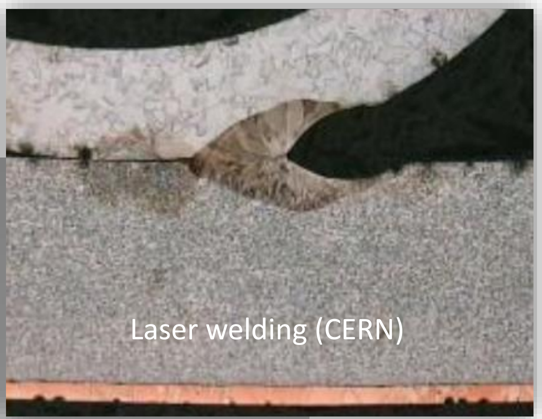
- Finalize primary pumping strategy
  - Still evaluating linear ZAO modules
- Develop details for prototype chamber
  - Exit absorber and flanges
  - Short 'proof of principle' unit to validate design features
  - Full length prototype chamber(s)
- Complete ESR bellows prototype
  - Life cycle testing to finalize coatings
  - Proof out RF-vacuum seal geometry

Hadron Storage Ring - HSR

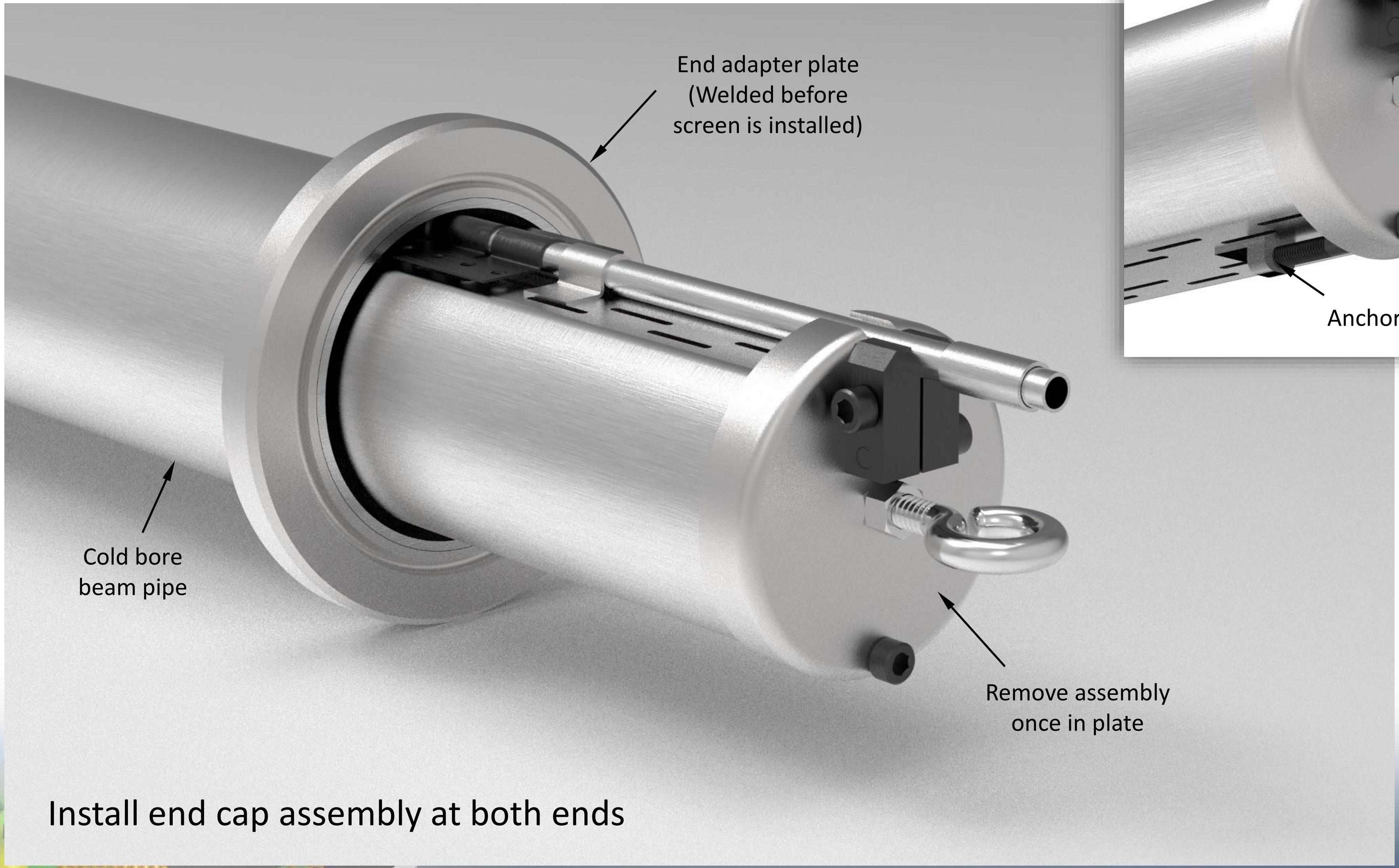
- Beam screen
  - Resistive wall heating
  - Reduction of SEY
- Replace RF bellows
- Replace stripline pickups

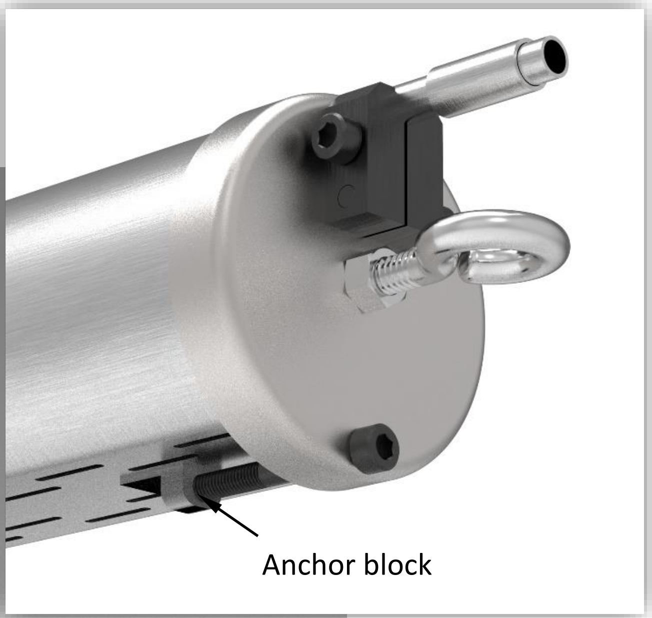


HSR Beam Screen

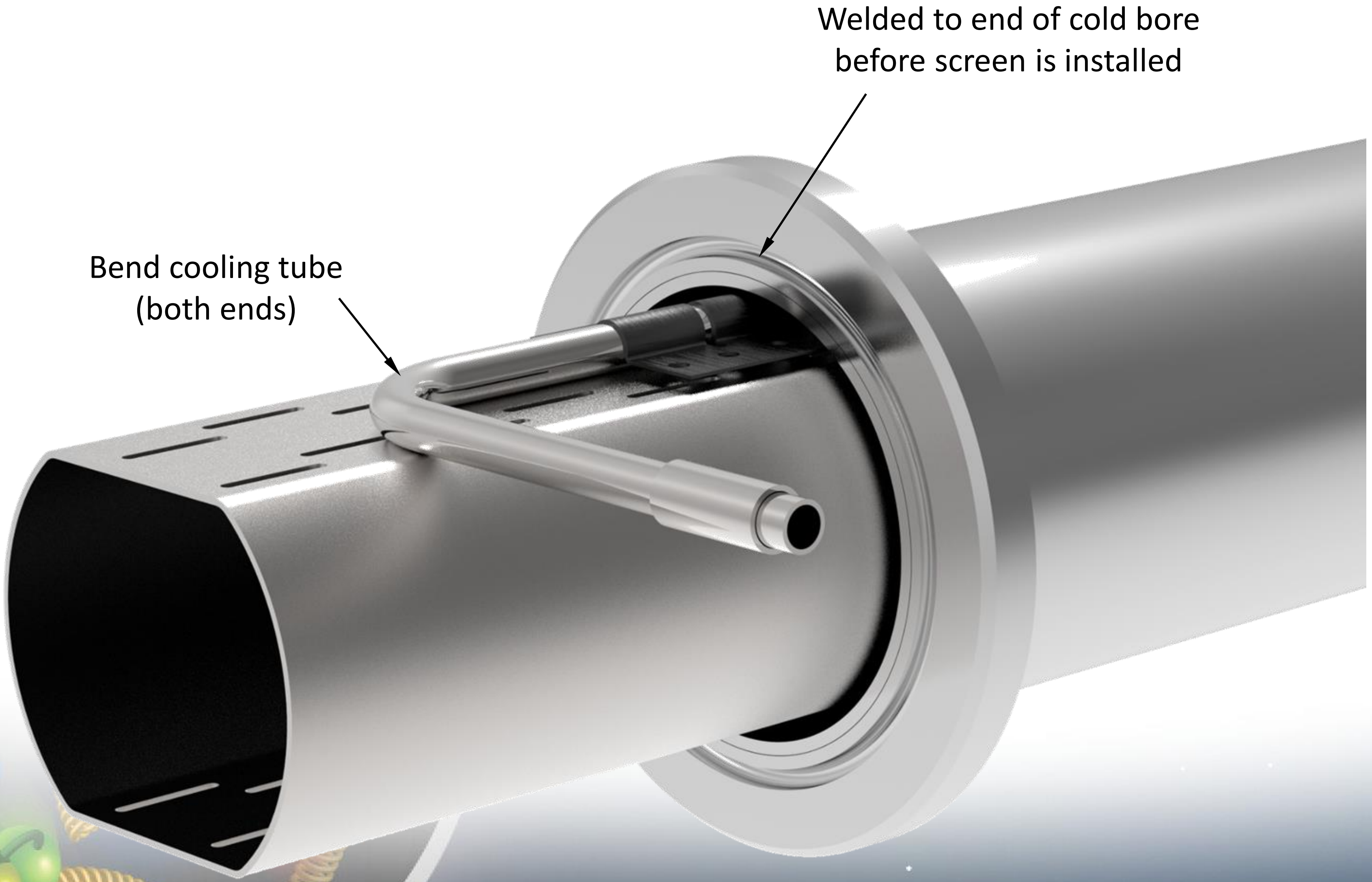


HSR Beam Screen

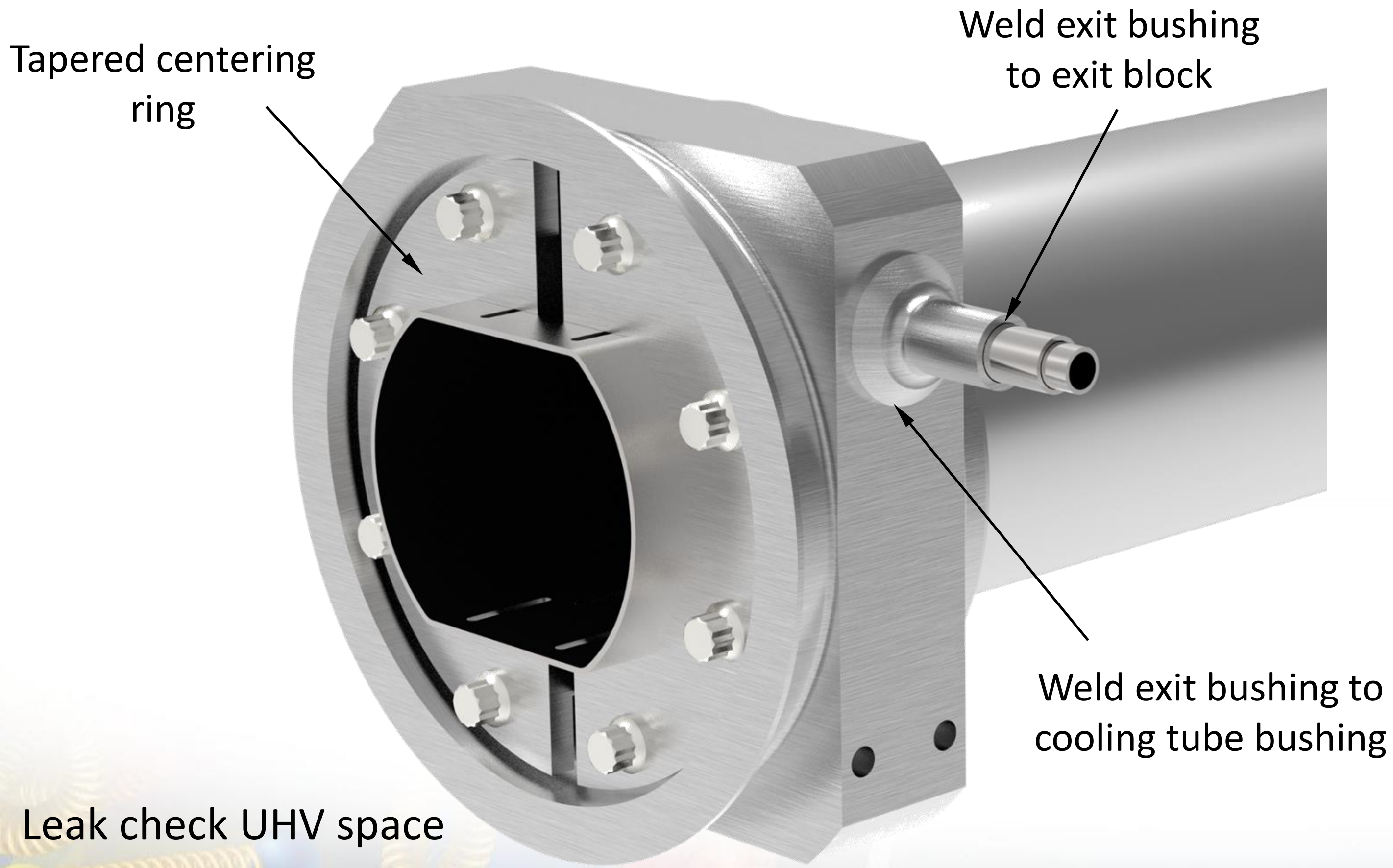


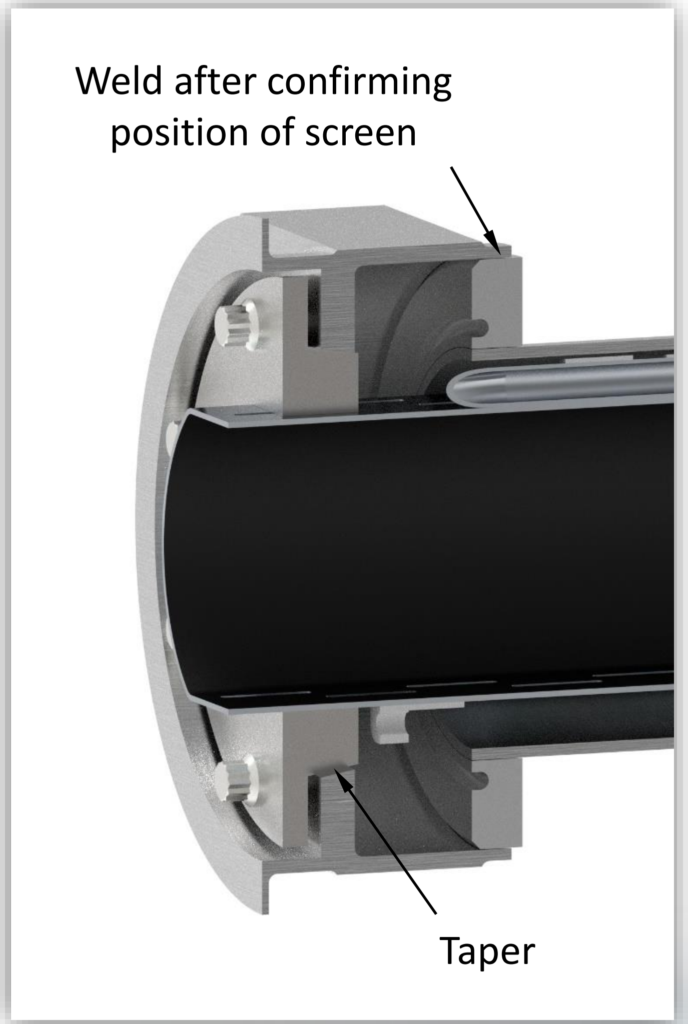


Cooling Pipe Exit Block

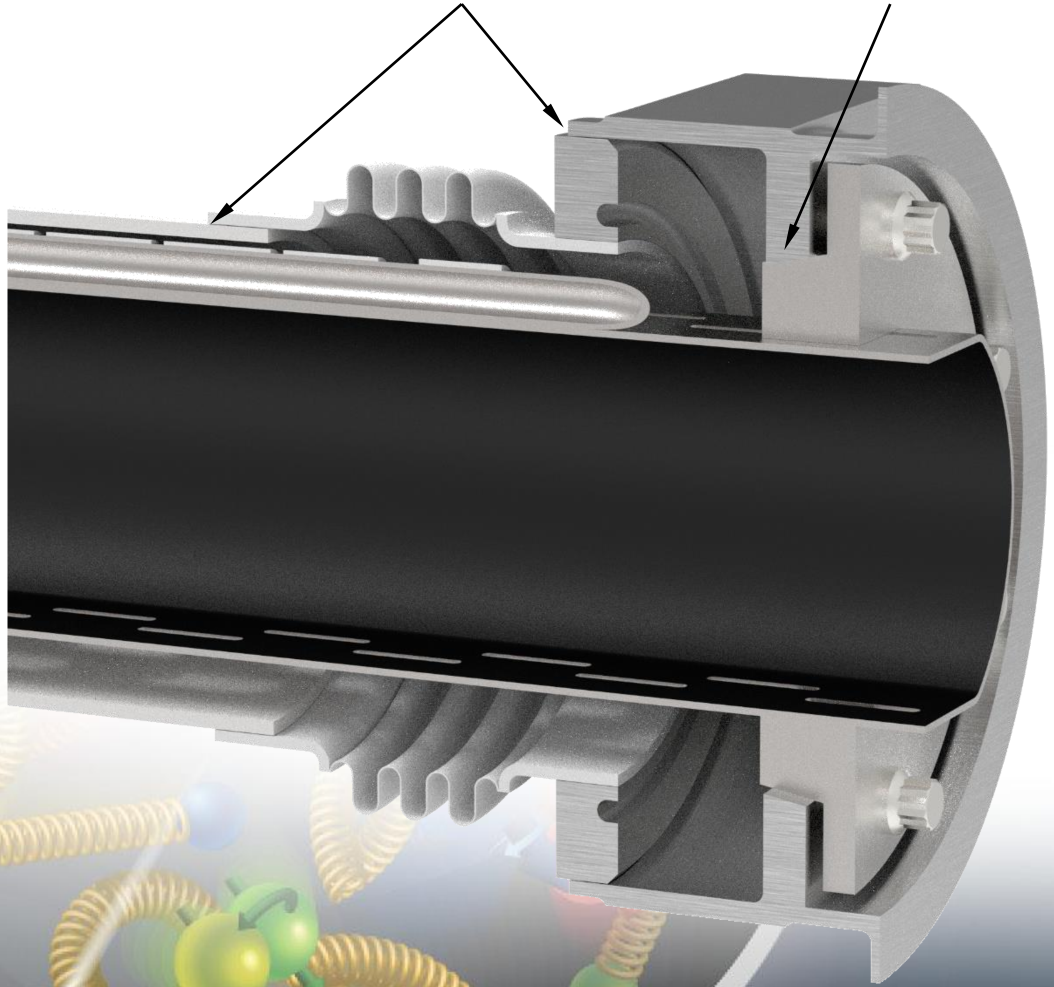


Cooling Pipe Exit Block



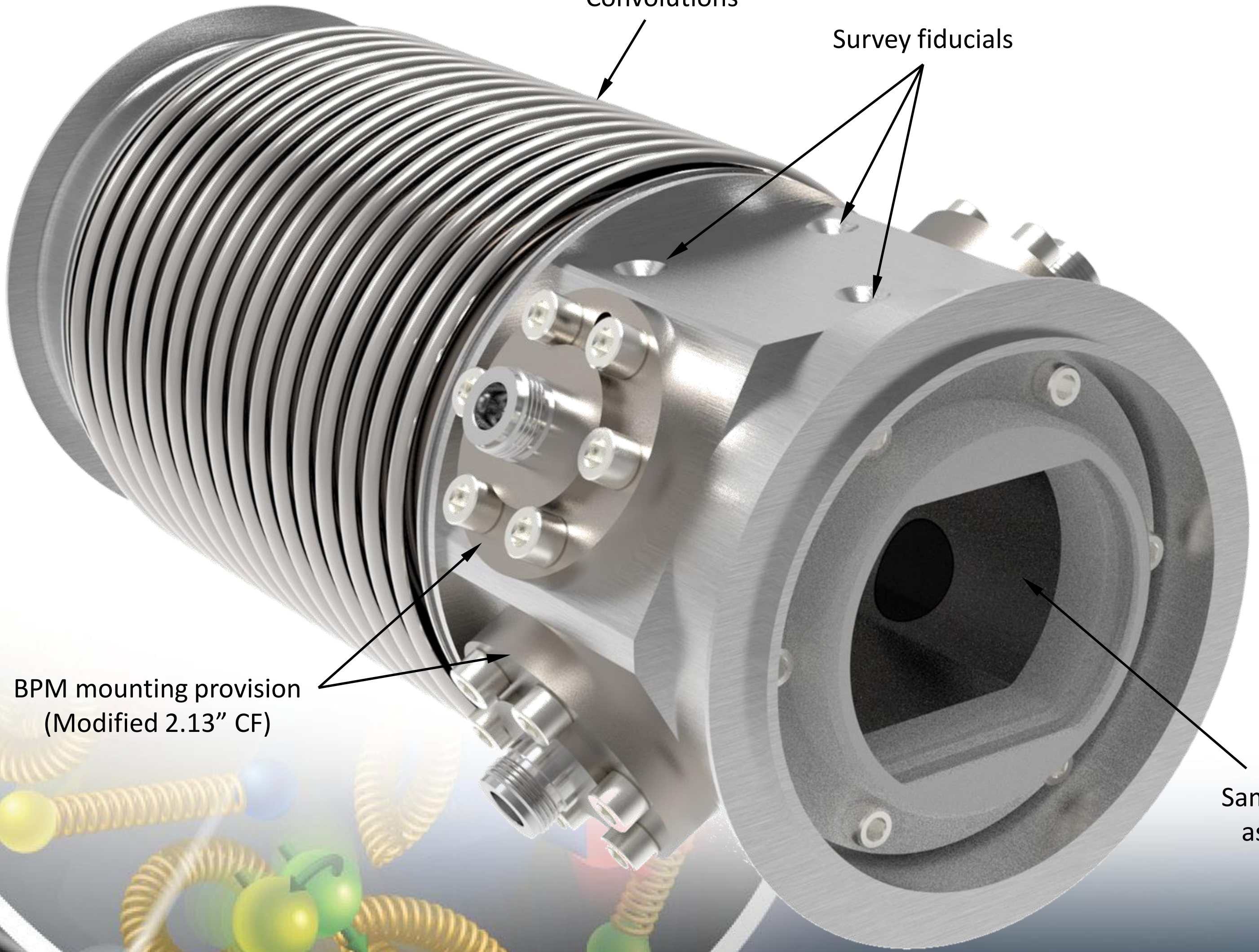


Cooling Pipe Exit Block - Movable



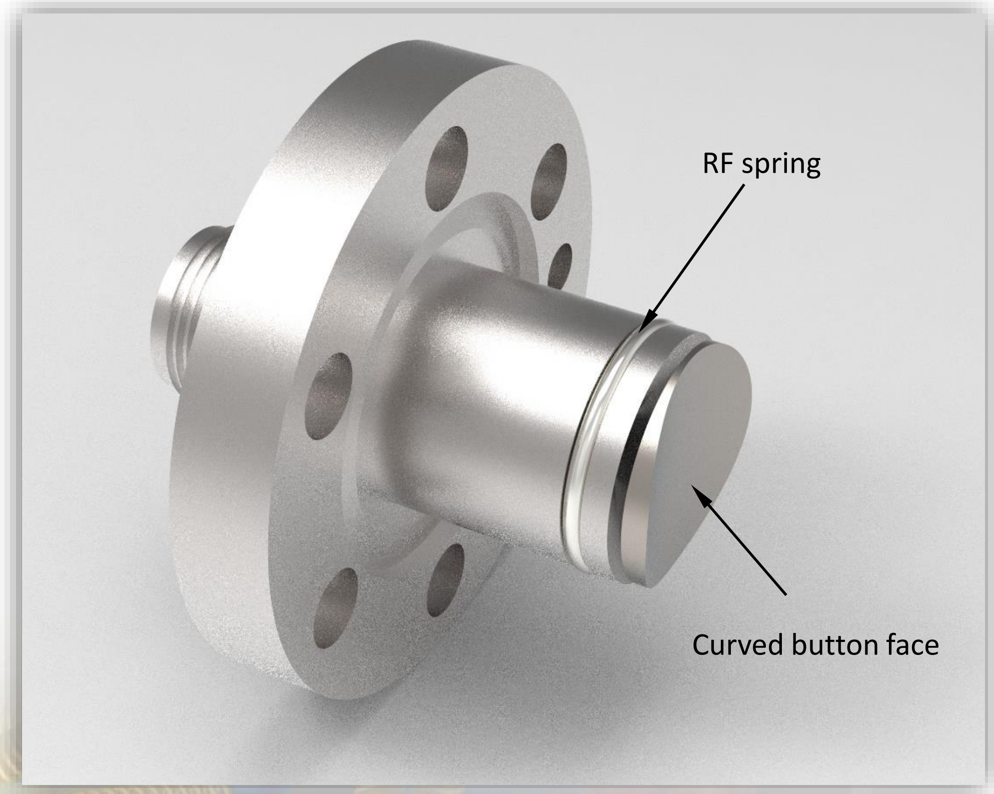
Bellow separates cold bore and beam screen thermal contraction

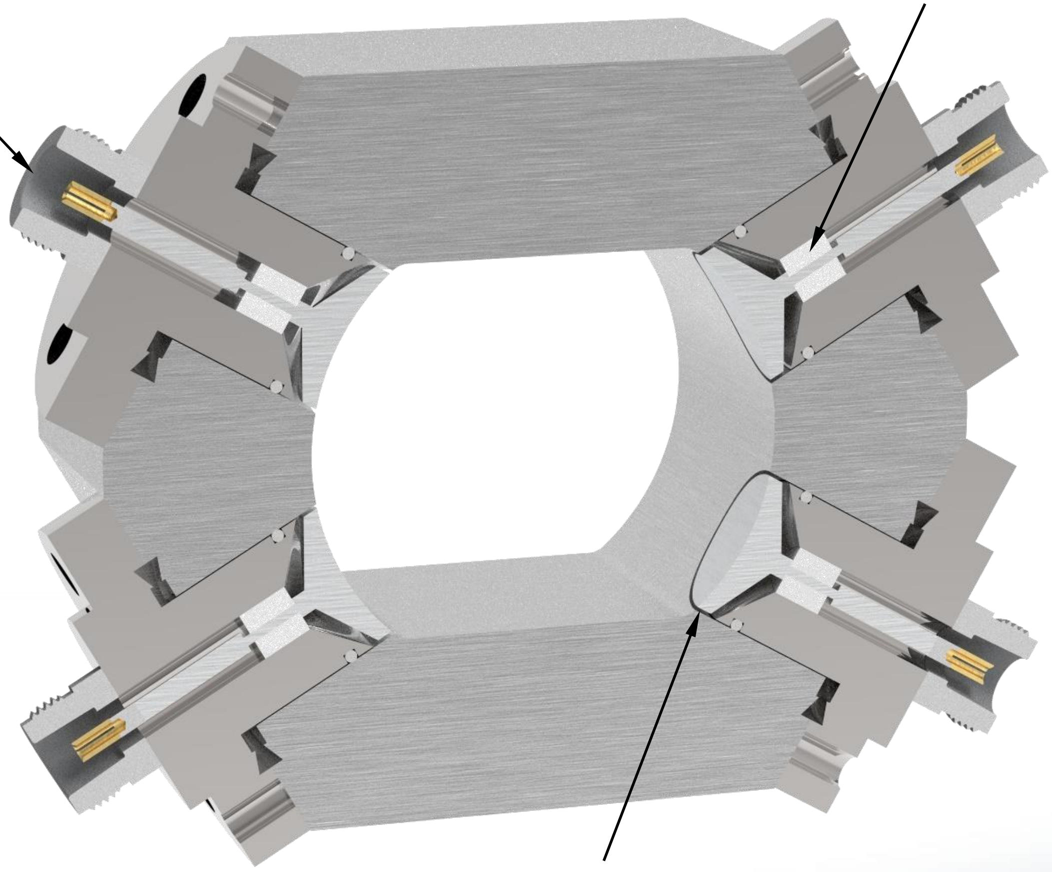
HSR Bellows/BPM Module



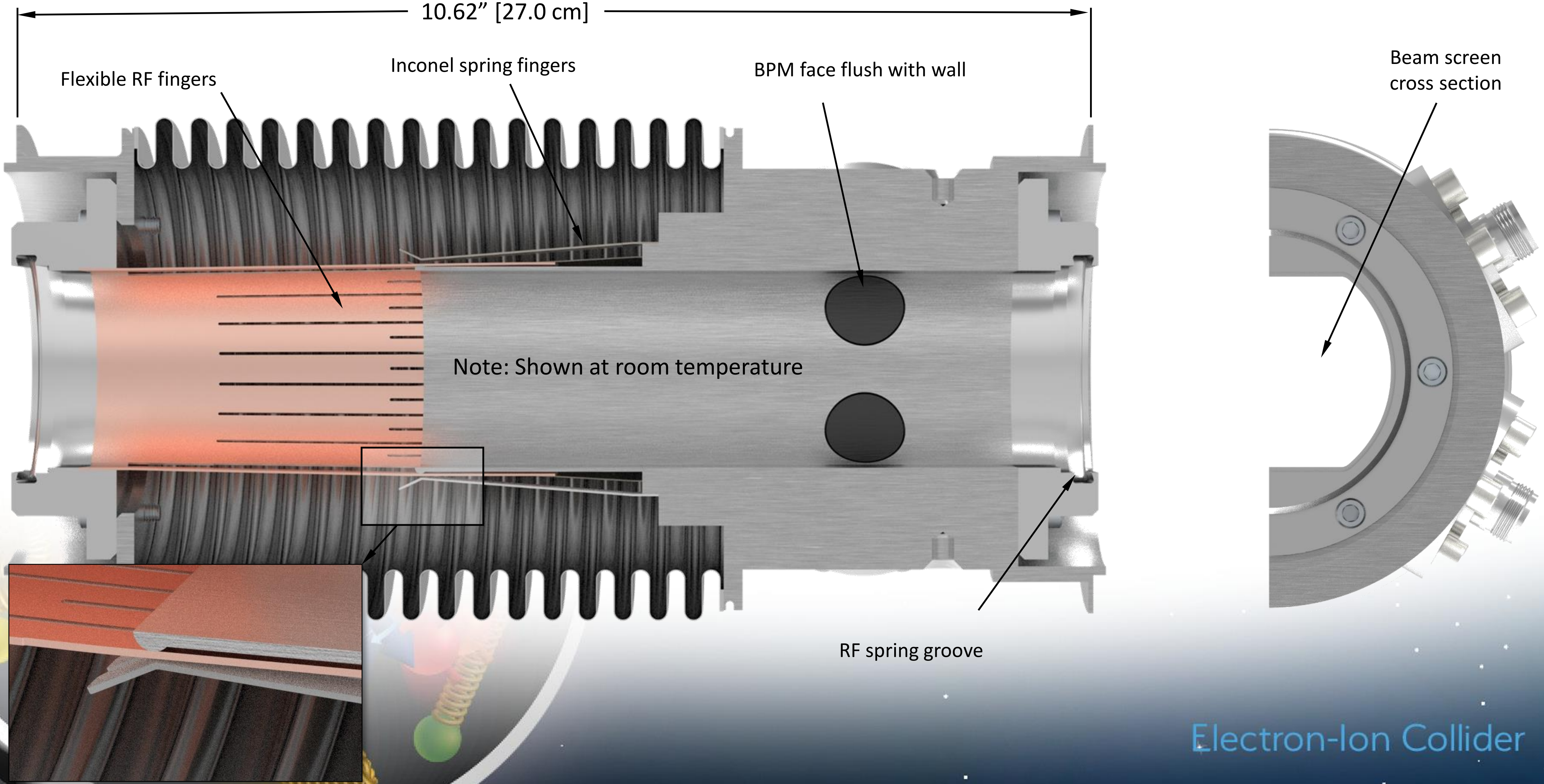
- Fit existing interconnect space
- RF Interface with beam screen
- 30W beam induced heating
- Stroke Req: 50mm
  - Compression (Install): -16mm
  - Extension (cool down): +26mm
  - Interconnect length: +/-4mm
- Radial offset: +/-6mm
- Angular offset: +/-1° [17mrad]

HSR BPM Concept

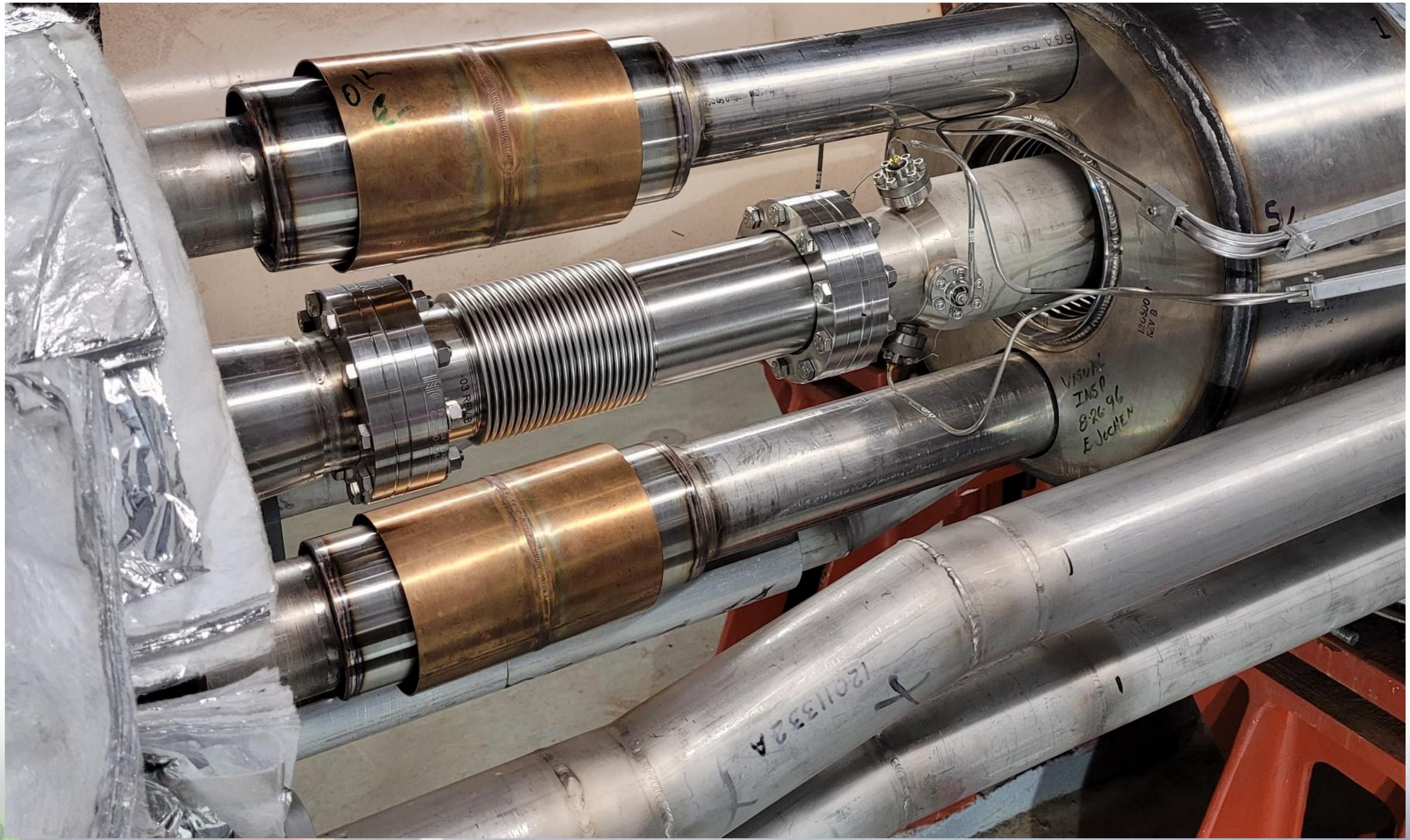




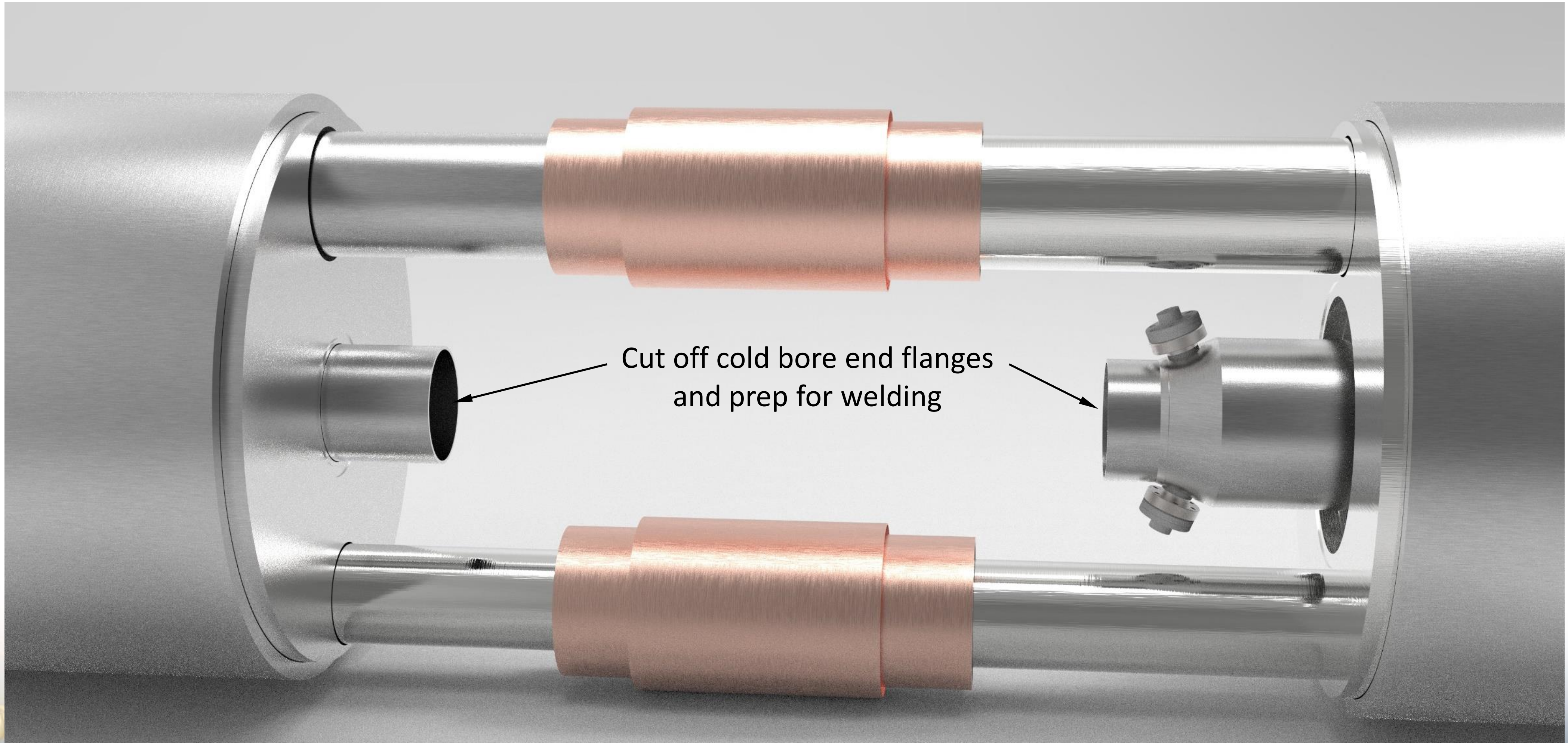
HSR Bellows/BPM Module



Existing RHIC Interconnect

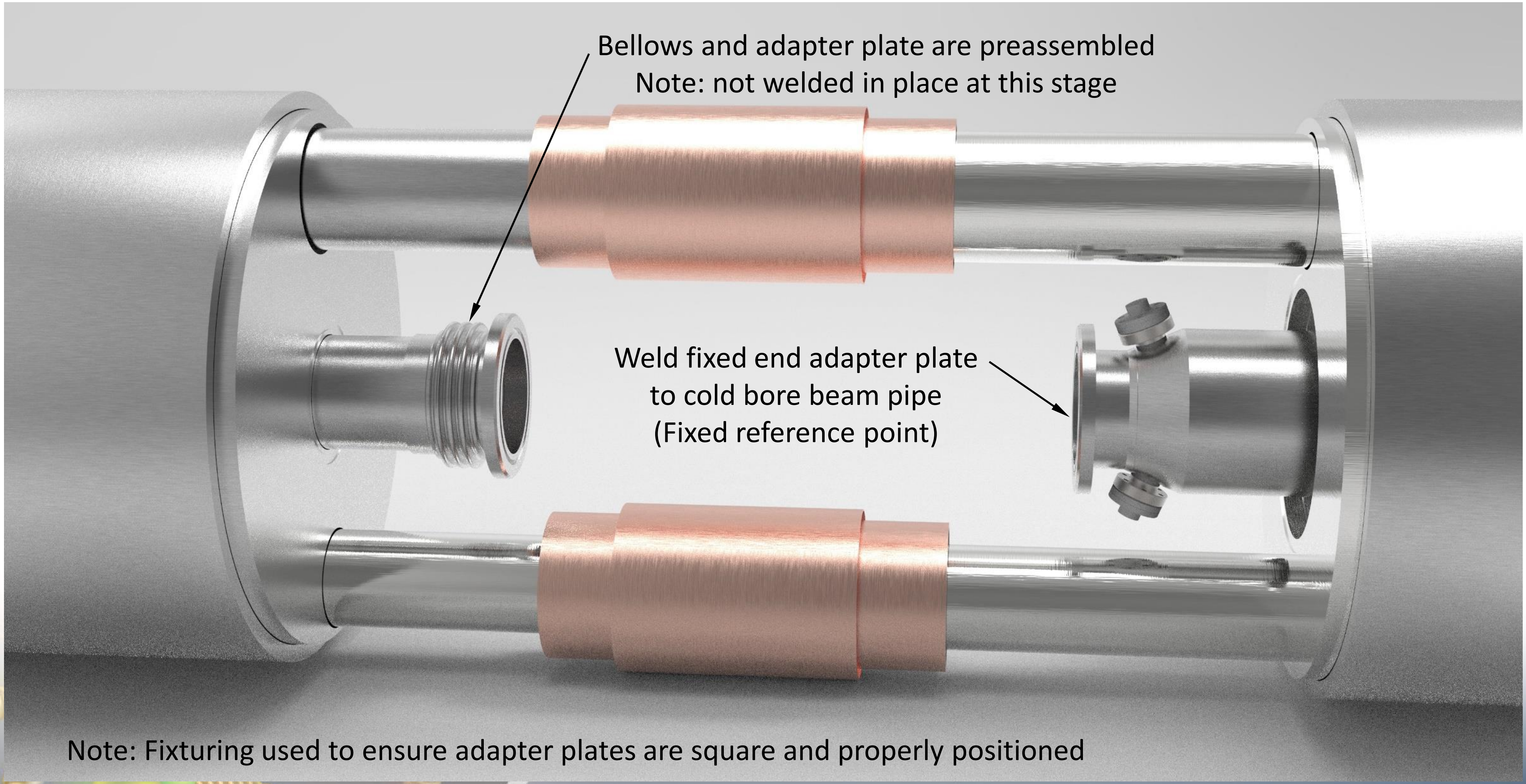


EIC Interconnect

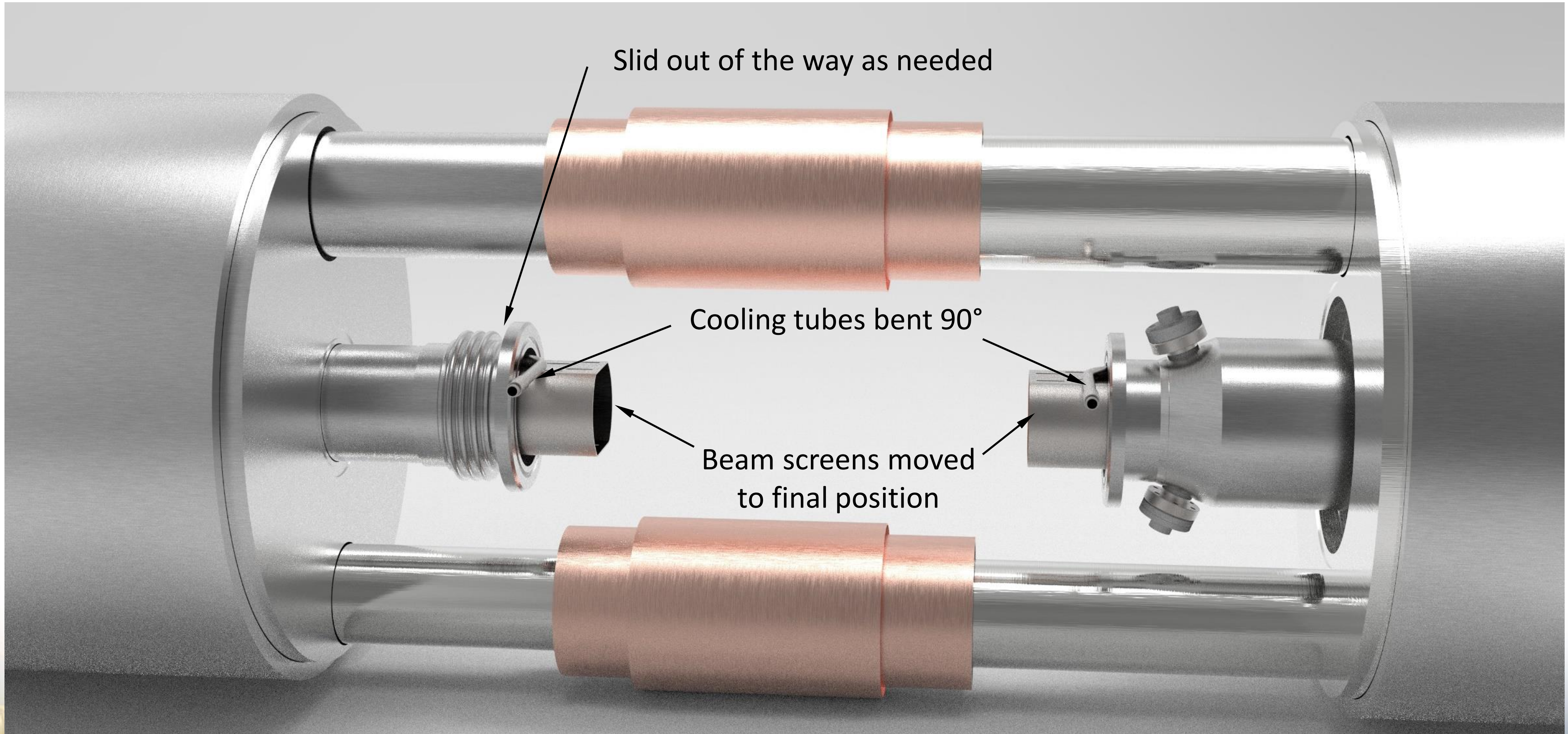


Note: Beam pipes are plugged prior to rework to prevent chips and contamination for entering the UHV space

EIC Interconnect

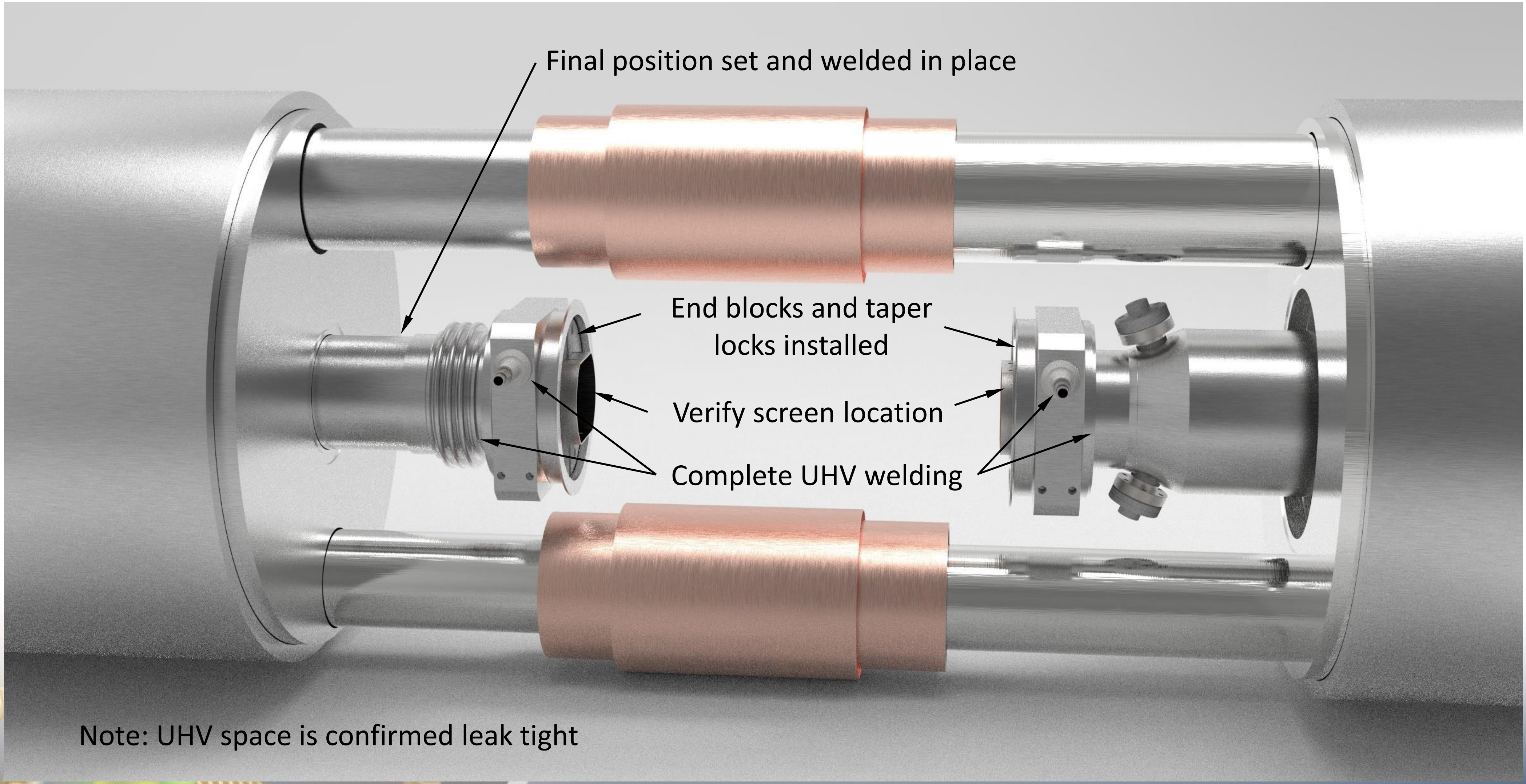


EIC Interconnect

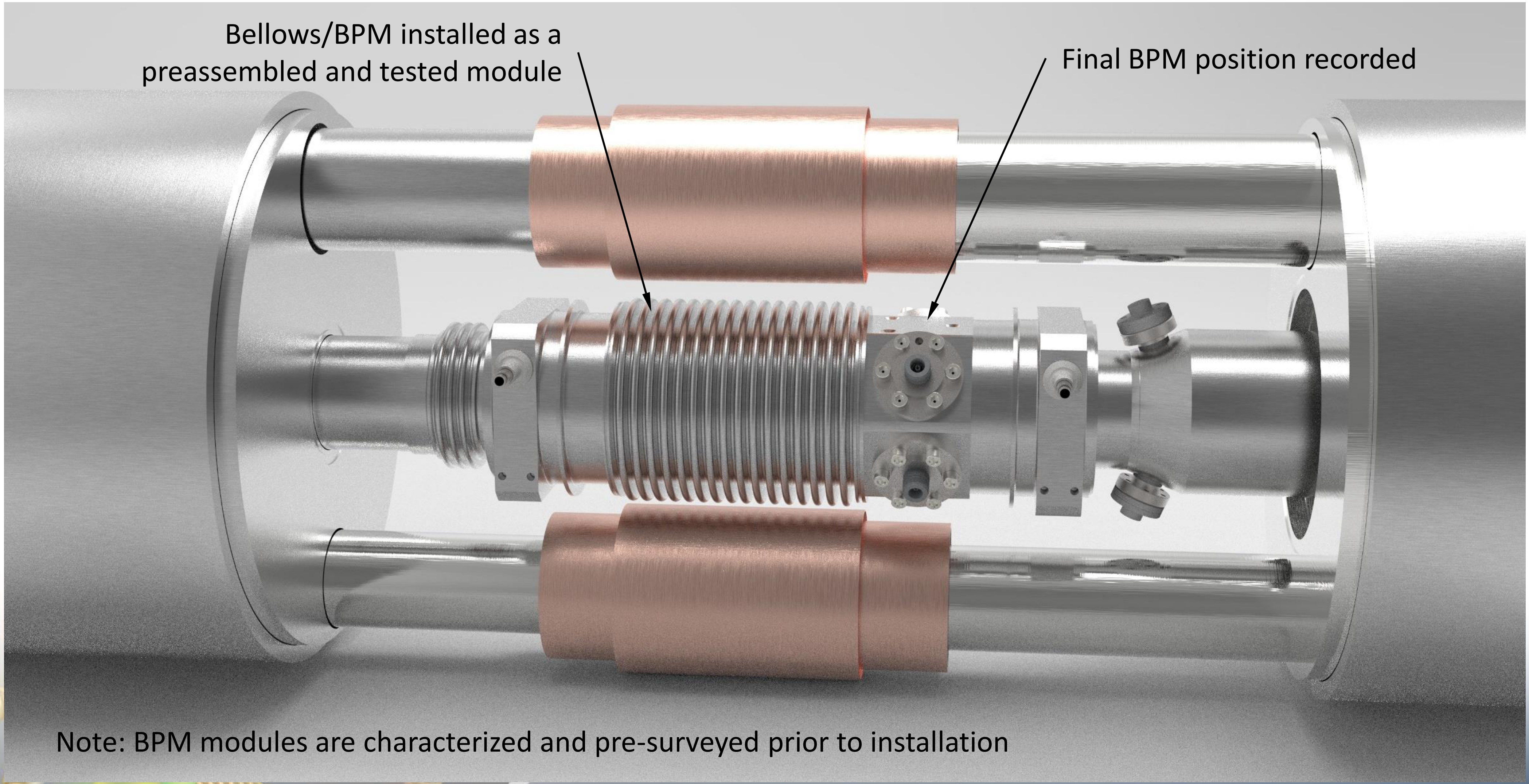


Note: UHV space is cleaned and plugs are removed prior to screen install. Area is treated as 'clean' going forward

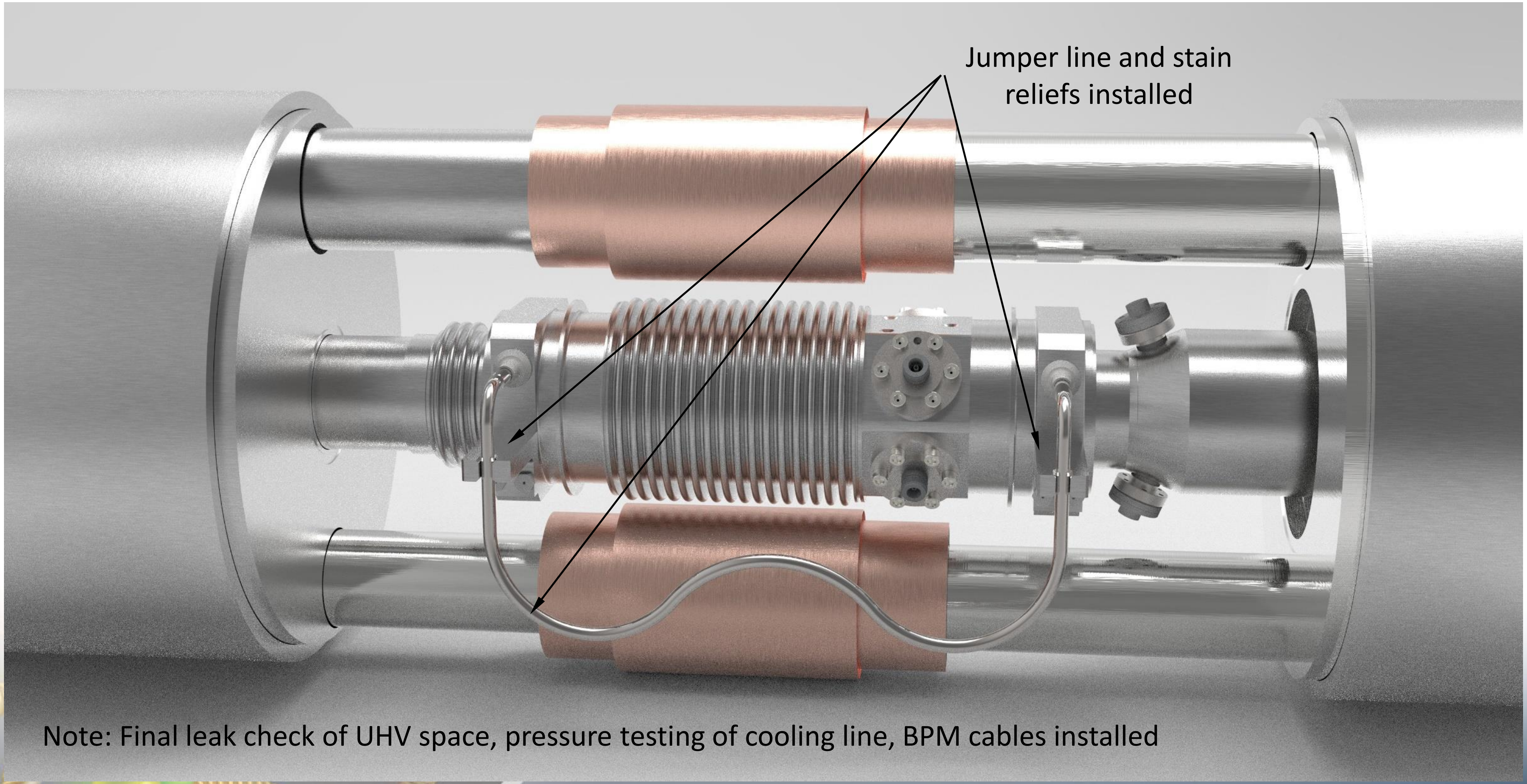
EIC Interconnect



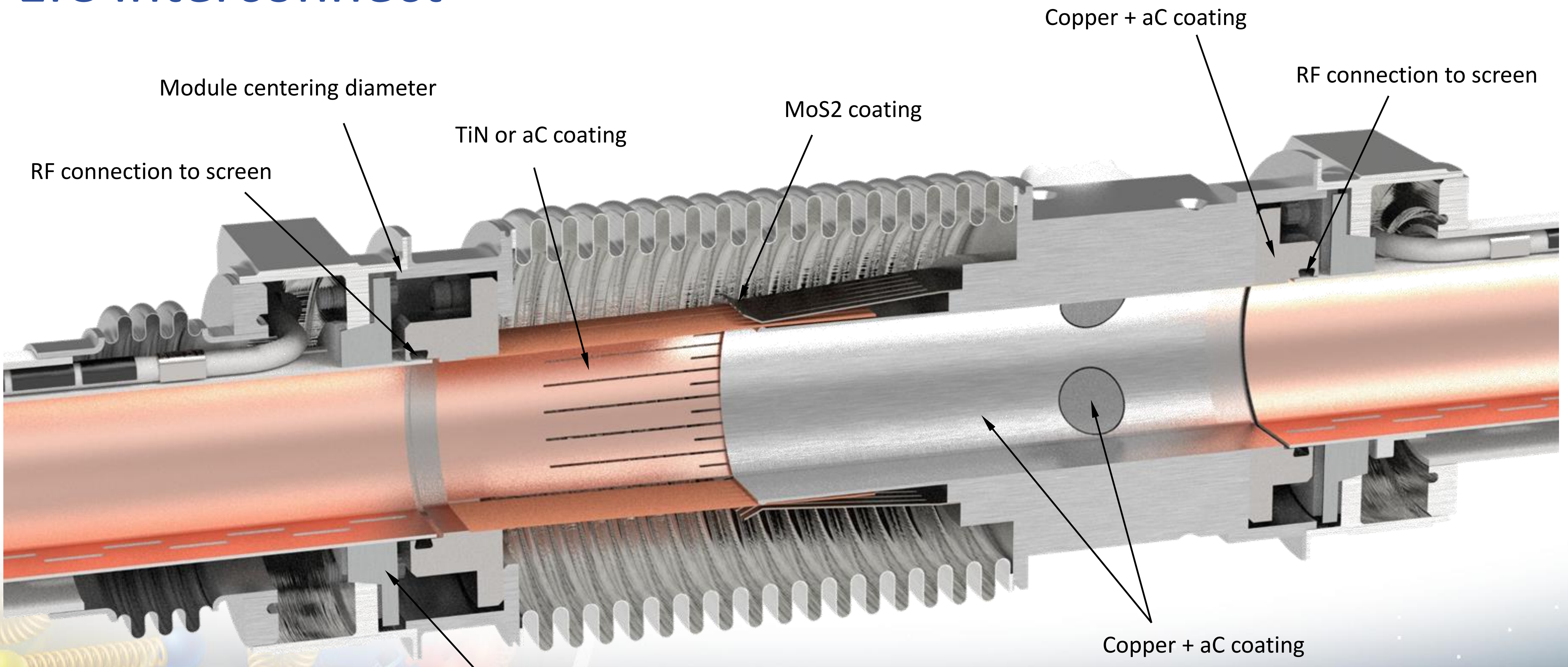
EIC Interconnect



EIC Interconnect



EIC Interconnect



Summary and Next Steps - HSR

- Preliminary design concepts for beam screen and BPM/bellows module are completed
  - Lots of analysis has been done but not shown (FEA, impedance, BPM signals, etc)
  - Details and tolerance requirements need to be established
- Work underway to determine the cold bore beam pipe size
  - Laser tracker measurement of existing magnets
  - ‘Mole’ under development
- R&D is planned to develop welding joint, tooling, procedures, etc
- aC coating development proceeding in parallel
  - Horizontal coating proof of principle
- Plan to build prototype BPM/bellows module
  - Similar features to ESR and RCS bellows

Thank you for your attention

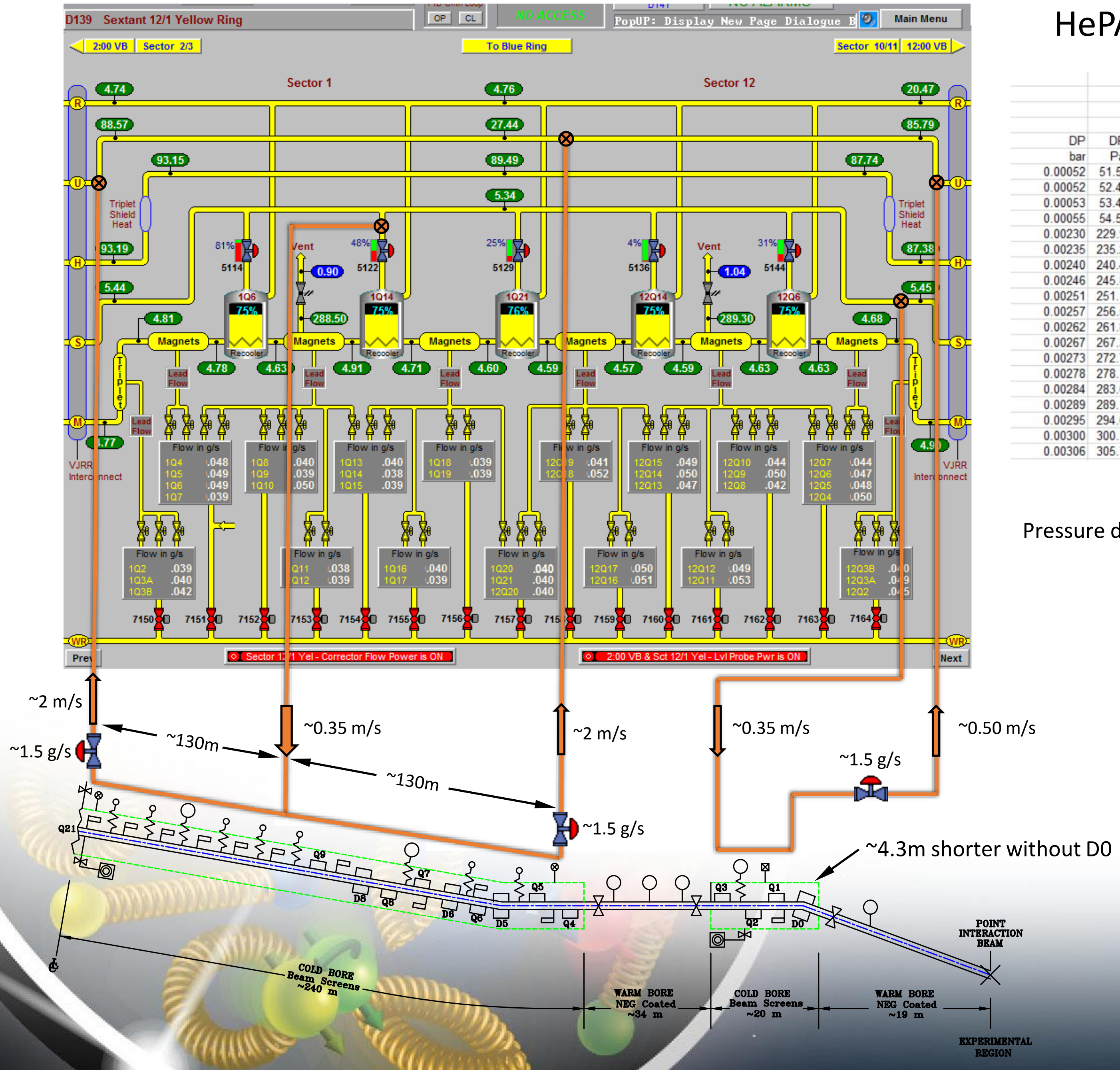
And thank you to the team

J. Bellon
A. Blednykh
P. Braunius
D. Gassner
B. Gallagher
D. Holmes

F. Micolon
M. Sangroula
P. Thieberger
J. Tuozzolo
S. Verdu Andres
D. Weiss

C-AD Vacuum Group
C-AD Survey Group
Central Shops
And many more

Backup Slides



HePAK calculations (R. Than)

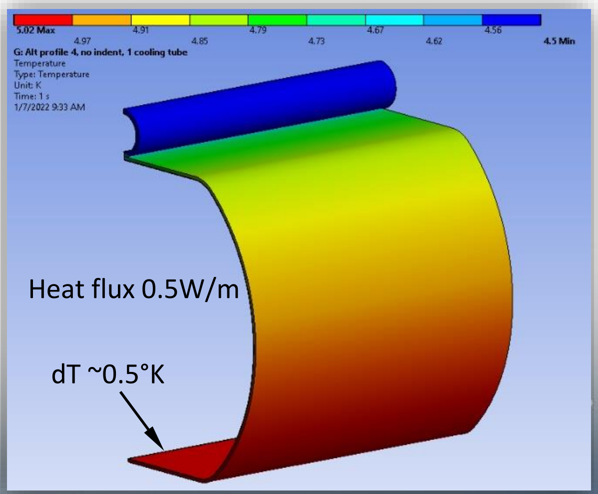
Heat input

						OD	0.3125	inch							
						Wall	0.028	inch							
						0.65151	0.2565	inch	1.5						
		13.27463						0.018			65.00	W			
DP	DP	DP	DPvalve	Cv	T	P	Dia	Flow	SR	H	dQ	dH	Q/L	dL	Length
bar	Pa	mbar	mbar		K	bar	m	kg/s	m	J/kg	W	J/kg	W/m	m	m
0.00052	51.513	0.515	3.01E-11	0	4.6	3.5	0.006515	0.0015	4.50E-06	12379.14	1.00	6.67E+02	5.00E-01	2	2
0.00052	52.432	0.524			4.74	3.499	0.006515	0.0015	4.50E-06	13045.81	1.00	6.67E+02	5.00E-01	2	4
0.00053	53.427	0.534			4.87	3.499	0.006515	0.0015	4.50E-06	13712.47	1.00	6.67E+02	5.00E-01	2	6
0.00055	54.505	0.545			4.98	3.498	0.006515	0.0015	4.50E-06	14379.14	1.00	6.67E+02	5.00E-01	2	8
0.00230	229.928	2.299			7.64	3.440	0.006515	0.0015	4.50E-06	45712.47	1.00	6.67E+02	5.00E-01	2	102
0.00235	235.200	2.352			7.73	3.438	0.006515	0.0015	4.50E-06	46379.14	1.00	6.67E+02	5.00E-01	2	104
0.00240	240.496	2.405			7.82	3.436	0.006515	0.0015	4.50E-06	47045.81	1.00	6.67E+02	5.00E-01	2	106
0.00246	245.813	2.458			7.92	3.433	0.006515	0.0015	4.50E-06	47712.47	1.00	6.67E+02	5.00E-01	2	108
0.00251	251.153	2.512			8.01	3.431	0.006515	0.0015	4.50E-06	48379.14	1.00	6.67E+02	5.00E-01	2	110
0.00257	256.514	2.565			8.10	3.428	0.006515	0.0015	4.50E-06	49045.81	1.00	6.67E+02	5.00E-01	2	112
0.00262	261.897	2.619			8.20	3.426	0.006515	0.0015	4.50E-06	49712.47	1.00	6.67E+02	5.00E-01	2	114
0.00267	267.300	2.673			8.29	3.423	0.006515	0.0015	4.50E-06	50379.14	1.00	6.67E+02	5.00E-01	2	116
0.00273	272.725	2.727			8.39	3.421	0.006515	0.0015	4.50E-06	51045.81	1.00	6.67E+02	5.00E-01	2	118
0.00278	278.171	2.782			8.49	3.418	0.006515	0.0015	4.50E-06	51712.47	1.00	6.67E+02	5.00E-01	2	120
0.00284	283.637	2.836			8.59	3.415	0.006515	0.0015	4.50E-06	52379.14	1.00	6.67E+02	5.00E-01	2	122
0.00289	289.124	2.891			8.69	3.412	0.006515	0.0015	4.50E-06	53045.81	1.00	6.67E+02	5.00E-01	2	124
0.00295	294.633	2.946			8.79	3.409	0.006515	0.0015	4.50E-06	53712.47	1.00	6.67E+02	5.00E-01	2	126
0.00300	300.162	3.002			8.89	3.406	0.006515	0.0015	4.50E-06	54379.14	1.00	6.67E+02	5.00E-01	2	128
0.00306	305.712	3.057	1499.444	0.04	8.99	3.403	0.006515	0.0015	4.50E-06	55045.81	1.00	6.67E+02	5.00E-01	2	130

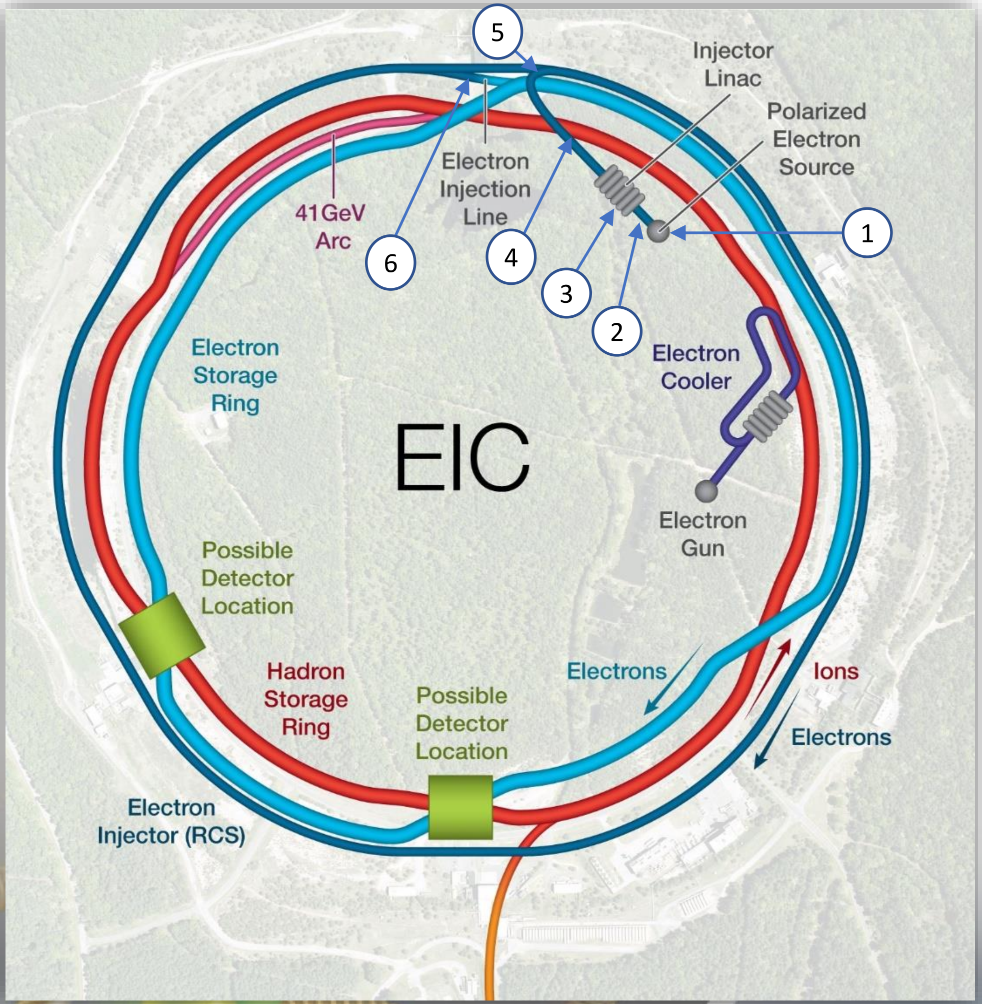
Pressure drop [mbar]

dT [°K]

Mass flow [kg/s]



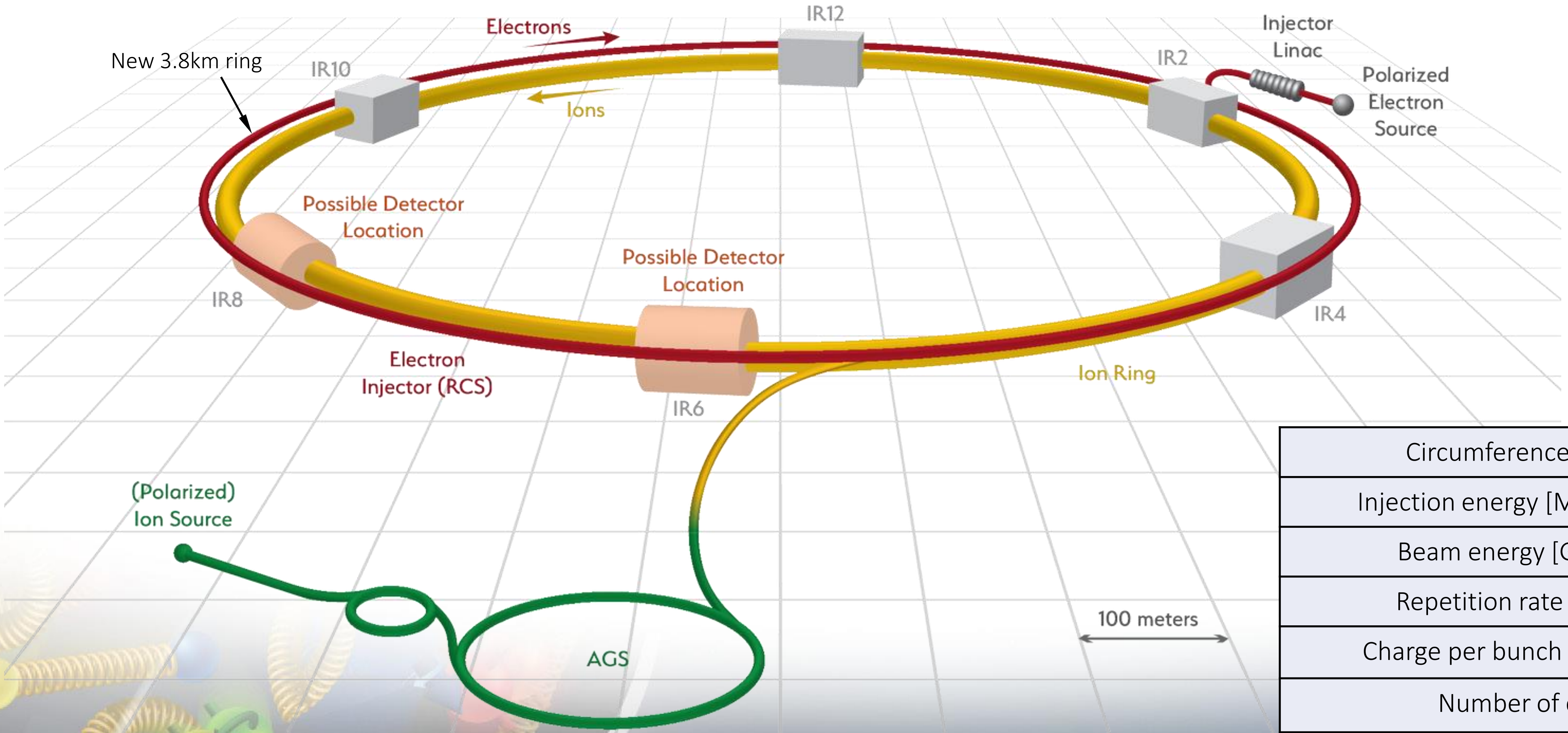
Electron Injector Chain



1	Polarized source
2	Low energy beam transport (0.4MeV)
3	400 MeV LINAC
4	Med energy beam transport (400 MeV)
5	Injection to RCS
6	Injection to ESR (up to 18 GeV)

- Window between laser and beam vacuum
- Particulate free cleaning and assembly
- XHV required for source
- Cathode exchange system
- ‘Turn-key’ LINAC will use EIC specified vacuum equipment and controllers
- Various diagnostics to be incorporated

Rapid Cycling Synchrotron Ring



Circumference [m]	3841.35
Injection energy [MeV]	400
Beam energy [GeV]	Up to 18
Repetition rate [Hz]	1
Charge per bunch [nC]	Up to 28
Number of cells	192

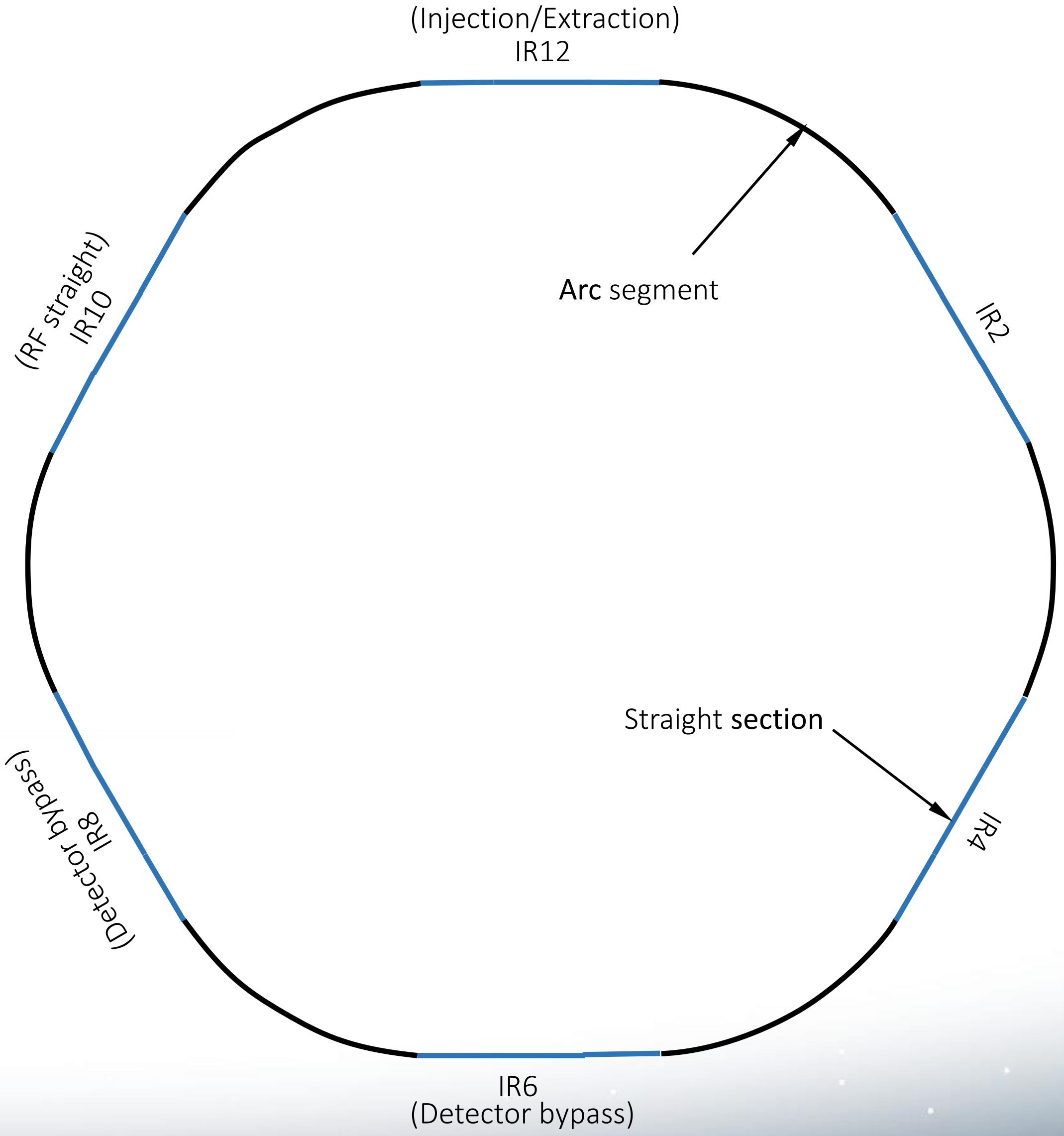
Electron-Ion Collider

RCS Vacuum Chambers

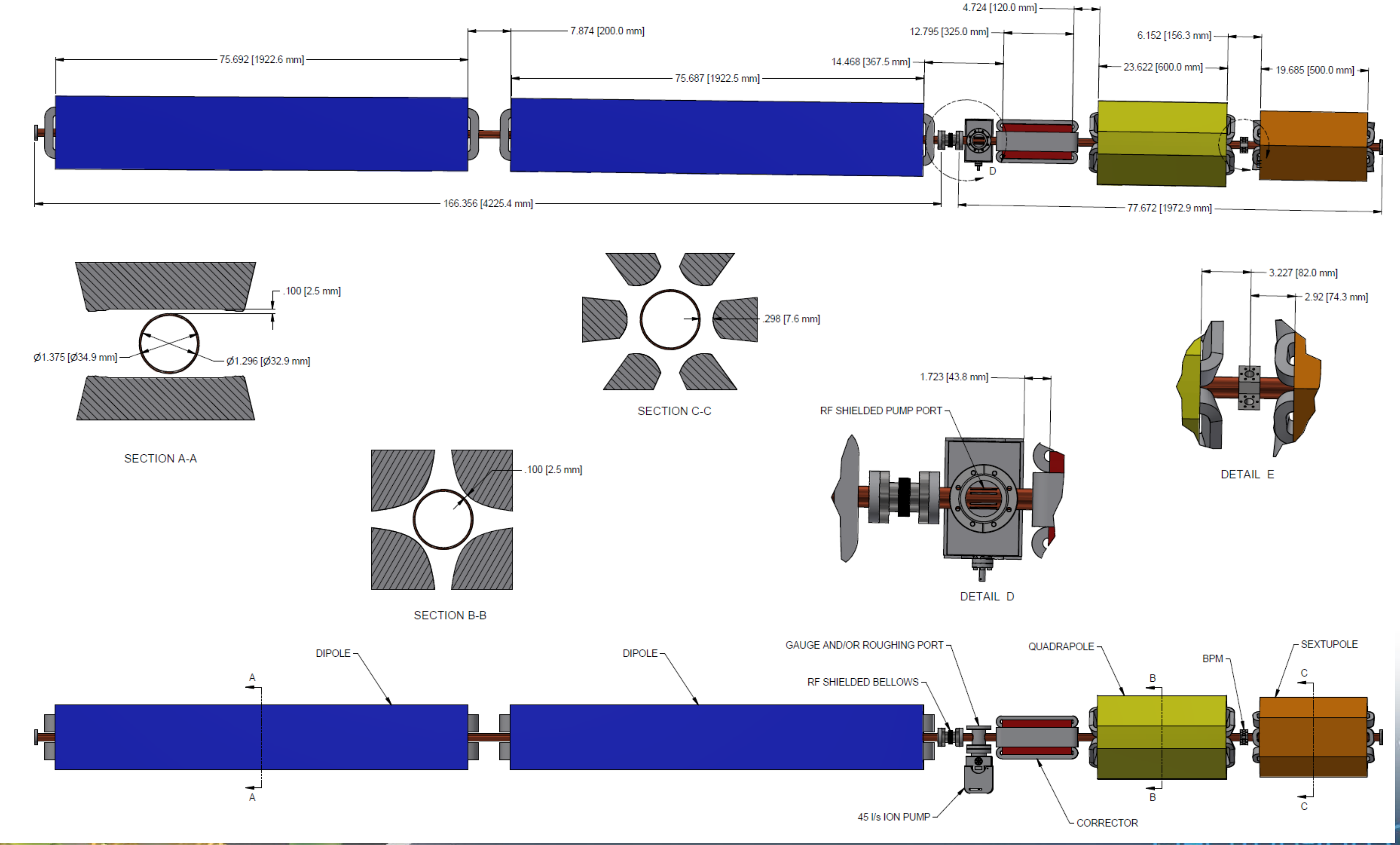
- Multipole (MP) and dipole (DP)
  - 34.9mm x 1mm wall copper (C12200)
  - Commercial 1.375 DWS tubing
  - BPMs mounted on MP chambers
- One RF bellows per half cell
- Common cross in straights

Arc component	Length [m]	Qty
MP chamber	2.0	384
DP chamber	4.2	384
RF bellows	0.082	384

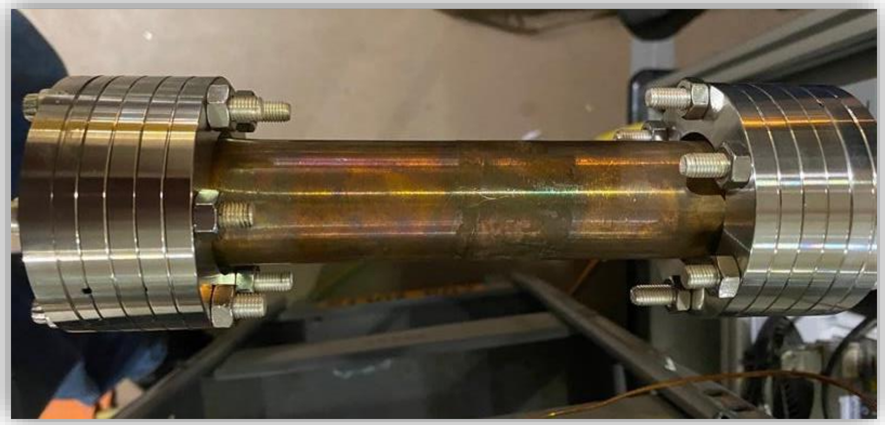
Straight component	Length [m]	Qty
Chamber	3.8	300
Pump tee	0.80	300
RF bellows	0.082	300

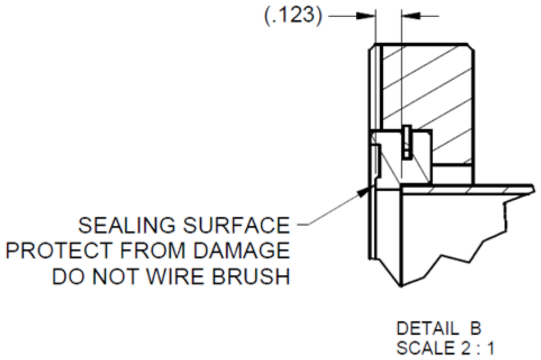


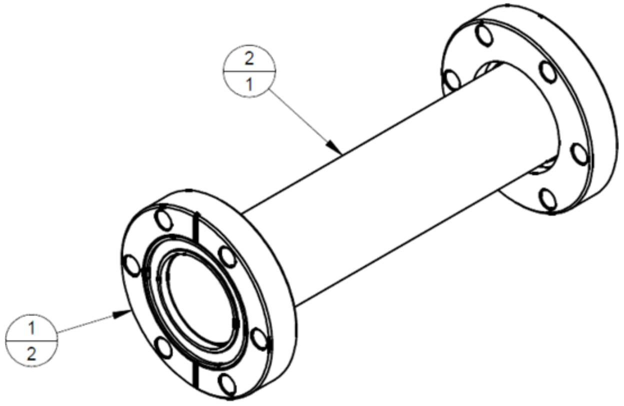
RCS Half Cell Layout

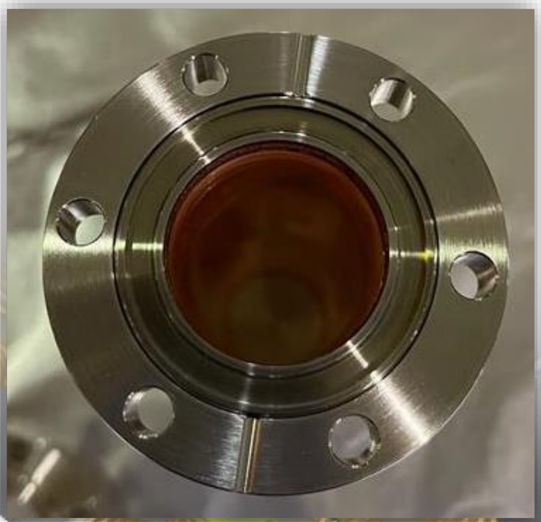


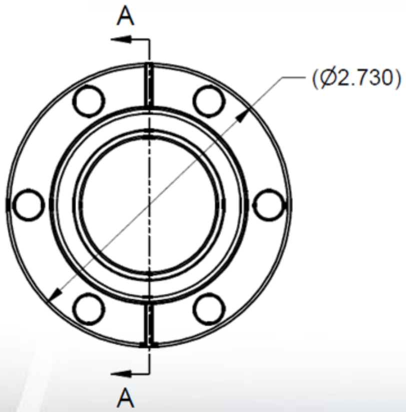
CF Flange Test

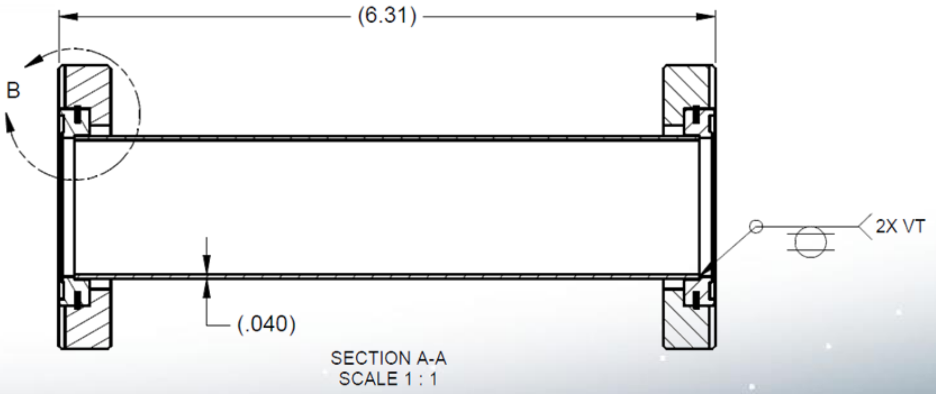




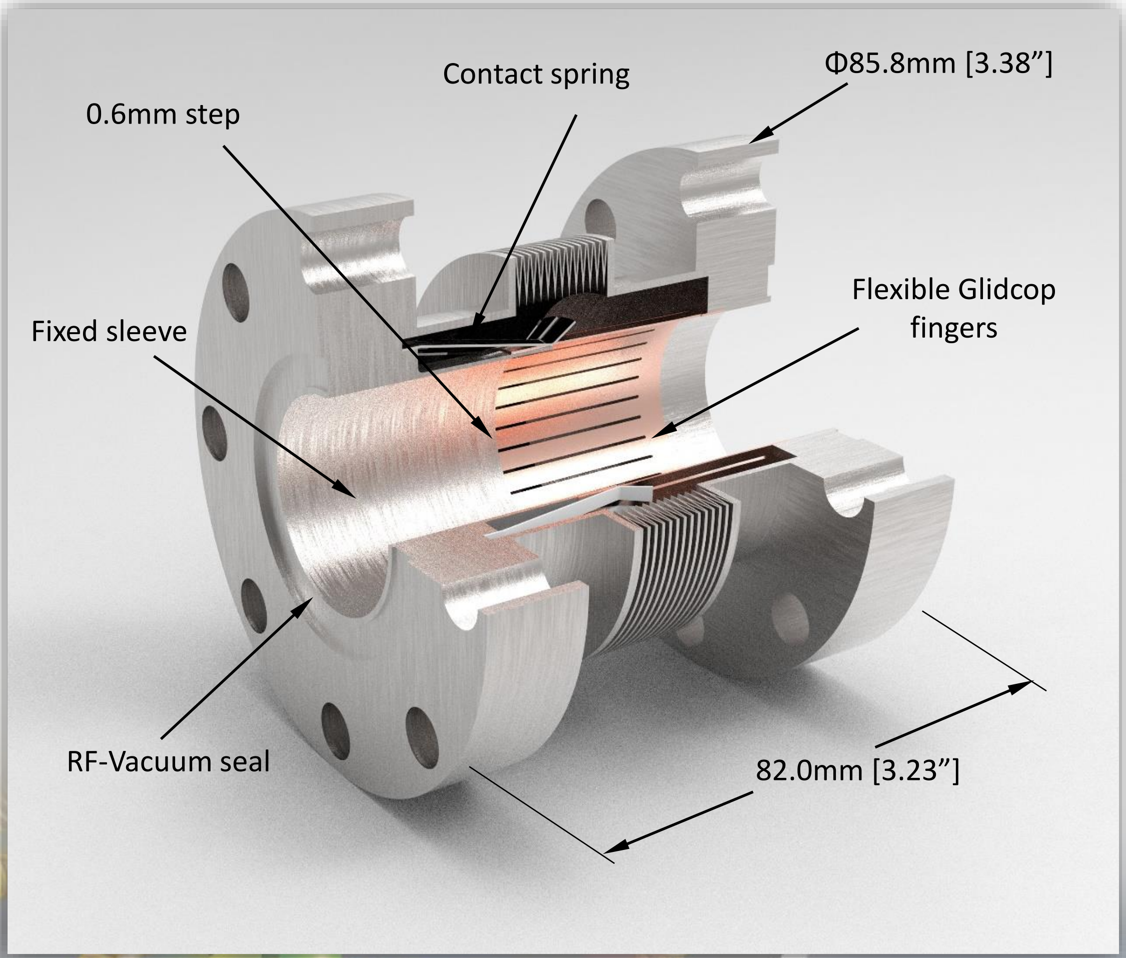






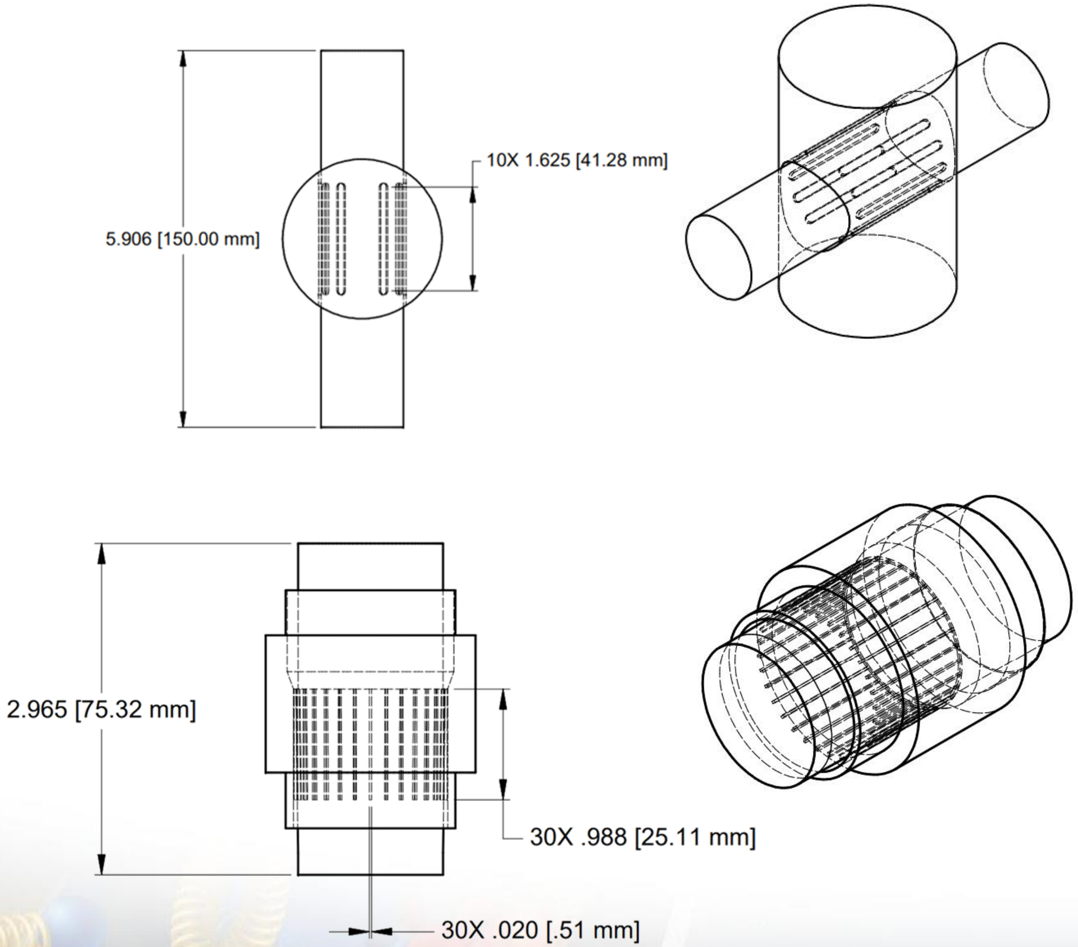


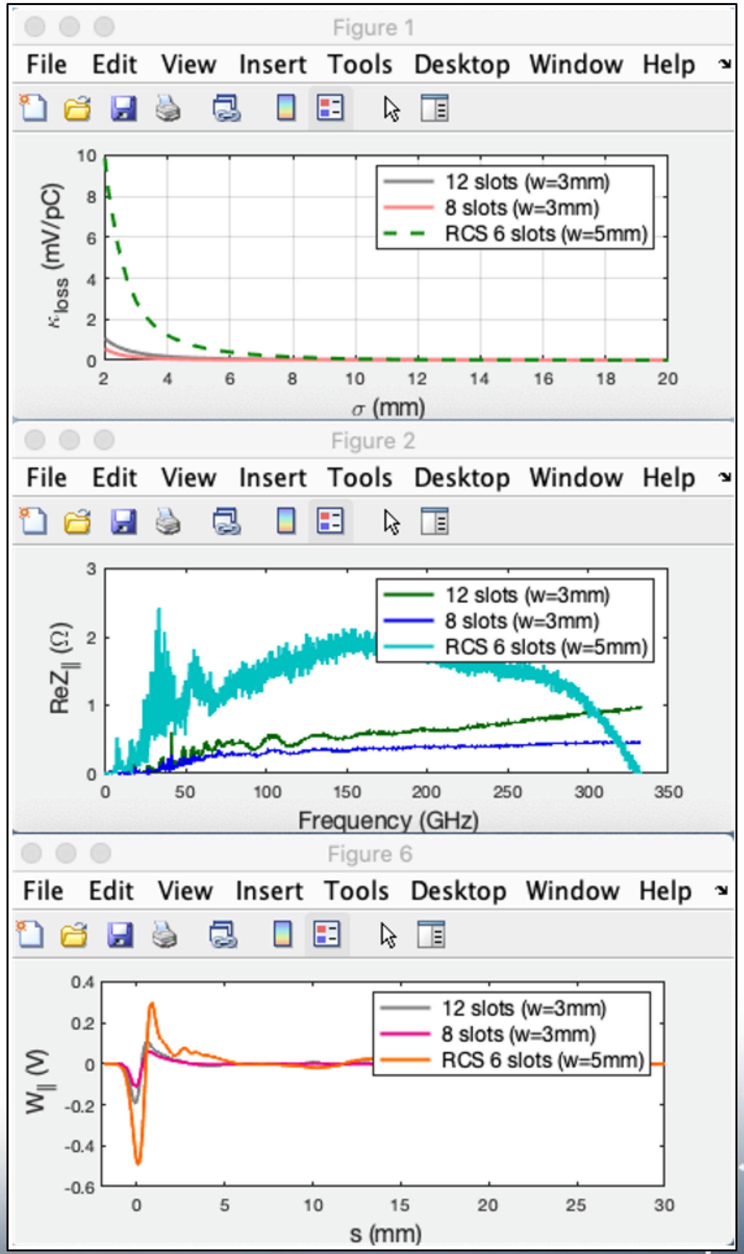
RCS RF Shielded Bellows



- Common design strategy (RCS, ESR, HSR)
- Compact footprint
- Combination RF-Vacuum seal
- Stroke Req: +/-5mm
- Radial offset: +/-2mm
- Angular offset: +/-0.5° [8.7mrad]

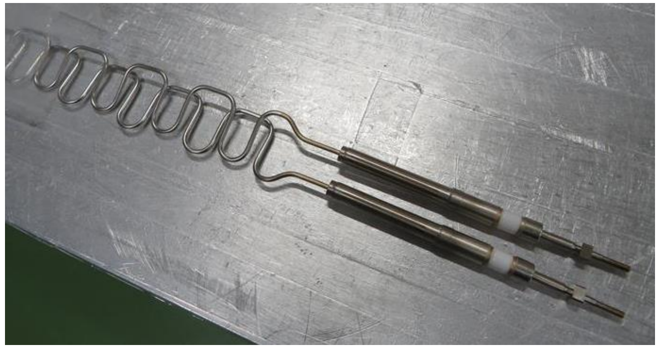
Impedance Simulations - RCS

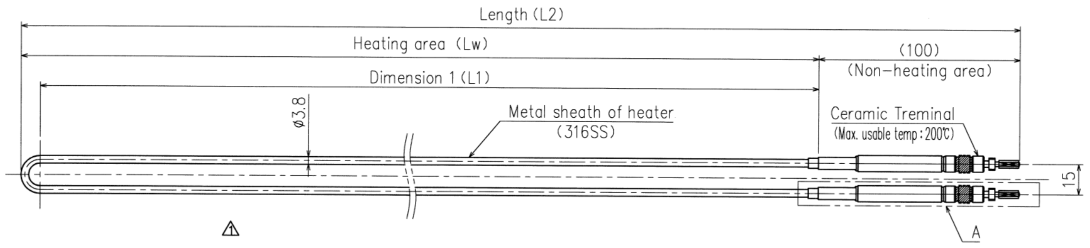


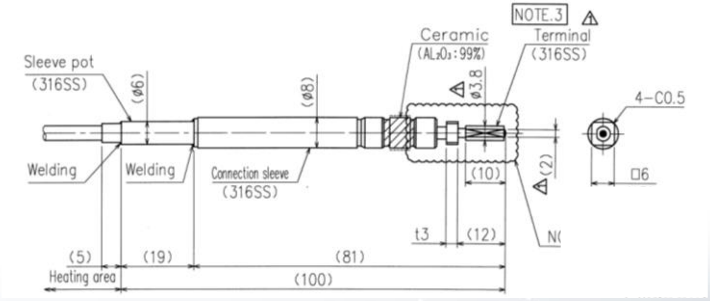


NEG Pump Concept

Resistive heater approach based on SuperKEKB







Summary and Next Steps - RCS

- Work on preliminary design models will resume soon
  - Prototype chamber(s) and bellows
- Conceptual design for BPMs and mounting to chamber
- Evaluate thermal issues
  - Eddy currents
  - Resistive wall heating
  - Electrical isolation between chamber and magnets
- Chamber support concept
- Interfaces between groups (RF, transfer lines, diagnostics, etc.)
- Cost and schedule updates