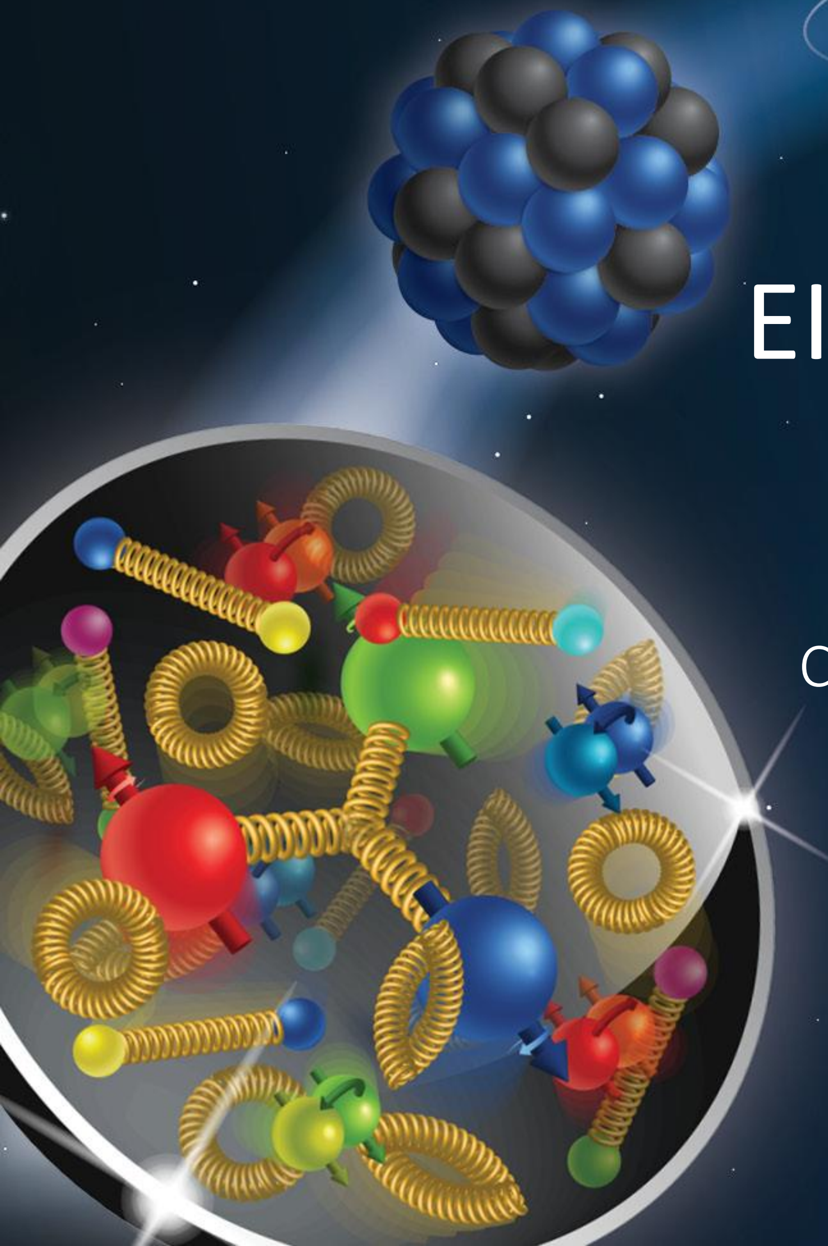


EIC ESR Vacuum System Overview

Charles Hetzel, EIC Vacuum Group Leader

EIC Accelerator Partnership Workshop

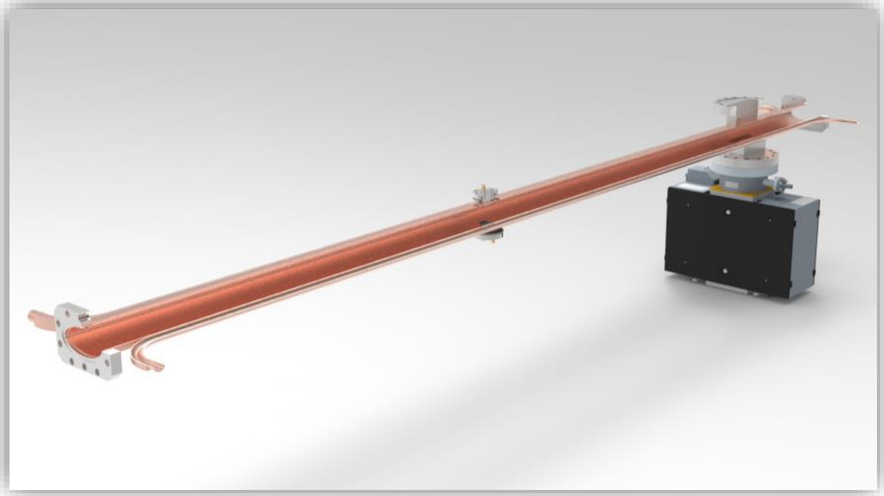
October 26-29, 2021

Electron-Ion Collider

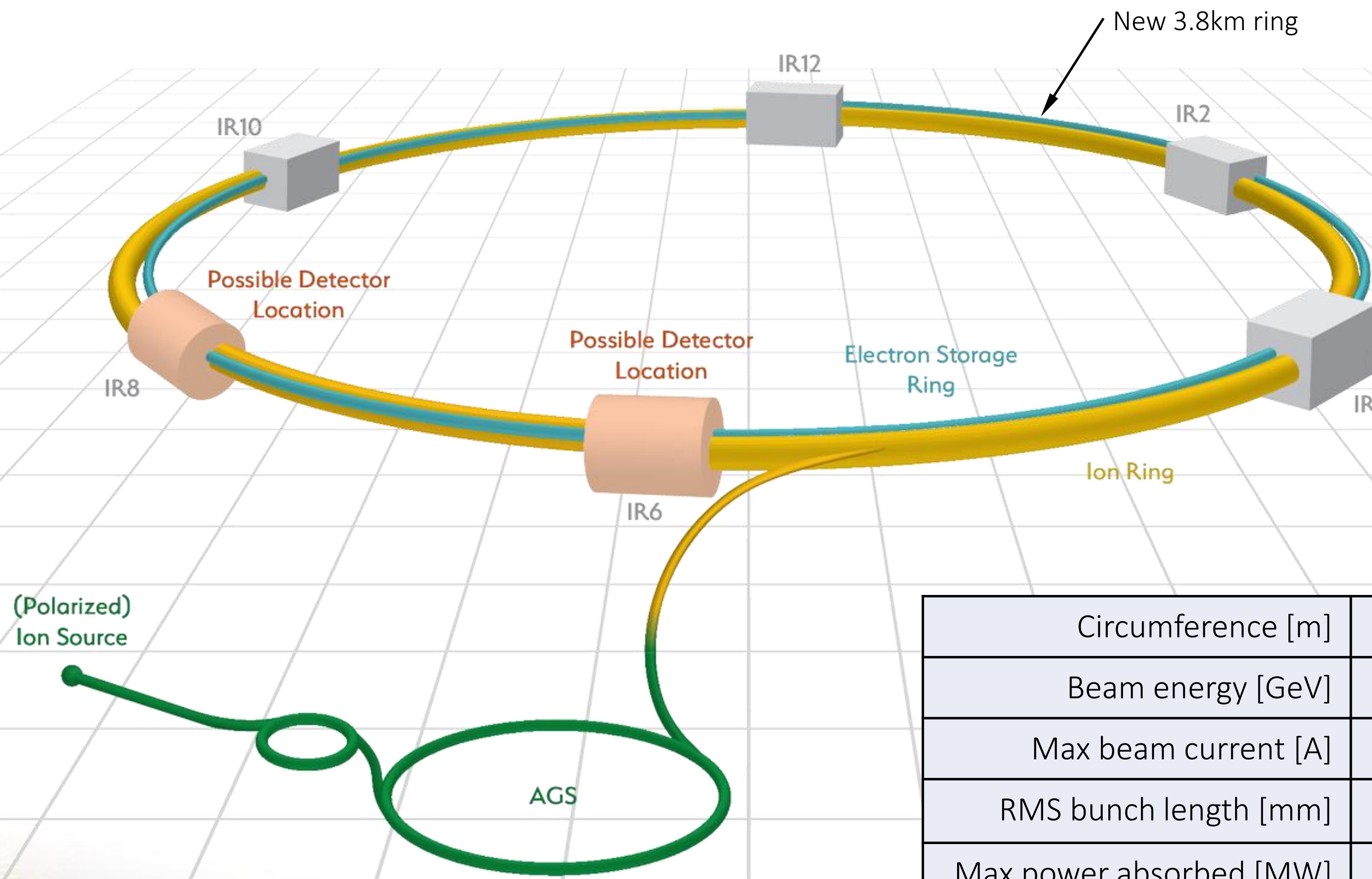
BROOKHAVEN NATIONAL LABORATORY · Jefferson Lab · U.S. DEPARTMENT OF ENERGY | Office of Science

Outline

- ESR Vacuum System
  - Requirements
  - Overview
  - Layout
  - Component Details
  - Current Status
  - SynRad/MolFlow
- Interaction Region
  - Requirements
  - Overview
  - Synchrotron Radiation Studies
  - Heat Loads in Final Focusing Magnets
- Summary



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

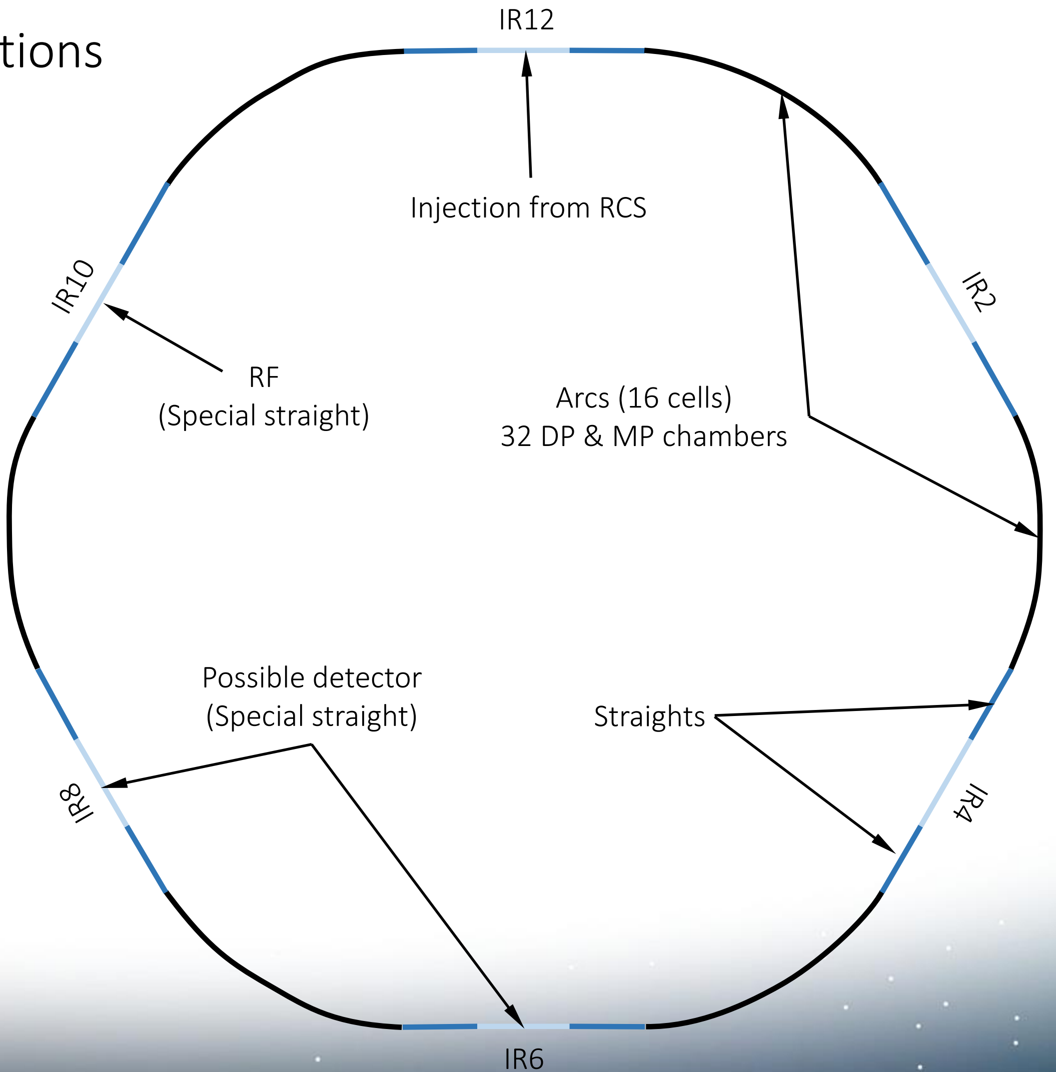
ESR Vacuum Requirements

- Provide a sufficient aperture for the electron beam
  - 5, 10 and 18 GeV operating modes
  - $15\sigma_x/25\sigma y$ + 10/5mm for orbit distortion
  - Reverse bends required for 5GeV operations
  - Low impendence
- Maintain adequate magnet to chamber clearance
- Protect vacuum components from synchrotron radiation
  - Maximum of 10MW of SR power
  - Shielding for non-water cooled components
  - Damage to components from high energy x-rays
- Ultrahigh vacuum conditions
  - Average dynamic pressure < 1×10^{-8} torr
  - Beam-gas lifetime > 20 hours
- Modular installation to minimize in tunnel work

ESR Overview

- Ring is divided into several sections

Section	Qty	Length [m]	Total [m]
Arcs	6	257	1542
Straights	12	123	1476
IRs	6	136	816
			3834



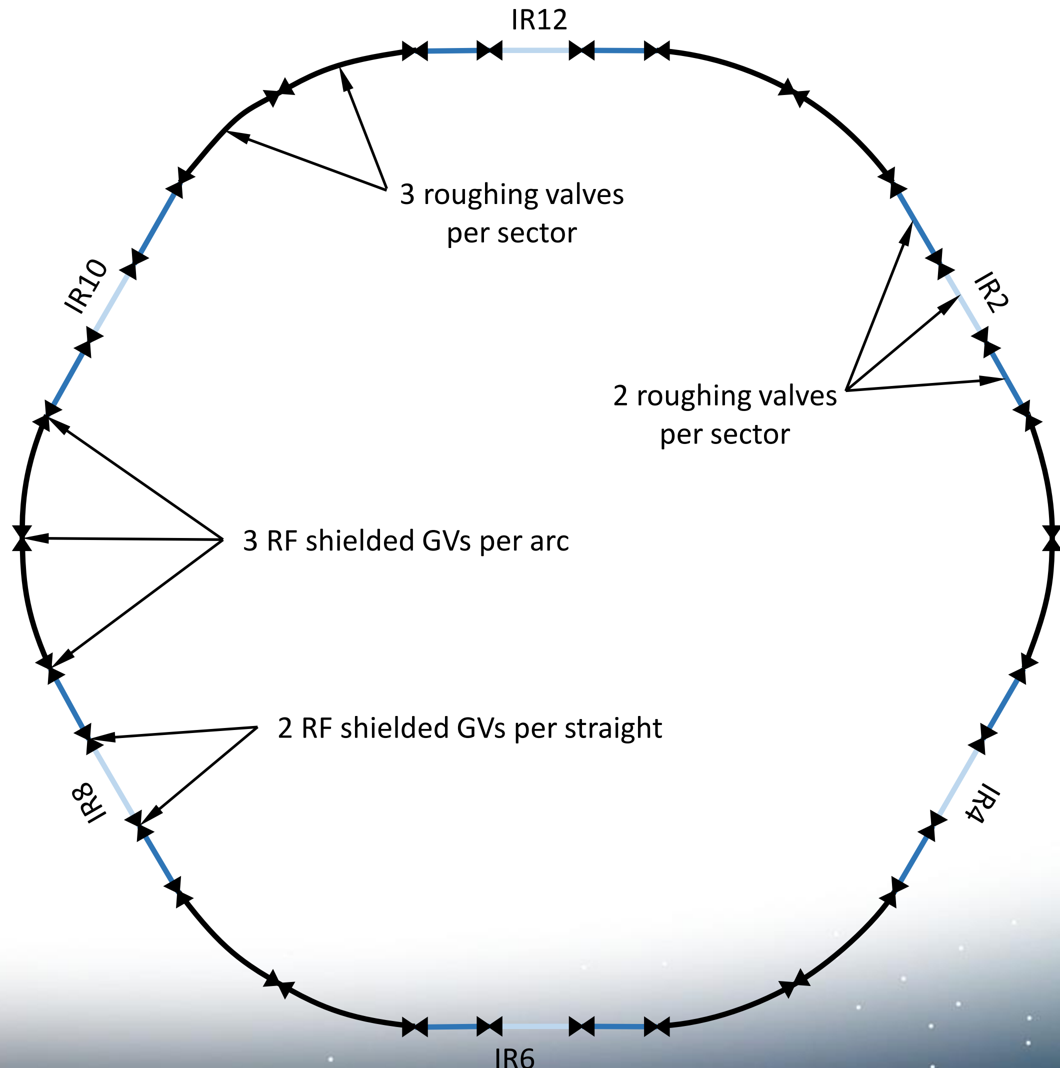
- Multipole and dipole chambers
  - 80mm x 36mm aperture
  - OFS copper
  - BPMs mounted on MP chambers
- ~700 RF bellows

ESR Vacuum Valves

- 30 vacuum sectors (~128m)
- RF shielded gate valves
- All metal roughing valves

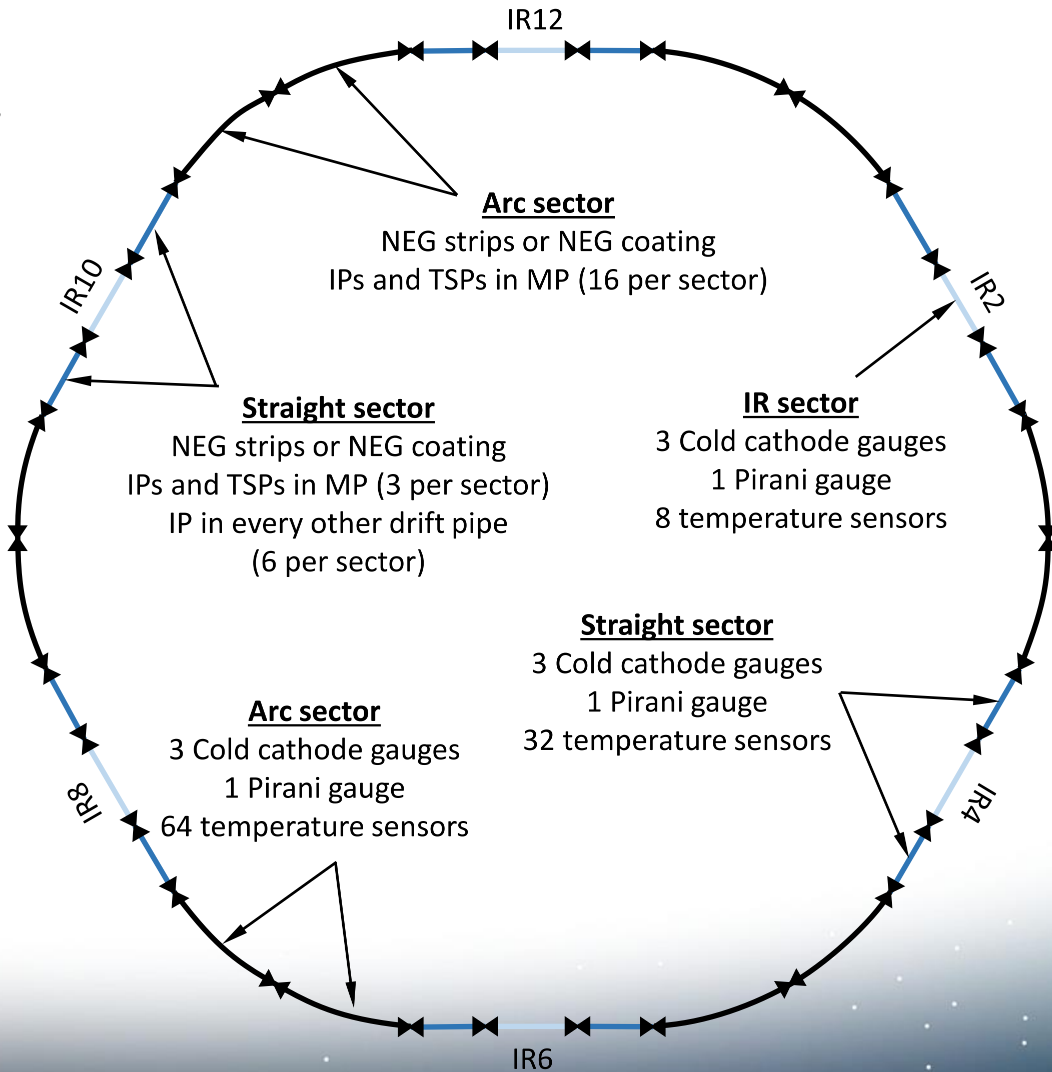
RF shielded GVs			
Location	Valves/sect.	# sect.	Total
Arcs	3	6	18
Straights	2	6	12

Roughing valves			
Location	Valves/sect.	# sect.	Total
Arcs	3	12	36
Straights	2	20	40

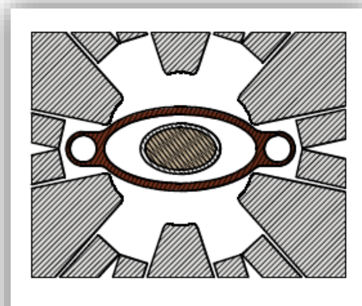


ESR Vacuum Pumps, Monitoring and Control

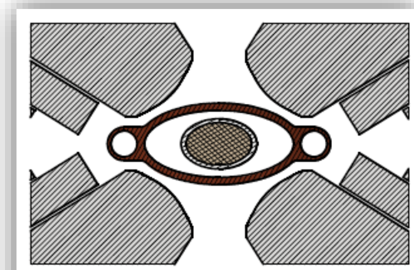
- Ion pumps, TSP, NEG
  - One IP and TSP every half cell in arcs
  - Distributed NEG pumping
- Standard gauging layout
  - Three CCGs/vacuum sectors (90)
  - One TCG/vacuum sector (30)
- 1 wire temperature monitoring
  - ~1200 sensors
- RGAs in special sections
- Support equipment
  - 40 turbo carts
  - 10 leak detectors



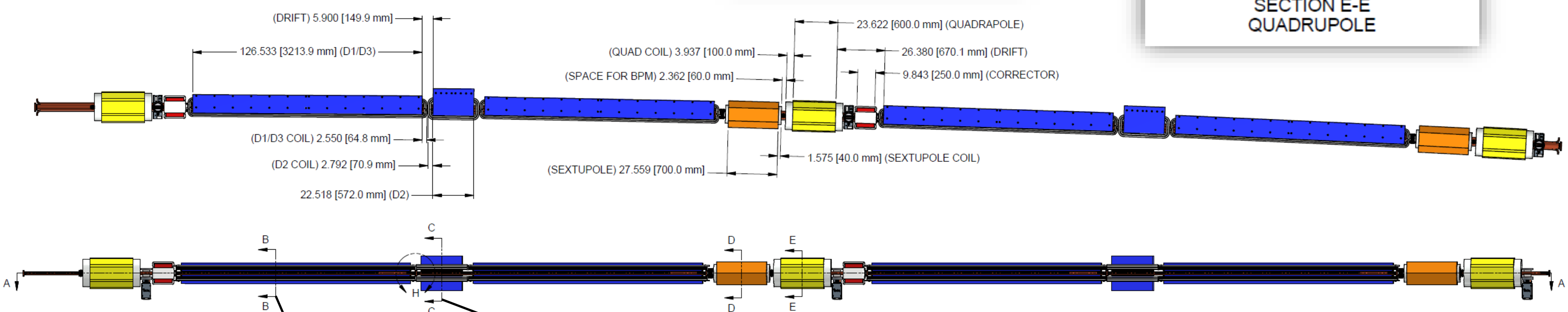
ESR Arc Layout

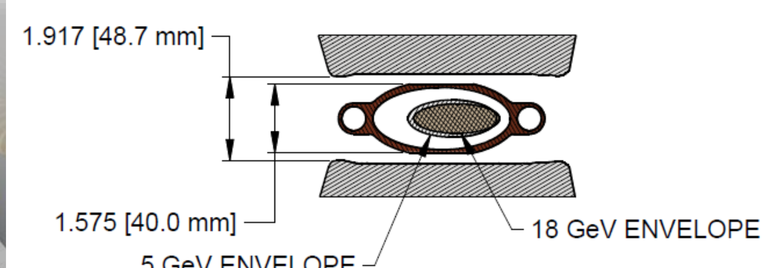


SECTION D-D
SEXTUPOLE

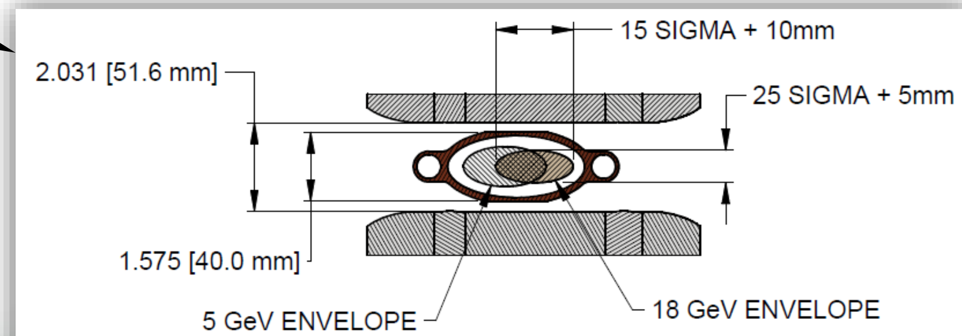


SECTION E-E
QUADRUPOLE





SECTION B-B
D1/D3

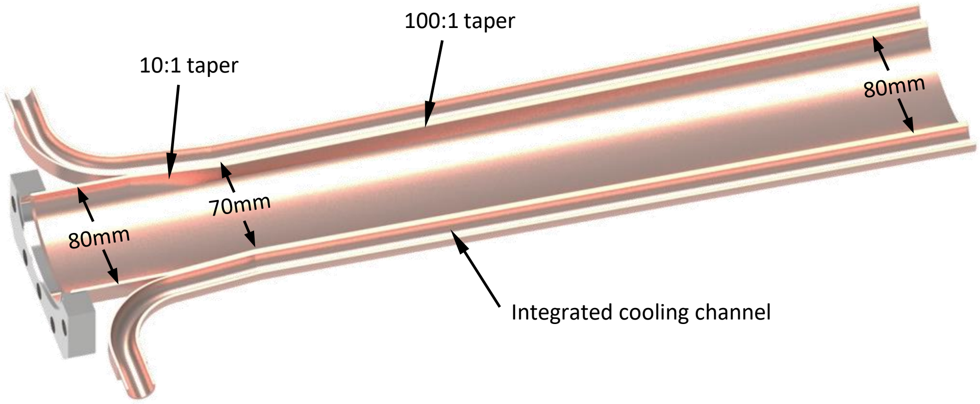


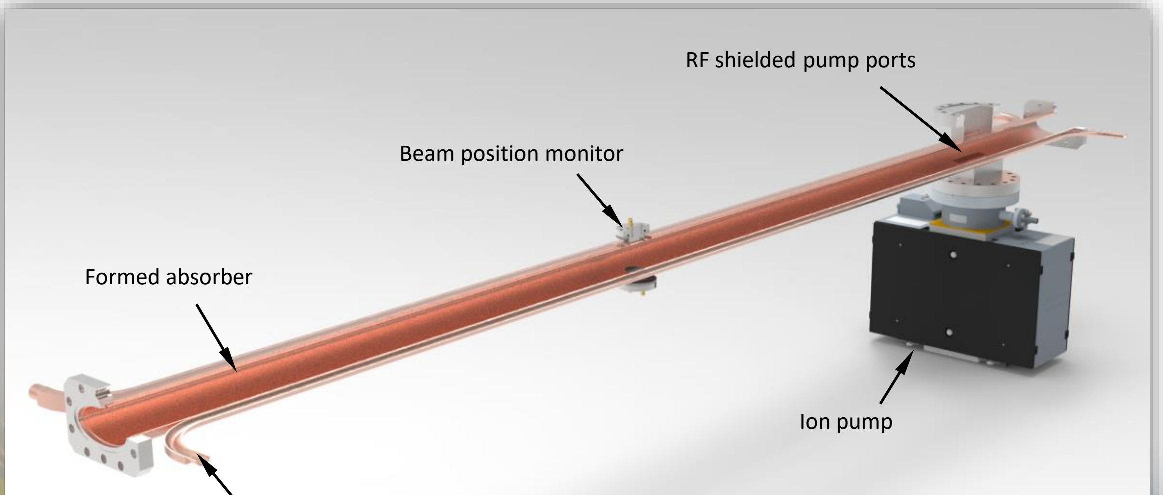
SECTION C-C
D2

Arc Vacuum Components

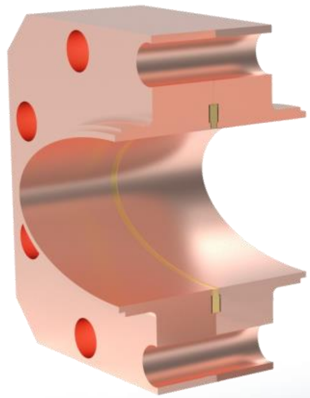
<u>Arc Vacuum Chambers</u>

- OFS copper extrusions
- High heat load components (up to 10MW)
- Low impedance geometry (zero step flanges, etc.)
- Copper to stainless steel welding
- >1000 chambers to fabricate, process and integrate



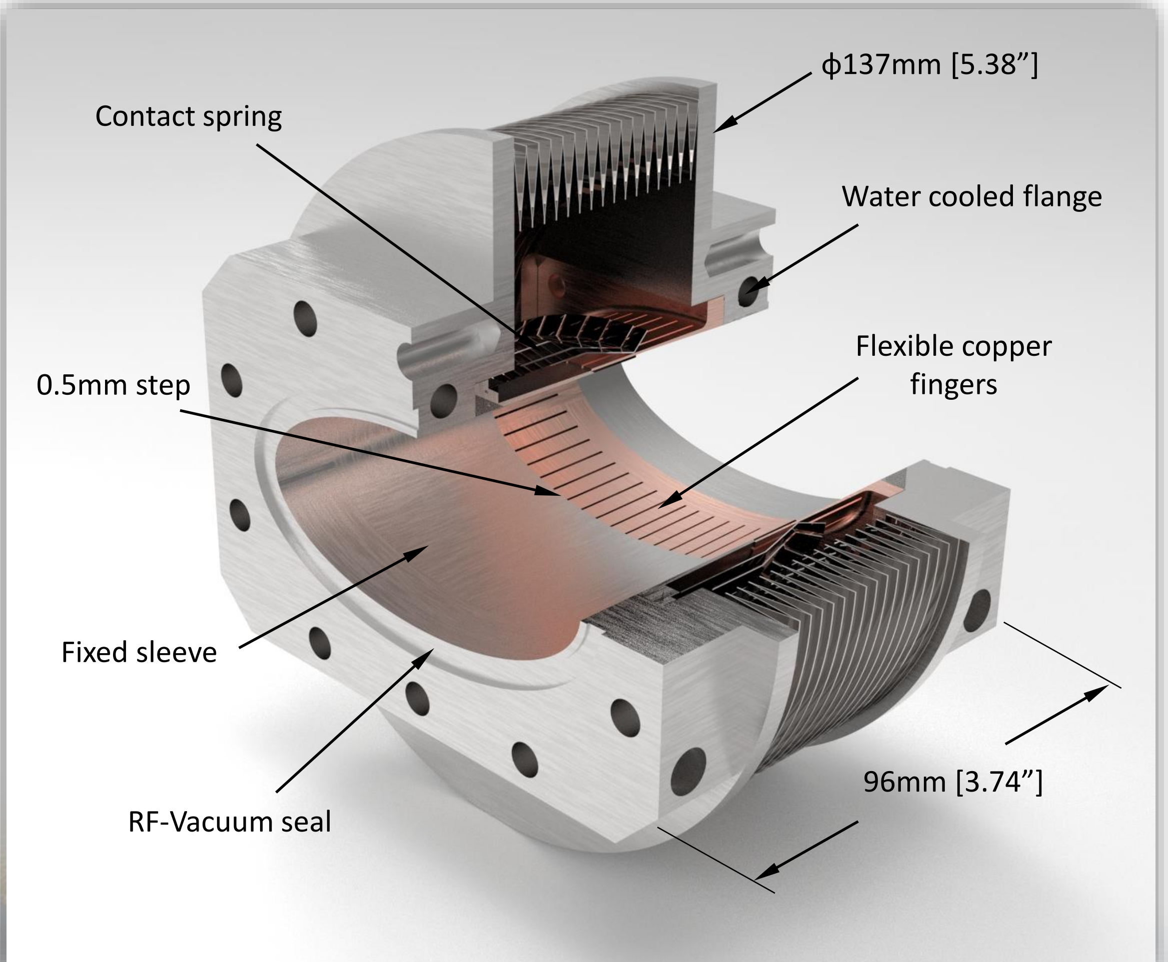


Multipole chamber



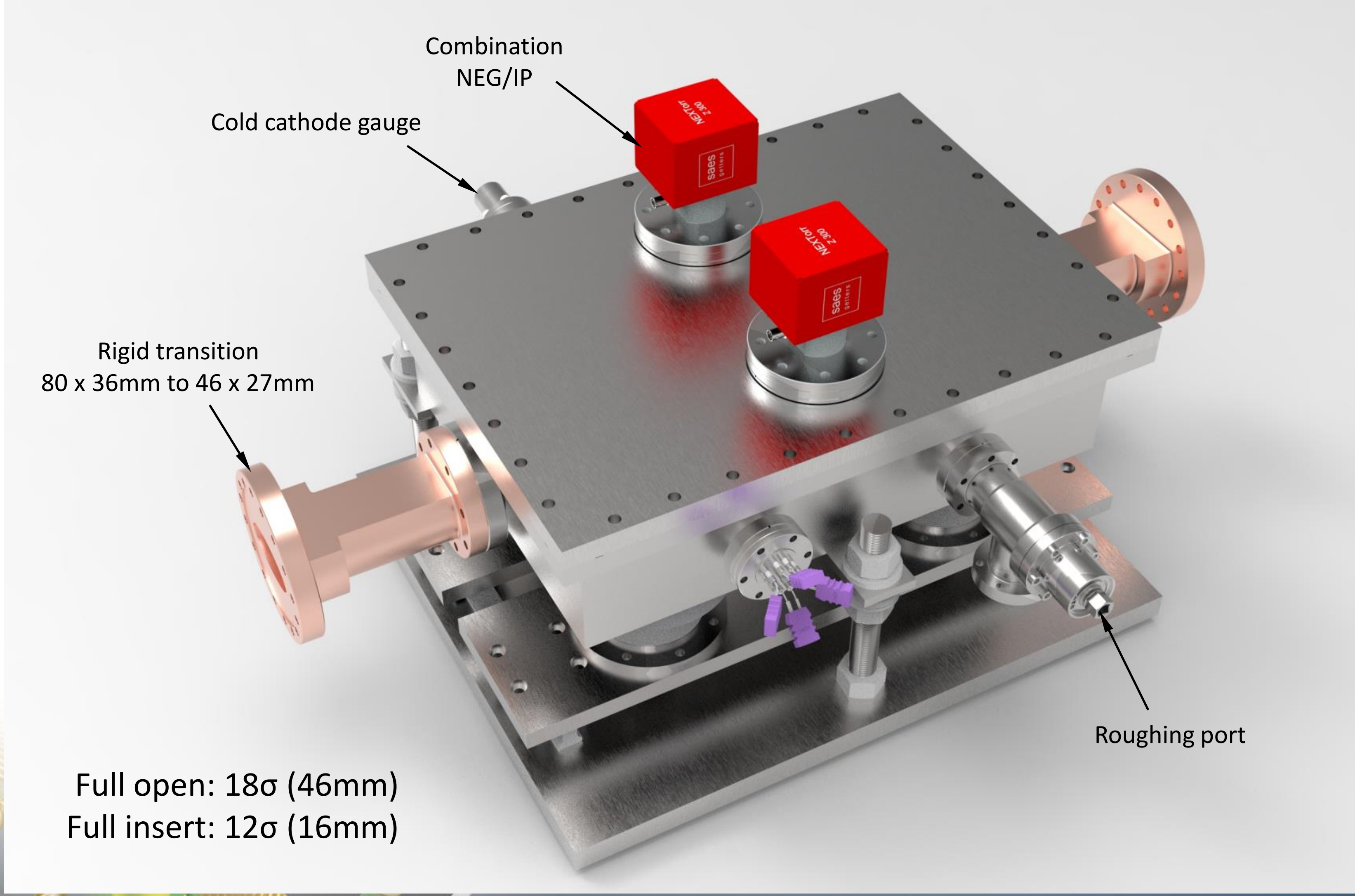
Zero step flange joint

ESR RF Shielded Bellows



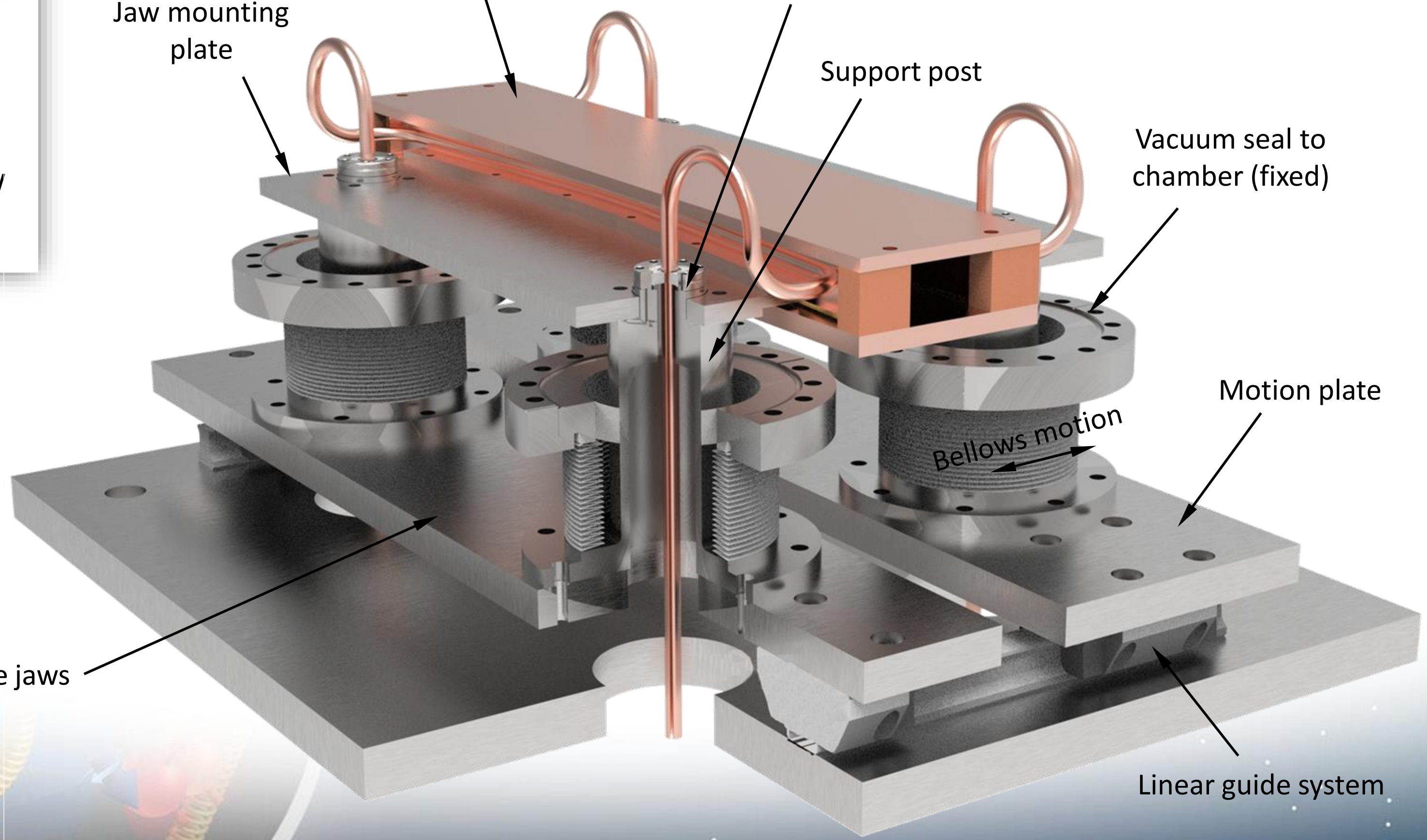
- Combination RF-Vacuum seal
- Water cooled flanges
- Compact footprint
- Stroke Req: -25/+10mm
  - Cell length variation: +/-5mm
  - Compression (NEG): -15mm
  - Extension: +3mm
  - Chamber length: +/-2mm
  - Alignment: +/-1mm

ESR Horizonal Collimator



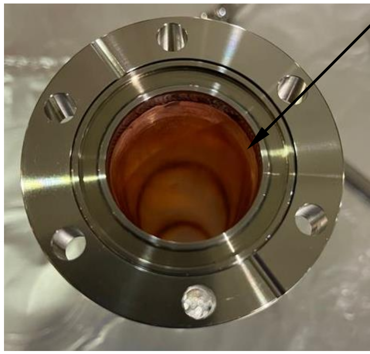
ESR Horizonal Collimator

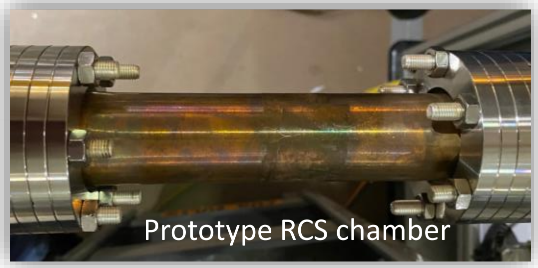
Chamber removed for clarity



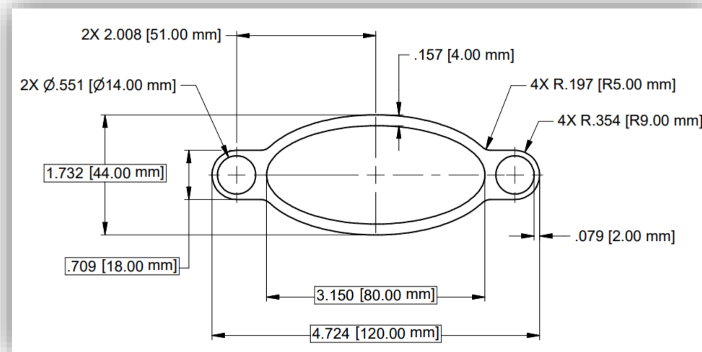
Current Status

Stainless steel
to copper weld

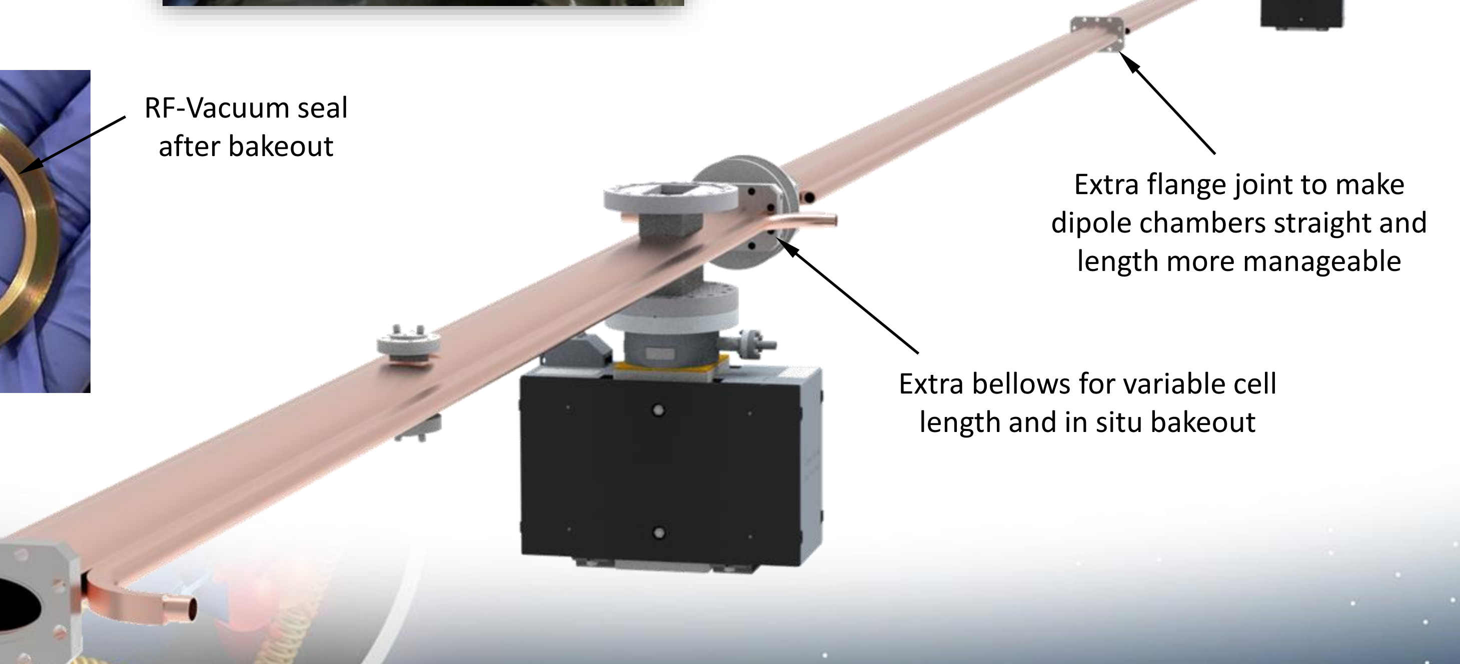




Extrusions on order



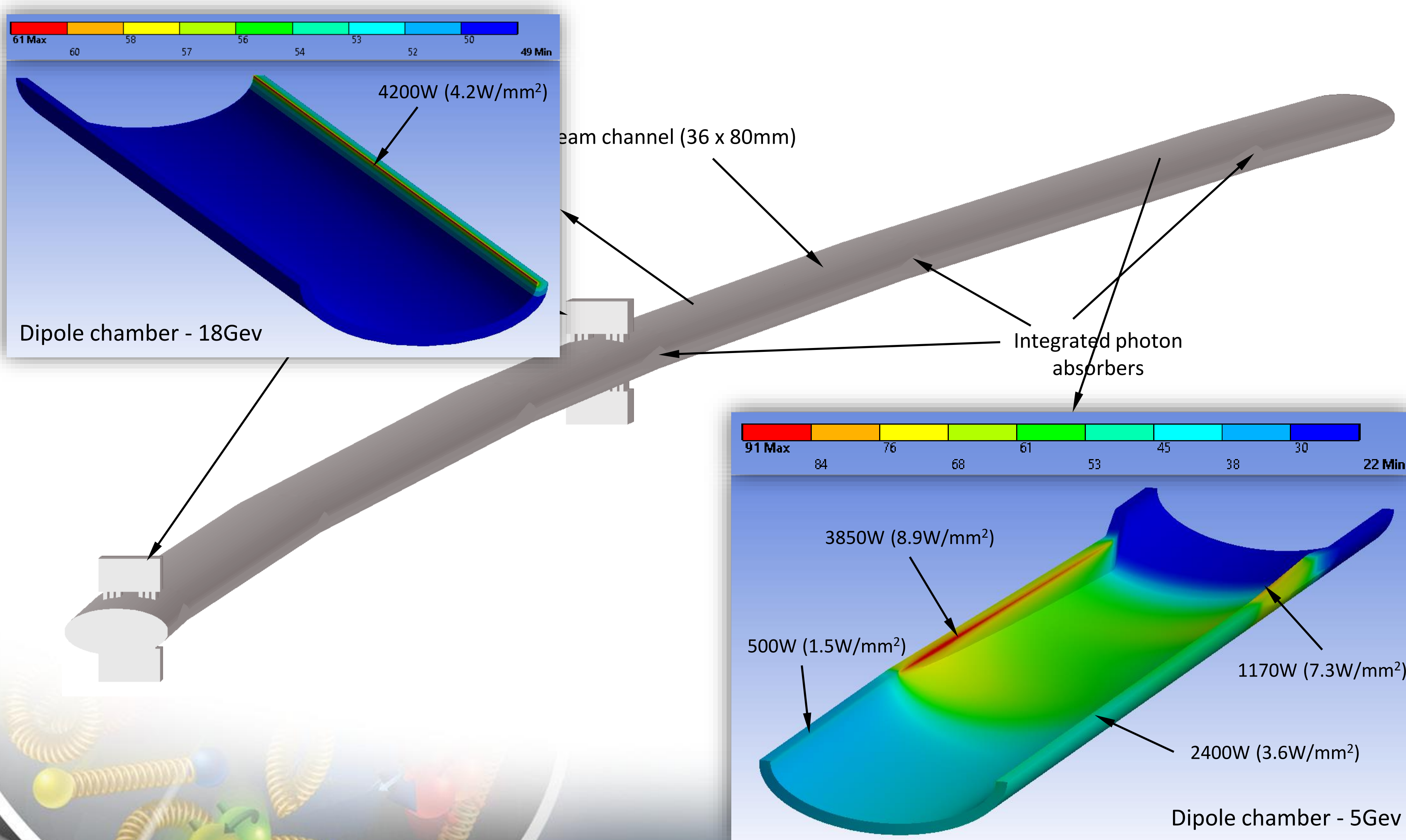
RF-Vacuum seal
after bakeout



Extra flange joint to make
dipole chambers straight and
length more manageable

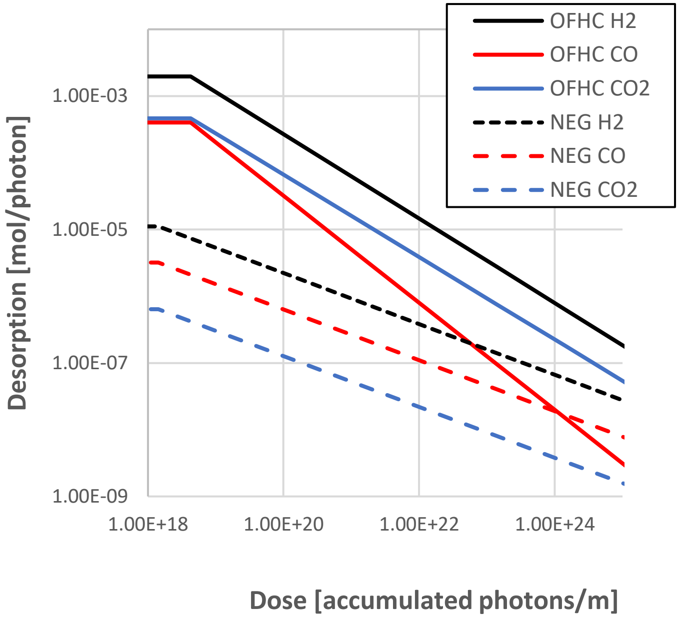
Extra bellows for variable cell
length and in situ bakeout

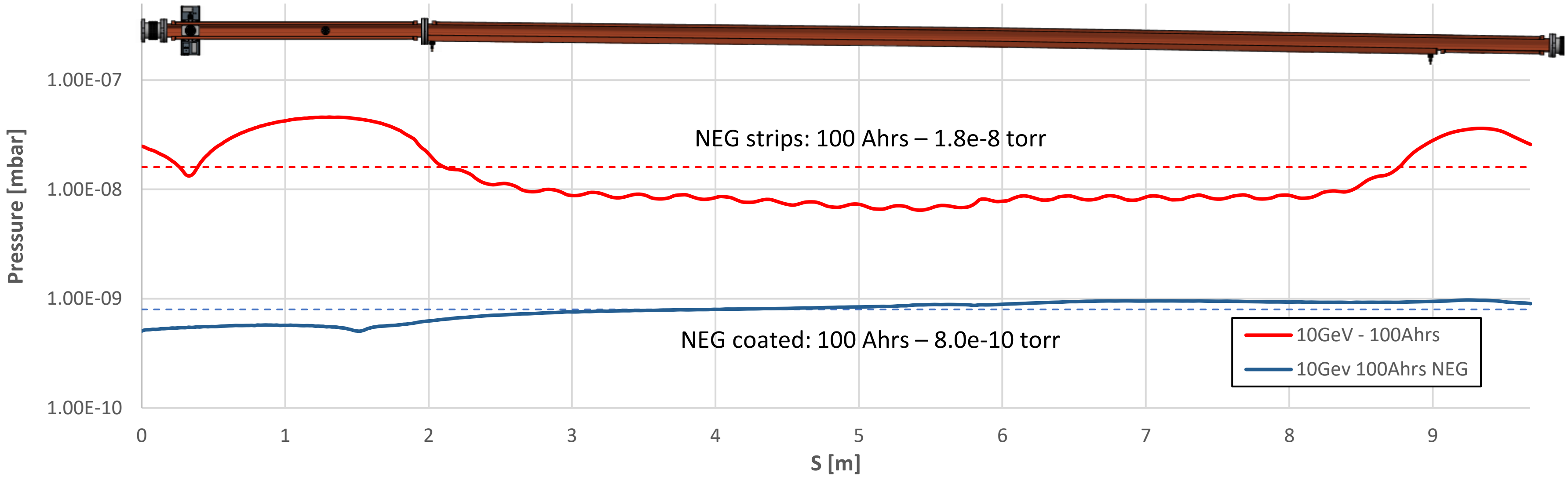
ESR Synchrotron Radiation Studies



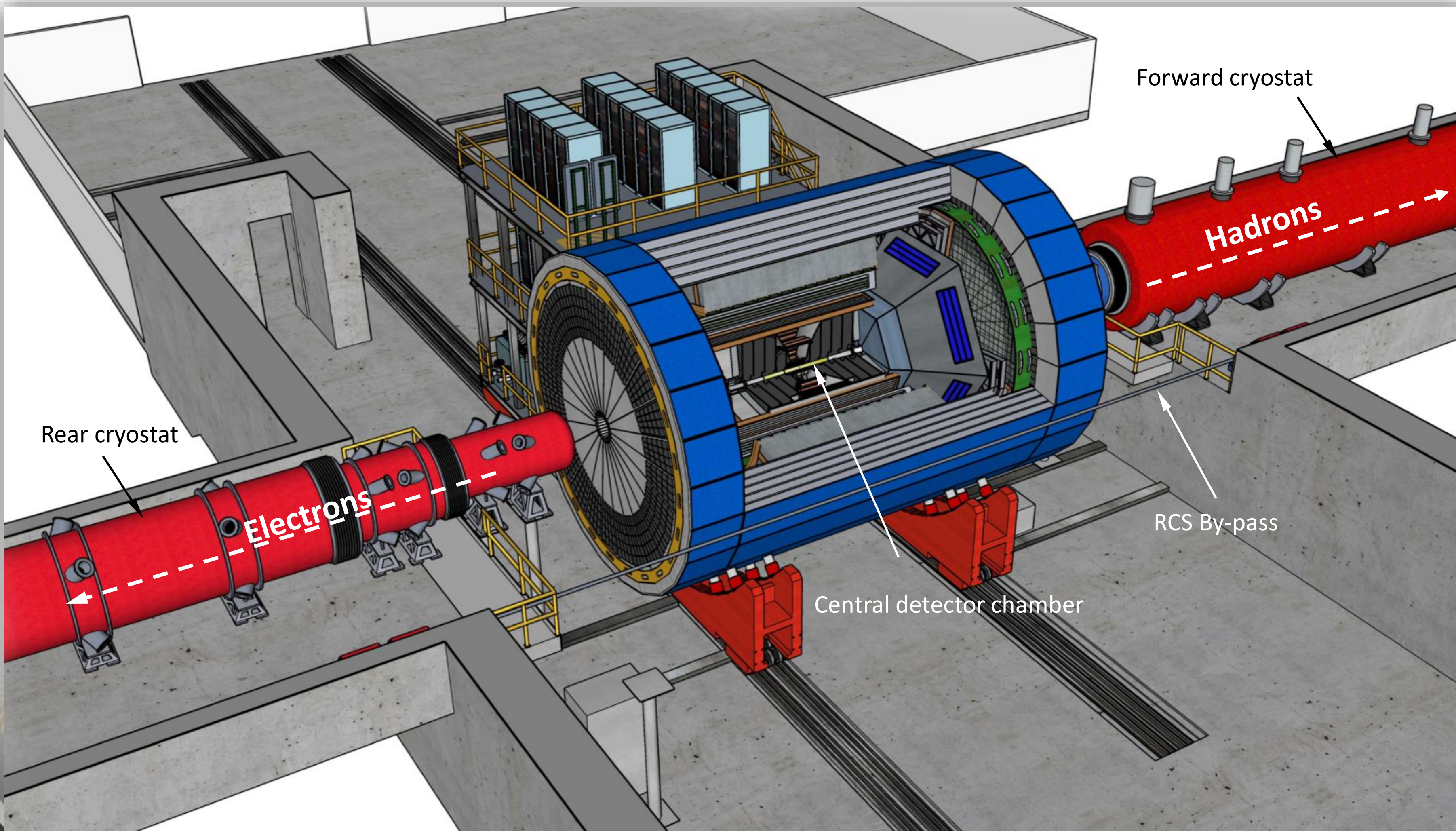
ESR Pressure Simulation

- Operating pressure dominated by PSD
- ESR average pressure populates ‘tails’
- Need to reduce vacuum conditioning time
- NEG coating option
- Simplifies chamber, commercial options
- Requires more bellows and in situ bakeout





Interaction Region Overview

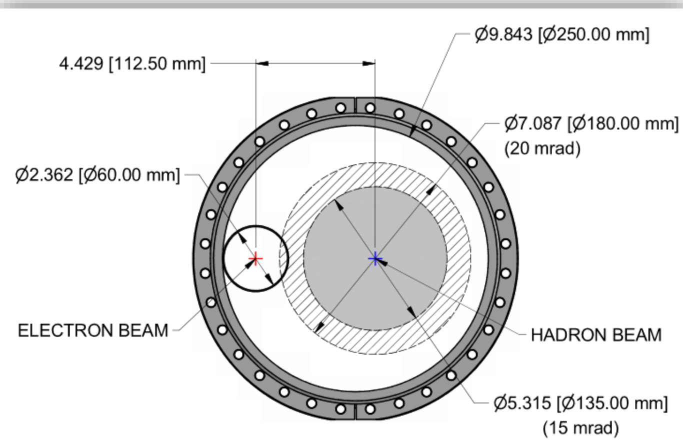


Interaction Region Requirements

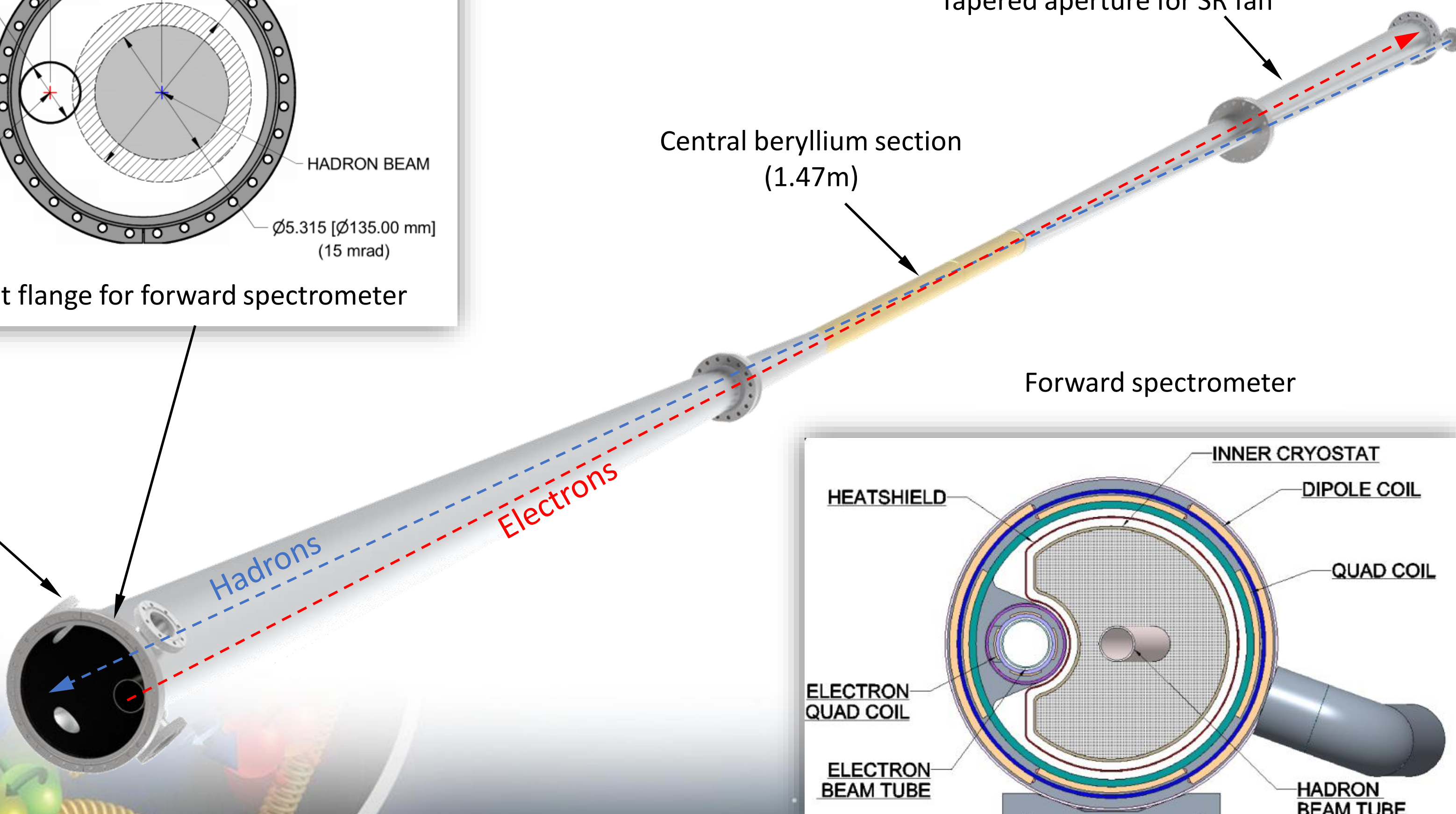
- Provide clearance for the particle beams as well as the SR fan
  - Large beam sizes through strong focusing quads near IR
- Detectors must be placed as close as possible to IP
- Minimize wake fields and longitudinal impedances
- Accommodate shallow crossing angle (25mrad)
- Minimize high energy photons hitting the central beryllium pipe
- Reduce residual gas pressure to minimize beam-gas interactions
  - High pressure results in high background
- Minimize interaction between beam pipe and collision products
- Accommodate various ancillary detectors near the IP
- Average dynamic pressure < $1x10^{-9}$ torr

Interaction Region Main Detector Chamber

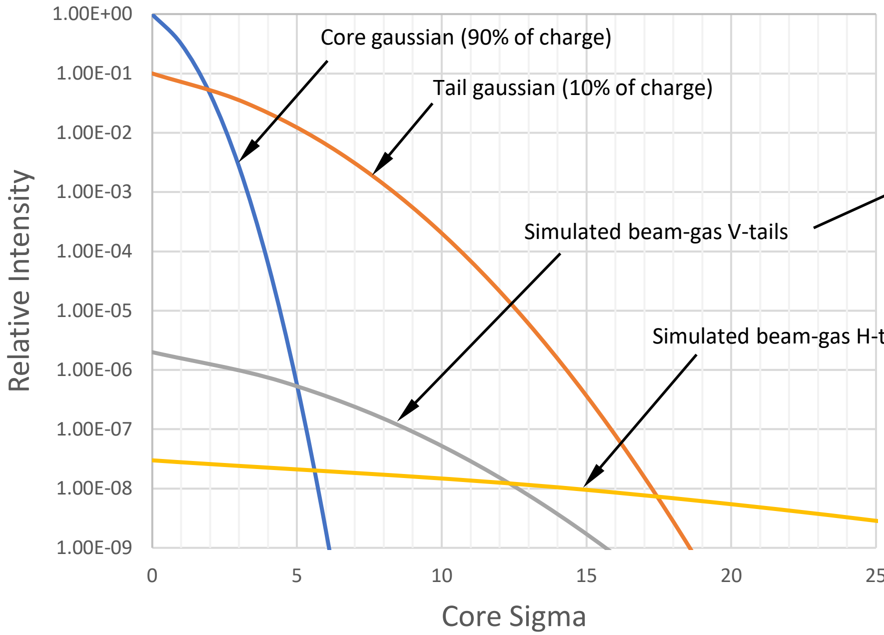
Working closely with detector group to sequence installation and removal steps



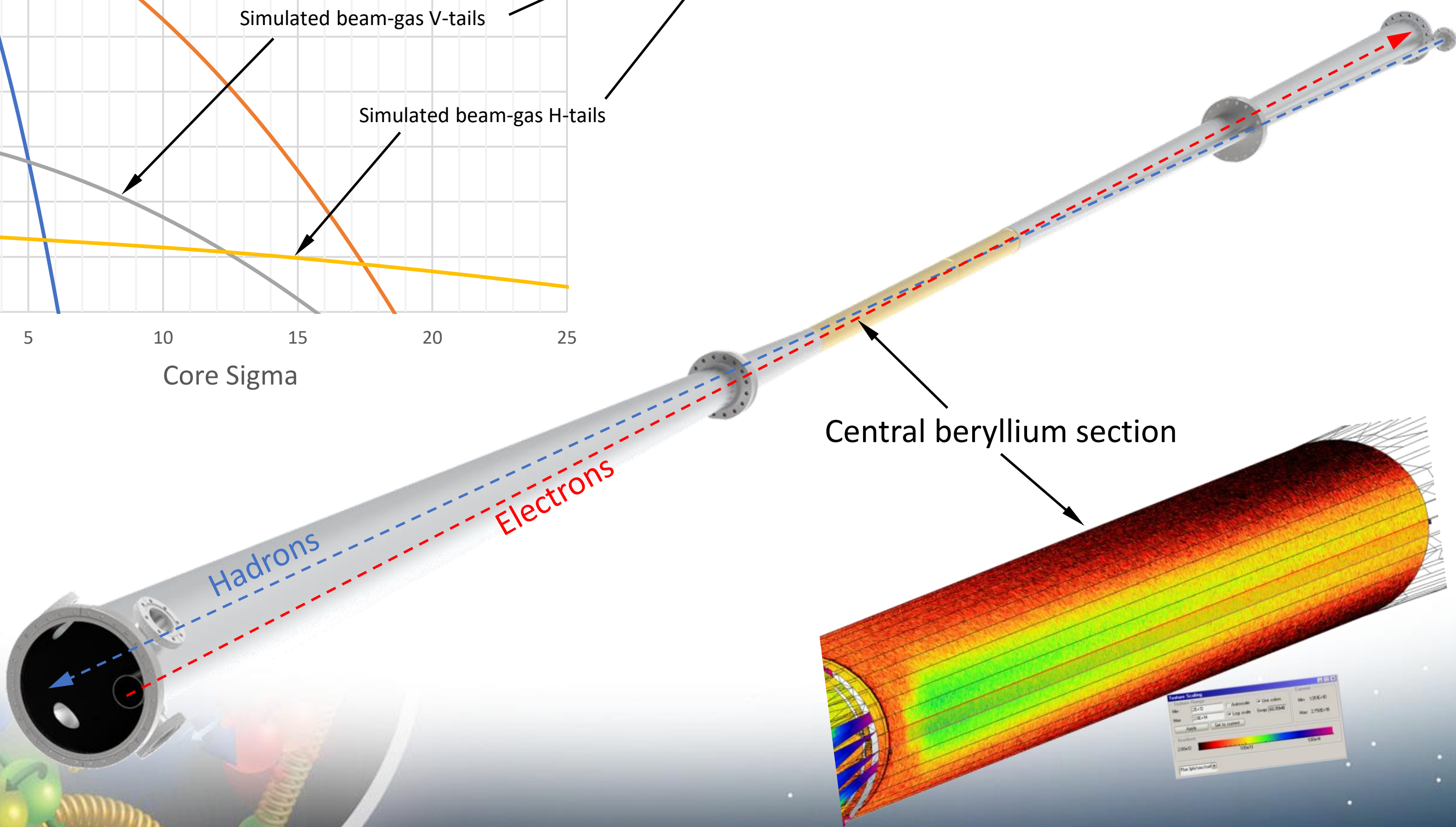
Large exit flange for forward spectrometer



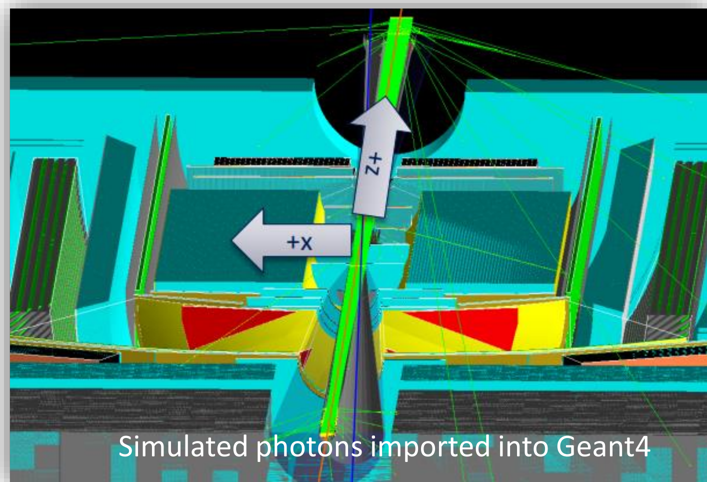
Synchrotron Radiation Simulations

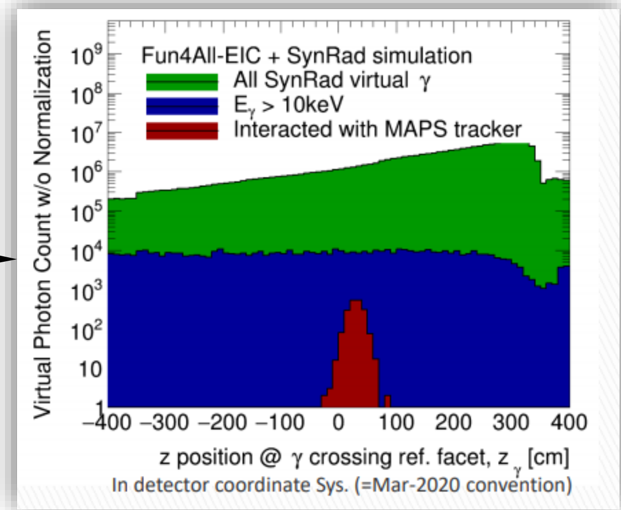


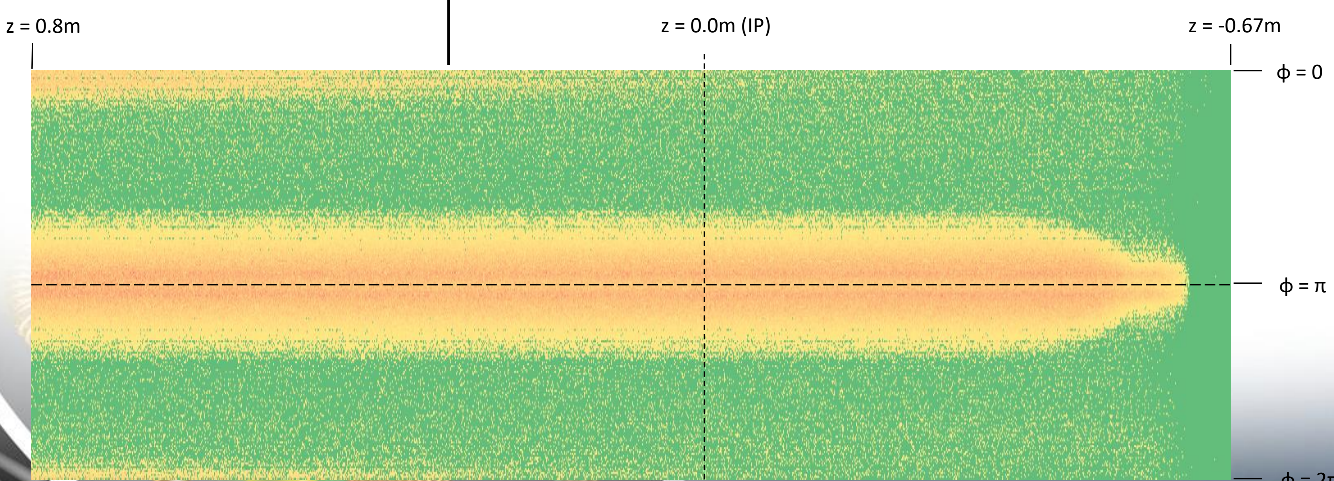
See tech note by C. Montag for more detail on transverse beam tail and beam lifetime studies



Photon Distribution on Detector Chamber



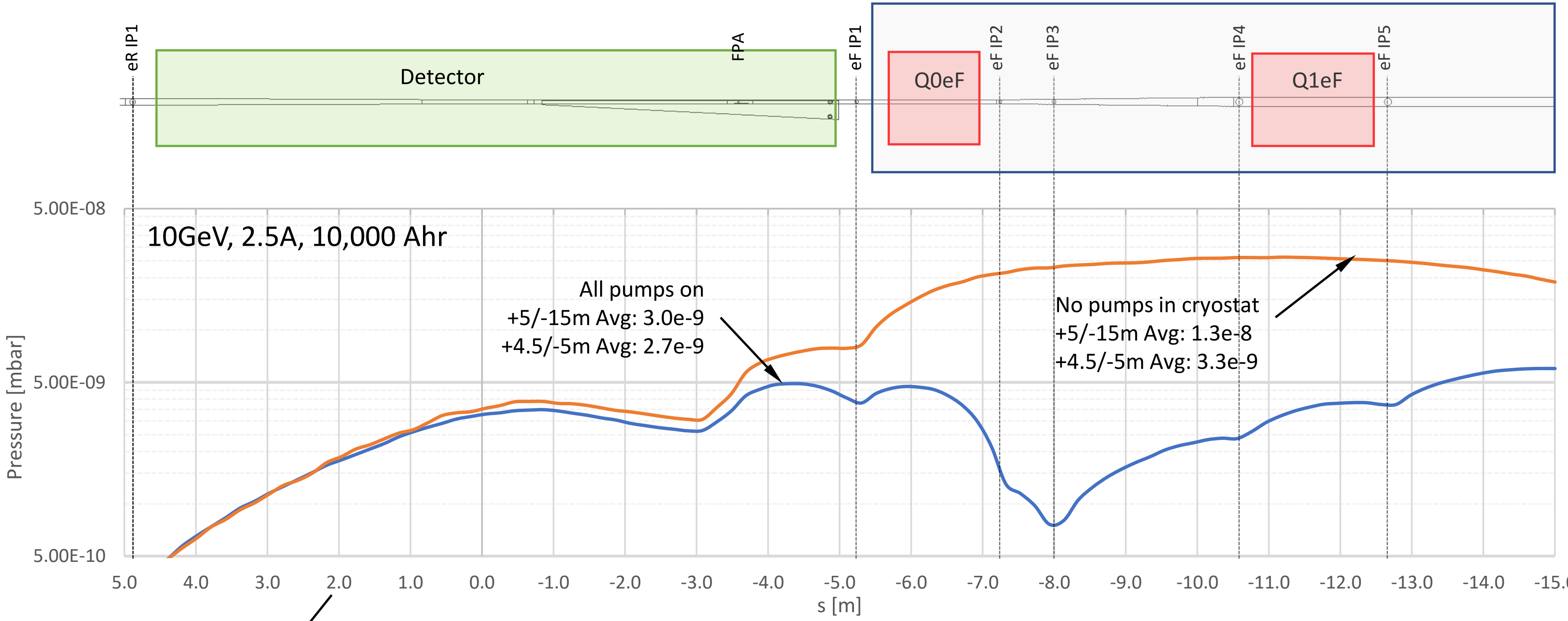


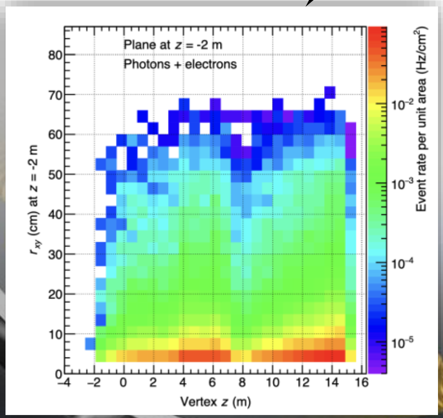


Photons > 5keV

Total Flux: 2.7x10^{14} ph/sec
Power absorbed: 0.3W
(~3.0x10^6 ph/crossing)

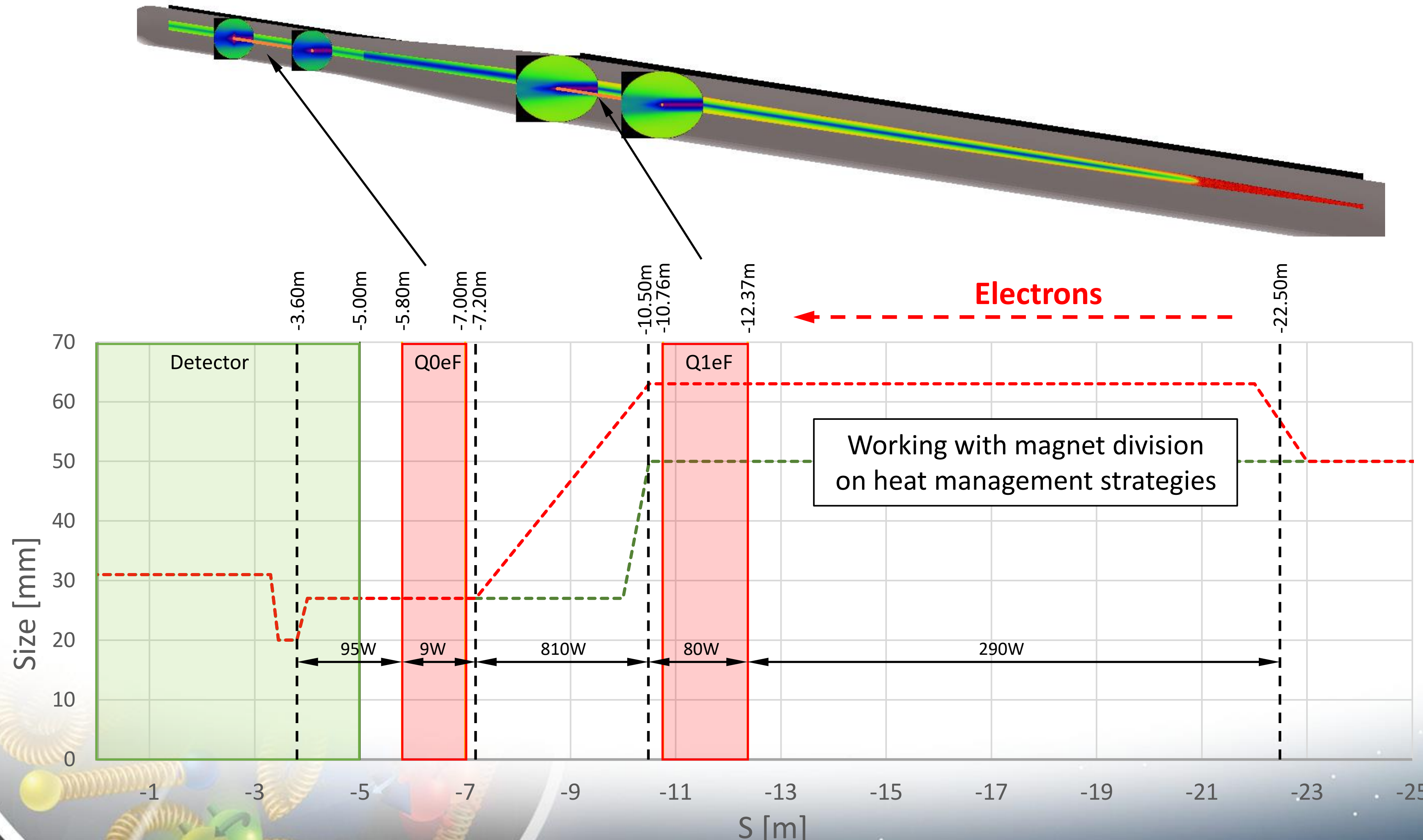
Pressure Profile Inside Forward Cryostat





- Beam interactions with residual gas molecules generate high energy photons and scattered electrons which result in high backgrounds

Heat Loads in Forward Magnets



Summary

- Preliminary layouts for complicated vacuum areas have been completed
- Electron storage rings with similar parameters have been built (B factories)
- Interaction region layout is progressing and looks promising
- Vacuum R&D is underway to retire significant risks prior to baselining
  - RF shielded components (bellows, flange joints, GVs)
  - Chamber prototyping (ESR, central detector)
  - Movable collimators
  - Central detector chamber prototype
- Close collaboration with beam physics, magnets and detector groups
- Eager to open active collaborations with other institutions

Thank you for your attention