BNL e-Cooling High Beta Cavity & Cryomodule Final Design Review

Cryomodule Design

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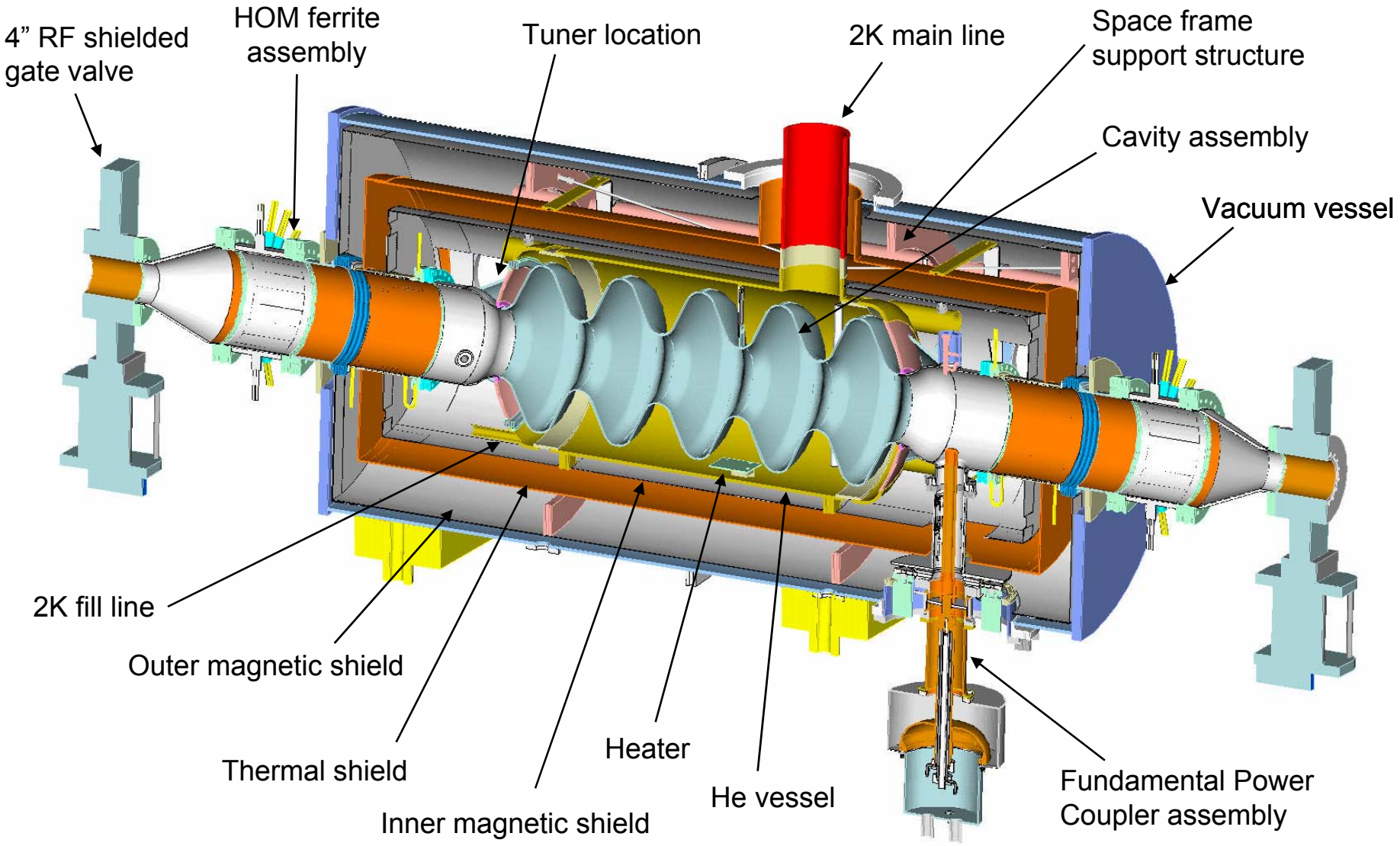
Outline

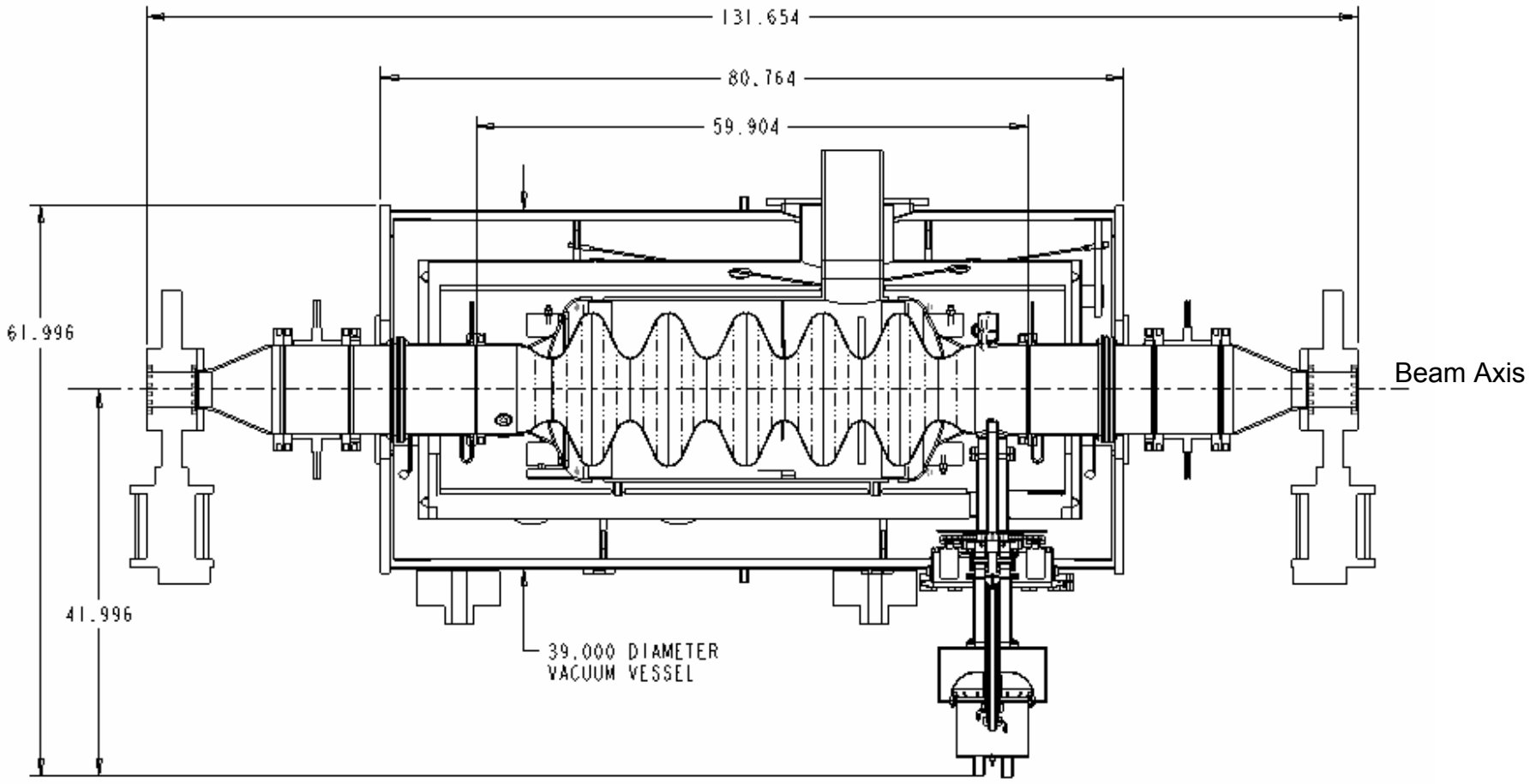
- Cryomodule Configuration
- Cavity Assembly and Finite Element Analysis
- Helium Vessel Assembly
- Beam Tube Assemblies and Thermal Analysis
- Fundamental Power Coupler
- Space Frame Support Structure
- Magnetic and Thermal Shielding
- Vacuum Vessel Components
- Cavity String Assembly
- Cryomodule Interfaces
- Summary

Cryomodule Assembly Configuration



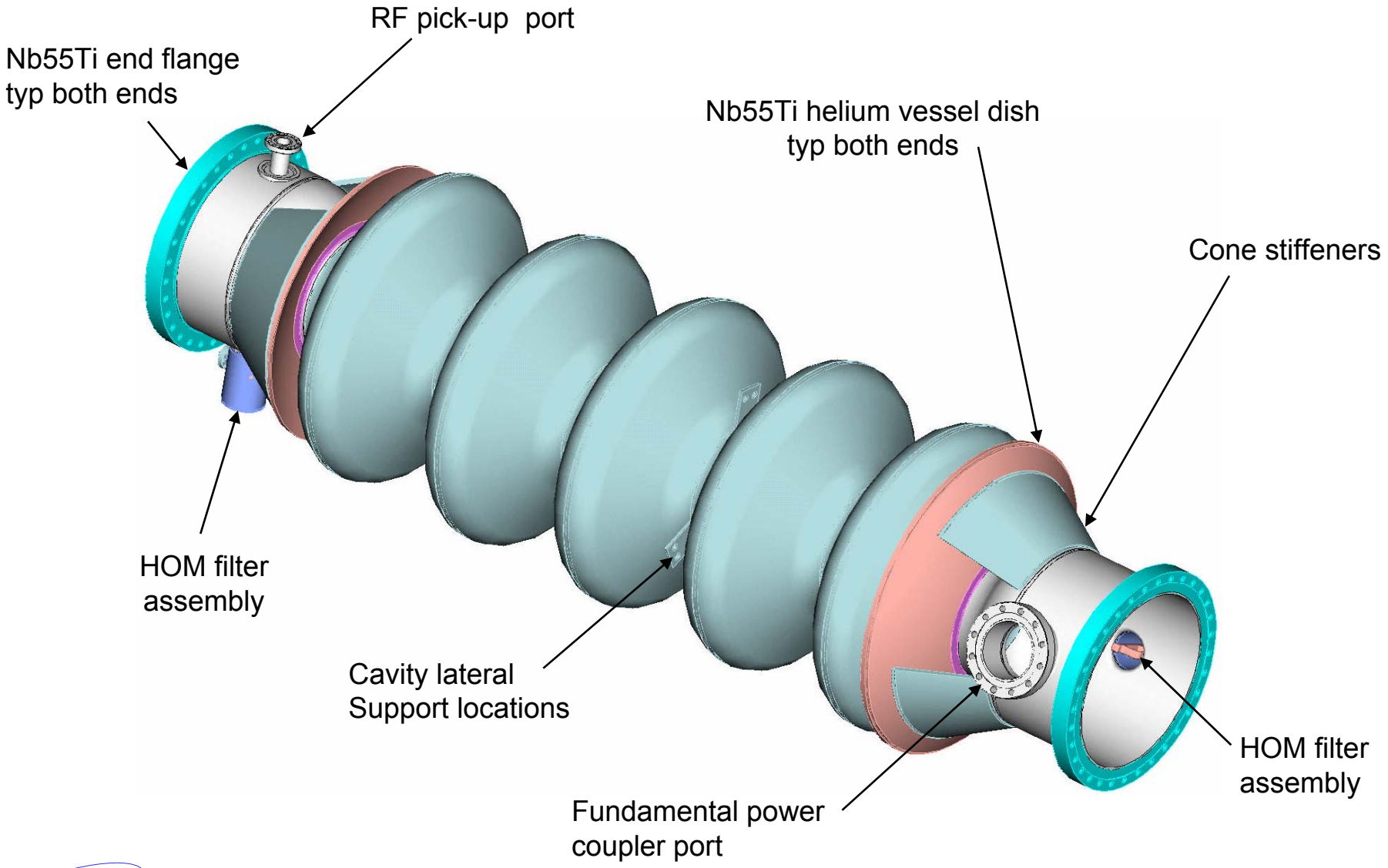
Cryomodule Assembly Configuration

e-Cooling High β Cavity & Cryomodule



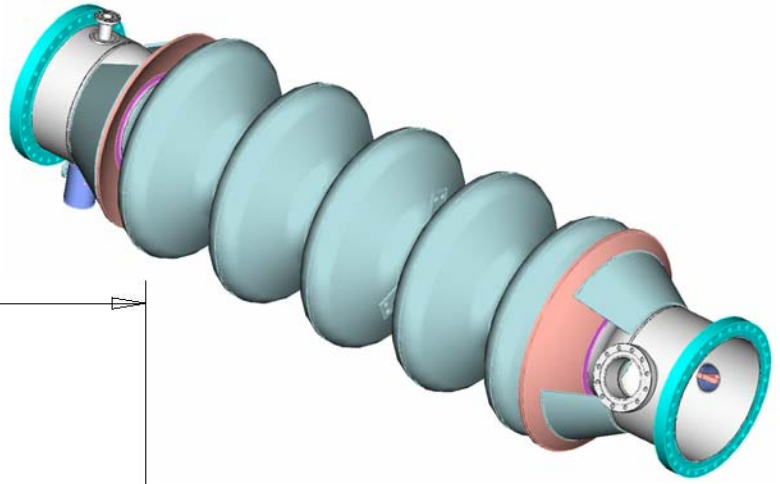
Dimensions in inches

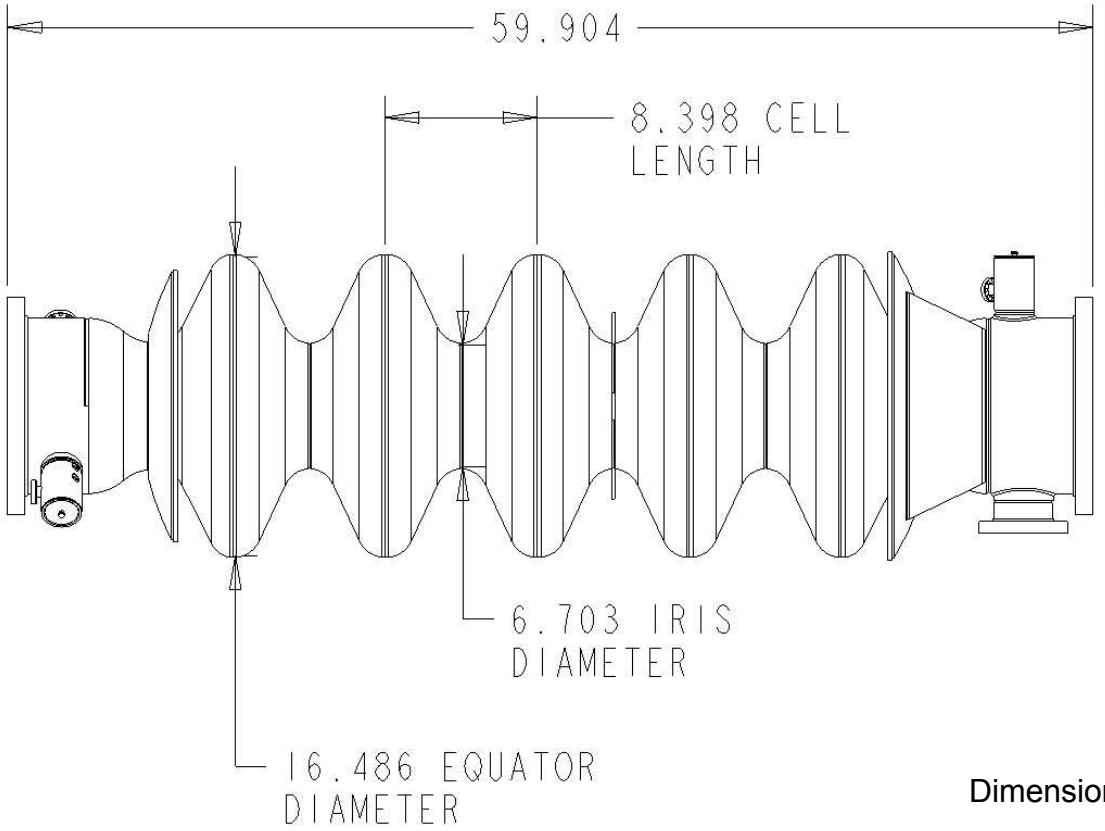
Cavity Assembly



Cavity Assembly

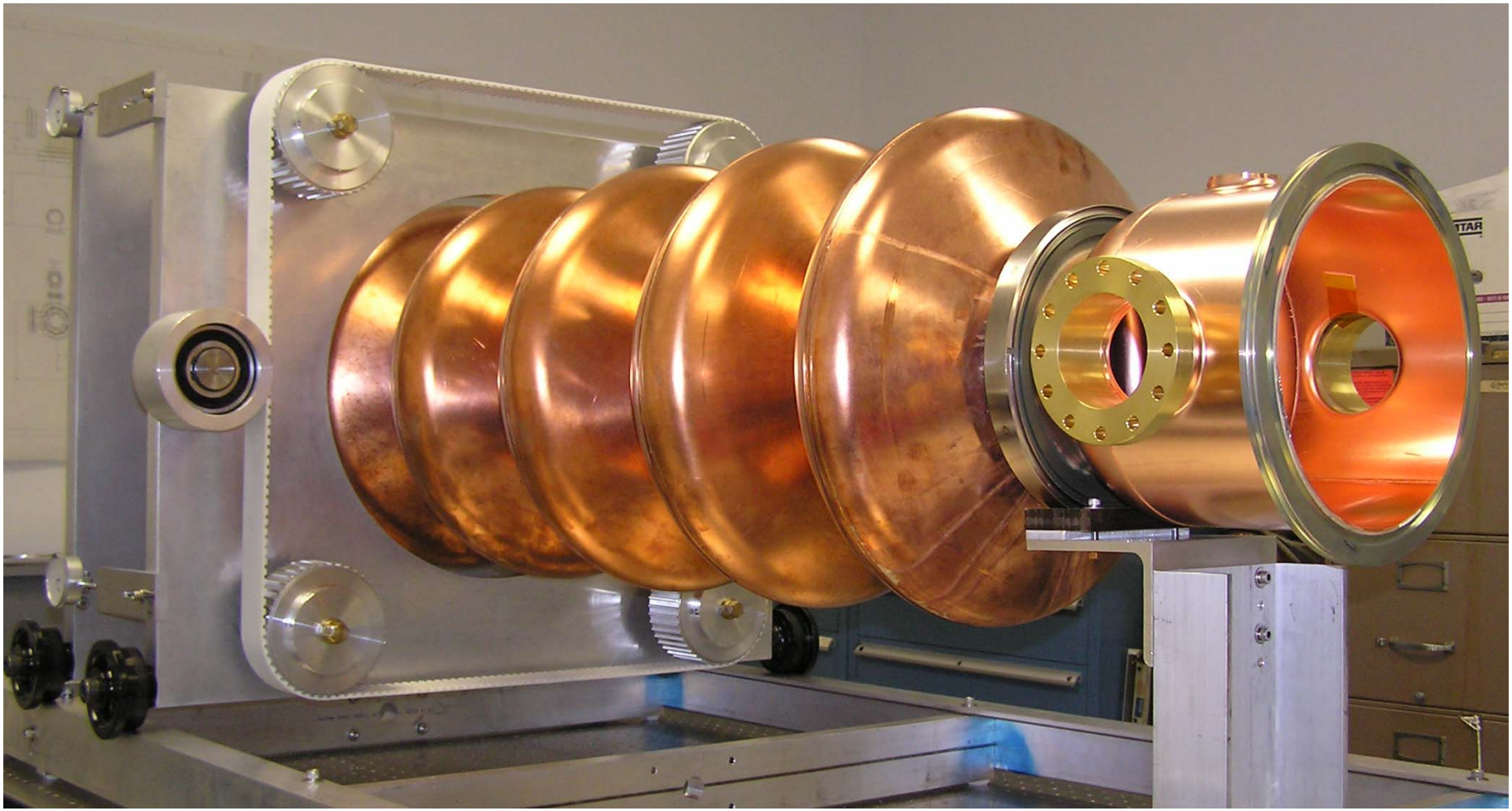
e-Cooling High β Cavity & Cryomodule





Dimensions in inches

Cavity Cold Model in Tuning Fixture

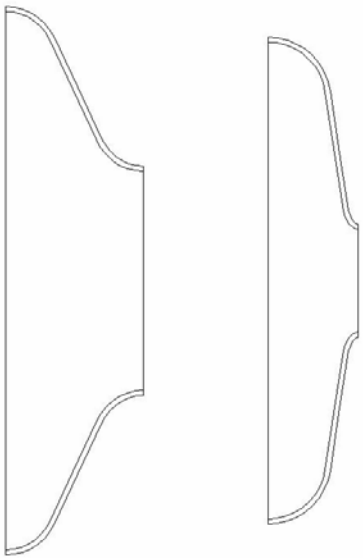


Cavity Tuning Parameter Comparison

e-Cooling High β Cavity & Cryomodule

Selected Config. →

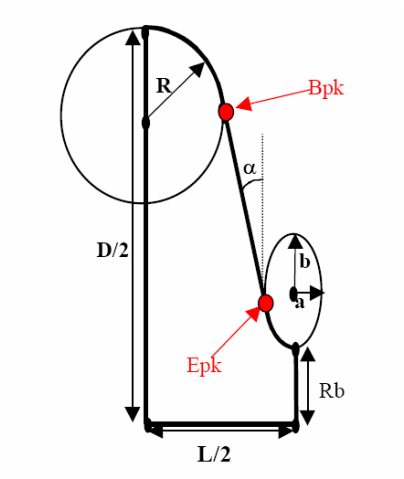
Cavity Configuration	Freq.	Cells	Tuner Load (400 kHz)	Tuning Coef.	Cavity Deflection (for 400 kHz Shift)	Cavity Spring Rate	Cavity Stress (for 400 kHz)	Lorentz-force detuning
3 mm Unstiffened	703 MHz	5	6300 lbs	2460 kHz/in	.162 inches	38900 lbs/in	11720 lbs/in^2	1.5 Hz/(MV/m)^2
4 mm Unstiffened	703 MHz	5	8500 lbs	2570 kHz/in	.156 inches	54500 lbs/in	11860 lbs/in^2	.91 Hz/(MV/m)^2
3 mm with Iris Stiffeners (1/2 way up)	703 MHz	5	19300 lbs	1040 kHz/in	.385 inches	50200 lbs/in	38100 lbs/in^2	.86 Hz/(MV/m)^2
4 mm with Iris Stiffeners (1/2 way up)	703 MHz	5	27100 lbs	1050 kHz/in	.381 inches	71100 lbs/in	45200 lbs/in^2	
Tesla	1.3 GHz	9	600 lbs	10160 kHz/in	.040 inches	15240 lbs/in		
SNS Cavity .61 Beta	805 MHz	6						3.4 Hz/(MV/m)^2
SNS Cavity .81 Beta	805 MHz	6	790 lbs	5080 kHz/in	.079 inches	10000 lbs/in		0.7 Hz/(MV/m)^2
CEBAF Upgrade	1.5 GHz	7	2050 lbs	6350 kHz/in	.063 inches	32500 lbs/in		
700 MHz .65 Beta Proton Cavity (CEA-Saclay/IPN-Orsay Collaboration)	700 MHz	5	570 lbs	6350 kHz/in	.063 inches	9100 lbs/in		



BNL e-CX Cavity Shape

CEA-Saclay/IPN-Orsay Cavity Shape

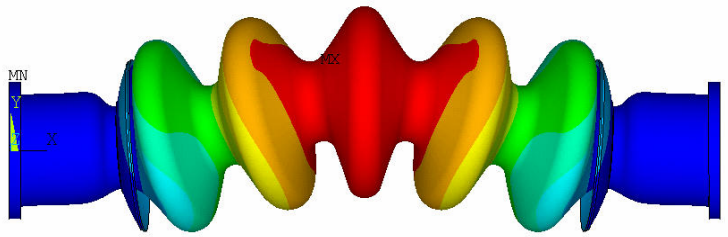
Cavity Geometry Comparison



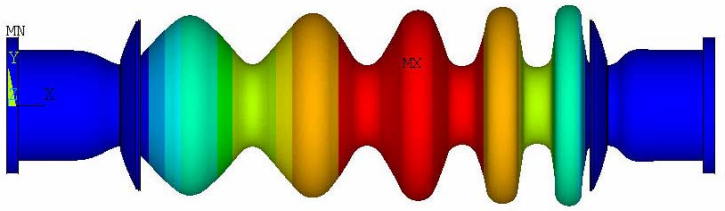
Parameter	CEA-Saclay/ IPN-Orsay 700 MHz Cavity	BNL e-CX Cavity
L/2 (mm)	70.0	106.5
D/2 (mm)	185.5	209.1
R (mm)	45.0	37.1
a (mm)	12.7	40.9
b (mm)	25.5	45.0
α (deg)	8.5	25.0
Rb (mm)	40.0	85.0
Wall Thickness (mm)	4 mm	3 mm

FEA Results: Mechanical Resonant Modes

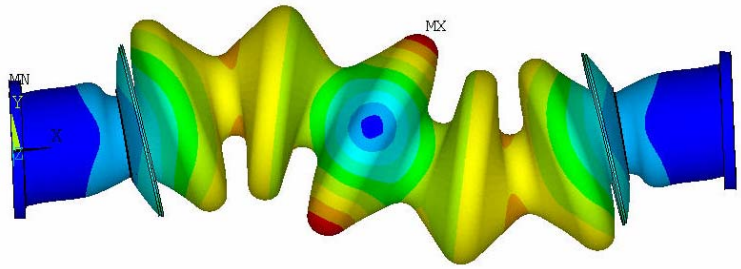
Thickness	Mech. Resonant Freq.	
	Unstiffened	Stiffened
3mm	96 Hz	124 Hz
4mm	97 Hz	126 Hz
3mm	200 Hz	200 Hz
4mm	204 Hz	204 Hz
3mm	213 Hz	264 Hz
4mm	214 Hz	269 Hz



First/Second Mode

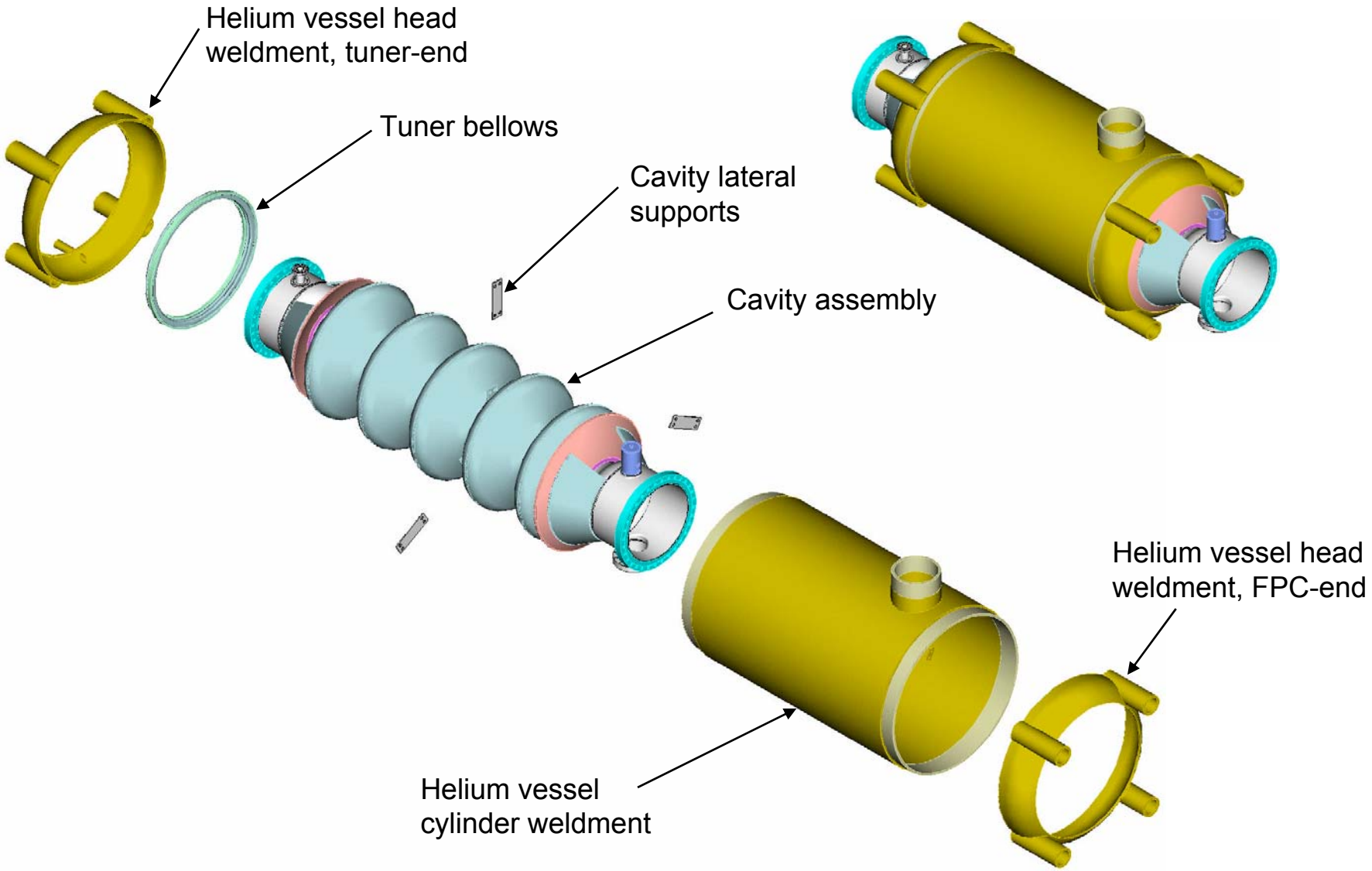


Third Mode

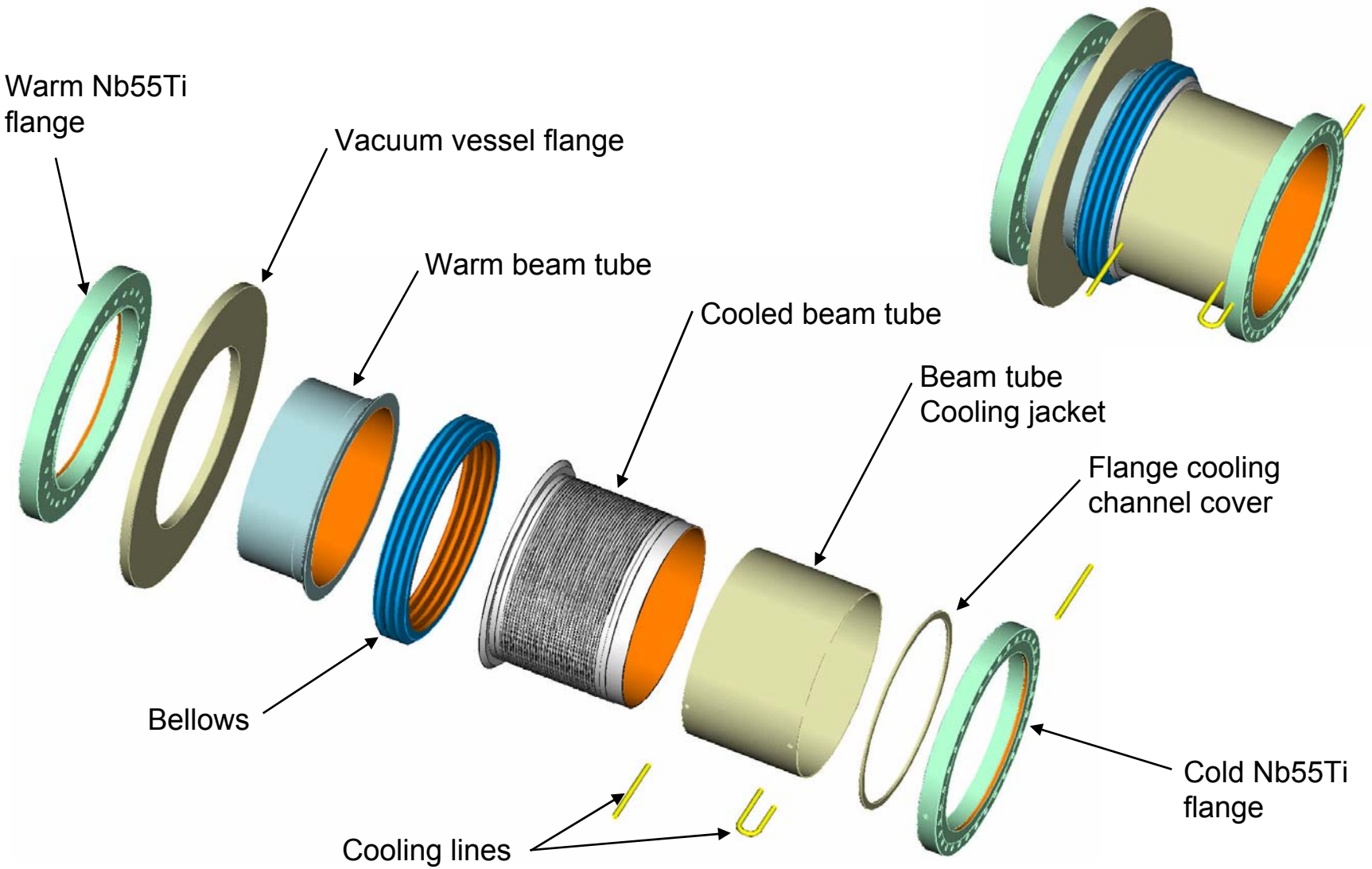


Fourth/Fifth Mode

Helium Vessel Assembly



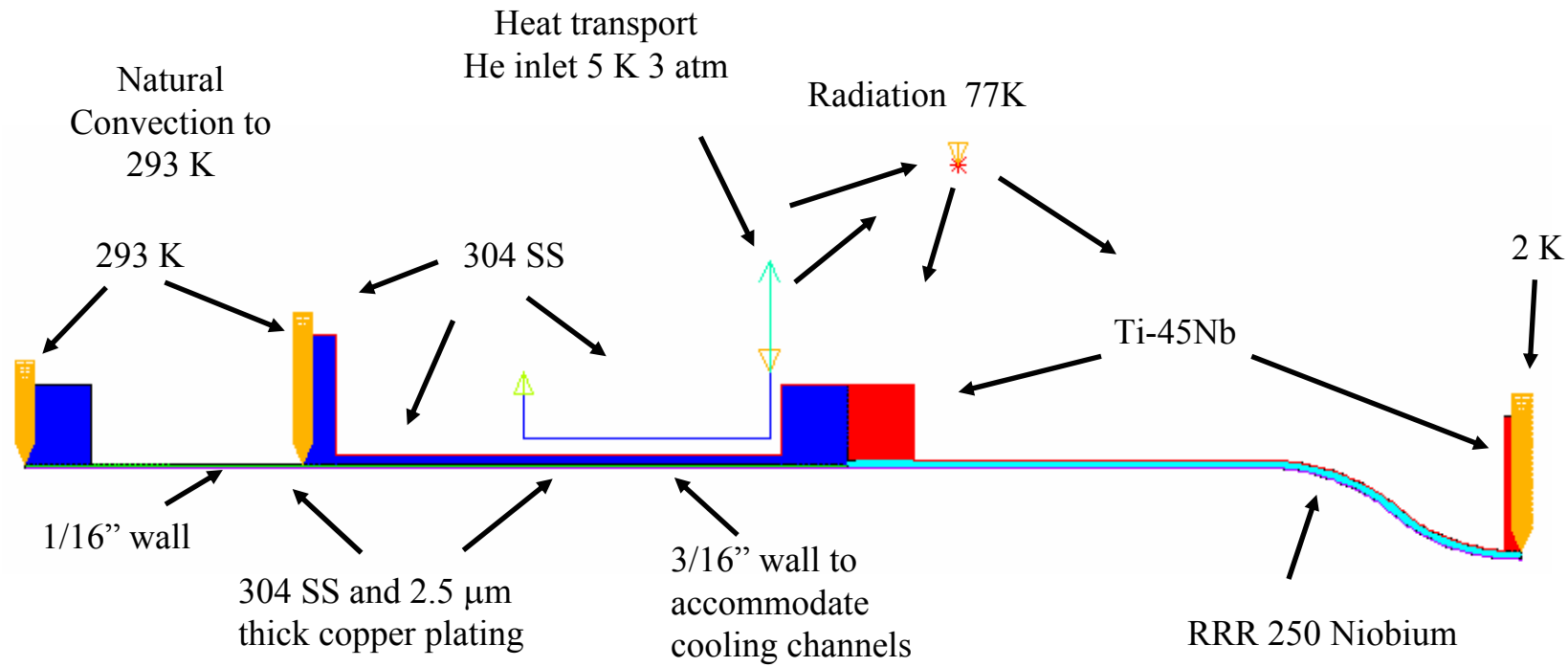
Beam Tube Assembly



Beam Tube Thermal Analysis Model

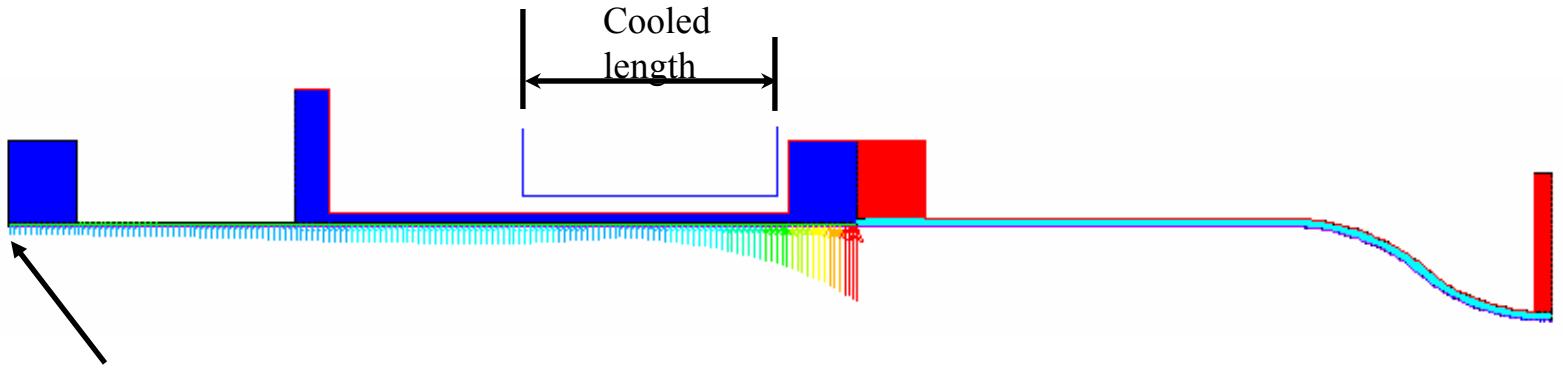
- Skin depth and heat load into copper plating and SS tube vary as a function of temperature and location
  - Copper thickness 2.5 μm properties are OF copper properties (electrical and thermal conductivity)
  - RRR 250 thickness 3 mm
  - 304 SS thickness shown below

Helium channels .09" wide x .063" deep helical pitch of .153" (SNS FPC)
Inlet and outlet edge channels are .25" wide
Inlet and outlet tubes are .25" OD x .049" wall

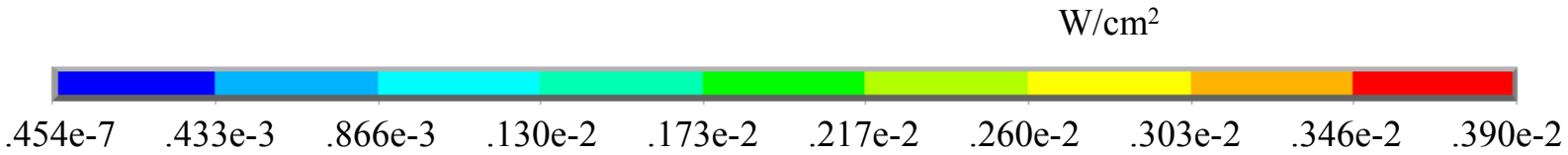


Beam Tube RF power loads at temperature

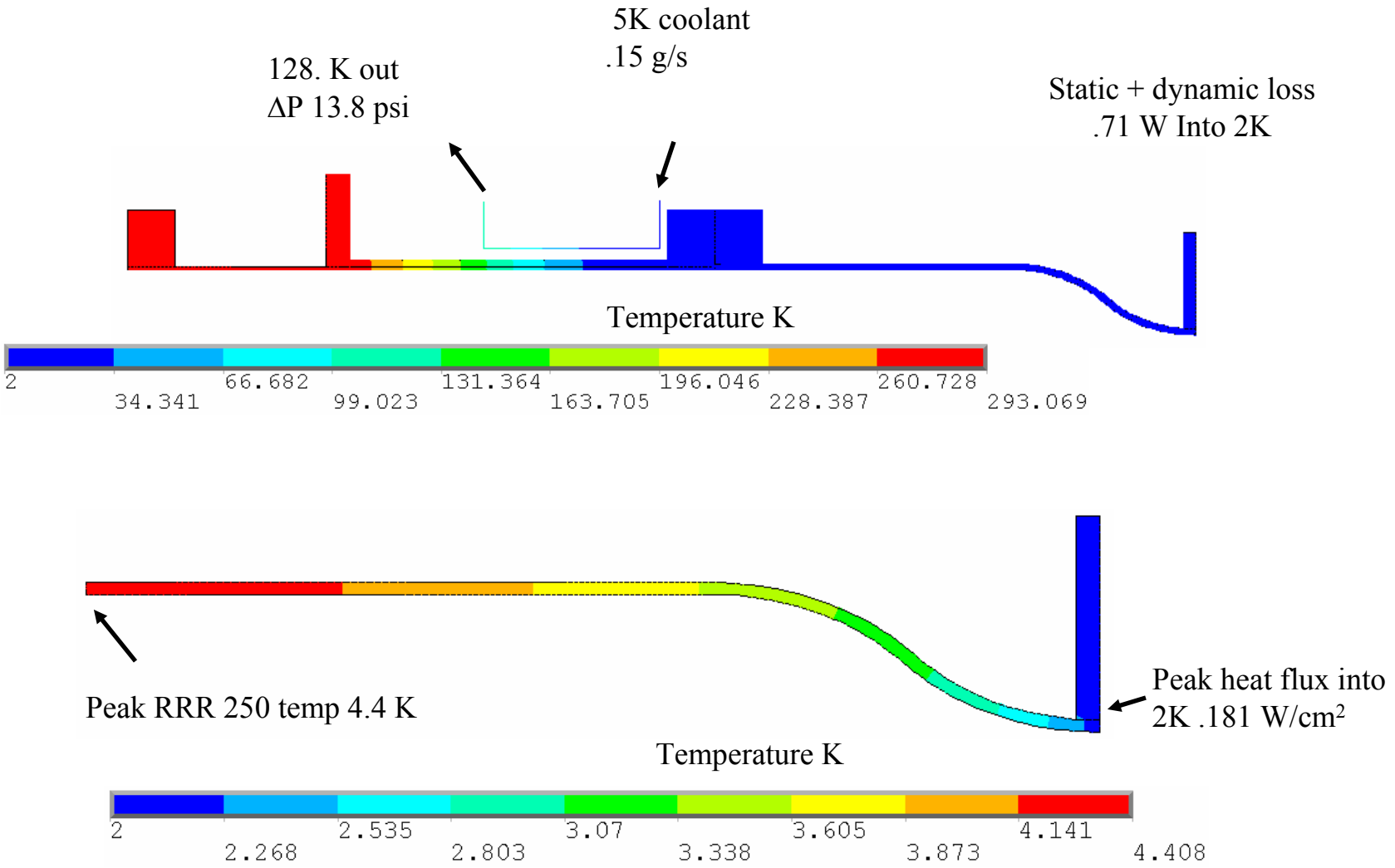
He inlet temp 5K
He inlet Pres = 3 atm
He flow rate .15 g/s
Cooled length 3.71”
Copper plating thickness 2.5 μm



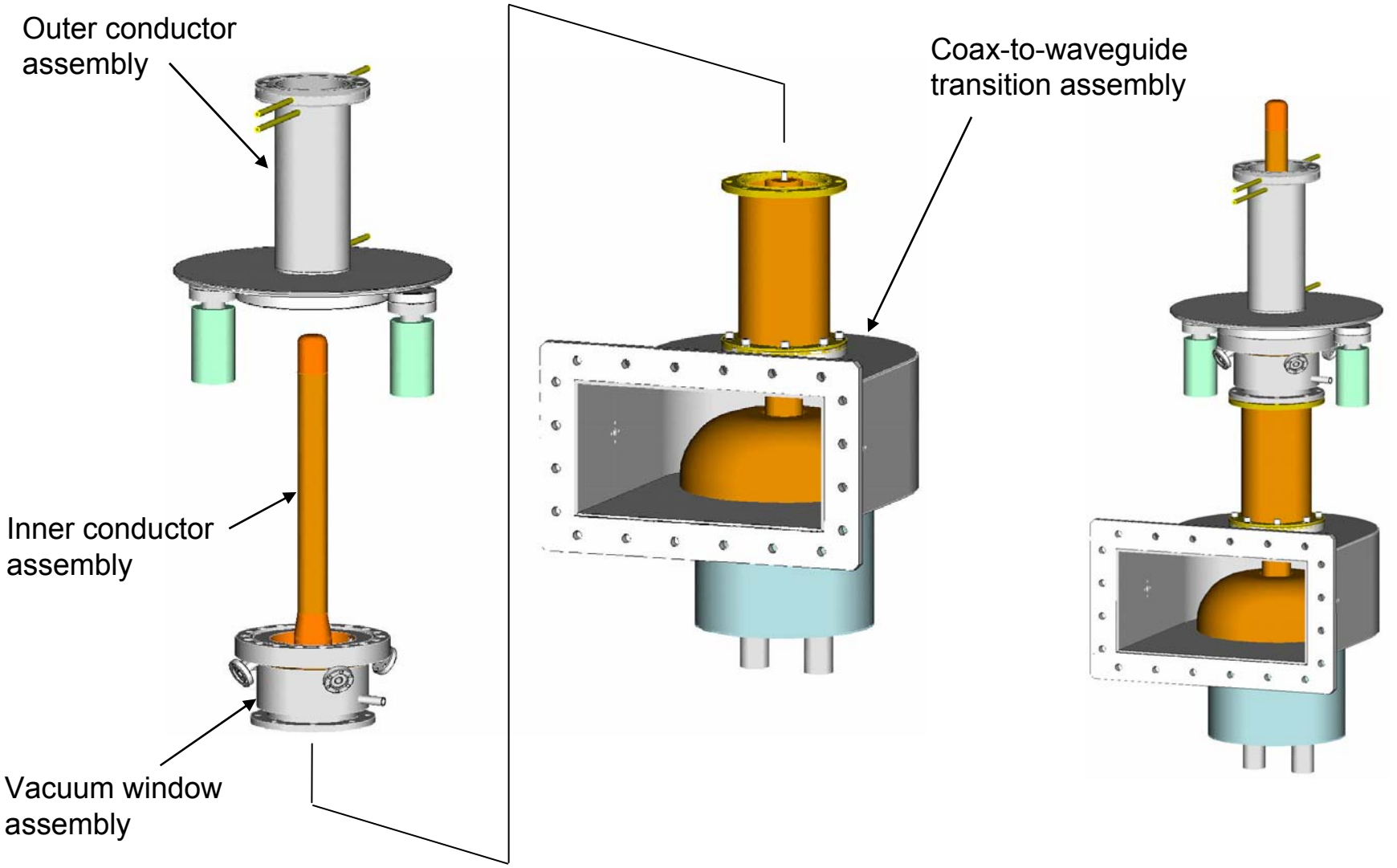
92% of field level at location of pointer is from HOM (26.5A/m)
Heat load from HOM .422 e-3 W/cm^2



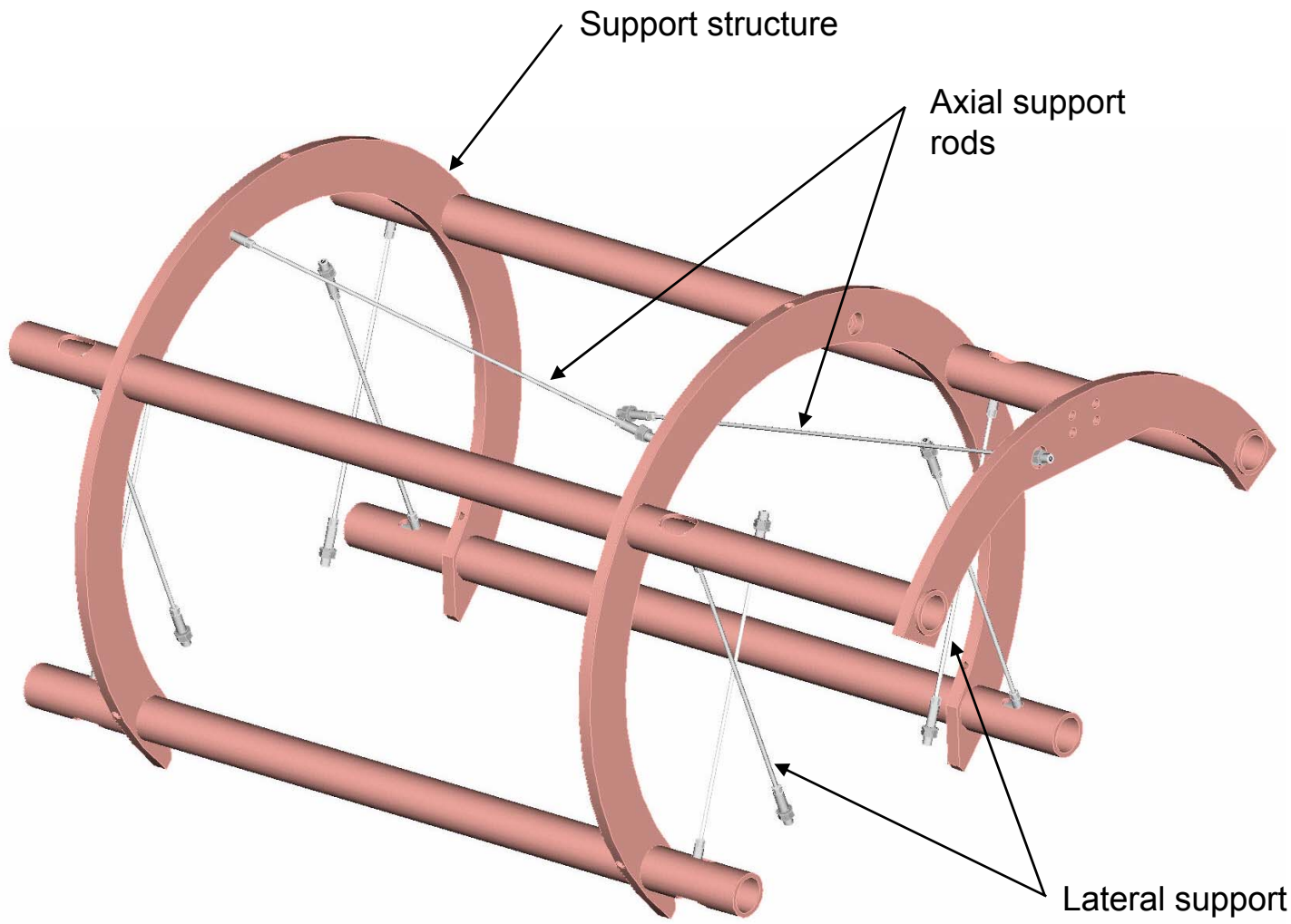
Thermal Analysis Results – with 5K cooling



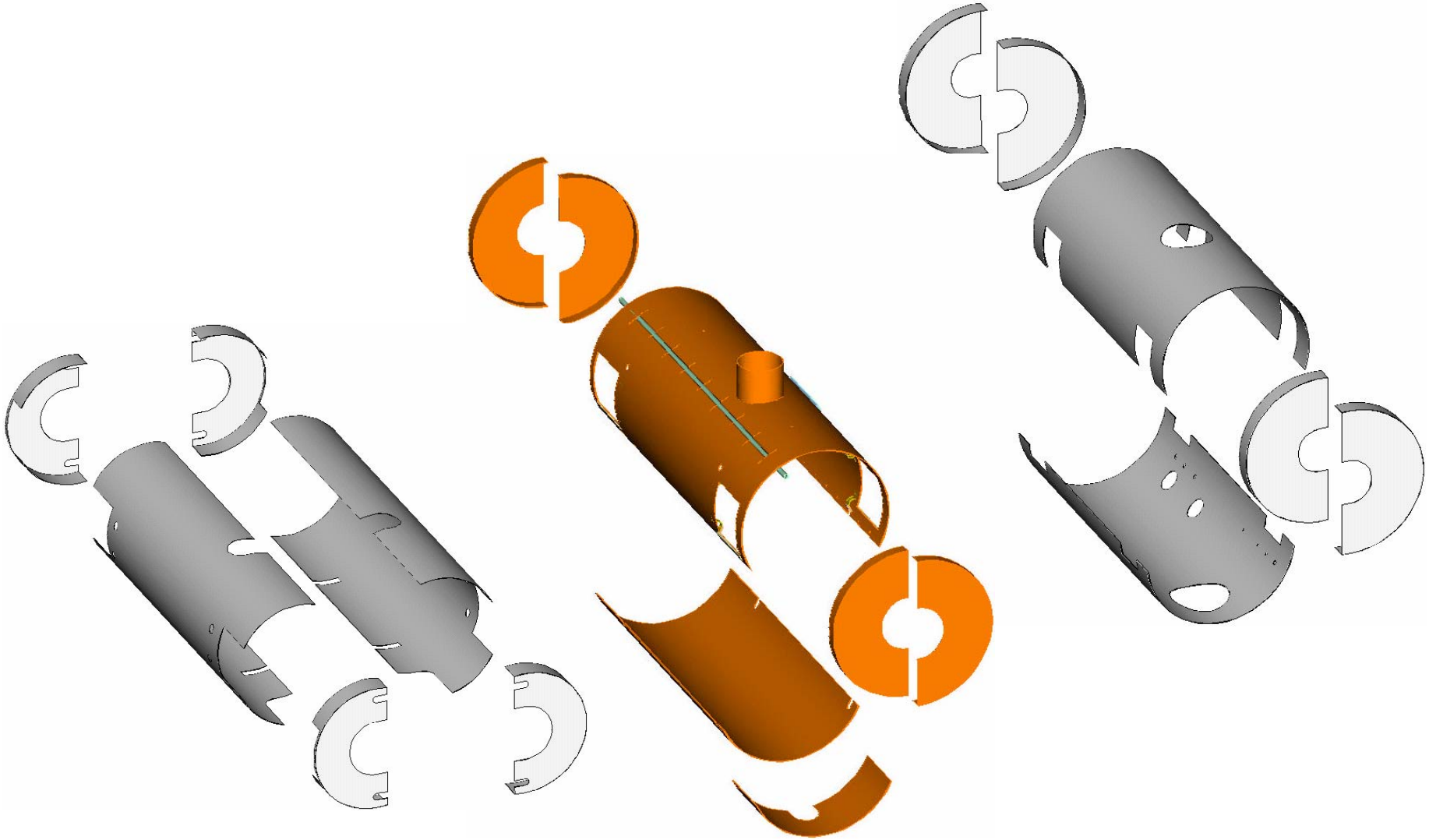
Fundamental Power Coupler



Space Frame with Support Rods



Magnetic and Thermal Shielding

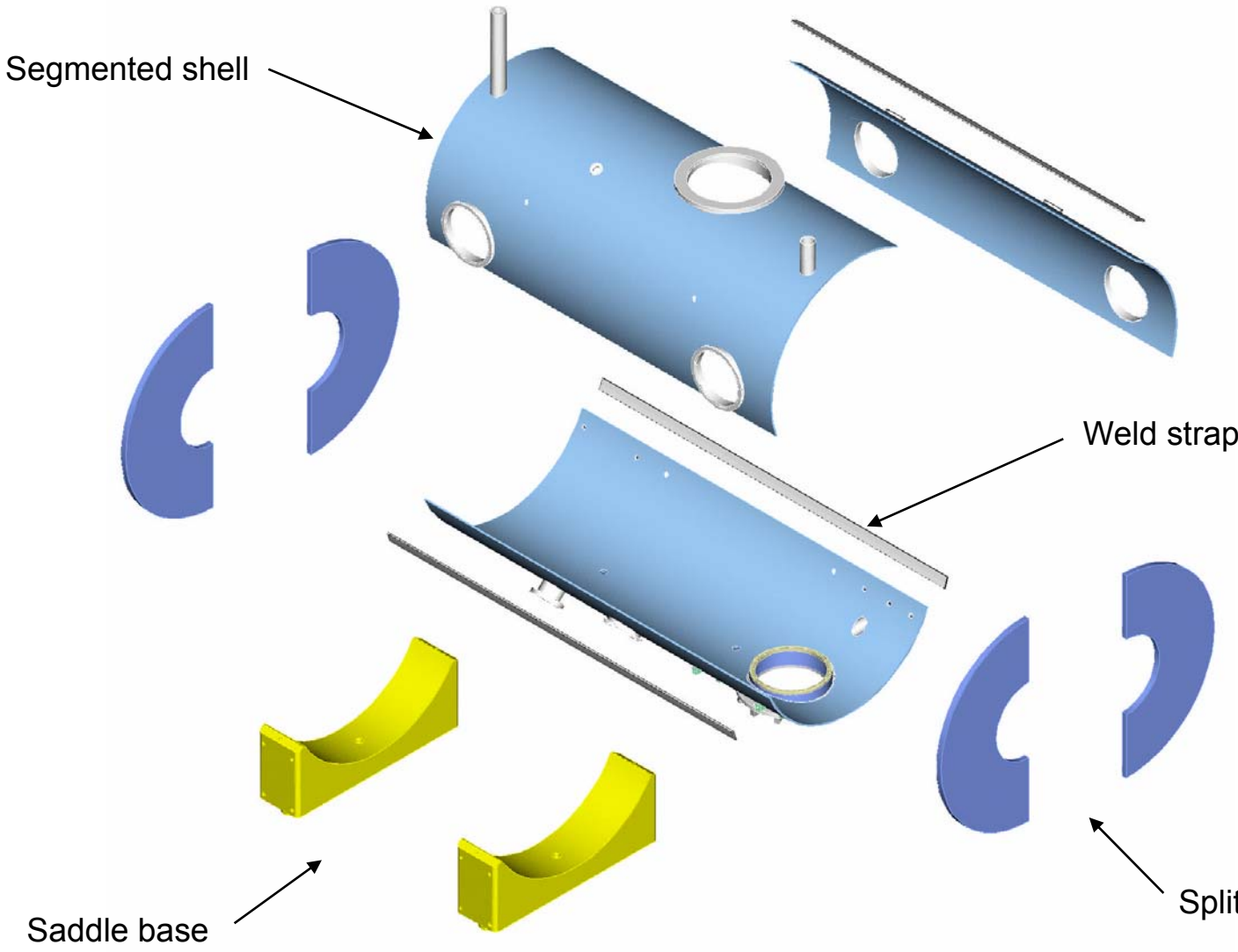


Inner (cold) magnetic shield

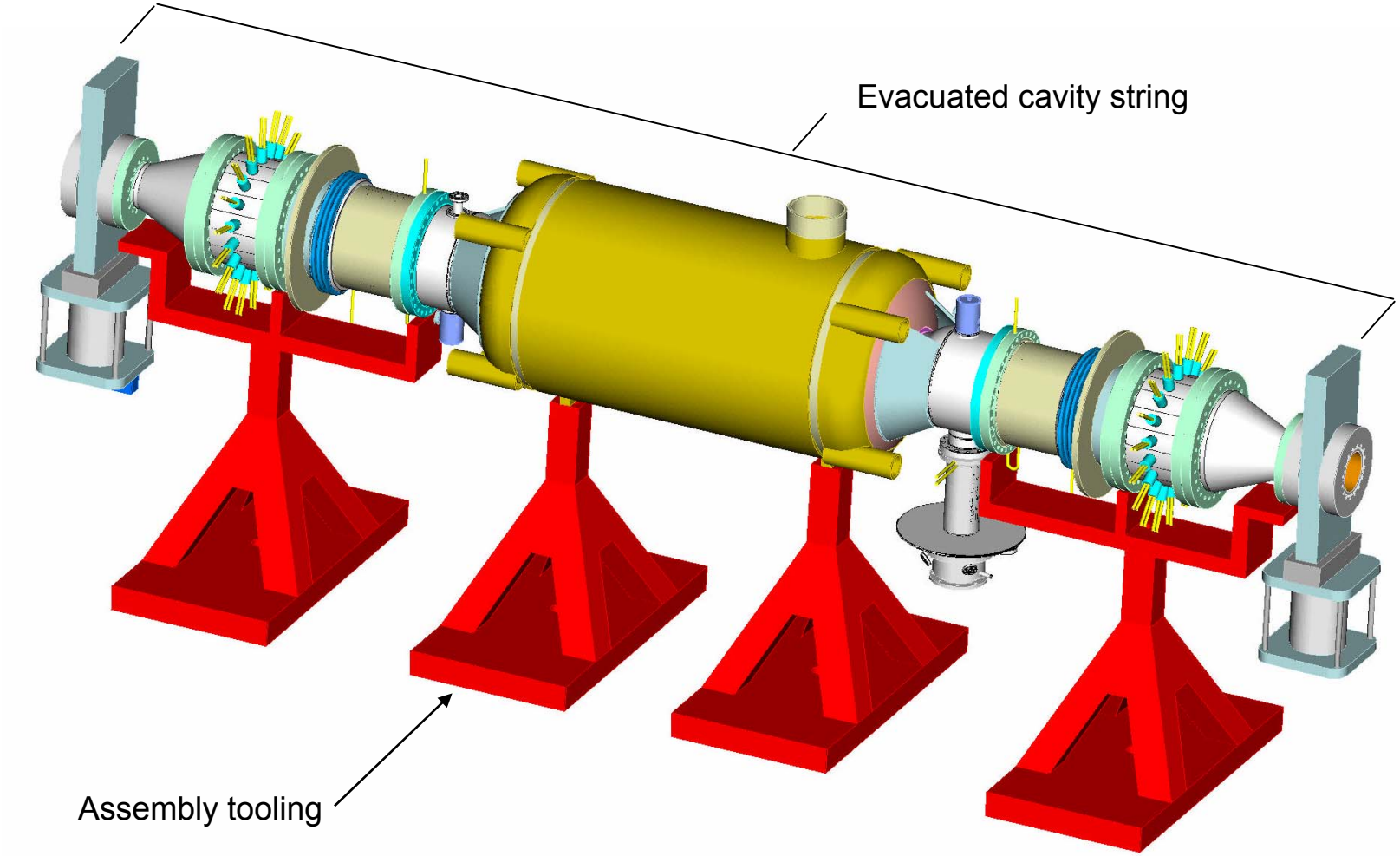
Thermal shield

Outer (warm) magnetic shield

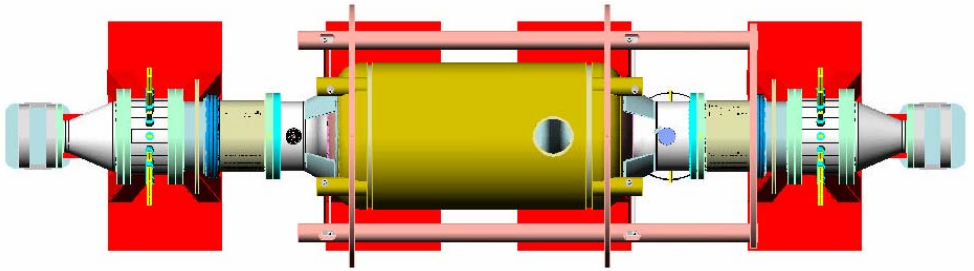
Vacuum Vessel Components

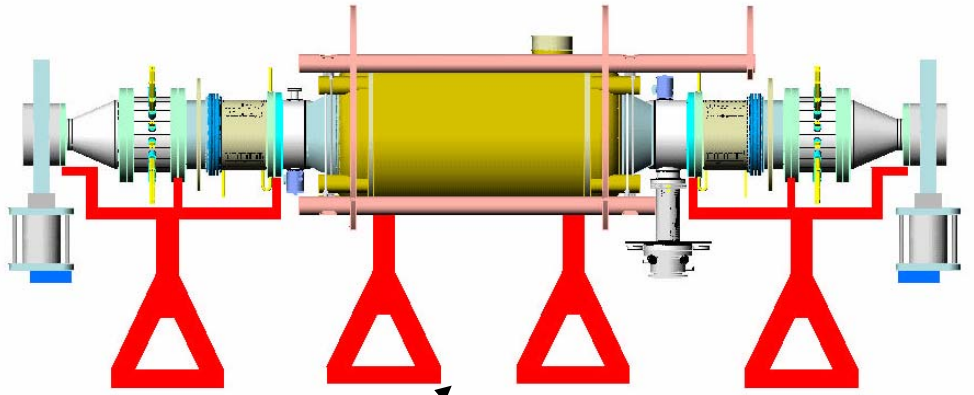


Cavity String Assembly on Support Posts



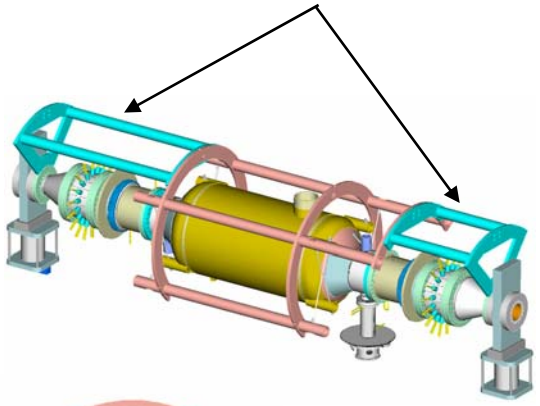
Cavity String in Space Frame on Support Posts

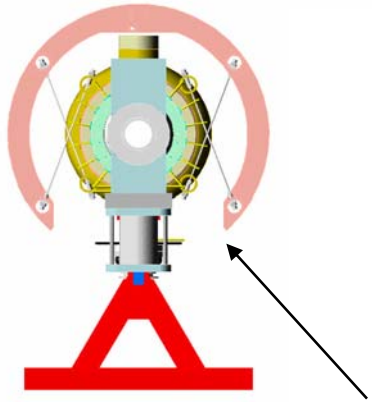




Assembly tooling support posts

Cryomodule integration tooling illustrated here can also be used for shipping string to BNL after cavity BCP treatment

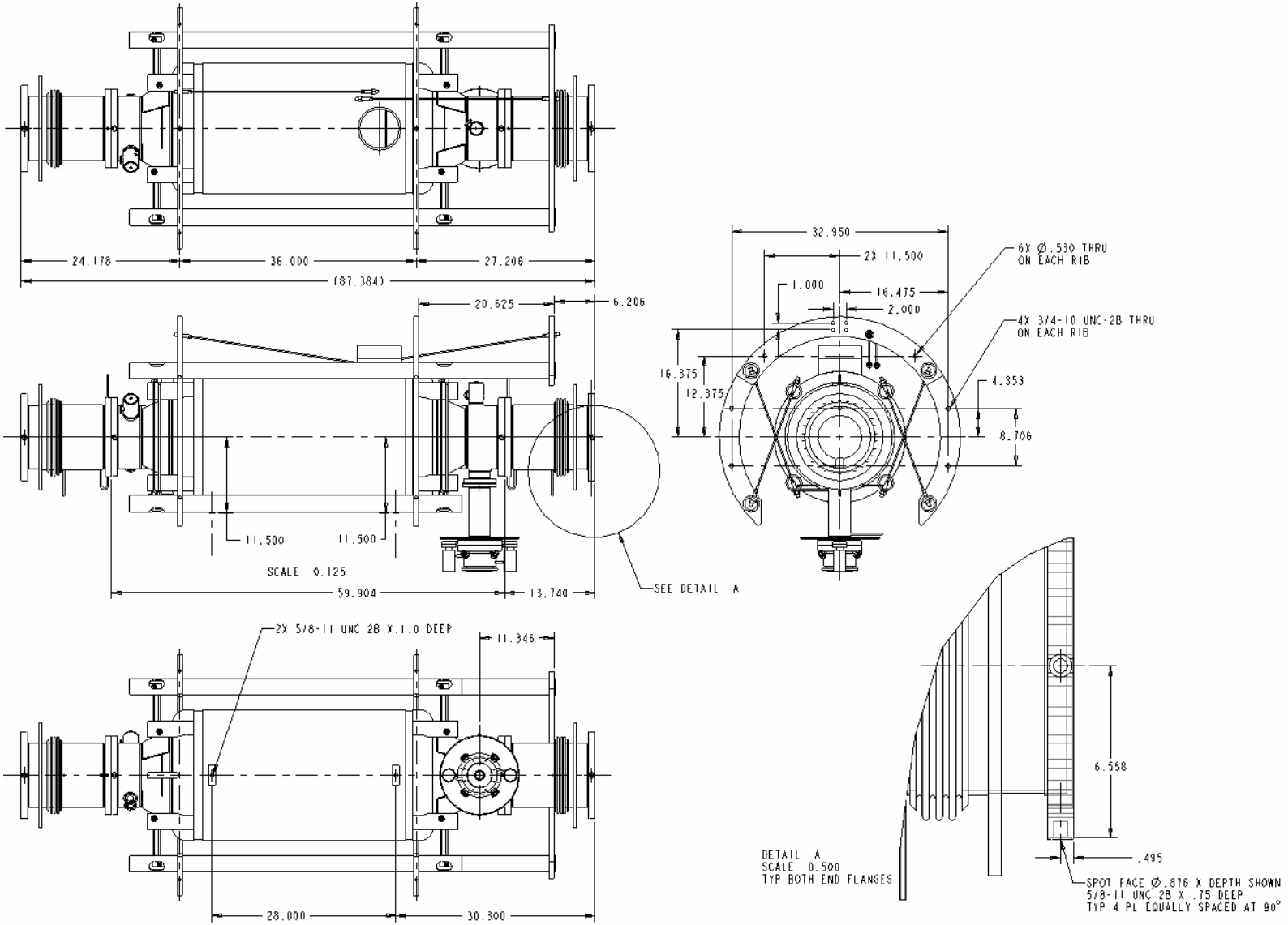




Open frame design allows axial and top-down integration

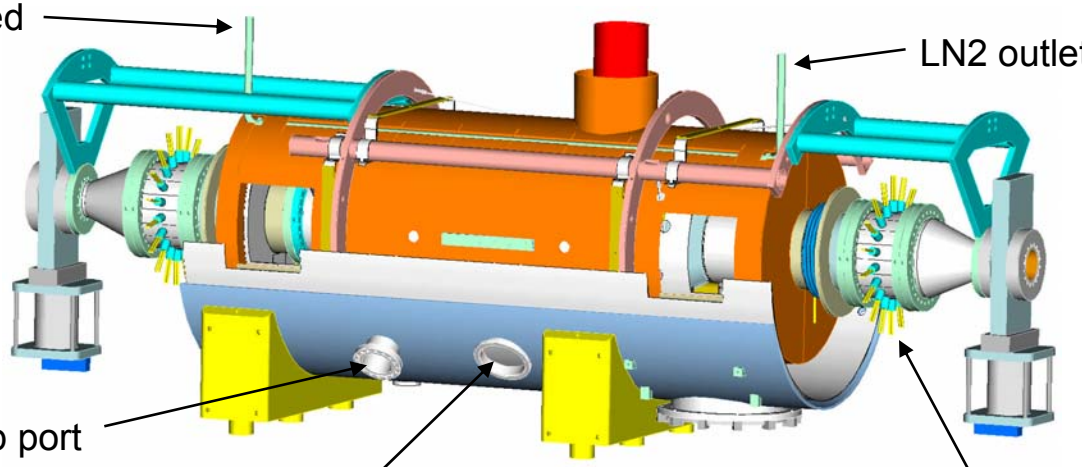
Cavity String Tooling Interfaces

e-Cooling High β Cavity & Cryomodule

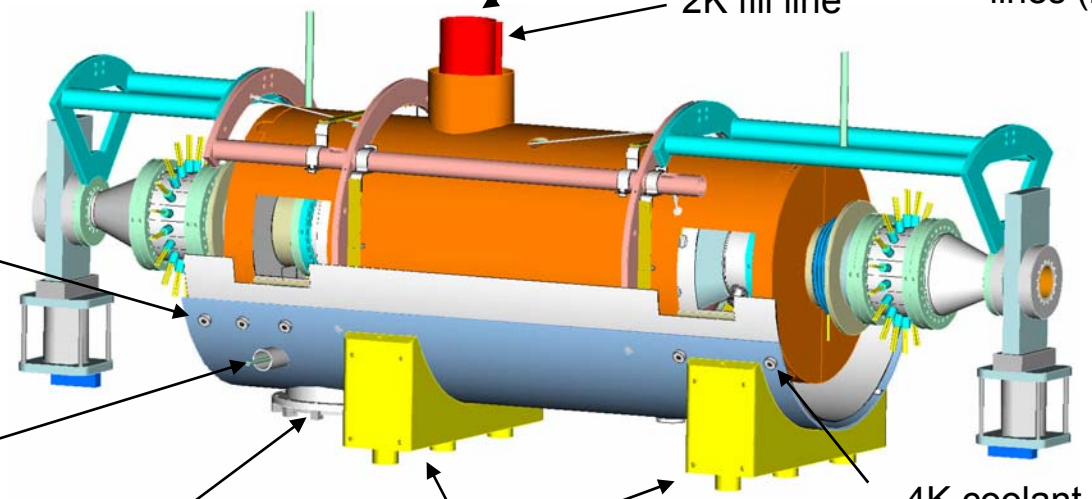


Cryomodule Interface Locations

Right side view



Left side view



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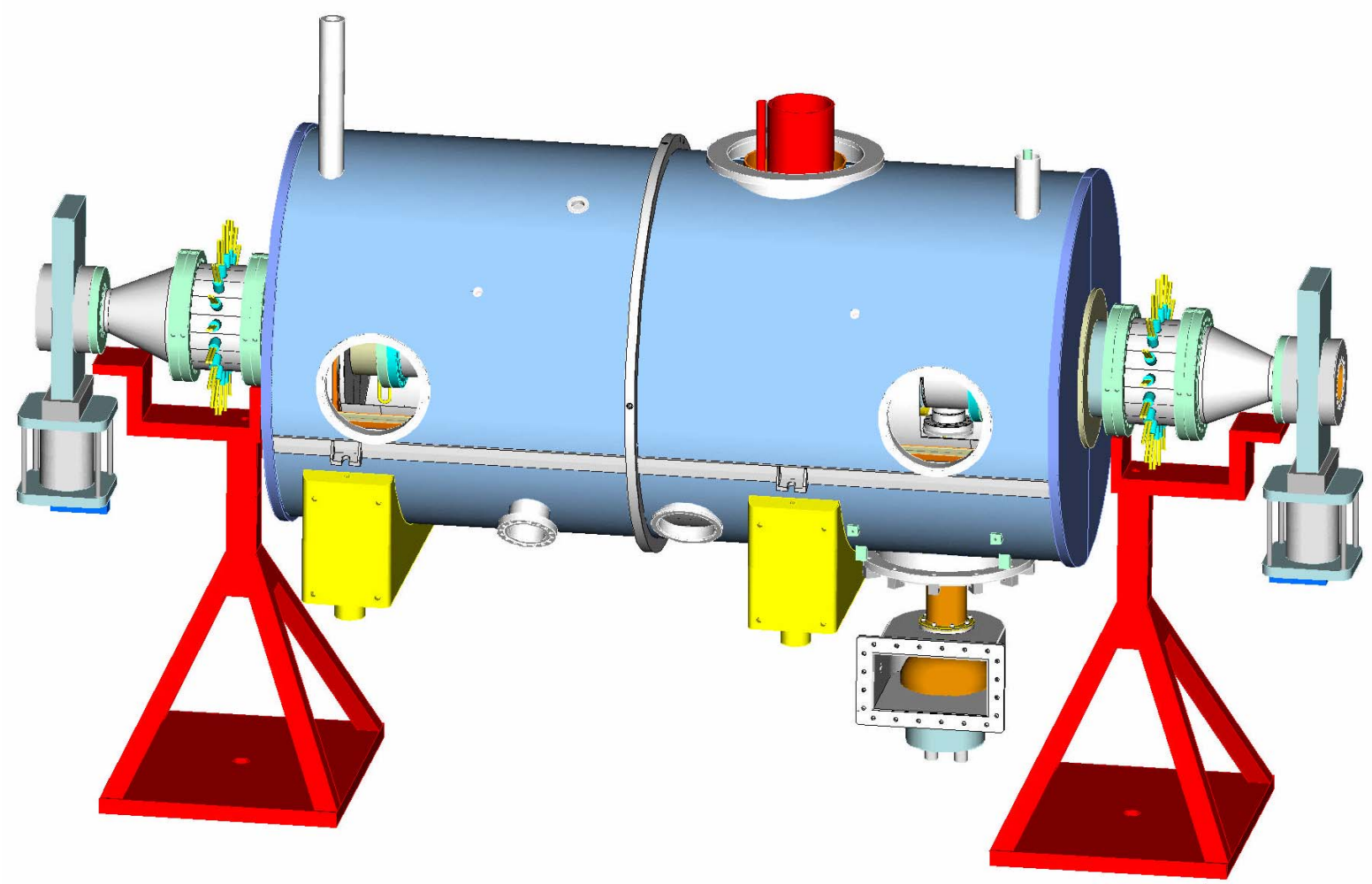

Summary

- **Cold model design and fabrication of two cavities complete**
- **Cavity Tuning fixture design and fabrication complete**
- **Cold model tuning to begin next week**
- **Cryomodule design complete**
  - **–RF, thermal, modal finite element analysis performed**
  - **–Manufacturing process well planned**
  - **–Design Leverages SNS tooling**
  - **–Minimal tooling requirements for integration at BNL**
- **Manufacture of Niobium cavity underway**
  - **–Design and fabrication of forming tools and machining fixtures is complete**
  - **–Niobium End / Mid cells hydroformed**
- **Engineering design and manufacturing skills in place**