CeC Engineering

Jean Clifford Brutus

ICFA Mini-Workshop CeC

July 25, 2019

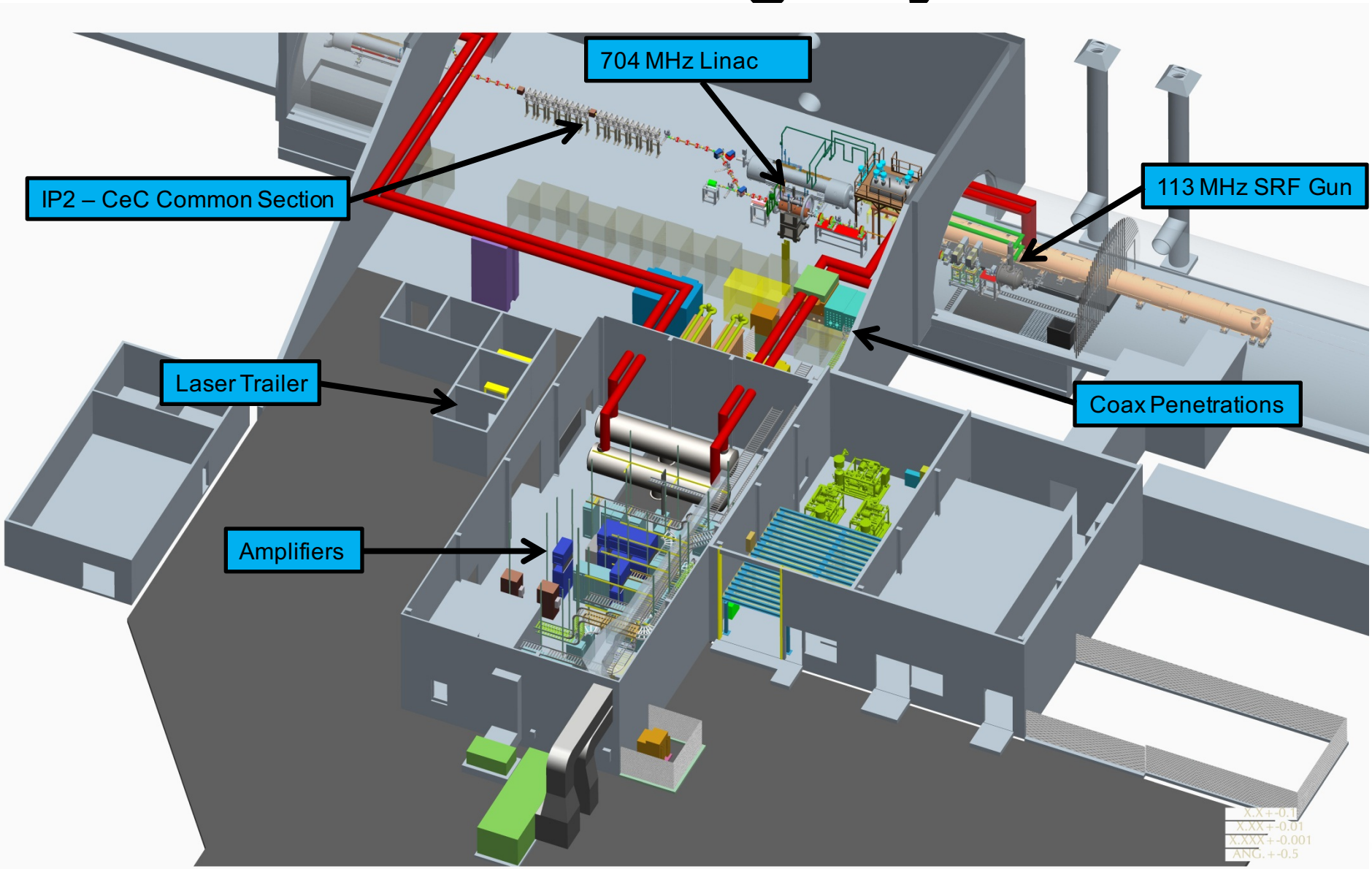
BROOKHAVEN NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

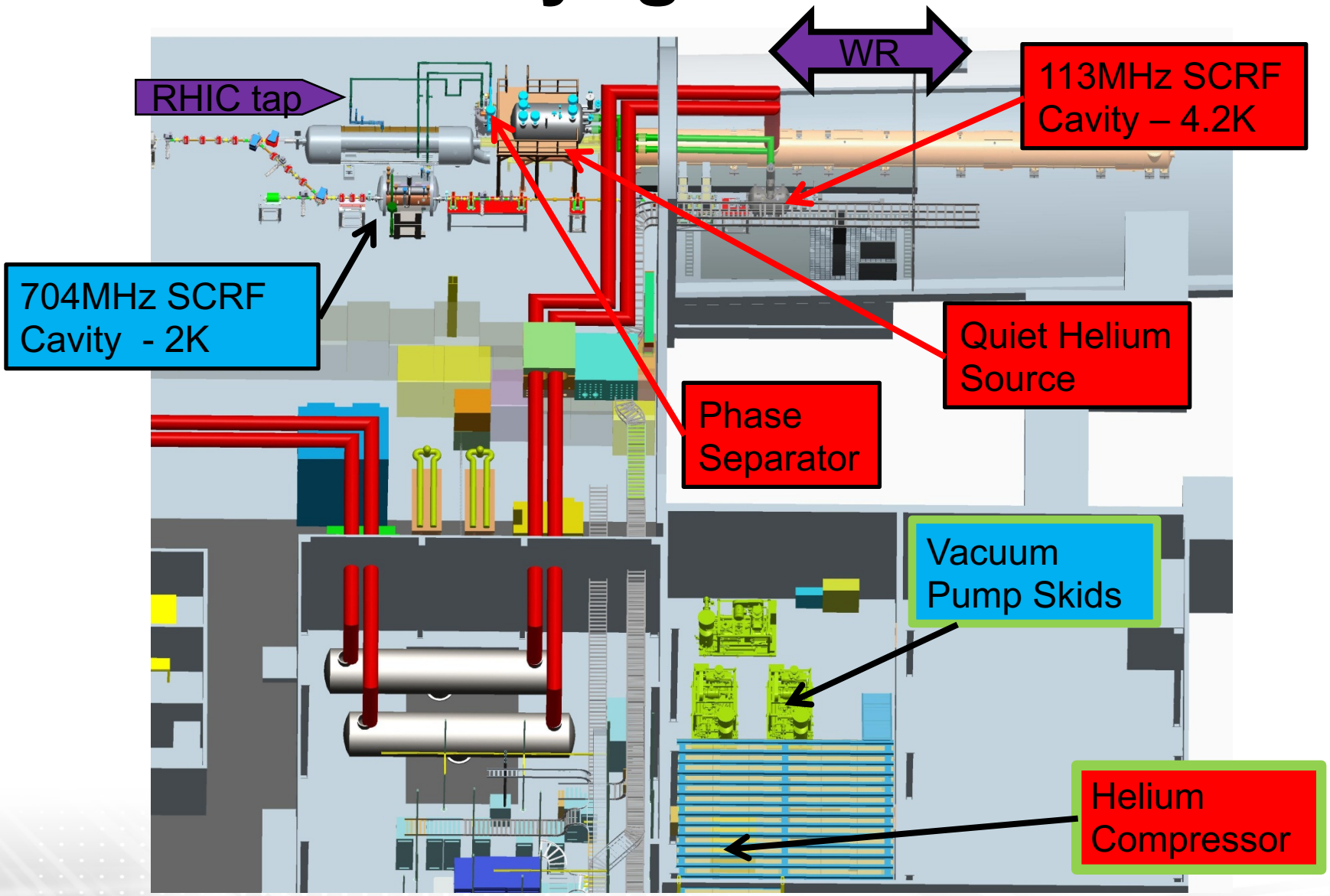
Outline

- 1002 Building Layout
- CeC Cryogenic Model
- CeC PoP Beam line layout
- CeC PCA Beam line layout
- 113 MHz SRF Gun, FPC, Cathode Stalk and Cathode Injection Design
- 500 MHz Dual Buncher Cavities
- 704 MHz 5-Cell LINAC Design, Components and Repair
- 45^{o} Dipole Modification
- PCA Water cooled Solenoids
- Summary

1002 Building Layout

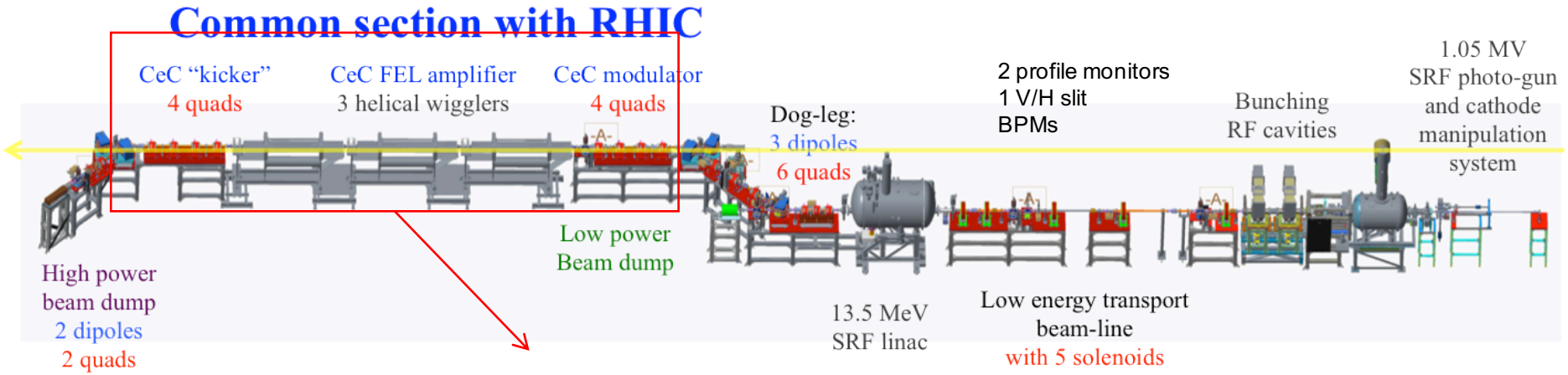


CeC Cryogenics Model

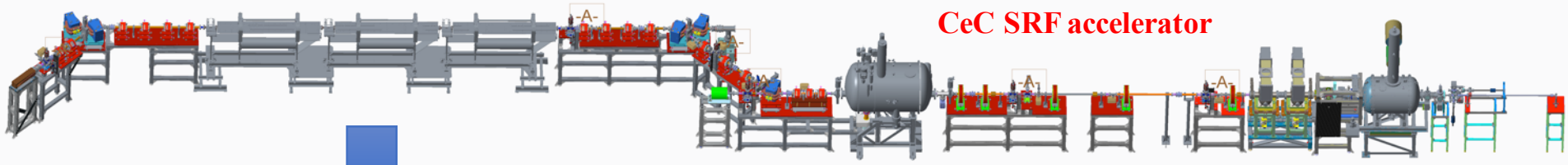


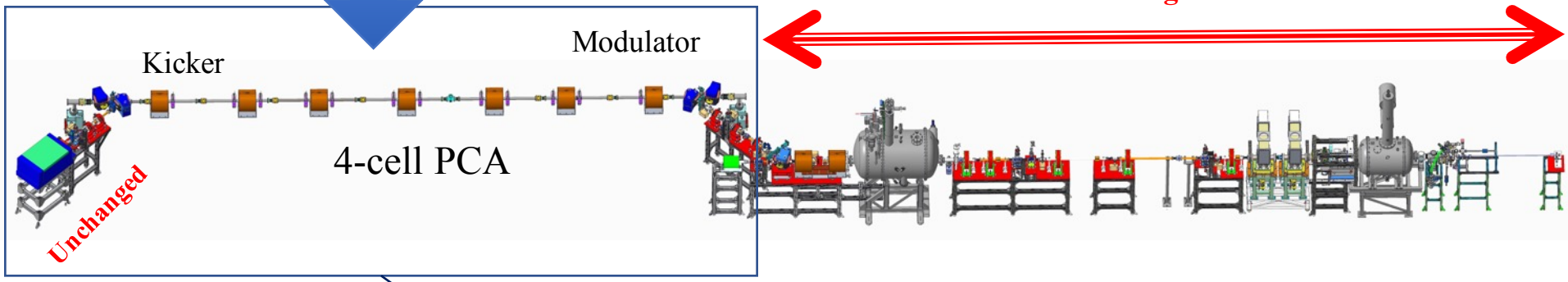
- 20 Torr of vacuum heater is to warm up 2k gas from 704 and LeREC. Need to warm gas before it gets to vacuum pumps.
- Vacuum pump skids are needed to get from 4k to 2K.

CeC PoP Beam Line

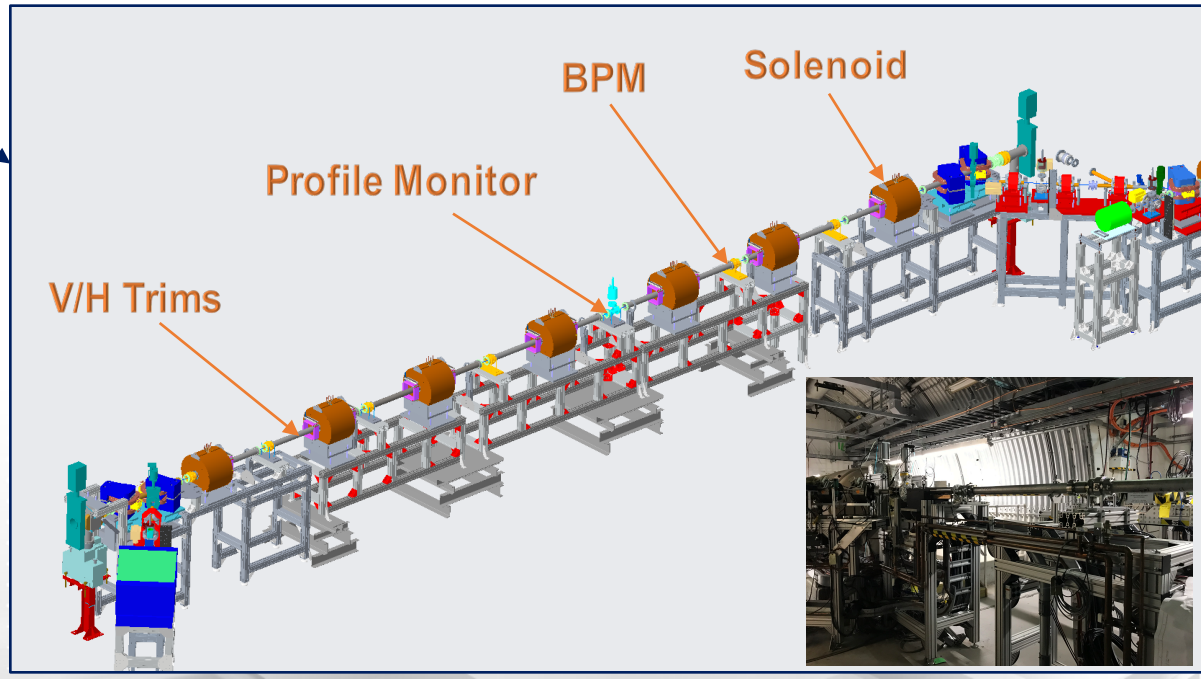


CeC PCA Beam Line



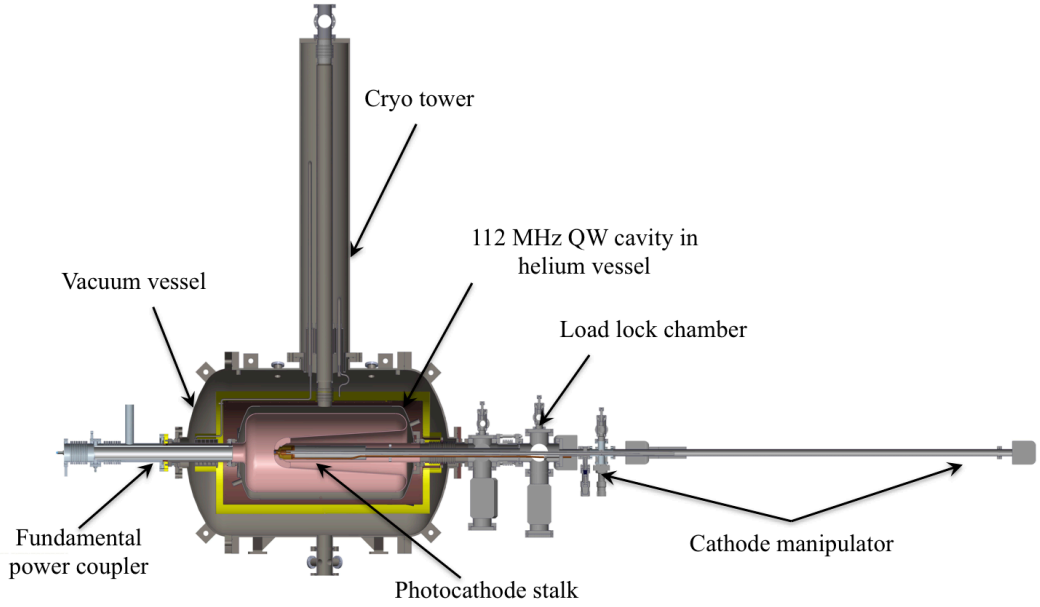


1) New water cooled solenoids
2) Dipoles gap modification
3) New Stands
4) New Profile Monitor
5) New BPM housing and buttons
6) 6 pairs of corrector magnets
7) New Y vacuum chamber for dipoles
8) New NEG coated beam line vacuum chambers
9) New stand supports for magnets
10) New RF shielded bellows
11) New conical transitions to RHIC
12) New beam line supports
13) Water Manifold for Solenoids



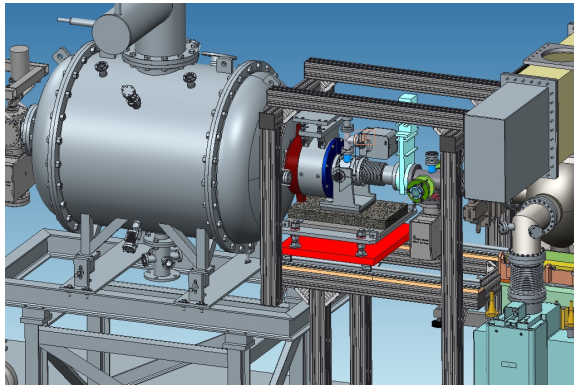
U.S. DEPARTMENT OF ENERGY

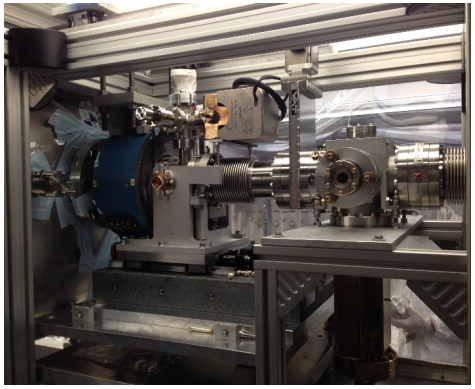
113 MHz SRF Gun

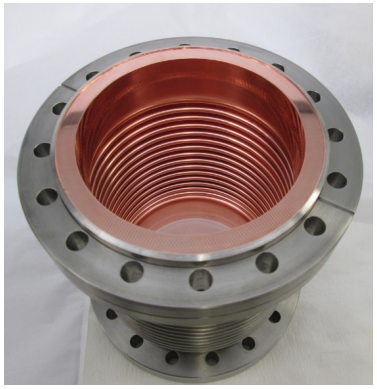


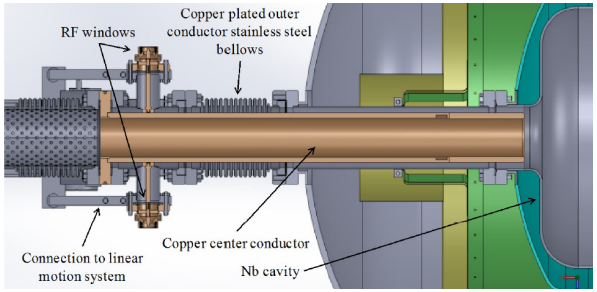
- Quarter wave design
- Operates at 4.2ºK
- Cathode is at room temperature
- Stalk serves as field pick-up
- Manual coarse tuners
- FPC serves as fine tuner
- Maximal CW voltage 1.25 MV
- Maximal charge 10.7 nC

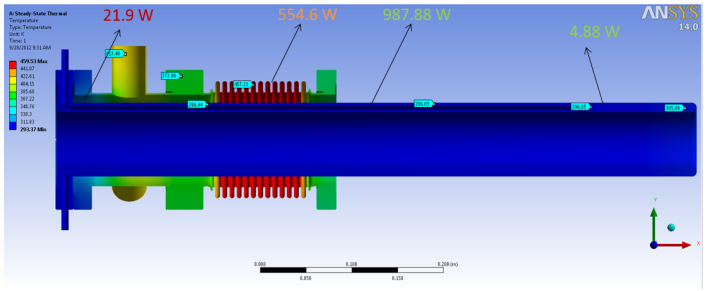
113 MHz Fundamental Power Coupler

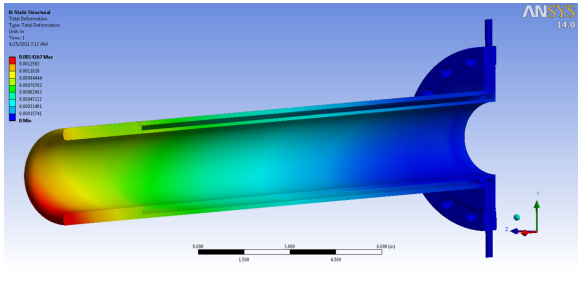








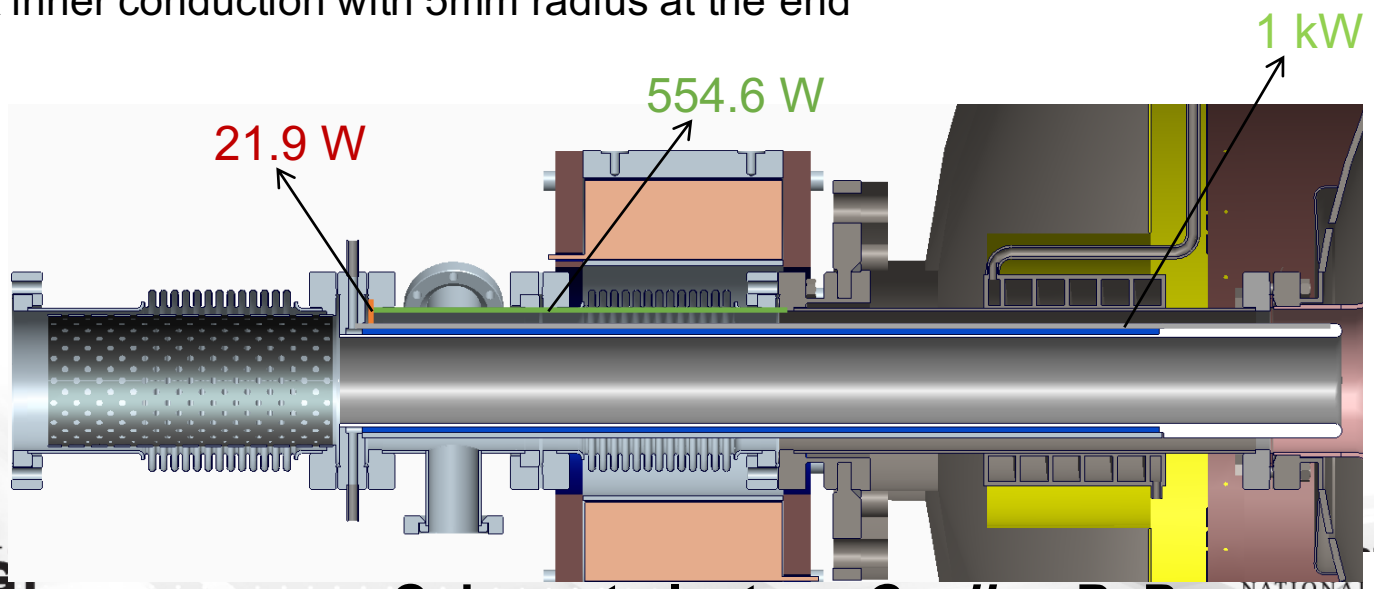




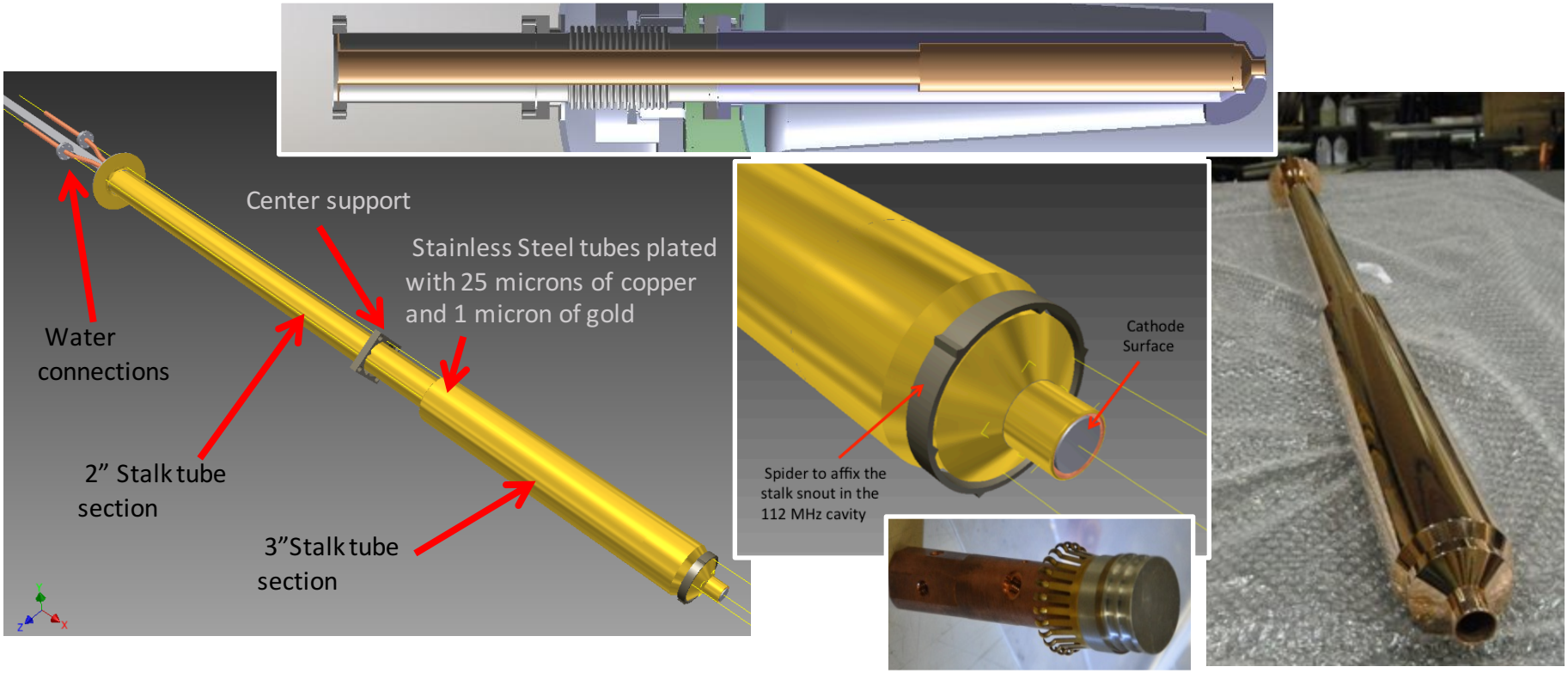
- The fundamental power coupler(FPC) is a coaxial-type coupler similar to one used in the Naval Postgraduate School (NPS) gun.
- The FPC is attached to the beam exit port of the SRF gun.
- Its hollow center conductor, or coupling tube, allows the passage of the laser and electron beams.
- The cavity's resonant frequency can be tuned by adjusting the penetration of the coupling tube as well as adjust the coupling strength.
- The FPC is gold plated to reduce radiation heat load into 4.2K niobium cavity.

113 MHz Fundamental Power Coupler

- Cooling of inner and outer conductor for heat load shown below
- FPC Inner conductor is Water Cooled
- FPC Outer conductor is forced Air Cooled
- Tuning range 4cm with special bellows allowing ± .984” travel from Ameriflex
- Position Resolution 500nm
- Copper plate (25 microns) ID of outer conductor (including formed bellows and antenna)
- Copper plate (25 microns) OD of inner conductor
- 1 cm thick inner conduction with 5mm radius at the end

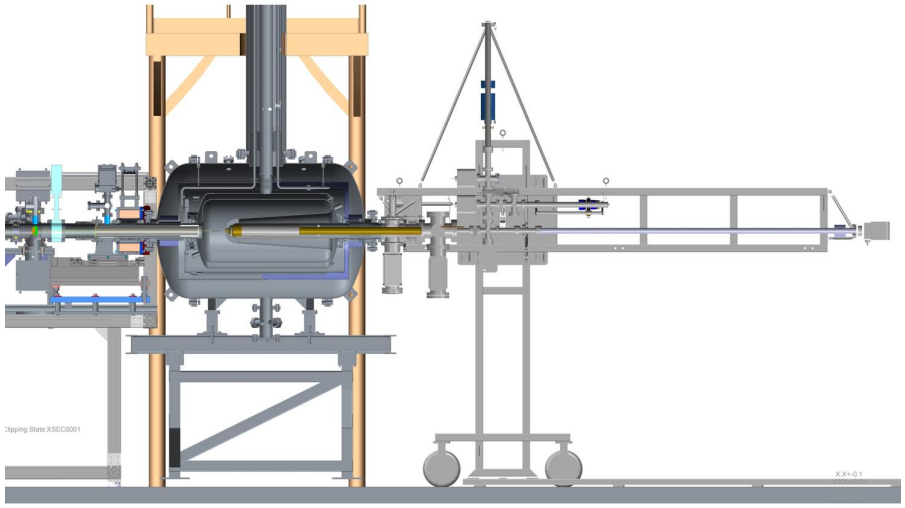


113 MHz RF Cathode Stalk

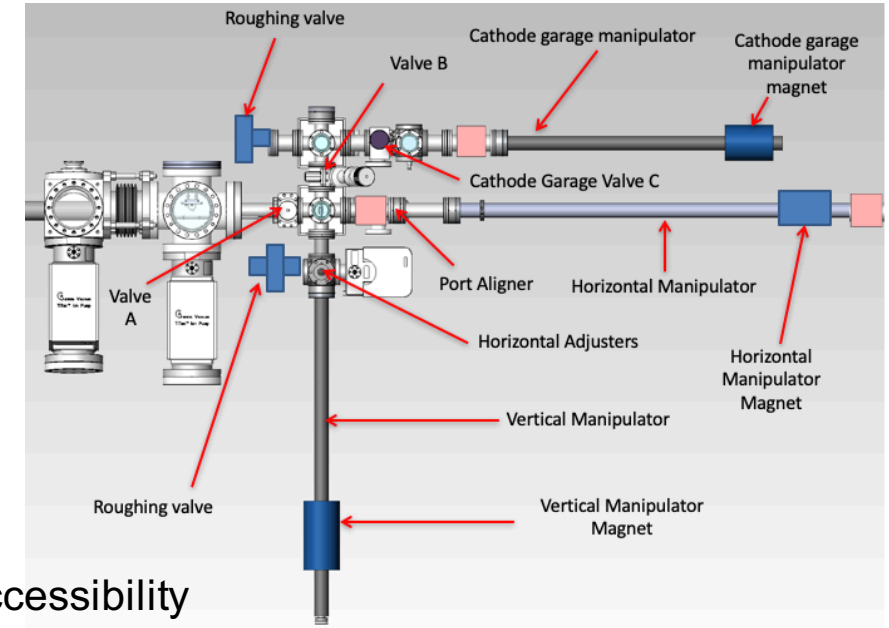


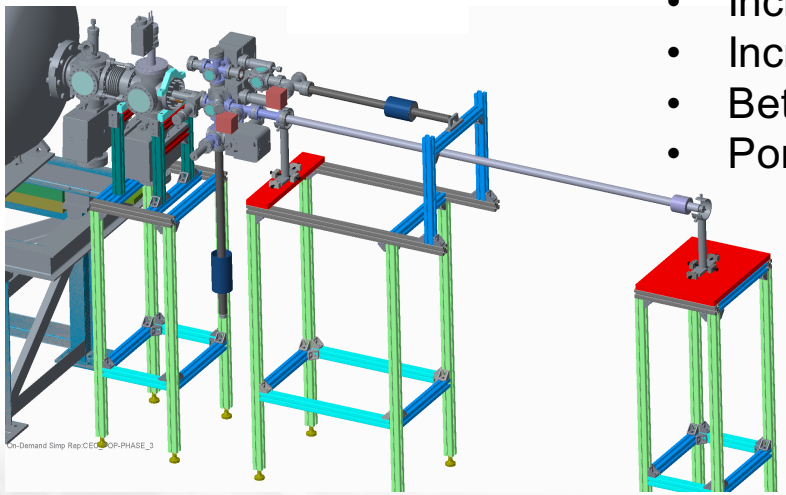
- The cathode stalk is a hollow center conductor of the coaxial line formed by the stalk and the cavity.
- The stalk is shorted at one end and is approximately half wavelength long. It will be permanently installed in the gun.
- A step at l/4 from the short creates a quarter-wave impedance transformer and reduces RF losses in the stalk from ~65 W to ~25 W.
- The gold plating is aimed to reduce radiation heat load from the RT stalk to the cold (4.2 K) niobium.
- A small cathode puck is inserted inside the stalk and can be replaced when necessary with a new one.

113 MHz Cathode Injection System



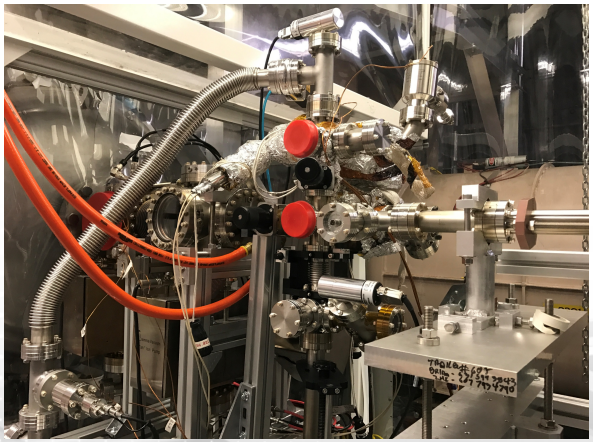
Original Design

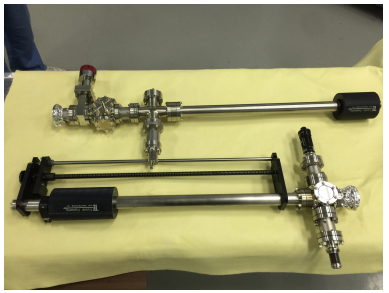


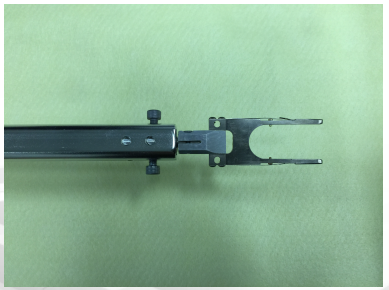


New Design

- Increase accessibility
- Increase stability
- Better pumping
- Port aligner for cathode alignment

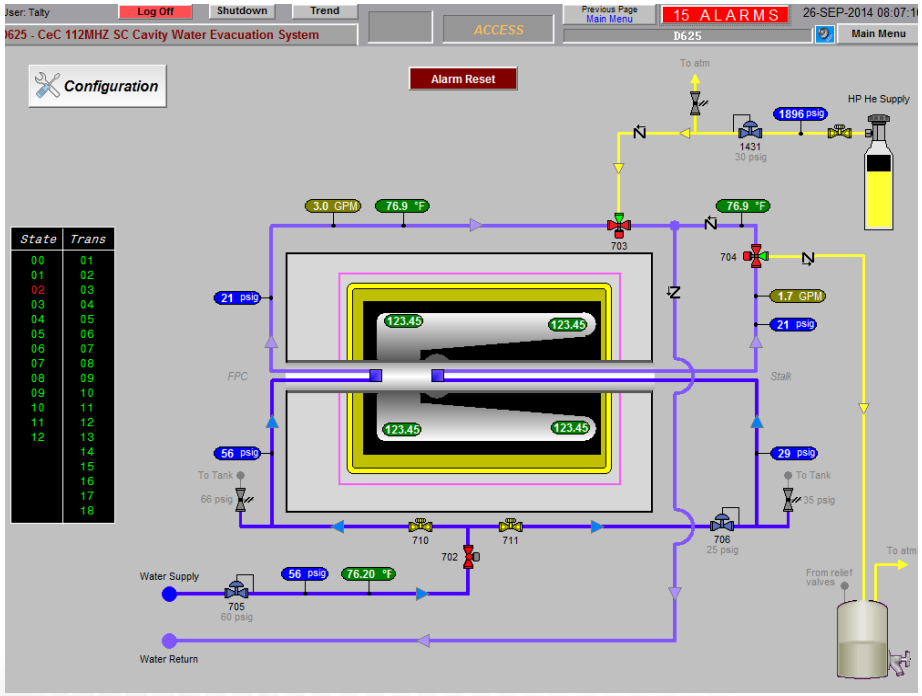


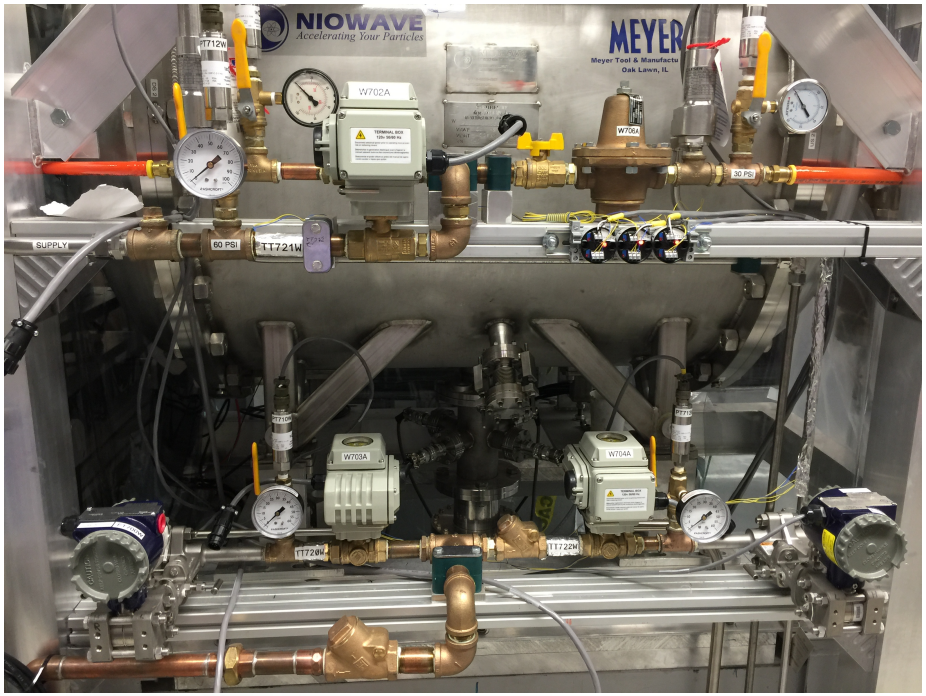




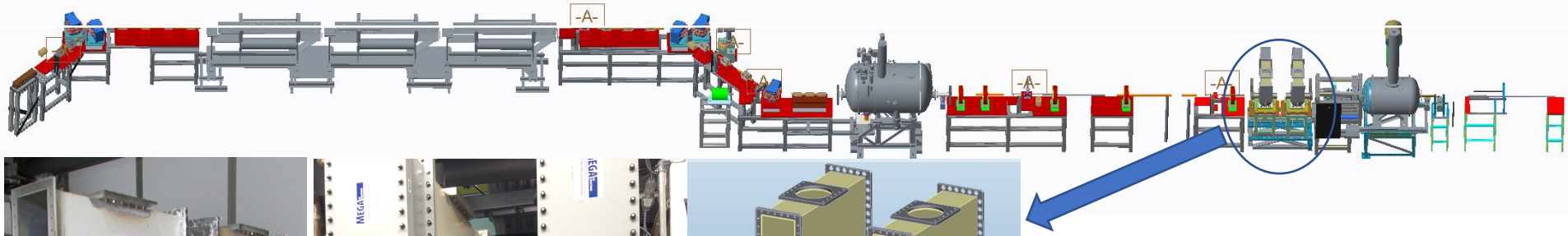
113 MHz Water Interlock System

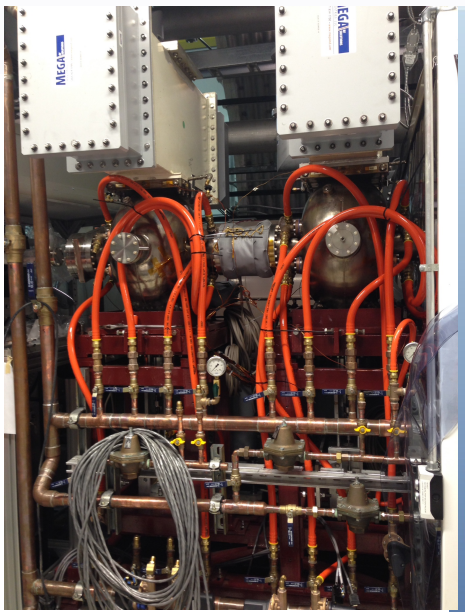
- Prevent catastrophic damage from water freezing
- Fully automated system
- Helium bottle
- Monitor: temp, flow and pressure
- Blows down water in FPC and Cathode Stalk

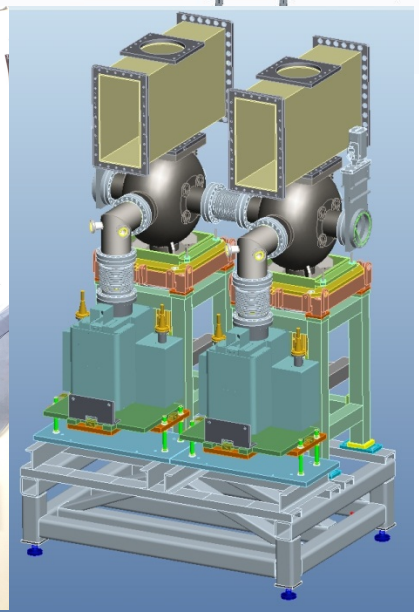




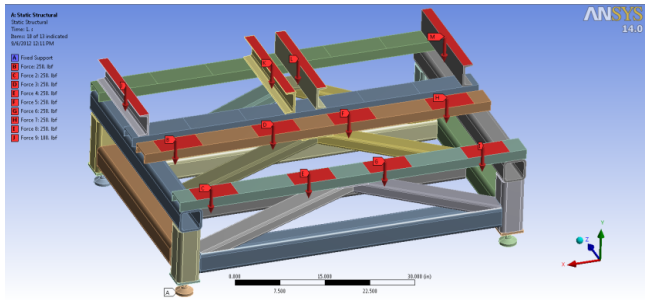
500MHz Buncher Cavity System



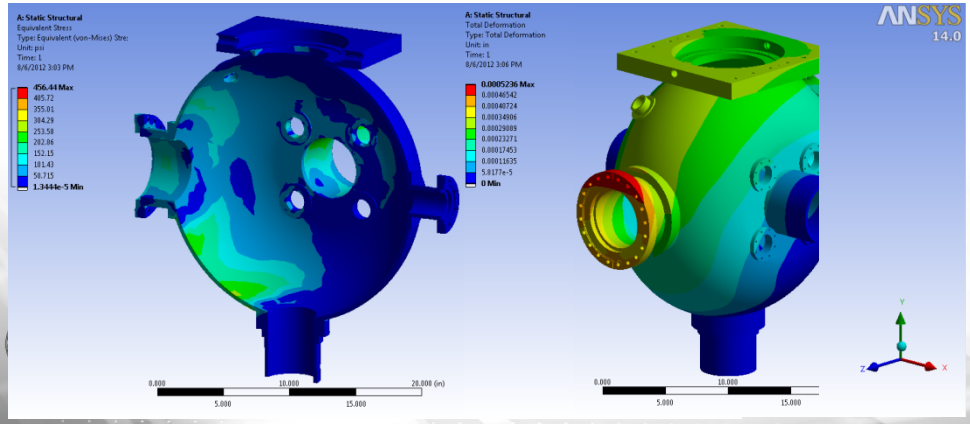


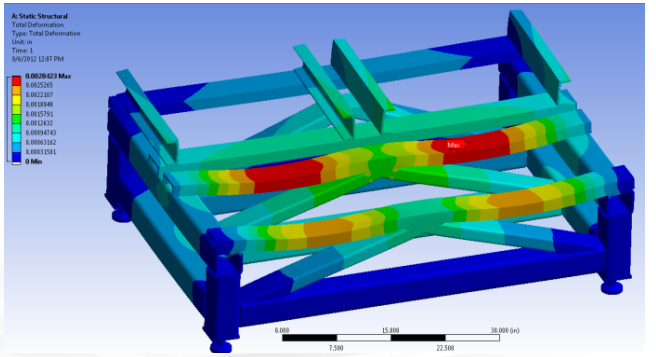


- Stress 6547.2 PSI
- Deflection 0.0028”



- Stress 456.44 PSI
- Deflection 0.0005”





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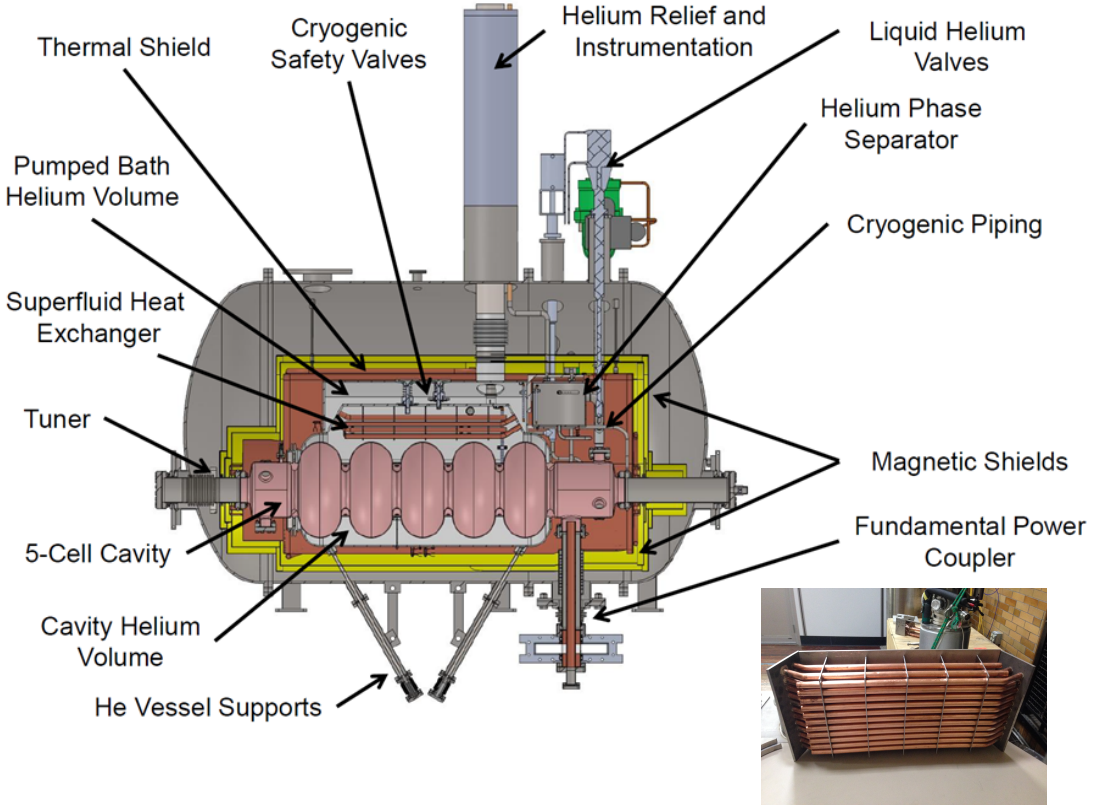
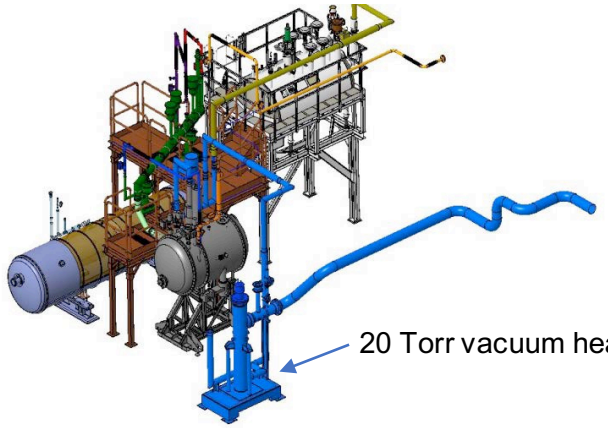
704 MHz SRF Booster Cryomodule



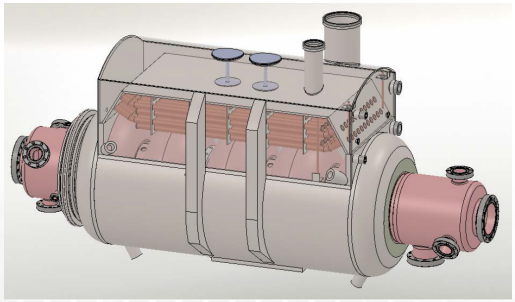
Booster parameters

RF frequency	704 MHz
Maximum energy gain	13.5 MeV
Cavity RF losses	37 W
Frequency tuning range	78 kHz
Available RF power	20 kW
RF power amplifier	Solid State



ASME Code Stamped Vessel

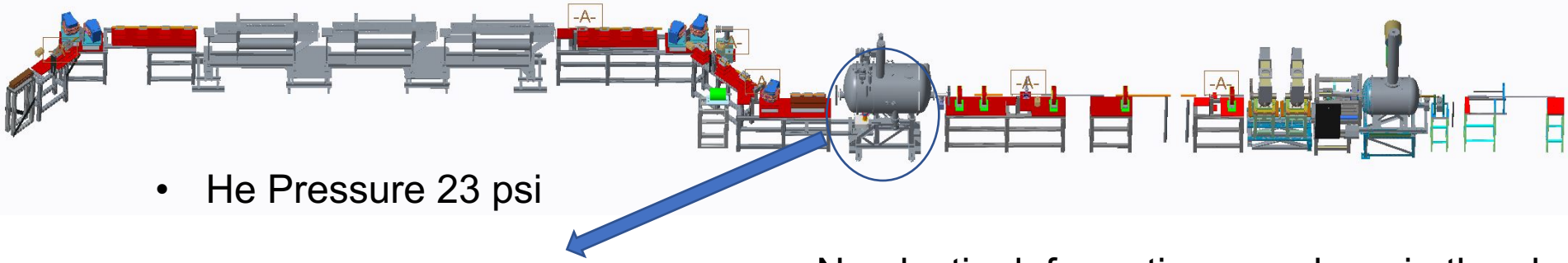
Cavity in helium vessel



- Operates at 2K with an internal HEX to better isolate the cavity from microphonic noise coming from cryogenic system.
- 704 MHz booster limited at 13.5 MeV due to quenching

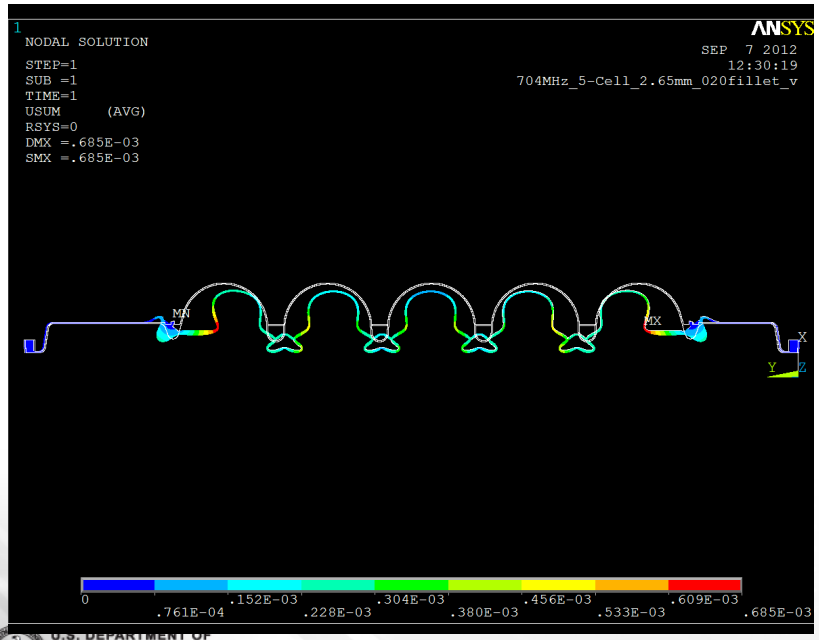
Maximal voltage – 13.5 MV

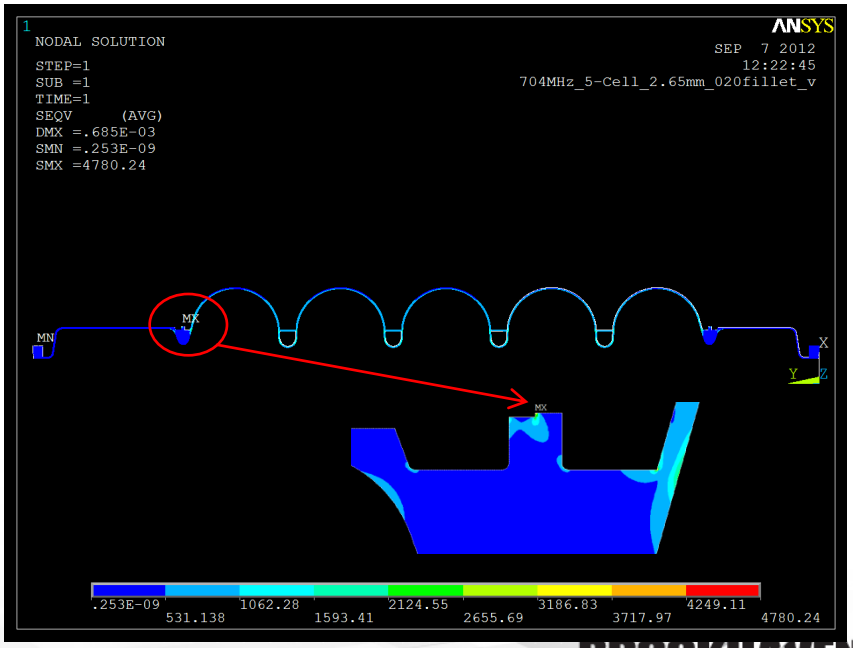
704 MHz 5-Cell Cavity



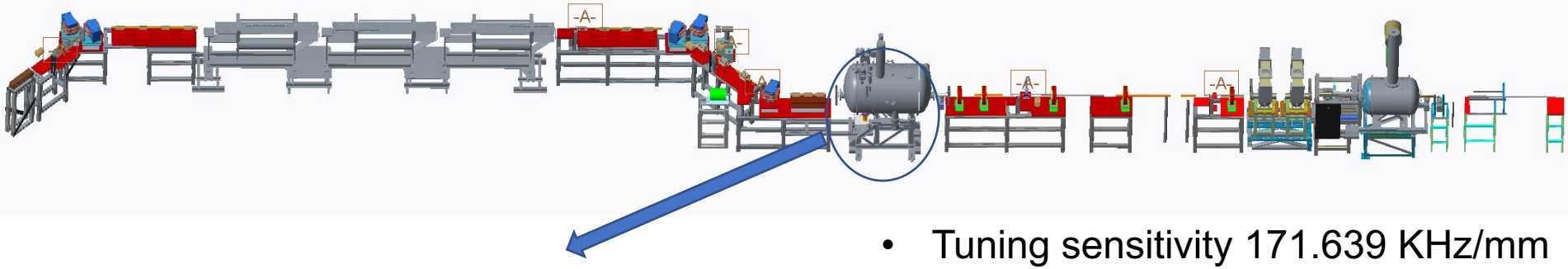
- He Pressure 23 psi

- No plastic deformation anywhere in the shel
- Stress 4780.24 PSI
- Deformation .0006”

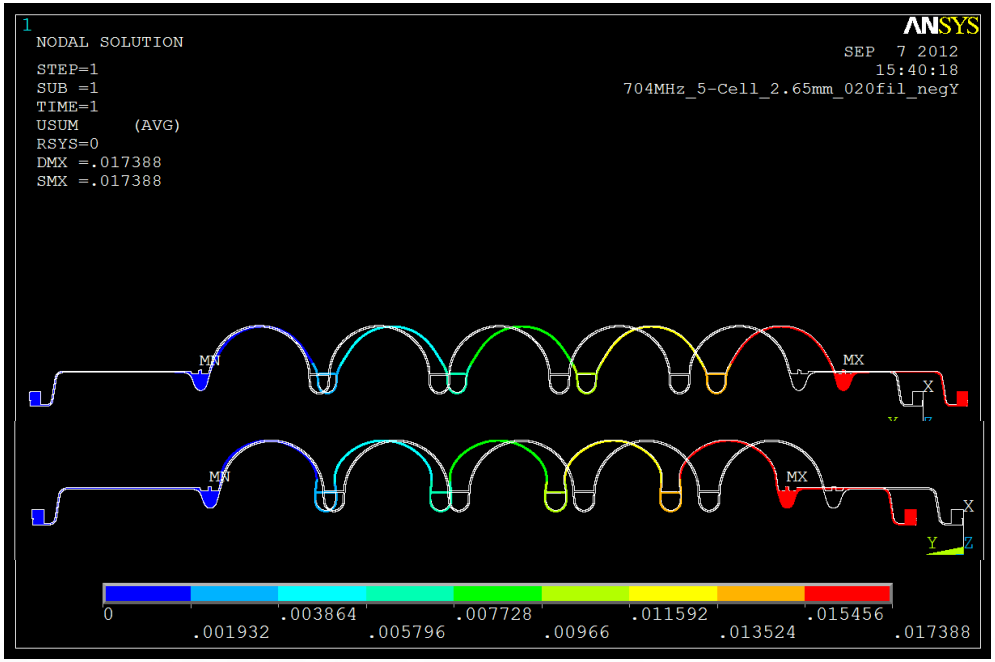


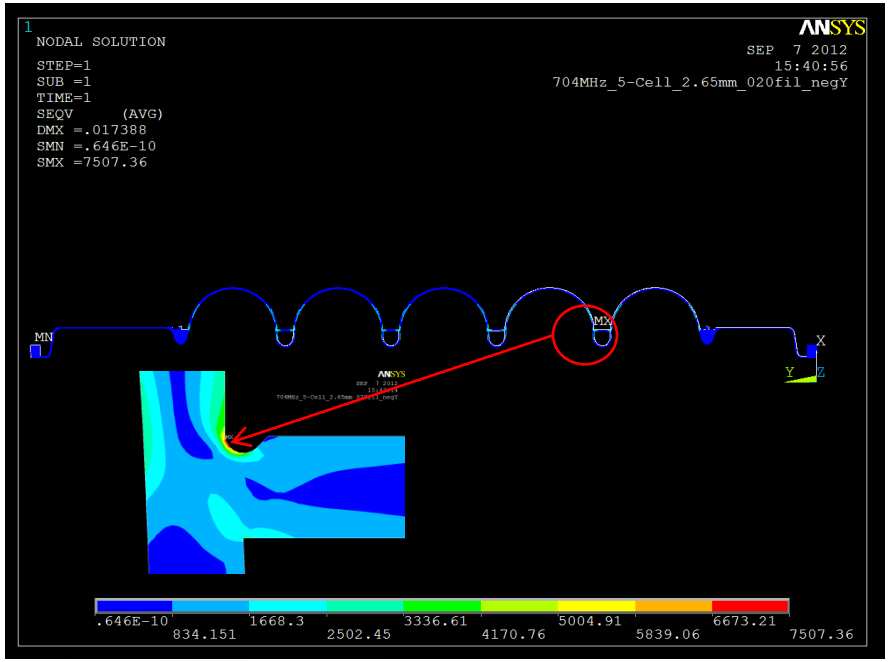


704 MHz 5-Cell Cavity Tuning Analysis



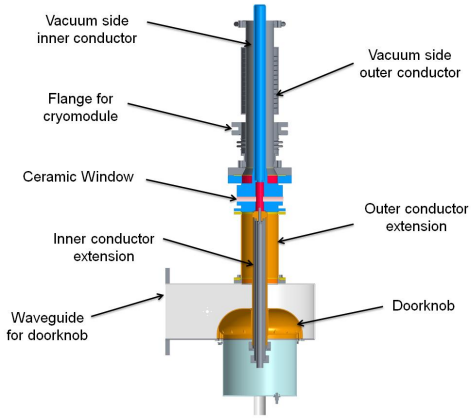
- Tuning sensitivity 171.639 KHz/mm

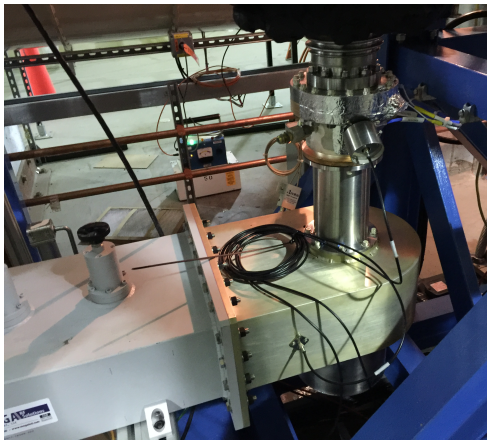


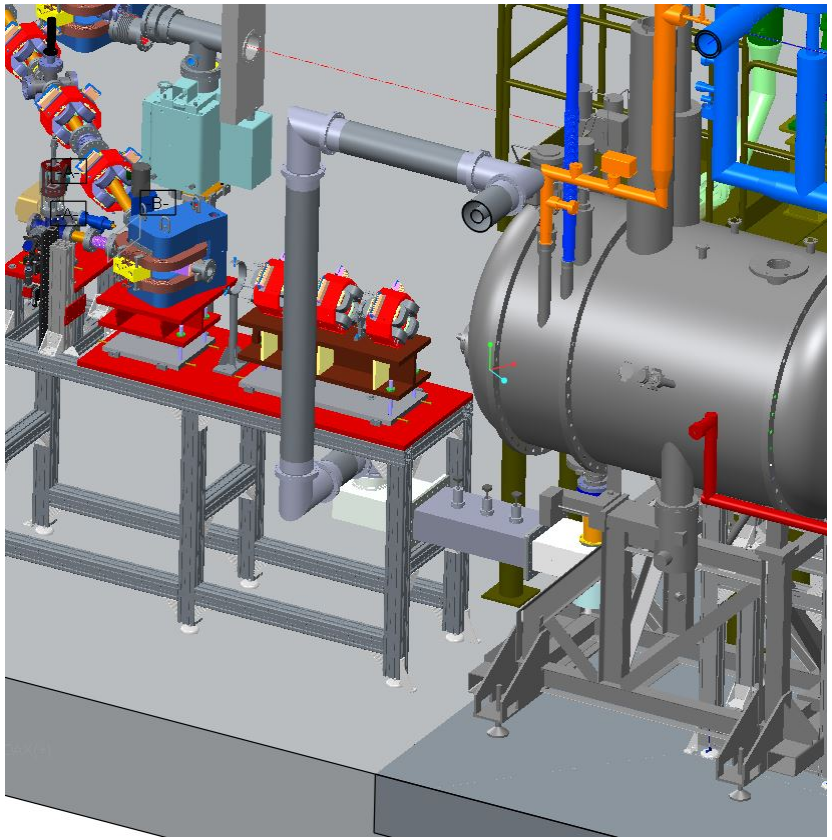


- 384lbs force deformed the cavity by 0.442mm up to the yield point of Niobium at room temperature

704 MHz SRF Cavity FPC

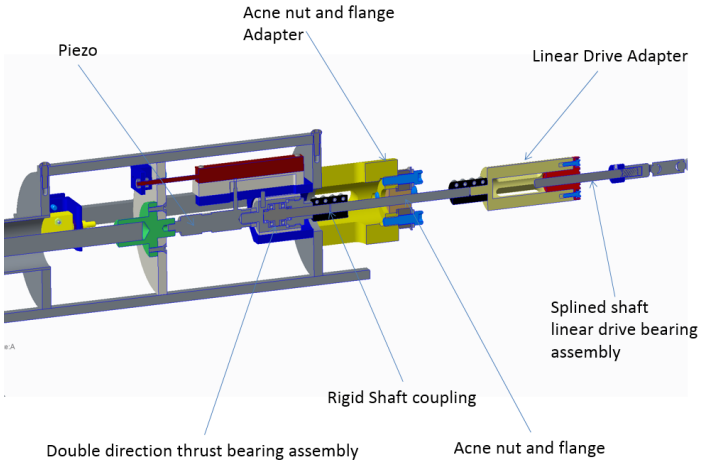


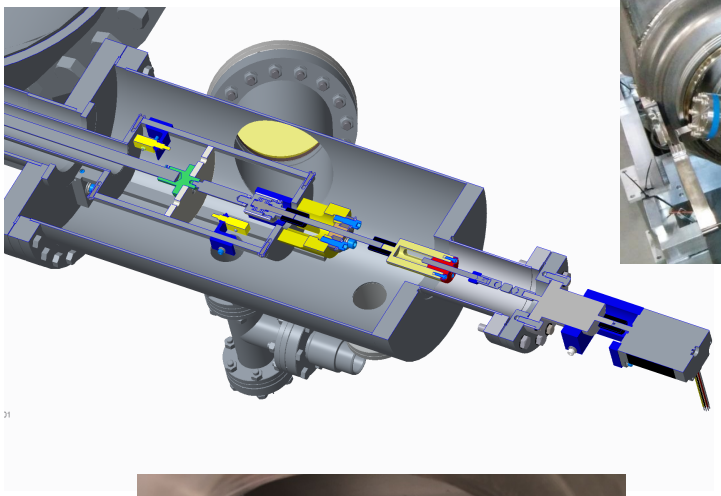




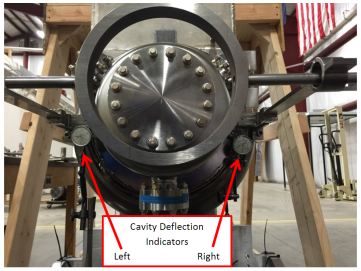
- Conditioned during commissioning of cavity
- Arc detector
- Capable to deliver up to 20 kW CW RF power to the SRF cavity.
- Coaxial RF window/antenna assembly from Toshiba Electron Tubes & Devices Co.
- The vacuum side outer conductor of the coaxial line will be cooled by 5K helium gas, the vacuum side of the inner conductor will be cooled by air and the RF window will be cooled by water.

704 MHz SRF Cavity Tuner

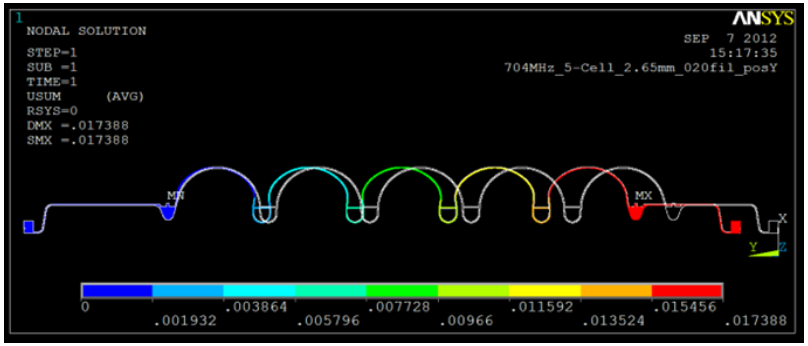


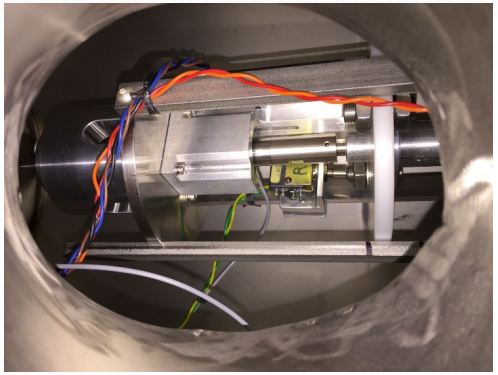


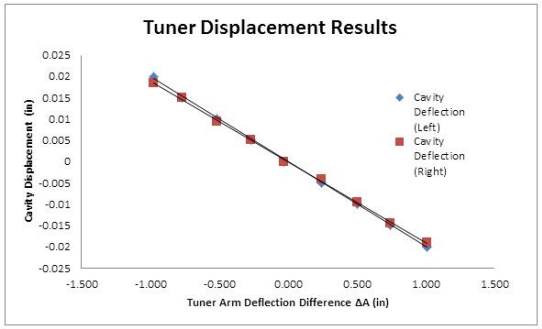
Dial Indicators for Deflection Measurements



Relaxed and deformed shapes of the cavity



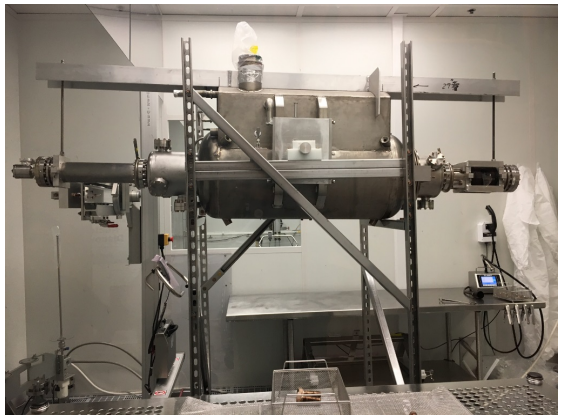


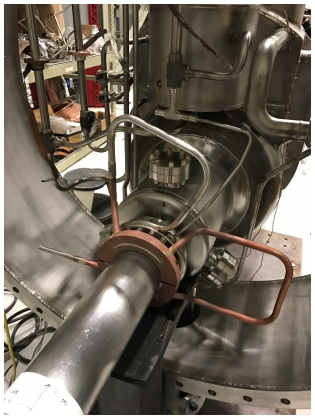


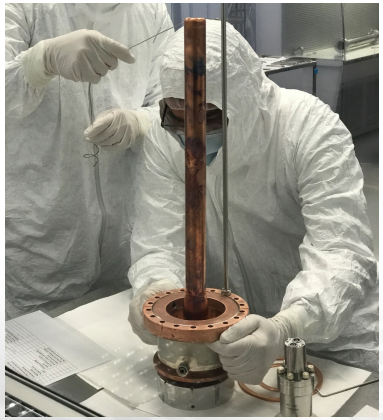
- Original design very problematic
- Full range of tuner was tested.
- The results show that the cavity is tuned linearly with the actuator displacement.
- Tuning is uniform across the cavity
- Tuner was redesigned to include a piezo, potentiometer, encoder and relocate the stepper motor outside the cryomodule.

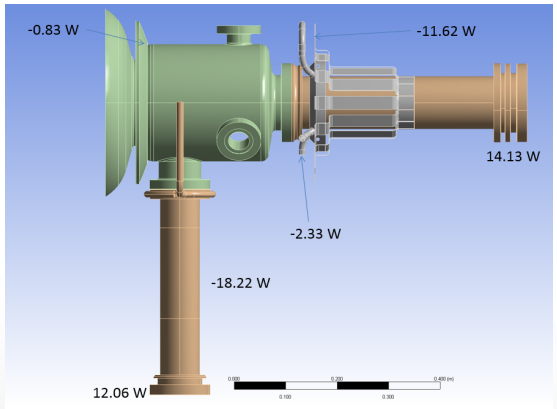
704 MHz SRF Cavity Repair

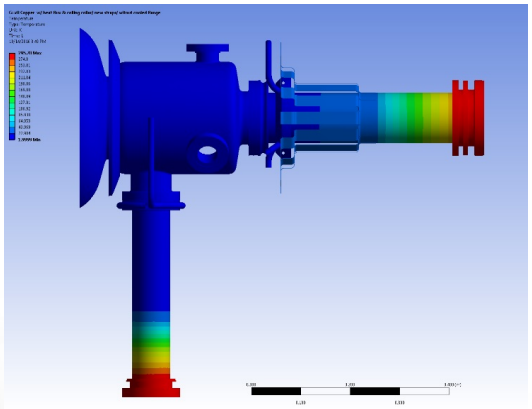
- BCP and HPR by ANL
- He vessel and phase separator leak repair (3 leaks)
- New 4.5K heat intercept to reduce heat leak into Nb cavity
- FPC cleaning and inspection
- New heat shield heat intercept straps location based on simulations.
- After repair, cavity field emission dropped significantly, but max voltage stayed to same around 13.4 MeV



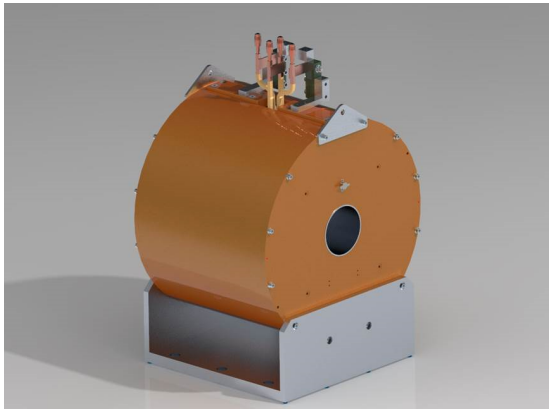


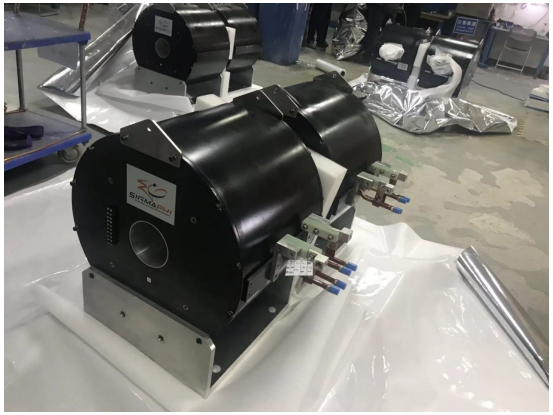




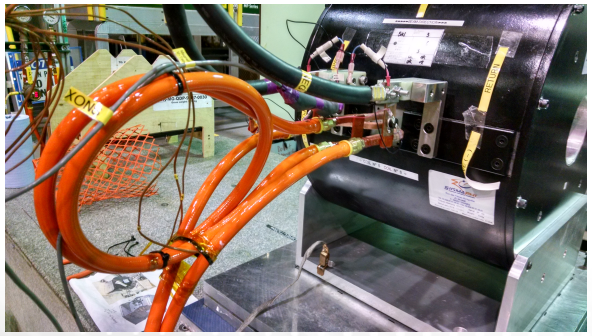
Solenoids

- Sigmaphi China
- Magnetic Field Measurement in progress
- Installation RHIC shutdown 2019
- New water manifold required at IP2

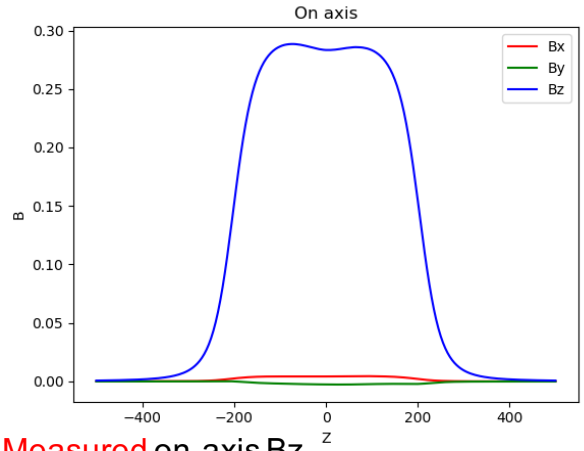




Number of Wraps, Na	36
Number of layers	18
Number of circuits	2
Circular Flow Diameter [in]	0.25
Pressure Drop, psi	76.5
Flow, GPM/ path	.375
Velocity, ft/s	2.5

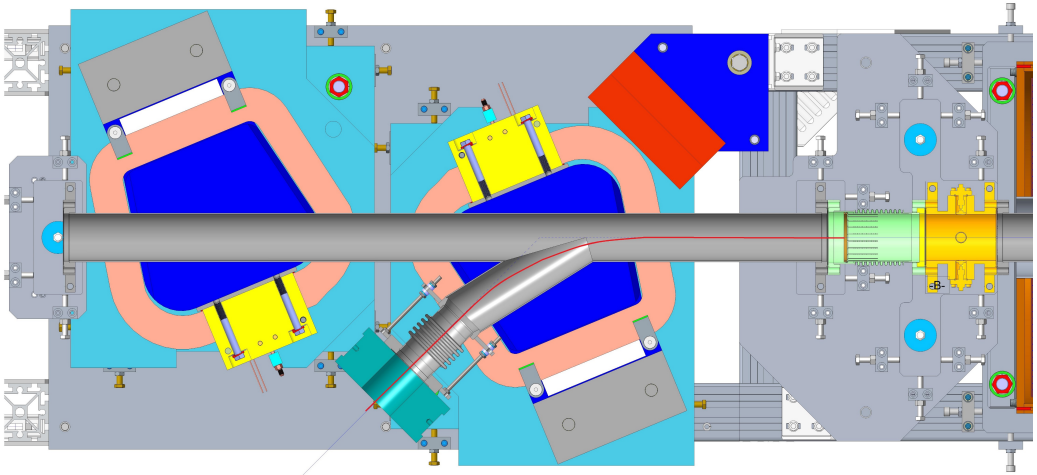


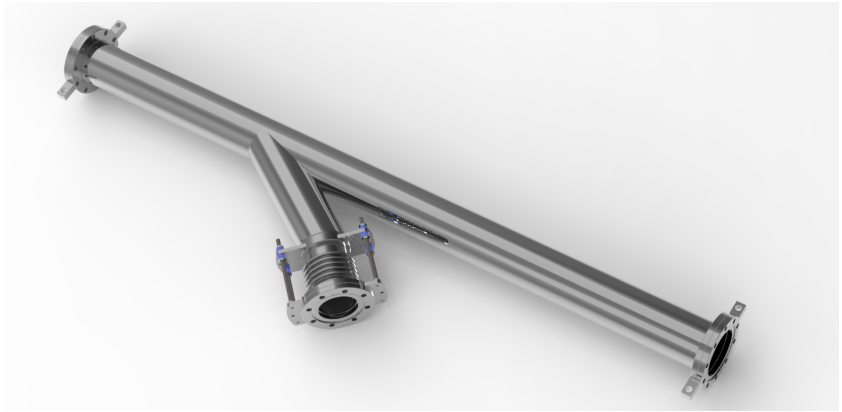
Hollow Conductor Size, mm	9.52 x 9.52
Conductor Area, in^2	0.09
Power, W	3860
Current Density, J [amps/mm2]	2.48
Total Voltage, V	26.75
Resistance, ohms	.186
Current, A	144.3

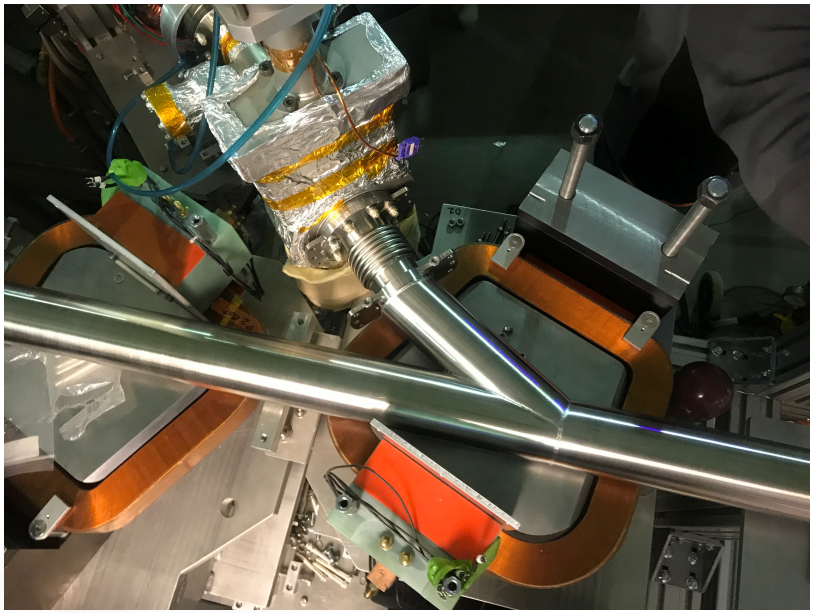


Measured on-axis Bz,
Bz = 0.283 T at center (0,0,0)
Max Bz = 0.288 T, ~7.5 cm away from center

Y dipole chamber



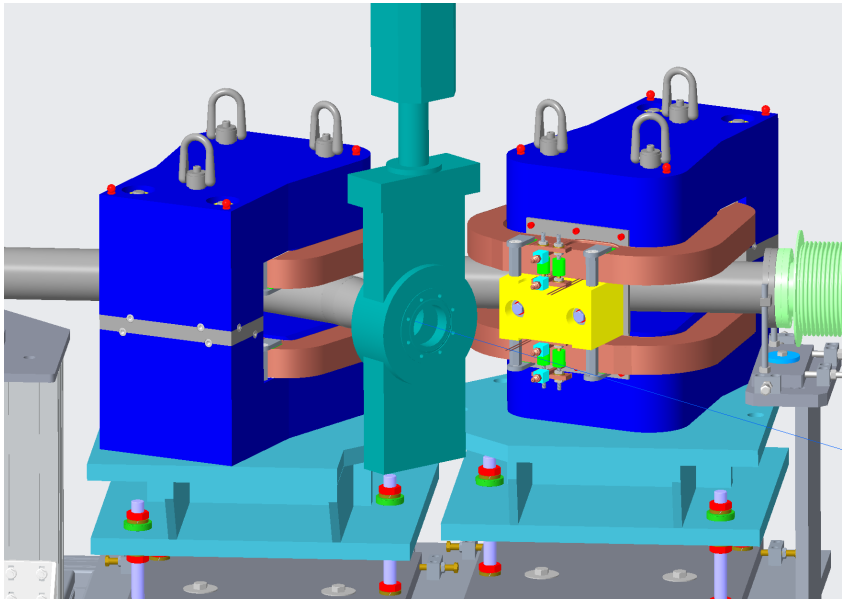


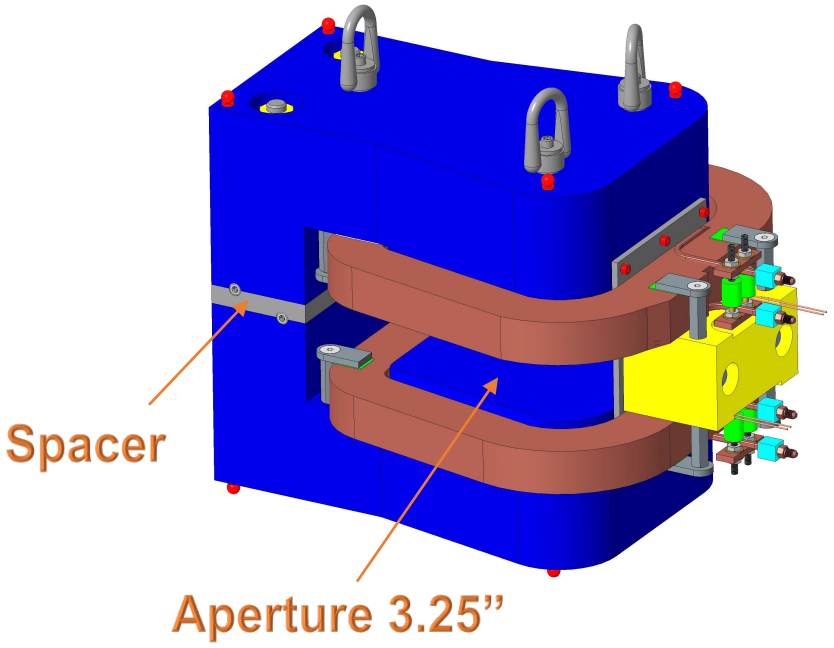


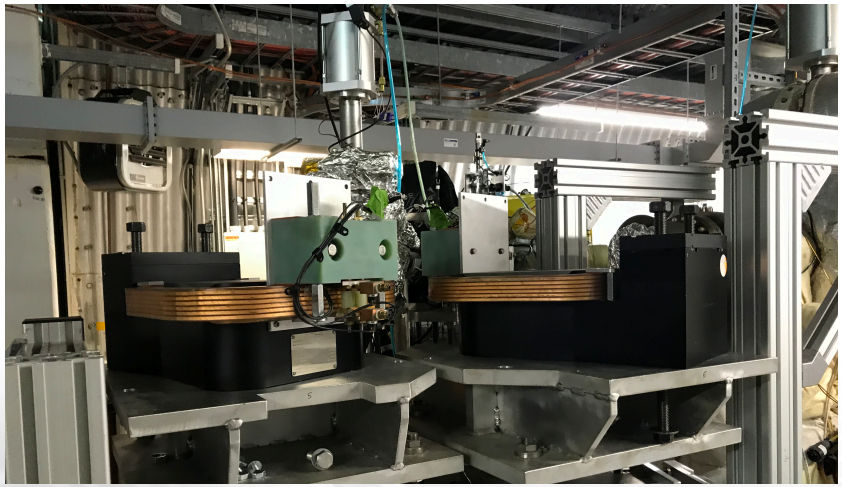
Old Y chamber

New Y chamber

Dipole Gap Modification

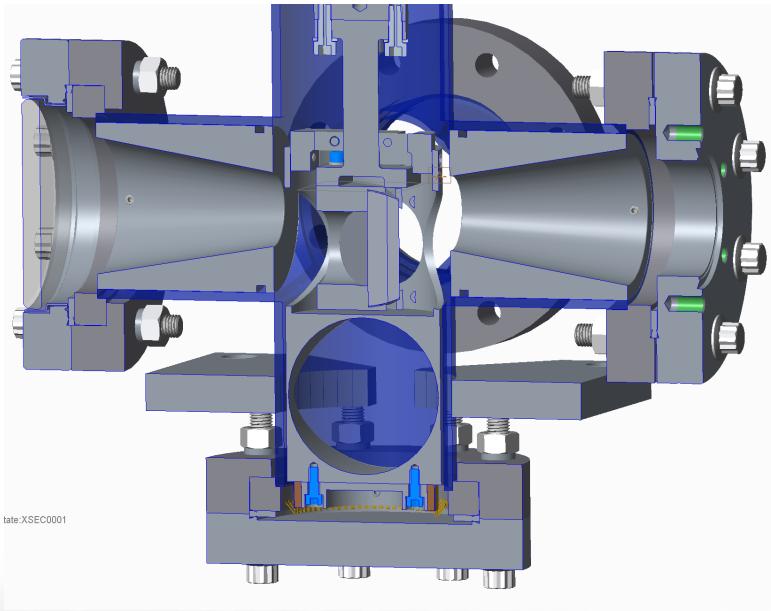


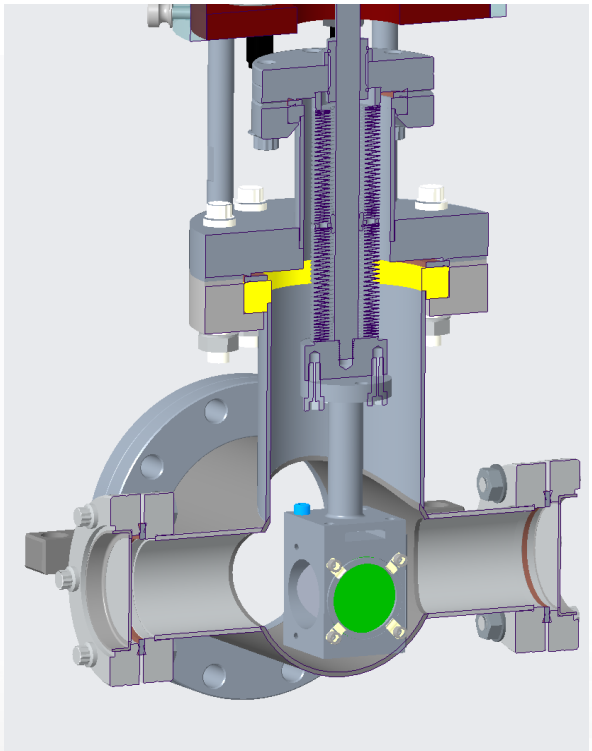


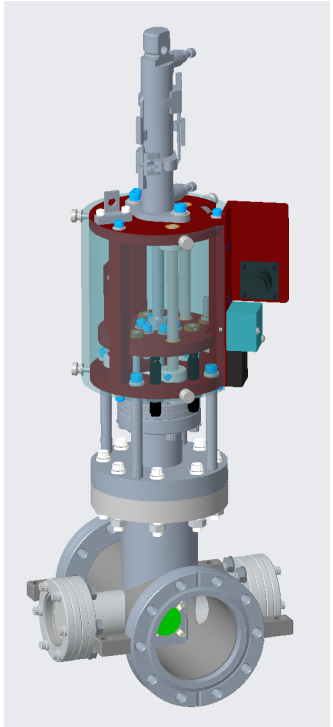


Profile Monitor

- Simplified design
- Removed RF finger, RF shields
- Using existing actuator assembly
- 2.75CF viewport with a glass size of 1.44” instead of a 4.5CF viewport
- ID of the nipple tube is 1.375”



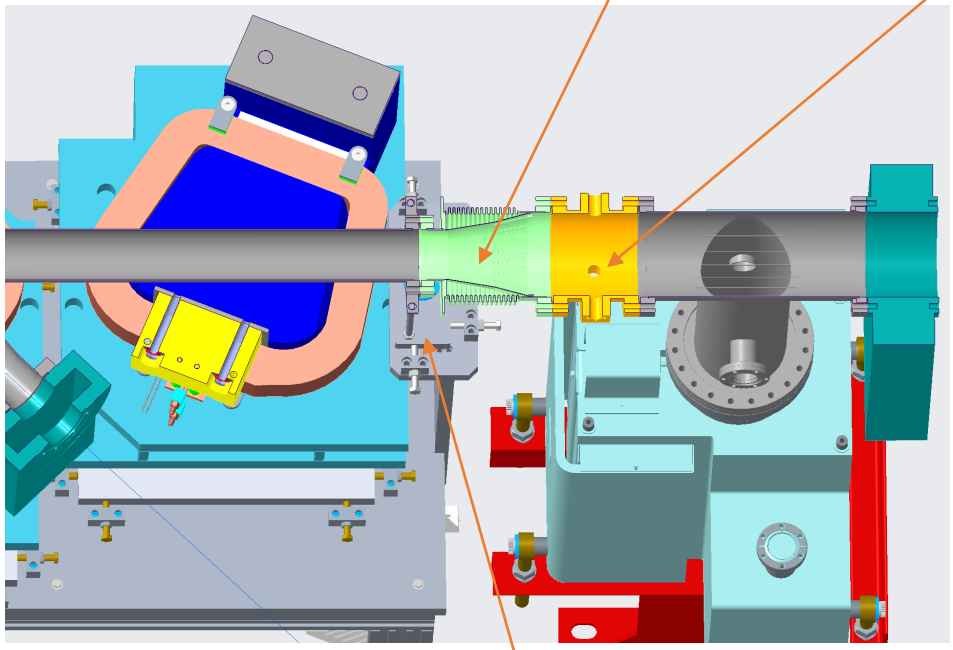


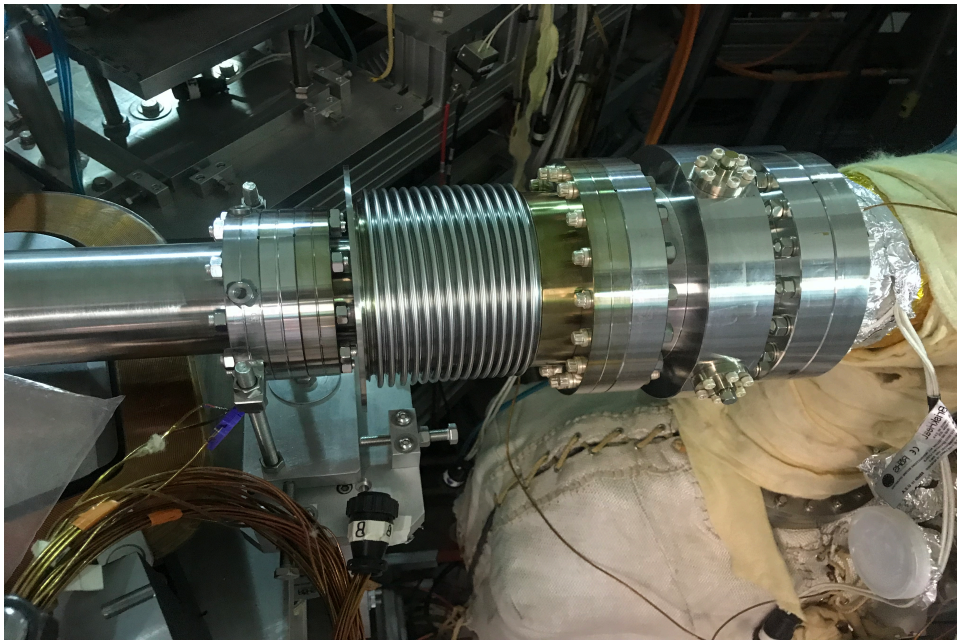


RHIC to CeC Transition

Shielded Bellows
Conical Reducer

RHIC BPM

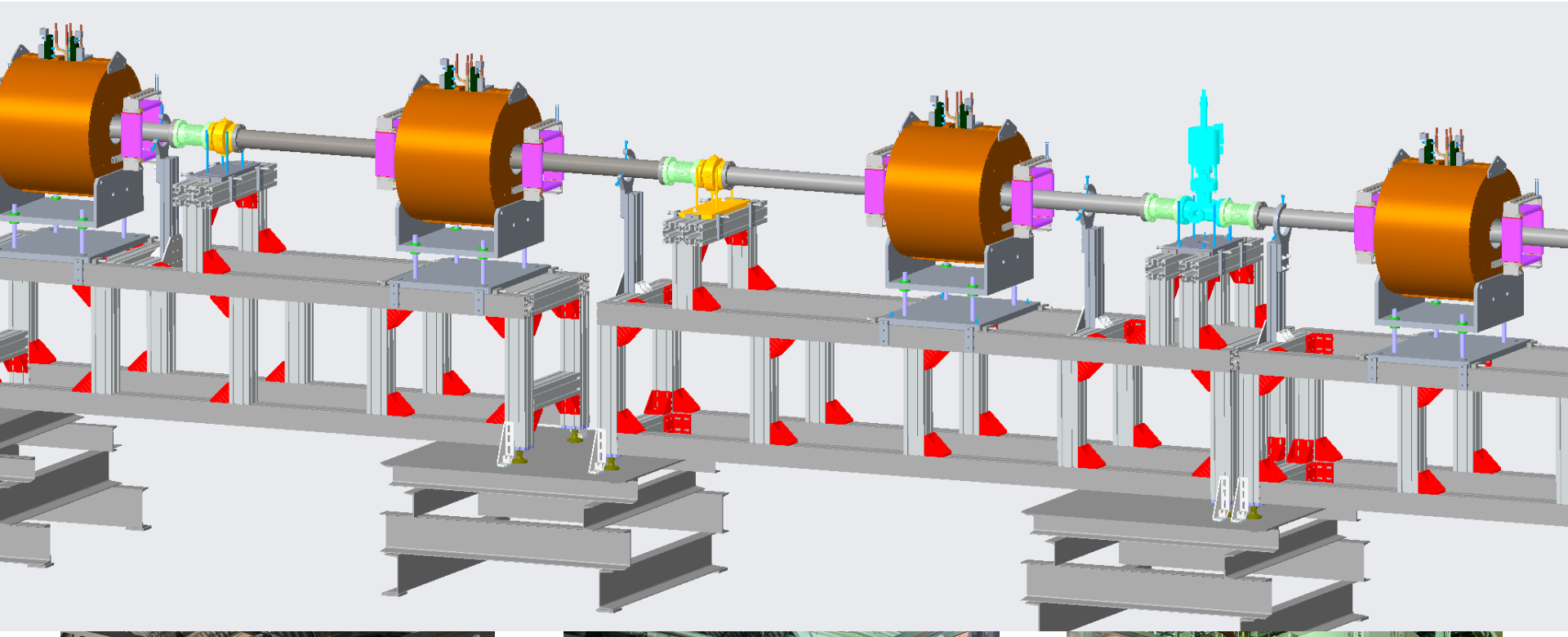


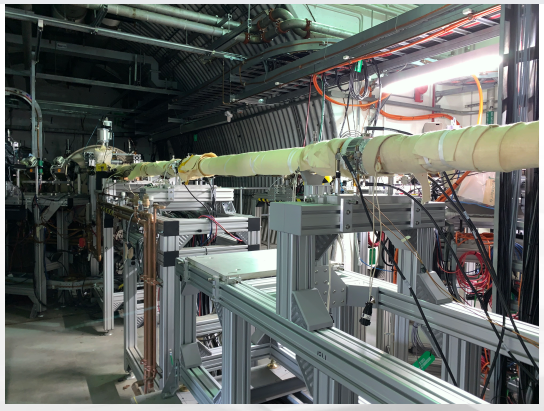


Independent Y
Chamber support

CeC CPA Common Section

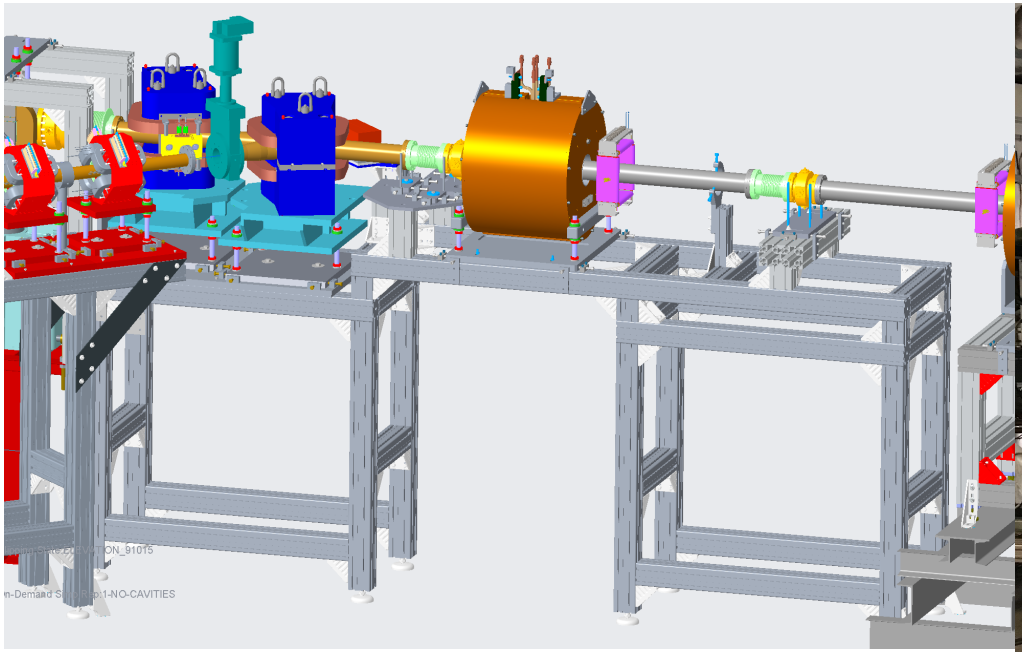
- Use of existing wiggler stands
- New magnet stands have been installed
- Supply/Return water manifold to be installed
- Magnet cables on order





CeC CPA Common Section

- Modified solenoid support
- Stand will remain the same



Summary

- Many challenges during commissioning were addressed with design changes:
  - 704 MHz: tuner, microphonic suppression, repair
  - Aluminum beam dump
  - Shielding from RHIC magnets
  - Cathode injection stand
  - Profile monitor RF shielding
  - New BPMs
  - Ion pump shielding
  - Wriggler polarity and RF shield fingers
  - New correctors
  - water interlock system

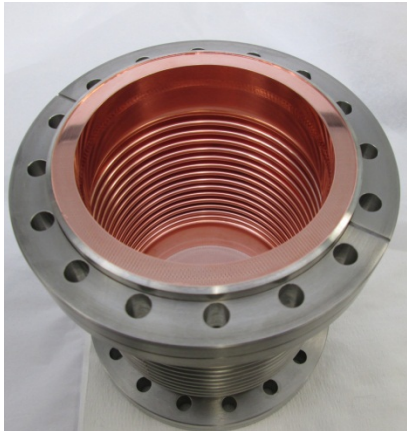
- 704 MHz booster limited at 13.4 MeV even after repair

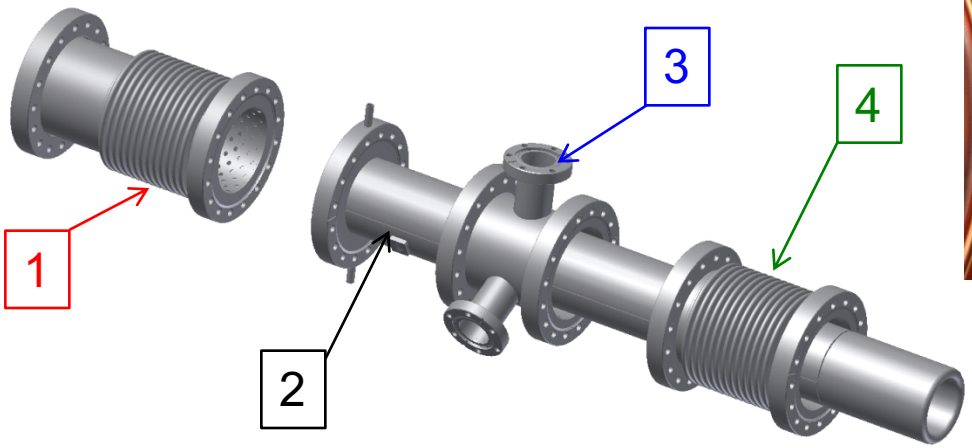
- Magnetic field measurement of solenoid in progress

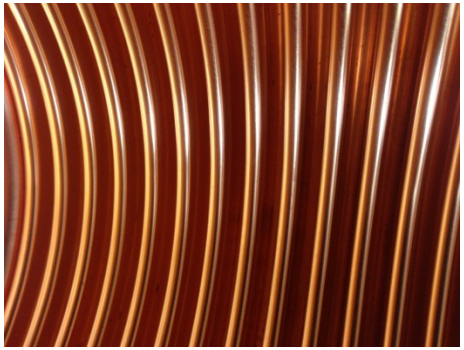
- Installation RHIC Shutdown 2019

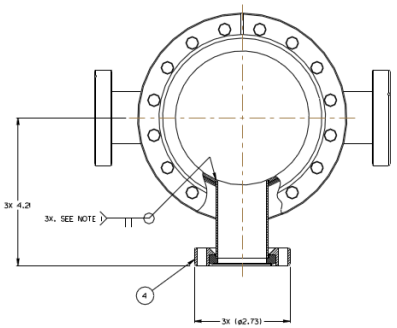
113 MHz FPC Components

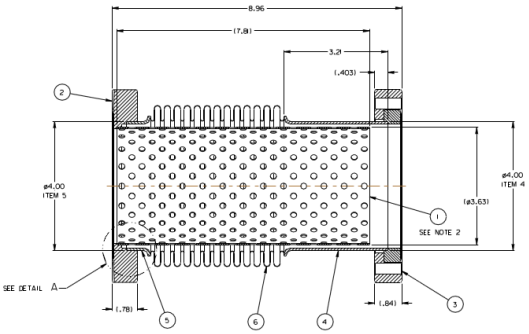
1. Shielded bellows
2. FPC Inner conductor
3. FPC outer conductor with antenna and ion pump
4. Copper plated bellows

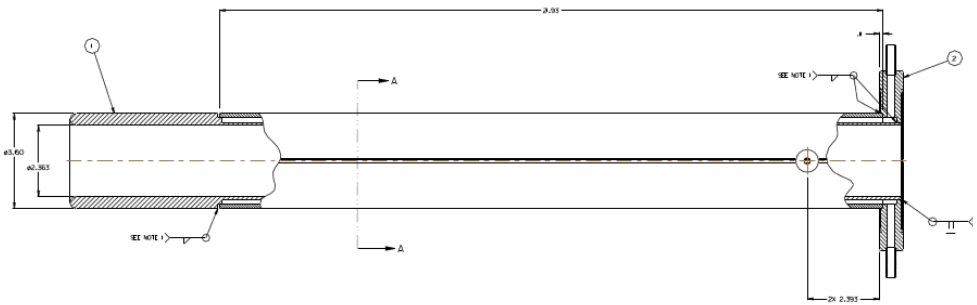


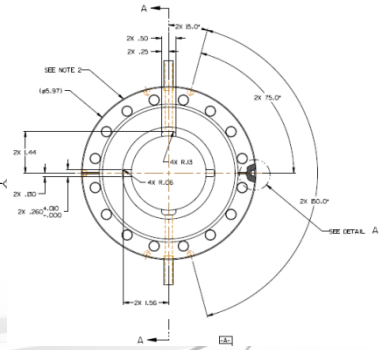




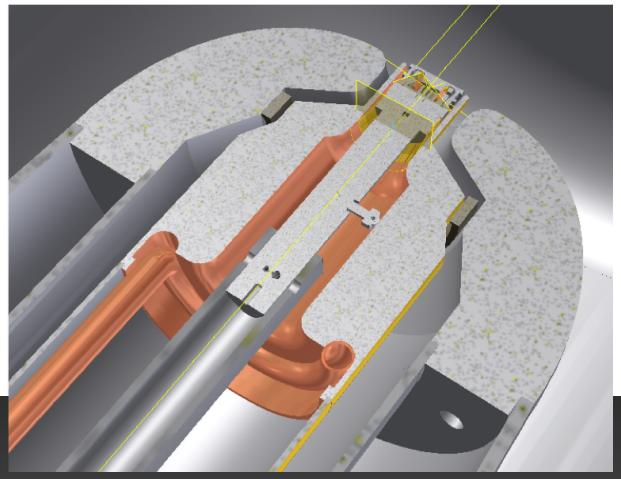


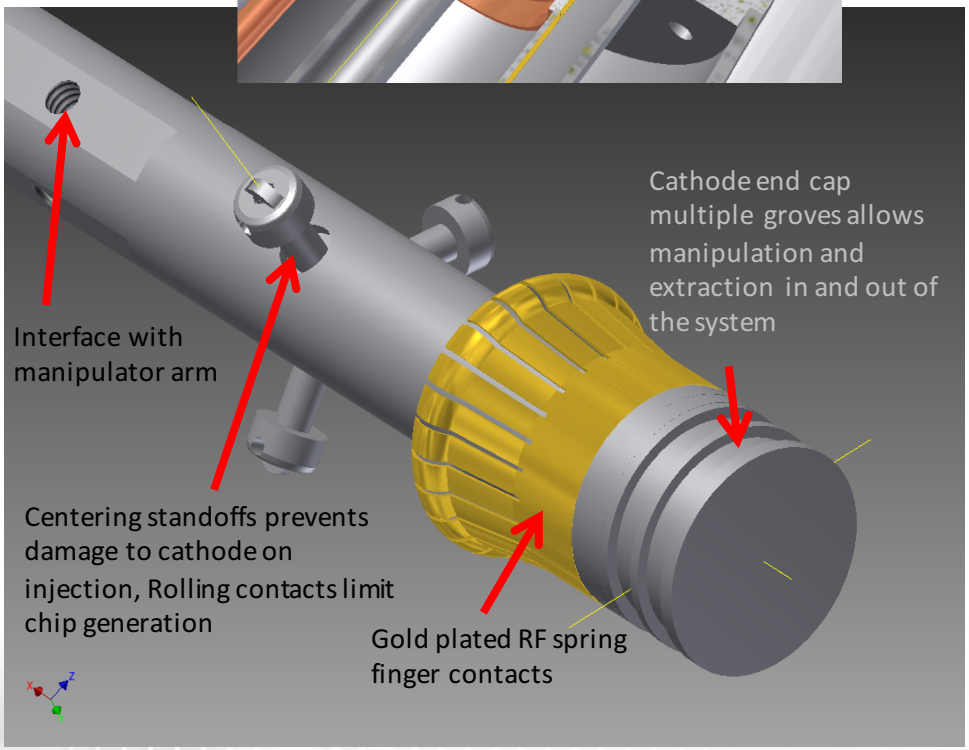


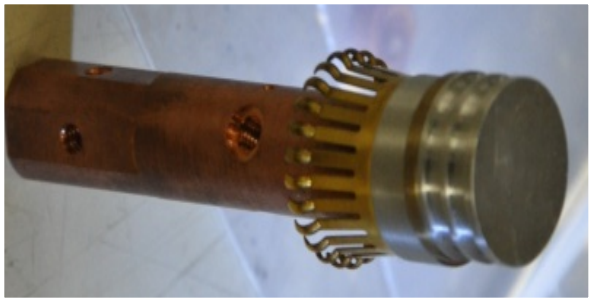




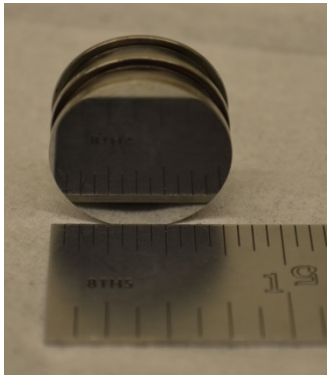
113 MHz RF Cathode End



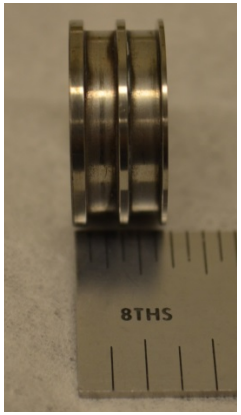




Photocathode end assembly

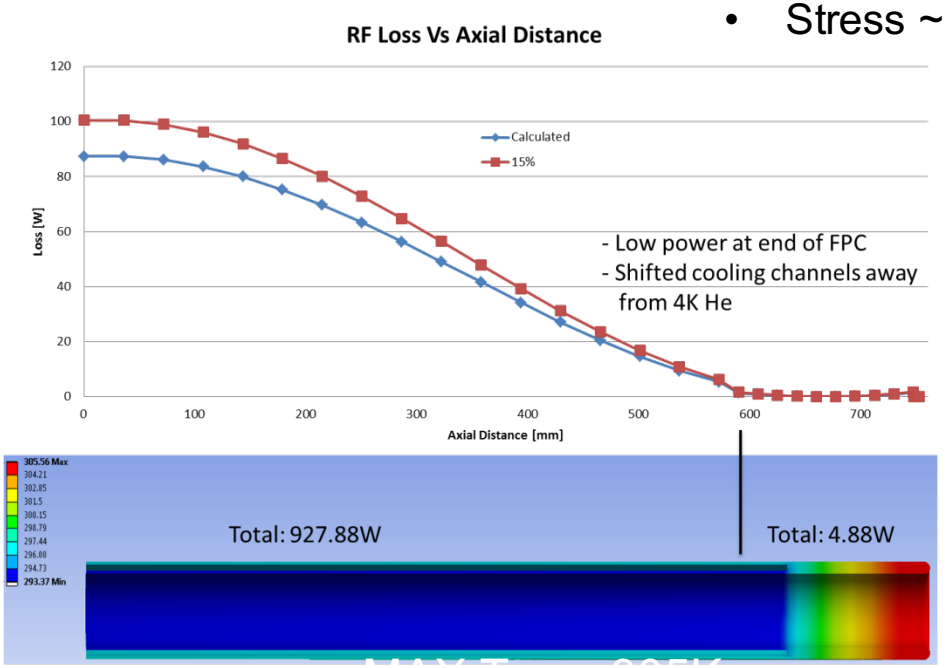


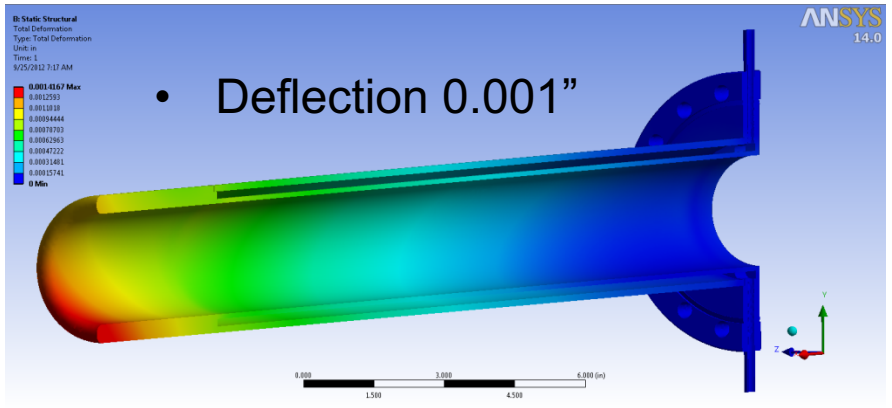
Cathode puck

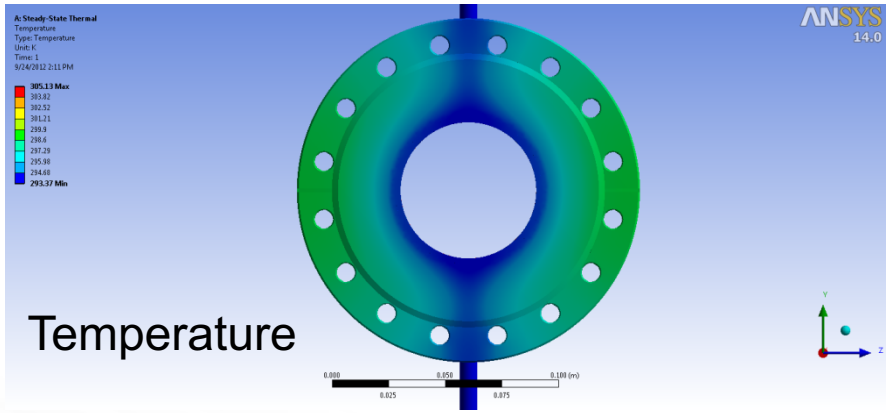


112 MHz FPC Inner Conductor Analysis

- Stress ~ 2600psi







- Temperature

Water Volume Flow Rate, Q	4.0023	gpm
Pressure Drop	< 2	psi
Inlet - Outlet Temp Difference	0.8805	K
Top and Bottom Inside Wall Temp Difference	0.4402	K
Temperature Difference between Fluid and Inside Surface	2.0648	K
Local heat transfer coefficient h =	3217.3941	W/m^2-K