Cryogenics of SRF Spoke Cavity Development at SMTF

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Overview of Topics

- SMTF Overview
- CTF Cryogen Supply
- Vacuum Skid for Helium Service
- SRF Spoke Cavities
- SMTF Vertical Test Cryostat
- HINS Cryomodules

Superconducting Module Test Facility

- SMTF is a facility for testing future accelerator components that require cryogenic temperatures
- Housed in Meson Detector Building
- Current work is focused on ILC and HINS components

Inside Meson Detector Building

Planned & Proposed Experimental Areas at SMTF

- Capture Cavity 2
  - For testing A0 photoinjector cavities
- Vertical Test Cryostat
  - For testing 325 MHz Spoke SRF Cavities
- Horizontal Test Cavity
  - For testing ILC 1.3 GHz Elliptical SRF Cavities
- HINS Cryomodules
  - For testing the front end of the proposed High Intensity Neutrino Source

Cryogenic Test Facility (CTF)

- Three Tevatron Satellite Refrigerators operating in parallel
- 500 m from CTF to MDB

Transfer Lines

- Single Phase Helium
  - Sub-cooled Liquid Helium Supplied to SMTF from CTF
- Two Phase Helium
  - Helium with useful Refrigeration returned to CTF
- LN2
  - Sub-cooled Liquid Nitrogen Supplied to CTF
- Nitrogen Header
  - Vents Nitrogen Gas from Experiments and Relief Valves to Atmosphere
- Helium Header
  - Returns warm gas from experiment cool downs, vacuum pump discharge, and relief valves

Vacuum Pump Skid… Then

Vacuum Skid at PAB Being Refurbished
After Years in Storage

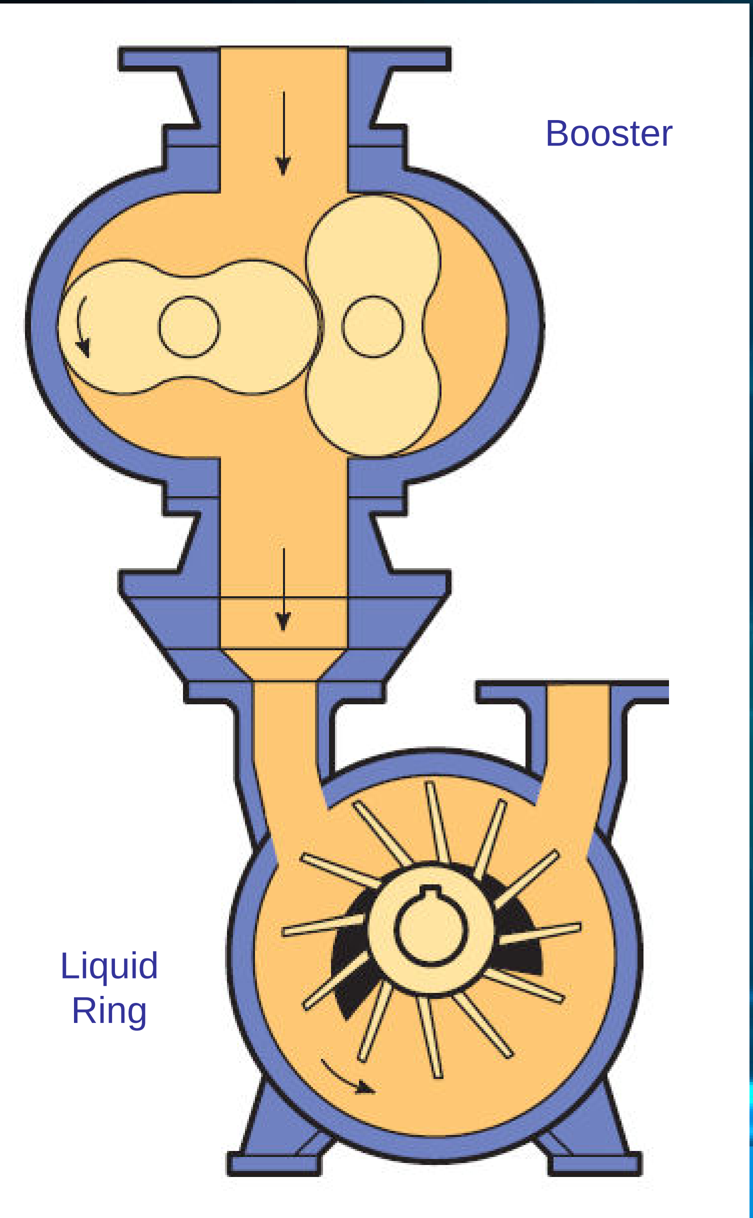
- Originally Designed & Built at JLAB in 1993
- Purchased & Modified by Fermilab for Helium Service
- Used to Decrease Temperature of Helium Baths
- Capable of Pumping on Several Experiments Simultaneously

Arkadiy Klebaner, FNAL

Vacuum Pump Skid… Now

- Gaseous Helium Guard Placed around Dynamic Shaft Seals
- Helium Guard Placed around Relief Valves
- Variable Speed Drive added to Booster Pump

Vacuum Pump Skid Specs

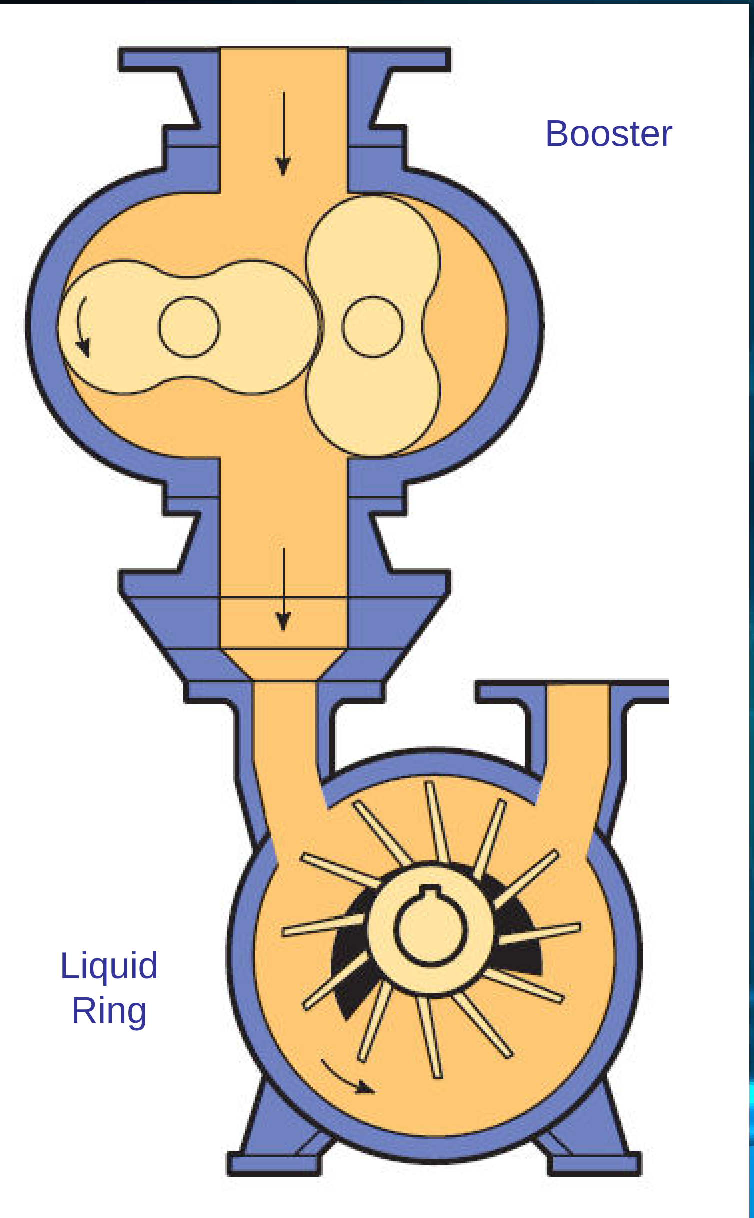


- Liquid Ring Pump
  - Used for pump down & maintaining booster discharge pressure
  - Kinney Model #KLRC-2100
  - 3-phase 200 hp Magnetex Motor
  - 2100 CFM Displacement at 870 RPM & 100 torr suction pressure

Left: Booster-Liquid Ring Vacuum System

http://vacuum.tuthill.com

Vacuum Pump Skid Specs

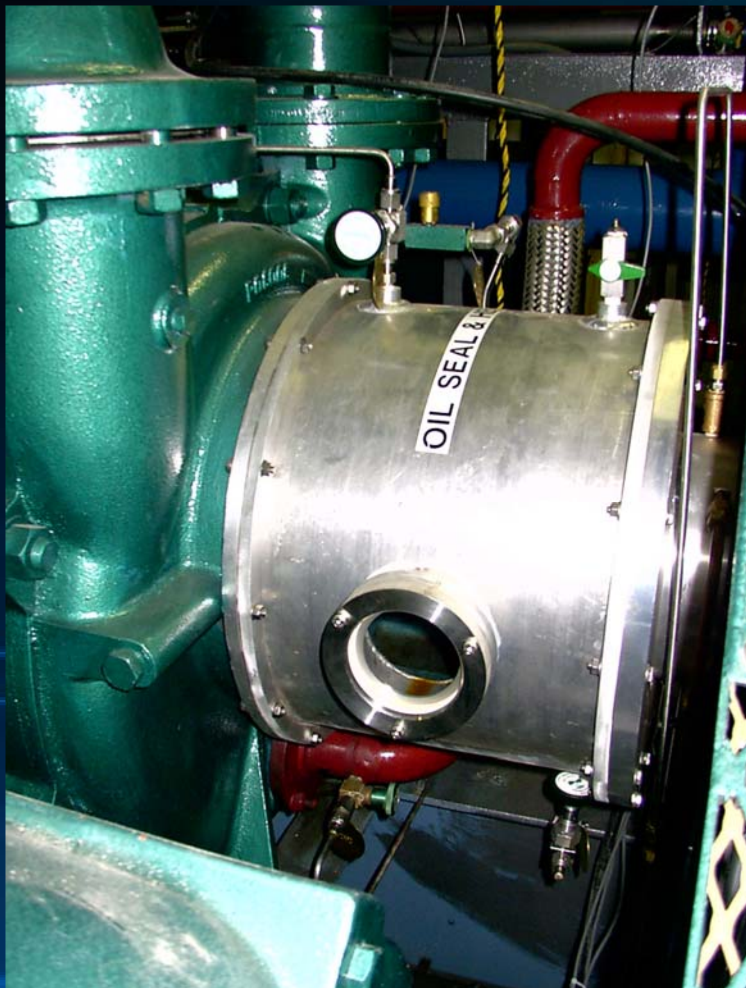


- Booster Pump
  - Regulates Suction Pressure
  - Kinney Pump Model #KMBD 10000
  - 3-phase 100 hp US Motors Motor
  - 100 hp Automation Direct Variable Speed Drive
  - 12700 CFM Displacement
  - Discharge pressure <100 torr

Left: Booster-Liquid Ring Vacuum System

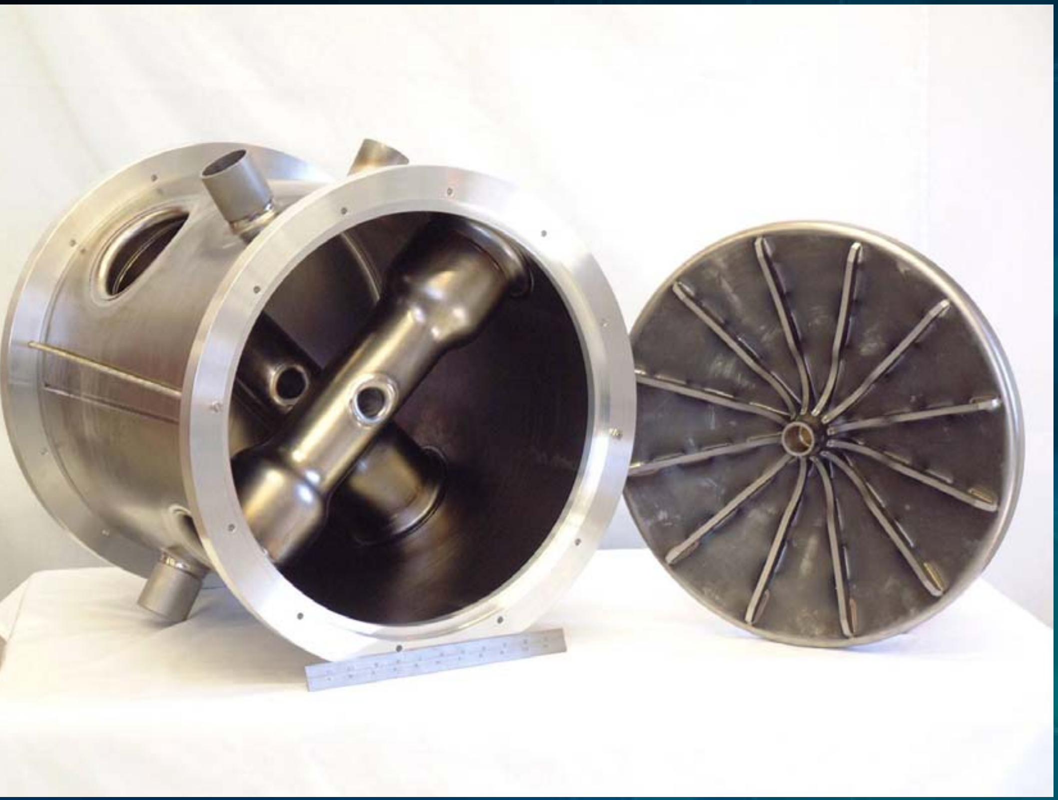
http://vacuum.tuthill.com

Vacuum Pump Dynamic Seal



Liquid Ring Pump & Motor

What is a SRF Spoke Cavity?



RIA Double Spoke Cavity

Joel Fuerst, ANL

- Used for Accelerating Charged Particles
- Made from Niobium
- Superconducting at Liquid Helium Temperatures

Typical Room Temperature RF Cavity

Inside Fermilab's Linac

Fermilab Visual Media Services

- Rapidly alternating electrical pulse
- In Fermilab's Linac H^- ions are accelerated in bunches
- Pulse timed so positive charge in front of bunch and negative charge behind bunch

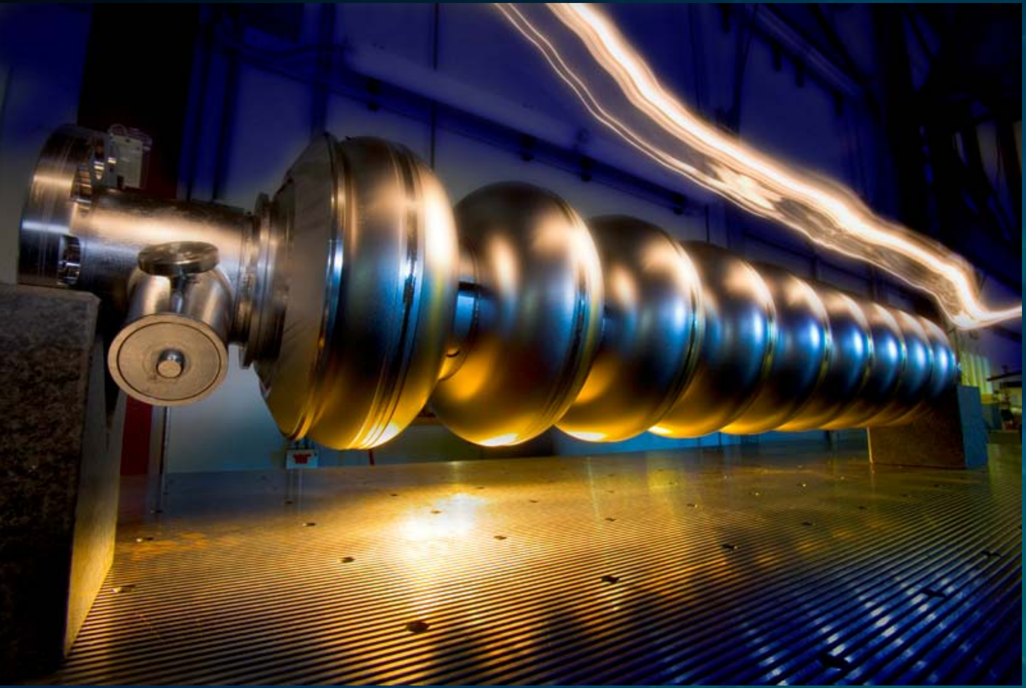
Disadvantages of Room Temperature RF Cavities

- Large Electrical Losses
  - Heat Distorts RF Volume
  - Cooling System Required
  - Many Klystrons required ($$$)
- Low Accelerating Gradient
  - Longer Beamlines
  - Higher Civil Construction Costs

Fermilab Power Lines

Fermilab Visual Media Services

Typical Elliptical SRF Cavity



Tesla 9-Cell 1.3 GHz Cavity

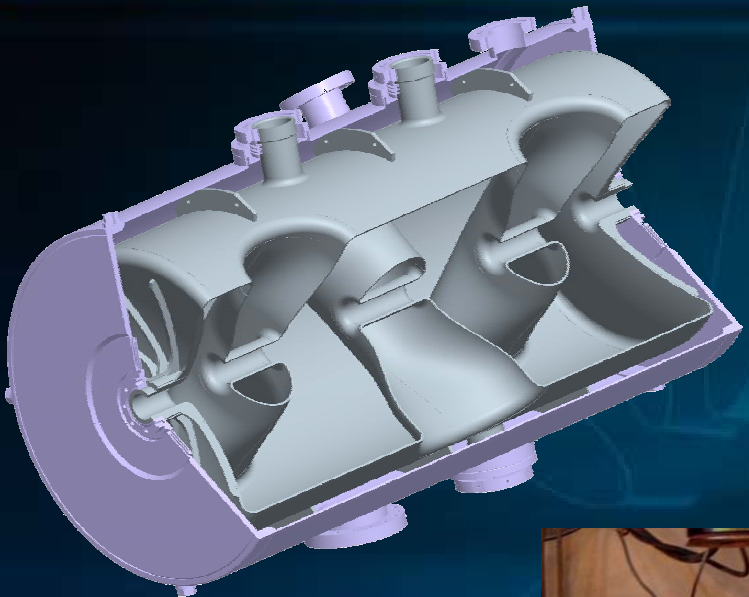
Fermilab Visual Media Services

- Has Elliptical "Dumbbell" Shape
- Made from Niobium
- Superconducting at Liquid Helium Temperatures

Disadvantages of Elliptical SRF Cavities

- Effects at Low Beta
  - Dumbbells increase in diameter
  - Distance between dumbbells decreases
  - The result is large bellow shaped cavities
  - Tuning becomes very difficult to maintain

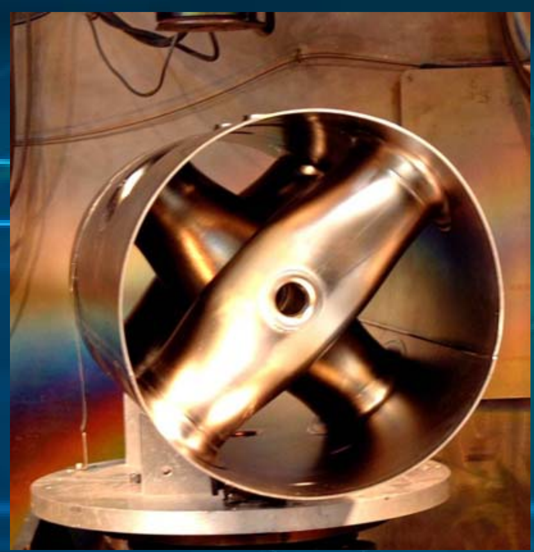
Spoke Cavity Advantages



RIA Triple

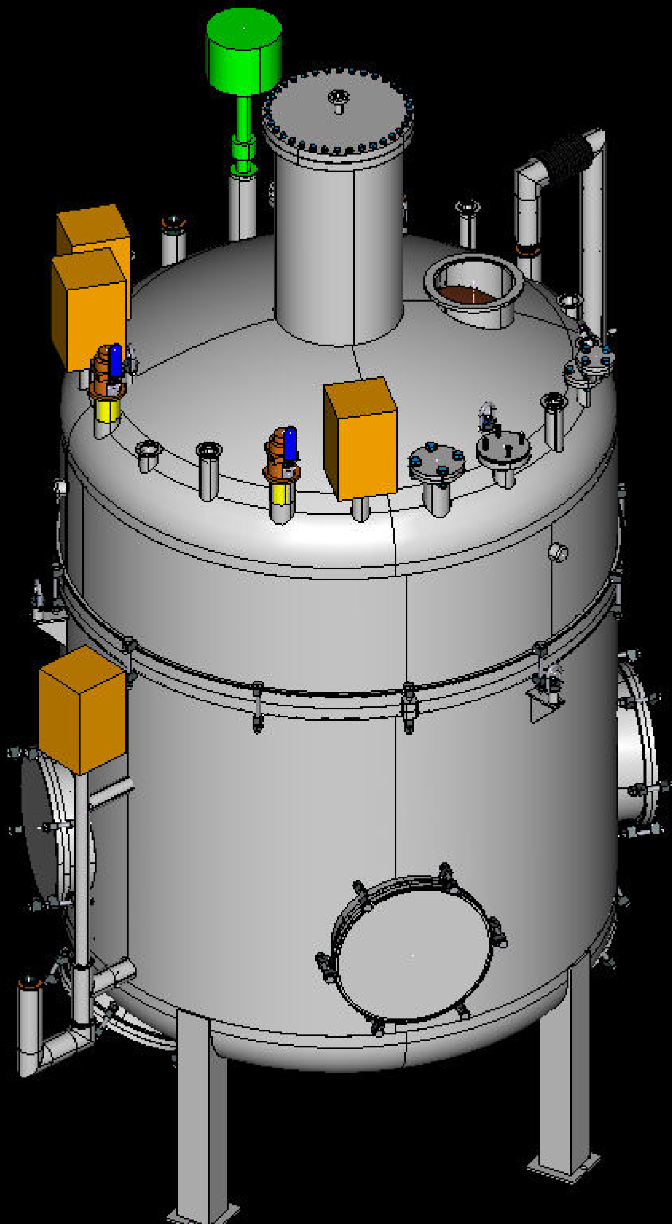
Spoke Cavities

Joel Fuerst, ANL



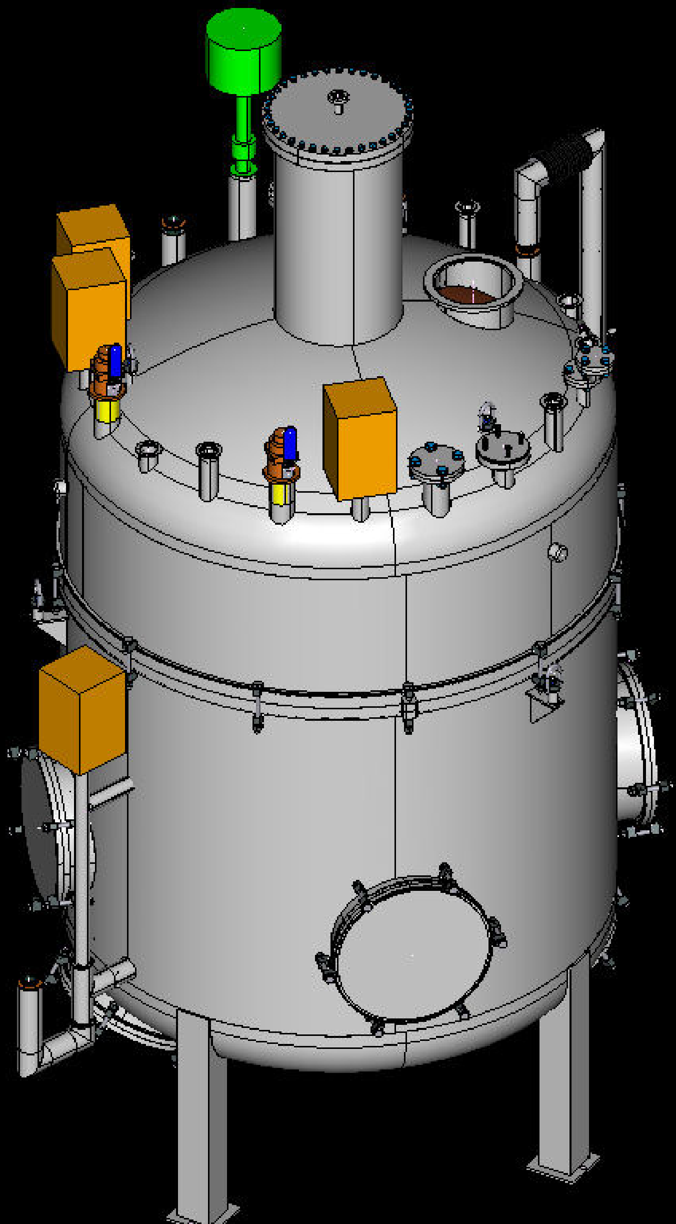
- Easier to tune than elliptical cavities
- Lower equipment & electrical power costs than copper cavities
- Shorter beamlines
- Uses Cryogenics!

Spoke Cavity Collaboration



- Argonne is helping Fermilab develop spoke cavity technology for HINS
- Fermilab is designing the cryostat so that it can be duplicated & used at Argonne

SMTF Vertical Test Cryostat



- 60” Diameter
- 120” Tall
- 7 x 16” Access Ports
- 10” Neck for Possible Viewing and Cavity Instrumentation
- 10” Vertical Access Port

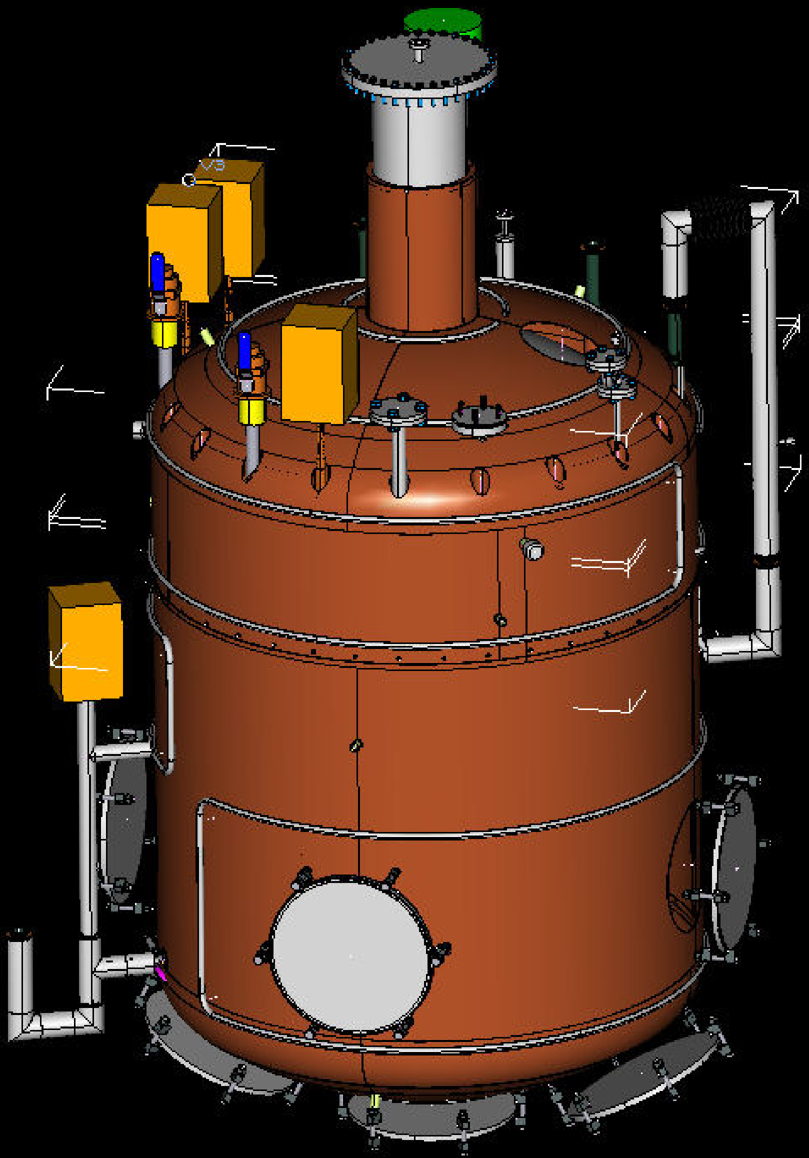
Cryostat Objectives

- Primary Objective:
  - To provide a facility for testing SRF spoke cavities and their interactions with components such as tuning mechanisms, RF couplers, vacuum couplers, solenoids and quadrupoles
- Secondary Objective:
  - To be a “universal” cryostat
  - Easily adaptable to testing many types of accelerator components

Notable Characteristics

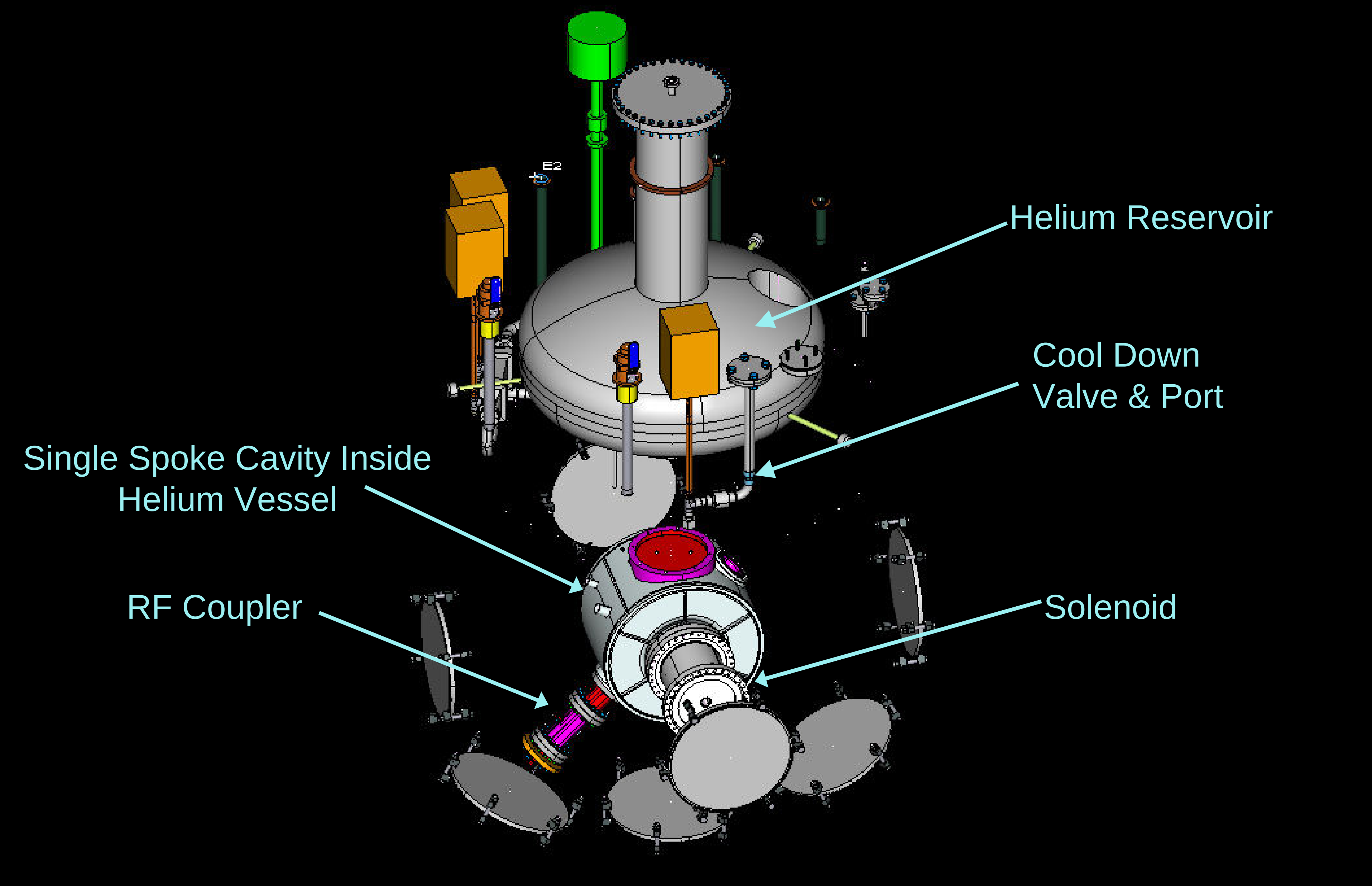
- Designed for 30 W load at 4 K
- Capable of Extended 2 K Operation
  - Utilizing a CERN HXA-style Heat Exchanger and the SMTF Vacuum Skid
- Helium Reservoir Allows for Batch Filling
  - 43 gallon Storage Volume
  - Cryogenic refrigeration system connection not essential
- Multiple Coupler Angles
  - Vertical, Horizontal, and 45 Degrees
- Large Neck
  - Allows for Cavity Instrumentation
- Magnetic Shielding
  - Less than 20 mGauss around Cavity

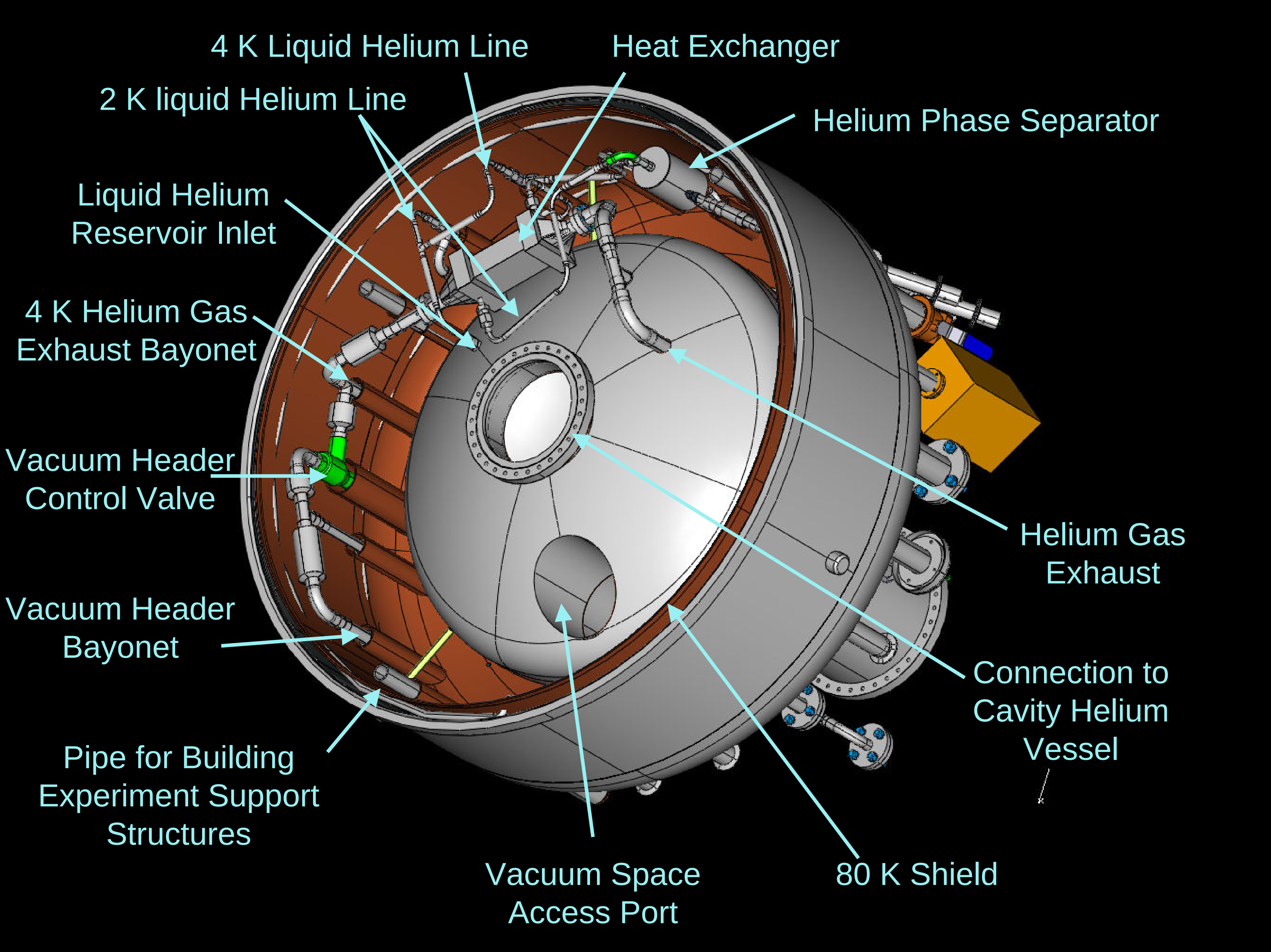
Vertical Test Cryostat
Thermal Shield



- Nitrogen flows through tubing wrapped around a copper shield
- Jumper to connect both halves of cryostat
- Attached with SST braiding

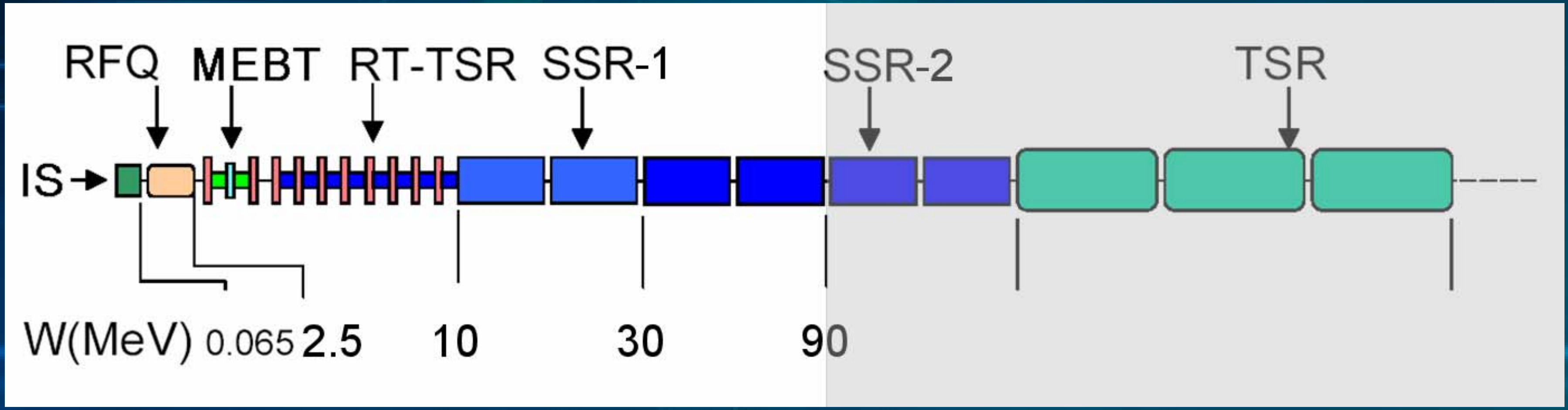
SMTF Vertical Test Cryostat Physics Components



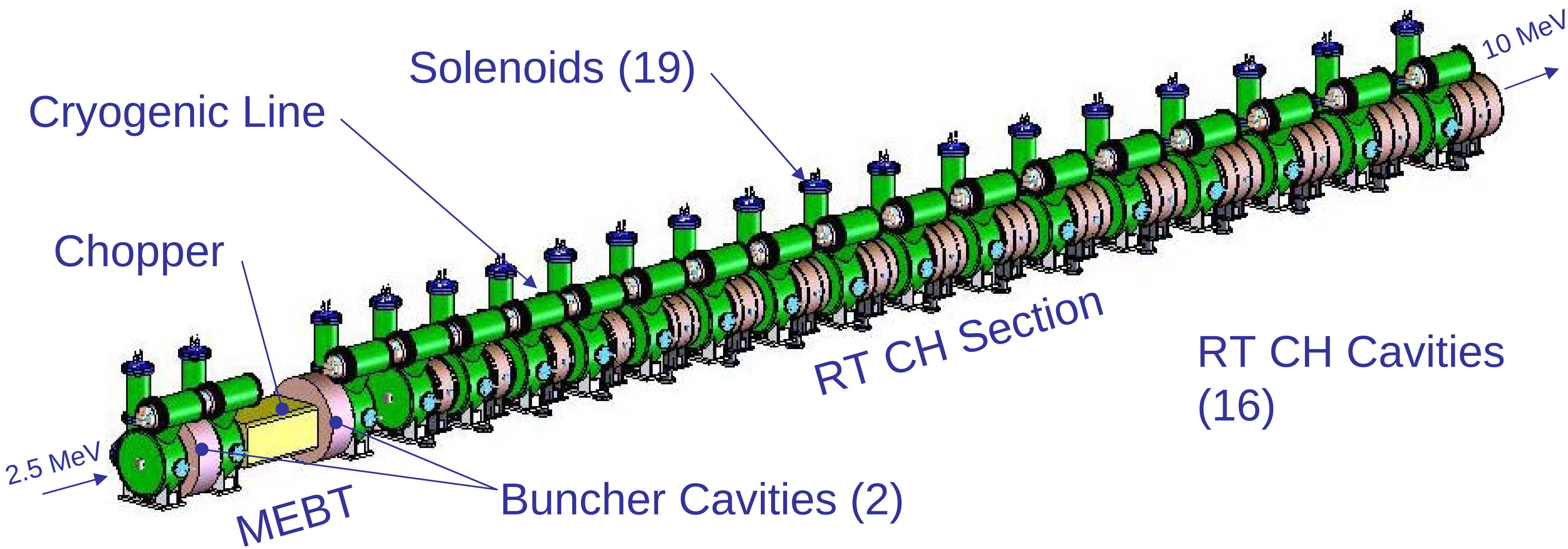

4 K Liquid Helium Line
Heat Exchanger
2 K liquid Helium Line
Helium Phase Separator
Liquid Helium Reservoir Inlet
4 K Helium Gas Exhaust Bayonet
Vacuum Header Control Valve
Helium Gas Exhaust
Vacuum Header Bayonet
Connection to Cavity Helium Vessel
Pipe for Building Experiment Support Structures
Vacuum Space Access Port
80 K Shield

High Intensity Neutrino Source

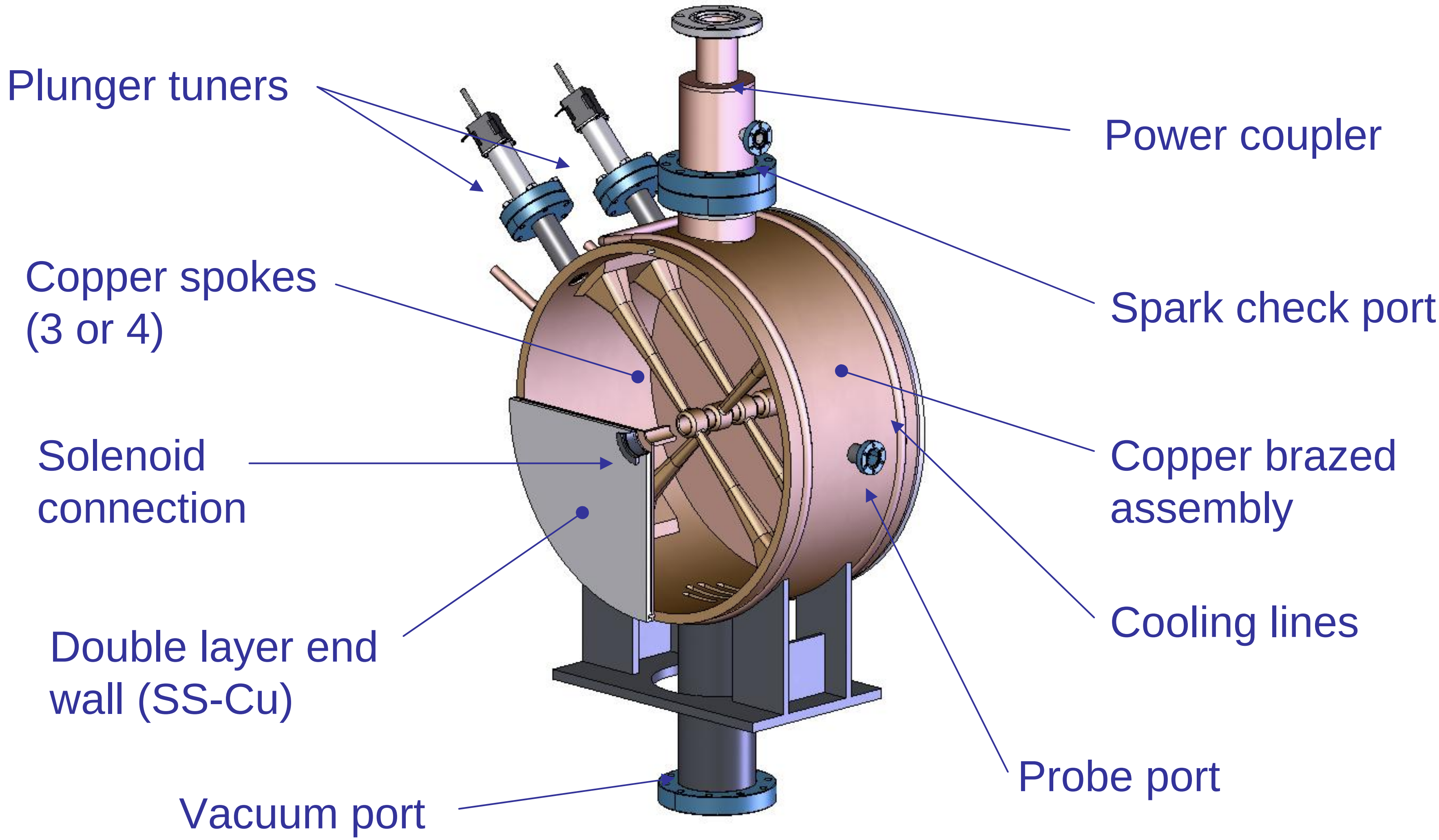
- Fermilab is developing a plan to replace the current linac with a new High Intensity Neutrino Source (HINS)
- HINS will enable Fermilab to be a leader in neutrino physics for years to come



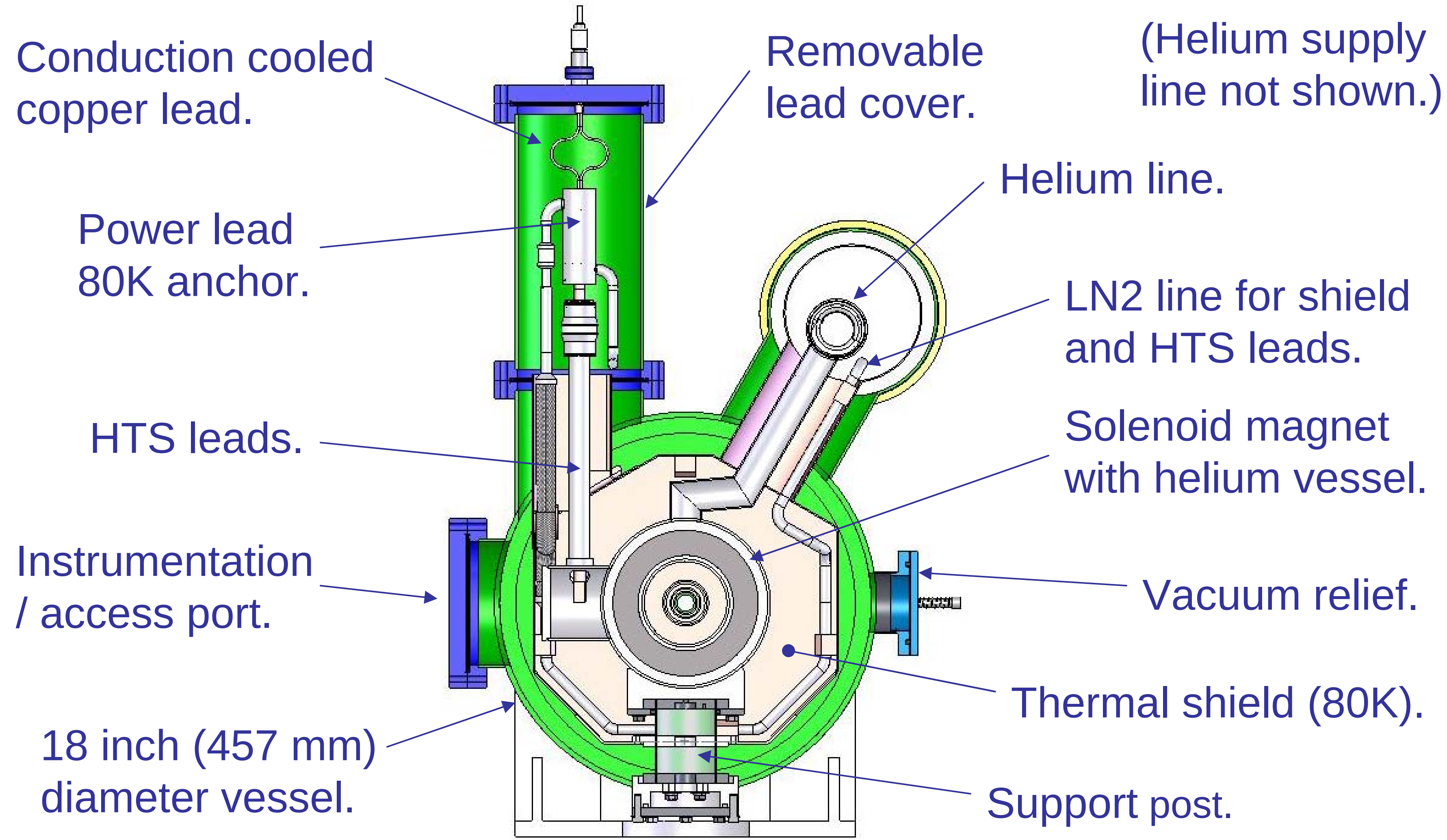
Medium Energy Beam Transport (MEBT) & Room Temperature Cross-bar H-type (RT CH) Section



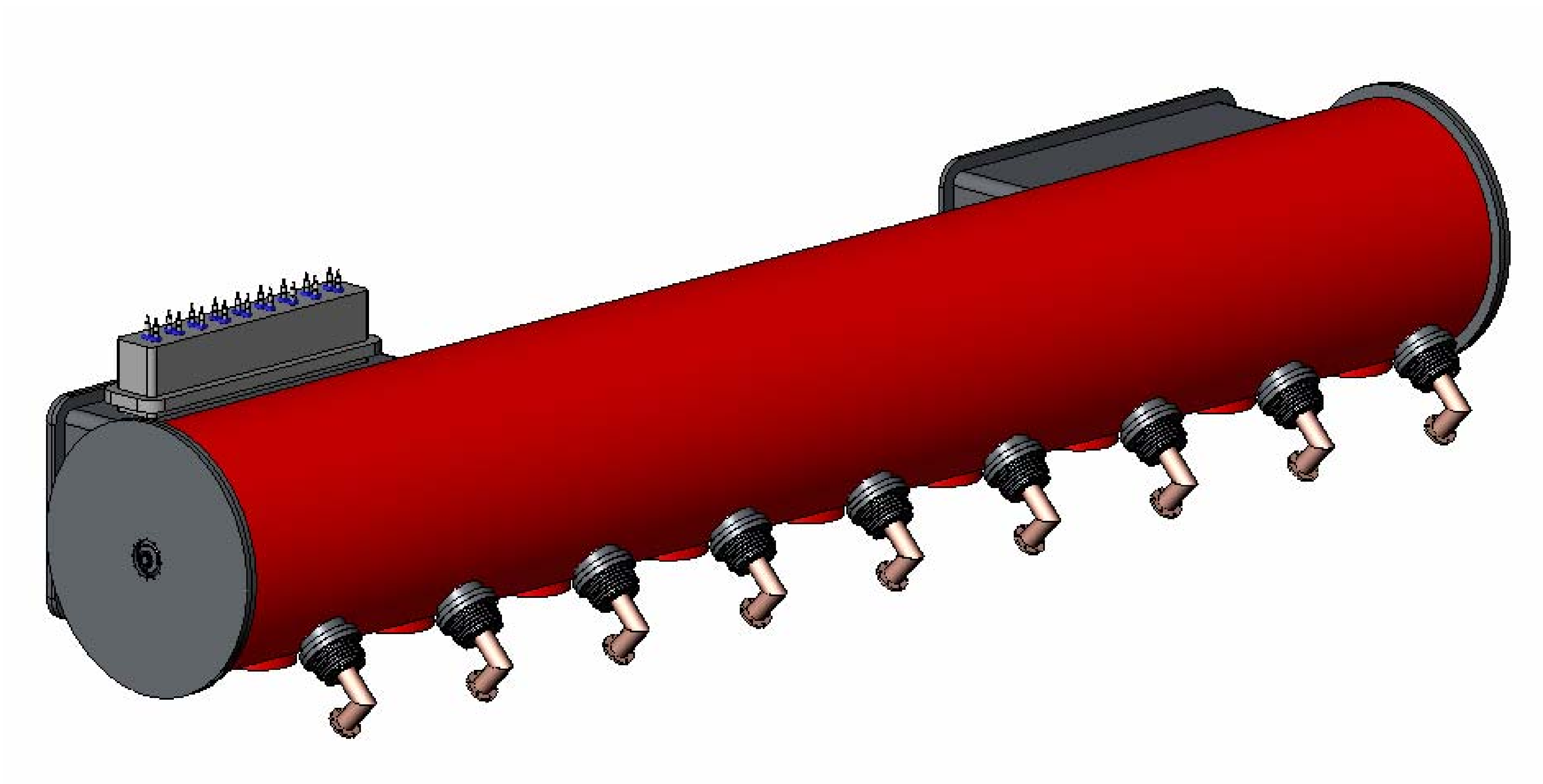
RT CH Cavity


Plunger tuners
Power coupler
Copper spokes
(3 or 4)
Spark check port
Solenoid
connection
Copper brazed
assembly
Double layer end
wall (SS-Cu)
Cooling lines
Probe port
Vacuum port

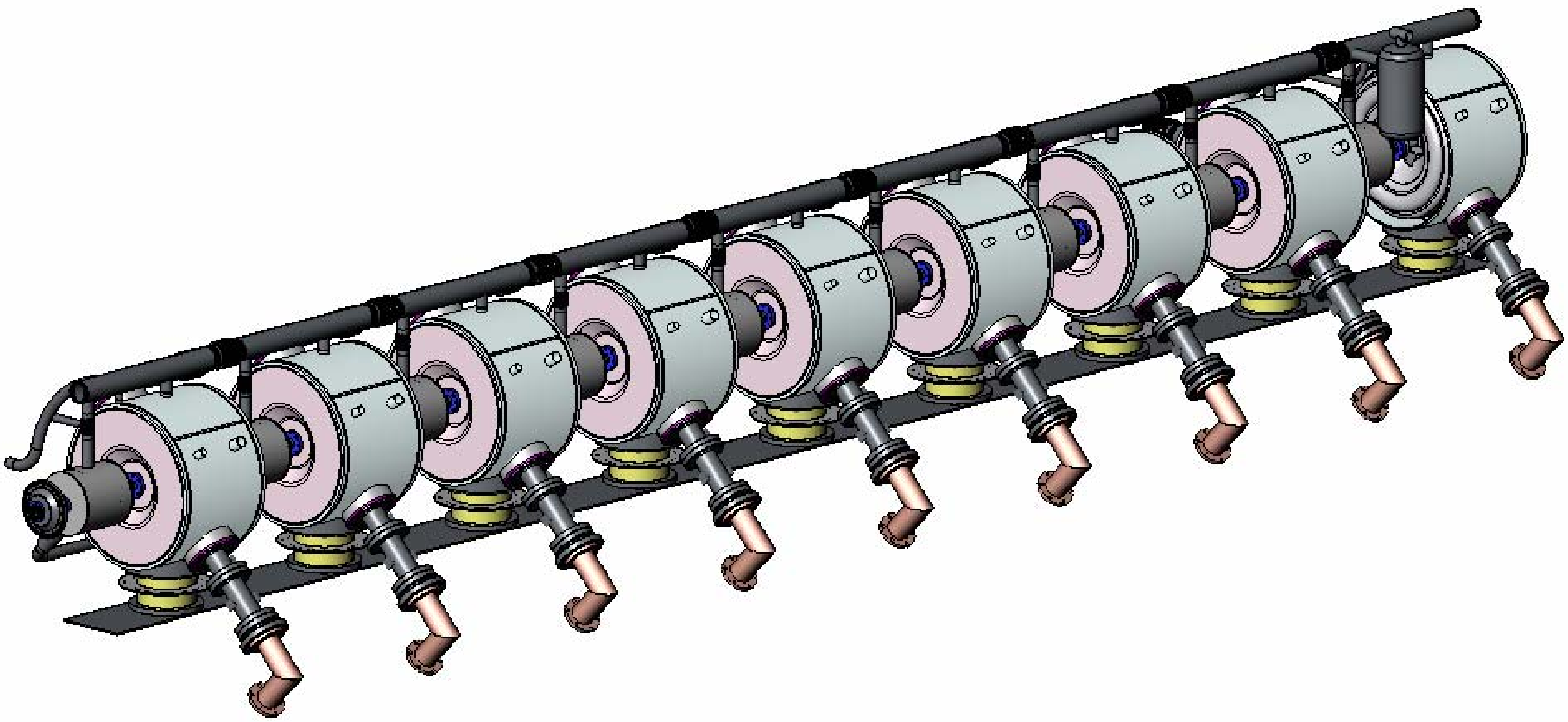
MEBT/RT CH Solenoid Cryostat



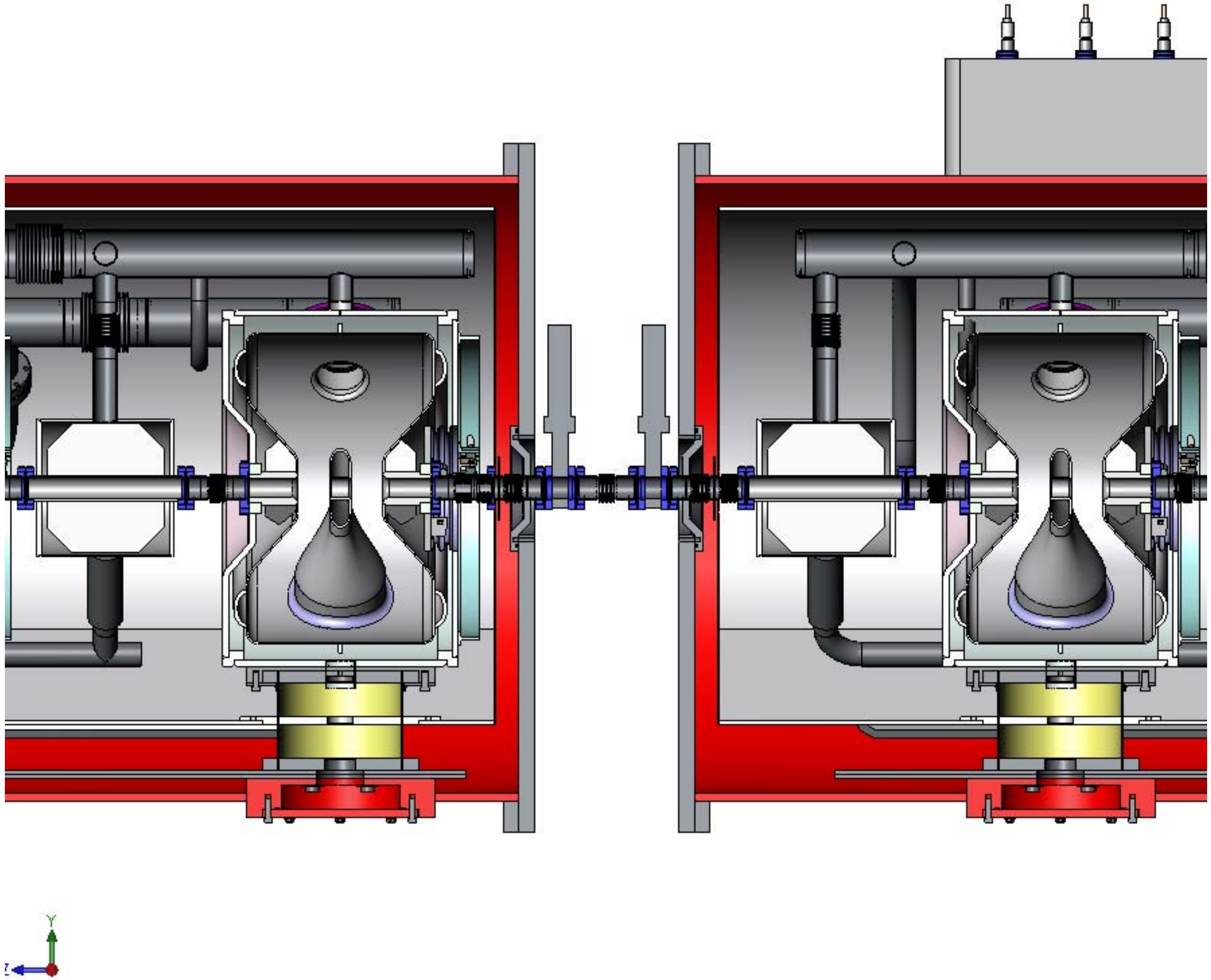
β=0.22 Cryomodule Assembly



Spoke Cavity Cryomodules



Transition Between Cryomodules



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  - For helping me with this presentation & teaching me cryogenics over the past couple years
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  - For helping me to develop the HINS portion of the presentation
- And the many others that didn't fit on this page…