SNS Proton Power Upgrade

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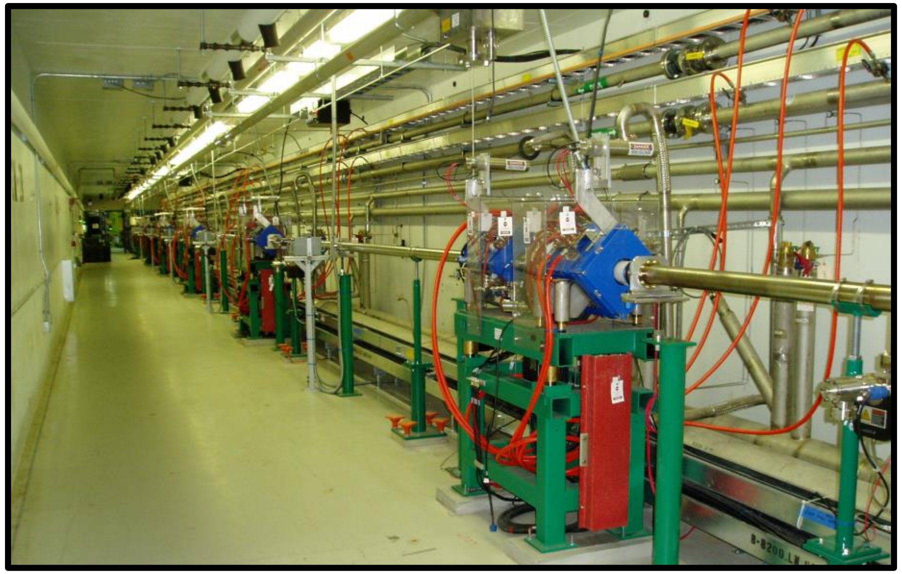
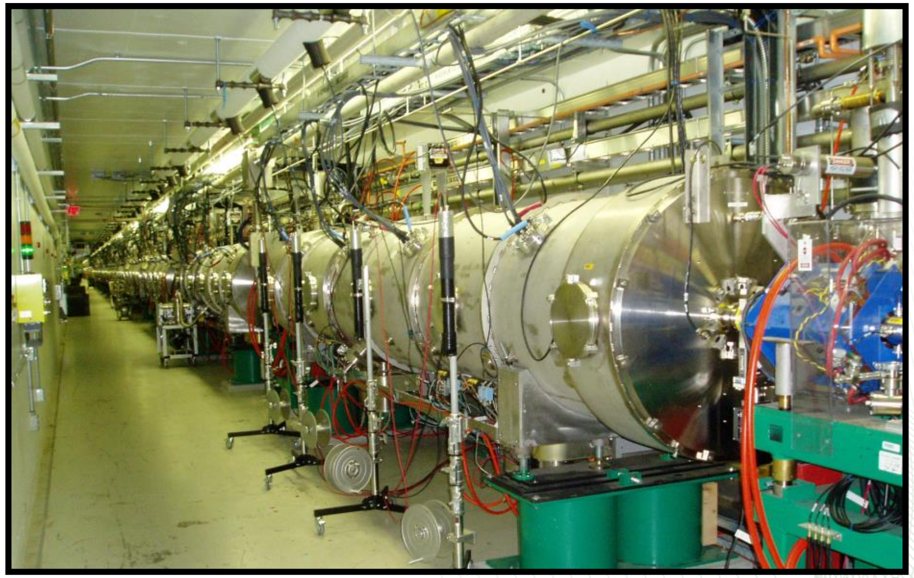
Presentation Outline – Plenary

- Scope
- Design Criteria
- SCL Performance
- PPU HB Cavity Design
- PPU Fundamental Power Coupler
- Cryomodule Design Changes
- Cryomodule Assemmbly
- Summary

Scope

- Increase beam energy from ~1.0 GeV to 1.3 GeV
- Procure, fabricate, test, install, and commission seven new high beta cryomodules
- Nine empty slots
  - Warm sections and magnets are already in place





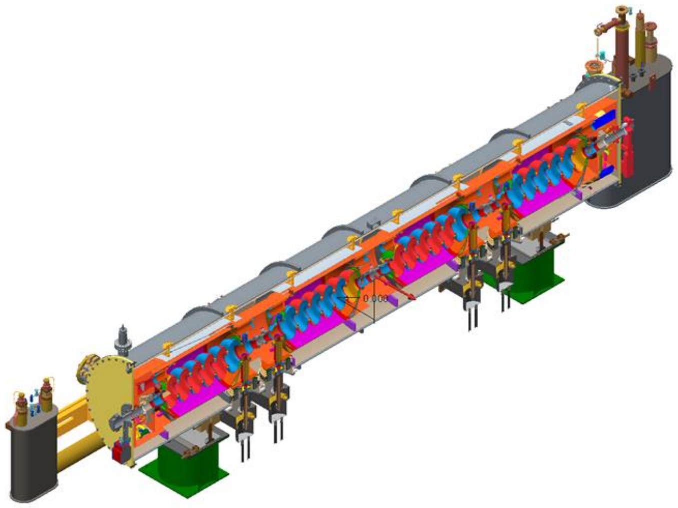
Design Criteria

- Lessons learned from over 10 years of operating experience are incorporated into the design to achieve 1.3 GeV

Parameters	Original SNS high-beta cryomodule design	PPU high-beta cryomodule
E_{acc} (=E_oT_g, T_g: Transit time factor at β=0.81) (MV/m)	15.8	16.0
Fundamental power coupler (FPC) rating, peak and average (kW)	550, 50	700, 65
External Q of FPC, Q_{ex}	7×10^5 (±20%), fixed type	8×10^5 (±20%), fixed type
Material of cavity	High RRR niobium (RRR>250) for cells, reactor-grade niobium for end groups	High RRR niobium (RRR>250) for both cells and end groups
Higher-order mode couplers per cavity	Two (one at each end group)	None
Tuner	One mechanical tune, one fast piezo tuner	1 mechanical tuner (no fast piezo tuner)
Pressure vessel	Good engineering practice	Code stamp required

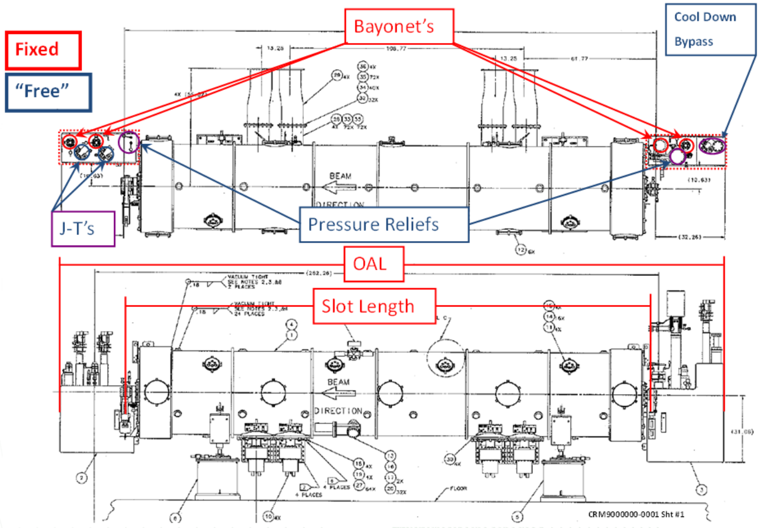
HB Spare CM has demonstrated this gradient for five years of operation

Design Criteria (Cont'd)



- Utilize HB spare cryomodule as design standard for PPU
- Pressure boundary is compliant with 10 CFR 851
  - Conducted internal and external reviews
  - Vacuum boundary built to ASME BPVC Section VIII
  - Helium piping built to ASME B31.3
  - All welding conducted in accordance with ASME code
- Interface points are the same as previous design
  - U-tube connections held constant
  - Waveguide connections held constant
  - Instrumentation connections are very similar

Parameter	Value
Slot Length	7.891 m
CM length (bore tube)	6.291 m
# of bayonets	4
# of control valves	5



SCL Performance - SCL Parameters

Key Parameters	Present	PPU
Proton beam power capability (MW)	1.4	2.8
Linac output energy (GeV)	0.97	1.3
Beam pulse length (ms)	1	1
Pulse repetition rate (Hz)	60	60
Average linac macro-pulse current (mA)	27	38
Additional cavities/cryomodules		28/7
Cavity accelerating gradient (MV/m)	13.5*	16

* Average accelerating gradient of high beta cavities as of October 2016

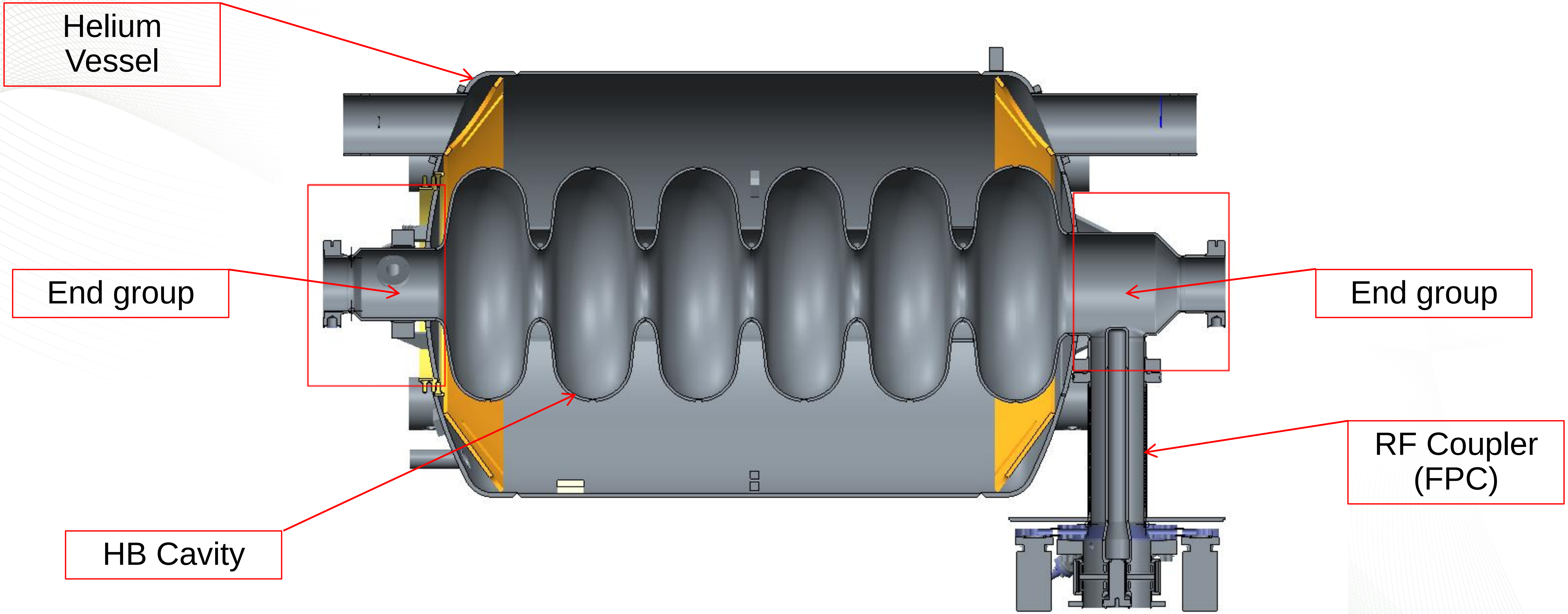
SCL Performance - PPU Energy

Charges 1, 3, 7

SCL Performance	PPU
Beam Output Energy of MB Cavities (MeV)	460
Beam Output Energy of Existing HB Cavities (MeV)	965
Beam Output Energy of PPU Cavities (MeV)	1,300

- Three PPU cavities in reserve providing margin
- Spare MB and HB cryomodules will be available to allow for repairs while maintaining energy
- Plasma processing and repair of 11b increases performance of MB cavities
- For PPU, a large fraction of existing HB cavities will be reduced in gradient due to RF power limitation

PPU HB Cavity Design



- Cavities will have high RRR end groups and no HOM couplers

Design Changes for new HB Cavities

- High RRR material will be used for end groups to improve thermal stability
  - Main SCL operational issue
- Cavities will have no Higher Order Mode couplers and no Piezo fast tuner
  - Experienced multiple failures
  - Operational experience shows they are not needed
- Electropolish will be used for cavity processing which has shown reduced field emission and increased gradients

A spare HB cryomodule was built in-house and installed in the linac 2012 (CM20). The cavities were processed by electropolish and gradients meet PPU requirements with no field emission!

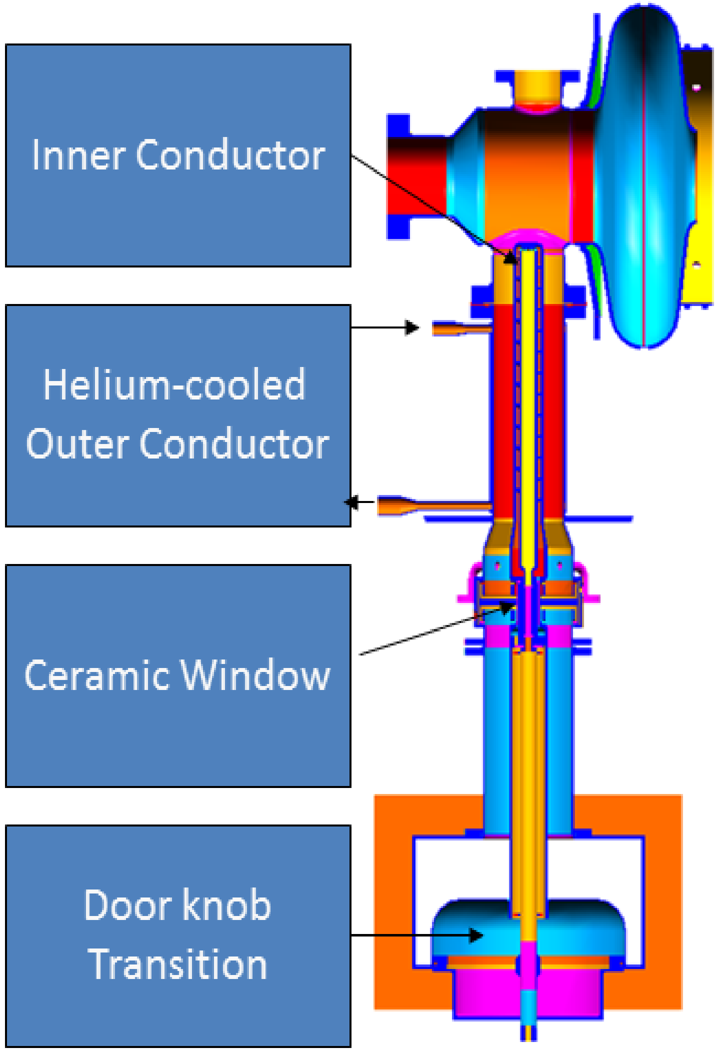
Many cavities in the linac have HOM probes and piezo tuners removed with no operational performance issues !

Design Changes for New RF Couplers

- Center conductor wall thickness will be increased by 3.5mm to reduce thermal radiation to end group (performance)
- Center conductor length will be shortened by 1.5 mm to meet design Qext (efficiency)

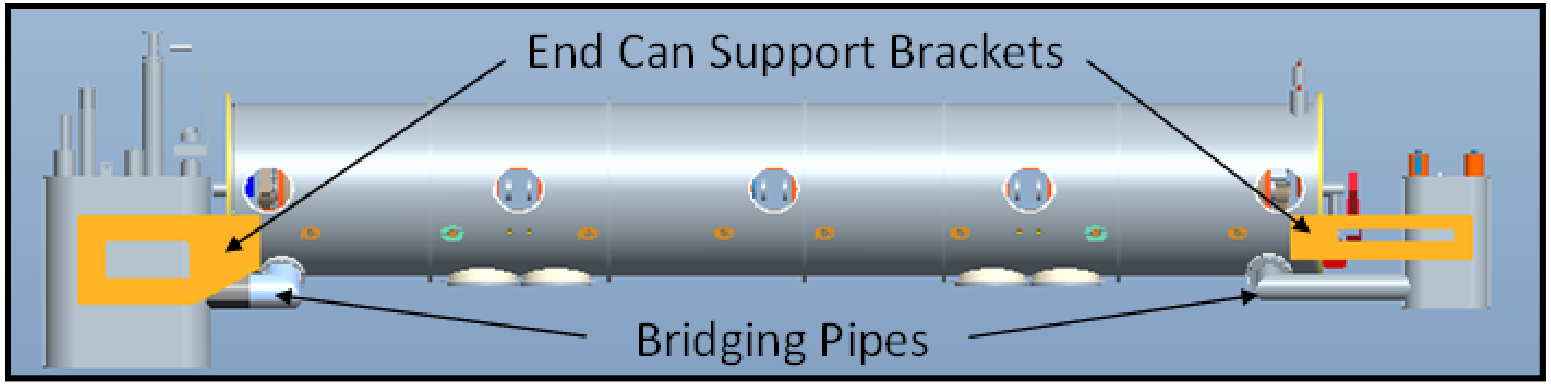
Four new HB couplers were fabricated in industry with thicker material and had initial test completed, additional testing is planned

PPU Coupler Design

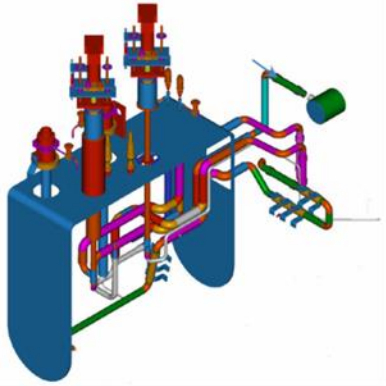


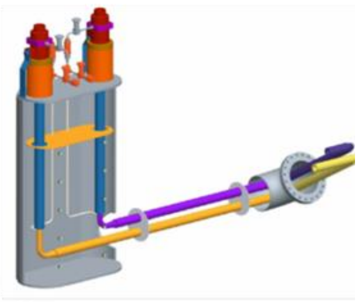
Cryomodule Design Changes - Vacuum Vessel and End Cans

- Vacuum vessel and end cans
  - To be manufactured in industry
  - Code stamped vessels ASME BPVC
  - Can be provided by code shop
  - Designed with weld pad to allow partner laboratory to complete assembly without needing code stamp



Return End Can
Original Design | New Design





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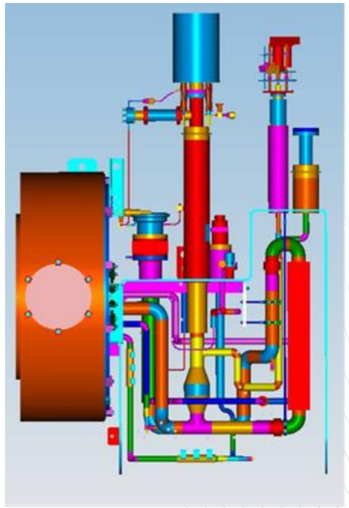
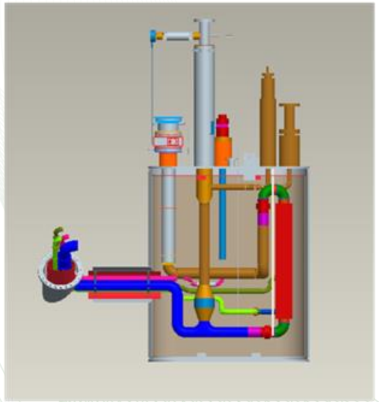
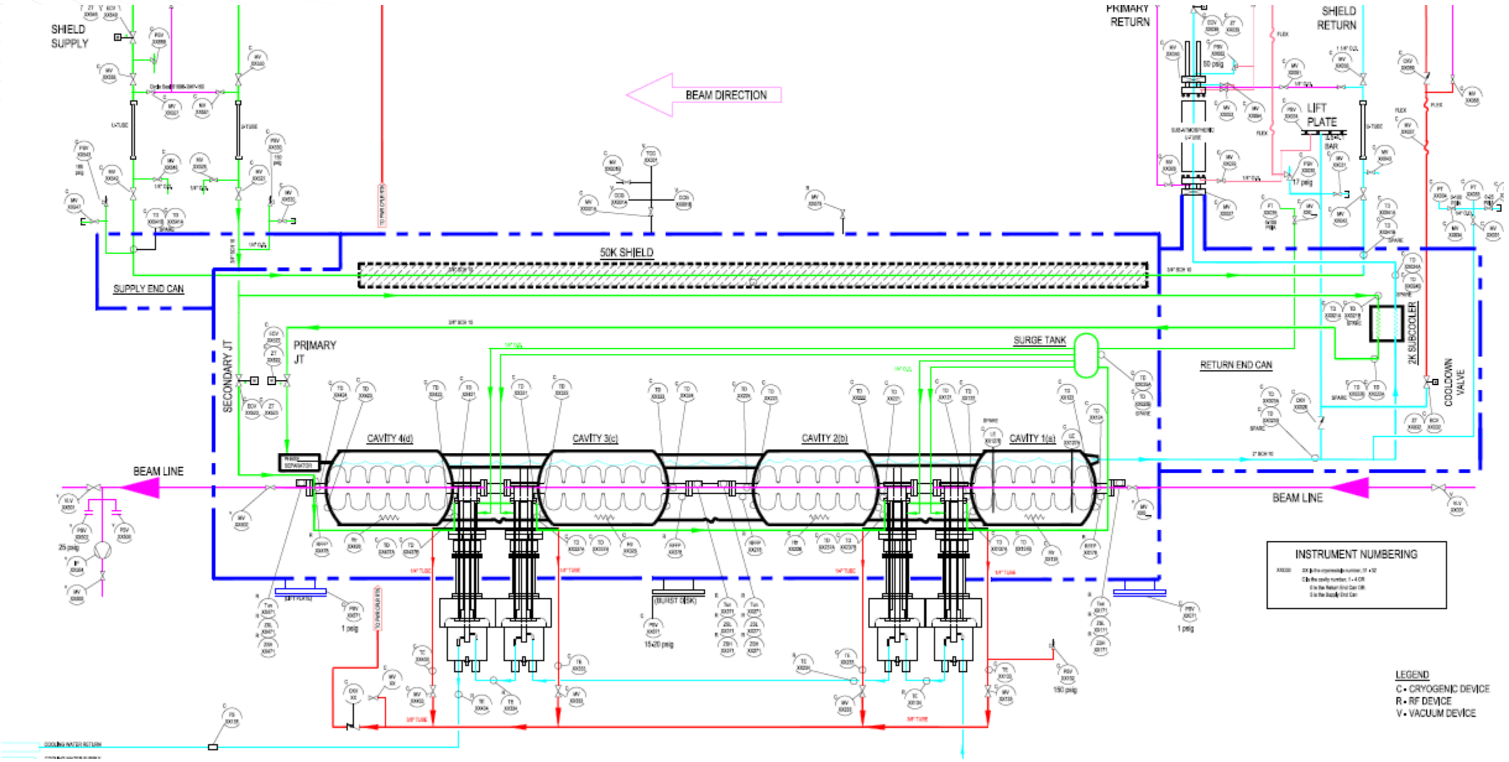
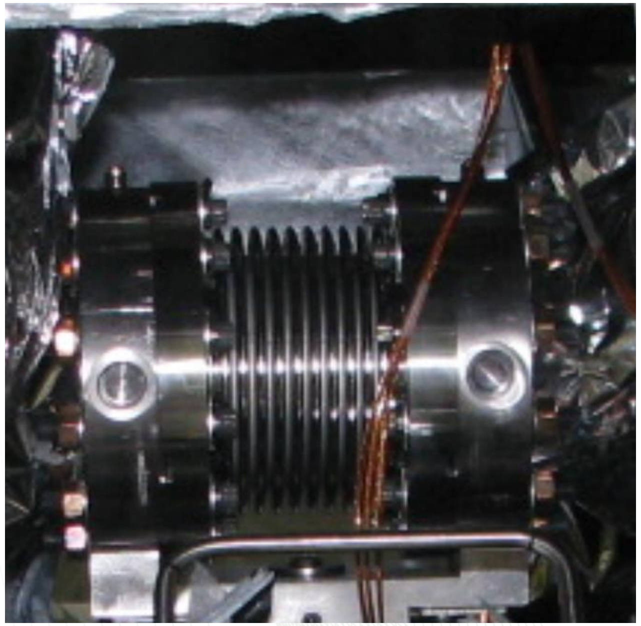




Cryomodule Design Changes - Instrumentation Hardware

- Lessons learned incorporated based on operational experience
- Cernox sensors will be used in place of silicon diodes
- Pressure instruments with no internal electronic components (strain gauges)

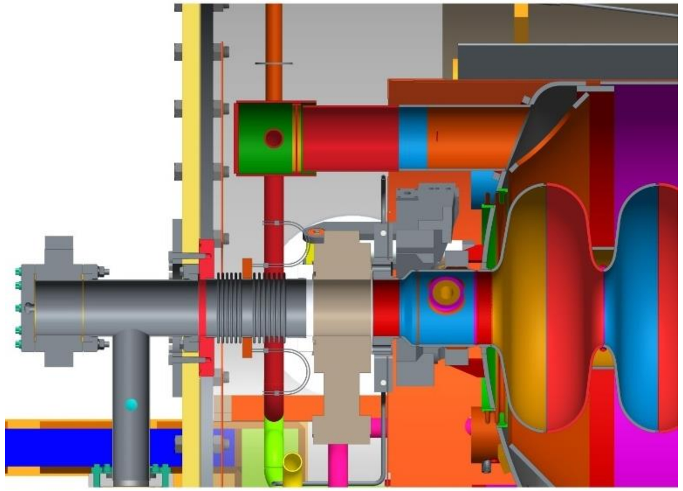


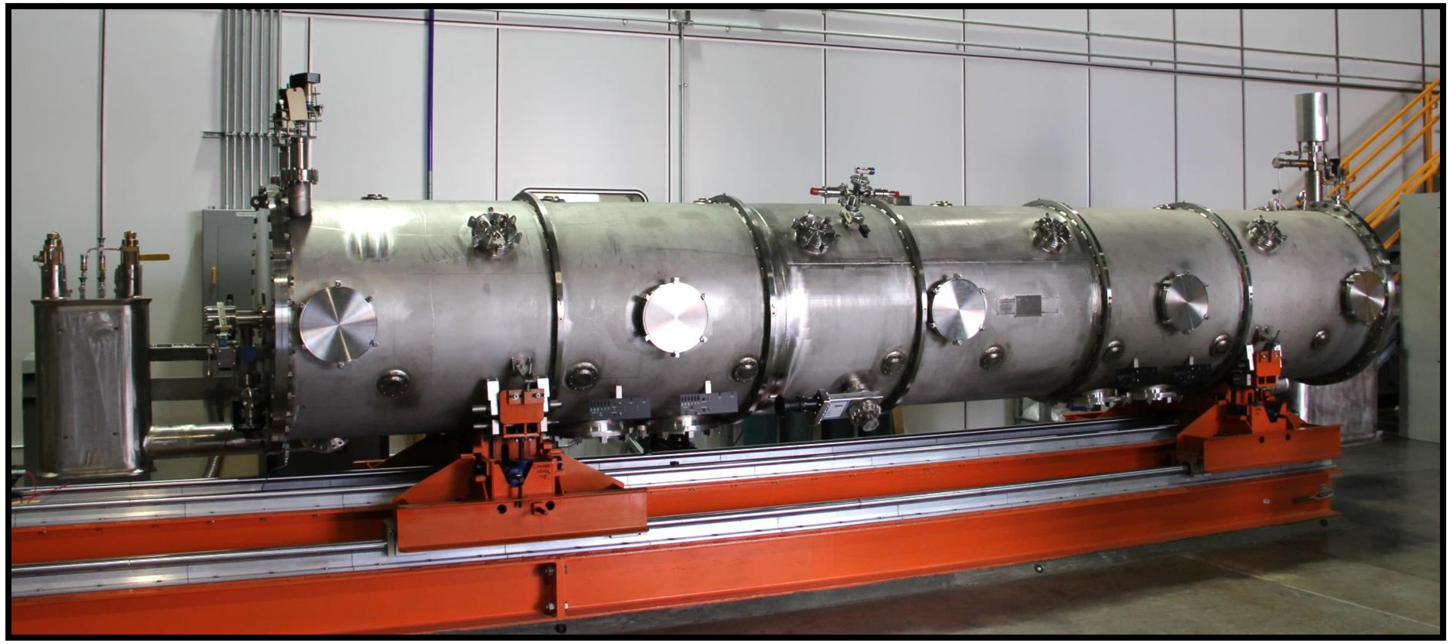


OAK RIDGE
National Laboratory

Cryomodule Assembly

- Methodology demonstrated in spare HB build
- Alignment methodology is significantly improved
- Warm to cold transition assembly procedure developed for new design
- All technical insight will be transferred to a partner





Summary

- SNS is embarking on a Proton Power Upgrade to double the beam power capability
- Seven new high beta cryomodules will be incorporated into the Linac
- The high beta spare cryomodule serves as the PPU prototype
- SNS will partner with another institute to perform this scope
- Key design changes to the cavities and cryomodules have been incorporated from lessons learned during greater than ten years of operation