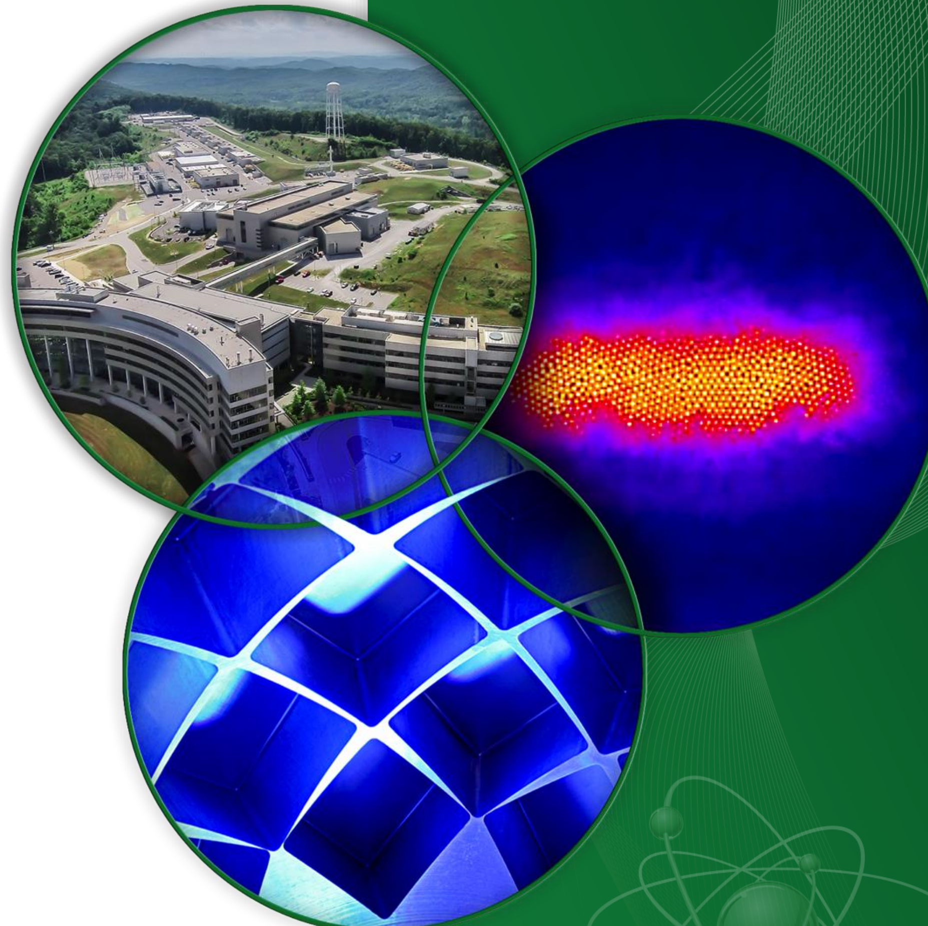
Commissioning and Operation of the Horizontal Test Apparatus at SNS



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Overview

- Background
- Design & Fabrication
- Commissioning & Operation
- Current R&D using HTA
- Summary

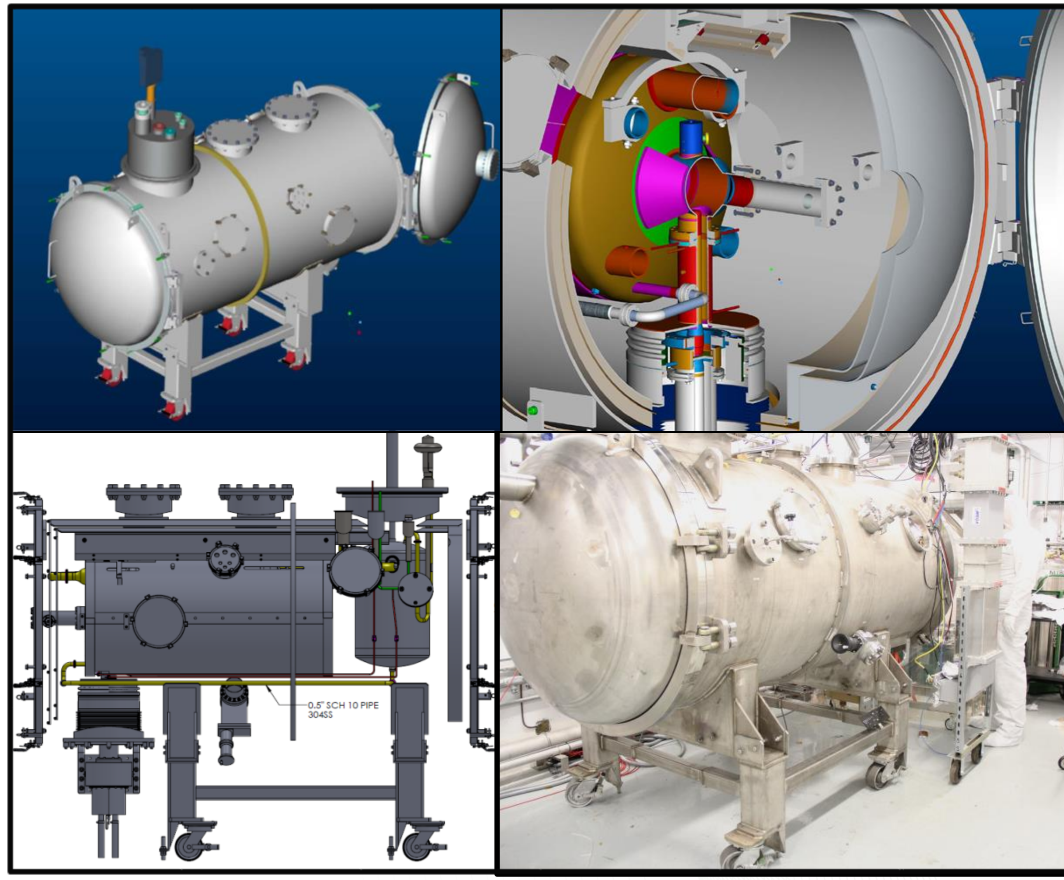
Background

Motivation for HTA at SNS

- **SNS in operation since 2006**
  - Highest average proton beam linac in the world, 1.4 MW demonstrated
    - SCL: 81 SRF cavities in 23 cryomodules
    - Cryoplant: 2.4 kW at 2.1 K
  - Excellent availability of SCL systems ~98% (including supporting sub-systems)
  - Linac output energy 940 MeV
- **Limiting factor for SRF cavity performance**
  - Electron activity (field emission, multipacting) resulting in end group quench
  - End groups made of reactor grade niobium with lower thermal conductivity
- **Testing cavity performance in horizontal configuration**
  - Aim to reach 1 GeV to provide margin for reliable 1.4 MW operation
  - Horizontal Test Apparatus for R&D in cryomodule-like environment
    - Better understand limiting factors of SNS cavities
    - R&D for performance improvement

What is HTA?

- **Multi purpose test vessel**
  - Demountable cavity for rapid testing
  - Similar RF and cryogenic parameters as cryomodule
  - Cryogenic connection to operating CTF test system
  - Flexible instrumentation capability
  - Three cryogenic helium circuits:
    - Primary liquid helium supply
    - Coupler cooling at 5K
    - Shield cooling



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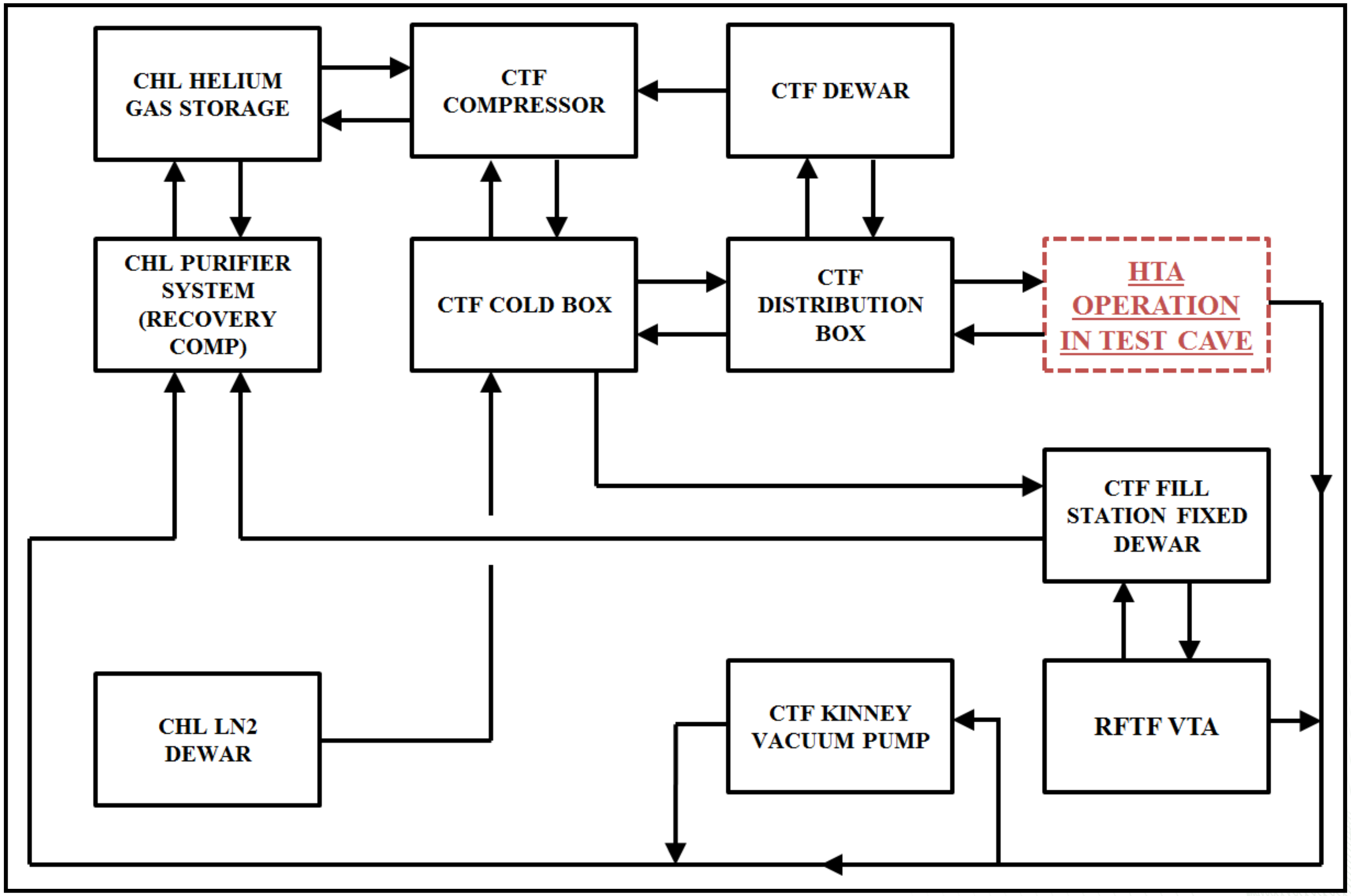
HTA cooling block diagram

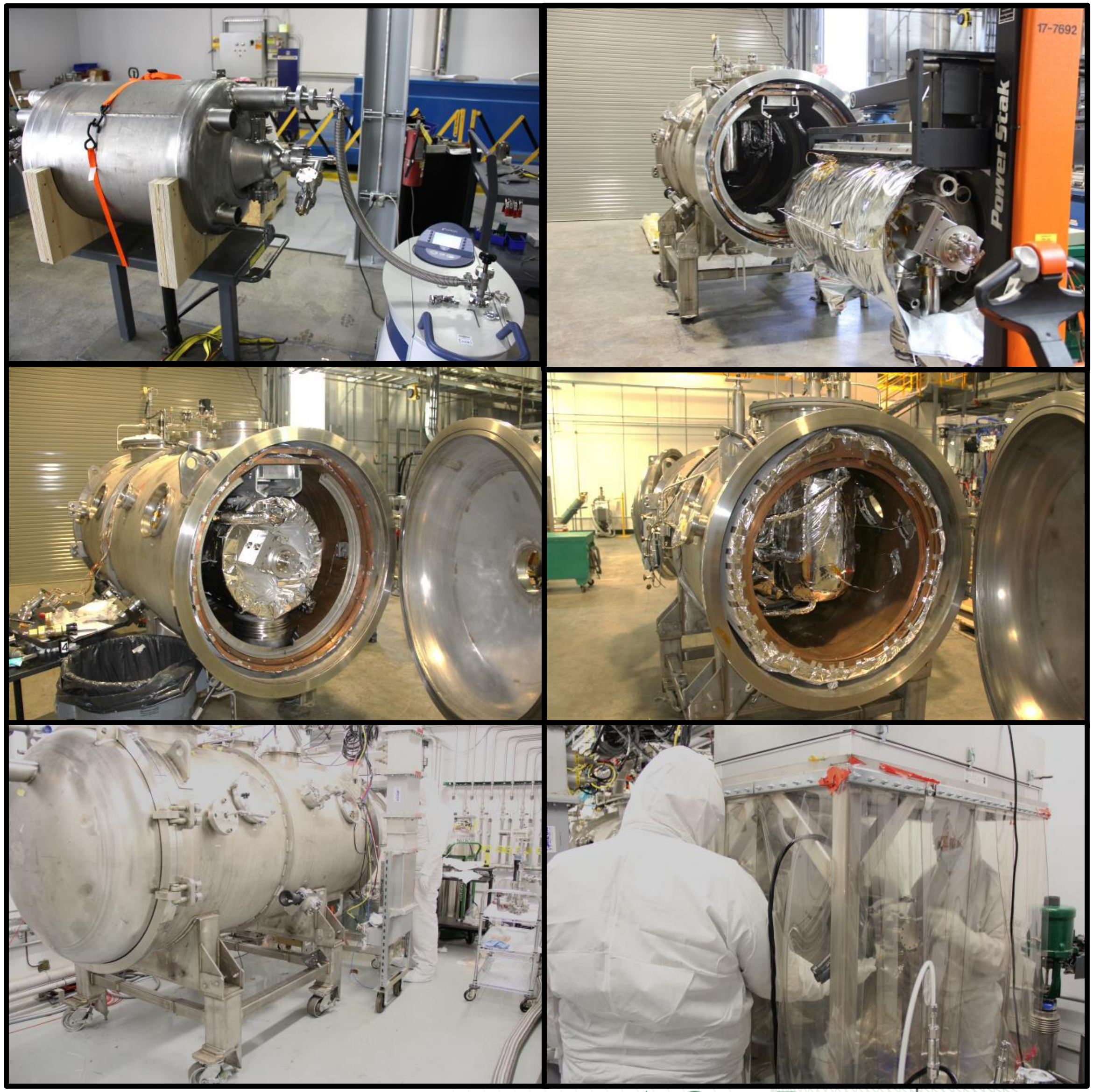
- HTA operates in conjunction with the CTF system:



Design & Fabrication

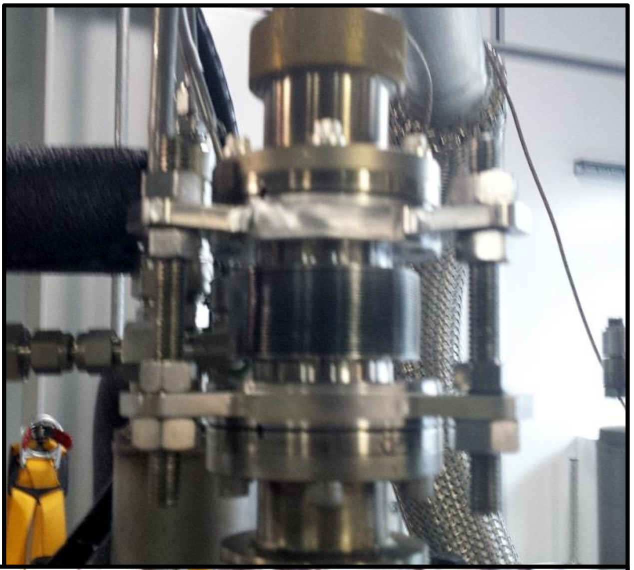
HTA main design features

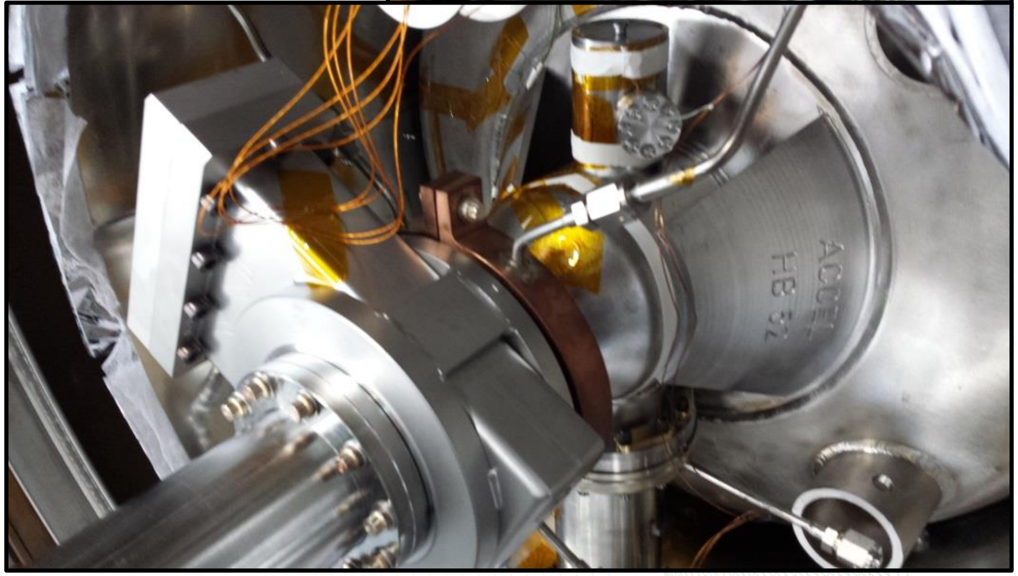
- Vacuum vessel with two main doors & access ports
- Copper thermal shields cooled to 50 - 20 K with helium
- Access ports to open/close cold manual valves
- Demountable support rails
- P and T instrumentation
- U-tube connections to CTF transfer line
- Fixed dewar for testing without cavity (redundant LL & heater)
- Primary and shield circuit pressure reliefs (1.68 atm & 9 atm)
- SNS coupler & RF connections



HTA specific cooling features

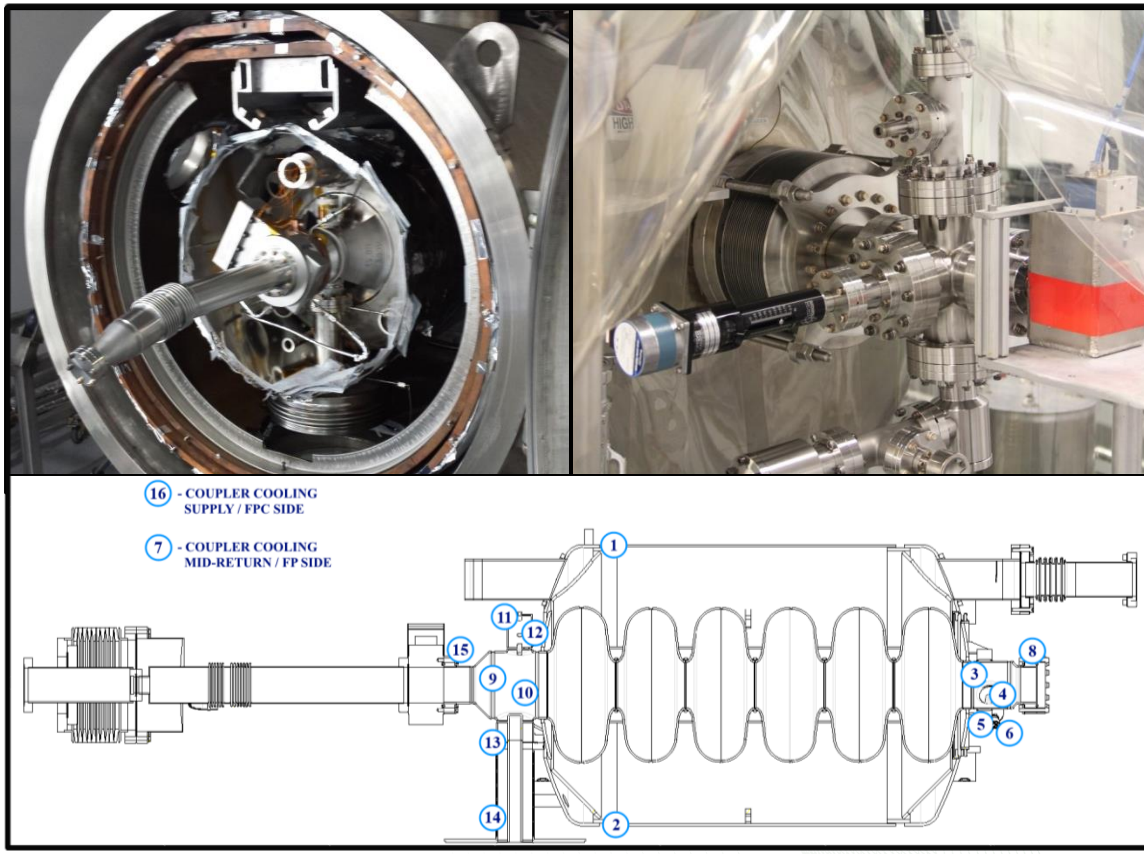
- **Movable primary helium supply bayonet**
  - Single supply and return pipe to HTA Dewar
  - Movable bayonet on primary stinger to control flow path
    - Demonstrated that cavity cooling is possible without adjustment
- **Flanged helium connections within vessel**
  - Minimizes turn around time
- **Copper cooling blocks on cavity end flanges**
  - Improves cooling for cavity end groups (~5 K additional cooling)
  - Shortens recovery time after quench





Examples of HTA instrumentation

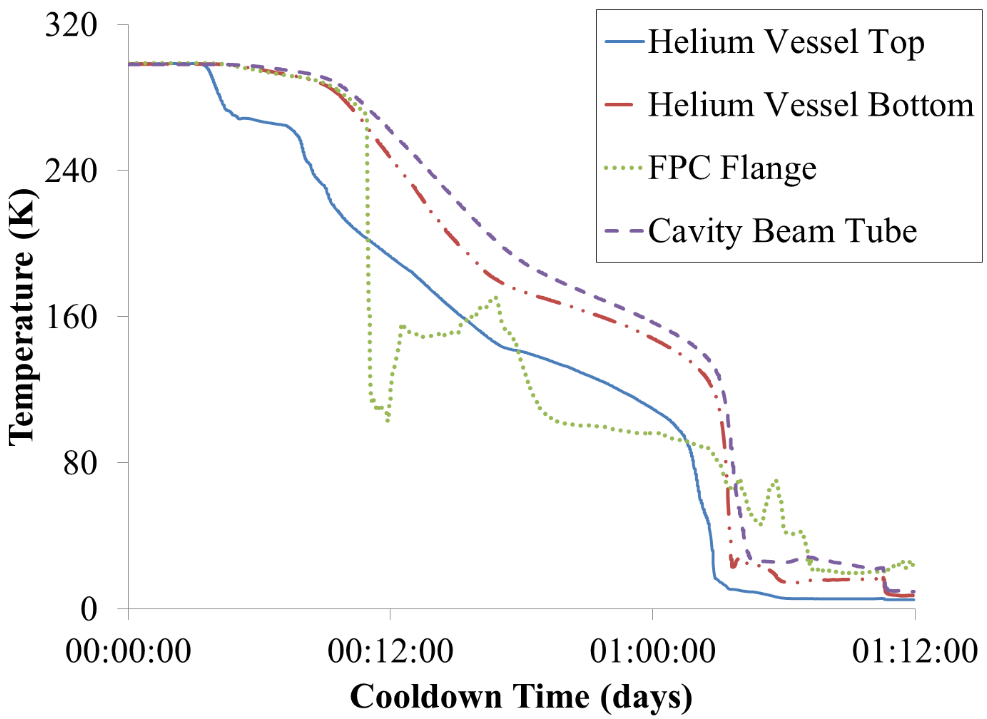
- **Instrumentation box outside of HTA**
  - Connected to the beam tube extension through the HTA door
  - Phosphorous screen and faraday cup to monitor e- activity
  - Camera with direct view of cavity volume
- **Additional diodes**
  - Monitoring of end-group temperatures
  - Help better understand their thermal behavior



Commissioning & Operation

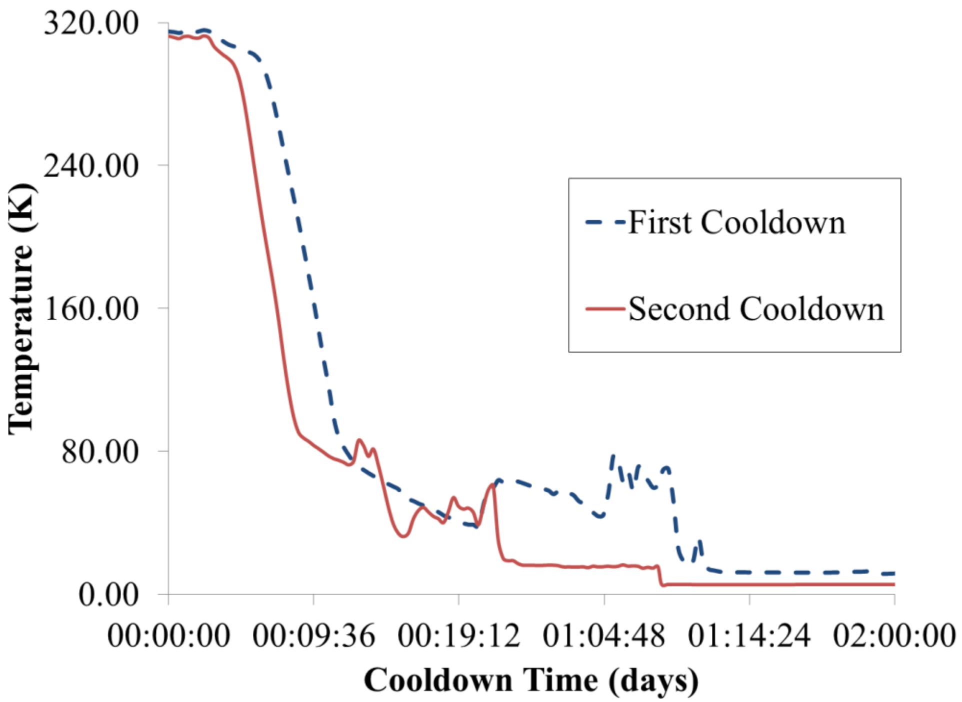
First HTA cool down in June of 2014

- **Initial cryogenic commissioning successful**
  - Cool down using the CTF cryogenic plant
  - Cooling all three helium circuits in parallel (primary, coupler & shield)
  - 28 hours to build liquid helium in the HTA Dewar and cavity helium vessel
  - 60 hours to reach thermal stability in end-groups without copper cooling blocks on cavity end flanges



Second HTA cool down

- **Copper cooling blocks installed on cavity end flanges for the second cool down**
  - Provides additional cooling to end-groups
  - Shortens cool down time
  - Improves thermal stability of end groups
  - Thermal stability reached in 33 hours



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HTA cryogenic loads

- **Static heat load**
  - 9.6 W static heat load to the cavity liquid helium bath calculated by measuring the liquid level drop with the primary JT valve closed
  - Static heat load to the shield circuit not determined as no flow meter is available
- **Dynamic heat load**
  - Cavity heat dissipation below CTF cooling capacity
- **Liquefaction load to secondary He circuit**
  - Circuit cooling the FPC & end-groups cooling blocks
  - Cooling flow measured with the outlet valve fully open
    - 0.75 g/s in the range of 6 K to 10 K

Current R&D using HTA

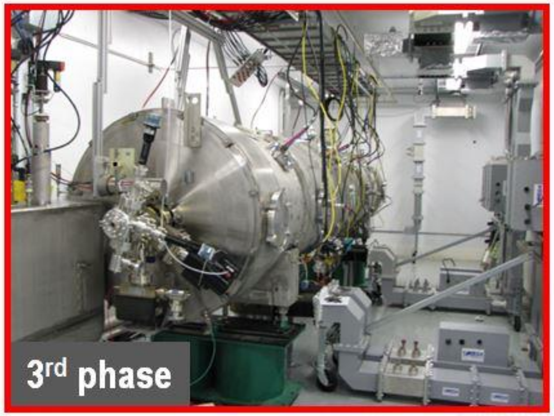
Example of HTA use for R&D

- **HTA used is the 2nd step in the plasma R&D**

R&D with 3-cell and 6-cell cavities

Processing of 6-cell cavity in HTA

In-situ processing in linac tunnel



Processing of cryomodule in test cave

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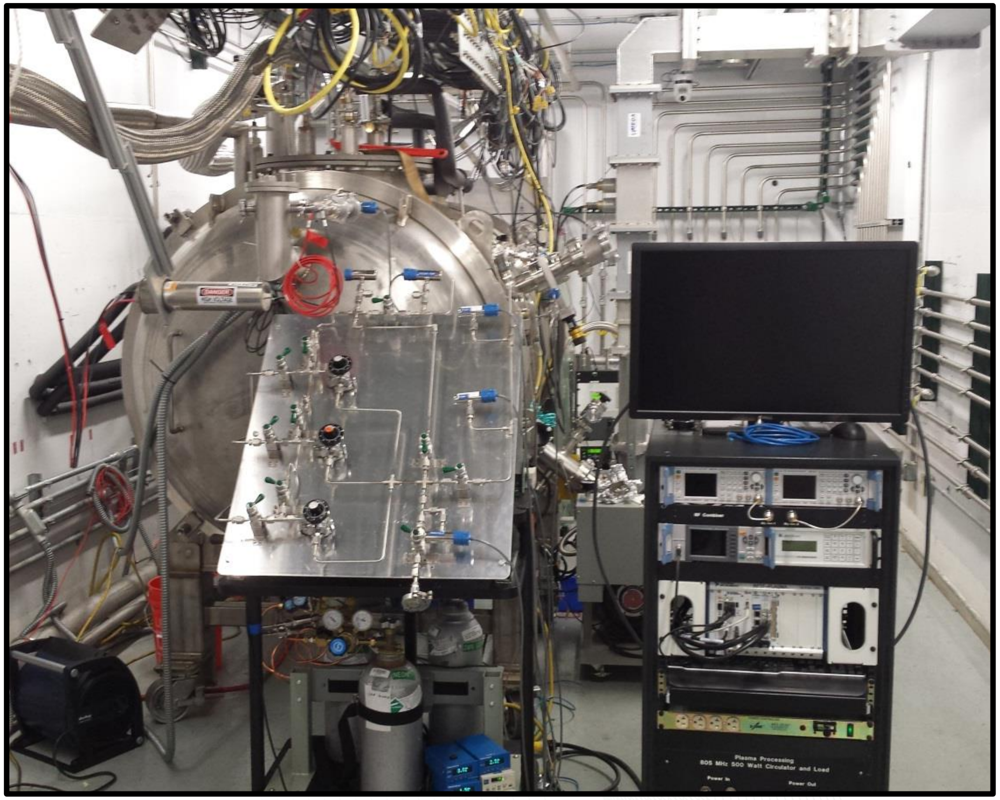
In-situ plasma processing using HTA

- **Test of plasma processing on single dressed cavities prior to test on cryomodule**
- **Plasma processing hardware adjacent to HTA vessel**
  - Processing occurs with cavity at room temperature
  - Gas manifold to supply process gas (~100 mTorr)
  - RF plasma station to ignite, tune and monitor plasma
    - Processing by-products monitored using RGA
- **Two cavities successfully plasma processed in-situ and tested in the HTA**



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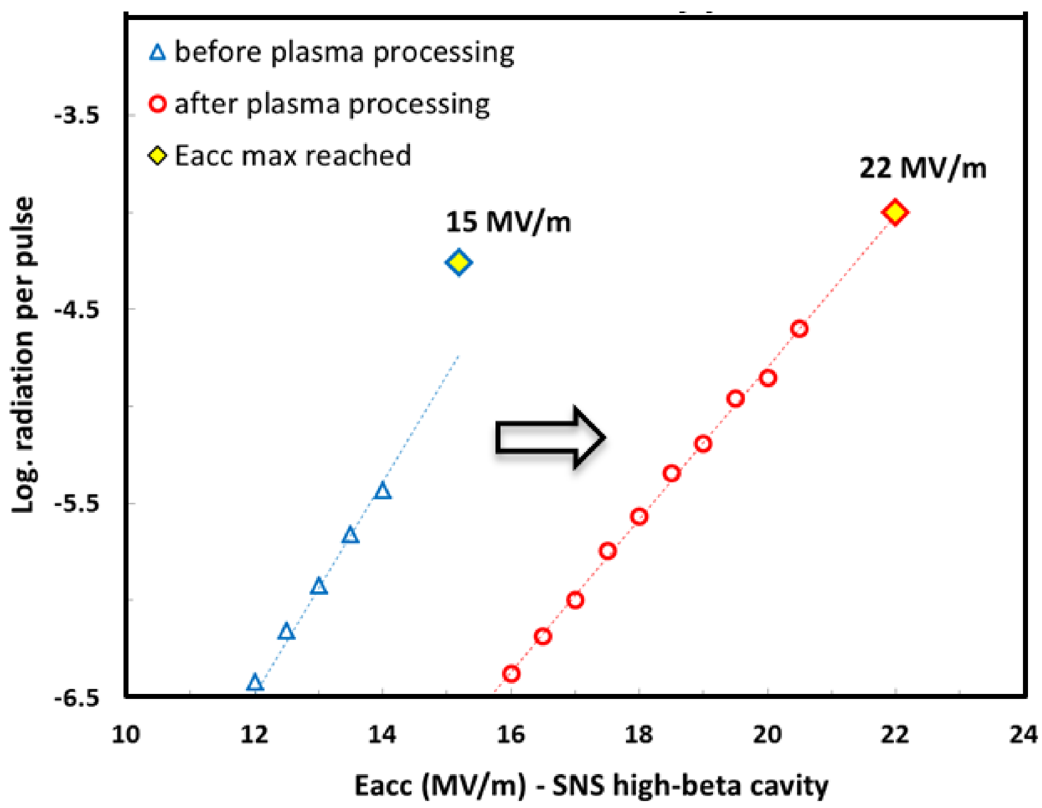
Highlight of plasma processing result using HTA

- **In-situ plasma processing improves cavity performance**

- **Before plasma processing**
  - Measured field emission onset 12 MV/m
  - Peak gradient 15.2 MV/m
- **After Plasma processing**
  - Measured field emission onset 16 MV/m
  - Peak gradient 22 MV/m

[M. Doleans, SNS 2015]



Summary

- **The HTA was successfully commissioned in 2014**
- **It performed as desired over five cryogenic tests over the past two years**
- **Ideal platform for testing cavities and subsystems in a cryomodule like environment while providing great flexibility for instrumentation, for example**
  - Two Cavities were successfully plasma processed in-situ and tested using the HTA
- **Planned activities**
  - Cold-test of cavity with high RRR end-groups
  - Test of 700 kW fundamental power coupler with a cavity
  - 2 K HTA operation using Kinney system

Acknowledgements

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Backup Slide

- **HTA P&ID:**