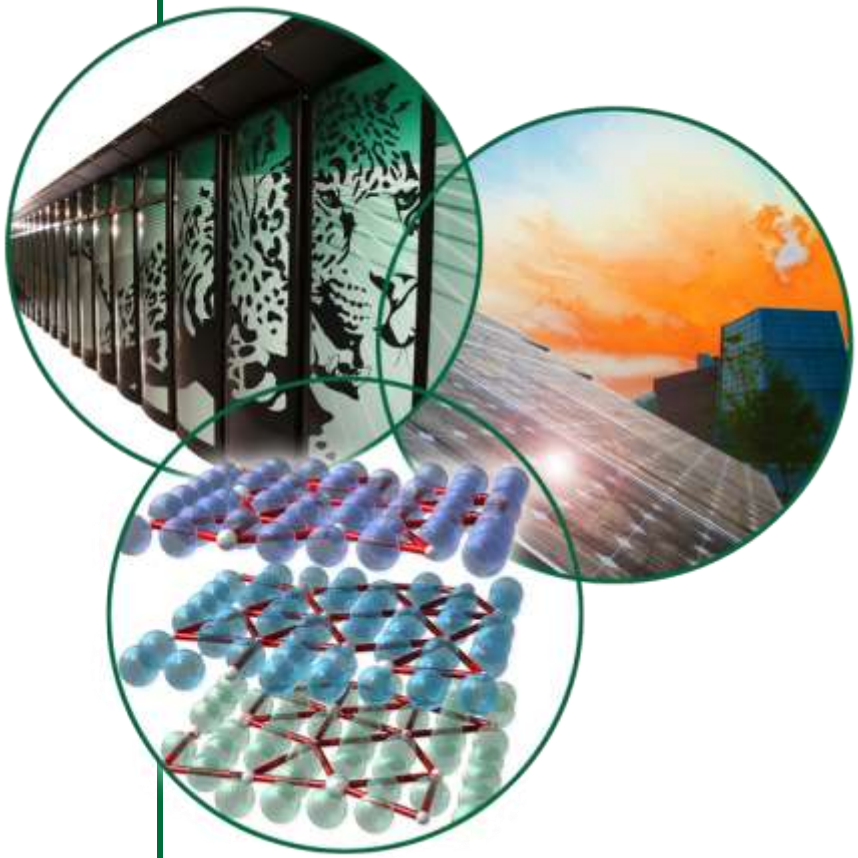
Superconducting RF Activities and Plans



SNS AAC Review

January 11, 2012

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Superconducting Linac Systems Group

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Outline

- Status at around last review
- Action items
- SRF activities since last review
- Summary

Status at last review (I)

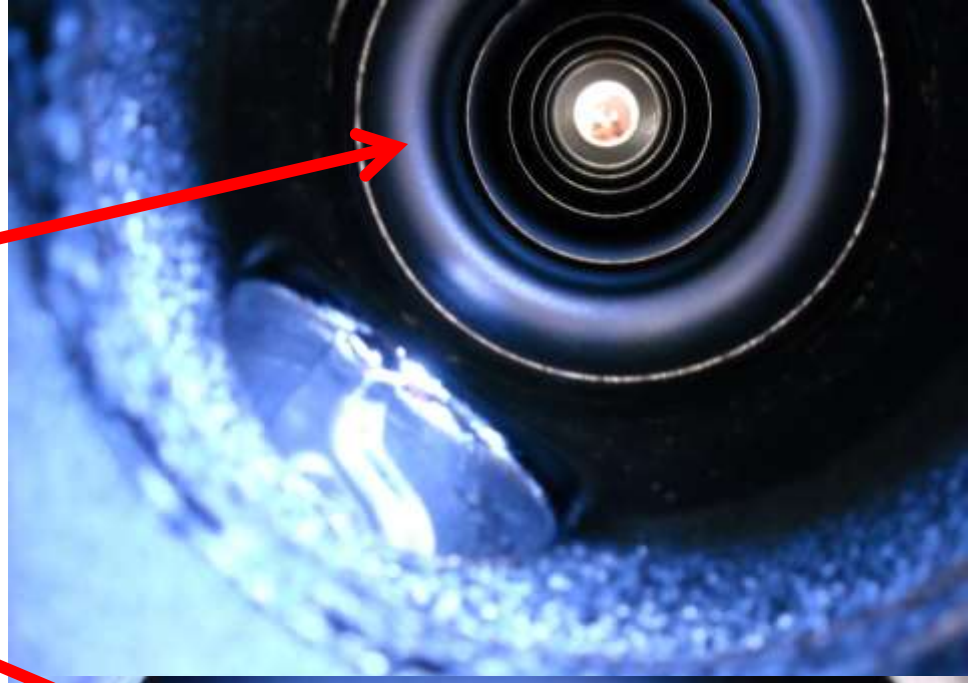
- High Beta Spare Cryomodule
  - Cryomodule design was in progress
  - Cavity preparation
    - Goal was to reduce field emission at the design operating gradient for all four cavities (proceessing & VTA tests were done at Jlab)
      - Vertical test data has traditionally not been a good indicator of module performance due mainly to field emission limiting the collective gradients of all installed cavities
      - Since the original SNS production, Jlab has significantly improved their procedures and processes. Jlab results have significantly reduced and eliminated field emission for most β =1 cavities
      - This was not the case for the four HB cavities !!
    - We suspected that the end-groups are the cause of many of the cavity performance issues
      - Multipacting
      - Field Emission
      - We can not ensure end-group performance statistically with the spare cavities
    - We demonstrated direct correlation between VTA and operational data in the machine

Status at last review (II)

- 6-cell, 3-cell, TM020 cavity and plasma chamber preparations for plasma processing R&D
- Facilities
  - New DI water system and HPR pump installed.
  - CTF development was at starting phase

End-group Roughness

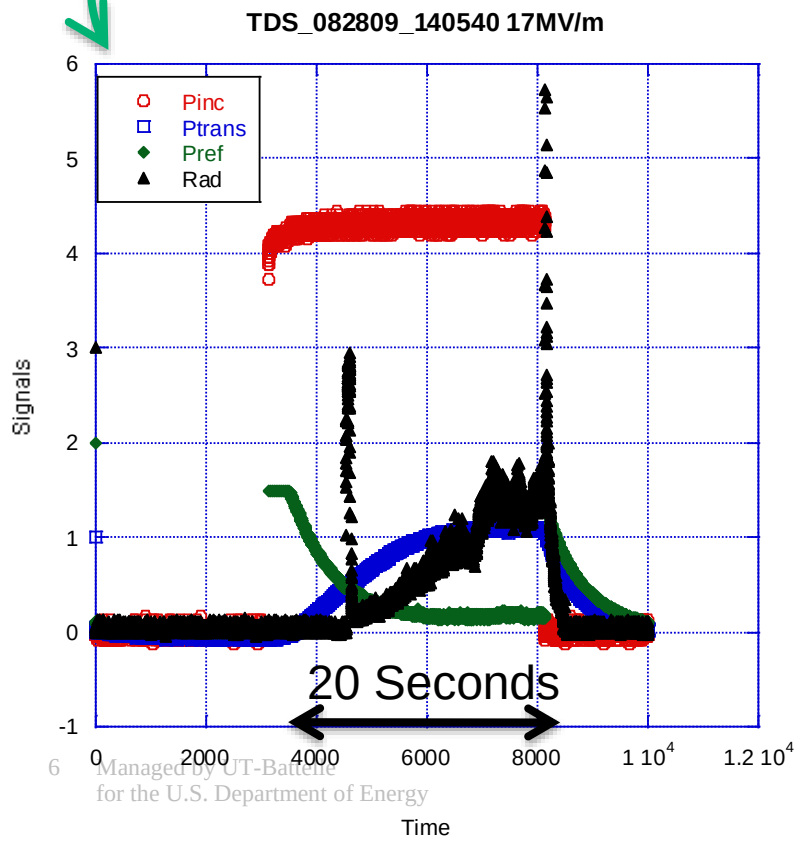
Cells have normal surface finish



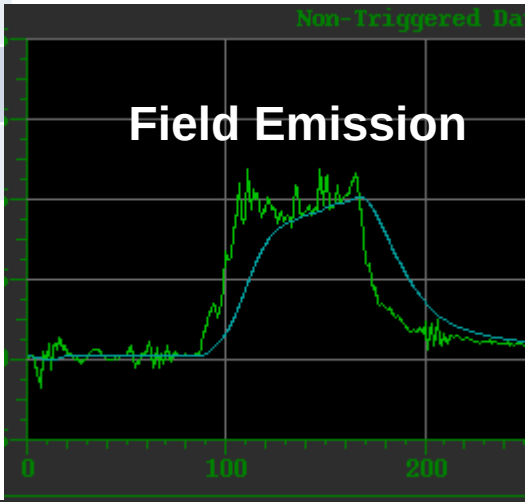
Rough Surface to the First IRIS

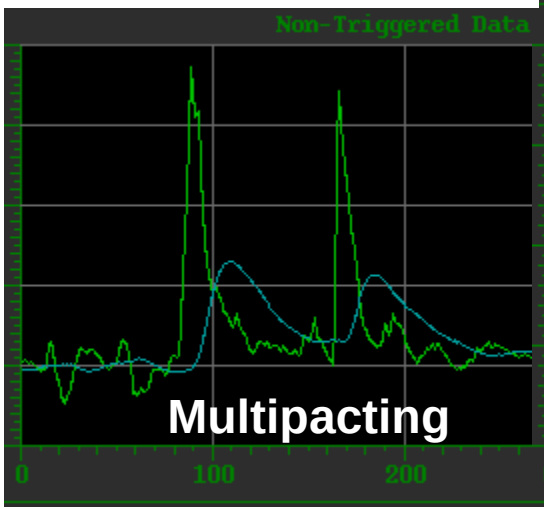
Summary of Cavity VTA Performance:

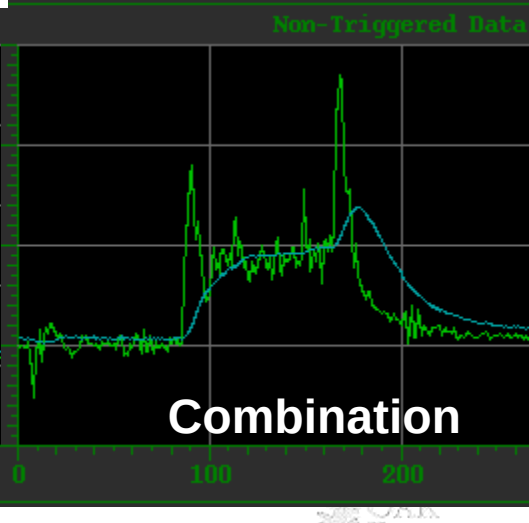
Cavity Number	Emax (MV/m)	Rad at Emax (mR/hr)
HB53	17.6	2.0
HB58	17.2	0.0
HB56	17.5	408
HB54	13.0	850



Tunnel Radiation monitor
RF Only







Action Items (I)

- Complete the planned spare high beta cryomodule (CM). The spare cryomodule should meet the requirements of the Power Upgrade Project (PUP). Consider utilization of this spare to enhance operating energy margin via continuous swapping of spares with lower performing CM's. (AAC2010)

→ 98 % completion. The spare cryomodule is planned to be completed in the middle of February 2012 and tested in March/April 2012 in the test cave.

- For the medium term: Any new cryomodules (spares or for PUP) should use newly fabricated SRF cavities built and processed using J. Mammosser's recipe. (AAC2010)

→ This recommendation has been fully accepted for new cryomodule development in the future. John's recipe was using VEP. Horizontal EP is still in the consideration.

Action Items (II)

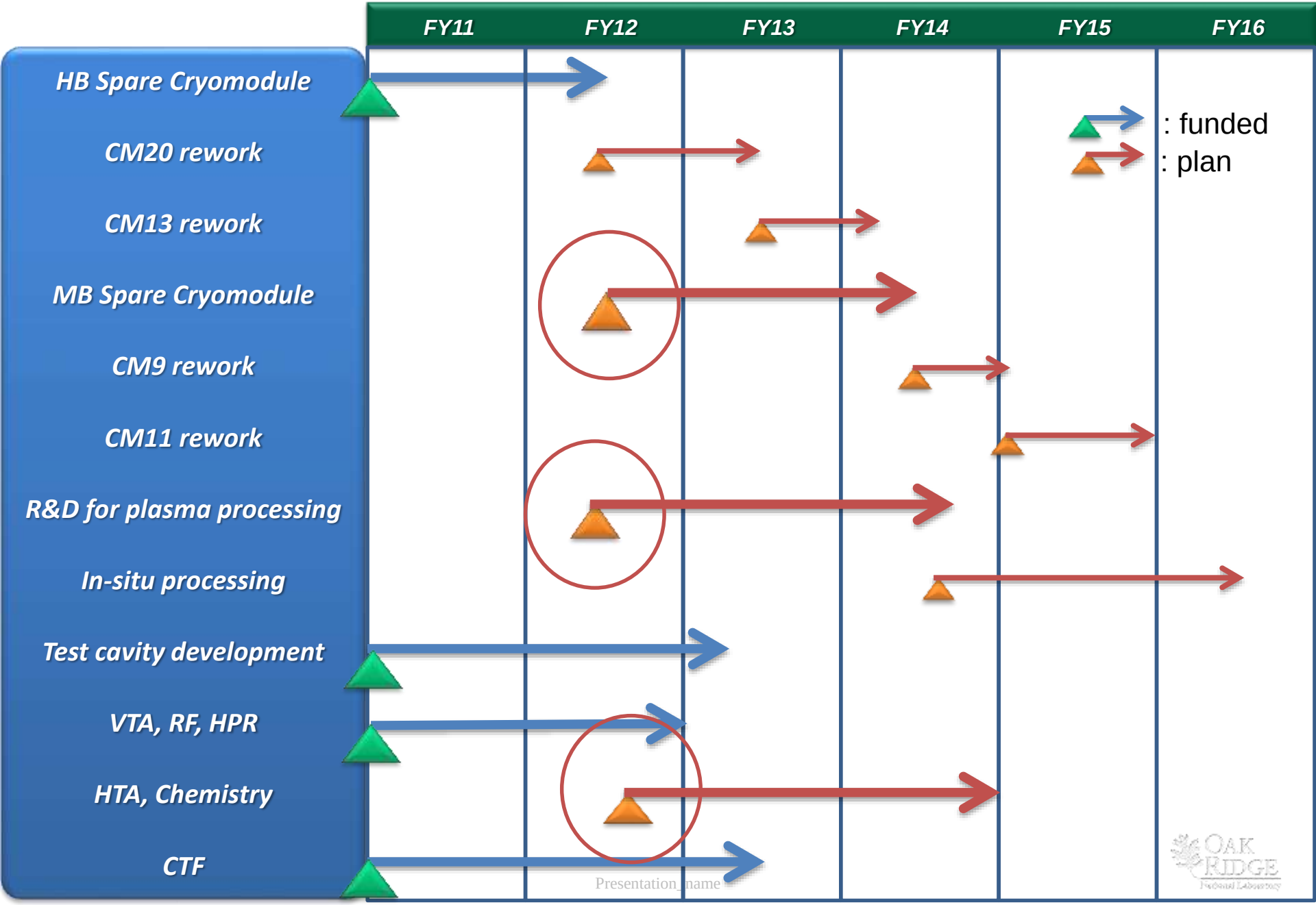
- Use new cavities in the PUP cryomodules, not SNS spares. (AAC2010)

→The baseline plan for PUP was to use new cavities. Drawing package for new cavities for PUP has been updated accordingly, which includes high RRR material for the end group, no HOM couplers, no connection ring between end-cell and end group pipe. A program to validate the updated design has been started.

5-yr Goal for SCL systems group

- Operation at high duty factor results in lower achievable gradients:
  - 925 MeV+10MeV (present) → 1000MeV+25MeV
  - Need 90 MeV more: Acc. gradient in high beta cavities needs 15 % improvement
- Initiatives
  - Spare cryomodules
    - high beta spare cryomodule (CM) is under construction: 98 % ← 2 HB CMs need rework
    - In planning: Need a medium beta spare cryomodule (CM) ← 2 MB CMs need rework
  - Cost effective In-situ plasma processing for cavity performance improvements
    - First attempt in 2009 showed a promising results
    - In planning: 2.5yr R&D + 2 yr in-situ processing
  - Rework capability in house (not production scale):
    - Expensive but the only option for unrecoverable damages of parts/surfaces
    - Ensure long term sustainability
    - Also direct impact on 1.3GeV energy upgrade for STS
    - In progress: VTA, HPR, CTF, HB spare cryomodule, Test cavities, spare power coupler
    - In planning: horizontal test apparatus (HTA) and chemistry system

Overall Plan



Spare Cryomodules (M. Howell, J. Saunders, S. Stewart et al.)

- **Allows removal of operating cryomodule for repair/rework**
  - Maintain same beam energy
  - Increase time for conducting complex repairs
  - Removes complexity of repairing cryomodules in LINAC tunnel
  - Necessity for beam reliability and availability goals for SNS
- **High beta spare serves as prototype for PUP**
  - High beta spare is first priority over medium beta spare
  - Meets pressure requirements put forth in 10 CFR 851
  - Incorporates design upgrades to vacuum vessel and end cans
  - Fabrication techniques are being developed
  - Alignment methodology is being refined
- **Medium beta spare to be built as funding is available**

High Beta Spare Cryomodule Status

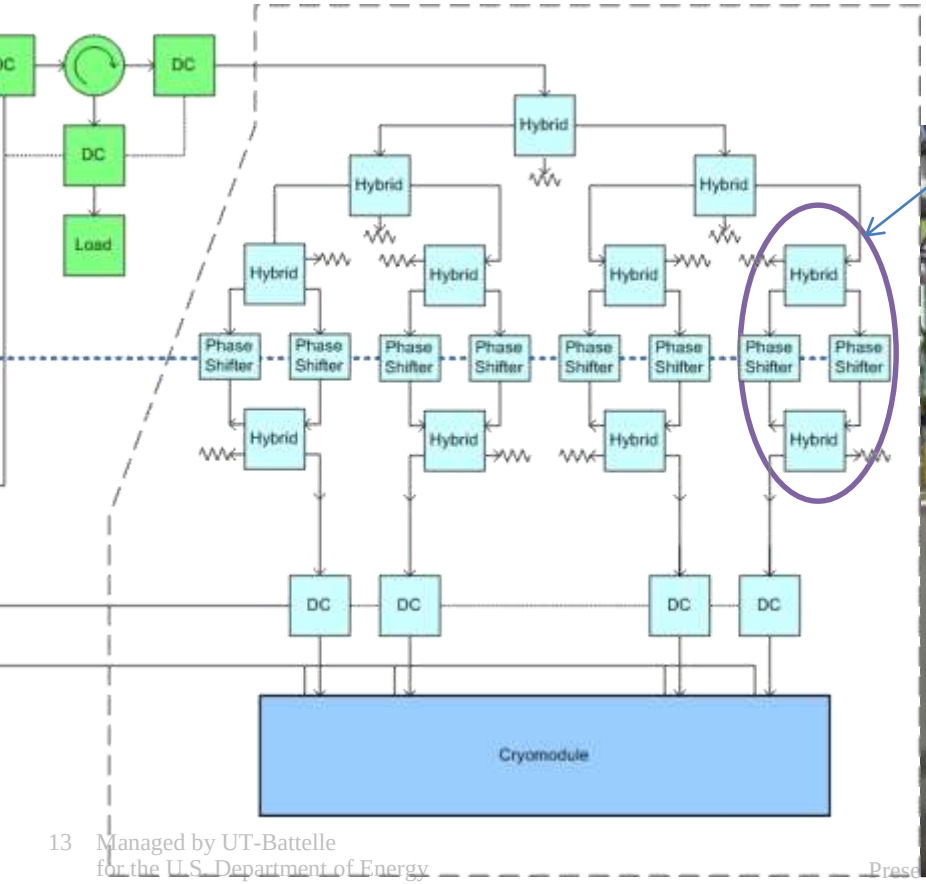





-Scheduled to be finished next month
-Test plan in March-April, 2012 time frame
-Plan is to replace CM20 in summer down 2012

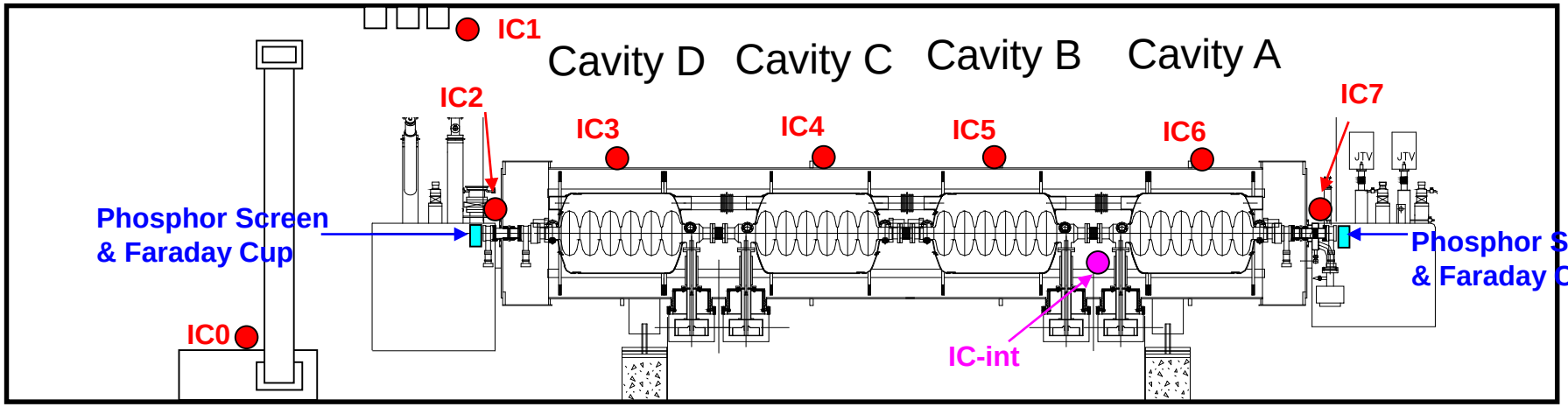
Test Cave (Y. Kang, M. Crofford, et al.)

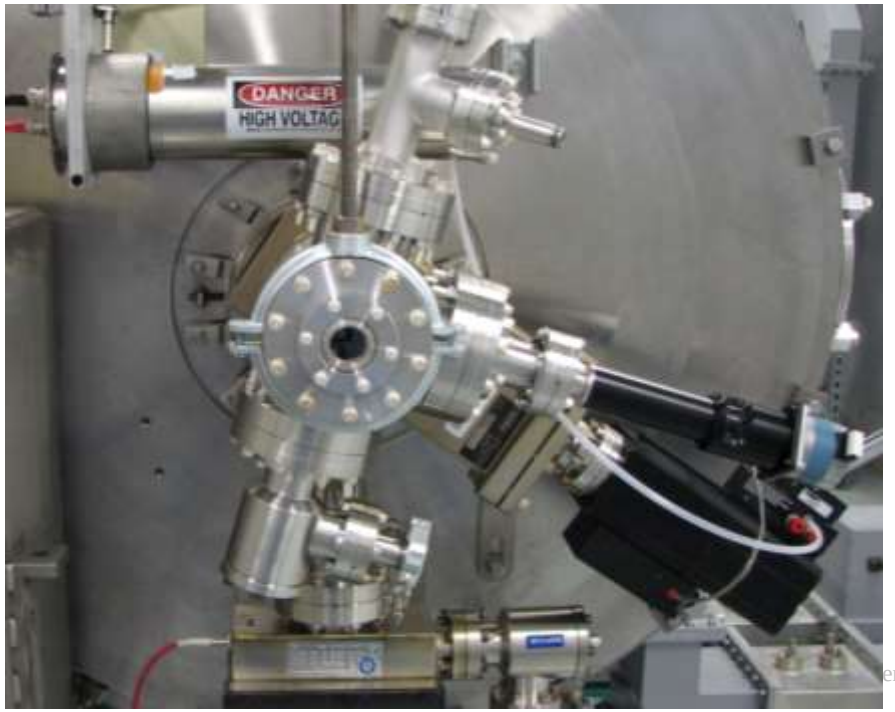
- RF system upgrade to power 4 cavities at the same time
- 4-way RF split system is under development
  - HPRF, LLRF, water cooling for loads



Vector modulator (slow)

Radiation/electron activity diagnostics in the Test Cave





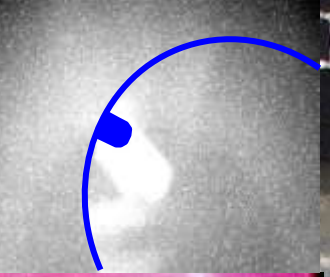
- Ionization Chamber
- Internal Ionization Chamber
- Phosphor Screen, Camera, Faraday Cup

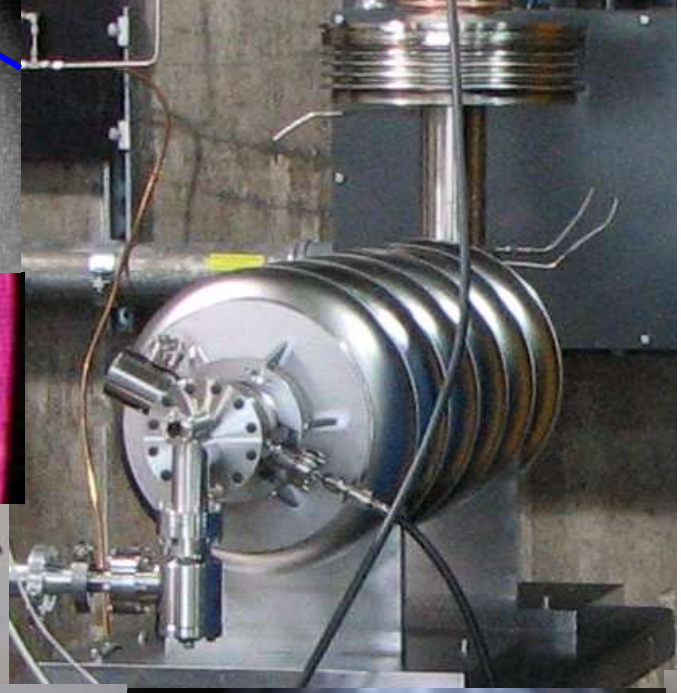
To reach 1 GeV

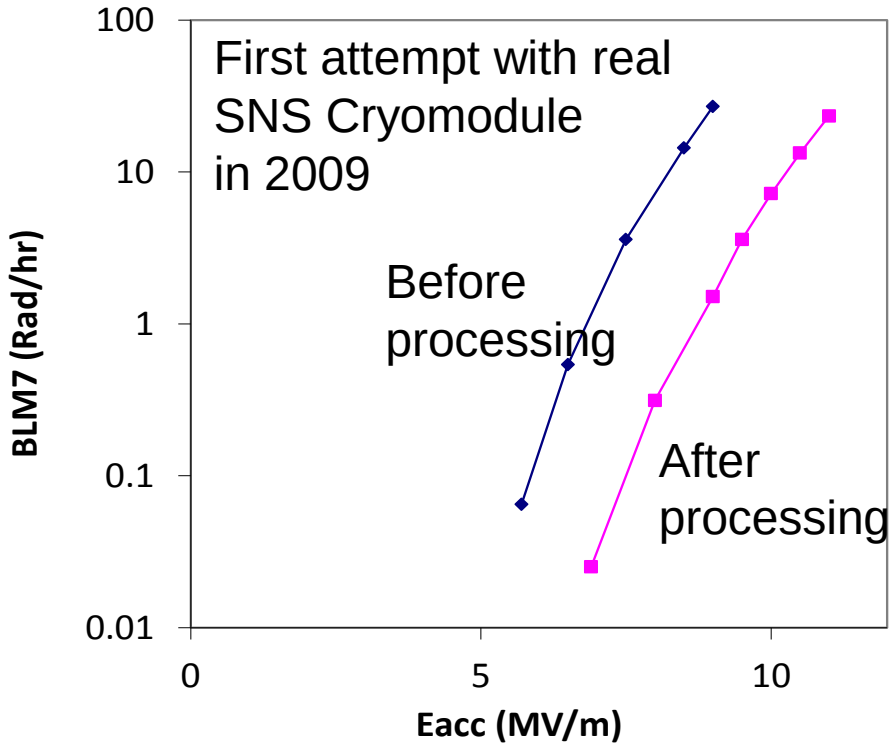
- Main limiting factor is 'field emission'
- In-situ processing in the tunnel: Cost effective method with minimal impact on machine operation & possible post-processing method for completed cryomodules
- The in-situ processing w/ H01 (reported at last review)
  - Plasma processing
  - The first attempt (very mild condition for a short time)
  - Very promising results
- R&D program is needed to develop a procedure for statistical improvements

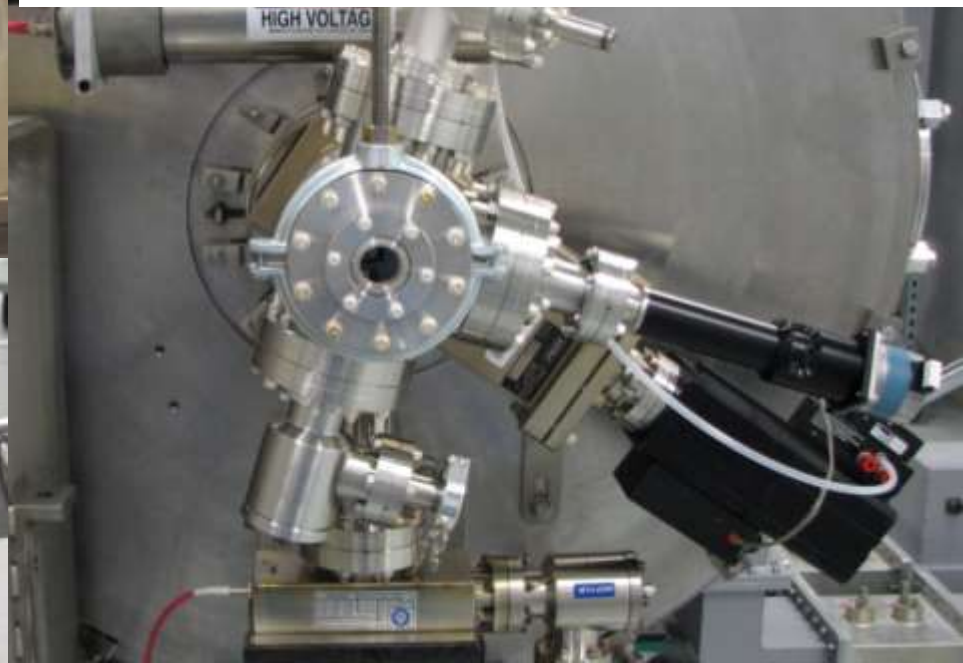
R&D for In-situ plasma processing in the tunnel (M. Doleans et al.)

- Systematic studies are needed
  - Figure out what we can do/can't do
  - Find a statistically optimal procedure
- Some hardware set-ups are ready
- Expected gains (preliminary)
  - Removal of absorbed/trapped gases
  - Removal of oxide layer
  - Removal of small-size contaminants via physical bombardment or chemical reaction
  - Low temperature baking effect
- Pending (seeking funding)



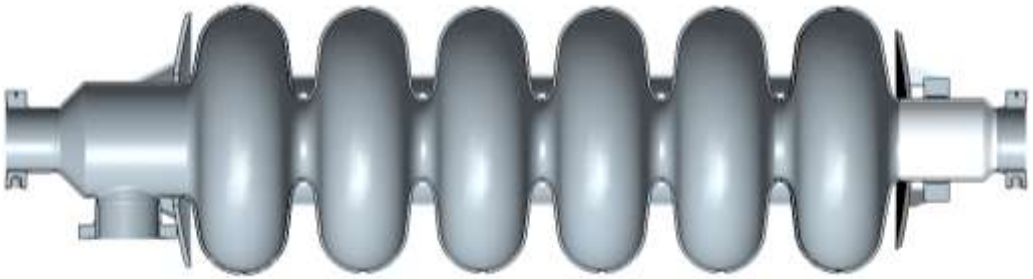



First attempt with real SNS Cryomodule in 2009
Before processing
After processing
BLM7 (Rad/hr)
100
10
1
0.1
0.01
0
5
10
Eacc (MV/m)


HIGH VOLTAG

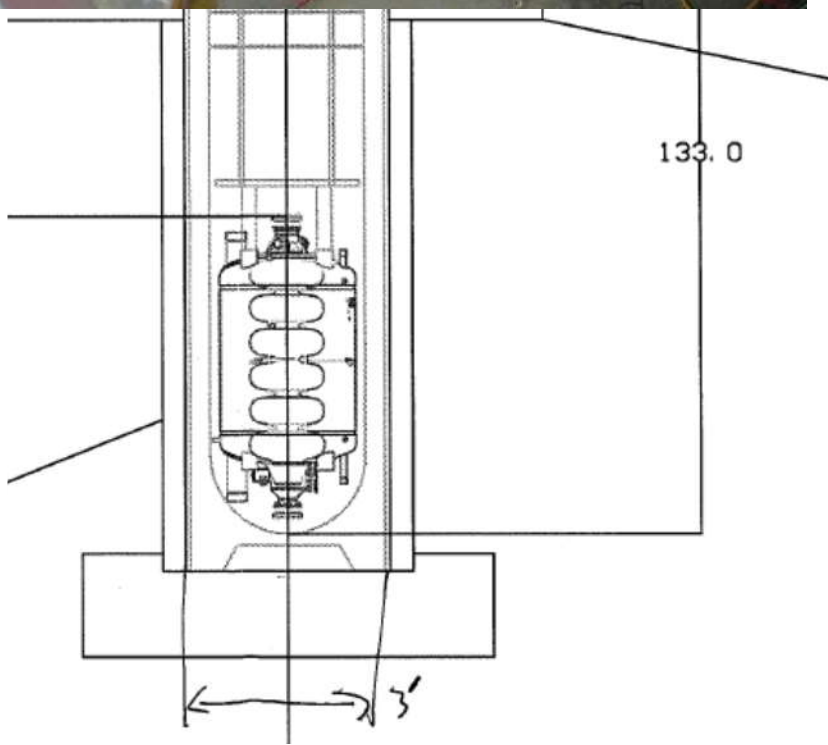
Design updates of the high beta cavity & test cavity efforts (M. Howell, S. Stewart)

- **Modify two existing high beta cavities**
  - For processing development & basis for future cryomodules
  - Cut at the equator weld at each end
  - New half end cell and end group (all high RRR Nb)
  - No HOM couplers
  - No connection ring between end cell and end group
- **Status**
  - Material ordered
  - Statement of work is complete
  - 3D model being finalized
  - Vendor quotes received to perform work



Vertical Test Area (M. Howell, et al.)

- **Vertical Test Requirements**
  - Bare cavity qualification
  - Cavity in helium vessel testing
  - Accommodates 2K and 4K tests
    - CTF + (kinney pump)
  - Shielded and equipped with radiation monitoring
  - Fits within tight footprint
- **Current Status**
  - Civil construction complete
  - Dewar in fabrication at Eden Cryogenics
  - Preliminary radiation shielding modeling complete
  - Lead for shielding obtained

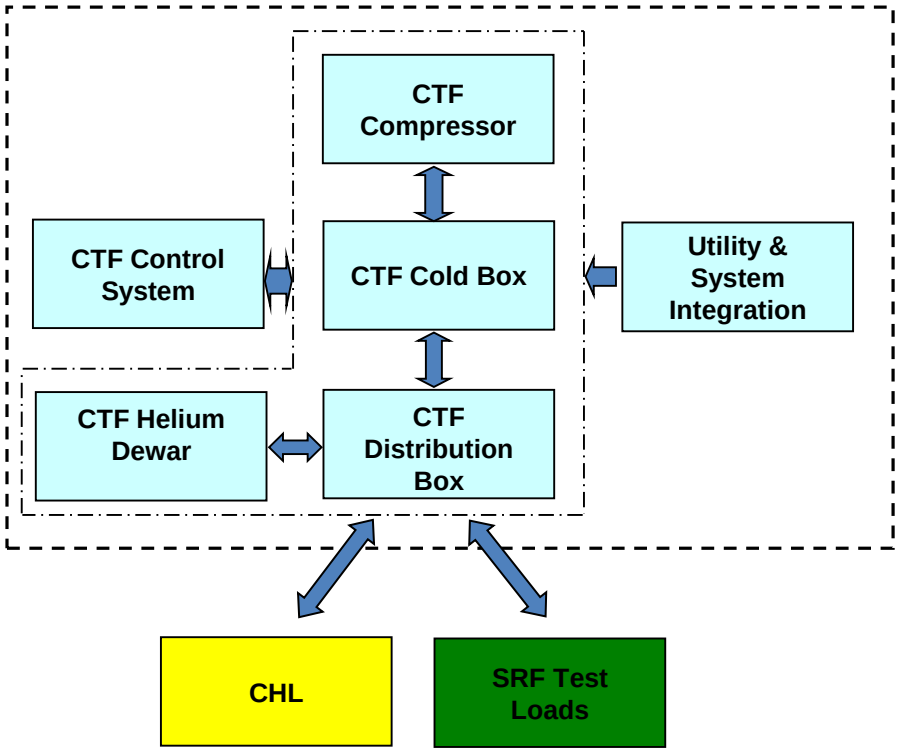


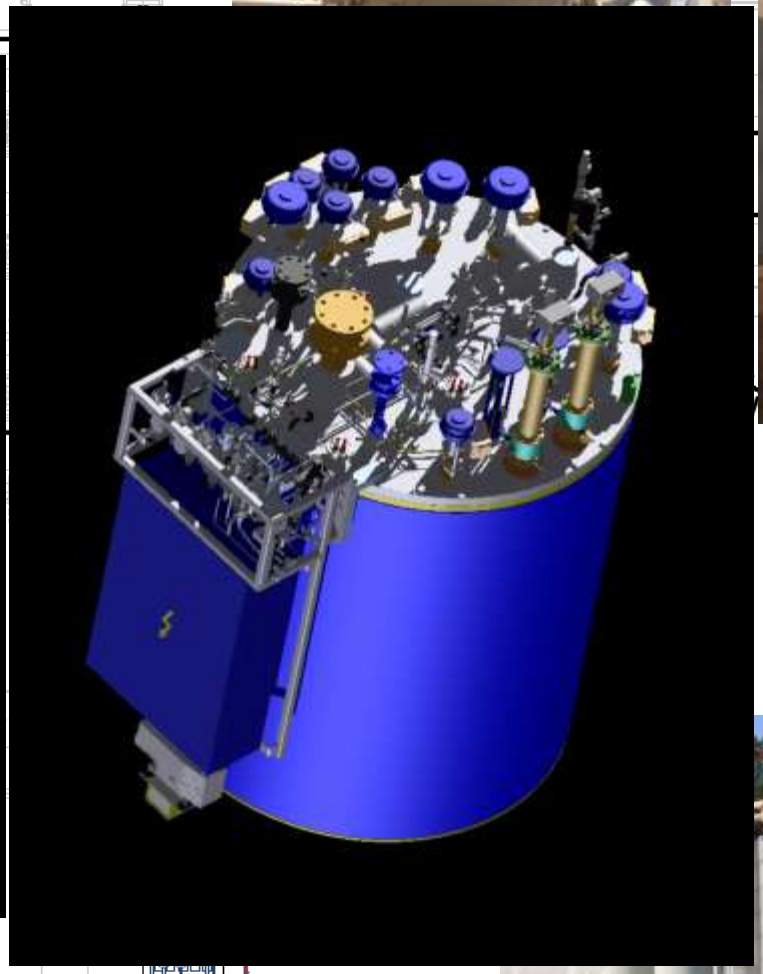
Vertical Test Area (VTA) RF Controls (M. Crofford et al.)

- Based on the Fermilab VTA control system
  - Self Excited Loop topology
  - System software is LabView based
- Design is complete – four major subassemblies
  - VCO/RF Drive chassis
  - Cavity Input PLL chassis
  - Power Monitoring Chassis
  - Signal Conditioning Chassis
- Major procurements have been placed and awaiting delivery of components
- Alternate RF power sources for cavity testing
  - 2 kW 805 MHz solid state amplifier – VTA systems
  - 500 W 805 MHz amplifier – Plasma processing
  - 250 W 3.4 GHz amplifier – Plasma processing/materials research

Cryogenic Test Facility (T. Xu et. al.)

- Independent 4K cryogenic plant to support SRF testing facilities.
- System capacity:
  Refrigeration load 640 W @ 4.5 K,
  Liquefaction load 225 liter/hour
- System Design includes the upgrade path for 2K SRF testing (200W Max) and CHL 4K backup.
- Status
  - System design has been finished.
  - Major components are procured.
- Project time line
  - Started Jan. 2010
  - Dewar system 01/2012
  - Distribution box 06/2012
  - Cold box 09/2012
  - Commission 03/2012
- Project progress well.

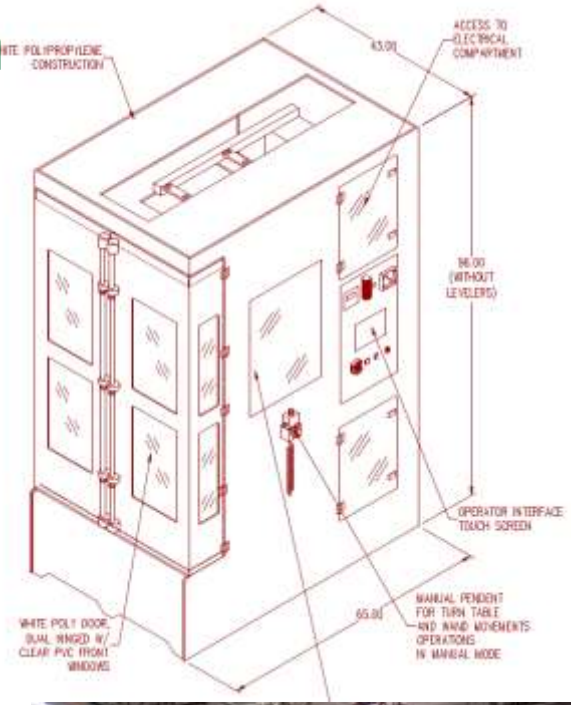


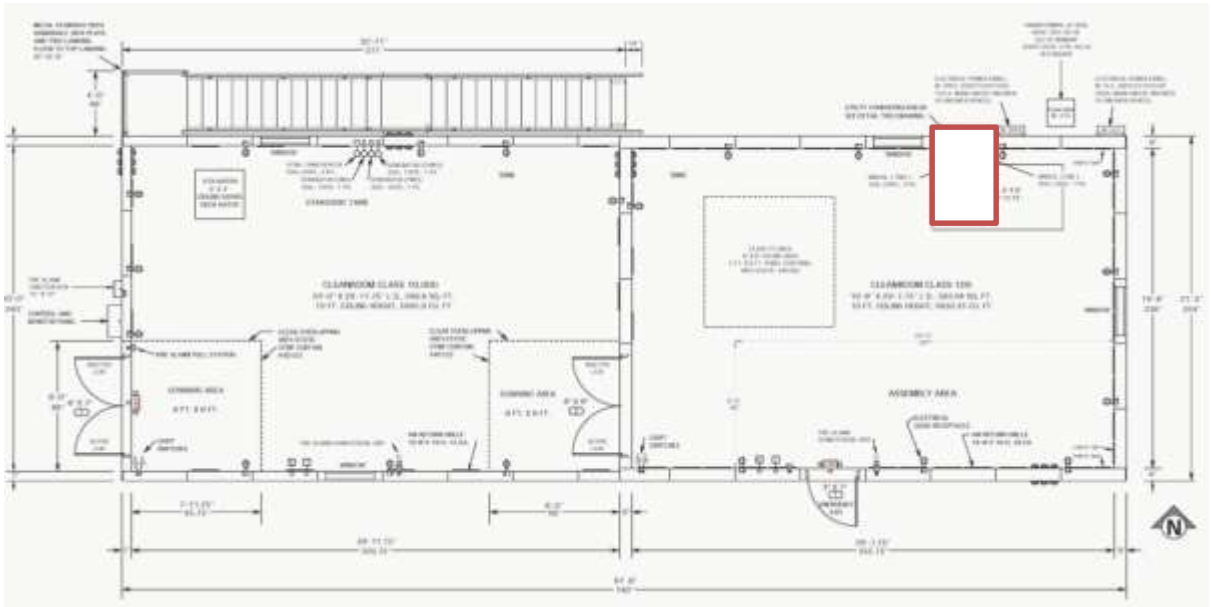


CTF Oil Removal System

High Pressure Rinsing System (J. Saunders et al.)

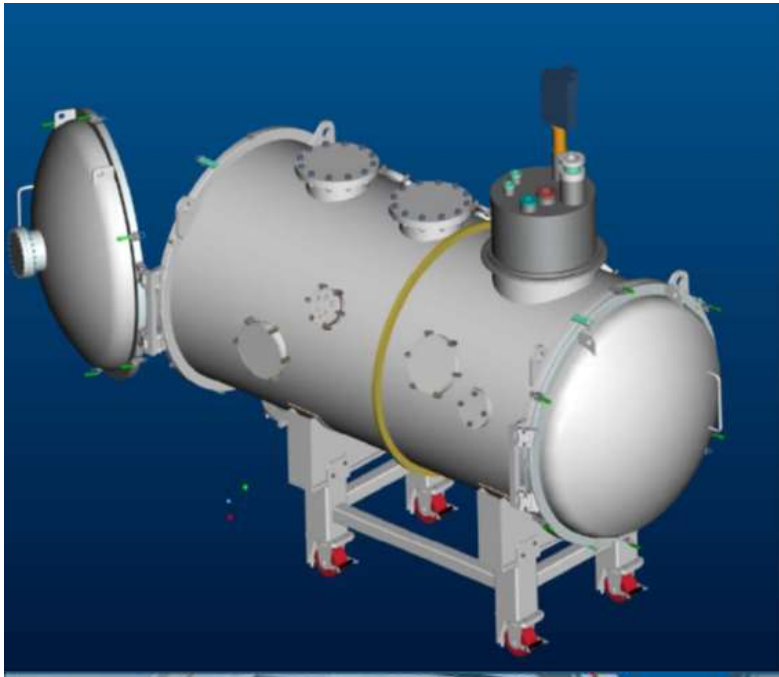
- Design completed with Semiconductor Process Equipment Corp (SPEC)
- Build in progress
- Expected Delivery March 2012
- Ultra pure water system is complete

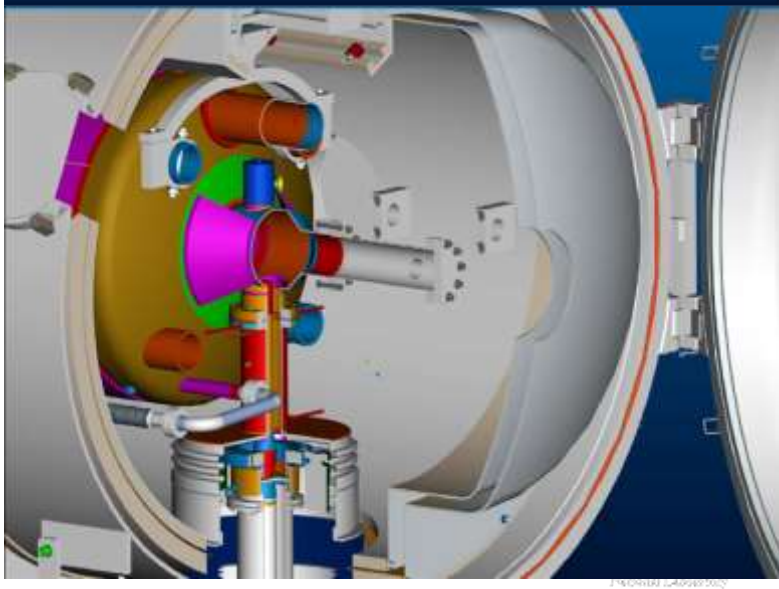




Horizontal Test Apparatus (HTA)

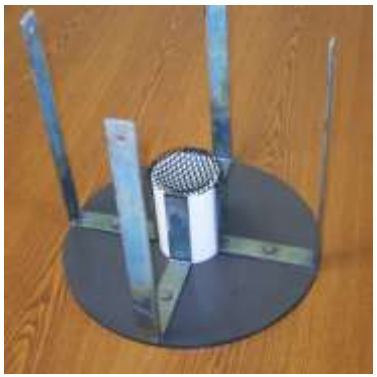
- Cavity in helium vessel testing integrated with coupler
- Same condition in the CM & pulsed RF operation
- Keep under vacuum till final string assembly
- Flexible instrumentation for studies
- Also nice tool for plasma processing R&D
- Status
  - Vacuum vessel has been fabricated
  - Further works: cryogenics and upgrade of vessel for PV issue





Chemistry (J. Saunders et al.)

- SNS requirement
  - Safety by engineering design
    - Zero safety incident
    - Zero environmental incident
  - Small footprint
  - Minimum BCP/EP system (Production rate is not a concern)
- In preliminary conceptual design stage
- Regulatory/licensing for waste neutralization is under discussion
- For long term future, R&D with HF-free processing is on going with Faraday Technology



acility

dule
bly

Class 10,000

Class 100

Ultra pure
water system

Mezzanine

Summary

- Up to now at SNS
  - Operation, understand machine during power ramp-up (main focus)
  - Maturation and sustained improvement of SCL operation for high power beam
  - Overall machine availability >92 %, SCL portion >98 %
  - Accelerating gradient degradations have been observed in some cavities
- SRF efforts at SNS
  - Substantial gains in the last 6 years in understanding SCL operation including system, equipment limiting factors and resolution of system and equipment issues
  - Significant effort and focus is required to assure ongoing success in the operation, maintenance, to improve SCL performances and to address the requirements of the power upgrade project for STS
  - This interdependent effort includes implementation of demonstrated improvements, fabrication of spare cryomodules, cavity R&D to enhance machine performance, upgrade project and related SRF facility developments