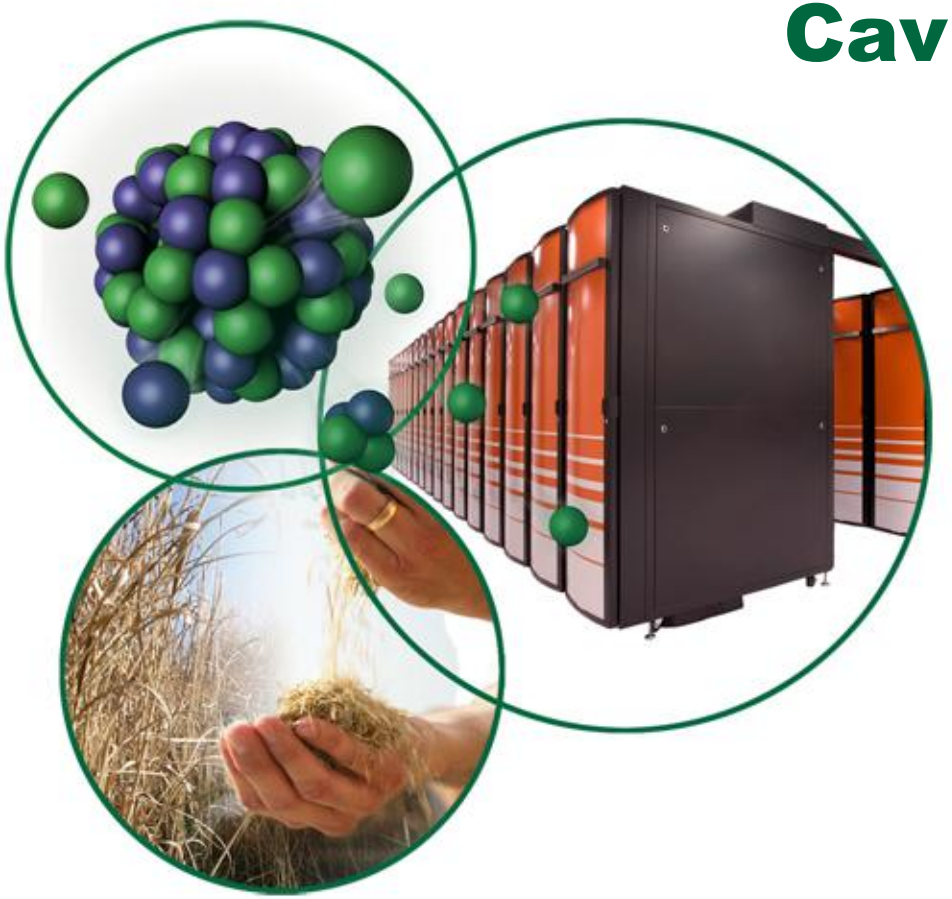
High Power RF Processing of Couplers/Windows and Cavities for SNS Linac



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RAD/SNS/ORNL

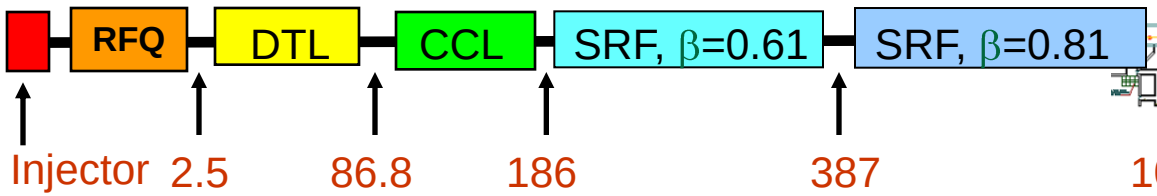
6th CW and High Average Power RF Workshop
ALBA, Barcelona, Spain
May 4-7, 2010

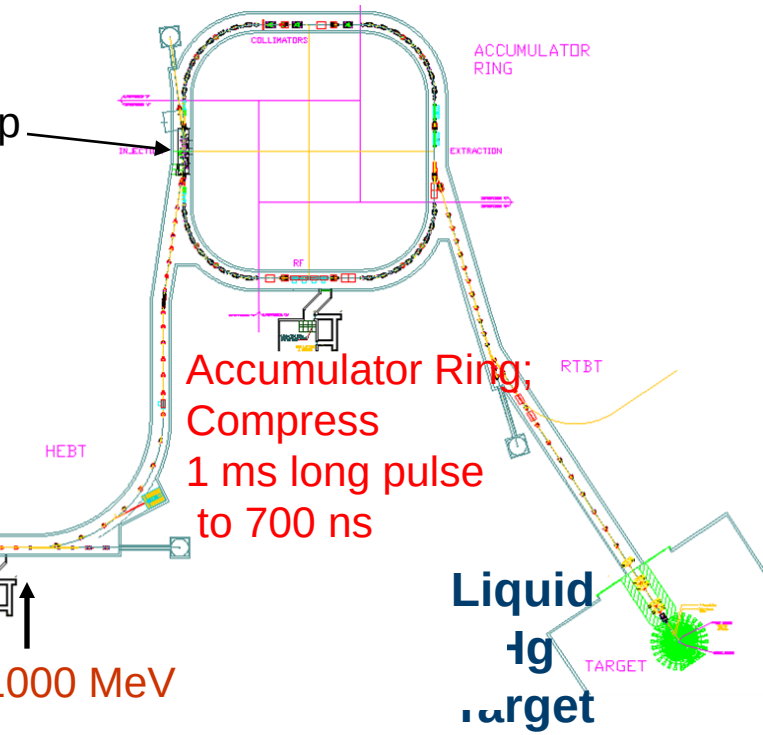
Machine layout

Front-End:
Produce
a 1-msec long,
chopped, H-beam

H- stripped to p

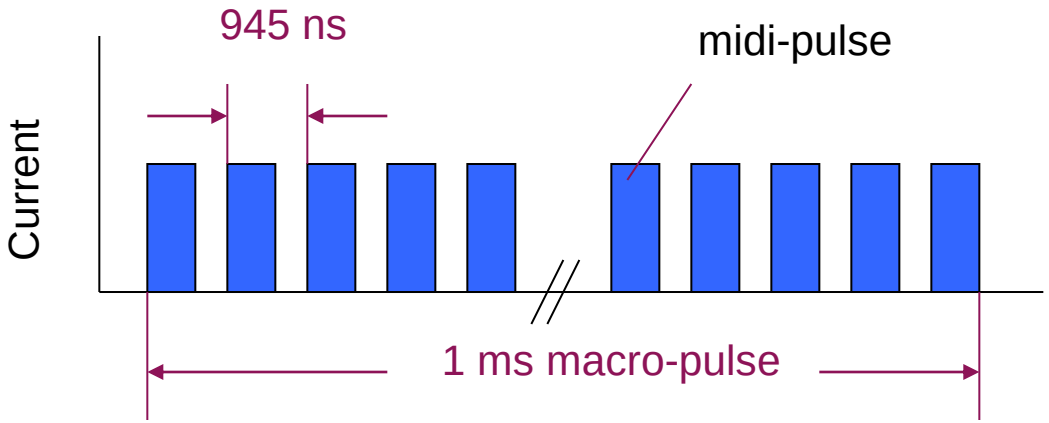
Linac; 1 GeV acceleration

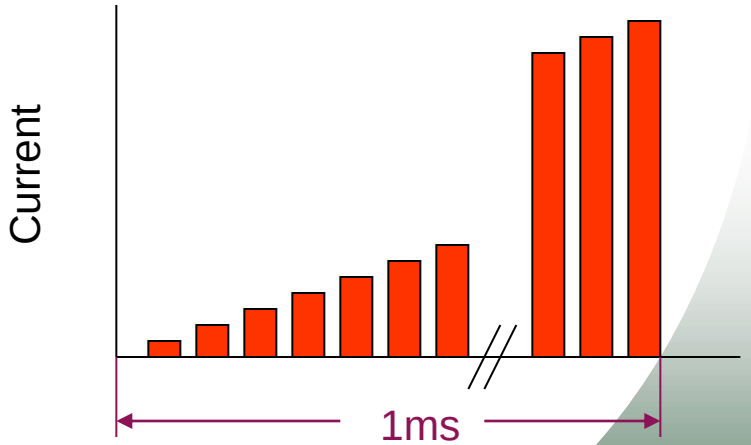




Accumulator Ring;
Compress
1 ms long pulse
to 700 ns

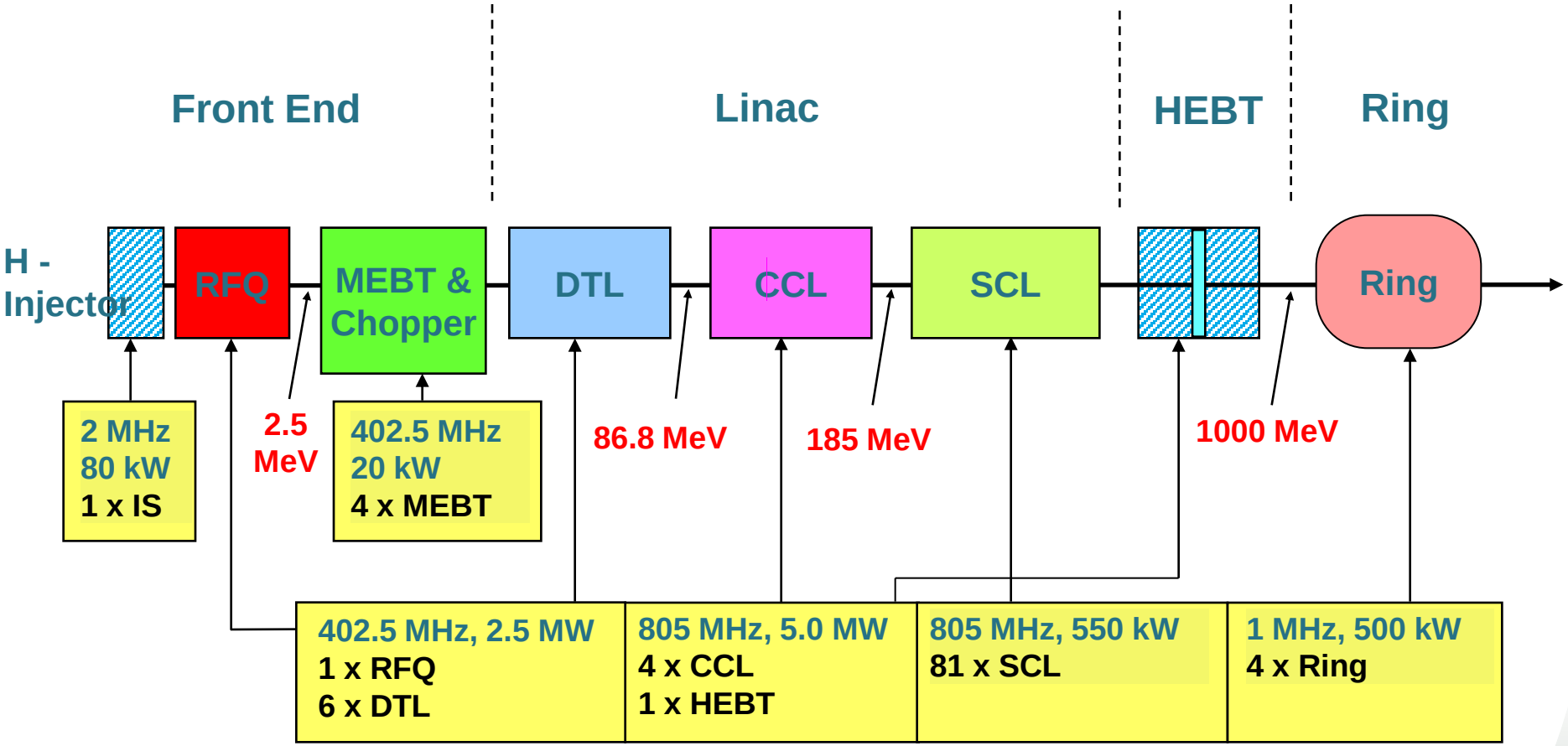
Liquid Hg Target





Chopper system makes gaps

SNS RF Systems



All SNS linac RF systems are pulsed at 8% duty cycle (1.3 msec, 60 Hz)

High Power Window/Couplers in SNS Linac

- RFQ powered by one 2.5 MW Klystrons
  - 2 windows for 402.5 MHz Radio-frequency Quadrupole (RFQ)
- 6 DTL tanks powered by 2.5 MW Klystrons
  - 6 windows for 402.5 MHz Drift tube linac (DTL) cavities
- 4 CCL structures powered by 5 MW Klystrons
  - Each CCL structure has 2 input ports
  - Klystron output is divided with a quadrature hybrid
  - 8 windows for 805.0 MHz Coupled cavity linac (CCL) cavities
- SCL cavities
  - 33 medium beta cavities in 11 cryomodules (with 0.55 MW Klystrons)
  - 48 high beta cavities in 12 cryomodules (with 0.55 MW Klystrons)
  - 81 windows for 805.0 MHz Superconducting linac (SCL) cavities
  - 36 high beta cavities will be added (9 cryomodules) in future power upgrade project

RF Processing in SNS RF Test Facility

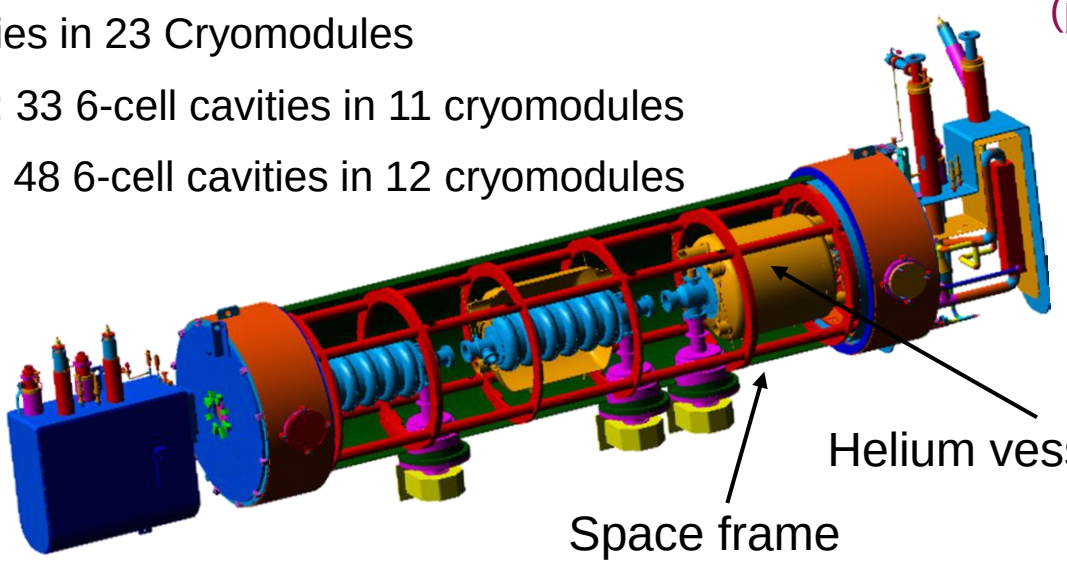
- High power RF testing and processing can be performed at 8% duty (1.3 msec 60 Hz)
  - 805 MHz, up to 5 MW peak power
  - 402.5 MHz, 2.5 MW max. peak power
  - Complete low-level RF control and monitoring for reliable processing and operation in EPICS environment

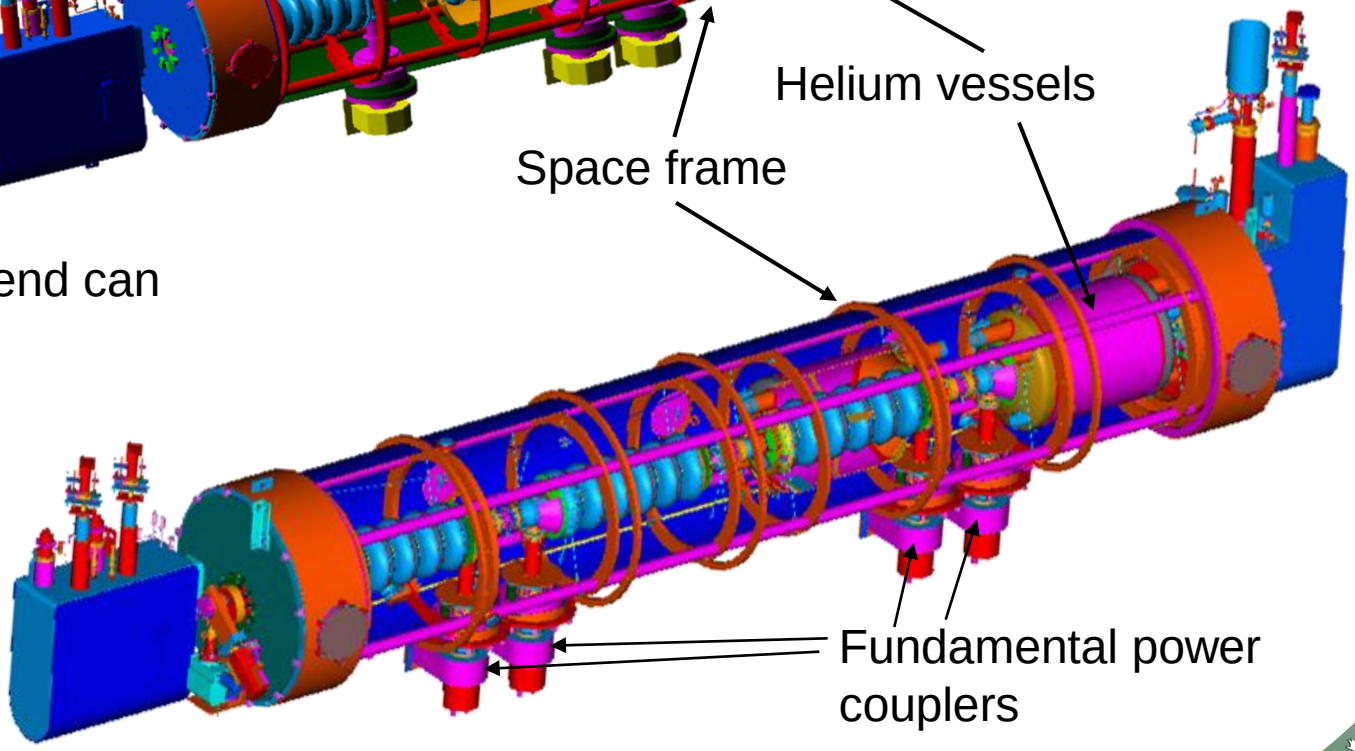
- SCL cavities and cryomodules are prepared and processed
  - Cryomodules high power RF tested in test cave after repairs
  - New cryomodule is being assembled (Building a medium-beta cryomodule will start)
  - SRF cavities are plasma processed
- More than 60 windows/couplers including new spares have been conditioned for RFQ, DTL, CCL, and SCL
  - 42 of 81 power couplers of the SNS SRF cavities were RF processed in the RF Test Facility during construction of SNS cryomodules
  - Several cavity window/couplers for RF frequencies different from SNS frequencies were processed

SNS SCL Cryomodules

- Designed to operate at 2.1 K (superfluid helium)
- Total 81 cavities in 23 Cryomodules
  - med-β: 33 6-cell cavities in 11 cryomodules
  - high-β: 48 6-cell cavities in 12 cryomodules

Medium Beta Cryomodule (β=0.61)

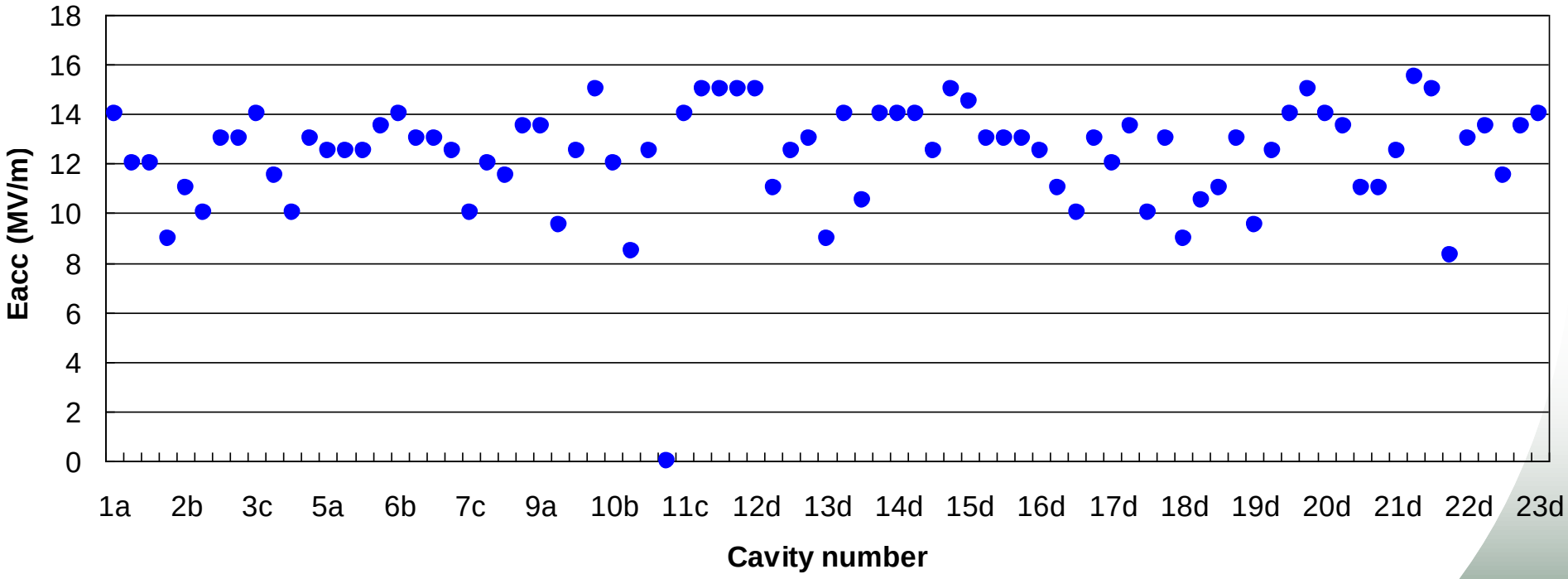




High Beta Cryomodule (β=0.81)

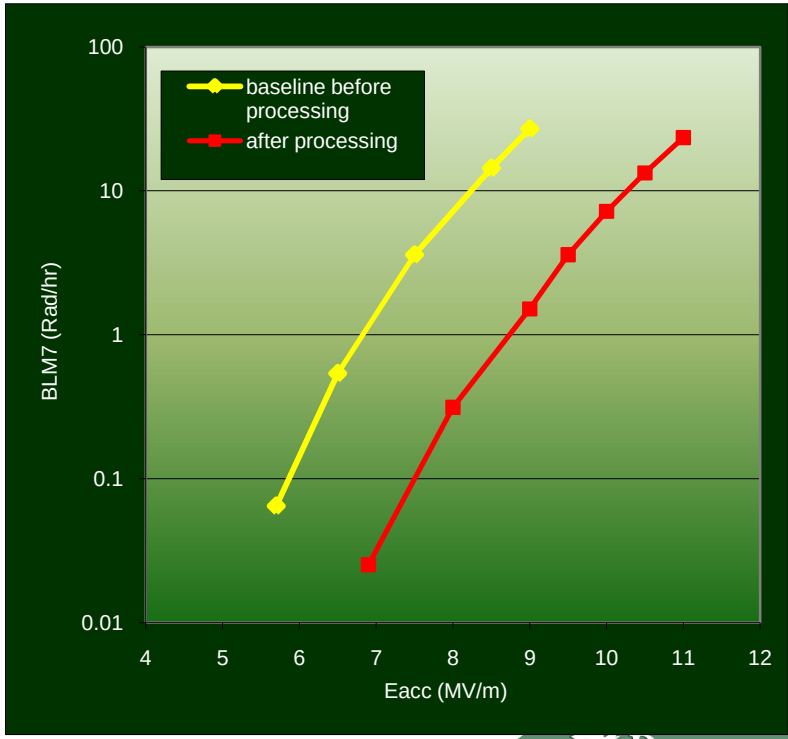
SCL Present Status

- Careful high power testing delivered practical operational limits of cavities (not fundamental limits) but to set a safe operating gradient (Sang-ho Kim)
- SCL is providing a reliable operation for neutron production following SNS power ramp-up
- 930 MeV + 10 MeV (energy reserve)

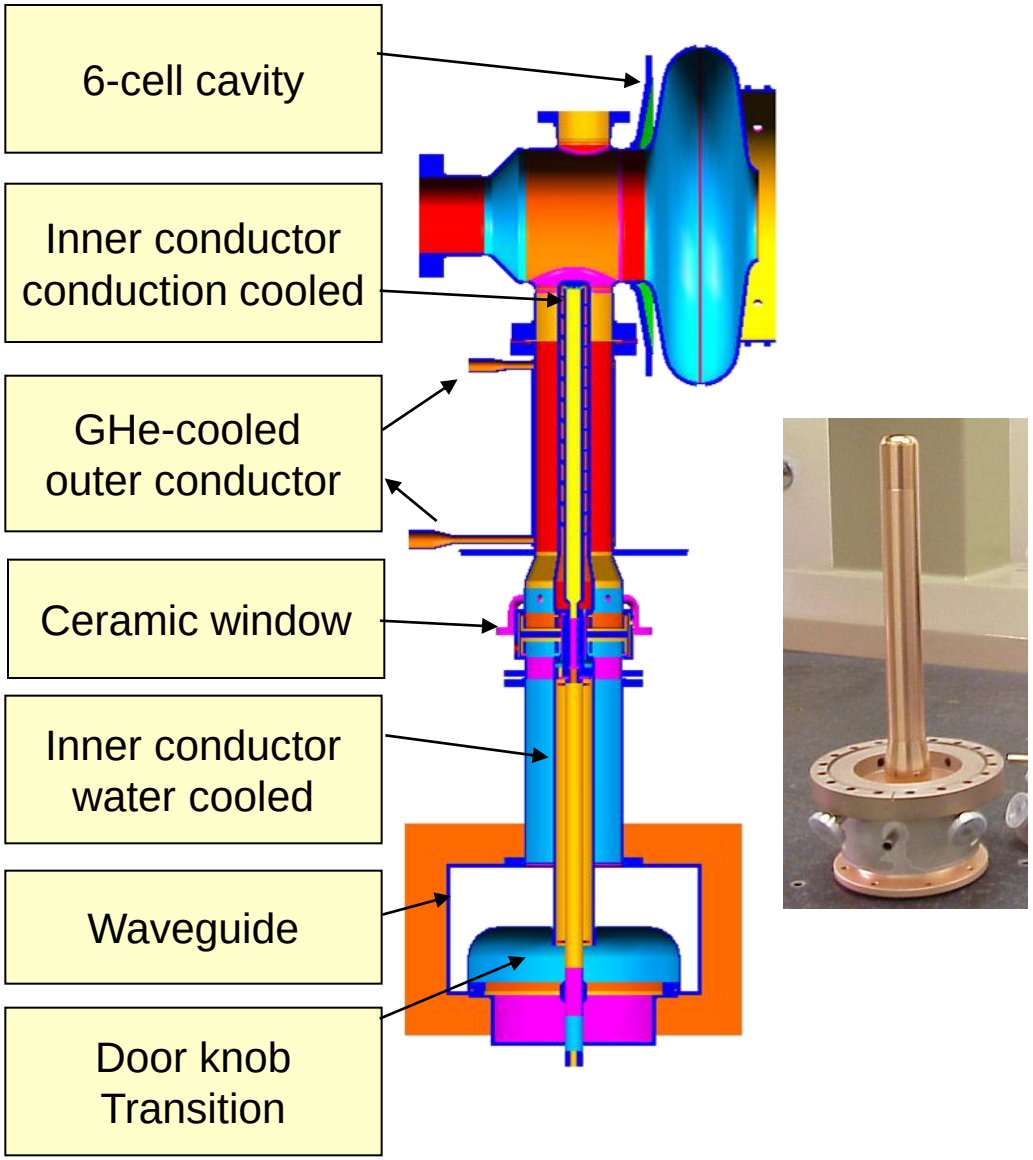


SCL Considerations (J. Mammosser, S-H. Kim)

- For > 1GeV operation with high system availability
  - high-beta gradients need to be improved
  - Collective system performance with other improvement
- In-situ plasma processing of cavities successfully tested with possibility of 2 - 3 MV improvement per cavity
  - More poorly performing **high-beta** cavities will be processed
- Production of spare cryomodules with better performing cavities
  - Building one high-beta cryomodule is under way and one medium-beta cryomodule will start
  - Completion of SRF Facility (AIP Project)
- Changes on the Cavities
  - couplers are interlocked with e-current measurement (interlock using degrading CCGs abandoned)
  - HOM feedthroughs will be taken out as needed
  - Will not have HOM couplers for new cavities

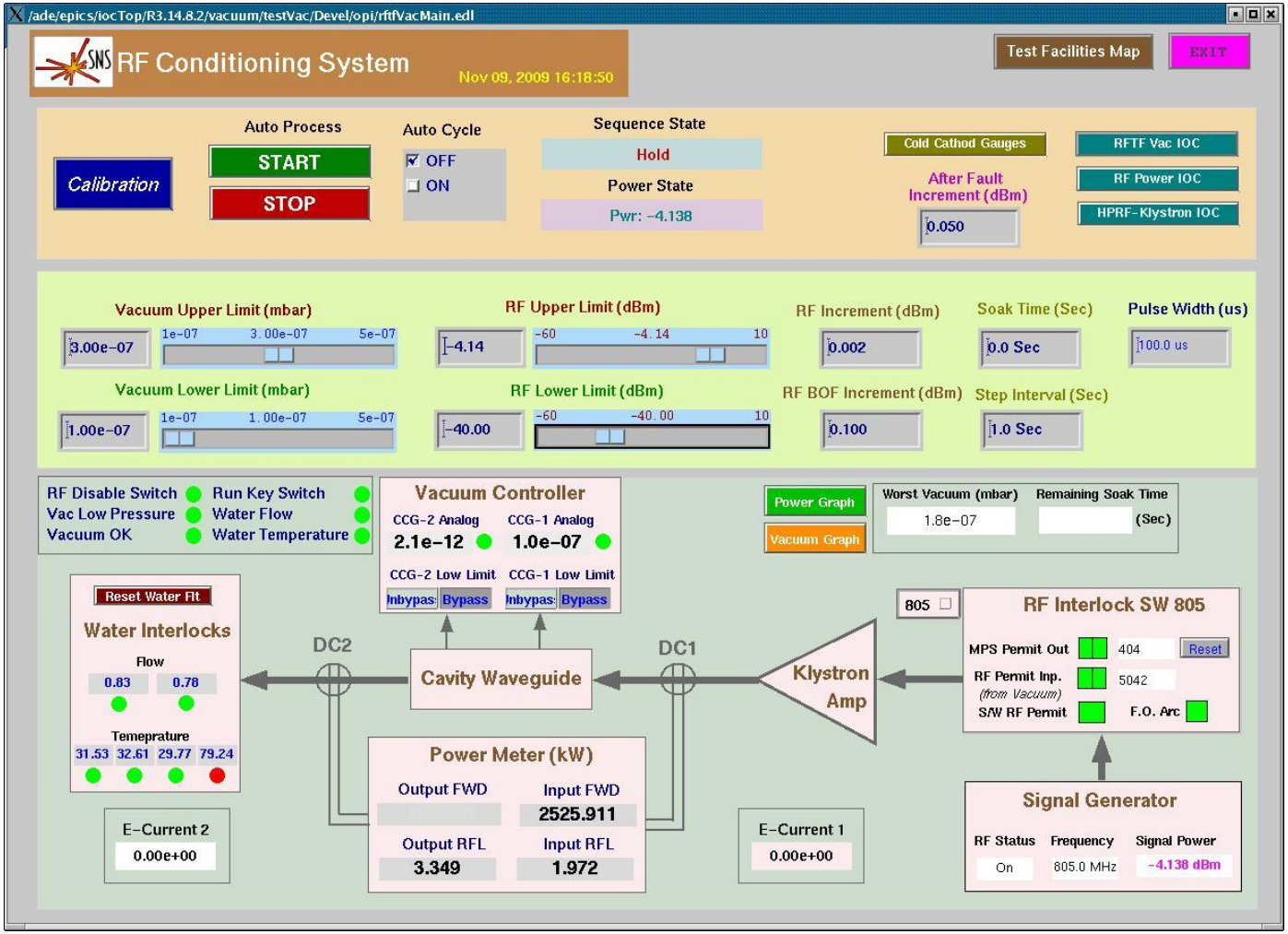


SCL Fundamental Power Coupler



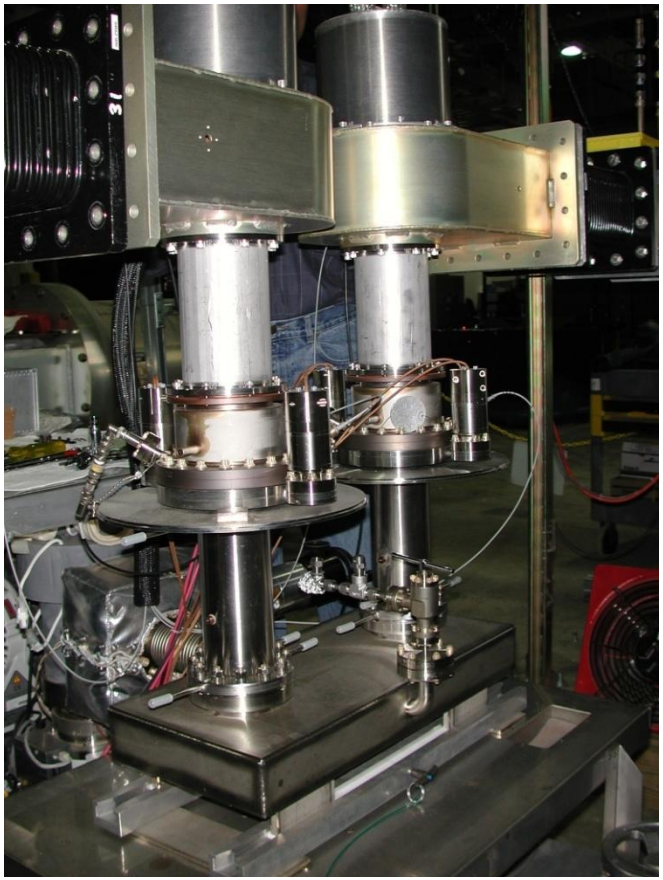
- Present coupler specifications:
  - 550 kW peak
- 50 kW average
  - Qext ~ 7 x 10^5
- Performance:
  - Conditioned up to 650 kW power in traveling wave and 2.4 MW power in standing wave
  - Over 500 kW peak power in linac cavity operation
- Consideration
  - Higher peak and average power capability for the future SNS power upgrade & more stable operation may require additional cooling at the antenna tip

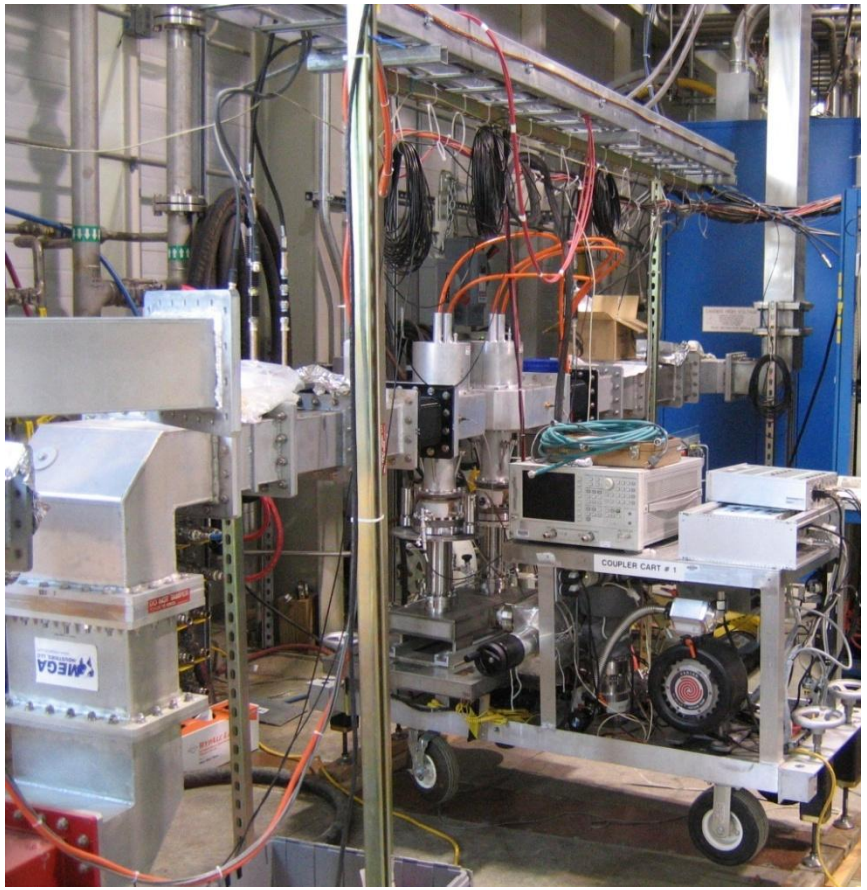
Coupler RF Processing in EPICS



RF Processing Control Screen

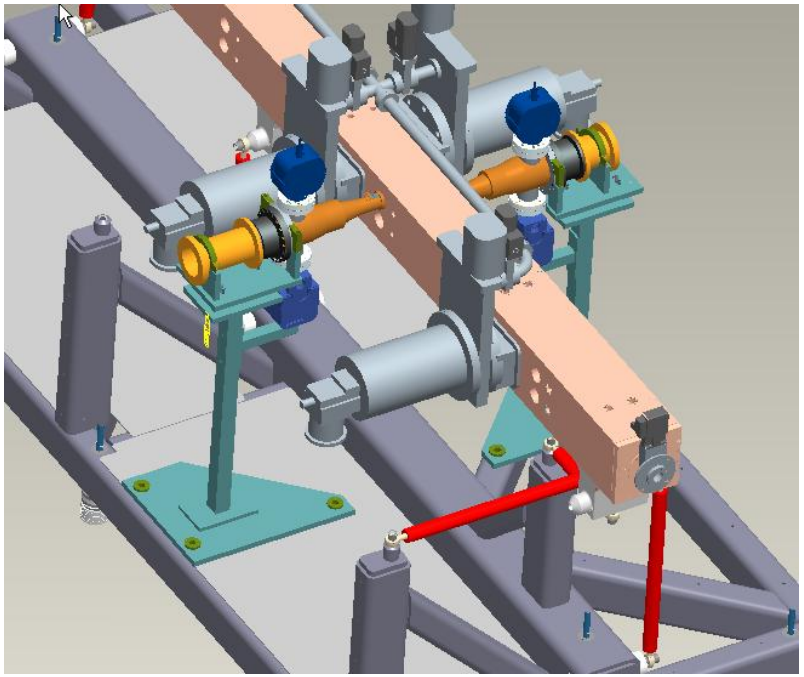
SCL Coupler Conditioning Setup





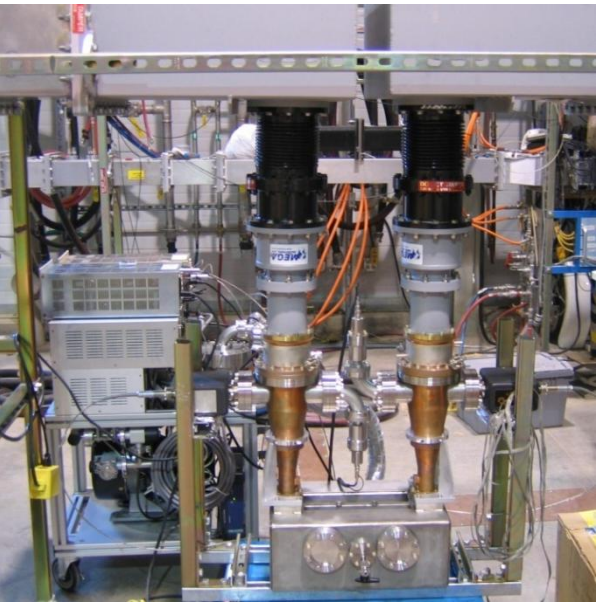
- Coupler conditioning processes:
  - Baked up to 200 °C with controlled slow ramp-up and cool down
  - 650 kW traveling wave to 6% duty cycle
  - 600 kW standing wave (2.4 MW peak) with variable waveguide short
  - Use of DC biasing during conditioning

RFQ Window/Coupler Construction

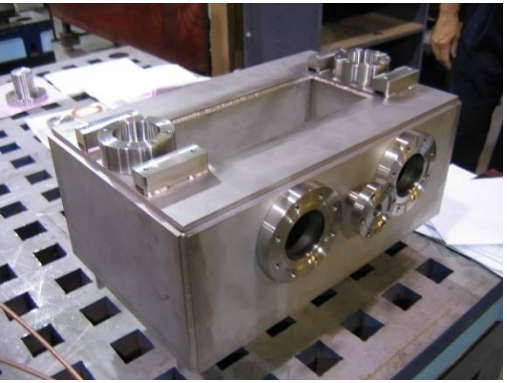


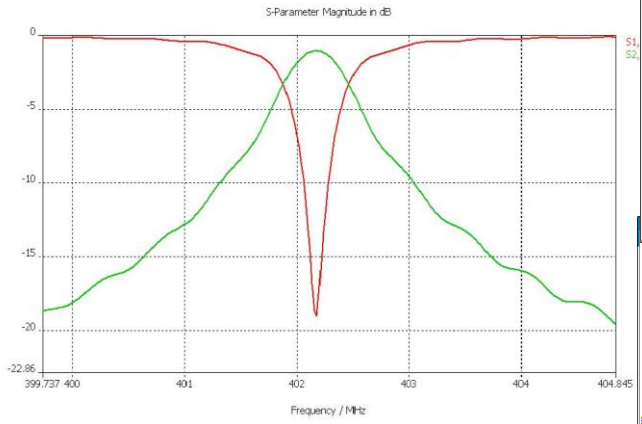
- RFQ system was upgraded with two coupler configuration (from 8 coupler configuration)
  - Use a magic-T hybrid power splitter with a water load on the isolation port
  - Operate at ~ 800 kW (400 kW / coupler)
  - Use coupler ports farther away from the H- ion-source for better vacuum condition
- New couplers designed using SCL coupler window routinely conditioned to 600 kW peak power @ 6% duty in traveling wave
  - 6 new couplers manufactured and RF conditioned at SNS/RFTF
  - RF conditioned up to 450 kW @ 1 msec, 30 Hz through bridge waveguide

RFQ Coupler RF Conditioning

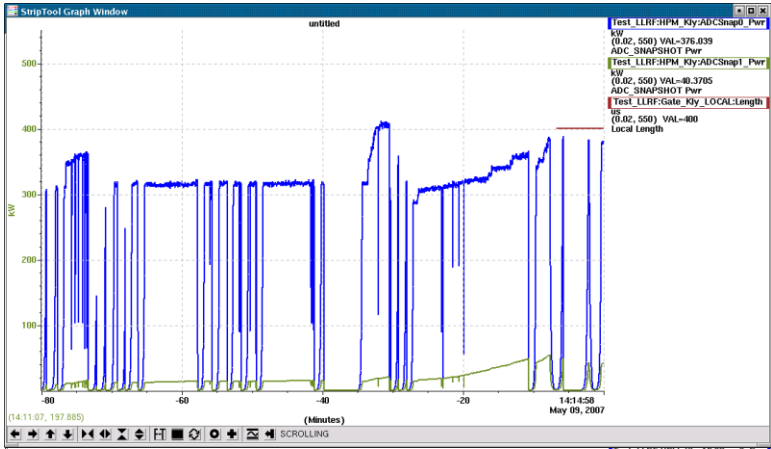


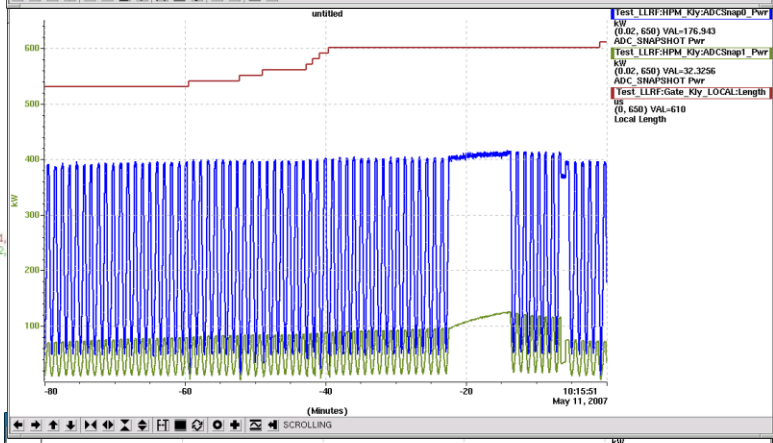
- 402.5 MHz operating frequency
- Rectangular re-entrant cavity type (or ridge waveguide) is used as the bridge waveguide
- Used special vacuum ports to accommodate the coupler loop antenna tip design

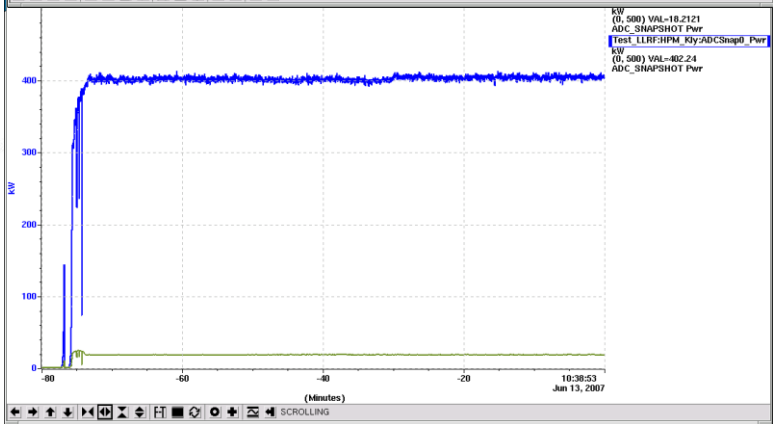




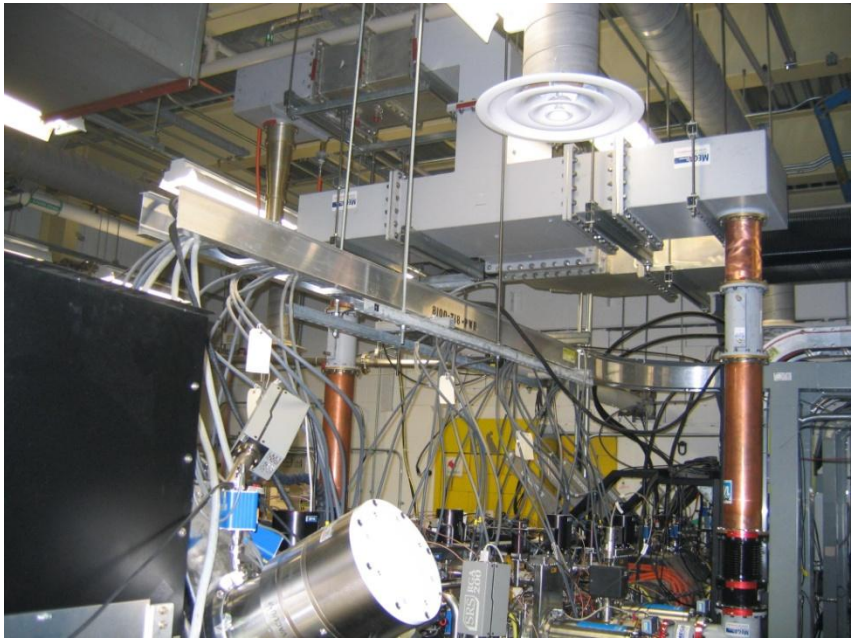
Return and insertion losses through bridge waveguide and couplers

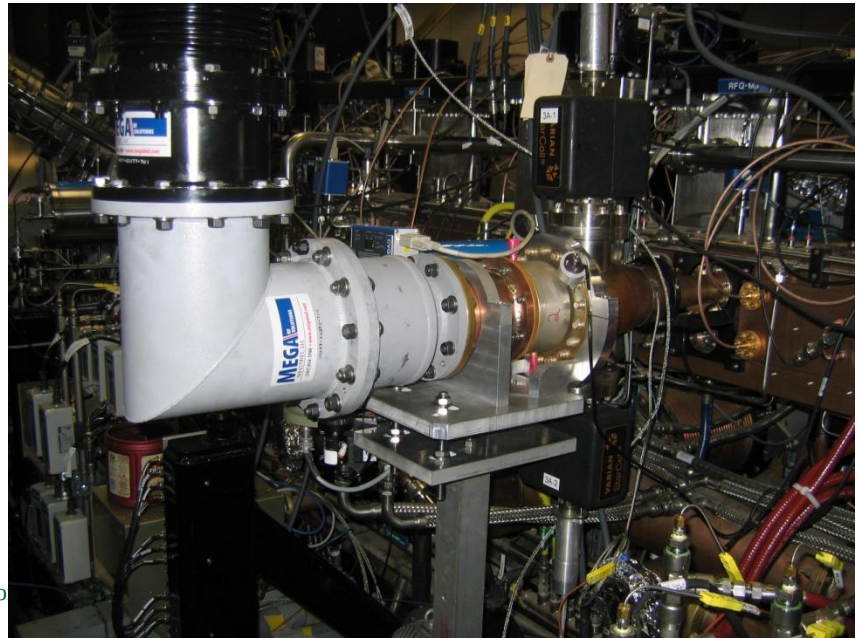


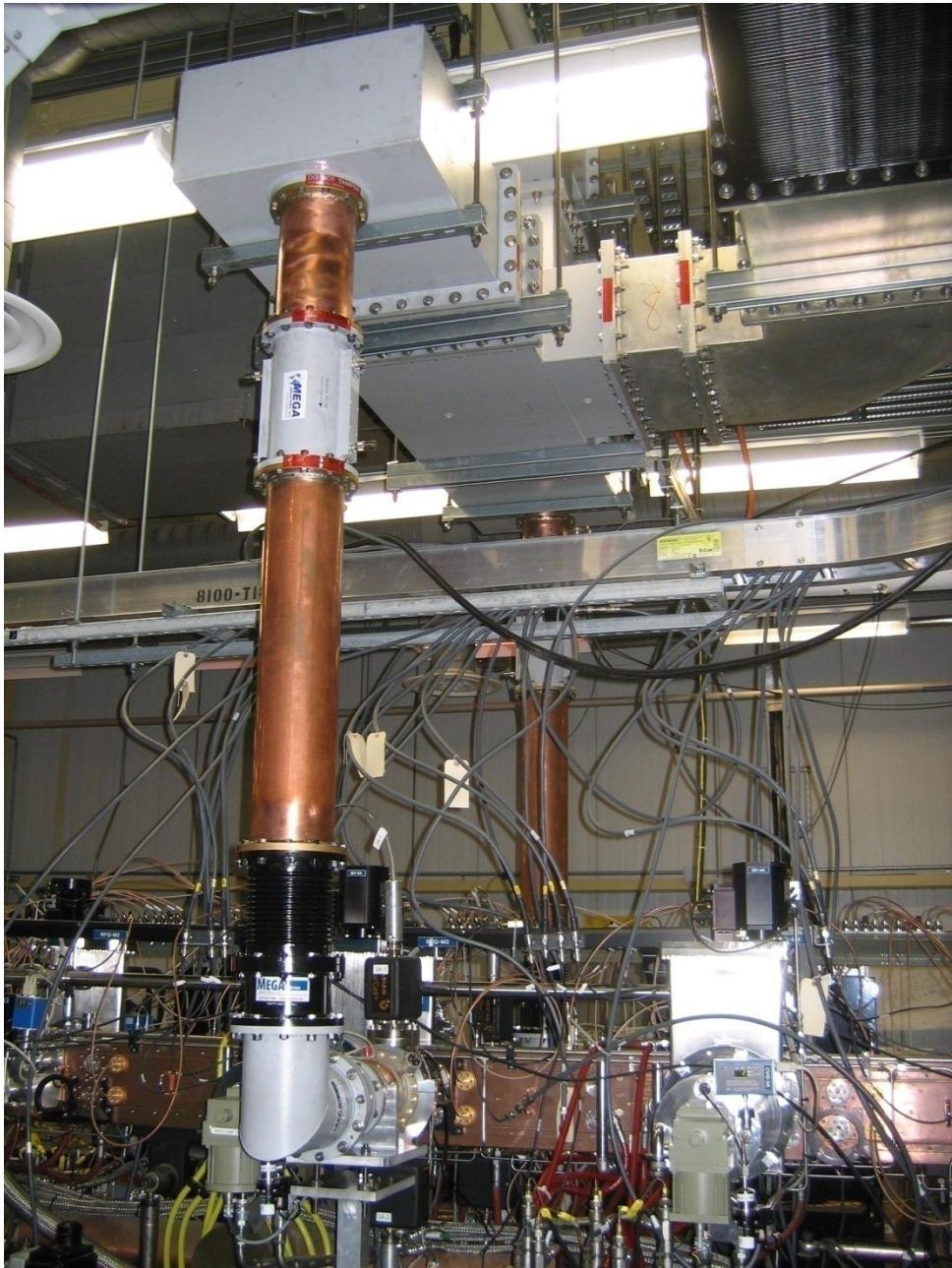




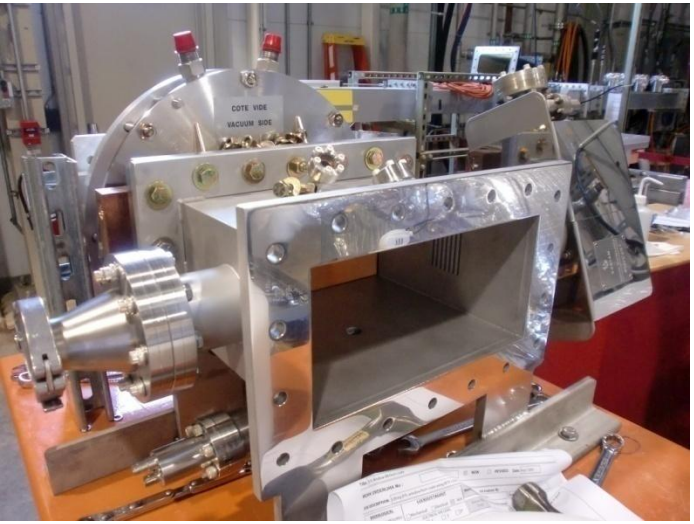
Upgraded RFQ Couplers



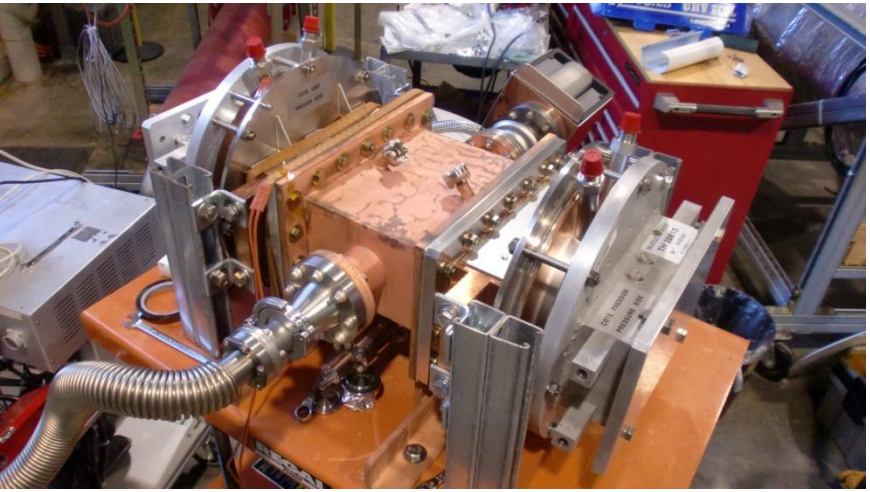


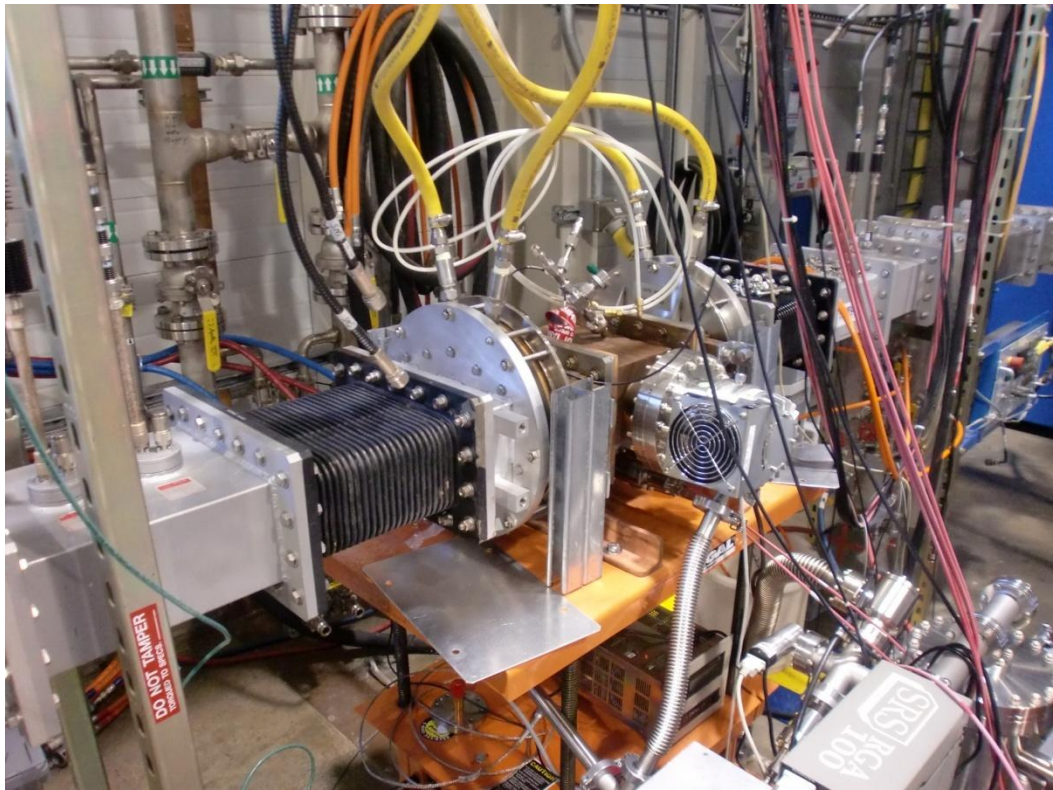


SNS CCL Window/Coupler Preparation

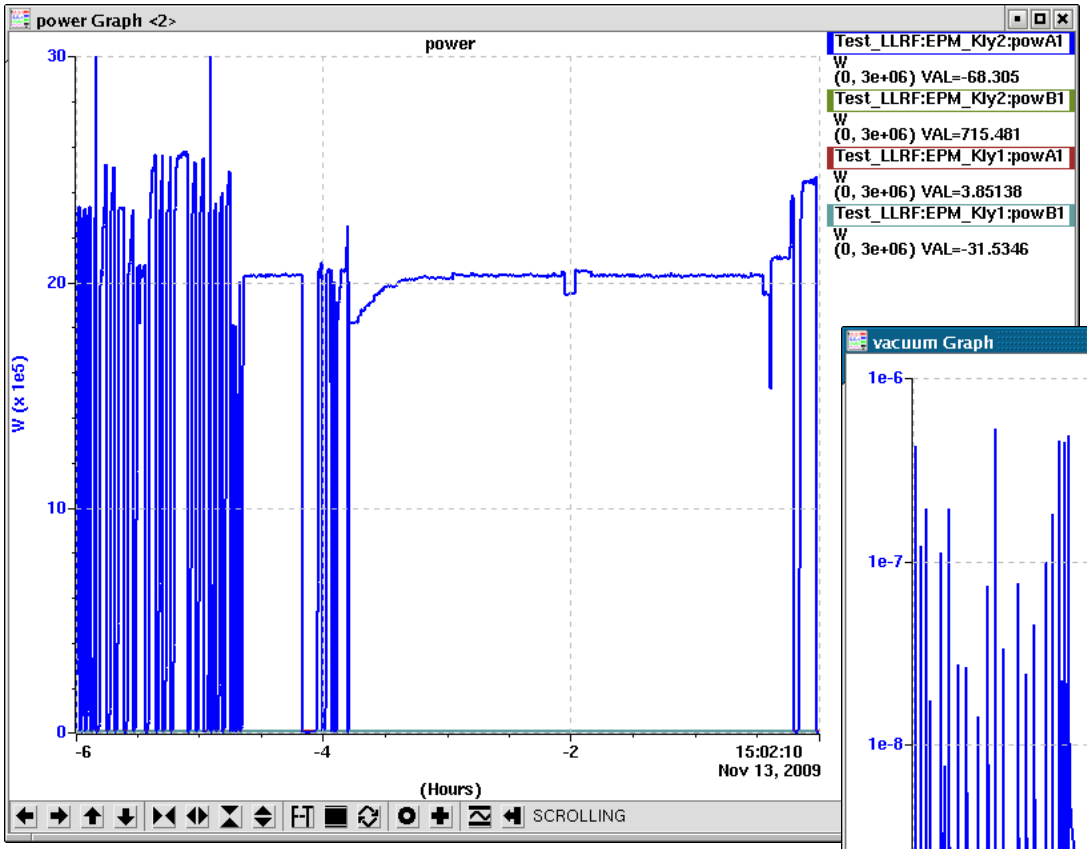


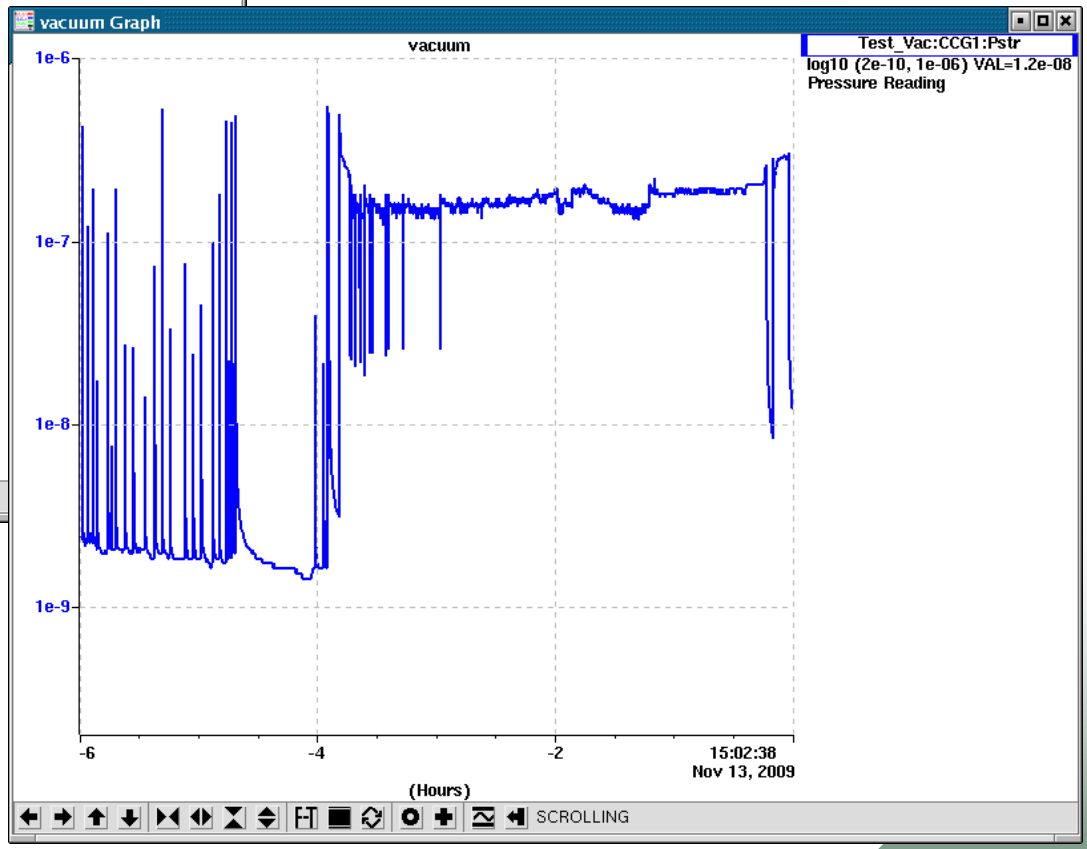
- Bridge waveguide is copper plated
- Pumping ports are equipped with RF screen
- Extra ports are for arc detectors and vacuum gauges
- Insertion loss of two windows with the bridge waveguide is <-0.03 dB
- Baked for 48 hrs at 150 °C with 12 hrs ramp-up and 12 hrs cool down





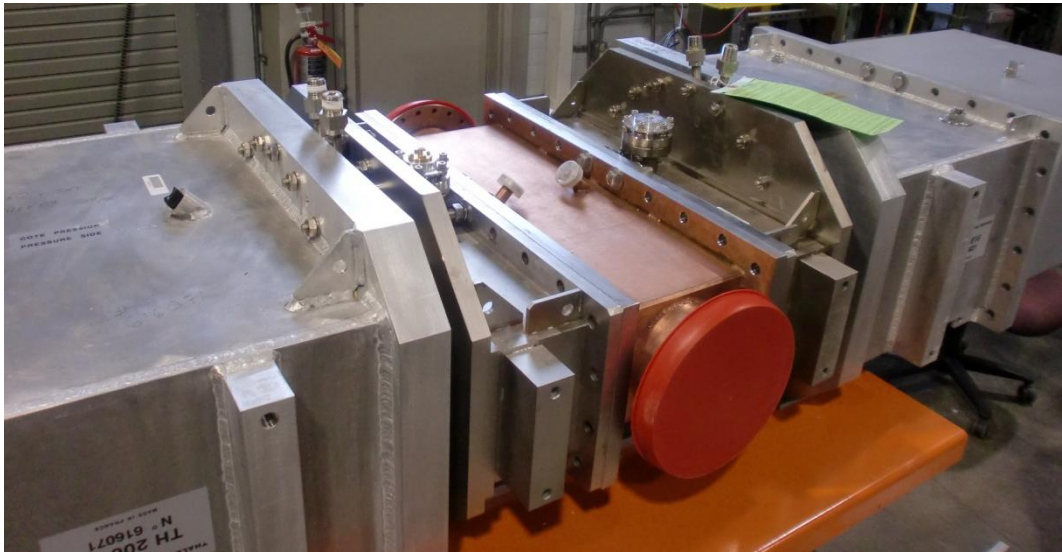
CCL Window RF Processing

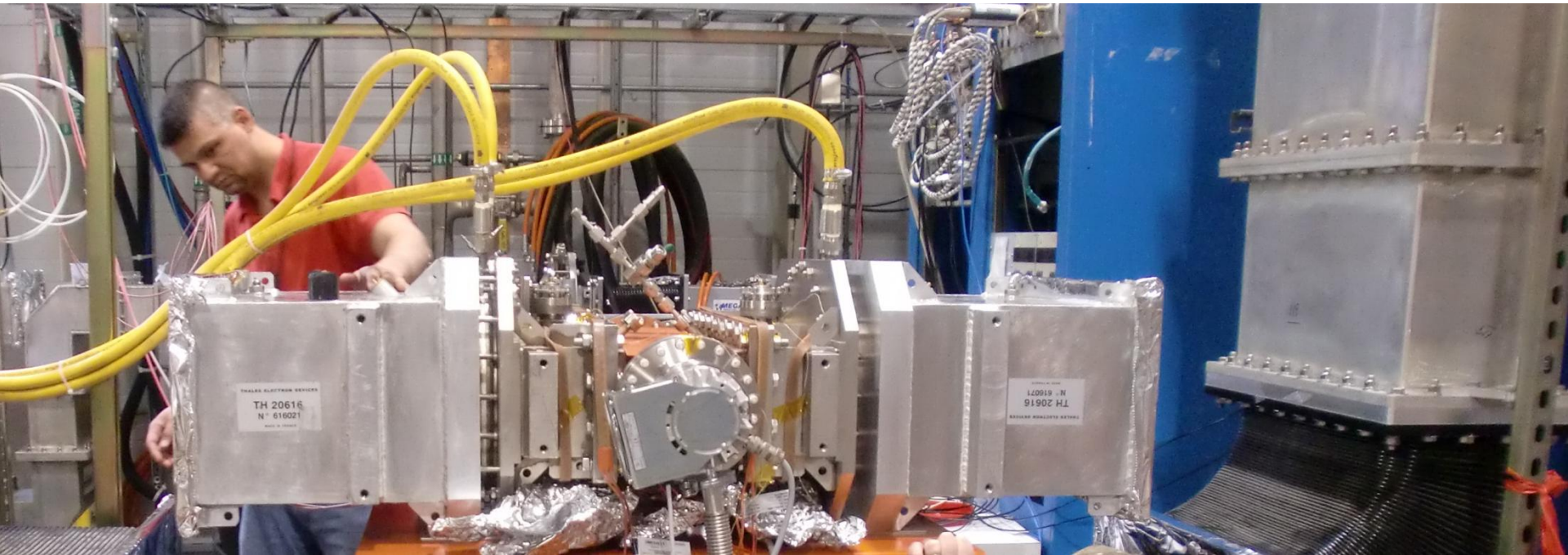




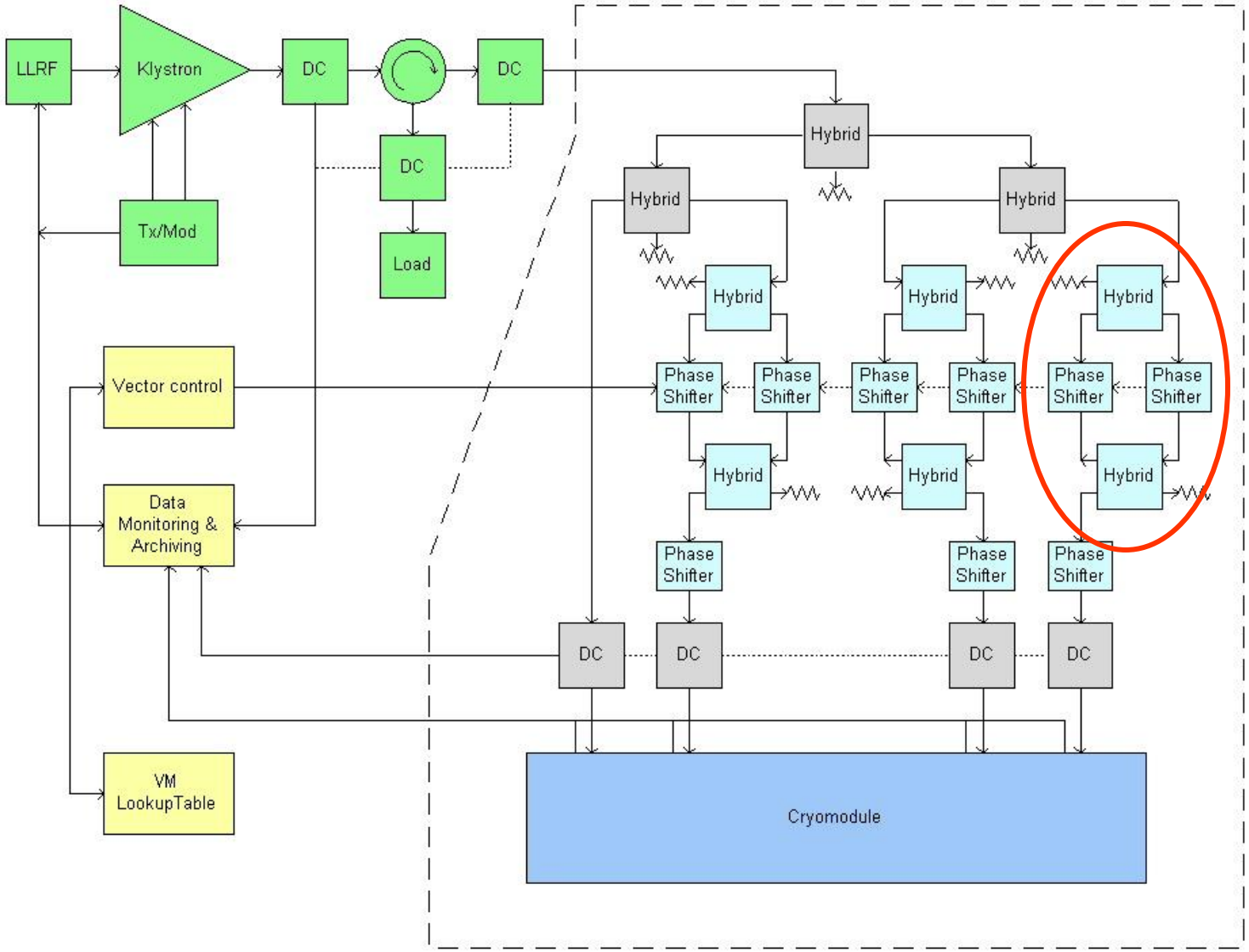
SNS DTL Window/Coupler Conditioning

- Compact bridge waveguides have been built and copper plated
- Spare windows for 402.5 MHz, 2.5 MW cavities have been conditioned
- Conditioning setups for the DTL and CCL windows are similar except the waveguide dimensions





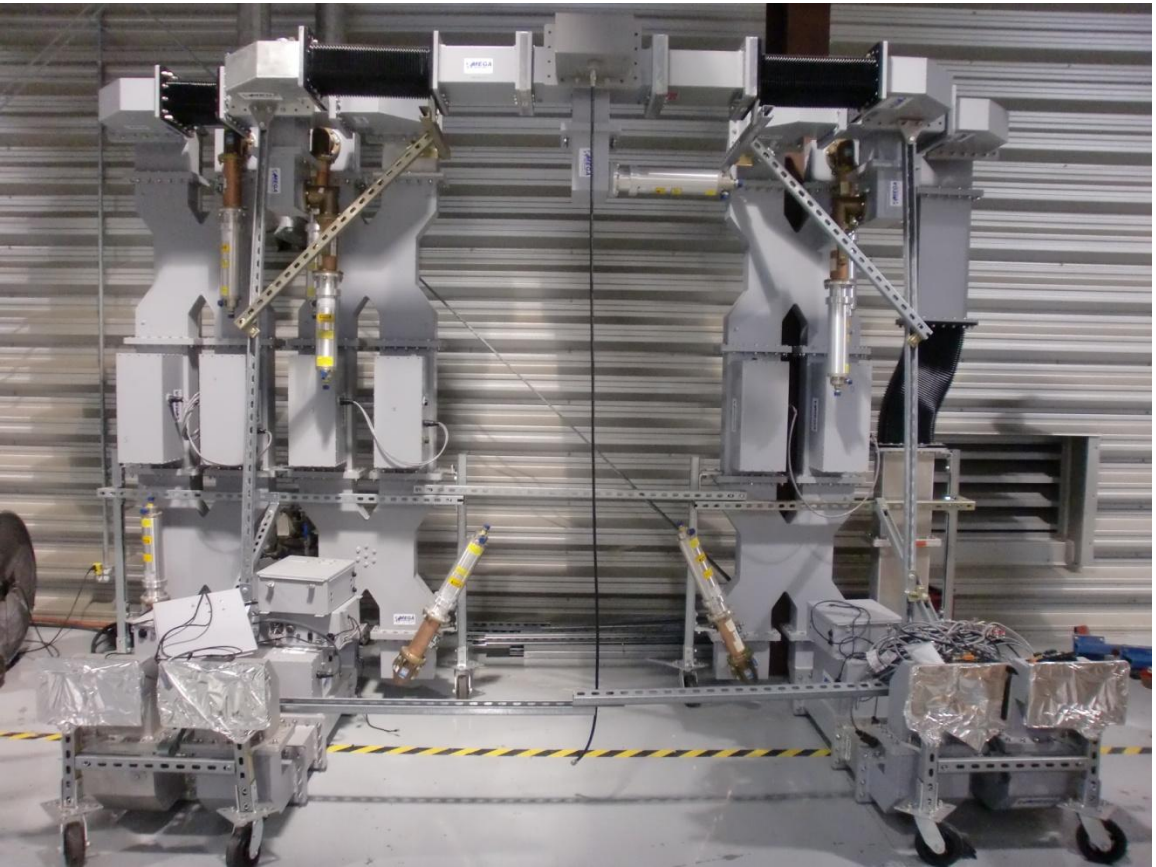
RF Distribution Setup for Cryomodule Test (up to 4 cavities)



Vector modulator

Waveguide Feed Network for Four Cavity Conditioning

- Feed four SCL cavities with one klystron (available 5 MW tubes)
- Use waveguide vector modulator employing the mechanical phase shifters
- Adjust the power of four outputs connected to cavities to ±40% in amplitude and ±30° in phase



Summary

- LINAC RF structures and their high power components are performing reliably with continuous improvements
- RFTF completely equipped and operational:
  - Two klystron tanks with complete waveguides in WR2100 (402.5 MHz) and WR1150 (805 MHz)
  - One 11 MW peak power high voltage converter modulator (HVCM) for powering the klystrons up to 8% duty in 60 – 135 kV.
  - Test cave measures 3.6 m x 8 m
  - Clean room facility for SRF processing and other utilities for He cryo systems, vacuum, and water cooling
  - Complete low-level RF control and monitoring for operation in EPICS environment
  - Programmable bake out setup
- Performed RF processing tasks successfully during construction, commissioning, and post-commissioning operation
  - Conditioned new spare window/couplers have been conditioned for RFQ, DTL, CCL
  - Conditioned more than 50 couplers for SCL
- Ready for the upcoming power upgrade project (PUP) with assembling, testing, and conditioning of couplers and cavities