

Design, Conditioning, and Operation of Upgrade RFQ Coupling System



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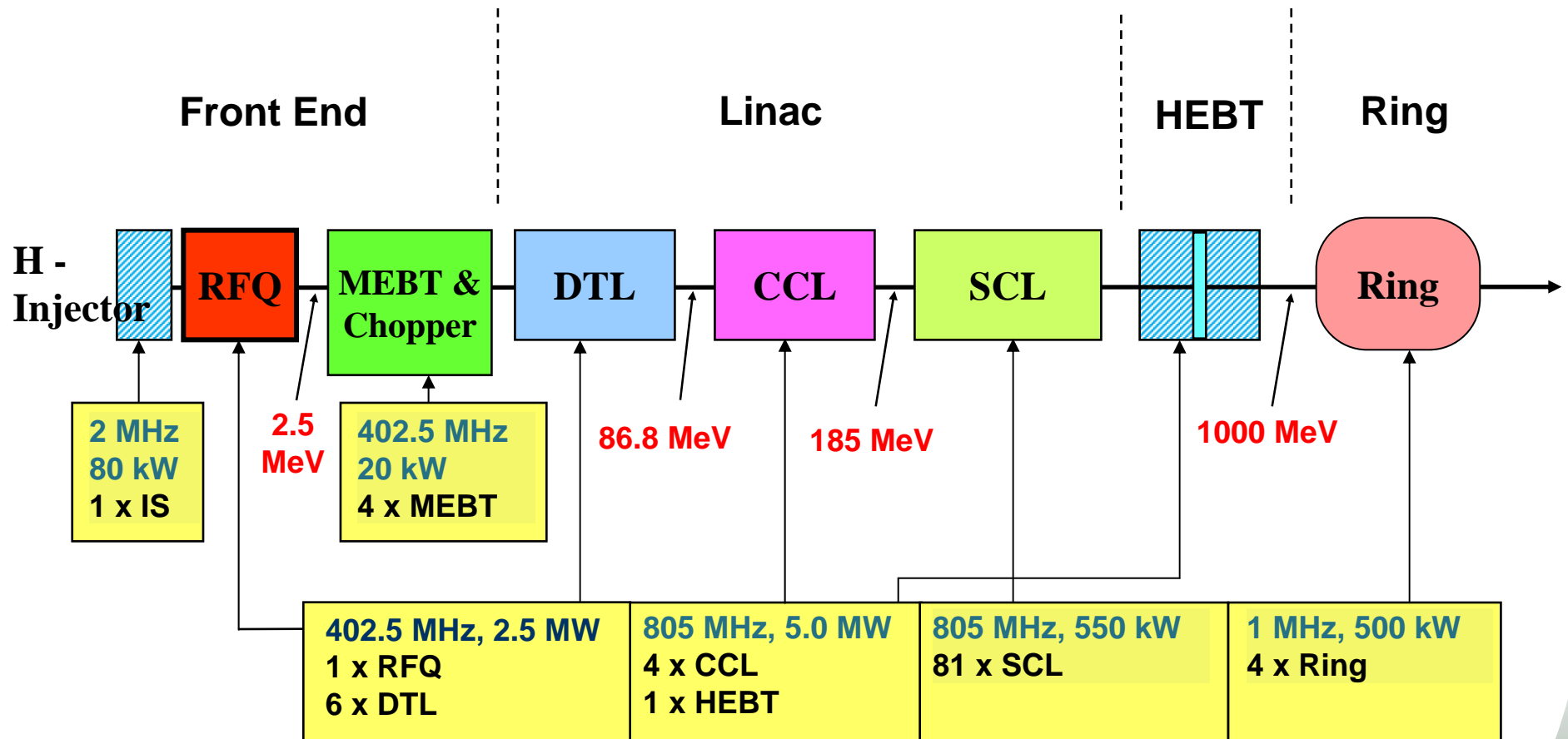
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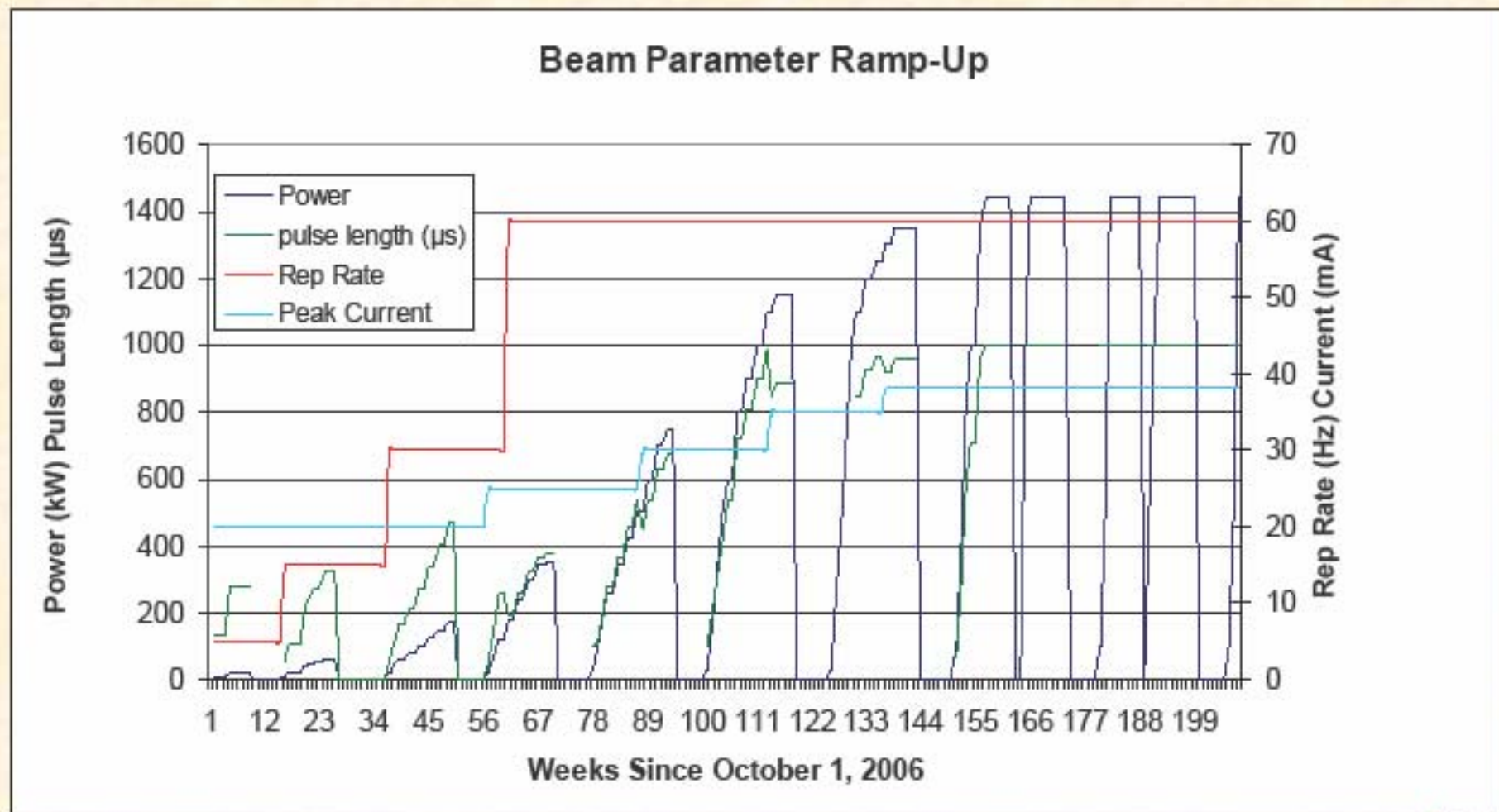
**Fifth CW and High Average Power RF Workshop
March 25-28, 2008**

SNS RF Systems



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

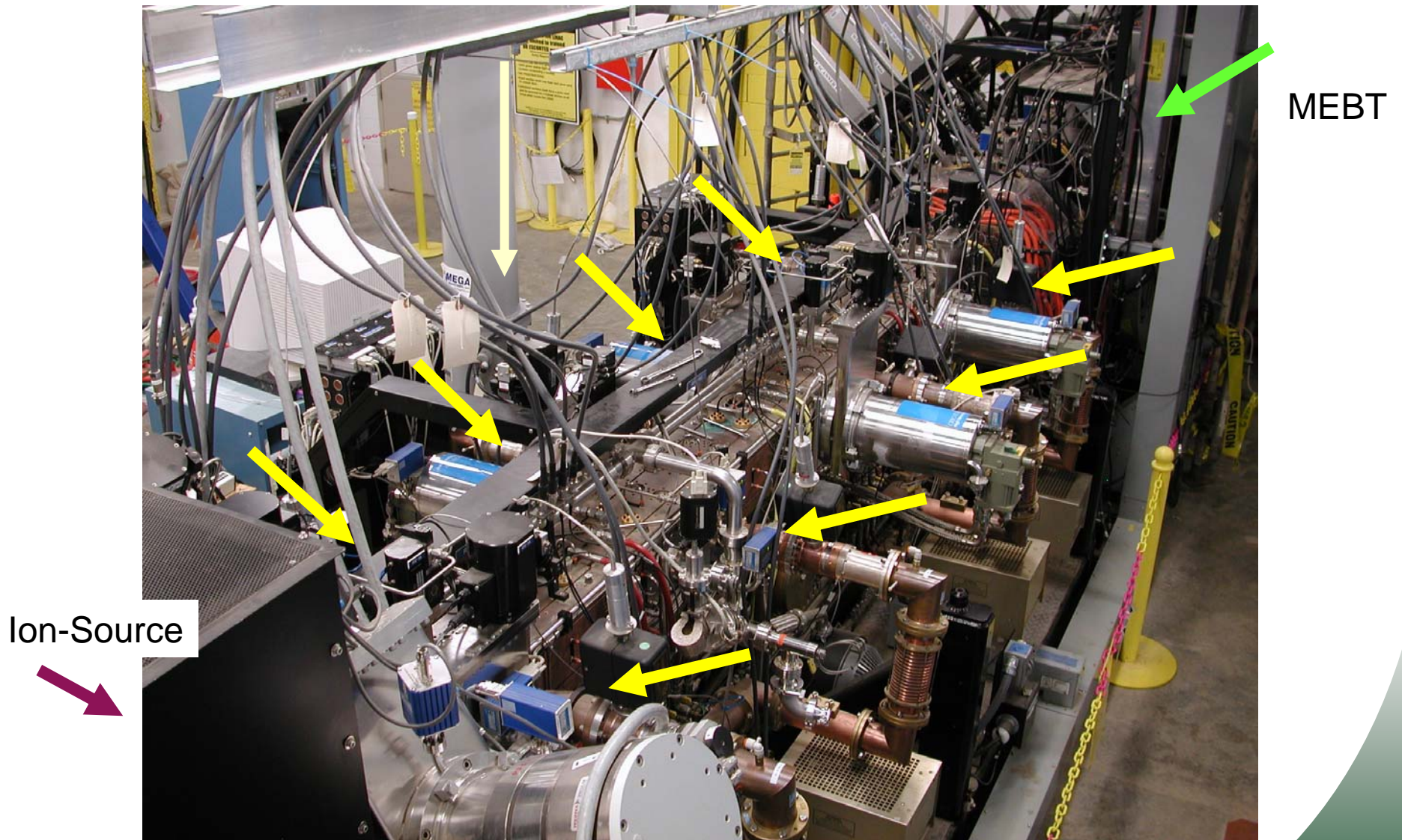
Projected Ramp-Up in Beam Parameters



Motivation – Old Coupling System

- RF power required in RFQ: ~ 800 kW peak (8% duty) total power (402.5 MHz) for 1GeV, 26 mA baseline operation and will have higher power in future upgrade
- Eight coupler configuration was used
 - Each window was rated to 100 kW peak power at 6% duty cycle
 - an eight-way coaxial power splitter was supposed to deliver uniform power, 100 kW to each coupler
 - Could not operate at full duty cycle needed for baseline operation
 - Matching all eight was difficult
 - power distribution was not uniform (4:1)
- Windows close to the H⁻ ion-source have been replaced few times due to contamination damages from operation
- For upcoming full beam power operation, a very reliable RFQ coupling system was needed

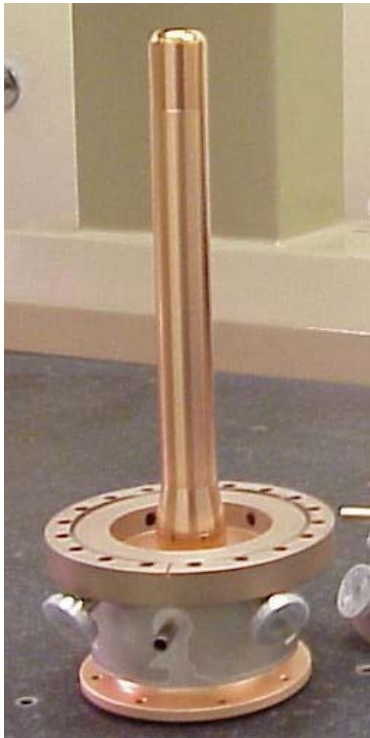
SNS Front End (Ion-Source, RFQ, MEBT)



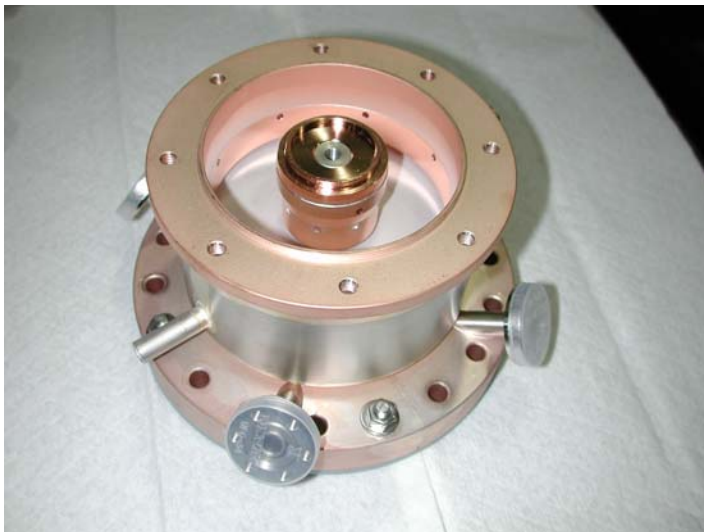
Coupler Window Consideration

- Use either two coupler (400 kW each) or one coupler (800 kW) configuration
- Use the ceramic window design used in the SNS/SCL Fundamental Power Couplers
 - More than 85 window were conditioned to 600 kW peak power @ 6% duty (some to 700 kW @ 6% and 1 MW peak @ 3% duty) in traveling wave and 2.4 MW peak in standing wave
 - The RF conditioned windows have been performing well in the SNS/SCL
- Proposed coupling system must handle the peak power and maintain good vacuum
 - Can maintain good vacuum in the ceramic window area? Vacuum in the RFQ may not be good enough due to ion-source
 - The designs of loop tip and custom flange of the old coupler design stayed to use the existing RFQ cavity
 - Coaxial outer conductor diameter near the coupling loop is 1.4" which is still sufficient to handle > 2 MW rms pulsed power with good vacuum

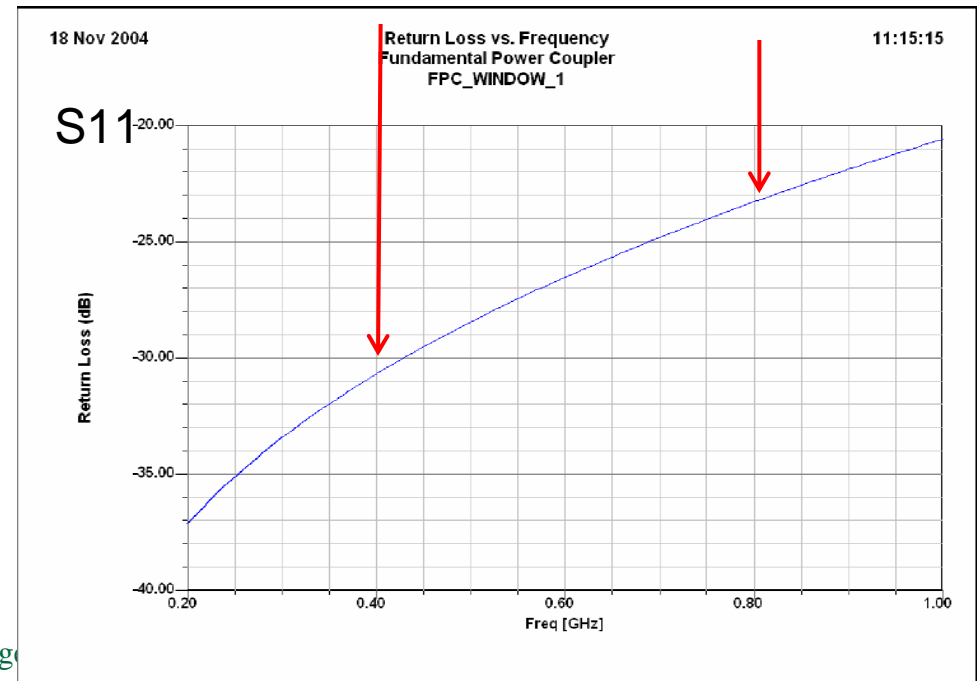
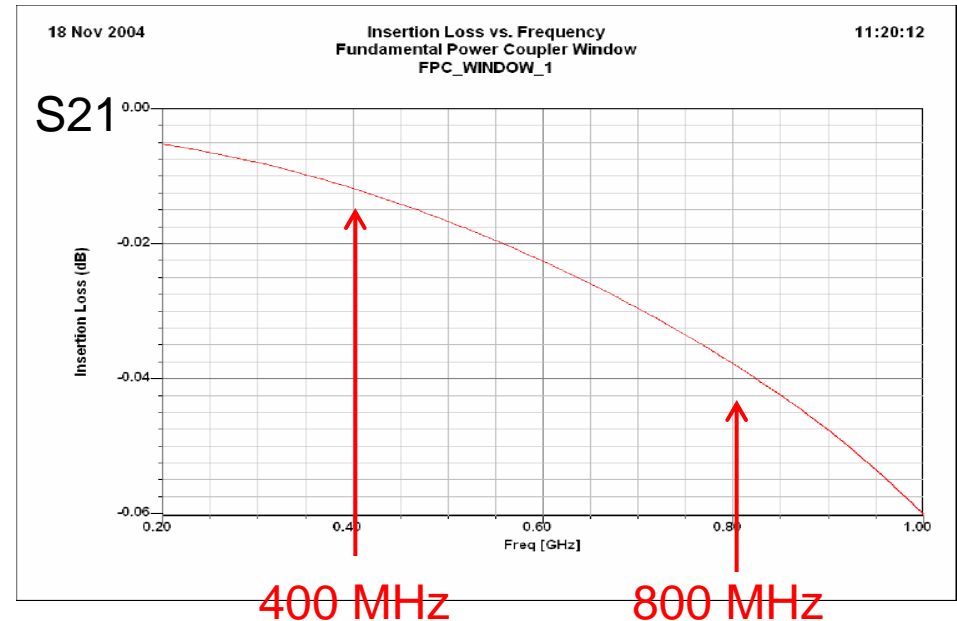
SCL FPC Window Assembly



- **For SRF cavities:**
 - Probe antenna for 805 MHz SCL
 - Vacuum gauge and arc detector ports for interlocks
 - Electron pickup probe port for current monitoring
- **For RFQ:**
 - Loop antenna for 402.5 MHz
 - Window has better RF performance at lower frequencies



W and High Average

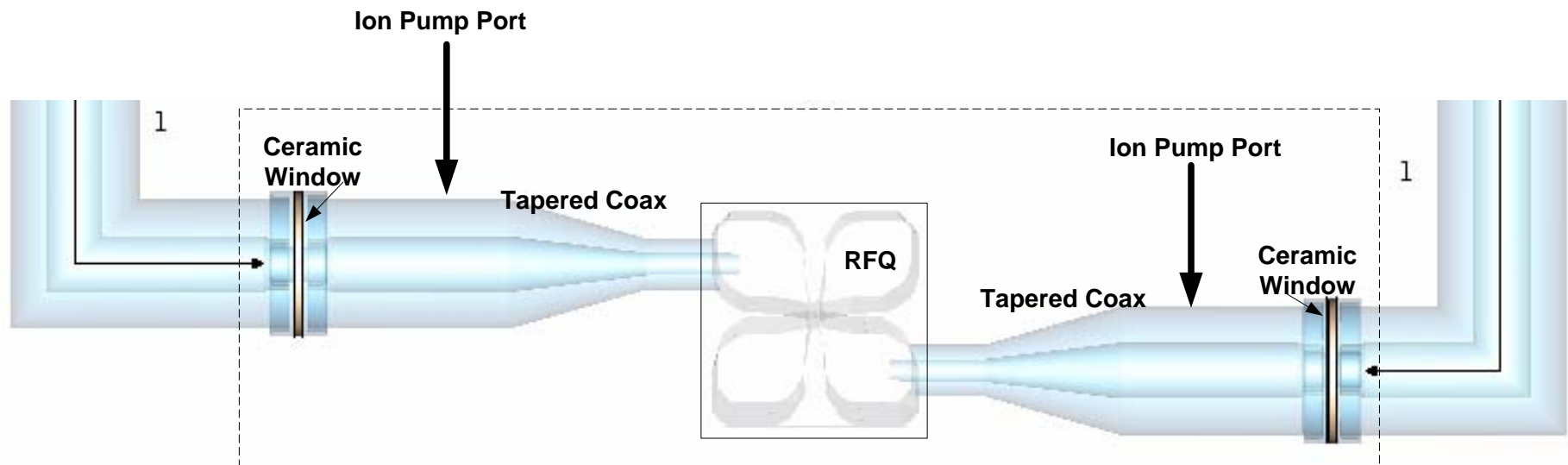


New RFQ Coupling System

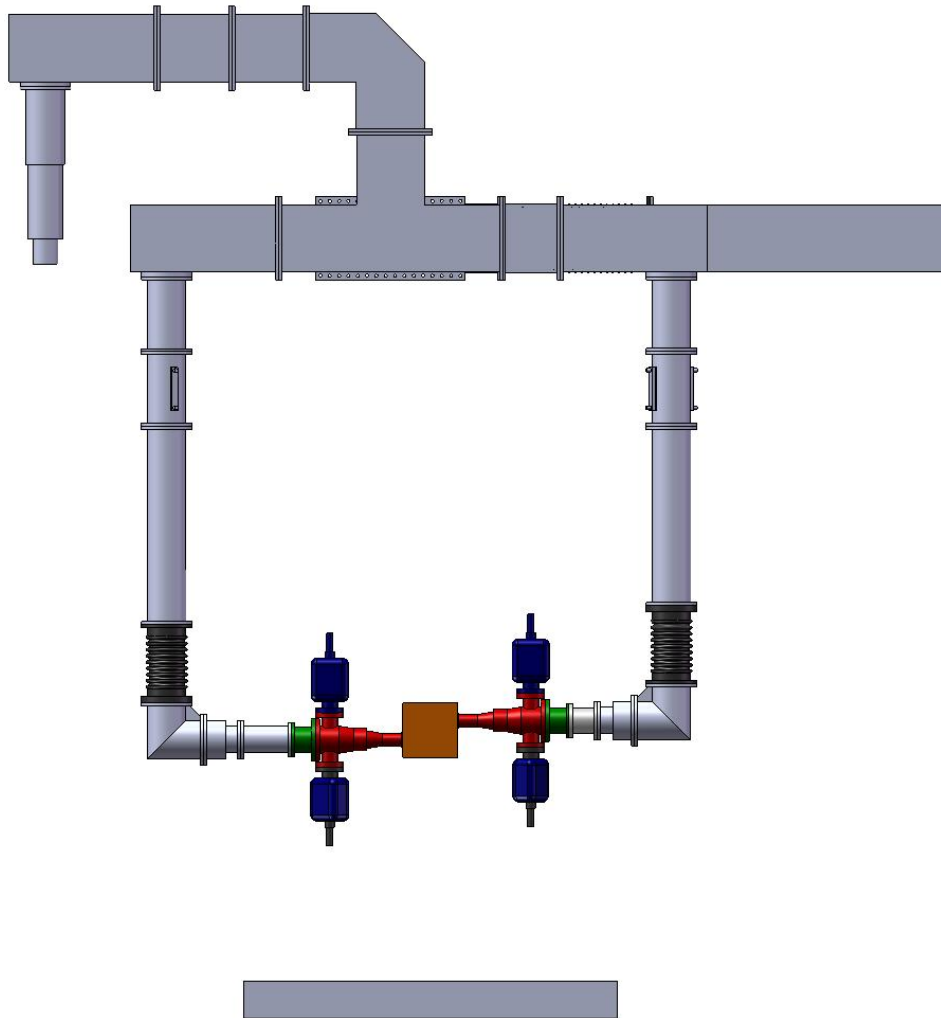
- **Two coupler configuration:**
 - Use a magic-T hybrid power splitter with a water load on the isolation port for better isolation between ports and matching
 - Operate at ~ 400 kW / coupler
 - Use coupler ports farther away from the H- ion-source for better vacuum condition
- **Goal was to replace coupler system during February - March shutdown period in 2008 and get ready for operation**
- **3 new couplers manufactured and conditioned**
 - using SCL coupler window design routinely conditioned to 600 kW peak power @ 6% duty in traveling wave
 - all 3 new couplers have been RF conditioned at SNS/RFTF
 - RF conditioned up to 450 kW @ 1 msec, 30 Hz through bridge waveguide
 - After installation two couplers conditioned to 900 kW total power
- **3 more spare couplers ready for RF conditioning**

Using 2 Couplers on RFQ

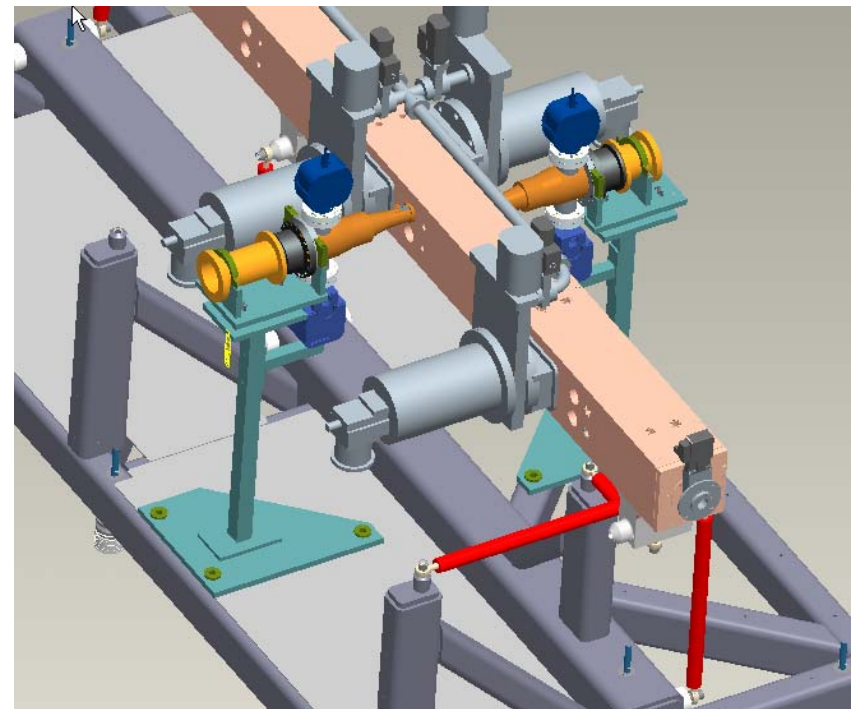
- RF phase matching between the two couplers with waveguide/coaxial transmission line
- Balanced coupler matching
- Bi-directional signal coupler in each splitter output
- Arc detector and e-probe on the ceramic window
- Field probes unchanged on RFQ
- Two ion-pumps/coupler instead eight all together (CCG on one ion-pump port during conditioning)
- other vacuum/mechanical configuration unchanged



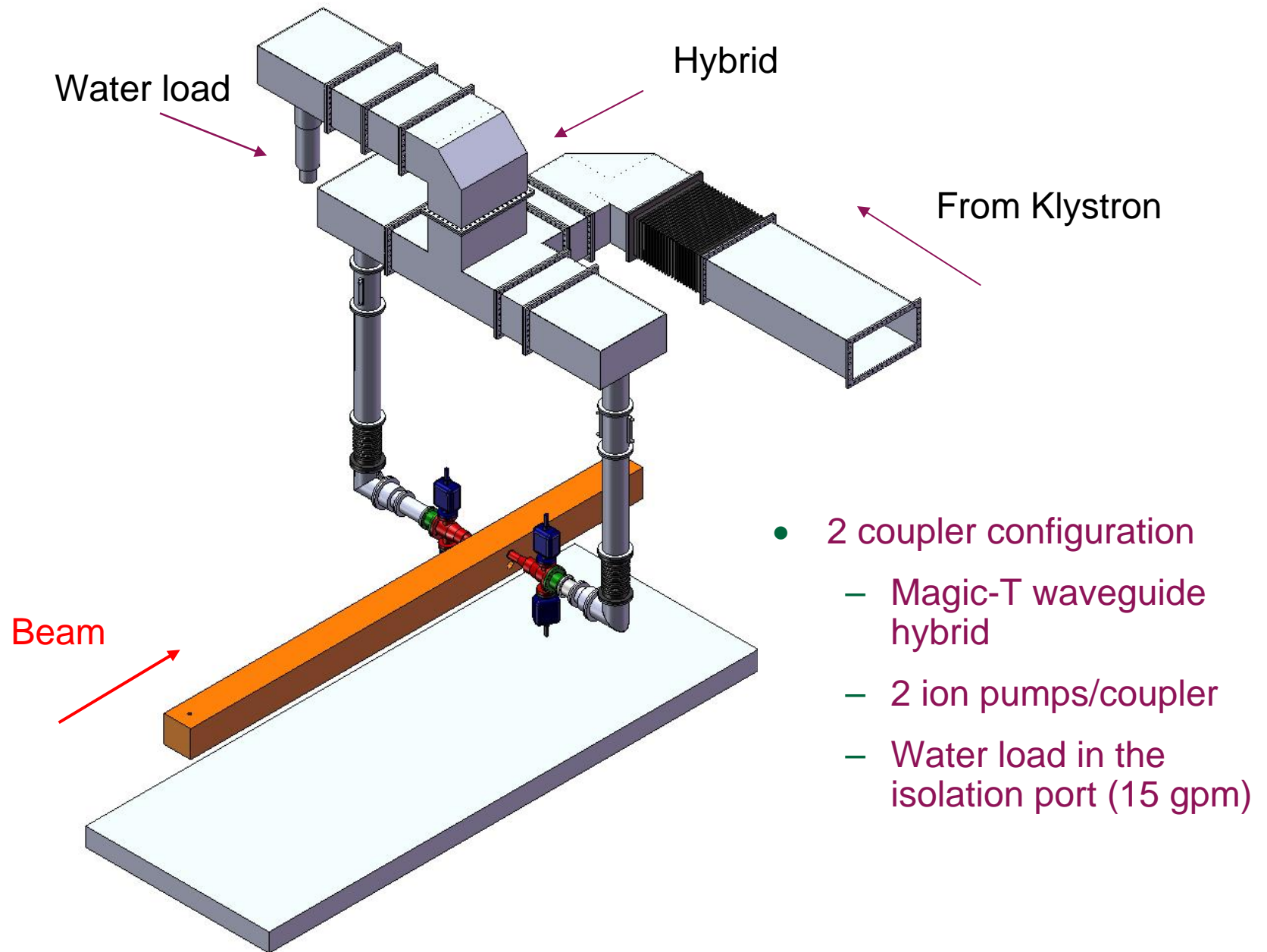
Two Coupler Configuration



Couplers and Support Structures



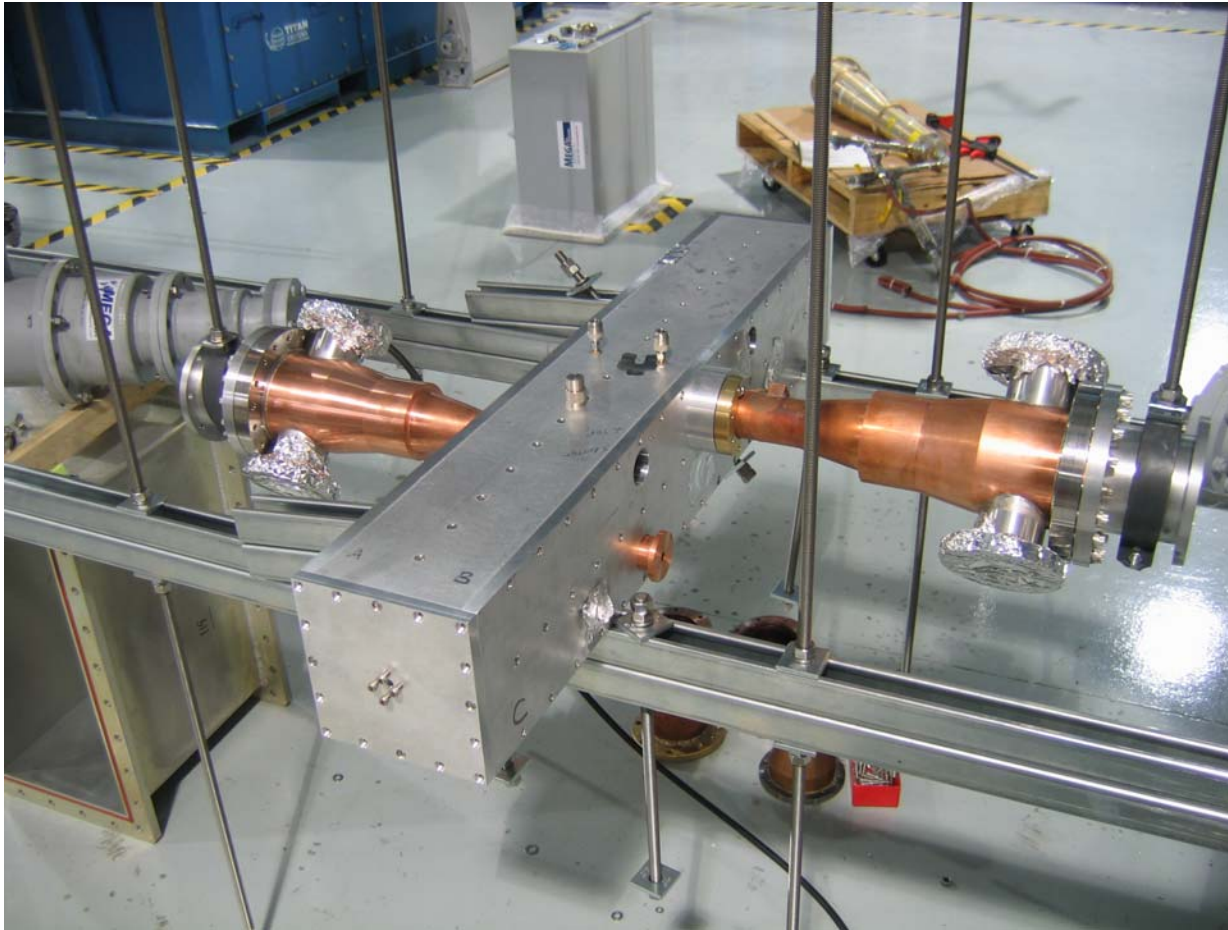
Two Coupler Configuration



Mockup Built prior to Installation

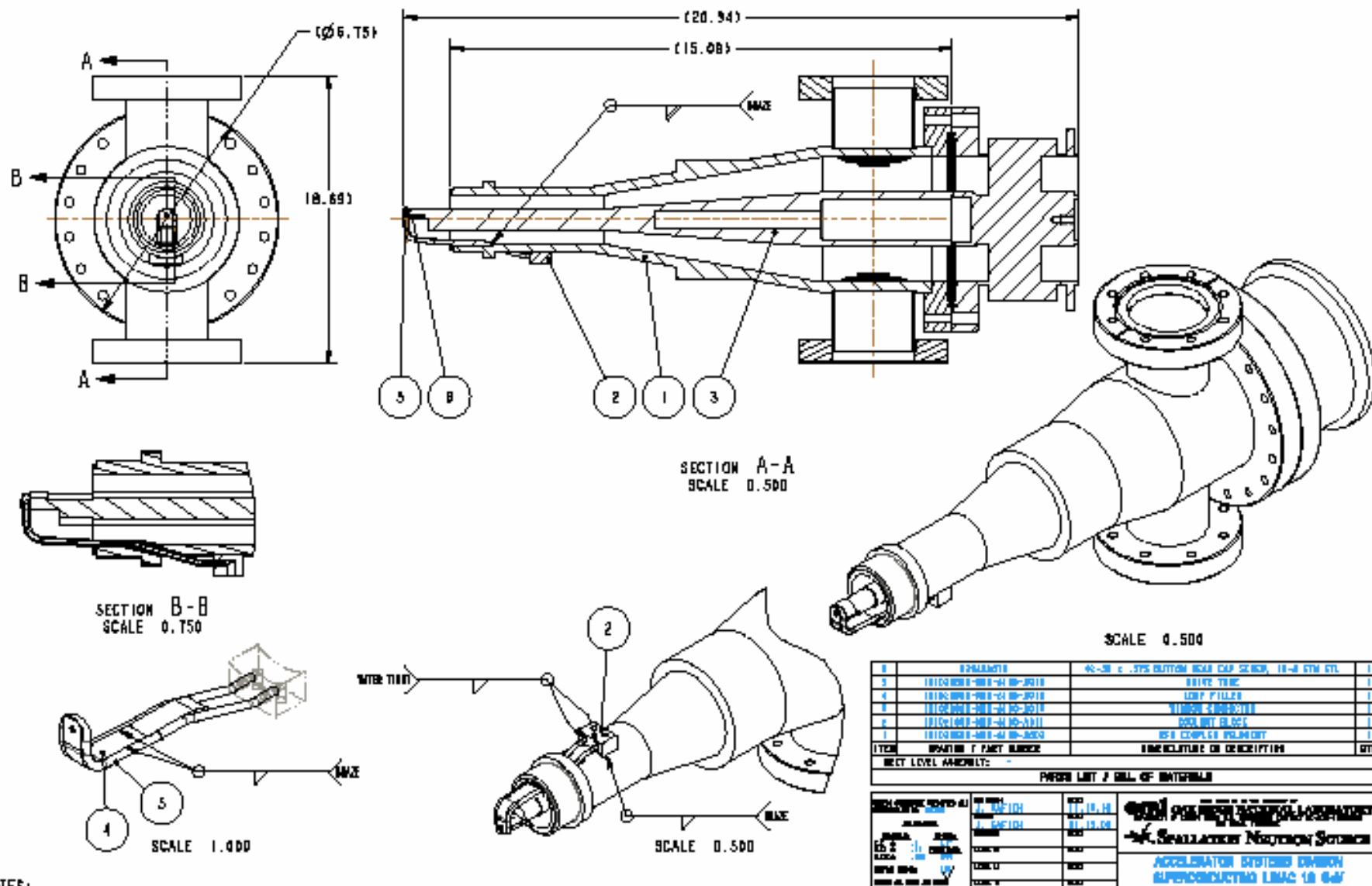


Mockup with Test RFQ and Couplers

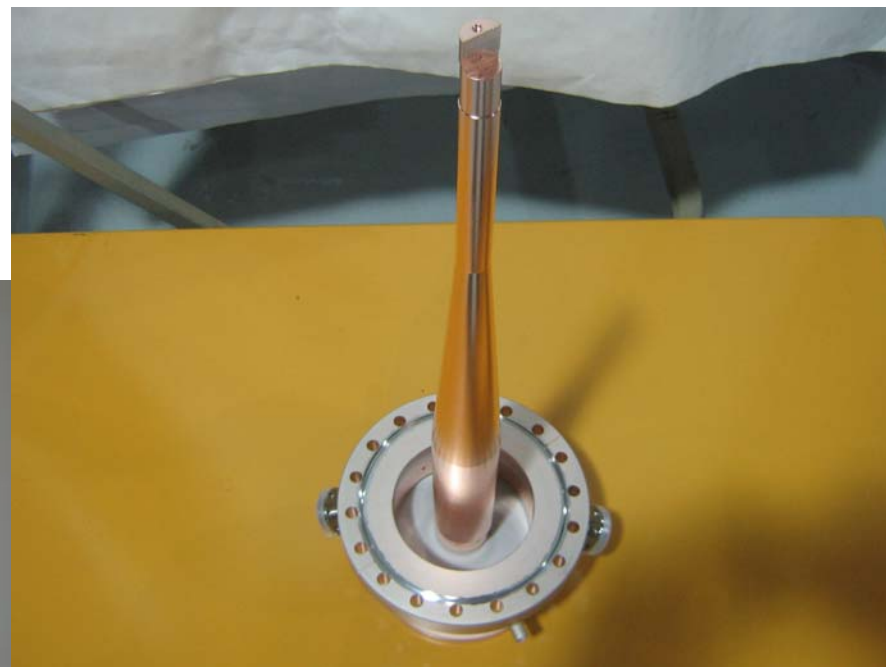


- RFQ test module and couplers were used to
 - tune to 402.5 MHz quadrupole mode,
 - phase matching Waveguide transmission line, &
 - match couplers for the cavity and beam loading.

New Coupler Assembly



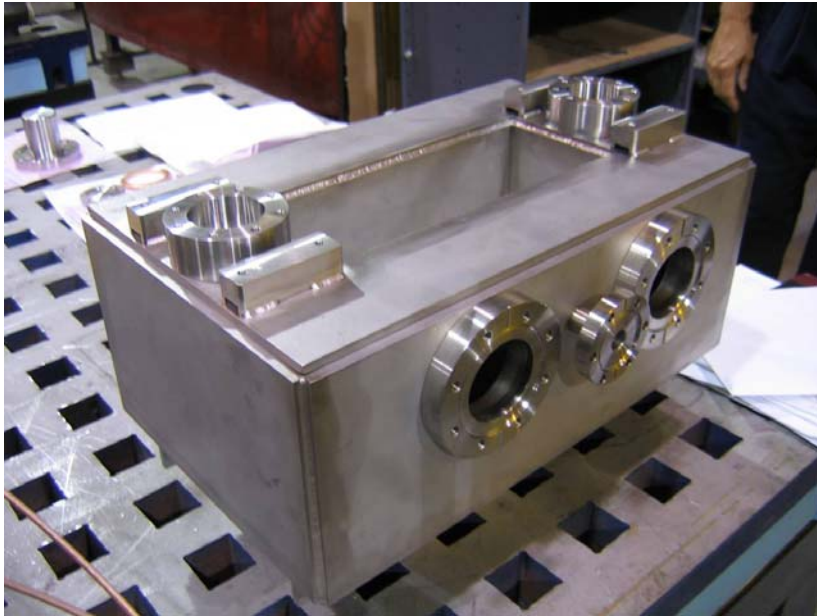
Coupler Outer & Inner Conductors



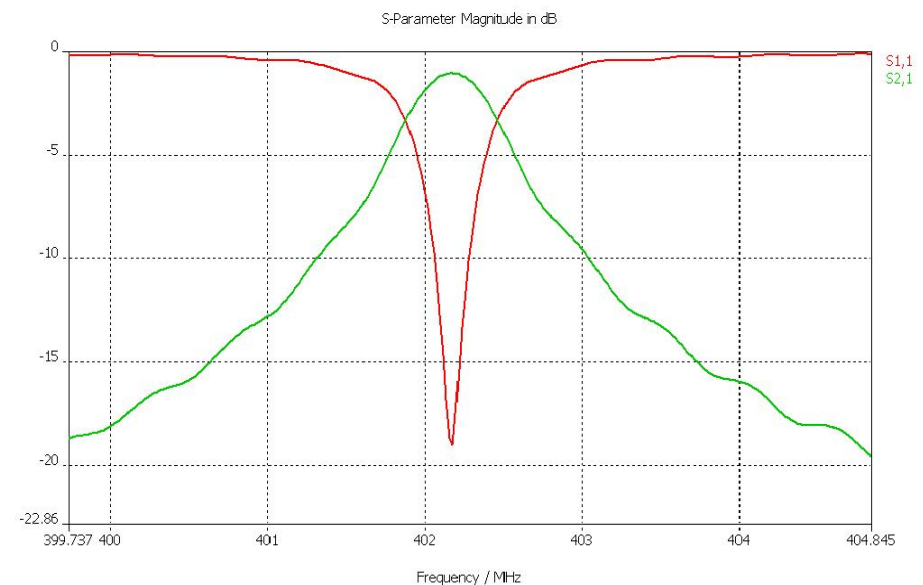
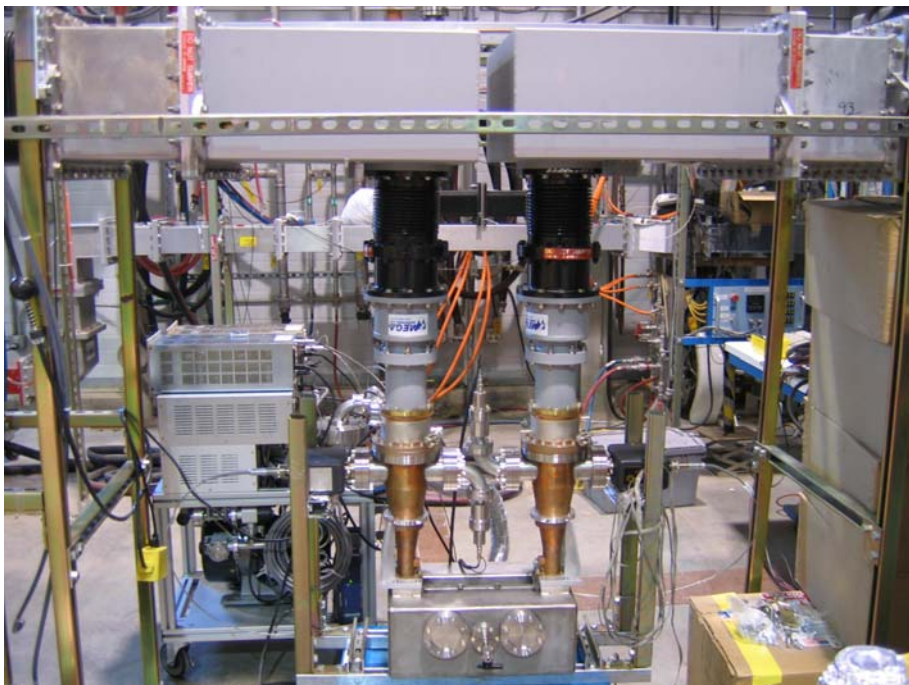
High Power RF Conditioning and Operation

- **Install couplers on the bridge waveguide, vacuum leak check, and low power RF test**
 - Rectangular re-entrant cavity used as the bridge waveguide to reduce the size of the waveguide for 402.5 MHz
 - Stainless steel construction with ± 1 MHz mechanical tuning
- **Bake the couplers and the bridge waveguide**
 - Increase temperature linearly to 200° C in 12 hours
 - Stay at 200° C for 24 hours
 - Lower temperature linearly to ambient in 12 hours
- **Perform RF Conditioning**
 - Preconditioning to 450 kW in RFTF
 - 0.1 – 1.0 msec, 30 Hz
 - In situ conditioning to 900 kW total power after installation
 - 0.5 – 1.0 msec, 60 Hz (completed)
- **Perform beam transmission measurement with the ion-source**

Couplers Setup for RF Conditioning



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

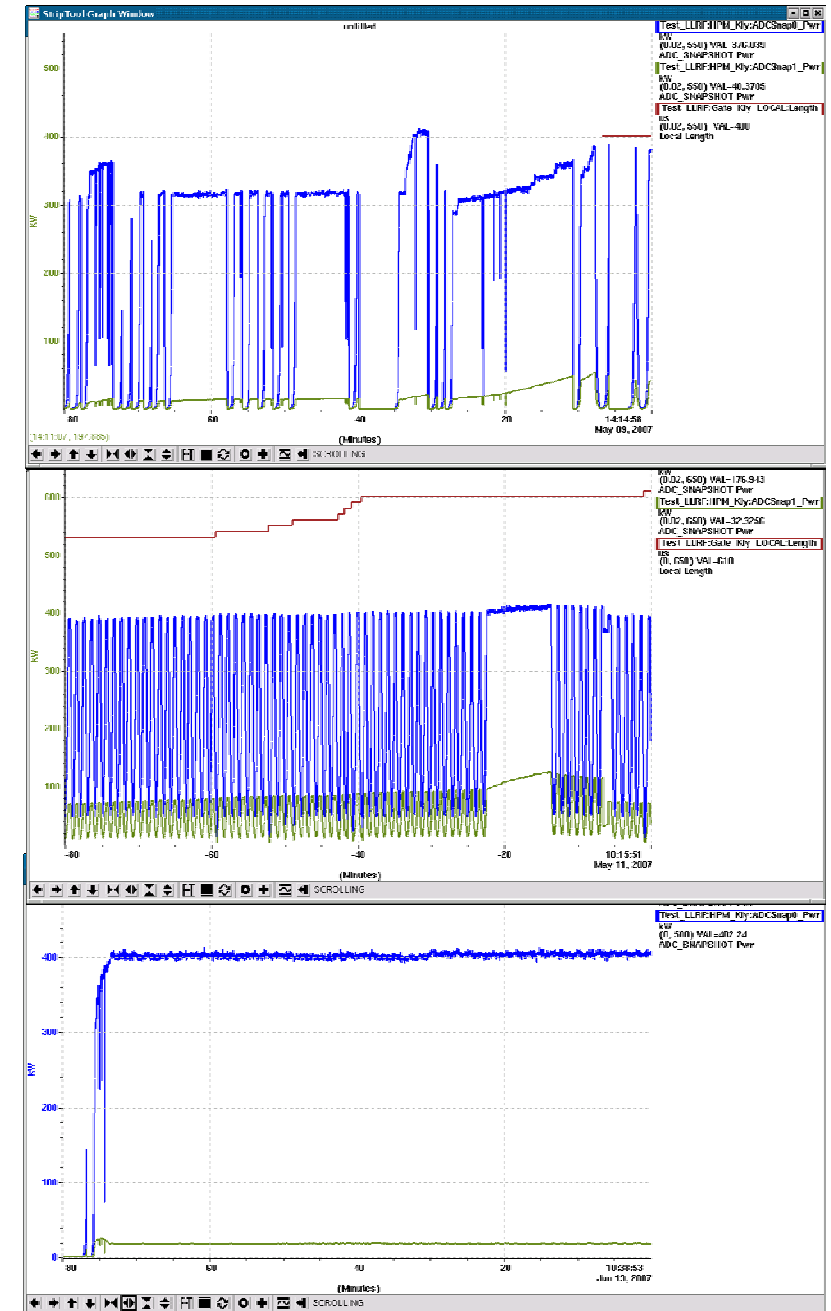


Return and insertion losses
through bridge waveguide

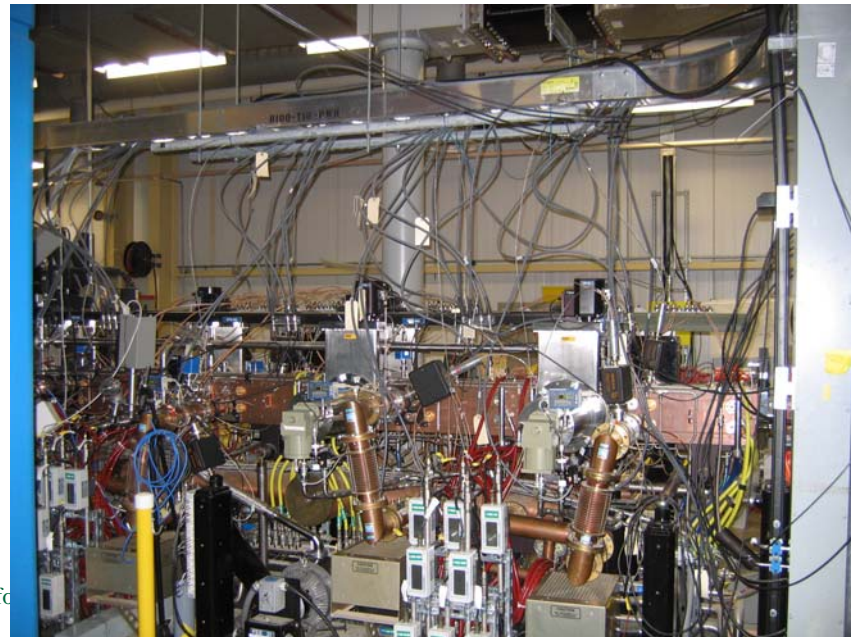
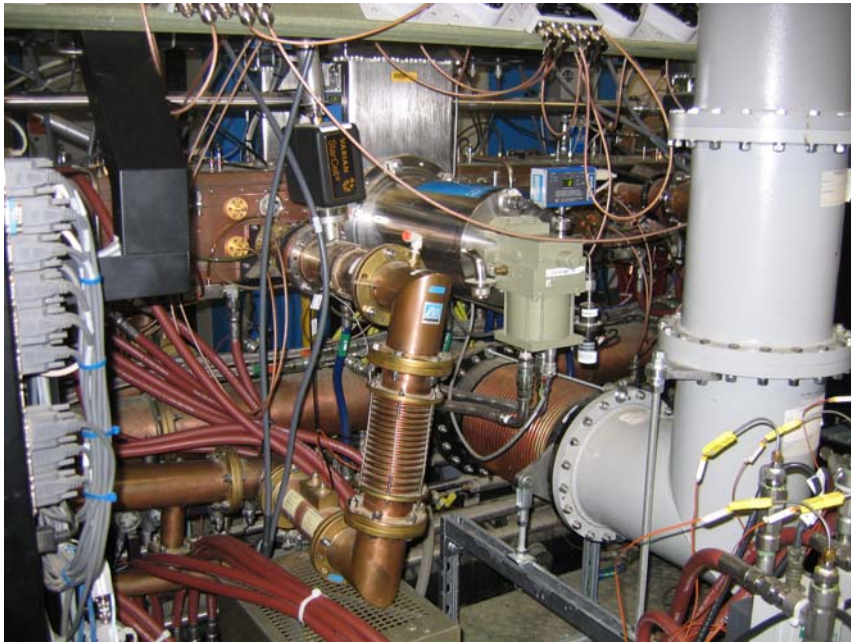
RF Conditioning Setup in RFTF



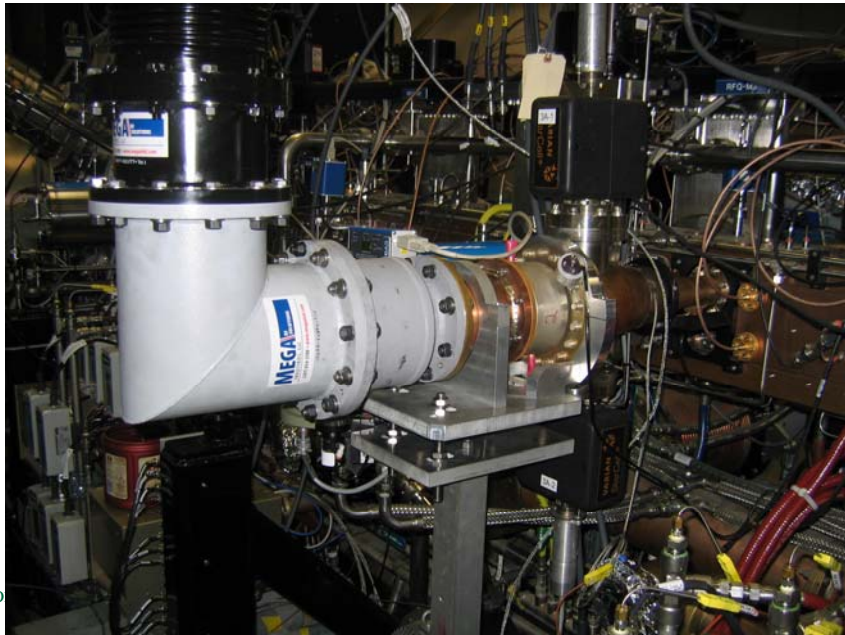
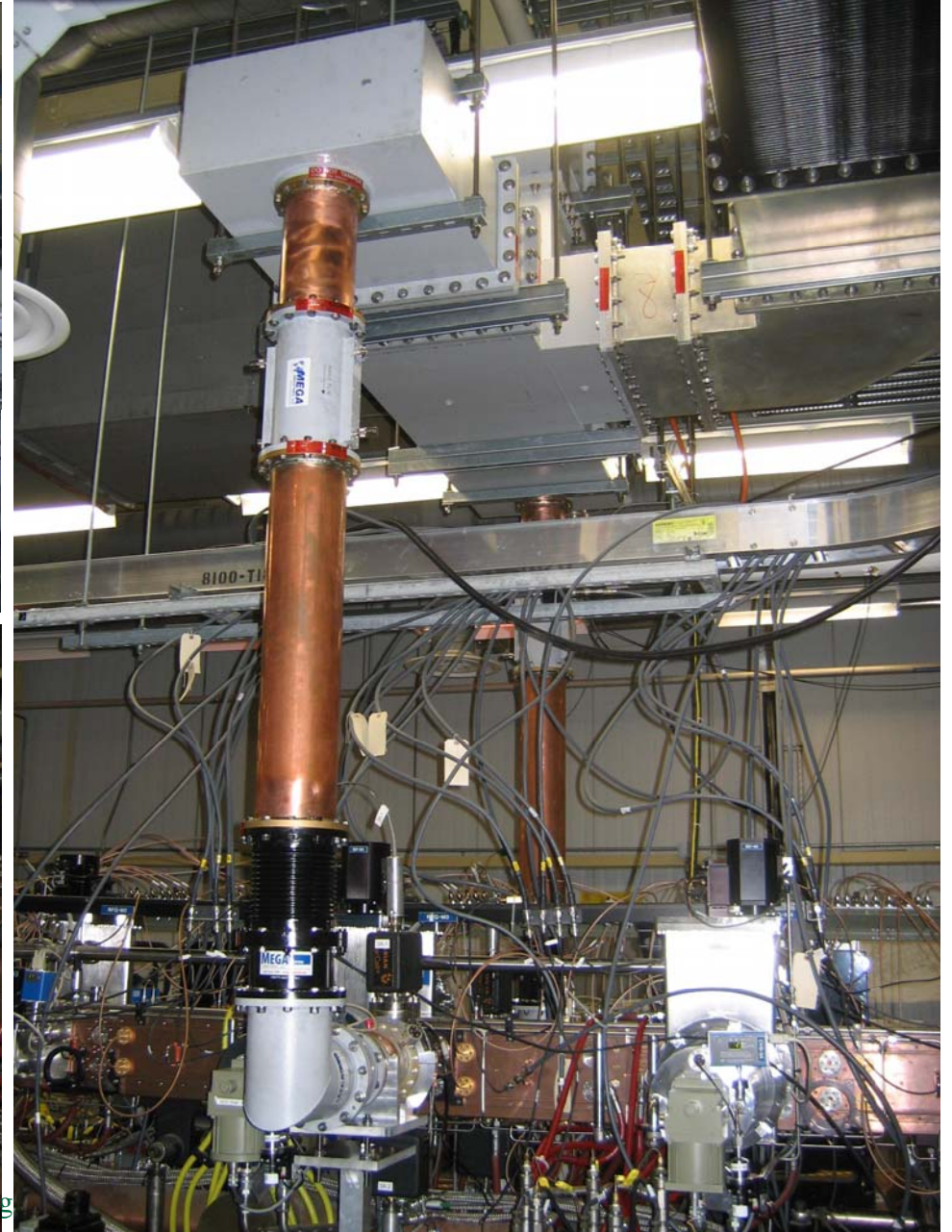
- Conditioning done by slowly increasing the power and then the pulse width at a fixed pulse repetition rate
- Conditioning done with cycling the power between 5 – 100% at levels with higher vacuum activities and at the full power



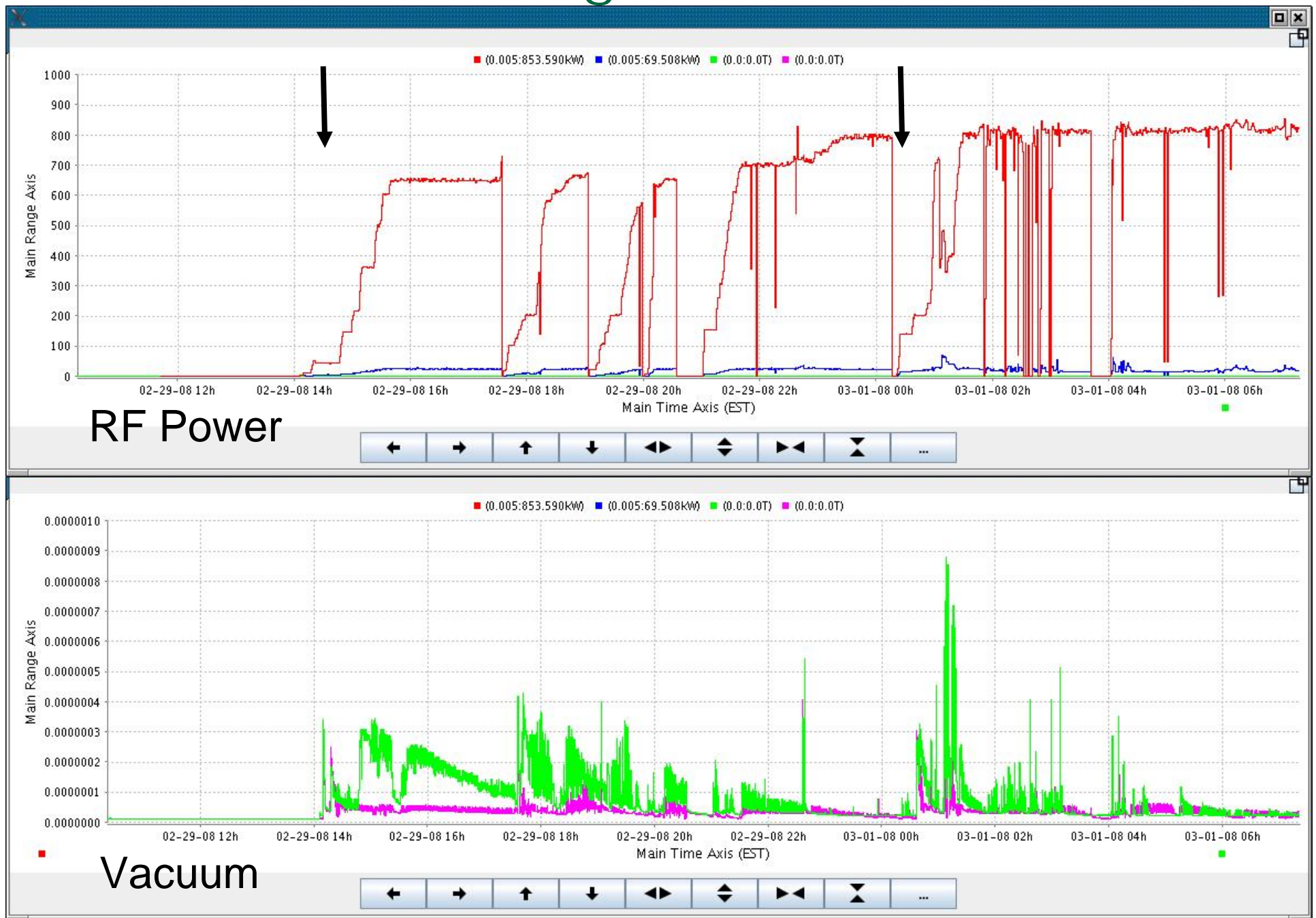
Previous System



Upgrade System



Full RF Conditioning after Installation



Summary

- New coupling system for the RFQ was important for the full beam power operation
- 2 coupler coupling system developed for the existing RFQ cavity
- 3 couplers procured and RF (50%) conditioned at RFTF in 2007
- New coupler design employs the ceramic window used in 805 MHz SNS/SRF cavity couplers
- New couplers installation completed as planned during the 2/4 – 3/23, 2008 shutdown period
 - Removal of old system 2/04 - 10 '08
 - Installation waveguides, couplers, supports 2/11 - 19 '08
 - Tuning & phase matching 2/20 - 28 '08
 - Full RF testing/conditioning 2/29 – 3/14 '08
- Coupling system has been fully conditioned on RFQ cavity at full power and duty cycle: ~ 900 kW, 1msec, 60 Hz
- H⁻ beam transmission through the RFQ has been tested and verified by accepting and measuring the beam at the MEBT beam stop
- 3 more spare couplers purchased and readied for RF conditioning