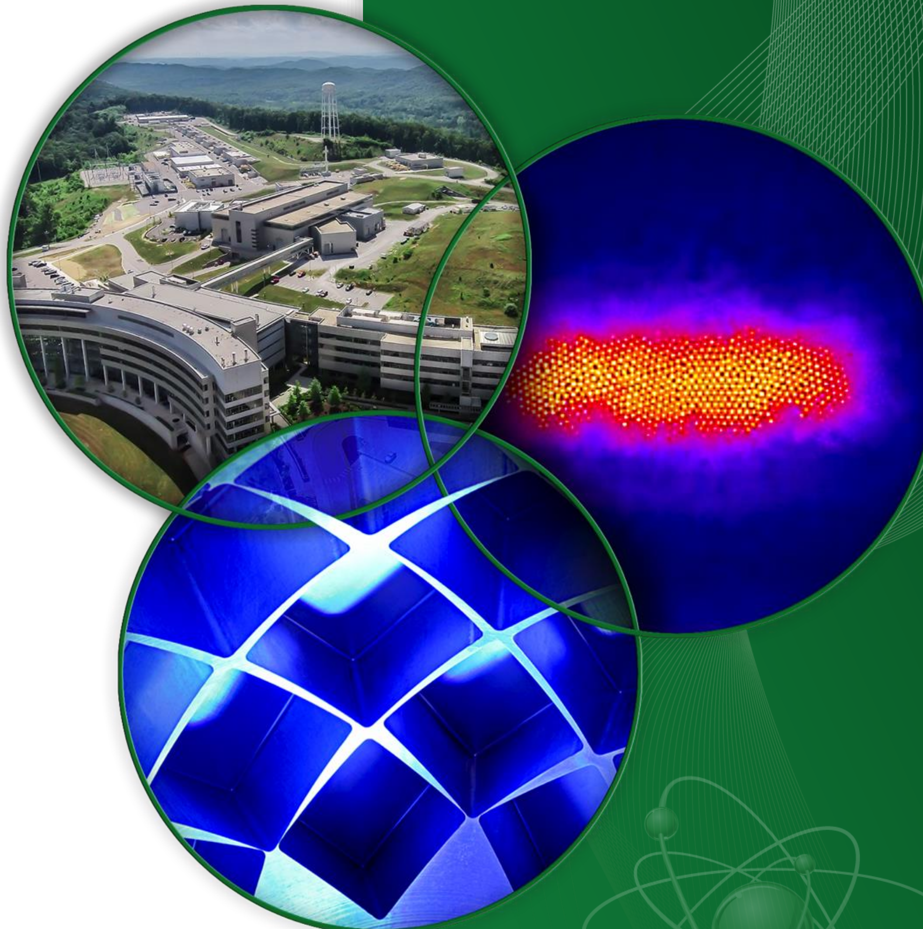
RFQ Performance and Status of Spare RFQ

Mark Champion, Group Leader
Electrical and RF Systems



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Outline

- Status at previous AAC review – May 2013
- Production RFQ
  - Progress, status, and plans
- Spare RFQ
  - Progress, status, and plans

Status at Previous AAC Review – May 2013

Production RFQ

- The Production RFQ was operational but required retuning during the upcoming summer shutdown.
  - 3rd detuning event in lifetime of RFQ occurred in summer 2011, but it was not immediately noticed because the resonant frequency did not change. Only the field flatness changed.
  - Decreased beam transmission through the RFQ (~70% vs. historical maximum of 90%)

Spare RFQ

- The Spare RFQ had recently been assembled and tuned at Research Instruments near Cologne, Germany.
- Factory acceptance testing was planned for the summer of 2013.
  - Dimensional verification and review of manufacturing data
  - Pressure and flow testing of water circuits
  - RF tuning verification
  - Vacuum testing
- Delivery expected in July 2013

Progress Since the Previous AAC Review

RFQ History

- Oct 2012: Vacuum degradation during power outage. Impact uncertain.
- Jun 2013: RFQ retuned; transmission increased ~15%.

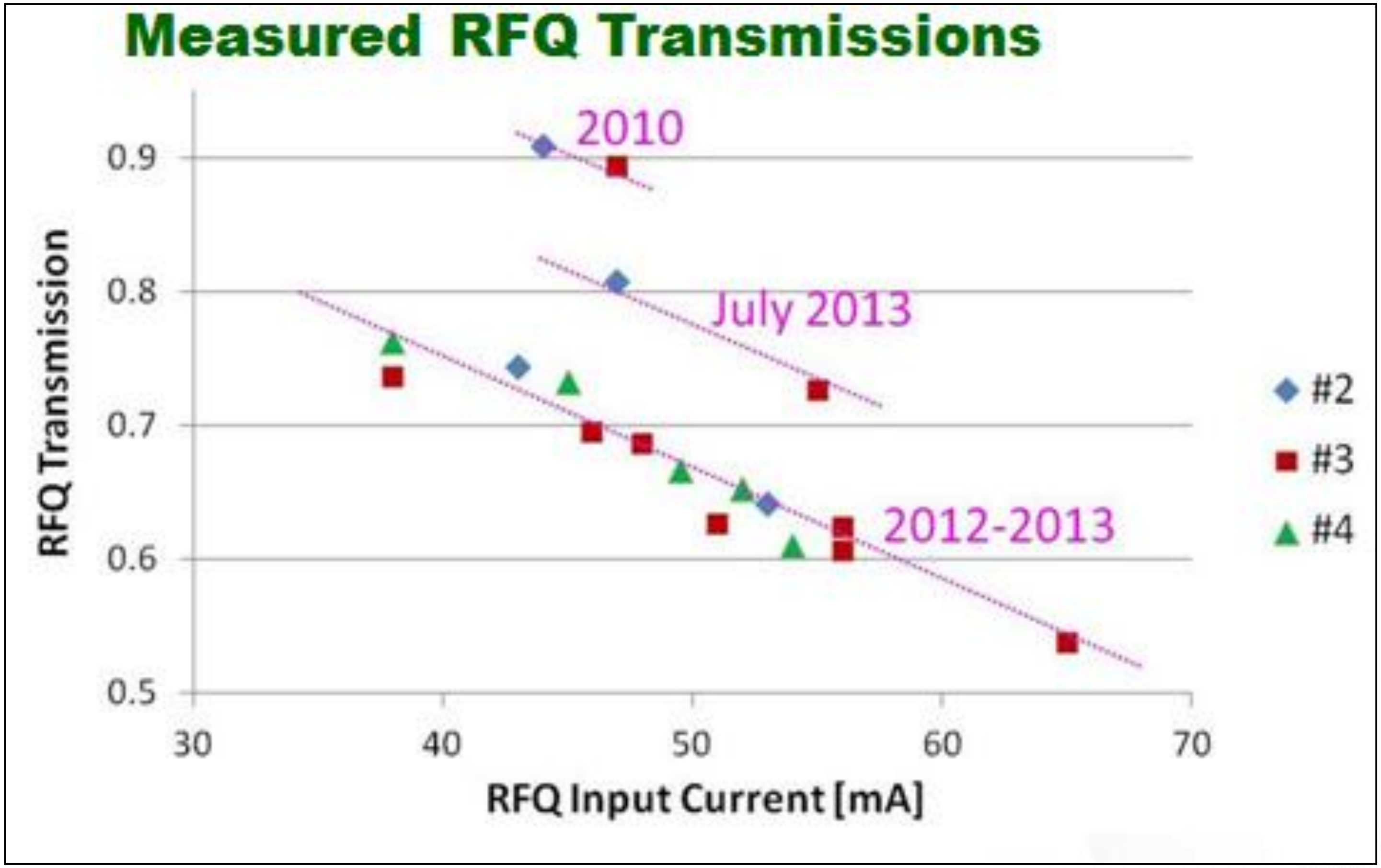
  Replaced B coupler due to flow restriction in the loop cooling circuit.
- Oct 2013: Replaced B coupler due to heating.
- Jan 2014: Replaced A coupler due to heating.

  The RFQ performance was adequate for sustained 1.3-1.4 MW beam power on target through Jun 2014.
- Jul 2014: RFQ accidently vented and exposed to water vapor.
- Aug 2014: RFQ accidently vented and exposed to water vapor *again*.

  ➔ RFQ performance degraded as result of these events.
- Oct 2014: Removed and inspected B coupler.

  No damage observed ➔ reinstalled coupler.

RFQ Retune in June 2013 improved transmission by ~15%



Courtesy of M. Stockli

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Future Plans for the Production RFQ

- Apr 2015: Plan to replace B coupler with a freshly conditioned spare.

  Plan to install X-Ray view ports.

  Plan to replace at least one field probe.

- Later: Plan to install a vacuum gate valve in the beamline between the LEBT and the RFQ.

  - The original valve was removed long ago due to reliability problems.

  - Experience has shown that a functioning gate valve is essential.

- Ongoing: Ensure adequate spares to meet neutron production goals.

  - RF couplers and field probes

- Eventual: Remove the production RFQ from the Front-End and reinstall in the Integrated Test Stand Facility.

RFQ Couplers Status

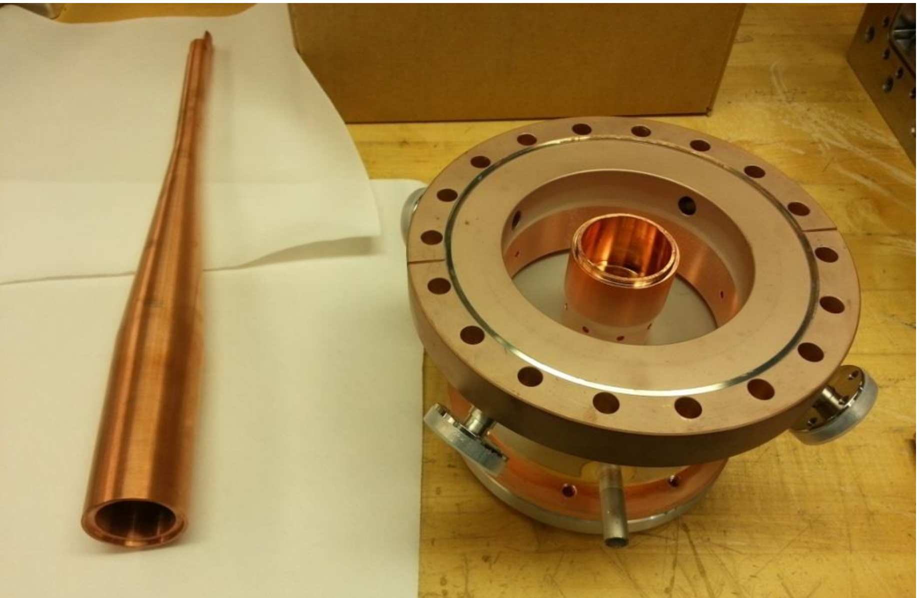
- One new spare has been RF conditioned and is ready for installation
  - Installation on production RFQ planned for April 13, 2015
- Two reconditioned spares have been used on the spare RFQ
  - They performed reliably during the spare RFQ acceptance testing in August, 2014
- Three spares have been ordered from a US vendor (CPI)
  - Delivery has been delayed due to technical challenges
- Four spares have been ordered to a Japanese manufacturer (Toshiba)
  - Delivery planned for end of May, 2015
  - Toshiba produced all of the RF couplers presently used in the superconducting linac and RFQ
- Two couplers are being constructed in house using spare ceramic windows
- Four outer conductors are available

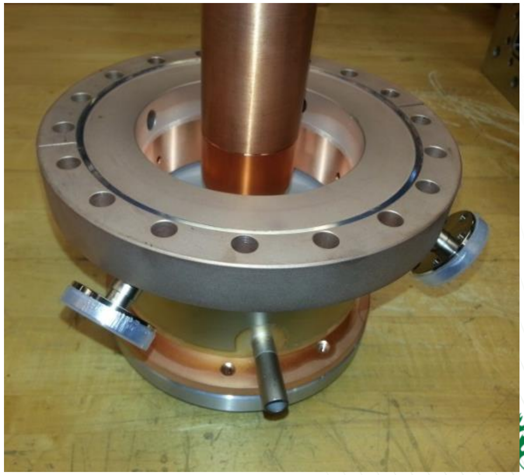
Courtesy of Y. Kang

Fabrication of two additional RFQ Couplers

Courtesy of Y. Kang

- The coupler inner conductor assembly has been built as a single structure at the manufacturer.
- Two coupler inner conductors have been built by joining the antennas onto the ceramic windows
  - Two ceramic windows manufactured as prototypes have been available (on the shelf at SNS)
  - The antennas for the coupling loop have been separately manufactured
  - Joining Copper parts has been performed successfully for the two assemblies
  - Vacuum leak check has been performed successfully
  - High power RF conditioning is to be performed



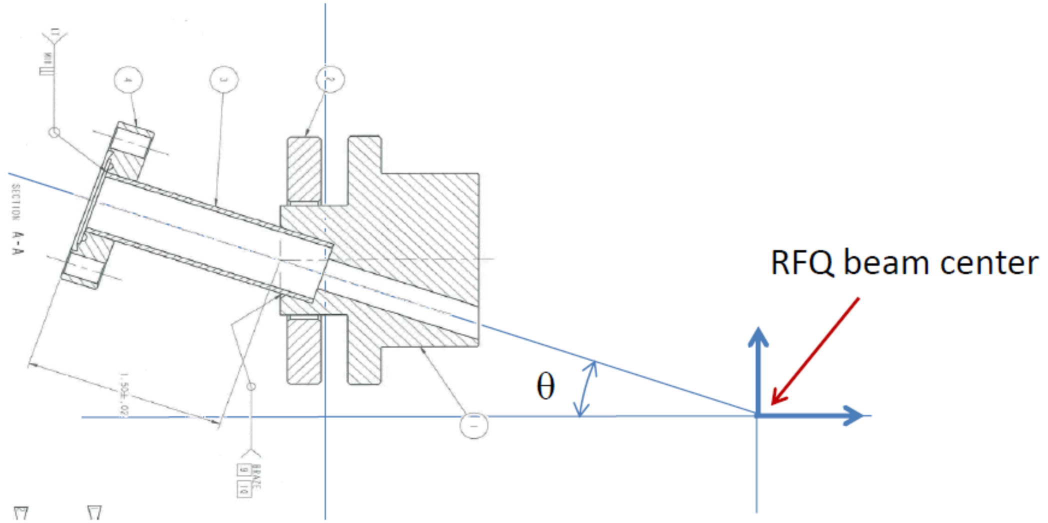


RFQ Coupler Outer Conductors (on the shelf)

Courtesy of Y. Kang

X-Ray View Ports to be Installed for Independent Measurement of Vane Voltage

View Port Adapter in Coupler Ports



- Quantity: 5 ---- One view port on each RFQ section + 1 spare
- View ports to be installed in unused coupler ports one on each of four RFQ sections
- A hole is directed to see the beam axis (0.25" diameter hole is shown)
- 1.0" long Copper blank tuners with tuner retaining disk modified
- Copper slug + S-S CF flange

Courtesy of Y. Kang

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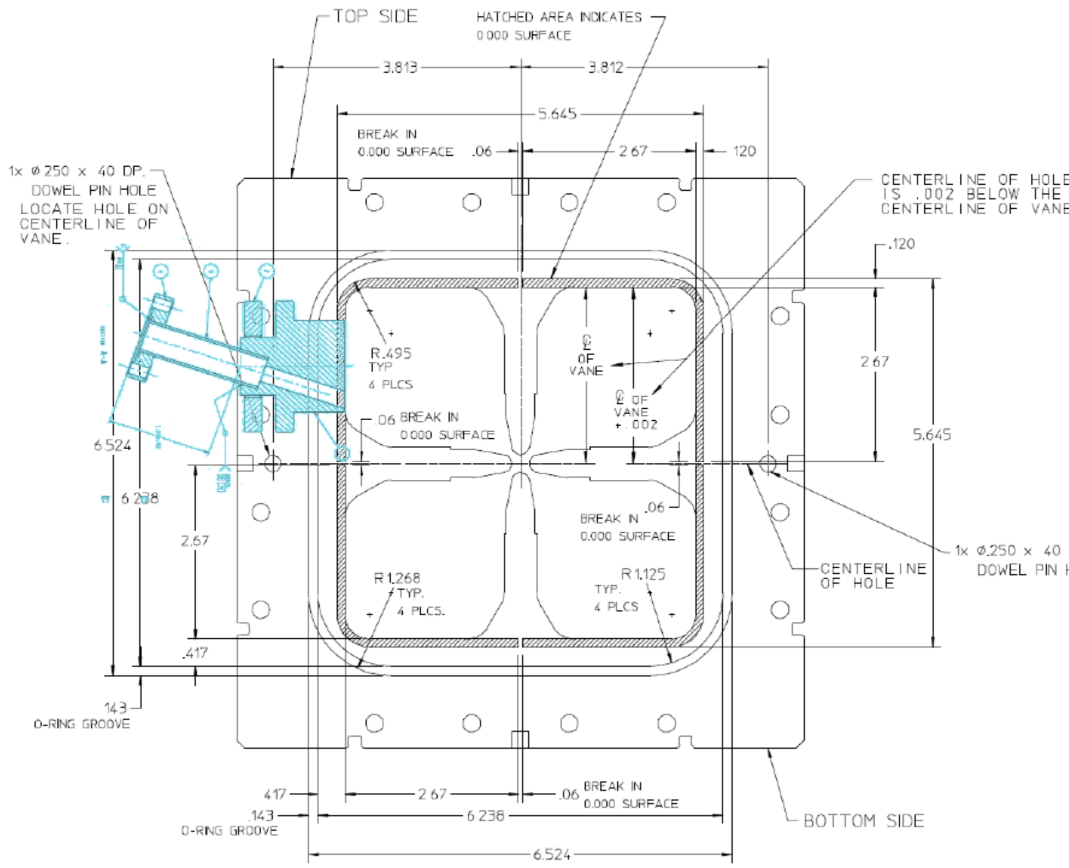
Cross Section of RFQ + View Port

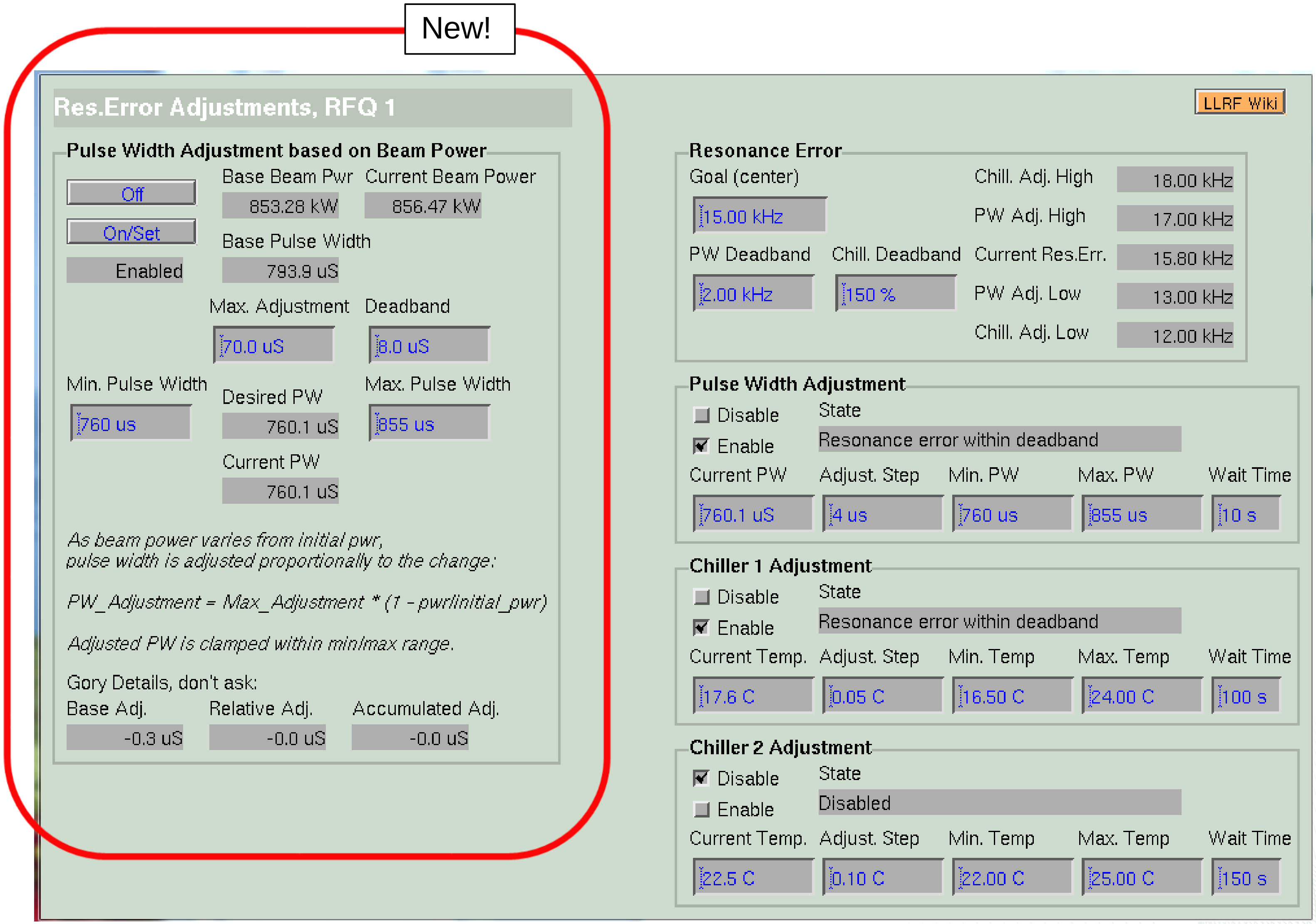


Courtesy of Y. Kang

New Field Probes have been developed and procured for RFQ and MEBT rebuncher cavities

Courtesy of Y. Kang

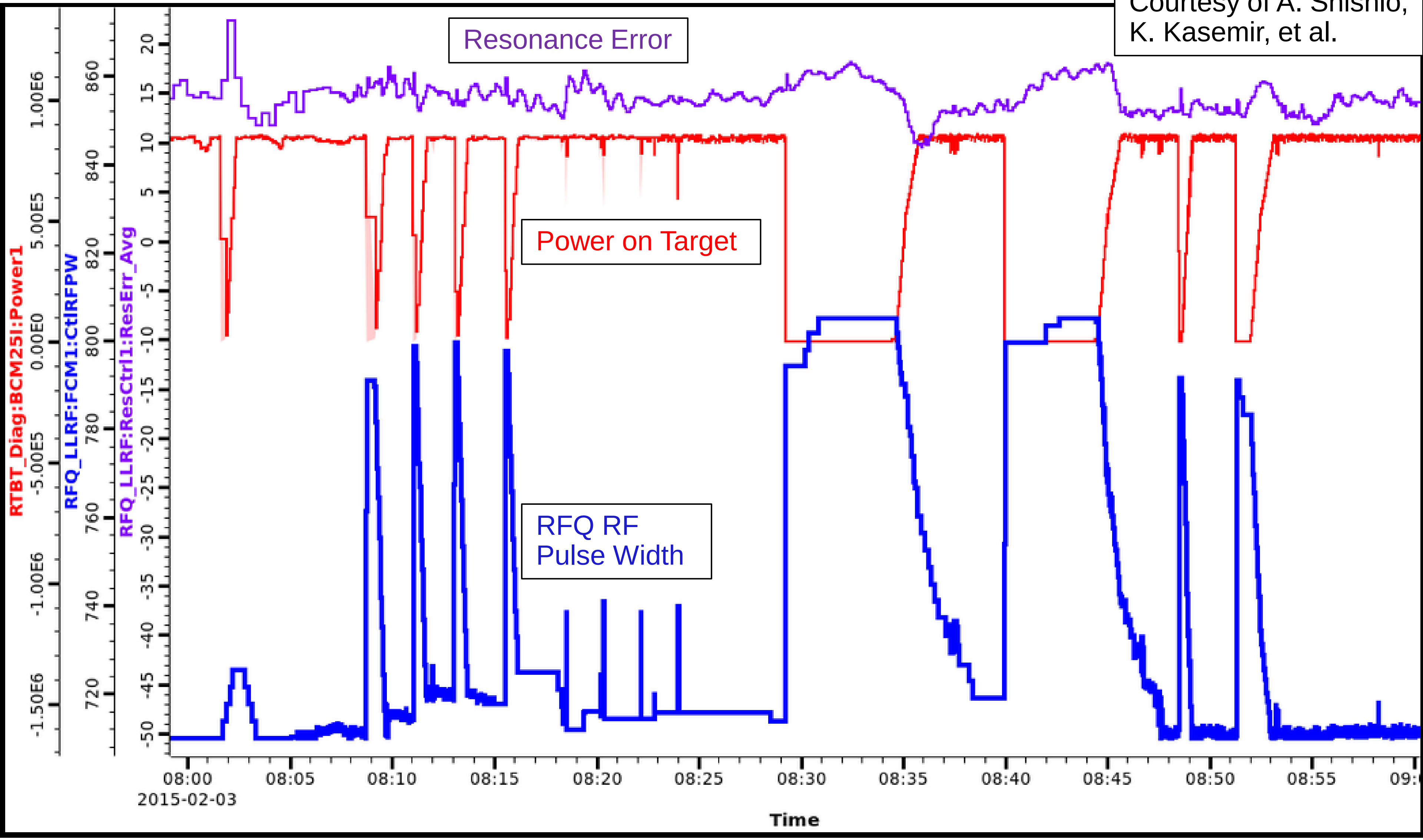
RFQ Keeper went live in Feb 2015



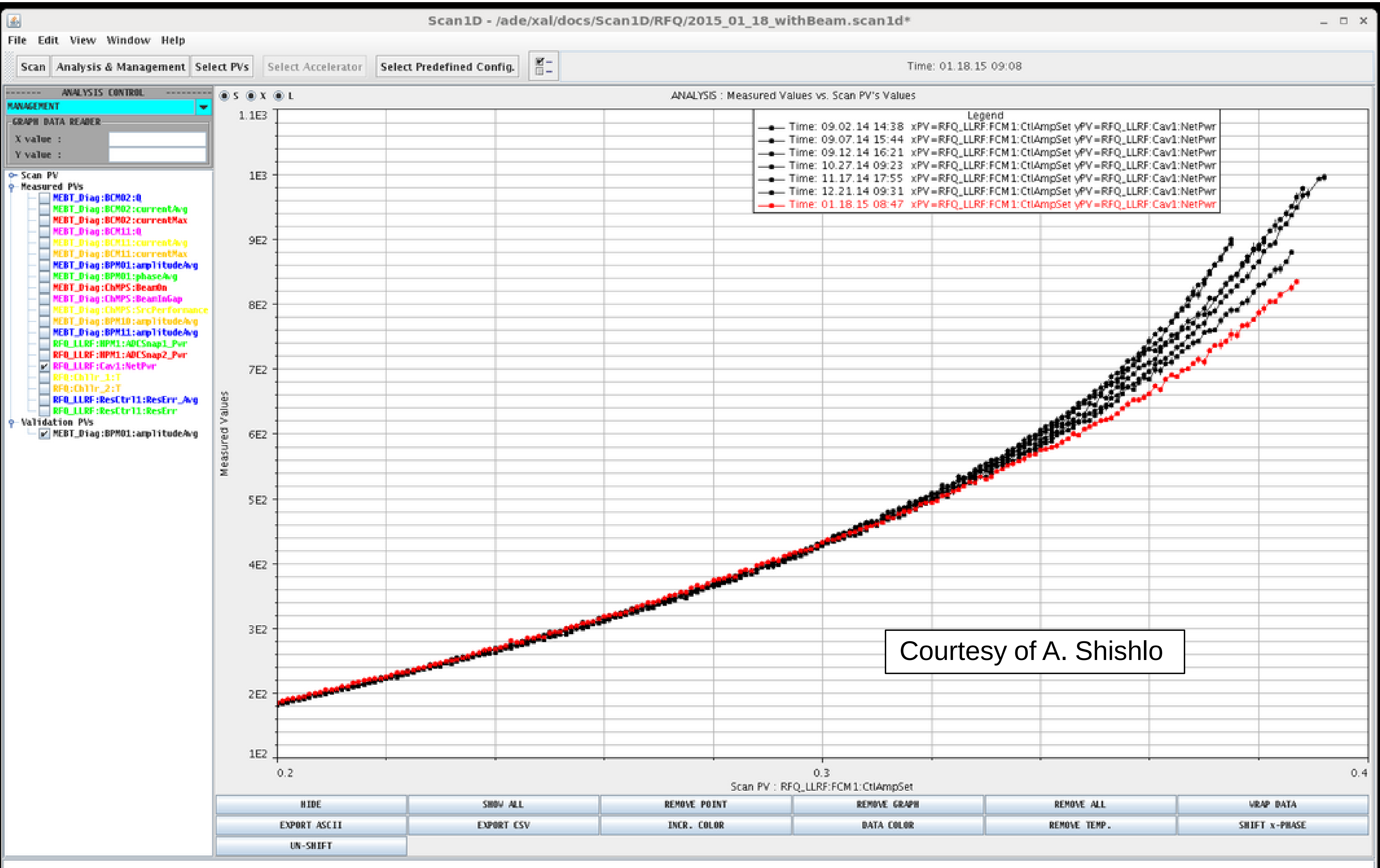
Courtesy of A. Shishlo, K. Kasemir, et al.

RFQ Keeper modulates RF pulse width to maintain steady heat load during beam on/off transitions

Courtesy of A. Shishlo, K. Kasemir, et al.



RF Net Power vs. RFQ amplitude setpoint improving since last summer



Power vs RFQ Amp. The red is the latest data. It shows a big improvement.

Spare RFQ Received 13 Nov 2013

RF Tuning of Assembly

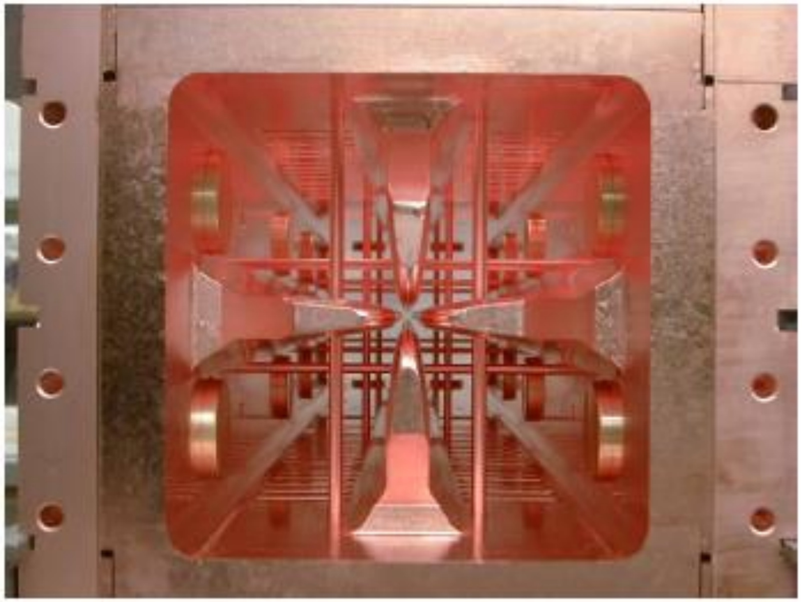
Refer to Yoon Kang's presentation from previous AAC meeting for more background information.

Overview

- Retuning of RFQ performed for sudden changes in frequency and field distribution
  - Resonant frequency shifted by -400 ~~Hz~~ kHz and the field distribution changed by ±15% (9/23/2003)
  - Resonant frequency shifted again by -230 kHz and the field distribution changed (1/26/2009)
- Started writing equipment specification (7/2009)
- Equipment specification was prepared and delivered to potential vendors (10/2009)
- Supplier selected based on the track record, capability, and pricing (4/2010)
- Design completed with reviews and manufacturing started (3/2011)
- Maintain the beam dynamics of the original SNS RFQ design
  - Vane tip modulation data was supplied as the core design requirement
  - Supplier was asked to have structural design and prototyping
- Construct a robust structure for direct replacement spare with minimal modifications on the SNS linac
  - RF frequency, power, cooling, vacuum, and physical dimensions to be satisfied

Courtesy of Y. Kang

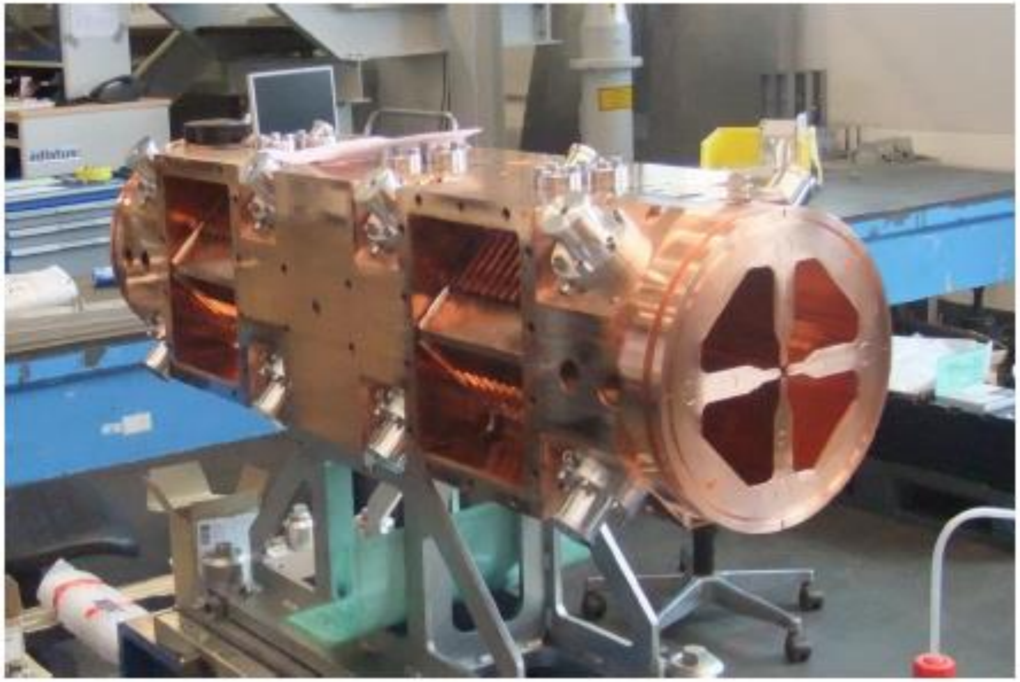
Comparison of RFQ
(Existing RFQ)

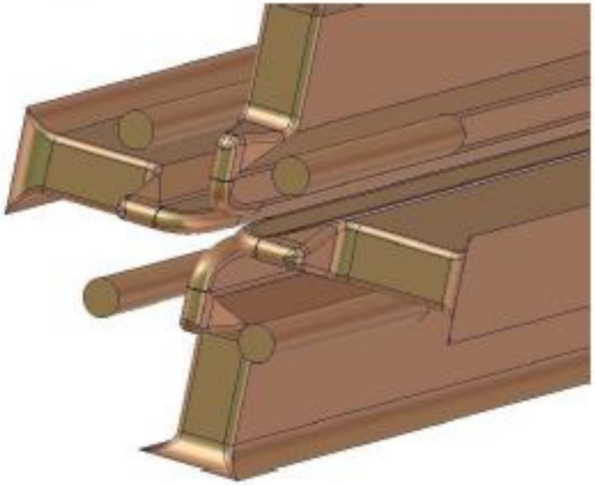


- 3.7 m length in 4 sections
- Two layer copper structure with GlidCop exoskeleton for strength
  - Strength needed to use minimally supporting kinematic structure design
- 4 vane type with PISL for dipole stabilizing
- 80 slug tuners (1.4" dia each) and 46 field probes
- 2 input couplers (originally 8)

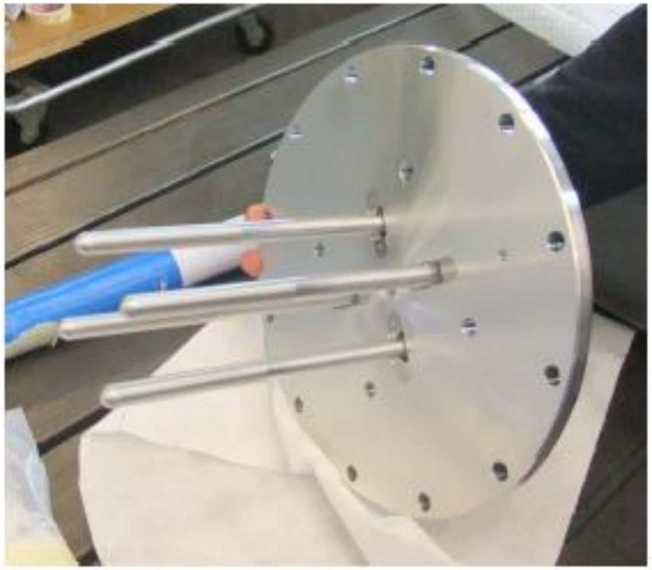
Courtesy of Y. Kang

Comparison of RFQ
(New spare RFQ)



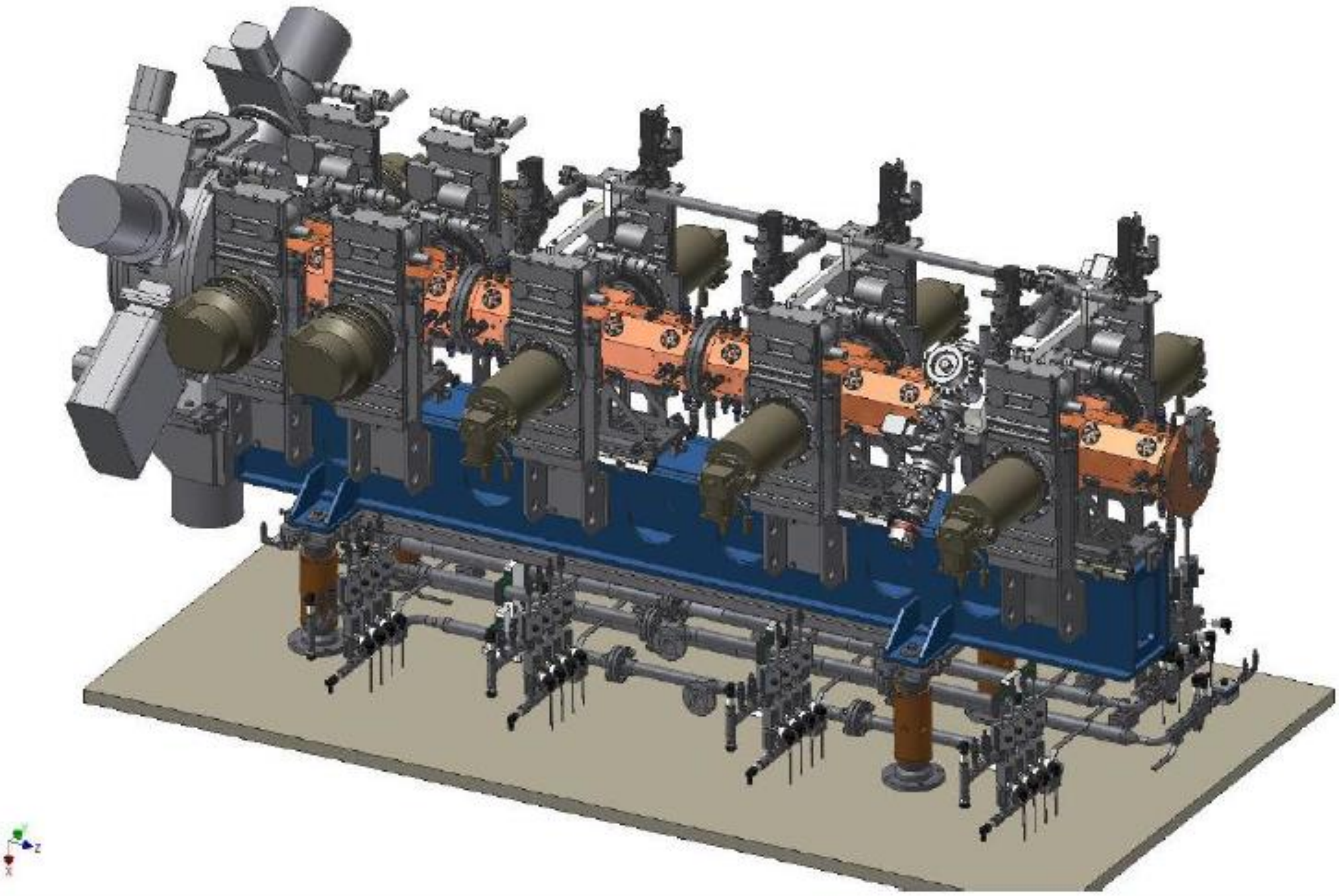


- 3.7 m length in 4 sections
- 4 vane type with end wall rods for dipole mode stabilizing
- Robust uniformly supported structure
- 64 slug tuners (1.4” dia each) and 48 field probes
- 2 coaxial input couplers



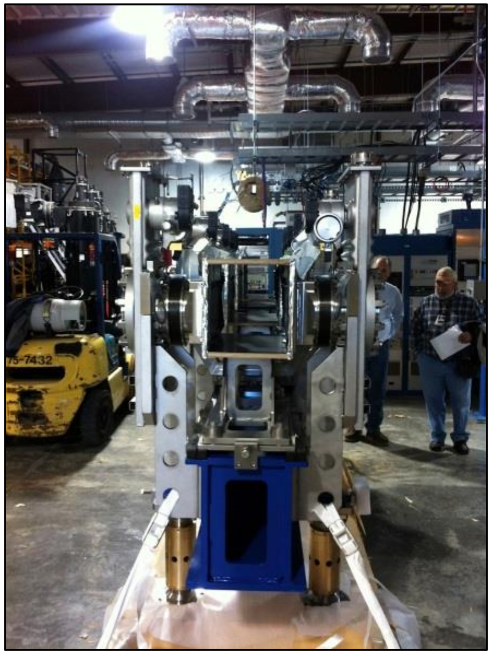
Courtesy of Y. Kang

Final Assembly

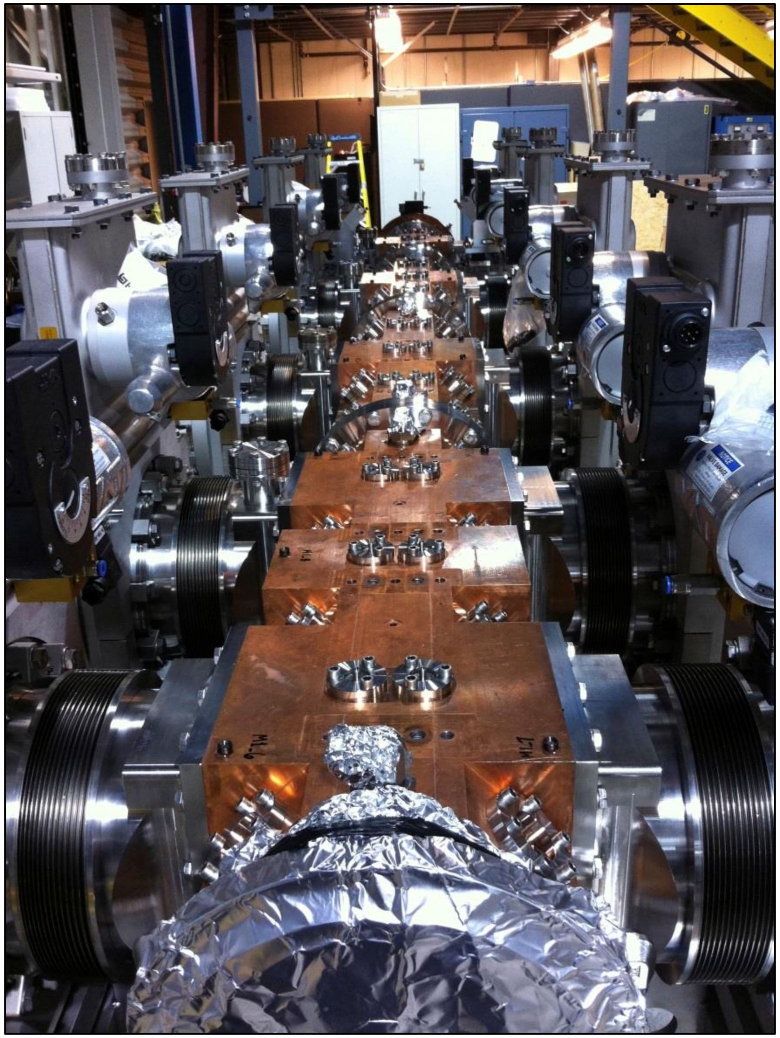


Courtesy of Y. Kang,
T. Roseberry, et al.

Unpacked 14 Nov 2013

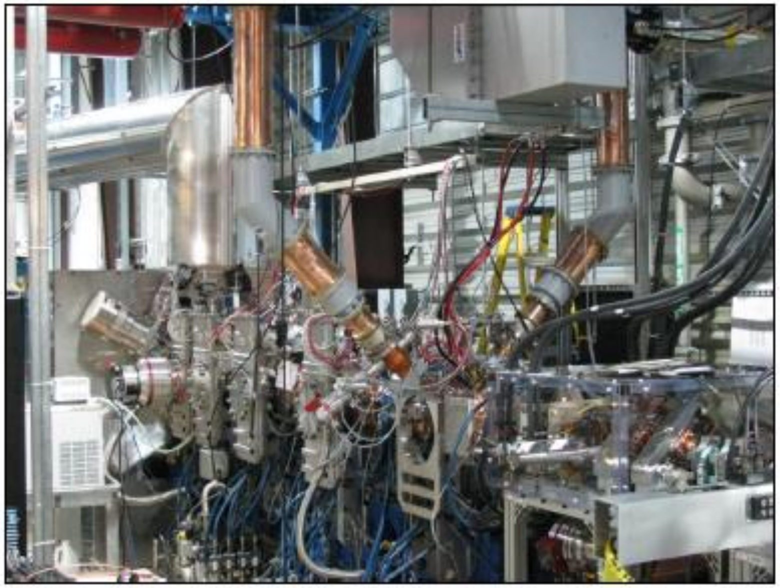


Segment Mounting Complete 21 Nov 2013



Scope: High-Power RF Testing of the Spare RFQ

- Scope of this review is high-power RF testing only (no beam).
- The RFQ will be tested as a stand-alone unit.
  - Adjacent beamline components are not included in this review or in the planned testing.
- Successful acceptance test at SNS will complete the procurement process and sets the stage for further development of the ITSF.



Spare RFQ – view from downstream
Ion source at left, MEBT at right

Spare RFQ – side view
Ion source at left, MEBT at right

Operational Readiness Review Charge and Agenda

Charge

1. Assess the readiness of the technical systems required to support high-power RF testing of the spare RFQ.
   a) Have the systems been designed, constructed, and tested adequately to ensure personnel safety and equipment protection?
   b) Is the level of integration between the subsystems sufficient?
2. Assess the plans for mitigation of ionizing and non-ionizing radiation hazards.
3. Assess the adequacy of the test plan.

4 Presentation name

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Agenda

1. Introduction – Mark Champion
2. Electrical System – Mark Middendorf
3. Water System – Jim Schubert
4. Vacuum System – Chris Stone
5. Control System – Derrick Williams
6. Timing System – Alan Justice
7. High-Power RF System – Mark Middendorf
8. Low-Level RF Control System – Mark Crofford
9. RFQ Structure and Test Plan – Yoon Kang
10. Discussion – All
11. Walk through – All

5 Presentation name

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Positive Outcome of ORR

- "The team is to be commended on the thorough installation work and preparation for the review. The team was engaged and responded to questions during the review."
- "The control of ionizing and non-ionizing radiation appears to be appropriate and commensurate with the hazard."
- "The technical systems appear to be ready for commissioning activities and both personnel and equipment protection concerns have been adequately addressed."
- 20 pre-start action items
- 14 post-start action items

RF Testing – Timeline and Results

- Approval to begin granted May 30, 2014
  - Upon satisfactory completion of pre-start action items
- Commenced RF conditioning Jun 02, 2014
  - Test conducted according to a written test procedure
  - Began at low duty factor and low RF power level
  - RF and X-ray survey performed at numerous “hold points”
  - Gradually increased RF power and duty factor as allowed by vacuum levels ➔ much conditioning and outgassing
  - No unattended operation due to lack of appropriate fire protection system
- Conditioning completed Aug 01, 2014
  - 60 Hz, 925 us, 550 kW

Status Today and Path Forward

- The remainder of the vacuum pumps have been installed; checkout of vacuum controls, read backs, and interlocks in progress.
- Installation and testing of other ITSF components in progress (see Aleksandrov's presentation)
- The fire detection system has been completed
  - unattended overnight operation will be possible in future
- Plan to resume RF operation of the RFQ within the next month
  - some RF conditioning is anticipated
- Ready to support beam testing upon completion of RF conditioning
- Plan for RFQ replacement in Front-End is developing
  - Project manager selected; regular meetings with shareholders.
  - Definition of project scope and measures of success in progress.
  - Planning for replacement in summer 2016 (dependent on IRP schedule)

Summary

- The production RFQ continues to support neutron production goals despite performance challenges.
- The lack of a gate valve between the LEBT and RFQ is a serious threat to RFQ performance sustainability.
- Maintenance of ready RF coupler spares is essential to sustained RFQ performance.
- The spare RFQ passed initial non-beam acceptance testing in summer 2014.
- Successful beam testing is a prerequisite to RFQ replacement.
- Planning for the RFQ replacement is underway.
- RFQ replacement will be a major challenge.
  - We have to get it right the first time!