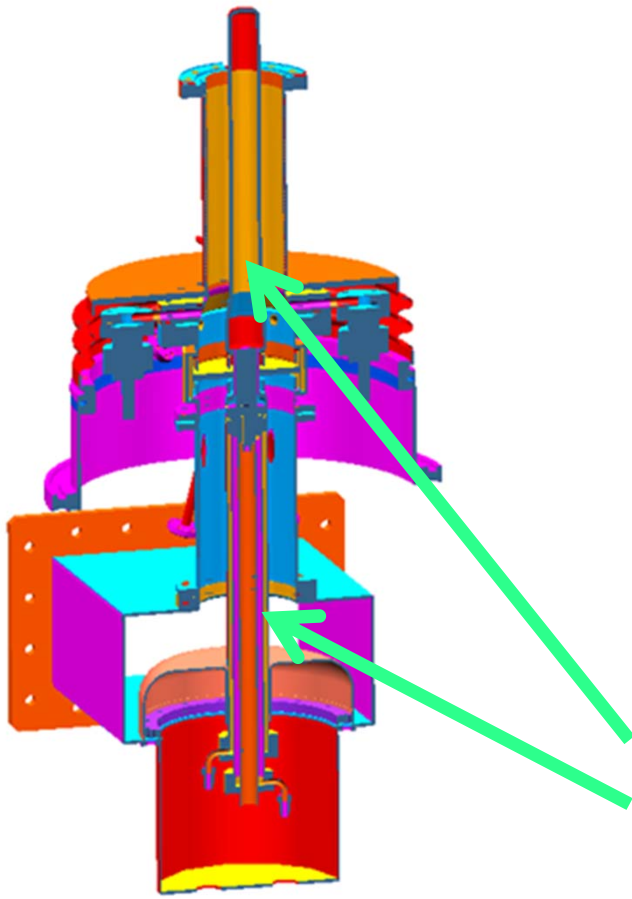
Cleaning Methods of SRF Power Couplers

Mircea Stirbet

Principles

- The FPC cleaning should start at the design stage
- Continue during component manufacture, storage and transportation to the final destination.
-The FPC components should be manipulated and cleaned using procedures specific for UHV components to be clean-room assembled on superconducting cavities
- FPC's component transfer to the assembly clean room. (Sash, glove box water basket)
- Cleaning and surface control during preparation for and RF power qualification (RF conditioning and power tests on room temperature test stand)
- Waveguide gas barrier on the air side of the FPC during RF operation.
- Cleaning with RF during cavity qualification tests
- Cleaning the external surfaces of FPCs for admission in clean room after RF qualification.
- Airside RF contact preservation after FPC assemble on cavity
- Cleaning with RF after a long period of machine shut down (if the FPCs are not exposed to RF for a long period of time – months)

FPCs for the SNS Project

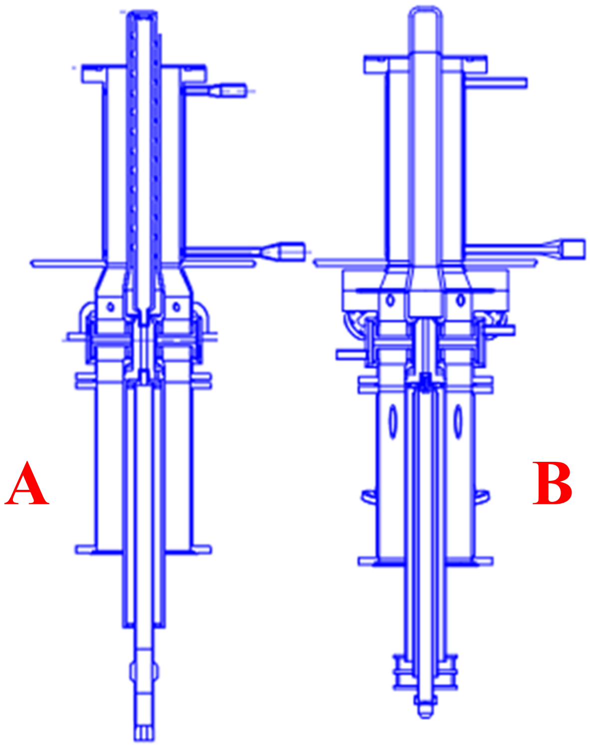


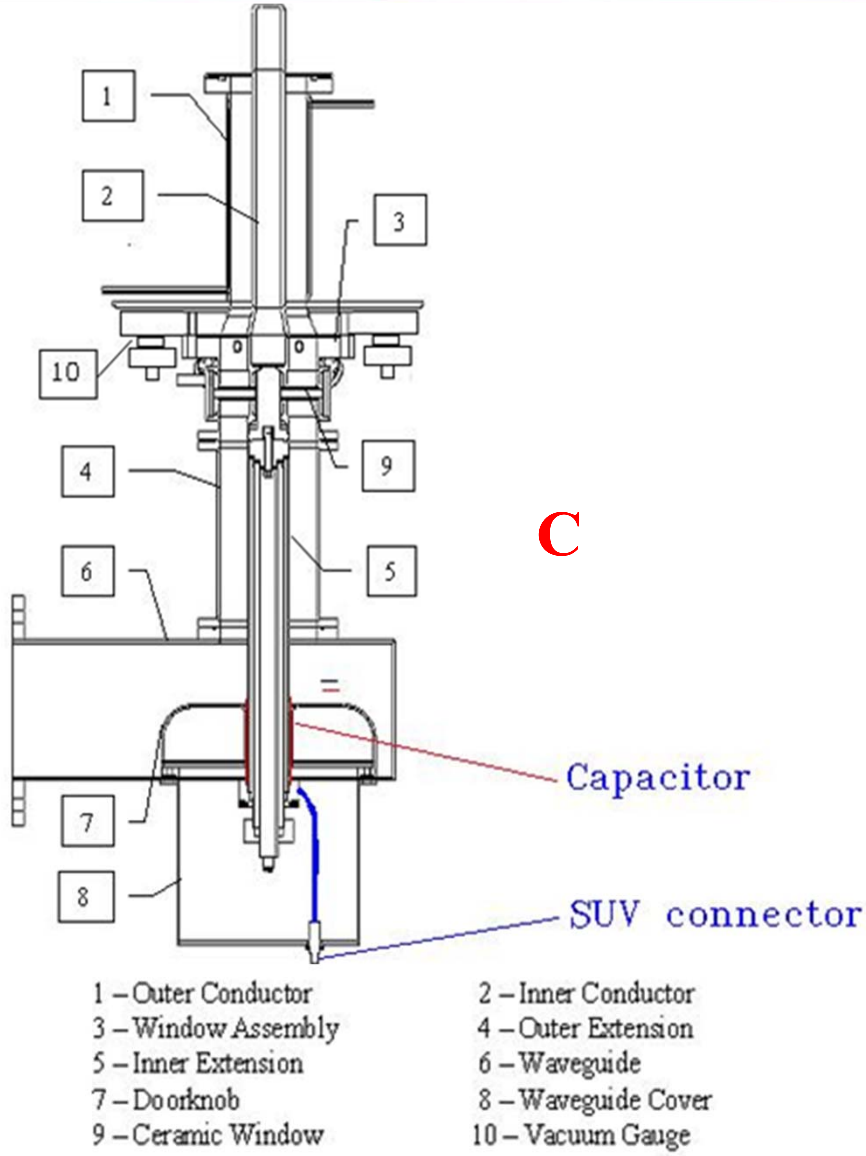
- 50 Ω coaxial line
- VSWR <1.1 at 805 MHz
- required Q_{ext} Range = 5 x 10^5 ± 20%
- power ratings: 550 kW at 1.3 msec 60 Hz (for 1 GeV)
- operating pressure: < 5 10^{-9} mbar
- ± 2.5 kV Bias Voltage
- He gas cooling on the outer conductor (0.3 g/s, 3 atm, inlet 5K exit 300 K)
- Water cooling on inner conductor extension (300 K)
- Possibility to water cool the ceramic border (300 K)

Two major components:

- Vacuum side of the FPC
- Air side of the PFC

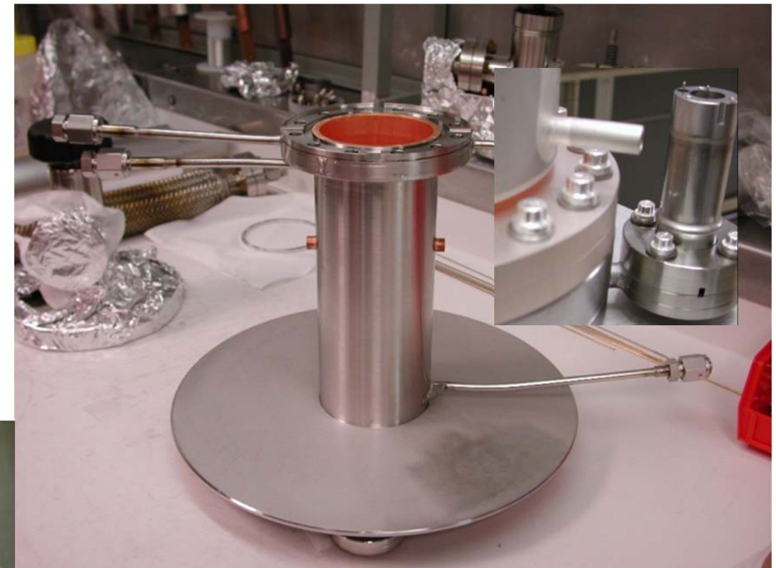
FPC for SNS at design stage





A- FPC initial concept welded outer conductor
impact on cleaning!!!
B - FPC prototype independent outer conductor
C - FPC final concept

SNS FPC – vacuum-side components

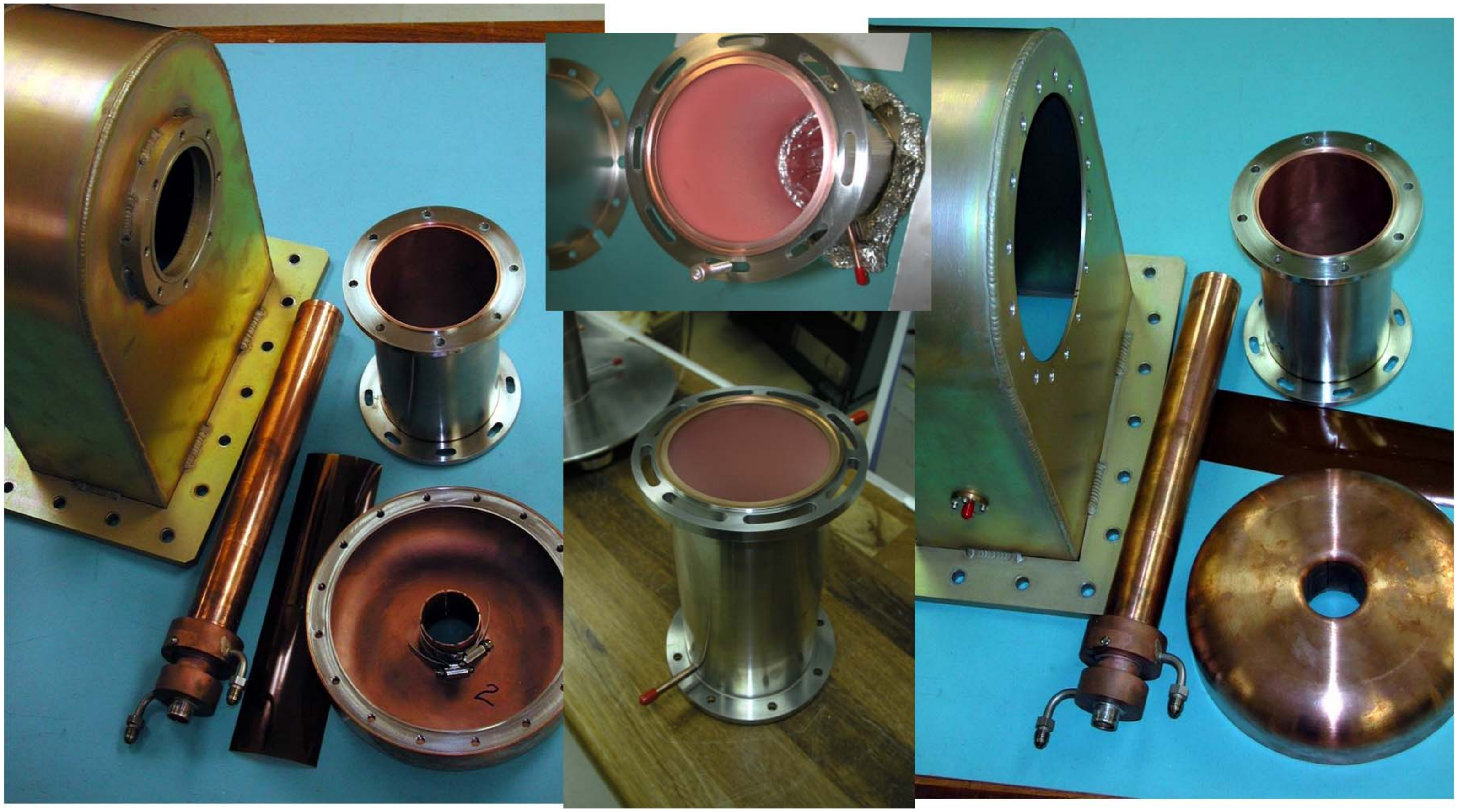


Outer conductor with two ports for vacuum gauges, He gas cooling channels, copper blocks for heater (ice-ball) and temperature

Window assemble and instrumentation: electron pick up antenna and sapphire window for arc detector

Plenty of bolts, and different gaskets

SNS FPC – air-side components



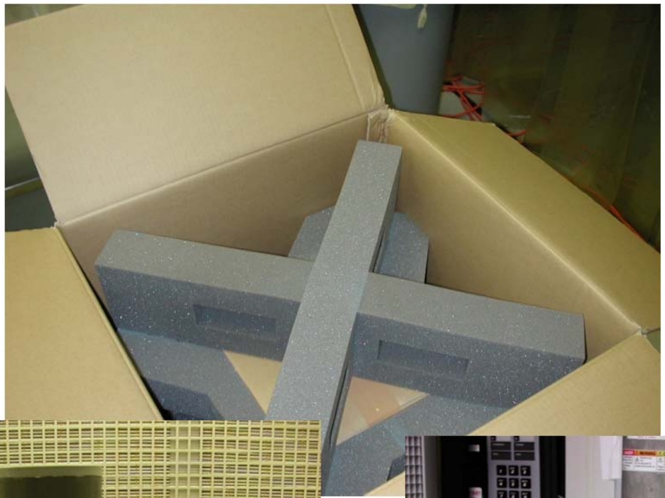
Waveguide for doorknob, outer conductor extension, inner conductor extension and Kapton foil for capacitor. Also on the air side optical view port for arc detector and protection cap for capacitor (“fez”).

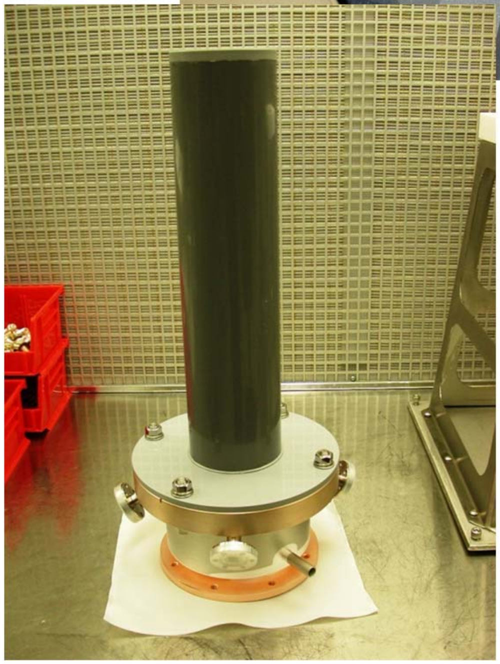
Operations done with SNS FPC – window assembly

- Visual inspection – controlled manipulation - gloves
- CMM measurements-controlled manipulation - gloves
- Copper plating
- Vacuum sealing surfaces, eventual mechanical **cleaning** of scratches
- Vacuum instrumentation ports
- **Cleaning** (degreasing, cleaning UHV) for:

a) Vacuum leak check of the window assembly
b) FPC assemble in the clean room

Window transport and storage





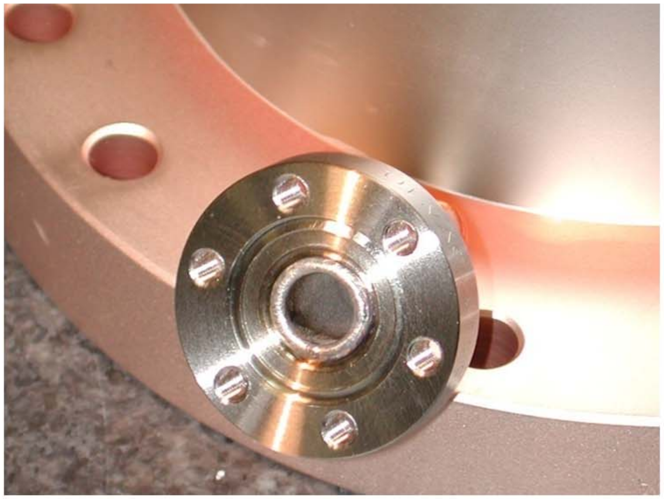
Initial with **plastic** protection cup ----> metallic cup

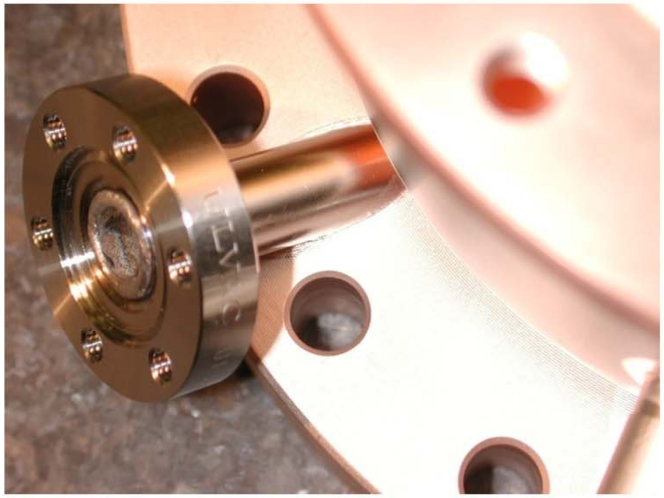
Operations done with SNS FPC – outer conductor

- Visual inspection – controlled manipulation - gloves
- CMM measurements-controlled manipulation - gloves
- Copper plating
- Vacuum sealing surfaces, eventual mechanical **cleaning** of scratches
- Vacuum instrumentation ports
- HWP rinsing for copper adherence – **also cleaning**
-Acetone **cleaning** of cooling channels
- **Cleaning** (degreasing, cleaning UHV) for:

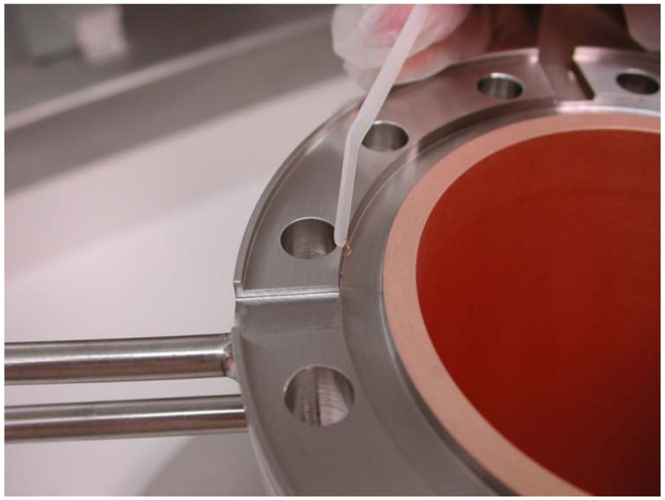
a) Firing under vacuum for blister test
b) Vacuum leak check of the outer conductor internal volume, He gas cooling channels.
c) FPC assemble in the clean room

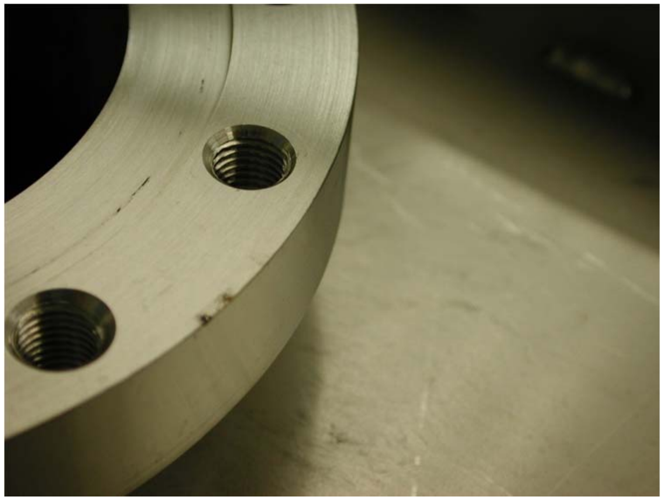
Initial issues on window side

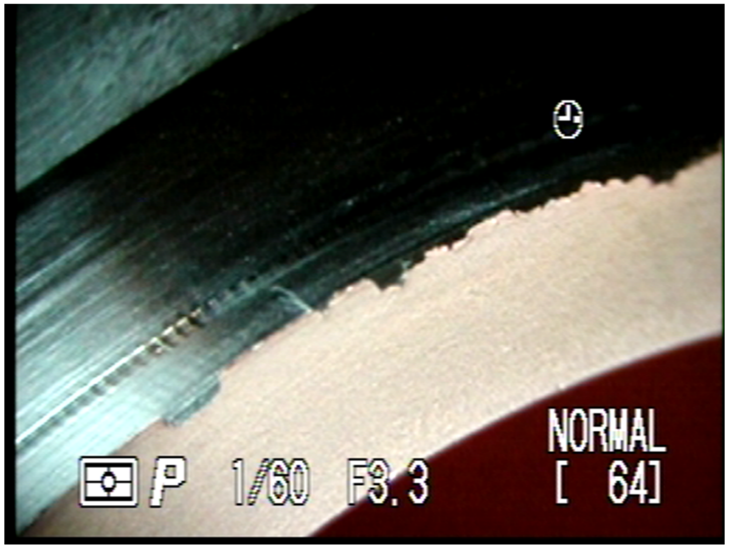


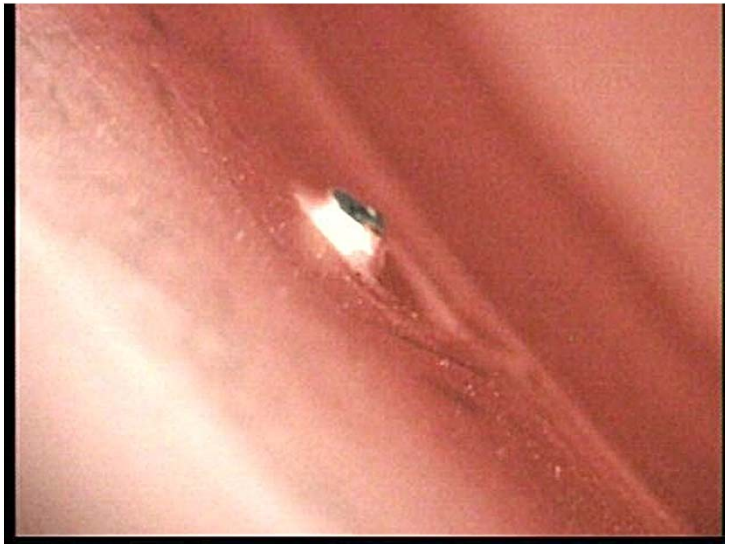


Mechanical cleaning

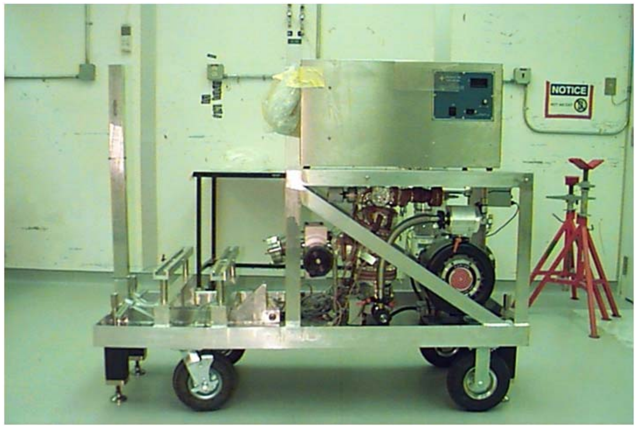


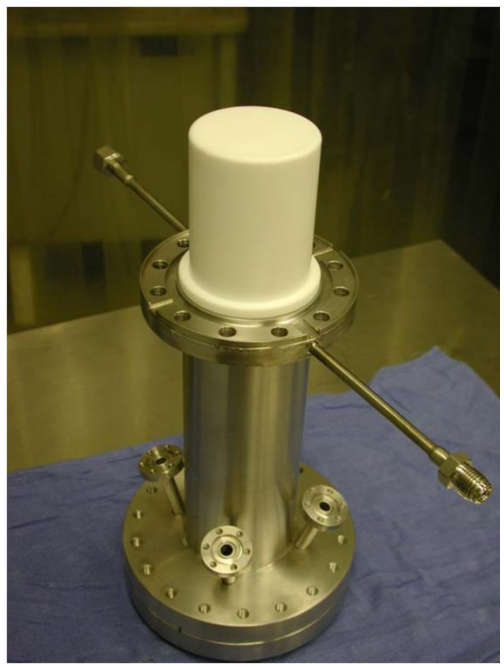


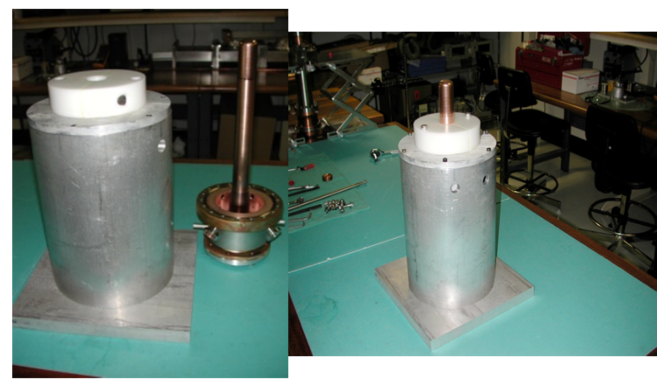




Dedicated tooling for FPC manipulation

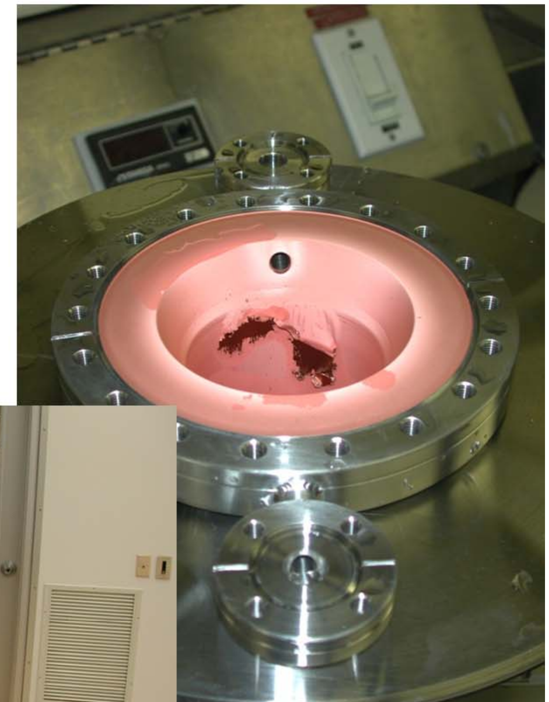




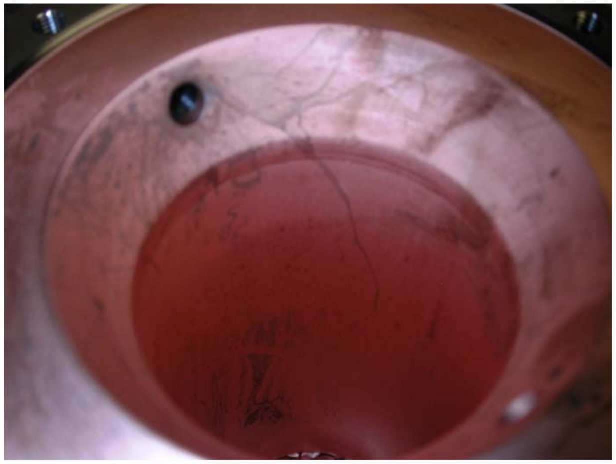


2π factor

SNS FPC degreasing UHV cleaning and HPR rinse



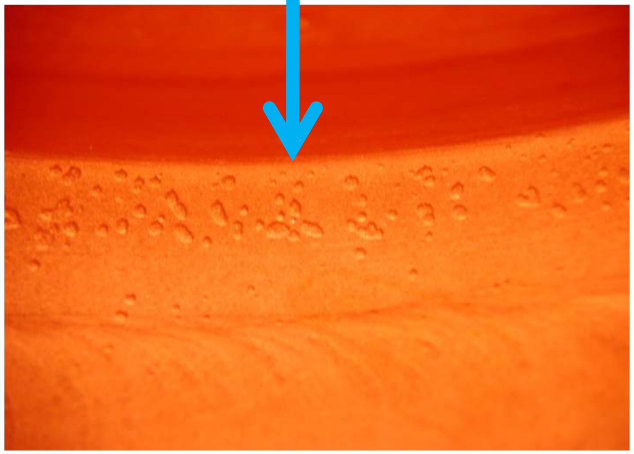
Outer conductor cleaning



As received from plating (no brighteners!)

Copper cleaned with micro-clean detergent

Copper plated with blisters after firing. Outer conductor sent back to be re-plated.



Firing under vacuum

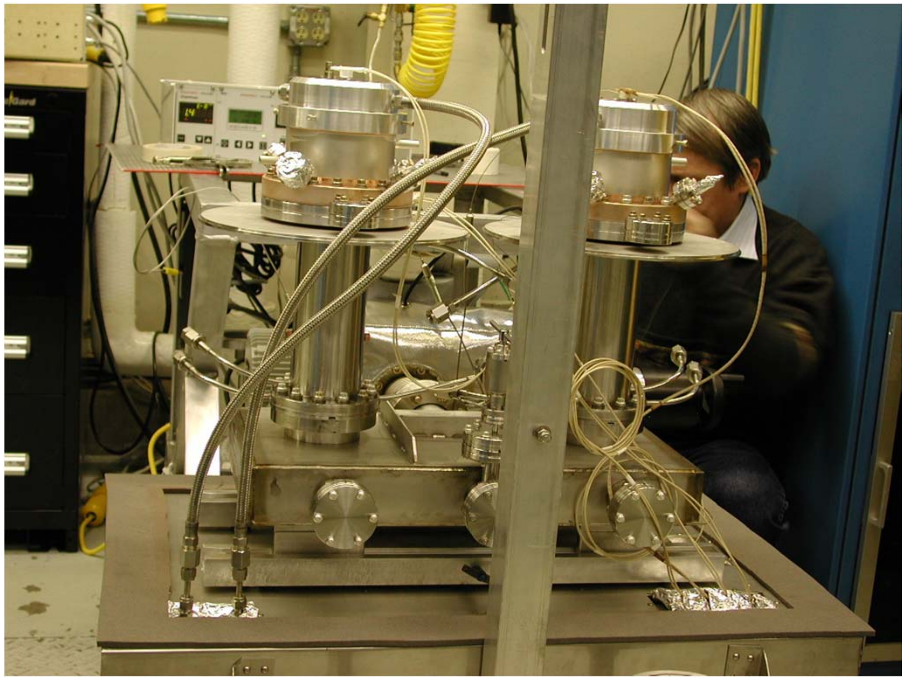
Cleaning the SNS FPC window assembly

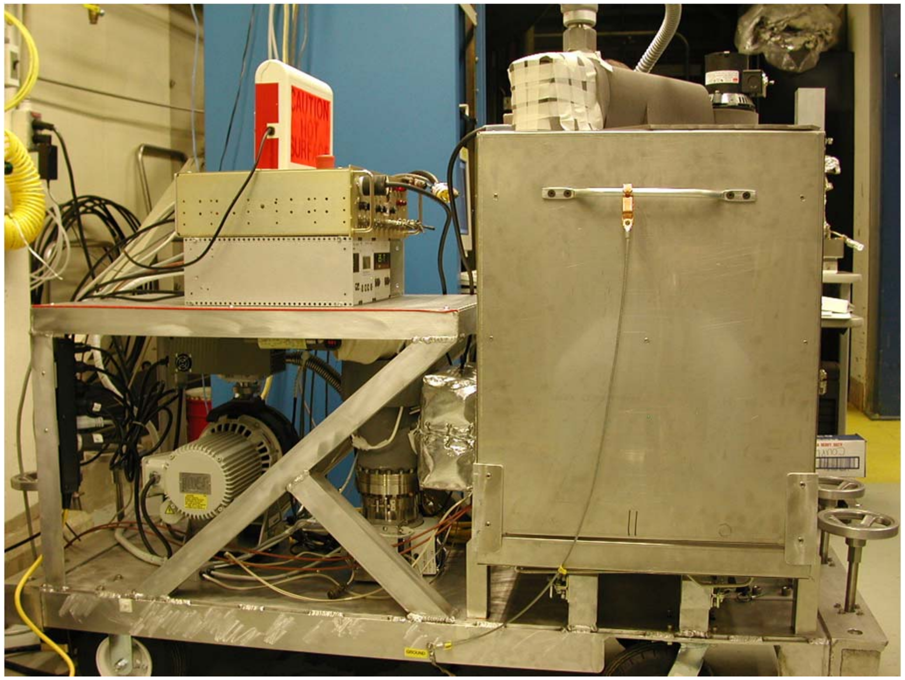
-Transport : plastic protections, metallic protection on the air side and air side of the window
-Tooling (plastic tube) for initial visual inspection (gloves during CMM)
- Instrumentation ports
- UHV cleaning for initial qualification (vacuum leak check)
- UHV cleaning for FPC clean room assemble on connecting waveguide for bake and RF qualification

Connecting waveguide and clean room FPC assemble

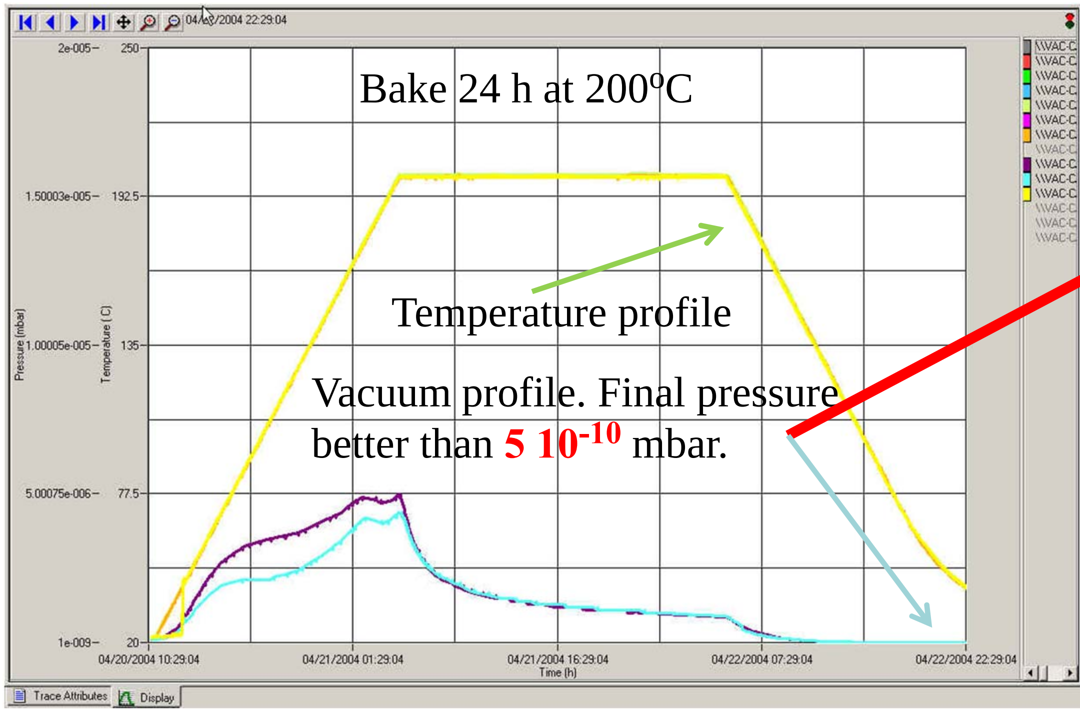
SNS FPCs during baking

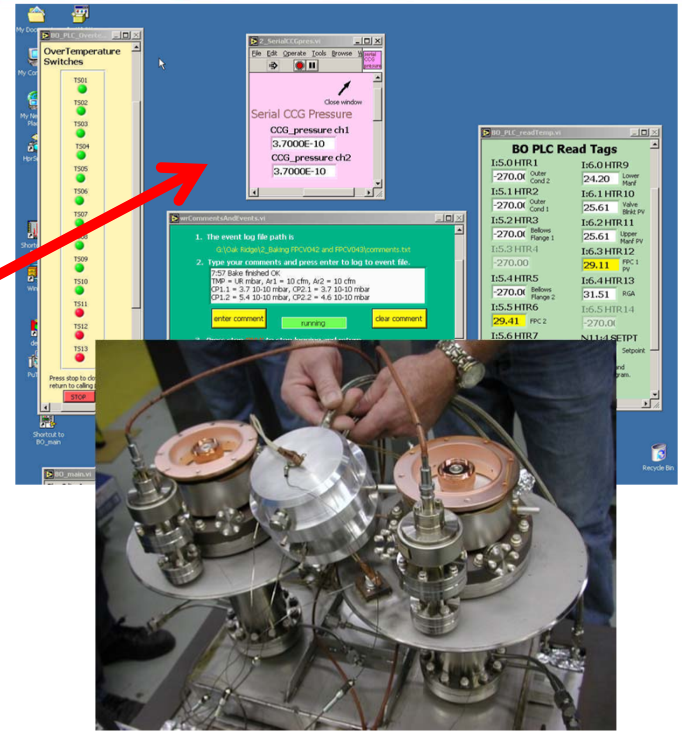
- Bake under vacuum: RGA information on gas “contaminants” and getting rid of H_2O molecules…**cleaning**!
- Protection of air-side RF contacts and RGA follow up during bake.
- Vacuum after bake conform with UHV requirements (usually was better than **5 10^{-10} mbar**).

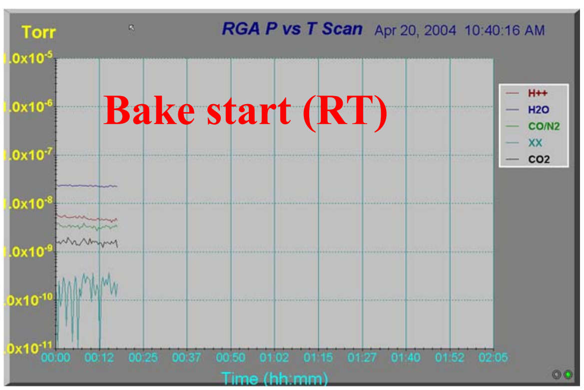


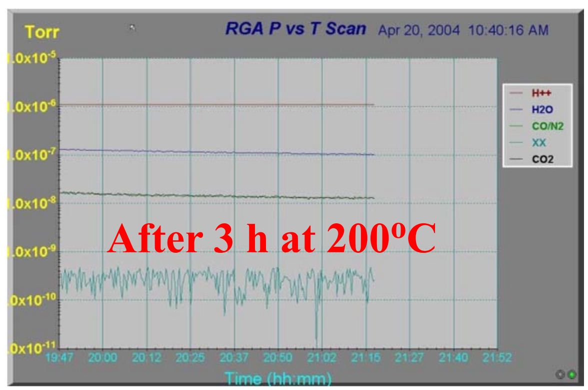


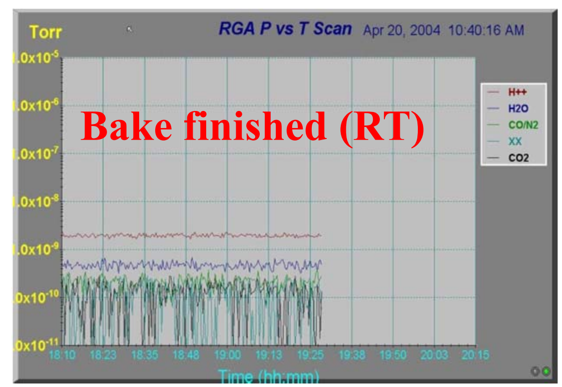
Typical bake temperature and vacuum profile for SNS FPCs











SNS FPCs RF qualification on room temperature test stand

Demonstrate RF power capabilities
Of each coupler before FPC assemble on cavity.

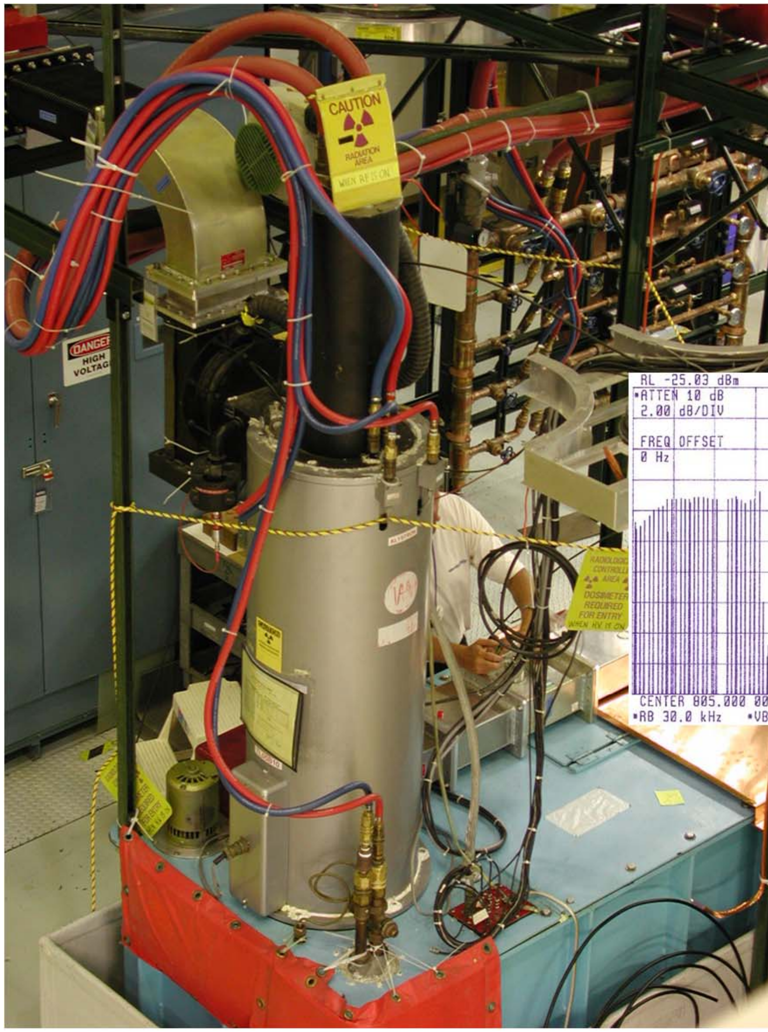
Check functionality of almost all instrumentation: vacuum gauges, electron pick up antenna, arc detectors, water flow, temperature sensors, DC bias.

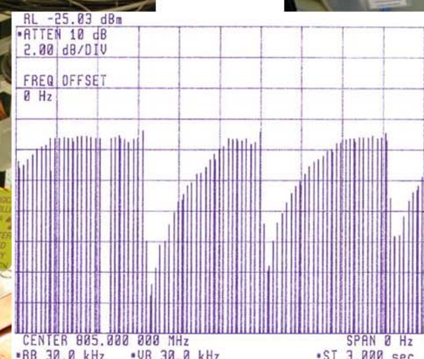
RF qualification is done after bake, started in TW mode with RF conditioning as function of vacuum followed by RF power tests and then finalized with RF tests in SW mode.

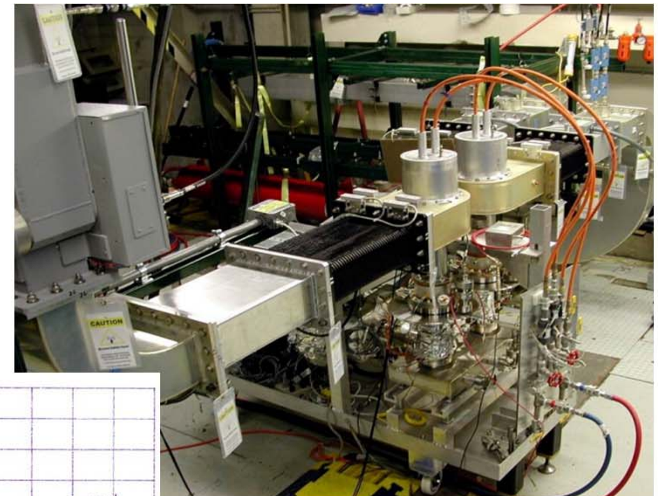
$5\ 10^{-7}$ mbar max vacuum allowed during RF conditioning

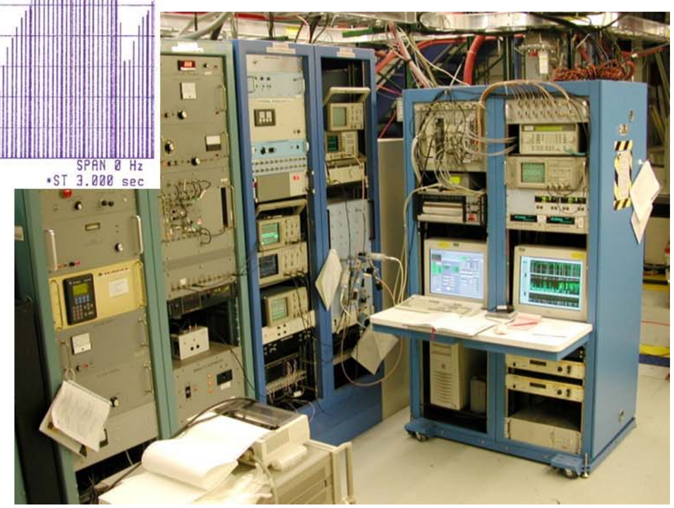
All 81 FPCs for SNS RF power qualified by summer of 2004 ! €€€

805 MHz 1 MW pulsed RF test stand at JLAB

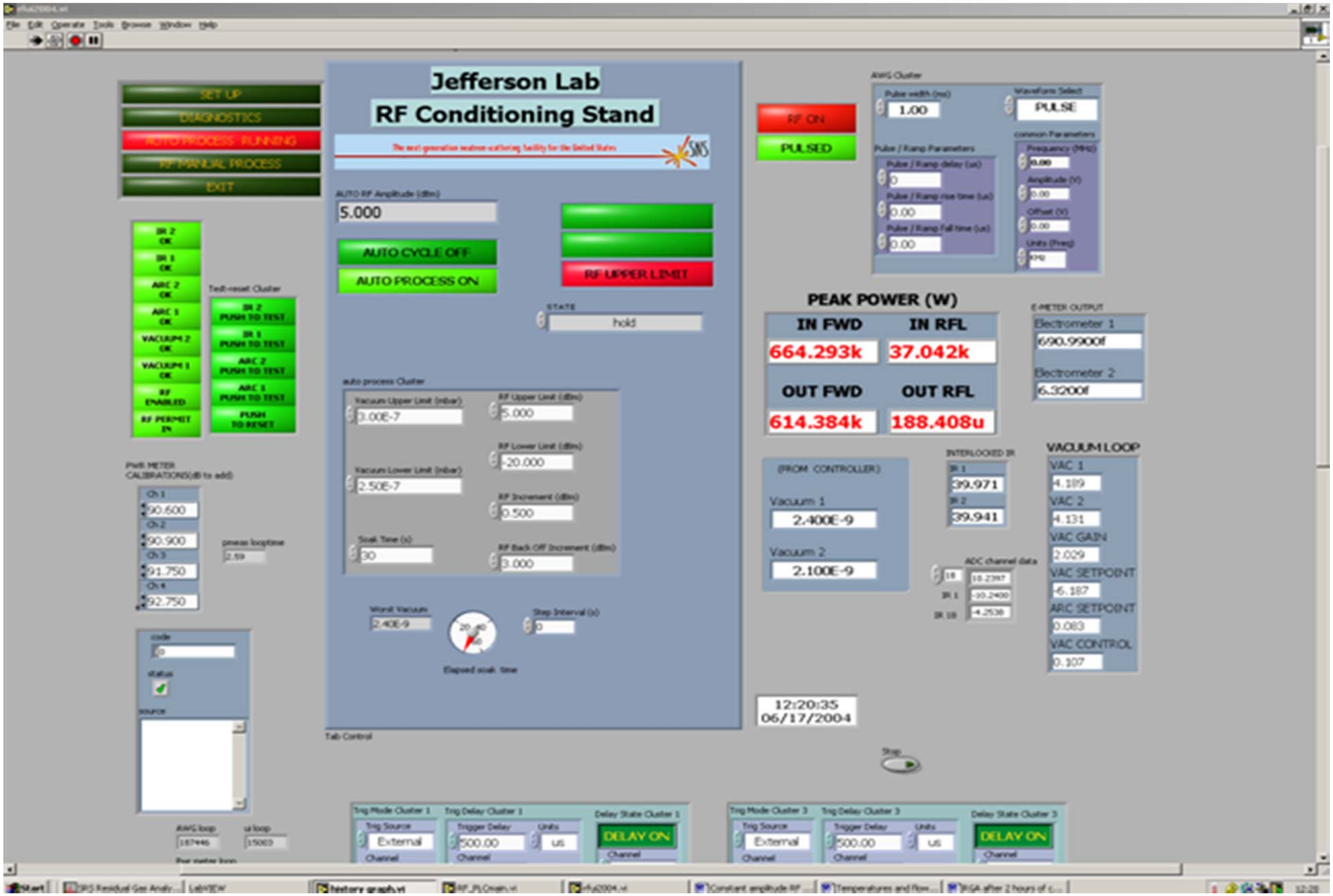




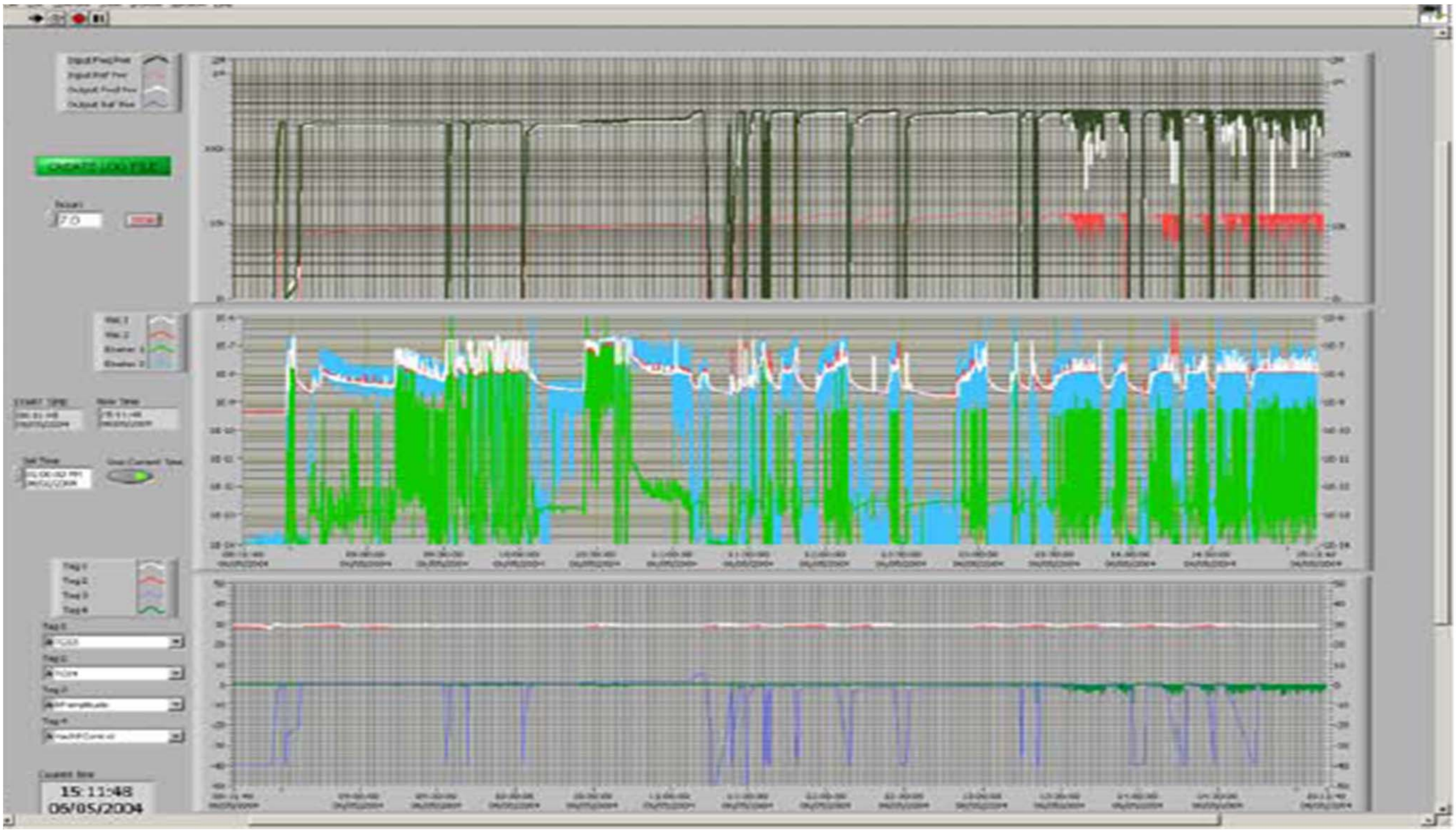




LabView operator interface for RF conditioning stand

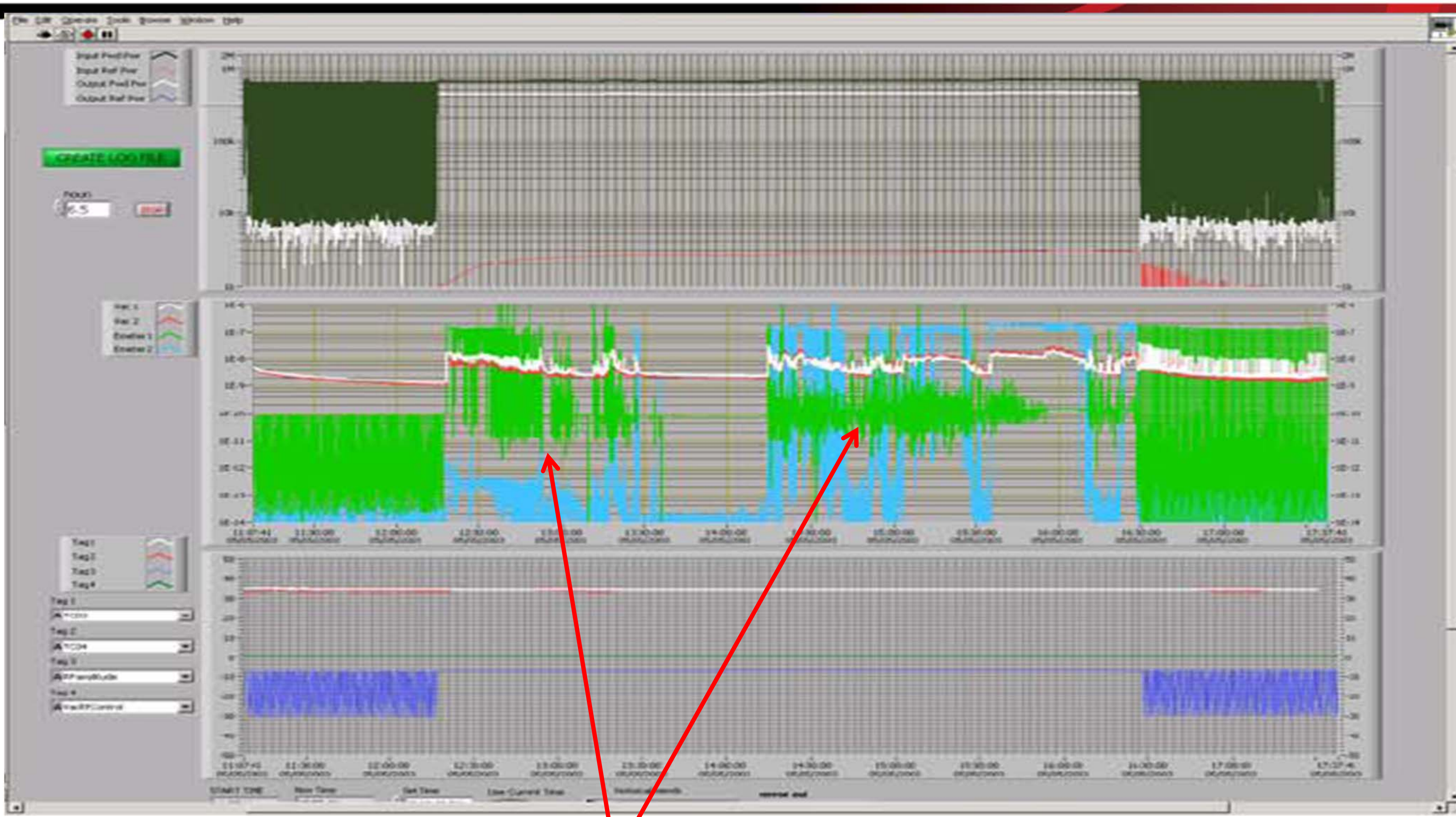


RF conditioning in TW mode RF power, vacuum and eec vs time



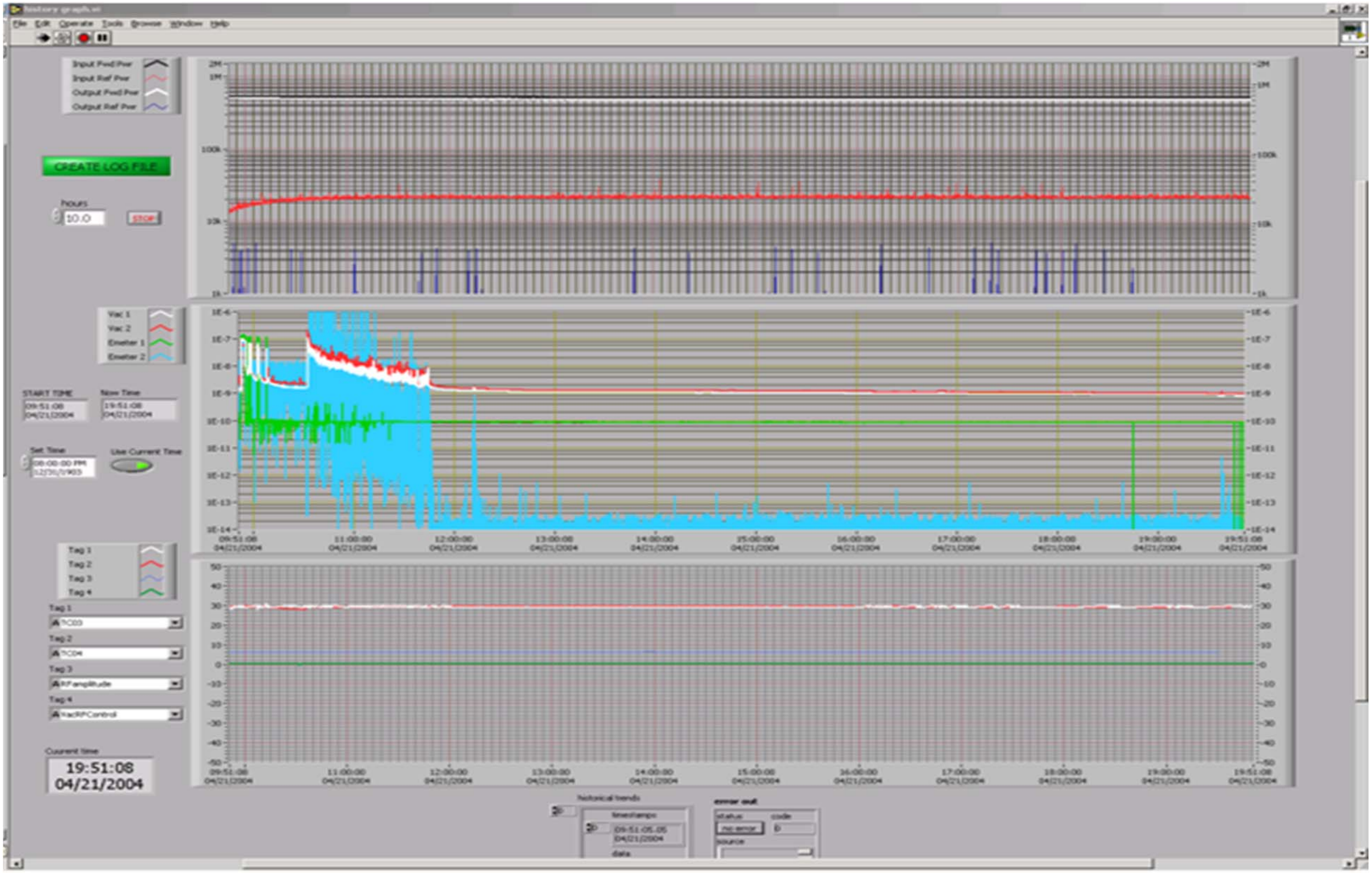
Vacuum and electron activity at the beginning of RF conditioning in TW mode

CCC test



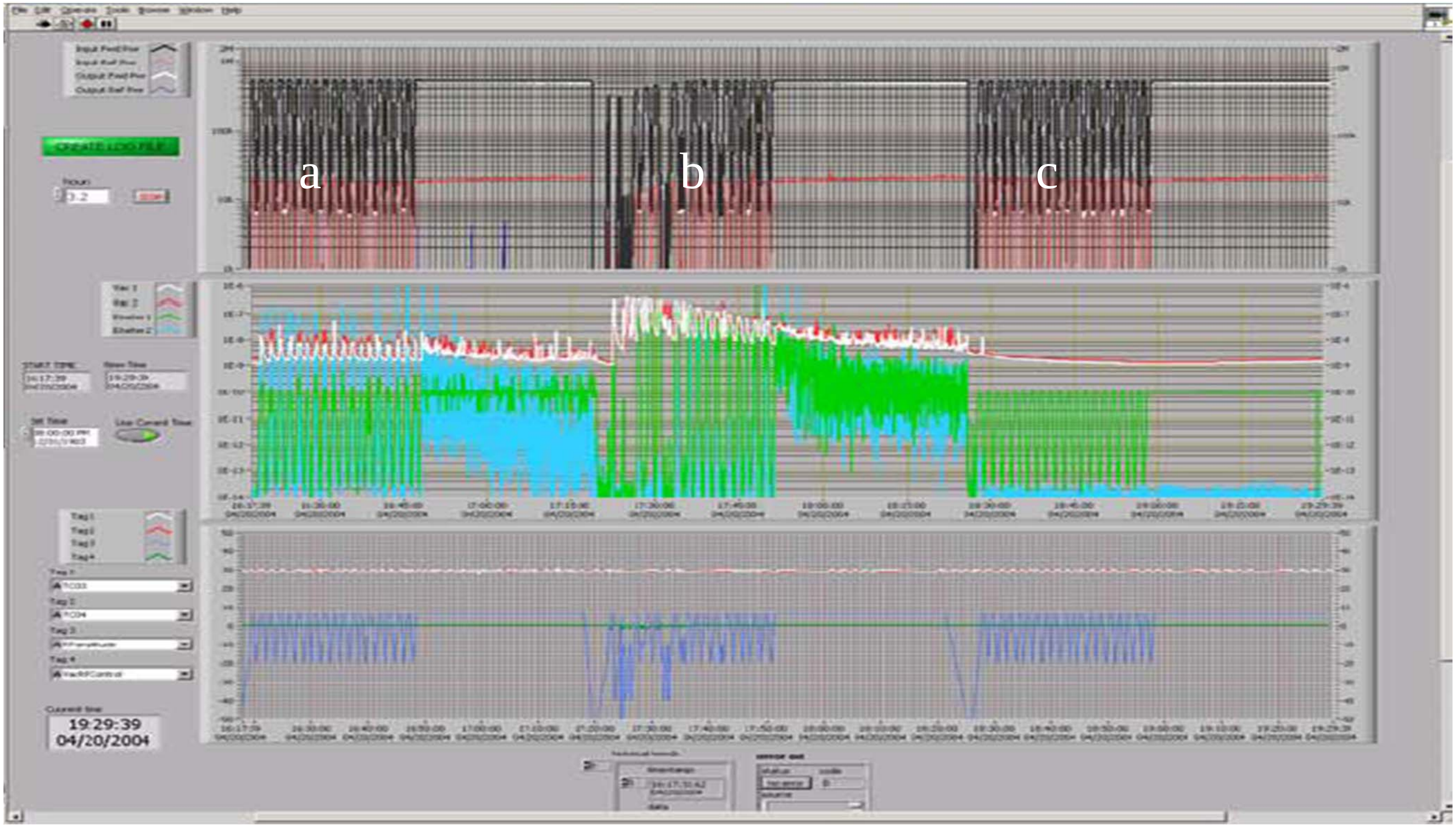
De-conditioning during high power RF tests

CW test – long run test CW in TW mode



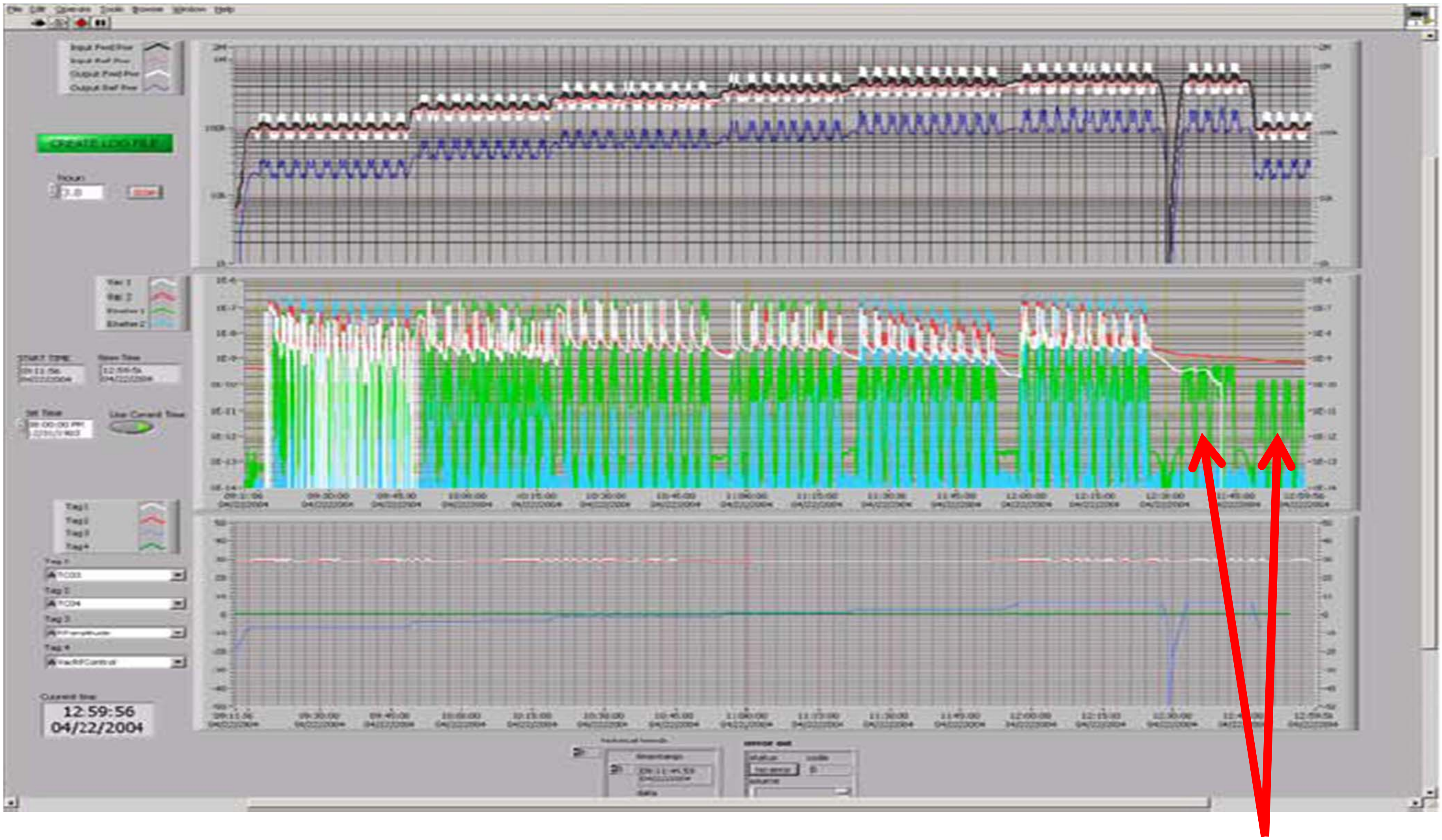
10 hours run with constant pulse amplitude 650 kW 1 msec 60 Hz

Testing DC bias efficiency in TW mode



DC bias test: a) No dc bias ; b) -2.5 kV c) +2.5 kV

RF power tests in SW mode



Vacuum and electron activity in SW mode up to FWD 600 kW. DC bias at the end

Issues during SNS FPCs during RF power qualification

- Normal RF qualification procedure using an "optimized" (administrative) timing: for RF conditioning in TW mode (defined as reaching the maximum klystron output 8 – 12 hours) the remaining power tests including SW mode, about 38 hours.

- Enough RF time? **NO!** Had to use only day time RF… and fit the RF qualification of 2 FPCs in 5 days. Weekends were eventually used for bake.
- RF qualification using CW or pulsed RF systems. **BIG** difference in FPCs RF cleaning efficiency.
- What can go wrong during RF power qualification on room temperature test stand:

A) On the vacuum side – arcing events
B) On the air side – arcing events

On room temperature test stand, lost one of the two, **clean**, already qualified coupler due to uncontrolled RF and subsequent arcing events on vacuum side.

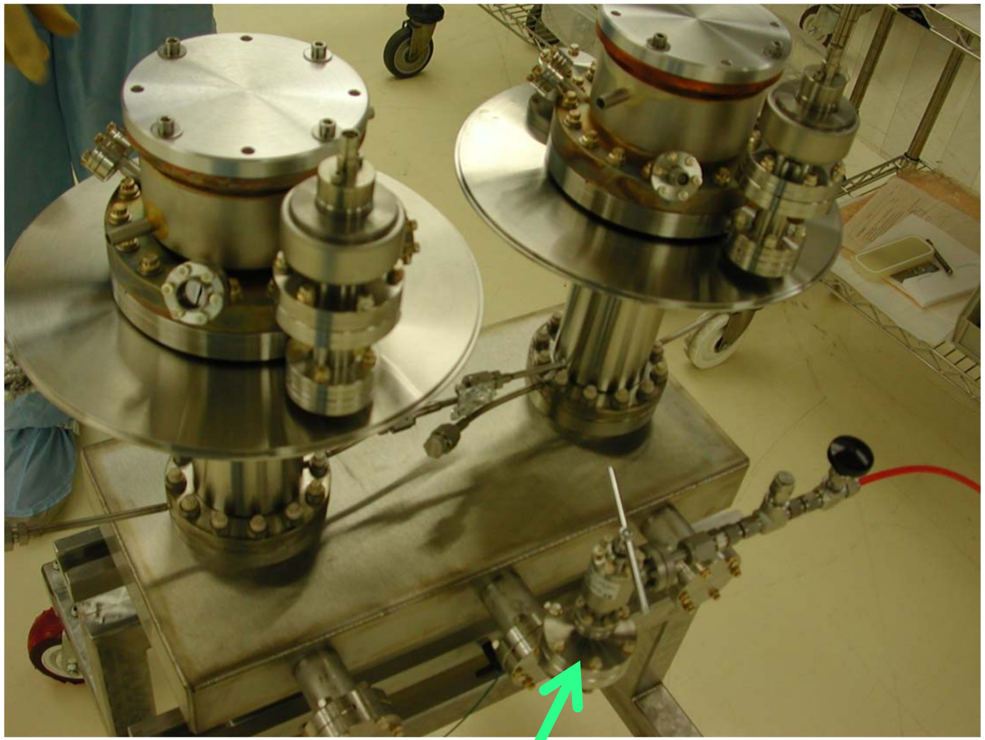
For the remaining 81 couplers the total number of arcing events less than **10**.

Arcing in waveguide and subsequent smoked the air side of the ceramic – cleaned and FPC is in used on cryomodule

Arcing marks on the air side – can and should be mechanically cleaned.

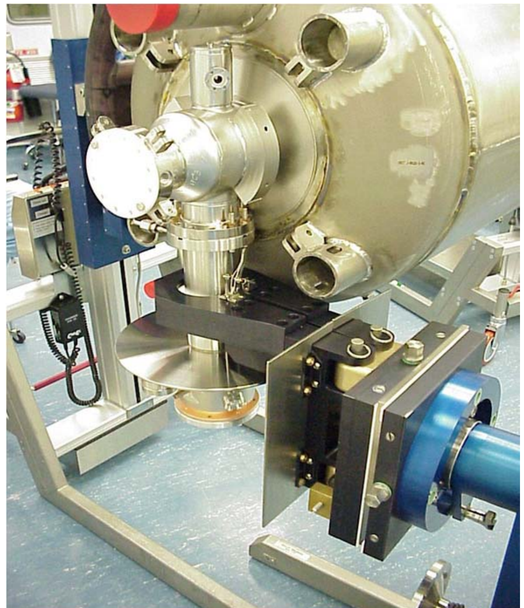
FPCs storage after RF power qualification

Storage on outer conductor using protection cup, under dry dust free nitrogen.



Storage on connecting waveguide under dry, dust free nitrogen.
Use Millipore® ceramic filter.

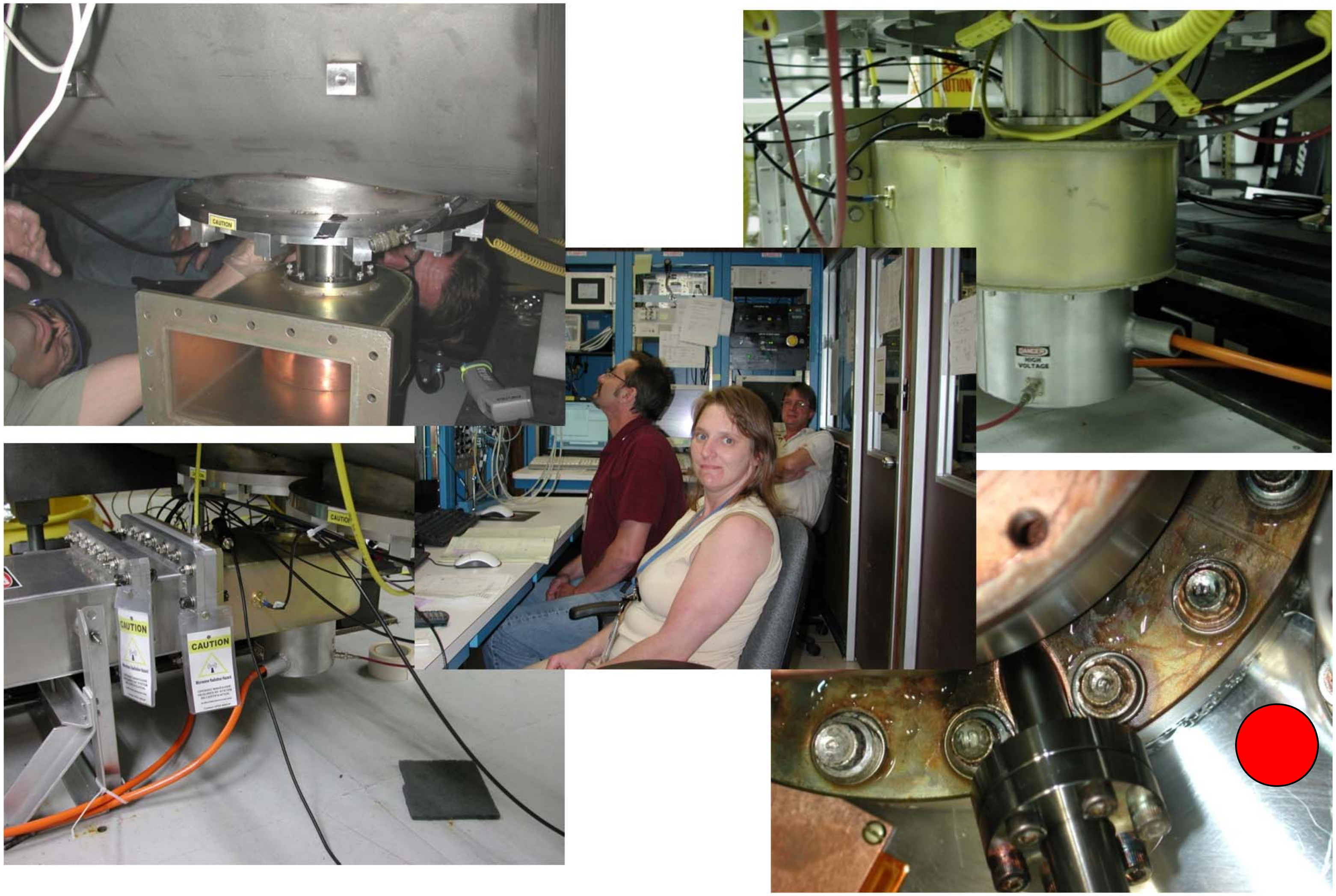
Clean room assemble of SNS FPCs on cavity



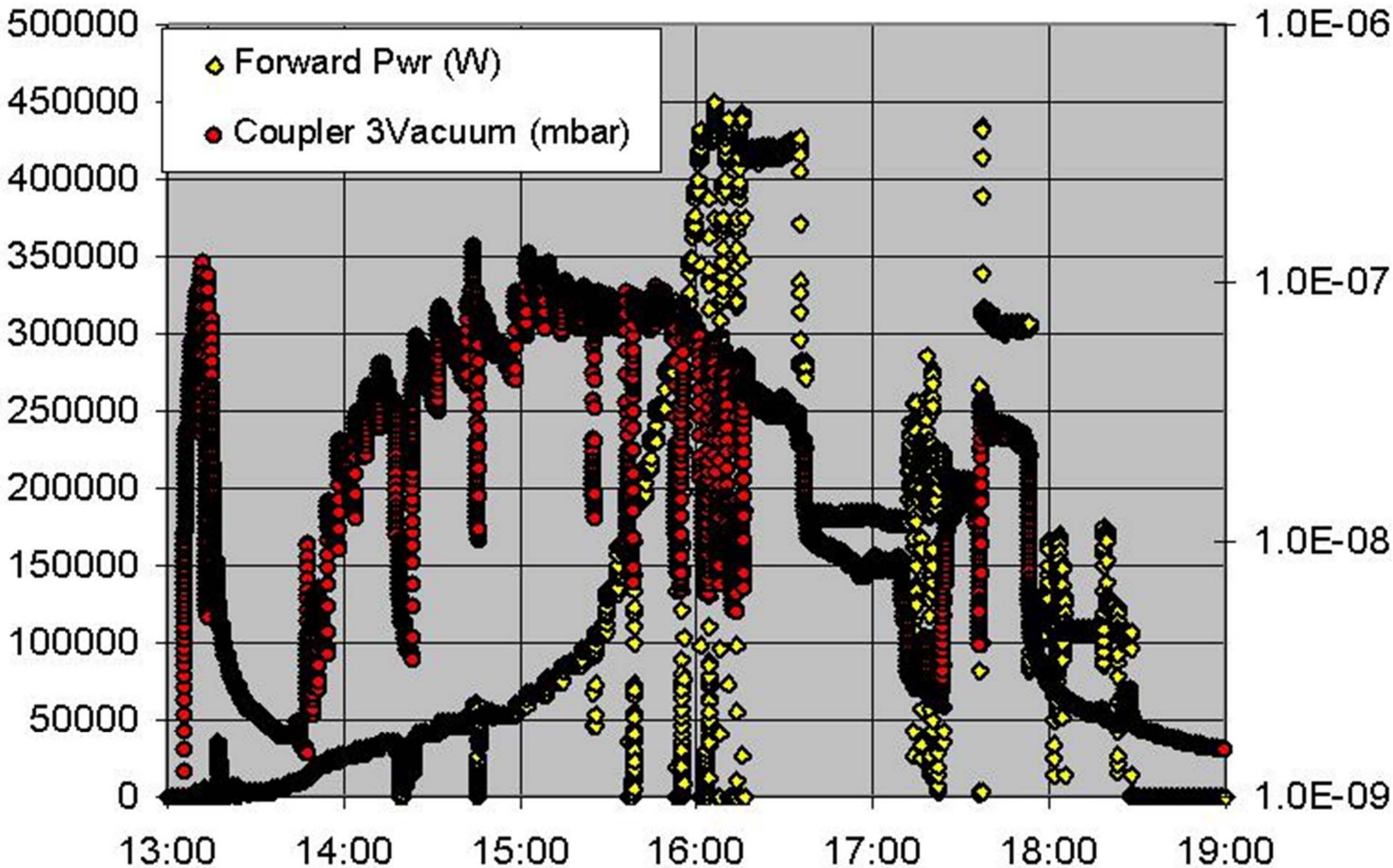
Avoid qualified FPC contamination during alignment on cavity port.

Avoid cavity contamination

FPC air-side on cryo-module during qualification tests in CMTF



SNS Cavity Qualification in CMTF at JLAB



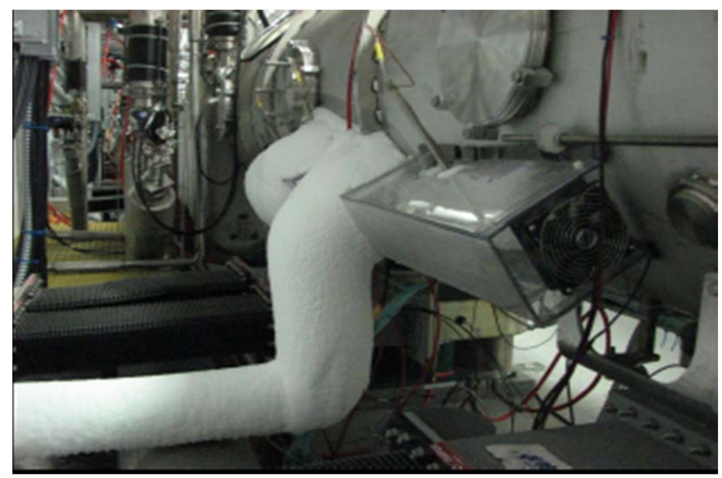
FPC RF conditioning as function of vacuum

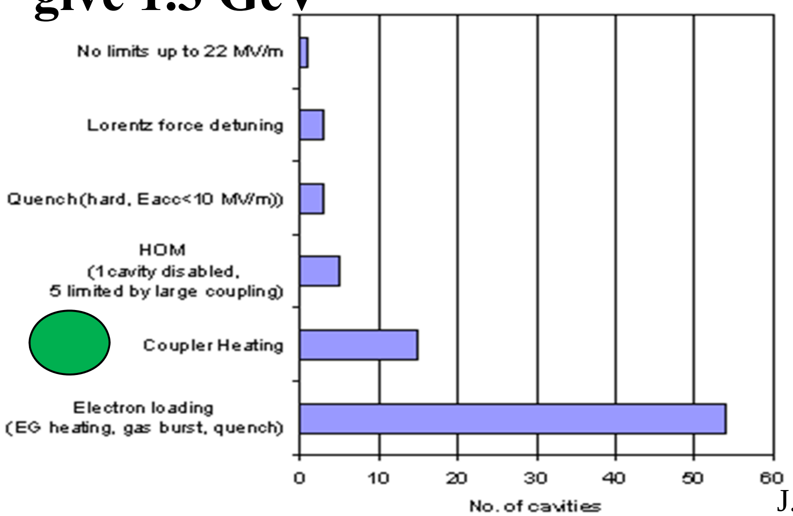
Last cryomodule delivered to SNS Oak Ridge

In Spring of 2005, all 23 cryo-modules (with medium and high beta cavities) have been installed in the SNS SRF linac at Oak Ridge.

SNS FPCs Operation at Oak Ridge

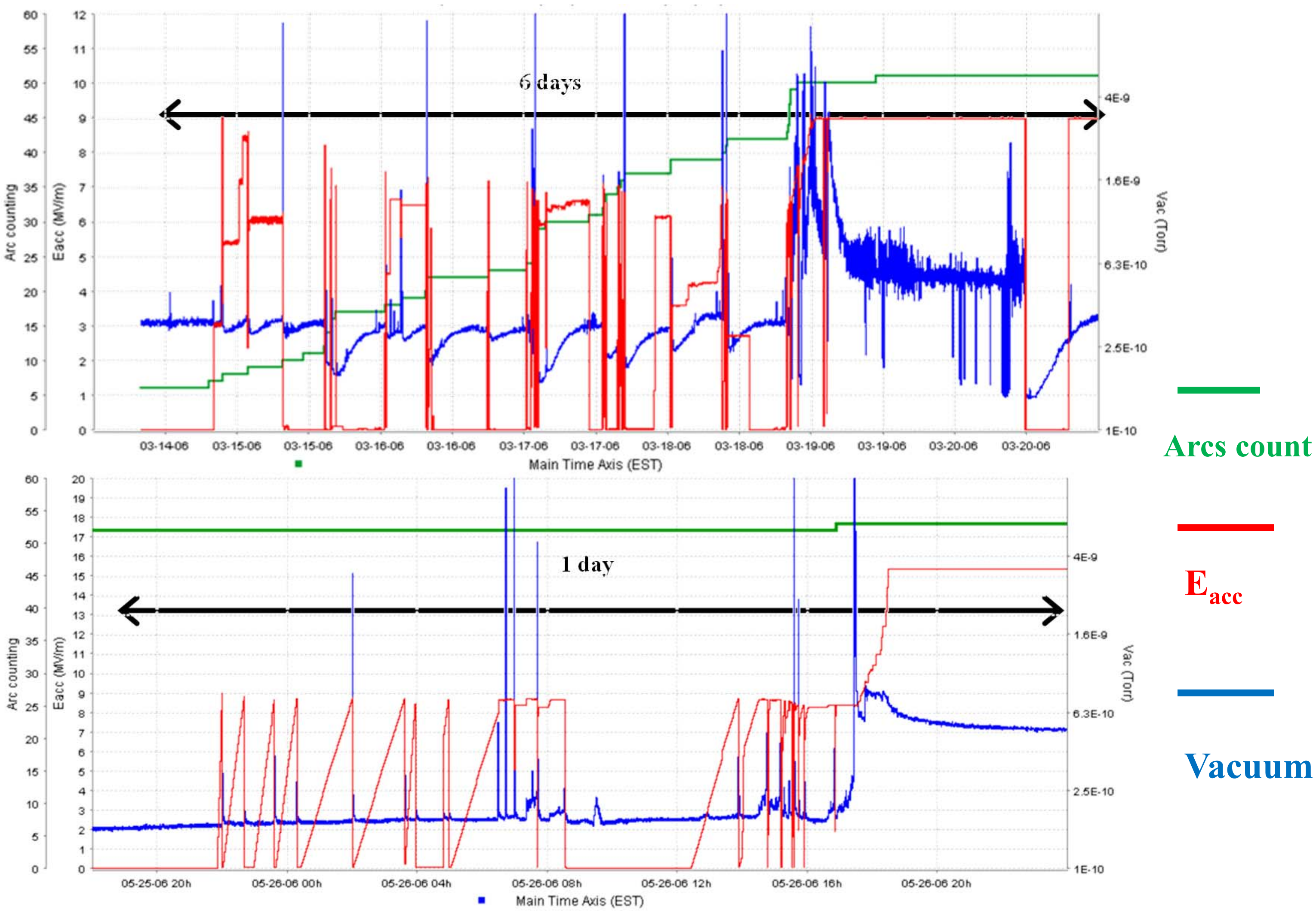
- **World's first high-energy superconducting linac for protons**
- **81 independently-powered 805 MHz SC cavities, in 23 cryomodules**
- **Space is reserved for additional cryomodules to give 1.3 GeV**





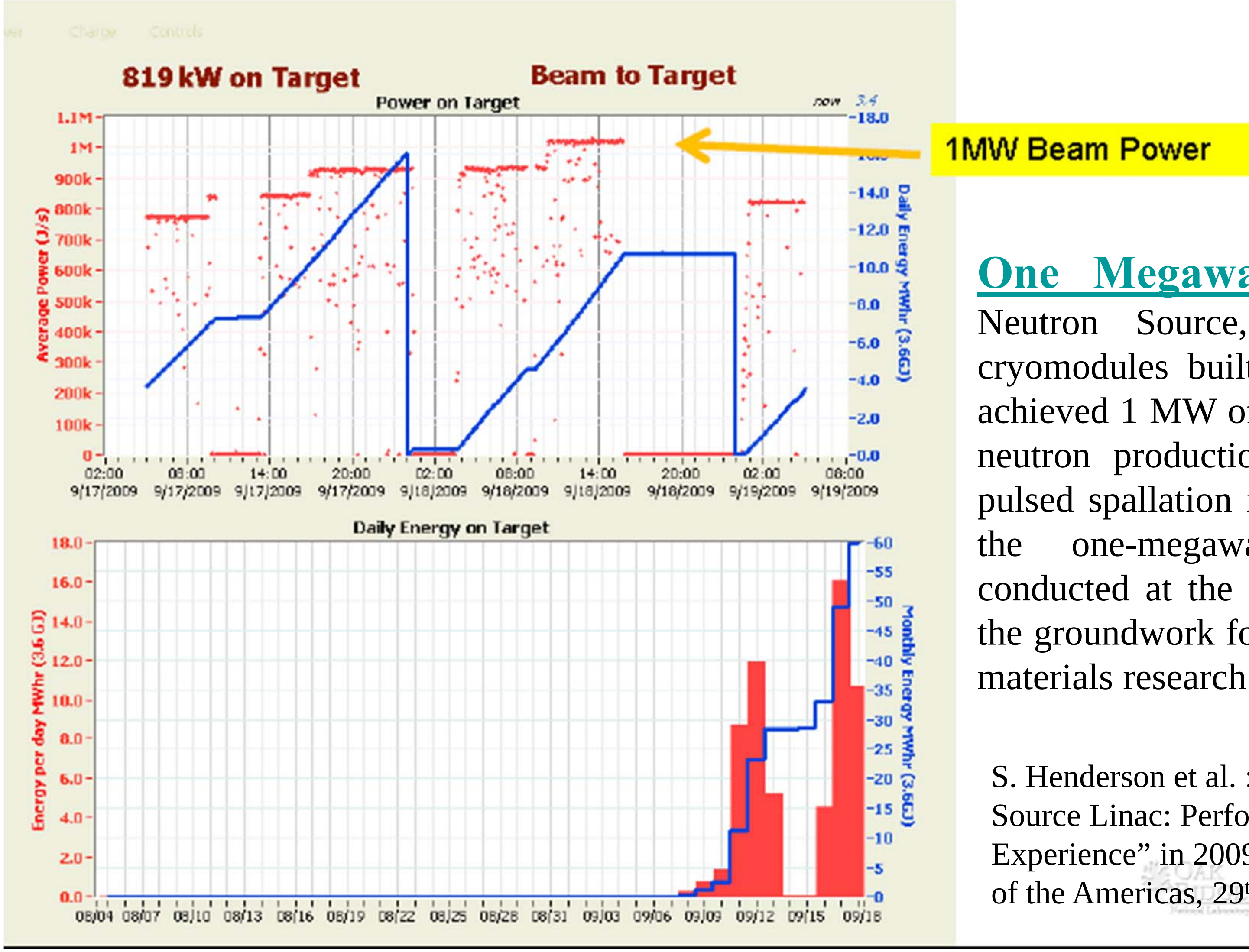
J. Mammosser: SPALLATION NEUTRON SOURCE STATUS AND UPGRADE PLANS in: SRF2009 – Berlin, 20-25 September 2009

FPCs operation at Oak Ridge



Conditioning and operation after long shutdown, in summer of 2006. **No DC bias.**

SNS Operation: Beam to target 1 MW



One Megawatt - The Spallation Neutron Source, which contains 23 cryomodules built at Jefferson Lab, has achieved 1 MW of beam power in routine neutron production operation. The first pulsed spallation neutron source to break the one-megawatt barrier, research conducted at the SNS is expected to lay the groundwork for the next generation of materials research.

S. Henderson et al. : " The Spallation Neutron Source Linac: Performance and Operational Experience" in 2009 Linear Collider Workshop of the Americas, 29th September 2009

Other cleaning procedures

A consommé avec moderation:

- He processing (done at low vacuum levels, delicate procedure to control the amount of He injected, can lead to ceramic metallization, high He gas levels are difficult to pump out, can make subsequent vacuum leak checks impossible).
- Plasma cleaning (if not properly controlled, leads to metallization of ceramic components)
- CO2 cleaning (attention to thermal shocks, adherence of anti-multipacting layer)

Conclusions

Adequate infrastructure:
- Production chemroom
- Clean rooms, PP
- Specific tools: HWP systems, US cleaning baths, DI water, filtered, dry N2 gas, cleanroom carts, cleanroom moving devices, cleanroom supports, clean room particulate counters
- Working space for UHV component qualification
- Meticulous control of FPCs component cleanness, tooling and infrastructure at all production stages
- Bake under vacuum
- RF power test stand and adequate controls
- **Trained personnel**

Cleaning Recipes

The importance of meticulously cleaning the power coupler before it is installed on a clean SRF cavity is widely accepted. Most labs use a combination of ultrasonic cleaning and deionized water rinsing with some high pressure water rinsing.