NSLS-II RF Systems

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Presentation Topics

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1.	Introduction
2.	NSLS-II RF systems overview
3.	Early operational Experience
4.	Next steps

NSLS-II RF systems overview

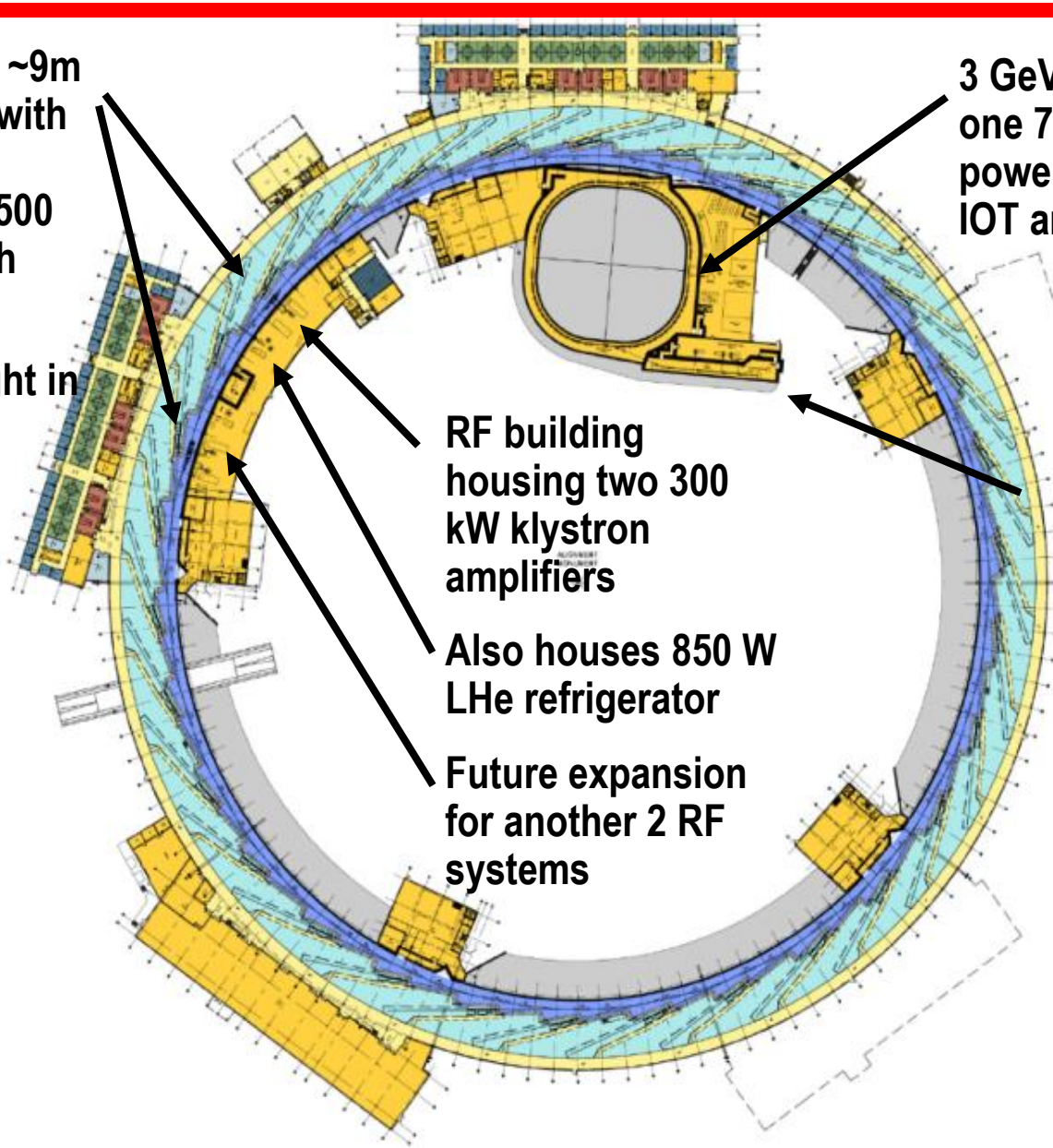
The NSLS-II RF system is comprised of:

- Master Oscillator and distribution
- Digital RF cavity controllers
- Linac RF systems and PLC
- Booster RF systems
  - 7-cell “PETRA” Cavity
  - 80 kW IOT transmitter
- Storage Ring RF systems
  - 500 MHz “CESR-B” SRF cavity
  - 300 kW klystron transmitter
  - 1500 MHz SRF cavity
  - 840 W 4.5 K Helium Refrigerator

NSLS-II RF Systems

Storage Ring: Two ~9m RF straights each with two 500 MHz SRF cavities and one 1500 MHz passive bunch lengthening cavity

Only one RF straight in initial operations



3 GeV booster with one 7-cell cavity powered by 80 kW IOT amplifier

RF building housing two 300 kW klystron amplifiers

Also houses 850 W LHe refrigerator

Future expansion for another 2 RF systems

200 MeV linac with four 5.2 m TW structures powered by two 42 MW klystrons with SS modulators and third "hot spare"

NSLS-II Commissioning status

Linac-

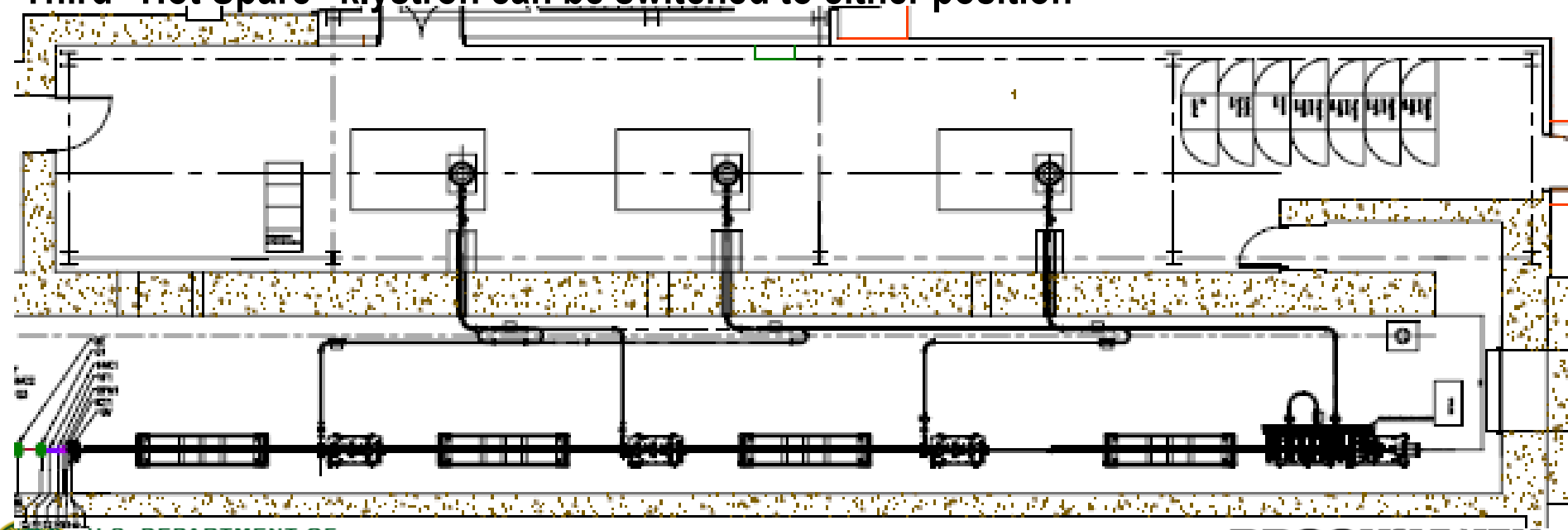
- Commissioned by vendor (RI) in 2012 successful
- Beam mis-steering incident shut down for 18 months
- Commissioning re-started in November 2013
- Most requirements met – working towards 15nC bunch trains in <0.5 mm-mrad emittance

Booster-

- Commissioning started in December 2013
- Still in progress- working toward 300ns bunch trains and 10nC extraction

Linac RF Systems

- 200 MeV S-band linac: 15 nC/pulse requires beam loading compensation using a feedforward algorithm in the cavity field controller
- 500 MHz modulated gun with 500 MHz buncher, 3 GHz pre-buncher, 3 GHz TW buncher and four 5.2m TW structures
- Two 42MW klystrons with Solid State Modulators using IGBT switches on multiple-primary, split-core pulse transformer
- Third “Hot Spare” klystron can be switched to either position



S-Band Pulsed LINAC

RI build with 3 Scandinova SS modulators with Thales 2100 klystrons; Two operational, third is hot spare: This configuration has proven essential in commissioning as often one system is down

LINAC Early Operational Experience

Overall experience is excellent with some early failures and some recurring problems

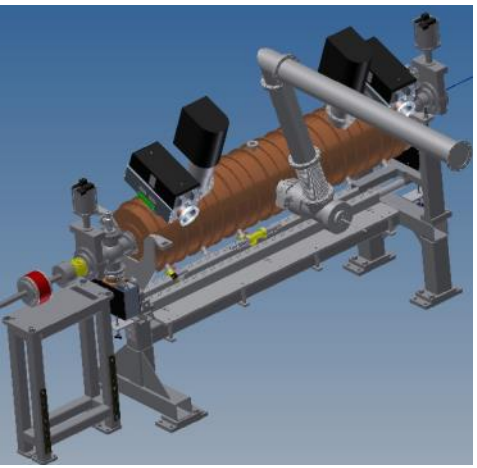
- SS drive amplifier failures due to capacitor design flaw- problems investigated by vendor, amplifiers repaired
- Frequent internal arcs in TH2100B, no time for conditioning to higher voltage
- Klystron modulator HVPS failed, replacement failed
- Noise in modulators may be causing spurious trips- still under investigation
- Modulator controls read backs give intermittent false readings

If not for redundant third klystron the driver, HVPS failures would have affected operations

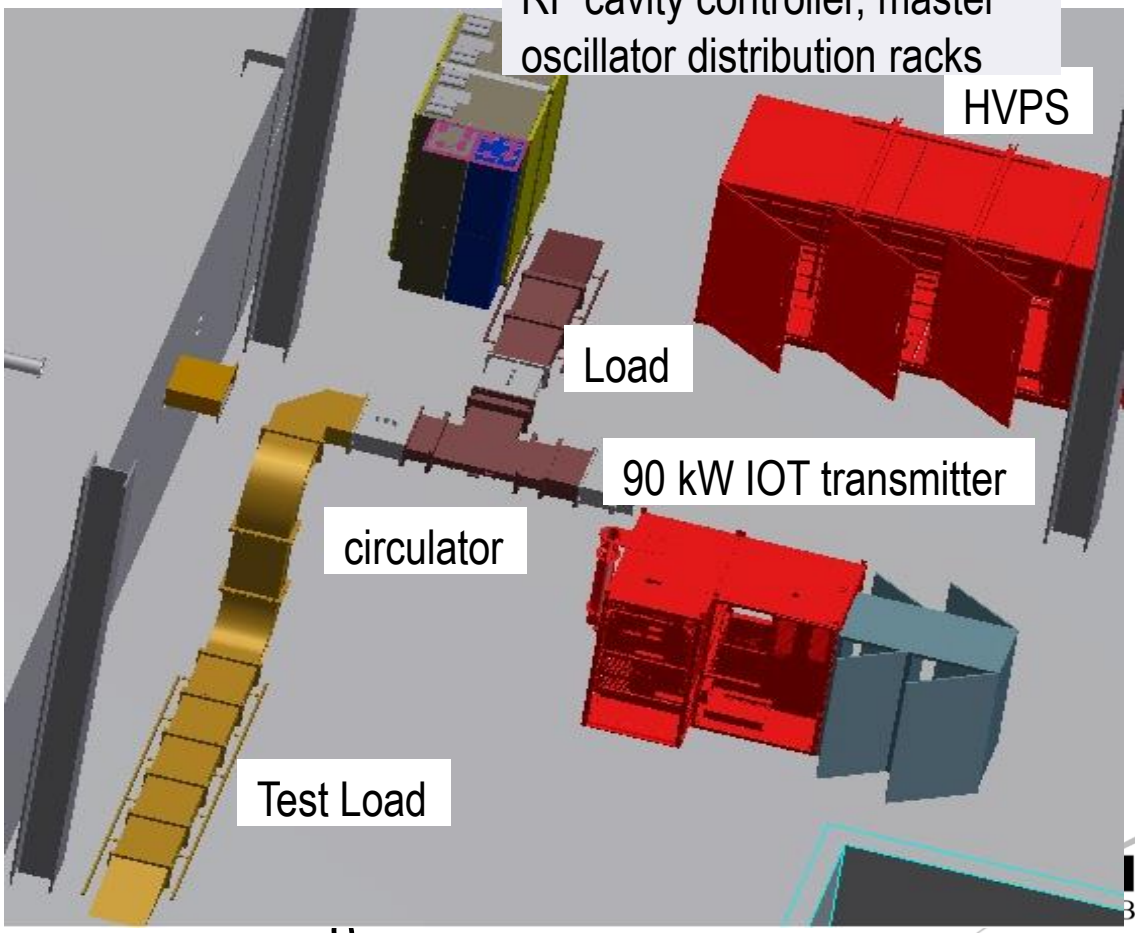
Booster RF system

System tested to 90 kW, ramps from 600 W to 60kW at 1 Hz. Petra cavity temperature adjustable +/- 5° C to move HOM's- not required yet..

System has been very reliable- No problems with Thomson (Comark/Ampegon) transmitter, L3 IOT, Ferrite Inc. circulator, AFT loads



Some nuisance trips with arc detectors (probably false), low water flow (real, water system pressure is marginal



RF Cryogenic System Overview- Lower Mezzanine

1.Cold Box
Max. Ref. Capacity – 816 W
Max. Liq. Capacity – 255 L/hr

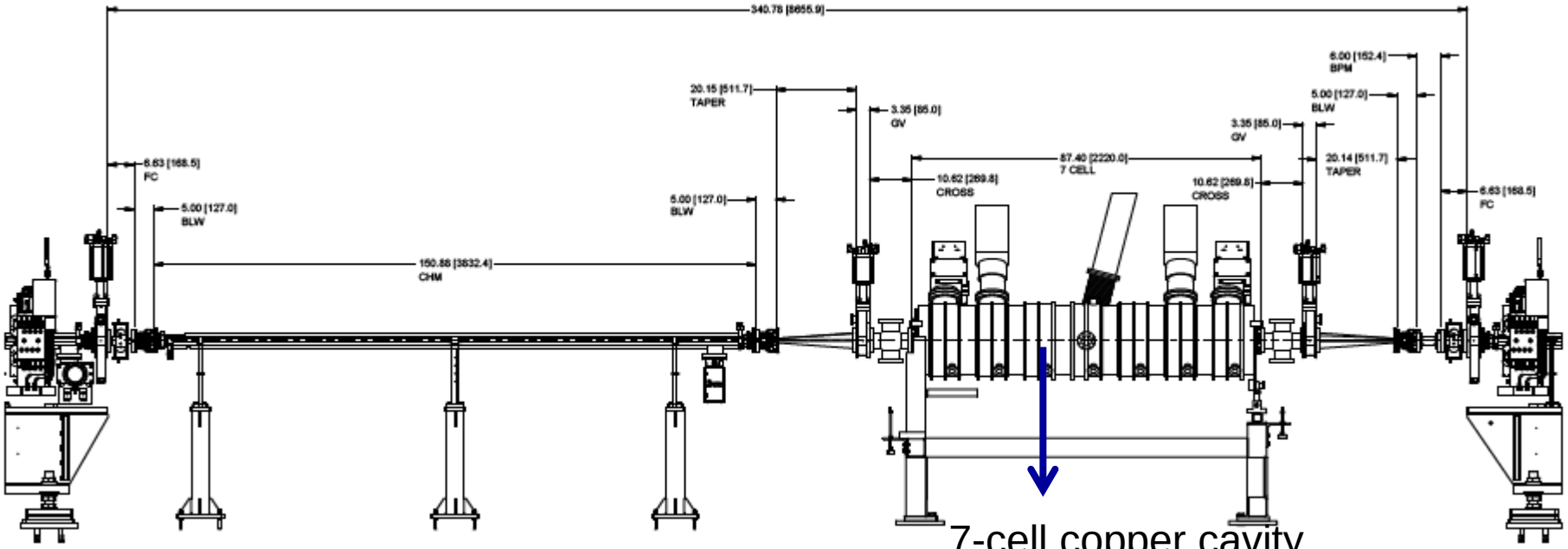
2. Lhe Dewar
Volume – 3500 L
Operating Pressure – 1.34 Bar.A

4. 200 Lt LN2
Phase Separator

3. Manifold Box
Dis. Sys- Block House, Valve Box A and Future Valve Box B

Both liquid helium system and SRF cavity too late (4 months) for initial commissioning and so the 7-cell copper cavity was installed. However commissioning with the 7-cell cavity was discussed as an option from day one as it simplifies the commissioning, this was found to be true. However now we pay the price as we install the SRF cavity and expectations are higher.

SR Commissioning with Copper 7-Cell Cavity



7-cell copper cavity

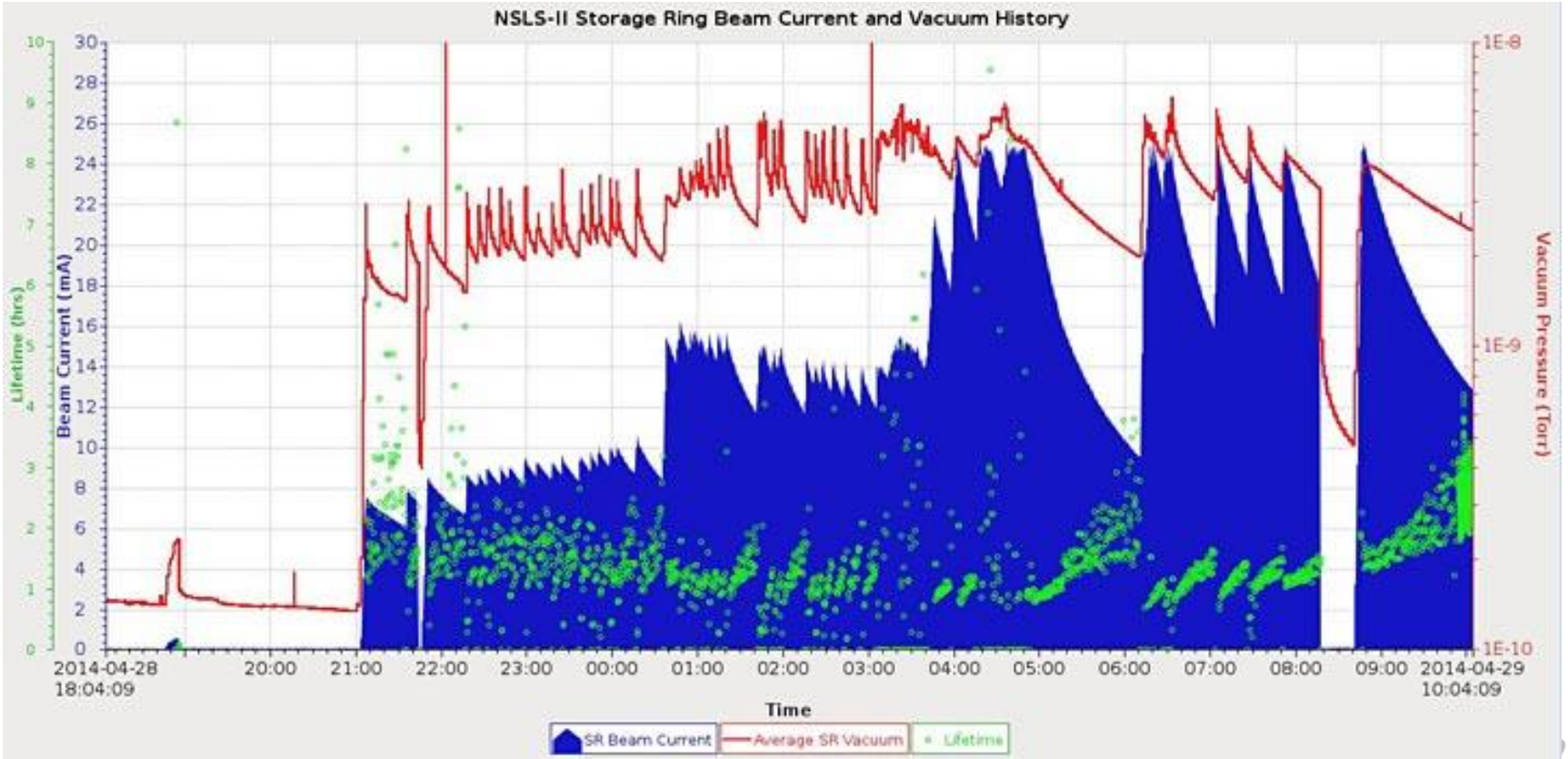
- The cryogenic system for the RF super-conducting cavities is still in final commissioning stages and superconducting cavity was not available at start of commissioning
- 7-cell PETRA cavity (spare booster cavity) installed and powered by 300 kW klystron transmitter. No temperature compensation of HOM's
- Cavity conditioned to 2.4MV, no problems during early operations
- Commissioning achieved 25mA (early goal) halted for installation of SRF cavity

NSLS-II Commissioning- Storage Ring

Commissioning starts February 2014 using spare PETRA cavity

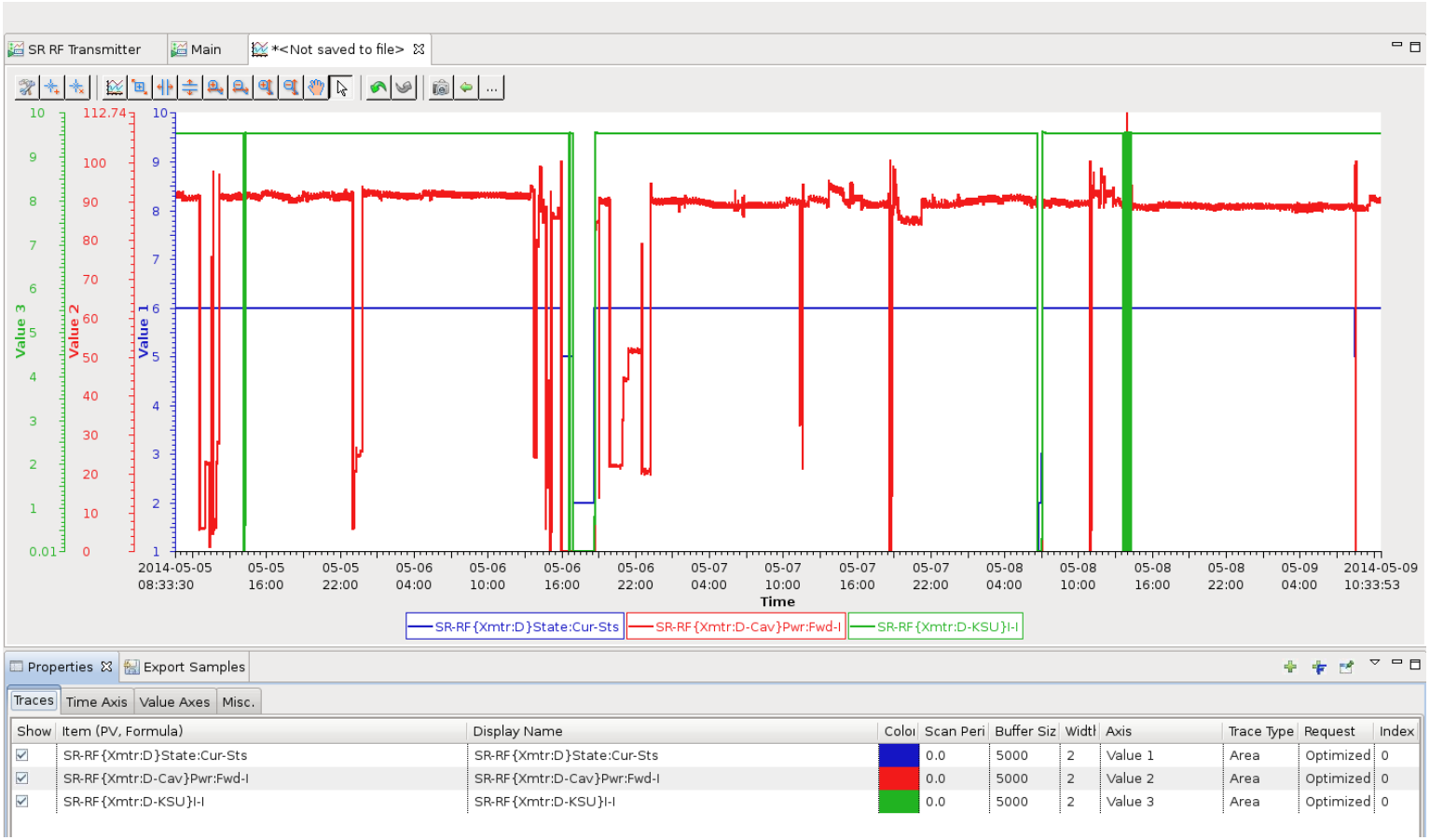
Beam current limited to 25mA (no active beam interlocks)

Single and coupled bunch instabilities seen, not limiting progress



Early klystron transmitter operations data

Several trips per day nearly equally divided between external (EPS, PPS) and RF interlocks
Most annoying are false trips of the AFT arc detectors, this is common to booster and SR systems



Lack of automatic fault logging and data mining programs makes getting staticstics difficult

Storage Ring RF Trip Log

Storage Ring	Transmitter C	Transmitter D
27-Apr		Arc Det Fault
28-Apr		Trip back to filament
eps water trip		
29-Apr		vacuum trip
		trip back to beam
		trip back to beam
30-Apr		RF trip no alarm
2-May		RF trip fwd/rev pwr=tunerPLC
		RF trip = Tuner PLC
		Rf trip=no faults
		SRRF trip
3-May		SRRF trip
		SRRF Cathode I high
		SR RF Global Arc=no reprt PLC
		SRRF Vac intlk
		SRRF Vac intlk
		SRRF Cathode I High
4-May		SRRF Trip
		srrf Trip TO AUX
5-May		srrf Vac trip
		SR RF alarm to beam state
8-May		SR RF Circ watr flow
		SR RF trip back to beam
		SRRF VAC trip
		SR RF VAC trip
9-May		SR RF trip to beam status

In absence of operator tools for fault logging RF group resorts to manually mining the operator's log for RF trips. Also, individual RF PLC's log faults, however this is time consuming to data mine.

At left are some representative fault log entries. Not shown are many machine or personnel protection (EPS, PPS) faults that trip RF. However, some un-named faults

Until SRF is installed there is no time for troubleshooting all faults, after SRF installed it is too late.

Ampegon (Thomson) PWM switching power supply

The HVPS allows the module switching frequency to be modified to avoid exciting the beam

PWM_FREQ(0=3.125kHz and 255=800kHz) where PWM_FREQ can be set to values PWM_FREQ=0…161
FMS=FPWM/N where N is the number of modules engaged

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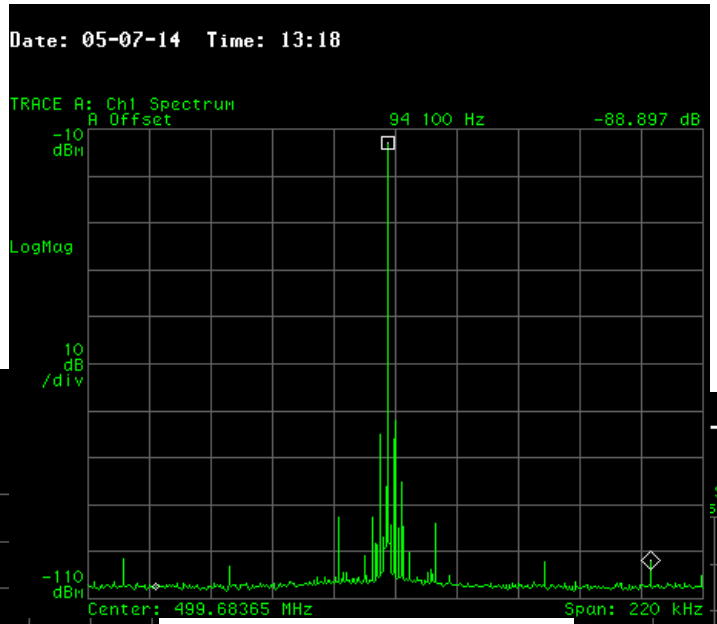
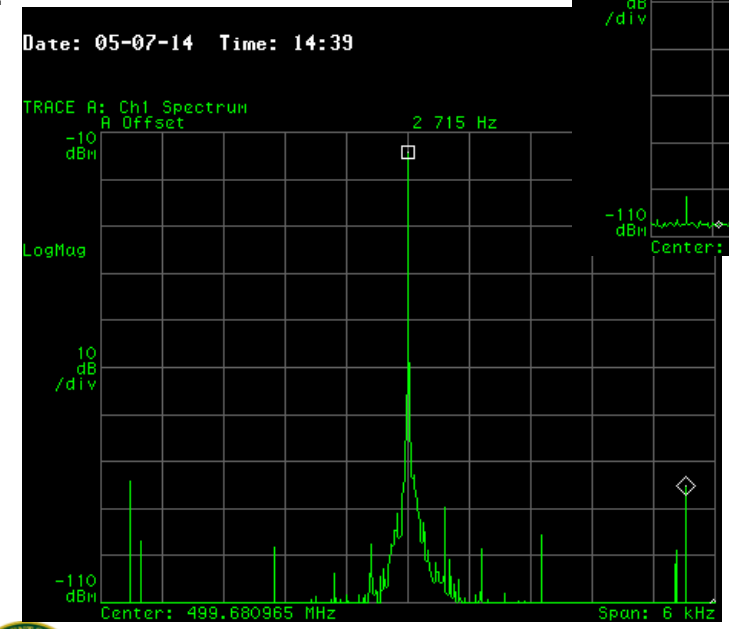
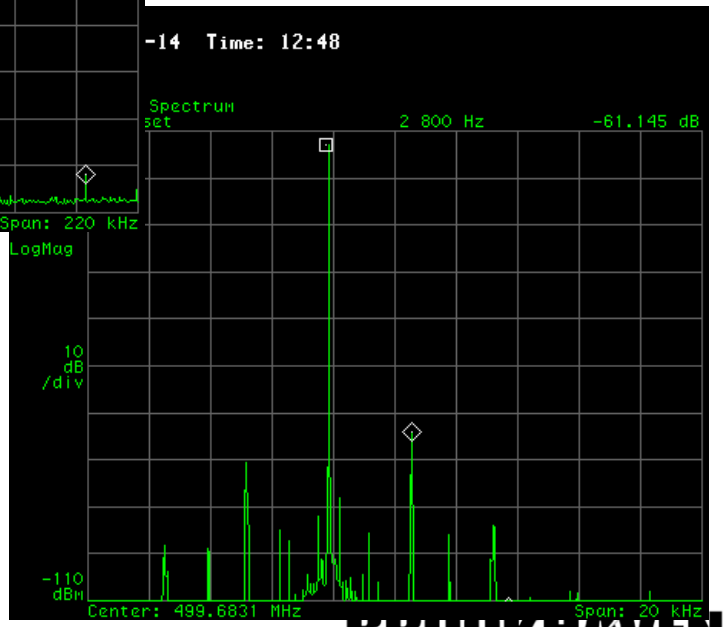


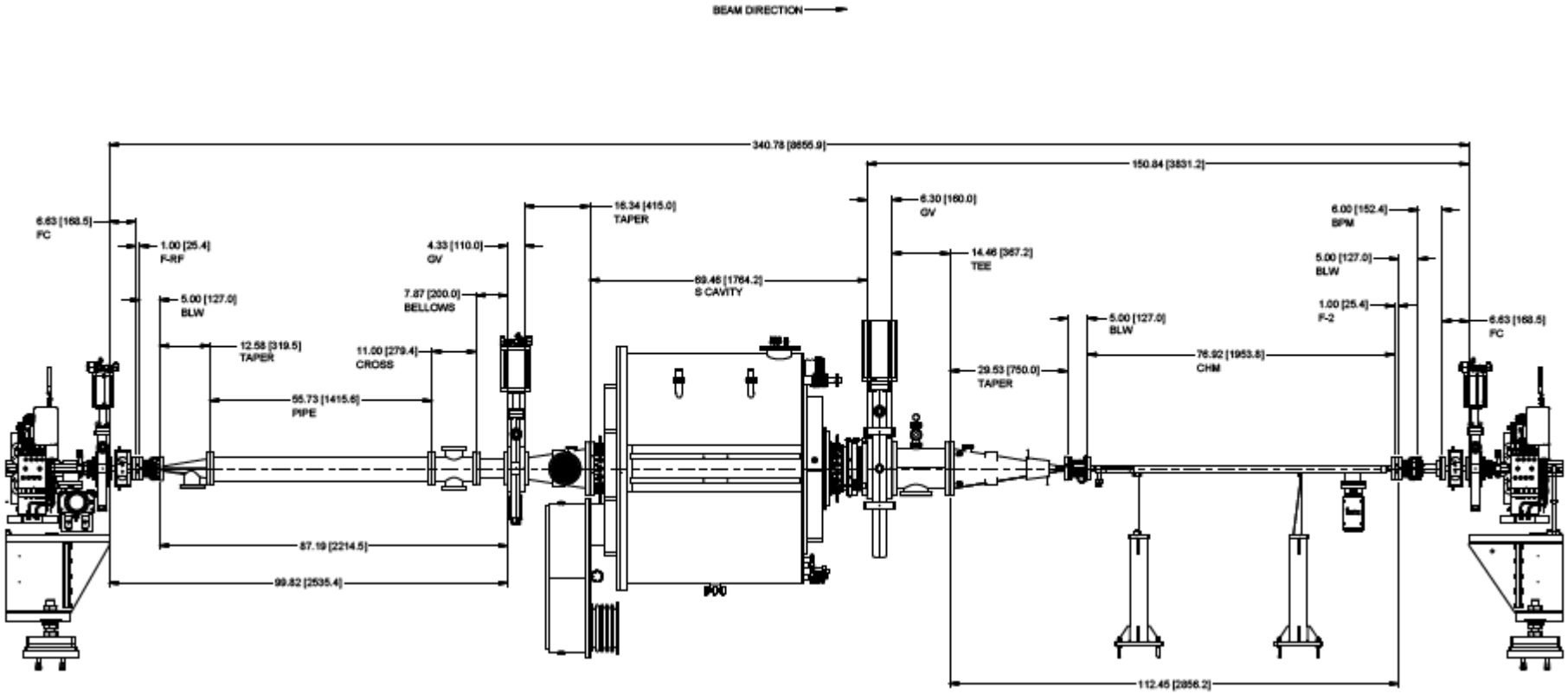
We will adjust PWM_FREQ over the shutdown to avoid the synchrotron frequency





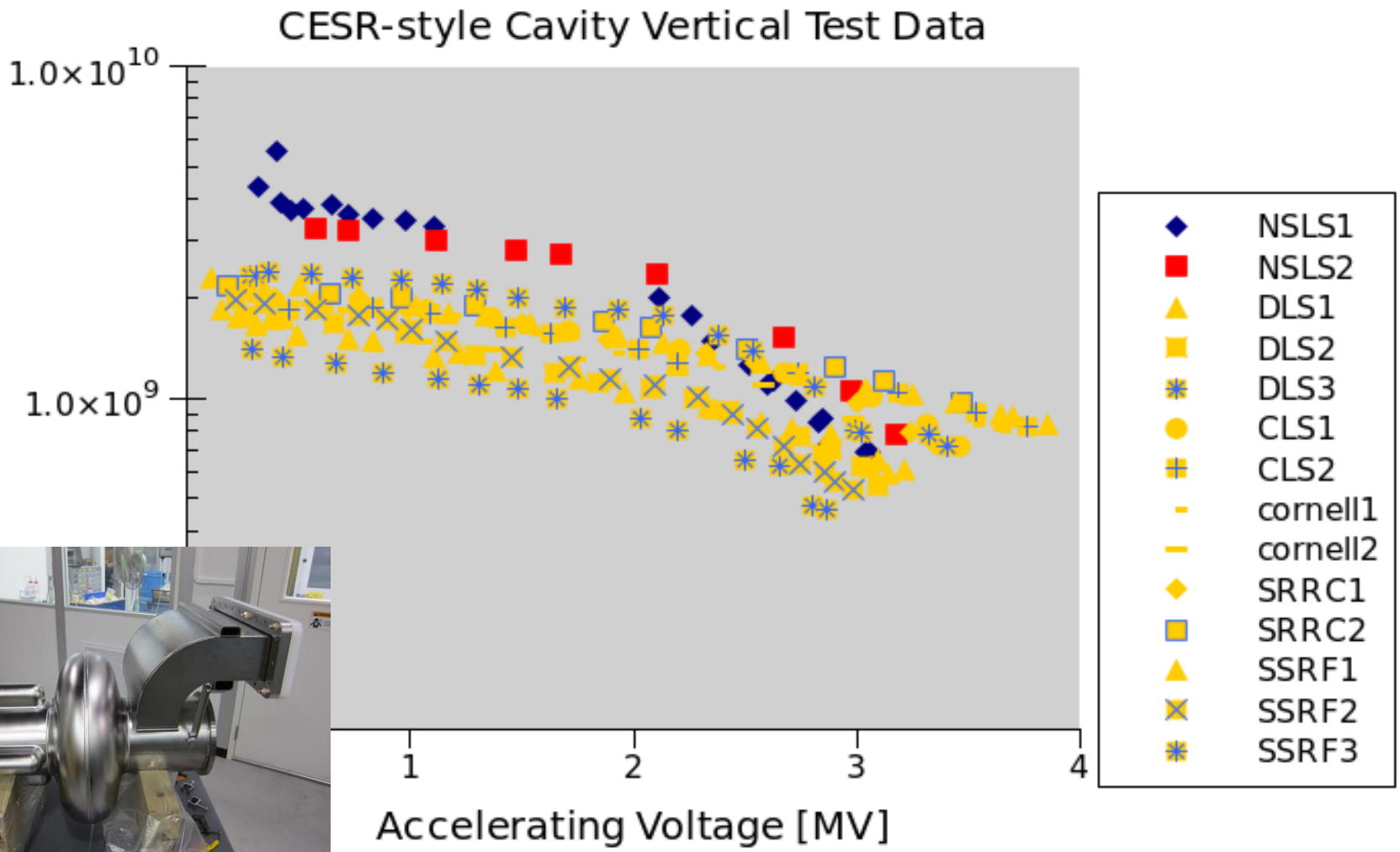
The HVPS controls also allows setting the weights of the switching algorithm to minimize the 60 (50) Hz harmonics

RF straight in Cell 24 for commissioning with SRF



- Super-conducting RF cavity will replace the 7-cell copper cavity after storage ring commissioning
- Installation date: May-June 2014

500 MHz "CESR-B" Vertical Test Data



- All data from Cornell VT stand except NSLS2
- Helium conditioning on NSLS2

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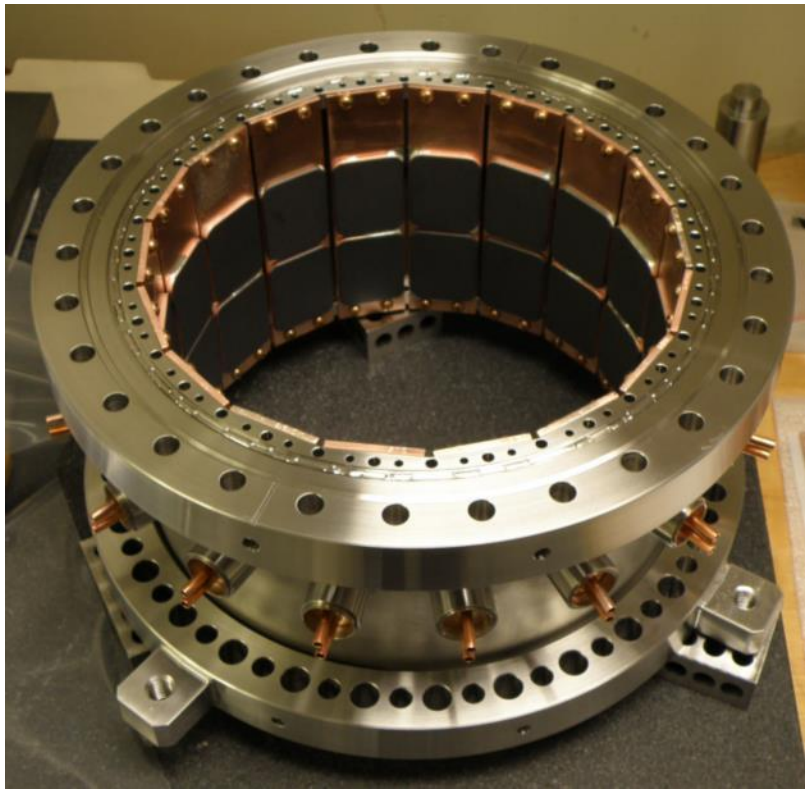
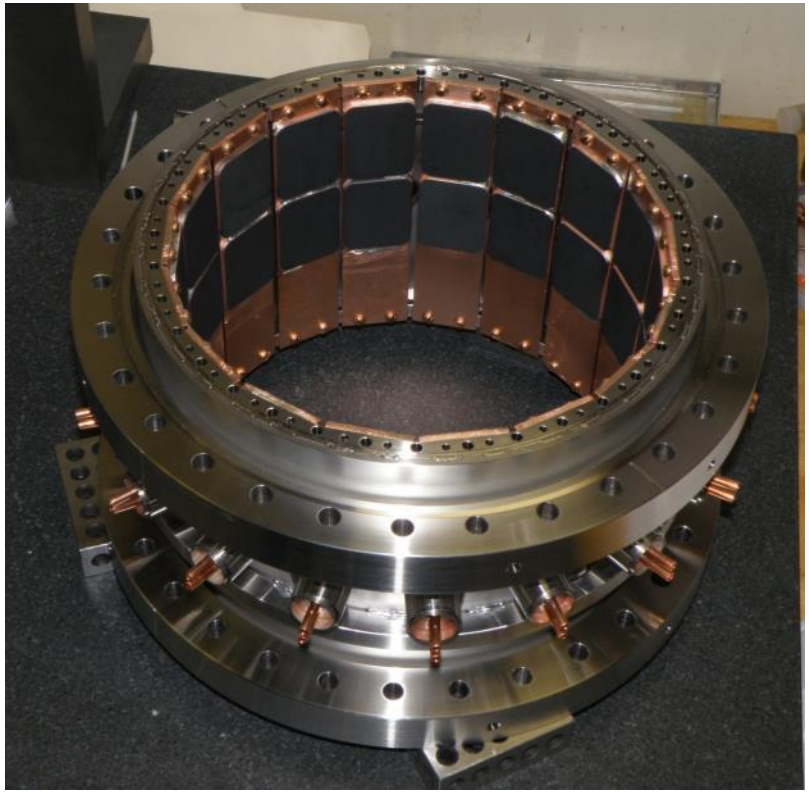
CESR-B Ferrite HOM Fabrication

Soldering of ferrite tiles to Elkonite backers initially a problem. Working with AES and Koral labs to improve process 95% yield of ferrite/Elkonite assemblies passed the 600 Watt microwave heating test with less than 2 ° C temperature variation across the ferrite



Short Upstream HOM Assembly



Long Upstream HOM Assembly

Next steps: Horizontal test and installation

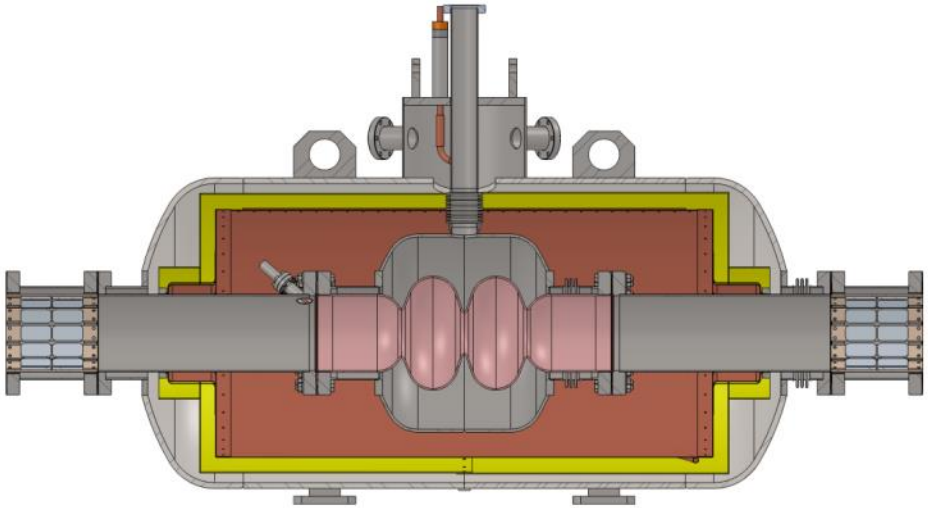
Cavity installed in blockhouse and connected to cryo-system, 300 kW klystron

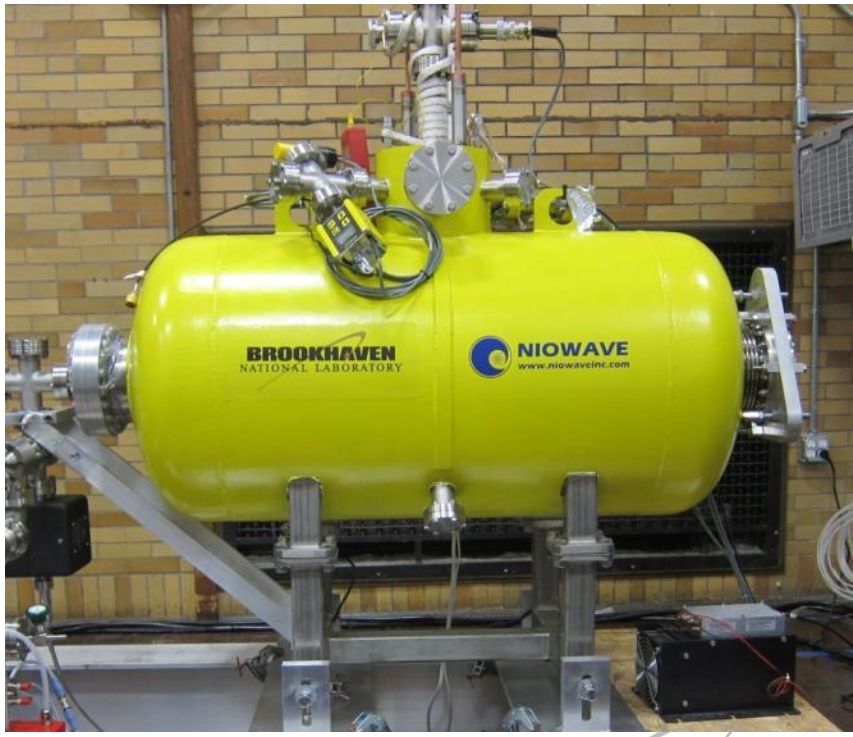
After test it will be installed into the tunnel

Commissioning will start up again in early July

Landau Cavity: Little change since 2011

Work on the passive 1500MHz cavity has been slow. Design of HOM damper complete, purchase delayed until after project end. Cold test planned in late summer. Tuner design in progress- very difficult due to stiffness, space constraints.





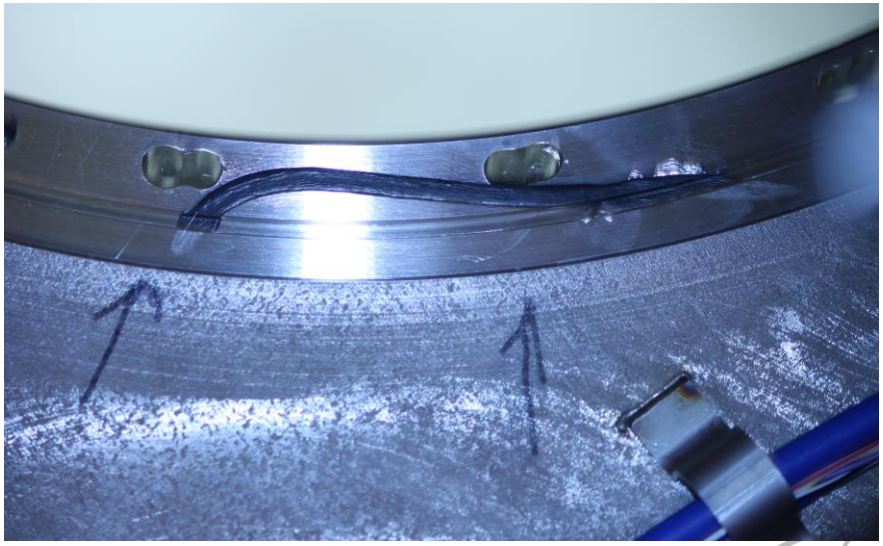
Tuner design in progress- difficult due to stiffness, space constraints

Conclusions

- Initial commissioning of the storage ring with warm cavity to 25 mA is complete.
- We are currently in a shutdown to install the SRF cavity- but first have to complete horizontal test. Scheduled completion and start of commissioning is June 26. The shutdown also includes several ID's taxing manpower, especially vacuum group.
- A second shutdown is scheduled for early August to install the last of the project funded ID's.
- We are on schedule, under budget and, according to upper management, over-staffed

Requisite failure slide: Assembly of the first cryomodule at AES

NSLS-II has worked very closely with the vendor, AES, with BNL staff assisting AES. During the assembly of the cavity string into the helium vessel the instrumentation cable was not properly constrained and across the indium joint flange and was cut in two.



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Thank You

Particular thanks to all of you in this room who helped us with discussions about your experience with similar systems and have either accepted our visits or have visited us during the design, fabrication, installation and commissioning phases of the project.