HIE-ISOLDE SC-Linac performance and plans for the shut down

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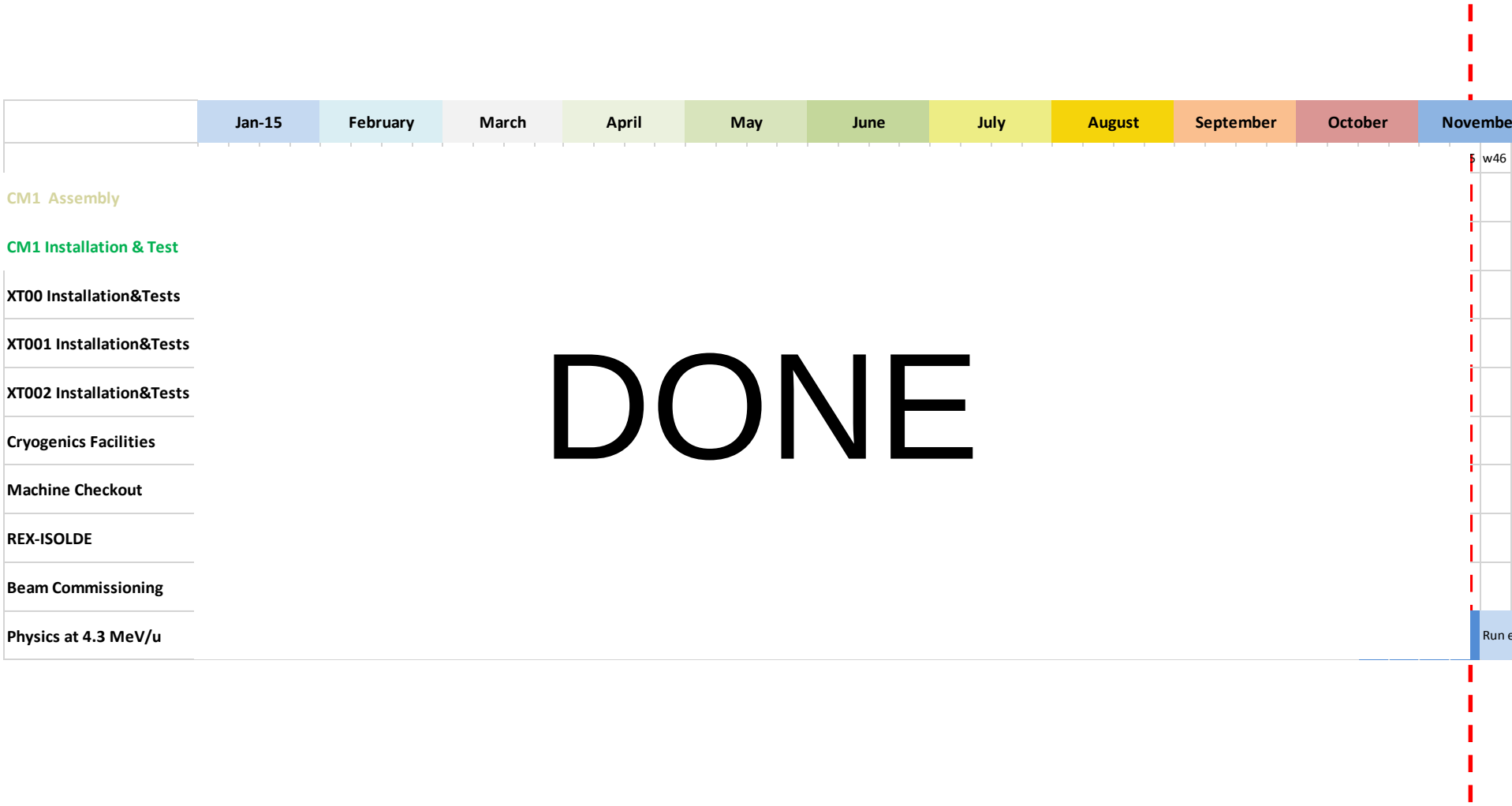
on behalf of the HIE ISOLDE Commissioning Team

74th ISOLDE Collaboration Committee meeting, November 10, 2015

Outline

- HIE ISOLDE roadmap for 2015
- Commissioning organization, goals and procedures
- HEBT commissioning results
- CM1 commissioning results
- Beam commissioning
- Running with beam
- Main pending (technical) issue for Phase 1
- Plans for the shutdown

HIE ISOLDE roadmap 2015

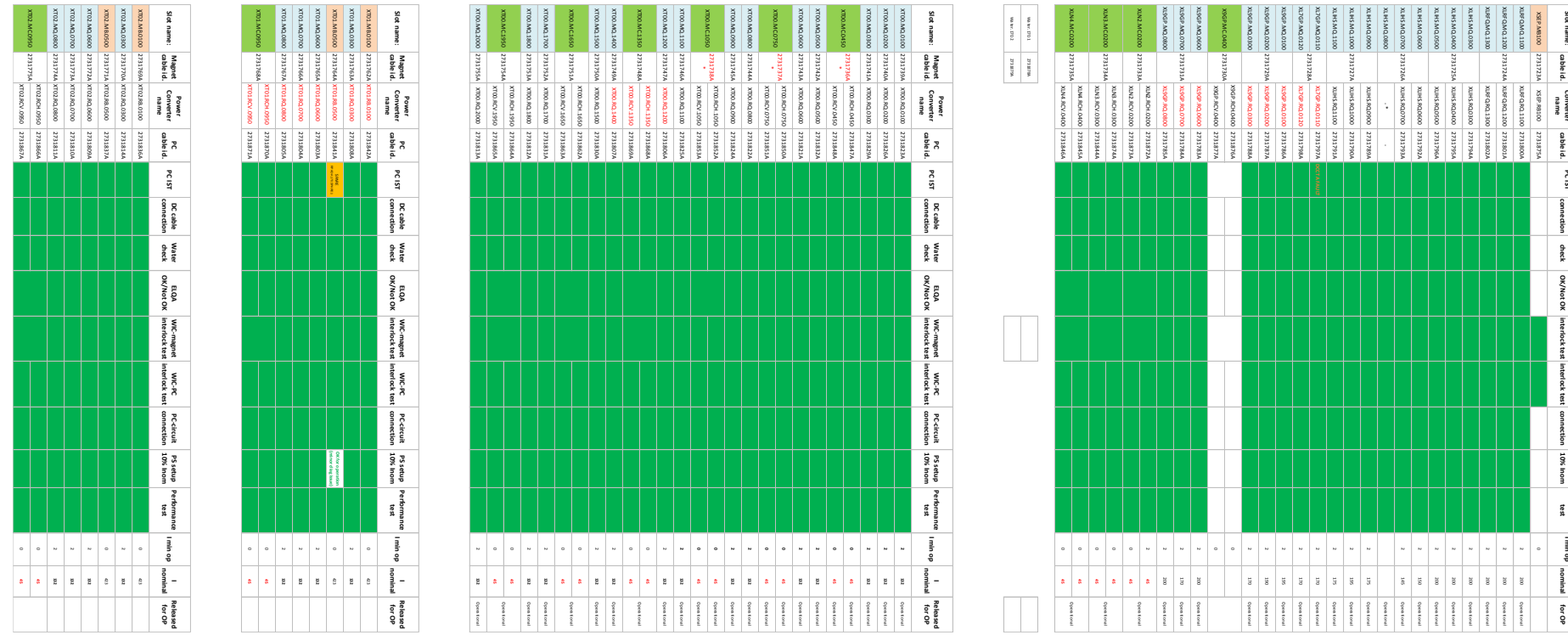


Hardware Commissioning

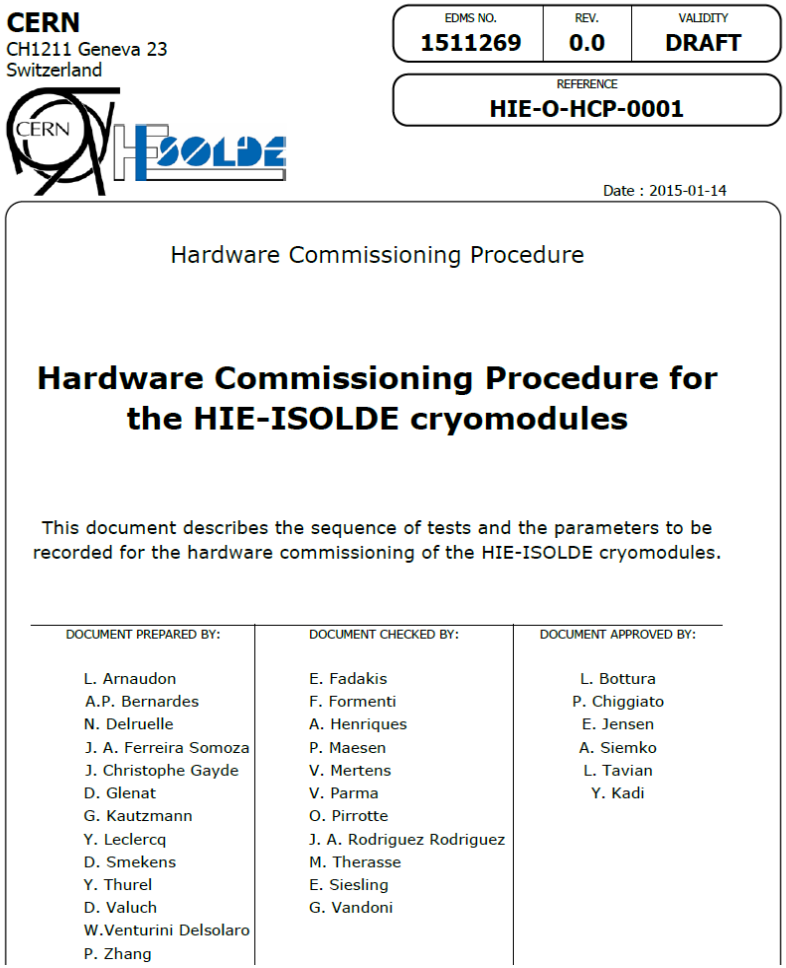
- Goals of HC work:
  - define the envelope of parameters within which the machine could be operated by BE-OP during the physics run
  - Validate software and controls
  - Identify, investigate and document the weak points and limitations preventing hardware to reach nominal performance
- HIMAC Working group gathering all equipment owners with strong involvement of BE-OP
- Accurate preparation work→ written procedures
- For HEBT circuits, we used well oiled LHC methods
- Cryomodule commissioning procedure will be retrofitted with experience of CM1

HEBT commissioning results

- All XT00, XT01 and XT02 circuits released for operation
- Operational currents set for the needs of 2015 physics run
- B field control for dipoles validated



CM 1 main commissioning steps



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Hardware Commissioning Procedure

Hardware Commissioning Procedure for the HIE-ISOLDE cryomodules

This document describes the sequence of tests and the parameters to be recorded for the hardware commissioning of the HIE-ISOLDE cryomodules.

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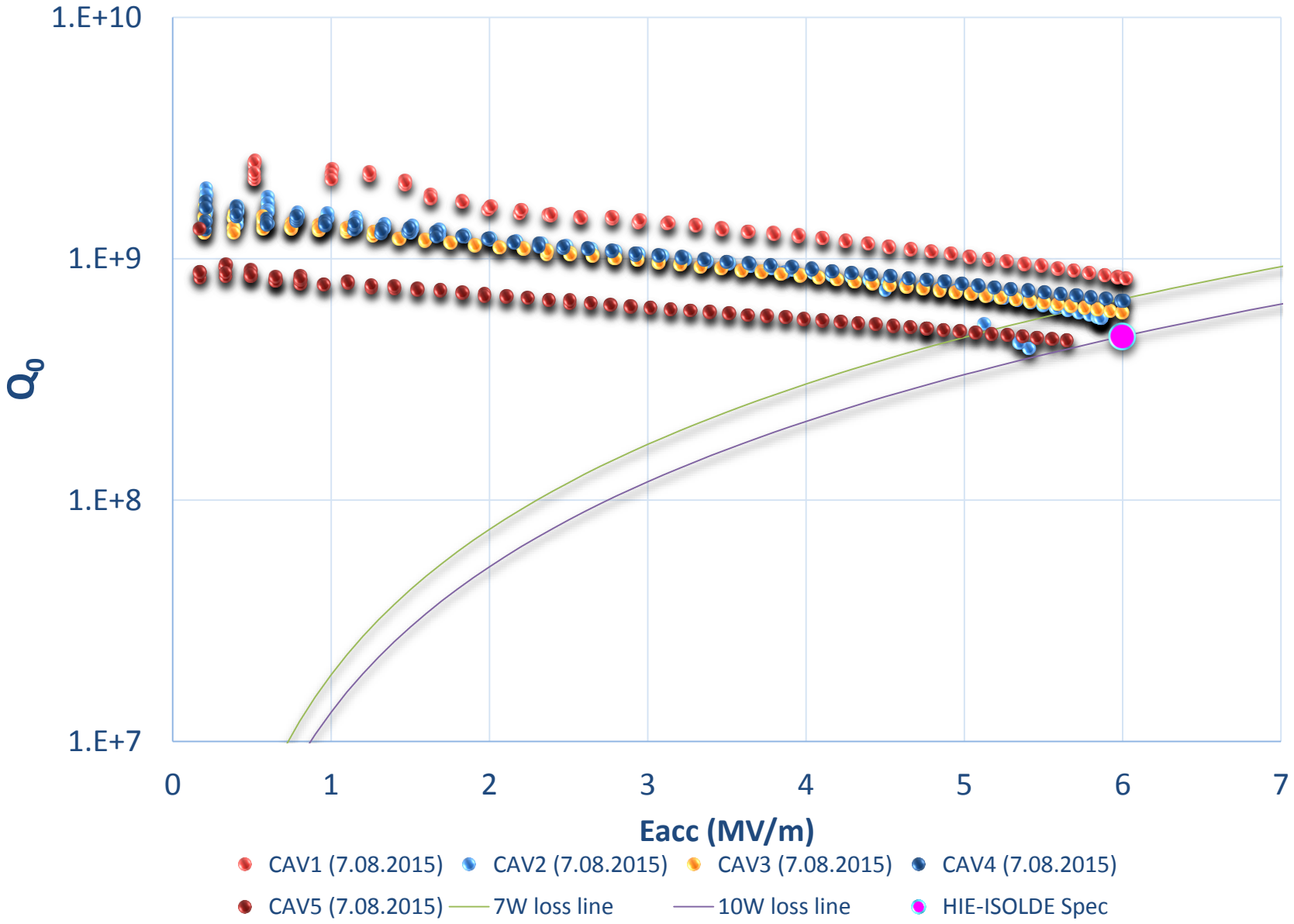
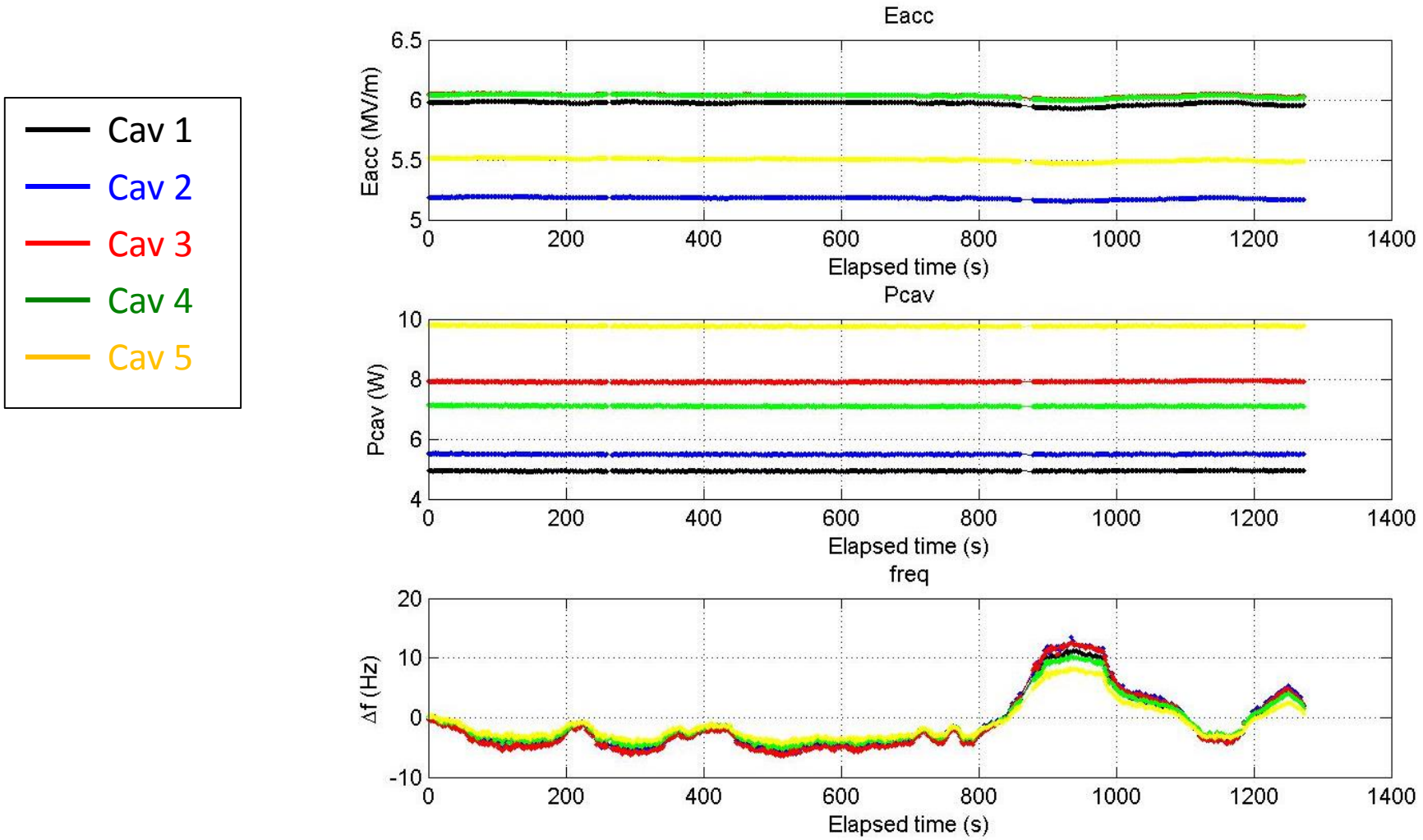
1. Interlock tests
2. Slow pump down
3. RF, Instrumentation, ELQA tests before cool down
4. Low Level RF tests
5. Cool down
6. RF conditioning above Tc
7. RF tests at 4.5 K
8. SC solenoid test
9. Survey and Alignment
10. Heat load measurements
11. Thermal cycles

CM1 cavity test results



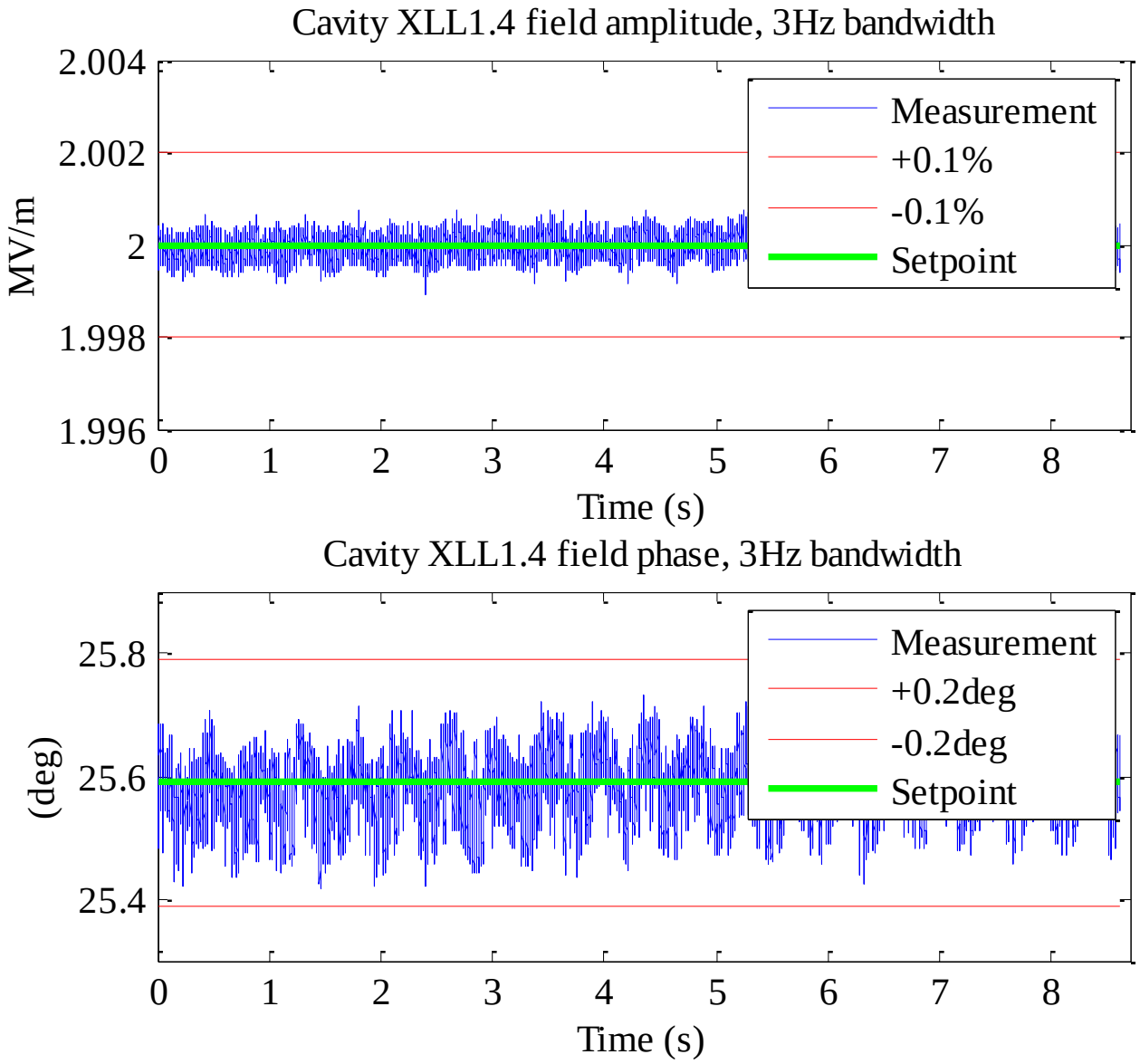
Combined powering of cavities and solenoid



Solenoid current: 0A → 100A → 0A

Pei Zhang

Performance of the LLRF system

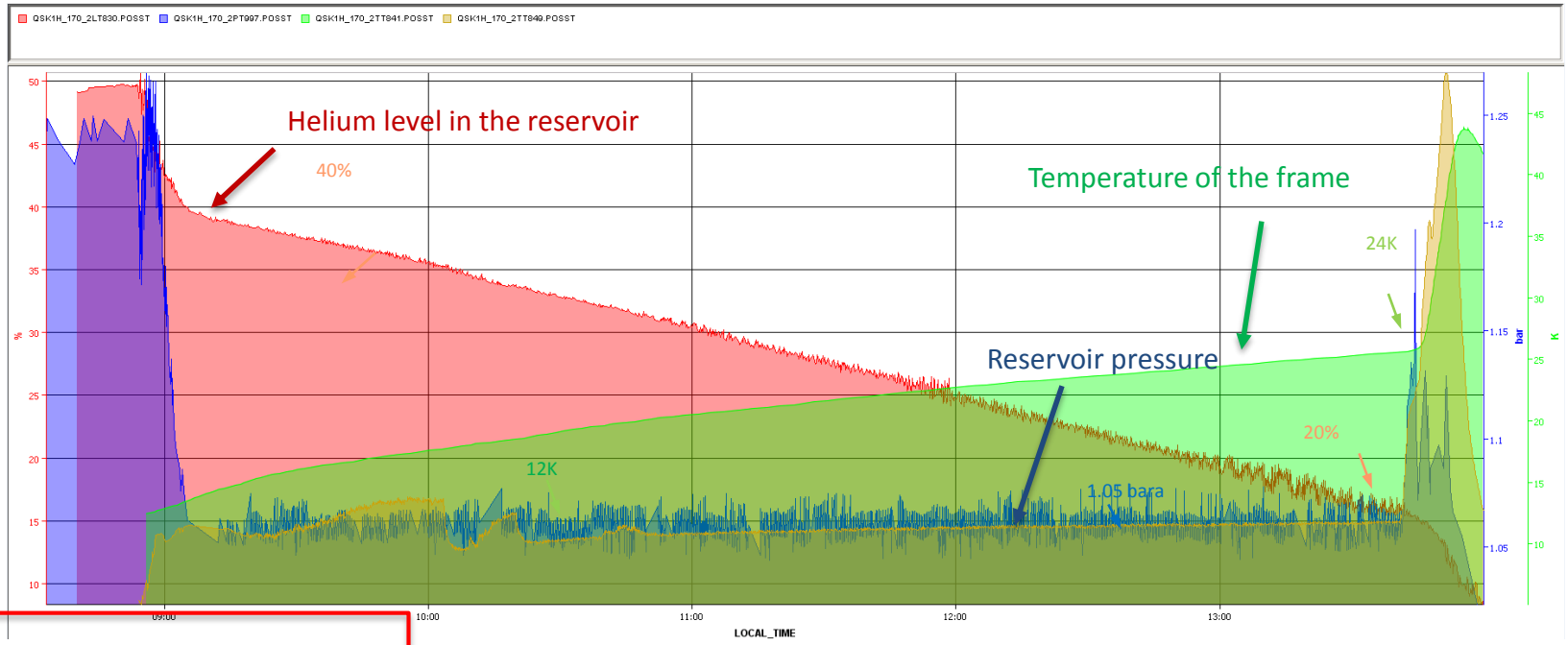


Static heat load measurement at 4.5 K

Distribution of heat into boil-off of liquid and structure warm-up;

Limitation: no flow meter for mass flow monitoring;

Temperatures on Thermal Shield, Cavities/Solenoid, etc. constant during the test;

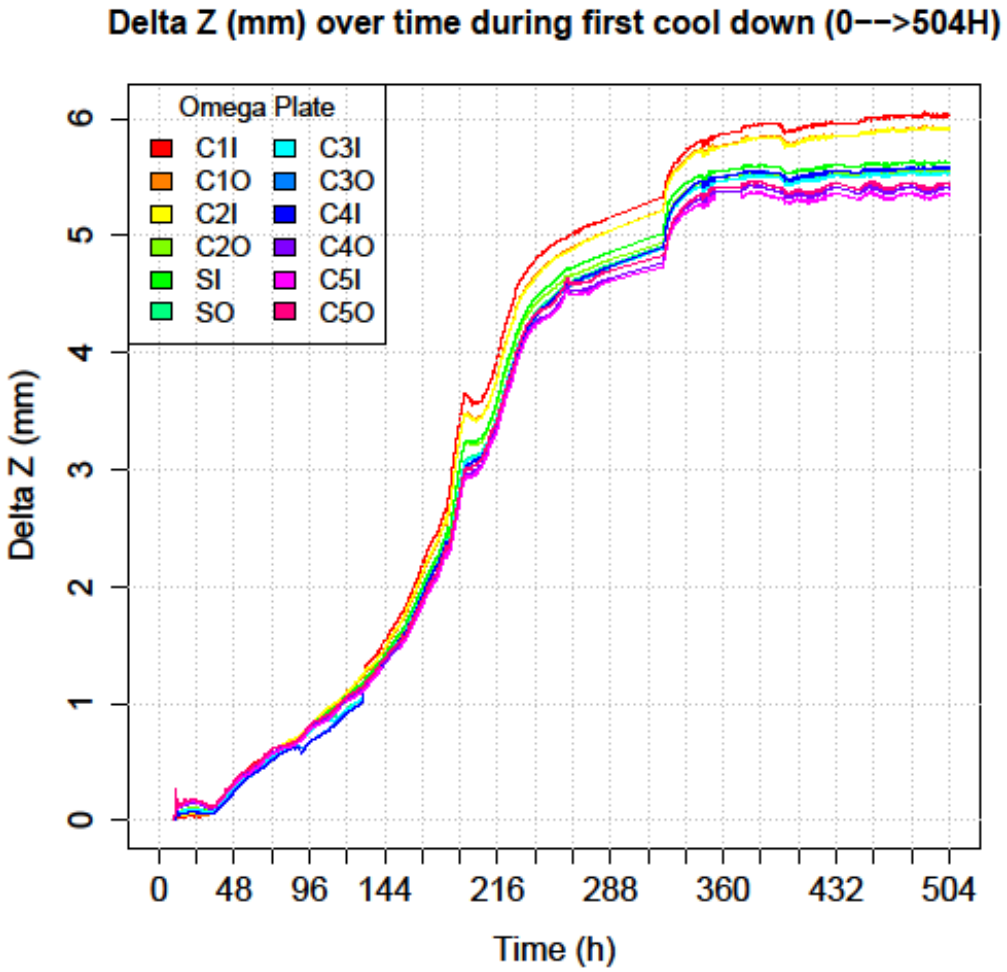


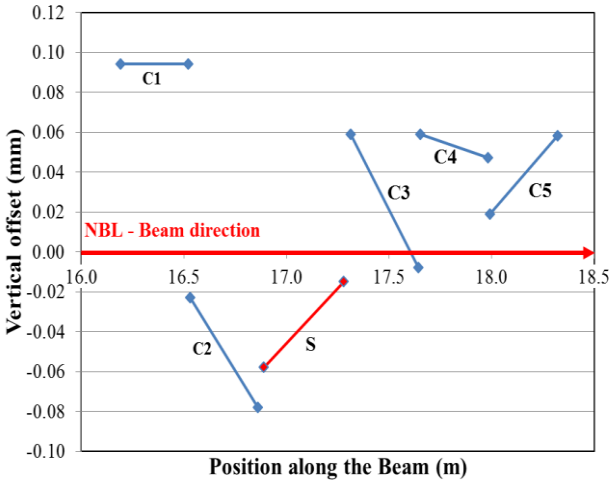
Measurement results:

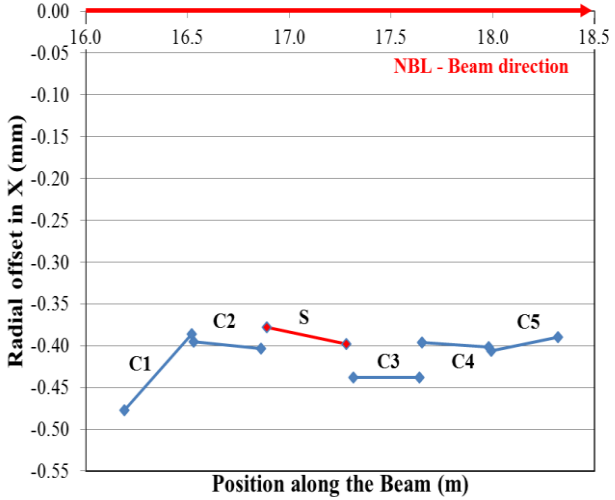
-
-

STATIC HEAT LOAD WITHIN EXPECTATIONS; NO ANOMALY. CRYOSTAT DESIGN QUALIFIED

Survey and alignment

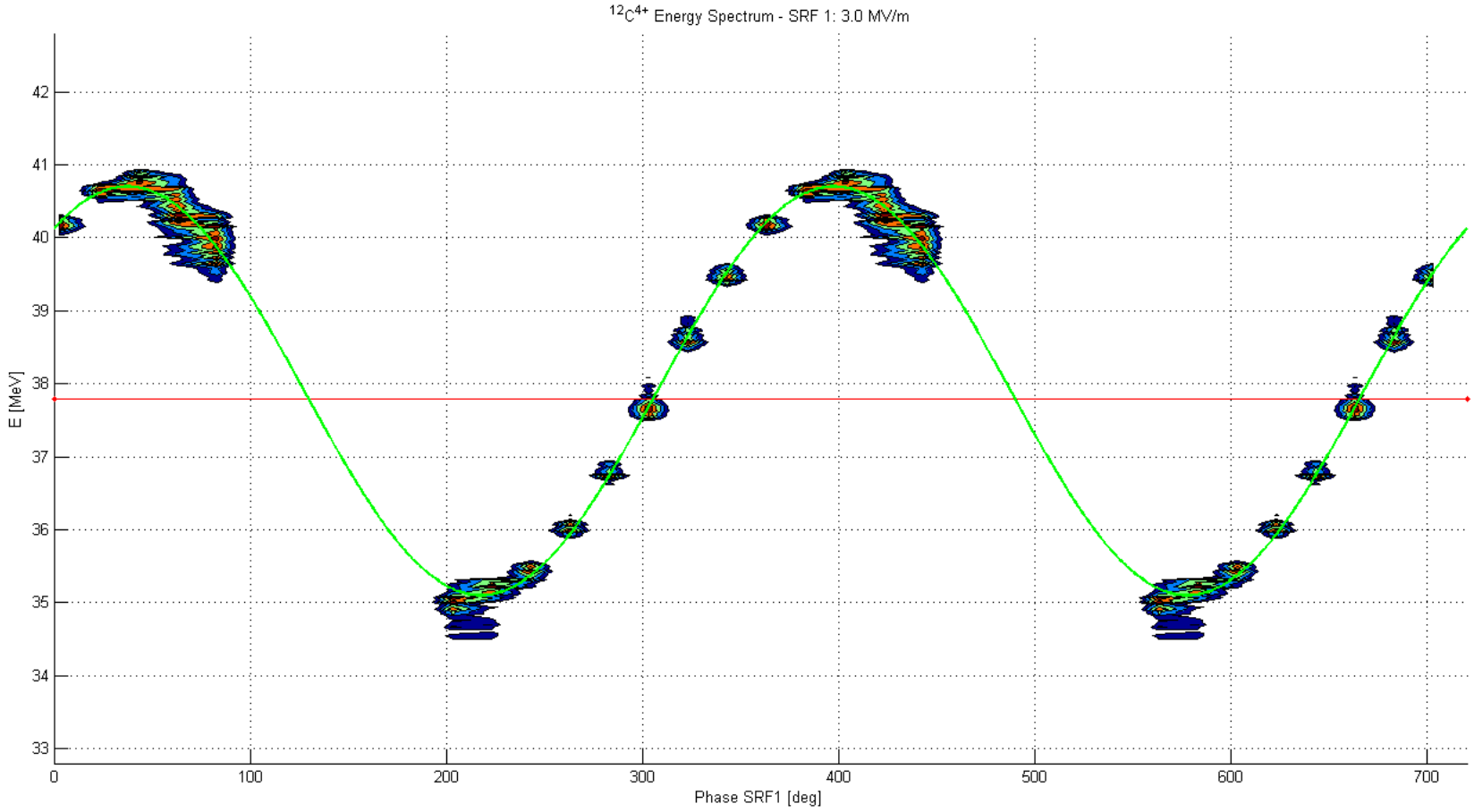




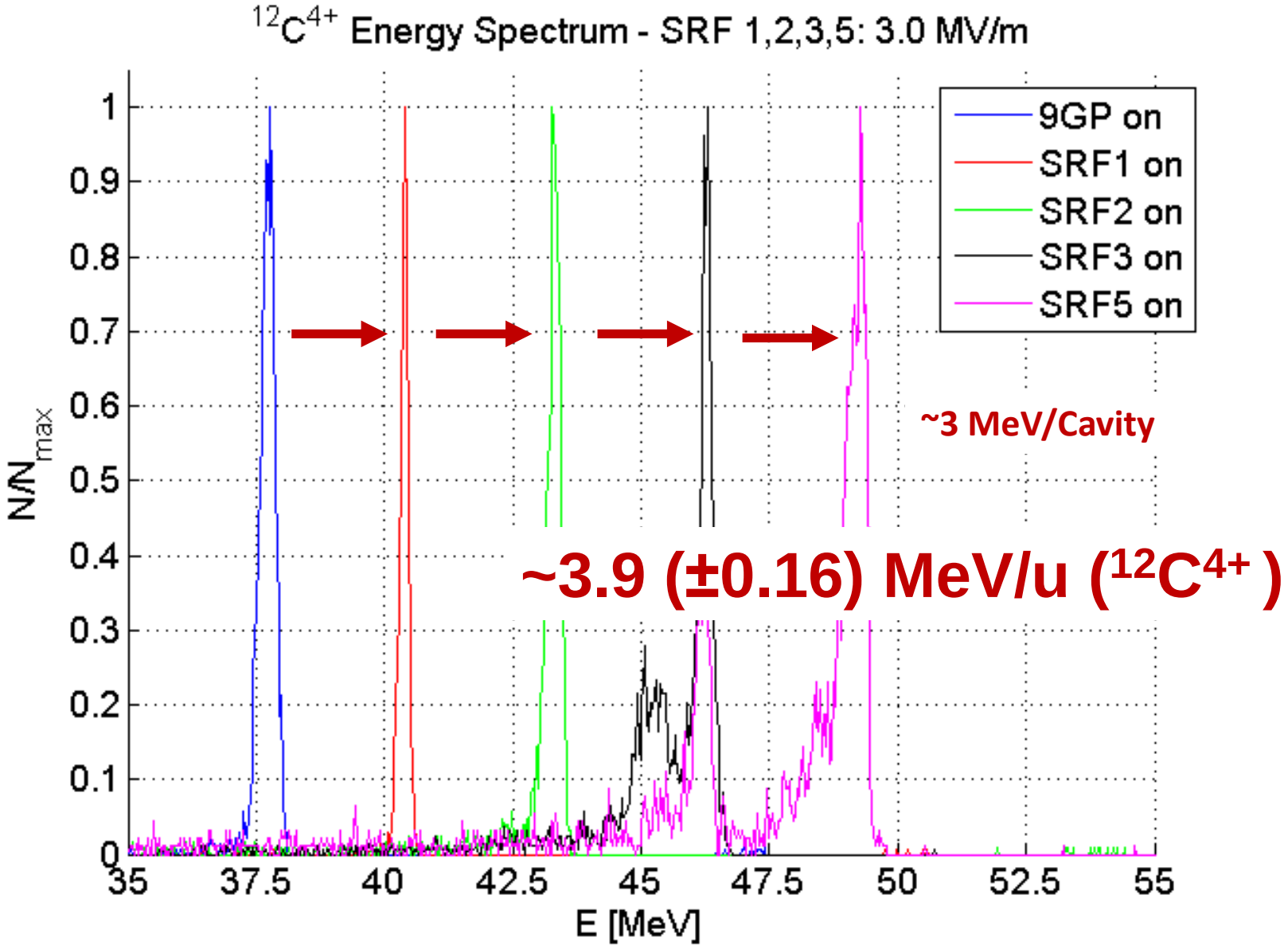


Beam vacuum from REX to the experimental stations

First beam acceleration with a HIE ISOLDE superconducting QWR



Cavity phasing with 4 cavities: first try



Commissioning with beam

Stage 1: REX diagnostics box: w25-w26

- ✓ Commissioning with beam started on June 16th

Stage 2: First HIE-ISOLDE diagnostics box: w27-w33

Stage 3: Commissioning and phasing of RF Structures in REX:

- ✓ Cavities and their amplifiers were commissioned after they were turned on by the RF team
- ✓ Many of the problems listed in previous slides were discovered at this time
- ✓ Finally, operational settings (phases and amplitudes) for all RF cavities were determined

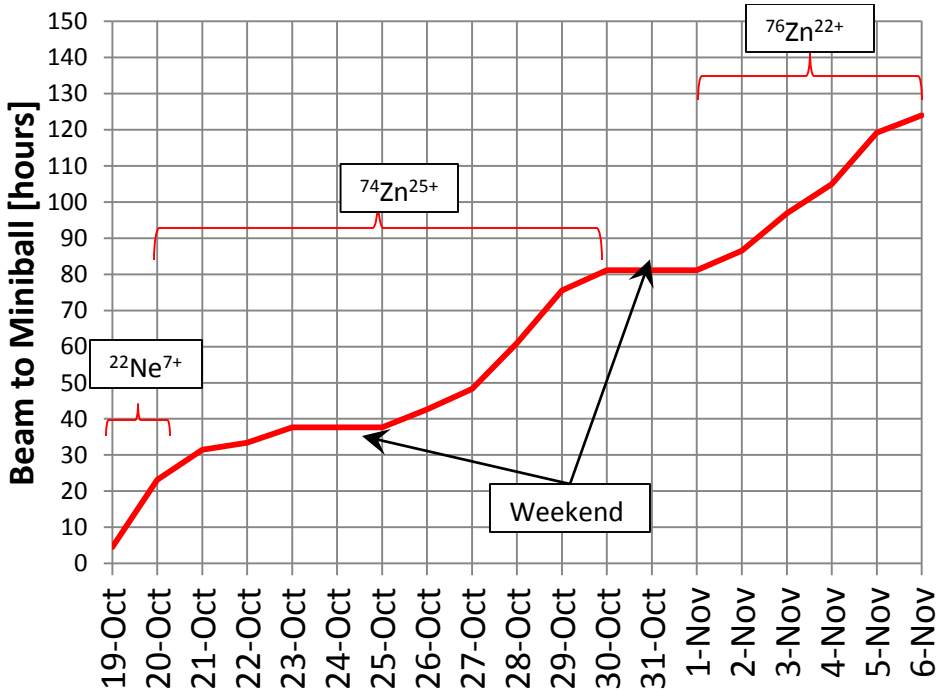
Stage 4: Commissioning the High Energy Beam Transfer (HEBT) line w33-w38:

Stage 5: Acceleration with SRF cavities: w40-w43

- ✓ First attempt to accelerate beam on wk. 40
- ✓ Lots of work to reduce the amount of power needed to reach the necessary gradient and to increase their stability during wk. 40-41
- ✓ All cavities phased for $^{12}C^{4+}$ with a final energy of 4 MeV/u on wk. 42
- ✓ $^{12}C^{4}$ beam with 4 MeV/u transported to the end of XT01 on wk. 43

Operations: Beam to Miniball

- Three different ions delivered to Miniball (one stable and two RIBs)
- Two different energies per nucleon



Week 43	Mon - 19-Oct	$^{22}Ne^{7+}$ - 2.85 MeV/u
	Tue - 20-Oct	
	Wed - 21-Oct	
	Thu - 22-Oct	$^{74}Zn^{25+}$ - 4.0 MeV/u
	Fri - 23-Oct	
Week 44	Mon - 26-Oct	$^{74}Zn^{25+}$ - 4.0 MeV/u $^{74}Zn^{25+}$ - 2.85 MeV/u
	Tue - 27-Oct	
	Wed - 28-Oct	
	Thu - 29-Oct	
	Fri - 30-Oct	
Week 45	Mon - 02-Nov	$^{76}Zn^{22+}$ - 4.0 MeV/u $^{76}Zn^{22+}$ - 2.85 MeV/u
	Tue - 03-Nov	
	Wed - 04-Nov	
	Thu - 05-Nov	
	Fri - 06-Nov	

Ion	Energy [MeV/u]	Ibeam [1E6 pps]	time [hours]
$^{22}Ne^{7+}$	2.85		31.4
$^{74}Zn^{25+}$	2.85	1-2	15.5
$^{74}Zn^{25+}$	4	1-2	34.3
$^{76}Zn^{22+}$	2.85	0.5-1	26.7
$^{76}Zn^{22+}$	4	0.5-1	16.2
Total			124.0

Jose Alberto Rodriguez, BE-OP-PSB (x167538)

Operations: Beam time accounting

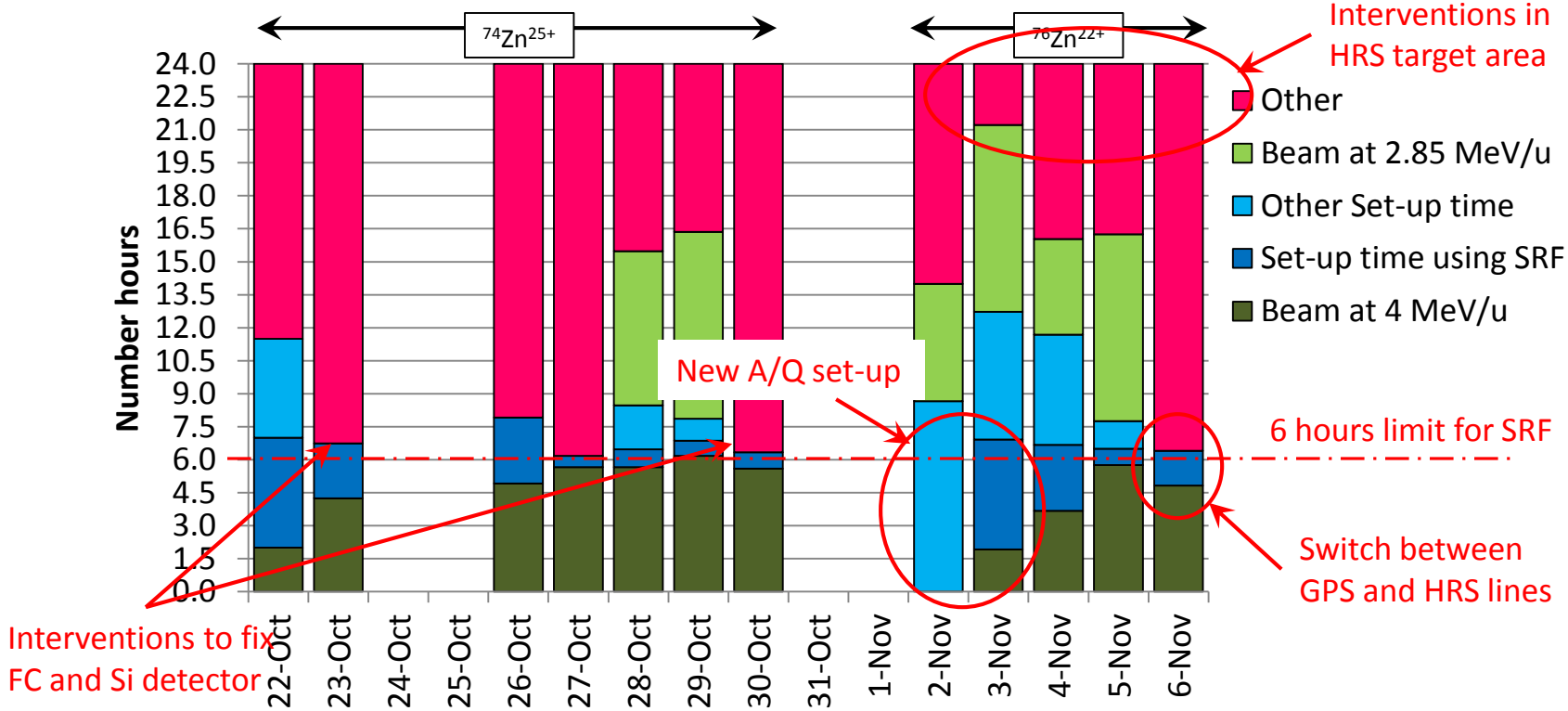
SRF limited to running ~ 6 hours per working day due to heating problem in couplers

Impact of parallel experiments using the other target:

- Delay start-up due to multiple interventions in the target area
- No 2.85 MeV/u energy beam run in the evening or weekend

Two interventions to replace damaged Si detector and fix problem with FC on Fridays

Approximately 2.5 days needed for a non-scalable new A/Q set-up of the machine



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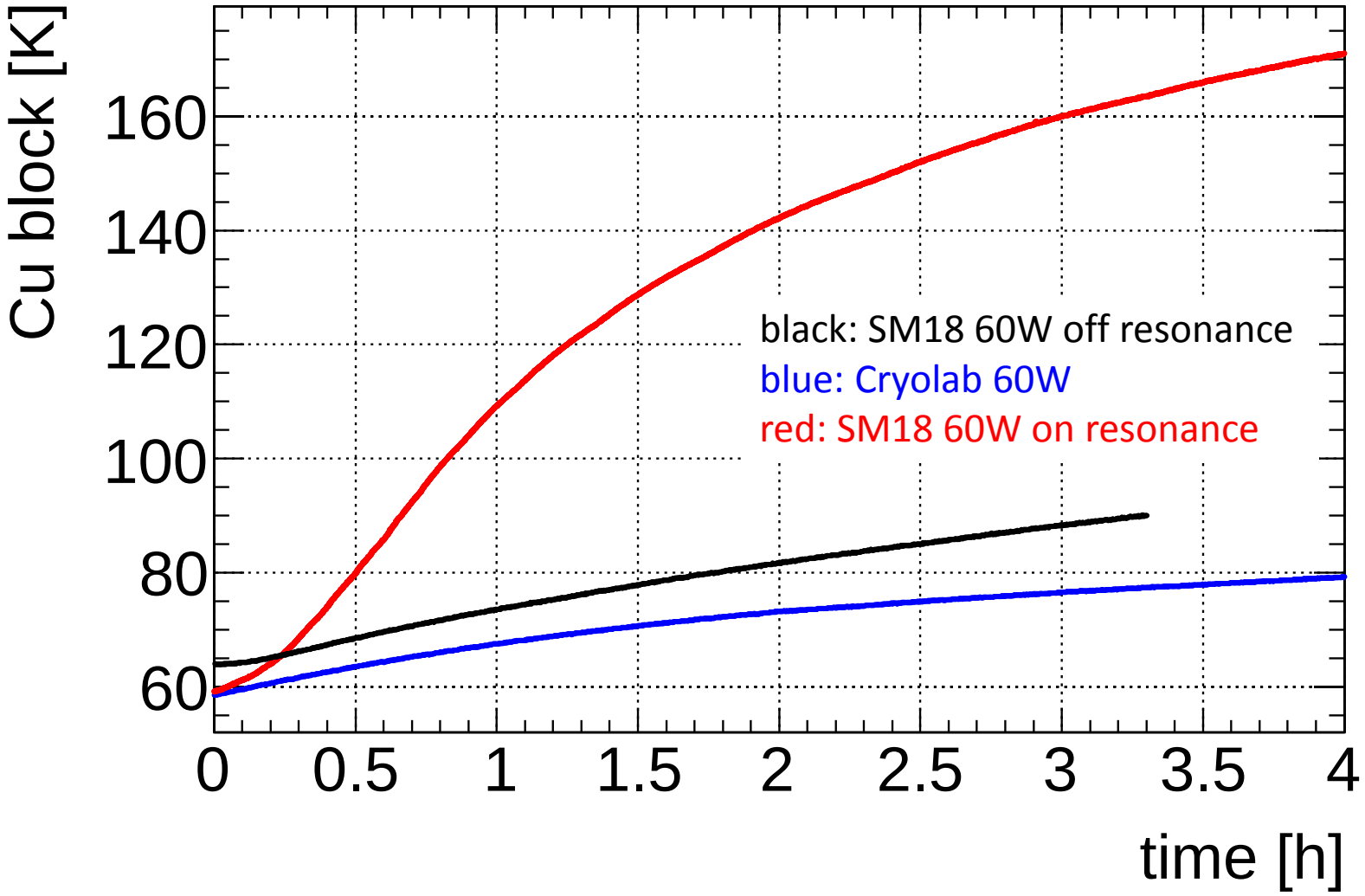
PENDING ISSUE(S)

RF couplers issue: recap

- First observations in CM1: RF shifts → thermal expansion hypothesis
- Near-failure in CM1
- Cold test1 at SM18 (failure at 200 W)
- Looking for source of heat in the coupler
- Comparative survey of LNL and TRIUMF solutions
- Failure tests of antennas in oven to find limit temperature
- Cold test2 at SM18: copper braid thermalization on coupler OK
- Vacuum calculations + warm test bench (plasma hypothesis challenged)
- DC current measurements (plasma hypothesis revived)
- Thermal + RF models (ANSYS + CST)
- Cold test3 at SM18 (60 W): incipient failure
- Cold test at Cryo-lab reproducing CM1 thermalization
- Benchmarking thermal simulations
- Cold test 4 at SM18: modified coupler (Bz4→ Cu-Be, Macor→ Shapal, holes)
- New detailed RF simulations of antenna tip fields

The problem

Cold test4 at SM18



Preliminary conclusions and actions taken

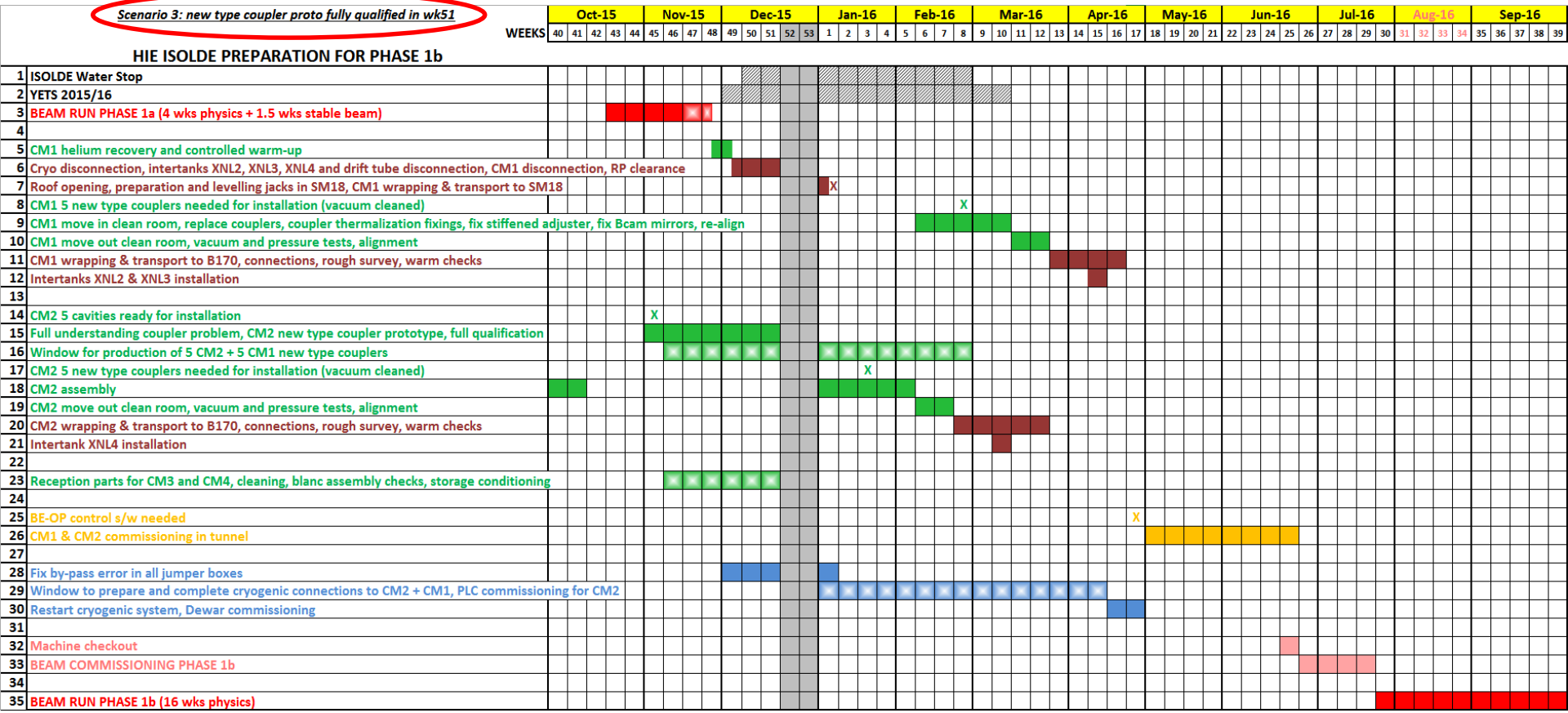
- Triggering phenomenon is pure RF heating
- Glow discharge, if present was due to consequent outgassing
- Key is cooling of the coupler antenna
- New thermalization of copper and cable launched
- Change antenna material (Cu OFE), weld antenna to cable
- Crash program: need to test new solution asap (critical path)

Next steps, directions for 2016

- Design & procurement of parts for CM2 and CM1 (ongoing)
- Uninstall CM1 before Christmas
- Full validation in SM18 of coupler solution
- Cold test new couplers
- Install cavities and ancillaries in CM2 (now on hold)
- If possible, condition parts for CM3
- Carry out cryogenics works over the winter
- Ship CM2 to ISOLDE, retrofit CM1
- Ship CM1 to ISOLDE
- Recommissioning of CM1+CM2
- Goal: start physics at 5.5 MeV/u (Phase1) in Summer 2016

Planning end-of-year & shutdown

F. Formenti



Based on having a new type of coupler fully qualified by WK51

Commissioning with beam

Even though a basic program of commissioning with beam has been completed, there are still many tests and measurements that need to be conducted:

- Beam to XT02 (tentatively on week 47)
- New RF amplifier for 9gap structure (tentatively early 2016)
- Characterize the behavior of REX's amplifiers at a higher peak and average power
- Understand limits in machine scalability (A/Q and energy)
- Understand sources of beam losses and improve beam transmission
- Systematic checks with beam of polarities of all optics magnetic elements
- Complete the final implementation and commission the field regulation of the power converters for the dipole magnets
- Systematic commissioning of all the devices in the beam diagnostics boxes
- Individual calibration of each Faraday cup
- TOF sytem
- Finalize and commission the beam diagnostics high level control application
- Complete the cross-calibration of SRF cavities, Si detectors and the dipole magnets. Determine error bars in beam energy measurements
- Systematic measurements of beam properties (e.g. emittance, Courant-Snyder parameters…)
- Benchmarking optics model and implement modifications if necessary

Conclusions

- The 2015 Hardware Commissioning campaign achieved its goals:
  - Envelopes for OP defined
  - Software & Controls operational
  - Weaknesses and limits identified and investigated
- CM design choices validated:
  - Cavity cleanliness preserved during assembly
  - Heat loads according to specs.
  - Alignment specifications fulfilled
- SC cavities field measurements confirmed with beam
- RF input lines/coupler problem identified, being addressed
- **Physics run started on 19th October, on schedule**
- Beam Commissioning was limited to the bone: to be revised for 2016!
- (Ambitious) draft planning leading into 2016 physics run is available