Status of HIE ISOLDE:
SC linac commissioning and production of spare cavities set

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On behalf of the HIE ISOLDE teams

82nd ISOLDE Collaboration Committee meeting, CERN, 26 June 2018

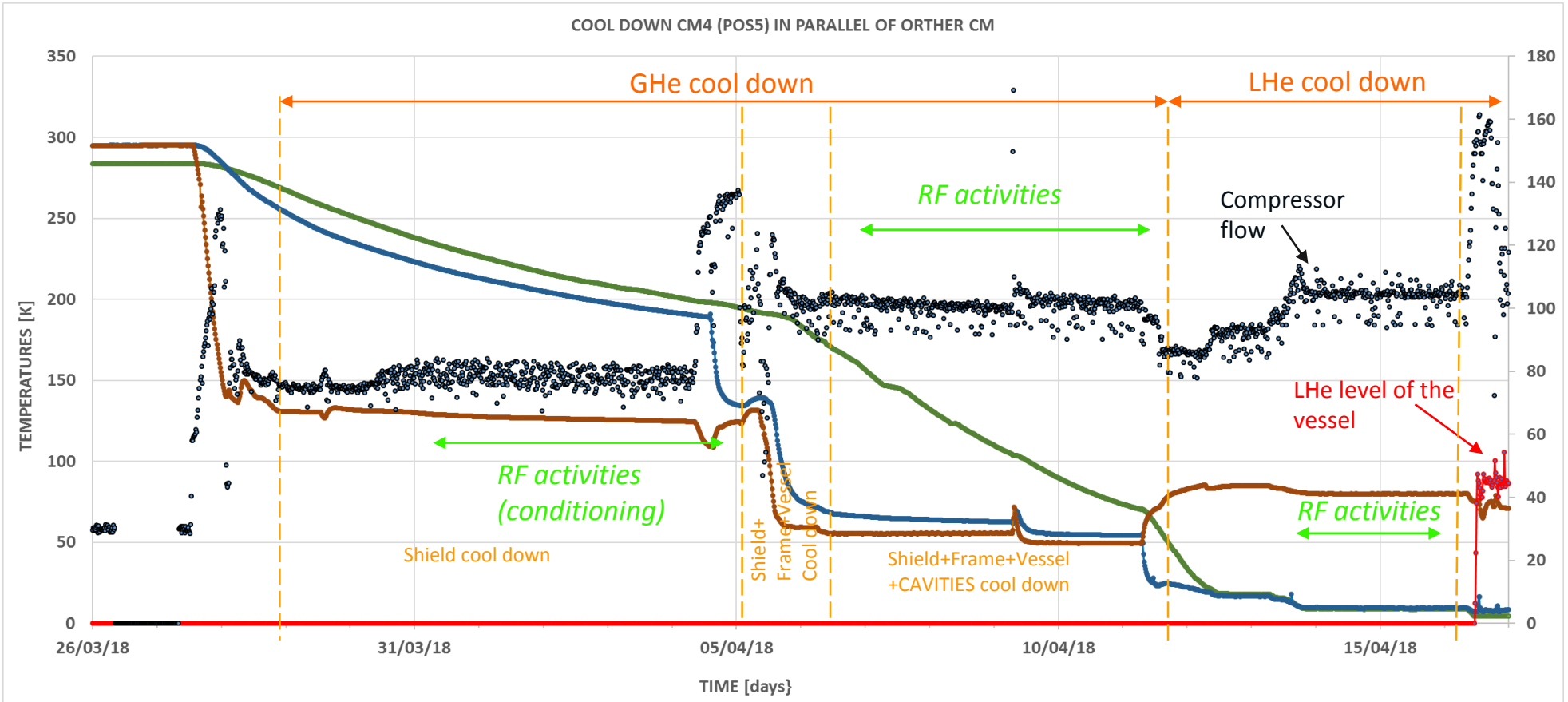
HIE ISOLDE phase II completed

Hardware commissioning sequence

1 INTERLOCK TESTS
2 SLOW PUMP DOWN
3 RF, INSTRUMENTATION AND ELQA CHECKS BEFORE COOL DOWN
4 LLRF TESTS
5 COOL DOWN
6 ALIGNMENT MONITORING AND CORRECTION
7 RF CONDITIONING ABOVE TC
8 RF TESTS AT COLD
9 SOLENOID TESTS
10 HEAT LOAD MEASUREMENTS
11 THERMAL CYCLES

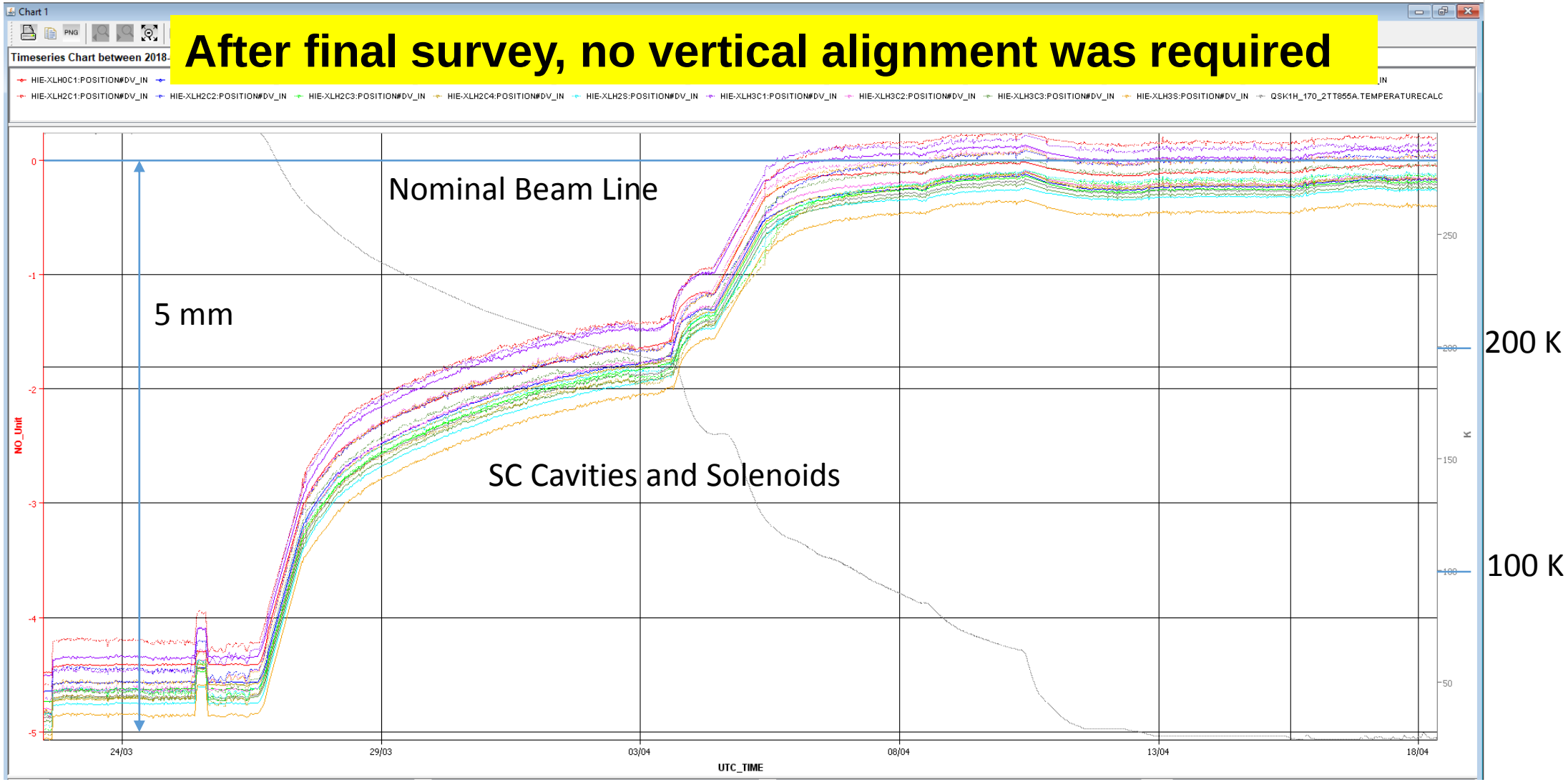
2018 hardware commissioning campaign finished on time

Overview of 2018 cool down with 4 CM

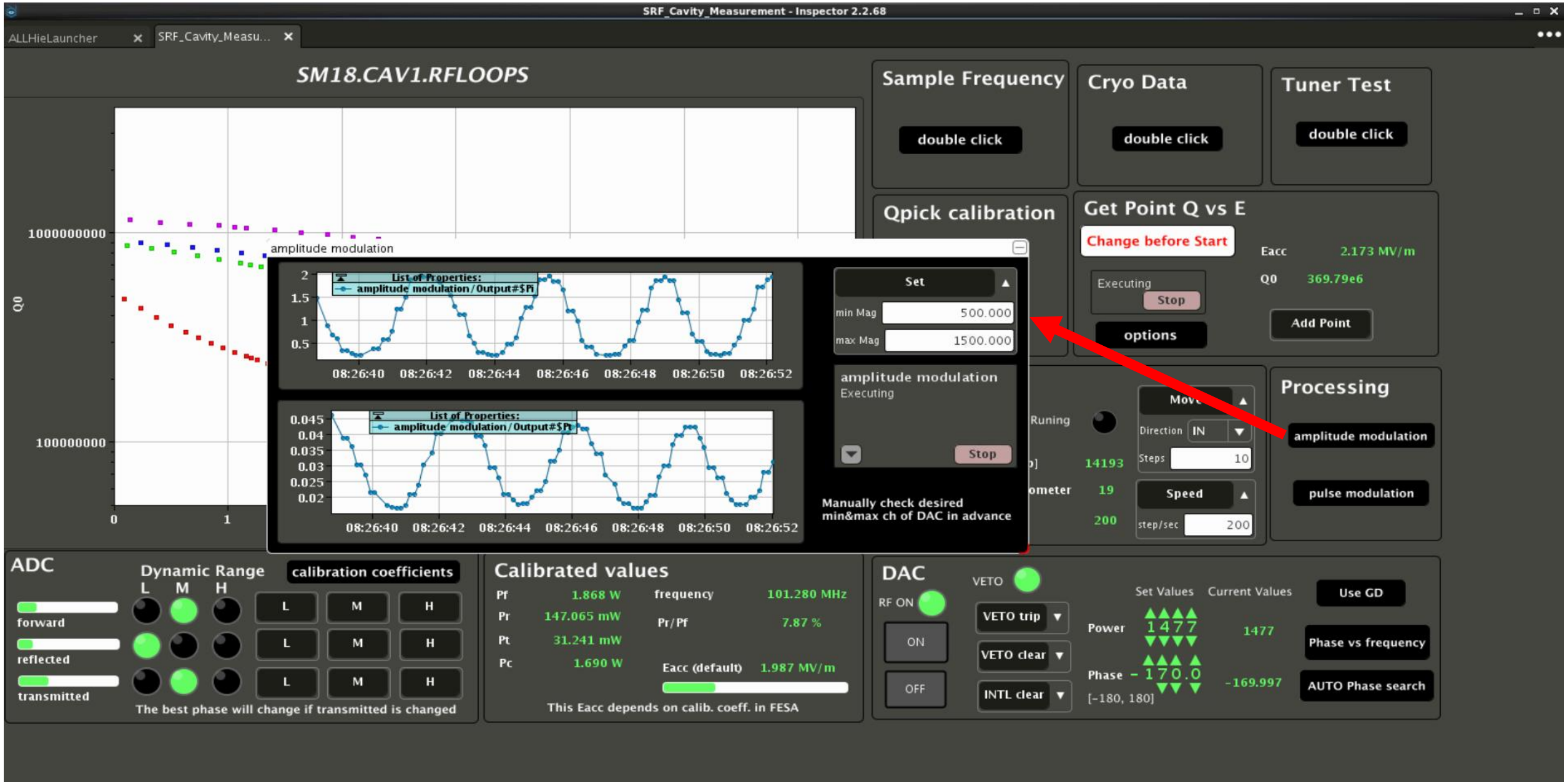


- **Repairs of cryogenics distribution line during winter stop have paid off**
- **Full cool down from room T in ~ 3 weeks, including stop for RF conditioning**
- **Optimization of thermal gradients… almost right ;-)**
- **Anomalous static heat load in CM2, still not understood**

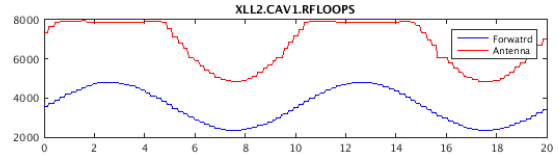
Monitoring vertical positions during cool-down

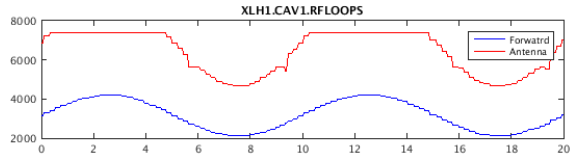


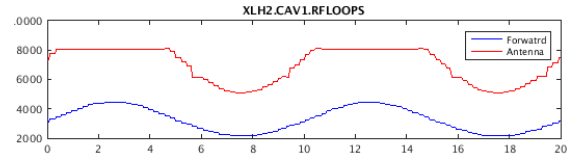
Cavity processing: amplitude modulation for MP cond.

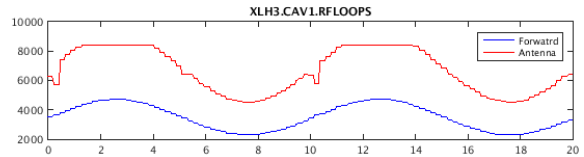


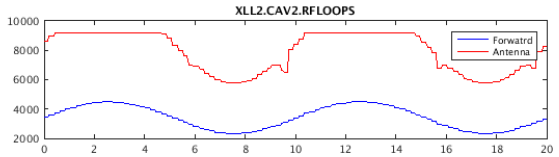
Multipacting conditioning above Tc

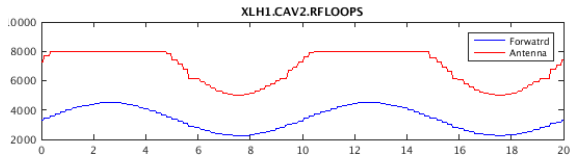


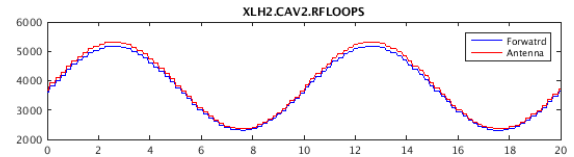


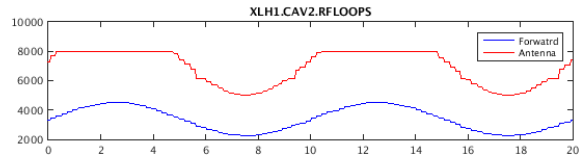


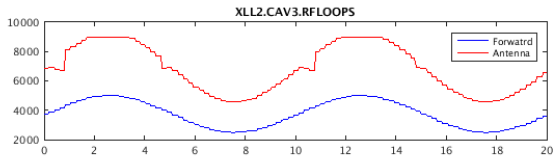


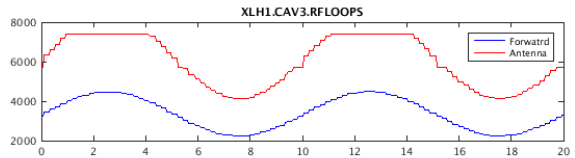


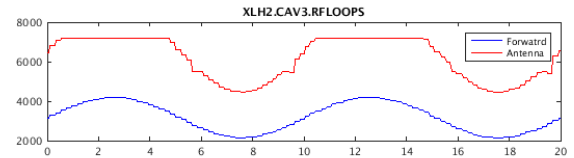


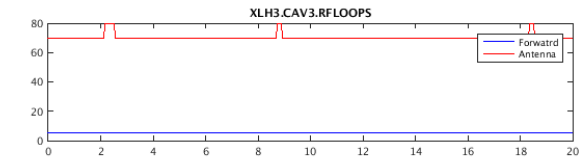


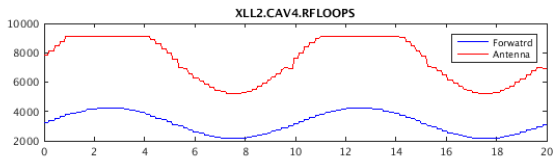


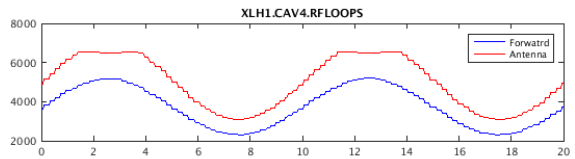


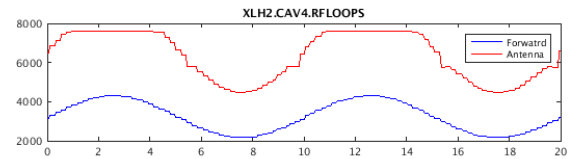


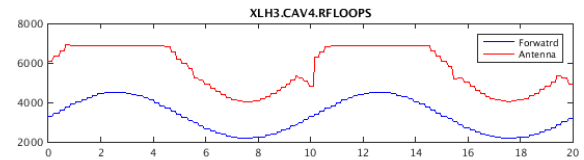


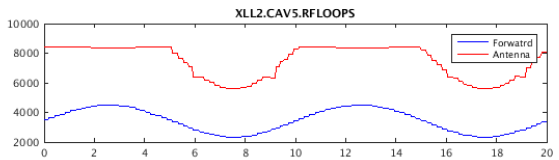


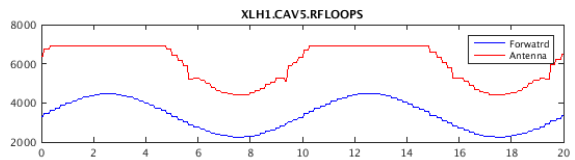


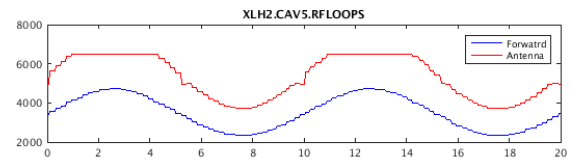


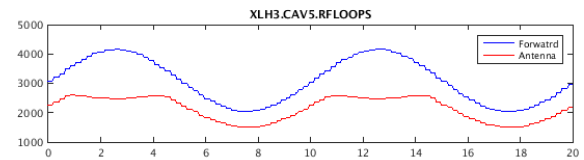




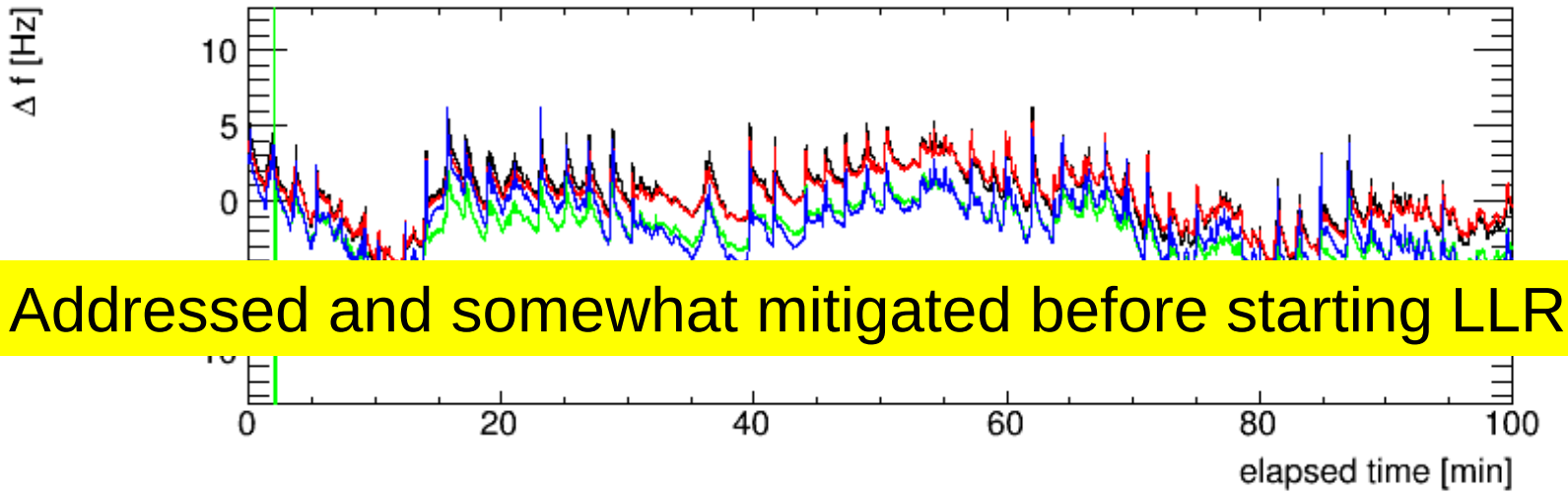




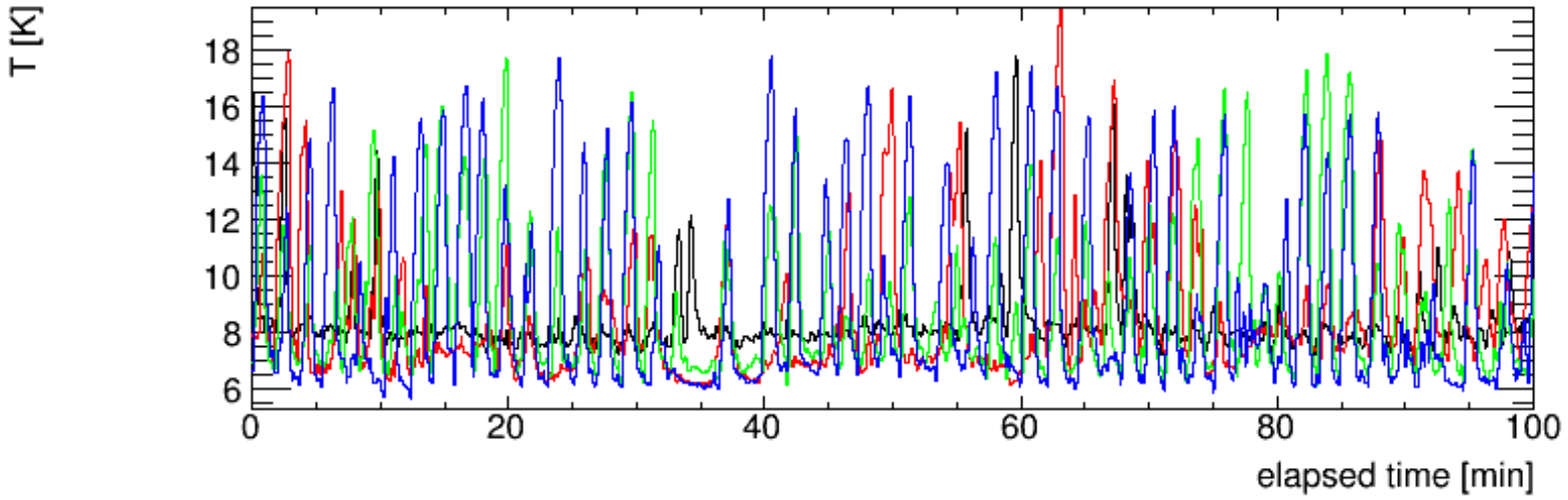




Cavity detuning and cryo-plant tuning up

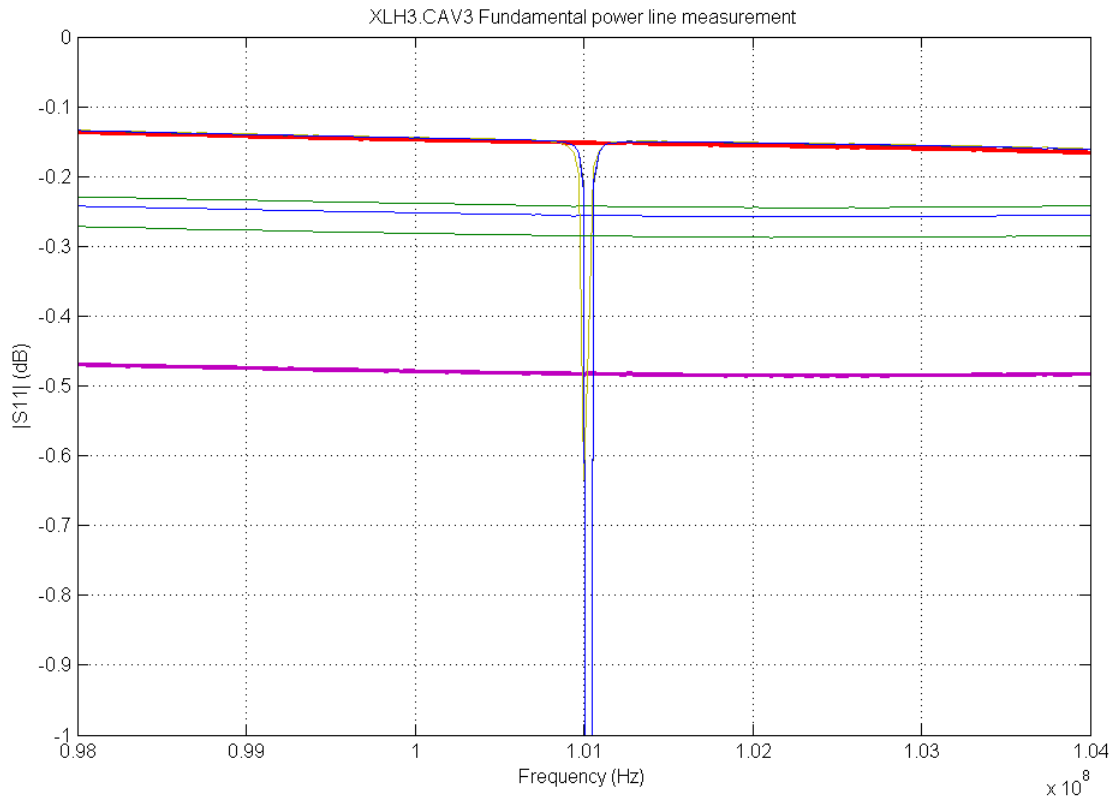


Addressed and somewhat mitigated before starting LLRF work

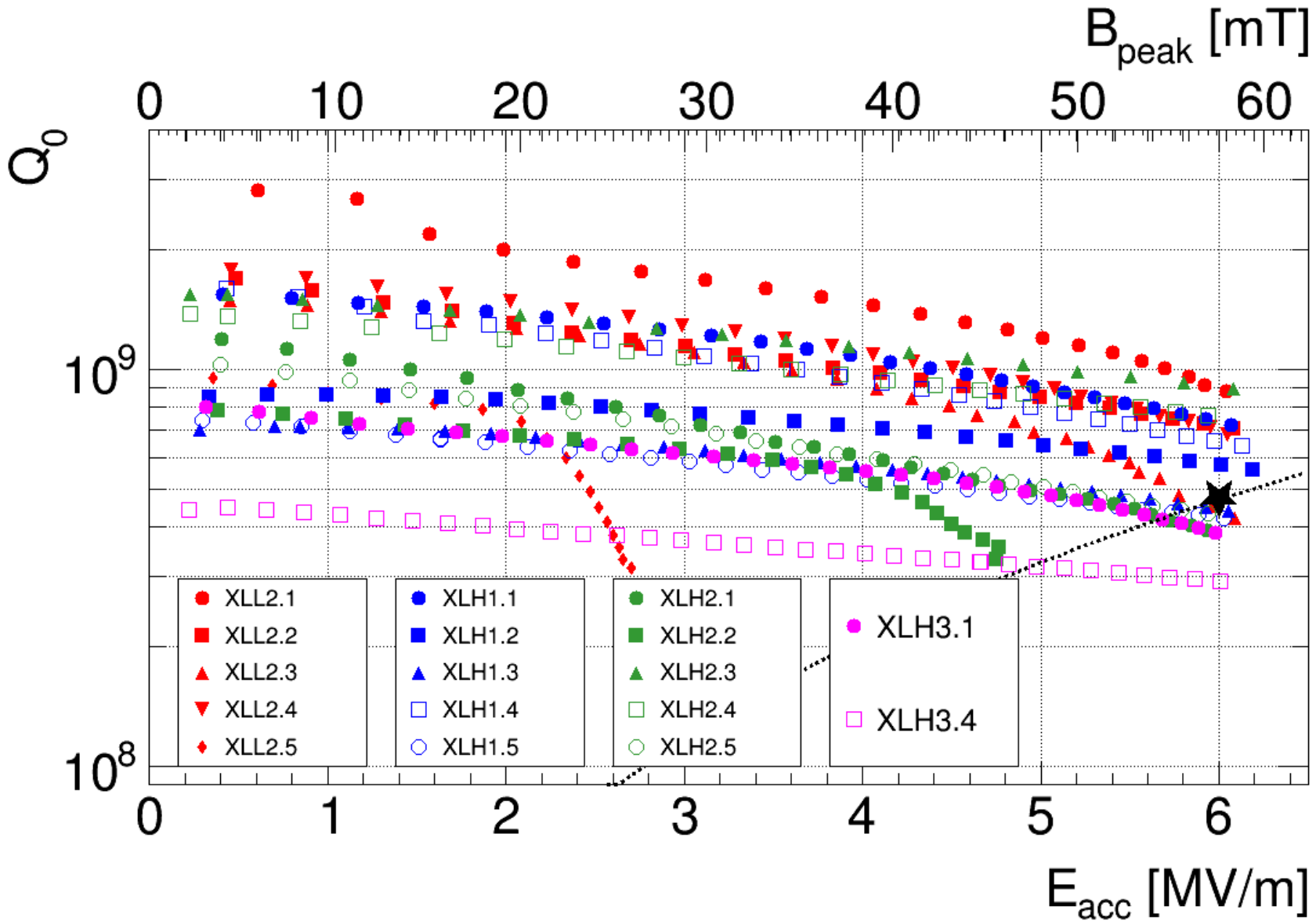


XLH3.CAV3 anomaly

- After cool down to 200 K it turned out, it is not possible to inject power into Cavity 3 of CM4
- Warm measurement were normal
- Investigations narrowed down the problem to the connection to the fundamental power coupler
- There is a range of states from good contact and power passing, through 3dB dissipated in the fault to full reflection
- We decided not to put power in this cavity: the risk is to contaminate the whole cryomodule in case of release of material in the common vacuum



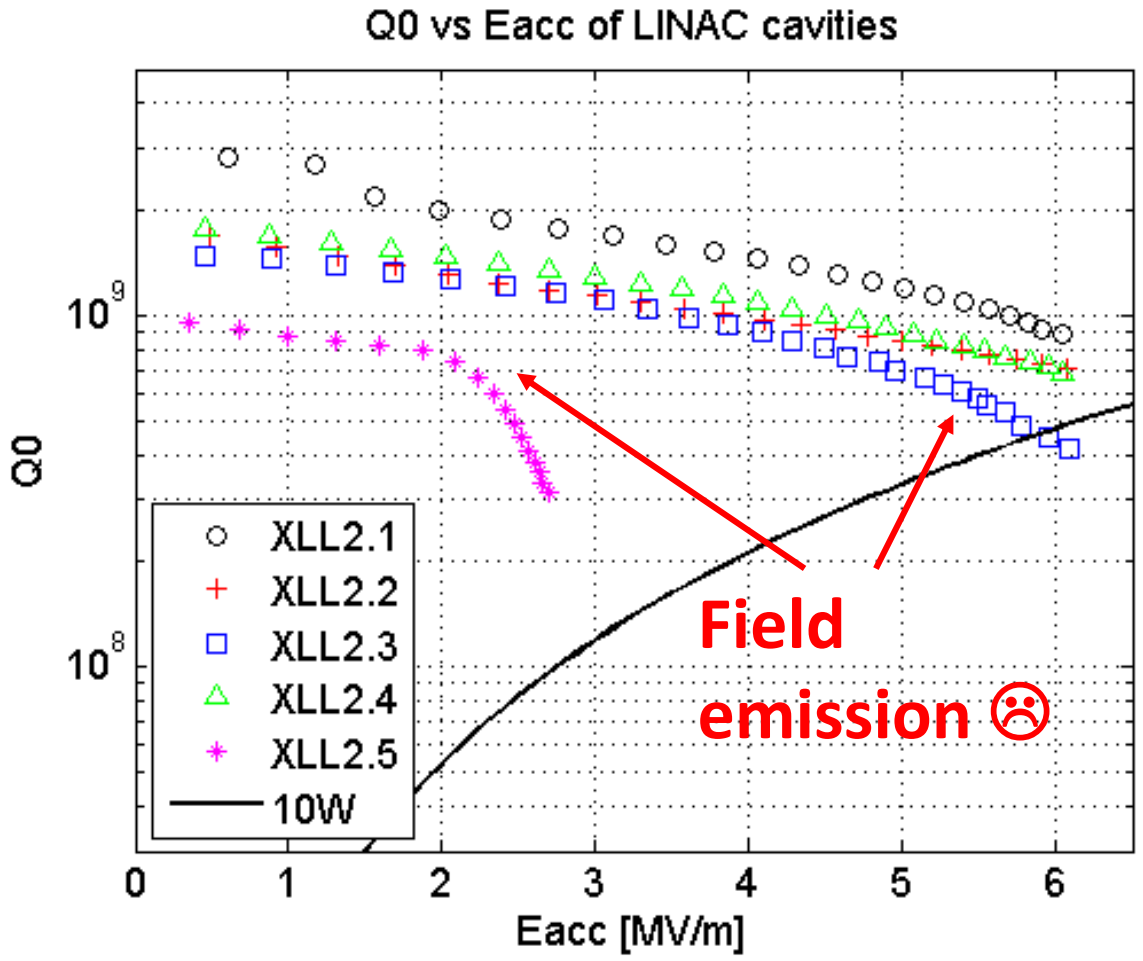
Cavity performances



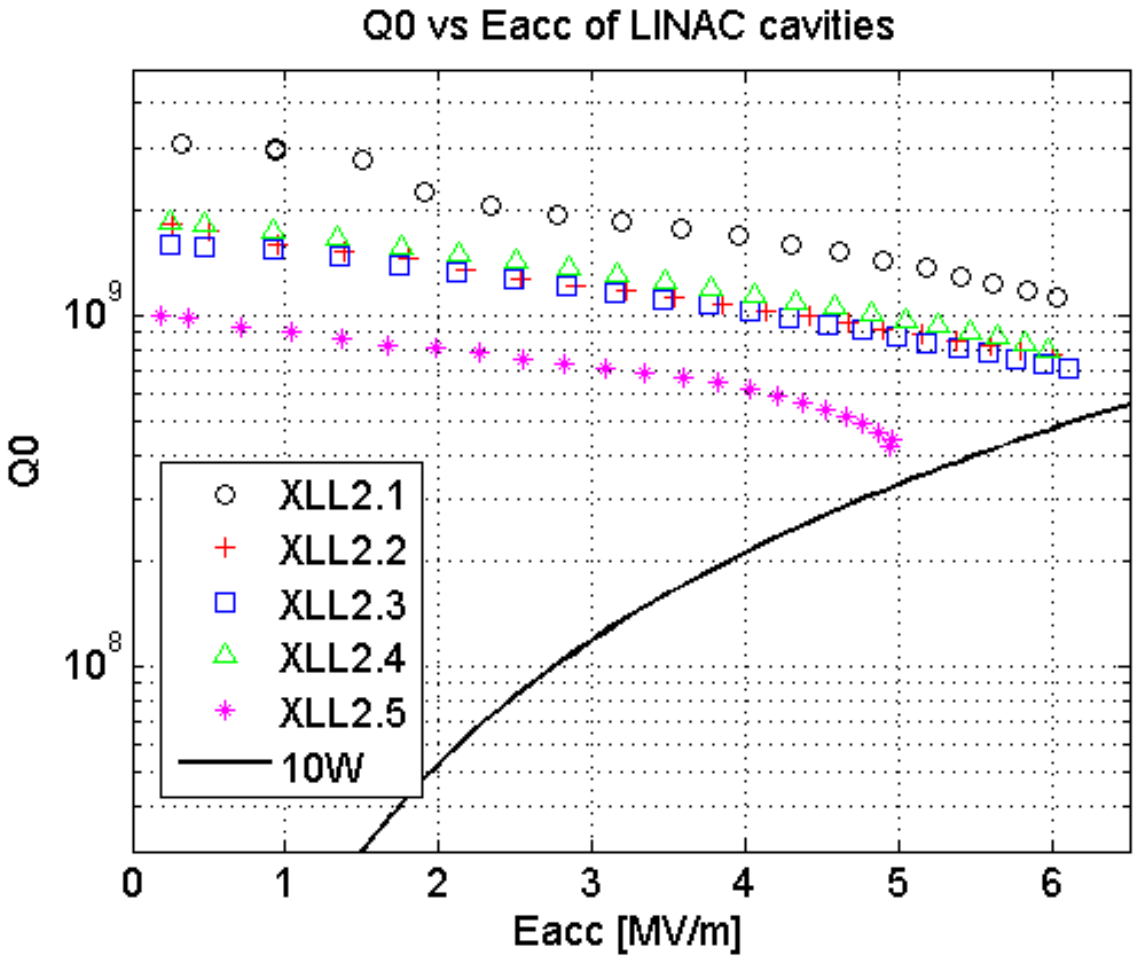
- Cool down gradients over Tc less favourable than in the past
- Most cavities reaching 6 MV/m above specified Q
- 3 cases of field emission (one new). For the moment, no He processing
- CAV3 of CM4 will not be used in 2018

CM1

This year



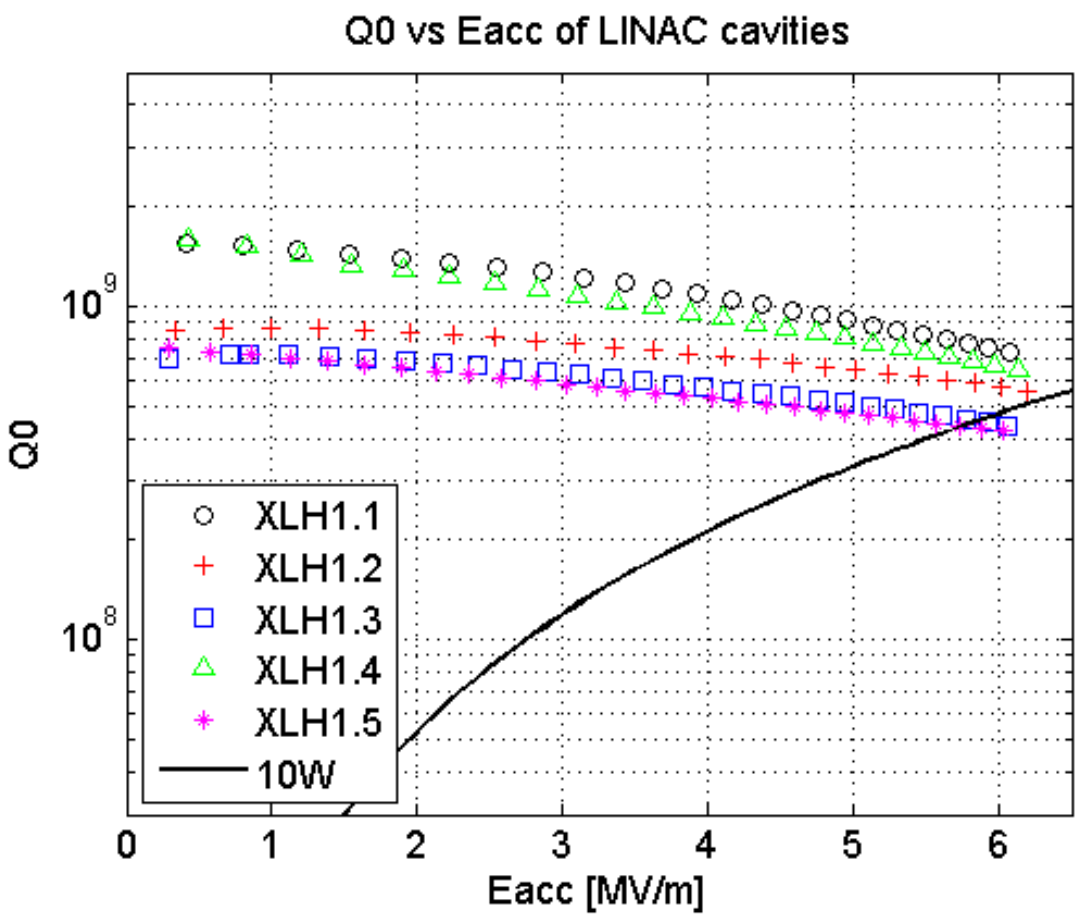
Last year



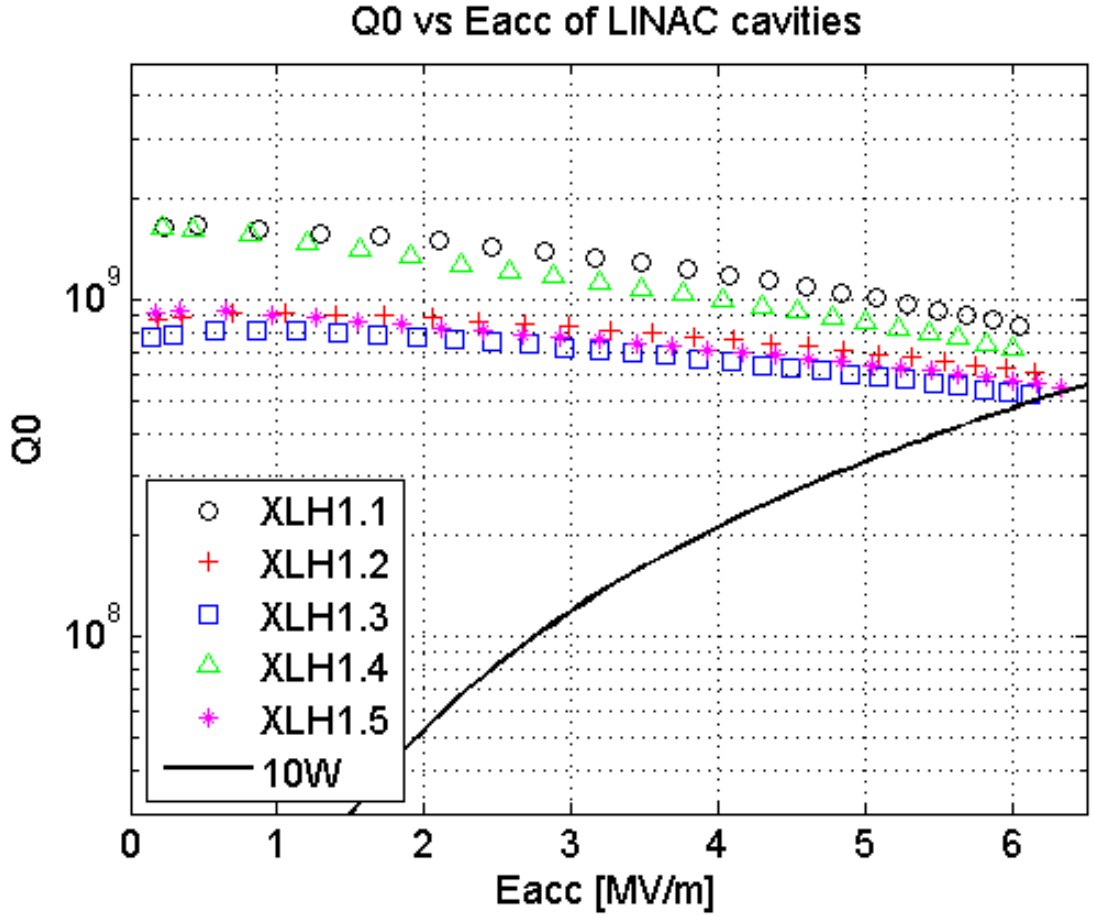
Performance is comparable but contamination produced when coupler was changed at the end of 2015 is still present and a different cavity shows field emission

CM2

This year



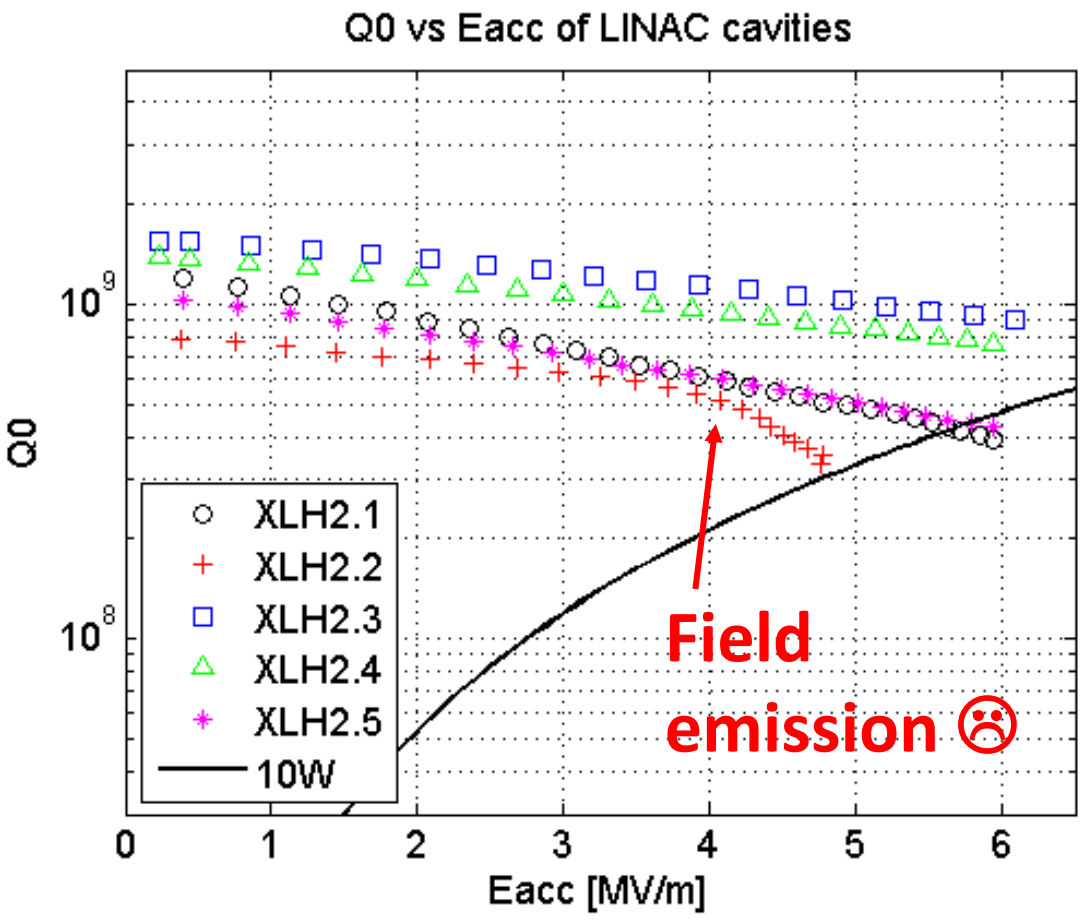
Last year



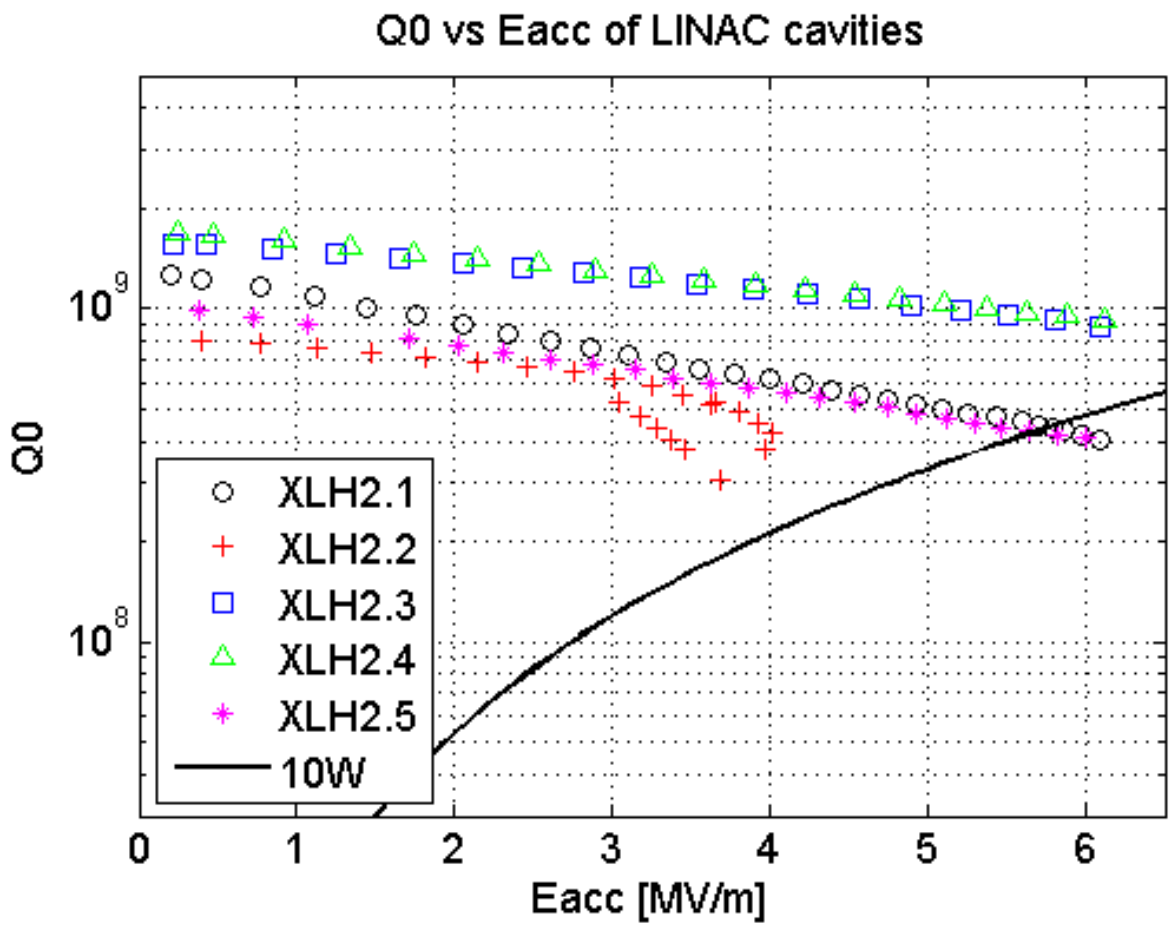
Comparable result (slightly worse Q caused by slightly worse cool down)

CM3

This year



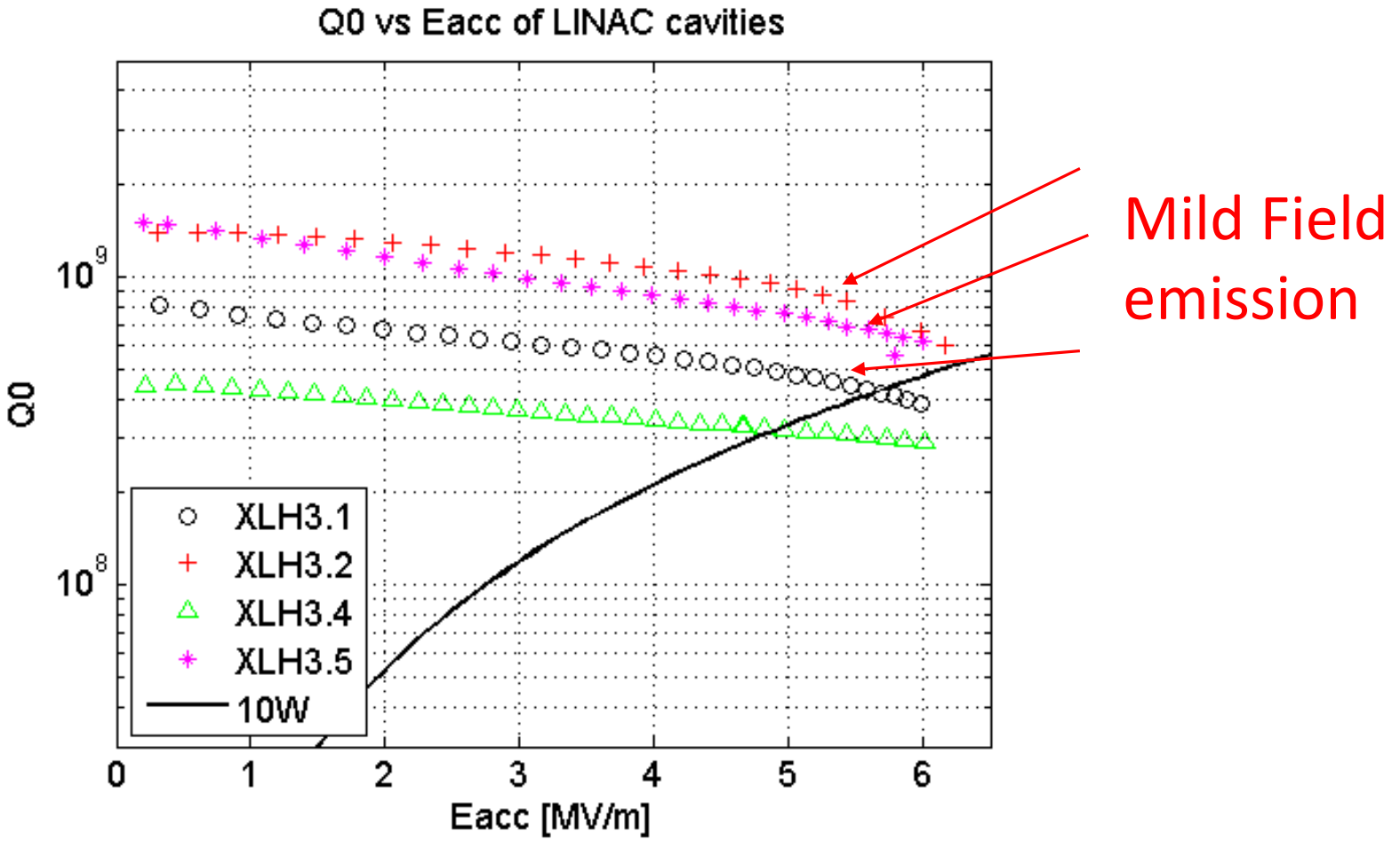
Last year



- Comparable result (slightly worse Q caused by slightly worse cool down)

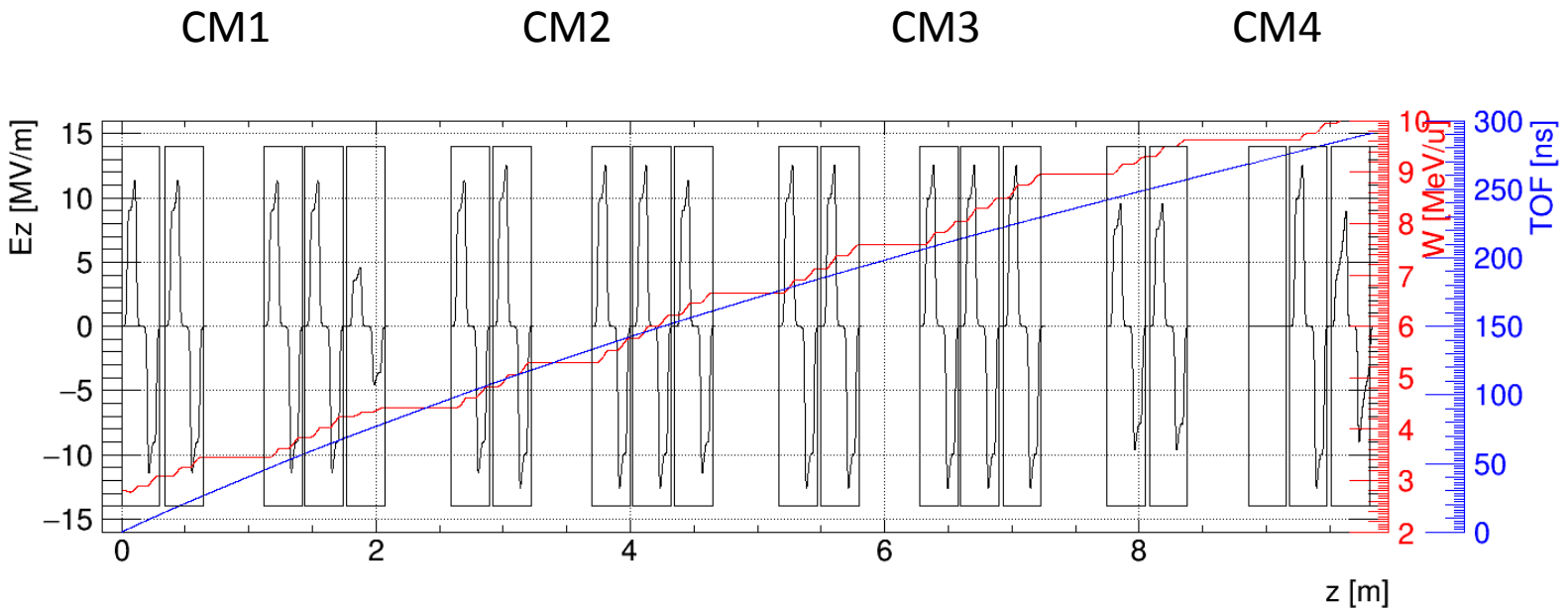
CM4

This year



- XLH3.3 was not powered due to the doubtful RF contact at the coupler
- The other cavities reach 6MV/m, with mild field emission. Not an issue for LLRF

2018 settings & beam dynamics



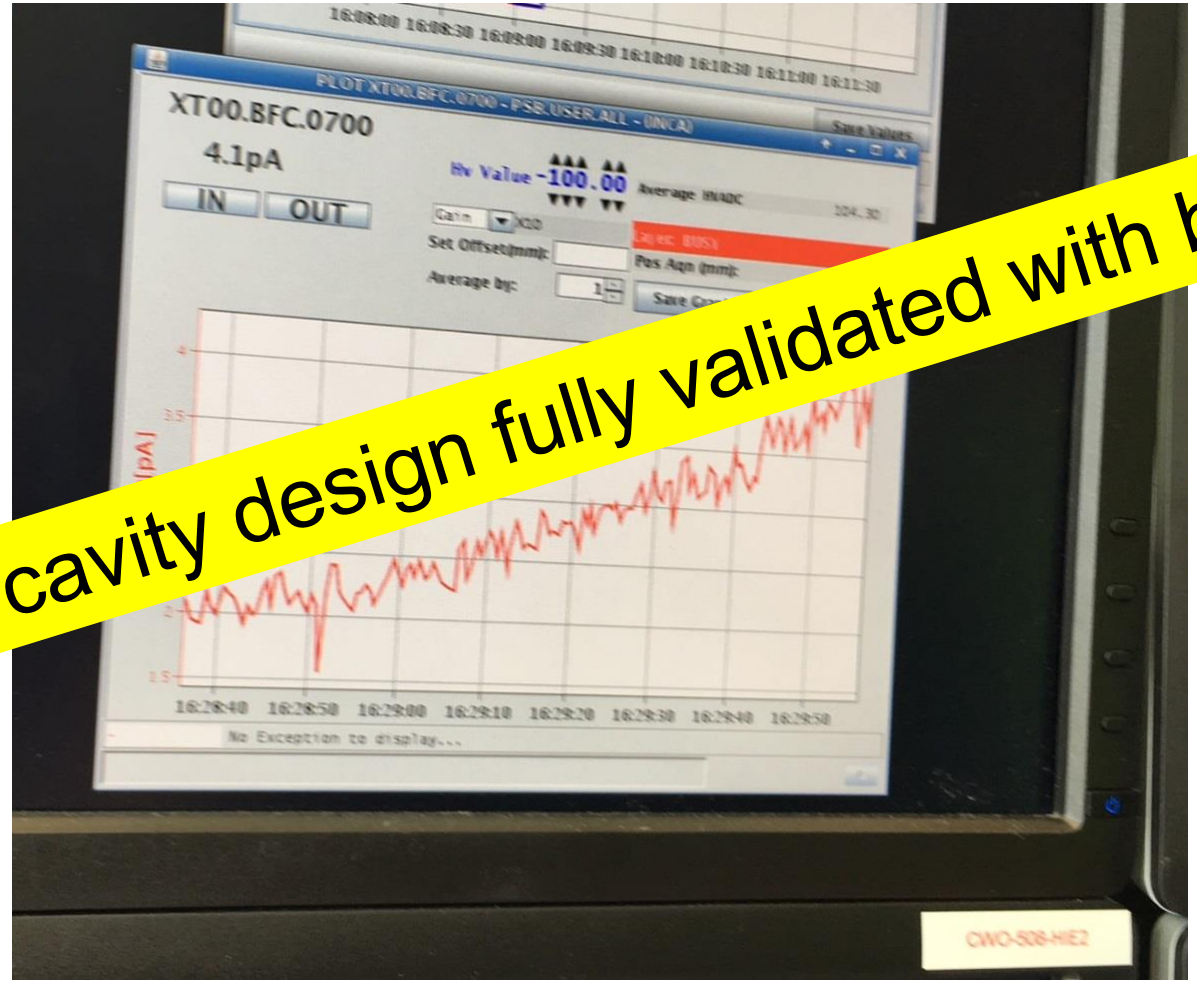
- **10.172 MeV/u for A/q=3.0 expected**
- **7.7 MeV/u for A/q=4.5**
- **Further adjustments of LLRF loops after reliability assessment**

cavity	proposal [MV/m]	Achieved [MV/m]
XLL2.1	5	5
XLL2.2	5	5
XLL2.3	5	5
XLL2.4	5	5
XLL2.5	2	2
XLH1.1	5.5	**5**
XLH1.2	5.5	5
XLH1.3	5.5	5
XLH1.4	5.5	5
XLH1.5	5.5	**5**
XLH2.1	5	**5.5**
XLH2.2	4	**5.5**
XLH2.3	5	**5.5**
XLH2.4	5	**5.5**
XLH2.5	5	**5.5**
XLH3.1	**5**	**4.2**
XLH3.2	**5**	**4.2**
XLH3.3	**0**	**0**
XLH3.4	5	**5.5**
XLH3.5	**5**	**4**

CONTROL LINE					SETPOINT MAG [MV/m]	SETPOINT PHASE [deg]	SEQ STATUS	RUNNING	SETPOINT MAG [MV/m]	SETPOINT PHASE [deg]	CAV FIELD MAG [MV/m]	CAV FIELD PHASE [deg]	RF POWER FWD [W]	RF POWER RFL [W]	LIMIT	RF OUT SATUR	FAST ILOCK	CAV DISS [W]	T CAB [K] / T CAV [K]	He LEV VESSEL [%]	DETAILED STATUS
XLH2	CAV1	OFF	STANDBY	READY	ON	5.000	-53.0	ON		5.000	-53.0	5.001	-49.6	57.3	51.5				2.7	55.4 / 4.6	50.3	State ON reached
	CAV2	OFF	STANDBY	READY	ON	3.000	60.0	ON		3.000	60.0	3.000	77.6	36.5	32.4				1.1	50.6 / 4.6		State ON reached
	CAV3	OFF	STANDBY	READY	ON	5.000	-45.0	ON		5.000	-45.0	4.999	7.0	54.6	47.1				4.8	61.7 / 4.6		State ON reached
	CAV4	OFF	STANDBY	READY	ON	5.000	-110.0	ON		5.000	-110.0	4.999	-93.4	50.2	42.6				3.7	63.8 / 4.6		State ON reached
	CAV5	OFF	STANDBY	READY	ON	2.000	140.0	ON		2.000	140.0	2.001	-170.7	9.1	7.7				0.7	58.0 / 4.5	51.1	State ON reached
XLH1	CAV1	OFF	STANDBY	READY	ON	3.000	76.0	ON		3.000	76.0	2.999	116.4	105.9	104.0				1.0	25.2 / 4.6		State ON reached
	CAV2	OFF	STANDBY	READY	ON	6.000	5.0	ON		6.000	5.0	5.998	63.2	80.3	67.0				8.3	32.6 / 4.8	51.9	State ON reached
	CAV3	OFF	STANDBY	READY	ON	5.500	68.0	ON		5.500	68.0	5.497	121.9	64.9	52.0				8.4	27.1 / 4.8		State ON reached
	CAV4	OFF	STANDBY	READY	ON	5.000	-38.0	ON		5.000	-38.0	5.000	32.4	93.4	82.9				4.2	29.3 / 4.6		State ON reached
	CAV5	OFF	STANDBY	READY	ON	3.000	47.0	ON		3.000	47.0	2.998	57.2	19.3	16.2				2.0	23.0 / 4.6	49.6	State ON reached

CONTROL LINE					SETPOINT MAG [MV/m]	SETPOINT PHASE [deg]	SEQ STATUS	RUNNING	SETPOINT MAG [MV/m]	SETPOINT PHASE [deg]	CAV FIELD MAG [MV/m]	CAV FIELD PHASE [deg]	RF POWER FWD [W]	RF POWER RFL [W]	LIMIT	RF OUT SATUR	FAST ILOCK	CAV DISS [W]	T CAB [K] / T CAV [K]	He LEV VESSEL [%]	DETAILED STATUS
XLH2	CAV1	OFF	STANDBY	READY	ON	5.000	0.0	ON		5.000	0.0	4.999	39.6	45.2	35.2				6.7	...95.7 / 4.6	50.0	State ON reached
	CAV2	OFF	STANDBY	READY	ON	5.000	0.0	ON		5.000	0.0	4.999	55.5	54.5	44.8				11.6	70.2 / 4.7		State ON reached
	CAV3	OFF	STANDBY	READY	ON	5.000	0.0	ON		5.000	0.0	5.000	10.3	124.2	113.1				3.3	76.2 / 4.6		State ON reached
	CAV4	OFF	STANDBY	READY	ON	5.000	0.0	ON		5.000	0.0	5.000	24.8	48.8	42.4				3.9	61.0 / 4.6		State ON reached
	CAV5	OFF	STANDBY	READY	ON	5.000	0.0	ON		5.000	0.0	5.001	59.4	49.7	40.4				6.5	72.5 / 4.6	48.3	State ON reached
XLH3	CAV1	OFF	STANDBY	READY	ON	2.000	0.0	ON		2.000	0.0	1.999	71.5	53.0	51.8				0.8	62.7 / 4.6		State ON reached
	CAV2	OFF	STANDBY	READY	ON	2.000	0.0	ON		2.000	0.0	1.999	88.0	54.6	52.9				0.4	65.1 / 4.5	50.4	State ON reached
	CAV3	OFF	STANDBY	READY	ON	1.000	0.0	OFF		1.000	0.0	0.002	-65.6	0.0	0.0				-0.0	50.4 / 4.5		State OFF reached
	CAV4	OFF	STANDBY	READY	ON	2.000	0.0	ON		2.000	0.0	2.001	34.8	36.4	32.5				1.3	50.1 / 4.6		State ON reached
	CAV5	OFF	STANDBY	READY	ON	2.000	0.0	ON		2.000	0.0	2.003	74.3	54.7	51.8				0.5	64.4 / 4.5	51.0	State ON reached

Tuesday 29 May at 16:30: first beam through the full linac: mechanical aperture is clear!



Proposed intervention for XLH3.CAV3

- **Bring back the cryomodule #4 to SM18, open and repair the cable**
  - Dis-installation, transport to SM18 (right after physics run?)
  - Conditioning for ISO5, slow venting
  - Repair works in clean room
- **Profit to replace some of the cavities with the best spares**
  - Spares will be prepared prior to the intervention (minimise “open” time)
  - Anyway advisable to LPW rinse all cavities (→ dismounting)
- **Possibly cold test the cryomodule in M9 bunker**

Required resources, schedule constraints, risks if not done

Required resources (estimates based on experience with CM1 refurbishment):

BE-OP: coordination of de-installation and re-installation
BE-RF: coordination, clean room assembly work, rinsing, RF testing in SM18 (~ [illegible] FTE)
EN-HE: roof shielding removal, handling, special transport (~ 10 days*[illegible])
EN-SMM: survey/alignment in clean room and in the linac (~ [illegible])
HSE-RP: radiation verification (very low dose rate) (~ [illegible])
TE-CRG: disconnection in linac, cool down [illegible] TE)
TE-VSC: disconnection, controlled [illegible]own, leak detection, etc. (~ 20 days*FTE)
TE-MSC: advise, assistan[illegible]ical points in dis-assembly/assembly (~ 25 days*FTE)

Endorsed by LS2C on 22 June

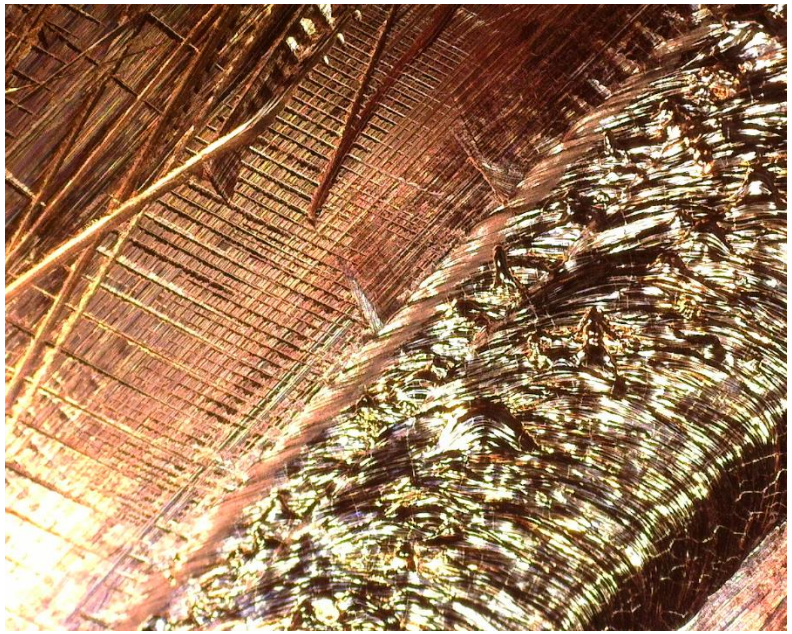
Scheduling aspects/constraints:

Time for preparation: (finalization of spare cavity set by May 2019)
Time for dis-installation and transport: ~2 weeks (special transports take 1 day)
Time for intervention in clean room: 5+2 weeks
Time for re-qualification: (cold test in M9): 6 weeks (with SM18 cryogenics availability)
Time for re-installation: ~3 weeks
→ About 4 months: may start anytime between May and October 2018

Risks if not done: Physics program at 10 MeV/u with A/q=4.5 would be compromised

Spare cavities

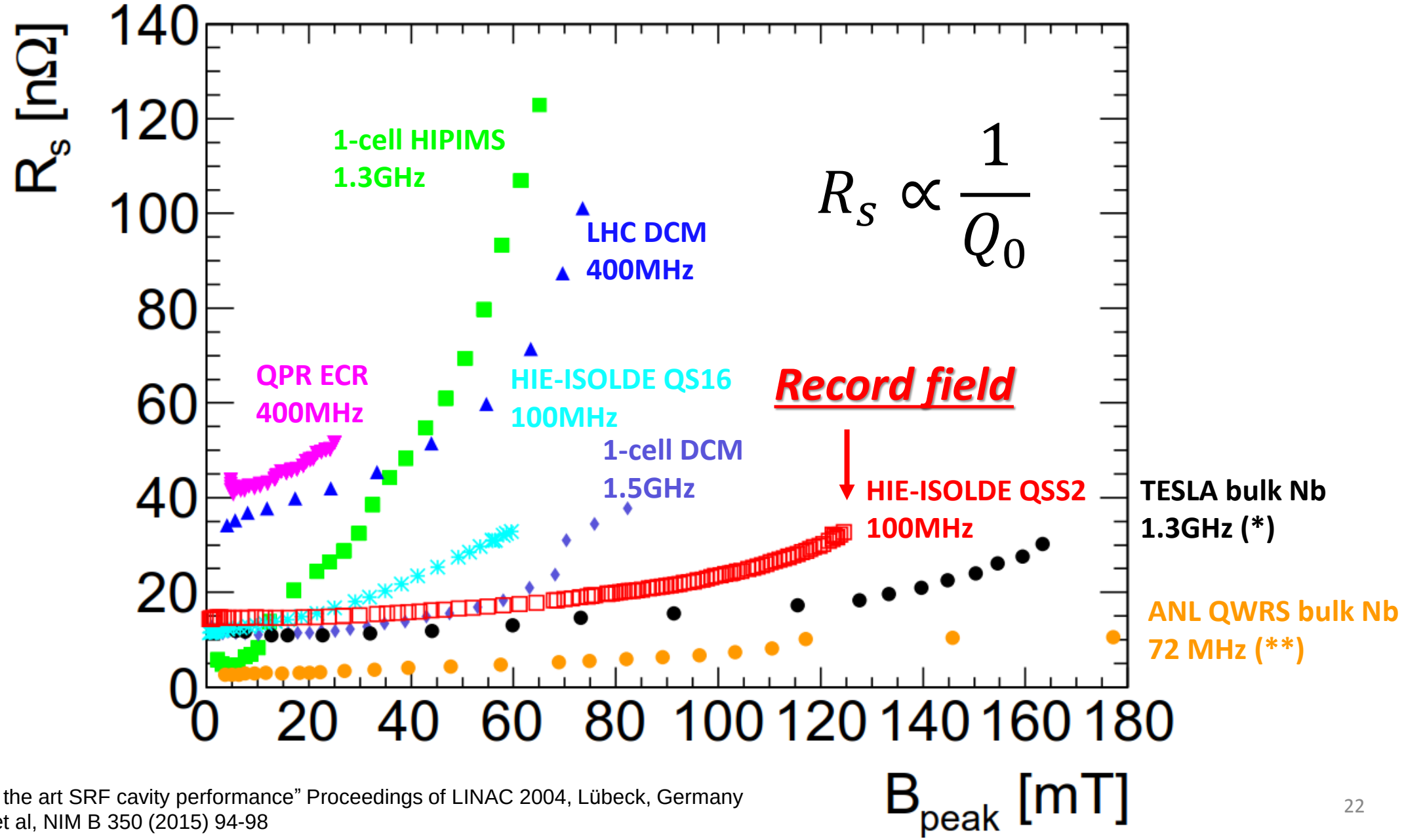
- **QSS2, QS18, QS20** are fully qualified as spares
- **QS20** has the lowest Q, it could be stripped and re-coated
- QSS3 substrate delivered at CERN and just accepted→ to be processed
- The fifth spare cavity should come from either QS6 or QS18, both substrates are in bad conditions
- A fourth seamless substrate will be ordered (raw material is available, pending acceptance)



Summary

- HIE ISOLDE phase II is deployed
- The 2018 commissioning campaign is over, machine is operational
  - Anomalous static heat load in CM2… not understood
  - Issue with CAV3 of CM4: not a showstopper for 2018, when enough experiments are within the energy reach of the machine
  - An intervention during LS2 was requested and got first approval by LS2C
  - BE-RF manpower for intervention is to be “shared” with crab cavities (High Luminosity LHC) and LHC spares programs
  - BE management reserved to see 2018 operations before final decision
- Spare cavities production is in progress, already 3 units are secured

Seamless HIE ISOLDE Cavity→ world record for Nb/Cu



*L. Lilje "State of the art SRF cavity performance" Proceedings of LINAC 2004, Lübeck, Germany
** Z.A. Conway et al, NIM B 350 (2015) 94-98