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Test of the SOLEIL Superconducting Cavity Prototype on the ESRF Ring

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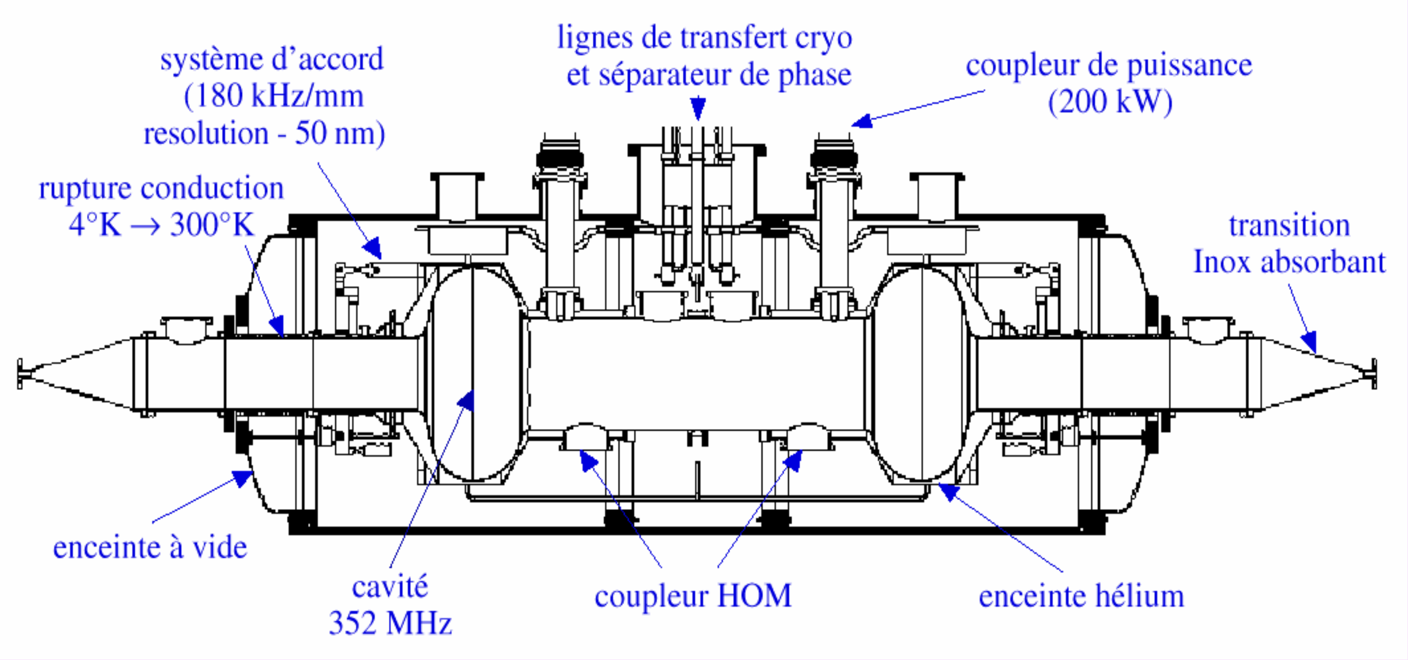
History of the project

- June 1996: Start of a collaboration CEA-DAPNIA / CERN / ESRF
  - ◊ Design, build and test a strongly HOM damped SC cavity for SOLEIL, optimized for high beam loaded SR light sources
  - ◊ SOLEIL RF frequency: *500 MHz → 352.2 MHz*
    - → *use CERN-LEP couplers*
    - → *possible application to ESRF*
- December 1999: → Successful test at CERN: 7 MV/m
- January 2000: → Decision to test the cavity prototype with beam at the ESRF
  - → Liquid helium from Dewars
  - → Passive operation at 300 K for normal User Service Mode

History, continued ...

- January 2002:
  → Installation on the ESRF storage ring
  → Cavity tested at 300 K with beam
  → 4 tests periods at 4K, following shut downs:
  March, May, August, October 2002
    - 1 week required to cool down
    - Tests at 4 K during machine restart time
    - Cavity warmed up before beam delivery to users
  → 2 test series at 4 K already performed
- December 2002:
  → Straight section needed for a beam line under construction
  ⇒ SC cavity to be removed from the ESRF storage ring

HOM free SC cavity for SOLEIL



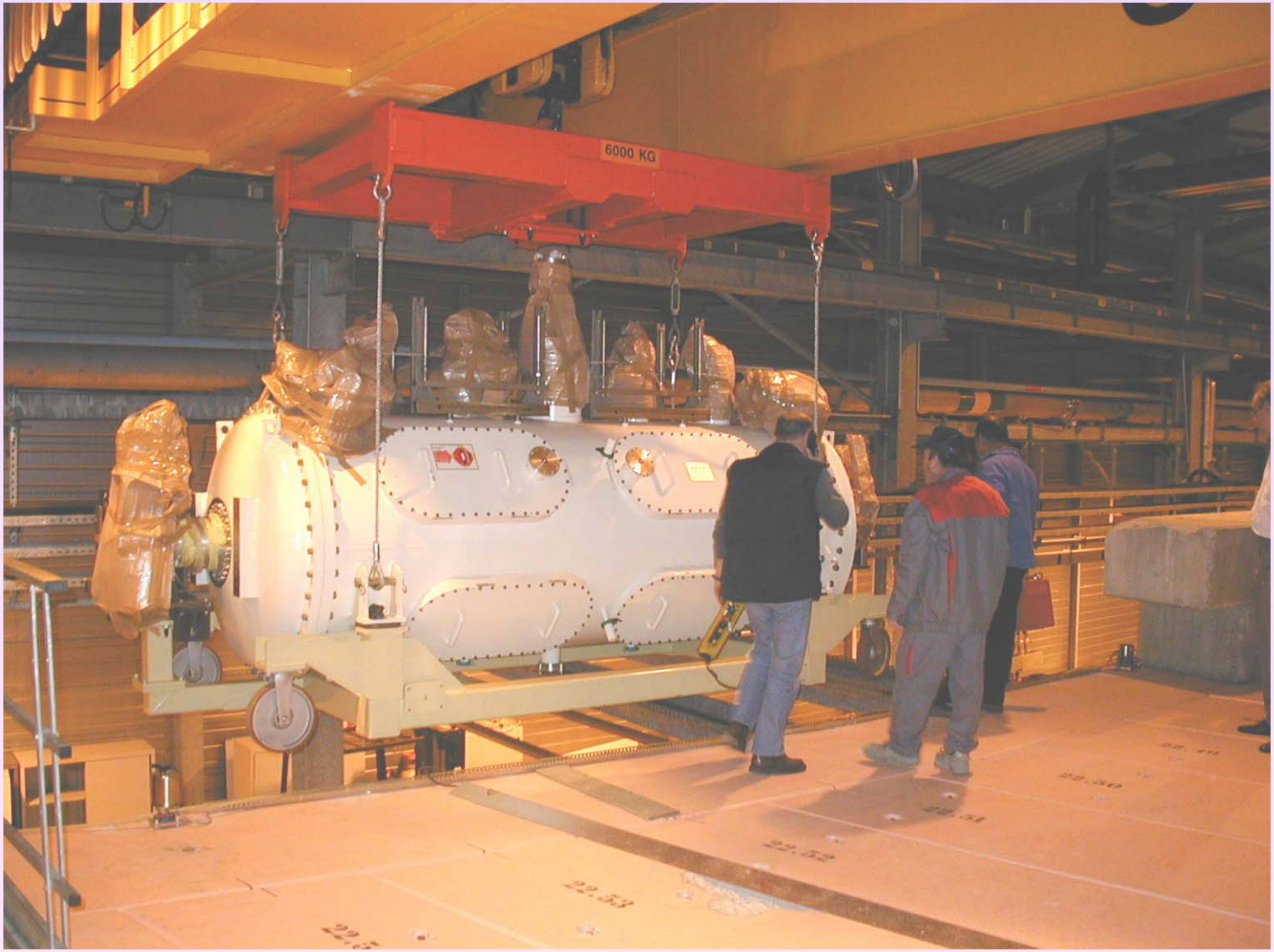
- Extremely low R/Q for all modes
- Accelerating mode R/Q = 2 x 45 Ω → superconducting ⇒ 5 MV
- 400 mm diameter between cells ⇒ HOM power extracted with conventional HOM couplers
- No need for ferrite absorbers in the beam tube ⇒ possible vacuum contamination avoided
- Open structure ⇒ efficient pumping through the extremities
- Expected good vacuum performance ⇒ expected high reliability → essential for light sources
- First application of CERN technology of Nb plated Cu to a cavity for high beam loading

Extremely high Longitudinal CBI thresholds for the ESRF

Monopole modes							
ESRF 5-cell copper cavity				SOLEIL SC-cavity			
f_H/[MHz]	R/Q [Ω]	Q_{ext}	Ithresh [mA]	f_H/[MHz]	R/Q [Ω]	Q_{ext}	Ithresh [mA]
500.2	73	30000	91	587	1.1	180	858648
908.4	23	36000	133	596	3.8	470	93754
				611	10.3	10	1585769
				637	0.1	1000	1566675
				669	7.8	13	1471141
				702	8	400	44425
				724	1.3	1000	106032
				746	0.3	3300	135128
				791	0.8	2000	78854
				854	0.3	1700	229134

Installation on the ESRF storage ring ….

SC Cavity delivered at ESRF on 30th October 2001



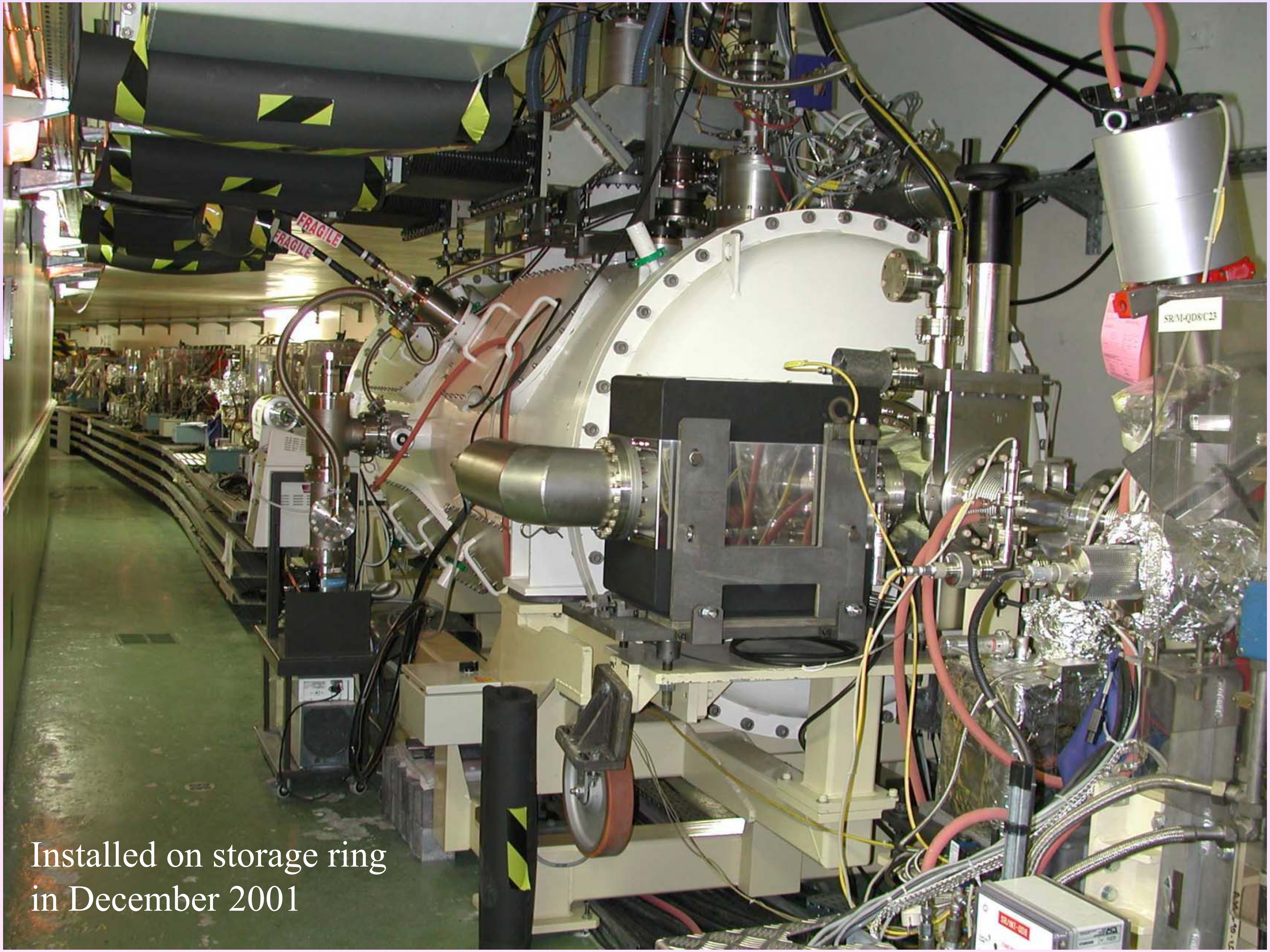
Only 1 month for huge preparation work ...

Local clean room class 100 quality implemented at ESRF to mount the Ti sublimation pumps

... to prepare a first cryogenic test and validate the cooling scheme with the cavity outside the tunnel on 30th November 2001 (general rehearsal)

Vacuum configuration

- Main tapers: → lossy stainless steel 430: to absorb HOM above 1.5 GHz
  → water cooled
  → 500 l/s ion pumps with Ti sublimators: close to the cavity
    - sublimators activated regularly during machine interventions
- Isolation valves: → connection to the ring without venting
- Schielded belows
- Photon absorbers: → prevent synchrotron light from hitting the Nb/Cu structure
  → water cooled
  → 150 l/s ion pumps
- Penning gauges: → on tapers and on each RF power coupler
  → connected to fast RF interlock system to protect windows against sputter deposition of metal


FRAGILE
FRAGILE
SR/M-QDS/C23
Installed on storage ring
in December 2001

Connection to the 3rd RF transmitter

- Waveguide system, switching between

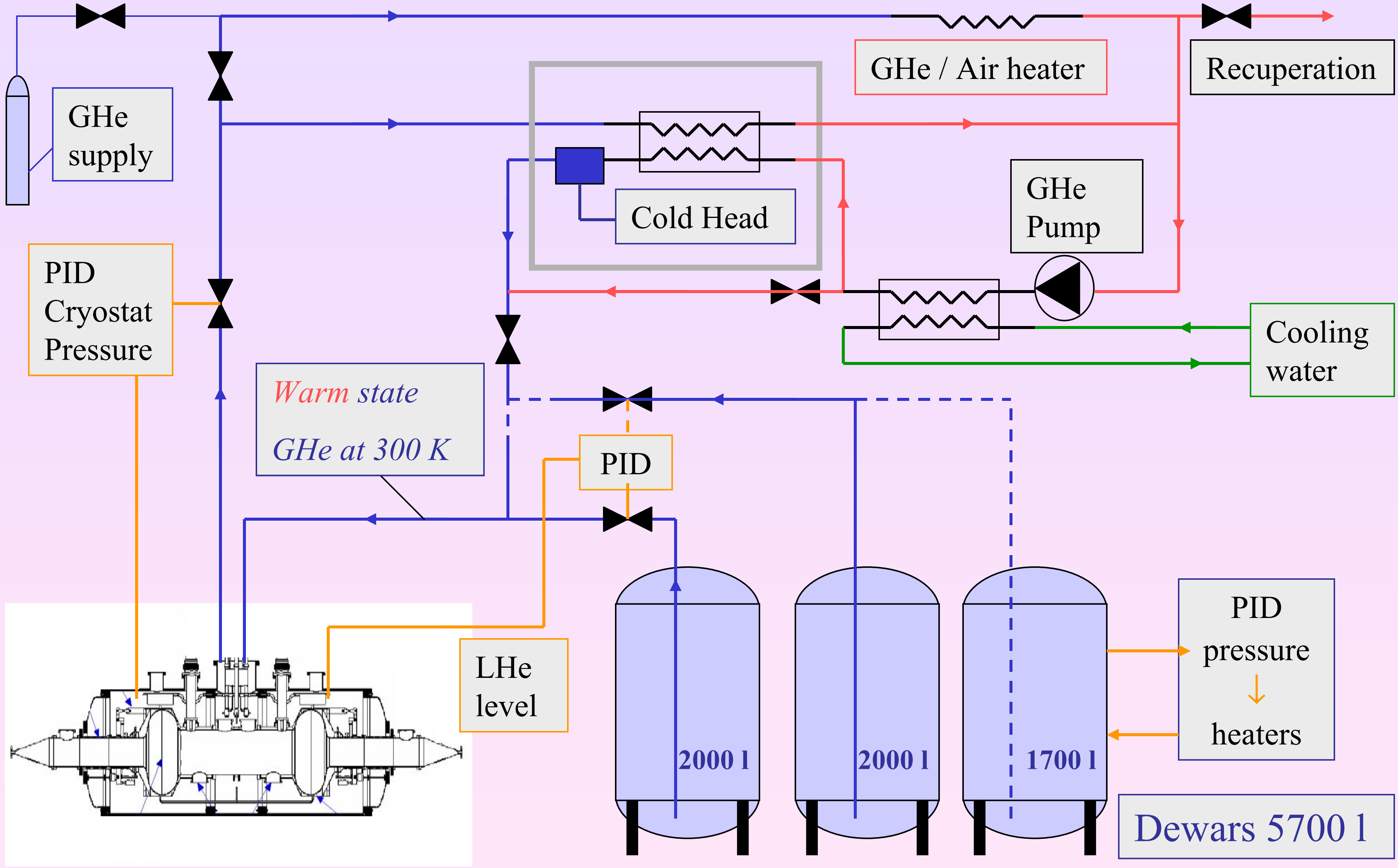
  → NC cavities 5 & 6 in cell 25

  → SC cavity module in cell 23

- Easy adaptation of standard RF control system to the SC module
- Temperatures at several strategic points monitored and interlocked for operation at 300 K
- Interlock also for vacuum, GHe cooling, RF signals, …
- At 4 K: validation of interlock from existing SOLEIL cryogenic control cabinet (developed for CERN tests and adapted to operation at ESRF with Dewar)
- Existing software frequency tuning control adapted to SC cavity

Waveguide distribution above the tunnel

Cooling plant for the ESRF Tests



Performance of the cooling and cryogenic system

- GHe cooling: → maximum 40 Nm^3/h

  → 15 Nm^3/h sufficient in passive operation at 300 K to remove a maximum of 83 W of heat load

- GHe Pre-cooling: → 10 Nm^3/h: Nb/Cu Temp → 110 K after 6 days (most heat evacuated without waste of LHe)

- LHe Cooling: → started 1 day before machine restart
  → 24 hours at 45 l/h exploiting cold gas cooling
  → 3.5 hours at 200 l/h to fill the cryostat with LHe
  → 17 hours at 160 l/h in steady SC state at 4 K

- Unexpected high static losses of 117 W:

  → Super isolation degraded after many manipulations during R&D phase at CERN

  → A cold shield seems necessary for the final design

Estimated heat load for passive operation at 300 K

(prior to installation on the ring)

- Cavity detuned by thermal expansion at 300 K:

  → $f_{resonance} = f_{rf} - 3.4\, f_{revolution}$

  → excellent parking position: little power extraction from beam harmonics, also in partial filling

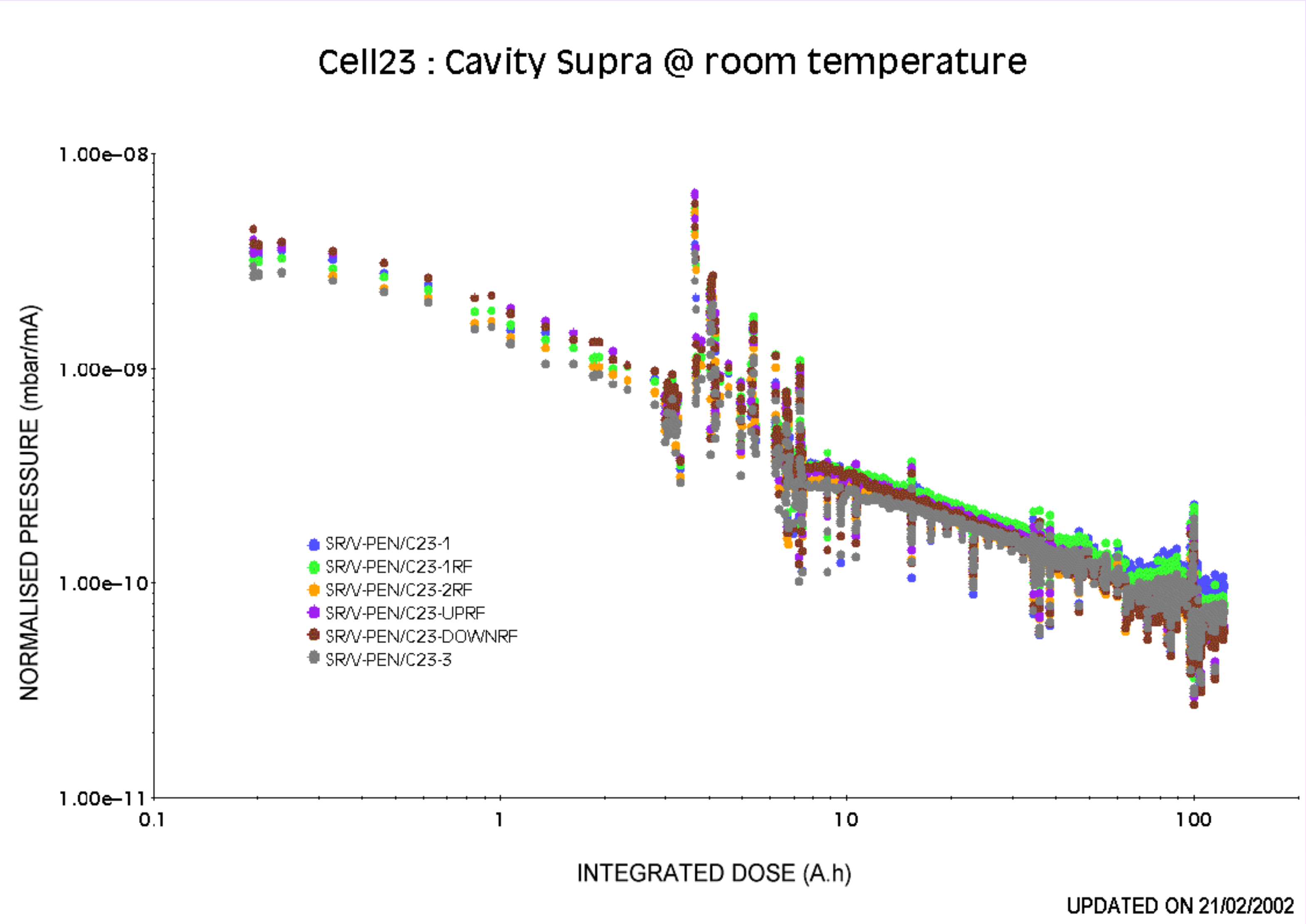
PREDICTION: by thorough computation of fundamental and HOM power up to highest frequencies, for all standard ESRF fillings:

→ HOM dampers & main RF couplers

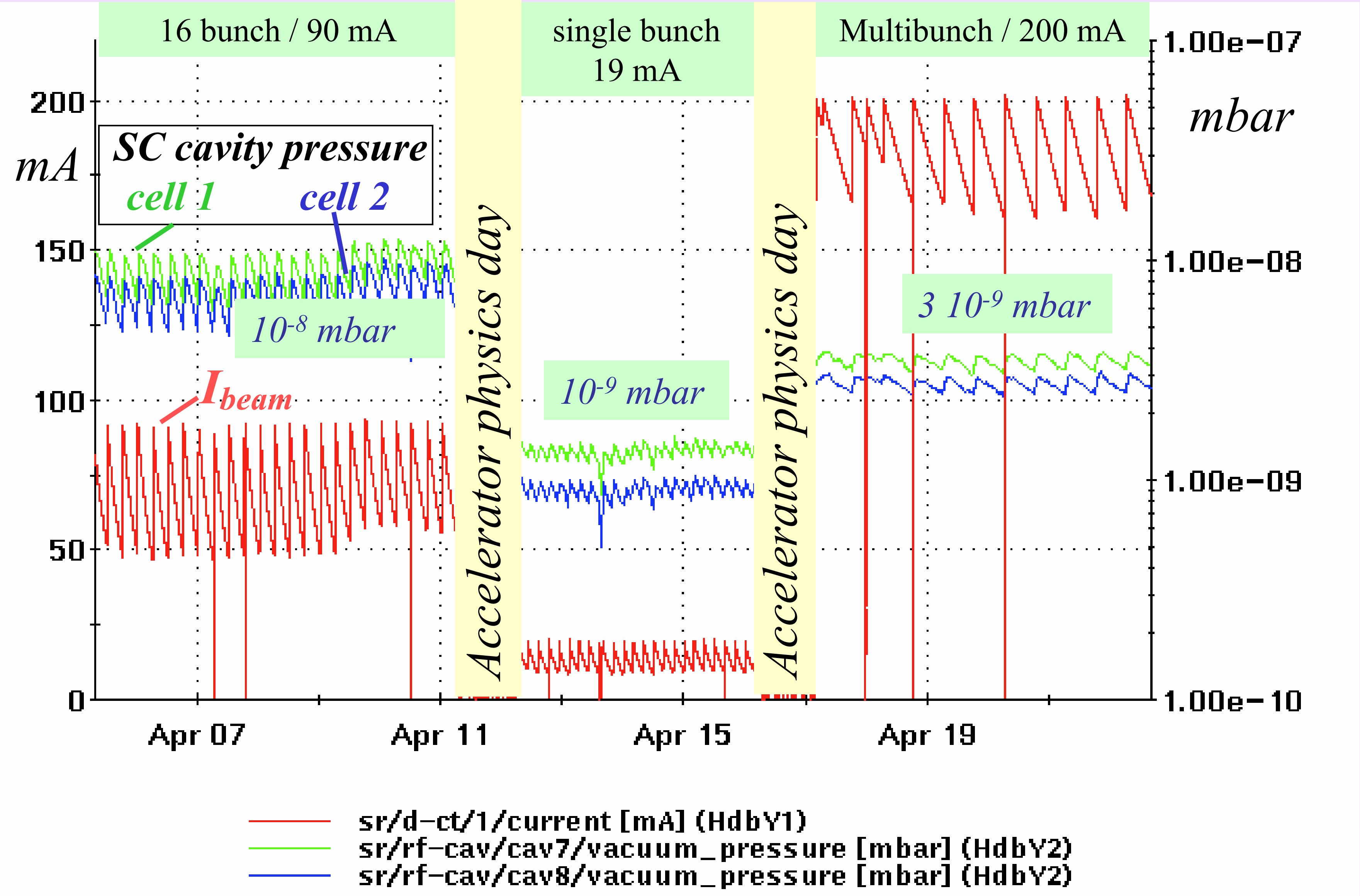
→ Tapers

→ in small proportion also in warm Nb/Cu structure: max 200 … 300 W

Measured vacuum conditioning in passive operation at 300 K

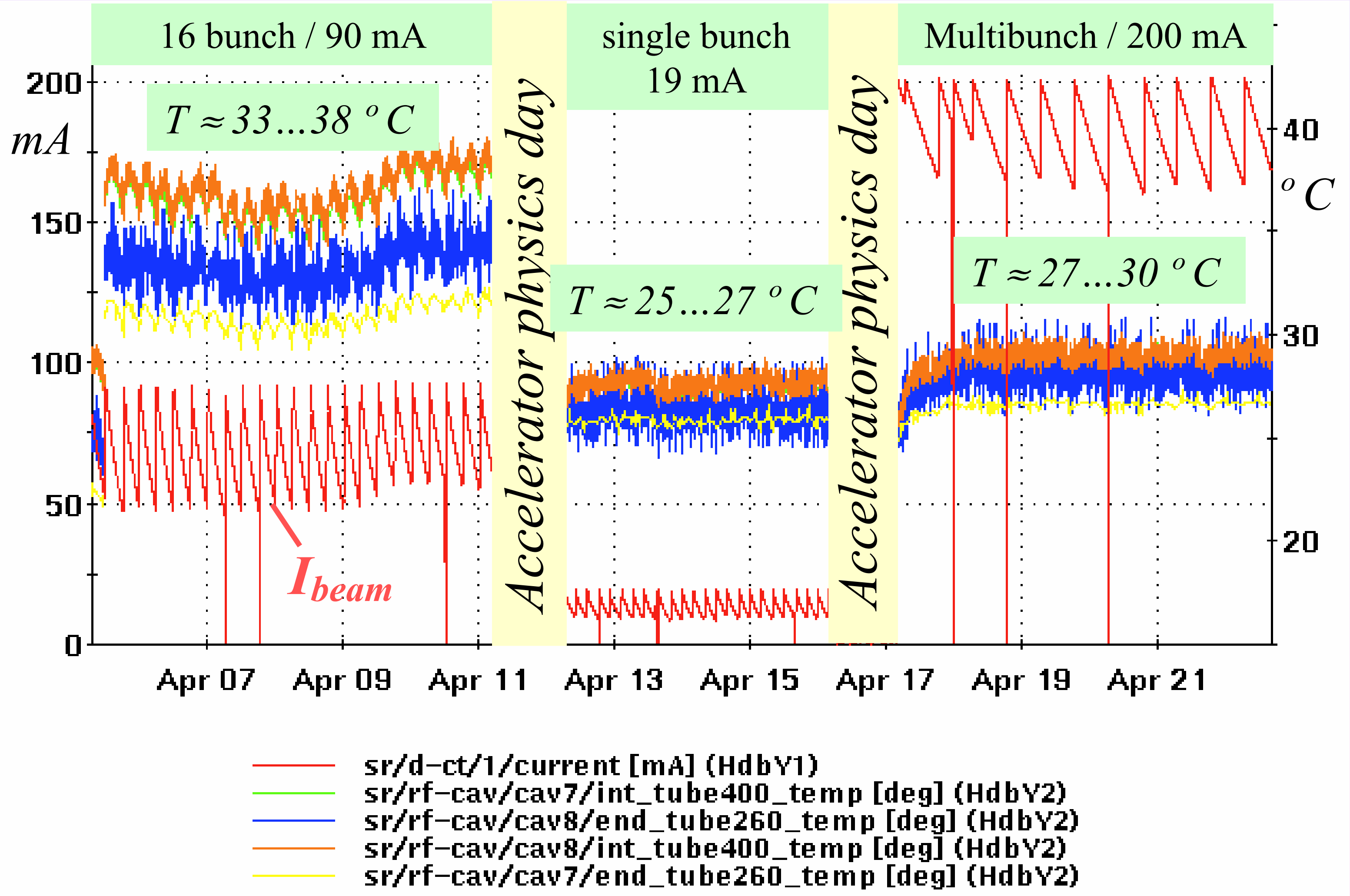


SC Cavity Pressure at 300 K with beam: unbaked system !



SC Cavity Temperature at 300 K with beam

4 sensors: internal beam tubes a few ºC higher than external tubes



SC cavity transparent to the beam in passive operation at 300 K

- Measured power extracted with 15 Nm^3/h GHe from the cryostat:

→ *In 16 bunch*	*90 mA*	$\Delta T = 16\ ^oC$	*P = 83 W*
→ *In single bunch*	*19 mA*	$\Delta T = 5\ ^oC$	*P = 26 W*
→ *In multibunch*	*200 mA*	$\Delta T = 8\ ^oC$	*P = 42 W*

below predictions !

- Satisfactory Vacuum pressure in all modes
- Maximum 50 W extracted from dipole HOM couplers in 16 bunch at 90 mA
- No sign of coherent HOM driven instability
- Only 2 beam trips in 5 months due to the system: could not clearly be attributed to the cavity itself

First test results with the SC cavity at 4 K

- Passive operation at 4 K with 200 mA of beam
  - → No sign of HOM driven instability ⇒ HOM power effectively absorbed in the dampers
  - → No detectable increase in LHe consumption
- RF voltage conditioning
  - → 2.2 MV achieved in CW so far
  - → 5 MV achieved with short RF pulses
  - → Conditioning speed limited by coaxial line of one dipole HOM coupler:
    - ◊ Coupler notch filter not well tuned coupling to fundamental mode
    - ◊ Break downs in the coaxial line: needs inspection at next shut down
- Storage of 6 mA of beam and 17 hours lifetime with
  - → 3.3 MV from NC existing RF system: (well below U0/e = 5 MV/turn)
  - → 2.1 MV from SC SOLEIL cavity ⇒ first beam acceleration on 30th May 2002

CONCLUSION

The test of the prototype SC SOLEIL cavity is progressing well

- Passive operation of a SC cavity at room temperature on a high intensity storage ring has been demonstrated:
  - → The warm SC cavity is transparent to the beam in any ESRF standard filling
  - → Only little power has to be evacuated from the cryostat *(< 100 W)*
- Achievements after 2 test periods at 4 K in March and May 2002:
  - → 17 hours of stable operation at 4 K with liquid helium from Dewars
  - → The detuned cavity at 4K is transparent to 200 mA of beam
  - → The SC cavity module is conditioned up to 2.2 MV
  - → First beam has been accelerated with the SOLEIL cavity
- *2 more test periods at 4 K are planned in August and October 2002:*
  - → *Solve the problem with the coaxial HOM line*
  - → *Further conditioning to 4 MV*
  - → *Accelerate higher beam currents*

Acknowledgement

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