12th European Synchrotron Light Sources RF Meeting 2008

1st & 2nd October 2008

Second SOLEIL cryomodule: Installation in the storage ring and first tests

N. Guillotin, F. Ribeiro , M. Louvet

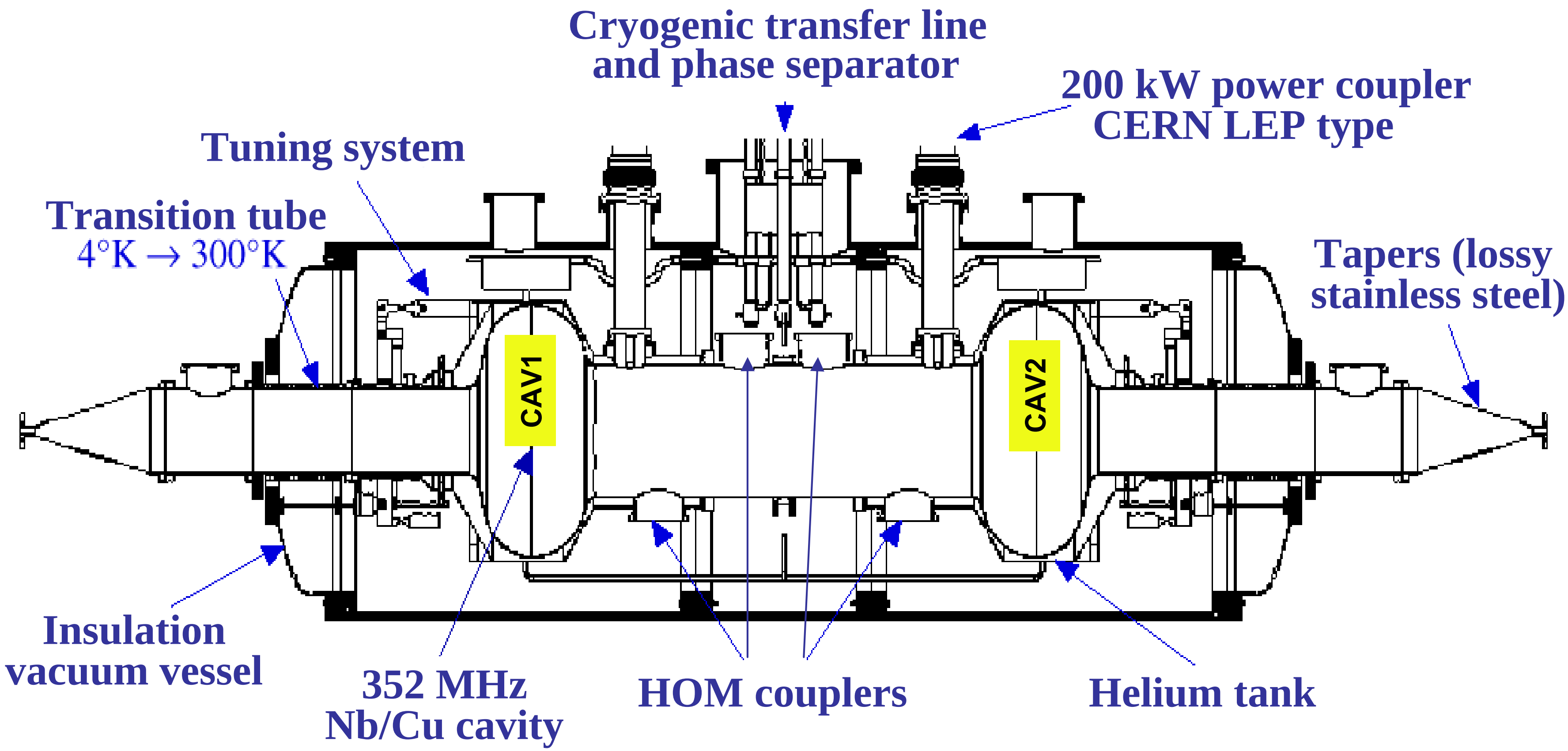
on behalf of the RF group

Layout of the SOLEIL cryomodule with two 352 MHz single-cell cavities *(Nb/Cu)*

Two such cryomodules are needed at SOLEIL
@ 2.75 GeV & 500 mA

($\Delta U \cong$ 1 MeV/turn)

Target End 2008

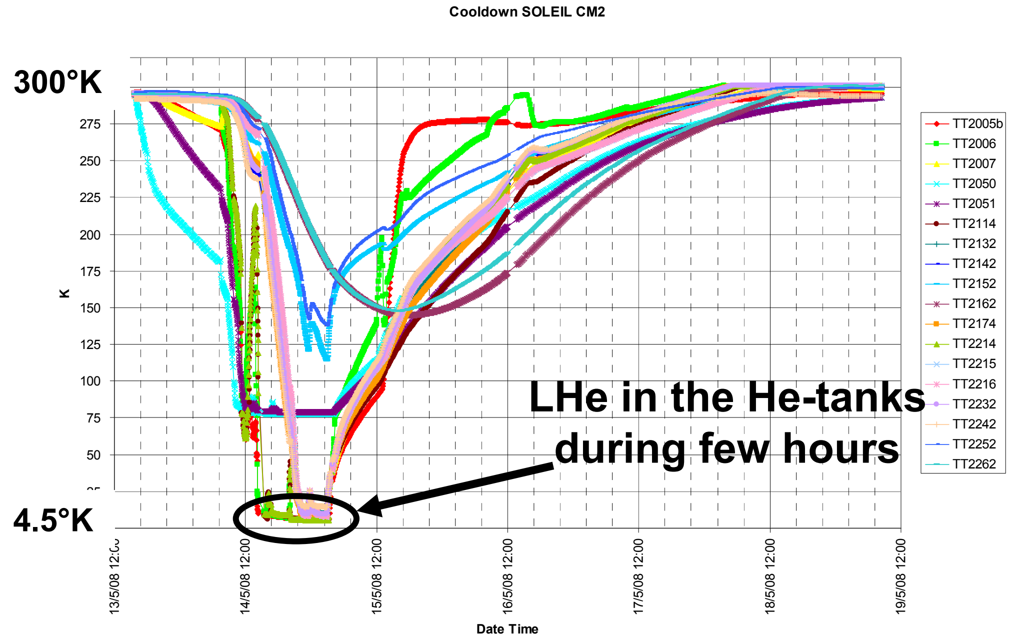


LHe : cooling at 4.5°K of the Nb/Cu cavities and the HOM couplers.
GHe : cooling of the FPC and extremity tubes.
LN2 : cooling at 77°K of the copper thermal shield.

L = 3.65 m
Φ = 1.3 m

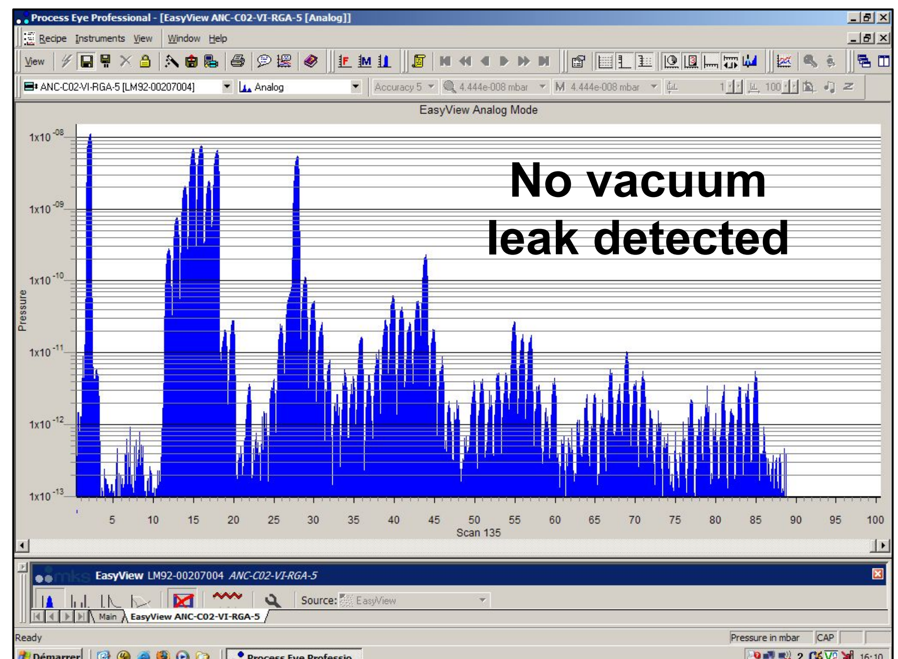
The CM2, manufactured by ACCEL, is based on the same design than the CM1, manufactured by the CERN

Factory Acceptance Tests at ACCEL (May 2008)



Estimated static losses on the cold mass at 4.5°K: 25-30W

Estimated RF dynamic losses at 4.5°K: 20W/cavity



Insulating vacuum ≈ 10^{-6} mBar
Cavity vacuum ≈ 10^{-10} mBar

About 1 year late for the CM2, compared to the initial planning

=> So, no final tests at CERN and direct installation at SOLEIL

Tuesday, the 20th of May 2008

Main milestones for the CM2 installation
-May / June 2008-

Week 21:
Monday, the 19th of May: machine shutdown; removal of the concrete blocks (shield).
Tuesday, the 20th of May: CM2 delivery at SOLEIL; Installation in the storage ring; connection to the vacuum chambers; pumping & leak tests.

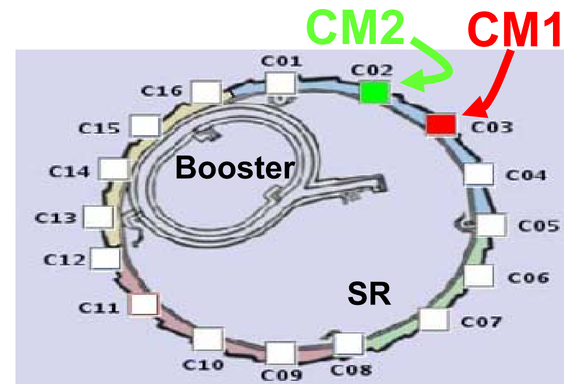
Week 22:
Baking out of the elements preceding and following the CM2; electrical connections; connection to the cryogenic system.

Week 23:
Conditioning of the cryogenic system; CM2 cooling in parallel with CM1.
2nd optimization of the dipolar HOM notch filter tuning.

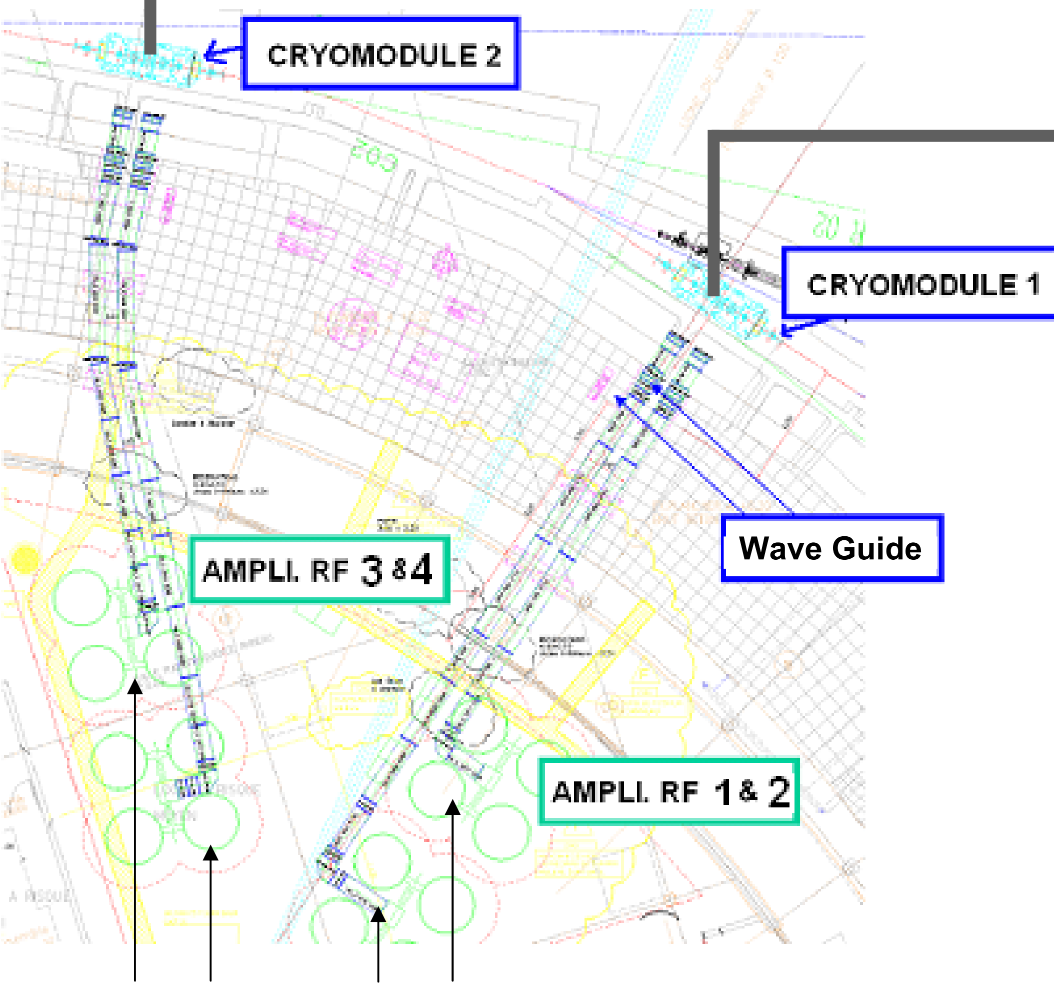
Week 24:
Re-installation of the concrete blocks; preparation for the operation of the RF amplifiers.
Week-End: beginning of the CM2 RF conditioning without beam.

Week 25:
RF Conditioning of the CM2 without beam during shifts.
Thursday, the 19th of June: detuning of the CM2 and CM1 prepared for operation.
Friday, the 20th of June: preparation for the machine start up *(with CM1 only).*

Layout of the global RF system
(Power amplifiers, Cryomodules, Cryogenic plant)

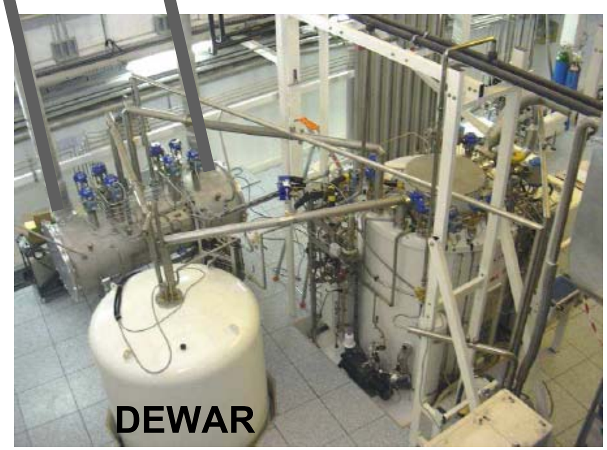


A single cryogenic plant supplies in LHe both CM



(4 amplifiers: 4 x 180 kW)

One could achieve more than 50 L/h of liquefaction and 400 W of refrigeration at 4.5 K

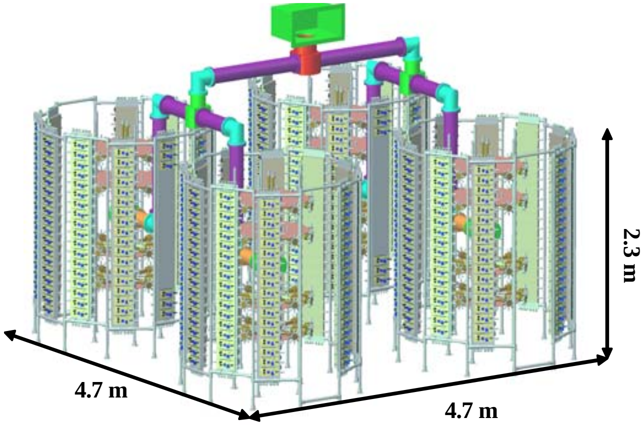


The two 180 kW RF solid state amplifiers for the CM2 are operational

Successful power tests of the 2 complete amplifiers
in April 08 for the Amp. 3 and June 08 for the Amp. 4

Amplifiers A3 & A4 operational

Tests on dummy load



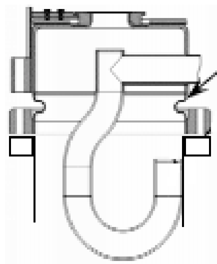
1 Amplifier : 4 towers of ~ 45 kW

Modules manufactured by BBEF (Beijing)
(MOSFET : LDMOS LR301 from POLYFET)

2nd tuning of the dipolar HOM notch filters

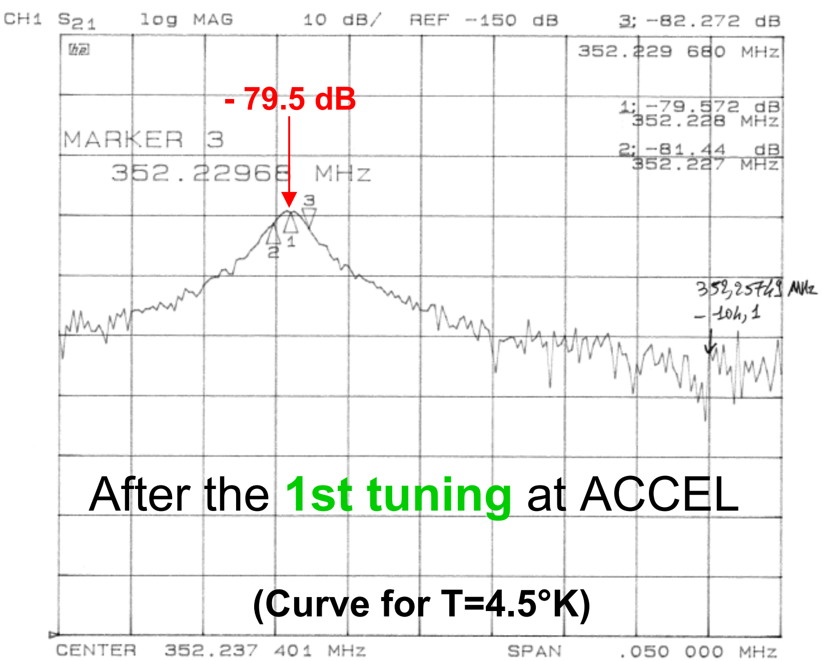
G. Devanz, C. Thomas-Madec (CEA)

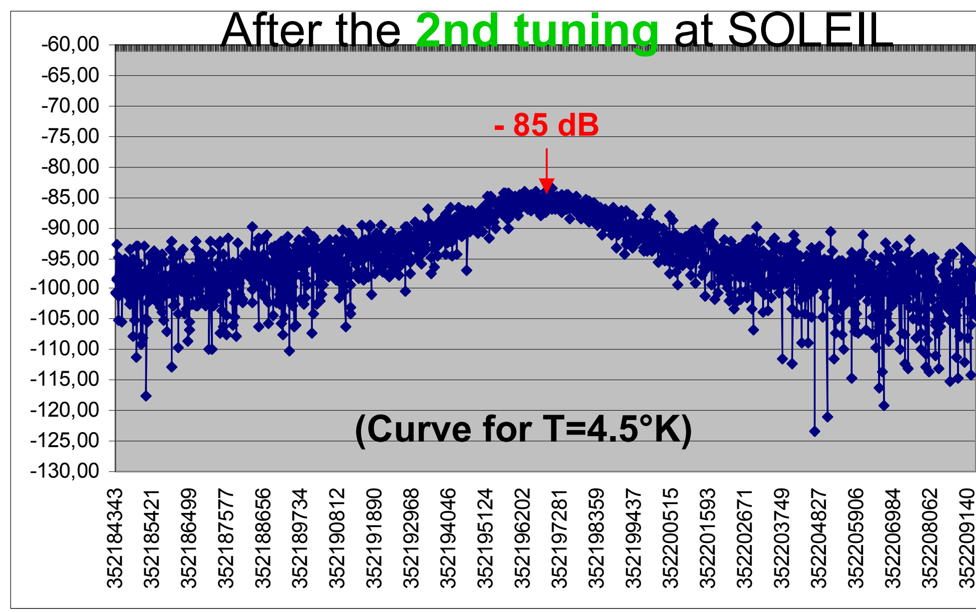
Nb flexible wave



Pick-up

To tune D2, the transmitted signal D2-PU2 must be minimized for the fundamental mode frequency





Transmitted signal: Dipolar HOM coupler2 - Pick Up2

RF conditioning of the CM2 at SOLEIL

Conditioning of the cavity 3: from Friday the 13th of June to the 31st of August 2008

➢ We started to condition without beam.
We limited the conditioning to 150kW in pulsed mode and 70kW in CW

$(V_{RF}^{max} \cong 1.6 MV / cav.)$

⬇

Within two days we reached typically a peak power of 140kW,
with the cavity detuned, for pulses with τ = 70μs and rep = 1kHz

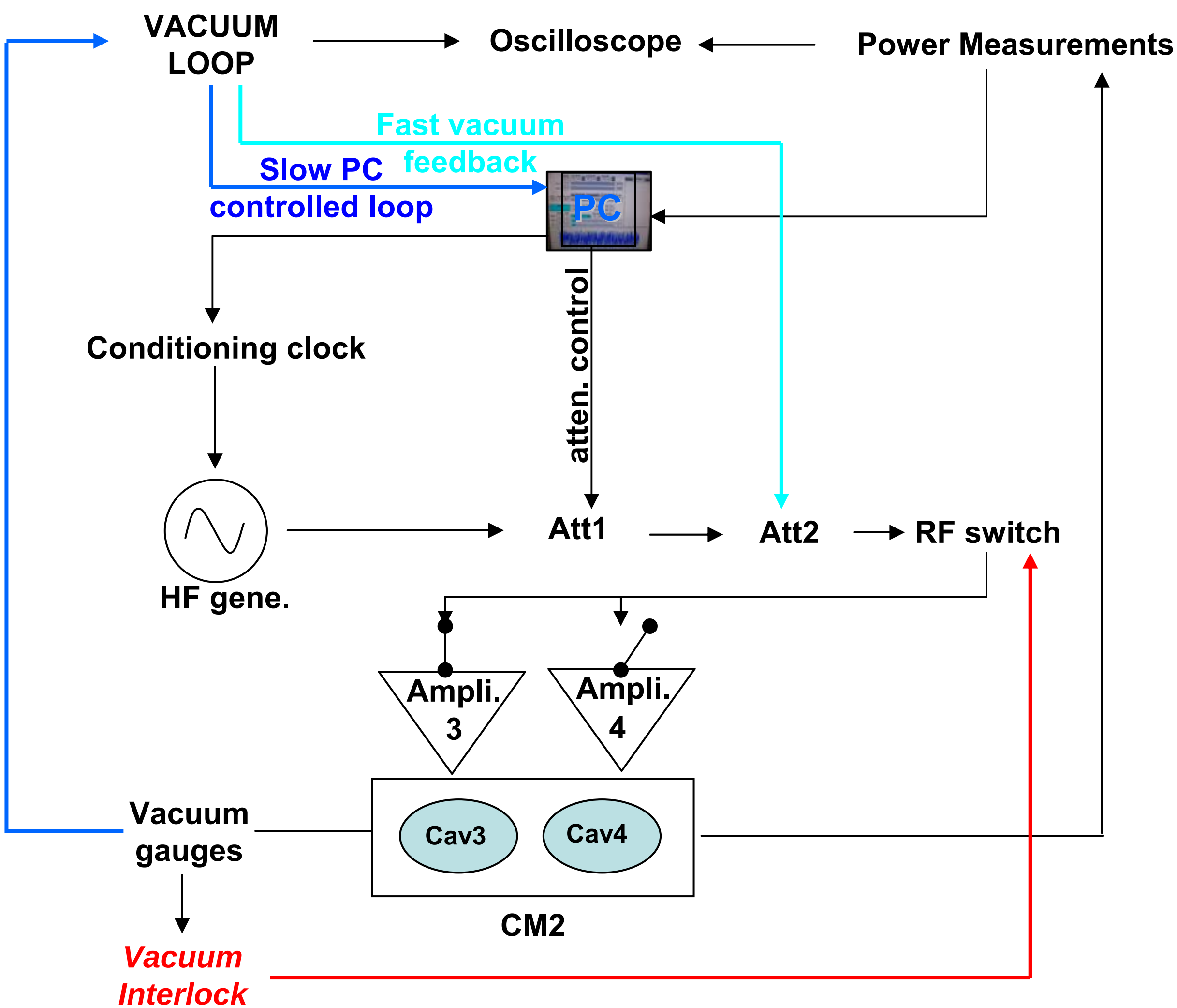
We also conditioned the cavity 3 around the resonance (pulsed mode and CW)
In pulsed mode we observed during the first WE a fast He evaporation for $P_{peak} \approx 50 - 60$ kW
=> ''Quench-like'' phenomena *(thermal breakdown)* and vacuum increase to 3.10^{-6} mBar.

➢ We also conditioned the cavity 3 with the beam *(with the contribution of the CM1).*
The incident power on the main coupler of the cavity 3 was increased step by step by adjusting the phase.

Conditioning of the cavity 4: from the 21st of July to the 31st of August 2008

We started with an automated conditioning system provided by the CERN

Pulsed RF power is applied to the cavity and controlled with a vacuum feedback:
A slow computer controlled loop to generate AM envelope and increase field and power as conditioning progresses (+ a fast vacuum interlock can switch the RF off)



[E. Montesinos et al.]
"A fully integrated controller for RF conditioning of the LHC superconducting cavities"

RF control system of SOLEIL and automated conditioning system

Only 1 week available during the machine shutdown of August for the conditioning of the CM2

- In pulsed mode, we reached 150kW with duty cylces τ/T of ≈ ¼, with the cavity 4 detuned.
  (An other ‘’quench-like’’ phenomena occurred)

In parallel, we conditioned the cavity 3 in CW in presence of beam

(We could have conditioned cavities 3 & 4 during machin runs, but too much risk of beam loss)

The 21st of July, the cavity 3 contributed with the CM1 to store an e-beam of 300 mA

The phase of the cavity 3 was adjusted for a higher power on the cavity 3

CAV1: Pi=74.7kW, Pr=4.6kW; CAV2: Pi=69.6kW, Pr=11.2kW; CAV3: Pi=150kW, Pr=10kW

- Beginning of the cavity 4 conditioning in CW, without beam, the 27th of August

We achieved 70kW with a detuning of the cavity and 65 kW while tuned $(V_{RF}^{max} \cong 1.53 MV / cav.)$

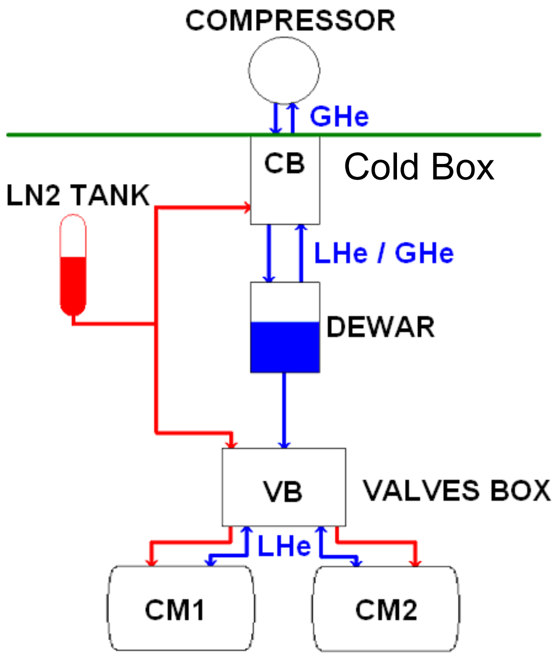
(An other ‘’quench-like’’ phenomena occurred between 65 and 70kW)

- 31st of August: conditioning of the cavity 4 with the beam

This cavity contributed with the cavity 1 of the CM1 to store 150 mA *(V_{cav}=1.2 MV/cav.)*

CAV1: Pi=60.3kW, Pr=25.1kW; CAV4: Pi≈150kW, Pr=50kW

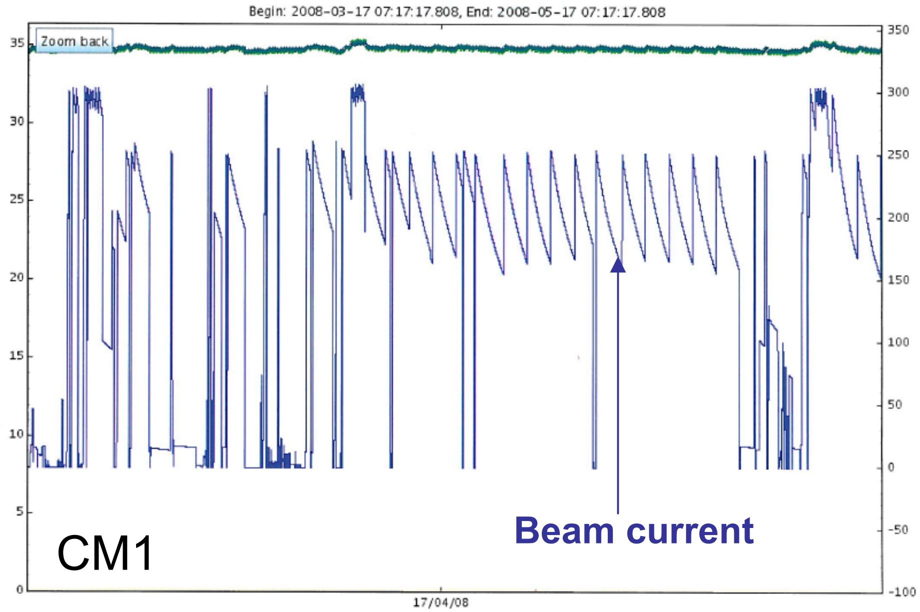
Cryogenic operation



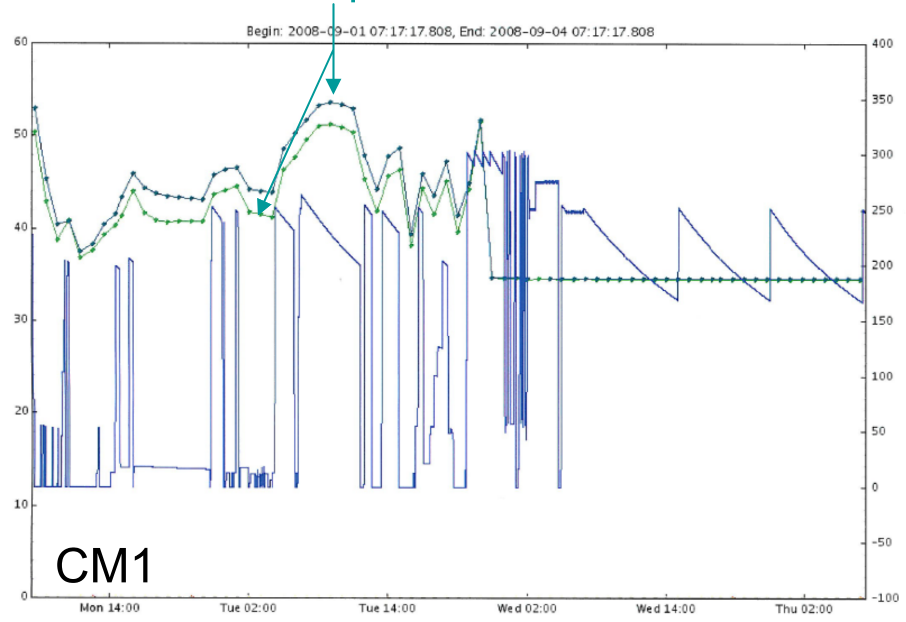
The installation of the CM2 has required new settings for the cryogenic parameters
(Dewar pressure, cryomodule pressure, LHe flow for cavity and HOM cooling, GHe flow for FPC cooling etc)

e.g: Inappropriate GHe flow during the first run, in July.
=> over-heating of the FPC
(35°K before the CM2 installation and about 50°K after)

High LHe consumption



FPC temperature

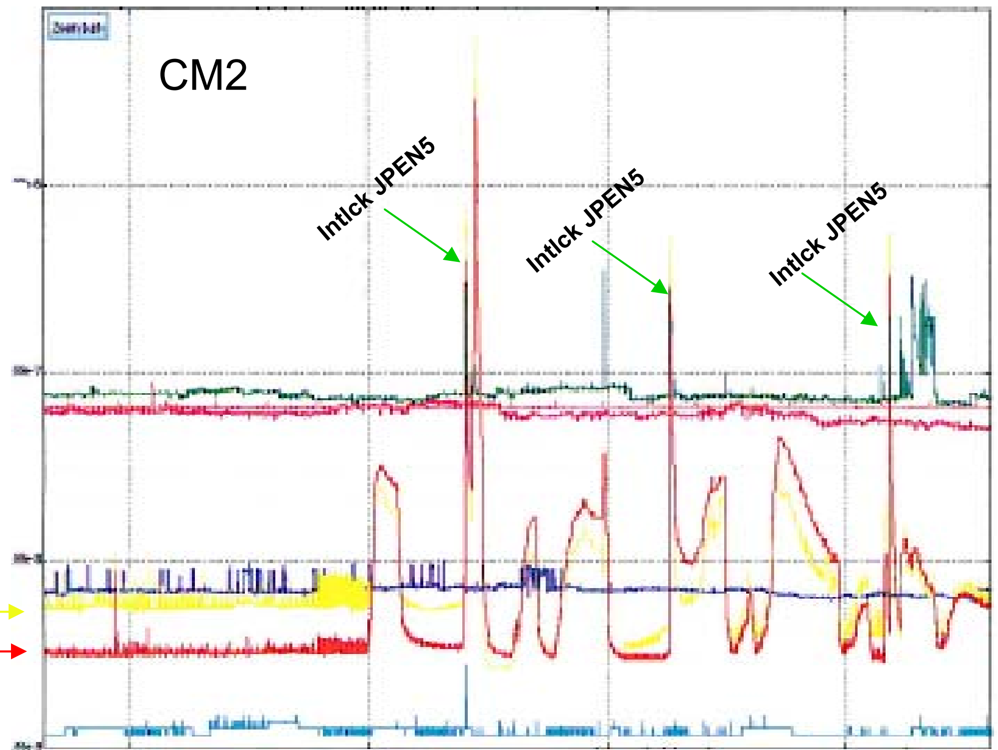


Tests for machine operation at 300 mA with both CM1 & CM2 (14/09/2008)

First test with V_{RF}=1 MV on each cavity and equilibrated incident powers
(All cavities were tuned and RF feedback in operation on the four cavities)

=> Many interlocks due to the vacuum level of the FPC of the cavity 4 (CM2)
while ramping the e-beam current.

Abrupt variations of the vacuum level measured by JPEN5 (FPC cav. 4)



Insulation vac. {

Max. stored current in such conditions: 273.8 mA

We also remarked a vacuum interlock on the cavity 4 (while tuned) with Pi=30kW only and no beam

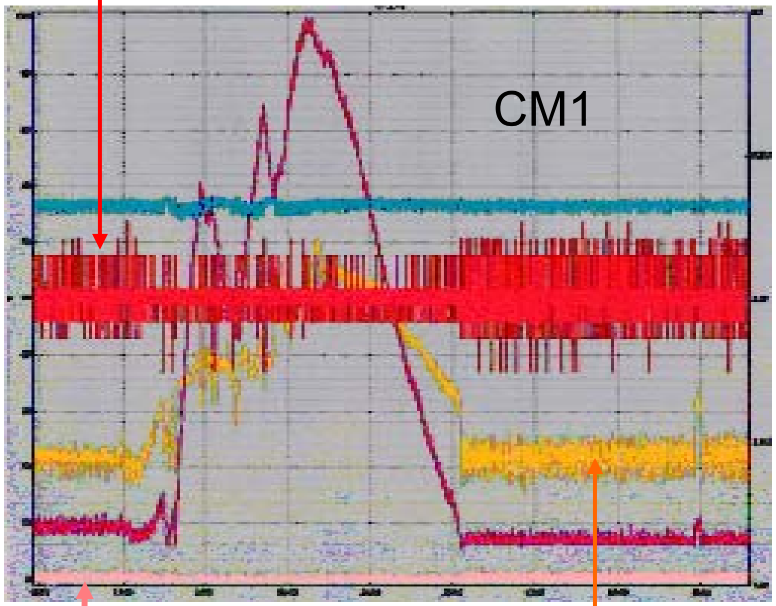
We suppose that the cav. 4 has not been sufficiently conditioned around the operating freq.

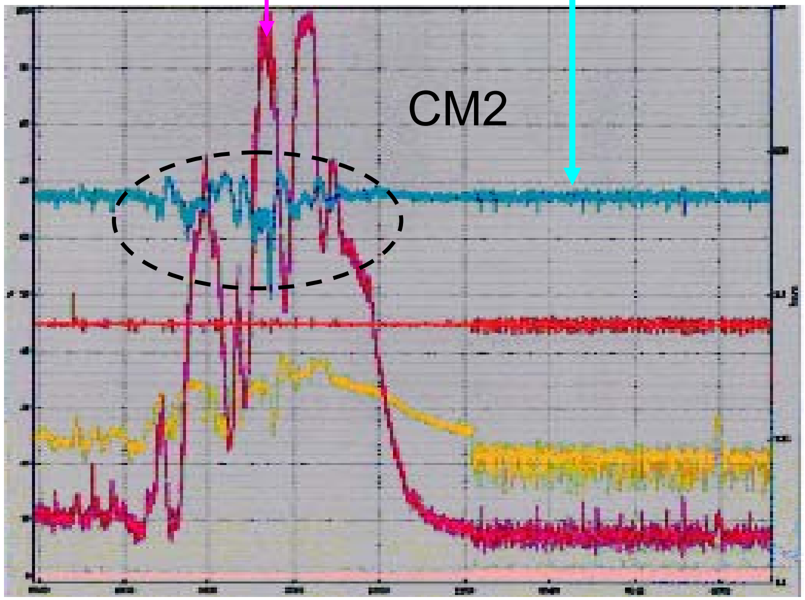
Finally, we set a phase of the tuned cavity 4 that allowed to store **300 mA** in the storage ring with the CM1 & CM2, but less incident power on the cavity 4

(Pi cav1=77kW, Pi cav2=70kW, Pi cav3=87kW, Pi cav4=58kW)

↓

Unfortunately, oscillations occurred at 300 mA on the LHe input valves of both CM and led to an interlock due to the LHe level of the CM2





To solve these problems, some parameters on the cryogenic system have been modified:

- PID: Gain increase on the LHe input valve
- Increase of the Dewar output pressure from 1.35 to 1.39 Bar
- Cooling intensification for the extremity tubes

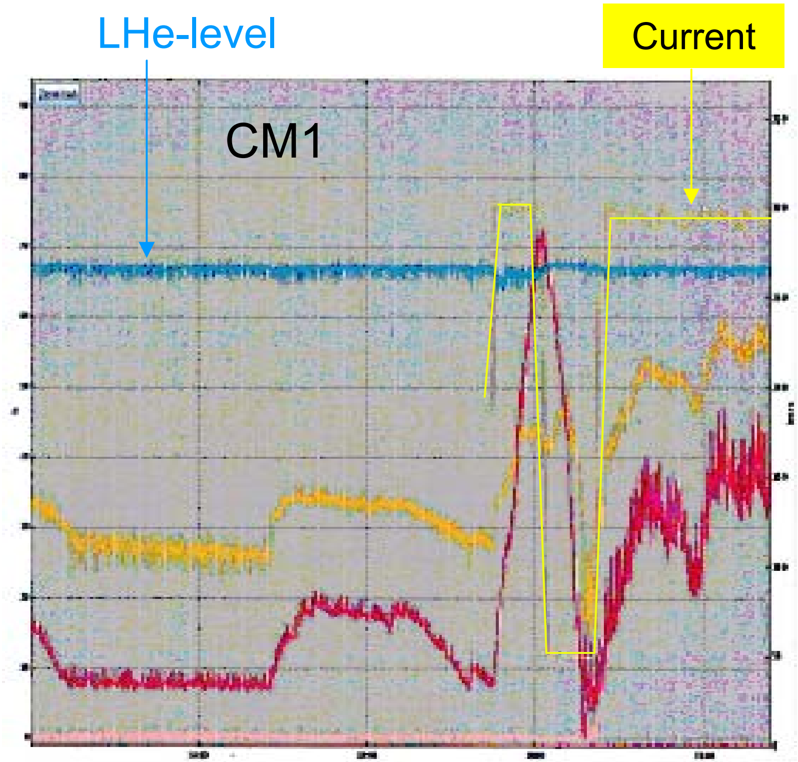
=> But, no noticeable improvement for the operation at 300 mA *(oscillations persist).*

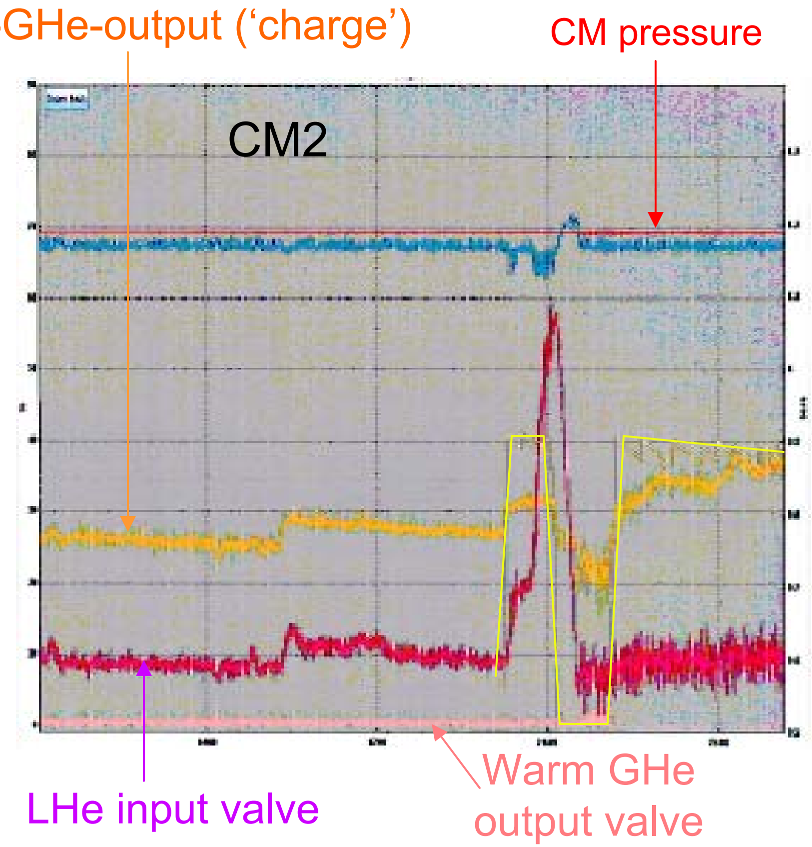
Finally, we considered that the Dewar pressure *(@1.39 Bar)* was too small to ensure an acceptable ΔP with the CM *(@1.19 Bar)*

Increase of the beam current to 300 mA with both CM1 & 2,
during radio-protection tests
Tuesday, the 16th of September 2008

Dewar pressure: from 1.39 to 1.42 Bar
('probably' limited to 1.45 Bar max.)

→ Seems efficient for 300 mA.
To be confirmed on a long term.

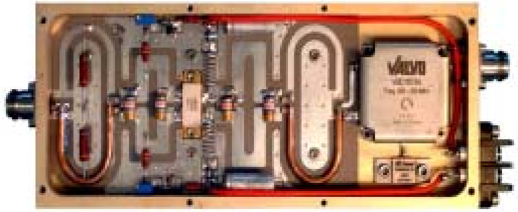




We also have to confirm that such regulation parameters will allow stable conditions for the CM to operate routinely @500 mA in the first quarter 2009

Status of the high power 352 MHz solid state amplifiers

The two 180 kW solid state amplifiers of the CM1 have demonstrated
a good reliability in operation
= No trip during operation directly due to the amplifiers between Sept. 2007 and Sept. 2008



330 W amplifier module

A1 has been operating since ≈ 10100h *(72 modules 'broken' => especially on 2 towers)*,
A2 ≈ 9800h *(20 modules 'broken')*,
A3 ≈ 1100h *(17 modules 'broken')*,
A4 ≈ 300h *(7 modules 'broken')*

Permanent R&D for RF power sources based on solid state amplifiers

- We are now testing modules working with transistors of the sixth-generation LDMOS RF technology *(while those currently in use at SOLEIL are V3)*

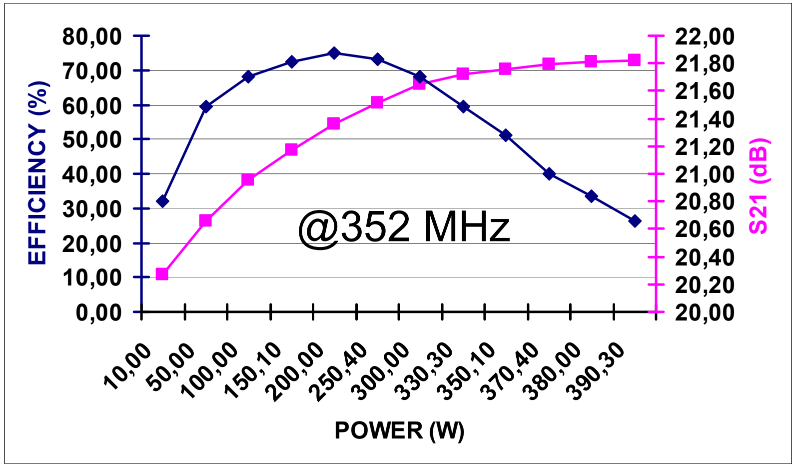
50V ⏎ *30V*

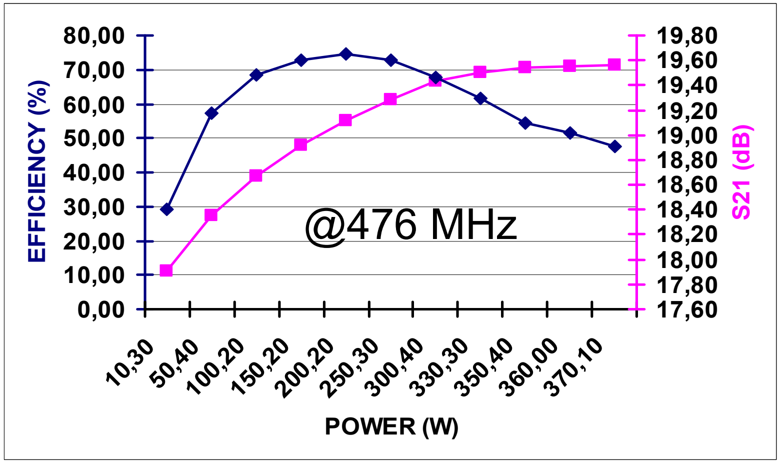
✓ High reliability

For a system with 10 000 transistors, the estimated MTBF ≈ 1400 hours.

If operation 7000 h/year, for maintenance => need to change only 5 transistors per year, i.e. ≈ 500 €/year.

✓ High efficiency





- A 350W module @500MHz has been developed by SOLEIL. Based on this module, 2 amplifiers 40 kW have also been developed in collaboration with the Brazilian light source (LNLS)

- A contract of technology transfer to a private company for the solid state amplifiers is about to be concluded

SOLEIL SYNCHROTRON

Improvements of the low level RF system

- New design of the interlock system => faster response time
  Any interlock will make the RF power OFF on the 4 RF systems simultaneously *(= on the 4 cav.)*
  + First fault detection on the 4 independent RF systems

- Development of a fast digital FPGA based IQ feedback in collaboration with the CEA, the last experimental results at 300 mA indicate a stability of 0.2% rms in amplitude and 0.12° rms for the phase of the accelerating voltage

- Development of arc detection system with using a fast photodiode with a large effective active area

- Development of an absolute encoder for the tuner system

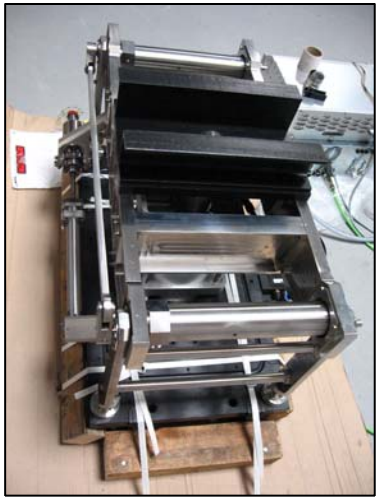
New developments for the cold tuning system of the cavities

Considering the difficulties encountered with the tuning system that doesn't wear well after millions of motor steps, it was proposed to operate in hybrid modes:

For Ib < 120 mA the Vrf is ramped up to 700 kV at 0 mA and 1200 kV at 120 mA. The tuning system is blocked at a position corresponding to an optimal detuning at 120 mA.

For Ib > 120 mA the Vrf is fixed to 1.2MV, but the tuning system is active.

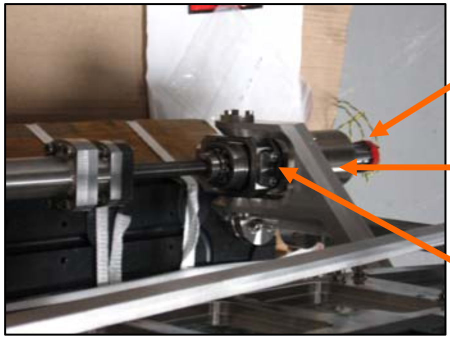
(the displacement of the tuner is significantly reduced by this way)

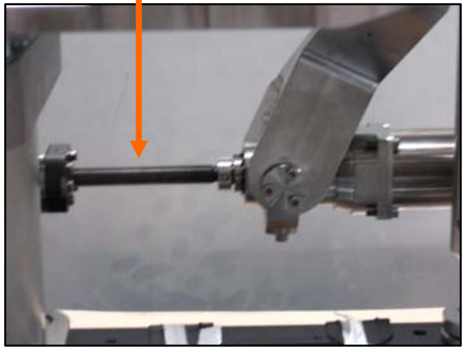


Test bench that simulates the force exerted by a cavity

In parallel new developments are made for the mechanical tuning system *(K. Tavakoli)*

Some tests to perform with the new system:
- Tests at 300°K
- Behavior after many turns at 4.5°K
- Influence of the motor sub-division (1/20, 1/64 …)





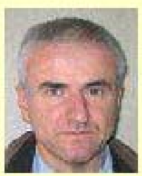
Acknowledgement

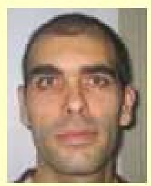
SOLEIL RF & LINAC GROUP


Fernand RIBEIRO


Patrick MARCHAND


Ti RUAN


Jean-Pierre POLLINA


Robert LOPES


Massamba DIOP

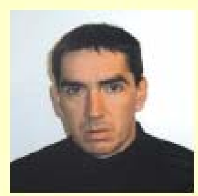

Rajesh SREEDHARAN


Marc LOUVET


Nicolas GUILLOTIN

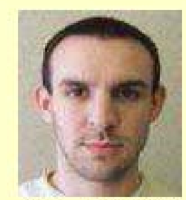

Jean-Pierre BAETE


Helder A. DIAS


Jocelyn LABELLE


Cyril MONNOT


Moussa EL AJJOURI


Julien SALVIA

Keihan Tavakoli *(Mechanical Engineer, **SOLEIL**)*

+ C. Thomas-Madec, G. Devanz, E. Jacques, P. Bosland (CEA / Saclay)