DAPNIA

RF superconductivity application to synchrotron radiation light sources

Third Harmonic Superconducting passive cavities in ELETTRA and SLS

2 cryomodules (one per machine) with 2 Nb/Cu cavities at 1.5 GHz

DAPNIA

Collaboration

CEA – PSI – Sincrotrone Trieste and CERN

P. Bosland, P. Brédy, S. Chel, G. Devanz, CEA Saclay France

M. Pedrozzi, W. Gloor, PSI Switzerland, A. Anghel, EPFL-CRPP, Switzerland

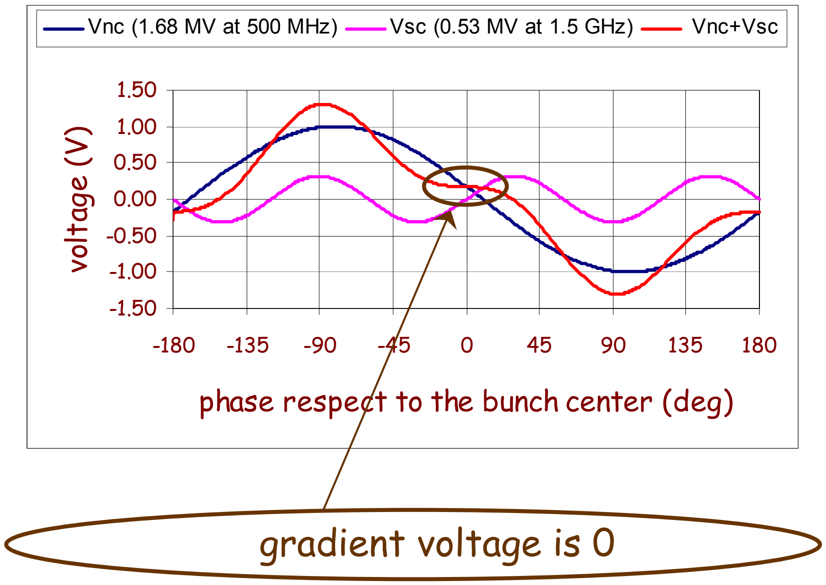
P. Marchand, SOLEIL, Synchrotron SOLEIL France

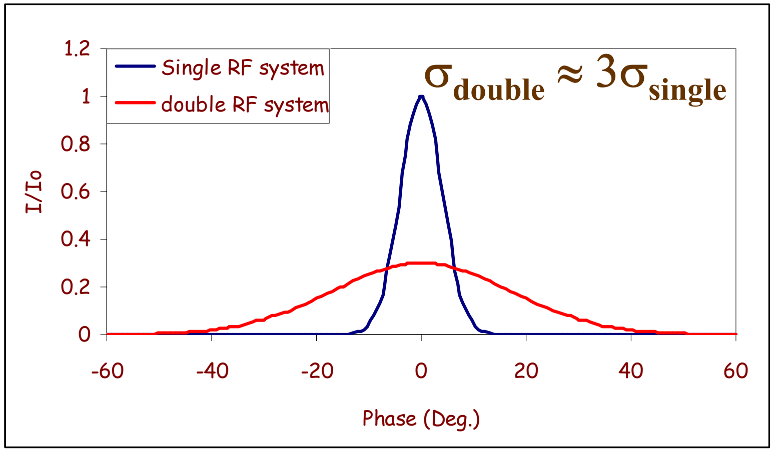
P. Craievich, G. Penco, M. Svandrlick, Sincrotrone Trieste Italy

E. Chiaveri, R. Losito, O. Aberle, S. Calatroni CERN Switzerland

DAPNIA

Increase of the Touschek dominated beam lifetime





A 3rd harmonic (1.5 GHz) RF system allows:

bunch lengthening → decrease of charge density

→ increase of beam lifetime

DAPNIA

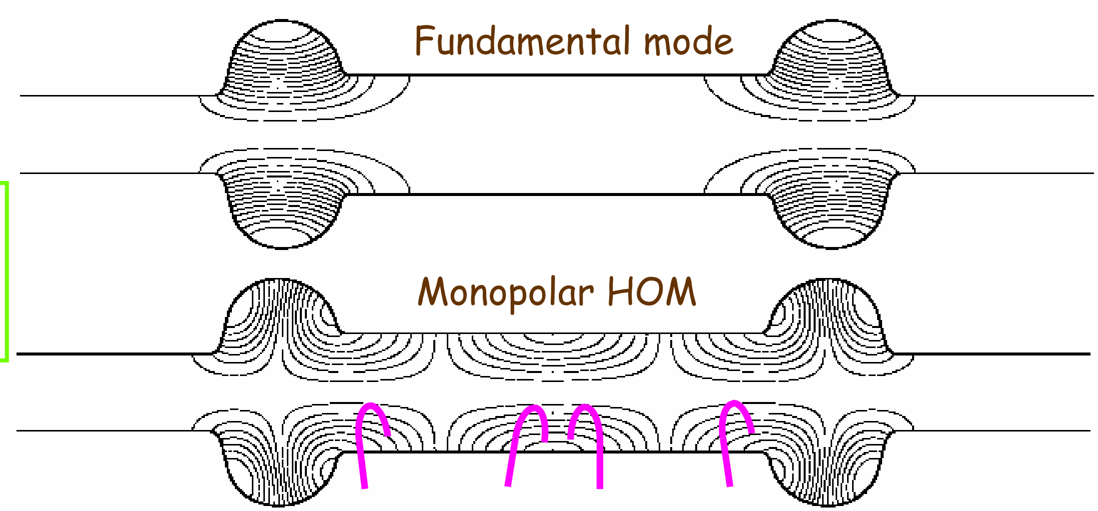
Passive superconducting cavities

SOLEIL RF structure type

No power coupler (beam powered)

HOM free RF structure

2 cavities linked by a large tube on which are placed superconducting loop couplers for damping HOMs.



Superconducting Nb loop couplers on inner tube: geometry optimized for HOMs damping (number of couplers, axial and angular position, loop geometry, etc.)

Spécifications

Bunch lengthening mode:

Temperature :	4.4 to 4.5 K
Fundamental mode frequency :	F_0=1498.95 MHz
Total max accelerating voltage:	V=1.0 MV
Tuning range:	DF=±500 kHz
Tuning resolution:	R ≈ 10 Hz
Q_0 vertical tests at CERN:	> 2. 10^8 at 5MV/m and 4.5 K
Q_0 cryomodule tests at Saclay:	> 2. 10^8 at 4MV/m and 4.4 K
Q_l loaded:	> 1. 10^8 at 4MV/m and 4.4 K

Damping:

Longitudinal HOMs : $f_R.R_{//} < 7.0$ kΩ.GHz

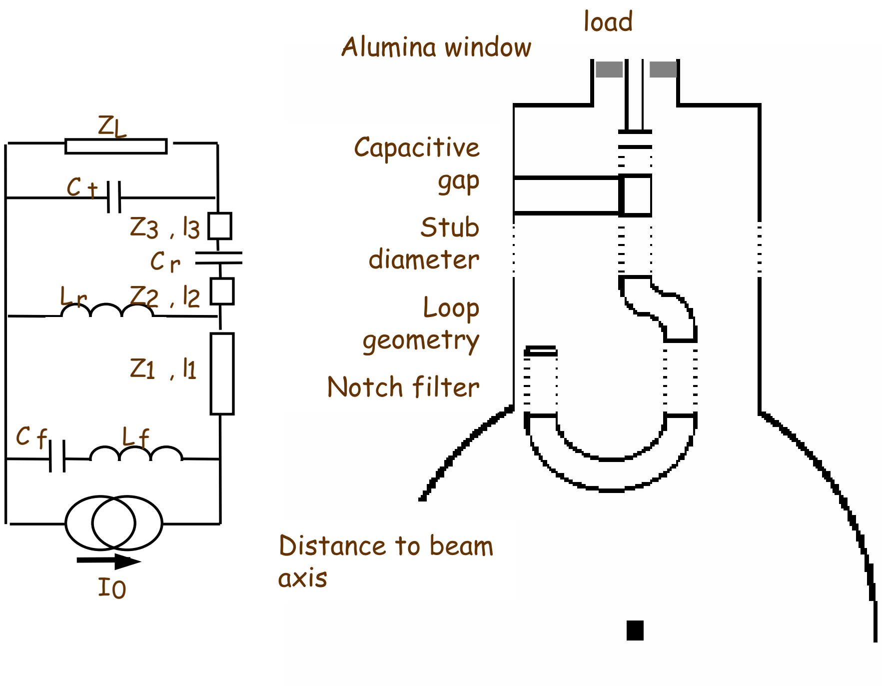
Transverse HOMs : $R_\perp < 130$kΩ/mm

Parking mode at 300 K or 4.5 K: cavities tuned between 2 revolution harmonics

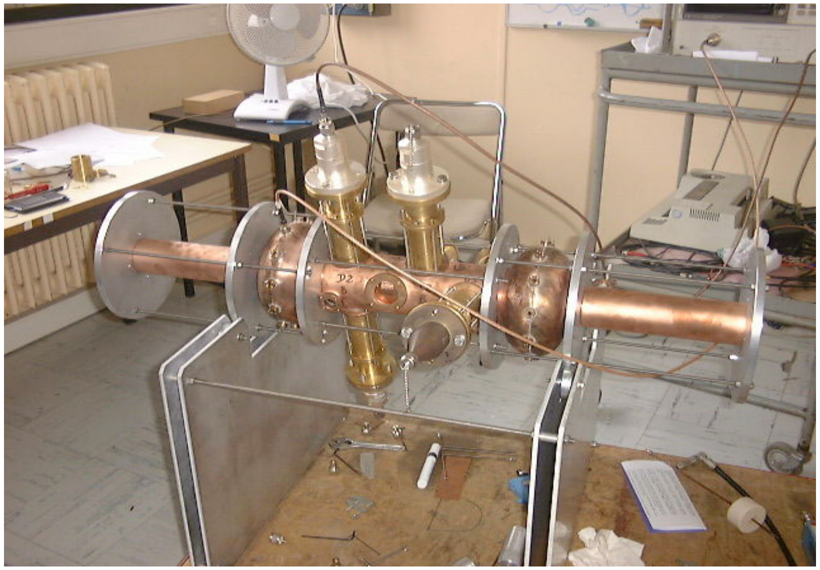
Max. cryomodule length: 1.1 m

DAPNIA

Optimisation of HOMs damping



Geometric parameters for HOM coupler design optimisation



Model cavity for HOMs damping optimisation

HOMs Damping requirements

10 transverse modes + 10 longitudinal modes:

- Transverse modes: f_{cutoff} = 3762 MHz
- Longitudinal modes: f_{cutoff} = 2880 MHz

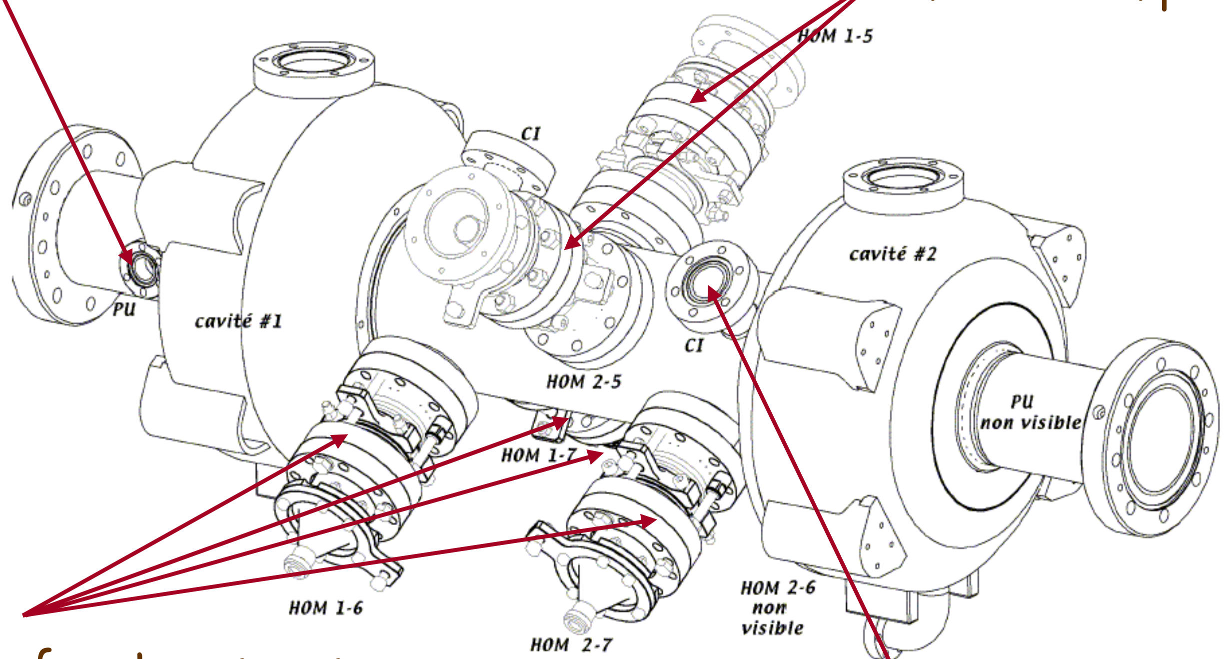
F (MHz) Monopolar	R/Q (Ω)	Q_{max}	F (MHz) Dipolar	R/Q (Ω/m)	Q_{max}
2466	0.17	16000	1721	20.0	6500
2532	2.60	1100	1723	21.8	600
2606	11.0	240	1935	0.01	1.10^7
2695	0.12	22000	2056	255	510
2826	6.57	380	2103	27.6	4710
2979	8.61	270	2148	437	300
3084	1.93	1200	2303	10.1	12900
3180	0.30	7500	2503	11.1	11700
3358	0.86	2400	2712	63.8	2040
3594	0.43	4500	2865	10.3	12600

DAPNIA

The RF structure

1 Pick-up port per cavity

2 couplers for longitudinal modes damping



4 couplers for transverse modes damping

1 incident coupler port per cavity for RF measurements

Super-3HC

couplers for transverse modes

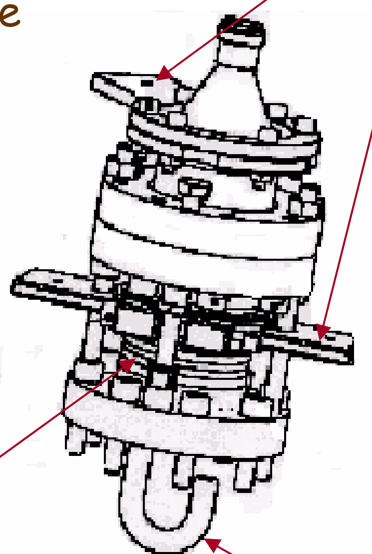
couplers for longitudinal modes

N connector for RF power output with a semi rigid Kaman cable

cooling copper fan connected to liquid helium via braids

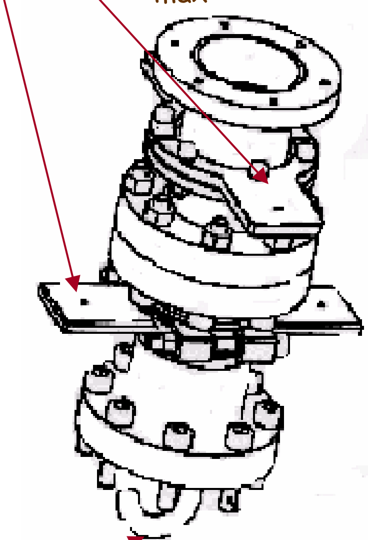
5/8 connector for RF power output with a coaxial line

P_{max}=1.2kW



Ceramic windows brazed on copper with stainless steel flanges

Superconducting niobium with stainless steel flanges

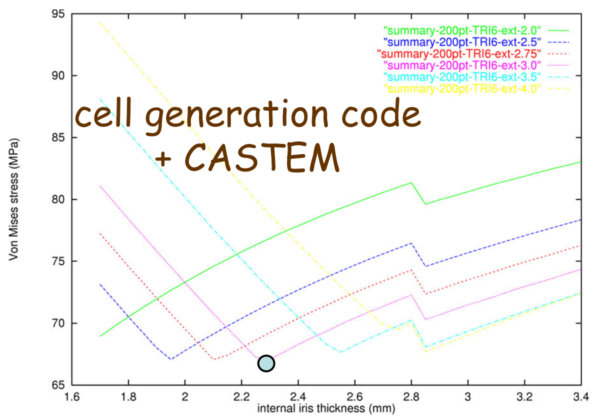


Flexible Nb wave for notch filter tuning

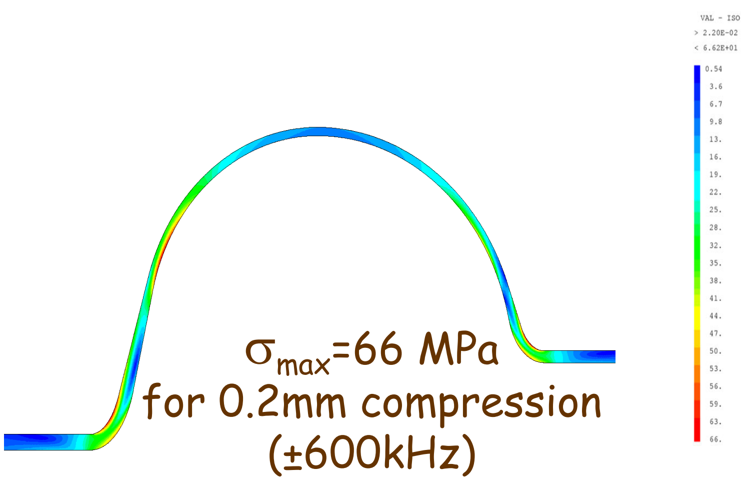
Niobium loop extremities

DAPNIA

Optimisation of the cell wall thickness



For a constant wall thickness of 3mm, the copper elastic limit (60MPa) is reached for a detuning of ±400kHz (<±500kHz specifications).



Sensitivity to deformation for tuning:

$\Delta F / \Delta l$ = 3.2 MHz/mm calculated and measured

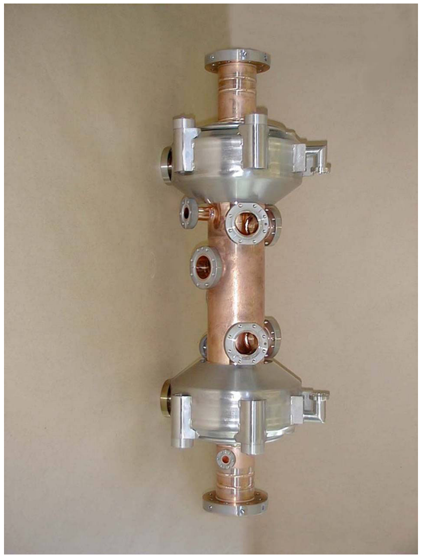
Sensitivity to helium pressure variations:

Calculated:
- $\Delta F / \Delta P \sim$ 150 Hz/mbar cavities ends free
- $\Delta F / \Delta P \sim$ 30 Hz/mbar cavities ends fixed

Measured: $\Delta F / \Delta P \sim$ 65 Hz/mbar

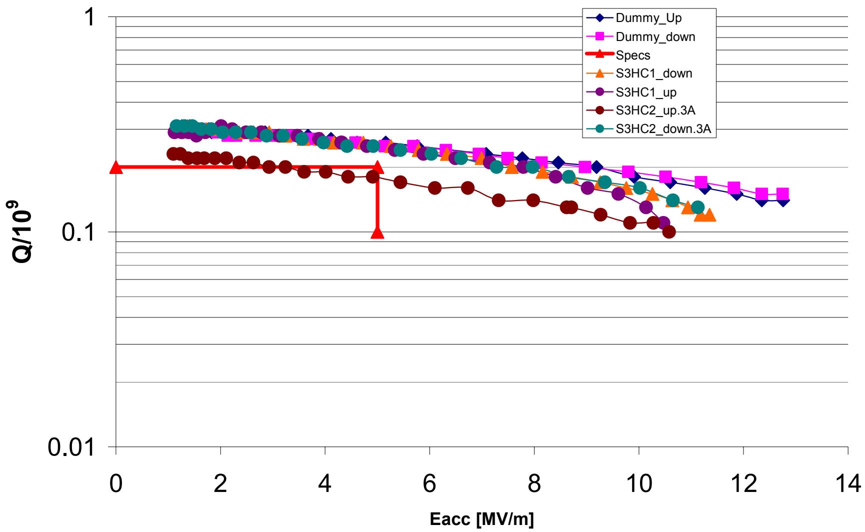
DAPNIA

1.5 GHz Nb/Cu cavities fabricated and tested at 4K in vertical cryostat at CERN



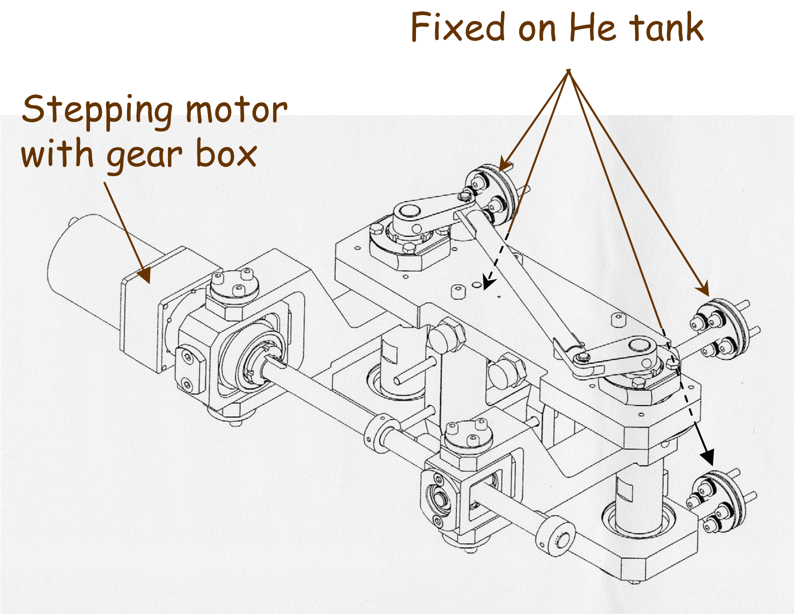
A small magnetron cathode was especially developed to sputter the niobium inside the outer tubes Φ61mm in diameter

1.5 μm Nb coating was deposited by magnetron sputtering inside the copper cavities

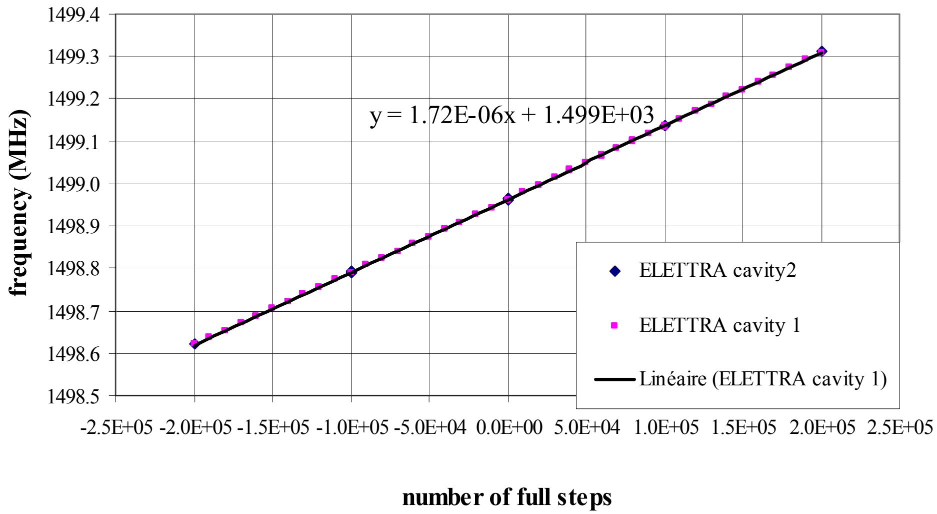


DAPNIA

The tuning system is used to control the voltage (passive cavity) acting on the cavity frequency



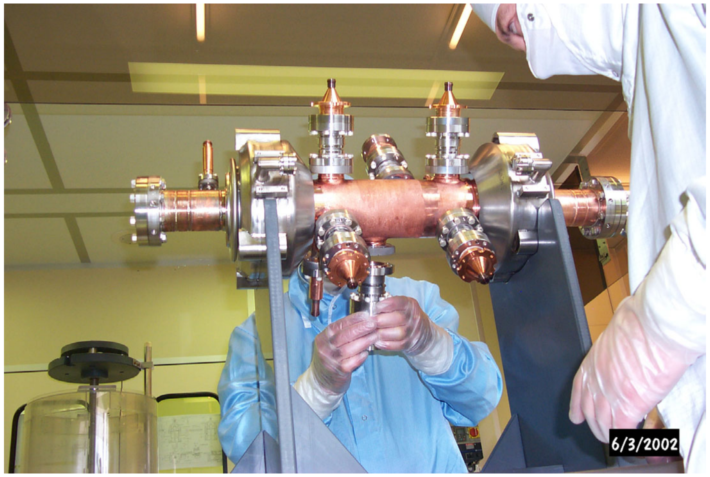
The tuner works in vacuum at 4K



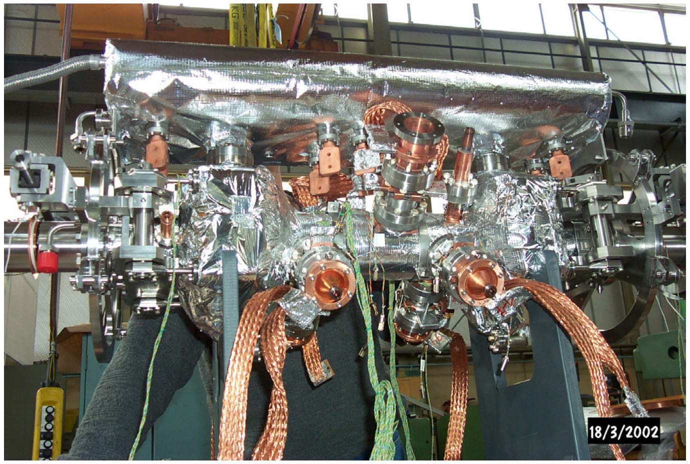
Linearity of the frequency versus motor steps number

- stiffness > 1000 kN/mm
- stiffness with He tank: 220 kN/mm (10x cavity)
- maximal amplitude: ± 0.5 mm, or ± 1.5 MHz
- theoretical resolution : 0.5 nm, or 1.7 Hz

Cryomodule assembling at Saclay

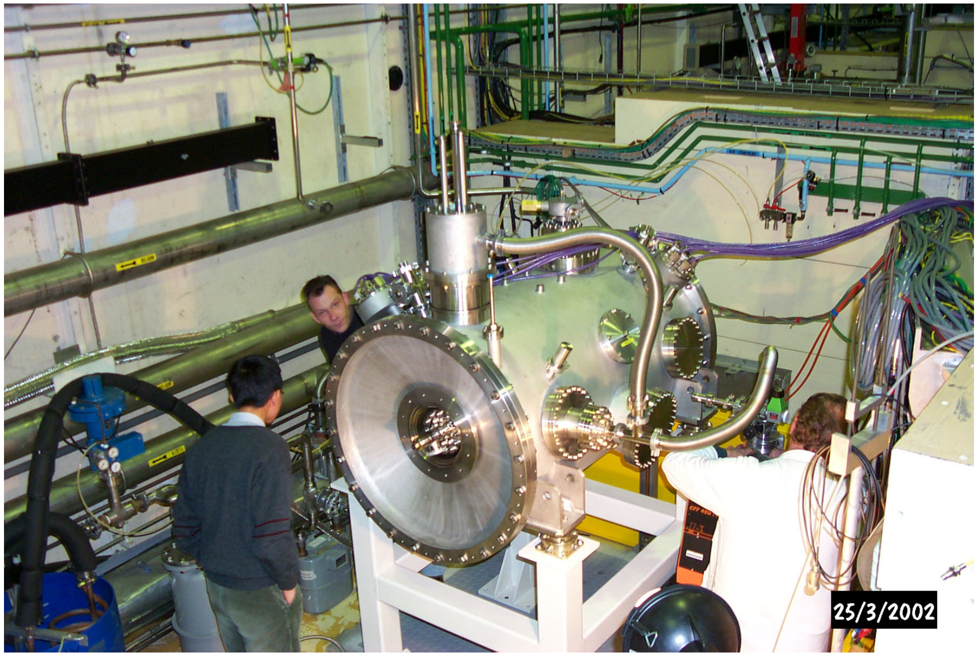


In class 100 clean room



Cold mass assembling in the workshop

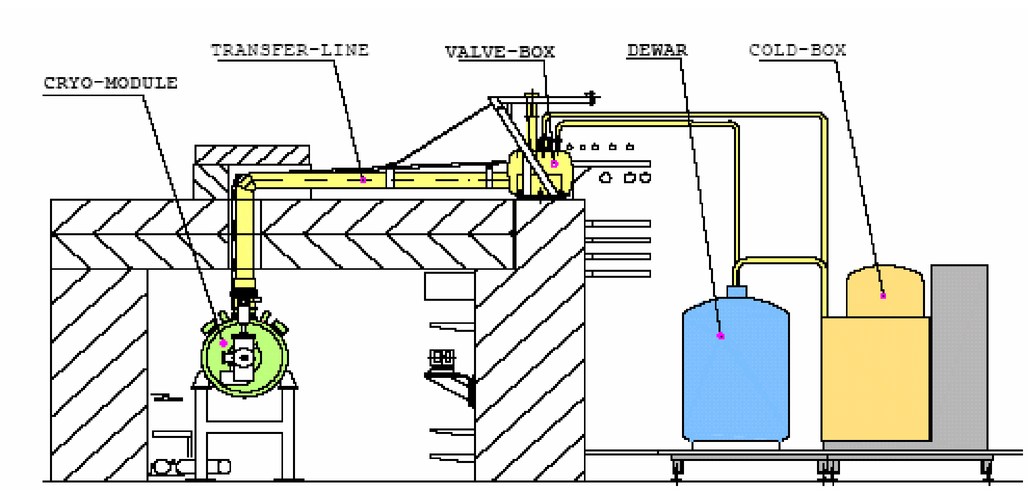
DAPNIA



Preparation of the cryomodule test at Saclay

Super-3HC

DAPNIA



Layout of the SLS cryogenic system

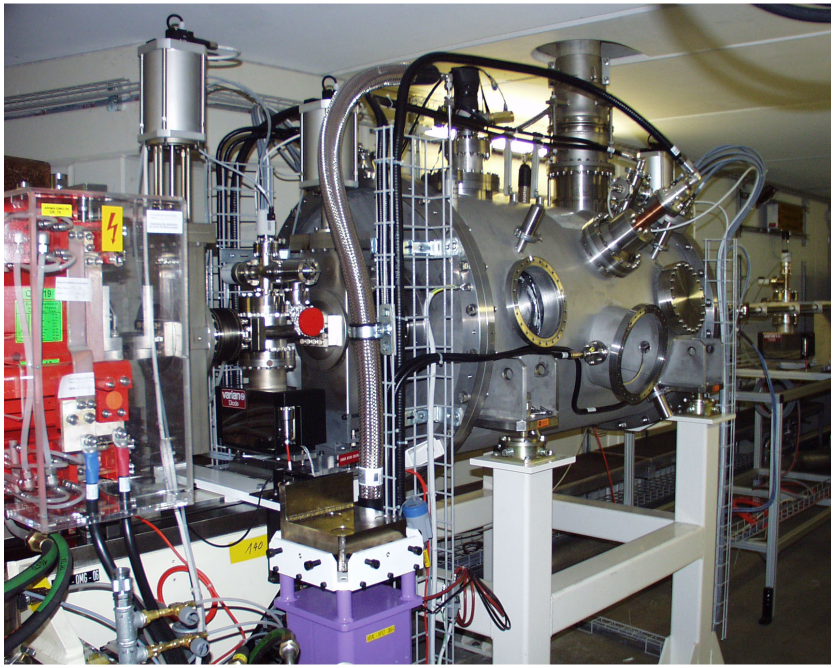
Helial 1000 liquefier/refrigerator

7.5 l/h liquefaction, and 65 W refrigeration at 4.5 K

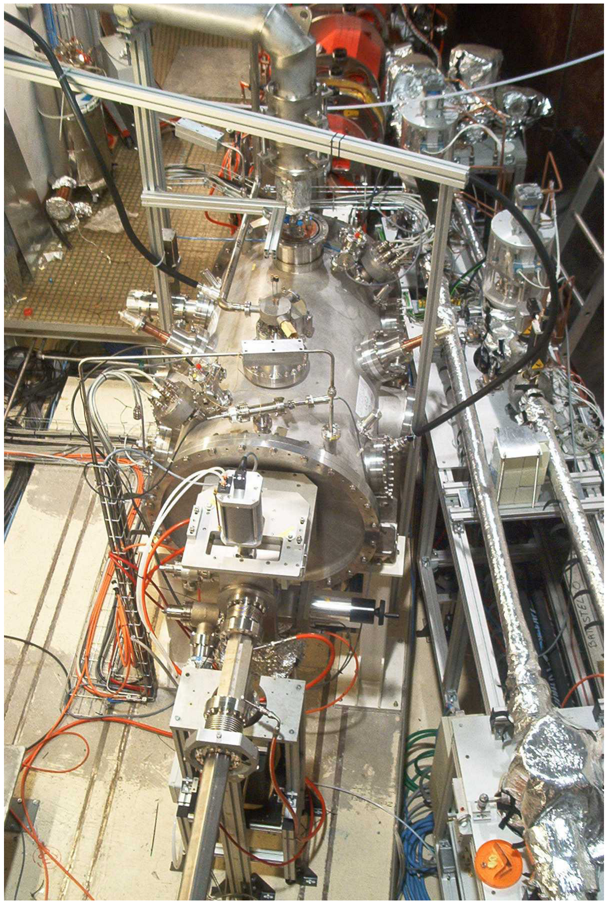
Component	Load	Comments
2 RF cells	22 W	Directly in LHe bath
2 L – couplers	3 W	Cooled by conduction
4 T – couplers	8.5 W	Cooled by conduction
2 Extremity tubes	0.2 W	With 2 x 0.05 g/s cold GHe
Cryomodule static losses	5.1 W	With 0.071 g/s cold GHe in thermal shield (60 K)
Transfer-lines	6.5 W	Assuming 0.5 W/m load
Total refrigeration power at 4.5 K: 45.3 W		
Total GHe flow: 0.171 g/s → 5.2 l/h of liquefaction duty		

Estimated cryogenic load at 4MV/m, 400mA and Q=2.10^8 (for SLS cryomodule)

DAPNIA



SLS cryomodule



ELETTRA cryomodule

DAPNIA

SLS cryomodule

- cryomodule installed in June 2002
- "warm operation" (200mA) starting June 2002
- cavity cool down September 23-27 2002
  (400 mA stable operation with cold cavity)
- "cold operation" with beam 30 September 2002

Warm operation: current limited at 200 mA due to overheating of the cavities (with vacuum insulation)

Cold operation: stable operation at 400 mA – maximum elongation demonstrated
bunch lengthening: x3 - beam life time: x 2.2
Landau damping: suppression of coupled bunch instabilities
stable users operation at 300 mA with reduced Super-3HC voltage

ELETTRA cryomodule

- cryomodule installed in August 2002
- "warm operation" starting September 2002
  (140mA at 2.4 GeV)
- cavity cool down January 9th, 2003
- 300 mA at 2.0 GeV stable operation with cold cavity

Warm operation: operational mode at 2.0 GeV forbidden due to interaction between the parked fundamental mode and the beam spectrum lines

at 2.4 GeV, 140 mA the cavities can be parked transparent to the beam

Cold operation: the parked cavities don't influence the beam injection at 0.9 GeV and energy ramping to 2.0 or 2.4 GeV

suppression of longitudinal coupled bunch instabilities at 2.0 GeV and 320mA

bunch lengthening: x 3 - beam life time: x 3.5

period March to June: cavities were parked because of problems on the tuner of cavity1 that were sorted out during the shutdown in June.

CEA
DAPNIA

Conclusions:

First demonstration of synchrotron radiation operation with superconducting Landau cavity

Both machines gained a factor 3 on bunch lengthening, and a factor higher than 2 on beam life time (3.5 at ELETTRA).

Landau damping allows suppression of coupled bunch instabilities.

In cold operation, both cryomodules are very stable: no abnormal temperature increase, stable voltage, stable vacuum pressure. No interlock due to the cryomodule during the first year of operation on the SLS cryomodule.

For more information on the commissioning of the cryomodules:

Poster MoP25:

SLS Operational Performance with Third Harmonic Superconducting System

Poster MoP27:

Performance of the 3rd Harmonic Superconducting Cavity at ELETTRA