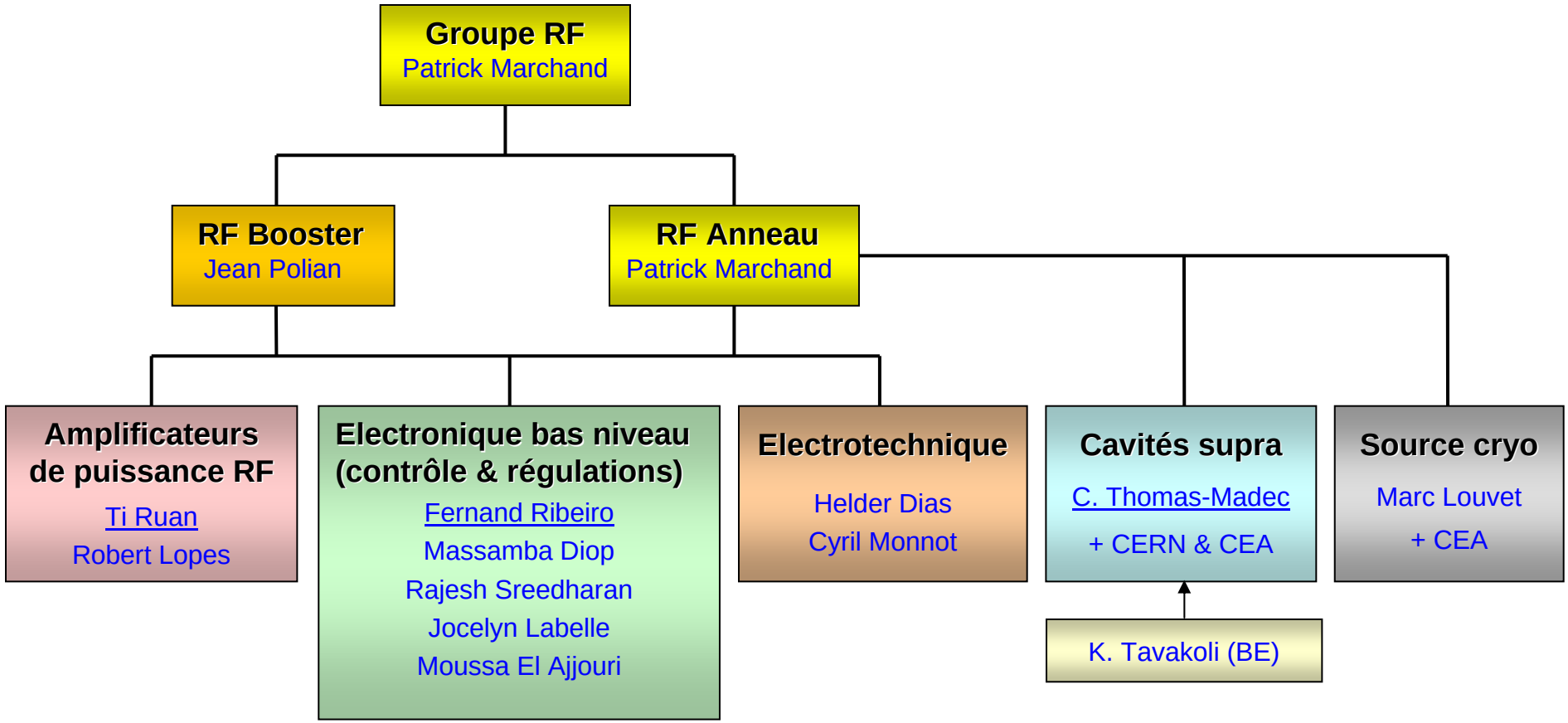
Status of the SOLEIL RF systems

180 kW per solid state amplifier achieved in April 2006

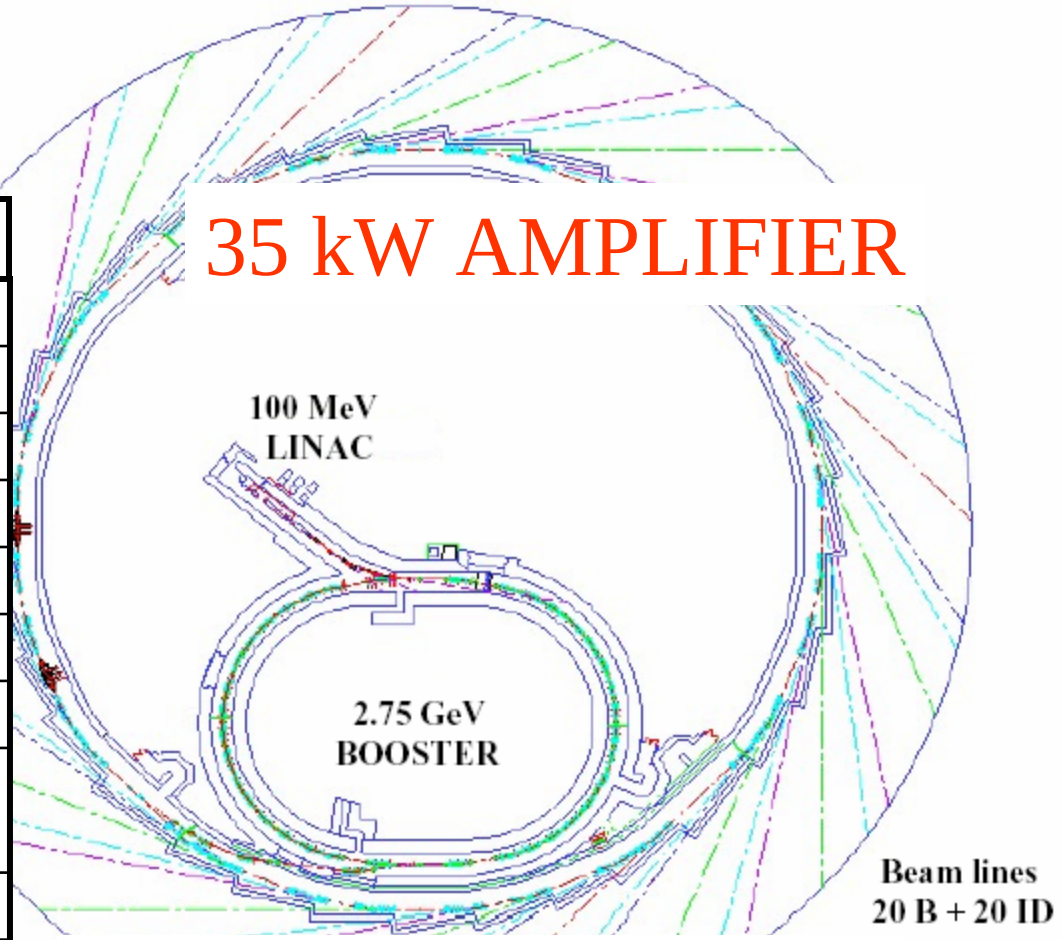
On behalf of SOLEIL RF group



What is SOLEIL ?

French Light source
of the 3rd generation

Booster Parameters	
Circumference	156.6 m
Revolution frequency	1.91 MHz
Repetition rate	3 Hz
Injection energy , E_i	100 MeV
Final energy , E_f	2.75 GeV
Energy loss / turn @ E_f	410 keV
Beam current (max)	12 mA
RF acceptance @ E_f @ E_i with V_{RF} = 200 kV	± 0.35 % ± 1.5 %
Harmonic number	184
RF frequency	352.2 MHz
RF voltage @ E_f	0.85 MV
Beam power @ E_f	5 kW



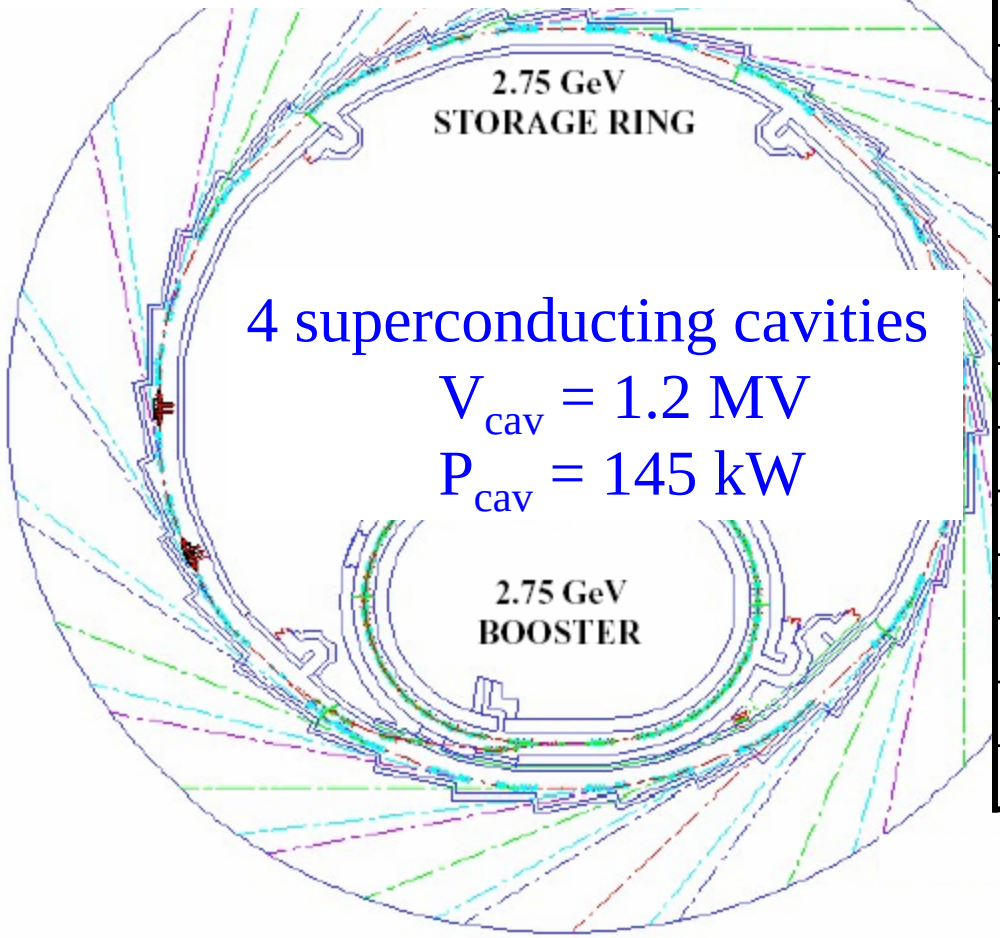
CERN-LEP 5-cell Cu cavity

P_{dis} : 15 kW
P_{beam} : 5 kW

} **P_{tot} : 20 kW**

What is SOLEIL ?

4 X 190 kW AMPLIFIER

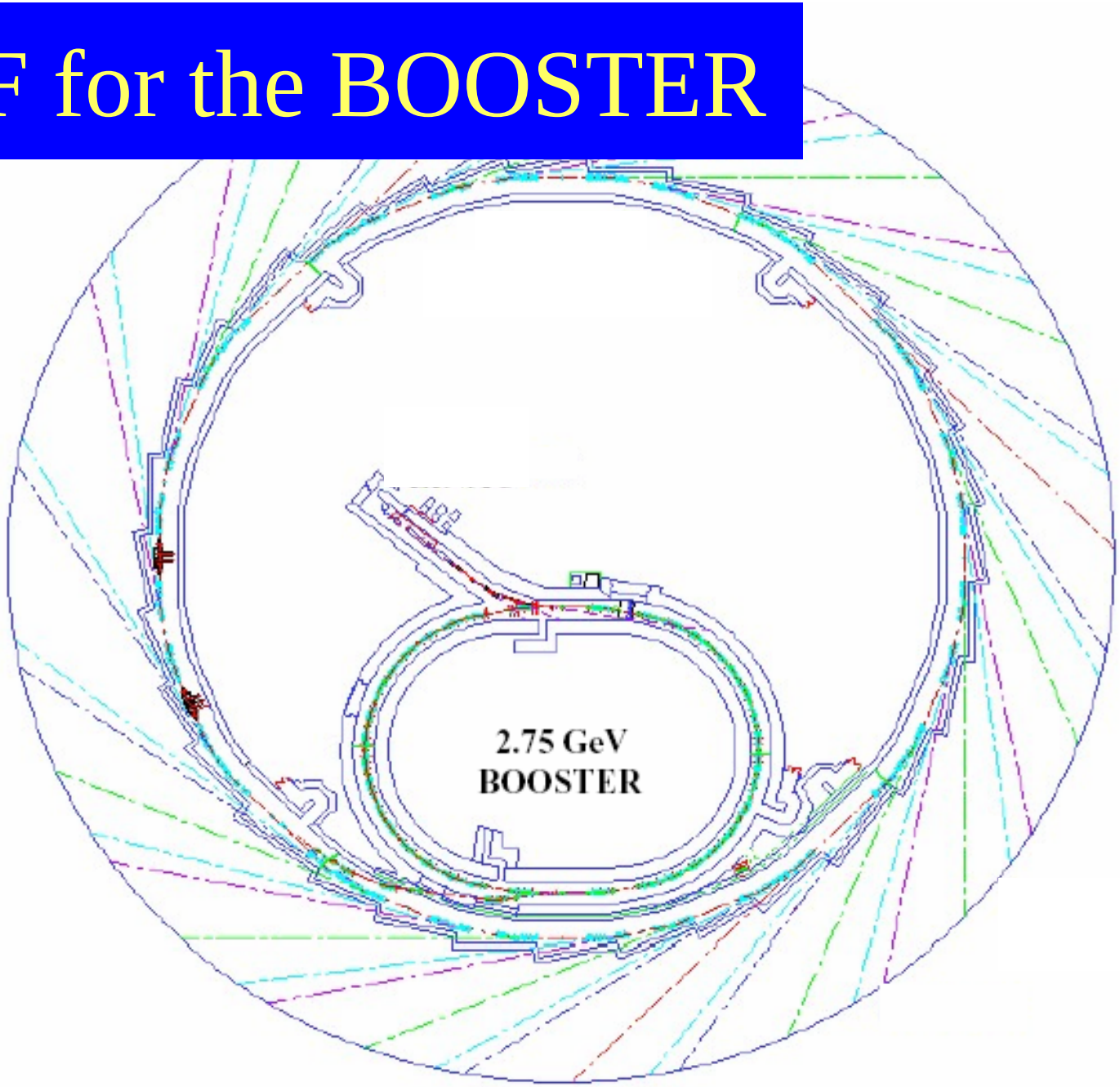


SR Parameters	
Circumference	354 m
Revolution frequency	0.85 MHz
Energy	2.75 GeV
Energy loss / turn	1.15 MeV
Beam current	500 mA
Momentum compaction	4.4 E-4
Momentum spread	0.1 %
RF acceptance	± 6.15 %
Bunch length	4.2 mm
Synchrotron frequency	5.9 kHz
Harmonic number	416
RF frequency	352.2 MHz
RF voltage	4.8 MV
Beam power	575 kW

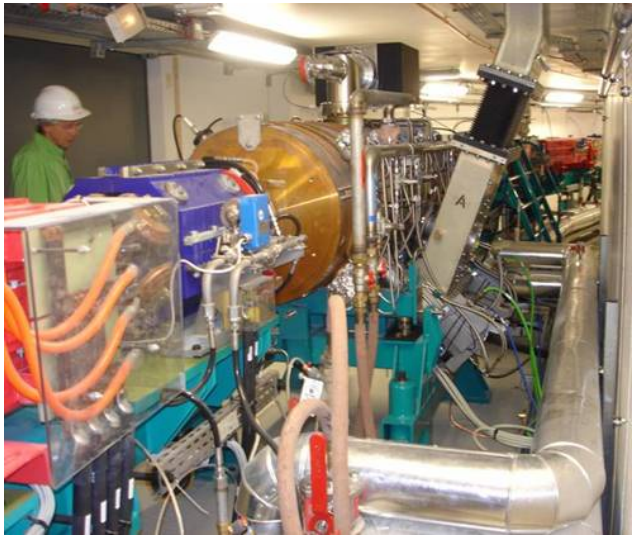
Status of the SOLEIL RF systems

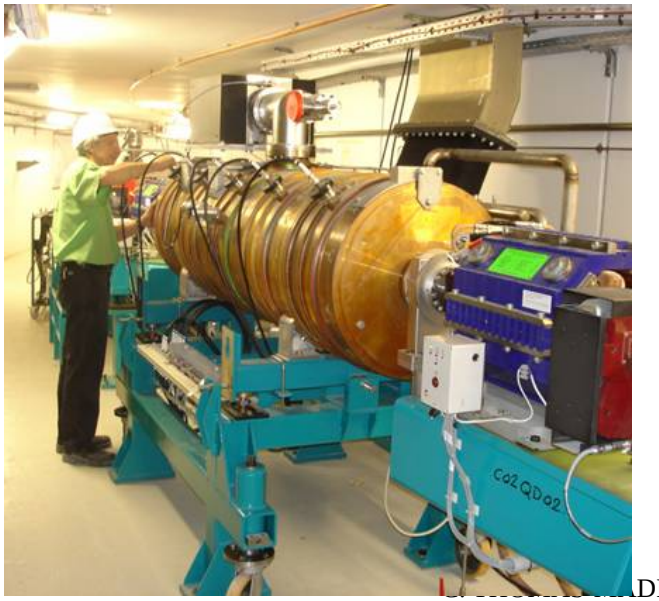
- Booster :
  - Cavity
  - Results
- Storage ring :
  - Cryomodule
  - Cryogenic source
  - Results

RF for the BOOSTER

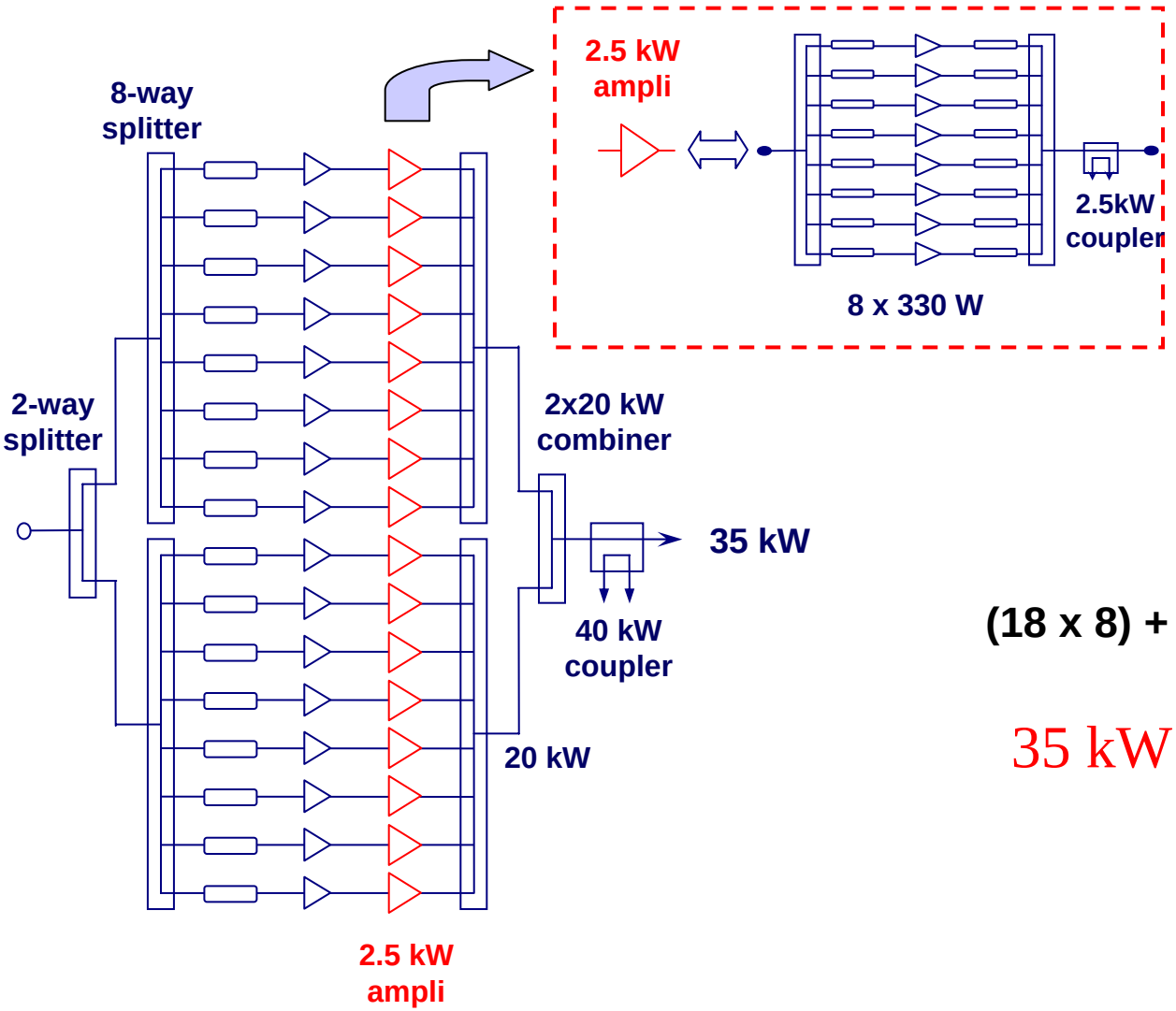


BOOSTER cavity





Booster Amplifier :

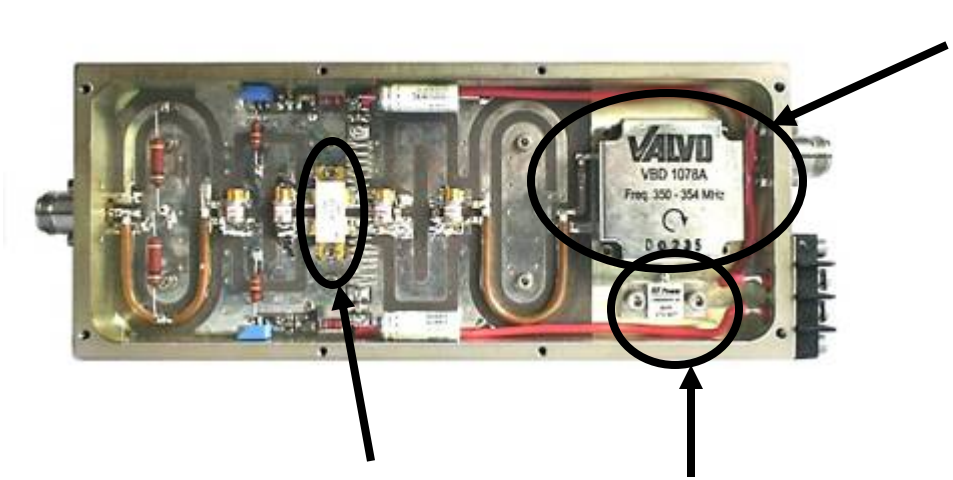


(18 x 8) + 3 = 147 modules

35 kW AMPLIFIER

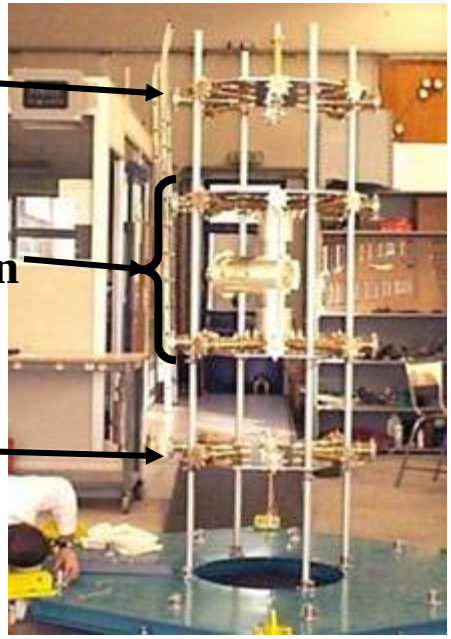
Module and Converter

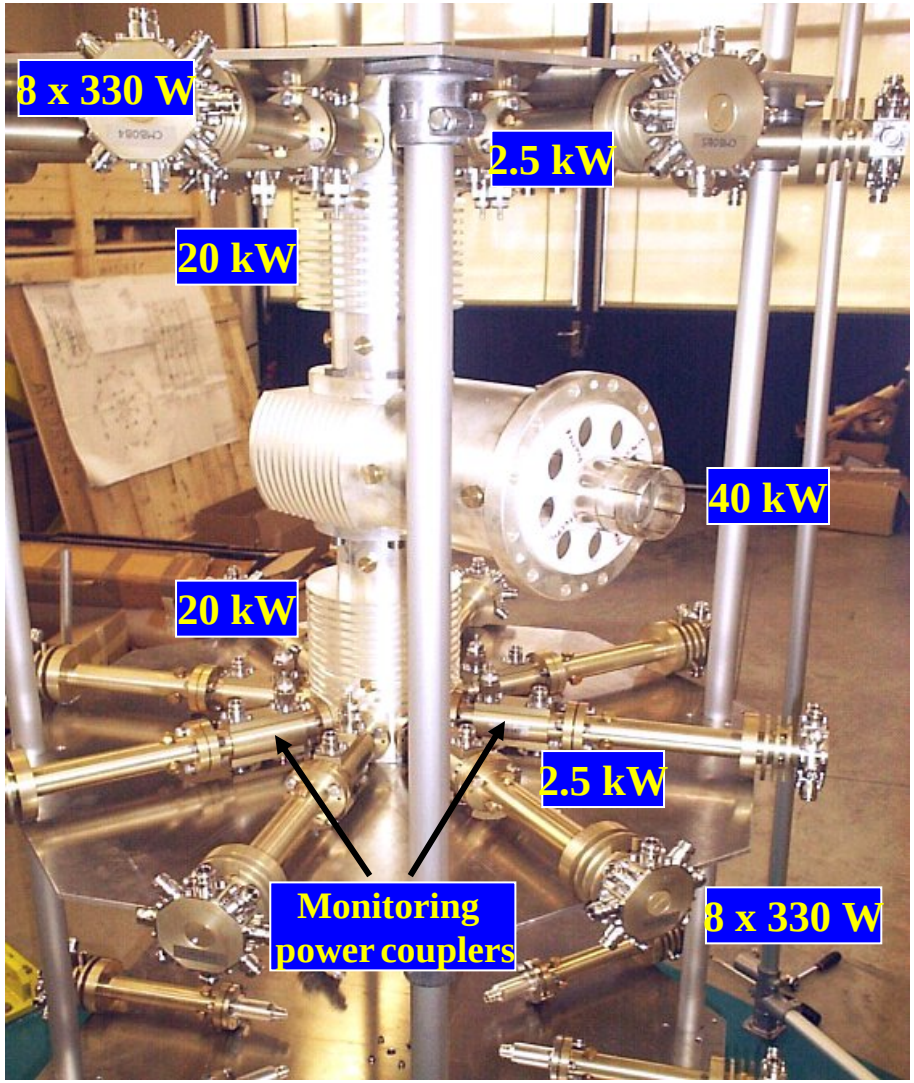
330 W solid state amplifier module



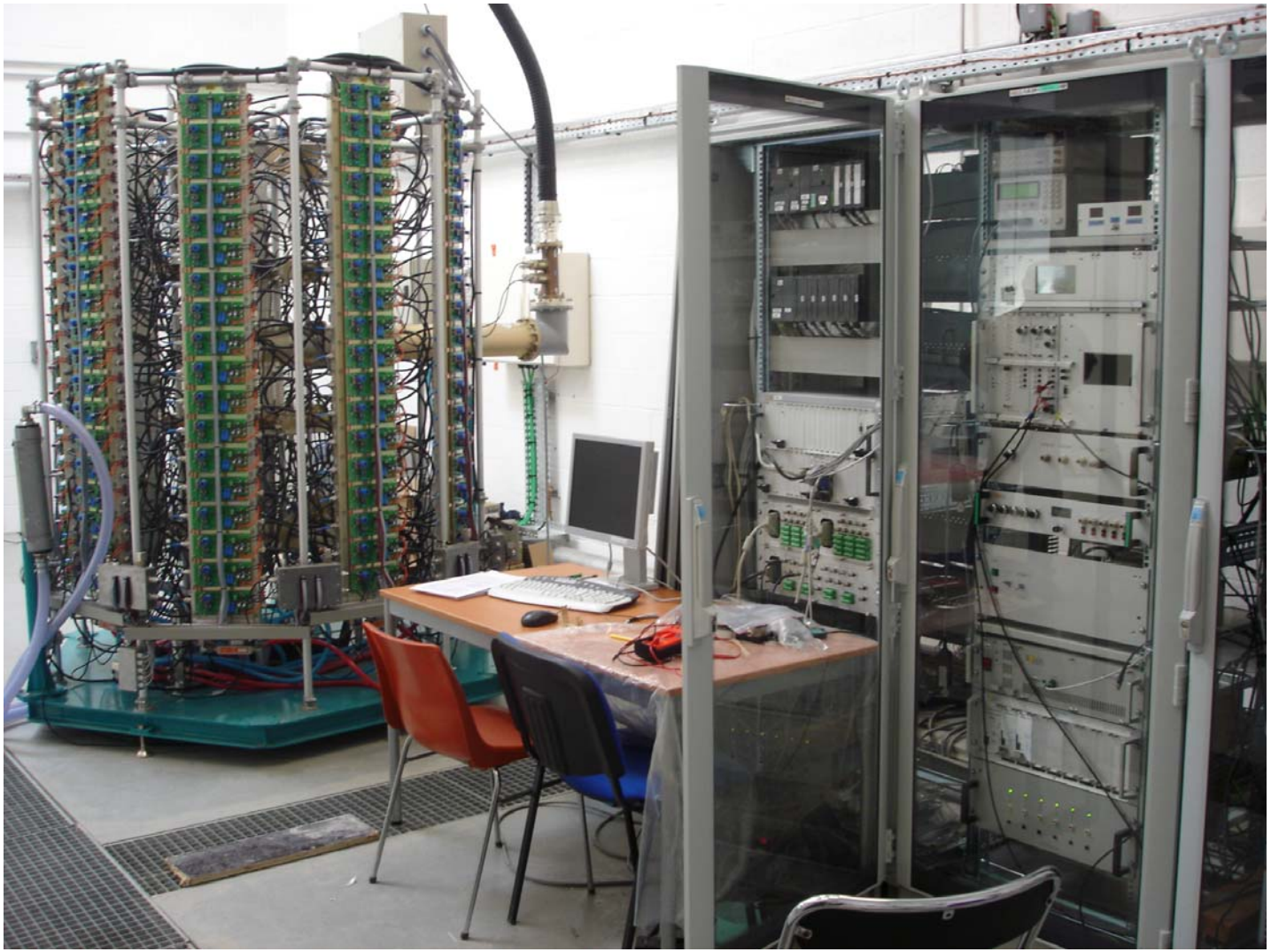
600 W, 300 Vdc / 30 Vdc converter

Splitting and recombination

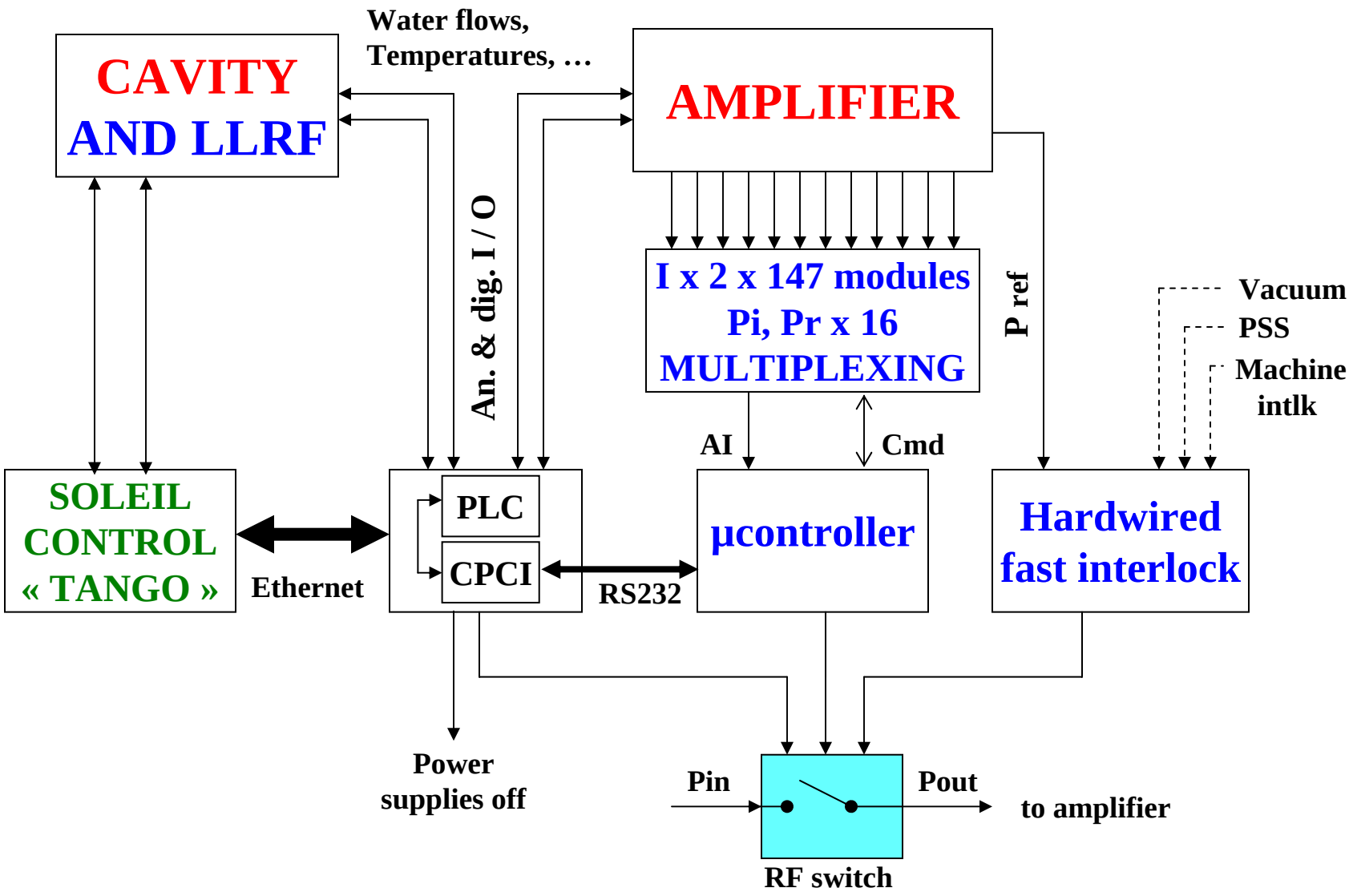




Amplifier for Booster

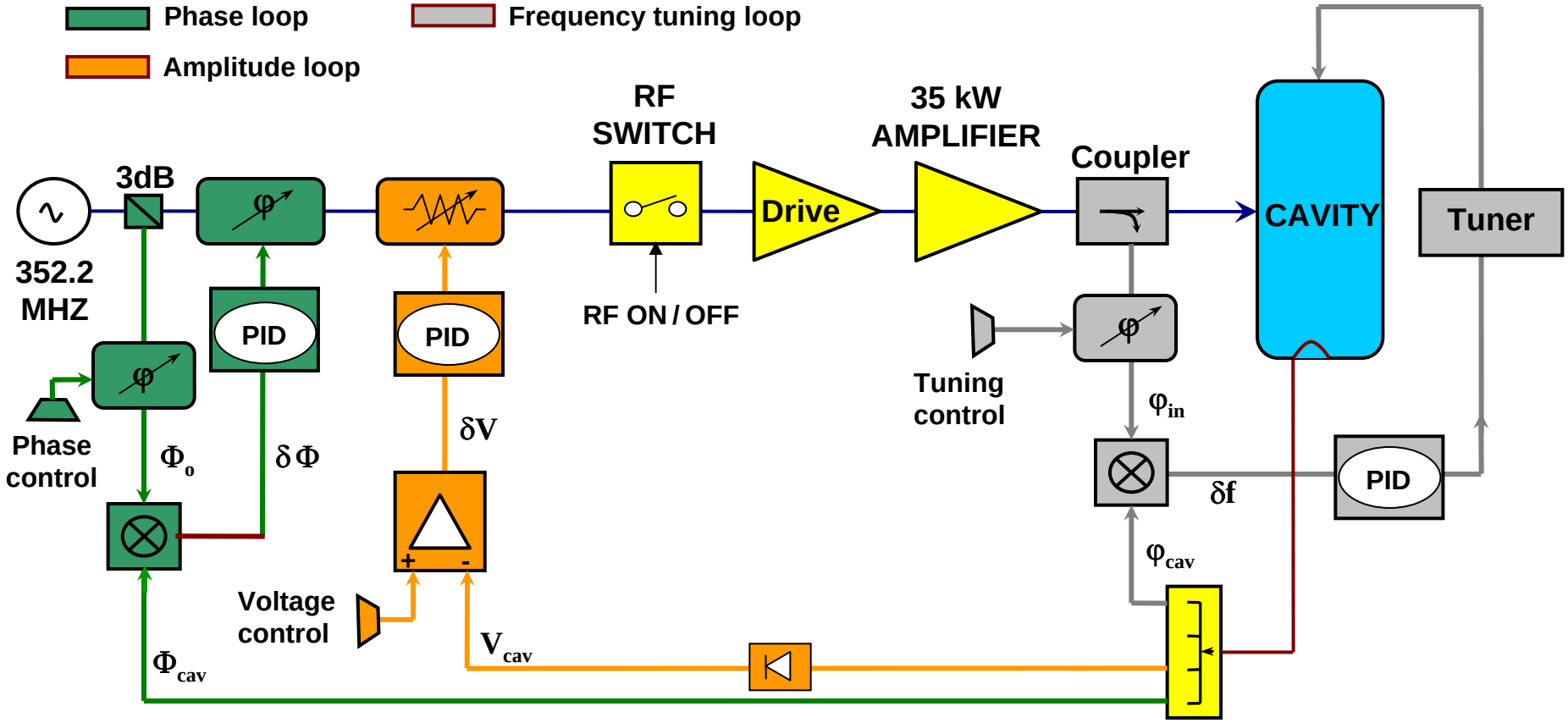


BOOSTER RF control system



Low Level Electronics

3 conventional « slow » control loops for the frequency, amplitude & phase
remake of a LURE design adapted to the SOLEIL needs



	Amplitude	Phase	Frequency
Accuracy	± 0.25 %	± 0.4°	± 30 Hz
3 dB BW	12 kHz	7 kHz	5 Hz

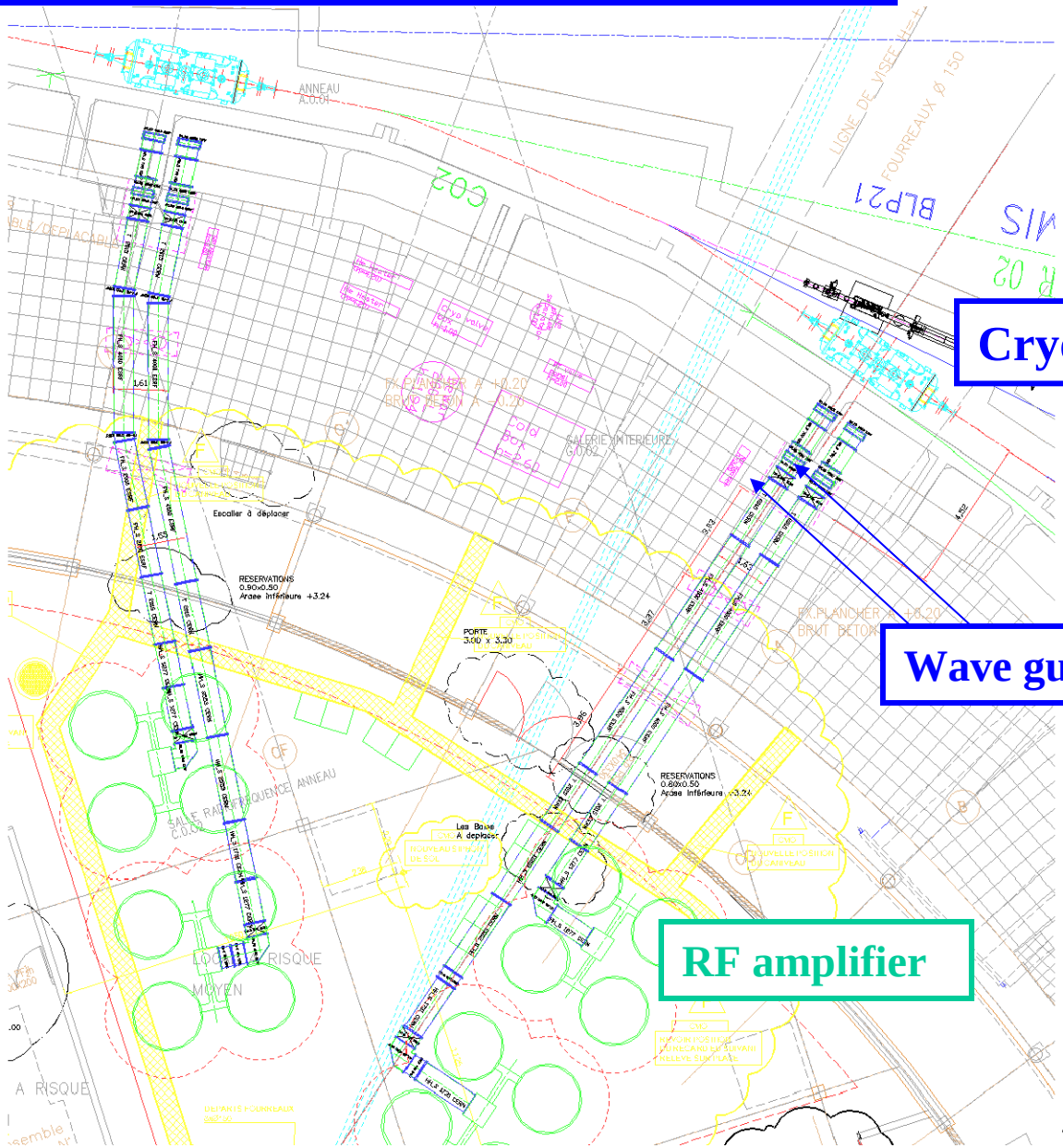
RF BOOSTER status

- *Autumn 2004 :* tests of the complete BO RF plant (cavity, amplifier, control & LLRF) at 30 kW CW for more than 1500 h

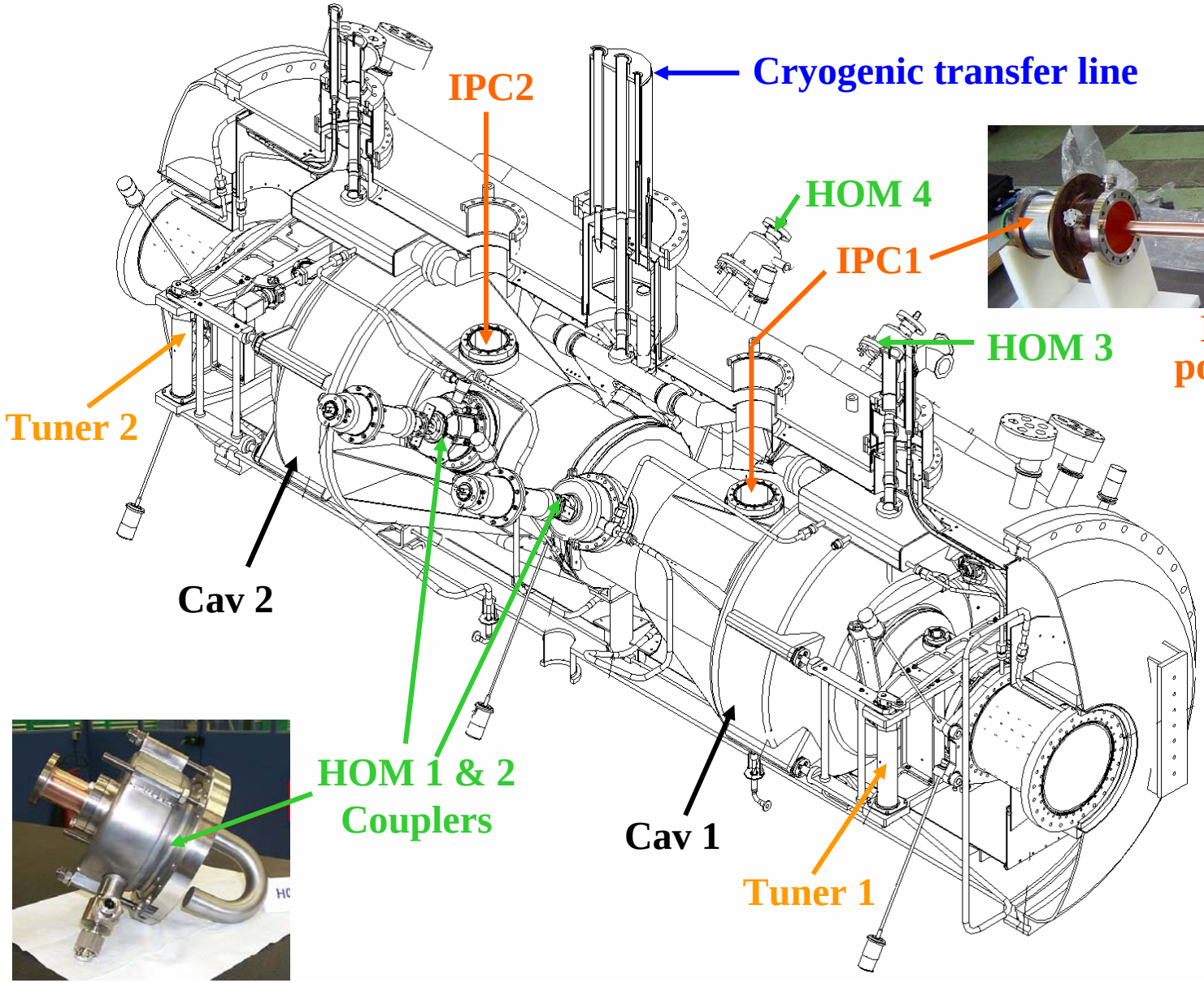
- *July 2005 :* complete Booster RF plant tested and operational on site

- *April 2006 :* Booster RF plant running

Storage ring RF system



SOLEIL Cryomodule



IPC : input power coupler

SOLEIL Cryomodule

• *2002 :* test of the prototype in the ESRF e^- beam, using LHe from Dewar, 200 mA :

- ✓ 1.5 MV / cav
- ✓ 190 kW / IPC

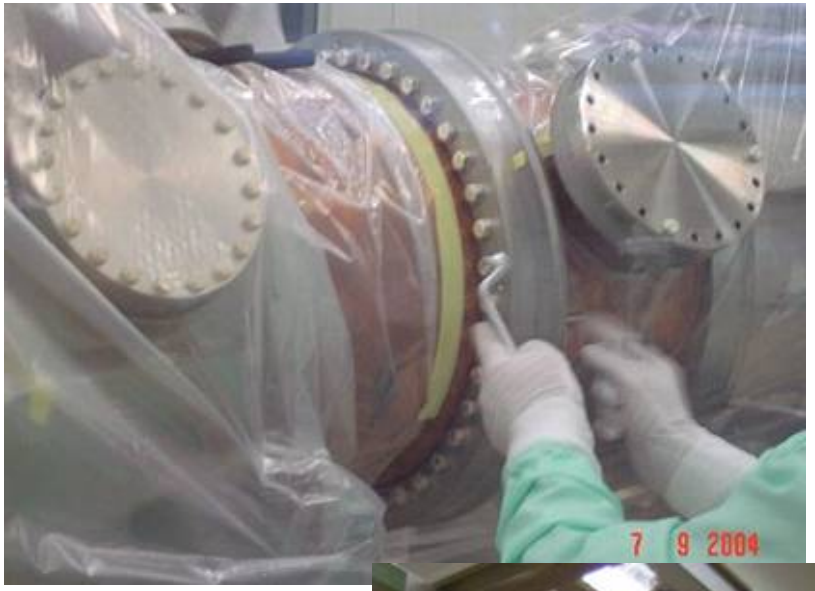
} ok for SOLEIL 1st phase (300 mA)

• *End of 2002* : prototype will be the 1st cryomodule ; "Refurbishment" before installation in SOLEIL (HOM & input power couplers, thermal screen, cryogenic circuitry & instrumentation) ; Order of a 2nd cryomodule

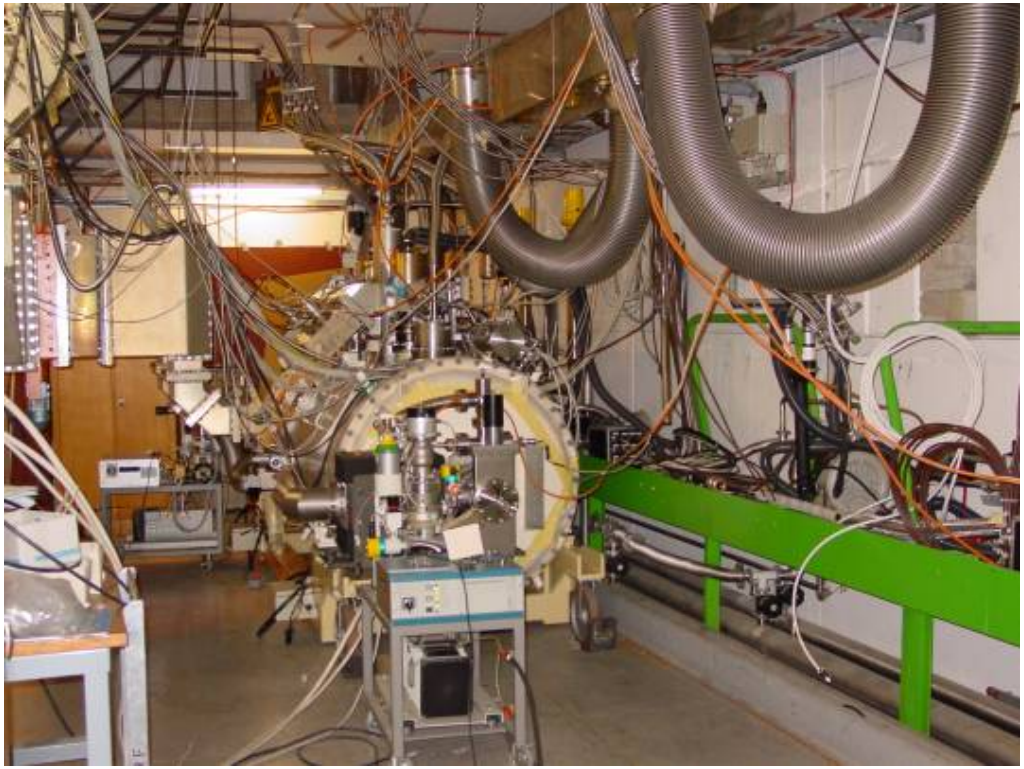
• *2004* : re-assembling of CM1 at CERN

•*2004-2005* : cryogenic & RF power tests of CM1 at CERN

Cryomodule reassembling



Ready for test at CERN



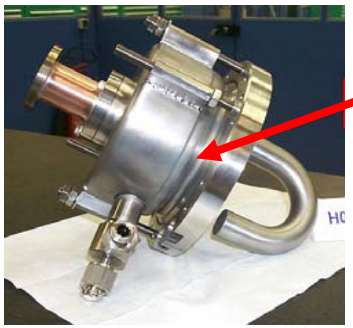
Successful tests

- Each IPC was conditioned up to 200 kW CW with full reflection and V_{cav} > 2.5 MV in each cavity (SOLEIL normal operation : $P_{coupler}$ ~ 150 kW and V_{cav} ~ 1.5 MV)

- Lengthening of the IPC antennas : $Q_{ext} = (1 \pm 0.1)\ 10^5$, as expected

- Cooling improvements :
  - ✓ ½ cryogenic losses
  - ✓ He collector 50% filled
  - ✓ Liquid He at the HOM couplers inlet

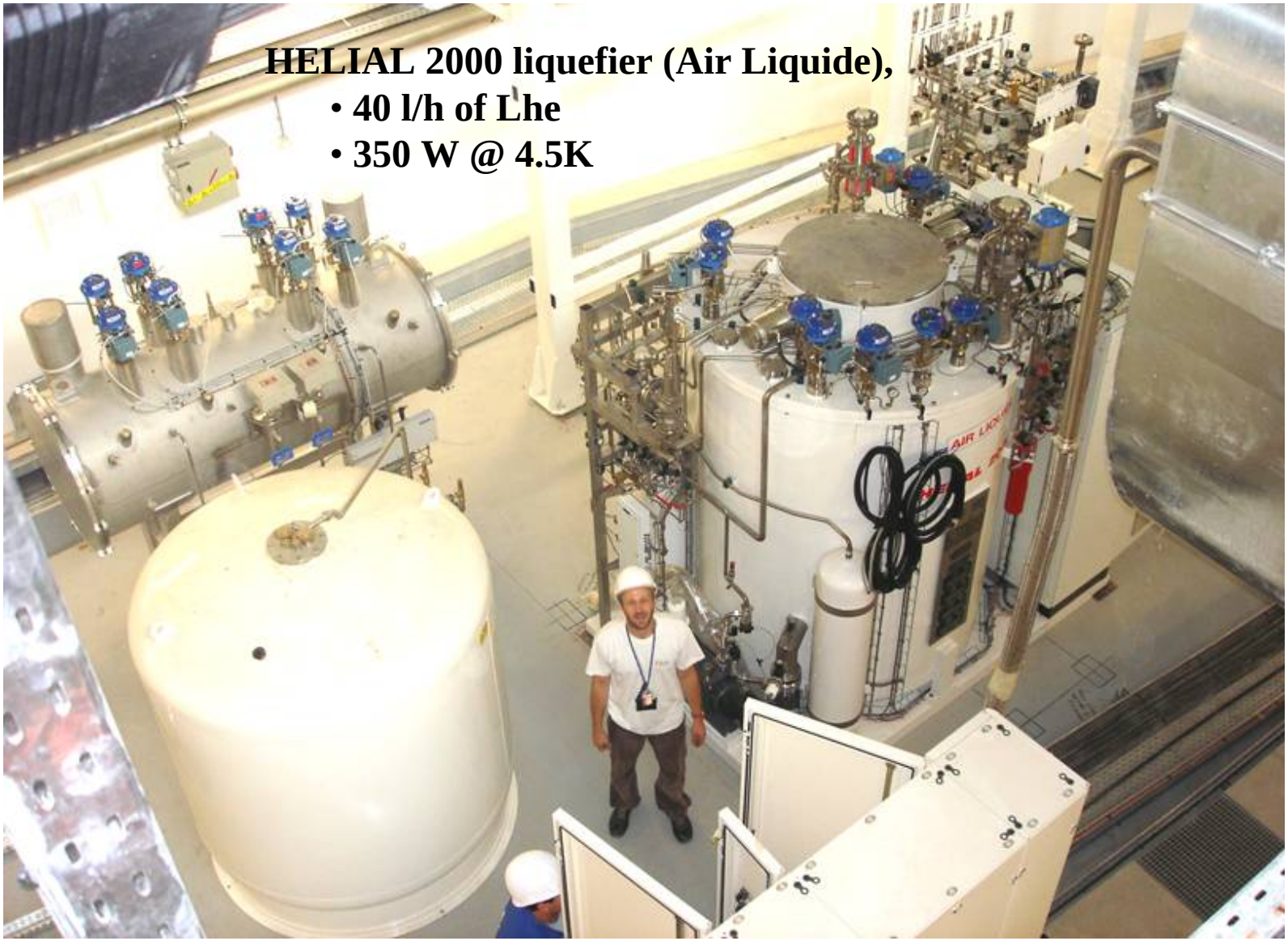
- After a proper redesign of the single wave bellow of HOM couplers : rejection of 34 dB instead of 19 dB



Cryomodules status & schedule

- ✓ CM1 installed on the ring, ready for cool-down
- ✓ CM2 ordered at ACCEL in September 05, implementation by May 2007

RF cryogenics area



Technological options for SR RF amplifier

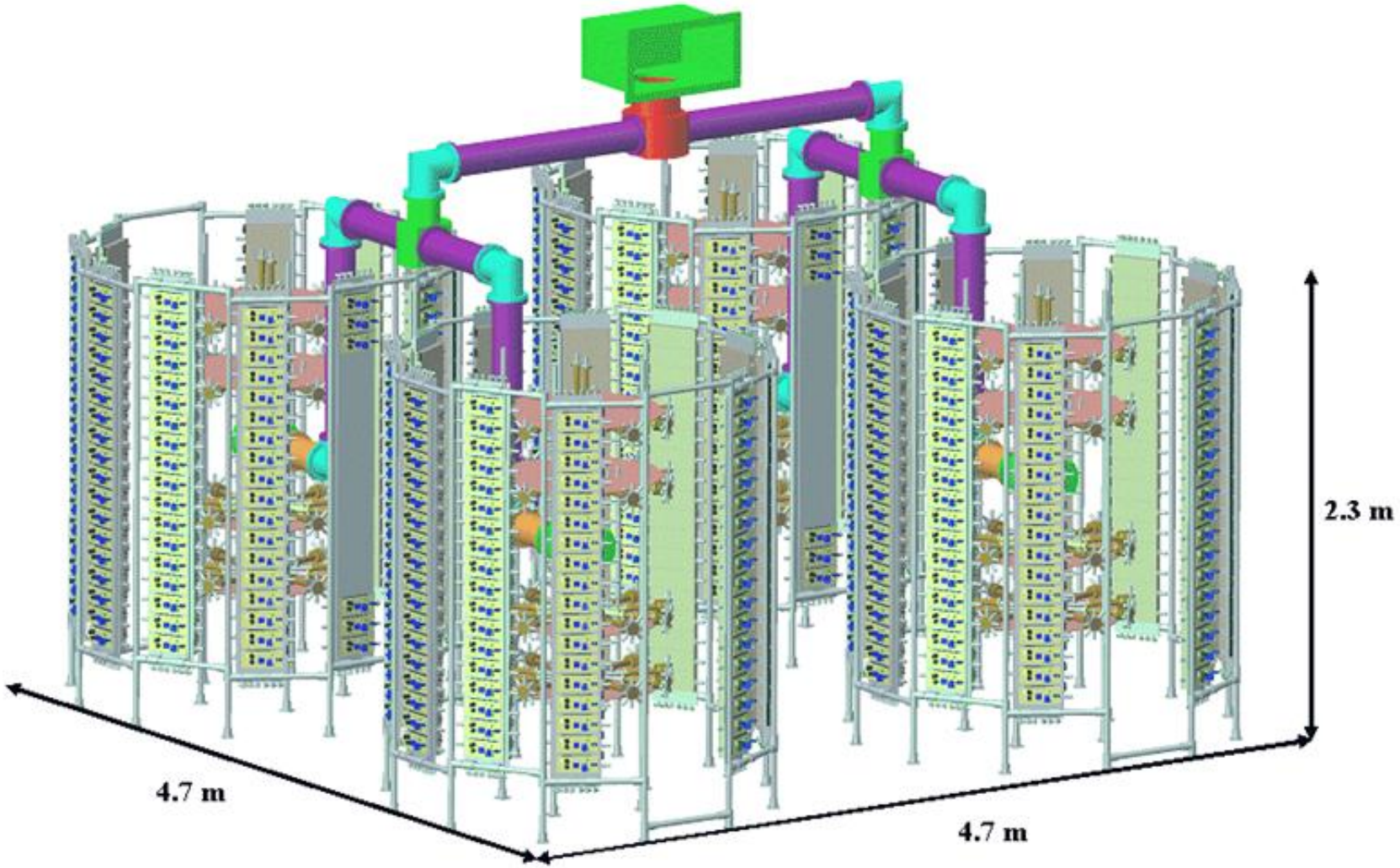
Vacuum tubes
- Klystron
- IOT

– 400 kW

Solid state amplifiers

Solid state amplifier
- Modularity → redundance
- Experience from BOO, reliability
- No HV, no high power circulator
- Simple start-up procedures & controls
- Low cost (investment, running and maintenance)
- In house expertise

Storage Ring 190 kW amplifier

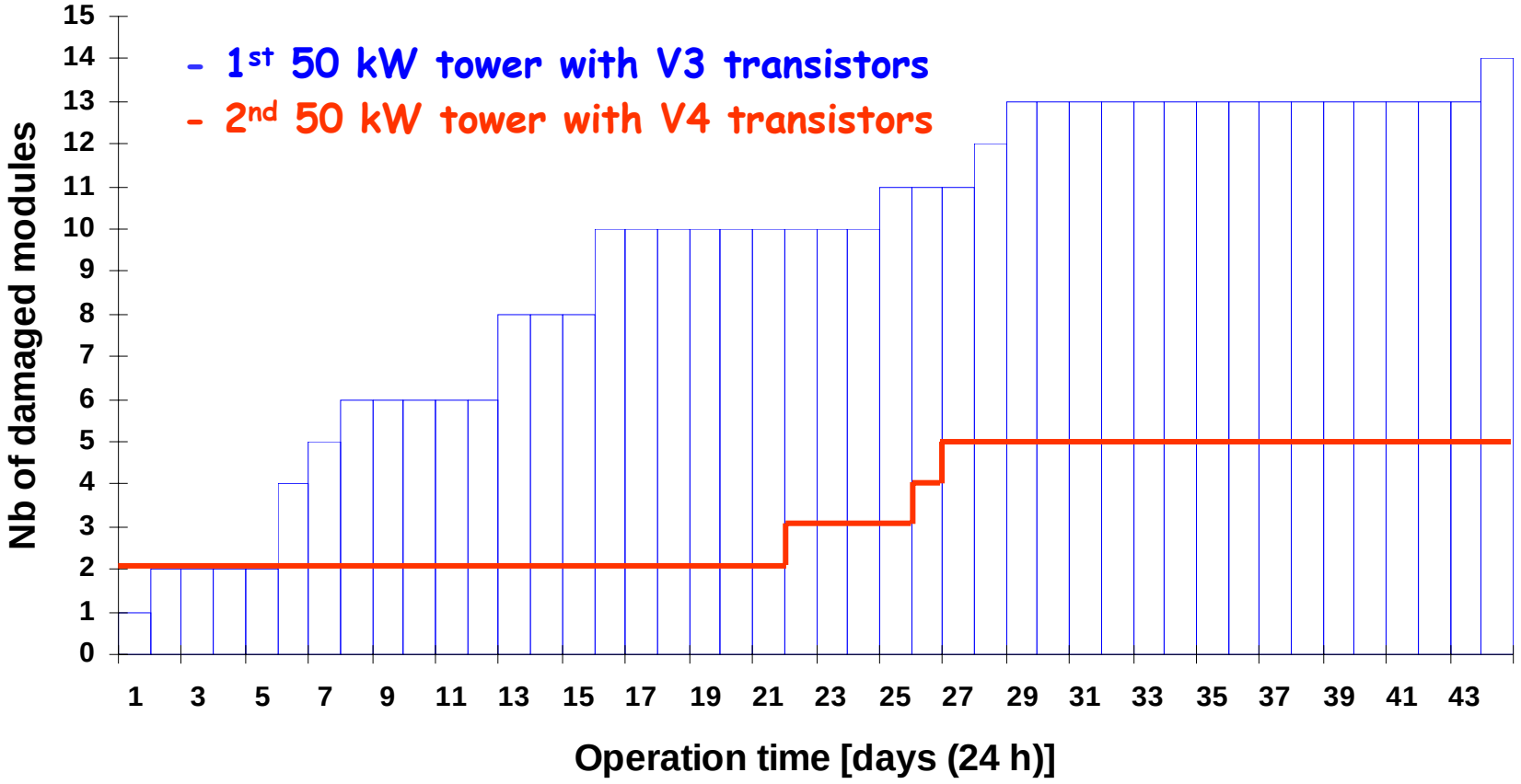


Storage Ring amplifier

- SR : SOLEIL-POLYFET development of LDMOS : LR301-V3
- Contract with BBEF for 3000 modules with validation on a pre-series of 10 pcs
- June 04 : a 2.5 kW unit, 8 pre-series modules, successfully run for ~ 4 weeks
  production of 180 modules for one “50 kW tower”
- Dec. 23rd 04 : the first “tower” delivered 48 kW CW for ~ 2 hours
- Feb. 05 : long duration tests : after ~ 1000 hours of operation, 14 over 180 modules had failures (high gate leakage current at one side of the push pull pair)

  That did not stop the amplifier
- Fabrication by POLYFET of a new version (V4), designed to be tougher, at the expense of a gain reduction of about 1 dB

Transistor failure rate



Damaged transistors after ~ 1000 hours of operation randomly distributed on the amplifier

14 of V3

5 of V4

Control system

Dissipater n°

$I_{1,2}$ for the 9 upper modules

Pi, Pr @ 2.5 kW

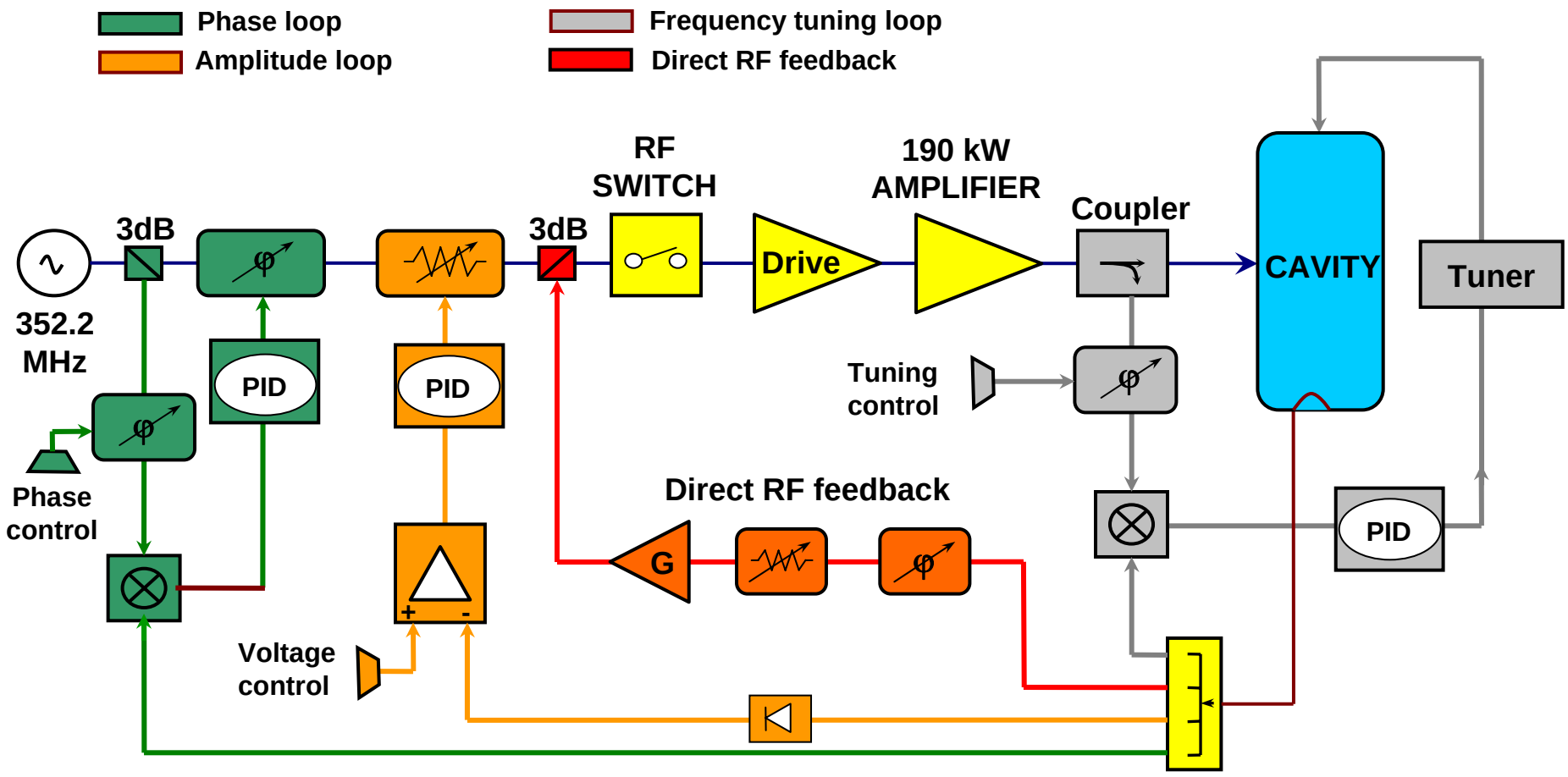
$I_{1,2}$ for the 9 lower modules

Pre-ampli or stand-by

Low Level Electronics

Phase 1 : SR LLRF = BO LLRF + direct RF feedback

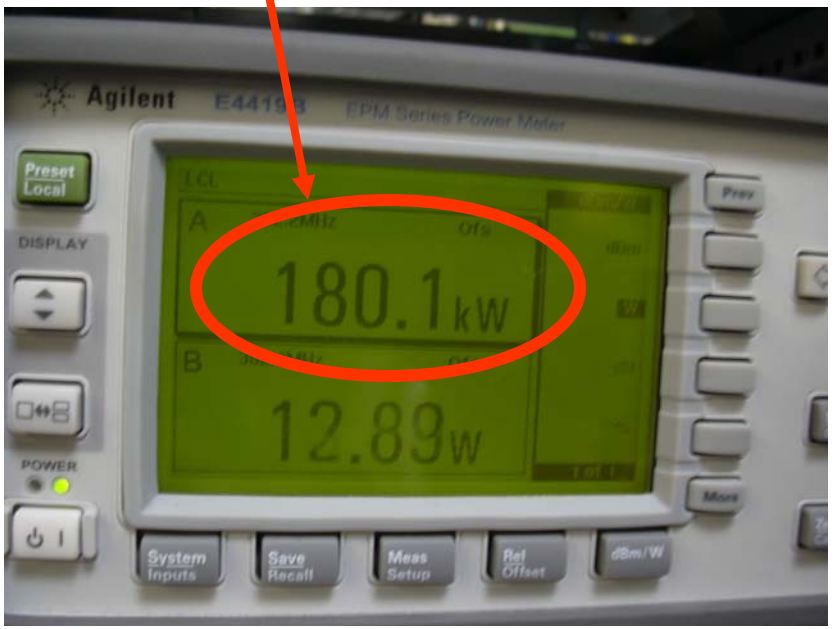
Phase 2 : fast digital (FPGA based) phase and amplitude loops, under development in collaboration with CEA



World record !

Amplifiers reached

180 kW !



Conclusion and Future :

- Cryomodule 1, Cryogenic source, 2 amplifiers

- May, 6th : SR commissioning without RF (1st turns)
- May 15th to 28th : RF conditioning
- From May 29th : SR commissioning with RF
- May 2007 : 2nd CM with 2 amplifiers implemented

- Amplifier sold to CEA and other labs collaboration
- Development : crab cavity, multibunch transverse feedback, Arc-en-Ciel (4th generation)