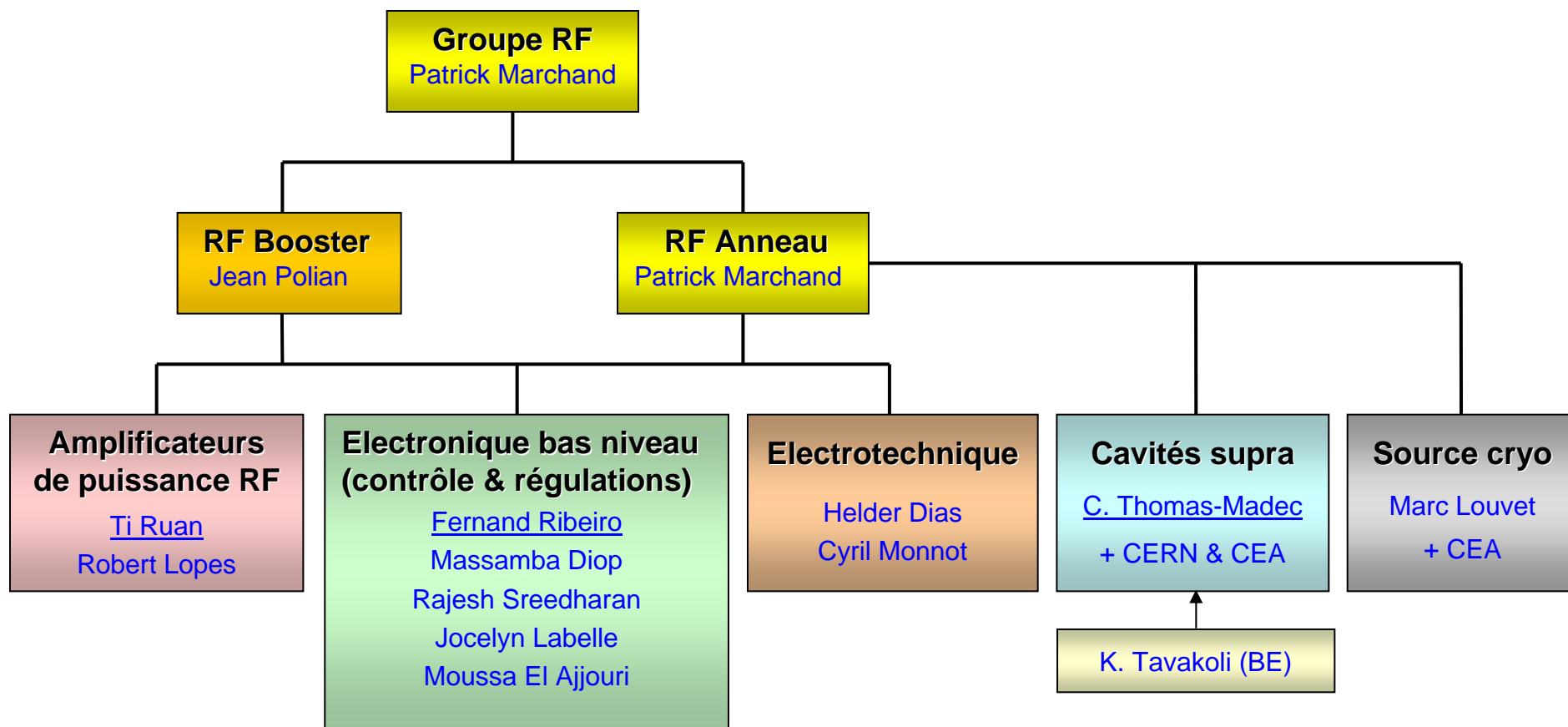


Status of the SOLEIL RF systems

180 kW per solid state amplifier
achieved in April 2006

On behalf of SOLEIL RF group

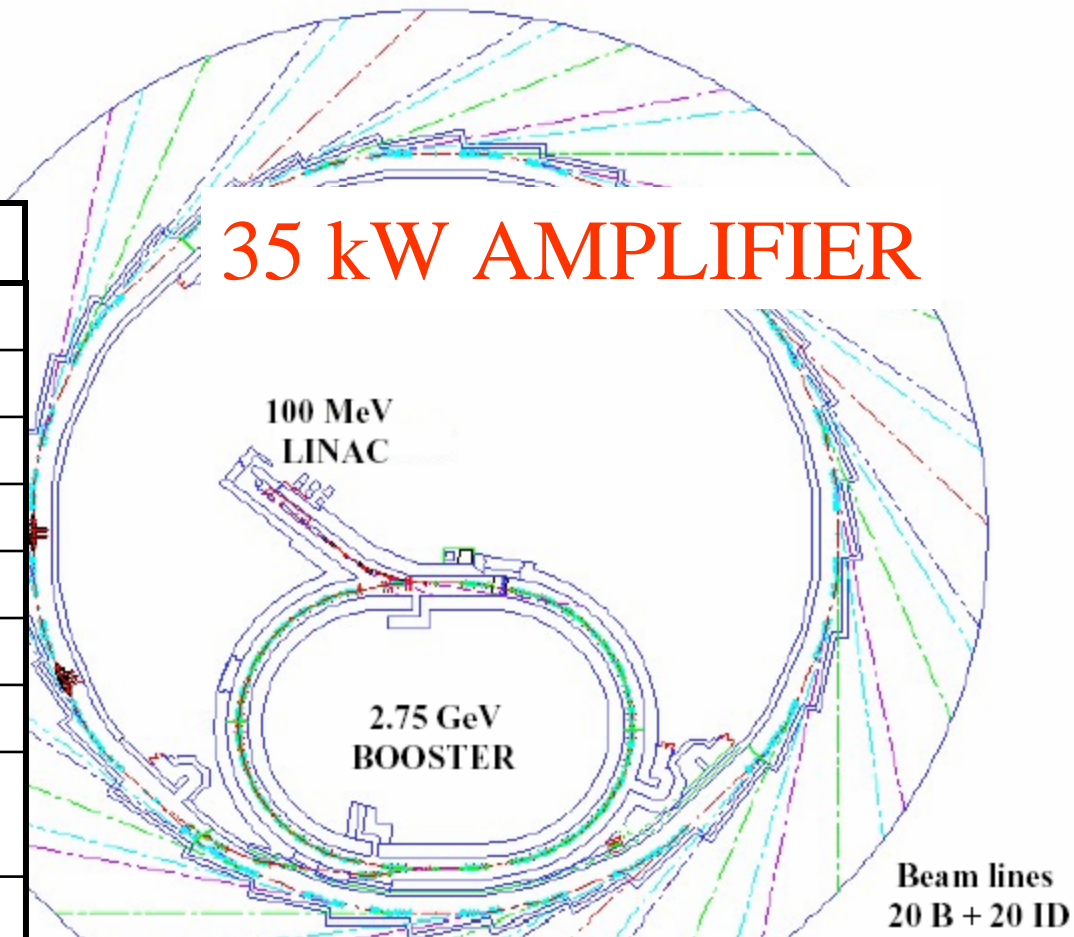


What is SOLEIL ?



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



35 kW AMPLIFIER

CERN-LEP 5-cell Cu cavity

$P_{dis} : 15$ kW

$P_{beam} : 5$ kW

$P_{tot} : 20$ kW

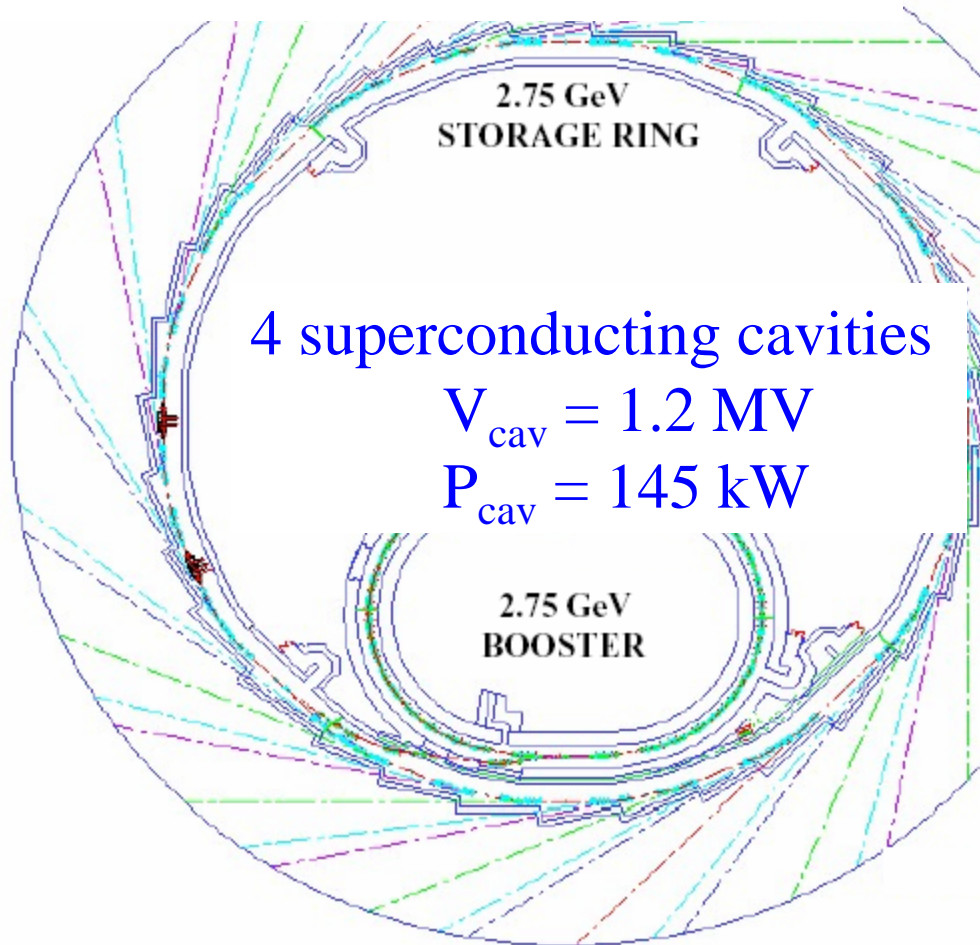
4th CWHAP 2006

C. THOMAS-MADEC

What is SOLEIL ?



4 X 190 kW AMPLIFIER



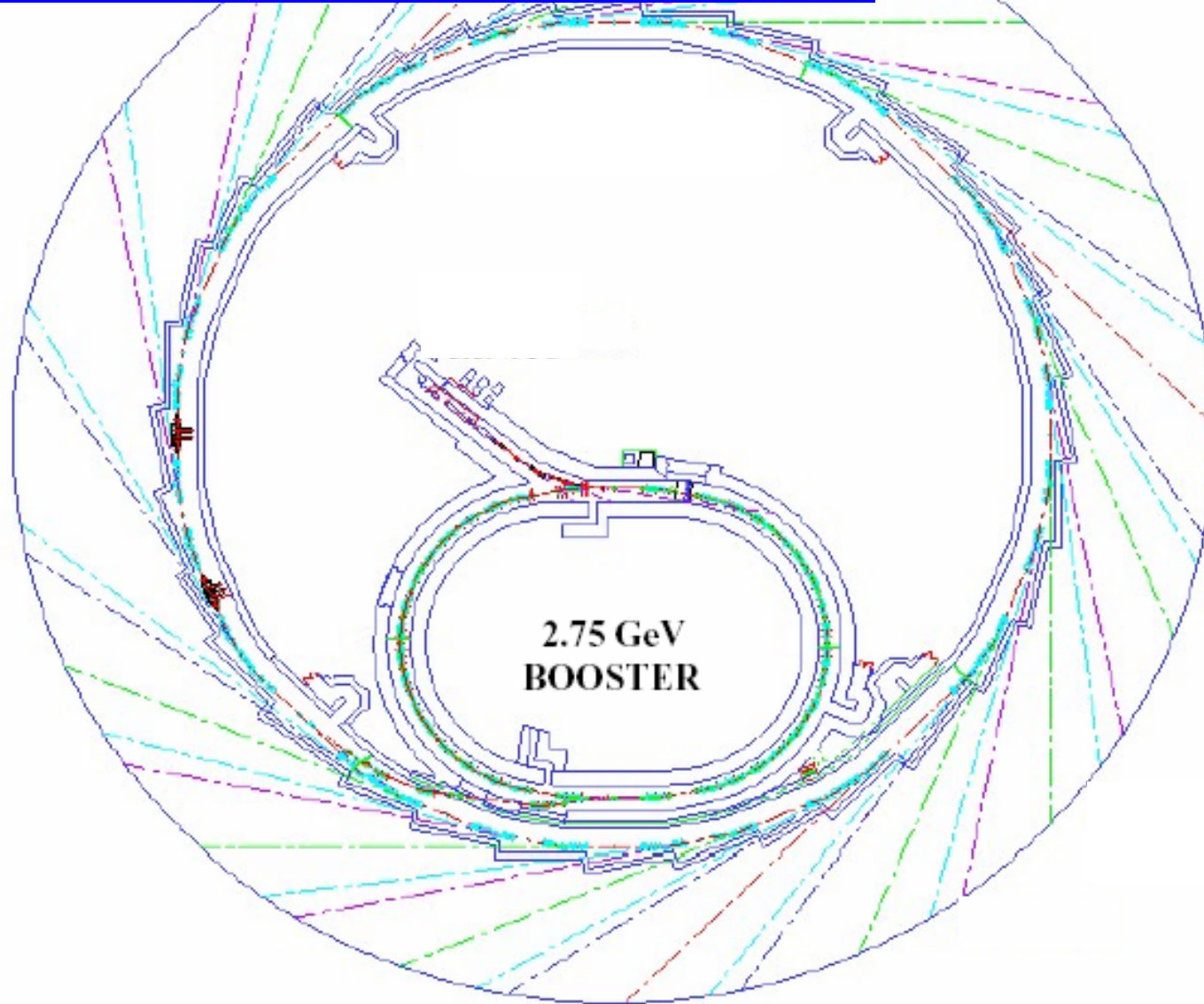
SR Parameters	
Circumference	354 m
Revolution frequency	0.85 MHz
Energy	2.75 GeV
Energy loss / turn	1.15 MeV
Beam current	500 mA
Momentum compaction	4.4 E-4
Momentum spread	0.1 %
RF acceptance	$\pm 6.15 \%$
Bunch length	4.2 mm
Synchrotron frequency	5.9 kHz
Harmonic number	416
RF frequency	352.2 MHz
RF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

Status of the SOLEIL RF systems



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

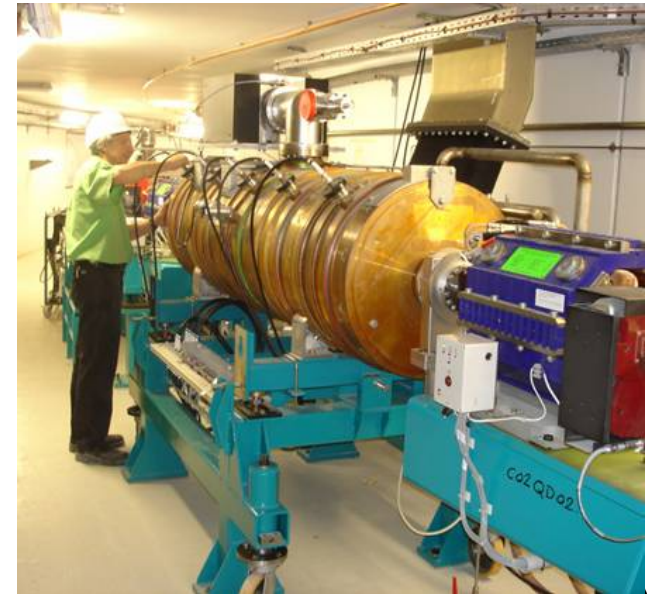
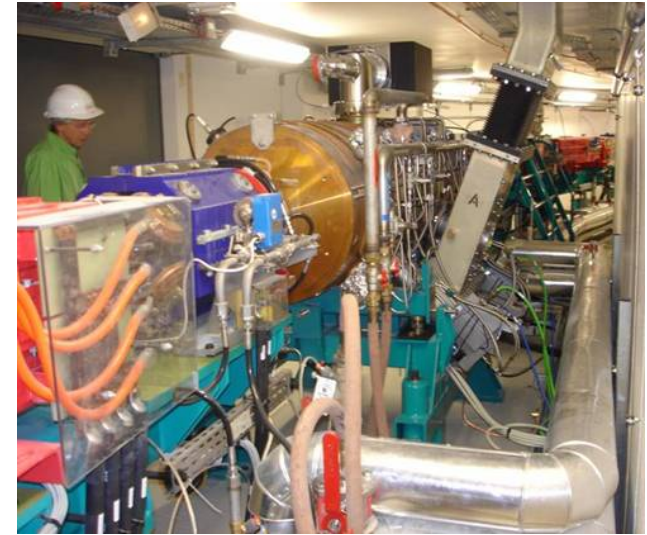
RF for the BOOSTER



BOOSTER cavity



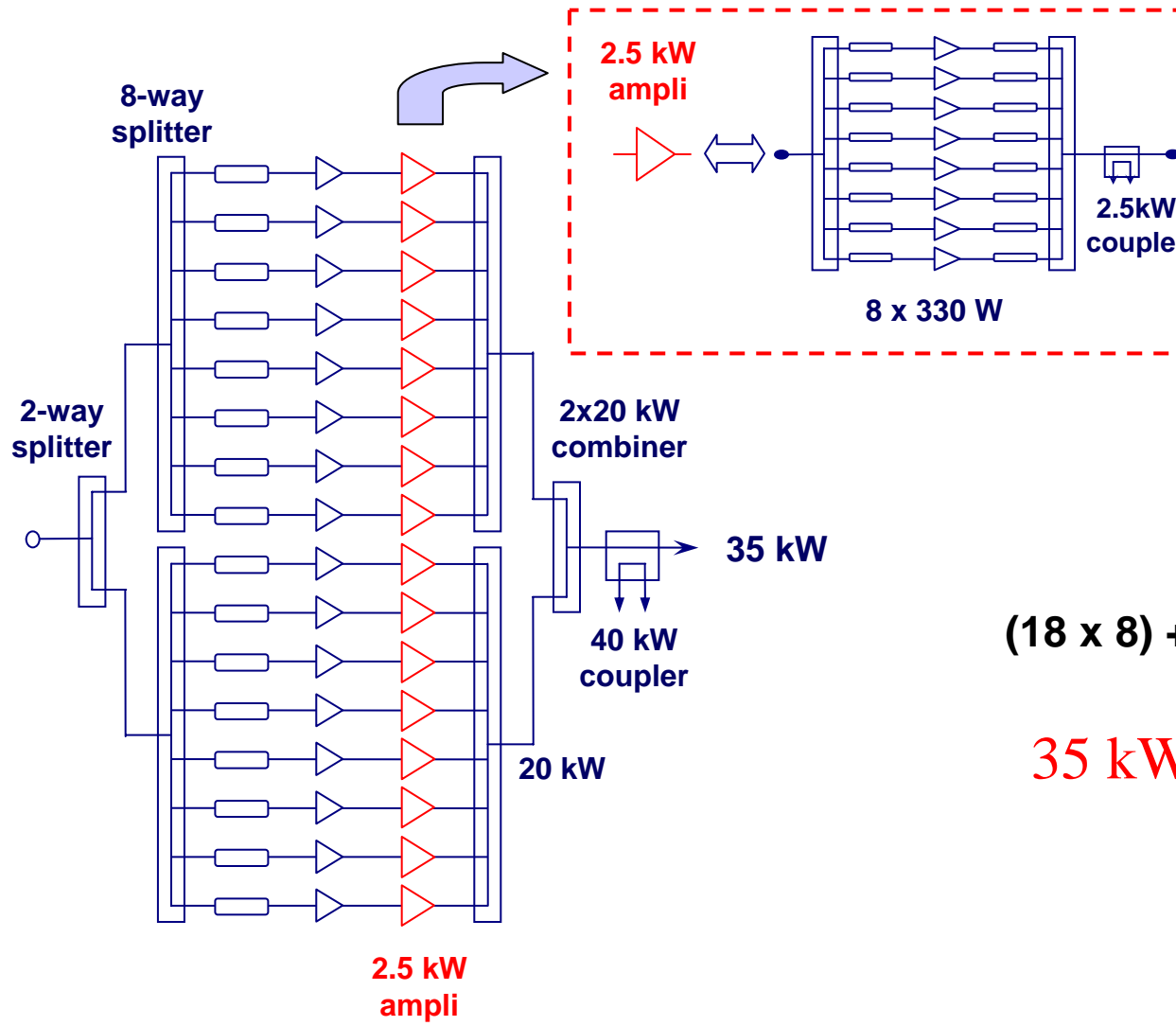
12-04-05



4th CWHAP 2006

DEC

Booster Amplifier :

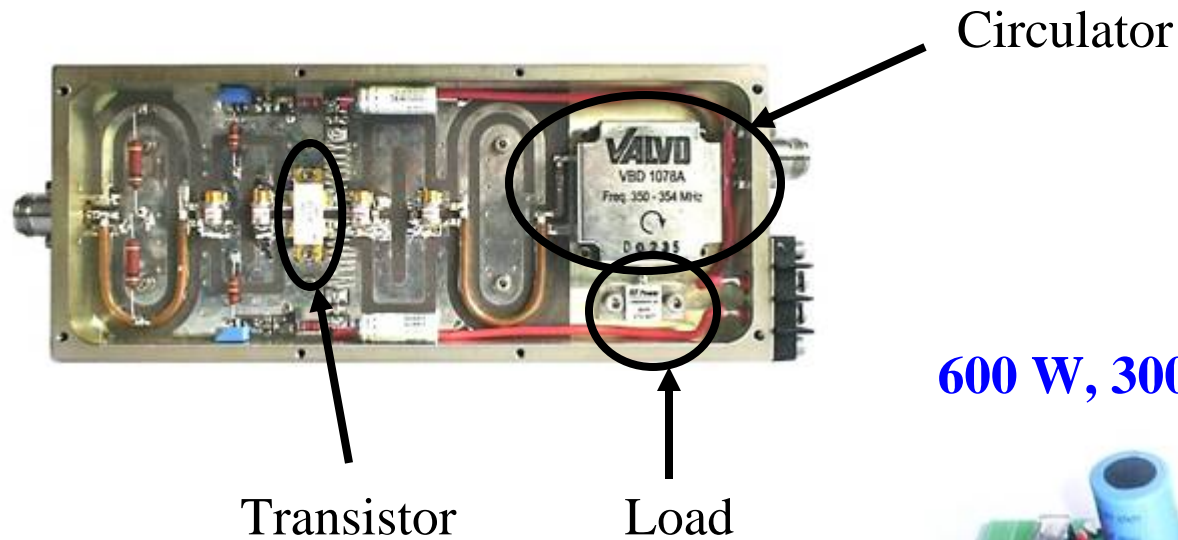


(18 x 8) + 3 = 147 modules

35 kW AMPLIFIER

Module and Converter

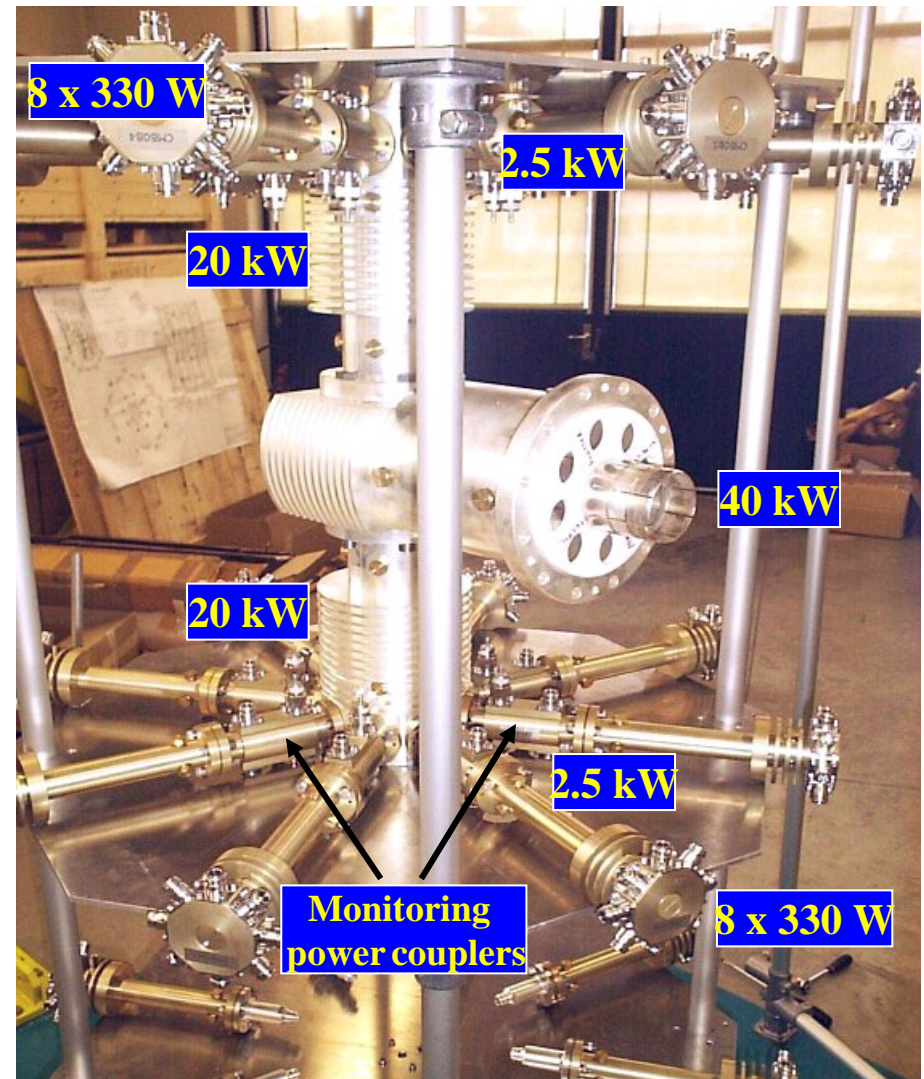
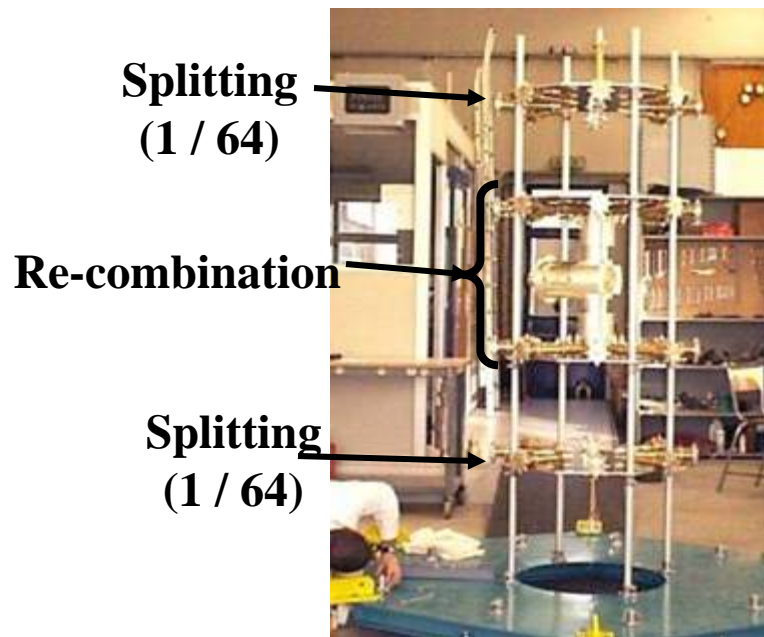
330 W solid state amplifier module



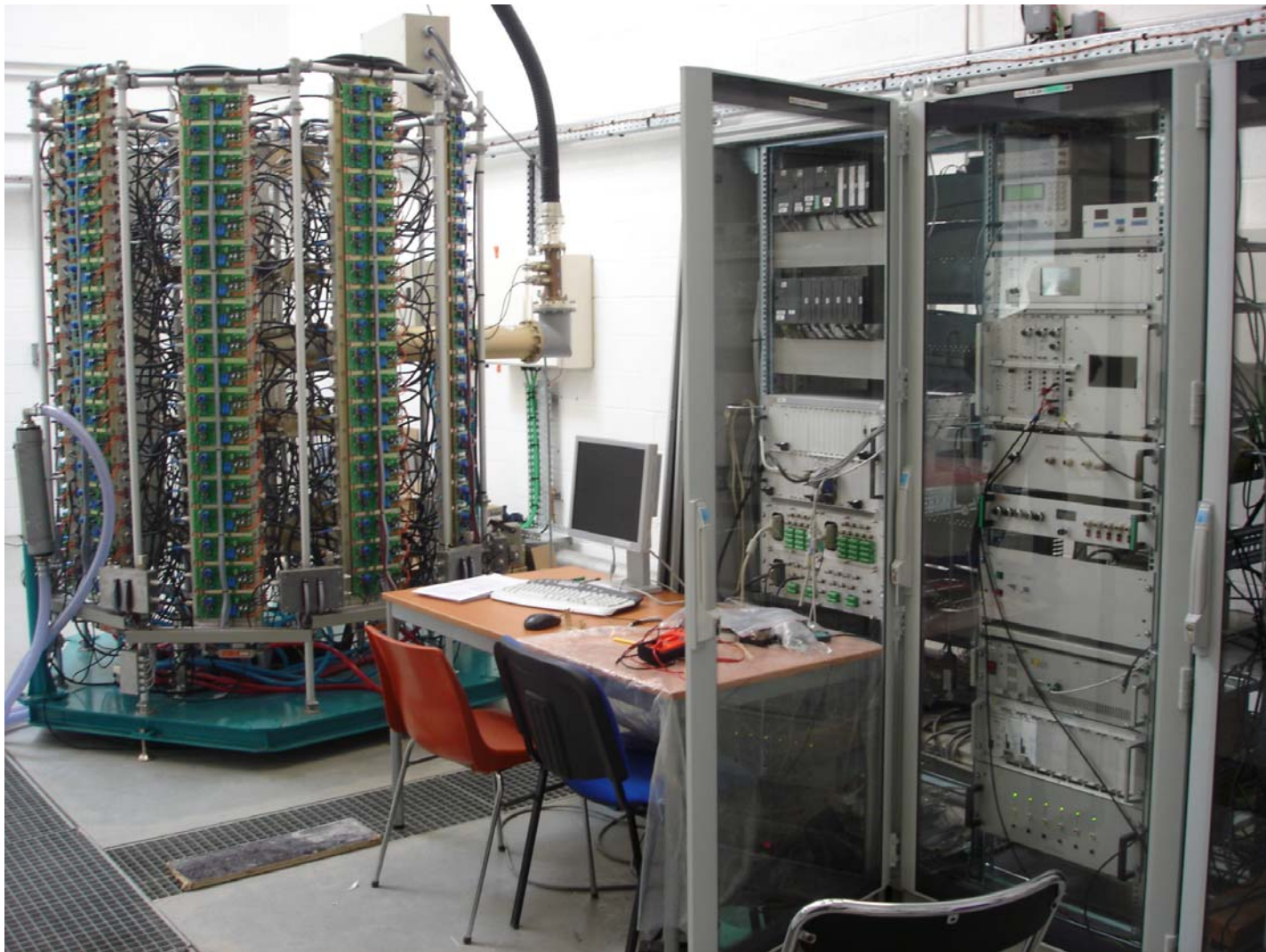
600 W, 300 Vdc / 30 Vdc converter



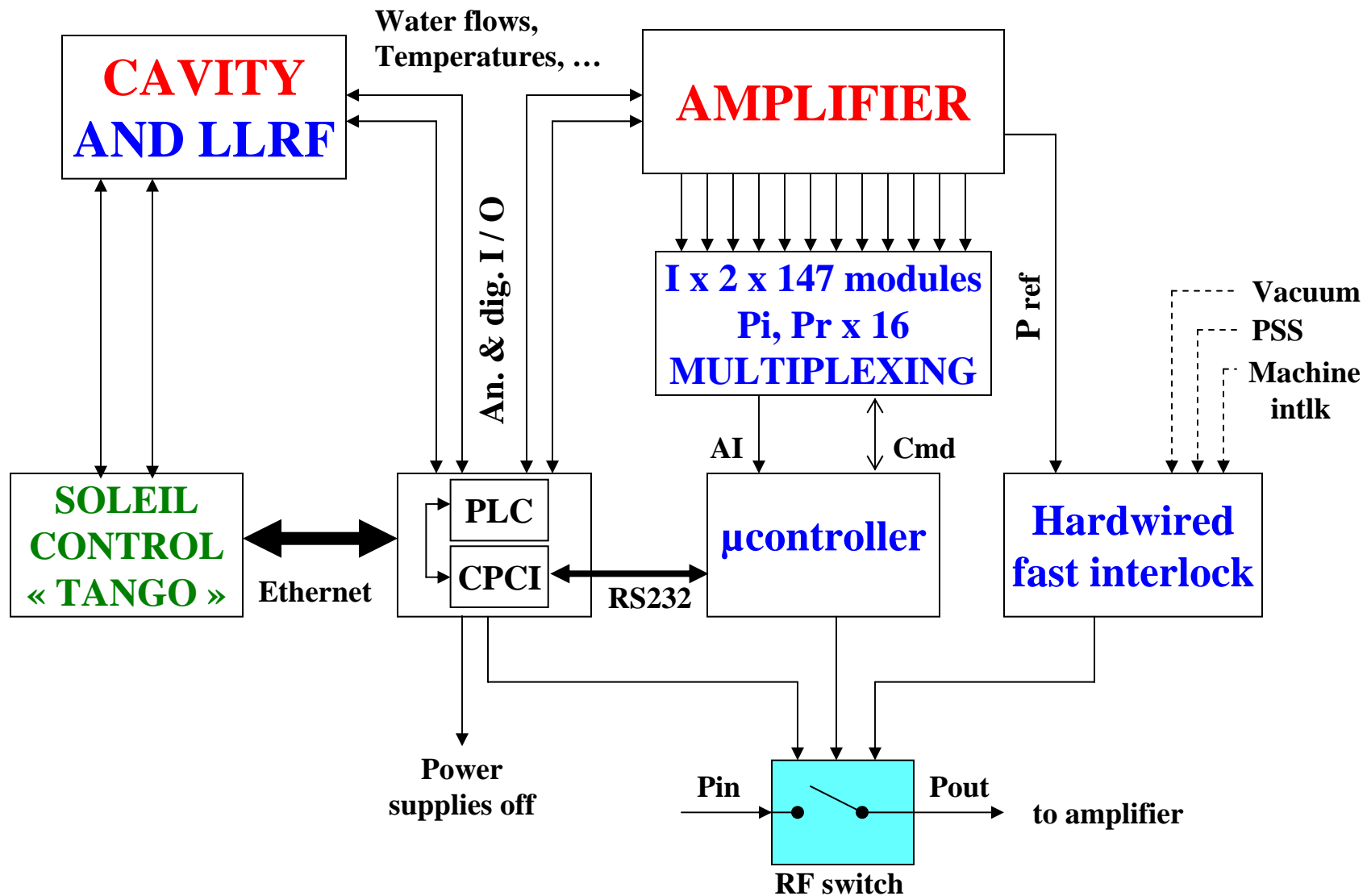
Splitting and recombination



Amplifier for Booster

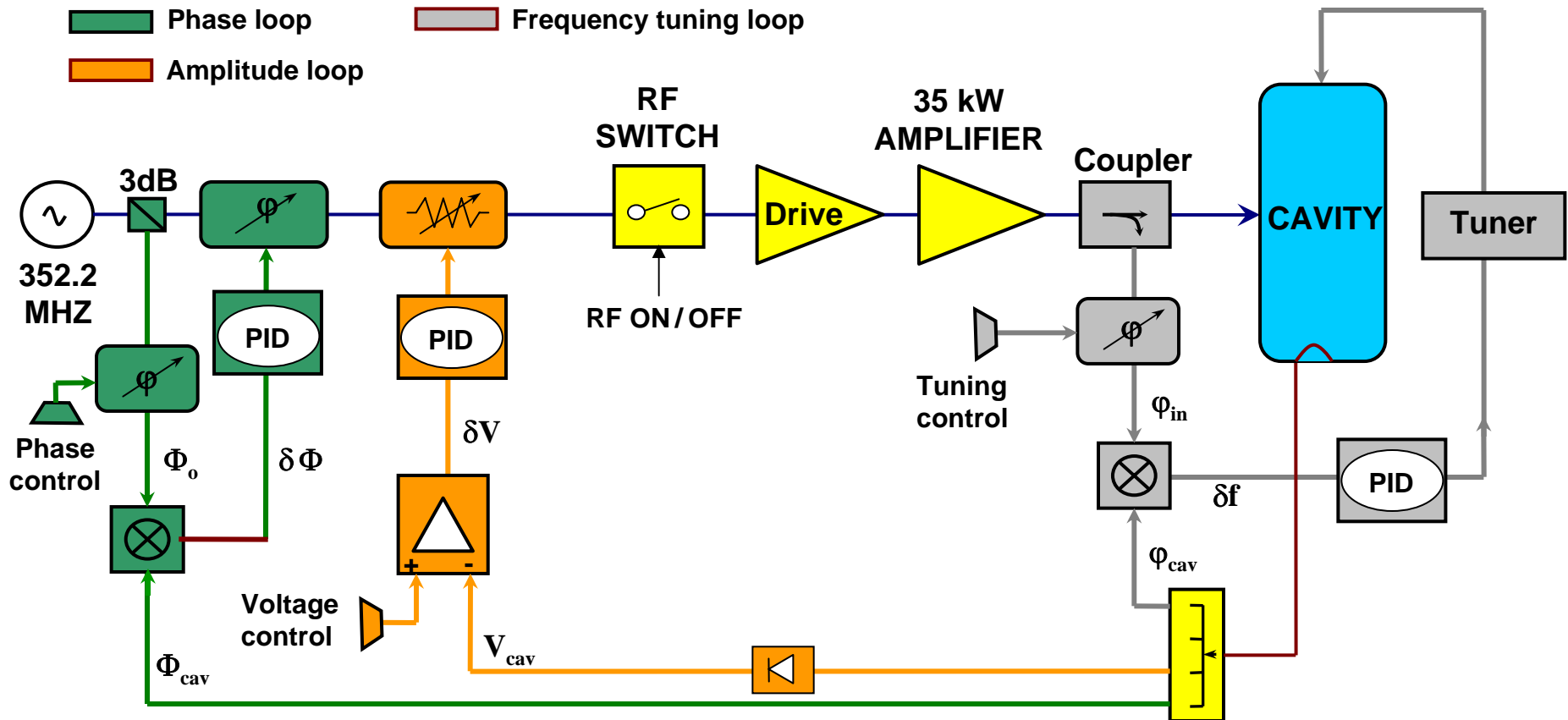


BOOSTER RF control system



Low Level Electronics

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



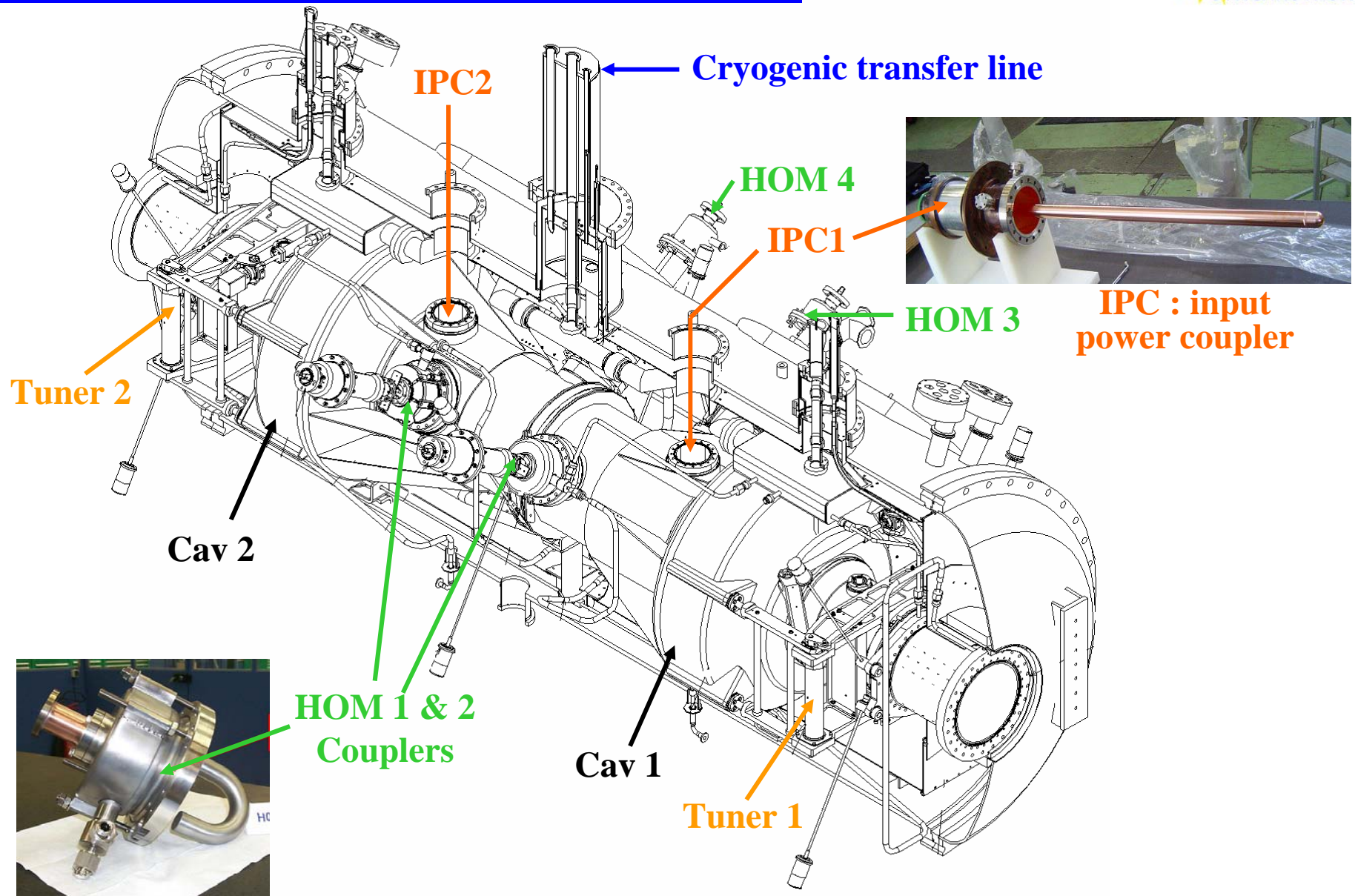
	Amplitude	Phase	Frequency
Accuracy	$\pm 0.25 \%$	$\pm 0.4^\circ$	$\pm 30 \text{ Hz}$
3 dB BW	12 kHz	7 kHz	5 Hz

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

SOLEIL Cryomodule



SOLEIL Cryomodule



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

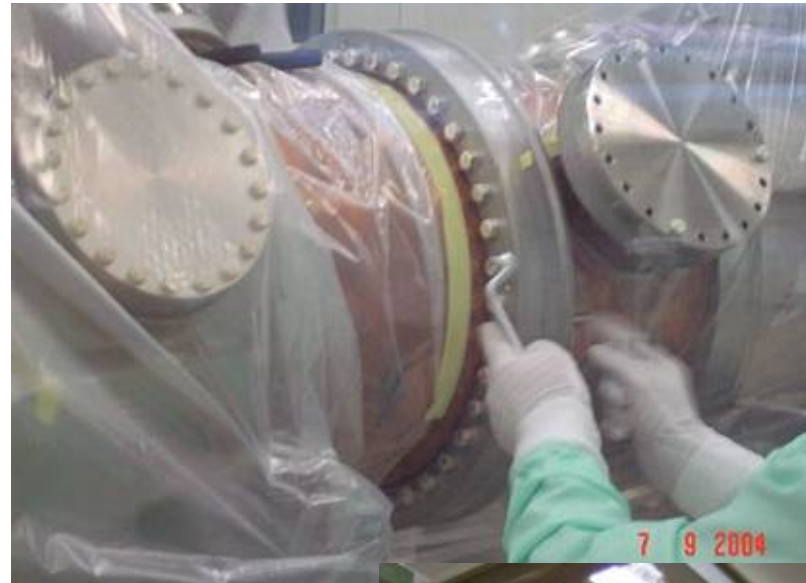
✓ 1.5 MV / cav

✓ 190 kW / IPC

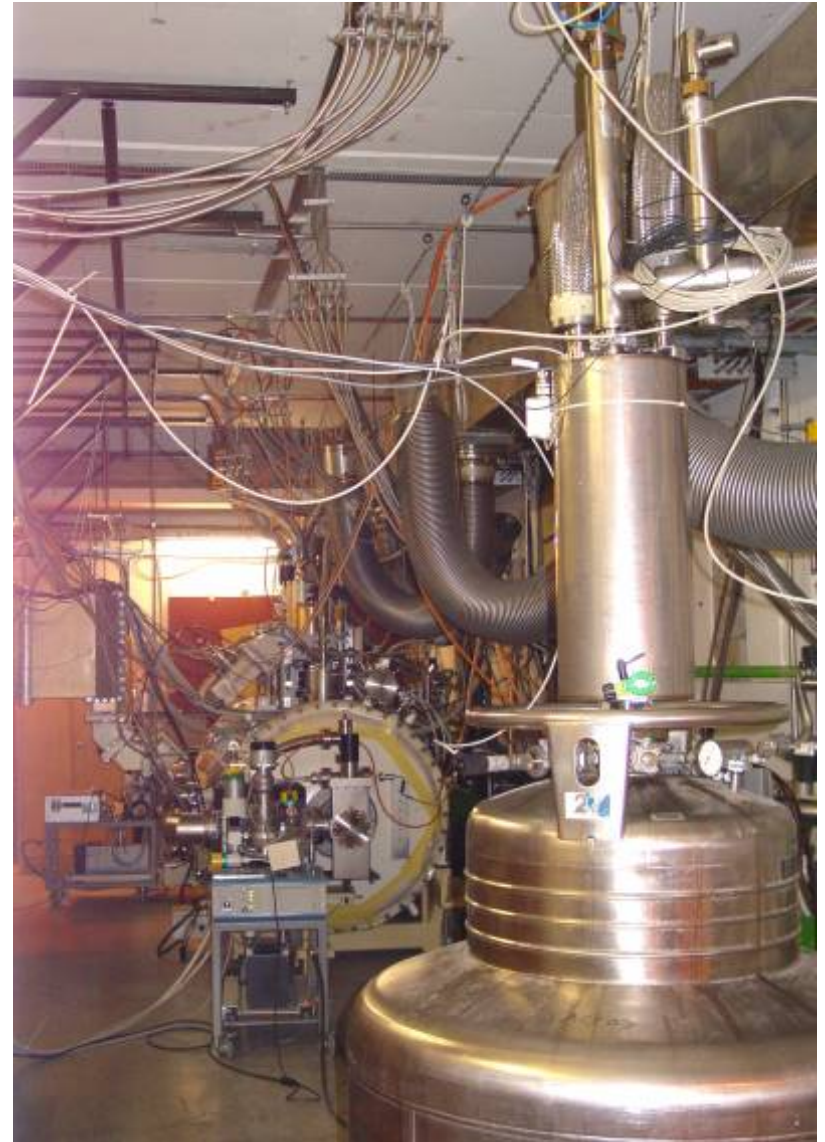
} ok for SOLEIL 1st phase (300 mA)

- *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



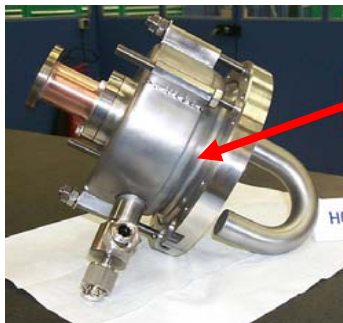
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Successful tests



- Each IPC was conditioned up to **200 kW CW** with full reflection and $V_{\text{cav}} > 2.5 \text{ MV}$ in each cavity (SOLEIL normal operation : $P_{\text{coupler}} \sim 150 \text{ kW}$ and $V_{\text{cav}} \sim 1.5 \text{ MV}$)
- Lengthening of the IPC antennas : $Q_{\text{ext}} = (1 \pm 0.1) 10^5$, as expected
- Cooling improvements :
 - ✓ 1/2 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



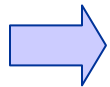
Vacuum tubes

- Klystron
- IOT

Solid state amplifiers

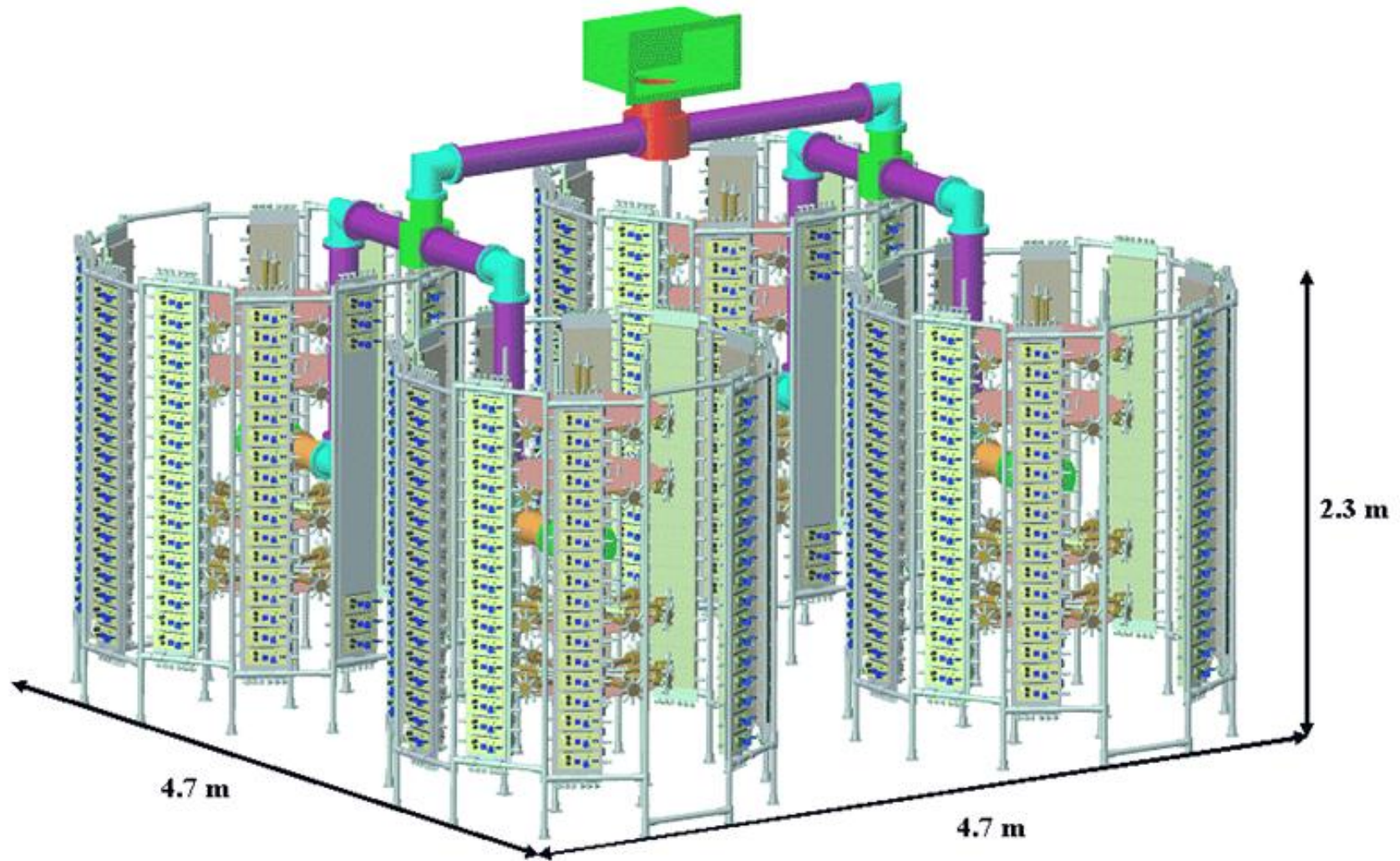
~ 400 kW

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

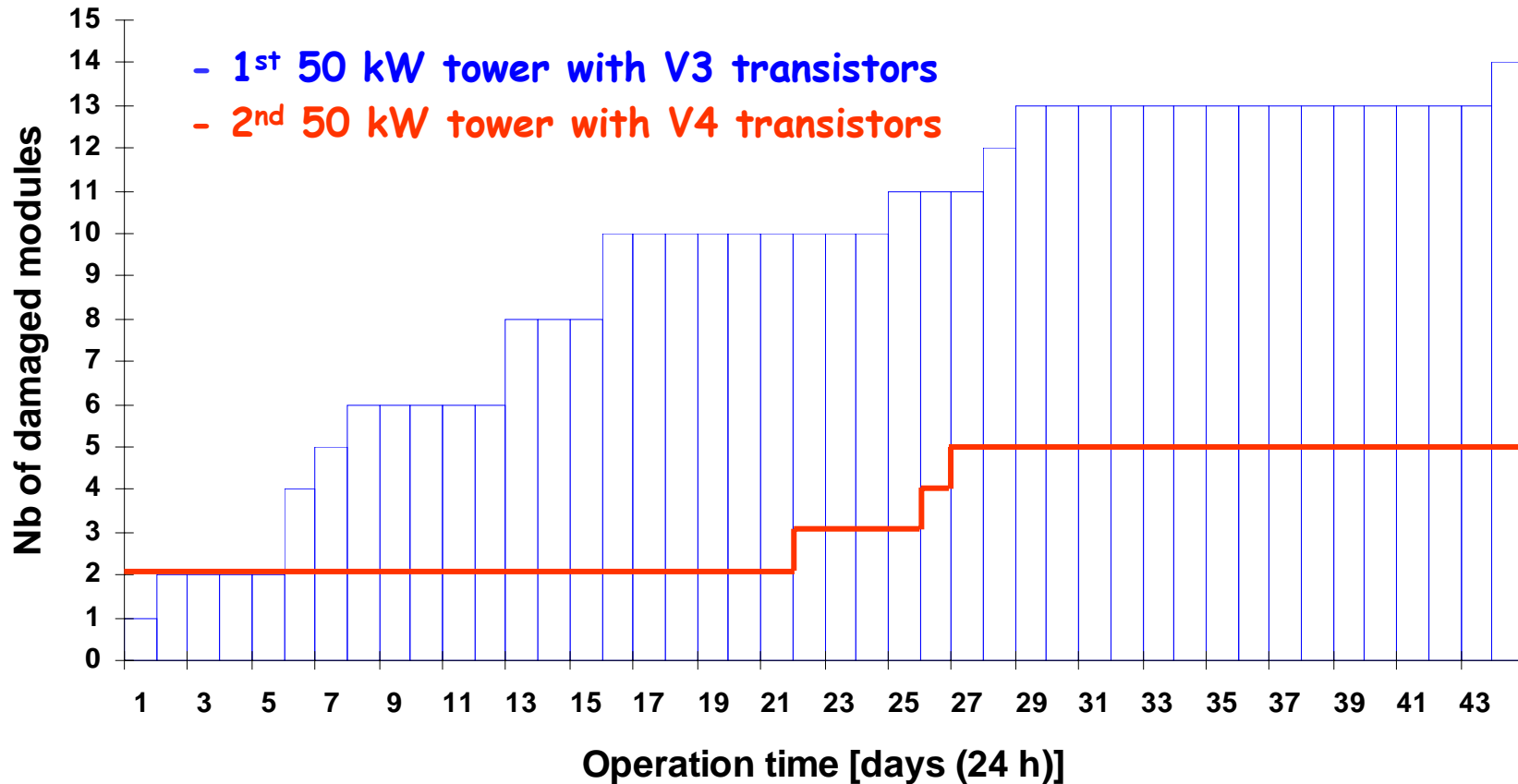


- SR : SOLEIL-POLYFET development of LDMOS : LR301-V3
- Contract with BBEF for 3000 modules with validation on a pre-series of 10 pcs
- June 04 : a 2.5 kW unit, 8 pre-series modules, successfully run for ~ 4 weeks
production of 180 modules for one “50 kW tower”
- Dec. 23rd 04 : the first “tower” delivered 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



AMPLI ANNEAU

D0		D1		D2		D3		D4		D5		D6		D7		D8		D9		D10		Préamplis	
		<input checked="" type="checkbox"/> On/Off	<input type="checkbox"/> On/Off	<input type="checkbox"/> On/Off	<input type="checkbox"/> On/Off	<input checked="" type="checkbox"/> On/Off	<input type="checkbox"/> On/Off	<input type="checkbox"/> On/Off	<input type="checkbox"/> On/Off	<input checked="" type="checkbox"/> On/Off	<input type="checkbox"/> On/Off	<input type="checkbox"/> On/Off	<input checked="" type="checkbox"/> On/Off	<input type="checkbox"/> On/Off	<input checked="" type="checkbox"/> On/Off	<input type="checkbox"/> On/Off	<input checked="" type="checkbox"/> On/Off	<input type="checkbox"/> On/Off	<input type="checkbox"/> On/Off	<input type="checkbox"/> On/Off	<input type="checkbox"/> On/Off		
		6.8	6.7	0.0	0.0	6.9	6.8	0.0	0.0	7.0	6.9	0.0	0.0	7.0	6.8	0.0	0.1	6.8	6.8	0.1	0.1	0	
0.0	0.0	9.2	9.2	9.2	9.3	9.0	9.2	8.9	9.0	9.0	9.3	9.3	9.3	9.2	9.3	8.9	9.0	8.9	9.2	9.2	9.1	1	
0.0	0.0	9.4	9.3	9.1	9.4	8.8	9.1	8.9	9.3	9.4	9.4	9.0	9.3	9.1	9.2	9.2	9.3	9.2	9.2	9.3	9.5	9.0	2
0.0	0.0	9.0	9.0	9.2	9.4	9.0	9.1	8.9	8.9	9.1	9.2	9.1	9.1	9.0	9.3	9.1	9.1	9.3	9.5	9.0	9.0	3	
0.0	0.0	9.1	9.1	9.0	9.3	8.9	9.1	8.9	8.9	9.2	9.2	9.2	9.4	9.1	9.3	9.1	9.3	9.3	9.3	9.1	9.2	4	
0.0	0.0	9.0	9.2	9.1	9.2	9.2	9.1	9.0	9.1	9.1	9.2	9.0	9.2	8.9	9.3	9.1	9.3	9.1	9.4	9.1	9.2	5	
4.2	4.0	9.1	9.3	9.0	9.2	8.8	9.3	8.9	9.2	9.1	9.2	9.1	9.3	9.1	9.3	9.0	9.1	9.3	9.3	9.3	9.1	6	
		8.8	9.2	9.1	9.0	9.0	9.3	9.1	9.3	8.8	9.0	9.0	9.2	9.1	9.1	9.1	9.3	9.1	9.3	9.0	9.2	7	
		9.2	9.3	9.1	9.1	9.2	9.3	8.8	8.9	8.9	9.0	9.3	9.1	9.1	9.4	9.0	9.3	9.0	9.0	8.9	9.2	8	
		2.3	0.0	2.6	0.0	2.2	0.0	2.6	0.0	2.4	0.0	2.4	0.0	2.6	0.0	2.2	0.0	2.4	0.0	2.3	0.0	9	
		2.5	0.0	2.4	0.0	2.6	0.0	2.5	0.0	2.4	0.0	2.4	0.0	2.4	0.0	2.4	0.0	2.2	0.0	2.2	0.0	10	
		8.9	9.1	9.2	9.2	9.4	9.5	9.0	9.2	9.4	9.4	9.1	9.4	8.9	9.1	9.3	9.5	9.4	9.6	9.2	9.5	11	
		9.1	9.1	9.2	9.3	9.0	9.3	9.0	9.1	9.2	9.2	9.2	9.3	9.3	9.5	9.2	9.4	9.0	9.2	9.2	9.3	12	
		8.7	9.0	9.3	9.1	8.9	9.2	9.3	9.1	9.5	9.4	9.1	9.4	9.0	9.1	9.4	9.5	9.1	9.1	9.2	9.2	13	
		9.1	9.1	9.2	9.3	9.2	9.2	9.2	9.1	8.9	8.9	9.2	9.2	9.2	9.1	9.2	9.3	9.1	9.2	9.5	9.6	14	
		9.0	9.3	8.9	9.0	9.0	9.2	9.1	9.3	8.9	9.2	9.0	9.1	9.1	9.3	9.3	9.4	9.1	9.4	8.9	9.2	15	
		8.9	8.9	9.2	9.3	9.0	9.1	9.1	9.1	9.1	9.0	9.2	9.3	8.9	9.2	9.3	9.3	9.1	9.2	9.3	9.3	16	
		8.9	9.1	8.8	9.3	9.2	9.1	9.2	9.2	9.2	9.3	9.1	9.2	8.9	9.2	9.6	9.5	9.0	9.3	9.0	9.0	17	
		9.0	9.1	9.2	9.4	9.4	9.3	9.2	9.3	9.2	9.4	9.0	9.0	9.1	9.1	9.2	9.3	9.1	9.4	9.2	9.3	18	
		7.2	7.1	0.0	0.1	6.9	7.1	0.1	0.0	7.3	7.3	0.0	0.0	7.2	7.3	0.0	0.0	7.6	7.7	0.0	0.0	19	
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TOUR ACTIVE

T1 ON T2 OFF

T3 OFF T4 OFF

Durée de cycle (s) 10.00

PORT RS232 COM2 COM1

ACQUISITION ON

SEUILS ALARME

I (A) 9.60

Pr(kw) 0.30

Pi T = 48.00 kW PiMax = 2.60 kW D2 PrMax = 0.00 kW D3

Pr T = 0.00 kW PiMin = 2.20 kW D3 PrMin = 0.00 kW D1

Pdc = 84.28 kW IMax = 9.60 A D8 IMin = 6.80 A D1

COPY GRAPH SAVE BMP SAVE FILE PRINT QUIT

Dissipater n°

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

Pi, Pr @ 2.5 kW

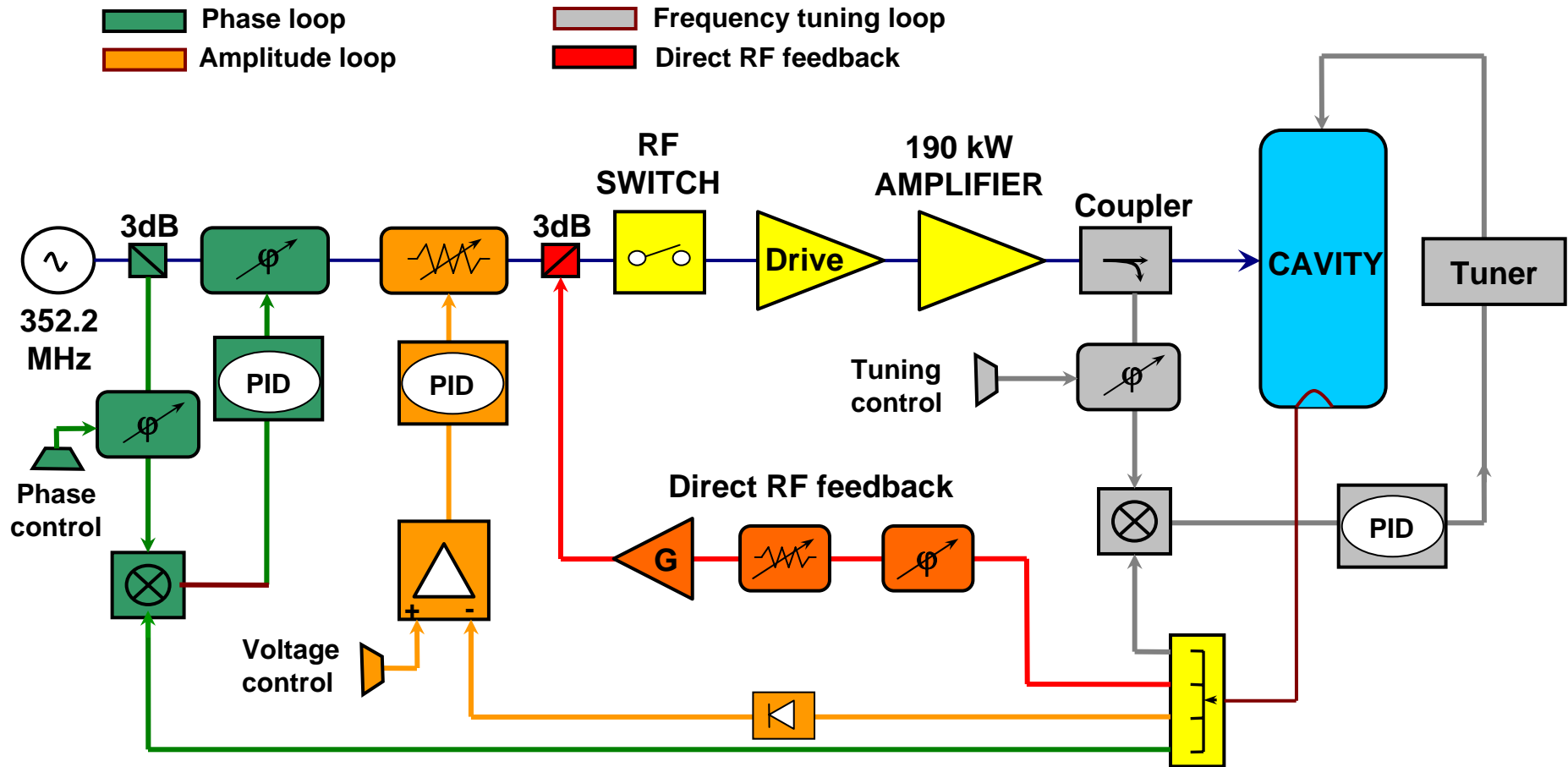
$I_{1,2}$ for the 9 lower modules

Pre-ampli or stand-by

Low Level Electronics

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

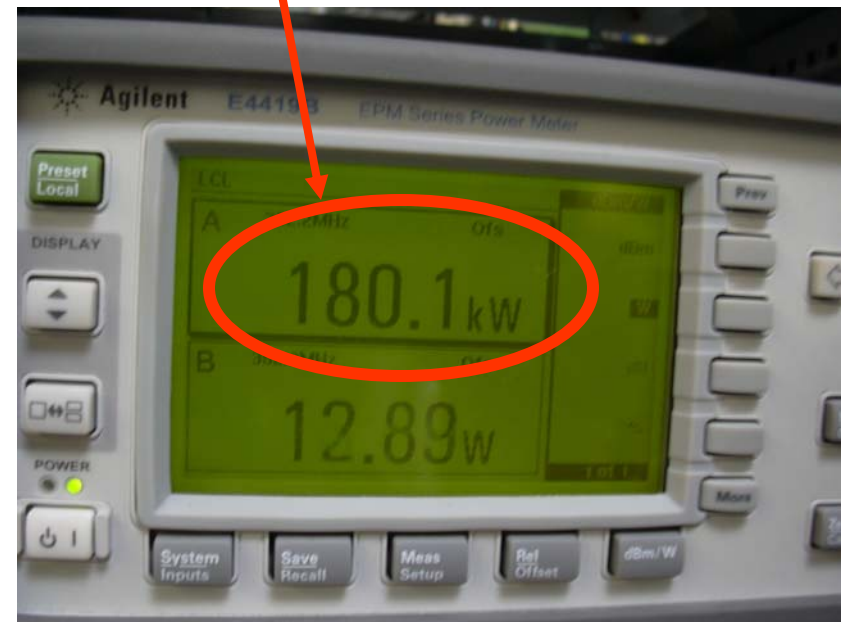
Phase 2 : fast digital (FPGA based) phase and amplitude loops, under development in collaboration with CEA



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)