Status of the RF Activity at ESRF

A Light for Science

ESRF

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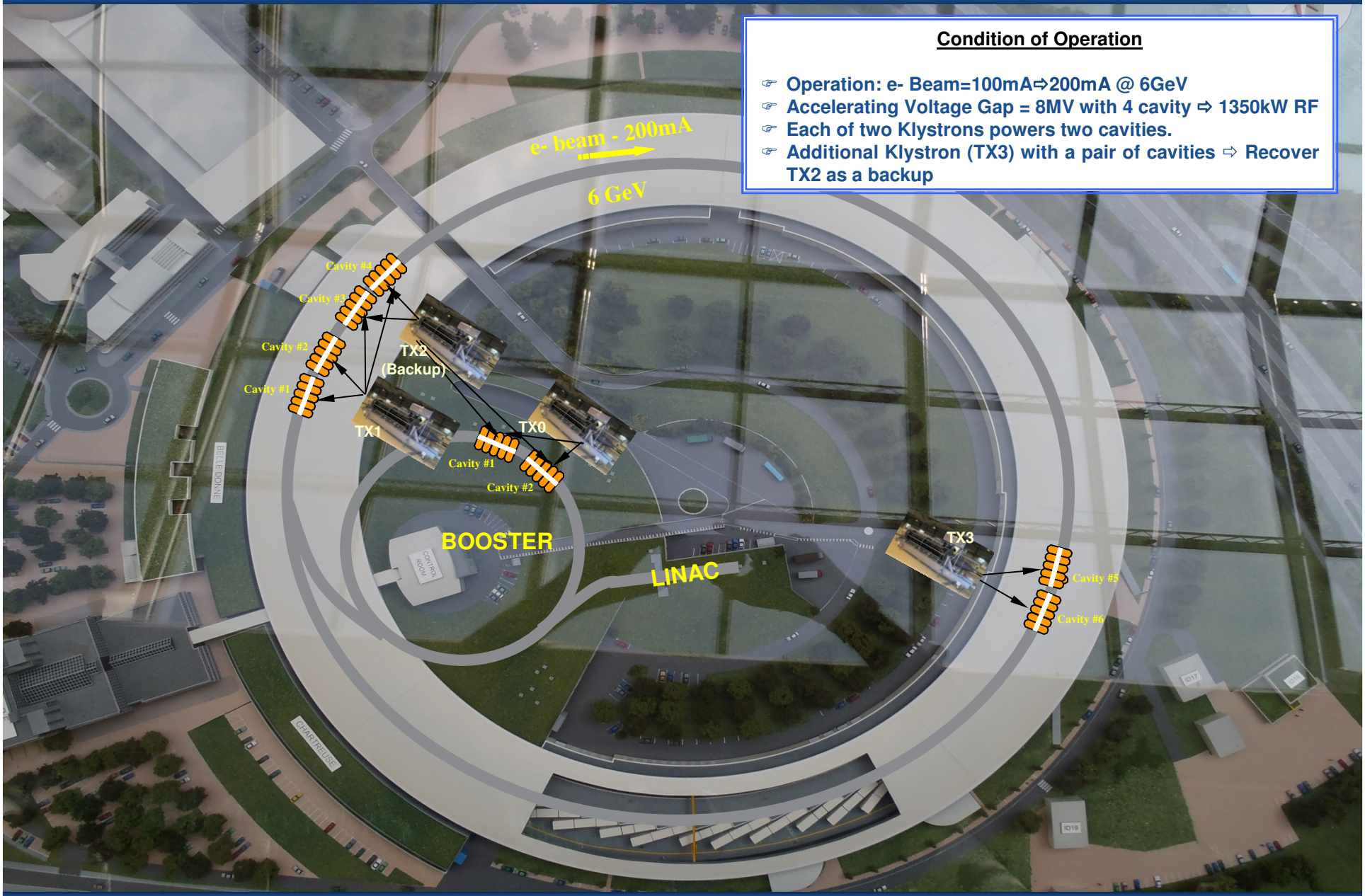
European Synchrotron Radiation Facility

Outline

- RF Operation Status
  - Last year
  - Last 18 years
- High Power Solid State Amplifier

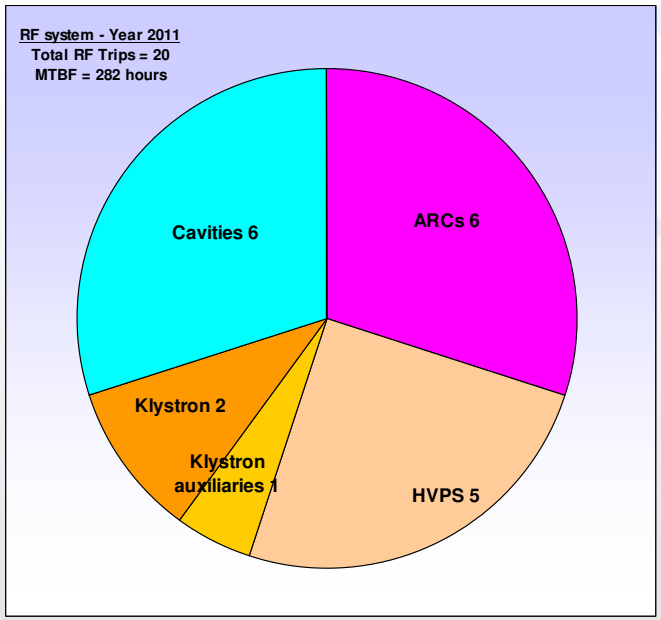
RF Distribution



Condition of Operation

- Operation: e- Beam=100mA⇨200mA @ 6GeV
- Accelerating Voltage Gap = 8MV with 4 cavity ⇨ 1350kW RF
- Each of two Klystrons powers two cavities.
- Additional Klystron (TX3) with a pair of cavities ⇨ Recover TX2 as a backup

RF Failures statistic 2011



HVPS
Control air Leakage in HV cage

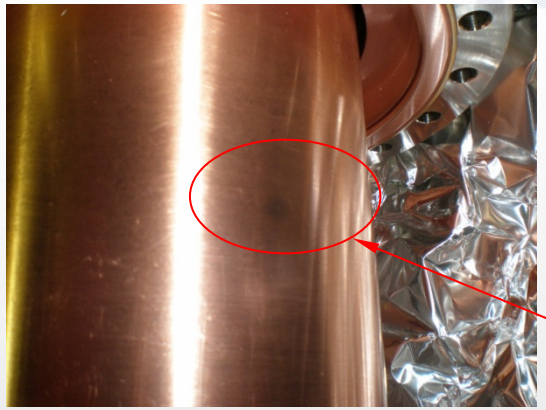
- 5 Beam interruptions within 2 days
- Air hoses "cooked" and weakened
- Refurbishing of the complete circuit
  8 hours shutdown
- The next machine shutdown the other transmitters are also refurbished

HV deck – Bad connection

- Over the past years the Klystron was suspected of making HV gun breakdowns
- Beginning of 2011, the transmitter can't restart due to intermittent cut-off of the filament power supply
- Finally a bad connection is found on the isolating transformer's junction block

Magic ! We no longer have HV breakdown

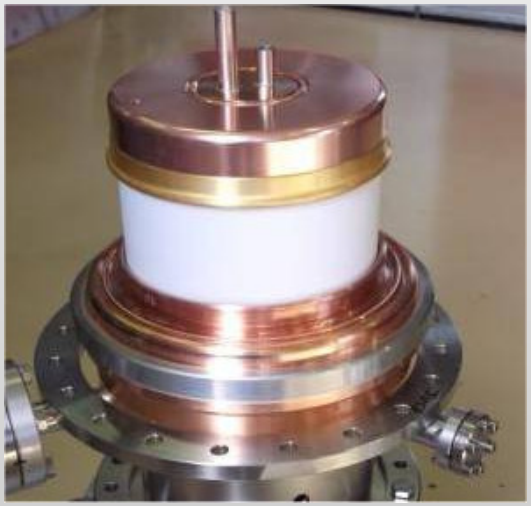
RF Failures statistic 2011



Polishing with "diamond paper"

Cavity outgasing / Tuner

- **Cavity #2** - 5 Beam interruptions
  Suffered of outgasing due to vacuum leak at the tuner
  It is observed for a certain position of one of the two tuners. Arcing trace is found, which has been repaired by polishing and cleaning

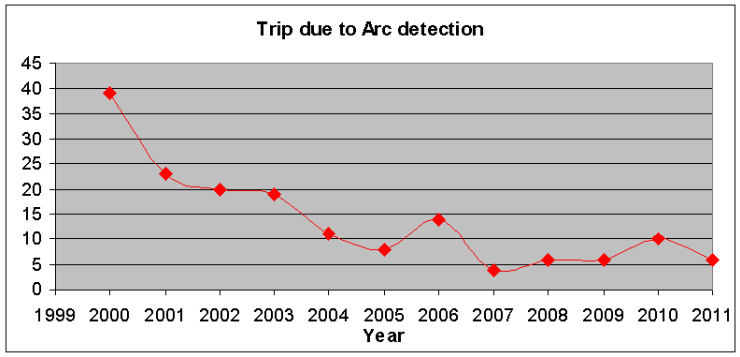


Cavity outgasing / Coupler

- **Cavity #3** - 1 Beam interruption
  Micro-leakage at ceramic window.
  Leakage is detected at the brazing junction ceramic/collar.
  Repaired with varnish.

- **New coupler** designed by Eric Montesinos (CERN)
  Using LHC ceramic, no collar and no door-knob
  Tested at ESRF at 300 kW 20mn, further test at higher power is planned soon.
  Two of this coupler have been mounted on cavity #3
  Only 16 hours for conditioning with beam

RF Failures the last 18 years



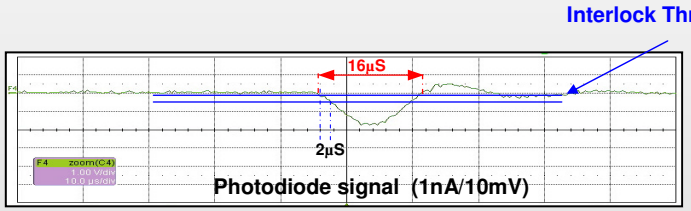
Arc Detection

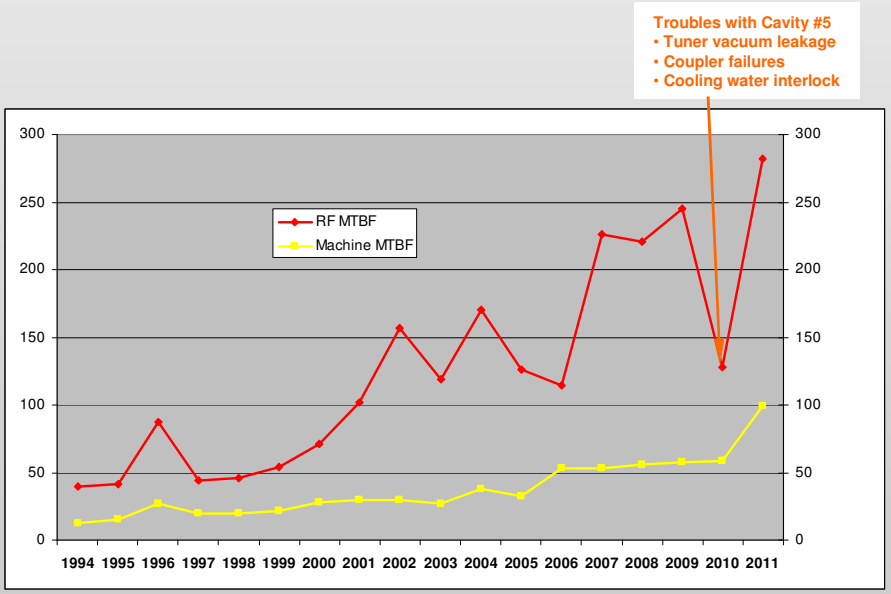
Improvement

- Interlock threshold too low ⇨ Lot of **false detection**
- Threshold is relaxed ⇨ 40 trips → 20 trips
- Threshold generalized ⇨ ≈ **6 trips / year**

causes of arcing

- Arcing in to waveguide switches – **main cause**
- Magic Tee – between post and wall angle
- Circulator ??





History

- **1991** Start operation with a turnkey RF-system
- **1997** Setup of a third transmitter (TX3) entirely by ESRF
- **1999** Refurbishing of TX2 with new control
- **2000** Refurbishing of TX1 with new control
- **2001** Refurbishing of Booster TX with new control
- **2005** Replacement of Ion Pump power supply (homemade)
- **2007** Replacement of Modulating Anode PS and Filament PS. The control electronic is homemade

Klystron Status

Klystron ID	Born	Dead	Run Hrs(*)	Socket	Comment
THOMSON TH89012	Nov. 1990	**Nov. 1998**	8,395		Calcium deposit on collector suspected when the klystron was tested at Hamburg. Used for ESRF's museum
THOMSON TH89016	Dec. 1990	**Apr. 1997**	6,400		Filament broken - Vacuum leakage - Dead at the factory
THOMSON TH89018	Jan. 1991		27,379	TRA3	Second life after repairing in December 1998 at 11,306hrs (vacuum leakage)
THOMSON TH89022	Apr. 1991		18,428		Second life after repairing in March 1996 at 8,174hrs (vacuum leakage)
EEV #esrf-1	Feb. 1995		32,506		
EEV #esrf-2	Mar. 1997		17,110	TRA2	Second life after repairing in November 1998 at 1,898hrs (vacuum leakage cav2 probe)
EEV #esrf-3	Dec. 1997		8,374		
EEV #esrf-4	Feb. 2000		39,734	TRA1	
EEV #esrf-5	May 2000		10,631		
PHILIPS 54-301-53	Mar. 1995		13,107		

Klystron total hours = 8 x 40,000 = 320,000
Klystron total burnt hours = 167,269
Klystron total available hours = 152,731
Klystron total average hours per year = 13,500
Years of operation available = 11

(*) Counter is reset at new life

RF Failures the last 18 years

Summary

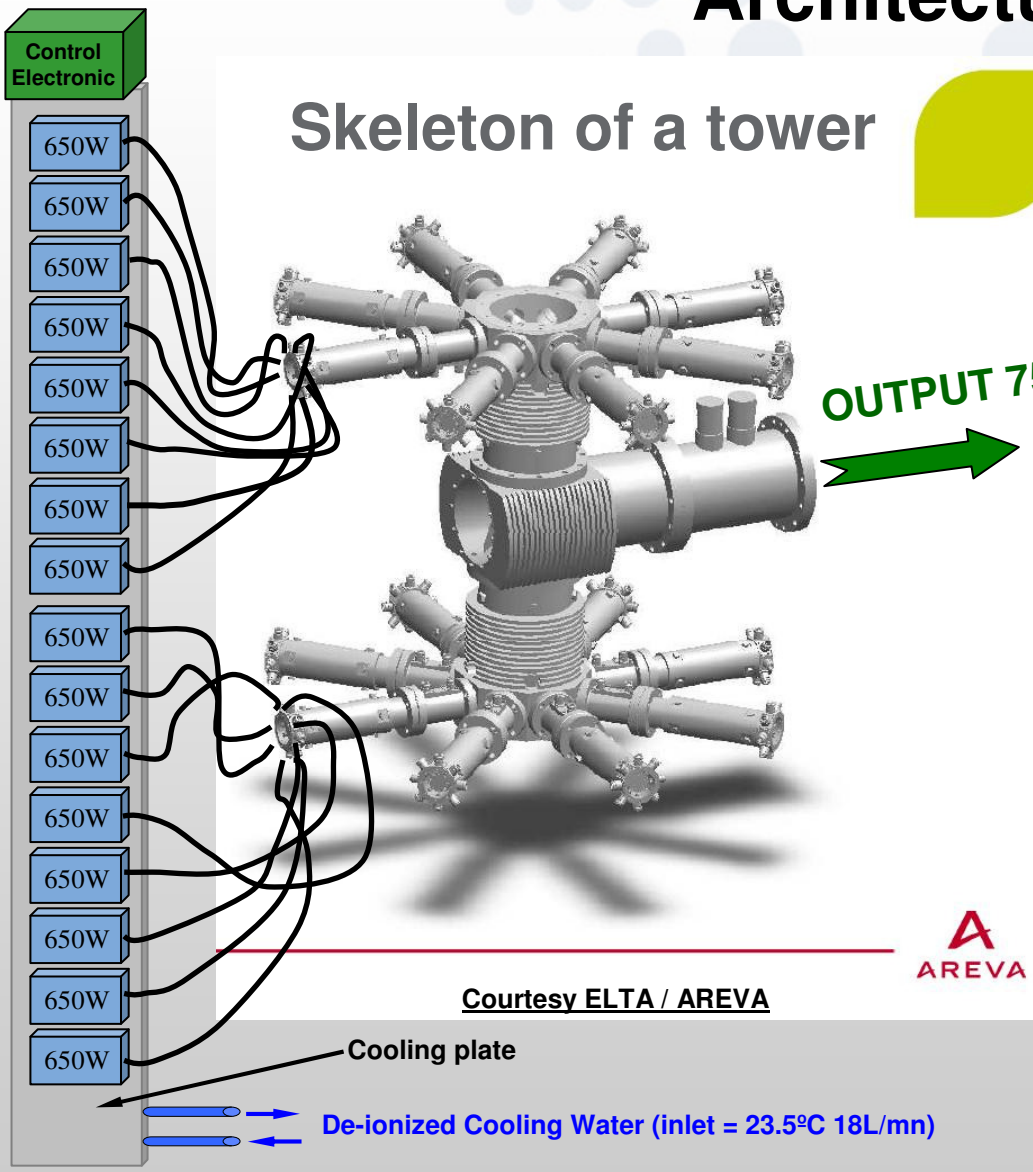
- Despite the lack of the backup-transmitter, MTBF for 2011 is the best that we ever had
- Homemade electronics is an advantage: A good knowledge of the equipment allows to improving the system.
- RF system operated with Klystron remains a good system – suitable for High Power

- RF Operation Status
- High power Solid State Amplifier

Motivation for SSA

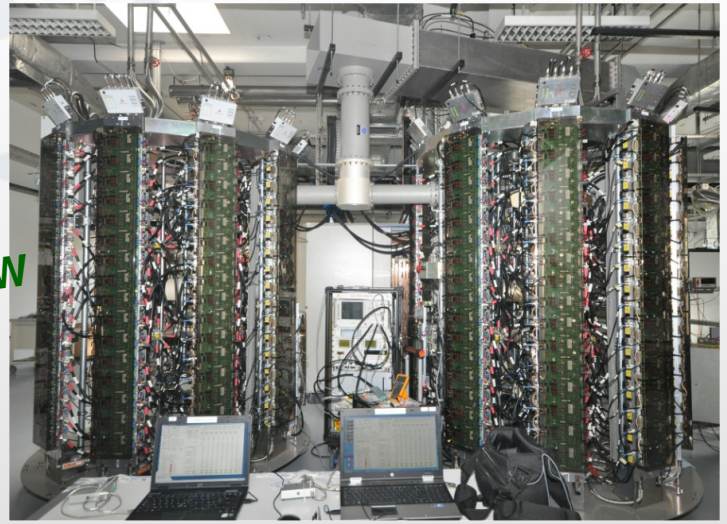
- Higher **Modularity** ⇨ Suitable for single cell Cavity
- Better **MTBF** is expected and Maintenance at **Low Cost**
- Booster's transmitter **Over Dimensioned**
  1300kW available for 600kW needed
- **Power Saving** in pulsed mode
- **Flexibility: Top-up** filling mode ⇨ Start and Stop frequently
- New Technology - **Challenge**
- **Future of Klystron** @ 352MHz ?

Architecture



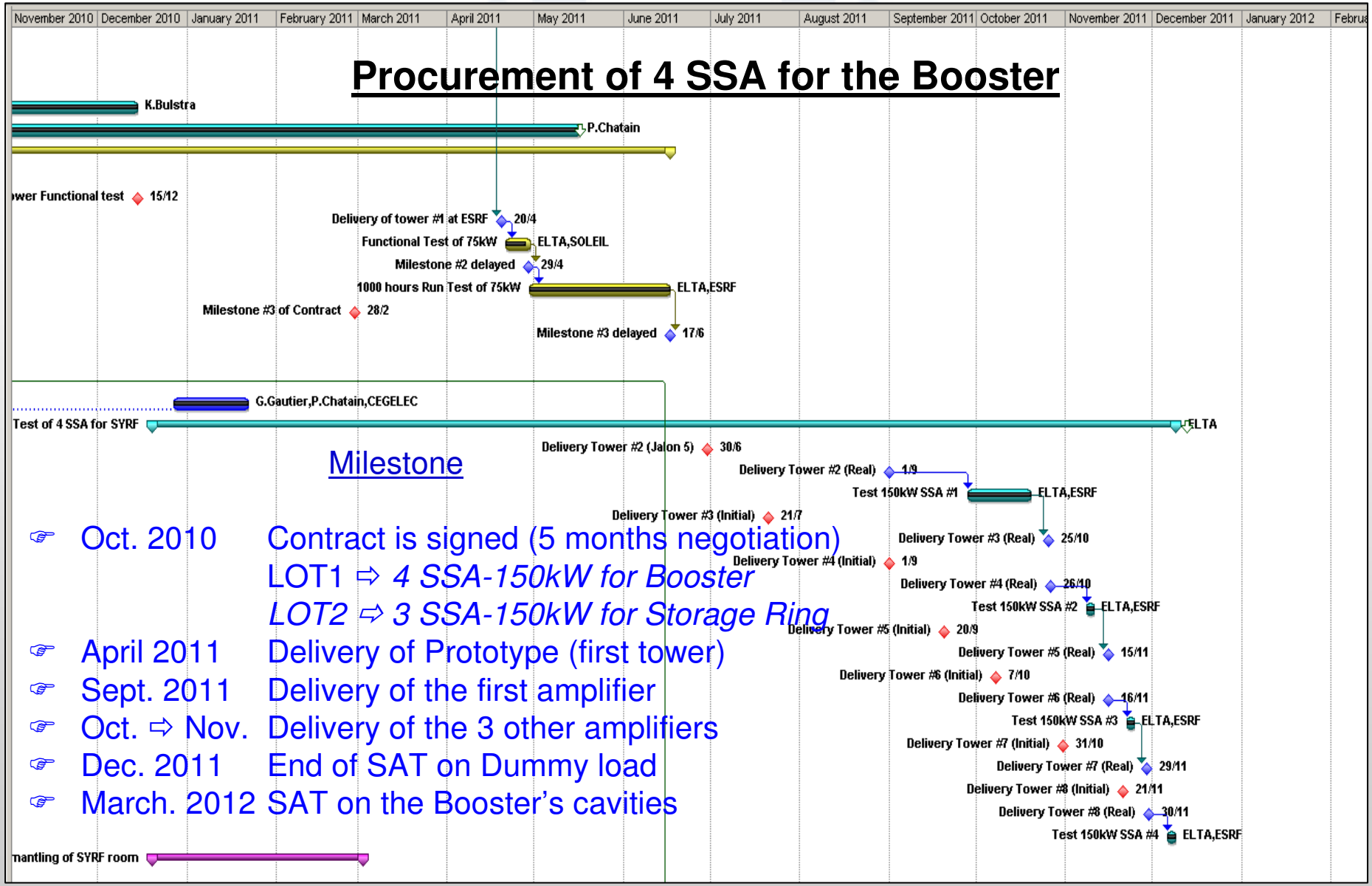
Skeleton of a tower

Courtesy ELTA / AREVA



- **2 x 128 RF modules** of 650W (+ 4 drivers)
- 2 x 8 modules per water cooled heatsink
- **8 heatsinks** combined ⇨ 1 tower **75 kW** (+ ½ heatsink drivers)
- **2 Towers** combined ⇨ Amplifier **150 kW**

High power Solid State Amplifier

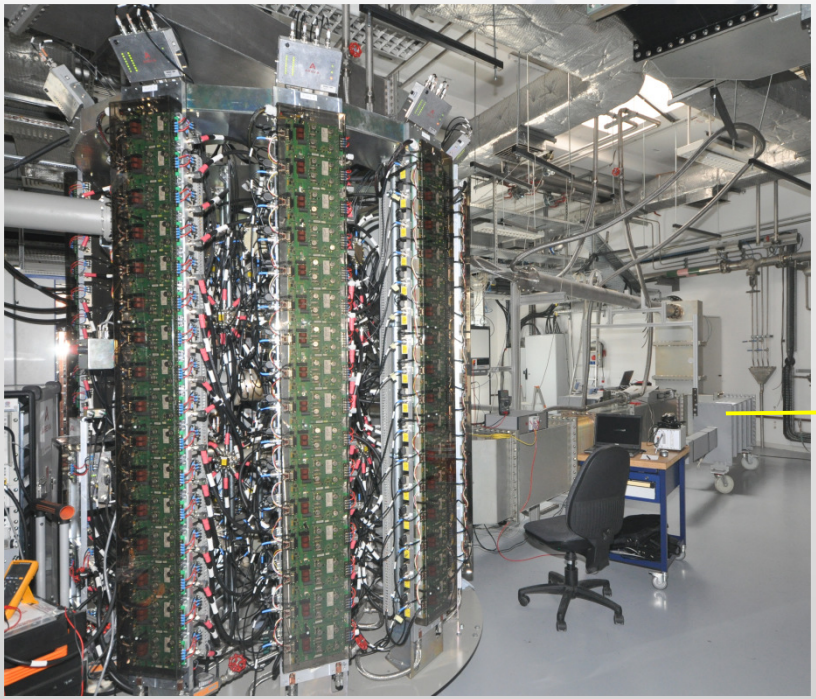


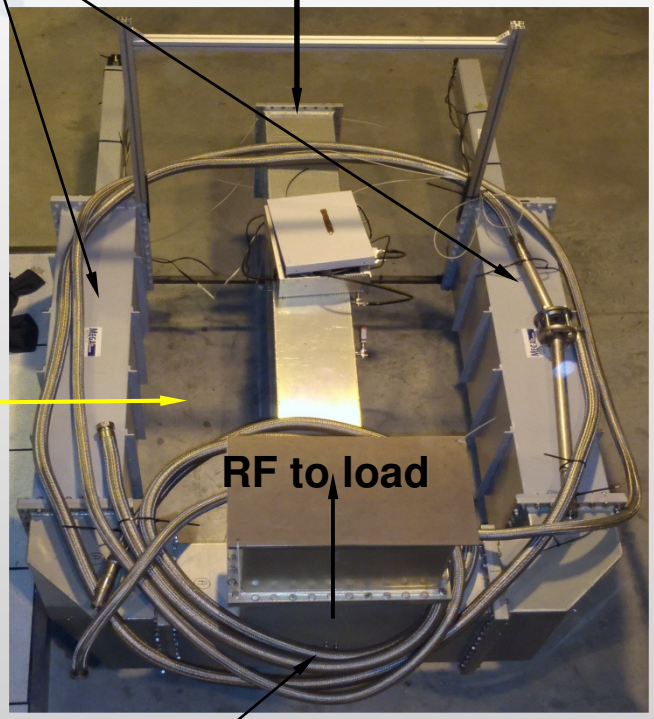
Milestone

- Oct. 2010 Contract is signed (5 months negotiation)
  LOT1 ⇨ *4 SSA-150kW for Booster*
  LOT2 ⇨ 3 SSA-150kW for Storage Ring
- April 2011 Delivery of Prototype (first tower)
- Sept. 2011 Delivery of the first amplifier
- Oct. ⇨ Nov. Delivery of the 3 other amplifiers
- Dec. 2011 End of SAT on Dummy load
- March. 2012 SAT on the Booster's cavities

Prototype (first tower) – Tests

Movable short-circuit
Make vary the ratio reflected/ forward at any phase





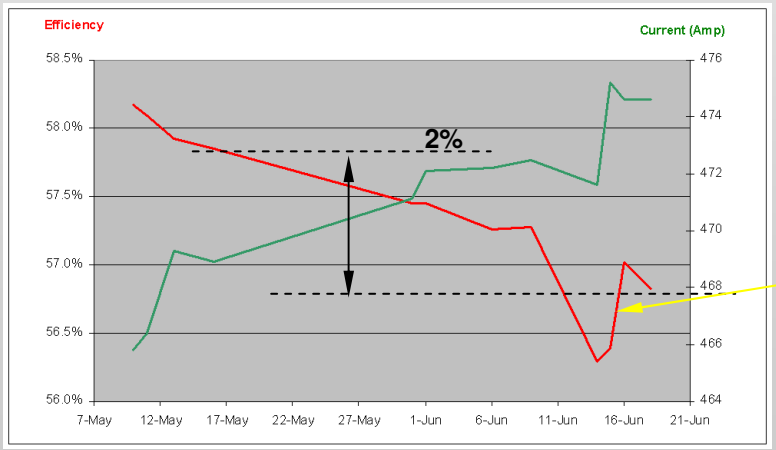
Condition of Test

EH tuner – Top view

Prototype (first tower) - Tests

Functional Test

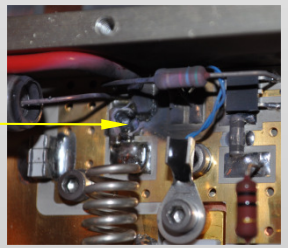
- ☞ Efficiency
  - ☐ @ 47kW 47.9% (2/3 power)
  - ☐ @ 75kW 59.4% (full power)
- ☐ ☞ 3 modules OFF ⇨ No degradation of performances
- ☐ ☞ Spurious at 390kHz – Fixed by filtering of pre-driver DC supply
- ☐ ☞ Harmonics: H2 -36dB, H3 -50dB, Higher -60dB
- ☐ ☞ VSWR: Full reflection at Pnom/2
- ☐ 1/3 reflection at Pnom
- ☐ 1/3 reflection at Pnom with 3 modules OFF



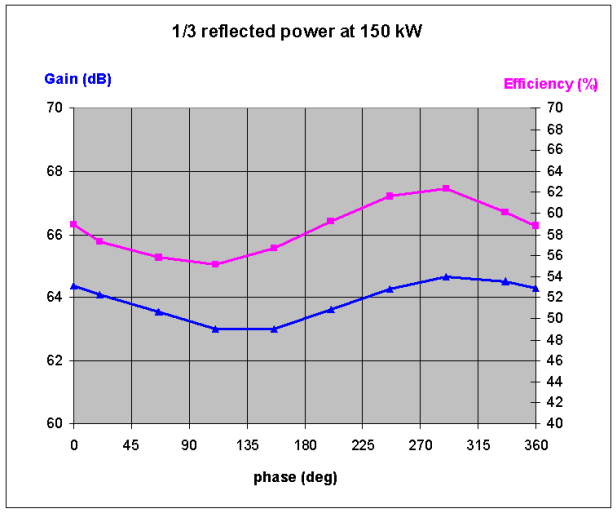
1000hrs Run Test

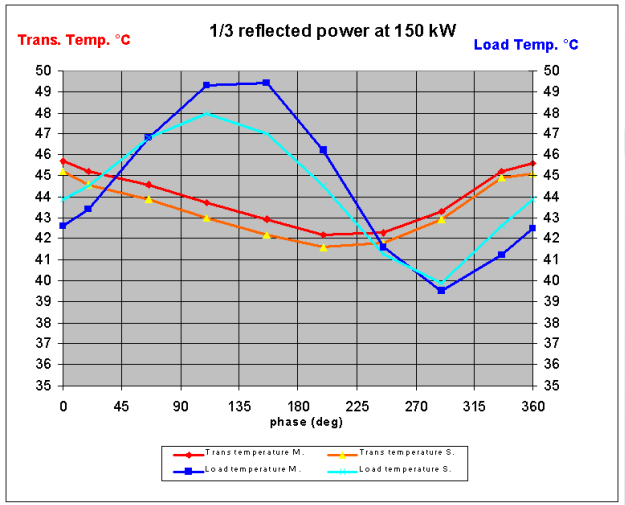
☞ **1 Failure** @ 827hrs – Filter burnt of the 50VDC supply in the RF module

☞ **Efficiency degradation** observed during the 1000hrs test



High power Solid State Amplifier

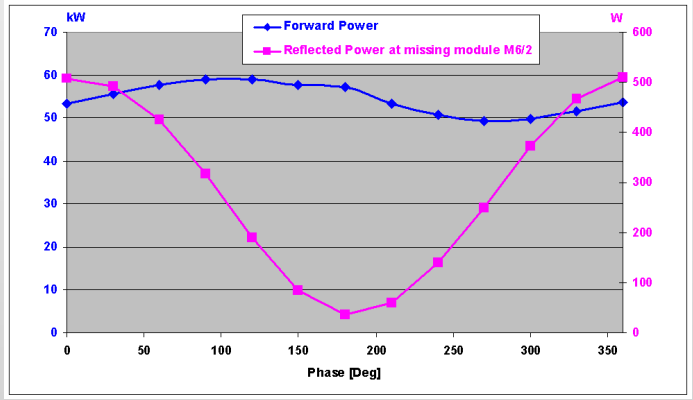




For each amplifier all points of the spec are checked again

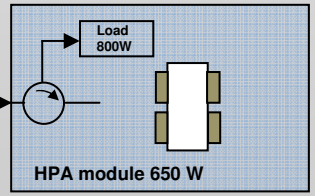
Full Power 1/3 VSWR (all modules ON)

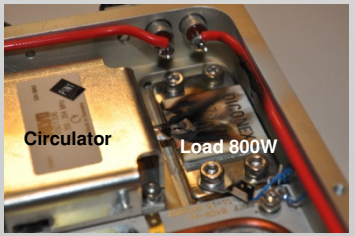
For all phases, the temperatures of the transistor and the circulator's load are monitored, as well the gain and efficiency



1/3 VSWR with 6 HPA modules OFF (output disconnected)

1st Test: some HPA modules were damaged !
2nd Test (after repair): reflected power from combiner 8 ways to the missed module is monitored ⇨for 83 kW at SSA output we can measure 800 W that **yields 1500 W at 150 kW**
HPA module is tested in **pulsed mode 10Hz** - Reflected peak power up to **3000 W can be sustain by the circulator's load.**
3rd Test: at 150 kW in pulsed mode has **confirmed the previous test** - Reflected power measured is in the range 1400W - 1600W.





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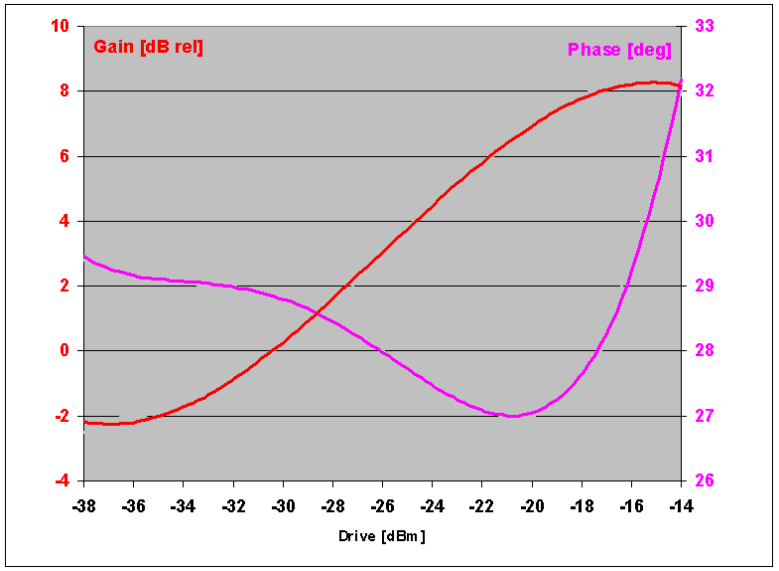
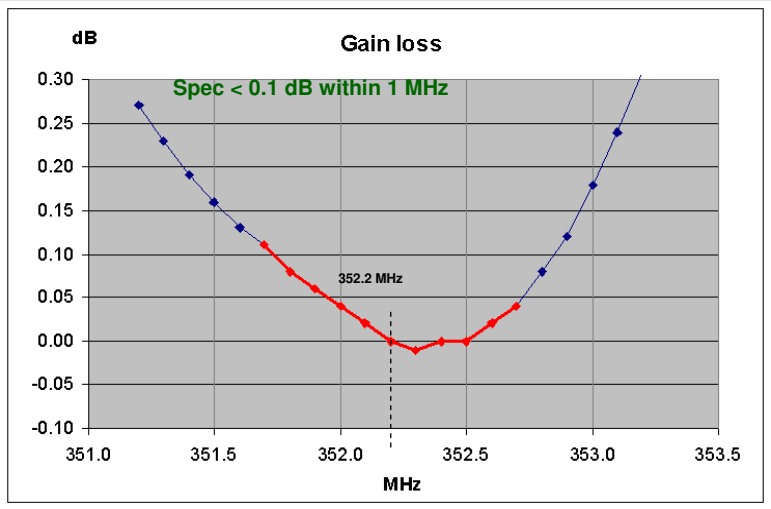
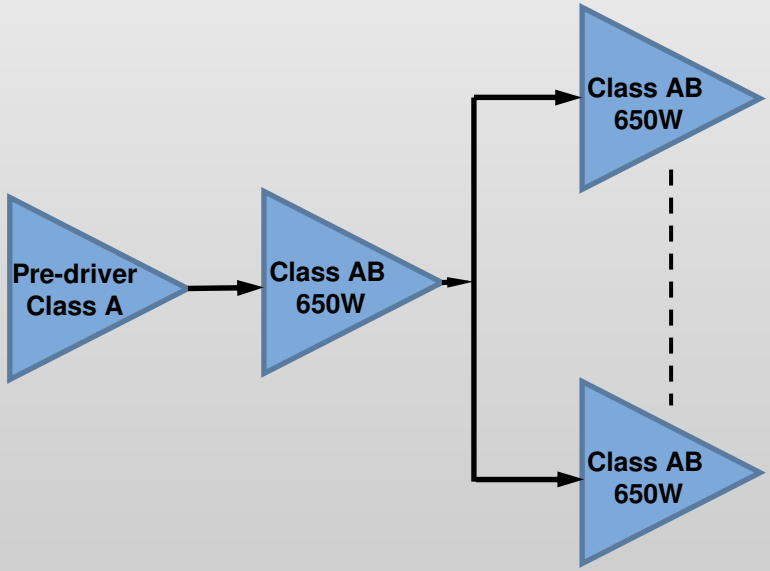


Gain curve

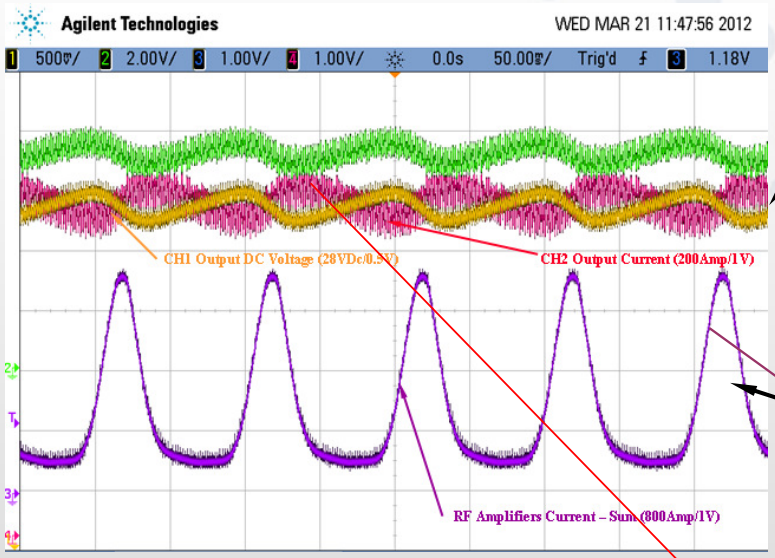
- SSA total **Gain ≈ 64dB**.
- Large **excursion of gain (≈10 dB)** in the 35 dB dynamic. HPA modules (class AB) are driven by the same HPA module. Could be a problem for the cavity voltage regulation loop with square wave

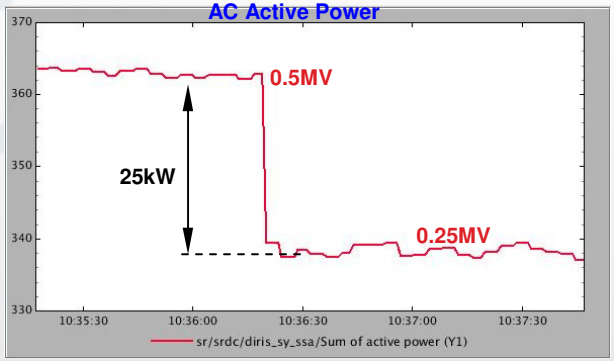




AC / DC Converter – 450kVA

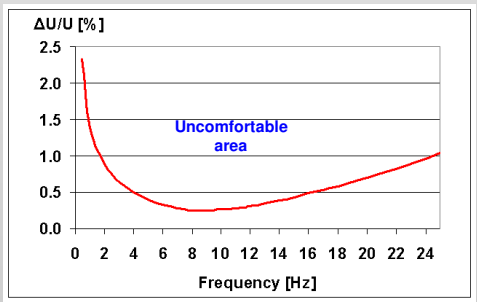
Output DC voltage and Current in opposite phase ⇨ Constant AC power

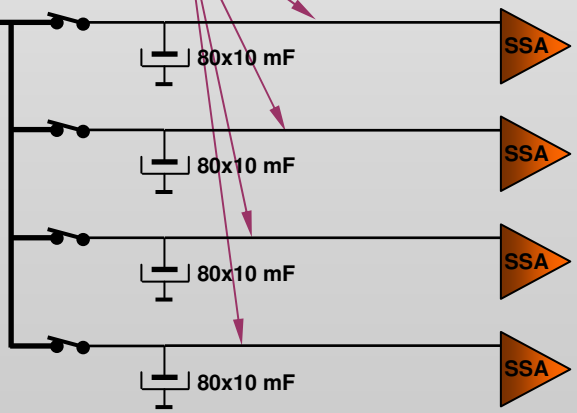




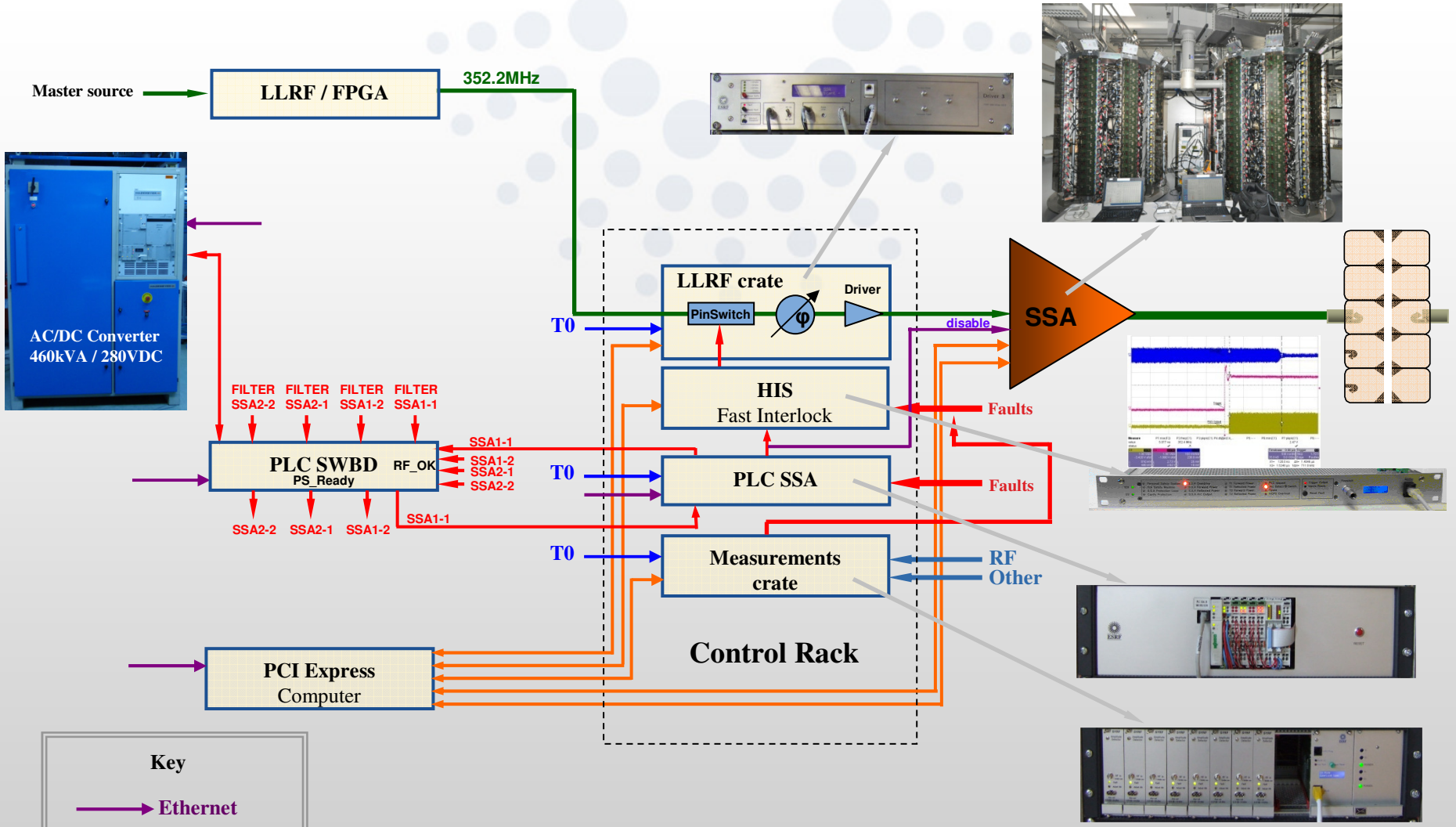
Pulsed Current delivered by capacitor Filter (3.2F) ⇨ ≈3000A

Output ⇨ 280VDC / 1500A





High power Solid State Amplifier



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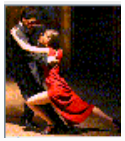
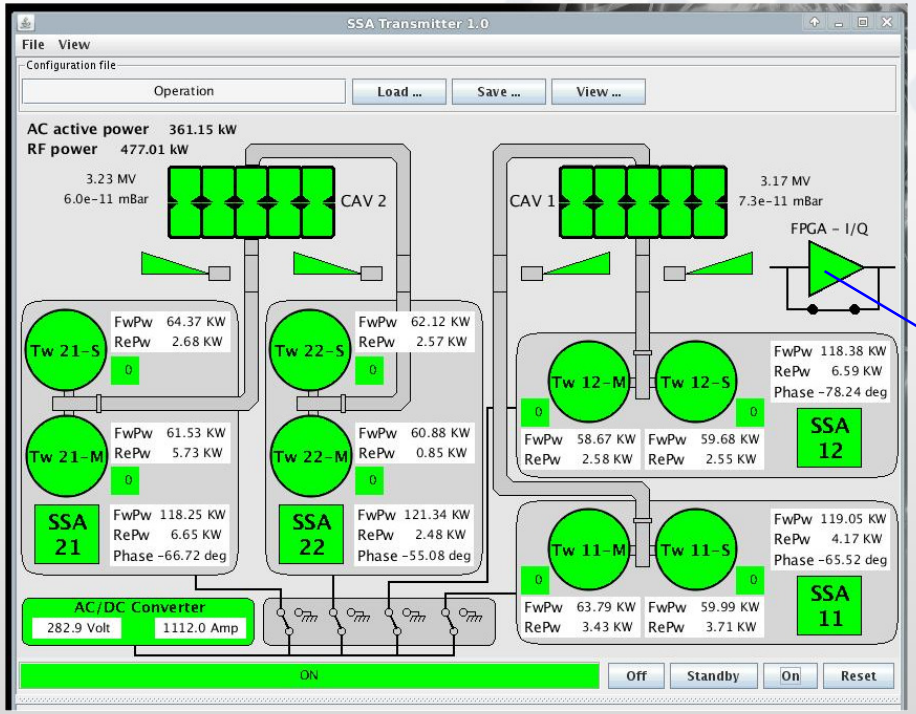
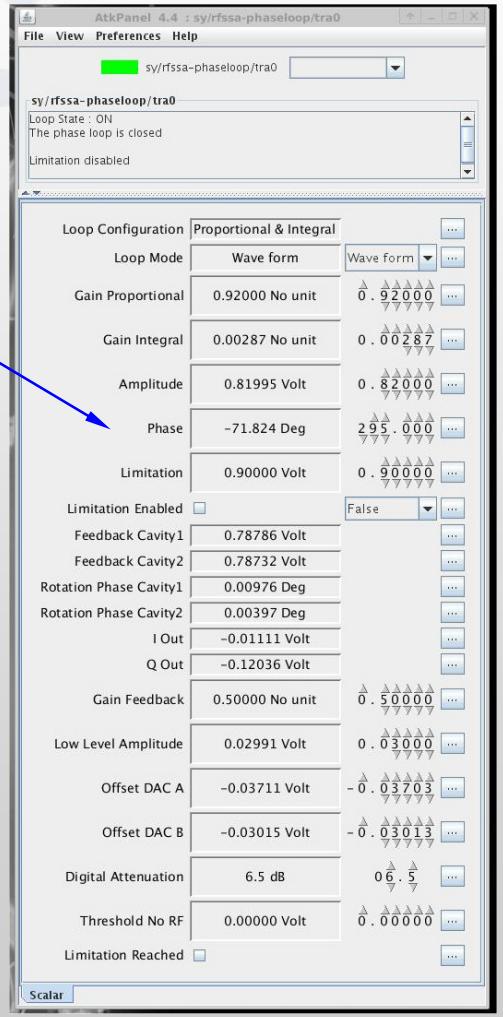


Implementation with ESRF high level Control (TANGO)





High power Solid State Amplifier

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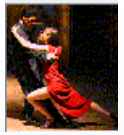

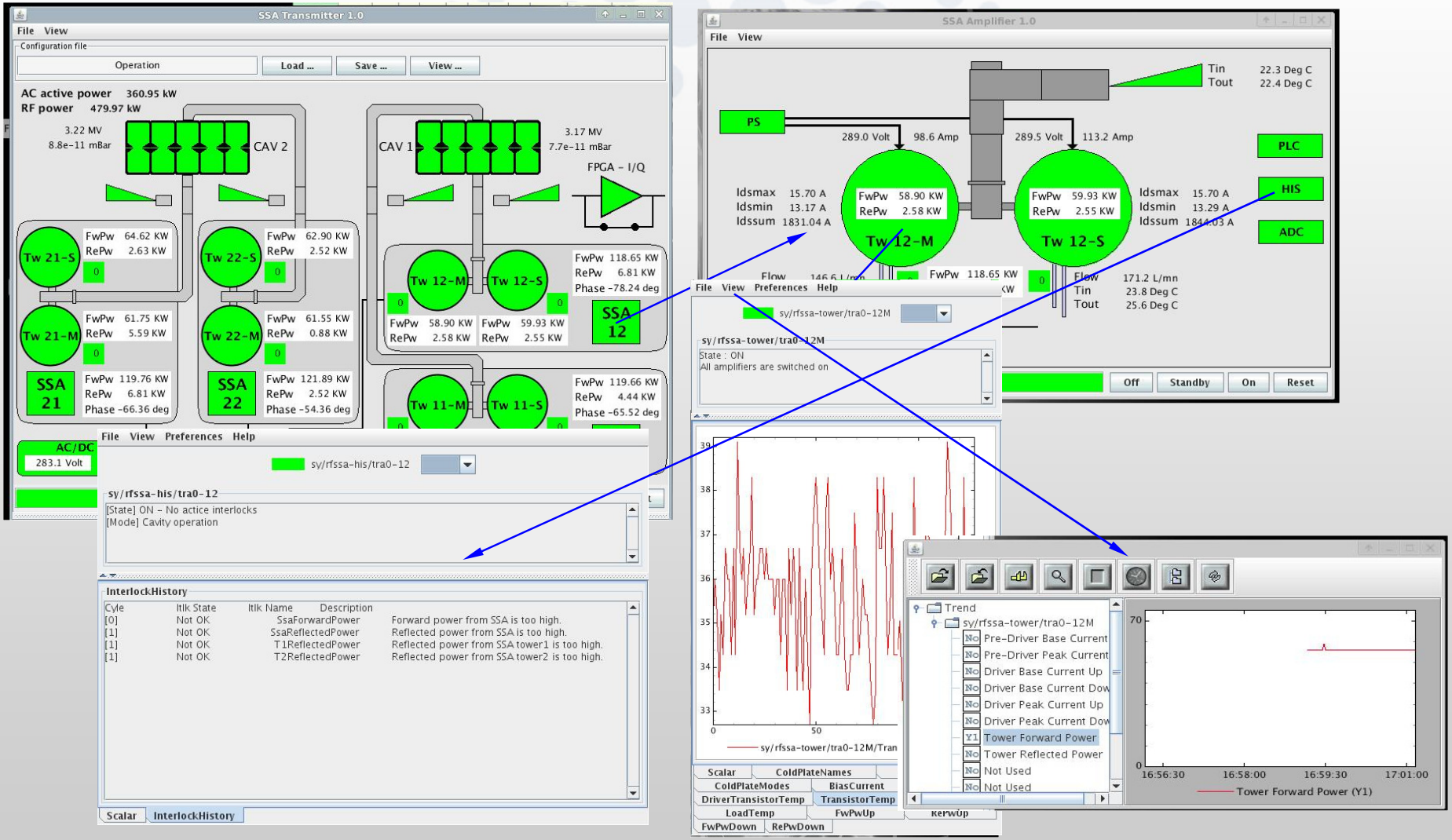

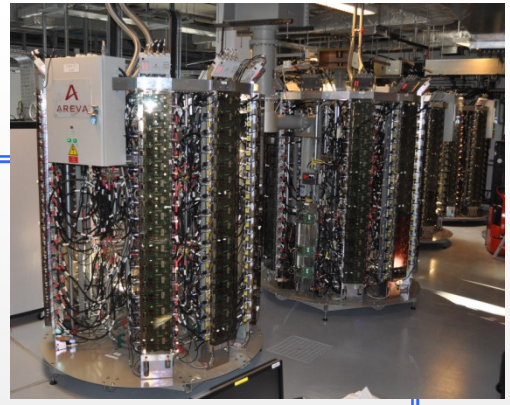

Conclusion

- Current & temperature **Monitoring** is very **useful**
- Attention must be paid for the follow-up of maintenance
- The first steps with our SSA seems to be **promising**
  SOLEIL has proven that SSA is a good system, ESRF will confirm
- Next step is **3 SSA** for single cell cavities in the **Storage Ring**
  High power **circulator [or not]** at the combined output ?

Acknowledgements

Many thanks to ..

- my colleagues who contributed to the success of this project
- ELTA and SOLEIL who developed a nice amplifier
- Jim Rose and his colleagues for organizing **CWRF-2012**
- for your attention