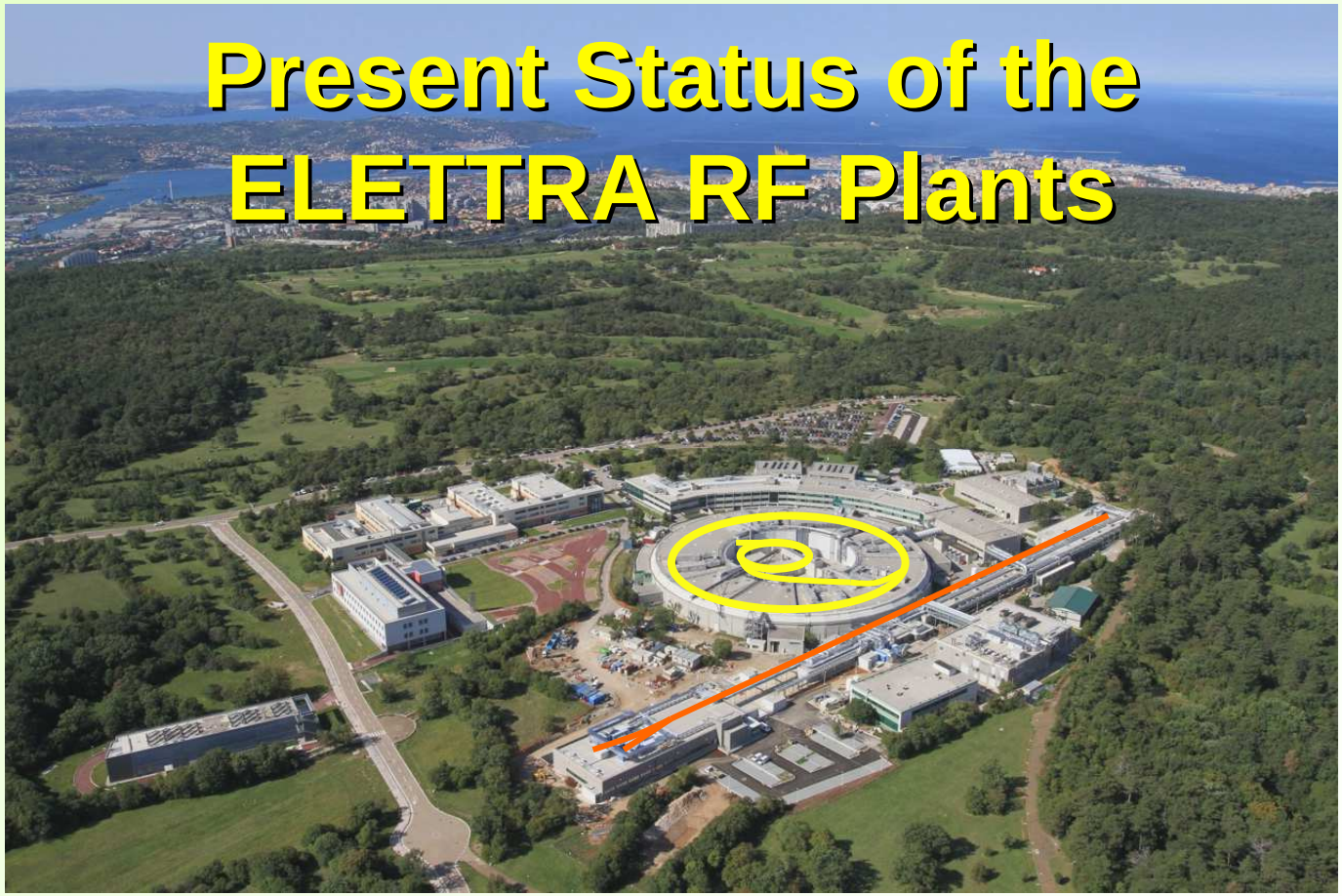
Present Status of the ELETTRA RF Plants



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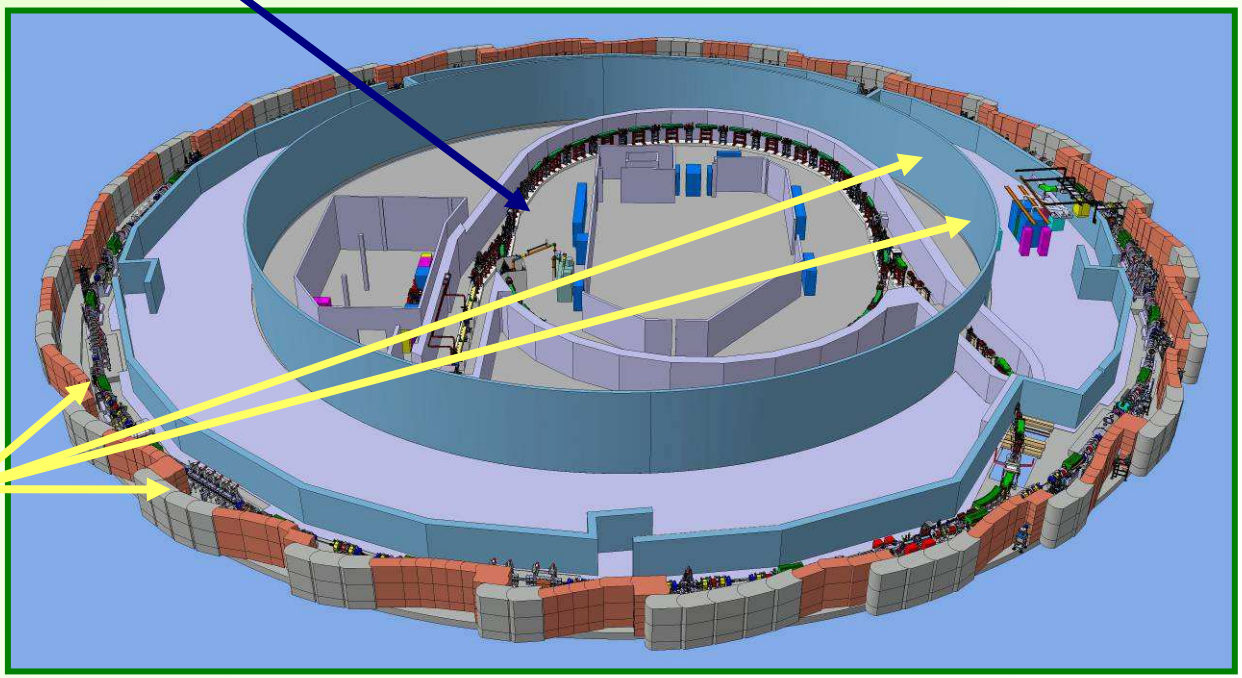
16th ESLS RF Meeting
ALBA - Barcelona, Spain, *9 -10 October 2012*

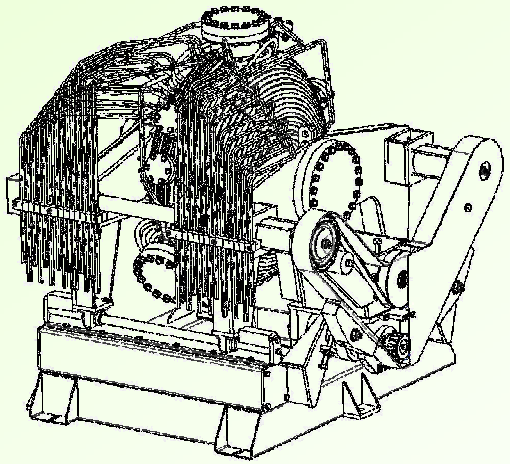
Elettra : Full Energy Injection & TOP-UP; Energies 2.0 & 2.4 GeV

User time ~ 5000 hrs/year ⇒ UpTIME goal > 95%

1 Booster RF Plant
1 cavity - 5 cells
60 kW transmitter
Linear voltage ramp @ 2Hz
Power at extraction ~20 kW
Voltage at extraction ~ 600kV

4 Storage Ring Plants
4 cavities
4 transmitters c.w. :
  60 kW x 3 plants
  2x80 kW x 1 plant
Total Power : 315 kW
Acc. Voltage: 1.68 MV

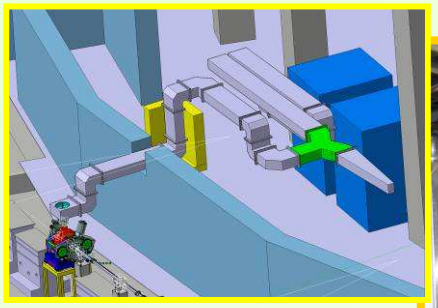




Energy (GeV)	2.0	2.4
Average Beam Current (mA)	310	160
frequency (MHz)	499.654	
RF plants	4	
cavity	single cell normal conducting copper	
copper losses (kW)	120	
power to the beam (kW)	70	71
available RF power (kW)	315	
3 Transmitters	60 kW UHF VARIAN TVT	
Power Source	E2V K3672 B.C.D.	
1 Transmitters	2 * 80 kW Electrosys	
Power Source	E2V D2130	

60 kW UHF Varian Transmitter
3 storage ring + 1 booster

150 kW I.O.T. Electrosys Transmitter: 80 kW TXA +80 kW TXB



Transmitter	heater hour	model	serial	tube hour
TXA	29394	D2130	302-1017	12522
TXB	28230	D2130	368-1208	1403
#2	108994	K3672BCD	1177-0748	17004
#3	110567	K3672BCD	1105-0428	21810
#8	110112	K3672BCD	1184-0823	16833
booster	96080	K3672 BCD	1083-0351	22166

Table update: Sep 2012

I.O.T. D2130 s/n 302-1017
10 trips in 2010, running hours 3011
6 trips in 2011, running hours 6200
2 trips in 2012, running hours 3311

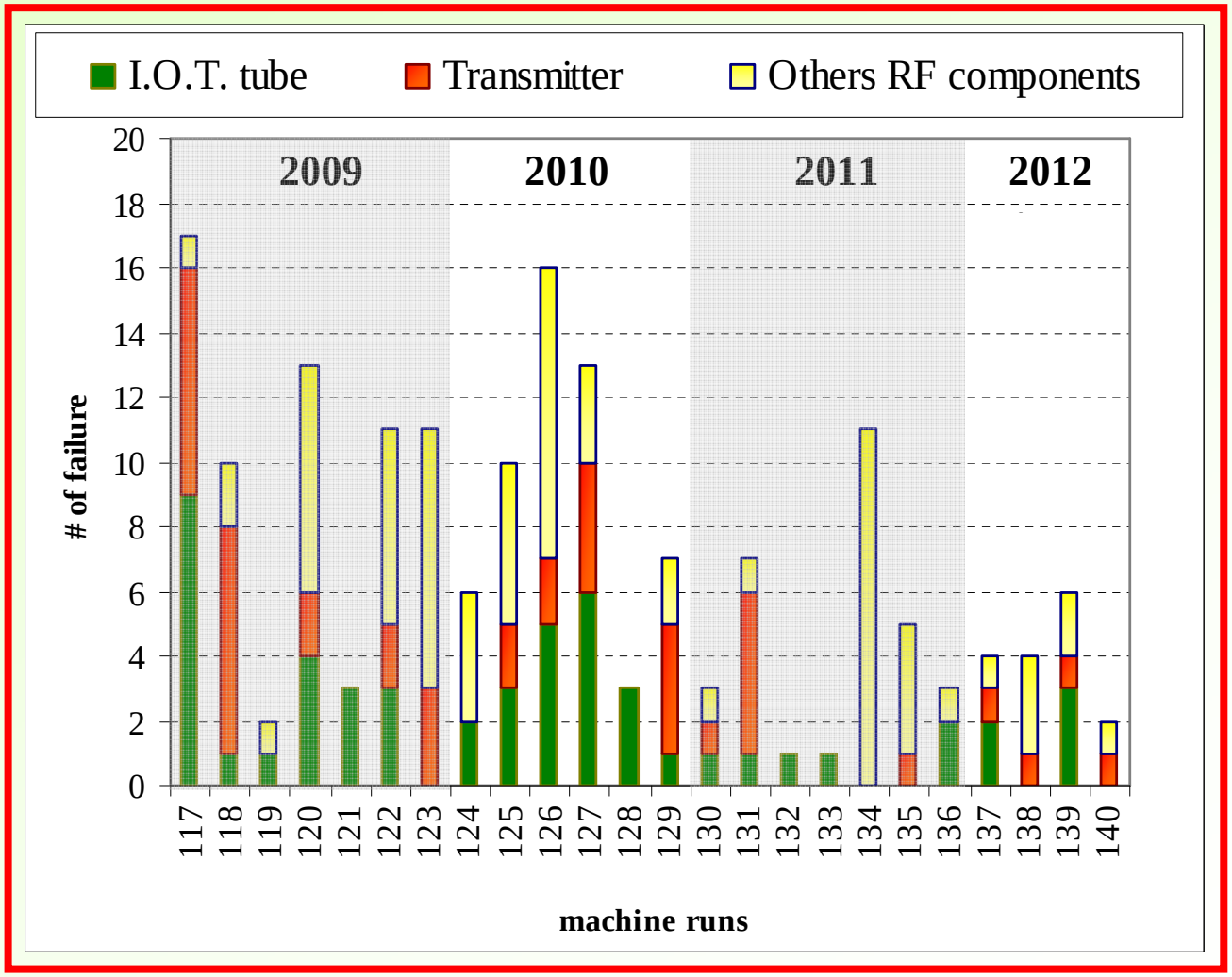
I.O.T. D2130 s/n 368-1208
3 trips in 2012, running hours 1403

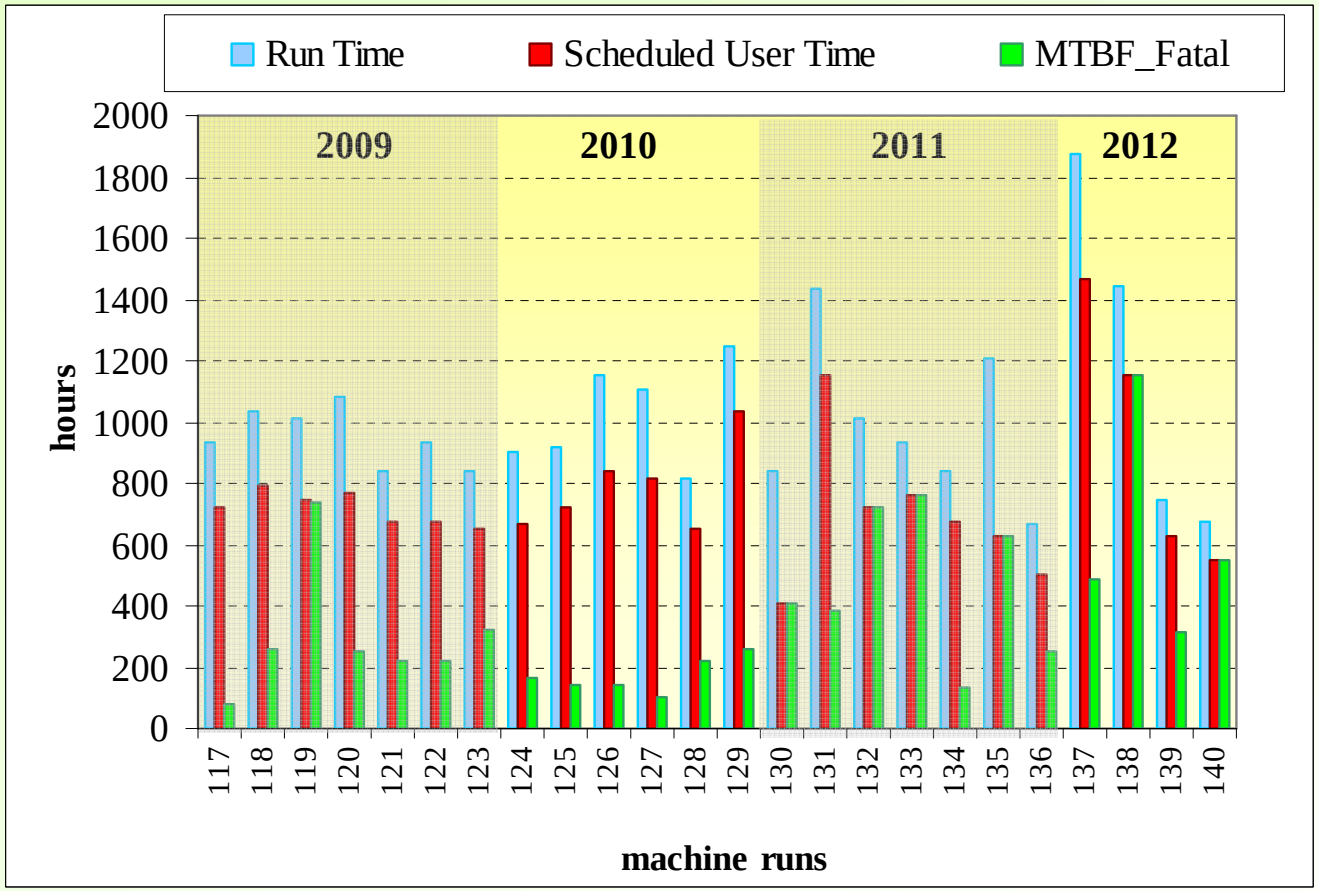
Typical output power 55 ÷ 60 kW cw

Usually the storage ring beam is lost in case of a RF failure. Few exceptions: warnings (transmitters' pre-driver insufficient gain, booster tuning alarm, ...) , but these events are also included.

Run 127: first E2V IOT tube running in TXA
Run 134: "trivial" fault of the fan of 500 MHz signal generator
Run 139: second E2V IOT tube running in TXB

Number of failure is decreasing!





The "most wanted" figure Mean Time Between Failure for the Fatal fault during the scheduled user time is progressively increasing

Planned preventative and routine maintenance:

Last two old cavities to be replaced within two years

- Actually the two old cavities have also a non-optimized input power coupling value and their reference temperature is around 77 °C, the measured temperatures at some spot are above 100 ° C.

Yearly tuning of all the klystrons

Yearly calibration of the RF measured data

Yearly test of the Amplitude and Phase and Tuning loops performances

Extraordinary repairs:

Water leaks of the cavity cooling rack pump

Replacement of the broken 3phase 300 A main switch of the klystron transmitter

Repair of the electronic power supply high voltage electronic board of the transmitter

Repair of the pre-driver amplifier of the IOT transmitter

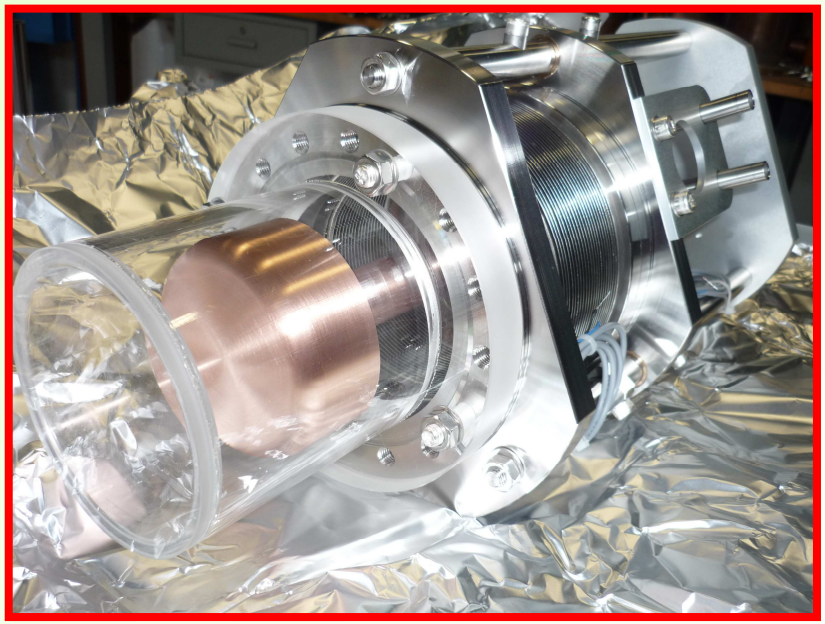
...

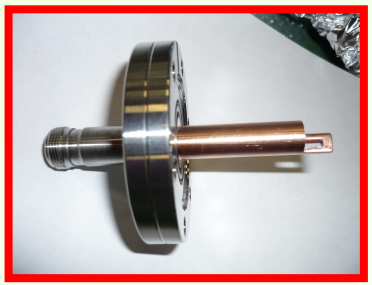
Replacement of the klystron/IOT tube at the end of their life.

...

Several hardware spare parts obtained:

- ✓ High Order Mode Frequency Shifter - PLUNGER
- ✓ RF PICK UP for the cavities - new manufacturer
- ✓ Two klystrons and one IOT



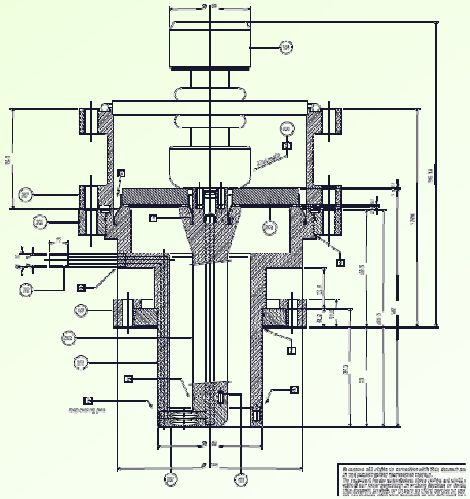


Main parts to be achieved:

- ✓ Four Input Power Coupler (following the new prototype results)
- ✓ One new cavity

INPUT POWER COUPLER:

a new prototype of the Elettra cavity has been realized and tested. The aim was to improve the mechanical design and to strengthen the brazing joints, keeping the same external sizes and the 6 1/8" adapter.



Performances:

New coupling range : from 1.0 - critical to 2.7 max - over coupled (instead of 2.9)

Vacuum level ~ 5 10^{-10} mbar after a bake-out cycle of 24 hours, copper parts at 150 °C; the flanges at 200 °C

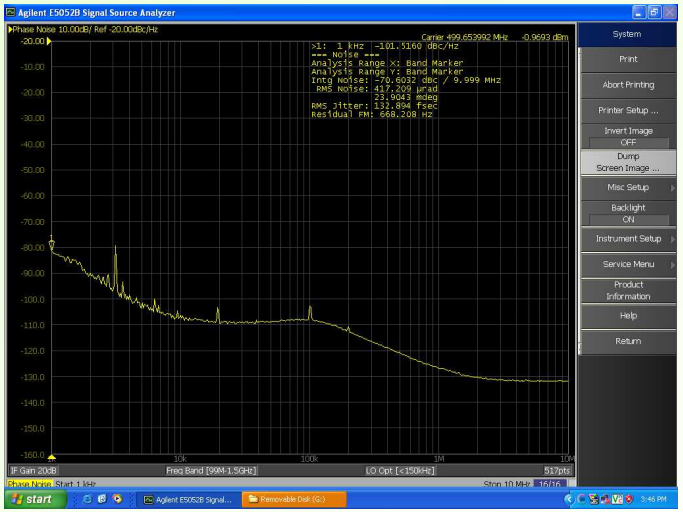
RF power conditioning
20 hours to reach 55 kW CW matched @ 1.3 10^{-8} mbar
24 hours to reach 50 kW CW full reflection @ 1.0 10^{-9} mbar

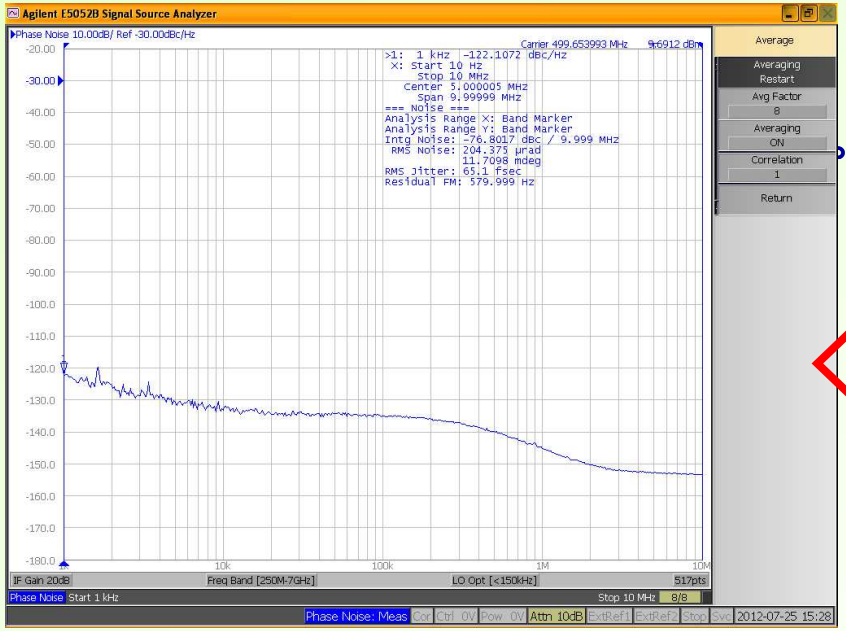
But still the final vacuum level at 55 kW is too high ~ 9.0 10^{-9} mbar !

Weak Point: the Alumina window

The 500 MHZ ELETTRA CLOCK:

Till now the Rohde & Schwarz SMG Signal Generator with high stability option from is the machine clock.
RMS jitter = 133 fsec at 0 dbm (1 kHz -10 MHz)





"middle class" signal generator SMB100A - B1H
RMS jitter = 66 fsec at 0 dbm (1 kHz -10 MHz)
Electronic step attenuator and OXCO reference oscillator, high performance

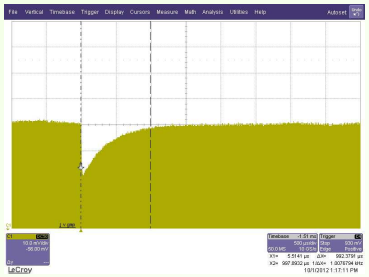
DIGITAL LOW LEVEL RF:

Last week the first tests on the DDLL RF equipment in the final implementation started

- Down-Conversion, (RF=500MHz IF=20MHz).
- ADC (16 bit, 160MS/s)
- FPGA digital board
- DAC (16 bit, 160MS/s).
- Low Noise filters.
- 500 Mhz Modulator.

Preliminary results - no DLL optimization
Re-action to the RF cavity signal modulated at 40% in amplitude, duty cycle 50%, f=30 Hz

Analogic A Loop
H=2 ms/div ; V=50 mV/div



Digital A Loop
H=500 µs/div; V=10 mV/div

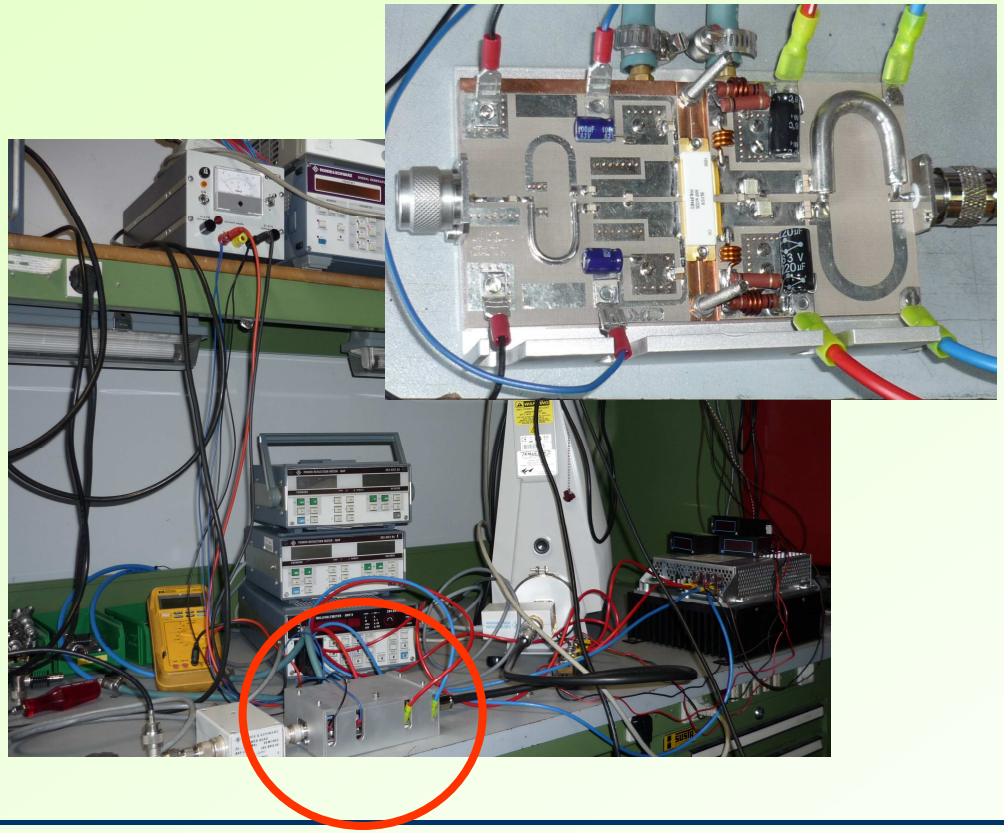
DLL Features- bench measurement:

Dynamic range > 90 dB
ADC RF sampling resolution
IF (20 MHz)
φ < 0.04°
|ρ| < 0.024%

Control system settling time < 1 µs
DAC + modulator resolution
φ < 0.04°
|ρ| < 0.05%
Mod. BW > 40 kHz

SOLID STATE AMPLIFIER:

Tests have been carried out on the NXP BLF578 (HV LDMOS) Demo Board number NA-1331 ⇒ 700 W with no troubles



What we learned:

- ✓ **The transistor itself can easily deliver around 700 Watt of CW RF power @ 500 Mhz. The maximum output level threshold is given by the transistor proper matching and cooling. The limits are input and output circuit' components and the boundary conditions**
- ✓ **<u>The hundreds watt power combination is the real challenge</u>: the efficiency and the fail-safe of the system strongly depends on the chosen combination topology.**
- ✓ **The CW requirement for the synchrotron radiation power source forces a different approach with respect to the broadcast market.**
- ✓ **Obsolescence of the transistor as well as the thermal fatigue of the board shall be taken into account (maintenance budget).**

- The great effort performed in the maintenance of the “old-aged” transmitters has given good results in term of failures. Their ageing has been slowed down, but nobody knows how long they will be working

- The E2V IOT have shown the required reliability, but klystron tube are still unmatched for reliability and performance**.** Not enough data about the tube’s operating hours in the CW applications

- The project to re-new the main RF hardware equipment is going on (cavities, IPC …)

- DLL RF is going to be tested on the field: its mass production is foreseen middle next year

- What will be the next RF power sources for the scientific application ?
  - Is the tube market still attractive for the companies?
  - The CW requirement for the synchrotron radiation power source forces a different approach for the solid state transmitter with respect to the broadcast market. Is it an attractive market too?