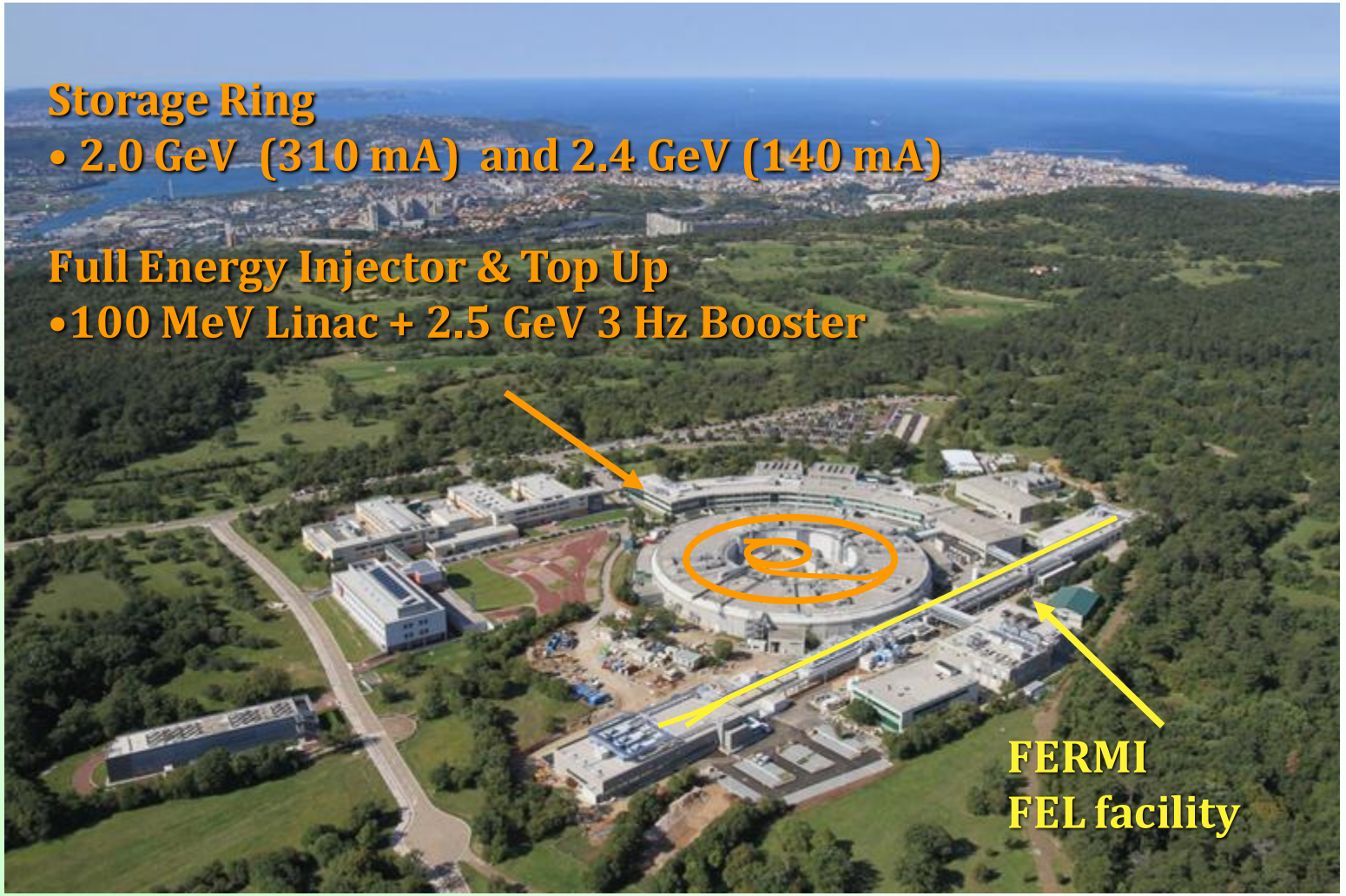
Elettra 500 MHz RF Power Plants

M. Bocciai, C. Pasotti, P. Rinaldi

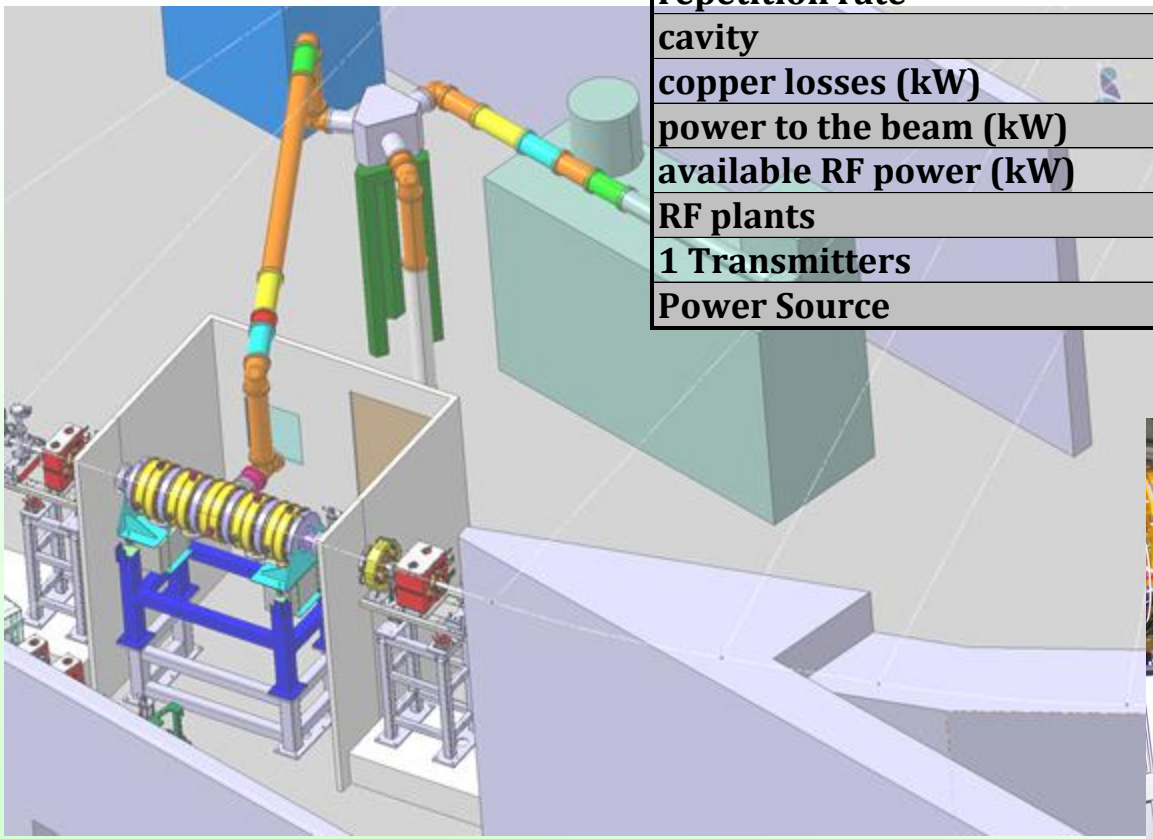
CW and High Average Power RF Workshop
May 7th -11th 2012, Brookhaven National Laboratory
Port Jefferson, NY

ELETTRA : 3rd generation synchrotron light source



Booster RF Plant

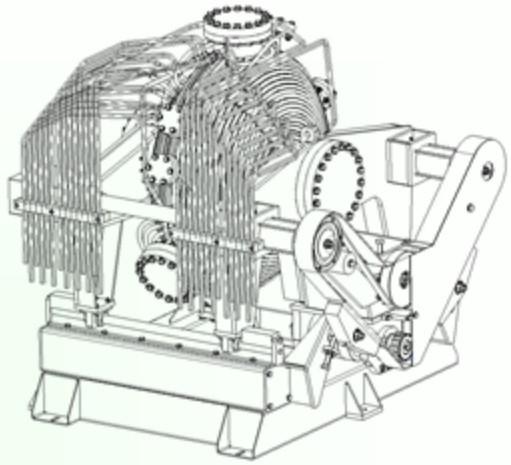
Energy (GeV)	0.1	2.5
repetition rate	2.14 Hz	
cavity	5 cells PETRA like	
copper losses (kW)	---	15
power to the beam (kW)	---	1
available RF power (kW)	55	
RF plants	1	
1 Transmitters	60 kW UHF VARIAN TVT	
Power Source	K3672 B.C.D.	



- ✓ CW RF Power linearly ramped from minimum (~ 500 W) to the higher level at extraction (~ 16 kW)
- ✓ Free from failure requirement in top-up mode
- ✓ Main concern of having a single transmitter: redoubling the transmitter is mandatory!

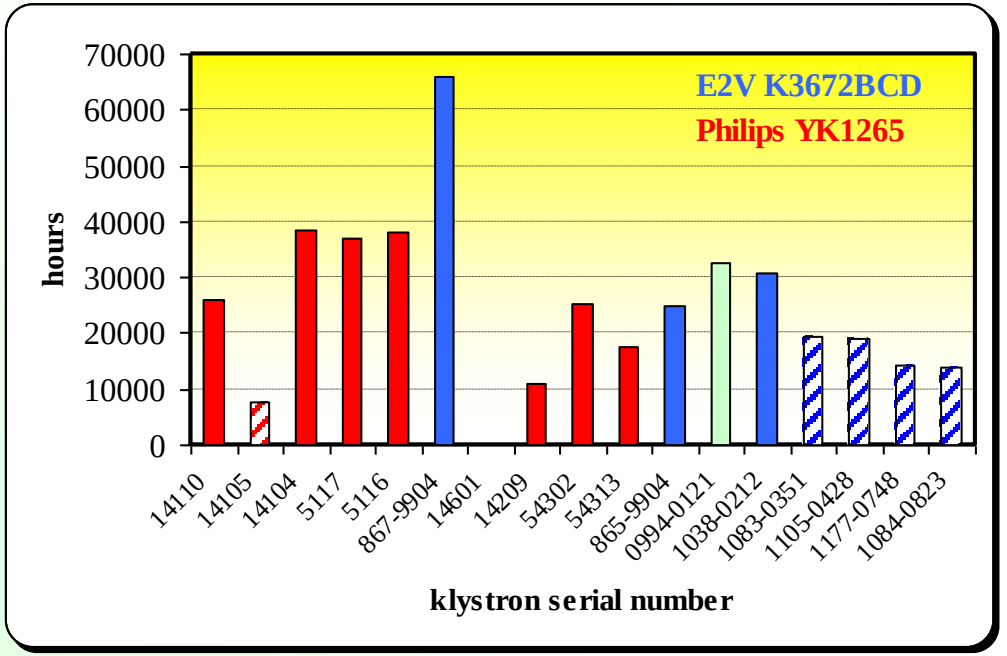
500 MHz Storage Ring Plants

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	K3672 B.C.D.	
1 Transmitters	2 * 80 kW Electrosys	
Power Source	TH793 & D2130	



500 Mhz 60 kW CW Klystron

- ✓12 klystrons replaced in four transmitters since 1993
- ✓5 klystrons in operation (including the lab's RF power plant)
- ✓2 spare klystrons available (last two off-the-shelf ready)
- ✓No spare trolley, a quotation is hard to obtain!
- ✓Replacement occurs when the klystron's parameters show some degradation
- ✓Klystron replacement: 3 days
- ✓Klystron average operating hours 31600
- ✓Servicing: one check/year (that is every 6000 hours of operation. Cavity's tuning, gain, output power level calibration, etc.)
- ✓<u>Down time due to the any klystron's trip: none at all</u>, unless the device is close to the ultimate failure.



Klystron operating hours before replacement, sorted according to their installation time. Pattern columns refer to klystron in operation (installed in Aug '07 , April '09, Dec '09, Jan '10, hours on Apr '12).

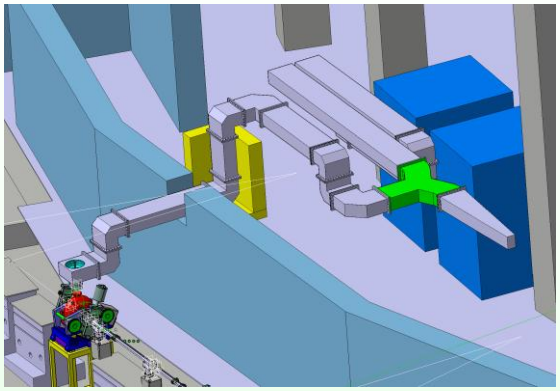
Klystron's Transmitters

60 kW UHF VARIAN TVT	heater' hours April 2012
booster	93351
RF #3	107784
RF #2	106238
RF #8	107352
RF lab	8200

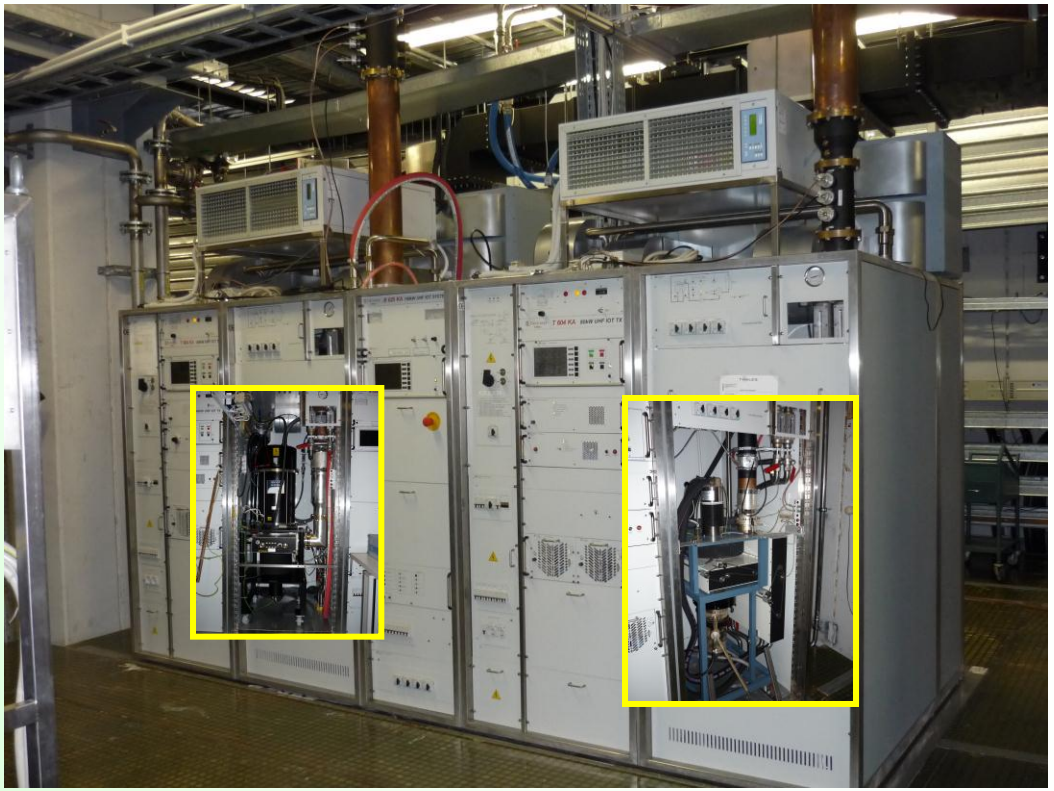
- ✓ **The storage ring's transmitter installed late 1992, beginning 1993**
- ✓ **No more guaranteed, neither new spare parts**
- ✓ **Some components (even second hand ones) have been collected in past years to be used as spare parts**
- ✓ **Main concern are the electronic boards: their components not any longer in production**
- ✓ **Maintenance and extraordinary repair occurs every shut-down time!**

500 MHz Klystron transmitter, coaxial run, circulator and dummy load in the service hall. The storage ring is located beyond the wall.

IOT Transmitter (2 · 80kW)



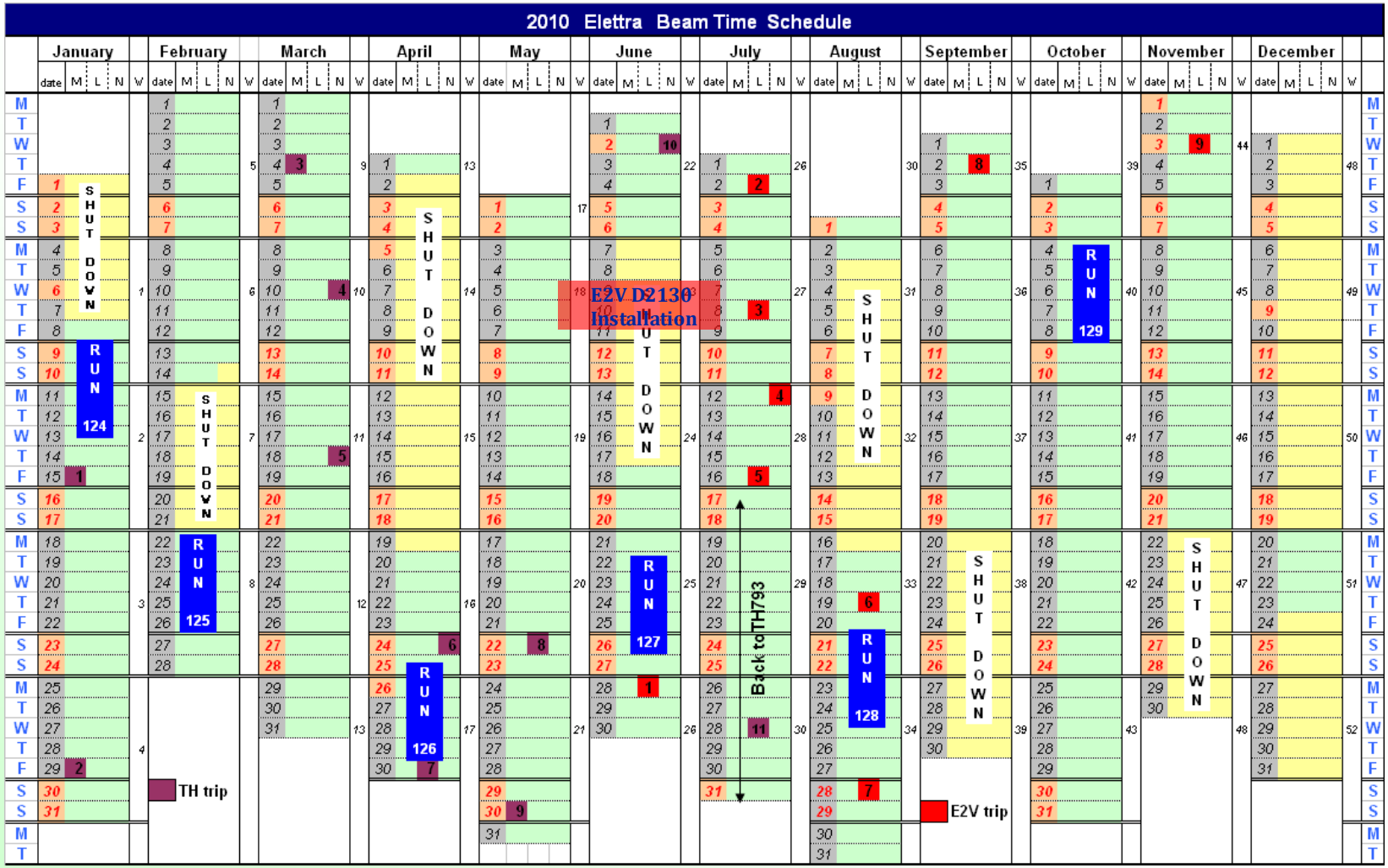
- ✓ 2* 80 kW transmitters installed during summer '06. Source: TH 793 IOT tubes
- ✓ 150 kW of output power level is obtained adding up the two source by means of a WG switchless combiner
- ✓ After the initial successful commissioning' phase (six months) in 2007 the transmitter was set into operation, but Thales tubes didn't fit the reliability request for the synchrotron radiation users.
- ✓ Finally, the E2V D2130 tube was installed in Jun '10



April 2012: One transmitter is equipped with D2130 E2V tube and it is feeding the storage ring cavity. The second transmitter is still fitted with the TH793 tube, and it is used as a spare transmitter.

June 2012 the E2V tube will be installed in the 2nd transmitter too.

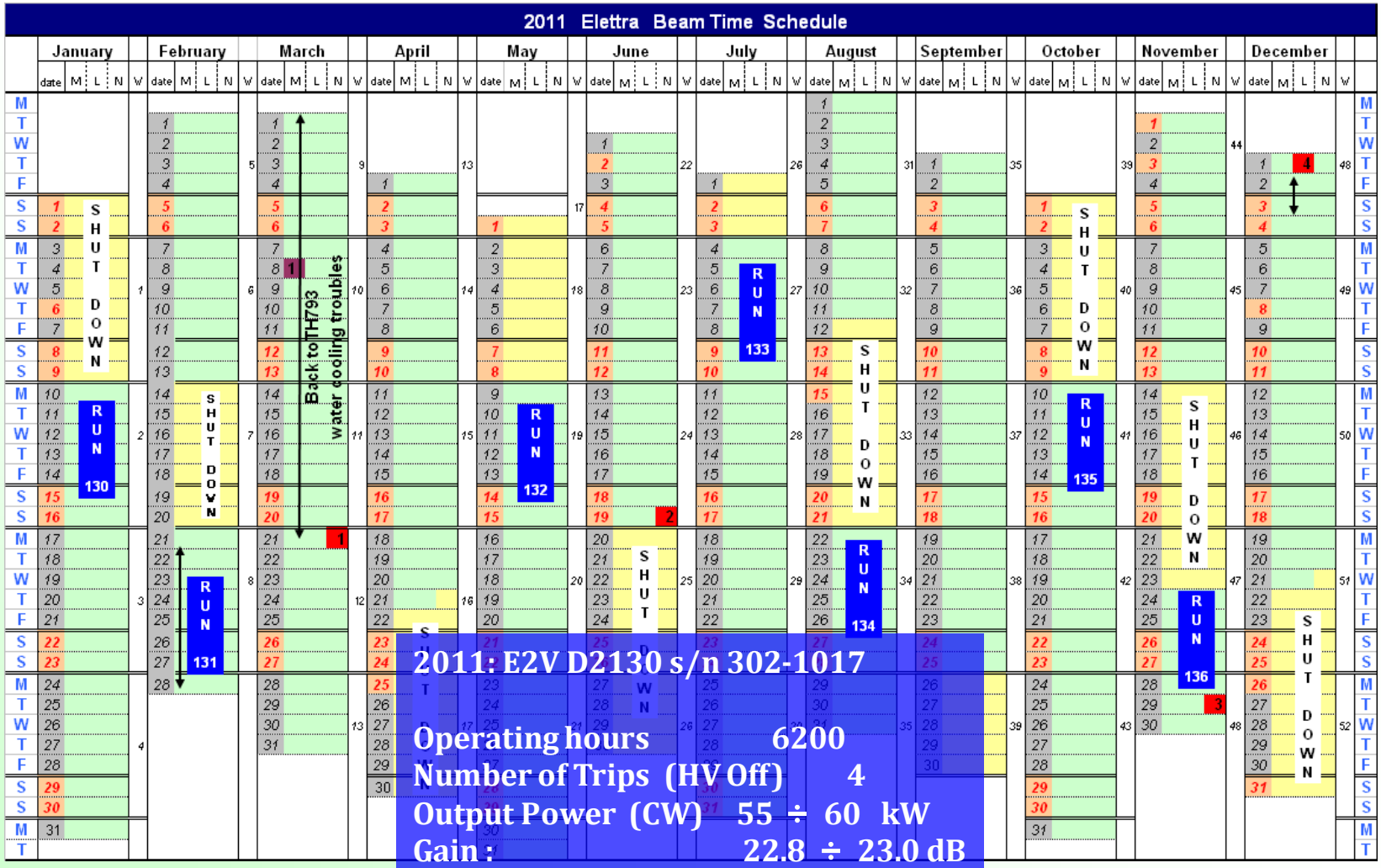
2010 IOT Statistic



Any tube trip causes a beam dump, that means new injection should be performed.
11 Thales tube trips (plum square) ⇒ MTBF* =252 hours
10 E2V tube trips (red square) ⇒ MTBF* =306 hours

* Tube trip only

2011 IOT Statistic



RF Plants Statistic

Elettra is a USER FACILITY:
UP TIME is mandatory
Maintenance and repair service term and time comes under the user requirement

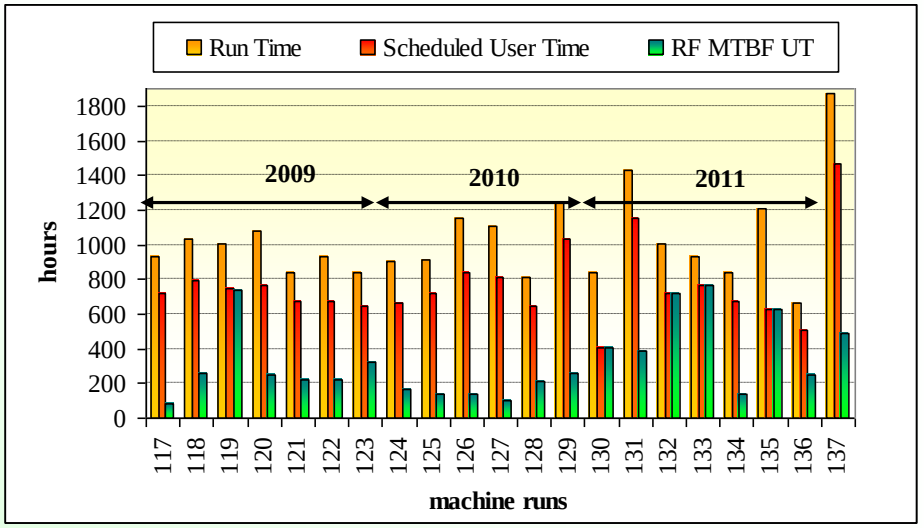
The reliability of the Elettra RF systems strongly depends on the IOT tube trips and transmitter's failure.

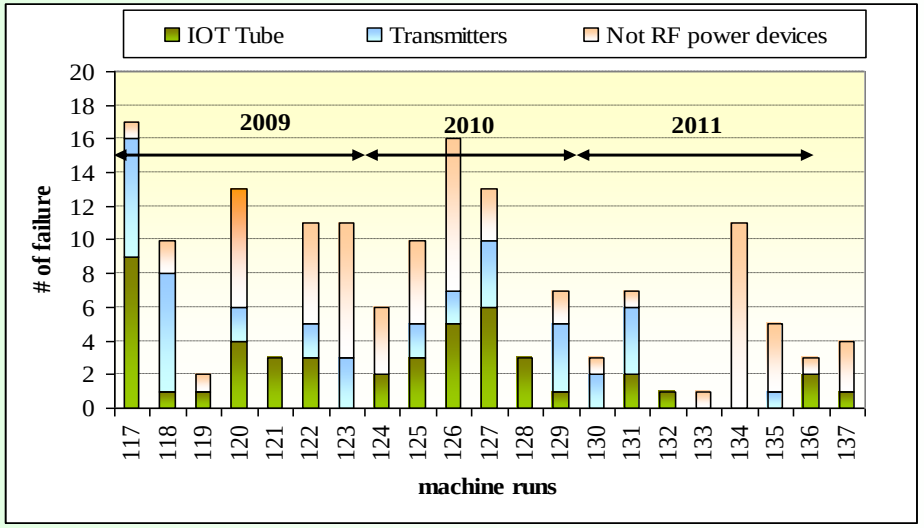
✓Transmitter faults have long recovery time
- **run 117: 25kV dc cables discharge!**
- **run 118: klystron replacement**
- **run 127: Heater PS faults**
- **run 126: Solid state PA drives**

✓Transmitter's maintenance and service has been strongly pushed. Failures decrease, but aging is going on!
✓IOT Trips just need a reset

✓2011 has good numbers, even though other RF components fail!
- **run 131: transmitter's cooling water pipe leak, not a severe fault but striking anyway**
- **run 134: well hidden bad functioning of the storage ring signal generator**

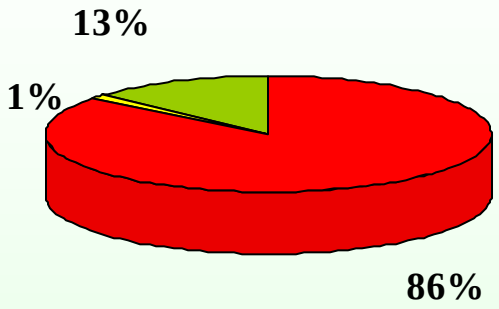
Mean Time Between Failure during scheduled User Time due to RF systems, scheduled user time and run time.



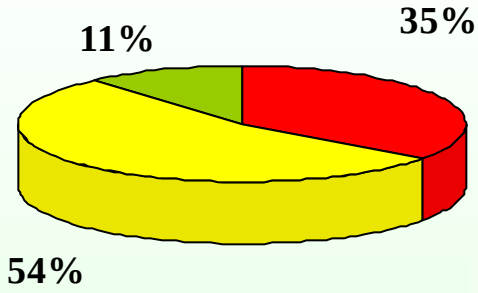


Maintenance & Budget

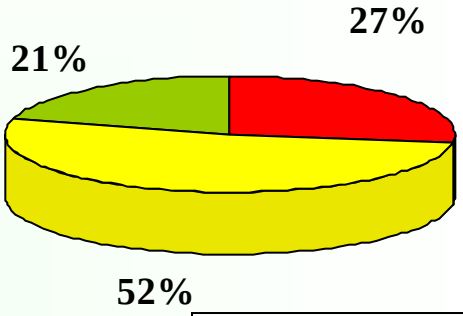
2009 RF Budget



2010 RF Budget



2011 RF Budget



Maintenance and repair of the transmitters exploit 80% to 90% of the yearly budged, including the purchasing of spare tubes

188 KVA Transformer

Klystron's output coaxial line

Replaced klystron

Future Power Source/Transmitter at ELETTRA

✓The following power sources have been used at Elettra:

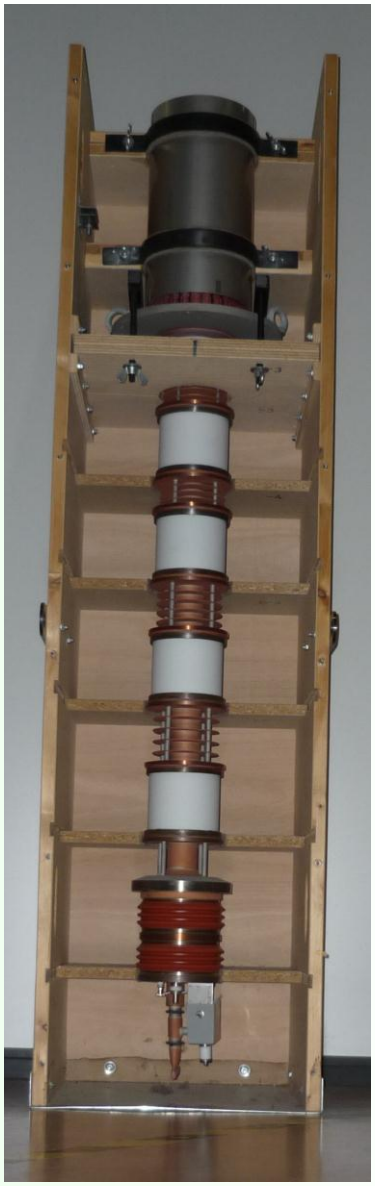
- •60 kW Klystron (Philips, Marconi ,E2V)
- •80 kW IOT from E2V D2130 (Thales also used)

✓Good performances of klystron tubes, but the broadcast market is declining, **know-how could be lost and production's cost will rise**

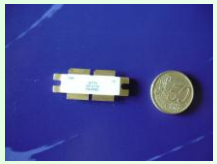
✓The implementation of the IOT tube had had an hard start up. Now things are going on smoothly, but no enough statistic to figure out the overall performances of these tubes for the storage rings. E2V tube has 11000 operating hours on April 2012

✓The development of LDMOS technology is continuously growing in HV, power handle and frequency capability

✓<u>Successful performances of solid state amplifier</u> (SOLEIL 200 kW CW @ 352 MHZ)



The next 500 MHZ power source for Elettra will be a transistor?



RF Power Source Main Requirement for ELETTRA

✓**Any new installation should take into account that Elettra is an already operating machines, so there is not much room for "strong" changes.**

✓**Fixed point:**

- ✓**Keep the existing high power coaxial run and 80 kW circulator (6 1/8" EIA - 50 Ω)**

⬇

60 ÷ 70 kW CW TRANSMITTER

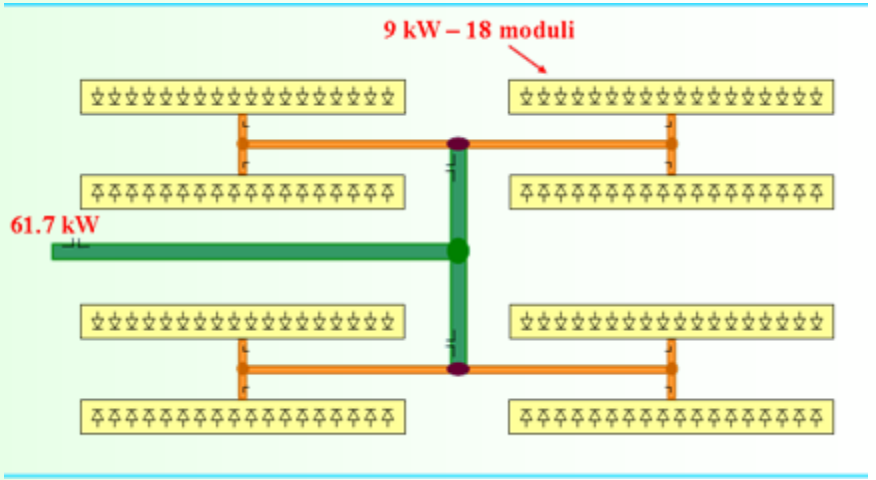
- ✓Keep the cooling system for the klystron amplifier (6 m3/hrs - 5 bar)
- ✓Keep the existing AC Voltage Stabilizer (380 VAC ±0.5 %, 240 kVA, 370 A max)

✓**Other specs:**

- ✓**Power Redundancy**
- ✓**Linear gain**
- ✓**Phase and amplitude stability**

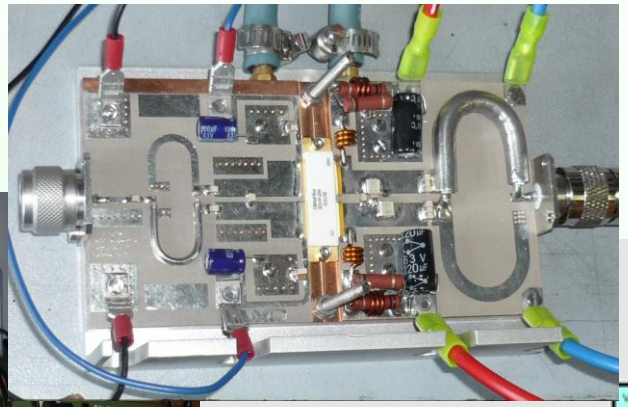
✓**ELETTRA lay-out exercise:**
(conservative design)

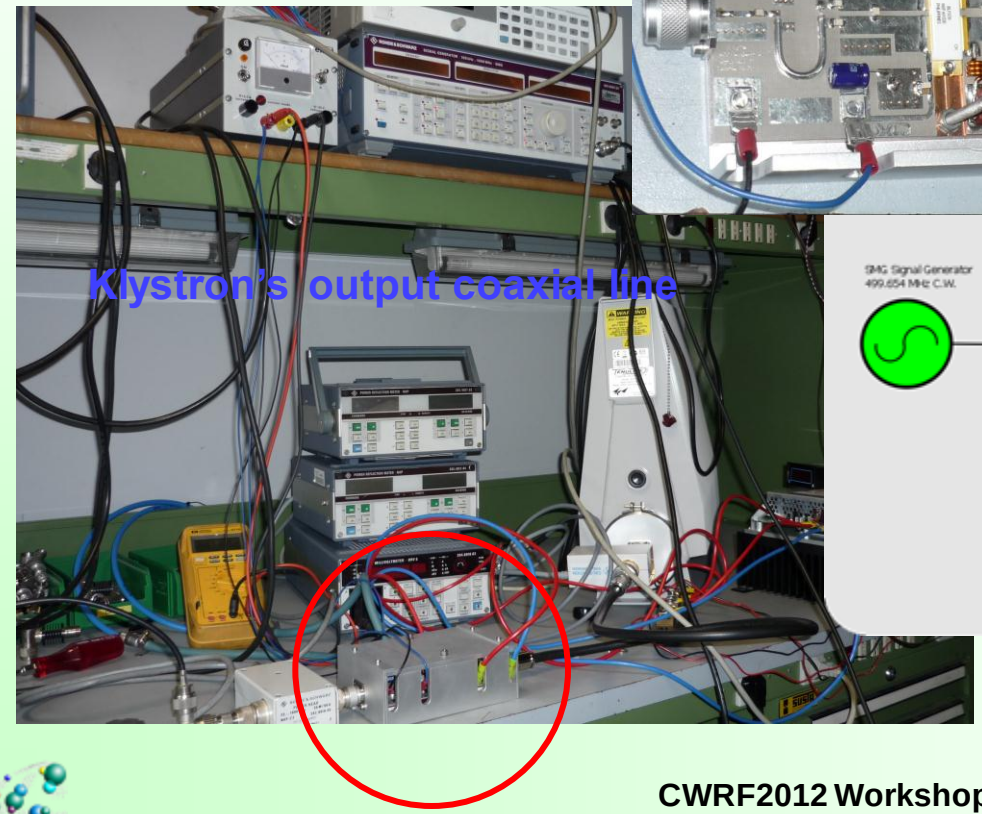
500 Watt/module
combining losses 5% for each stage
Maximum output power 61.7 kW
 # RF Solid state Modules ~ 160

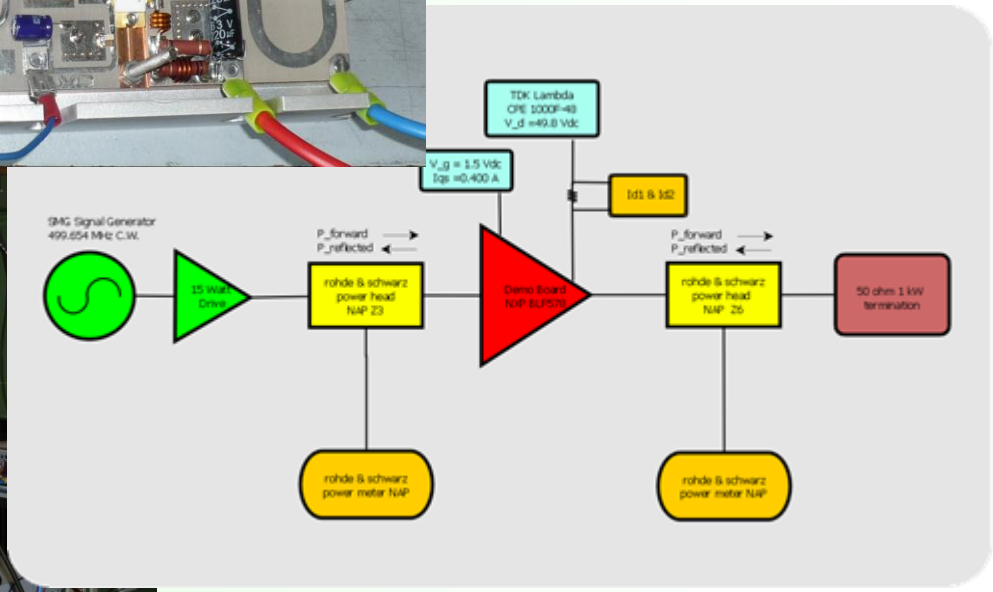


Solid State Investigation

To understand the features of the solid state amplifier, some tests have been carried out on the NXP BLF578 (HV LDMOS) Demo Board number NA-1331





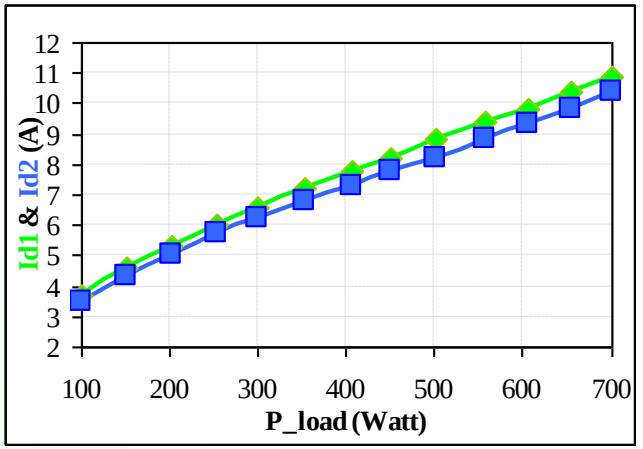


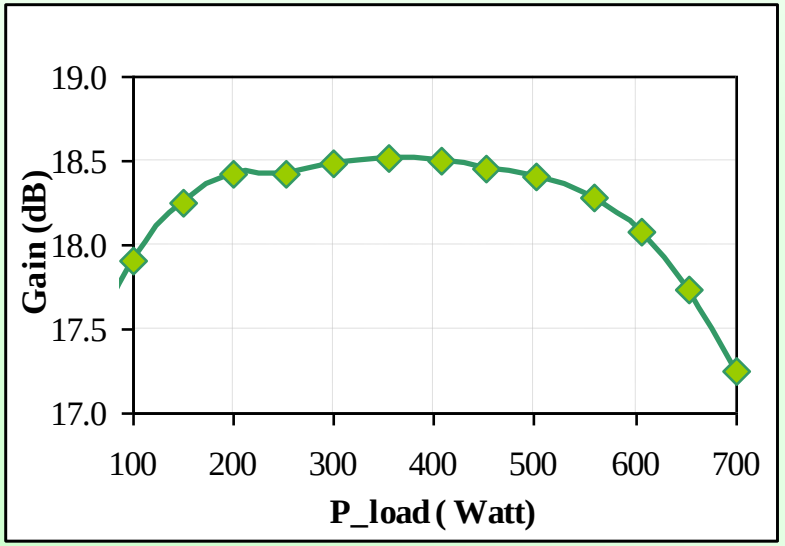
Measurement SET UP:
A shielded box fully encloses the board, cooled down by city water, flow 200 l/h

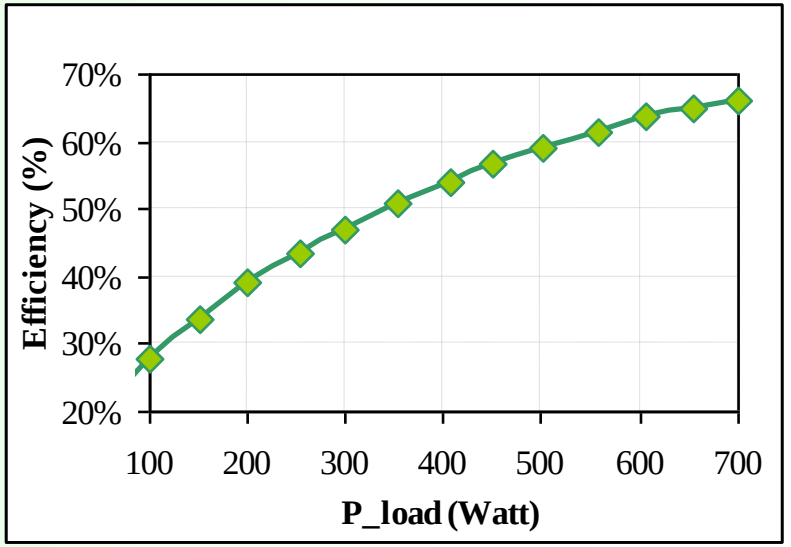
Solid State Investigation

BLF578 parameters:
VDD (drain supply voltage) 50 Vdc
V gg (gate bias voltage) 1.5 Vdc
I_dq (quiescent drain current) 0.400 A (total)

Freq.	P input (watt)		P load (watt)		Id 1	Id 2	Gain	Eff.
MHz	forward	reflected	forward	reflected	A	A	dB	%
499.654	13.2	0.8	702	0.15	10.9	10.4	17.2	66

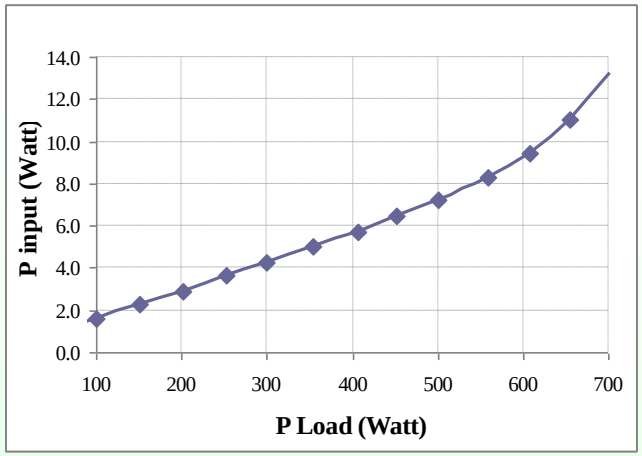




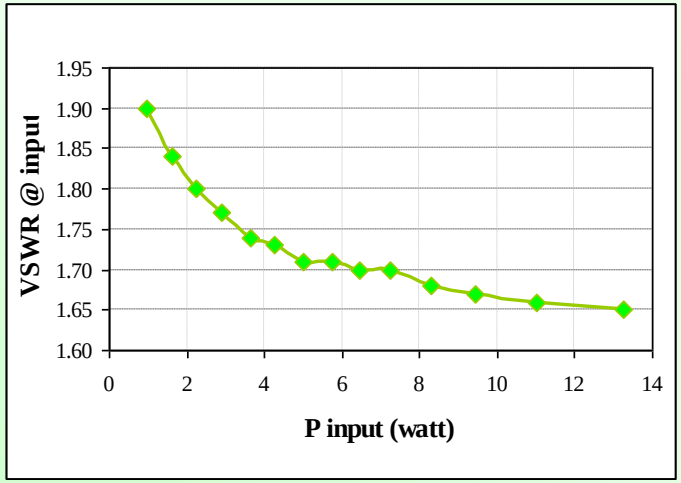


The measured data are well in agreement with those reported in NA-1331 measurements Application Measurement Report from NXP

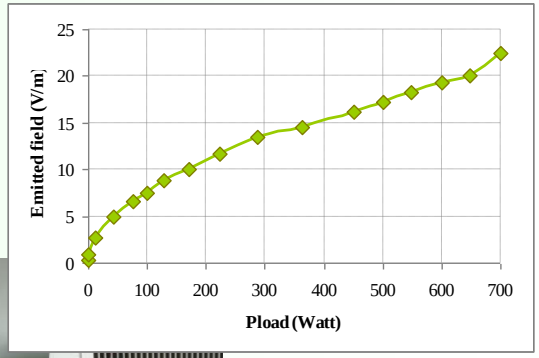
Solid State Investigation

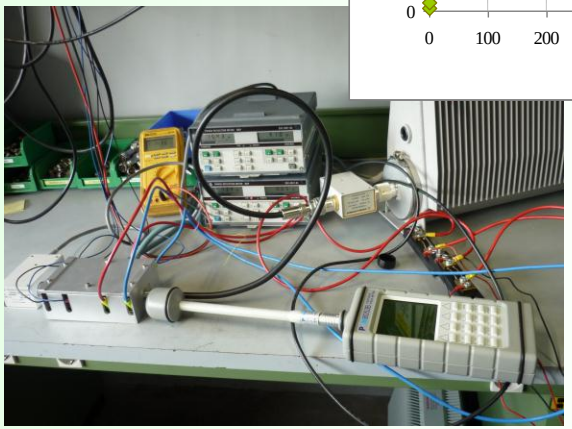


The gain is almost constant from 495MHz to 500 MHz at the output level of 650 Watt (±0.05 dB). Highest measured harmonic: the 2nd, always below 44 dB to the 1st from 490 MHz to 510 MHz
Max phase rotation = 3.6 deg @ 499.654 MHz. Max phase rotation = 3.0 deg in the useful gain



The input board mismatch decreases with the power rise.





Field emission measurement as a function of the output power. The board is shielded with a 3 mm depth aluminum box

Conclusion

- Klystron tube are still unmatched for reliability and performance but the transmitters are aging. The worth doing maintenance shall be carefully weighed up.
Moreover, the 500 Mhz 60 kW klystron will be custom made for us.
What could be a valid replacement for the klystrons and their transmitter ?

- The IOT transmitters had a labored start up and finally some reliability comes out.
Still no enough data about the tube's operating hours in CW applications.
The replacement of klystrons with IOT allows some standardization and brings the spare part' costs down.

- Hundreds watt @ 500 MHz CW using transistor technology is a fact. A challenging questions for some tens kW Solid State Amplifier are the power combining technique and their cost.
The replacement of klystrons with solid state amplifier takes Elettra to the state of the art technology and could mean a long term investment.

Thank you very much