Elettra Sincrotrone Trieste

20 Years of Operation of the Elettra RF System

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- ✓ Maintenance and Revamp
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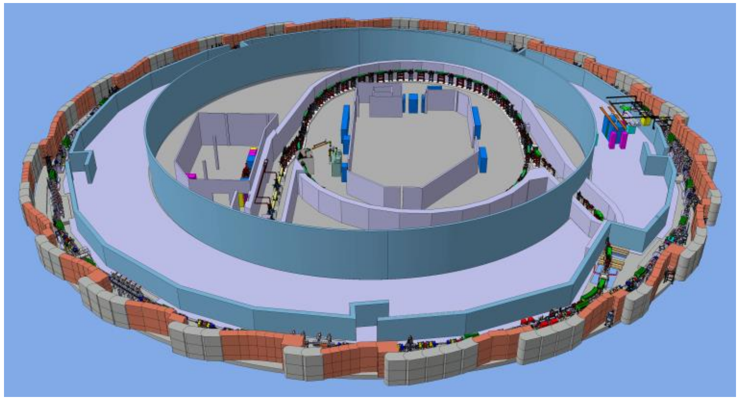
The Elettra facility

Elettra has 20 years of operation: first beam in October 1993!

- ✓ 3rd generation light source 2.0 - 2.4 GeV
- ✓ 5000 hours/year scheduled for the user
- ✓ goal uptime > 95%

Beam energy [GeV]		2	2.4
Storage ring circumference [m]	259.2		
Number of achromats	12		
Straight sections length [m]	6 (actual 4.8 for ID's)		
Beam revolution frequency [MHz]	1.157		
Number of circulating electron bunches	1 - 432		
Tunes: horizontal/vertical	14.3 / 8.2		
Natural emittance [nm-rad]		7	9.7
Maximum energy lost per turn with ID's [keV] (all)		315	618.5
Bending magnet field [T]		1.2	1.45
Geometrical emittance coupling %	±1%		
Injected current [mA]		320	150
Energy spread (rms) %		0.08	0.12
Lifetime [h] (natural)		8.5	32
Bunch length (1 σ) [mm]		5.4	7
RF frequency [MHz]	499.654		
Total accelerating voltage [MV]	1.68		
Number of nc singel cell cavities	4		
Synchronous Frequency [kHz] (no 3rd HC)		11	9.8
RF Acceptance		± 2 %	± 1 %



The RF System

Nominal Frequency 499.654 MHz

Storage ring

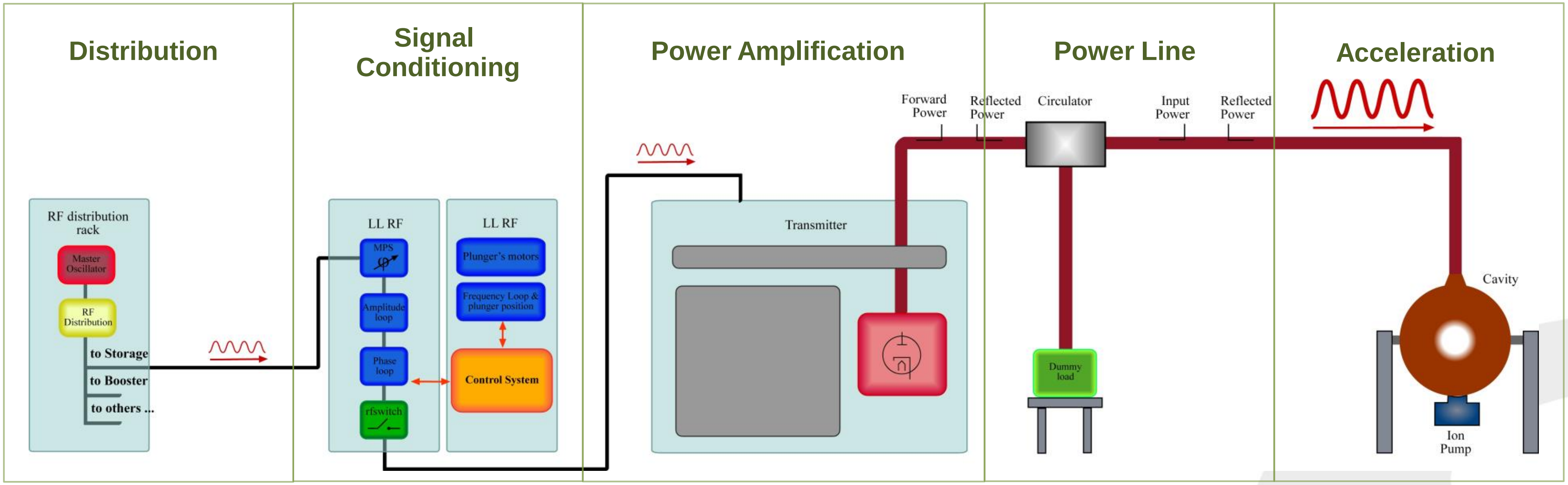
4 RF stations
NC single cell copper cavity
3x 60 kW klystron plants
1x150 kW 2*I.O.T.s plant

Power dissipation @ Vacc [kW]	120
Power to the beam @ 2.0 GeV [kW]	100
Total nominal Power [kW]	310

Booster

1 station
5 cells Petra type cavity
1x60 kW klystron plant

Power dissipation @ Vacc [kW]	14
Power to the beam @ 2.5 GeV [kW]	2
Total Nominal Power [kW]	55



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UP Time and MTBF

Twenty years of operation: strengths and weakness of the RF stations

RF station section	Operational Behaviour	Upgrade	Spare Part
Distribution & RF switch OFF safety system	never fail except one mulfunctioning (we missed the periodic check up!)	new signal generator	Several, never used
Signal conditioning: LLRF, frequency tuning, RF monitors and interlock	never fail except one DC power supply	driven by new and with more performences integrated circuit of the shelf availability	Several, never used. They'll become obsolete
Power Amplification	klystron-based: excellent functioning, but extraodinary maintenance is required because of their ageing!	RF power project!	It's strategic and mandatory have the proper spare parts set!
	I.O.T. trouble: high failure rate of some tubes. First signal of electronic ageing	Switched to different tube brand	
Power Line + Input Power Coupler	circulator arc 3 ÷ 4 per year, easy to reset	To do!	
	Severe troubles with HOMs energy, but the last fail was in 2005. Now the coax flange's soldering worn out is evident	Not a issue anymore with full energy injector	Spare part set is mandatory
Acceleration	Cavities never fail except one poor vacuum jaust after installation, need some e-beam conditioning	Three over four cavities replaced with improved heat exchange capability. The total accelerating voltage potentially increased to 40%	Always one spare cavity fully high RF power conditioned in the lab

UP Time and MTBF

Elettra Operations:

Injecting at 900 MeV and energy ramping to the final energy (2.0 and 2.4 GeV) till 2007;

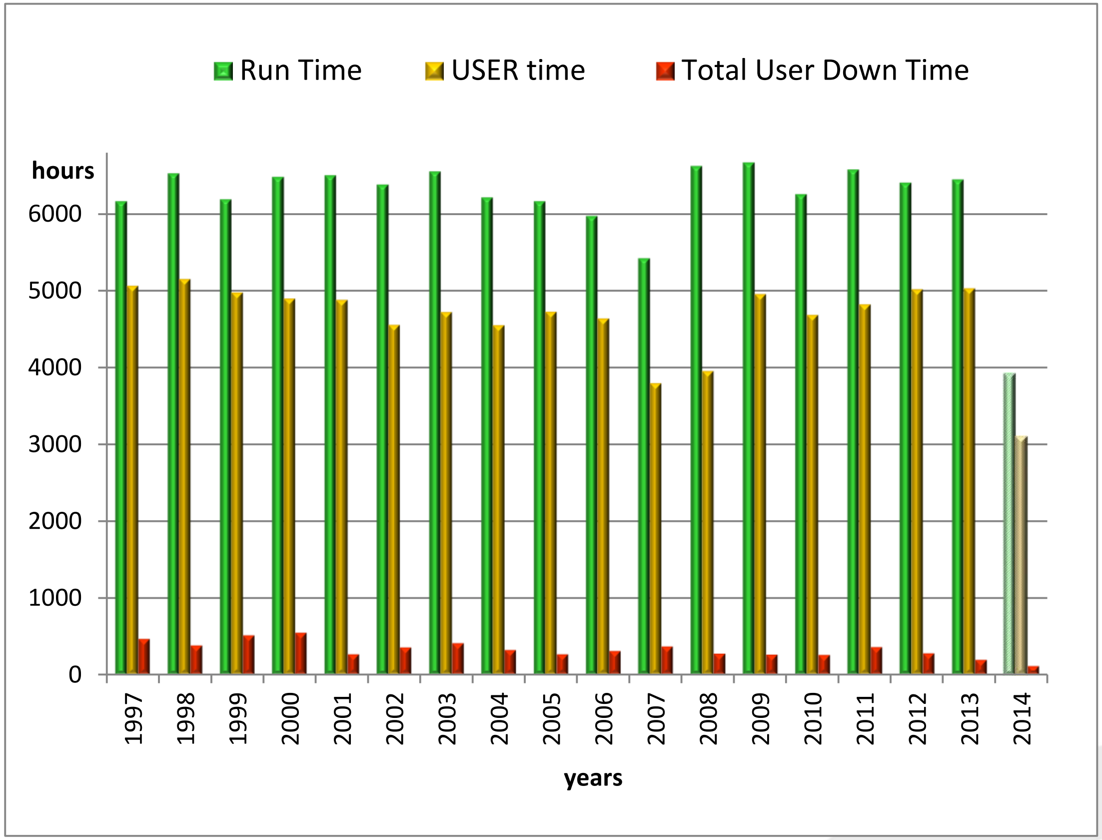
full energy injection from 2008

top up since 2010

The statistic:

- First years of operation with poor statistic data
- Down time includes power outages
- User time = scheduled–injection
- In 2007-2008 full energy injector construction & commissioning
- Year 2014 statistic up to August

Elettra has still good performances

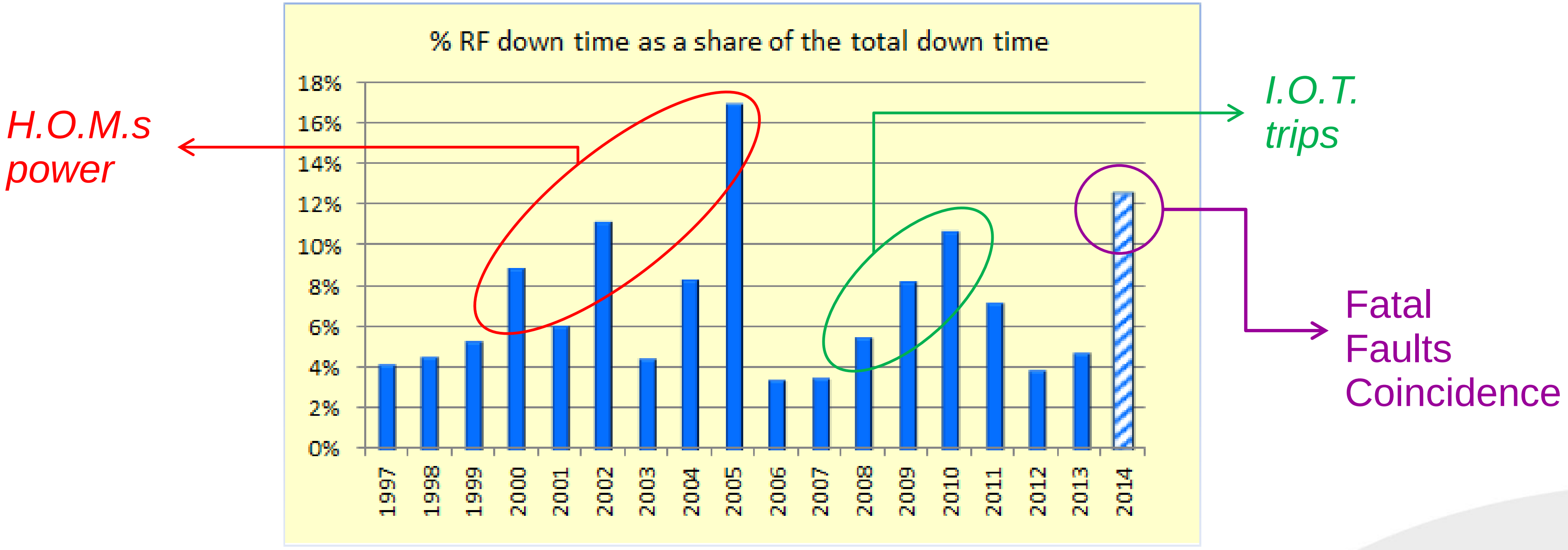


UP Time and MTBF

Up to 2007: Different parameters between injection and final energy for RF system. At the accumulation energy the cavities should provide the right longitudinal instability to storage and ramp the beam. Moreover the current decay mode slowly “moved” the cavity working point. That years the main RF failures where due to HOMS mode energy picked up by the input power coupler and trapped in the coaxial line (evanescent modes).

From 2008: Full energy injection and no further need to tune the RF parameters. One booster RF station added, but also, new RF power source : I.O.T.s with new problems.

In 2014: Coincidence of several faults. I.O.T.s trip and blower failure of the swapped transmitter.



4 % of the total down time is the standard behaviour of the Elettra RF system

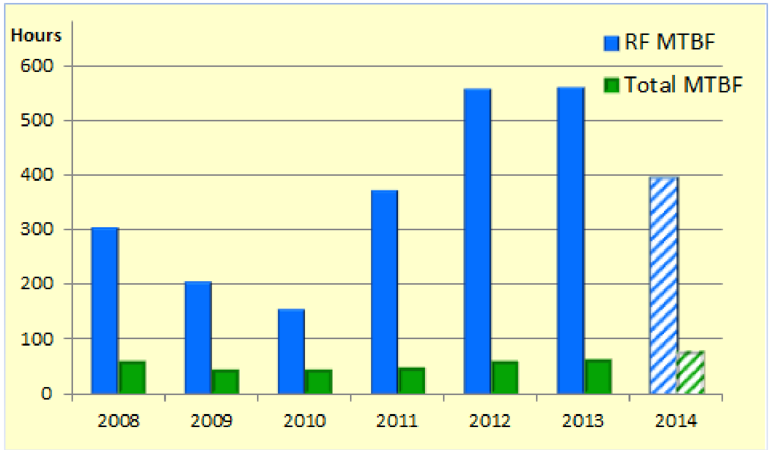
UP Time and MTBF

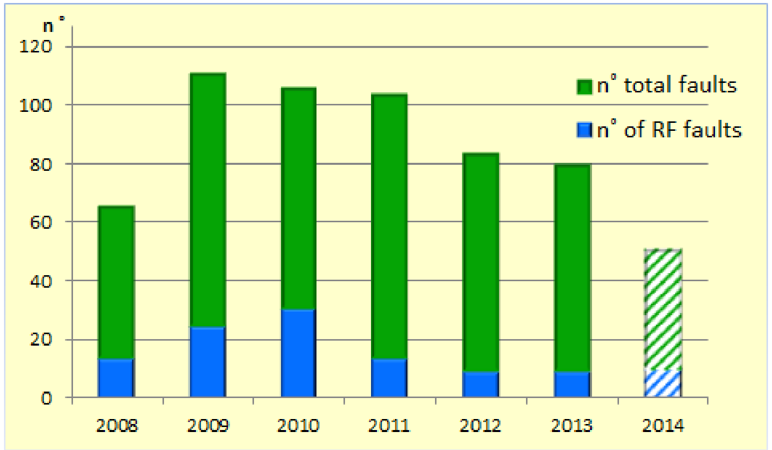
2014 RF MTBF is unsatisfactory

- 20 years of operation
- normal conducting system

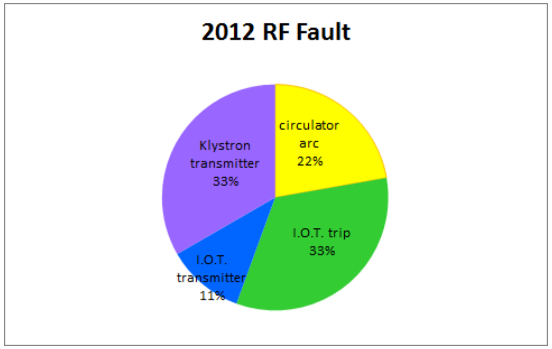
2014 RF faults are the 20% of the total faults

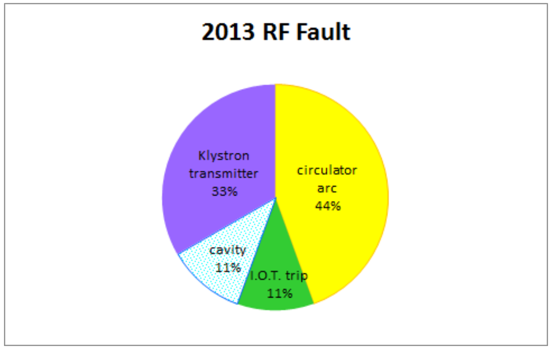
- total faults number decreases
- lowering RF fault's number proves impossible!

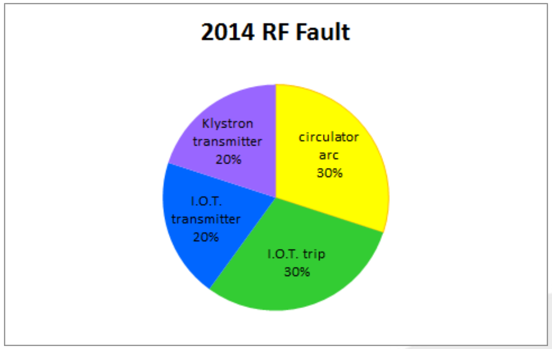




Faults type statistic







Klystron and I.O.T. transmitters faults have typically long recovery time (hardware to fix). Circulator arc and I.O.T. need just a reset (recovery time ≈ 40 minutes), but the last I.O.T. trip was not so easy to manage

UP Time and MTBF

I.O.T. Statistic

Transmitter	Tx-A		Tx-B	
Heater time*	40000		39700	
Tube	E2V D2130		E2V D2130	
serial number	302 - 1017		368 - 1208	
installation date	2010 June		2012 June	
Year	operating hours	trip	operating hours	trip
2010	3700	7	---	---
2011	10700	4	---	---
2012	15500	3	3250	3
2013	20650	0	9650	1
2014*	23150	0	12950	2

till August

150 kW twin I.O.T.s based transmitter.

Output power is the sum of 80 kW + 80 kW by means of a switchless WG hybrid combiner

In 2014 it has been decided to run one or the other of two transmitters (requested power ≈ 65 kW) and to keep the second one ready for swap.

The IOT 302-1017 has and excellent behavior, but the youngest one still have some trips. After its last trip it was not possible to switch on the HV and the swap to the second transmitter was mandatory.

It needed a fine tuning before it could withstand the HV and full RF output power.

Maintenance and Revamp

Constant and continuous maintenance is required to keep good performances. These work, together with the revamp program, shall be done during the Elettra shut down time, that is a limited time, 60 to 65 working days per year.

Maintenance's recipe :

- ✓ Standard periodic tests, to do at least once per year ➡ *klystron tuning, BW and dynamic range of the LLRF, system interlock, power calibration, etc…*
- ✓ Prestart-up system check up (**BORING** but highly effective to detect malfunctions, like worn out soldering etc…)
- ✓ Planned servicing to improve the RF performances ➡ *HOM plungers, cavity replacement - three among four up to now, new RF power transmitter, signal generator, etc …*
- ✓ Planned servicing to overcome the production discontinuity and component obsolescence ➡ RF driver, *frequency tuning loop, etc …*
- ✓ Dedicated servicing triggered by the failure … **Be ready to fix any device !**

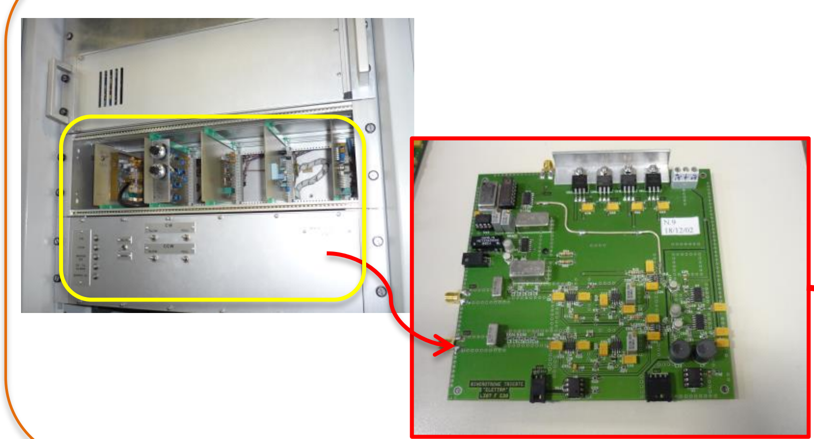
Maintenance and Revamp

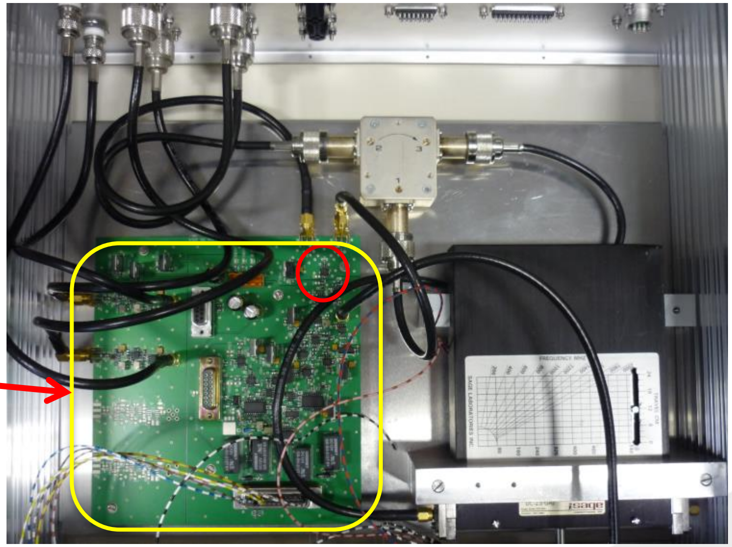
Over 20 years **the LLRF never failed** except for one DC power supply.

- ✓ LLRF spare part units are ready for swap
- ✓ Last year the DLLRF prototype has been tested and validated (amplitude and phase regulation). The final version of the DLLRF shall come ASAP. No revamp of the installed devices is foreseen.
- ✓ For the frequency tuning loop the availability of electronic devices with enhanced performances & the in-house know-how allows you to revamp the system more effectively!

New frequency tuning Loop

Two 3U units composed by several boards replaced by <u>new single board</u>, the AD8302 IC performing the same RF phase detection of the 1990s single board.





Maintenance and Revamp

Monitoring of the RF signal in the control room, new idea to revamp it in collaboration with **S. Cleva** (Elettra control group) using off-the-shelf cheap embedded system.

Goal: power measurement with good accuracy, easy to remote control, further power monitoring independent from any future DLLRF system. Once calibrated, it could become a cheap power meter bench tool.

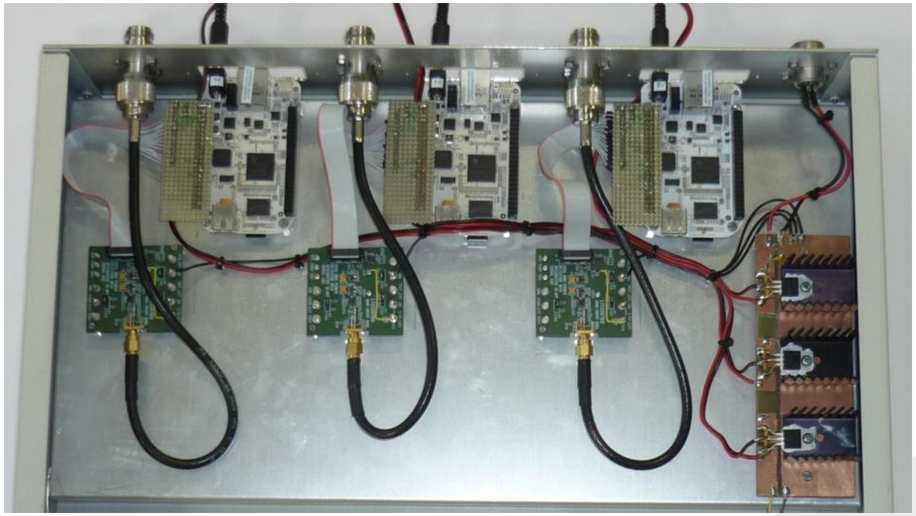
The original lay-out for the RF signal monitoring is based on HP 2800 family Schottky diodes, which is good but the rectified signal is filtered, amplified, calibrated, analog to digital converted and integrated in the control system,…

LTC 5587 IC rms power detector

with 12-Bit ADC - SPI compatible

demo board + BeagleBone board

Three channels 500 MHz power meter unit is currently installed to test its measurement accuracy and resolution



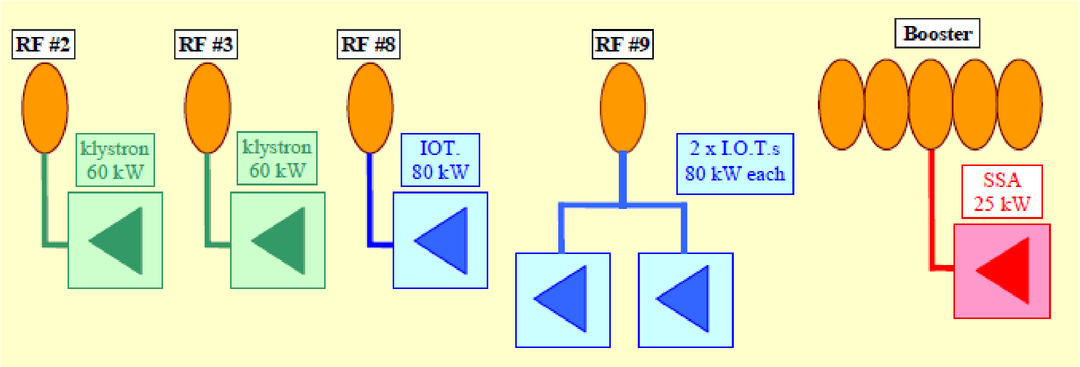
RF Power Project

The RF power plants at Elettra:

RF Station	power source	brand - model	s/n	nominal power	tube hours	heater hours
Booster	klystron	E2V K3672BCD	1083-0351	60 kW	33,700	107,600
RF # 2	klystron	E2V K3672BCD	1184-0823	60 kW	28,800	120,800
RF # 3	klystron	Philips YK1256	14105.265	60 kW	16,500	122,400
RF # 8	klystron	E2V K3672BCD	1184-0823	60 kW	28,600	121,900
RF # 9	I.O.T.s	E2V D2130	302-1017	80 kW	23,150	40,000
	I.O.T.s	E2V D2130	368-1208	80 kW	12,950	39,700

Project to start the RF transmitters revamp approved in April 2013:

- new IOT 80 kW for the SR
- new SSA 25 kW for the Booster



Goal:

- ✓ Some extra RF power in the SR
- ✓ Minimize the installation impact
- ✓ Energy saving for the Booster
- ✓ Gain experience running a medium-size SSA

The project has been voluntary delayed to acknowledge the Elettra 2 project requirement

Elettra 2

Courtesy of **E. Karantzoulis***

The future for Elettra?

A new machine following the Ultimate Storage Rings developments

Established items:

- Same building, same position Circumference ~259.2 m
- Energy 2.0 GeV
- Brilliance increase at 1 keV by more than 1 order of magnitude
- Spot size less than 40 um

and

- Maintain the existing ID straight sections
- Maintain the existing bending magnet beam lines
- Multi-bunch current 400 mA, maintain the filling patterns as before (hybrid, single bunch etc.)
- free space not less than that of Elettra, LS: 6 m (4.5 for Ids) + (SS: 1.1 m , SLS: 1.46) total 8.56 m
- Use off axis injection

** MOPRO075, IPAC2014*

Elettra 2

Courtesy of **E. Karantzoulis**

New optic design with a 6-bend achromat

Elettra 2 will have:

- larger magnets number with higher field strength
- larger power supply number
- Smaller diameter vacuum chamber (halved)
- Upgraded injection system
- Dedicated wiggler for the dipole beam line (user request)

Parameter	Units	Current Elettra	Elettra 2.0
Circumference	m	259.2	259.8
Energy	GeV	2 - 2.4	2
Horizontal emittance	pmrad	7000	250
Vertical emittance	pmrad	70 (1% coupl)	2.5 (250 round beam)
Beam size @ ID (σx, σy)	μm	245 , 14 (1% coupl)	43,3 (31,22 round beam)
Beam size at short ID	μm	350 , 22 (1% coupl)	45,3 (39,21 round beam)
Beam size @ Bend	μm	150, 28 (1% coupl)	17,7 (12,48 round beam)
Bunch length	ps	25 (100 with 3HC)	12.5 (70-100 with 3HC)
Energy spread	ΔE/E %	0.08	0.07
Bending angle	degree	15	5.5 and 4

The RF system:

✓ Relaxed requirement for the RF power (ΔE/turn =180 keV)

✓ Possibility to add one more 3rd cavity

Open question for the RF system:

Moving to lower frequency (100 MHz – 87 bucket)?

Conclusion

- ✓ Growing reliability of the Elettra facility, the RF system does not follow the same trend, even if it has still a good operating fact. Some improvement shall be done…
- ✓ Several parts of the RF station have been already revamped (next year the last new cavity). The priority is the revamp of the RF power source is mandatory. The operational experience of the other facility will greatly help.
- ✓ Several collaboration/contract in progress:
  - *four Elettra cavities, fully equipped, will be realized and commissioned for the SESAME facility (Jordan – Middle East) within 2 years.*
  - *one Elettra cavity, fully equipped, will be realized and commissioned for the INDUS II facility (Indore- India) within 2 years.*
- ✓ The Elettra 2 project is starting. The first step is the conceptual design.

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Thank you!

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