Elettra Sincrotrone Trieste

Towards Elettra 2.0

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- ✓ Klystron-based and IOT-based transmitter
- ✓ MTBF and RF failure statistic
- ✓ RF power revamp project
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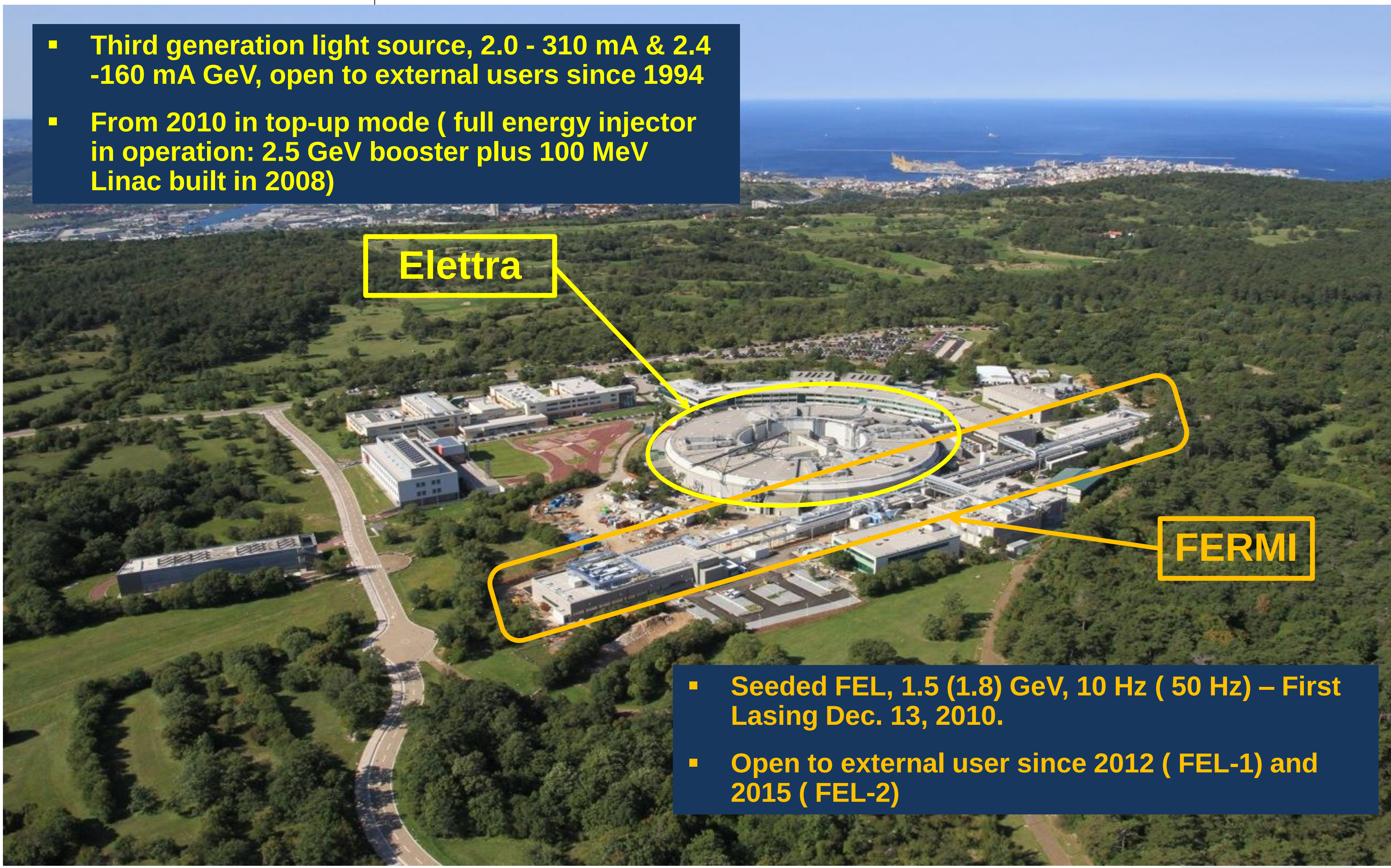
Elettra RF system

- **Third generation light source, 2.0 - 310 mA & 2.4 -160 mA GeV, open to external users since 1994**
- **From 2010 in top-up mode (full energy injector in operation: 2.5 GeV booster plus 100 MeV Linac built in 2008)**



- **Seeded FEL, 1.5 (1.8) GeV, 10 Hz (50 Hz) – First Lasing Dec. 13, 2010.**
- **Open to external user since 2012 (FEL-1) and 2015 (FEL-2)**

Elettra RF System

Nominal Frequency 499.654 MHz

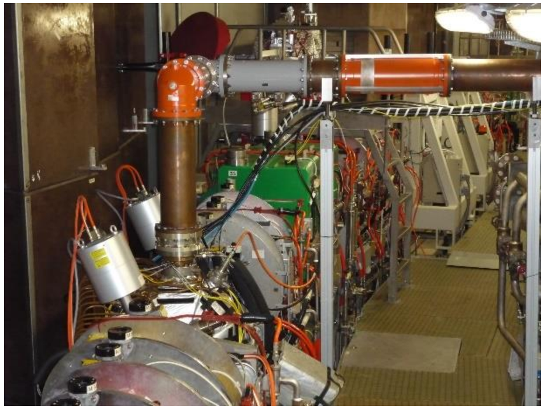
Storage ring ΔE/turn ≈ 300 keV @ 2.0 GeV

Storage ring

4 RF stations

NC single cell copper cavity
3 x 60 kW klystron-based plants
1x150 kW with 2 x I.O.T.s based plant

Power dissipation @ Vacc [kW]	120
Power to the beam @ 2.0 GeV [kW]	100
Max Available Power [kW]	310



Booster

1 station

5 cells Petra type cavity
1x60 kW klystron plant

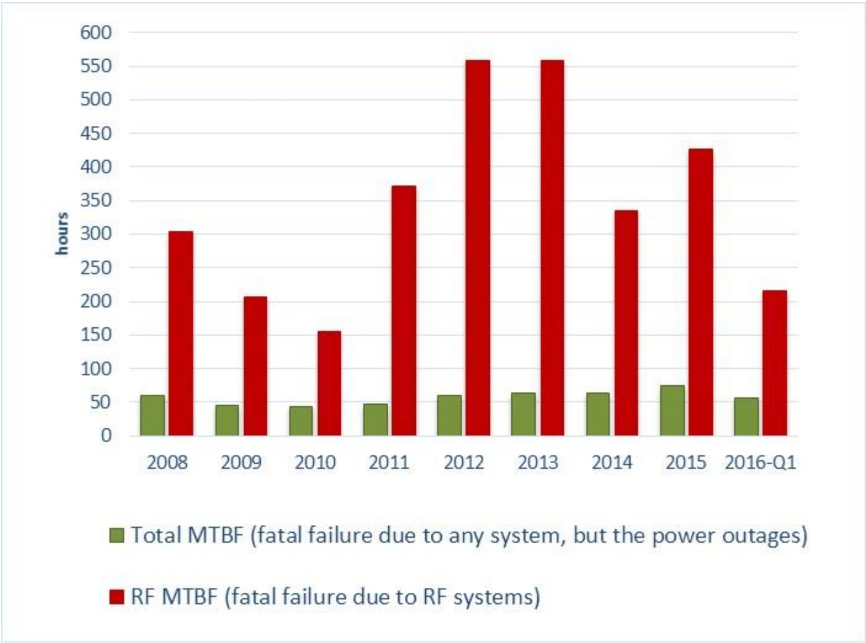
Power dissipation @ Vacc [kW]	14
Power to the beam @ 2.5 GeV [kW]	1
Max Available Power [kW]	55

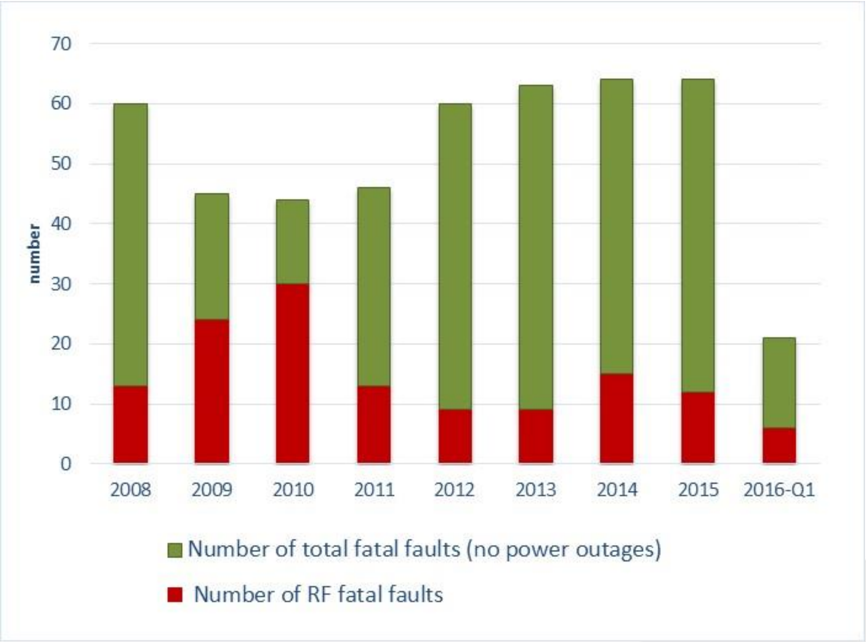
MTBF and RF Failure Statistic

- ✓ **M**ean **T**ime **B**etween **F**ailure during the scheduled user time. Failure means beam lost or its intensity drops below 50%).
- ✓ Top Up downtime not yet an issue.
- ✓ *2016 data first quarter*

Average RF MTBF ≈ **364 h,** but Q1 2016 MTBF = **217 h**

Average # of RF failure ≈ **16/year,** but Q1 2016 # RF failure = **6**



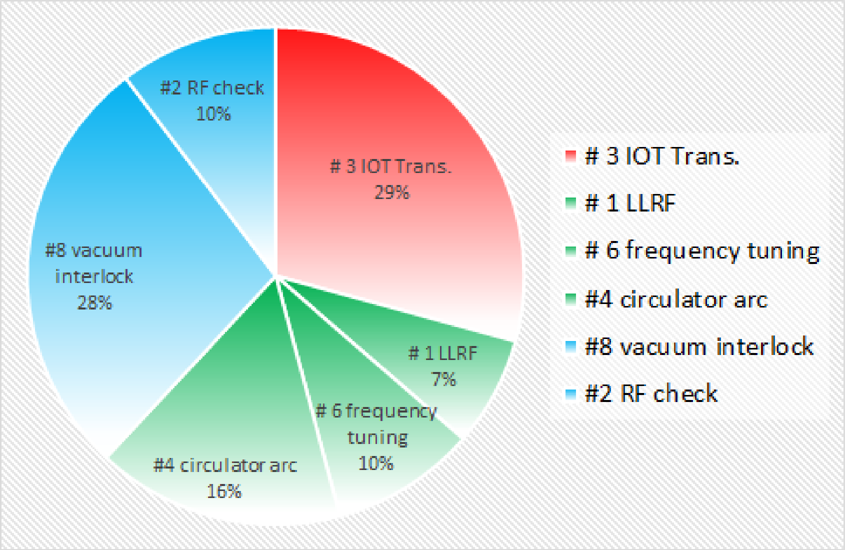


MTBF and RF Failure Statistic

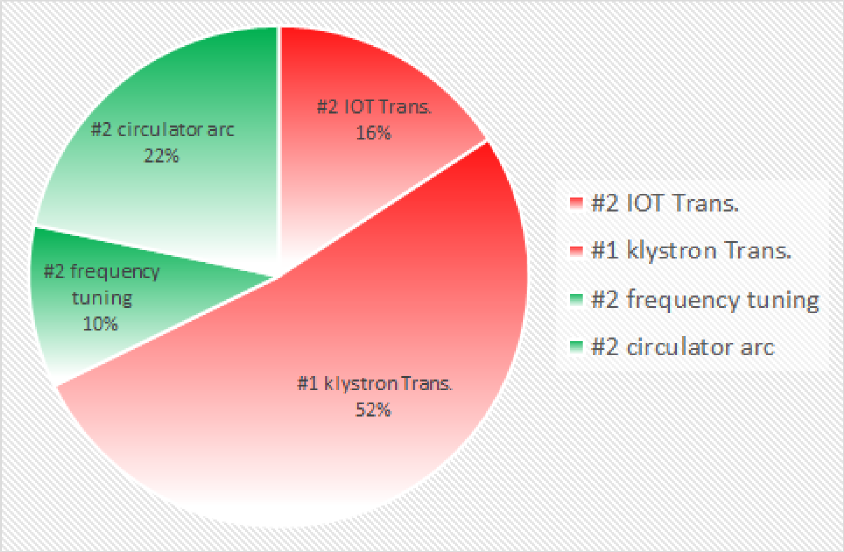
RF fault classification	Examples
Power station	IOT trip, solid state amplifier drive, transmitter's cooling equiment
Cavity + beam	cavity vacuum interlock, RF parameters's check
LLRF, diagnostic	frequency tuning, amplitude loop, circulator arc

Individual RF fault lasting time, % with respect to the total RF downtime

2015



Q1 - 2016



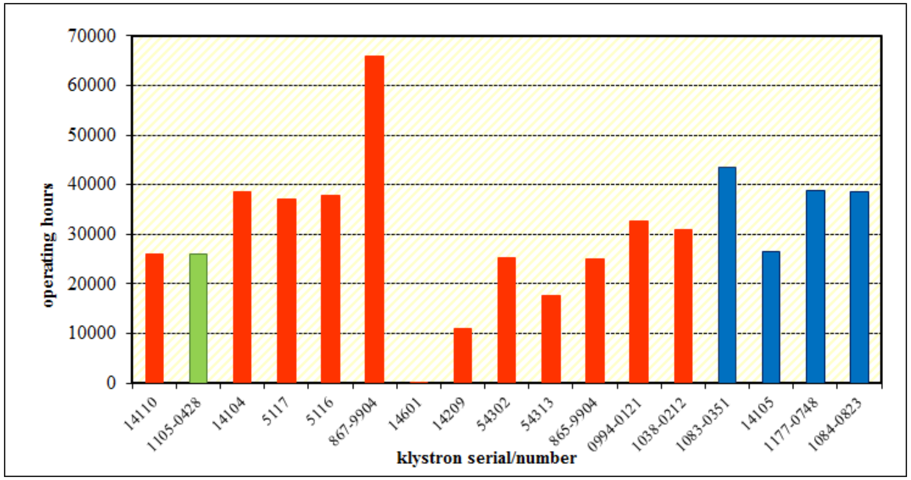
Klystron's Transmitter

RF station (60 kW cw plant)	Transmitter installation	heater' hours Q1- 2016	klystron s/n	klystron Installation	klystron hours
booster (*)	2007 (1993)	117442	1083 -0351	2007	43528
RF #2	1993	130842	1177-0748	2009	38852
RF #8	1993	131945	1184-0823	2010	38666
RF #3 (**)	1992	132435	14105	2013 **(1991)**	26550
RF lab (**)	1991	8590	1105-0428	2013 (2009)	26000

* Trasmitter installed in section RF#9 in 1993 and afterword moved to Booster station

** In 2013 the RF lab and RF#3 klystrons were swapped due to an "unwanted shower" taken by the RF #3 trasmitter

60 kW E2V (ex. Philips) klystron's statistic and fact



- discontinued in 2012
- Qty used at Elettra since 1991: **17** pcs
- de-installed average hours: **29000** hours
- Operating average hours: **34700** hours
- Spare : **3** pcs
- **More than 20 years of operation with NO FAILURE until the operation's end!**

I.O.T. Transmitter

- 80 kW + 80 kW I.O.T.s based transmitters in operation on the storage ring in 2008
- Dual use: single transmitter operation or sum of both outputs

- **I.O.T. performance: from 1 to 3 trip/year – two tubes, 6000 hours/year of operation**

RF station (Tx-A + Tx-B)	Transmitter installation	heater' hours Q1- 2016	I.O.T. s/n	I.O.T.s Installation	I.O.T.s hours
Tx-A	2006	50230	302 - 1017	2010	33400
Tx-B	2006	49800	368 - 1208	2012	23100

- Minor servicing problems for the whole transmitter, mainly for the cooling system
- Air cooled RF pre-drivers need a “warm up” time before performing the proper phase and gain adjustment

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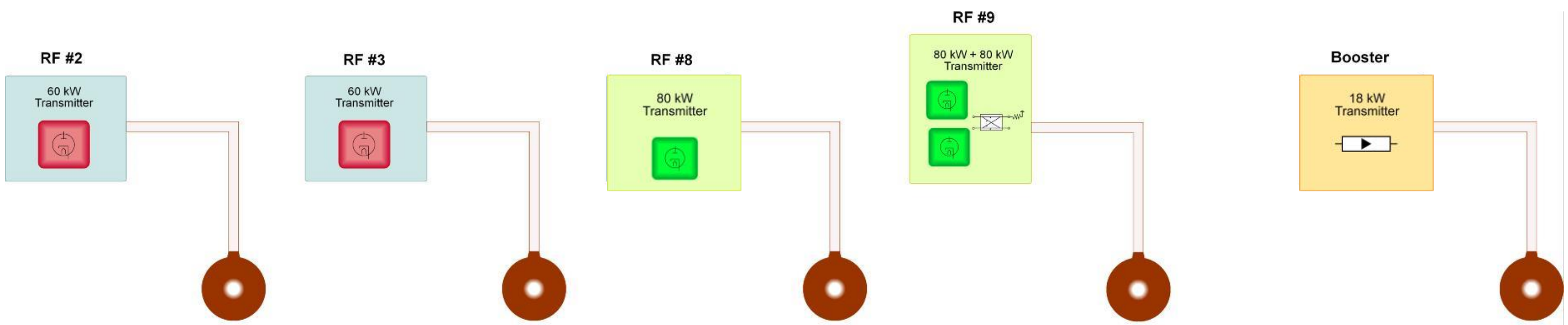
RF Power Revamp

RF power transmitter ageing and klystron discontinuity pushes for a revamp project started in 2013.

- 1st step new single IOT transmitter for RF#8
- 2nd step 18 kW solid state for the Booster



New I.O.T.s transmitter in RF#8 was “frozen” due to financial problem of the Supplier

Tendering procedure of the18 kW SSA for the Booster is at the final stage

Solid State Specification

Writing the specs of the SSA make use of every opportunity given by the modularity of the solid state with reference to the:

- ✓ possibility to fix and servicing RF pallet and board components (entirely different approach from the “tube transmitter” where the tube itself can not be fixed …)
- ✓ graceful degradation and RF power redundancy (minimum output power with one or some component in fault)
- ✓ hot swap operation (quick fittings…)
- ✓ test subcomponents in the lab (individually powered modules…)

Moreover

- ✓ Given the Booster power size take benefit from the broadcast technology, well commissioned systems and solutions
- ✓ Test the technology in view of the complete revamp of the RF power for the storage ring (efficiency check in cw, effective balance of gain and phase of the modules vs time and thermal drift, reliability)

On top of these considerations the Elettra 2.0 project appears…

Elettra 2.0 Project

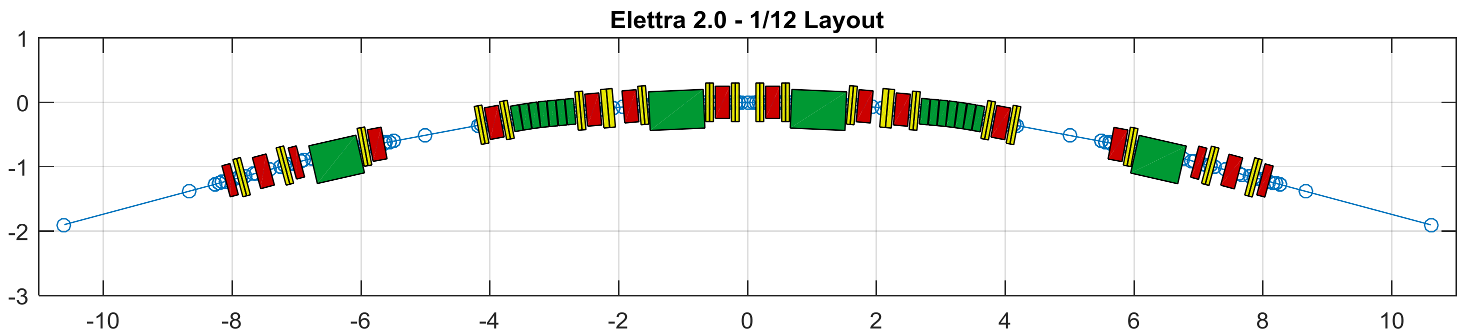
Project's fundamental points:

- ✓ Same circumference (~ 260 m), same position of the beam lines
- ✓ Energy 2 GeV
- ✓ Keep the existing bending magnet beam line and ID straight section
- ✓ Off axis injection
- ✓ Straight section equivalent to the existing (long section~ 4.5 m)

Project commitments:

- ✓ Brilliance increase at 1 keV of more than 1 order of magnitude
- ✓ H-spot size < 60 um
- ✓ Minimum downtime for installation and commissioning

New magnet lattice design 6-bend achromat → **H- emittance < 0.3 nm rad**



Courtesy
E. Karantzoulis

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RF system for Elettra 2.0

Lowering RF frequency

PROS:

same RF acceptance with less voltage (and thus RF power) and longer bunch lengths (less current density and reduced instabilities)

CONS:

Injection scheme more complex (full energy injector with 500 Mhz modulation)

Cost increases: new accelerating sections and power plants

Superconducting Technology

PROS:

larger stored current without beam instability issue (dedicated HOM damping). Cryogenic temperature allows good accelerating gradient with “relatively” low RF power.

CONS:

RF power saving balanced by the cryogenic plant consumption and servicing costs.

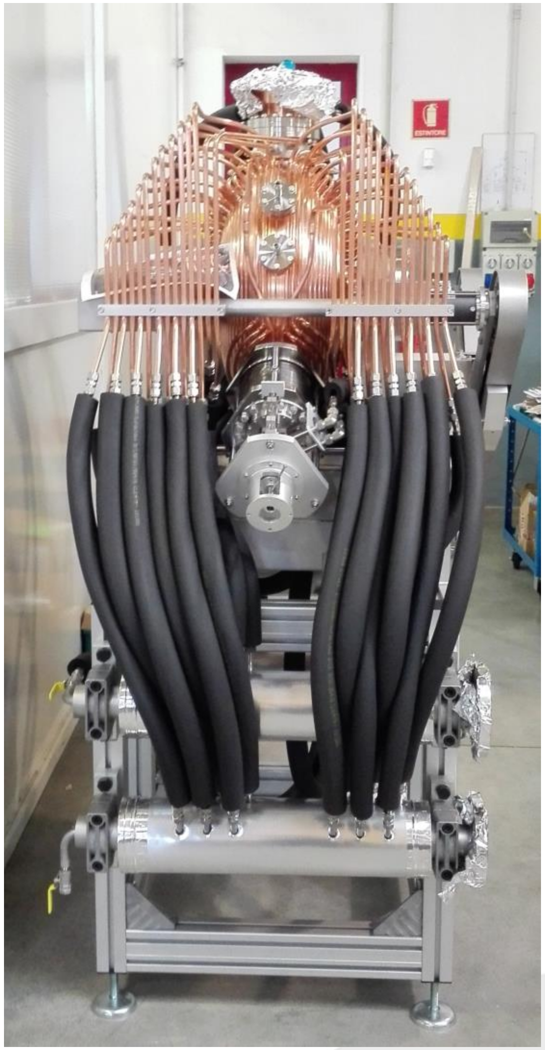
Reliability (good skill and know how required).

Cost increases.

Final CHOICE for Elettra 2.0: **SAME FREQUENCY , SAME CAVITIES**

RF parameters for Elettra 2.0

Energy [GeV]	2.0
Current [mA]	400
Momentum compaction	$3.0\ 10^{-4}$
Harmonic number	433
Energy losses [keV]	500
Beam Power [kW]	200
Accelerating voltage [MV]	2.2 MV
Number of cavities	4
RF acceptance	± 6%
Synchrotron frequency [kHz]	5.4
Synchrotron Tune Q_s	$4.71\ 10^{-3}$
Cavity voltage [kV]	800
Cavity R_{shunt} [MΩ]	3.3
Cavity losses (Cu) [kW]	50
Total cavity power [kW]	**100**



Conclusion

- ✓ Present RF stations are performing really well. The installed klystron tubes hours of operation are amazing! <u>They are still a valid RF power source but for the efficiency</u>.

- ✓ Within June 12017 a Solid State transmitter will operate in the booster. For such "small" power size it is more appropriate to split the cost in "€/watt + system integration".

- ✓ New SS transmitter will be a test bench for the future choice (not for the technology, but for the topology).

- ✓ The revamp of the present Elettra RF power will "anticipate" the requirement for the Elettra 2.0 project. Even if not strictly necessary, the 100 kW power size – or a "integer part of" of this size - will likely be the next candidate for next RF power system.

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Thank you!

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