Performances of the Elettra Booster and Storage Ring RF Systems

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- 3 types of 500 MHz RF systems in Elettra
  - Booster:
    - 5-cells cavity, 60 kW (klystron).
  - SR plants in sections 2,3,8:
    - Elettra type cavity, 60 kW (klystron).
  - SR plant in section 9:
    - Elettra type cavity, 150 kW (2 x 80 kW IOTs).

Booster RF System Design Specifications		
	Nominal	Low emittance
Beam energy	2.5 GeV	2.5 GeV
Beam current	4 mA	4 mA
RF frequency	499.654 MHz	499.654 MHz
Rep. frequency	3 Hz	3 Hz
RF voltage	840 kV	730 kV
Cavity power	25.2 kW	19.1 kW
Beam power	1.9 kW	1.9 kW
Total power	27.1 kW	21.0 kW

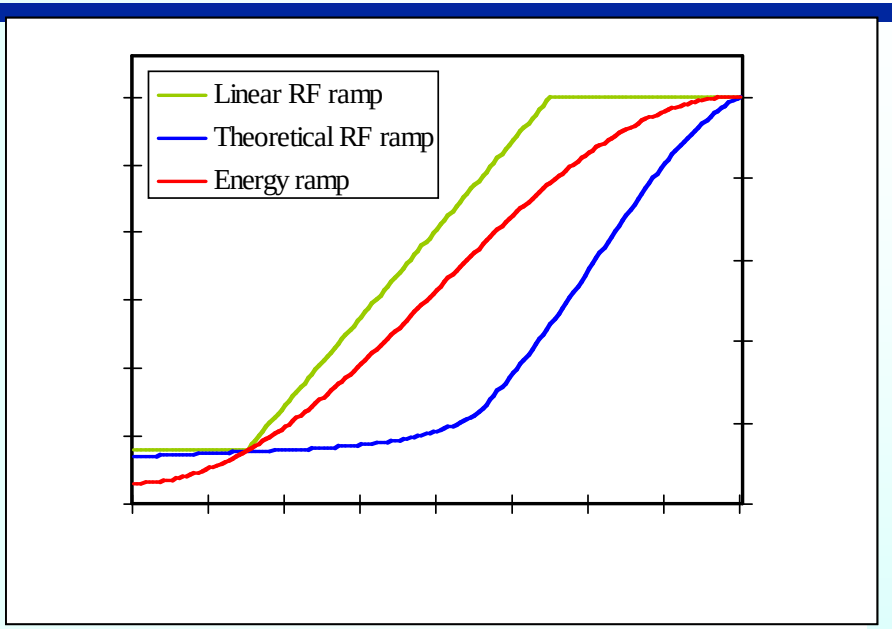
- **CAVITY**
- **5 cells cavity.**
- **Tested at 54 KW.**
- **Multipacting strong up to 8 kW.**
- **Implemented an automatic conditioning procedure via control system.**

- **BOOSTER MILESTONES:**
  - **Installation from April 2007.**
  - **Commissioning from September 2007.**
  - **First injection for users: March 3rd, 2008 as planned.**

- POWER PLANT
- 60 kW 500 MHz.
- Klystron based power amplifier (K3672BCD from E2V).
- All components from SR upgrade.

- LLRF
- Three loops:
  - Frequency and field flatness.
  - Amplitude.
  - Phase.
- Analog system.
- System can work with almost any duty cycle up to cw and different waveforms.

- **RF VOLTAGE WAVEFORM**
- **Sinusoidal energy ramp (160 ms).**
- **Capture: 40 kV (33.7 kV theoretical).**
- **Extraction 2 GeV: 300 kV (1 sec τ_q).**
- **A linear curve has been used (delayed with respect to the energy ramp).**

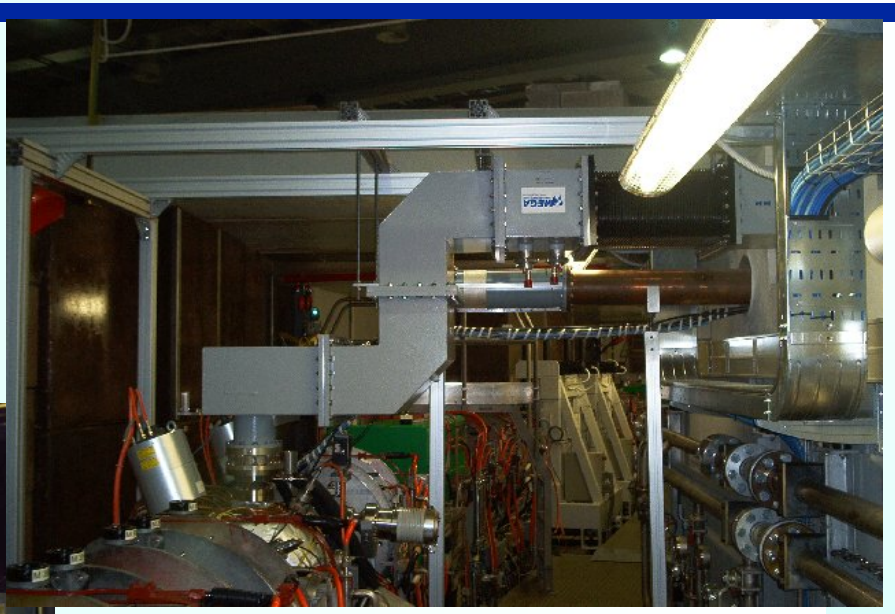


- **PERFORMANCES:**
  - **4000 hours of operation.**
  - **System has been reliable and easy to use for the operators.**
  - **Faults:**
    - **Spurious circulator arc trips during the first commissioning weeks, related to radiation (improved the shielding).**
    - **Random reflected power trips related to a malfunctioning of the trigger signal to the frequency loop (trigger provided by the control system).**
  - **In view of top-up operation, the system has been kept in ramped operation on a 24 hours/day basis for two months: no problem encountered.**

- 60 kW PLANTS (SECTIONS 2,3,8):
  - Original plants installed in 1993.
  - Operating hours around 85000.
  - Elettra type cavities.
  - Klystron based amplifier (K3672BCD from E2V).

- PERFORMANCES (last two years)
- The system is very reliable.
- AMPLIFIERS
  - The last klystron replacement was in October 2004 (oldest klystron now nearly 60000 hours).
  - Klystron emission quite stable. Periodically retuned.
  - Body current trips on plant 3 and 8 caused by overdrive when beam was killed, solved by retuning the tube at the following shutdown.
- CIRCULATORS AND COAXIAL LINES
  - Few circulator arc trips (two in the last 2 years).
  - We tolerate them.
- CAVITIES
  - No faults, except one vacuum trip related to HOMs excitation during tests.
- LLRF
  - No faults.

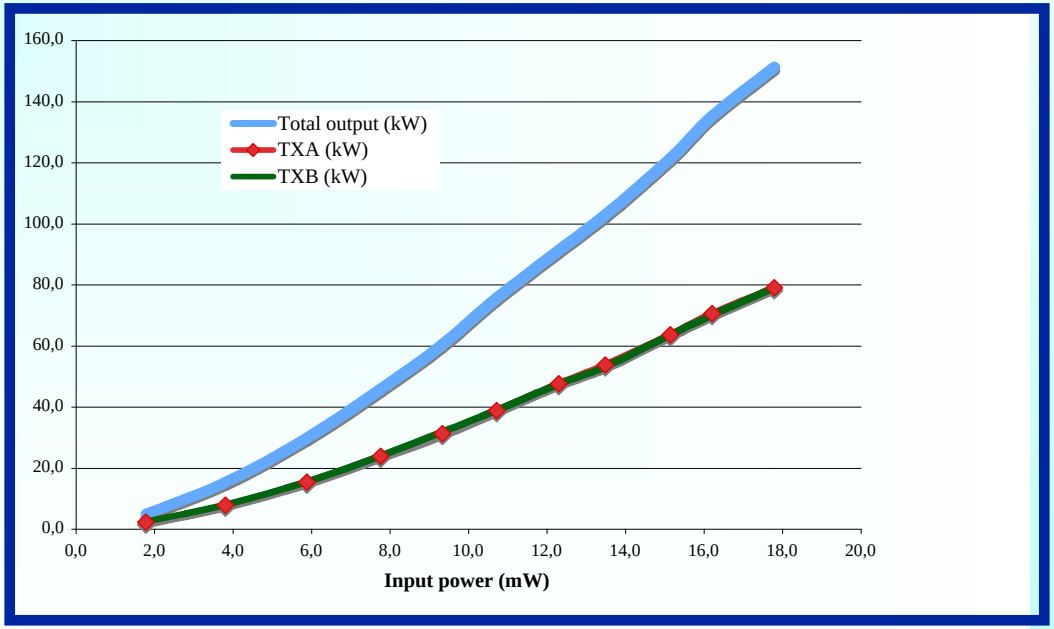
- **150 kW PLANT (SECTION 9):**
  - **Installed in 2006.**
  - **Elettra type cavity (upgraded type).**
  - **150 kW amplifier.**



- The 150 kW power amplifier is made combining two 80 kW transmitters.
- It has been acquired as a turn-key system from industry (Electrosys).
- The final stage of each transmitter is a 80 kW IOT (TH 793 from THALES).
- HV POWER SUPPLY (for each tube):
  - Switched mode power supply
  - 37 kV, 3.8 A.
- Power supplies specified with redundancy.
- Each transmitter is completely independent to allow standalone operation.
- The transmitters are combined by means of a switchless combiner.

- **Installation took place during Summer 2006**
- **Operation on the machine started in Jan.07, after 24 hours/day -2000 hours test at levels from 100 to 150 kW.**
- **Power was limited to 60 kW for 2007 (cavity conditioning to be completed).**

Output power	150 kW
Frequency	499.654 MHz
Bandwidth (±0.5 dB)	> ±2 MHz
Total gain	69.3 dB
Gain IOT A	24.0 dB
Gain IOT B	24.1 dB
I.L. combining system	<0.1 dB
Total phase variation	11 degrees



- **EXPERIENCE WITH THE NEW PLANT (NOW AROUND 11000 HOURS OF OPERATION).**
- **Operation of the new system has been very reliable (no faults) till middle September 2007 (i.e. roughly 5000 hours of machine operation).**
- **From September we started having problems first in TXA and then also in TXB.**
- **Generally they are random trips and the system can be restarted immediately.**
- **If the rate of trips increase, we are required to switch the transmitter to the combiner load and power the cavity with the other transmitter only.**
- **Since we do not need all the power for the beam yet, we can operate also with one tube.**
- **Flexibility of the layout has greatly helped in minimising downtime.**

- **WHAT WE HAVE LEARNED UP TO NOW AND WHAT WE HAVEN' T YET.**

- **Trips are detected as a fast increase in beam current as if there were a discharge (HV inhibit) or as an overload in the HVPS.**
- **They happen only when RF drive is provided.**
- **HV inhibit faults do not seem related to the power level or to particular operating conditions.**
- **Few of the faults could be related to machine beam dumps (some of the ones related to overload in HVPS).**
- **We tested the HV capability and we did not find problems with the input cavity. Anyway, still under discussion if the problem starts in the tube or in the cavity.**
- **In case of high failure rate, this could be generally recovered following a high voltage reconditioning or grid cleaning procedure.**
- **However the final effect could be an arc on the ceramic with possible damage of the tube. Most probable in the lower part of the output window.**

- **NEXT STEPS.**
- **We have decided to change the tube and circuit assembly type.**
- **We will install one TH 793-1 in circuit assembly TH 18793 LS, i.e. the ones developed for ALBA.**
- **The new tube will be installed in the next shutdown (middle October 2008).**
- **No need to modify the power supplies or solid state amplifier. The HV and ancillary supplies are ok for the new tube.**
- **Modifications are mechanical:**
  - **Rotation of the output lines, to shift trolley position inside the cabinet.**
  - **Change of the output line to 6 1/8".**
  - **Additional water cooling.**

- **CAVITY**
  - Conditioned in December 2007 up to 62 kW.
  - Installed the new WG to coaxial transition.
  - New diagnostics:
    - Arc detection in the coaxial part of the coupler (air-side).
    - HOM interlock board: developed, to be tested with beam.
- **LOW LEVEL ELECTRONICS**
  - Still the original one with few modifications for the control and interlocks of the new plant.
  - It works very reliably.
  - We will modify the amplitude loop to avoid the risk of fast increase of driving power to the IOT in case of beam dumps.

- **BOOSTER AND 60 kW SR PLANTS ARE WORKING RELIABLY.**
- **150 kW NEW PLANT:**
  - **Percentage of machine downtime due to the new plant is 6.5 % of the total machine downtime in 2008 up to now(the contribution of the other three plants is 0.5 % totally).**
  - **Reliability aspects must be understood and improved in collaboration with manufacturers.**
- **NEXT STEPS:**
  - **Installation of the new IOT.**
  - **Test with higher power of the WG to coaxial transition.**
  - **Implement HOM board.**
- **NEW PROJECTS:**
  - **Development of a prototype of digital low level RF.**