STATUS AND DEVELOPMENTS OF THE 500 MHz RF SYSTEMS FOR THE ELETTRA BOOSTER AND STORAGE RING

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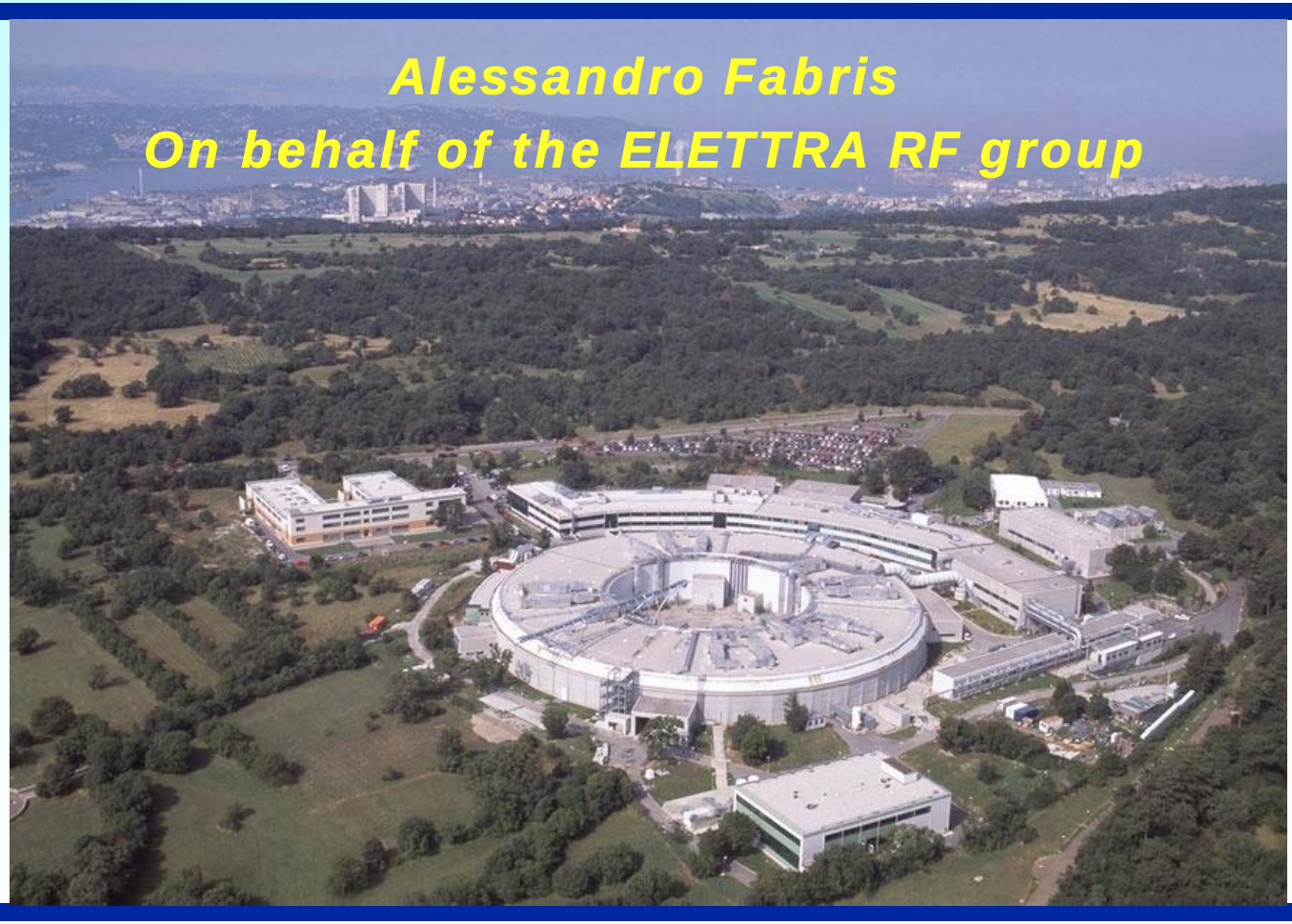
On behalf of the ELETTRA RF group



Overview / Status / RF Upgrade / Booster / Summary

GENERAL

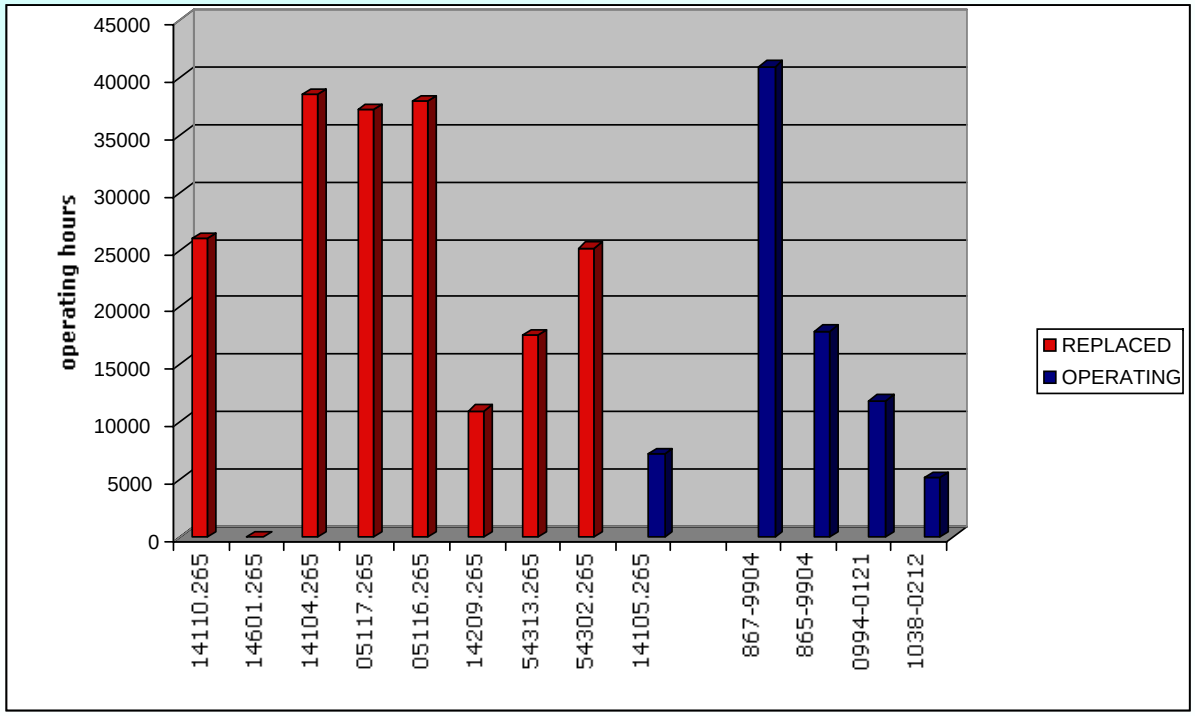
- During the first months of year 2005 the funding problems that plagued ELETTRA during the previous two years were solved.
- All major projects of development of the laboratory (FERMI, New booster injector, RF upgrade) got a new impulse.

MACHINE OPERATION

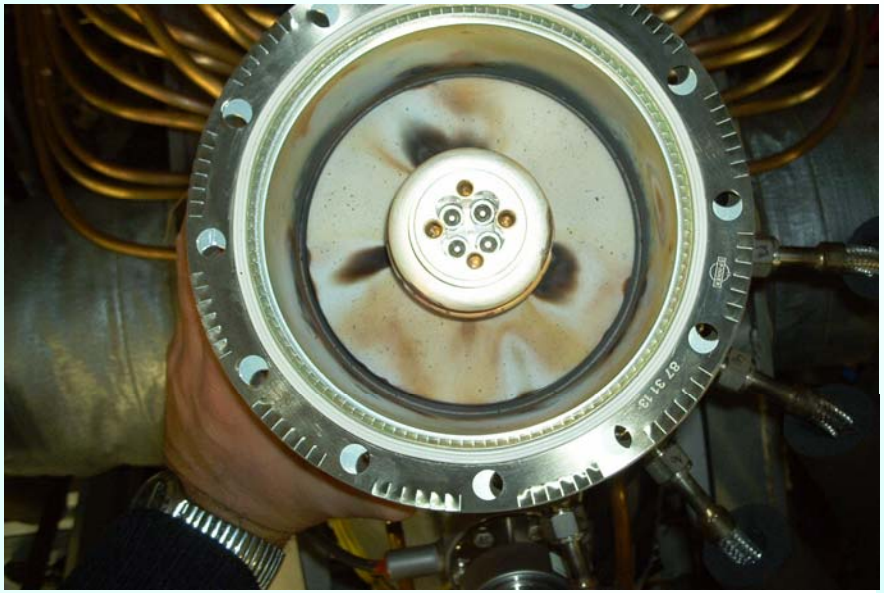
- During the last two years, the machine continued to operate roughly 6500 hours/year, providing more than 5000 hours of light to the users, with an uptime around 94 %.
- Operating modes:
  - Multibunch (90% contiguous): **2 GeV, 330 mA**
  - Multibunch (90% contiguous): **2.4 GeV, 150 mA**
  - 4 bunches: **2 GeV, 40 mA**
  - SR FEL: **0.75-0.9 GeV, 40 mA (4 bunches)**
  - Injection at **0.9 GeV**

GENERAL

- RF system is **12 years old**.
- **Operating hours** are higher than 67000.
- User downtime due to RF system in year 2004 has been of 8 %.
- No particular problems from power amplifiers and low level electronics.
- 60 kW Klystron replacements driven by loss of emission.



➢CAVITIES



- We had to replace one input power coupler following a discharge.
- This event happened at injection energy, when:
  - **500 MHz RF power is at minimum level (28 kW).**
  - A **controlled longitudinal instability** is allowed to facilitate the completion of this procedure, relaxing the optics (useful also for the ramping procedure).This is obtained exciting one cavity HOM.
  - **The event regarded the cavity where we excite the HOM that produces the longitudinal excitation.**

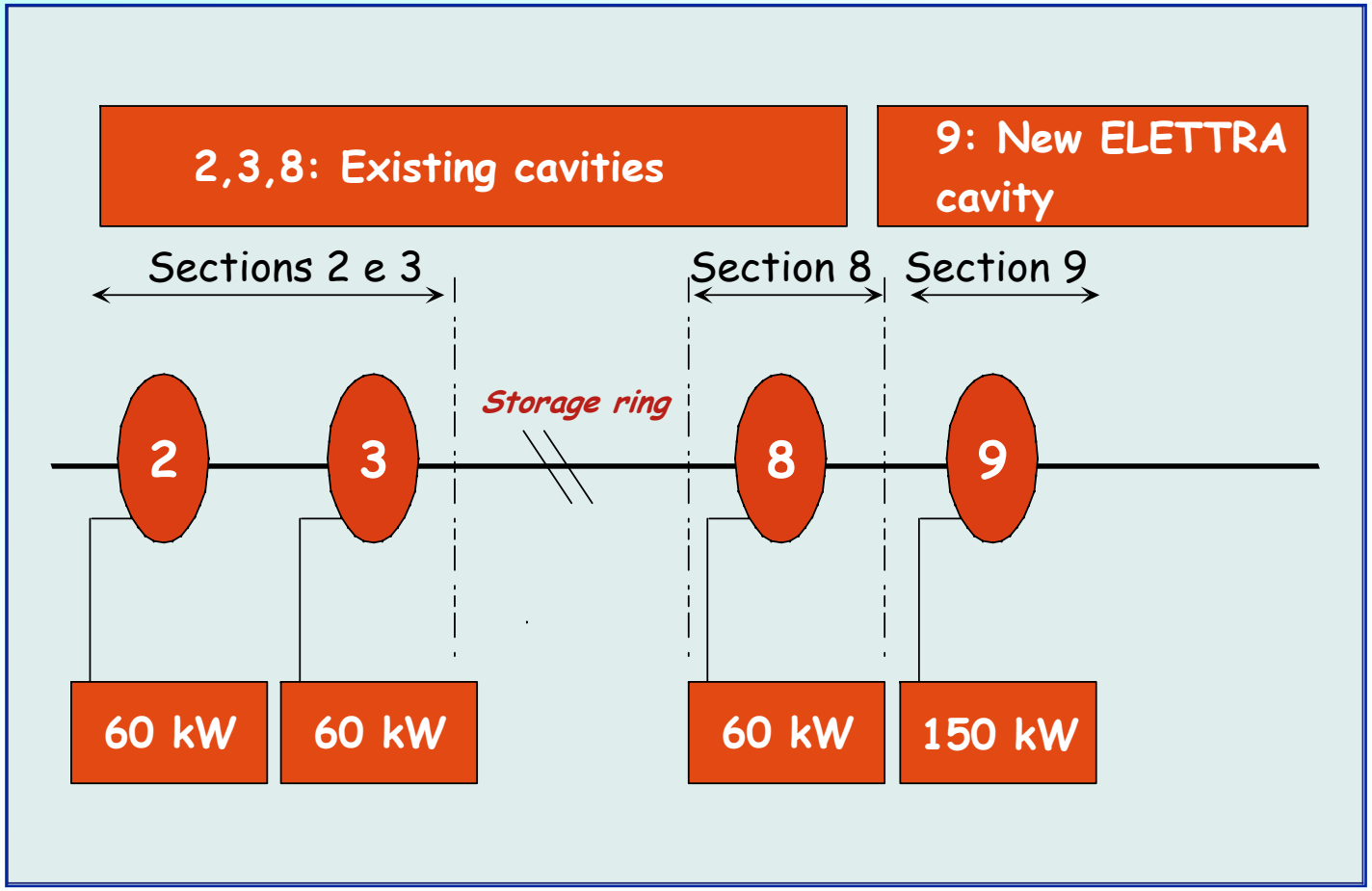
➢This confirmed the need to improve the performance of the power **coupler also at HOM frequencies**, keeping unchanged the under-vacuum part, especially in view of the RF Upgrade project.

- **TARGET OF THE PROJECT**
  - Provide the RF system with the necessary **operating margins**, when all IDs are operational (with a slight improvement also in beam lifetime) and in view of possible increase of beam current and energy.

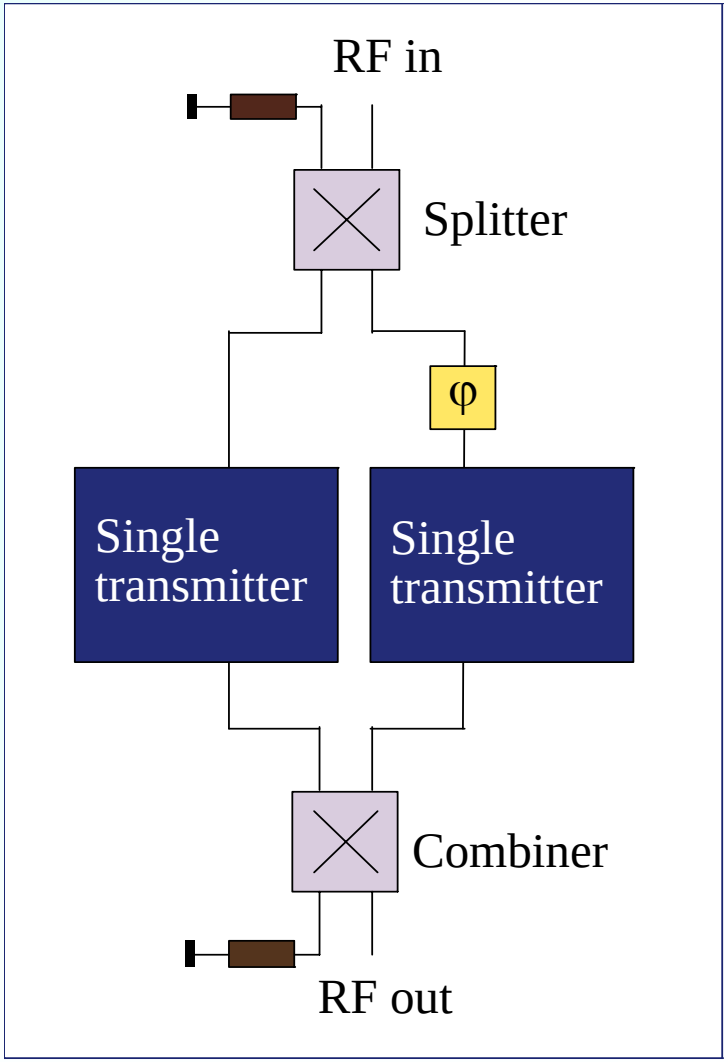
- **DESIGN STRATEGY**
  - **Minimum interference** with machine operation
    - Gradual approach
    - No increase in the number of cavities
  - **Consistency** with other upgrades of the facility
  - **Take benefit of working in the UHF band**
    - Use as much as possible solutions adopted in broadcast applications

- **MULTI-STAGE APPROACH**
  - **PHASE A**: upgrade one 60 kW plant to 150 kW
  - **PHASE B**: repeat phase A on another plant
  - **PHASE C**: upgrade the two remaining plants in the same way

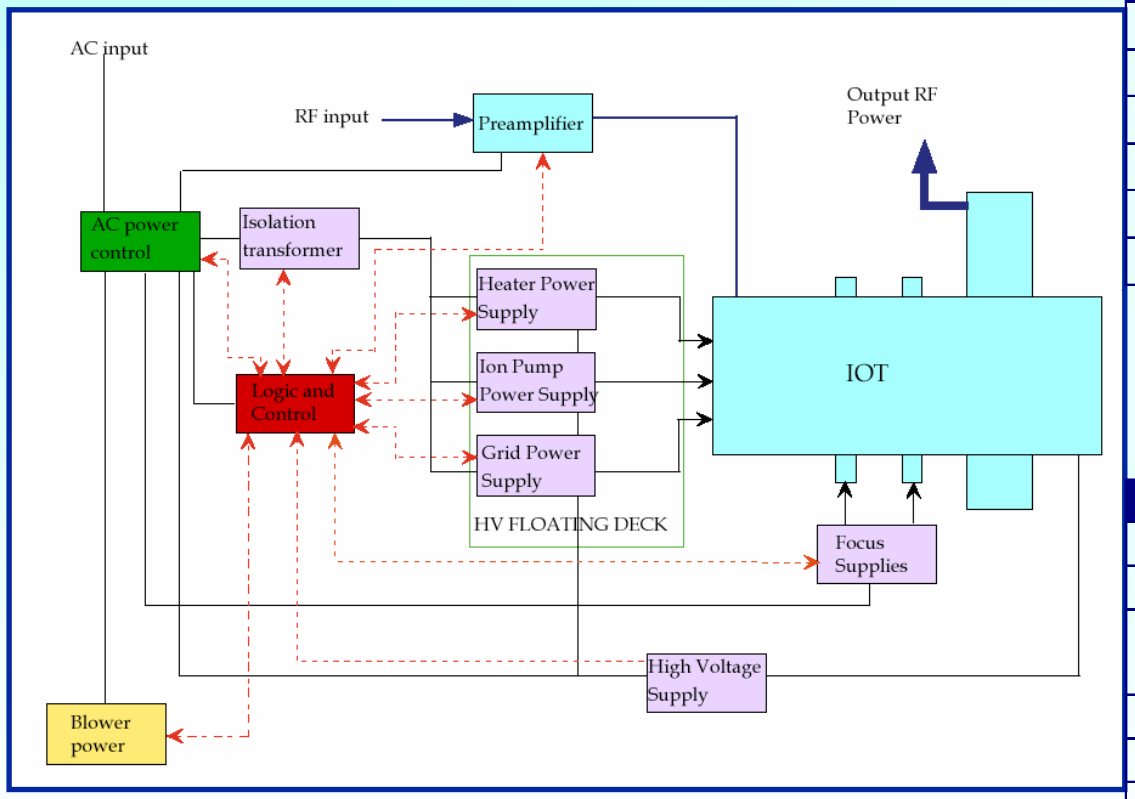
- **PHASE A HAS BEEN APPROVED AND IS BEING IMPLEMENTED**



- The Power Amplifier will be made **combining two 80 kW IOT** transmitters providing 150 kW at the amplifier output.
- It will be acquired as a **turn-key system from industry.**
- Following a call for tender, the order of the power amplifier is being signed these days.
- The tube adopted is Thales TH 793. The use of other tubes assemblies could eventually be possible by use of a replacement kit.
- The amplifier will be composed of **two independent complete 80 kW transmitters**, thus increasing operational flexibility.
- The output of the two transmitters will be combined by means of a **switchless combiner.**



Power Amplifier - Abridged specifications	
Operating frequency	499.654 MHz
Bandwidth (-1dB)	± 1 MHz
Output power higher than	150 kW cw
Input power	13 dBm
Max. admissible VSWR(all phases)	1.3
Output power dynamics	> 35 dB
Harmonic content at output power	< - 30 dBc
Spurious and sidebands levels in ± 20 MHz	< -60 dBc
Signal to noise ratio within bandwidth	better than 70 dBc
Efficiency at full output power	> 65 %
Maximum RF phase variation vs. output power for full drive modulation	30 ° overall
Power stability	± 1% at each output level
Phase stability	± 0.5 ° at each output level



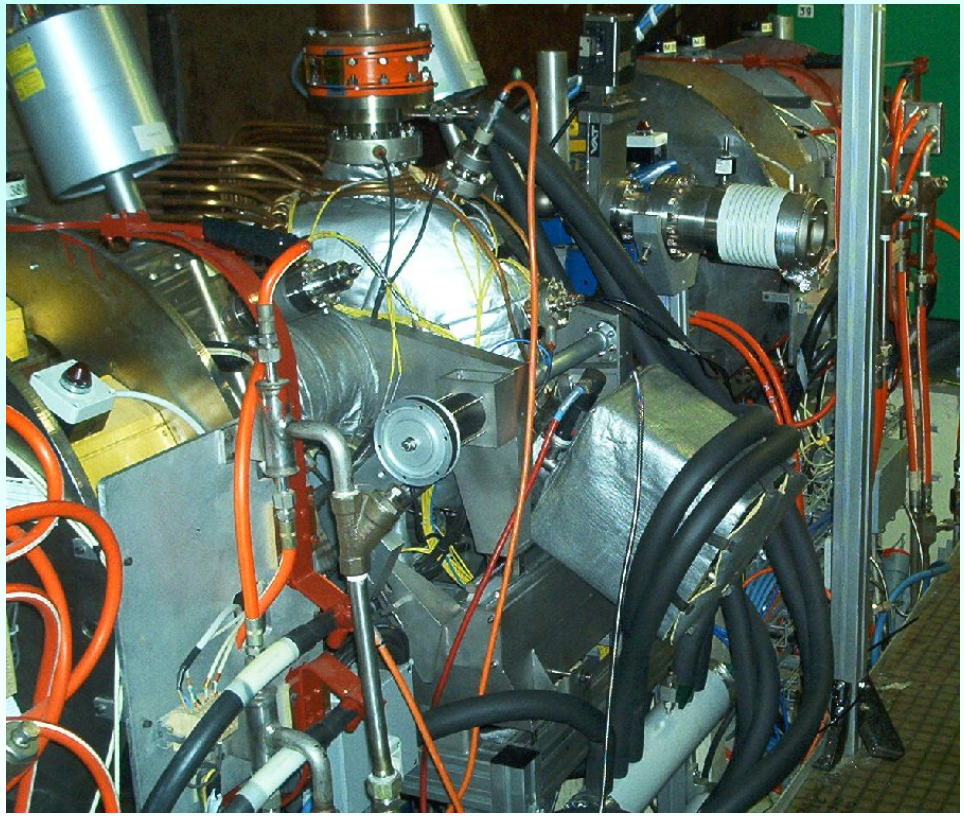
Typical Specifications	
Output power	80 kW
High Voltage Supply	38 kV, 4 A
Heater power supply	12 V, 40 A
Ion pump supply	4 kV, 3 mA
Grid power supply	-200 V, ±130 mA
Focus power supply	12 V, 30 A

Requirements for one 80 kW IOT

Electrical Consumption	
Solid state amplifiers	2.2 kW
IOT amplifier	130 kW
Transmitter water cooling unit	2.3 kW
Transmitter blowers	3.4 kW
Ancillary equipment	2.0 kW
TOTAL CONSUMPTION	**139.9 kW**
Power factor	0.9

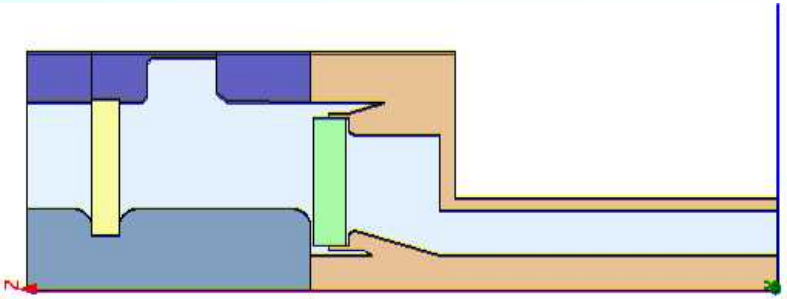
Requirements for one 80 kW IOT

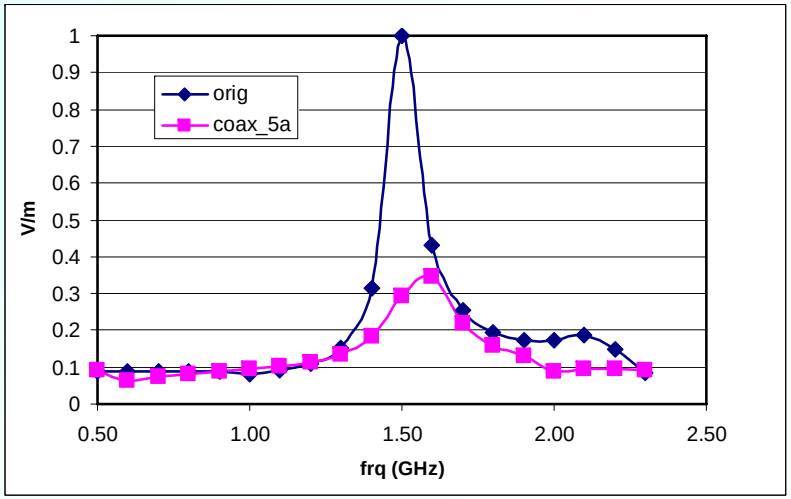
- **Each of the two transmitters will be completely independent**.
  - The fault or the maintenance of one transmitter does not imply the interruption of the operation, but only a 3 dB reduction, since the other transmitter continues to operate.
- **The HV power supply of each IOT will be a switched mode power supply.**
  - The structure is **more compact**.
  - At the same switching frequency, the beam voltage ripple is about the half in comparison with a unique power supply, since the maximum smoothing capacity is bound by the maximum admissible energy in case of discharge inside the single IOT.
  - If needed, **switching frequency can be adjusted** in the range 16 to 21 kHz.
  - No oil capacitors or transformers are used.
  - No crowbar.
  - Beam voltage is stabilised independently of:
    - Output power variations.
    - Mains input variations.



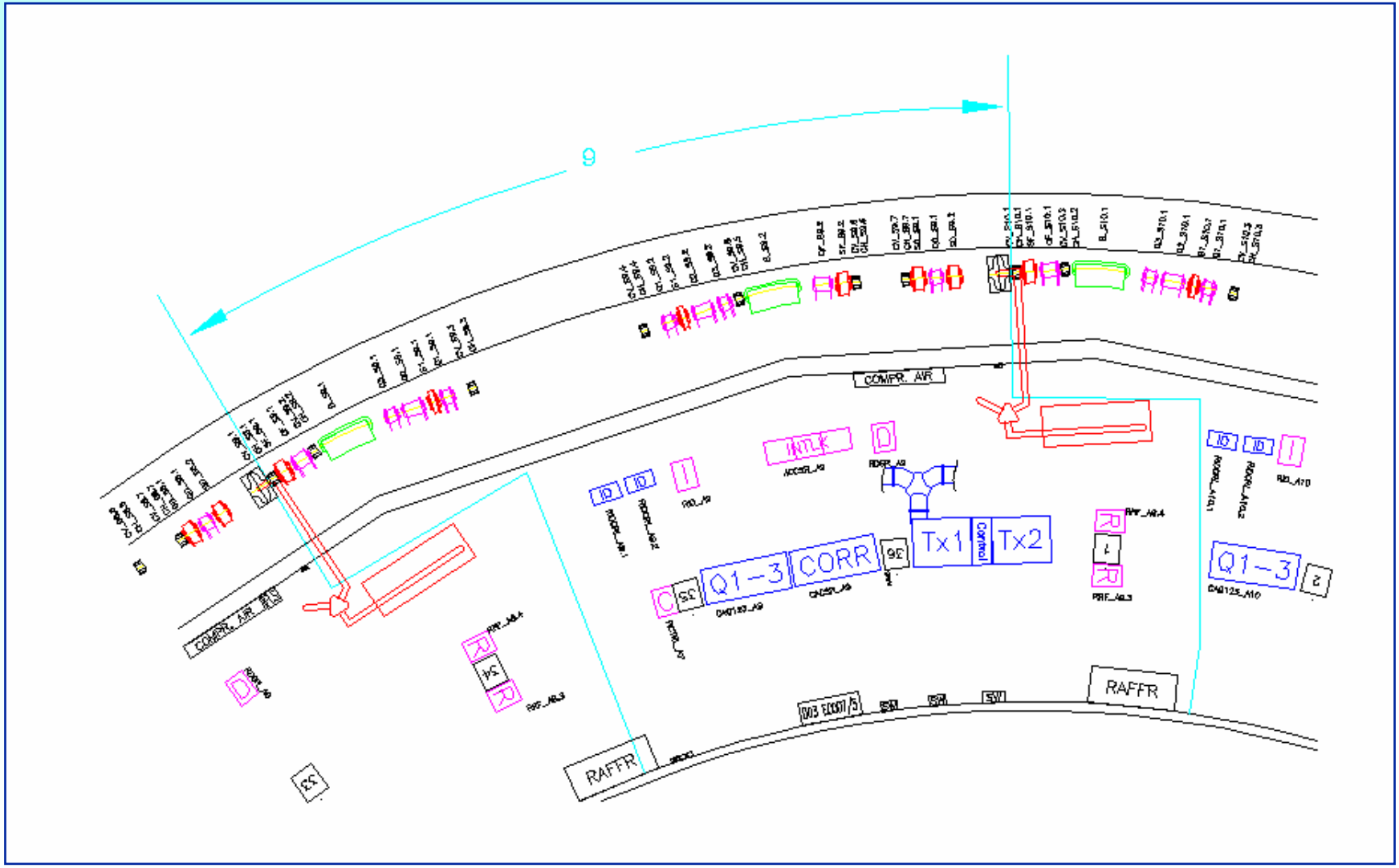
- The new cavity was installed in section 9 in **November 2003**. It is similar to the ones provided to SLS and ANKA (upgraded cooling efficiency).
- In parallel a design study is in course to improve the performances of the power coupler both at fundamental and HOM frequencies.
- This includes:
  - Design of a **new coaxial transition element** (air side).
  - **Modification of standard waveguide to coaxial transition.**
  - Installation of **diagnostic devices** in the coaxial element (arc detector and strongly undercoupled inductive loop to monitor HOM frequencies).

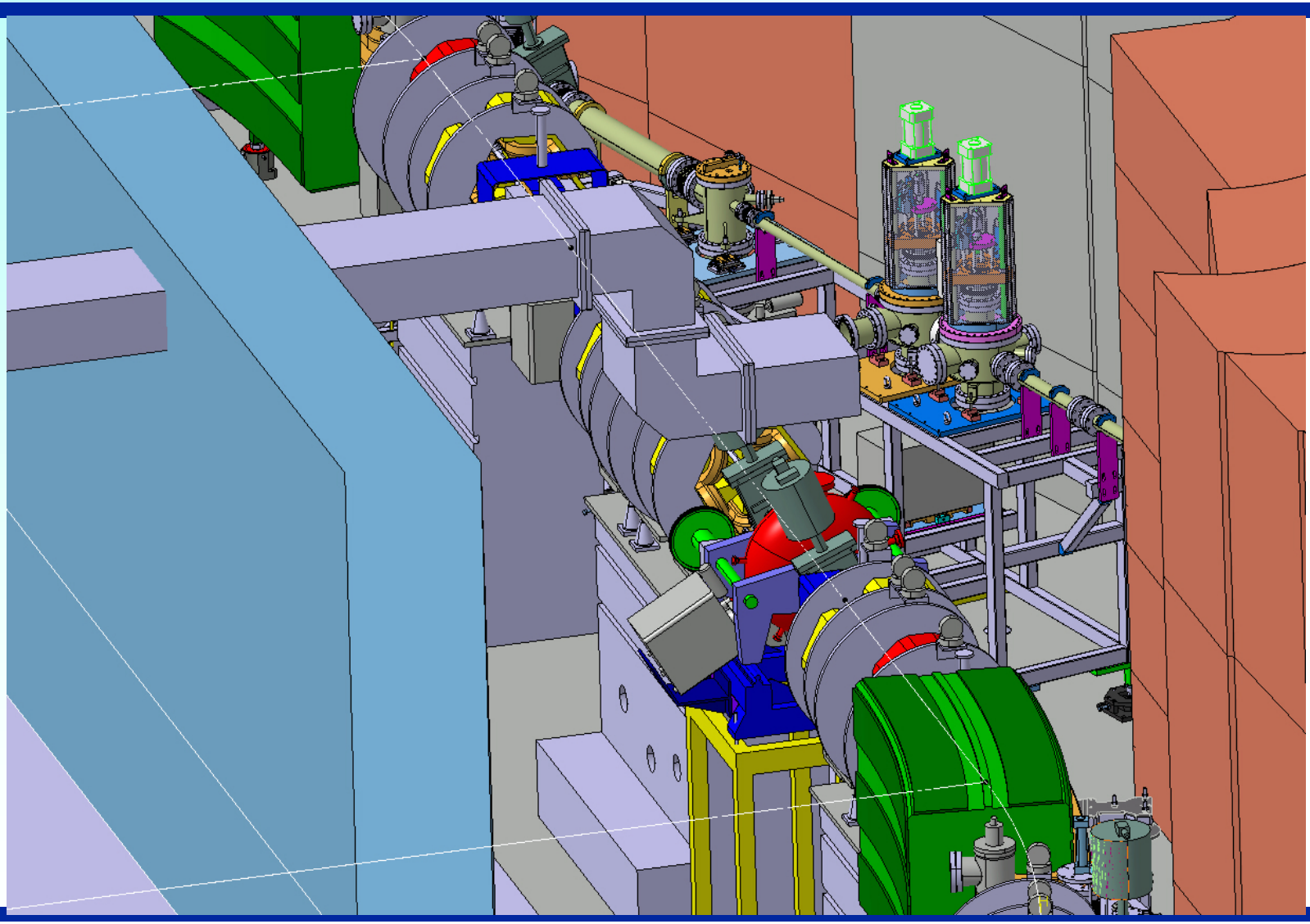
- **Power coupler studies**.
  - Coaxial input power coupler, adapter element to standard coaxial size and coax to waveguide transition **treated as a unique element**.
  - Study its performance to:
    - **Lower as much as possible the impact of HOMs field**.
    - **Increase the efficiency of the cooling** of the inner conductor.
    - Keep unchanged the present design of the under vacuum part.



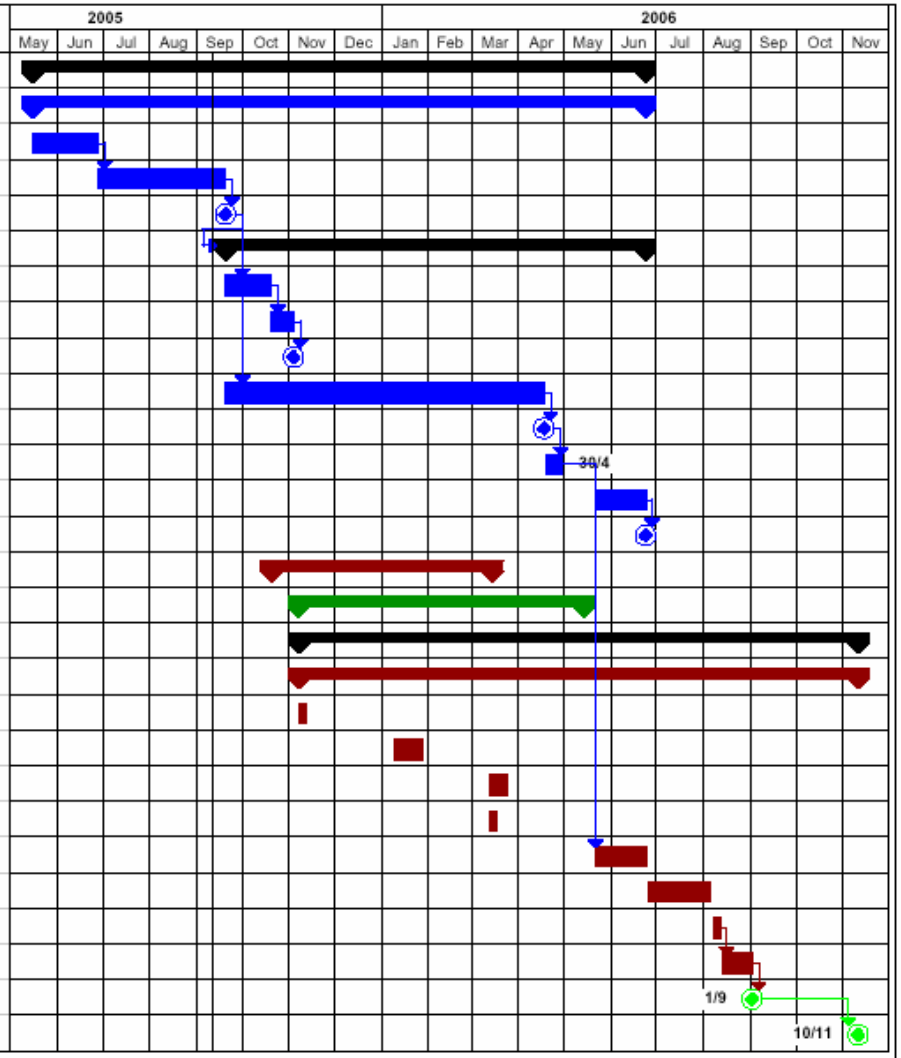


- EM layout completed.
- Interaction with industry for feasibility study and construction of a prototype.


9
CONFFR. AIR
CONFFR. AIR
Tx1
Tx2
Q1-3
CORR
Q1-3
RAFFR
RAFFR



ID	Task Name
1	**COMPONENTS**
2	**AMPLIFIER**
3	Tender
4	Evaluation and Negotiations
5	Order
6	**Construction and delivery**
7	Design
8	Design evaluation
9	FDR
10	Construction, assembly and test
11	FAT
12	Delivery
13	Installation
14	SAT
15	**CONVENTIONAL FACILITIES**
18	**WAVEGUIDE COMPONENTS**
21	**INSTALLATIONS**
22	**ACTIVITIES**
23	Conventional facilities (1st part)
24	Conventional facilities (2nd part)
25	Conventional facilities (3rd part)
26	Waveguide hole
27	Amplifier installation
28	Amplifier test (standalone)
29	Circulator and waveguide installation
30	Connection to the cavity
31	150 kW plant in operation
32	Old amplifier ready for demounting



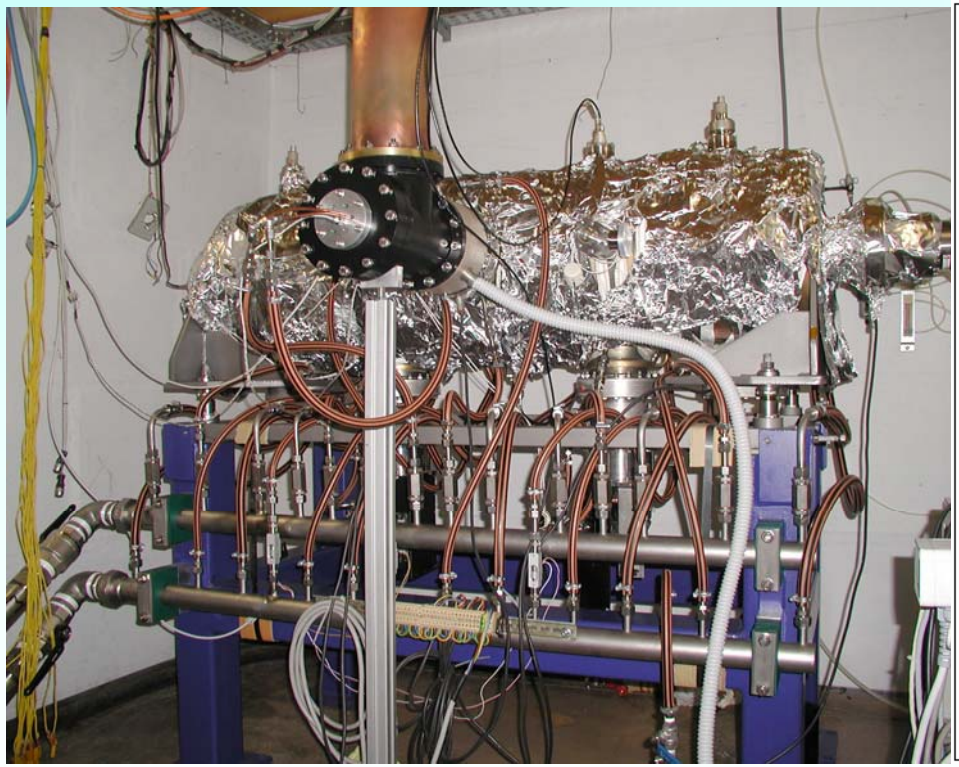
Note: installations depend on the availability of shutdowns

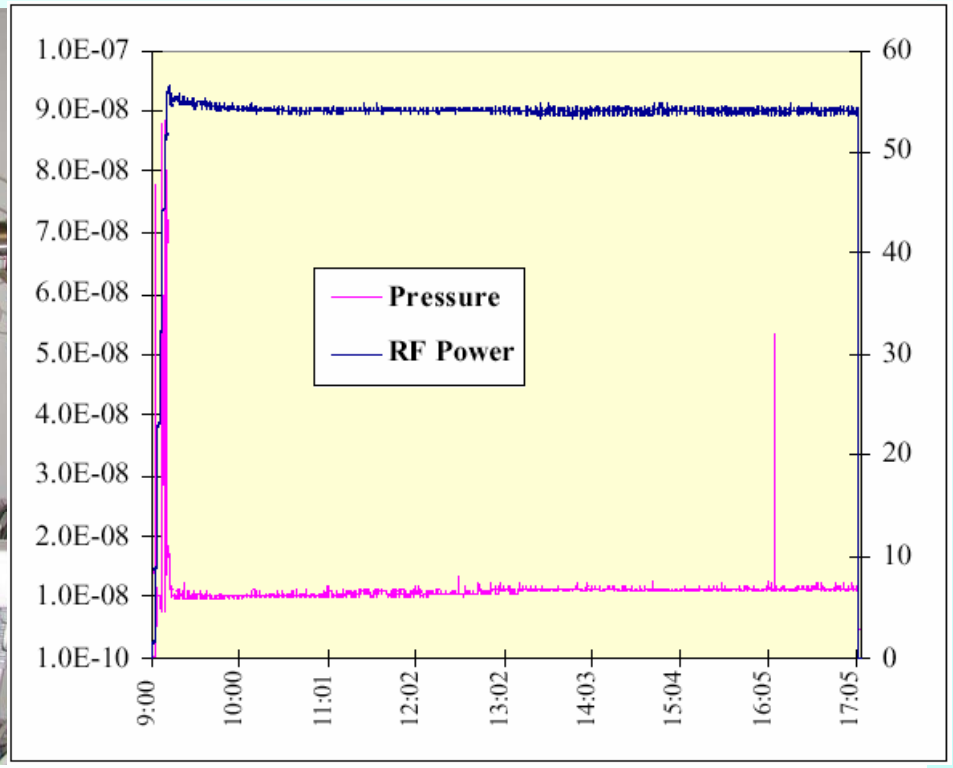
- **DESIGN REQUIREMENTS:**
  - Provide **sufficient energy acceptance** to the injected beam and ramp the beam.
  - **1 sec quantum lifetime** at 2.5 GeV: sufficient for extraction, keeping RF voltage requirements reasonable.
  - Same frequency as the storage ring to assure the matching between the two machines.
  - As simple, conservative and reliable as possible.
- **CAVITY**
  - **5- cell DORIS type cavity.**
  - Supplied by ACCEL.
  - Since multibunch instabilities will not be an issue for the booster, the advantages compared to ELETTRA type cavities (two needed) are:
    - Only one RF plant is needed.
    - All this results in an important cost reduction.
- **POWER PLANT**
  - The power plant will be the one now in operation in section 9, which will be released following the completion of the first phase of the RF upgrade.

PARAMETERS	NOMINAL (LOW EMITTANCE) OPTICS	
Beam energy	2.5	GeV
Beam current	5	mA
Energy loss/turn at 2.5 GeV	**388**	keV
Harmonic number	198	
Revolution frequency	2.524	MHz
RF Frequency	**499.654**	MHz
Momentum compaction factor	0.0433 (0.0308)	
Quantum lifetime (2.5 GeV)	> 1	sec
Overvoltage factor	**2.16 (1.58)**	
Total effective RF voltage	**840 (730)**	kV
Energy acceptance(2.5 GeV)	3.07 e-3	
Cavity power	**25.2 (19.03)**	kW
Beam power	1.94	kW
Total power required	27.14 (20.97)	kW
Generator power	**30 (24)**	kW

➤RESONANT CAVITY

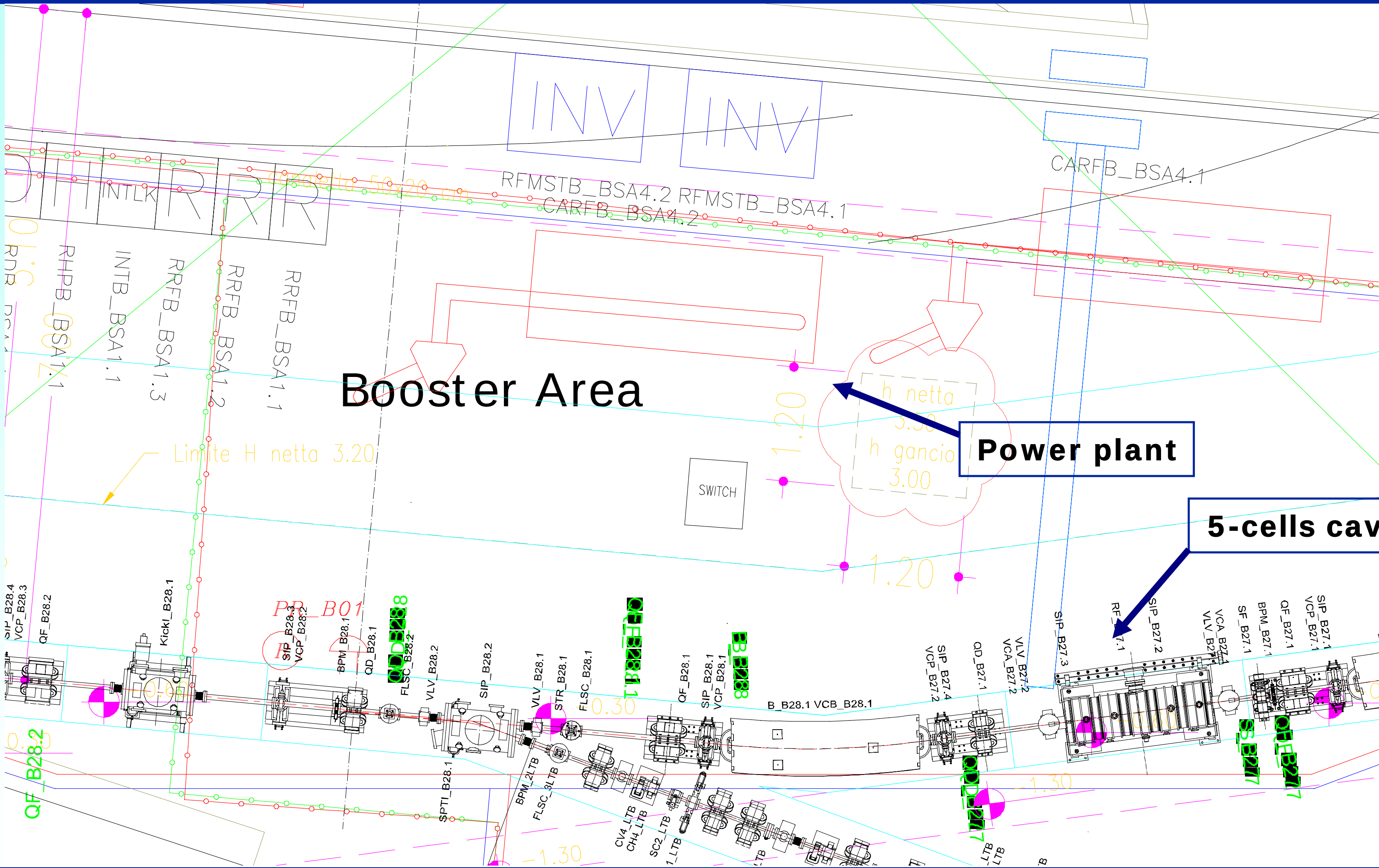
- ➤Cavity characterisation performed at low power
- ➤Cavity conditioned up to 54 kW





- **POWER PLANT**
  - 60 kW klystron based amplifier
  - Full power circulator and dummy load
  - Power transmission realised with 6 1/8” rigid coaxial lines

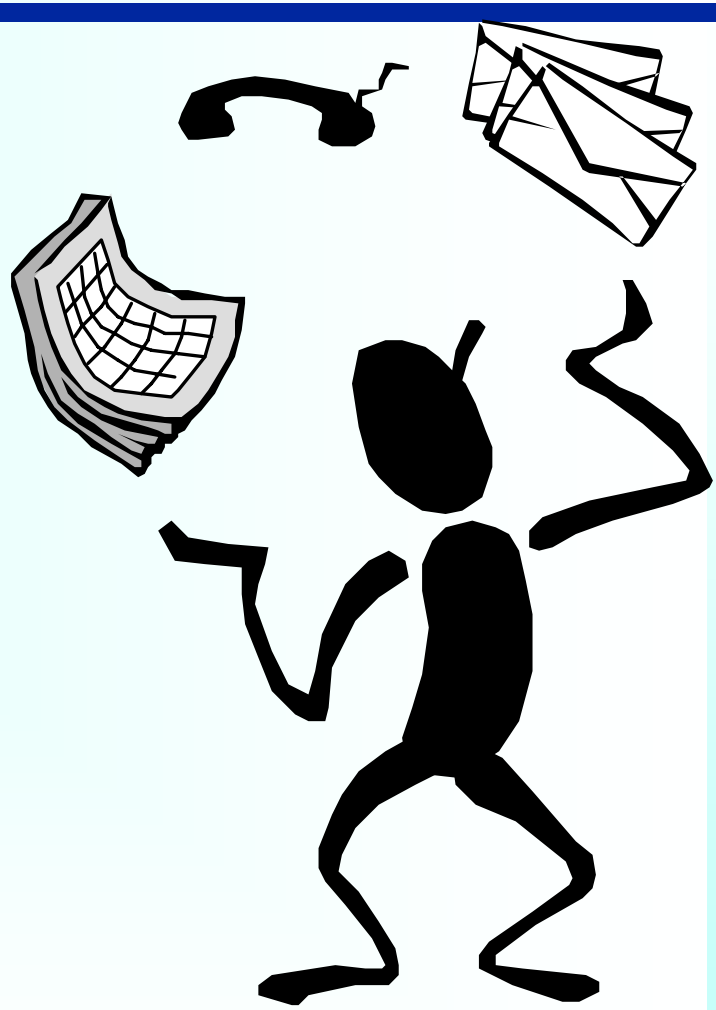
- **LOW LEVEL**
- The Low Level system is under construction, based on previous constructions (analog LLRF system).
- Main components:
  - **Frequency and field flatness loop**
  - **Amplitude loop**
  - **Phase loop**
  - **Mechanical Phase shifter**
  - **RF switch**


Booster Area
Power plant
5-cells cavity

- MILESTONES
  - Start of installations: beginning 2007
  - Commissioning: spring 2007
  - Connection to SR: summer 2007
  - First injection in SR: autumn 2007

- **Therefore Power plant installation will start soon after completion of SR upgrade.**

- **Design of SR RF upgrade and booster RF are well advanced.**
- Activities are started.
- The work on SR RF upgrade and Booster RF are strongly correlated.
- **SR upgrade will have to be finished to provide the Booster RF plant.**
- Activities will have to be well scheduled to minimise interference.
- **In addition, existing SR will require maintenance and servicing.**



- ***CONCLUSION:***
- **THE NEXT TWO YEARS WILL BE VERY BUSY**