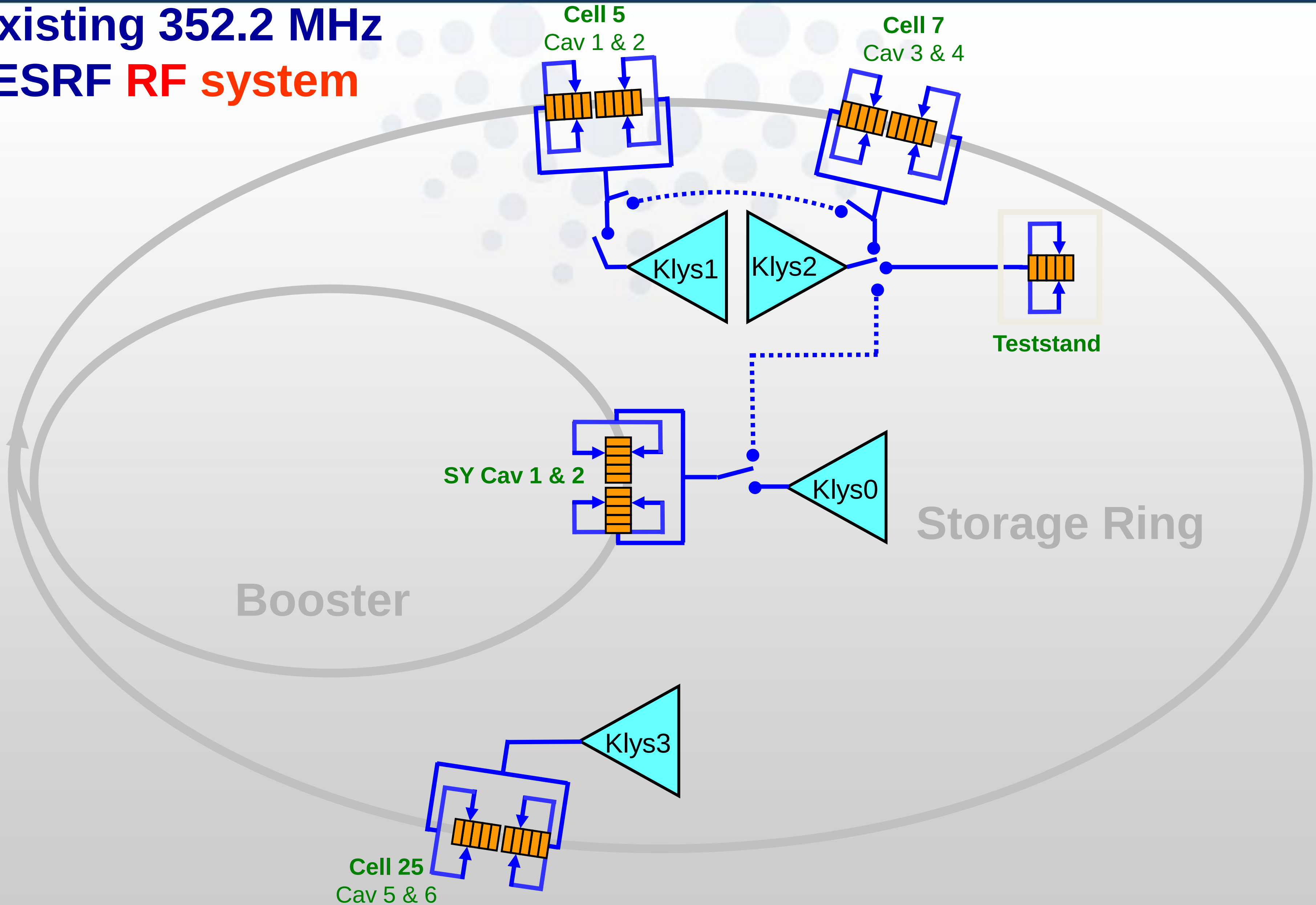
14th ESLS RF Meeting 2010
ELETTRA, 29th – 30th September

ESRF RF System Status – Operation & Upgrade

Jörn Jacob, ESRF

on behalf of the colleagues of the RF Group and many other ESRF Groups

Existing 352.2 MHz ESRF RF system



Existing Operation at 200 mA

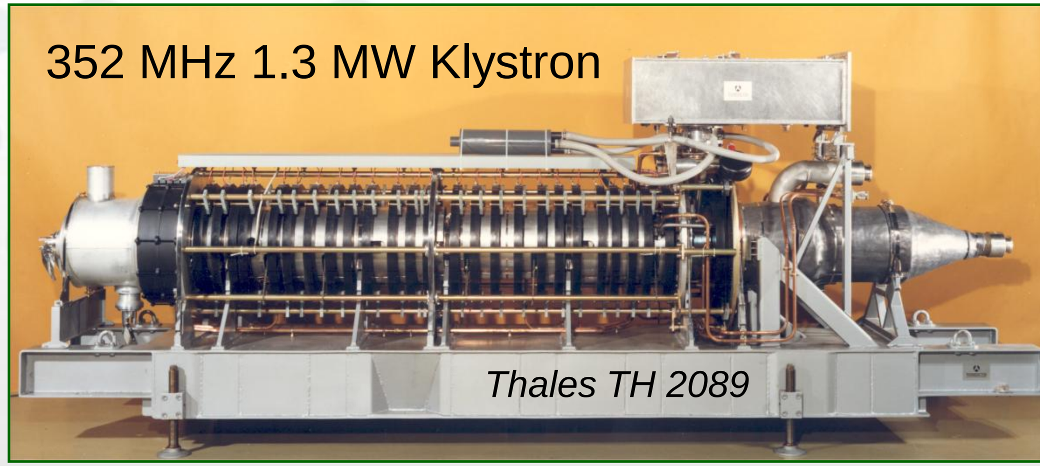
- 1.3 MW klystron transmitters: Redundancy in case of any transmitter failure (waveguide switching)
- Suppression of HOM driven Longitudinal Coupled Bunch Instabilities by Cavity Temperature regulation

Current upgrade to 300 mA

- No transmitter redundancy
- Need LFB to stabilize HOM driven instabilities
- Increased voltage to master Robinson Instability

Long term

- Only 1 manufacturer left for this type of klystrons
  ☞ possible obsolescence



R/Q = 139 Ω / cell

Qo = 38500

Rs = 26.8 MΩ (5 cells)

V_{nom} = 1.4 … 2.5 MV

2 couplers: β_{max} = 4.4

Max 170 kW / coupler

Existing 352.2 MHz ESRF RF system

Problem with SR Cavity 5:

1997 installation in the machine

- ➢ Bad welding joint on tuner ports, scraping the piston

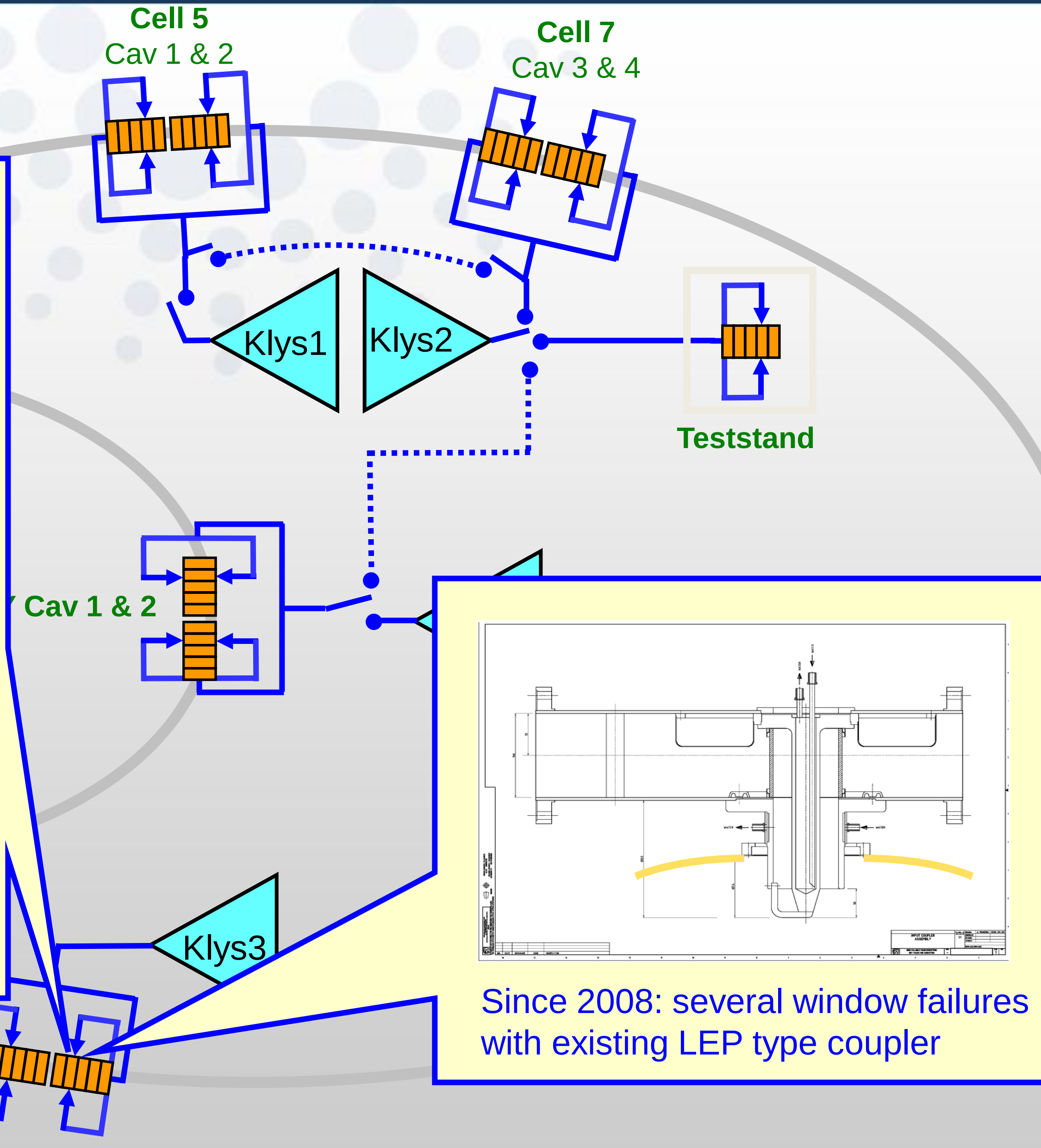
2007 Leak developed on 1 tuner port: 300 mA tests had to be stopped

2008 Replaced with spare cavity, however: bad conditioning with beam due to a previous accidental venting during storage ⇒ no 300 mA test

2010 Re-installation of repaired cavity 5 but still problem with 1 coupler:

- • Degassing
- • Glow discharges

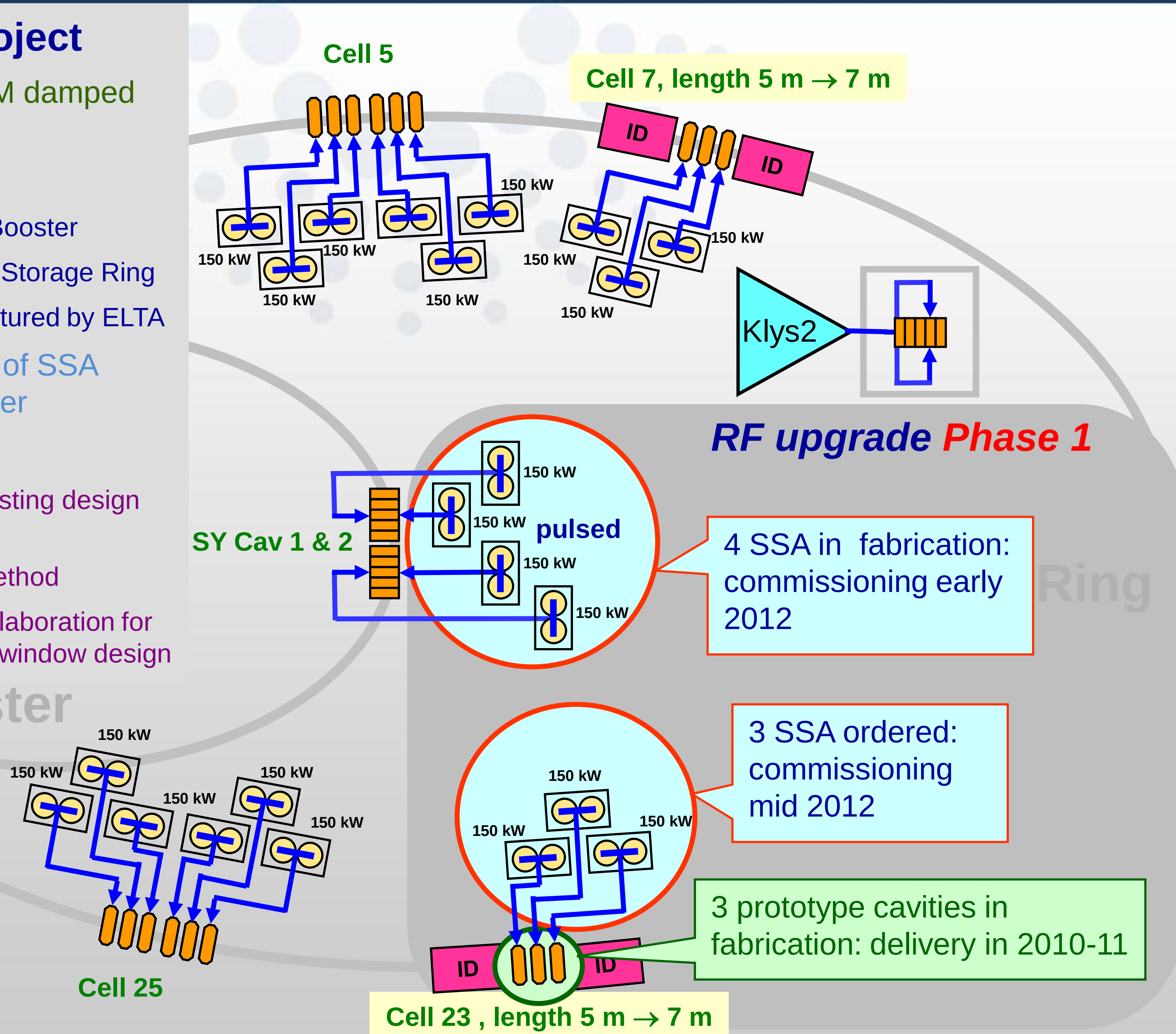
- ➢ Nevertheless: successful resuming of 300 mA tests
- ➢ Exchange of coupler in August 2010 solved vacuum problems



Since 2008: several window failures with existing LEP type coupler

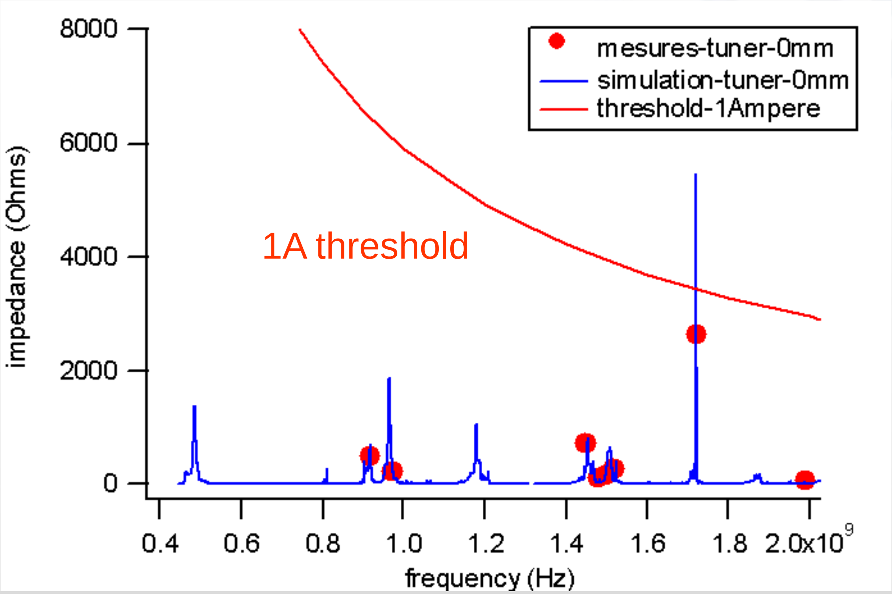
RF upgrade project

1. 18 new single cell HOM damped cavities
2. Solid State Amplifiers
   - 4 x 150 kW SSA for the Booster
   - 18 x 150 kW SSA for the Storage Ring
   - Phase 1: 7 SSA manufactured by ELTA
3. In house development of SSA using a Cavity Combiner
4. Cavity Power couplers
   - New Spare couplers / existing design with improvements
   - Improved conditioning method
   - CERN/ESRF/SOLEIL collaboration for new couplers using LHC window design



1. Single cell NC HOM damped cavity prototypes

DESIGN, checked with aluminum model

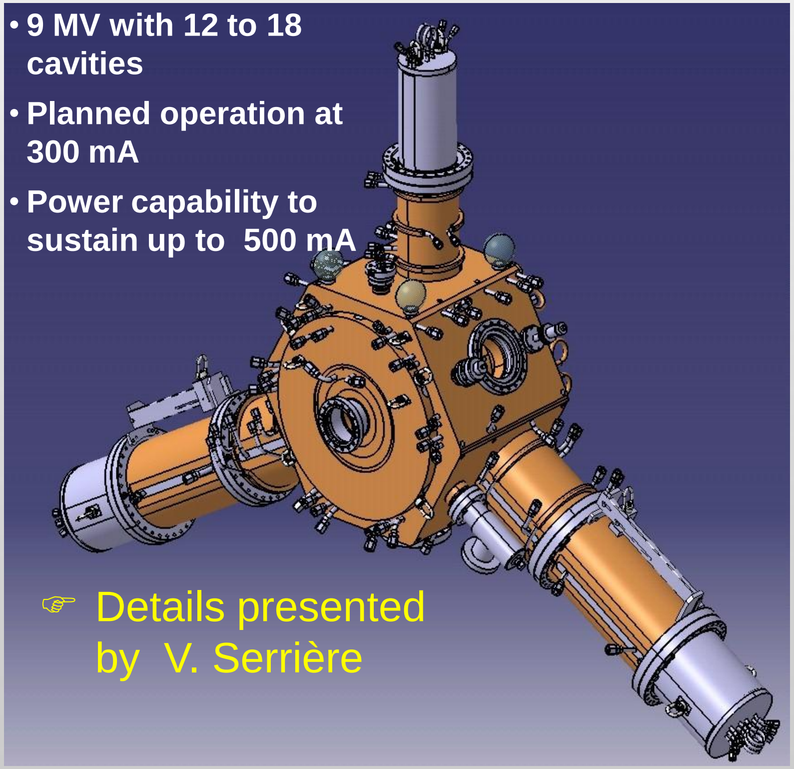


All the **longitudinal HOM impedances** are well below the threshold of 1A / 18 cavities

3 power prototypes in fabrication:

- validate the design
- validate 2 different manufacturing procedures
- qualify 3 companies: RI, SDMS, CINEL
- obtain 3 operational cavities for ID23

- **9 MV with 12 to 18 cavities**
- **Planned operation at 300 mA**
- **Power capability to sustain up to 500 mA**

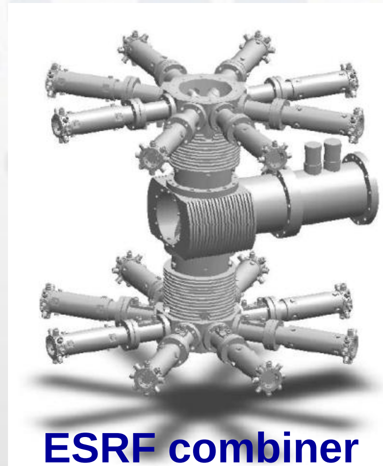


- Details presented by V. Serrière

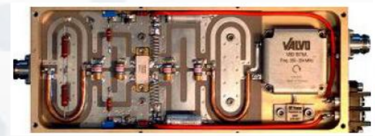
** This work, carried out within the framework of the ESRFUP project, has received research funding from the EU Seventh Framework Programme, FP7.*
2007 - 2013

2. Contract for 7 SSA of phase 1 with ELTA

SOLEIL SSA



ESRF combiner



SOLEIL 315 W module

SOLEIL 300 V / 30 V dc-dc converter

- Offer essentially along the initial SOLEIL design
- New 6th generation LDMOS-FET transistors allow for a more compact design with only **2 towers** to obtain **150 kW:**

  315 W → 650 W per module

  Coaxial combiners: 650 kW x 8 x 8 x 2 – losses = 75 kW / tower
- November 2009, contract with ELTA for:
  - 4 x 150 kW SSA for the booster (10 Hz pulsed operation)
  - 3 x 150 kW SSA for the SR (CW operation)
- First 75 kW tower built in close collaboration between SOLEIL and ELTA (transfer of technology)

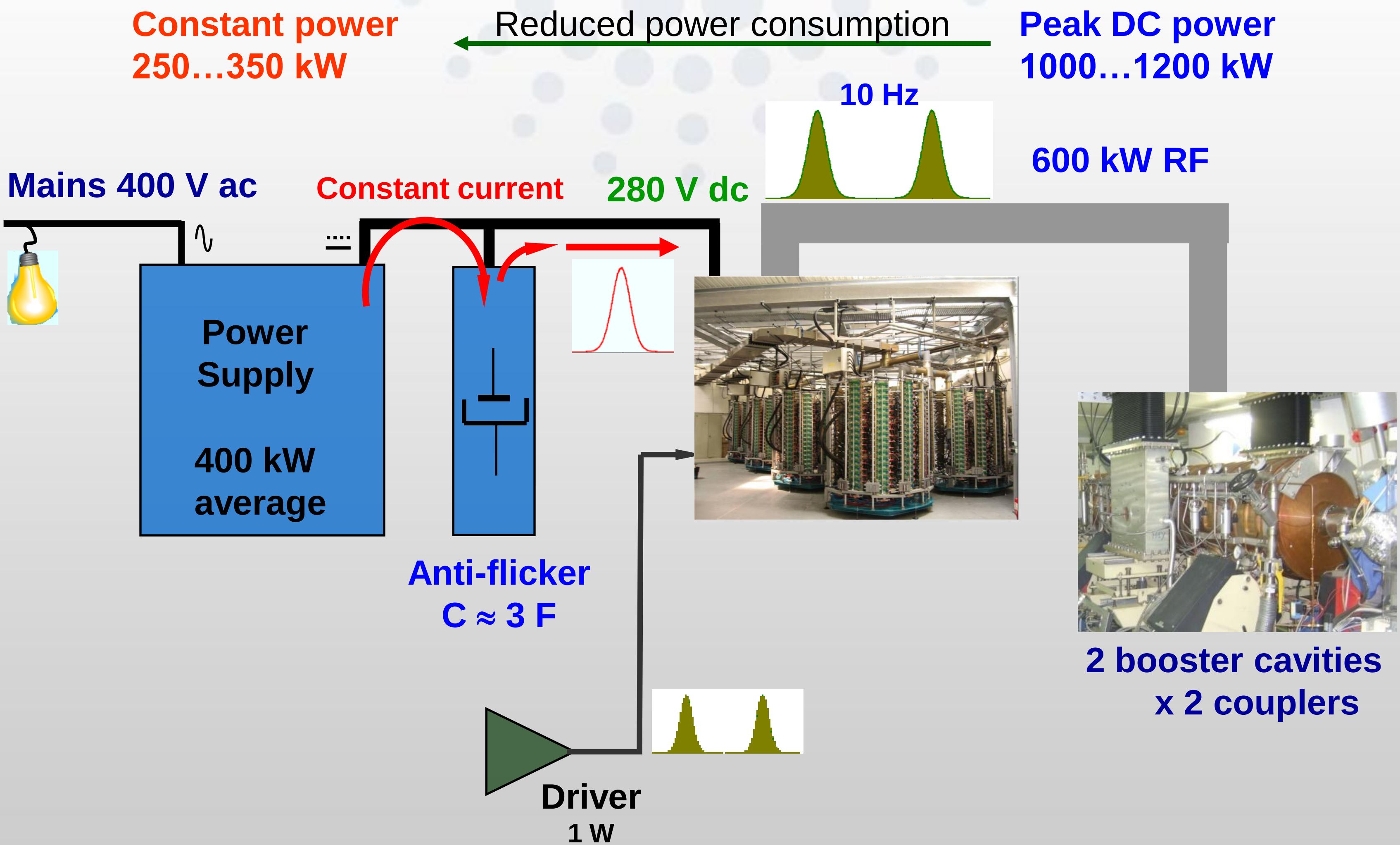
Schedule:

- February 2010: Successful test of the first RF module, validation of the design:

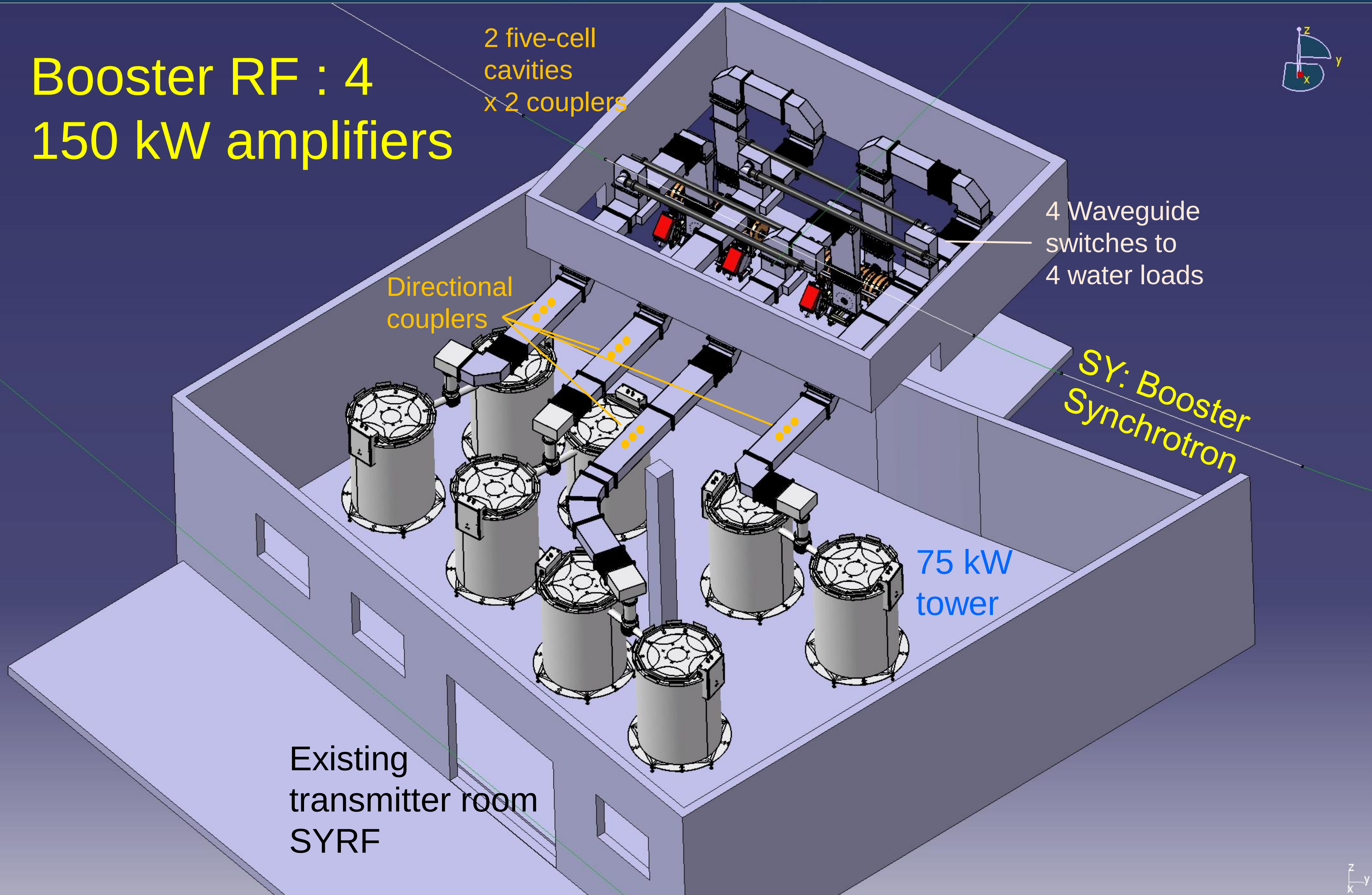
  η_{module} > 72 % (measured)

  ⇒ **expected total η_{SSA} > 55 % (> spec)**
- July 2010: Successful test of the first combination of 16 RF modules, including 500 hours ON/OFF fatigue test (7500 x 4 min on/off cycles)
- February 2011: Acceptance test of the first 75 kW tower at ESRF
- January 2012: commissioning of the 4 x 150 kW SSA connected to the ESRF booster cavities
- August 2012: commissioning of 3 x 150 kW SSA connected to the first 3 single cell HOM damped cavities in cell 23 of the Storage Ring

400 V ac / 280 V dc power supply for the booster SSA



Booster RF : 4 150 kW amplifiers



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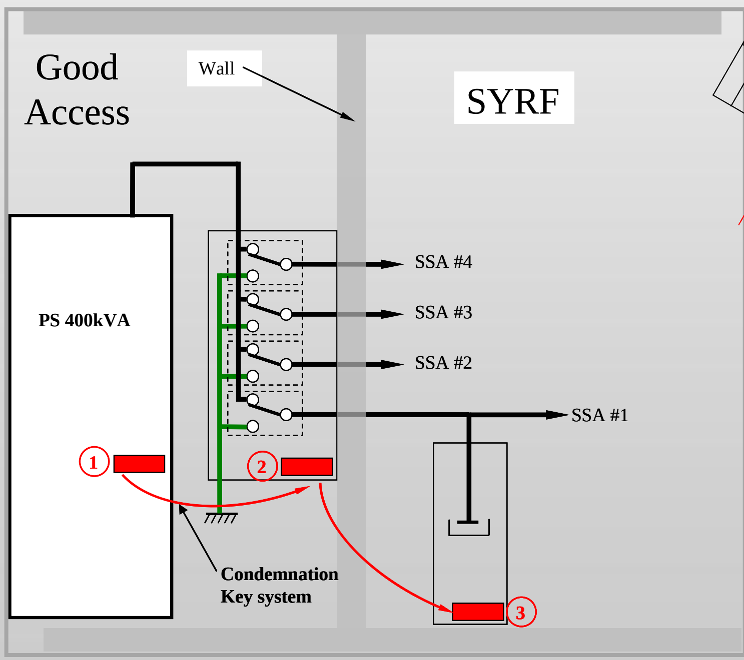
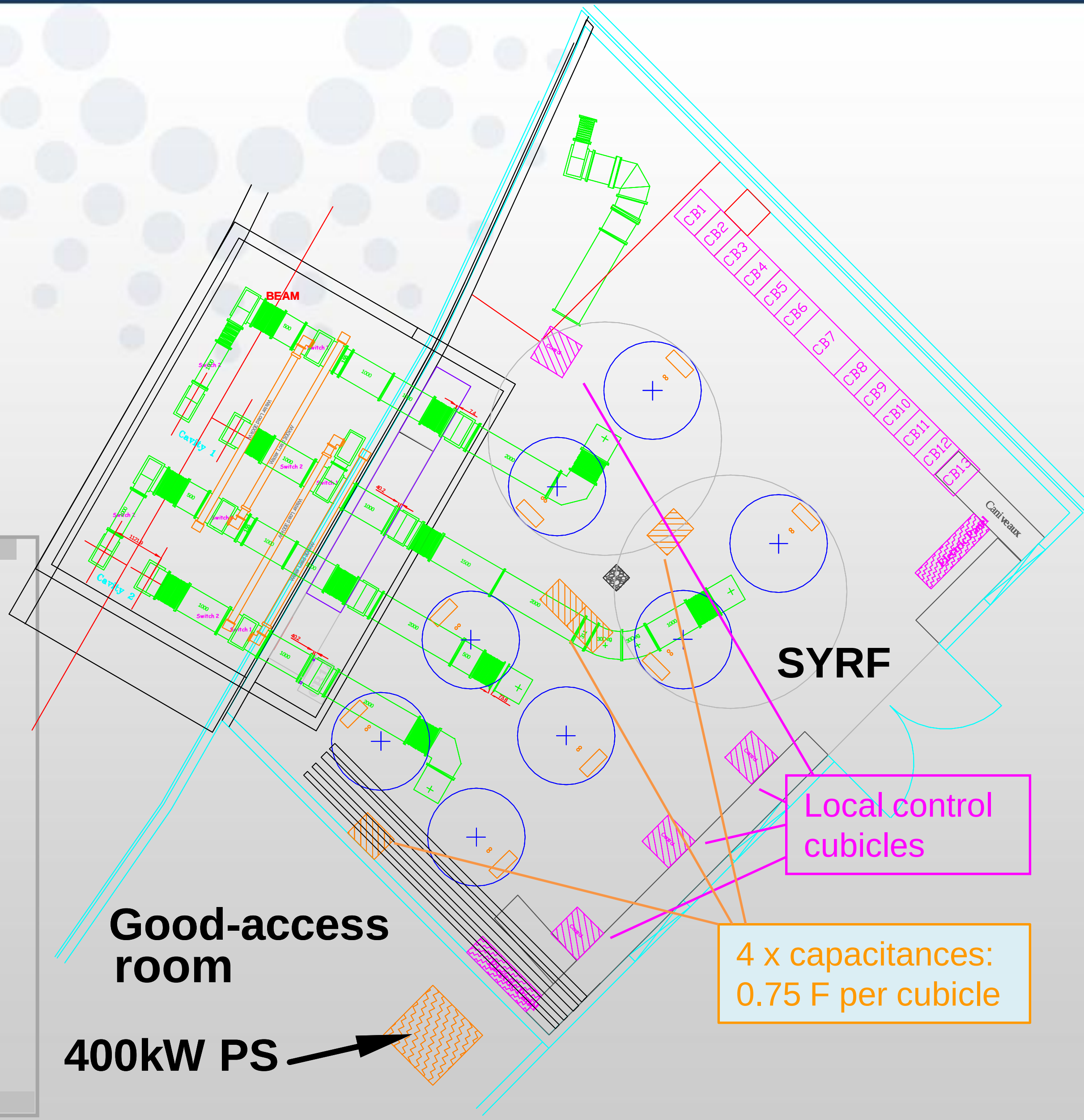
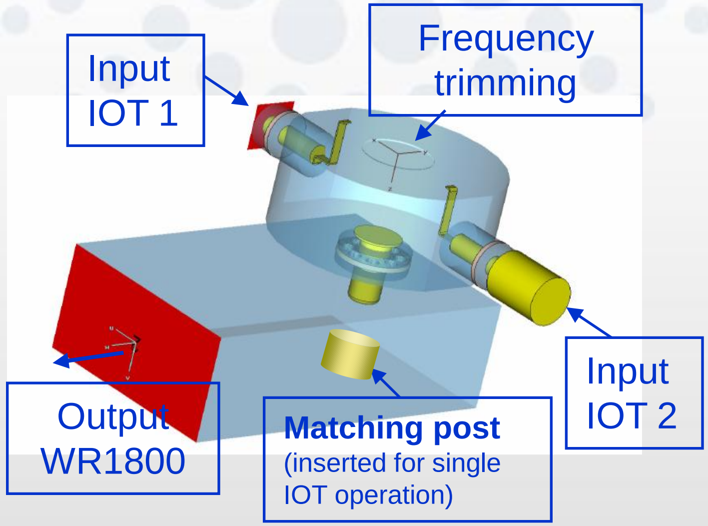


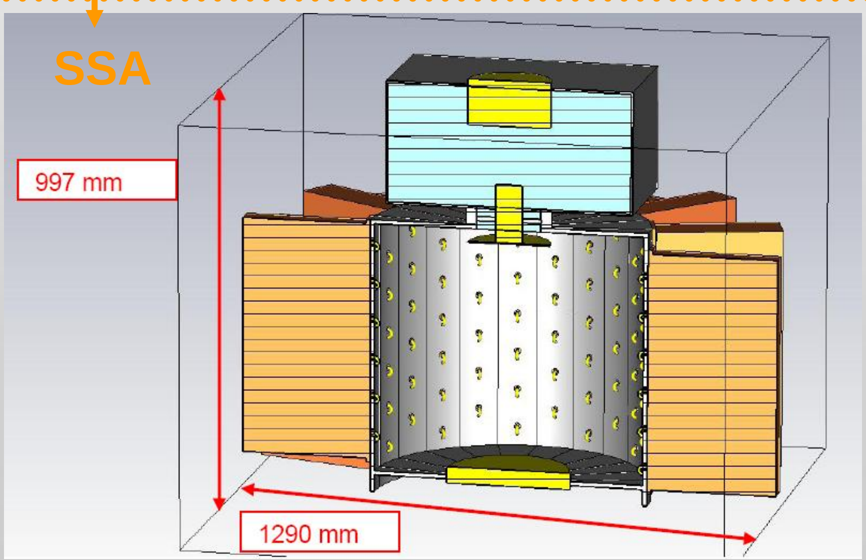


3. R&D – SSA using a Cavity Combiner *[M. Langlois, ESRF RF Group]*



ALBA Cavity Combiner:

- MWS design / ALBA
- 100 % match for 2 IOTs
- One IOT off and detuned:
  - ⇒ Adjust tuning plunger in output waveguide
  - ⇒ Re-establish match > 99%



For ESRF application:

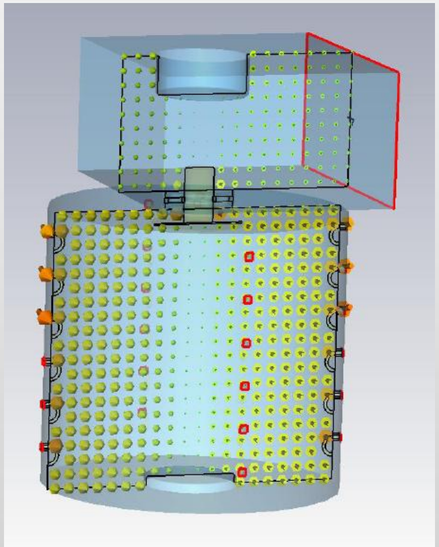
- **6** raws x **22** Columns x [**600 …800 W** per transistor module]

  ⇒ 75 … 100 kW
- More compact than SOLEIL type coaxial combiners

  Coupling: $\beta_{waveguide} \approx n_{module} \times \beta_{module} >> 1$
- Easy to tune if n_{module} is varied
- Substantial reduction of losses ⇒ higher η

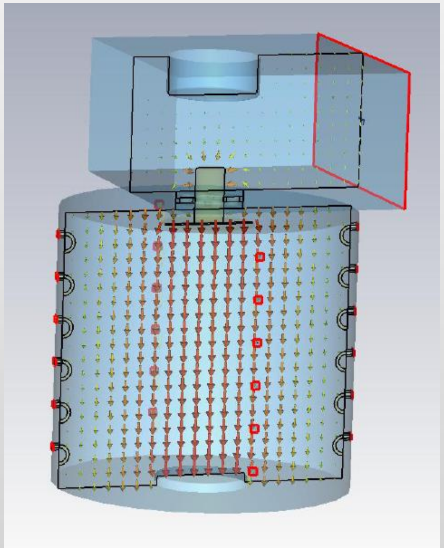
Strongly loaded E_{010} resonance

- Modest field strength
- Cavity at atmospheric pressure
- 1 dB - Bandwidth ≈ 500 kHz



H field

Homogenous magnetic coupling of all input loops



E field

Strong capacitive coupling to the output waveguide

- SSA with Cavity Combiner
  - Mechanical design almost ready to build a 12 kW prototype (18 modules)
  - Main goal: develop an adequate electrical & mechanical interface between RF modules & cavity
- In parallel:
  - In house development of amplifier modules,
  - Using latest LDMOS-FETs
  - Goal:
    - Acquire expertise in SSA design,
    - Contribute to the design improvement
    - Prepare the future operation follow up
    - Set reference for coming procurements
- Prepare next step:
  - Full scale prototype at 75…100 kW

4. Cavity Power Coupler

Brief history *see [J. Jacob & E. Montesinos, 12th ESLS RF meeeting'2008]*

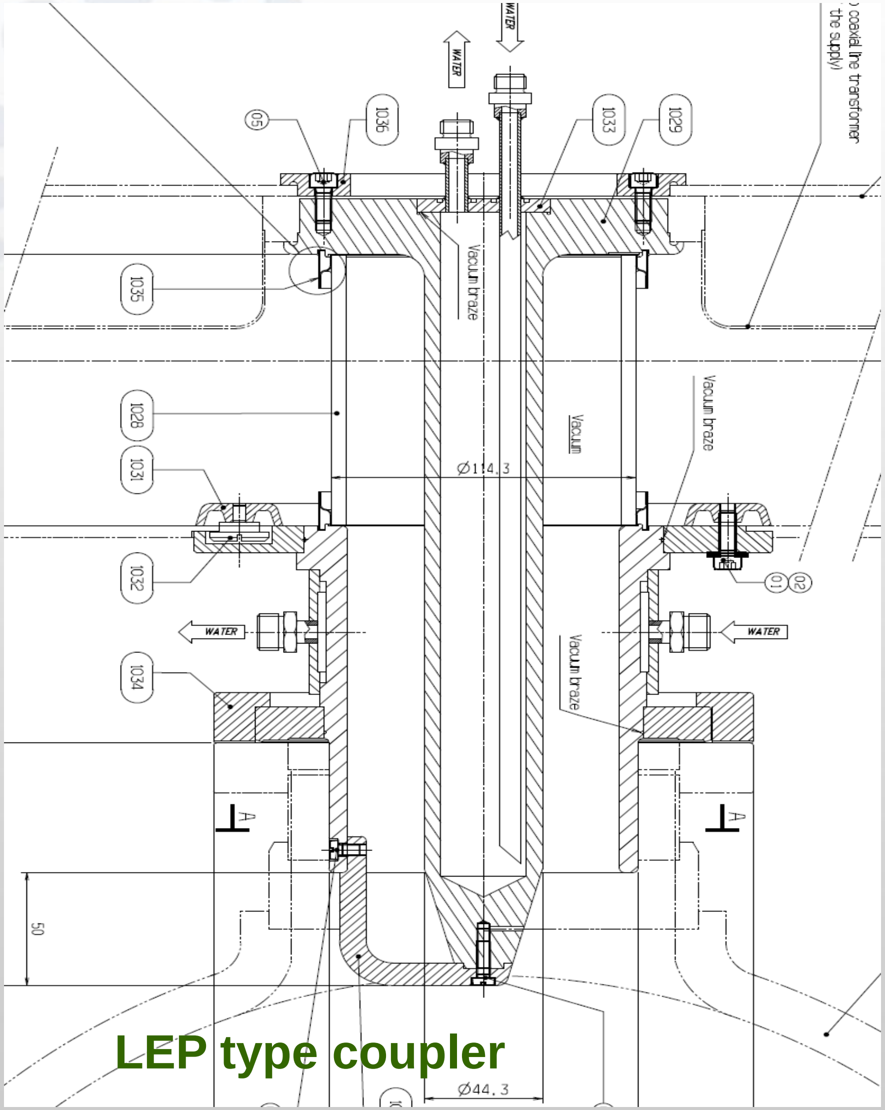
1. 2008: after 17 years of quiet operation, suddenly
   - ◊ 5 leaks the booster cavity windows
   - ◊ 1 ceramic metallization on SR cavity 5
   - ☞ Fortunately: 6 pre-conditioned couplers in house but critical situation !

2. With support from CERN
   - ◊ Application of improved RF conditioning algorithm developed for LHC
   - ◊ 20 times thicker anti-multipactor Ti-coating on 12 spare windows

3. Repair damaged couplers
   - ◊ 4 times: welding a new window (new coating)
   - ◊ 2 times: brazing a new window (also new coating)

4. Improve Vacuum on the booster cavities
   - ◊ Add NEG inserts on the ion pumps
   - ◊ Bake out applied for the first time during summer (so far only done on SR)

5. Since 2008:
   - ◊ 24 new LEP type windows from PMB
   - ◊ Order of 2 x 10 new LEP type couplers from FMB and RIAL, respectively



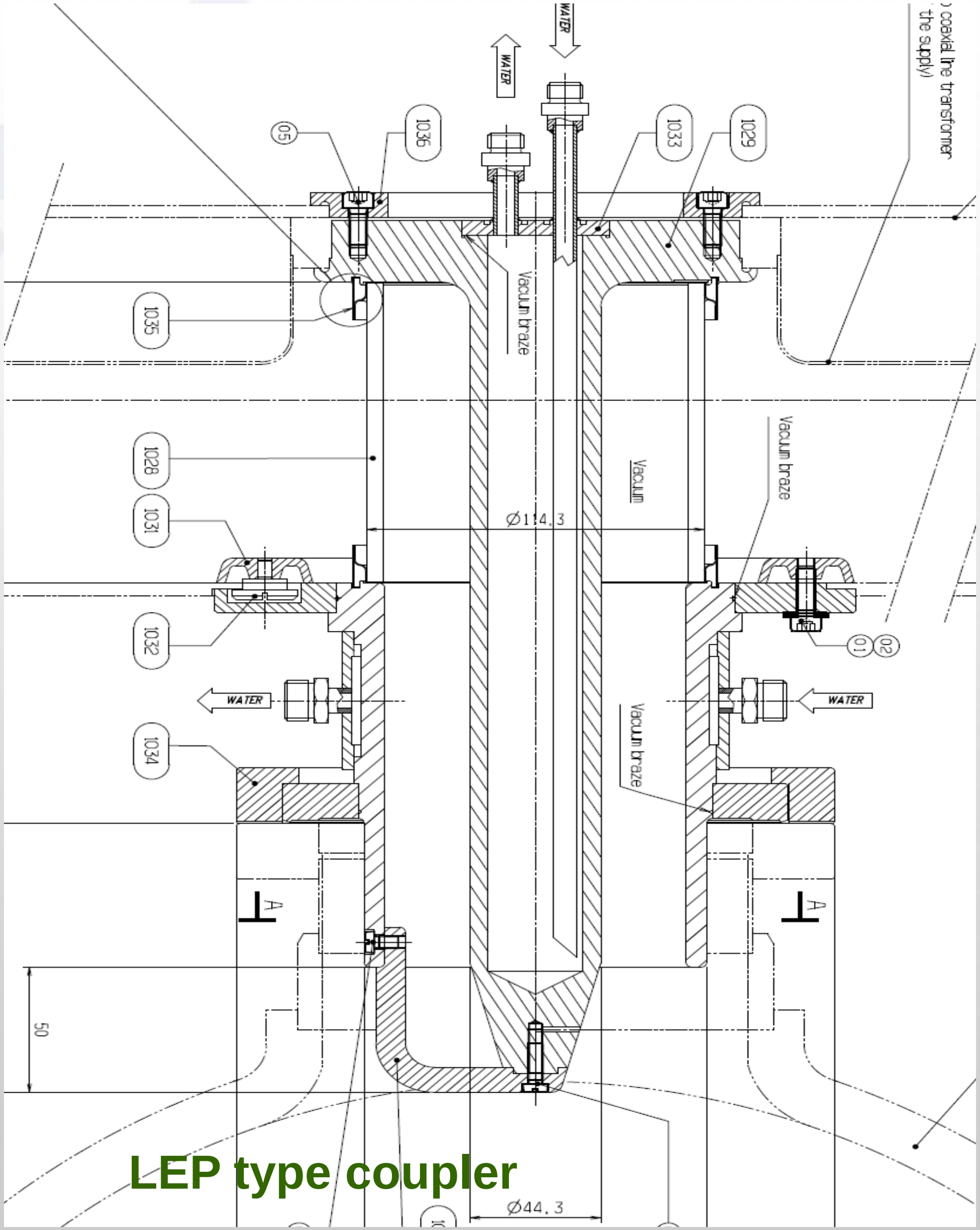
LEP type coupler

We learnt so far:

- Ceramic chemistry had to be re-established, know how gets lost with time
  - ☞ finally bare ceramics from Wesgo
- Brazing of kovar rings on windows:
  - ◊ brazing material preventing correct welding
  - ◊ 1st series: repair by hand milling
  - ◊ Then: brazing specification refined
- Problem of cleanliness during manufacturing
- Apply correct pressure during assembly weld
- We are now testing:
  - ◊ Removal of Copper oxide from a "dirty couplers" that was arcing by sulfamic acid: it conditioned well
  - ◊ Waiting for one coupler with electro-polished inner conductor: to be tested soon
- Conditioning further improved:

Essentially **standing** wave — Essentially **traveling** wave

- CERN Conditioning set up [Eric Montesinos] now rebuilt at ESRF using today's technology

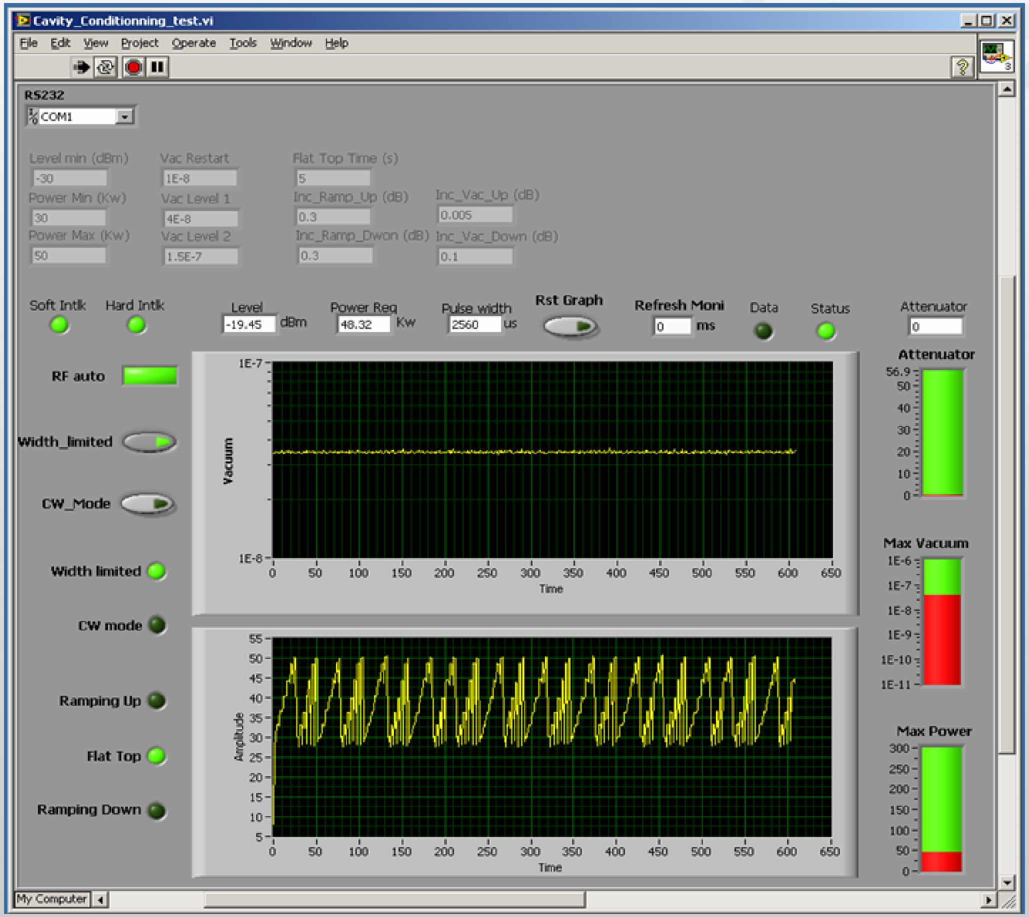


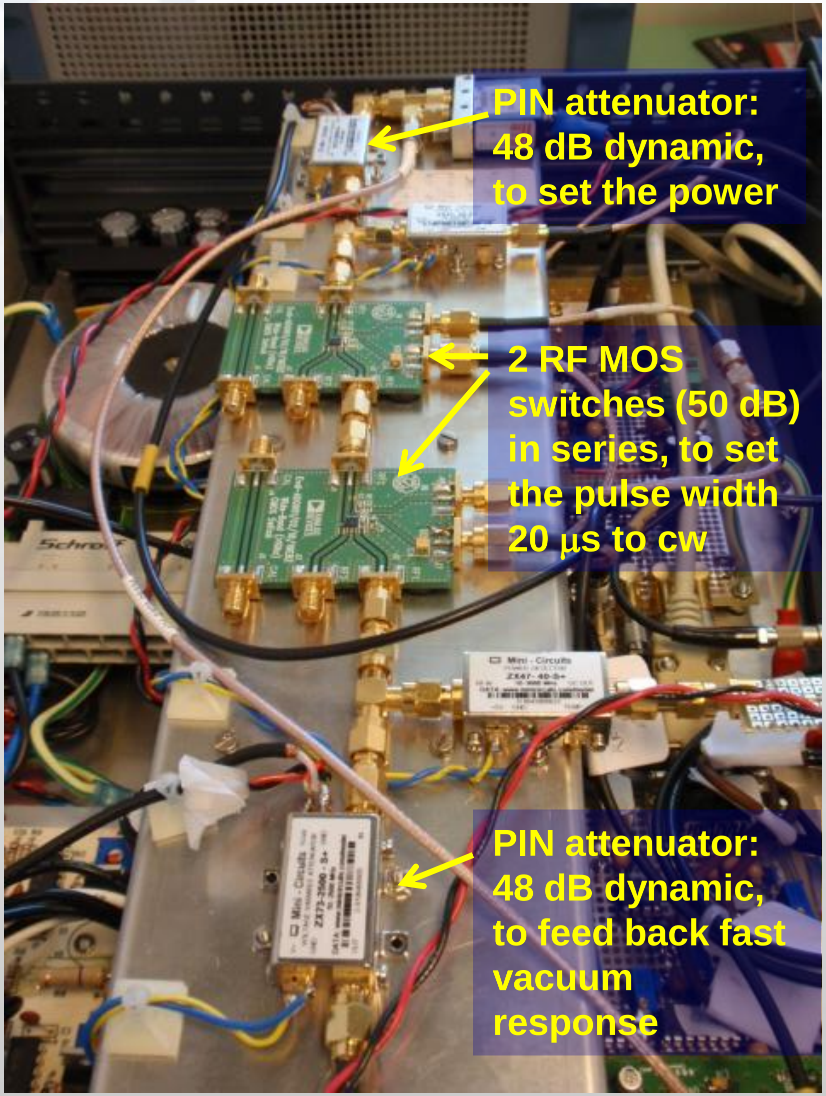
LEP type coupler

New conditioning set up (new ESRF hardware implementation of LHC system)

☞ design available to other labs, if interested.

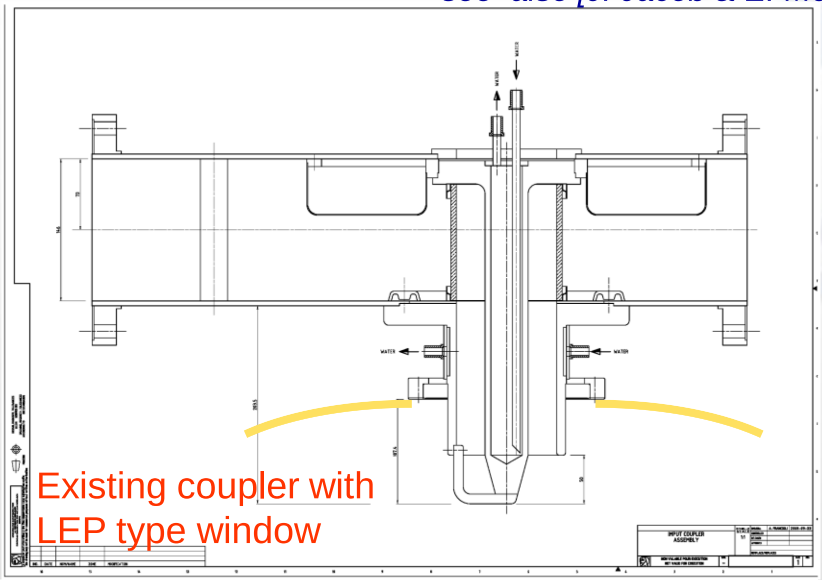
LabView control

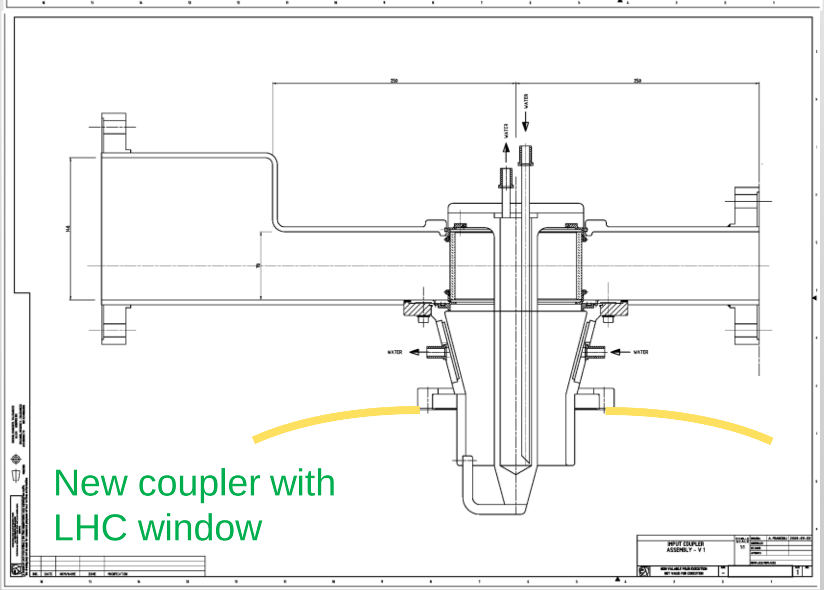


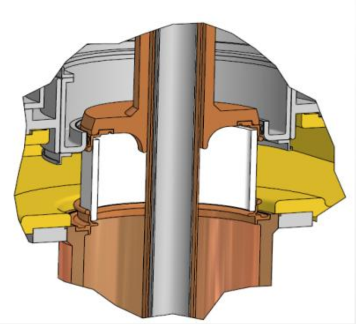


New coupler using LHC window - CERN-ESRF-SOLEIL collaboration

see also [J. Jacob & E. Montesinos, 12th ESLS RF meeeting'2008]







Reminder: LHC window directitly brazed into copper collars:
- ◊ No sharp edges
- ◊ Well defined current paths
- ☞ Sustains very high power: tested at 575 kW full reflection without damage

1. Develop couplers for ESRF and SOLEIL using LHC window to
   - ◊ Increase the power capability and improve the reliability
   - ◊ Obtain a new standard and high performance plattform for high power couplers
   - ◊ Electrical & mechanical compatibility with existing LEP coupler for both NC and SC applications
   - ◊ ESRF: 1 prototype for high power tests + 2 production prototypes
   - ◊ SOLEIL: 2 production prototypes
   - ◊ Including waveguide transformers

2. CERN's interest
   - ◊ Re-develop the brazing and subsequent electron beam welding in the CERN workshops
   - ◊ Safeguard specialized know-how and guarantee durability of this strategic component

3. Status
   - ◊ Successful ceramic / copper brazing at CERN (inspection of a cut sample)
   - ◊ Prototype expected in December 2010
   - ◊ Production prototypes for ESRF and SOLEIL in June 2011

Thank you for your attention !

ESRF Linac/Injection-Extraction/RF Group