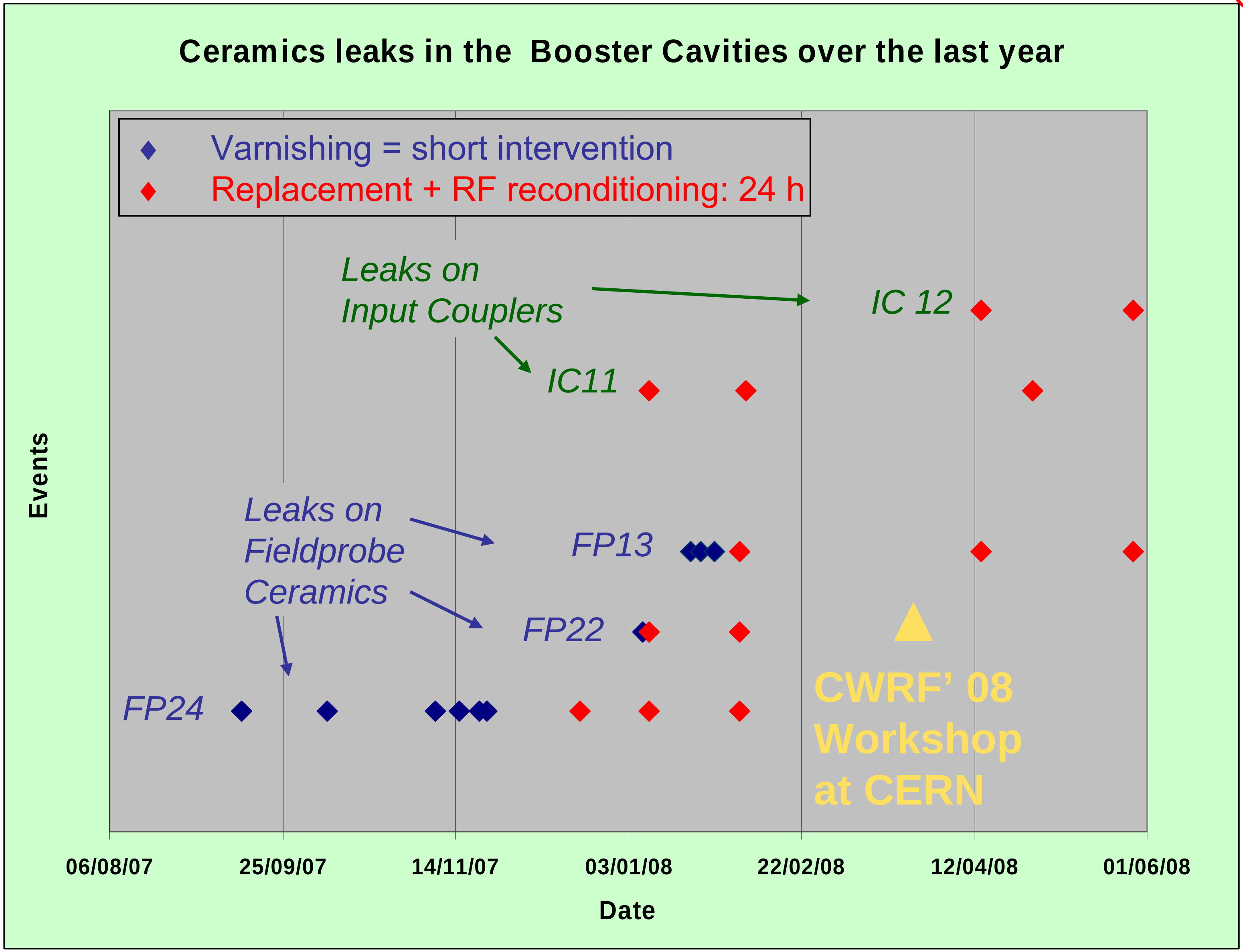
Status of the ESRF RF System

- Repeated **Ceramic Leaks** on the Existing Cavities
- Preparation of the Ambitious **RF Upgrade**

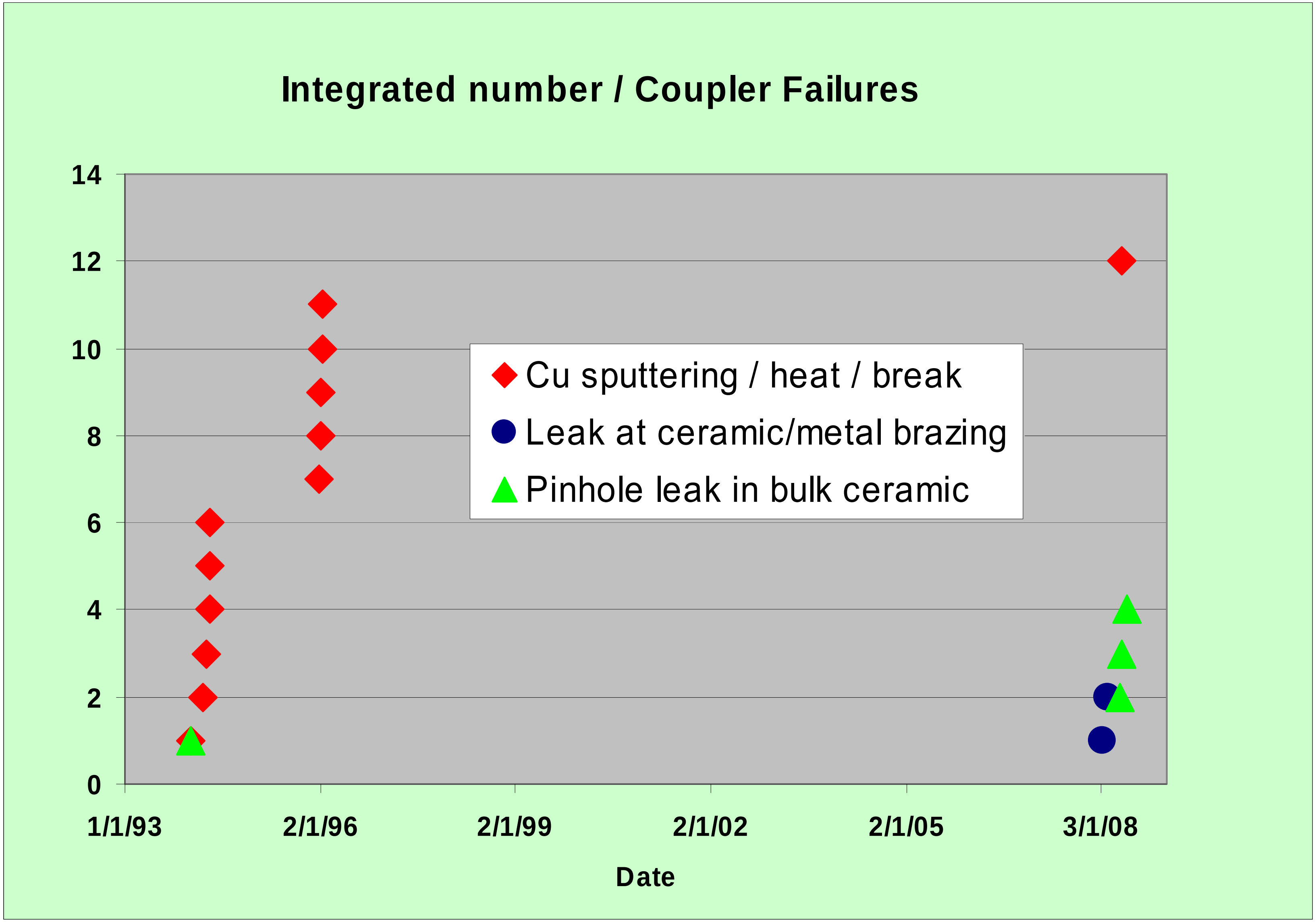
J. Jacob & E. Montesinos (ESRF - CERN)
on behalf of all our colleagues

12th ESLS RF meeting
Diamond, 1st-2nd October, 2008

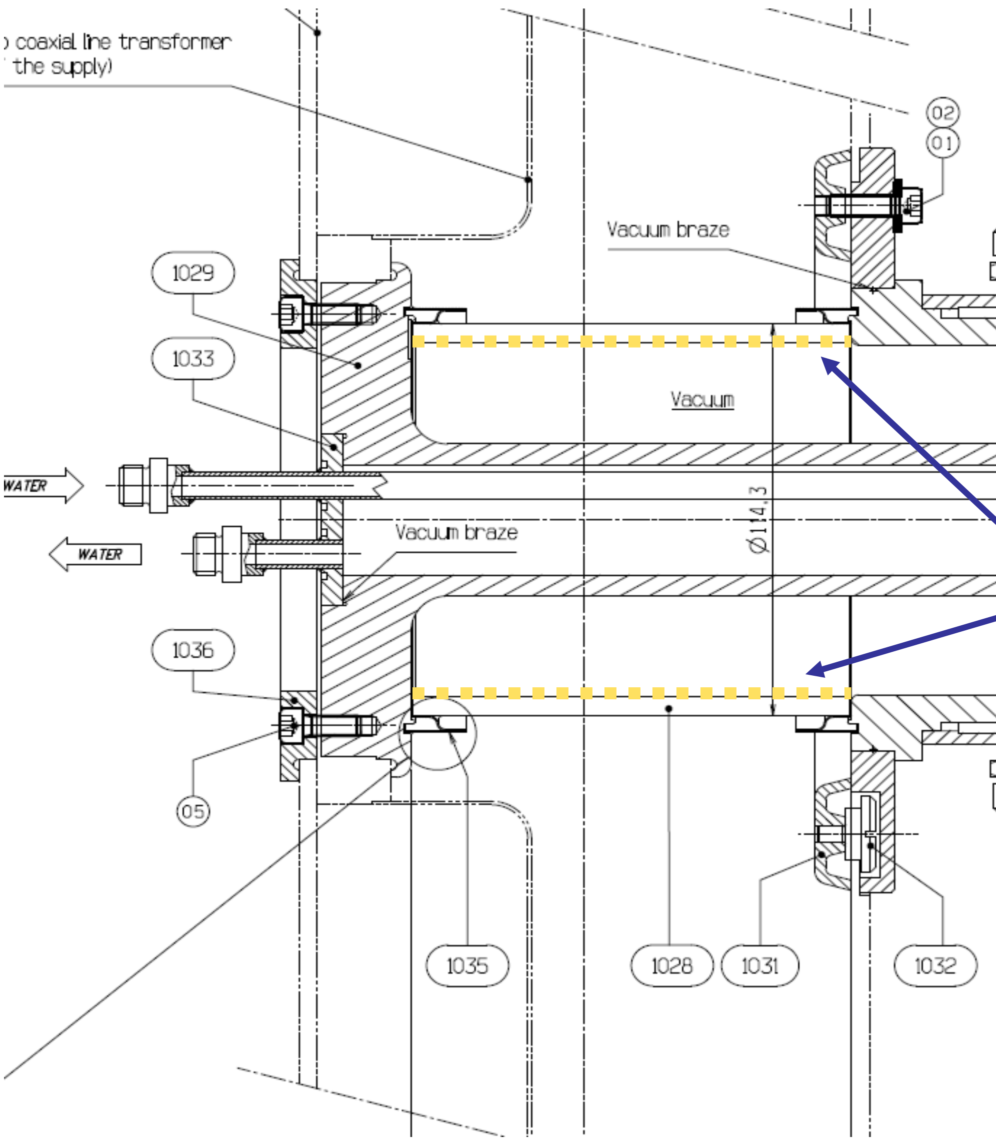
Ceramic Leaks



History of Coupler Failures



ESRF = LEP coupler



In the 1994-96's:

Window failures after accidental metallization:

RF power + bad Vacuum

⇓

Glow discharge

⇓

Sputtering of Copper

⇓

Heating + eventually breaking

Successful solution:

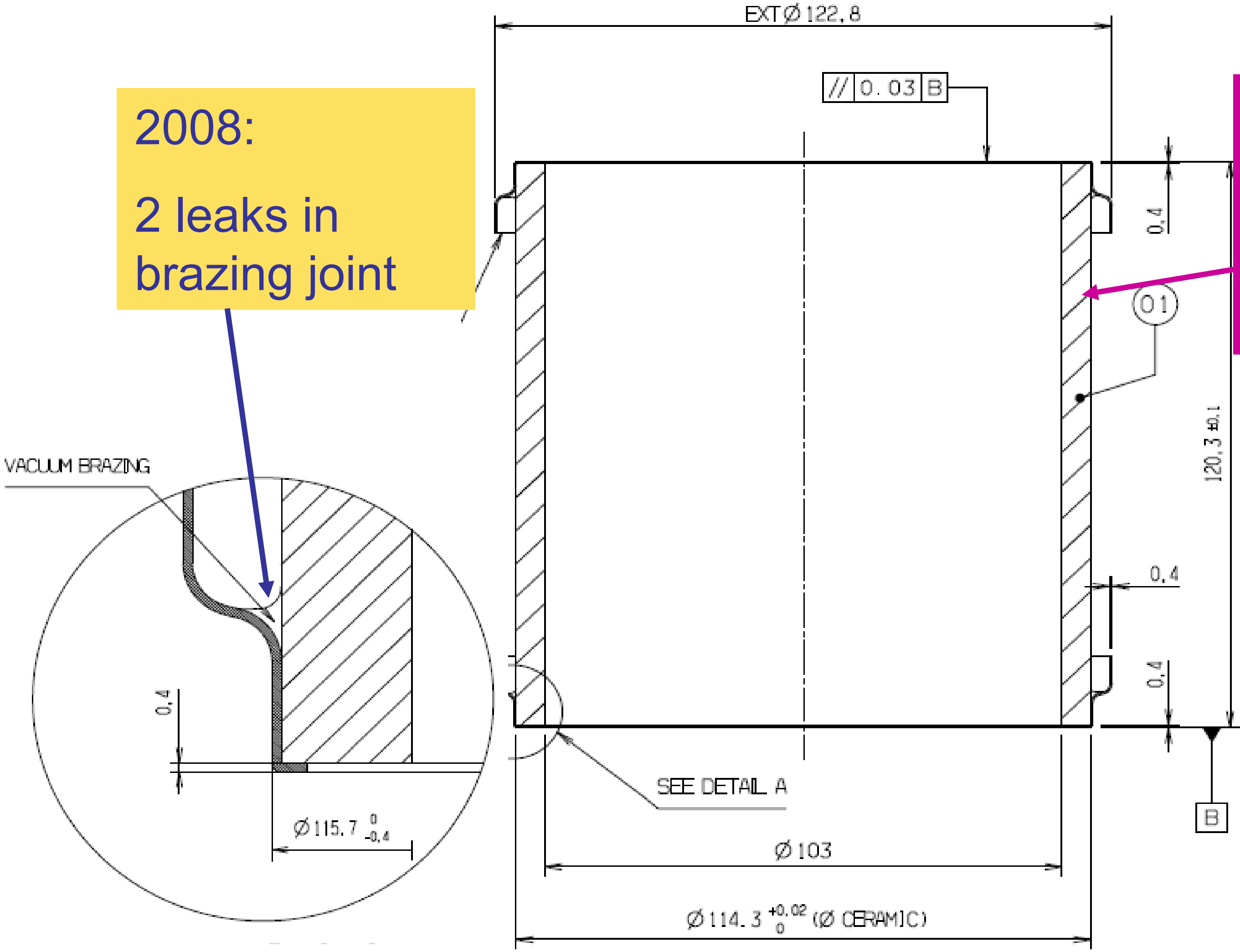
- Fast vacuum interlock
- Fast light detection (CCD)

⇒ to cut the RF and the sputtering process

Ceramic window

2008:

2 leaks in brazing joint



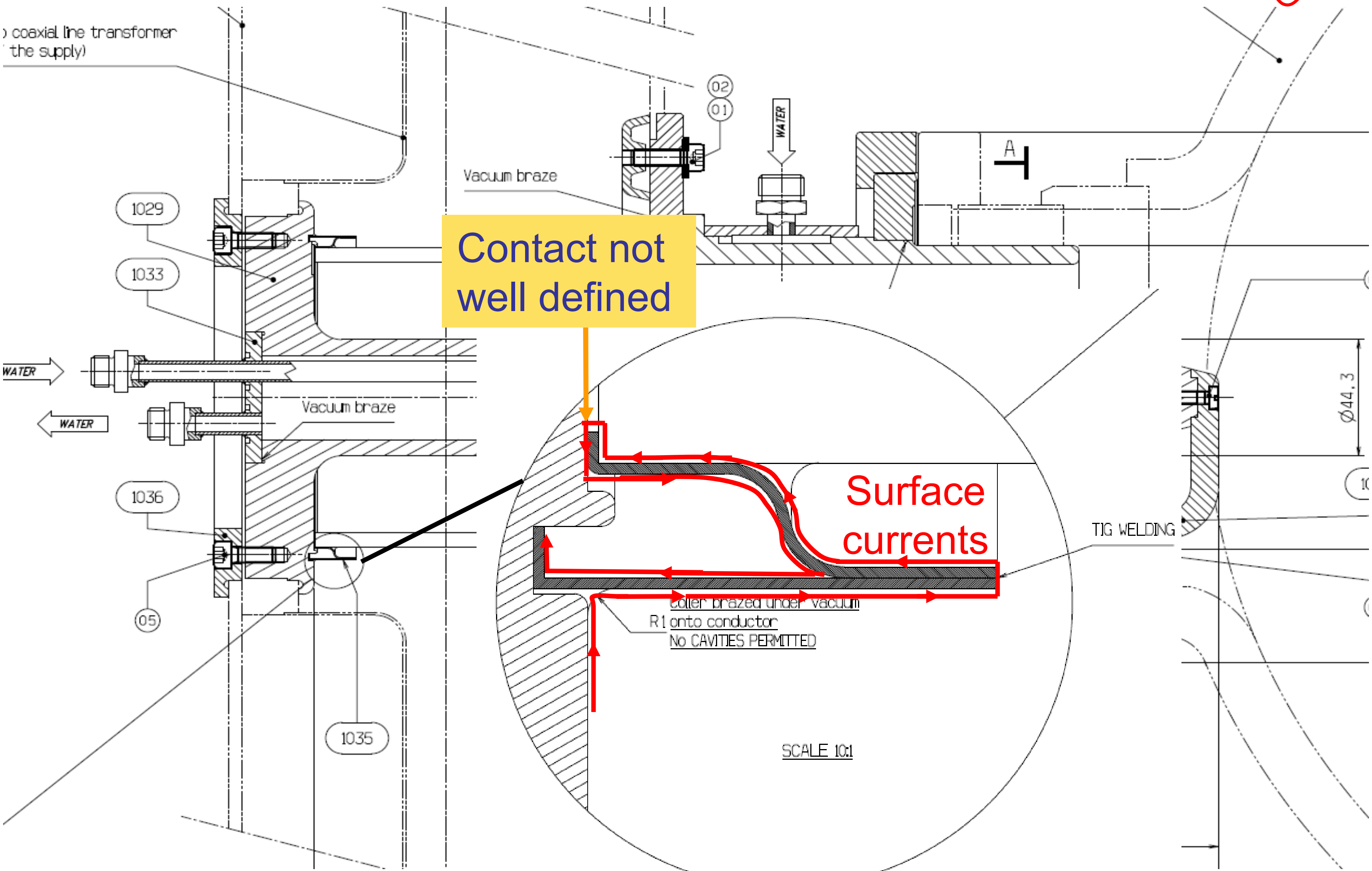
2008:

3 pinhole leaks in the bulk of the ceramics

Similar problems also last year:

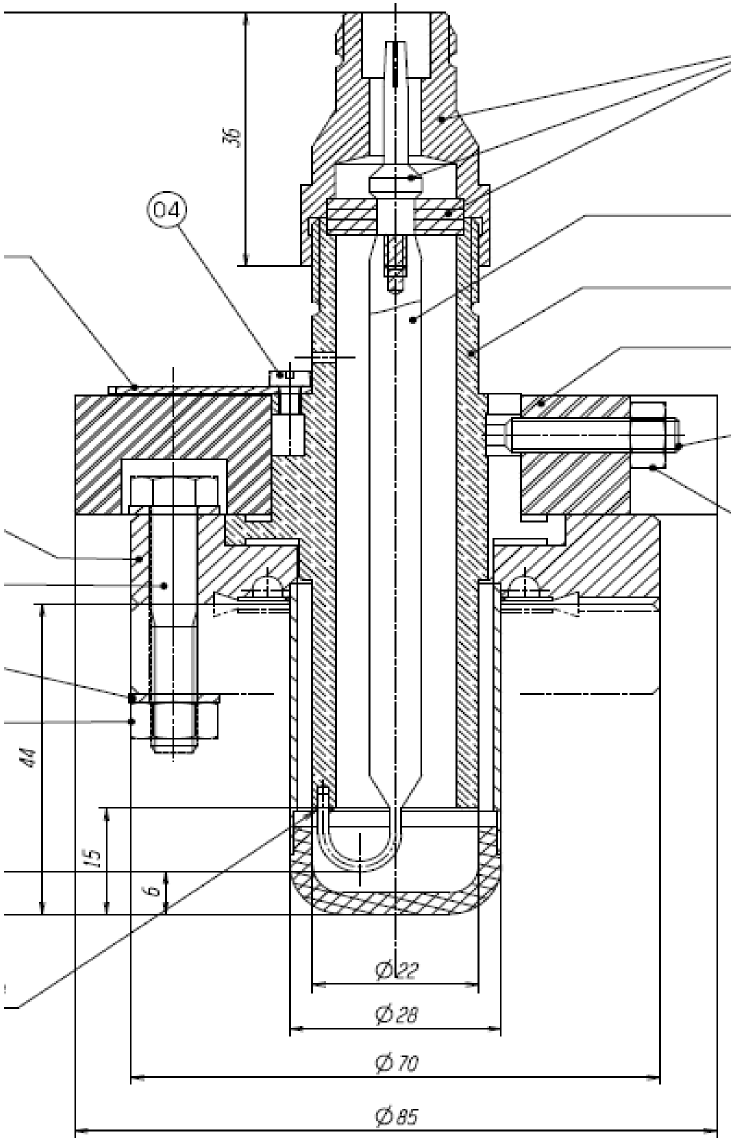
- at APS
- at one large tube manufacturer

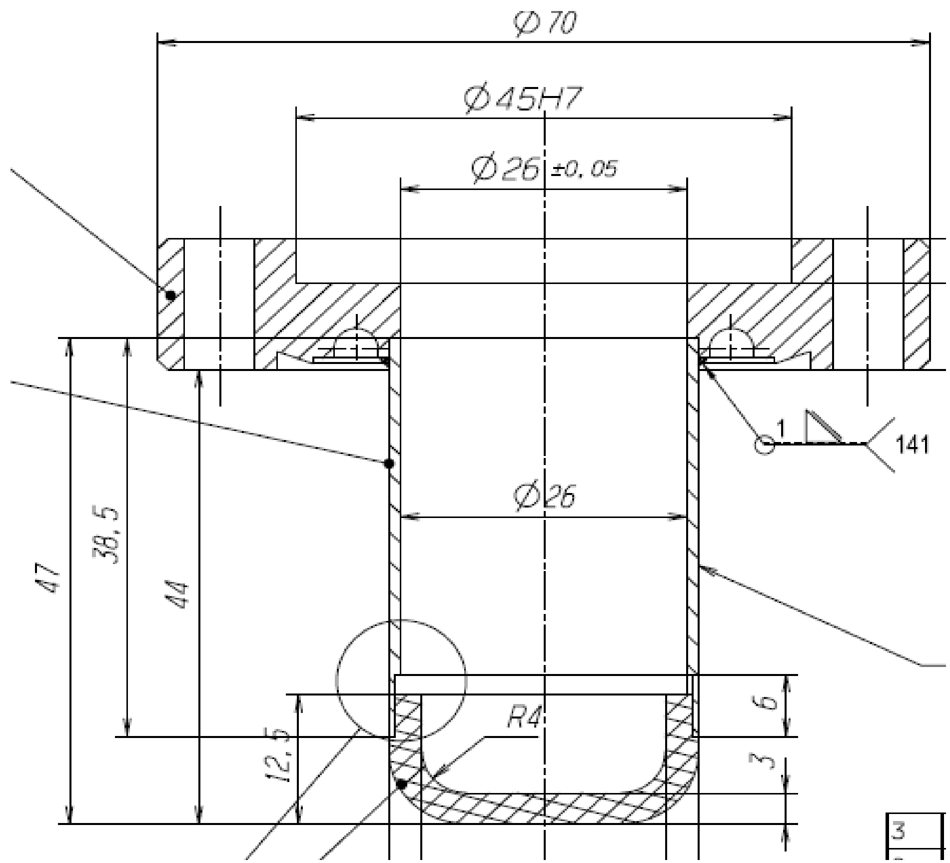
Weak point



coaxial line transformer
the supply)
Vacuum braze
02
01
WATER
A
1029
1033
WATER
WATER
Vacuum braze
1036
05
1035
Contact not well defined
Surface currents
Collar brazed under vacuum
R1 onto conductor
No CAVITIES PERMITTED
SCALE 10:1
TIG WELDING
Ø44,3

Field probe / Feedthrough





Short term measures

1. Fortunately still enough spares in house:
   - 10 field probe feedthroughs
   - 6 pre-conditioned couplers
   - 13 ceramic windows
   - Some unconditioned couplers

2. With the support from CERN (thanks also to information exchange at CWRF'2008):
   - Application of the improved RF conditioning algorithm developed for LHC (using CERN Hardware)
   - 20 times thicker anti-multipactor Ti coating on 12 spare windows (done at CERN)

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)
   - 20 nm Ti coating on field probe ceramics (as suggested by D. Horan / APS)

RESULT:

Points 2, 3, 4 applied on SY cavity #1 at last summer shut down

→ so far = success: excellent vacuum behaviour

5. SEM analysis of ceramics: no large difference was detected between long lasting and short lasting ceramics

6. To safeguard operation:
   - Order of 24 new LEP type windows from PMB, for the fabrication of 20 new LEP type couplers,
   - Order of 50 new fieldprobe feedthroughs

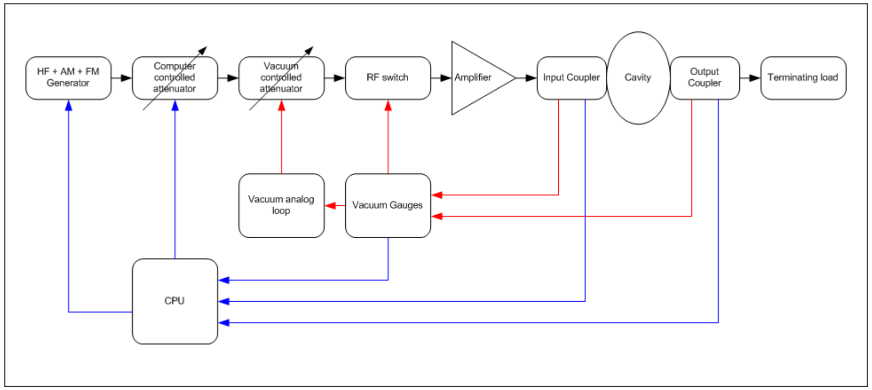
7. Collaboration CERN-ESRF for a new coupler
   - Adaptation of the high power LHC window to the LEP coupler

RF conditioning / CERN procedure

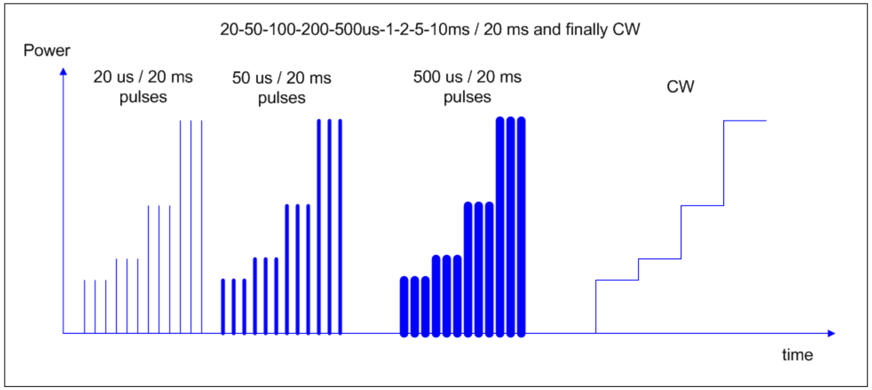
Automated conditioning system

- RF is never applied if pressure exceeds 1.0 x10^{-7} mbar.
- Process always starts with very short pulses of 20 µs every 20 ms.
- Power level is increased with short pulses up to full power, passing slowly through all power levels.
- Finally, restart the same process from low power level with longer pulses.

- This principle has been used with success since 1999 for several couplers such as the SPS 200 MHz and LHC 400 MHz coupler conditioning.
- This process is now also used with ***ESRF*** and ***SOLEIL*** couplers.



Principle of the conditioning system :
- An analog loop always looks at the vacuum
- A digital vacuum controlled loop increases the power



- Always starting with short pulses
- Steady increase in power
- Cycles with increased length of the pulses

Long Term: New ESRF coupler based on LHC design

LHC power coupler:

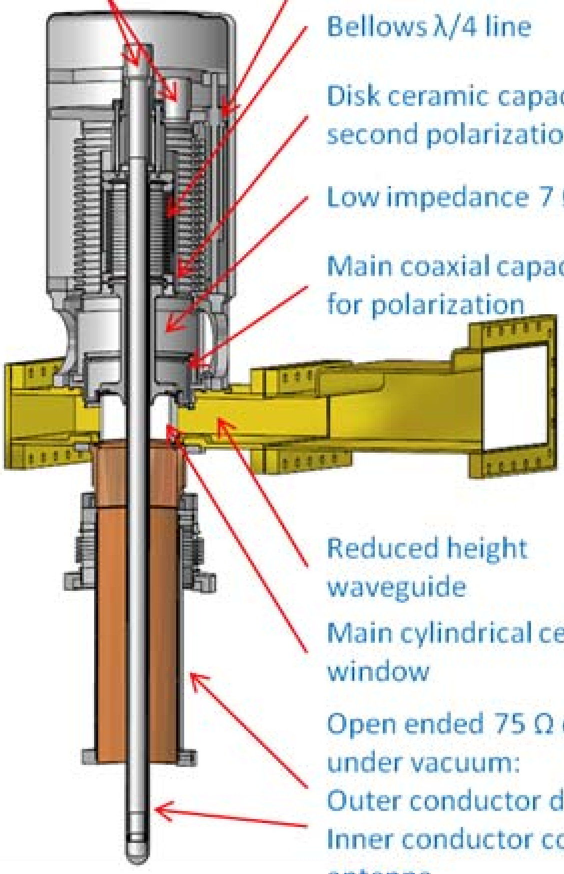
- 400 MHz **mobile** RF power coupler with very high power requirements :
- Continuous : **250 kW**
- Pulsed : 300 kW fwd + 670 kW rev, including beam loading, i.e. **1.85 MW local peak power.**

Challenge

- To design a **mobile RF power coupler without sliding contacts** for these very high power levels.

Main design features

- A Cylindrical ceramic window with **solid copper rings brazed** to the ceramic ends, placed in the waveguide-to-coaxial transformer, provides vacuum integrity.
- A **Reduced height waveguide** directly provides matching to the coaxial line, **avoiding the usual "doorknob".**
- Air cooling is provided on the window and other critical elements of the coupler.
- A **Vacuum gauge** is located **close to the window** and is used for coupler conditioning and interlock.



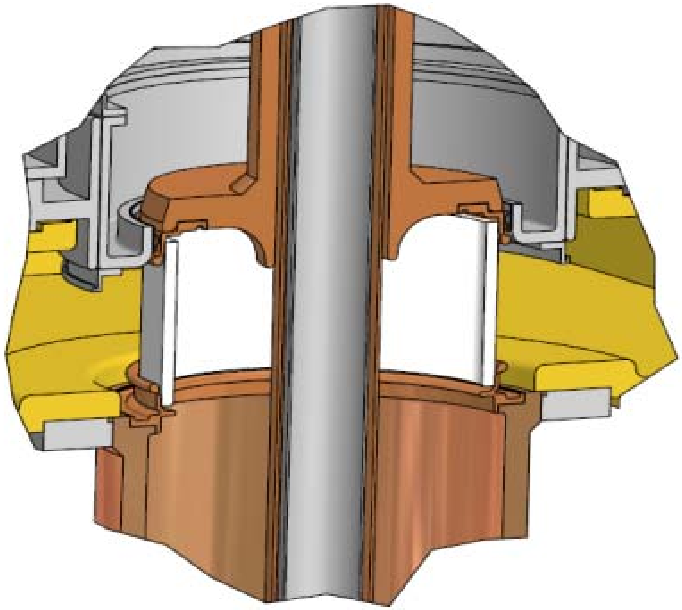
LHC main window

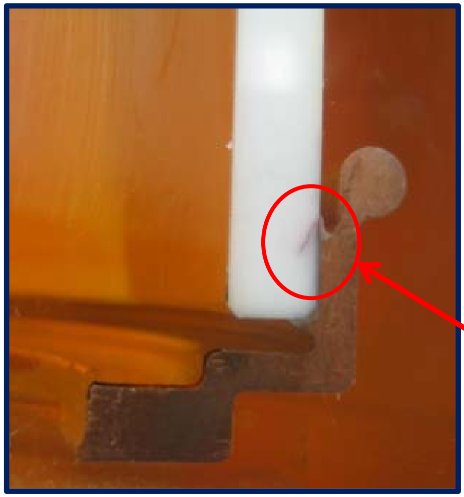
Designing the coupler

• Every coupler components was carefully studied in detail, simulated and tested, ***from the simple screw*** to the ***specially forged copper***.

• The ***main ceramic*** proved extremely challenging in fabrication, major problems with semi-cracks developing with time.

• The final design was obtained after many versions and more than ***six years*** studying different ways to braze the plain copper rings to the ceramic.





To find a developing crack masked by a copper ring in a ceramic :

clean the ceramic, paint it with colorized leak detection ultra fluid, clean it again, mould it, cut it.

Coloured cracks are those ***originally present***, ***un-coloured cracks*** are those induced by ***cutting process***.

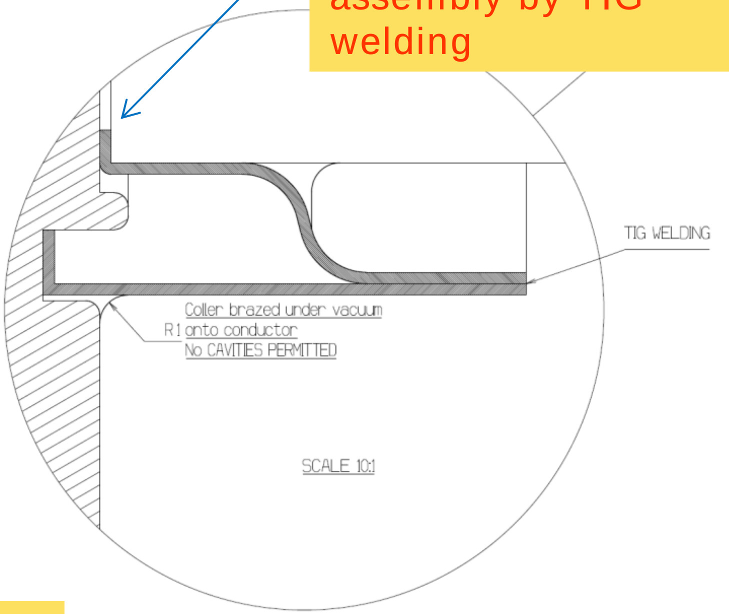
Comparison LEP / LHC window constructions

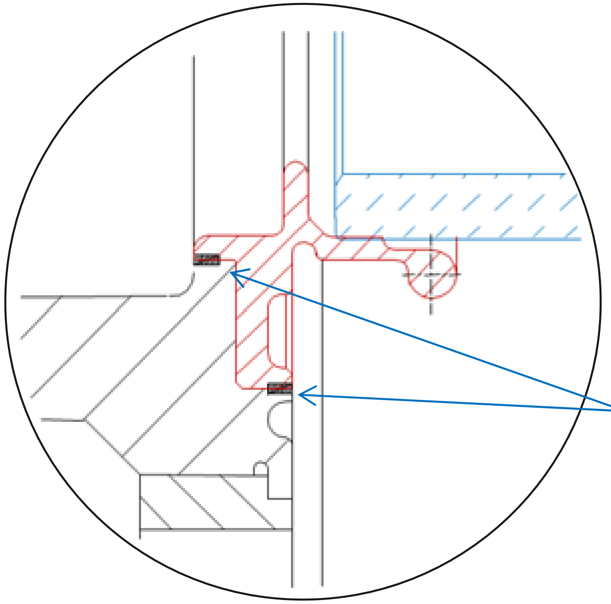
Improvements of LHC window compare to LEP design:

- Very well designed massive copper collars instead of kovar sheet :
  - ➢ Less losses, much more power capability
  - ➢ Metallic continuity, avoiding RF contact made by kovar compressed while TIG soldered
- Improved Titanium sputtering
- Wave guide without doorknob for less arcing

LEP kovar collars

RF contact only via compression during assembly by TIG welding



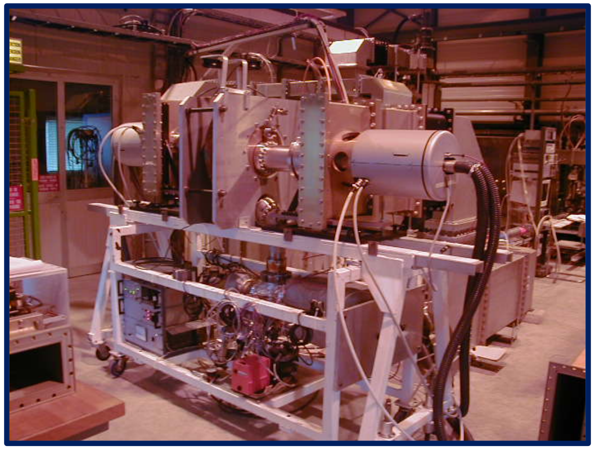


LHC copper collars
Directly EB welded

Metallic continuity

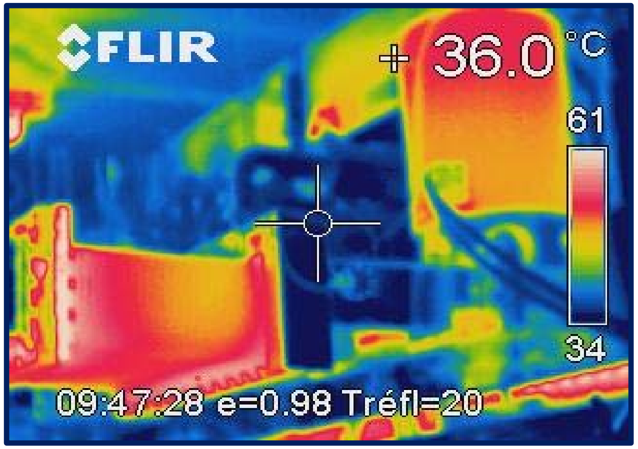
LHC windows: power test results

- Finally, powers up to ***575 kW cw full reflection* were achieved *for some hours*** at 400 MHz (Local peak power equivalent of ***2.3 MW)***
- All our test area equipment was at its limits, the waveguides ***heated up to 70 °C***, but the copper couplers worked perfectly
- We also tested ***one LHC and one LEP coupler together*** up to ***500 kW cw full reflection*** : the ***LEP coupler*** test stopped after several minutes due to ***over heating***.



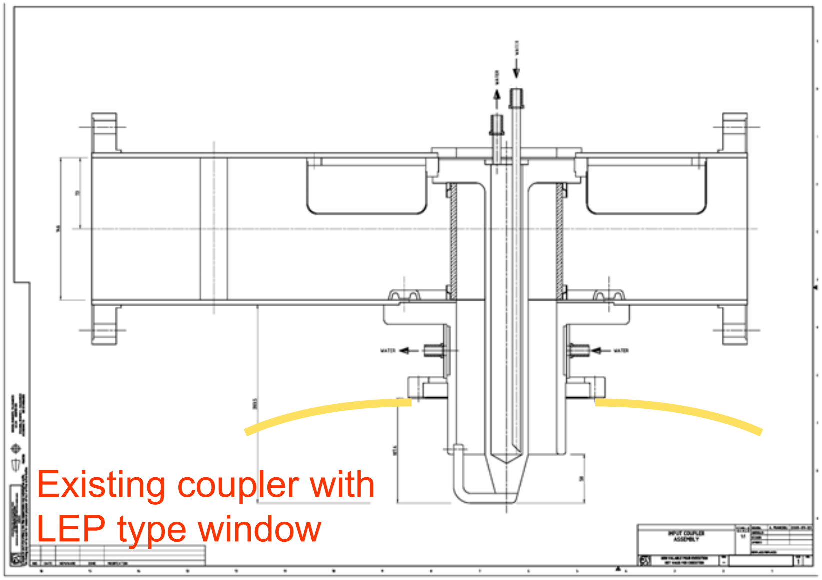
Two couplers face to face through the test cavity

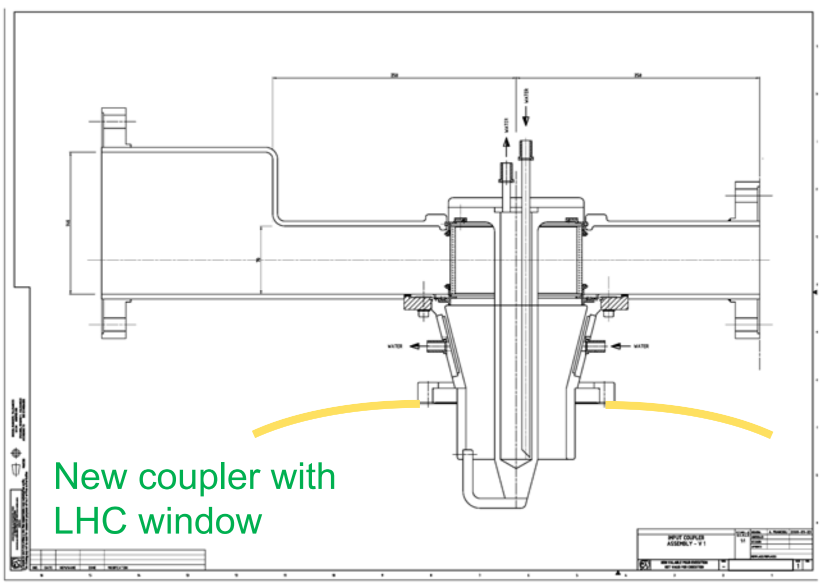
LEP kovar based coupler overheated



Wave guide system at its upper thermal limit

New ESRF coupler with LHC window



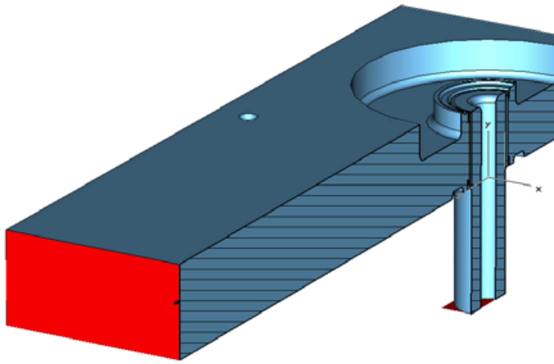


CERN – ESRF collaboration :

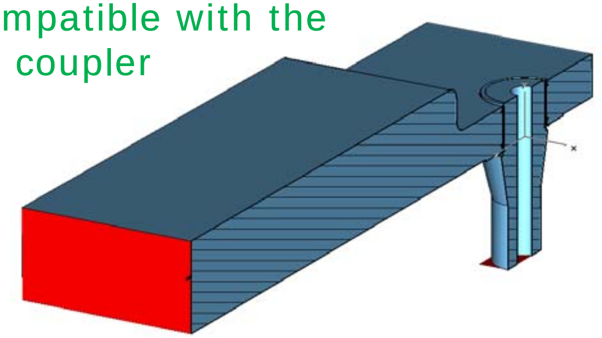
- Adapt ESRF-LEP type coupler to LHC window
- Full electrical and mechanical compatibility with the existing coupler
- No need to change any waveguide
- One ceramic available for tests
- One new coupler already under study
- CERN Main Workshop ready to make the brazing and Electron Beam soldering of the lines (previously done by VERELEC Deutsch Company)

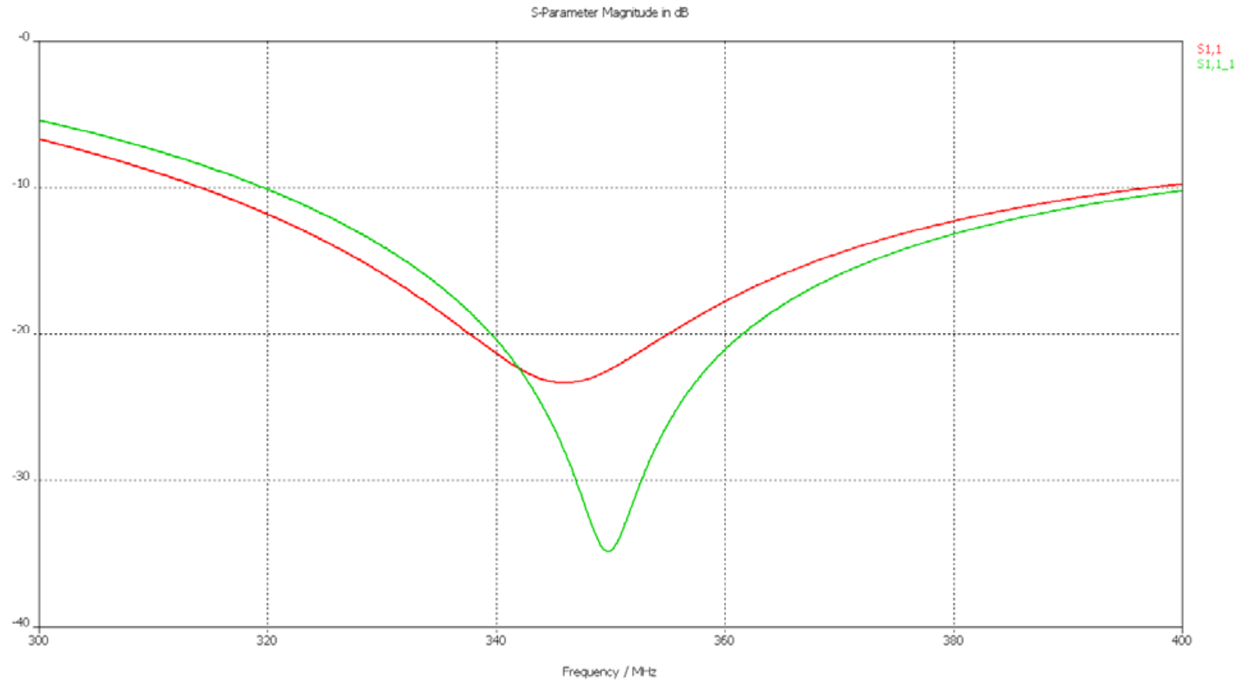
New ESRF coupler with LHC window

ESRF coupler study:
- LHC ceramic
- Matching without doorknob
- Fully compatible with the existing coupler



Existing ESRF coupler:
- LEP kovar/ceramic
- Matching with doorknob



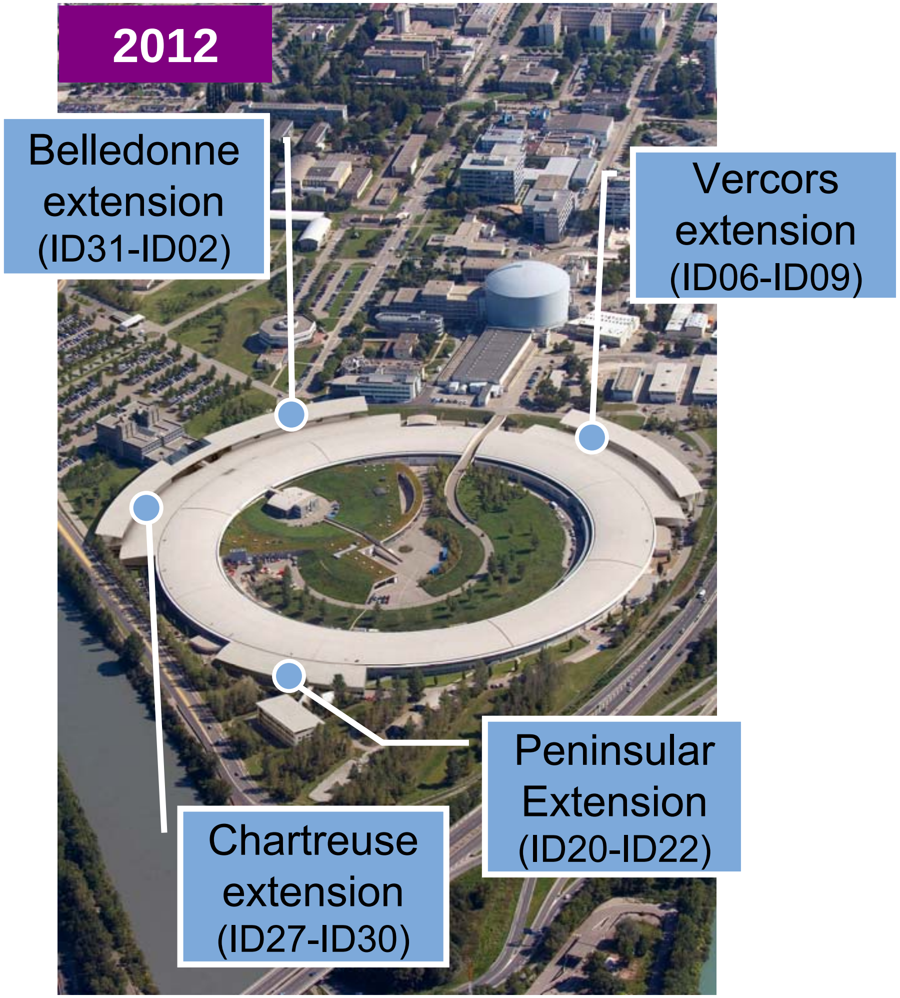


RF Coupler R&D ☞ Impact on RF community

- Coupler R&D recognized as central subject for years
- **CERN – ESRF collaboration:**
  - Window design was very demanding, successfully done by CERN
  - Very powerful coupler, @ 400 MHz, more than 500 kW CW full reflection, i.e. more than 2.0 MW peak power
  - Can be adapted to 352 MHz system, and other frequencies
- Could become a **standardized component** for several places
- **We would like to collaborate with others!**

ESRF upgrade for coming 10 years

- Science oriented ESRF upgrade
  - Reconstruction of X-ray beam lines
  - Extension of the experimental hall, new labs and offices ⇒ +30% increase in building surface
  - Nano science → creation of up to 130 m long beam lines
- Accelerator – upgrade
  - Current increase from 200 mA to 300 mA, R&D for 500 mA
  - Lattice modification for longer ID straights: 5 m → 7 m
  - Top up for few bunch operation / high I_{bunch} ⇔ short lifetime
  - Vertical emittance reduction ε_z : 25 → 10 pm
  - Equipment upgrade for performance increase and to strengthen durability
  - **Substantial RF upgrade for stable and safe operation at 300 mA**
    - ◊ **HOM damped cavities**
    - ◊ **Solid state amplifiers**



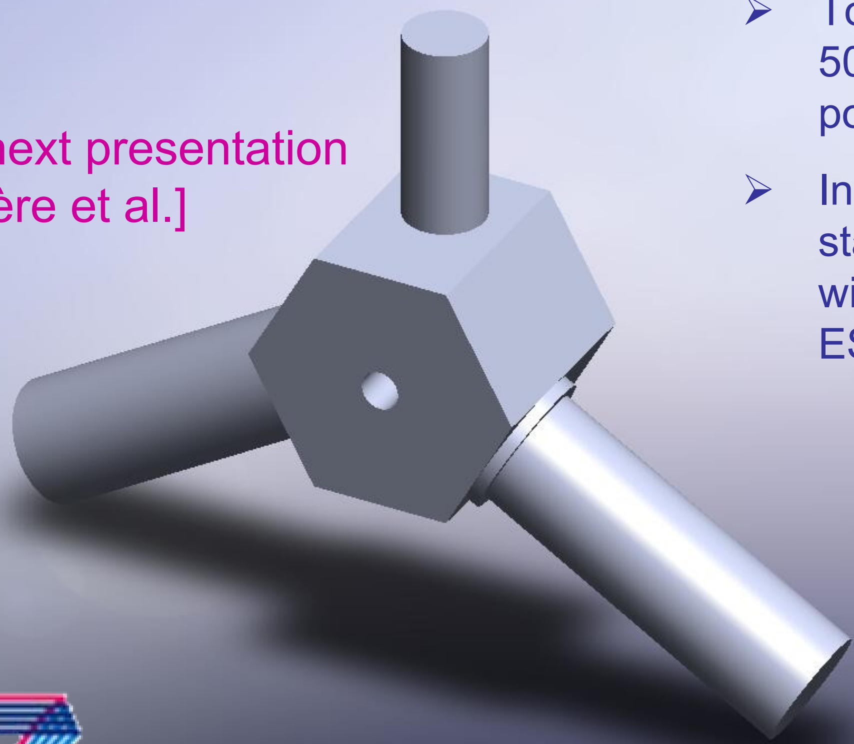
Planned RF upgrade / coming 8 years

- Replacement of all 6 SR five-cell cavities with 6 x 3 new single cell HOM damped cavities
- 9 MV / 300 mA with 18 cavities at 115 to 130 kW
- 18 solid state amplifiers for the SR
  - 150 kW per amplifier
  - Modularity → Currents above 300 mA will be possible by adding amplifier modules
- 4 solid state amplifiers for the two booster cavities
  - 2 cavities x 2 input couplers/cavity
  - Can be switched ON/OFF within 10 seconds: better adapted to frequent top up operation than klystrons
  - 150 kW per amplifier

HOM damped single cell cavities

- Specified for:
  - Planned 300 mA upgrade of the ESRF
  - To allow a maximum of 500 mA in terms of power
  - Inconditional HOM stability up to 1000 mA with 18 cavities at the ESRF

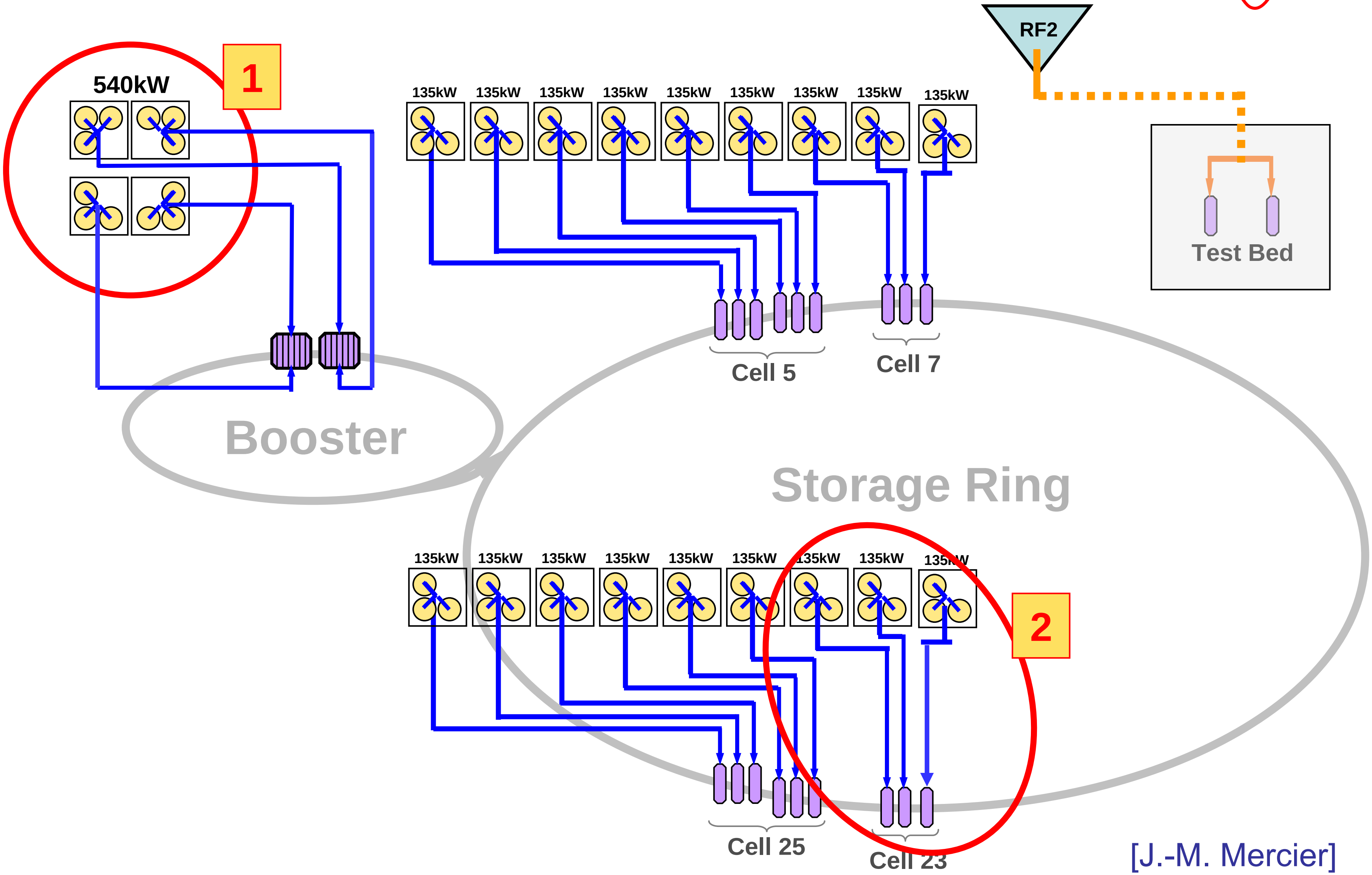
For details see next presentation [V. Serrière et al.]



Based on BESSY, MLS, ALBA design

[E. Weihreter et al.]

Overview RF upgrade – new cavities and SSA



[J.-M. Mercier]

Upgrade planning

Solid state amplifiers - SSA

- July 2008: Pre-qualification exercise issued for
  - 4 x 150 kW for the booster
  - 3 x 150 kW for the 3 first HOM damped cavities in cell 23
- 3rd October 2008: opening of replies
- November 2008: expected official agreement to Upgrade by ESRF council
- December 2008: call for tender for SSA
- July 2011: delivery of booster system
- Early 2012: delivery of SSA for new RF section in SR-cell23
- Mid 2012: installation on the machine and connexion to 3 new cavities
- Option for further SSA

Single cell HOM damped cavities

- R&D project partly funded from the EU within the FP7 grant agreement
  - Early 2008: recruitment of 2 Post Docs: A. Triantafyllou & A. Bandyopadhyay
- Today: design almost ready
- End of 2008: Validation with an aluminum model
- Early 2009: call for tender for 1 copper prototype
- Mid 2010: prototype delivery and power tests with RF and, if possible, with beam
- Call for tender for 19 cavities
- Early 2012: delivery of first 3 series cavities for new RF section in cell 23
- Mid 2012: installation on the machine

Thank you for your attention !