

20th ESLS RF Meeting - PSI
Villigen, 16 – 17 November 2016

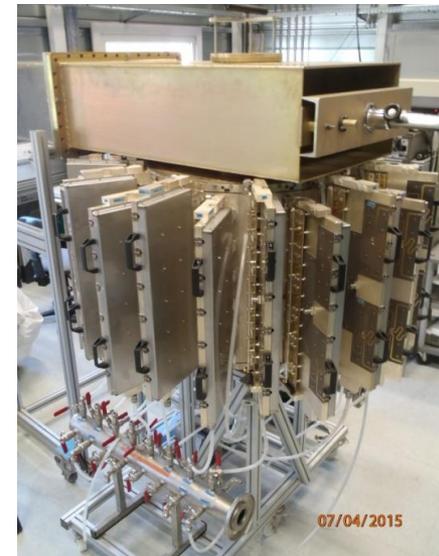
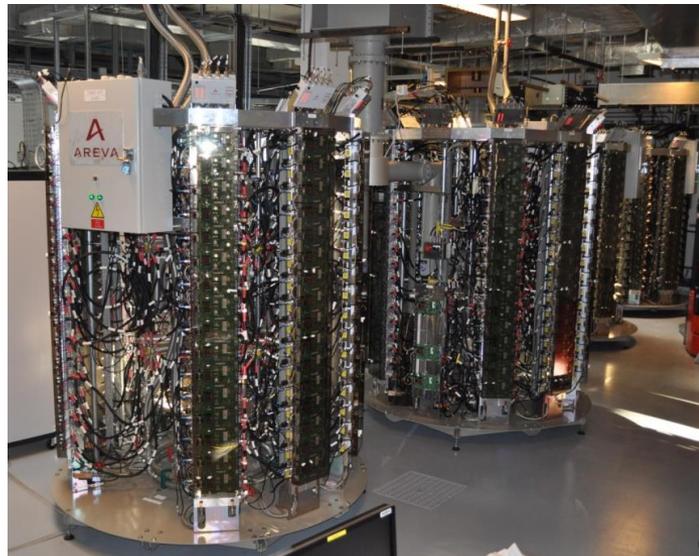
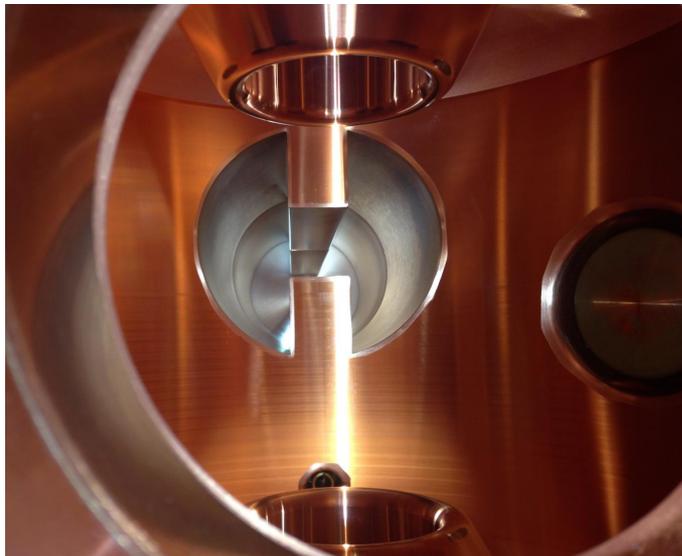
**Status of RF operation and RF upgrade
for the future Extrremely Brilliant Source (EBS) at the ESRF**

Jörn Jacob

On behalf of the ESRF RF Group



The European Synchrotron

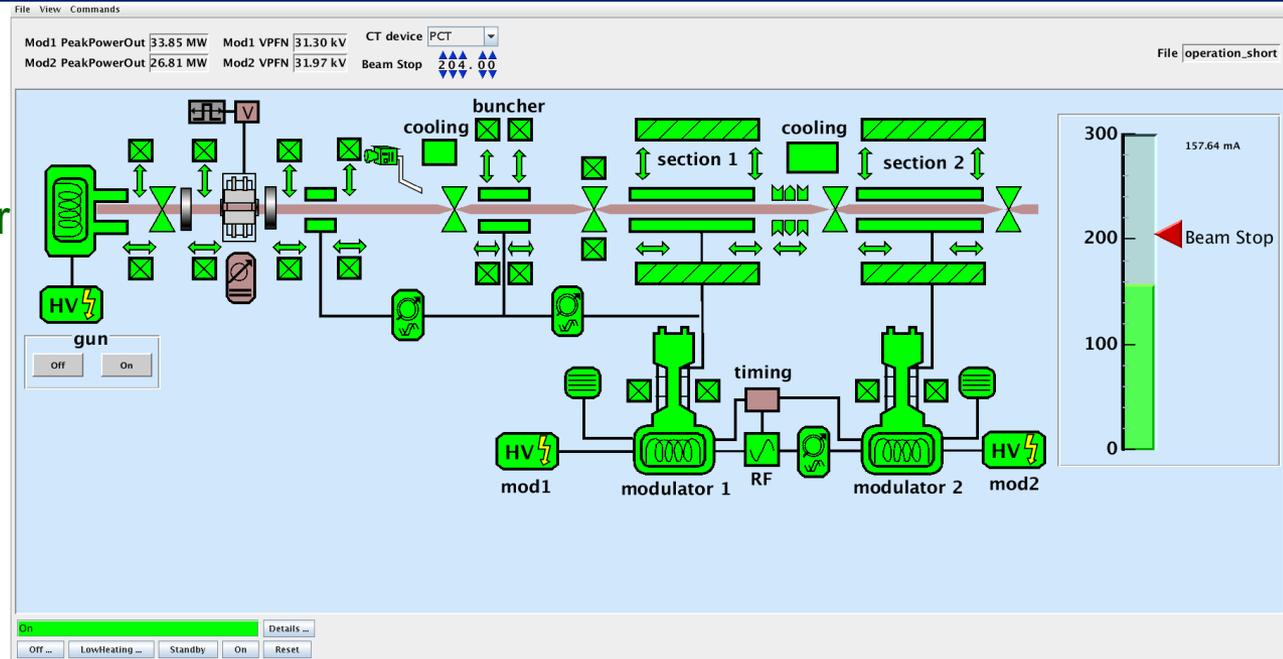


- **Linac upgrade**
- **Booster RF upgrade**
- **Storage Ring RF operation statistics**
 - MTBF / Downtime
 - Tentative comparison Klystron / SSA
- **RF upgrade for future ESRF-EBS**
 - RF design and main parameters (Reminder from ESLS RF 2015)
 - HOM Damped Cavities – procurement / RF conditioning
 - Waveguide run
 - Transmitter control upgrade

S-BAND LINAC UPGRADE: ALMOST COMPLETED

DONE:

- ✓ New gun
- ✓ New 3 GHz pre-buncher
- ✓ New buncher
(old one = spare)
- ✓ Various refurbishments
(PS's, ...)



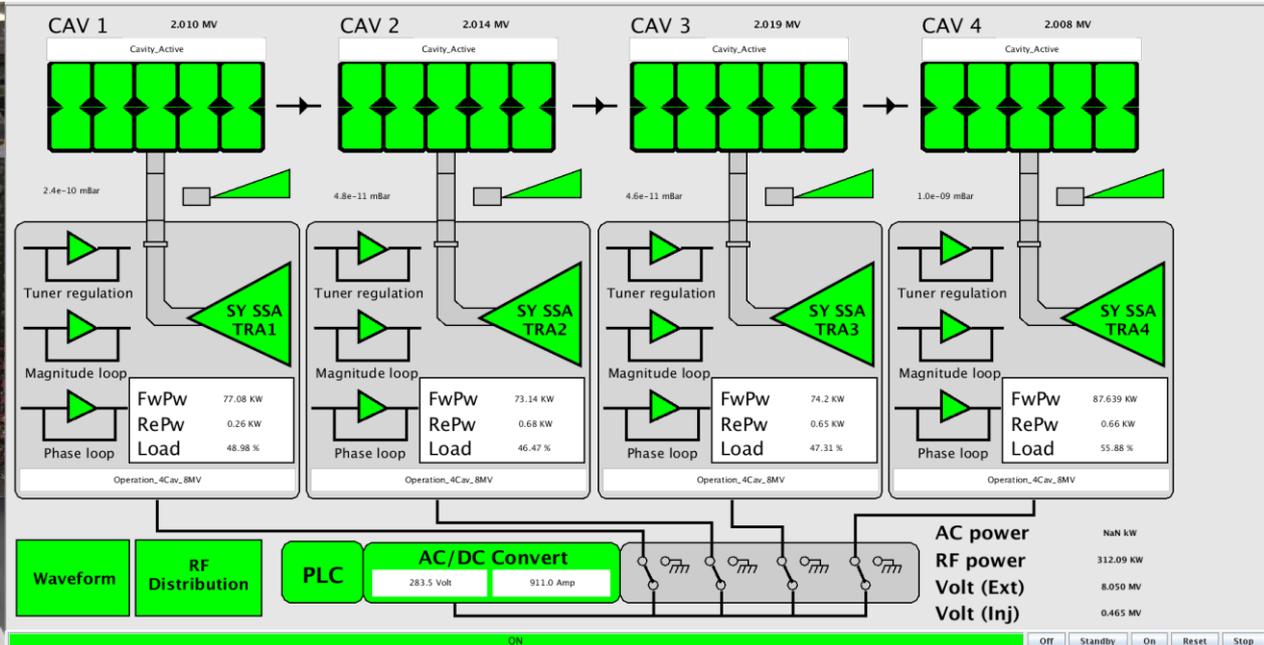
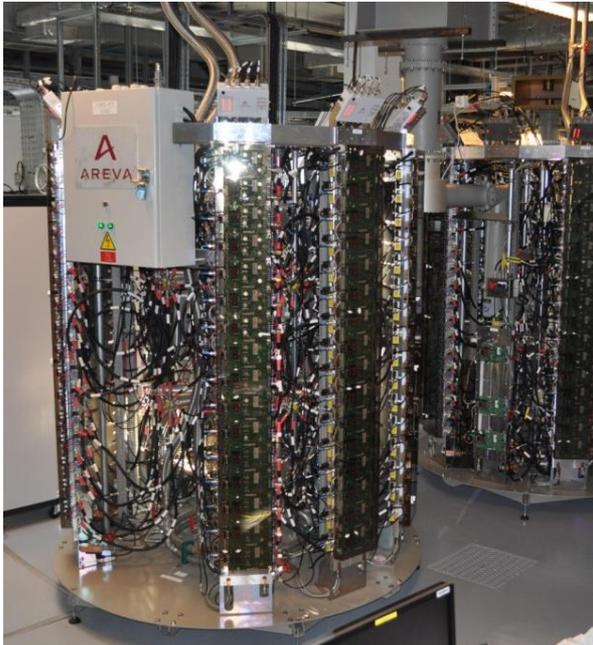
- ✓ 3rd modulator built in house
(hot spare for top-up operation)
 - ✓ Spare for Mod 1 or Mod 2 (Control and Waveguide switching)
 - ✓ Currently in operation in place of Mod 2
 - Replacement of Mod 1: still to be validated

STARTED:

- Control upgrade: replacement of obsolete VME

[Eric Rabeuf]

BOOSTER RF UPGRADE: ACCOMPLISHED



Initially since 1991:

- 1 klystron powered 2 five-cell cavities
- via 2 couplers/cavity
- 600 kW in total
- Total V_{acc} up to **8 MV**

April 2012 upgrade:

- **4 x 150 kW SSAs** feeding **2 cavities**

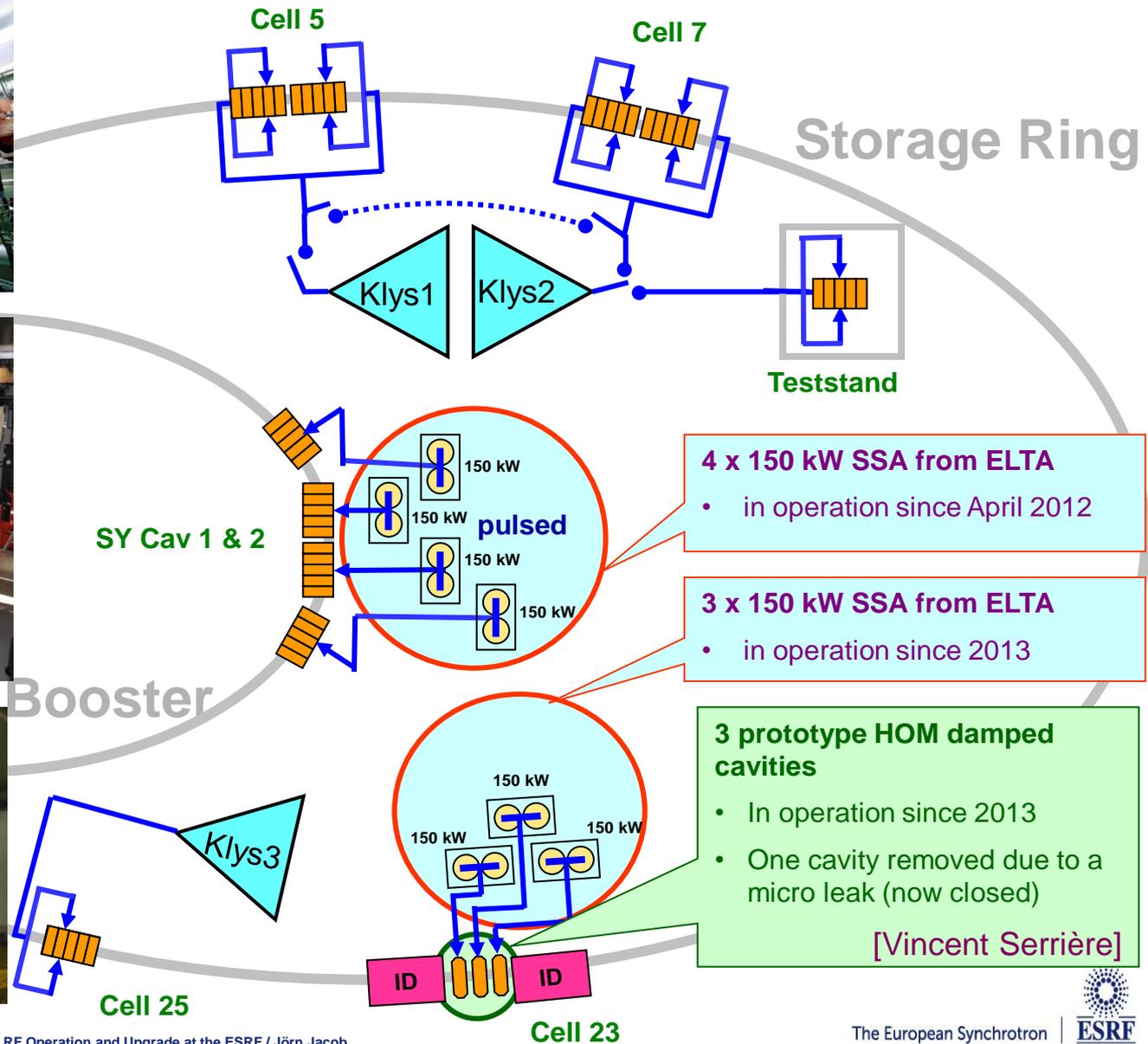
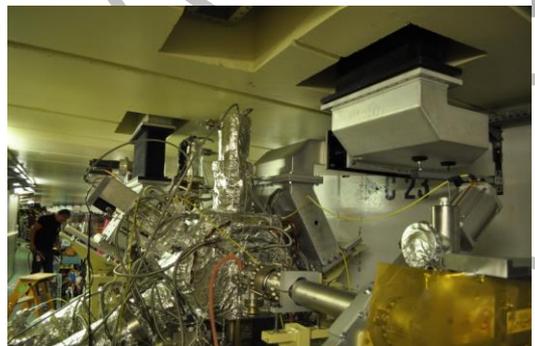
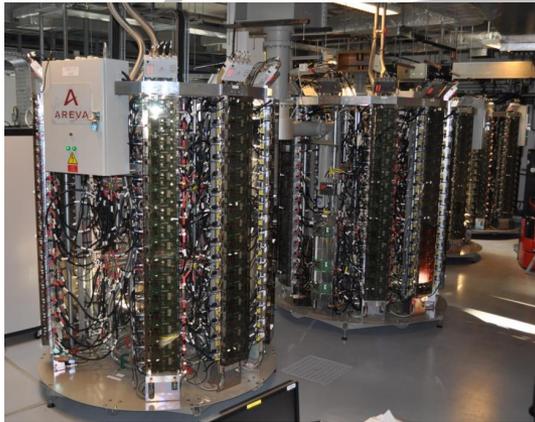
January 2016 upgrade:

- 4 x 150 kW SSAs feeding **4 cavities**
(1 SSA/cavity via 1 coupler/cavity)
- Total V_{acc} up to **11 MV**
- 8 MV with only 300 kW
- Redundancy: 8 MV operation with 3 systems
(i.e. if 1 cavity or SSA fails)

Frequent top up in 16 bunch since April 2016

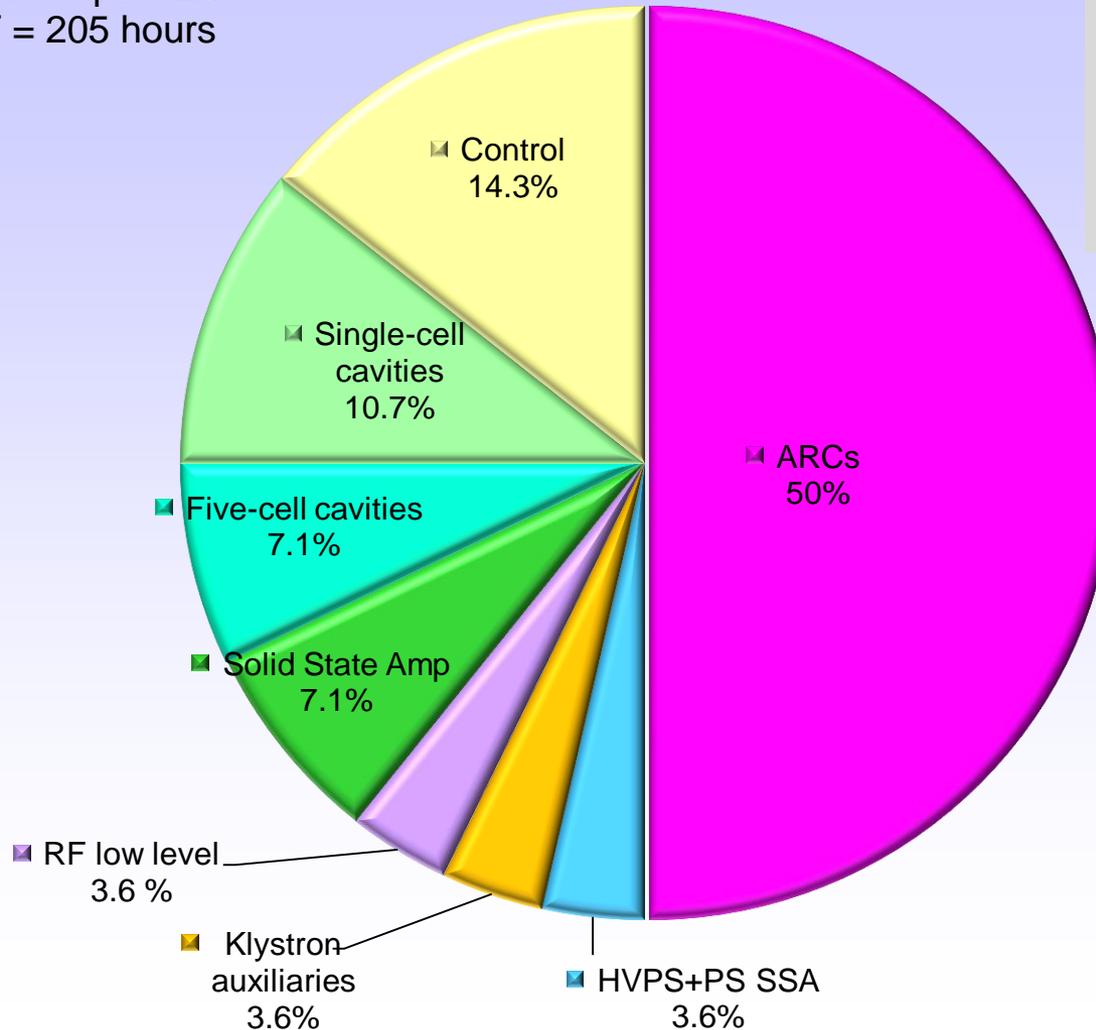
[J.-M. Mercier, A. D'Elia, G. Gautier, B. Ogier (TID)]

352.2 MHZ RF SYSTEM TODAY



OPERATION STATISTICS 2015

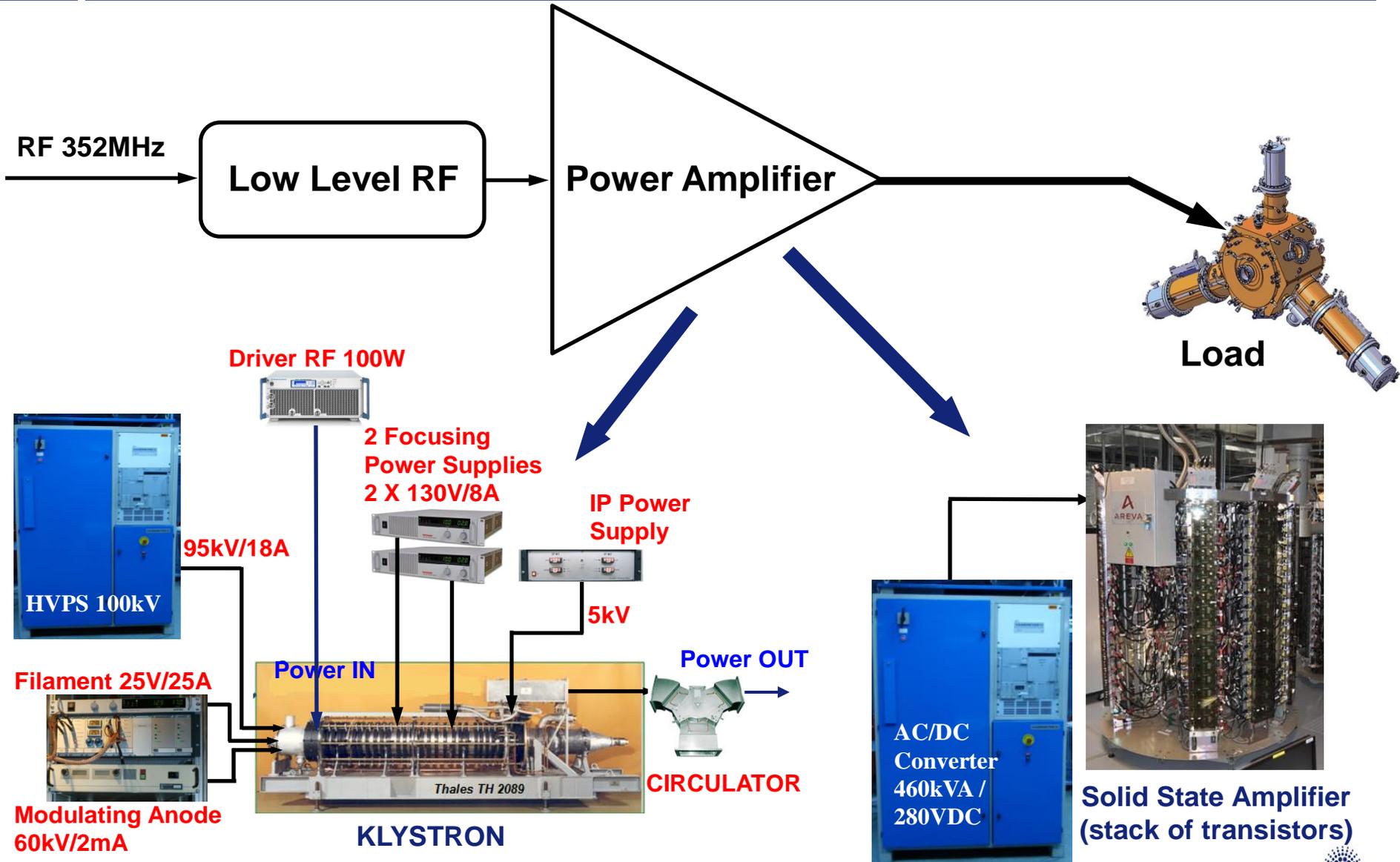
RF system - Year 2015
Total RF Trips = 28
MTBF = 205 hours



New LHC type Arc detectors (slightly modified) will be installed at the ESRF to minimize spurious detections
[Daniel Valuch / CERN]

[Jean-Maurice Mercier]

TENTATIVE COMPARISON KLYSTRON / SSA



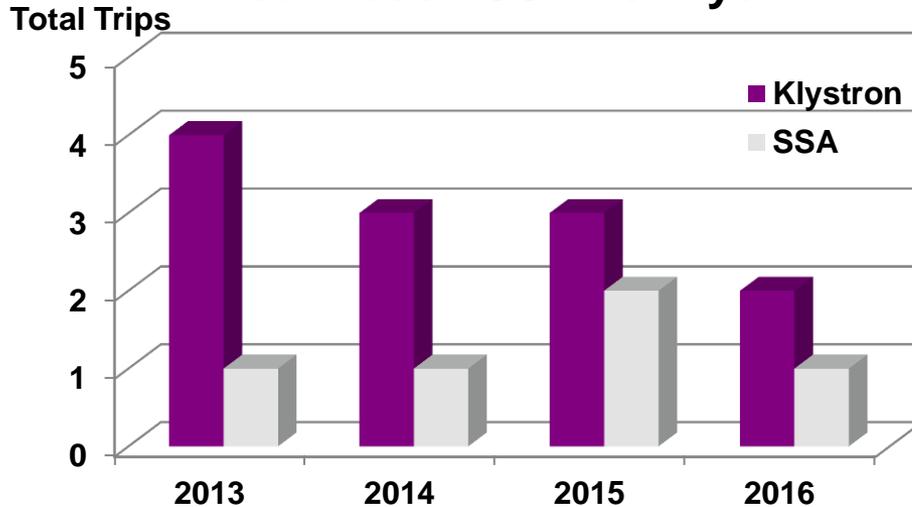
[Jean-Maurice Mercier]

The European Synchrotron



TENTATIVE TRIP COMPARISON

Beamloss : SSA vs Klystron



Average **1.5 KLYSTRONS** in operation:

→ **3 trips / year for 8 MV**
(4 to 5 five-cell cavities)

2 SSA in operation:

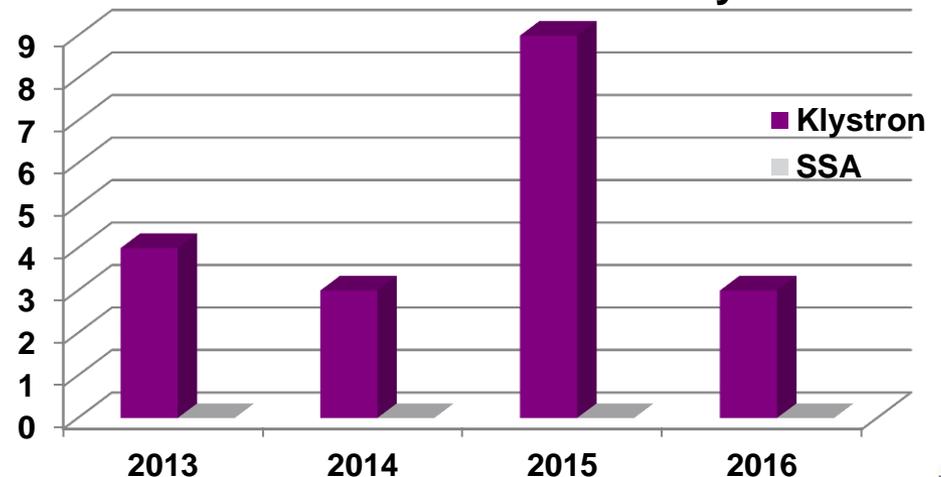
→ **1 trip / year for 1 MV**
(2 mono-cell cavities)

Note: Arc detections not taken into account

HOWEVER: no arc detection with SSAs !

- ➔ Explained by lower power in the waveguides?
- ➔ In average: arc events close to the RF transmitters represent 32% of the beam failures due to RF

Transmitter Arcs : SSA vs Klystron



[Jean-Maurice Mercier]

ESRF upgrade in 2019 / restart in 2020: EBS = Extremely Brilliant Source

Energy [GeV]	6
Circumference [m]	843.978
Natural emittance [pm]	134
Damping time (H/V/L) [ms]	8.5/13/8.6
$E_{\text{loss}}/\text{turn}$ [MeV]	2.61
Momentum compaction	$0.84 \cdot 10^{-4}$
Tunes (H/V)	76.21/27.34
Natural chromaticity (H/V)	-109/-82
Operation chromaticity (H/V)	6/4
Oper. Emittance (H/V) [pm]	110/5
Lifetime multibunch at 200 mA [h]	19
Lifetime 16 bunch at 90 mA [h]	1.8
Lifetime 4bunch at 4 x 10 mA [h]	1.2

} for $\epsilon_{\text{vert}} = 5 \text{ pm}$

Total energy loss:

- ☞ Energy loss from dipole radiation:
- ☞ Energy loss from ID radiation:

3.1 MeV/turn

2.6 MeV/turn

0.5 MeV/turn

Maximum RF Voltage:

6.6 MV

RF transmission losses:

- ☞ including RF losses, spurious mismatches

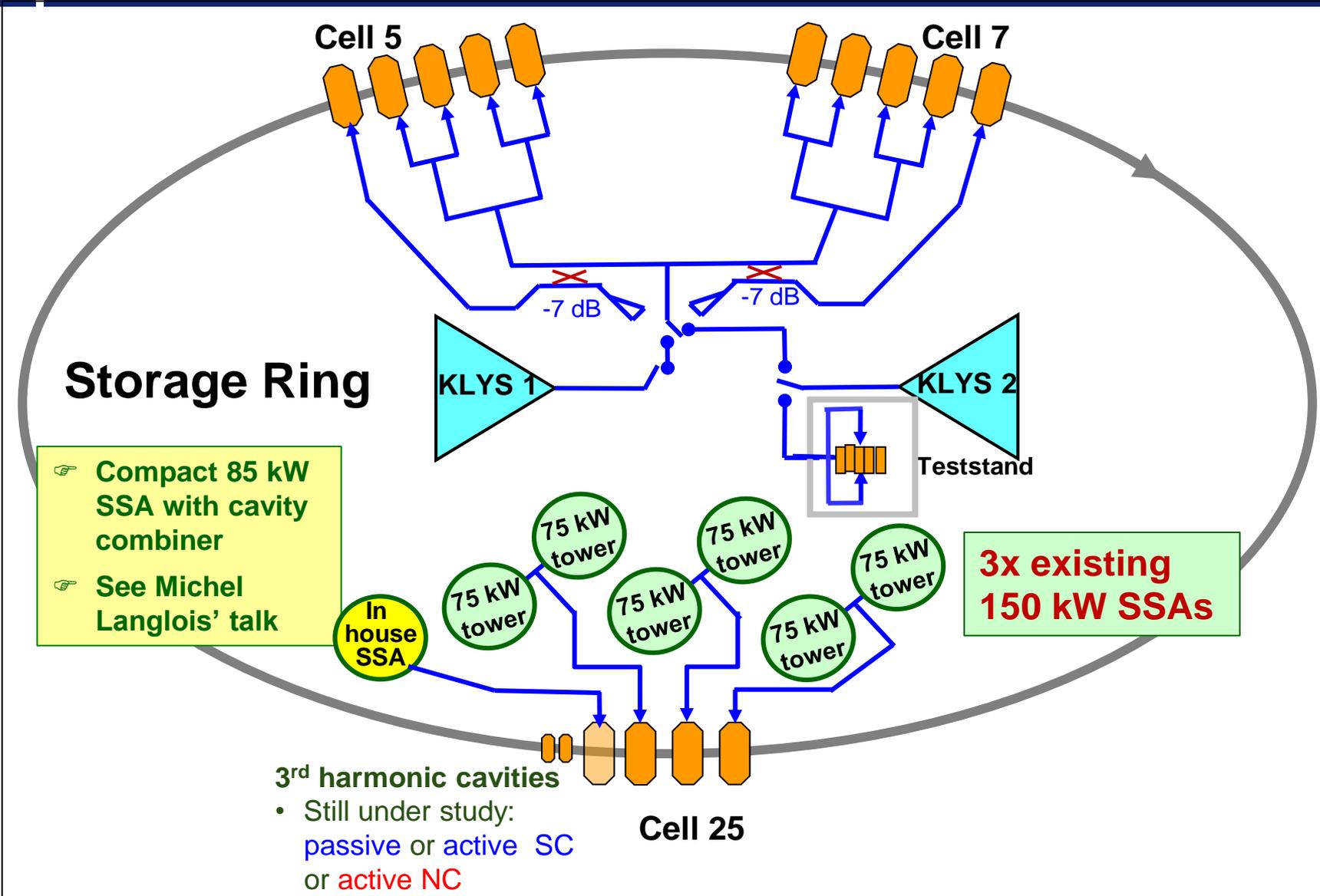
15 %

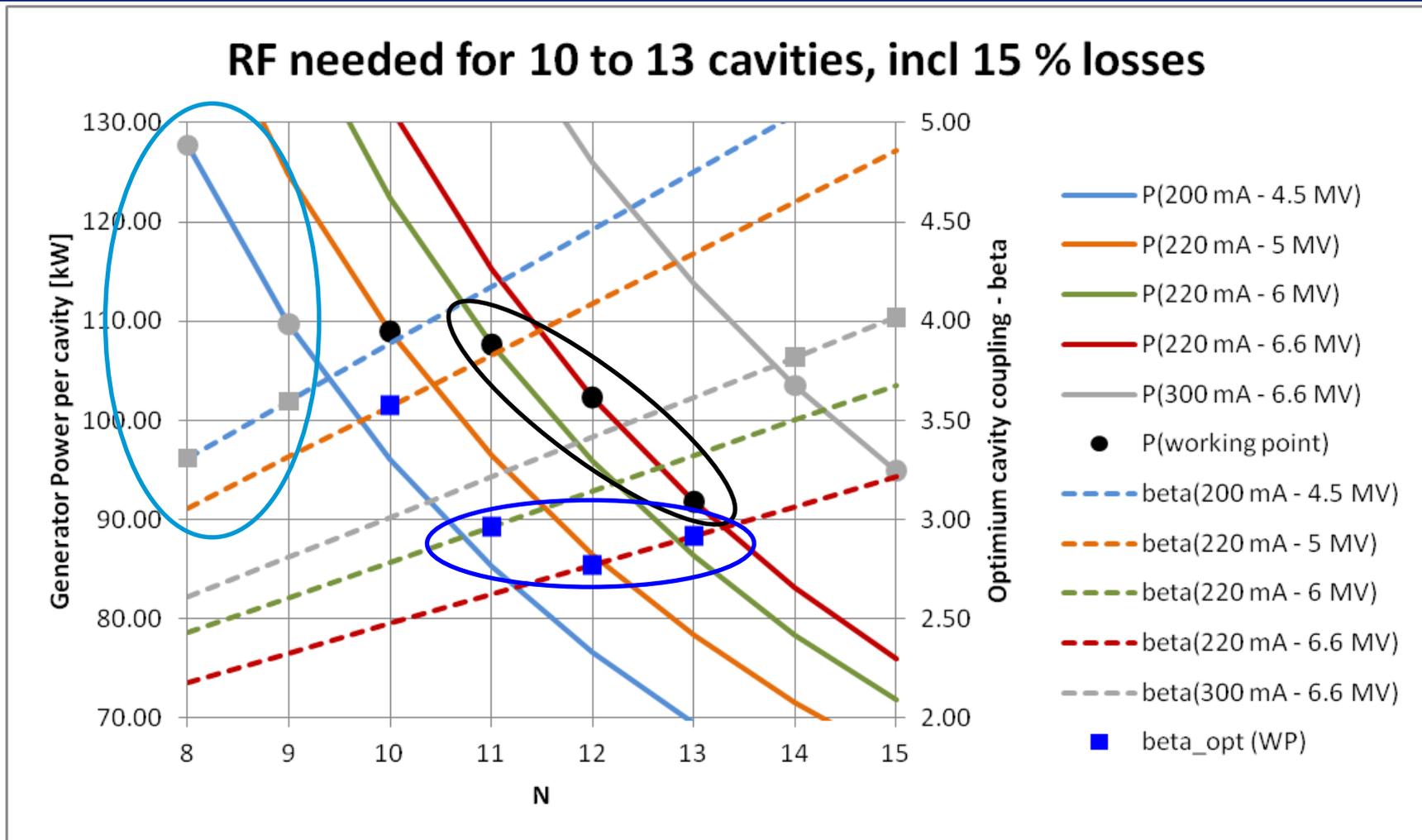
Stored current with operational margin:

220 mA

HOM damped cavity prototypes:

validated for 0.6 MV / 150 kW

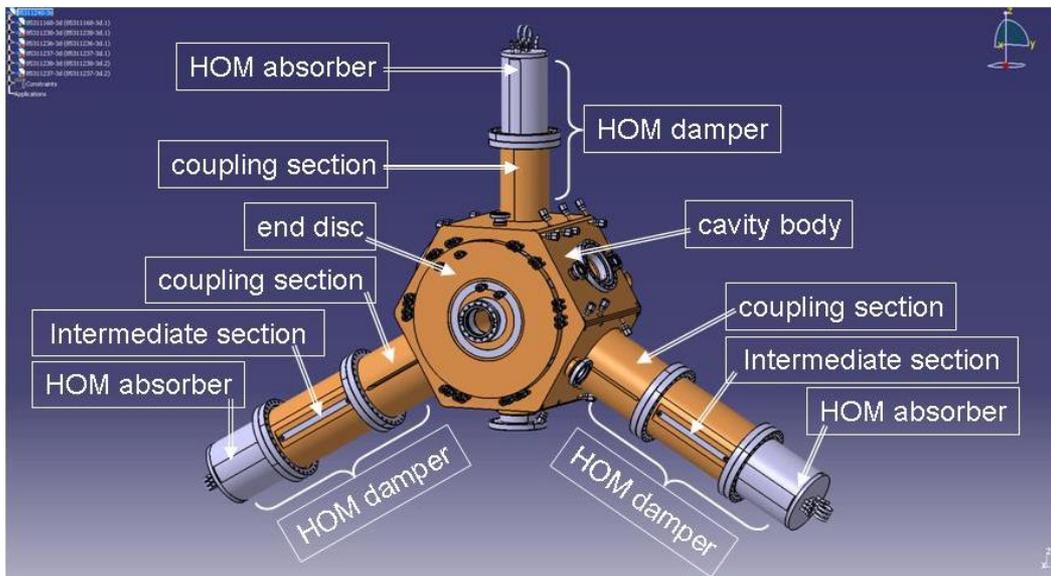




- Even with 5 cavities in fault (1 complete cell) ➡ operation at 4.5 MV / 200 mA still possible
- Also room left for performance upgrade

December 2013: contract with RI - Research Instruments GmbH

- Fabrication of 12 HOM damped cavities without HOM absorbers
- No electron beam welding: **only vacuum brazing**
- Process optimization → some delay
- June to November 2016: delivery of 4 cavities, now about 1/month
- Base pressure $< 10^{-10}$ mbar
- Conditioning to 750 kV within 2 weeks!



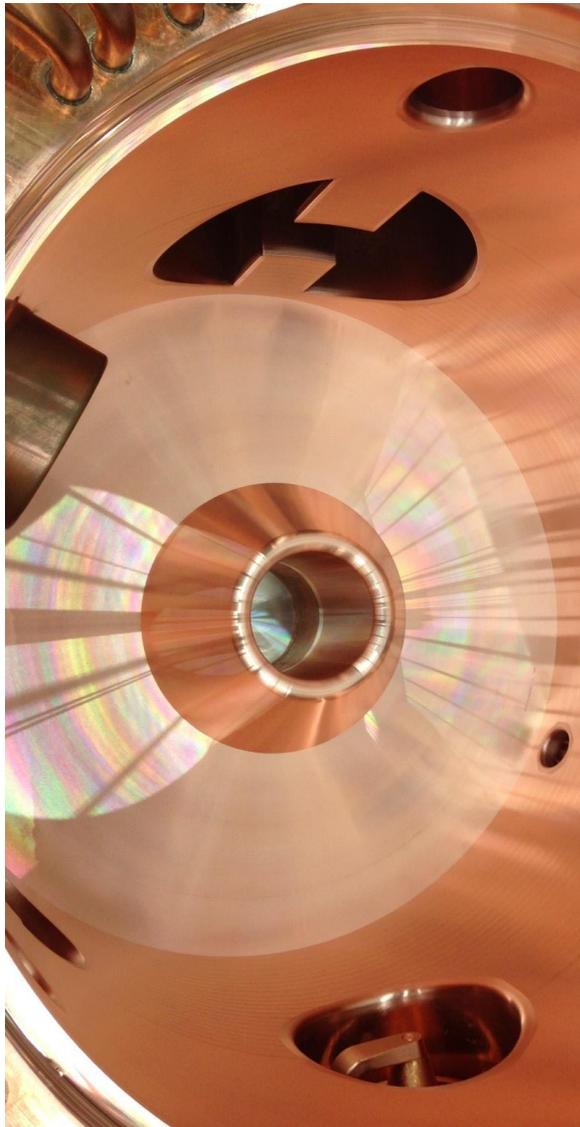
[Cavity designed by Vincent Serrière]

Difficulties with delivery of HOM absorbers

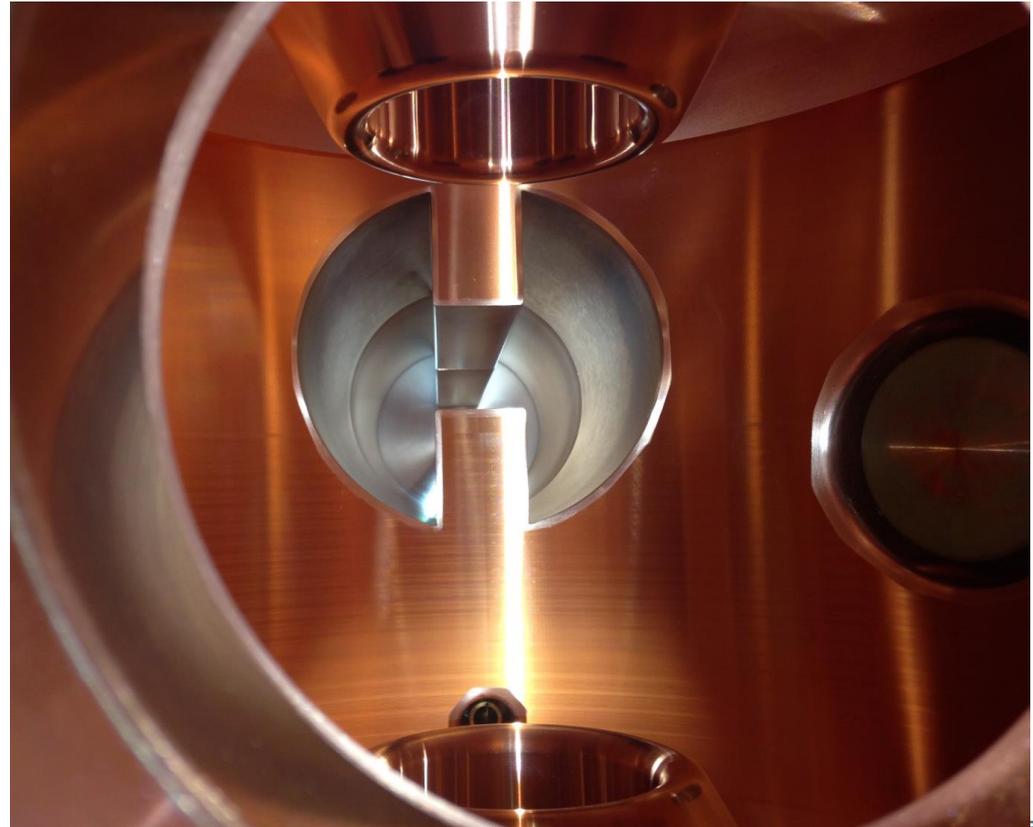
- HOM absorbers only in about 1 year from now
- RF conditioning without HOM absorbers
- Installation of HOM absorbers in 2018, prior to installation of cavities on new ring in 2019
- HOM absorber power < 100 W at $f_{rf} \Rightarrow$ no problem expected for re-conditioning

CAVITY FABRICATION

1st cavity: RI-1



Parameter		specified	measured	unit
f_{res}	(vented)	-	352.329	MHz
f_{res}	(converted to vacuum and operating temp.)	352.372	352.379	MHz
Q_0		-	35700	-
Tuning range		-	-357 / +925	kHz



CAVITY ASSEMBLING ZONE (ID8)



All the girders
in house

Conditioned
cavities, fully
equipped and
cabled: ready
for installation
(except HOM
absorbers)

Clean room conditions for cavity assembly:

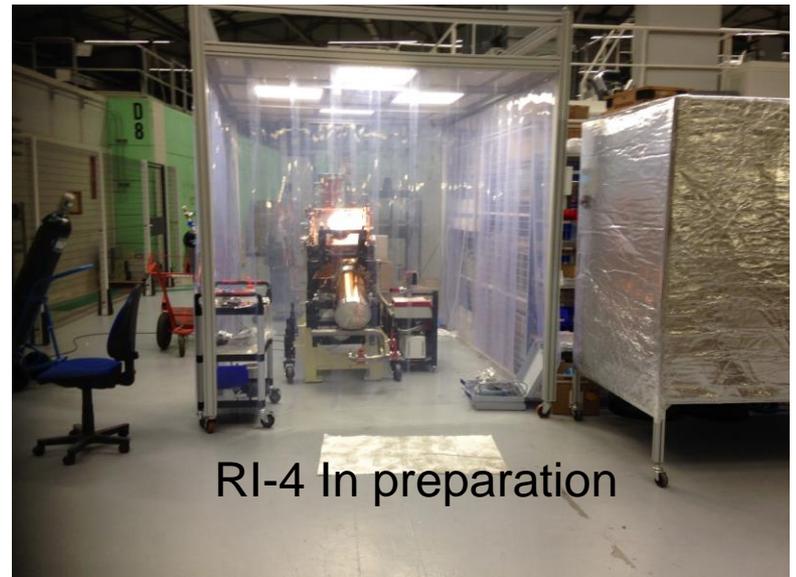
- ⇒ excellent base pressure
- ⇒ short RF conditioning time

[Alessandro D'Elia]

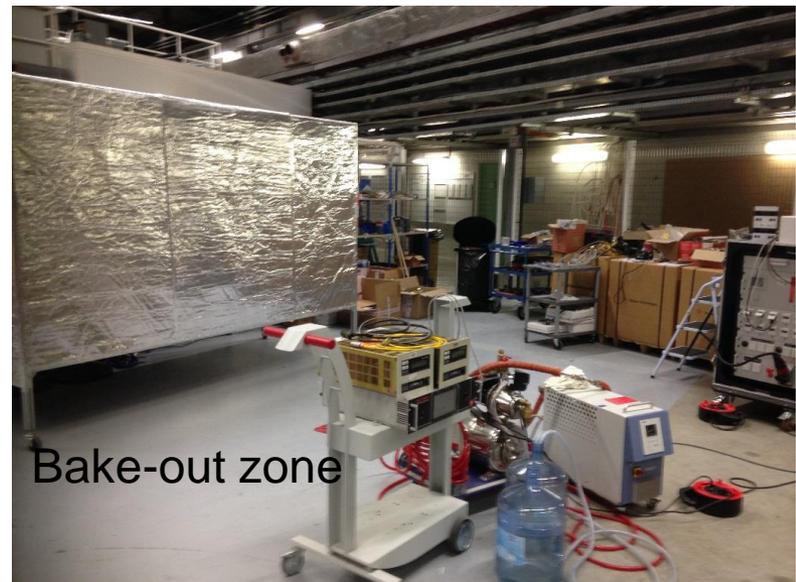
CAVITY ASSEMBLING ZONE - DETAILS



RI-1 and RI-2 already conditioned



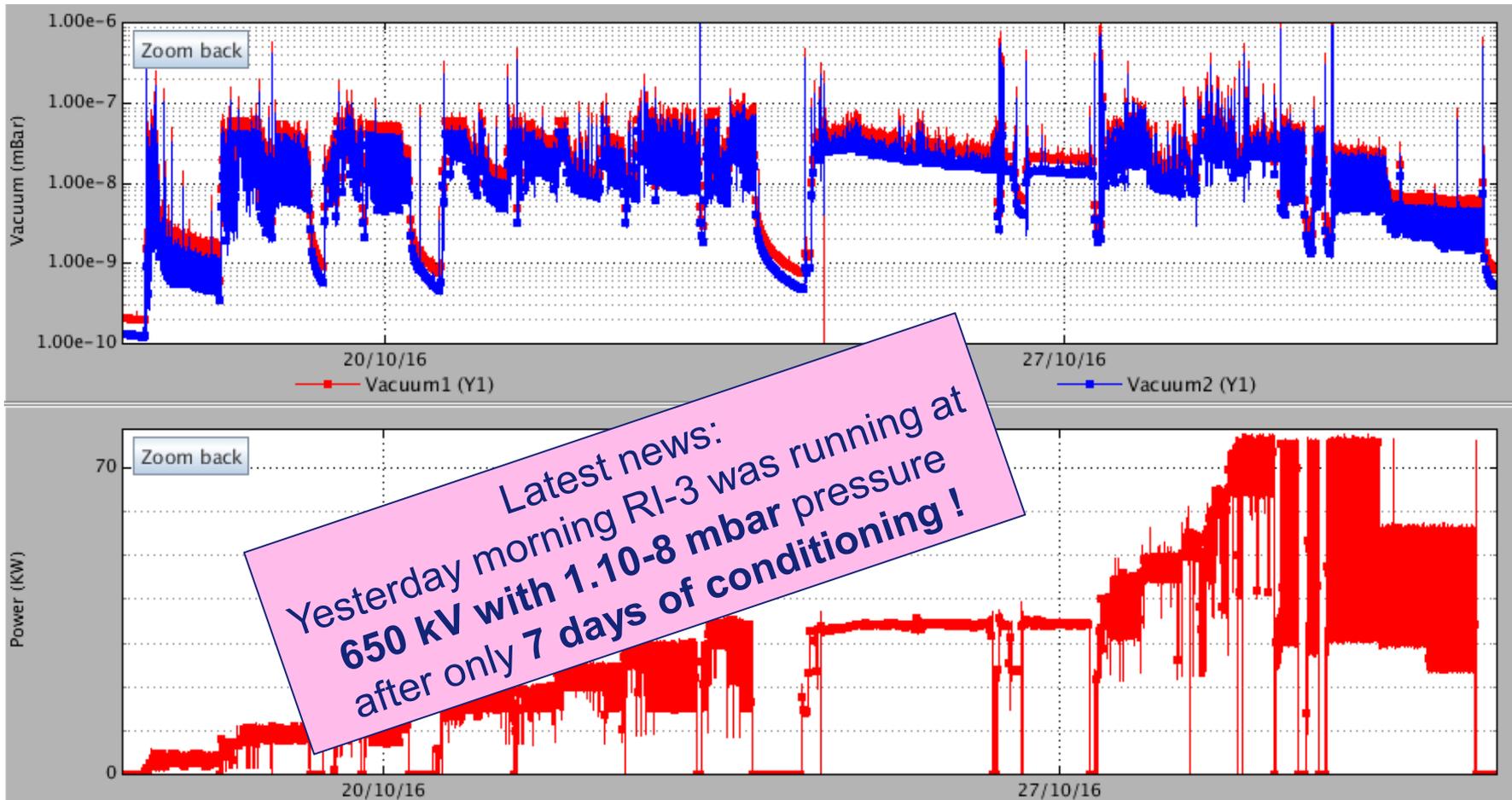
RI-4 In preparation



Bake-out zone

RF CONDITIONING – EXAMPLE OF RI-2

< 14 days for RF conditioning !



Short conditioning thanks to:

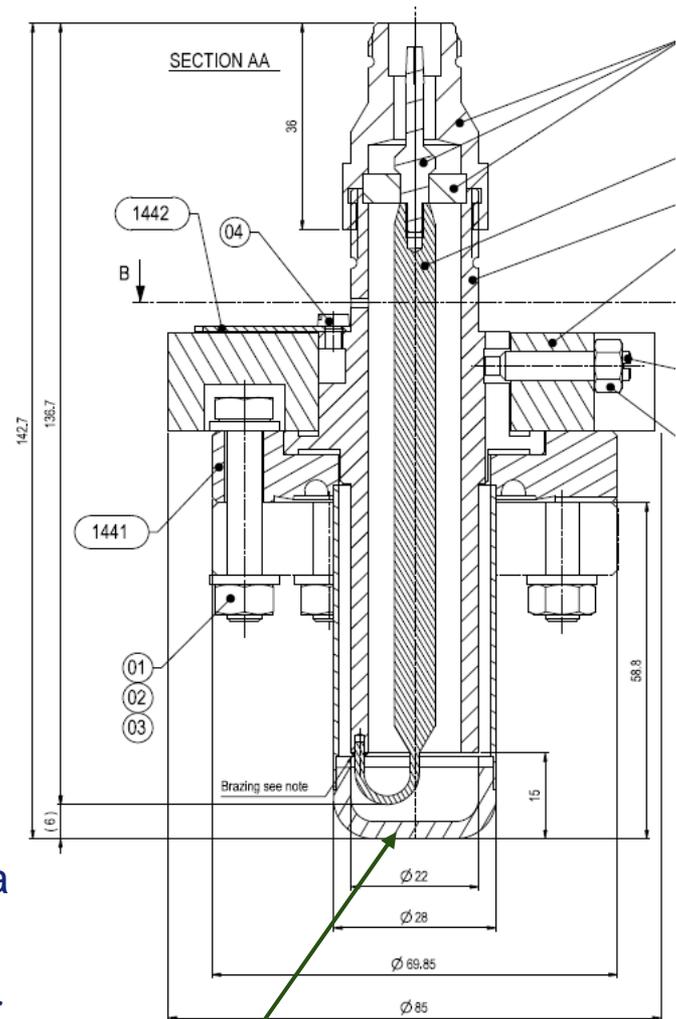
- Only brazing process during manufacturing (?)
- Careful assembling in clean room conditions (!)

[Alessandro D'Elia]

AUXILIARY COMPONENTS

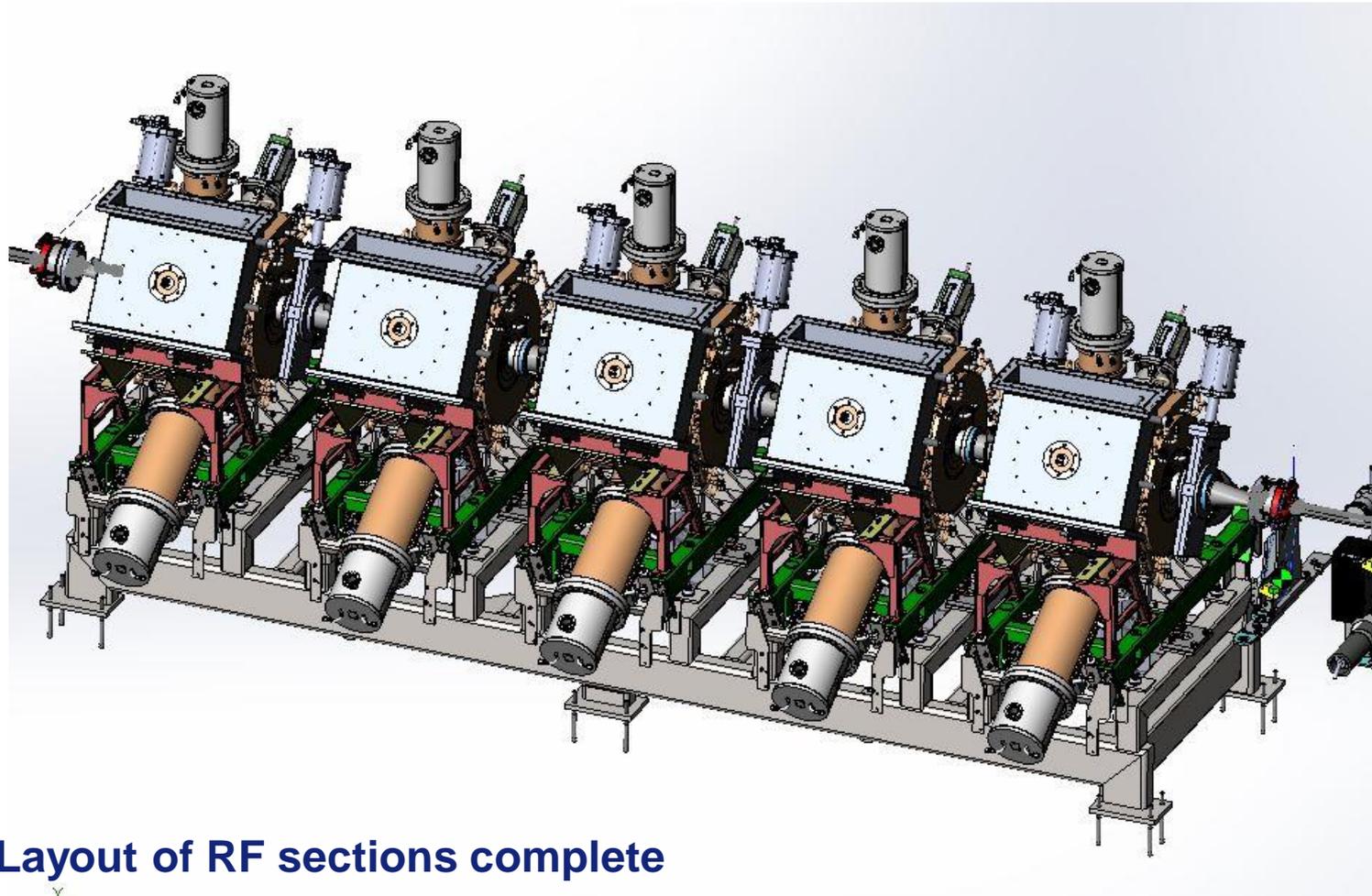
- **Sufficient RF power couplers in house, mostly already pre-conditioned**
 - **Movable piston tuners:**
 - For RI-1 to RI-4: existing spare tuners from five-cell cavities + one new fabrication prototype by CECOM
 - Series fabrication: delivery delayed, now expected by December 2016 / January 2017 (⇒ cavity RI-5 expected beginning of December: preparation delayed)
 - If too long delay: still 2 tuners available from hot spare five-cell cavity
 - **Field probes in house:**
 - Without Ti-coating: during RF conditioning, around 600 kV every 2nd ceramic developed a leak in the bulk (not on brazing joint)
- ⇒ No more leak experienced, up to 750 kV after Ti-coating (charge evacuation and anti-multipactor effect)

[Vincent Serrière,
Alessandro D'Elia]



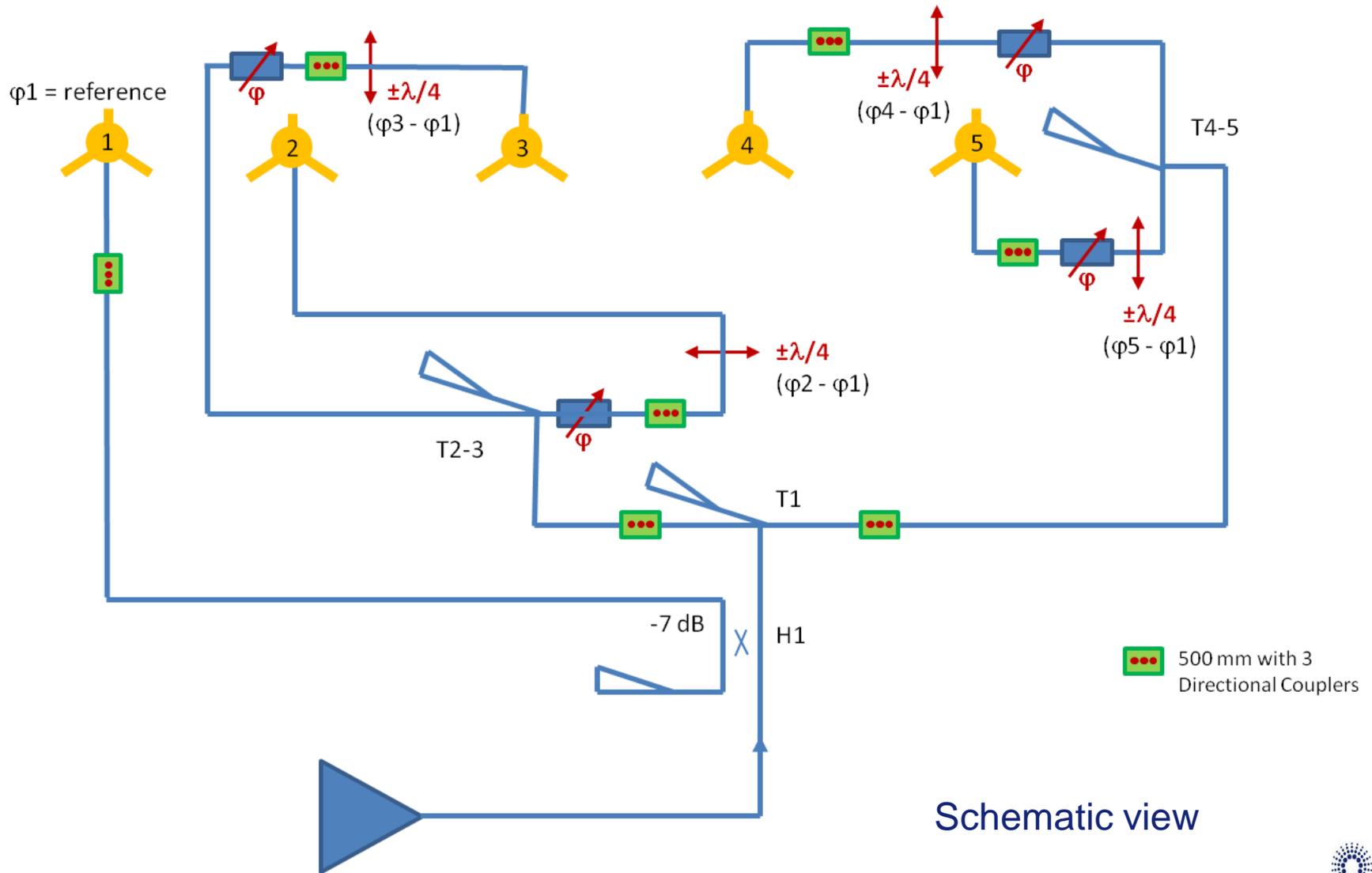
Ceramic cap: ≈ 50 nm
Titanium coating on vacuum
side [H. Pedroso-Marques,
ESRF vacuum Group]

RF SECTIONS ON EBS MACHINE



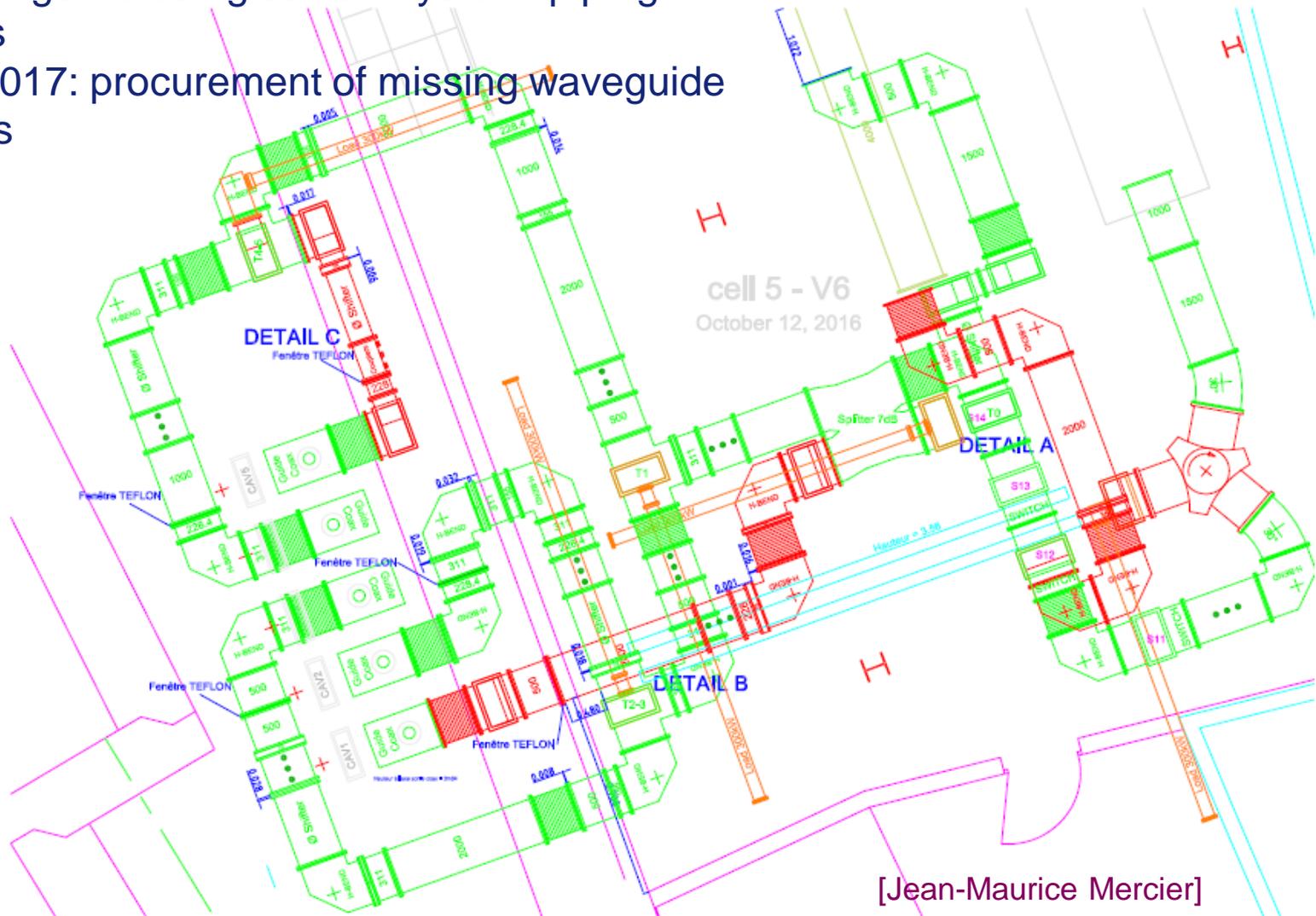
- **Layout of RF sections complete**
- **Detailed design of connecting vacuum chambers: almost complete**

WAVEGUIDE DISTRIBUTION: EXAMPLE OF CELLS 5 AND 7



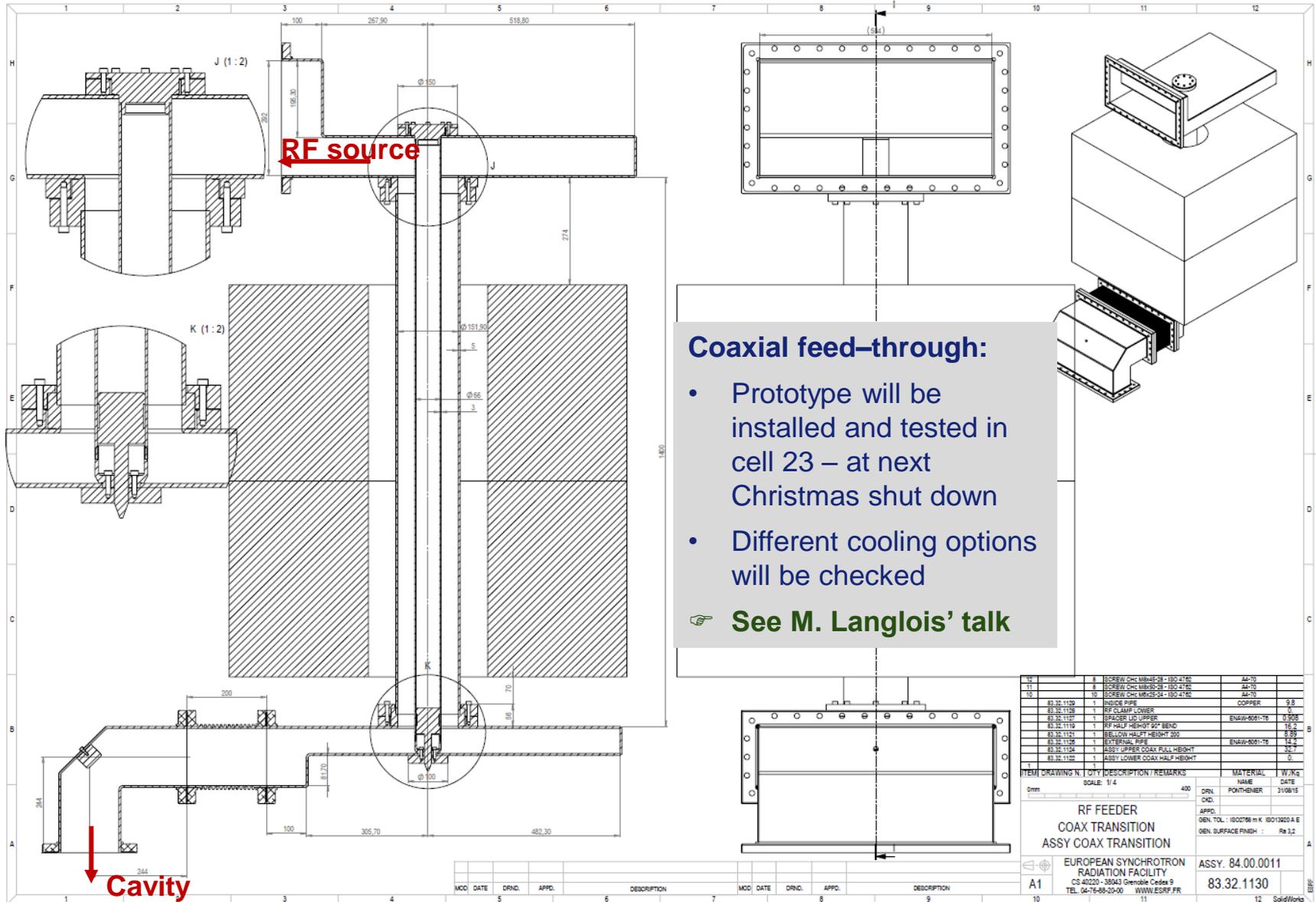
WAVEGUIDE DISTRIBUTION: EXAMPLE OF CELLS 5 AND 7

- Waveguide distribution designed
- 3D drawings including cable trays and piping in progress
- Spring 2017: procurement of missing waveguide elements



[Jean-Maurice Mercier]

COAXIAL FEED-THROUGH FOR SRTU ROOF BEAMS (REMINDER / ESLS RF 2015)



- **Existing VME controllers of klystron transmitters: obsolete**
 - ☞ need to be replaced, especially also in view of future operation on EBS

- **New control architecture:**
 - As already implemented on SSAs / new cavities in cell 23
 - Analog and slow digital signals through WAGO Modbus/Ethernet couplers
 - WAGO's <-> PCI dialog via Ethernet
 - Device servers on PCI
 - Fast digital signals (fast interlocks): still old HIS (Hardware Interlock System) (new generation HIS of SSA-type will be retrofitted later)
 - Former VME loops and higher level control: PCI

- **KLYSTRON transmitter 2 upgrade completed in 2016:**
 - Required rebuilding and re-cabling transmitter signal interface (many signals)
 - Graceful upgrade: only little interference with heavy test program on RF power teststand, not available for SR operation from August to October 2016
 - Back to operation on storage ring cavities in October 2016

- ⇒ **KLYSTRON transmitter 1 upgrade planned in December 2017 shut down**

- **Good Operation performance of existing RF system**
- **Linac upgrade almost complete**
- **Booster RF system upgrade complete**
- **Storage Ring RF upgrade for EBS is progressing well**
- **New cavity production now in full swing**
 - ✓ Cavities show excellent vacuum behavior
 - ✓ RF conditioning to 750 kV in 2 weeks: much faster than anticipated 3 months
 - ⇒ Lowers the impact from delays in the delivery of HOM absorbers and tuners
- **Waveguide system well defined → procurement in 2017**
- **Klystron transmitter control upgrade**
 - ✓ Successfully implemented on klystron transmitter 2
 - ✓ Simple repetition foreseen end 2017 on klystron transmitter 1

