21st ESLS RF Meeting - SOLARIS

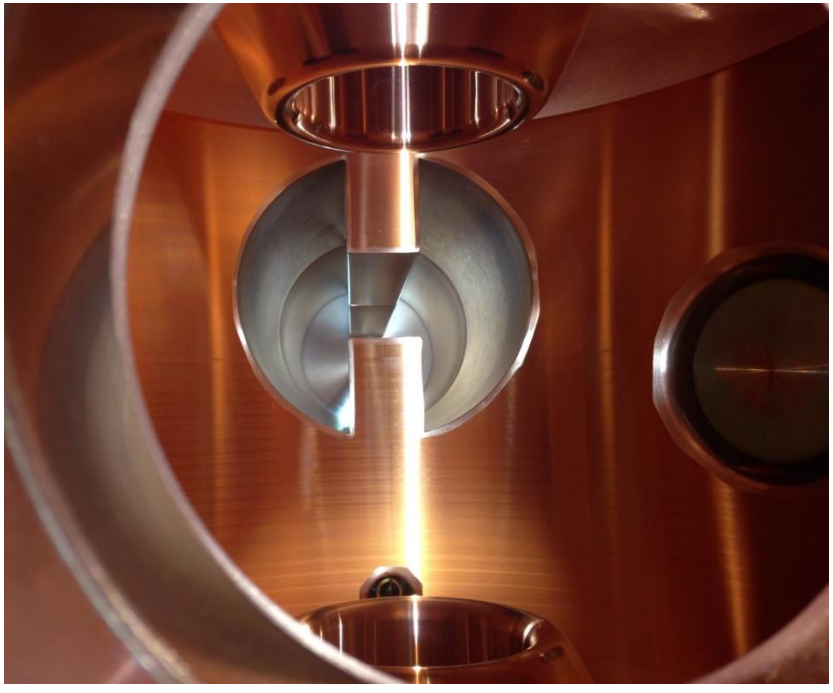
Krakow, 15 – 16 November 2017

RF operation at the ESRF and EBS upgrade (EBS = Extremely Brilliant Source)

Jörn Jacob

On behalf of the ESRF RF Group

ESRF | The European Synchrotron



OUTLOOK

I. LINAC: acoustic localization of arcing

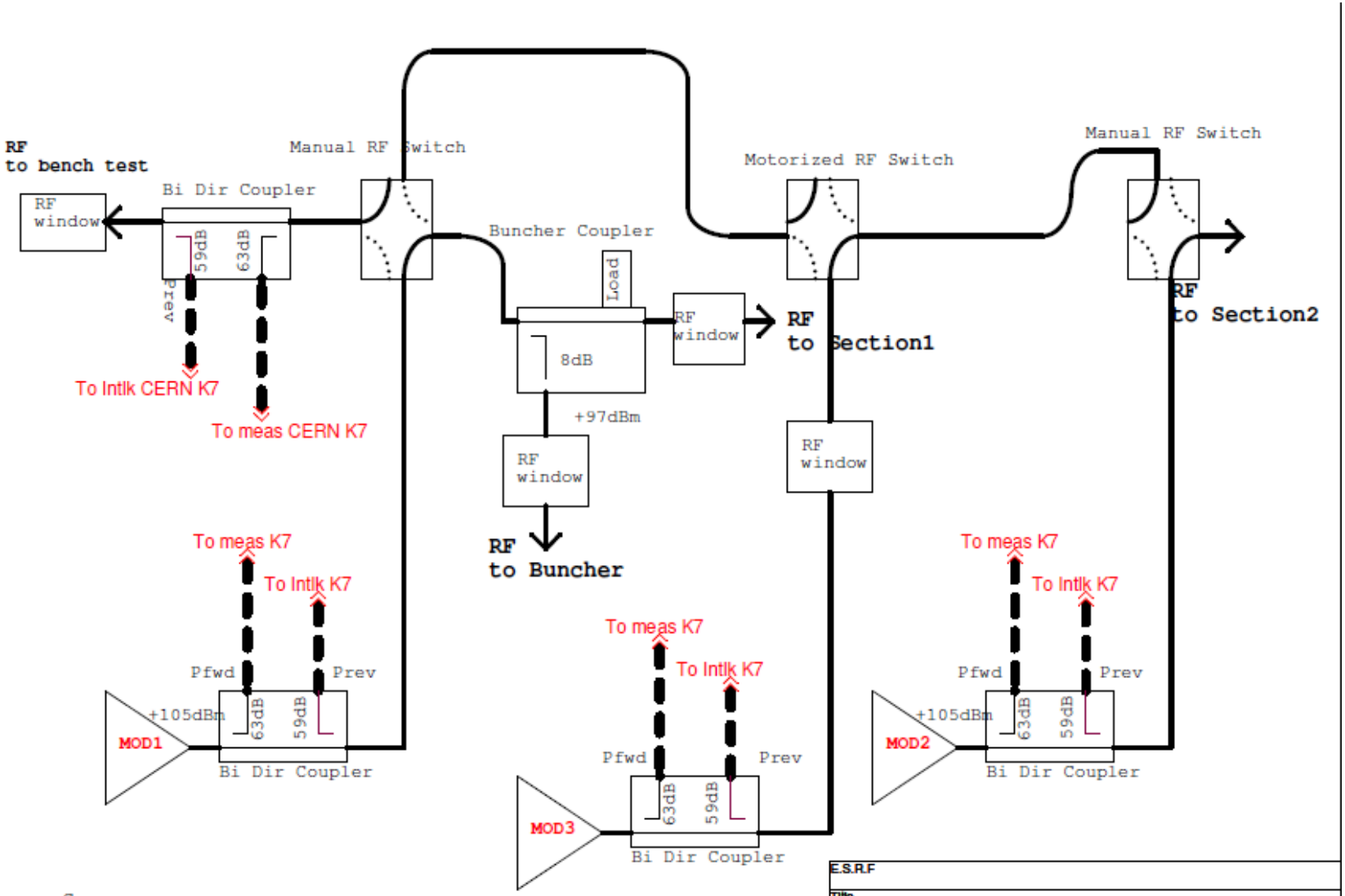
II. 352.2 MHz RF system of booster and storage ring

- Storage Ring RF operation statistics
- Arc detections: real or false? …or why we should consider them seriously!

III. Status of RF upgrade for future ESRF-EBS

- RF layout and main parameters
- HOM Damped Cavities

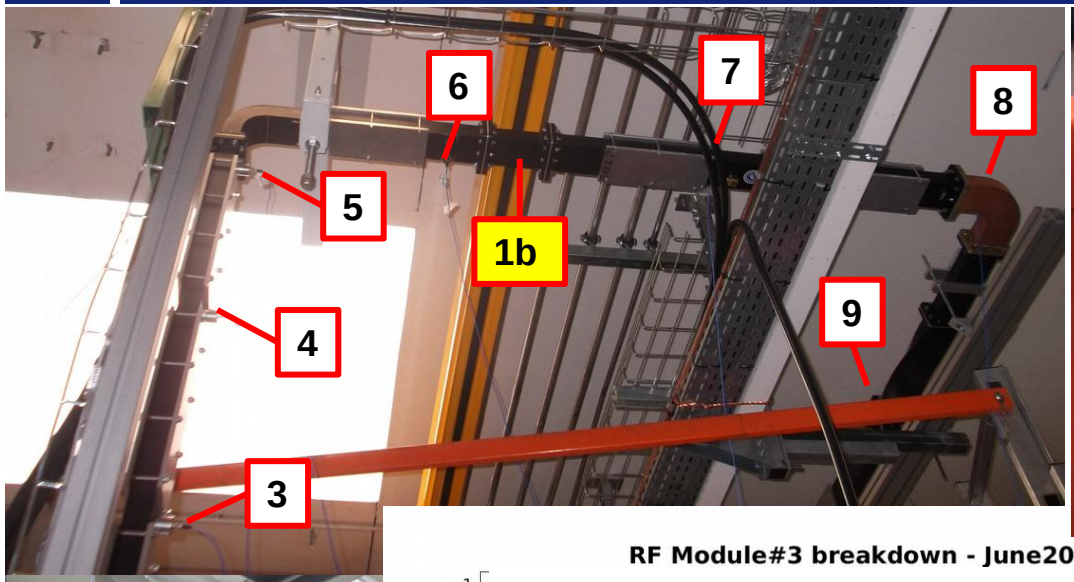
200 MEV S-BAND LINAC

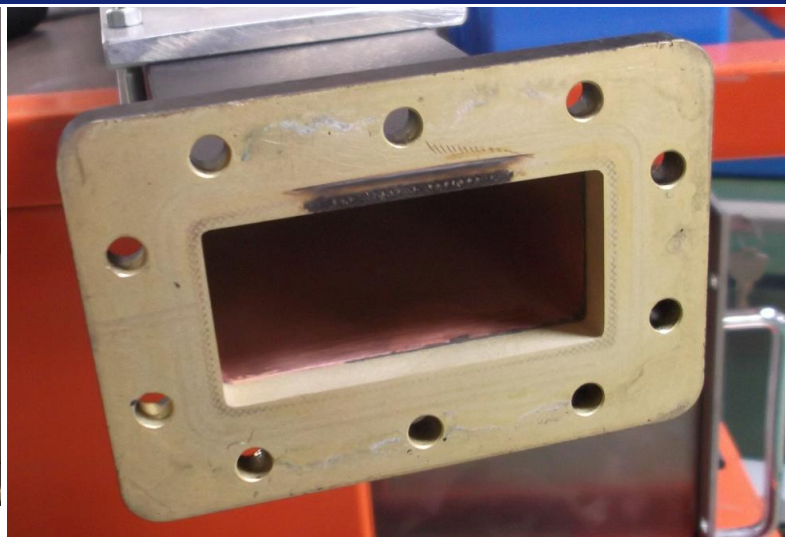


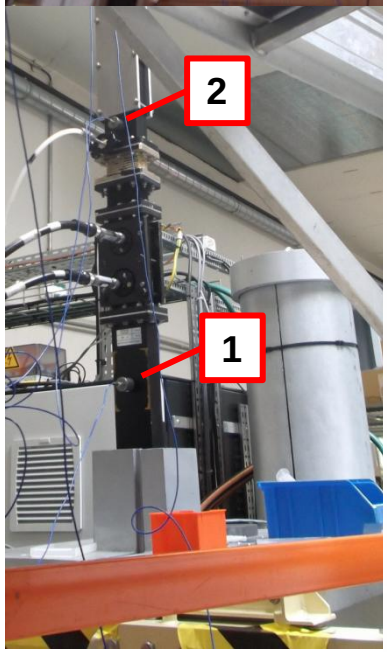
Third 37 MW klystron modulator

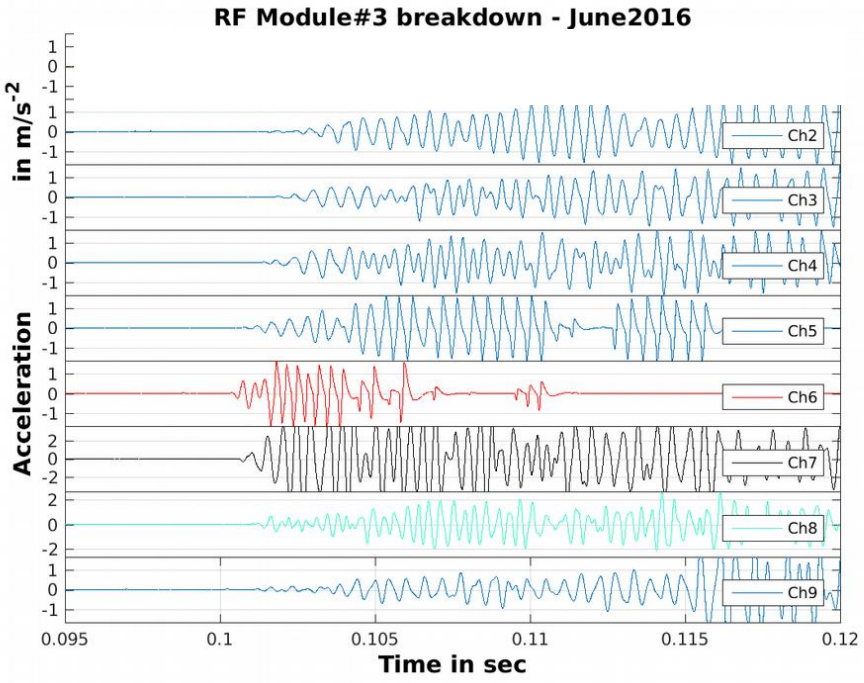
⇒ Redundancy to safeguard operation

LINAC: ARCING LOCALIZATION BY SOUND PROPAGATION [1 - 40 KHZ]



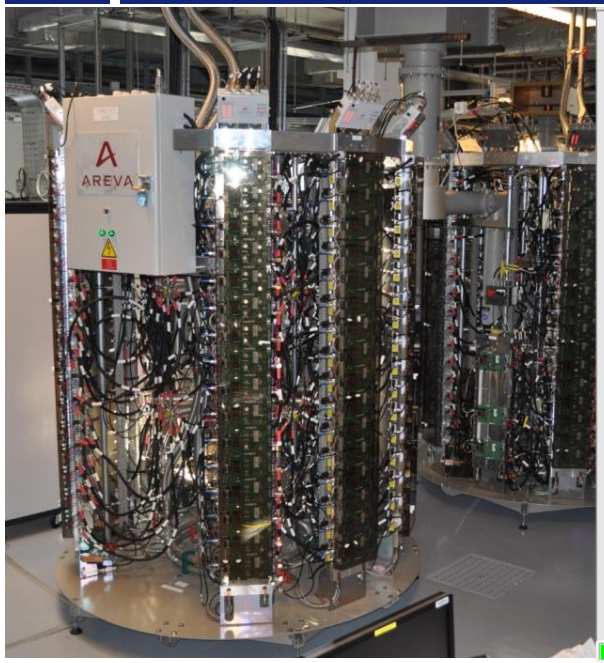


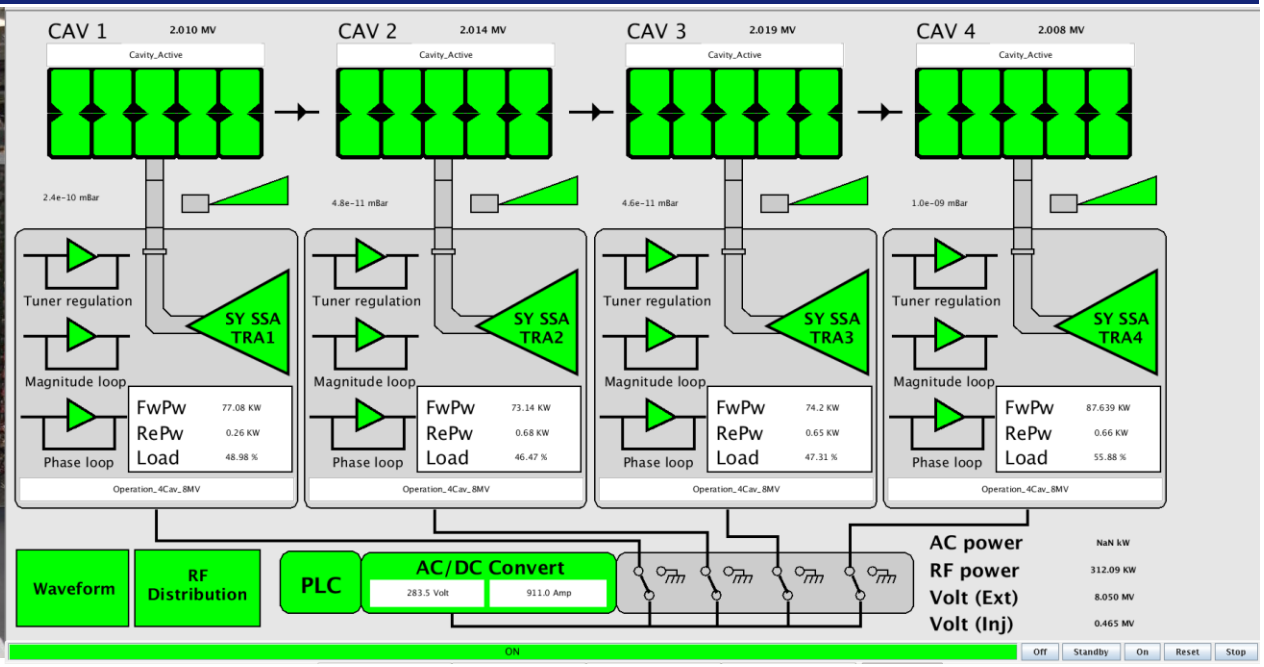




[E. Rabeuf, M. Lesourd et al.]

BOOSTER RF





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:

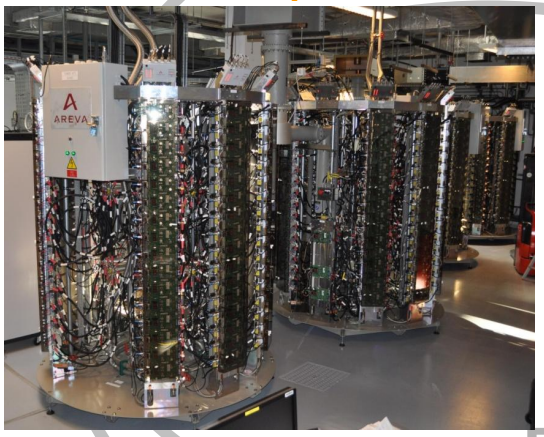
- 4 x 150 kW SSAs feeding 4 cavities
  (1 SSA/cavity via 1 coupler/cavity)
- Total V_{acc} up to **11 MV**
- 8 MV with only 300 kW
- Redundancy: 8 MV operation with 3 systems (i.e. if 1 cavity or SSA fails)

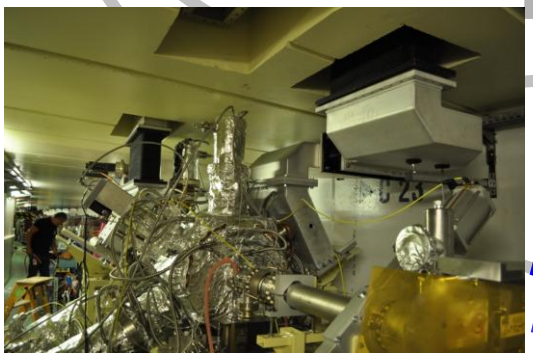
Frequent top up in 16 bunch since April 2016

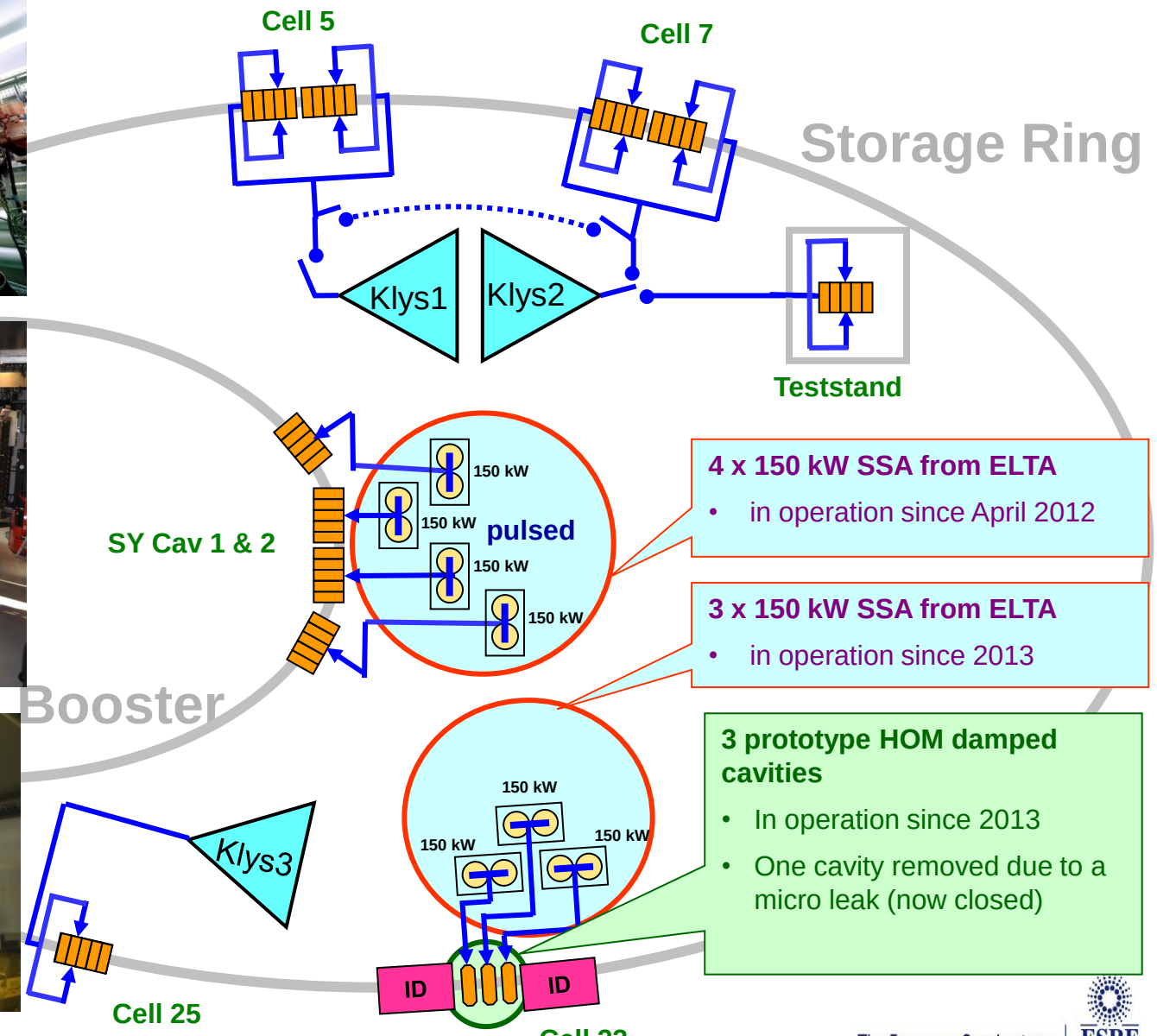
352.2 MHZ RF SYSTEM TODAY

5-cell cavities: strong HOM

!







4 x 150 kW SSA from ELTA

- in operation since April 2012

3 x 150 kW SSA from ELTA

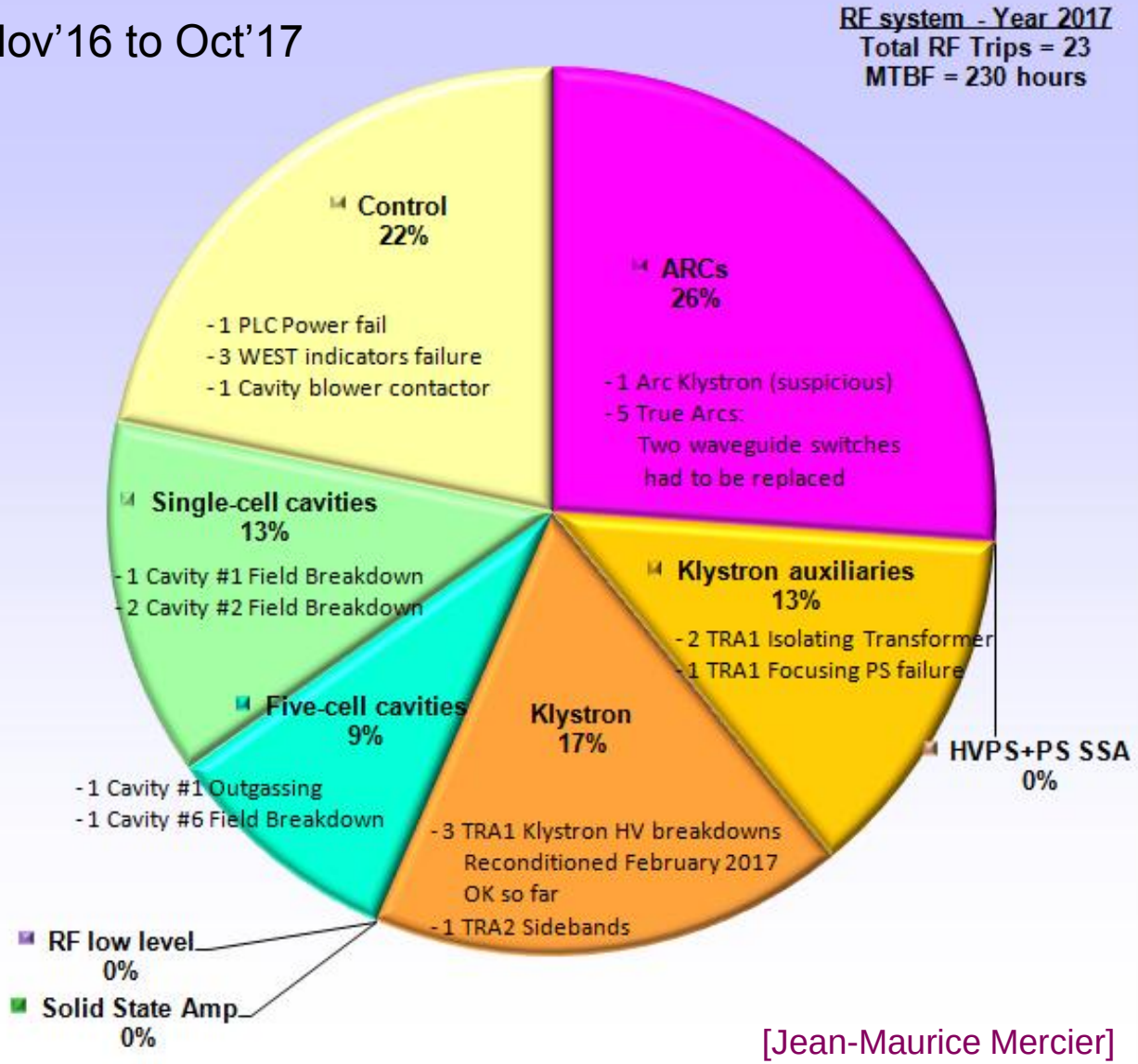
- in operation since 2013

3 prototype HOM damped cavities

- In operation since 2013
- One cavity removed due to a micro leak (now closed)

OPERATION STATISTICS 2017

Nov'16 to Oct'17



[Jean-Maurice Mercier]

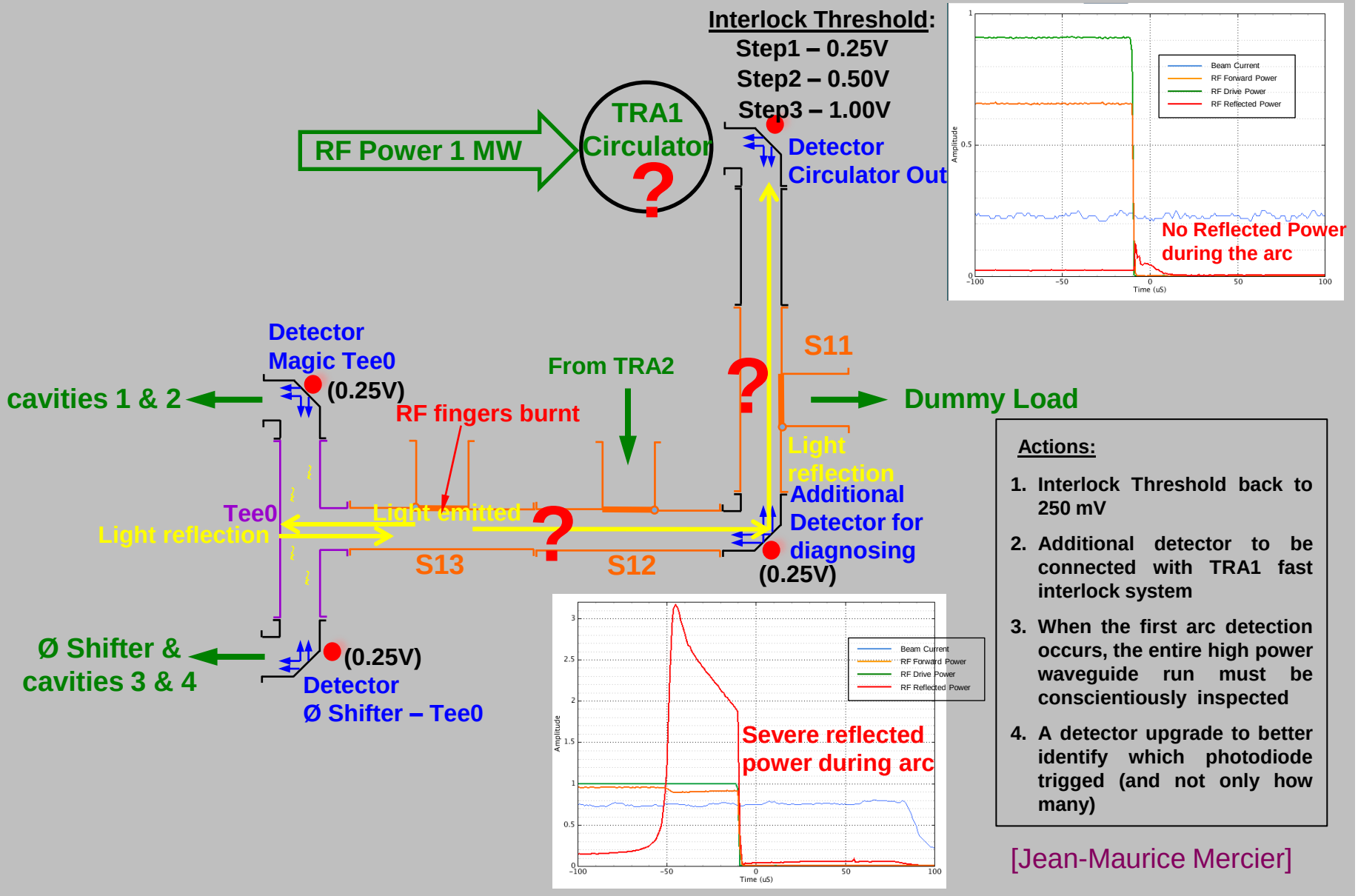
Major Events

- In February we suffered 3 HV cathode/anode breakdowns with EEV4 klystron at 71,000 HV hours. One hour of cold HV reconditioning ⇒ no problem so far @ 76,000 hr.
- HV deck isolating transformer failure (broken insulation) after 25 years of operation. Replacement with spare one, which failed 3 months later identically. Now with old booster transformer.

  ⇒ New Isol Transf. ordered
- Replacement of 70% of Arc detectors with new model (CERN design adapted for ESRF)

  Since, only one suspicious detection (still from old system).
- Field breakdowns with cavities.
- No Beam interruption due to Solid State Amplifiers

ARCS AT WAVEGUIDE SWITCHES S12 AND S13

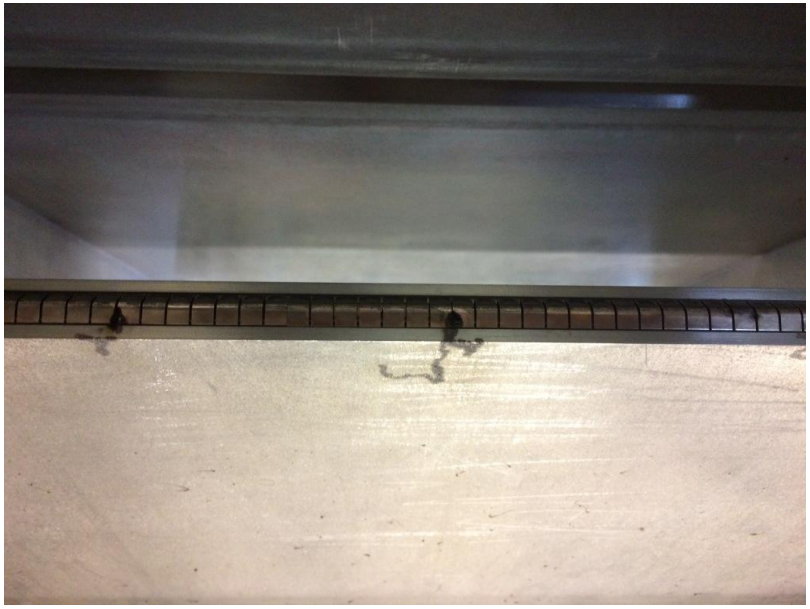


Actions:

1. Interlock Threshold back to 250 mV
2. Additional detector to be connected with TRA1 fast interlock system
3. When the first arc detection occurs, the entire high power waveguide run must be conscientiously inspected
4. A detector upgrade to better identify which photodiode trigged (and not only how many)

[Jean-Maurice Mercier]

DAMAGED WAVEGUIDE SWITCHES S12 AND S13



ESRF-EBS PARAMETERS

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

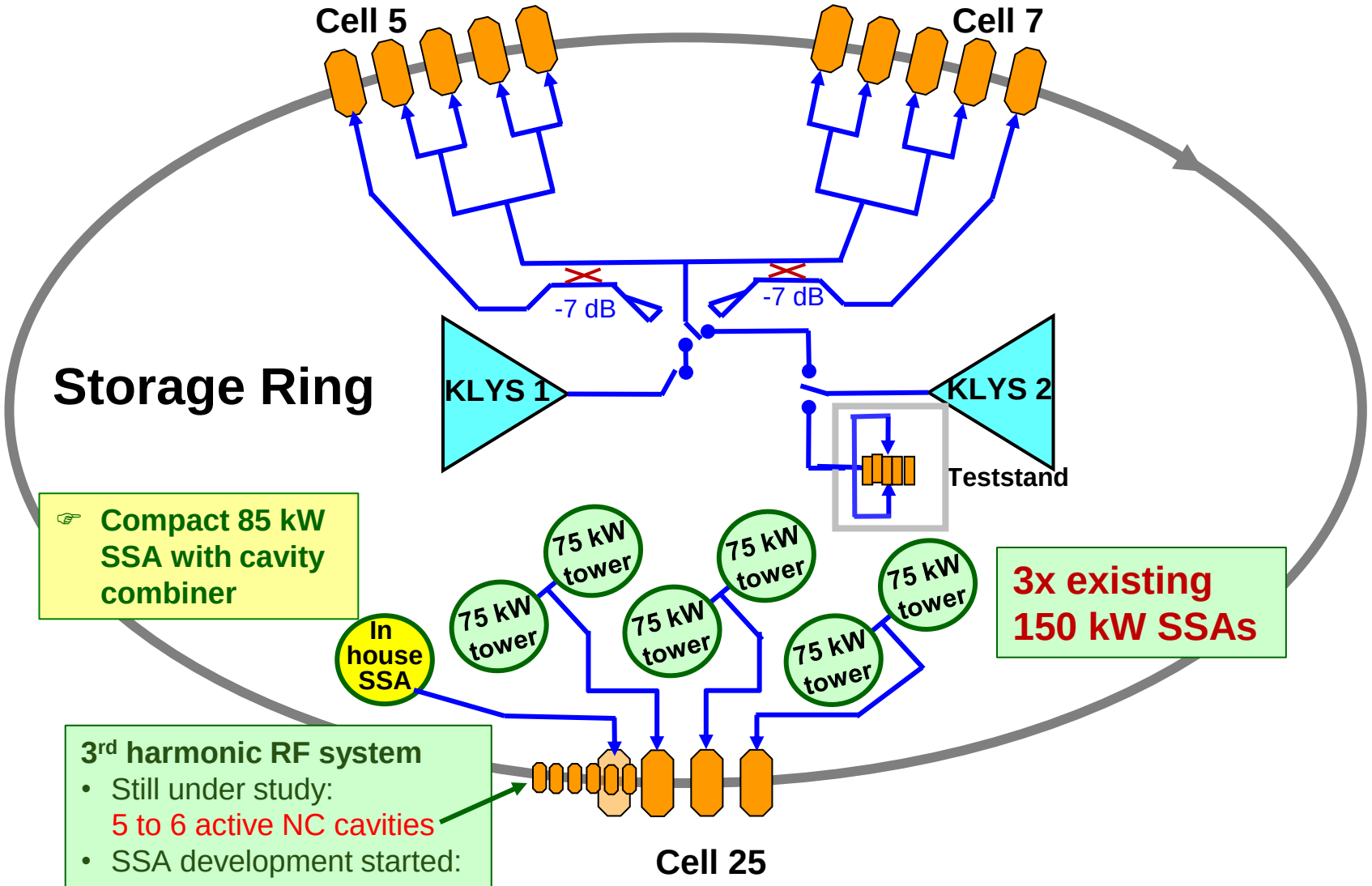
Energy [GeV]	6
Circumference [m]	843.978
Natural emittance [pm]	134
Damping time (H/V/L) [ms]	8.5/13/8.6
E_{loss}/turn [MeV]	2.61
Momentum compaction	$0.84\ 10^{-4}$
Tunes (H/V)	76.21/27.34
Natural chromaticity (H/V)	-109/-82
Operation chromaticity (H/V)	6/4
Oper. Emittance (H/V) [pm]	**110/5**
Lifetime 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 ε_{vert} = 5 pm

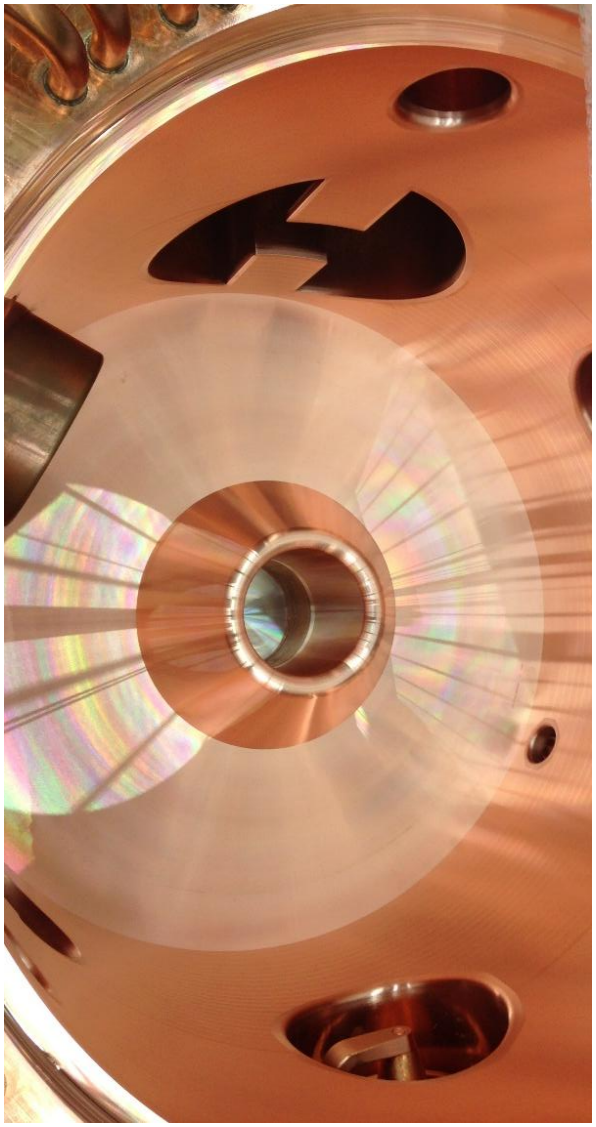
MAIN RF PARAMETERS FOR ESRF-EBS UPGRADE

Total energy loss:	**3.1 MeV/turn**
☞ Energy loss from dipole radiation:	2.6 MeV/turn
☞ Energy loss from ID radiation:	0.5 MeV/turn
Maximum RF Voltage:	**6.6 MV**
Stored current with operational margin:	**220 mA**
HOM damped cavity prototypes:	**validated for 0.6 MV / 150 kW**
EBS 30 % less total RF power:	**≈ 1 MW at nominal 200 mA**

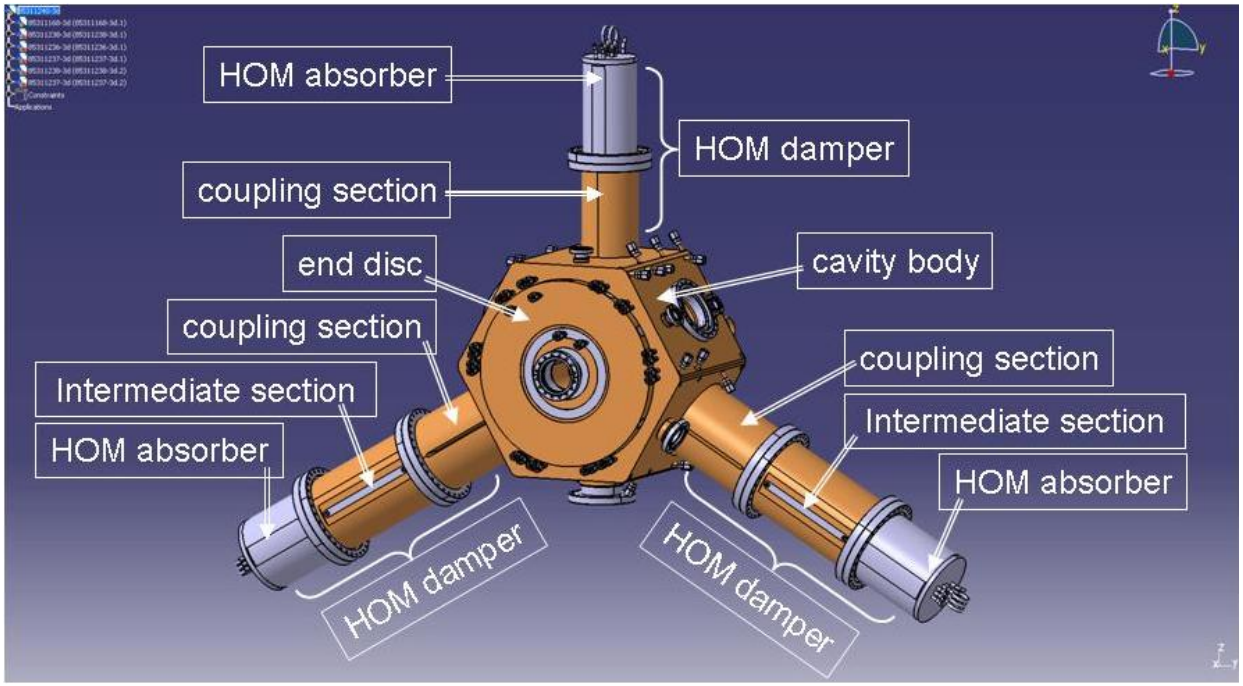
RF LAYOUT


Cell 5
Cell 7
-7 dB
-7 dB
Storage Ring
KLYS 1
KLYS 2
Teststand
Compact 85 kW SSA with cavity combiner
75 kW tower
75 kW tower
75 kW tower
75 kW tower
75 kW tower
75 kW tower
In house SSA
3x existing 150 kW SSAs
3rd harmonic RF system
• Still under study:
5 to 6 active NC cavities
• SSA development started:
≈ 40 kW per cavity
Cell 25

HOM DAMPED CAVITIES FOR EBS



[ESRF design by V. Serrière]



f_{res}	352.372	MHz
Q_0	35700	(measured)
R/Q	145	Ω
R_s	≈ 5	MΩ
Tuning range	-350 / +900	kHz
V_{acc} nominal / max	500 / 750	kV

STATUS: FABRICATION OF 12 CAVITIES FOR ESRF-EBS

- All 12 cavities delivered by RI - Research Instruments
- 11 cavities already RF conditioned to 750 kV (without HOM absorbers)
- Last cavity conditioning in the coming 2 weeks
- Installation of HOM absorbers in 2018

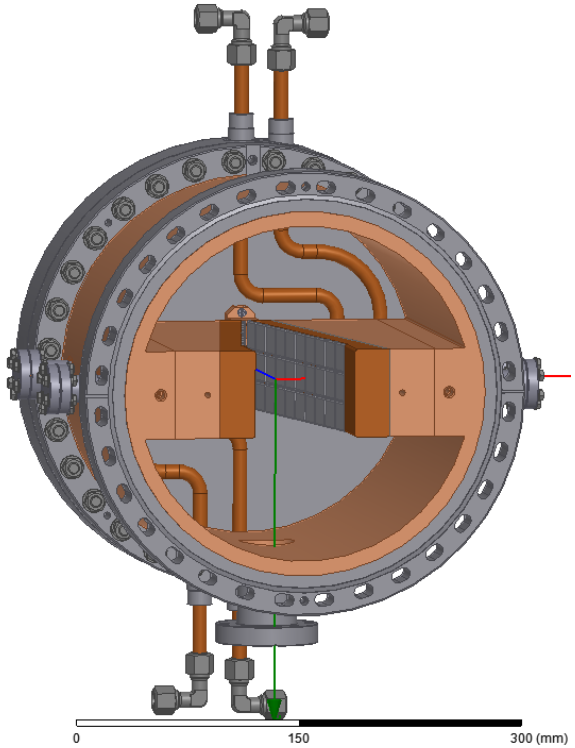
Pre-conditionned cavities in assembly zone

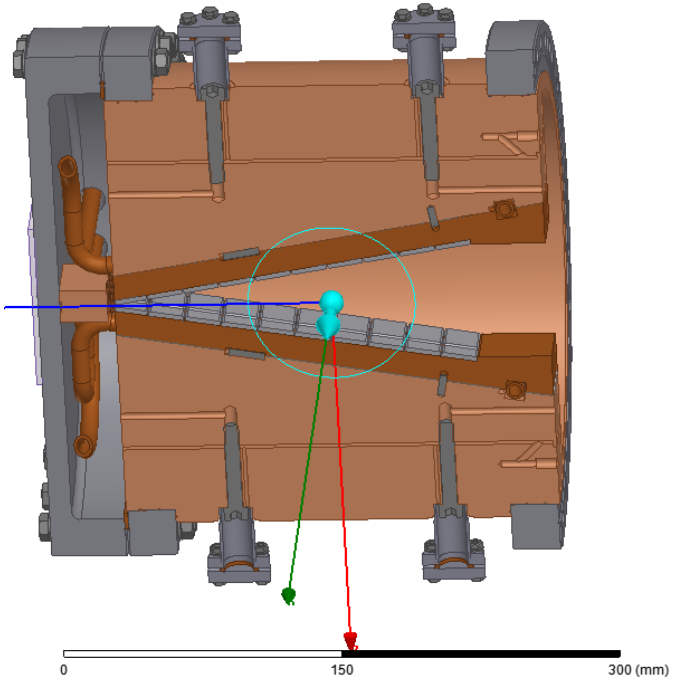
[A. D' Elia et al.]

STATUS: HOM ABSORBERS

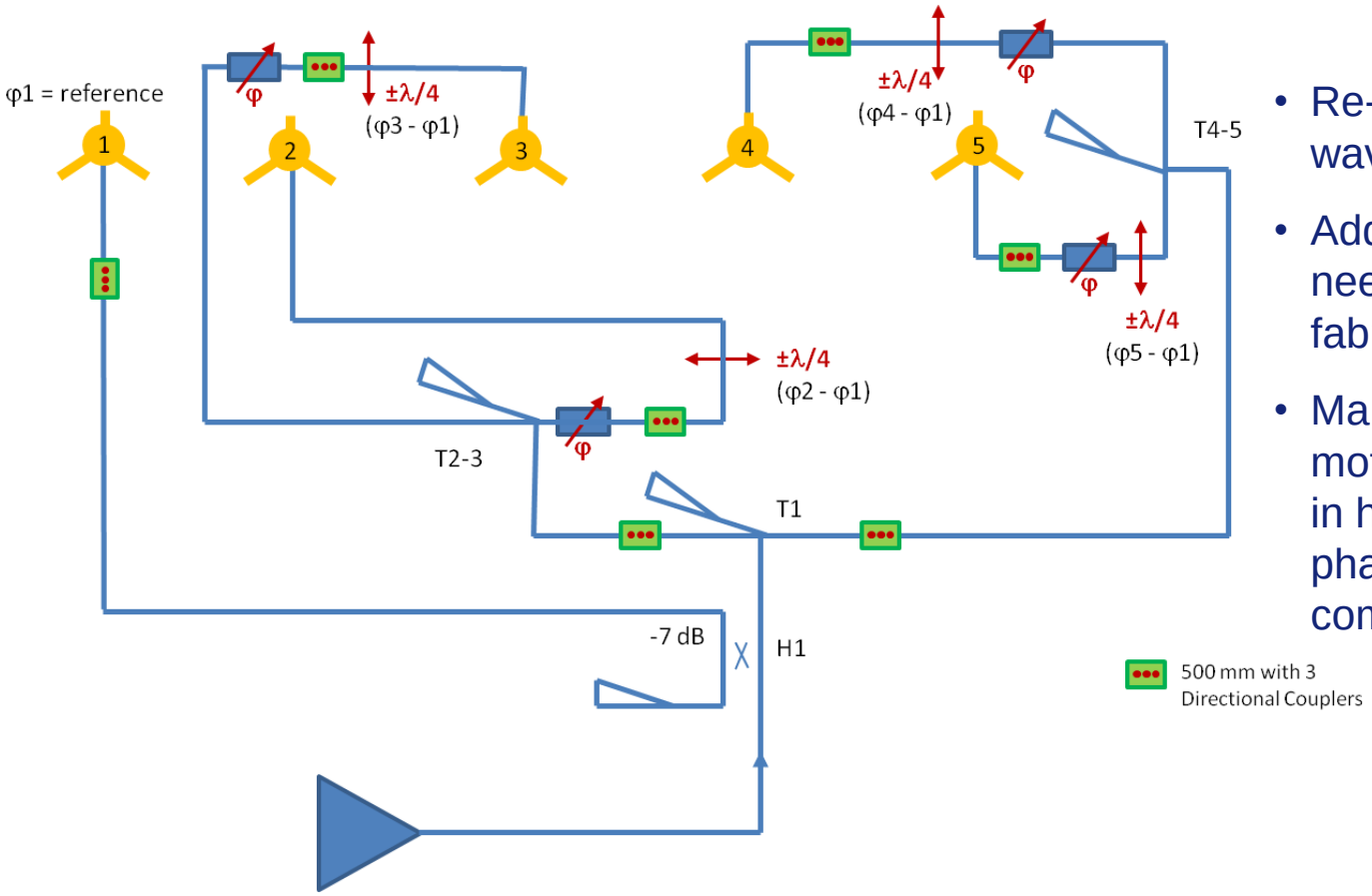
HOM absorbers still in fabrication by RI - Research Instruments

- Challenging brazing of ferrite tiles on Copper wedges
- Apr. – Oct. ‘17: thorough ultrasonic tests of brazing samples
- Nov./Dec. ‘17 : just starting RF power cycling of 1st HOM absorber to check soundness with time
- First half 2018: delivery of HOM absorbers in several batches, and installation on cavities





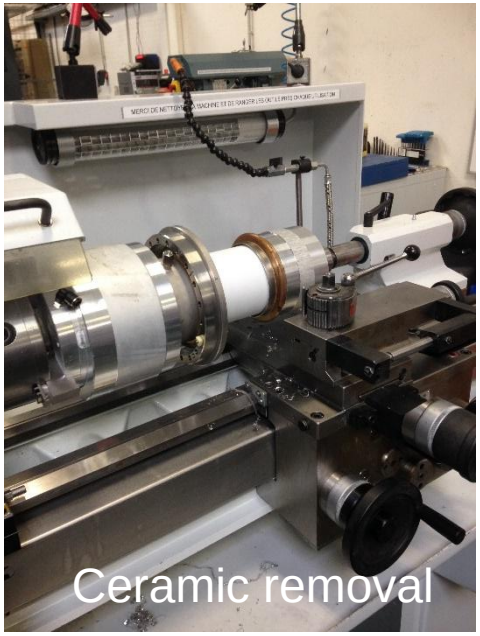
WAVEGUIDES

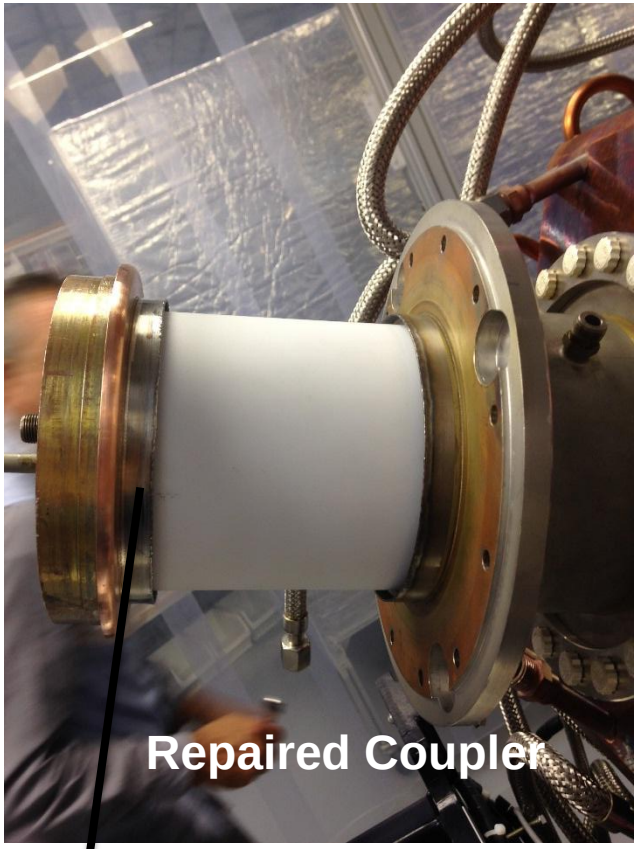


- Re-use of existing waveguide elements
- Additional waveguides needed for EBS in fabrication
- Manual phase shifters: motorisation developed in house for easier phase tuning at machine commissioning

Waveguide layout – Example of cell 5, powered by a klystron

IN HOUSE REPAIR OF POWER COUPLER: CERAMIC WINDOW REPLACEMENT





- Repaired coupler on Cavity#12
- Power test during RF conditioning in the coming 2 weeks
- If it works we will get many spares !

[V. Serrière & B. Cocat]

CONCLUSION

- **Good RF performance: we are optimistic for the last year of operation of our 25 years old storage ring**

- **We are also confident for the new EBS machine to be installed in 2019**
  - ✓ RF system upgrade in good progress
  - ✓ All cavities perform extremely well (750 kV i.e. 50 % more than nominal)
  - ✓ Remaining: HOM absorbers and waveguide elements in production for a delivery in the first half of 2018

- **Confirmation that Arc Detectors are crucial at MW power level**
  - ✓ ESRF adaptation of CERN/LHC detectors perform well
  - ✓ Tripping indicates that something starts to deteriorate: one must inspect
  - ✓ Arcing of RF contact fingers: not necessarily linked with high reflection


Thank
you !!!