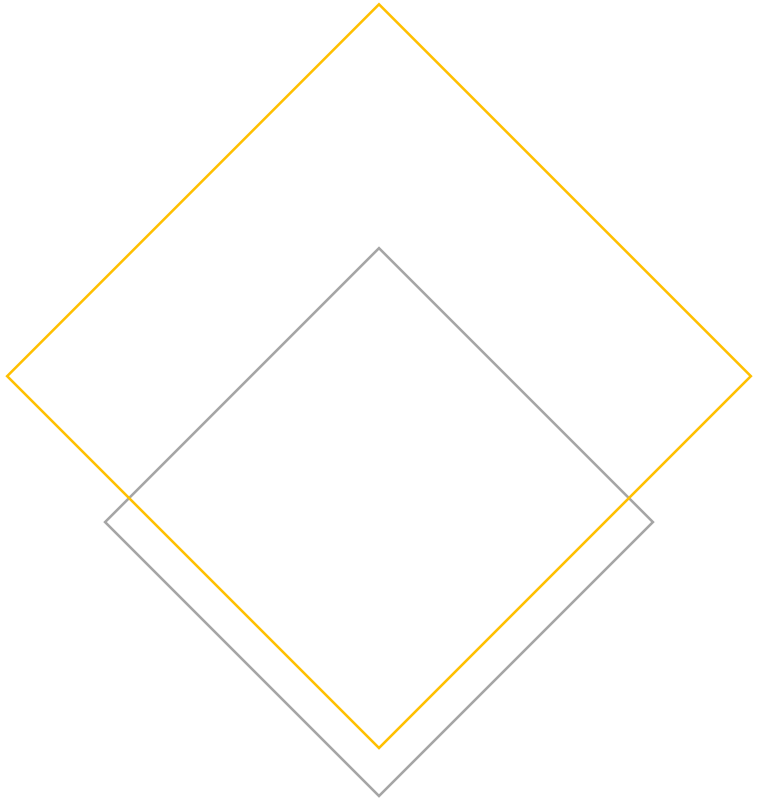


IOT operation in the SPS Long term experience

TWC 800 MHz

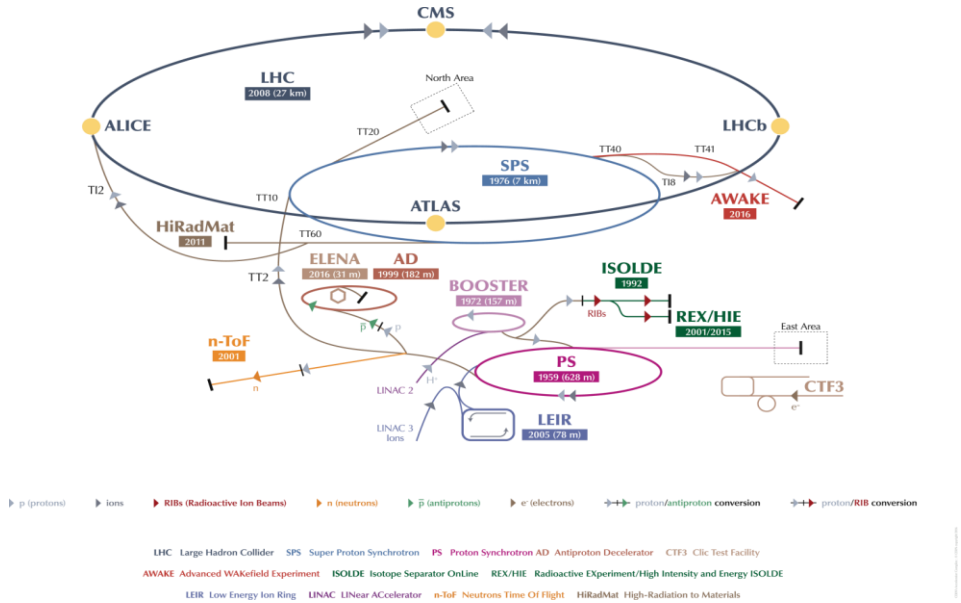
24 - 25 October 2019, Diamond Light Source
Simon Rains, Frederic Killing, eric.montesinos@cern.ch

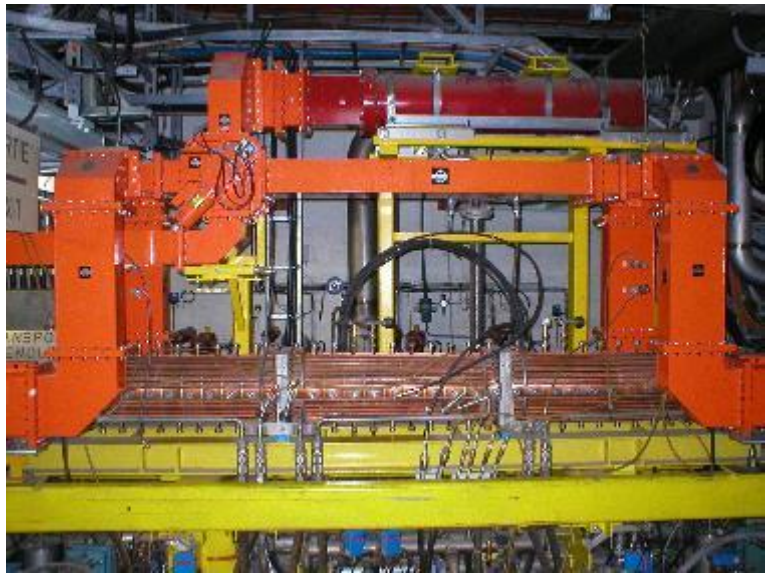
CONTENTS

Simon Rains, Frederic Killing, eric.montesinos@cern.ch

SYSTEM PRESENTATION

CERN Accelerator complex





2 x 800 MHz
TW Cavity

TH795

160 KW CW per
Cavity

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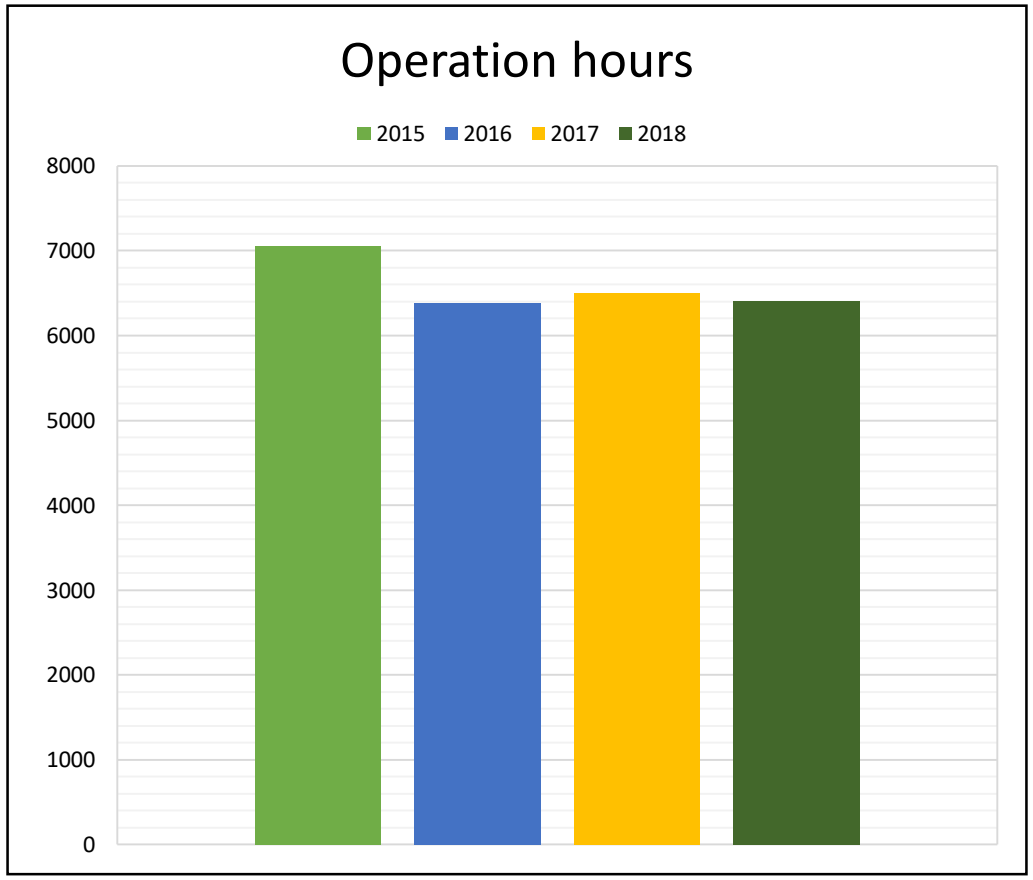
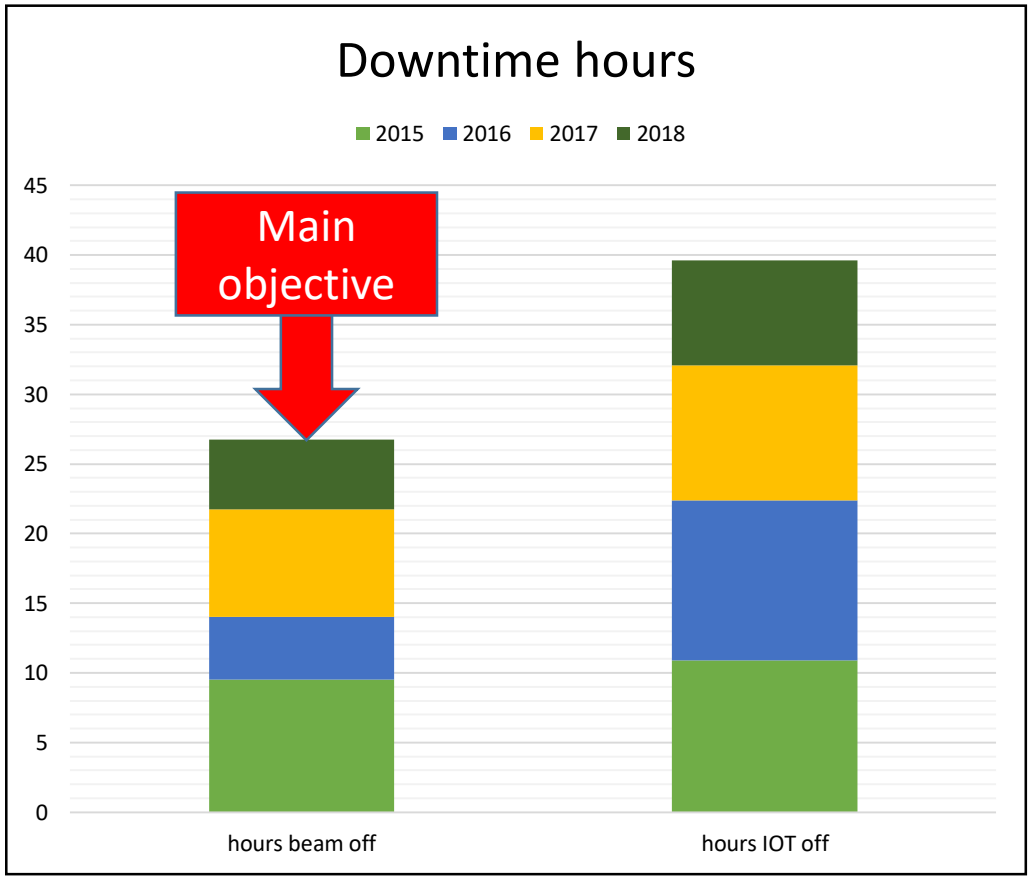
OPERATION STATISTICS





On average there was around 7000 hours off operation per year.
The availability for beam in SPS was more than 99.9 %

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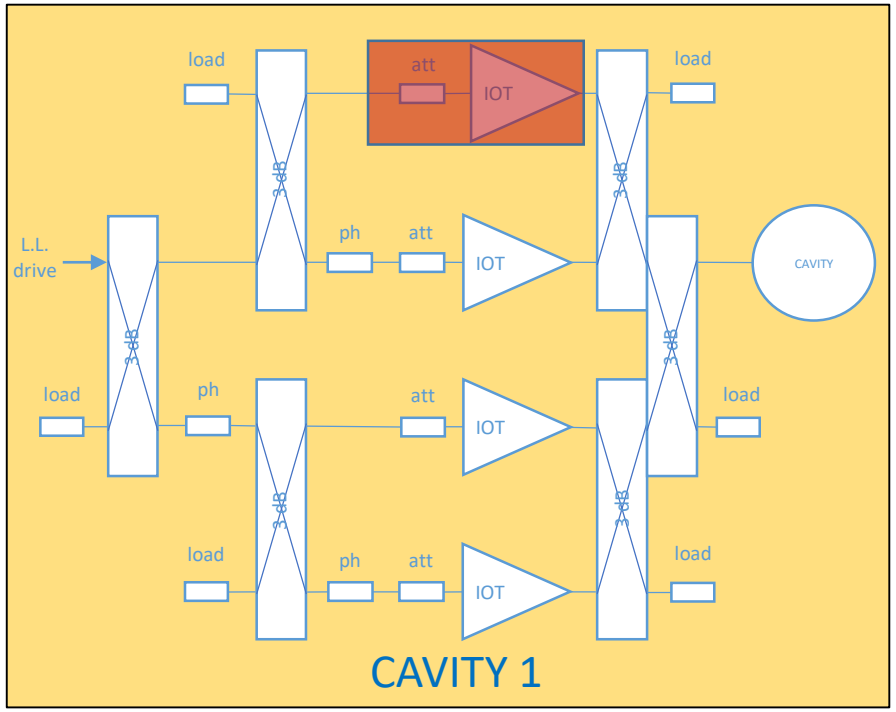
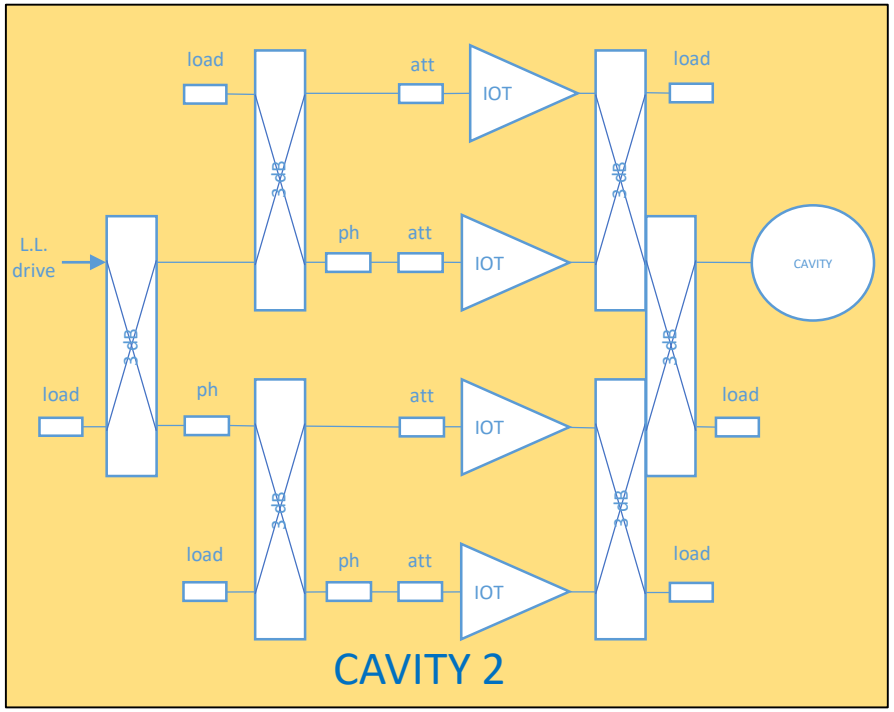
800 MHZ OPERATION SCENARIO





- 4 IOTs combined for 1 cavity
- The beam operation allows for 1 IOT offline per cavity
- And also, depending the users, the system allows us to have 1 cavity off !

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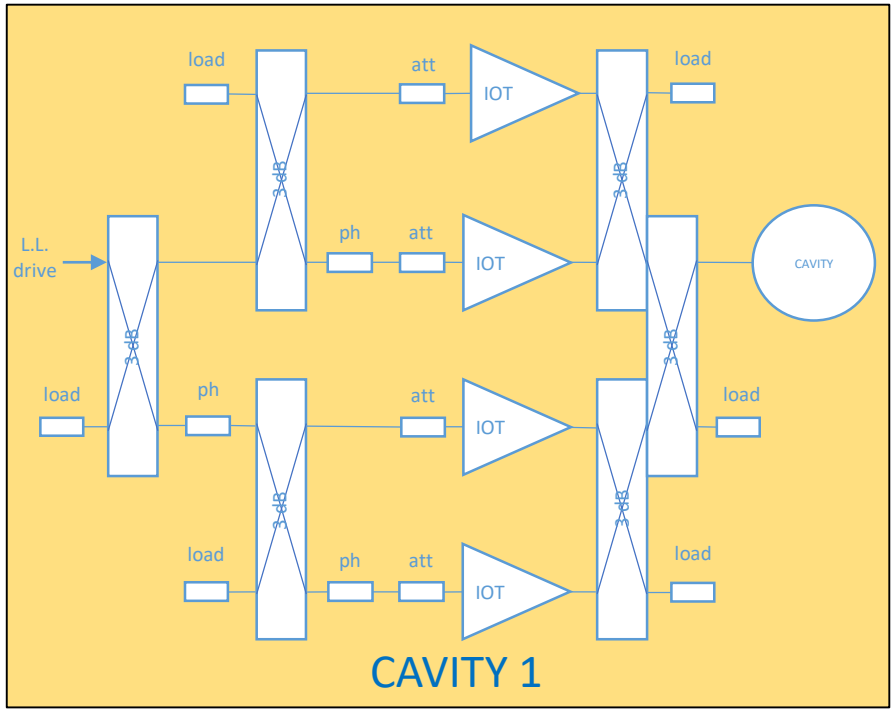
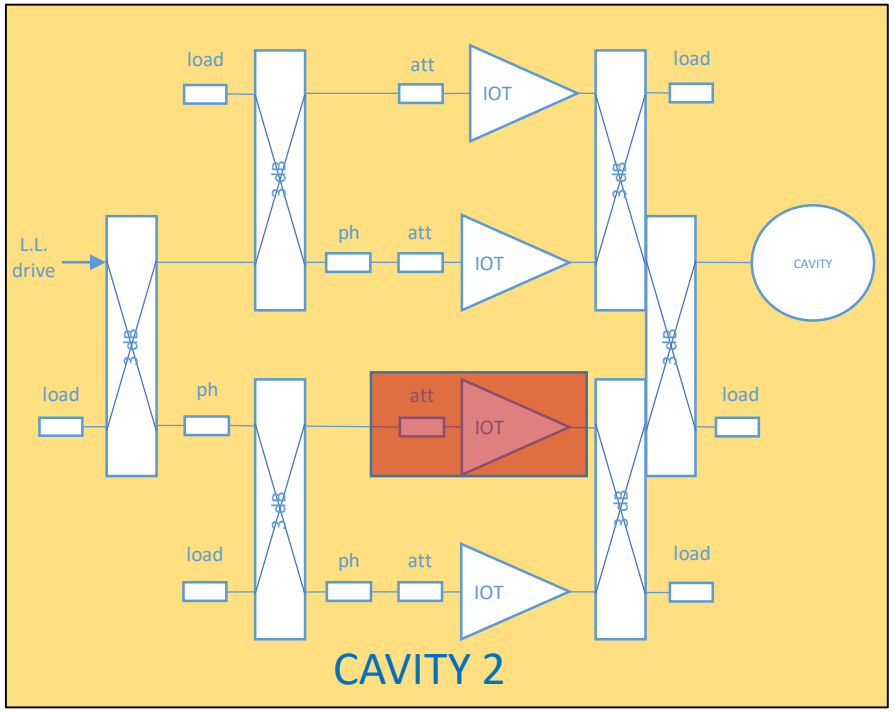
800 MHZ OPERATION SCENARIO





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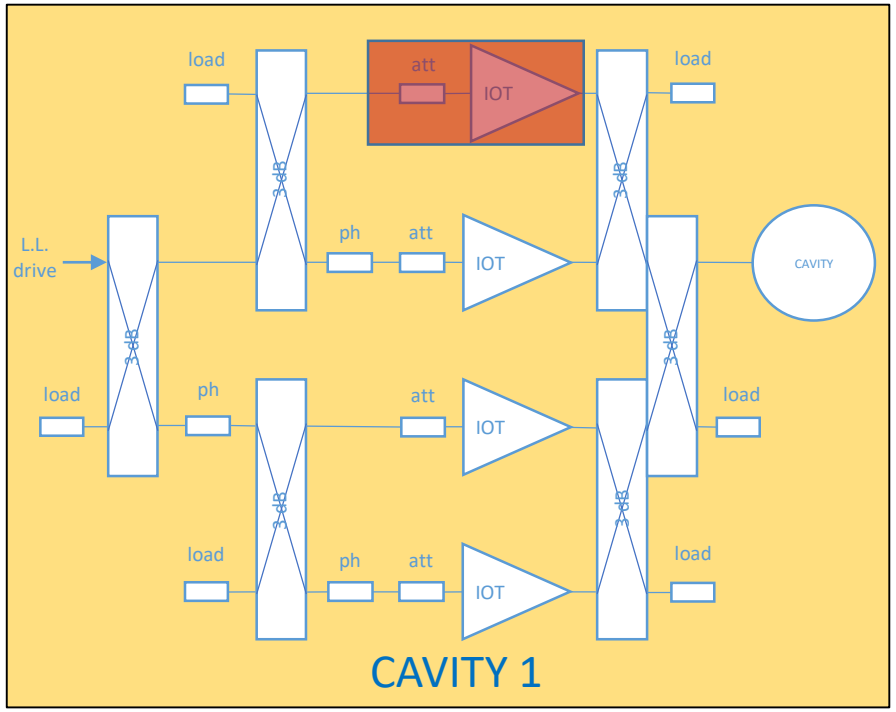
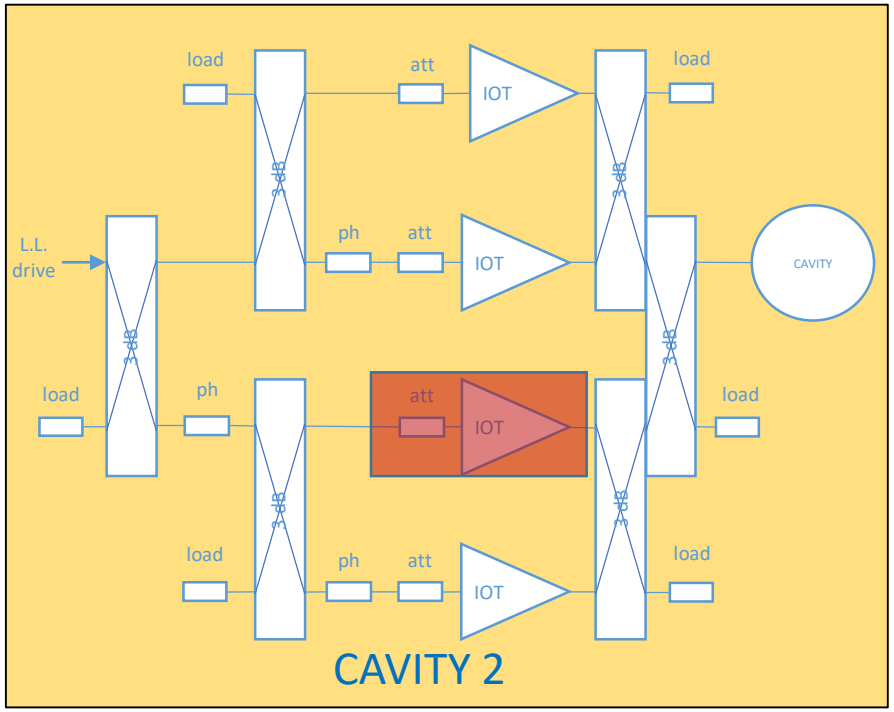
800 MHZ OPERATION SCENARIO





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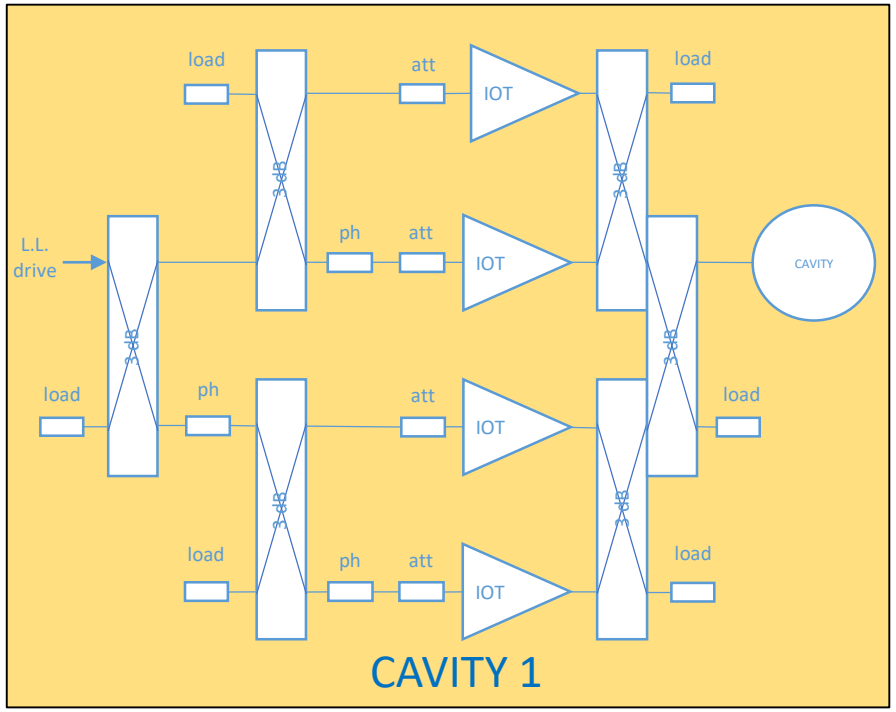

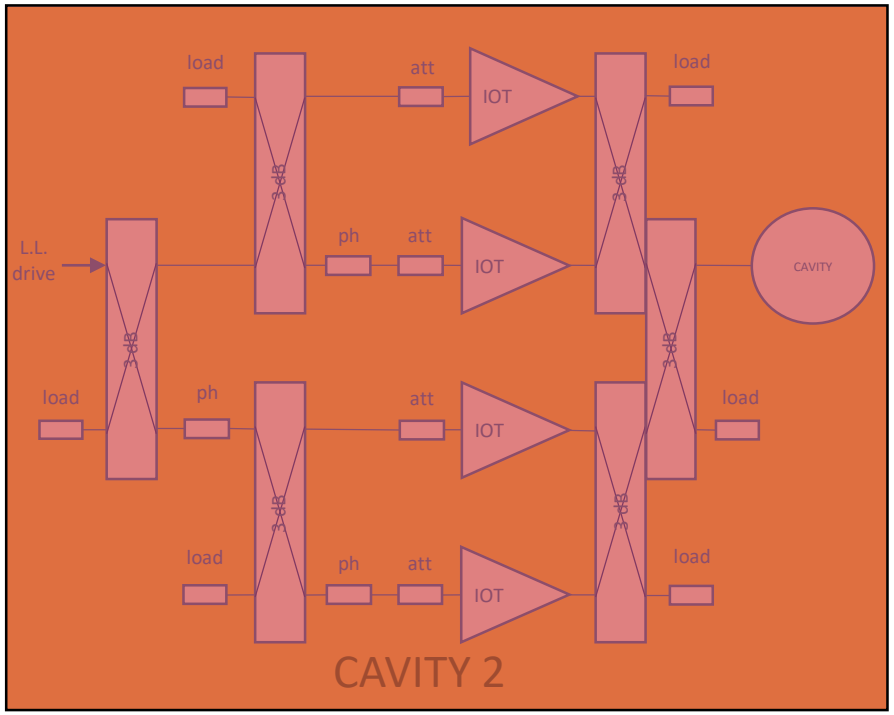

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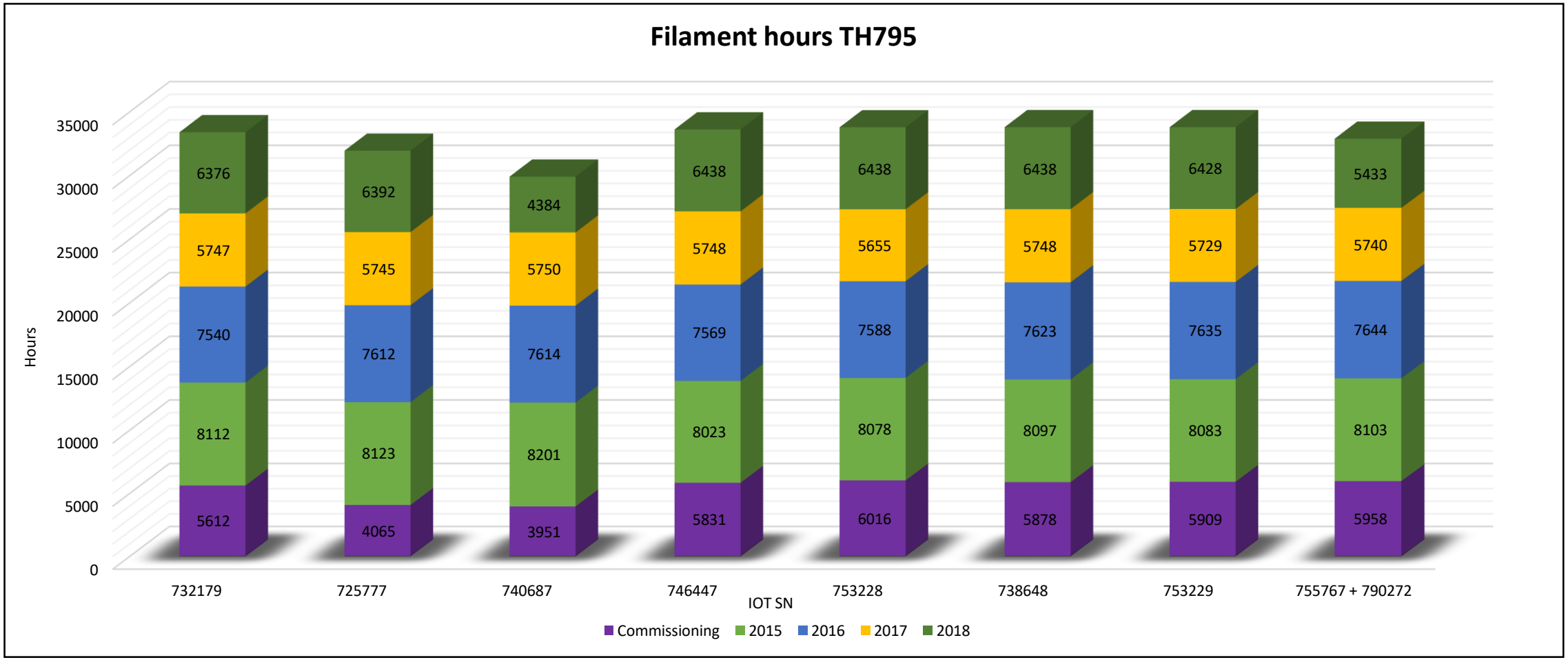
LIFE TIME DATA

- 4 years of operation
- 6 tubes now have more than 30’000 filament hours
- Only one had to be replaced current of 2018 with a ‘possible’ arc failure (still to be confirmed, the tube could be ok)



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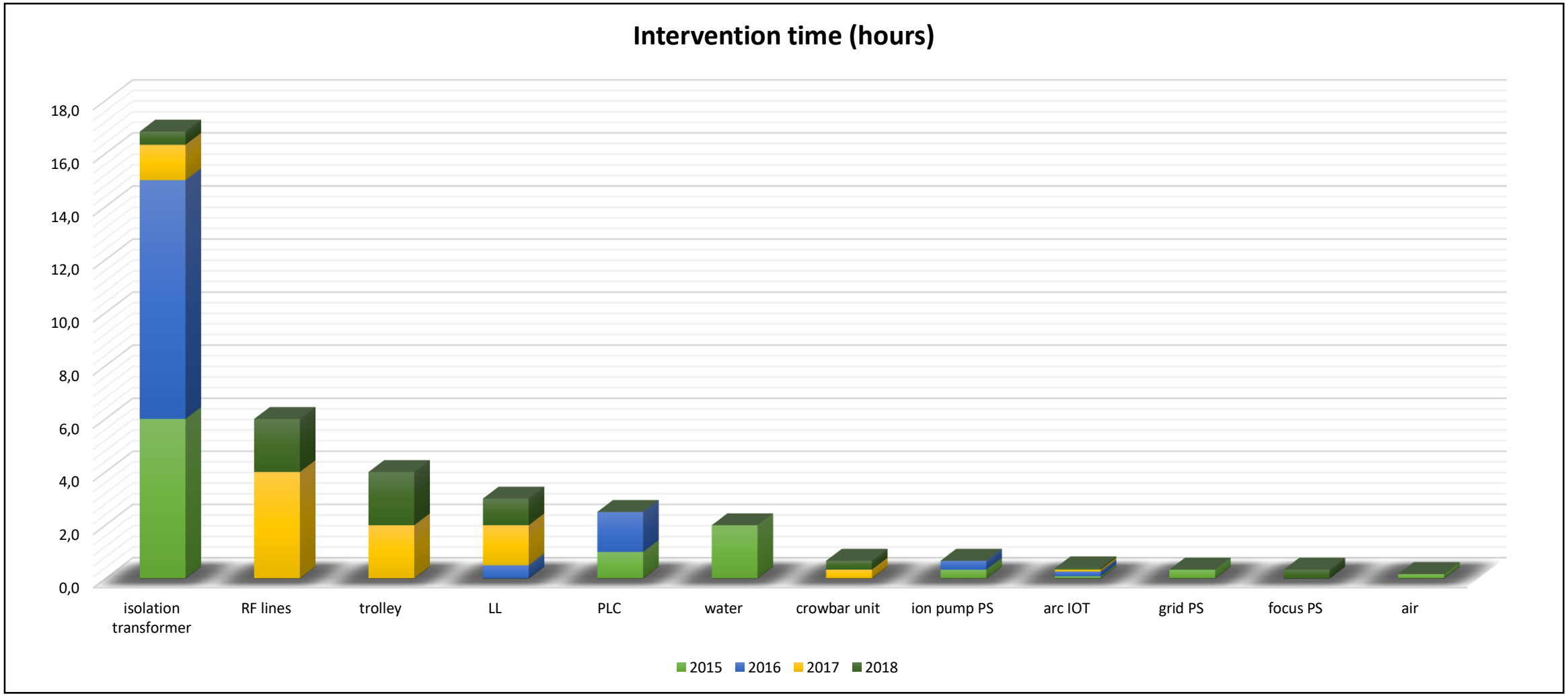
FAULTS



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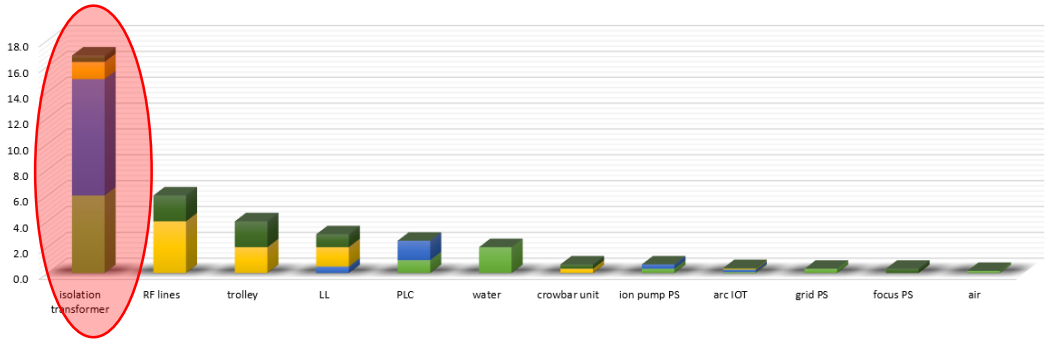
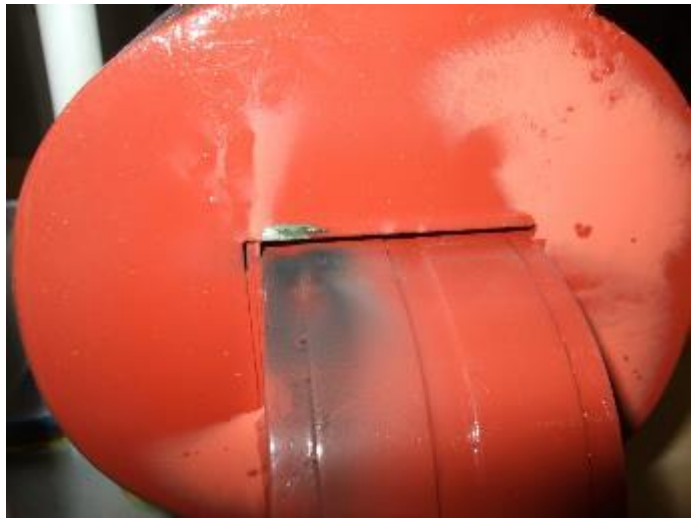
FAULTS

- Isolation Transformer :
  - Resin transformer isolated up to 60 kV DC
  - All first transformers installed came from a bad series
  - During the first two years of operation, it was difficult to identify that the problem was the transformer
  - New transformers were bought with an improved isolation
  - Interventions were always necessary to fix the trouble, main circuit breaker tripped



Not a thermal cause !



But a HV arc!

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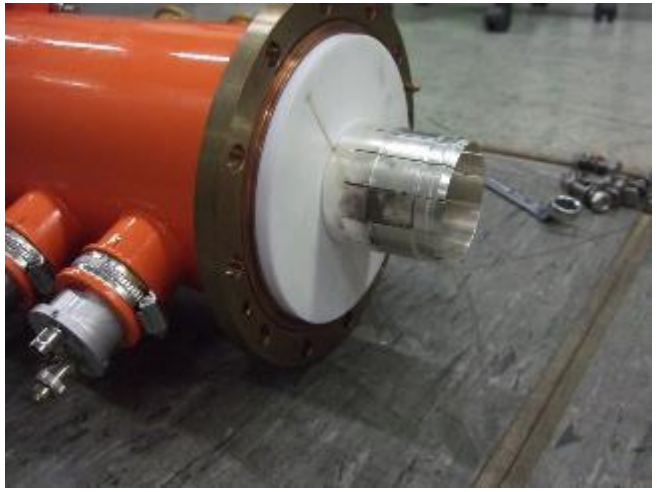
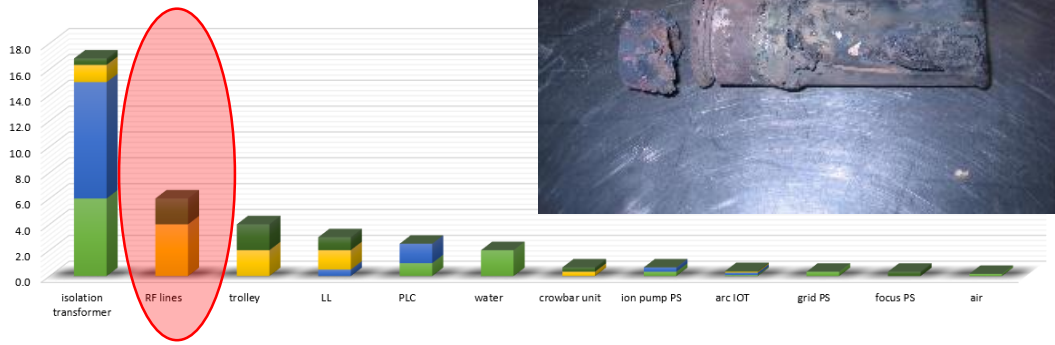
FAULTS

- Coaxial lines :
  - Some difficulties with the coaxial line assemblies were experienced
  - This was human error
  - Can appear several days after the bad contact was made.
  - The time of intervention for repair is several hours



4-1/2’’ coaxial line

Inner elbow burned



Bad contact from the inner clamp

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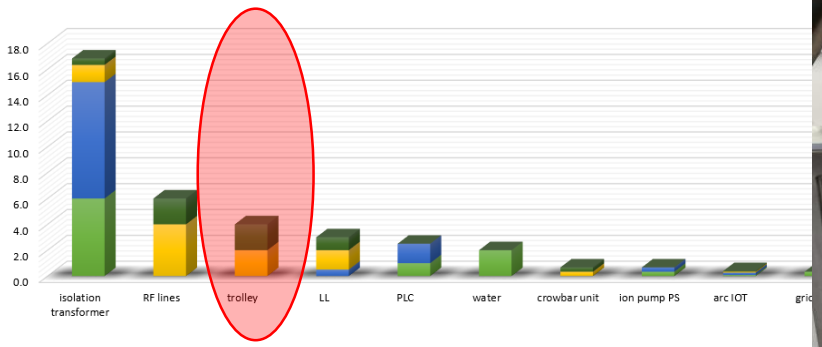
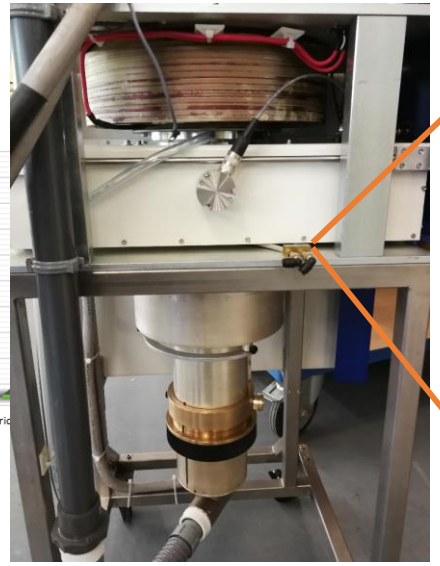
FAULTS

- Trolleys :
  - The pieces between Ion pump and cathode melted due to bad soldering.
  - A second default found was a water leak on the anode contact also due to a bad brazing
  - The time to replace a trolley from the transmitter is as well several hours

Ion pump isolation piece





Anode cooling pipes

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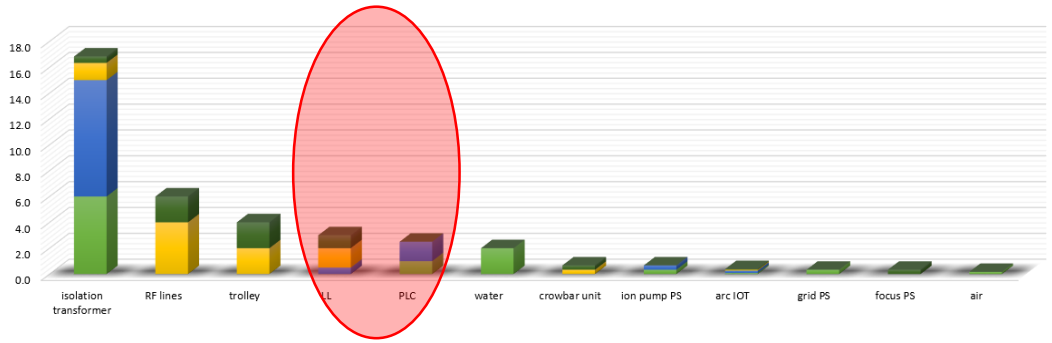
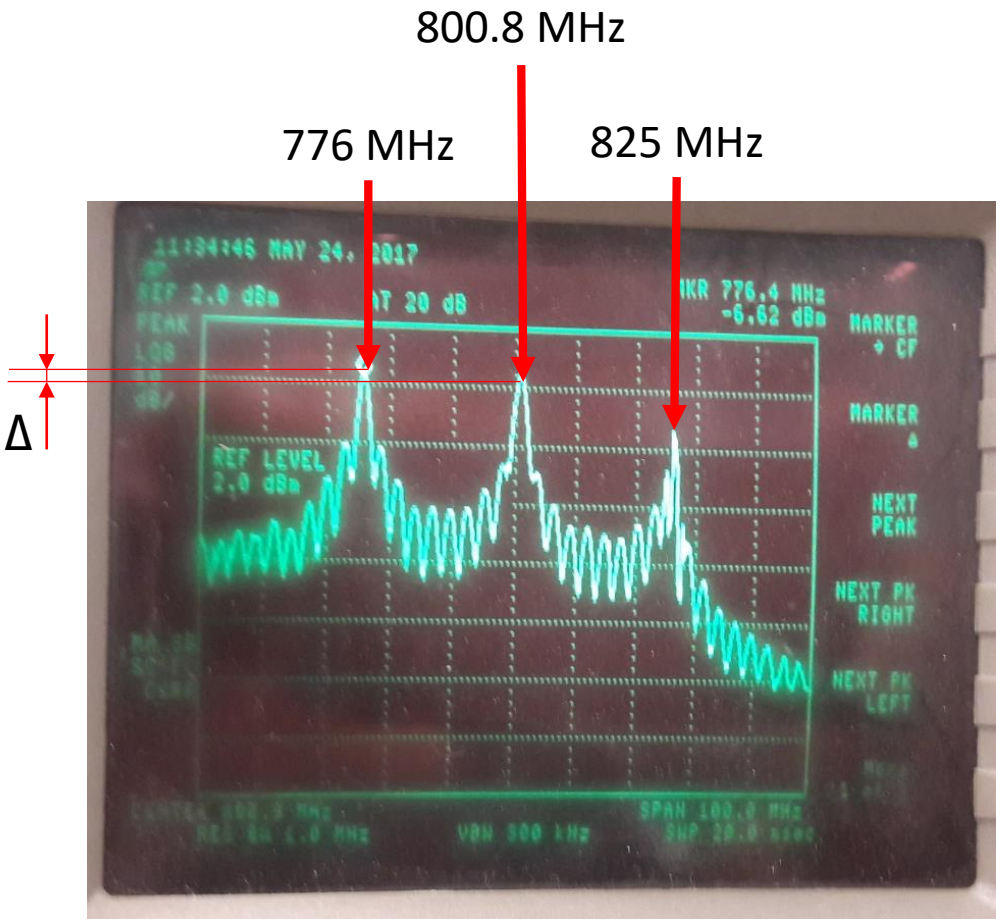
FAULTS

- Low Level RF and PLC :
  - Following the LLRF upgrade two years ago, the new ‘Switch & Limit’ system generated strange injections to the power system.
  - Concerning the PLC and controls, we fixed some initial problems linked with the start-up, and later troubles linked with the ‘S&L” system.





‘Switch & Limit’ system generated harmonics (- 25 MHz / + 25 MHz) even higher than the fundamental !

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IOT STARTING UP MANAGEMENT

First start (at reception of the tube before storage or after a long (years) storage)

IonPump & Filament : 24 hours

HV (20 kV / 0.2 A) : 1 hour

HV (30 kV / 0.2 A) : 1 hour

HV (35 kV / 0.6 A) : 1 hour

HV (35 kV / 0.15 A) : 1 hour

RF (CW half power) : 30 min

RF (CW full power) : 30 min

Second start (after storage, less than a year)

IonPump & Filament : 2 hours

HV (20 kV / 0.2 A) : 30 min

HV (30 kV / 0.2 A) : 30 min

HV (35 kV / 0.6 A) : 30 min

HV (35 kV / 0.15 A) : 30 min

RF (CW half power) : 30 min

RF (CW full power) : 30 min

Long stop (hours or days)

IonPump & Filament : 2 hours

HV (20 kV / 0.2 A) : 30 min

HV (30 kV / 0.2 A) : 30 min

HV (35 kV / 0.6 A) : 30 min

HV (35 kV / 0.15 A) : 30 min

RF (CW half power) : 30 min

Short stop (minutes)

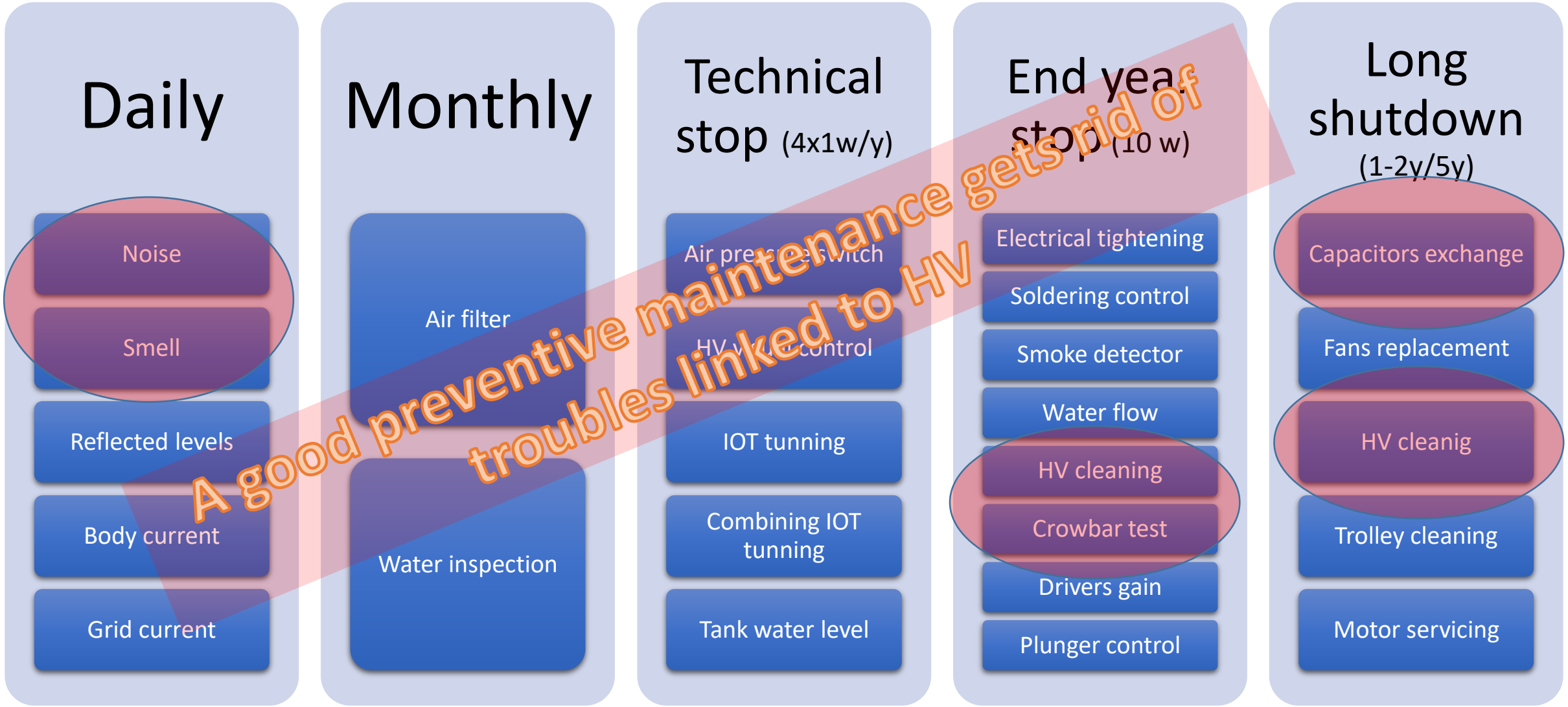
IonPump & Filament : 10 min

HV (35 kV / 0.15 A) : 0 min

RF (CW full power) : 0 min

In case of more difficulties for the start up of an IOT, we do a conditioning on table up to 45 kV (35 kV in operation).
In addition we also reduce the filament current with respect to ageing given Thales indications.

PREVENTIVE MAINTENANCE



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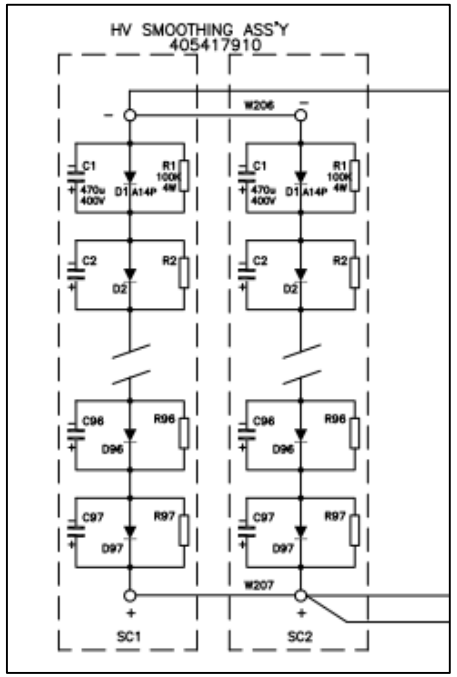
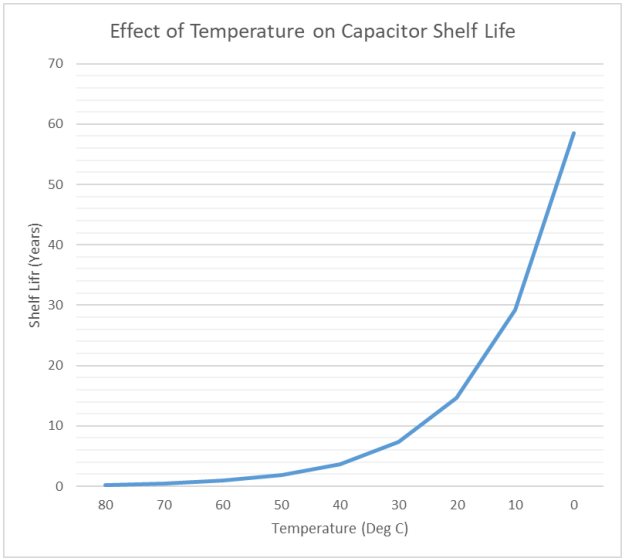
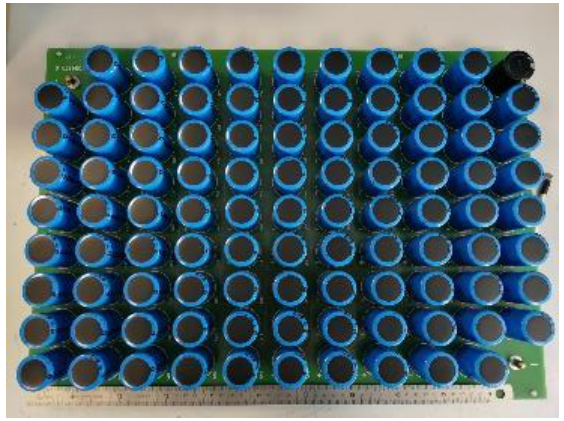
PREVENTIVE MAINTENANCE

- Smoothing capacitors :
  - The Low Voltage capacitors (400 VAC) for the HV smoothing in Electrosys cubicle is an important point for the maintenance and operation
  - The lifetime in operation is rated 20’000 hours
  - The shelf life is variable depending on temperature







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PREVENTIVE MAINTENANCE

- Grid cleaning process :
  - Following the recommendation from Thales, we do a grid cleaning
  - The initial excess of barium from the cathode moves to the grid, and after around 5’000 hours this starts to induce thermal grid current
  - We implemented our own system, and after our process the complete thermal grid current disappears by removing this excess of barium from the grid
  - The cleaning was for the moment necessary only one time for each IOT

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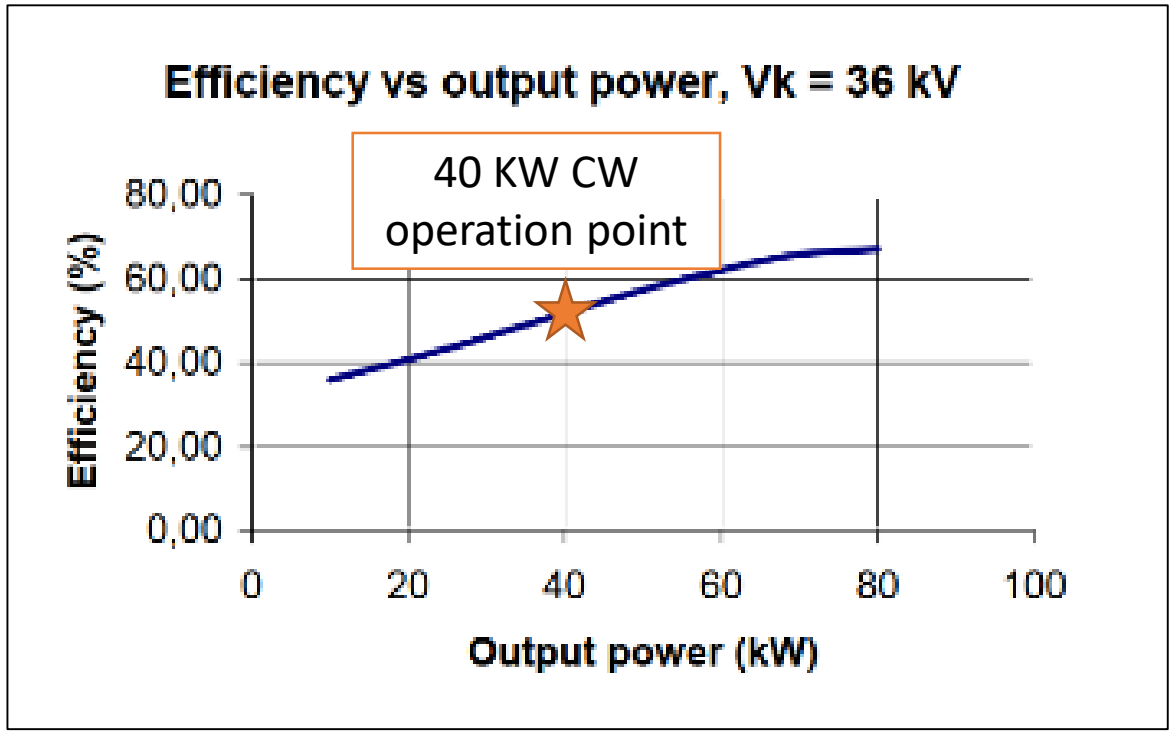
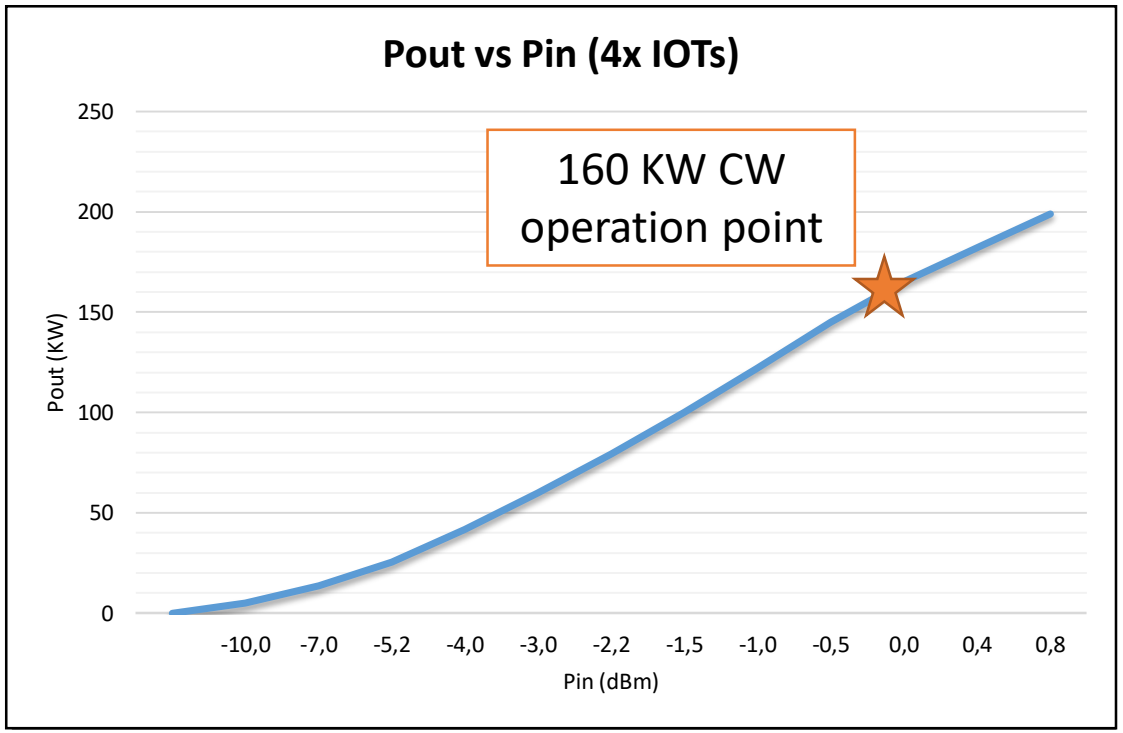
EFFICIENCY





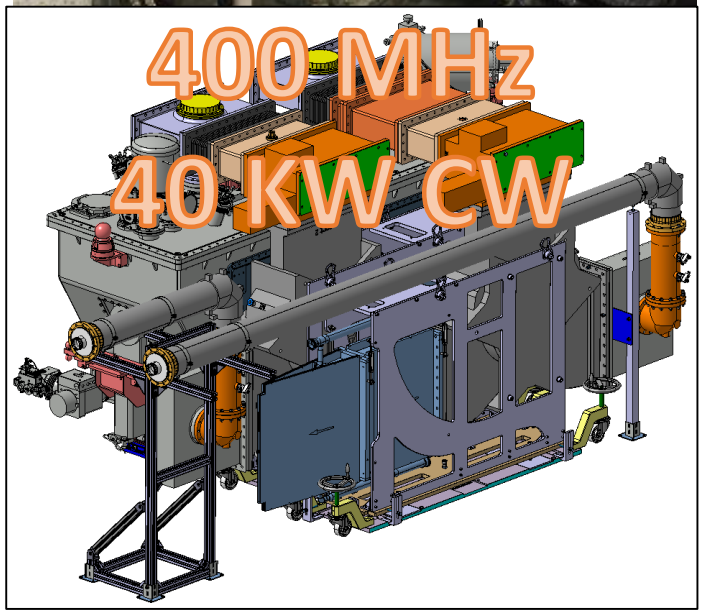
In order to guarantee availability for the beams, and include margin requested by the LLRF, we decided to operate the tubes at a lower point of operation than the maximum available.
Lower point of operation also increases lifetime of tube.
We demonstrated that this is very efficient for the availability of the system.

OTHER IOT INSTALLATIONS @CERN

SPS Crab cavity

400 MHz

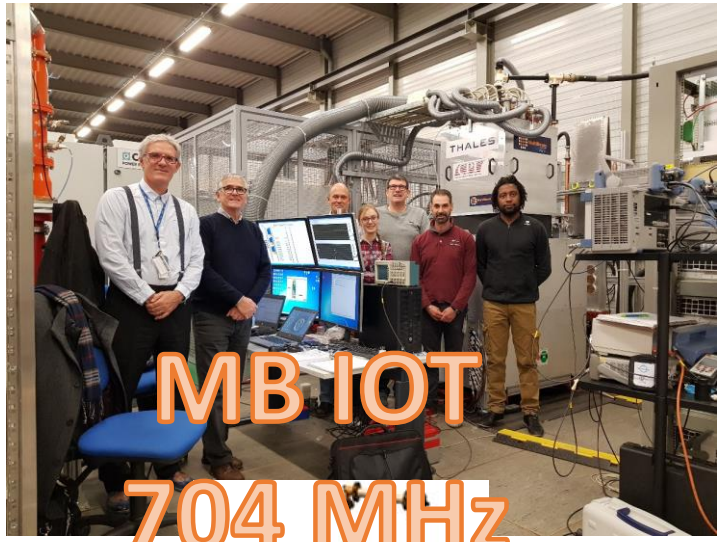
40 KW CW



Medical RFQ

750 MHz

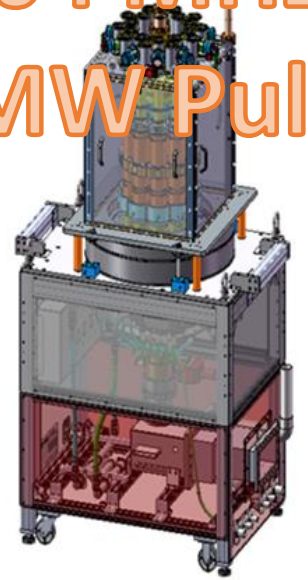
100 KW Pulsed



MB IOT

704 MHz

1.2 MW Pulsed



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CONCLUSION

- Our IOT system is now mature and has proven to be very reliable, ensuring a high availability for the beams
- IOT itself demonstrated to be very robust and easy to operate
- IOT has the advantage of a high gain, needing only a few hundreds of Watt driver
- IOT offers a high power density (HVPS can be aside and quite far away)
- Given the LLRF requirements of margin, IOT offers a very good DC to RF efficiency

- IOTs are absolutely fantastic !
- IOTs should always be considered for RF systems for accelerators !

- Thank you for your attention