Status and New Developments of RF Systems of ALBA

ESLS RF Meeting – PSI – Nov 2016

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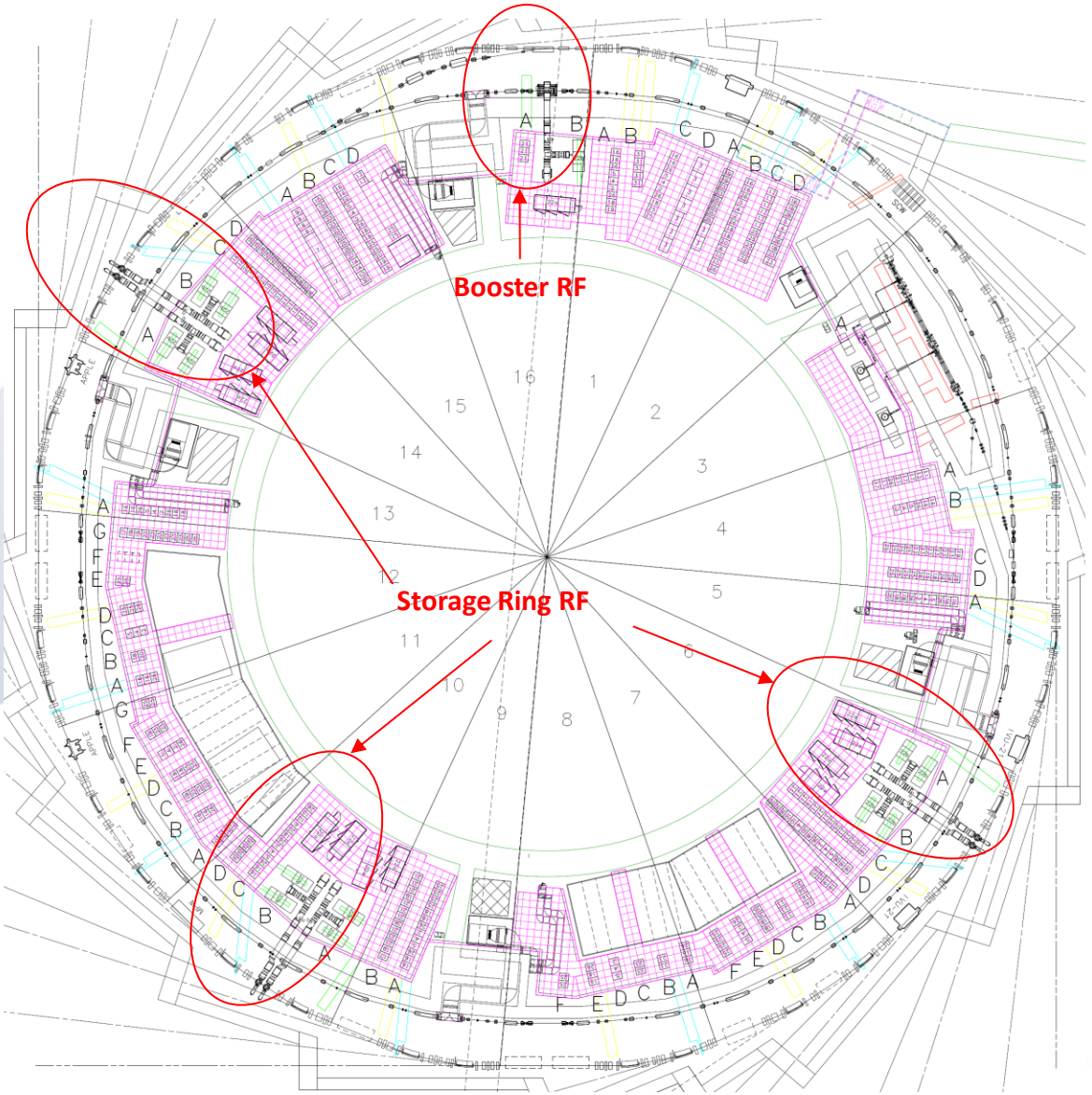
Outline

- ✓ ALBA RF Overview
- ✓ 2016 Operation
  - Statistics
  - Main operation issues of RF systems
- ✓ RF upgrades
  - Thales IOT TH-795
  - 500W SSA Pre-drivers: TTI and Btesa
  - LLRF: Phase modulation for RF Trip Compensation
- ✓ RF Lab
- ✓ New developments and future upgrades
  - 1.5GHz SSA transmitter
  - 3rd Harmonic Active Cavity – HOM
  - 50kW SSA Transmitter for Booster

ALBA RF Overview

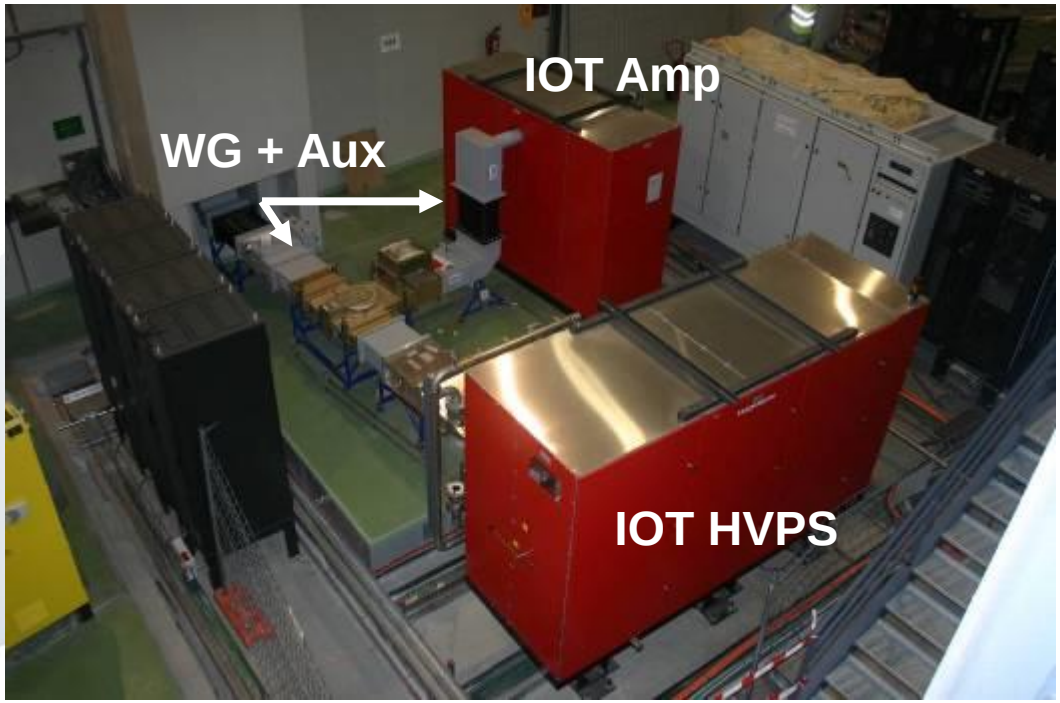
RF at ALBA Overview

- Linac
  - 2 Klystrons + WG system + travelling wave cavities at 3Ghz
  - 90keV to 100MeV
- Booster
  - IOT + WG System + 5-cell cavity @ 500MHz
  - 100MeV to 3GeV
- SR
  - 12 IOTs + WG system + 6 cavities @ 500MHz
  - Beam stored @ 3GeV



BOOSTER RF

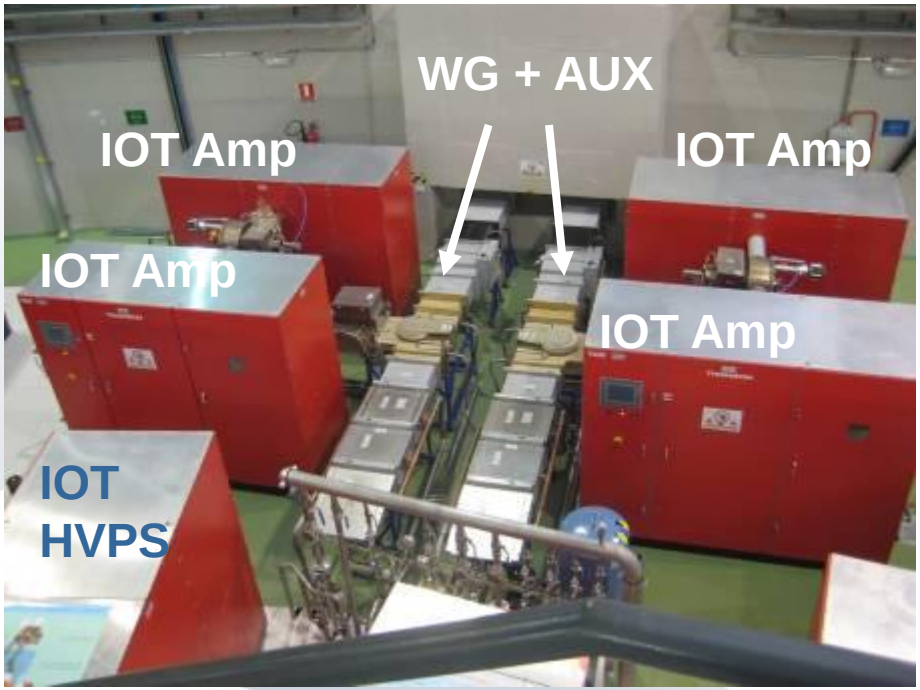
Tunnel:
5Cell Cavity – 500MHz



Service Area: RF amplifier + Auxiliaries

SR RF

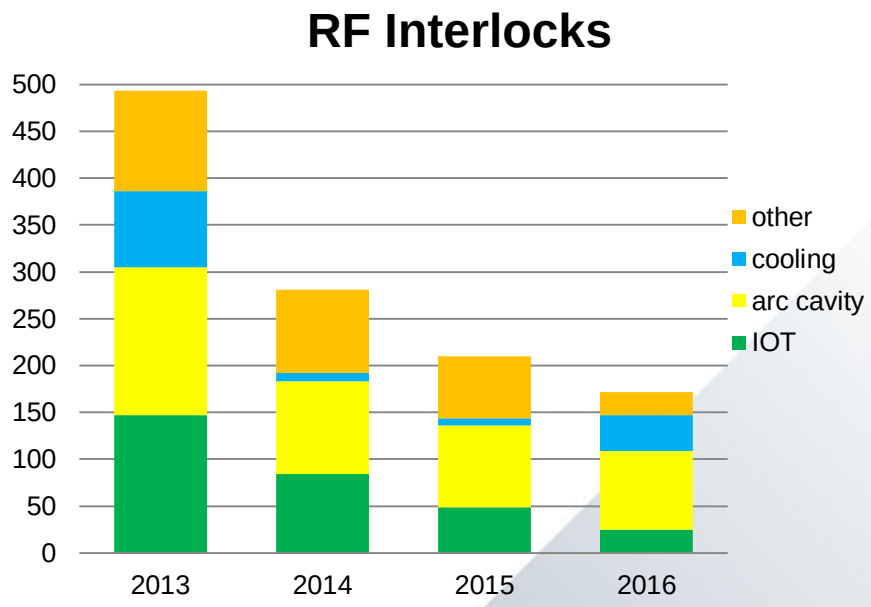
Tunnel: Dampy Cavities 1Cell – 500MHz

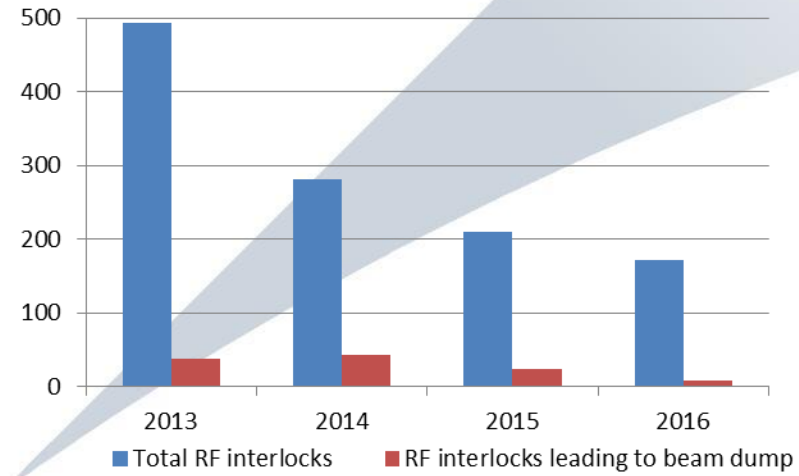


Service Area: RF amplifier + Auxiliaries

2016 Operation

RF Statistics of 4 years operation





✓ 2016 Operation:

- Top-up 130mA (140mA since Oct)
- FOFB & BbB$_{vert\&hor}$

RF ITCK Types	2013	2014	2015	2016
IOTs	147	84	49	25
Arcs cavity	158	99	87	84
Cooling	81	9	8	38
Other	107	89	66	25
Total RF interlocks	493	281	210	172
Beam Downtime due to RF (h)	38	43	23	8
Beam Downtime due to RF (%)	1.4%	0.8%	0.4%	0.3%

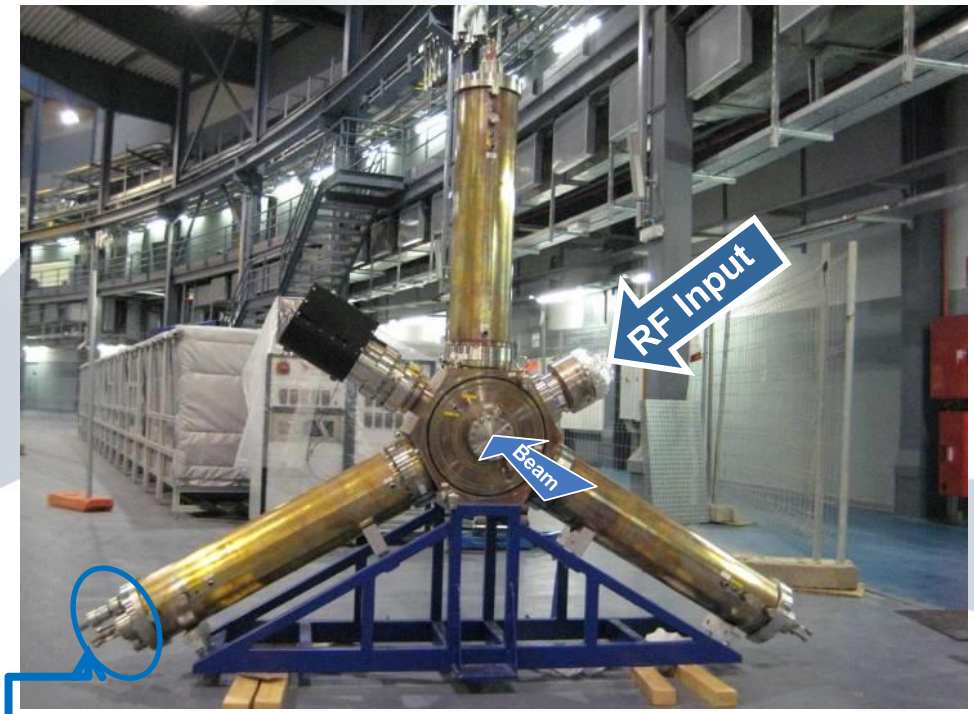
- ✓ IOT interlocks drastically reduced
- ✓ Still problems with cavity arcs
- ✓ Cooling interlocks increased

Main RF Interlock sources:

- ✓ Arcs in cavities (48%)
- ✓ Cooling (22%)
- ✓ Body current interlocks IOTs (14%)

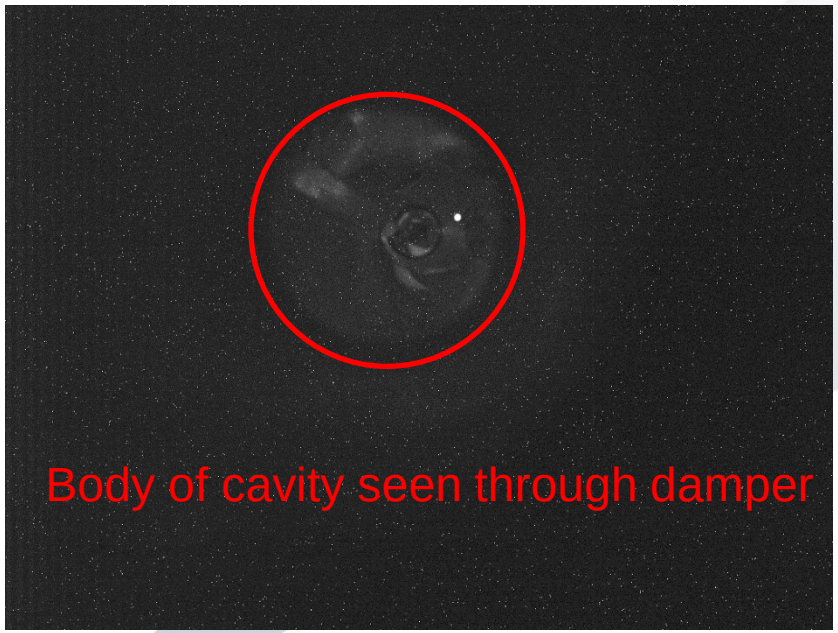
Arcs In Cavity

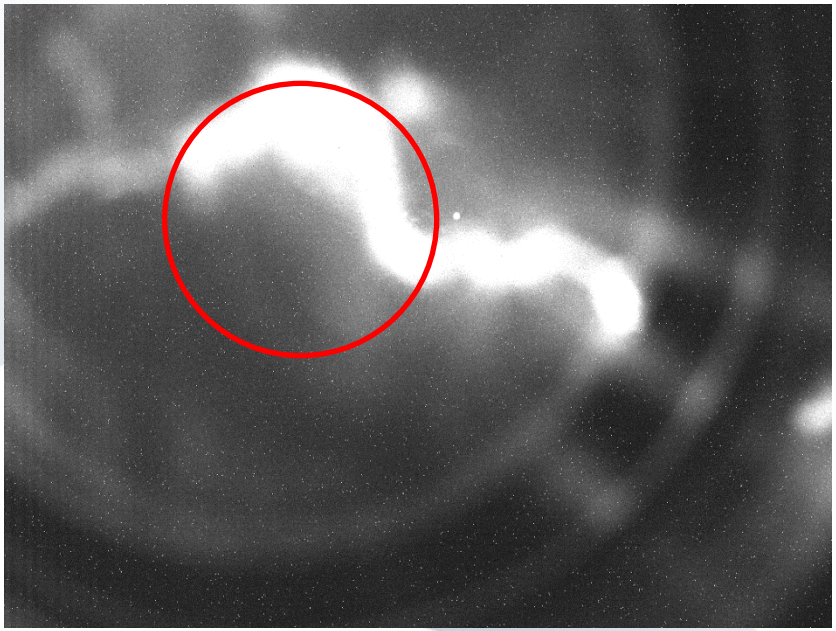
- ✓ 6 Dampy cavities in SR, each working at 450kV
- ✓ With Beam, since 2013, one cavity detects arcs if VCav > 350kV
- ✓ Installed CCD Camera



Arcs In Cavity

- ✓ Light detected inside cavity
  - CCD Camera + Script acquire frames before and after light is detected*

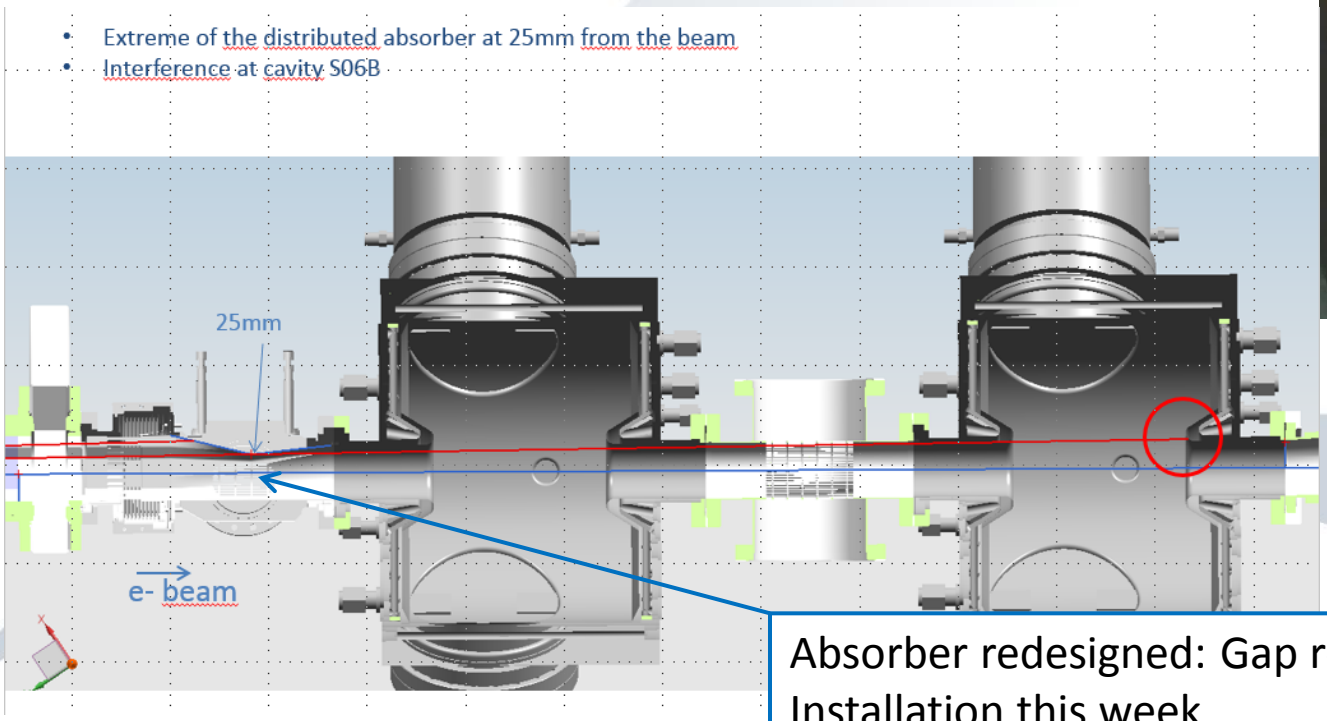




**Info provided by A. Nosych – Diagnostics Group*

Arcs In Cavity

- ✓ Cavity 06B opened in Jan 2016
  - Found marks of Radiation impact inside cavity
  - Ray Tracing done by R. Monge confirmed radiation impacts on cavity



Absorber redesigned: Gap reduced to **19mm**
Installation this week

Water Incidents

✓ Water leaks in circulators:

- During last 12 months: 3 CIRC (out of 7) developed water leaks.
- Circulator replacement time: 4h
- Reparaton in house: glue added to water leak point
- Preventive action: remove all circulators one by one and glue to be added before water leak happens

Water Incidents

- ✓ New water flow meters installed to measure flow of IOT Cav
  - Water flow meter sampling rate = 0.5s
  - From time to time samples are lost → fake water interlocks
  - Temporary solution: OFF Relays added to disregard interlocks
  - Looking for water flow meter replacement

IOTs

✓ IOTs Status

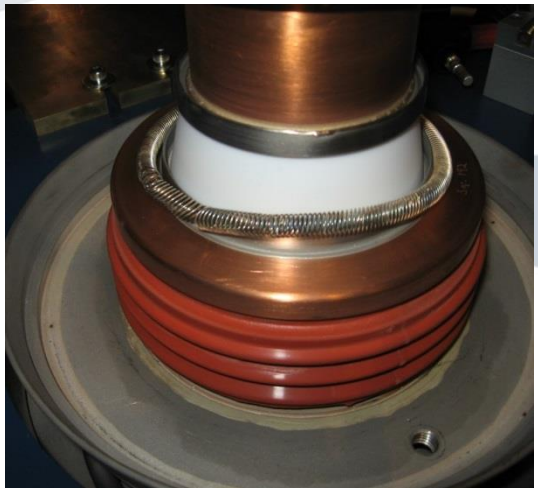
	# IOTs	Operation	Average age [h]	Oldest IOT	Body current interlocks
L3	5	35kW – 37kV	7340	10000	10
Thales	8	35kW – 32kV	12000	22000	15

✓ Thales Body Current Interlocks

- Body current interlock only in IOTs older than 15,000h
- New Thales IOTs (younger than 10,000h) no body current interlocks in operation

✓ L3 IOT body current interlock

- 70% L3 BCI happened in same IOT
- Found pinched finger
- After reparation, no body current interlocks



RF Upgrades

New Thales IOTs

✓ New Thales IOT: Th-795

- Based on TH-793: smaller output ceramic diameter
- Cylindrical input ceramics
- New e-gun with laser cut

✓ Advantages of smaller output ceramic:

- Problems with ceramic brazing solved
- Production flow more regular
- Smaller magnetic field in ceramic → less chance to have arcs/body current ITCKs

✓ Easy to adapt to Thales Trolley for TH-794:

- Rings added to ouput ceramics contacts to fit in output cavity for Th-794

✓ TH-795 in ALBA:

- 1 x TH-795 since Jun 2016
- 2 x TH-795 since sept 2016 (one kept as spare)

New SSA Pre-Drivers

✓ Thales SSA

- Gain jumps of Thales SSA in operation → IOTs combined power unbalanced → Reverse Power Interlocks

✓ New SSA Pre-drivers

- Two Spanish companies: TTI & BTesa
- 0.1dB gain linearity over 20dB [5W, 500W]
- Less than 3º phase variation over 20dB [5W, 500W]
- Interfaces compatible with Thales SSA driver

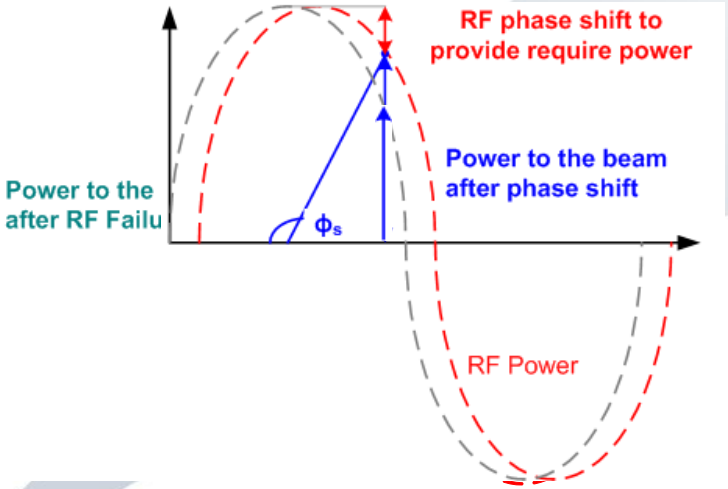
TTI SSA

BTesa SSA

RF Phase Modulation for Trip Compensation

✓ Normal Operation

- 6 Cavities (2.6MV) and 140mA
- After RF interlock, beam oscillates longitudinally → VCav of remaining cavities oscillates
- After RF interlock, less SR Voltage and new synchronous phase



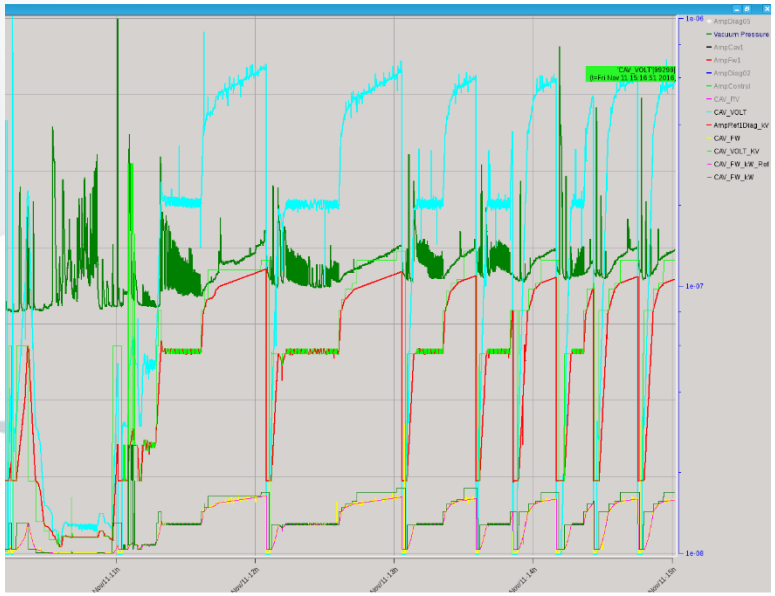
✓ RF Phase Modulation for Trip Compensation

- Phase jump to anticipate new synchronous phase of the cavity
- RF Phase modulation afterwards to minimize longitudinal oscillations
- In operation since Oct 2015

RF lab in Warehouse

- ✓ IOTs Recovery in RF lab: Conditioning
- ✓ Cavities Conditioning:
  - Agreement signed with CIEMAT to condition cavities: 2 Bunchers for IFMIF and cavity for cyclotron

Cyclotron Cavity



Conditioning up to 64kV – CW

Future Upgrades and New Developments

1.5GHz RF System

✓ CLIC Collaboration to develop 1.5GHz System between CELLS and CERN

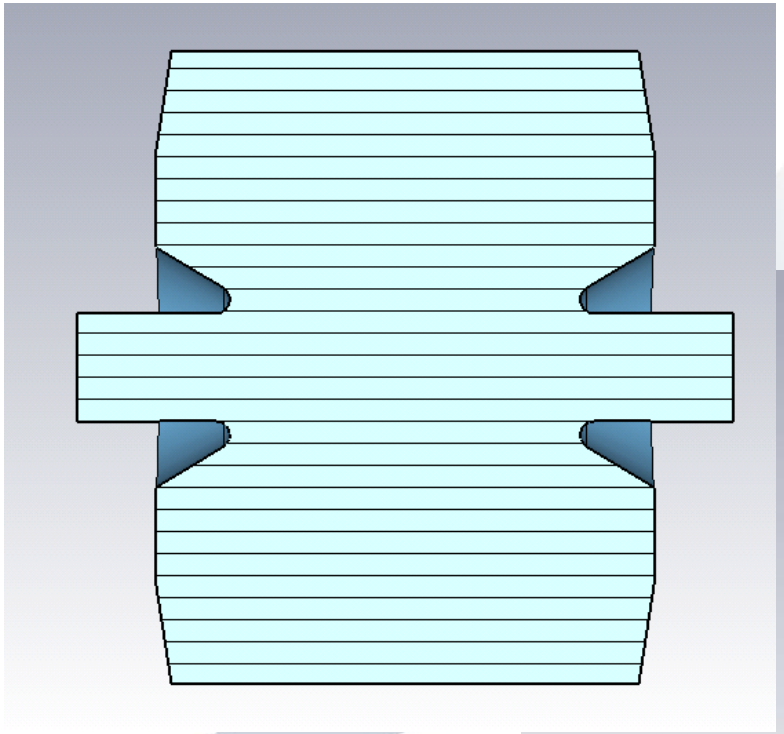
- To be used as an RF accelerator system in CLIC
- To be used as third harmonic cavity in CELLS
- New Staff:
  - PhD Student for 1.5GHz SSA design
  - Mechanical Engineer for 1.5GHz HOM Active Cavity Design
  - Electronics Engineer for LLRF and beam loading studies (selection pending)

✓ Characteristics of 1.5GHz for ALBA

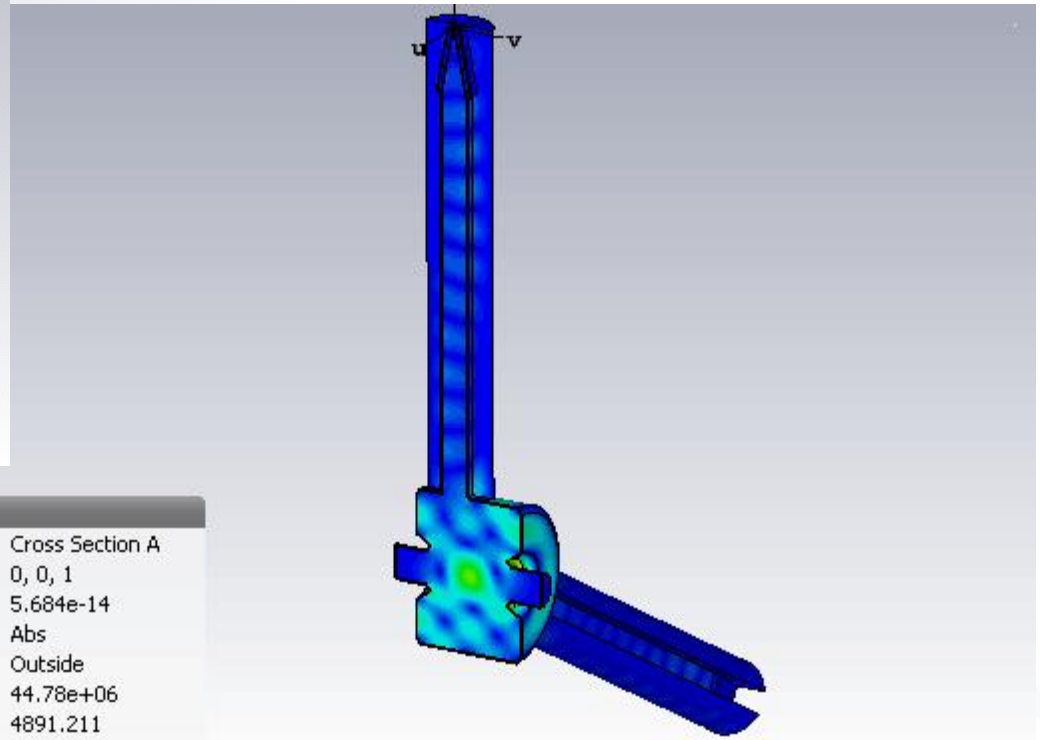
- 4 x SSA Tx: 25kW – 1.5GHz
- 4 x Third Harmonic Cavities: 250kV

1.5GHz HOM Active Cavity

✓ Cavity CST Simulaions



- Cavity: 1/3 Direct scale of Dampy
  - Rs = 2.35MΩ
  - Q = 20000
  - Fr = 1499MHz
- HOM being analyzed
- Dampers and input coupler being designed

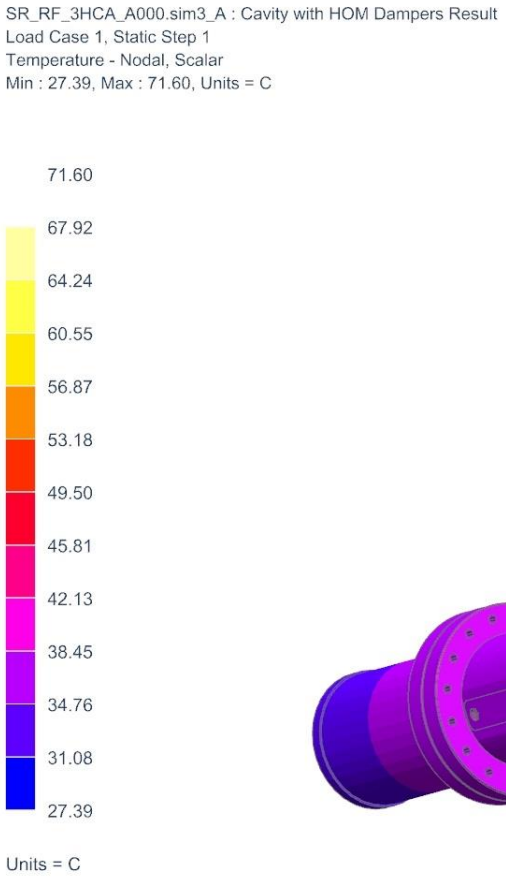


Mode 141 (peak)	
Cutplane Name:	Cross Section A
Cutplane Normal:	0, 0, 1
Cutplane Position:	5.684e-14
Component:	Abs
Orientation:	Outside
2D Maximum [V/m]:	44.78e+06
Frequency:	4891.211
Phase:	11.25

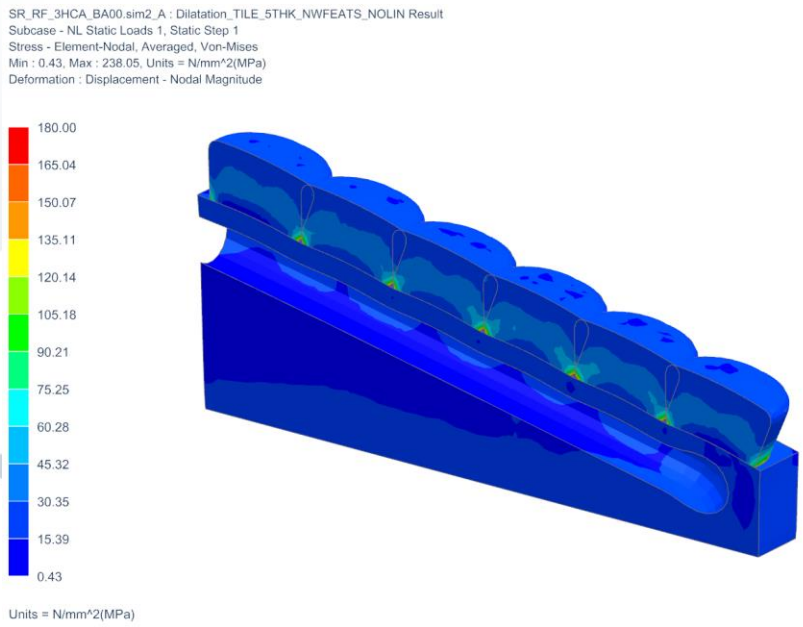
1.5GHz HOM Active Cavity

✓ Mechanical and thermal calculations

Main challenges: small size, difficult cooling, high thermal and mechanical stress



3HC Thermal simulations

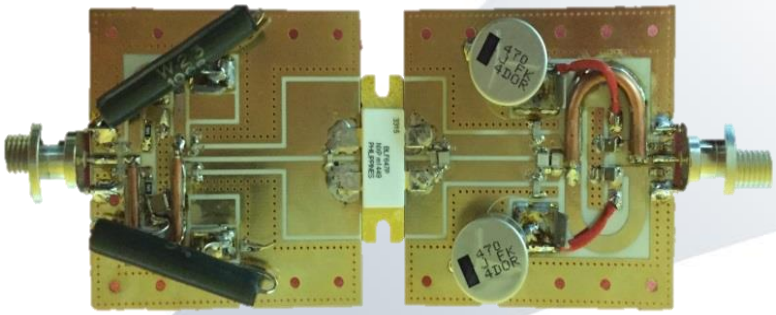


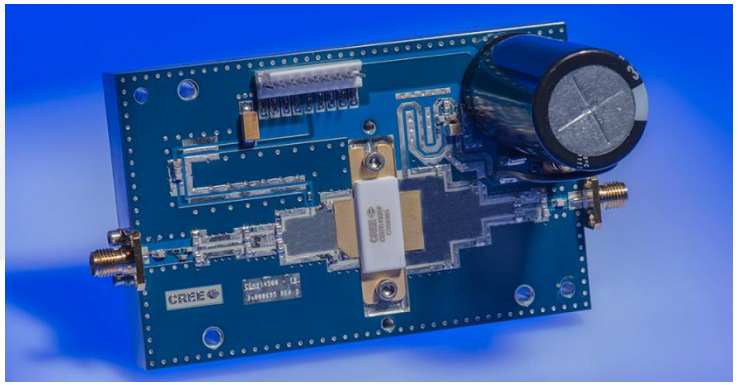
Mechanical analysis of dampers ferrites

1.5GHz SSA

✓ SSA Commercial transistors being analyzed

- LVDMOS (NXP BLF647P) vs GaN (CREE CGH14500 & CGH14250)



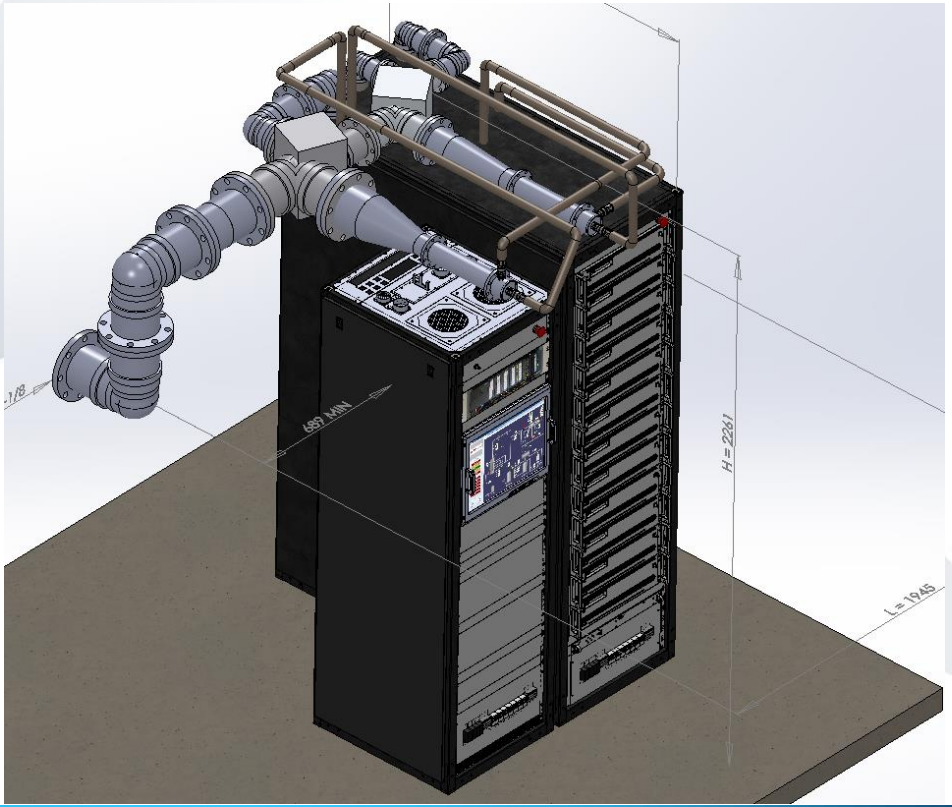


- Modules tested at 1.3GHz
- Modules being adapted to 1.5GHz

Booster SSA Tx

✓ Tender awarded to BTesa to provide 50kW SSA for Booster

- No RF redundancy in Booster (only one amplifier)
- Modularity of SSA amplifiers offers better reliability and redundancy
- SAT foreseen in February 2018



Conclusions

✓ RF Operation:

- 1 or 2 RF interlocks per week, but “only” 1 beam dump every 1 or 2 months
- Main Interlock sources: Arc in cavities and cooling
- Improvements being implemented in RF Systems to add reliability:
  - New Thales IOTs: TH-795
  - New SSA Pre-Drivers
  - Active RF Trip Compensation

✓ RF lab

- Recovery of old IOTs
- Cavities Conditioning

✓ Future RF Upgrades:

- Active 3rd Harmonic System
- Booster SSA Tx

Thanks for your attention

Questions?