Status and New Developments of ALBA RF Systems

ESLS RF Meeting – Soleil – Nov 2018

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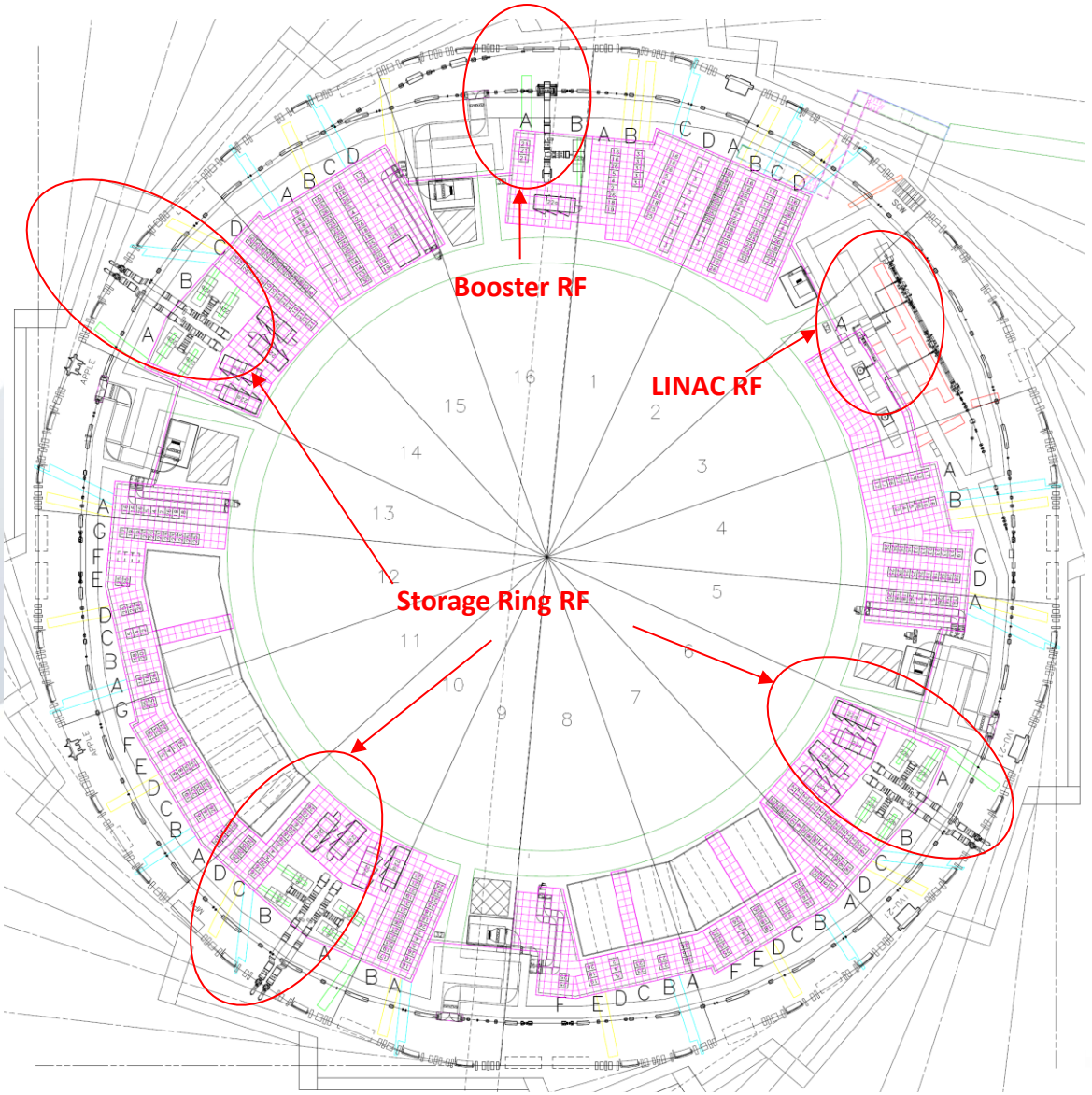
Outline

- ✓ ALBA RF Overview
- ✓ 2018 Operation
  - Statistics
  - Main operation issues of RF systems
- ✓ RF upgrades
  - 50kW SSPA for Booster
  - Fiber optics of cavities
  - HW of LLRF
- ✓ New developments and future upgrades
  - 3rd Harmonic Active Cavity with transdampers
  - 1.5GHz SSA transmitter

ALBA RF Overview

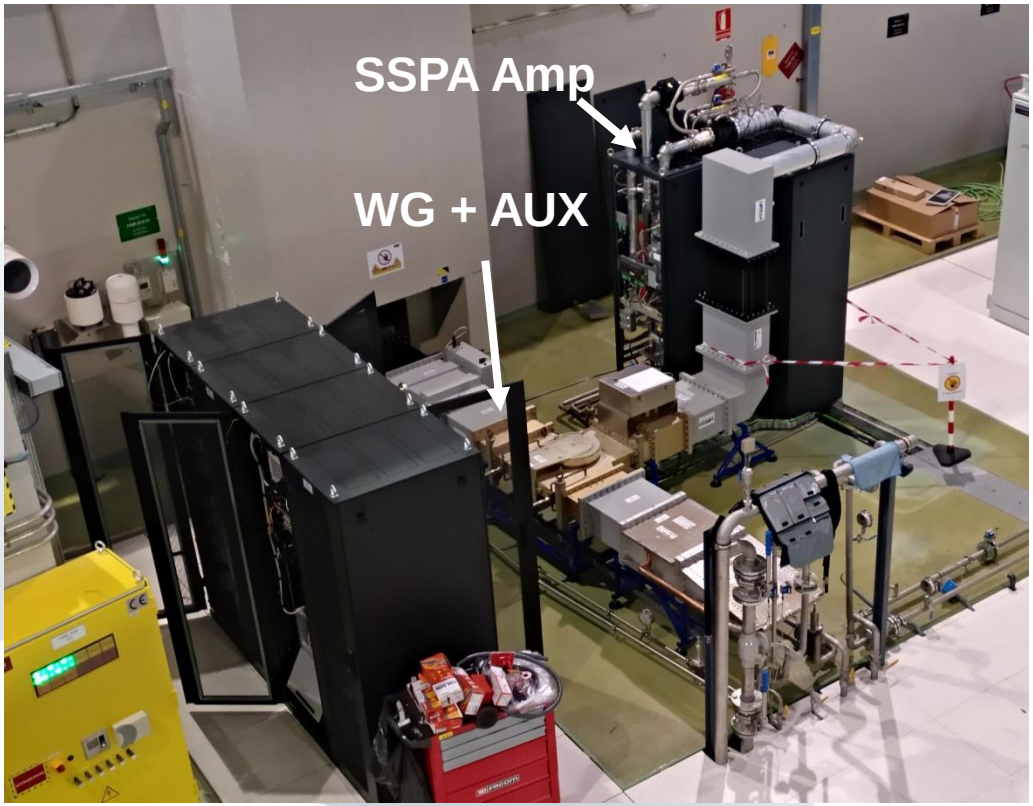
RF at ALBA Overview

- Linac
  - 2 Klystrons + WG system + travelling wave cavities at 3GHz
  - 90keV to 100MeV
- Booster
  - 50kW SSPA + WG System + 5-cell cavity @ 500MHz
  - 100MeV to 3GeV
- SR
  - 12 IOTs + WG system + 6 cavities @ 500MHz
  - Beam stored @ 3GeV



BOOSTER RF

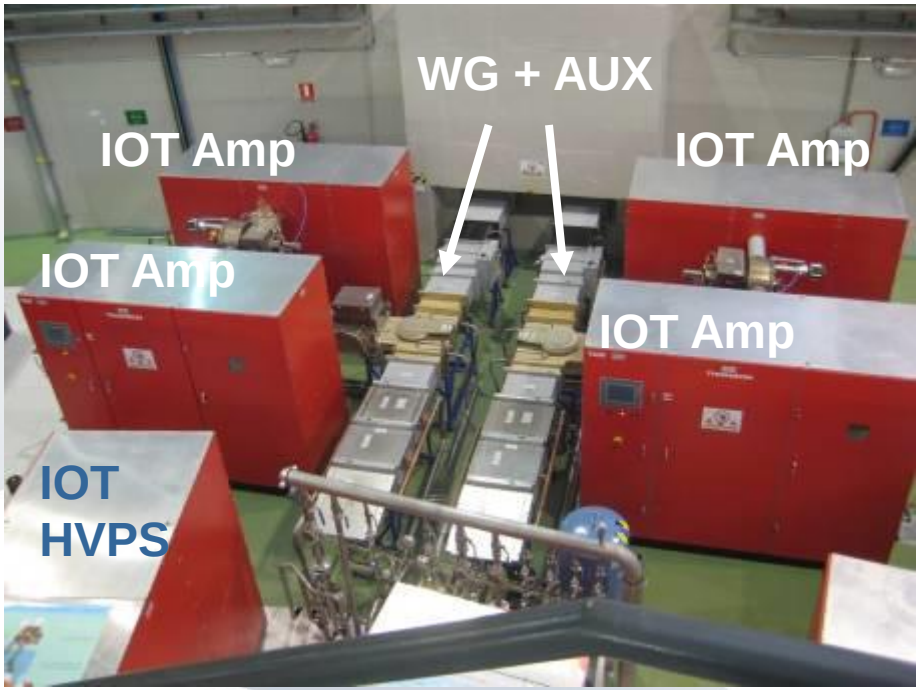
Tunnel:
5Cell Cavity – 500MHz



Service Area: RF amplifier + Auxiliaries

SR RF

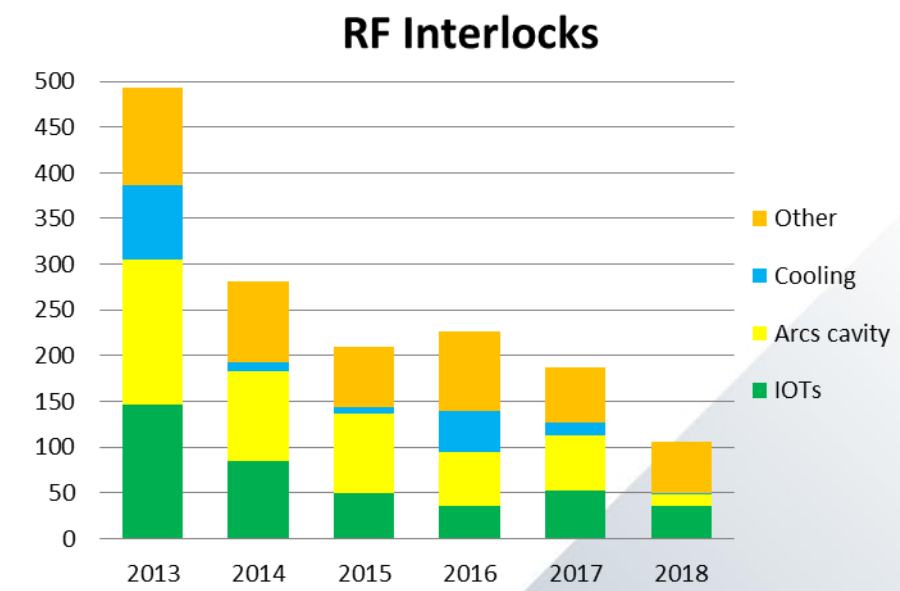
Tunnel: Dampy Cavities
1Cell – 500MHz

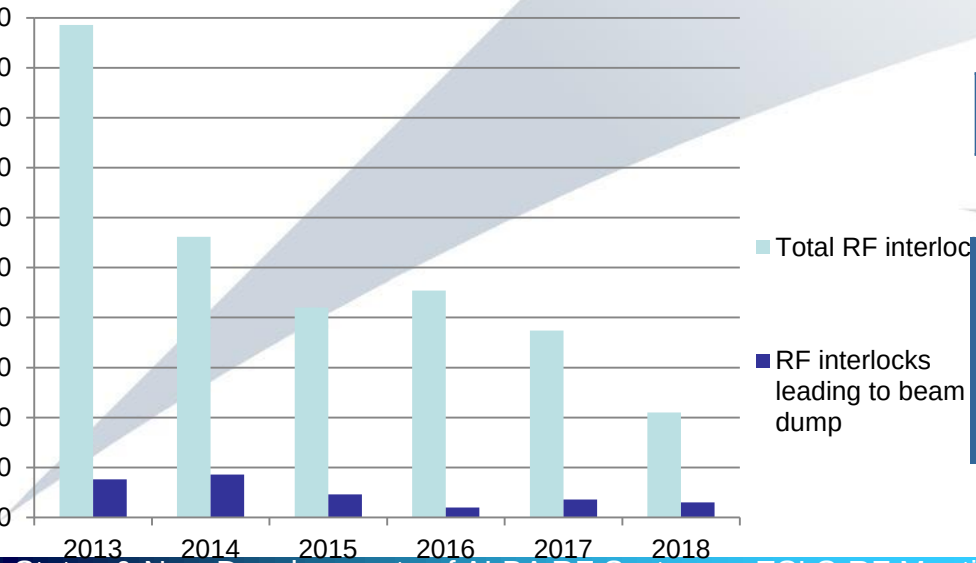


Service Area: RF amplifier + Auxiliaries

Operation Statistics

RF Statistics of 6 years operation





- ✓ 2018 Operation:
  - Until june 2018 - Top-up 180mA
  - From june 2018 on - 150mA to avoid quenches in SC Wiggler
  - 2.3MV of RF Voltage

RF ITCK Types	2013	2014	2015	2016	2017	2018
IOTs	147	84	49	36	52	36
Arcs cavity	158	99	87	58	61	12
Cooling	81	9	8	45	13	1
Other	107	89	66	88	61	56
Total RF interlocks	493	281	210	227	187	105
Beam Downtime due to RF (h)	38	43	23	11.2	12.3	10.64

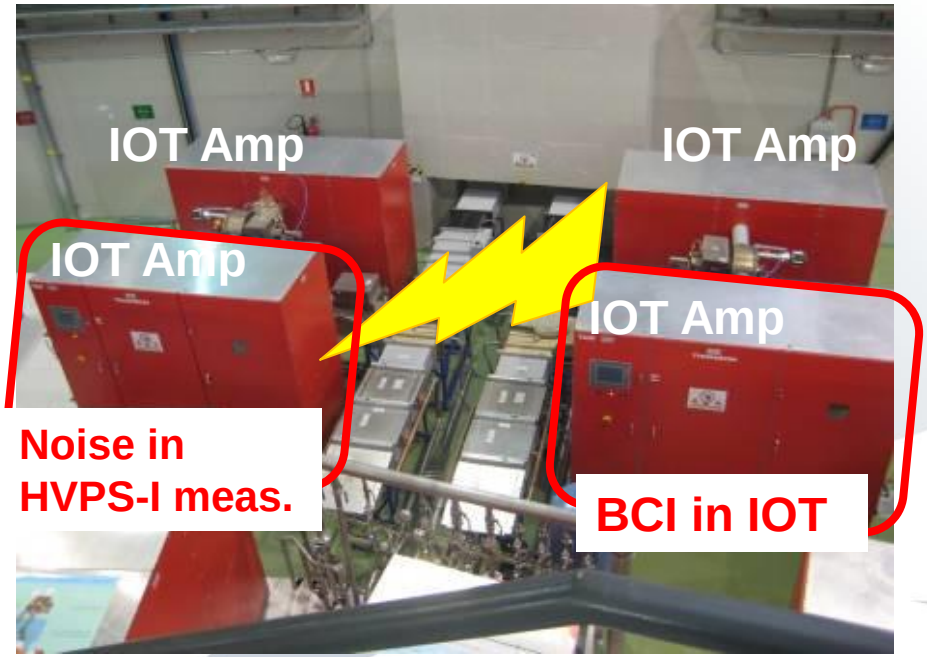
- ✓ Interlocks number reduced
- ✓ Only 15% of RF interlocks produce beam dumps

Beam dumps due to RF interlocks

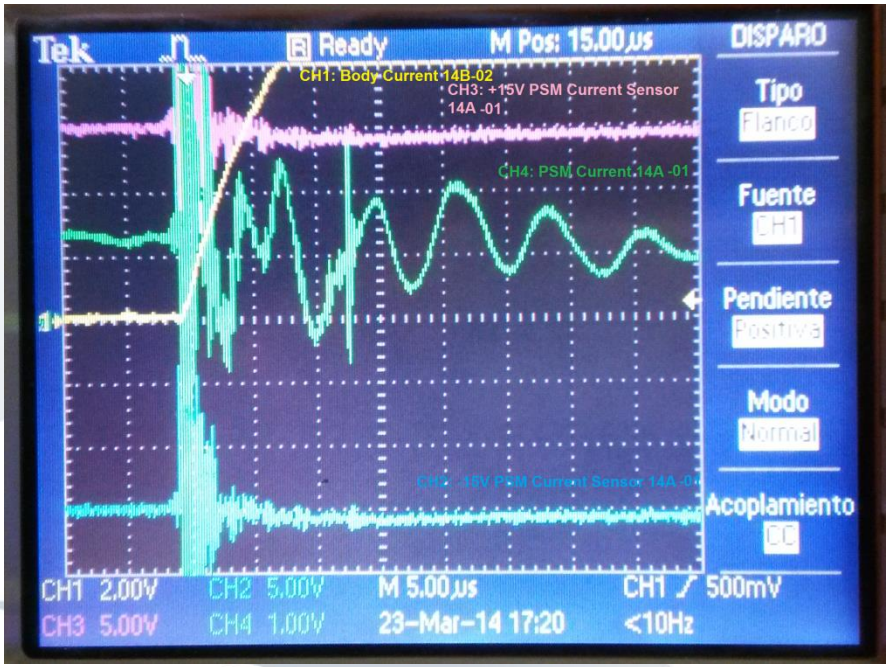
- ✓ Electrical noise produced by IOTs discharges (73%)

Electrical noise induced by Body Current Interlocks

- ✓ Body current interlock in an IOT produce electrical noise in HVPS current measurement of partner IOTs



4 IOTs in Service Area



HVPS-I measurement of partner IOT after BCI in next plant

Provisional solutions

- ✓ Earth improvement
  - IOTs and HVPS connected to earth using 60cm wide plates
  - Earths of IOTs isolated from earth of neighbor IOT
- ✓ Analogue filter added to affected control signals
  - Noise level reduced but not completely removed.
- ✓ IOT Trolley earth connection improved

IOTs Performance

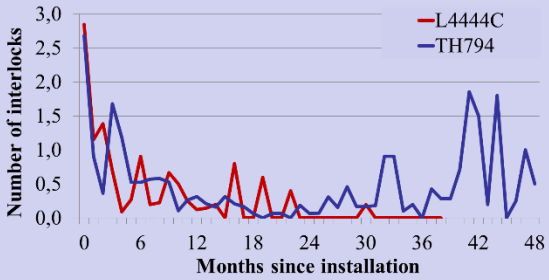
✓ ALBA IOTs: At present 12 IOTs installed in SR from L3 and Thales

- Thales TH-794 kept as spare (started operation in 2012)
- Thales TH-795 in operation since 2015
- L3 L4444C in operation since 2015

HV Arcing

	TH794	TH795	L4444C
Number of hours	160450	15970	82825
Number of arcs	349	29	127
Mean time between arcs [days]	19.2	21.5	27.6

TH795 & L4444C resume operation immediately



TH795 & L4444C resume operation immediately
L4444C rarely arc after 9 months
Not enough data yet for TH795

Durability

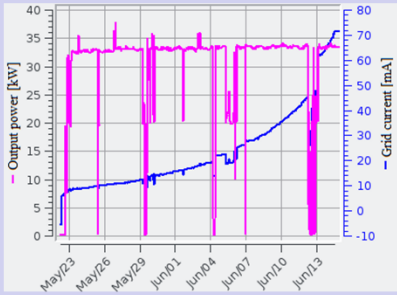
	TH794	TH795	L4444C
Total number of units	33	3	15
Units failed before 2000h	7	0	0
Units failed after 2000h	16	0	0
Average failure time of units older than 2000h	13340	0	0
Average age of available units	23498	7989	8583
Oldest unit	31910	12246	21519

TH794 failure modes:

- Fissure in input window due to HV arc
- Output window crack due to RF field
- Available units already average > 20000 h

TH795 and L4444C no failures yet. To soon to determine durability.

Grid emission



- Cathode material evaporates from cathode and is deposited on grid causing emission
- Ionized gas is attracted by lower potential of the cathode, raising the temperature

Delicate balance between:

- A colder grid with low enough emission
- A hotter cathode to achieve nominal power

Check regularly heater setting!

RF Upgrades

Booster IOT Tx replaced by SSPA

50kW SSPA for Booster

✓ New SSPA Tx in Booster

- No High Voltage, no vacuum, no ceramics
- Modularity: 12 modules with 8 transistors each. Only 10 modules required for operation at 35kW
- Hot Swap of modules possible in operation at full power

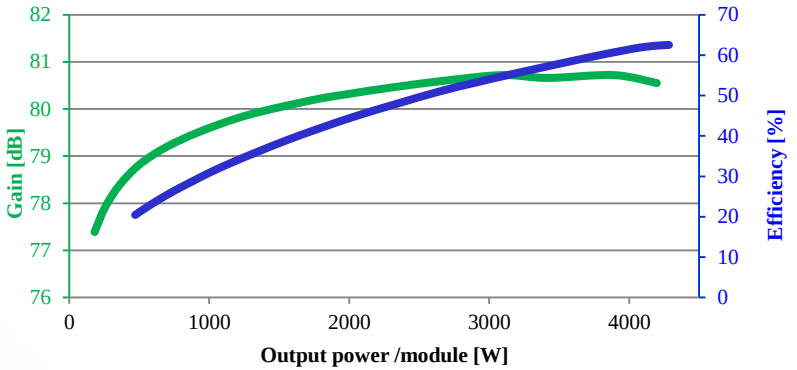
✓ SAT problems

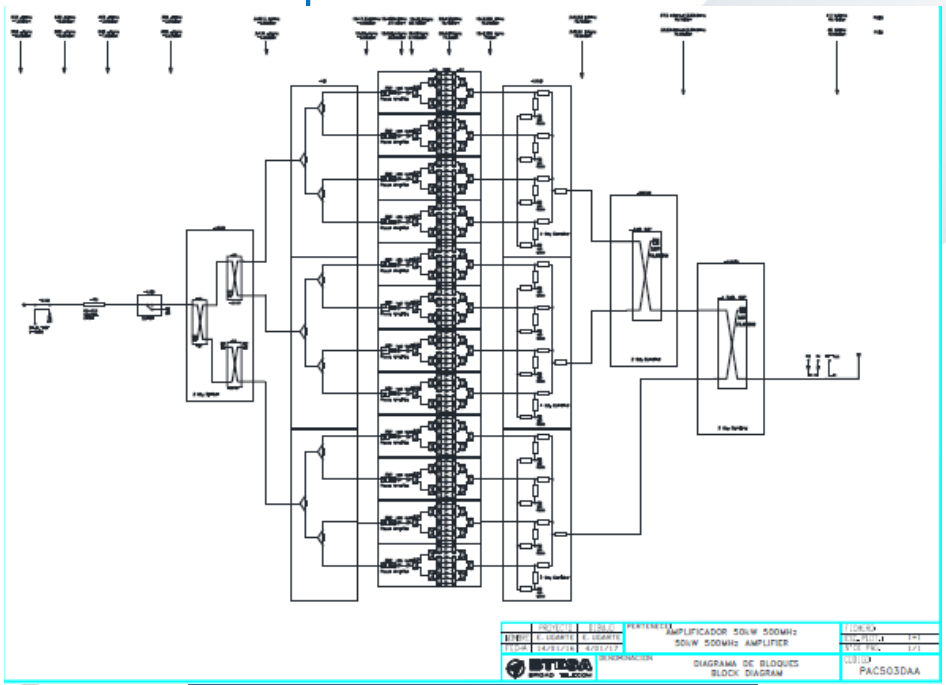
- Noise induced in LLRF Drive by power supplies of SSPA ➔ Optical link installed between LLRF and SSPA to isolate earths
- Already 3 modules replaced

BTESA
BROAD TELECOM

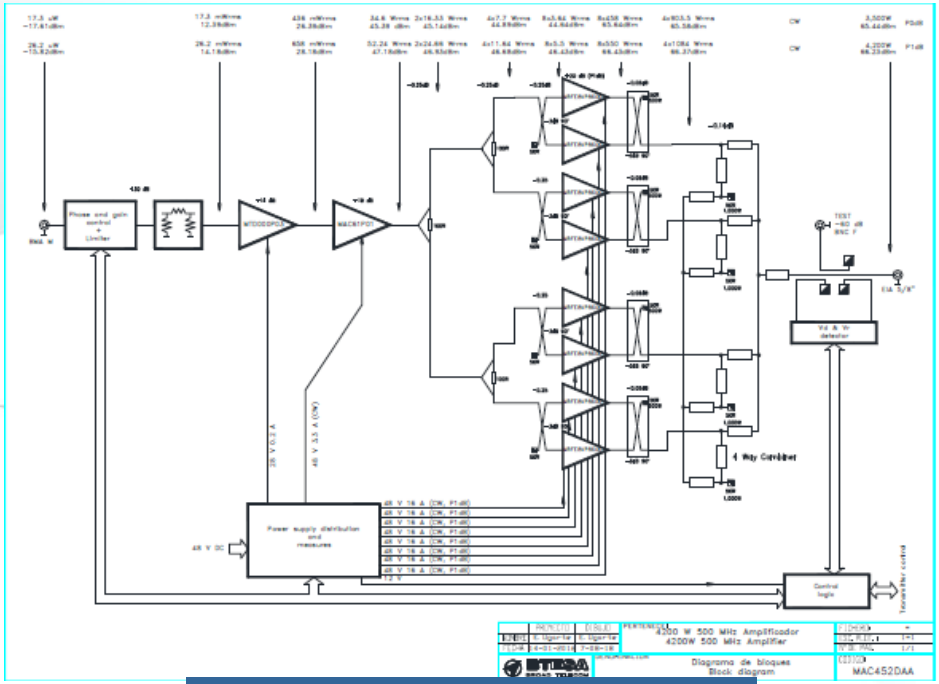
General Parameters of 50kW SSPA

- ✓ 96 transistors – 50V – 600W
- ✓ 12 modules – water cooled
- ✓ 500MHz CW, 48kW @ 2dB compression
- ✓ Gain > 78dB, Effiencieny > 60%
- ✓ Hot swap





Tx Electrical Scheme



Module Electrical Scheme

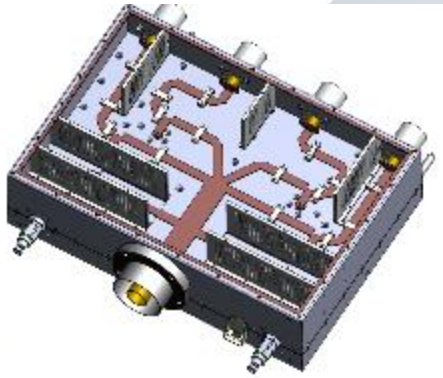
Technology of 50kW SSPA for Booster

No pre-driver needed

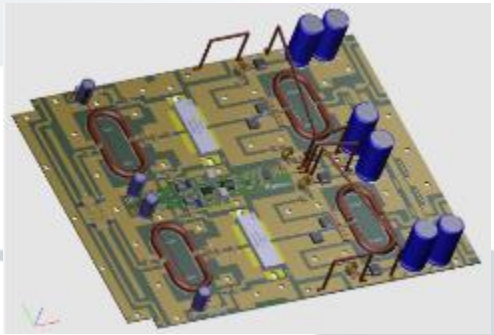
12 Modules combined in Groups of 4 using Gysel Topology

Basic Module with 8 transistors grouped in pairs:

- 3 Power Supply Sets per module – 3000W (only 2 needed)
- 4 Different pre-programmed Drain Voltages: 41V, 43V, 48V and 50V
- P Out = 4200W per module



Main lines of the 4-way combiner



Basic unit with 2 transistors – 600W @ 50V

- Coaxial baluns for push-pull structure
- Gate voltage adjustable by potentiometer

Other upgrades

- ✓ Cavities fiber optics replaced inside tunnel
  - Fibers inside tunnel got darkened due to radiation
  - 30m fibers replaced by 25m fiber outside tunnel + 5m of disposable fiber inside tunnel joint by a splice

- ✓ LLRF HW Motherboard being replaced
  - Present LLRF HW based on Windows XP drivers
  - FPGA board being replaced by stand-alone system based on Linux drivers: picodigitizer

Future Upgrades and New Developments

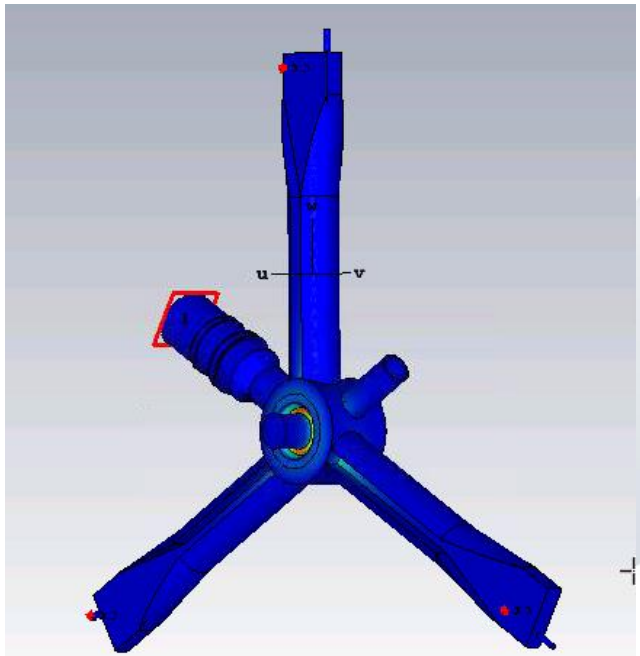
1.5GHz RF System

- ✓ 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

- ✓ Characteristics of 1.5GHz for ALBA
  - 4 x SSA Tx: 25kW – 1.5GHz
  - 4 x Third Harmonic Cavities: 200kV

1.5GHz HOM Active Cavity

✓ Cavity CST Simulaions



Mode 1 E-Field	
Orientation	Outside
Component	Abs
Frequency	1498.31 MHz
Phase	0
External Q	16721.3
Maximum	5.14702e+07 V/m

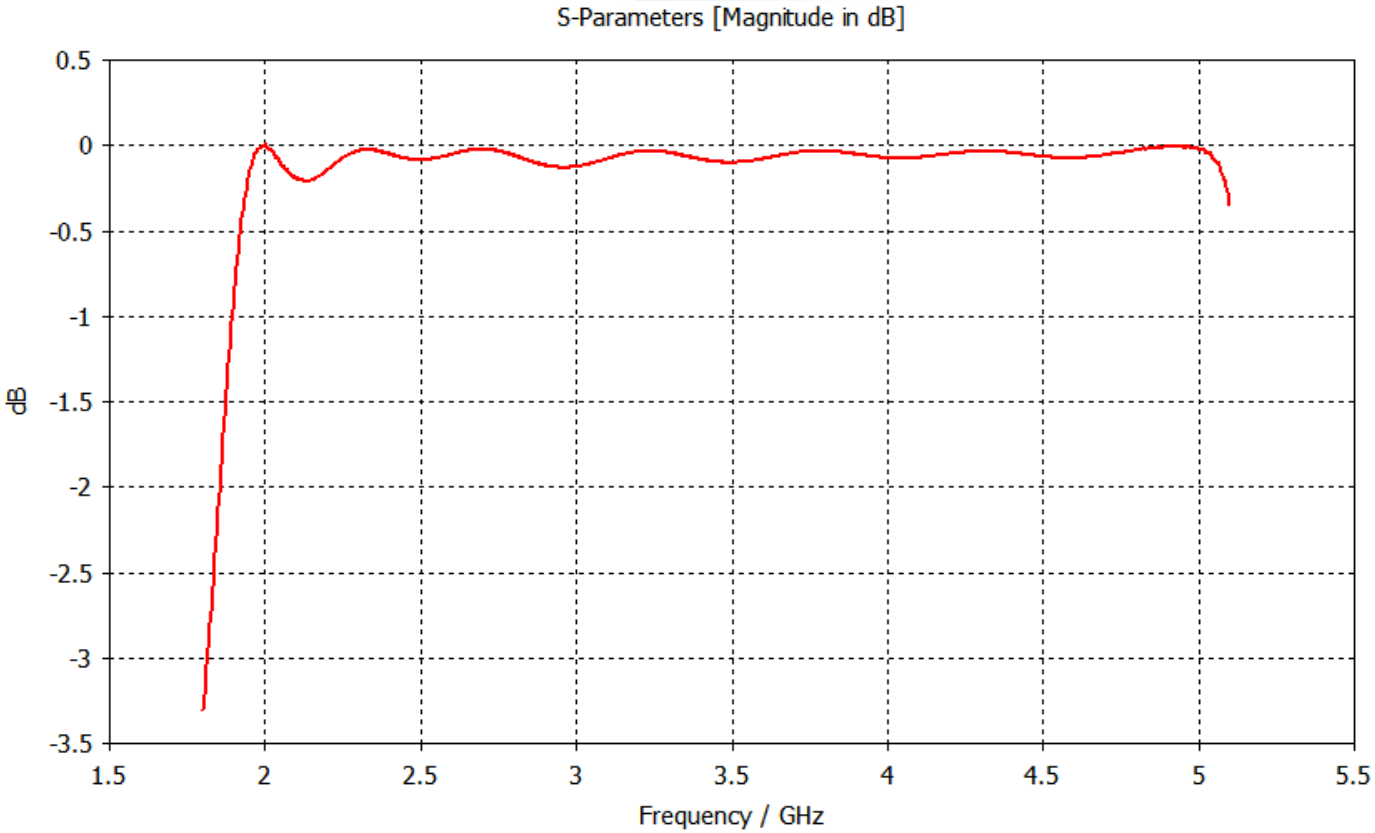
- Cavity: 1/3 Direct scale of Dampy
  - Rs = 1.5MΩ
  - Q = 17000
  - Fr = 1499MHz
  - V = 215kV
- New design of dampers
- EM design and Mechanical design finished
- Tender to be published by the end of the year
- Commissioning expected in 2020

Thanks Bea for all the work!!!

Transdampers

✓ Coaxial damper transition to waveguide

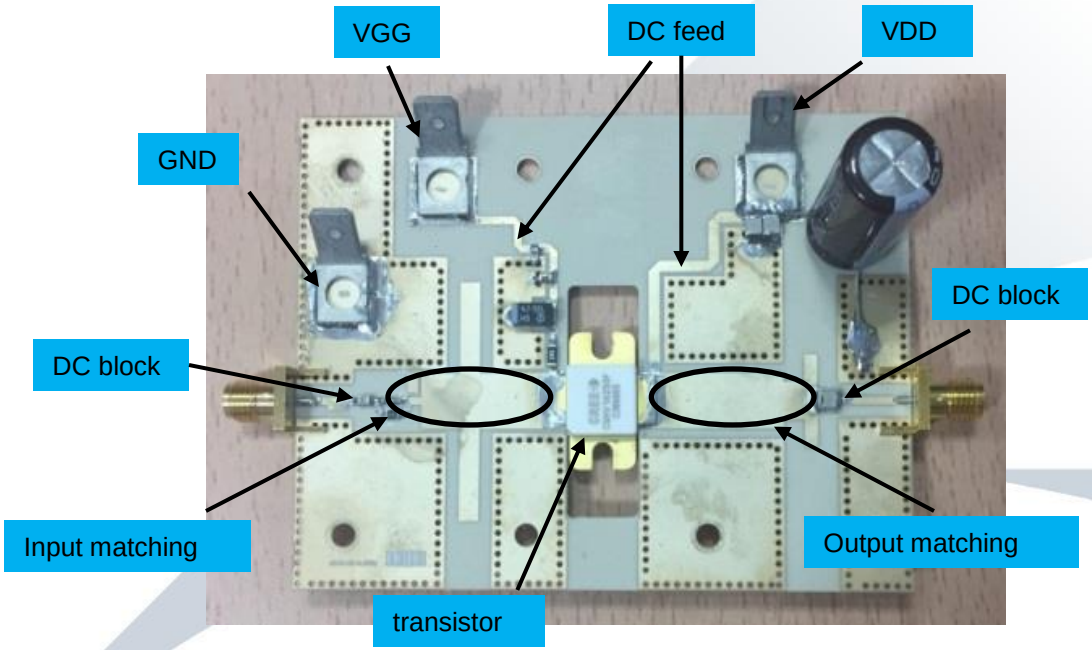
- No ferrites required
- External load to dissipate power of HOM



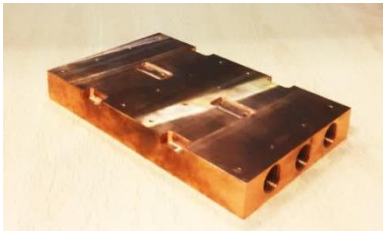
1.5GHz SSA

✓ SSA 250W module based on GaN CREE CGH14250

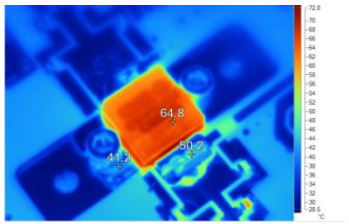
- Input and output matching done with stubs
- No baluns and no trimmers



water cooling

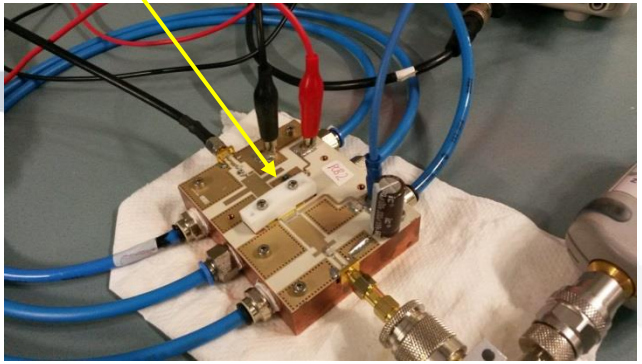


Copper base plate



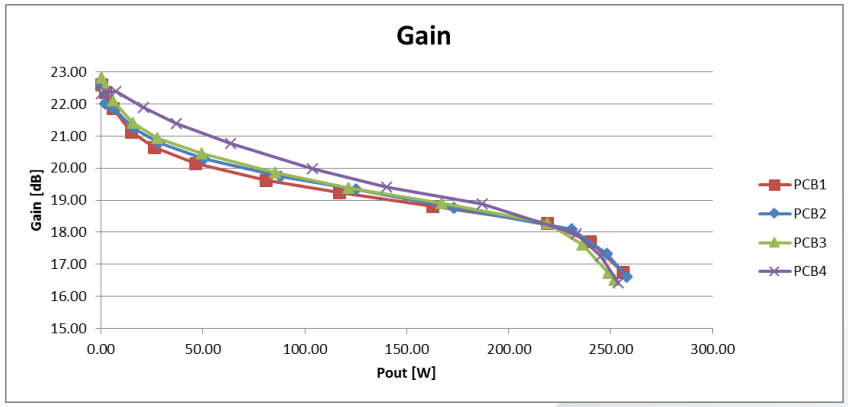
Thermal inspections

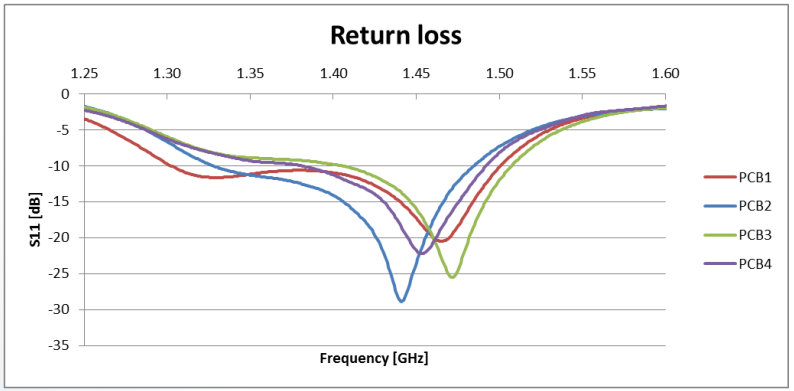
Transistor support

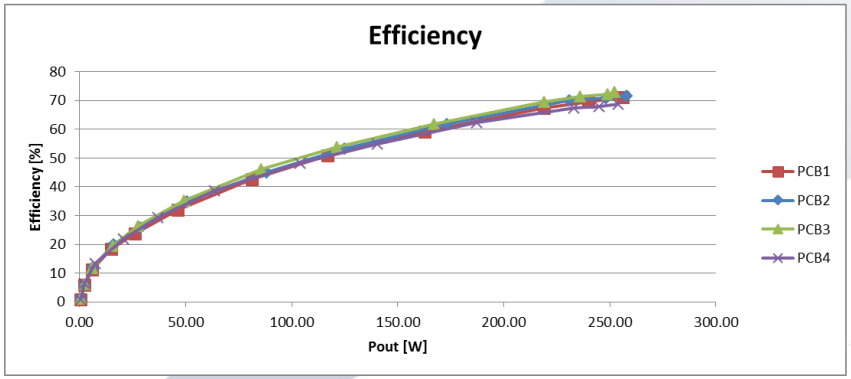


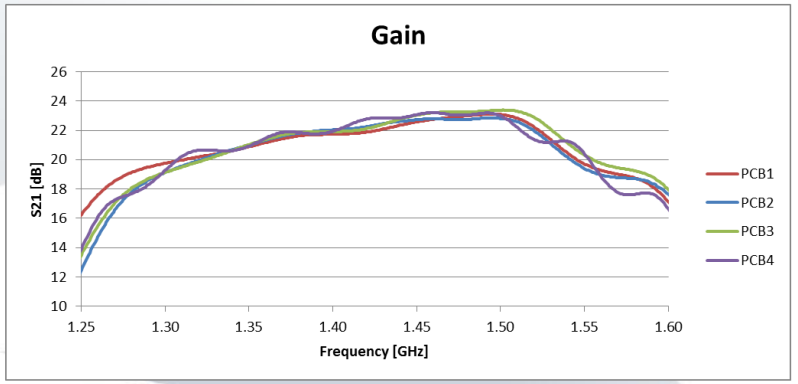
3rd PA module design under test

1.5GHz SSA: Power tests of 4 modules







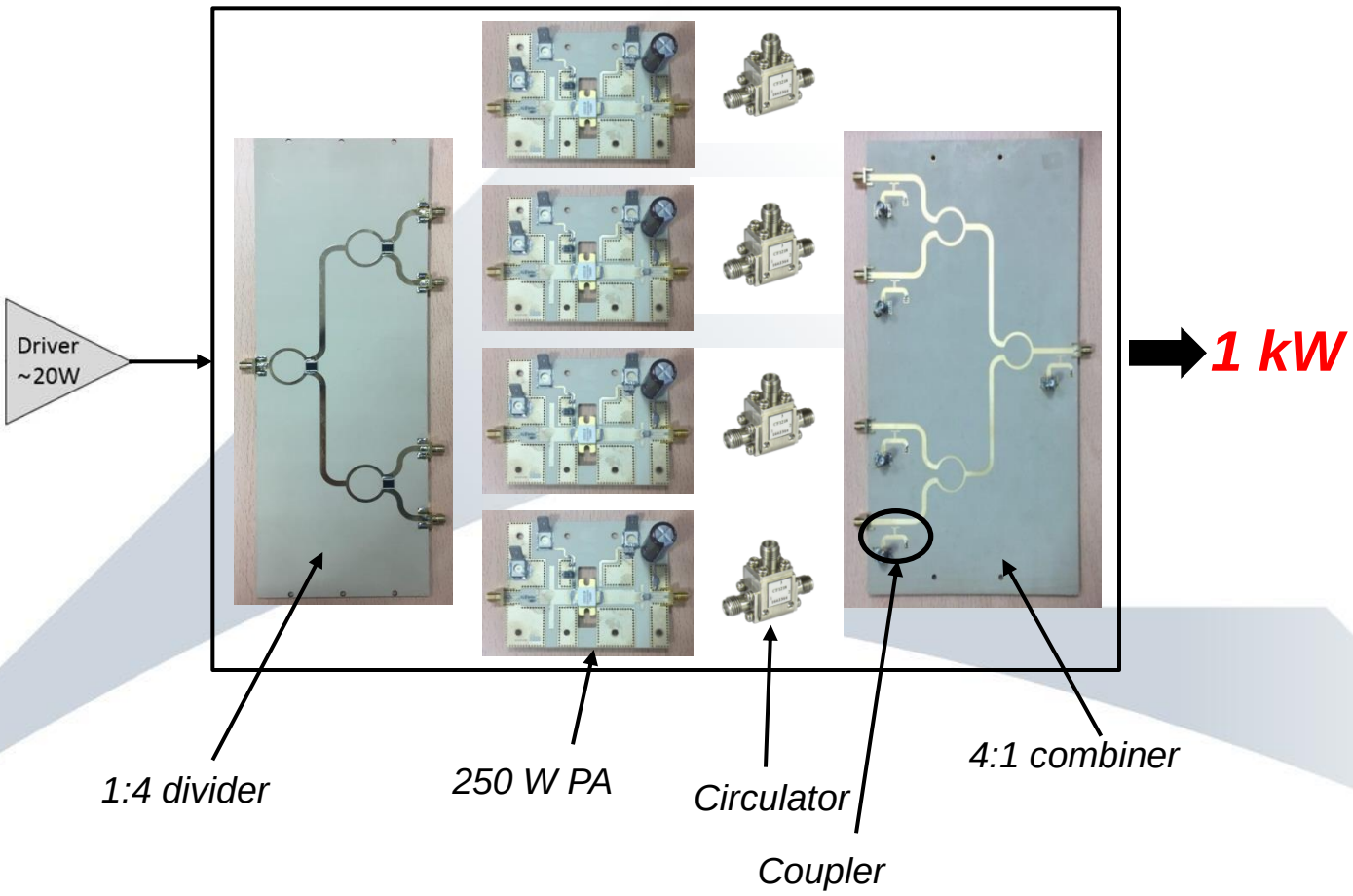


Values at 37.5dBm input

Board	Gain [dB]	Power [W]	Efficiency [%]	J tem [ºC]	C temp [ºC]	AM/PM [ºC]
PCB1	16.58	256.00	71.11	53	109	-32.40
PCB2	16.62	258.00	71.67	57	122	-38.34
PCB3	16.51	252.00	73.04	54	113	-32.94
PCB4	16.43	254.00	68.65	50	130	-

1.5GHz SSA 1kW tests

Next step



Conclusions

✓ RF Operation:

- 1 or 2 RF interlocks per week, but “only” 1 beam dump every 1 or 2 months
- Main Interlock sources: Electrical noise
- New SSPA installed in Booster

✓ Future RF Upgrades:

- 3rd Harmonic Cavity prototype
- 1.5GHz SSPA Tx

Thanks for your attention

Questions?