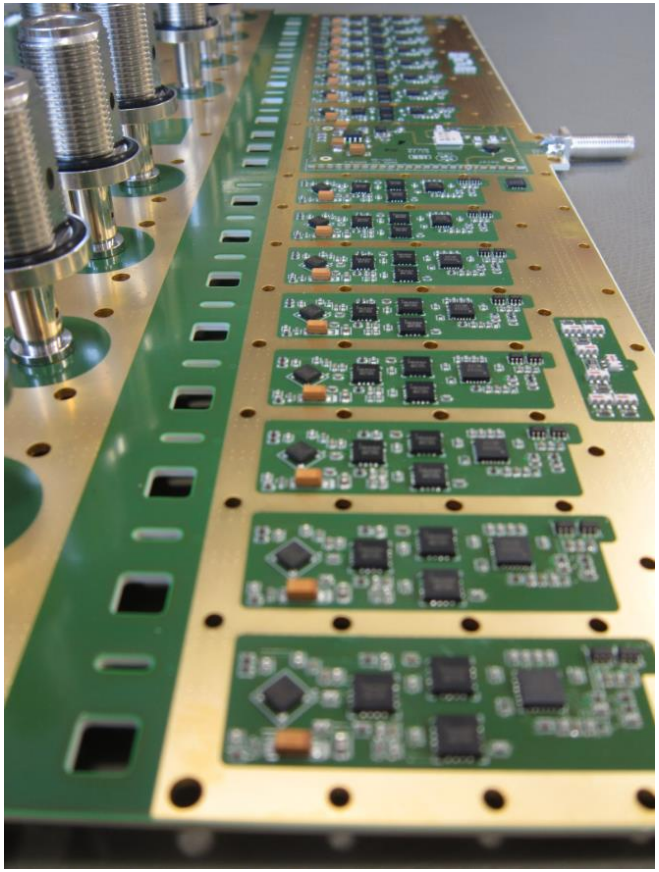
LLRF Workshop 2017



Drift calibration
for the European XFEL

Frank Ludwig, (DESY)
Uros Mavric, (DESY)
Jan Piekarski, (WUT)
Christian Schmidt, (DESY)
Lukasz Butkowski, (DESY)
Matthias Hoffmann, (DESY)
Guenter Möller, (DESY)
Krzysztof Czuba, (WUT)
Holger Schlarb (DESY)
for the LLRF-Team

Barcelona, 18.10.2017

HELMHOLTZ GEMEINSCHAFT

DESY

Drift calibration for the European XFEL

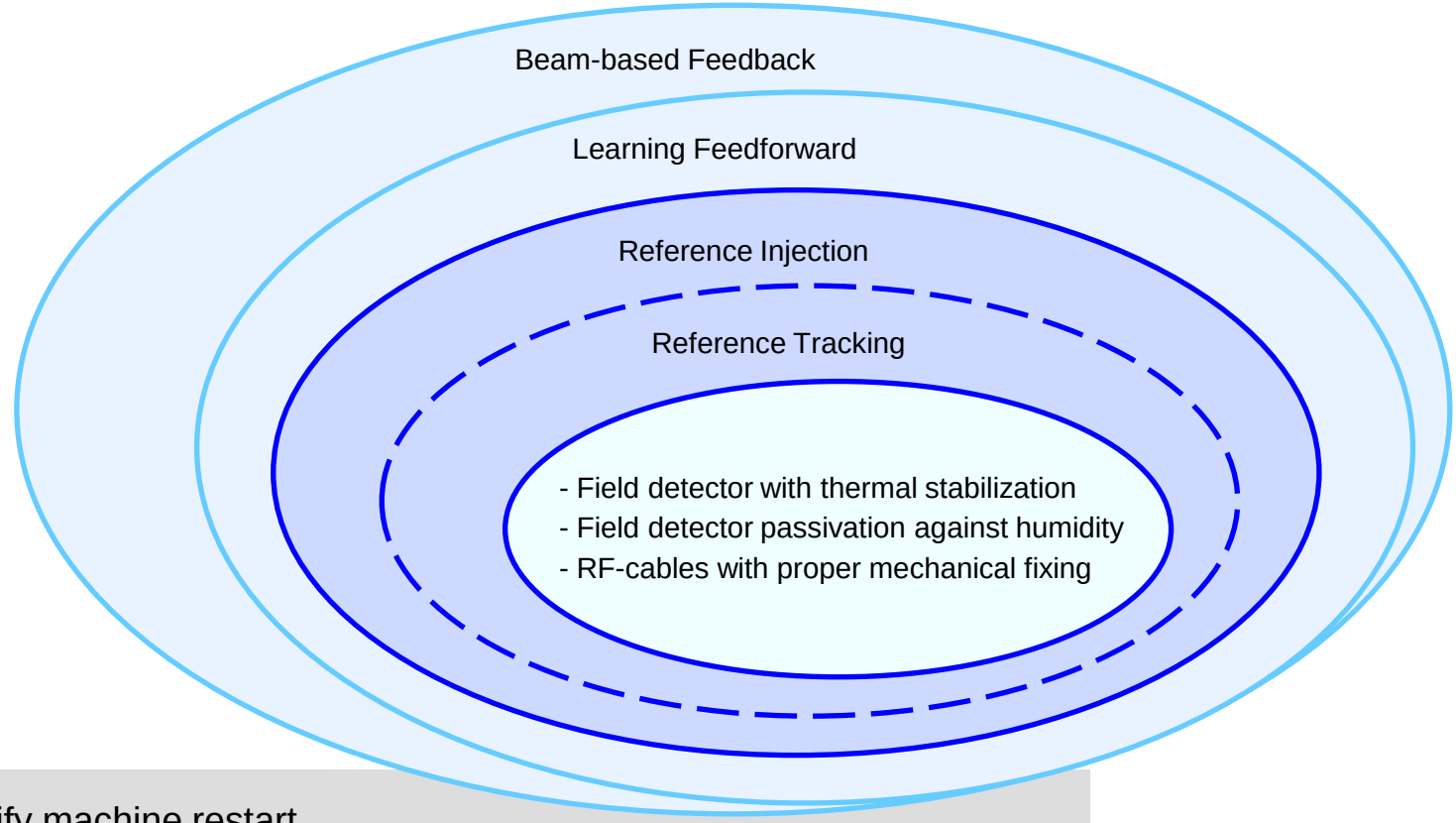
FIL

Content

1 Motivation – Robust machine operation - Options

XFEL desired long-term requirements [forever]:

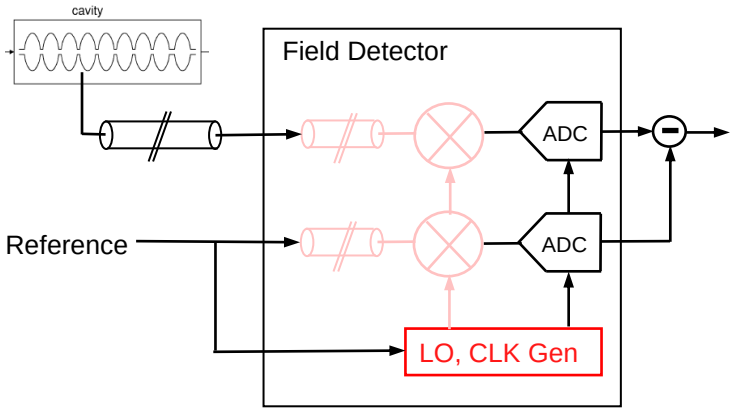
Amplitude stability <0.01%, Phase stability <0.01deg @1.3GHz



- Simplify machine restart
- Minimize LLRF system recalibrations for vector sum

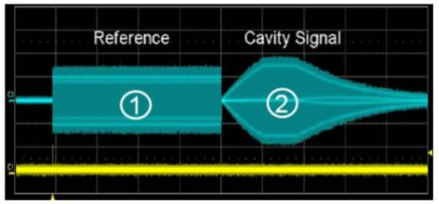
2 Concepts – long-term stable Cavity Field Detection

- No stabilization :
  - +/- Fully rely on beam-based feedbacks
- Passive stabilization :
  - \+ Simple method
  - \- Requires rack stabilization <0.2deg_pp
  - \- Requires metal rf-package with sealing
- Reference tracking :

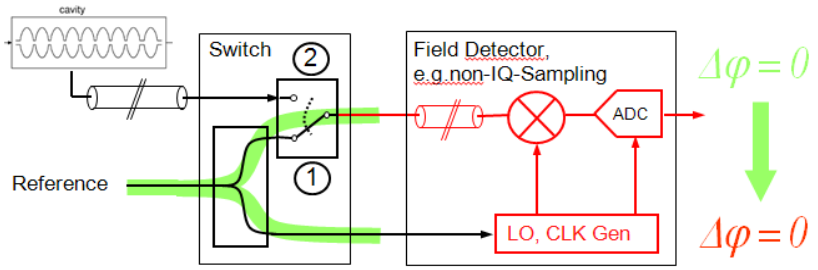


  - \- Suppress only correlated noise, not mixer 1/f-noise
  - +/- Efficient only for symmetric receivers (Demonstrated, e.g. with direct sampling)
  - +/- Depends on packaging and rf-cable properties

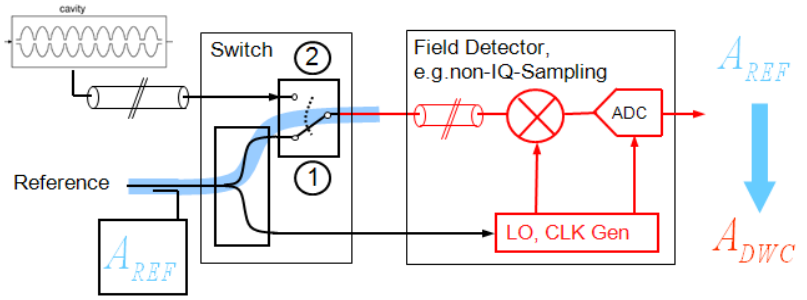
- Reference injection :
  (only for pulsed machines)



Relative Phase Calibration :



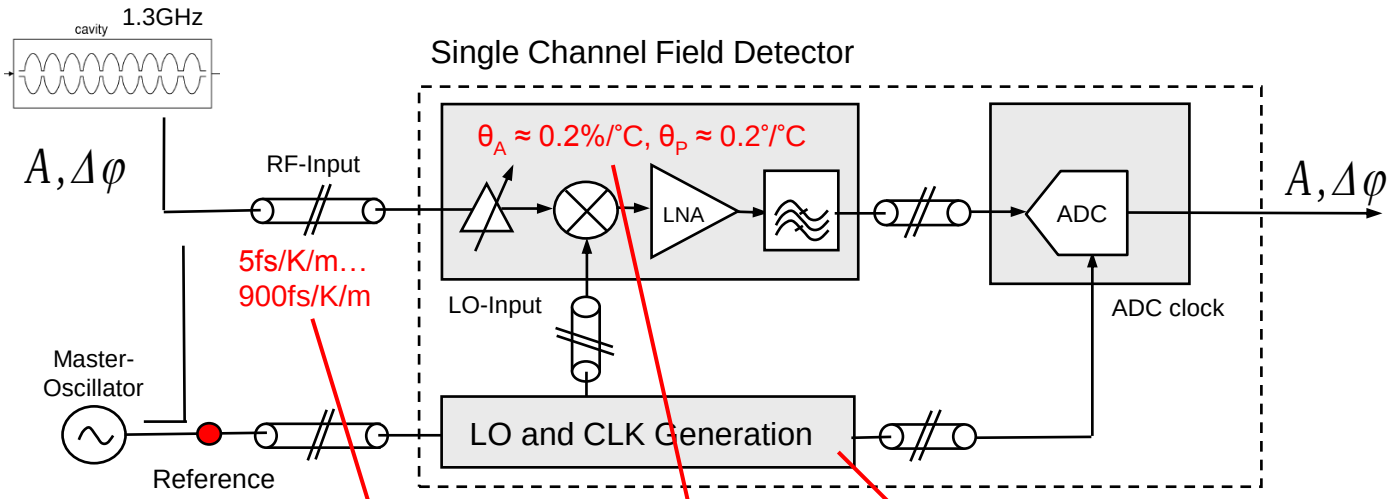
Absolute Amplitude Calibration :

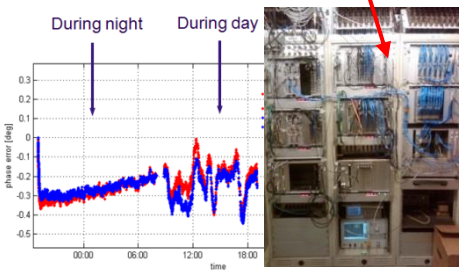


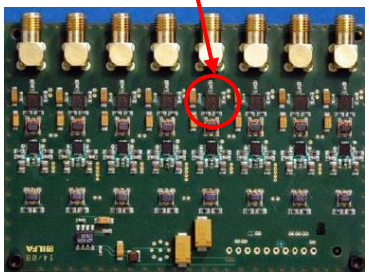
- Reference injection (2nd-tone) :
- Reflection at the cavity :

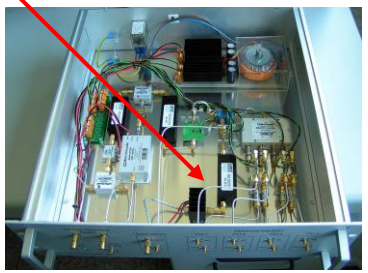
1 Motivation – Examples of long-term Instabilities

- Distributed down converters using the non-IQ-sampling scheme







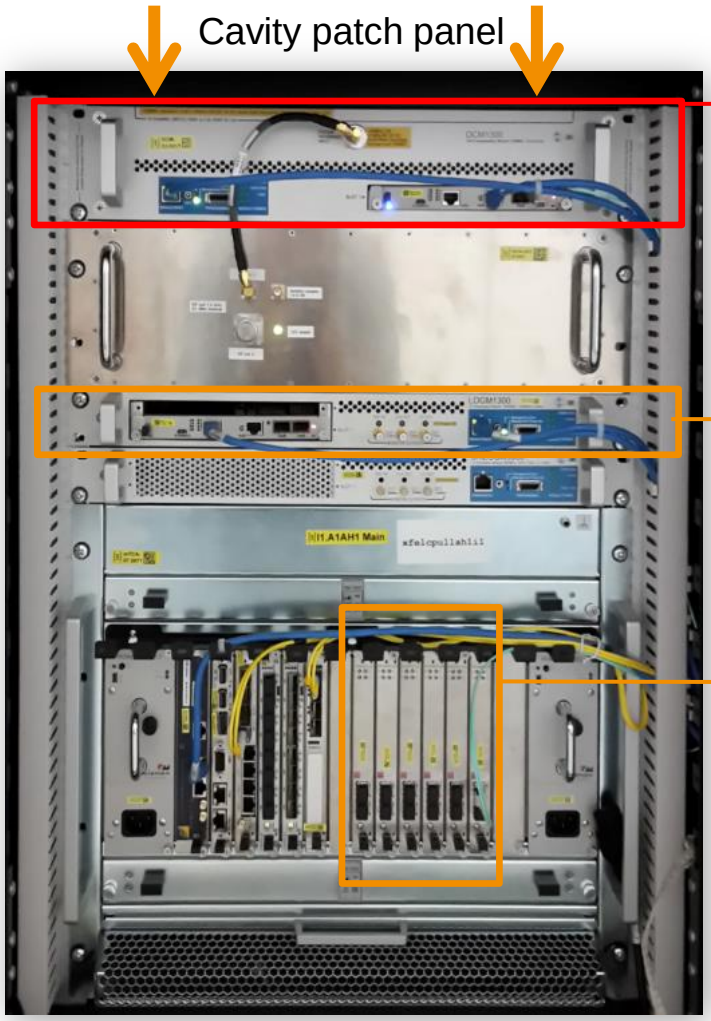


cables,
dividers,
amplifiers,
filters…

Long-term stability depends on temperature and humidity

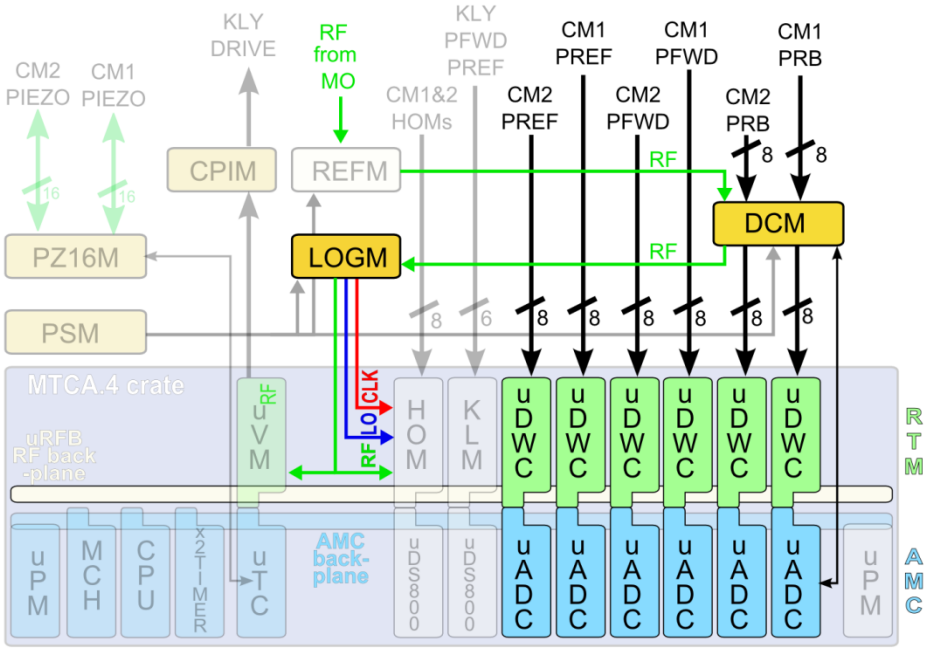
2 Overview – XFEL LLRF System

- XFEL 48-channel LLRF station:



- Sub-components and signal-flow:
  (standard non-iq sampling scheme)

Drift Compensation	DCM	2U 19” Module
LO-Generation	LOGM	1U 19” Module
Down-Converter	DWC	RTM MicroTCA.4
Low-noise Digitizer	ADC	AMC MicroTCA.4

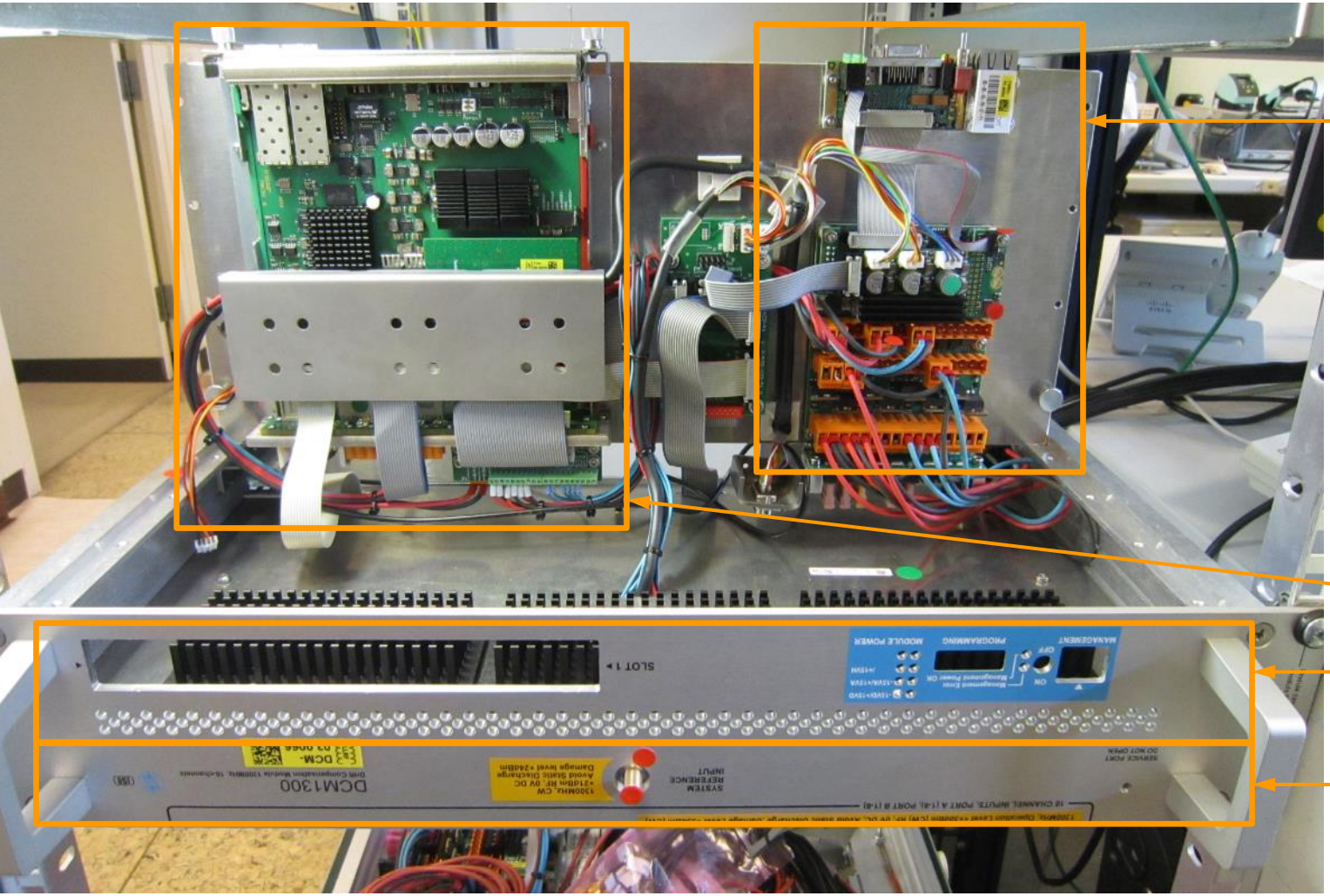


3 DCM – Hardware

Front view

Rear view

3 DCM – Hardware – Service Plate



Power-Management:
- Control 8 voltages. max 10A
- Voltage/current tracking
- 3xfan support
- Fuse support

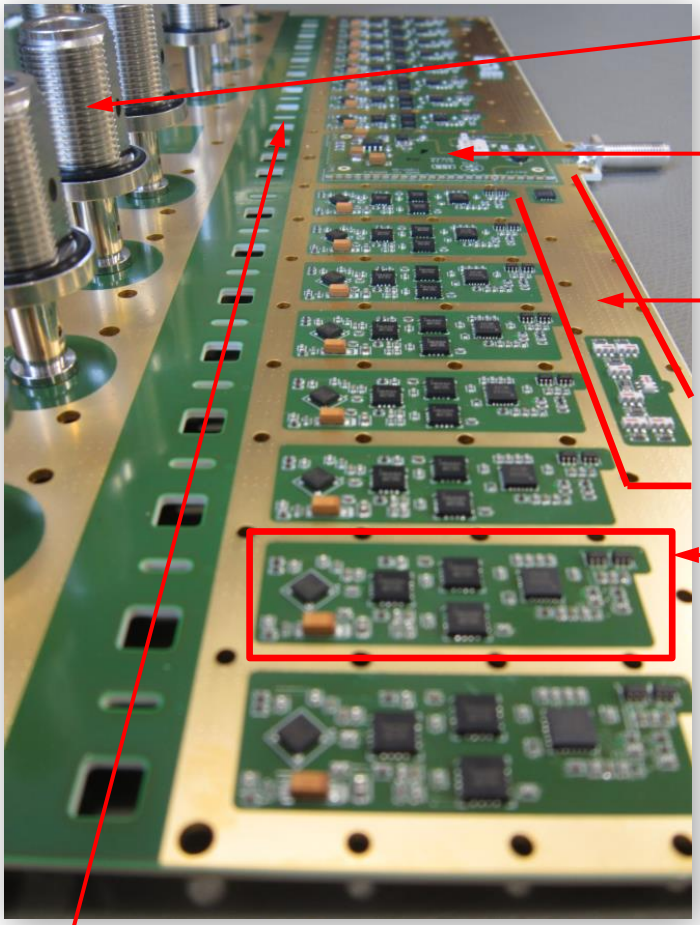
TMCB-Diagnostic/Control:
- 3x peltier temperature control via FMC-board
- rf-switch control
- rf-attenuator control
- rf-amplitude readout (24-bit)
- 2xSFP connection

Unsealed section:
- Transport of heat dissipation

Sealed section:
- Houses rf-components
- Sensors

3 DCM – RF-Compensation

- 16-channel rf-switches:



Course attenuation:
- 10dB integrated

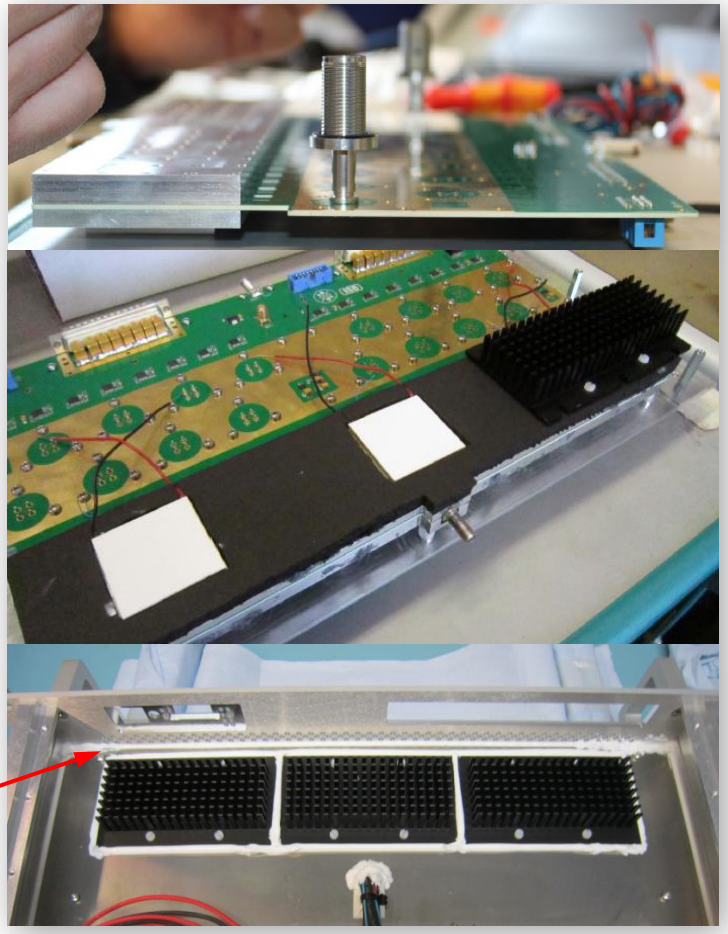
Reference injection:
- rf-amplitude detection

Reference distribution:
- passive

Switch-cell:
- Triplett rf-switches
- Cavity front-attenuation

Thermal bridge to rack temperature

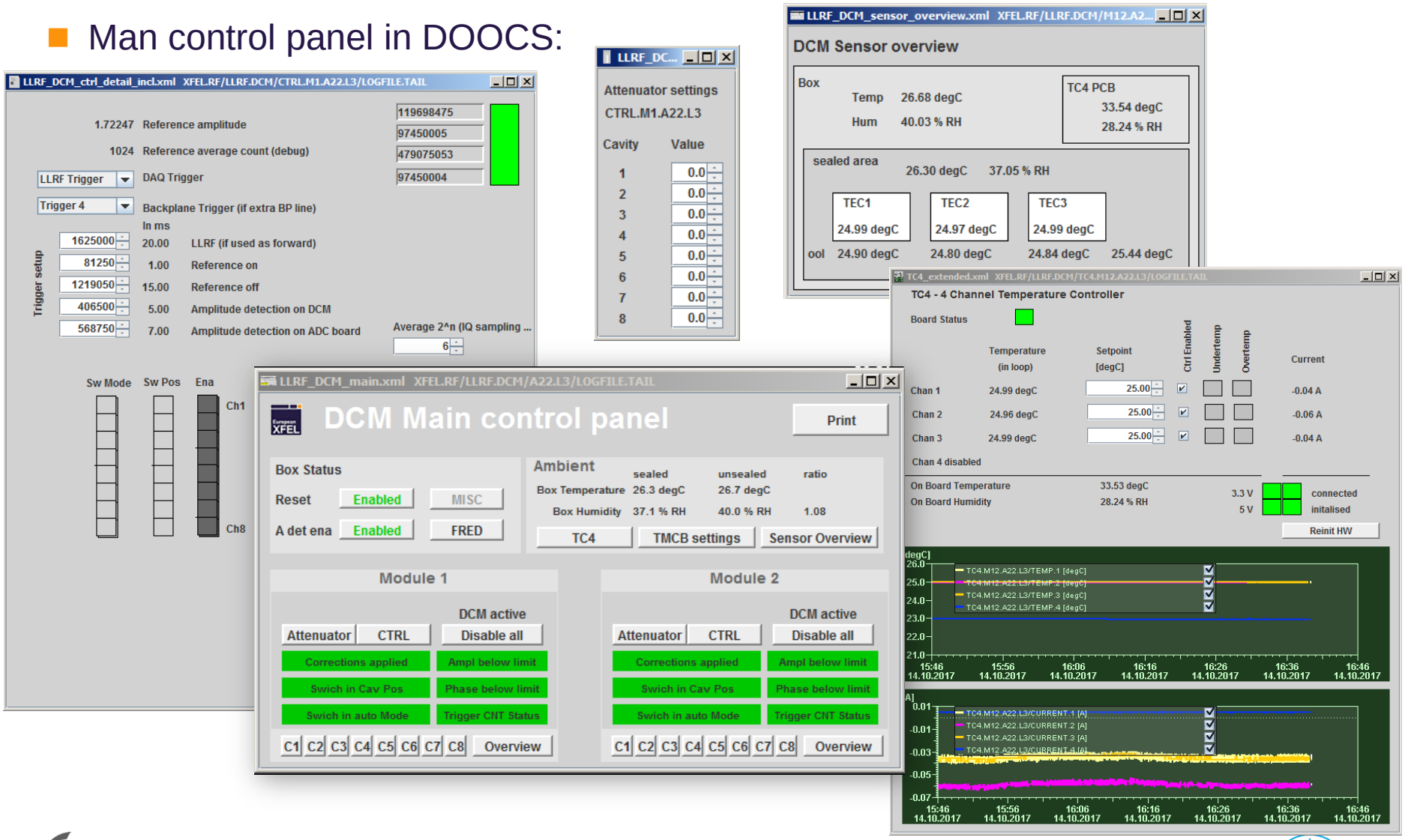
- Thermal stabilization / Sealing



Sealing with silicone

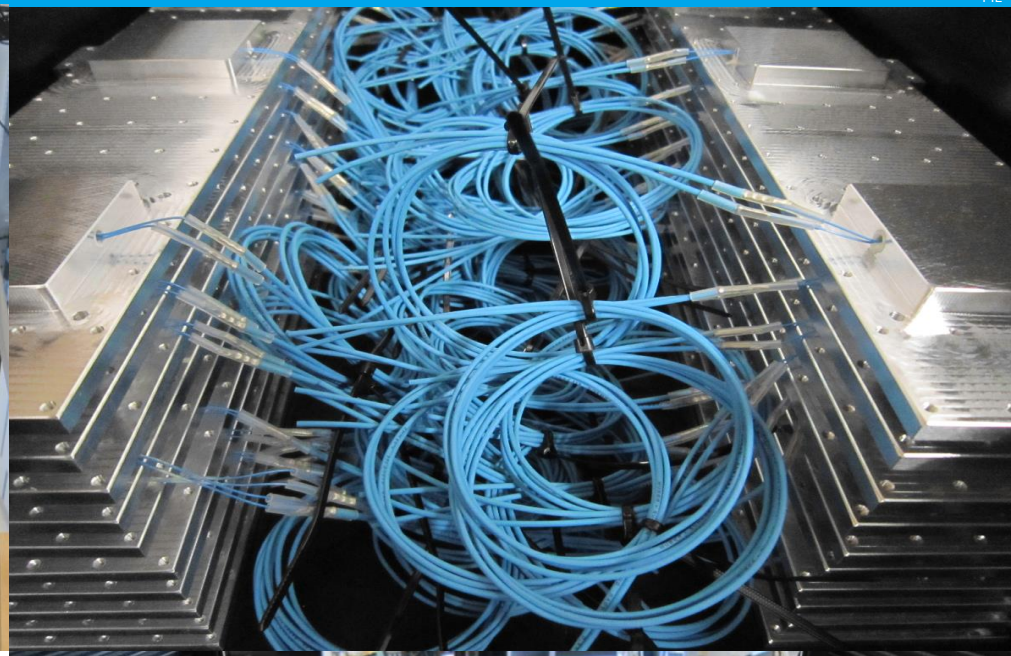
3 DCM – Software

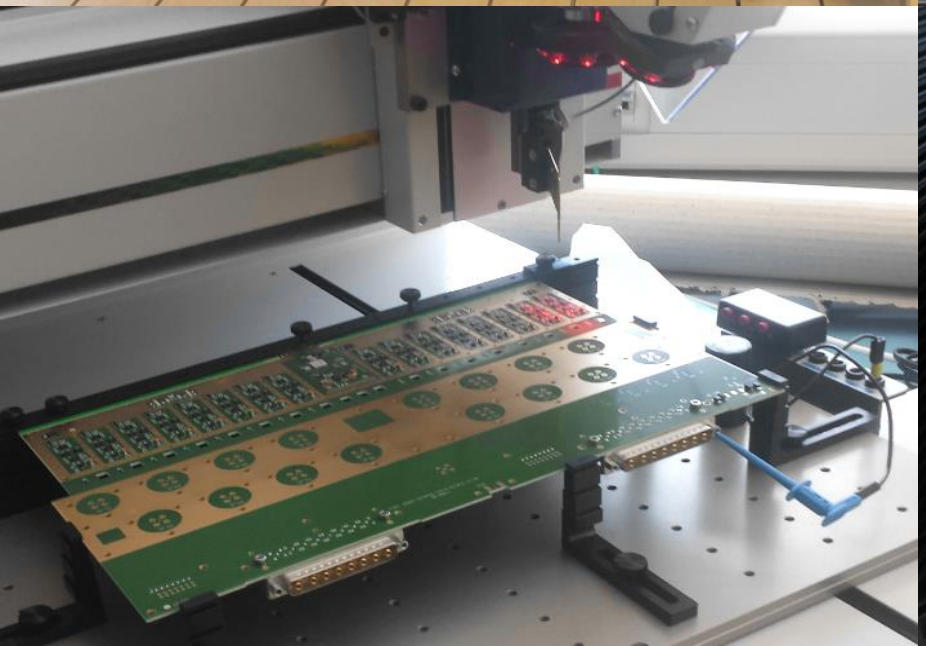
- Man control panel in DOOCS:

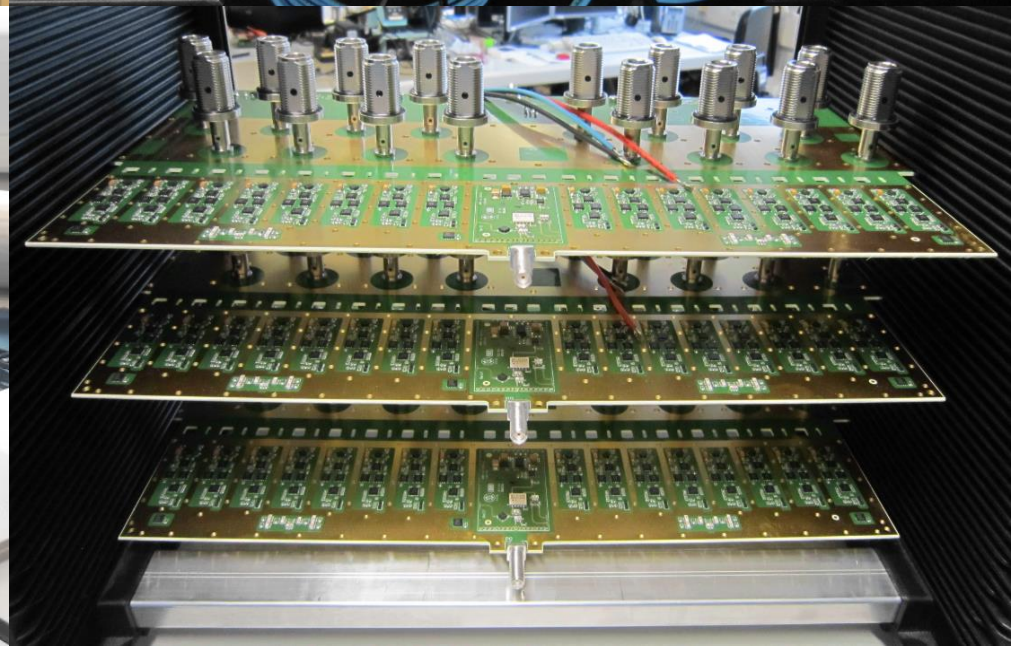


3 DCM – Production – Sub-Components – 60 Modules

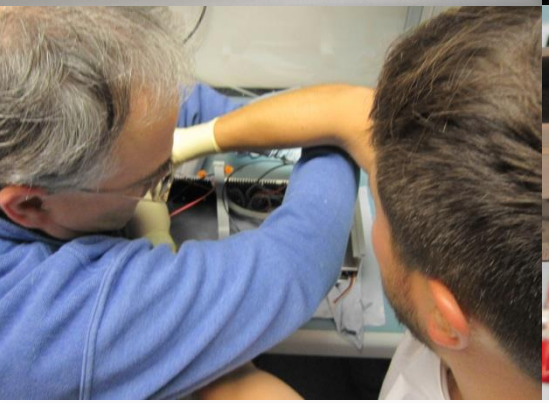
FIL

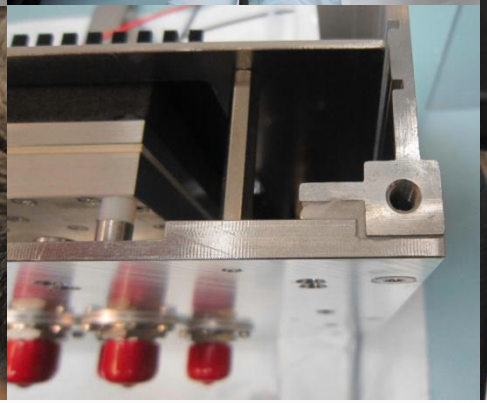




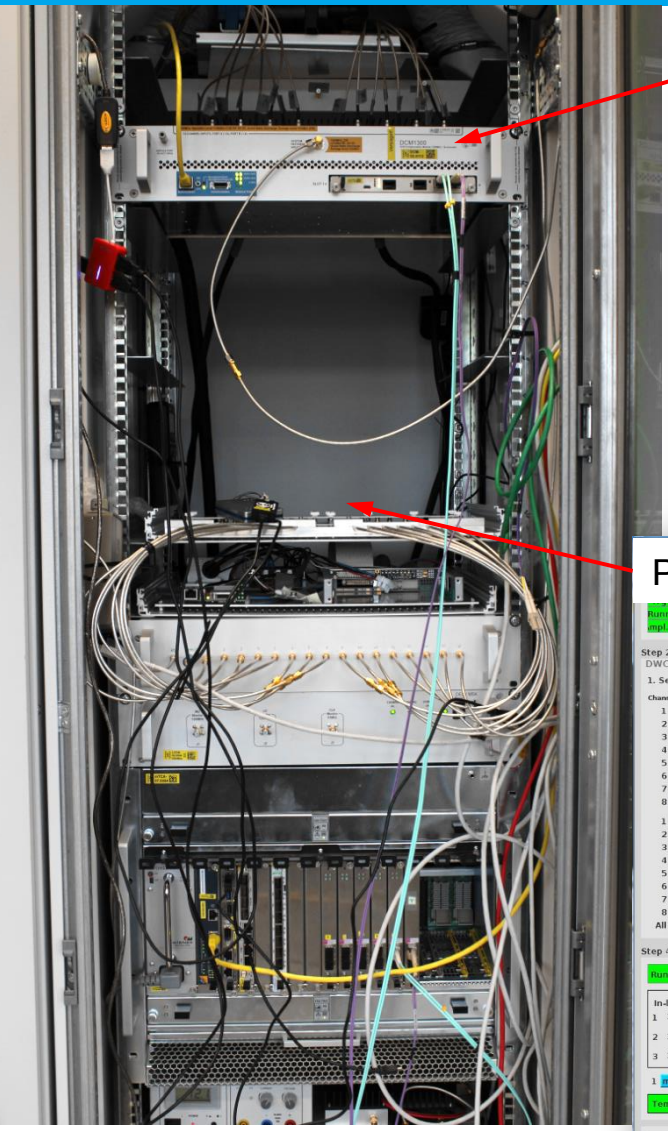


3 DCM – Production – Assembly – 60 Modules

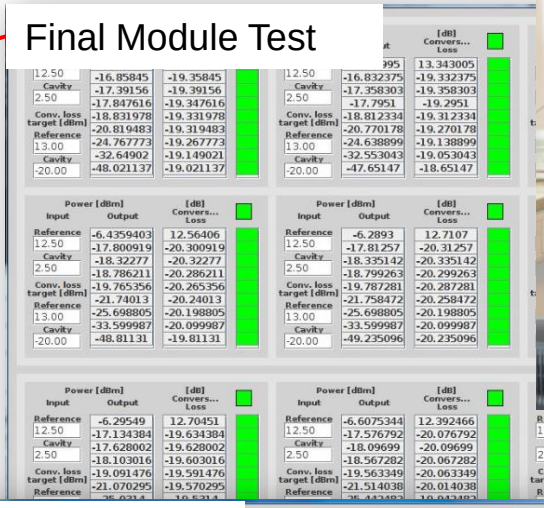




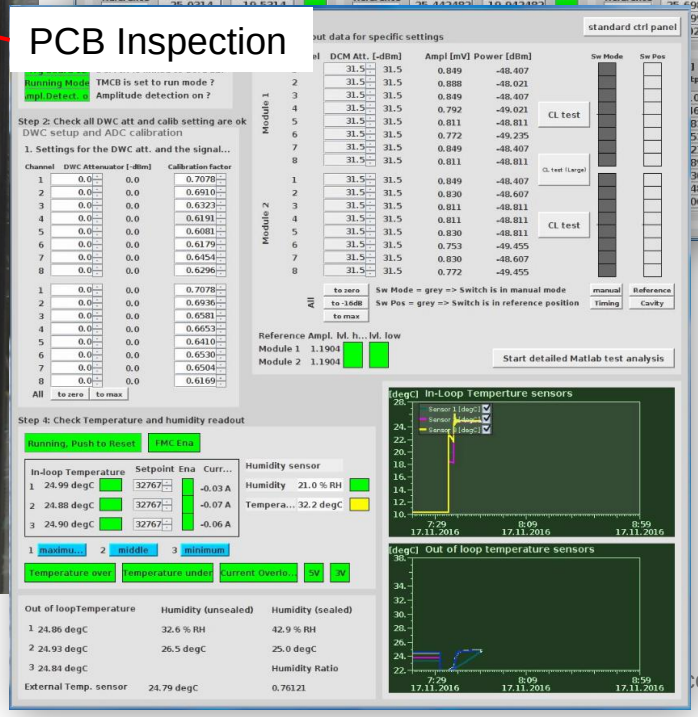
3 DCM – Functional Tests



Final Module Test



PCB Inspection



Documentation & Teststand:

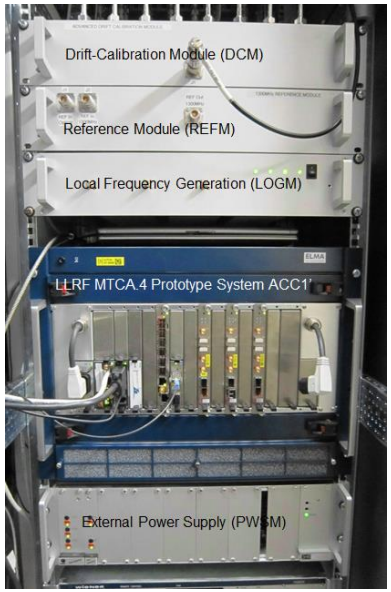
- Production Instruction
- Assembly Instruction
- Test Procedure Definition
- Teststand Software
- Failure Reports
- Bug fixing

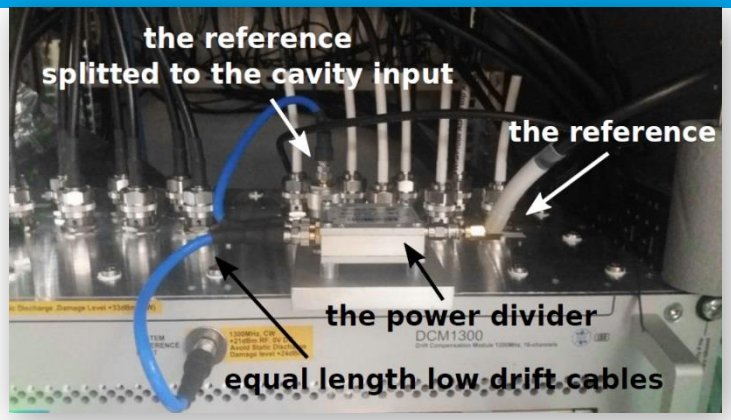
… a lot of work …

4 Long-term performance (Laboratory) – Constant Temperature

FIL

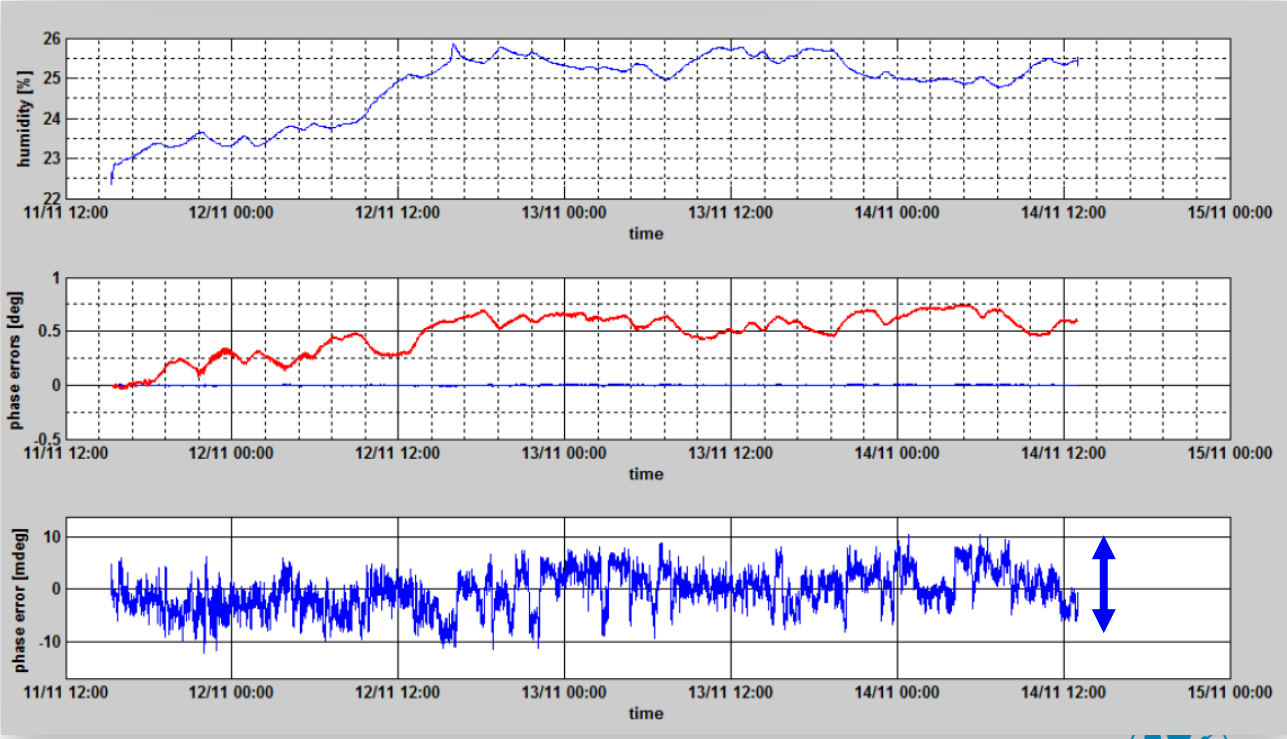
- FLASH injector hutch :
  (stability <0.2degC_pp)





[Courtesy of J. Piekarski]

FLASH injector hutch ACC1' operation

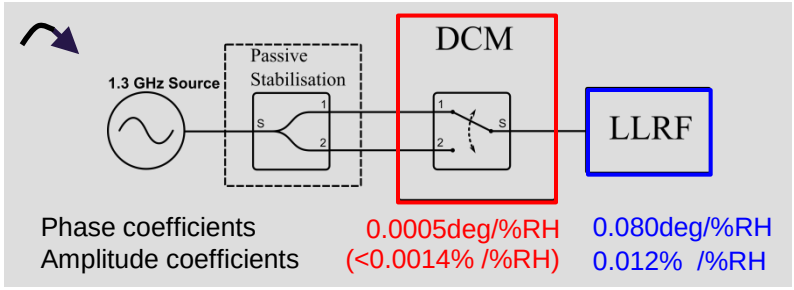


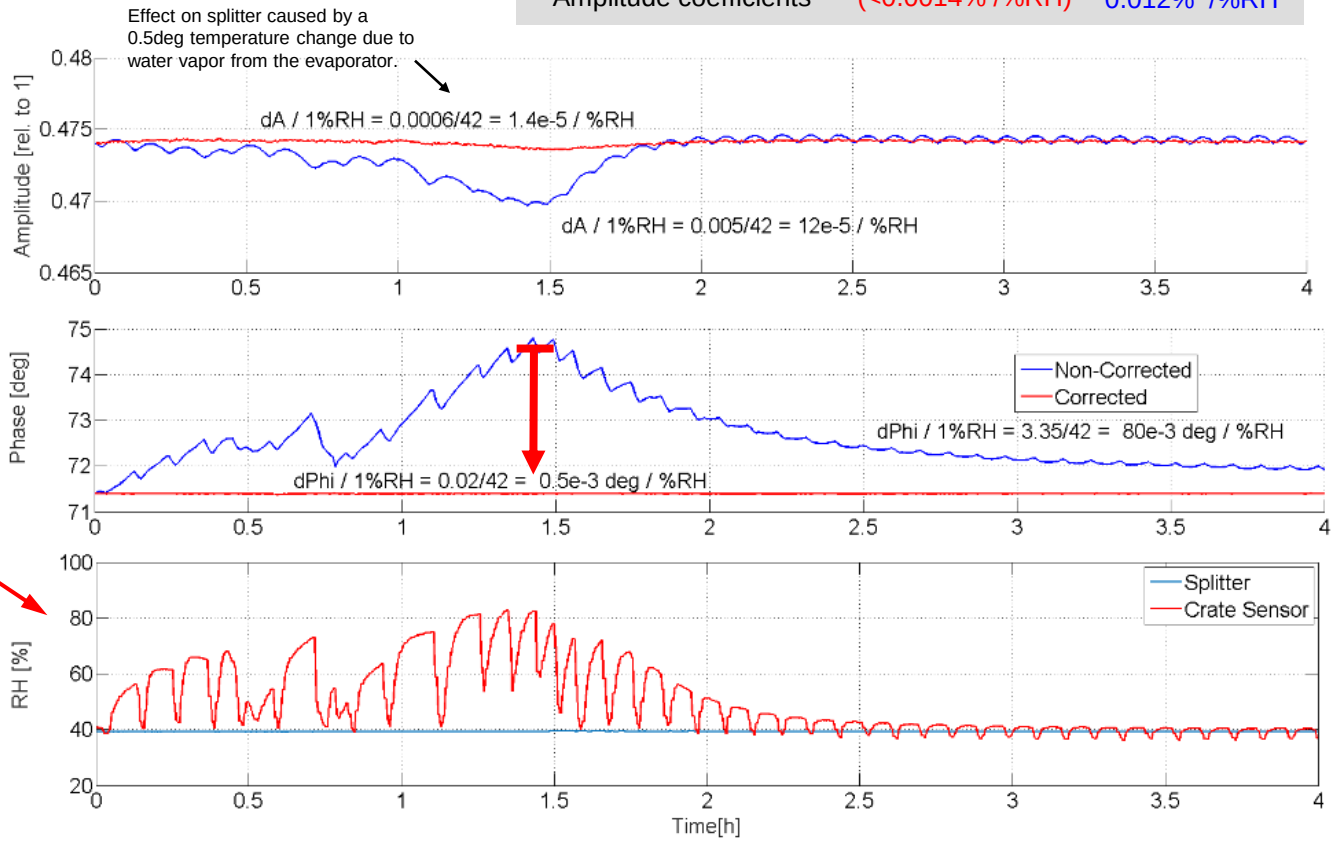
<40fspp over 3 days (1.3GHz)
<50mK internal temp stability

4 Long-term performance (Laboratory, 22h) – rough environment

- Humidity step response :

3.3deg_pp->0.02deg_pp
1/160 reduction (1.3GHz)



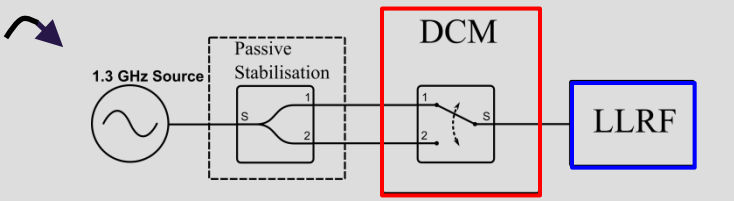


[Courtesy of U.Mavric]

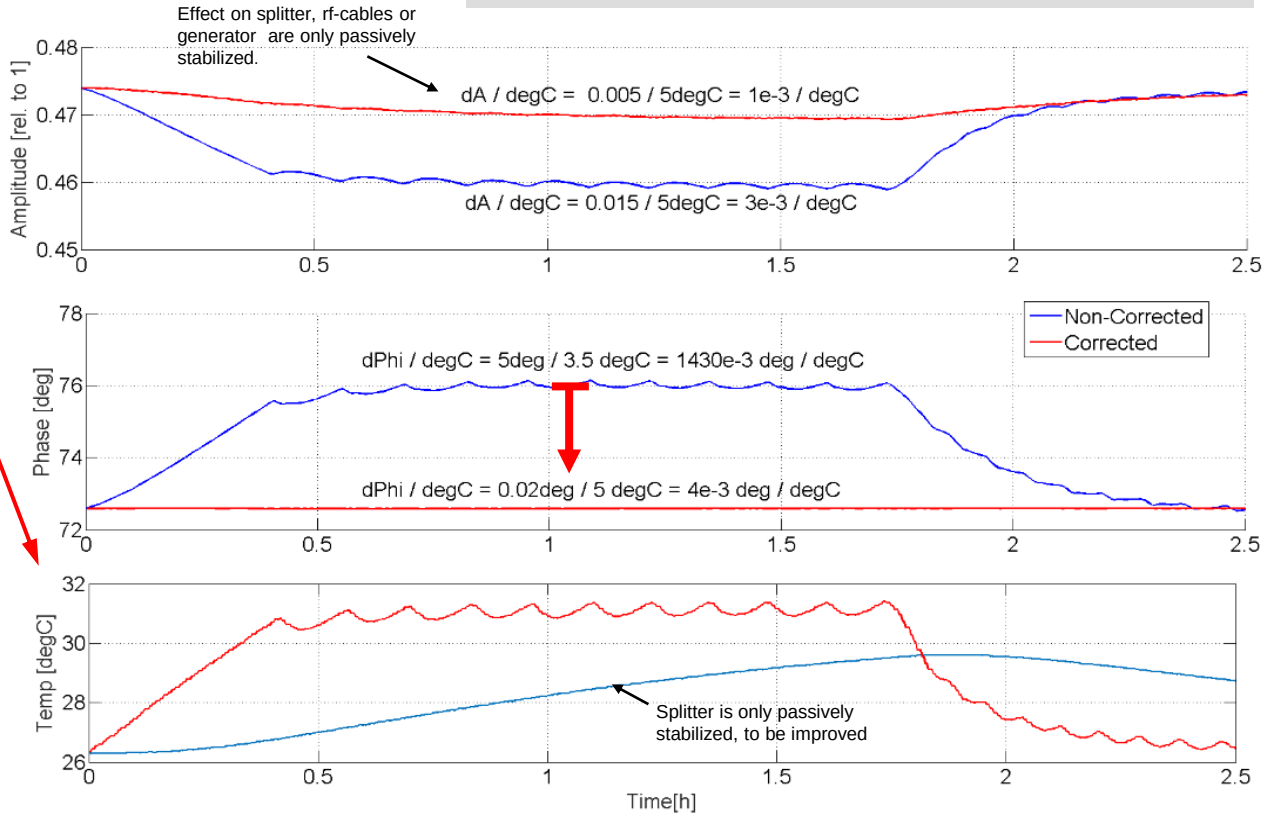
4 Long-term performance (Laboratory, 22h) – rough environment

- Temperature step response :

5deg_pp->0.02deg_pp
1/250 reduction (1.3GHz)



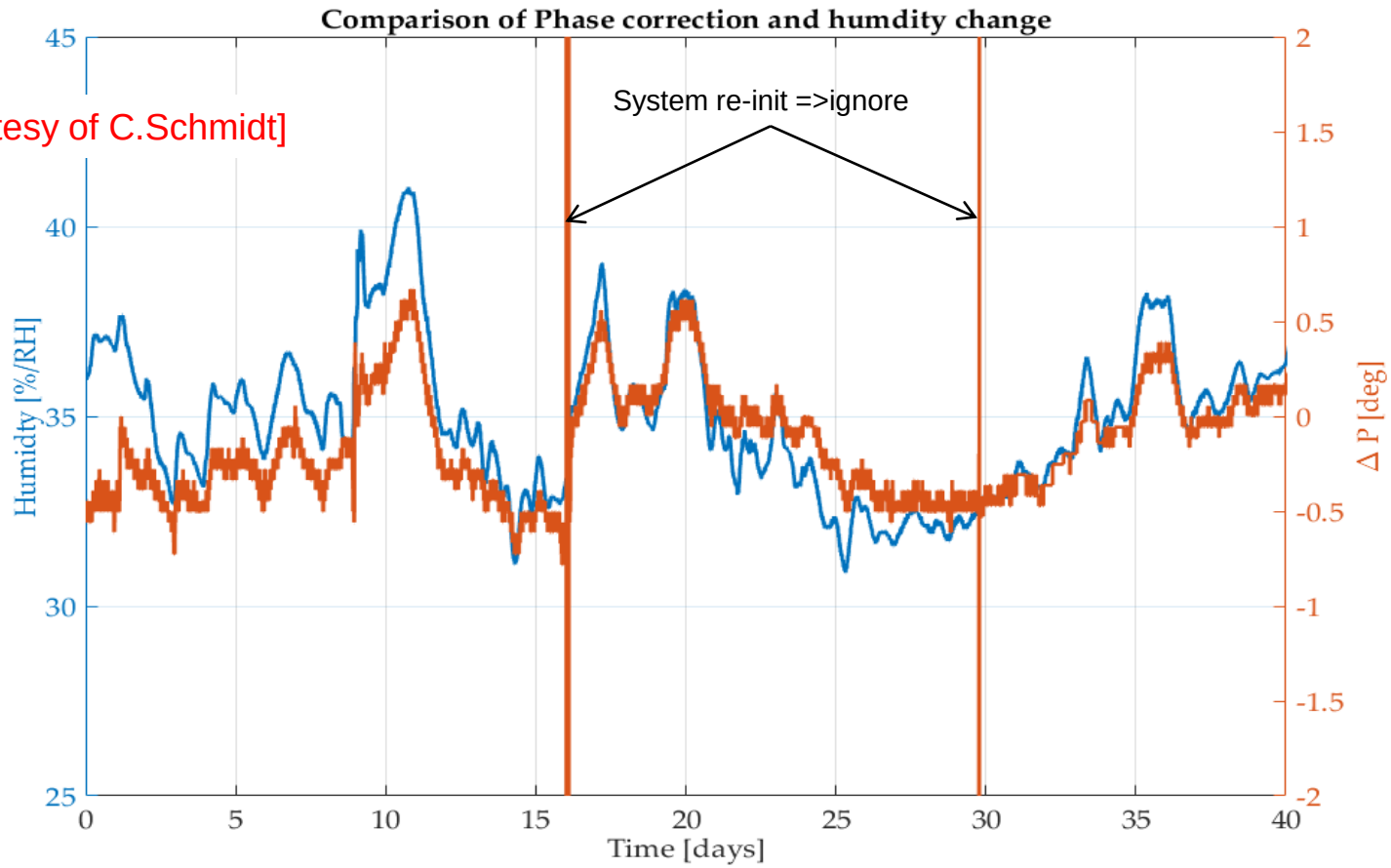
Phase coefficients	0.004deg/degC	1.4deg/degC
Amplitude coefficients	(<0.1% /degC)	0.3% /degC



[Courtesy of U.Mavric]

4 Long-term performance (FLASH) – DCM in Action

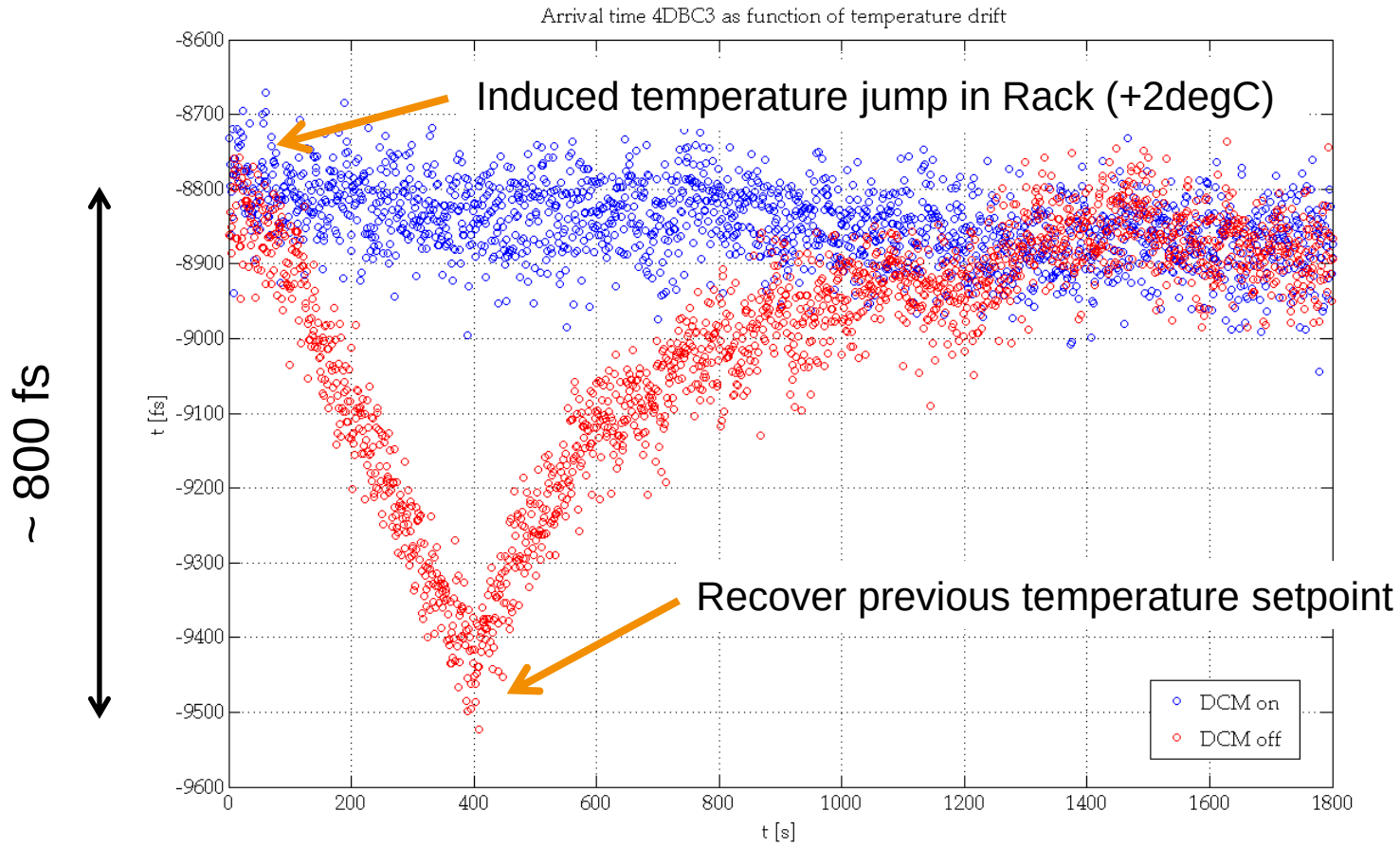
[Courtesy of C.Schmidt]



- Humidity induced phase drifts dominates and compensated using the DCM
- Rule of thumb => **1% Humidity change ~ 0,1deg Phase change**

4 Long-term performance (FLASH) – Arrival time

- Arrival time at 4DBC3 with ACC23 DCM on/off :
  [Courtesy of C.Schmidt]



5 Summary and Outlook

- The Drift-Calibration Module stabilizes LLRF-systems down to 0.02deg_pp and 0.02%_pp at 1.3GHz for pulsed machines.
- A module for CW-operation is under construction.

Thanks for your attention!