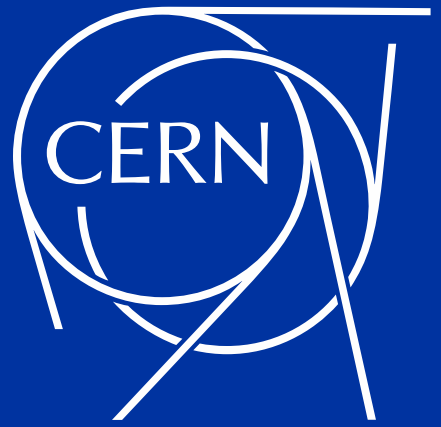


My work with the ECAL DCS software and a Non-invasive isolation damage system for the preshower detector

Jakub Wieczorek

02/12/2019

Presentation plan

- A few words about ECAL DCS
  - What is that
  - My participation
- Isolation damages detection project
  - Problem definition
  - Solution proposal
  - Constructed systems
  - Outcome

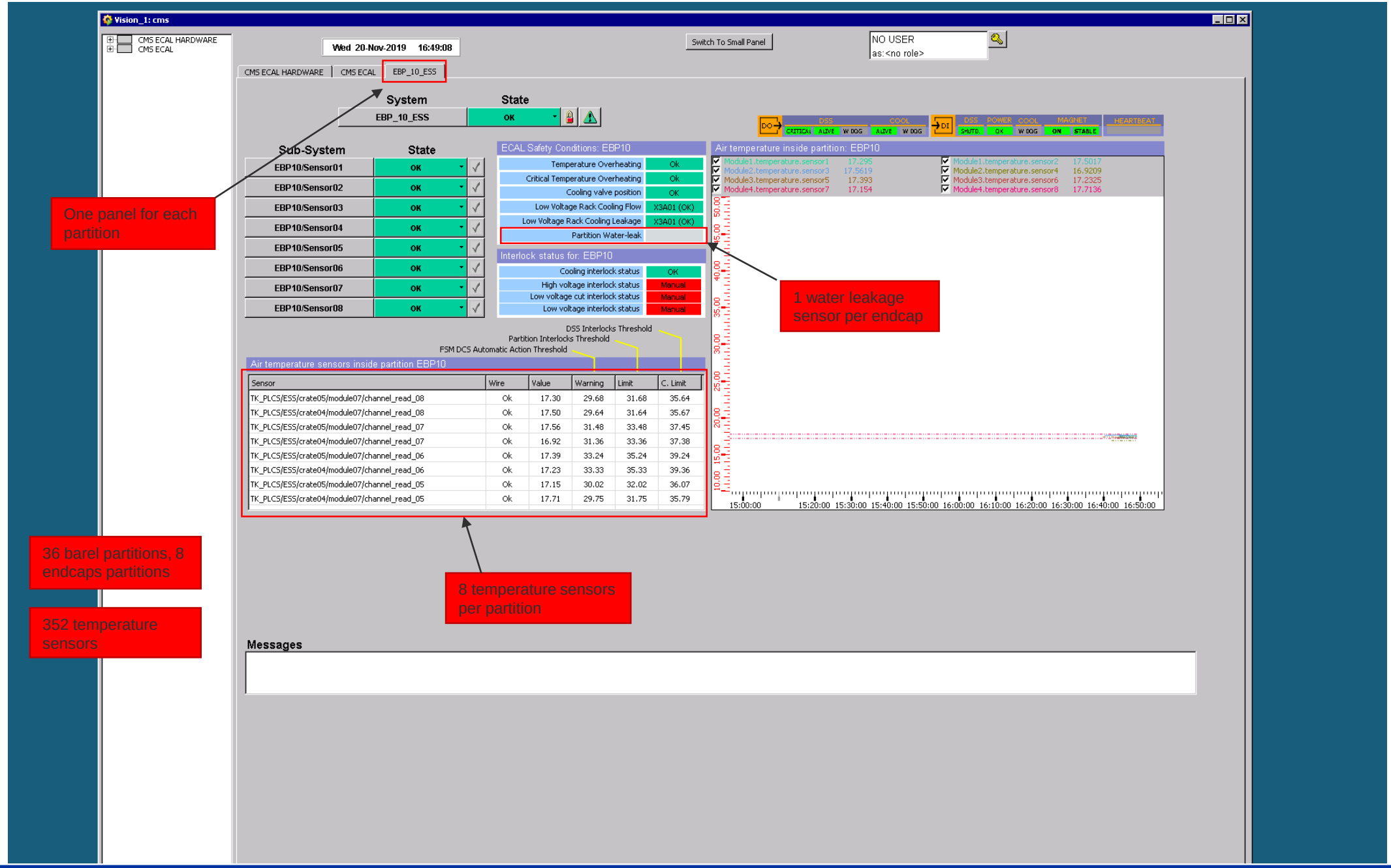
ECAL Detector Control System

ECAL DCS

- Detector Control System
- ECAL DCS one of the nodes of CMS DCS
- SCADA systems which allows controling and operating the detector

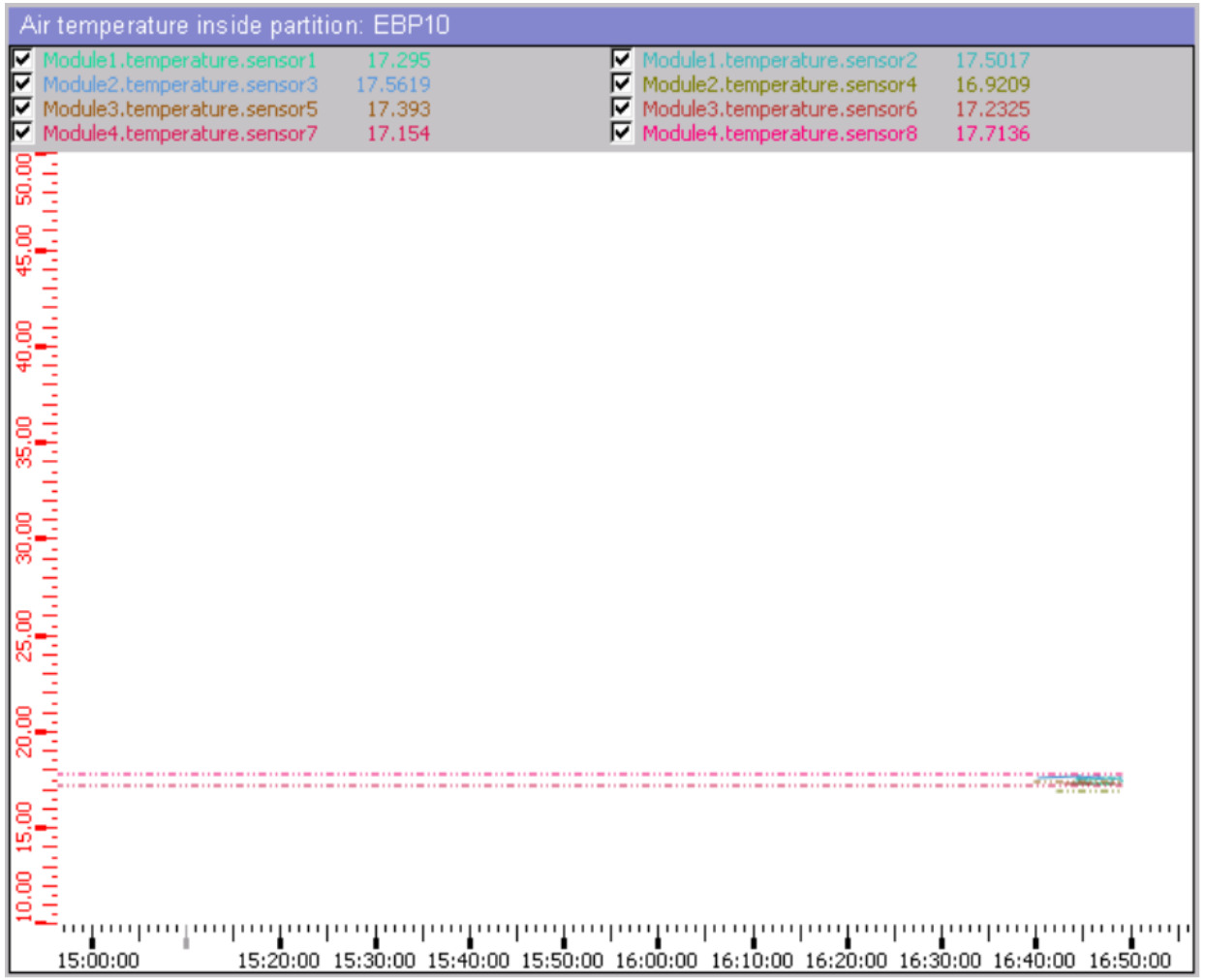
My participation:

- Panel development
- Integration test for interlocks with final report
- Parts of technical documentation


Vision_1: cms
CMS ECAL HARDWARE
CMS ECAL
Wed 20-Nov-2019 16:49:08
Switch To Small Panel
NO USER
as:<no role>
CMS ECAL HARDWARE
CMS ECAL
EBP_10_ESS
System
State
EBP_10_ESS
OK
Sub-System
State
EBP10/Sensor01
EBP10/Sensor02
EBP10/Sensor03
EBP10/Sensor04
EBP10/Sensor05
EBP10/Sensor06
EBP10/Sensor07
EBP10/Sensor08
OK
ECAL Safety Conditions: EBP10
Temperature Overheating
Critical Temperature Overheating
Cooling valve position
Low Voltage Rack Cooling Flow
Low Voltage Rack Cooling Leakage
Partition Water-leak
Ok
Ok
OK
X3A01 (OK)
X3A01 (OK)
Interlock status for: EBP10
Cooling interlock status
High voltage interlock status
Low voltage cut interlock status
Low voltage interlock status
OK
Manual
Manual
Manual
DSS Interlocks Threshold
Partition Interlocks Threshold
FSM DCS Automatic Action Threshold
Air temperature sensors inside partition EBP10
Sensor
Wire
Value
Warning
Limit
C. Limit
TK_PLCS/ESS/crate05/module07/channel_read_08 Ok 17.30 29.68 31.68 35.64
TK_PLCS/ESS/crate04/module07/channel_read_08 Ok 17.50 29.64 31.64 35.67
TK_PLCS/ESS/crate05/module07/channel_read_07 Ok 17.56 31.48 33.48 37.45
TK_PLCS/ESS/crate04/module07/channel_read_07 Ok 16.92 31.36 33.36 37.38
TK_PLCS/ESS/crate05/module07/channel_read_06 Ok 17.39 33.24 35.24 39.24
TK_PLCS/ESS/crate04/module07/channel_read_06 Ok 17.23 33.33 35.33 39.36
TK_PLCS/ESS/crate05/module07/channel_read_05 Ok 17.15 30.02 32.02 36.07
TK_PLCS/ESS/crate04/module07/channel_read_05 Ok 17.71 29.75 31.75 35.79
DSS CRITICAL ALIVE W DOG COOL ALIVE W DOG
DSS SHUTD. POWER OK COOL W DOG MAGNET ON STABLE
HEARTBEAT
Air temperature inside partition: EBP10
Module1.temperature.sensor1 17.295
Module2.temperature.sensor3 17.5619
Module3.temperature.sensor5 17.393
Module4.temperature.sensor7 17.154
Module1.temperature.sensor2 17.5017
Module2.temperature.sensor4 16.9209
Module3.temperature.sensor6 17.2325
Module4.temperature.sensor8 17.7136
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
15:00:00
15:20:00
15:30:00
15:40:00
15:50:00
16:00:00
16:10:00
16:20:00
16:30:00
16:40:00
16:50:00
Messages
One panel for each partition
1 water leakage sensor per endcap
36 barel partitions, 8 endcaps partitions
352 temperature sensors
8 temperature sensors per partition

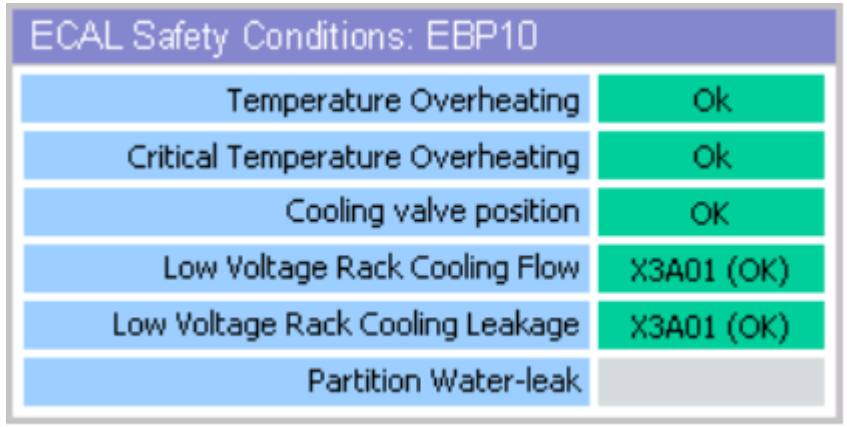
Temperature sensors plot widget

- Shows readouts from temperature sensors in real time
- Plot can be checked and unchecked by user
- When sensor is disabled there is no plot available for that sensor



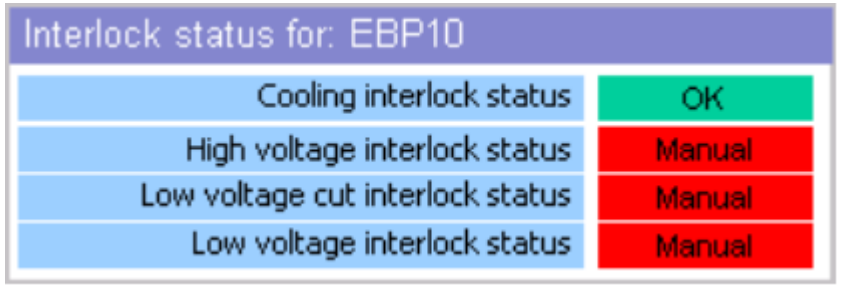
Conditions monitoring widget

- Partition conditions in real time
- When one of the temperature sensors exceeds threshold, then alarm and suitable automatic actions for the partition is perfomed
- Cooling status
- Water leakage available only for endcap partitions



Interlock status widget

- Interlocks for current partition
- Temperature sensor exceeds limit, then high voltage, low voltage and low voltage cut interlocks are set
- Cooling interlock for water leakage sensors in endcaps
- Interlocks can be set manually



Interlock status widget

- Crucial values for every sensor
- Wire connection
- Current value
- Warning status if value two degrees lower than overheating limit
- Crossing overheating limit causes partition interlocks
- Crossing critical overheating causes general DSS interlock, which turns off the detector

DSS Interlocks Threshold
Partition Interlocks Threshold
FSM DCS Automatic Action Threshold

Air temperature sensors inside partition EBP10

Sensor	Wire	Value	Warning	Limit	C. Limit
TK_PLCS/ESS/crate05/module07/channel_read_08	Ok	17.30	29.68	31.68	35.64
TK_PLCS/ESS/crate04/module07/channel_read_08	Ok	17.50	29.64	31.64	35.67
TK_PLCS/ESS/crate05/module07/channel_read_07	Ok	17.56	31.48	33.48	37.45
TK_PLCS/ESS/crate04/module07/channel_read_07	Ok	16.92	31.36	33.36	37.38
TK_PLCS/ESS/crate05/module07/channel_read_06	Ok	17.39	33.24	35.24	39.24
TK_PLCS/ESS/crate04/module07/channel_read_06	Ok	17.23	33.33	35.33	39.36
TK_PLCS/ESS/crate05/module07/channel_read_05	Ok	17.15	30.02	32.02	36.07
TK_PLCS/ESS/crate04/module07/channel_read_05	Ok	17.71	29.75	31.75	35.79

Integration test for interlocks

Test for every partition – 352 temp + 8 WLD

1) Set value to fake sensor – exceed threshold

4) Exceed critical threshold

6) Exceed WLD threshold

```
/08/02 17:55:49: ### Test for partition: EBP01                          ###
/08/02 17:55:54: ACTION:   Setting 415 value for sensor System1:TK_PLCS/ESS/crate14/module03/channel_read_01.: 700 -> 415 OK
/08/02 17:55:59:    EVENT: Interlock LV HV LVCut  set for the partition EBP01, OK
/08/02 17:56:04: ACTION:   Setting 700 value for sensor System1:TK_PLCS/ESS/crate14/module03/channel_read_01.: 415 -> 700 OK
2019/08/02 17:56:10: ACTION:   Acknowladging interlock LV HV LVCut  for EBP01: success after 1 attemps OK

2019/08/02 17:56:15: ACTION:   Setting 410 value for sensor System1:TK_PLCS/ESS/crate15/module03/channel_read_01.: 700 -> 410 OK
2019/08/02 17:56:20:    EVENT: Interlock LV HV LVCut  set for the partition EBP01, OK
2019/08/02 17:56:25: ACTION:   Setting 700 value for sensor System1:TK_PLCS/ESS/crate15/module03/channel_read_01.: 410 -> 700 OK
2019/08/02 17:56:31: ACTION:   Acknowladging interlock LV HV LVCut  for EBP01: success after 1 attemps OK
```

2) Check if interlocks is set

```
9/08/02 17:59:04: ACTION:   Setting 100 value for sensor System1:TK_PLCS/ESS/crate15/module03/channel_read_01.: 700 -> 100 OK
9/08/02 17:59:09:    EVENT: Interlock LV HV LVCut  set for the partition EBP01, OK
9/08/02 17:59:09:    EVENT: General interlock DSS_CRITICAL_Overheating set OK
9/08/02 17:59:14: ACTION:   Setting 700 value for sensor System1:TK_PLCS/ESS/crate15/module03/channel_read_01.: 100 -> 700 OK
9/08/02 17:59:20: ACTION:   Acknowladging interlock LV HV LVCut  for EBP01: success after 1 attemps OK
2019/08/02 17:59:20:    EVENT: General interlock acknowledged OK

2019/08/02 17:59:25: ACTION:   Setting 100 value for sensor System1:TK_PLCS/ESS/crate14/module03/channel_read_02.: 700 -> 100 OK
9/08/02 17:59:30:    EVENT: Interlock LV HV LVCut  set for the partition EBP01, OK
9/08/02 17:59:30:    EVENT: General interlock DSS_CRITICAL_Overheating set OK
9/08/02 17:59:35: ACTION:   Setting 700 value for sensor System1:TK_PLCS/ESS/crate14/module03/channel_read_02.: 100 -> 700 OK
9/08/02 17:59:41: ACTION:   Acknowladging interlock LV HV LVCut  for EBP01: success after 1 attemps OK
2019/08/02 17:59:41:    EVENT: General interlock acknowledged OK
```

3) Come back to the normal state and acknowledge interlocks

5) Check if DSS interlock set

```
/08/02 21:18:50: ACTION:   Setting 3500 value for sensor System1:TK_PLCS/ESS/crate09/module09/channel_read_01.: 4500 -> 3500 OK
/08/02 21:19:01:    EVENT: Interlock COOL  set for the partition EEP01, OK
/08/02 21:19:06: ACTION:   Setting 4500 value for sensor System1:TK_PLCS/ESS/crate09/module09/channel_read_01.: 3500 -> 4500 OK
/08/02 21:19:12: ACTION:   Acknowladging interlock COOL    for EEP01: success after 1 attemps OK
```

6) Exceed WLD threshold

7) Check if COOL interlock set

```
2019/08/02 22:04:33: ### Test for partition: EEM04 finished with OK      ###
2019/08/02 22:04:33: INFO: Interlocks test for all partitions were successfully completed, OK
2019/08/02 22:04:33: *** Sensors remove     ***
2019/08/02 22:04:33: ACTION: delete 352 temperature sensors and 8 WLD
```

Problems with 2 sensors detected!

Isolation damages detection project

Introduction and problem definition

- The CMS Preshower detector is cooled down to -20°C by C6F14 based liquid
- Pipes are isolated using Armaflex
- Armaflex is subjected to ageing and damage
- Air gets inside an isolation and condensates on the pipes
- Energy dissipation

Solution proposal #1

- Cut the isolation
- Mount humidity and temperature sensors
- Connect sensors to PLC
- Build SCADA system
- Detect isolation damages
- Replace damaged isolation

What are the problems?

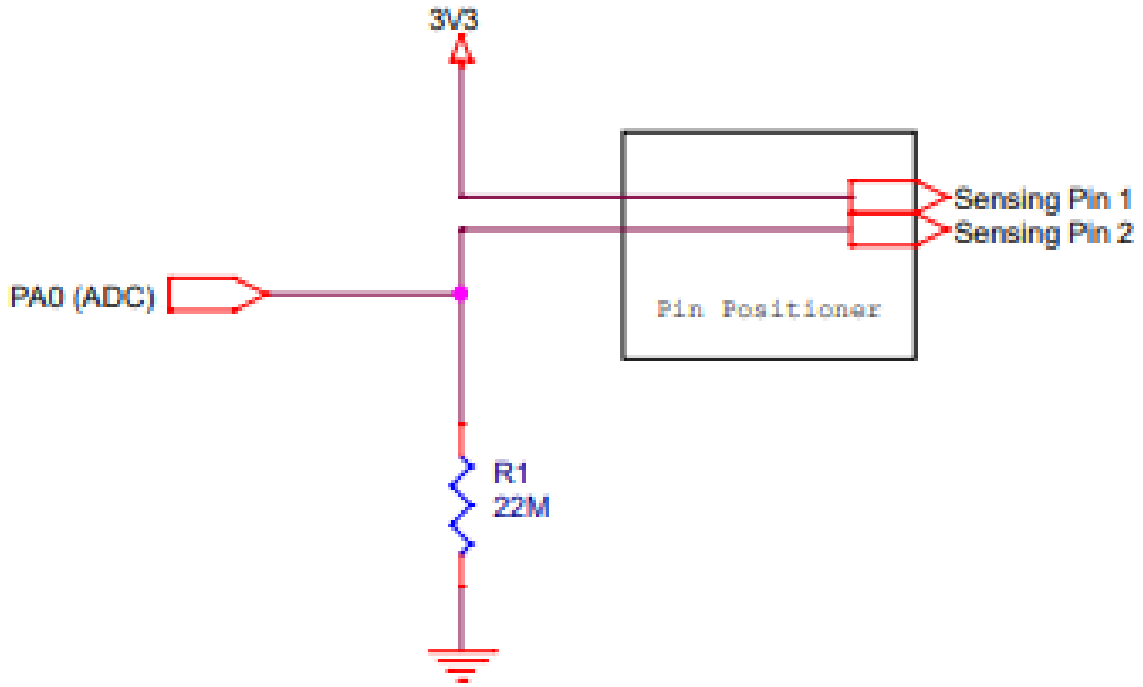
Solution proposal #2

- Use simple sensors, radiation resistant – pair of needles
- Stick them into isolation and measure resistance
- Measuring infinite resistance – isolation not broken
- Measuring something else – potential isolation damage

What are the problems?

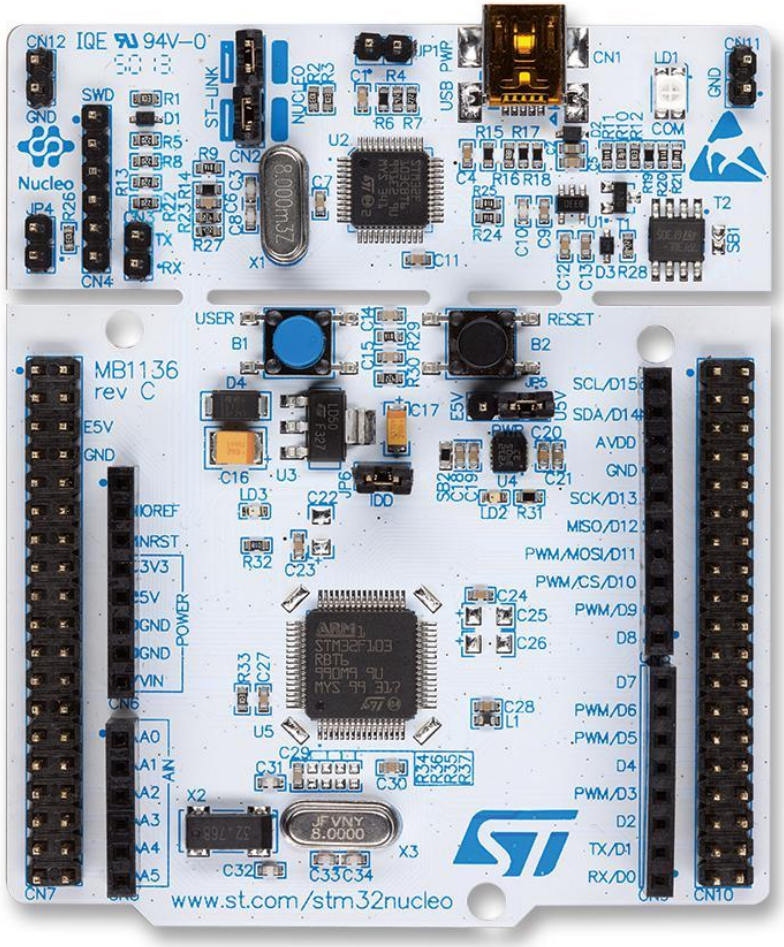
Hardware and electronics

- Pair of needles
  - 100% radiation resistant
  - Potentially subject to rust
- High valued resistor
- Voltage divider



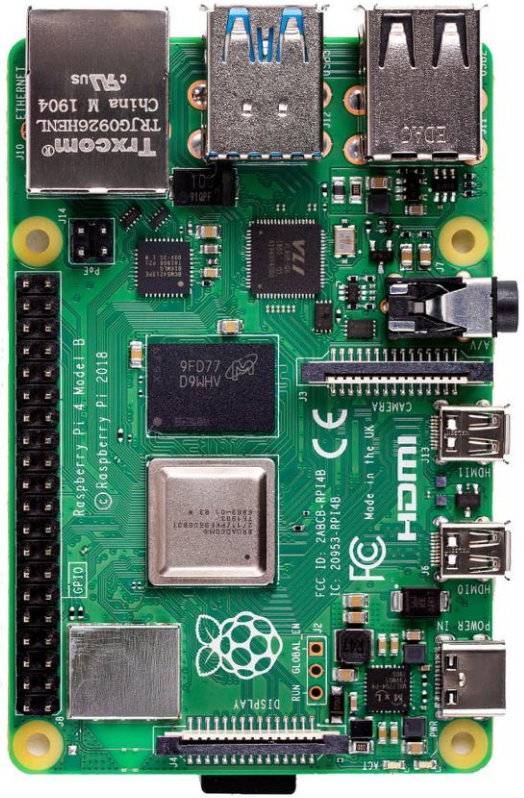
Microcontroller

- ARM Cortex M3
- STM32F103RBT6 on the Nucleo board
  - Price 10chf on Digi-Key
  - Community
  - Very fast microcontroller with many periphals – 2xADC 16 channels each
- HAL Library, no CUBE MX code generation
- C++
- Few words about logic
  - ADC readout using DMA every second
  - Average of 20 readouts
  - Transfer data by UART using DMA



Raspberry OPC UA Server

- Raspberry PI 4
- Ubuntu Docker image
  - docker-compose
  - Very easy to configure and run server – one comand
- OPC UA Server
  - Generic industrial protocol
  - Easy to transfer data to SCADA
  - Python 3.7 implementation using opcua library



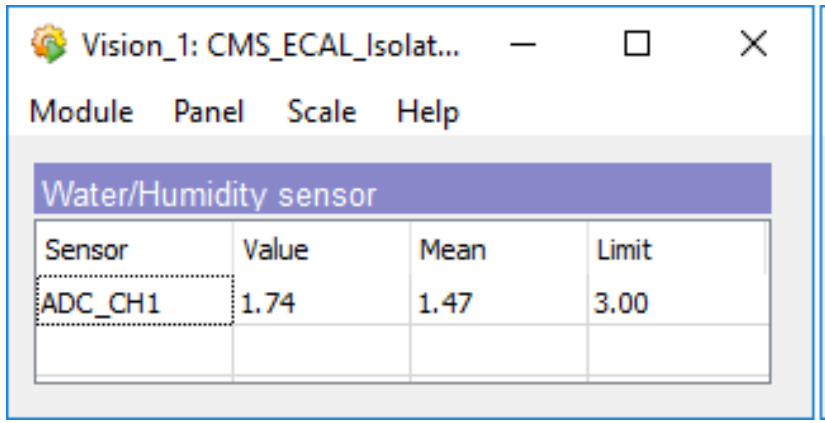
Why raspberry?

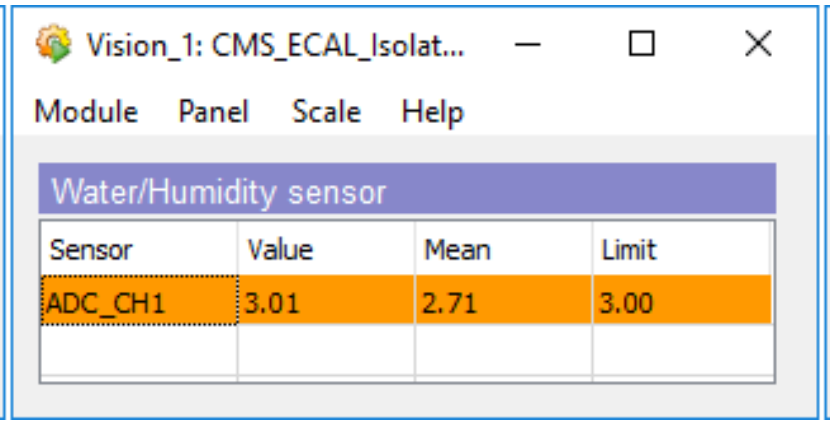
- Impossible to deploy OPC Server on microcontroller

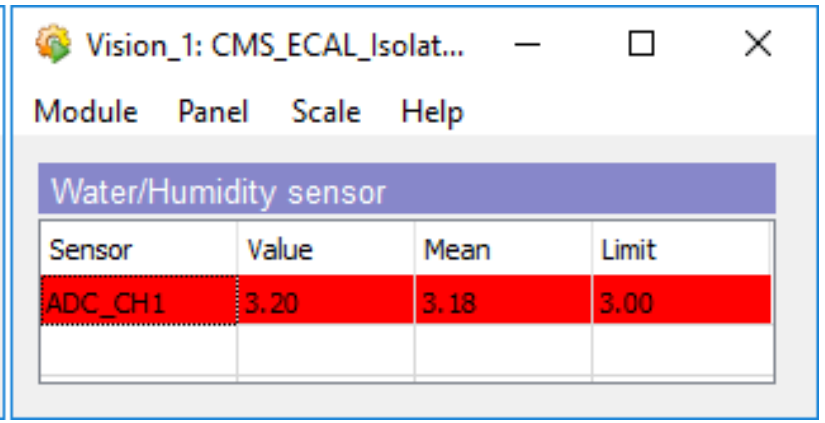
SCADA

- Front-end part of the system
- Panel (widget) to visualize data
- Alarms
- WinCC OA 3.16 Patch 15, JCOP 8.4.0 Beta

- Simple instalation of the component
  - Adding managers
  - Configuring addresses
  - Establishing connection with OPC UA Server



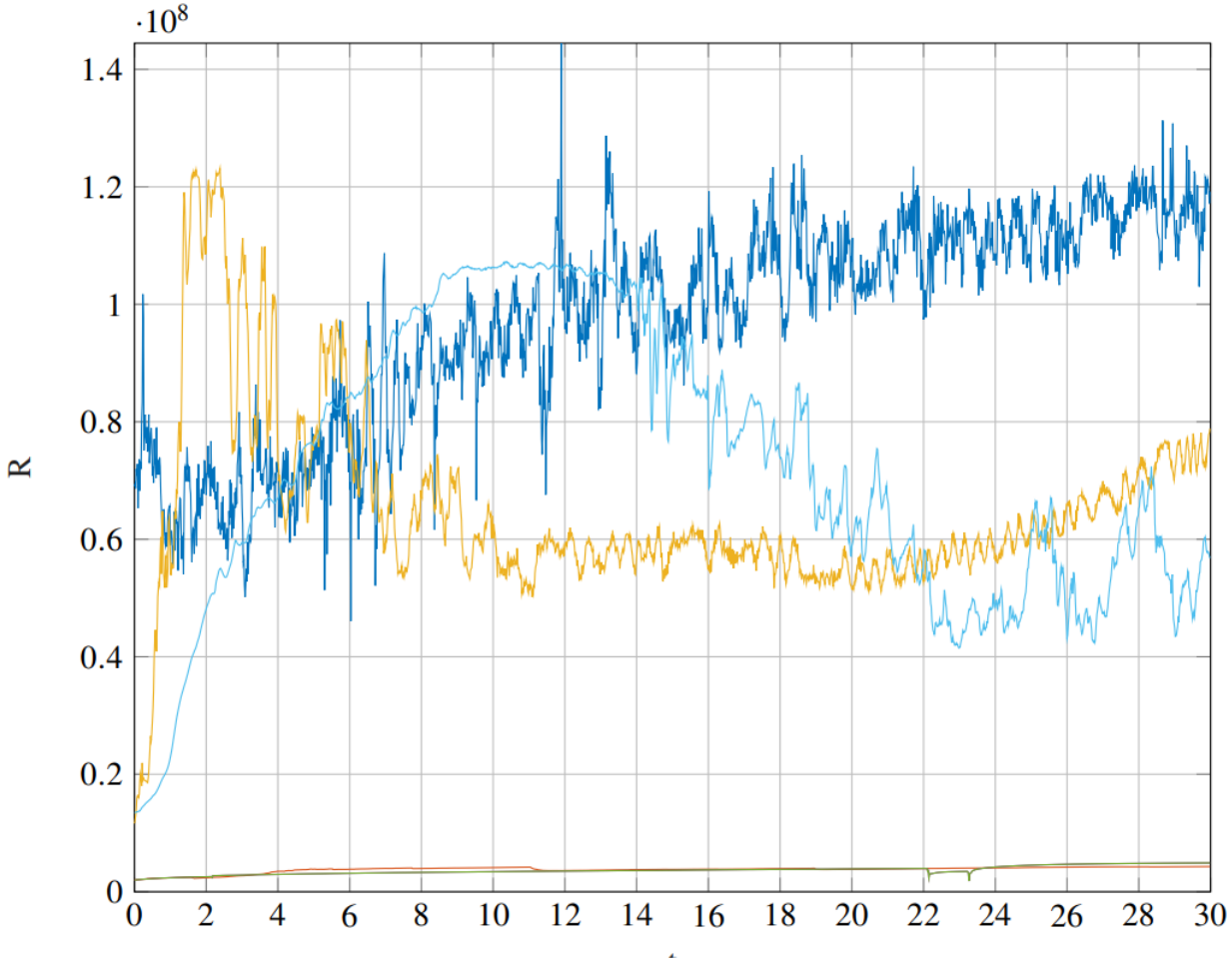




Project outcome

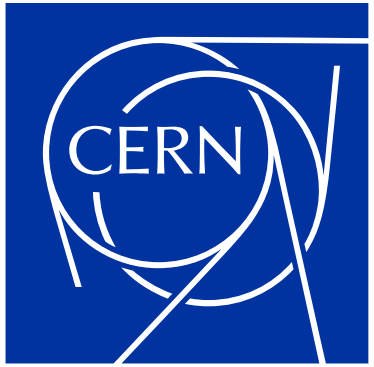
Few about measurements

- It matters where needles are stuck
- Really difficult to measure something between no water and water
- Water typically several hundreds of kΩ
- Dry isolation typically dozen MΩ



Future work

- Test system in real operational environment
- Adapt to the new conditions – change resistors, change thresholds
- Add more set of needles and measure over a whole length



https://gitlab.cern.ch/jawieczo/isolationverifier

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