Upgrade of the CMS ECAL Detector Control System During the CERN Large Hadron Collider Long Shutdown II

L. Marchese, D. Di Calafiori, G. Dissertori, L. Djambazov, R. J. Estupiñán, W. Lustermann

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Whova platform

Luigi Marchese, ETH Zürich
on behalf of the CMS Collaboration

ETH zürich

CMS

The CMS Experiment

➤ One of the four proton-proton interaction points of the LHC ring
➤ Multi-purpose detector with a broad physics programme
➤ After two successful data-taking runs, we are currently in the LHC second-long shutdown (LS2) for machine maintenance and upgrade of the LHC detectors
➤ Due to the COVID-19 pandemic, the LHC LS2 has been extended by one year (2019-2021) giving more time for detector upgrades
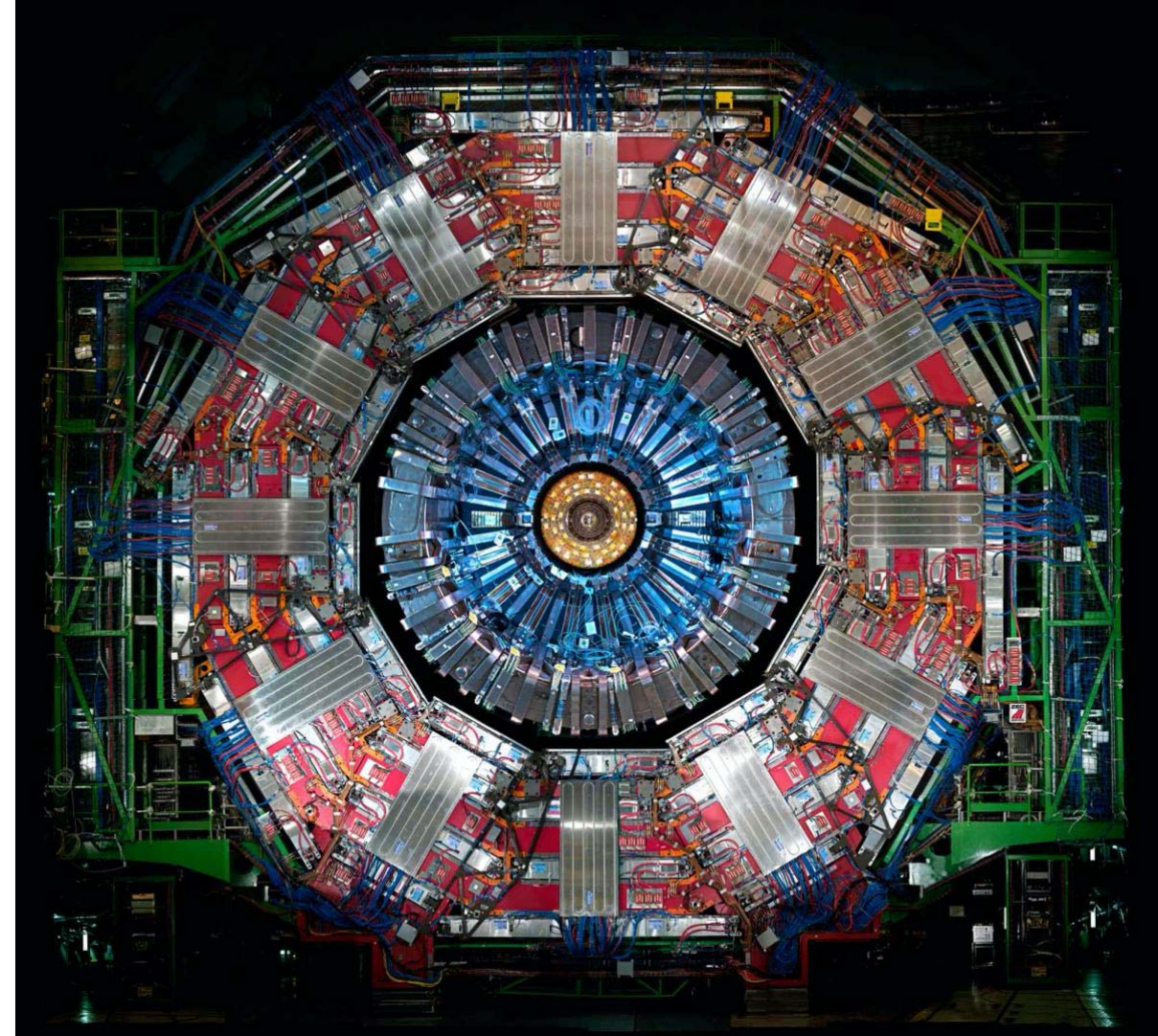
The CMS Electromagnetic CALorimeter (ECAL)

➤ Hermetic, fine grained, homogeneous calorimeter

➤ 75848 lead tungstate scintillating crystals

➤ Depending on the coverage*, conventionally split into two regions, Barrel and Endcaps

➤ A lead/silicon-based preshower is also included

➤ Designed to operate for at least 10 years, so far it has successfully supported CMS Run 1 and Run 2 data-taking operations

Barrel (EB) $|\eta| < 1.48$

Endcaps (EE) $1.48 < |\eta| < 3.0$
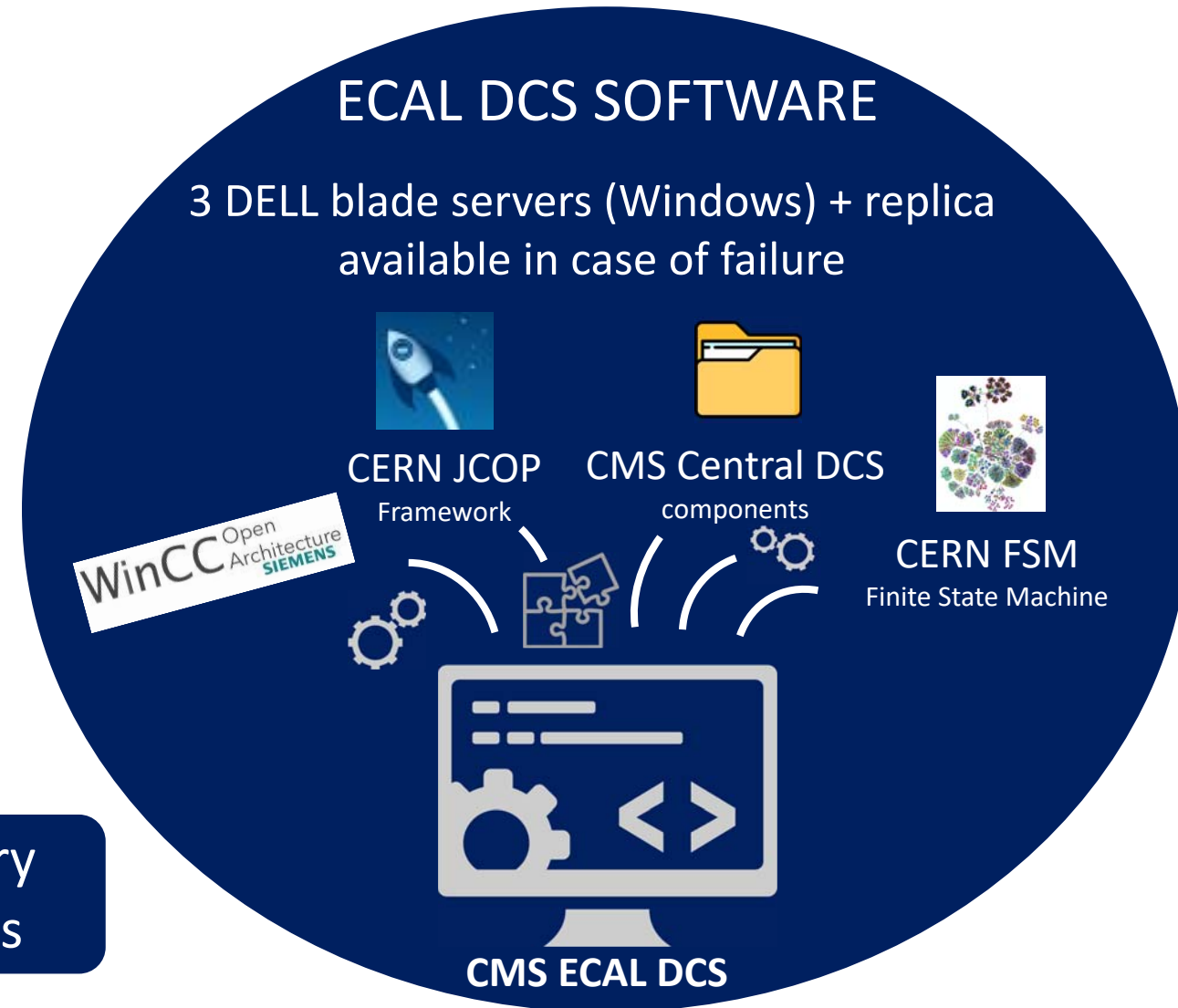
Preshower (ES) $1.65 < |\eta| < 2.6$
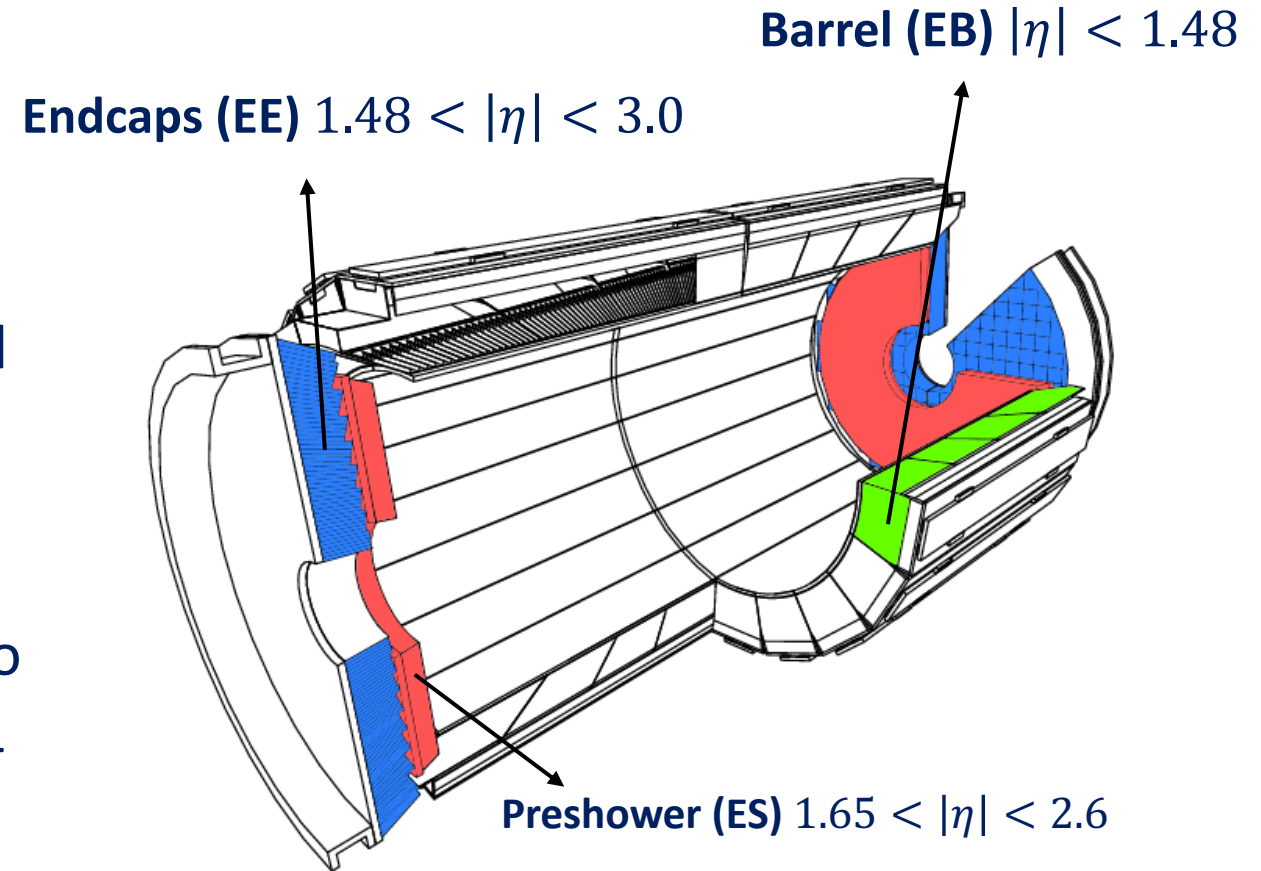
* In particle physics detector coverage (central/forward) is conventionally indicated by using the pseudorapidity variable η

The CMS ECAL Detector Control System (DCS)

The challenging design constraints of ECAL required a sophisticated Detector Control System:

- ➢ Autonomous control of ECAL to ensure data-taking operations
- ➢ Monitoring of ECAL working conditions
- ➢ Communication with several services
- ➢ Distributed and redundant system

Hardware communication based on industry standards as OPC, Modbus and S7 protocols

ECAL DCS SOFTWARE

3 DELL blade servers (Windows) + replica available in case of failure

WinCC Open Architecture SIEMENS

CERN JCOP Framework

CMS Central DCS components

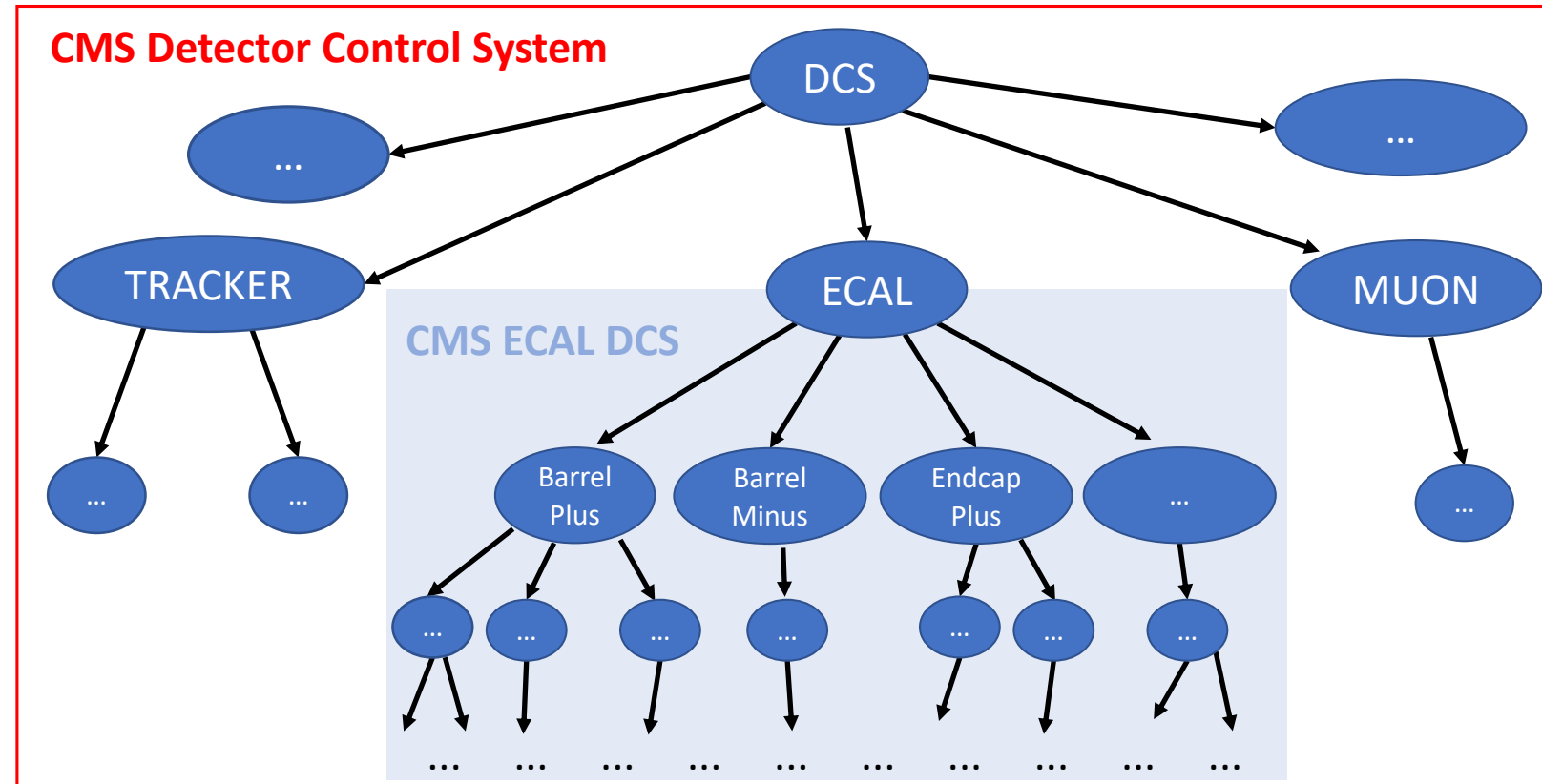CERN FSM Finite State Machine

CMS ECAL DCS

The ECAL DCS Structure

The CERN FSM allows for a simplified representation of the detector:

➢ logical grouping into a hierarchical tree-like structure

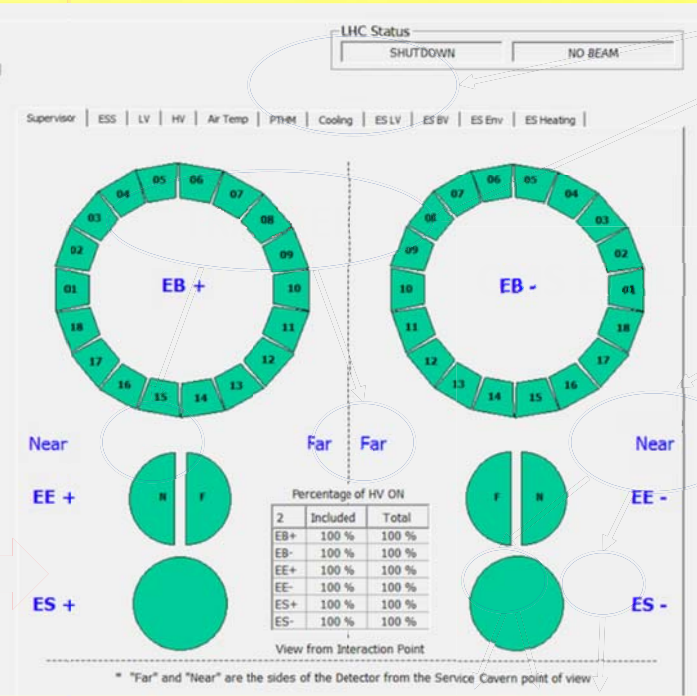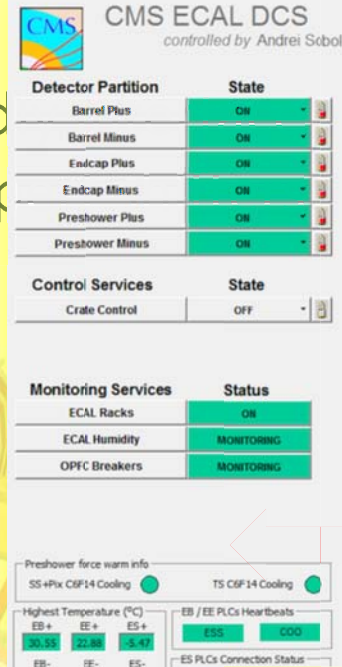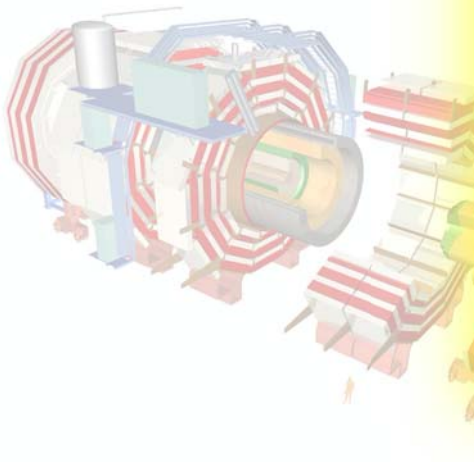➢ User-friendly interface for non-expert shifters
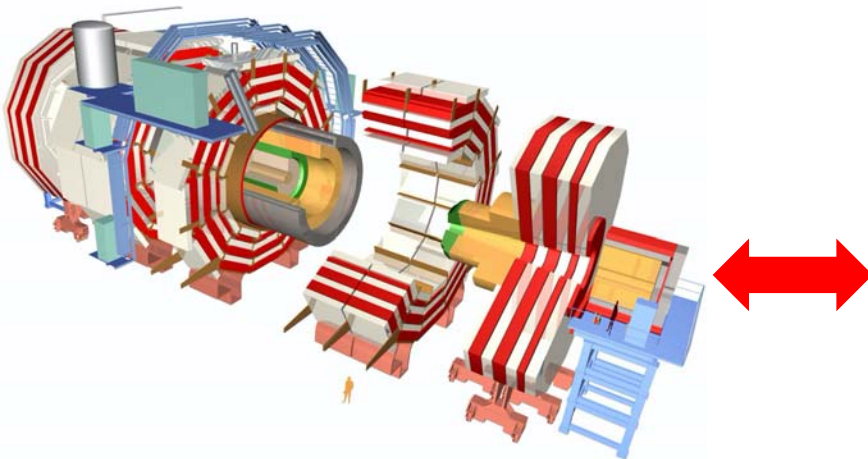
The ECAL DCS Structure

The CERN FSM allows for a simplified representation of the detector:

- ➤ logical grouping into a hierarchical tree-like structure
- ➤ User-friend~~ly~~ for non-exp~~erts~~


CMS DCS shifter

CMS Detector Control System

ECAL DCS COMPLEXITY

- > 1300 sensors (temperature/humidity)
- Almost 2500 channels for LV/HV
- > 100 000 monitoring parameters
- 27 software components

Precision Monitoring in the ECAL DCS

- ➢ Precision Temperature Measurements are needed to monitor temperature stability in the environment of the ECAL crystals and of the photo-detectors
  - ➢ 440 high quality NTC thermistors with a relative **precision better than 0.01C**
- ➢ Precision humidity measurements are needed to monitor air humidity inside the ECAL electronics compartments
  - ➢ 176 humidity sensors with **5-7% relative precision**
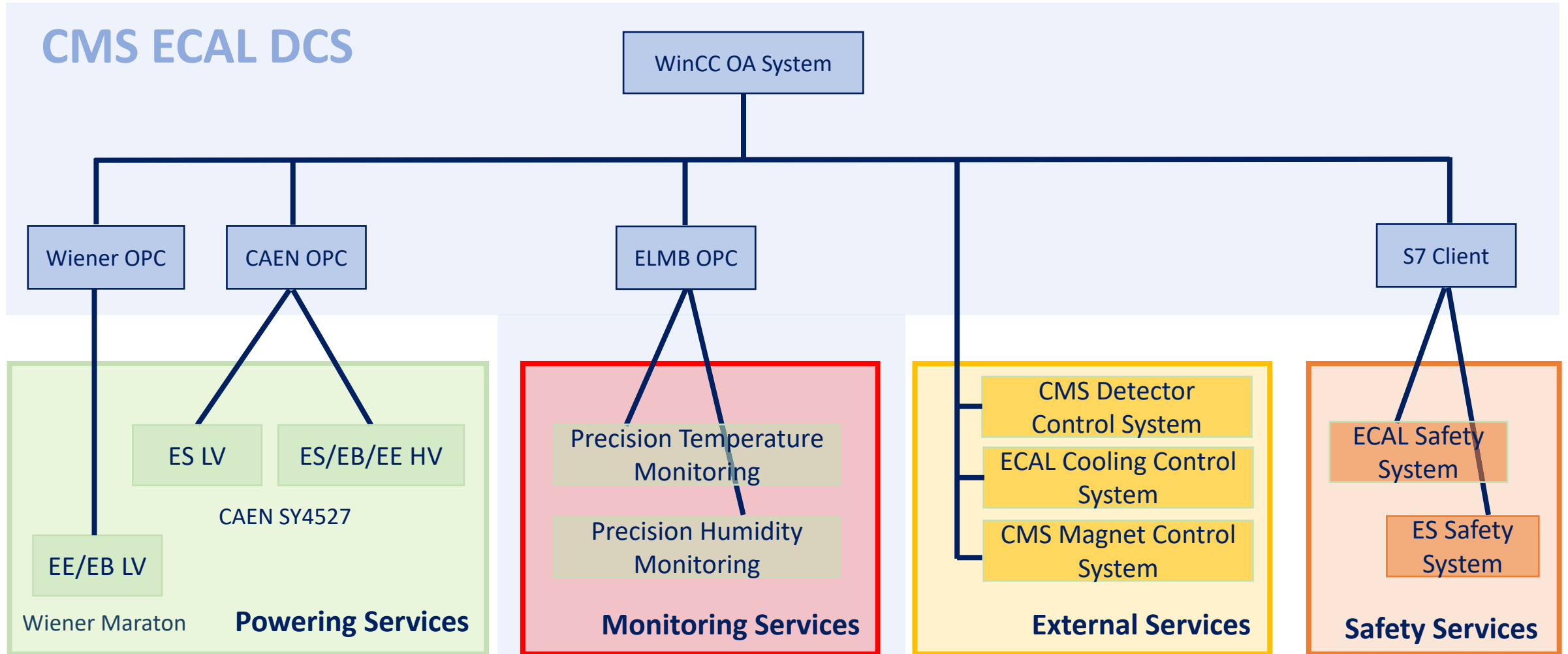

M1   M2   M3   M4

Patch panel
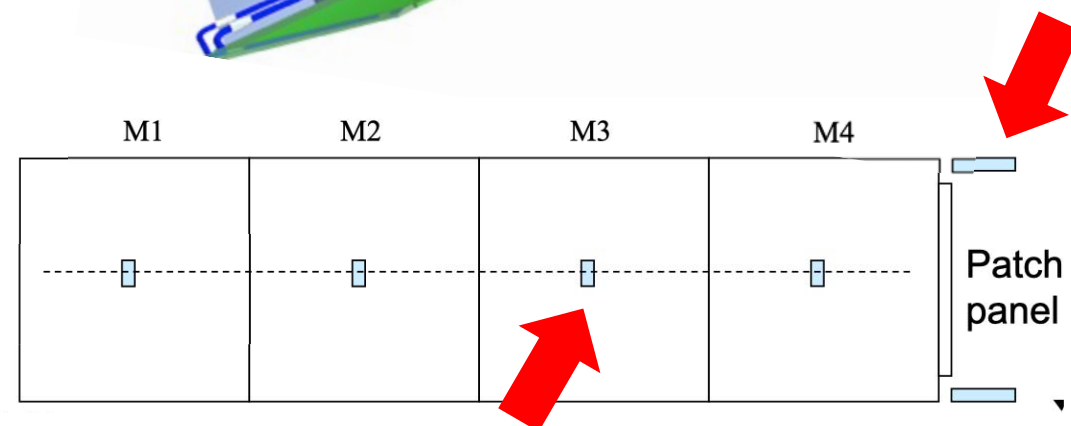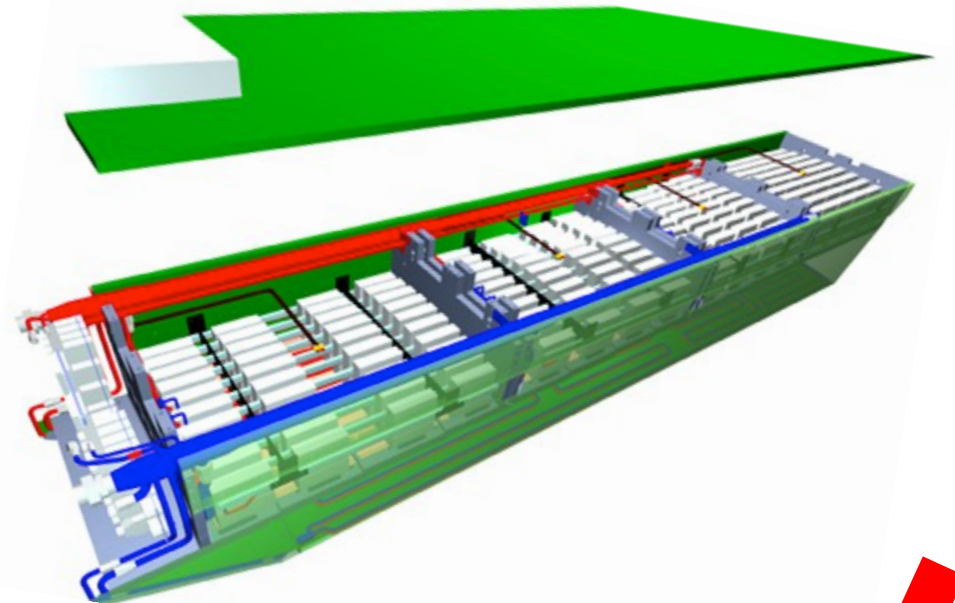
Example of Precision Temperature Monitoring Sensors in one ECAL Super Module, in total

$4 \times 2 + 2 = 10$ **sensors per ECAL Super Module**

The ECAL DCS Services

The ECAL DCS is organised according to several services it provides/interacts with:

ECAL DCS Migration: WinCC OA

During the current LHC LS2, the ECAL DCS went through some software migrations:
1. WinCC OA and JCOP control framework
2. Version-control system
3. OPC UA

1 **WinCC OA platform from version 3.15 to version 3.16**
- ➢ CMS-wide plan to migrate all the sub-detector DCSs to up-to-date releases
- ➢ WinCC OA 3.15 was based on the ISO-8859-1 (Latin) encoding, WinCC OA 3.16 is based on the UTF-8 encoding
- ➢ New XML file format for panels in WinCC OA 3.16

STRATEGY: automatic tools to check for encoding compatibility
- ▪ Special care for strings which needed to be treated as vectors of characters

- ✓ **11**/304 ECAL DCS files required changes
- ✓ **11** new Unicode-compatible functions were developed
- ✓ **>200** Panels converted to the new xml file format

ECAL DCS Migration: JCOP and Git

1

JCOP framework from version 8.1.2 to version 8.4.0

➢ The Joint Control Project (JCOP) is a CERN collaboration aiming for a shared control system architecture used LHC-wide

➢ Following updated WinCC OA versions, JCOP versions are updated periodically by CERN

➢ On the contrary of the JCOP framework version 8.1.2, in version 8.4.0 functions require an explicit call of required libraries

STRATEGY: automatic tool *codePurger* to check for unresolved calls and to implement automatic changes

✓ **240 code transformations**/120 ECAL DCS files

2

Version Control system

➢ In 2018 CERN abandoned the Apache Subversion system (SVN) for the Git distributed version system

▪ The ECAL DCS team took the chance for some hierarchy reorganisation

✓ The **single SVN** ECAL DCS repository was migrated to a set of **35 different Git repositories** organised according to their functionality

ECAL DCS Migration: OPC UA

3 **OPC DA to OPC UA**

➢ OPC Data Access (DA) industrial standard largely used for hardware communication at CERN since the '90s

➢ Following the release of the new standard OPC Unified Architecture (UA), CERN decided to migrate all the OPC DA servers
   ✓ In CMS the migration took place in July 2021 with preliminary tests before

➢ Some important OPC UA highlights:
   ▪ Platform independence
   ▪ Improved security
   ▪ Improved modelling

ECAL DCS Migration: OPC UA in ECAL DCS

3 OPC DA to OPC UA
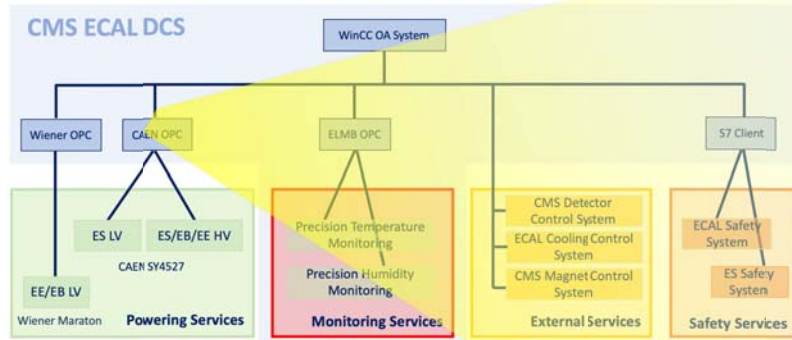
- ➢ Three different types of OPC servers in ECAL DCS :
    1. Wiener for EE/EB LV,
    2. CAEN for EE/EB HV and ES LV and HV,
    3. CERN-made module Embedded Local Monitor Boards (ELMBs) for Precision Temperature Monit.
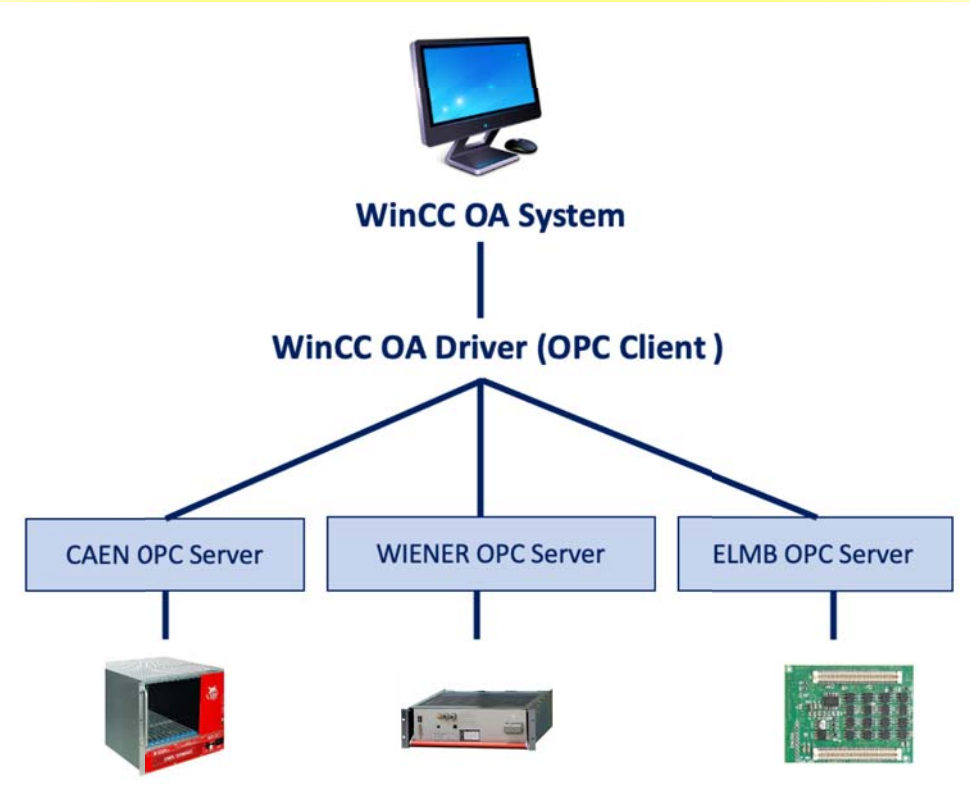
STRATEGY: automatic tool to reconfigure the address space
- ✓ paradigm change from monolithic-server to multiple-server configuration
- ✓ anticipation of some granularity changes which will be required for the next upgrade (for instance removal of EEs and ES)

All ECAL DCS components successfully upgraded

ECAL DCS Migration: Additional Modifications

An additional software modification was needed:

➢ Following the JCOP migration, the component-dependency chain to be followed when installing a new component was affected
   ✓ The *ECAL DCS Installation* toolkit has been modified

Updated Notification System

➢ In parallel to the migration, the ECAL DCS notification system was also improved
   ▪ In the past notification system, multiple messages could be sent to the same group of users
   ▪ The new system is reorganised by application domains
   ▪ Users can now subscribe/unsubscribe directly to independent CERN e-groups for specific notification domains preventing multiple messages to be sent

Conclusions

➢ After several successful years during Run-2 operations, the CMS ECAL DCS project went through major modifications during the LHC second-long shutdown

➢ A multiple migration took place progressively with the final migration happening in July 2021 together with the rest of the CMS DCSs:
  - WinCC OA platform version 3.15 migrated to version 3.16
  - JCOP control framework version 8.1.2 migrated to version 8.4.0
  - SVN version control system migrated to the Git distributed version control system
  - OPC DA servers migrated to OPC UA servers
  - In parallel, the notification system was also improved

➢ The ECAL DCS team was one of the first teams to migrate the project
  - within the deadline: start of Run 3
  - with a small group of 6 people and only 2 more involved
  - This is one of the most complex migrations since the start of the project

➢ The system is ready for Run 3 data-taking operations (2022-2024)