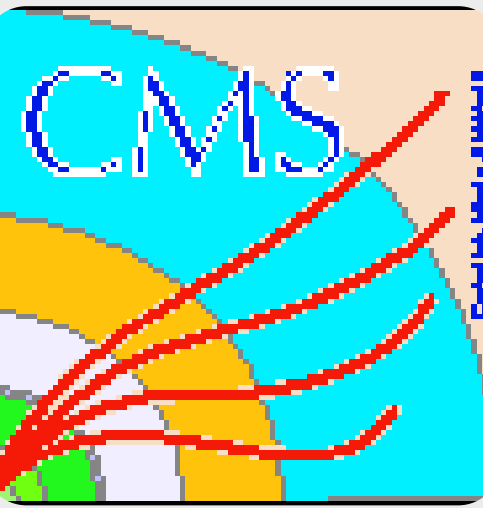




# The Detector Control System for the electromagnetic calorimeter of the CMS experiment at LHC



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## 1 CMS experiment

**Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider (LHC) in CERN, Geneva**

**Structure of the CMS:**

- Tracker and pixel detectors
- Electromagnetic calorimeter (ECAL)**
- Hadronic calorimeter (HCAL)
- Superconducting magnet
- Muon chamber

## 2 ECAL design issues

**Physics goal that determines main design requirements:**  
The discovery of the postulated Higgs boson

**ECAL design requirements:**

- High energy & angular resolution
- High degree of hermeticity
- Compactness
- Radiation tolerance
- Fast response time

**Decision:**  
ECAL is built as a homogenous scintillating detector based on  $PbWO_4$  crystals, avalanche photo-diodes (APD) and vacuum photo triodes (VPT)

**Scintillation crystals –  $PbWO_4$**

**Photo-detectors – APD and VPT**

**Design issue 1:** Irradiation induces changes in  $PbWO_4$  crystal transparency

**Design issue 2:** APD gain is rather sensitive to bias voltage (HV)

**Design issue 3:** Both crystal and APD response are highly sensitive to temperature changes (approx. ~ 2.4% per °C)

**Control of these parameters is of crucial importance for ECAL**

## 3 ECAL DCS objectives

**Design objectives of the ECAL Detector Control System (DCS):**

- Monitoring of the crystal and APD **temperature stability** (18.00 °C +/- 0.05 °C) and **humidity level** inside the ECAL
- Monitoring of temperature and water leakage sensors inside of the ECAL electronics compartments
- Automatic **ECAL protection in case of problematic situations** (hardwired interlocks, predefined control actions, alerting etc.)
- Software control** of parameterization and functioning of ECAL sub-systems (HV, LV, Cooling, Laser, DCU etc.)

**Hardware (autonomous) subsystems:**

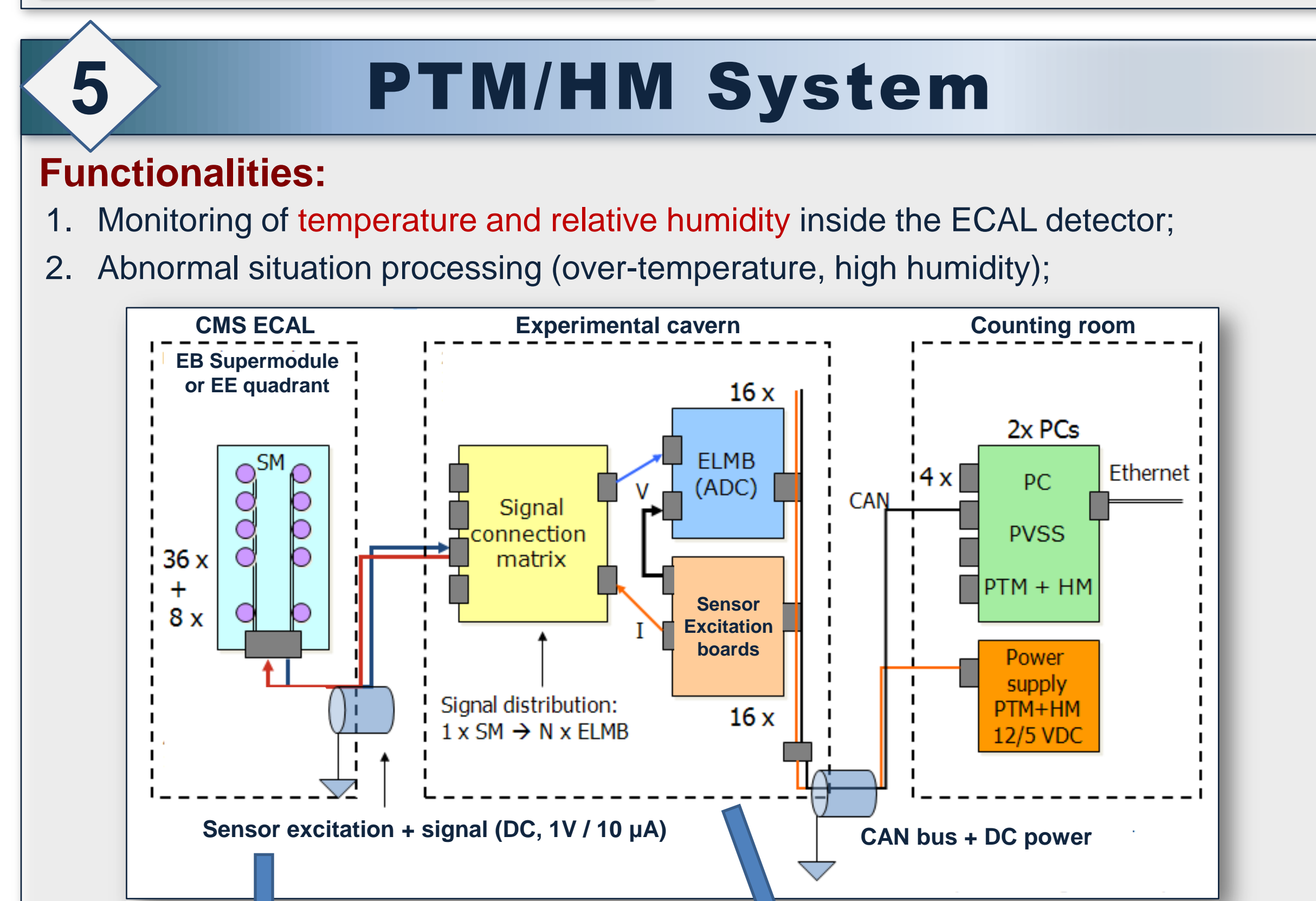
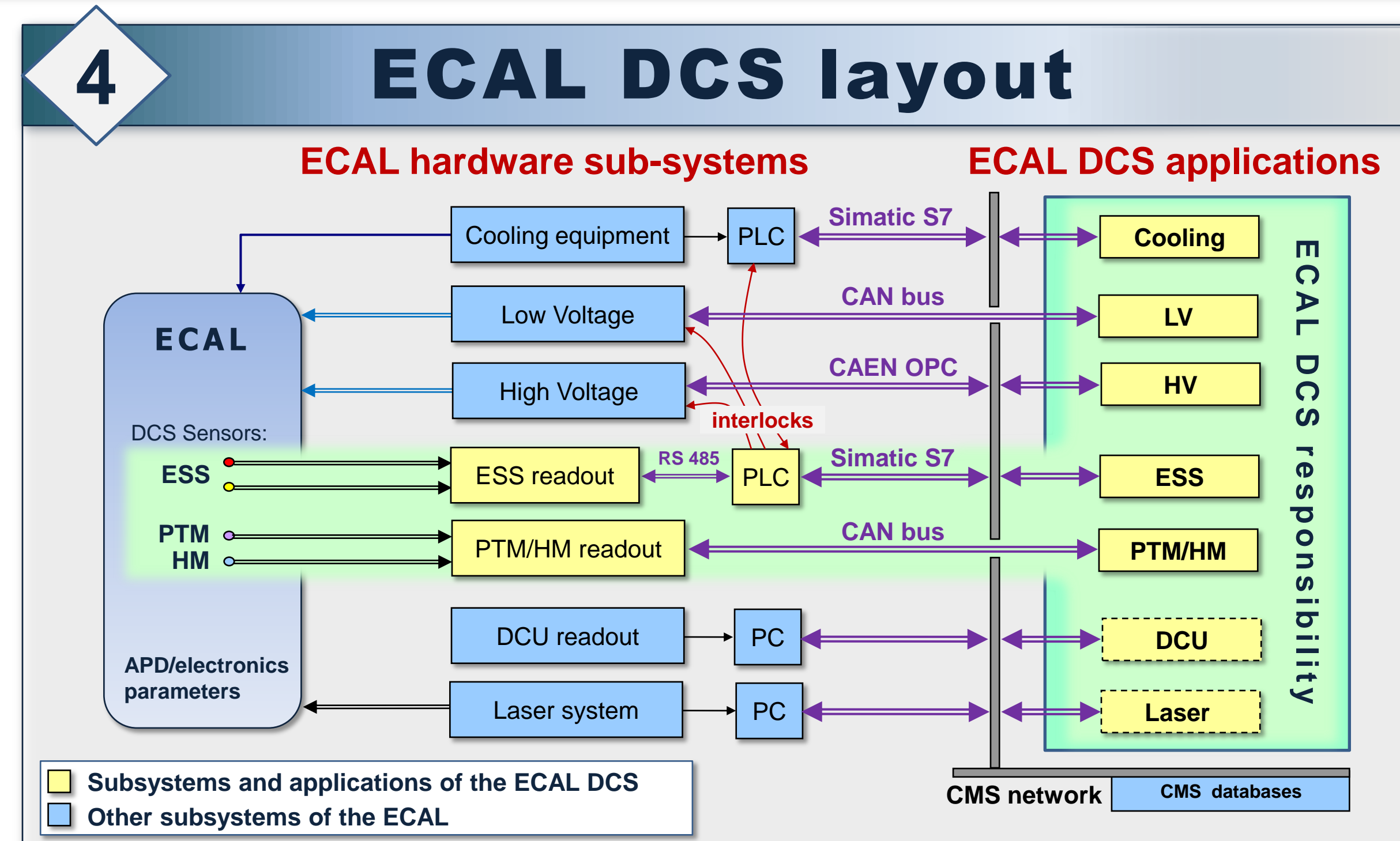
- Precise Temperature Monitoring (**PTM**)
- Humidity Monitoring (**HM**)
- ECAL Safety System (**ESS**)

developed in collaboration of ETHZ, Protvino and Belgrade groups

**PTM/HM system**

**ESS system**

**DCS applications**



**Temperature and humidity sensors:**

- 360 + 80 NTC thermistors (EB+EE); pre-calibrated by manufacturer; Precision better than 0.01°C.
- 144 + 32 RH probes (EB+EE); Precision 5% RH [20 – 90% RH].
- Tested for radiation tolerance

**Readout system with ELMB boards:**

- Independent from the ECAL DAQ
- Based on ELMB modules (by ATLAS)
- Features 16-bit ADC, 64 channels analog MUX, DI/DO signals, CAN bus,

**An example of the performance of the readout system:**

- Excellent resolution
- Low noise level (~ 0.008 °C)

## 6 ECAL Safety System

**Functionalities of the system:**

- Full autonomy of the system
- Temperature monitoring of ECAL electronics Precision better than 0.1 °C
- Detection of water leakage (WLD) inside the ECAL
- Radiation tolerance according to specifications
- Reliable hardware interlocks and control signals to:
  - HV system crates (hardware interlocks)
  - LV system crates (hardware interlocks)
  - Cooling system (flow and temp., WLD, watch-dog)
  - operator and system experts (PVSS, SMS, Email)

**CMS ECAL**

**ESS PLC System**

**ESS control PC (PVSS II, SIMATIC S7)**

**Interfaces:** Alarm interface, S7 connection

**ESS readout signals:** ESS units (FE electronics)

**ESS units (FE electronics)**

**Temperature and WLD sensors:**

- 352 SMD 470 Ω NTC thermistors positioned in **redundant pairs**
- 44 leakage detection sensors by RLE Technology
- Tested for radiation tolerance up to the equivalent dose of 200 kGy

**ESS Readout Units**

- Digital resistant bridge front-end
- Redundant architecture
- Radiation tolerance to doses of up to 60 Gy
- Low noise level (fluctuations ~ 0.01 °C)

**Temperature fluctuations**

**ESS PLC**

- Siemens SIMATIC PLC system (S7-400H and S7-300 family)
- Redundant system
- Effective MTBF ~ 10 years
- Fault-tolerant / Fail-secure
- Digital filtering (2<sup>nd</sup> IIR NF filter)

## 7 ECAL DCS software

**Control software based on:**

- ETM PVSS SCADA tool for development and running of control systems
- Standard LHC JCOP Framework components (Finite State Machine (FSM), Access Control etc.)

**FSM control tree of CMS ECAL DCS**

**ECAL DCS applications integrated into the CMS DCS**

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- CEFET/RJ, Rio de Janeiro, Brasil
- CERN, Geneva, Switzerland
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