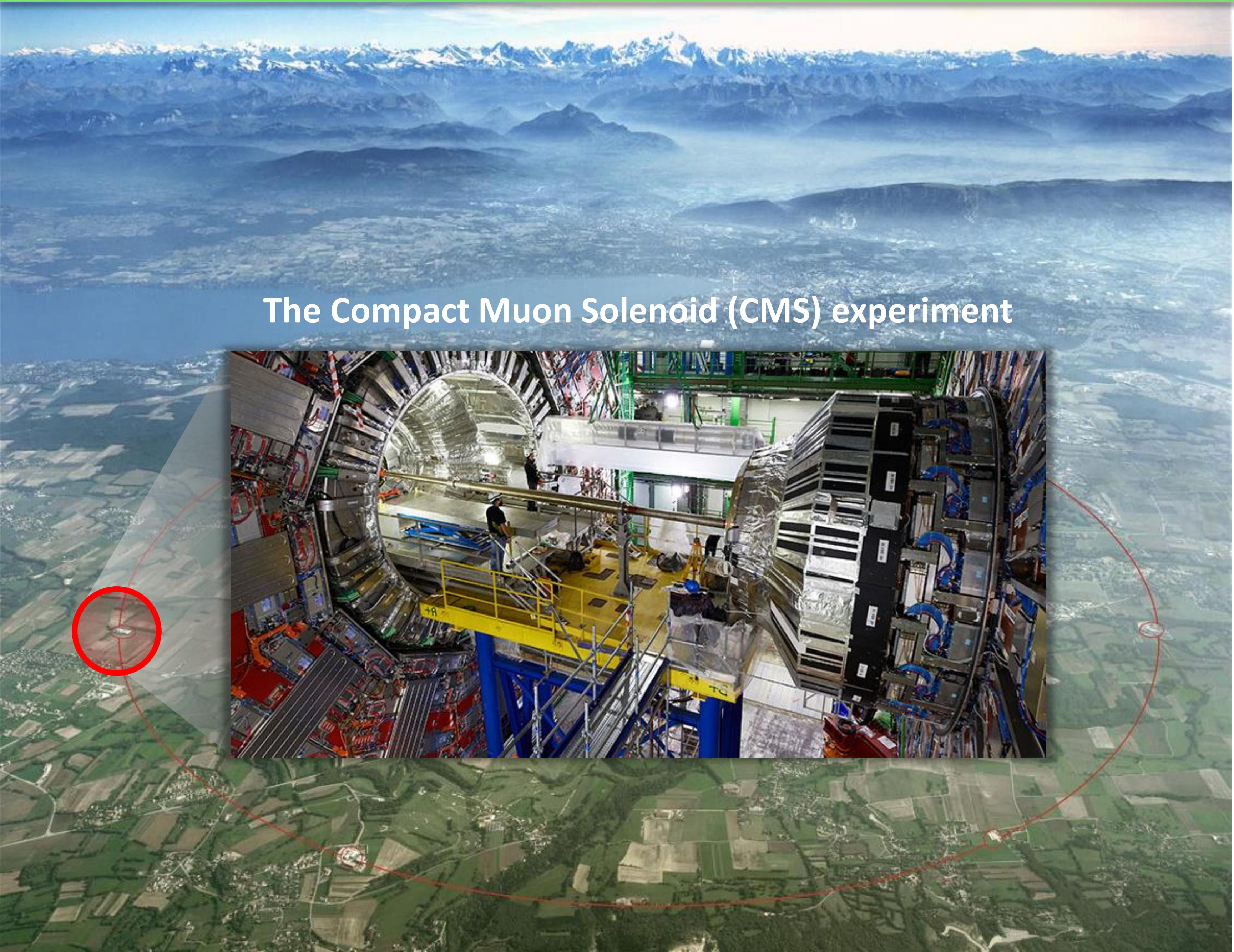
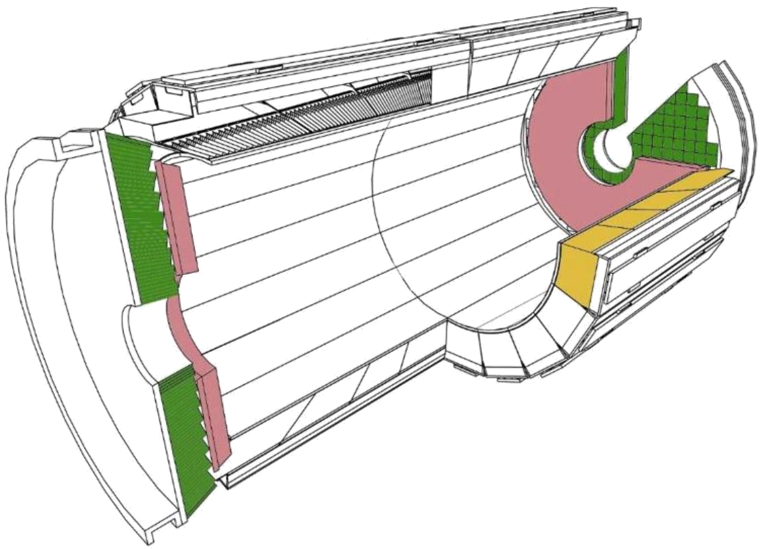
Software migration of the CMS ECAL Detector Control System during the CERN Large Hadron Collider Long Shutdown II

Raúl Jiménez Estupiñán on behalf of the CMS collaboration



The CMS ECAL Detector



- Composed of scintillating crystal calorimeter and lead/silicon preshowers.
- Three major partitions known as the ECAL Barrel (EB), the Endcaps (EE) and the Preshowers (ES).

The CMS ECAL Detector Control System (DCS) Software

- Software running on a **large**, **distributed** and **redundant** environment
- Mostly developed in **CTRL language** in the **Siemens WinCC OA** platform
- Use of the CERN Joint Controls Project (**JCOP**) and the **CMS DCS** frameworks for developing control systems.
- Detector modelling using a **Finite State Machine** (FSM)
- **Modular** architecture: **27 dedicated software components**
- **Multiple databases** for control data archiving and software configuration
- Multiple **drivers**, **protocols** and **interfaces** to a large collection of hardware

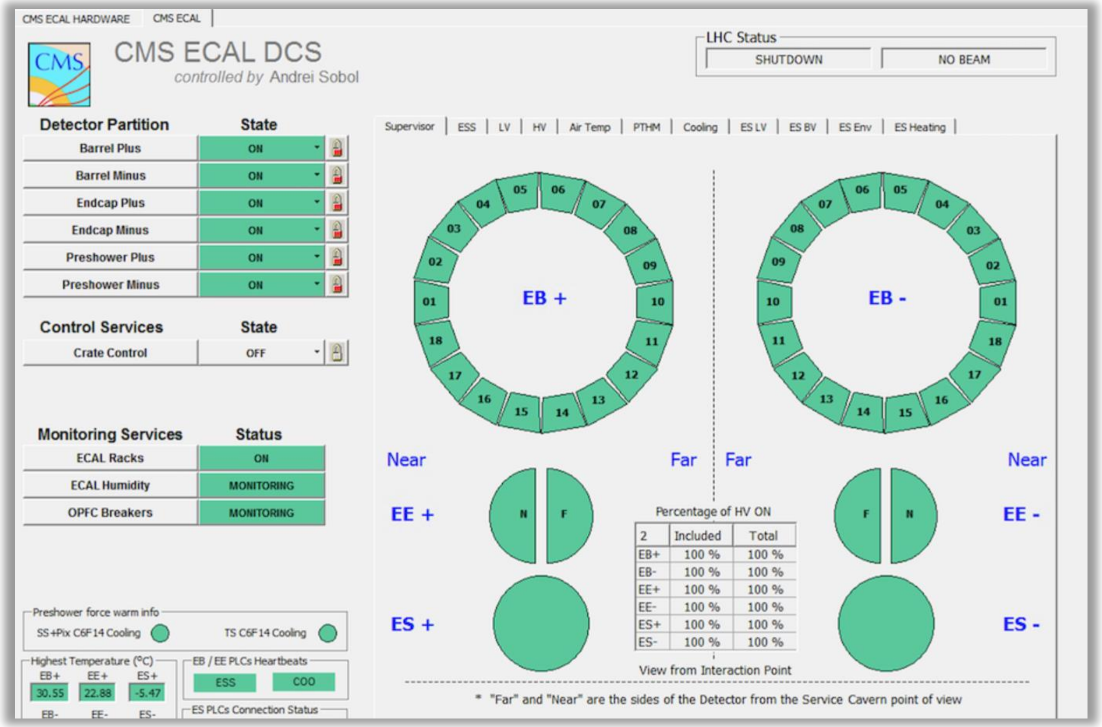


Fig. 1. Main graphical user interface of the CMS ECAL DCS.

The DCS in numbers	*Control and Monitoring*		*Monitoring*		
	Low Voltage channels	Bias Voltage channels	Temperature Sensors	Humidity Sensors	External parameters
Barrel / Endcaps	**860**	**1240**	**908**	**164**	**> 1000**
Preshower	**200**	**192**	**216**	**16**	

Fig. 2. Number of channels and sensors monitored by the CMS ECAL DCS.

Migration campaign to port the DCS source code

SVN → CERN GitLab

- Breakdown a single monolithic repository into a hierarchy of 35 individual repositories.
- Separation between source code and project documentation.
- Migration of all historical records on SVN.
- Toolkit integration into the test and production environments.

Results: After several weeks of work, all source code and its historical records were migrated into 27 independent repositories, benefitting from a faster, more powerful and better integrated configuration management tool.

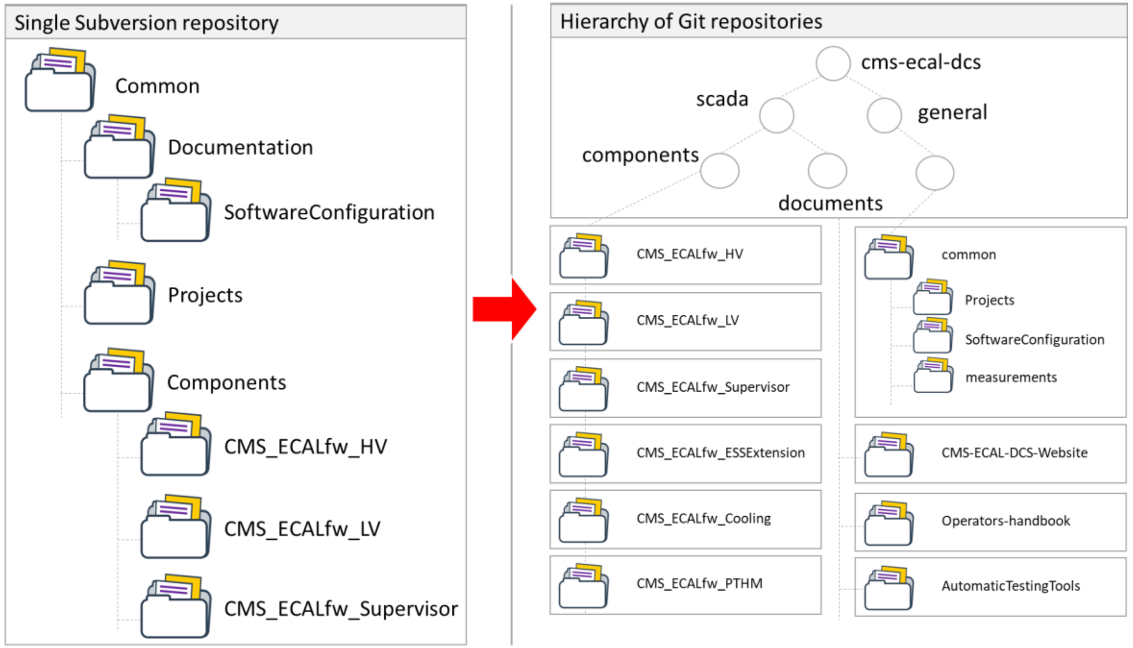


Fig. 3. Migration from a single Subversion code repository to a hierarchy of Git repositories.

Two major types of conversion:

1. Conversion of graphical user interfaces into **XML** formats.
2. Character encoding from **ASCII** (ISO-8859-1) to **Unicode** (UTF-8): New version of WinCCOA only supports **Unicode** (UTF-8) encoding, requiring a major revision of all the code sources, with many important exceptions and potentially dangerous implications.

Version	ASCII code	String	strlen	Comments
3.15	ALT 167	"°"	1	Extended character seems to be identified and extracted correctly from the array
3.16	ALT 167	"�"	2	Extended character expanded to various bytes

Table 1. Example of a different behaviour for a standard function *strlen*, for a non-compatible character in the WinCCOA 3.16 version.

Complexity

- Identification of context dependent code sections for character/string processing (e.g., **strings** as **array of characters**).
- Approximation to detect problematic statements using **regular expressions**.
- Thorough analysis and manual **correction** (refactoring) **case by case**.

Success story: The incremental, early deployment of **compatible code** permitted the testing and installation of new components for both versions of the control systems, optimizing maintenance and development cycles.

JCOP Framework functions no longer part of the global scope: Extensively used framework functions require now an explicit library inclusion in every source file.

- Large pieces of codes affected by this change, requiring a programmatic approach to resolve and insert library uses.
- Combination of tools to analyse, create a symbols cross-reference database to resolve code dependencies and perform automatic code transformations.

Outcome

- Optimization of resources required by user processes.
- General gain of performance.
- Framework library inclusions are now part of the developer's responsibility.

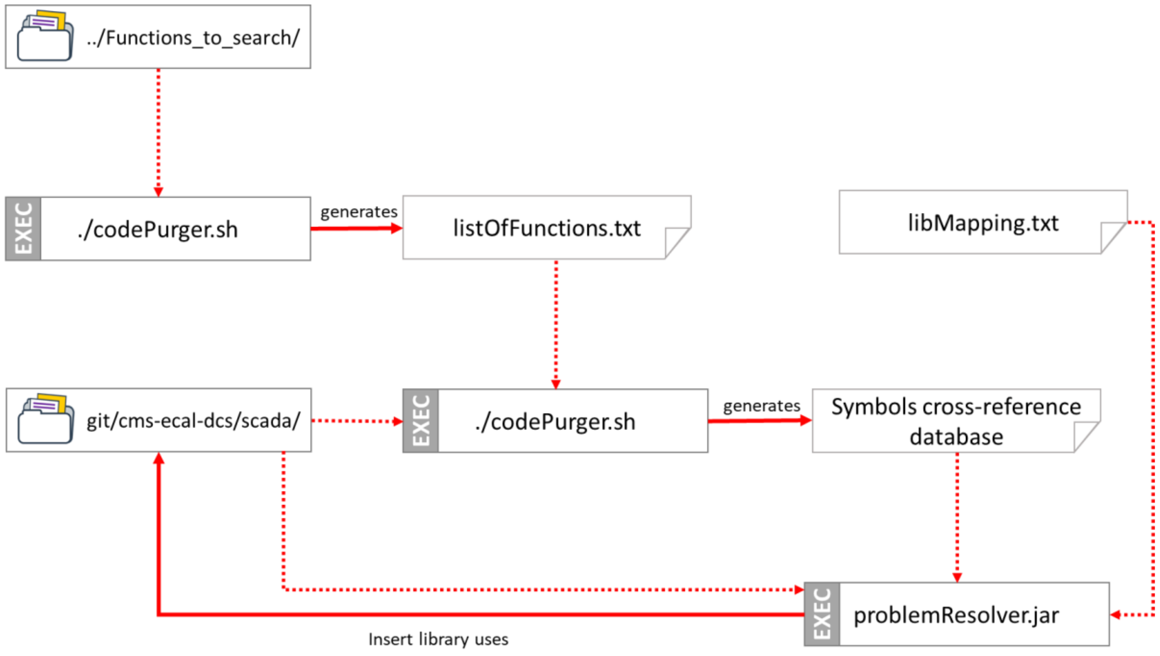


Fig. 4. Look-up, cross-reference database and automatic transformation process for library inclusions.

OPC server is an industrial standard and a fundamental software component in the control system to access:

- **Wiener Maraton power supplies** feeding Low Voltage (LV) power to the ECAL Endcaps (EE) and Barrel (EB).
- **CAEN power supplies** feeding power to the Preshower detector and High Voltage (HV) power to the EE/EB.
- CERN made Embedded Local Monitor Boards (**ELMB**) for various applications.

OPC Server type	Number of address transformations
CanOpenOPC	7408 addresses
CaenOPC	46297 addresses
WienerOPC	24408 addresses

Table 2. Number of transformations (migrated addresses) per OPC Server type.

OPC Servers	OPC Server type	Number of devices
OPC UA CAEN HV EB	CaenOPC	18
OPC UA CAEN HV EE	CaenOPC	2
OPC UA CAEN LV ES	CaenOPC	1
OPC UA CAEN LV ES	CaenOPC	2
OPC UA Wiener LV	WienerOPC	136
CMS_ECALfw_LV	CanOpenOPC	24

Table 3. List of OPC UA Servers running after the migration.

The new **OPC UA Server** provides a complete, modern, secure and platform independent standard for industrial process control with various interesting features:

- Several server instances to provide a better separation of concerns.
- Service discovery and fast initialization.

Hot switch over: Interesting exercise, **swapping between versions** of the Control System **with the detector ON**.

- Individual subsystem validation and general test sending **massive commands** (turning ON/OFF).
- Useful insight about the Control system during a network black-out (disconnection from the detector hardware).
- Reduced number of power cycles (only one turn ON/OFF operation) for both, testing and participation in the Middle Week Global Run (global commissioning exercises, each lasting 3–10 days and occurring monthly or bimonthly).

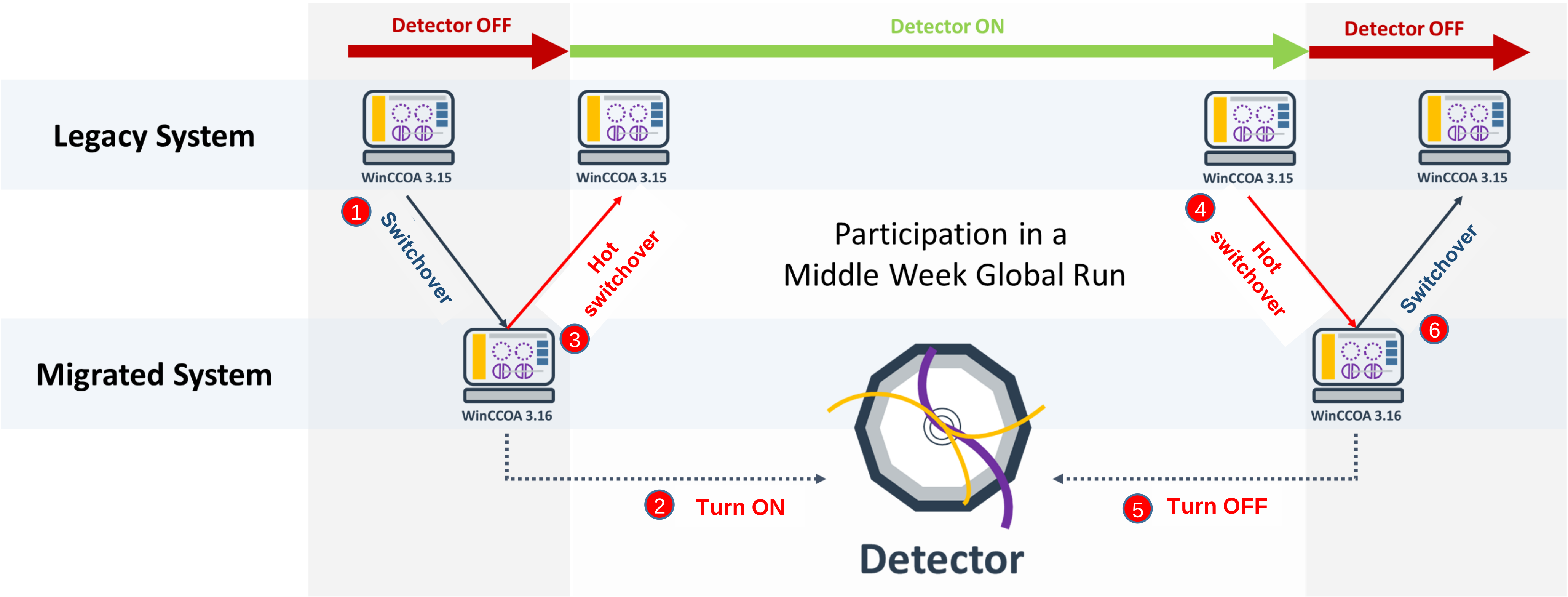


Fig. 8. Hot switch over intervention between versions to validate the newly migrated system.

Conclusions

- **Complex migration,** taking around 6-9 months to update the CMS ECAL DCS with the latest versions of the control platform, software frameworks, drivers and utilities.
- All **code sources** have been **thoroughly reviewed** and **updated**, keeping the **history from the past 12 years**.
- Accomplished firstly by the **ECAL and Tracker** teams in mid 2020**,** final migration including all the CMS subdetectors planned for July 2021.
- The **ECAL DCS software** has been **successfully deployed** and **validated** in a pre-production environment, running on the **next generation of computing servers**.
- **Proper planning** and partial backwards **compatibility strategy** have been decisive to accomplish the large number of updates, permitting the evolution of the software with intermediate deployments and testing, while supporting ECAL operations.

Questions

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