The evolution of the ALICE Detector Control System

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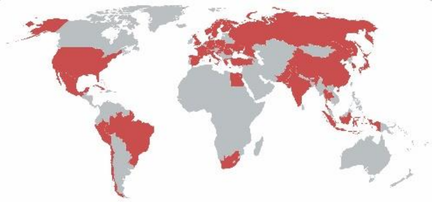
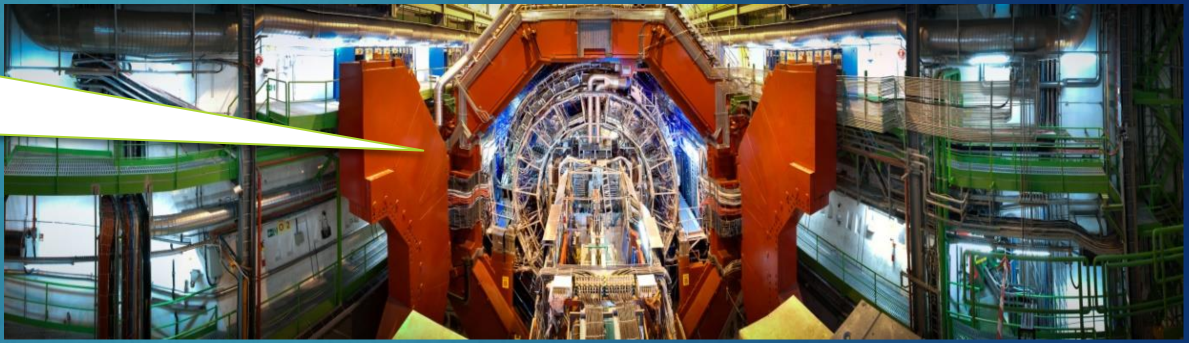
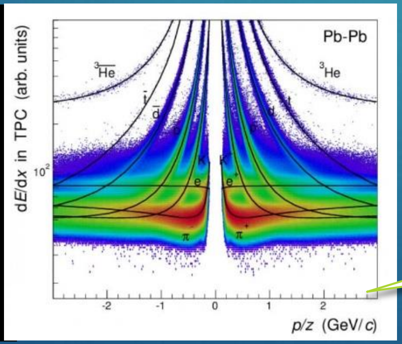
The ALICE experiment at CERN



Collaboration:
- 37 countries
- 154 institutes
- 1500 members

The Detector:
- 10 000 tons
- 19 subdetectors built on different technologies
- 2 magnets

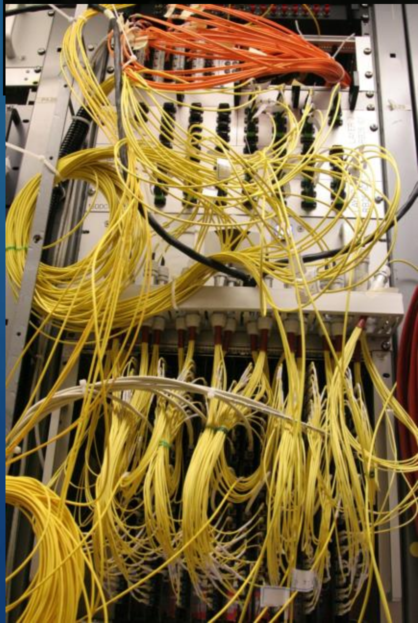




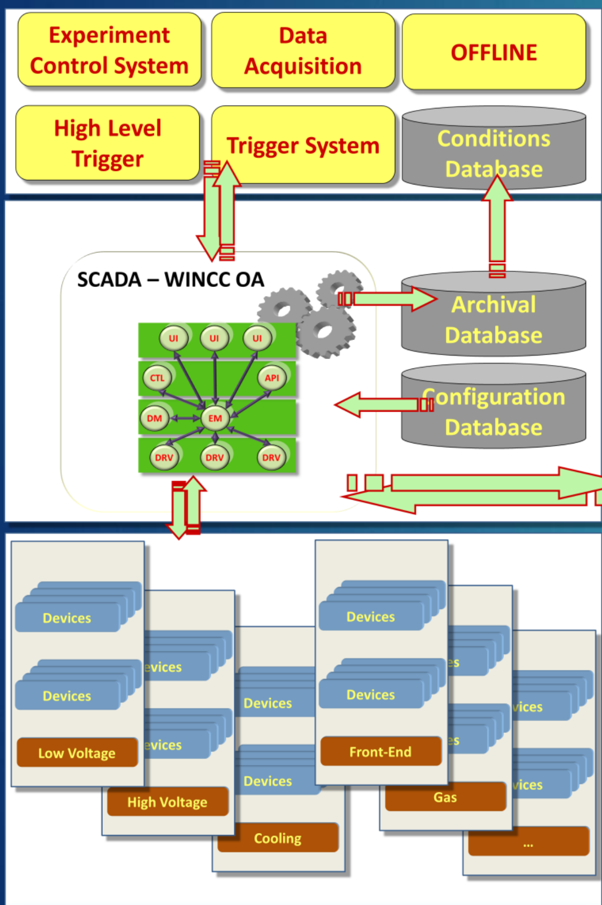
Main physics focus:
- Heavy ion physics at LHC energies
- Proton-proton physics

ALICE Detector Control System (DCS)

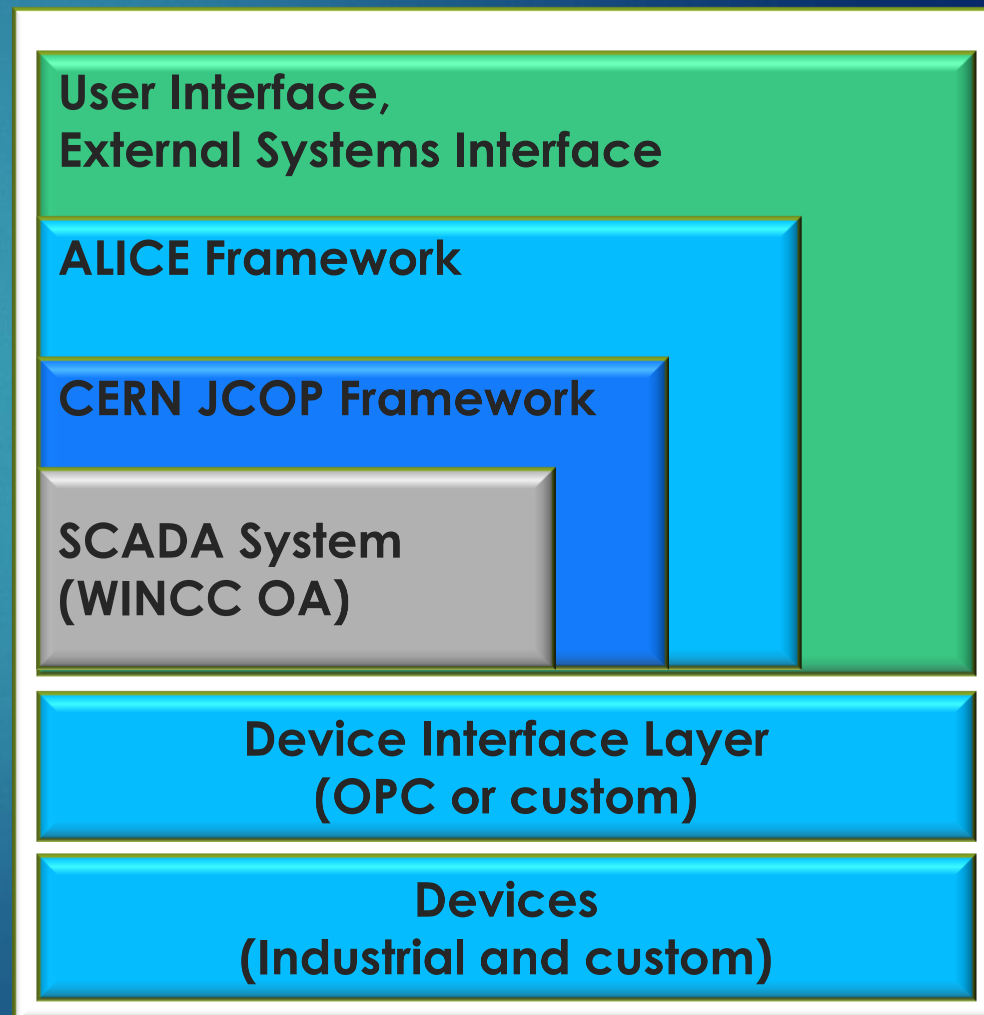
- Guaranties:
  - 24/365 safe and stable operation of the experiment
- Partial detector control systems are built by experts of the detector teams
- The Central DCS Team provides:
  - Distributed control system based on commercial components
  - Computing and network infrastructure
  - Software framework and tools
  - Implementation guidelines and operational rules
  - Integration of detector systems
  - Interfaces to external systems and LHC
  - Training of operators and uninterrupted expert on call service
  - First line support for software developers



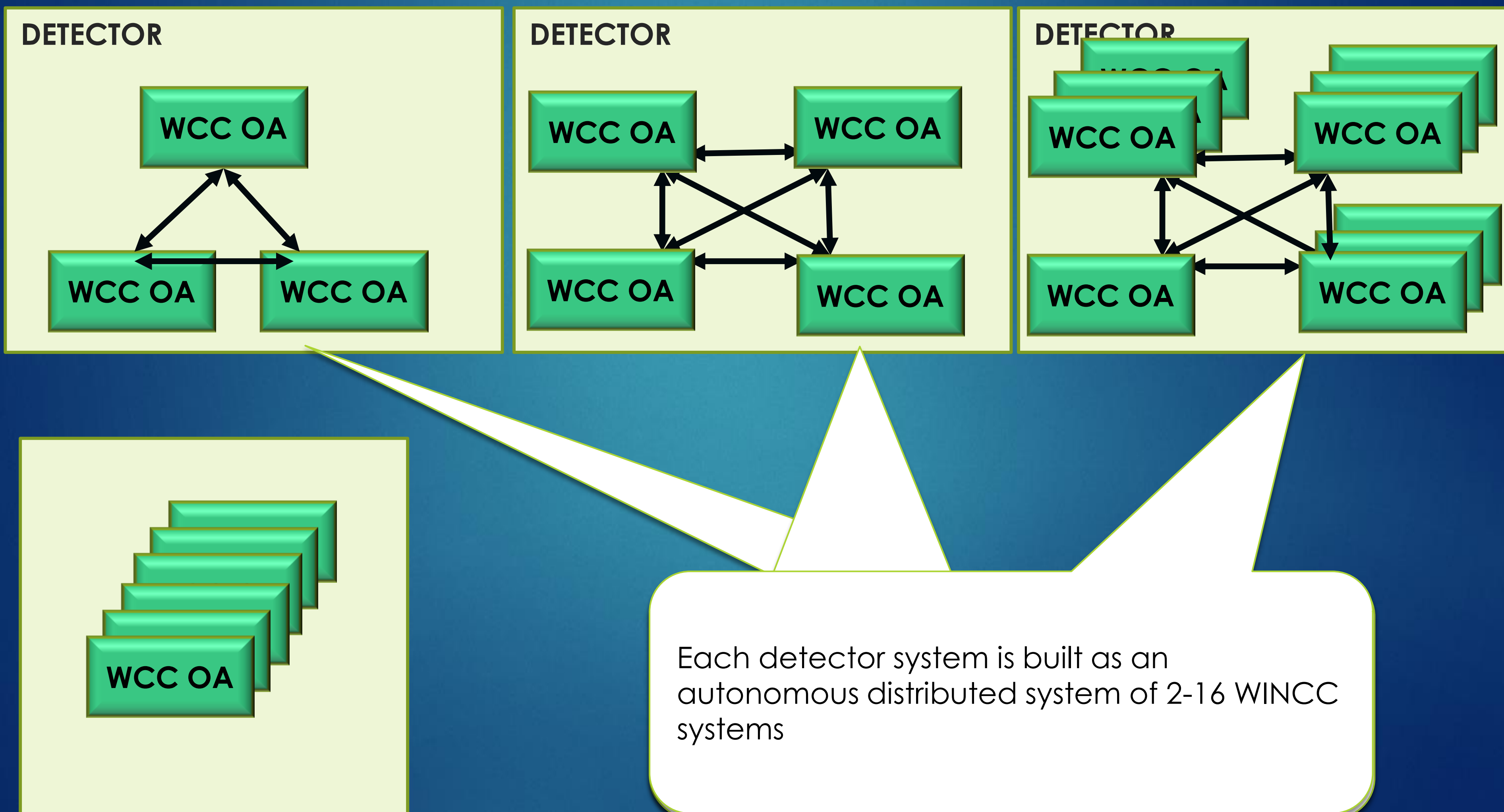
The ALICE DCS – Context and Architecture



Devices with similar functionality are grouped into subsystems. About 100 different subsystems are implemented in ALICE. .



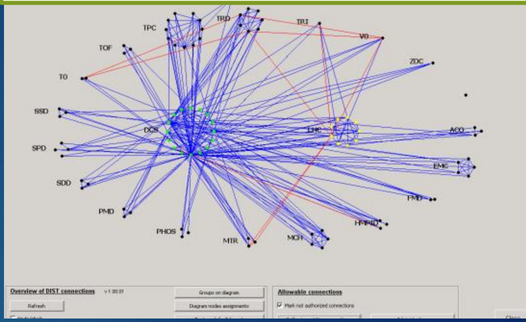
Each detector builds its own distributed control system

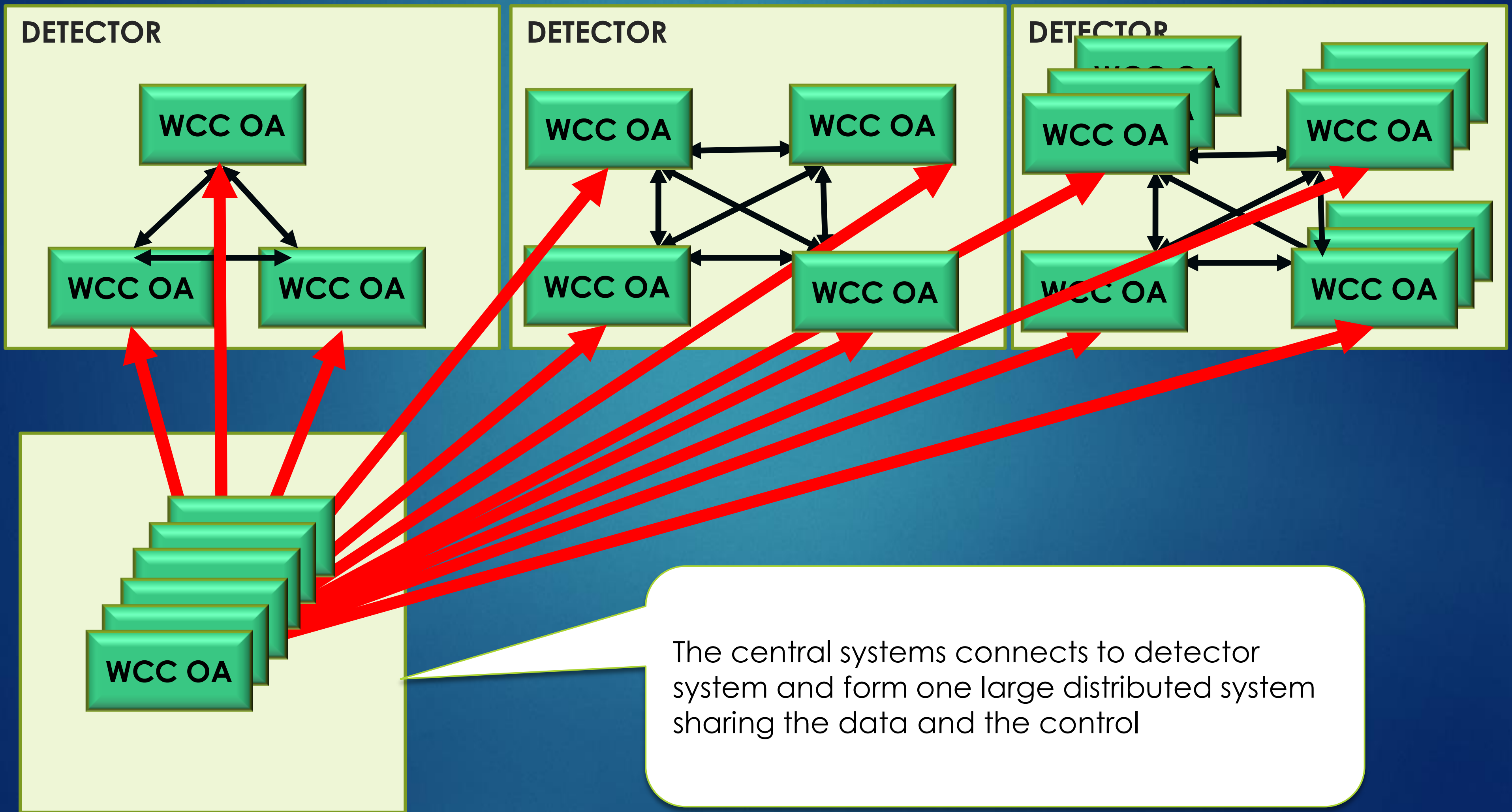


Each detector system is built as an autonomous distributed system of 2-16 WINCC systems

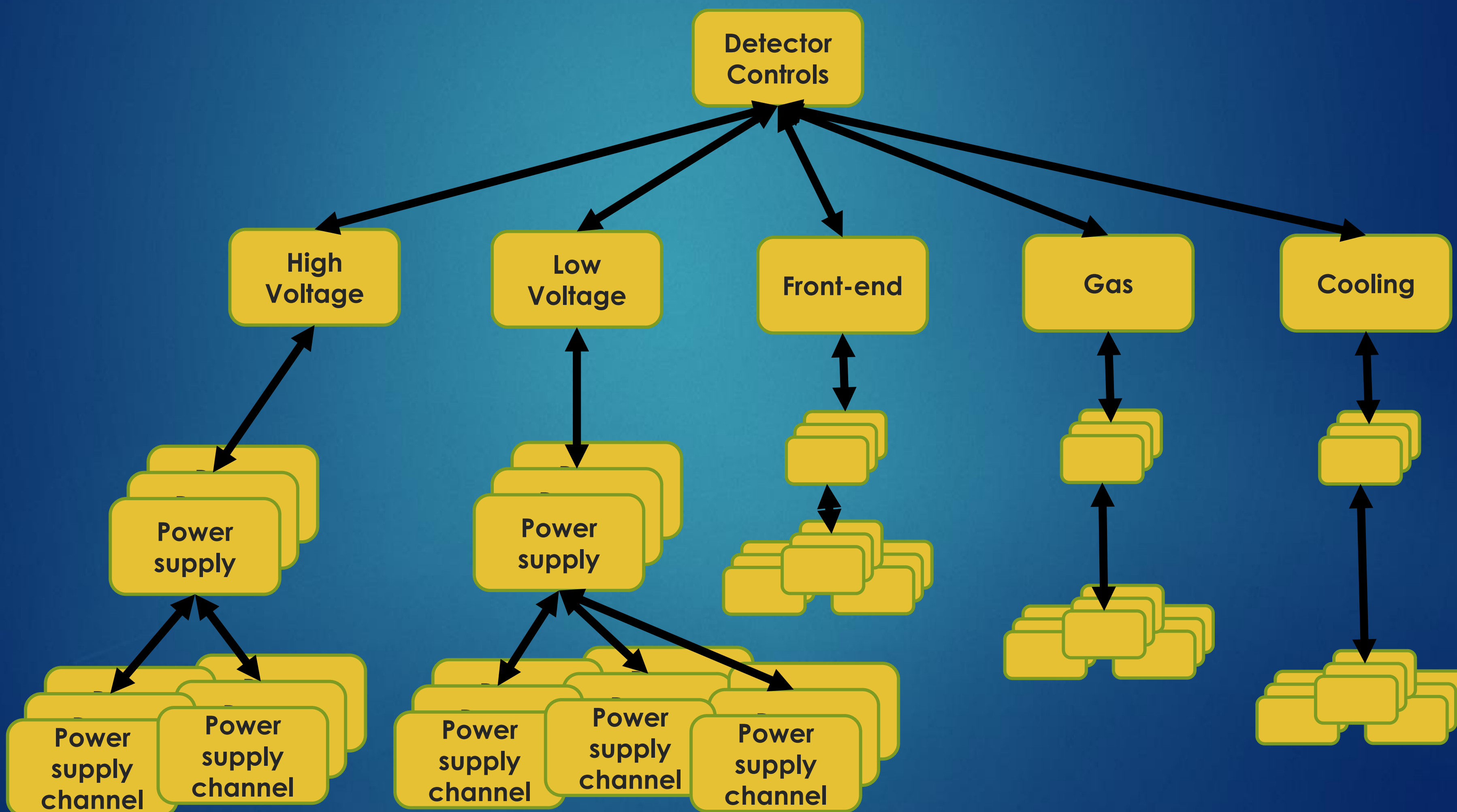
Central systems connect to all detector systems

ALICE DCS Systems

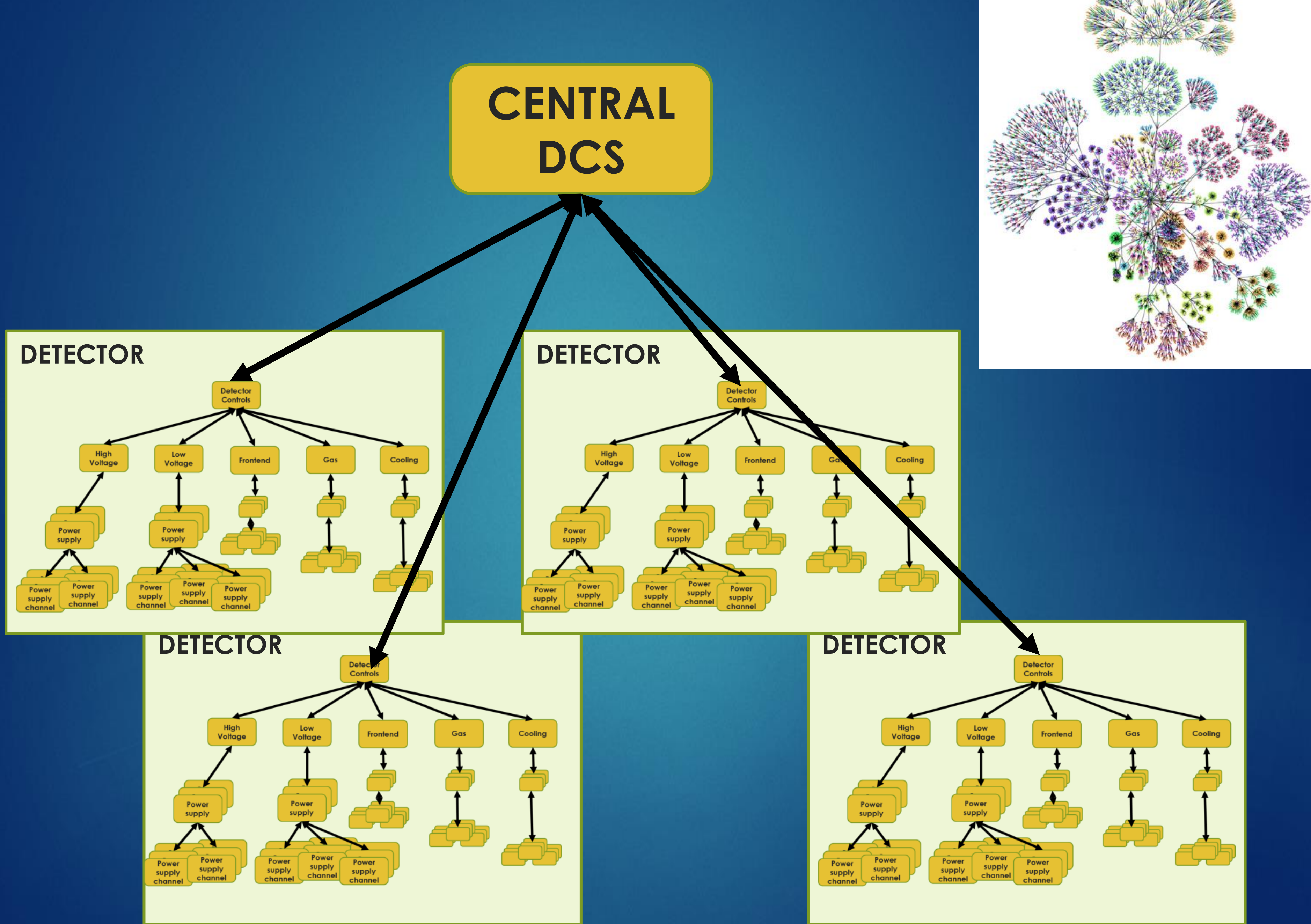




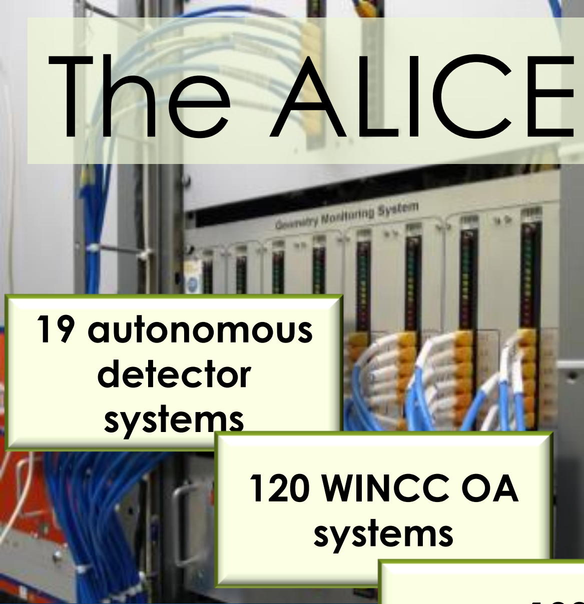
Using the CERN SMI++ framework, the control system is presented as hierarchical tree of controlled objects

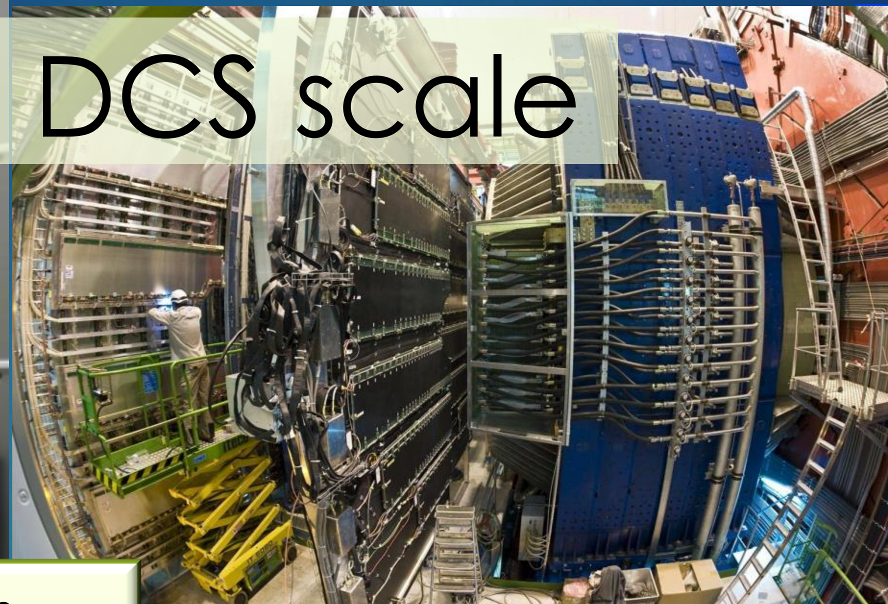


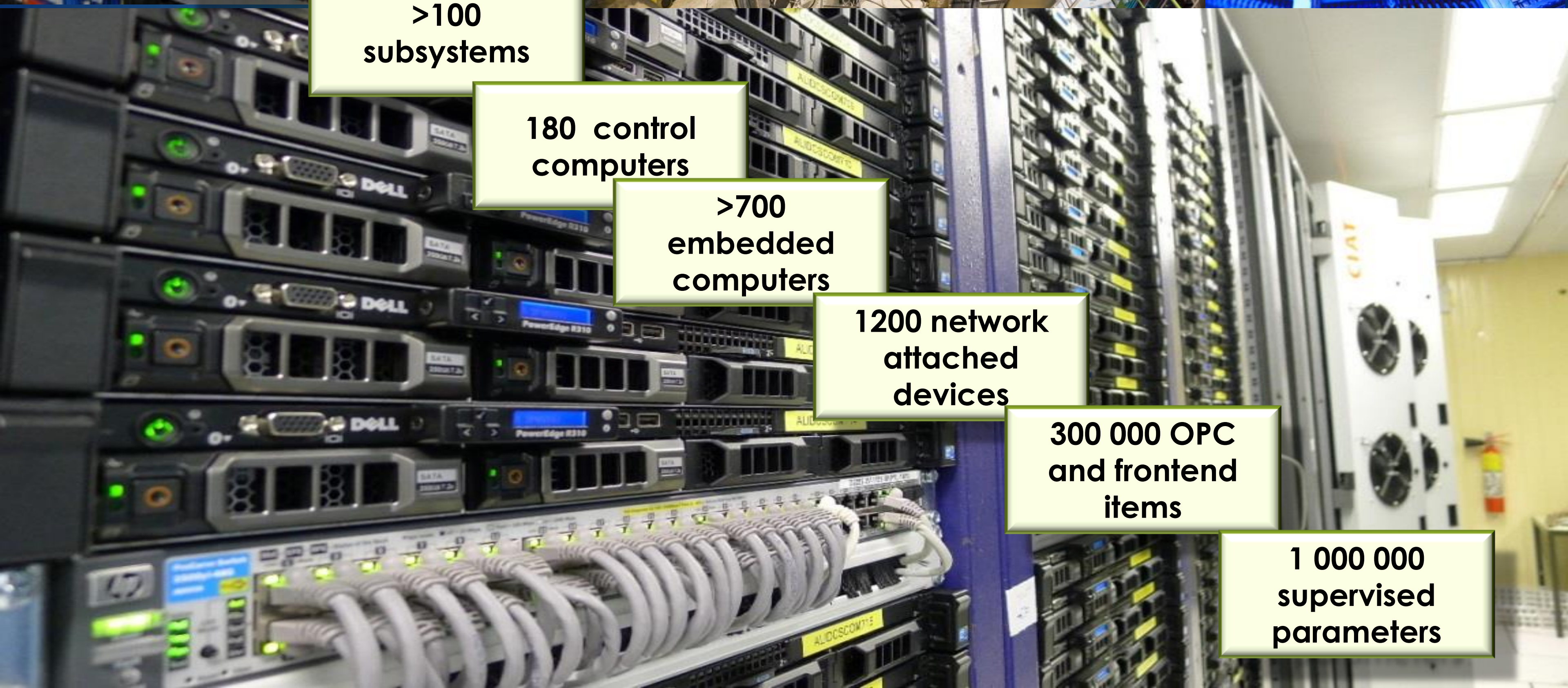
Central DCS connects to all detector trees



The ALICE DCS scale







19 autonomous detector systems

120 WINCC OA systems

>100 subsystems

180 control computers

>700 embedded computers

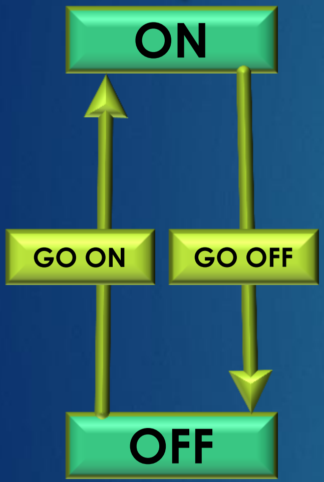
1200 network attached devices

300 000 OPC and frontend items

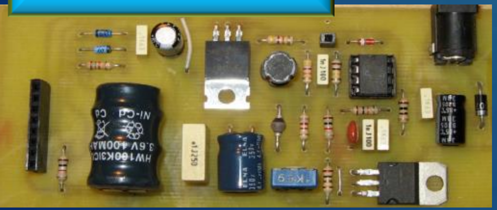
1 000 000 supervised parameters

Simplified complexity

- The behavior of controlled objects is modeled as a finite state machine (FSM)
- At the channel level, the logic is simple

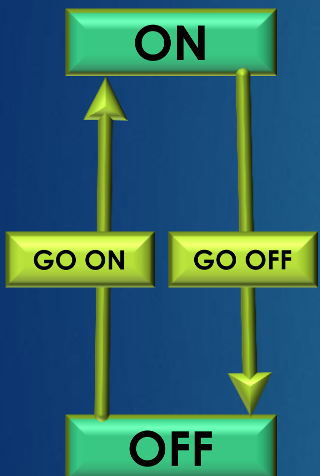


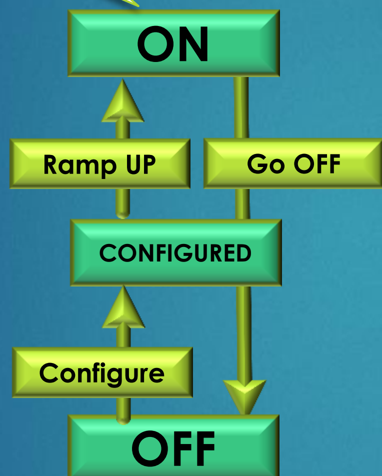
Channel



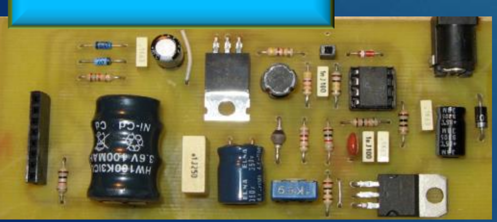
Simplified complexity

- Devices need to be configured (target values, trip limits…)





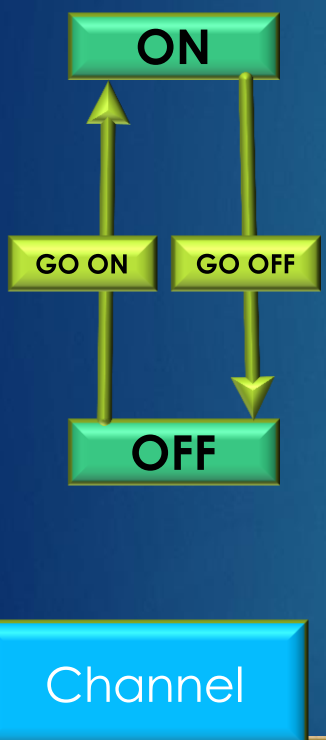
Channel

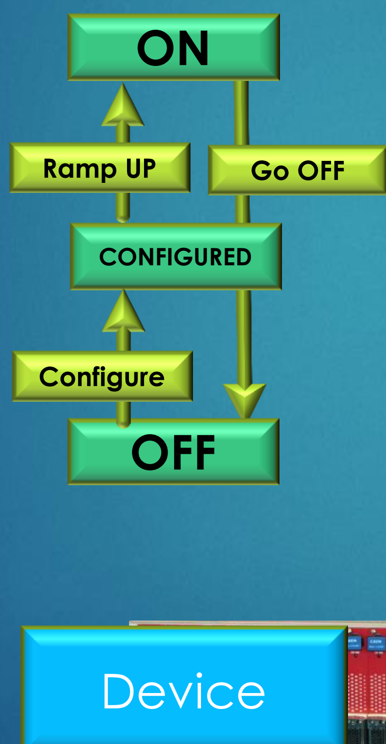


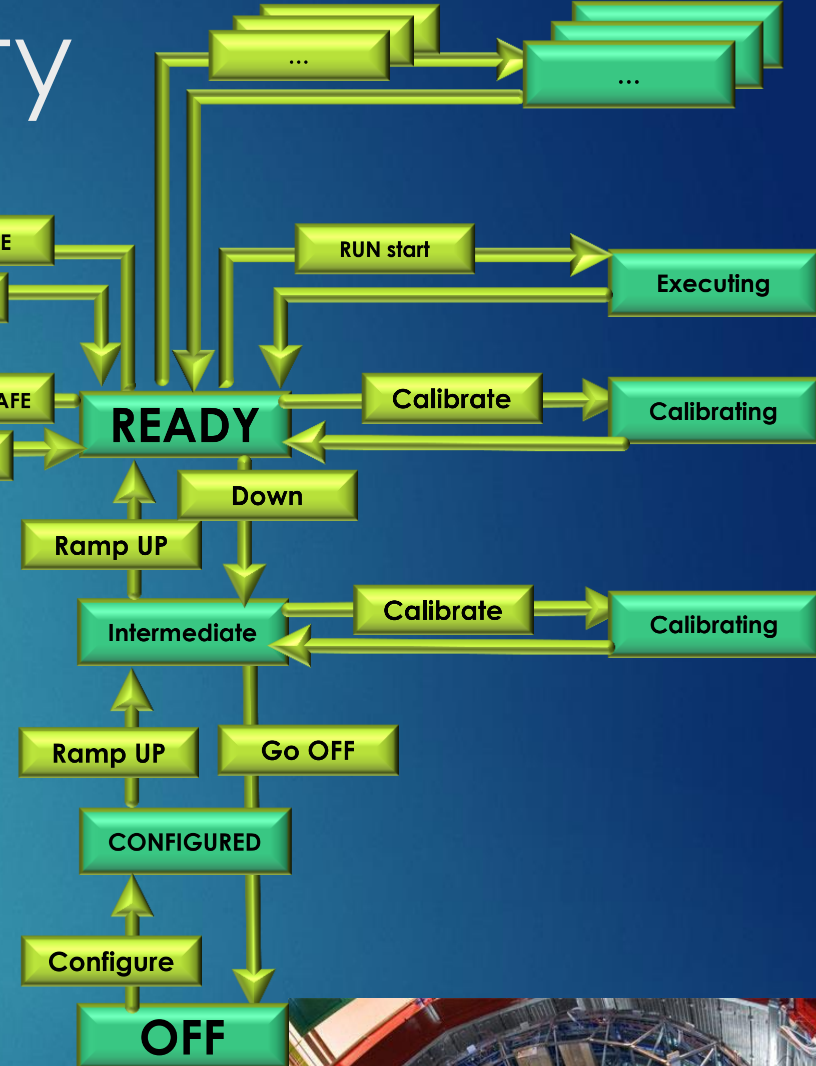
Device

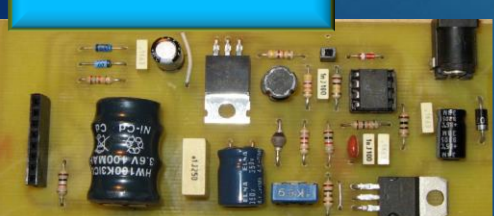
Simplified complexity

- The detector FSM covers advanced actions related to its operation

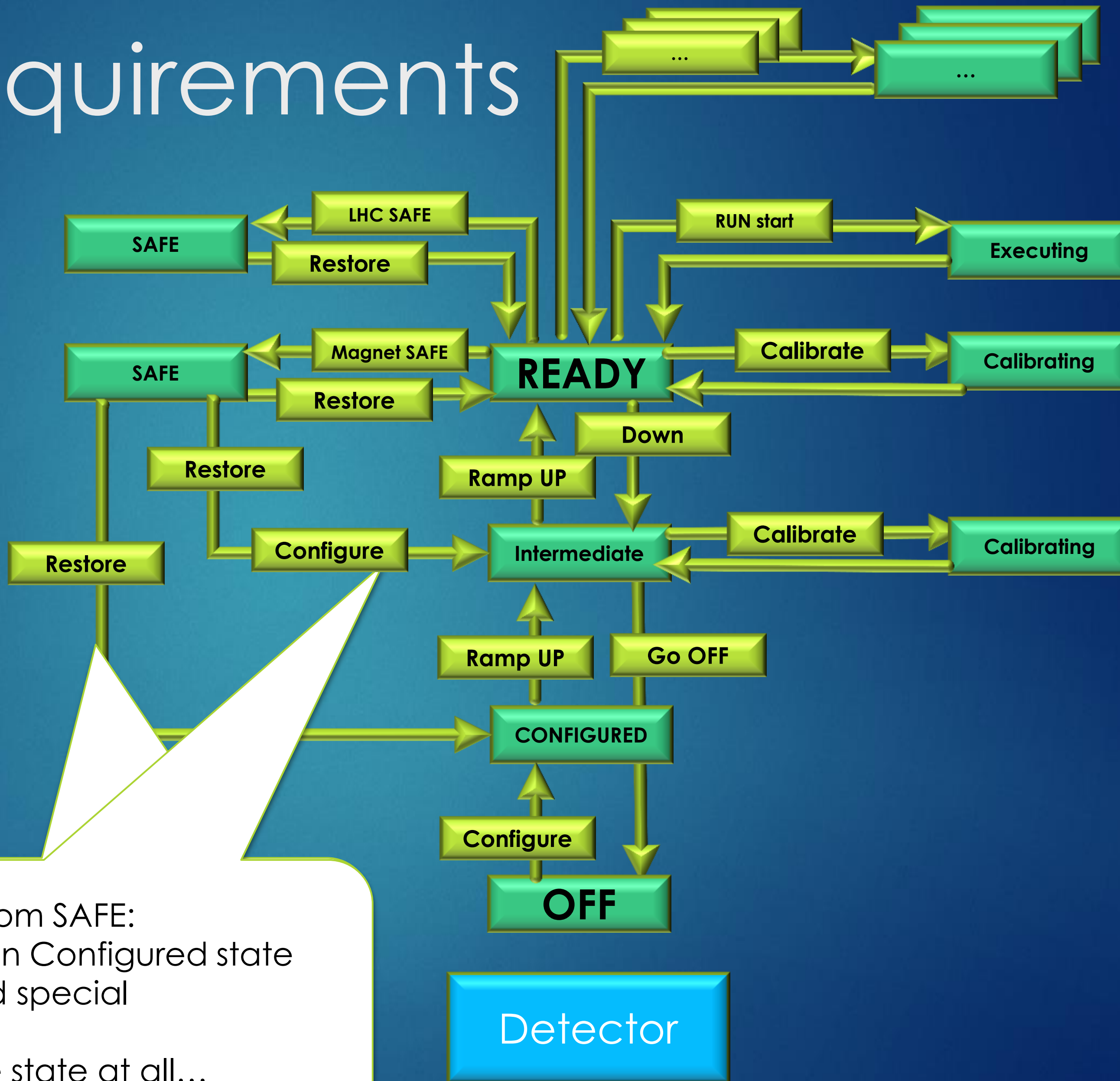








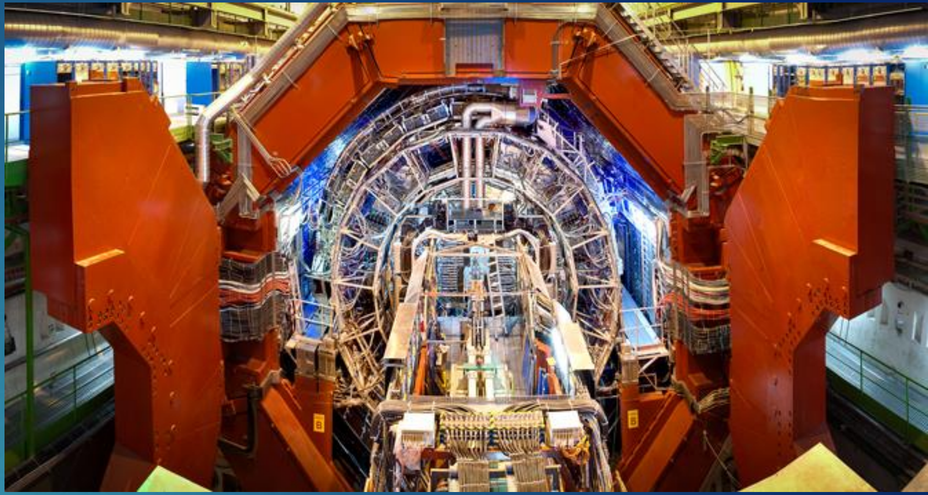
… each detector has specific requirements

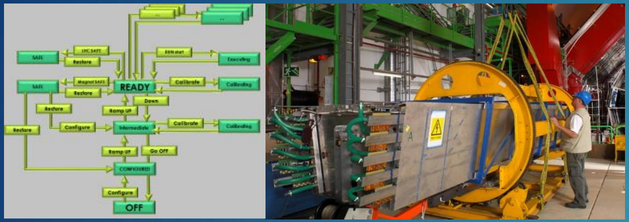


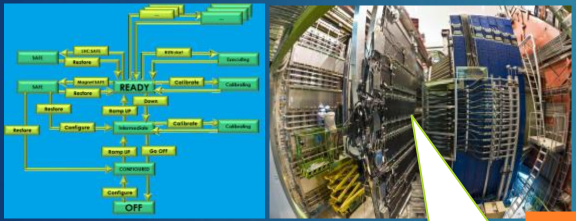
For example to restore from SAFE:

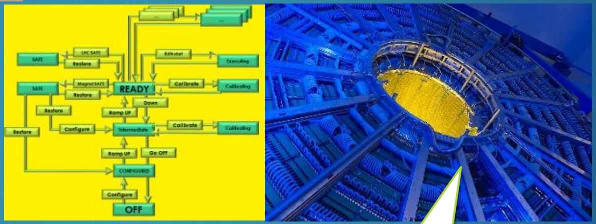
- Some detectors end in Configured state
- Other detectors need special configuration
- Other do not change state at all…

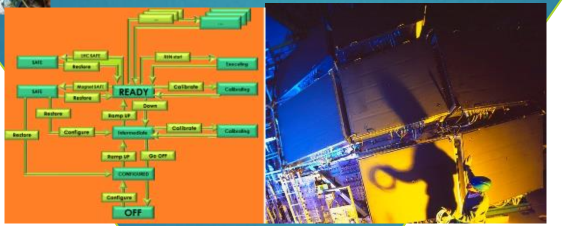
… and finally the experiment …

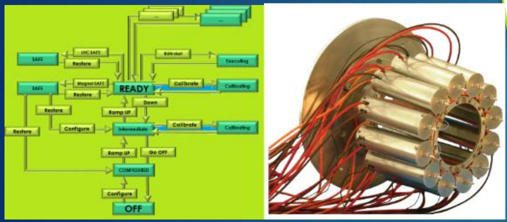












The state of the experiment depends on:

- The state of each subdetector, each having its own control logic
- Internal and external services
- ALICE online and offline systems…

Are the magnet settings compatible with datataking?

Are radiation levels within tolerance?

Are safety systems OK?

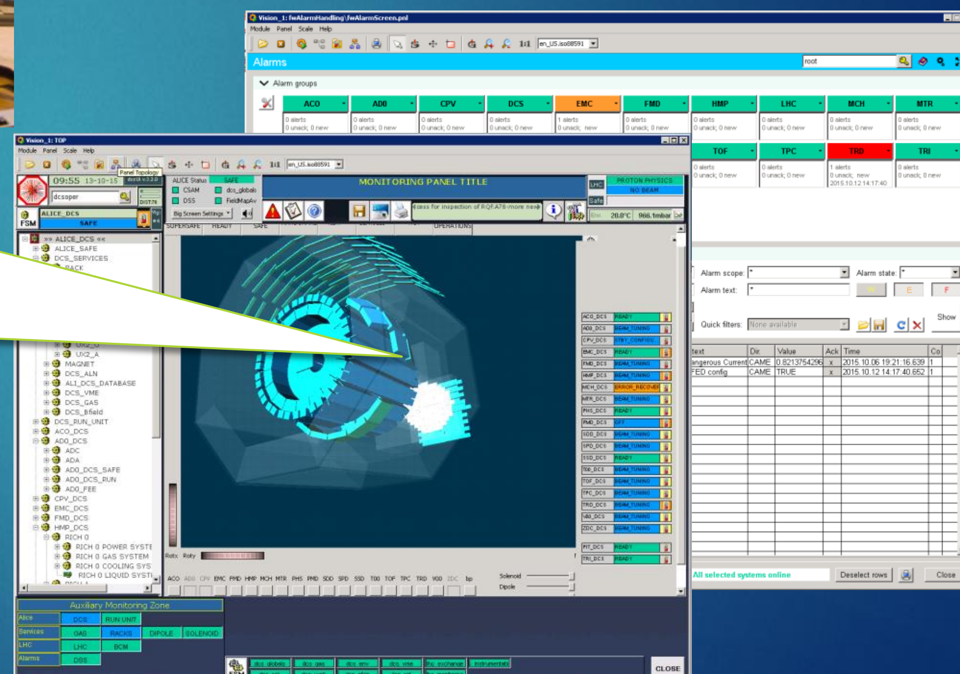
What is the status of LHC?

• • •

Is the infrastructure OK?

ALICE DCS operation

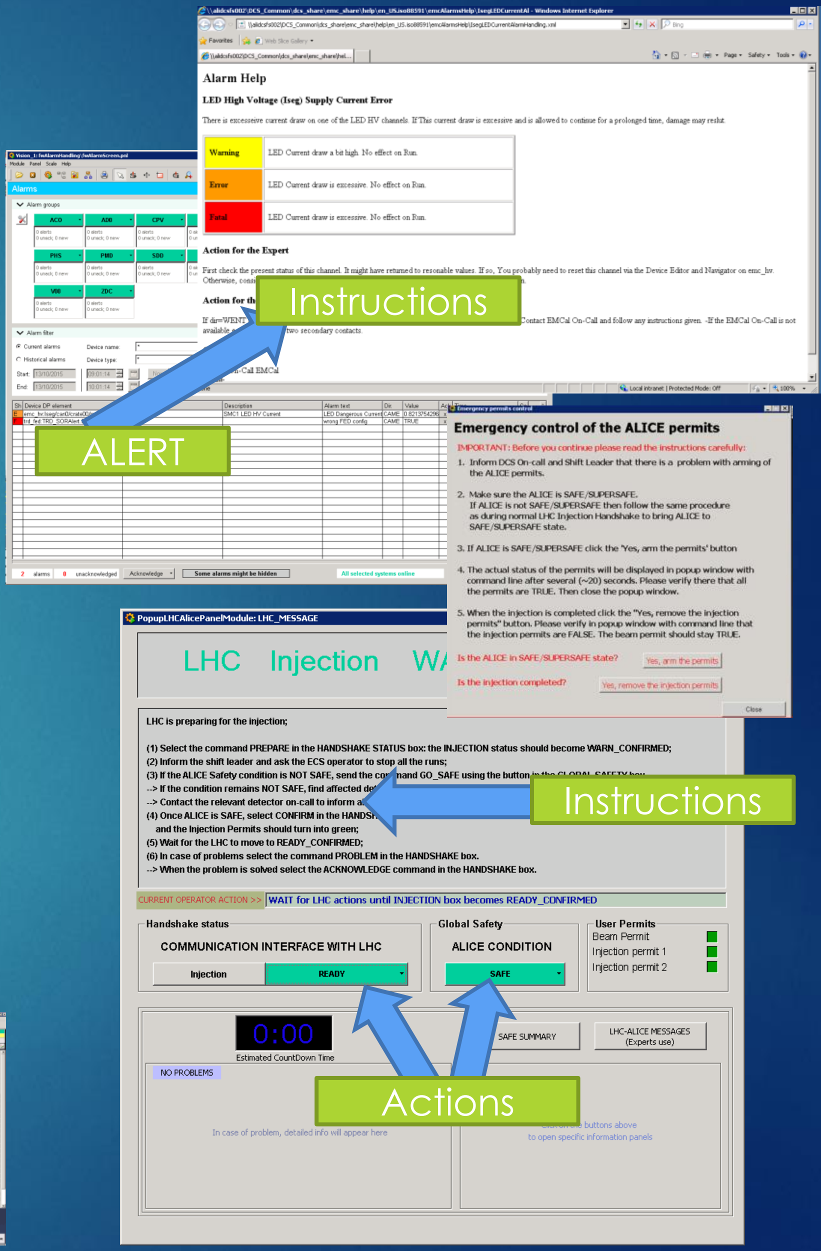
- The DCS is operated by a single operator
- In 2015 more than 150 operators were trained to aensure the 24/7 operation
  - Most of the operators did not have prior experience with the DCS

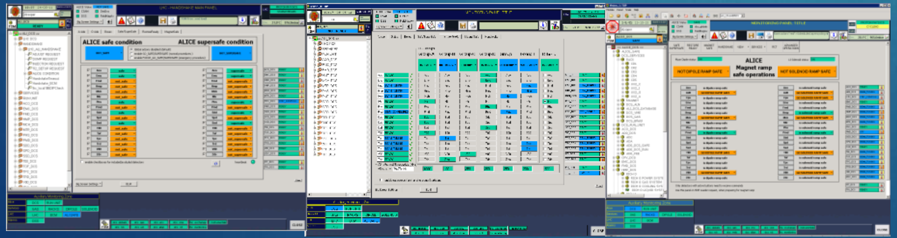


- The interface to the DCS is based on set of intuitive graphics interfaces
- From a single screen, the operator can access all controlled parameters

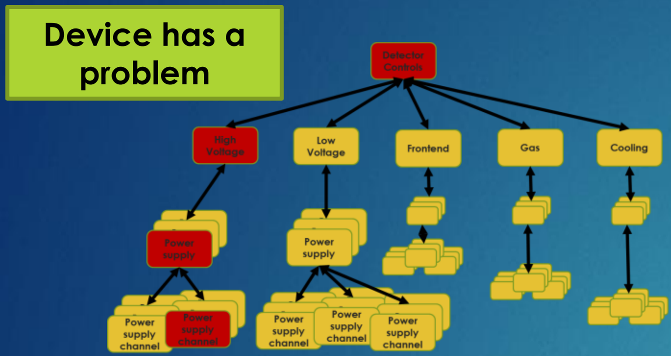
Lessons learned – simplicity and documentation are essential

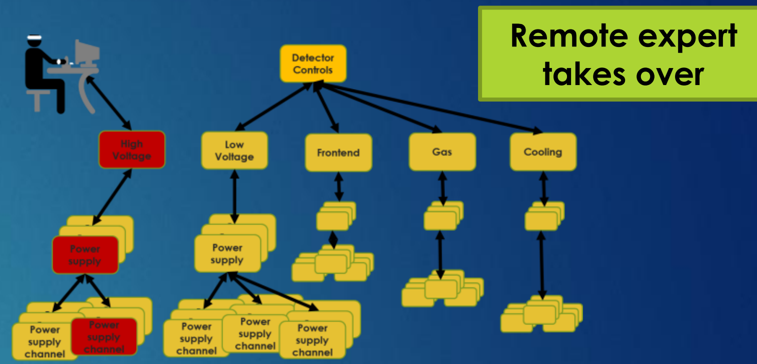
- Main changes in the DCS were focused on human interfaces and operational procedures
- Although all information is accessible through the UI, the top level interfaces display only the essential information
- The operational panels guide the operators
- To cope with the experiment complexity, the FSM actions are not invoked by the operator. The high-level procedures take care of the complex actions, using FSM as a underlying technology
- Many actions can be executed in parallel. Configurable panels allow for grouping detectors for certain operations. Instead of operating individual detectors, the operator sends a command to a group



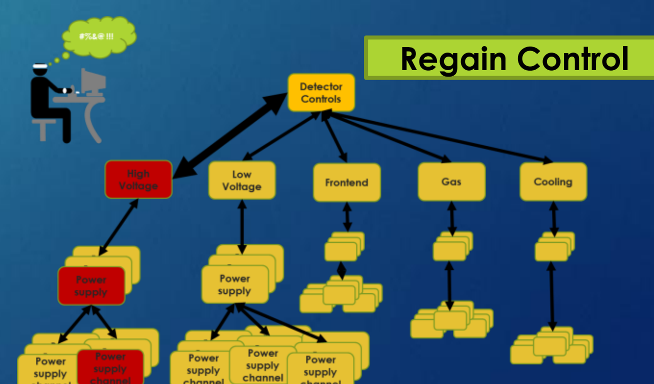


Lessons learned – backdoors are useful





- Partitioning is a powerful mechanism implemented in SMI++
  - Part of the controls tree can be detached (excluded) from the system, e.g. for troubleshooting
  - Excluded components do not react to commands sent by the central operator and do not report back their states
- For critical actions alternative reporting has been implemented – specialized procedures monitor critical parameters directly
- The central operator can force the commands also to excluded parts, overwriting the settings done by the local expert



(Some of) the present ALICE and DCS challenges

ALICE Pixel detector (SPD):

- 10 000 000 configurable pixels
- 1.3 kW power dissipation on (200+150)µm assemblies
- Contingency in case of cooling failure less than 1 minute

ALICE Pixel detector

ALICE Transition Radiation Detector (TRD):

- 760 m^2 covered by drift chambers
- 17TB/s raw data
  - processed by 250 000 tracklet processors directly on the detector
- 65kW power provided by 89 LV power supplies

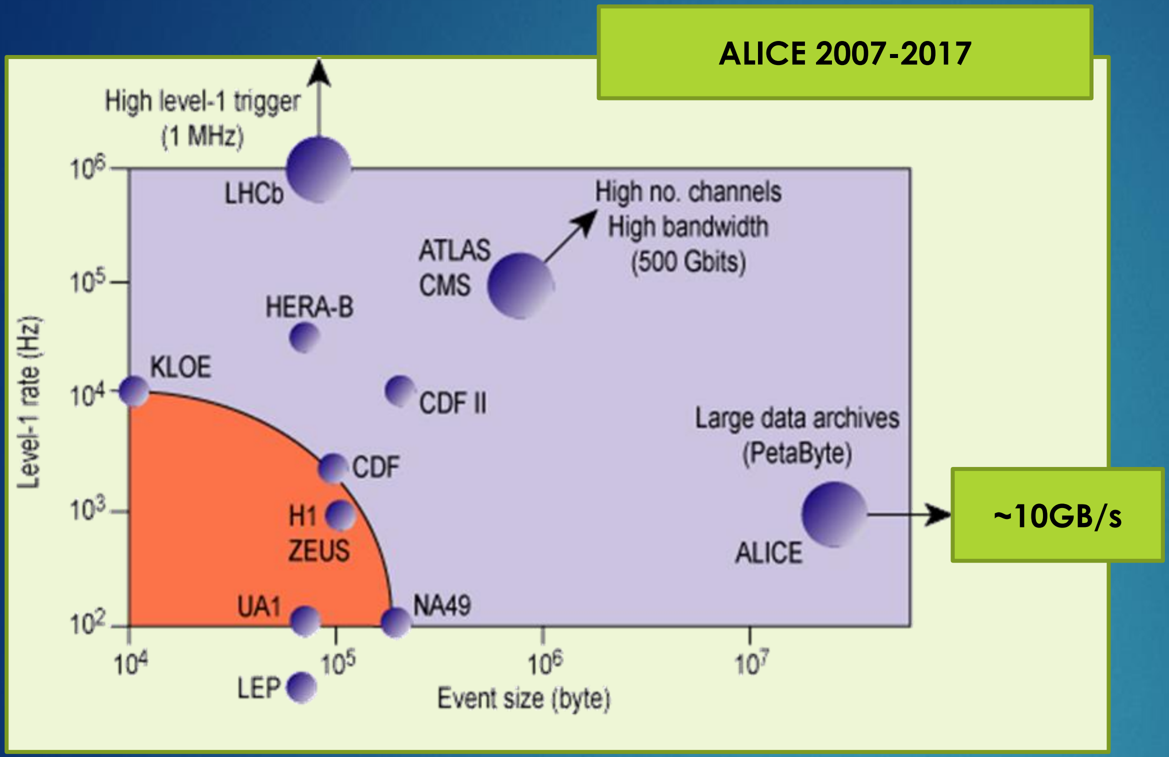
Transition Radiation Detector

ALICE Time Projection Chamber (TPC):

- 96 m^3 gas volume (largest ever)
  - stabilized at 0.1^0C
  - Cooling system has to remove 28kW of dissipated power
  - Installed just next to TRD
- 557568 readout pads
- 100kV voltage in the drift cage

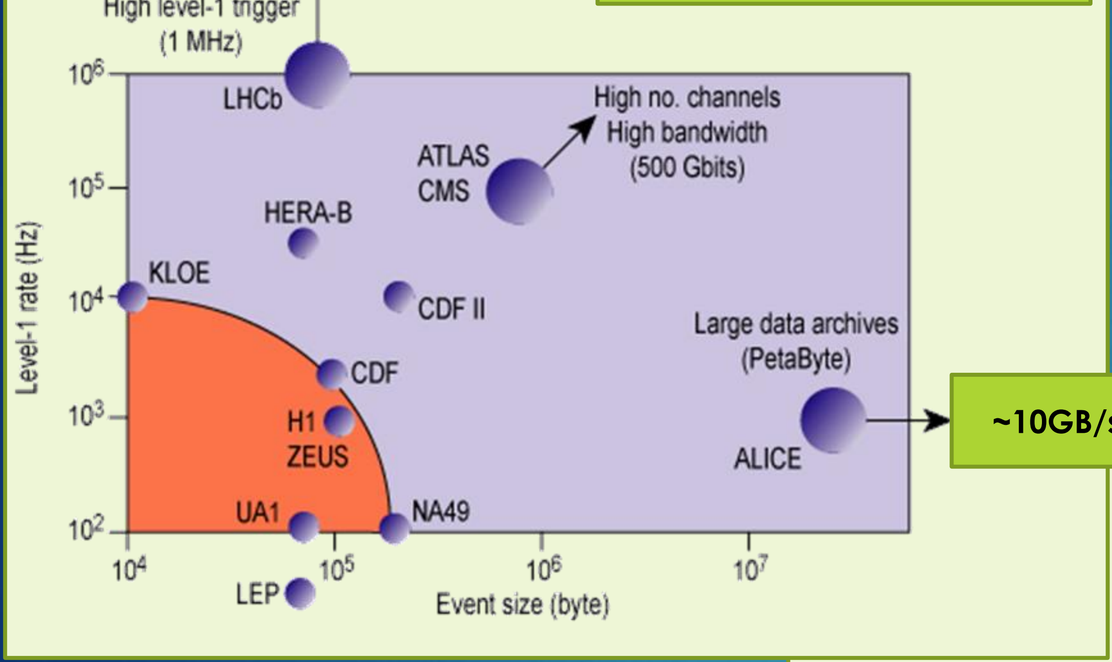
Time Projection Chamber

The ALICE O2 Project



The ALICE O2 Project

ALICE 2007-2017



~10GB/s

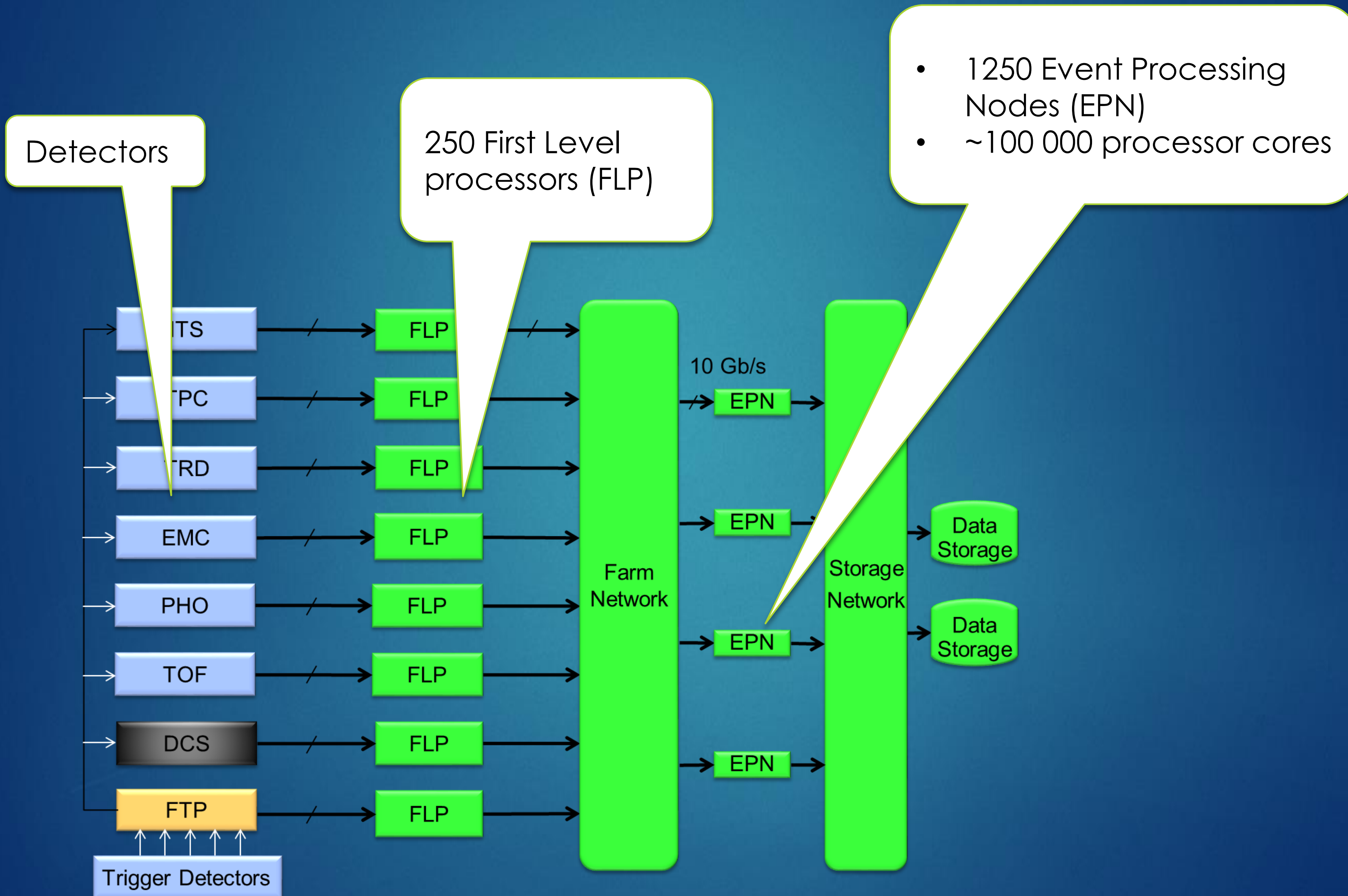
ALICE 2019-2027

LHC will provide for RUN3 ~100x more Pb-Pb collisions compared to RUN2 (10^{10} – 4.10^{11} collisions/year)

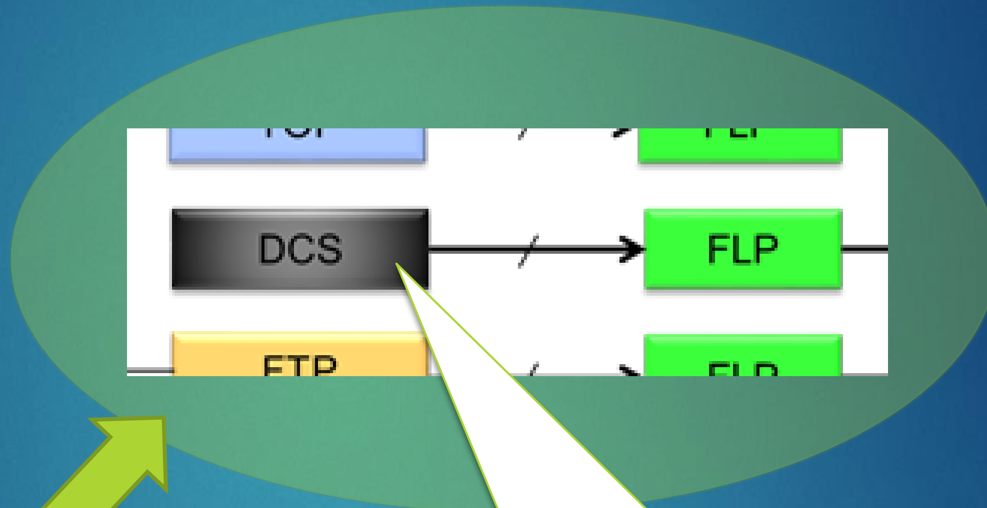
- **ALICE O2 Project merges online and offline into one large system**
  - **TDR approved IN 2015 !**

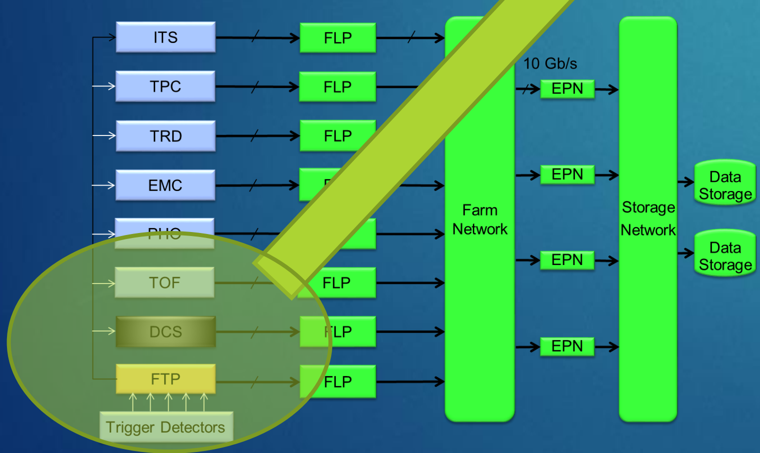
- **Some O2 challenges:**
  - **New detector readout**
    - **8400 optical links**
  - **Data rate 1.1TB/s**
  - **Data storage requirements: ~60PB/year**

The O2 architecture



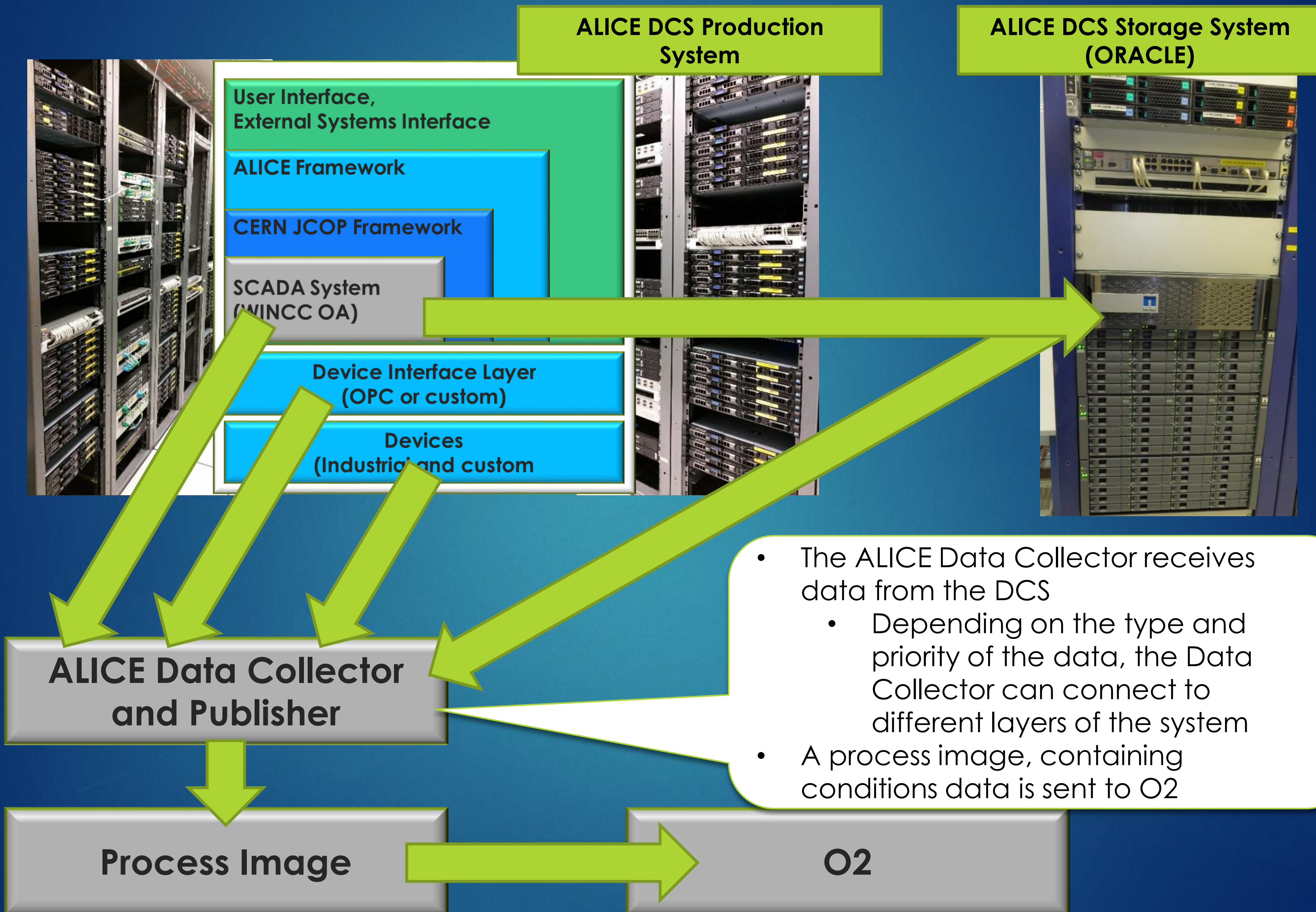
DCS in the context of O2





- DCS provides input to O2
- ~100 000 conditions parameters are requested for the event reconstruction
- Data has to be injected into each 20ms data frame

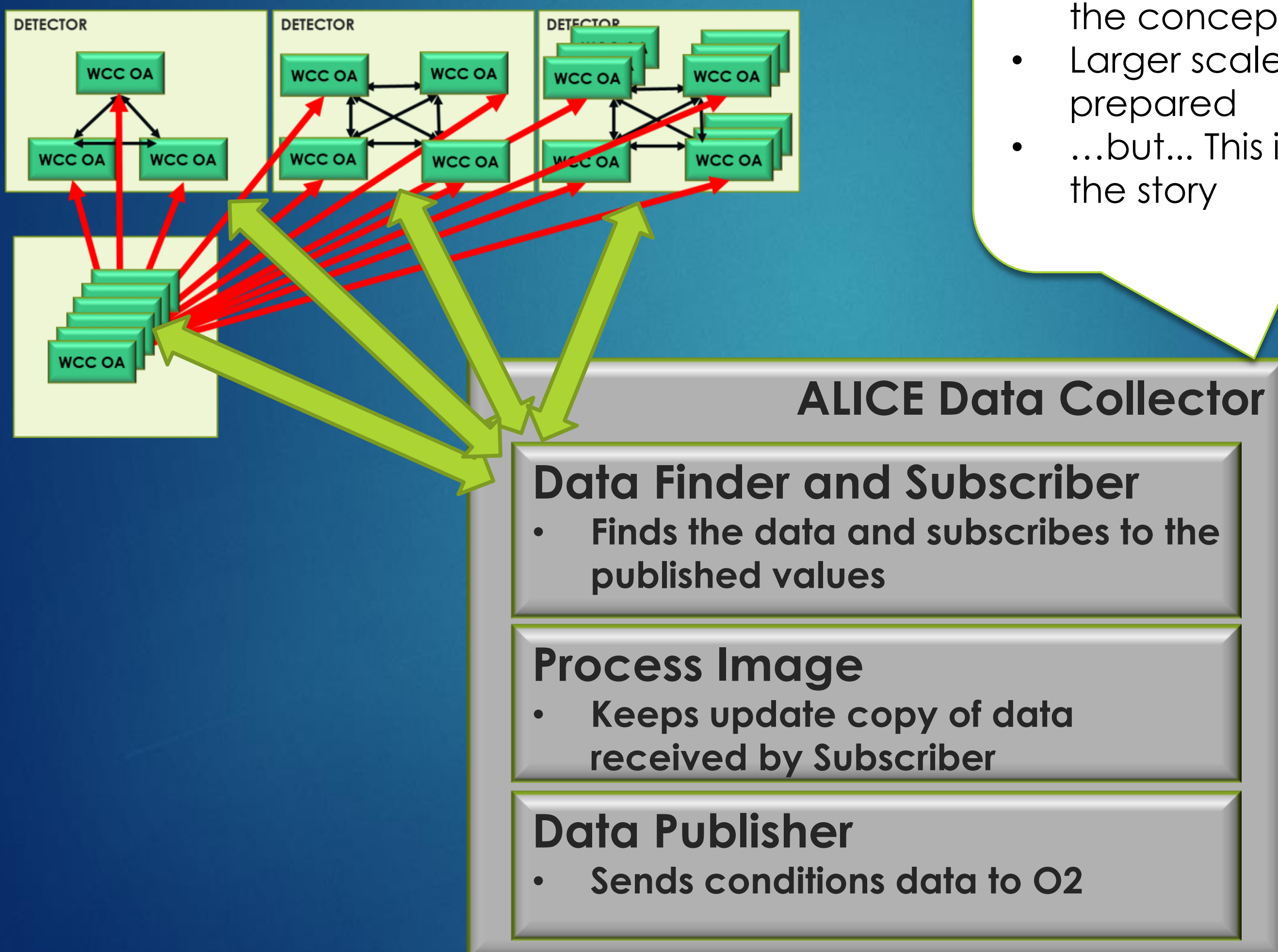
DCS-O2 interface



- The ALICE Data Collector receives data from the DCS
  - Depending on the type and priority of the data, the Data Collector can connect to different layers of the system
- A process image, containing conditions data is sent to O2

DCS-O2 interface

- Prototypes proved the feasibility of the concept
- Larger scale prototypes being prepared
- …but... This is just the beginning of the story



Conclusions

- The DCS provides stable and uninterrupted services to the ALICE experiment since 2007
- Modular and scalable design minimized the need for system modifications and coped well with the evolution of hardware and software
- As a response to increased complexity of operational procedures, high-level procedures and parallel operations were introduced
- Challenging O2 project requires the full redesign of ALICE DCS data flow
  - Prototyping ongoing
  - More to come…