



# The evolution of the ALICE Detector Control System

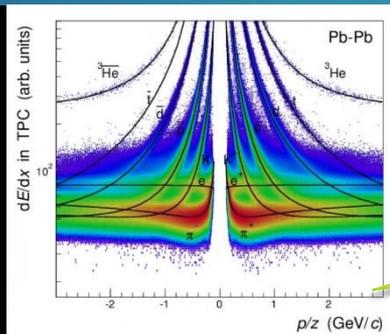
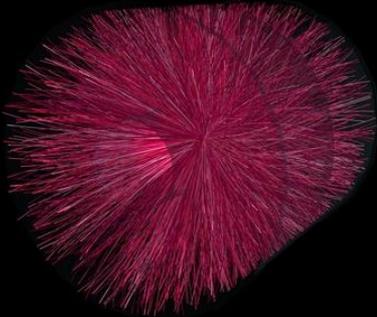
PETER CHOCHULA, CERN, GENEVA , SWITZERLAND

# 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



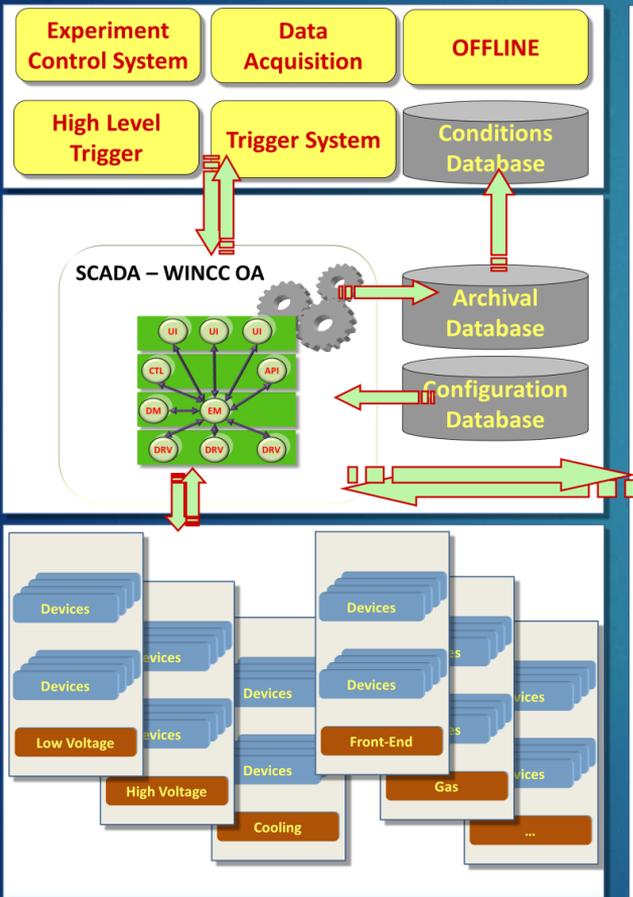
- Main physics focus:
- Heavy ion physics at LHC energies
  - Proton-proton physics

# 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

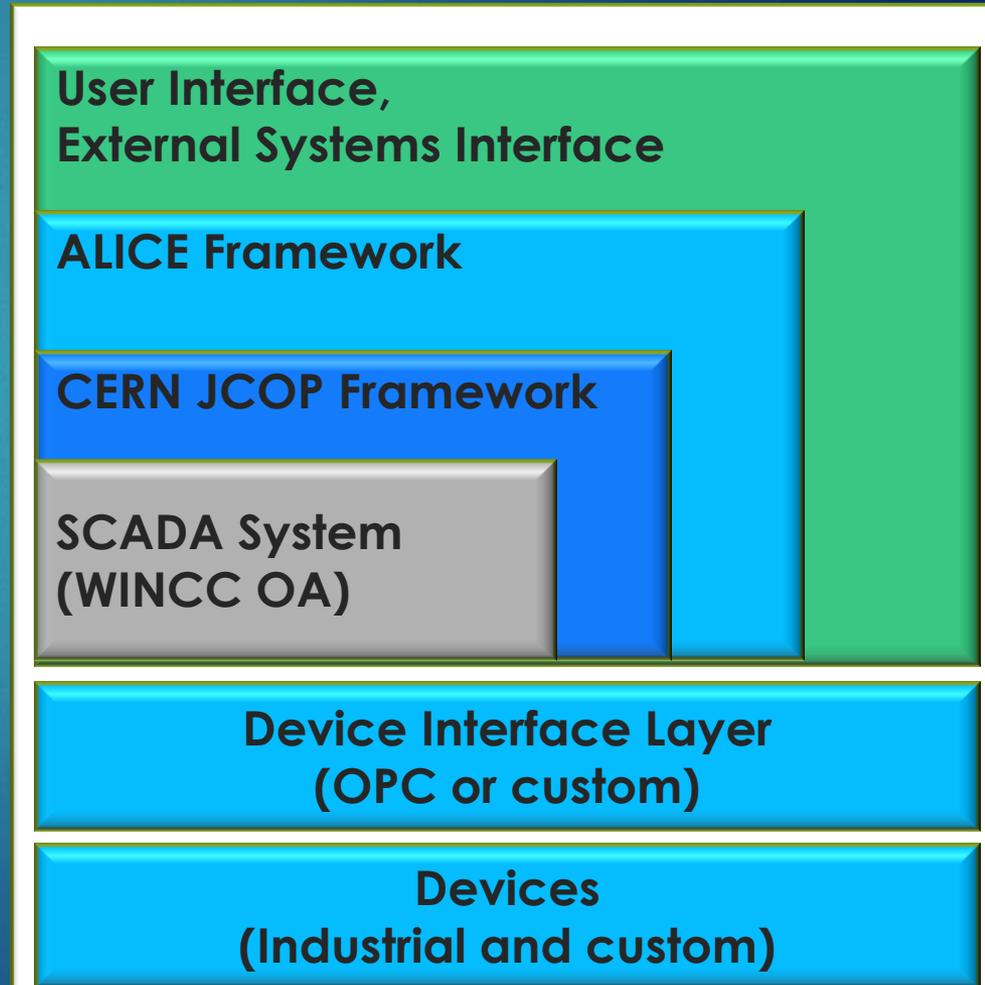


# The ALICE DCS – Context and Architecture

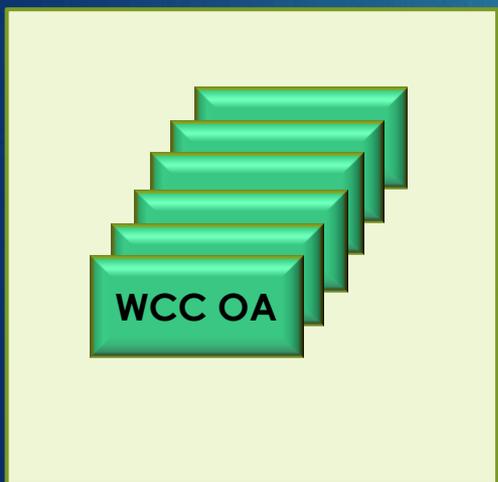
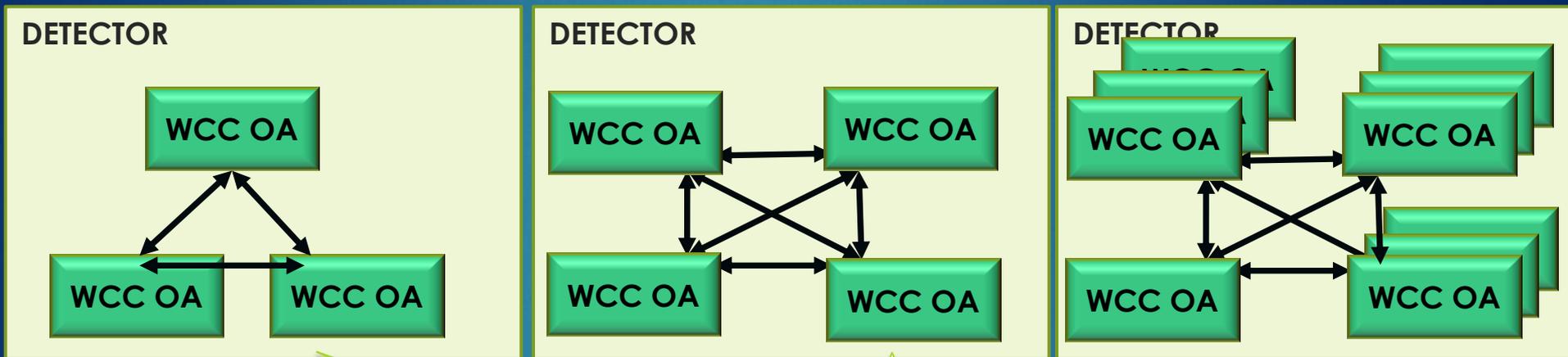


Devices with similar functionality are grouped into subsystems. About 100 different subsystems are implemented in ALICE. .

- Electricity
- Ventilation
- Cooling
- Magnets
- Gas
- Access Control
- LHC
- Safety
- B-field
- Space Frame
- Beam Pipe
- Environment
- Radiation

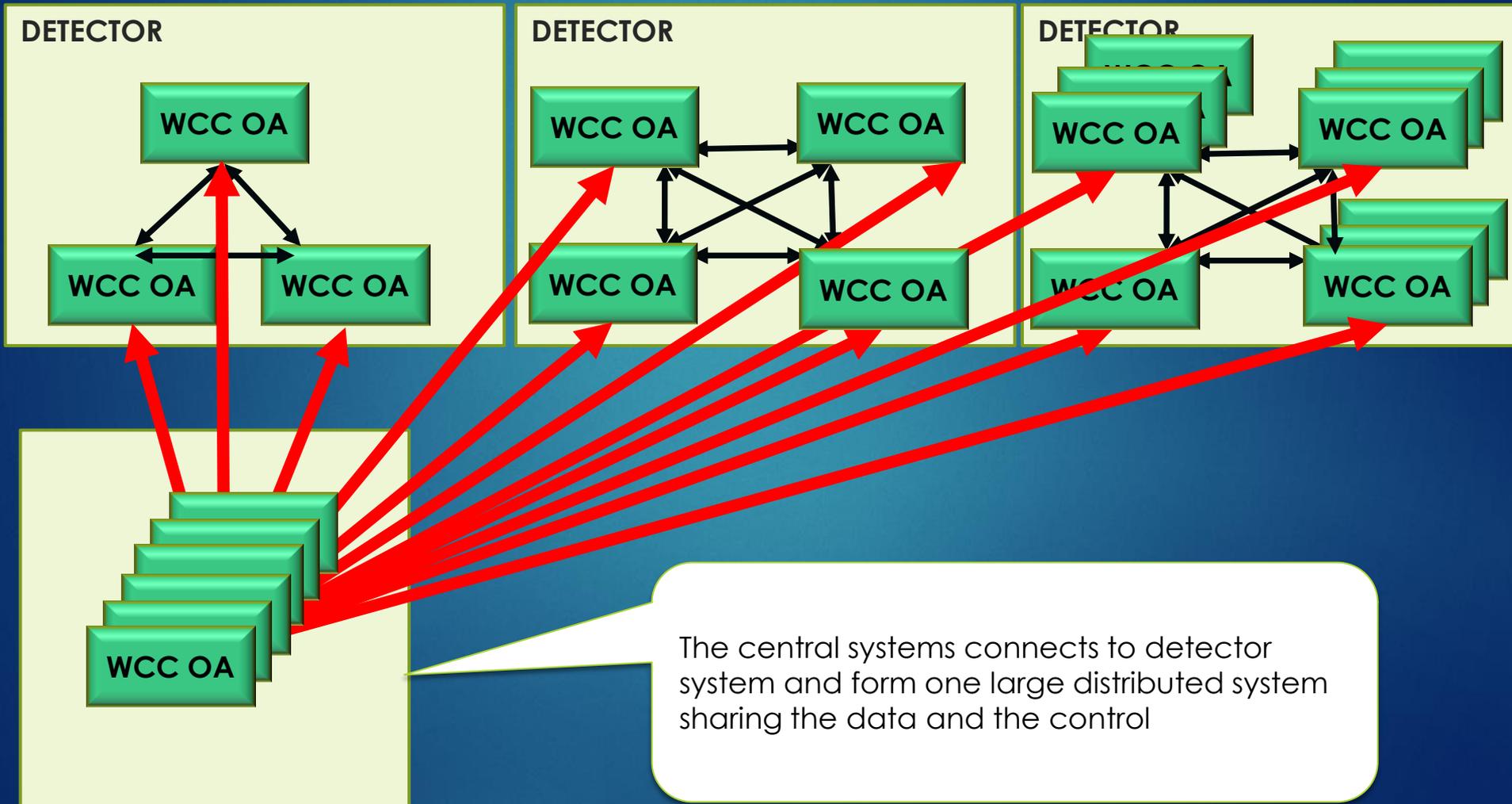
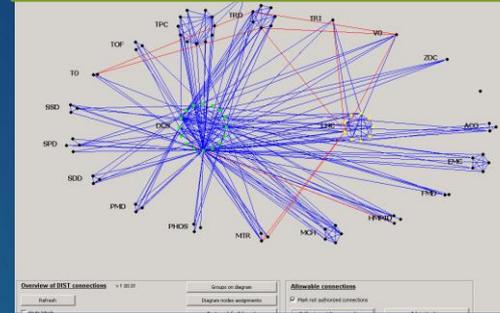


# Each detector builds its own distributed control system

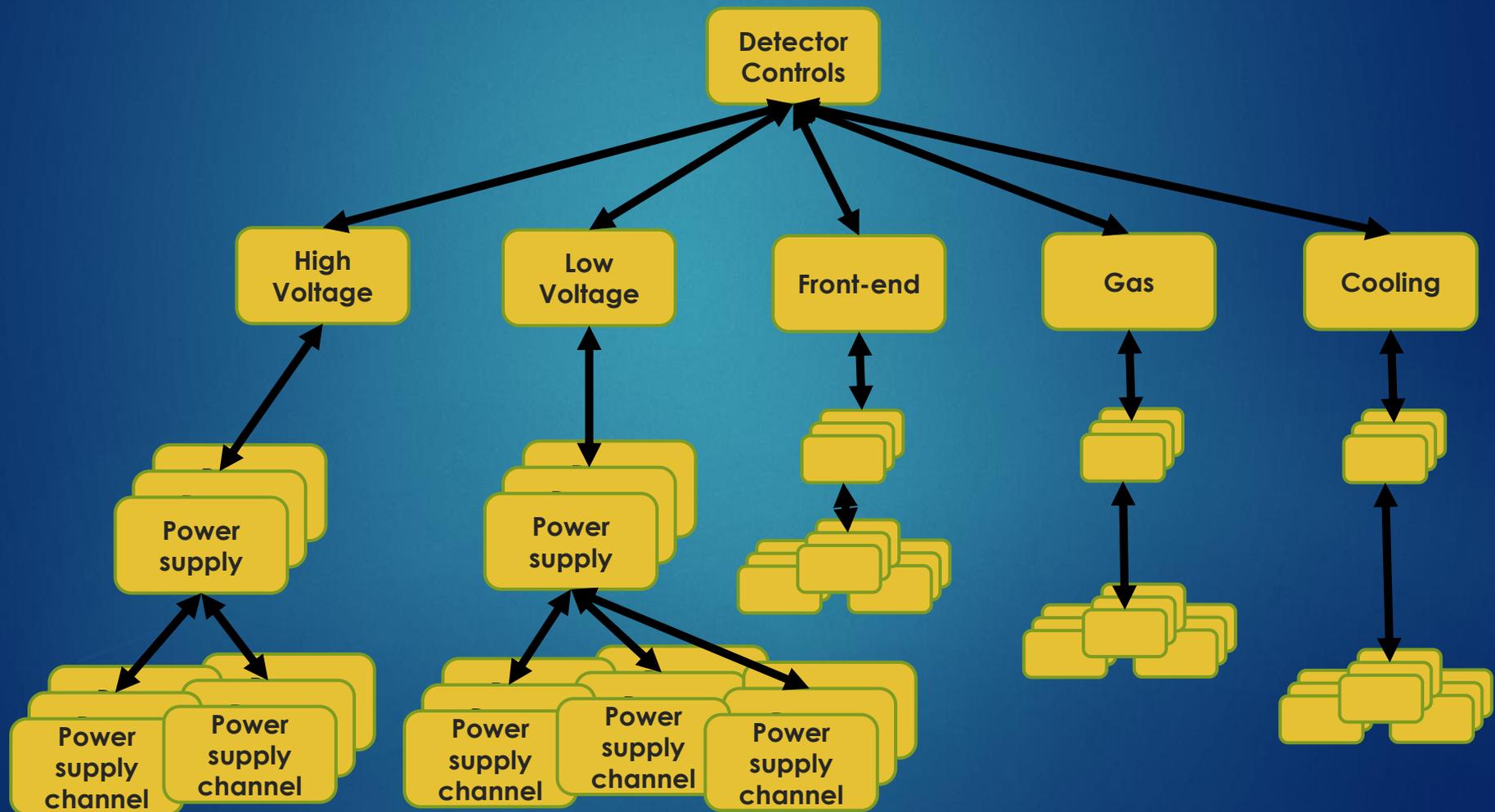


Each detector system is built as an autonomous distributed system of 2-16 WINCC systems

# Central systems connect to all detector systems

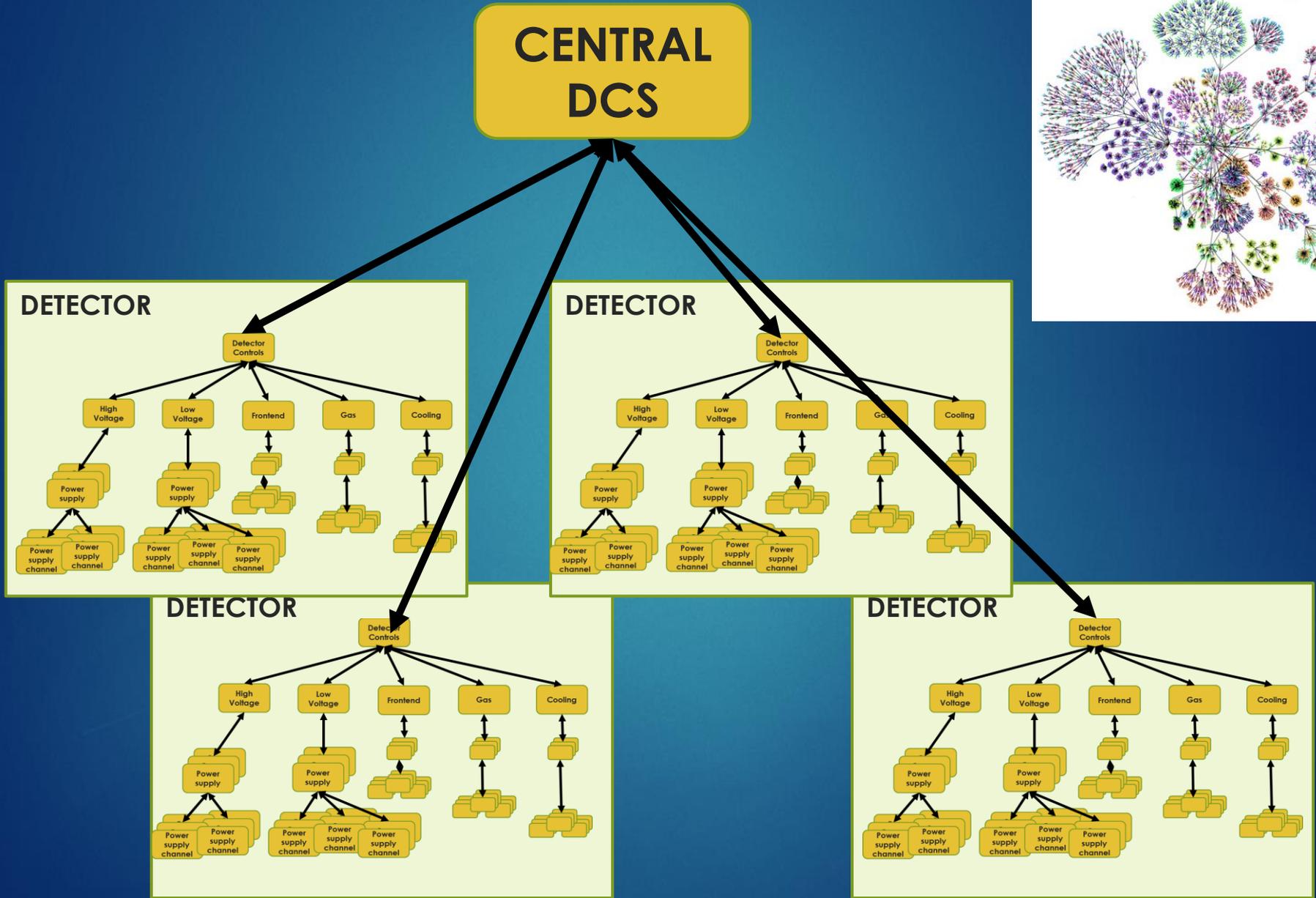
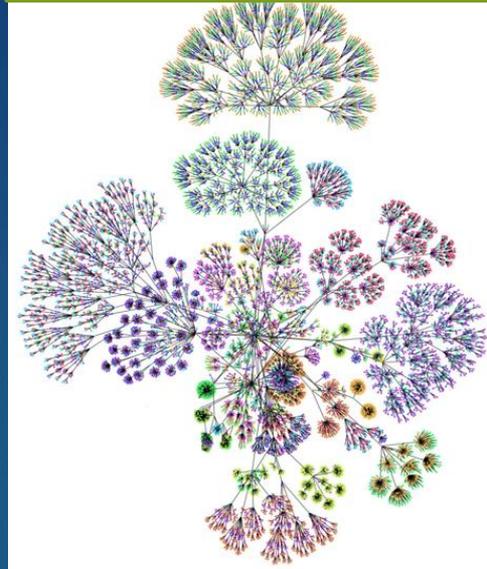


Using the CERN SMI++ framework, the control system is presented as hierarchical tree of controlled objects

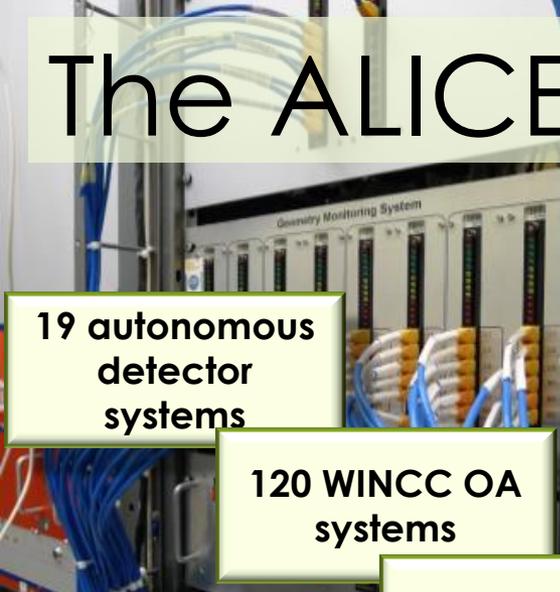


# Central DCS connects to all detector trees

ALICE DCS Tree



# The ALICE DCS scale



19 autonomous  
detector  
systems

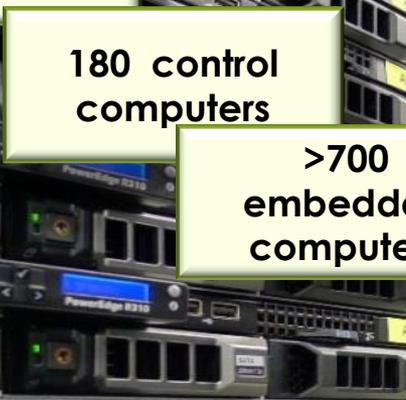
120 WINCC OA  
systems



>100  
subsystems

180 control  
computers

>700  
embedded  
computers



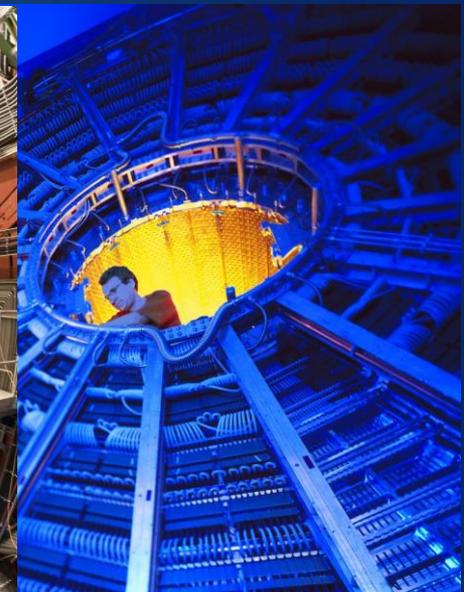
1200 network  
attached  
devices



300 000 OPC  
and frontend  
items



1 000 000  
supervised  
parameters

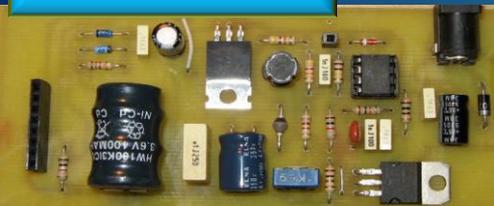


# Simplified complexity

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

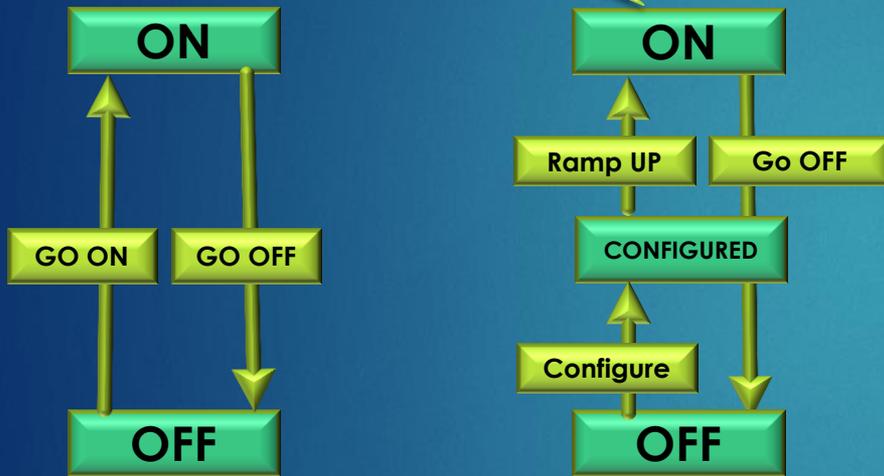


Channel

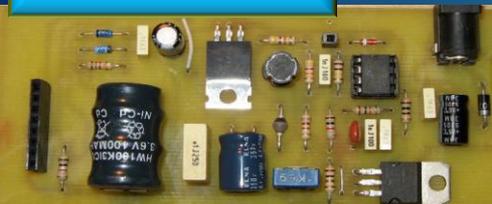


# Simplified complexity

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



Channel

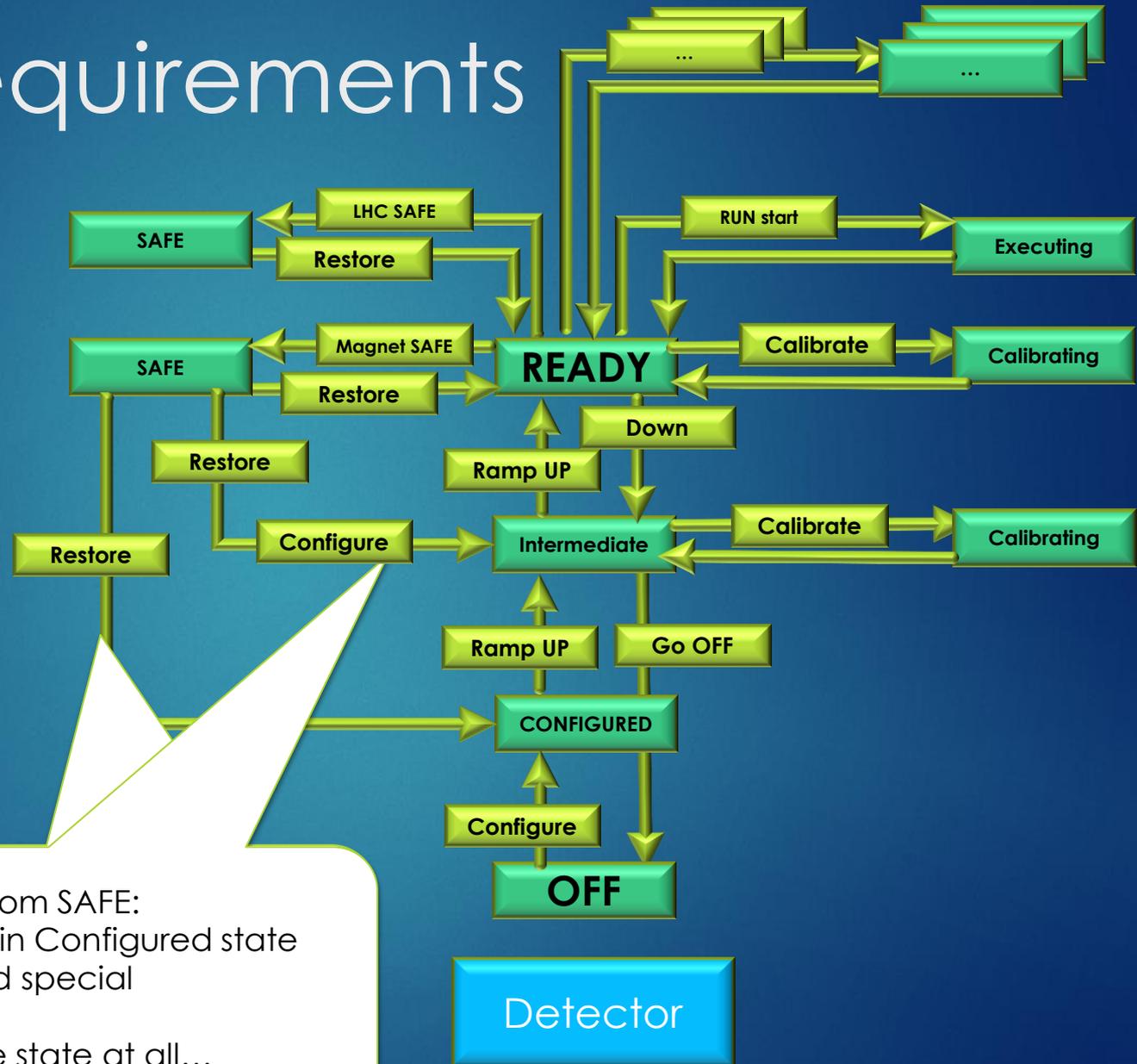


Device



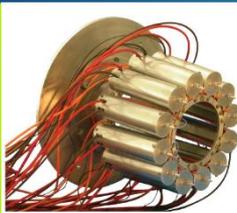
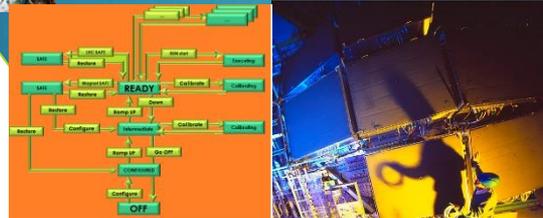
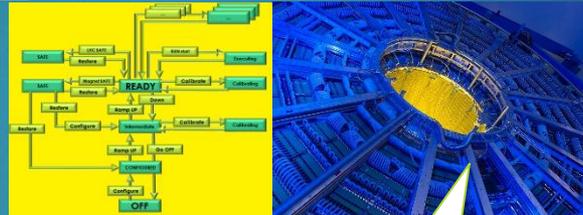
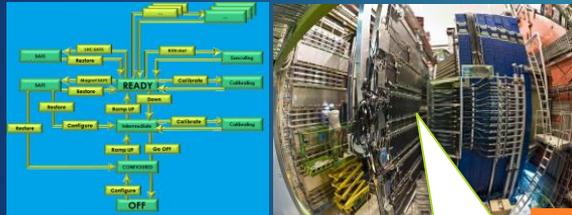
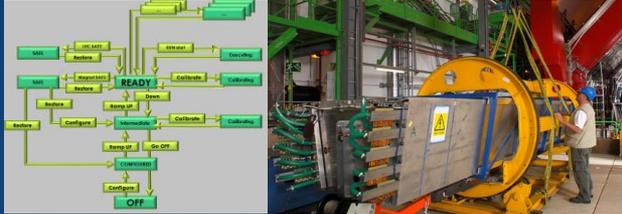
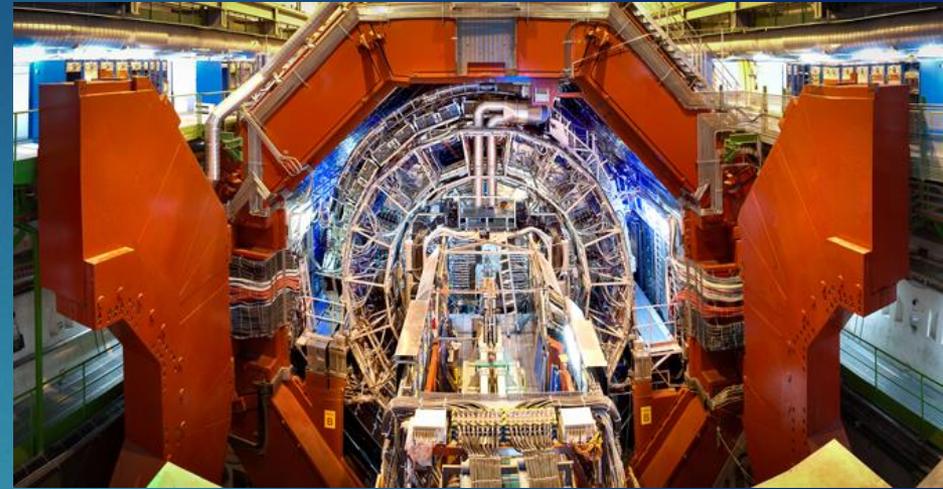


# ... each detector has specific requirements



- 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 ensure 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

System	Value	Act	Time	Col
Ingenious Current	GAME	0.8413754768	x 2015.10.06.19:21:16.639	1
EEO config	GAME	TRUE	x 2015.10.12.14:17:40.662	1

# 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

**Alarm Help**  
LED High Voltage (5seg) Supply Current Error

There is excessive current draw on one of the LED HV channels. If the current draw is excessive and is allowed to continue for a prolonged time, damage may ensue.

Warning	LED Current draw is a bit high. No effect on Run.
Error	LED Current draw is excessive. No effect on Run.
Fatal	LED Current draw is excessive. No effect on Run.

**Action for the Expert**  
First check the present status of this channel. It might have returned to reasonable values. If so, you probably need to reset this channel via the Device Editor and Navigator on emc2\_for Observers, console.

**Action for the Operator**  
If an EMC2 Co-Call is available, contact EMC2 Co-Call and follow any instructions given. If the EMC2 Co-Call is not available, contact the shift leader.

Instructions

ALERT

**Emergency control of the ALICE permits**

**IMPORTANT: Before you continue please read the instructions carefully:**

1. Inform DCS on-call and Shift Leader that there is a problem with arming of the ALICE permits.
2. Make sure the ALICE is SAFE/SUPERSAFE. If ALICE is not SAFE/SUPERSAFE then follow the same procedure as during normal LHC Injection Handshake to bring ALICE to SAFE/SUPERSAFE state.
3. If ALICE is SAFE/SUPERSAFE click the 'Yes, arm the permits' button.
4. The actual status of the permits will be displayed in popup window with command line after several (2-20) seconds. Please verify there that all the permits are TRUE. Then close the popup window.
5. When the injection is completed click the 'Yes, remove the injection permits' button. Please verify in popup window with command line that the injection permits are FALSE. The beam permit should stay TRUE.

**LHC Injection W/**

Is the ALICE in SAFE/SUPERSAFE state?

Is the injection completed?

LHC is preparing for the injection;

- (1) Select the command PREPARE in the HANDSHAKE STATUS box; the INJECTION status should become WARN\_CONFIRMED;
- (2) Inform the shift leader and ask the DCS operator to stop all the runs;
- (3) If the ALICE Safety condition is NOT SAFE, send the command GO\_SAFE using the button in the GLOBAL SAFETY box. -> If the condition remains NOT SAFE, find affected det. -> Contact the relevant detector on-call to inform about the problem.
- (4) Once ALICE is SAFE, select CONFIRM in the HANDSHAKE STATUS box and the Injection Permits should turn into green;
- (5) Wait for the LHC to move to READY\_CONFIRMED;
- (6) In case of problems select the command PROBLEM in the HANDSHAKE box. -> When the problem is solved select the ACKNOWLEDGE command in the HANDSHAKE box.

CURRENT OPERATOR ACTION >>> WAIT for LHC actions until INJECTION box becomes READY\_CONFIRMED

Handshake status: COMMUNICATION INTERFACE WITH LHC (Injection: READY)

Global Safety: ALICE CONDITION (SAFE)

User Permits: ESDm Permit, Injection permit 1, Injection permit 2

0:00 Estimated Countdown Time

NO PROBLEMS

In case of problem, detailed info will appear here

SAFE SUMMARY

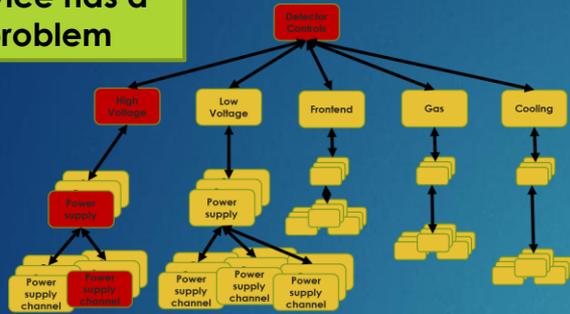
LHC-ALICE MESSAGES (Experts use)

Instructions

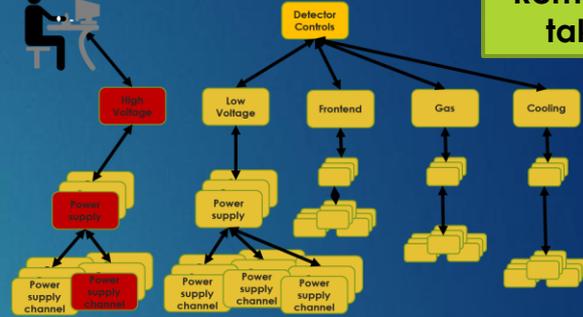
Actions

# Lessons learned – backdoors are useful

Device has a problem



Remote expert takes over



- ▶ 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



Listen



Regain Control



# (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) $\mu\text{m}$  assemblies
- Contingency in case of cooling failure less than 1 minute

## ALICE Pixel detector



## ALICE Transition Radiation Detector (TRD):

- 760 m<sup>2</sup> 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



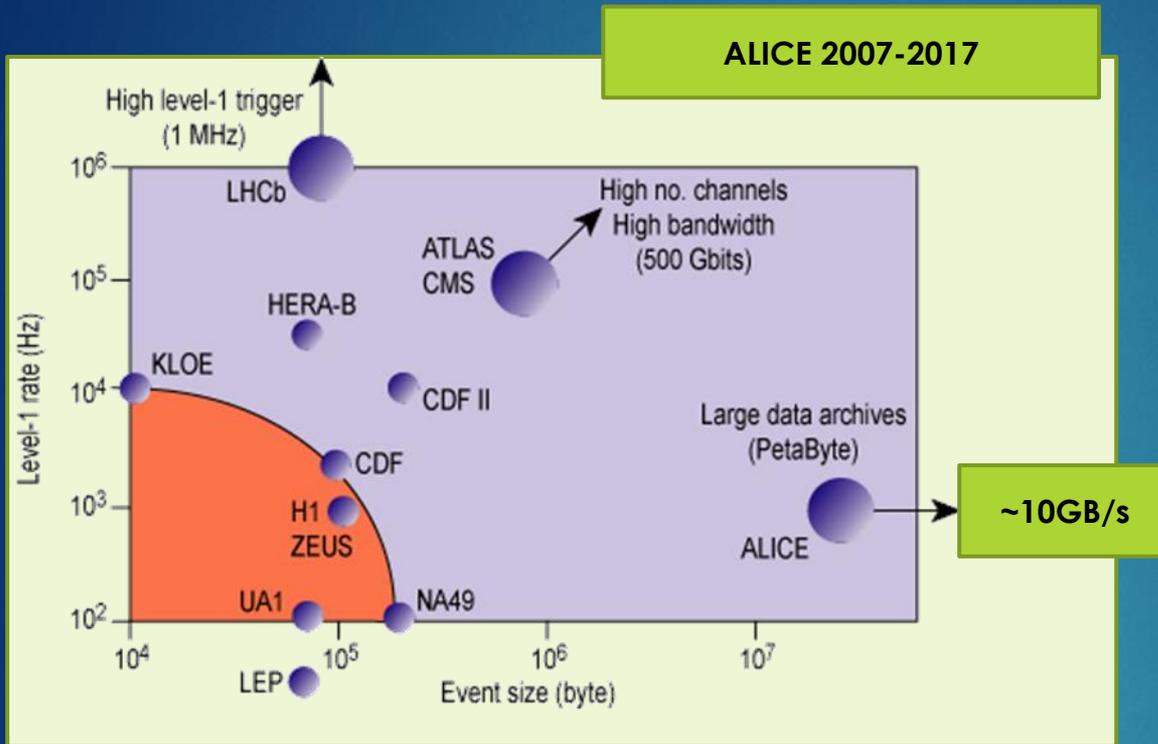
## ALICE Time Projection Chamber (TPC):

- 96 m<sup>3</sup> gas volume (largest ever)
  - stabilized at 0.1<sup>o</sup>C
  - 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

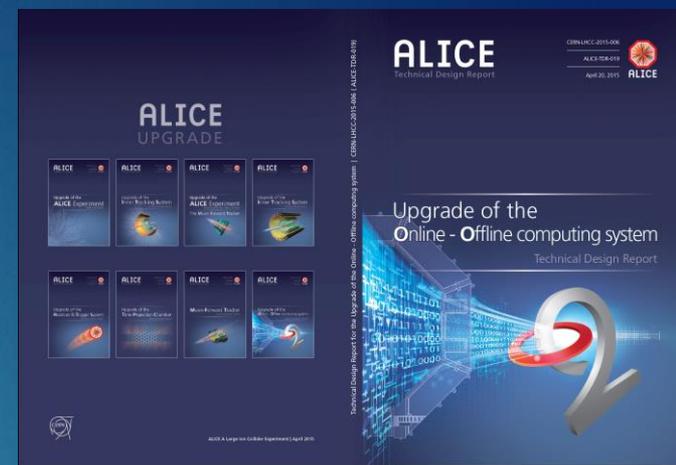
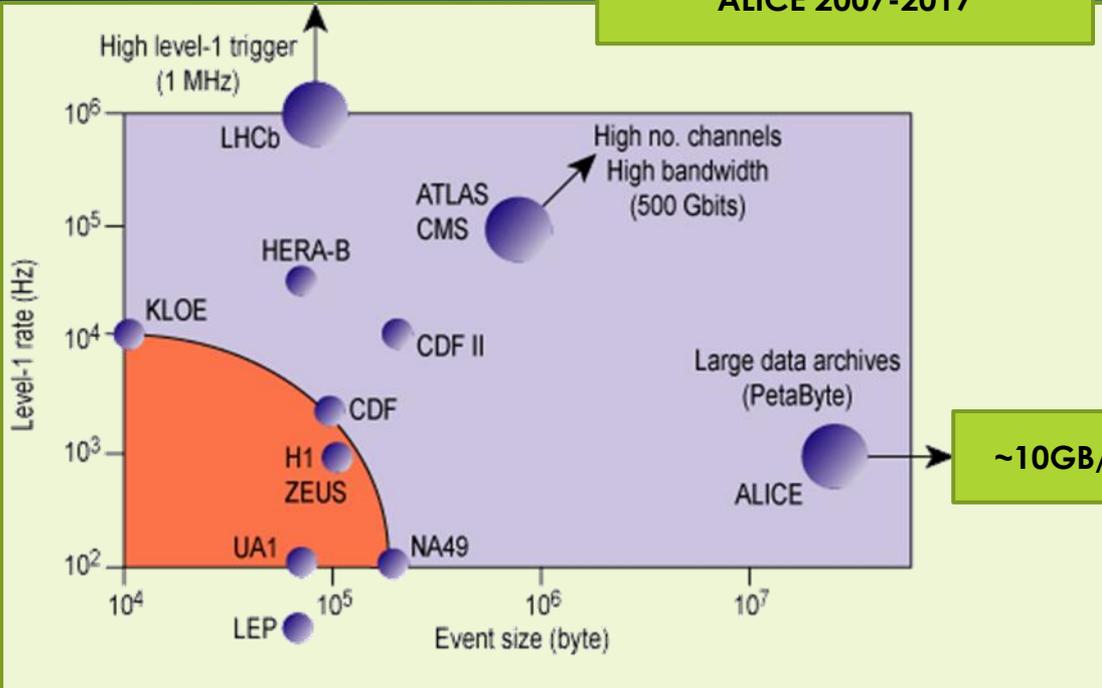


# The ALICE O2 Project



# The ALICE O2 Project

ALICE 2007-2017

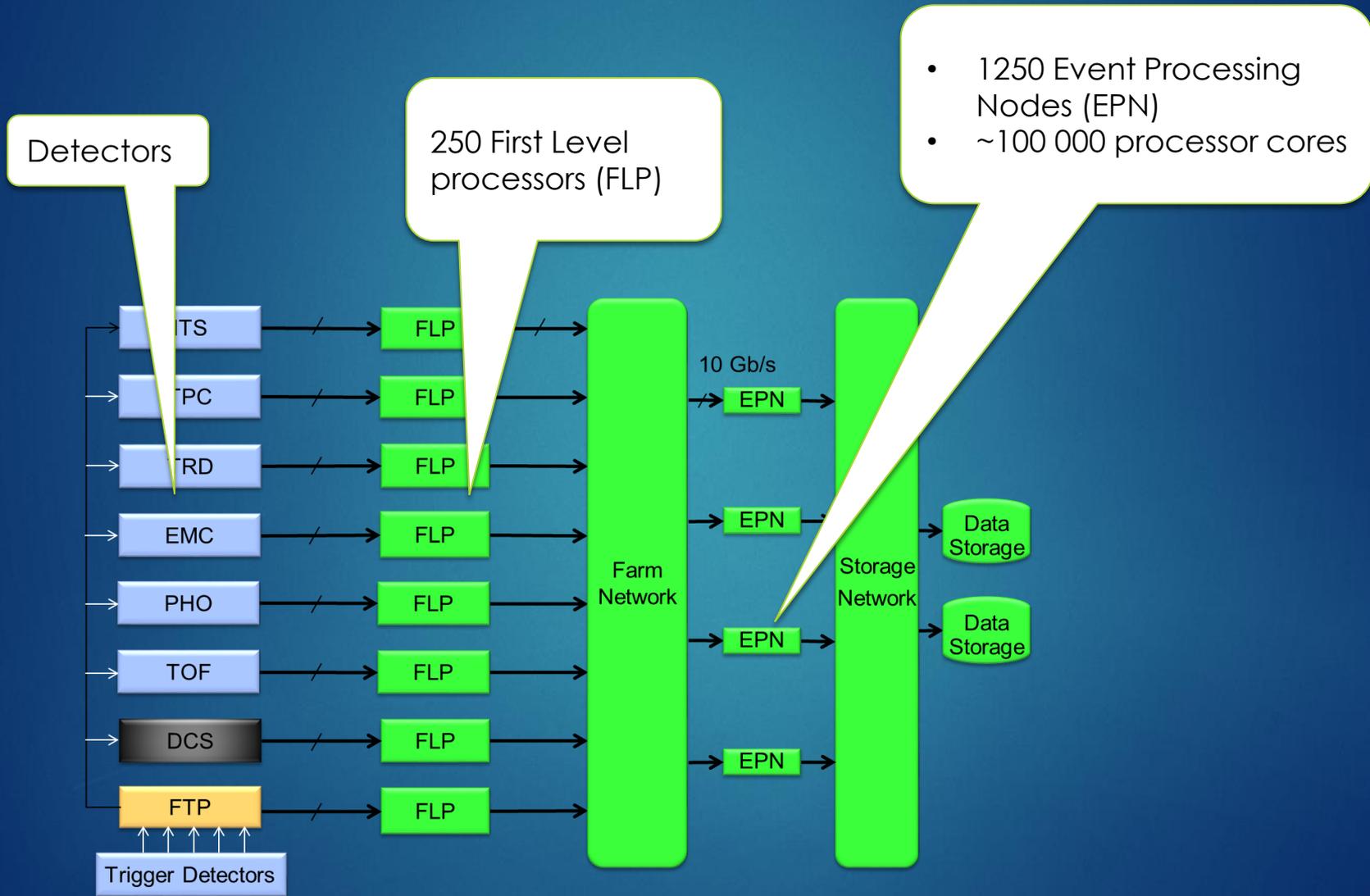


ALICE 2019-2027

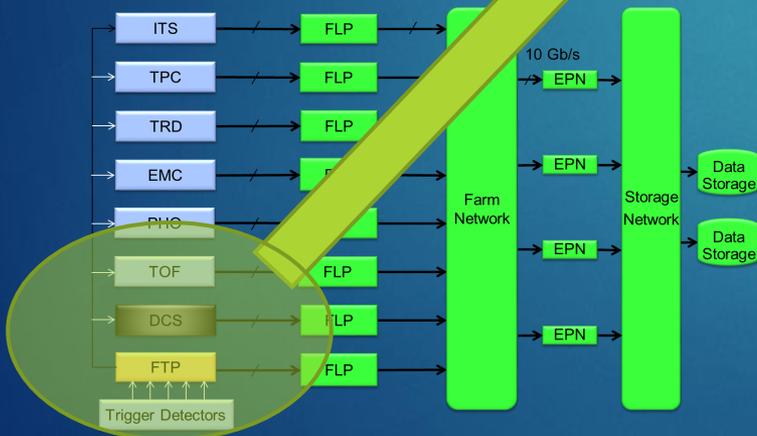
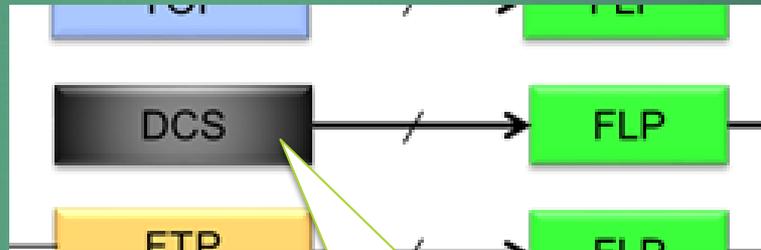
LHC will provide for RUN3 ~100x more Pb-Pb collisions compared to RUN2 (10<sup>10</sup> – 4.10<sup>11</sup> collisions/year)

- 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

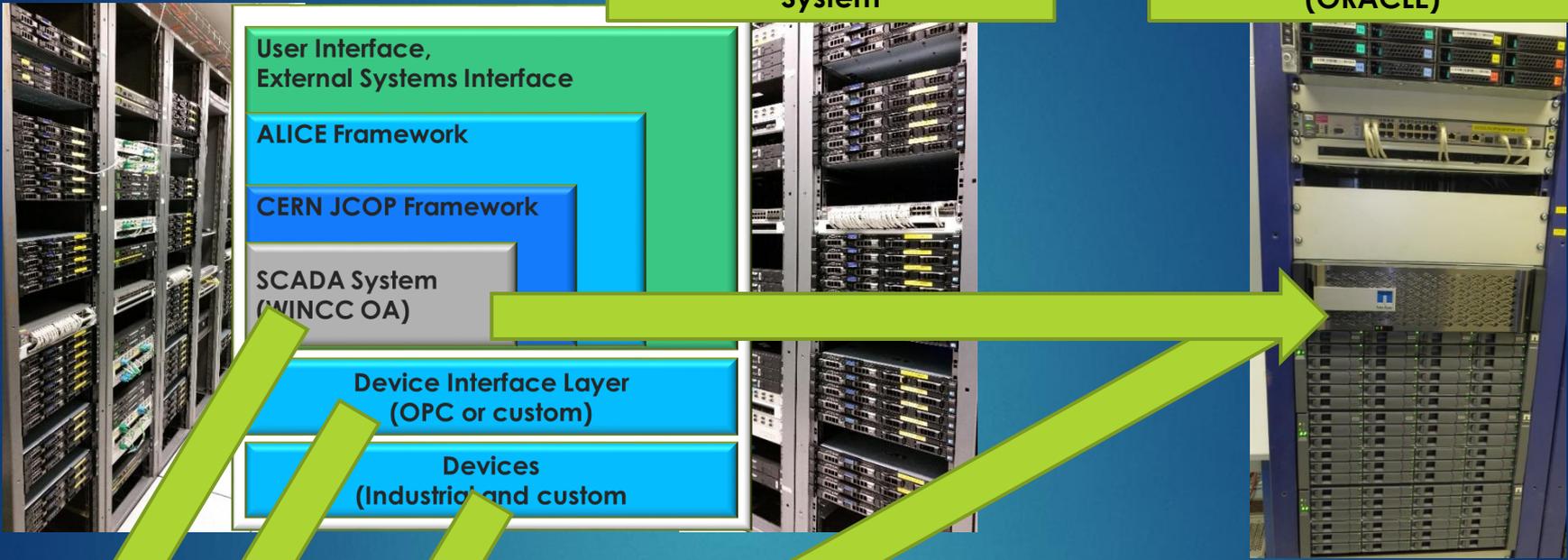


- DCS provides input to O2
- ~100 000 conditions parameters are requested for the event reconstruction
- Data has to be injected into each 20ms data frame

# DCS-O2 interface

ALICE DCS Production System

ALICE DCS Storage System (ORACLE)



**ALICE Data Collector and Publisher**

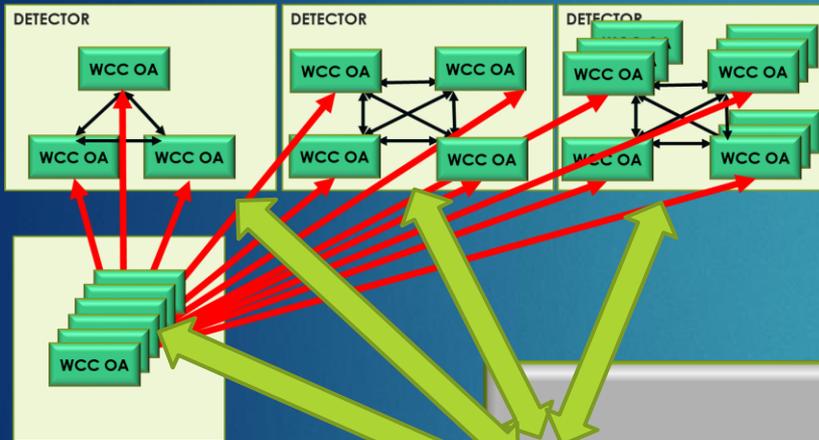
**Process Image**

**O2**

- 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

## ALICE Data Collector

### Data Finder and Subscriber

- Finds the data and subscribes to the published values

### Process Image

- Keeps update copy of data received by Subscriber

### Data Publisher

- Sends conditions data to O2

# 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...