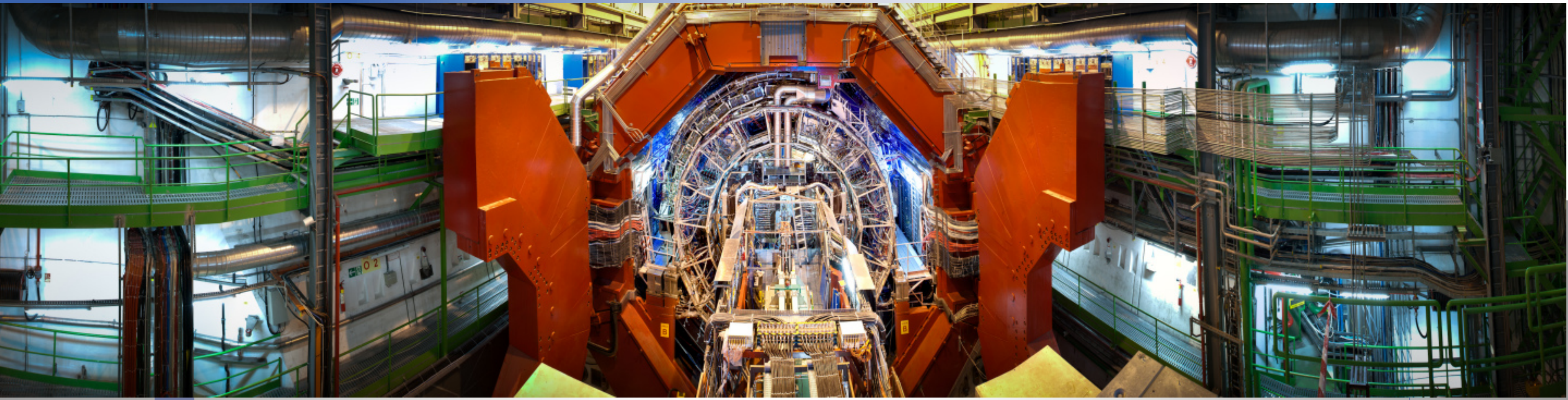
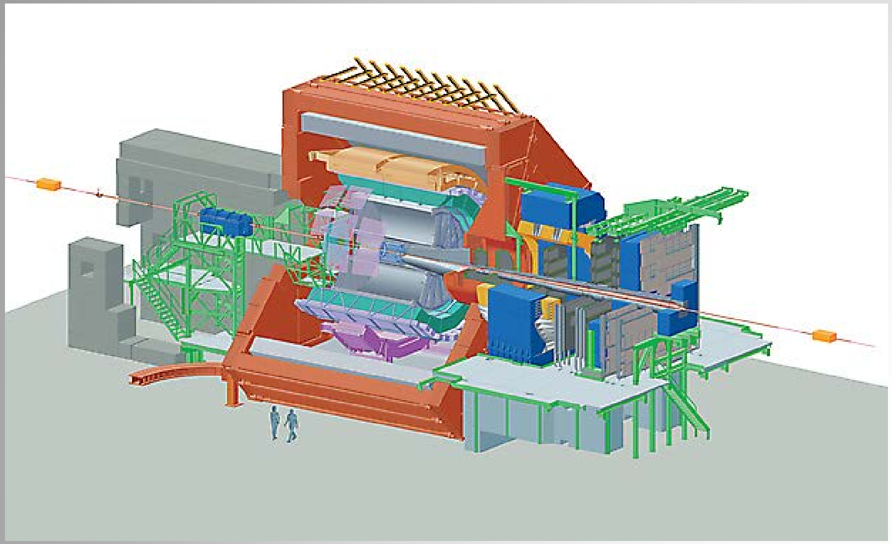


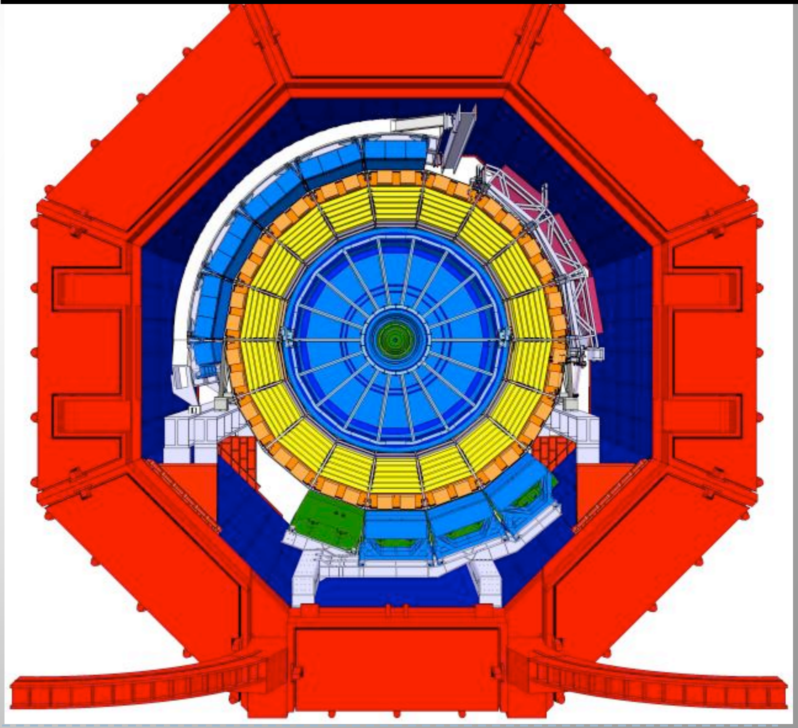
OPERATIONAL EXPERIENCE WITH THE ALICE DETECTOR CONTROL SYSTEM

Peter Chochula
for the ALICE collaboration

ALICE – Heavy ion experiment at the LHC

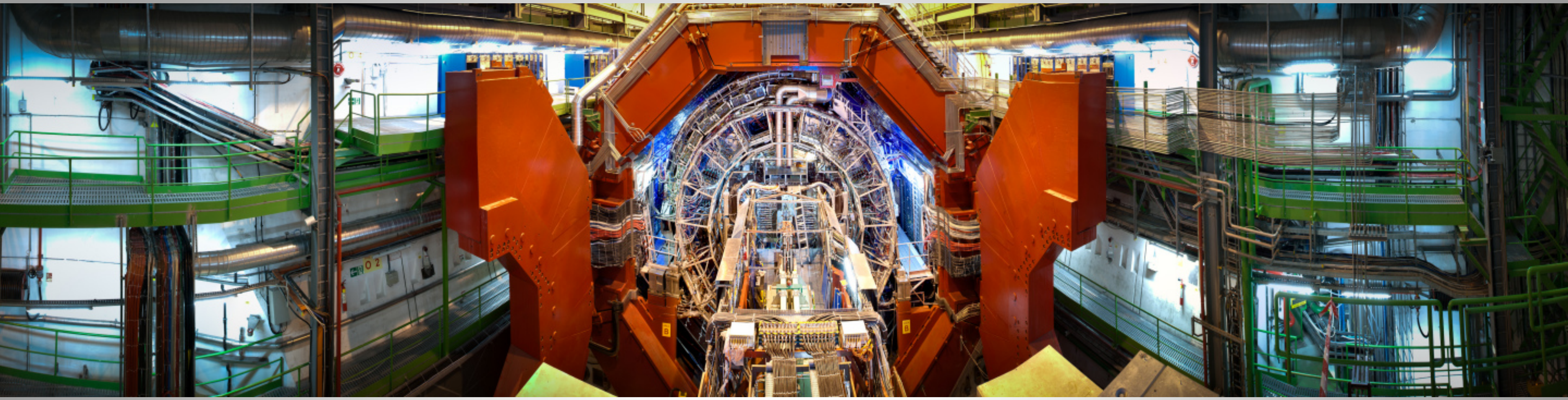


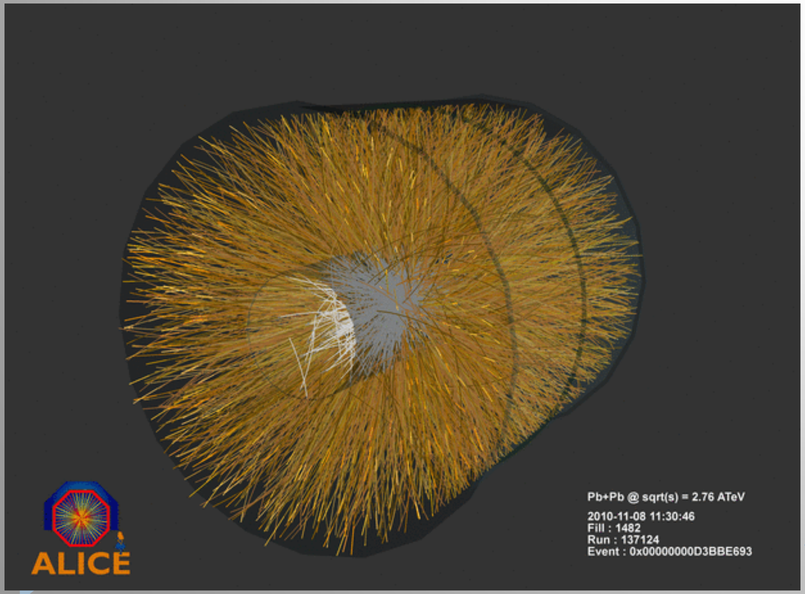
Detector:
Size: 16 x 16 x 26 m (some components installed >100m from interaction point)
Mass: 10,000 tons
Sub-detectors: 18
Magnets: 2

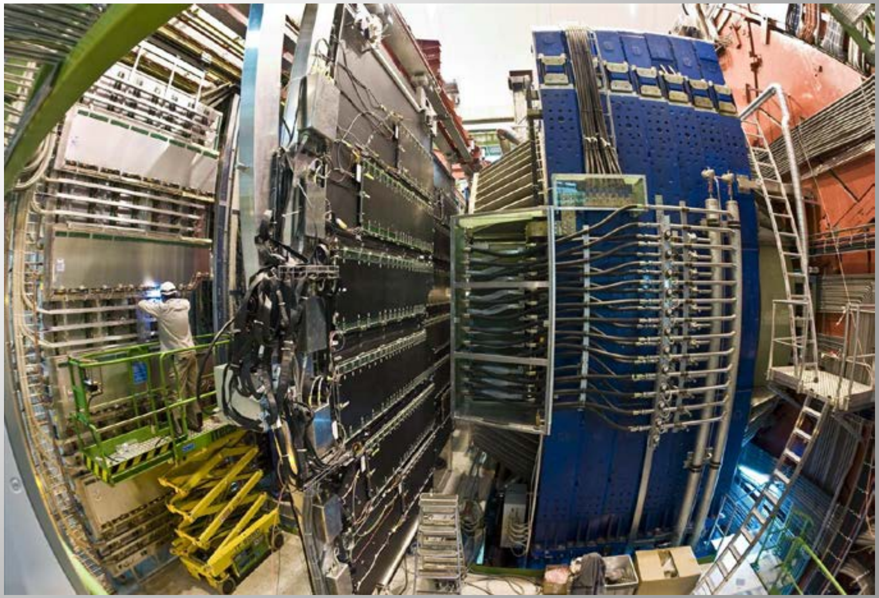


Collaboration
Members: 1500
Institutes: 140
Countries: 37

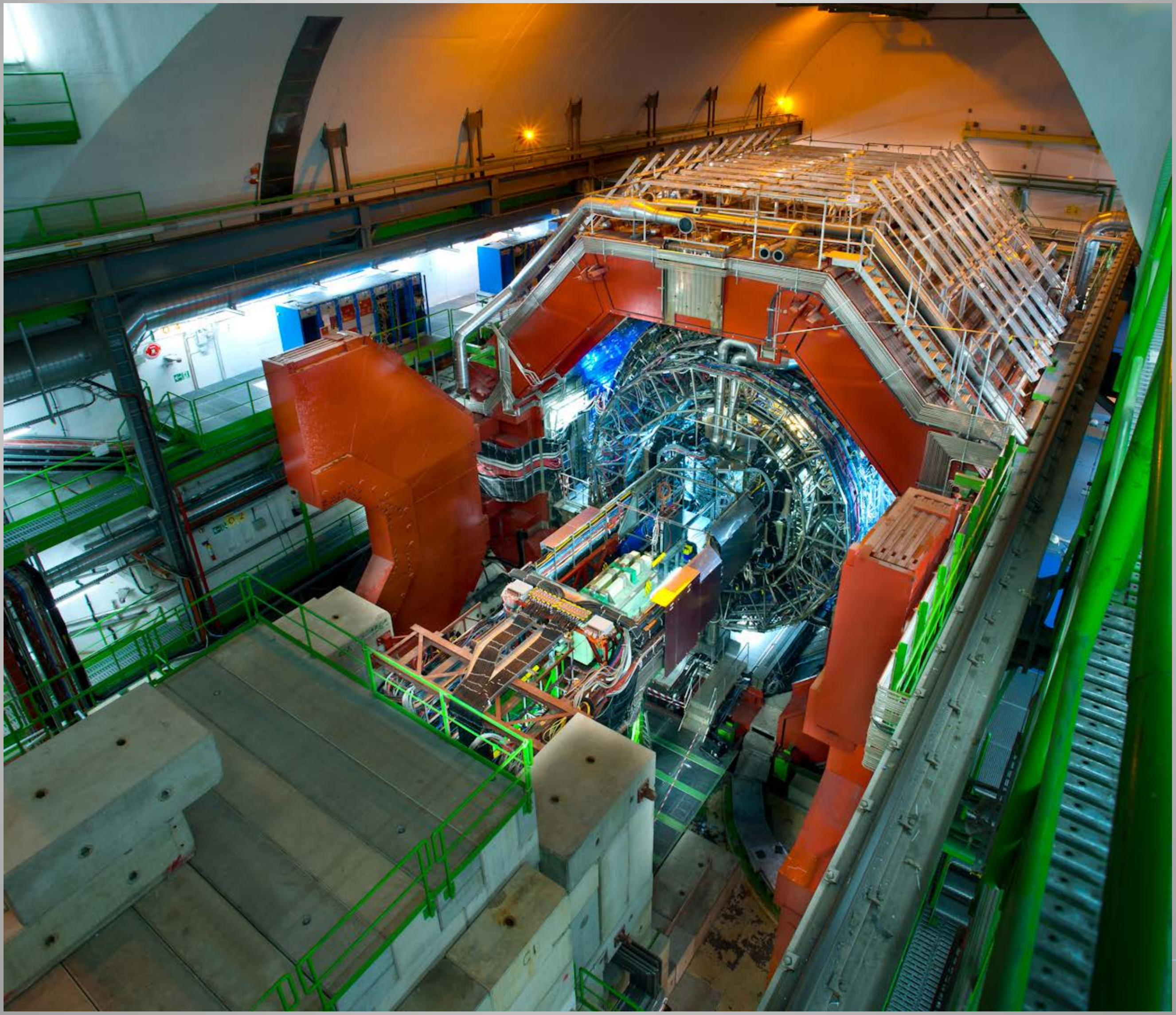
ALICE – Heavy ion experiment at the LHC



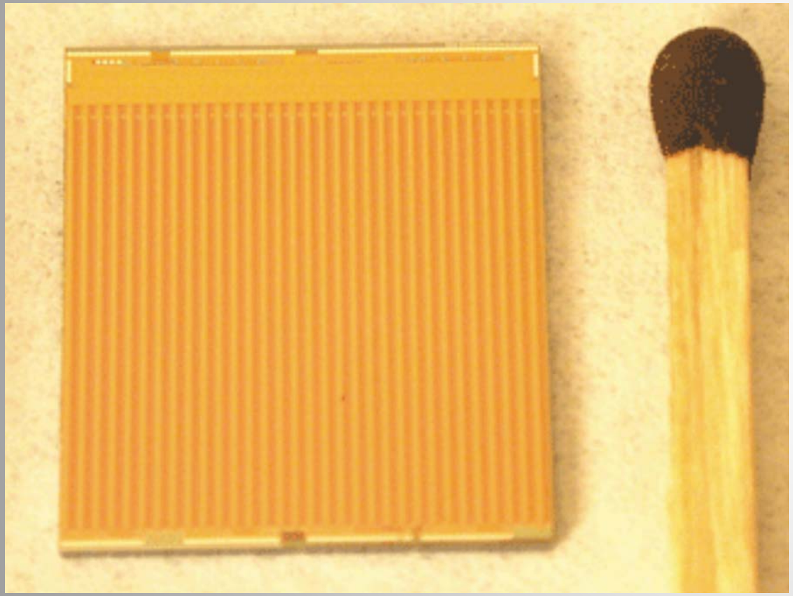


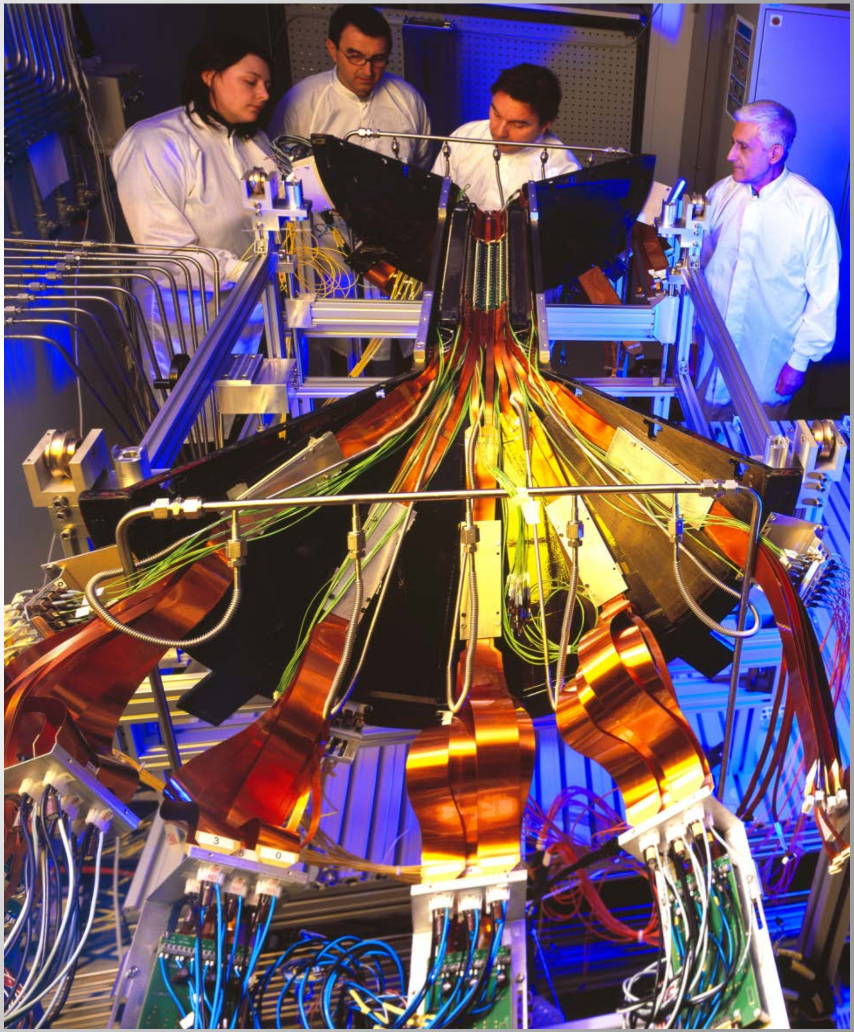


ALICE – Heavy ion experiment at the LHC

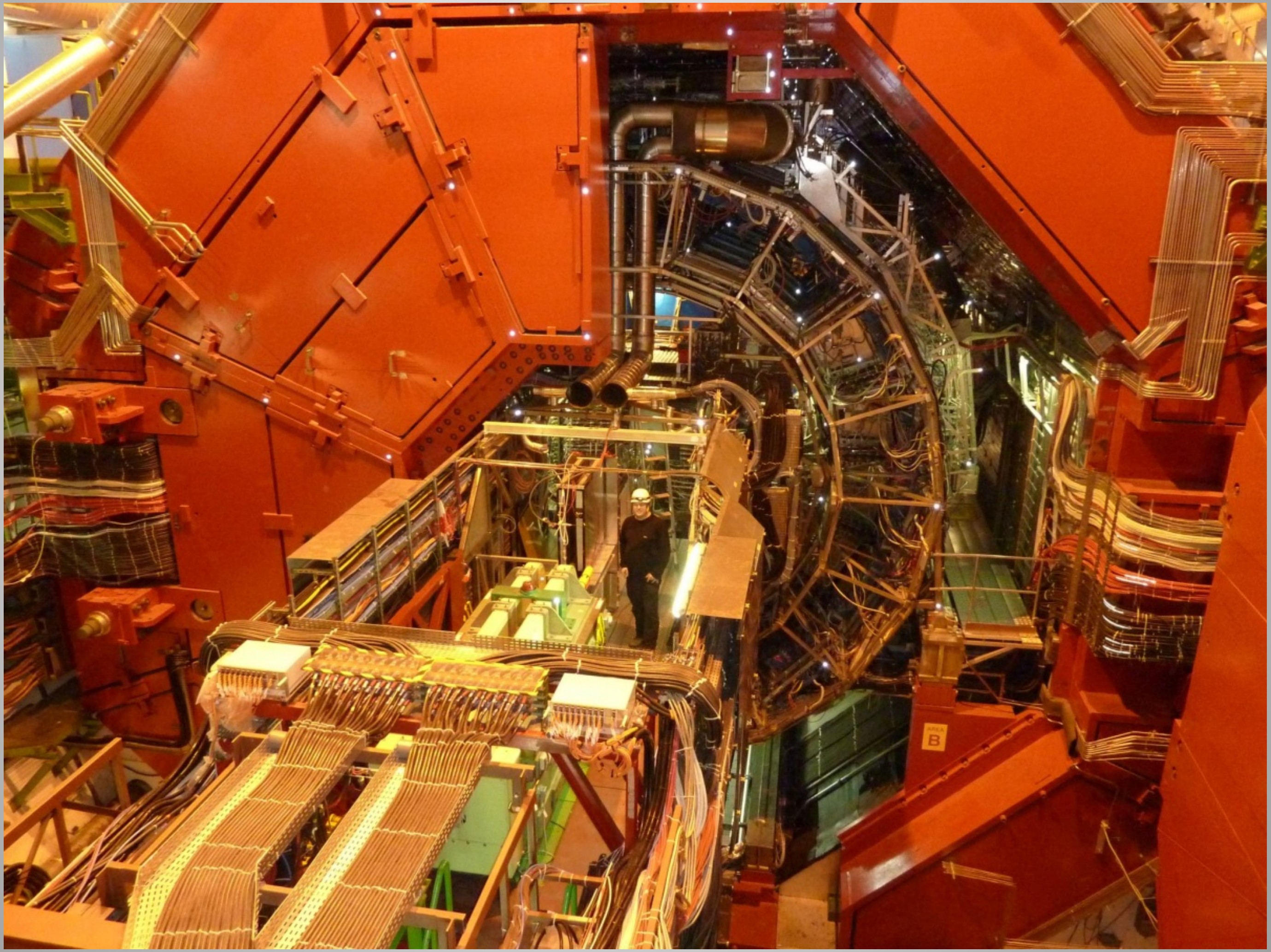


From components (Inner tracker)…





… to ALICE

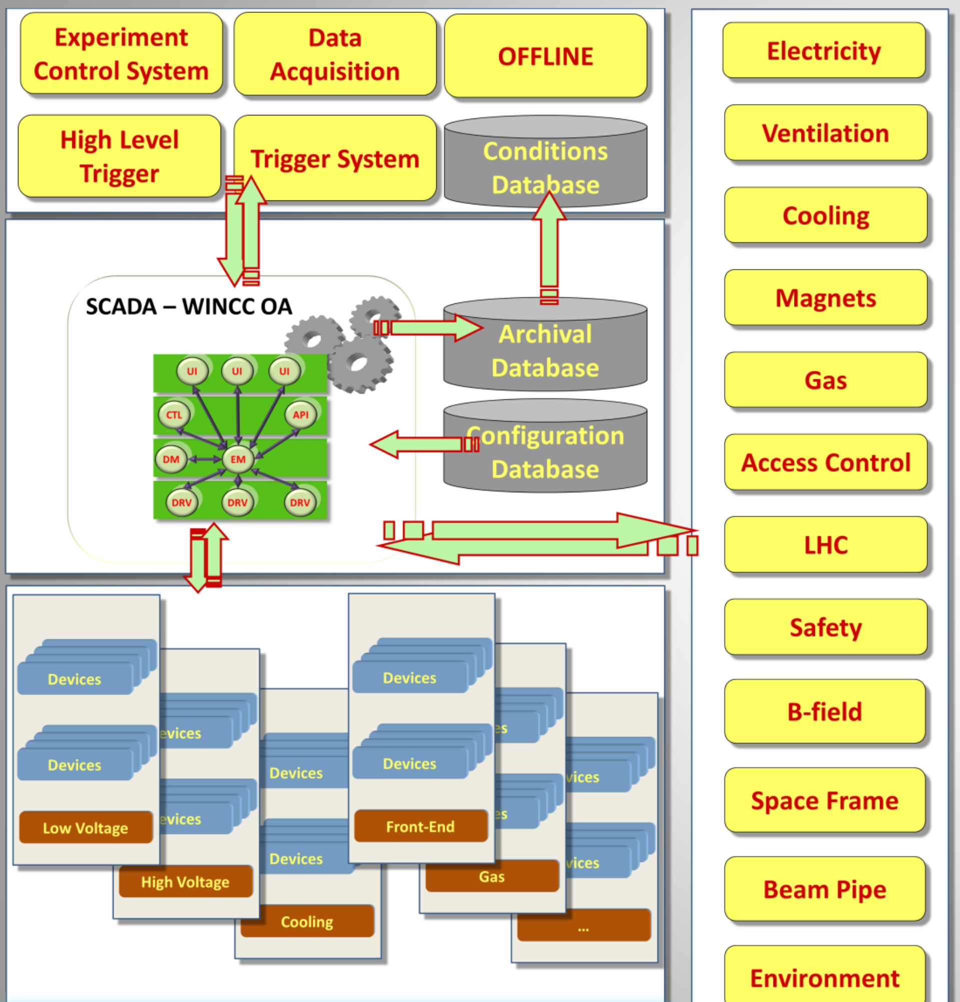


The Detector Control System

- Responsible for safe and reliable operation of the experiment
  - Designed to operate autonomously
  - Wherever possible, based on industrial standards and components
  - Built in collaboration with ALICE institutes and CERN JCOP
  - Operated by a single operator

THE ALICE DCS ARCHITECTURE

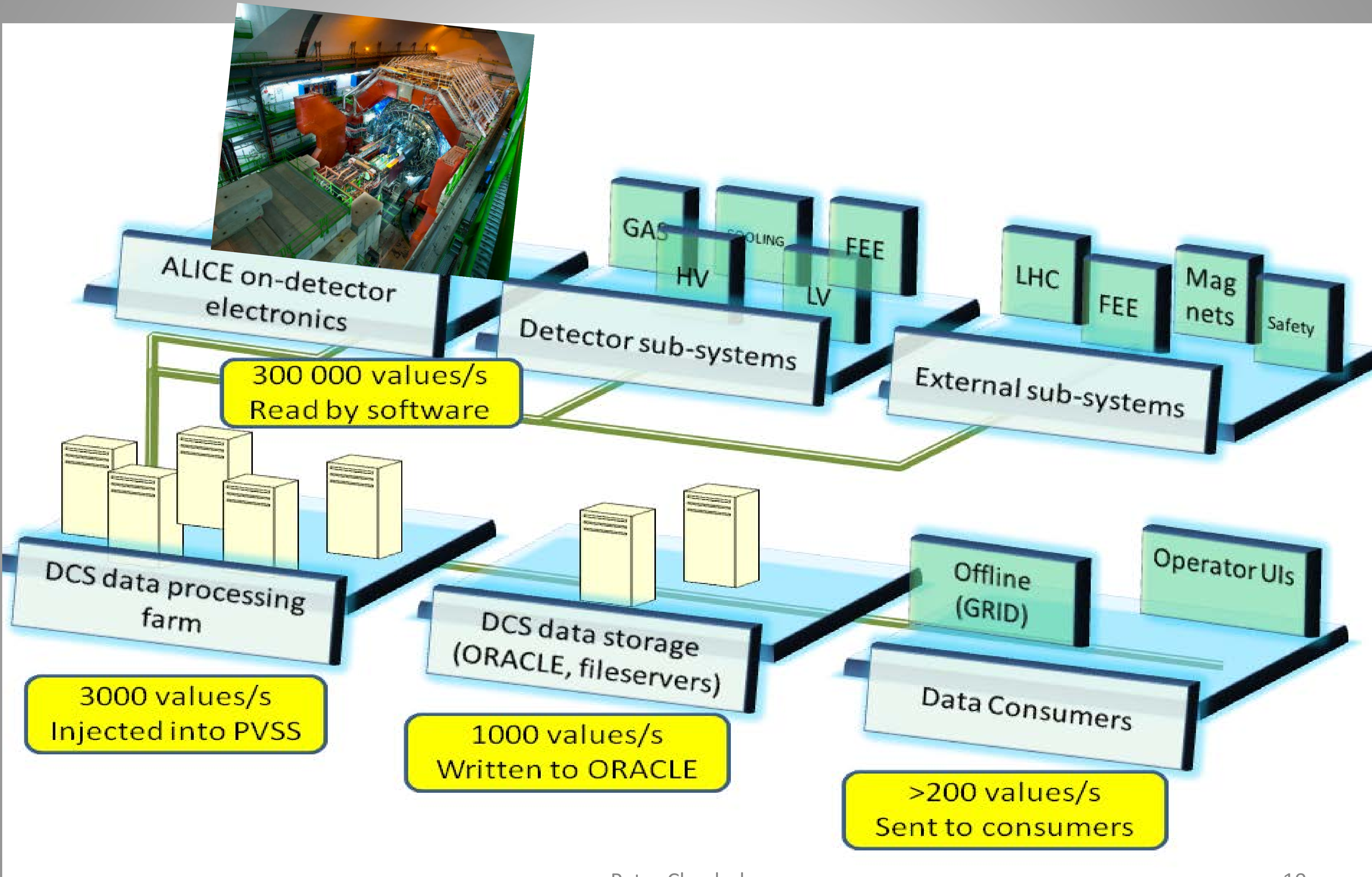
The DCS context and scale



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

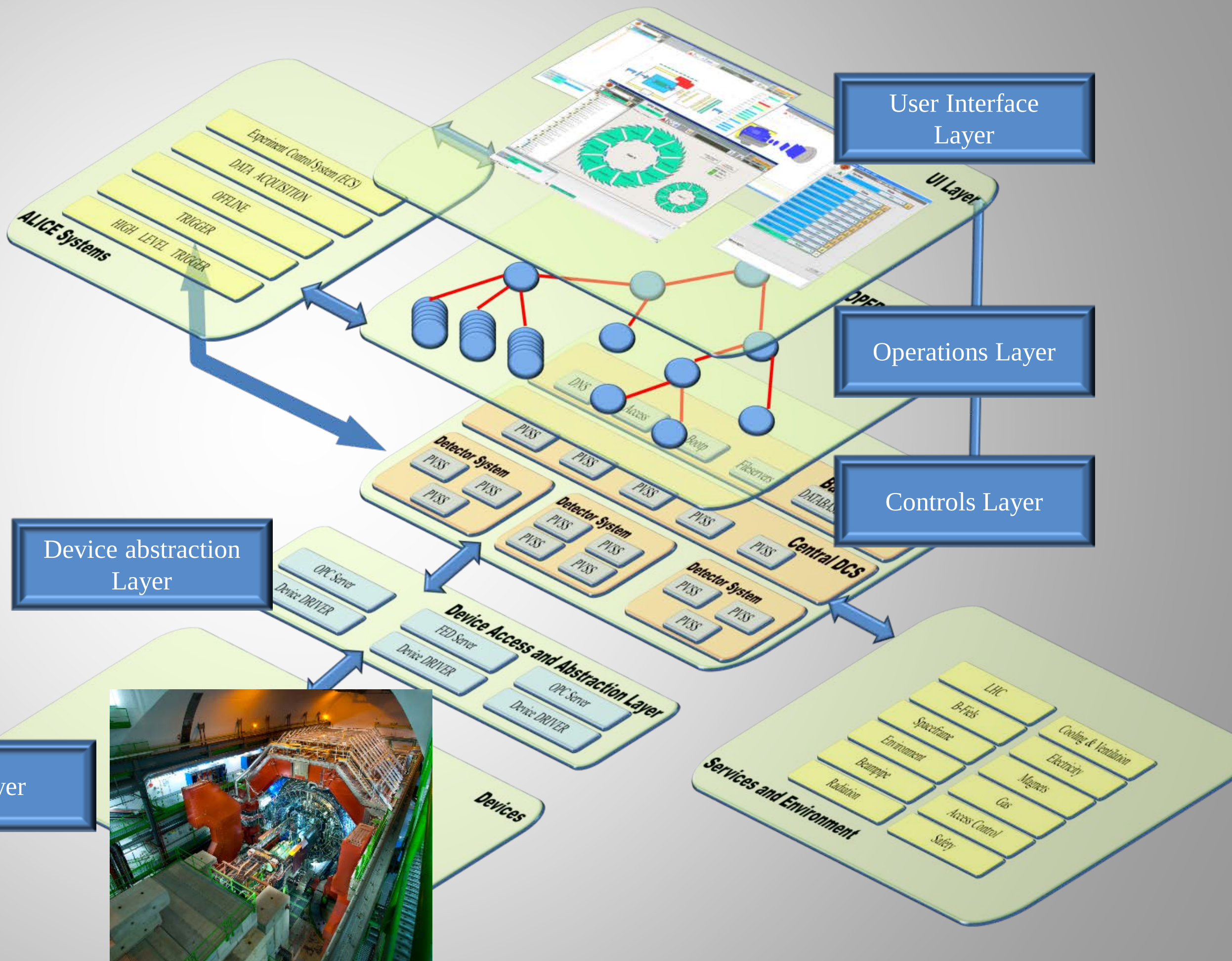
18 autonomous detector systems	1200 network attached devices
100 WINCC OA systems	>700 embedded computers
>100 subsystems	170 control computers
270 crates	200 000 OPC items
1 000 000 supervised parameters	100 000 frontend services

The DCS data flow

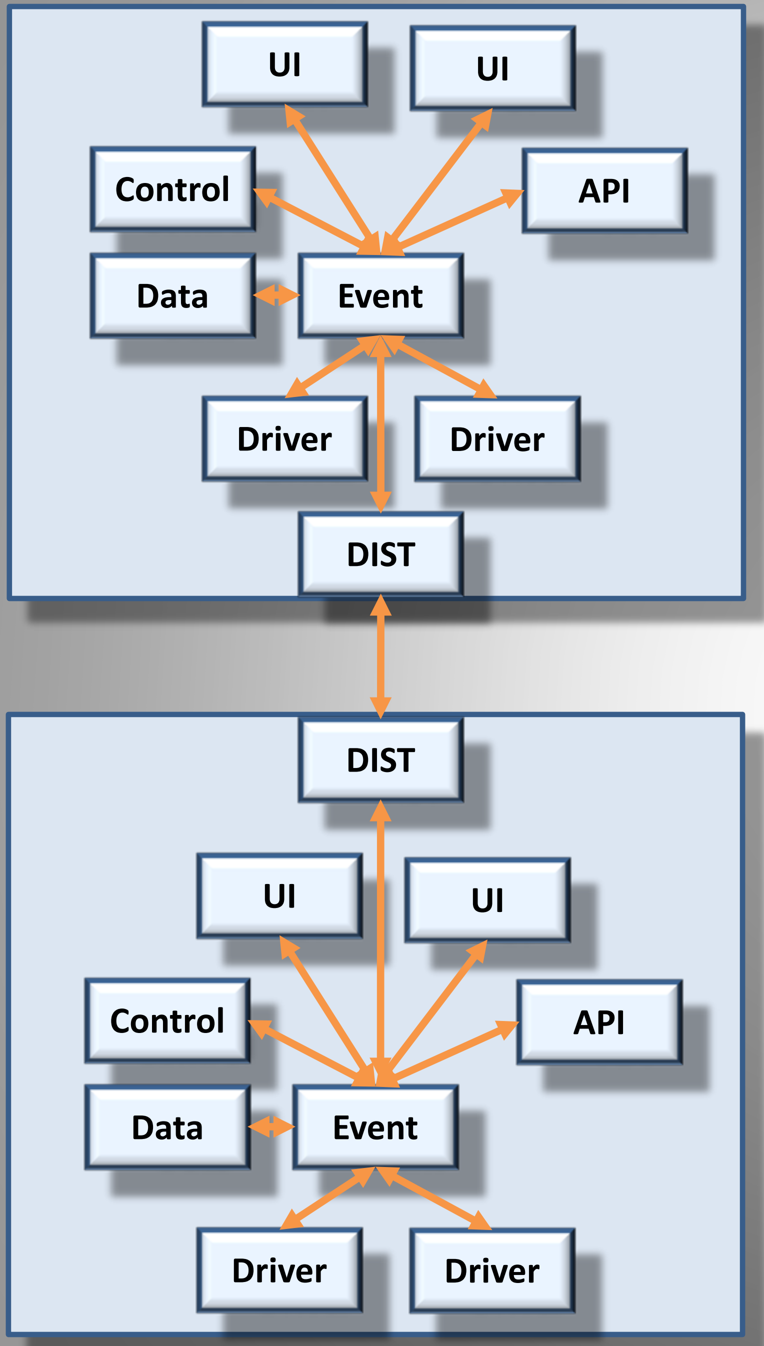


DCS Architecture

User Interface Layer	Intuitive human interface
Operations Layer	Hierarchy and partitioning by FSM
Controls Layer	Core SCADA based on WINCC OA
Device abstraction Layer	OPC and FED servers
Field Layer	DCS devices



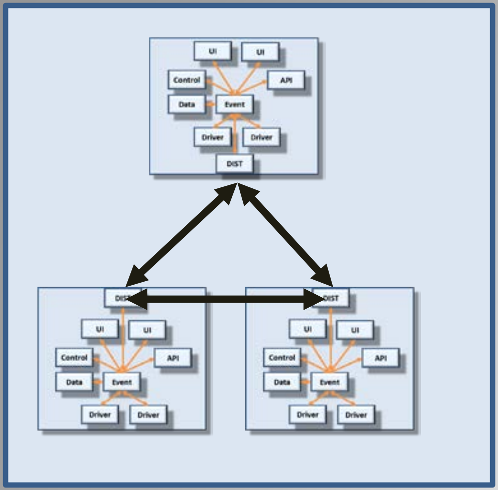
THE DCS CONTROLS LAYER

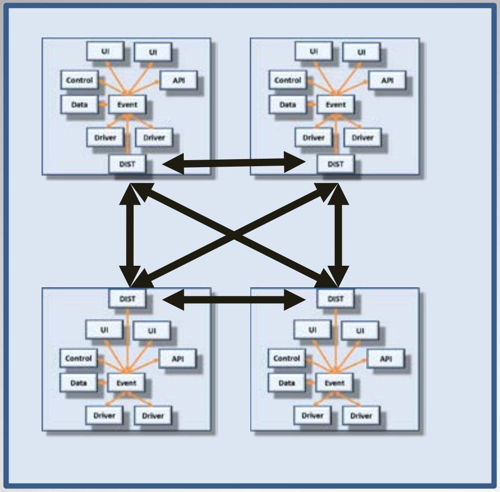


- Core of the Control Layer runs on WINCC OA SCADA system
- Single WINCC OA system is composed of managers
- Several WINCC OA systems can be connected into one distributed system

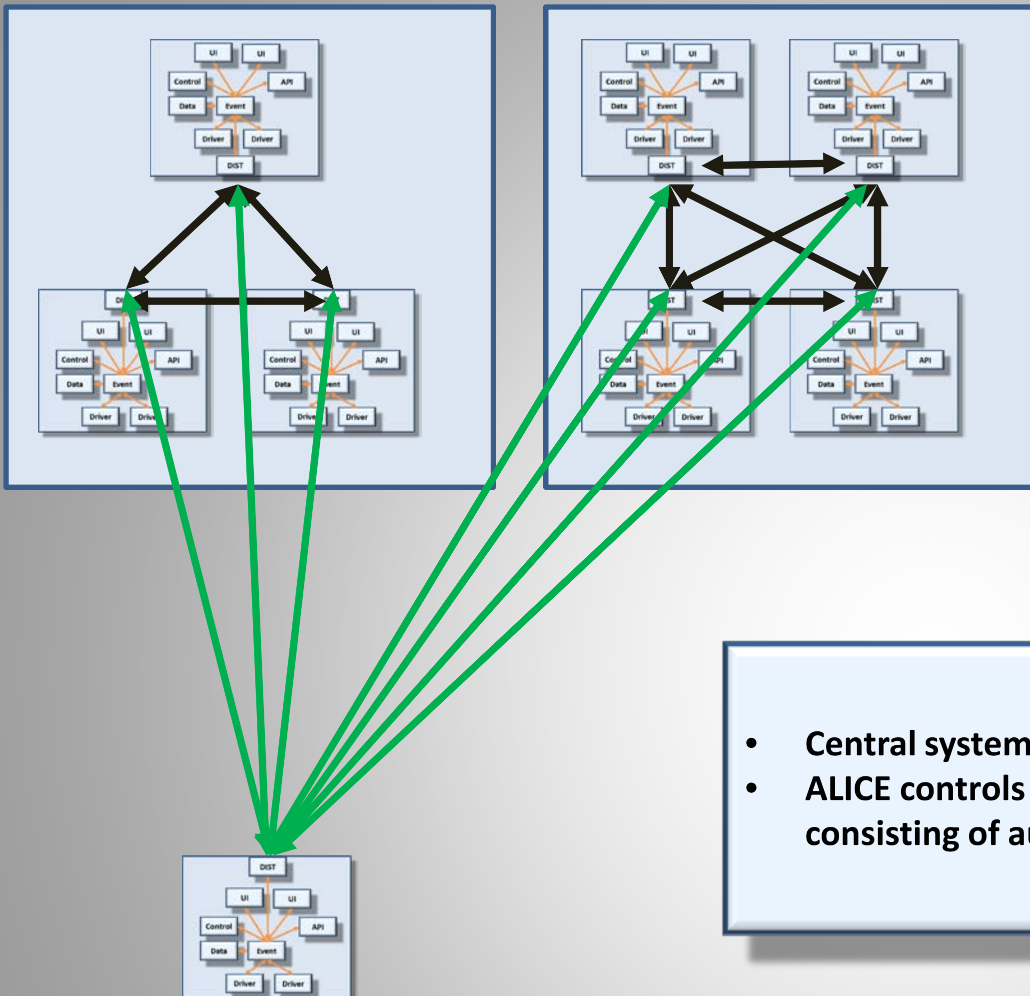
100 WINCC OA systems

2700 managers



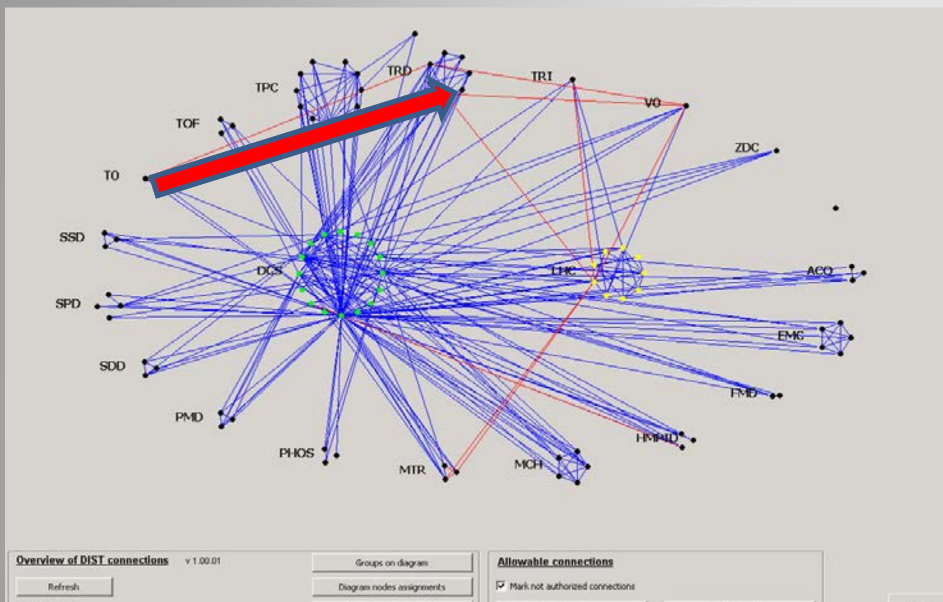


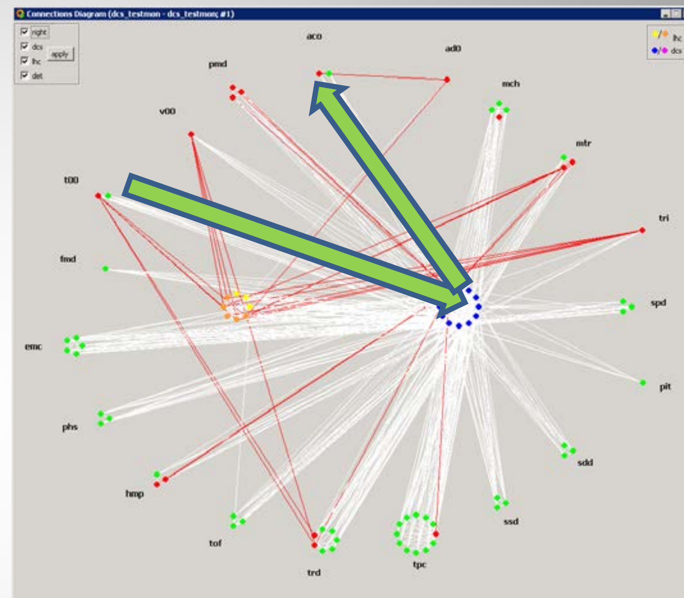
- **An autonomous distributed system is created for each detector**



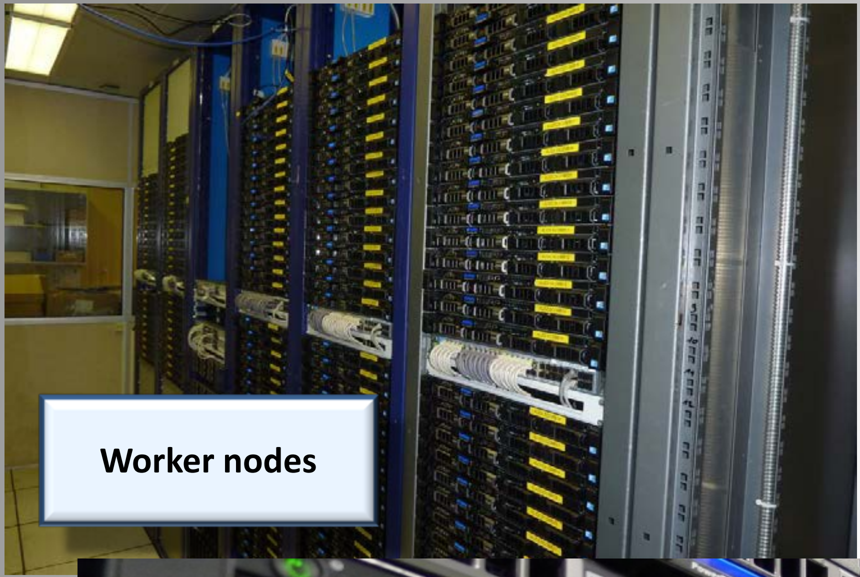
- Central systems connect to all detector systems
- ALICE controls layer is built as a distributed system consisting of autonomous distributed systems

‘illegal’ connection





- To avoid inter-system dependencies, connections between detectors are not permitted
- Central systems collect required information and re-distribute them to other systems
  - New parameters added on request
- System cross connections are monitored and anomalies are addressed

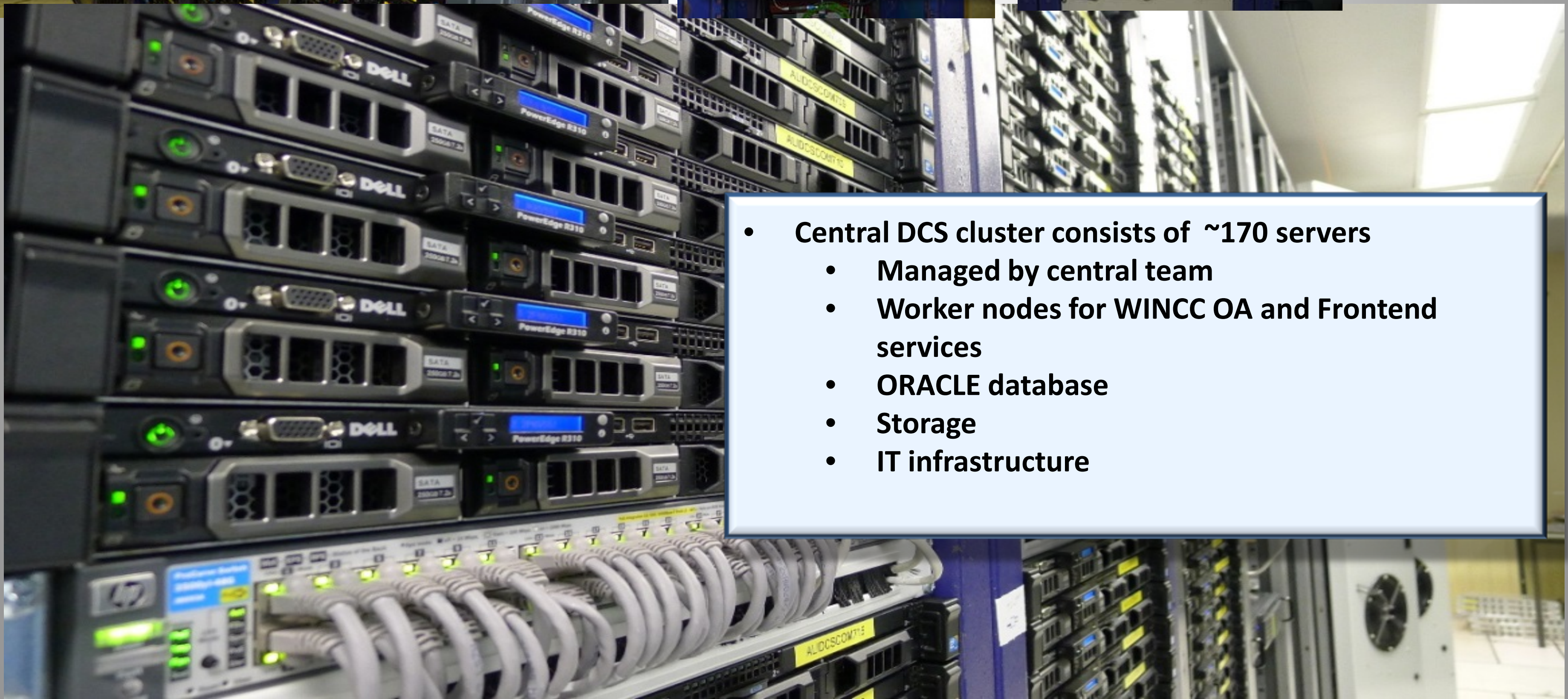


Worker nodes

Fileservers

DB servers

ORACLE size: 5.4 TB

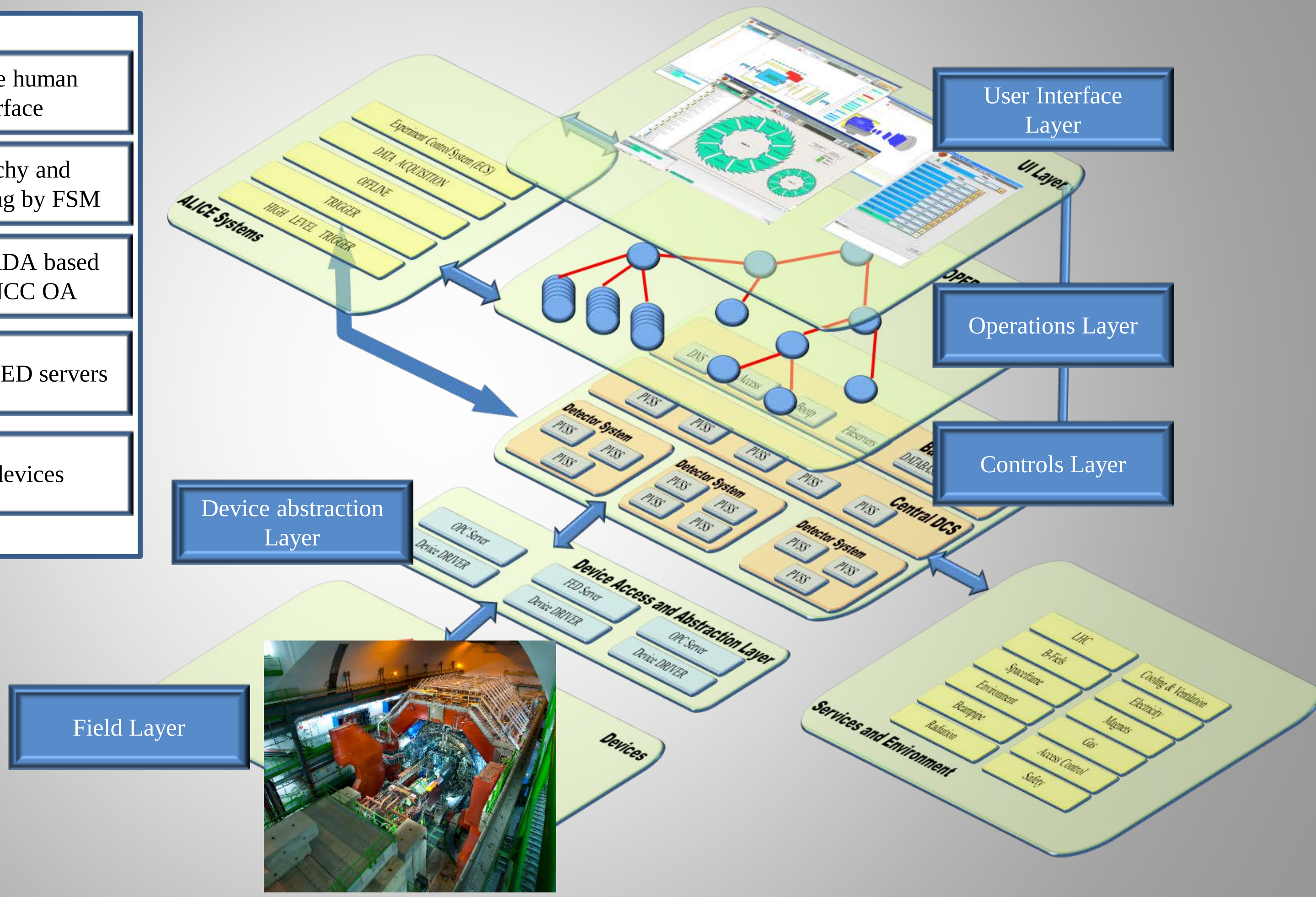


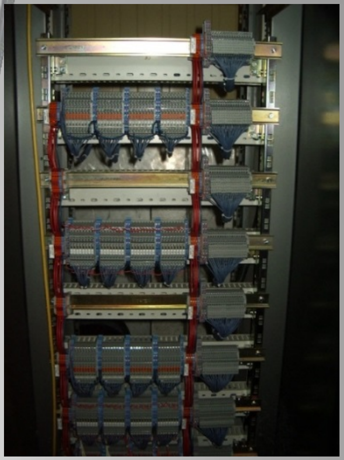
- Central DCS cluster consists of ~170 servers
  - Managed by central team
  - Worker nodes for WINCC OA and Frontend services
  - ORACLE database
  - Storage
  - IT infrastructure

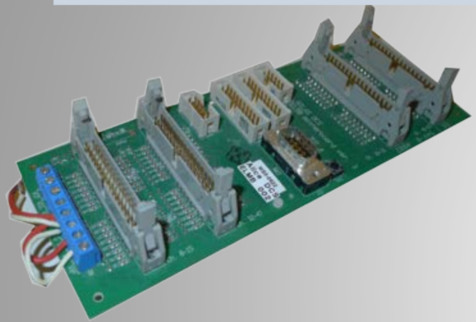
THE DCS FIELD LAYER
THE POWER OF STANDARDIZATION

DCS Architecture

User Interface Layer	Intuitive human interface
Operations Layer	Hierarchy and partitioning by FSM
Controls Layer	Core SCADA based on WINCC OA
Device abstraction Layer	OPC and FED servers
Field Layer	DCS devices

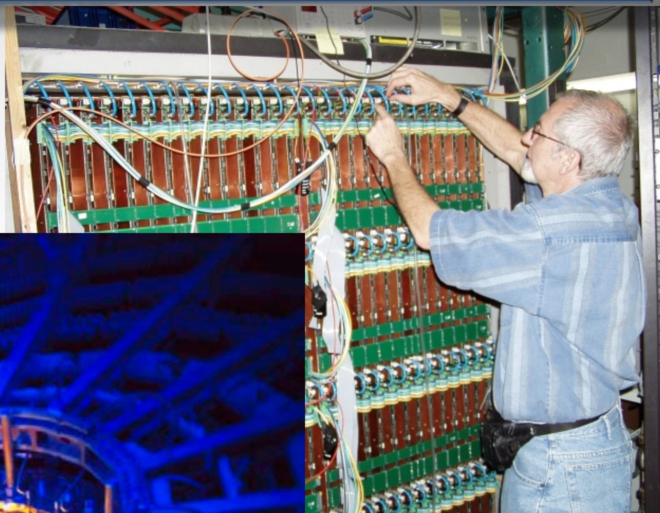


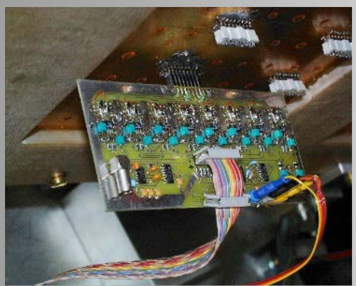


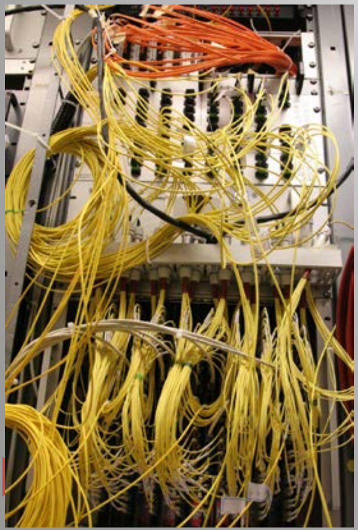


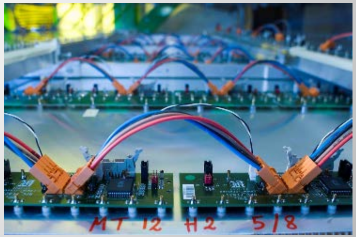
- Wherever possible, standardized components are used
  - Commercial products
  - CERN-made devices

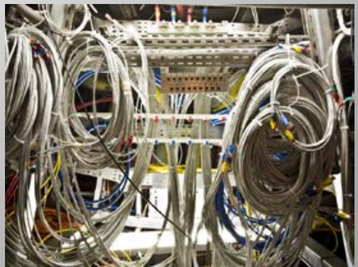
- Frontend electronics
    - Unique for each detector
    - Large diversity, multiple buses and communication channels
        - Several technologies used within the same detector











CAN

ETHERNET

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JTAG

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PROFIBUS

Custom links…

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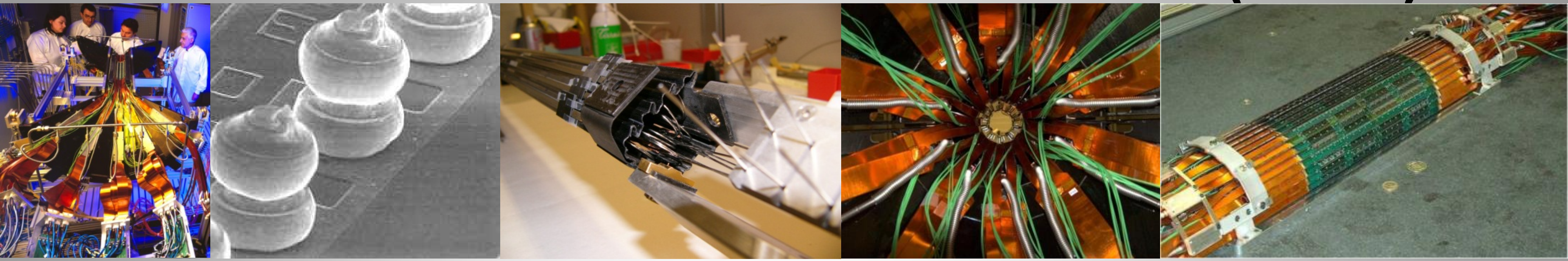
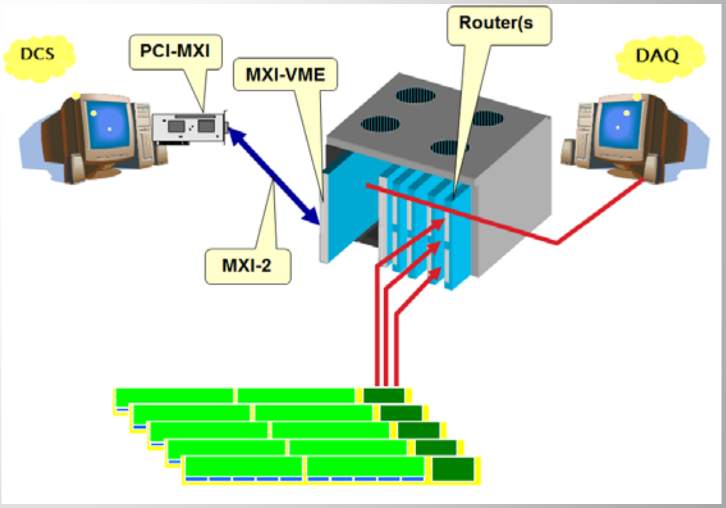
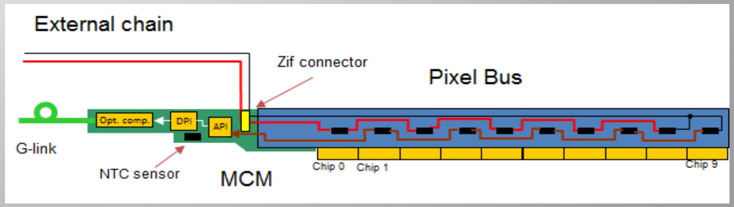
ALICE Silicon Pixel Detector (SPD)

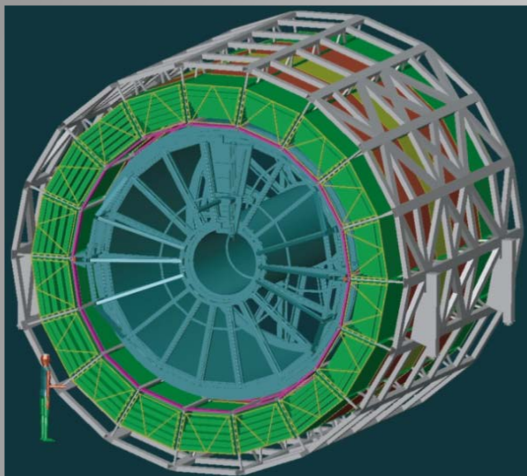


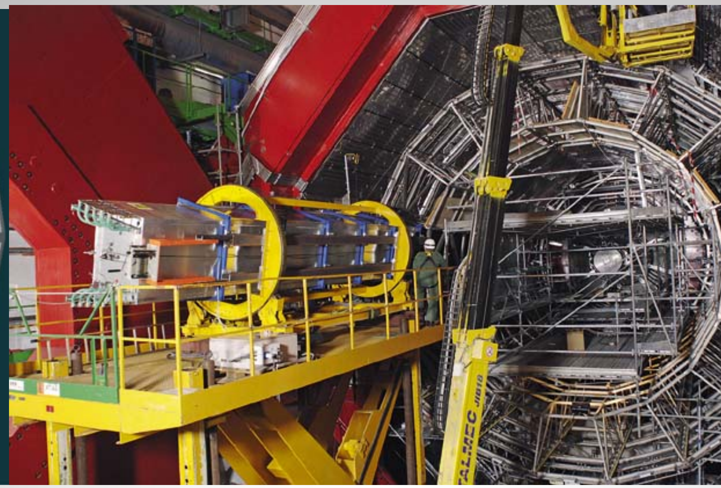
- 2 layers
  - 2.5 and 7 cm away from beam
- 10 000 000 pixels bump-bonded to 1200 readout chips
- Power dissipation 1.3kW
  - Total thickness of pixel assembly (200+150)µm
  - 1^0C/s increase in case of cooling failure
    - Less than 1min contingency!
- Reliable frontend control is essential!

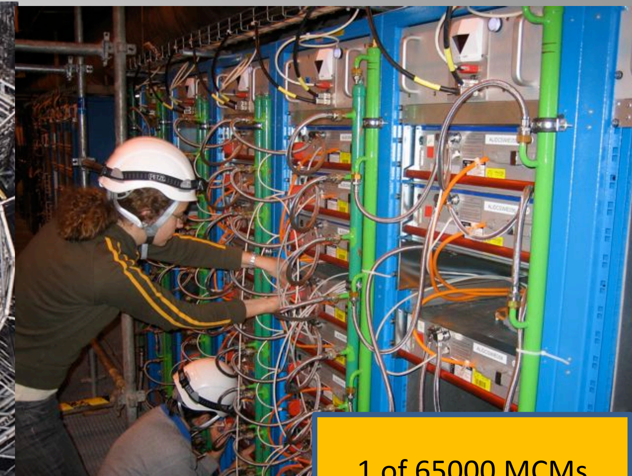




ALICE Transition Radiation Detector (TRD)





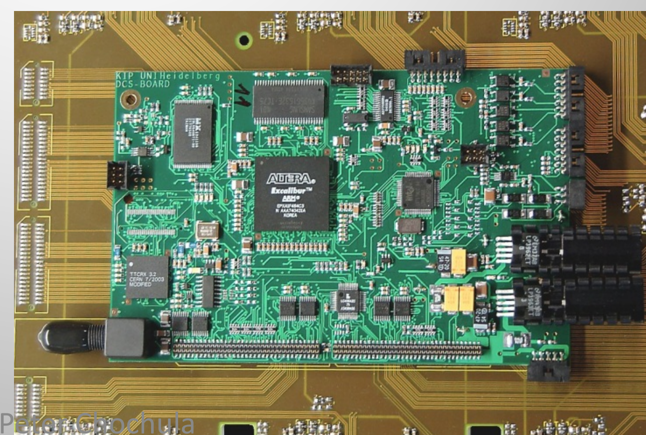


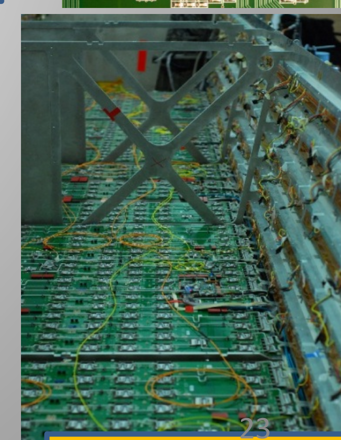
- > 500 drift chambers, 760 m^2
- 28 m^3 Xe based gas mixture
- 1.2M electronics channels
  - 65000 MCM
  - 250 000 tracklet processors
  - 17TB/s raw data

- 89 LV Power supplies
  - ~65 kW heat

1 of 65000 MCMs

DCS control board (~750 used in ALICE)





Readout boards

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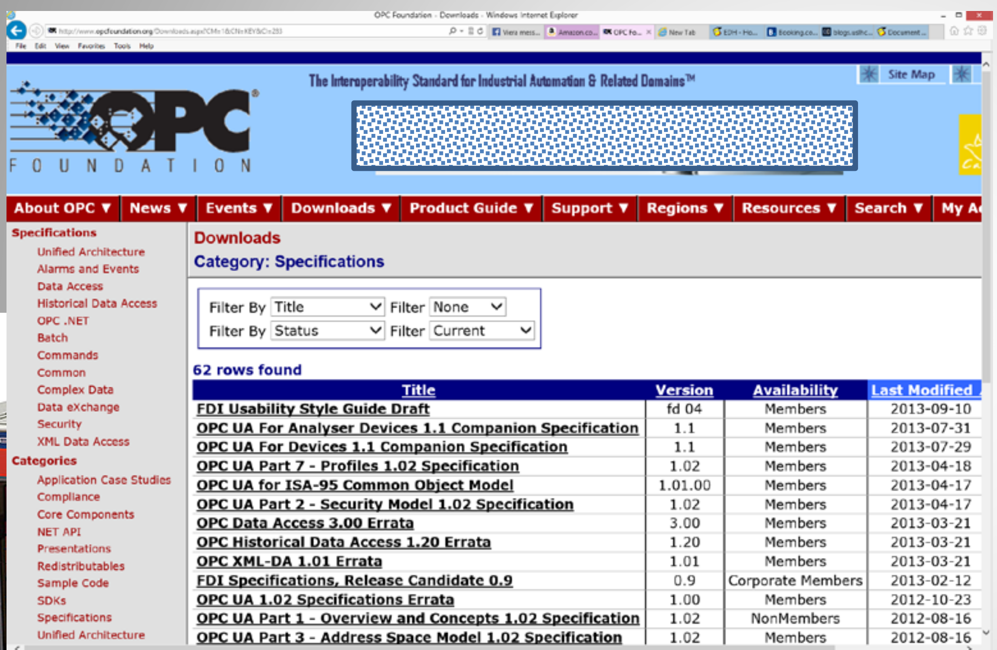
- **OPC used as a communication standard wherever possible**
  - **Native client embedded in WINCC OA**



The Interoperability Standard for Industrial Automation & Related Domains™

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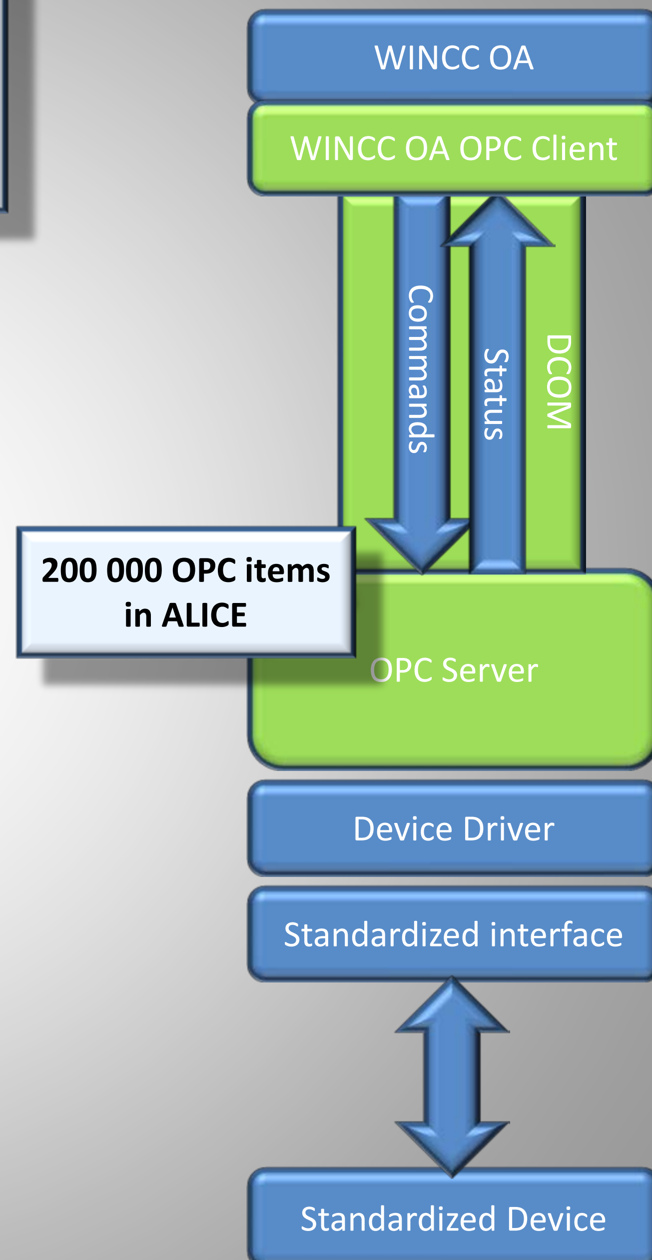
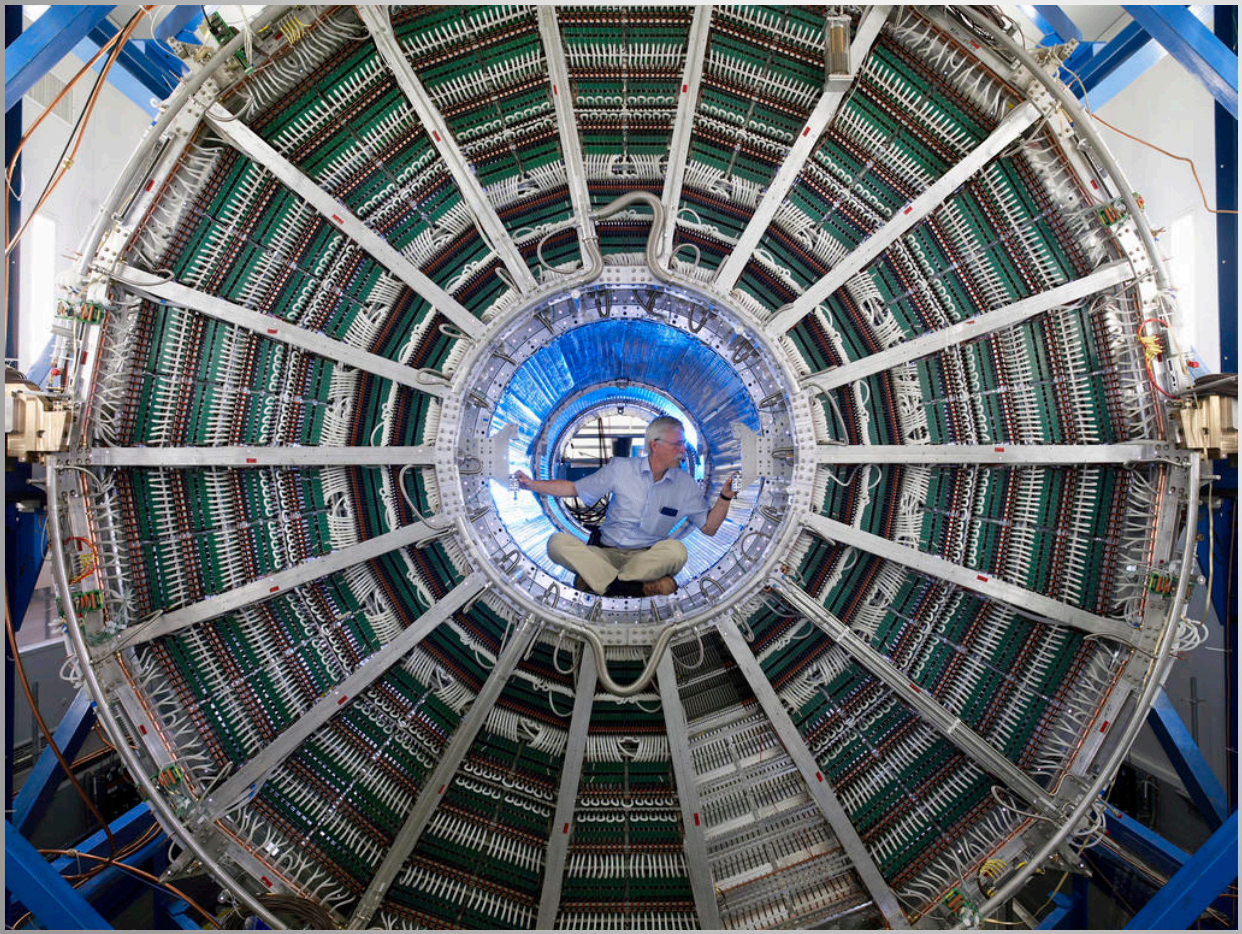
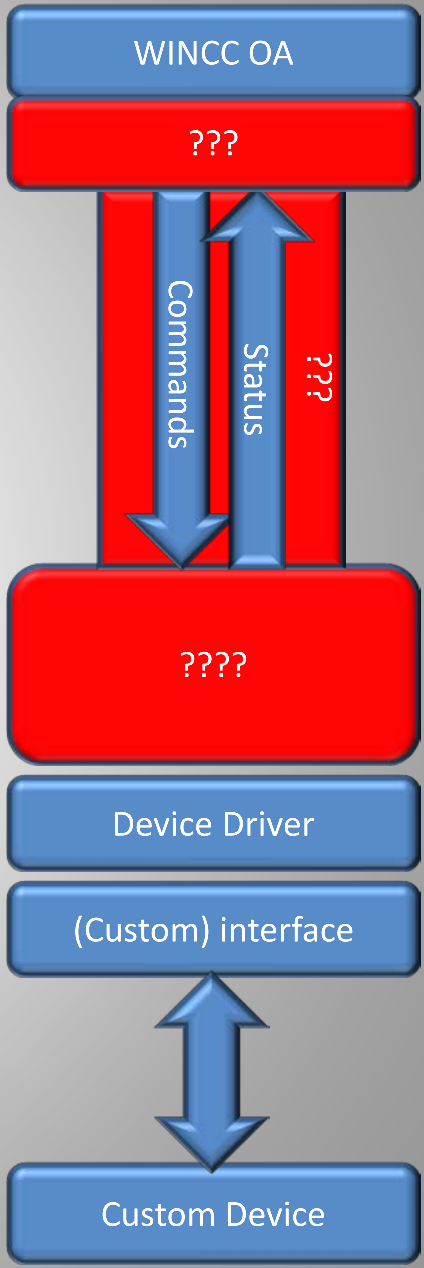
Title	Version	Availability	Last Modified
FDI Usability Style Guide Draft	fd 04	Members	2013-09-10
OPC UA For Analyser Devices 1.1 Companion Specification	1.1	Members	2013-07-31
OPC UA For Devices 1.1 Companion Specification	1.1	Members	2013-07-29
OPC UA Part 7 - Profiles 1.02 Specification	1.02	Members	2013-04-18
OPC UA for ISA-95 Common Object Model	1.01.00	Members	2013-04-17
OPC UA Part 2 - Security Model 1.02 Specification	1.02	Members	2013-04-17
OPC Data Access 3.00 Errata	3.00	Members	2013-03-21
OPC Historical Data Access 1.20 Errata	1.20	Members	2013-03-21
OPC XML-DA 1.01 Errata	1.01	Members	2013-03-21
FDI Specifications, Release Candidate 0.9	0.9	Corporate Members	2013-02-12
OPC UA 1.02 Specifications Errata	1.00	Members	2012-10-23
OPC UA Part 1 - Overview and Concepts 1.02 Specification	1.02	NonMembers	2012-08-16
OPC UA Part 3 - Address Space Model 1.02 Specification	1.02	Members	2012-08-16

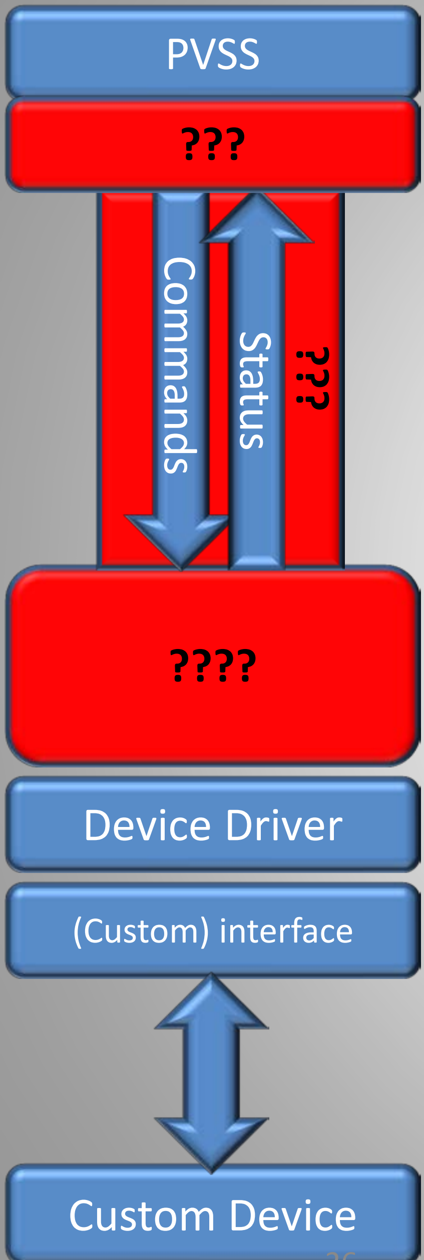


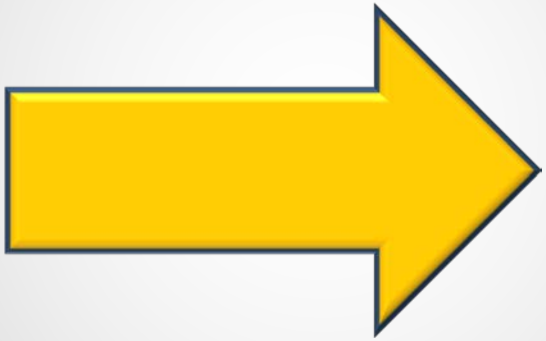
- Missing standard for custom devices
  - OPC to heavy to be developed and maintained by institutes
  - Frontend drivers often scattered across hundreds of embedded computers (Arm Linux)

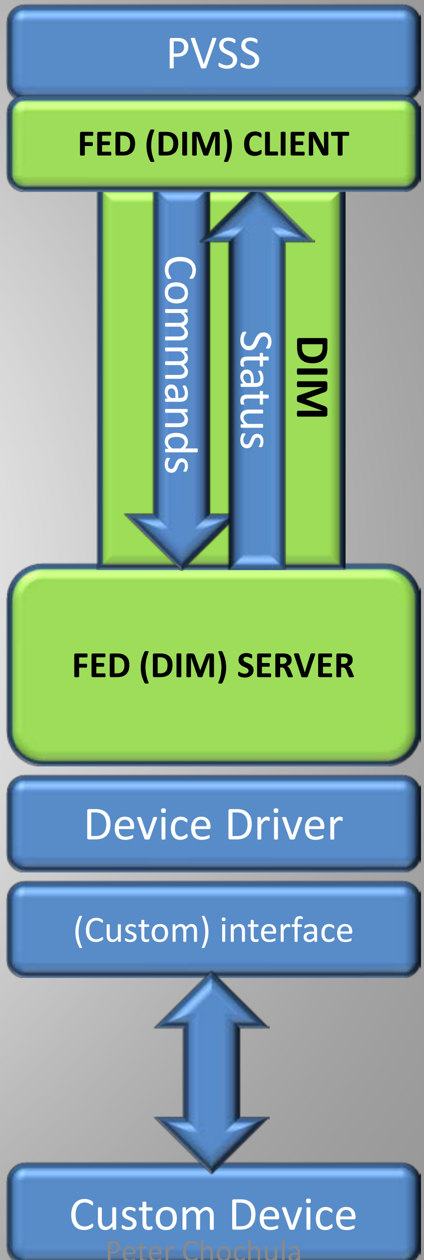




Filling the gap







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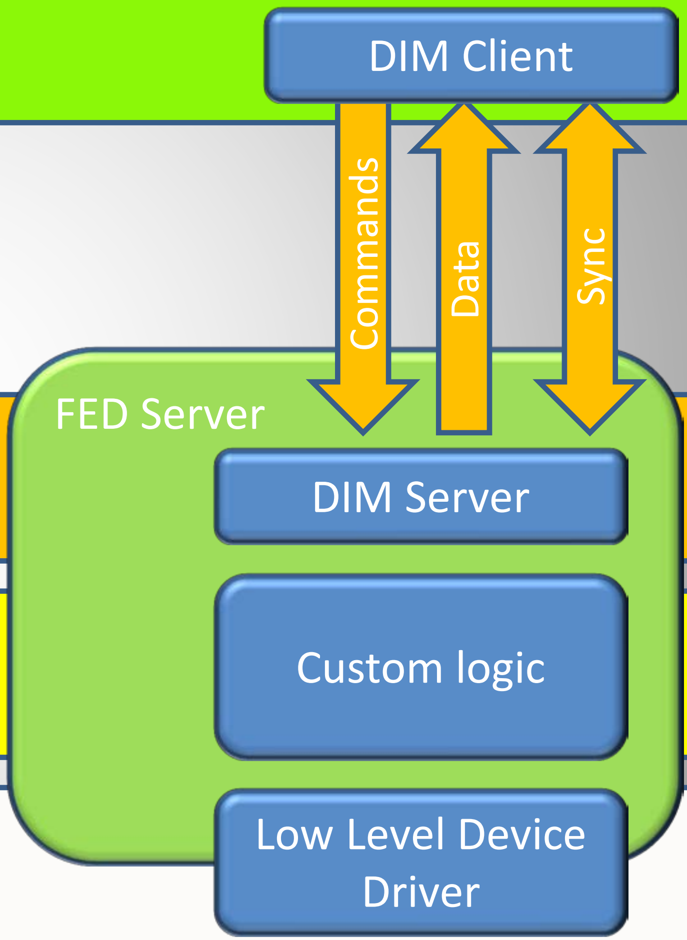
Generic FED architecture

Generic client implemented as PVSS manager

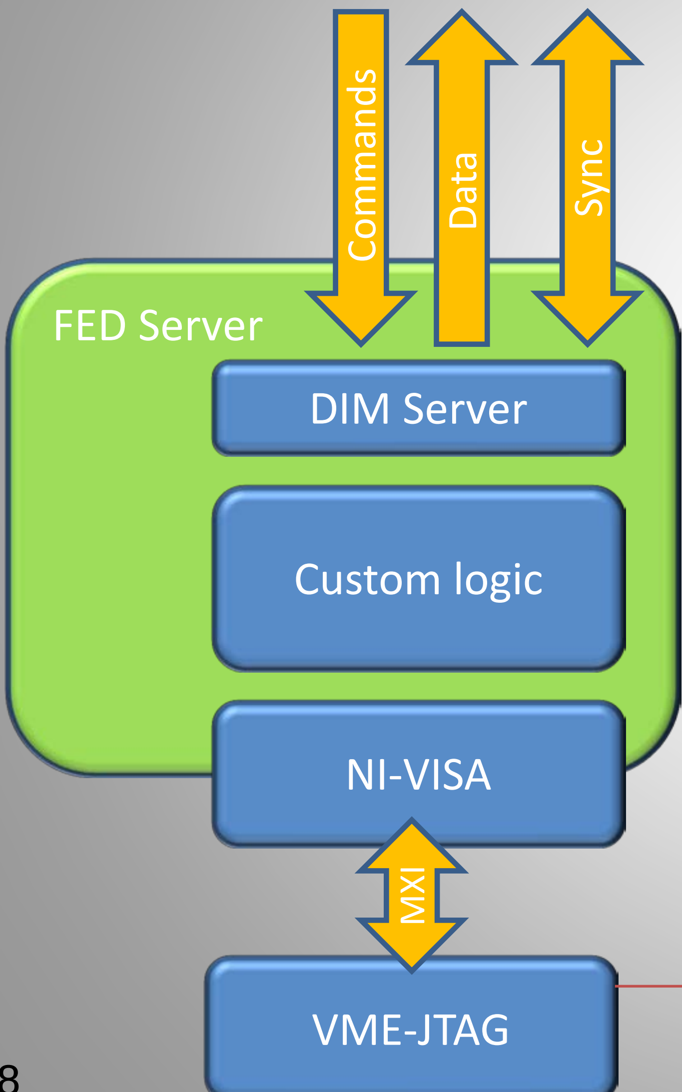
Communication interface with standardized commands and services

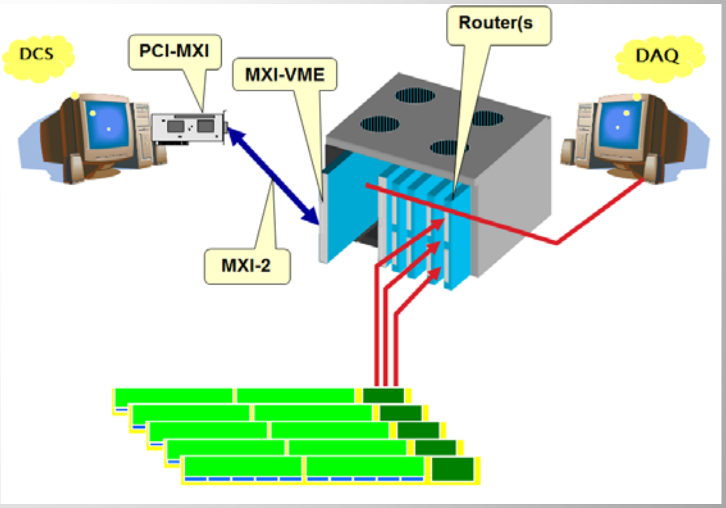
Device/specific layer providing high-level functionality (i.e. Configure, reset...)

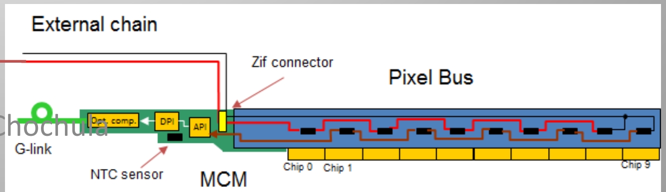
Low-level device interface (i.e. JTAG driver and commands)



SPD FED Implementation







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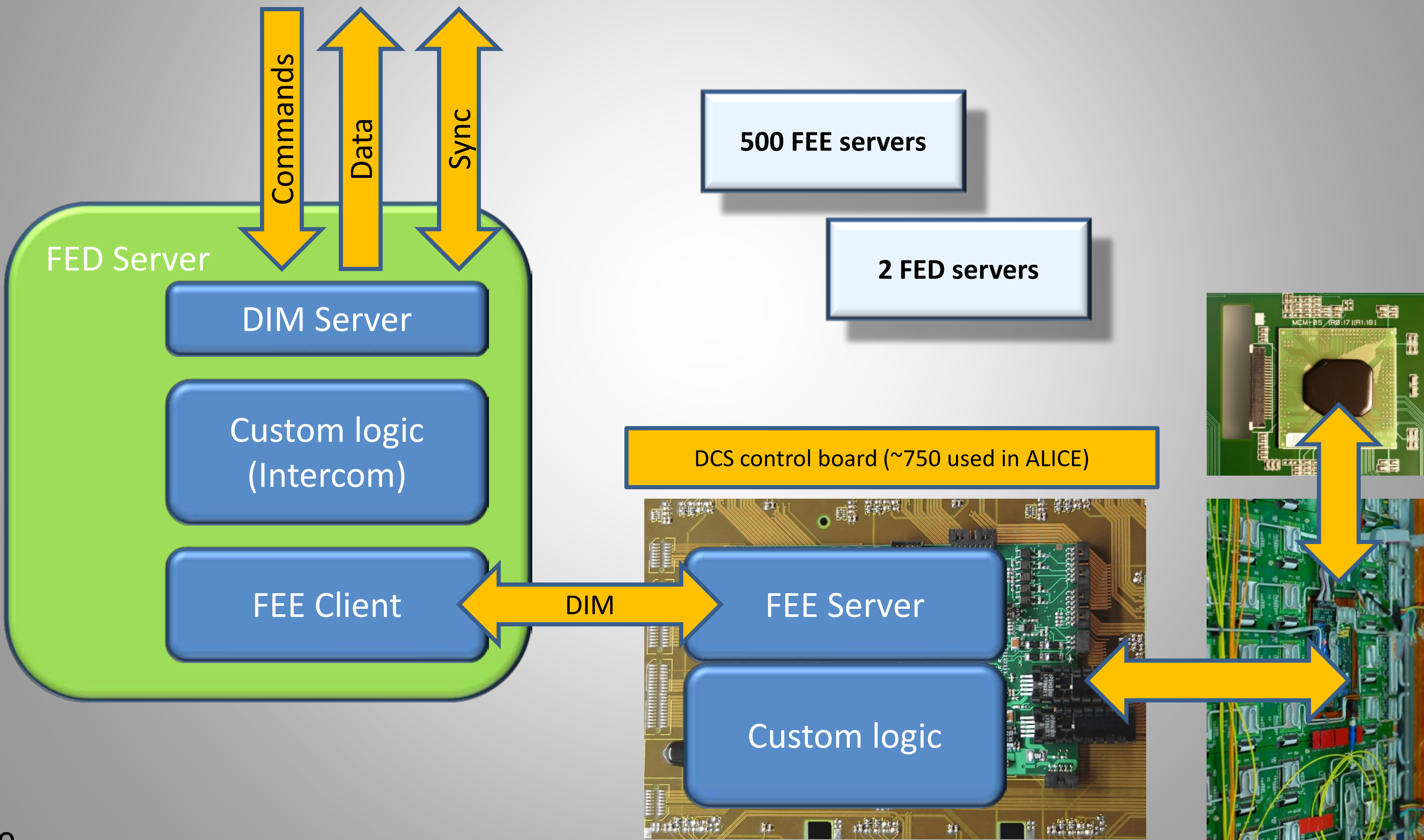
TRD FED Implementation



THE DCS OPERATION LAYER

Hierarchical approach

Based on CERN toolkit (SMI++)

Each node modelled as FSM

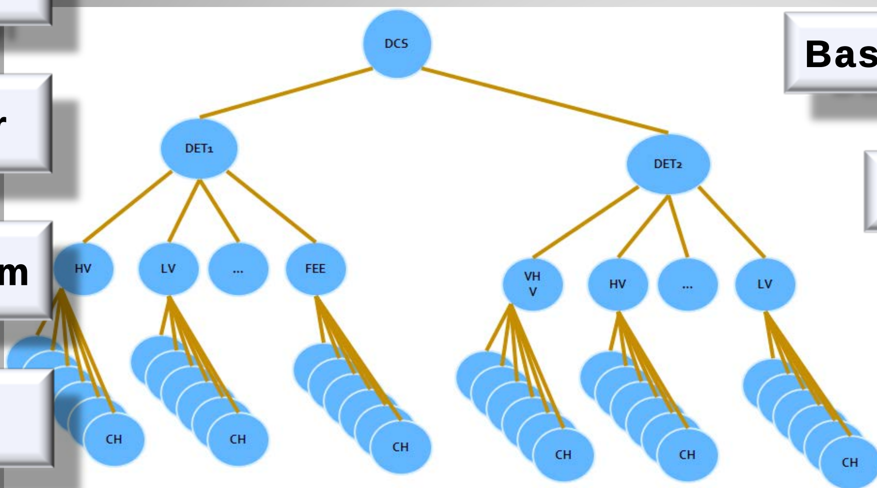
Integrated with WINCC OA

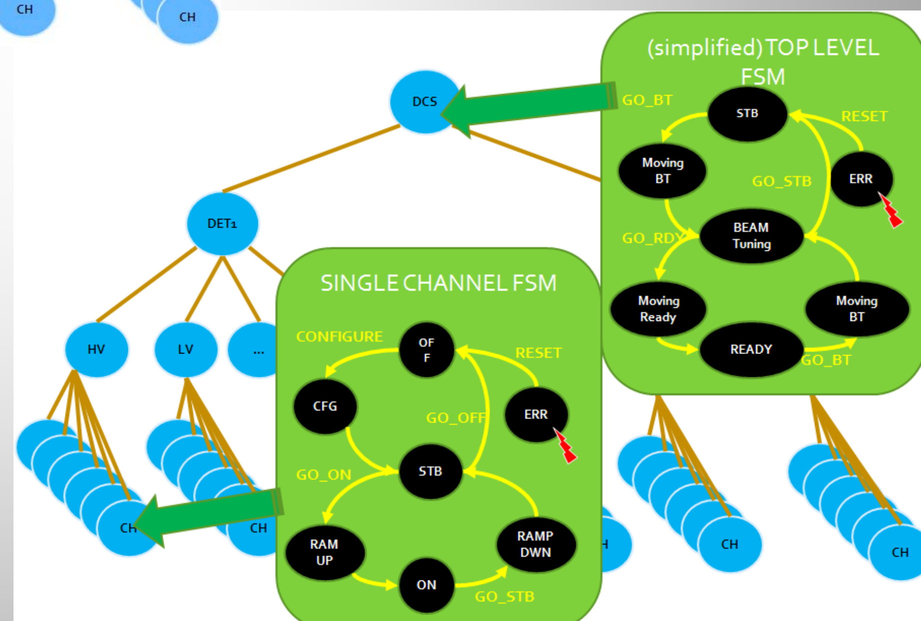
Central control

Detector

Subsystem

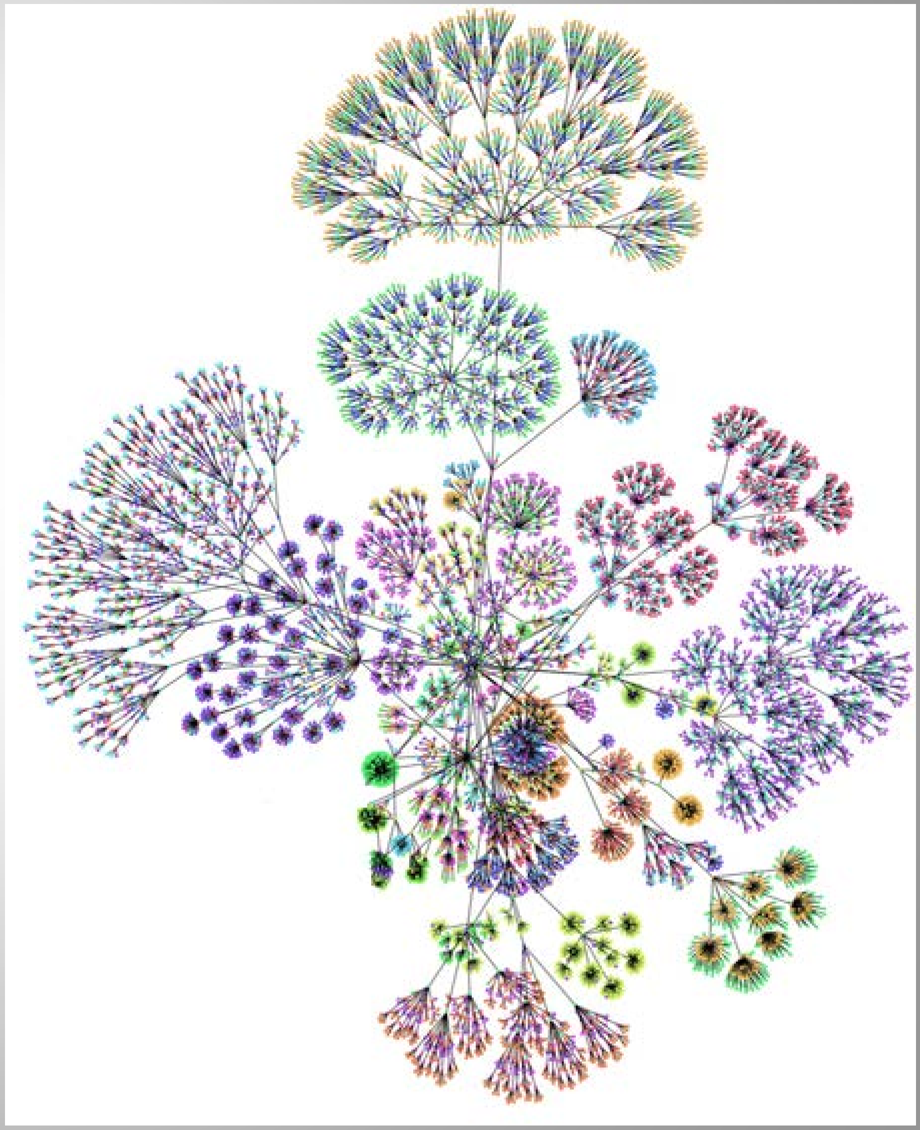
Device

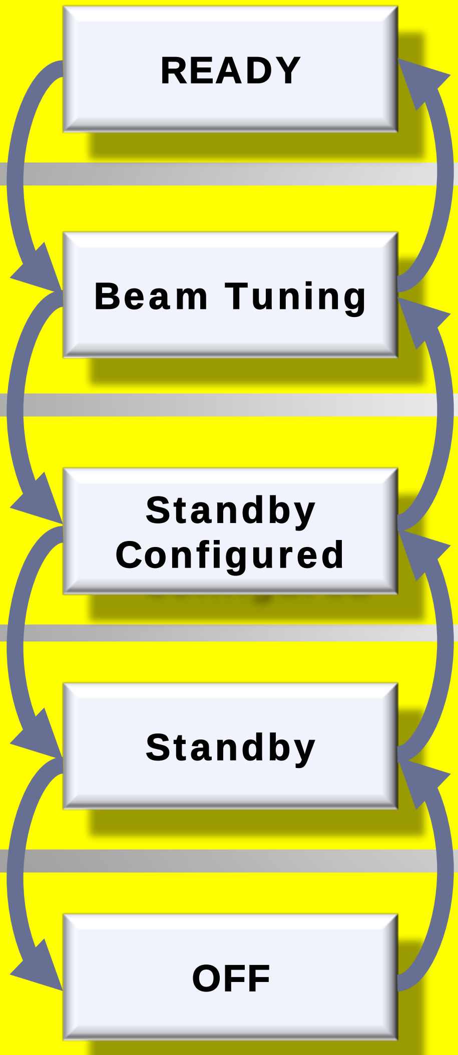




ALICE central FSM hierarchy

- **1 top DCS node**
- **18 detector nodes**
- **100 subsystems**
- **5000 logical devices**
- **10000 leaves**





READY for Physics

Compatible with beam operations

Configuration loaded

Devices powered ON

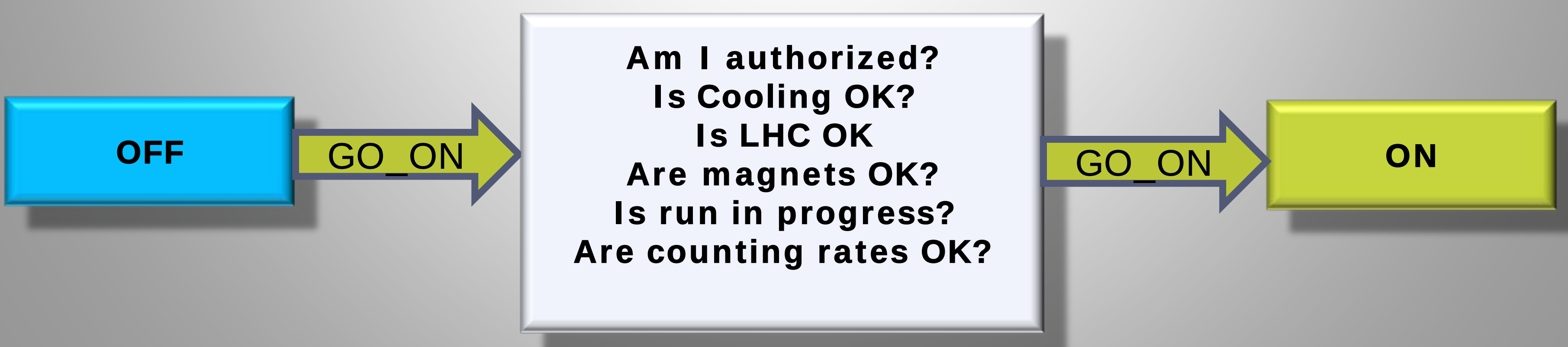
Everything OFF

Atomic actions sometimes require complex logic:

Some detectors require cooling before they turn on the low voltage
But
Frontend will freeze if cooling is present without low voltage

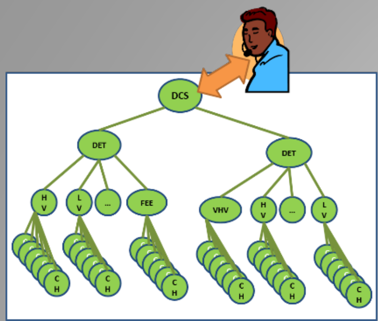
Unconfigured chips might burn (high current) if powered
But
The chips can be configured only once powered

Originally simple operation become complex in real experiment environment
Cross-system dependencies are introduced.

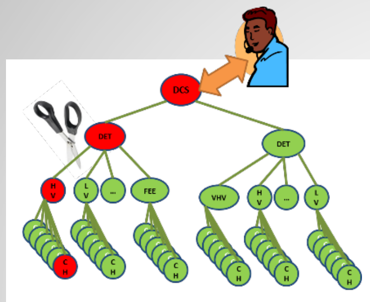


- Each detector has specific needs
- Operational sequences and dependencies are too complex to be mastered by operators
- Operational details are handled by FSM prepared by experts and continuously tuned

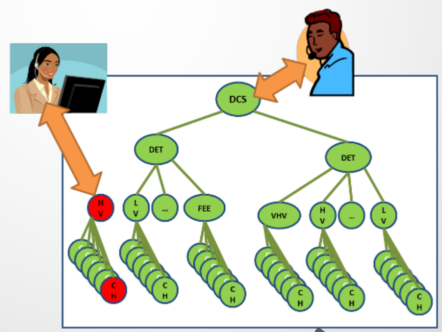
Partitioning



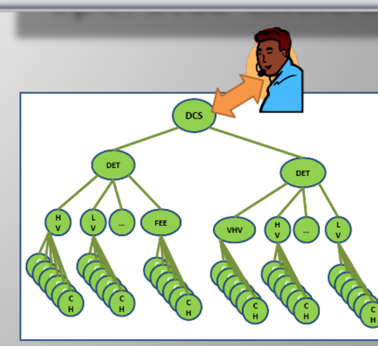
Single operator controls ALICE



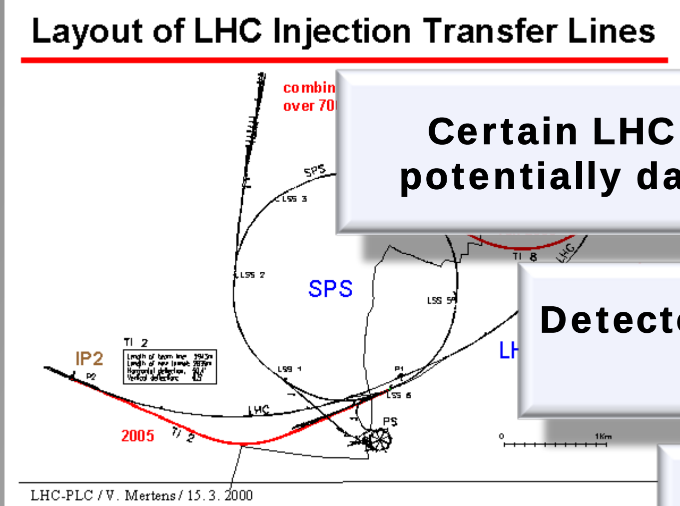
Failing part is removed from hierarchy



Remote expert operates excluded part



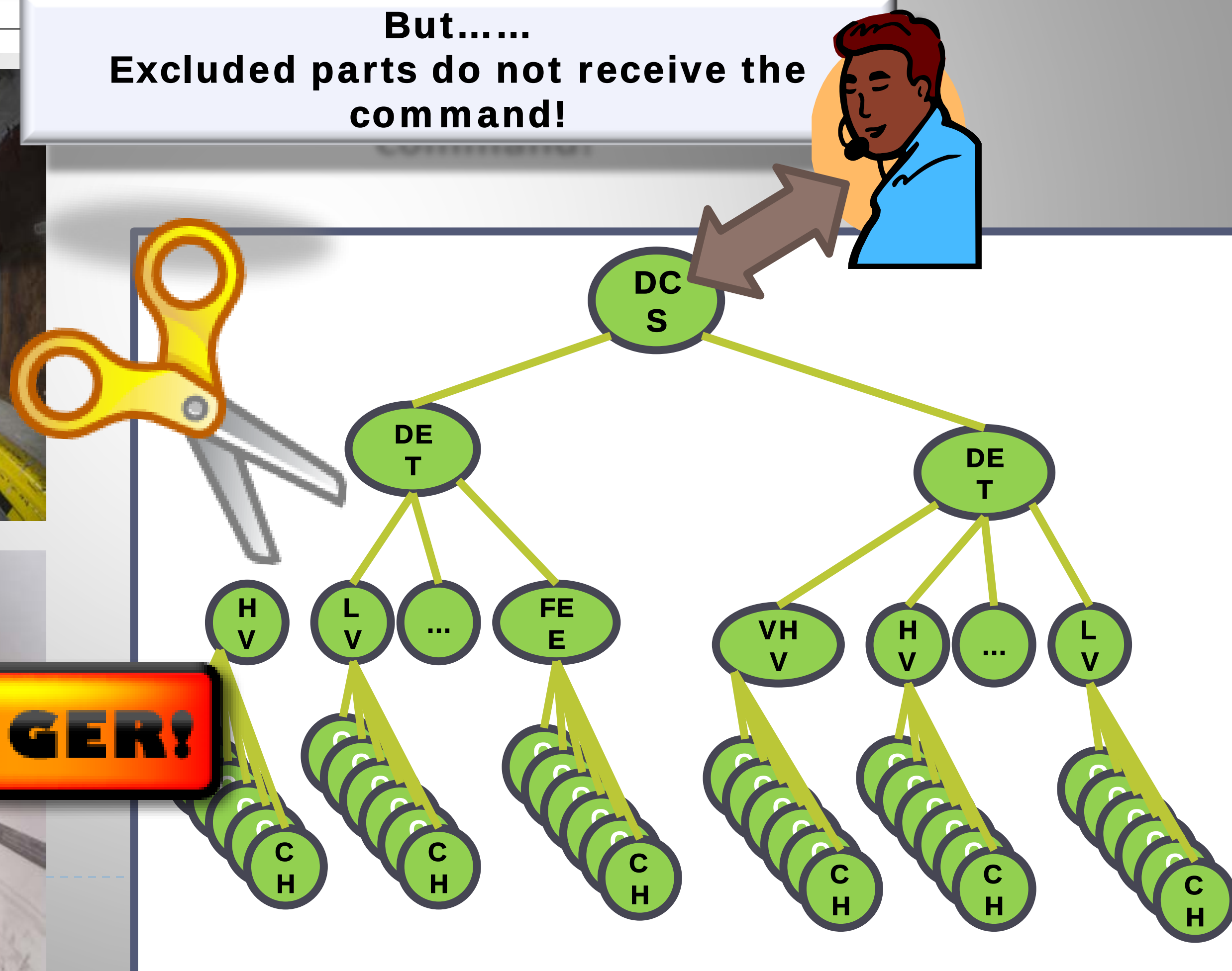
- ALICE is primary interested in ion physics
- During the LHC operation with protons, there is small room for developments and improvements
- Partitioning is used by experts to allow for parallel operation



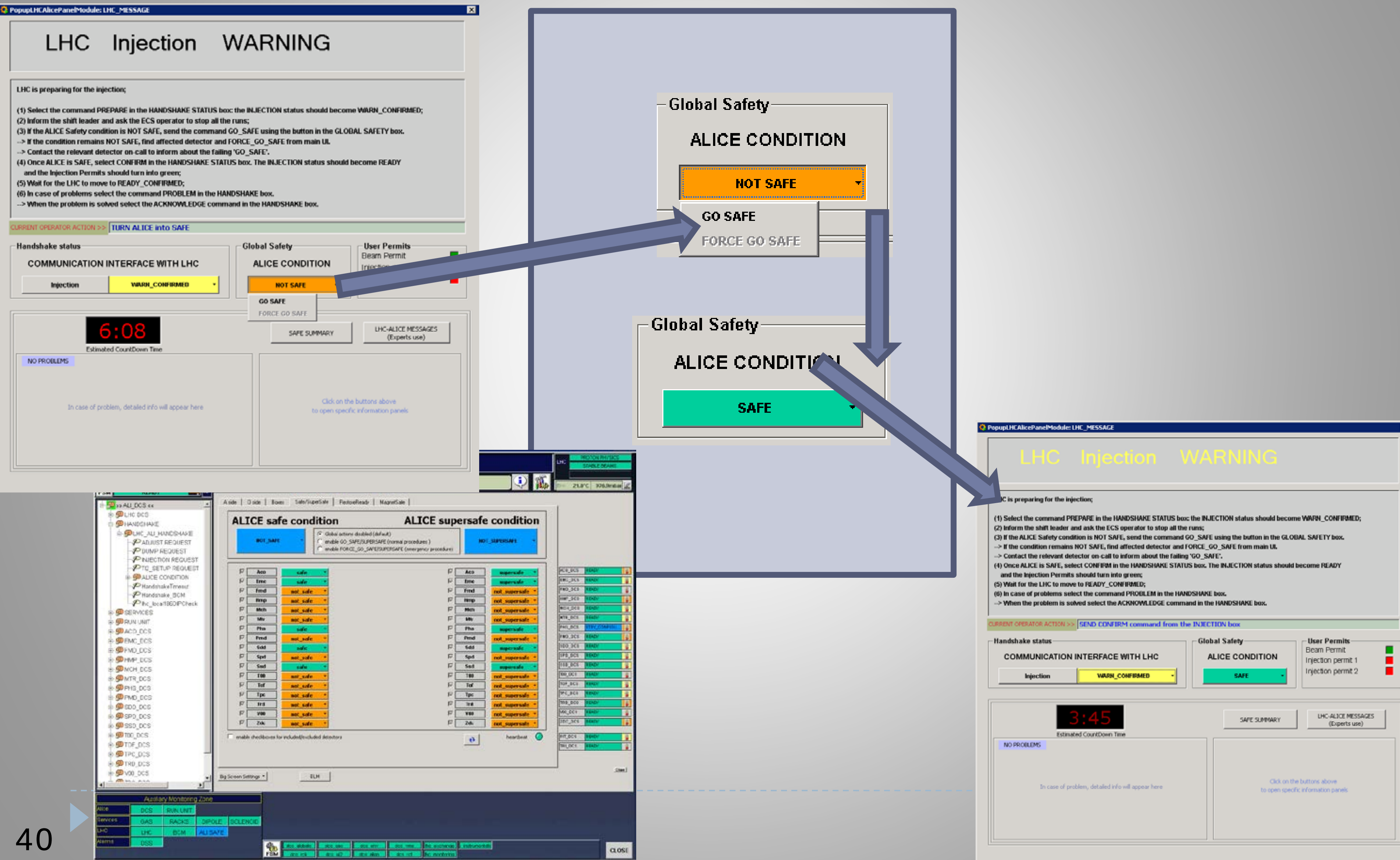
Certain LHC operations might be potentially dangerous for detectors

Detectors can be protected by modified settings (lower HV…)

But……
Excluded parts do not receive the command!



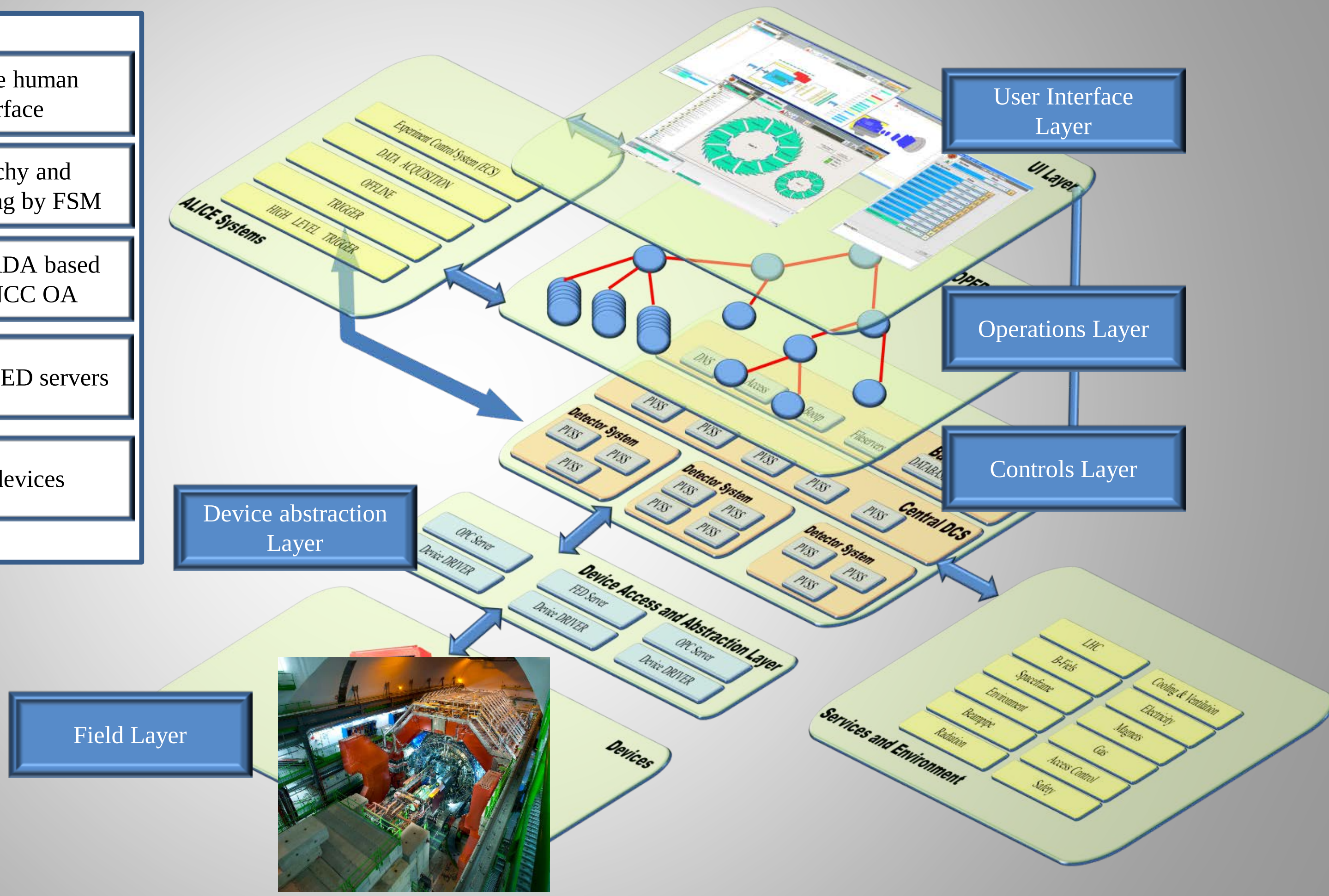
- For potentially dangerous situations a set of procedure independent on FSM is available
- Automatic scripts check all critical parameters directly also for excluded parts
- Operator can bypass FSM and force protective actions to all components

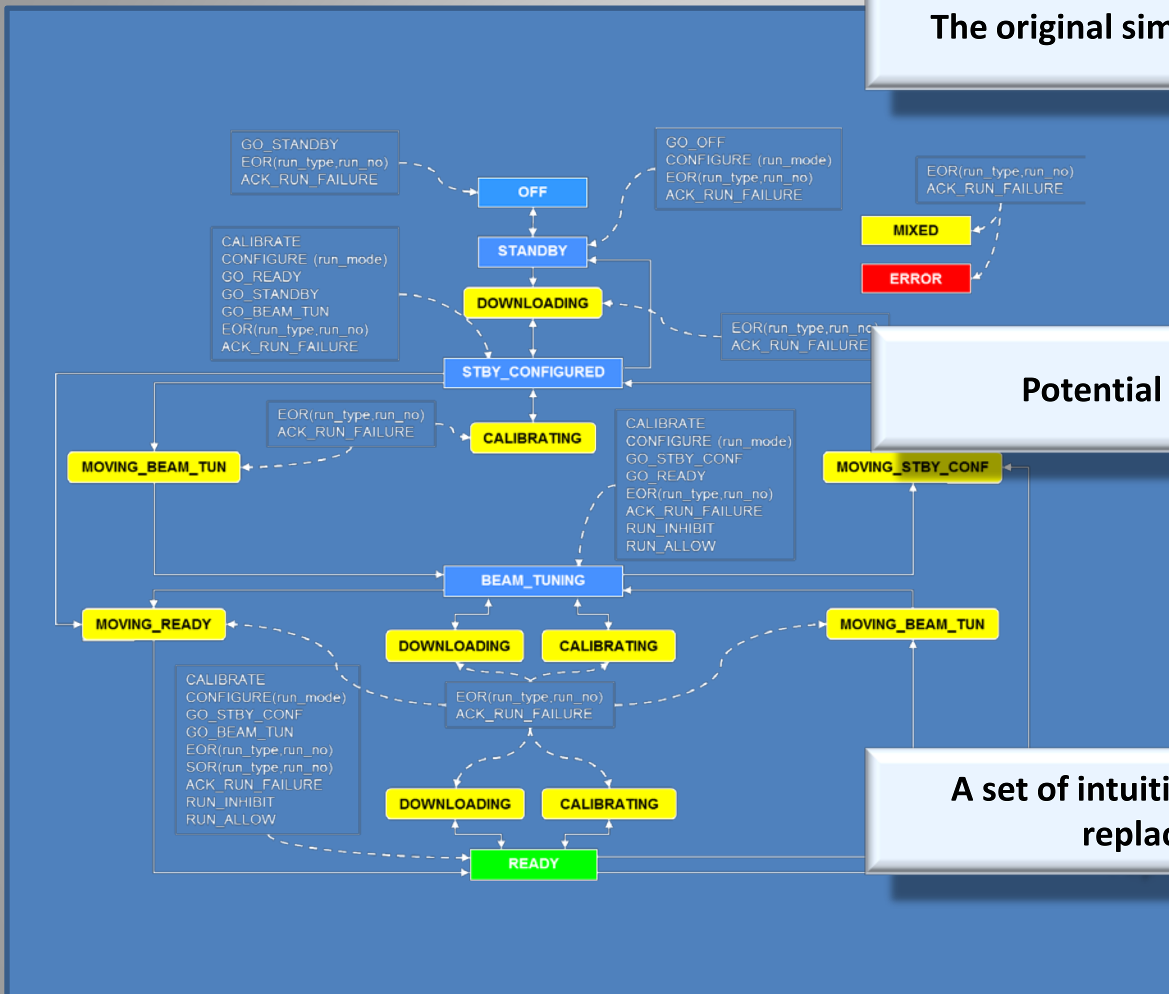

PopupLHCAlicePanelModule: LHC_MESSAGE
LHC Injection WARNING
LHC is preparing for the injection;
(1) Select the command PREPARE in the HANDSHAKE STATUS box: the INJECTION status should become WARN_CONFIRMED;
(2) Inform the shift leader and ask the ECS operator to stop all the runs;
(3) If the ALICE Safety 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 detector and FORCE_GO_SAFE from main UI.
--> Contact the relevant detector on-call to inform about the failing 'GO_SAFE'.
(4) Once ALICE is SAFE, select CONFIRM in the HANDSHAKE STATUS box. The INJECTION status should become READY 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 >> TURN ALICE into SAFE
Handshake status
COMMUNICATION INTERFACE WITH LHC
Injection
WARN_CONFIRMED
Global Safety
ALICE CONDITION
NOT SAFE
GO SAFE
FORCE GO SAFE
User Permits
Beam Permit
6:08
Estimated CountDown Time
SAFE SUMMARY
LHC-ALICE MESSAGES (Experts use)
NO PROBLEMS
In case of problem, detailed info will appear here
Click on the buttons above to open specific information panels
ALICE safe condition
ALICE supersafe condition
Global Safety
ALICE CONDITION
NOT SAFE
GO SAFE
FORCE GO SAFE
Global Safety
ALICE CONDITION
SAFE
PopupLHCAlicePanelModule: LHC_MESSAGE
LHC Injection WARNING
CURRENT OPERATOR ACTION >> SEND CONFIRM command from the INJECTION box
Handshake status
COMMUNICATION INTERFACE WITH LHC
Injection
WARN_CONFIRMED
Global Safety
ALICE CONDITION
SAFE
User Permits
Beam Permit
Injection permit 1
Injection permit 2
3:45
Estimated CountDown Time
SAFE SUMMARY
LHC-ALICE MESSAGES (Experts use)
NO PROBLEMS
CLOSE

THE DCS USER INTERFACE LAYER

DCS Architecture

User Interface Layer	Intuitive human interface
Operations Layer	Hierarchy and partitioning by FSM
Controls Layer	Core SCADA based on WINCC OA
Device abstraction Layer	OPC and FED servers
Field Layer	DCS devices



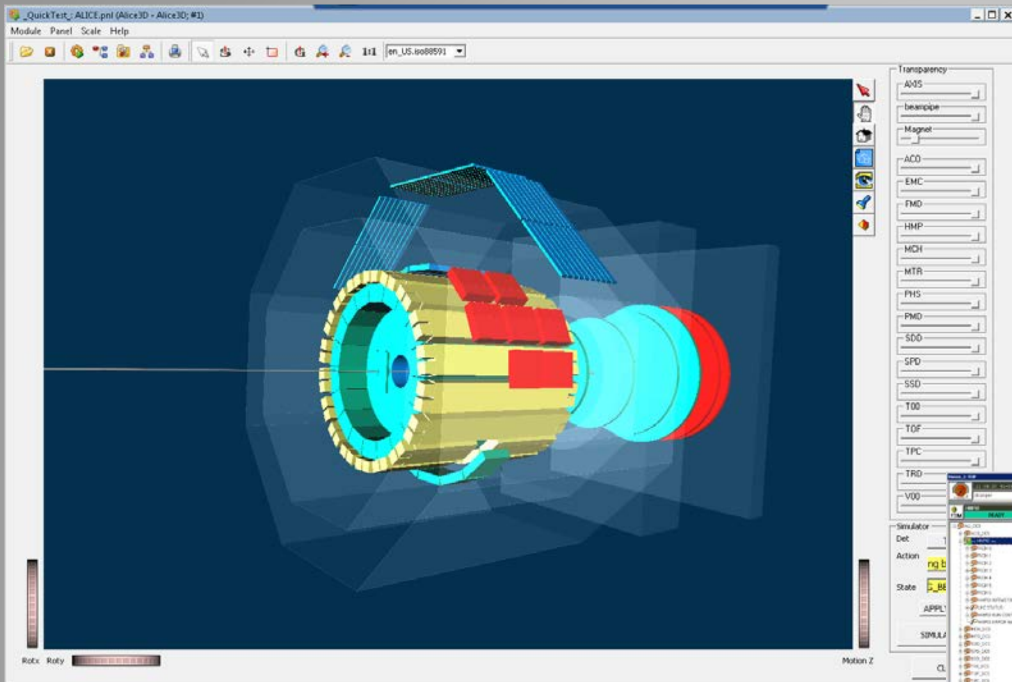


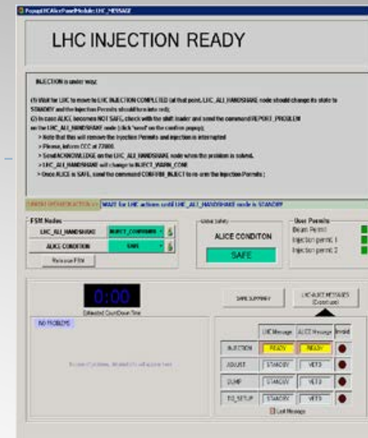
The original simple FSM layout got complex with time

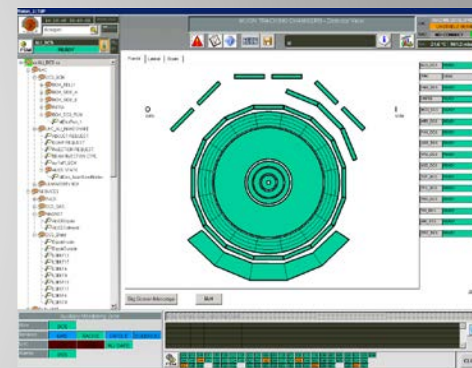
Potential risk of human errors in operation

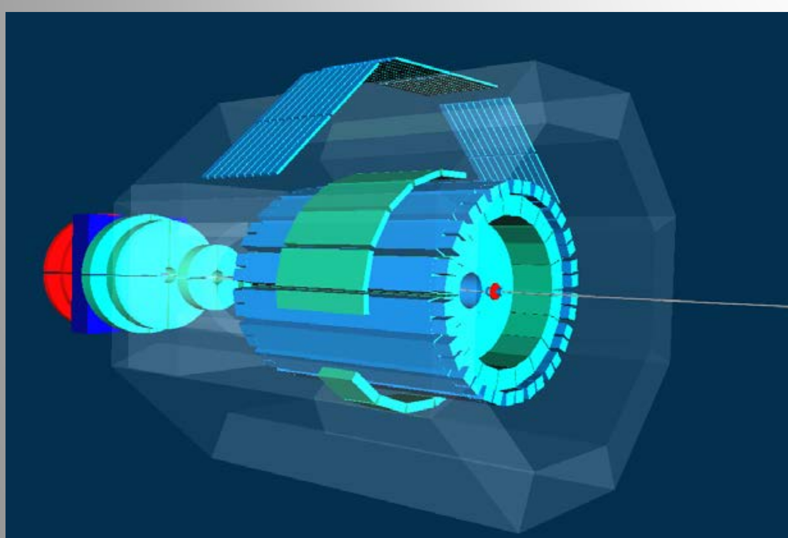
A set of intuitive panels and embedded procedures replaced the direct FSM operation

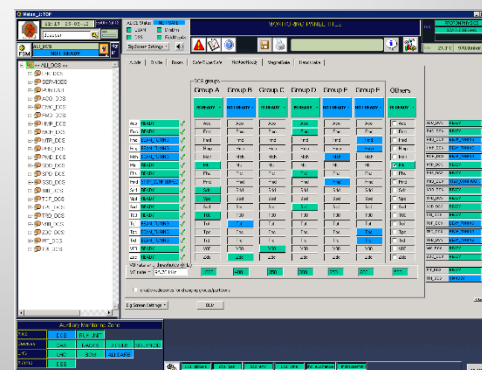
Peter Chochula

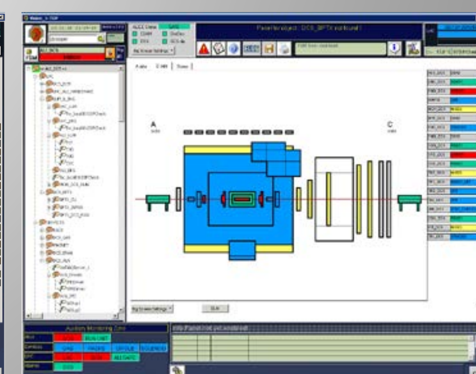












DCS Operation

- Central operator is responsible for all detectors
- Detector systems are maintained by detector experts
  - Oncall expert reachable during operation with beams
    - Remote access for interventions
  - In critical periods, detector shifts might be manned 24/7 by detector shifters
    - Central operator might delegate part of the tasks (alert handling, etc.) to detector sifters

DCS Organization

- Detector systems are developed in collaborating institutes
  - **Experts** can modify their systems
  - **Operators** can use their systems
- Original expectations evolved with time:
  - ~30 expected experts → 167 experts
  - ~100 detector operators → 610 operators
- Small central team (7 people) based at CERN
  - Provides infrastructure
  - Guidelines and tools
  - Consultancy
  - Integration

Central shift organization

- DCS operator is fully responsible for the experiment
  - 24/7 shift coverage during ALICE operation periods
  - Detector babysitting if devices are ON

- In the period 2011-2013:
  - 1800 manned shifts
    - 80 different shifters in 2011
    - 100 different shifters in 2012
  - Shifter training and non-stop on call service provided by central team

Conclusions

- ALICE DCS provided excellent and uninterrupted service since 2007
- Operational experiences gained during the operation are continuously implemented into the system in form of procedures and tools
- Looking forward to ALICE RUN2 (2014-2018)