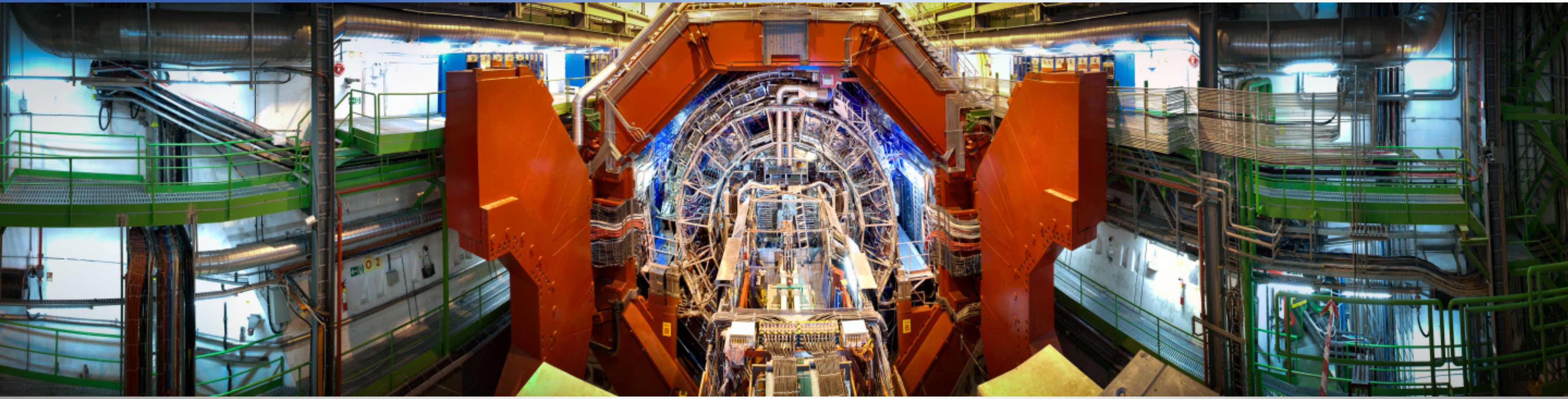


ALICE Detector Control System Management and Organization

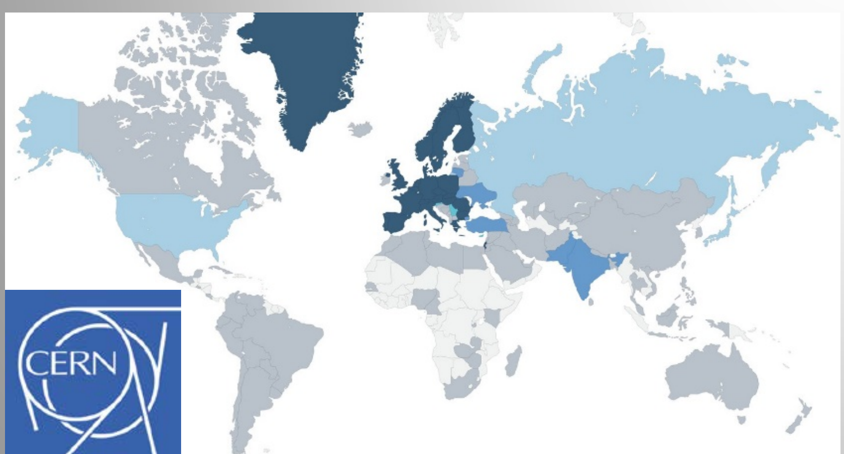
Peter Chochula, Mateusz Lechman
for ALICE Controls Coordination Team

Outline

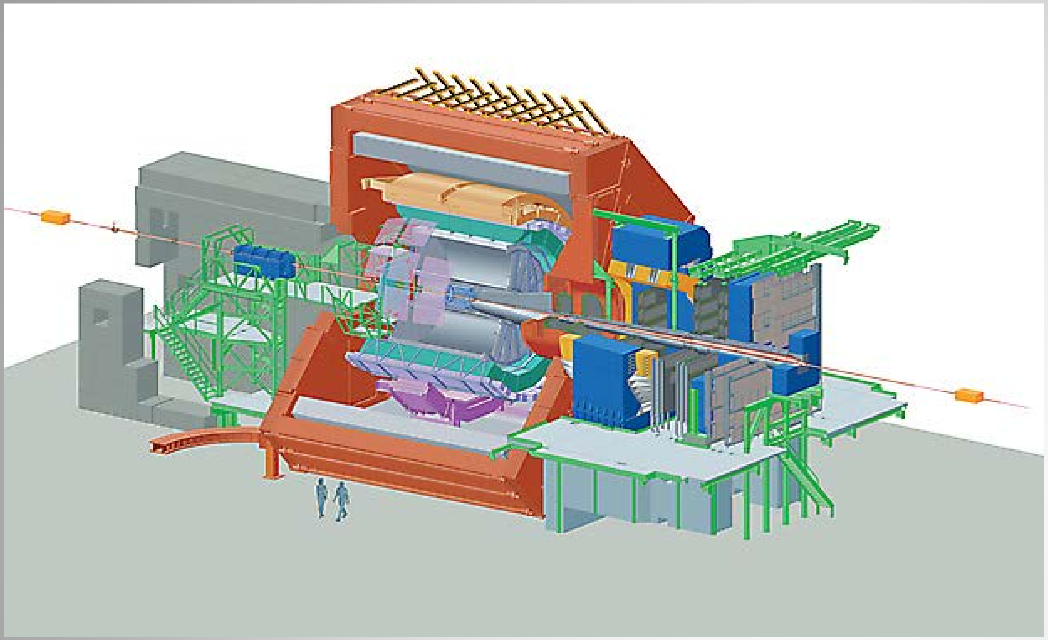
- The ALICE experiment at CERN
- Organization of the controls activities
- Design goals and strategy
- DCS architecture
- DCS operation
- Infrastructure management
- Summary & Open discussion

CERN & LHC

- European Organization for Nuclear Research
  - *Conseil Européen pour la Recherche Nucléaire*
- Main function: to provide particle accelerators and other infrastructure needed for high-energy physics research
- 22 member states + wide cooperation: 105 nationalities
- 2500 employes + 12000 associated members of personnel
- Main project: Large Hardron Collider

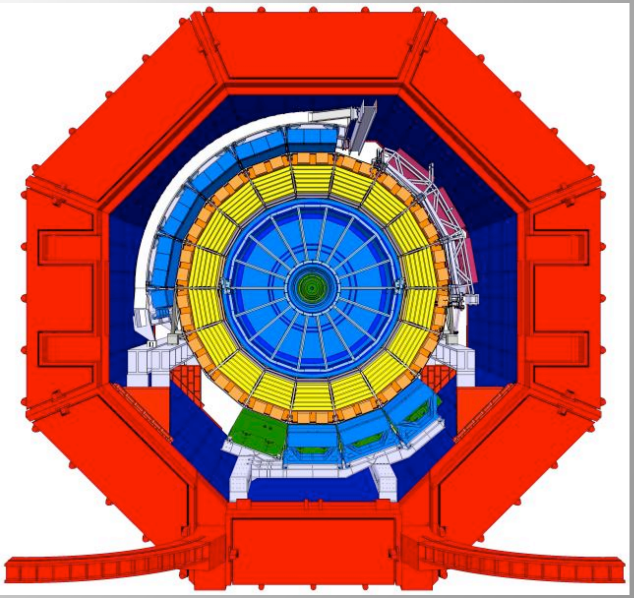


ALICE – A Large Ion Collider Experiment

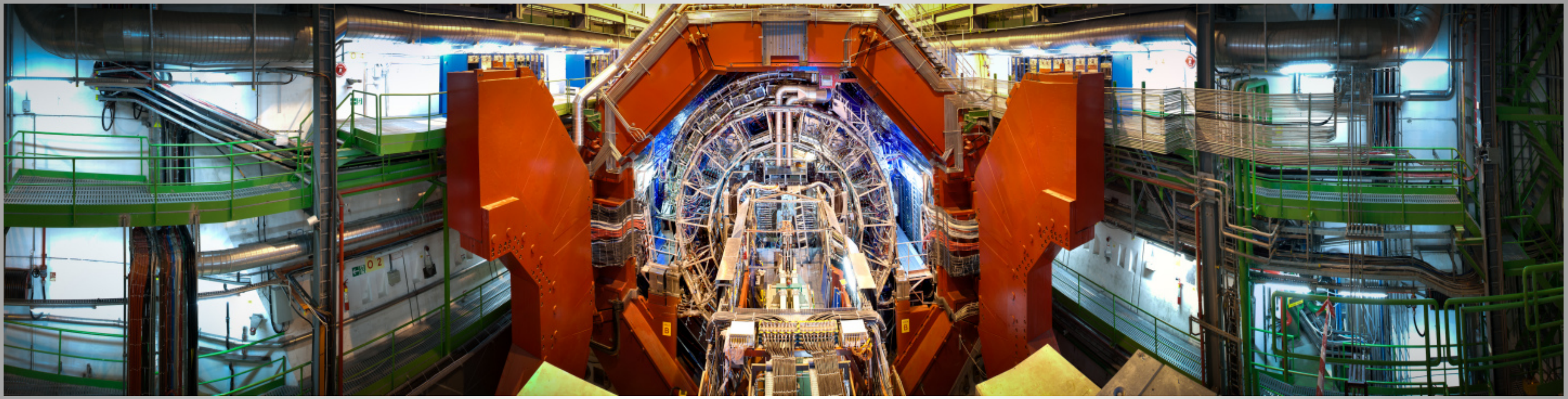


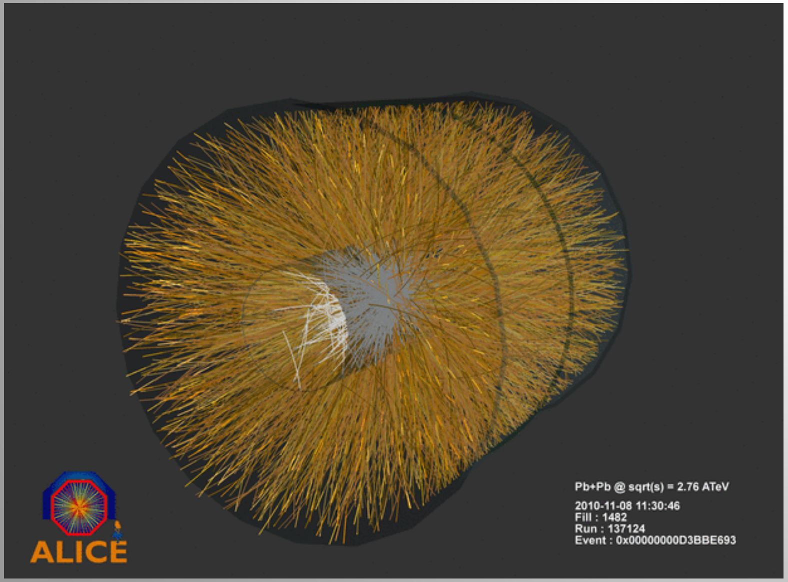
Collaboration:
Members: 1500
Institutes: 154
Countries: 37

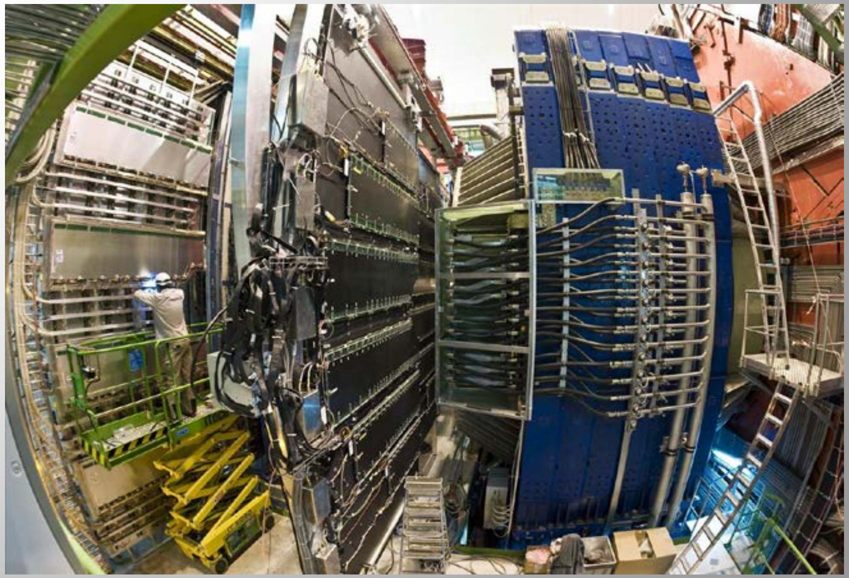
Detector:
Size: 16 x 16 x 26 m (some components installed >100m from interaction point)
Mass: 10,000 tons
Sub-detectors: 19
Magnets: 2



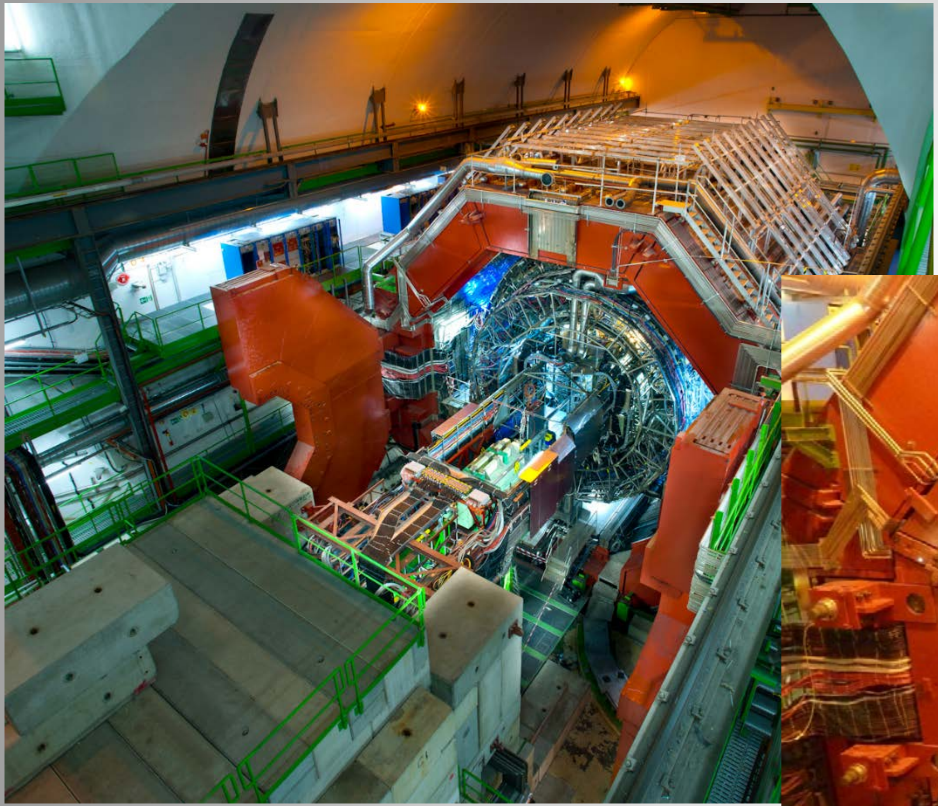
ALICE – A Large Ion Collider Experiment

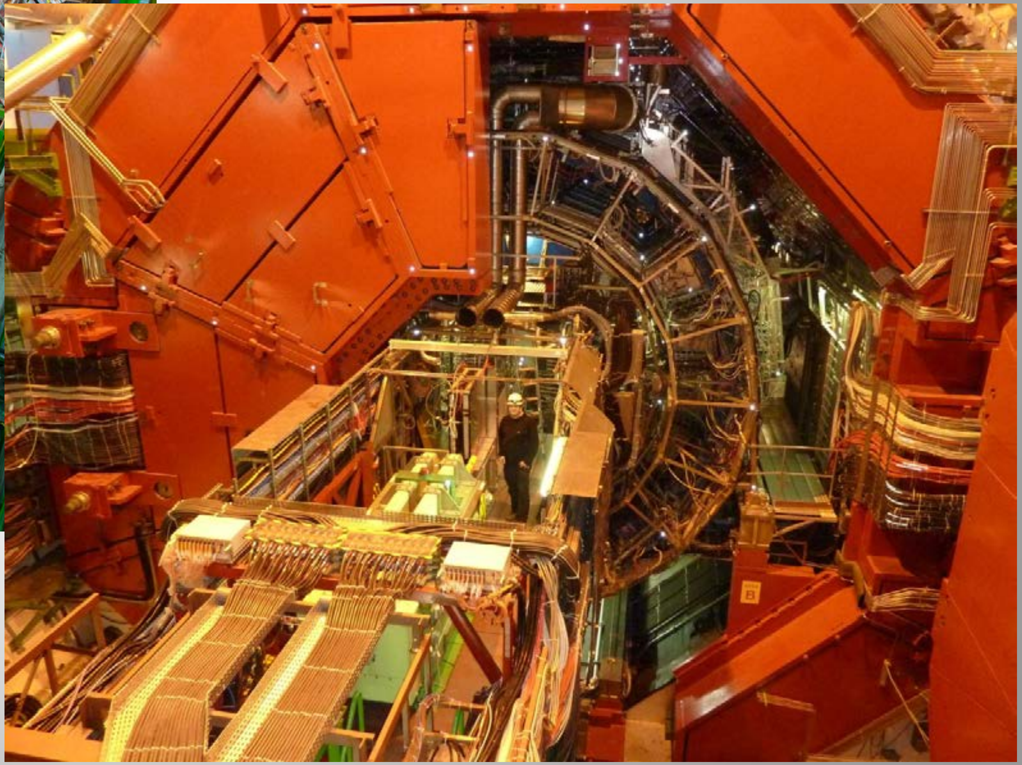






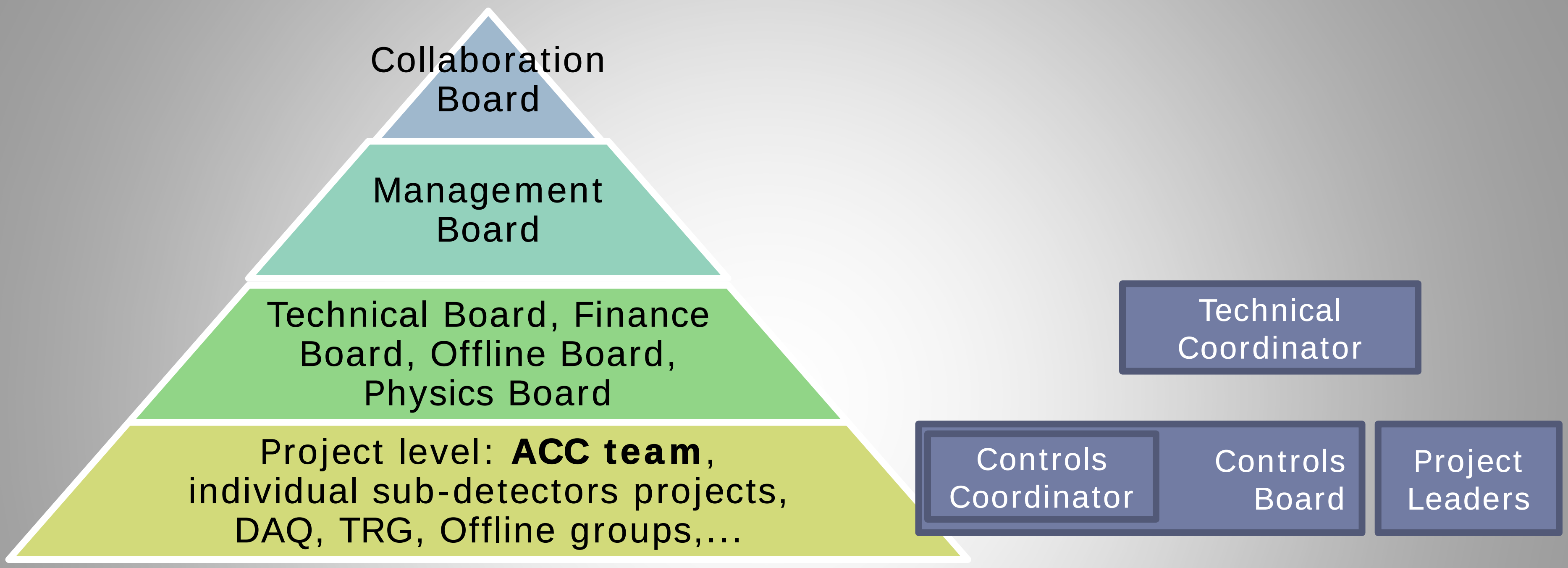
ALICE – A Large Ion Collider Experiment





Organization of controls activities

Decision making in ALICE



- Mandate of **A**LICE **C**ontrols **C**oordination (ACC) team and definition of Detector Control System (DCS) project approved by Management Board (2001)
  - Strong formal foundation for fulfilling duties

Organization structures

- ALICE Control Coordination (ACC) is the functional unit mandated to co-ordinate the execution of the Detector Control System (DCS) project
- Other parties involved in the DCS project:
  - Sub-detector groups
  - Groups providing the external services (IT, gas, electricity, cooling,...)
  - DAQ, Trigger and Offline systems, LHC Machine
- Controls Coordinator (leader of ACC) reports to Technical Coordinator and Technical Board
- ALICE Controls Board
  - ALICE Controls Coordinator + one representative per each sub-detector project and service activity
  - The principal steering group for DCS project, reports to Technical Board

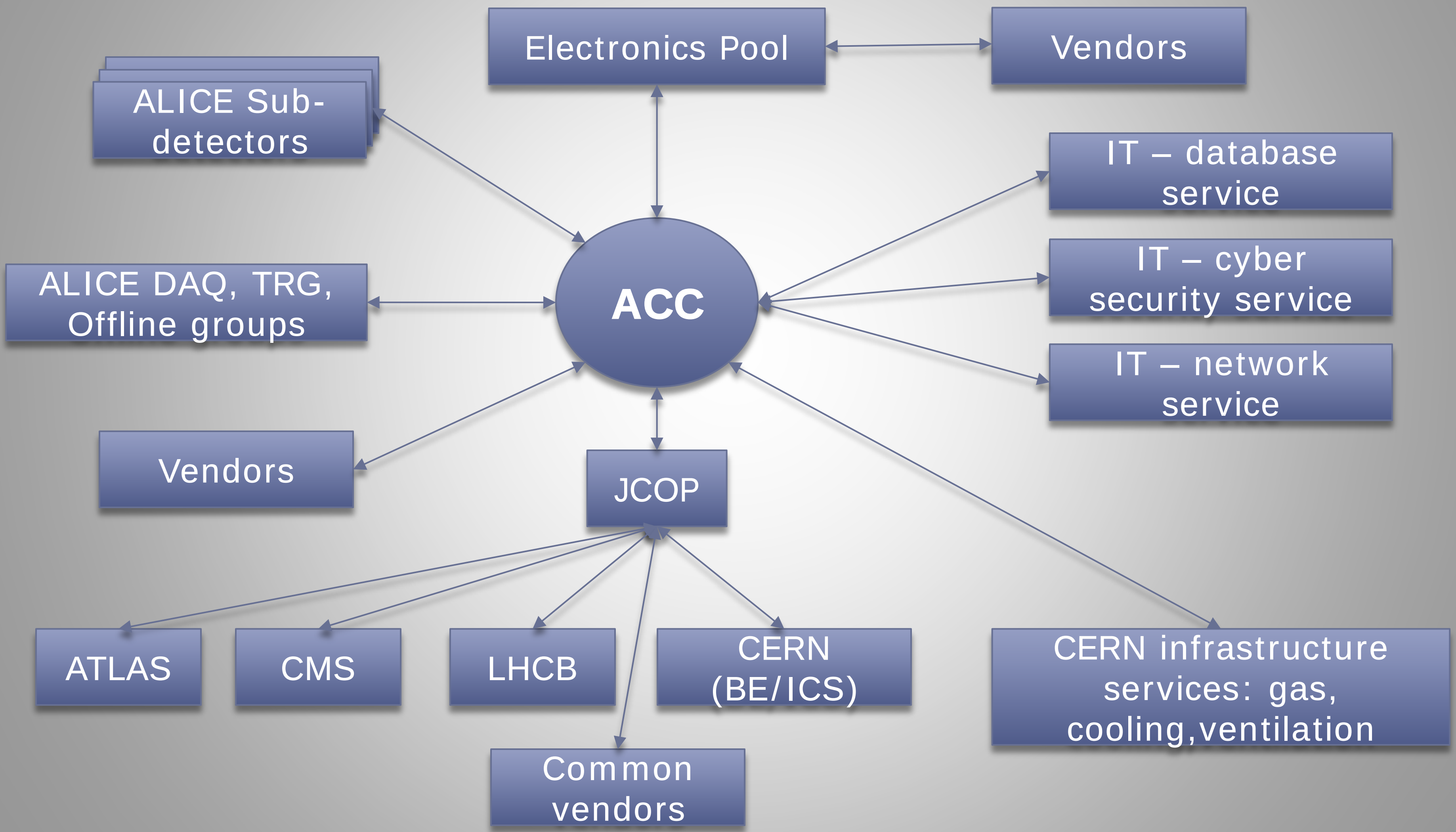
Controls activities

- The sub-detector control systems are developed by the contributing institutes
  - Over 100 developers from all around the world and from various backgrounds
  - Many sub-detector teams had limited expertise in controls, especially in large scale experiments
- ACC team (~7 persons) is based at CERN
  - Provides infrastructure
  - Guidelines and tools
  - Consultancy
  - Integration
  - Cooperates with other CERN experiments/groups

Technical competencies in ACC

- Safety aspects (member of ACC is deputy GLIMOS)
- System architecture
- Control system developement (SCADA, devices)
- IT administration (Windows, Linux platforms, network, security)
- Database development (administration done by the IT deparment)
- Hardware interfaces (OPCS, CAN interfaces)
- PLCs

ACC- relations



Cooperation

Joint **CO**ntrols **P**roject (JCOP) is a collaboration between CERN and all LHC experiments to exploit communalities in the control systems

- Provides, supports and maintains a common framework of tools and a set of components
- Contributions expected from all the partners
- Organization: two types of regular meetings (around every 2 weeks):
  - Coordination Board
    - defining the strategy for JCOP
    - steering its implementation
  - Technical (working group)

JCOP Coordination Board - mandate

- Defining and reviewing the architecture, the components, the interfaces, the choice of standard industrial products
  - SCADA, field bus, PLC brands, etc
- Setting the priorities for the availability of services and the production as well as the maintenance and upgrade of components
  - in a way which is --as much as possible- compatible with the needs of all the experiments.
- Finding the resources
  - for the implementation of the program of work
- Identifying and resolving issues
  - which jeopardize the completion of the program as-agreed, in-time and with the available resources.
- Promoting the technical discussions and the training
  - to ensure the adhesion of all the protagonists to the agreed strategy

Design goals and strategy

Design goals

- DCS shall ensure safe and efficient operation
  - Intuitive, user friendly, automation
- Many parallel and distributed developments
  - Modular, still coherent and homogeneous
- Changing environment – hardware and operation
  - Expandable, flexible
- Operational outside datataking, safeguard equipment
  - Available, reliable
- Large world-wide user community
  - Efficient and secure remote access
- Data collected by DCS shall be available for offline analysis of physics data

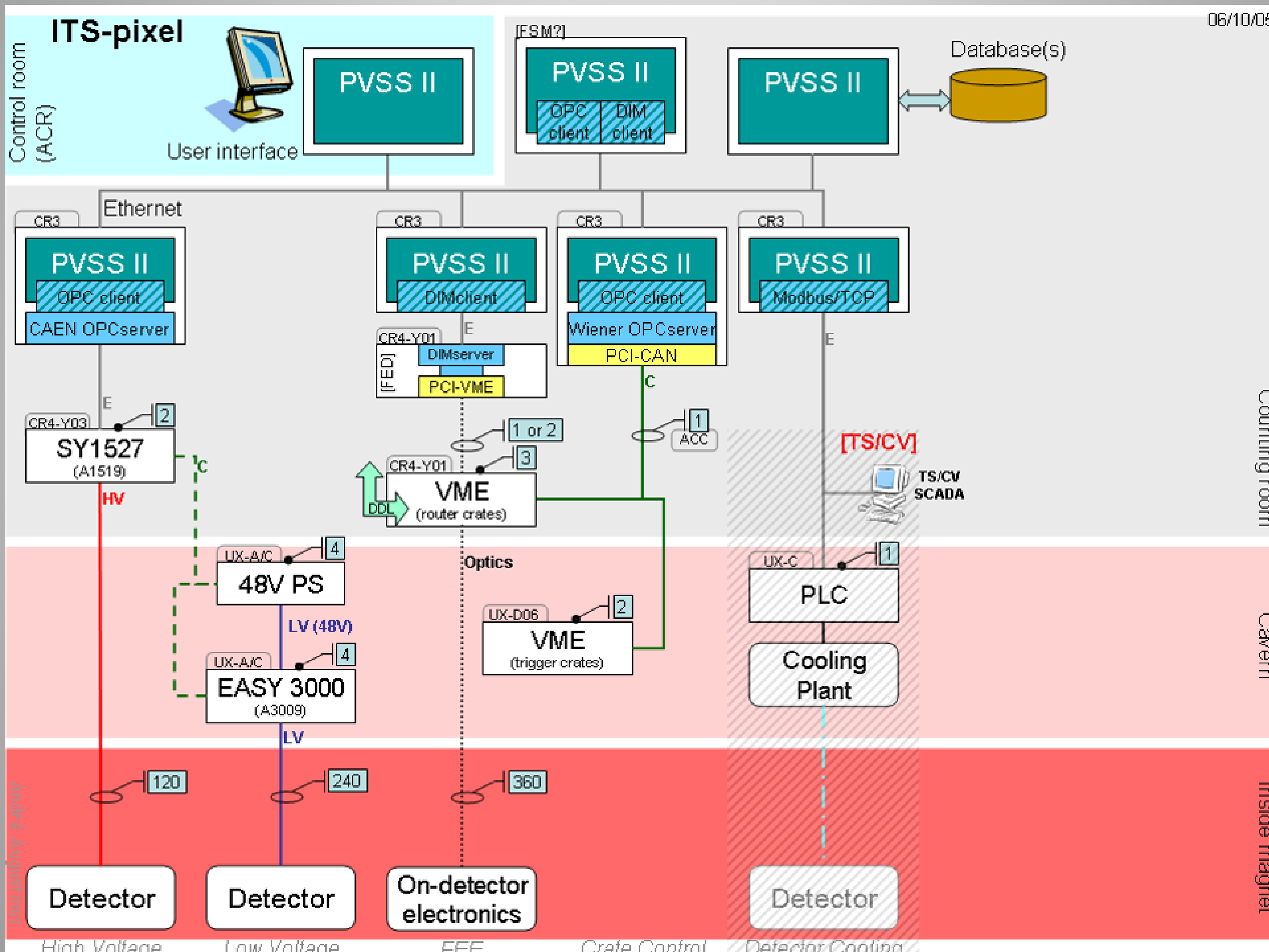
Strategy and methods

- Common tools, components and solutions
  - Strong coordination within experiment (ACC)
  - Close collaboration with other experiments (JCOP)
  - Use of services offered by other CERN units
- Standardization: many similar subsystems in ALICE
  - Identify communalities through:
    - User Requirements Document (URD)
    - Overview Drawings
    - Meetings and workshops

User Requirement Document

- Brief description of sub-detector goal and operation
- Control system
  - Description and requirement of sub-systems
    - Functionality
    - Devices / Equipment (including their location, link to documentation)
    - Parameters used for monitoring/control
    - Interlocks and Safety aspects
    - Operational and Supervisory aspects
  - Requirement on the control system
    - Interlocks and Safety aspects
    - Operational and Supervisory aspects
- Timescale and planning (per subsystem)
  - For each phase:
    - Design, Production and purchasing, Installation, Commissioning , Tests and Test beam

Overview Drawings



Prototype development

- In order to study and evaluate possible options of ‘standard solutions’ to be used by the sub-detector groups it was necessary to gain "hands-on" experience and to develop prototype solutions
- Prototype developments were identified after discussions in Controls Board and initiated by the ACC team in collaboration with selected detector groups
  - Examples:
    - Standard ways of measuring temperatures
    - Control of HV systems
    - Monitoring of LV power supplies
- Prototype of complete end-to-end detector control slices including the necessary functions at each DCS layer
  - from operator to electronics

ACC deliverables – design phase

- DCS architecture layout definition
- URD of systems, devices and parameters to be controlled and operated by DCS
- Definition of ‘standard’ ALICE controls components and connection mechanisms
- Prototype implementation of ‘standard solutions’
- Prototype implementation of an end-to-end detector controls slice
- Global project budget estimation
- Planning and milestones

Coordination and evolution challenge

- Initial stage, development
  - Establish communication with all the involved parties
  - To overcome cultural differences: Start coordinating early, strict guidelines
- During operation, maintenance
  - HEP environment: original developers tend to drift away
    - (apart from a few exceptions) very difficult to ensure continuity for the control systems in the projects
  - In many small detector projects, controls is done only part-time by a single person
- The DCS has to
  - follow the evolution of the experiment equipment and software
  - follow the evolution of the use of the system
  - follow the evolution of the users

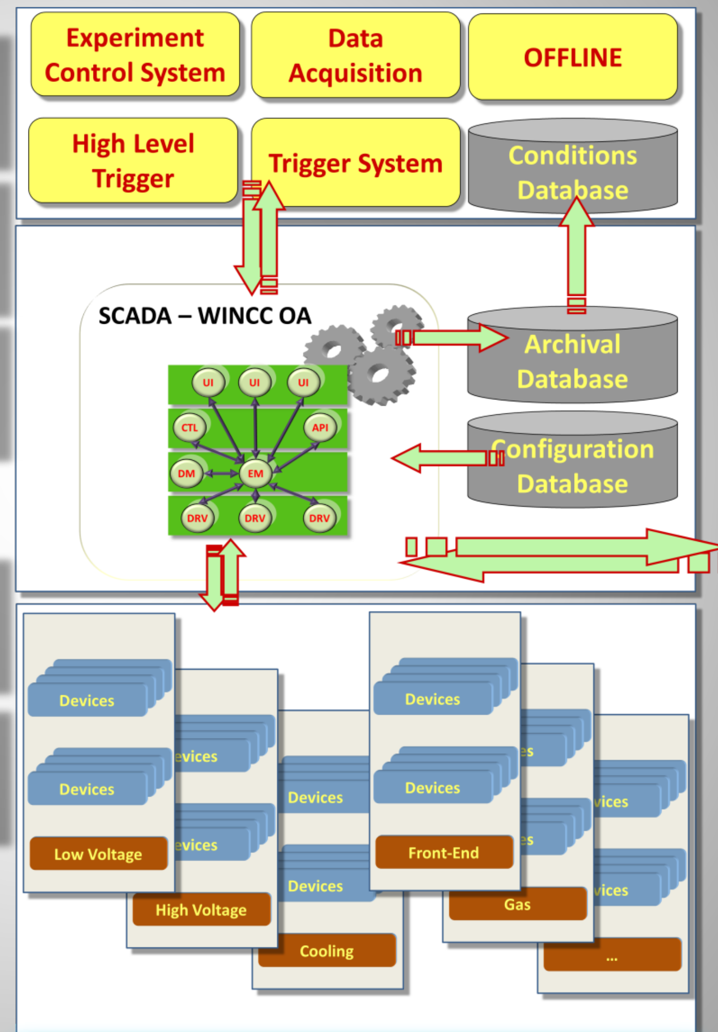
DCS Architecture

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 DCS context and scale

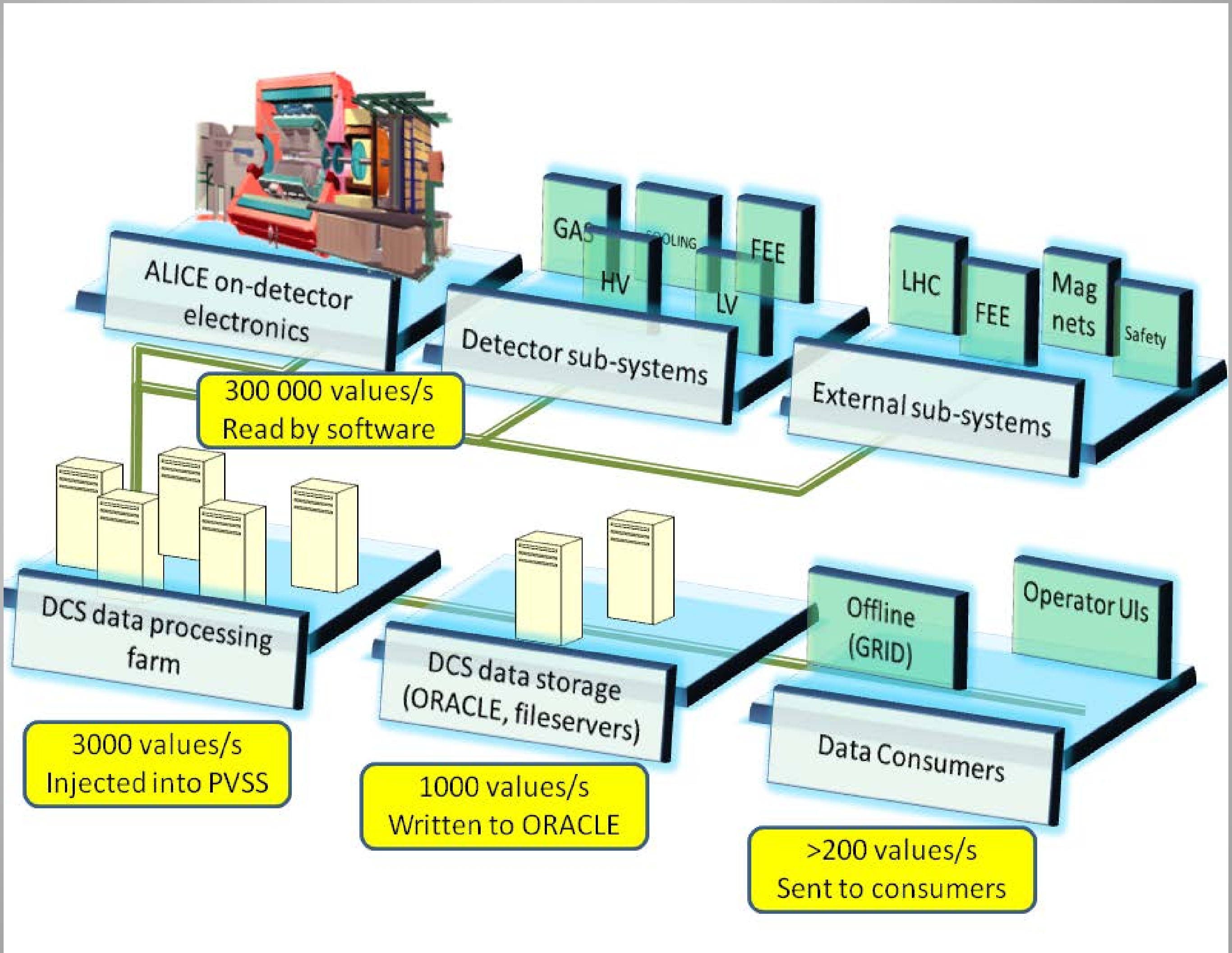
19 autonomous detector systems	1200 network attached devices
100 WINCC OA systems	>700 embedded computers
>100 subsystems	170 control computers
270 crates	200 000 OPC items
1 000 000 supervised parameters	100 000 frontend services



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

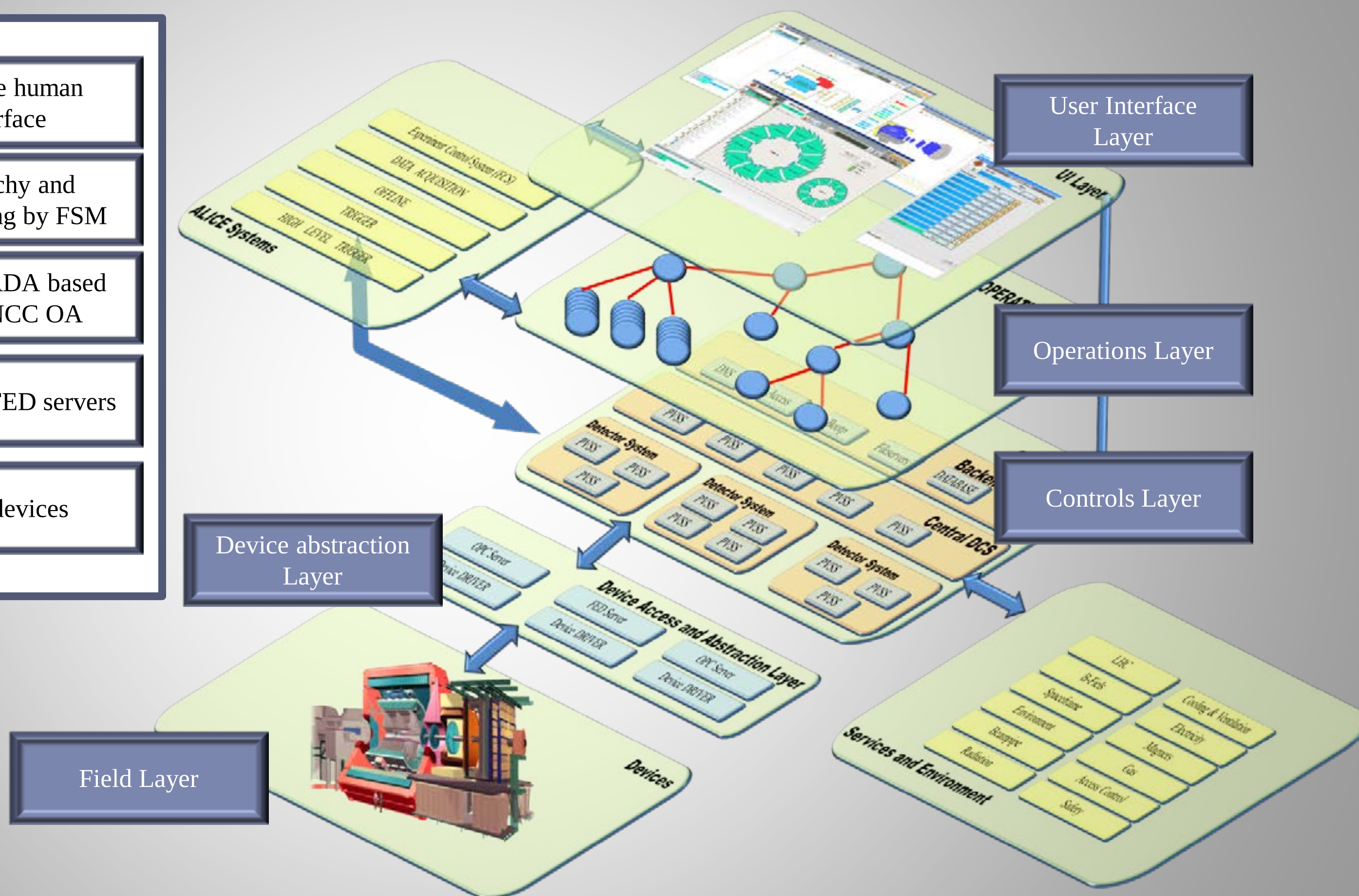
- Electricity
- Ventilation
- Cooling
- Magnets
- Gas
- Access Control
- LHC
- Safety
- B-field
- Space Frame
- Beam Pipe
- Environment
- Radiation

The DCS data flow



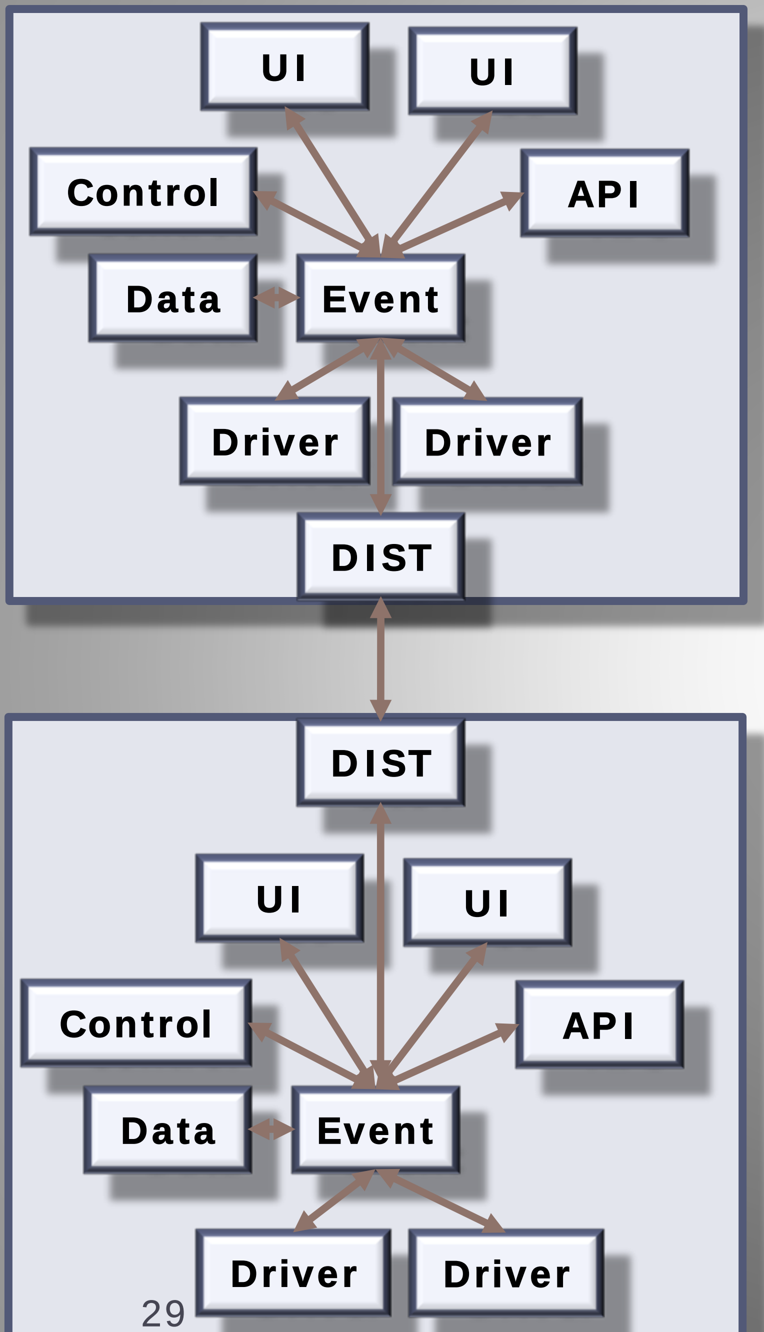
DCS Architecture

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



DCS Architecture

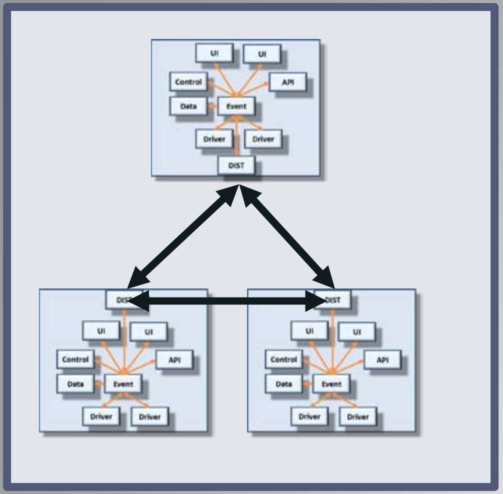
The DCS Controls Layer

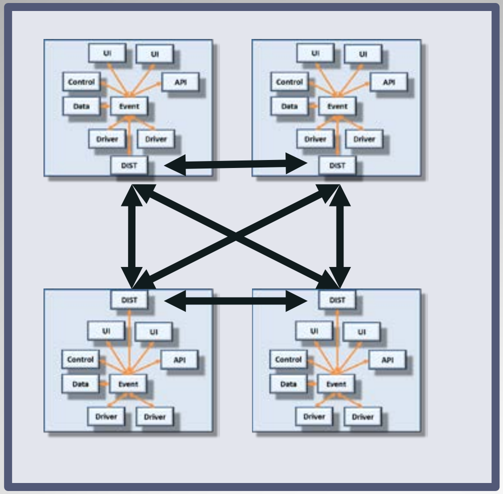


- Core of the Control Layer runs on WINCC OA SCADA system
- Single WINCC OA system is composed of managers
- Several WINCC OA systems can be connected into one distributed system

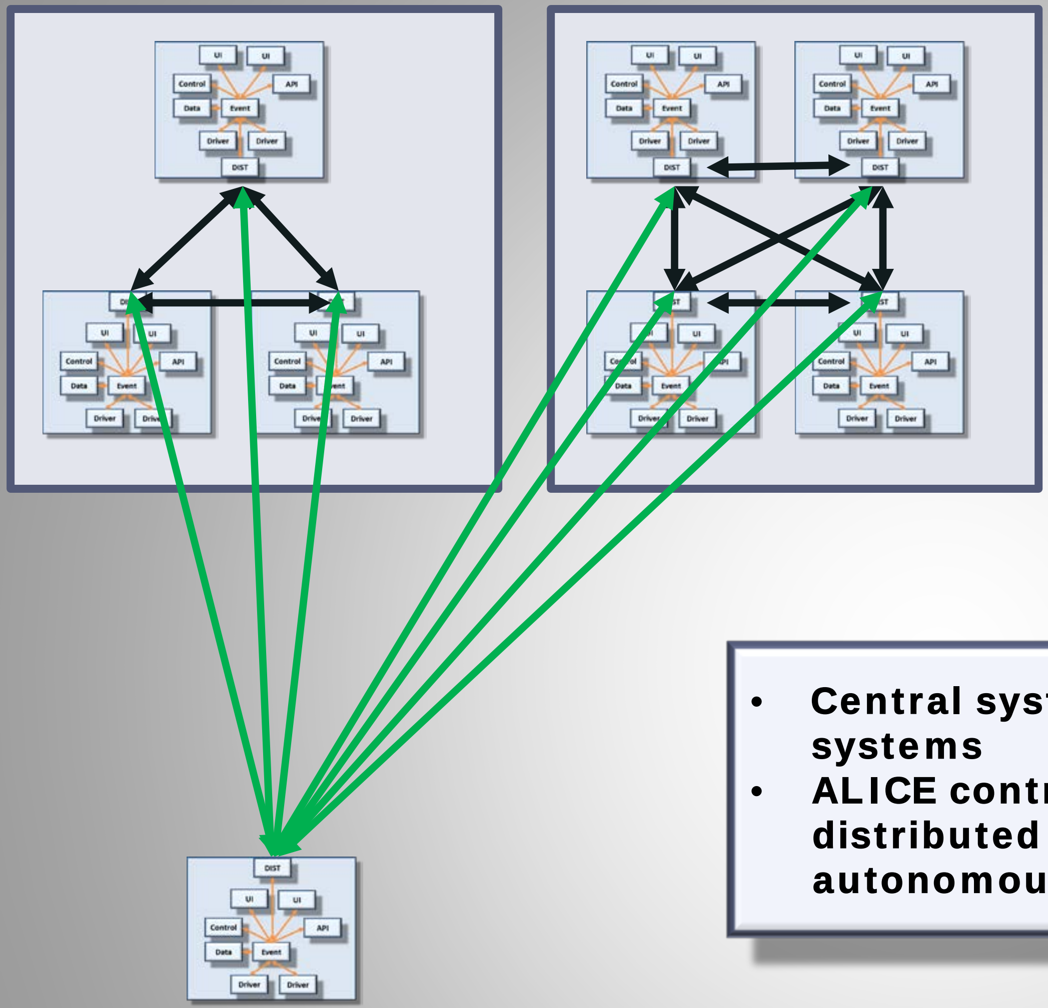
100 WINCC OA systems

2700 managers



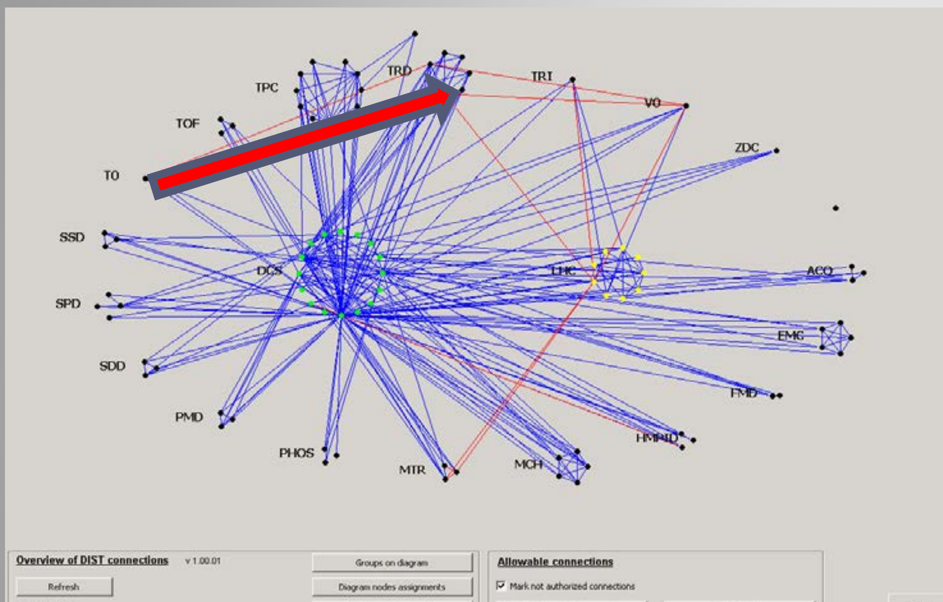


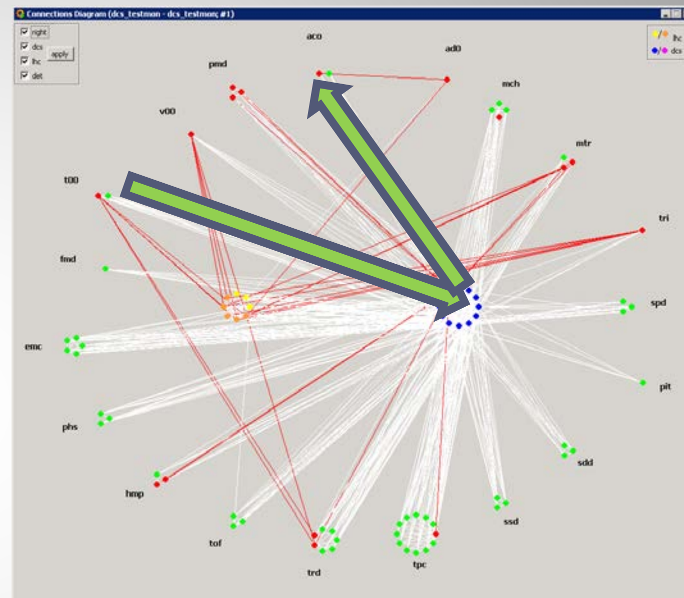
- **An autonomous distributed system is created for each detector**



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

‘illegal’ connection





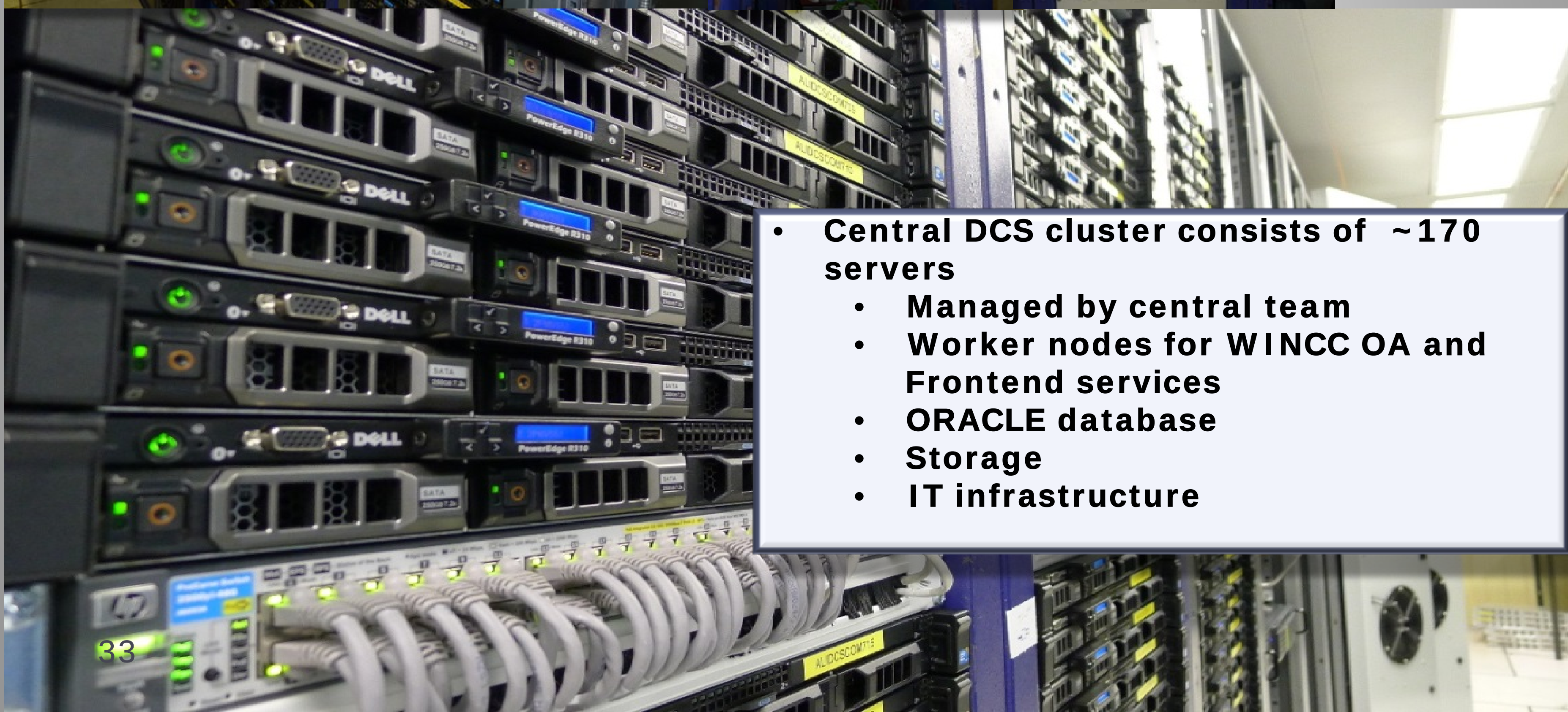
- To avoid inter-system dependencies, connections between detectors are not permitted
- Central systems collect required information and re-distribute them to other systems
  - New parameters added on request
- System cross connections are monitored and anomalies are addressed

Worker nodes

Fileservers

DB servers

ORACLE size: 5.4 TB



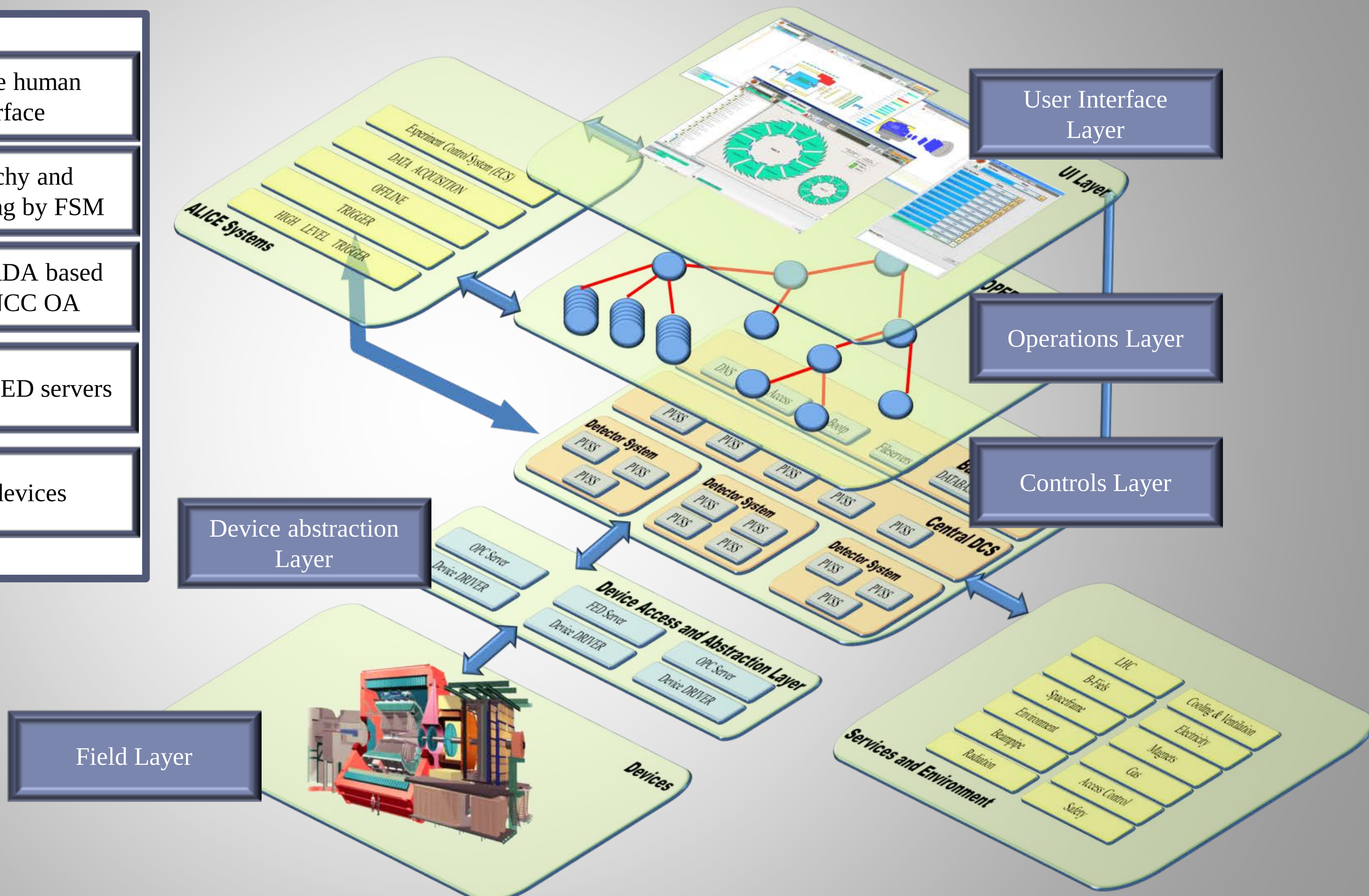
- Central DCS cluster consists of ~170 servers
  - Managed by central team
  - Worker nodes for WINCC OA and Frontend services
  - ORACLE database
  - Storage
  - IT infrastructure

DCS Architecture

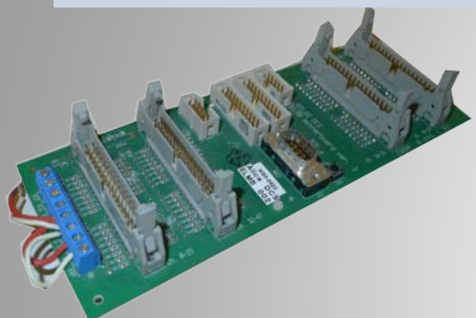
Field Layer
The power of standardization

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



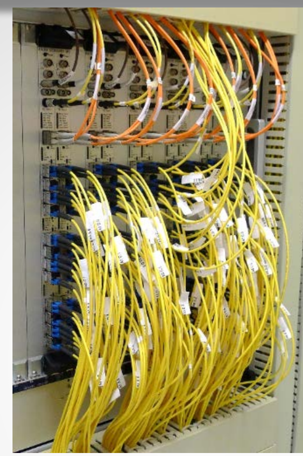
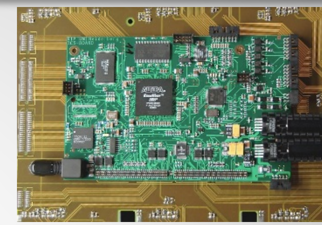
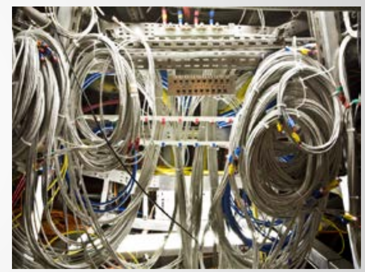


- **Wherever possible, standardized components are used**
  - **Commercial products**
  - **CERN-made devices**


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

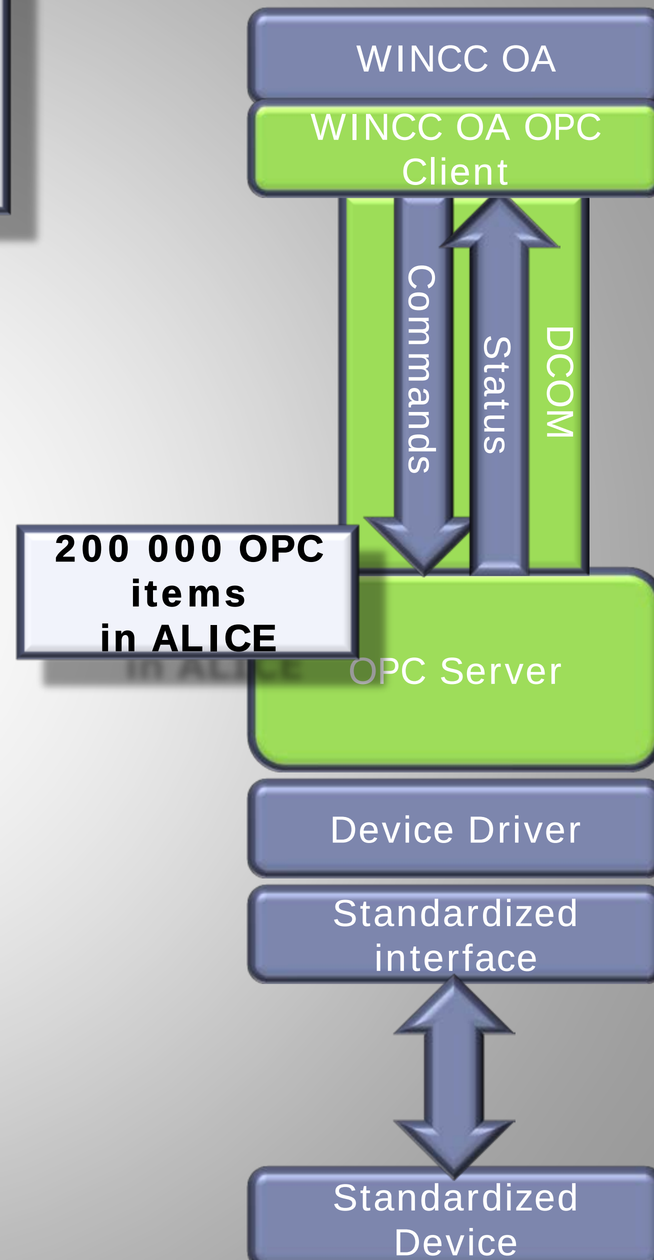


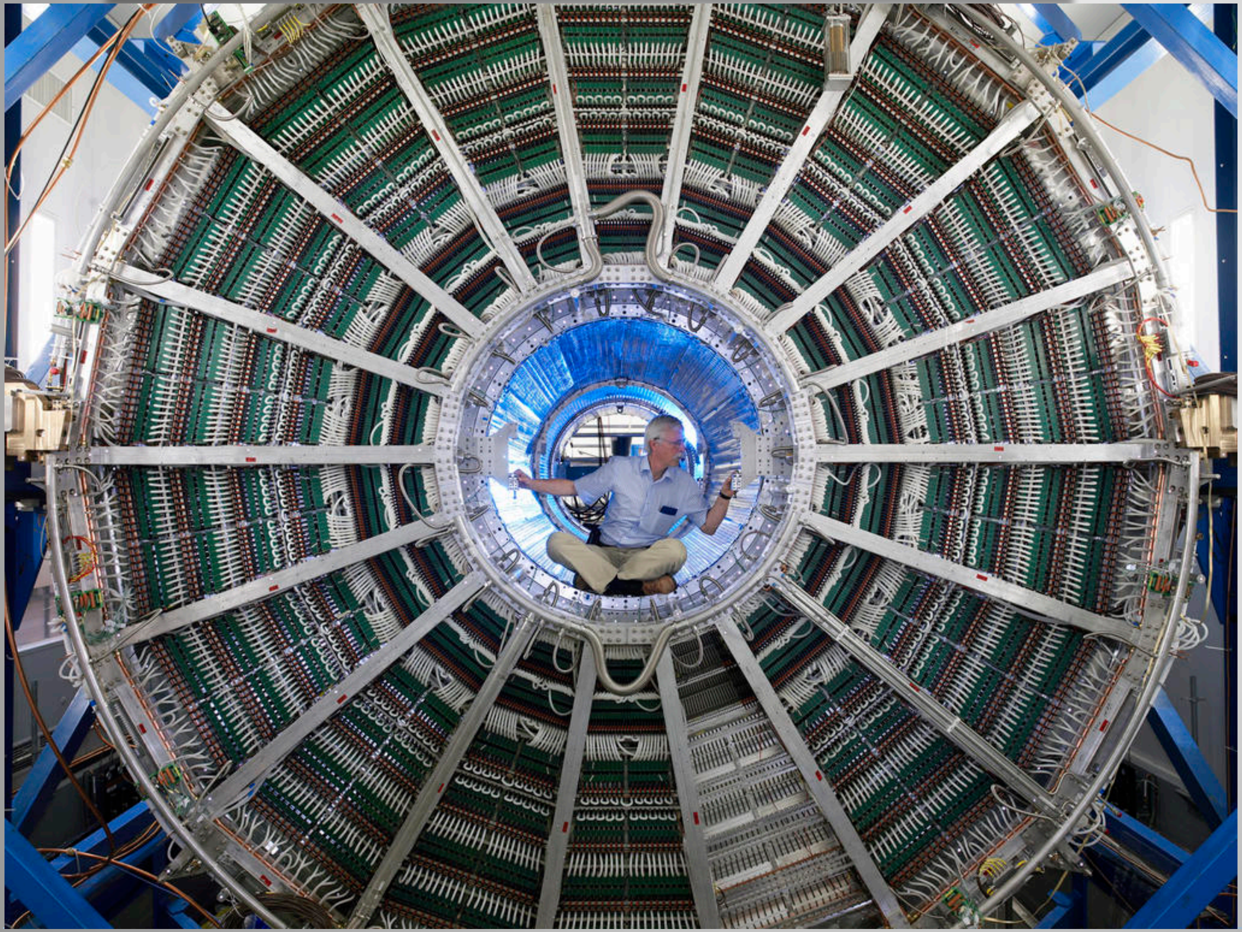

- CAN
- ETHERNET
- EASYNET
- VME
- JTAG
- RS 232
- PROFIBUS
- Custom links…

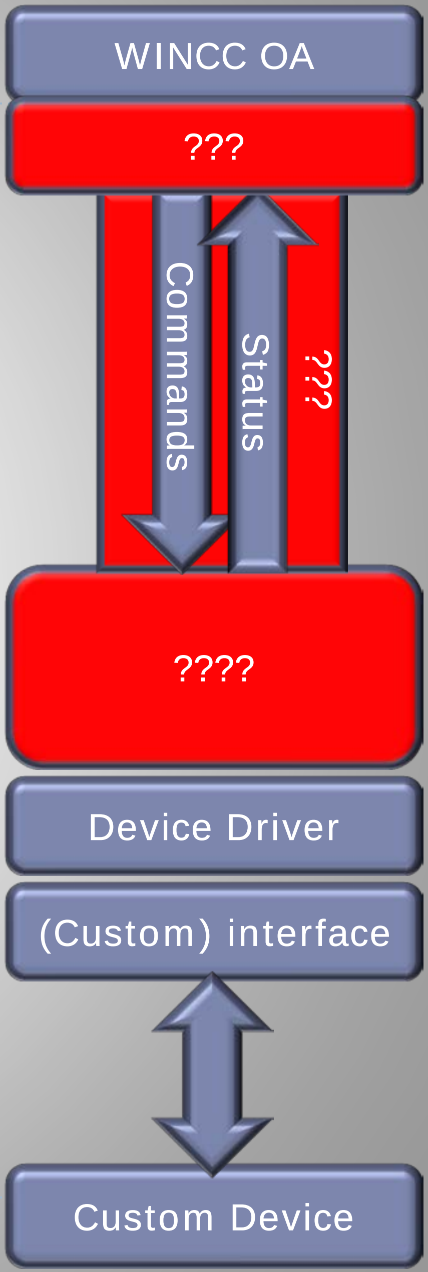
- **OPC used as a communication standard wherever possible**
  - **Native client embedded in WINCC OA**

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

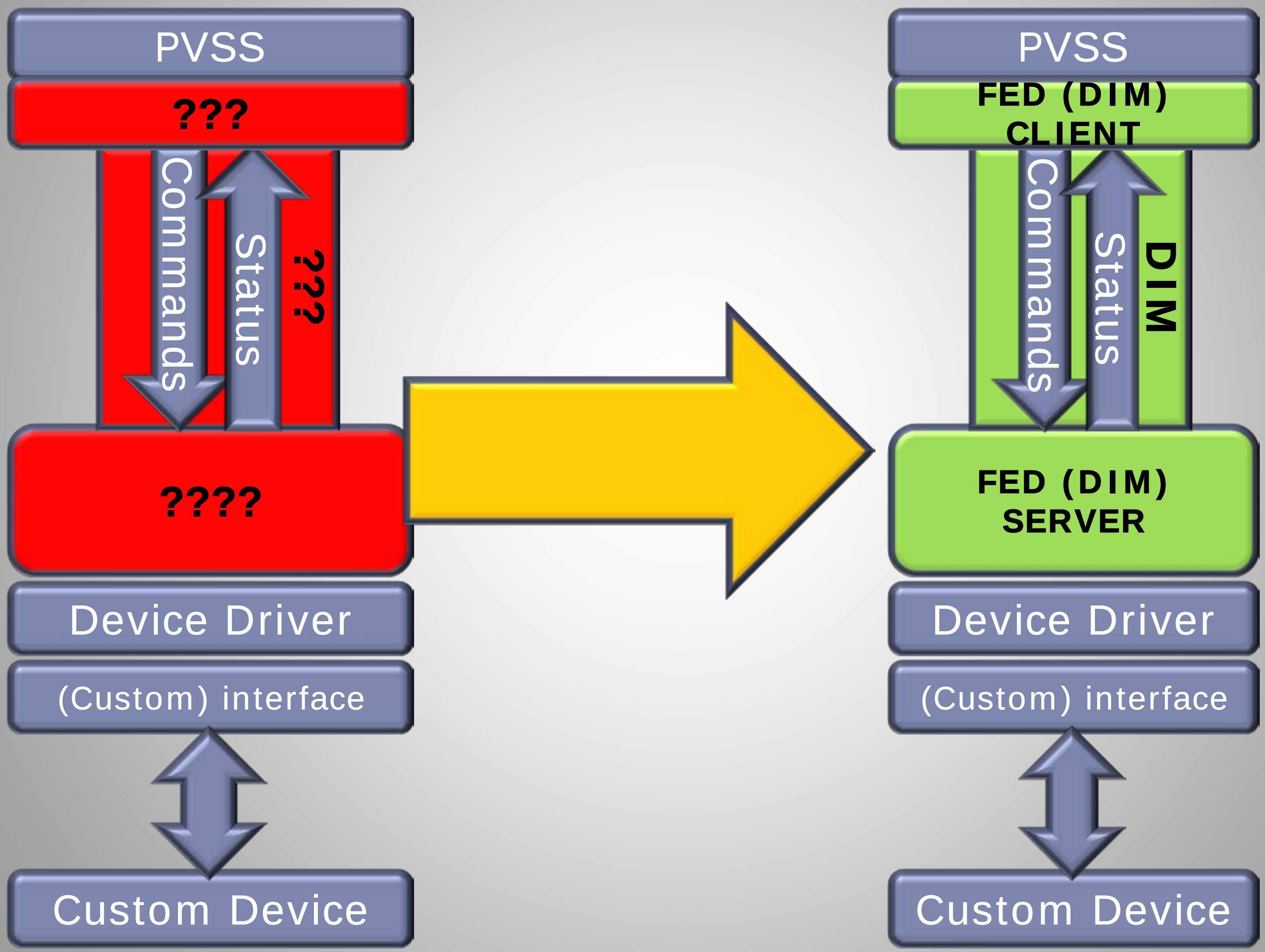


- Missing standard for custom devices
  - OPC too heavy to be developed and maintained by institutes
  - Frontend drivers often scattered across hundreds of embedded computers (Arm Linux)





Filling the gap



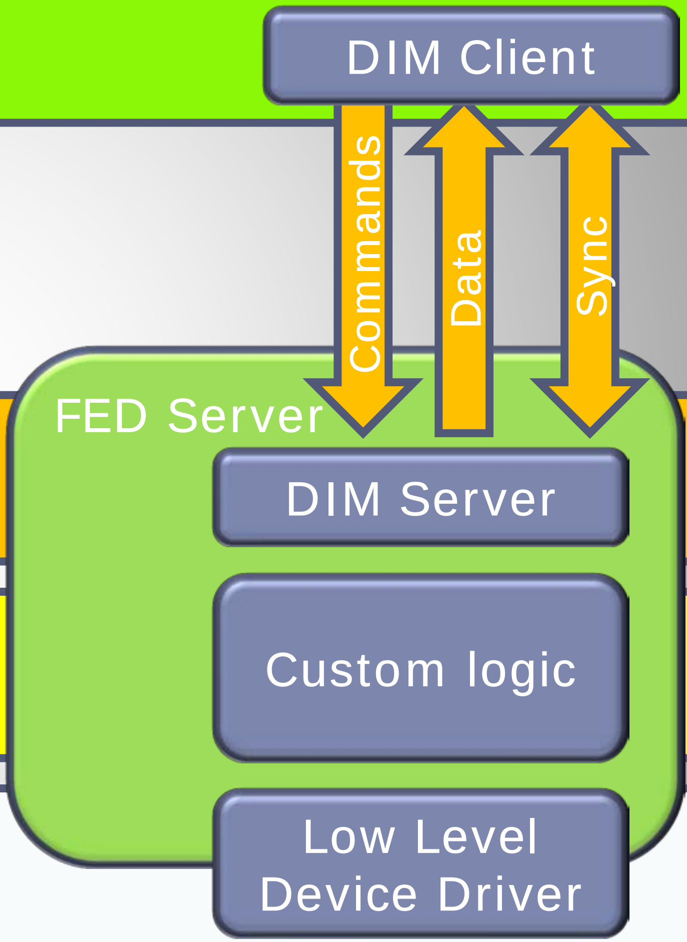
Generic FED architecture

Generic client implemented as PVSS manager

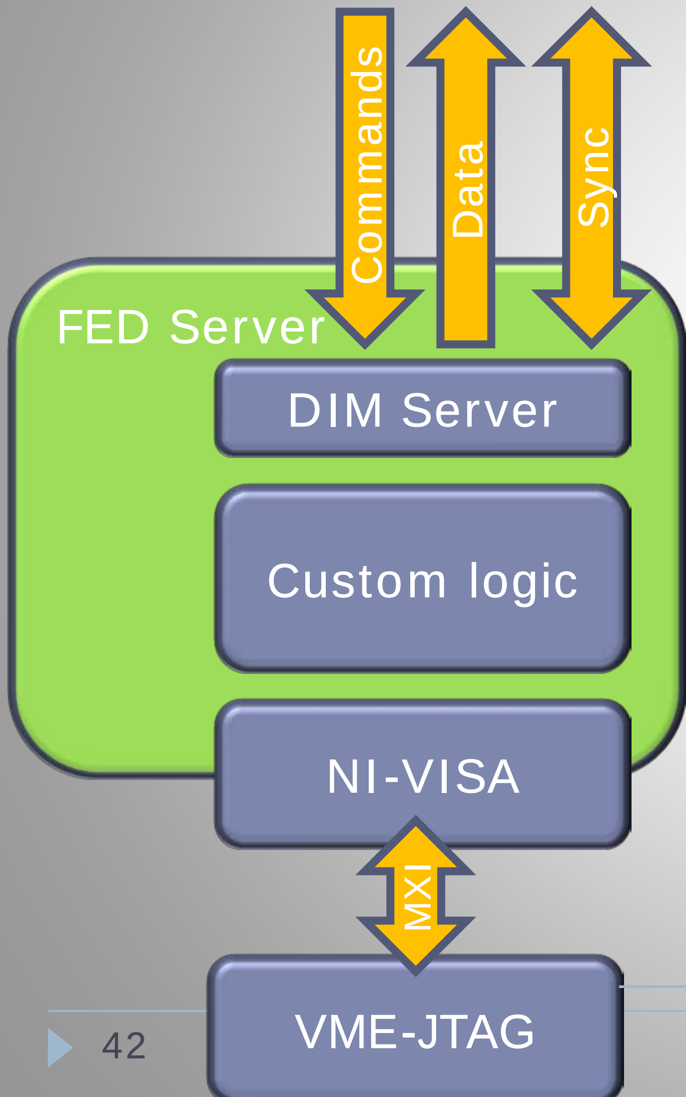
Communication interface with standardized commands and services

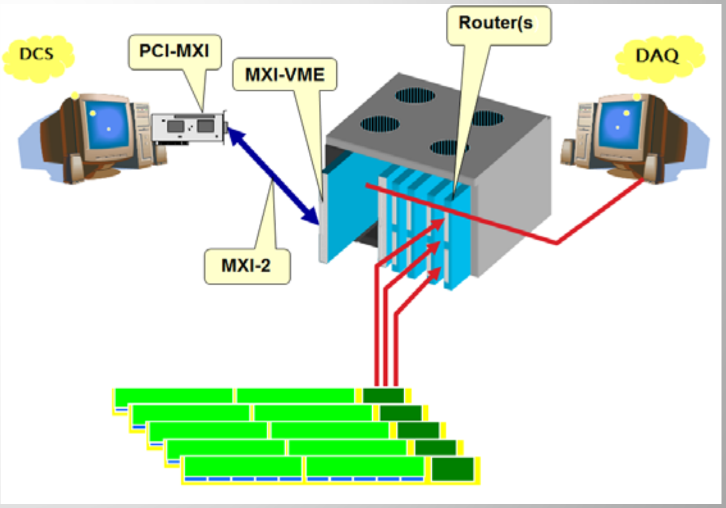
Device/specific layer providing high-level functionality (i.e. Configure, reset...)

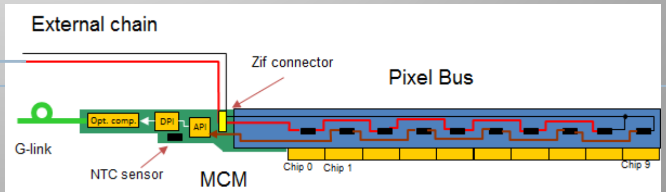
Low-level device interface (i.e. JTAG driver and commands)



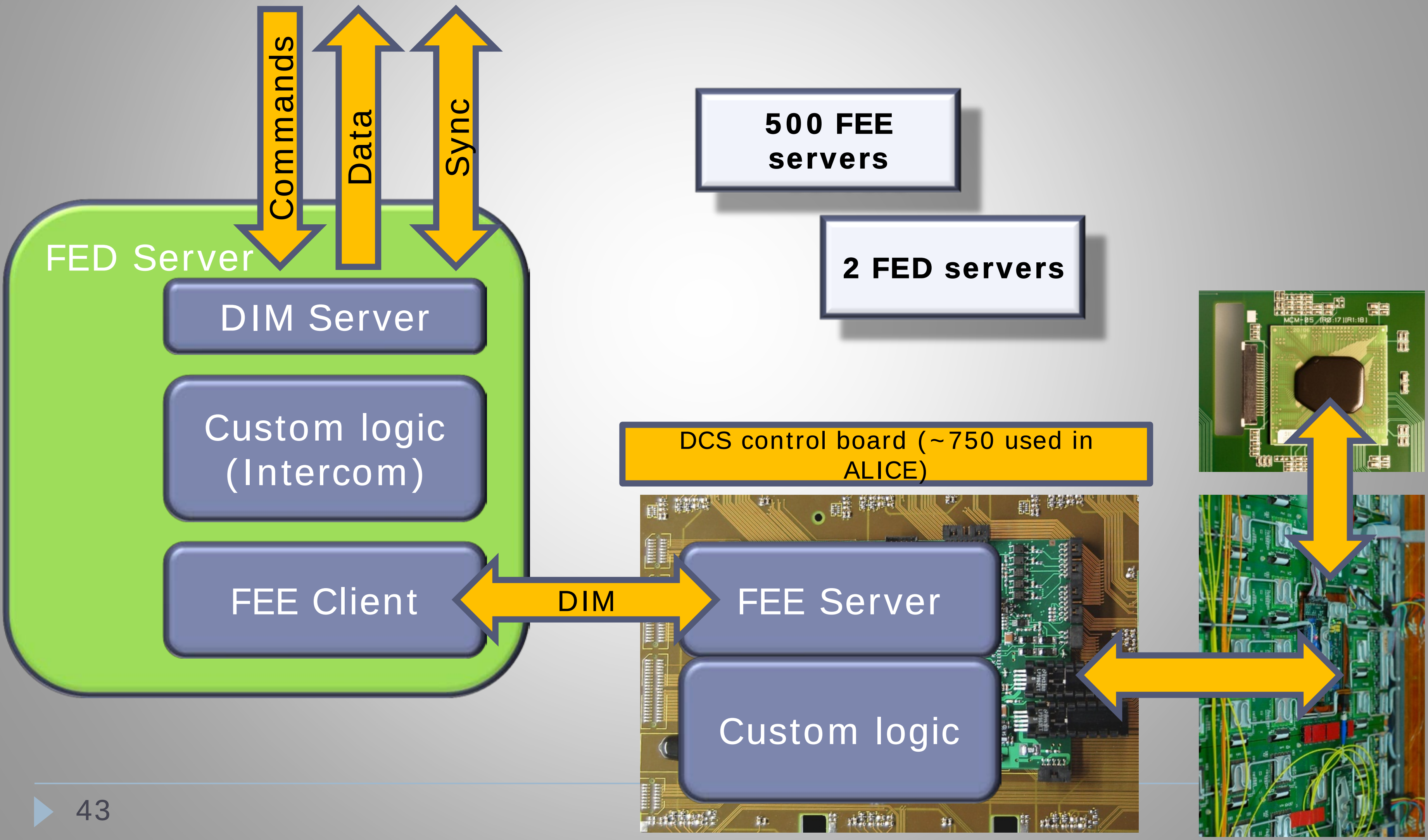
SPD FED Implementation







TRD FED Implementation



DCS Architecture

Operation Layer

Hierarchical approach

Based on CERN toolkit (SMI++)

Each node modelled as FSM

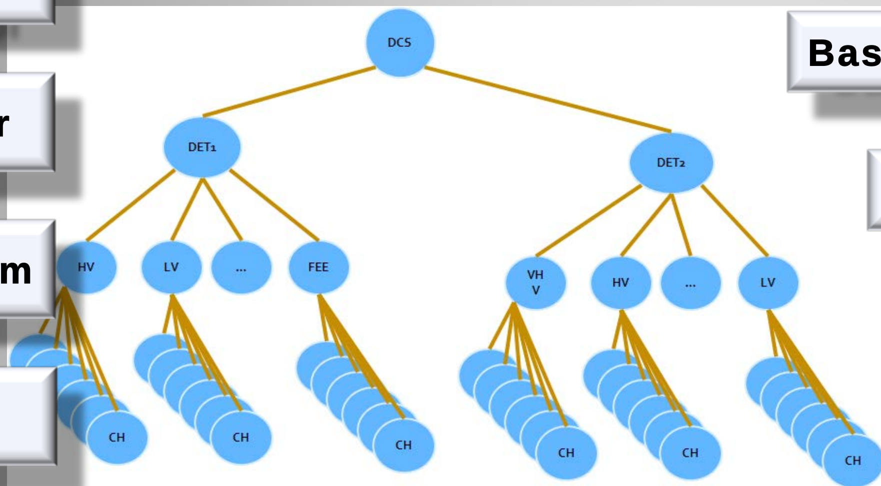
Integrated with WINCC OA

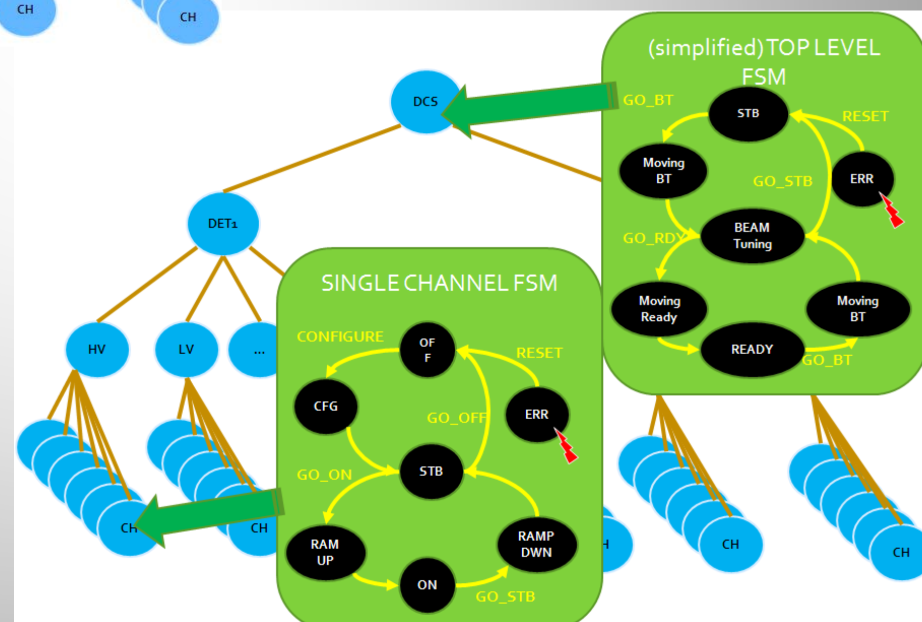
Central control

Detector

Subsystem

Device





ALICE central FSM hierarchy

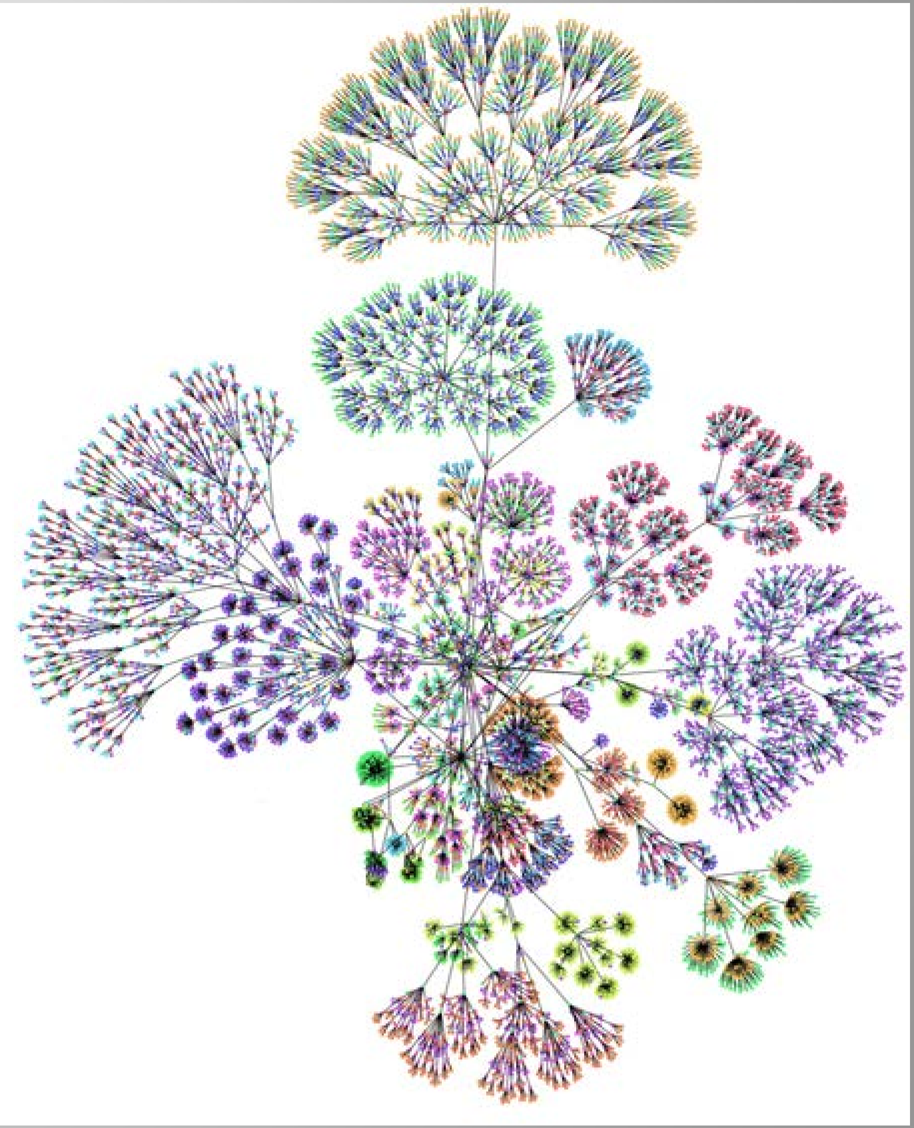
1 top DCS node

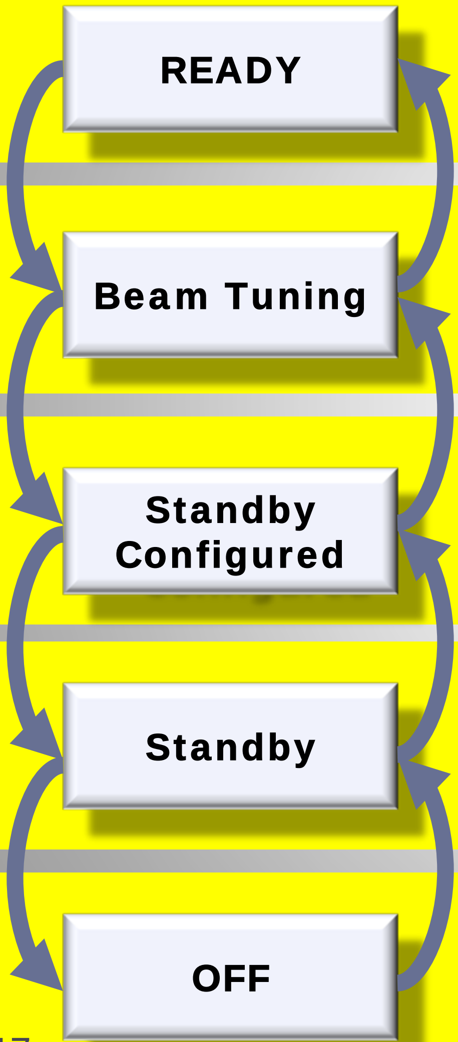
19 detector nodes

100 subsystems

5000 logical devices

10000 leaves





READY for Physics

Compatible with beam operations

Configuration loaded

Devices powered ON

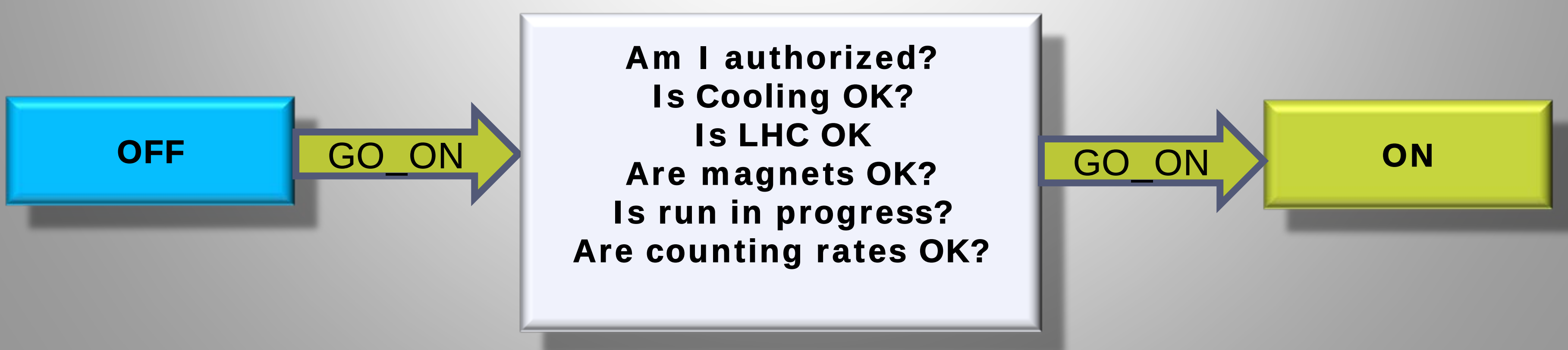
Everything OFF

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

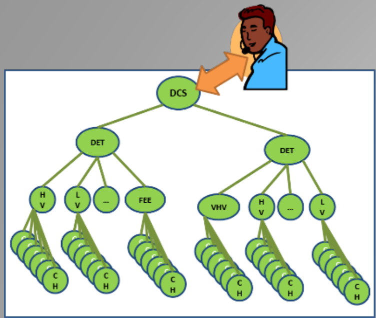
Unconfigured chips might burn (high current) if powered
But
The chips can be configured only once powered

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

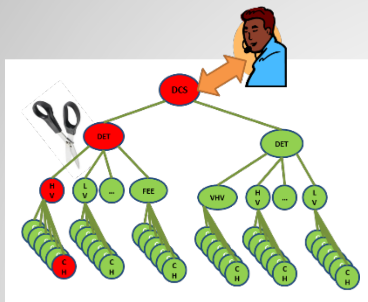


- Each detector has specific needs
- Operational sequences and dependencies are too complex to be mastered by operators
- Operational details are handled by FSM prepared by experts and continuously tuned

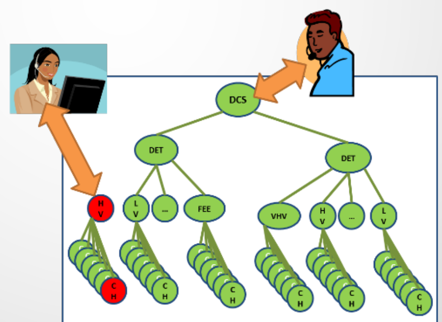
Partitioning



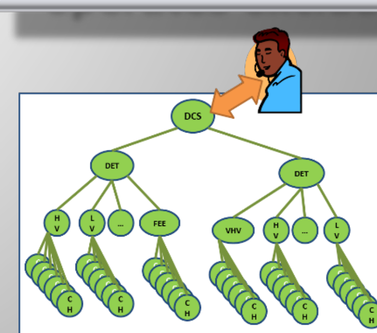
Single operator controls ALICE



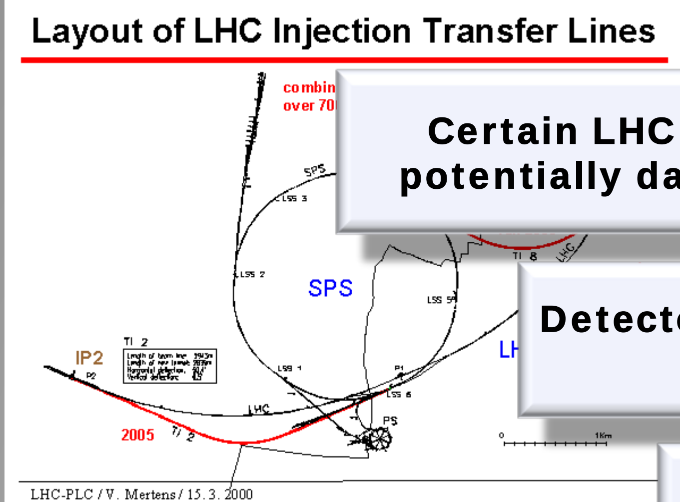
Failing part is removed from hierarchy



Remote expert operates excluded part



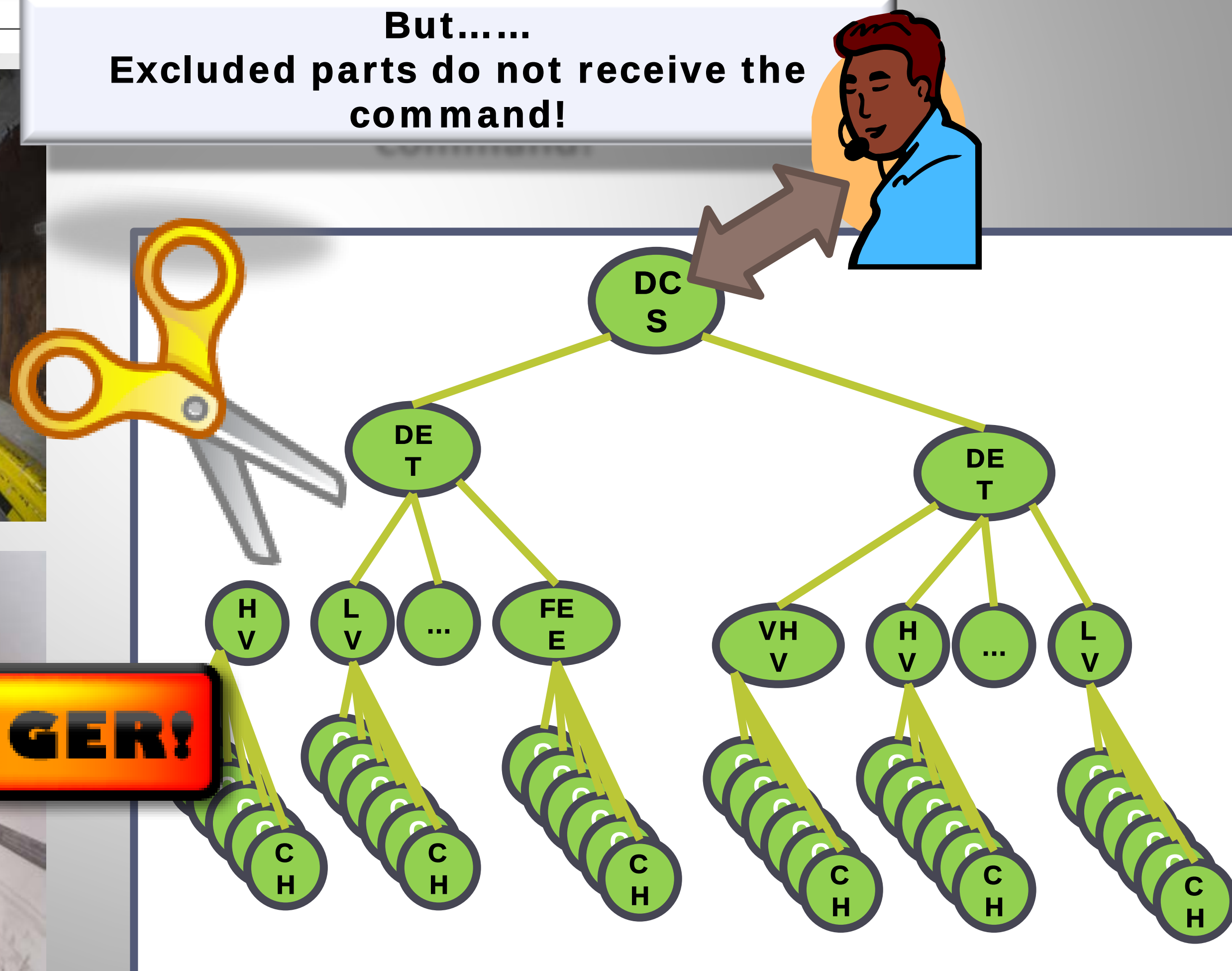
- **ALICE is primary interested in ion physics**
- **During the LHC operation with protons, there is small room for developments and improvements**
- **Partitioning is used by experts to allow for parallel operation**



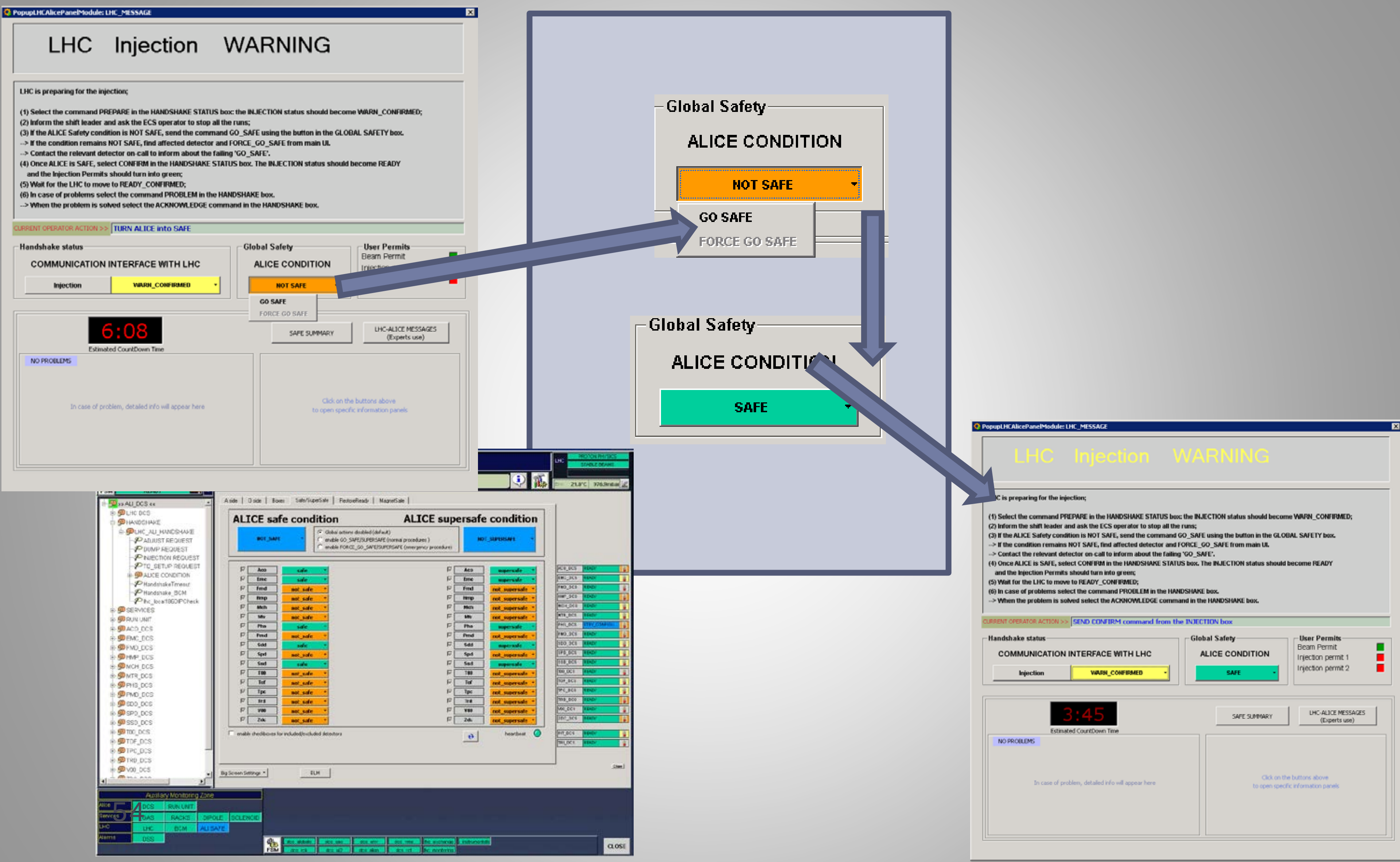
Certain LHC operations might be potentially dangerous for detectors

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



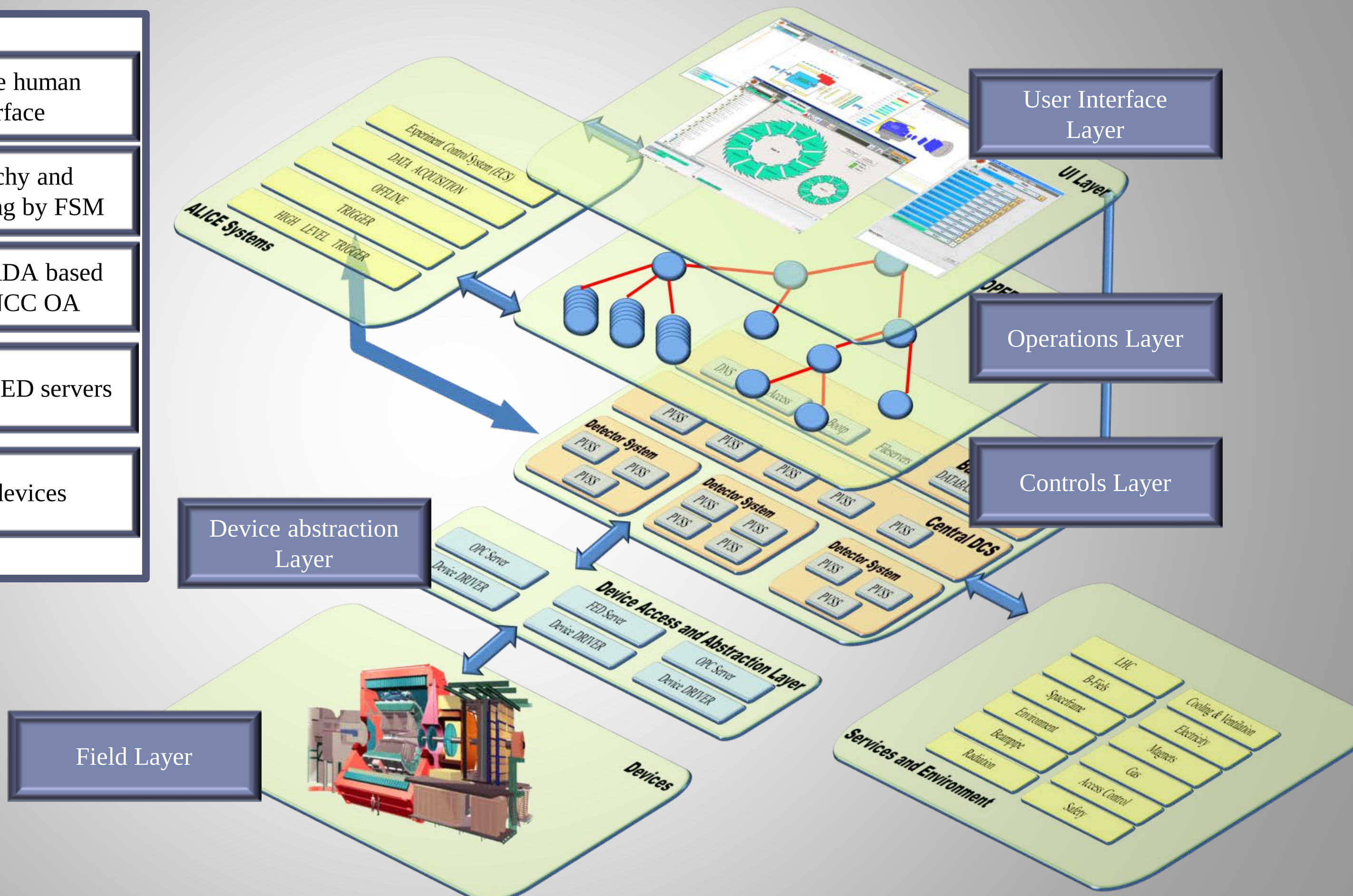
PopupLHCAlicePanelModule: LHC_MESSAGE
LHC Injection WARNING
LHC is preparing for the injection;
(1) Select the command PREPARE in the HANDSHAKE STATUS box: the INJECTION status should become WARN_CONFIRMED;
(2) Inform the shift leader and ask the ECS operator to stop all the runs;
(3) If the ALICE Safety 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
Global Safety
ALICE CONDITION
NOT SAFE
GO SAFE
FORCE GO SAFE
Global Safety
ALICE CONDITION
SAFE
ALICE safe condition
ALICE supersafe condition
NOT_SAFE
NOT_SUPERSAFE
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
In case of problem, detailed info will appear here
Click on the buttons above to open specific information panels
CLOSE

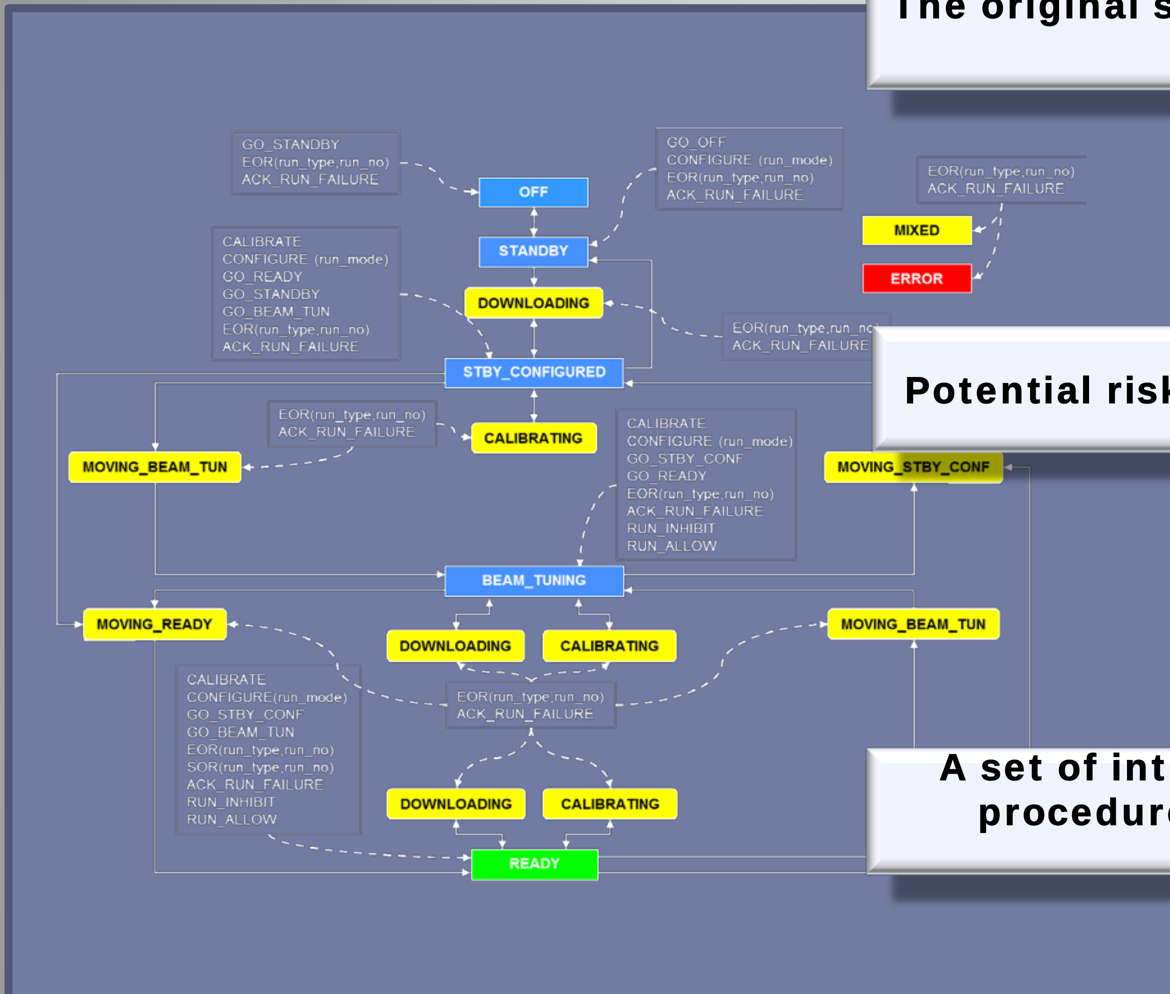
DCS Architecture

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

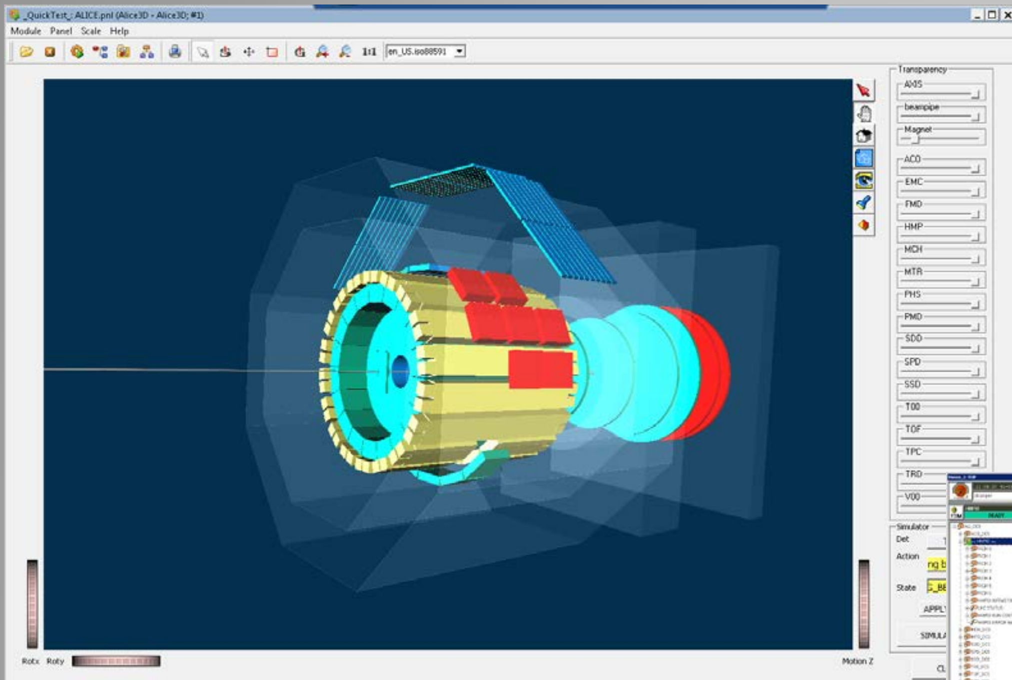


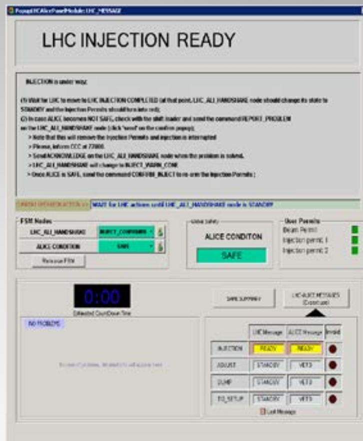


The original simple FSM layout got complex with time

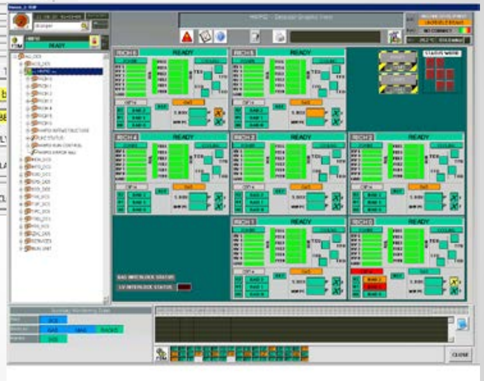
Potential risk of human errors in operation

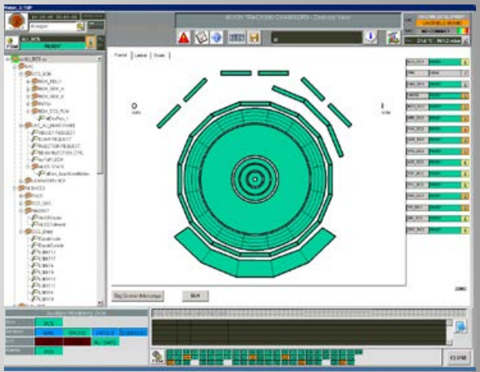
A set of intuitive panels and embedded procedures replaced the direct FSM operation

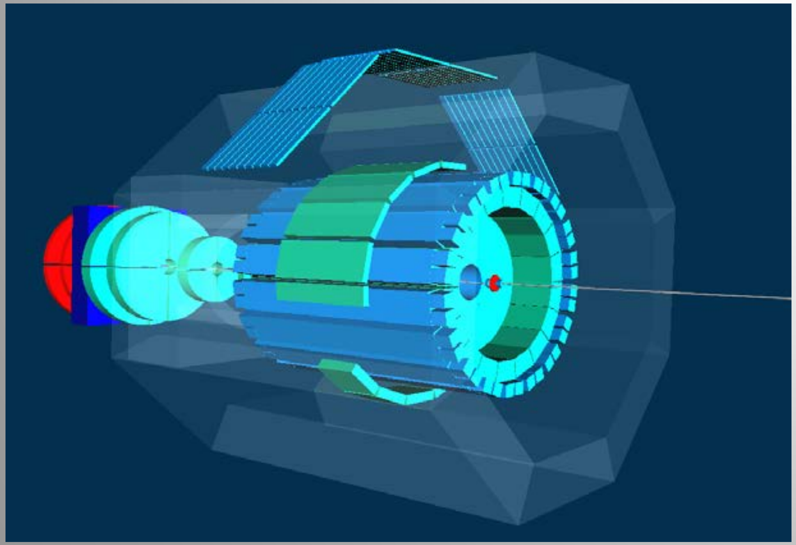

Module Panel Scale Help
Transparency

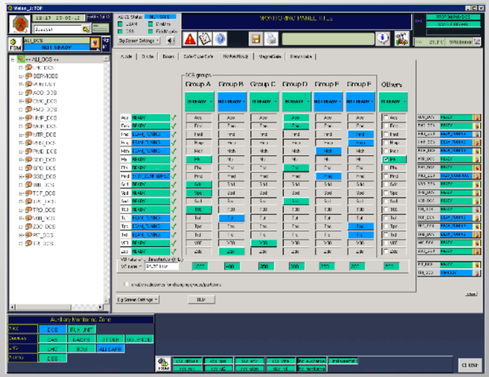

LHC INJECTION READY

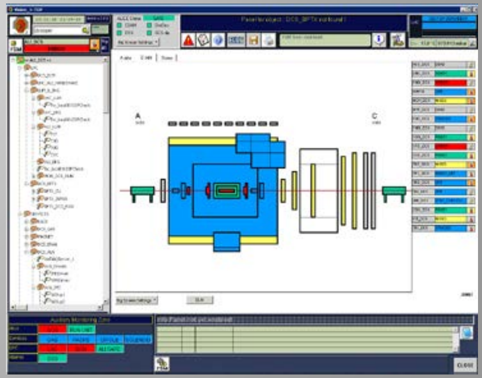

LHC INJECTION WARNING











DCS Operation

Organization

- Central operator is responsible for all subdetectors
  - 24/7 shift coverage during ALICE operation periods
  - High turnaround of operators – specific to HEP collaborations
  - Shifters training and on-call service provided by the central team
  - Requires clear, extensive documentation understandable for non-expert, and easily accessible

- Sub-detector systems are maintained by experts from the collaborating institutes
  - Oncall expert reachable during operation with beams
    - Remote access for interventions
  - In critical periods, detector shifts might be manned by detector shifters
    - Very rare and punctual activity e.g. few hours when heavy ion period starts – the system has grow mature

Emergency handling

- Sub-detectors developers prepare alerts and related instructions for their subsystems
  - These experts very ofter become on-call experts
  - Automatic or semi-automatic recovery procedures

- 3 classes of alerts:

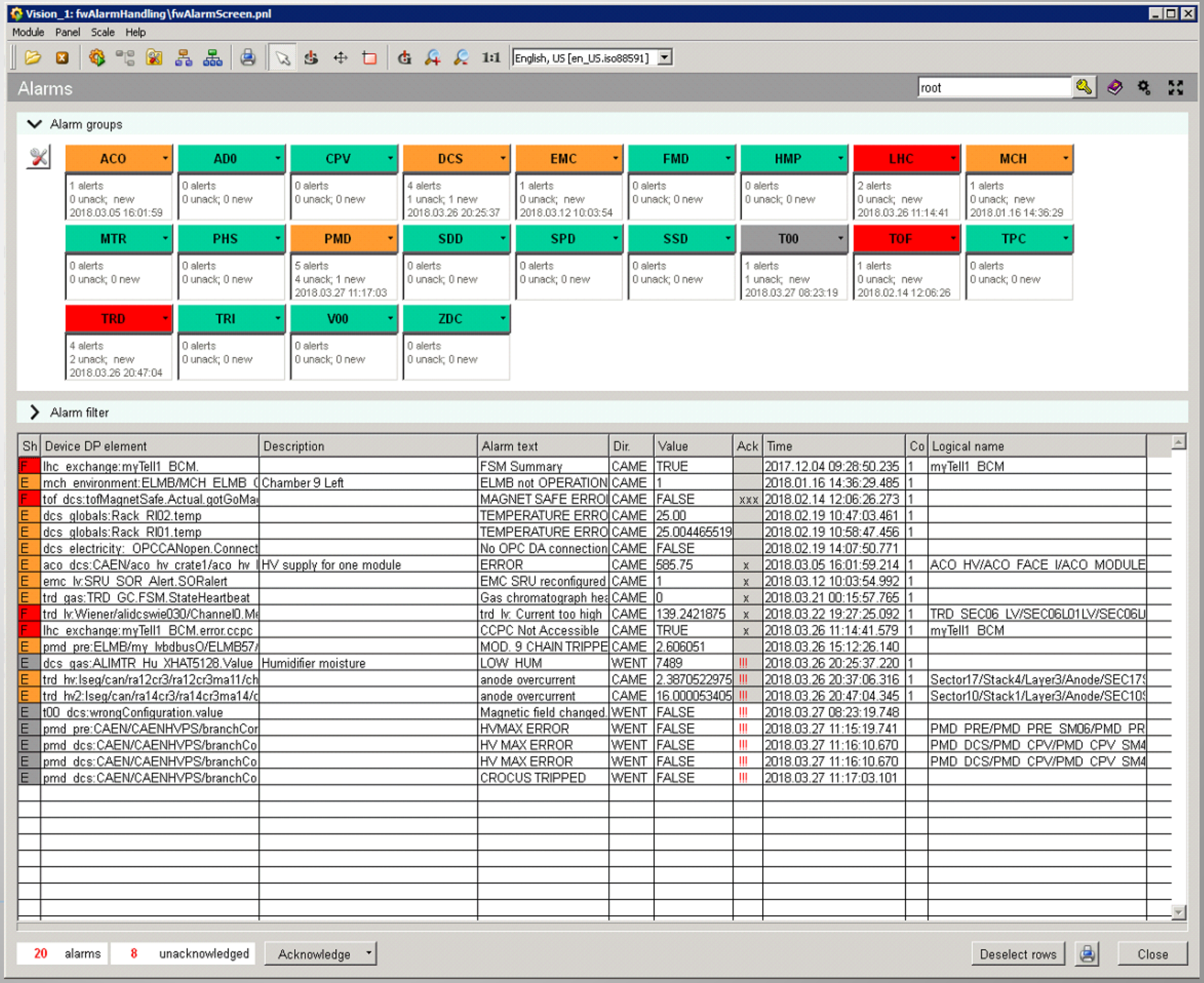
Fatal	high priority - imminent danger, immediate reaction required
Error	middle priority - severe condition which does not represent imminent danger but shall be treated without delay
Warning	low priority - early warning about possible problem, does not represent any imminent danger

Alert handling

- Reaction to DCS alerts (classes fatal and error) is one of the main DCS operator tasks

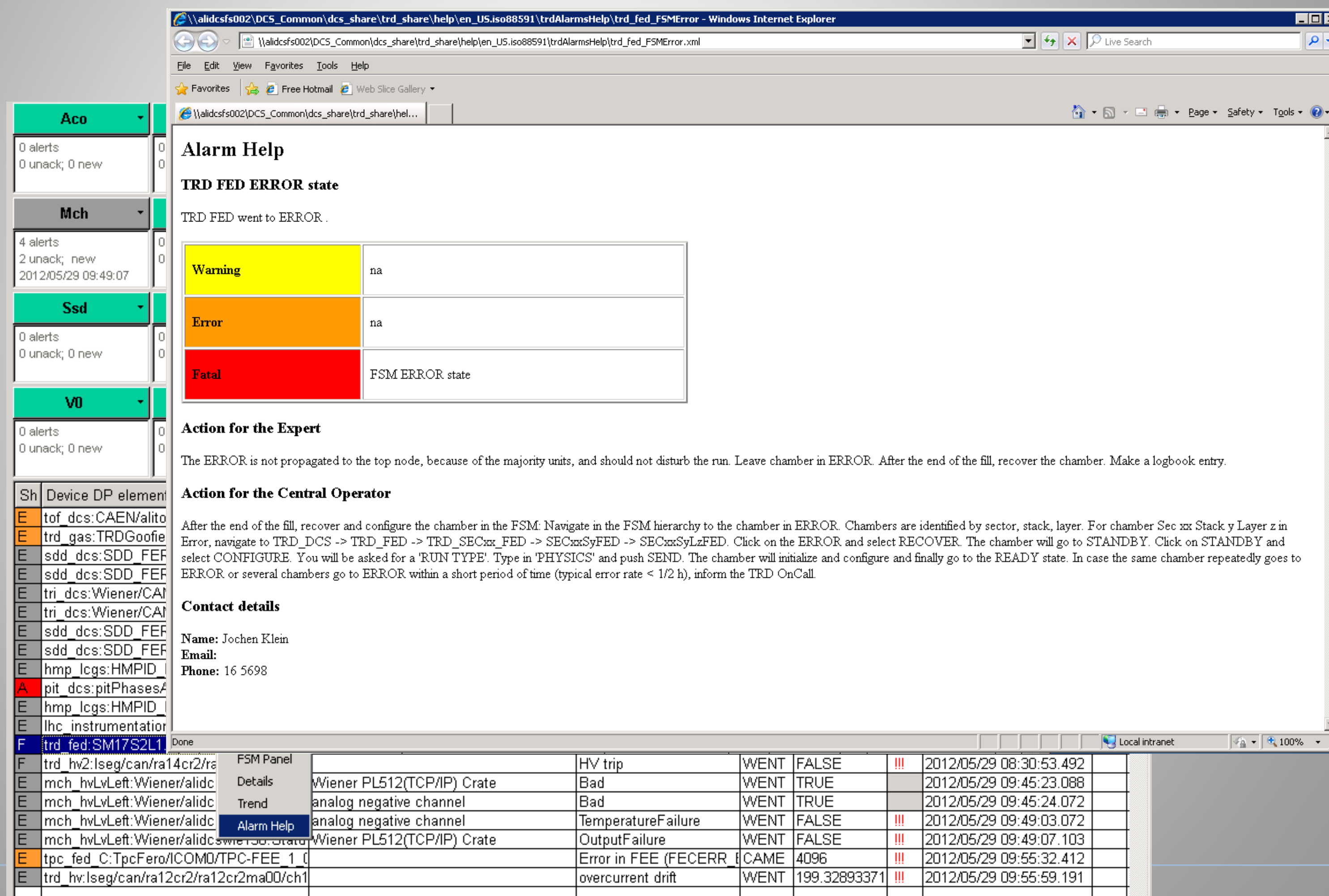
- Warnings:
  - Under responsibility of subsystems shifters/experts
  - No reaction expected from central operator

- Dedicated screen displays alerts (F,E) arriving from all connected DCS systems as well as from remote systems and services

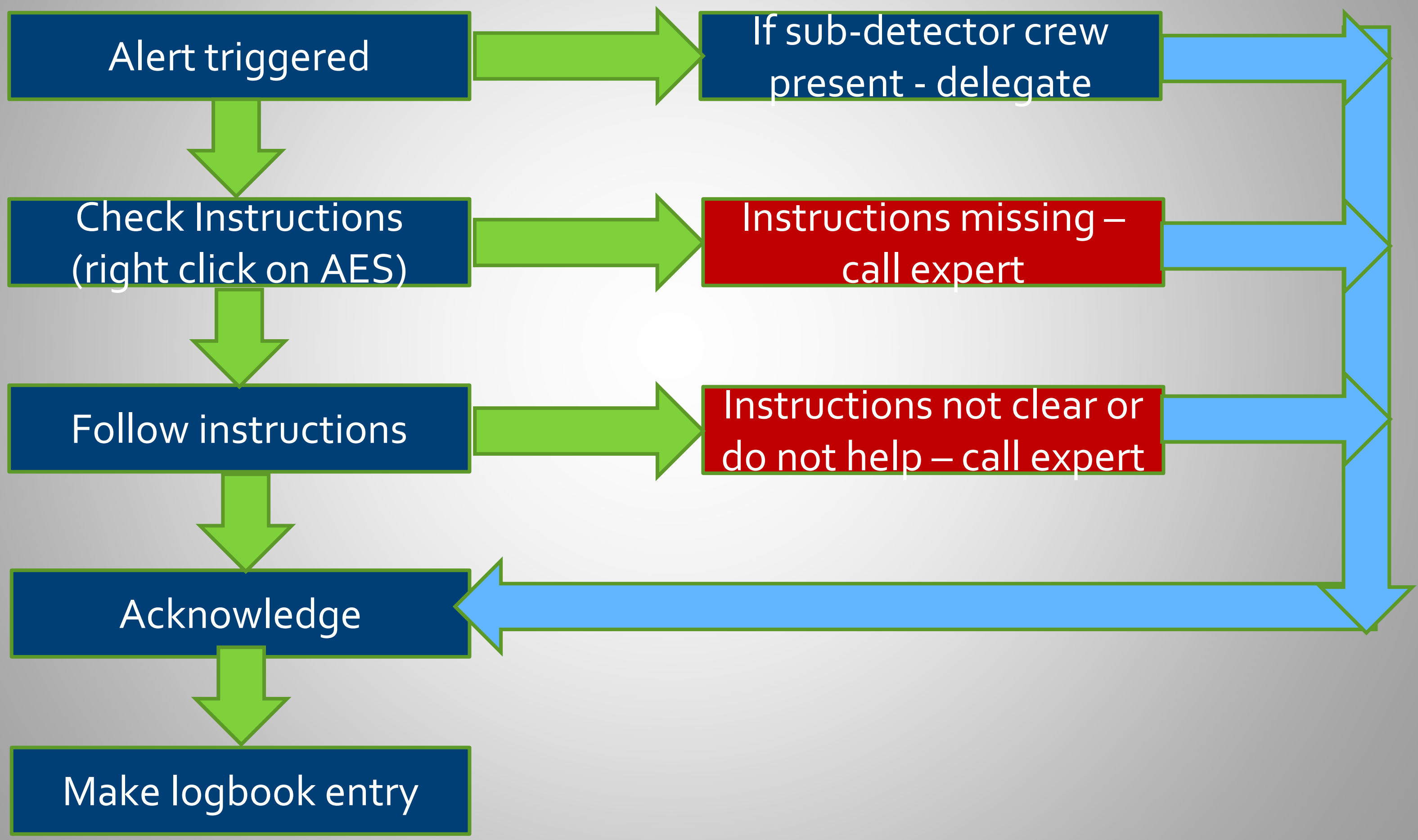


Alert instructions

- Available directly from the alerts screen



Alert handling procedure



Infrastructure Management

DCS Network

- The *controls network* is a separate, well protected network
  - Without direct access from outside the experimental area
  - With remote access only through application gateways
  - With all equipment on secure power

Computing Rules for DCS Network

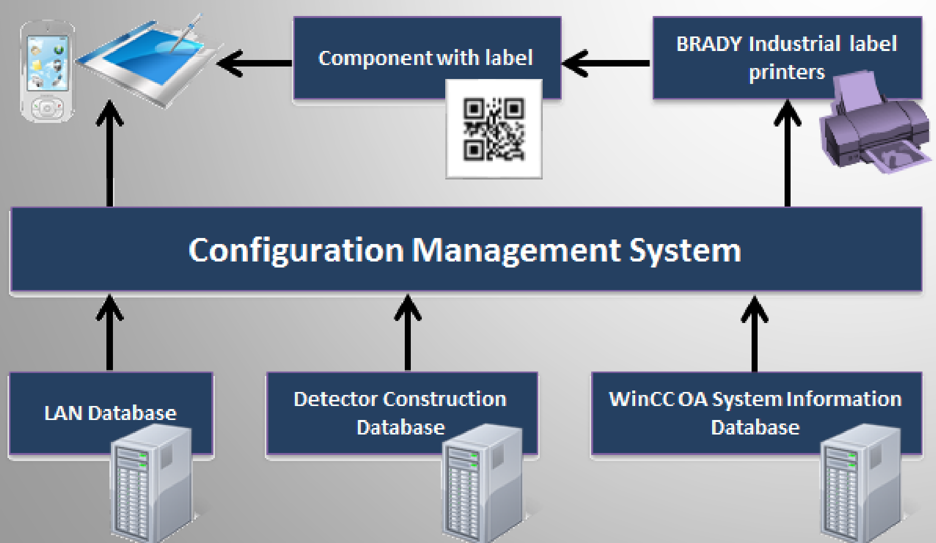
- Document prepared by ACC and approved on the Technical Board level
- Based on
  - CERN Operational Circular Nr. 5 (baseline security document, mandatorily signed by all users having a CERN computing account)
  - Security Policy prepared by CERN Computing and Network Infrastructure (CNIC)
  - Recommendations of CNIC
- Describes services offered by ACC related to computing infrastructure

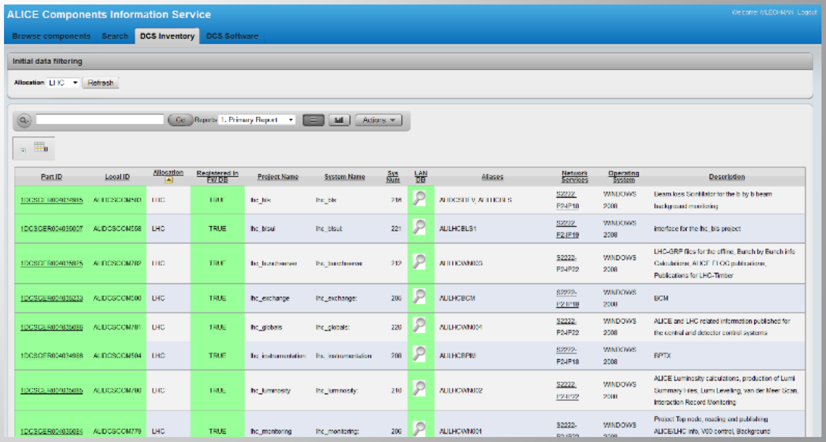
Scope of Computing Rules

- Categories of network attached devices
- Computing hardware (HW) purchases and installation
  - Standard HW -> by ACC
  - Rules for accepting non-standard HW
- Computer and device naming conventions
- DCS software installations
  - Rules for accepting non-standard components
- Remote access policies for DCS network
  - Access control and user privileges
    - 2 levels: operators and experts
  - Files import and export rules
- Software backup policies
- Reminder that any other attempt to access the DCS network is considered as unauthorized and in direct conflict with CERN rules and subjected to sanctions

Managing Assets

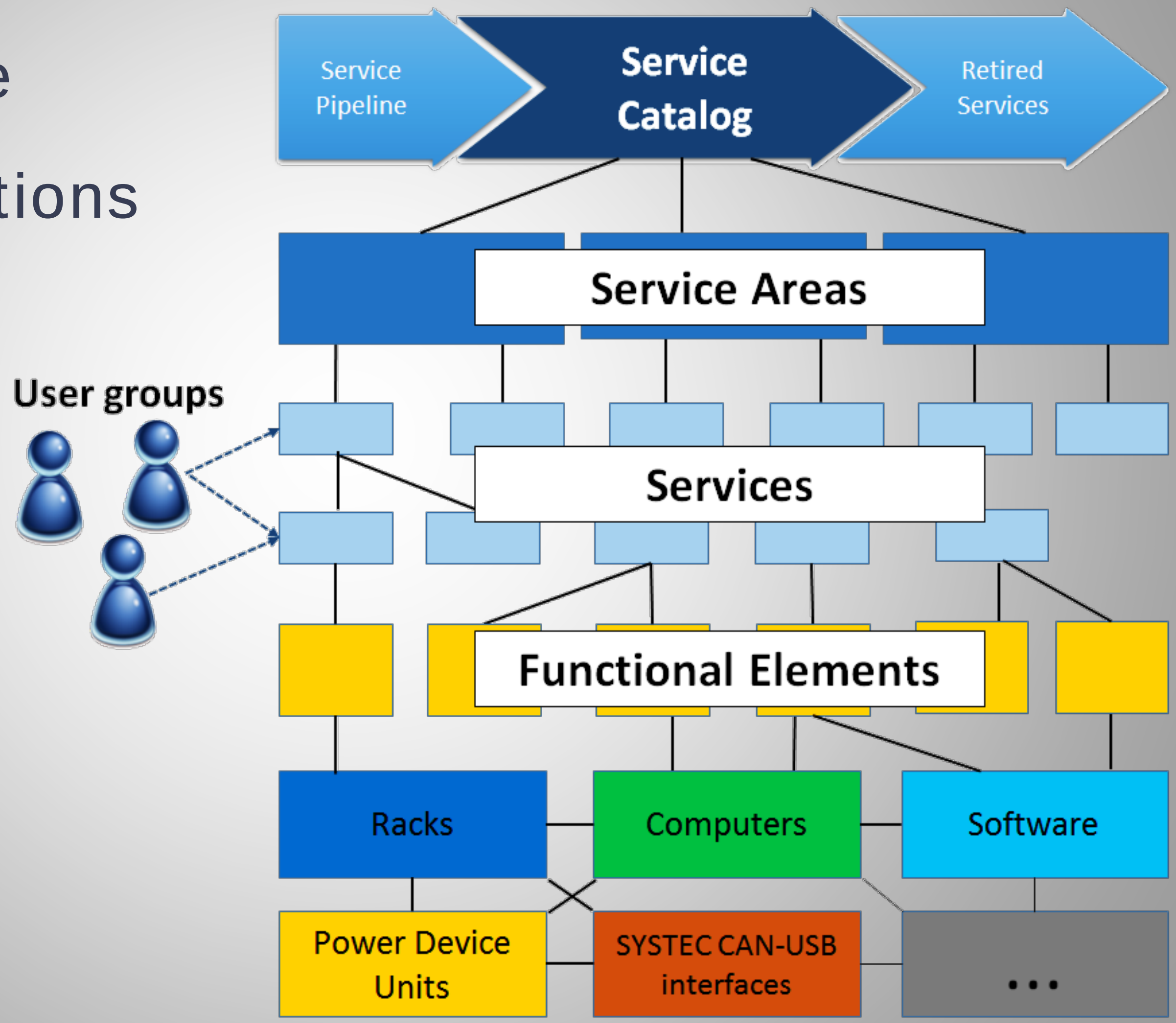
- DCS services require numerous software and hardware assets (Configuration Items)
- Essential to ensure that reliable and accurate information about all these components along with the relationship between them is properly stored and controlled
- CIs are recorded in different configuration databases at CERN
- Configuration Management System - integrated view on all the data
- Repository for software





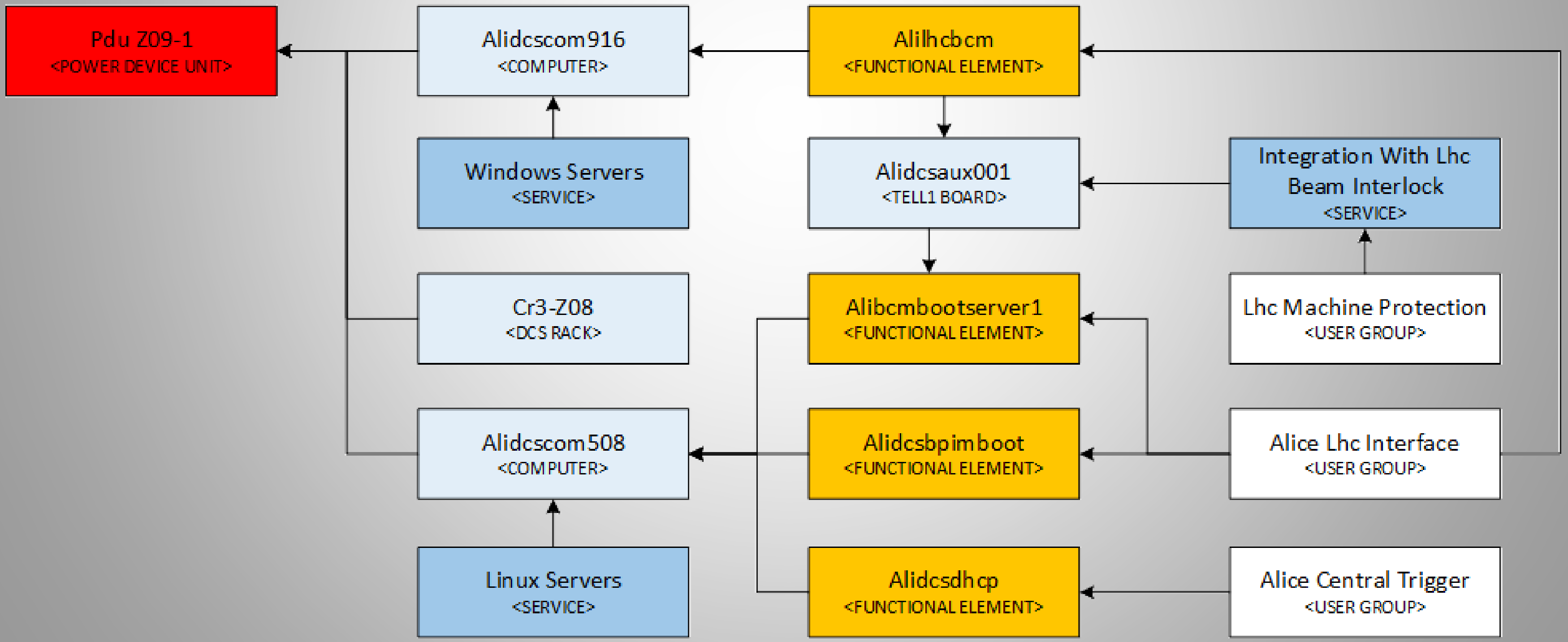
Hierarchy of Configuration Items

- Based on IT Infrastructure Library (ITIL) recommendations



Managing dependencies

- Generation of diagrams showing dependencies between CIs for impact analysis



Knowledge Management

- Implemented via:
  - MS SharePoint - documents management and collaboration system
    - before TWiki & custom ACC webpages were in use
  - JIRA – issues tracking

- Scope – all deliverables from ACC
  - Technical documentation for experts
  - Operational procedures
  - Training materials
  - DCS Computing Rules
  - Known Errors register
  - Operation reports
  - Publications
  - …

Summary

- Standarization is the key to success
- Experiment environment evolves rapidly
  - Scalability and flexibility play important role in DCS design
  - Stable central team contributing to the conservation of expertise
- Central operation
  - Cope with large number of operators
  - Adequate and flexible operation tools, automation
  - Easily accessible, explicit procedures
- Experiment world is dynamic, volatile
  - Requires a major coordination effort
- ALICE DCS provided excellent and uninterrupted service since 2007

Summary

- Operational experiences gained during the operation are continuously implemented into the system in form of procedures and tools
  - Relatively quiet on-call shifts for ACC members
    - Number of calls decreased significantly over time (from ~1 per day at the start to ~1 per week now)
      - More automation
      - Better training and documentation
      - Better procedures
      - Better UIs that make operation more intuitive (hiding complexity)

THANK YOU FOR YOUR ATTENTION

ALICE