DETECTOR CONTROL SYSTEM FOR THE ALICE EXPERIMENT AT CERN -LHC

ICTDHEP JAMMU
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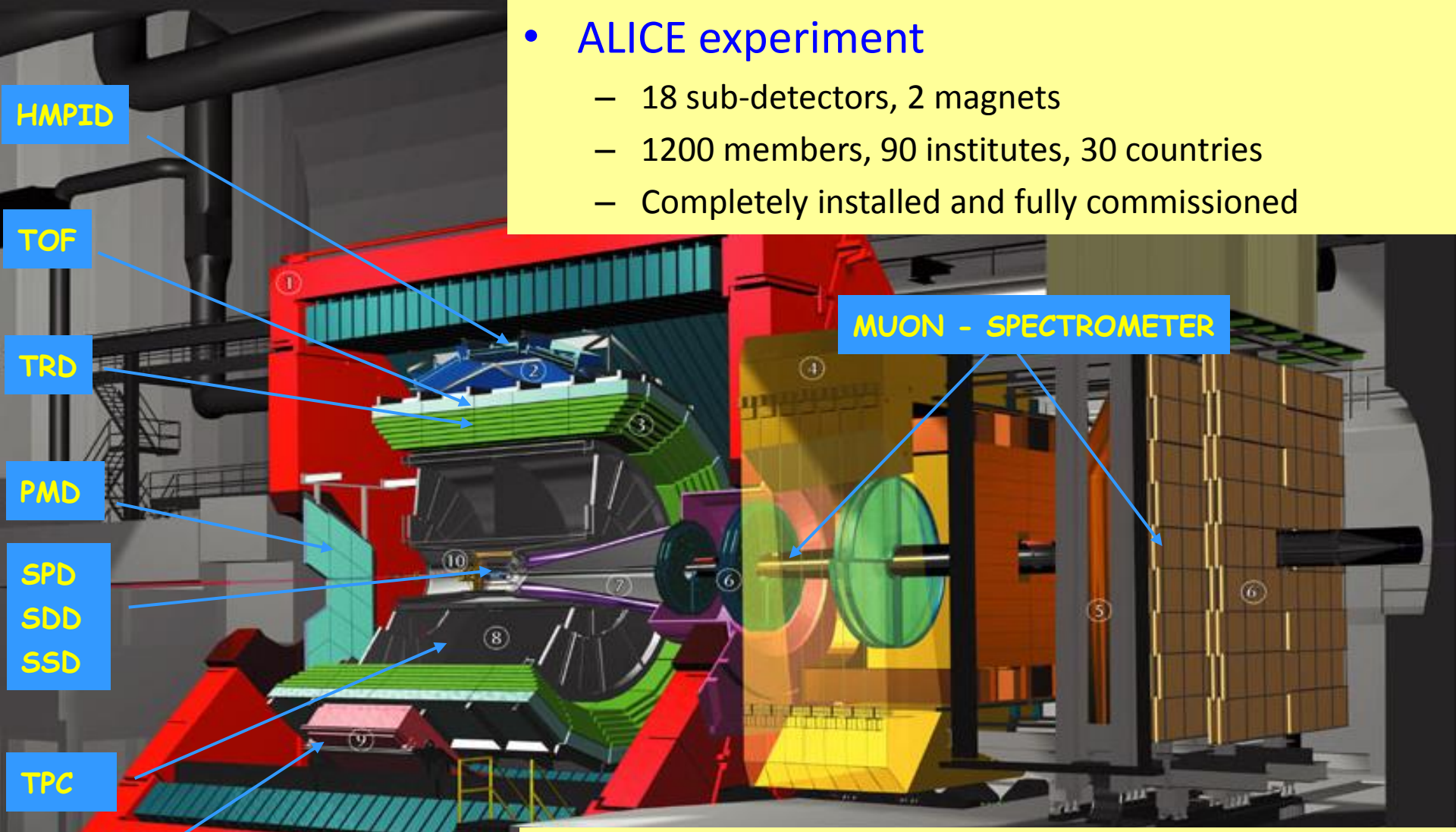
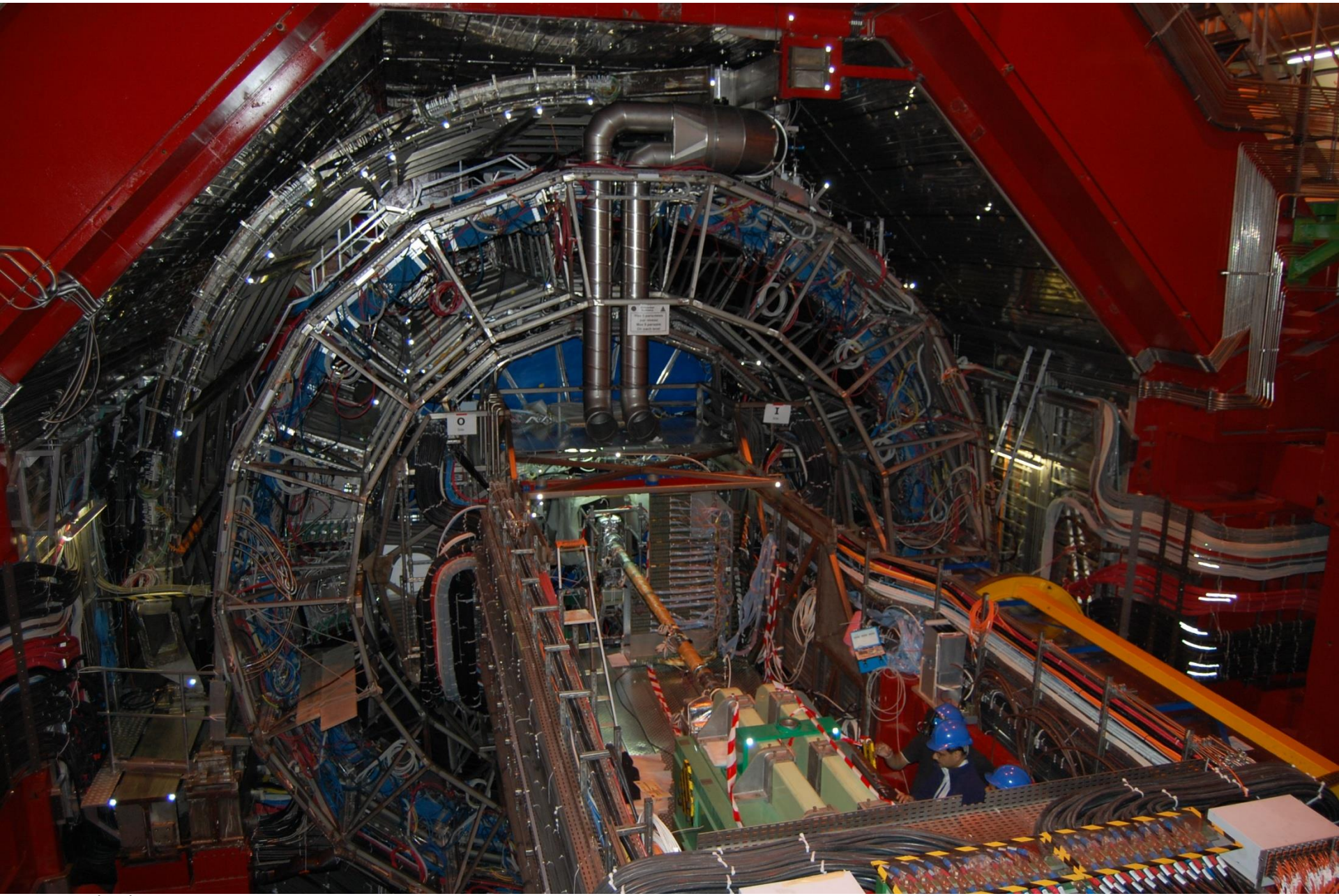
Special Thanks to the ALICE CONTROLS COORDINATION

Based on slides given by Peter Chochula, Andre Augustinus and ALICE DCS TRAINING SLIDES

- ALICE experiment
  - 18 sub-detectors, 2 magnets
  - 1200 members, 90 institutes, 30 countries
  - Completely installed and fully commissioned



- ALICE Controls
  - Started 12 years ago
  - Small(Very Important) central team
    - Detector groups & LHC experiments (JCOP)
    - In total ~100 people involved



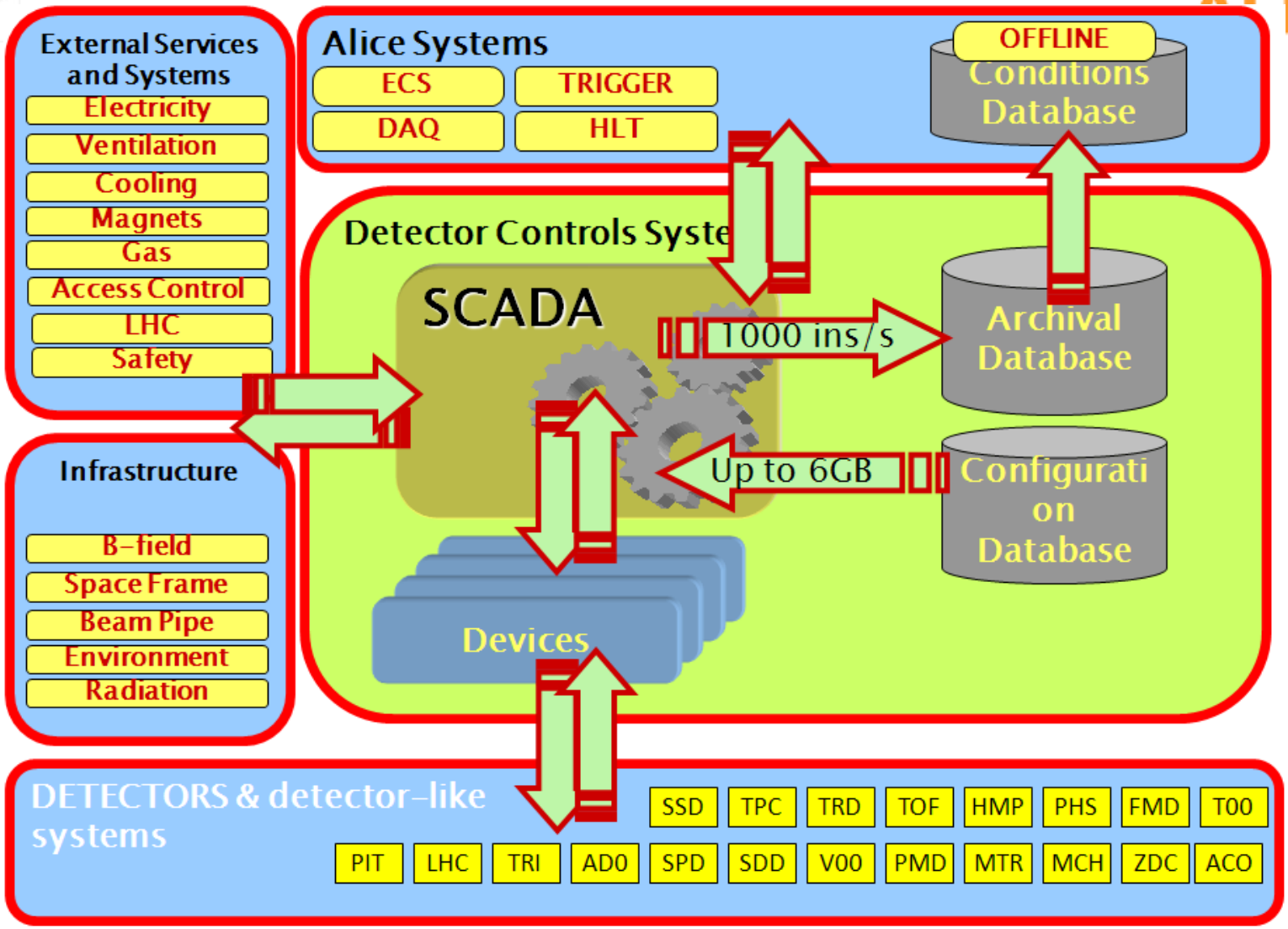
ALICE DCS

- The two main tasks of the ALICE Detector Control System (DCS) are
  - To assure maximum protection such that detector equipment cannot be damaged by adverse beam conditions
  - To assure that, whenever beam conditions allow, the detector is in optimal condition to take physics data

ALICE DCS

- To achieve this, the ALICE DCS
  - controls all relevant detector equipment,
  - maintains the synchronization with the LHC machine operation,
  - monitors and controls the experiment infrastructure and services,
  - provides reliable communication with LHC and other online systems,
  - has adopted the PVSSII SCADA as main tool (a CERN-wide standard for control systems)
    - PVSSII has recently be re-branded as “WinCC Open Architecture” after purchase by Siemens

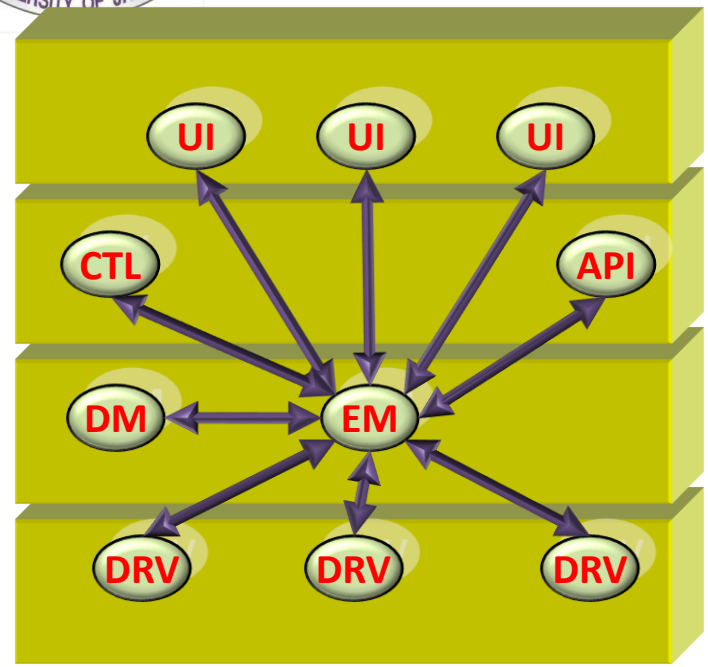
The DCS Context

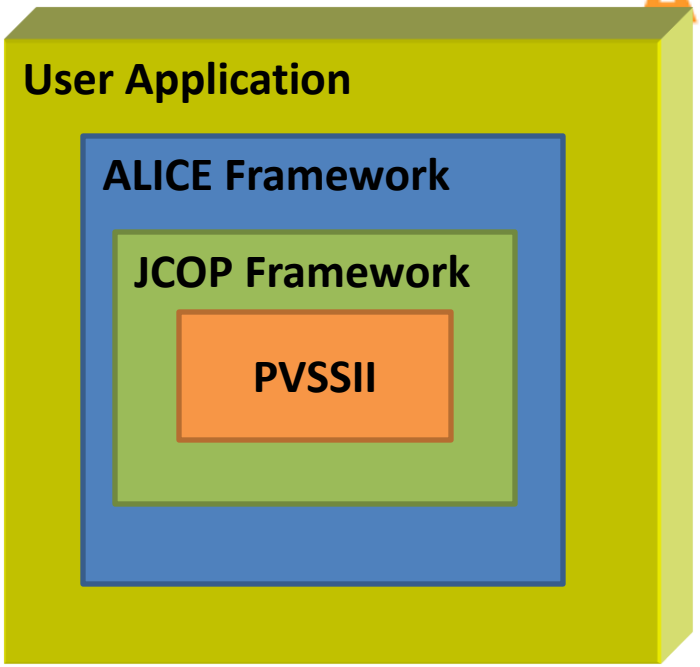


ALICE DCS

- Detector systems are responsibility of detector projects
  - Detector experts implement the local detector controls
- DCS central team (6 people):
  - provides standards, guidelines, infrastructure and support
  - supervises implementation of detector systems
  - implements the overall control of all local control systems
  - implements the interfaces with external systems and the other ALICE online systems
  - assures smooth operation during data taking campaigns

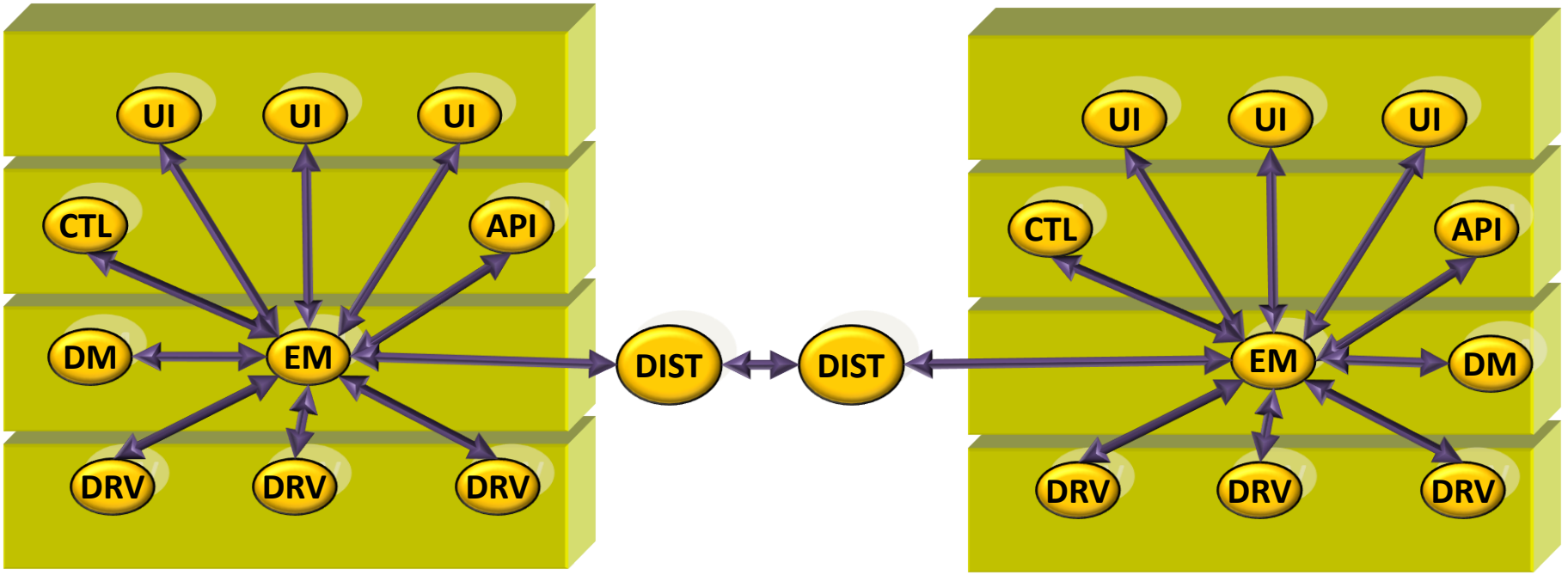
PVSSII Architecture





- PVSSII system is composed of specialized program modules (managers)
- Managers communicate via TCP/IP
- ALICE DCS is built from 100 PVSS systems composed of 900 managers
- PVSSII is extended by JCOP and ALICE frameworks on top of which User applications are built

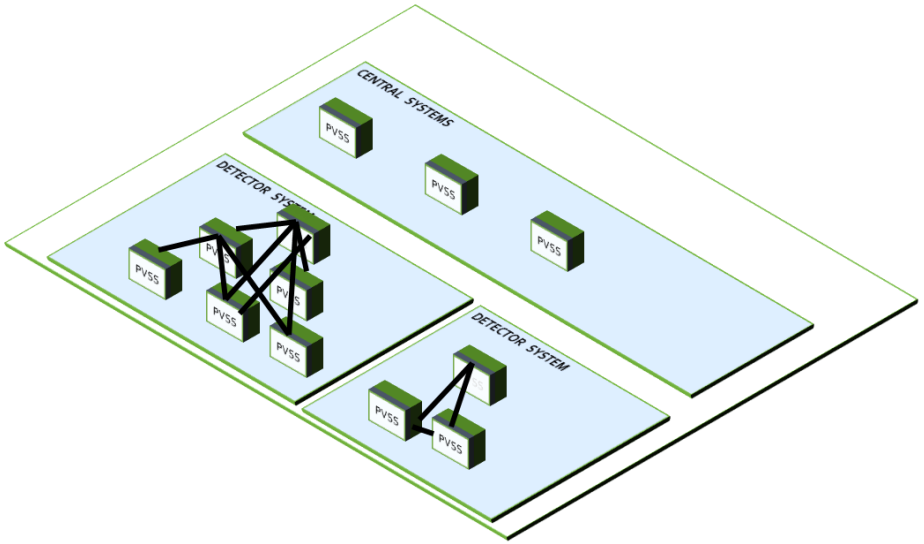
Distributed PVSS System



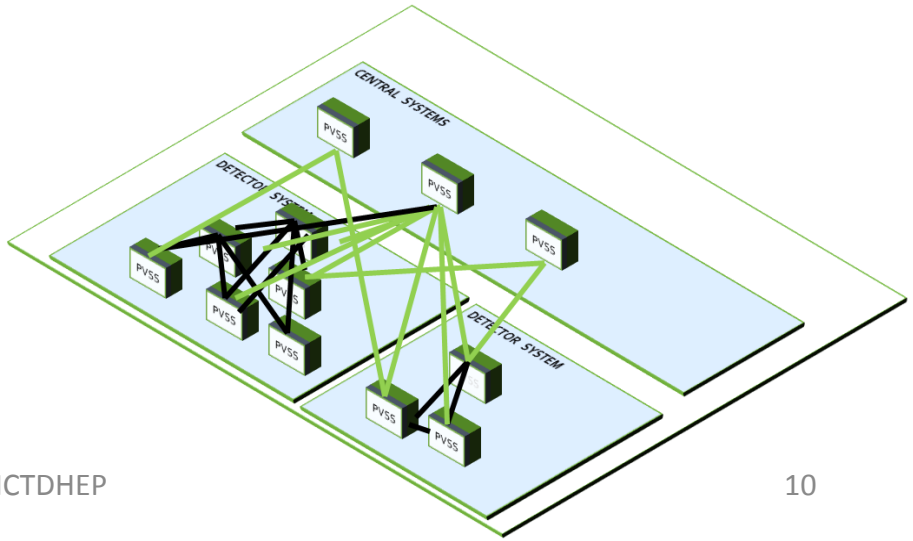
- Several PVSSII systems can be connected into one distributed system using a specialized manager (DIST)
- The ALICE distributed system consists of over 100 individual systems

ALICE DCS Distributed System

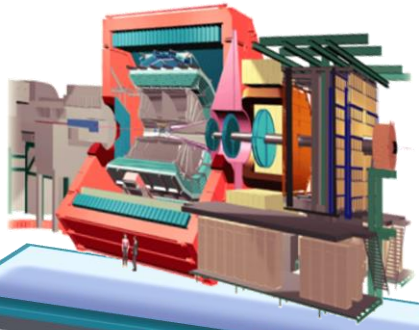
- Each detector provides an autonomous distributed system



- Central servers connect to all detectors providing one large distributed system



DCS Dataflow



ALICE on-detector electronics

GA S

COOLIN G

HV

LV

FEE

Detector devices

LHC

FEE

Mag nets

Safety

External sub-systems

300 000 values/s read by software

DCS data processing farm

DCS data storage (ORACLE, fileservers)

Offline (GRID)

Operator UIs

Data Consumers

30 000 values/s Injected into PVSSII

1000 values/s Written to ORACLE after smoothing in PVSSII

>200 values/s Sent to consumers

DCS Computing

- 170 servers
- 700 embedded computers
- Oracle DB with 144TB raw storage
- 1200 network attached devices

Challenges

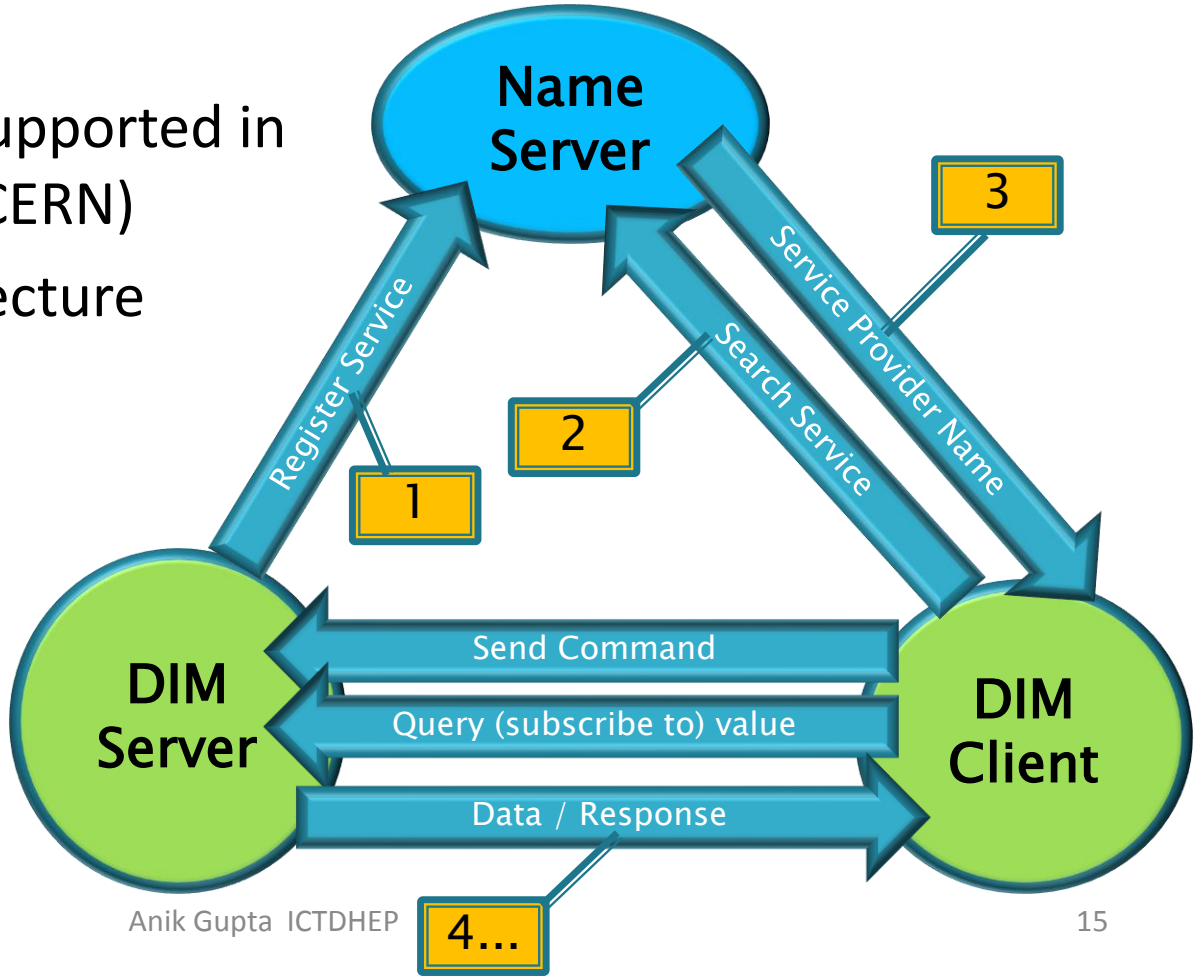
- The DCS project in ALICE has been launched relatively late, when many of the detector developments were in advanced stage, and technology choices already made
- The ALICE experiment consists of 18 different detectors
  - Compared to ~5 for ATLAS/CMS
- In order to guarantee a smooth integration a huge effort went into hiding complexity and diversity, and standardization on all levels

Challenges - standardization

- ☺ High level of standardization achieved for power supplies and services (cooling, PLC based applications…)
  - Limited number of device models, supported centrally at CERN
  - Accessed by standard interfaces: CANbus, Profibus or Ethernet
  - OPC technology used as software interface
    - industry standard, supported in PVSSII
- ☹ Large diversity in the front-end part
  - Different architectures and requirements
  - Variety of control buses (JTAG, CANbus, Profibus, RS232, Ethernet, custom buses – Easynet, DDL ...)
  - DIM technology used to hide diversity

Distributed Information Management (DIM)

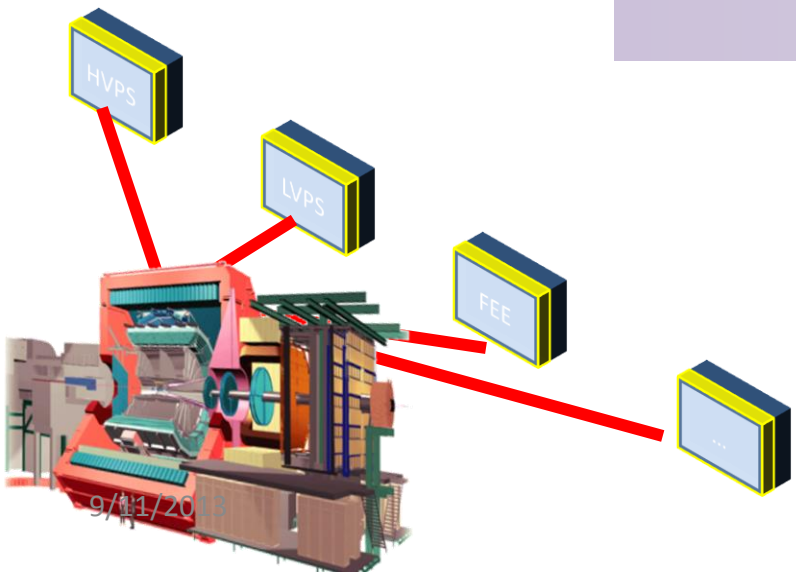
- CERN DIM used for command and data transfer
  - Implemented and supported in PVSSII and C++ (by CERN)
  - Client/server architecture
  - Robust and stable
  - Proven technology already in LEP era



Building blocks of ALICE DCS

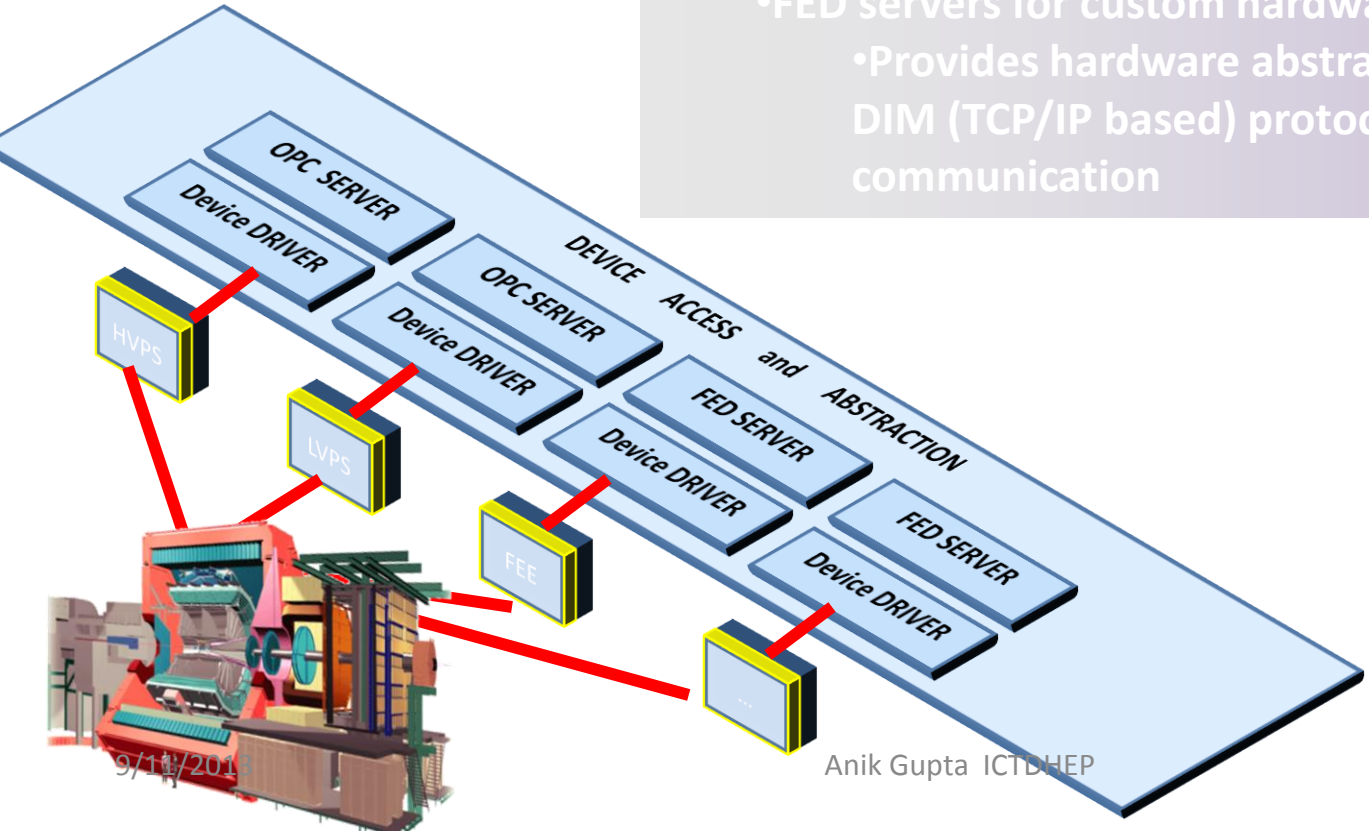
1200 network-attached devices
270 crates (VME and power supplies)
4 000 controlled voltage channels

- **18 detectors with different requirements**
  - **Effort to device standardization**
    - **Still large diversity mainly in FEE part**
      - **Large number of busses (CANbus, JTAG, Profibus, RS232, Ethernet, custom links…)**

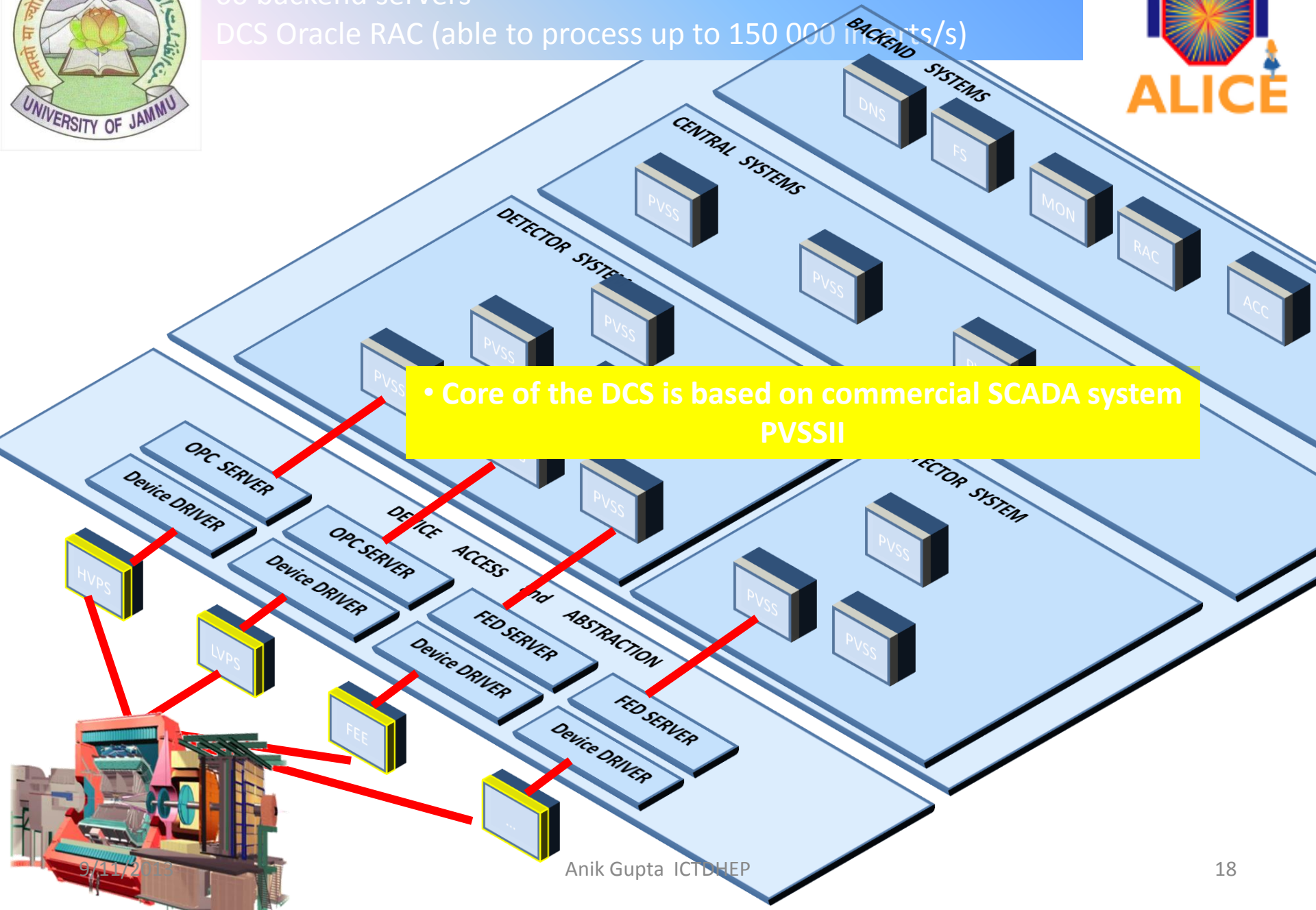


180 000 OPC items
100 000 Front-End (FED) services
1 000 000 parameters supervised by the DCS
Monitored at typical rate of 1Hz

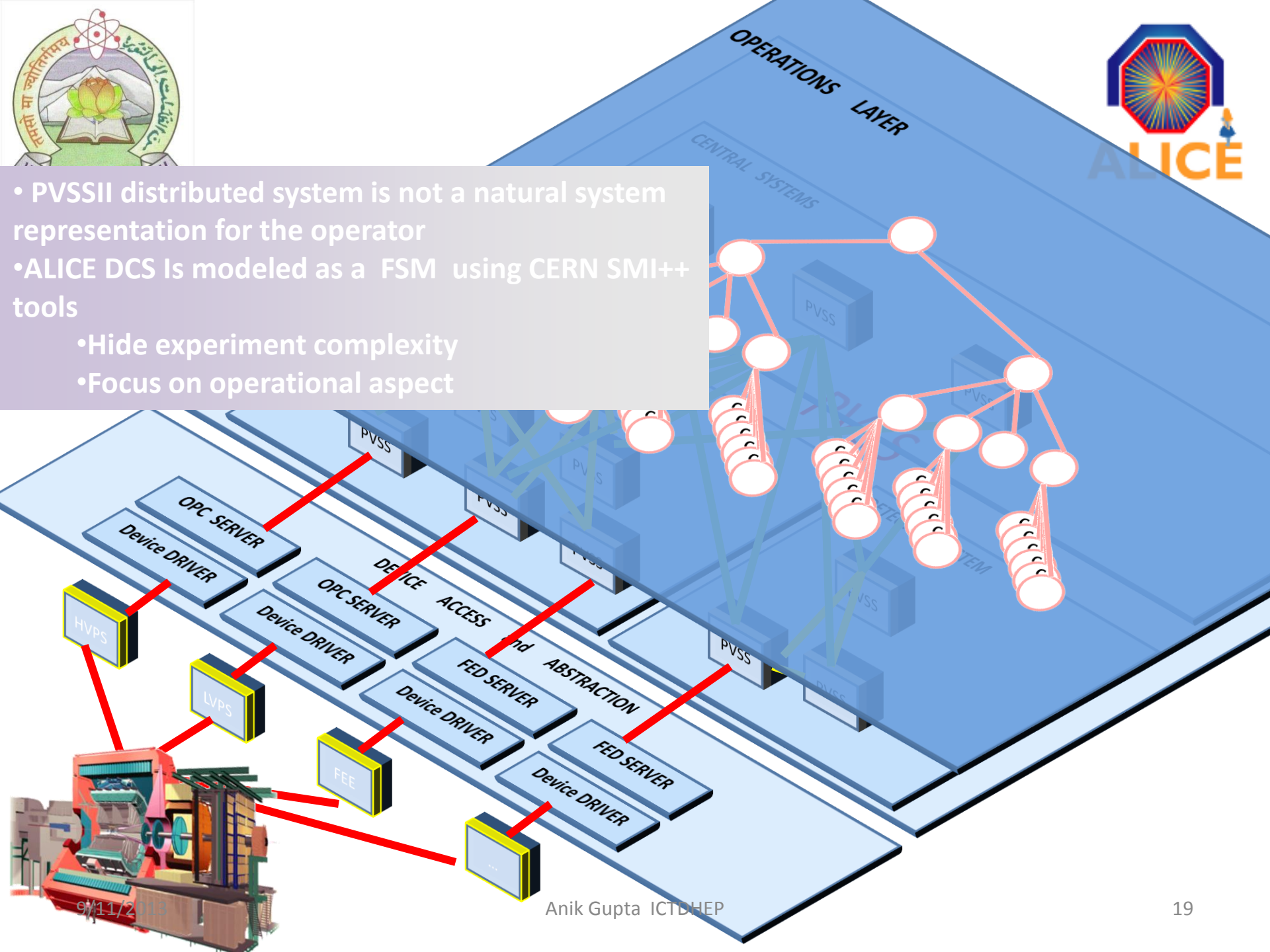
- Hardware diversity is managed through standard interfaces
  - OPC servers for commercial devices
  - FED servers for custom hardware
    - Provides hardware abstraction, uses CERN DIM (TCP/IP based) protocol for communication



110 detector computers
60 backend servers
DCS Oracle RAC (able to process up to 150 000 inserts/s)



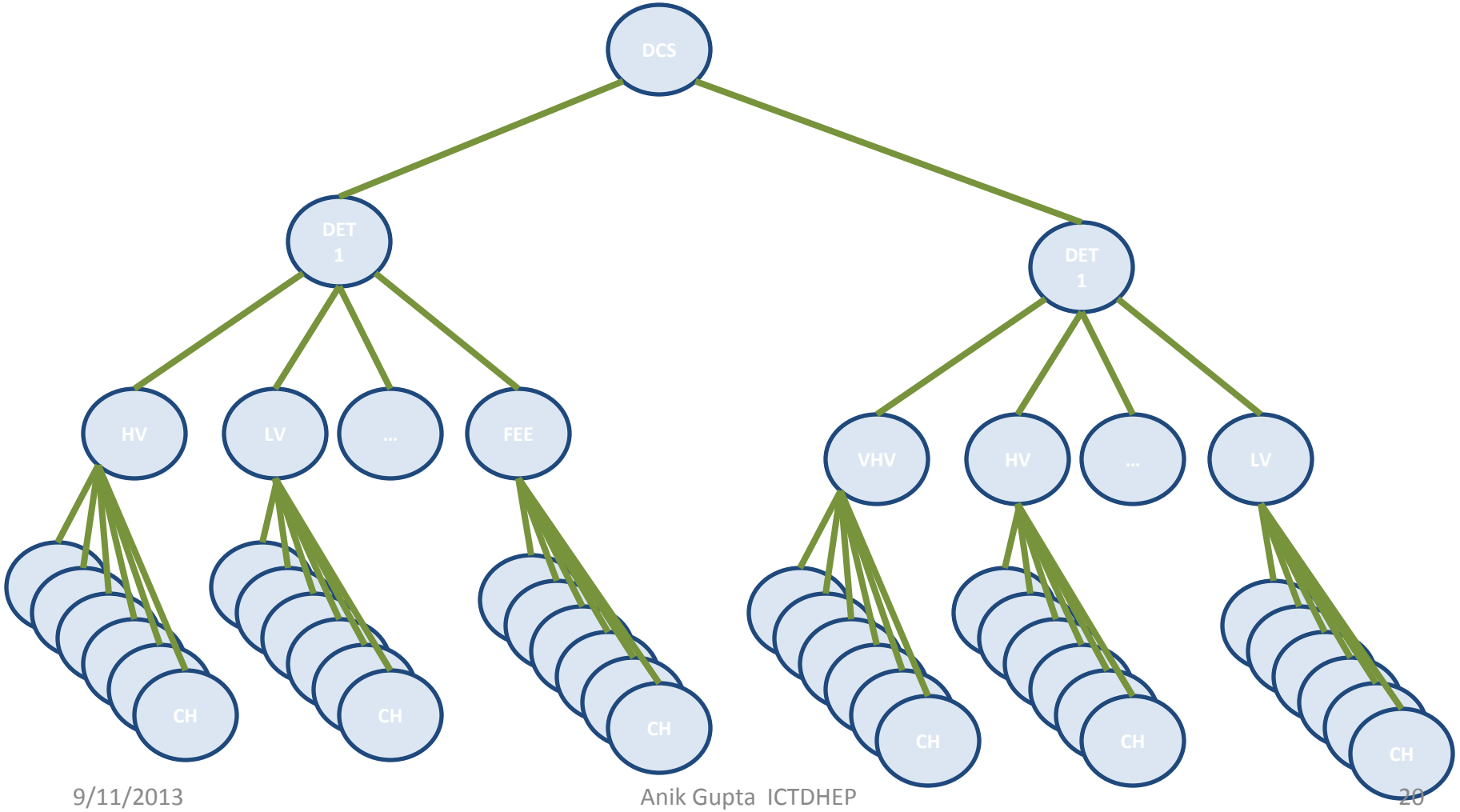
• Core of the DCS is based on commercial SCADA system PVSSII



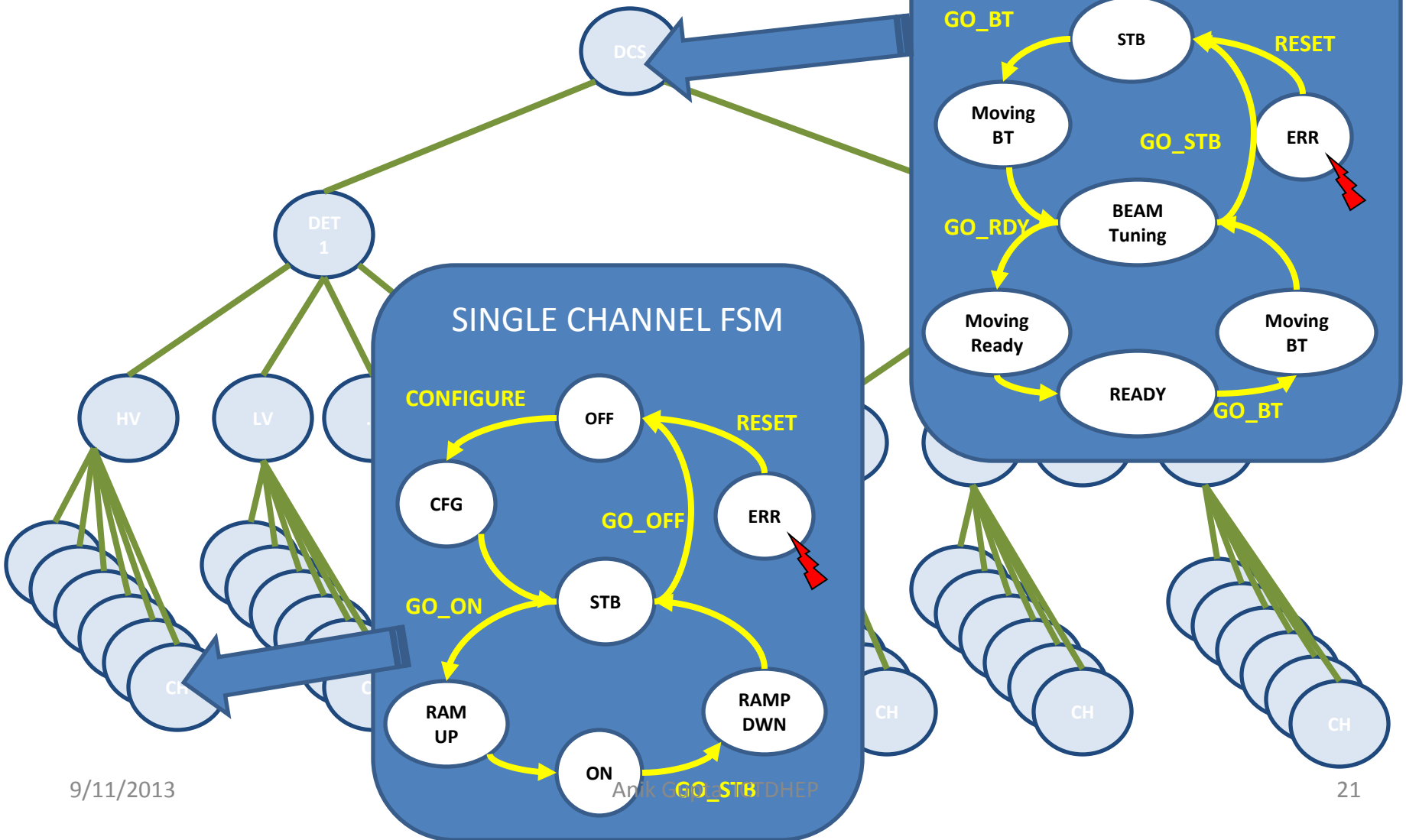
- PVSSII distributed system is not a natural system representation for the operator
- ALICE DCS Is modeled as a FSM using CERN SMI++ tools
  - Hide experiment complexity
  - Focus on operational aspect

•Hierarchical approach:

- ALICE DCS is represented as a tree composed of detector systems
- Each detector system is composed of subsystems
- Subsystems are structured to devices (crates, boards) and channels

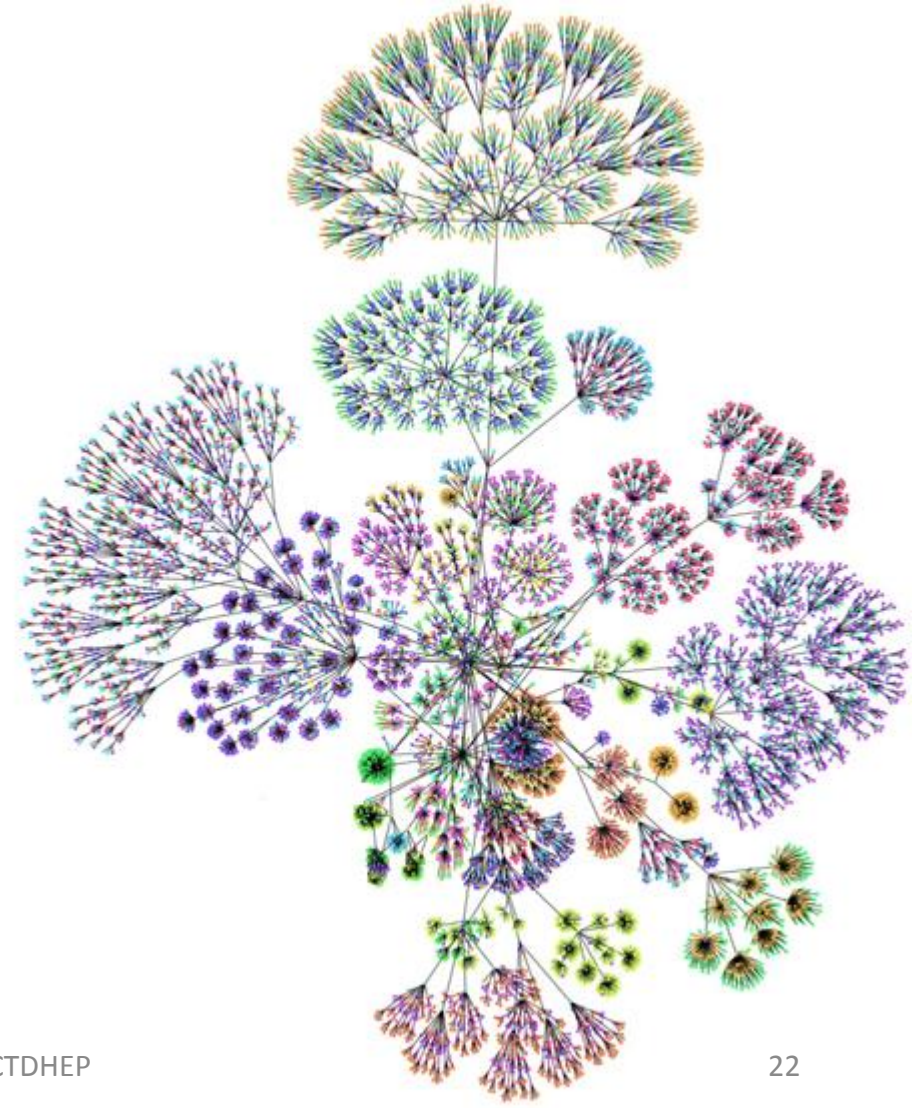


- DCS devices are described as FSM
- State diagrams are standardized for channels and devices of the same type
- Top level DCS takes into account status of all leaves



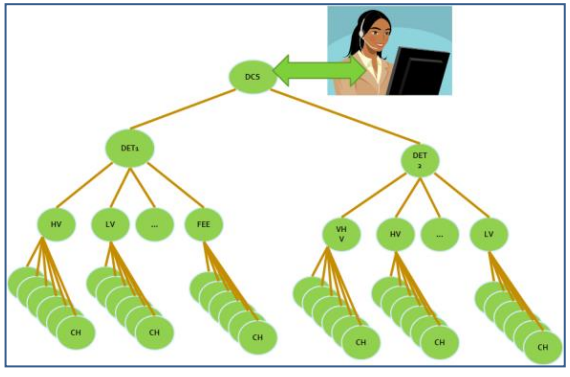
ALICE Central FSM Hierarchy

- Scale:
  - 1 top DCS node
  - 19 detector nodes
  - 100 subsystems
  - 5 000 logical nodes
  - 10 000 devices (leaves)
  - Each leaf can represent a complex unit containing many channels

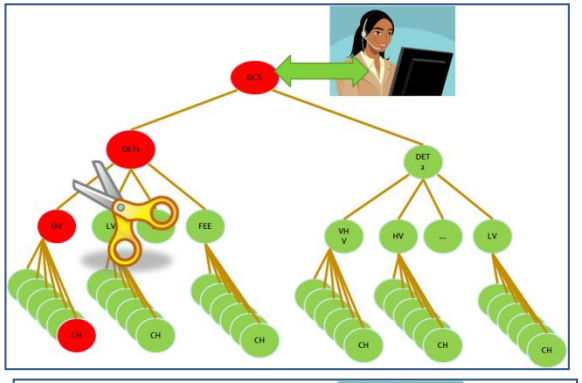


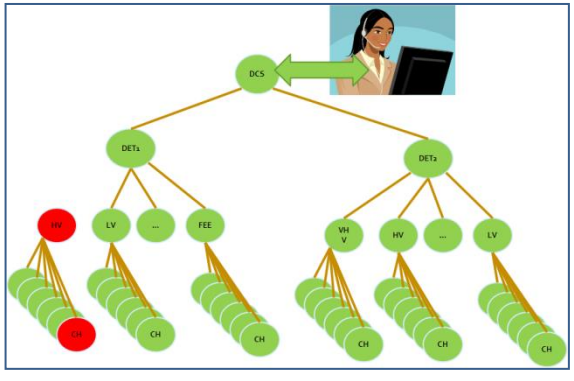
Hierarchy Partitioning

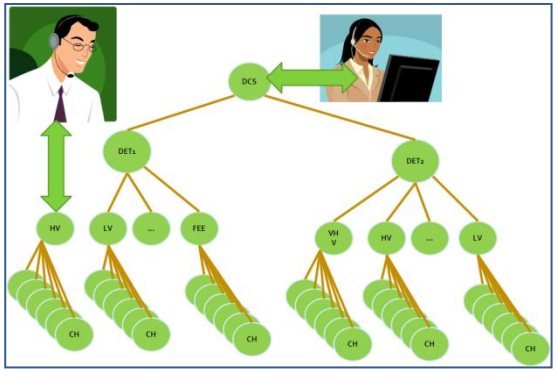
- Partitioning allows for concurrent operation

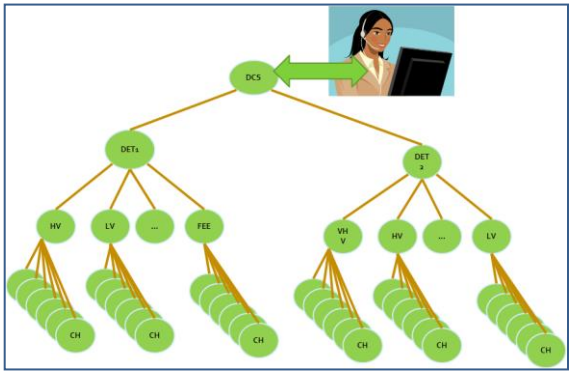


A single channel error can put overall DCS into error







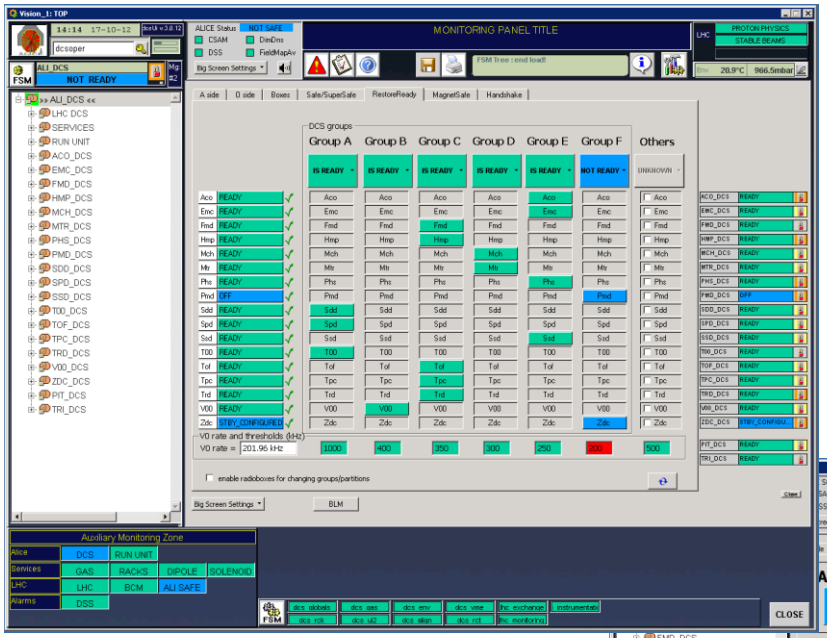


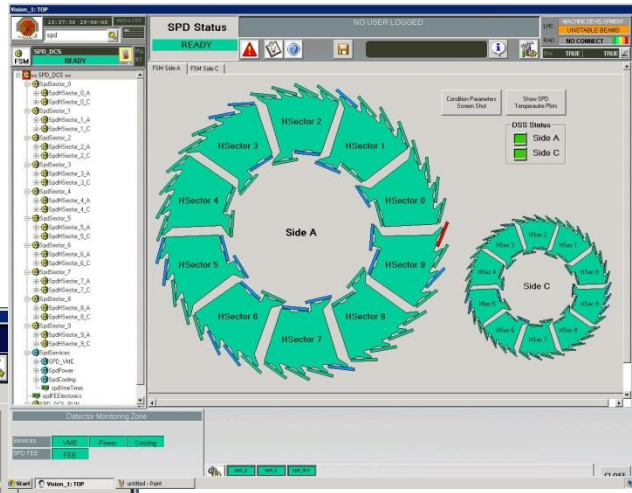
Operator excludes the affected part

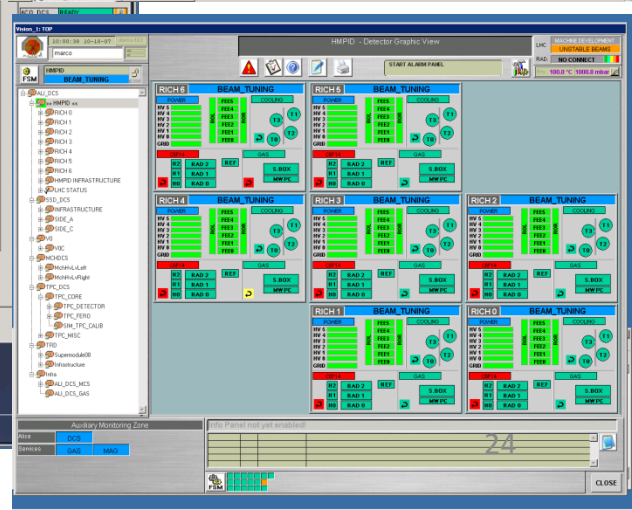
Remote expert cures the problem

Operator includes the repaired part

User Interface

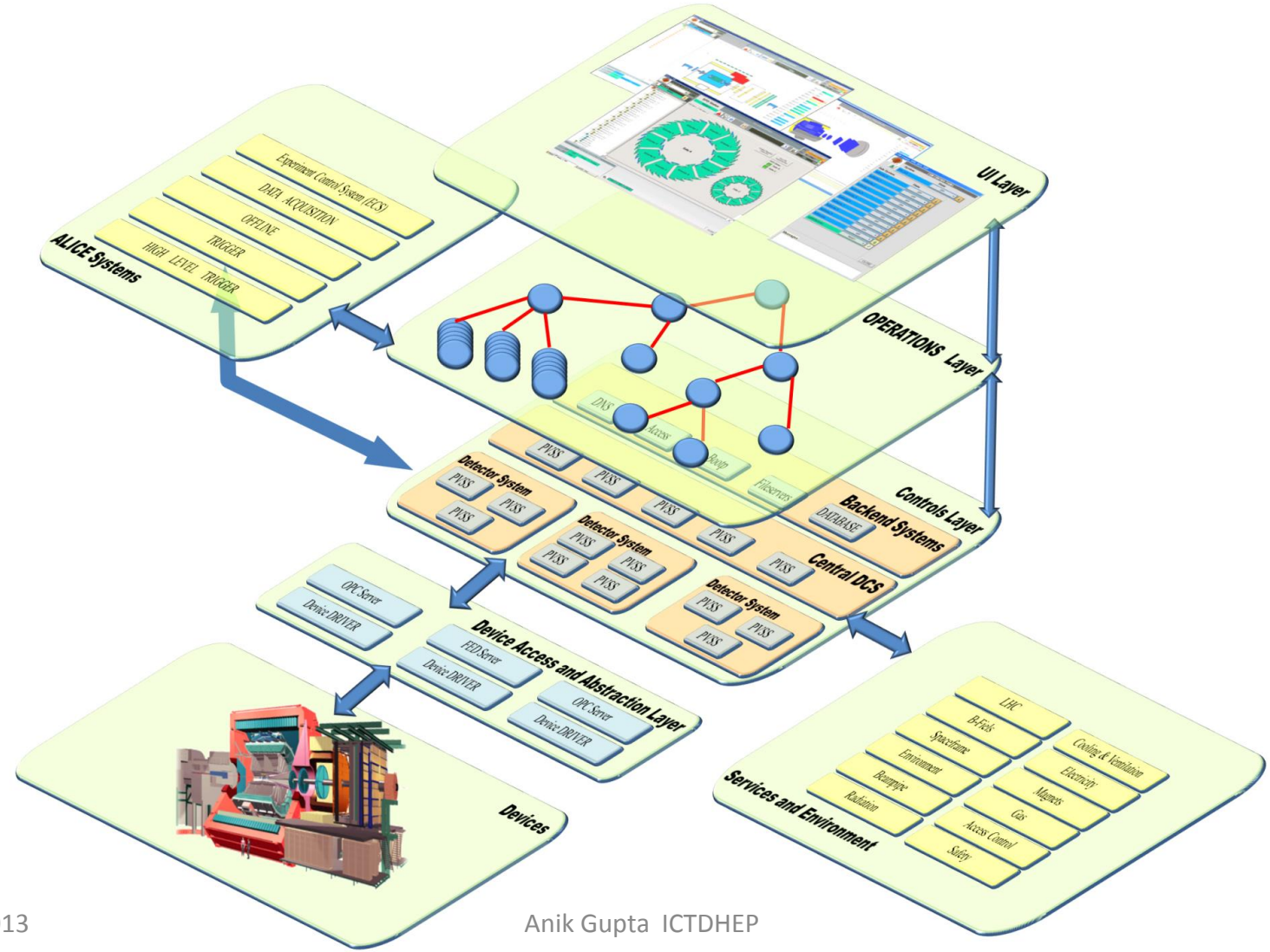


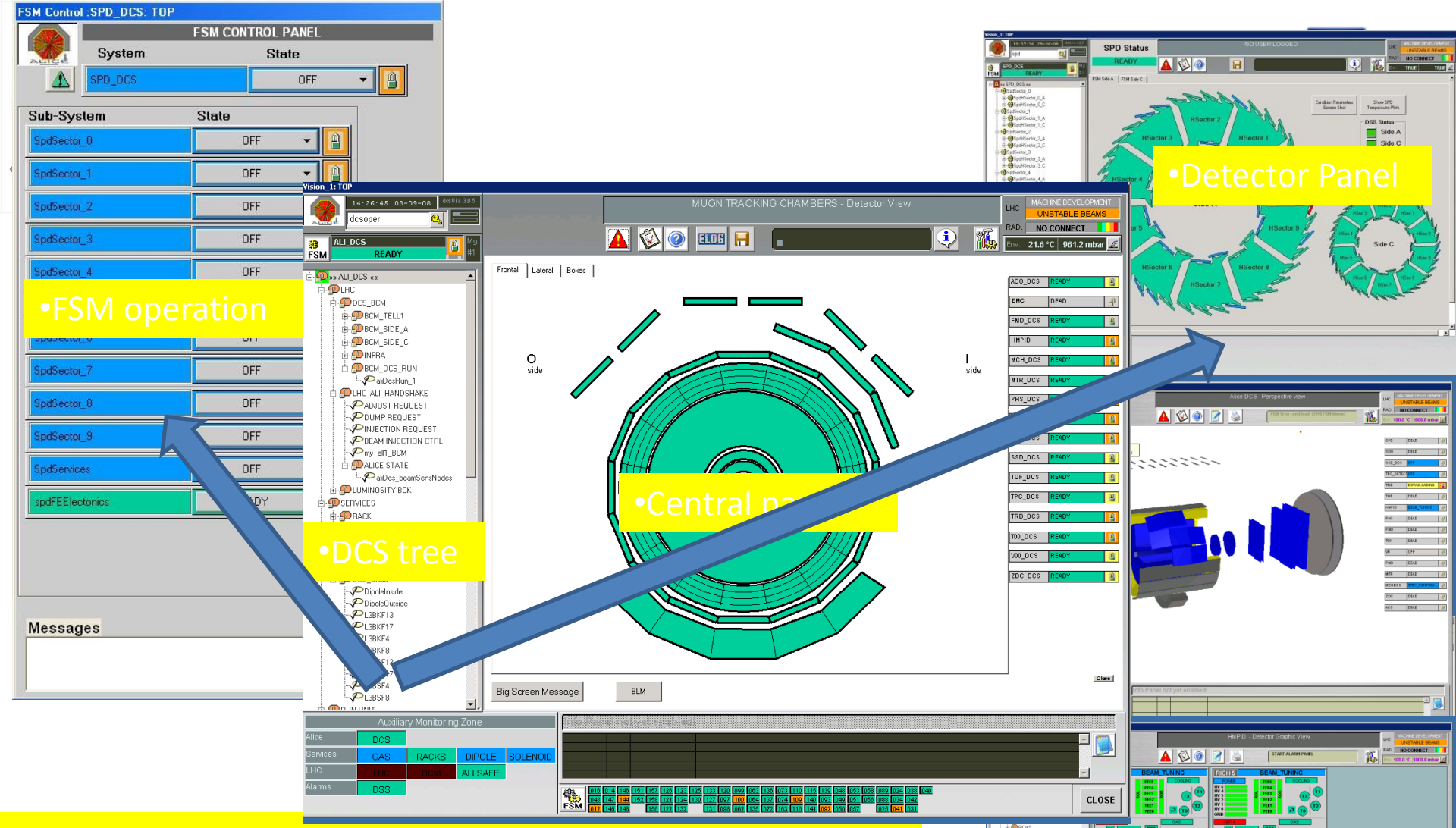




High level user interfaces allow to issue ‘meta commands’ to ease operator tasks

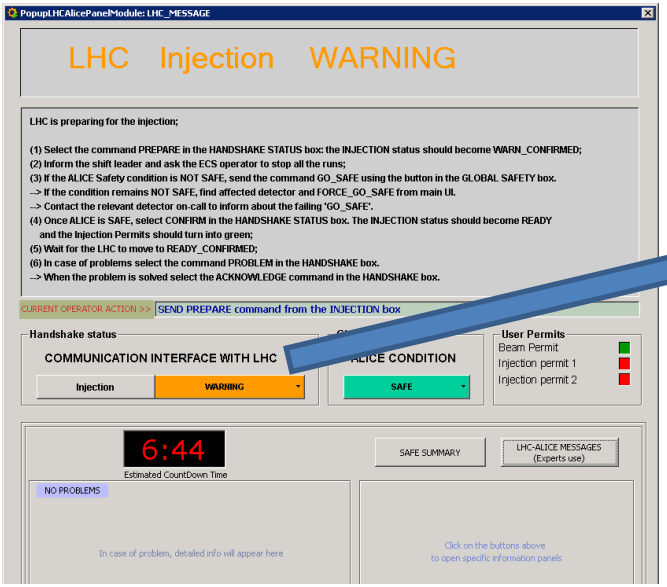
Putting pieces together

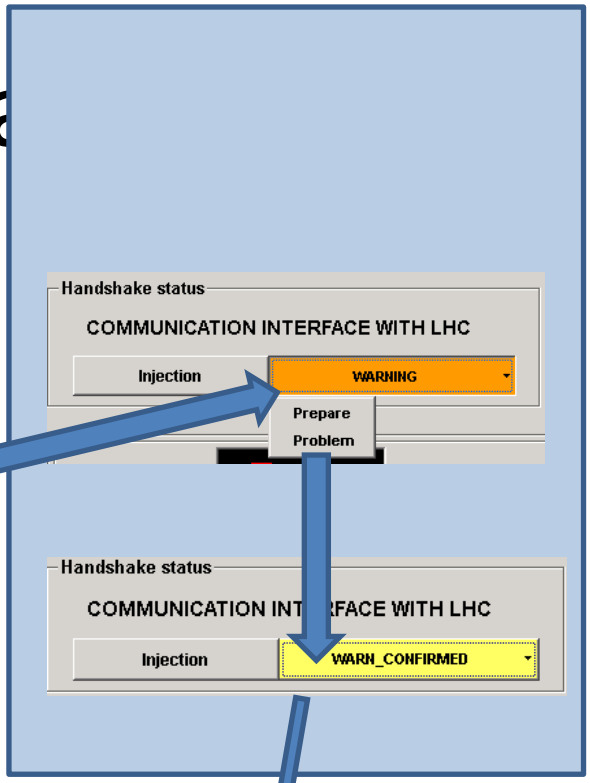




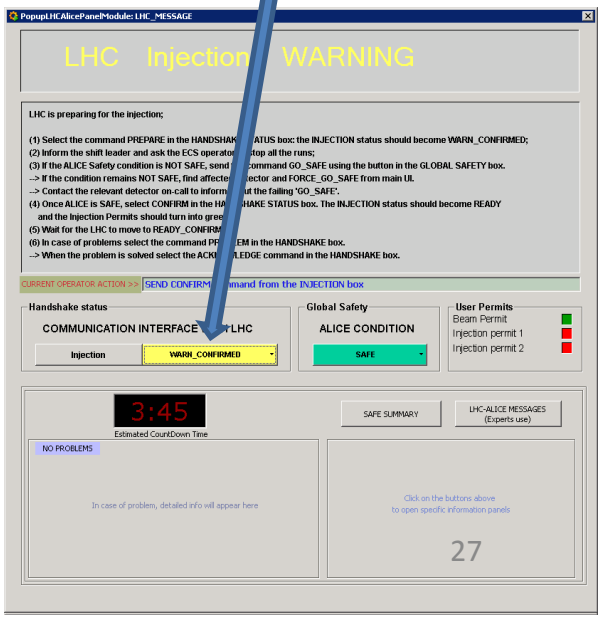
- •DCS UI
  - •ALICE component used by all detectors
  - •Standardized operation representation
  - •Detector specific panels
    - •Central operator can browse and operate detector panels

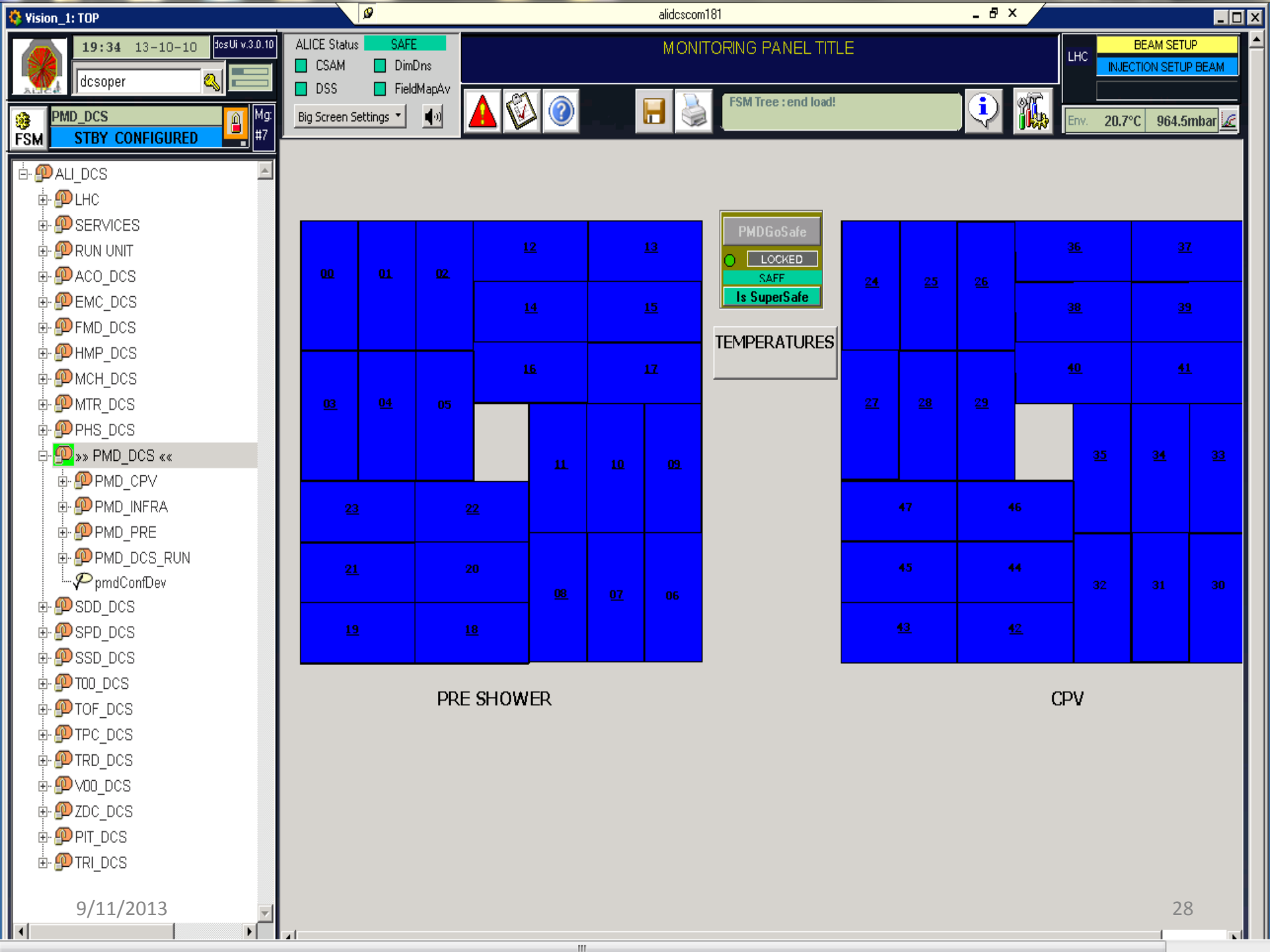
High Level Pa





- Critical actions use high level panels
- All tools needed for the task are available on the panel
- Expert system guides the operator

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dcsoper
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EMC_DCS
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PMD_CPV
PMD_INFRA
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PMD_DCS_RUN
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SDD_DCS
SPD_DCS
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T00_DCS
TOF_DCS
TPC_DCS
TRD_DCS
V00_DCS
ZDC_DCS
PIT_DCS
TRI_DCS
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LOCKED
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Is SuperSafe
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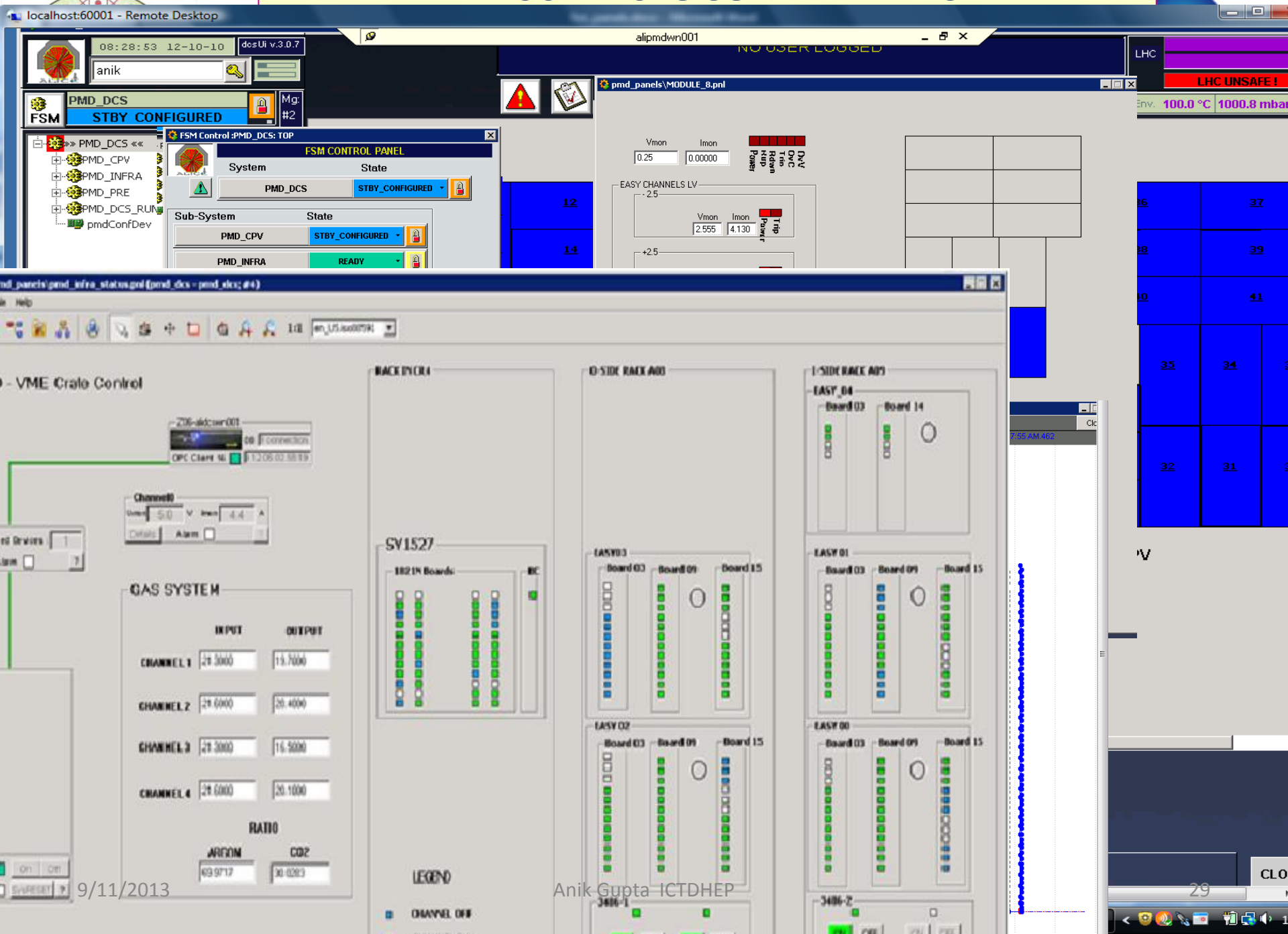
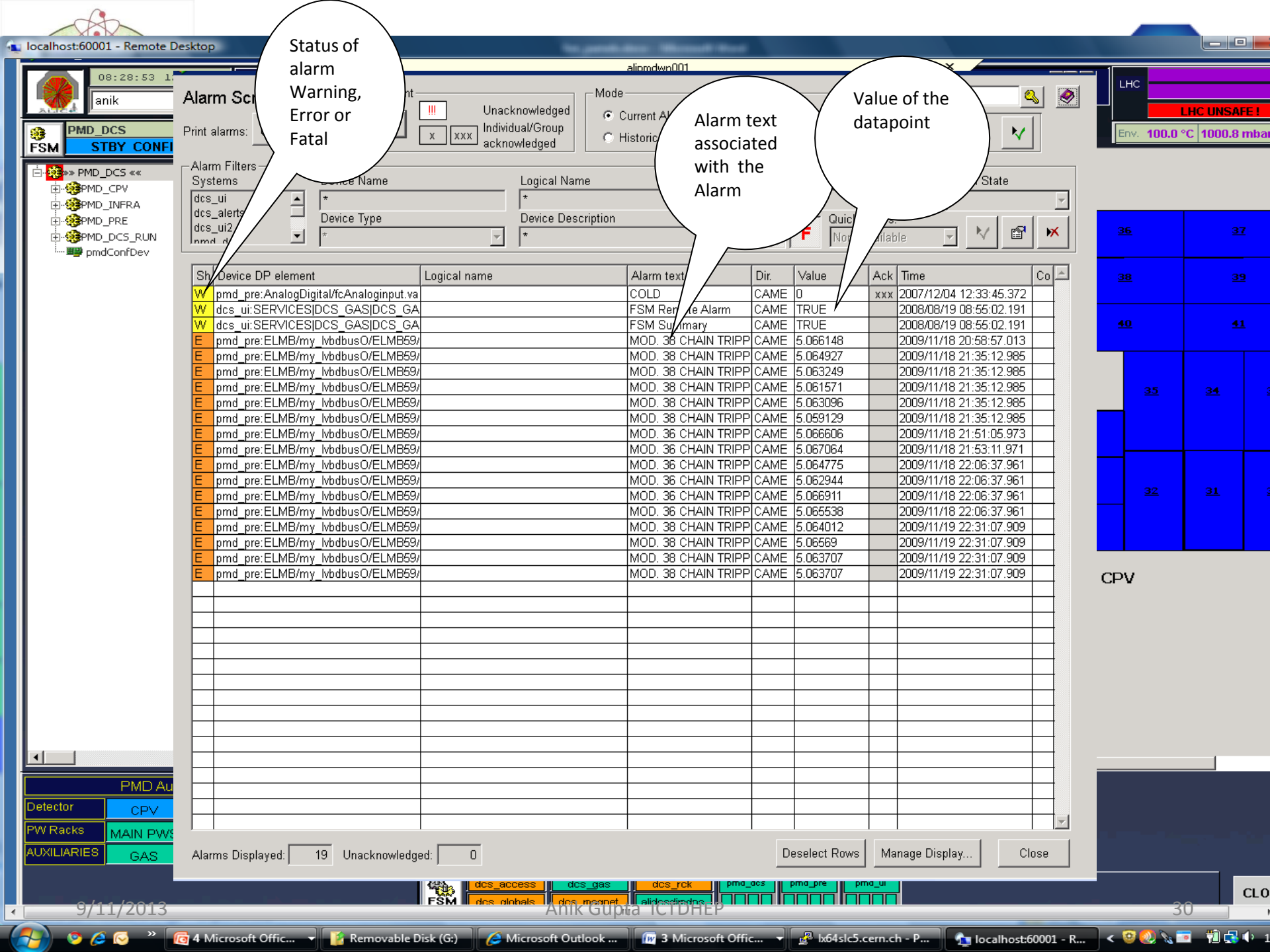
PRE SHOWER
CPV

PMD CONTROLS USER INTERFACE




Status of alarm Warning, Error or Fatal
Alarm text associated with the Alarm
Value of the datapoint
localhost:60001 - Remote Desktop
Alarm Scr
Print alarms:
Unacknowledged
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Historic
Alarm Filters
Systems
dcs_ui
dcs_alerts
dcs_ui2
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Manage Display...
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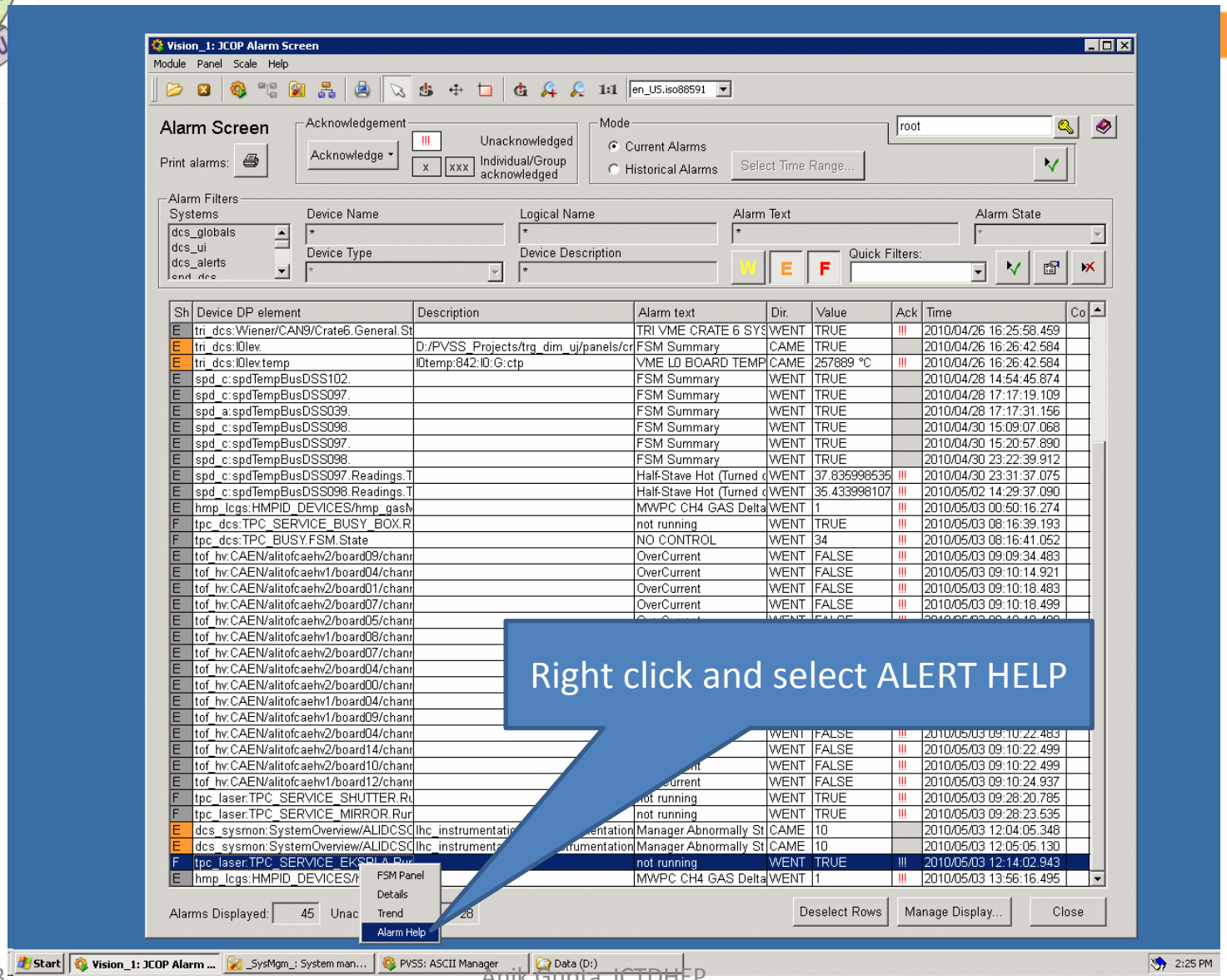
CPV
PMD_DCS
STBY CONFI
PMD_CPV
PMD_INFRA
PMD_PRE
PMD_DCS_RUN
pmdConfDev
Detector
CPV
PW Racks
AUXILIARIES
GAS


Vision_1: JCOP Alarm Screen
Module Panel Scale Help
Alarm Screen
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Acknowledgement
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Mode
Current Alarms
Historical Alarms
Select Time Range...
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Alarm Filters
Systems
dcs_globals
dcs_ui
dcs_alerts
Device Name
Logical Name
Alarm Text
Alarm State
Device Type
Device Description
Quick Filters:
Sh | Device DP element | Description | Alarm text | Dir. | Value | Ack | Time | Co
E | tri_dcs:Wiener/CAN9/Crate6.General.St | | TRI VME CRATE 6 SYS | WENT | TRUE | !!! | 2010/04/26 16:25:58.459
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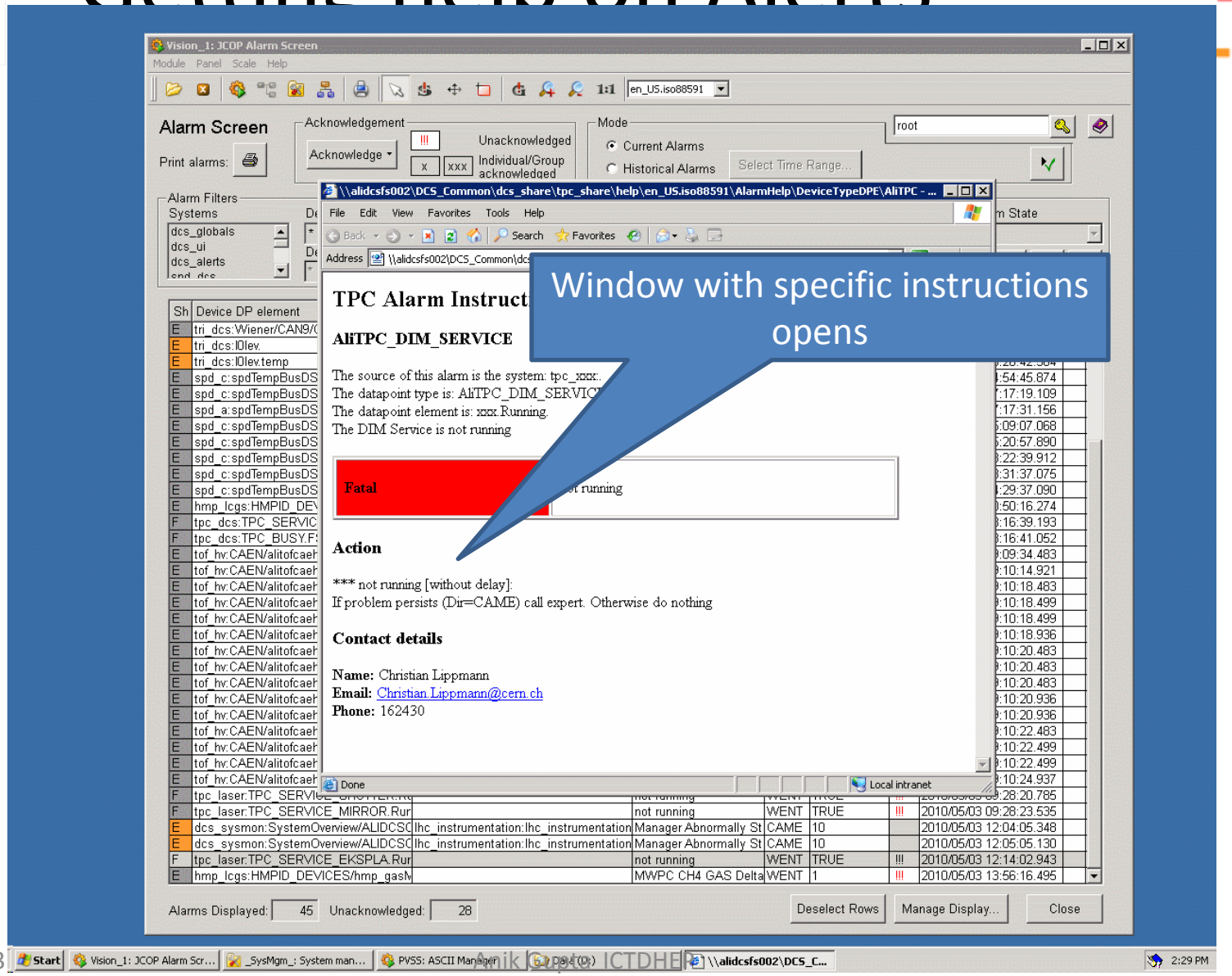
E | tri_dcs:l0lev.temp | l0temp:842:l0:G:ctp | VME L0 BOARD TEMP | CAME | 257889 °C | !!! | 2010/04/26 16:26:42.584
E | spd_c:spdTempBusDSS102. | | FSM Summary | WENT | TRUE | | 2010/04/28 14:54:45.874
E | spd_c:spdTempBusDSS097. | | FSM Summary | WENT | TRUE | | 2010/04/28 17:17:19.109
E | spd_a:spdTempBusDSS039. | | FSM Summary | WENT | TRUE | | 2010/04/28 17:17:31.156
E | spd_c:spdTempBusDSS098. | | FSM Summary | WENT | TRUE | | 2010/04/30 15:09:07.068
E | spd_c:spdTempBusDSS097. | | FSM Summary | WENT | TRUE | | 2010/04/30 15:20:57.890
E | spd_c:spdTempBusDSS098. | | FSM Summary | WENT | TRUE | | 2010/04/30 23:22:39.912
E | spd_c:spdTempBusDSS097.Readings.T | | Half-Stave Hot (Turned c | WENT | 37.835998535 | !!! | 2010/04/30 23:31:37.075
E | spd_c:spdTempBusDSS098.Readings.T | | Half-Stave Hot (Turned c | WENT | 35.433998107 | !!! | 2010/05/02 14:29:37.090
E | hmp_lcgs:HMPID_DEVICES/hmp_gasM | | MWPC CH4 GAS Delta | WENT | 1 | !!! | 2010/05/03 00:50:16.274
F | tpc_dcs:TPC_SERVICE_BUSY_BOX.R | | not running | WENT | TRUE | !!! | 2010/05/03 08:16:39.193
F | tpc_dcs:TPC_BUSY.FSM.State | | NO CONTROL | WENT | 34 | !!! | 2010/05/03 08:16:41.052
E | tof_hv:CAEN/alitofcaehv2/board09/chanr | | OverCurrent | WENT | FALSE | !!! | 2010/05/03 09:09:34.483
E | tof_hv:CAEN/alitofcaehv1/board04/chanr | | OverCurrent | WENT | FALSE | !!! | 2010/05/03 09:10:14.921
E | tof_hv:CAEN/alitofcaehv2/board01/chanr | | OverCurrent | WENT | FALSE | !!! | 2010/05/03 09:10:18.483
E | tof_hv:CAEN/alitofcaehv2/board07/chanr | | OverCurrent | WENT | FALSE | !!! | 2010/05/03 09:10:18.499
E | tof_hv:CAEN/alitofcaehv2/board05/chanr | | OverCurrent | WENT | FALSE | !!! | 2010/05/03 09:10:18.499
E | tof_hv:CAEN/alitofcaehv1/board08/chanr | | | | | | 2010/05/03 09:10:18.499
E | tof_hv:CAEN/alitofcaehv2/board07/chanr | | | | | | 2010/05/03 09:10:18.499
E | tof_hv:CAEN/alitofcaehv2/board04/chanr | | | | | | 2010/05/03 09:10:18.499
E | tof_hv:CAEN/alitofcaehv2/board00/chanr | | | | | | 2010/05/03 09:10:18.499
E | tof_hv:CAEN/alitofcaehv1/board04/chanr | | | | | | 2010/05/03 09:10:18.499
E | tof_hv:CAEN/alitofcaehv1/board09/chanr | | | | | | 2010/05/03 09:10:18.499
E | tof_hv:CAEN/alitofcaehv2/board04/chanr | | | | | | 2010/05/03 09:10:22.483
E | tof_hv:CAEN/alitofcaehv2/board14/chanr | | | | | | 2010/05/03 09:10:22.499
E | tof_hv:CAEN/alitofcaehv2/board10/chanr | | | | | | 2010/05/03 09:10:22.499
E | tof_hv:CAEN/alitofcaehv1/board12/chanr | | | | | | 2010/05/03 09:10:24.937
F | tpc_laser:TPC_SERVICE_SHUTTER.Ru | | not running | WENT | TRUE | !!! | 2010/05/03 09:28:20.785
F | tpc_laser:TPC_SERVICE_MIRROR.Rur | | not running | WENT | TRUE | !!! | 2010/05/03 09:28:23.535
E | dcs_sysmon:SystemOverview/ALIDCSC | lhc_instrumentati | Manager Abnormally St | CAME | 10 | | 2010/05/03 12:04:05.348
E | dcs_sysmon:SystemOverview/ALIDCSC | lhc_instrumenta | Manager Abnormally St | CAME | 10 | | 2010/05/03 12:05:05.130
F | tpc_laser:TPC_SERVICE_EKSPLA_Run | | not running | WENT | TRUE | !!! | 2010/05/03 12:14:02.943
E | hmp_lcgs:HMPID_DEVICES/h | | MWPC CH4 GAS Delta | WENT | 1 | !!! | 2010/05/03 13:56:16.495
FSM Panel
Details
Trend
Alarm Help
Alarms Displayed: 45
Deselect Rows
Manage Display...
Close
Right click and select ALERT HELP
Start
Vision_1: JCOP Alarm ...
SysMgm: System man...
PVSS: ASCII Manager
Data (D:)
2:25 PM

Getting help on Alerts

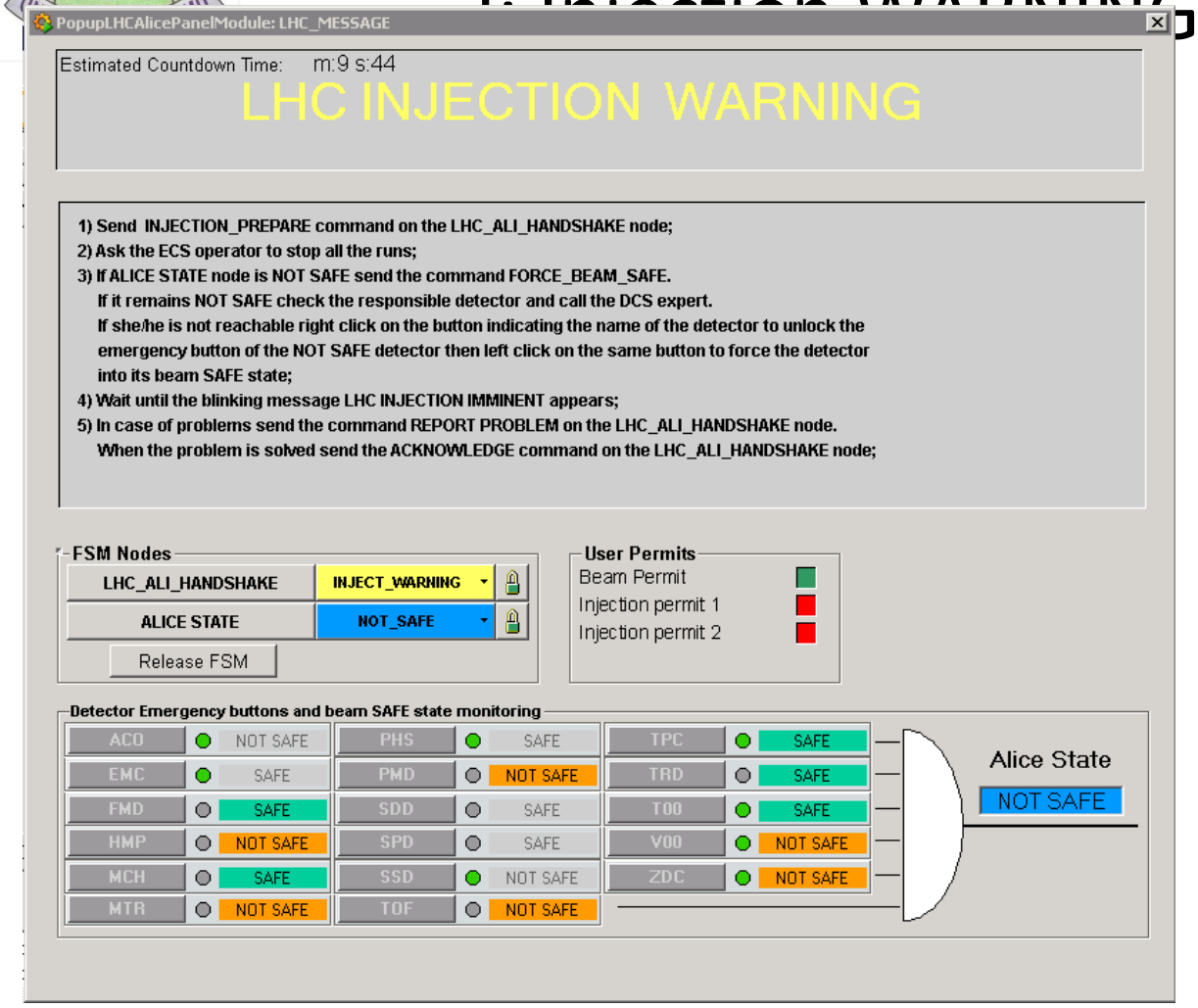


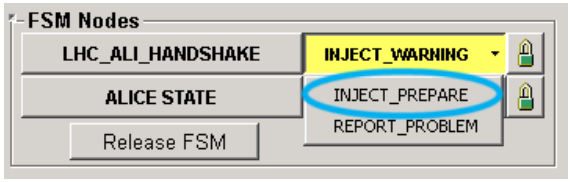
Alice-LHC handshake procedure

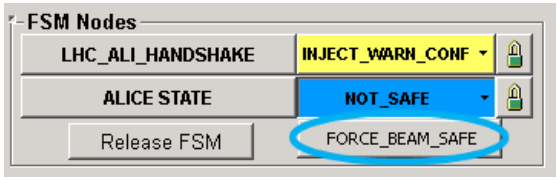
- This procedure is always executed before the LHC changes the operational mode
- The goal is to ring ALICE to safe mode and confirm this to LHC
- Handshake is initiated on LHC request and the DCS operator follows the instructions given at the operational panels (see following slides)

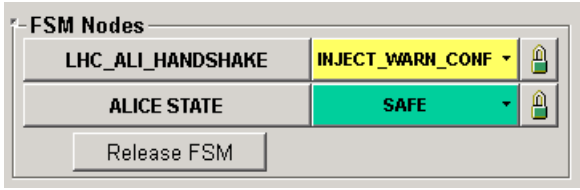
Handshake

I: Injection WARNING

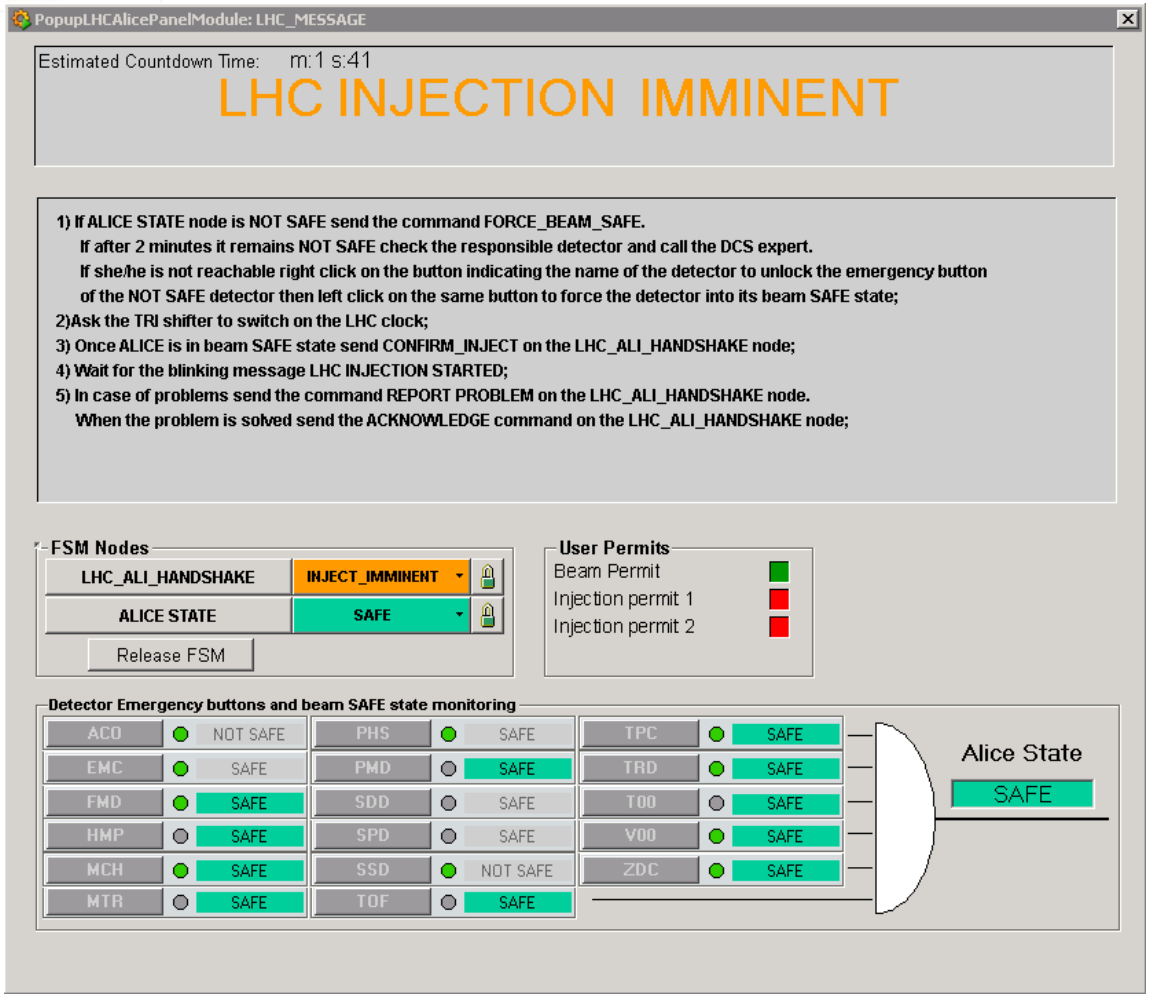


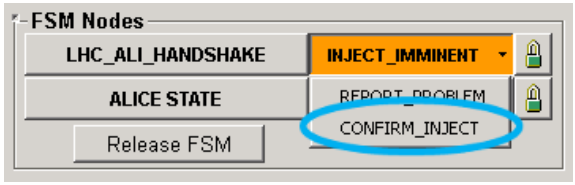


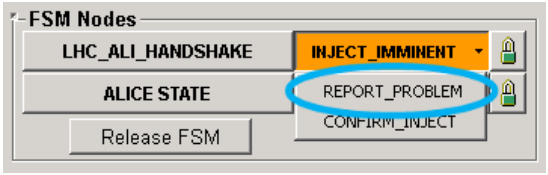




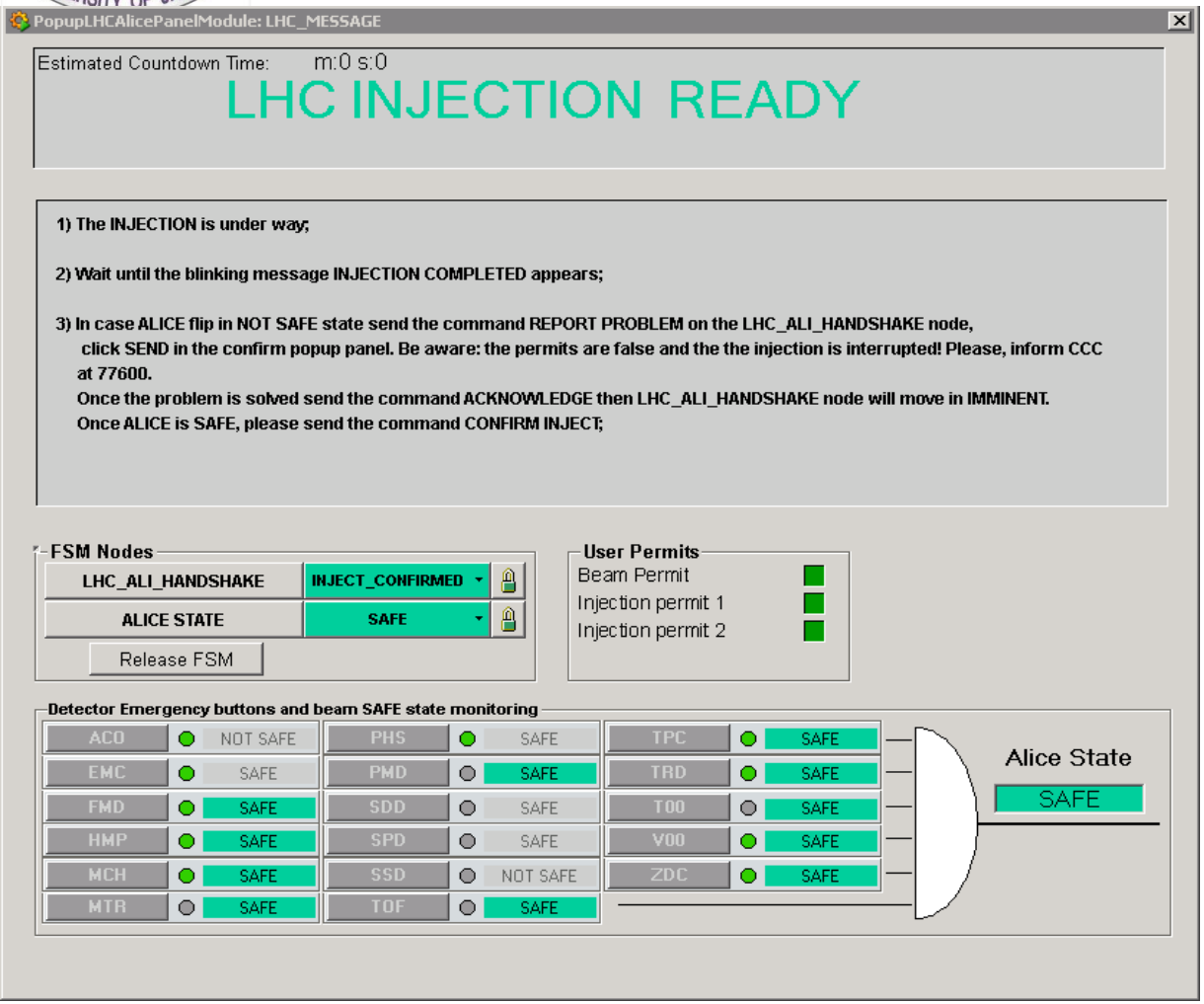
II: Injection Imminent



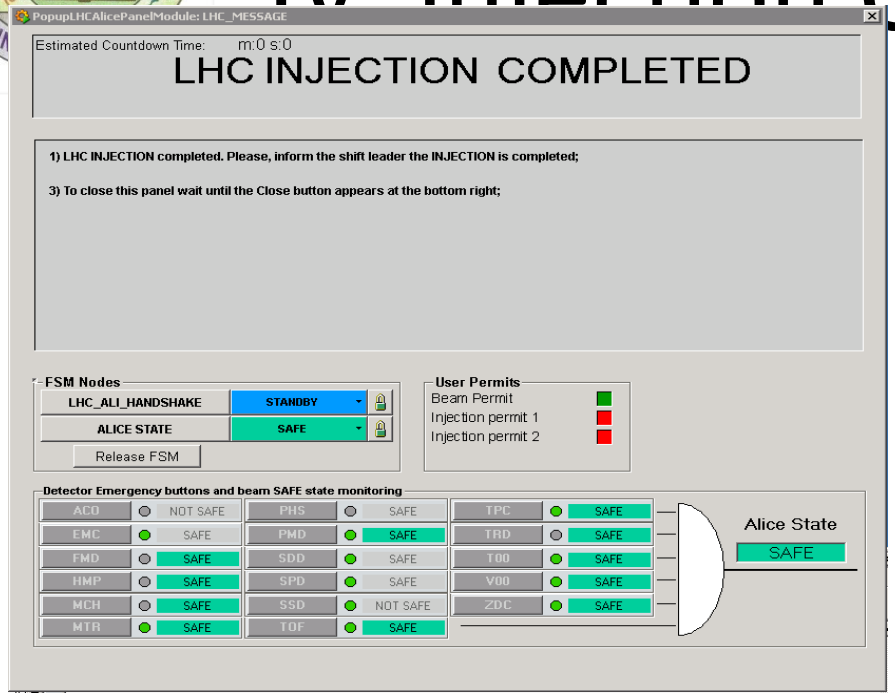


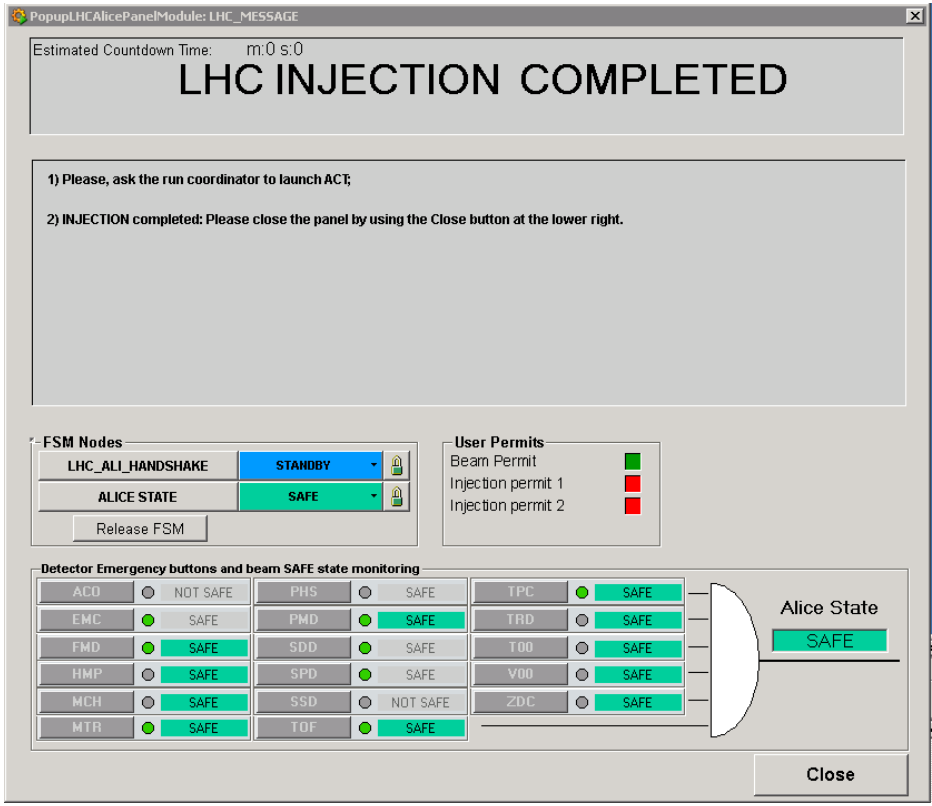


III: Injection READY

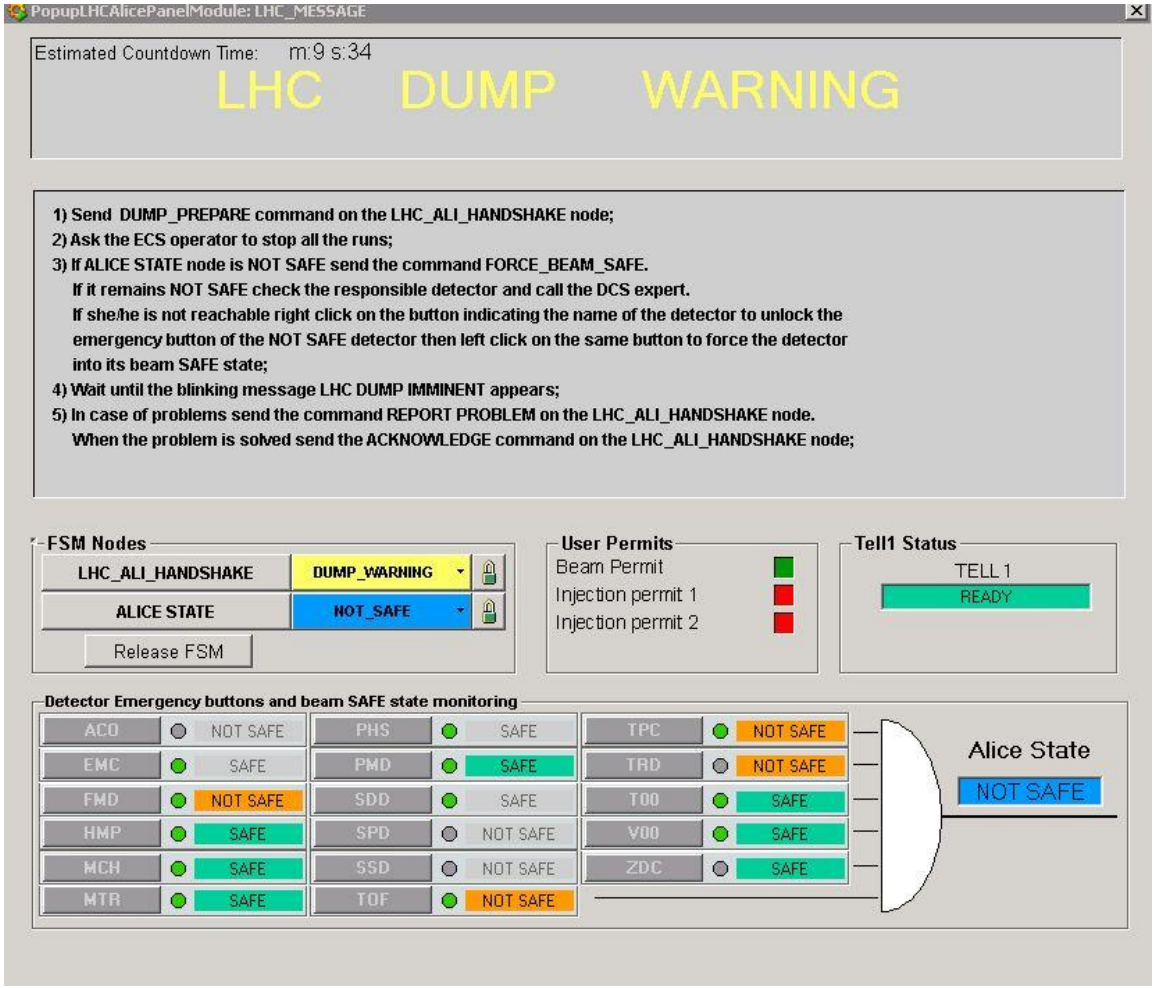


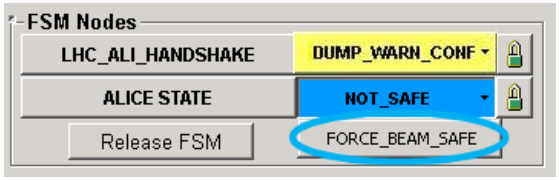
IV: injection Completed



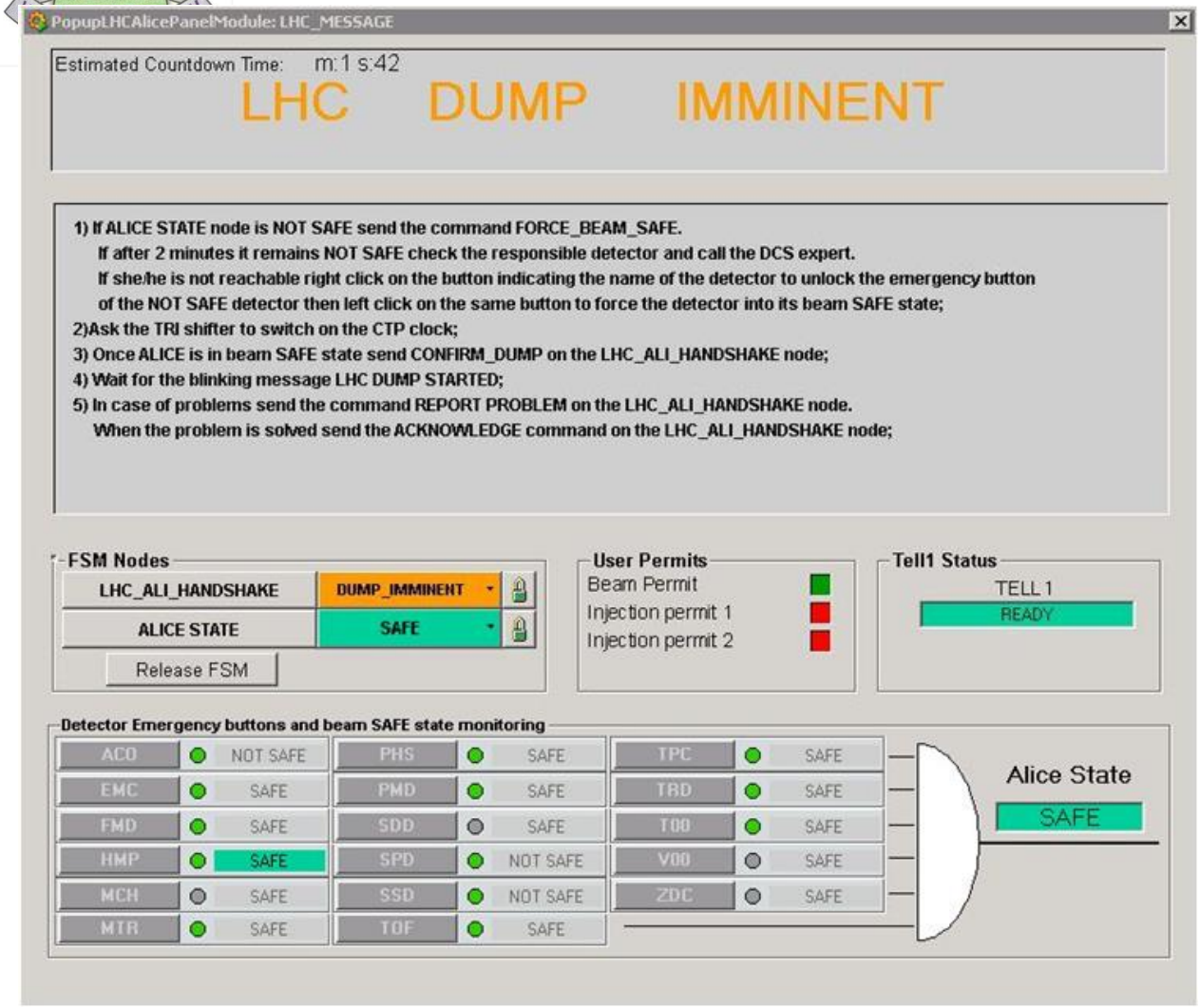


Handshake
I: Dump WARNING

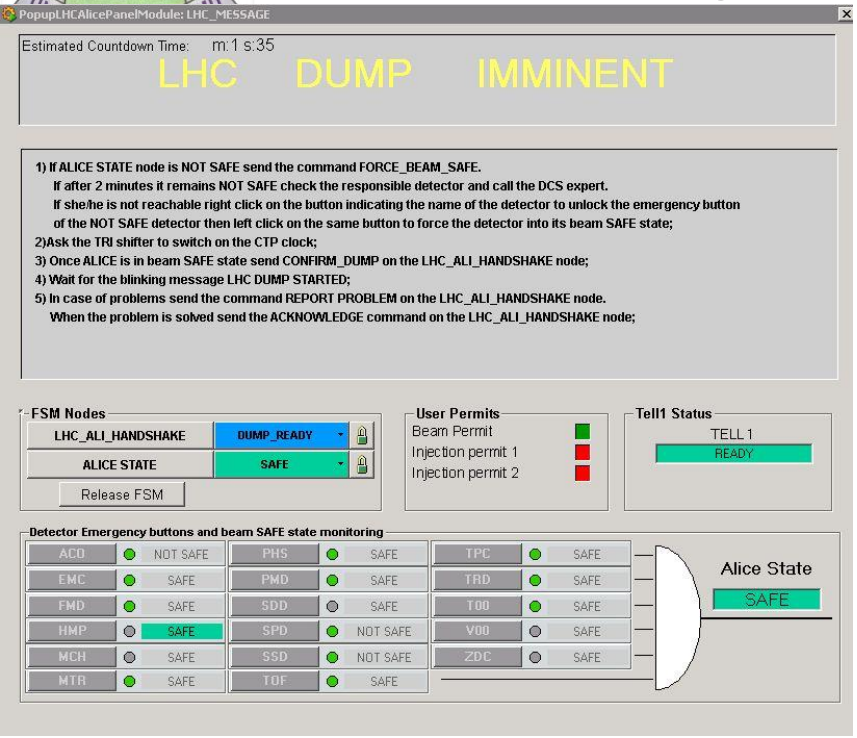


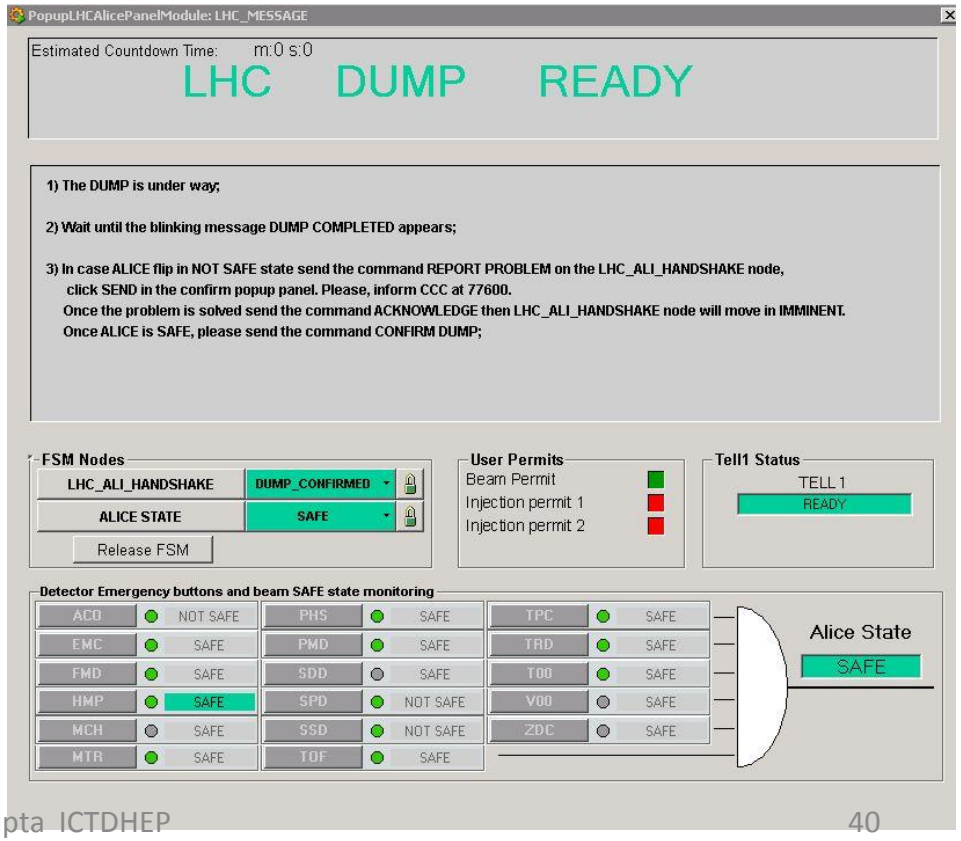


II: DUMP Imminent

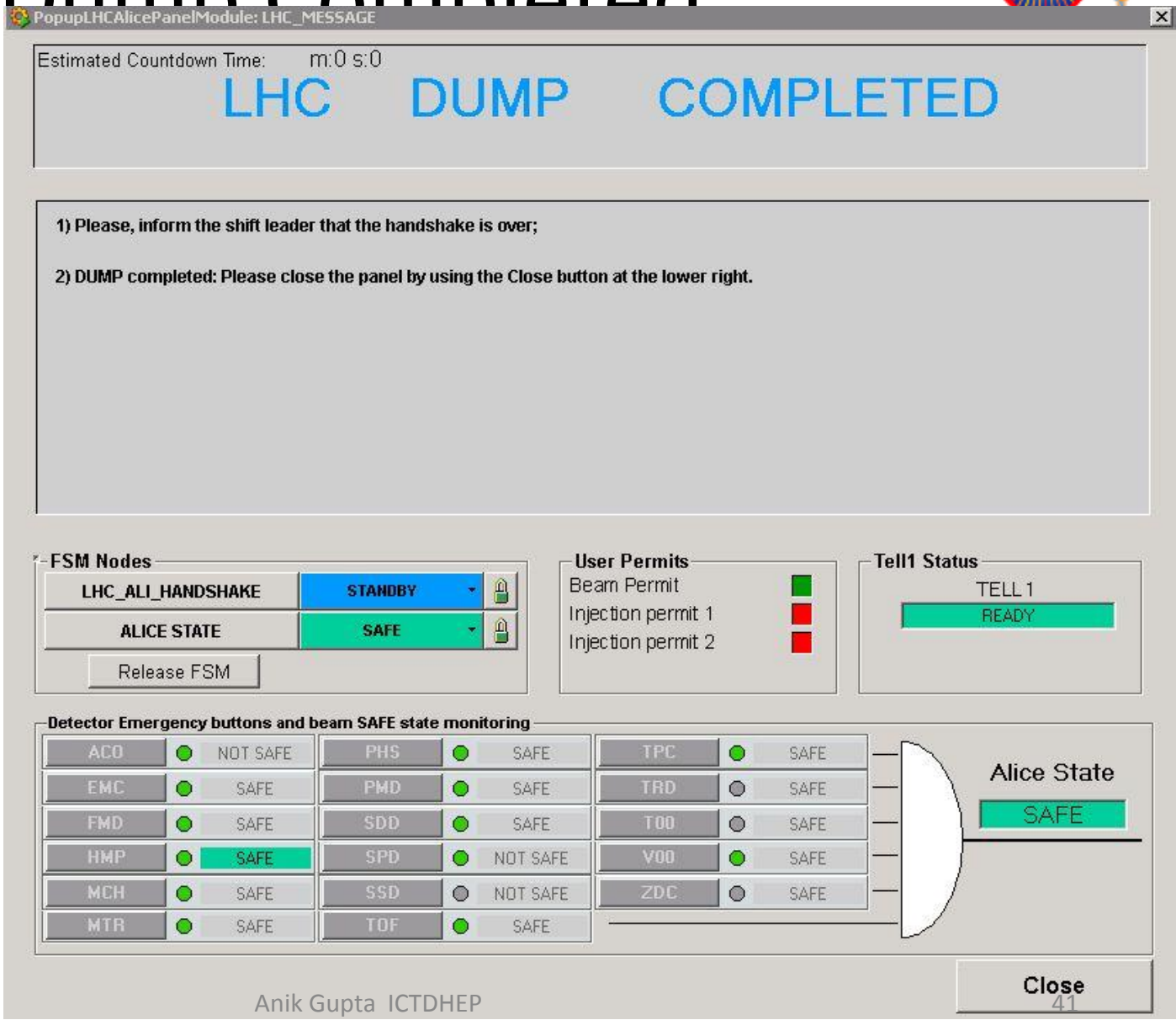


III: Dump READY

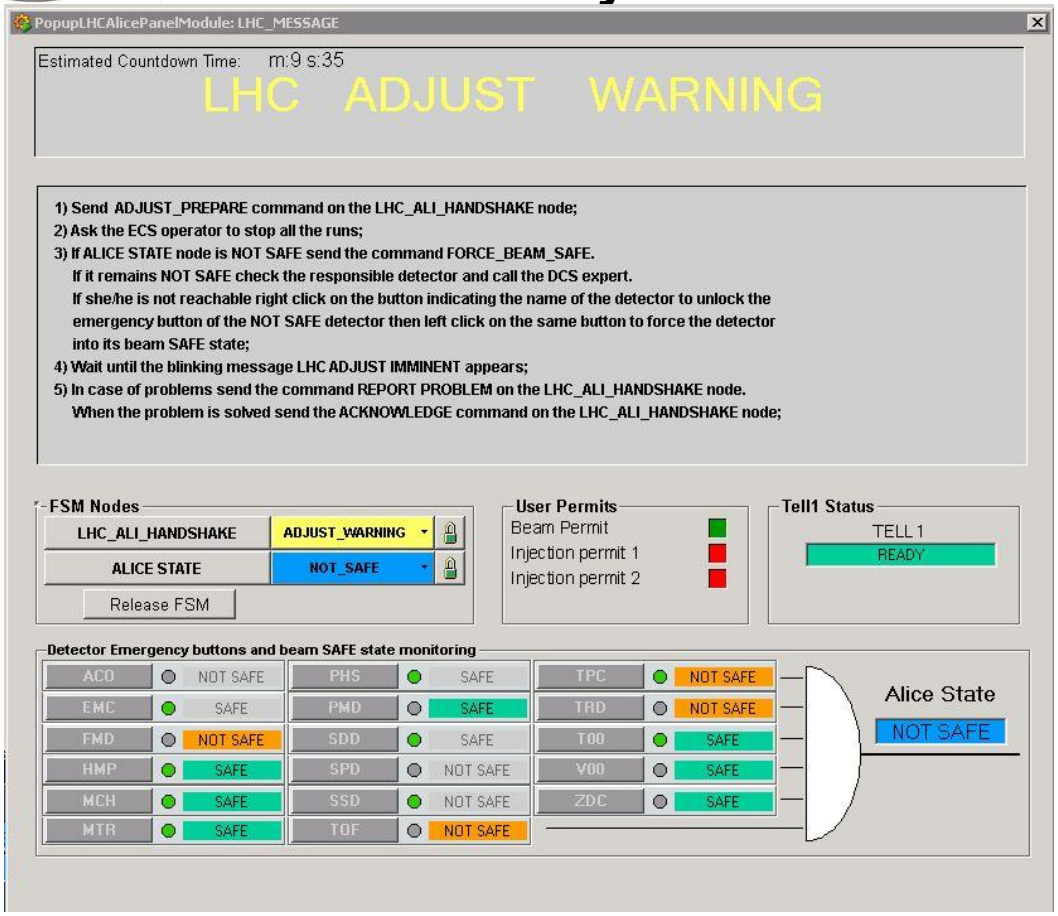




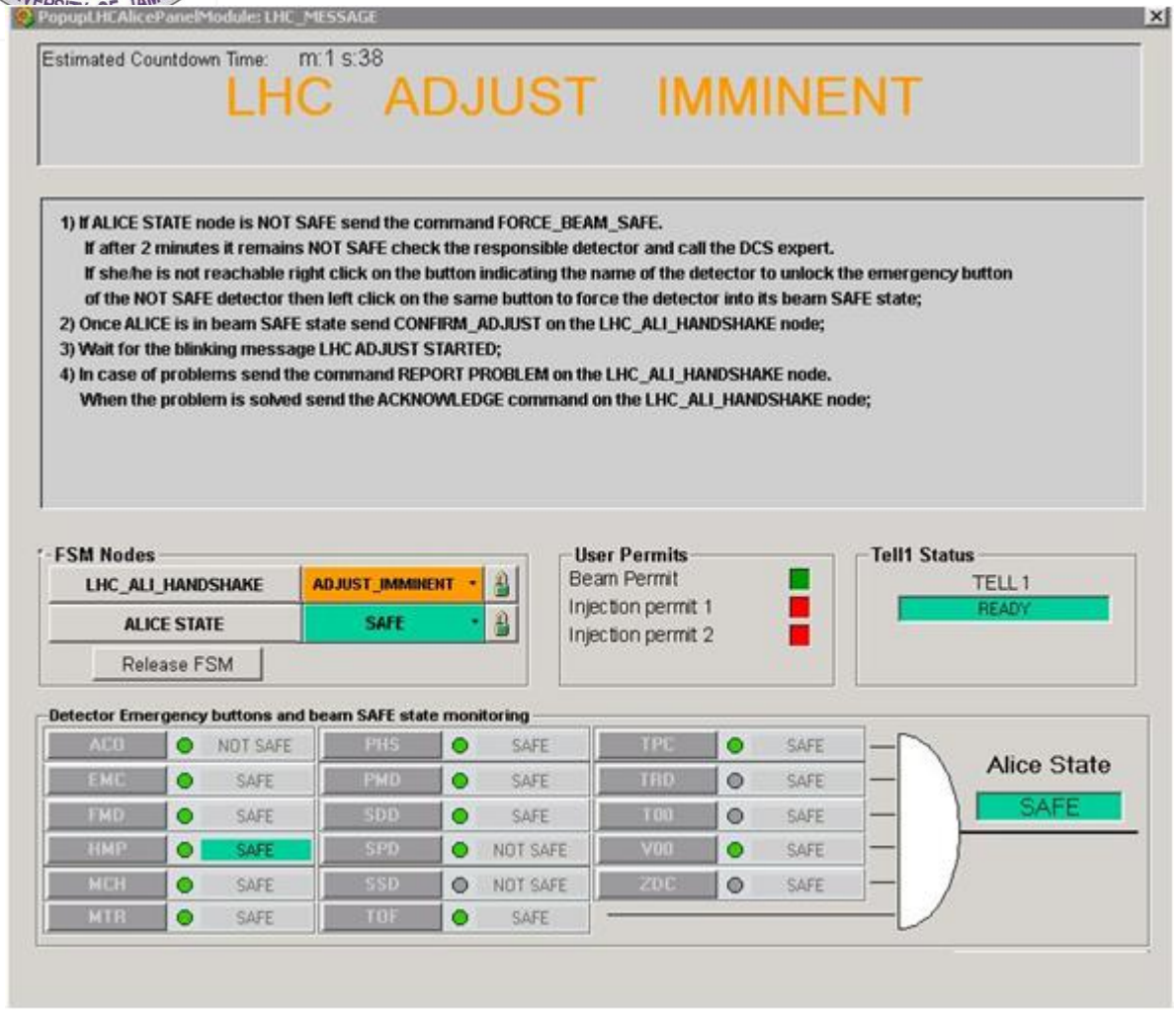
IV: Dump Completed



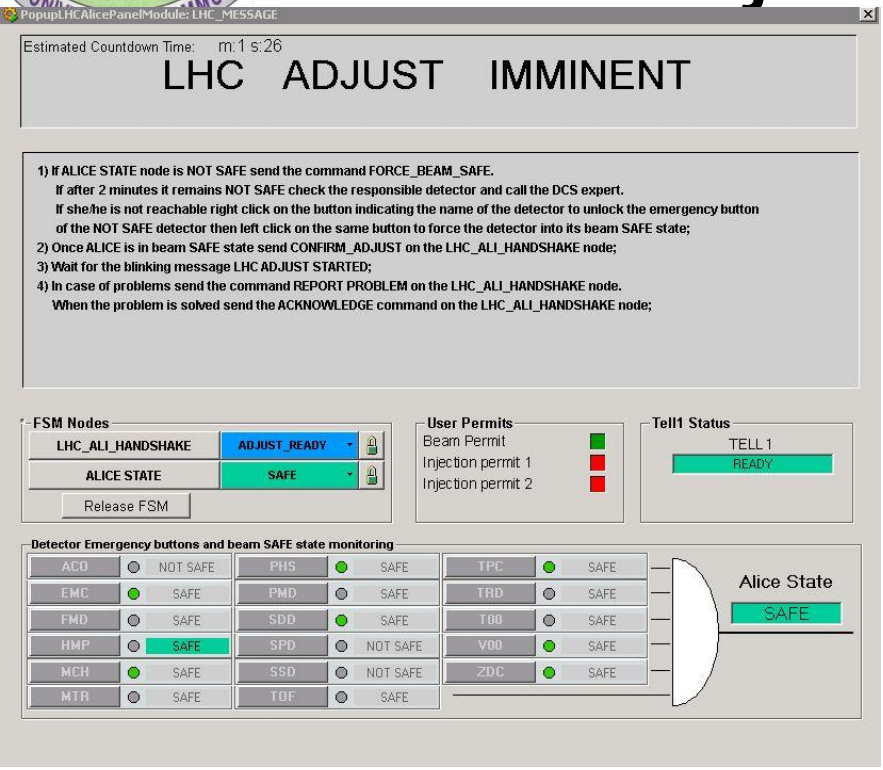
Handshake
I: Adjust WARNING

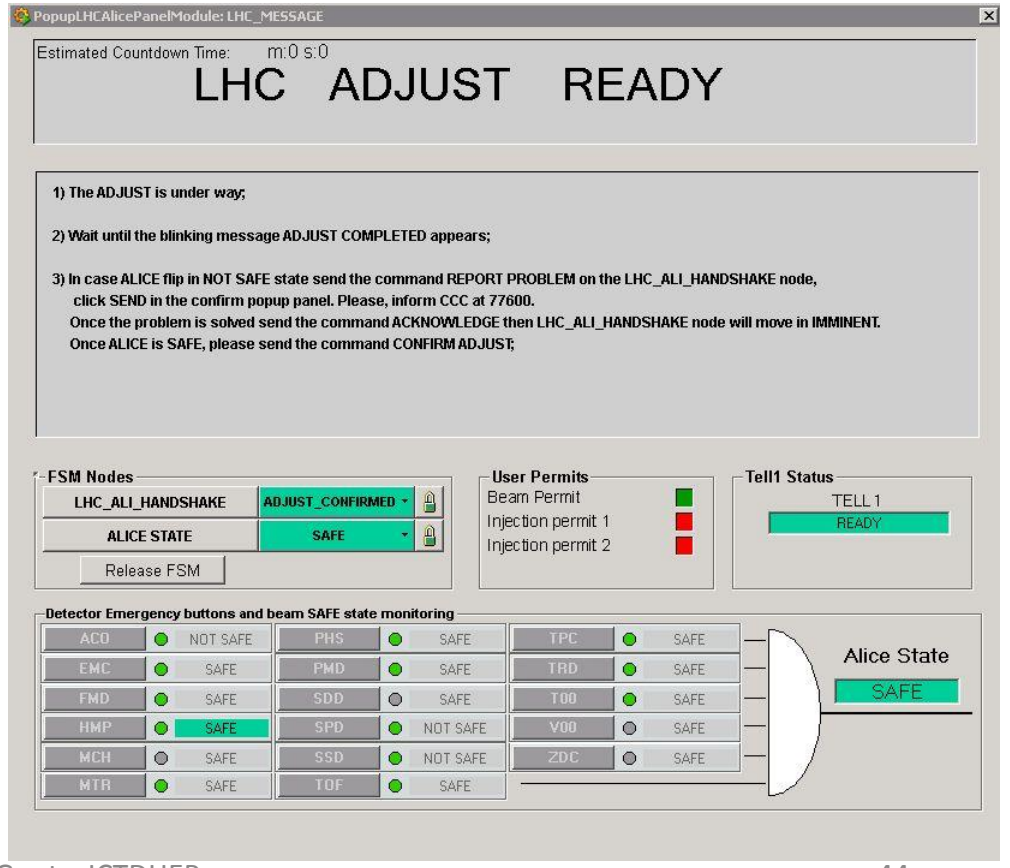


II: Adjust Imminent

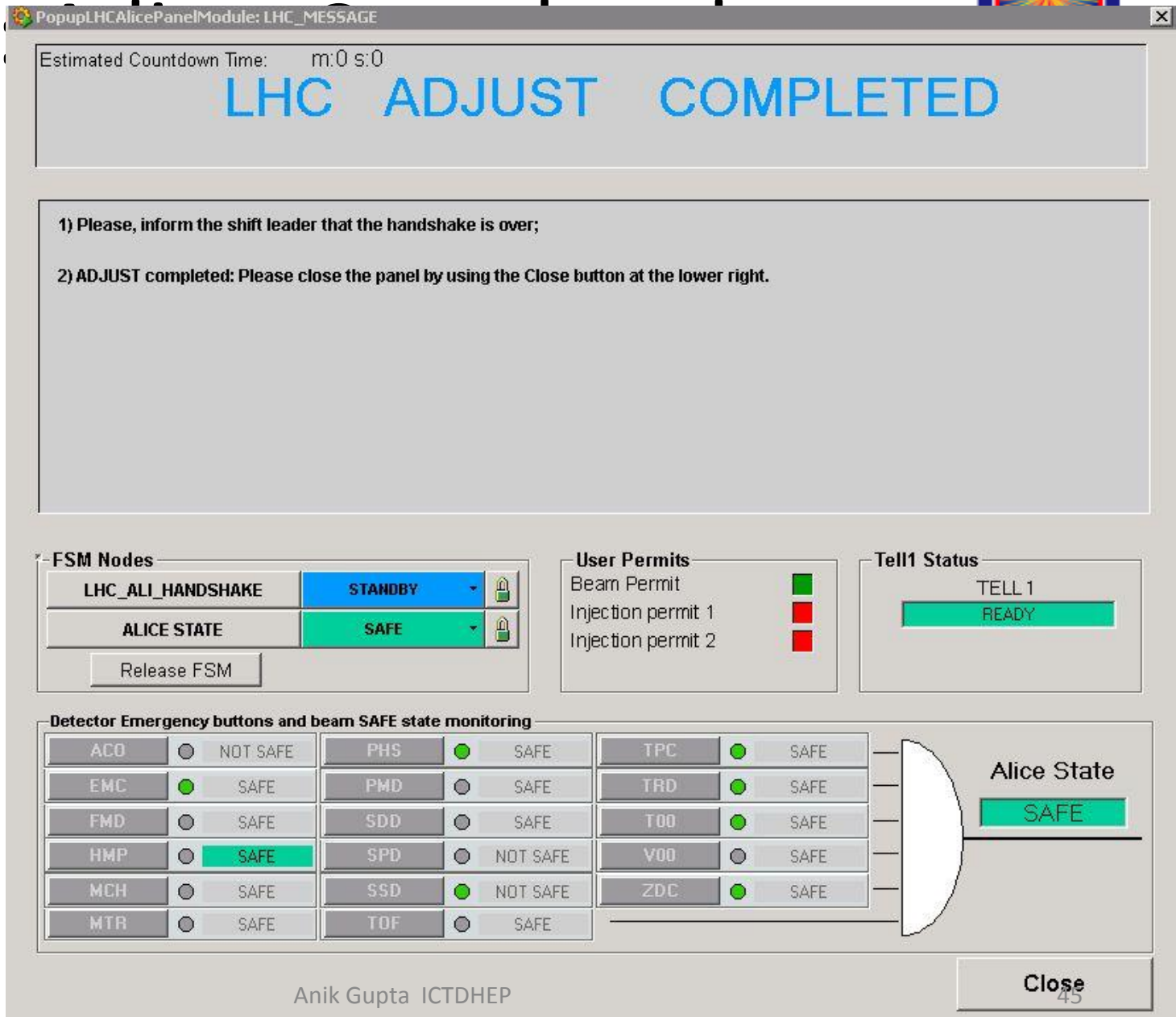


III: Adjust READY





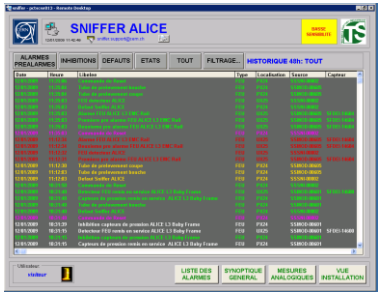
IV

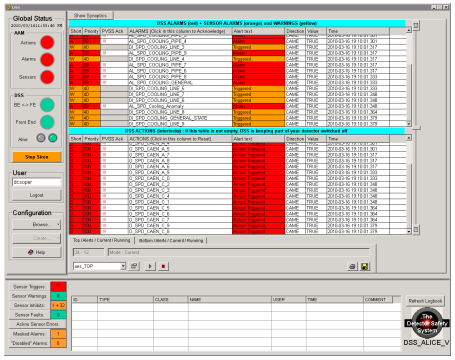

PopupLHCAlicePanelModule: LHC_MESSAGE
Estimated Countdown Time: m:0 s:0
LHC ADJUST COMPLETED
1) Please, inform the shift leader that the handshake is over;
2) ADJUST completed: Please close the panel by using the Close button at the lower right.
FSM Nodes
LHC_ALI_HANDSHAKE
STANDBY
ALICE STATE
SAFE
Release FSM
User Permits
Beam Permit
Injection permit 1
Injection permit 2
Tell1 Status
TELL 1
READY
Detector Emergency buttons and beam SAFE state monitoring
ACO NOT SAFE
EMC SAFE
FMD SAFE
HMP SAFE
MCH SAFE
MTR SAFE
PHS SAFE
PMD SAFE
SDD SAFE
SPD NOT SAFE
SSD NOT SAFE
TOF SAFE
TPC SAFE
TRD SAFE
T00 SAFE
V00 SAFE
ZDC SAFE
Alice State
SAFE
Close

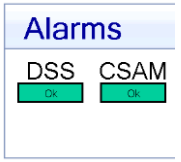
ALICE Safety

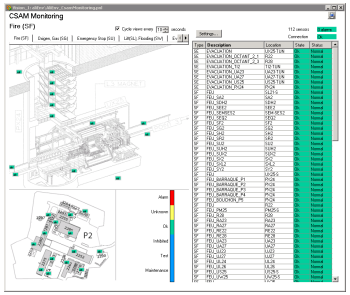
Safety

- The DCS receives safety related information:
  - DSS
  - Sniffer
  - CSAM



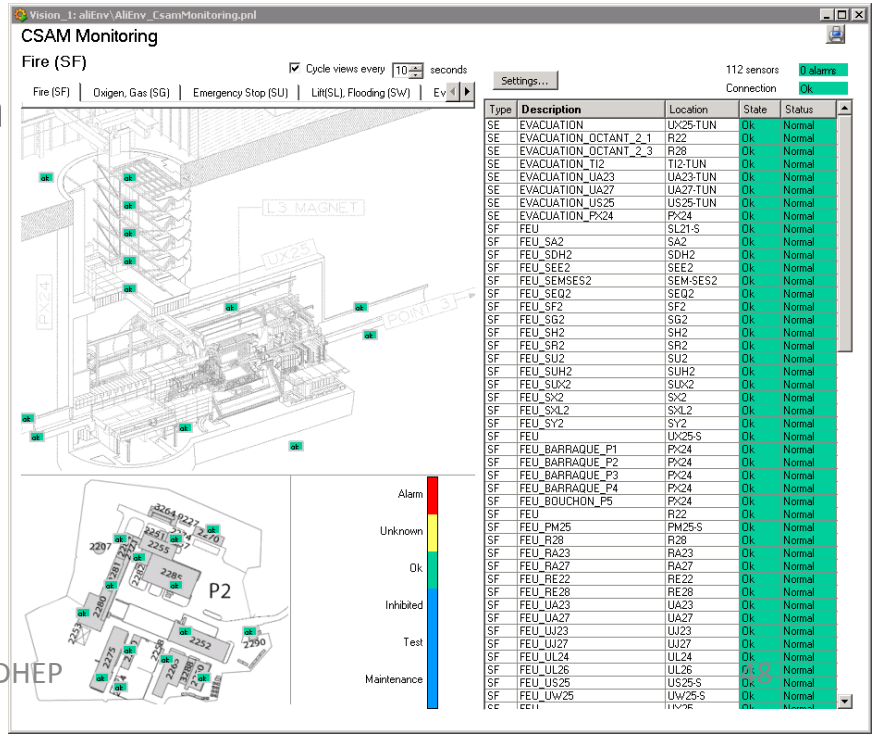




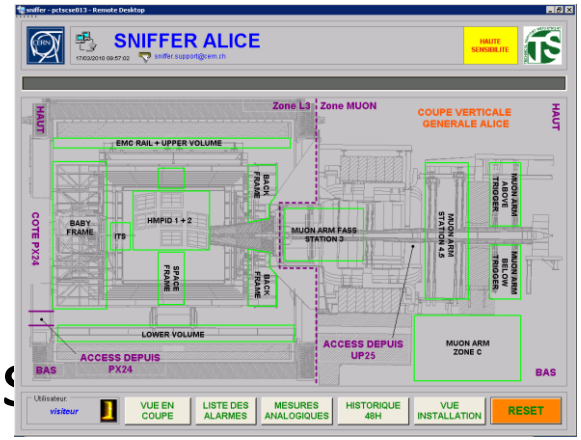


CSAM

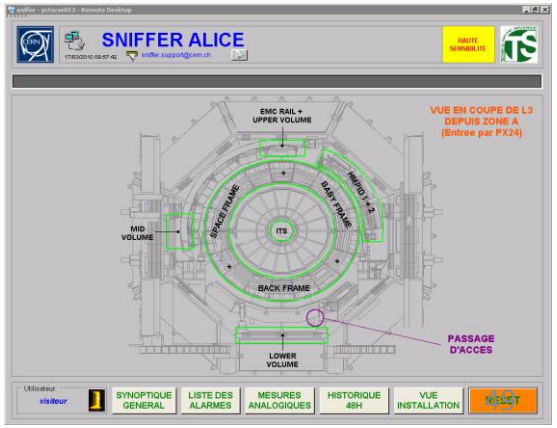
- CSAM (CERN Safety Alarm Monitoring)
  - Collects, transmits and presents all safety alarms
  - UI in ALICE presents all level 3 alarms relevant to point 2
    - Experiment, neighboring tunn



Sniffer

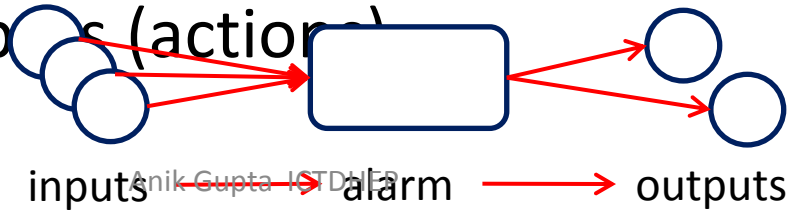


- Sniffer system monitors gas samples from solenoid volume and around/below muon arm
  - Detection of smoke, flammable gas and ODH
  - Alarm list view (default) and synoptic views

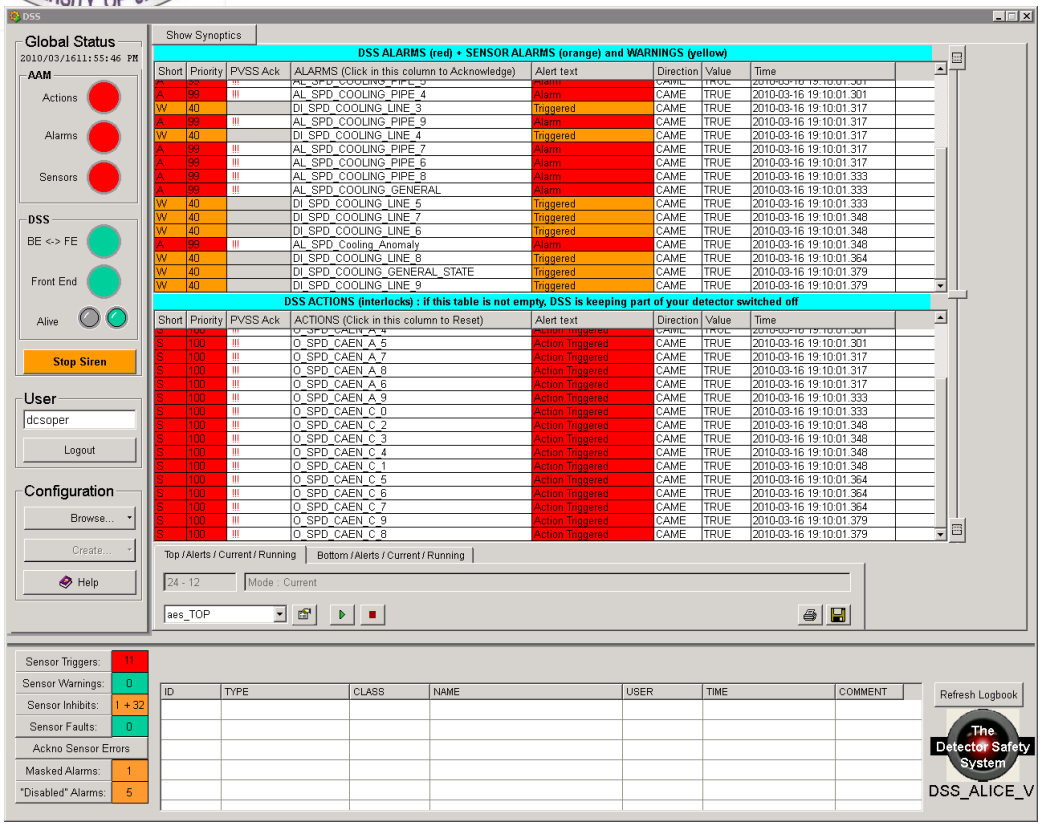


DSS

- DSS (Detector Safety System)
  - Robust, redundant part of DCS, PLC based
  - Shared by experiment safety and environment monitoring and detector interlocks
  - Can take pre-programmed actions
- Basic concept:
  - A logical (and, or) combination of (triggered) inputs can raise an alarm. An alarm can trigger one or more outputs (actions)



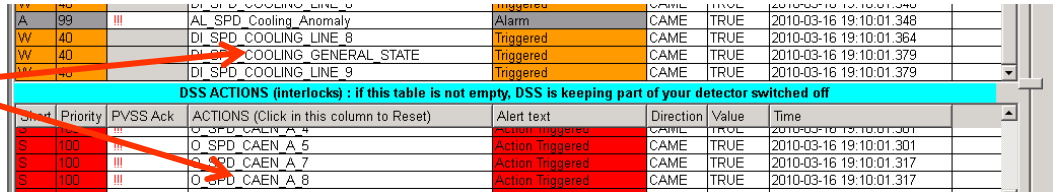
DSS



DSS inputs and alarms

DSS outputs (actions)

Alarms are acknowledged, and actions are reset by single click on the name (first alarm, then action)



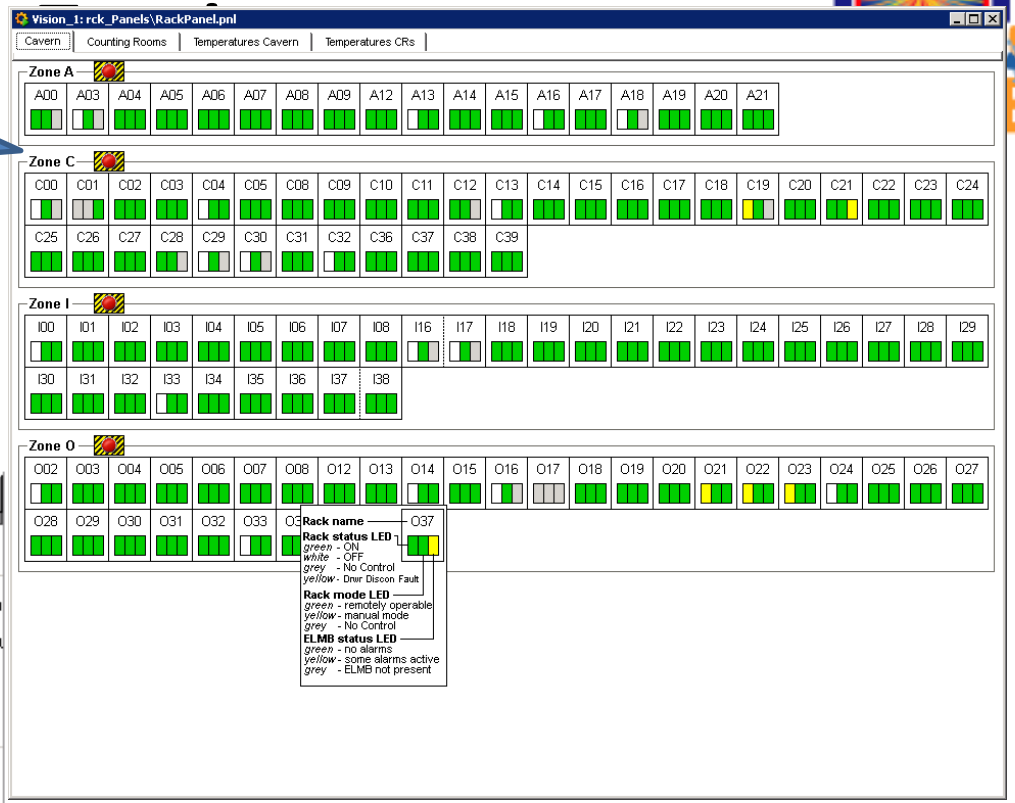
Services and Environment

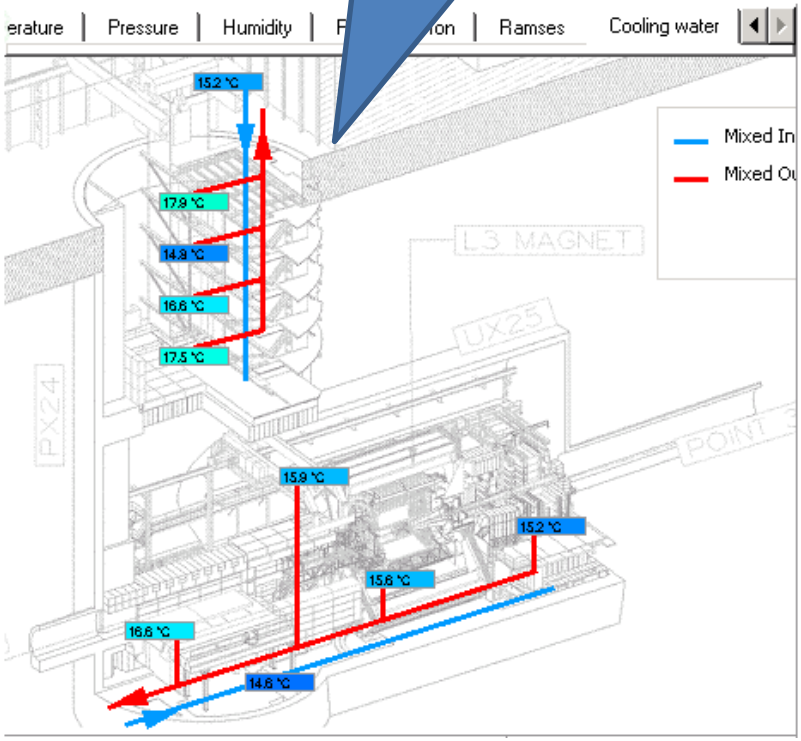
- To run the experiment, services are needed:
  - Power (electricity)
  - Cooling (water)
  - Magnet (solenoid, dipole)
  - Gas
- The DCS monitors the status of these services
- The DCS monitors the environment of the experiment
  - Temperatures, atmospheric pressure, humidity
  - Radiation
  - Magnetic field

Services and

Rack power distribution status

Cooling water temperatures

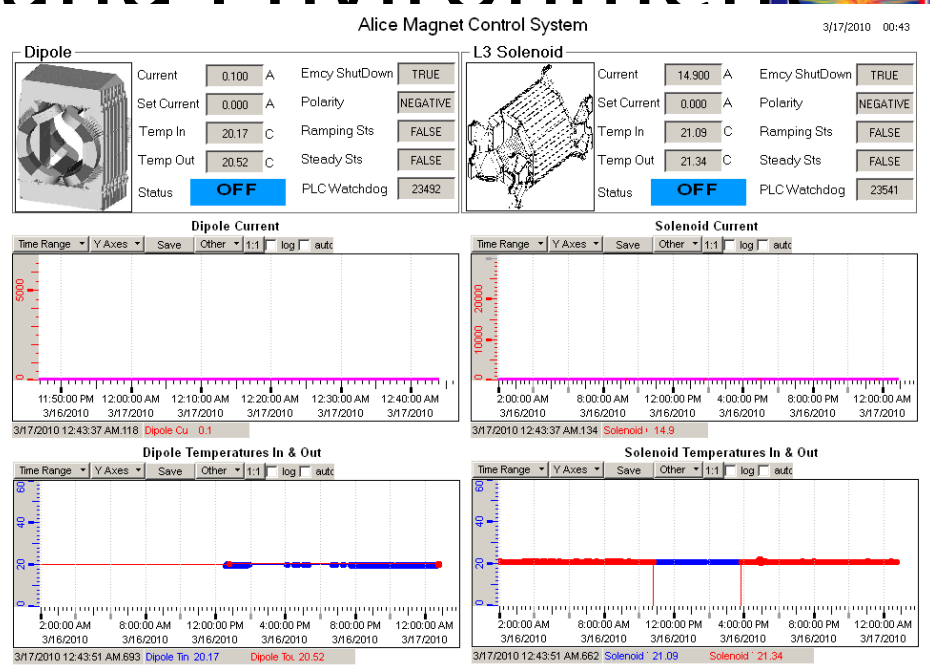




Services and Environment

Magnet status

Gas systems status



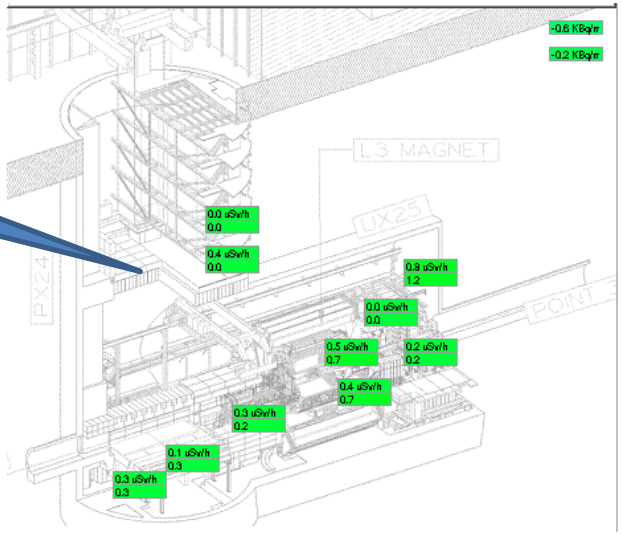
DIP OK	Mixer	Pump	Exhaust	Distribution	Purifier	Others
TOF	RunStable OK Line1Ratio 93.0 % Line2Ratio 0.0 % Line3Ratio 7.0 % TotalFlow 25.7 l/h	Run InPressure -10.0 mbar OutPressure 0.6 bar PressureSetpoint -10.0 mbar	Recirculating CirculationFlow 0.9 Nm3/h BufferPressure 0.6 bar CirculationPressu.. 0.6 bar	RunReady 61 62	Nominal Run CA C1 ColARunVolume 82.0 m3 ColBRunVolume 0.0 m3 ColAInFlow 0.6 m3/h ColBInFlow 0.0 m3/h	
TRD	RunStable Line1Ratio 0.0 % Line2Ratio 100.0 % TotalFlow 0.2 l/h	Run InPressure -25.2 mbar OutPressure 1.0 bar PressureSetpoint -25.0 mbar	Recirculating CirculationFlow 2.3 Nm3/h BufferPressure 1.0 bar CirculationPressu.. 0.9 bar	RunReady 51 52 53 54 65 66 67 68 69 70 71 72 73 74	Stop CA C1 ColARunVolume 343.0 m3 ColBRunVolume 0.0 m3 ColAInFlow 1.7 m3/h ColBInFlow 0.0 m3/h	Stop InFlowmeter 0.0 l/h OutFlowmeter 0.0 l/h Membrane
TPC	RunStable Line1Ratio 86.8 % Line2Ratio 9.0 % Line3Ratio 4.2 % TotalFlow 46.1 l/h	Run InPressure 0.2 mbar OutPressure 2.2 bar Pump1CurrentLoad 6.9 A Pump1CurrentSpeed 42.9 speed PressureSetpoint 0.4 mbar	Recirculating BufferPressure 2.0 bar CirculationPressu.. 1.4 bar	RunReady 61	Stop CA C1 ColARunVolume 0.0 m3 ColBRunVolume 15147.6 m3 ColAInFlow 0.1 m3/h ColBInFlow 17.0 m3/h	ColARunVolume 0.0 m3 ColBRunVolume 0.0 m3 ColAInFlow 0.0 m3/h ColBInFlow 0.0 m3/h Absorber
HMP	RunStable Line1Ratio 100.0 % Line2Ratio 0.0 % TotalFlow 270.0 l/h			RunReady 61		
MTR	RunStable OK Line1Ratio 89.7 % Line2Ratio 0.0 % Line3Ratio 10.0 % Line4Ratio 0.3 % TotalFlow 171.1 l/h			RunReady 61		RunReady EvaporatorPressur.. 0.0 bar Humidity 6145.1 ppm Humidifier
PMD	RunStable Line1Ratio 70.0 % Line2Ratio 30.0 % TotalFlow 89.5 l/h			RunReady 61		
MCH	RunStable Line1Ratio 80.0 % Line2Ratio 20.0 % TotalFlow 496.7 l/h			RunReady 61 62		
CPV	Stop Line1Ratio 0.0 % Line2Ratio 0.0 % TotalFlow 0.0 l/h			Stop 61		00:38 3/17/2010

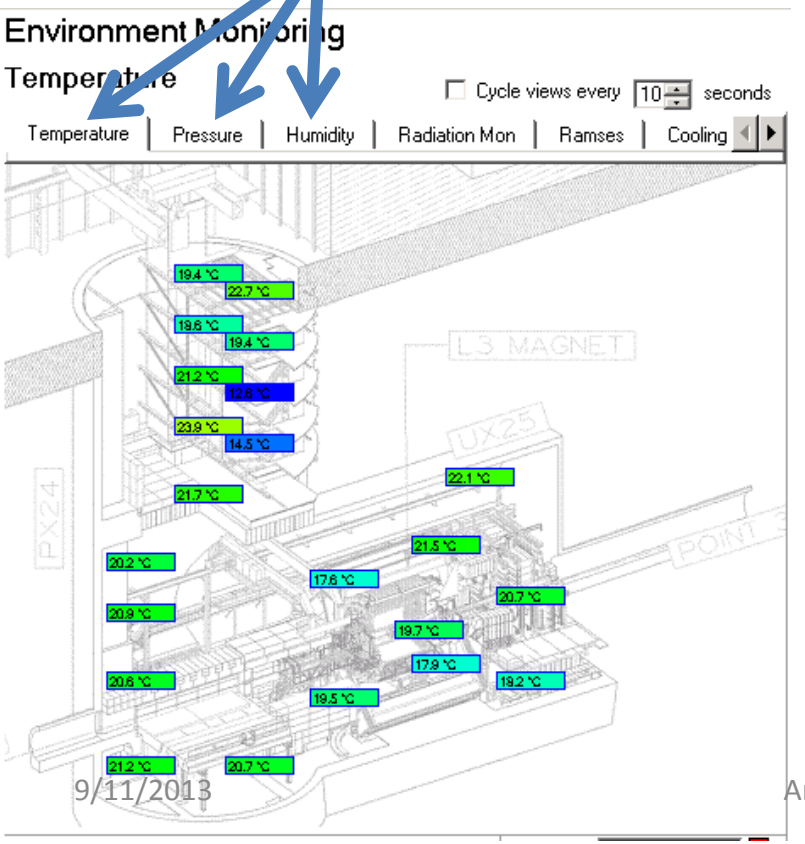
Services and Environment

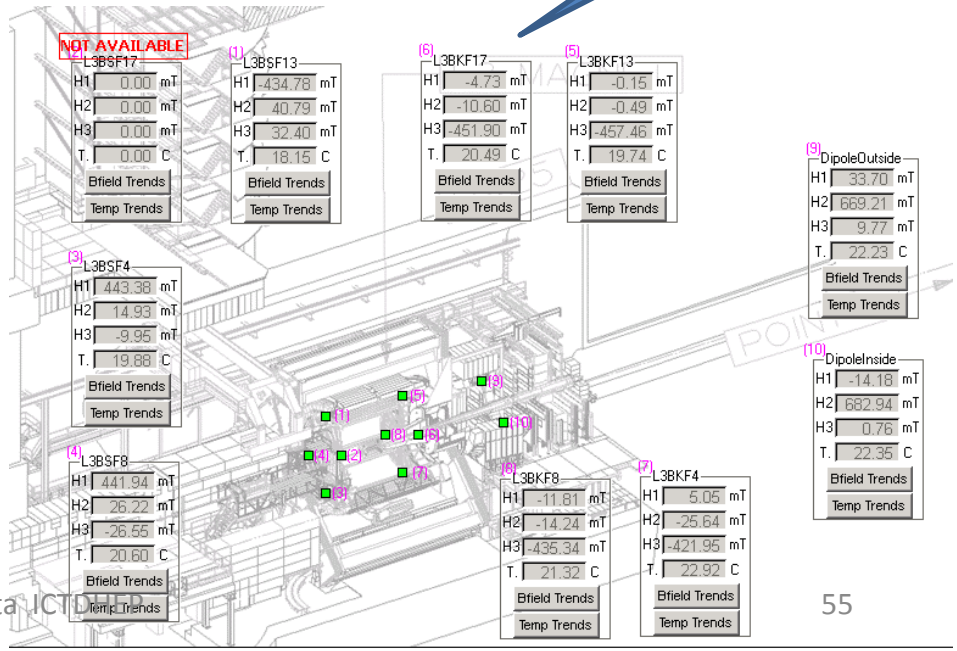
RAMSES radiation monitors

Temperature, pressure, humidity

B-field probes







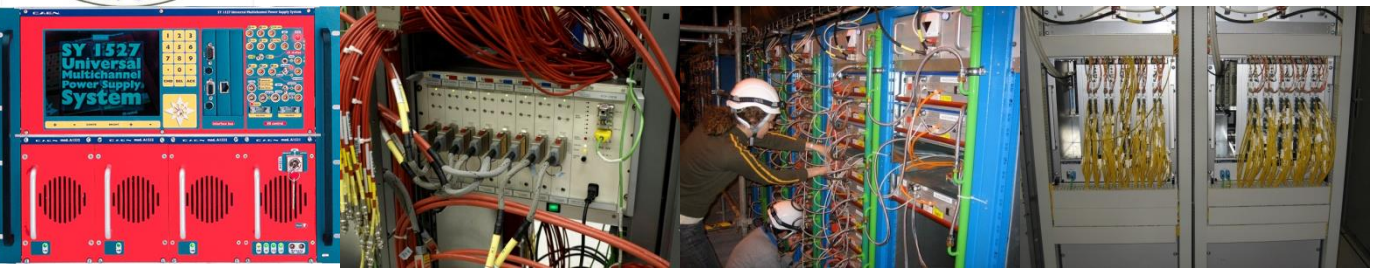
Summary

- ALICE DCS is based on commercial SCADA system called WinCC Open Architecture hitherto known as PVSSII

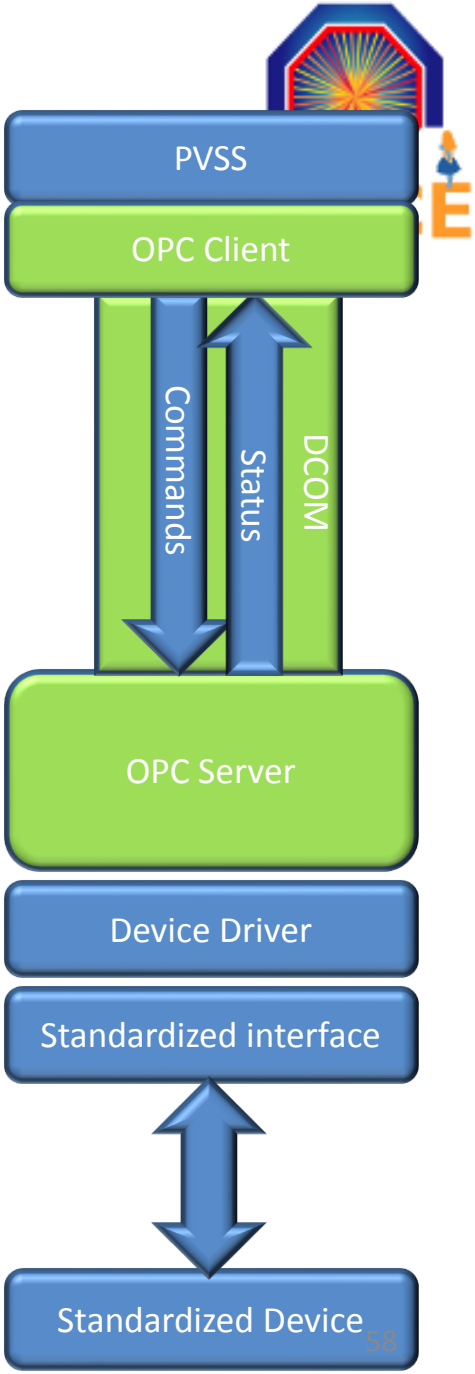
- DCS has to assure efficient, yet safe operation
  - Standardize where possible; hide complexity and diversity
  - Modelling through finite state machines
  - Continuously Develop user interfaces to ease operator tasks
- Future
  - Exploit experience of last years of operations
  - Review state machines, simplify where possible
  - Improve user interface
  - Aim for further automation in the operation
  - Improve robustness of the communication with external systems

BACKUP SLIDES

OPC Technology

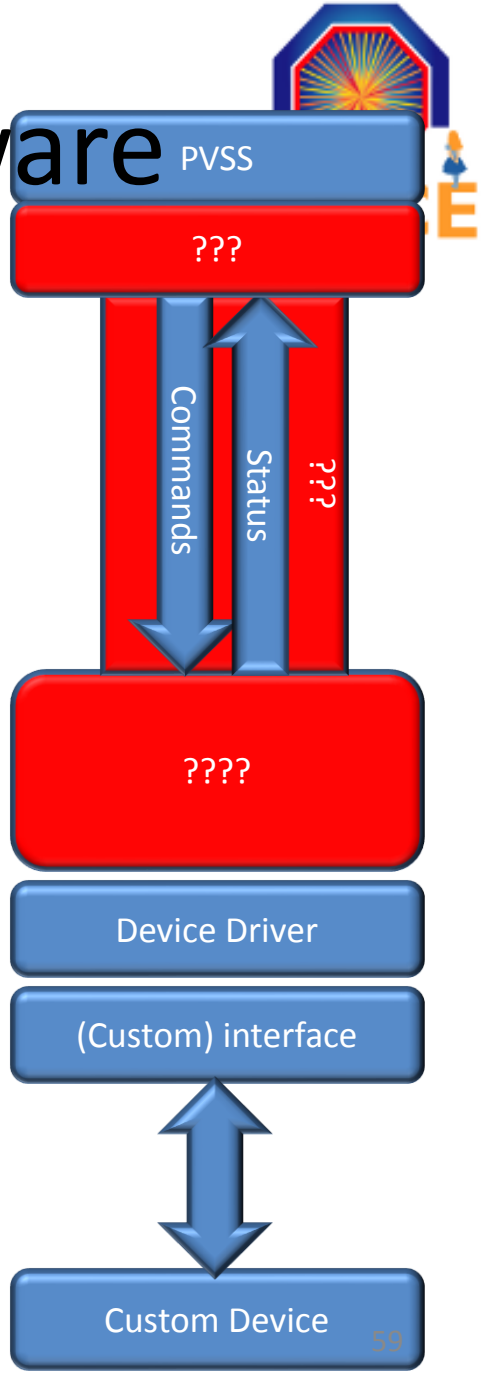


- OPC – industrial standard
- Implemented in PVSS as a manager providing generic interface
- In ALICE most commercial devices are controlled via OPC
- ~200 000 OPC items used in DCS



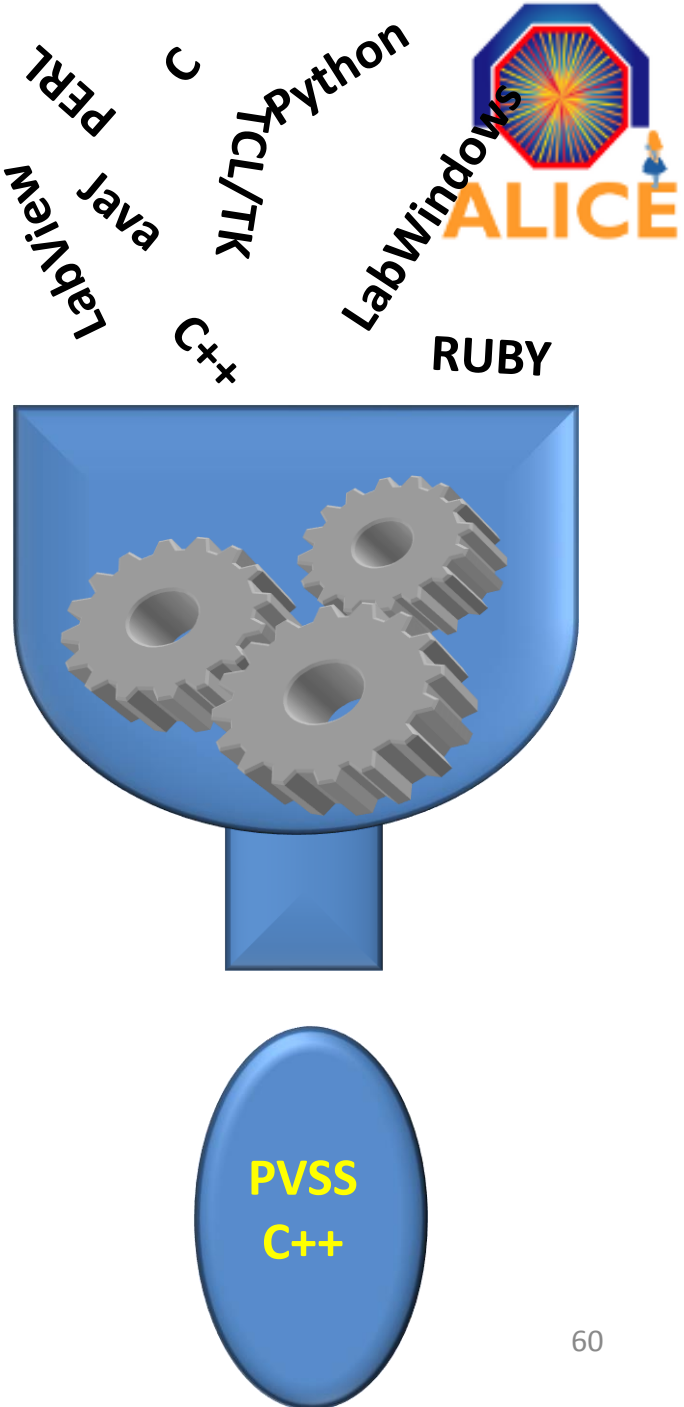
Controlling Custom Hardware

- Custom modules typically come with software packages developed by engineers
  - Incompatible with PVSS
- Missing link to PVSS
  - Transport protocol
  - Communication standard
- The main objective of ALICE DCS:
  - Hide the device complexity
  - Provide a generic communication protocol covering all custom architectures



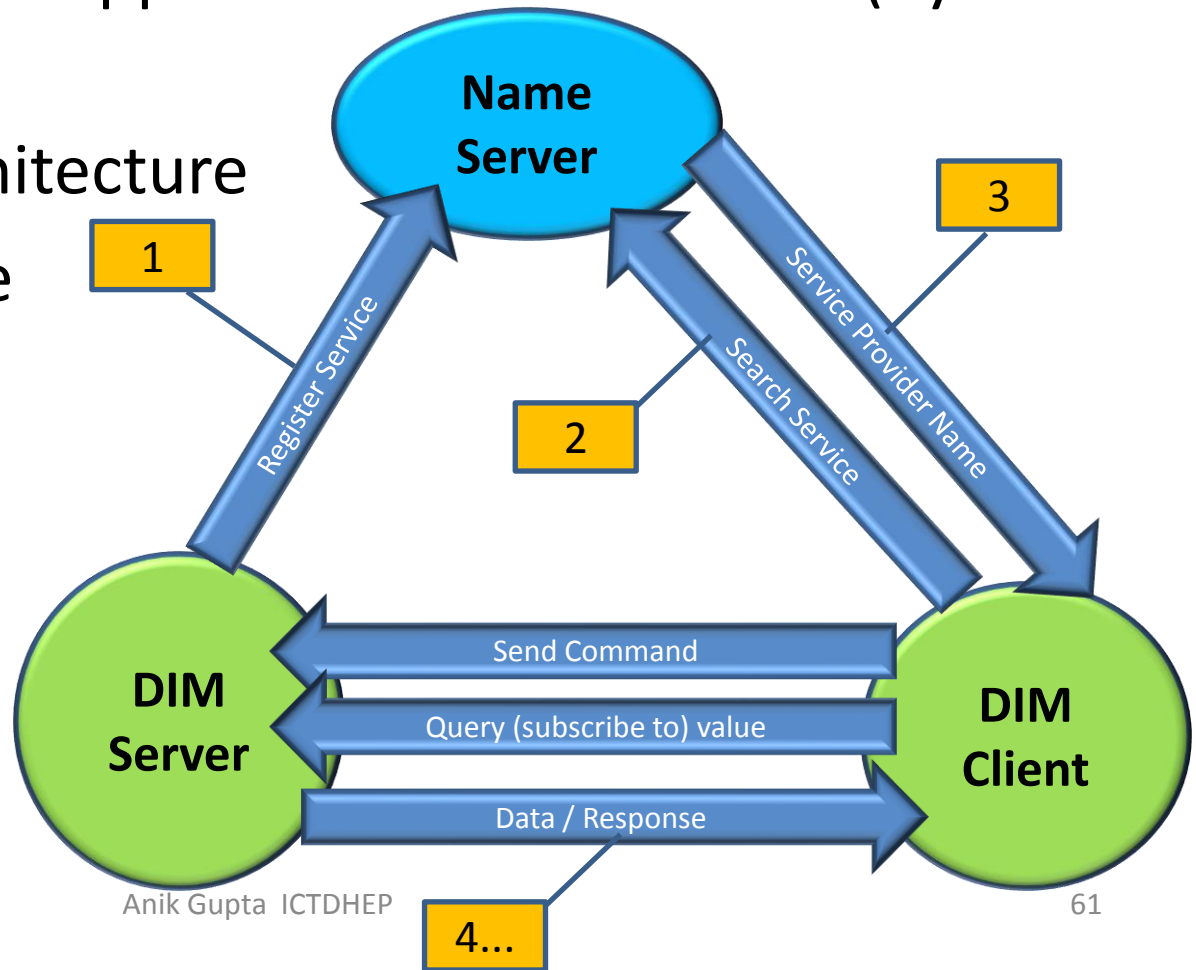
- The tools supplied with the hardware were designed for laboratory environment

- First step:
  - PVSS and C++ imposed as the only platforms for the production system

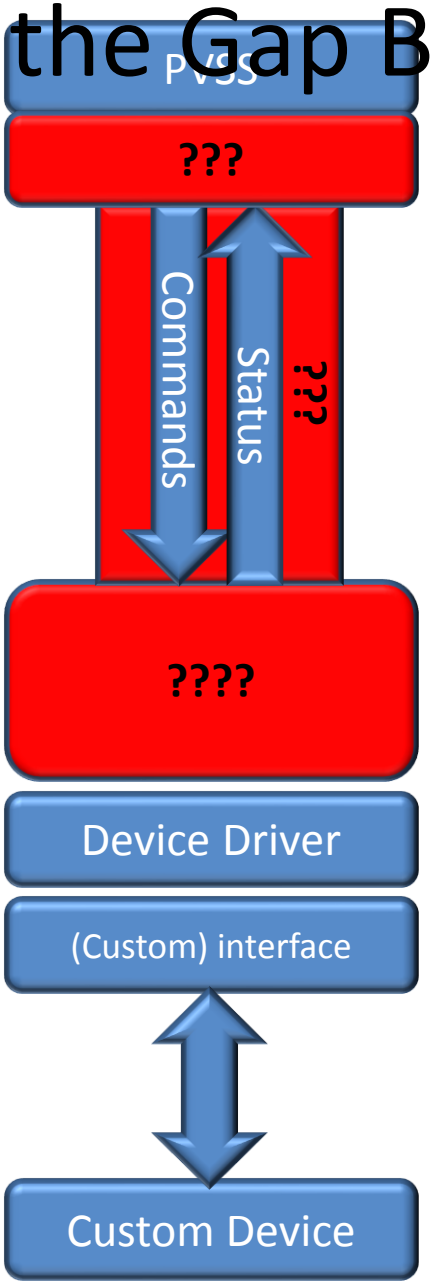


The Choice of the Transport Protocol

- CERN DIM used for command and data transfer
  - Implemented and supported in PVSS and C++ (by CERN)
  - Client/server architecture
  - Robust and stable

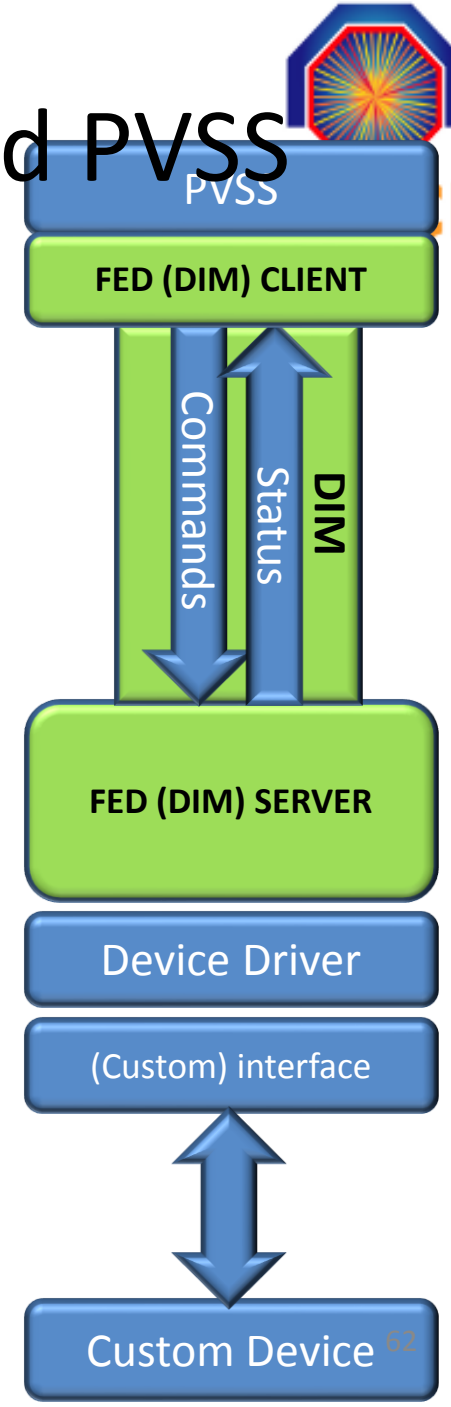


Filling the Gap Between FEE and PVSS



Transport based on DIM

Code embedded in FED framework



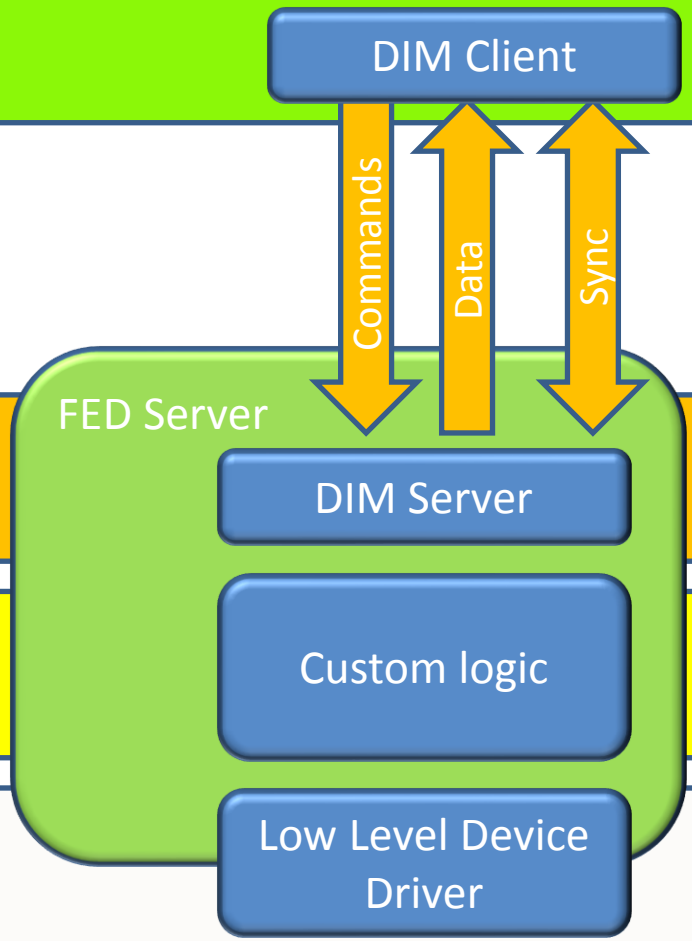
Generic Front-end Device (FED) Architecture

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)



~100 000 data channels serviced by FEDs in ALICE