An Integrated Control System for the LHCb experiment

Alba Sambade Varela

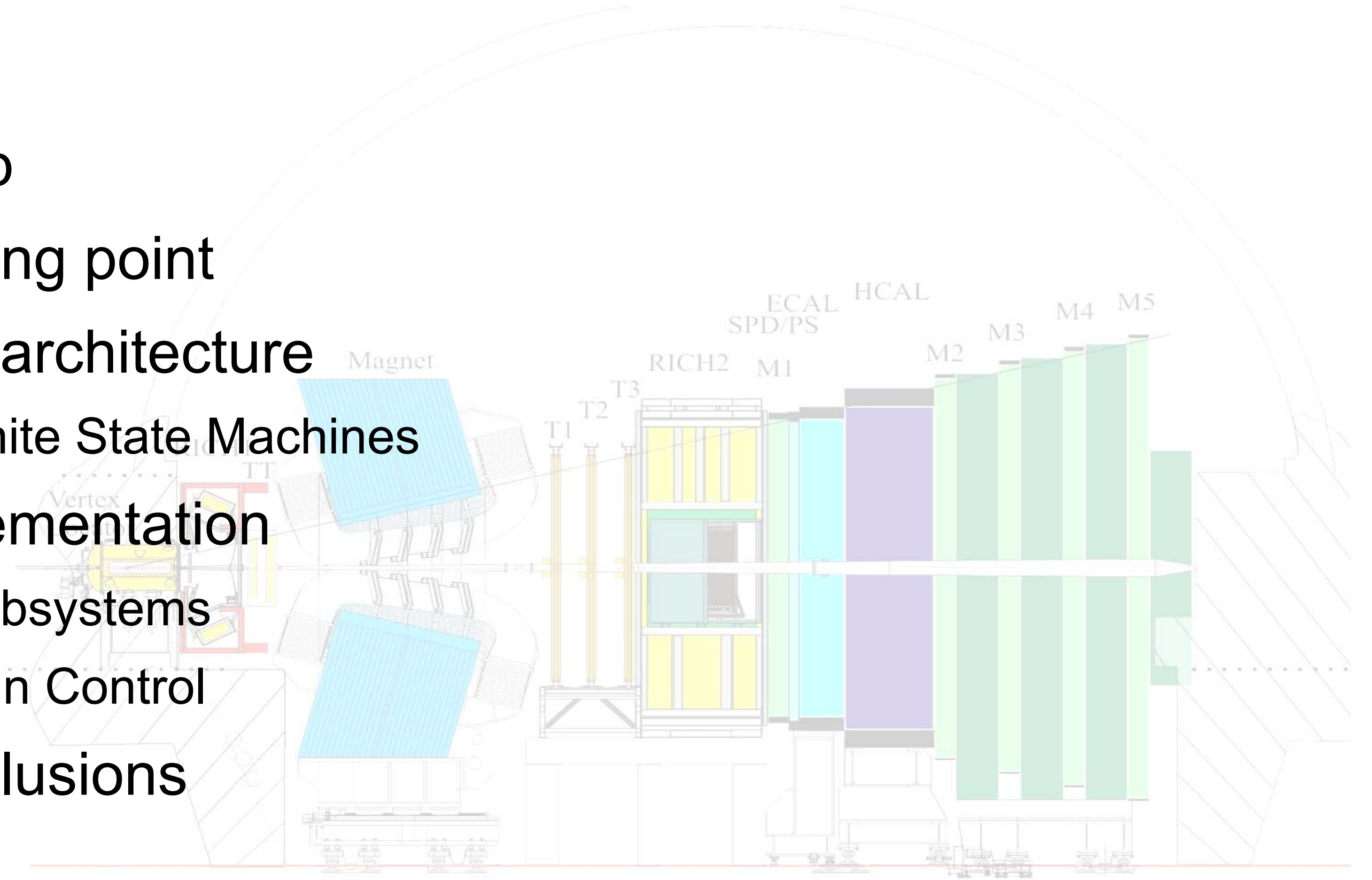
On behalf of the LHCb online group

16th IEEE NPSS Real Time Conference 2009

May 10-15 IHEP Beijing

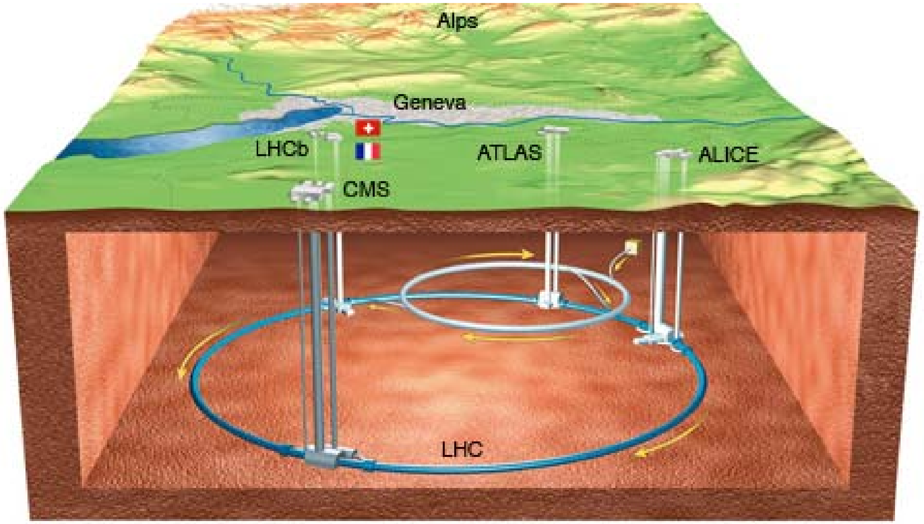
Outline

- LHCb
- Starting point
- ECS architecture
  - Finite State Machines
- Implementation
  - Subsystems
  - Run Control
- Conclusions



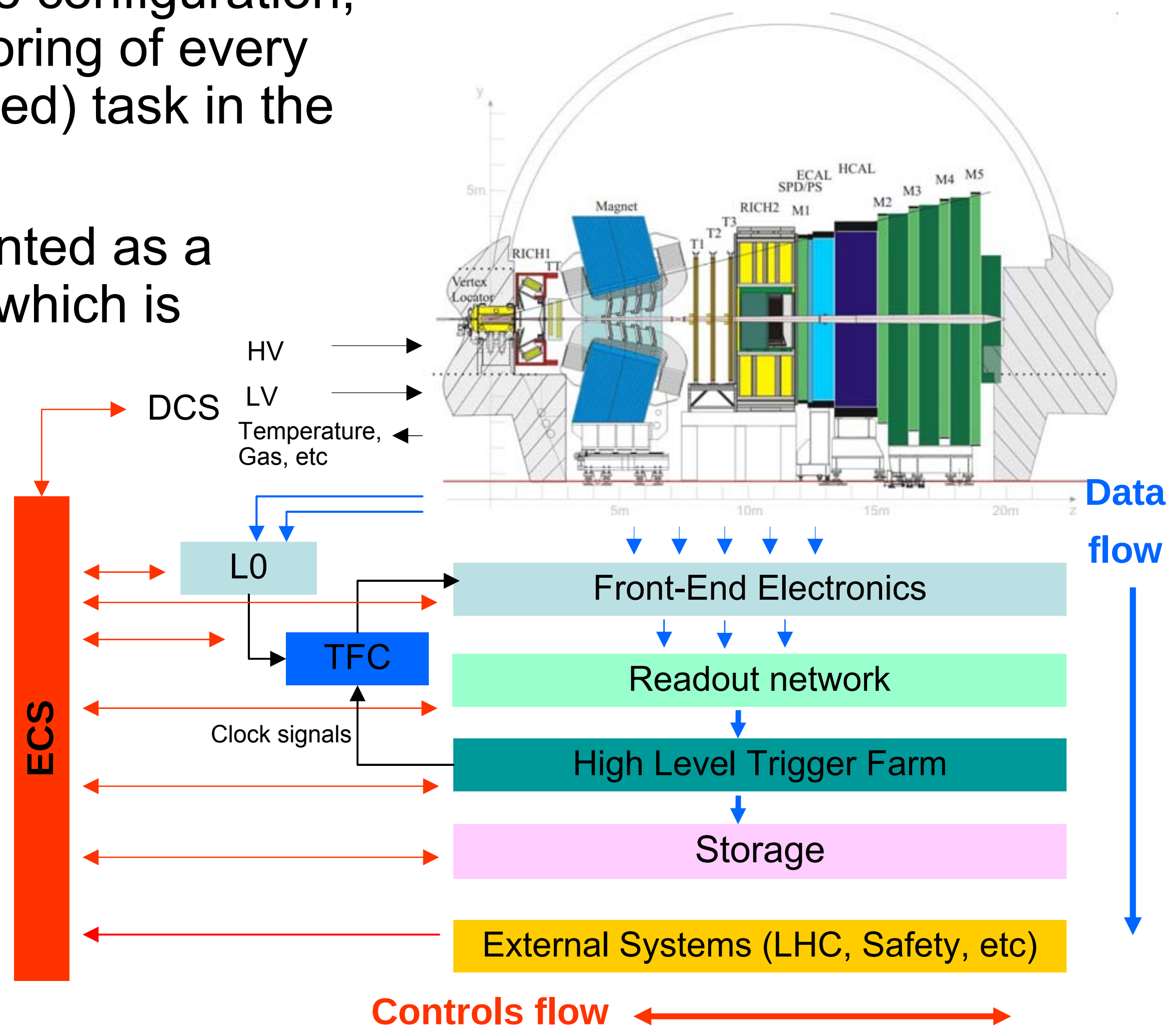
LHCb experiment

- It is one of the 4 detectors in the *Large Hadron Collider*
- Its aim is studying the production of pairs of *b* quarks (*beauty-antibeauty*) and the CP violation (asymmetry matter/antimatter).
- It is composed out of 5 groups of subdetectors:
  - VELO
  - RICH
  - Tracker
  - Calorimeters
  - Muon system.
- Each one focused in one property.



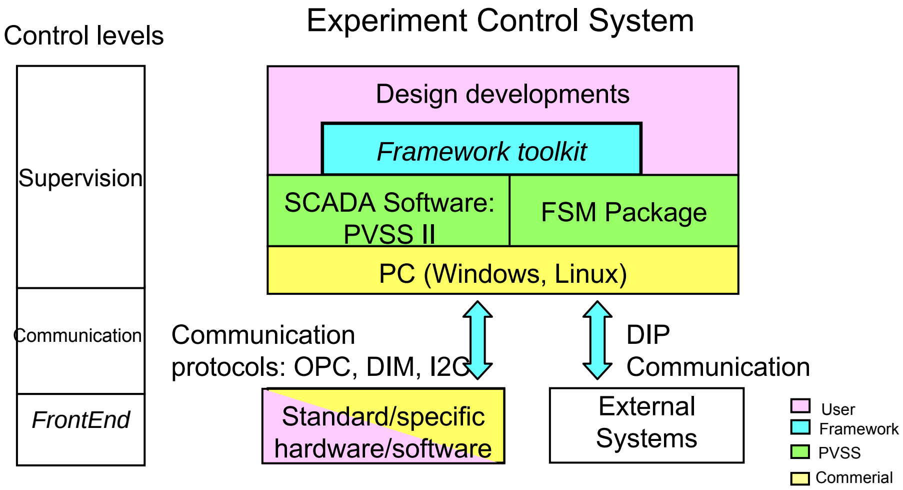
LHCb Experiment Control System

- The ECS handles the configuration, operation and monitoring of every online (run time related) task in the experiment.
- It has been implemented as a hierarchical control, which is
  - Homogeneous
- and provides:
  - Automation
  - Partitioning



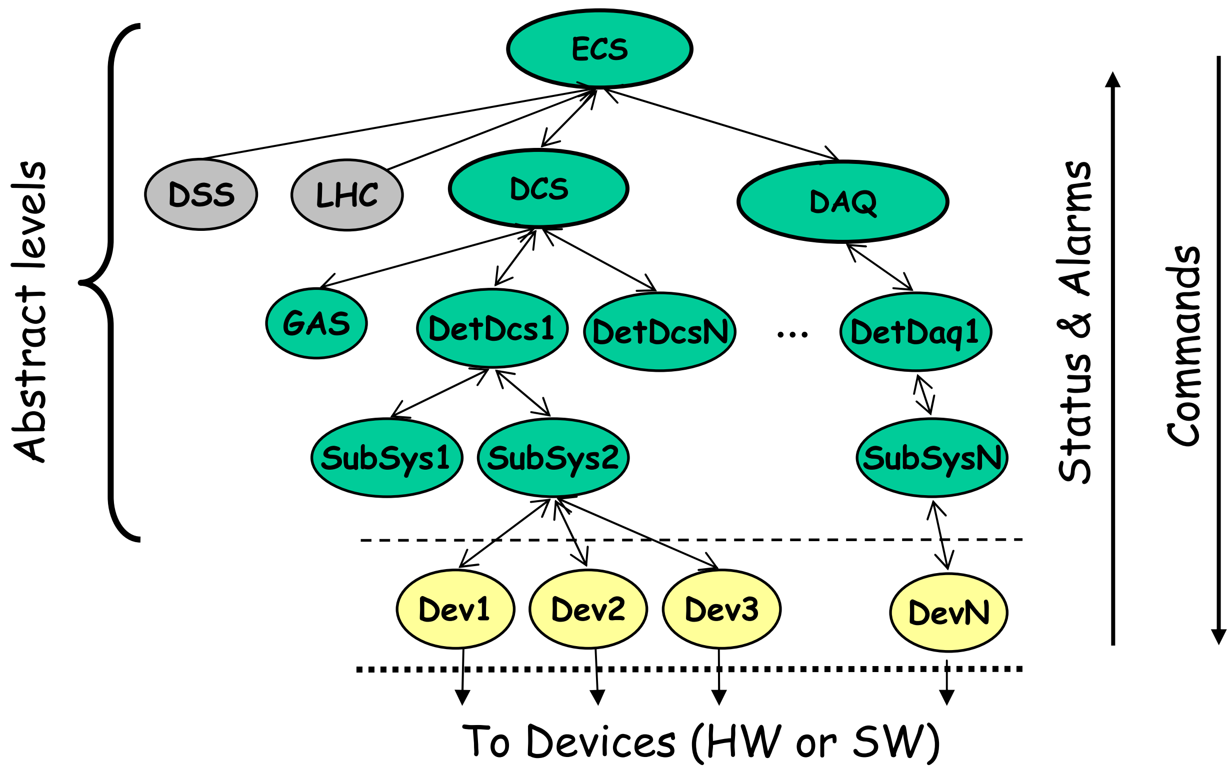
Common tools: Homogeneity

- Starting from a commercial SCADA software: PVSS,
- a Framework Toolkit,
  - Set of guidelines and sw tools, developed in common for the four LHC experiments.
- and a FSM package,
  - Allow the creation of hierarchies of Finite State Machine.
- a homogeneous design was achieved for the ECS.
  - The same behavior schema is used through the system to model all control nodes.
  - All data is stored in a run time database, allowing different external applications to interface it.
  - Common look & feel.
- Single system principles extrapolated to all systems!



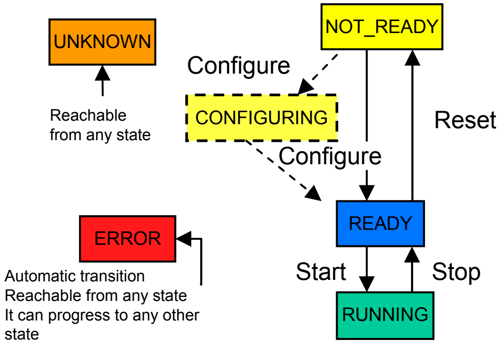
ECS architecture

- Hierarchical (tree like) structure
  - A structure of logical nodes integrates every item to be controlled (hardware device, software task, logical entity).



FSM concept

- FSM allows the definition and operation of hierarchies of objects (control nodes) behaving as Finite State Machines.
  - It is based on SMI++.
- The behavior of the nodes and its interactions are modeled in terms of STATES and COMMANDs.
  - Change process between states are TRANSITIONS.
  - These changes are induce either by sending a COMMAND or by a state change of a children.



Control nodes types

- **Control Unit**

  Implements the specific behavior and takes local decisions (automation and sequencing of actions, error recovering)

  — "Expand" actions.

  — Partitioning: included/excluded.

  — Can run in stand-alone mode.

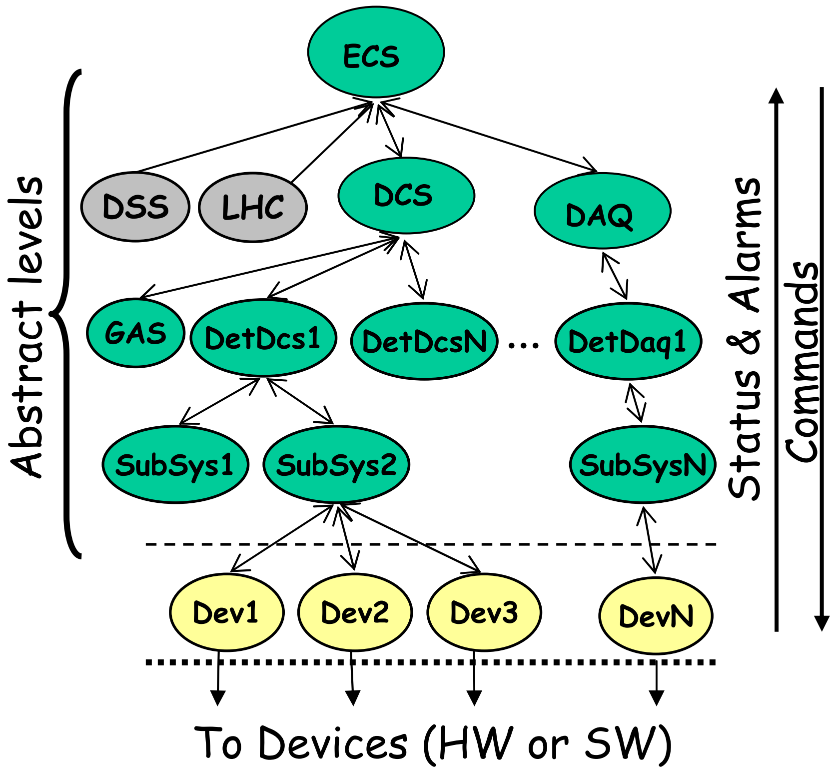
- **Device Unit**

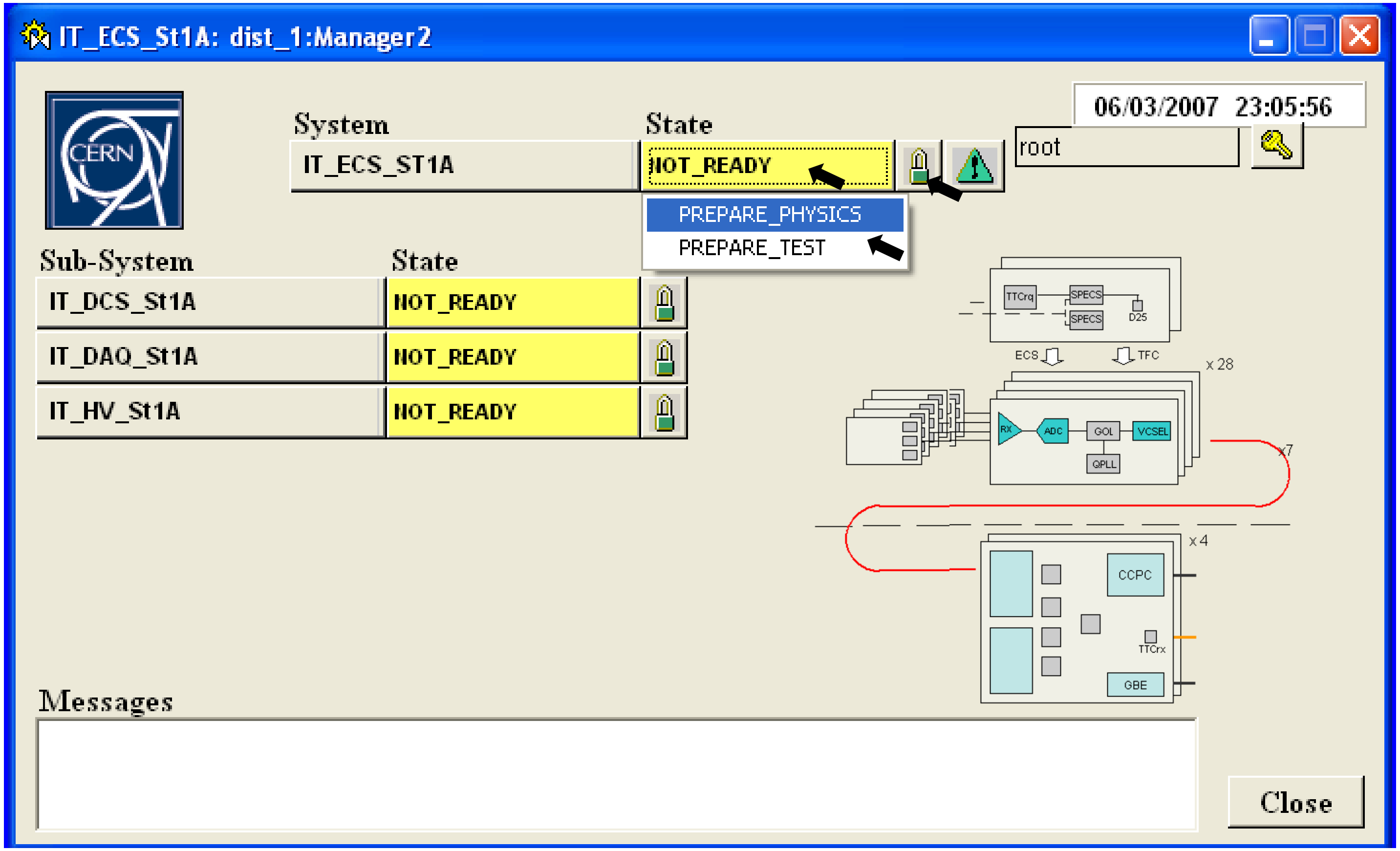
  Interface with the real devices (hardware or software)

  – Calculates a STATE from device readings.

  – Implements COMMANDs as device parameters.

  – Enabled /disabled.



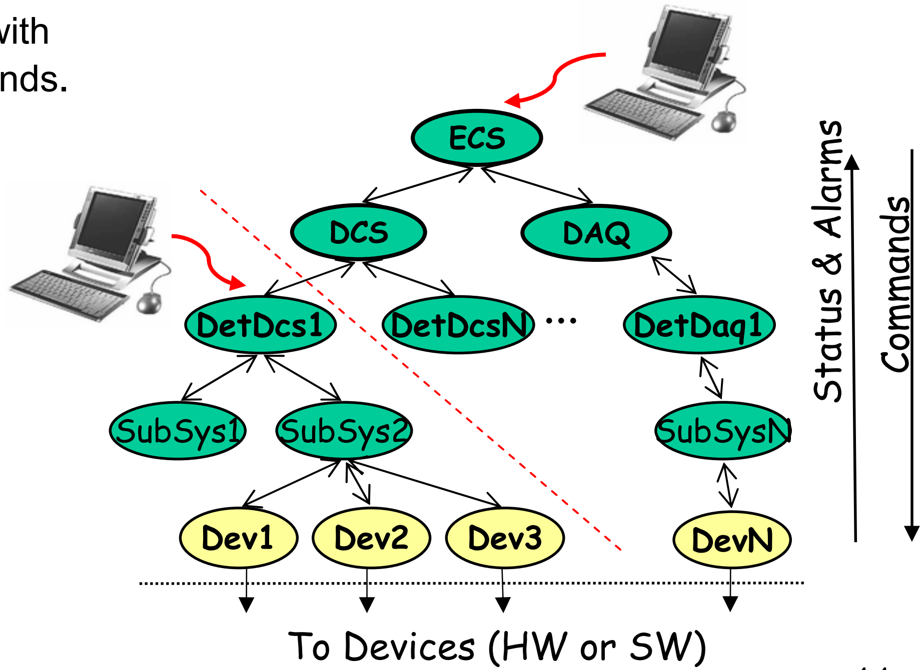

IT_ECS_St1A: dist_1:Manager2
06/03/2007 23:05:56
System
State
IT_ECS_ST1A
NOT_READY
root
PREPARE_PHYSICS
PREPARE_TEST
Sub-System
State
IT_DCS_St1A
NOT_READY
IT_DAQ_St1A
NOT_READY
IT_HV_St1A
NOT_READY
TTCrq
SPECS
SPECS
D25
ECS
TFC
x 28
RX
ADC
GOL
VCSEL
QPLL
x7
x 4
CCPC
TTCrx
GBE
Messages
Close

Partitioning (1)

- Different sub-detectors, many teams and possible configurations (operation modes) (commissioning stage).
  - Possibility to run hierarchies in parallel.
  - Possibility to modify dynamically the components included to control.
    - Typical case for an out of order device.
  - Different partitioning modes (included, excluded, manual and ignored).

Partitioning (2)

- Taking or releasing control
  - The operator can take the control at an intermediate level of the control tree.
  - Ownership: it is guarantied that only one user at a time can use a given part of the system.
    - Exception: shared mode, operator with certain rights can also send commands.
- Once a sub-set of the system is excluded, it can be taken separately and run in parallel (stand-alone) with other tree(s).



Automation

- Need coming from the complexity of the system and the operation by non-expert operators.
  - Sequencing of actions
    - An action on control units is specified by a sequence of instructions, mainly consisting on commands sent to their children and logical tests (on the states of these).
    - An action on device units is typically sent off as a message to the real hardware (which can cause a status change and will trigger the corresponding logical checks).
  - Error recovery
    - Logical state checks can trigger automatic actions whenever a malfunctioning is detected.

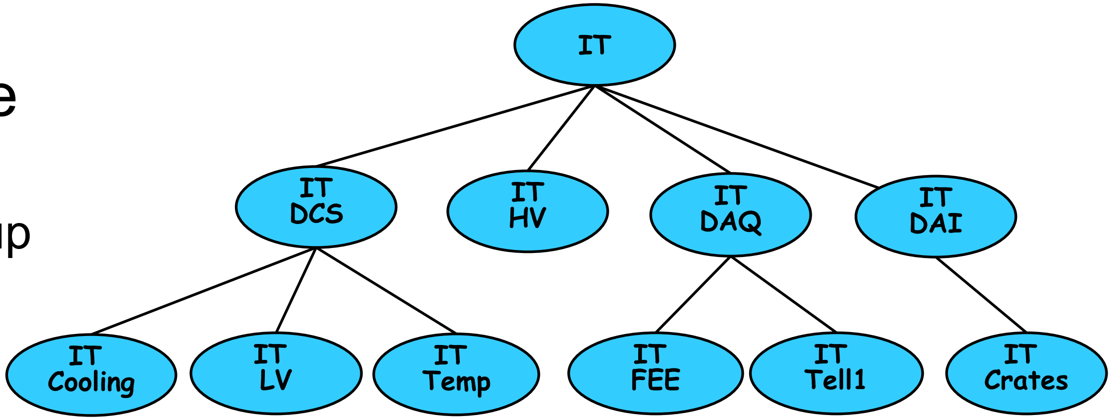
ECS implementation

- Sub-system integration
  - Sub-detectors
  - Common resources
- Set of guidelines proposed to unified procedures
  - Split sub-detector ECS into 4 identified control domains

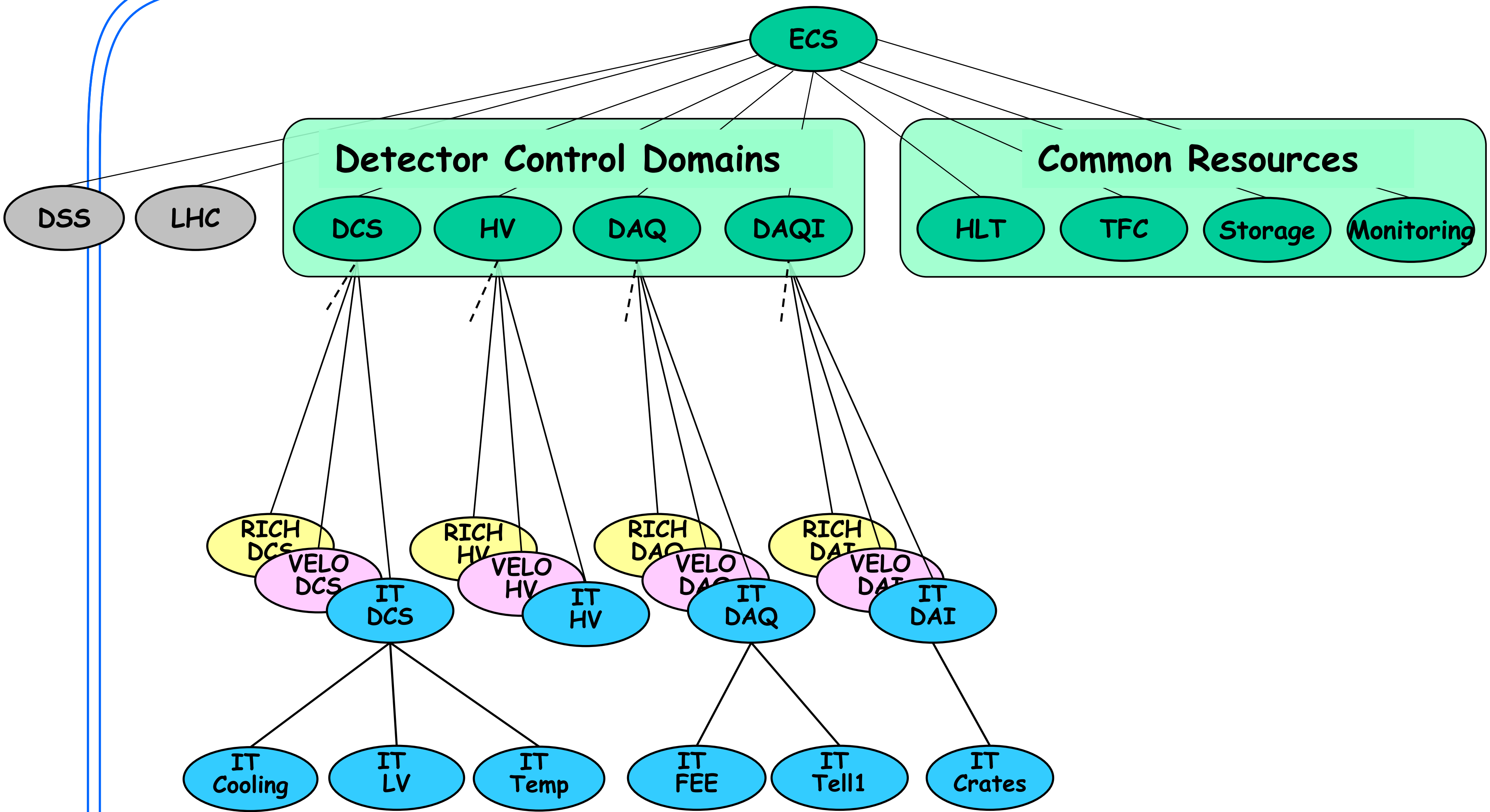
Sub-detector ECS

- Control domains
  - They cover all the activities necessary to manage, to supervise and to run a sub detector.
    - DAQ: all Electronics and components necessary to take data (run related).
    - DCS: infrastructure (Cooling, Gas, Temperatures, pressures, etc) that is normally stable throughout a running period
    - HV: equipment that normally depends on the LHC machine state (fill related)
    - DAI: Infrastructure necessary for the DAQ to work (computers, networks, electrical power, etc.) in general also stable throughout a running period.
  - Every domain has an specified FSM type with standardized states and actions.

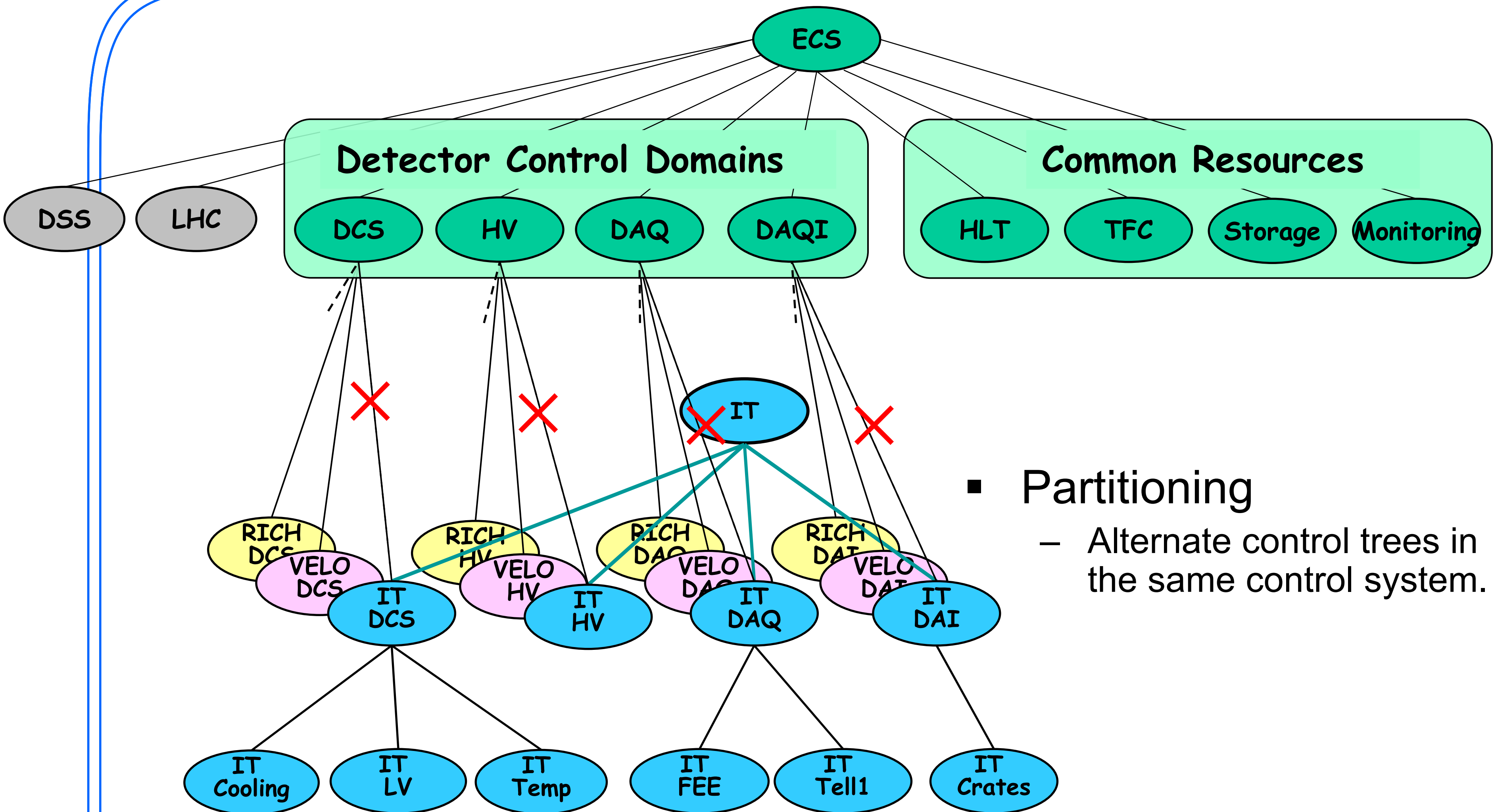
- Further domain tree breakdown
  - Physical or logical (up to the subdetector).



Sub-systems integration

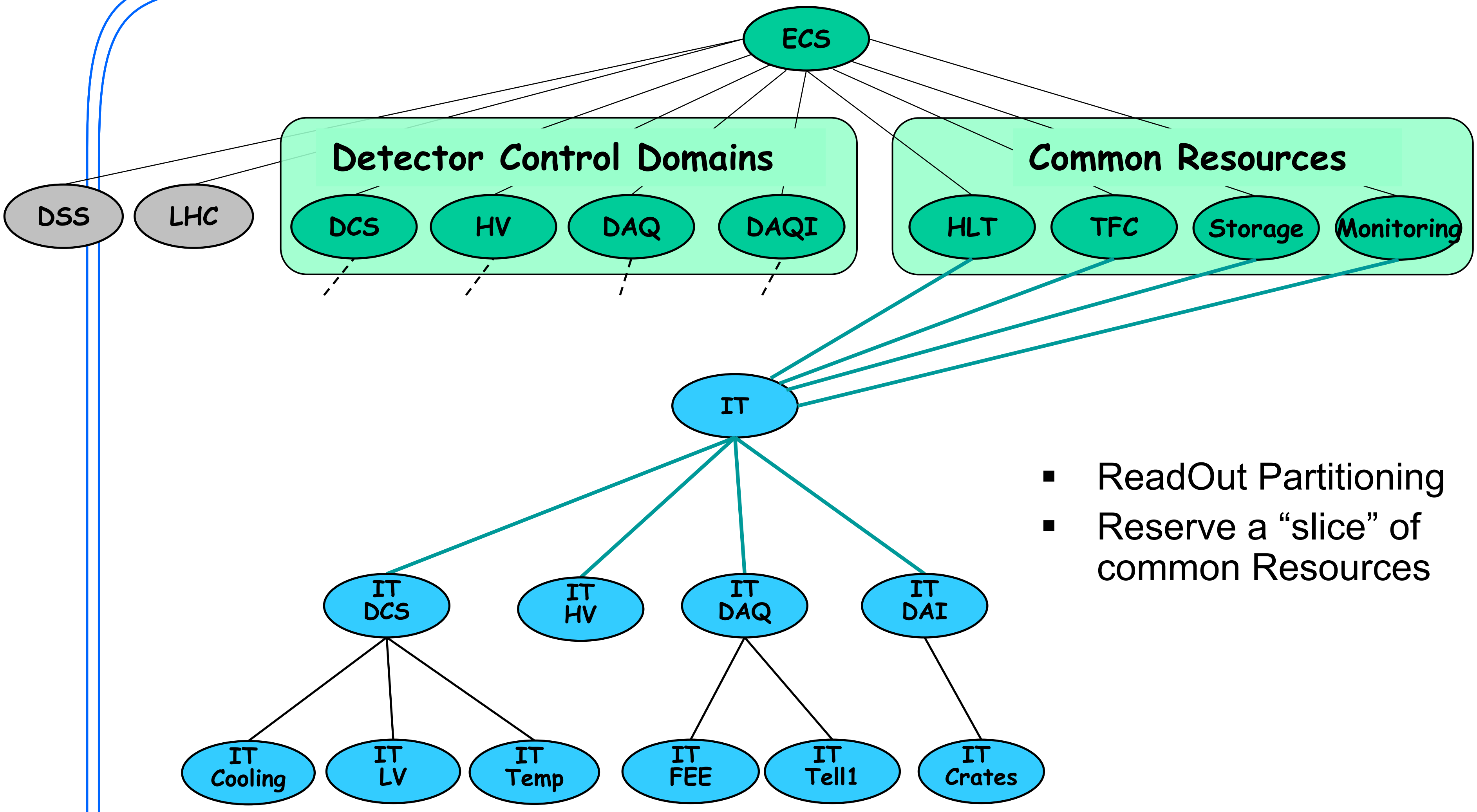


Parallel run controls



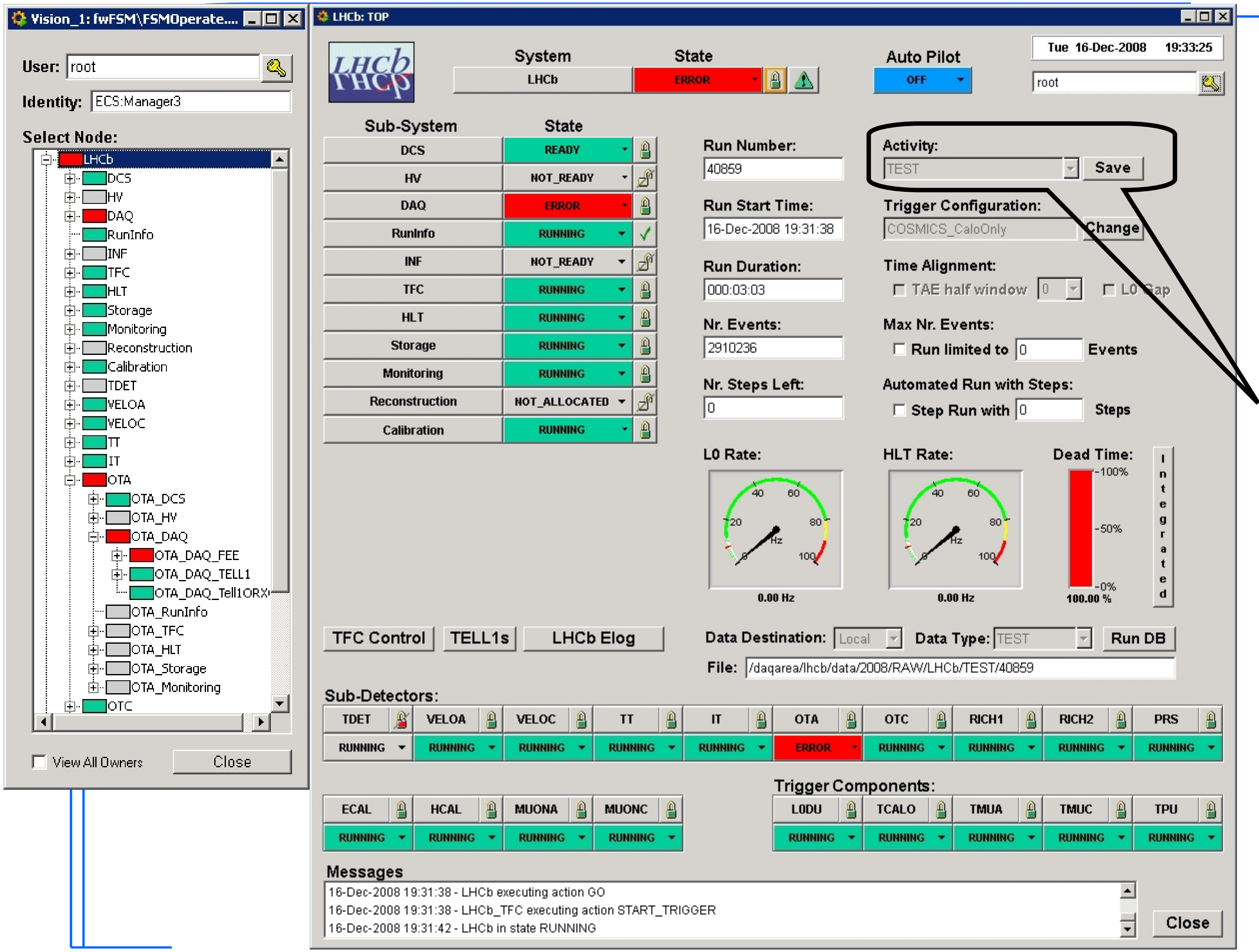
- Partitioning
  - Alternate control trees in the same control system.

Dynamic allocation



- ReadOut Partitioning
- Reserve a “slice” of common Resources

Run Control



- **Matrix**

  Domain
  x
  Sub-Detector

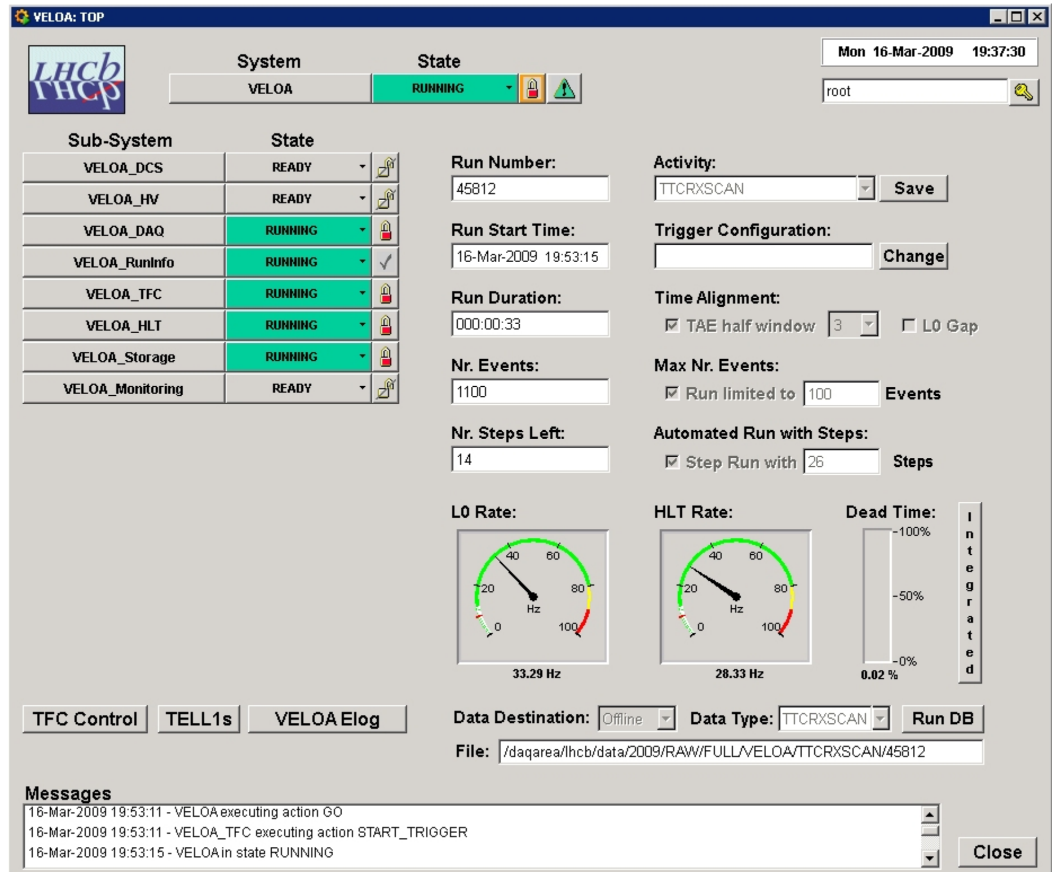
- **Activity**

  Used for configuring all Sub-Systems

Conclusions

- We have implemented the LHCb ECS:
  - Highly distributed
    - Control spread over 150 PCs (Windows and Linux).
      - ~2000 CU and ~30000 DU
  - Hierarchical
    - All "equipment" integrated
- And a daily used Run Control
  - Minimal operator intervention (~2 persons shift crew)
    - Automation: actions sequencing and error recovering
  - Non-expert user friendly
  - Subdetectors can run different instances in parallel.

Questions?


VELOA: TOP
System
State
VELOA
RUNNING
Mon 16-Mar-2009 19:37:30
root
Sub-System
State
VELOA_DCS READY
VELOA_HV READY
VELOA_DAQ RUNNING
VELOA_RunInfo RUNNING
VELOA_TFC RUNNING
VELOA_HLT RUNNING
VELOA_Storage RUNNING
VELOA_Monitoring READY
Run Number:
45812
Activity:
TTCRXSCAN
Save
Run Start Time:
16-Mar-2009 19:53:15
Trigger Configuration:
Change
Run Duration:
000:00:33
Time Alignment:
TAE half window
3
L0 Gap
Nr. Events:
1100
Max Nr. Events:
Run limited to
100
Events
Nr. Steps Left:
14
Automated Run with Steps:
Step Run with
26
Steps
L0 Rate:
HLT Rate:
Dead Time:
33.29 Hz
28.33 Hz
0.02 %
Integrated
TFC Control
TELL1s
VELOA Elog
Data Destination:
Offline
Data Type:
TTCRXSCAN
Run DB
File:
/daqarea/lhcb/data/2009/RAW/FULL/VELOA/TTCRXSCAN/45812
Messages
16-Mar-2009 19:53:11 - VELOA executing action GO
16-Mar-2009 19:53:11 - VELOA_TFC executing action START_TRIGGER
16-Mar-2009 19:53:15 - VELOA in state RUNNING
Close