

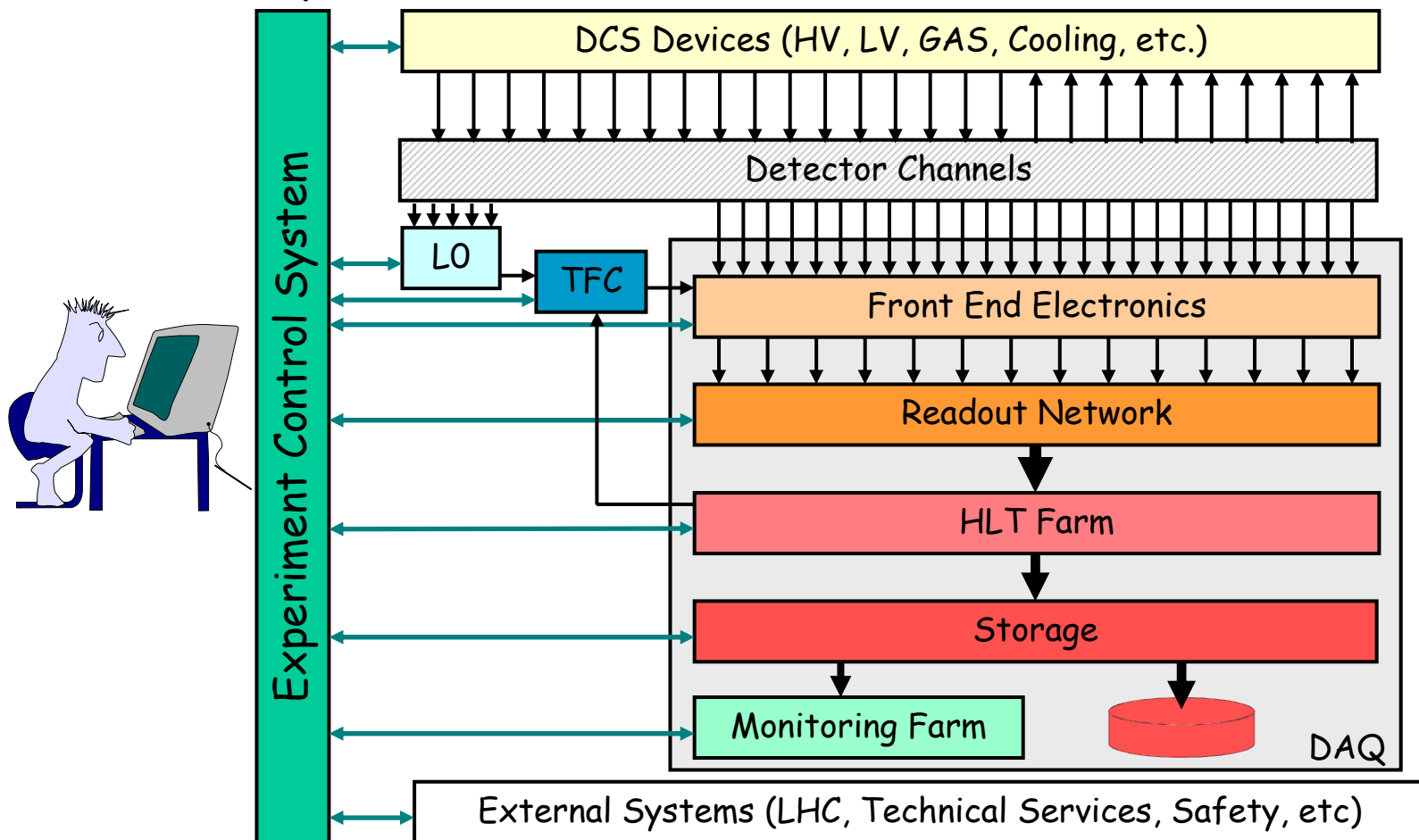
# The LHCb Experiment Control System:

On the path to full automation

*Clara Gaspar, October 2011*

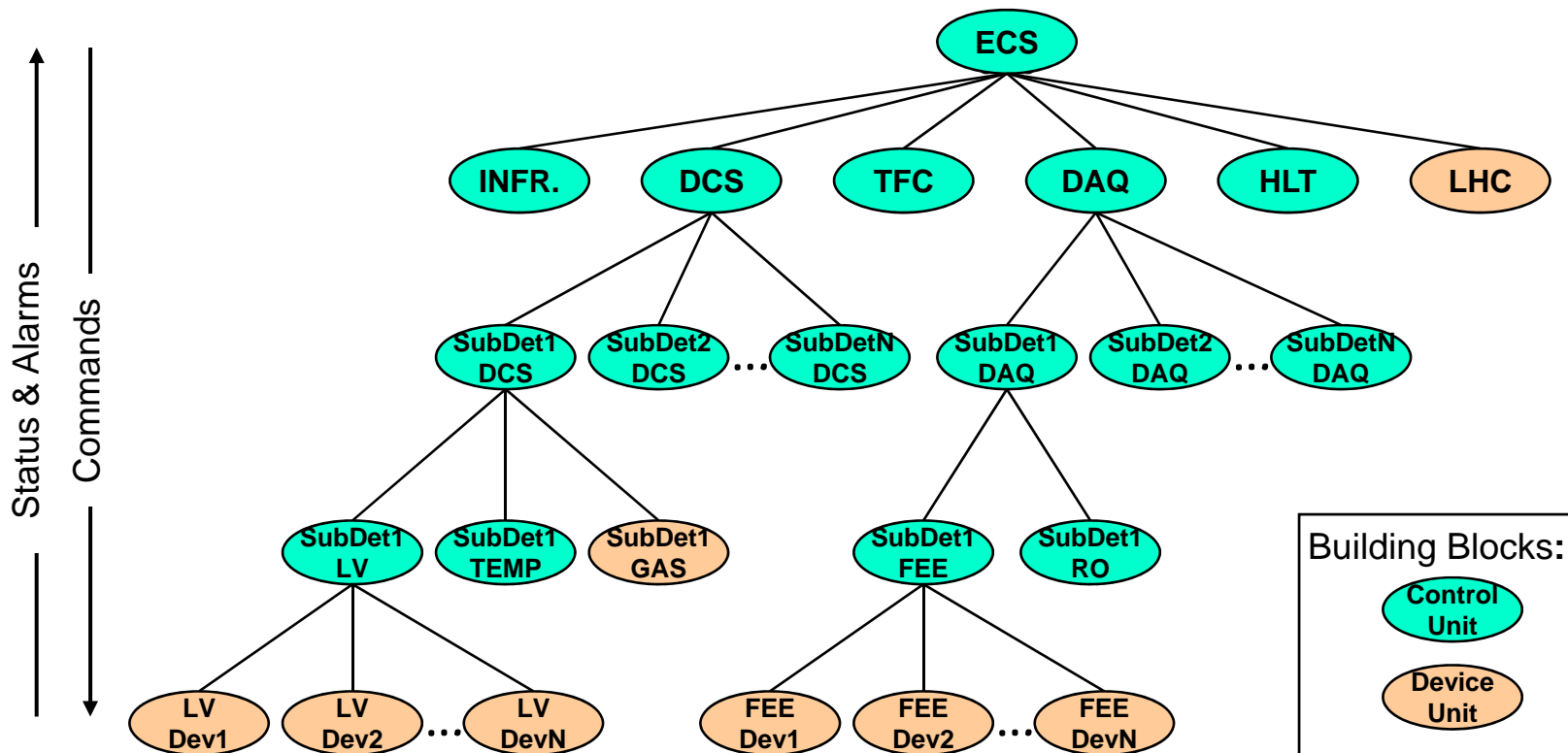
# The Experiment Control System

- Is in charge of the Control and Monitoring of all areas of the experiment



Clara Gaspar, October 2011

- Same architecture and same tools used throughout the Control System.
- Generic Architecture:



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# The Control Framework

- The JCOP\* Framework is based on:

- SCADA System - PVSSII for:

- | Device Description (Run-time Database)
    - | Device Access (OPC, Profibus, drivers) +DIM
    - | Alarm Handling (Generation, Filtering, Masking, etc)
    - | Archiving, Logging, Scripting, Trending
    - | User Interface Builder
    - | Alarm Display, Access Control, etc.

Device Units

Control Units

- SMI++ providing:

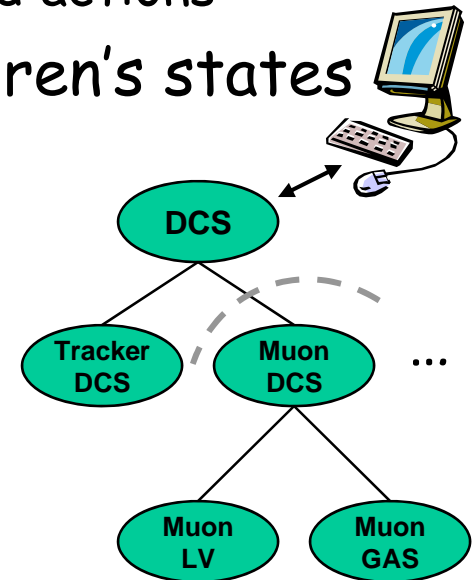
- | Abstract behavior modeling (Finite State Machines)
    - | Automation & Error Recovery (Rule based system)

\* - The Joint COntrols Project (between the 4 LHC exp. and the CERN Control Group)

- Provide access to “real” devices:
  - The FW provides interfaces to all necessary types of devices:
    - | LHCb devices: HV channels, Read Out boards, Trigger processes running in the HLT farm or Monitoring tasks for data quality, etc.
    - | External devices: the LHC, a gas system, etc.
  - Each device is modeled as a Finite State Machine:
    - | It's main interface to the outside world is a “State” and a (small) set of “Actions”.

## Each Control Unit:

- Is defined as one or more Finite State Machines
  - It's interface to outside is also a state and actions
- Can implement rules based on its children's states
- In general it is able to:
  - Include/Exclude children (Partitioning)
    - Excluded nodes can run is stand-alone
  - Implement specific behaviour & Take local decisions
    - Sequence & Automate operations
    - Recover errors
  - User Interfacing
    - Present information and receive commands



# FW - Graphical Editor

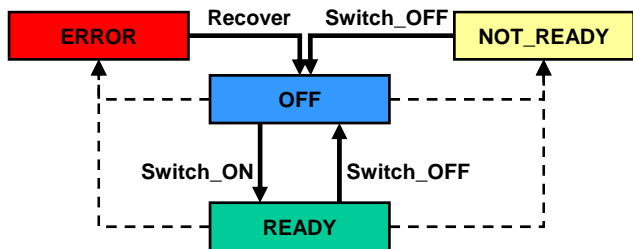
■ **SMI++**  
Objects  
States &  
Actions

- Parallelism, Synchronization
- Asynchronous Rules

# Operation Domains

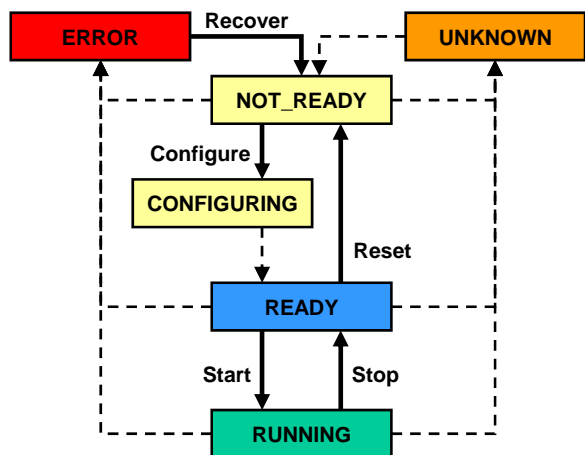
## DCS Domain

Equipment operation related to a running period (Ex: GAS, Cooling)



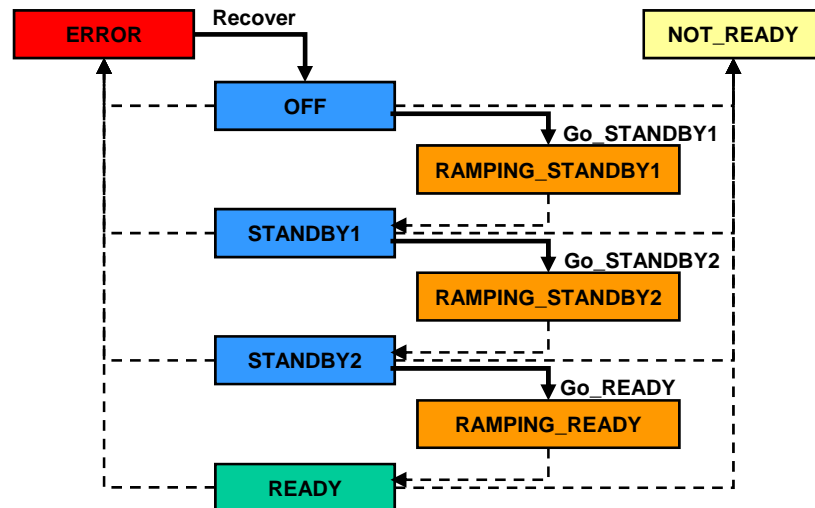
## DAQ Domain

Equipment operation related to a "RUN" (Ex: RO board, HLT process)



## HV Domain

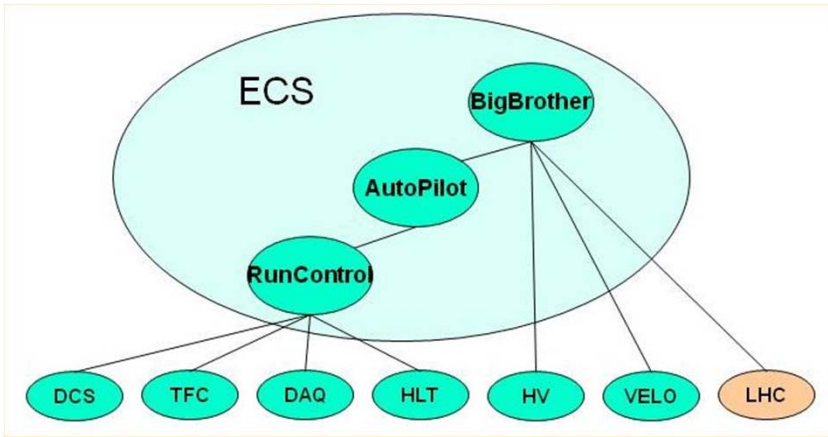
Equipment operation related to the LHC State (Ex: High Voltages)



- FSM templates distributed to all Sub-detectors
- All Devices and Sub-Systems have been implemented using one of these templates



# ECS - Automation



## Some Examples:

### HLT Control (~1500 PCs)

- | Automatically excludes misbehaving PCs (within limits)
- | Can (re)include PCs at run-time (they get automatically configured and started)

### RunControl

- | Automatically detects and recovers SubDetector desynchronizations
- | Can Reset SDs when problems detected by monitoring

### AutoPilot

- | Knows how to start and keep a run going from any state.

### BigBrother

- | Based on the LHC state:
  - | Controls SD Voltages
  - | VELO Closure
  - | RunControl

# LHCb Run Control

Matrix  
Domain  
X  
Sub-Detector

Activity  
Used for  
Configuring all  
Sub-Systems

The screenshot displays the LHCb Run Control interface. On the left, a 'Select Node' tree shows the system hierarchy from LHCb down to various sub-detectors and components. The main window shows the 'System' status as 'LHCb RUNNING'. A table lists sub-systems and their states: DCS (READY), DAI (READY), DAQ (RUNNING), RunInfo (RUNNING), TFC (RUNNING), HLT (RUNNING), Storage (RUNNING), Monitoring (RUNNING), Reconstruction (RUNNING), and Calibration (RUNNING). The 'Auto Pilot' is set to 'ON'. Configuration fields include Run Number (102088), Run Start Time (20-Sep-2011 15:50:22), Run Duration (000:00:32), and Nr. Events (22518863). Two gauges show L0 Rate (812092.82 Hz) and HLT Rate (5365.67 Hz). A 'Dead Time' gauge shows 5.37%. The interface also includes buttons for Efficiency, Trigger Rates, TFC Control, and LHCb Elog, along with a 'Sub-Detectors' table and a 'Messages' log at the bottom.

Sub-System	State
DCS	READY
DAI	READY
DAQ	RUNNING
RunInfo	RUNNING
TFC	RUNNING
HLT	RUNNING
Storage	RUNNING
Monitoring	RUNNING
Reconstruction	RUNNING
Calibration	RUNNING

Sub-Detectors:	TDET	VELOA	VELOC	TT	IT	OTA	OTC	RICH1	RICH2	PRS
State	HOT_READY	RUNNING	RUNNING	RUNNING	RUNNING	RUNNING	RUNNING	RUNNING	RUNNING	RUNNING

Trigger Components:	ECAL	HCAL	MUONA	MUONC	LODU	TCALO	TMUA	TMUC	TPU
State	RUNNING	RUNNING	RUNNING	RUNNING	RUNNING	RUNNING	RUNNING	RUNNING	RUNNING

# LHCb Run Control

Matrix  
Domain  
X  
Sub-Detector

Activity  
Used for  
Configuring all  
Sub-Systems

The screenshot displays the LHCb Run Control interface. On the left, a 'Select Node' tree shows the hierarchy of sub-systems, with 'LHCb' selected. The main window shows the 'System' status as 'ERROR' and 'Auto Pilot' as 'ON'. A table lists sub-systems and their states: DCS (READY), DAI (READY), DAQ (ERROR), RunInfo (RUNNING), TFC (RUNNING), HLT (RUNNING), Storage (RUNNING), Monitoring (RUNNING), Reconstruction (RUNNING), and Calibration (RUNNING). The 'Run Number' is 102088, and the 'Run Start Time' is 20-Sep-2011 15:50:22. The 'L0 Rate' is 812092.82 Hz and the 'HLT Rate' is 5365.67 Hz. The 'Dead Time' is 5.37%. The interface also shows 'Sub-Detectors' (TDET, VELOA, VELOC, TT, IT, OTA, OTC, RICH1, RICH2, PRS) and 'Trigger Components' (ECAL, HCAL, MUONA, MUONC, LODU, TCALO, TMUA, TMUC, TPU). A 'Messages' window at the bottom shows system logs.

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# LHCb Run Control

Matrix  
Domain  
X  
Sub-Detector

Activity  
Used for  
Configuring all  
Sub-Systems

The screenshot displays the LHCb Run Control interface. On the left, a 'Select Node' tree shows the system hierarchy from LHCb down to various sub-detectors like VELOA, VELOC, TT, IT, and OTA. The main window shows the 'System' state as 'RUNNING' and 'Auto Pilot' as 'ON'. It includes a table of sub-systems with their states (e.g., DCS: READY, DAQ: RUNNING). Configuration fields include 'Run Number: 102088', 'Run Start Time: 20-Sep-2011 15:50:22', and 'Run Duration: 000:00:32'. The 'Activity' is set to 'COLLISION' and 'Trigger Configuration' is 'Physics'. Two gauges show 'L0 Rate: 812092.82 Hz' and 'HLT Rate: 5365.67 Hz'. A 'Dead Time' gauge shows 5.37%. At the bottom, there are sections for 'Sub-Detectors' and 'Trigger Components' with their respective states, and a 'Messages' log.

**System State**  
 System: Big Brother | State: READY

**Sub-System State**

Sub-System	State
LHC	NO_BEAM
BCM	READY
Magnet	READY
LHCb Clock	EXTERNAL

**Handshakes**

LHC: WARNING\_INJECTION | LHCb: CONFIRM\_INJECTION

**Voltages**

Sub-Detector	State	Req. HV	%Ok	HV State (A/C)
VELO_LHC_HV	OK	OFF	100.00	OFF
TT_LHC_HV	OK	STANDBY1	100.00	STANDBY1
IT_LHC_HV	OK	STANDBY1	100.00	STANDBY1
OT_LHC_HV	OK	OFF	100.00	OFF
RICH1_LHC_HV	OK	OFF	100.00	OFF
RICH2_LHC_HV	OK	OFF	100.00	OFF
PRS_LHC_HV	OK	OFF	100.00	OFF
ECAL_LHC_HV	OK	STANDBY1	100.00	STANDBY1
HCAL_LHC_HV	OK	STANDBY1	100.00	STANDBY1
MUON_LHC_HV	OK	STANDBY1	99.01	STANDBY1

Sub-Detector	State	Requested LV	LV State (A/C)
VELO_LHC_LV	OK	READY	READY
TT_LHC_LV	OK	READY	READY
IT_LHC_LV	OK	READY	READY
RICH1_LHC_LV	OK	OFF	OFF
RICH2_LHC_LV	OK	OFF	OFF

**Messages**

INJECTION Handshake Detected  
Goto INJECTION?

**LHC Parameters**

Mode: PROTON PHYSICS | Fill Number: 2158 | Energy: 450 GeV

Magnet: Set Current: 5850 A | Measured Current: 5850.0 A | Polarity: DOWN

**DB Interfaces**

Run DB Server: ON | Cond DB Server: ON | PVSS Archive: ON

**VELO Closing Manager**

Motion: NOT\_ALLOWED | State: OPEN

Beam Position: X: -0.00 mm, Y: -0.03 mm

Motion System Position: XA: 29.00 mm, XC: -29.00 mm, Y: -0.03 mm

**Safety**

Sub-Detector	State
TT_Safety	READY
IT_Safety	READY
OT_Safety	DEAD
RICH_Safety	READY
MUON_Safety	READY

Two operators on shift:

- Data Manager
  - Shift Leader
- has 2 views of the System:
- | Run Control
  - | Big Brother

Big Brother

- Manages LHC dependencies:
- | SubDetector Voltages
- | VELO Closing
- | Run Control

**System State**  
 System: Big Brother  
 State: READY

**Sub-System State**

Sub-System	State
LHC	INJECTION
BCM	READY
Magnet	READY
LHCb Clock	EXTERNAL

**Handshakes**

Com	LHC	LHCb
READY_INJECTION	READY_INJECTION	

**Voltages**

System	State	Requested	Settings
LHCb_LHC_HV&LV	OK	INJECTION	PHYSICS

**Sub-Detector HV Status**

Sub-Detector	State	Req. HV	%Ok	HV State (A/C)
VELO_LHC_HV	OK	OFF	100.00	OFF
TT_LHC_HV	OK	STANDBY1	100.00	STANDBY1
IT_LHC_HV	OK	STANDBY1	100.00	STANDBY1
OT_LHC_HV	OK	OFF	100.00	OFF
RICH1_LHC_HV	OK	OFF	100.00	OFF
RICH2_LHC_HV	OK	OFF	100.00	OFF
PRS_LHC_HV	OK	OFF	100.00	OFF
ECAL_LHC_HV	OK	STANDBY1	100.00	STANDBY1
HCAL_LHC_HV	OK	STANDBY1	100.00	STANDBY1
MUON_LHC_HV	OK	STANDBY1	99.01	STANDBY1

**Sub-Detector LV Status**

Sub-Detector	State	Requested LV	LV State (A/C)
VELO_LHC_LV	OK	READY	READY
TT_LHC_LV	OK	READY	READY
IT_LHC_LV	OK	READY	READY
RICH1_LHC_LV	OK	OFF	OFF
RICH2_LHC_LV	OK	OFF	OFF

**Safety**

Sub-Detector	State
TT_Safety	READY
IT_Safety	READY
OT_Safety	DEAD
RICH_Safety	READY
MUON_Safety	READY

**VELO Closing Manager**

Motion: NOT\_ALLOWED (FULLY OUT)  
 State: OPEN

Beam Position:  
 X: -0.00 mm  
 Y: -0.03 mm

Motion System Position:  
 XA: 29.00 mm  
 XC: -29.00 mm  
 Y: -0.03 mm

Two operators on shift:

- Data Manager
- Shift Leader has 2 views of the System:
  - Run Control
  - Big Brother

Big Brother

- Manages LHC dependencies:
  - SubDetector Voltages
  - VELO Closing
  - Run Control

The screenshot displays the 'Big Brother' control interface for the LHCb system. The main status is 'PHYSICS' in a large green box. The system is in 'READY' state. Key parameters include Mode: PROTON PHYSICS, Fill Number: 2129, Energy: 3500 GeV, and Magnet Set Current: 5850 A. The interface includes several tables for system components, voltages, and safety status.

Sub-System	State
LHC	PHYSICS
BCM	READY
Magnet	READY
LHCb Clock	EXTERNAL

System	State	Requested
LHCb_LHC_HV&LV	OK	PHYSICS

Sub-Detector	State	Req. HV	%Ok	HV State (A/C)
VELO_LHC_HV	OK	READY	100.00	READY
TT_LHC_HV	OK	READY	100.00	READY
IT_LHC_HV	OK	READY	100.00	READY
OT_LHC_HV	OK	READY	100.00	READY
RICH1_LHC_HV	OK	READY	100.00	READY
RICH2_LHC_HV	OK	READY	100.00	READY
PRS_LHC_HV	OK	READY	100.00	READY
ECAL_LHC_HV	OK	READY	100.00	READY
HCAL_LHC_HV	OK	READY	100.00	READY
MUON_LHC_HV	OK	READY	99.54	READY

Sub-Detector	State	Requested LV	LV State (A/C)
VELO_LHC_LV	OK	READY	READY
TT_LHC_LV	OK	READY	READY
IT_LHC_LV	OK	READY	READY
RICH1_LHC_LV	OK	READY	READY
RICH2_LHC_LV	OK	READY	READY

Sub-Detector	State
TT_Safety	READY
IT_Safety	READY
OT_Safety	DEAD
RICH_Safety	READY
MUON_Safety	READY

Two operators on shift:

- Data Manager
- Shift Leader has 2 views of the System:
  - Run Control
  - Big Brother

Big Brother

- Manages LHC dependencies:
  - SubDetector Voltages
  - VELO Closing
  - Run Control

# ECS: Some numbers

## Size of the Control Tree:

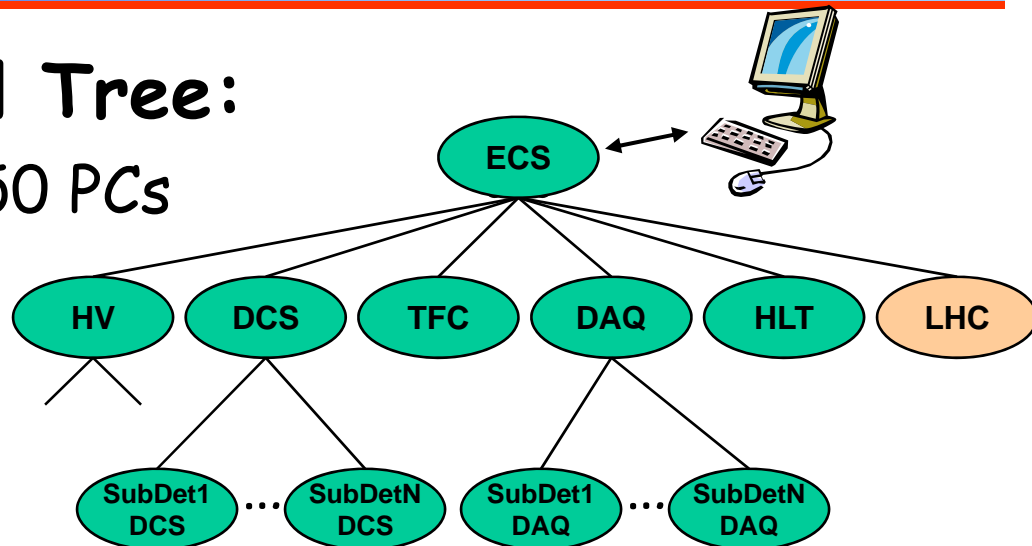
- Distributed over ~150 PCs

- ~100 Linux (50 for the HLT)

- ~ 50 Windows

- >2000 Control Units

- >50000 Device Units



## Run Control Timing

- Cold Start to Running: 4 minutes

- Configure all Sub-detectors, Start & Configure ~40000 HLT processes (always done well before PHYSICS)

- Stop/Start Run: 6 seconds



- LHCb has designed and implemented a coherent and homogeneous control system
- The Experiment Control System allows to:
  - Configure, Monitor and Operate the Full Experiment
  - Run any combination of sub-detectors in parallel in standalone
- **Some of its main features:**
  - Partitioning, Sequencing, Error recovery, Automation
  - ➔ Come from the usage of SMI++ (integrated with PVSS)
- **LHCb operations now almost completely automated**
  - Operator task is easier (basically only confirmations)
  - DAQ Efficiency improved to ~98%