

Configuring and Automating an LHC Experiment

For faster and better Physics Output

Clara Gaspar, October 2017

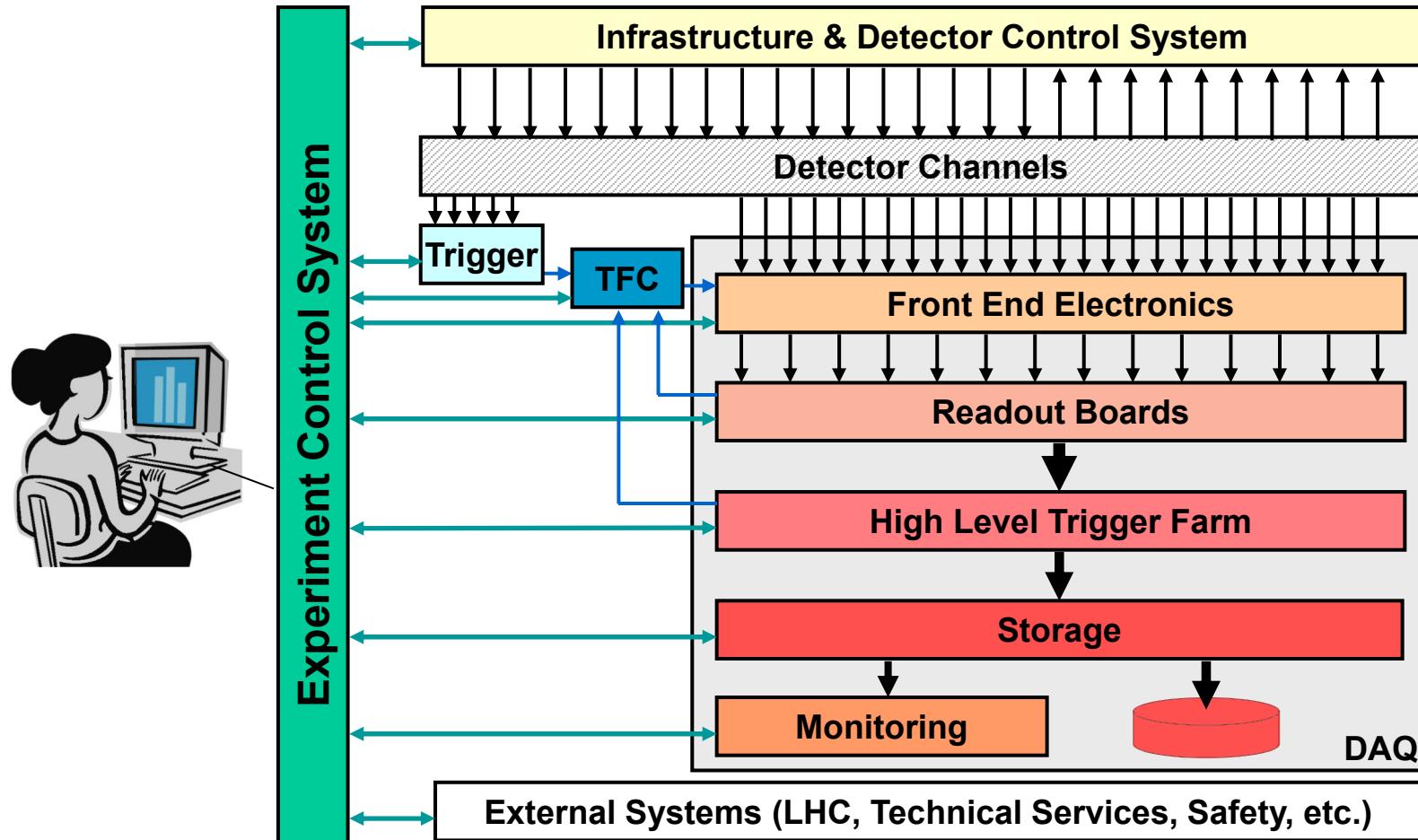
Introduction

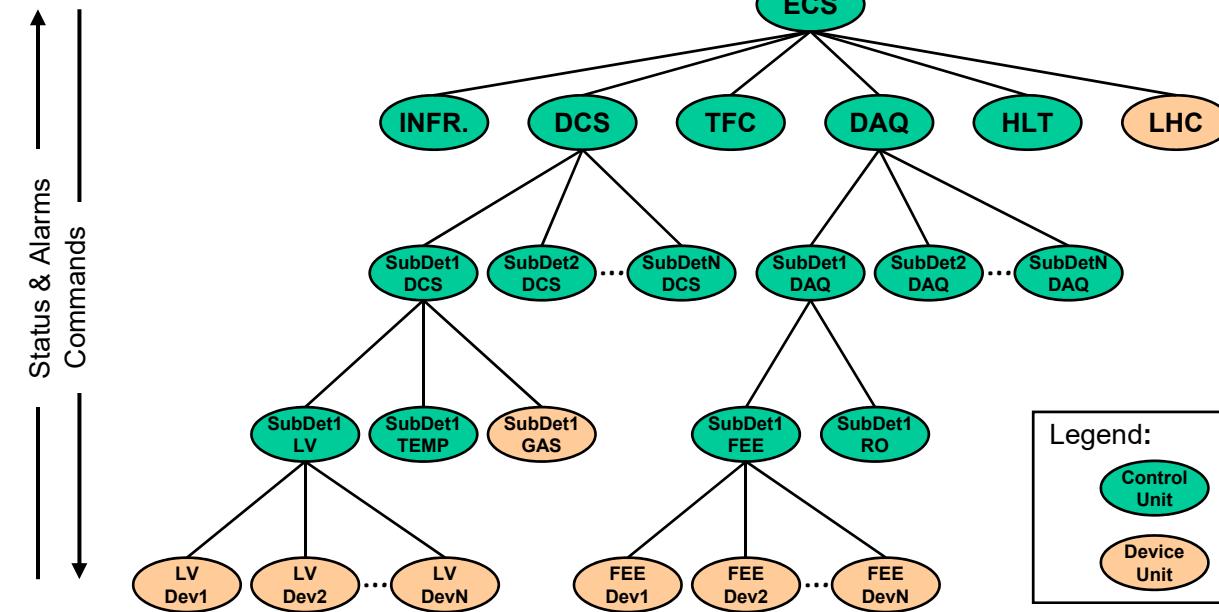
■ LHCb's New Online Dataflow in Run II

- Introduced Prompt Calibration and Alignment
- Aims:
 - Better Trigger Efficiency
 - Full offline-quality data directly out of the Online System
-> straight to Physics Analyses
 - By Making better use of online farm resources
 - Take advantage of LHC's duty cycle and shutdown periods

■ Represented a challenge for the control system

Scope:





- **Implementation:**
(JCOP project)
 - WinCC-OA
 - SMI++

- **Deployment:**
 - Runs distributed over ~160 PCs (Virtual Machines)

■ Control Units are logical entities:

- Behave as a Finite State Machine / Rule Based system:
 - Capable of Partitioning: Exclude/Include children
 - Can take local decisions: Sequence & Automate Operations or Recover Errors

■ Device Units

- Provide the interface to the device (hardware or software)

The High Level Trigger

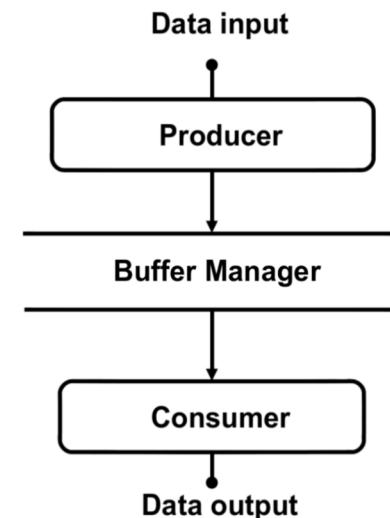
- Selects interesting events for Physics
- Runs distributed on the HLT Farm

■ Farm Hardware

- | ~1600 nodes, ~ 50000 cores, heterogeneous
- | Organized in 62 sub-farms, 24 to 32 nodes each

■ Farm Software

- | Dataflow Pattern
 - | Buffer Manager Concept
- | Dataflow Tasks
 - | Based on Gaudi Online
 - | Integrated in Control System like any other Device via FSM states&actions

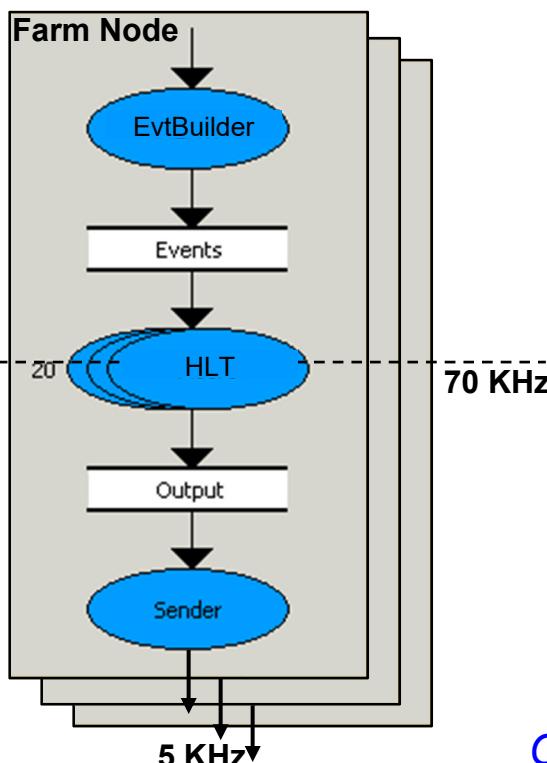


Resource Optimization in 2012 -> Deferred HLT

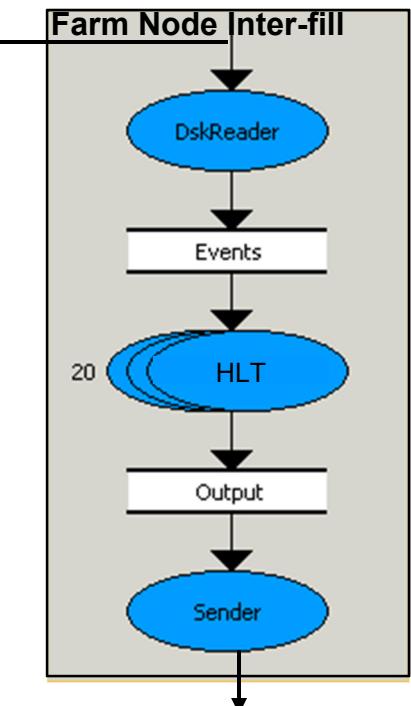
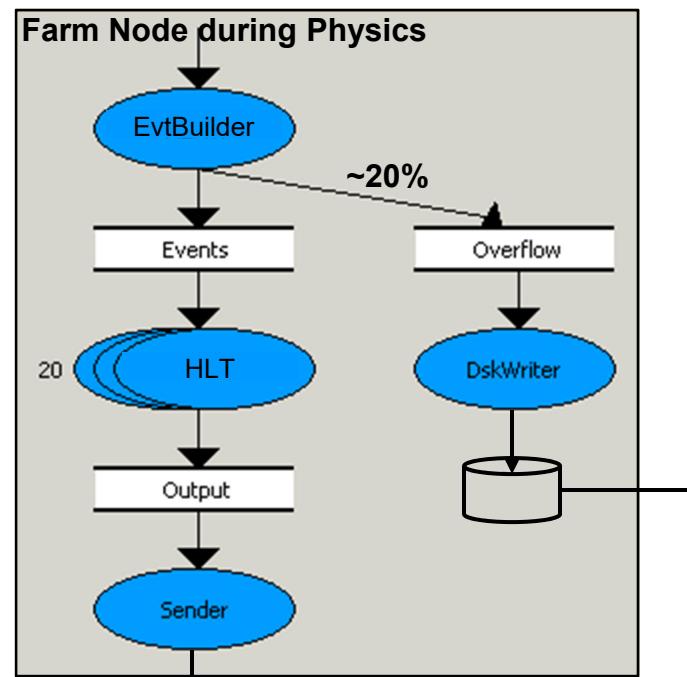
- Idea: Buffer data to disk when HLT busy / Process in inter-fill gap
- Reconfigure the whole farm at start/end of Physics

Standard HLT

1 MHz

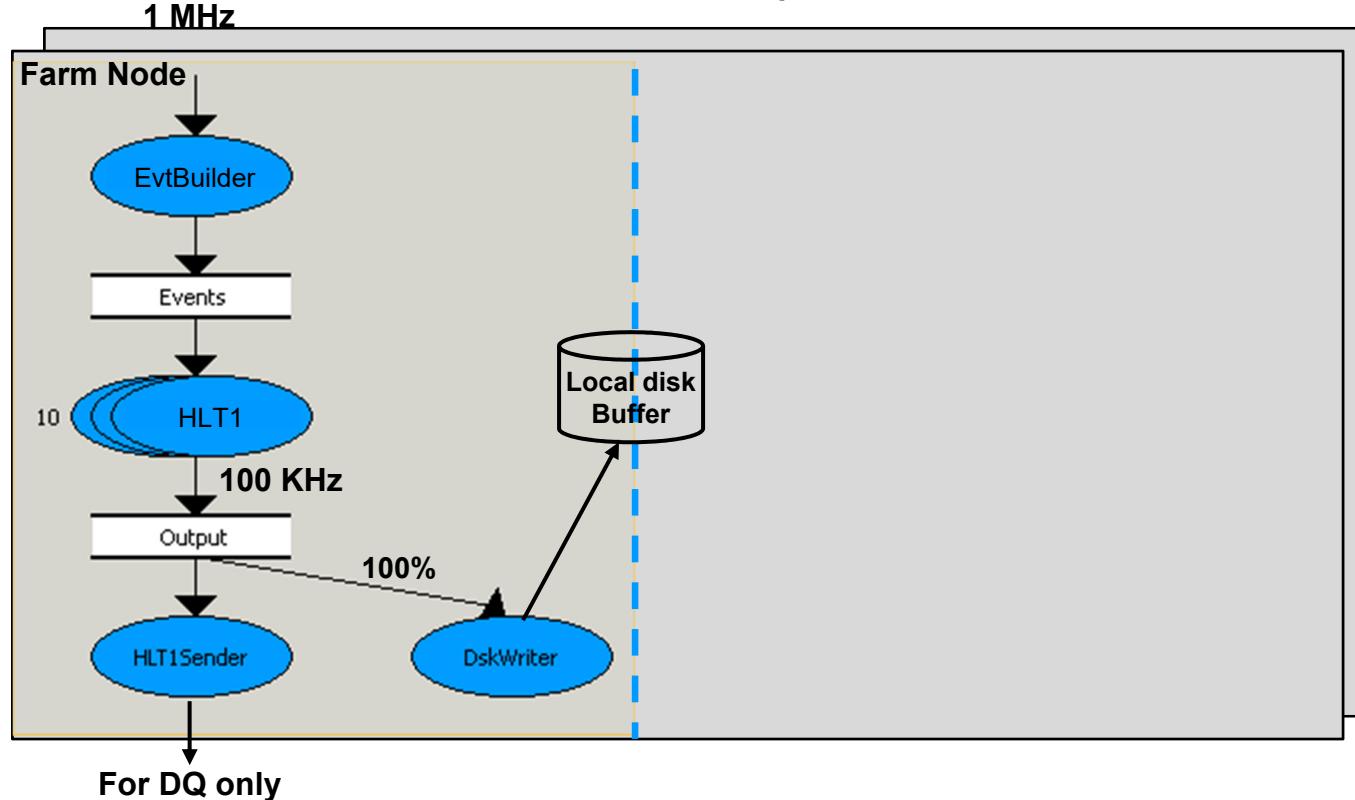


Deferred HLT



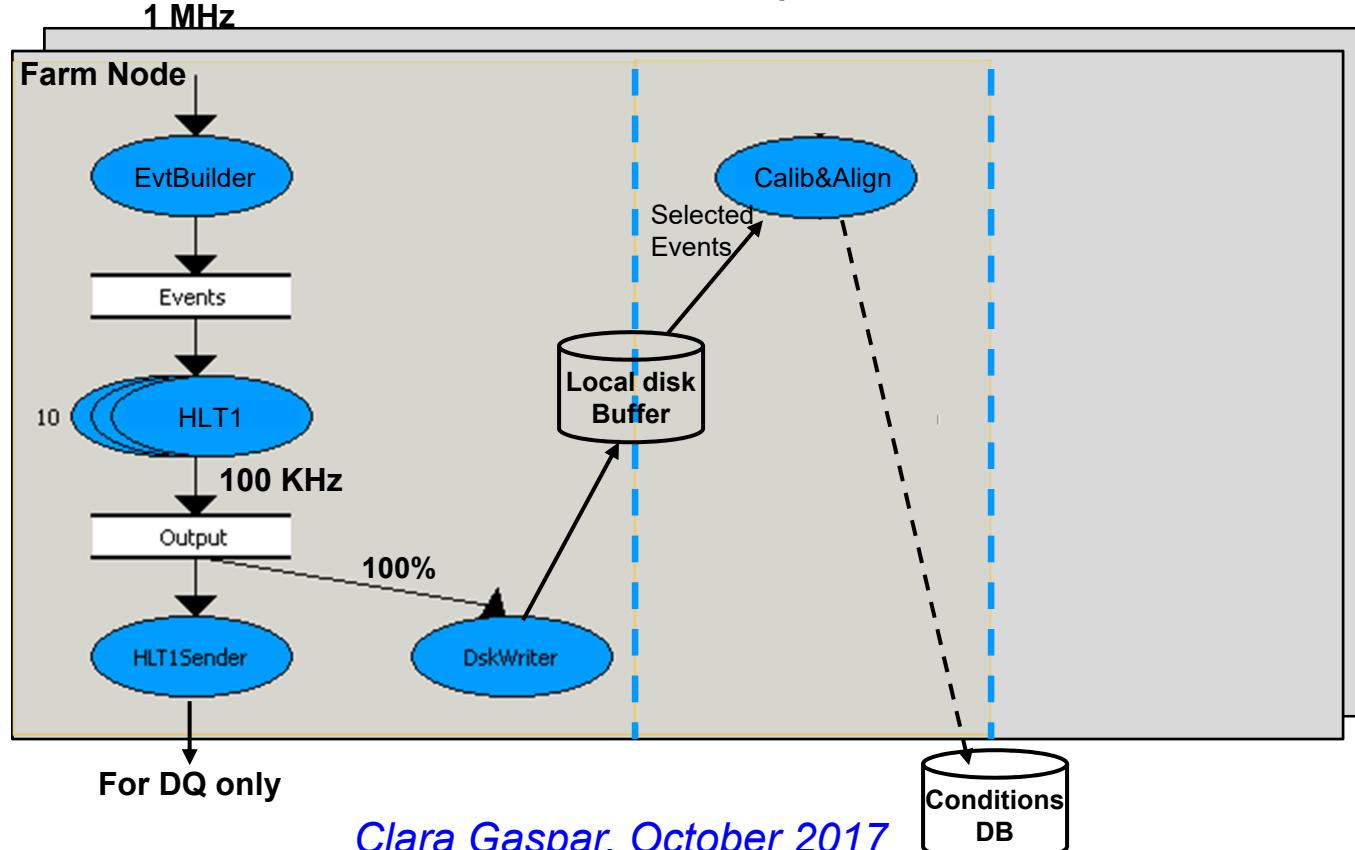
Even better Resource Optimization in 2015 -> Split HLT

- Idea: Buffer ALL data to disk after HLT1 / Perform Calibration & Alignment / Run HLT2 permanently in background
- Each node has 3 concurrent/independent dataflow slices



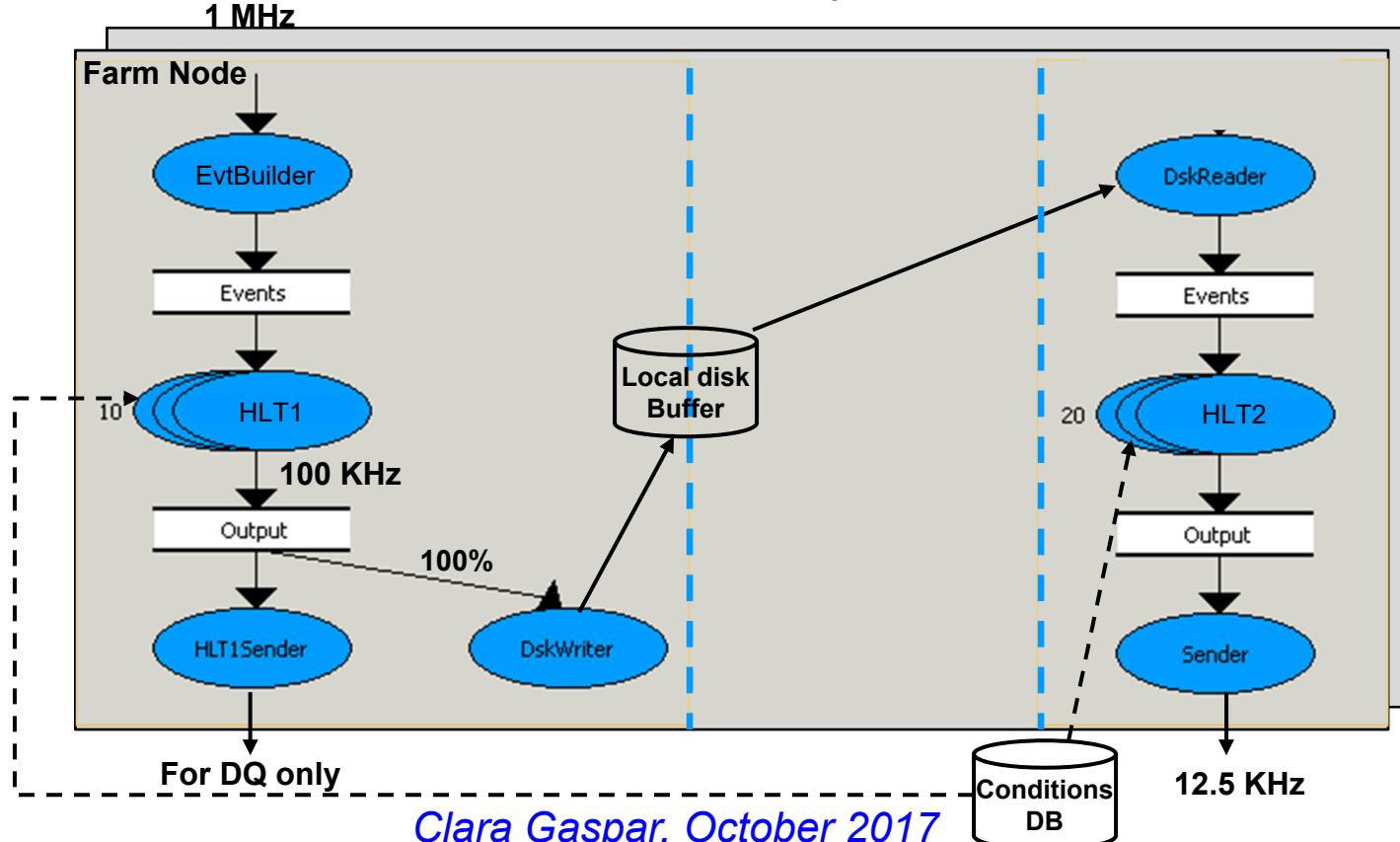
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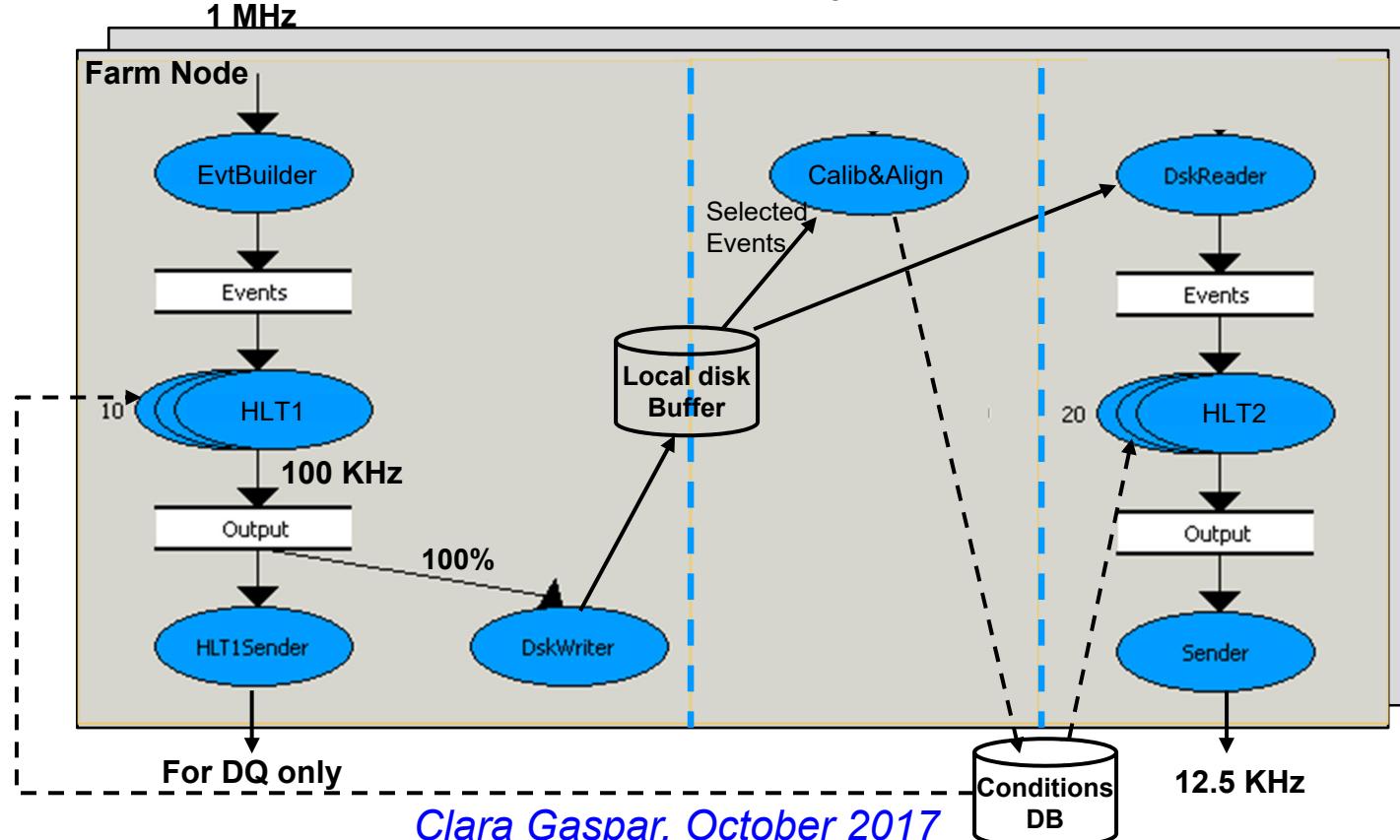
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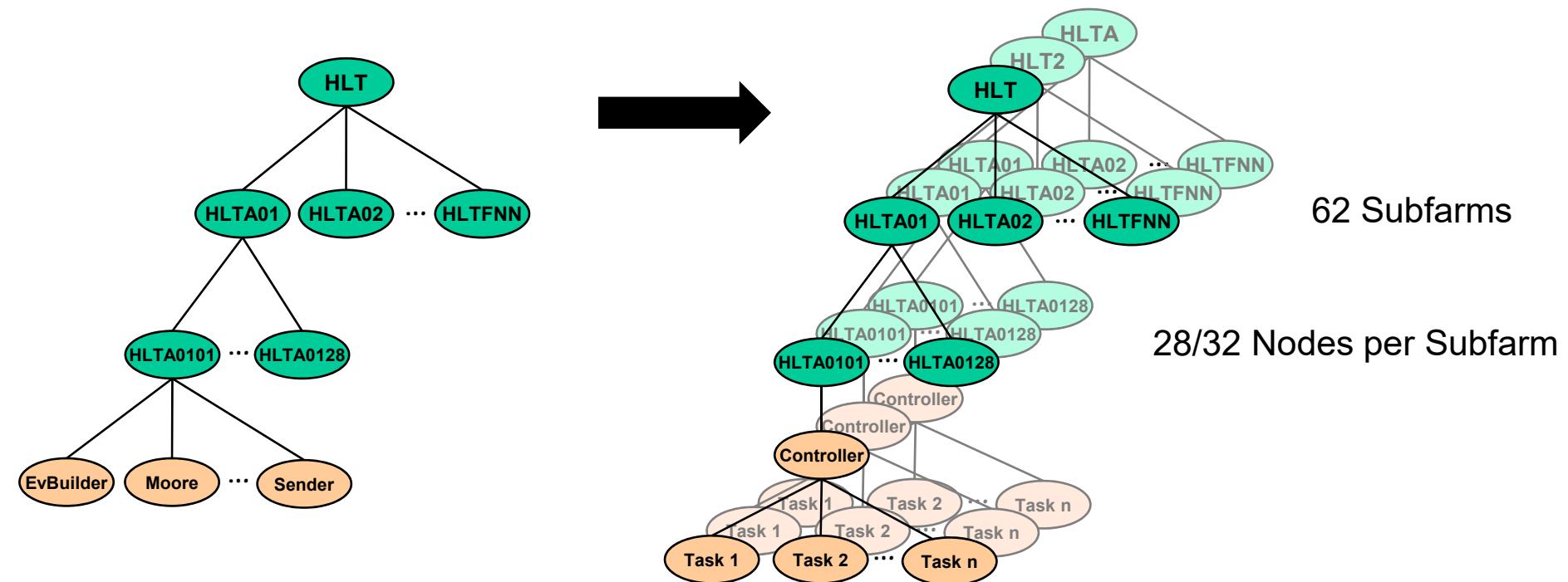
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Control Tree

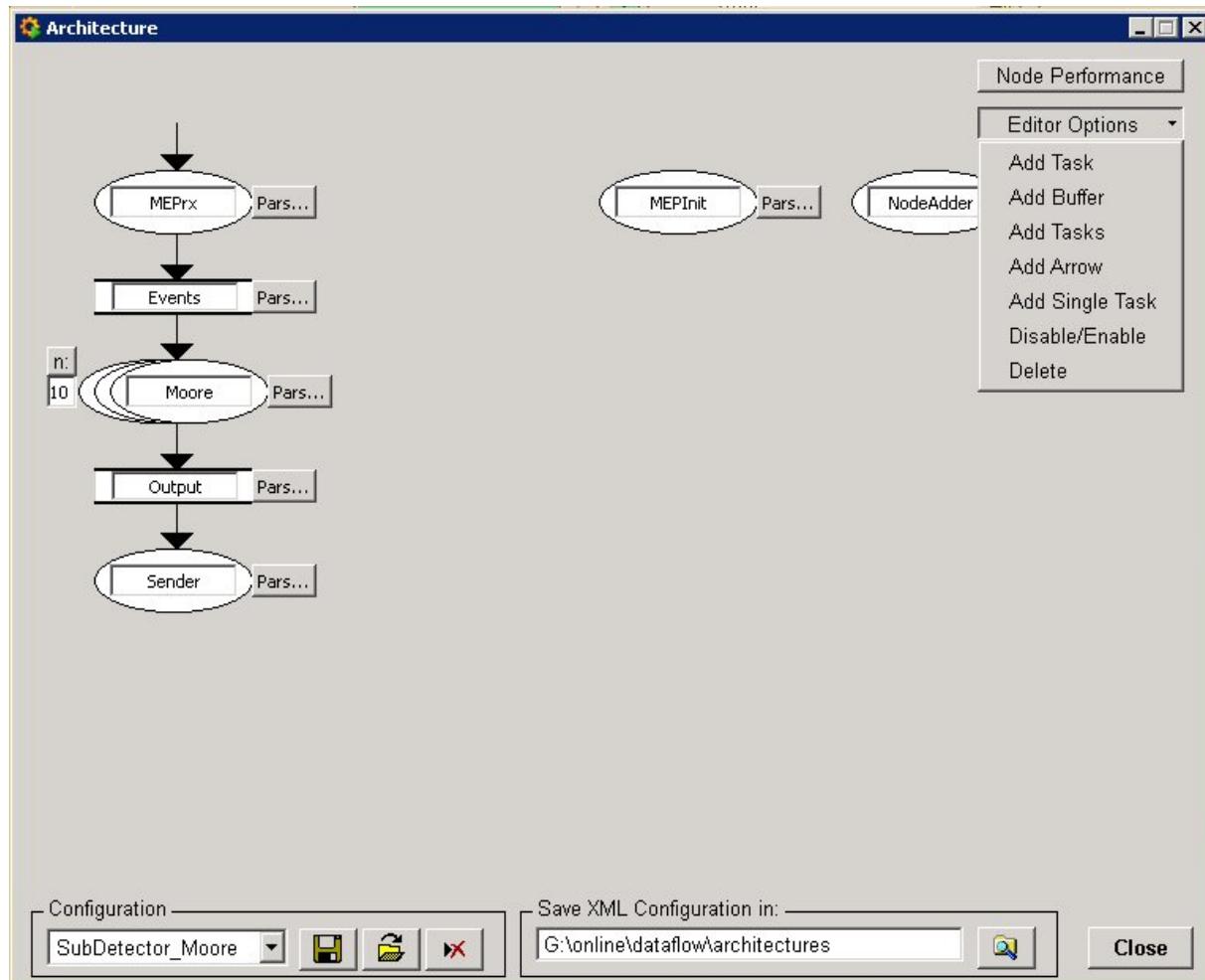
- From 1 to 3 Independent Trees (actions, states and partitioning)

Dataflow Tasks:

- In the past were Hardwired in the Control Tree
- Now Dynamic via a Controller which receives an “Architecture”

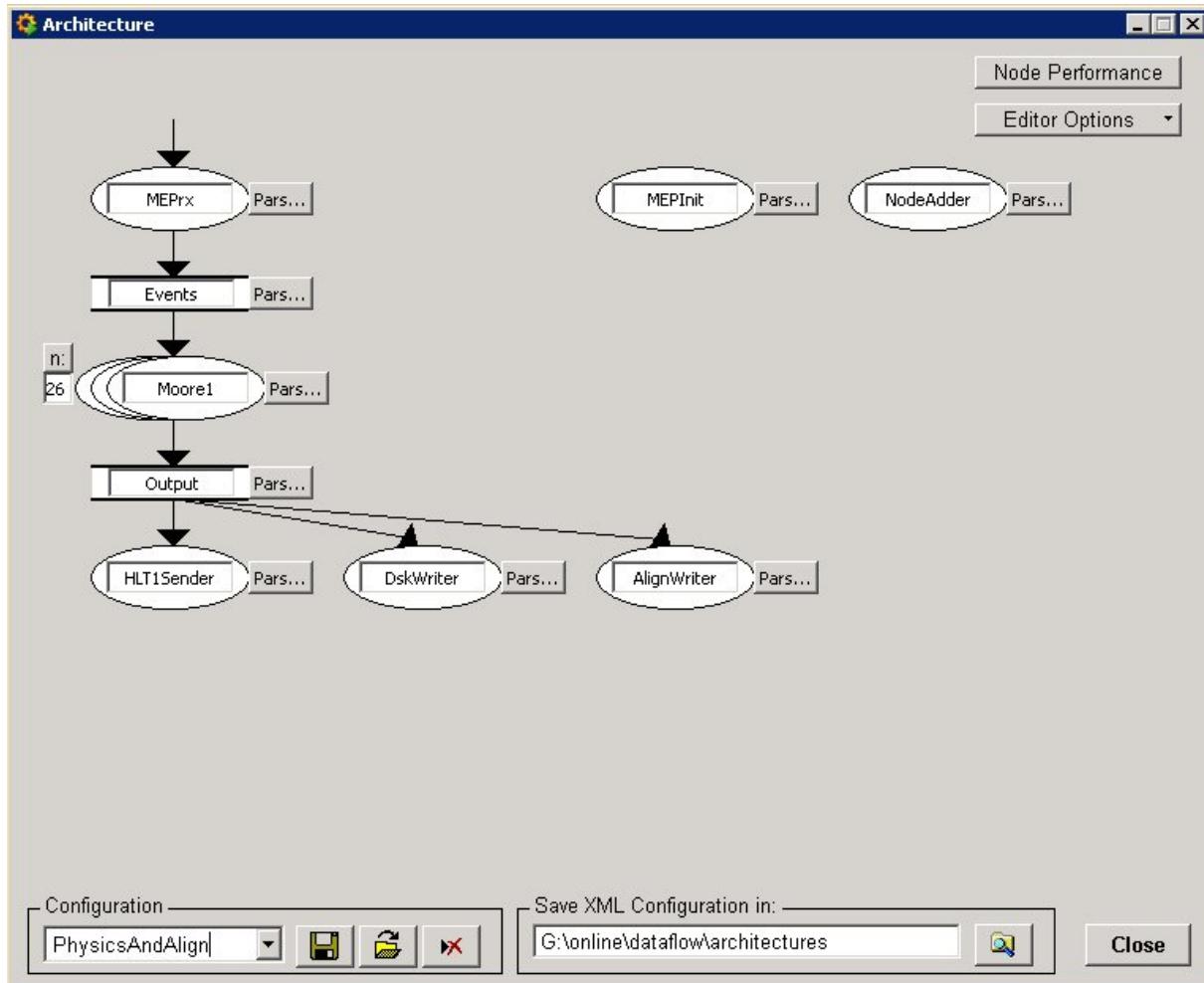
“Architecture” Concept

- Defines the dataflow / task layout on each (farm) node



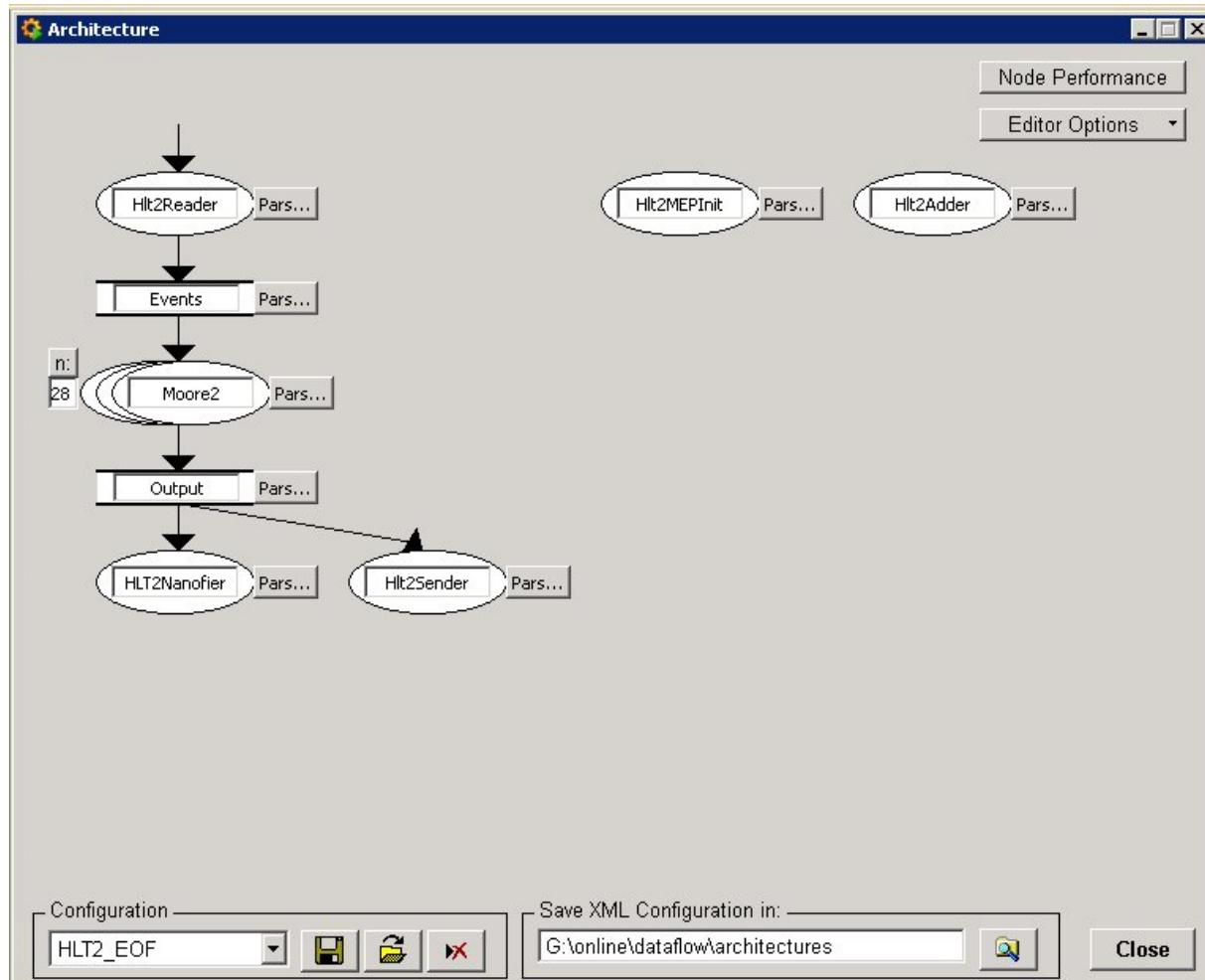
- Graphic Editor:
 - Examples:
 - Old-style HLT
 - HLT1
 - HLT2
 - Calibration, Alignment, etc.
 - Graphic Used at Run Time

- Defines the dataflow / task layout on each (farm) node



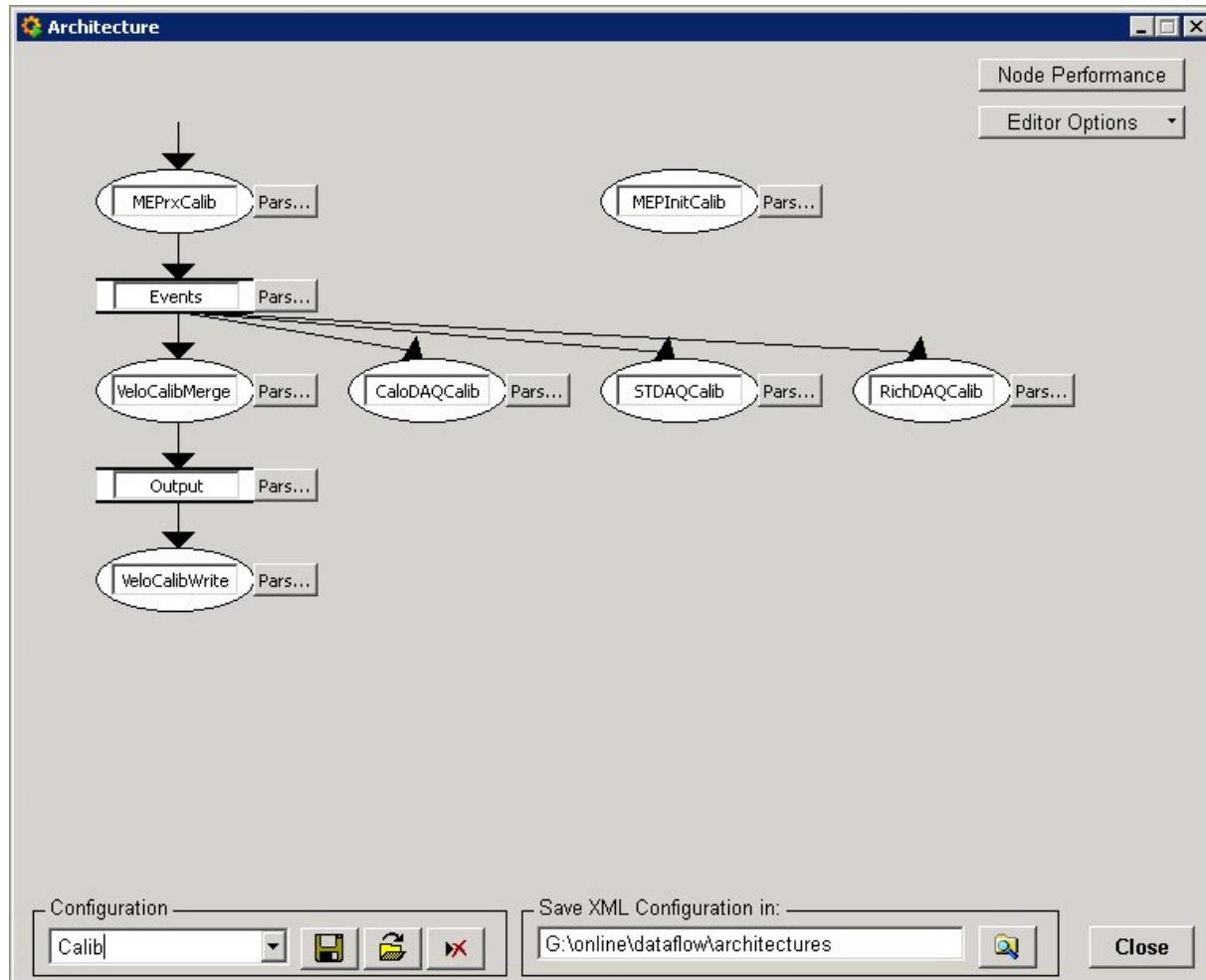
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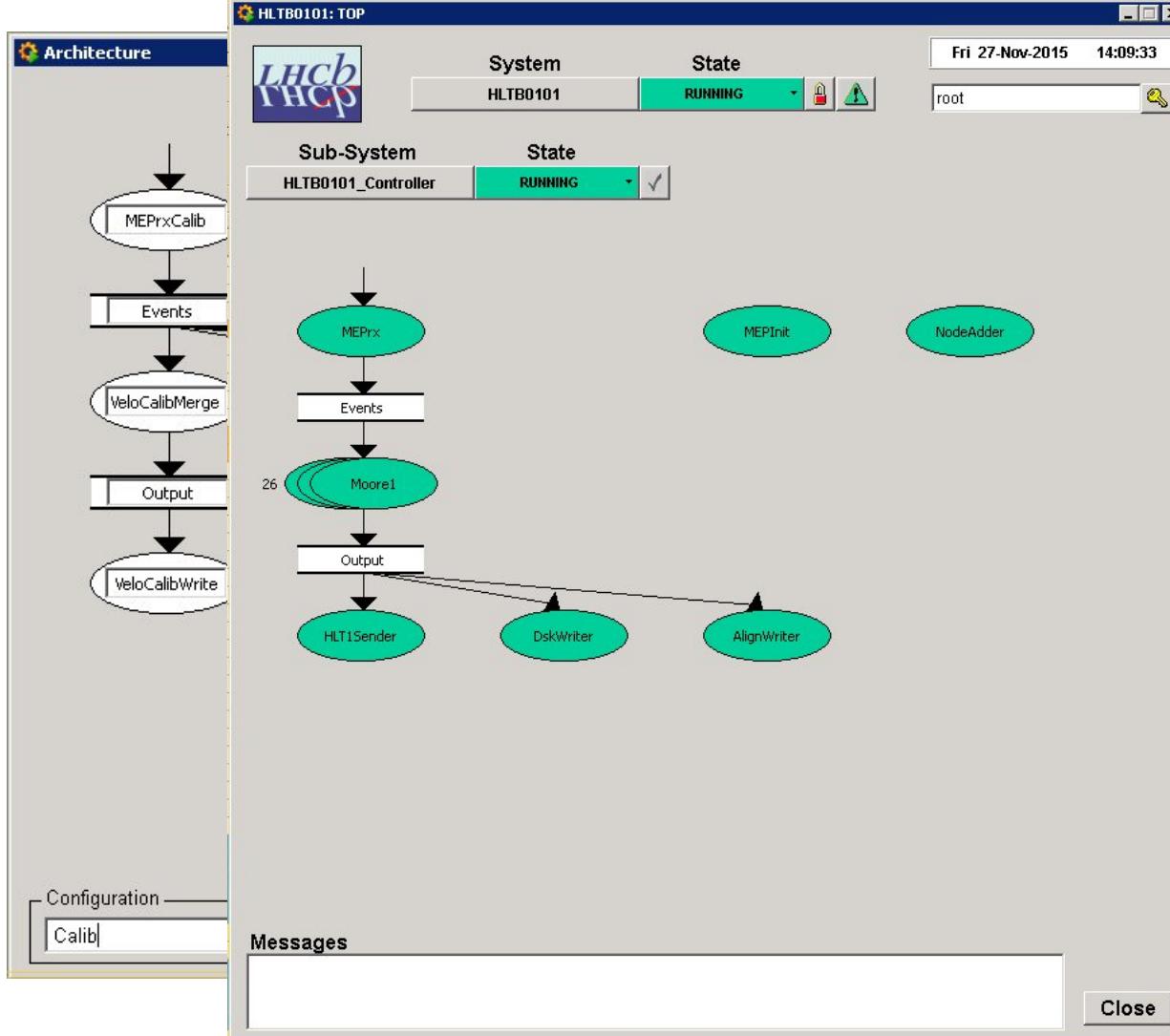
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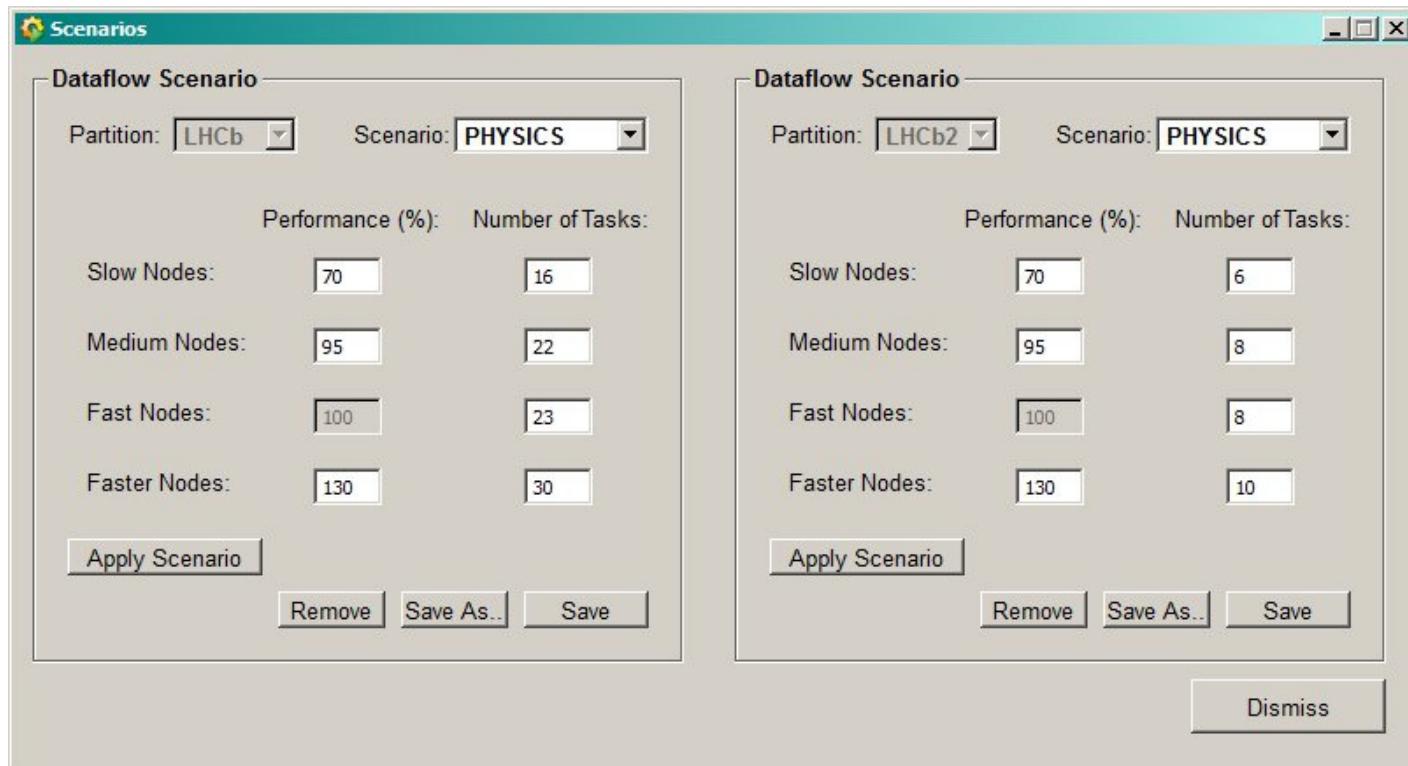
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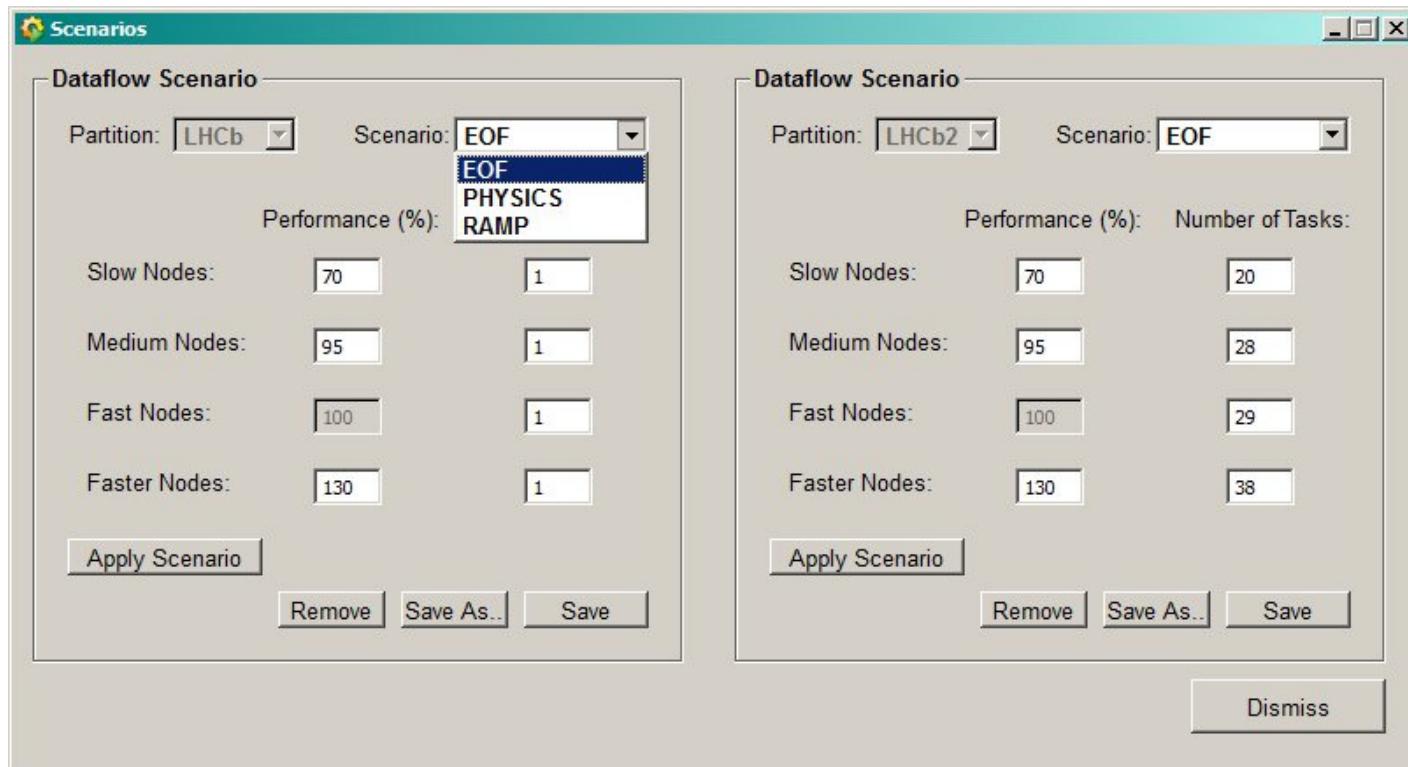
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“Scenario” Concept

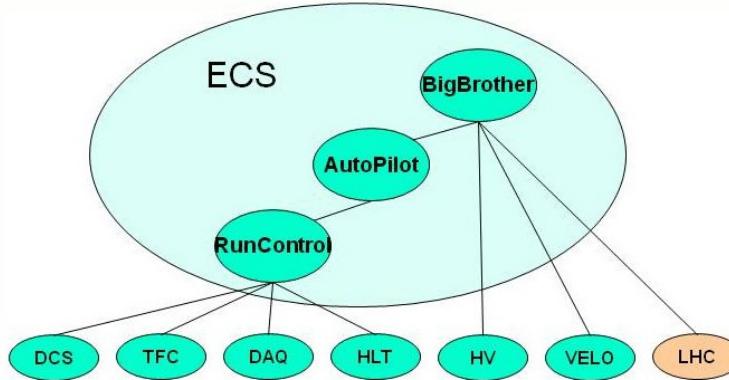
- Defines number of HLT1 & HLT2 tasks for load balancing (initially hardwired in the Architecture)
 - Depending on the LHC/LHCb State and type of node
 - Can be applied at RunTime and takes effect within a second



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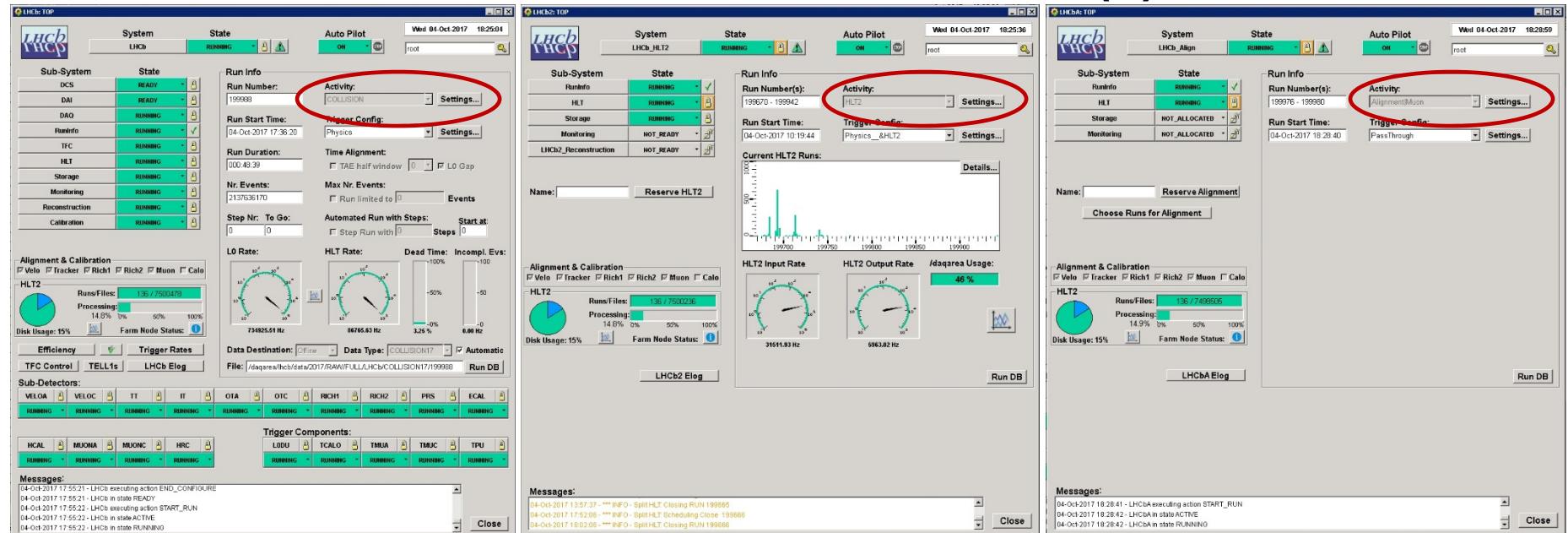
“Activity” Concept



Run Control driven by an Activity:

- | Run Control defines the set of parameters (“recipe”) which is applied by each sub-system.
- | Example: “PHYSICS|LEAD”
- | Contains, for example, the “Architecture”

Three Farm Slices -> Three Run Control(s):



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“Activity” Concept

LHCb: TOP

System State

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

Alignment & Calibration

Velo Tracker Rich1 Rich2 Muon Calo

HLT2

Runs/Files: 136 / 7500478
Processing: 14.8% 0% 50% 100%
Disk Usage: 15%

Efficiency **Trigger Rates**

TFC Control **TELL1s** **LHCb Elog**

Sub-Detectors:

VELOA	VELOC	TT	IT	OTA	OTC	RICH1	RICH2	PRS	ECAL
RUNNING									

Trigger Components:

L0DU	TCALO	TMUA	TMUC	TPU
RUNNING	RUNNING	RUNNING	RUNNING	RUNNING

Messages:

```
04-Oct-2017 17:55:21 - LHCb executing action END_CONFIGURE
04-Oct-2017 17:55:21 - LHCb in state READY
04-Oct-2017 17:55:22 - LHCb executing action START_RUN
04-Oct-2017 17:55:22 - LHCb in state ACTIVE
04-Oct-2017 17:55:22 - LHCb in state RUNNING
```

Run Control driven by an Activity:

Defines the set of parameters (“recipe”) which is applied by each sub-system.

Example: “PHYSICS|LEAD”

Contains, for example, the “Architecture”

Run Control(s):

LHCb: TOP

System State

Sub-System	State
RunInfo	RUNNING
HLT	RUNNING
Storage	NOT_ALLOCATED
Monitoring	NOT_ALLOCATED

Run Info

Run Number: 199988 **Activity:** **Settings...**

Run Start Time: 04-Oct-2017 17:36:20 **Trigger Config:** Physics **Settings...**

Run Duration: 000:48:39

Time Alignment: TAE half window 0 L0 Gap

Nr. Events: Run limited to 0 Events

Automated Run with Steps: Start at 0 Step Run with 0 Steps 0

L0 Rate: 734925.51 Hz
HLT Rate: 86765.63 Hz
Dead Time: 3.25 %
Incompl. Evs: 0.00 Hz

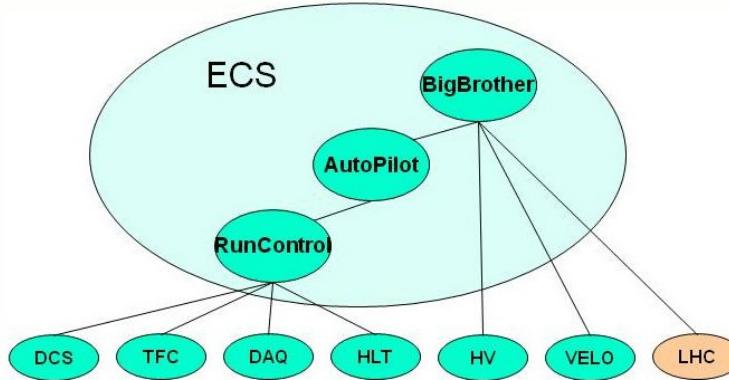
Data Destination: Offline **Data Type:** COLLISION17 Automatic
File: /daqarea/lhcba/data/2017/Raw/FULL/LHCb/COLLISION17/199988 **Run DB**

HLT2 Output Rate: /daqarea Usage: 46 %

Messages:

```
04-Oct-2017 18:28:41 - LHCbA executing action START_RUN
04-Oct-2017 18:28:42 - LHCbA in state ACTIVE
04-Oct-2017 18:28:42 - LHCbA in state RUNNING
```

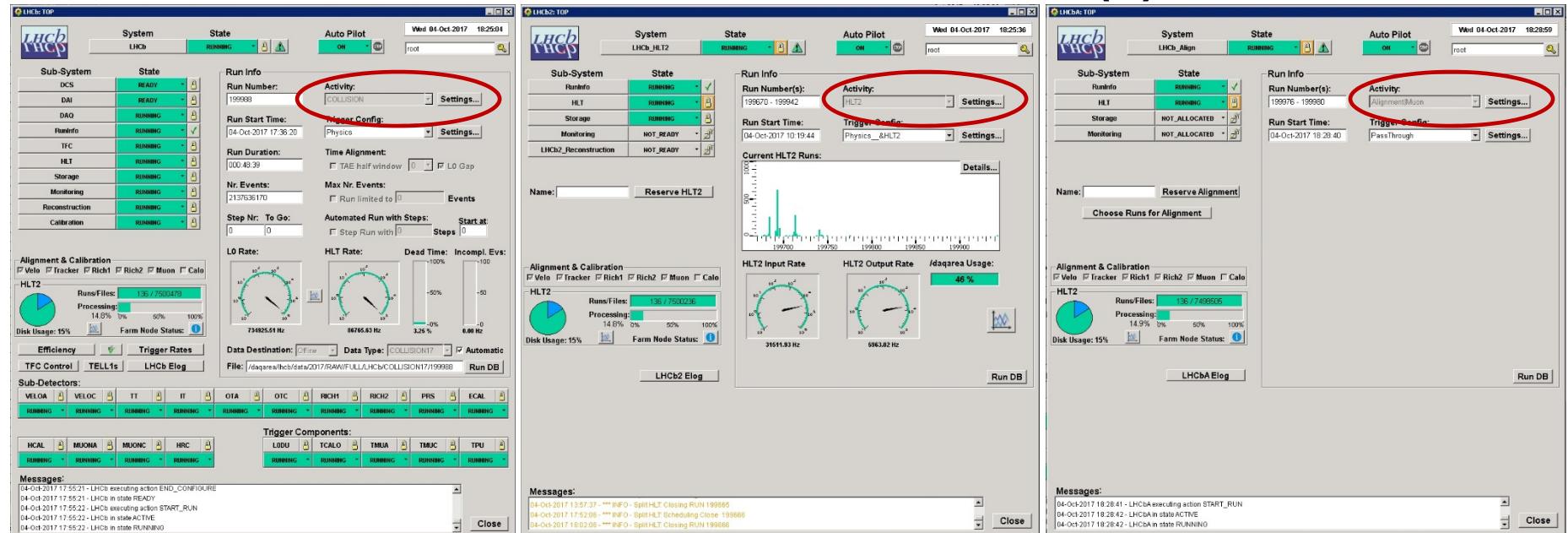
“Activity” Concept



Run Control driven by an Activity:

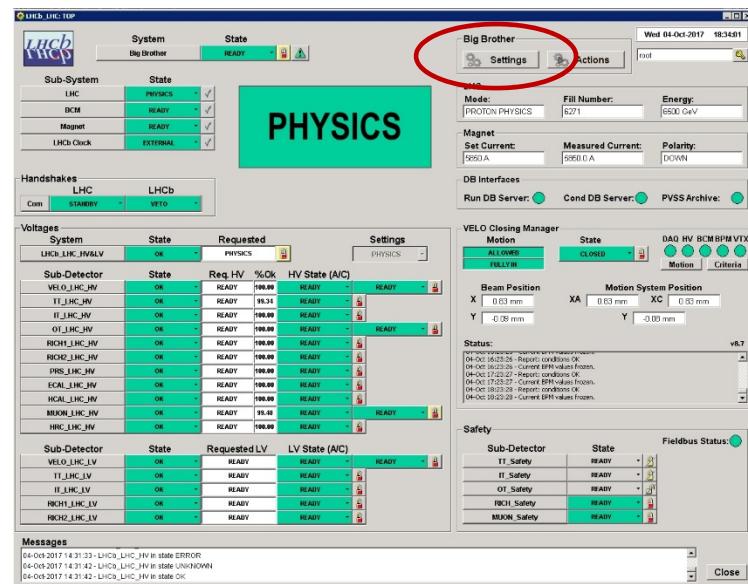
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“Scheduler” Concept



■ **Big Brother automates operations based on the LHC State, driven by Scheduler(s):**

- Define sequences of Activities/Scenarios
- Complete Automation of each Run Control with very few lines
- 3 lines to automate main Run Control

The three screenshots show the Activity Scheduler interface with the following configurations:

- LHCb2 Scheduler:**

Start	Activity	Active
At RAMP	COLLISION	<input checked="" type="checkbox"/>
At EOF	IVSCAN	<input checked="" type="checkbox"/>
After Previous	EOFCalib	<input checked="" type="checkbox"/>
At INJECTION		
At RAMP		
At FLATTOP		
At PHYSICS_ADJUST		
At PHYSICS		
At ADJUST		
At EOF		
After Previous		
Always		
- LHCbA Scheduler:**

Start	Activity/Scenario	Active
Always	HLT2	<input checked="" type="checkbox"/>
At EOF	Scenario:EOF	<input checked="" type="checkbox"/>
At RAMP	Scenario:RAMP	<input checked="" type="checkbox"/>
At PHYSICS	Scenario:PHYSICS	<input checked="" type="checkbox"/>
At ADJUST	Scenario:EOF	<input checked="" type="checkbox"/>
When Enough LHCb_Velo Events	Alignment Velo	<input checked="" type="checkbox"/>
When Enough LHCb_Tracker Events	Alignment Tracker	<input checked="" type="checkbox"/>
When Enough LHCb_Rich Events	Alignment RICH1	<input checked="" type="checkbox"/>
After Previous	Alignment RICH2	<input checked="" type="checkbox"/>
When Enough LHCb_Muon Events	Alignment Muon	<input checked="" type="checkbox"/>
At EOF	Calibration Calo	<input checked="" type="checkbox"/>

“Scheduler” Concept

LHCb Big Brother interface showing system status (Sub-System: LHC, Physics, BCM, Magnet, UHC Clock; State: READY) and a large green "PHYSICS" button.

Activity Scheduler:

Start	Activity	Active
At RAMP	COLLISION	<input checked="" type="checkbox"/>
At EOF	IVSCAN	<input checked="" type="checkbox"/>
After Previous	EOFCalib	<input checked="" type="checkbox"/>
At INJECTION		
At RAMP		
At FLATTOP		
At PHYS_ADJUST		
At PHYSICS		
At ADJUST		
At EOF		
After Previous		
Always		

Buttons at the bottom: Save, Close.

■ **Big Brother automates operations based on the LHC State, driven by triggers (e.g. beam position, luminosity, etc.):**

- Consequences of Activities/Scenarios
- Automation of each Run
- In very few lines
- Automate main Run Control

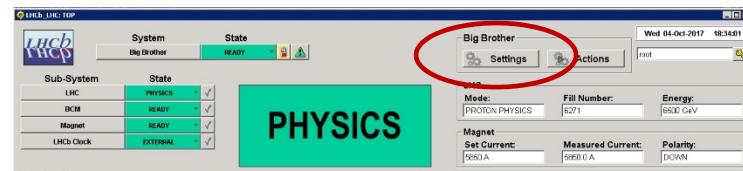
Scheduler window titled "LHCbA".

Activity Scheduler:

Start	Activity	Active
When Enough LHCb_Velo Events	Alignment Velo	<input checked="" type="checkbox"/>
When Enough LHCb_Tracker Events	Alignment Tracker	<input checked="" type="checkbox"/>
When Enough LHCb_Rich Events	Alignment RICH1	<input checked="" type="checkbox"/>
After Previous	Alignment RICH2	<input checked="" type="checkbox"/>
When Enough LHCb_Muon Events	Alignment Muon	<input checked="" type="checkbox"/>
At EOF	Calibration Calo	<input checked="" type="checkbox"/>

Buttons at the bottom: Save, Close.

“Scheduler” Concept



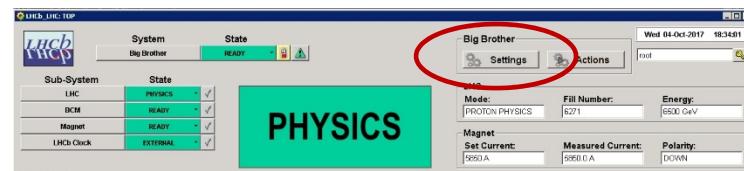
■ Big Brother automates operations based on the LHC State, driven by

The screenshot shows the 'Activity Scheduler' dialog box. On the left is a sidebar with a list of start conditions: Start, At RAMP, At EOF, After Previous, At INJECTION, At RAMP, At FLATTOP, At PHYS_ADJUST, At PHYSICS, At ADJUST, At EOF, After Previous, and Always. The 'After Previous' item is highlighted with a blue bar. The main area is titled 'Activity Scheduler:' and shows a table for 'LHCb2' with the following data:

Start	Activity/Scenario	Active
Always	HLT2	<input checked="" type="checkbox"/>
At EOF	Scenario:EOF	<input checked="" type="checkbox"/>
At RAMP	Scenario:RAMP	<input checked="" type="checkbox"/>
At PHYSICS	Scenario:PHYSICS	<input checked="" type="checkbox"/>
At ADJUST	Scenario:EOF	<input checked="" type="checkbox"/>

At the bottom are 'Save' and 'Close' buttons. To the right, there's another table for 'LHCbA' with similar columns and data, also with 'Save' and 'Close' buttons at the bottom.

“Scheduler” Concept



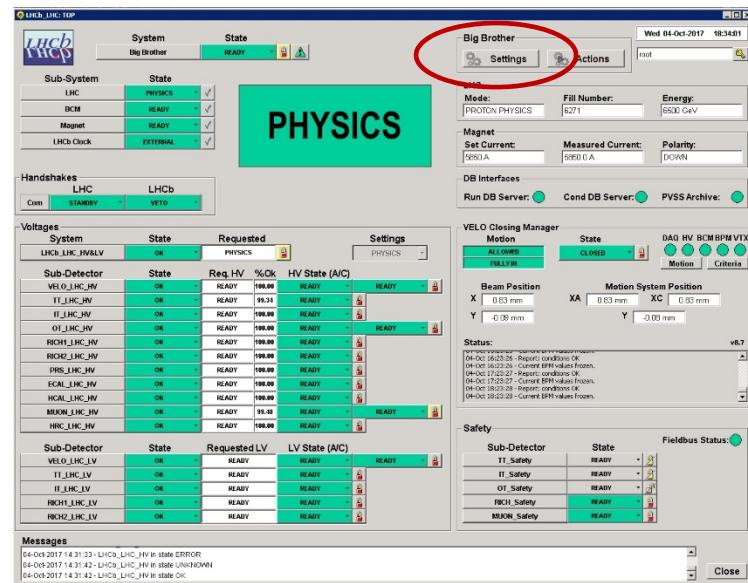
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Start	Activity	Active
Always	Alignment Velo	<input checked="" type="checkbox"/>
At EOF	Alignment Tracker	<input checked="" type="checkbox"/>
When Enough LHCb_Velo Events	Alignment Rich1	<input checked="" type="checkbox"/>
At RAMP	After Previous	<input checked="" type="checkbox"/>
At PHYSICS	Alignment Rich2	<input checked="" type="checkbox"/>
At ADJUST	When Enough LHCb_Muon Events	<input checked="" type="checkbox"/>
	Calibration Calo	<input checked="" type="checkbox"/>

LHCbA

Save Close

“Scheduler” Concept



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At RAMP	COLLISION	<input checked="" type="checkbox"/>
At EOF	IVSCAN	<input checked="" type="checkbox"/>
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- LHCb2 Scheduler:**

Start	Activity/Scenario	Active
Always	HLT2	<input checked="" type="checkbox"/>
At EOF	Scenario:EOF	<input checked="" type="checkbox"/>
At RAMP	Scenario:RAMP	<input checked="" type="checkbox"/>
At PHYSICS	Scenario:PHYSICS	<input checked="" type="checkbox"/>
At ADJUST	Scenario:EOF	<input checked="" type="checkbox"/>
- LHCbA Scheduler:**

Start	Activity	Active
When Enough LHCb_Velo Events	Alignment Velo	<input checked="" type="checkbox"/>
When Enough LHCb_Tracker Events	Alignment Tracker	<input checked="" type="checkbox"/>
When Enough LHCb_Rich Events	Alignment RICH1	<input checked="" type="checkbox"/>
After Previous	Alignment RICH2	<input checked="" type="checkbox"/>
When Enough LHCb_Muon Events	Alignment Muon	<input checked="" type="checkbox"/>
At EOF	Calibration Calo	<input checked="" type="checkbox"/>

Conclusions

- LHCb's New Online Dataflow represented an Operational challenge, but due to:
 - The modular architecture and flexibility of the original design
 - Some new concepts (architectures, scenarios, schedulers)
- It is now:
 - Seamlessly Integrated
 - Completely automated
- And the farm is kept as busy as possible
 - Also offline simulation (concurrently) when still free resources.

