The ATLAS Detector Control System

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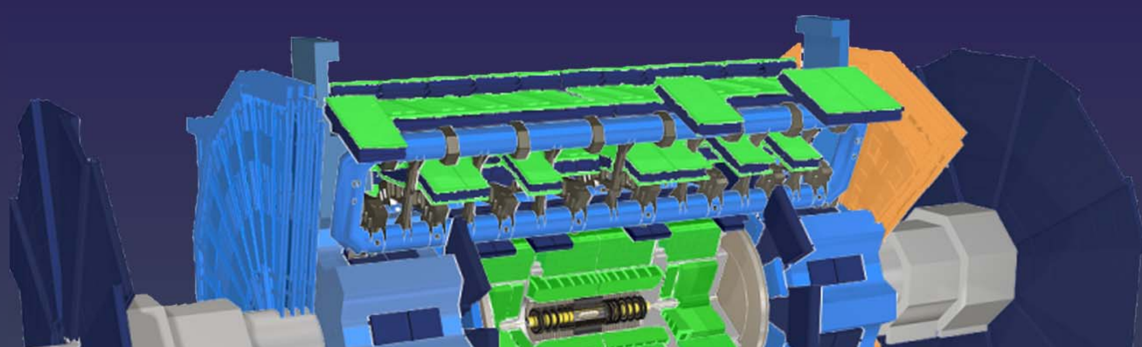
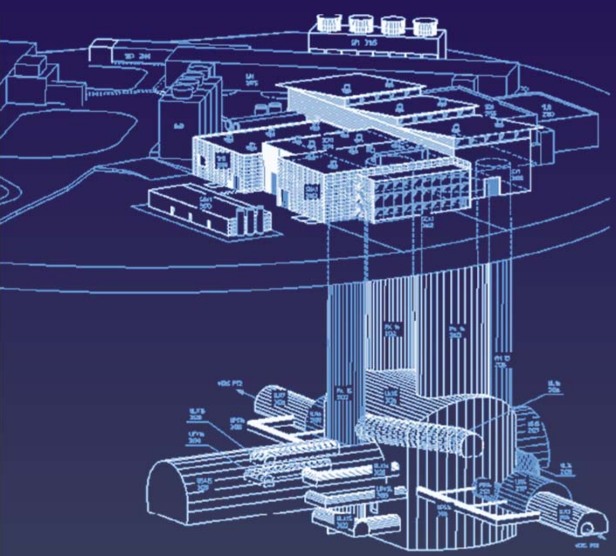
for the ATLAS DCS Community

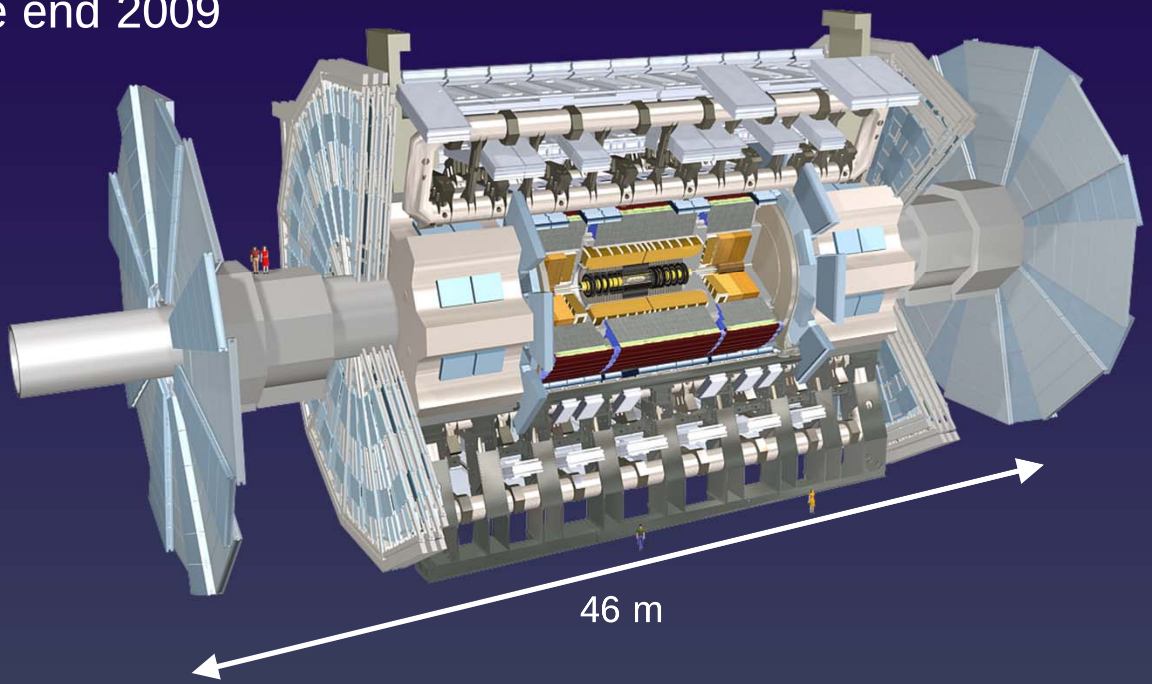
http://atlas.ch



The ATLAS Detector

- Largest of four LHC experiments
- 7000 tonnes, ~100 million read-out channels, 3000 km of cables
- Contains 11 sub-detectors of different technologies in layer structure
- Built and operated by collaboration of >3000 physicists
- Operation with collisions since end 2009





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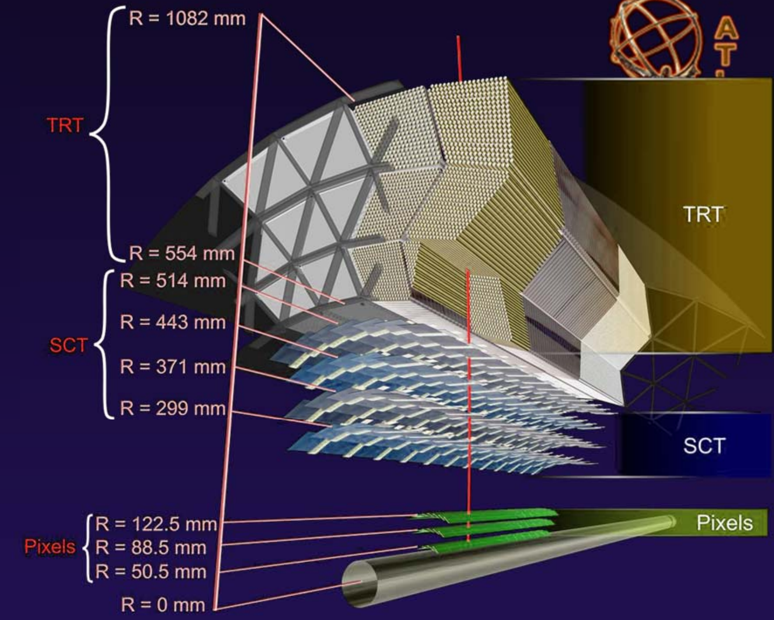

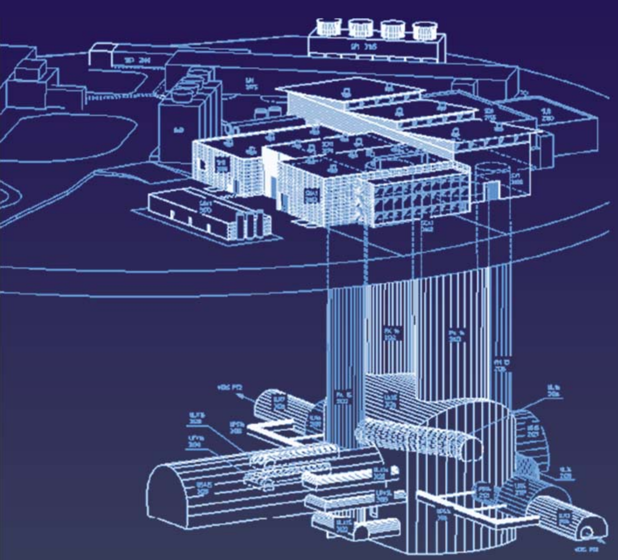

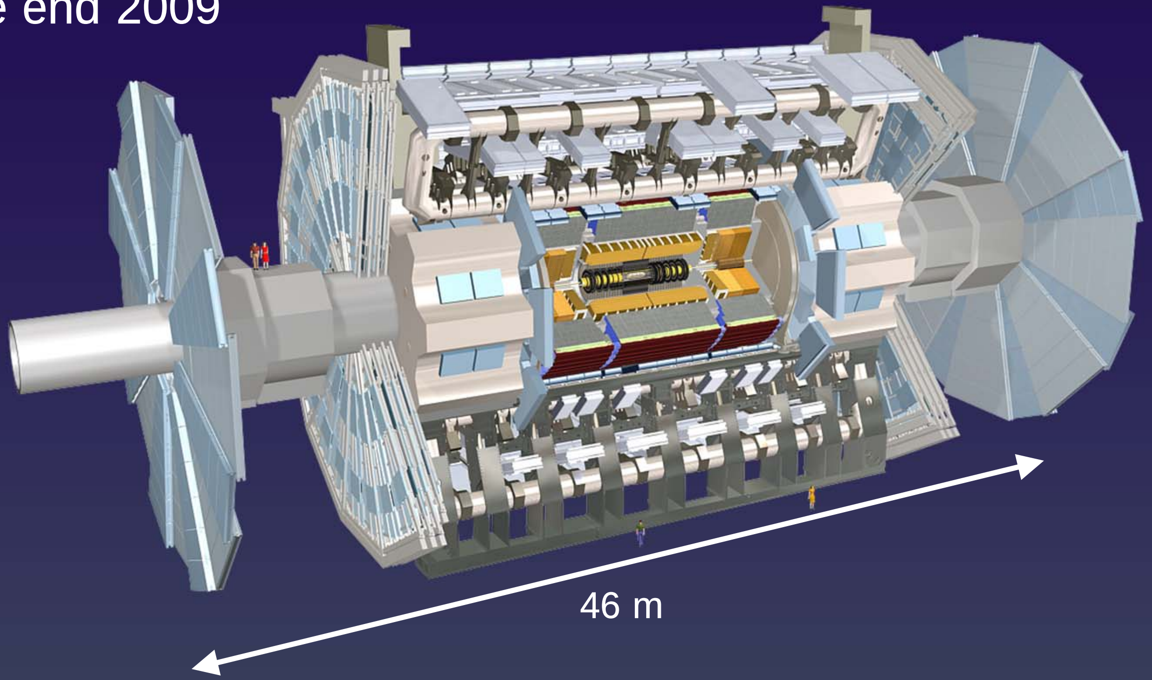

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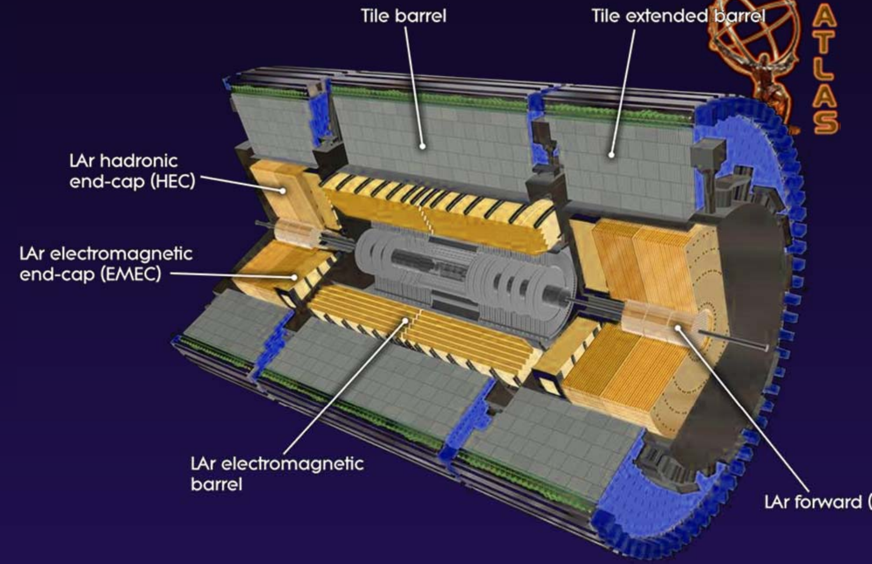

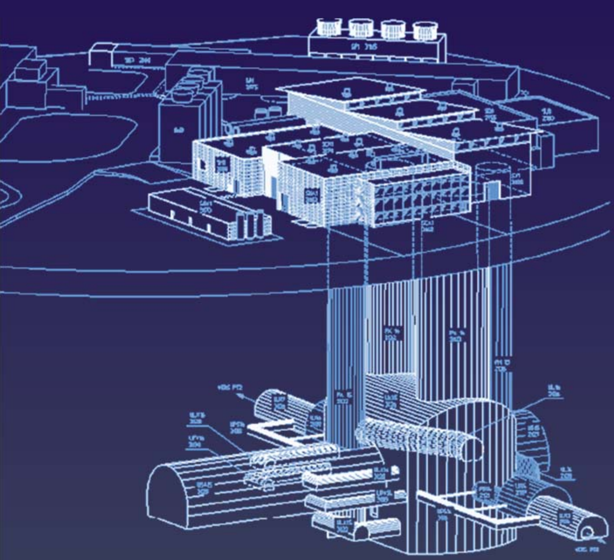

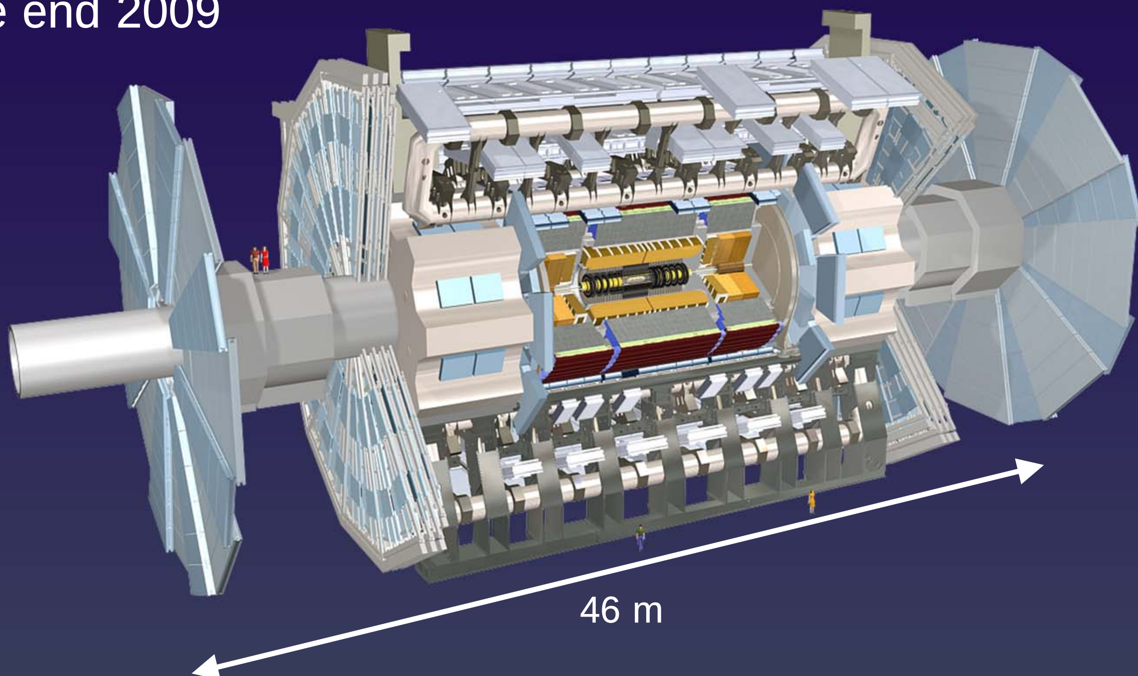

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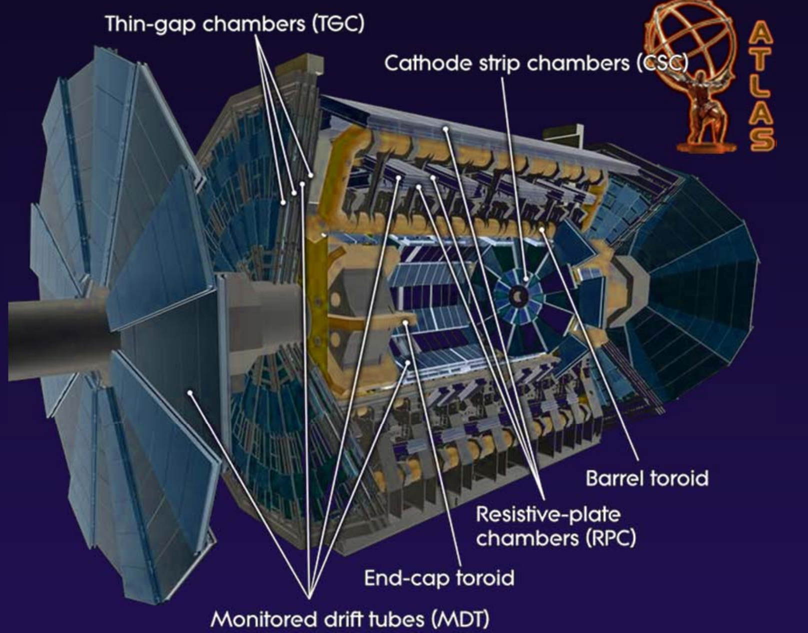
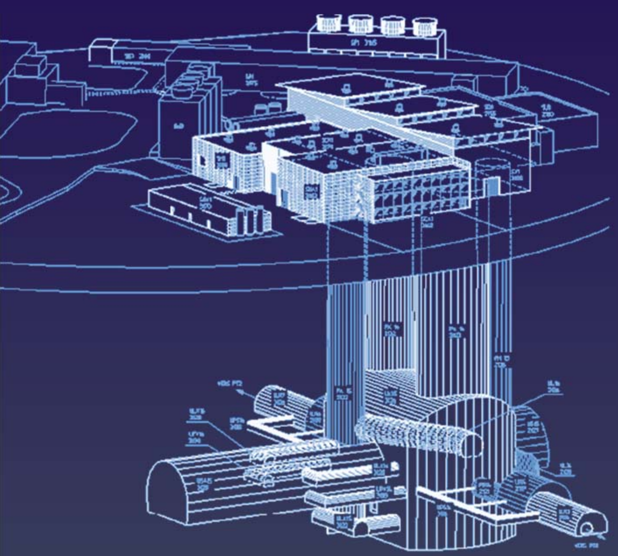
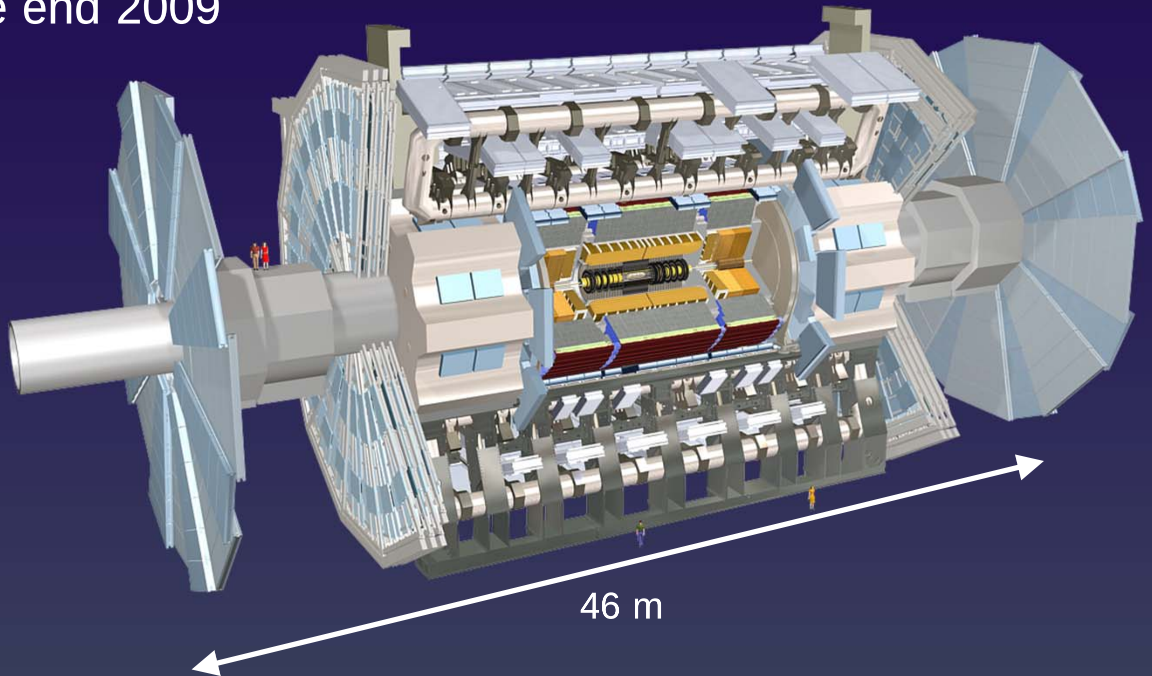


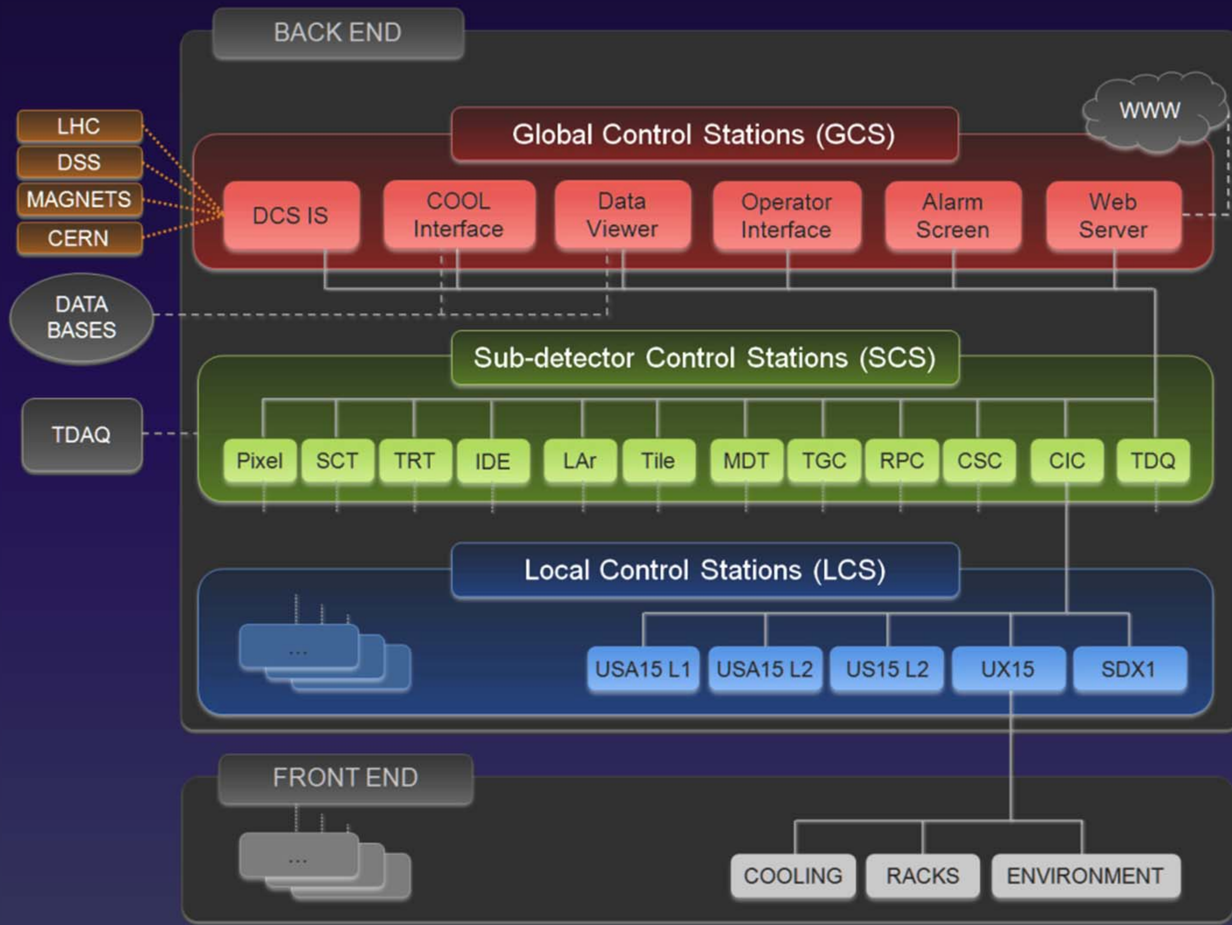




DCS Architecture

- Facilitate management of implementation, operation and maintenance by using standard building blocks
  ➲ **J**oint**CO**ntrols**P**roject

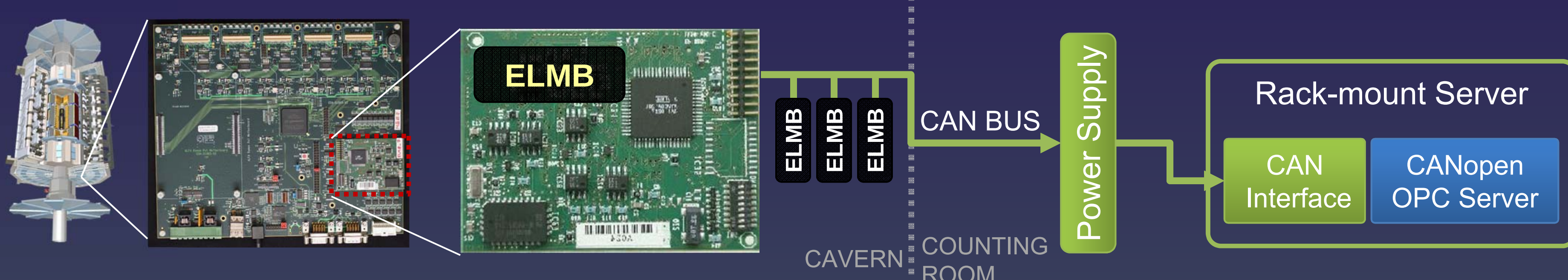
- Controls hierarchy:
  1. Front-End (FE): detector interface
  2. Local Back-End (BE): FE connection, readout, processing
  3. Sub-detector BE: grouping different technologies, standalone operation
  4. Global BE: interfaces to operators, storage and external facilities



DCS Front-End

DCS Front-End Components

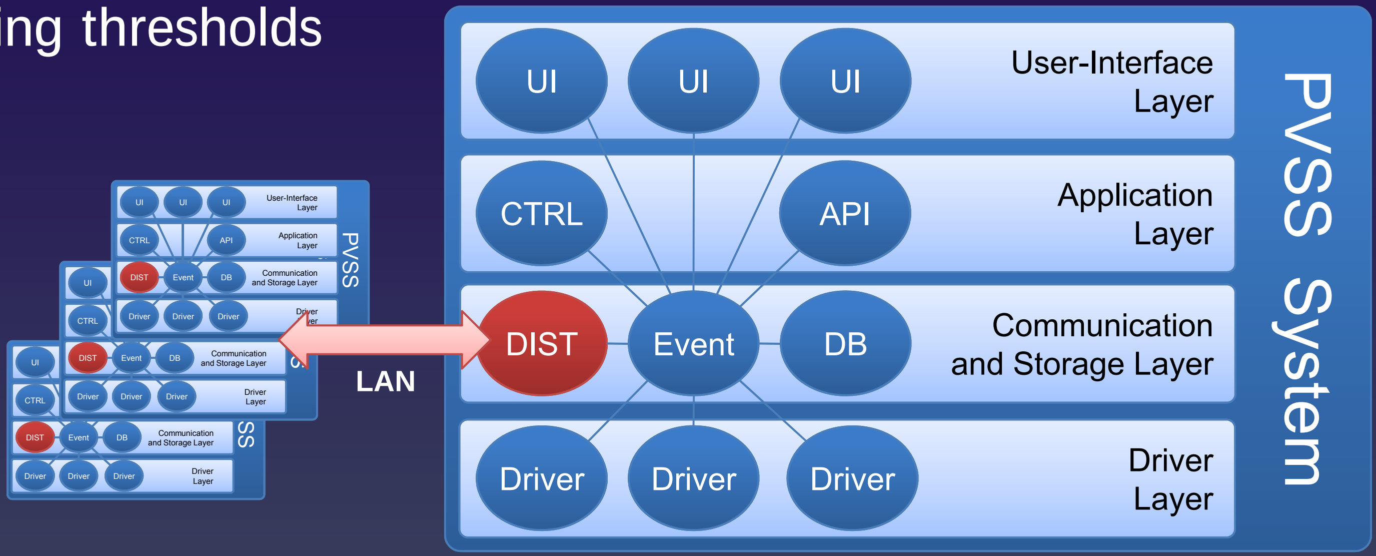
- Industrial Power Supplies & Crates
  (CAEN, Wiener, ISEG),
  read out and controlled via CAN/Ethernet
- Few PLCs read out via Mod-bus (managed by CERN infrastructure)
- Custom built low-cost I/O concentrator: Embedded Local Monitoring Board
  - 64 analog inputs (16-bit ADC) and 32 digital I/O channels
  - ATmega128 microcontroller (8 bits, 4 MHz)
  - CAN controller for communication over field-bus
  - Powered by custom power supply via CAN bus (or hosting board)
  - Modular, remotely upgradable firmware
  - CANopen OPC server for communication with back-end
  - Radiation hard up to 50 Gy, tolerant to magnetic field >1.4T
  - More than 5000 ELMBs in use in ATLAS (detector, counting rooms), >10k LHC-wide



DCS Back-End

Components and Usage

- Front-End interfaced to individual control stations (server PCs), Windows/Linux
- Stations run SCADA software PVSS II *(Siemens)*, allows distribution of applications
- Data exchanged via OPC (standard), Modbus (PLCs), DIM (anything else)
- Conditions data can be streamed to relational database (Oracle)
- Low level alarm system for individual parameters crossing thresholds



Back-End Integration

Sub-systems

- Distributed system of >130 stations in private network
- Control applications implemented by ~50 different sub-system developers based on event driven processing of $>10^7$ data elements

External Systems

- Information servers dedicated to communication with external controls systems (Safety, Magnets, Cryo, Gas, Cooling,..., LHC)
- Middleware: JCOP **D**ata **I**nterchange **P**rotocol

Scaling Behavior

- Hierarchy approach pays off
- PVSS scaling becomes an issue on global level (influencing next version...)

System	Component	# Servers (Appl.)	# Archived Parameters	Total # Parameters	# FSM Objects
Inner Detector	Pixel	11(12)	57k	1'086k	9.1k
	Silicon strips	11(11)	106k	1'265k	14.7k
	Transit. radiation	11(11)	69k	123k	13k
	Services	7(8)	16k	494k	3.7k
Calorimeters	Liquid Argon	13(13)	27k	910k	8.3k
	Tile	5(5)	51k	719k	2.4k
Muon Spectrometer	Drift tubes	29(29)	214k	3'229k	19.2k
	Cathode strip	2(2)	1.3k	109k	0.6k
	Resistive plate	7(7)	139k	1'597k	2.5k
	Thin gap	7(7)	81k	1'225k	10k
	Services	2(2)	0.7k	55k	0.04k
Forward detectors		4(4)	4.9k	194k	0.9k
Common Services	Counting rooms	7(7)	23k	568k	4.7k
	Trigger & DAQ	2(2)	11k	386k	1.3k
	External+safety	4(6)	8.0k	144k	0.4k
	Global services	9(13)	1.2k	222k	0.4k
Total		**131(139)**	**809k**	**12.3M**	**91.2k**

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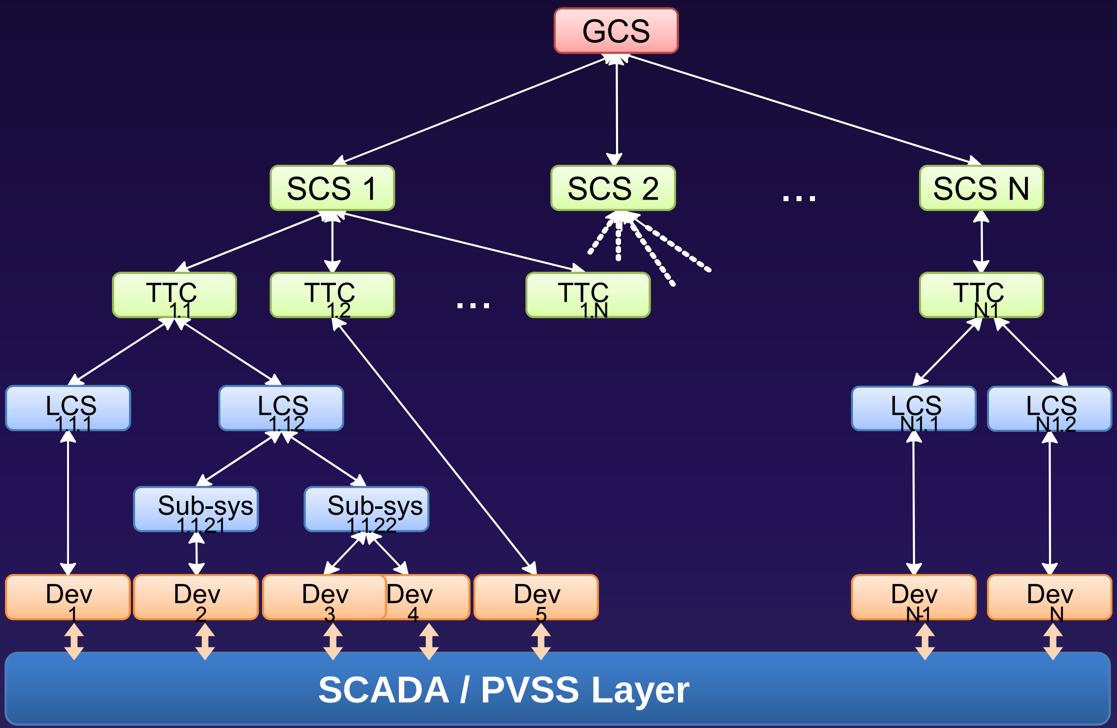
Need for higher level architecture due to heterogeneity and complexity

State Machine Hierarchy

Reduce complexity!

- Detector control mapped to state machine hierarchy above SCADA layer
- Using JCOP FSM software framework (C. Gaspar et al. 2006)
- Device *States* are propagated upwards using state rules, *Commands* propagated downwards
- Error handling upwards using parallel tree of *Status* objects linked to device alarms
- Allows for single operator



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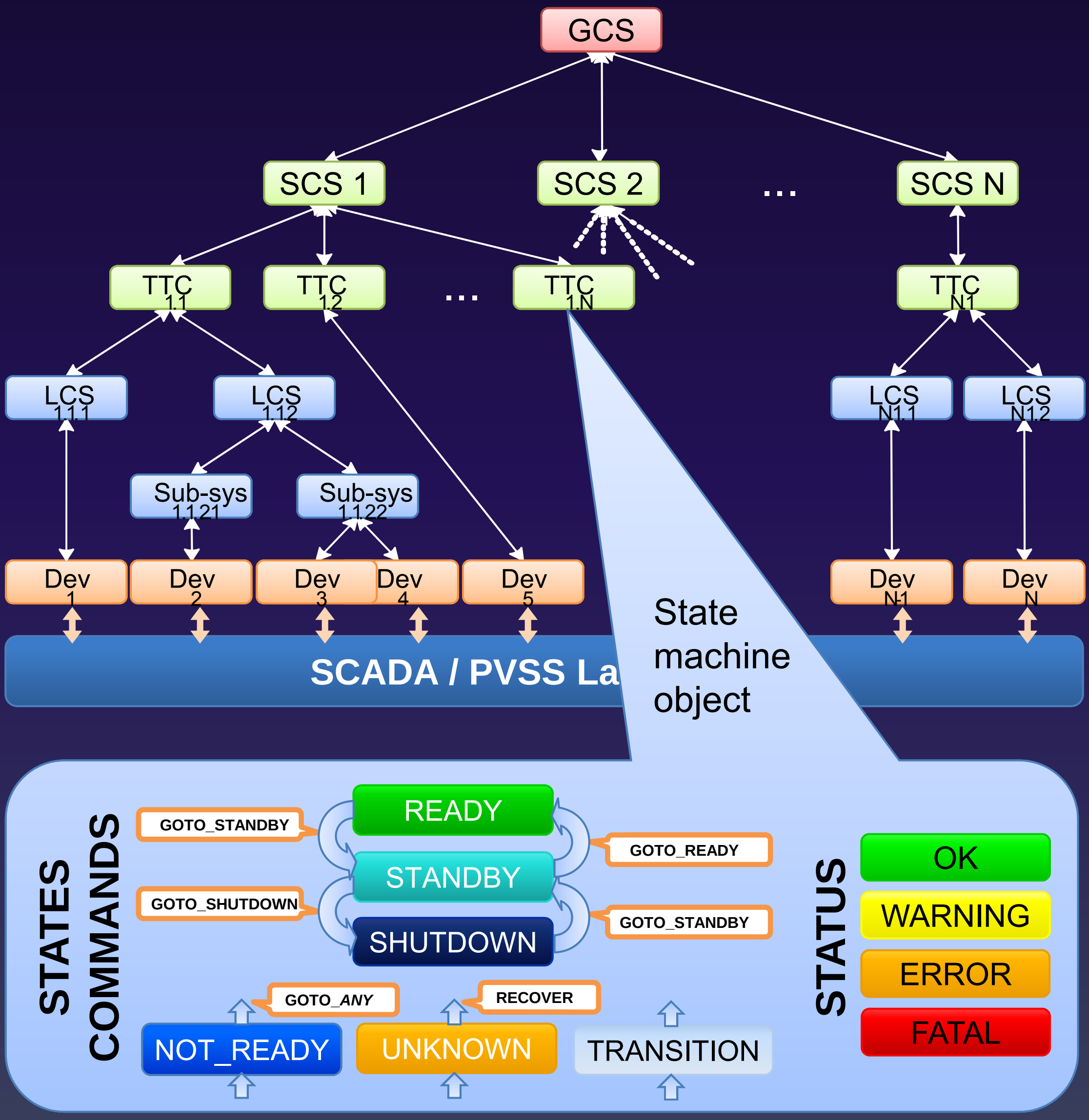

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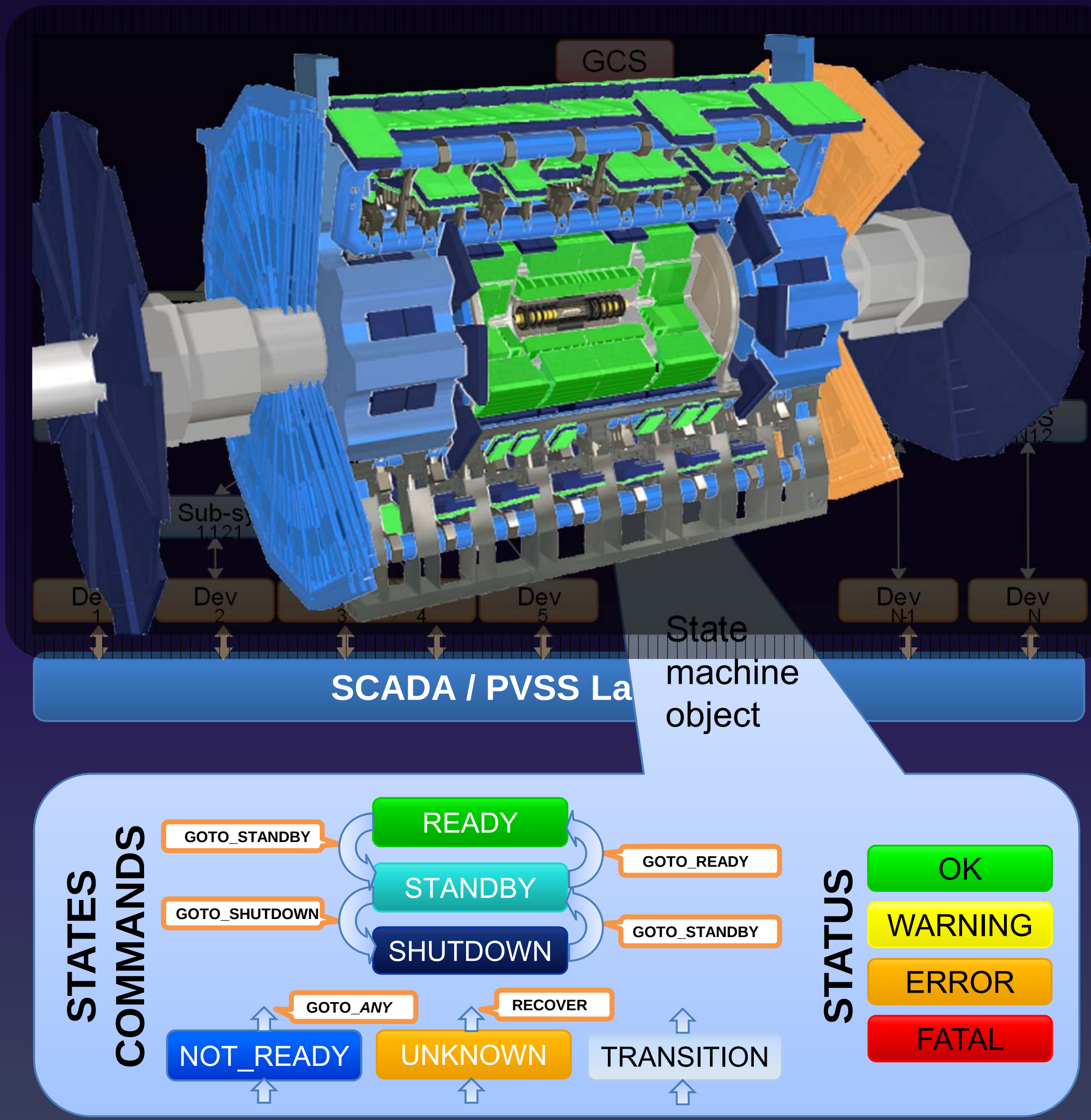
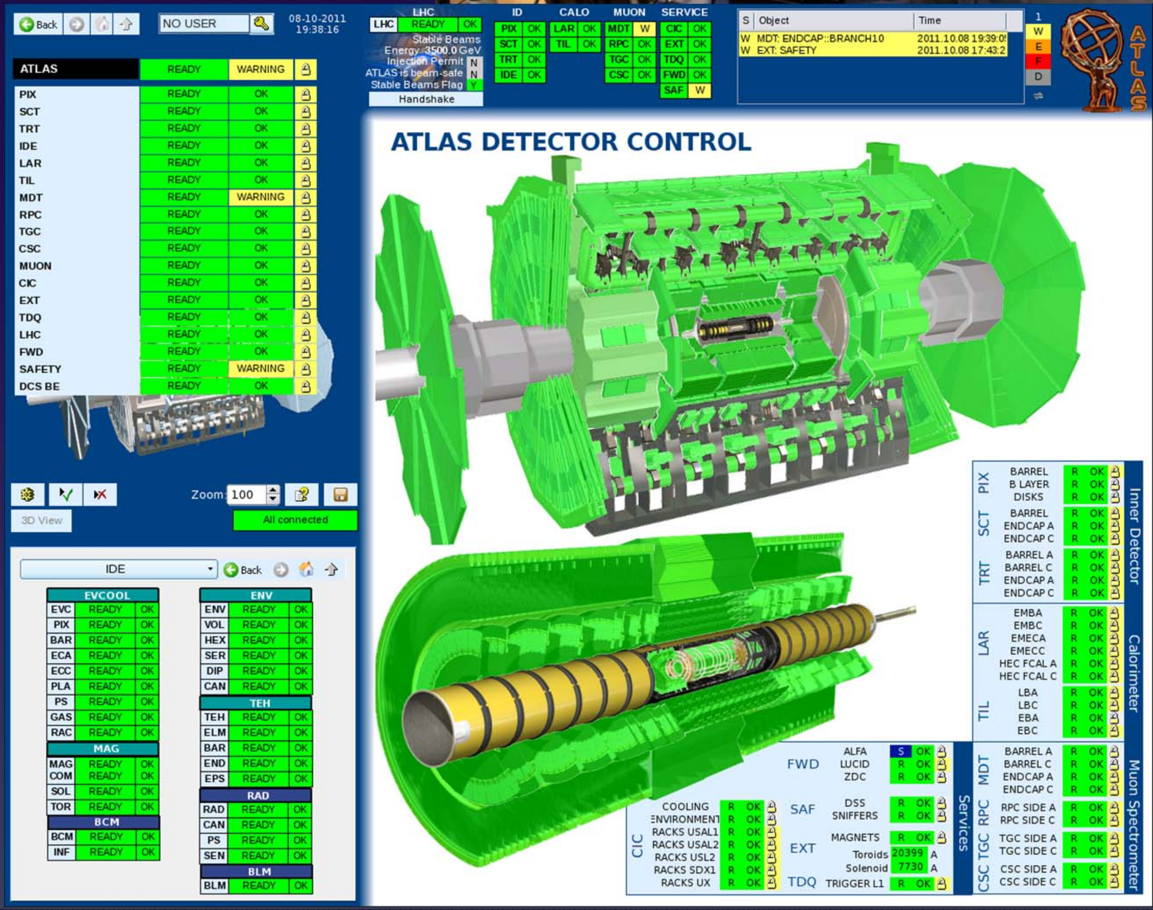


Operator Control

Human-Machine-Interfaces

- ► Alarm Screen enabling quick recognition and response to problems
- ► Homogeneous navigation through state machine hierarchy for operator with custom HMI
- ► Each state machine object has associated panel (synoptics, trends etc.)
- ► Access control mechanism fully synched with LDAP and shift management
- ► Web monitoring, no load on Back-End, history mode



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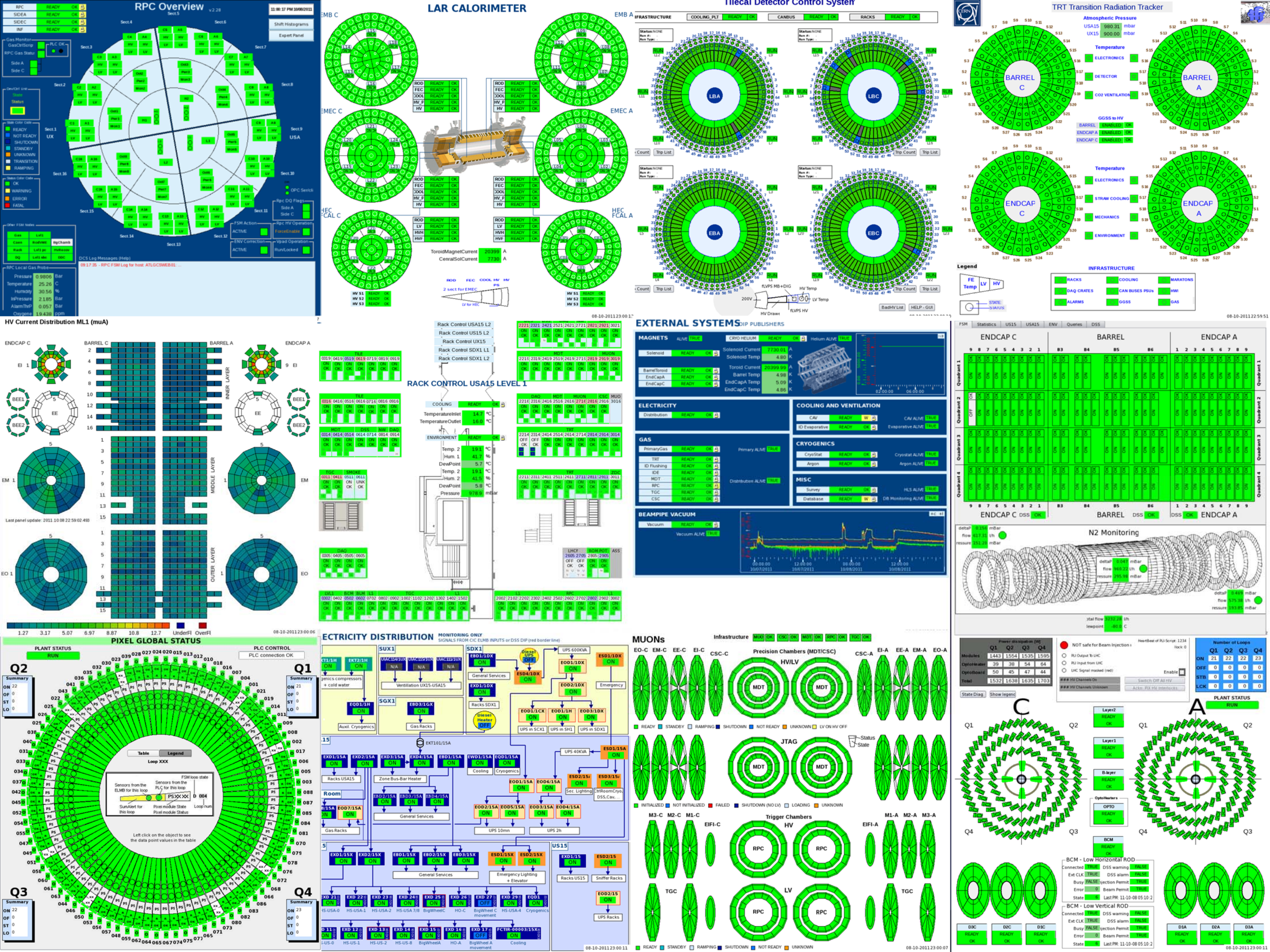
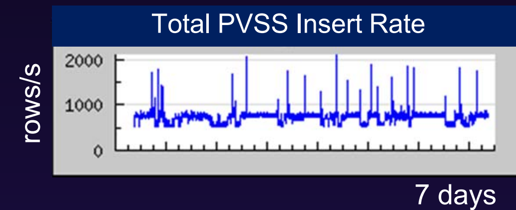


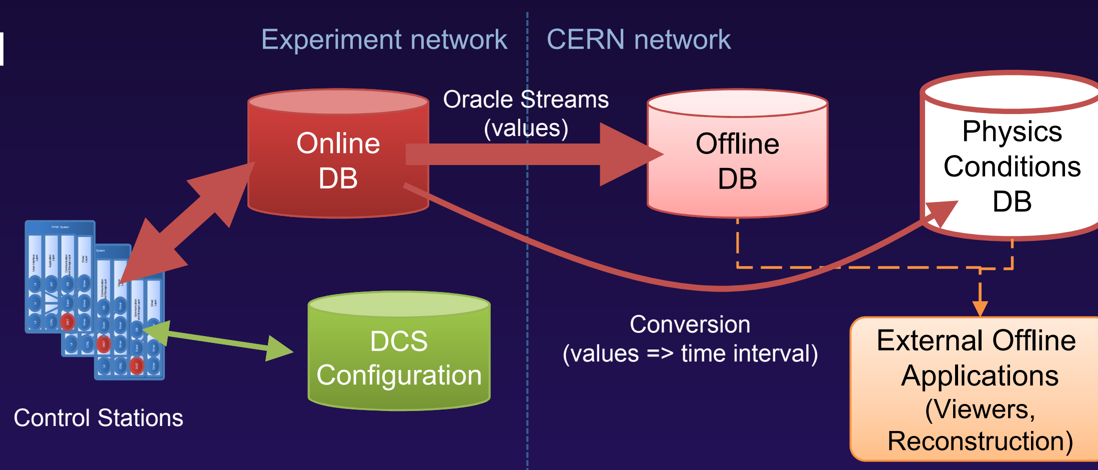
RPC Overview
LAR CALORIMETER
Tilecal Detector Control System
TRT Transition Radiation Tracker
HV Current Distribution ML1 (muA)
RACK CONTROL USA15 LEVEL 1
EXTERNAL SYSTEMS
MAGNETS
ELECTRICITY
COOLING AND VENTILATION
GAS
CRYOGENICS
MISC
BEAMPIPE VACUUM
ENDCAP C
BARREL
ENDCAP A
N2 Monitoring
PIXEL GLOBAL STATUS
PLANT STATUS
PLC CONTROL
ECTRICITY DISTRIBUTION
MUONs
Precision Chambers (MDT/CSC)
Trigger Chambers

Data Management



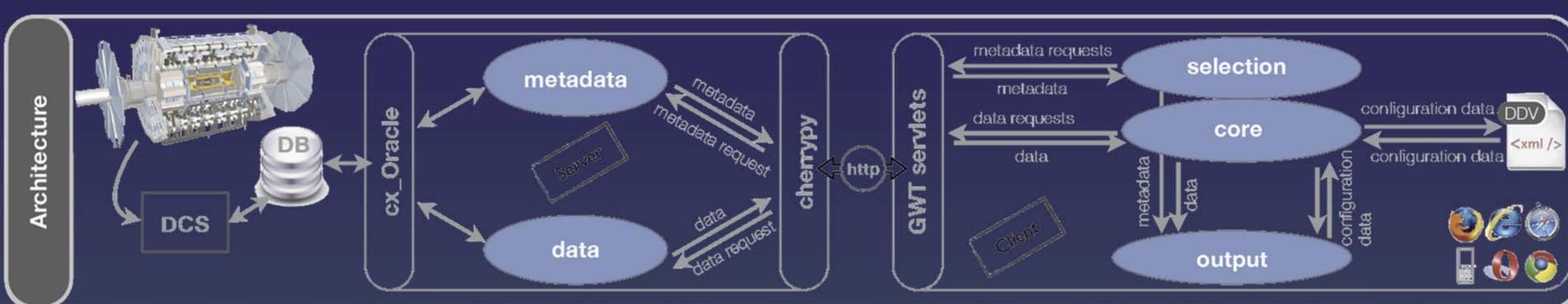
Data Handling

- Use of Oracle databases (CERN IT services)
- Configuration DB: 1.6 GB
- Conditions DB: 6.6 GB/day, replicated for offline use
- Non-negligible maintenance



Data Access

- Directly from PVSS (trends, script-based) via OnlineDB
- Implemented dedicated web-based DCS Data Viewer (DDV)
  - DCS data access world-wide, can be embedded in any web-page
  - Generic approach allows use in other experiments (done in COMPASS)



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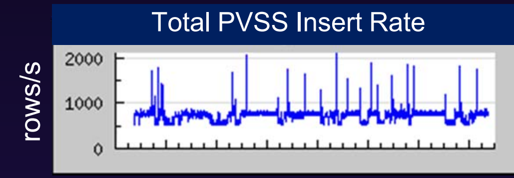

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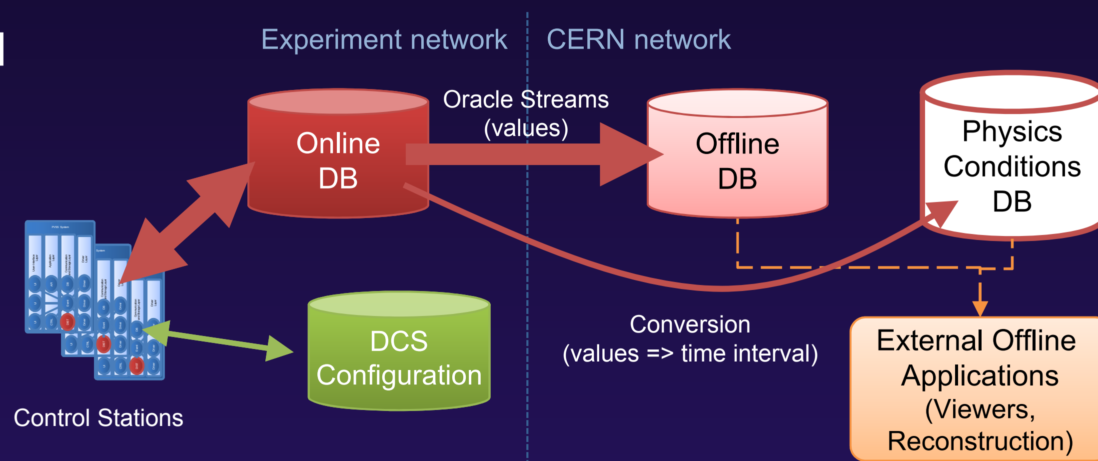

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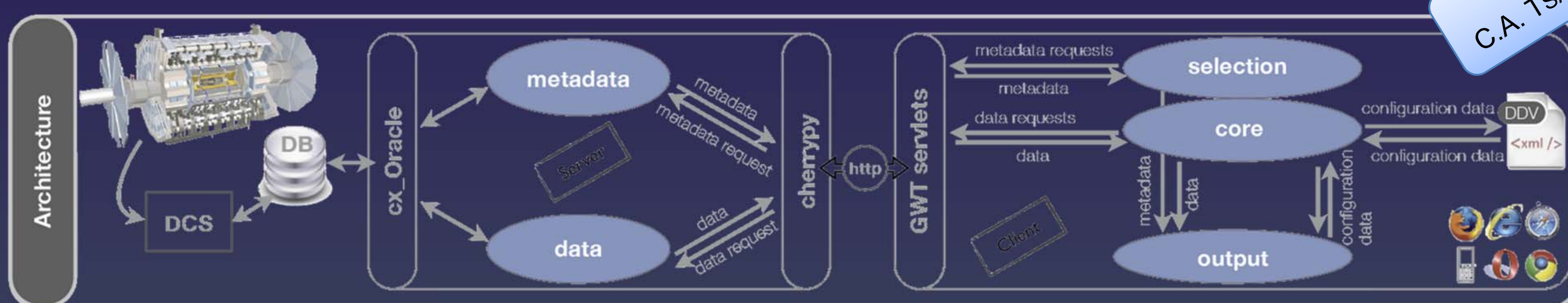
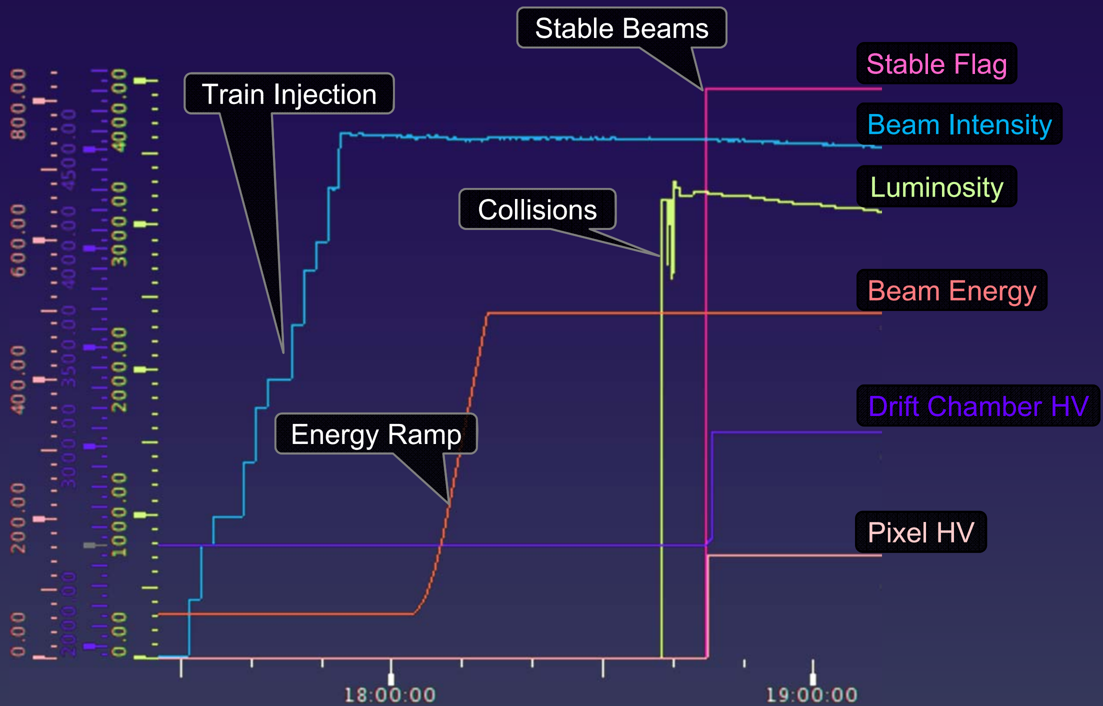
MOPKN019
C.A. TSAROUCHAS ET AL.

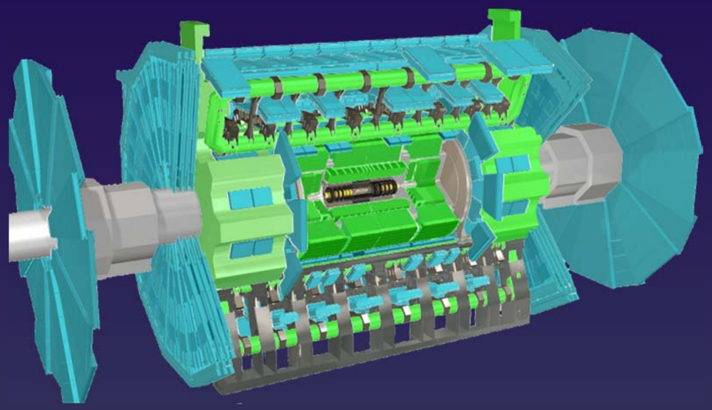


Automation of Data Taking

Example: Synchronization of DCS with LHC operation and physics run control

- Detector safety requires lower voltage levels during unstable beam conditions
- Communication with LHC control room using semi-automatic handshake procedure
- Detector state change automated, synchronization with DAQ run control system (trigger)
- Audible notifications from DCS to ease shift operation
- Beam backgrounds and luminosity monitored via DCS





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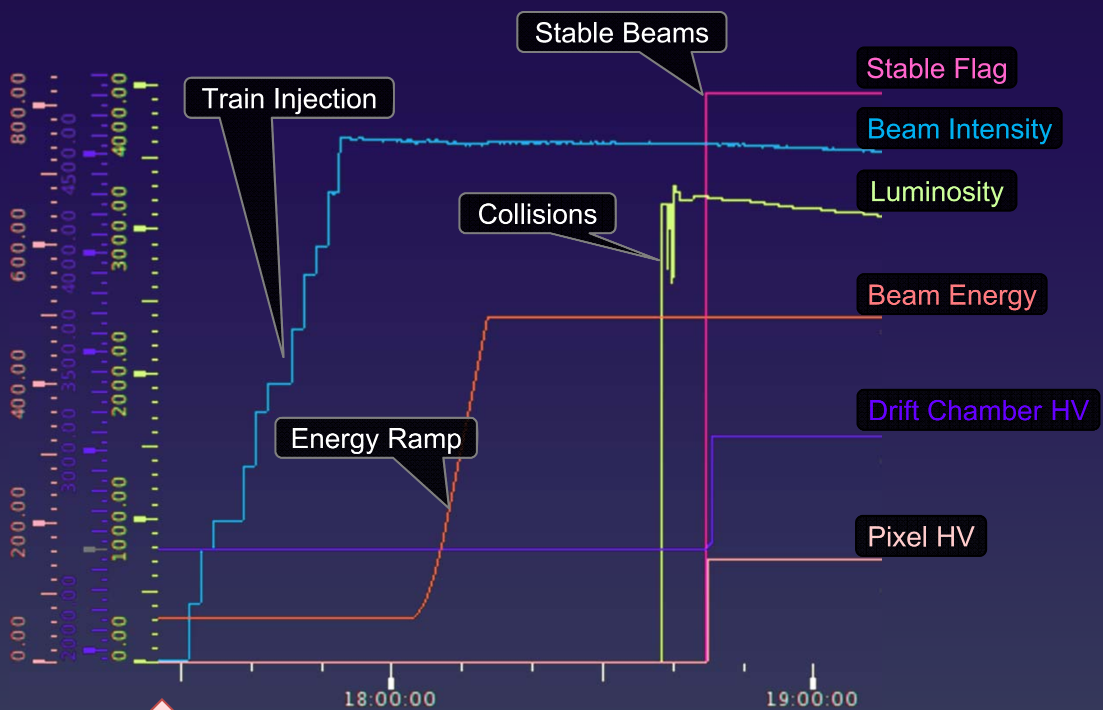

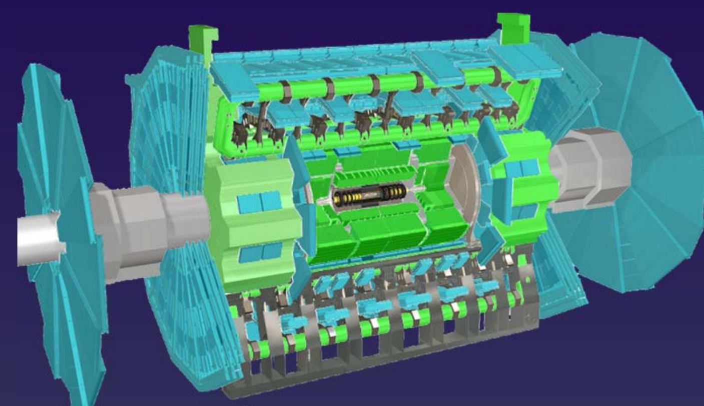

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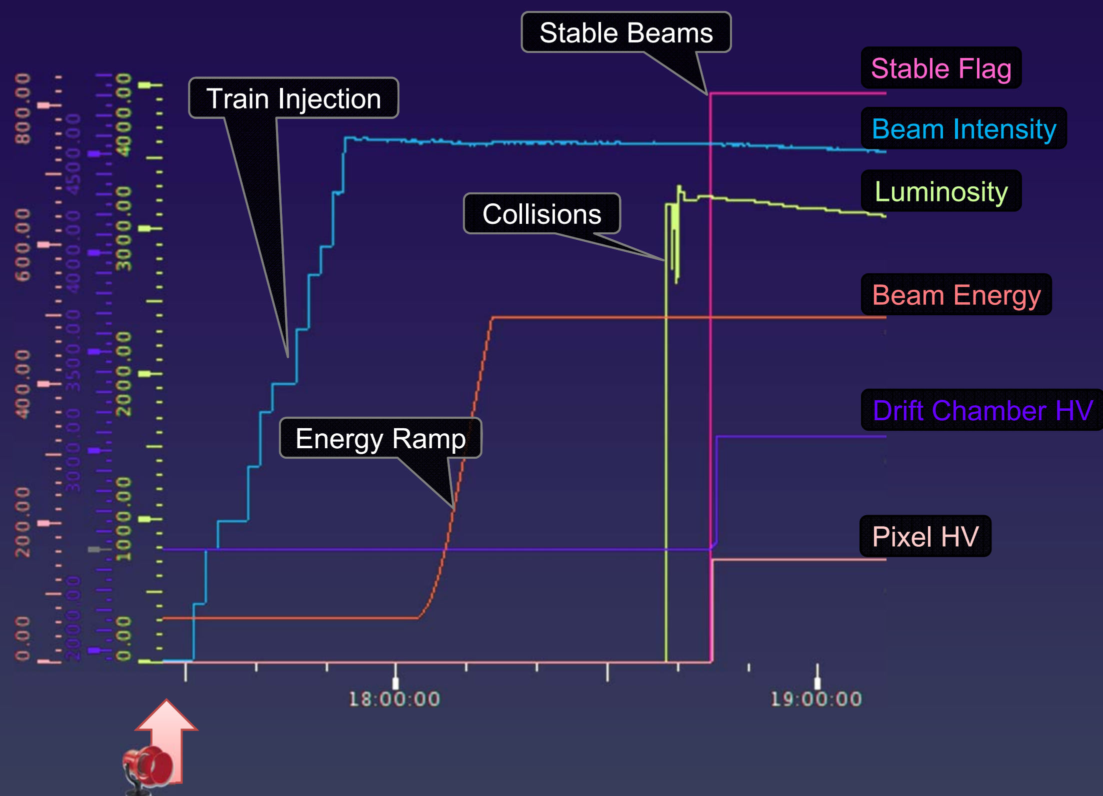

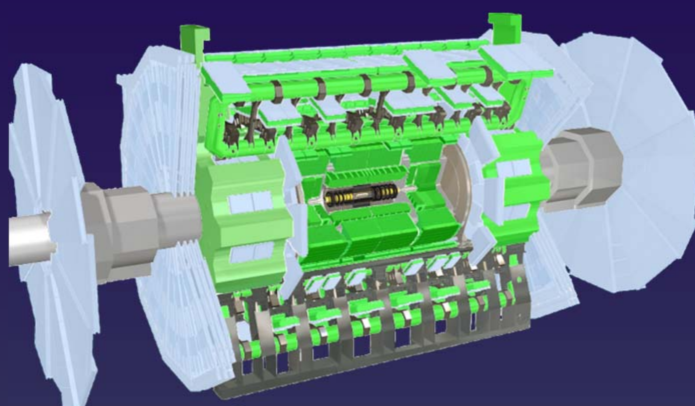

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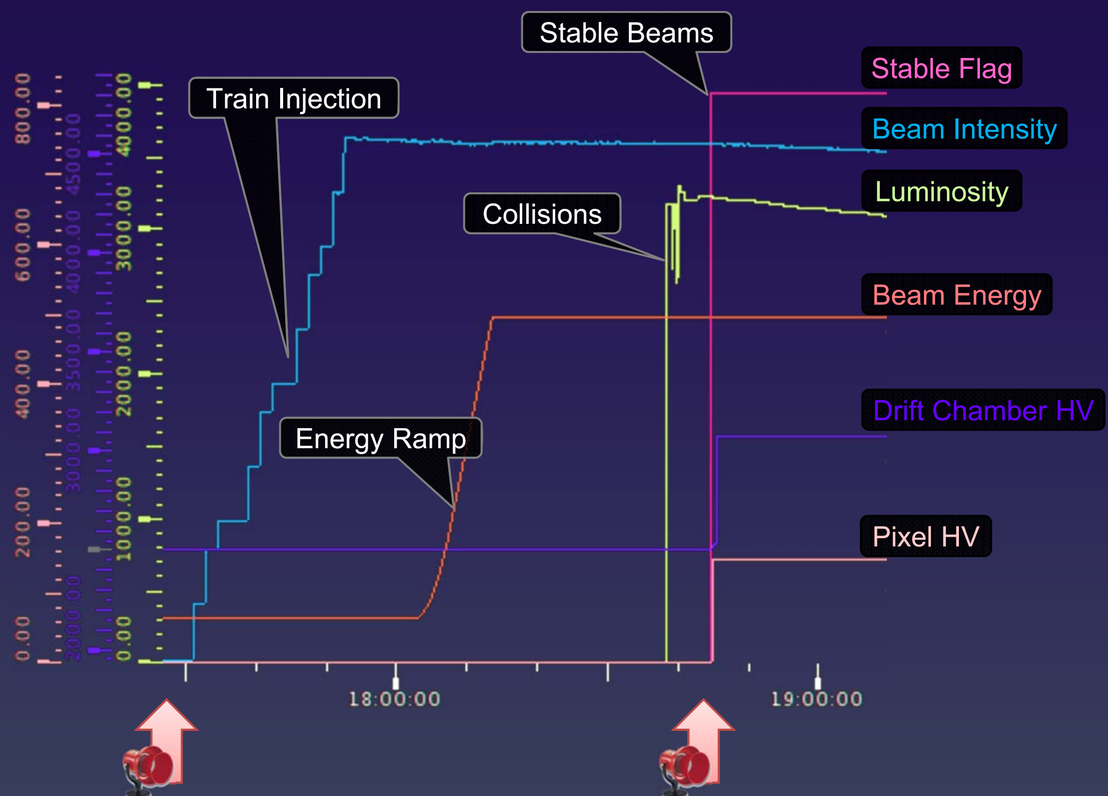

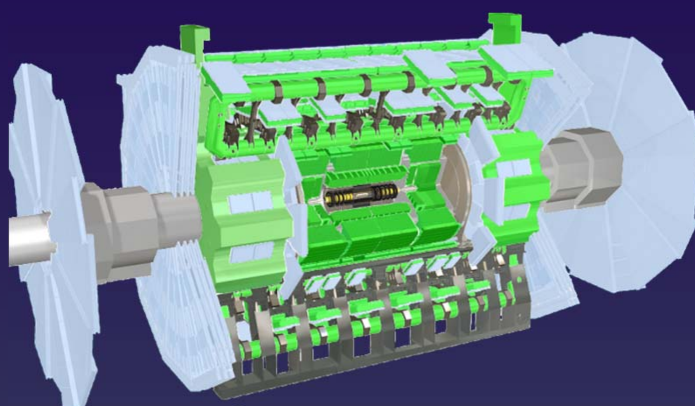

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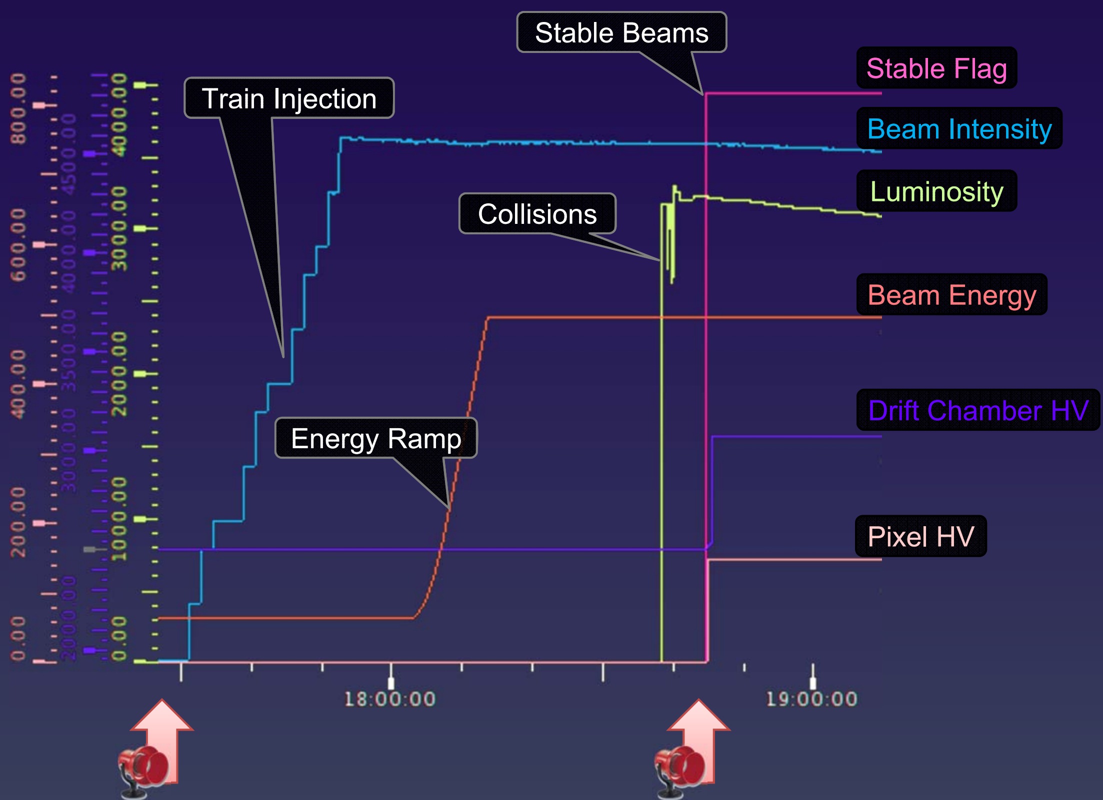

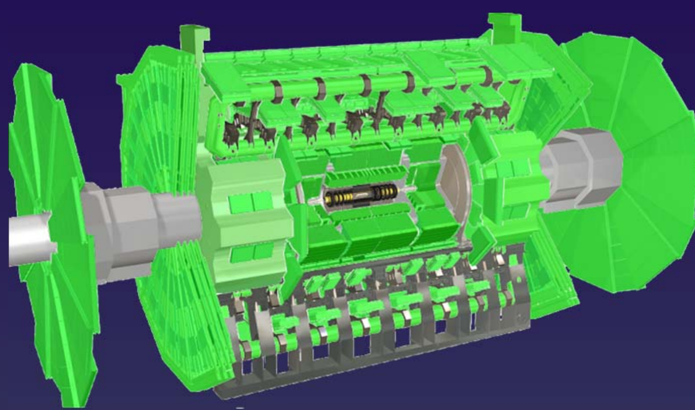

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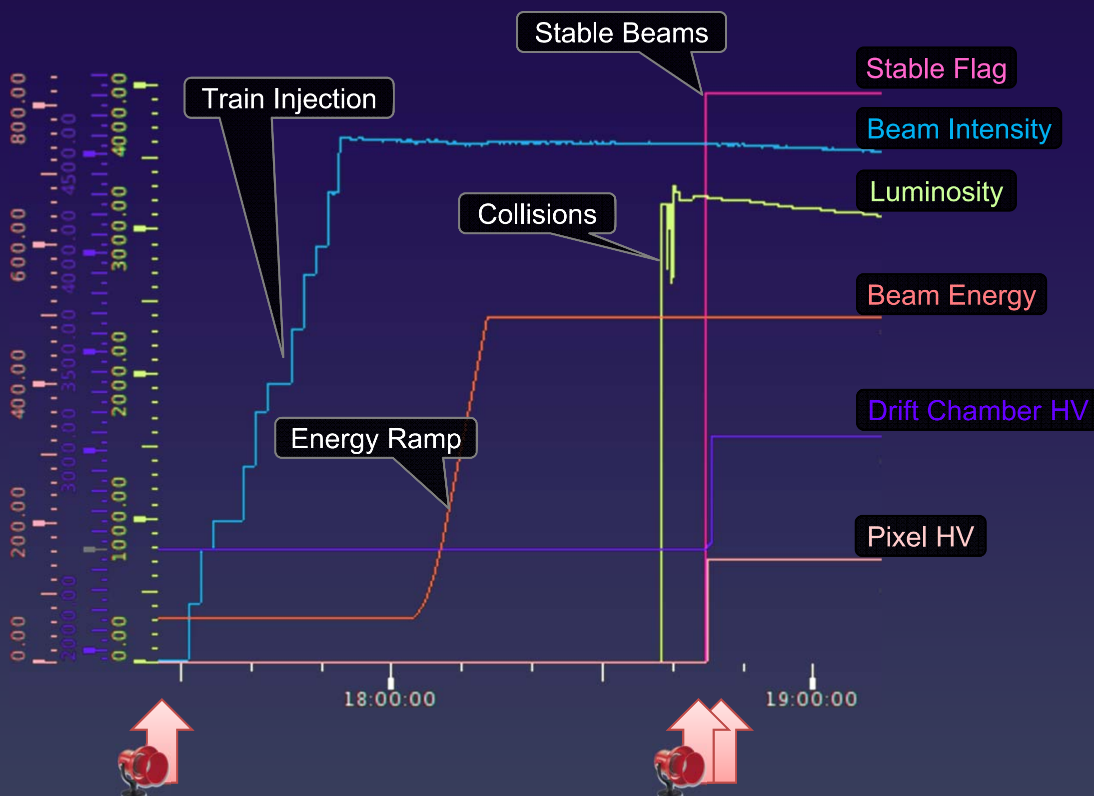

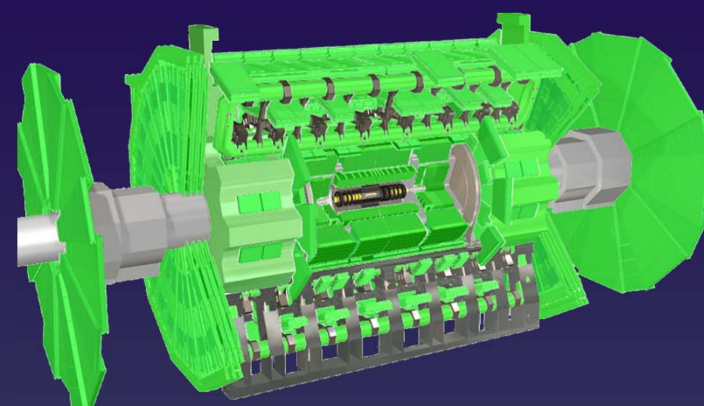

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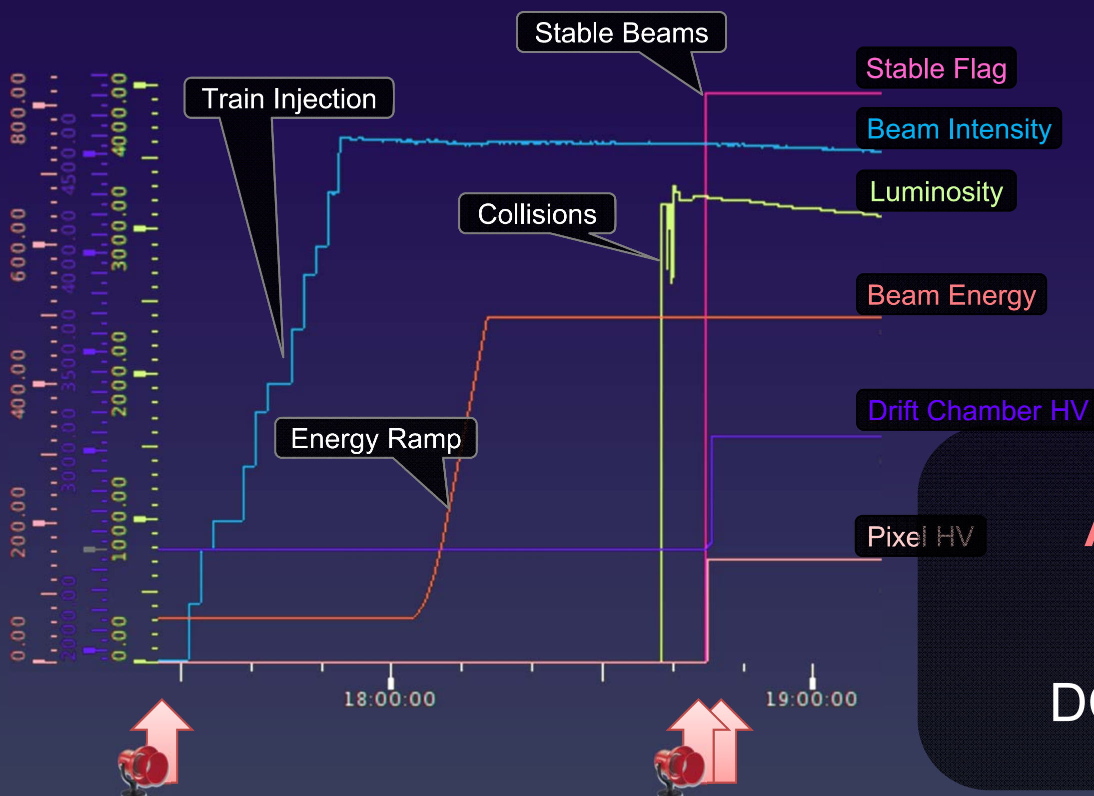

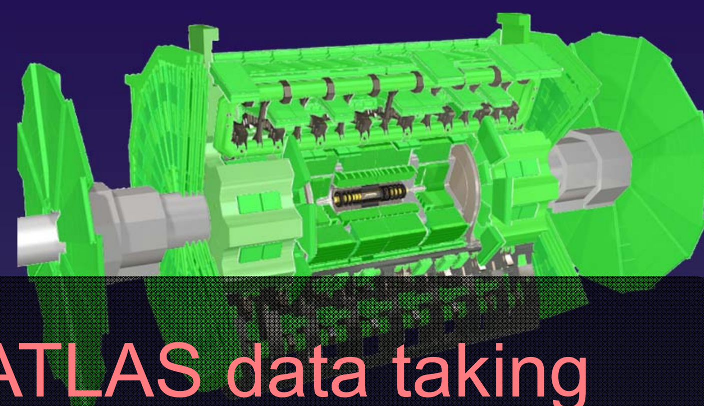

ATLAS data taking efficiency 94%

DCS incredibly reliable so far

Maintenance & Operations

Tasks

- Operations-driven consolidation (problem recovery automation etc.)
- Building documentation: direct access from UIs to generic TWiki
- Routine hardware replacements (PCs, FE-BE interfaces)
  - Replace PCI based solutions to USB/Ethernet

- Software maintenance (OS, security patches, PVSS, drivers etc.)
- Migration to Linux:
  - Windows needs high administration effort, high security constraints
  - Need to replace OPC standard: OPC Unified Architecture (under development for CANopen/ELMB, vendors interested)
- Development on test systems, production updates only in technical stops
  - Large scale production mirror (software only)
  - Small scale hardware setups
- Software organized in repository, versioning essential (SVN)
- Reduced manpower requires merging of expertise and responsibilities, time consuming!

Future Upgrades

Upgrade Constraints

- Higher luminosity ➲ need to increase radiation tolerance for cavern equipment by factor ~10
- ➲ ELMB successor: ELMB++, still in conception stage
  - ➲ Radiation hardness!
  - ➲ Backwards compatibility
  - ➲ Fix bugs, support new connectivity (Ethernet?) and users
- Phase I:
  - new Pixel Inner B-Layer (new powering, Cooling)
  - Fast Track Trigger (electronics)
- Phase II: Replace complete inner detector, needs at least complete new design of DCS Front-End

LHC Upgrade Schedule

E = 6.5-7 TeV
$L = 10^{34}$
2013
CONSOLIDATION

E = 7 TeV
$L = 2\ 10^{34} cm^{-2}s^{-1}$
2017
PHASE 1

E = 7 TeV
$L = 5\ 10^{34} cm^{-2}s^{-1}$
2021
PHASE 2

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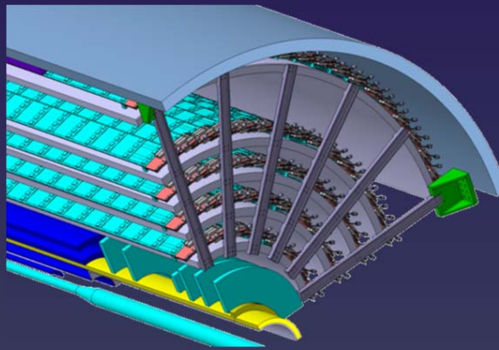
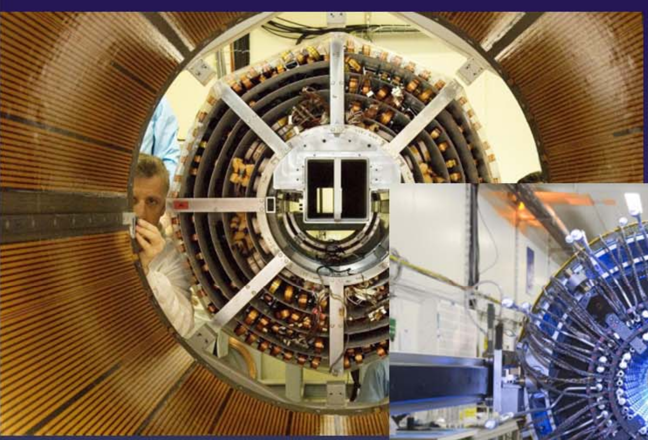
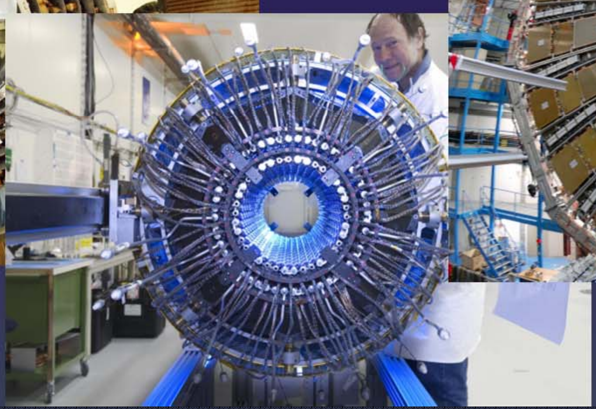
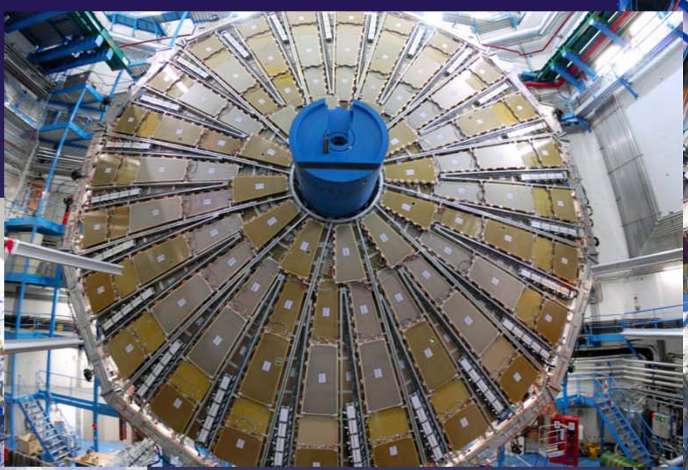
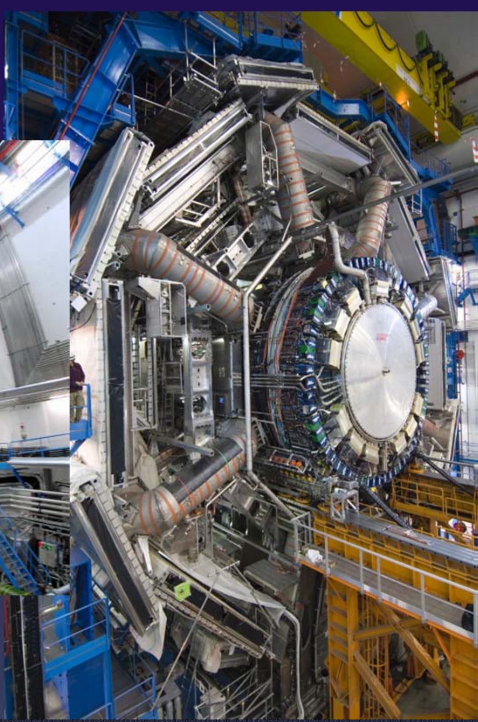
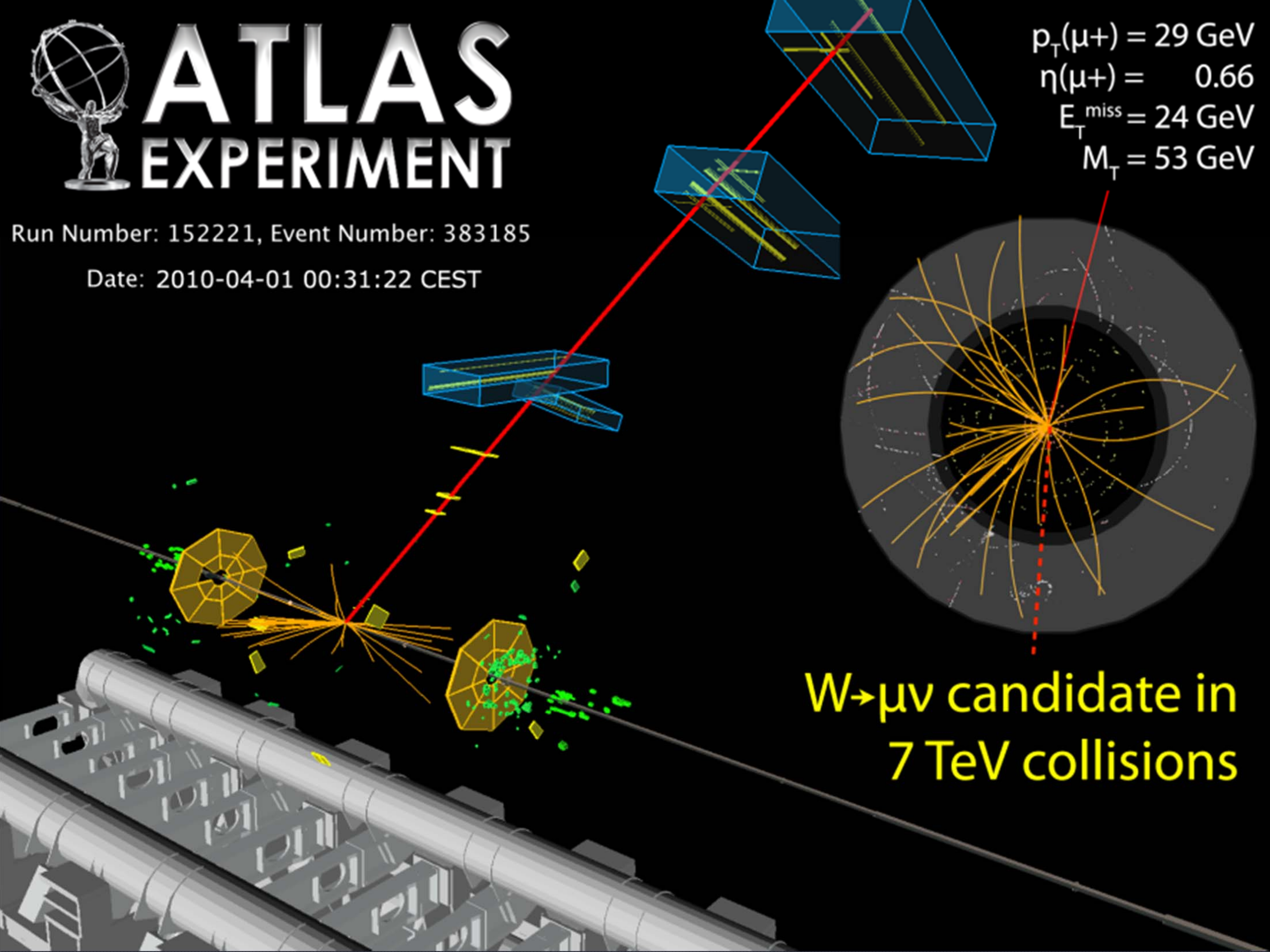


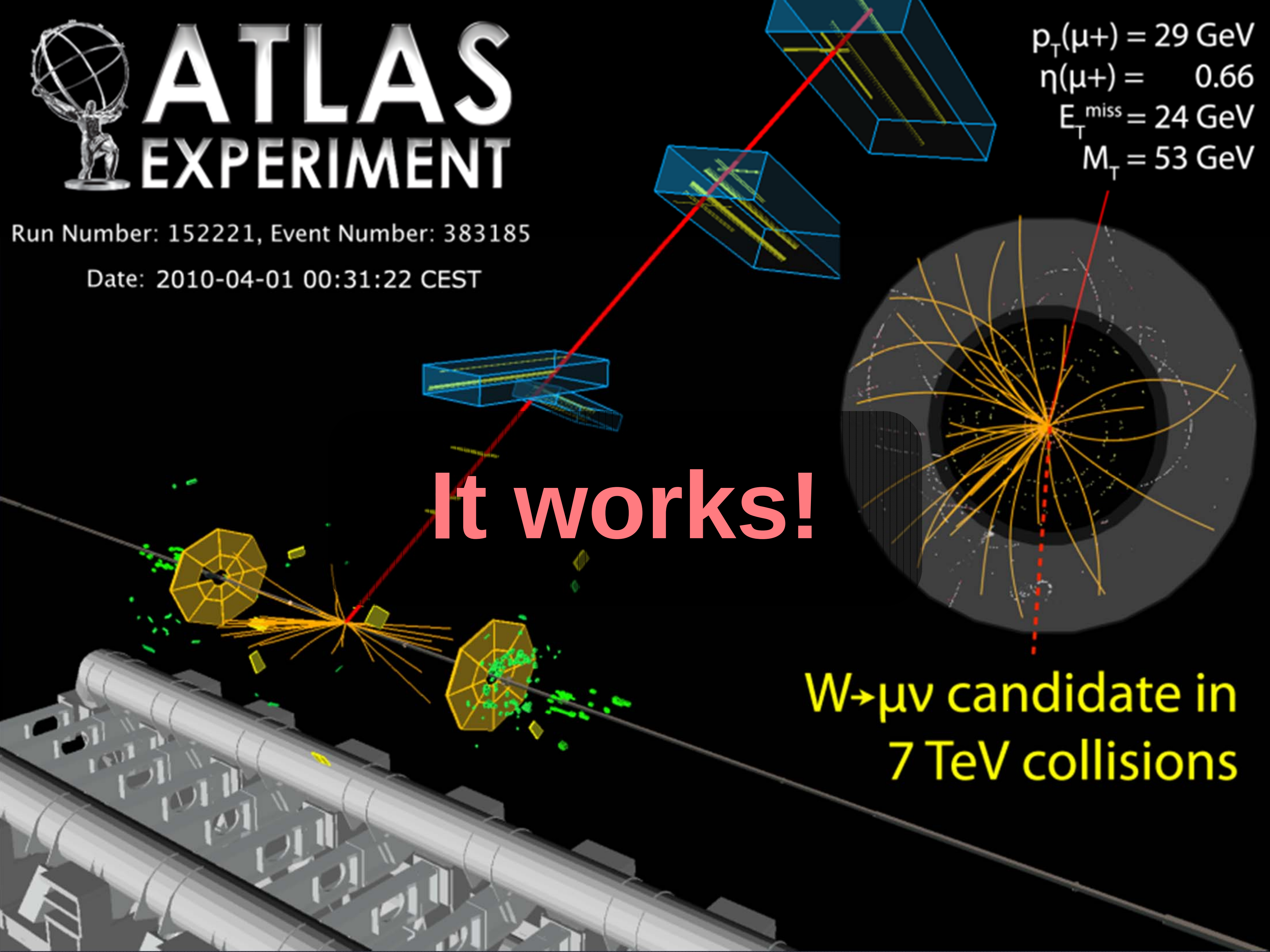
Summary

- Highly distributed control system using SCADA software PVSS scales well (10^7 parameters)
- Reducing complexity using hierarchical structure and state machine logic
- System proven to manage routine detector operation well
- Continuous consolidation and automation
- Preparation of future upgrade



ATLAS EXPERIMENT
Run Number: 152221, Event Number: 383185
Date: 2010-04-01 00:31:22 CEST
$p_T(\mu+) = 29$ GeV
$\eta(\mu+) = 0.66$
$E_T^{miss} = 24$ GeV
$M_T = 53$ GeV
W→μν candidate in 7 TeV collisions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$M_T = 53$ GeV
It works!
W→μν candidate in
7 TeV collisions