The detector Control Systems for ATLAS Roman Pots

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LIP

ATLAS EXPERIMENT

Outline

- Detector Control System (DCS) definition
- WinCC OA – Tool to build the DCS
- ATLAS Roman Pots (ARP) detectors
- ARP DCS
  - Overview
  - Systems (HV, LV, Movement, etc)
  - Operation
  - Data and archiving
- Summary

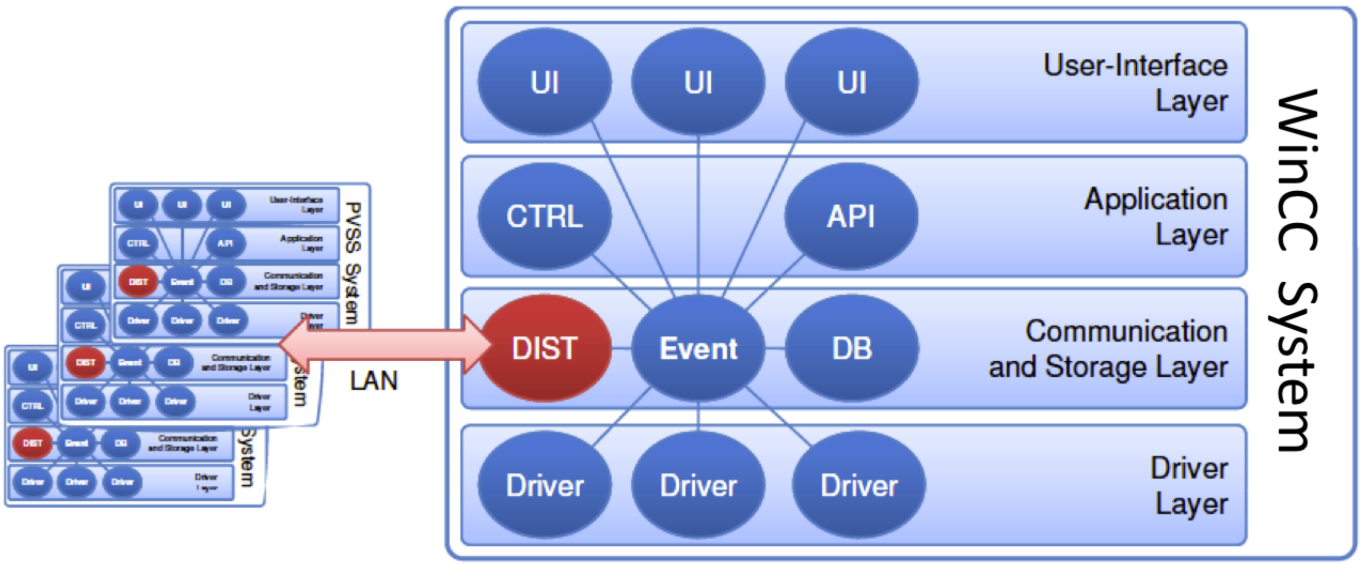
What is the Detector Control System (DCS)?

"Provides control and monitoring of the detector hardware and ensures the safe and reliable operation of the detector, assuring good data quality"

- Should be able to bring the detector into any desired operational state
- Handle a large variety of equipment
- Handle an enormous number of individual channels
- Continuously monitor and archive the operational parameters
- Signal any abnormal behaviour to the operator
- Allow manual or automatic actions to be taken
- Handle the communication between the ATLAS sub-detectors
- Handle the communication to other independent systems:
    - LHC accelerator
    - CERN technical services
    - ATLAS magnets
    - Detector Safety System (DSS)
- Interface between operator and detector

WinCC OA

- Supervisor Control and Data Acquisition (SCADA) system
- Commercial product from SIEMENS (previous PVSS)
- Tool to develop the DCS system for all LHC experiments
- Chosen by Joint Control Project (JCOP)
    - Standards for hardware components
    - Implementation policies
    - Back-End software
    - Operational aspects
- DCS software core is organized into a Project



Console managers

Control Manager

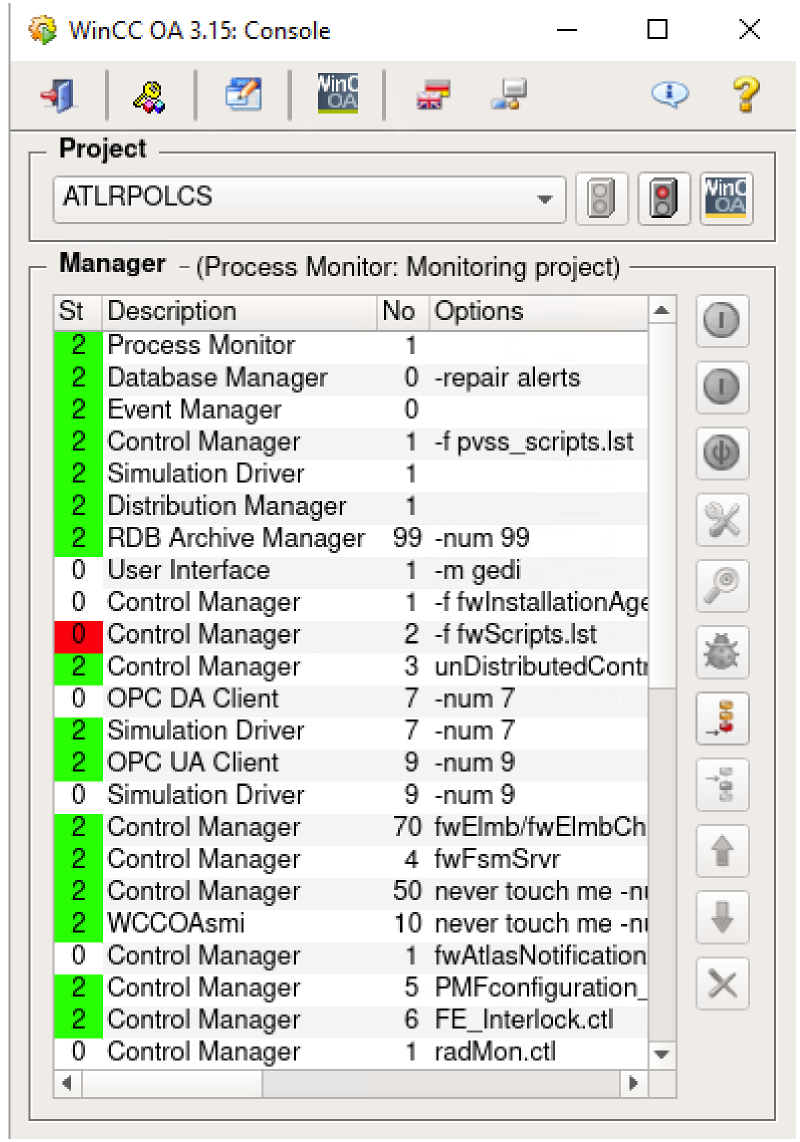
- Execute simple or complex scripts automatically
- Interpreter with syntax similar to C
- Scripts triggered on events
- Large library of functions

API Manager

- Application Programming Interface (API)
- Allows to incorporate other compiled code
- All WinCC OA's own Managers are based on this API

Driver Manager

- Communication protocol
- Standards Drivers
  - Open Platform Communications (OPC)
  - Distribution Information Management (DIM)
  - S7 (Programmable Logical Controller - PLC)
- Driver API for new drivers



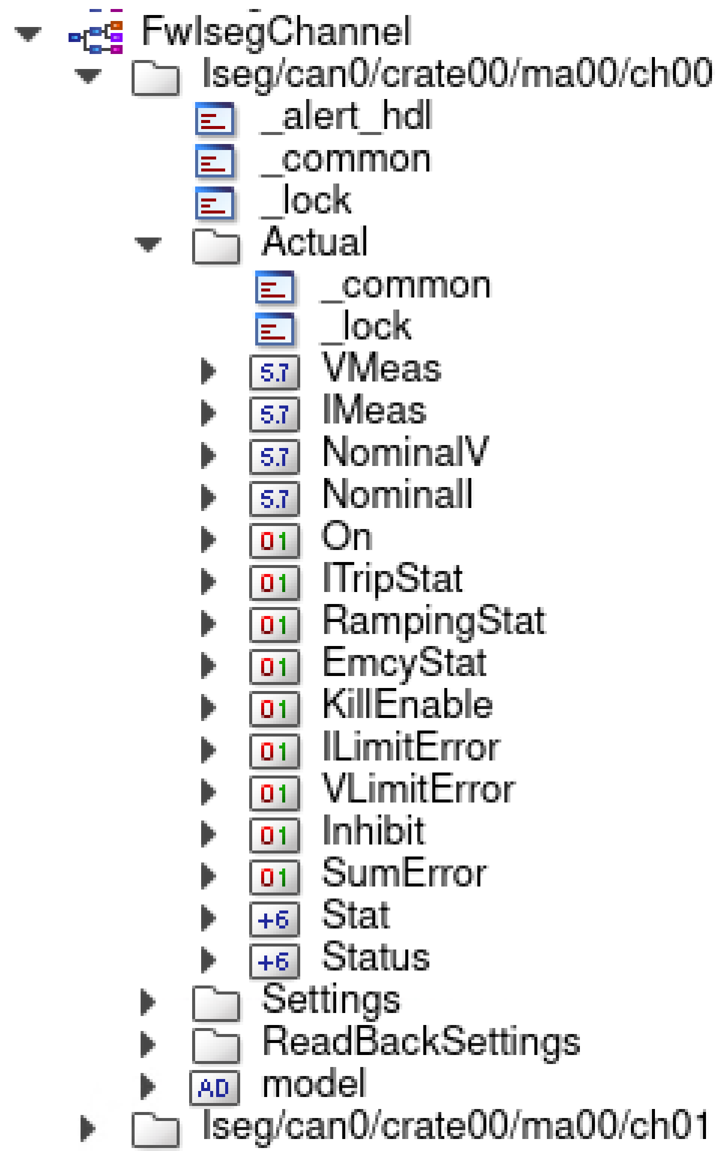
WinCC variables and alerts

Variables

- Variables organized in Data Points (DPs) composed of elements (DPEs):
- Emulates the hardware structure
- Configure addresses, alerts, archiving, etc

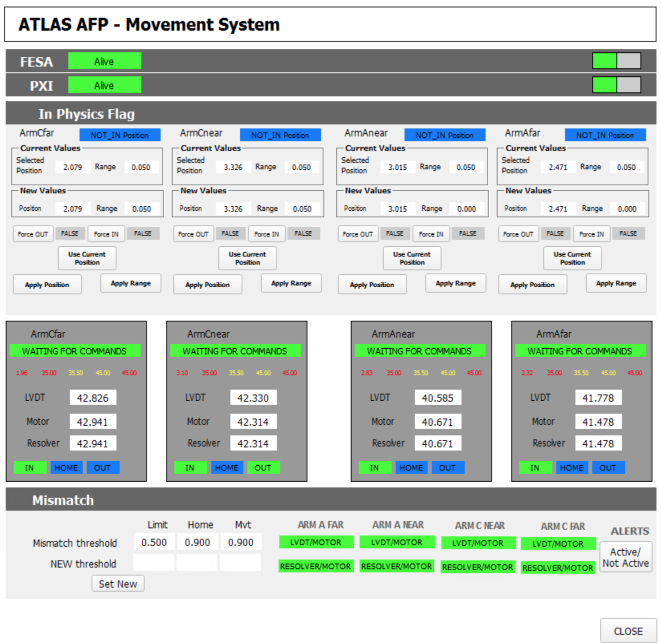
Alerts

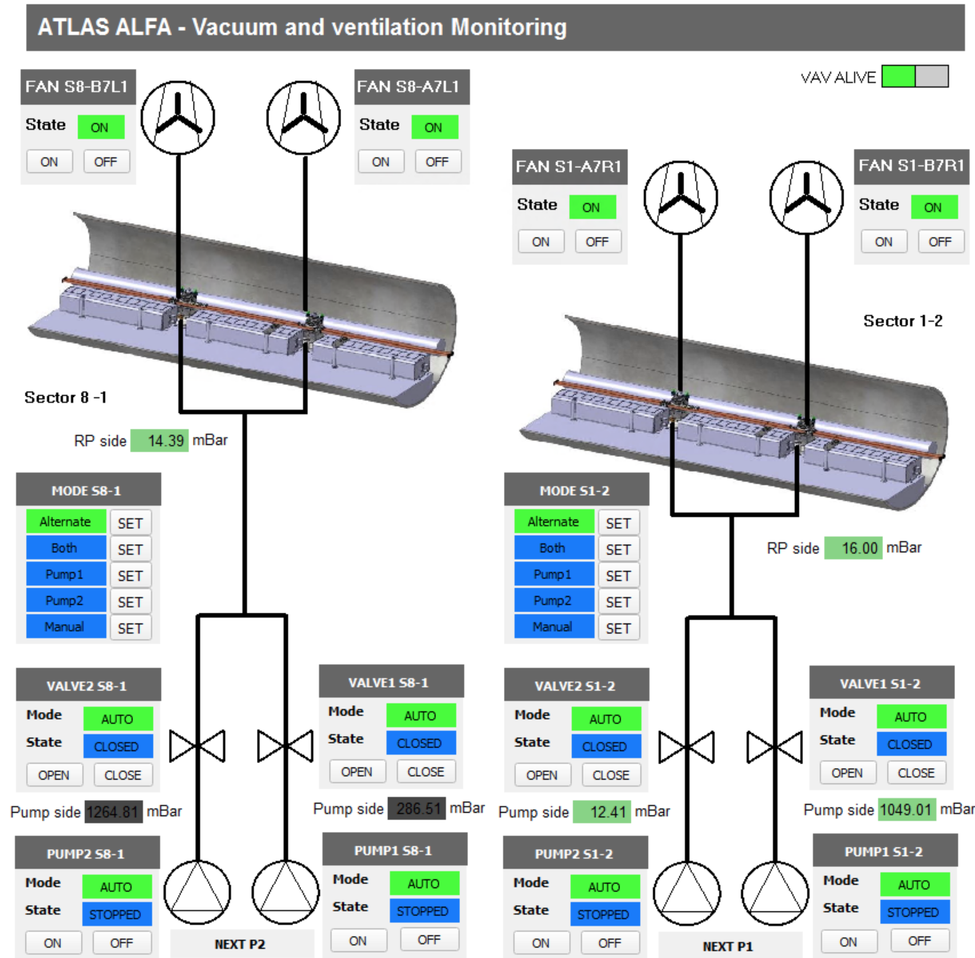
- Signals if a variable is outside of a predefined range or in a good range
- Represents the Status of a component
- Different levels:
  - OK
  - WARNING
  - ERROR
  - FATAL



Graphical User Interface (panels)

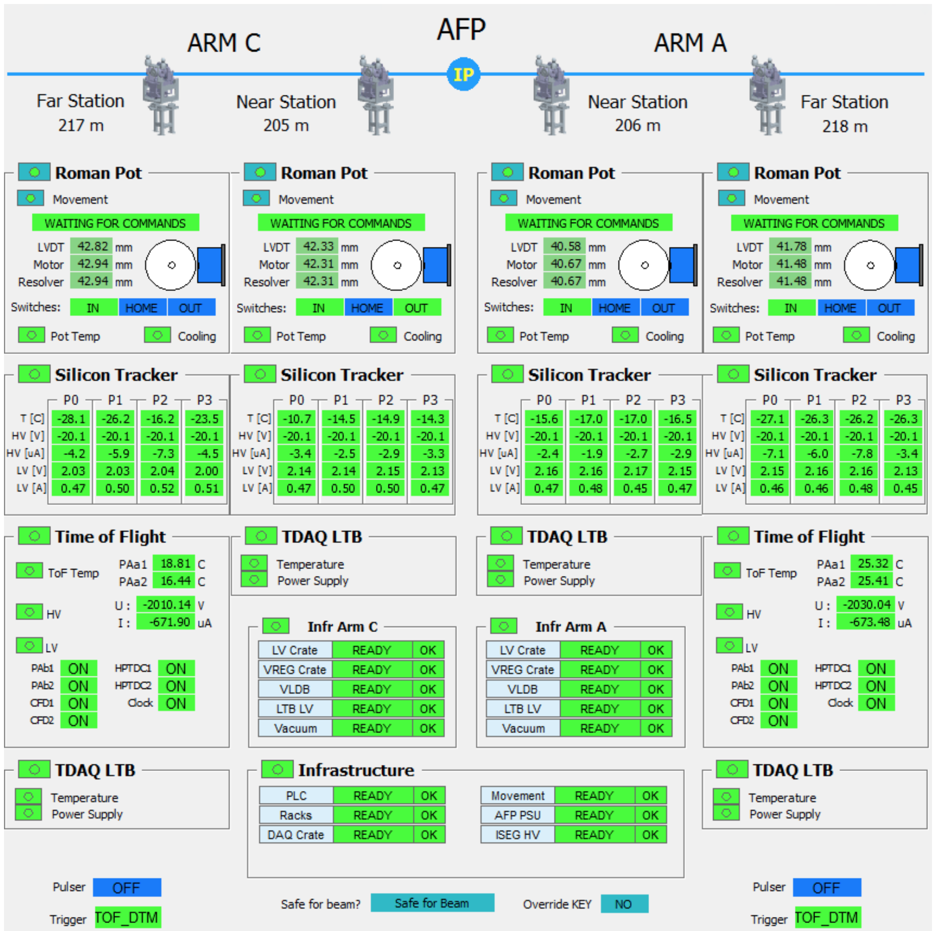
- Monitor detector parameters
- Possible to execute tasks by user command
- Technical Panels:
  - Monitor/control detector sub-systems
  - Complex actions that require special monitoring
  - Additional information
  - System tests/debug
  - For expert use

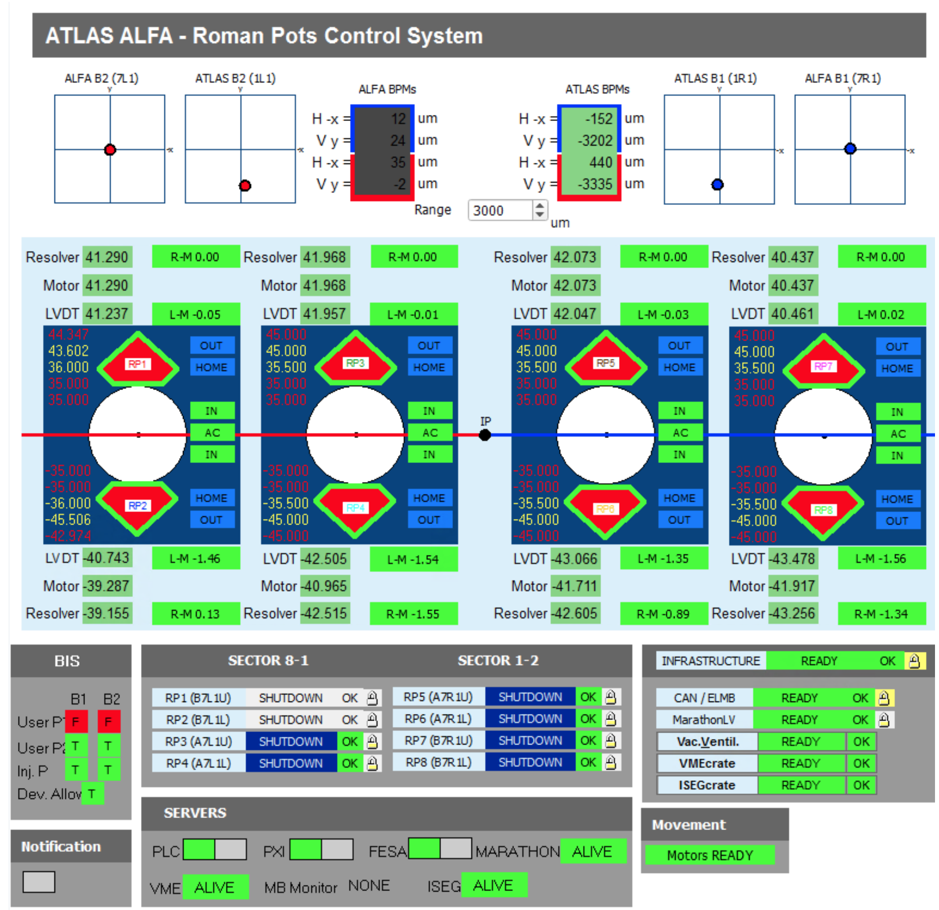




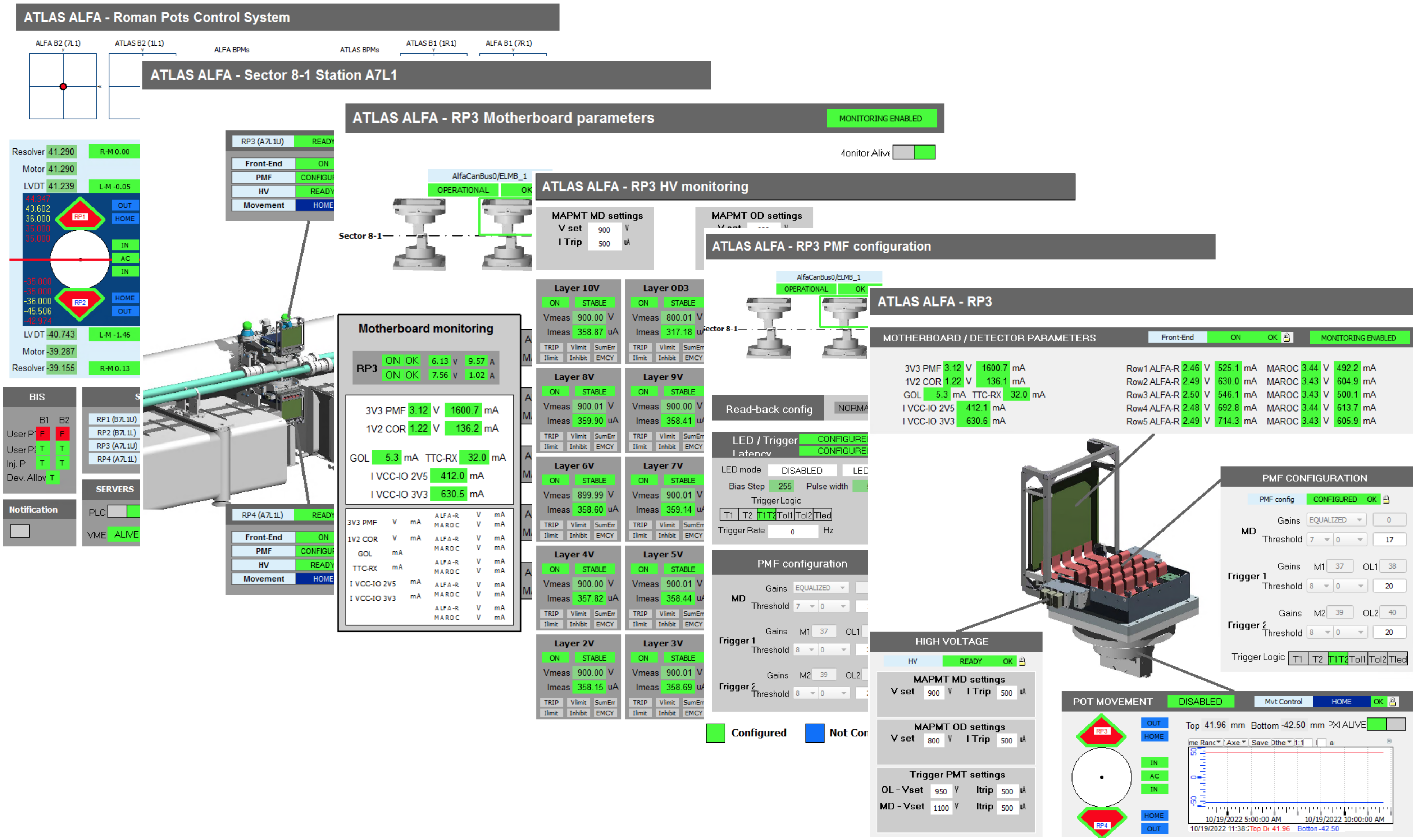
Graphical User Interface (panels)

- Monitor detector parameters
- FSM Panels:
  - Display only essential information during data taking
  - No actions available/visible for non-expert



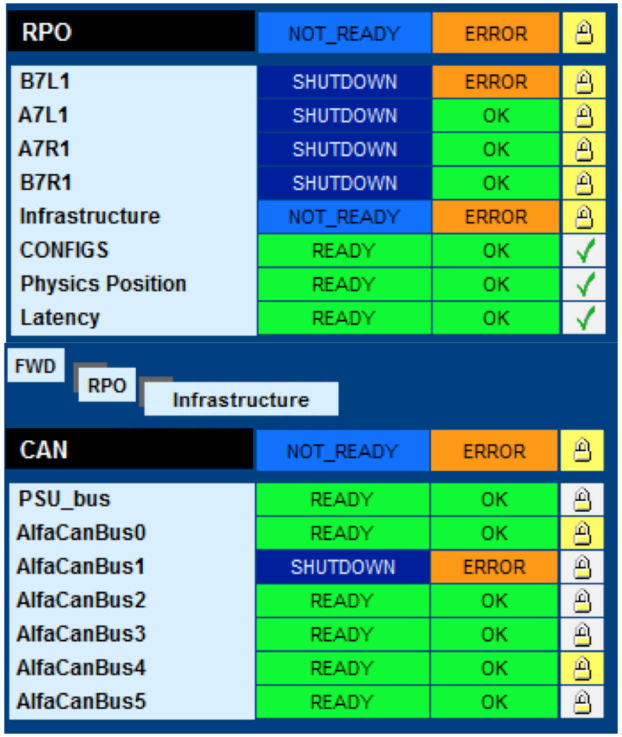


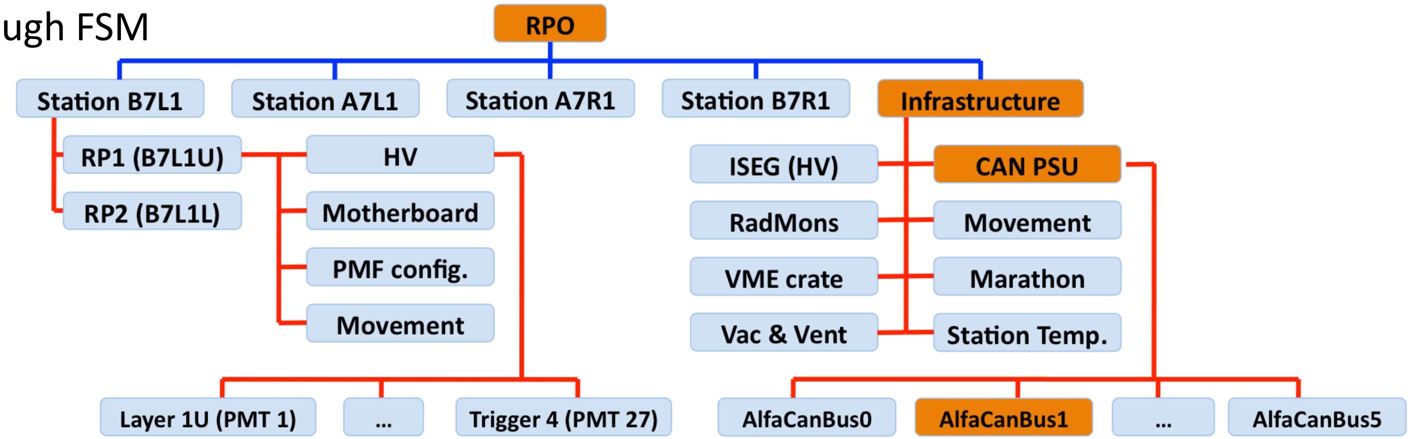
Graphical User Interface (panels)



Finite State Machine (FSM)

- Abstract representation of an experiment
- Monitor and control a huge number of parameters
- DCS Front-End (FE) correspond to FSM Device Units:
  - Calculate States based on detector components states
  - Calculate Status based on alarms
  - Commands setup for detector operation
- DCS Back-End (BE) is mapped onto a hierarchy of FSM elements (Control and Logical Units)
  - State/Status based on children's State/Status
- States and status are propagated upwards
- Commands are propagated downwards
- Main detector operation through FSM





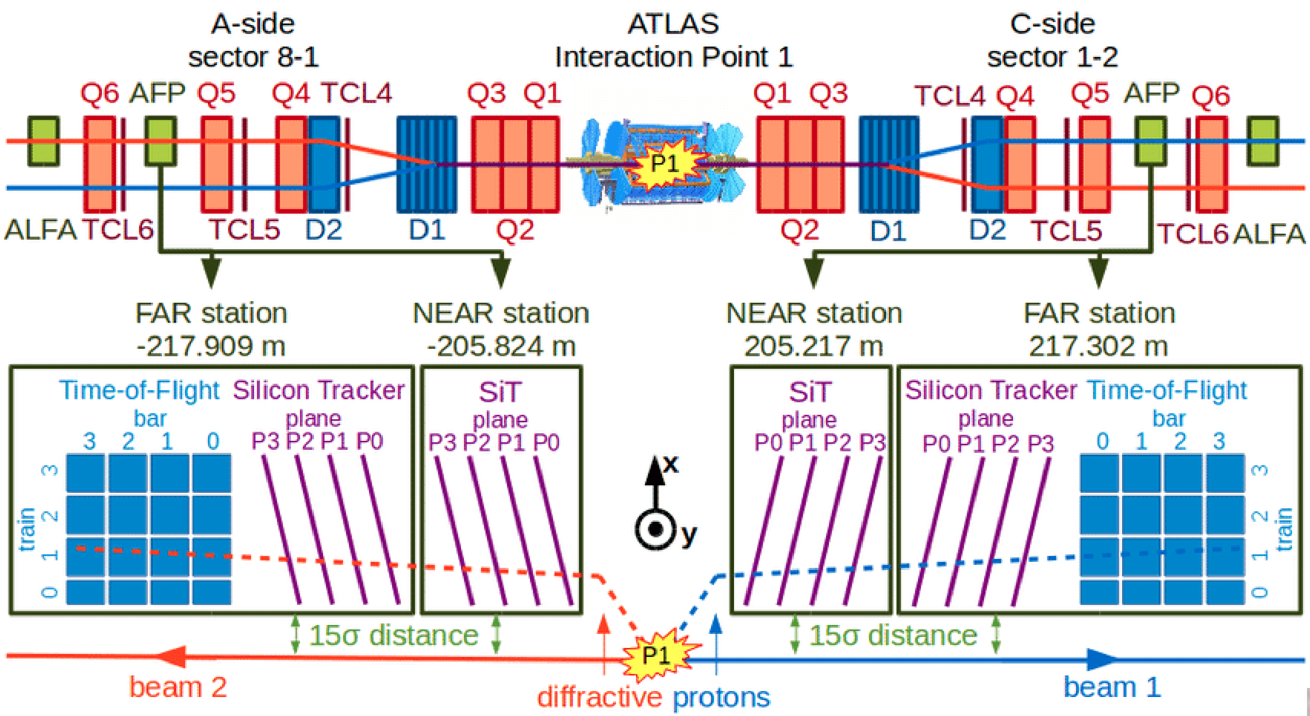
Finite State Machine (FSM)

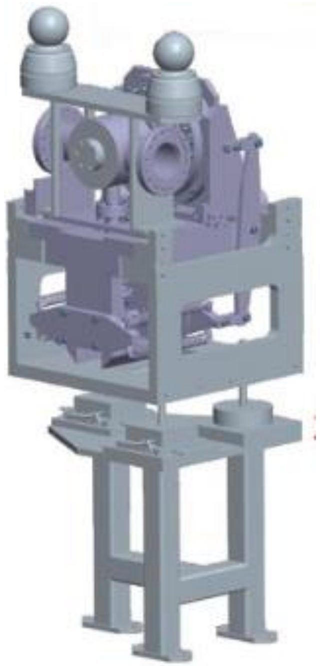
ATLAS Roman Pots (ARP)

ARP = ALFA + AFP

- “Similar” detectors
- People working on both detectors
- LIP responsibility in Forward DCS:
    - Full responsibility in ALFA
    - Deputy in AFP (Movement, Vacuum and cooling systems)

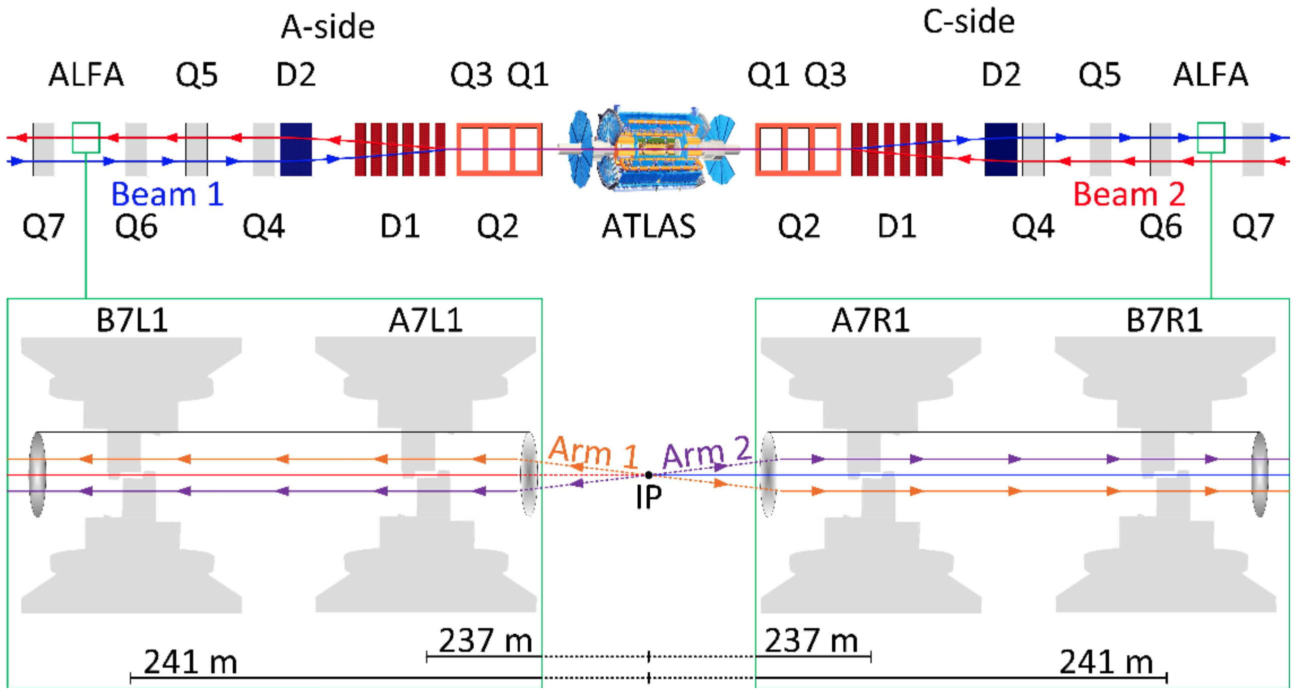
ATLAS Forward Protons (AFP)

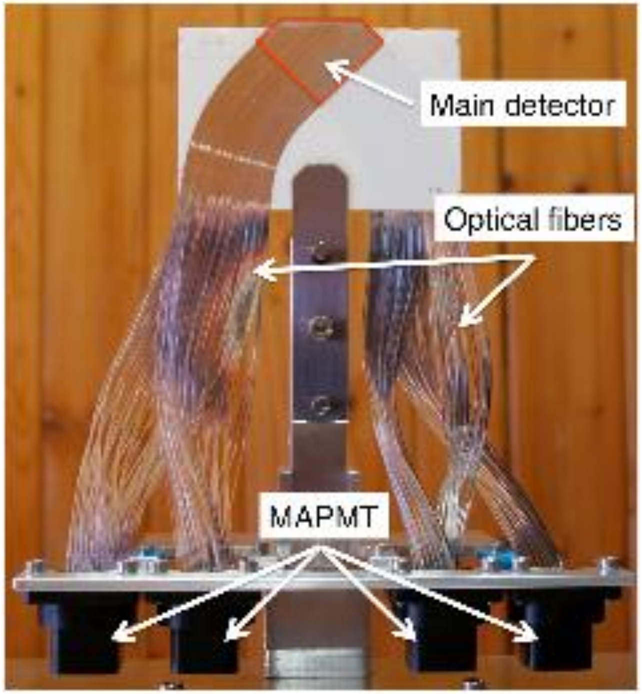




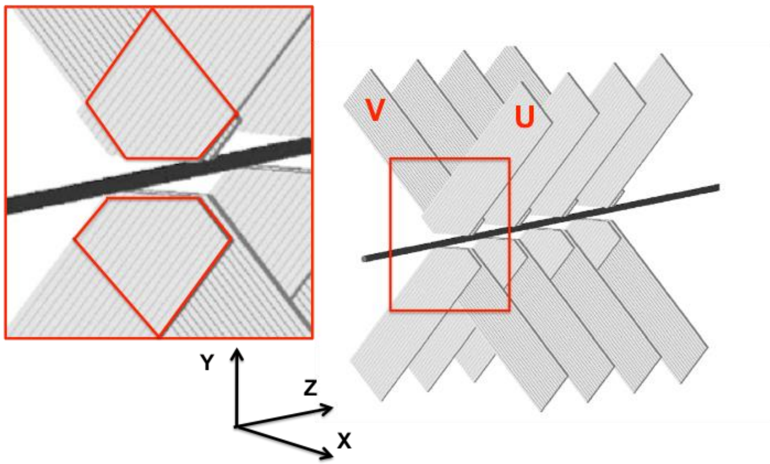
- Sub-detector of the ATLAS experiment
- Tracking (SiT) + Timing (ToF) detector
- SiT with 4 silicon sensors planes in each station
- ToF with 44 L shape Quartz bars readout by PMT in FAR stations only
- Both detectors inside a Roman Pot
- Independent horizontal movement

Absolute Luminosity For ATLAS (ALFA)





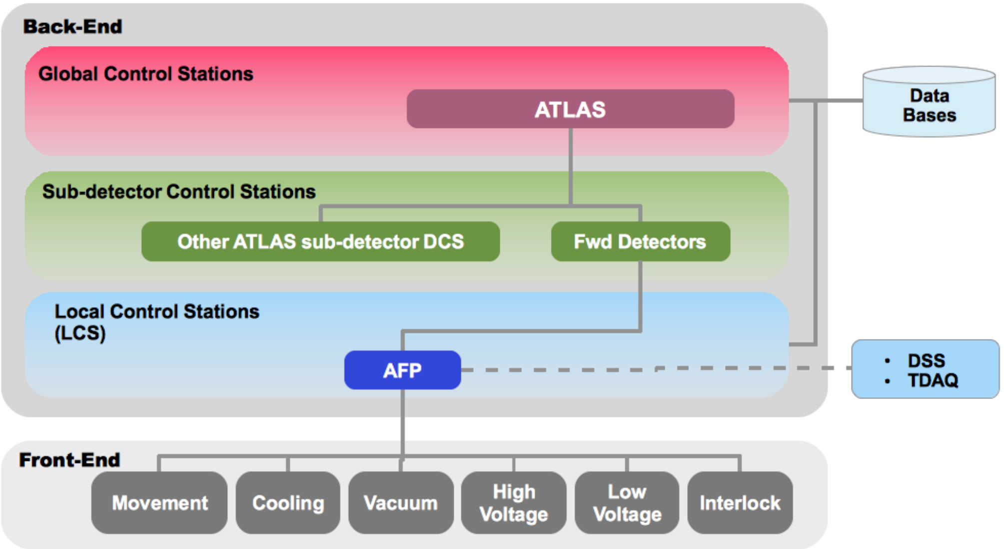
- Sub-detector of the ATLAS experiment
- Scintillating optical fibers arranged in a UV geometry
- Read-out from a multi-channel PMT (32 channels) MAPMT
- Each fibers to a single PMT channel
- Composed by Main detector and Overlap detector
- Detector inside a Roman Pot
- Independent vertical movement



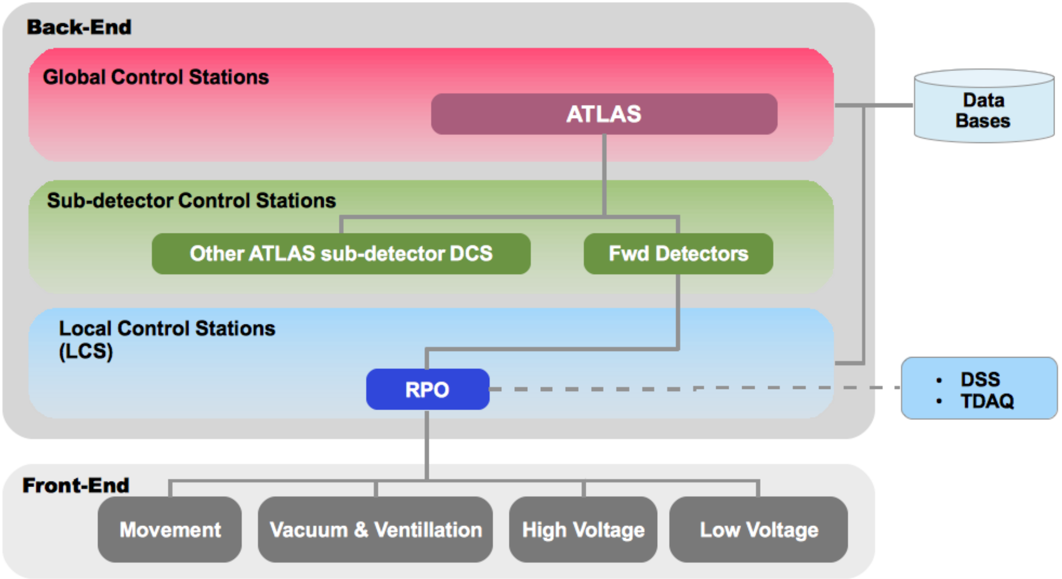
ARP DCS Overview

- One Machine (LCS) with a single WinCC OA project
- CAN-USB interfaces (Systec + PEAK)
- Linux CC7 OS and WinCC OA 3.16
- Data from Front-End includes, voltages, currents, temperatures, states, etc
- Only a few thousands of monitoring/control channels
- **Large variety of Front-End systems**

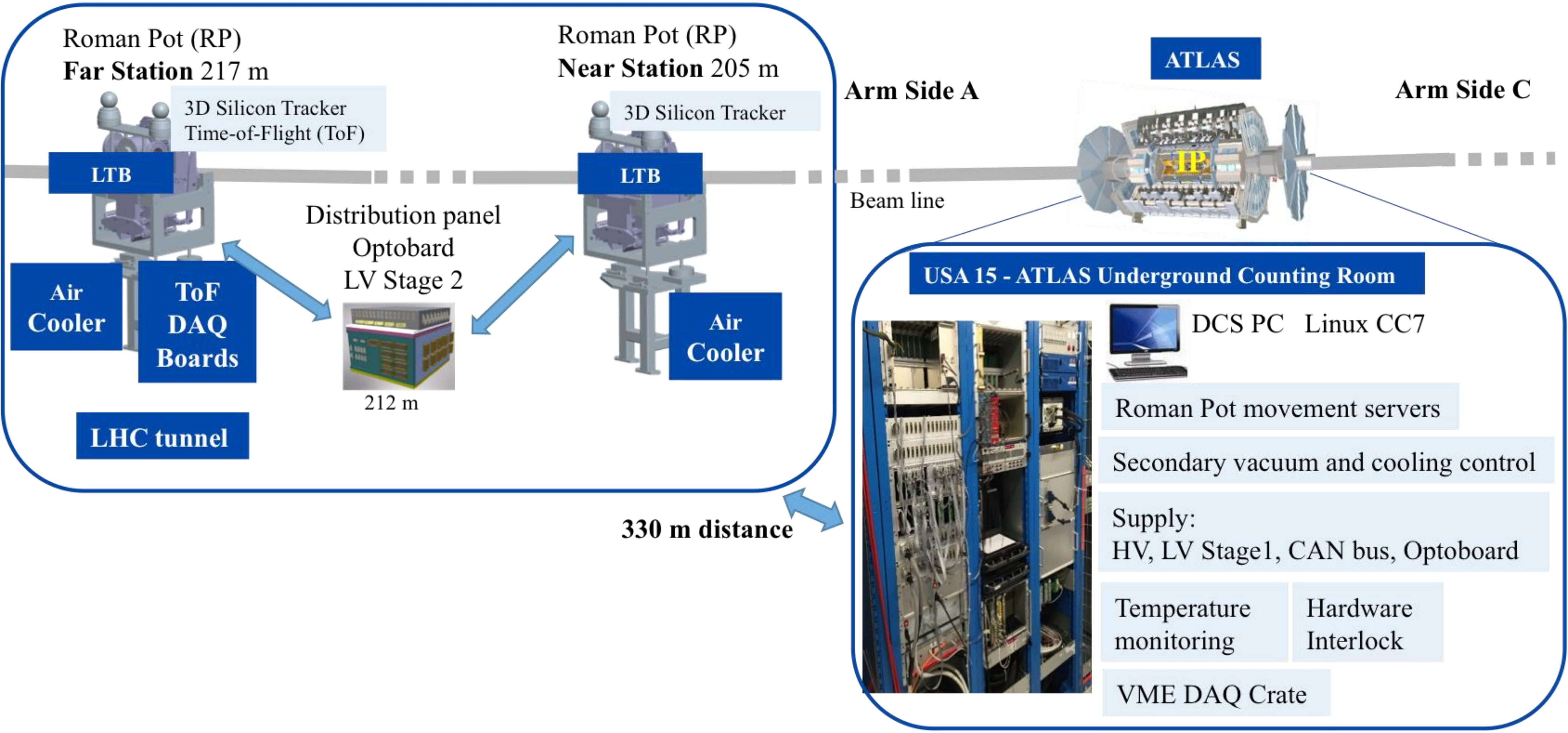
AFP



ALFA

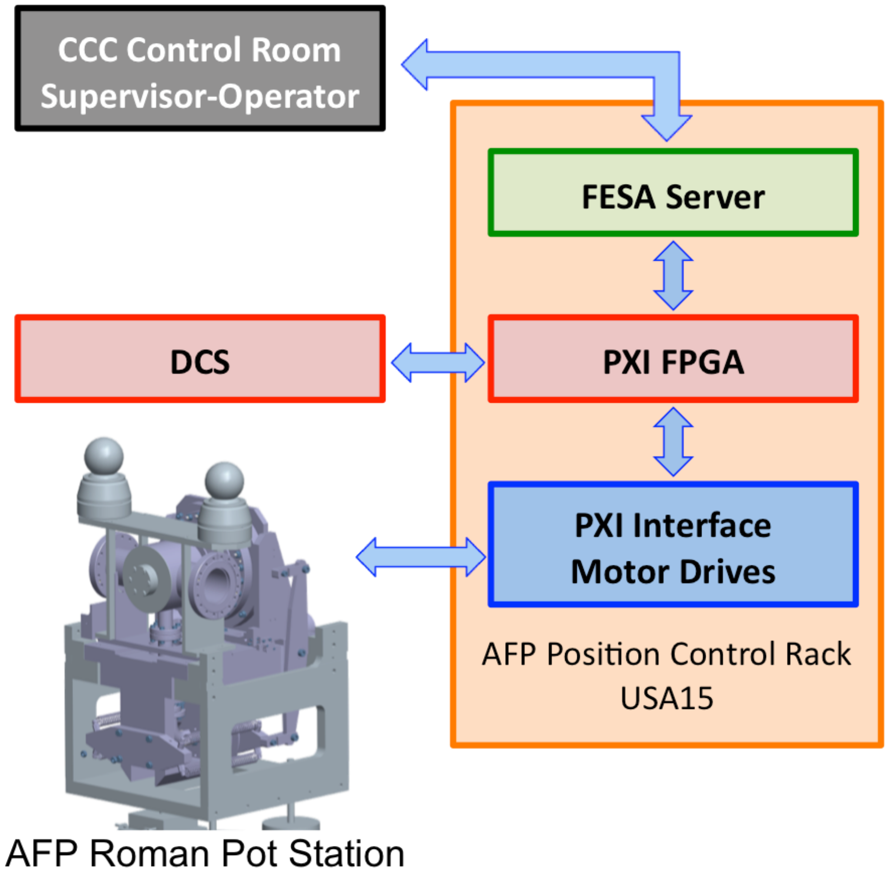


AFP Hardware supervised by DCS



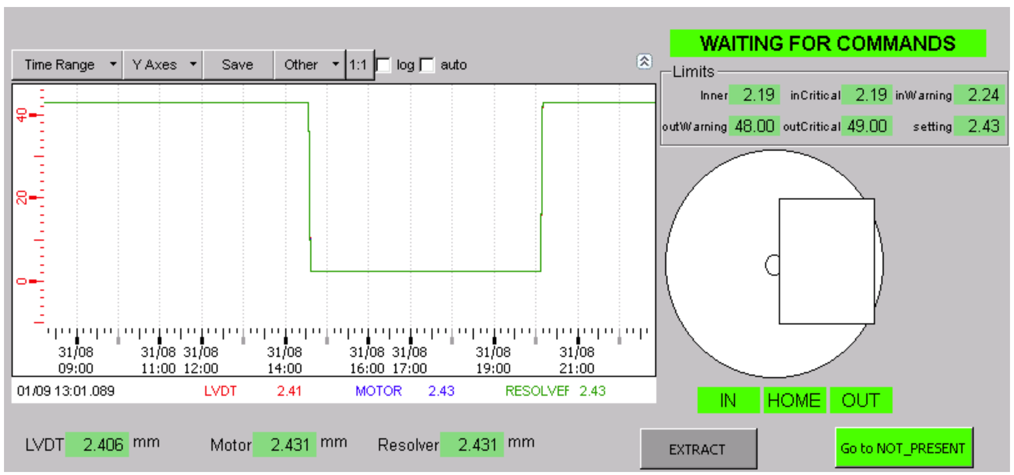
Movement System

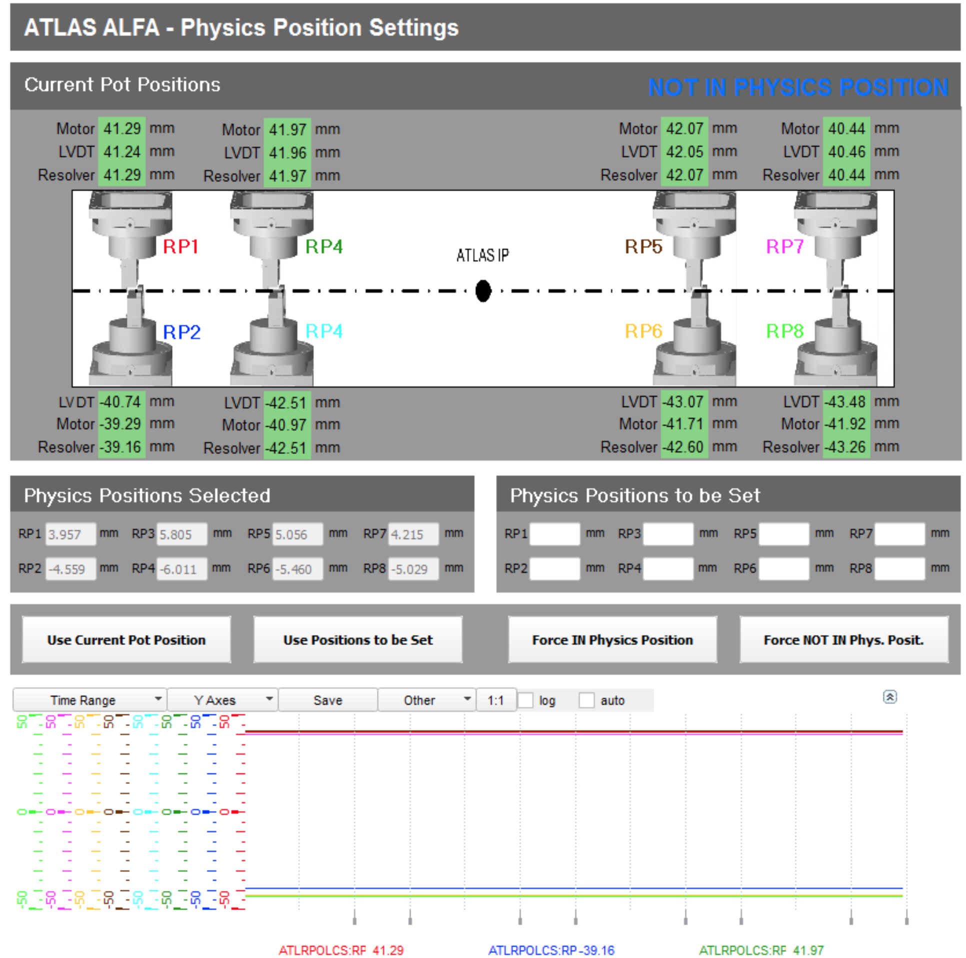
- DCS monitors the Roman Pots (RPs) positions inside the LHC beam pipe
- Similar for both AFP and ALFA
- Independent horizontal (AFP) and vertical (ALFA) movement of 5 micro meters step
- Toggle switches for movement range/limits and electrical stop switch for calibration
- Two systems involved:
    - National Instruments PXI for motors
    - Front-End Software Architecture (FESA) server for DIM DNS host
- DCS in the movement system:
    - Monitors RPs positions and states
    - Disables movement
    - Extracts RPs with springs in case of emergency



Movement System

- Position information given by:
  - LVDT (Linear Variable Differential Transformer)
  - Step motor
  - Resolver
- Mismatch alarms if different readings from different measurement systems
- Good position for physics data tagged by DCS



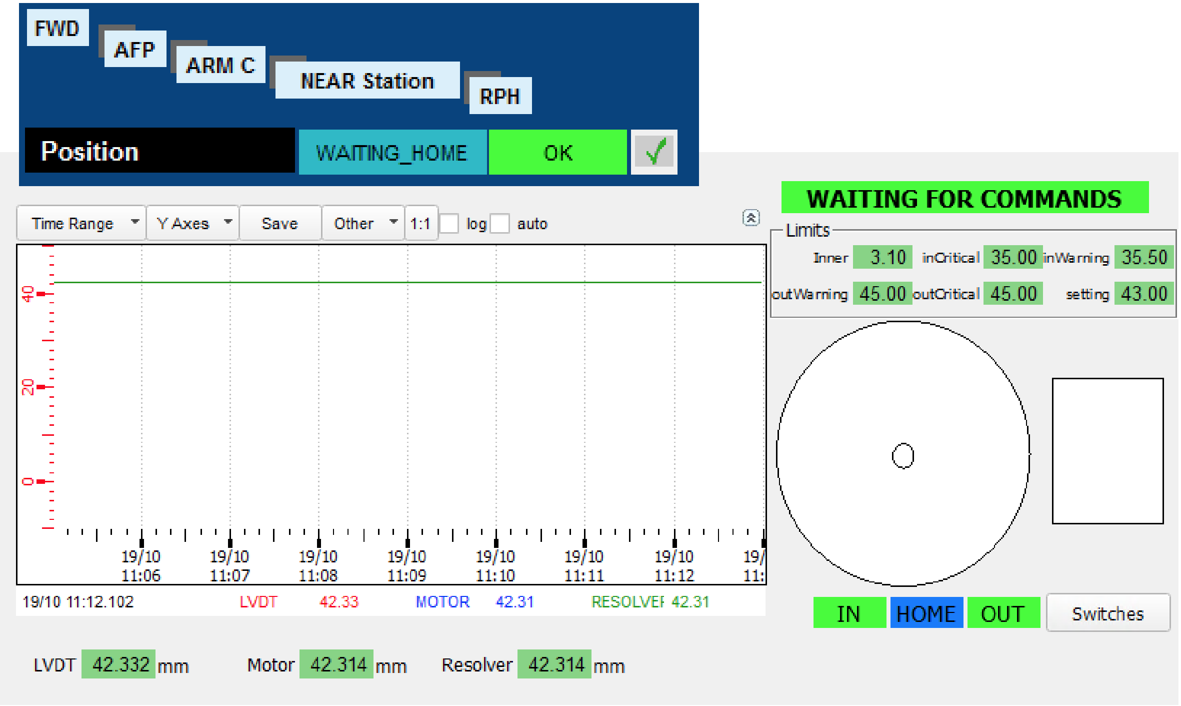


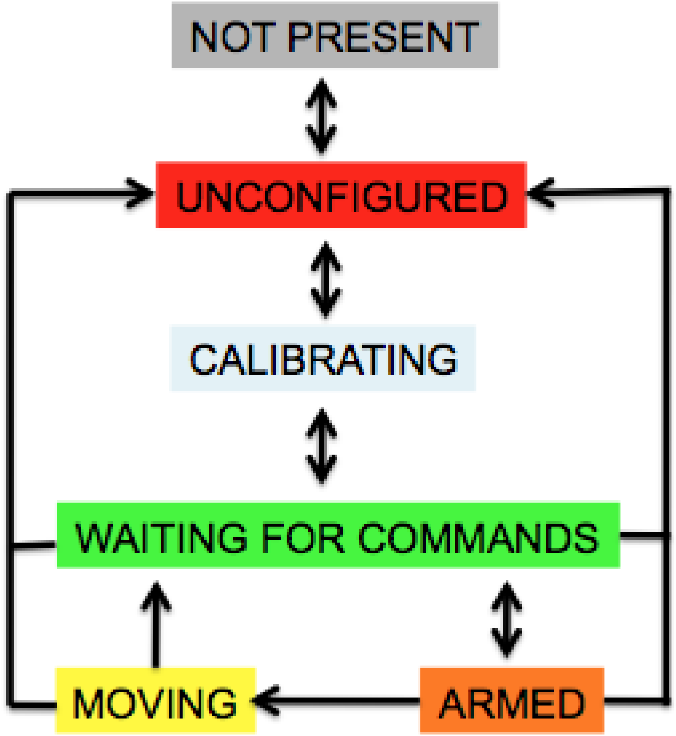
Movement System – State evaluation

- Movement state and switches will be used the calculate FSM state for the movement system in the DCS
- Pots movement follows a sequence
- ALFA and AFP have different state calculation
- AFP only in READY state when Pots inserted

Pots in HOME

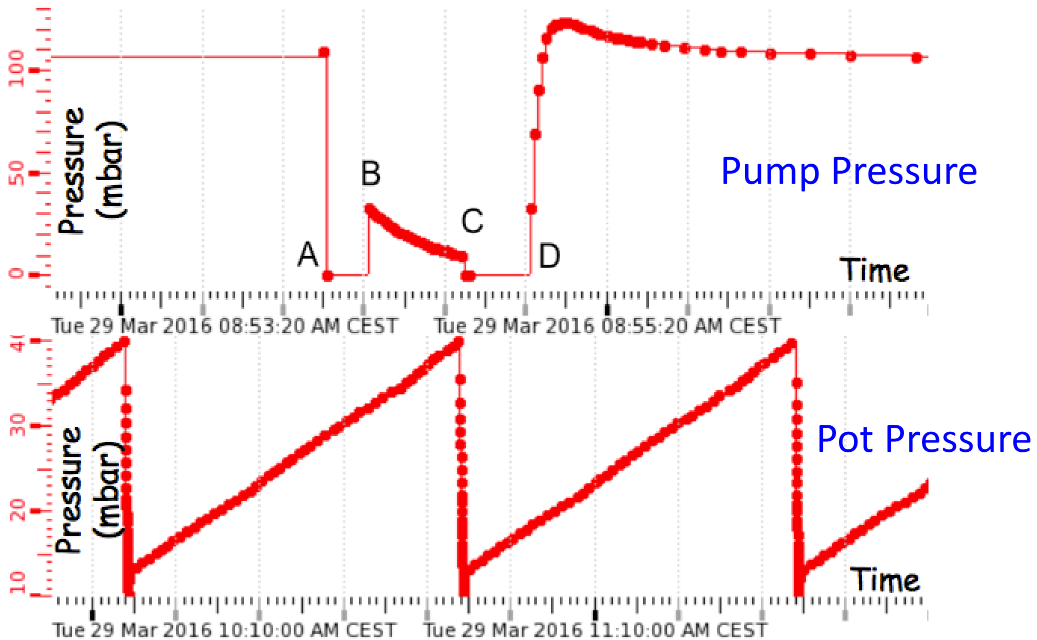
Pots IN

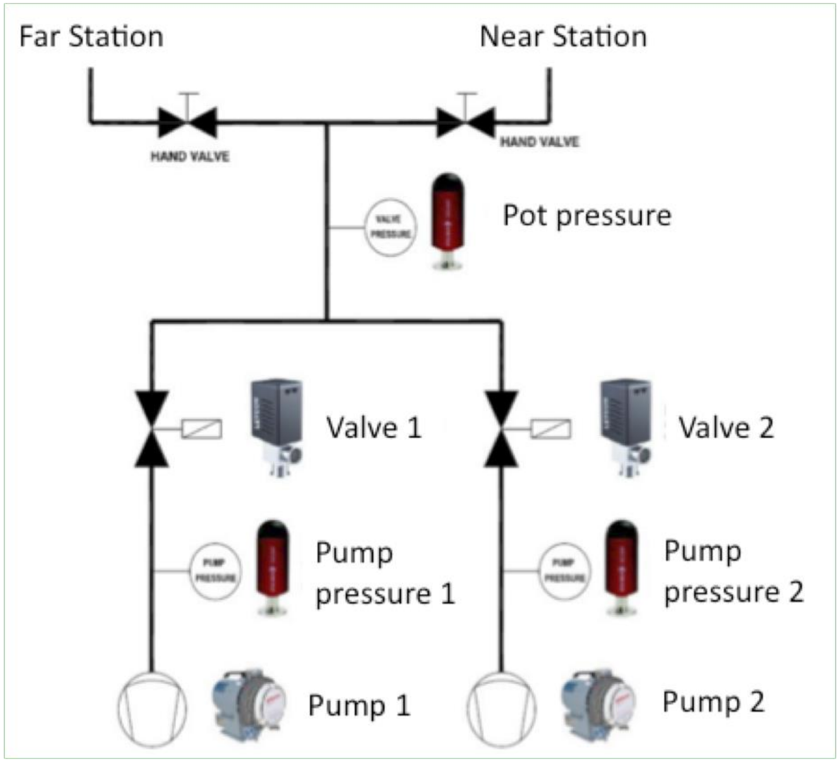




Secondary Safety Vacuum

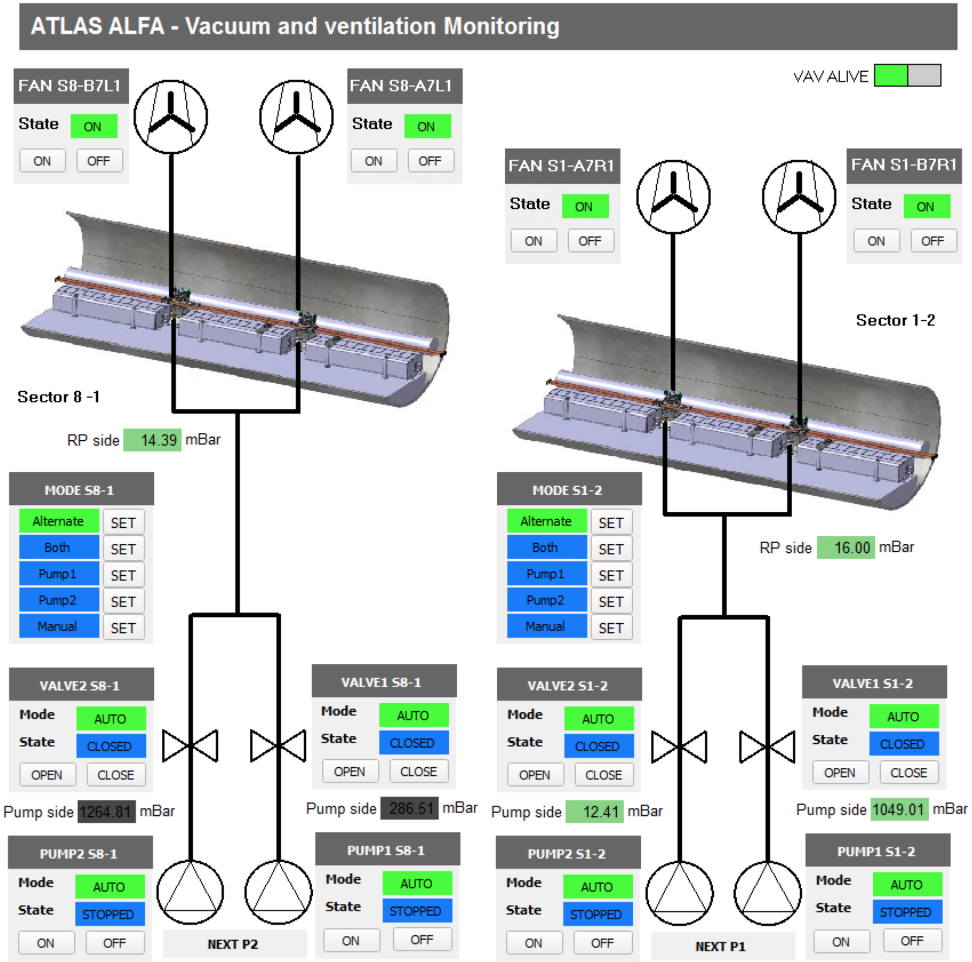
- Protection against the LHC high vacuum and icing inside the Roman Pot (RP)
- Similar for ALFA and AFP
- Independent vacuum in each arm: 10-40 mbar (AFP) and 10-20 mbar (ALFA)
- Redundant components to increase durability and cope with failures
- Control and Monitoring through a Programmable Logic Controller (PLC)





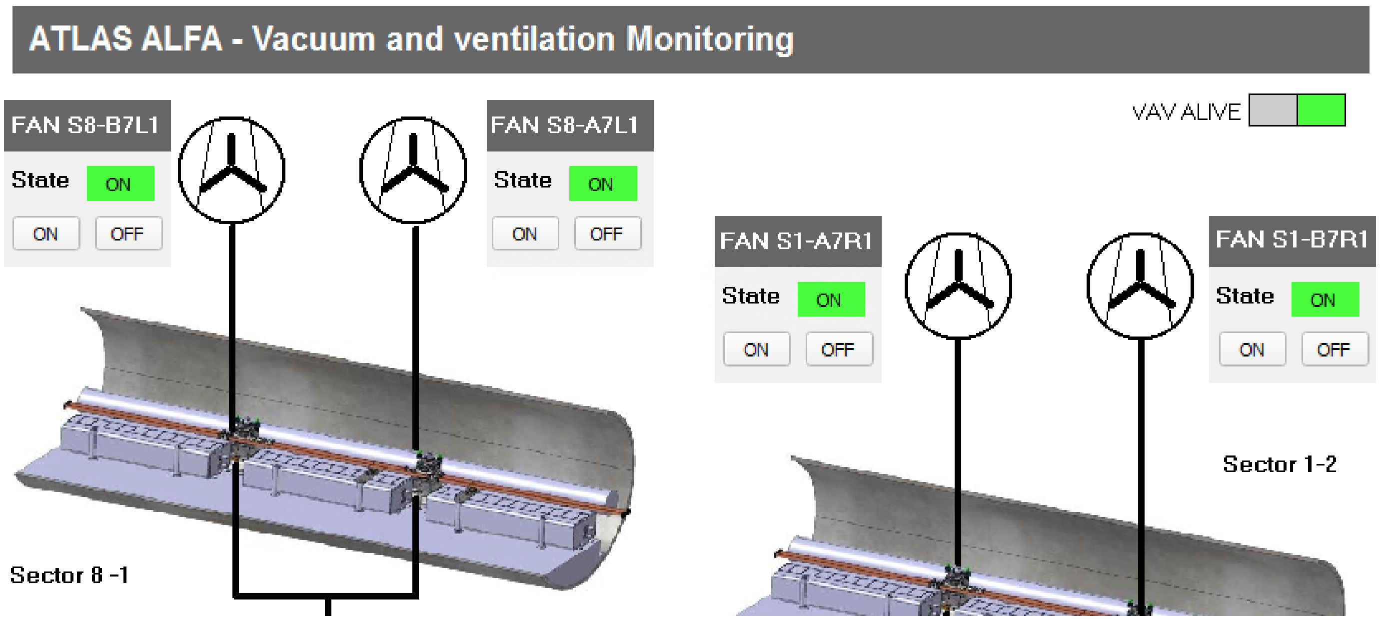
Secondary Safety Vacuum

- AFP uses PLC S7-1200 from Siemens
  - Communication between the PLC and the DCS through the WinCC OA S7 driver via TCP/IP
- ALFA uses PLC S7-100 from Siemens (very old)
  - Communication between the PLC and the DCS through OPC DA server in a machine outside ATLAS network connected through DIP
- DCS in the secondary vacuum system:
  - Monitors pressure at Pump and RP
  - Monitors Pumps and Valves states
  - Selects the mode in which the PLC will work
  - Allows full system control if in Manual mode
- Pumping rate monitored
- Interlock system in AFP: Extract pots in case of vacuum failure
- Notification via e-mail and SMS in case of alarm



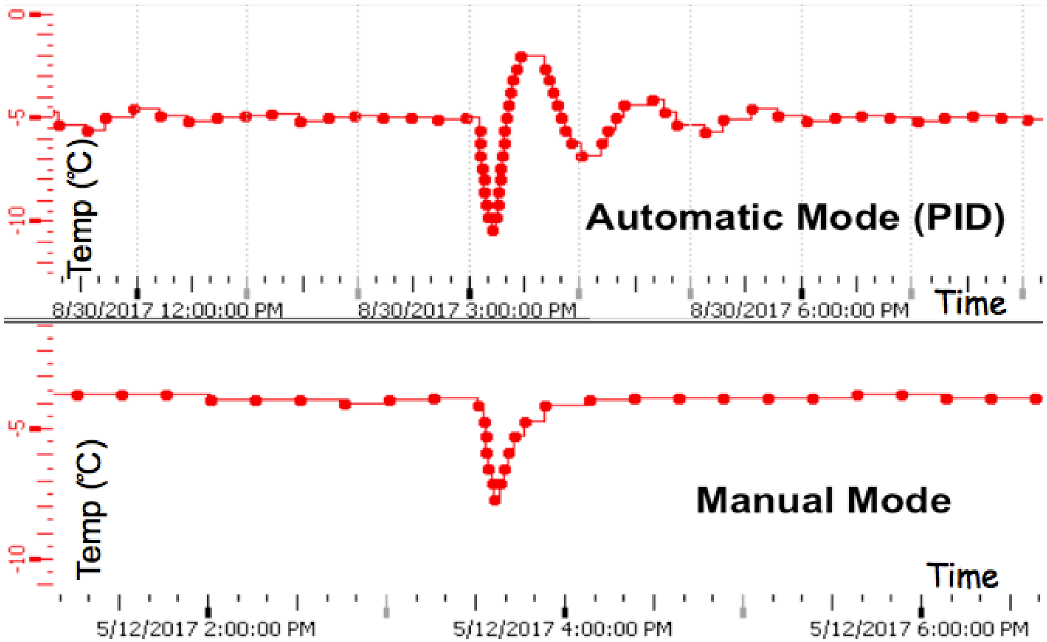
Cooling System

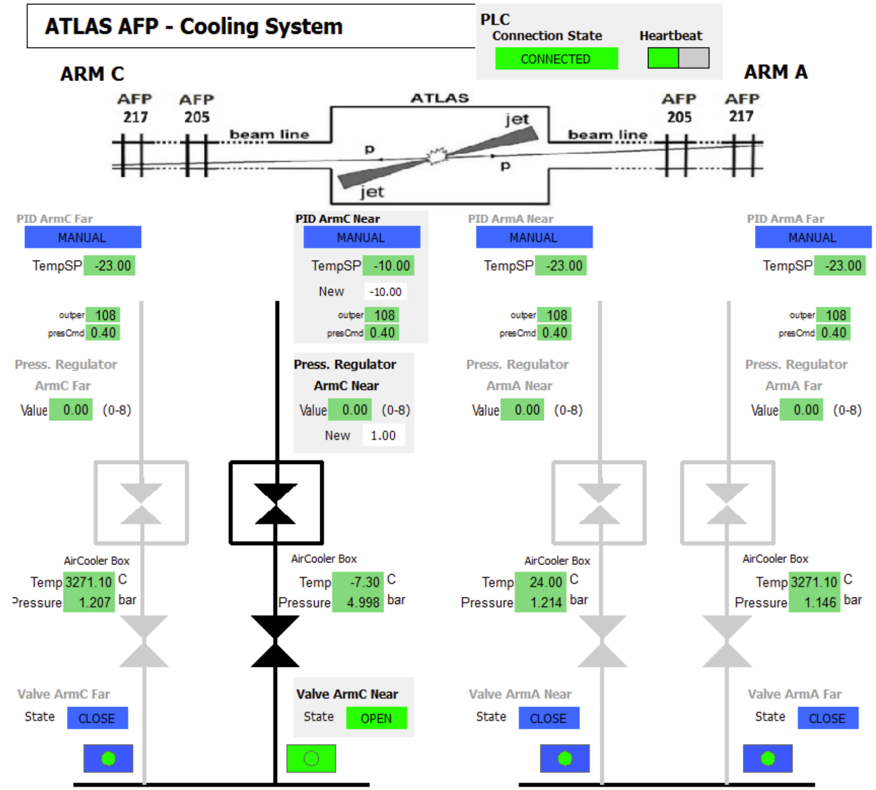
- Cooling of the electronics and detectors
- Both system are controlled and monitored by PLC (same as vacuum)
- ALFA uses fans and AFP a Dry Air Vortex Cooling System (next slide)
- In ALFA no electronics is inside Roman Pot
  - Roman Pot Filler is used to conduct heat
  - Ventilation is provided to PMTs box and Motherboards



AFP Cooling System

- Cooling of the electronics and detectors
- Heat conducted to a Heat exchanger inside the Roman Pot
- Cold air provided by Dry Air Vortex Cooling System (AirCooler) controlled and monitored through the PLC
- Manual mode: full operator control
- Automatic mode: PLC control through a PID (Proportional Integral Derivative)



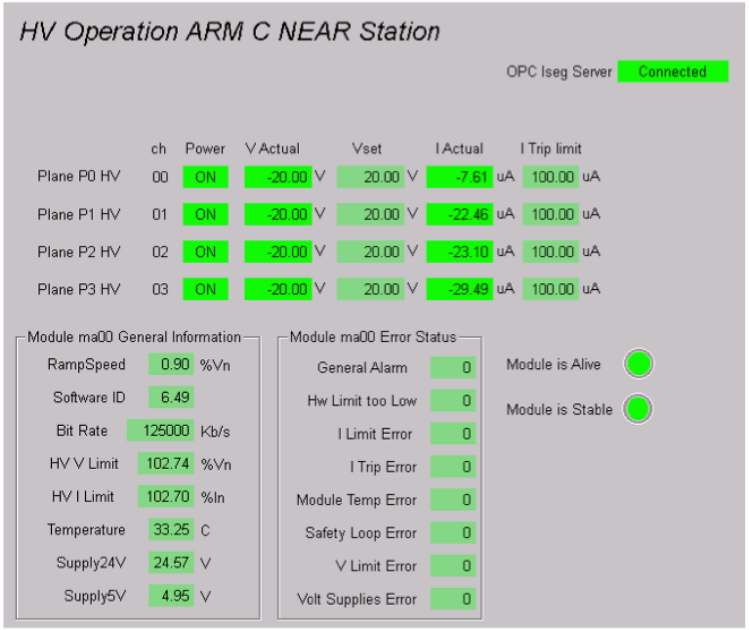


- AFP DCS in the cooling system:
  - Controls and monitors electrovalves
  - Monitors temperature (PT 1000)
  - Monitors air pressure before AirCooler
  - Sets operation mode (Automatic/Manual)

AFP Power Supply

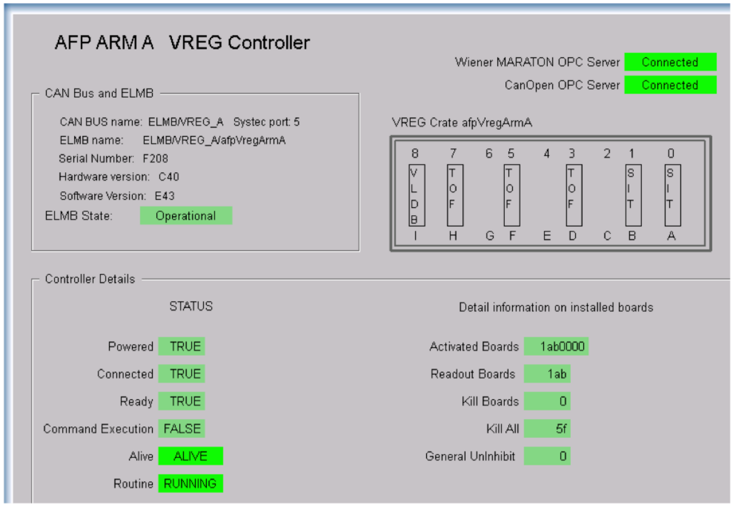
High Voltage (HV)

- HV to SiT sensors and ToF PMTs
- ISEG HV system:
  - ECH 238 crate
  - EHS F405n module (-500V) for SiT
  - EHS F430n module (-3000V) for ToF
- CAN-controlled with OPC UA server



Supply Control - OptoLink (SCOL)

- For optoboard modules (3 voltages)
- In USA15 and ELMB controlled



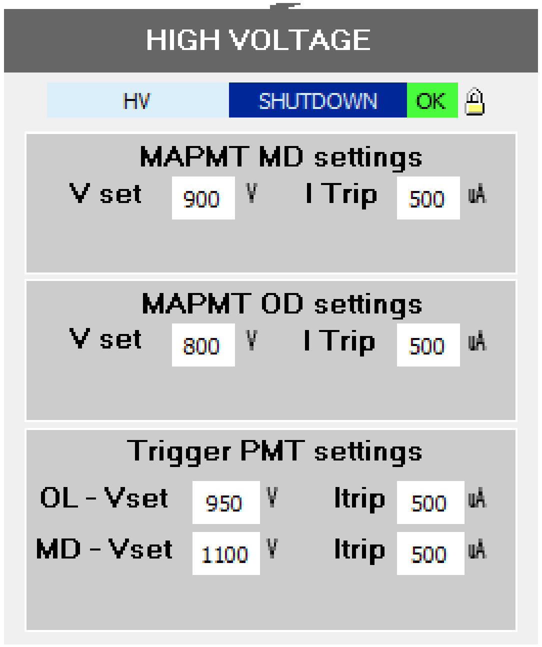
Low Voltage (LV)

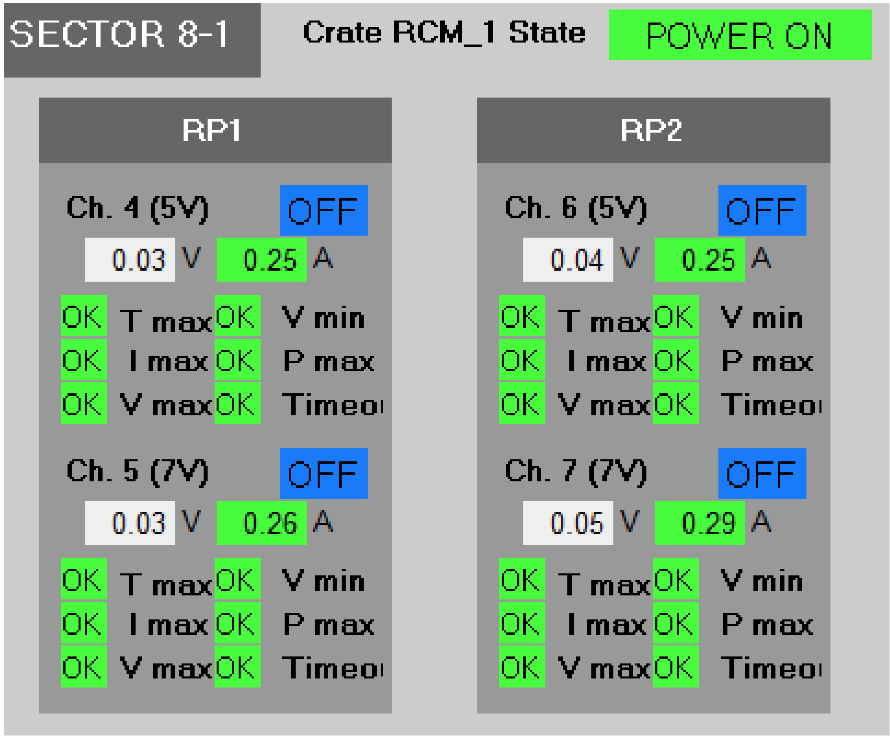
- 1st stage: Wiener PL512 power supply + LVPP4 crate located in USA15 (12 X 4 channels)
  - Ethernet controlled with OPC UA server
  - Current measurement with ELMB
- 2nd stage: Low Voltage Regulator (VREG) Crate + VREG Controller located on the tunnel
  - CANbus controlled through ELMB

ALFA Power Supply

High Voltage (HV)

- HV to 23 MAPMT + 4 Trigger PMTs
- ISEG HV system:
  - ECH 238 crate
  - 8 X EDS 20 module (3000V)
- CAN-controlled with OPC UA server





Low Voltage (LV)

- 2 front-end crates provide the (5V and 7V) to the front-end electronics (motherboards)
- 2 rectifiers (PFC, one per side) provide regulated input voltage to the front-end crates
- 2 controllers in the VME crate allow remote control and monitoring of the front-end crates
- Ethernet-controlled with OPC UA server

AFP Temperature monitoring and Interlock Matrix Crate

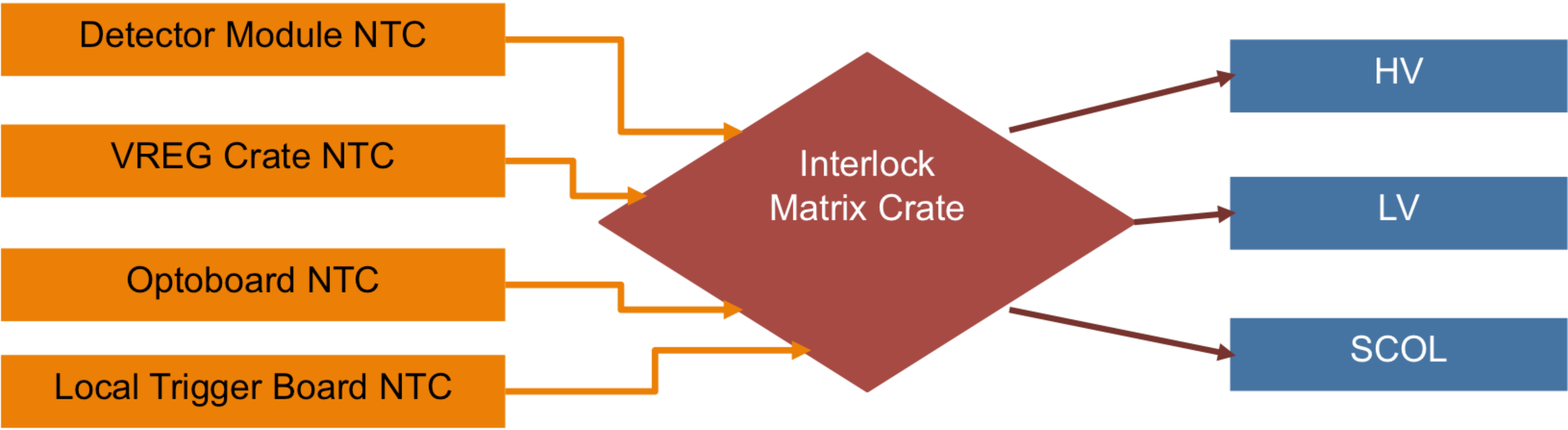
Temperature monitoring

- Temperature sensors (NTC's):
  - Inside the pots (wall, SiT planes, heat exchanger, ...)
  - Station (Stepper motor and Local Trigger Board)
  - Air Cooler, Optoboard, VREG
- CANbus monitored through ELMB

Interlock Matrix Crate

- Interlock system for the LV Wiener PL512 and HV Iseg
- Triggered if a temperature exceeds a threshold value
- CANbus controlled through ELMB

All power supplies are interlockable



ALFA Temperature monitoring and RadMons

Temperature monitoring

- Temperature sensors (PT100):
  - Inside the pots (wall and detector)
  - Station (PMT box, Motherboard, etc)
  - Beam pipe
- CANbus monitored through ELMB

ATLAS ALFA - Temperature monitoring of stations

Top Detector	B7L1	A7L1	A7R1	B7R1	
Detector Sensor1	26.2	20.9	23.2	21.8	oC
Detector Sensor2	15.1	20.9	23.1	21.8	oC
BlackBox PMF1	14.9	19.9	29.3	28.7	oC
BlackBox PMF19	14.8	20.0	26.7	26.5	oC
BlackBox PMF23	1.9	20.4	26.8	26.6	oC
BlackBox AirIn		19.6	23.3	21.5	oC
BlackBox AirOut	14.9	19.6	22.4	22.2	oC
Detector Outside baseplate	15.4	20.5	24.6	23.4	oC
Roman Pot1	15.6	21.0	23.4	22.3	oC
Roman Pot2	15.6	21.1	23.3	22.3	oC
Roman Pot3	15.7	21.0	23.3	22.2	oC
Roman Pot4	15.5	21.0	24.6	22.3	oC
Roman Pot5	15.7	20.9	23.3	22.0	oC
Roman Pot6	15.5	20.9	23.4	23.4	oC
Roman Pot Outside flange	15.7	20.7	22.5	21.1	oC

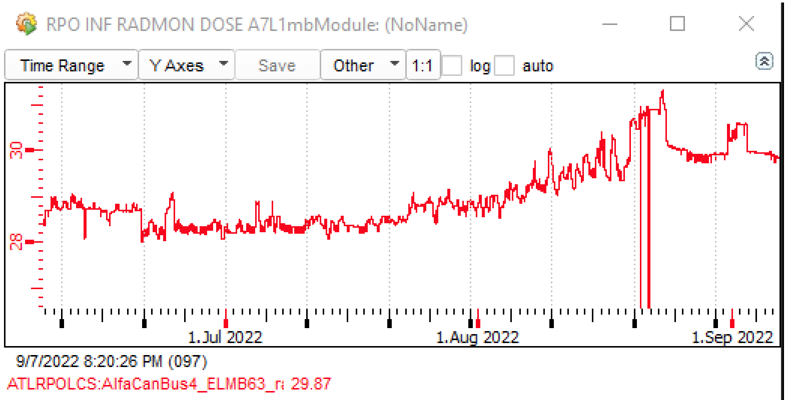
Bottom Detector	B7L1	A7L1	A7R1	B7R1	
Detector Sensor1	15.8	21.1	23.9	22.8	oC
Detector Sensor2	15.7	21.0		22.8	oC
BlackBox PMF1	16.1	20.3	28.3	26.9	oC
BlackBox PMF19	16.1	20.4	32.5	28.2	oC
BlackBox PMF23	16.2	20.6	38.0	32.2	oC
BlackBox AirIn	16.6	20.2	22.7	21.1	oC
BlackBox AirOut		19.9	23.2	22.1	oC
Detector Outside baseplate	15.9	20.9	23.3	21.9	oC
Roman Pot1	15.8	20.8	22.7	21.5	oC
Roman Pot2	15.8	20.9	22.6	21.4	oC
Roman Pot3	-7.0	20.9	22.7	21.4	oC
Roman Pot4	-10.9	20.8	22.6	21.5	oC
Roman Pot5	15.9	20.9	22.6	21.4	oC
Roman Pot6	16.0	20.8	22.6	21.4	oC
Roman Pot Outside flange	15.3	20.8	22.7	21.3	oC

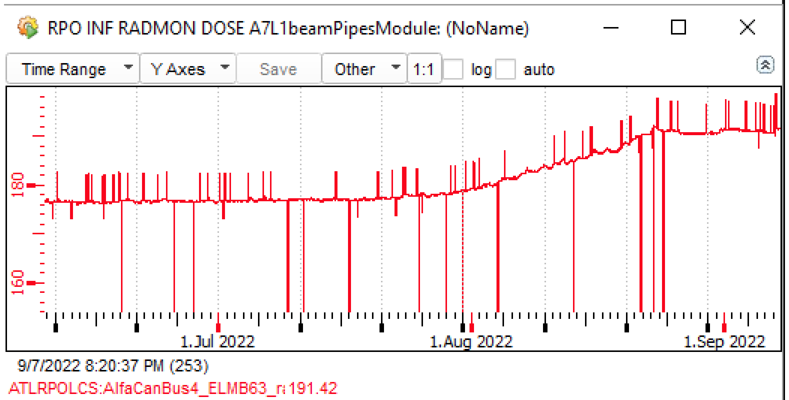
Tunnel	B7L1	A7L1	A7R1	B7R1	
Air	14.7	20.5	21.1	19.6	oC

Cross	B7L1	A7L1	A7R1	B7R1	
	15.5	20.5	22.0	21.0	oC

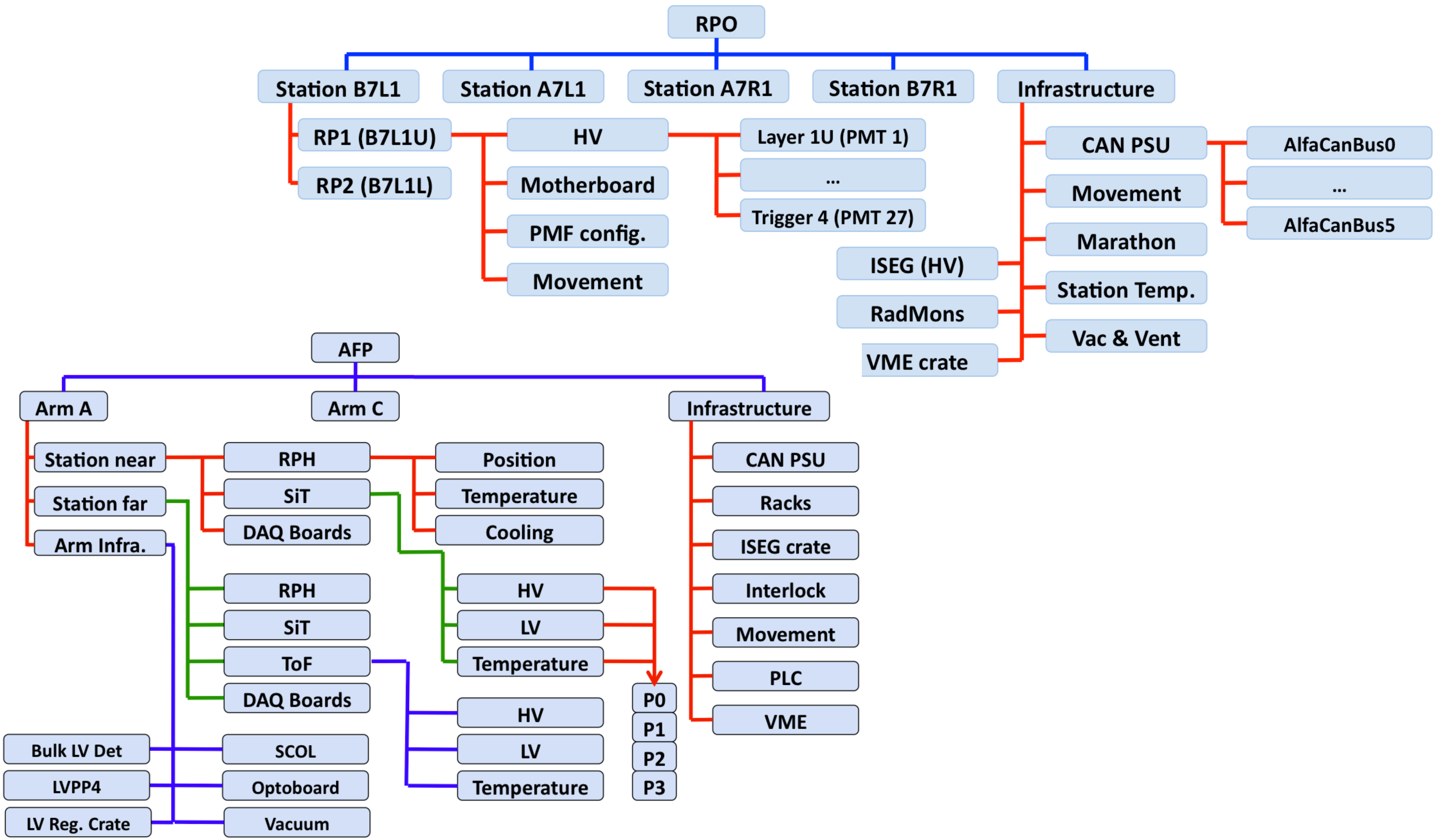
RadMons

- In one side (both stations and beam pipe)
- Readout every hour by a control script
- CANbus monitored through ELMB





ALFA and AFP FSM



ALFA Operation

- AFP runs continuously when ATLAS is taking data and when inserted
- ALFA runs in low luminosity runs (mostly OFF during the year)
- ALFA goes through a power ON procedure which takes several minutes
  - Switch Motherboards ON (LV)
  - PMF (PMT Front-End) configuration
  - Power ON to the PMTs (HV)
- Each powering ON/OFF set corresponds to a different FSM state

RPO	READY	OK	
B7L1	SHUTDOWN	OK	
A7L1	SHUTDOWN	OK	
A7R1	SHUTDOWN	OK	
B7R1	SHUTDOWN	OK	
Infrastructure	READY	OK	
CONFIGS	READY	OK	✓
Physics Position	READY	OK	✓
Latency	READY	OK	✓

RPO	FE_ON	OK	
B7L1	FE_ON	OK	
A7L1	FE_ON	OK	
A7R1	FE_ON	OK	
B7R1	FE_ON	OK	
Infrastructure	READY	OK	
CONFIGS	READY	OK	✓
Physics Position	READY	OK	✓
Latency	READY	OK	✓

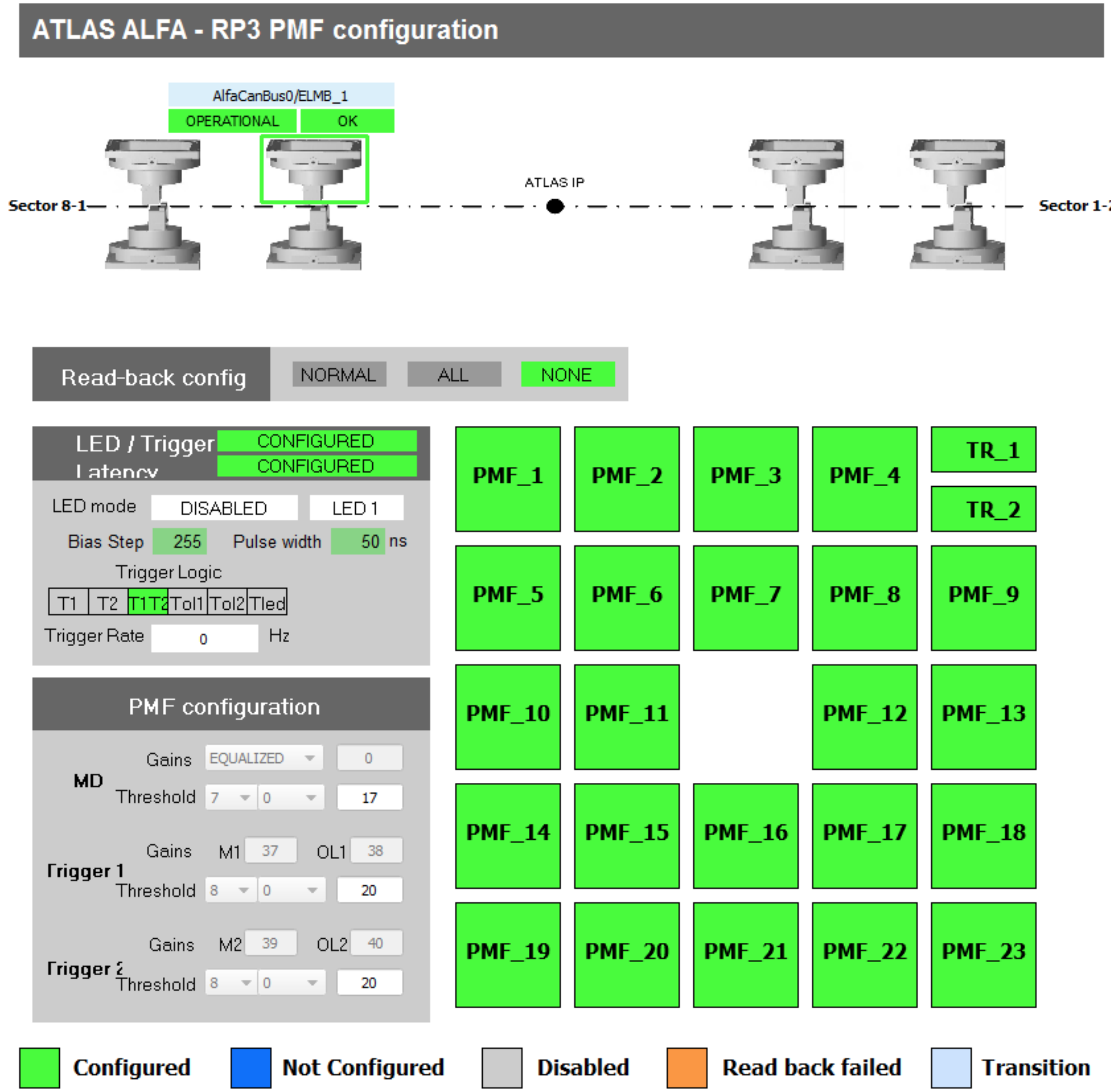
RPO	FE_READY	OK	
B7L1	FE_READY	OK	
A7L1	FE_READY	OK	
A7R1	FE_READY	OK	
B7R1	FE_READY	OK	
Infrastructure	READY	OK	
CONFIGS	READY	OK	✓
Physics Position	READY	OK	✓
Latency	READY	OK	✓

RPO	READY	OK	
B7L1	READY	OK	
A7L1	READY	OK	
A7R1	READY	OK	
B7R1	READY	OK	
Infrastructure	READY	OK	
CONFIGS	READY	OK	✓
Physics Position	READY	OK	✓
Latency	READY	OK	✓

ALFA Front-End Handling - PMF configuration

- Configuration of 23 FPGAs (one for each PMF) and two FPGAs in the trigger mezzanine
- Dedicated user interface (progress and check failures)
- Data sent to the FPGAs
  - PMF (gains, thresholds and control bits for each PMF)
  - Trigger (pattern, rate and latencies)
  - LED configuration (pulse width, voltage and mode)
- Configured through the serial peripheral interface of the ELMBs
  - Exchange of 16 bits words between ELMB and FPGA
- ReadBack test

- Motherboard readout and PMF configuration share the same CANbus so no MB monitoring during PMF configuration



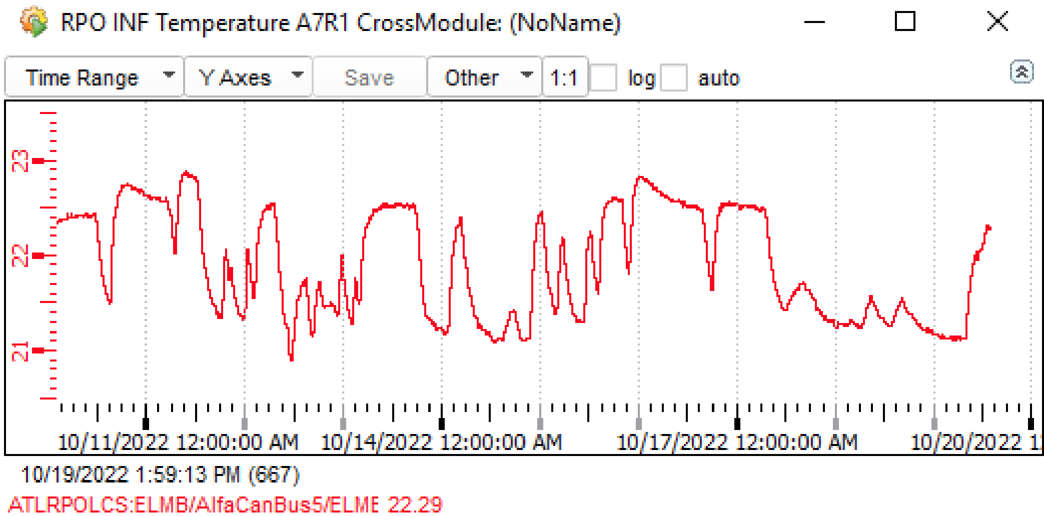
Archiving and notification

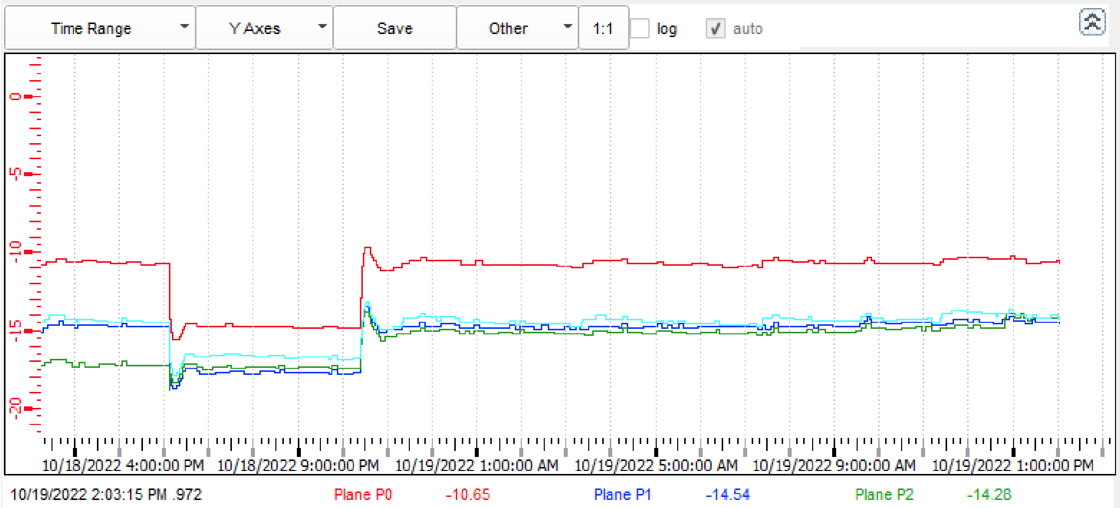
Data Archiving

- Relevant data related with the detector operation (voltage, currents, etc)
- Smoothing mechanism based on value and/or timestamps
- Online database - Oracle
  - Available inside ATLAS technical network
  - Online monitoring
- Offline database - COOL
  - Available outside ATLAS technical network
  - Physics analysis and data quality
- DCS Data Viewer (DDV)

Notification

- Provides e-mail or SMS notification
- Based in triggered alarms from critical systems





DCS data for analysis

- DCS data is stored manly for hardware debugging
- Other studies can be performed:
  - Relation between pressure (secondary vacuum) and showers
    - In the simulation we assume that pot bottom (thin window) is flat. However, this is only an approximation. Operational pressure of 5(10)-30(40) mbar results in bulging the window. In principle this may change the cross section (as the interaction area changes in shape and effective width) for having showers induced from station
  - Relation between pot temperature and showers
    - Similar to above, the heat may change the length of pot moving its bottom closer to the beam. In such case probability to have shower may increase
  - Impact of temperature on SiT efficiency
    - SiTs are actively cooled (PID algorithm), but the temperature is not perfectly stable. It would be interesting to check if there is a correlation between hit multiplicity in a given plane and temperature on module.
  - Impact of HV on SiT efficiency
    - When in the run, HV in one plane (out of 4) may be varied. Analysis should reveal the efficiency (wrt other 3 planes) as a function of HV.

Summary and final remarks

- WinCC OA provides the tools to build the ARP DCS
  - Variables (DPEs) configuration: alarms, archiving, etc
  - Control scripts, APIs, drivers, etc
  - Graphical Users Interface and FSM
- ARP DCS is:
  - Able to monitor and control a large variety of systems
  - Fully integrated in ATLAS DCS
  - Operating continuously without any big issue
  - Coping with ATLAS upgrade in terms of software improvements and maintenance
  - Attending wishes and new requirements
- DCS support is always available

Thanks for your attention