The Control System of the New Small Wheel Electronics for the ATLAS experiment

18th International Conference on Accelerator and Large Experimental Physics Control Systems
ICALEPCS 2021
Virtual

Polyneikis Tzanis[1,2], on behalf of ATLAS Muon Collaboration

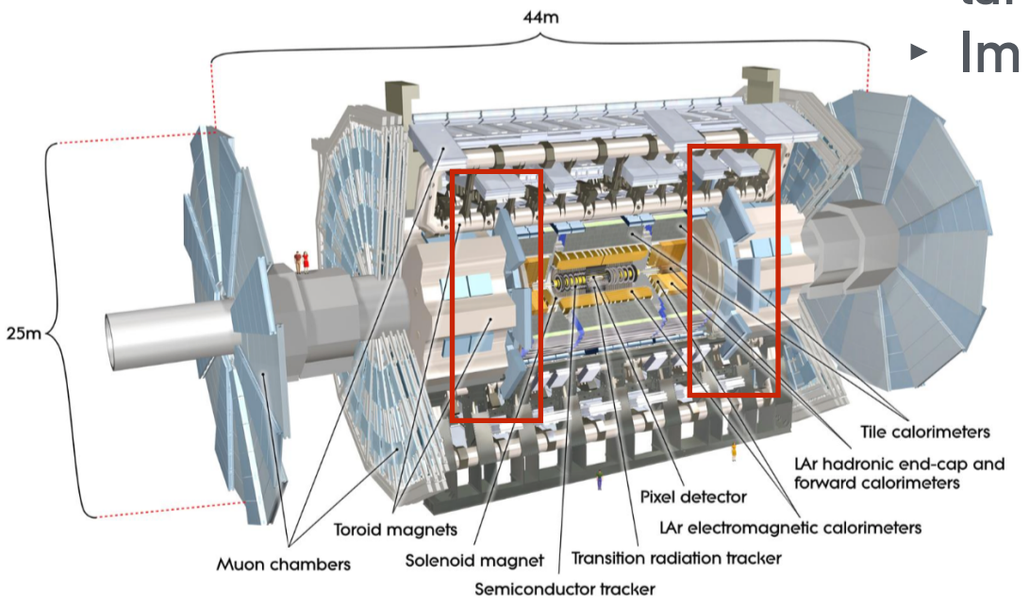
1. National Technical University of Athens 2. Brookhaven National Laboratory

Outline

- Large Hadron Collider & ATLAS experiment
- New Small Wheel
- Electronics Overview & Architecture
  - FELIX & GBT-SCA
  - SCA OPC UA Server & Back-end APIs
- ATLAS Detector Control System
- NSW Detector Control System
- Electronics Control System
- DCS & DAQ interaction

New Small Wheel

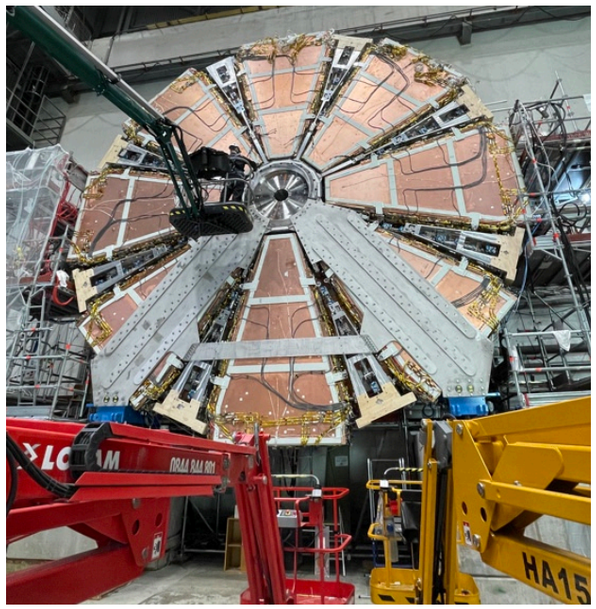
- The New Small Wheel (NSW) upgrade will replace the current Small Wheel of the ATLAS muon spectrometer to handle larger particle rates
- Important for Run 3, vital for High Luminosity LHC (2028)

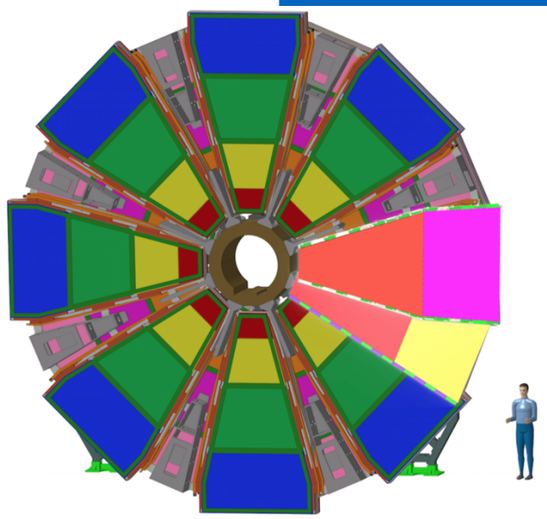



Small Wheel


New Small Wheel

New Small Wheel





The NSW will provide high precision muon track reconstruction and trigger information to ATLAS, at high rates, thus eliminating the issues of the present SW.

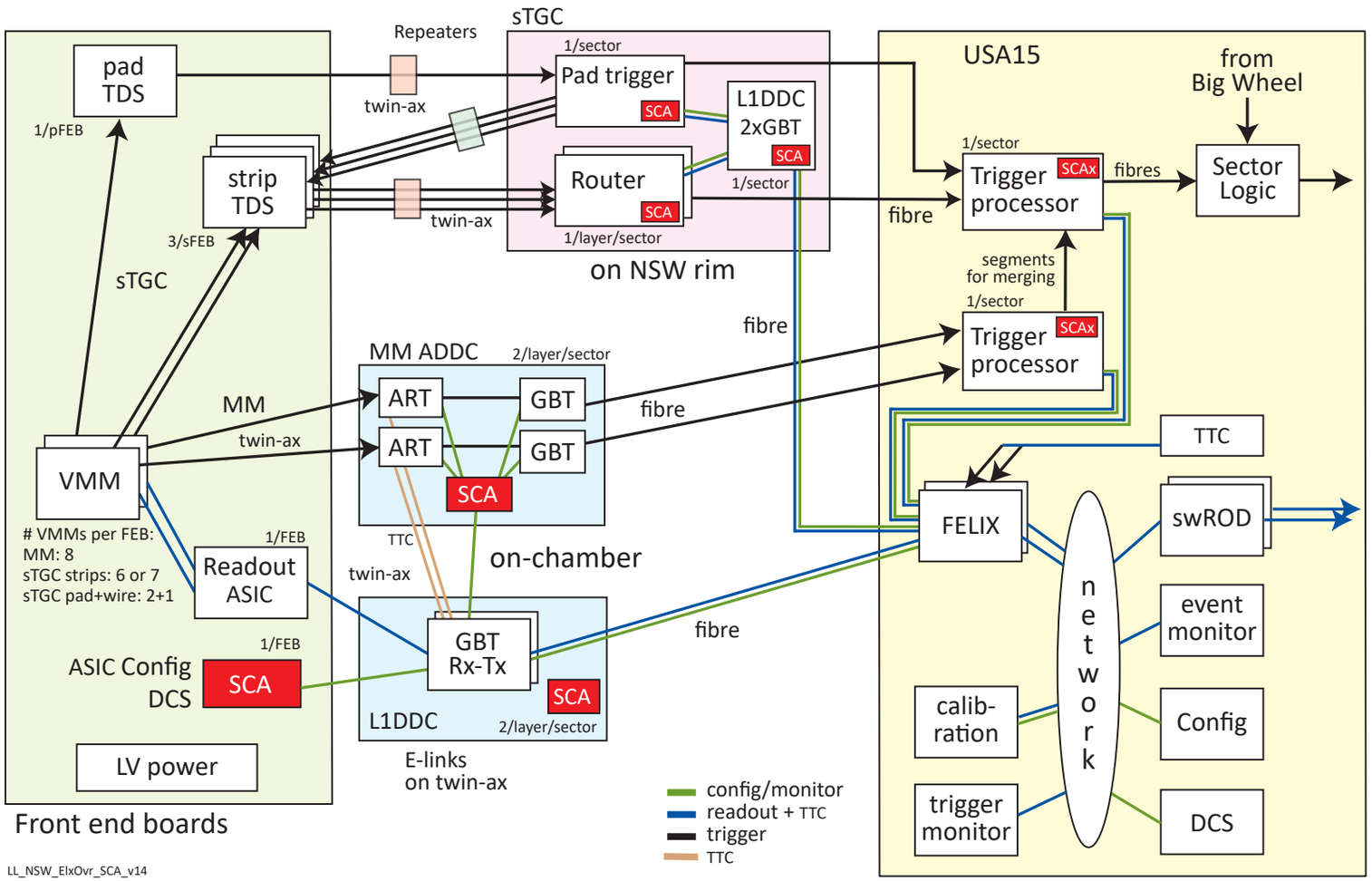
- 16 sectors for each NSW
- 16 layers for each sector

The NSW detectors:

- Micromegas (MM), mainly for precision tracking, also for trigger
- small Thin Gap Chambers (sTGC),mainly for trigger, also for precision tracking

NSW Electronics Overview

The New Small Wheel is a fully redundant trigger and tracking detector system, adequately supported by an advanced electronics scheme and ready to handle the challenges of increased instantaneous luminosity at the High Luminosity LHC.



Is NSW electronics system really “Small”?

- Separate configuration/monitor, readout and trigger path
- ~2.4 millions readout channels
- ~7.5k electronics boards
- ~60k ASICs
- ~100k parameters for monitor
- ~1M registers for Configuration

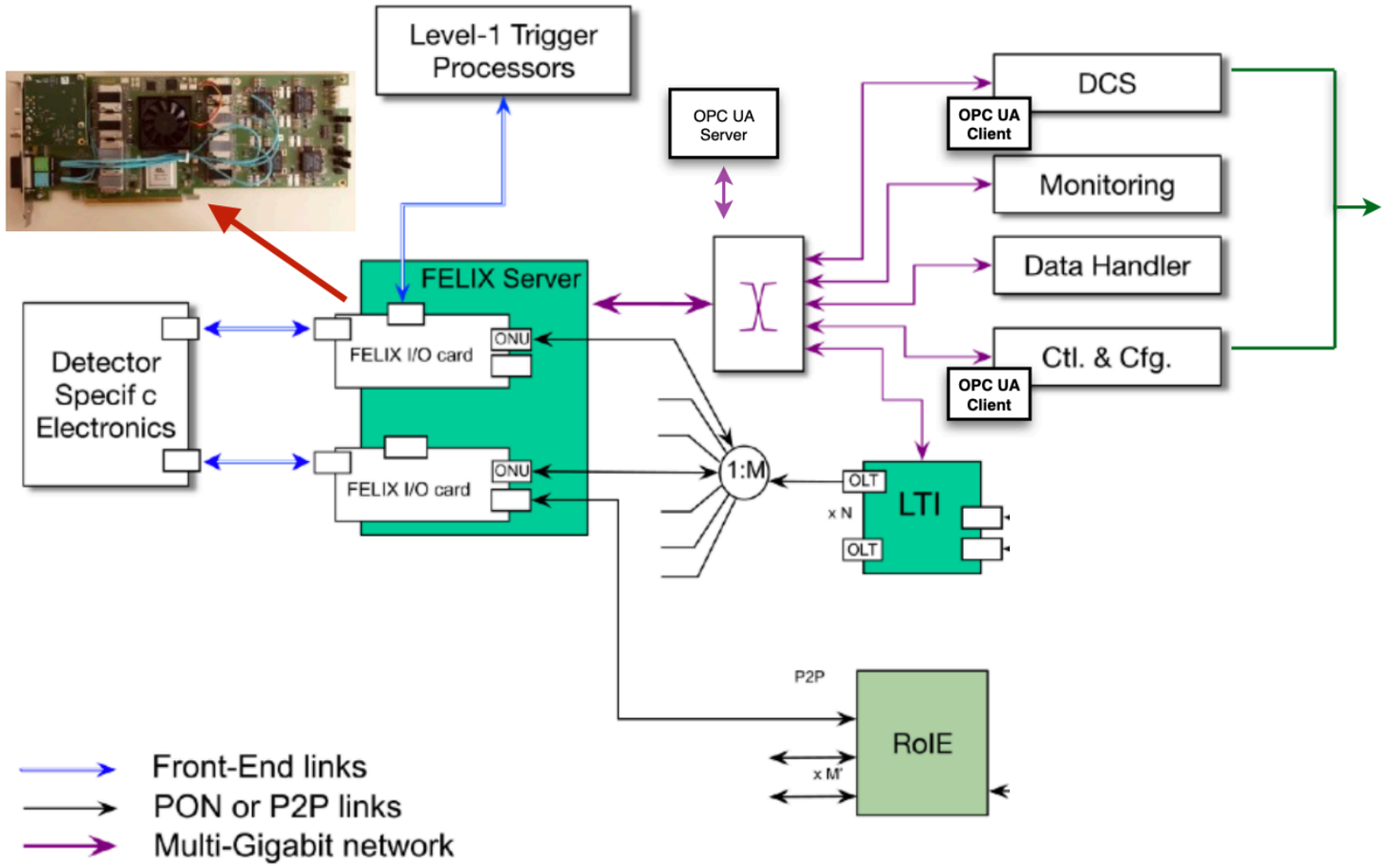
- 54k on detector readout ASICs read out by E-links to GBTx ASICs
- 1024 on-detector trigger encoders configured by 512 GBT-SCAs
- 256 Router FPGAs and 32 Pad Trigger FPGAs on the rim of the NSW
- All of the above configured and monitored by ~6400 GBT-SCA ASICs
- 64 FPGAs for Trigger Processor in USA15

E-links used for:

- L1 Accept data + Data monitoring
- BC clock and TTC signals
- Configuration of ASICs
- Monitoring temperatures and voltages
- FPGA configuration

NSW Electronics Architecture

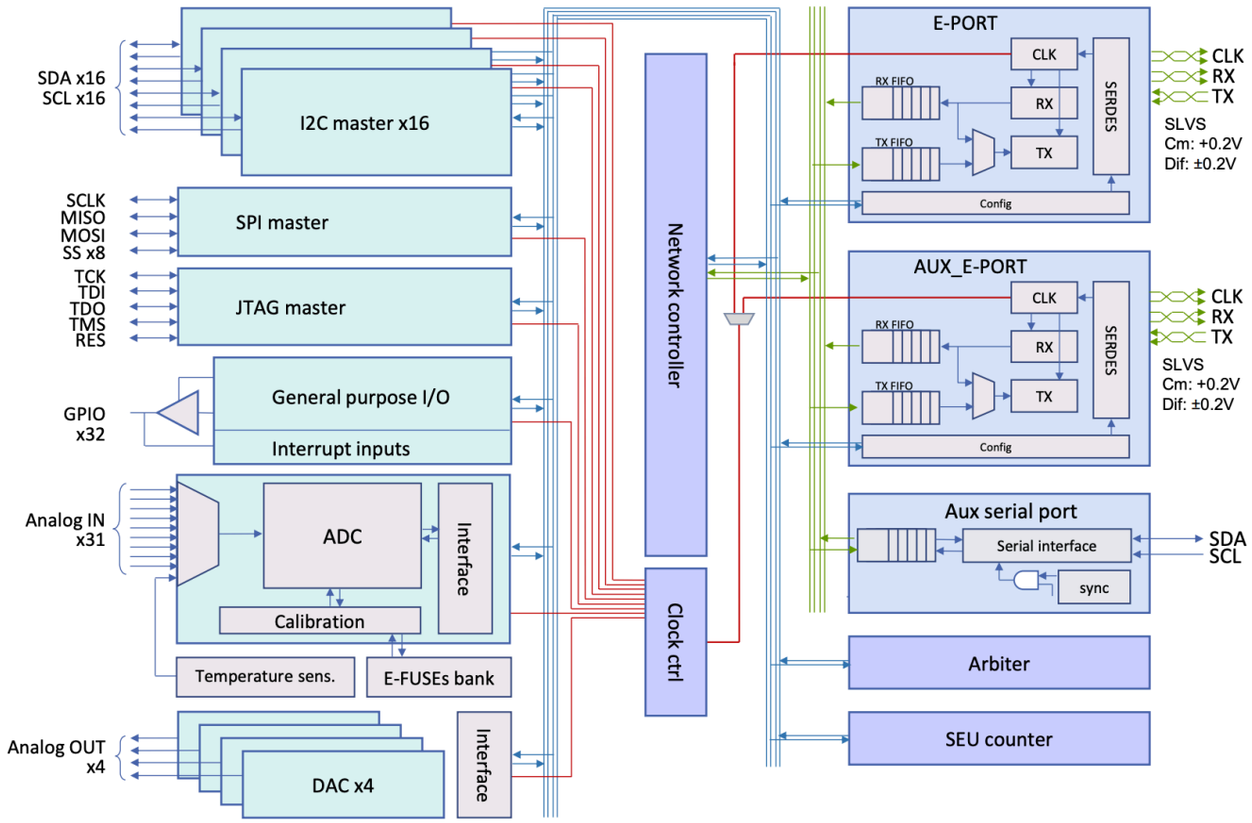
- The NSW Electronics architecture lies on the newly introduced readout scheme of ATLAS
- It has mainly three new hardware components:
  - FELIX - Optical link aggregator system / TTC distributor / Busy. This is a server PC which host two BNL712 PCIe boards (24 optical links / each on NSW)
  - Data handler server or swROD system - Software based readout driver
  - ALTI TTC system - Replacement module of the legacy TTC system (vi/vx LTP)



- DCS, Calibration & Configuration share the common path to the detector electronics (through GBT-SCA) and the SCA OPC UA Server which developed by ATLAS Central DCS

GBT-SCA

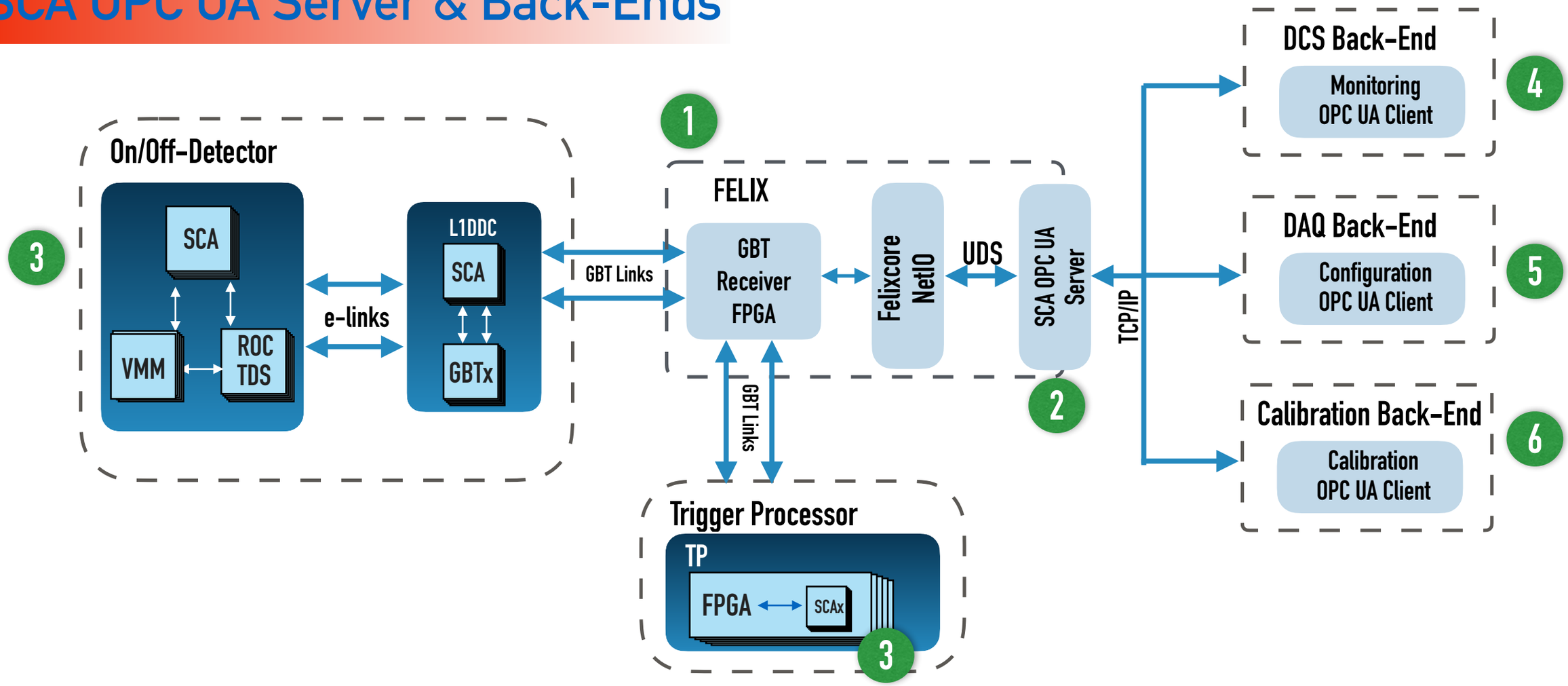
The GBT-SCA ASIC (Giga-Bit Transceiver - Slow Control Adapter) is the part of the GBT chipset which purpose is to distribute control and monitoring signals to the front-end electronics embedded in the detectors.



The user interface ports are:

- 1 SPI serial bus master Interface
- 16 independent I²C master serial bus channels
- 1 JTAG master Interface
- 4 DAC (8-bit)
- 32 General Purpose digital IO lines (GPIO)
- 31 ADC (12-bit)

SCA OPC UA Server & Back-Ends

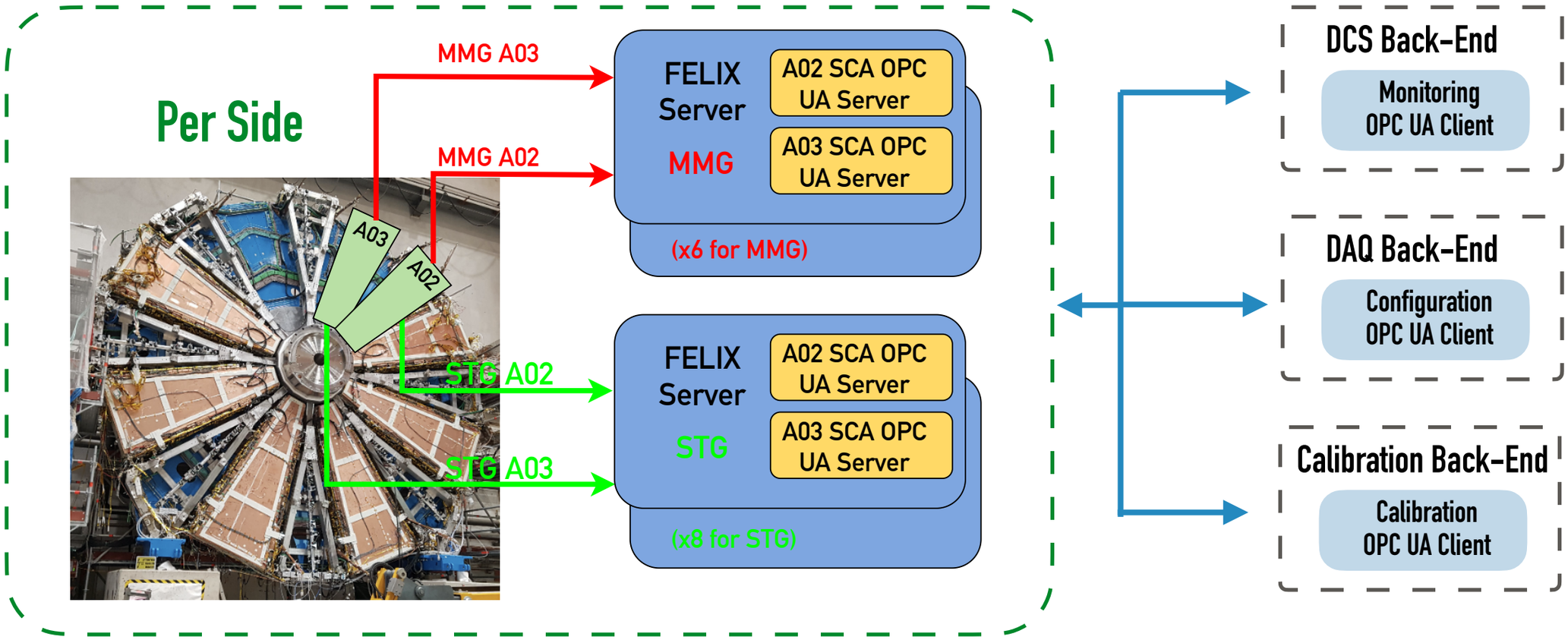


1. Prepare FELIX by configuring the e-links ports
2. Initialise SCA OPC UA server by indicating the e-links to connect to
3. Establish communication between SCAs and SCA OPC UA Server via the FELIX
4. Monitor the various temperature and voltage levels of the electronics via SCA OPC UA Server and DCS
5. Configuration of the various electronics via the SCA OPC UA Server and the NSWConfiguration
6. Calibration of the various electronics via the SCA OPC UA Server and the NSWCalibration

System setup

The system setups consists of:

- 28 FELIX servers (12 for MMG, 16 for STG)
- 32 SCA OPC UA Servers
- 1 SCA OPC UA Server per sector



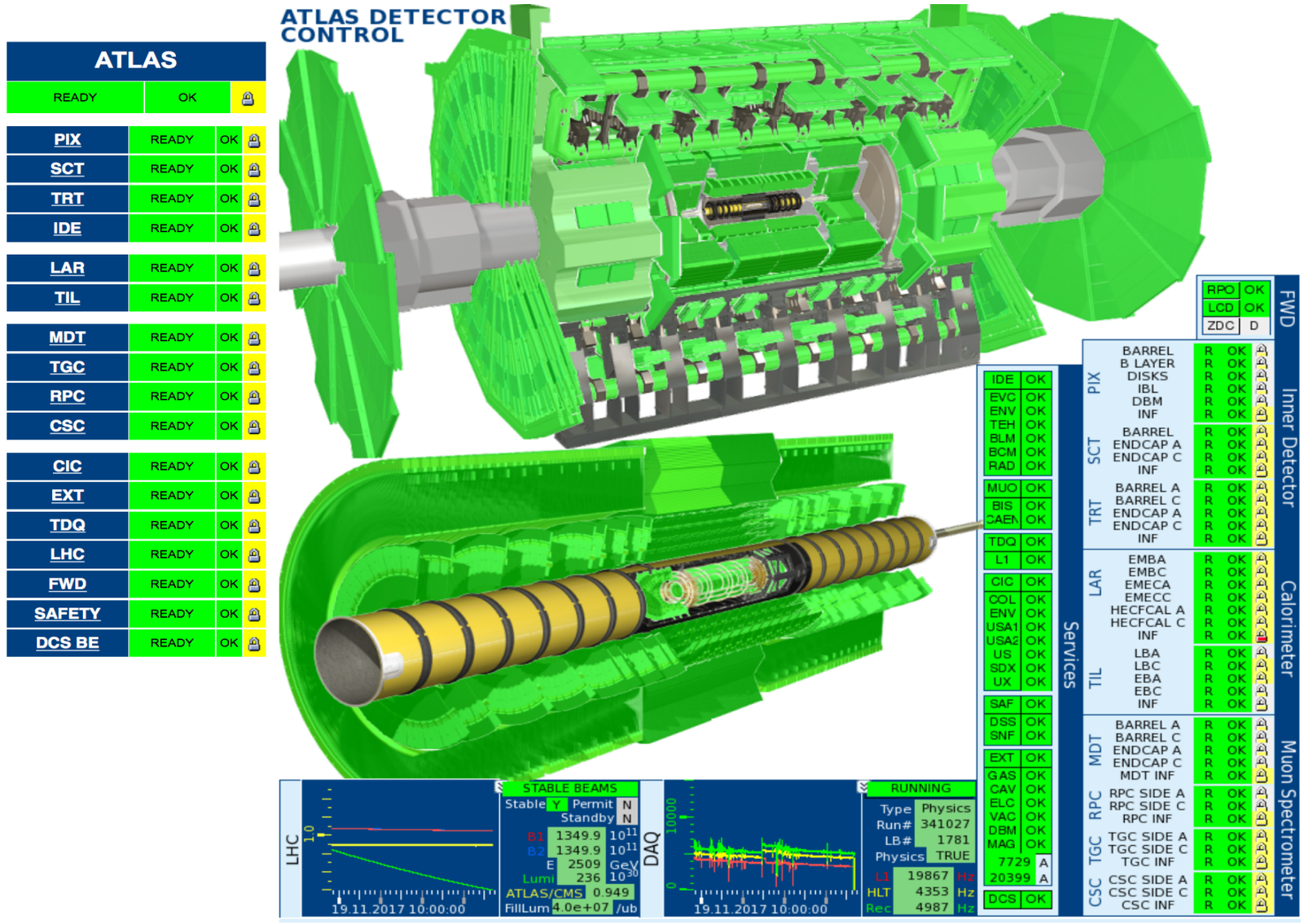
ATLAS Detector Control System

The ATLAS DCS has the task to permit coherent and safe operation of ATLAS and to serve as a homogeneous interface to all sub-detectors and the technical infrastructure of the experiment. The DCS must bring the detector into any desired operational state, continuously monitor and archive the operational parameters, signal any abnormal behaviour.

The various detector control systems developed via WinCC-OA

Main characteristics:

- Flexibility
- Hardware connectivity
- Connection protocols
  - OPC, Modbus, DIM, …
- Distributed systems
- OS independent
- GUI design
- CTRL managers
- Database managers

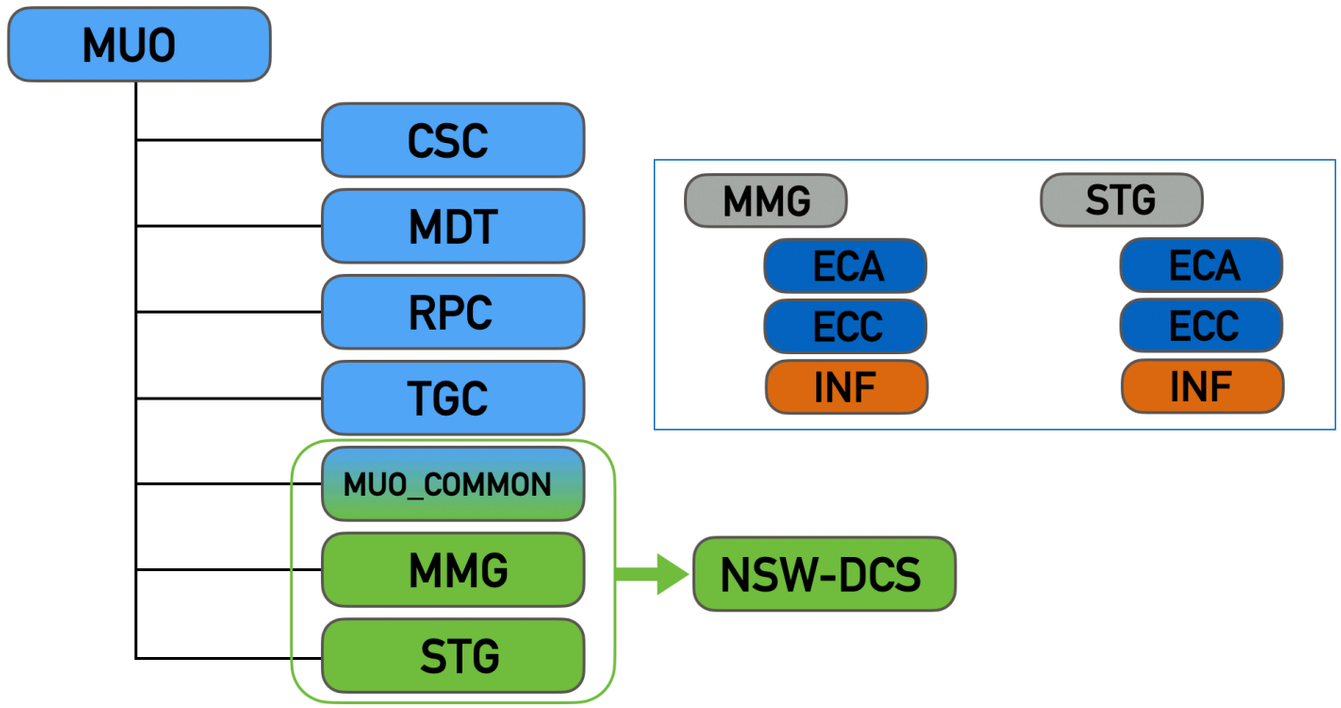


NSW Detector Control System

Due to its complexity and long-term operation, the NSW requires the development of a sophisticated DCS. The use of such a system is necessary to allow the detector to function consistently and safely as well as to function as a seamless interface to all sub-detectors and the technical infrastructure of the experiment.

The plan is to have 2 new sub-detectors:

- MMG (Micromegas)
- STG (sTGC)



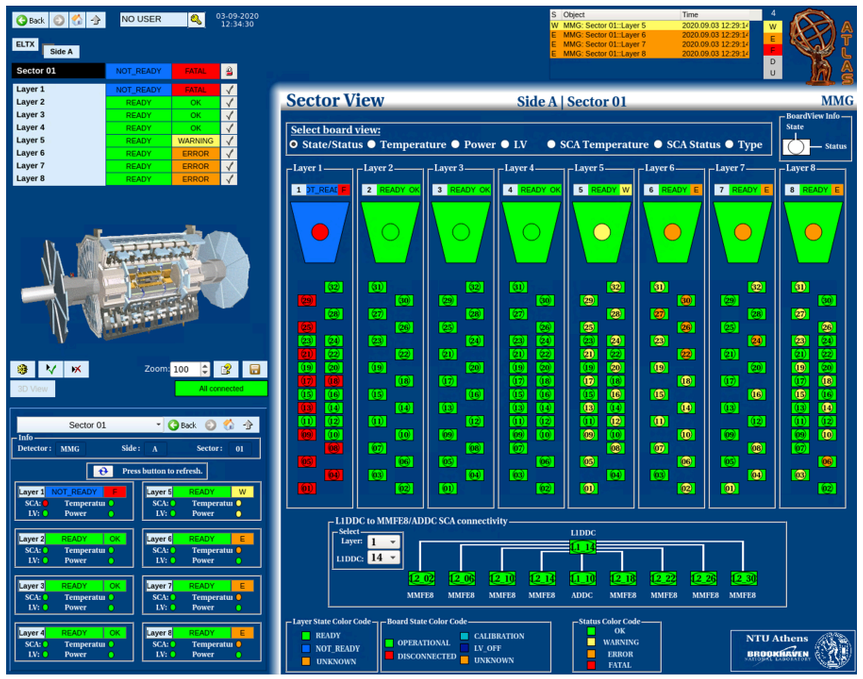
Main projects:

- High Voltage
- Low Voltage
- ELTX-SCA
- MDM-ELMB
- VME-ATCA
- Cooling
- Gas
- Infrastructure

NSW DCS architecture and it's integration with the Muon DCS have been finalised. The top node of both MMG and STG will propagate its state and receive commands from the ATLAS overall DCS.

Electronics control system

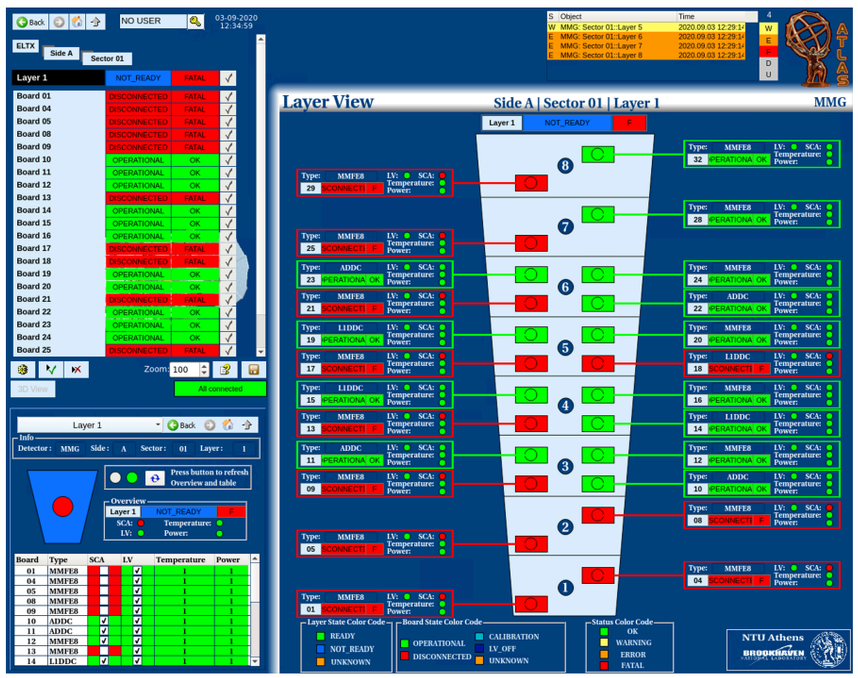
For the NSW electronics safe operation, an advanced control system within the ATLAS DCS is required for the electronics monitoring using the SCA chip, which is installed on the 8000 front-end boards of the NSW.

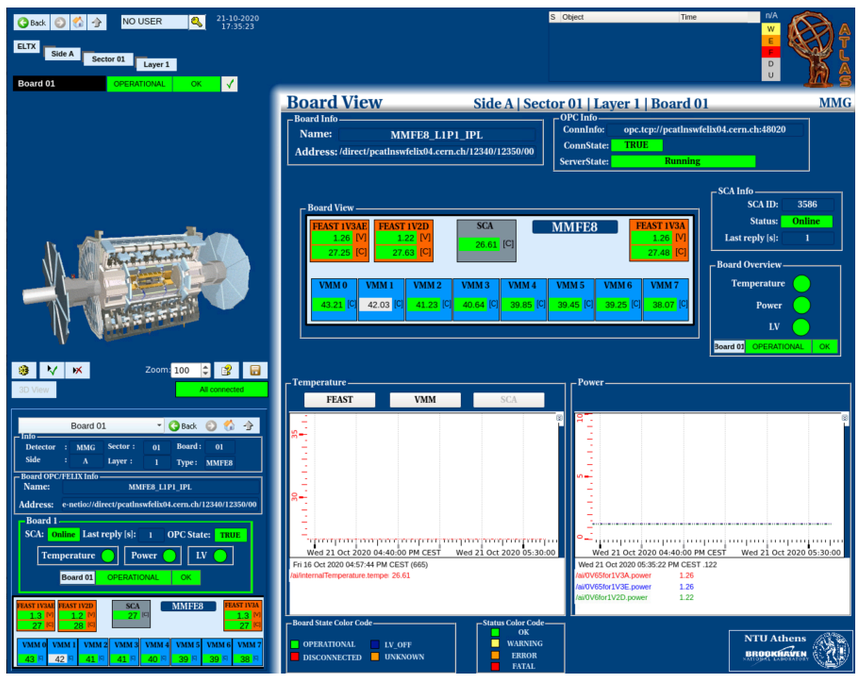


Features:

- ~6.4k GBT-SCA
- Run over the common SCA OPC UA Server
- ~100k parameters
  - Power & temperature sensors
  - On-chip temperatures and information
  - Diagnostics information
  - Alarm handling on each parameter
- Following Muon's existing look and command architecture
- Hierarchy of Finite State Machine (FSM)
- Facilitate the shifter/expert operations

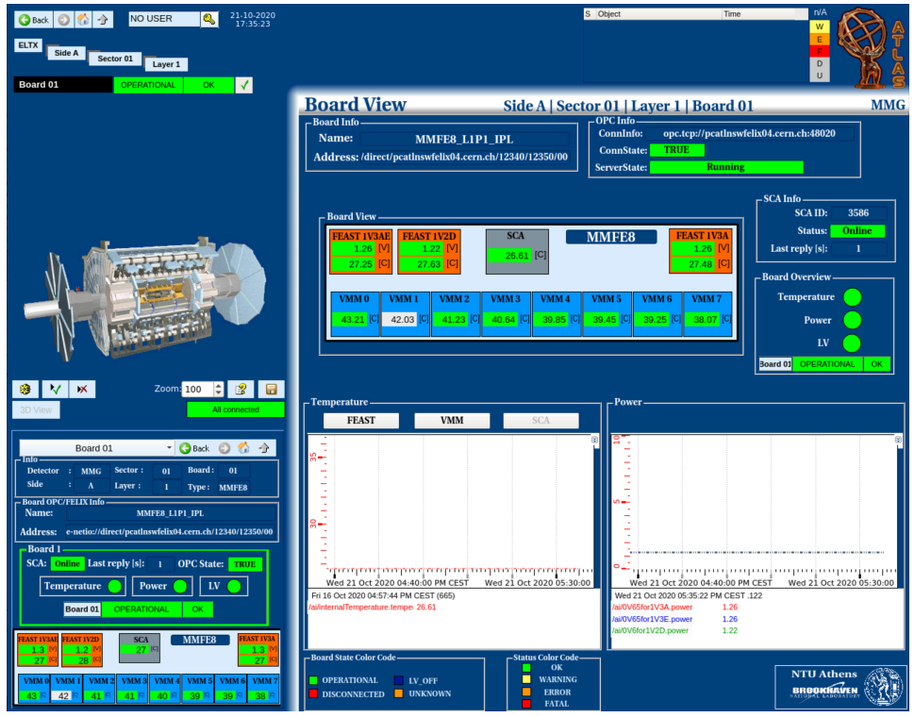
For each individual layer, a main panel has been developed, providing the user with useful information, reflecting the state and status of the detector.

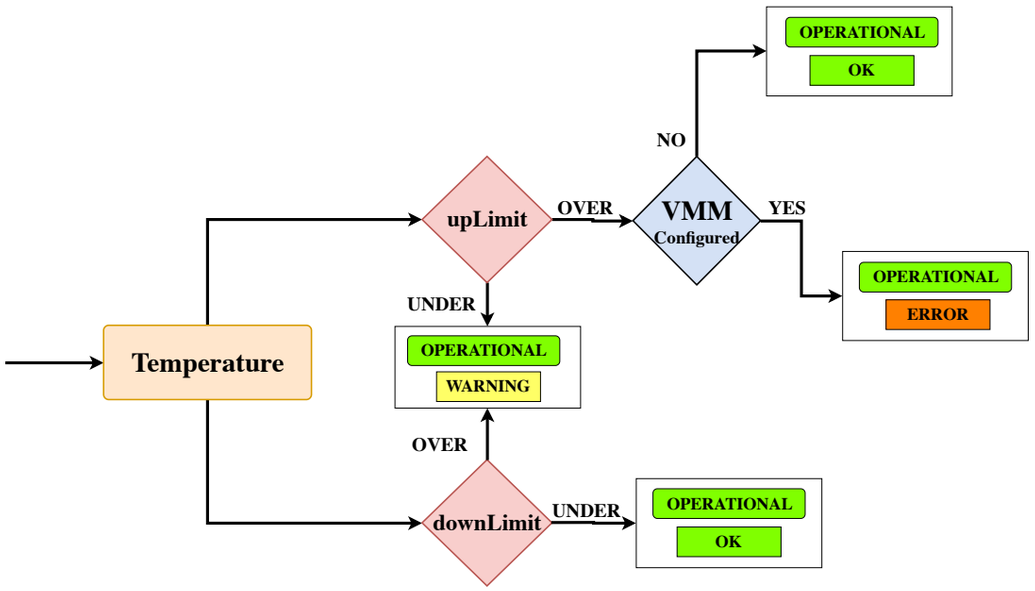




DAQ-DCS Interaction

DCS and DAQ are on the same SCA OPC UA path





- On FEBs equipped with VMM, SCA Analog Input common for VMM calibration and temperature monitoring
- Thus, during calibration VMM shows fake temperature values so a DDC plug between DCS-DAQ should be implemented
  - Solution found via the common SCA OPC UA Server!
  - Central DCS developed the FreeVariable concept, which is a OPC UA item which can be controlled and monitored in both DCS and DAQ clients.
- So, during Calibration run, the DCS will monitor the configuration status for this specific VMM of the FEB and the alarm will be disabled corresponding FEB's VMM

- More DAQ-DCS interaction:
  - FELIX monitoring
  - GBT e-link health status
  - Plugin for Low voltage status

Summary

- The NSW is a fully redundant trigger and tracking detector system supported by an advanced electronics scheme and ready to handle the challenges of increased instantaneous luminosity at the HL LHC
- Due to its complexity and long-term operation, the NSW requires the development of a sophisticated DCS
- The NSW Electronics system is really challenging due to the massive number of boards (ASICs, FPGAs)
- Another challenge is the dependance of the NSW DAQ on new technologies based on FELIX and GBT-SCA
- Use of common SCA OPC UA Server path in order to simplify the NSW DCS/DAQ procedure
- System setup, architecture and operation has been finalised
- The low-level segment of the project has been fully deployed with the main components being fully functional.
- Currently the NSW Electronics control system is under implementation phase for ATLAS cavern

Thanks for your attention!