Detector Control System for the ATLAS Muon Spectrometer and Operational Experience after the first year of LHC data taking

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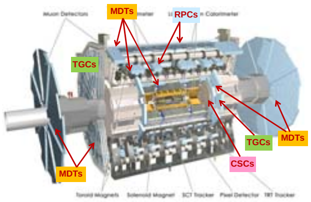
ATLAS Muon Spectrometer



- Standalone momentum resolution $\Delta p_t/p_t$<10% up to 1 TeV
- Geometry: 3 layers of gas-filled muon detectors
- 3 supra-conducting air core toroid magnets, 8 coils each, providing a peak field strength up to 4 T
- 4 different detector technologies:
  - Precision tracking
    - 1150 **M**onitored **D**rift **T**ubes Chambers
    - 32 **C**athode **S**trip **C**hambers close to the beam pipe
  - Muon trigger and 2nd coordinate determination
    - 605 **R**esistive **P**late **C**hambers (Barrel)
    - 3588 **T**hin **G**ap **C**hambers (Endcap)

MDTs	CSCs	RPCs	TGCs
• 380k 3cm Ø drift tubes • operating gas Ar:CO_2 93:7 at 3 bar (abs.) • gain $2\cdot 10^4$, 3080V op. voltage • tube resolution < 80 µm • track resolution 50µm per muon station • optical alignment system to monitor in situ chamber deformations /movements	• multi-wire proportional chambers with wires in radial direction and perpendicular segmented cathodes • 4 wire planes/chamber • operating gas Ar:CO_2 80:20 at 1 bar • track reconstruction from signal charge distribution • resolution/plan < 60 µm	• double layers of gas gaps made of bakelite plates separated by 2mm spacer • proportional mode • operating gas freon : i-butane : SF_6 94.7:5:0.3 • perpendicular readout strips on both sides of the gas gaps • fast readout, intrinsic time jitter < 1.5 ns • efficiency/layer > 98.5%	• multi-wire proportional chambers, wire-wire distance < wire-cathode distance • operating gas n-pentane : CO_2 in quasi-saturated mode • gain $3\cdot 10^5$, 2800V op. voltage • readout of both wires and cathode strips for 2D track reconstruction

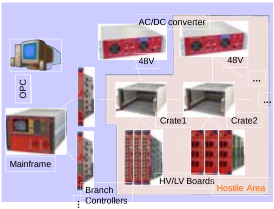
Muon DCS – Architecture and Hardware

The Muon Controls System is responsible for

- Controlling the detector power system (chamber HV, frontend electronics LV)
- Monitoring environmental conditions (temperatures, magnetic field), adjusting operating parameters to maximize efficiency
- Monitoring parameters of the on-chamber electronics (voltages, RPC trigger rates, temperatures)
- Monitoring the detector gas system, reacting to changed or abnormal situations by adjusting or turning off detector HV
- Configuring the MDT and TGC frontend electronics
- Reacting on information from the data acquisition, reinitializing chambers when needed
- Controlling and reading out the muon spectrometer optical alignment system
- Archiving information on the detector status and storing information needed for data analysis to the ATLAS conditions DB

Power System

- CSC LV uses commercial Wiener [1] Marathon Power supplies, water cooled and controlled over ethernet. Connection to the DCS is via a dedicated Wiener OPC server
- Muon HV and MDT, RPC, TGC LV is based on the commercial CAEN [2] EASY system; LV and HV boards are located in the experimental cavern (withstand ATLAS radiation levels and a magnetic field up to 2kG)
  - approx. 6000 HV channels, individually configurable, support 2 programmable voltage levels V0 and V1
  - approx. 2000 LV channels, individually configurable
  - CAEN A3801 128 channel ADC boards are used for dedicated monitoring of RPC individual gap currents and RPC environmental parameters (~3100 channels)

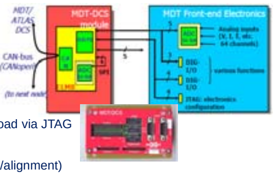


RPC frontend electronics threshold control

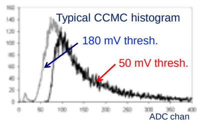
- via CAEN A3802 DAC boards, ~3100 channels, individually configurable, same controls chain as for LV/HV

MDT/TGC Environmental Monitoring, MDT frontend electronics initialization, TGC threshold control

- based on the ATLAS custom **E**mbedded **L**ocal **M**onitoring **B**oard [3]: 64 channel 16bit ADC, bi-directional digital IO, digital In- and output channels, communicates via CAN fieldbus
- MDT
  - ~ 1300 'MDT DCS Modules (MDM)', custom firmware/motherboard
  - readout for ~14000 temperature probes
  - readout for ~1650 3D-hall probes for magnetic field
  - readout for > 50k voltages/temperatures from frontend electronics
  - frontend electronics initialization (incl. thresholds) /parameter download via JTAG

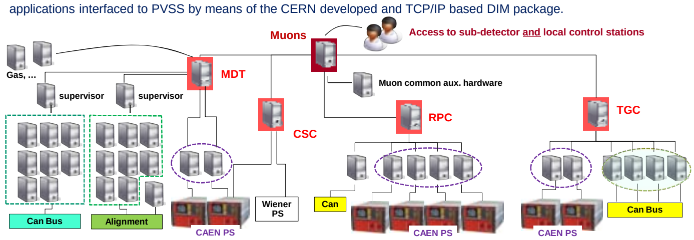


- TGC
  - ~ 1500 ELMBs, custom firmware (except for temperature monitoring/alignment)
  - readout on-chamber temperature probes and ~3700 sensors to monitor chamber displacement
  - control frontend electronics thresholds
  - together with 1500 dedicated DCS-PS boards: **C**hamber **C**harge **M**easuring **C**ircuit . Allows detailed monitoring of chamber noise and performance



DCS Architecture

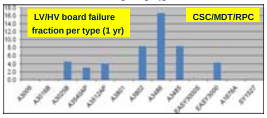
- Muon DCS software layer is based on the commercial SCADA system PVSS
- making use of the CERN Joint Controls Project (JCOP) framework [4] for common functionalities, benefitting from re-usable and standardized code
- Due to the size, number of controlled devices and diversity of muon DCS functions, emphasis has been put into an optimal distributed design and load distribution over in total 40 dedicated PCs running either Windows XP, Windows 2003 or Scientific Linux SL5.
- CAEN and Wiener hardware is interfaced using the PVSS built in OPC client connected to the CAEN/Wiener OPC servers; ELMBs are controlled via the CERN developed CanOpen OPC server for the MDT and a custom driver in case of TGC, with Kvaser PCI cards as Can Interface. The alignment system finally uses custom standalone readout applications interfaced to PVSS by means of the CERN developed and TCP/IP based DIM package.



Operational Experience

(CAEN) Power System - Hardware

- Few failures of primary 48V power ACDC converter : mostly related to a power cut/power spike
- Recently several cases of failed CAEN EASY crates due to connector melt-down, first effects of 'ageing' (gradual degradation of connectivity ?)
- Failures of LV and HV boards are well below the 10%/year rate planned for;
  - initial very high failure fraction for TGC HV board → traced to a under-dimensioned electronics component + overheating, under control
  - few cases of Vout > Voltage limit (both soft/hardware) and Vout > Vset potentially very dangerous → add more sophisticated monitoring/alerts
  - often problematic behavior of a channel does not reproduce once board is removed from ATLAS and tested in the lab



Power System – Remote Board Communication

- Occasional loss of communication with remote CAEN boards, required in the beginning manual board reset in the AT:LAS cavern → Beginning 2011 implemented 'CAEN reset network' for doing so from remote via DCS, proved very useful !
- Remaining occasional communication failure requiring reset of branch controllers: ongoing work together with CAEN to implement a 'DCS reset' as well

Power System - CAEN OPC Server, DCS monitoring and commands

- Both MDT and RPC #mainframes was doubled in 2010 → drastic improvement on stability/reduction of hang-ups of communication with mainframes to 1/few months level ….
- CAEN OPC server 'Event Mode' proved unusable for both MDT and TGC systems due to large number of HV channels and large number of simultaneously changing parameters during HV ramping → Fall back to operation in polling mode, not ideal since bandwidth 'wasted' for rarely changing parameters
- Update rates for voltage/current readings achievable from DCS via OPC chain are far smaller than the internal refresh rate of channel information in the mainframe -- clear interest in future improvements and upgrades !
- Rare bur recurring cases of failed communication between DCS PVSS and CAEN OPC server and/or mainframe → added watchdog mechanisms based on changing settings and checking for readback → proved crucial to spot abnormal situations

Muon power system probably the component where one would benefit most from hardware upgrades (mainframe level) !

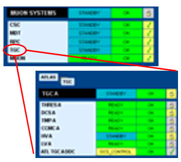
ELMB and ELMB controlled functionality

- Very high reliability; manual interventions on the system are very rarely needed, most common case are MDT B-field sensors requiring a ELMB power cycle to reset
- so far 1 failed MDT-type ('MDM') ELMB module due to power regulator, 1 MDT ELMB with ADC failure only, 0 failures for TGC ELMBs.

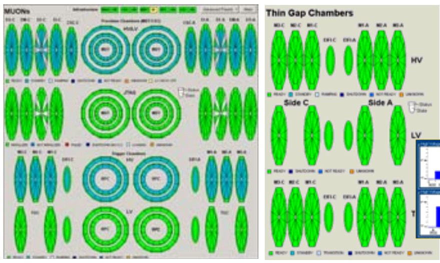
MDT on-chamber electronics initialization via JTAG

- Very reliable, method independent from the DAQ proved advantageous since configuration can be done prior to starting a run → safe time
- Time needed to initialize a chamber is ~ 7 secs → parallel operation on all 96 CanBusses → need ~2.5 mins for full MDTs

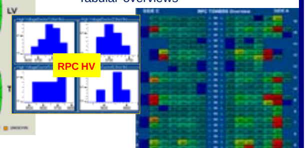
Shifter and Expert Tools and User Interfaces



- For mass operation and to allow to assess the state of the muon system w.r.t. to being ready for physics data taking, the **F**inite **S**tate **M**achine (FSM) concept widely in use in Atlas has been adopted and implemented as a tree structure following the detector technologies and geometrical granularity
  - Actions and commands propagate from parent to children nodes
  - Children can be in- or excluded
  - Each node has a **state**, indicating readiness for data taking, and a **status** indicating the 'health' of the represented hardware or group of equipment
- For shifter operation, 'look and feel' of operations panels has been standardized



- FSM based Uis work very well for shifters and if most of the detector is 'READY'
- for experts work and checks on configuration FSM Uis are complemented by
  - Color map overview plots
  - Distributions shown as histograms
  - Tabular overviews

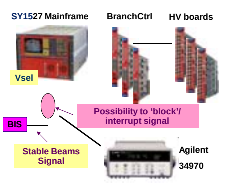


RPC trigger rates – correlating with HV current data allows to spot trigger misconfig or reduced efficiency !

Automatic actions and adjustments – dedicated control scripts – improved operations efficiency

Example: Automatic transition between 'safe' (Standby) and nominal HV according to beam state

- Use 2 programmable voltage level feature of CAEN A3540, A3535, A3512 HV boards with specially adapted firmware
- Switch between safe (V0) and nominal (V1) is governed by presence/absence of a TTL signal input to the CAEN mainframe Vsel input → link to LHC stable beams signal received from ATLAS Beam Interlock System (BIS)



- HV should go from Ready to Standby automatically on loss of stable beams signal
- HV should not go from Standby to Ready automatically on reaching stable beams, but only after confirmation from DCS
- Provide a override mode to achieve nominal HV outside beam operations without need to reconfigure HV set points
- Implemented using Agilent 34970 SwitchUnit + A34903 actuator card (controllable 'switch'), interfaced to DCS via RS232 interface
- In DCS represented by a separate sub-tree in the Finite State Machine
- **Since this year fully automatic "beam actions" (HV transitions) , very good experience and excellent reliability !**

Conclusions

- Muon Detector Control System is working very well and proved to be a very important factor for efficient data taking and in achieving optimal detector performance
- Few weak points, mainly in the power system have been identified
- Last months of LHC operations at luminosity > 10^{33} cm^{-2} s^{-1} showed that DCS HV current monitoring is an extremely powerful tool to study detector performance for future upgrades and to efficiently spot problems incl. in the trigger or readout
- Direct line of communication with CAEN and, via CERN EN/ICE team and ETM for PVSS issues proved extremely helpful

References and Further Information

[1] http://www.wiener-d.com

[2] http://www.caen.it

[3] http://elmb.web.cern.ch/ELMB/ELMBhome.html

[4] http://itcobe.web.cern.ch/itcobe/Projects/Framework/welcome.html

[5] http://www.home.agilent.com

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