The LHCb Silicon Tracker: Control system specific tools and challenges

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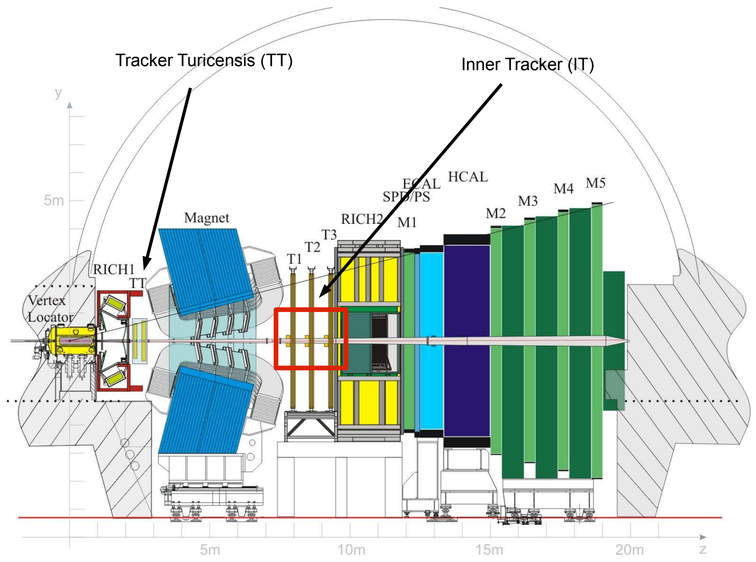
The LHCb Silicon Tracker is part of the main LHCb tracking system and provides data in the region of high track densities. For the tracking station in front of the main dipole magnet (TT), the Silicon Tracker covers the full angular acceptance of the experiment, while for the stations T1-T3 after the magnet, the Silicon Tracker (IT) only covers the region directly around the beam pipe. The analogue hit information of the silicon strip detectors, which is amplified by the Beetle readout chip, is transmitted via copper cables to the Services Boxes, located outside the acceptance area. This not only reduces the amount of material inside the detector but also relaxes the requirements on the Service Box electronics concerning radiation tolerance. The Service Boxes hold the Digitizer Boards, on which the analogue signals from the Beetle front-end chips are digitized and encoded into a Gigabit data stream for transmission via VCSEL diodes and 120m of multi-ribbon optical fibre to the counting house. In the counting house, the optical ribbons can be directly connected to TELL1 preprocessor boards equipped with two multi-channel optical receiver cards.

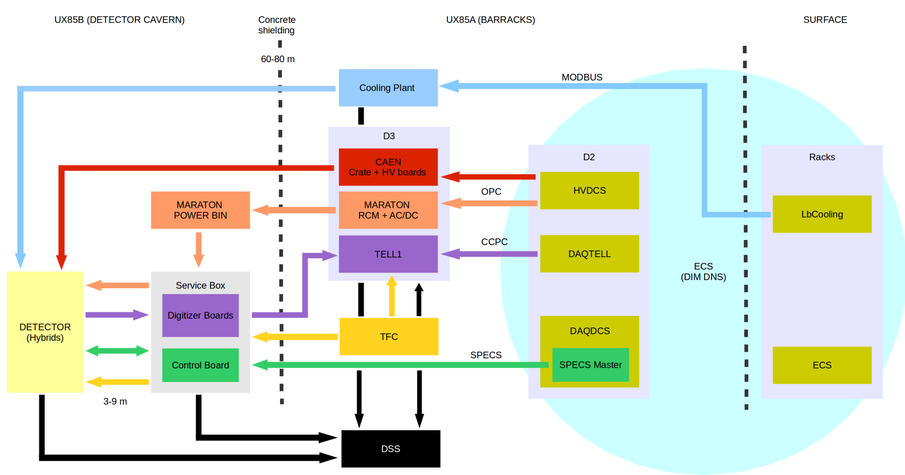


LHCb experiment

The Experiment Control System (ECS) is implemented using a Finite State Machine (FSM) where the device logical nodes are grouped hierarchically and the state of each node depends on the state of its children.

The IT and TT require some additional features in terms of operation and monitoring as the silicon sensors need to be cooled at all times. Both sub-detectors use similar technologies and the ECS electronics were designed to exploit those similarities. This allowed the ECS software to be designed in parallel.

Tools have been designed and deployed to cover the specific needs of the sub-detectors and the system runs smoothly most of the time. However the design and implementation process lead to a situation where a re-optimization is needed. The first period of the LHC long shutdown (LS1) offers the possibility to perform the required changes to be able to keep improving the system operation and response.



Experiment Control System electronics distribution

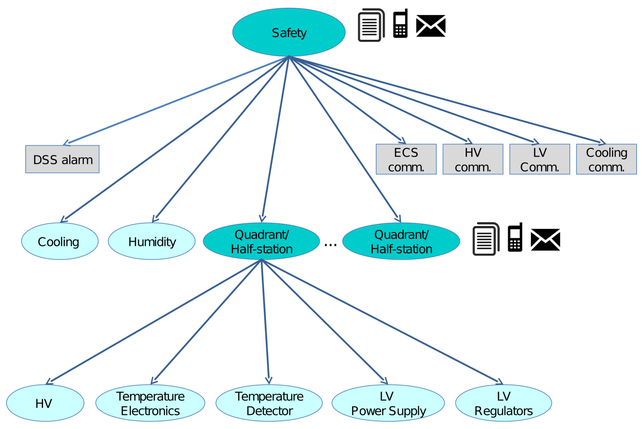
Detector Safety FSM

In order to protect the detector electronics automated power off actions must be in place. The LHCb experiment uses the Detector Safety System (DSS). This system is independent from the Experiment Control System (ECS) and it monitors dedicated sensors, such as thermo switches, water leak detectors or smoke detectors, placed close to the detector and the service electronics.

The sub-detectors, have a dedicated Finite State Machine (FSM) which uses the ECS cooling, temperature, humidity, low voltage and high-voltage readings to detect potentially dangerous situations and power off the electronics in a controlled way.

The main tasks of the Safety FSM are:

- Prevent ice formation on the detector box.
- Protection against over-current or over-voltage in the LV power supplies or LV regulators.
- Protection against high temperature of the control electronics.
- Protection against high temperature in the silicon sensors.
- Protection against high leakage current in the silicon sensors.
- Protection against communication or readout problems when monitoring the operation conditions.
- Prevent DSS alarms and brutal actions.
- Prevent unsafe operation states combinations.
- Log and report, via email or SMS, changes in the system.



Detector safety tree hierarchy

To accomplish this, the Safety FSM is linked to the main operation ECS FSM and monitors state changes of some of its nodes. When a non-allowed state combination occurs, the Safety FSM executes automatically a power off action of the affected electronics.

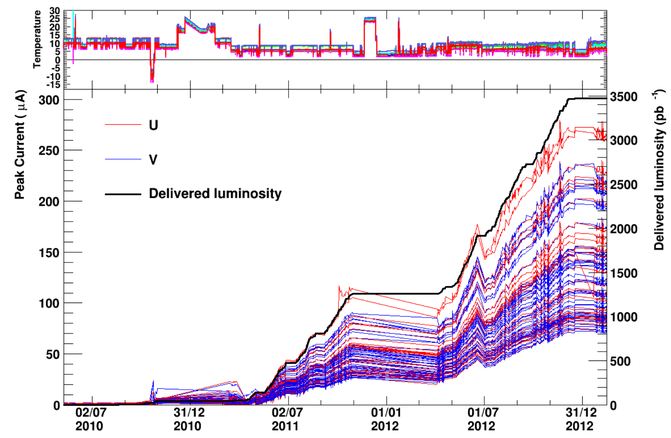
Safety state	High Voltage	Low Voltage Power Supply	Low Voltage Regulators	Cooling	Temperature Electronics	Temperature Detector	Humidity Detector
OK	--	ON	ON	ON	ON	ON	ON
OFF	OFF	OFF	OFF	--	OFF	OFF	OFF
NOT SAFE	Any ON			≠ ON	--		
NOT SAFE	Any ON			ON	Any OFF		
ERROR	Any ERROR						

Logical definition of safety states

Detector Specific Tools

Automated data monitoring

Regular extensive monitoring data extraction is needed to produce fast ageing studies of the silicon sensors. The task is automated by a control manager executing a dedicated script which collects the maximum leakage current and average temperature for each sensor, producing a single file for each run. Those files are then used as an input for the python script generating the ageing plots. This production is also automated by a cron job running in a linux machine on the LHCb online cluster.



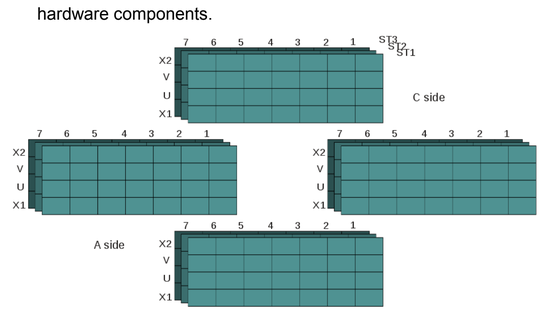
TT ageing plot: leakage current, integrated luminosity and temperature vs time

Mapping

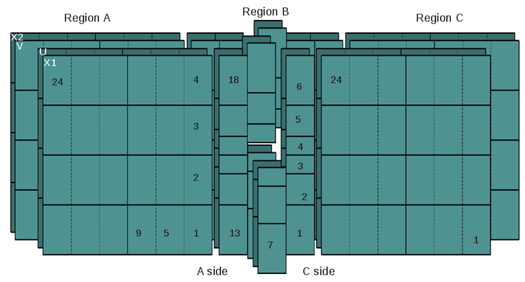
The partitioning schema for the sub-detectors is different for each of the domains:

- High voltage distribution.
- Low voltage distribution.
- Clock, fast control and slow control signals distribution.
- Data readout.

In order to ease the diagnosis and troubleshooting of operational problems, several mapping tools depicting the location of the silicon sensors and the service electronics have been put in place. These tools use a graphical interface to show the link between the different hardware components.



IT detector diagram



TT detector diagram

Experiment Control System LHC long shutdown consolidation

The Experiment Control System for the Silicon Tracker in the context of the LHCb ECS framework, was first designed and implemented from 2007 to 2009 during the detector assembly and commissioning. This had the following disadvantages:

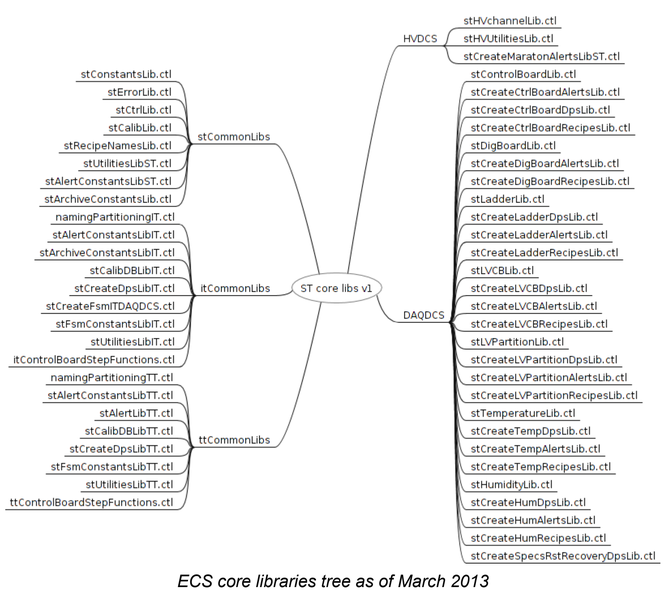
- Several authors (not always overlapping).
- Different implementations for IT and TT detectors.
- No clear library structure.
- Little or no documentation.
- No version control.
- Built in a need basis.

Some effort was made at the end of 2009 and beginning of 2010 to merge the FSM hierarchy and behavioural definition domain, and the control libraries. However, the system was already in production so the extent of these modifications was limited. Since then, only some changes and fine tunning were needed to address very specific functionalities.

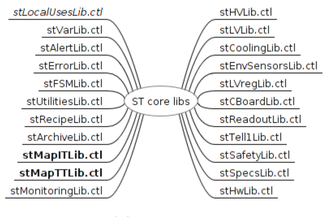
As a result the ECS libraries have more than 50 thousand lines of highly patched and replicated code distributed among too many files. Also the FSMs of IT and TT need to be maintained separately as they are equivalent but not identical.

During the LHC Long Shutdown (LS1), full access to the control system is possible, and so a redesign can now be implemented.

The structure of the control libraries has been redefined and the old functions have been revised, cleaned, documented and placed in the new assigned library.



ECS core libraries tree as of March 2013

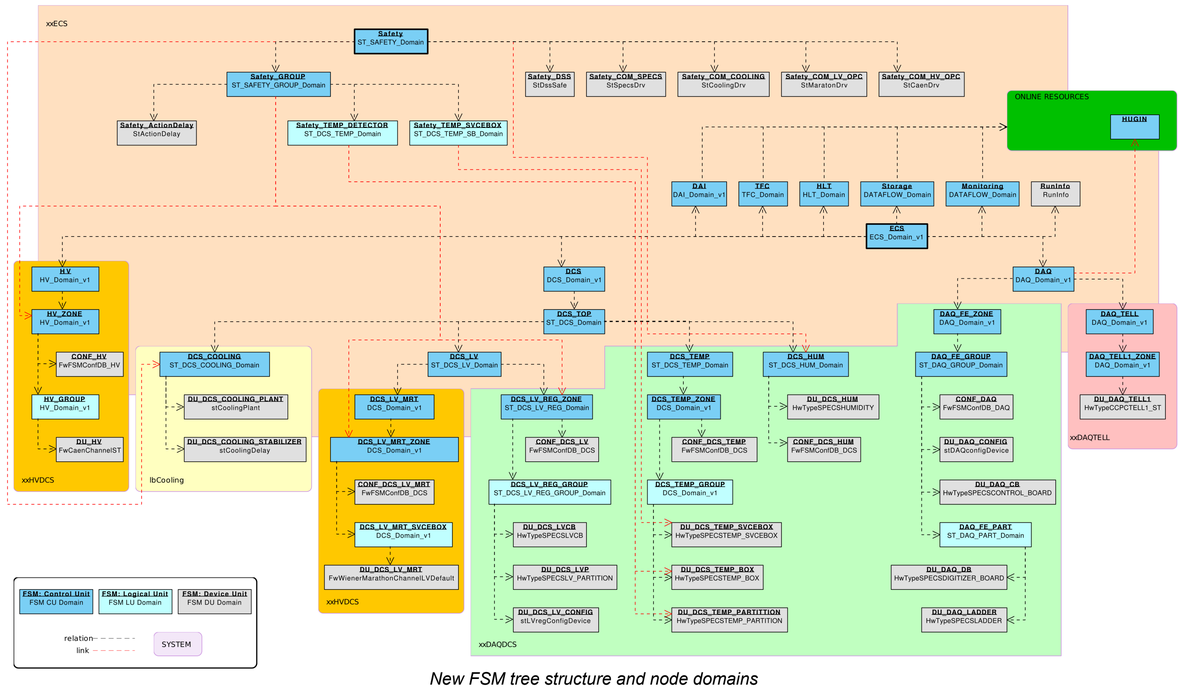


New ECS core libraries tree

The new control libraries are fully documented using the open source code documentation tool *doxygen (www.doxygen.org)* and version control has also been implemented using *git (www.git-scm.com)*. The new control libraries are common for both IT and TT and the code size has been reduced to around 20 thousand lines of code and documentation.

The FSM hierarchy has also been modified and is now also common for both sub-detectors

The implementation of all these changes has already been tested in a virtual environment and is now being changed in the production system.



New FSM tree structure and node domains

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