THE LHCb RICH DETECTOR CONTROL SYSTEM

A. Papanestis, Rutherford Appleton Laboratory, Didcot, UK
on behalf of the LHCb RICH collaboration

Abstract

The efficient operation of the two Ring Imaging Cherenkov (RICH) detectors of the LHCb experiment is essential for hadron identification. This operation is achieved by the Detector Control System (DCS) with the integration of the control and monitoring functions of the various subsystems. The DCS controls the various power supplies required for the operation of the Hybrid Photon Detectors (HPDs) and related electronics, collects information about the operating environment of the HPDs to ensure safe operation, and monitors the RICH radiators (pressure, temperature, humidity, gas quality). The system is able to inform the operator or take automatic actions when any monitored quantities go outside predefined safe limits. It is fully integrated in the LHCb Experiment Control System and can apply different configurations using recipes. The LHCb RICH DCS has been fully commissioned and is ready for the LHC start-up.

INTRODUCTION

The LHCb experiment [1] (Fig. 1) at the LHC will study the differences between matter and anti-matter by precise measurements of the decays of B particles. Particle identification is an important task as many of the decay modes of the B hadrons cannot be separated using kinematics. The Ring Imaging Cherenkov (RICH) system aims to contribute to particle identification by separating pions, kaons and protons in the momentum range 2-100 GeV/c. For this purpose, there are two RICH detectors and three different radiators. Cherenkov light produced in the radiators is focused into rings using segmented spherical mirrors, and the rings are detected using Hybrid Photon Detectors (HPD).

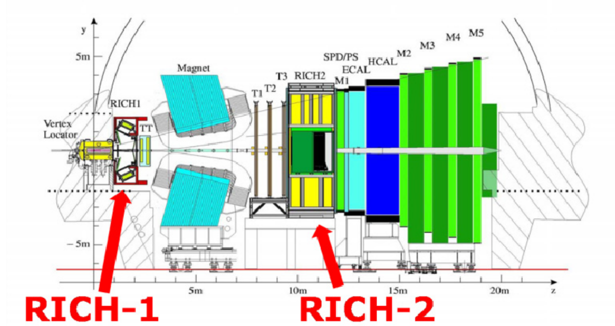

Figure 1: The LHCb experiment. There are two RICH detectors, RICH-1 and RICH-2.

THE LHCb RICH DCS

The Detector Control System (DCS) for the LHCb RICH has the functions to power the detectors, ensure their safe operation and collect and archive all environmental information required for the analysis of the RICH data.

The basic detector unit controlled by the DCS is an HPD column. A column is made up of 16 HPDs (14 in RICH-1) and all the required electronics for the operation of the HPDs, the Level zero trigger and the High Voltage (18 kV) distribution.

System Description

The DCS has been built using components from the JCOP (Joint Controls Project) framework [2], developed by CERN and the four LHC experiments. PVSS-II [3] is used to provide a SCADA (Supervisory Control And Data Acquisition) system and SMI++ [4] is used for abstract behaviour modelling. More specifically, PVSS-II is used for device description and access, alarm handling, archiving, logging and trending, user interface and access control. SMI++ provides Finite State Machines (FSM) for automation and error recovery. The finite state machines are fully integrated with PVSS and can be operated using PVSS user interfaces. The FSM tree for the RICH DCS can be seen in Fig. 2, while an example of a PVSS user interface panel can be seen in Fig. 3. The FSM state transitions for a typical DCS object can be seen in Fig. 4.

A number of connected PVSS projects, forming a distributed system, are used to control the required hardware and collect information from sensors.

.

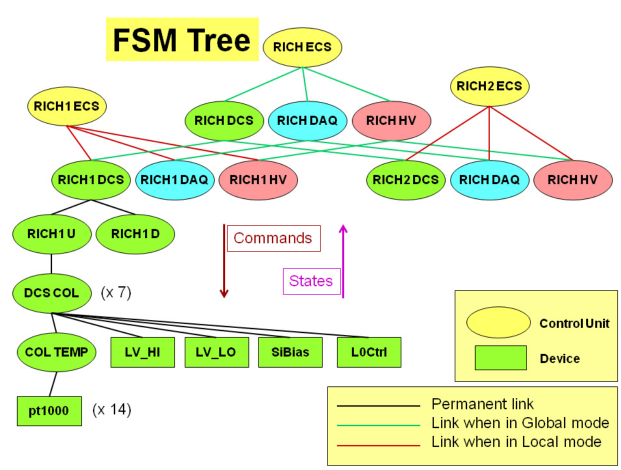

Figure 2: The RICH DCS FSM tree. The Global and Local mode links are mutually exclusive.

Power Supplies

The low voltage (~5 V) for the electronics is provided by Wiener MARATON supplies. Communication with PVSS is achieved via an OPC server, provided by Wiener. Each HPD column requires two channels at slightly different voltages, and these must be turned on and off in the correct order to avoid hardware damage. The channel switch on/off order has been introduced as a rule in the “turn on” procedure in the FSM, and control of the individual channels has been disabled to prevent the users accidentally changing the order and possibly damaging the hardware.

The bias voltage for the silicon sensors (80 V) is provided by CAEN power supplies. Again an OPC server is used for communication with PVSS. The voltage applied to each channel can be configured using recipes (sets of data in the configuration database) to match the detector activity.

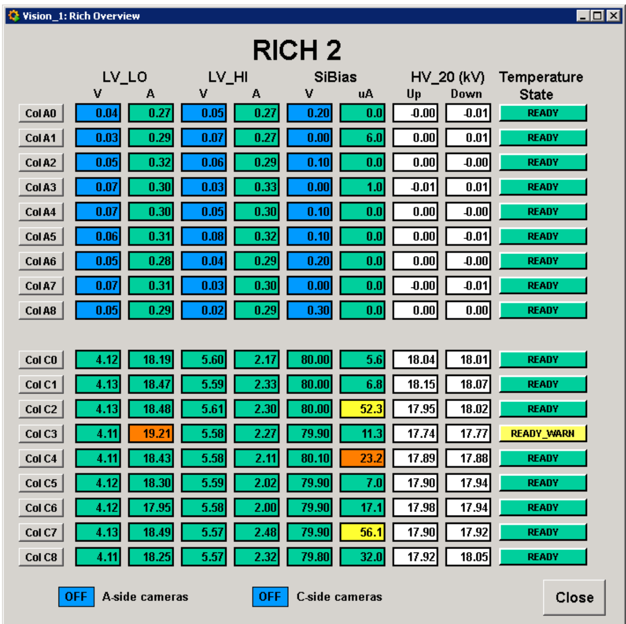

Figure 3: The RICH-2 Overview PVSS panel. Colour coding allows immediate identification of the state of the detector and parameters outside predefined limits.

The current of all the power supply channels is monitored continuously and archived. Any mis-configuration of the front end electronics usually results in abnormal low-voltage current values, while unexpected high activity in the HPDs (the result of vacuum degradation) can be detected from high values of the silicon bias current. Monitoring the current (and being able to go back in time to see previous values) has proved to be a very valuable tool in the commissioning of the RICH detectors.

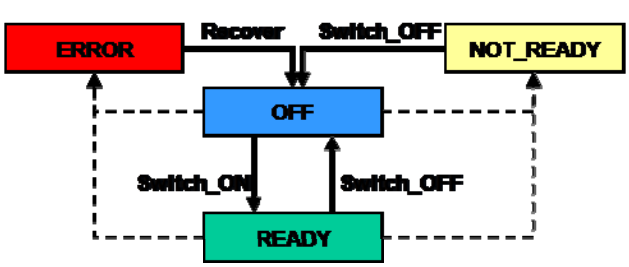

Figure 4: The state transitions of the DCS domain FSM.

SPECS

The low voltage provided by the MARATON supplies, is further controlled using voltage regulators that can be switched on and off. The state of the voltage regulators is controlled via the SPECS (Serial Protocol for the Experiment Control System) [5]. A SPECS mezzanine card is placed on every HPD column and the voltage regulators are switch on and off by changing the state of 32 bits on the mezzanine card. The “turn on” procedure ensures that the MARATON channels are on before enabling the voltage regulators to power the HPDs and Level zero electronics via SPECS. The DIM protocol [6] is used for communication between PVSS and the SPECS hardware.

Monitoring

Most of the information collected by the DCS is collected using ELMBs (Embedded Local Monitoring Board) [7]. An ELMB provides 64 differential ADC channels and three, 8 bit, digital ports. The ADC is 16 bit and the full range is configurable between 25 mV and 5 V. The ELMBs use the CAN bus for communication and an OPC server is used to transfer data from/to PVSS. A variety of adapters allows easy connection of various temperature sensors (pt100, pt1000, NTC). Sensors that provide output in the form of 4-20 mA are connected to the ELMB using a 1 Ω resistor transforming the current to a voltage. The resistor is placed in line with the negative electrode to avoid high common mode voltage.

Every HPD column has up to 16 pt1000 sensors in contact with high power voltage regulators monitoring the temperature. The three values of the high voltage required for the electrostatic focusing of the electrons inside the HPD vacuum tube are also monitored on the HPD columns.

The temperature and humidity of the HPD environment are monitored using pt100 sensors and radiation hard Xeritron humidity sensors [8]. The pressure of the cooling fluid is also monitored for detector safety.

ELMBs are also used to collect temperature, pressure and humidity information from the RICH gas radiators, and as an interface to custom made devices. Figure 5 shows pressure data from the RICH-1 gas radiator volume. The pressure difference between the top and bottom of the gas enclosure allows the prediction of the quantity of C_4F_{10} in the gas volume.

Automatic Actions

The logic of the DCS FSM has been equipped with automatic actions to ensure the safety of the detectors. If any of the temperature sensors on an HPD column goes outside predefined and individually adjusted limits, a shutdown of the particular column is triggered. Also the automatic shutdown of a whole HPD enclosure is triggered if the temperature sensors for the HPD environment show a value outside a predefined range, or if the cooling pressure drops below a certain level.

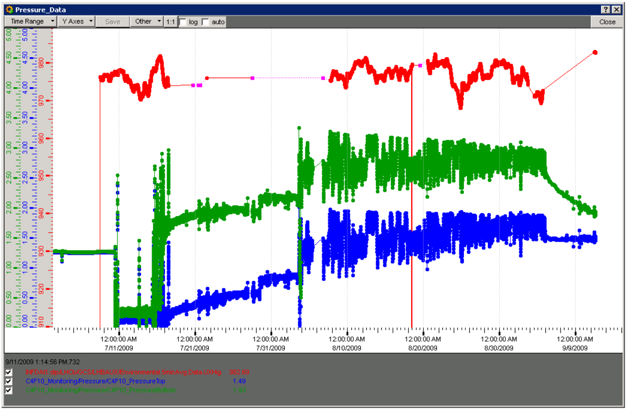

Figure 5: Seventy five days of RICH-1 gas radiator pressure data. The introduction of C_4F_{10} in the radiator area can be seen as the bottom sensor (green, middle) registers higher pressure that the top sensor (blue, bottom). The atmospheric pressure data is in red (top).

The Mirror Alignment Monitoring System

There are a total of 116 mirror segments in the LHCb RICH detectors (20 in RICH-1 and 96 in RICH-2) with the purpose of focusing and guiding the Cherenkov light. Alignment of the mirrors is very important for the Cherenkov angle reconstruction and the segments need to be aligned with a precision of 0.2 mrad. A number of these mirror segments is monitored for stability using laser beams and cameras. For each monitored mirror there is an optic fibre with a lens to provide a focused beam, a beam splitter, a mirror and a camera. The beam splitter creates two beams; one beam is directed to the camera (the reference beam), while the second one is reflected off the monitored mirror segment before reaching the same camera. Comparison of the relative position between the two spots on the camera can show whether the monitored mirror is stable or not. Images are taken at regular intervals, the position of the spots is analysed and the data communicated to PVSS via DIM for display and archiving. The final alignment of the whole RICH system to a precision of 0.1 mrad will be performed with data [9].

Ultrasound Gas Quality Monitor

In order to calculate the mass of a particle from the Cherenkov angle, it is necessary to know the refractive index of the radiator. Any impurities in the gas radiators will change the refractive index and affect the performance of the detector.

For this reason a device has been developed that can monitor the gas purity using a speed of sound technique. The device is based on the Polaroid 6500 ranging module and measures how long it takes for a 50 kHz sound wave to pass through a column filled with gas. Any change in the time (after correction for temperature effects) will be due to changes in the purity of the gas. Both the input and the output of the RICH detectors can be sampled so that the source of any impurities can be identified. The device is expected to detect impurities at the level of 1%.

CONCLUSIONS

The Detector Control System for the LHCb RICH is an essential part that ensures the safe operation of the detectors. It is robust, protects against operator mistakes and can take automatic actions. It is fully integrated in the LHCb Experiment Control System (ECS) and it is being used routinely for the operation of the RICH detectors. The information collected by the RICH DCS has been extremely useful in the effort to understand and characterise the RICH system.

REFERENCES

[1] The LHCb Collaboration, “LHCb Re-Optimised Detector Design and Performance Technical Design Report”, CERN/LHCC 2003-030 (2003).

[2] Holme, M. Gonzalez Berges, P. Golonka and S. Schmeling, “The JCOP framework”, Conf.Proc.C051010:WE2 (2005) 60.

[3] ETM Professional Control AG, http://www.etm.at.

[4] B.Franek and C.Gaspar, “SMI++ Object-Oriented Framework for Designing and Implementing Distributed Control Systems”, IEEE TRANSACTIONS ON NUCLEAR SCIENCE, 52 (2005) 891.

[5] Breton, D and Charlet, D, “SPECS: the Serial Protocol for the Experiment Control System of LHCb” LHCb note LHCb-2003-004.

[6] C. Gaspar, M. Donszelmann and Ph. Charpentier, “DIM, a Portable, LightWeight Package for Information Publishing, Data Transfer and Inter-process Communication”, International Conference on Computing in High Energy and Nuclear Physics (2000).

[7] Boterenbrood, H and Hallgren, B I “The Development of Embedded Local Monitor Board (ELMB)” 9th Workshop on Electronics for LHC Experiments (2003) 331.

[8] Brenner R, Bingefors N and Mohn B, “Evaluation of A Humidity Sensor for Use in An Environment Exposed to Radiation”, Journal of Testing and Evaluation, 35 (2007).

[9] Papanestis A, “The calibration and alignment of the LHCb RICH system”, NIM A 595 (2008) 248.