ISBN: 978-3-95450-221-9 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2021-THPV048

NOVEL CONTROL SYSTEM FOR THE LHCb SCINTILLATING FIBRE TRACKER DETECTOR INFRASTRUCTURE

M. Ostrega, M. Ciupinski, S. Jakobsen, X. Pons
CERN CH-1211 Geneva 23, Switzerland

Abstract

During the Long Shutdown 2 of the LHC at CERN, the LHCb detector is upgraded to cope with higher instantaneous luminosities. The largest of the new trackers is based on the scintillating fibres (SciFi) read out by SIlicon PhotoMultipliers (SiPMs). The SiPMs will be cooled down to -40°C to minimize noise. For performance and integration compatibility, the cooling lines are vacuum insulated. Ionizing radiation requires detaching and displacing the readout electronics from Pirani gauges to a lower radiation area. To avoid condensation inside the SiPM boxes, the atmosphere inside must have a dew point of at most -45°C. The low dew point will be achieved by flushing a dry gas through the box. 576 flowmeters devices will be installed to monitor the gas flow continuously. A Condensation Prevention System (CPS) has been implemented as condensation was observed in previous detector operation tests. The CPS powers heating wires installed around the SiPM boxes and the vacuum bellows isolating the cooling lines. The CPS also includes 672 temperature sensors to monitor that all parts are warmer than the cavern dew point. The temperature readout systems are based on radiation tolerant multiplexing technology at the the front-end and a PLC in the back-end.

INTRODUCTION

SciFi Tracker

The SciFi tracker consists of three stations each with four detection planes. The detector is built from individual modules (0.5 m ×4.8 m), each comprising 8 fibre mats with a length of 2.4 m as active detector material. The fibre mats consist of 6 layers of densely packed blue-emitting scintillating fibres with a diameter of 250 μm (see Fig. 1). The scintillation light is recorded with arrays of state-of-the-art multi-channel silicon photomultipliers (SiPMs). A custom ASIC is used to digitize the SiPM signals. Subsequent digital electronics performs clustering and data-compression before the data is sent via optical links to the DAQ system. To reduce the thermal noise of the SiPM, in particular after being exposed to a neutron fluence of up to 10^{12} neq/cm^2, expected for the lifetime of the detector, the SiPM arrays are mounted in so called cold-boxes and cooled down by 3D-printed titanium cold-bars to −40˚C. The detector is designed to provide low material budget (1 % per layer), hit efficiency of 99 % and a resolution better than 100 μm. These performance figures must be maintained over the lifetime of the detector which will receive radiation dose up to 35 kGy near the beam pipe. The full detector, comprising 590 000 channels, is read out at 40 MHz [1].

Detector Infrastructure

Three control systems have been developed in order to allow the operation with correct environmental parameters for the SciFi infrastructure were developed. In this paper, the vacuum system, condensation protection system and flowcells monitoring system were described.

Figure 1: LHCb SciFi Tracker assembly.

VACUUM SYSTEM

System Overview

The SciFi vacuum system consists of two subsystems that serve two detector sides (A & C). Each subsystem consists of a scroll pump (primary) and two turbomolecular pumps connected parallel for redundancy purposes. “Turbo” pumps set is connected to the central manifold, where are the manual valves. Those valves can insulate every C-Frame in case of maintenance. There are 48 vacuum lines (12 supply and 12 return lines per side), connecting two main manifolds with the 12 detector C-frames.

ISBN: 978-3-95450-221-9 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2021-THPV048

Figure 2: Turbomolecular pumps shielding.

Both vacuum subsystems are connected by the primary vacuum bypass valve, which allows the whole system for operation in case of one primary pump failure. In such a situation, both turbomolecular pumps (side A & C) runs with the same primary pump. This increases the whole system's redundancy (two turbomolecular pumps per side and two primary pumps).

Turbomolecular pumps are located on both sides, in close proximityof the detector and required to be protected against magnetic field. To allow safe operation, pumps, electro valves and two pressure gauges have been placed in the 2-layer iron shielded case (see Fig. 2). Additionally, pump drivers have been detached and located in the PLC (Programmable Logic Controller) rack in the LHCb service cavern.

Vacuum System Controls

Each of the 12 C-Frames has two vacuum gauges for the upper manifold and lower manifold, 24 Pirani sensors in total. The presence of ionising radiation, cumulating to 50 Gy over the lifetime of the experiment, requires detaching the readout electronics from those Pirani gauges that are mounted on the manifolds (see Fig. 3). Two 3U racks (one per side) with 12 readout electronic PCB are located in the safe distance from the detector (in the bunker area). Tests shows that detaching electronic and sensor adds small offset on the readout value, which is acceptable.

The SciFi Vacuum Control System is based on Siemens S7-1500 PLC technology. It operate the system in the automatic and safe mode as well it assure the readings of the Pirani probes. The PLC program follows the UNICOS framework which allows the PLC program software connection to the WinCC OA SCADA software used in the Supervisor Layer [2][3].

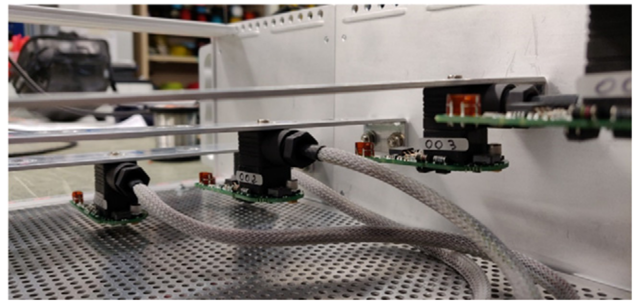

Figure 3: Pirani gauge electronic.

CONDENSATION PREVENTION SYSTEM

System Overview

Even though the good operation of the vacuum system, the collaboration has decided the implementation of high complex temperature measurement and heating system to avoid the condensation that may endanger the correct operation of the detector. This system, called CPS (Condensation Prevention System) consists in the installation of high-density temperature measurement network in the strategic places in the detector.

The CPS allows the monitoring, and the survey of 672 temperature sensors, Pt100 type, that are connected to radiation tolerant electronic interfaces, multiplexed and connected to a PLC, which collects all the information that is sent, a posteriori, to the Detector Control System. In case of condensation a heating wire that has been wrapped around the cooling transfer lines and the box housing the SiPMs. The heating wires can be powered by means of external power supplies. The heating power is distributed by the same electronic interfaces used for temperature measurements, in addition all the power consumption values of each circuit is measured by same interface through the PLC and sent up to the DCS for its control.

Each C-frame module (24 per C-frame) is equipped with one electrical heater and two Pt100 sensors. On each C-frame quadrant (4 per C-frame) there is one multiplexer box, which is responsible for reading 12 Pt100 signals and the measurement of the current of 6 electrical heaters. Additionally, on the MUX board, there is a power distribution and electrical protection (fuses) for six electrical heaters. One of the MUX installed on the C-frame, called MUX Master, will consist also additional multiplexer to multiplex all C-frame signals (see Fig. 4). Power to each heaters group is supplied by the MARATON power supplies. All the temperature signals (48 per C-frame, 576 in total) and heater power signals (24 per C-frame, 288 in total) are connected to the PLC located in the service cavern. Additionally, CPS monitor also cooling water temperature, which at the end gives total amount of 672 signals. All the MUX boards are based on electronics with sufficient radiation tolerance to cope with the radiation expected in the live time of the detector.

CPS Controls

The CPS control system is based on Siemens S7-1500 PLC technology commonly used and supported at CERN.

ISBN: 978-3-95450-221-9 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2021-THPV048

The PLC control program follow the CERN BE-ICS control system standards (UNICOS-COMM) which allows the PLC program software connection to the WinCC OA SCADA software used in the Supervision Layer (i.e. the SciFi Detector Control System or DCS). The WinCC OA software also archive all the relevant data in an ORACLE database.

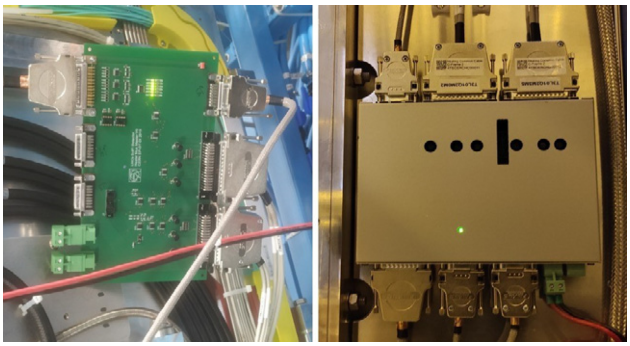

Figure 4. CPS Master multiplexing board.

FLOWCELLS DAQ SYSTEM

System Overview

The SiPM photodetectors are attached to cold bars through which Novec at about -40°C is flowing. The low temperature operation of the SiPMs mitigates radiation-related dark noise. To avoid condensation and frost formation inside the cold box, in particular on the SiPM arrays, the atmosphere inside the box must be free from humidity down to a dew point (DP) of approximately -50°C.

A complete sealing of the cold boxes is practically impossible, because the boxes need to ensure direct optical contact of the SiPMs to the scintillating fibres and also the passage of the SiPM signals via kapton flex cables to the electronic cards.

The low dew point will therefore be achieved by flushing a dry gas through the box. A small overpressure will compensate for potential leaks which could let humid air diffuse into the box. Flowmeter devices are installed on the outgoing line of each cold box in order to monitor continuously the gas flow. To insure a reliable measurement a fully redundant flow measurement is made with two flowmeters by outgoing line.

Controls

All the flow cells signals (48 per C-frame, 576 in total) are connected to two patch panels boxes, where power is distributed (two independent power supplies) and signals are separated (normal & redundant). The patch panel is connected with the DAQ rack using 12 MCA50 cables with the length around 60m each. The readout system is based on a 12 multiplexing boards (see Fig. 5). To preserve the redundancy, flow signals are separated into two multiplexers sub-racks. Multiplexed signals are connected to the SIEMENS S7-1500 PLC.

The PLC control program follows the CERN control system standards (UNICOS) which allows the PLC program software connection to the WinCC OA SCADA software used in the Supervision Layer. The WinCC OA software will also archive all the relevant data in an ORACLE database.

The PLC is installed in a dedicated 19'' rack for the dry gas DAQ system, which also contain the two multiplexers crate and two DC power supplies. Rack is also shared with the CPS PLC.

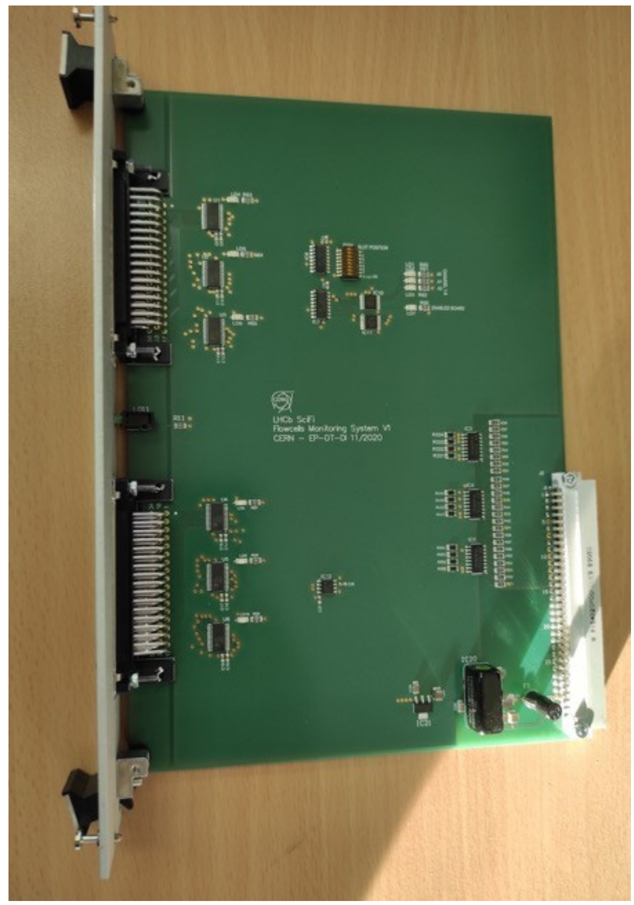

Figure 5. Flowcells multiplexing circuit.

SUMMARY

The multiplexing technology, used in the CPS and flowcells systems might be an interesting solution for the slow controls or monitoring systems. In the SciFi CPS system, almost 1000 channels are multiplexed and read by the PLC which is equipped with one DO (Digital Output) card and only three AI (Analog Input) cards. The multiplexers are installed on the detector which significantly reduces the number of cables between the experimental and service cavern, where the PLC is located. In the flowcells system, 12 multiplexers boards are installed in the accessible area, 576 signals are connected to the three AI cards, which reduce the signal readout time. The use of the Pirani gauges, with the detached electronic, reduced the cost of the vacuum system. Tests show that detaching the electronic has an acceptable effect on the readout vacuum pressure. It

ISBN: 978-3-95450-221-9 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2021-THPV048

might be also an interesting solution for the systems with a high number of readouts points, where vacuum sensors are affected by radiation.

REFERENCES

[1] P. Hopchev, "SciFi: A large Scintillating Fibre Tracker for LHCb", The Fifth Annual Conference on Large Hadron Collider Physics, Shanghai, China, May 2017.

[2] Ph. Gayet *et al.*, "UNICOS a Framework to Build Industry-like Control Systems Principles Methodo-logy", in *Proc. ICALEPCS'05*, Geneva, Switzerland, Oct. 2005, paper WE2.2-6I.

[3] B. Fernandez Adiego *et al.*, "UNICOS CPC6: automated code generation for process control applications", in *Proc. ICALEPCS 2011*, Grenoble, France, Oct. 2011, paper WEPKS033, pp. 871-874.