Engineered Hardware Interlock System for Hall B's RICH-2

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This note details the design of the hardware interlock system engineered for Hall B's RICH-2 detector. The status and effectiveness of the detector's air cooling system and the nitrogen purge system are monitored.

The interlock system uses a National Instruments single-board Compact RIO (sbRIO) programmable automation controller. The sbRIO's hardware architecture includes a reconfigurable field-programmable gate array and a real-time, embedded controller that runs LabVIEW's Real-Time Linux operating system. The sbRIO reads the 48 Sensirion SHT35 digital humidity and temperature sensors, reads the voltage and current data from modules in an expansion RIO chassis, compares the sensor data to user-set interlock limits, and reads the data from and writes the data to Hall B's established EPICS environment.

A benefit of using a dedicated sbRIO for this system is that if network communication were to be lost, the sbRIO will continue to monitor the detector and take action if needed, because of the sbRIO's ability to run without user interaction and because all sensors and interlock connections are directly hardwired to the interlock system. This capability of the sbRIO is in contrast to the EPICS alarm server and software interlocks, in which a working network connection between RICH-2's back-end electronics crate, an EPICS IOC, and the alarm handler is required, since these components can communicate with each other only over the network.

Since the electronics are sealed inside the detector, the heat load generated by the detector's high and low voltage systems could damage the electronics if left unmitigated, necessitating a cooling system for the safe operation of the detector.

To monitor the air cooling system's status, the sbRIO uses two mass flow meters to measure the cooling air flow through the left and right air cooling manifolds in the detector's electronic panel. The sbRIO uses a pressure transducer to also measure the cooling system's buffer tank pressure, as an indicator that the cooling system's air compressors are operating as expected. To determine the effectiveness of the cooling system, the sbRIO measures temperatures inside the detector volume at 12 locations, Fig. 1, using two Sensirion SHT35 digital integrated temperature and humidity sensors at each location.

Because moisture reduces the effectiveness of the aerogel as a Cherenkov radiator, a nitrogen purge system is necessary to minimize moisture absorption by the aerogel; the developed nitrogen purge system keeps the aerogel tiles in a <5% RH environment. The nitrogen purge system is monitored by measuring the nitrogen flow into the detector using a mass flow meter and its effectiveness is determined by measuring the humidity inside the detector volume at 12 locations, Fig. 2, using two Sensirion SHT35 digital integrated temperature and humidity sensors at each location.

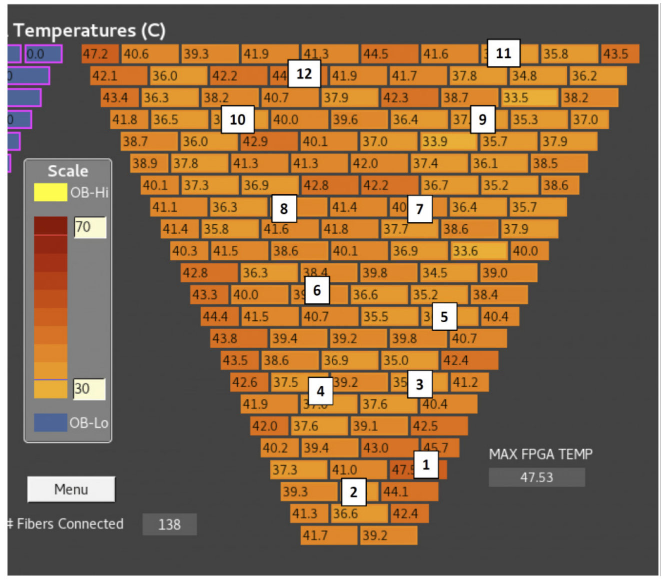

FIG. 1. Hardware interlock temperature and humidity sensor locations in the RICH-2 electronic panel. The number at each location in the image corresponds to the port number used to read those sensors on the hardware interlock chassis.

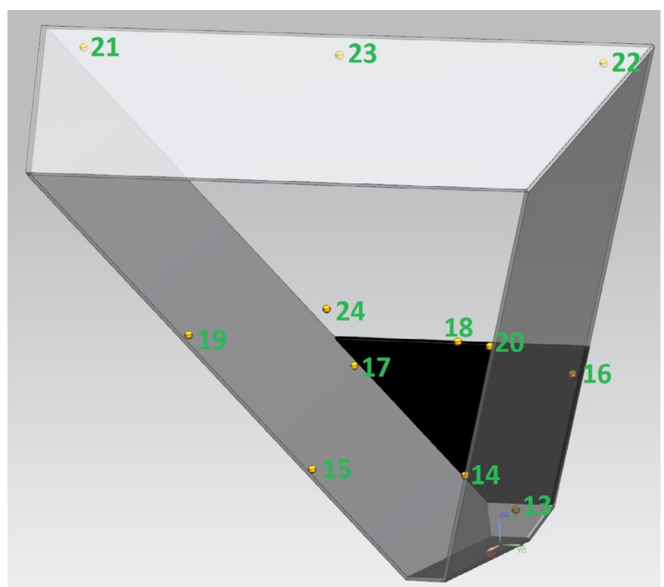

FIG. 2. Hardware interlock temperature and humidity sensor locations in the RICH-2 nitrogen volume. The number at each location in the image corresponds to the port number used to read those sensors on the hardware interlock chassis.

If the detector's internal temperature, cooling airflow, or cooling system buffer tank pressure falls outside of the programmed limits, the interlock system will disable high and low voltages to the detector. If the nitrogen flow or the detector's internal humidity falls outside of the set limit, the interlock system will indicate the problem and set off an alarm in Hall B's BEAST alarm handler. Table I details the type and number of signals monitored by the hardware interlock system. Table II details the limits used for interlocks and alarms.

Monitored area	Number of sensor locations	Details
Detector internal temperature	24	12 in nitrogen volume, 12 in electronic panel
Detector internal humidity	24	12 in nitrogen volume, 12 in electronic panel
Cooling airflow	2	one for manifold on left side of electronic panel, one on right side
Cooling system buffer tank pressure	1	pressure transducer on buffer tank
Nitrogen purge flow	1	measures nitrogen flow into detector volume

TABLE I. Type and quantity of signals monitored for RICH-2.

Measurement type	System action	Limit type	Limit value
Detector internal temperature	interlock detector power supply	high	48°C
Detector internal humidity	alarm	high	7% RH
Cooling airflow	interlock detector power supply	low	airflow 1: 300 L/min airflow 2: 450 L/min
Cooling system buffer tank pressure	interlock detector power supply	low	45 psi
Nitrogen purge flow	alarm	low	20 L/min

TABLE II. Interlock system limits and type.

In summary, RICH-2's hardware interlock system uses an sbRIO to monitor the status and effectiveness of the detector's nitrogen purge system and air cooling system. If any measured parameter falls outside the system's set limits, the interlock system automatically takes action, whether it be disabling the detector's high and low voltage power or triggering an alarm via an alarm handler.