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Multi-Channel Radiation-Tolerant Humidity Monitoring System for the CMS Inner Cold Sub-detectors

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In this presentation, we discuss a multi-channel radiation-tolerant and magnetic field-compatible humidity monitoring system developed for the needs of the CMS inner cold sub-detectors. The results of sensor irradiation tests, the tests conducted at different negative temperatures, and tests performed in the strong magnetic field are presented. Furthermore, a multi-channel readout unit has been designed, evaluated, and discussed. The proposed readout unit effectively nullifies both internal sensor parasitic effects and parasitic effects coming from long cables connecting the sensor to the readout electronics.

Summary (500 words)

In Silicon-based HEP detectors cooling is essential for two main reasons: i) to remove the heat generated by millions of densely packed bias and readout channels, ii) to compensate for the increase in leakage currents. Under such conditions of high-power density and cold operation, monitoring humidity becomes critical. However, selecting a humidity sensor that can survive such a harsh environment is challenging. We have developed a multi-channel radiation-tolerant and magnetic field-compatible humidity monitoring system that can operate in the HEP environment.

Before being compatible for installation in the accelerator/detector complex at CERN, sensing elements must be qualified for radiation tolerance, insensitivity to the strong magnetic field, and operability at temperatures well below 0℃.

The candidate capacitive humidity sensor was tested at the IRRAD facility of CERN up to a fluence of 3 x 1016 protons/cm2, equivalent to over ten years of HL-LHC operation for the inner sub-detectors. The tests were done in a temperature- and humidity-controlled environment at a nominal temperature of -20℃, using pre-calibrated gas mixtures to test the sensors' responsiveness. The tests showed a linear dependence of the sensor capacitance on the accumulated fluence which can then be corrected for.

Furthermore, sensor coming from the irradiation campaign, together with one non-irradiated sensor, were tested in the QART lab in a magnetic field of 2T. The sensor capacitance was not affected by the field. Then, the sensors were tested at negative temperatures (-10℃, -20℃, -30℃). While for positive temperatures, the sensor capacitance depends linearly on the relative humidity, for negative temperatures, the change in the sensor's capacitance can be fitted with a second-degree polynomial function.

The high granularity of the Phase-2 CMS cold detector requires the distribution of a large number of humidity sensors across the detector to ensure valid humidity monitoring. Therefore, it is crucial to design a multi-channel readout unit capable of conditioning as many humidity sensors as possible. Here, we present an 8-channel signal conditioning unit with two 4-channel ADC chips and MCU integrated on the same board that has the standard industrial 3U Eurocrate dimensions.

The conditioning is based on the auto-balancing bridge configuration. The bridge output signal contains information on the internal sensor leakage resistance caused by temperature variations, pollution, etc. Thus, the bridge output signal is demodulated by the control signal coming from the quadrature-phase shifter circuit to extract the sensor capacitance. The quadrature-phase shifter circuit is based on the TLV2474 chip and three RC networks. The same chip is used as an internal oscillator to generate the excitation sine wave. As the

capacitive-humidity sensor will be read out over long cables, the conditioning circuit must eliminate the cable parasitic effects. This issue is solved using the active shielding technique.
The proposed radiation-tolerant and magnetic field-compatible humidity monitoring system has already been tested in the IRRAD facility and in several other test facilities in preparation for the LS3 sub-detectors. Finally, it will be integrated as a part of the upcoming CMS Cold subdetector DCS system.

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