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The Readout Electronics of the Mu2e Electromagnetic Calorimeter

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Mu2e aims to measure the ratio of the rate of the neutrino-less muon to electron coherent conversion in the field of an aluminum nucleus relative to the rate of ordinary muon capture. In order to do that, Mu2e will exploit a detector system composed of a straw tracker and an electromagnetic calorimeter. The latter has to provide precise information on energy ($\sigma E/E < 10\%$), time ($\sigma t < 500$ps) and position ($\sigma x < 1$cm) for ~100 MeV electrons. It is composed of 1348 un-doped CsI crystals, each coupled to two large area Silicon Photomultipliers (SiPMs). Each SiPM is connected to a Front End Electronics (FEE) chip, which hosts the shaping amplifier and the high voltage linear regulator. Each group of 20 FEE is controlled by one Mezzanine Board (MB), which passes the amplified signals to the Digitizer ReAdout Controller board (DiRAC). The DiRAC samples the waveforms at 200 MHz with 12-bits ADCs, packs the data according to the Mu2e custom format and transmits them to the event builder through an optical transceiver. In order to limit the number of pass-through connectors and the length of the cables, the readout and digitization electronics will be located inside the detector cryostat, close to the interaction target. The boards are expected to sustain a neutron fluence of about 5x1010 n/cm2 @ 1 MeVeq (Si)/y and a Total Ionizing Dose of about 12 krad, while working into a 1T magnetic field and a vacuum of 10-4 Torr. This harsh operational environment has made the electronics design challenging, requiring an extended campaign of tests to select and qualify the employed electronic components. Moreover, to validate the performances of the system in terms of dynamic, SNR, bandwidth, and linearity, we assembled a full system chain (20 FEE board, one MB and one DiRAC prototype) to read the Module-0 (a medium scale prototype of the calorimeter) during a cosmic rays test. We demonstrated that the readout electronics performs satisfactorily: the signal shape is as expected from the Monte Carlo simulation, with an obtained time resolution of about 350 ps for MIP particles. In this paper we report on the board architecture and design, on the qualification of the prototypes and on the performance tests, as well as on the results of the first vertical slice test of the Mu2e calorimeter.

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