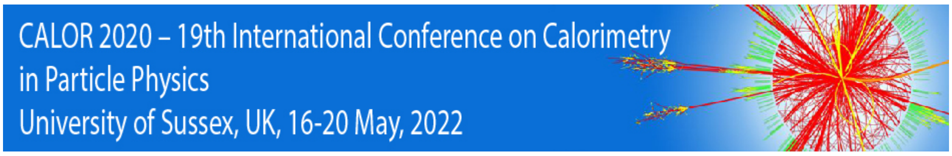

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Mu2e crystal calorimeter front-end electronics: design, characterisation, and radiation hardness

The Mu2e experiment at Fermi National Accelerator Laboratory will search for charged-lepton flavour violating neutrino-less conversion of negative muons into electrons in the coulomb field of an Al nucleus. The conversion electron has a monoenergetic 104.967 MeV signature slightly below the muon mass and will be identified by a complementary measurement carried out by a high-resolution tracker and an electromagnetic calorimeter (EMC), reaching a single event sensitivity of about $3 \cdot 10^{-17}$, four orders of magnitude beyond the current best limit. The calorimeter, composed of 1348 pure CsI crystals arranged in two annular disks, has high granularity, 10% energy resolution and 500 ps timing resolution for 100 MeV electrons and will need to maintain extremely high levels of reliability and stability and in a harsh operating environment with high vacuum, 1 T B-field and high radiation exposures.

Each crystal is readout by two custom UV-extended SiPMs (Mu2e-SiPM), each one corresponding to a separate readout channel. Each Mu2e-SiPM is coupled to a custom front-end electronics (FEE) board, mounted directly behind the SiPM, which will provide individually programmable bias voltages for each photosensor, perform signal amplification, while monitoring currents and temperatures. Each Mu2e-SiPM is composed of 6 individual cells, wired in two parallel connections of three elements each. Two fast, low-input impedance transimpedance stages combine SiPM pulses and feed them to a buffer stage, which in turn drives a pole-zero compensator, followed by a pulse stretching stage comprising a 3-pole Bessel filter, guaranteeing more than 5 sampled points on the rising edge available to the 250 Msps digitizer boards. A final balanced differential driver transmits the signals to the digitizing section. The FEE has selectable gain (2 or 4). A pulsed green laser is distributed via fiber optic to each Mu2e-SiPM to perform gain equalization. Each FEE will also handle all slow control functions via an SPI bus, by implementing a high-voltage, high stability linear regulator with local DAC, and readout systems for SiPM bias, temperature, and current monitoring.

The FEE design was validated for operation in vacuum and under magnetic fields. An extensive radiation hardness certification campaign, carried out with photons from Co-60, 14 MeV neutron beams, and 200 MeV protons certified the FEE design for doses up to 100 krad, neutron fluences up to $10^{12} n_{1MeV}/cm^2$ and for single-event effects occurrences and correction.

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