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CLARO-CMOS: a Fast, Low Power and Radiation-hard Front-end ASIC for Single-photon Counting in 0.35 Micron CMOS Technology

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The CLARO-CMOS is a prototype ASIC for fast photon counting with 5 ns peaking time, a recovery time to baseline smaller than 25 ns, and a power consumption of about 1 mW per channel. The chip was designed in 0.35 micron CMOS technology, and was tested for radiation tolerance with neutrons up to 10^{14} 1 MeV neq/cm^2 and protons and X-rays up to 8 Mrad. Its capability to readout single photons at high rate from a Hamamatsu R11265 Ma-PMT, the baseline photon detector for the LHCb RICH upgrade, was demonstrated.

Summary

The CLARO-CMOS is a prototype ASIC primarily designed for single-photon counting with multi-anode photomultipliers (Ma-PMTs). The chip allows fast photon counting up to 40 MHz with power consumption in the order of 1 mW per channel. It was developed in the framework of the LHCb RICH detectors upgrade at CERN, but also found application in the readout of Silicon photomultipliers (SiPMs) and microchannel plates (MCP-PMTs) [1,2].

The prototype has four channels, each made of a charge amplifier with settable gain (3 bits) and a comparator with settable threshold (5 bits) that allow tuning the response of the chip to the gain spread of the PMT pixels. The threshold can be set just above noise to allow an efficient single-photon counting with Ma-PMTs. In the readout of SiPMs, the threshold can be set above the single photon signals, allowing to count events with two or more photoelectrons with high efficiency and good separation of the photoelectron peaks.

The prototype is realized in a 0.35 micron CMOS technology. In the LHCb RICH environment, over ten years of operation at the nominal luminosity for the upgrade, the ASIC must withstand a total fluence of about 6×10^{12} 1 MeV neq/cm^2 and a total ionizing dose of 400 krad.

We present results of multi-step irradiation tests with neutrons up to the fluence of 10^{14} 1 MeV neq/cm^2, with protons up to the dose of 8 Mrad and with X-rays up to the dose of 8 Mrad. During irradiation, cumulative effects on the performance of the analog parts of the chip and single event effects (SEE) were evaluated. The chips were biased continuously and the chip threshold voltages were measured regularly, in order to detect possible single event upsets (SEUs) affecting the threshold DAC settings. Power consumption was also monitored online, and an additional circuit provided protection against Single Event Latchup (SEL). S-curves were measured before and after each irradiation step, to follow the evolution of counting efficiency, threshold shifts and noise during the irradiation.

The electrical performances of the CLARO-CMOS chip coupled to the Hamamatsu R11265 Ma-PMT are presented as well. For these tests a dedicated PCB was designed to connect the chips to the Ma-PMT with minimal contribution of parasitic capacitance at the input, and allowed to obtain very low noise and crosstalk. This readout scheme simulates the baseline read-out solution for the upgraded RICH detectors of the LHCb experiment. To mimic the conditions expected in the upgraded LHCb RICH environment, single photons in the blue range were generated using LED and diode laser. The speed of the CLARO signals and the low power consumption were demonstrated. Single-photon spectra from the Ma-PMT pixels were nicely reconstructed with a threshold scan, showing that the binary outputs allow precise characterization of the Ma-PMT. Also, crosstalk between neighboring pixels was shown to be negligible.

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