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High-speed front-end electronics and digitisation system for the Crilin calorimeter with enhanced timing performance

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Crilin –a semi-homogeneous, longitudinally segmented highly granular electromagnetic calorimeter with Cherenkov PbF₂ crystals has excellent timing and improved radiation resistance. A two-channel front-end prototype was tested at CERN-H2 with 120 GeV e⁻ using PbF₂ and PWO-UF crystals, yielding a single-cel timing resolution <30 ps for energy deposits <3 GeV. Crilin prototype consists of two sub-modules, housing a 3-by-3 crystal matrices and layers surface-mount 10 um pixel-size UV-extended SiPMs, handled via a fully custom microprocessor-controlled front-end, providing signal amplification/shaping and all slow control functions. The relative CAEN-V1742 based 5Gbps digitisation system employs a custom ultra-low-jitter trigger distribution electronics.

Summary (500 words)

Crilin - a semi-homogeneous, longitudinally segmented electromagnetic calorimeter concept based on Cherenkov PbF₂ crystals, features fine granularity, excellent timing, good pileup capability and energy resolution, along with improved radiation resistance. Its modular architecture, featuring stackable and interchangeable sub-modules, allows crystals granularity, transversal and longitudinal dimensions scaling to maximize performance. Crilin was optimised in the ambit of the Muon Collider experiment as a candidate for an electromagnetic barrel calorimeter. Its architecture was also adopted as a candidate for the Small-Angle-Calorimeter for the HIKE experiment. A two channel Crilin front-end prototype was tested at CERN H2 using 120 GeV e⁻ beams, to study light collection dynamics, and validate the readout chain using PbF₂ and novel PWO-UF crystals. A timing resolution < 30 ps for energy deposits > 3 GeV can be expected from a single calorimeter cell.

In its current design, Crilin prototype (Proto-1) consists of two sub-modules, each composed of a 3-by-3 crystals matrix and a photosensor board housing a layer of 36 surface-mount 10 um pixel-size UV-extended SiPMs –thermalized using an additively manufactured micro-channel heat exchangers –so that each crystal has two independently processed and digitized readout channels, composed by the series connection of two photosensors. SiPMs are handled via micro-coaxial transmission lines by a remote fully custom microprocessor-controlled front-end system. Each front-end houses a two-stage high-speed current-feedback amplifier and a pole-zero shaper for a total of 18 readout channels, while providing individual bias regulation, temperature, and current monitoring –for all photosensors. A high-speed switched-capacitor array digitization system based on CAEN V1742 DRS4 modules, employing a custom ultra-low-jitter trigger distribution and synchronization electronics, is being developed to allow Crilin Proto-1 digitisation at 5 Gbps and handle its improved timing performances.

A full description of the system and the qualification of custom high-voltage linear regulators, amplification, and digitisation stages will be shown. The custom trigger distribution allows a DRS4 synchronisation with a 5 ps channel-to-channel (within the same chip) and 30 ps board-to-board jitter capabilities, still under improvement.

Pictures of Crilin's front-end and SiPM boards are shown in attachment along with a photo of the assembled Crilin Proto-1.

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