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Crilin: a highly granular semi-homogeneous crystal calorimeter with excellent timing for future colliders

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Crilin is a concept of a semi-homogeneous calorimeter consisting in multiple layers of pure Cherenkov Lead Fluoride (PbF2) crystals interspaced with active surface-mounted UV-extended Silicon Photomultipliers (SiPMs).

This innovative design is now the baseline for the electromagnetic calorimeter of the MUSIC detector for the prospective Muon Collider. Considering the need to discriminate signal particles from the Muon Collider beam-induced background (BIB), Crilin employs an high level of granularity, both transverse (1 cm) and longitudinal ($4X_0$).
Due to the expected occupancy resulting from beam-induced backgrounds, with a photon flux of average energy of 1.7 MeV and approximately 4.5 MHz/cm^2 fluence, time-of-arrival measurements within the calorimeter becomes essential to reject out-of-time BIB. Thanks to its pure Cherenkov response, Crilin can not only achieve outstanding time resolutions, but also suppress part of the photon background which creates e^+/e^- under or close to the Cherenkov threshold.

The high granularity and the timing properties allow 5D particle flow tecniques, essential to reach good jet energy resolutions at any future collider.

Operation within a challenging radiation environment is also a crucial point, with exposure levels reaching 1 Mrad/year total ionizing dose (TID) and a neutron fluence equivalent to 10^{14} $n_{1MeV-eq}$/cm^2/year. An exhaustive radiation hardness study on both crystals and SiPMs confirmed the Crilin capability to work effectively in these extreme conditions, in terms of both dose and neutron fluences.

A prototype (Proto-1), consisting of two layers of 3x3 PbF2 crystals each, underwent testing in 2023 using 450 MeV electrons at the LNF Beam Test Facility and 40-150 GeV electrons at CERN H2. An outstanding timing resolution of less than 50 ps for energy deposits as low as 1 GeV was measured. A comprehensive overview of the prototype's mechanics and electronics, along with the outcomes of the test beams, is presented for consideration.

We are currently in the process of constructing a larger full-containment prototype featuring a 7x7 crystal matrix and comprising 5 layers, in the framework of the DRD6 collaboration. The realization is scheduled for completion in 2025, with testing set to commence in the spring of 2026.

Secondary track

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