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Efficient and precise Cherenkov-based charged particle timing using SiPMs

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In the framework of the DRD4 Collaboration, work package 4.4, dedicated R&Ds are ongoing on the coupling of a thin Cherenkov radiator to Silicon Photomultiplier (SiPM) arrays for precise charged particle Time-of-Flight (TOF) measurements. Cherenkov prompt radiation emission is indeed ideal for ultimate timing performance for a TOF detector. A thin radiation with high refractive index as synthetic quartz (fused silica) is able to provide a fast signal for charged particles which are above the Cherenkov threshold. A crucial requirement to approach the target time resolution is the optimization of both the radiator material and thickness, as well as the optical coupling with the SiPMs. We assembled small-scale prototypes instrumented with various Hamamatsu SiPM arrays sensors with pitches ranging from 1.3 to 3 mm coupled with various window materials, such as fused silica and MgF_2, featuring different thickness values. The prototypes were successfully tested in beam test campaigns at the CERN PS T10 beam line between 2022 and 2024. The data were collected with a complete chain of front-end and readout electronics based on the Petiroc 2A and Radioroc 2 together with a picoTDC to measure charges and times. By comparing the time measurements with two of such arrays we were able to measure a time resolution better than 50 ps at the full system level with a charged particle detection efficiency above 99%. We have also measured the time performance of similar SiPM arrays without the thin radiator resulting in both a worse efficiency and a time resolution worse than 200 ps. The present technology makes the proposed SiPM-based PID system attractive also for future high-energy physics experiments and for space applications. In this talk the results achieved in our beam test campaigns will be reported. The perspectives of the proposed TOF layout and its optimization will be also discussed.

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