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First experimental results on TOFHIR readout ASIC of the CMS Barrel Timing Layer

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The CMS Detector will be upgraded for the HL-LHC to include a MIP Timing Detector (MTD). The MTD will consist of barrel and endcap timing layers, BTL and ETL, respectively, providing precision timing of charged particles. The BTL sensors are based on LYSO:Ce scintillation crystals coupled to SiPMs with TOFHIR ASICs for the front-end readout system. A resolution of 30 ps for MIP signals at a rate of 2.5 Mhit/s per channel is expected at the beginning of HL-LHC operation. We briefly overview the design of the MTD BTL and present first measurements with silicon samples of the TOFHIR ASICs.

Summary

The MIP Timing Detector (MTD) will provide timing of charged particles with high precision allowing to extend to the time domain the association of charged particles to the ˜200 concurrent proton collision vertices occurring at each bunch crossing in the High-Luminosity LHC (HL-LHC). In the barrel section, the Barrel Timing Layer (BTL) is a thin standalone detector based on LYSO:Ce crystals read-out with silicon photomultipliers (SiPMs). The individual cell consists of a crystal bar associated to two SiPMs in both ends. The full BTL detector has about 330 thousand SiPM channels.

The readout the SiPMs uses the new TOFHIR chip optimised for timing performance at high rate with low-power dissipation. Each ASIC channel contains independent amplifiers, discriminators, time-to-digital converters and charge-to-digital converters. The input pre-amplifier provides a low impedance input to the sensor's current signal. The input current is replicated into three branches for timing, energy discrimination and charge integration. Pulse filtering in the TOFHIR chip was developed to mitigate the deterioration of time resolution due to the large SiPM dark noise induced by radiation.

A preliminary evaluation of the ASIC prototypes has been made. Digital communication with the chip was established, the configuration cycle was validated, as well as event triggering and data transmission using external test pulses. The assessment of the 10-bit 10 MHz SAR ADC developed in TOFHIR was made using a dedicated test input to scan the ADC input voltage. Good linearity of the ADC is observed. The measured ADC noise is 0.8 LSB. The TDC assessment was made using external test pulses shifted in time in steps of 300 ps. The timing scan shows the expected linearity of the TDC. The TDC time quantization bin size was confirmed to be 20 ps. The TDC time resolution was estimated by measuring the time difference between two channels triggered by a common digital test pulse. From these measurements, we estimate a TDC time resolution of 15 ps.

First tests with SiPM signals at TOFHIR1 input have been performed. Using the SiPM HPK S12572 operated at over-voltage 4 V and laser pulses with about 1000 p.e., the measured time resolution of the full channel is 20 ps, consistent with the expected timing performance of the ASIC. A total static power consumption of 220 mW was measured in TOFHIR1 (16 channels) corresponding to 13.8 mW per channel, which compares well with the simulation expectation (13 mW).

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