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OPTIMA, a board dedicated to Optimized Precision Timing for Multichannel Acquisition

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In the new era of HL-LHC experiments, fast-timing detectors are emerging as a critical priority. Typical requirements include a temporal hit resolution of ~ 50 ps, spatial resolution of ~ 12 μm , and radiation hardness up to 10^{16} neq/ cm^2 . To address these challenges, the development of non-standard sensor designs and advanced fast-readout electronics is required. The OPTIMA multichannel board addresses the need for testing small sensor demonstrators, providing fast readout up to 16 channels and compatibility with test beam environments. This contribution will present the design of the OPTIMA board, its integration in test beams and the first experimental results.

Summary (500 words)

The tracking detectors under development for the High Luminosity LHC and FCC upgrades will require significant performance improvements, introducing track time measurement while maintaining high spatial resolution and radiation hardness. Specifically, for the LHCb Upgrade 2, the vertex detector must achieve a hit time resolution of 50 ps and a spatial resolution of 15 μm , leading to an overall track time resolution of 20 ps. These stringent requirements are essential for reconstructing tracks in the high-pileup environment foreseen at LHCb for Run 5 and Run 6. Additionally, the front-end components must withstand radiation fluences on the order of 10^{16} neq cm^{-2} , posing a significant challenge for charge collection efficiency over the detector's lifetime.

New sensor technologies are being developed to meet these demands and replace current planar pixel sensors with devices capable of achieving the required performance, such as Low Gain Avalanche Detectors (LGADs) and 3D silicon sensors.

Preliminary tests of sensor technologies are done on small structures featuring a limited number of channels. Those structures are a cost-effective way to validate different sensor configurations and are the primary tool in the early stage of sensor technology development.

To measure and study the characteristics of the signal deposited by a MIP in such structures, it is convenient to use front-end discrete circuits based on high-bandwidth transistors without concerns regarding power consumption or circuit miniaturisation. Deposited charge, time of arrival (ToA), or signal development can then be investigated in detail in various experimental contraptions, ranging from beta sources or IR-laser setups to beam telescopes.

The OPTIMA (Optimized Precision Timing for Multichannel Acquisition) front-end board is a versatile platform designed to characterise test structures with up to 16 channels, targeting laboratory and test beam applications. Its primary objective is to provide precise measurements of the TOA on neighbouring pixels to understand how the charge is shared in a given device.

The amplification stage, based on a Transimpedance Amplifier scheme, is hosted on a motherboard, while the sensor structures are wire-bonded to a separate carrier board. This modular approach simplifies the characterisation process, as multiple sensor structures can be tested without the need to un-bond and re-bond devices on the main board. Additionally, the carrier board can be irradiated at high fluences without affecting the motherboard components.

OPTIMA, developed in 2024, demonstrated outstanding performance during test beam and laser campaigns, achieving a signal-to-noise ratio greater than 10 and a time resolution of 30 ps with LGADs. These results

confirm the system's suitability for R\&D on next-generation detectors.

This contribution will cover both the design of the board, the integration with the Timepix4 telescope system and the experimental results obtained.

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