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Development and characterization of hybrid MCP-PMT with embedded Timepix4 ASIC

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We introduce a novel single-photon detector that incorporates a vacuum tube design featuring a photocathode, a microchannel plate (MCP), and a Timepix4 CMOS ASIC serving as the readout anode. Designed to handle detection rates of up to 10^9 photons per second over a 7 cm^2 active area, the system achieves spatial resolution between 5-10 μm and timing resolution better than 100 ps. The Timepix4 ASIC contains approximately 230{,}000 pixels and integrated analog and digital front-end electronics, it operates in a data-driven acquisition mode with data transmission rates reaching a maximum of 160 Gb/s.
Control and readout of the Timepix4 are executed via FPGA-based external electronics. Initial experimental validation was performed using a prototype coupled to a 100 μm thick n-on-p silicon sensor and exposed to a pulsed infrared picosecond laser. This setup yielded a timing resolution of 110 ps per individual pixel hit, which improved to below 50 ps when analyzing clusters of pixels, with the silicon layer contribution taken into account.
Hamamatsu Photonics produced six prototype detectors featuring different MCP stack configurations and varying end-spoiling depths. These were characterized through measurements of gain, dark count rate, spatial and timing resolution, both in laboratory settings and in a test-beam environment at CERN's SPS facility. The results of these activities will be presented.

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