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Development of a single-photon imaging detector with pixelated anode and integrated digital readout

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We present the development of a single-photon detector and the connected read-out electronics.
This 'hybrid' detector is based on a vacuum tube, transmission photocathode, microchannel plate and a pixelated CMOS read-out anode encapsulating the analog and digital-front end electronics.
This assembly will be capable of detecting up to 10^9 photons per second with simultaneous measurement of position and time.

A microchannel plate with 5-10 μm pore spacing, operated at low gain and treated with atomic layer deposition, was chosen to allow a lifetime of more than 20 $\mathrm{C/cm^2}$ accumulated charge.
The pixelated read-out anode used is based on the Timepix4 ASIC (65 nm CMOS technology) designed in the framework of the Medipix4 collaboration.
This ASIC is an array of 512×448 pixels distributed on a 55 μm square pitch, with a sensitive area of $\sim$ 7 cm^2.
It features 50-70 e^- equivalent noise charge, a maximum rate of 2.5 $\mathrm{Ghits/s}$, and allows to time-stamp the leading-edge time and to measure the Time-over-Threshold (\textit{ToT}) for each pixel.
The pixel-cluster position combined with its ToT information allows to reach 5-10 μm position resolution.
This information can also be used to correct for the leading-edge time-walk achieving a timing resolution of the order of 10 ps.

The detector will be highly compact thanks to the encapsulated front-end electronics allowing local data processing and digitization.
An FPGA-based data acquisition board, placed far from the detector, will receive the detector hits using 16 electro-optical links operated at 10.24 Gbps.
The data acquisition board will decode the information and store the relevant data in a server for offline analysis.

These performance will allow significant advances in particle physics, life sciences, quantum optics or other emerging fields where the detection of single photons with excellent timing and position resolutions are simultaneously required.

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