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Timing resolution of a LAPPD prototype measured with CERN PS test beams

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ABSTRACT

The Electron-Ion Collider (EIC) facility is envisaged for the ultimate exploration of the nucleons, the nuclear matter and the strong force, thanks to its wide range of centre-of-mass energy, its large luminosity, and the polarization of its beams. The ePIC detector, designed to cope with the EIC physics potential, involves several Cherenkov radiation-based sub-systems for Particle Identification. They need reliable and effective Single Photo-Electron (SPE) sensors. We report about the timing performance of a LAPPD prototype tested with Cherenkov light produced in a quartz radiator at a CERN PS hadron test beam. Results show a SPE time resolution of 87 ps rms.

1. Introduction

High Rate Picosecond Photo-Detectors (HRPPDs) are Micro-Channel Plate (MCP) [1] based vacuum photosensors with good SPE timing resolution (<100 ps), tolerance in normal magnetic fields (<1.5 T), high gain (>10^6), high rate capability (MHz/cm^2), good radiation hardness (<10 C/cm^2) and low dark count rate (few kHz/cm^2). They are the baseline choice for the proximity focusing RICH [2] in the backward Endcap of the ePIC [3,4]. The Cherenkov photons produced in the HRPPD window will also provide TOF information. HRPPDs are also an alternative option for the high-performance DIRC in the detector barrel. The Large Area Picosecond Photo-Detector (LAPPD) [5] belongs to the same family with similar architecture and it is a first step towards HRPPD. The crucial technical differences between them, bringing better timing/spatial performances and more tolerance in the magnetic field for the latter, are listed below:

- 20 × 20 cm^2 vs. 10 × 10 cm^2 active surface.
- Capacitive coupling vs. DC-coupling of the vacuum photosensor to the readout PCB.
- 20 μm (the one tested at CERN) vs. 10 μm pore diameter.
- Further reduced transfer gaps in HRPPDs.

2. The LAPPD sensor

LAPPD unit #124[1] (Generation II) was a stack assembly of fused silica window with bialkali Photocathode (QE @ 365 nm ~30%) on inside surface, two MCPs (in chevron configuration) made of robust glass substrate, a resistive anode and a capacitively coupled readout PCB with 8 × 8, 1 inch square pads. The electrodes were powered by CAEN DT1415 HV power supply. Applied differential biasing voltages at which the timing studies had been performed were 50-800-200-900-200 (PC-MCP1entry-MCP1exit-MCP2entry-MCP2exit) in Volts, with respect to the grounded Anode. A schematic drawing of the LAPPD with distances between electrodes and a detailed HV scheme can be found in Ref. [6].

3. Experimental setup

The test had been performed at CERN PS T10 beamline in October 2022. The LAPPD, scintillating fibres read by a SiPM for triggering, and an MCP-PMT (Hamamatsu R3809U-50) for timing reference, were equipped in a light-tight dark-box that was aligned on the beamline. An acrylic filter to reduce the UV light and a plano-convex fused silica lens as Cherenkov light radiator were installed downstream the LAPPD. Fig. 1 illustrates a schematic sketch of the setup. Mixed hadron beams of momenta between 4 to 12 GeV/c produced Cherenkov photons both in the radiator lens and the LAPPD window. To reconstruct the Cherenkov rings *i.e.*, the hadron events, the LAPPD signals from 31 readout pads, one MCP-PMT signal and two fast trigger signals from the SiPM were fed to a CAEN V1742 digitizer module.

4. Results on timing

4.1. SPE time resolution

Time resolution for all Cherenkov ring pads were measured for SPE signals. Pulse height or integrated charge distribution, event by event,

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[1] https://incomusa.com/lappd/

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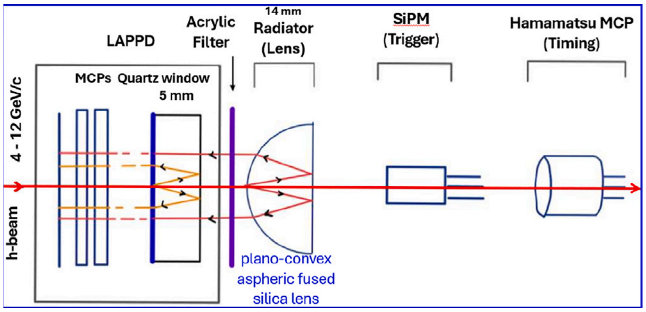

Fig. 1. An illustrative sketch of objects inside the dark-box. Direction of Cherenkov photons are indicated with arrows. See text (Section 3) for details.

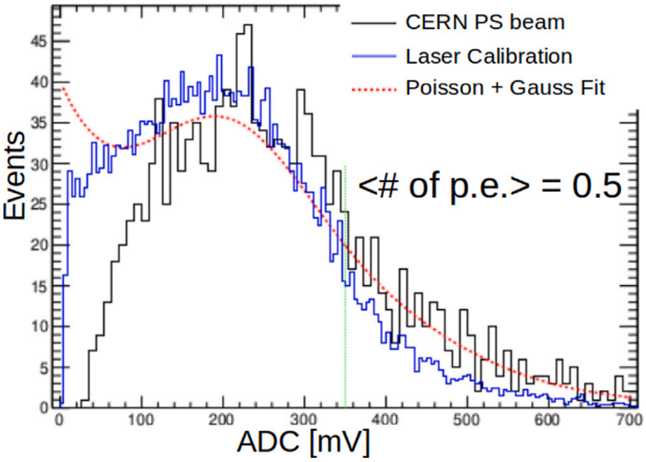

Fig. 2. The pulse height spectra from a Cherenkov ring pad for CERN PS data (black) and a laser source (blue) used for calibration. An SPE cut has been applied. The average number of PEs extracted from the fitting parameter is 0.5.

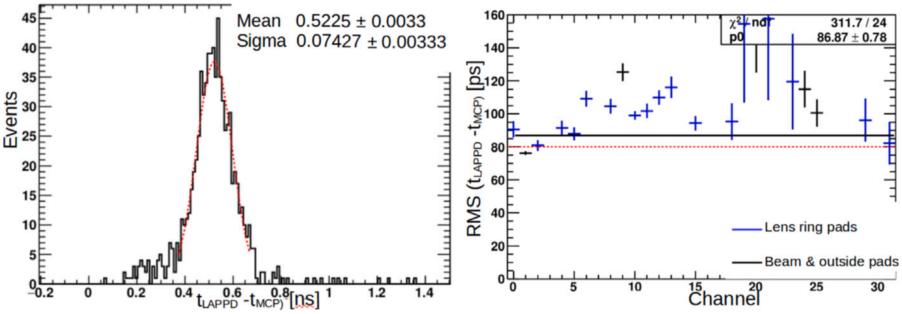

Fig. 3. Transit-time spread for a Cherenkov ring pad has σ of 74 ps (left). The average time resolution weighted with errors over all pads is measured to be 87 ps rms (right).

provided the average number of PEs per pad (Fig. 2). The gain of the LAPPD (at nominal biasing voltages) obtained from these spectra was 6.9 ±0.7 × 10^6. For digitized LAPPD and MCP-PMT signals, 10%–90% peak-height of the rising edge was fitted with a linear function in order to extract the signal arrival time *i.e.*, the 50% peak-height on the fitted line. The distribution of signal arrival time at the LAPPD with respect to that at the MCP-PMT had been defined as the Transit-Time Spread (TTS) (Fig. 3Left). The TTS standard deviation was the measured time resolution for one readout pad. The average time resolution weighted with errors over all pads was measured to be 87 ps rms (Fig. 3Right).

4.2. Dependency on rise-time

The measured time resolution was worse for some channels. This was investigated by correlating the distributions between the signal rise-time (20%–80%) and the signal amplitude; a different behaviour

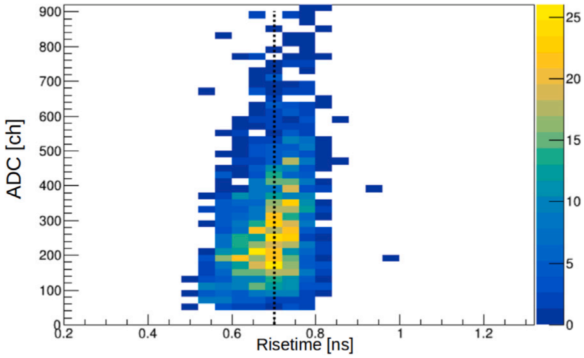

Fig. 4. For pad #5: Mild correlation between signal rise-time and signal amplitude shown as ADC channels. The good rise-time of 0.7 ns has slightly increased with the signal amplitude.

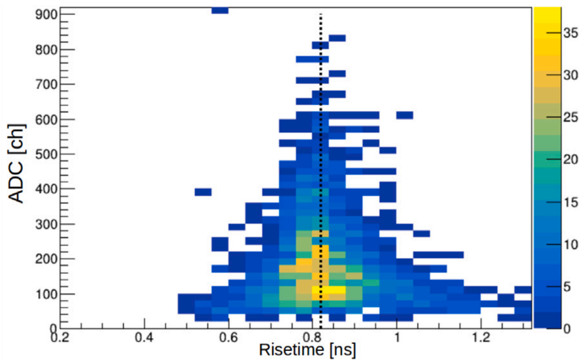

Fig. 5. For pad #6: Correlation distribution between signal rise-time and signal amplitude shown as ADC channels. The 17% larger rise-time is almost constant with the signal amplitude.

was observed for some readout pads. The LAPPD signal rise-time (20%–80%) was calibrated using LED light source to be ∼0.75 ns. It can be seen in Fig. 4 that signals from pad #5 showed a rise-time of 0.7 ns that is well aligned with the value obtained with the calibration. This value increased slightly for large signal amplitudes that showed a mild correlation between the rise-time and signal amplitude. On the other hand, signals from some pads had larger rise-time. As an example, signal from pad #6 showed a rise-time of 0.82 ns, a 17% increment from the calibrated value. In addition, unlike the case for pad #5, it does not show any rising trend with the signal amplitude. These observations can be explained as the presence of signals which were lower in amplitude and broader in width in some channels including pad #6 (see Fig. 5).

5. Conclusion

The time resolution of the LAPPD unit #124, measured with Cherenkov photons produced in the fused silica lens radiator by CERN PS hadron beams, is 87 ps rms. Ref. [6] provides a detailed overview of this work.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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