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Extending the time-over-threshold calibration of Timepix3 for spatial-resolved ion spectroscopy

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Hybrid pixel detectors have a well-established array of applications ranging from particle physics to life sciences. The small dimensions of Timepix3 [1] as well as its relatively low energetic expenses make it an intriguing option also for ion detection in nuclear physics experiments, as it reveals simultaneously precise temporal, spatial and energetic properties of recorded events from nuclear reactions. Currently, a limiting factor is the electronics behavior at high input charge resulting in improper energy determination of incident heavier ions. While the low-energy per-pixel calibration of Timepix3 is normally performed with the use of gamma rays up to 60 keV, the characteristic linear range permits a correct extrapolation up to only 200 keV/pixel.

We developed a global per-pixel energy correction method involving the use of short-ranged accelerated ions and spectroscopic alpha sources, similar to the one described in [2], to suitably extend the energy determination capability of Timepix3 for nuclear ion spectroscopy experiments, where spatial and temporal precision of recorded events are equally crucial.

The method implied two types of measurements with silicon-based Timepix3 detectors: firstly, protons in the range of 500 keV –1.9 MeV were delivered by the Van de Graaff accelerator of CTU in Prague and scattered on a thin gold foil at a backward angle, where the detectors were placed. In a second experiment, alpha particles emitted by a 241Am source were detected at different sensor bias voltage settings, to vary the maximal per-pixel recorded energy. The data then underwent an iterative process, thus calibrating recorded per-pixel events of gradually increasing energy.

It was found that upon applying this correction, the per-pixel energy range has been increased from the original 200 keV to 1.5 MeV (Figure 1), while improving the relative energy resolution to better than 2.5% for stopped protons (up to 2 MeV) and better than 3.1% for alpha particles up to 5.5 MeV (Figure 2).

Furthermore, to demonstrate the spatial resolution of Timepix3 detectors with silicon sensors, we performed a radiography measurement with the use of an alpha source, from which we are extracting the modulation transfer function (MTF).

In this presentation, we discuss our energy correction methods, as well as the study on the impressive spatial resolution of Timepix3, proving its suitability for high-precision three-dimensional kinematics reconstruction.

[1] T. Poikela et al 2014 JINST 9 C05013
[2] B. Bergmann et al 2022 JINST 17 C01025

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