POSITION SENSITIVE COINCIDENCE DETECTION OF TWO AND THREE PARTICLE NUCLEAR REACTIONS

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Abstract

In studies of low-energy nuclear reactions measurements of spectral and angular correlations of reaction products provide direct information on angular cross sections, spectroscopic factors and partial reaction widths. For this purpose we assembled a multi-detector system based on the pixel semiconductor detector Timepix. The granularity and per-pixel energy/time sensitivity of Timepix allows performing spatial- and time-correlated detection of reaction products with high spatial and time resolution and enhanced signal-to-noise resolving power. In this contribution we evaluate the response and resolving power of the basic coincidence system consisting of two pixel detectors Timepix operated via FITPix readout interfaces and a synchronizing DAQ module. Tests and preliminary measurements are performed with MeV protons on CH_2 and ^{11}B targets.In this contribution we demonstrate the spatial- and time-correlated method together with the principles of interaction plane reconstruction using the elastic scattering p+p reaction on a thin target.

Pixel Detector Timepix + FITPix Readout Interface + Pixelman Control/DAQ

The hybrid semiconductor pixel detectors of the Medipix type [1],[2] consists of a radiation sensitive sensor bump bonded to an ASIC readout chip with integrated electronics per pixel. The chip is divided into an array of 256 × 256 pixels of 55 µm pitch with full sensor size 14 × 14 mm^2. Hybrid technology allows using sensors of different materials (Si, GaAs, CdTe) and thickness (300, 700, 1000 µm). Per–pixel pulse processing electronics provides fast and noise free images**.**

The Timepix device [2]provides high granularity, wide dynamic range and per pixel threshold together with per-pixel energy- and time-sensitivity. In addition to information on position, energy, time also the stopping power and direction of trajectory can be obtained for energetic charged particles. Per-pixel threshold is 4 keV for a 300 µm silicon device. Interaction/arrival time can be determined with a time resolution of 25ns.Withevent-by-event pattern recognition analysis of the particle tracks, sub-pixel spatial resolution can be achieved down to few µm.

For integrated control, power and DAQ, the Medipix detectorscan be operated with integrated USB-based readout interfaces such as the USB 1.0 [3] and FITPix [4] devices (see Fig. 2). Operation and online visualization are enabled by the software package Pixelman [5],[6]. The assembled system serves as an online radiation camera [7] for table-top and vacuum operation, portability and configurability of different measurements and setups.

Coincidence operation of two Timepix detectors with synchronized readout

Measurements are performed at the Tandem Van de Graaff accelerator of the KINR, Kiev and in the Van de Graaff light ion accelerator of the IEAP CTU in Prague. As validation a 2.65 MeV proton beam was sent onto a thin plastic target. Two Timepix detectors, each equipped with a 300 μm silicon sensor, were placed at 45° along the beam axis as shown in Fig. 1. The trigger and DAQ of the pixel detectors were controlled and synchronized by a customized integrated coincidence unit[8].

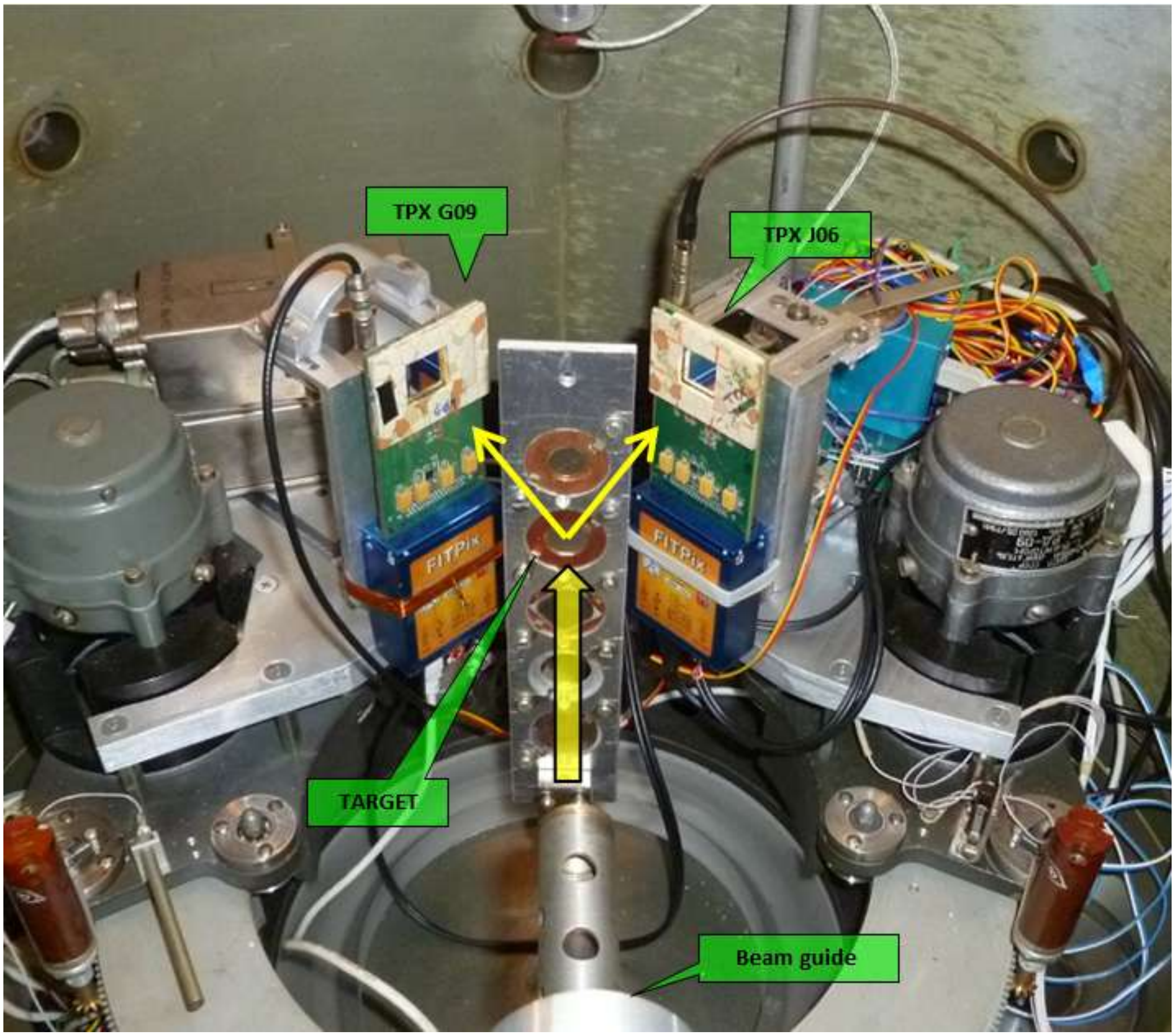

Figure 1: Setup and geometry of the elastic scattering reaction p+p on a CH4 thin target inside a vacuum experimental chamber at the Tandem VdG accelerator of the KINR, Kiev. Two Timepix detectors are placed at 45° along the beam axis.

Spatial- and time-correlated detection of two particles: p+p elastic scattering

The detection of scattered protons in the p+p elastic scattering reaction in the layout given in Fig. 1 is shown in Fig. 2.The spatial information (top) is correlated with the timinginformation (bottom). The Timepix detectors are operated in time-of-arrival (ToA) mode where the per-pixel electronics register the time of interaction of single particles(shown by the color bar in Fig..For the detector settings used (acquisition time 1 ms and clock frequency 10 MHz) the timing resolution was 100 ns. By fitting the particle signals in the pixelated sensor, which form a cluster of pixels, the spatial resolution can reach even sub-pixel scale down to about 5 to 10 μm.Coincidence particles are found by their time stamp. One such pair of elastically scattered protons in indicated in Fig. 2 (labeled by the arrows).

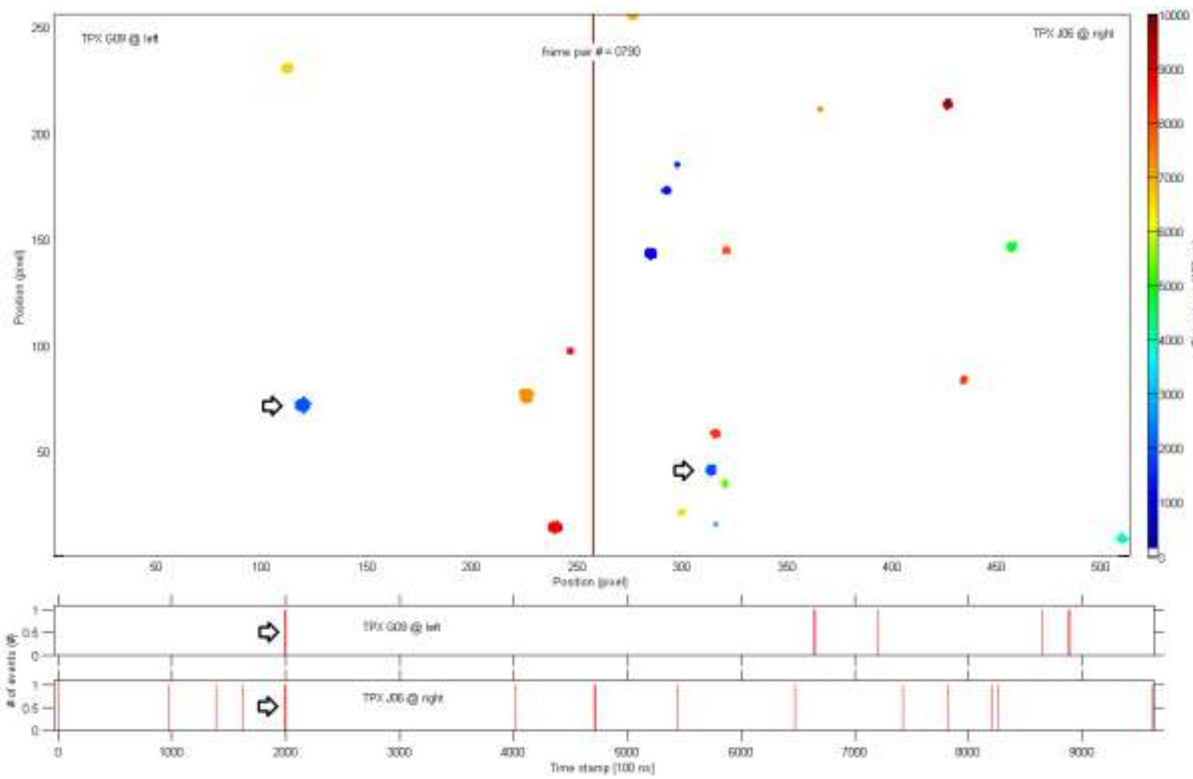

Figure 2:Spatial-and time-correlated detection of reaction products from a 2.65 MeV proton beam onto a CH_2 target. Single events are registered in two separate pixel detectors (top) which are operated in time-of-arrival mode (shown in color) providing their time stamp which can be plotted in time spectra (bottom). An elastically scattered pair of protons is indicated by the arrows. Data shown were collected in 1 ms exposure time. The spatial information, given by the 256 × 256 pixel matrix of each detector, is coupled to the time-correlated information given by the color scale shown in the range 0–1000 μs.

Vertex reconstruction + interaction plane geometry

The plane of interaction can be reconstructed from the spatial positions of the two particles detected in coincidencefor the given the target and detector geometry. The projection of the interaction plane along the horizontal plane (z-axis along the beam axis, x-axis transversal to the beam axis) is shown in Fig. 3. The projected data on the plane perpendicular to the beam axis is shown in Fig. 4 (horizontal x-axis, vertical y-axis). The spatial correlation of the coincidence pairs is reveals the position and shape of the target which formsonto the projected plane (Fig. 4). The principle of the technique is demonstrated by the derived scattering angle projected onto the horizontal plane (Fig. 3).

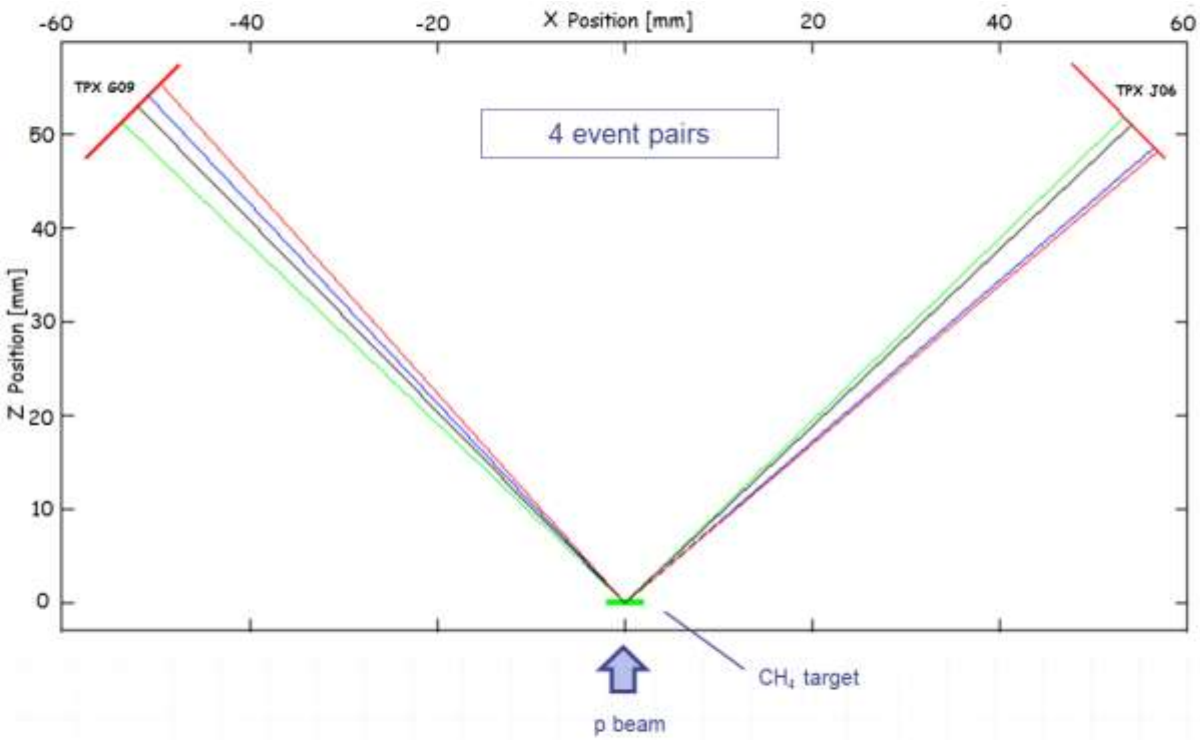

Figure 3: Reconstruction of the plane of interaction of four coincidence pairs of particles (each pair drawn in different color). The projection along the horizontal plane is shown (z-axis along the beam axis, x-axis transversal to the beam axis).Distances, reconstructed trajectories, target holder backingand detector size are displayed in real spatial dimensions(in mm). The projected scattering angle between pairs of coincidence events is maintained (nearly 90°).

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Conclusions

Timepix allows applying timing and spectral correlated techniques for enhanced background suppression and unambiguous event–by–event detection. The setup and operation of two pixel detectors for spatial and time coincidence detection of correlated nuclear reaction products have been demonstrated. Synchronized data acquisition and data readout require a devoted coincidence module to serve as arbiter for ready/busy/veto device management. The technique was demonstrated on p+p elastic scattering by reconstruction of the plane of interaction, target shape projection and measurement of scattering angle. Angular distributions and spatial correlations of coincident events registered can be obtained with high spatial resolution. Data evaluation of two- and three-particle product channels in the reaction $p+^{11}B$ is in progress.

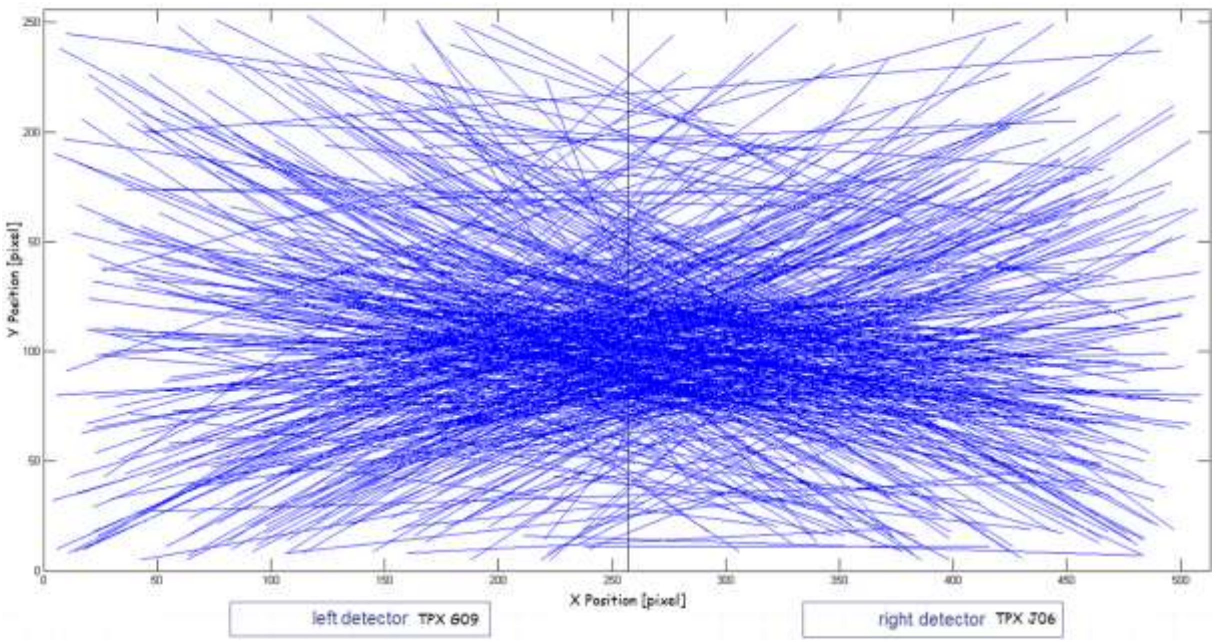

Figure 4: Projection of the interaction vectors of 300 coincidence pairs of particles onto the vertical plane (x-axis horizontal, y-axis vertical) transversal to the beam axis. Distances and projected reconstructed trajectories are given in pixel units (1 pixel = 55 μm).

Acknowledgements

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