Development of a large-scale VUPROM system as tracking trigger for the KAOS spectrometer

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The VME Universal Logic Modules VULOM and VUPROM were developed at the Experiment Electronics Department of GSI for general purpose logic operations. During the last 2 years, first modules were applied as tracking triggers in experiments at GSI and at the Mainz Microtron MAMI [1]. A large-scale VUPROM system with several thousand input channels is now in operation for the triggering of the hadron arm as well as the electron arm of the KAOS spectrometer at MAMI.

The KAOS spectrometer is maintained by the A1 collaboration with a focus on the study of $(e, e'K^+)$ coincidence reactions. For its electron arm tracking system two vertical planes of fibre arrays (x- and θ-plane), each covering an active area of $1600 \times 300\,\mathrm{mm}^2$ with 2 304 read-out channels, are operated close to zero degrees scattering angle and in close proximity to the electron beam.

A sophisticated trigger logic implemented in VUPROM modules was developed in order to to minimize accidental trigger rates in the electron arm instrumentation.

The trigger must satisfy the following requirements:
(i) detection of signal clusters in each detector plane;
(ii) reconstruction of particle tracks through both planes;
(iii) acceptance test for all reconstructed particle tracks;
(iv) expandability to build a missing-mass trigger by combination with the hadron arm trigger;
(v) on-line access and control of trigger parameters.

The hardware set-up comprises 37 VUPROM modules with 256 I/O channels each. Each 6U VME module is equipped with a Virtex-4 FPGA chip, capable of operating at 400 MHz. This set-up allows easy reprogramming via VMEbus. Furthermore, output and control information is accessible during trigger operation.

The modules are arranged in 4 stages. In the first stage signal clusters are detected, and the position information is passed on to the next stage. The signals from both planes are processed separately in the first and the second stage, which consists of 6 modules with the purpose of reducing the number of channels, and providing the same position information on several outputs.

In the third stage the position information from the first stage of the x-plane and the second stage of the θ-plane are checked for temporal coincidences and used to perform an acceptance test for the reconstructed tracks.

The last stage consisting of a single module receives the information of accepted trajectories from the third stage and produces the trigger output signal.

Due to the geometrical arrangement of the fibres, a particle hit always causes a cluster of correlated signal in neighbouring channels [2]. Signal clusters are identified by requesting a signal in n neighbouring channels within a given time period. By requesting the absence of a signal in the next higher and lower channel, it is guaranteed that the found cluster is exactly of the size n. Short pulses which are the result of different delays in the input signals are suppressed by a pulse-width discriminator. An upper and lower boundary for the accepted cluster sizes is specified. Clusters with a size above the given upper boundary are vetoed to reduce background from scattered particles, hitting the detector planes under large angles with respect to the normal on the detector plane. The position of each cluster is transmitted to the next stage by setting one bit in an 32-bit wide output bus.

For performing the acceptance test, the allowed combinations of hit positions in both planes are stored in a binary matrix. This matrix is externally computed. An output signal is produced when a cluster is found on both detector planes and the corresponding matrix element is non-zero. Each VUPROM in the third stage evaluates a range of 384 channels of the x-plane and up to 1 536 channels of the θ-plane. This set-up was chosen to cover the angular acceptance known from simulations with the highest possible granularity. The position resolution for the acceptance test is 6 channels in the x-plane (4.98 mm) and 12 channels in the θ-plane (9.96 mm).

The trigger for the electron arm was successfully tested during two beam-times in July and August 2009. Raw signal rates of several MHz were observed, measured trigger rates are shown in Table 1.

Table 1: Measured trigger rates in the electron arm of the KAOS spectrometer during beam-tests at MAMI in 2009.

	trigger rate (kHz)
raw signal rate	1120 ± 30
clusters in x	47.0 ± 0.2
clusters in θ	37.3 ± 0.2
x OR θ	83.9 ± 0.3
x AND θ	0.49 ± 0.02
random coincidences	0.140 ± 0.001

References

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