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VMM3 ASIC as a potential front end electronics solution for future Straw Trackers

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ABSTRACT

The custom Application Specific Integrated Circuits (ASICs) VMM3 and VMM3a were developed by Brookhaven National Laboratory (BNL) and are capable of simultaneous precise measurements of both the charge and time characteristics of signals in gaseous detectors. Its flexibility makes it attractive as a front-end electronics solution for a wide range of applications, including readout systems of Straw Trackers in future High Energy and Neutrino Physics experiments. We present first performance measurements done with straw drift tubes operated with VMM3 and VMM3a readouts implemented by the RD51 collaboration (CERN). Preliminary results obtained with the SPS muon beam at CERN are compared to the prediction of simulation studies done with GARFIEDL and LTSpice packages.

1. Motivation

A number of operating and future experiments use Straw Tube detectors for precise tracking. Small material budget and achievable large acceptance make Straw Tube Trackers attractive for such future facilities like Near-Detector Complex of the DUNE [1] experiment, the Spectrometer Straw Tracker of the SHiP [2] experiment, and Straw Tracker of the SPD [3] experiment. We present current results on our searches for efficient, flexible and chip solution for Straw Tracker readout electronics.

2. VMM3/3a architecture

The multifunctional ASIC VMM3 [4] is widely used for the readout of Micro-Pattern Gas Detectors and was used as the base for development of the advanced VMM3a version [5] dedicated to the ATLAS New Small Wheel readout. Its main benefit is a flexible settings for analogue input circuitry:

– charge measurements (nominally 10 bits ADC);
– time measurements (nominally 8 bits TDC);
– variable gain (0.5–16) mV/fC
– variable peaking time (25–200) ns;
– both triggered and trigger-less readout modes

This ASIC is capable of measuring both the signal peaking time (T@P) or the time of a threshold crossing (T@T). Basic principles of the time digitisation processes are illustrated in Fig. 1

3. Straw tube operation principles

Track coordinates are reconstructed from the measured signal arrival time which, in turn, is defined by the time needed for primary electrons to drift from the track to the anode wire. The drift time, t_{drift}, is measured as a difference between the time when an ionising particle crossed the straw, t_0, obtained from a scintillator placed before the tracker, and the time when the straw signal exceeds a given threshold. The distance between the track and anode wire, R, is obtained from a measured or simulated $R(t_{drift})$ dependence.

4. Simulation

A combination of Garfield [6] simulation of a straw tube response interfaced to the LTSpice [7] electronics simulation package allows efficient optimisation of the signal circuit path and VMM3/VMM3a operation parameters, and supports performance studies for Straw Trackers operated in the magnetic field and with different gas mixtures.

The straw response to a muon track passing at the distance R from an anode wire is fed into an LTSpice model of the VMM3. The drift time is obtained as the time when simulated signals exceed a given threshold, and is compared to the corresponding measurements done with NA62 [8] original straw readout based on the CARIOCA chip [9]. Fig. 2 demonstrates the observed comparable performance of the two readouts.

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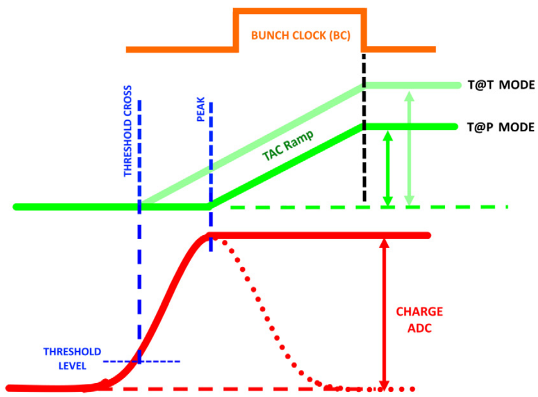

Fig. 1. VMM3 time and charge digitisation processes.

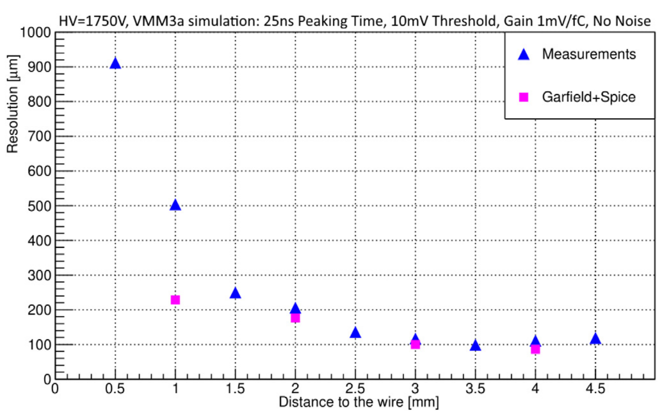

Fig. 2. Measured and simulated spatial resolution.

5. First measurement results

First systematic results on performance of straw drift tubes operated with VMM3 and VMM3a readouts are being obtained at lab and with the SPS muon test beam.

Persistent latching of the VMM3a has been observed in the time-at-threshold mode, that makes it inappropriate for the straw tube readout. Current information hints to an algorithmic issue in the cases when the time between the threshold crossing and signal peak is shorter than one bunch clock. No such effect was found for VMM3 since the logic of the time-at-threshold mode is implemented differently in the previous chip revision.

The VMM3 readout was tested with the SPS muon test beam. Fig. 3 shows the measurement setup consisting of the straw tracker under the test, a reference micromegas tracker, and two scintillators used in coincidence for t_0 time measurements. The drift time is obtained as a difference of t_0 and the time when the straw signal exceeds a threshold, both of them are measured with the VMM3 readout. As a preliminary result, the observed drift time distribution is compared to the simulated one in Fig. 4. Advanced analysis of the data collected during the test beam measurements is ongoing.

6. Conclusion

First measurements of a straw tracker operated with a VMM3 readout have been performed with the SPS muon test beam. Fundamental logic issues in the VMM3a architecture has been observed, what, in contrast to the VMM3, makes it inappropriate for straw drift tube readout. The drift time distribution measured with the VMM3 readout is in a good agreement with the simulation results. Advanced analysis of the data collected with the muon beam is ongoing.

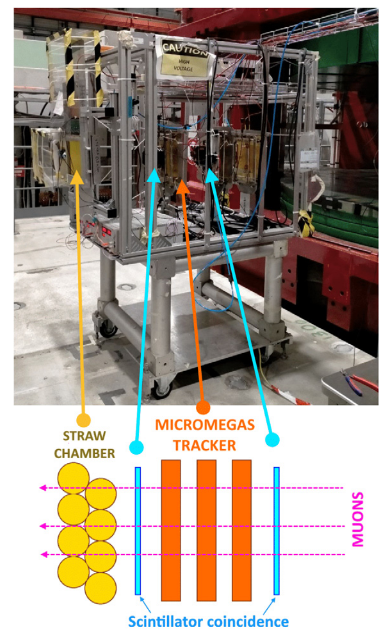

Fig. 3. Measurement setup at the SPS test beam with a straw tracker operated with the VMM3 readout. A micromegas tracker is used for reference track coordinate measurements, while a coincidence of scintillator signals provides the measurement of time t_0 when a muon crosses the straw tracker.

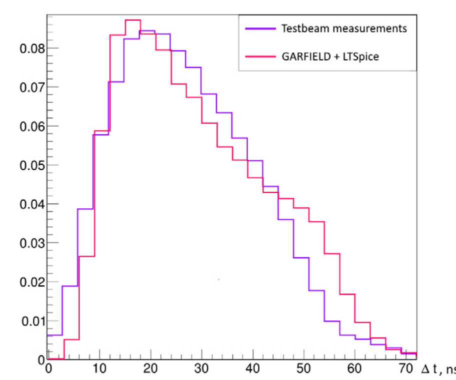

Fig. 4. Measured drift time compared to simulation results.

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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