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

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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.

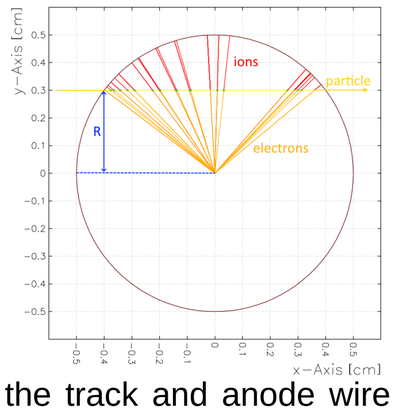
Example of successful operation of a large area Straw Tube Tracker: the NA62 [4] detector.

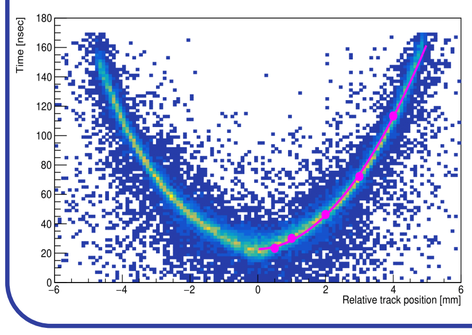
In some application additional measurements of the particle energy loss dE/dx may be required, for example for combined tracking and particle identification.

2. Straw Tube readout

Track coordinates are reconstructed on the measured signal arrival time defined by the drift time of primary electrons from the track to the anode wire.

The drift time $\boldsymbol{time_{drift}}$ is measured as a difference between the time when a particle crossed the straw and the time of straw signal crossing a low threshold.





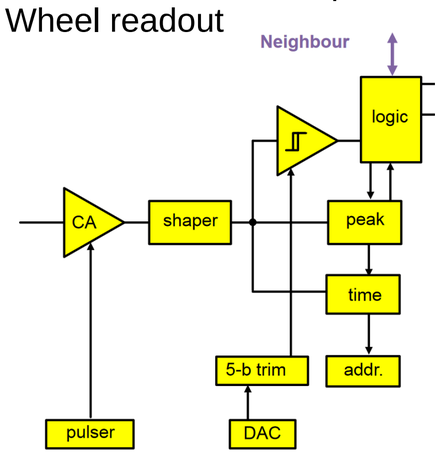
The distance between the track and anode wire is obtained from a measured or simulated $\boldsymbol{r}(\boldsymbol{time_{drift}})$ dependence.

Example of the calibration $\boldsymbol{r}(\boldsymbol{time_{drift}})$ dependence measured for an NA62 straw compared to GARFIELD [5] simulation of the signal arrival time for first primary ionization cluster.

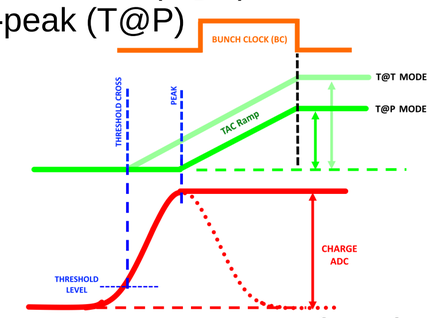
3. VMM3/3a in time-at-threshold mode

Multifunctional Application Specific Integrated Circuit (ASIC) VMM3 [6]

- widely used as readout of micro-pattern gas detectors
- was a base for the production VMM3a version for the ATLAS New Small Wheel readout



- flexible settings of analogue input circuitry
- charge measurements (nominally 10b ADC)
- time measurements (nominally 8b TDC)
  - time-at-threshold (T@T)
  - time-at-peak (T@P)

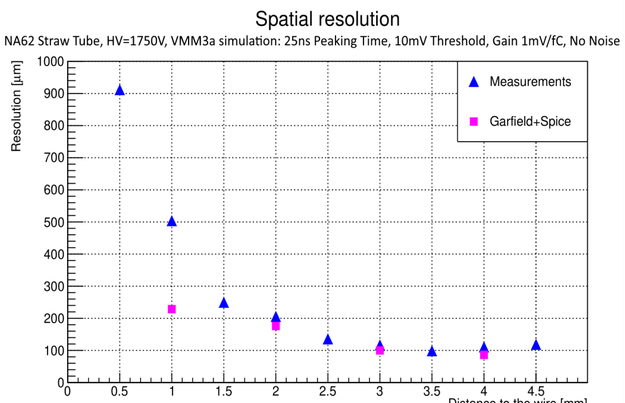


Though VMM3/3a implements precise time measurements of a threshold crossing (T@T), the most of applications measure signal peak time (T@P)

4. Simulation

A combination of Garfield simulation of a straw tube response interfaced to the LTSpice electronics simulation package allows efficient optimization of the signal circuit path and VMM3/3a operation mode, and supports performance studies for Straw Trackers operated in the magnetic field and with different gas mixtures.

- a straw response to a muon track passing at the distance $\boldsymbol{r}$ from the anode wire is fed into LTSpice [7] model of VMM3
- the time of the signal exceeding a given threshold is compared with the corresponding measurements for NA62 straw read out with the original CARIOCA-based readout [8]
- a comparable performance is observed

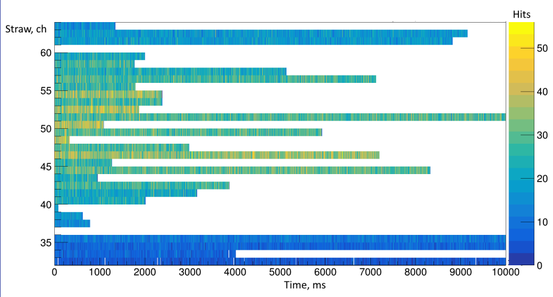


4. Testbeam measurements

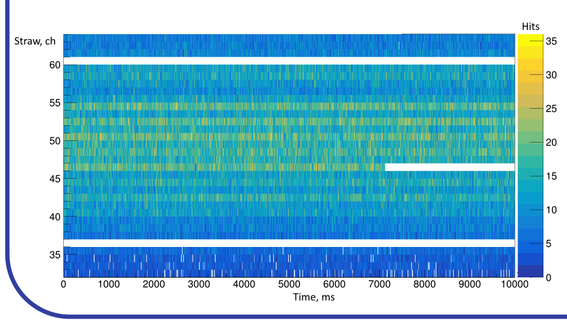
First systematic results on the performance of straw drift tubes operated with a VMM3 and VMM3a -based readout are being obtained at lab and at the SPS muon testbeam.

➢ VMM3a "latching" in T@T mode was observed. A possible explanation is an algorithmic problem in the cases when the time between the threshold crossing and signal peak is too short (<1 clock cycle).

A comparison of operation stability with 40MHZ and 80MHz clock frequency:



Peaking time 200ns, BC = 80MHz

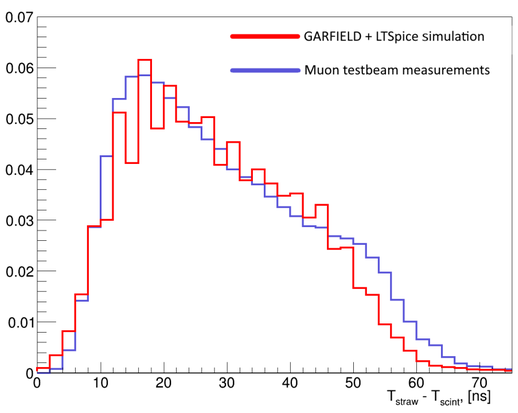


Peaking time 200ns, BC = 40MHz

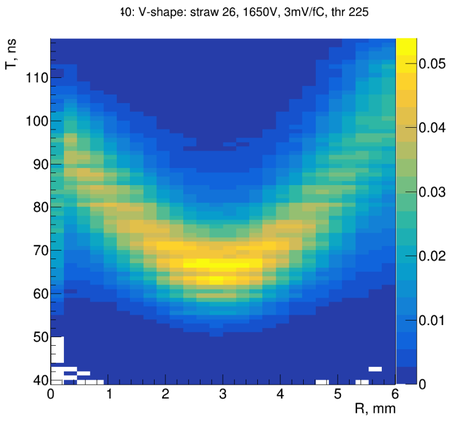
➢ No such effect was found with previous revision, VMM3:

- the logic of the T@T mode slightly differs between VMM3 and VMM3a
- test beam measurements with VMM3 are ongoing right now!
- very preliminary data (6mm straw, D_{wire} = 30um, HV = 1650V)

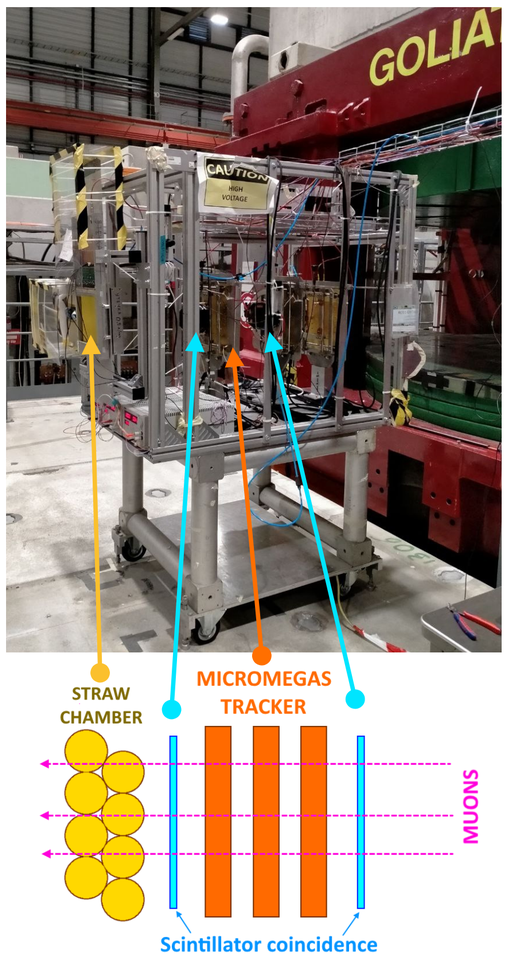
Preliminary measurements result
Work in progress



Measured drift time distribution compared to Garfield + LTSpice simulation results



Measured $\boldsymbol{r}(\boldsymbol{time_{drift}})$ dependence (reduced tracking information)



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