Straw simulation and beam tests

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on behalf of the JINR/PNPI straw TB & simulation team

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Outline

Introduction

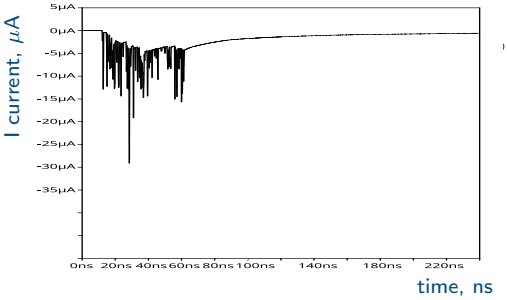
- We use Garfield + LTSpice simulation with given electronics model for choosing optimal parameters for TestBeam datataking
- VMM3 allows to measure both drift time and energy loss
- More dedicated parameters are set depeding on real measurement conditions *
- The testbeam data are compared with Garfield + LTSpice simulation *

* – work in progress

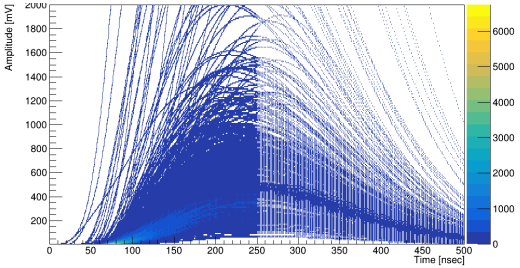
Garfield + LTSpice simulation

Simulation allows to select the optimal parameters for the detector.
Software used: Garfield (straw responce) + LTSpice (readout electronics simulation) .
Parameters simulated:

- Electronic gain
- Thresholds
- Peaking time



Simulated signal from straw tube



Simulated amplifier & shaper response

Electronic gain selection

Using simulation studies we choose optimal apmlification

Garfield text output for signal command execu

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Signal simulation:
==================
The track begins at (-0.60000002E+00, 0.40000001E+00, 0.00000000E+00)
and ends at         ( 0.60000002E+00, 0.40000001E+00, 0.00000000E+00)

A single group of electrodes is currently selected for read-out:
Group 1 consists of:
  Wire 1 with label 'S at (x,y)=(0,0) and at 1750 V

No solid is currently selected outside read-out.
Table of the clusters
=====================
   No    x-start    y-start    z-start  Drift time   Diffusion Pairs  Pair Arrival time Total charge
              [cm]       [cm]       [cm]  [microsec]  [microsec]       [microsec]  [electrons]

    1 -0.58225E+00  0.40001E+00 -0.10001E-04  0.00000E+00  0.00000E+00  0.00000E+00     1  Hit the tube, not read out
    2 -0.57035E+00  0.39996E+00 -0.31205E-05  0.00000E+00  0.00000E+00  0.00000E+00     1  Hit the tube, not read out
    3 -0.57036E+00  0.39991E+00 -0.62397E-05  0.00000E+00  0.00000E+00  0.00000E+00     1  Hit the tube, not read out
*****************************************************************************************************************
   22 -0.40832E+00  0.40000E+00  0.13213E-05  0.00000E+00  0.00000E+00  0.00000E+00     1  Hit the tube, not read out
   23 -0.29005E+00  0.40000E+00  0.22099E-05  0.18109E+00  0.25881E-02  0.18060E+00     1  Hit S wire 1, read out
                                                                                       1  0.17980E+05
   24 -0.26758E+00  0.40002E+00 -0.25891E-04  0.17146E+00  0.24561E-02  0.17313E+00     1  Hit S wire 1, read out
                                                                                       1  0.45919E+05
   25 -0.26758E+00  0.40005E+00 -0.51769E-04  0.17147E+00  0.24634E-02  0.17252E+00     1  Hit S wire 1, read out
                                                                                       1  0.18328E+05
*****************************************************************************************************************
   75  0.22119E+00  0.39992E+00  0.27980E-03  0.15403E+00  0.22965E-02  0.15032E+00     1  Hit S wire 1, read out
                                                                                       1  0.28830E+05
   76  0.22116E+00  0.39990E+00 -0.33574E-03  0.15400E+00  0.22968E-02  0.15414E+00     1  Hit S wire 1, read out
                                                                                       1  0.40571E+05
   77  0.22112E+00  0.39988E+00 -0.39167E-03  0.15398E+00  0.22967E-02  0.15176E+00     1  Hit S wire 1, read out
                                                                                       1  0.44243E+04
   78  0.30096E+00  0.40000E+00 -0.19983E-06  0.00000E+00  0.00000E+00  0.00000E+00     1  Hit the tube, not read out
   79  0.32922E+00  0.40000E+00  0.95340E-06  0.00000E+00  0.00000E+00  0.00000E+00     1  Hit the tube, not read out
   80  0.36628E+00  0.40000E+00 -0.11243E-05  0.00000E+00  0.00000E+00  0.00000E+00     1  Hit the tube, not read out
   81  0.47246E+00  0.39998E+00  0.87778E-05  0.00000E+00  0.00000E+00  0.00000E+00     1  Hit the tube, not read out
Plot completed, hit RETURN to proceed.
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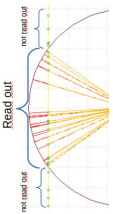
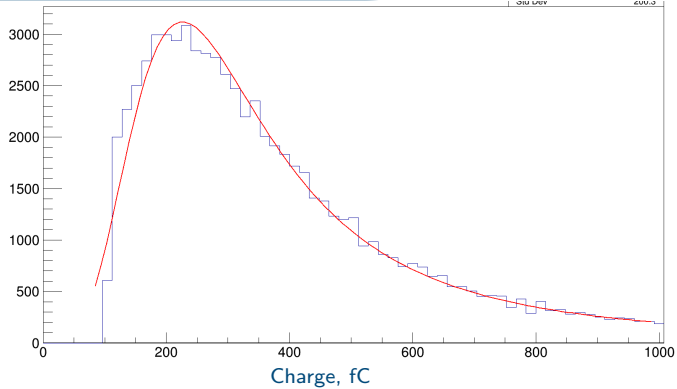
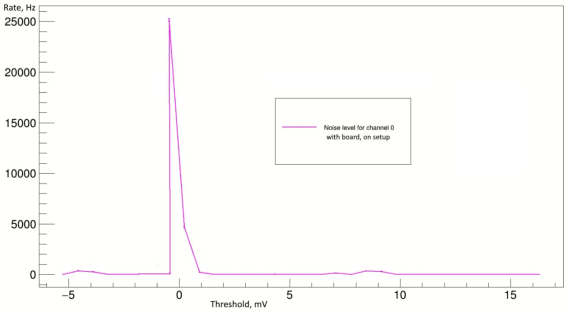
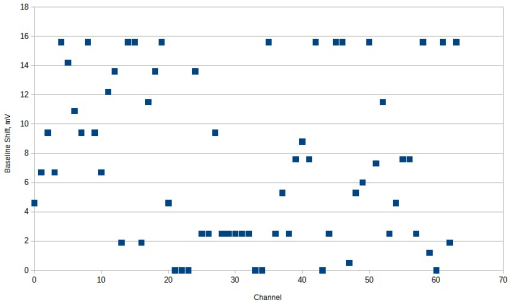




We measured MIP energy loss spectra and decided to use amplifier gain of 1mV/fC so that most events could stay in VMM3 ADC dynamic range.

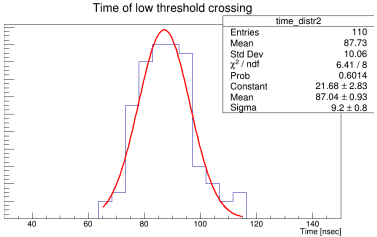
Threshold selection



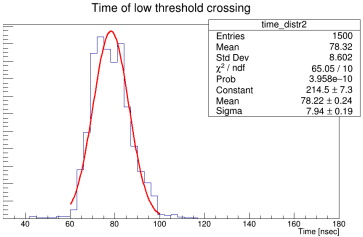


To set proper threshold we have made a threshold scan with Mu2E board on real setup.
The noise amplitude seem to be low, less than 3 mV for the most of channels.
Since each of 64 channel has its own baseline bias (right plot), 10mV was selected as optimal value for simulation and can be easily reached on real setup.

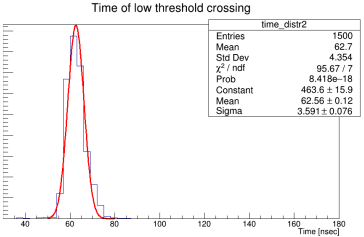
Peaking time selection



200ns p.Time 10mV THL



100ns p.Time 10mV THL



25ns p.Time 10mV THL

We simulated shaper output with different peaking times. It is clearly seen, that the less is peaking time, the better is time resolution.
We have chosen 25ns peaking time, so even with 10 mV threshold time resolution of 3.6 ns could be reached in ideal condition.

Outline

TestBeam setup

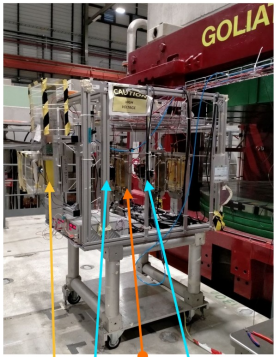
Setup during TestBeam

Our setup consist of:

- Reference tracker: 4 MicroMegas (3 X + 1 Y axis) with pitch of 250 μm
- MicroMegas trigger and timing: triple scintillator coincidence
- Straw chamber with VMM3-based Mu2E frontend board

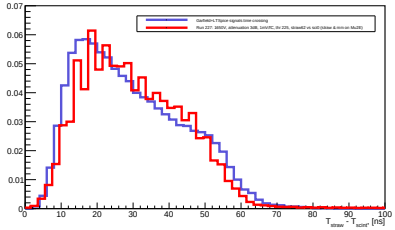
Options for tracking usage:

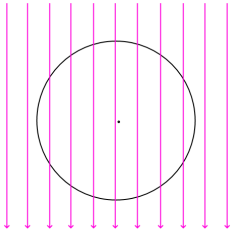
1. Reduced tracking information – only 1 MicroMegas:
   - Straw + 1 MicroMegas read-out with Mu2E board
2. Full read-out with independend DAQ systems:
   - MicroMegas read-out with APV25 boards
   - Straw & scintillator coincidence read-out with Mu2E board
   - One MicroMegas has strips connected in parallel to Mu2E and APV25
   - The 2 DAQ systems are "synchronized" with external clock coming from pulse generator and data synchronization is done offline

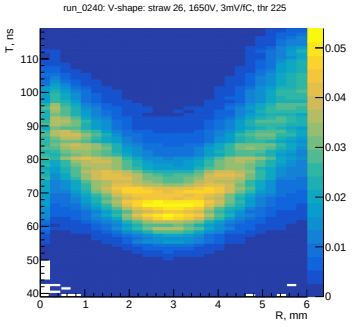


Analysis of the first option

Very prompt results – we can compare data from muon beam with (unform-distributed) Garfield + LTSpice predictions







Comparison of drift time distribution from muon beam data (red) with the Garfield + LTSpice predictions (blue)

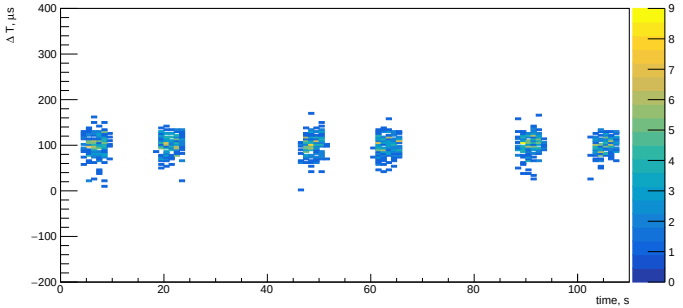
We have single MicroMegas, so the bin size in R-T curve is determined by the MicroMegas pitch

Analysis of the second option

Second option allow us to use track information, but need to merge two independent DAQ threads with pulse generators

Control plot: the number of merged events showing stability of the shifting reconstructed time of the two systems

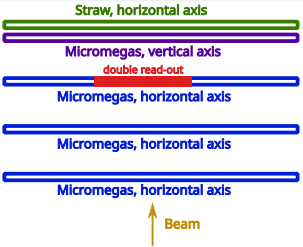
For using external synchronization we are using two synchronious signal generator pulses passed to both readouts.
For both readouts the 25-ns clock used for precision timing

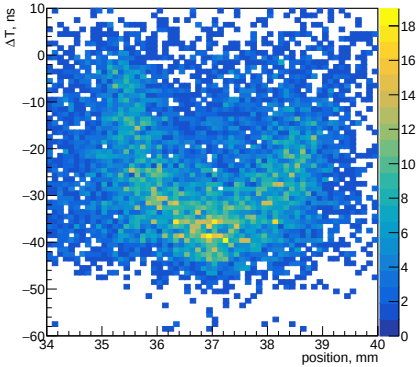


Analysis of the second option

Very first results with the synchronized data: 2% statistics, basic tracking.
Track reconstructed with two MicroMegas only; no alignment info taken into account

Next steps: use 3 MicroMegas for X (horizontal) axis

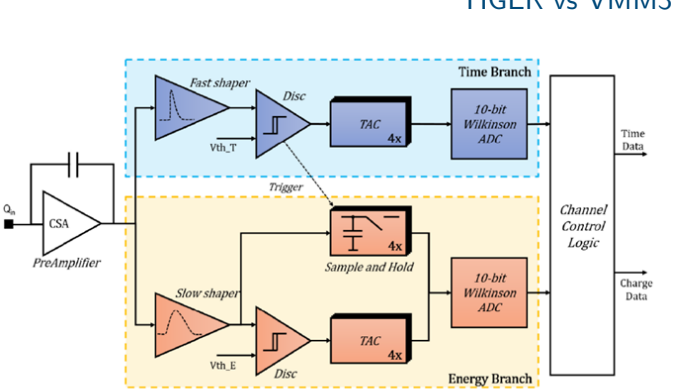




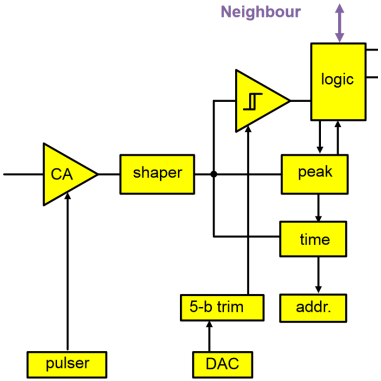
In total, 1M merged events may be available from summer TestBeam. Analysis ungoing.

Outline

TIGER vs VMM3



TIGER Architecture



VMM3 Architecture

Main difference: tiger has two different shapers for Time and Energy measurements

Outline

Summary

Summary and next steps

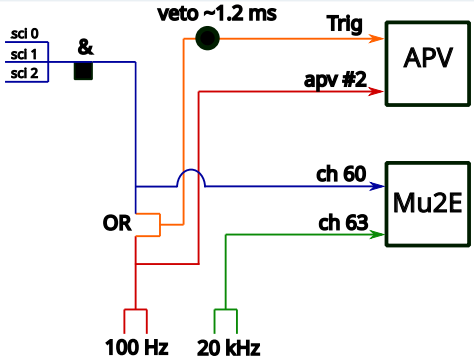
- TB measurement setup was developed in April-June 2022
- Data acquired with the combined Mu2E(VMM3) + APV25 readout are being analyzed
- Combination of GARFIELD and LTSpice signal simulation allows prompt predictions of different readout options of the straw tubes
- Very preliminary comparison of TB measurement and simulation study results shows a reasonable agreement
- More advanced studies to be done with the reconstructed TB data (in progress)
- As the result of detailed analysis of the VMM3a/VMM3 operation performance, a development of a new ASIC has been initiated
- Preparation for the next TB with an optional straw readout is ongoing: a long term parasitic use of the H8 SPS beam line allows to evaluate the basic performance of the TIGER readout, tune the data acquisition using permanent access to the setup, and perform remote data taking with low intensity muons
- The work is being performed in a close contact to the RD51 Collaboration. Access to the infrastructure and experience of the corresponding experts are of significant help in the carried studies

Thank you for attention!

Backup slides

External tracking synchronisation

For using external synchronization we have managed scheme with two synchronious signal generator signals passed to both readouts.
For both readout the 25-ns clock used for precision timing



TIGER vs VMM3

	VMM3	TIGER
Number of channels	64	64
Clock frequency	10...80 MHz	160...200 MHz
Input capacitance	<300 pF	<100 pF
Dynamic range	Linearity within ±2% up to 2 pC	50 fC
Gain	0.5, 1, 3, 6, 9, 12, 16 mV/fC	12 mV/fC
ENC (energy branch)	<3000 e^-	<1500 e^-
TDC binning	~1 ns	50 ps
Maximum event rate	4 MHz/ch	60 kHz/ch
Consumption	15 mW/ch	12 mW/ch