VMM3a hybrid noise measurements

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Contents



- Signal-Noise Ratio
- Threshold Examination
- 2 VMM Baseline RMS measurements
 - Initial Method
 - Noise Signals
 - New Configuration & Final Baseline Signal
 - ENC calculation method
 - Results and Observations

Signal-Noise Ratio Threshold Examination

Motivation

Testing a suitable ASIC for the new GEM detectors for the COMPASS++/AMBER experiment.



Karl Flöthner, Compass Gem Upgrade, Tuesday 12:00

Requirements:

- $\checkmark~$ Self-triggered readout
- $\checkmark~$ Time-space resolution
- $\checkmark~$ High rate environment
- APV25 at HV=4000 V:
 - \checkmark SNR_x = 110.86 ± 2.63
 - \checkmark SNR_y = 83.63 ± 2.29

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Signal-Noise Ratio Threshold Examination

S/N Ratio





Figure: First data obtained with the VMM: FE-55 spectrum.

Figure: Triple-GEM detector

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 $\checkmark\,$ May 2019: First data at HISKP lab with FE-55 source on Triple-GEM detector

Signal-Noise Ratio Threshold Examination



Cannot directly measure an S/N ratio because:

- ✓ Self-triggered VMM: For this measurement, the global threshold was too high, so little noise.
- $\checkmark~64$ channels with different thresholds: Threshold equalization necessary.

Next step:

 \Rightarrow Look at individual channels to better understand the noise.

Signal-Noise Ratio Threshold Examination

Threshold-Noise Examinations

Method:

For individual channels:

 $\checkmark\,$ Use VMM slow control interface to adjust global threshold over baseline.

$\checkmark\,$ Use Wireshark to count noise rate.



Figure: Schematic view of a threshold scan over the baseline.

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Signal-Noise Ratio Threshold Examination

Threshold-Noise Examinations



Figure: Noise rate vs. threshold for channels 5-9.

Treshold H8 Rato for Channels 9,10.30.31 32, manner da to dom x 10.20 or 0000 20000

Figure: Noise rate vs. threshold for channels 9,10,30,31,32.

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- $\checkmark~$ Maximum noise rate \neq baseline
- \Rightarrow Threshold step size > baseline rms.

Initial Method

Noise Signals New Configuration & Final Baseline Signal ENC calculation method Results and Observations

Initial Method

Method:

Use oscilloscope to monitor baseline of single VMM channel at no capacitance.

Individual Steps:

- ✓ plot the data from random scope frames at each individual gain setting (0.5 $-16\,{\rm mV/fC})$ of the VMM
- $\checkmark\,$ fit a Gaussian on the derived amplitude histograms

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Initial Method

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Initial Method



Figure: Chn 0 Baseline measured on the oscilloscope.



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Figure: Chn 0 Amplitude Histogram at Gain $9 \,\mathrm{mV/fC}$.

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Noise Signals

- ✓ Baseline rms 4x higher than previous measurements by M. Lupberger (GDD group).
- ✓ 160 MHz noise signal: Switch off VMM ART clock.
- ✓ 60 kHz & 400 kHz noise signals: measuring setup used (Euro crate, standard osci probes, no VMM shielding).
- \checkmark Oscilloscope noise: 0.14 mV.
- ✓ Data acquisition on: up to $\sim 1.19 \,\mathrm{mV}$.

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VMM Baseline with External Noise



Figure: VMM Chn 0 Baseline with External Noise, Gain:0.5 mV/fC.

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Initial Method Noise Signals **New Configuration & Final Baseline Signal** ENC calculation method Results and Observations

New Setup Configuration



Figure: Faraday Box



Figure: Setup with externally powered FEC.

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Initial Method Noise Signals **New Configuration & Final Baseline Signal** ENC calculation method Results and Observations

New Setup Configuration

- $\checkmark\,$ New external power supply removed 400 kHz noise signal.
- $\checkmark~$ No 60 kHz noise signal after VMM shielding with Faraday Box
- $\checkmark~$ LEMO/BNC cables provide less noisy signal

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Final VMM Baseline Signal



Figure: VMM Chn 4 Baseline 2D Histogram, Gain:0.5 mV/fC.

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Final VMM Baseline Signal

Chn0 Baseline RMS Vs. Gain



Figure: VMM Chn 4 Baseline Vs. Gain.

Initial Method Noise Signals New Configuration & Final Baseline Signal **ENC calculation method** Results and Observations

ENC Calculation Method

Next step: Convert baseline rms from mV to electrons.

Method:

- $\checkmark~$ Use test pulse of known charge.
- $\checkmark\,$ Pulse created with internal VMM test capacitance: 0.3 pF.
- $\checkmark\,$ Pulser step necessary to calculate charge.

Calibrations

To do the above measurement certain calibrations were needed:

- $\checkmark\,$ Pulser Step DAC calibration (from ADC Chn to mV)
- $\checkmark\,$ Pulser Step DAC change with gain increase (if existent)

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Initial Method Noise Signals New Configuration & Final Baseline Signal **ENC calculation method** Results and Observations

Pulser Step DAC Calibration

Step (mV) 50 45 40 35 30 25 20 10 30 40 50 DAC

Pulser Step Vs. DAC

Figure: VMM Chn 4 Pulser Step DAC Calibration.

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Initial Method Noise Signals New Configuration & Final Baseline Signal **ENC calculation method** Results and Observations

Pulser Step Vs. Gain



Pulser Step Vs. Gain

- $\checkmark\,$ Slight variations, but no systematic effect.
- $\checkmark\,$ Mean pulser step amplitude used for all gains.

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Initial Method Noise Signals New Configuration & Final Baseline Signal ENC calculation method Results and Observations

Results & Observations



Figure: VMM Chn 4 Noise RMS for different gains, preliminary

Initial Method Noise Signals New Configuration & Final Baseline Signal ENC calculation method Results and Observations

Results & Observations



Figure: VMM Chn 4 ENC for different gains, preliminary

Initial Method Noise Signals New Configuration & Final Baseline Signal ENC calculation method Results and Observations

Results & Observations



✓ ATLAS team tested the VMM chip on the bench.
✓ VMM on hybrid adds noise.

Initial Method Noise Signals New Configuration & Final Baseline Signal ENC calculation method Results and Observations

Results & Observations



Figure: VMM ENC for multiple channels, preliminary

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Outlook

- $\checkmark\,$ So far, measurements with no external capacitance only done at HISKP.
- $\checkmark\,$ Future goal: determine ENC with detector capacitance, as done in GDD group.
- $\checkmark\,$ Detector simulator PCB with variable external capacitor designed for that purpose.

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Initial Method Noise Signals New Configuration & Final Baseline Signal ENC calculation method Results and Observations

References & Citations

- M. Lupberger et al, Equivalent noise charge of the VMM hybrid of the Scalable Readout System.
- George Iakovidis, VMM3, an ASIC for Micropattern Detectors, ATL-MUON-PROC-2018-003, 22 March 2018.

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Initial Method Noise Signals New Configuration & Final Baseline Signal ENC calculation method **Results and Observations**

Thank you. Questions?

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ENC Calculation

$$\text{ENC(electrons)} = \frac{\Delta Q_{in}}{e} \times \frac{U_{Noise,RMS}}{U_{Pulse}}$$

$$\Delta Q_{in} = \Delta U \times C_s$$

$$C_s = 0.3 \,\mathrm{pF}$$

$$e = 1.602 \times 10^{-19} \mathrm{C}$$
ENC(electrons) = 1.864.500 $\frac{U_{Noise,RMS}}{U_{Pulse}} \Delta U$

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Noise signals: 60 kHz noise

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Figure: 60 kHz noise spike on scope, gain= 16 mV/fC, peaking time= 200 ns,fullbandwidth



Figure: 60 kHz noise amplitude

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Noise signals: 400 kHz noise



Figure: 400 kHz noise spike on scope, gain= 16 mV/fC, peaking time= 200 ns,fullbandwidth



Figure: 400 kHz noise amplitude

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APV S/N ratio



APV25: SNR vs. HV

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