VMM3a hybrid noise measurements

Emorfili Terzimpasoglou

University of Bonn Helmholtz Institute for Radiation and Nuclear Physics (HISKP)

eterzimp@hiskp.uni-bonn.com

COMPASS GEM Bonn Group: Bernhard Ketzer, Markus Ball, Michael Lupberger, Michael Hösgen, Christian Honisch, Karl Jonathan Flöthner

June 22, 2020

A (1) > A (2) > A

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

伺下 イヨト イヨト

JI DOG

Signal-Noise Ratio Threshold Examination

S/N Ratio





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

Figure: Triple-GEM detector

(I) < (I)

三日 のへの

 $\checkmark\,$ 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.

211 990

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.

◆□▶ ◆□▶ ◆豆▶ ◆豆▶ 三目目 のへの

- $\checkmark~$ 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

A 回 > A 回 > A

Initial Method

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

Initial Method



Figure: Chn 0 Baseline measured on the oscilloscope.



-2

= 990

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

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

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 $\sim 1.19 \,\mathrm{mV}$.

◆□▶ ◆□▶ ◆豆▶ ◆豆▶ 三目目 のへの

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

VMM Baseline with External Noise



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

A □ ▶ A □ ▶ A □ ▶ A

(星)▶ (星)国 のへ(や

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.

= 990

.....

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

A 回 > A 回 > A

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

Final VMM Baseline Signal



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

= ୬**૧**୯

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

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)

< ロ > < 同 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < 回 > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > < □ > <

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.

큰 ㅋ

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.

< A

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

= ୬**૧**୯

æ

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

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.

◆□▶ ◆□▶ ◆豆▶ ◆豆▶ 三目目 のへの

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.

JI DOG

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

Thank you. Questions?

<ロト < 目 > < 目 > < 目 > < 目 > の < 0</p>

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 $\frac{U_{Noise,RMS}}{U_{Pulse}} \Delta U$

212 DQC

• • = • • = •

Noise signals: 60 kHz noise

n vini	и типерале т	tipper Display	Cursons	Vessor	Wath Analys	n unna	нар		
10.15	A NUMBER OF STREET	1.1.1.1.1	1. 1.	1.46		1659	A. 11. 1. 1. 1.	FALLENTE	111111
PATKAR P	Statistics from	NY WATER AND	10.000	- CRAF	ANY COLUMN	A DEAL	ATTEN STORES	A STORAGE	16100.00
								1	
No.644TR	P1:base(C1)	P2.M@x(C1)	P3 sde	(C1) P41	91@M(C1) P5.66	kiay(Z2	P6x8elay(Z2)	P7:area(22)	P3 M(ghtF2)
133	149.0 m/s	193.0 mV	12.0	Vm0					
an	< 145.732 m/s	193.74 mV	> 12.949	1 m//					
e	< 124.1 m//	159.9 m/v	>11.8	9 miV					
×	< 169.3 mV	245.7 mV	> 14.10	9 mili					
89	< 8.004 m//	12.01 mV	÷ 355	A 94					
	1.752e+2	1.752e+3	1.75	28+3					
us	7			~					
	📾 🎮 🖬	(3-1)					Timeb	ise - 1.2 µs Tr	99% LOUGE
20.0 m	20.01	HCh .					VESSE	11 5.03 µS Au	00 250 2 mil
	10.011						and the second s	20.00	16 101 10
194.89	m 1						20 A	E 005110 1.00Vil	63 607 MMY
	m's r						744-1	sources for these	00.000 816
19.62	119 Ar								
tites S	tetus Renote	Hardcopy A	a Output	DateTine					clese
	233			_		. Vana	_		
	1 Distances	- historic Countil	and a secolo		States and a second	That is	COLUMN TWO IS NOT		
rinter Cha	toir	e raçontik oraşırı	stung	· 🗵	ON-CALISS_BOIL	0.063411	2001010		
-								and the second second	
		115			Lange Lang		Browse	and state	
	Part Part								
	Print cal	019-056-0				Harto	107 ANR 8		
	unite ta	chiproset6				DSOWE	direc.		
NOC.	10 00101	uterin							_
			sheet he will	and searcher and	mination.			304.000	0.041-10.0M

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



Figure: 60 kHz noise amplitude

ъ

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

문 문

APV S/N ratio



APV25: SNR vs. HV

212 990