VMM3a hybrid noise measurements

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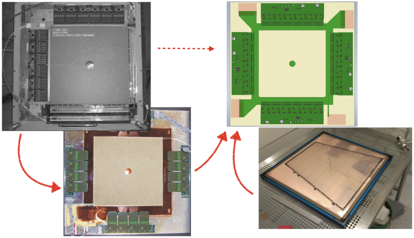
Motivation

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



Karl Flöthner, Compass Gem Upgrade, Tuesday 12:00

Requirements:

- ✓ Self-triggered readout
- ✓ Time-space resolution
- ✓ High rate environment

APV25 at HV=4000 V:

- ✓ $\text{SNR}_x = 110.86 \pm 2.63$
- ✓ $\text{SNR}_y = 83.63 \pm 2.29$

S/N Ratio

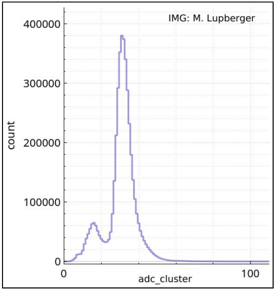


Figure: First data obtained with the VMM: FE-55 spectrum.

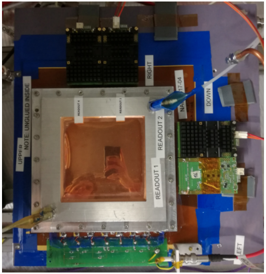


Figure: Triple-GEM detector

✓ May 2019: First data at HISKP lab with FE-55 source on Triple-GEM detector

S/N Ratio

Cannot directly measure an S/N ratio because:

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

Next step:

⇒ Look at individual channels to better understand the noise.

Threshold-Noise Examinations

Method:

For individual channels:

- ✓ Use VMM slow control interface to adjust global threshold over baseline.
- ✓ Use Wireshark to count noise rate.

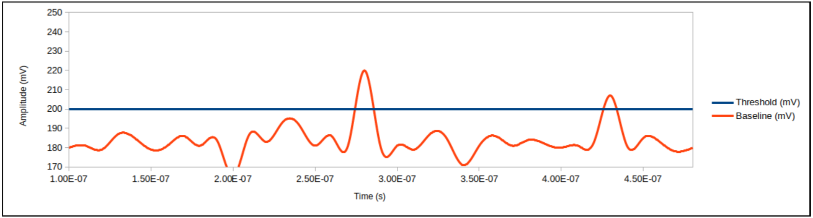


Figure: Schematic view of a threshold scan over the baseline.

Threshold-Noise Examinations

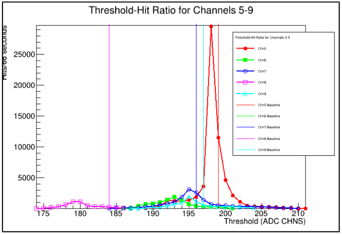


Figure: Noise rate vs. threshold for channels 5-9.

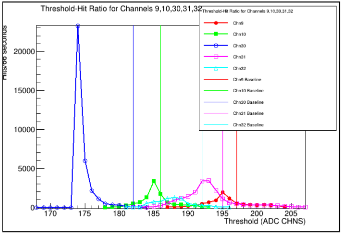


Figure: Noise rate vs. threshold for channels 9,10,30,31,32.

✓ Maximum noise rate $\neq$ baseline

$\Rightarrow$ Threshold step size $>$ baseline rms.

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($0.5 - 16\,\mathrm{mV/fC}$) of the VMM
- ✓ fit a Gaussian on the derived amplitude histograms

Initial Method

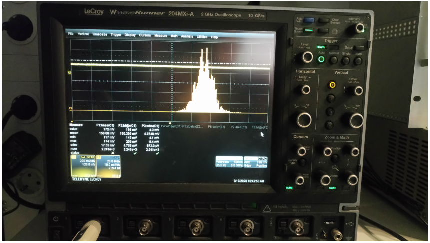


Figure: Chn 0 Baseline measured on the oscilloscope.

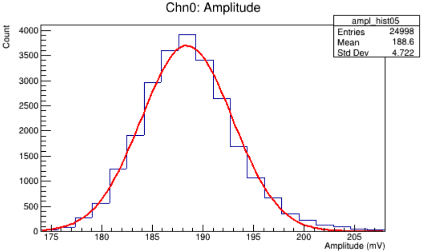


Figure: Chn 0 Amplitude Histogram at Gain 9 mV/fC.

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).
- ✓ **Oscilloscope noise:** 0.14 mV.
- ✓ **Data acquisition on:** up to $\sim 1.19\,\mathrm{mV}$.

VMM Baseline with External Noise

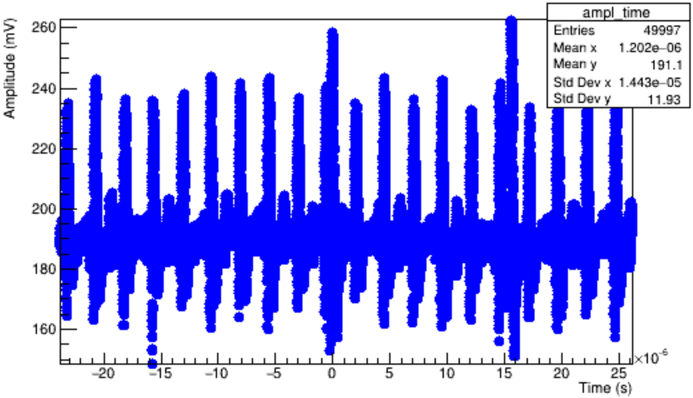


Figure: VMM Chn 0 Baseline with External Noise, Gain:0.5 mV/fC.

New Setup Configuration

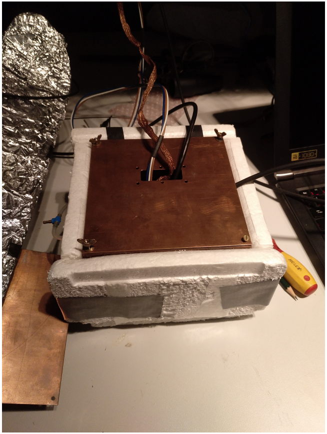


Figure: Faraday Box

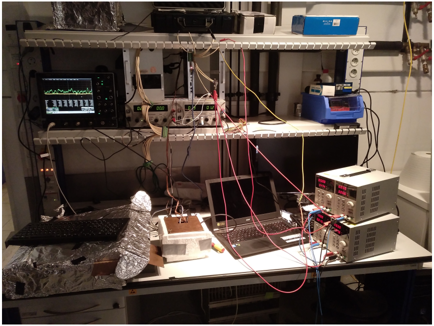


Figure: Setup with externally powered FEC.

New Setup Configuration

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

Final VMM Baseline Signal

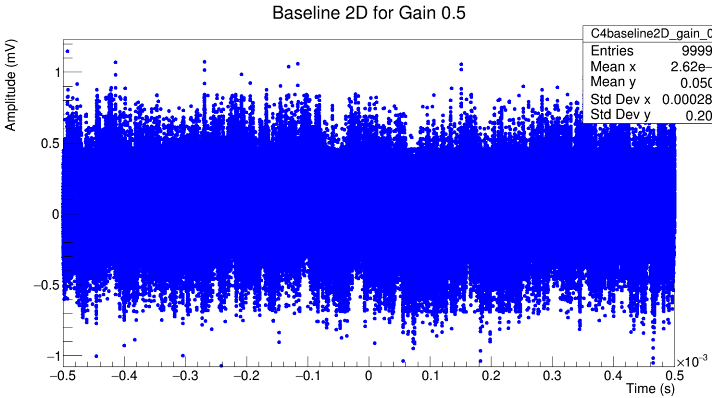


Figure: VMM Chn 4 Baseline 2D Histogram, Gain:0.5 mV/fC.

Final VMM Baseline Signal

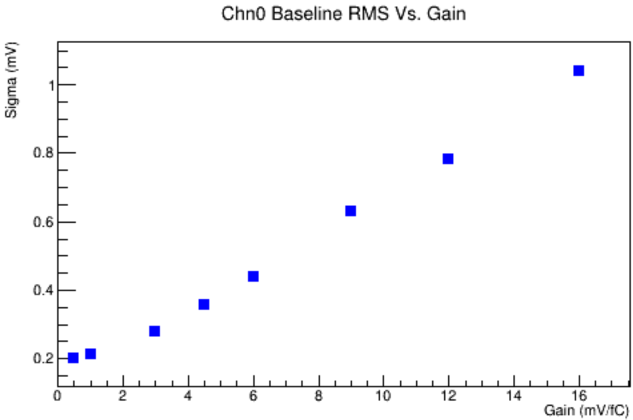


Figure: VMM Chn 4 Baseline Vs. Gain.

ENC Calculation Method

Next step: Convert baseline rms from mV to electrons.

Method:

- ✓ Use test pulse of known charge.
- ✓ Pulse created with internal VMM test capacitance: 0.3 pF.
- ✓ Pulser step necessary to calculate charge.

Calibrations

To do the above measurement certain calibrations were needed:

- ✓ Pulser Step DAC calibration (from ADC Chn to mV)
- ✓ Pulser Step DAC change with gain increase (if existent)

Pulser Step DAC Calibration

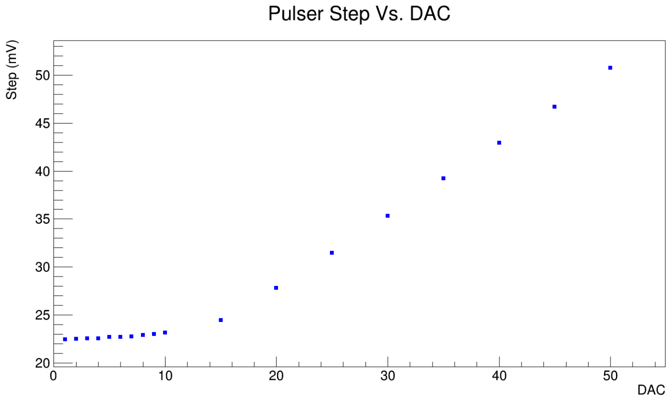
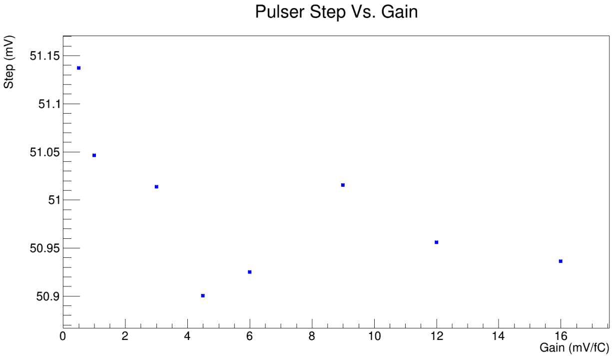


Figure: VMM Chn 4 Pulser Step DAC Calibration.

Pulser Step Vs. Gain



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

Results & Observations

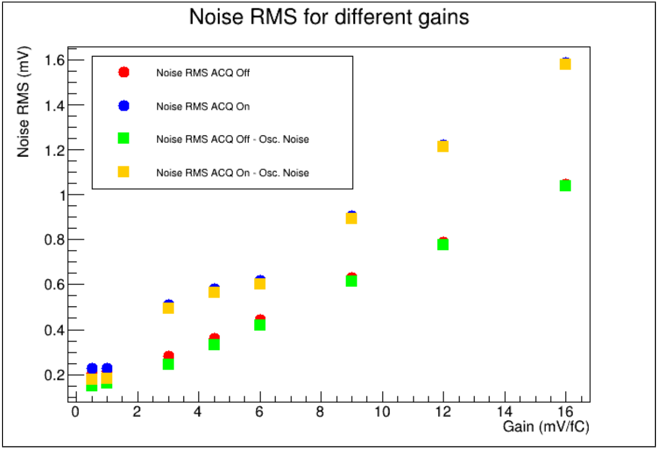


Figure: VMM Chn 4 Noise RMS for different gains, preliminary

Results & Observations

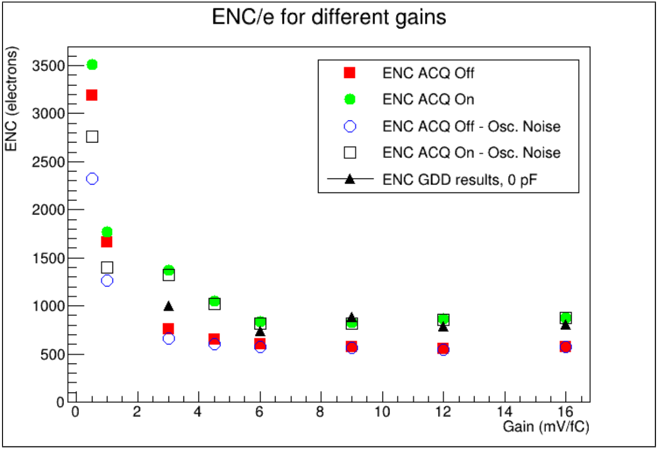
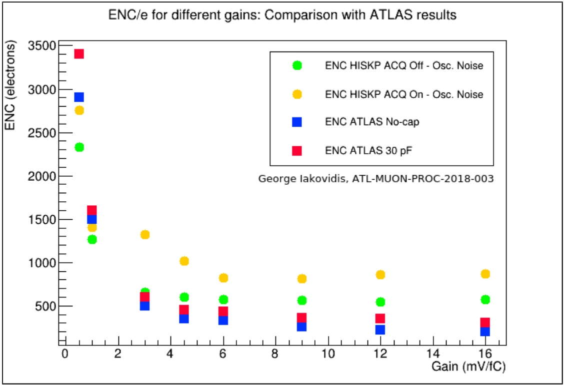


Figure: VMM Chn 4 ENC for different gains, preliminary

Results & Observations



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

Results & Observations

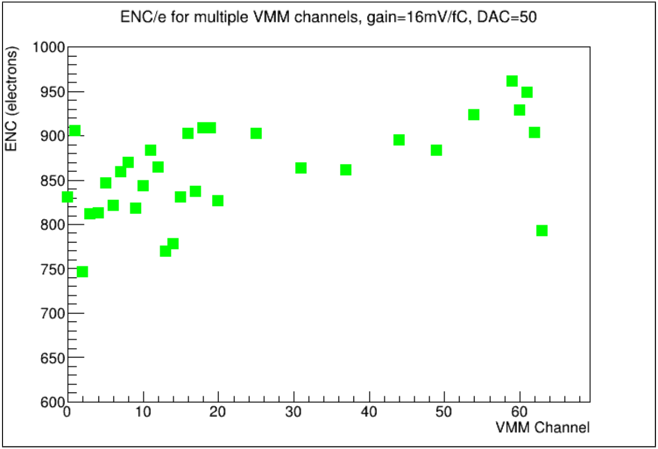


Figure: VMM ENC for multiple channels, preliminary

Outlook

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

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.

Thank you. Questions?

ENC Calculation

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

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

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

$$e = 1.602 \times 10^{-19}\text{C}$$

$$\boxed{\text{ENC(electrons)} = 1.864.500\frac{U_{Noise,RMS}}{U_{Pulse}}\Delta U}$$

Noise signals: 60 kHz noise

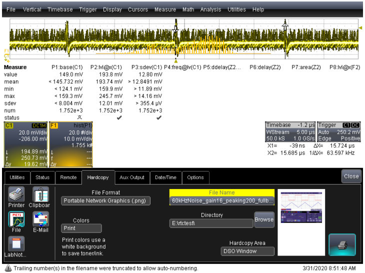


Figure: 60 kHz noise spike on scope, gain= 16 mV/fC, peaking time= 200 ns,full bandwidth

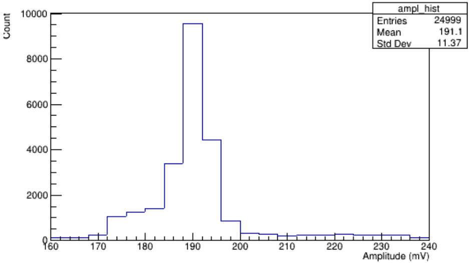


Figure: 60 kHz noise amplitude

Noise signals: 400 kHz noise

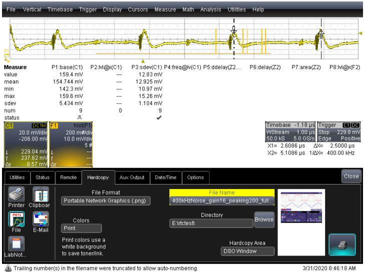


Figure: 400 kHz noise spike on scope, gain= 16 mV/fC, peaking time= 200 ns,full bandwidth

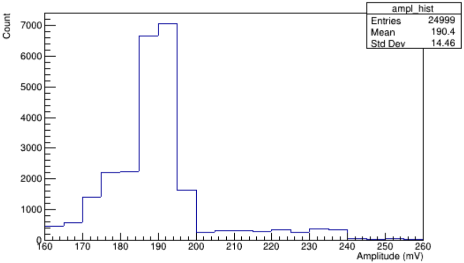
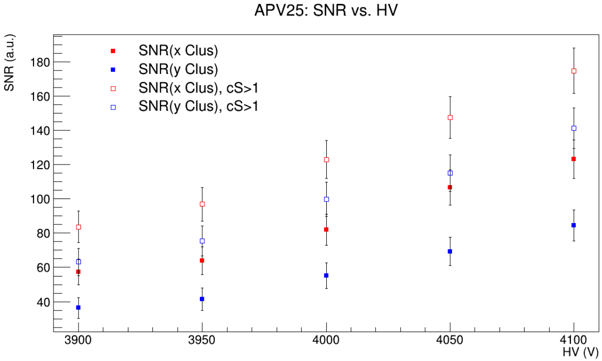


Figure: 400 kHz noise amplitude

APV S/N ratio


APV25: SNR vs. HV
SNR (a.u.)
180
160
140
120
100
80
60
40
3900
3950
4000
4050
4100
HV (V)
SNR(x Clus)
SNR(y Clus)
SNR(x Clus), cS>1
SNR(y Clus), cS>1