ENC measurements of VMM3a hybrid

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Motivation

Goal of the measurement:

Characterise VMM noise by means of equivalent noise charge (ENC).

✓ **Used configurations:**

- Gains [mV/fC]: 0.5, 1, 3, 4.5, 6, 9, 12, 16.
- Peaktime [ns]: 25, 50, 100, 200.

✓ **# of chips:**

- 10 VMMs (5 hybrids, 2 VMMs/hybrid).

✓ **Input capacitance:**

- No input capacitance
- Detector simulator PCB [pF]: 8, 30, 76, 98, 338, 360, 406, 428.

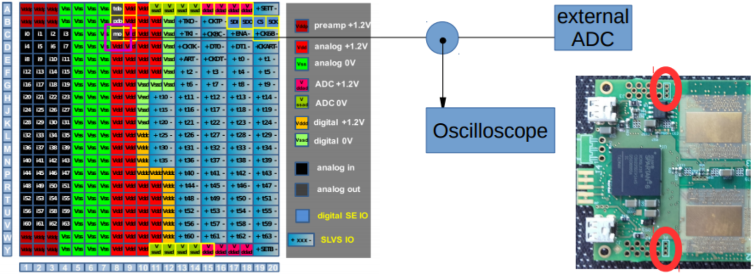
✓ **Settings:**

- All for 1-2 chips.
- Standard for others.

How to Measure the ENC

ENC = baseline rms in electrons → how to access baseline?

- ✓ VMM configuration: Route shaper output of single channel to MO pad on chip periphery,
- ✓ ASIC MO pad wire bonded to hybrid PCB with test point
- ✓ MO routed to low-resolution external ADC to measure rms → connect to oscilloscope.

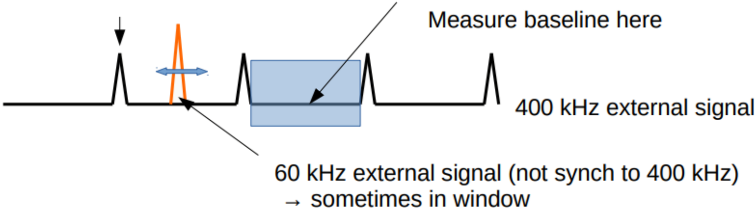


How to Measure the ENC

However...

→ Baseline rms is primarily dominated by external noise sources:

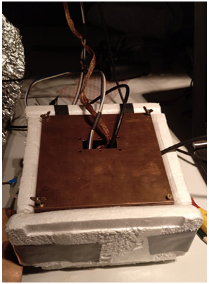
- ✓ from **backend electronics**
- ✓ from other **hybrid components**
- ✓ from **surrounding instruments**
- ✓ from **connection to oscilloscope**

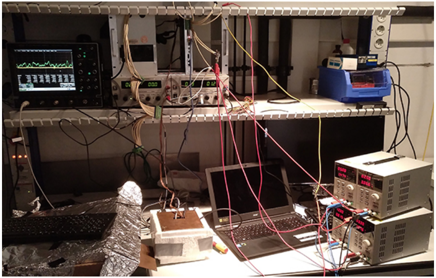


How to Measure the ENC

Dealing with the external noise:

- ✓ from **backend electronics** → Faulty ATX power supply, removed by powering backend externally (now: new SRS crate seems fine)
- ✓ from other **hybrid components** → measure at ACQ on/off; switched off 160 MHz ART clock.
- ✓ from **surrounding instruments** → Faraday Box
- ✓ from **connection to oscilloscope** → used BNC cable (best option); adds noise rms $\sim 0.14\,\mathrm{mV} <$ baseline rms.





How to Measure the ENC

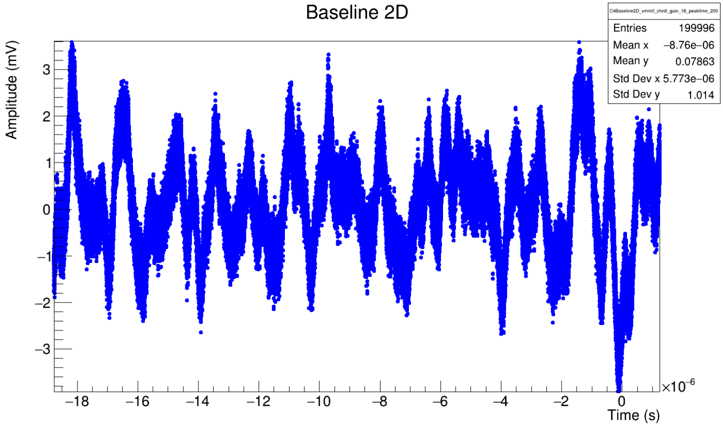


Figure: VMM 0, Channel 0, gain 16 mV/fC, peaktime 200 ns, no external capacitance.

How to Measure the ENC

Baseline is measured in mV → How to convert into #electrons?

Method:

- ✓ Induce signal of known charge into VMM channel (internal test pulse)
- ✓ Measure its amplitude at the MO (shaper output)

ENC calculation:

$$\frac{U_{pulse}}{Q_{pulse}} = \frac{U_{RMS}}{Q_{noise}}$$

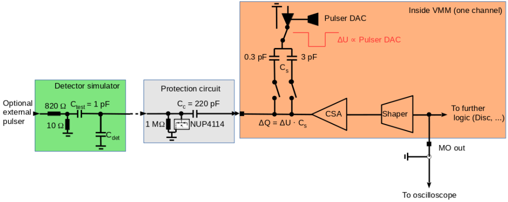
$$Q_{noise} \rightarrow ENC[e^-]$$

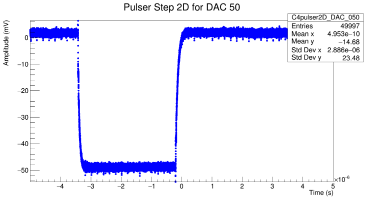
$$ENC[e^-] = \frac{\Delta Q_{in}}{e} \cdot \frac{U_{RMS}}{U_{pulse}}$$

How to calculate the input charge ΔQ_{in}?

How to Measure the ENC

How to calculate the input charge ΔQ_{in}?





From internal test pulse circuit of VMM channel:

- ✓ apply voltage step on test capacitance $C_s = 0.3\,\mathrm{pF}$
- ✓ adjust step size ΔU from configuring Pulser DAC.
- ✓ measure ΔU by routing test pulse step to MO → access on oscilloscope.

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

How to Measure the ENC

Finally:

$$ENC[e^-] = (1.8645 \times 10^6) \cdot \frac{U_{RMS}}{U_{pulse}} \cdot \Delta U$$

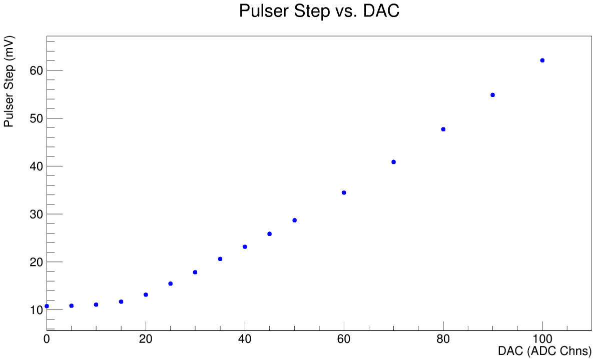
✓ For each parameter setting, need to measure: U_{RMS}, U_{pulse} and ΔU

↓

✓ All accessed at MO via VMM configuration.

Test Pulse Voltage Step

Pulser DAC - Voltage Step Calibration:



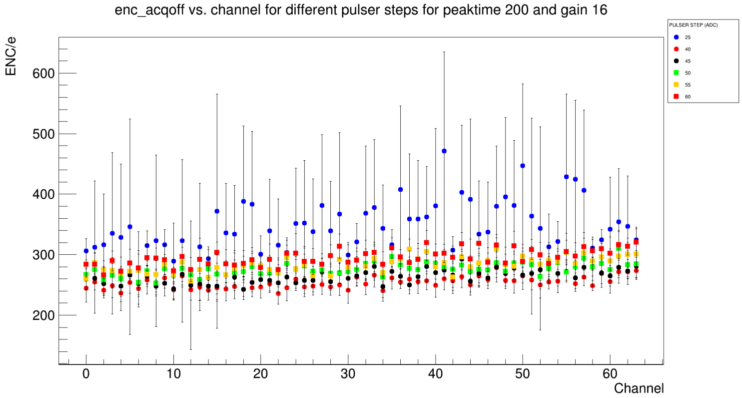
✓ Linear after onset $\sim$ 20 DAC

✓ Standard measurements: DAC 50 $\approx$ 28 mV

✓ Test charge: 53812.5 electrons (with C_s 0.3 pF)

Test Pulse Voltage Step

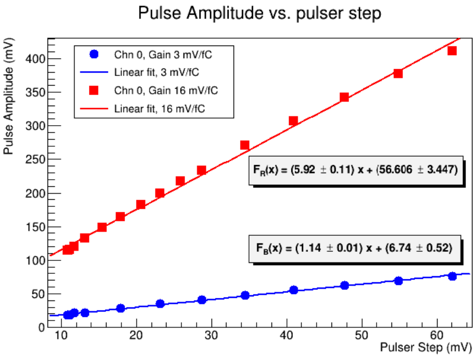
Tests with different DAC (preliminary):



✓ ENC does not depend on test charge.

Test Pulse Checks

Understanding of input charge is essential to get ENC correct.



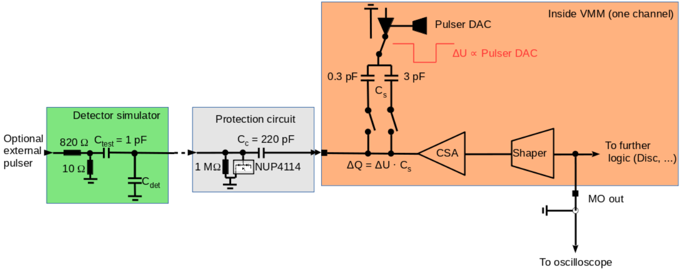
✓ Mostly linear; some saturation for high gain

✓ Scaling with gain correct ($\frac{16}{3} \approx 5.3$, $\frac{5.92}{1.14} \approx 5.2$)

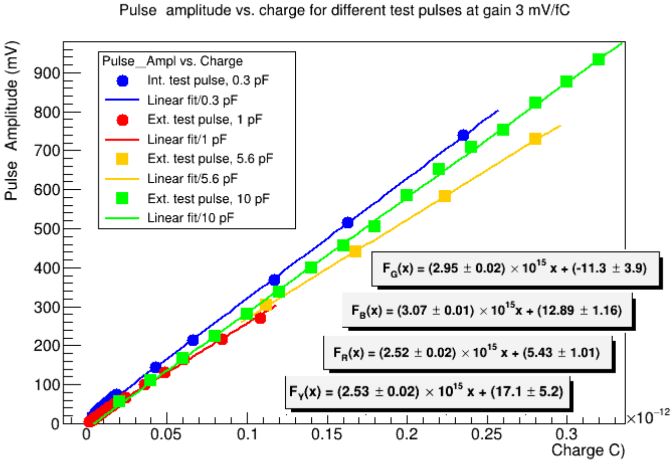
Test Pulse Checks

Is the internal capacitor 0.3 pF? → Check with pulses on external capacitors:

- ✓ Detector simulator: 1 pF (1%)
- ✓ 5.6 pF (10%) soldered to input
- ✓ 10 pF (10%) soldered to input

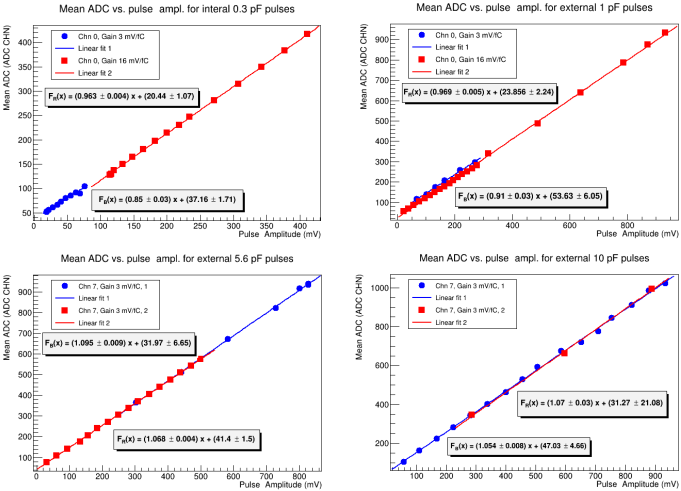


Test Pulse Checks



✓ Gain comes out correctly → $C_s = 0.3\,\mathrm{pF}$, 8.8% error

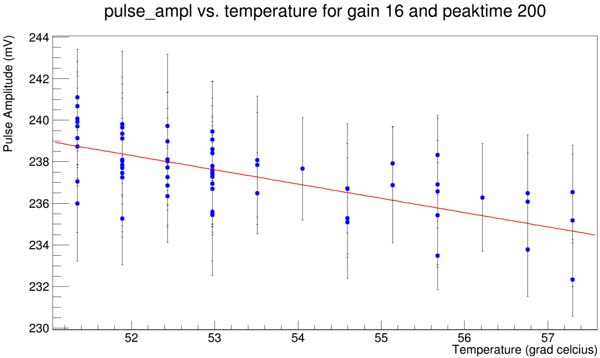
Test Pulse Checks



1:1 behavior with ADC offset $< 10\%$ variation (gain, channel, charge).

Temperature Effects

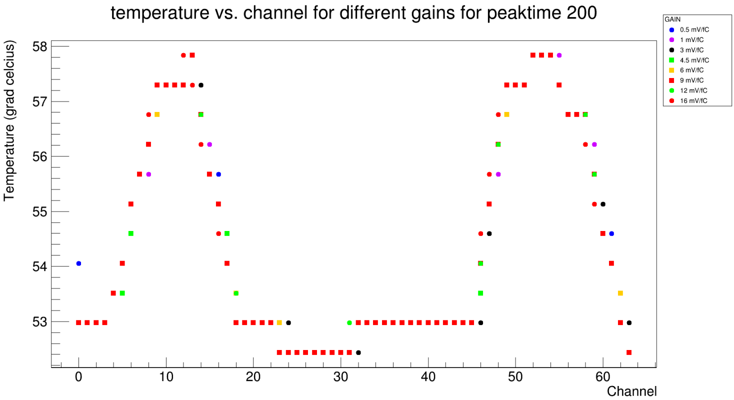
Despite cooling of setup, temperature variates between $\sim 51\,^{\circ}\mathrm{C}$ and $57\,^{\circ}\mathrm{C}$ (due to change in room temperature, fan position, etc.).



✓ Pulse amplitude seemingly depends on temperature, 3% effect.

Temperature Effects

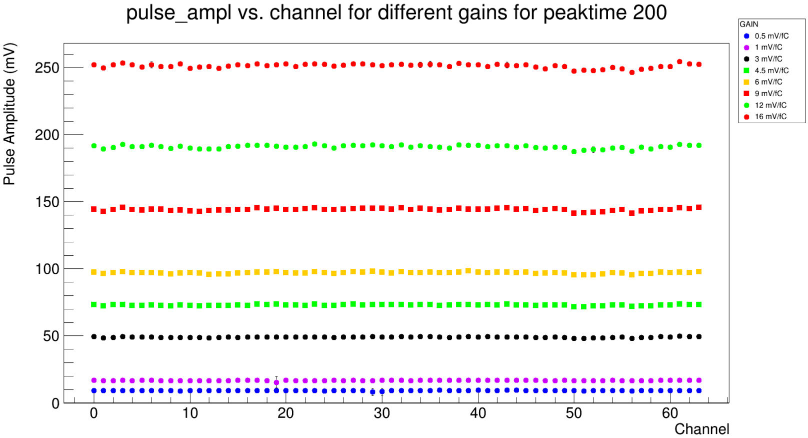
Example: Extreme measurement, pulser DAC 55.



$\sim 9\%$ variation

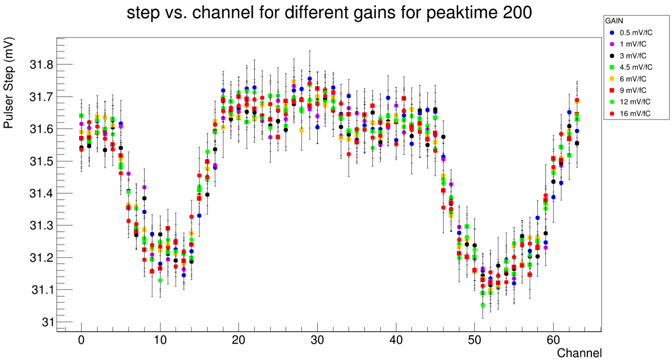
Temperature Effects

Example: Extreme measurement, pulser DAC 55.



Temperature Effects

Example: Extreme measurement, pulser DAC 55.

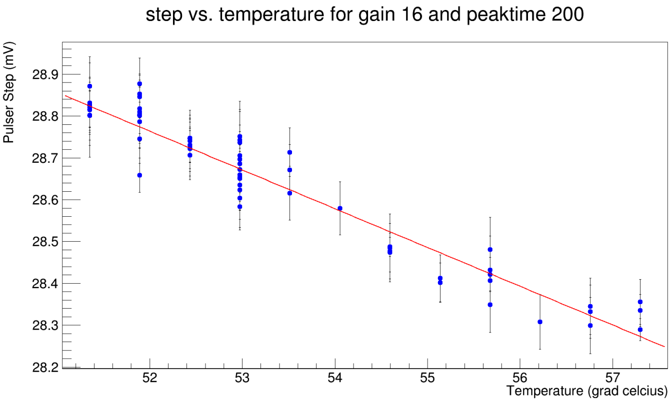


$\sim 1.6\%$ variation

Conclusion: It is the pulser step/test charge that is affected by the temperature, not the pulse amplitude.

Temperature Effects

In this measurement: Pulser DAC 50



$\sim 0.5\%$ variation

The Measurement Cycle: Overview

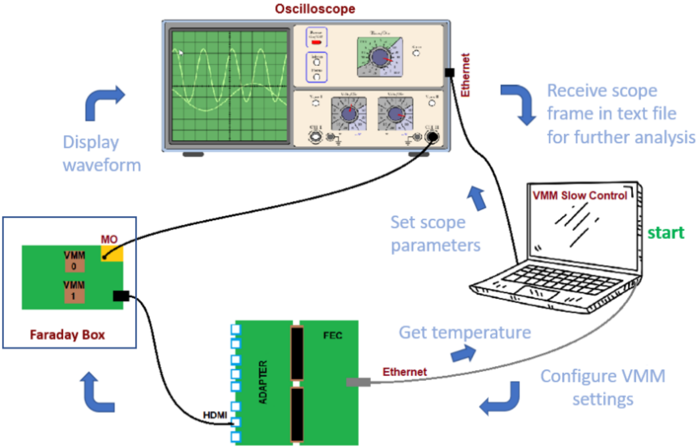
One measurement cycle corresponds to a single VMM channel, gain & peaktime.

Tasks:

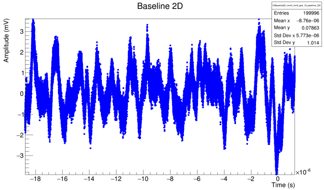
- ✓ Configure VMM settings
- ✓ Record measurement parameters (channel, gain, etc.)
- ✓ Display waveform at MO using oscilloscope
- ✓ Save ∼10 scope frames of RMS (ACQ on and off), test pulse & pulser step for data analysis
- ✓ Store waveforms if highest gain and peaktime
- ✓ Store analysis results & calculated parameters in table

Takes $\sim 2.5\,\text{min}$ (optimised with multi-threaded online analysis).

The Measurement Cycle: Overview



The Measurement Cycle: Data Analysis



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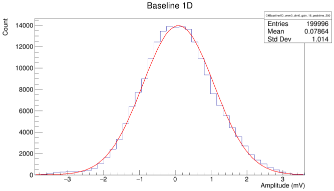

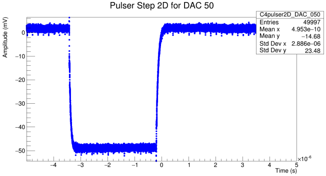

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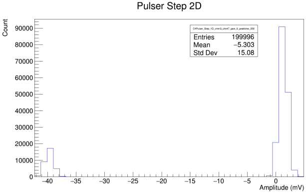
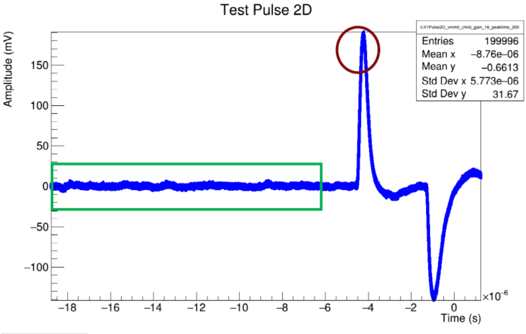


$\sim$ 200,000 data points

The Measurement Cycle: Data Analysis



Errors: From statistical analysis of 10 scope frames.

Finally: ENC Calculation.

The Measurement Cycle: Data Analysis

Full-reference measurement: all channels, gains, peaktimes ~ 72 hours

Table: Final Output

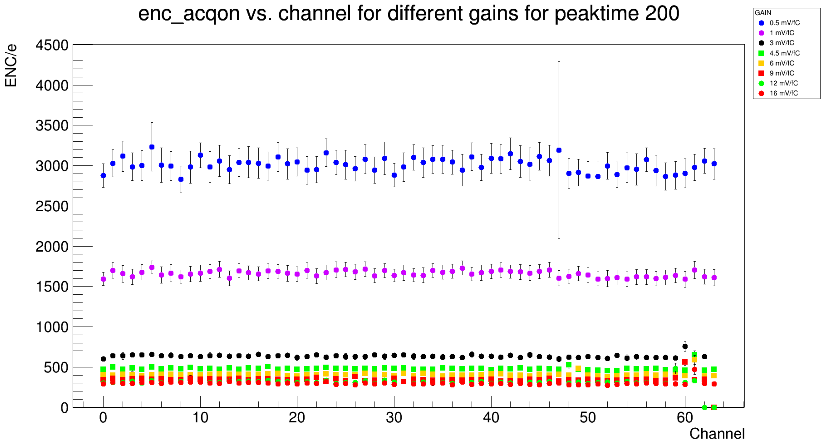
vmm_id	**channel**	**gain**	**peaktime**	**rms_off**	**rms_on**	**p_ampl**	**ENC_on**	**ENC_off**	ΔU	**temp**	**>>ERRORS**
0	0	0	0	0.3208	0.4063	5.7555	2935.13	4055.07	29.5917	56.2162	>>errors
0	0	0	1								
0	0	0	2								
0	0	0	3								
0	0	1	0								
0	0	1	1								
0	0	1	2								
0	0	1	3								
0	0	2	0								
0	0	2	1								
0	0	2	2								
0	0	2	3								
...	...	...	...	...	...	...	...	...	...	...	...
0	63	7	0								
0	63	7	1								
0	63	7	2								
0	63	7	3								

Measurement Log

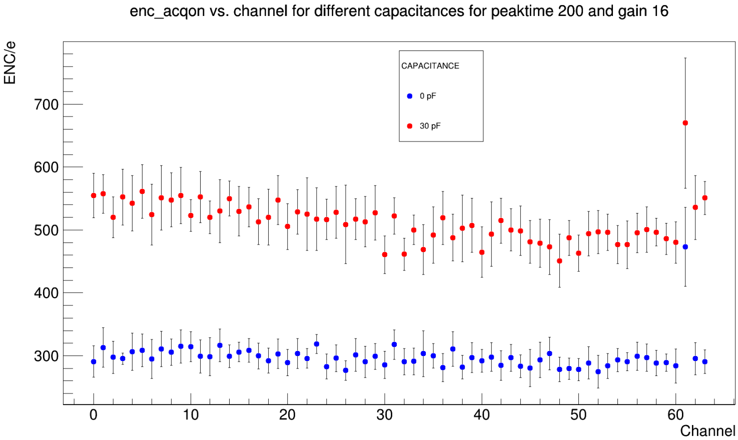
Table: Measurement Log

VMM ID	Comments
VMM 0	full-reference tests with 0, 8 and 30 pF cap.
VMM 1	full-ref. tests with 0, 8 and 30 pF cap.; for channels 62, 63: caps 30 - 428 pF also tested
VMM 2,3,4,5,7,9,10,11	ref. tests for gains 3, 6, 16 mV/fC, caps 0, 8, 30 pF

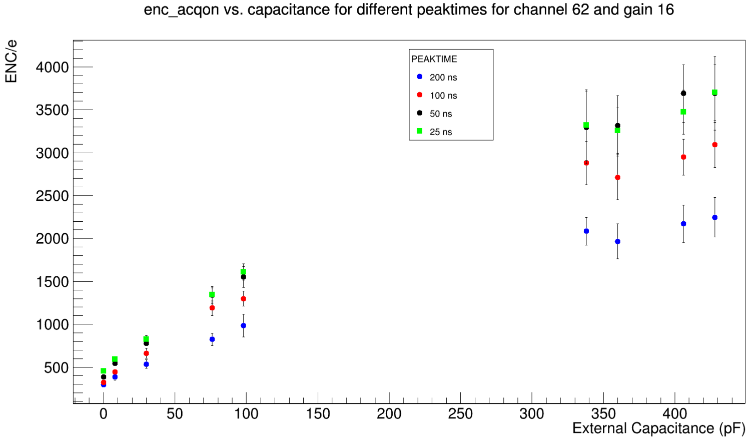
VMM1 Results, preliminary



VMM1 Results, preliminary

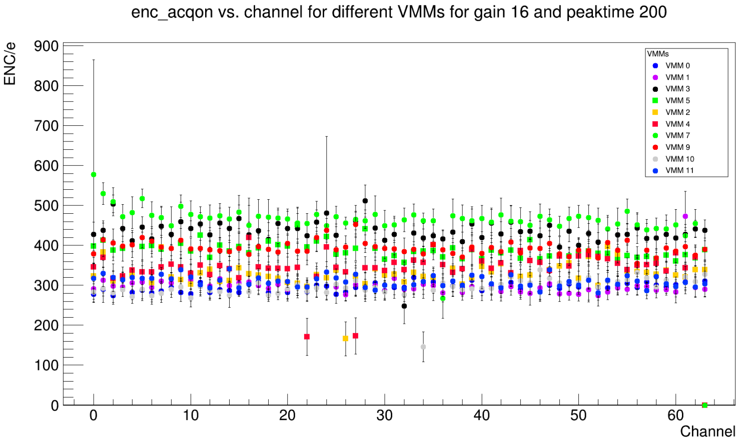


VMM1 Results, preliminary



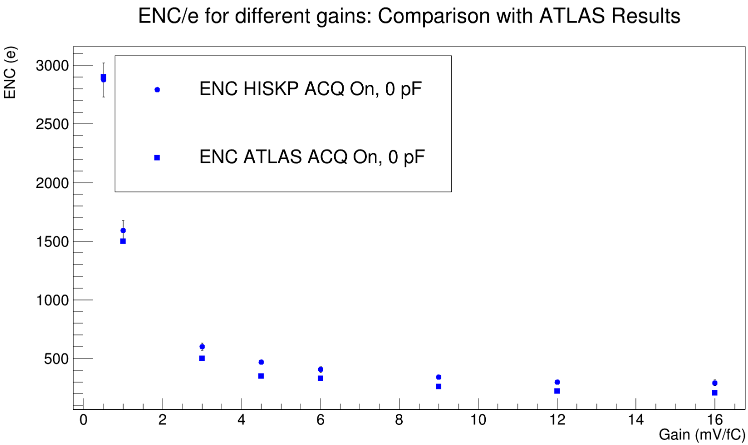
→ Unaccounted for: 470 pF capacitor in protection circuit.

Multiple VMM Results, preliminary

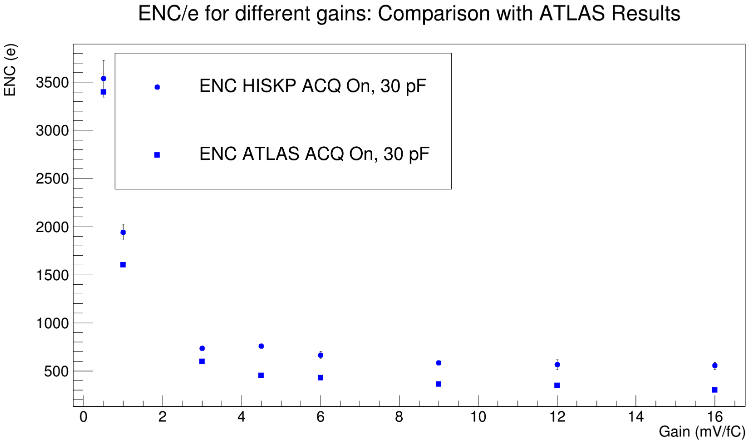


$\sim 16.5\%$

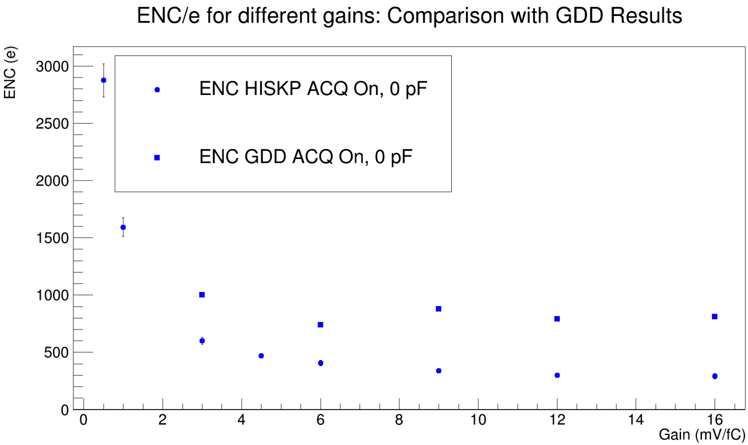
Comparison with ATLAS and GDD, preliminary



Comparison with ATLAS and GDD, preliminary



Comparison with ATLAS and GDD, preliminary



Outlook

To do:

Full cosmics measurement with VMMs installed on a standard triple-GEM detector.

Thank you. Questions?