Shaped Digital Readout Noise in CAL

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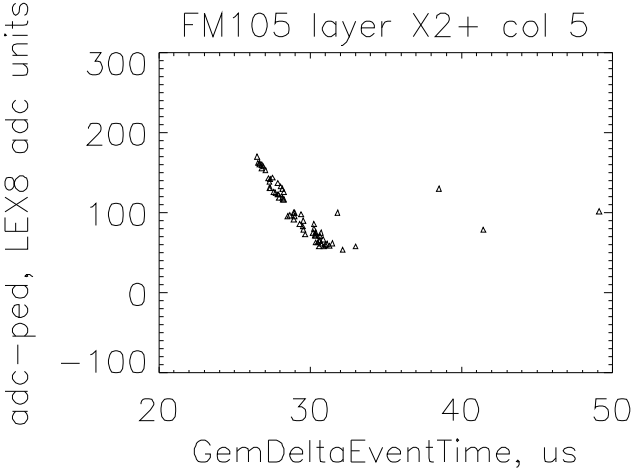
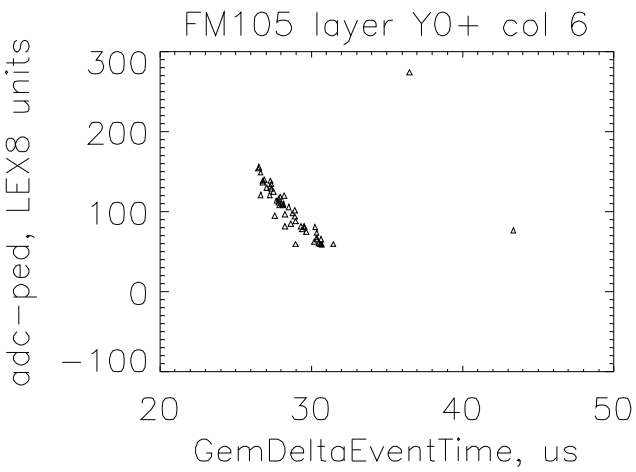
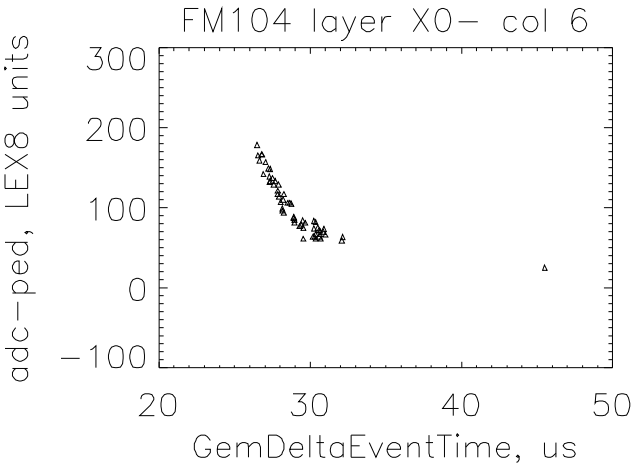
Conclusion

- We find evidence for a small bias in normal events that follow closely after a first event
  - What is it? Where is it from?
    - Digital readout noise picked up by channels nearest the digital path on each CAL AFEE board, shaped by the slow shaping amp, and added to readout of current event.
  - How large is the effect?
    - From 2-tower data, guesstimate per tower
      - ~1 channel contributing ~5 MeV, exponentially decaying
      - ~10 channels contributing ~1.5 MeV, exponentially decaying
  - How close in time must the events be?
    - $\Delta t <$ ~50μs (strongest at 25-30μs)
    - But note at 10 kHz trigger rate, that will be ~30% of events
  - Effect is strongly systematic, so it "can be calibrated out"
    - Specific channels are most susceptible
    - Shape is known
- Need more information
  - Data collected so far are not optimal to measure this effect
  - An STR is worth considering

Spurious signals at Δt<30 μs



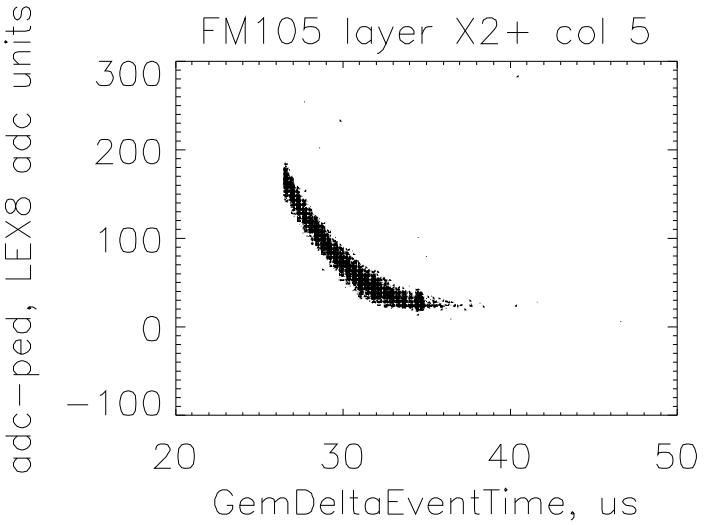


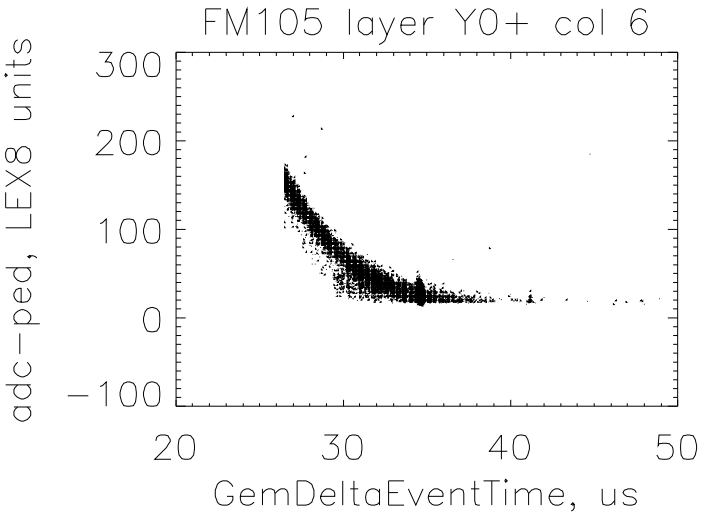


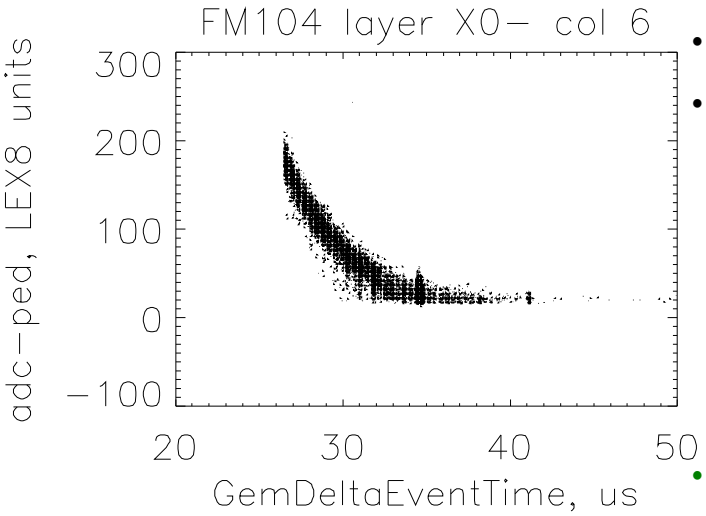
Data: 150k muons from run 135002134 (Flight config, 2 twrs)

- Spurious signal in a few channels
  - normal muon events within 31 μs from previous trigger show exponentially decaying signals in empty xtals
  - amplitude ~170 LEX8 ADC units (~1/2 MIP)
- These are normal, TKR-triggered muons
  - Statistics: ~50 events out of 150k, consistent with 80 Hz event rate:
    - (31 μs – 26.5 μs)*80 Hz*10^{-6} * 150,000 = 54 events
  - This is not a retriggering issue!

Same effect in trigger run 135001500







- Data: 2 tower muon run with low FLE/FHE thresholds
- Statistics are much greater because retriggering creates many more events just after dead time
  - But effect is exactly the same as in baseline muon run
  - It is detectable for a longer time (up to 40μs) because the LAC thresholds for this run were set lower (~25-30 ADC units) than for baseline run (~50 ADC units)
- **Time constant corresponds to the shaping time of the CAL GCFE slow shaper**

What is this? What can we do?

- We are seeing the tail of the pulse produced in the analog part of the front-end chip (preamp + slow shaper) by digital data readout from AFEE board to TEM.

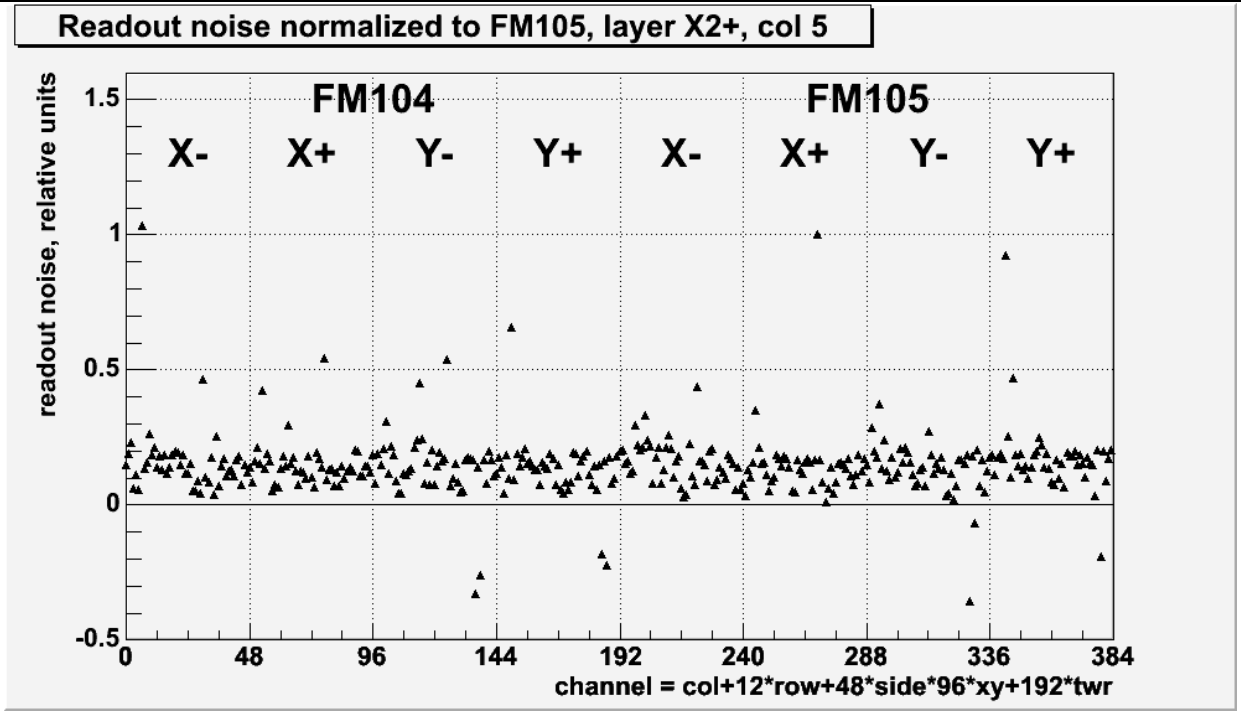
- This "shaped-noise" signal will add to any normal event that follows shortly after previous event
  - Could contribute to energy measurement error
  - Probability will be bigger for higher trigger rate
    - i.e. a larger fraction of events come closer together in time

- We can probably correct for this "shaped-noise" contribution
  - Mean shape and amplitude are well-defined functions of gemDeltaEventTime
  - Calibrate it out, use gemDeltaEventTime
    - Subtract the estimated noise contribution from measured signal

What happens in typical channels?

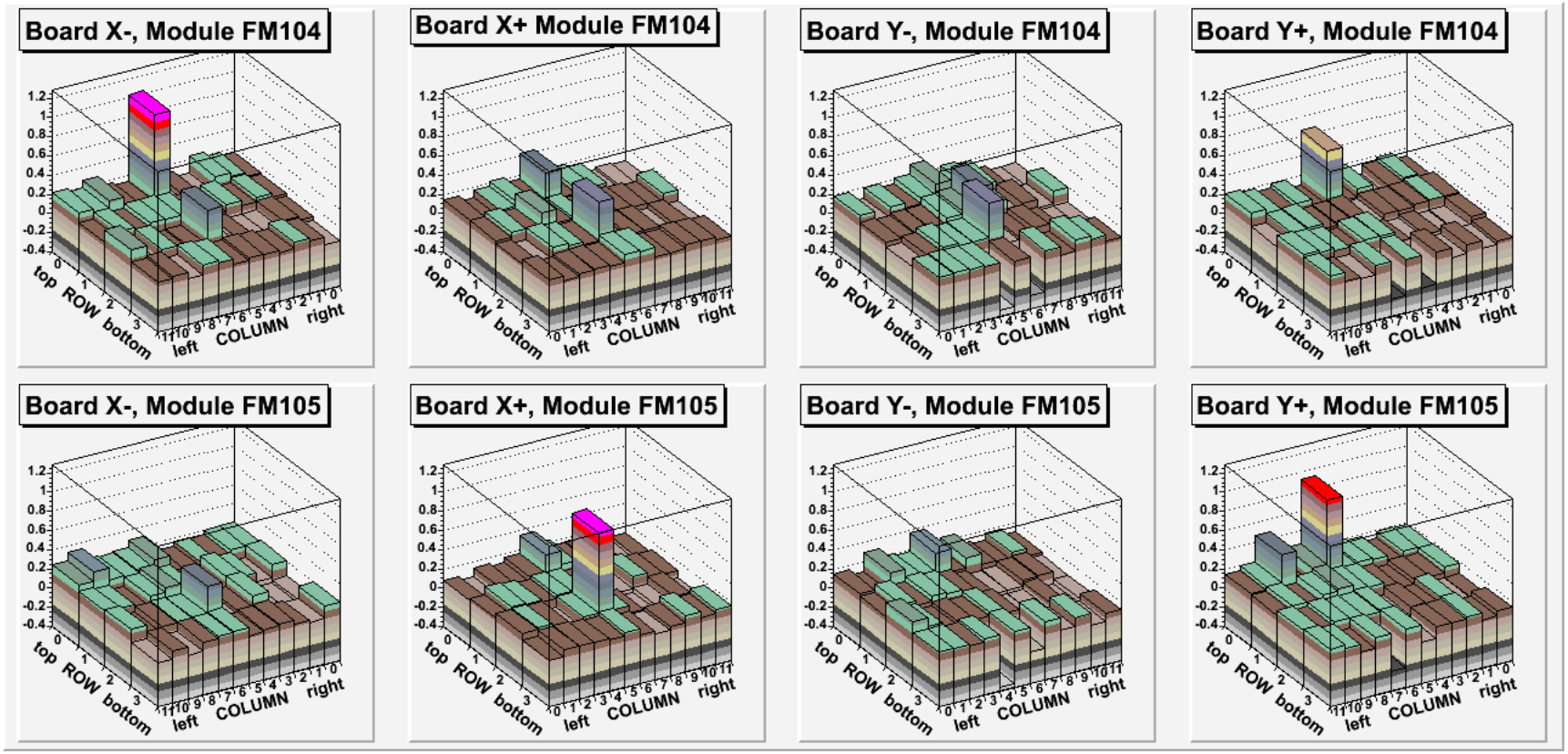
- Previous viewgraphs have shown the three most-susceptible channels (in two Modules).
- Effect is much smaller in typical channel, but has same time-dependence.
- To study all channels, we remove the exponential:
  - Pick one reference channel, with strong contamination
    - refChan = FM105, row X2, face +, xtal column 5
  - Event by event, normalize each channel to the reference channel
    - normSignal[iChan] = signal[iChan] / signal[refChan]
  - Calculate the mean of the normalized signal for all events with $\Delta t < 50\mu s$.
  - Plot mean normalized signal

Shaped noise, normalized to ref channel



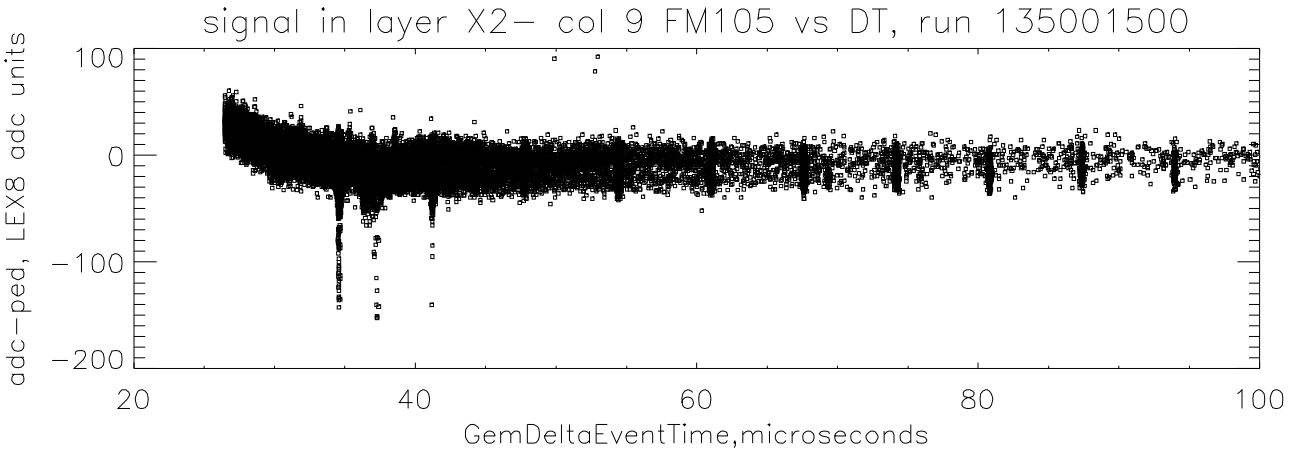
- Three channels shown on previous slides appear here with maximum noise ~1
  - Corresponds to ~150 ADC units or ~5 MeV at $\Delta t=26.5\mu s$
- There are ~20 channels with noise ~0.2-0.5
  - (1-2.5 MeV at $\Delta t=26.5\mu s$)
- Most of the channels have readout noise level ~0.1-0.2
  - ~15-30 ADC units or ~0.5-1 MeV at $\Delta t=26.5\mu s$
- There are a few channels where readout noise has opposite sign

Normalized readout noise for each AFEE board



- Channels with largest readout noise are mostly in column closest to digital data lines
  - in 6th column from left side of board
- Readout noise has negative sign (i.e., signal is below pedestal) in 2 channels in the bottom row of each Y board
  - in 5th and 7th column from left side of board

What happens below LAC threshold?



- In run 135001500, one channel was not zero-suppressed because LAC threshold was set incorrectly low (well below pedestal)
  - That's why we can see the negative signals
- This is a "typical" channel with "starting" readout noise ~30 ADC units (~1 MeV)
  - Readout noise level for the region 40μs < GemDeltaEventTime < 60μs is ~15 ADC units (0.5 MeV)
- Note also: big negative spikes up to 150 ADC units (5 MeV) from TEM->GASU data transfer
  - Remember this is a retriggering dataset (with very low FLE, FHE thresholds)
  - These are spikes, so pickup is after shaper….

Discussion

- High event rate on orbit means that many events will follow closely behind another event
  - If rate ~ 10 kHz, ~30% of events will be affected
    - 30% of good events will be in the region 26.5μs < dt < 60μs
  - How large is the effect?
    - From 2-tower data, guesstimate per tower
      - ~1 channel contributing ~5 MeV, exponentially decaying
      - ~10 channels contributing ~1.5 MeV, exponentially decaying

- To make energy corrections, we need more study, more info
  - To get realistic, thorough noise estimate
  - To understand what happens below LAC threshold

  - Need a new data run, not covered in existing plan
    - STR: collect unsuppressed events close together in time

Appendix: Special Test Request

- Two ways to get more information
  - Need small event size to allow 26.5μs deadtime
  - Need to keep TEM FIFO from filling
  - First alternative, to study several channels per twr
    - Flight mode
      - 1-range, auto-range, zero-suppressed readout
      - FLE ~ 100 MeV, FHE ~ 1 GeV, TKR trigger
      - Set LAC ~ 1 MeV, but intentionally lower the threshold in a few channels in each tower to see negative part of shaped readout noise
    - Add 10 kHz external trigger from random pulser
      - Need to read out from CAL to TEM to GASU
      - OK to prescale before writing to disk
  - Second alternative, to study all channels
    - Special mode
      - 1-range, auto-range, unsuppressed readout
      - FLE ~ 100 MeV, FHE ~ 1 GeV, TKR trigger
      - Set FIFO depth to enable trigger at space for one 1-range, unsuppressed event (rather than standard setting of one 4-range, unsuppressed event).
    - Add 10 kHz external trigger from random pulser
      - Need to read out from CAL to TEM to GASU
      - OK to prescale before writing to disk