CAL features and idiosyncrasies.

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Long list of unexpected features …

- Retriggering
  - Seen at low FLE/FHE thresholds or at high gain
  - Is not a problem at flight configuration
- Nonlinearity
  - Preamp nonlinearity – measured by charge injection and taken into account
  - Crosstalk from FLE/FHE discriminator to preamp – significant at low FLE/FHE, but could be neglected at flight configuration
- Some additional nonlinearity features, necessary to explain charge injection measurements with different gains and charge injection capacitors (ongoing study)
  - Nonlinearity of Charge injection DAC
  - DAC "pedestal" (DAC=0 injects nonzero charge)
- Incorrect best range selection or range numbering
  - Seen in Engineering Module beam test data from GSI: some crystals have end to end ratio ~8 (data specify the same range numbers for both ends, but in reality they were different).
  - Could be related to incorrect setting of range decision delay
  - Never tested for LAT (need high energy depositions at significant rate and data collection with "auto-ranging")
- Shaped readout noise
  - Affects energy and position measurements
  - Could be calibrated for LAT (see later in this talk) and should be corrected in reconstruction
- Crosstalk from LE diode to HE diode
  - Seen for FM119
  - Could affect nonlinearity in HEX8 and HEX1 ranges
  - Should be calibrated for LAT (modification of calibGen script required) and corrected in reconstruction
  - Should be verified by test beam linearity measurement (in the energy range 0.4- 8.0 GeV)

This presentation is focused on

- Two selected features:
  - Shaped readout noise
  - Crosstalk from Low Energy diode to High Energy diode
- Why ?
  - They are recently found
  - Significantly affect the result of energy/position measurement
  - Require modification of calibration/reconstruction procedure

Shaped readout noise – some history

- The resulting effects were seen since Engineering Module testing at NRL in 2003
  - Non-gaussian component in the pedestal shape (broad and asymmetric, but with usually with low probability)
  - We were unable to interpret this effect because there was no timing information at microsecond level.
- First real detection with 2-tower configuration in June 2005 (http://www-glast.slac.stanford.edu/IntegrationTest/SVAC/Instrument_Analysis/Workshop-4/Talks/CAL_readout_noise_study.pdf)
  - Noise signal in many channels, decreasing exponentially with GemDeltaEventTime (time constant ~ 4 μs - corresponds to slow shaper)
  - Based on trigger run 135001500 – effect was easy to see due to high retriggering rate (huge statistics at small GemDeltaEventTime)
  - Biggest signal ~10 MeV
  - in some channels the noise signal was negative
  - Confirmed in B2 run for 3 channels with biggest effect
- For full LAT – effect confirmed by Eric Grove in December 2005 (http://www-glast.slac.stanford.edu/IntegrationTest/SVAC/Instrument_Analysis/Meetings/01272006/MoreShapedReadoutNoise.pdf)
  - Zero suppression doesn't allow to see the effect if it is less than LAC threshold (~2 MeV) at both ends of the same crystal
  - We cannot turn zero suppression off, because this introduces long dead time and the effect becomes invisible.
  - We would like to correct for this effect and so we need to calibrate it for all calorimeter channels

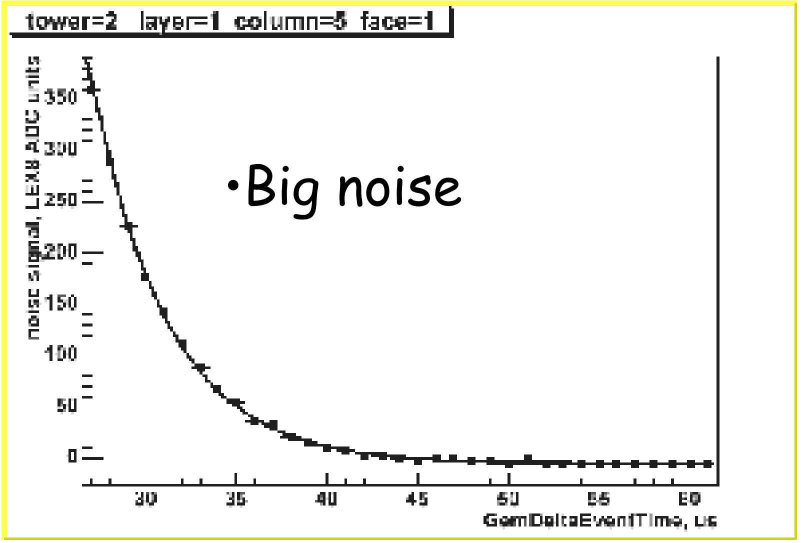
How to calibrate shaped readout noise ?

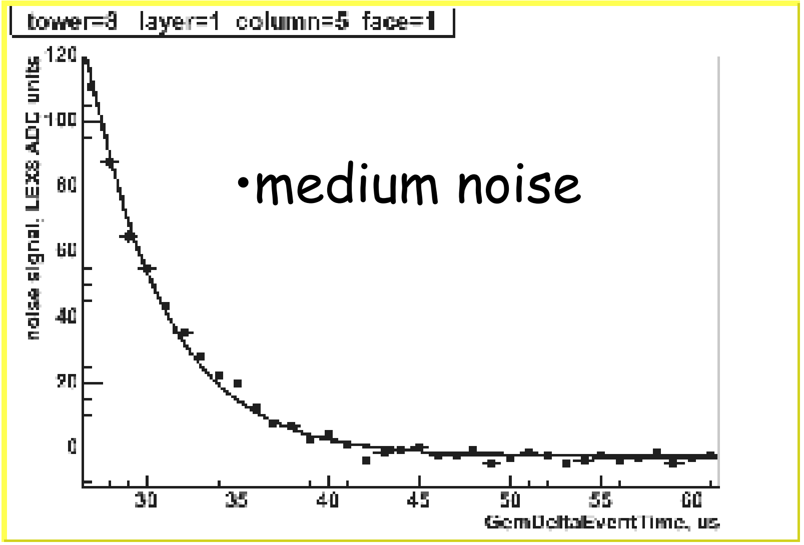
- One proposed solution – intentionally set LAC thresholds below pedestals, but only for limited number of channels (to avoid increase of dead time)
  - We tried this solution for FM119 with the help of our colleagues working in Italy – it works, but takes a lot of time (especially for full LAT)
- Natural solution – use 10 Hz periodic trigger events, included in flight trigger setup with multiple trigger engines
  - 5 runs (15 minutes each) have just been collected on Feb, 22
  - Because of some software bug (non-zero event markers) all events except periodic trigger were discarded from Ntuples
    - So I got a clean sample
      - 45K periodic triggers
      - 4 range readout
      - no zero suppression
      - no extra dead time

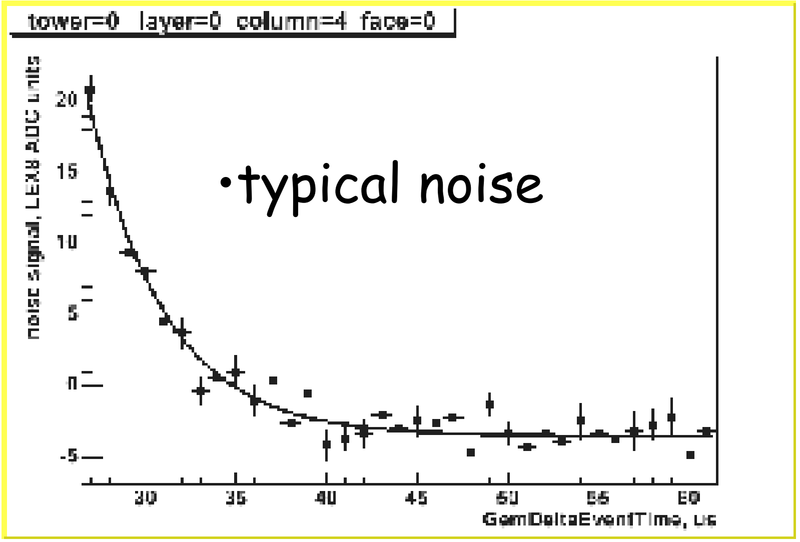
Calibration procedure

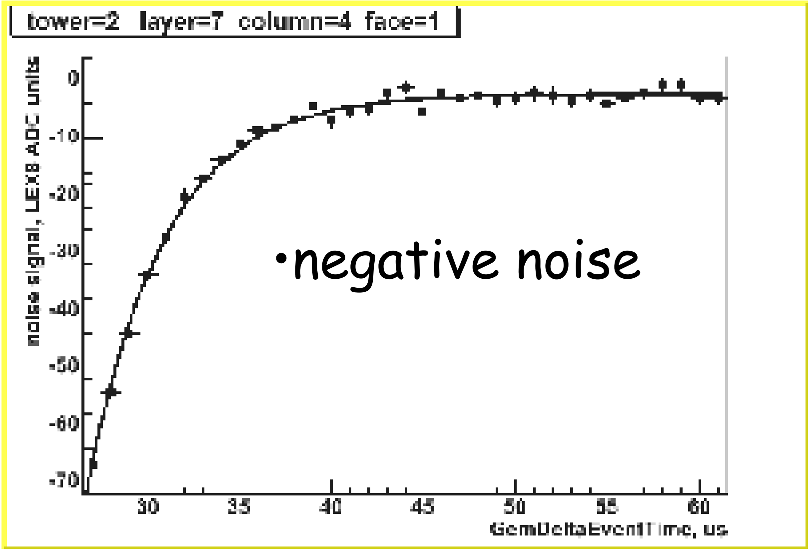
- Select events with GemConditionsWord == 32
- For each channel plot profile histogram: CalXtalAdcPed [twr][lyr][col][face]:GemDeltaEventTime*0.05
- Fit it with following function for 26.5<dt<60:
  - Signal = ped+peak*exp(-(dt-tdead)/tshp), tshp = 4.2μs, tdead=26.5 μs
- Store two fit parameters:
  - Peak – noise value right after dead time (at dt=26.5μs)
  - Ped – noise value at dt=60μs (pedestal bias ?)

Examples of histograms

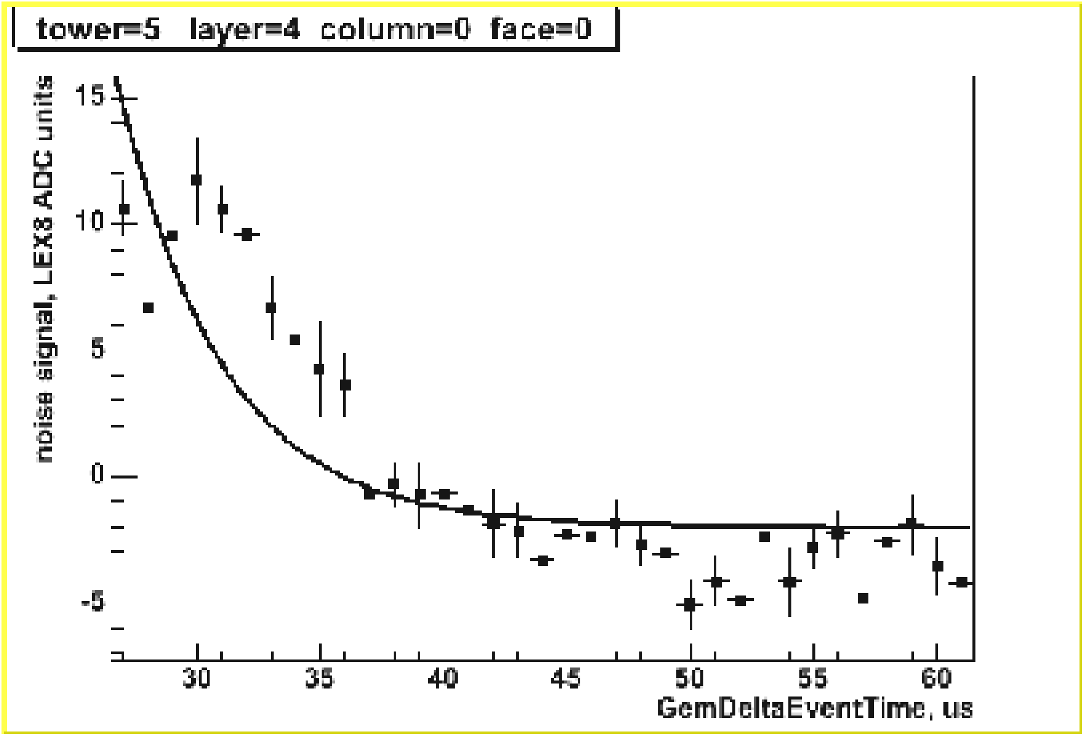






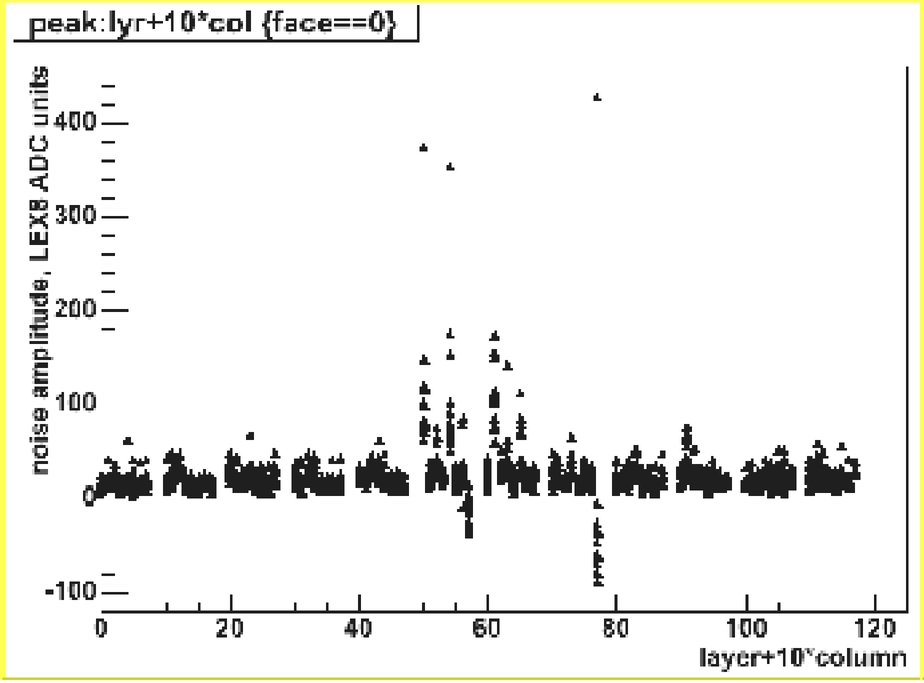


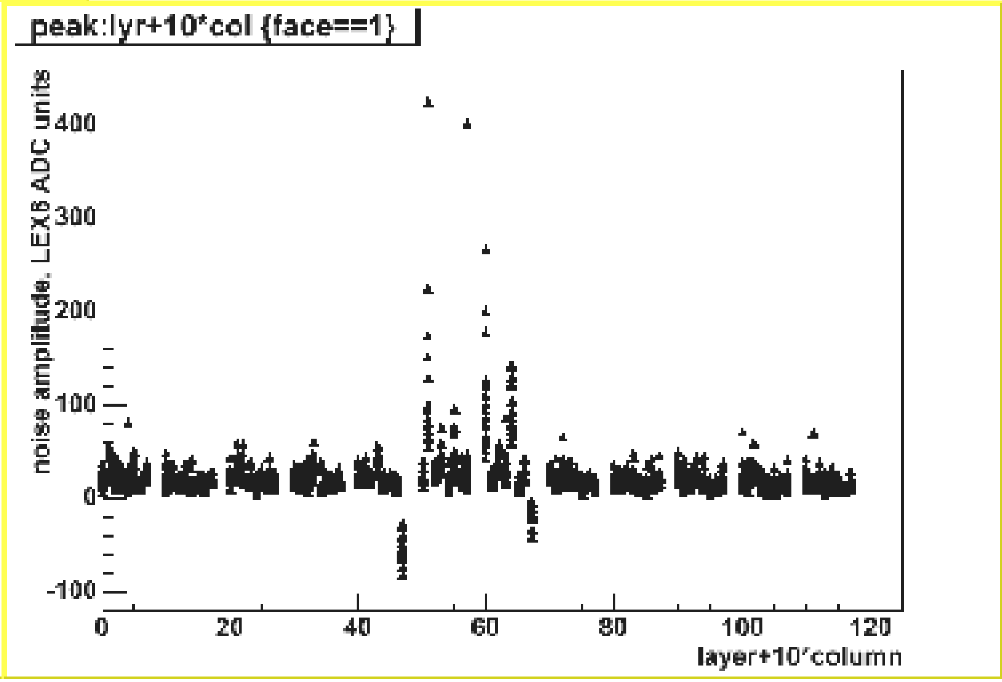
It is not always perfect …



- Some histograms have small (~5 adc units) but statistically significant deviations from exponential function:
  - Other sources of coherent noise ?

Noise amplitude vs column and layer (for all 16 towers)



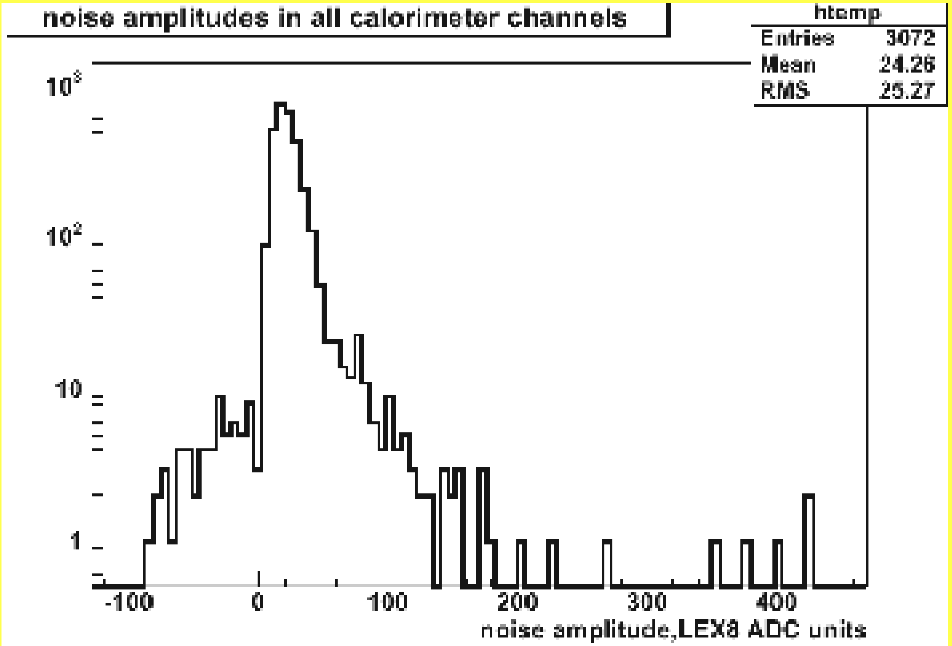


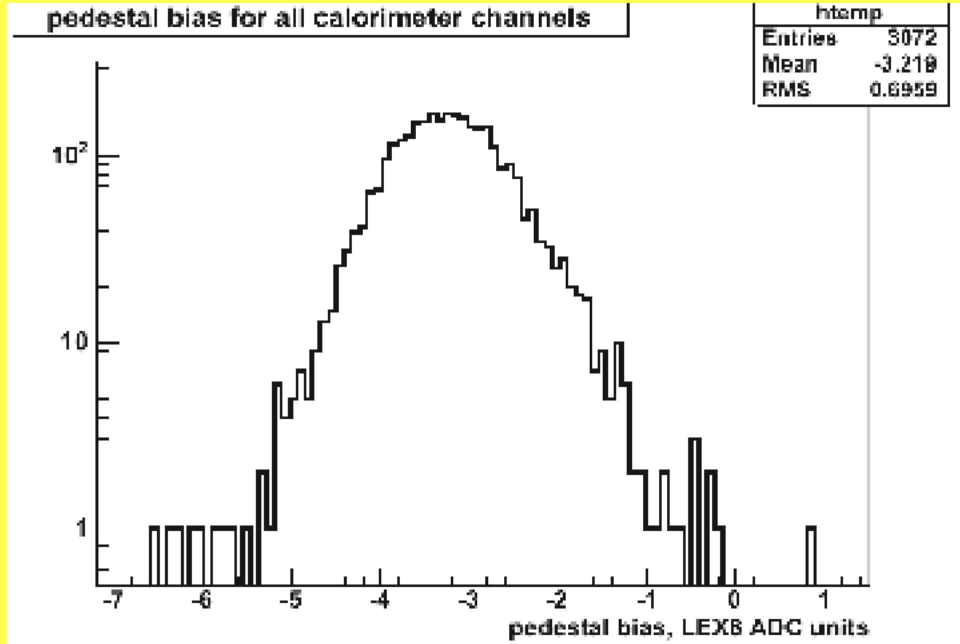
- Big positive noise amplitudes exist in columns 5, 6 and 7 (in certain layers)
- Negative amplitudes – in layer 7 only, in columns 5,7 for face=0 and columns 4,6 for face=1
- Big amplitude at one face usually corresponds to small amplitude at the opposite face of the same crystal
- Similar pattern for all towers

How to explain the pattern ?

- Column 5 (or 6) is the closest to digital data transmission line
  - This possibly could explain that the biggest noise signals are in these columns
    - Why it is layer dependent ?
- Another factor: data transmission from each row starts from columns 0 and 11 and ends on columns 5 and 6
  - Columns 5 and 6 are the last ones accessed before the next trigger
- May be TEM experts could look at readout noise pattern on previous slide and recognize some features (time sequence) of AFEE access by TEM ?

Histograms of noise fit parameters for all channels



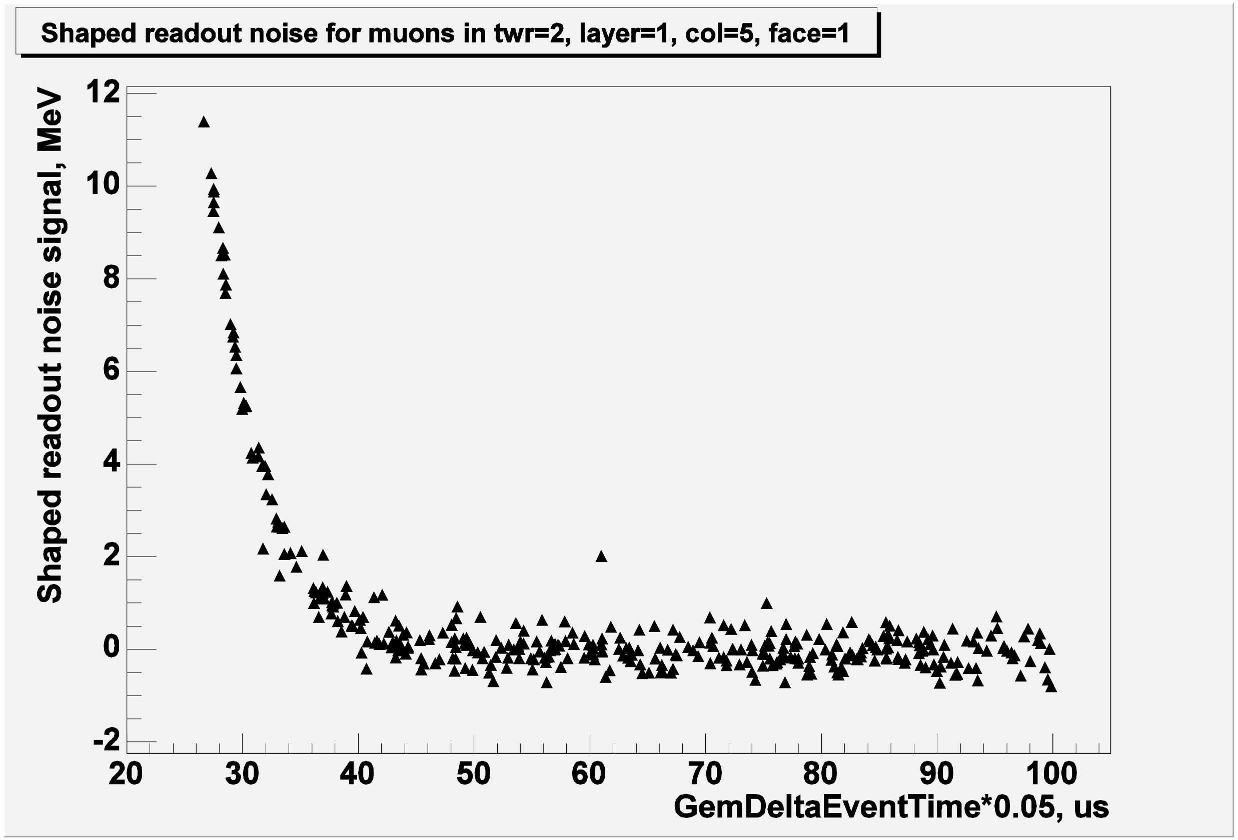


- Mean value of noise amplitude in all calorimeter channels is 24 adc units = 0.8 MeV
- There is small pedestal bias ~ 3adc units relative to B13 run used for LAT calibration.

Effect on position measurement

- Readout noise is often rather different at opposite faces of the same crystal
  - Could significantly affect the longitudinal position measurement even for modest noise amplitude
  - This effect could be measured for muons by comparing longitudinal position measurement from CAL with coordinate extrapolated from tracker and plotting the difference as a function of GemDeltaEventTime
  - I've done the inverse exercise:
    - Considered that difference in position measurement is produced by the noise signal at one end of crystal
    - Calculated this noise signal and plotted it as a function of GemDeltaEventTime

Shaped readout noise for muons calculated from position measurement



- This is an alternative way to calibrate shaped readout noise (only determine the difference between two crystal ends)

Shaped readout noise: conclusions

- The systematic effect has been calibrated using periodic trigger events from new trigger setup with multiple trigger engines (LAT701)
- Next step – use this calibration to correct the effect during reconstruction.

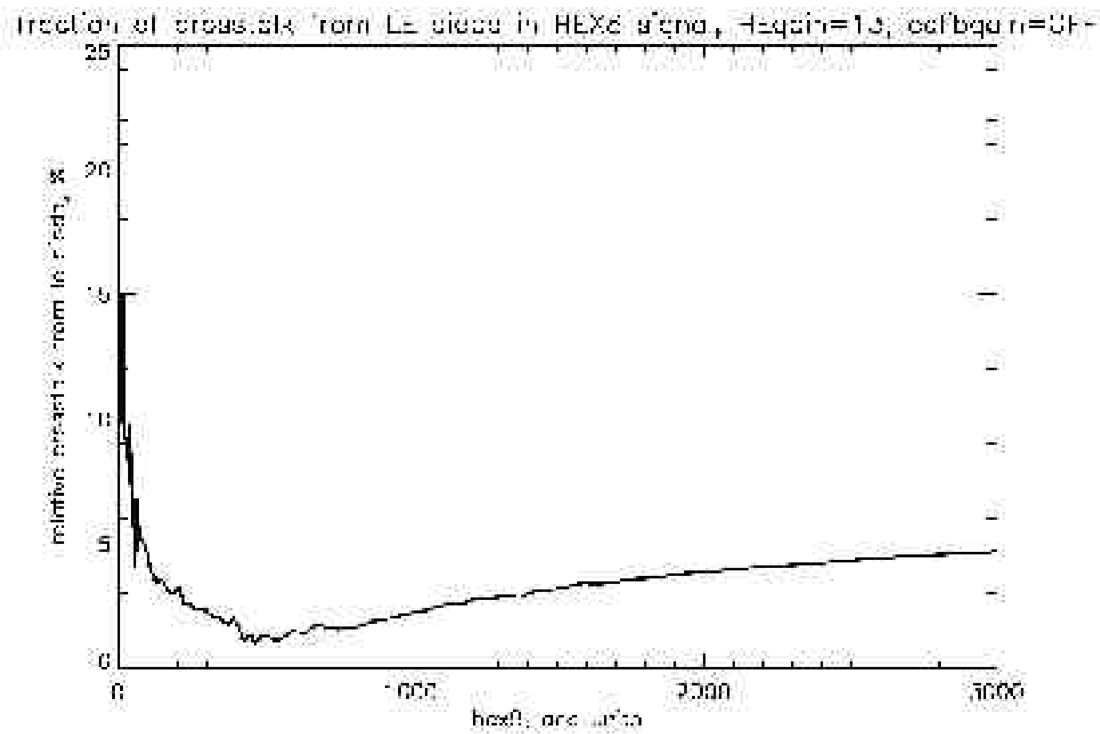
Crosstalk from Low Energy diode to High Energy diode

- we measure the crosstalk between channels of the same crystal end in standard charge injection calibration procedure (calibGen script):
  - We pulse only LE diode and measure output signals in both LE and HE channels – so, we can measure the crosstalk
  - The measured crosstalk value was always ~0.1% and considered insignificant
  - This statement is true only for LE/HE signal ratio ~1 (standard charge injection setup). But for scintillation signals LE/HE ~50, so 0.1% crosstalk from LE diode to HE diode becomes 5% of HE signal and should be taken into account.
  - for scintillation signals HE diode is used when LE diode channel is strongly saturated – we need to measure LE to HE crosstalk in this regime

How can we measure LE to HE crosstalk in realistic conditions

- There is special control bit (CALIBGAIN ON/OFF) which can change the capacitors, used to inject charge in LE and HE diodes
  - CALIBGAIN=ON – standard regime
  - CALIBGAIN=OFF:
    - Low Energy capacitor increased by the factor of 10
    - High Energy capacitor decreased by the factor of 10
    - This gives the LE/HE signal ratio ~100, which is two times bigger than for real scintillations
- I tried to do LE to HE crosstalk measurement in this mode for FM119 and I got rather unexpected result.

Crosstalk measurement results for FM119



- Crosstalk ratio to main HEX8 signal vary between 1% and 12%
- difficult to explain the increase of crosstalk for HEX8>500, when LEX1 channel is saturated

LE to HE crosstalk: conclusions

- Effect is not negligible and should be taken into account
- calibGen should be modified to include the charge injection run with flight gains, CALIBGAIN=OFF and LE diode pulsed
- The generation of nonlinearity curves by calibGenCAL should take this crosstalk measurement into account
- The only way to verify this correction with real scintillations is to measure CAL nonlinearity in the energy range 0.4 – 8 GeV during CERN beam test
  - Proposal to be discussed