Event-by-event pulse pileup recovery for PWO readout with LAAPD

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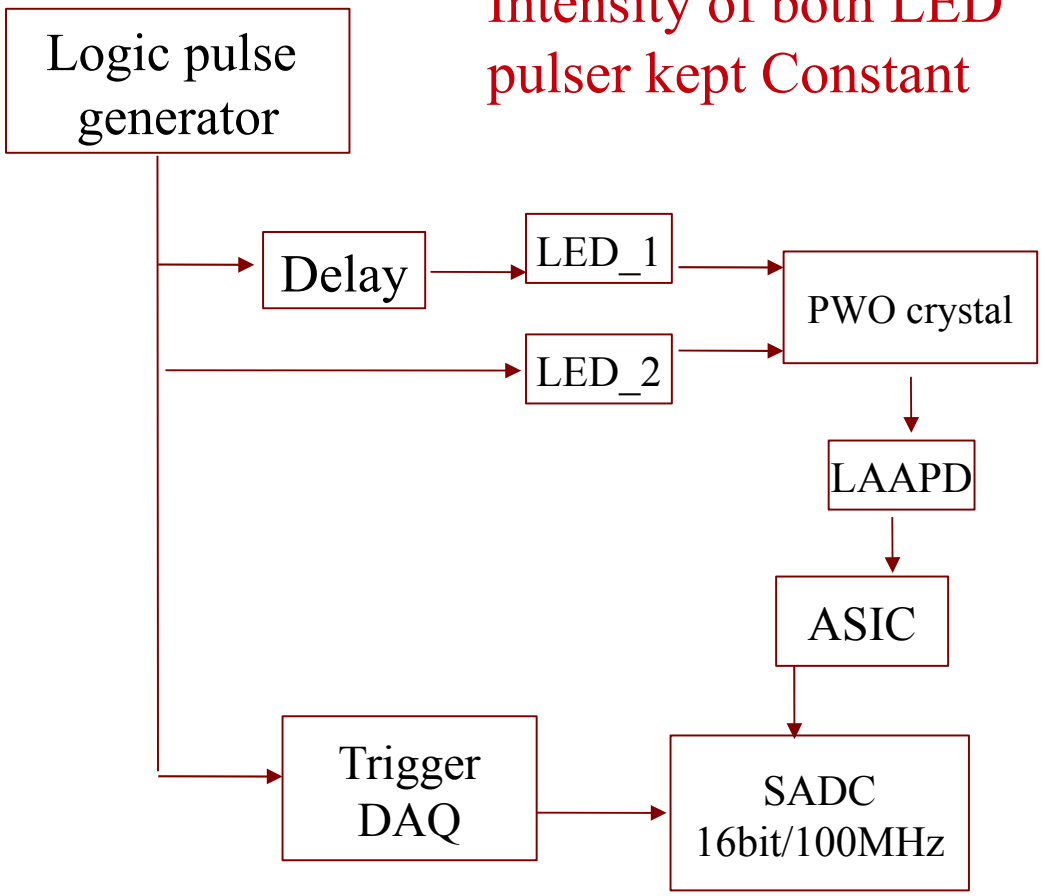
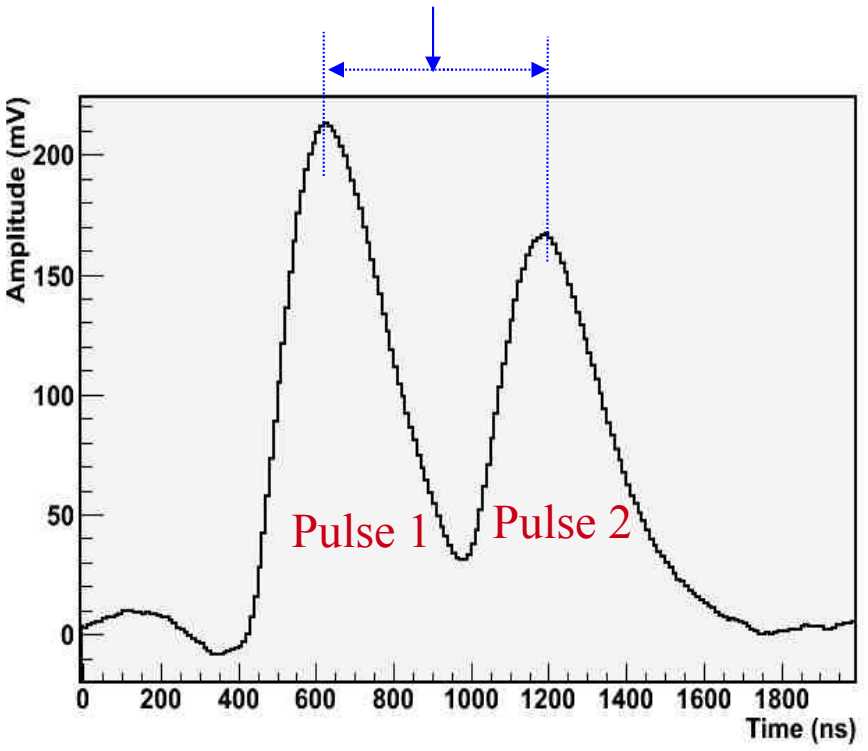
Pileup generation:

Intensity of both LED pulser kept Constant



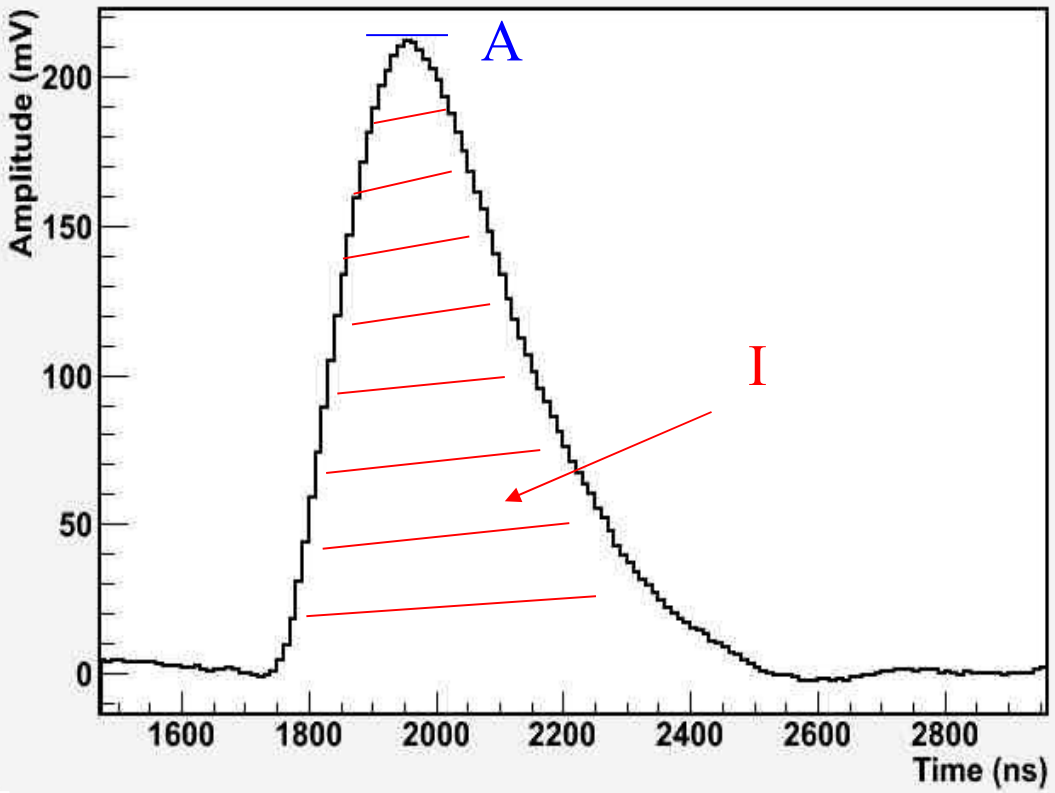
Varying delay time: Delta_t (ns)



Pileup trace for Delta_t of 560ns

Analysis for single pulse:

A – pulse amplitude & I – pulse integral

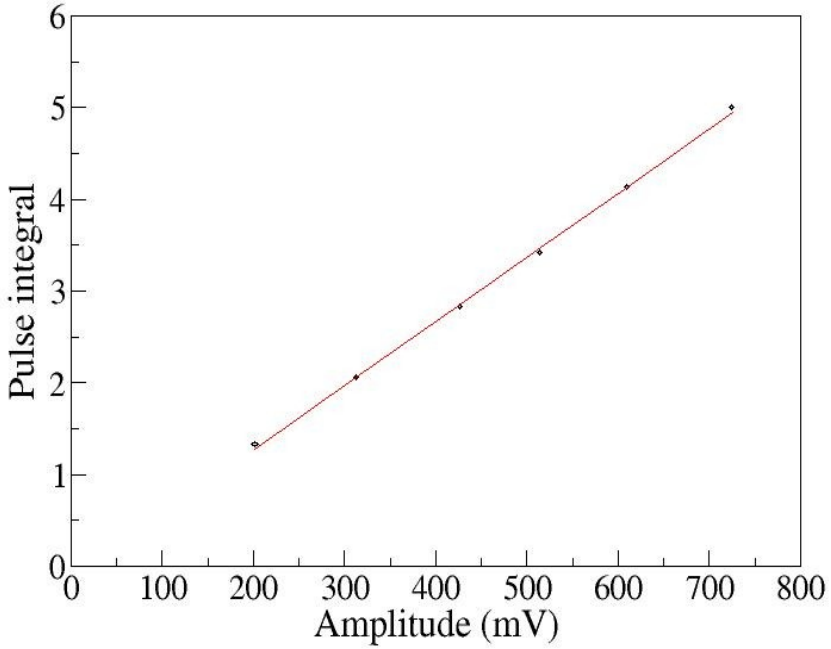


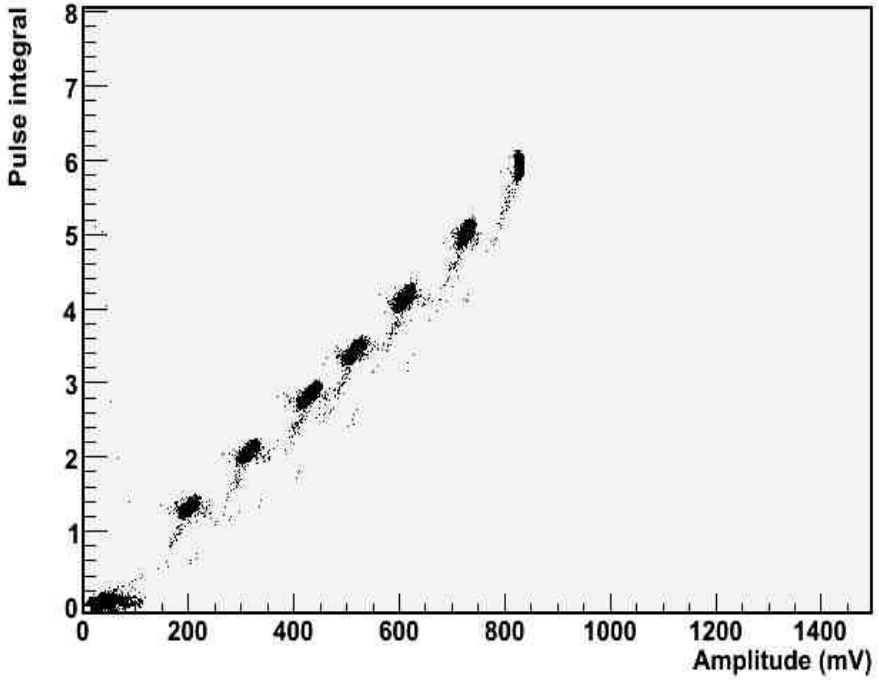
Trace: single pulse

* The relation between pulse amplitude & pulse integral is expected to be linear.
* The relation will not be linear if,
  (i) Pulse shape is changing or
  (ii) There is pulse pileup
* The ratio of amplitude and pulse integral has to be constant.

Analysis for single pulse:

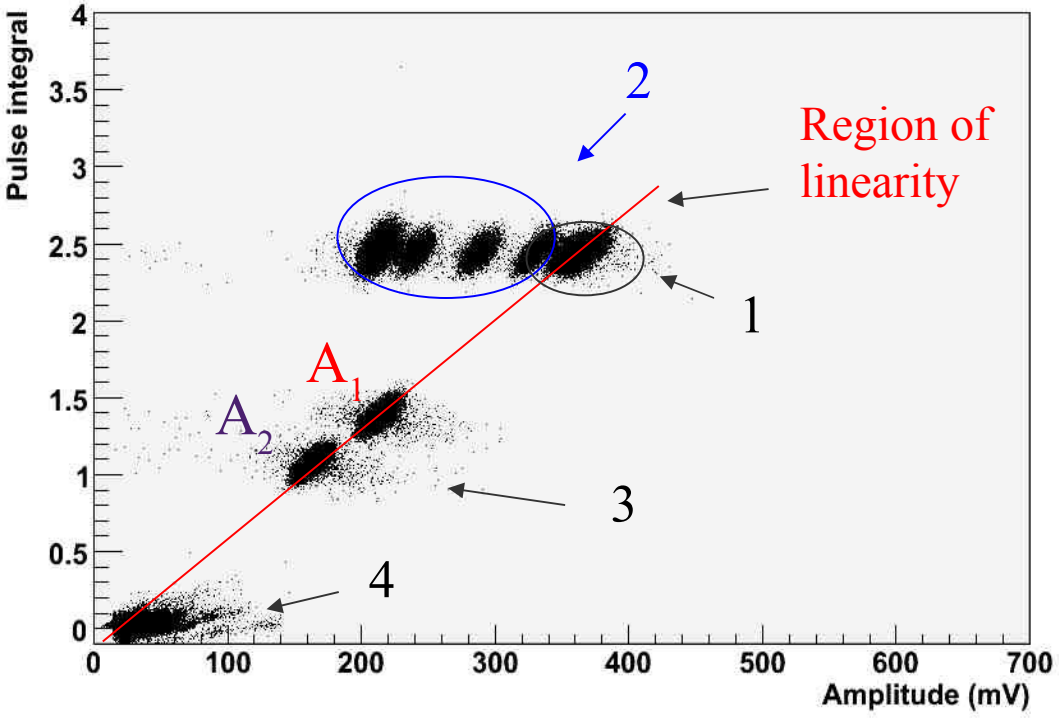
The relation is linear





Amplitude (mV) vs Pulse integral:

Pileup identification:



Amplitude(mV) vs Pulse integral

1. Delay time 41ns to 201ns:
both pulse amplitudes are summed and treated as a single pulse

2. Delay time 240ns to 560ns:
the second pulse amplitude is piled up on the first pulse. So with variation of delay time the blob position is changing.

3. Delay time 610ns to 1.2µs:
the pulses are well separated, amplitudes A_1 & A_2 are seen with their own integral.

4. Noise.

Analysis : Pileup

(1) Get the amplitude (A_1) of first pulse

(2) Take integration (I) of both pulses

(3) $A_2 = \{(I/k) - A_1\}$

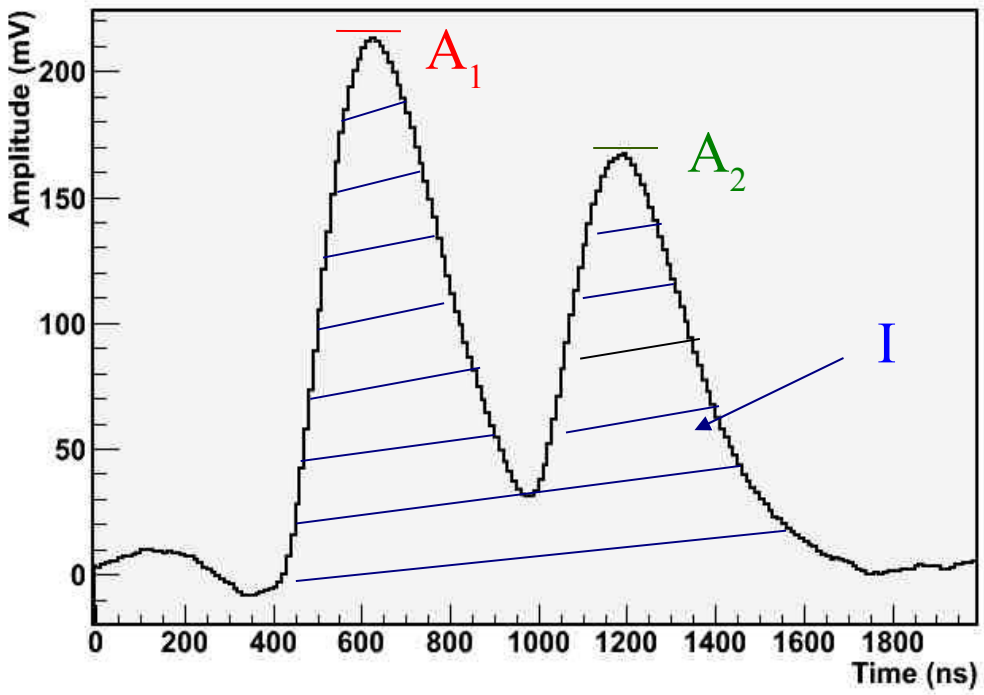
Where, I - integral

k- calibration constant

A_1- amplitude(pulse1)

A_2- amplitude(pulse2)

(4) A_1 & A_2 will be pileup-recovered amplitudes.



Pileup Trace:

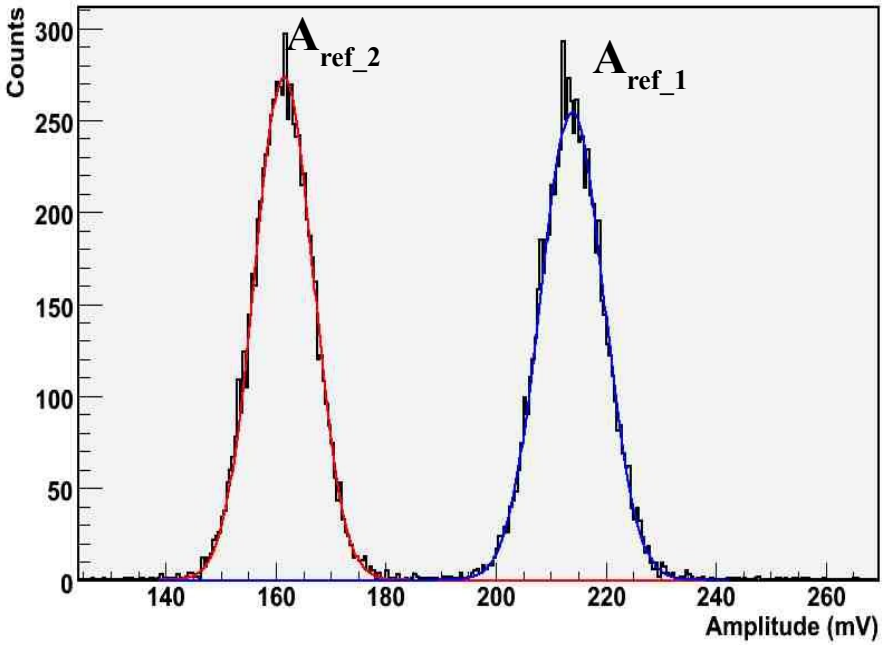
Analysis:

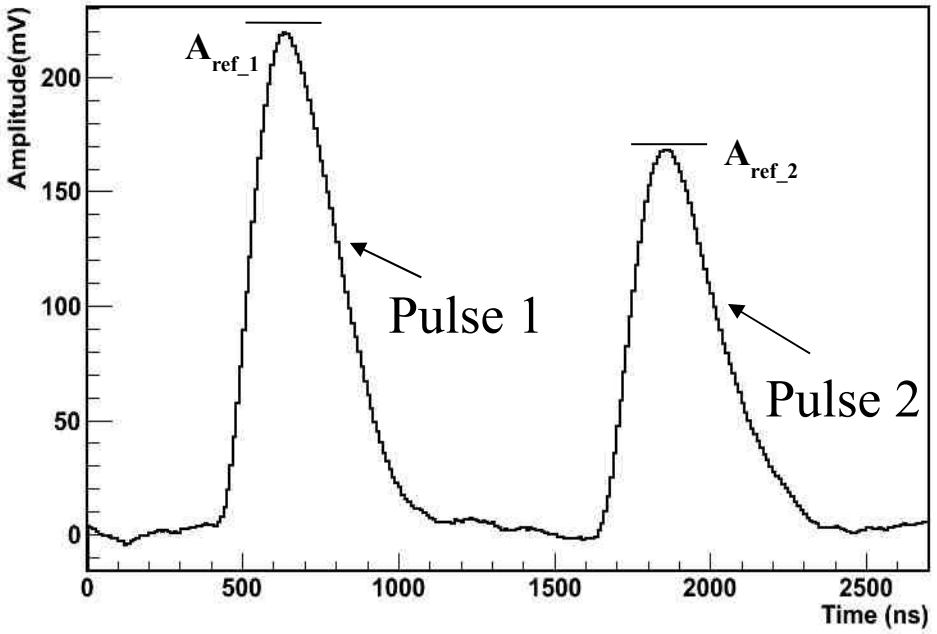
A_{ref_1}: Reference amplitude of pulse 1

A_{ref_2}: Reference amplitude of pulse 2

A_{ref_1} = 213 mV

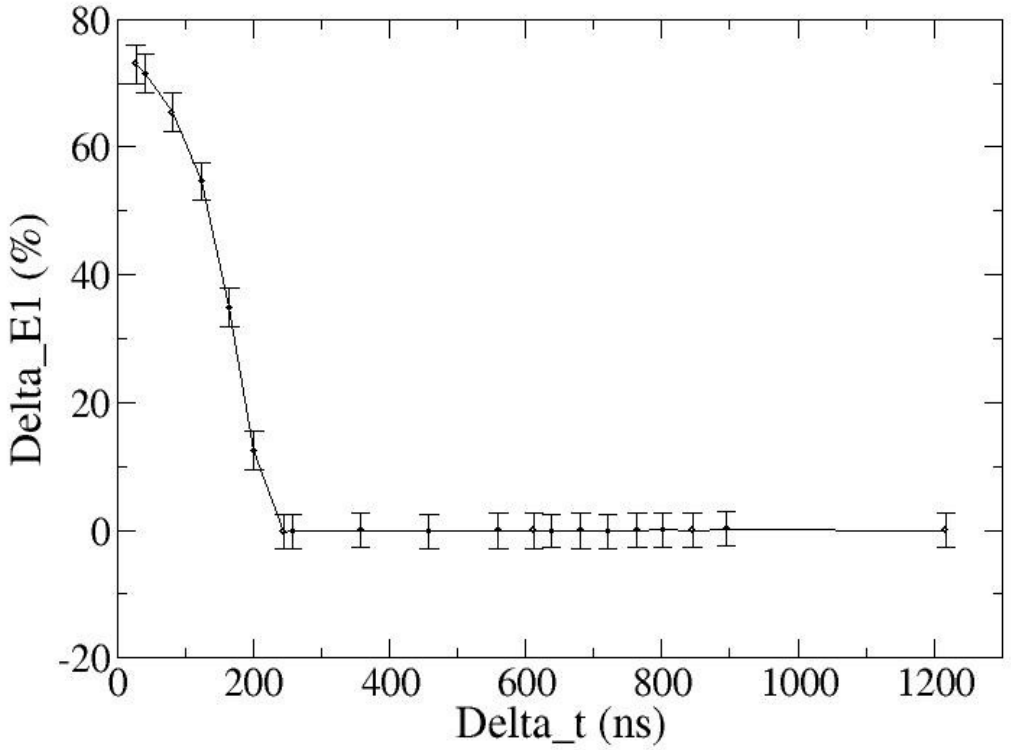
A_{ref_2} = 161 mV





Trace : 1.2µs delay time

Pileup recovery: pulse 1

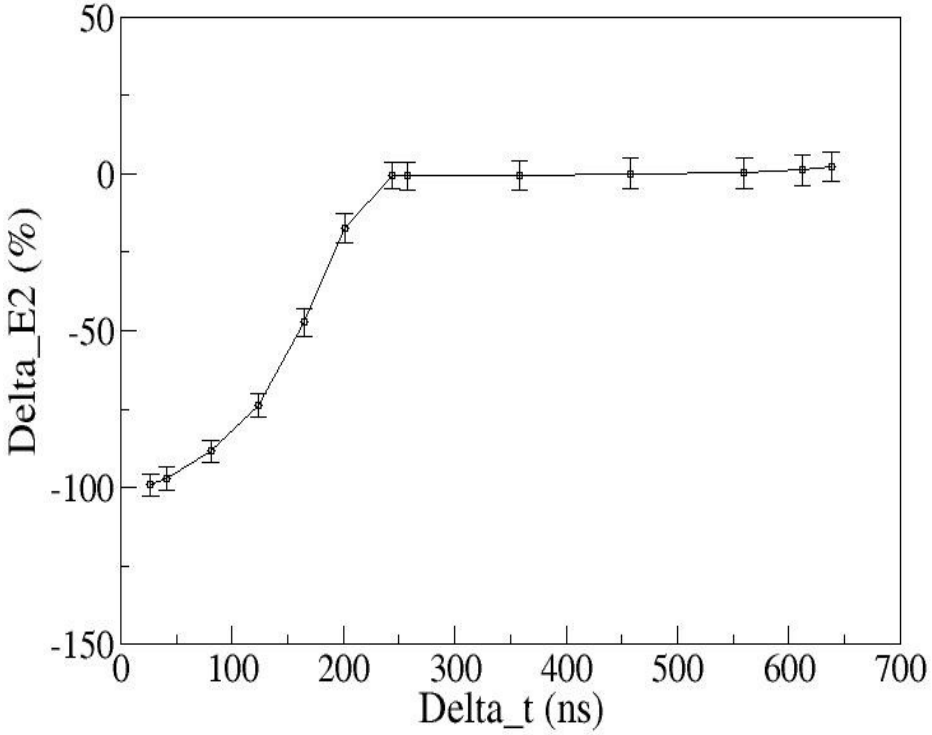


$$\text{Delta\_E1}(\%) = \{(A_1/A_{ref\_1}) - 1\}\text{x}100$$

Where, A_{ref_1}: reference amplitude
& A_1: amplitude of pulse 1

The pulse is not getting recovered below delay time of 240ns due to the rise time of ASIC

Pileup recovery: pulse 2



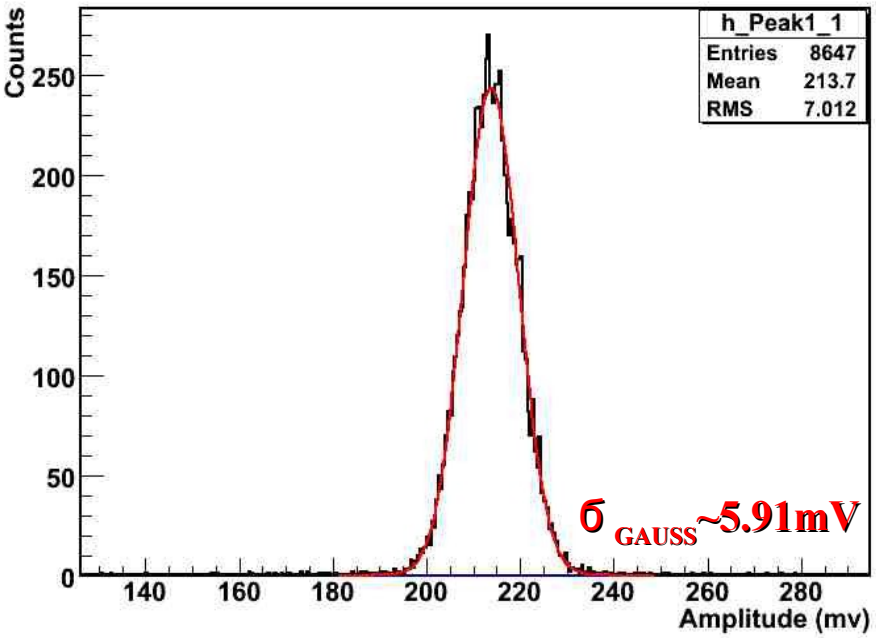
$$\text{Delta\_E2}(\%) = \{A_2/A_{ref\_2} - 1\}\text{x}100$$

Where, A_{ref_2}: reference amplitude &
A_2: amplitude of pulse 2

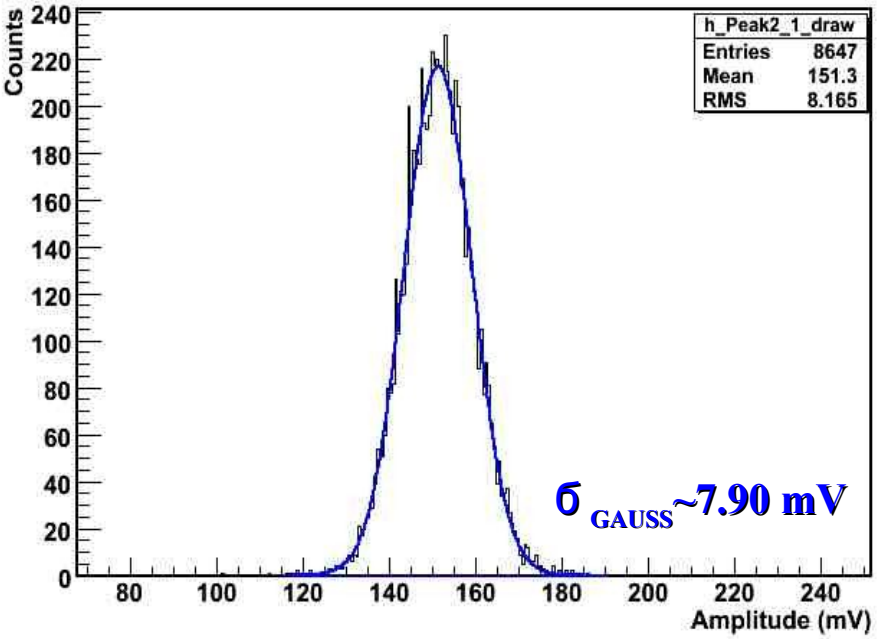
Since the pulses are well separated above delay time of 610ns, pulse 2 is treated as single pulse and its amplitude is found without pulse integration.

Energy resolution: 560ns delay time

Pulse 1 :



Pulse 2 :

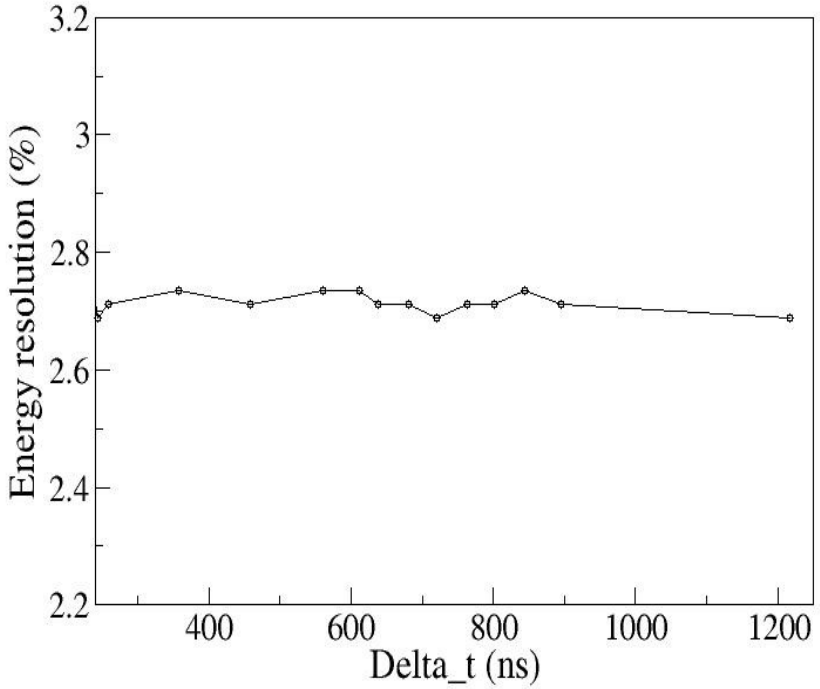


Energy resolution (%) = (σ/ A_{ref}) x 100

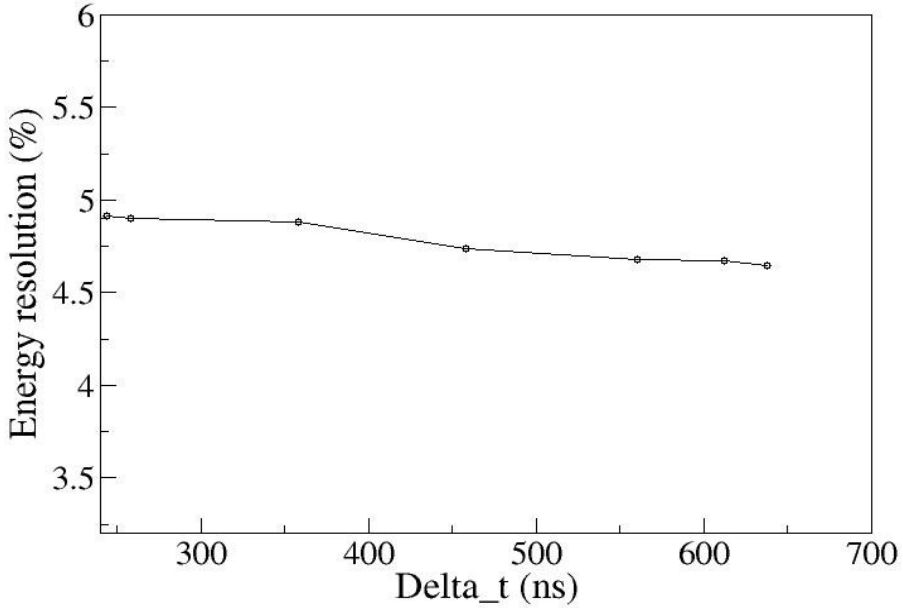
(pileup recovered) = 2.7 % (pulse 1) & 4.8 % (pulse 2)

Energy resolution: recovered pulses

Pulse 1



Pulse 2



Energy resolution (%) = (σ / A_{ref}) x 100

= 2.6 %

.....single clean pulse

Conclusion:

1. Pileup is recovered above delay time of ~ 240ns.
2. The rise time of ASIC is the reason for non recovery of pileup below 240ns.
3. At higher event rate, without recovery the probability of pileup is 6.1% .
4. The Panda TDR assumes for 100kHz event rate a pileup probability of 1%.
5. In the present analysis, the pileup probability remaining after recovery is reduced to 2.4 %