Pileup compensation in timestamped calorimetry

Progress report

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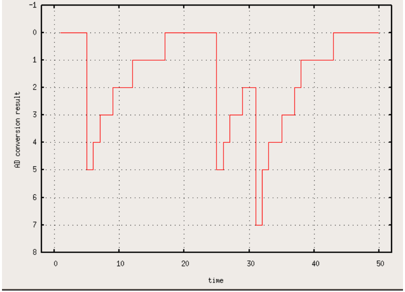
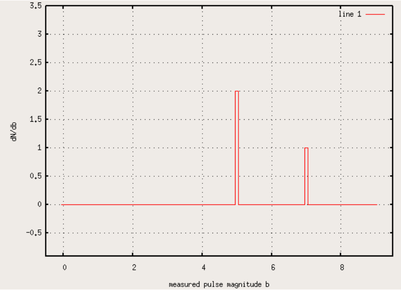
Pileup

Pileup affects measured pulse amplitudes.





Can pileup be compensated?

Assumptions

Assumption #1

Zero baseline

Otherwise:

- use optimal trigger, as in (Jungmann, Schakel, Vencelj, Wörtche, to be published)
- use digital filtering with zero-area FIR filter, that subtracts locally constant baseline

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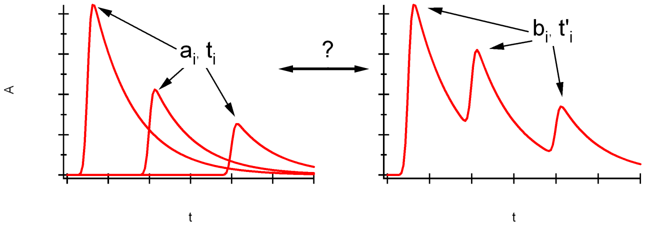
Assumption #2

Stable, fixed, known pulse shape

Idea

Pileup affects **amplitudes** and **timestamps** of extrema.
Distortion is deterministic.
Determined by the amplitudes and relative timestamps of the neighboring pulses.



From measured (b_i, t'_i), (b_{i+1}, t'_{i+1}), (b_{i+2}, t'_{i+2}) ...
can we get original (a_i, t_i), (a_{i+1}, t_{i+1}), (a_{i+2}, t_{i+2}) ...?

Pulse train description

$\mathcal{P}(t)$ is a pulse shape with maximum in $t = 0$, $\mathcal{P}(0) = 1$

$$S(t) = \sum_i a_i \, \mathcal{P}(t - t_i)$$

We measured a set of extrema at times t'_j with apparent amplitudes b_j

$$b_j = \sum_i a_i \, \mathcal{P}(t'_j - t_i)$$

Linearization

If we ignore distortion of timestamps: $t_j' = t_j$, we get

$$b_j = \sum_i a_i \, \mathcal{P}(t_j - t_i),$$

which represents linear relation

$$\mathbf{b} = M\,\mathbf{a}, \qquad m_{ij} = \mathcal{P}(t_j - t_i), m_{ii} = 1.$$

Matrix M:
- dominantly diagonal
- diagonal of 1
- off-diagonal elements vanish at long times ($M \to I$ as $\mathcal{P} \to 0$)

First neighbors approximation

First neighbours:

$$\mathbf{b} = M\mathbf{a}$$

$$M = \begin{pmatrix} 1 & p & 0 \\ r & 1 & q \\ 0 & s & 1 \end{pmatrix} \qquad (1)$$

p, r, q, s depend only on time differences (at given pulse shape)
They can be tabulated (look-up): r, q, pr, qs.

$$\mathbf{a} = M^{-1}\mathbf{b}$$

$$a(i) = \frac{b_i - r\, b_{i-1} - q\, b_{i+1}}{1 - pr - qs}$$

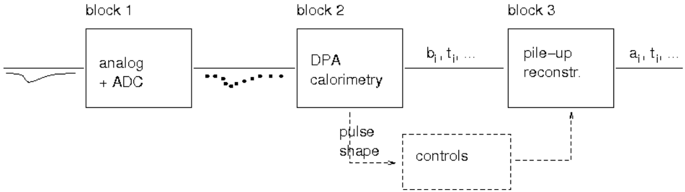
1 Basics

2 Idea

3 Implementation

4 Example

Architecture

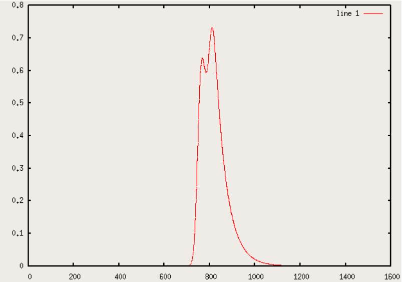


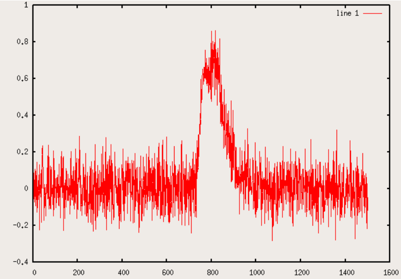
- within FEE
- outside FEE
- offline

Pileup sensing

Try to trigger on all the pulses. Pileup can be detected by comparing time differences with pulse width.

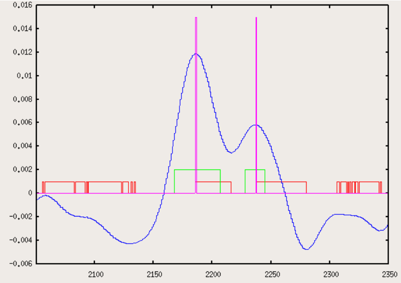
Our example: correlation of data stream with pulse shape + 2nd derivative





Pileup sensing

blue:	correlation with model + 2nd derivative
green:	blue higher than threshold
red:	blue changing slope from + to -
pink:	green is high and red triggers high



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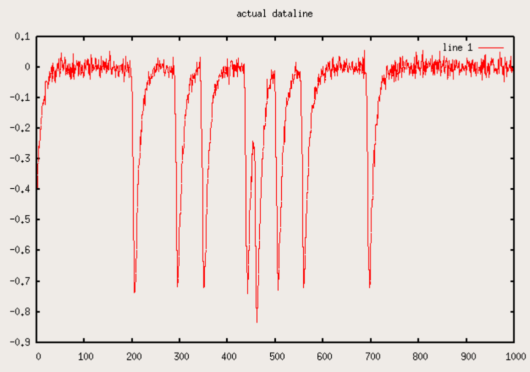
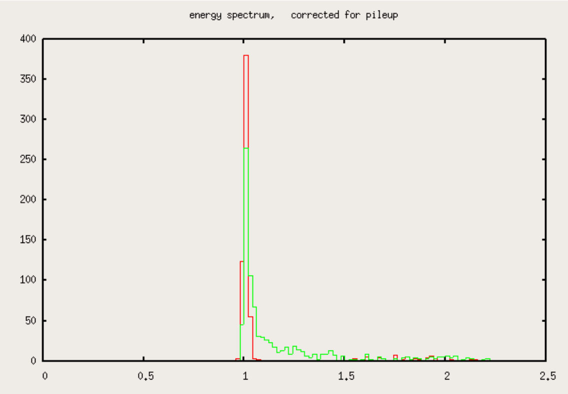
Offline example

Train of 1000 exponential pulses with amplitude 1, τ=10 adc points, stdev noise = 0.05 pulse heights, average time between pulses = 10 tau



Offline example

green: sliding box integration (10 points wide box)
red: pileup corrected spectrum



Real-time?

Preparations for real-time benchmarking on **Hades TRBv2** board:

I. Frohlich *et al.*
A General Purpose Trigger and Readout Board for HADES and FAIR-Experiments,
IEEE Transactions on Nuclear Science **55**, 59–66 (2008)

We aim to publish these results (NIM-A).

Thank you for your attention.

Suggestions & comments welcome.