Pulse reconstruction for ECAL-P
method from ZEUS BAC analysis (1992)

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My phd thesis

Method presented today was developed for the analysis of the ZEUS backing calorimeter (BAC) prototype beam test results and presented in my PhD thesis

Wyniki testów i symulacji kalorymetru uzupelniajacego dla detektora ZEUS

(*Test and simulation results of the ZEUS detector backing calorimeter*, supervised by Halina Abramowicz, University of Warsaw 1992).

Main results of the study were published in NIM A313 (1992) 126-134, but without BAC pulse reconstruction method details, which are only described in Appendix A of the thesis.

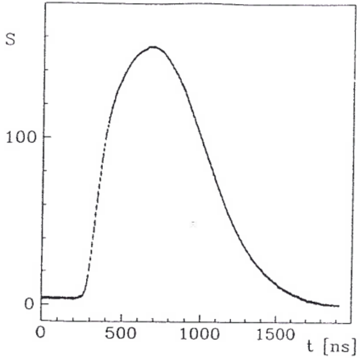
Presentation today is mainly based on this appendix.

BAC signals

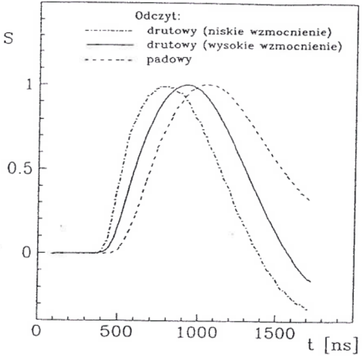
pulses are probed by FADC with 96 ns clock

Average puls shape after pre-amplifier and shaper electronics:

Lab test results:



Beam tests (different readout streams):



Pulse scaling

The output pulse has a fixed shape with amplitude proportional to the input charge, which we want to reconstruct. The FADC measurements should be described by the dependence:

$$a_i = A \cdot f(t_i) + f_r ,$$

where
- i - numbers FADC measurents
- t_i - is measurement time
- a_i - is the amplitude measured at t_i,
- f(t) - describes the normalized average pulse shape (shape template),
- f_r - is the reference (pedestal) level, including electronics and noise,
- A - is the amplitude we are looking for.

Pulse model

The next step is to present the template amplitude for each measurement by its value at nominal measurement time and correction depending on time shift:

$$f(t_i) \;=\; f_i \,+\, f_i' \cdot \delta t \;,$$

where f_i - is the template signal value at time i*96 ns,

f_i' - is the template shape derivative value at the same time,

δt - is the time shift between the actual pulse and the template.
The key assumption here is that this shift is small: $|\delta t| \;\leq\; 48$ ns.

We can then rewrite the initial formula as:

$$a_i \;=\; A \cdot \left(f_i \,+\, f_i' \cdot \delta t \right) \,+\, f_r \;.$$

Problem solution

We have vector of measurements $\mathrm{a_i}$ described by

$$\mathrm{a_i} \;=\; \mathrm{A} \cdot \left(\mathrm{f_i} \;+\; \mathrm{f'_i} \cdot \delta\mathrm{t}\right) \;+\; \mathrm{f_r} \;.$$

Finding amplitude A and time shift $\delta\mathrm{t}$ is an algebraic problem, looking for coordinates of vector $\mathrm{a_i}$ in the base of vectors $\mathrm{f_i}$ and $\mathrm{f'_i}$. The solution is equivalent to the least-square fit result.

Problem solution

We have vector of measurements a_i described by

$$a_i \; = \; A \cdot \left(f_i \, + \, f_i' \cdot \delta t\right) \, + \, f_r \, .$$

Finding amplitude A and time shift δt is an algebraic problem, looking for coordinates of vector a_i in the base of vectors f_i and f_i'. The solution is equivalent to the least-square fit result.

Solution is:

$$\delta t \; = \; \frac{\beta C_1 \, - \, C_2}{\alpha C_2 \, - \, C_1} \, ,$$

$$A \; = \; \frac{C_1}{1 \, + \, \alpha \, \delta t} \, ,$$

with:

$$C_1 \; = \; \sum_i a_i g_i$$

$$C_2 \; = \; \sum_i a_i g_i'$$

$$\alpha \; = \; \sum_i f_i' g_i$$

$$\beta \; = \; \sum_i f_i g_i'$$

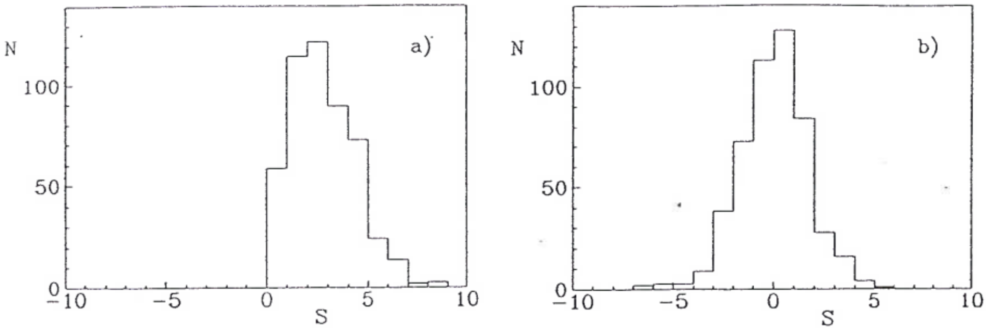
where g_i and g_i' are scaled template shape and derivative vectors:

$$\sum_i g_i \; = \; \sum_i g_i' \; = \; 0$$

$$\sum_i g_i \cdot f_i \; = \; \sum_i g_i' \cdot f_i' \; = \; 1$$

Results

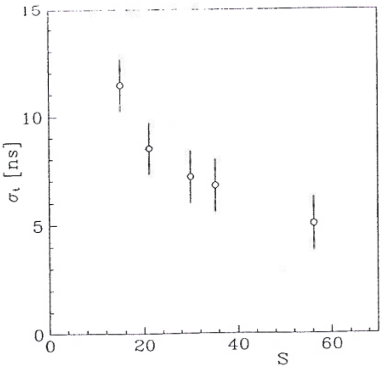
Pad tower signal distribution for old method (maximum finding) and new reconstruction:



Maximum finding gives bias, which is removed in the new method...

Results

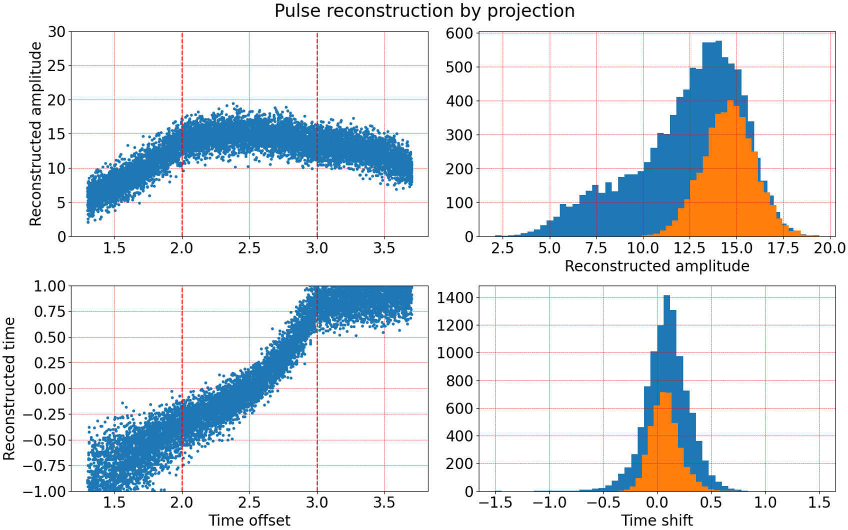
Time shift reconstruction precision as a function of the signal amplitude:



$\mathcal{O}(10\%)$ time shift reconstruction possible (96 ns FADC clock)

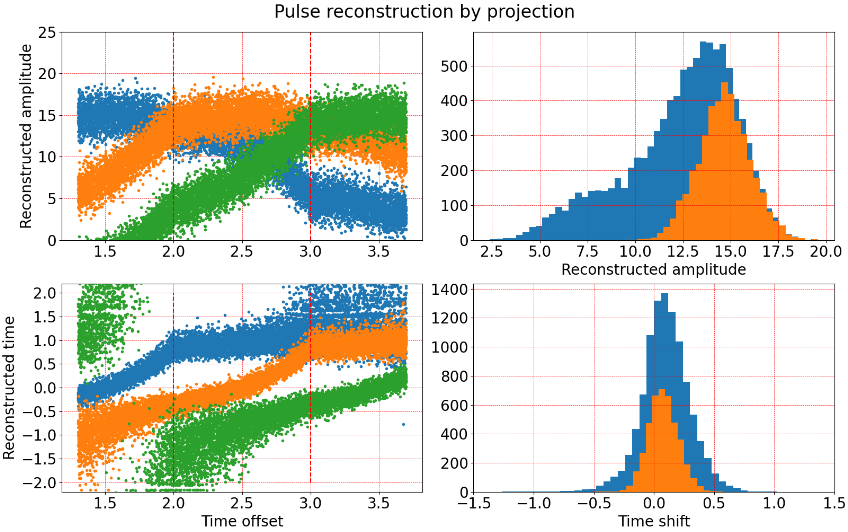
Modeling based on the expected ECAL-P pulse shape

A=15, Noise=1.3



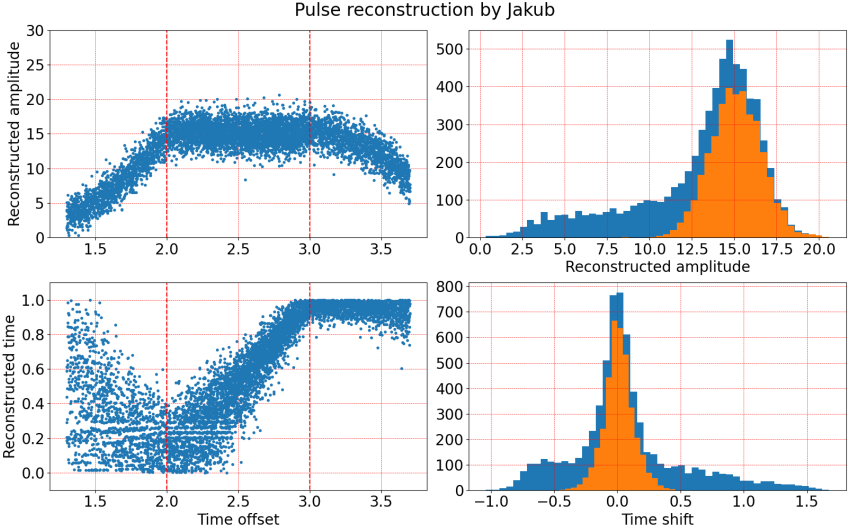
Modeling based on the expected ECAL-P pulse shape

A=15, Noise=1.3



Results from standard deconvolution method

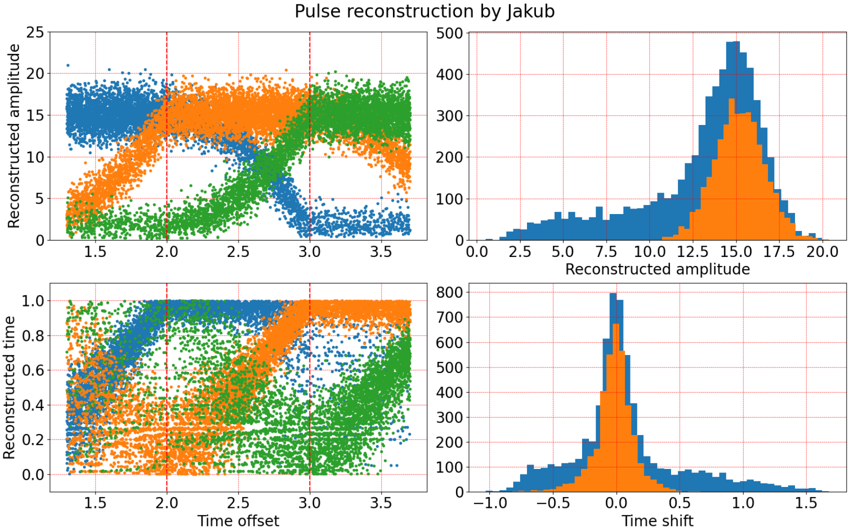
A=15, Noise=1.3



Application to ECAL-P

Results from standard deconvolution method

A=15, Noise=1.3



First comparison

"accepted" - higher than earlier and later

For amplitude A=15, Noise = 1.3

Template fit method (6 samples, reference pulse starting at 2.5)

Average reconstructed amplitude: 12.379 +/- 2.882
Average reconstructed time shift: 0.095 +/- 0.202
Average accepted amplitude: 14.629 +/- 1.343
Average accepted time shift: 0.079 +/- 0.125

Jakub's method (with perfect common mode subtraction !)

Average deconvoluted amplitude: 13.097 +/- 3.647
Average deconvoluted time shift: 0.065 +/- 0.421
Average accepted amplitude: 15.177 +/- 1.446
Average accepted amplitude: -0.015 +/- 0.150