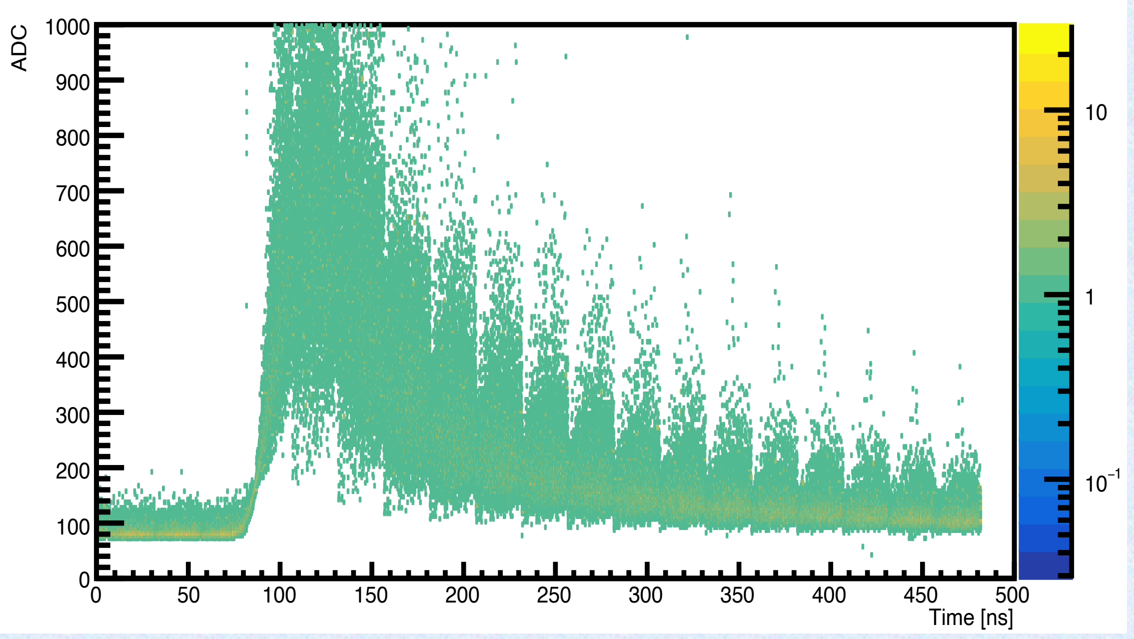
Calorimetry: Time Resolution Estimation

Olaiya Olokunboyo – University of New Hampshire
Supervisor: Nathaly Santiesteban; Norbert Novitzky - OAK

The Waveform



The event signals technically arrive in batches/packets every 25 ns .

A single-phase waveform with events saved as [asics][channel][sample], where we have 2 possible asics, 72 possible channels and 20 possible samples recorded.

Time Resolution

This is one of the critical performance parameters for the detector determination of the time for events reconstruction/recognition. - design -event reconstruction, -final physics results.

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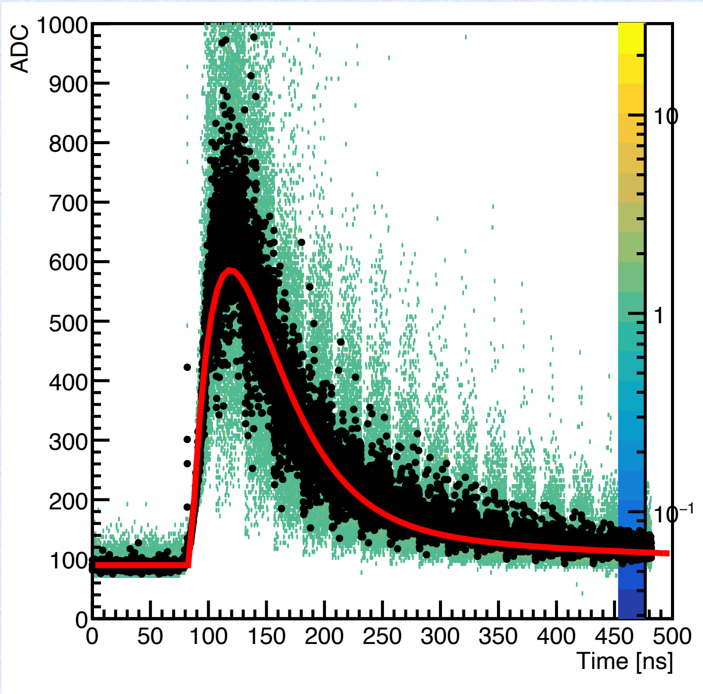
- Background/noise suppression
- TOF particle identification
- Energy and position reconstruction
- Trigger Performance – precise timing

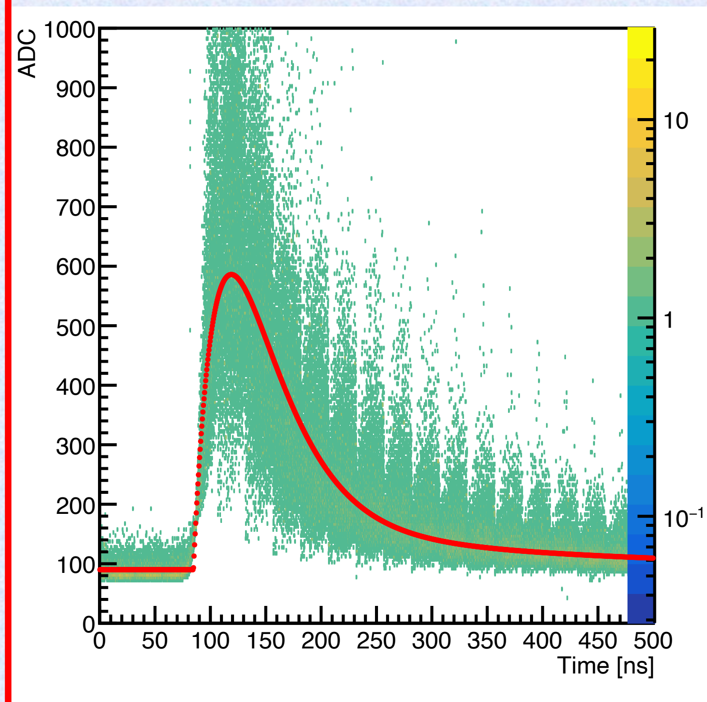
What Function Explains the Waveform?



Plot average of the signals (data – fit) vs time.
Fit the average:

$$y = B_0 + A_0\left(e^{-\Delta/\tau_1} + \alpha e^{-\Delta/\tau_2} - (1+\alpha)e^{-\Delta/\tau_{rise}}\right)$$

Where $\Delta = \max(0, t - t_0)$
B_0= Baseline
A_0 = Amplitude
t_0 = pulse start/time offset
τ_1 = fast decay, affecting slope just after the decay
τ_2 = slow decay/tail
τ_{rise} = rise-time, expressing how sharp/soft the leading edge is
α = relative weight of the second exponential



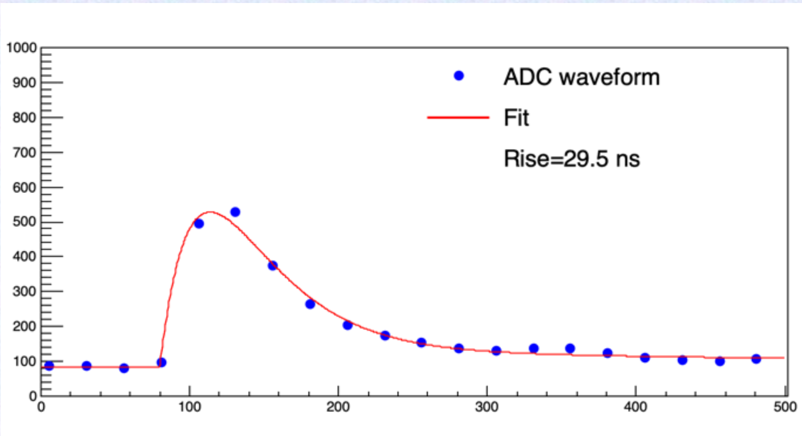
Fitting each Pulse

There are 7202 entries (signals) superimposed to form a single waveband, can we use the obtained expression with varying amplitude to obtain the signal waveform (starting point)?

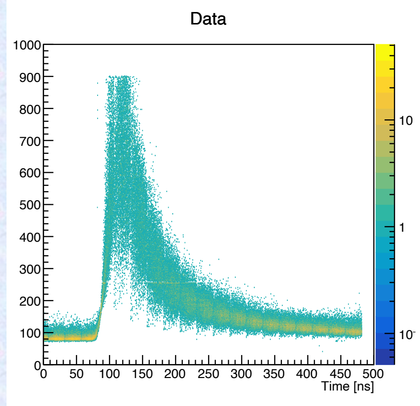
Lets fix some condition;

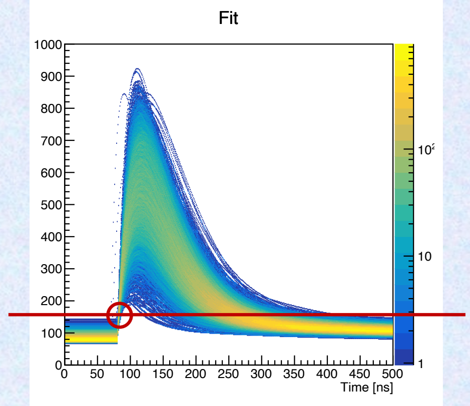
1. The ADC must not exceed 900
2. Time to rise takes value between 10 to 60 ns
3. Each event point are separated by 25 ns

These conditions further reduces the number separate fits to 7037.



Recovering the Total Pulse from Formular

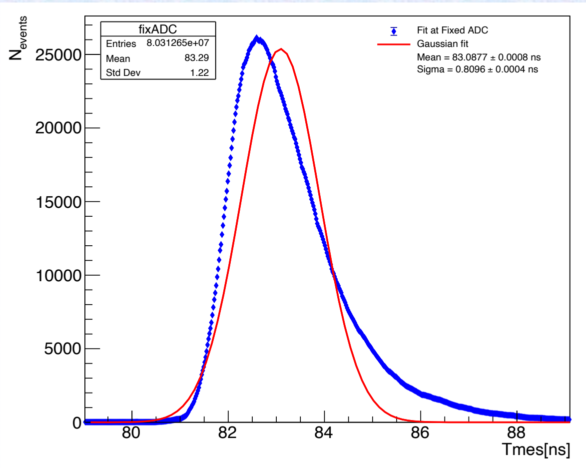


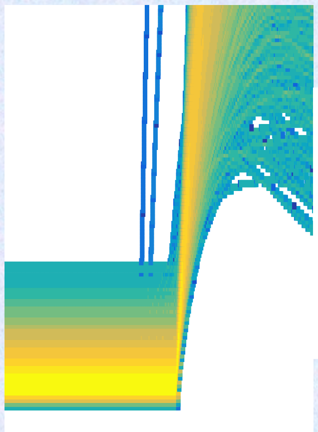


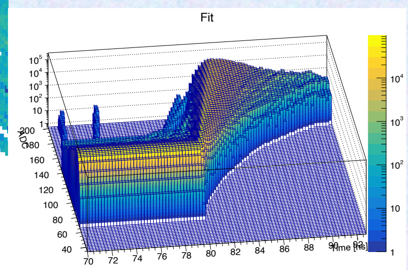
The goal is for the right-hand shape to reproduce the key features of the left-hand distribution: same rise time, peak position, amplitude, and decay constant. The fit is in step of 1 ns.

Why the long tail on the right?

$160 \leq ADC < 190$



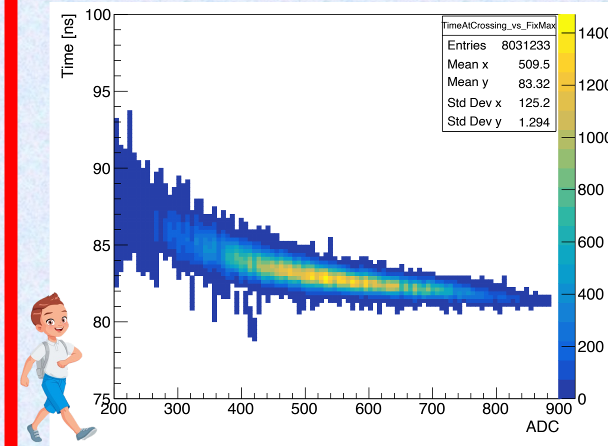




It is interesting to see the long tail and this suggests the following;

1. Time-walk / amplitude dependence; the measured time shifts with pulse amplitude. If the ADC slice is not infinitesimally narrow we mix slightly different amplitudes and therefore slightly different times leading to asymmetric shape and tail.
2. Pile-up / baseline recovery: overlapping pulses can produce extended right tails.
3. Two physical populations: that is direct pulses vs reflected/pile-up pulses or two detector channels merged into one histogram; can create a real double peak.

Sure Evidence of Time-Walk



Time-walk is simply a classic effect observable detector electronics and timing reconstruction when using a fixed threshold discriminator.

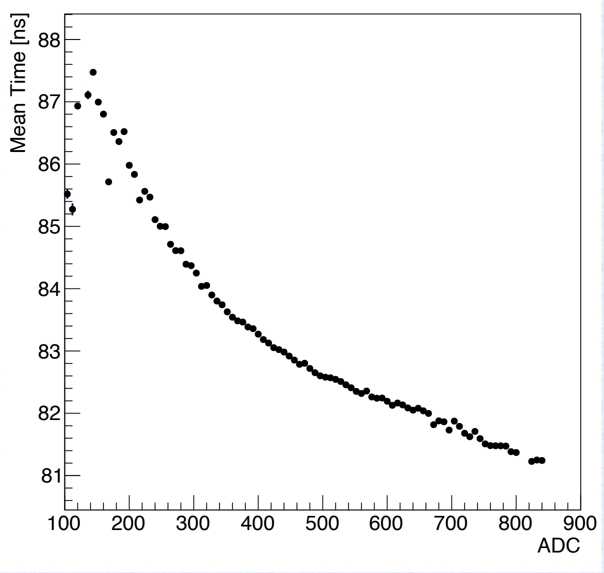
So:

i. A large pulse reaches the threshold earlier

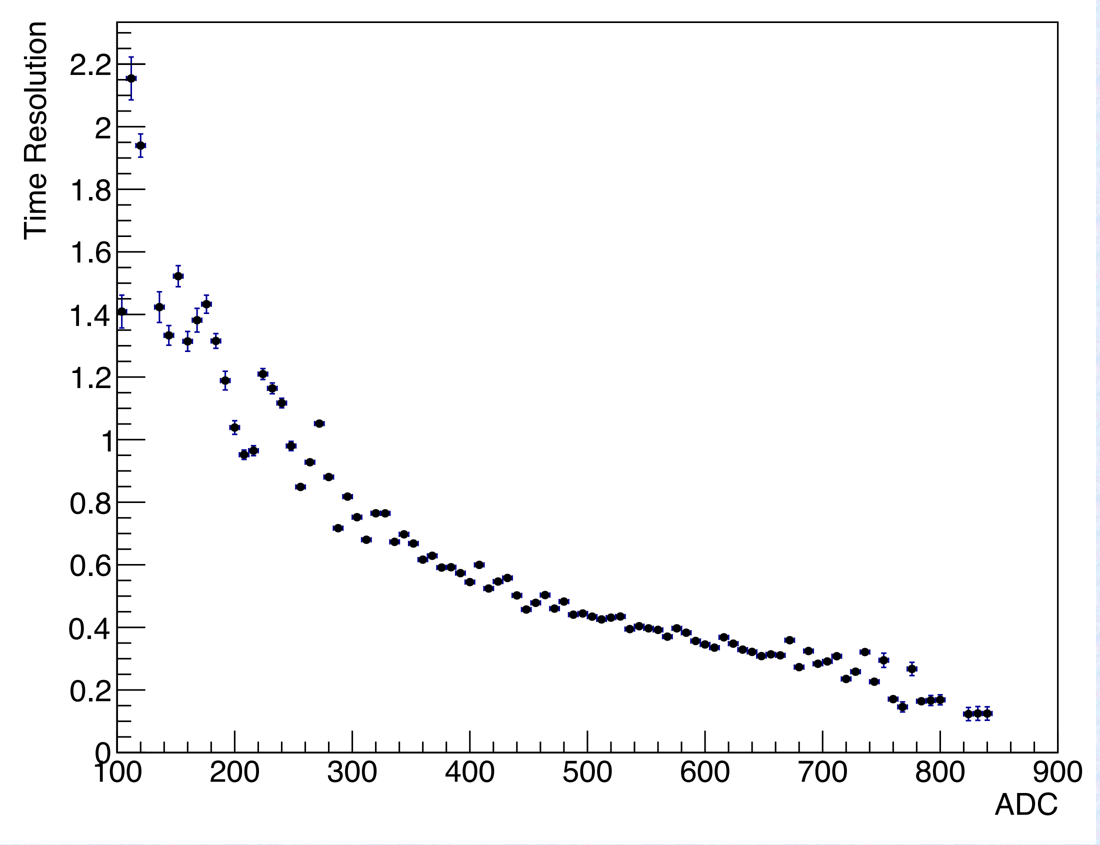
ii. A small pulse reaches the threshold later

Even though both pulses have started at the same true physical time, the measured time different due to pulse amplitude is called time-walk.

Mean Time and Resolution



This is the event-by-event timing uncertainty of the reconstructed time at threshold crossing.



How well can we determine the arrival time of signals?
How well can electronic noise be suppressed?
Timing reliability?

Relevance in BHCal?