Daphne optical waveform digitizer simulation for FD1

FD sim/reco meeting

Maritza Delgado

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Overview

PD Simulation in LArSoft:

- We can simulate and examine the photon signals on photon detectors in a physics events,
- Examine raw data,
- Define the specifications of the electronics.

PD Simulation

- 3 Stages in LArSoft:

1. Light production Stage

- 25000 ph/MeV in LAR->Geant4 Simulations.
- Semi-analytical model to get the number of photons reaching the photondetectors.

PD Simulation

2. **Digitalization stage**

The PDS is responsible for the Light Collection, which has three main elements:

-Light collection System: Arapucas
-Light detection: Silicon Multiplier (SiPMs)
-Readout electronics: Cold Amplifier-Warm Readout Electronic (DAPHNE)

- Electronic response: Waveforms are produced on each channel for each true Photon from single photoelectron (SPE) signal.

-We considering dark noise, crosstalk and afterpulsing

PD Simulation

- Stages in LArSoft

3. **Reconstruction stage**

Hit and flash finding**.**

• Hit finding-> identifying the time and the total amount of light.
• Flash finding-> searches for coincident hits across multiple channels.
(source of scintillation light at a particular place and time in the detector, such as an electron).

Introduction

- The photon detector waveforms shows a undershoot due to the SiPMs, electronics and cold-to-warm stage couplings.

Goals

- Implementing in digitizer module a SPE shape closer to the experimental results and deconvolution in hit finding.

The fhicl have a switch to choose between the ideal spe and the testbench spe.

```
SinglePEmodel    false       #false for ideal response,true for the testbench response.
```

•Update electronic response: The actual response of the cold amplifier coupled with DAPHNE

Introduction

•The DAPHNE parameters in Digitizer module with the DUNE FD-1 geometry (10kt-ProtoDUNE)

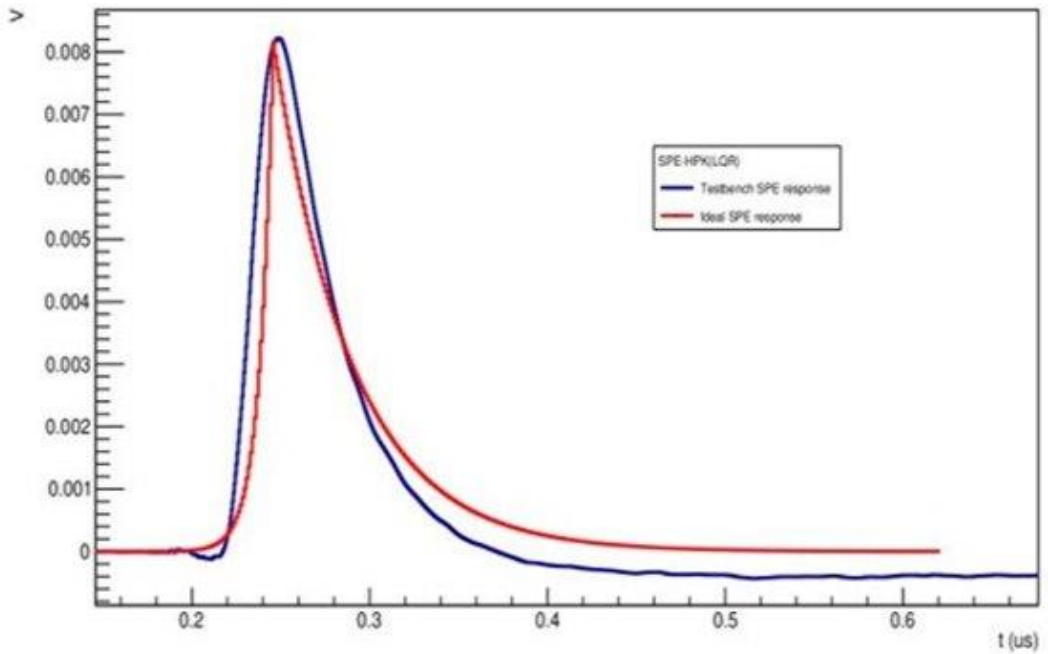
- There are 12 APA.
- 10 Photon Detectors (PD) modules per APA;
- 4 optical channels per PD;
- Total of 480 channels;

- Generate photon signals from a muons.

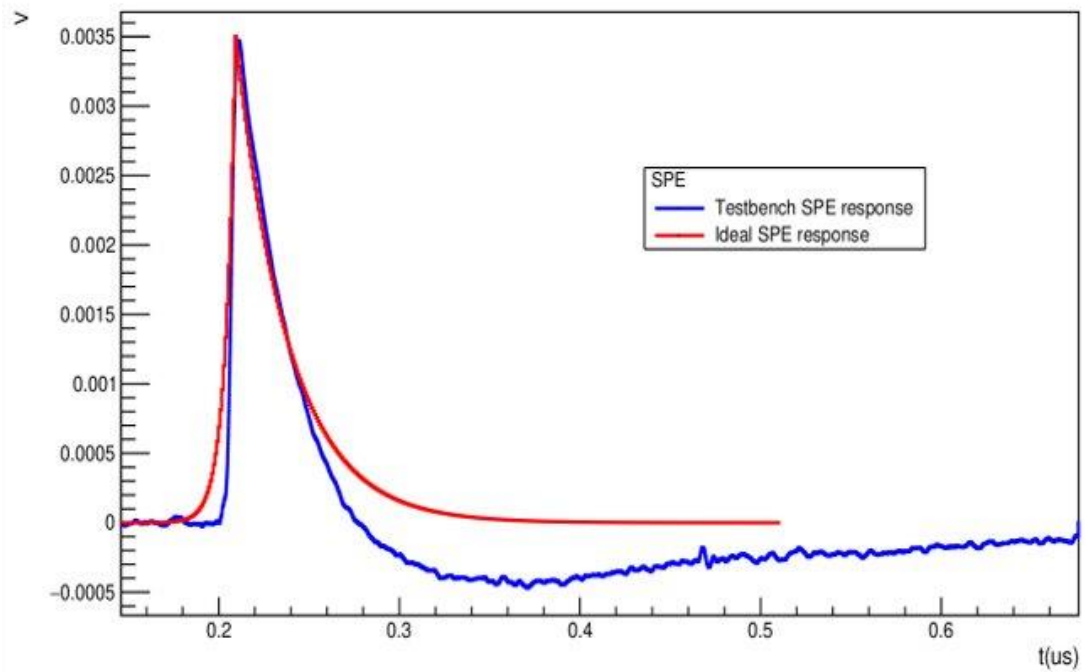
Digitization stage

- I examine the shape of the single photoelectron.
- SPE template obtained reading out 48 6 × 6 mm2 SiPMs (FBK) with the cold amplifier. (Ciemat-Milano Bicocca)
- Reviewed the tail and length of the SPE template.
- I wrote my own analyzer module.

Average SPE template (HPK)



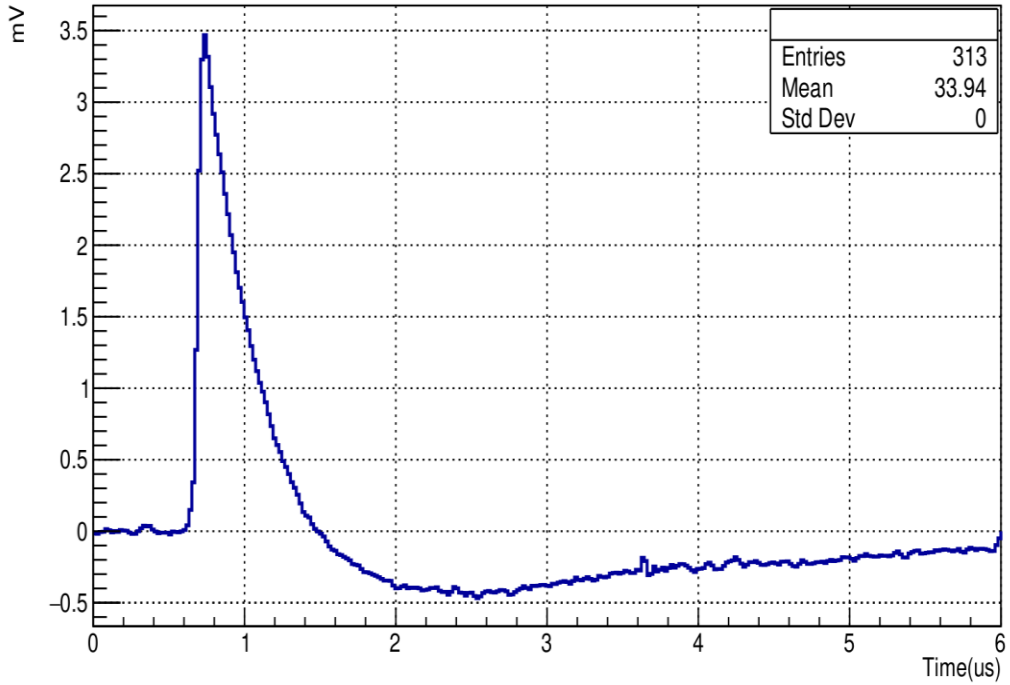
Average SPE template (FBK)



Update electronic response: **DAPHNE** responsible for digitizing signals.

- Modified the waveform and SPE parameters.

SPE Template (Cold Amplifier-> input DAPHNE)

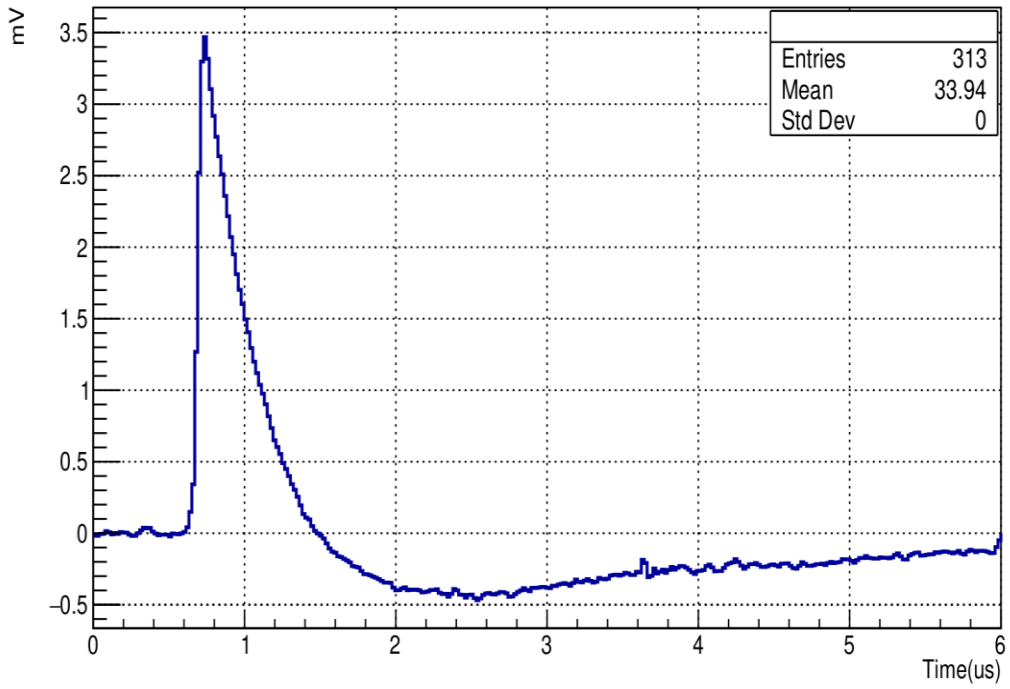


PulseLength: 6 us
MaxAmplitude 3.5 mV
Rise time ~100 ns
Fall time ~1 us

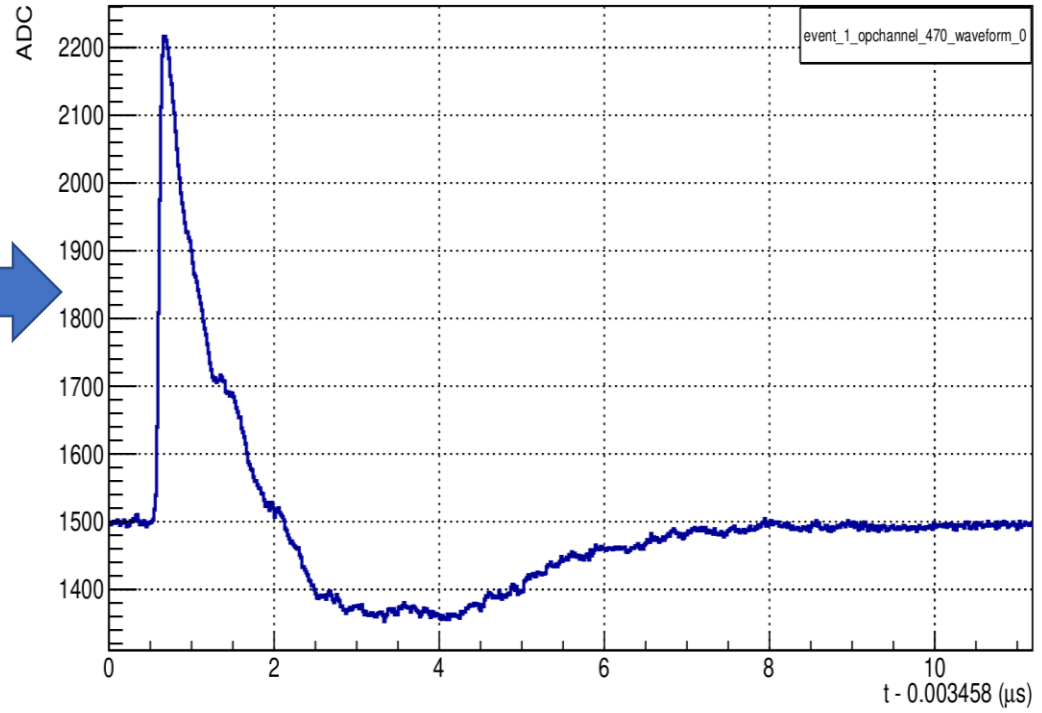
Digitization stage

Update electronic response: DAPHNE

SPE Template (Cold Amplifier-> input DAPHNE)

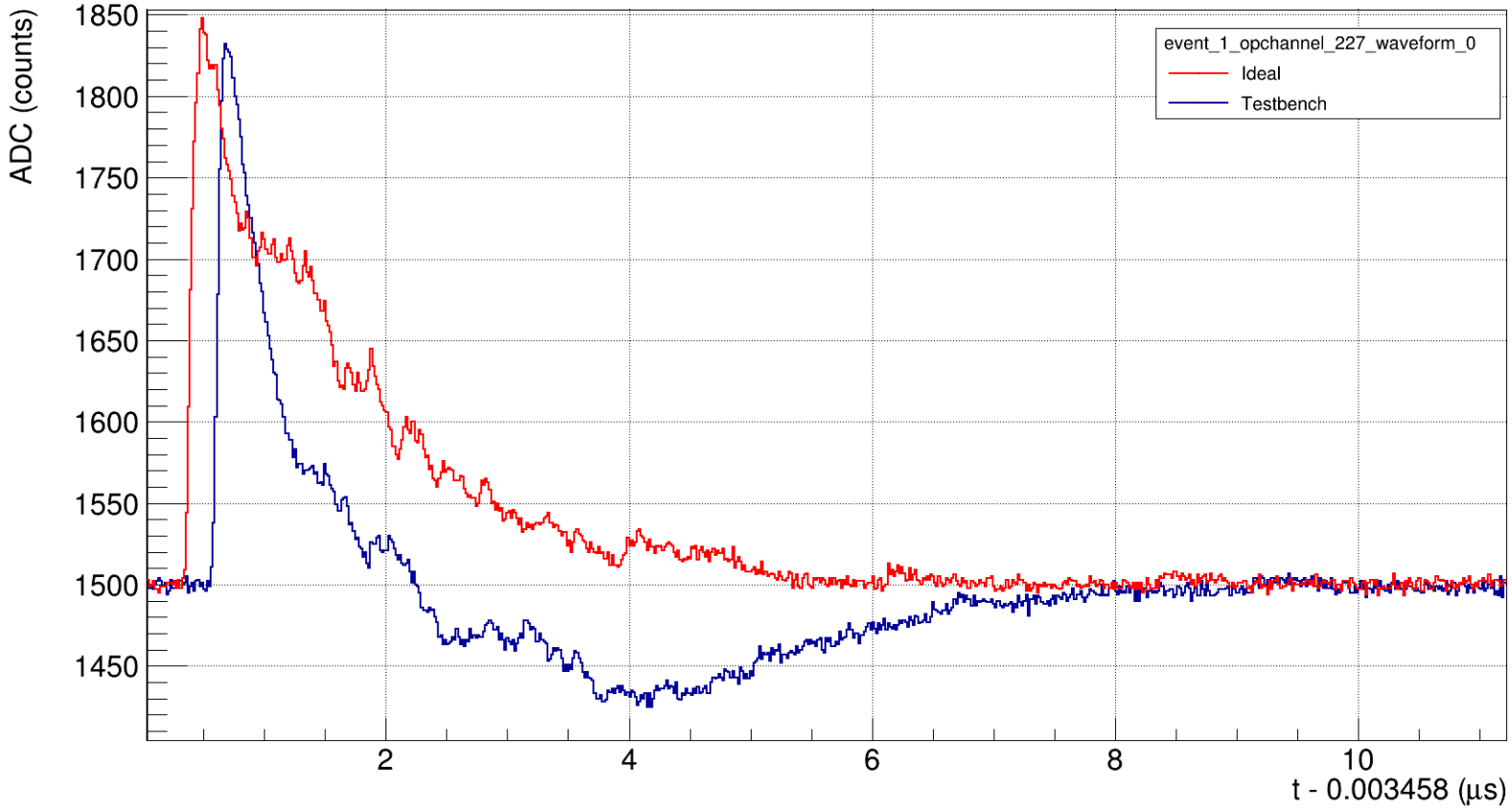


Waveform (Digitizer output)-DAPHNE



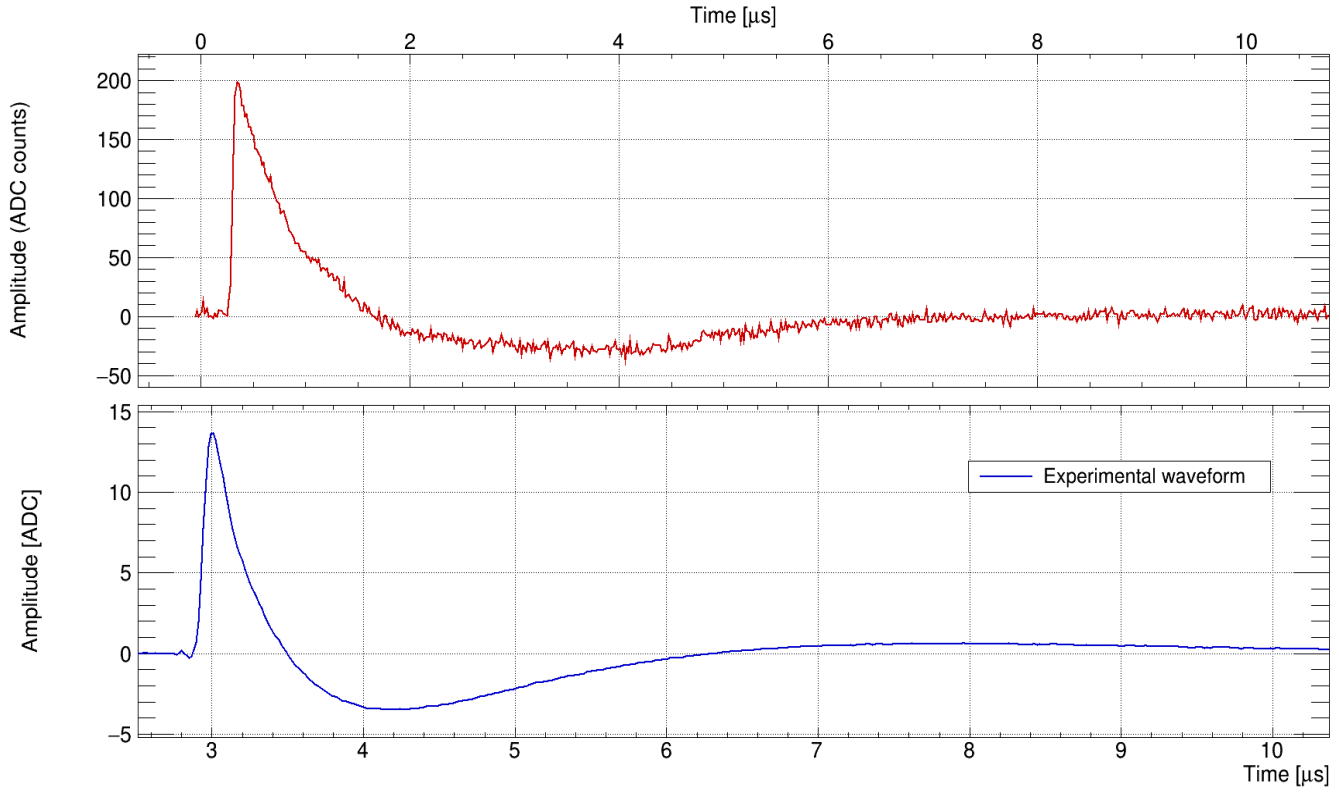
Digitization stage

Overlapping Waveforms.



Digitization stages

Update electronic response: DAPHNE



Simulated
(Output Digitizer)

Experimental
(Output DAPHNE-
Average Waveform)

- 62.5 MHz sampling time ->time bin is 16 ns.
- Fall time ~1us.
- Undershoot with maximum value 1 us after of the fall time.

Reconstruction stage:

- The reconstruction is divided into two parts: Deconvolution module and Ophits Finder module.

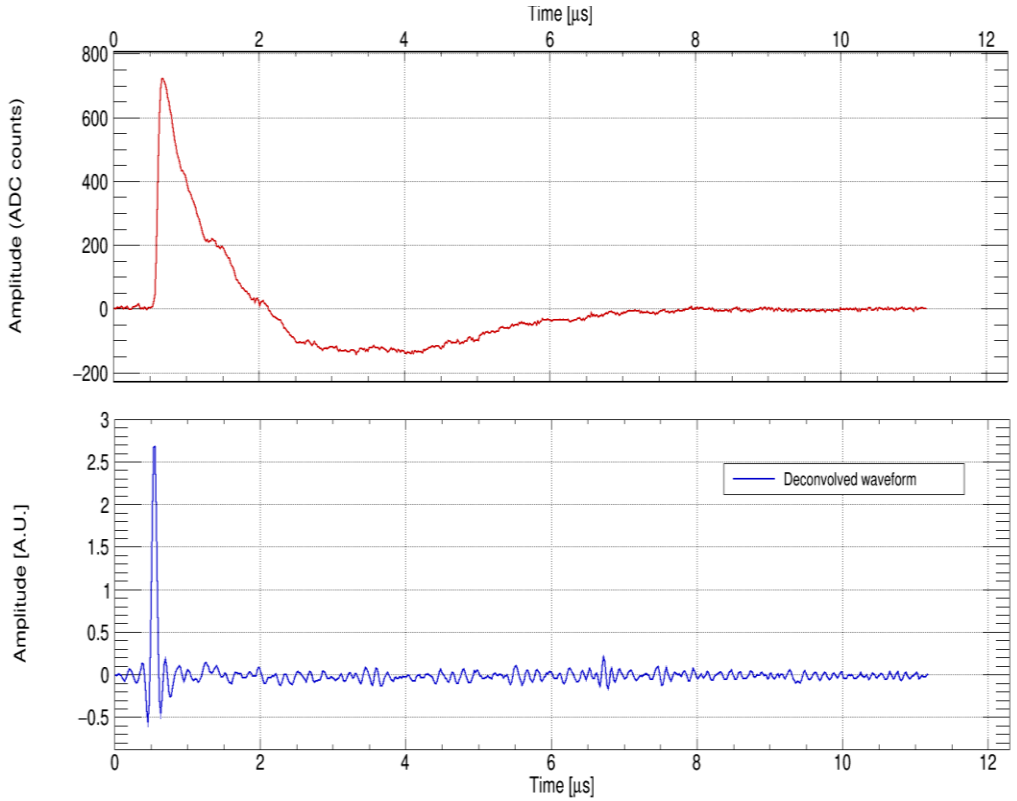
- Deconvolution is done with the Wiener deconvolution filter:
  -It works in the frequency domain.
  -FFT

- The Deconvolution module and the fhicl are compiled in LArSoft:

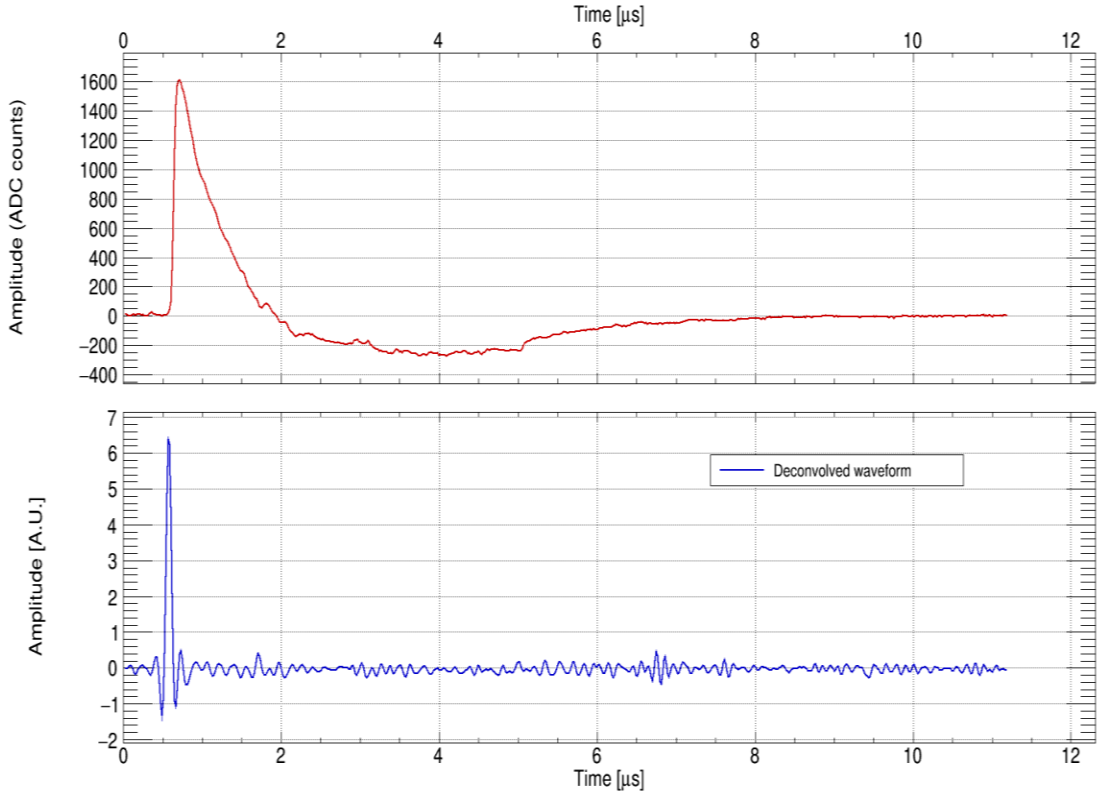
-The Root Macro written by Daniele Guffanti.

- Check Deconvolution Plot -> Generate a waveform with a single PE.

event_1_opchannel_470_waveform

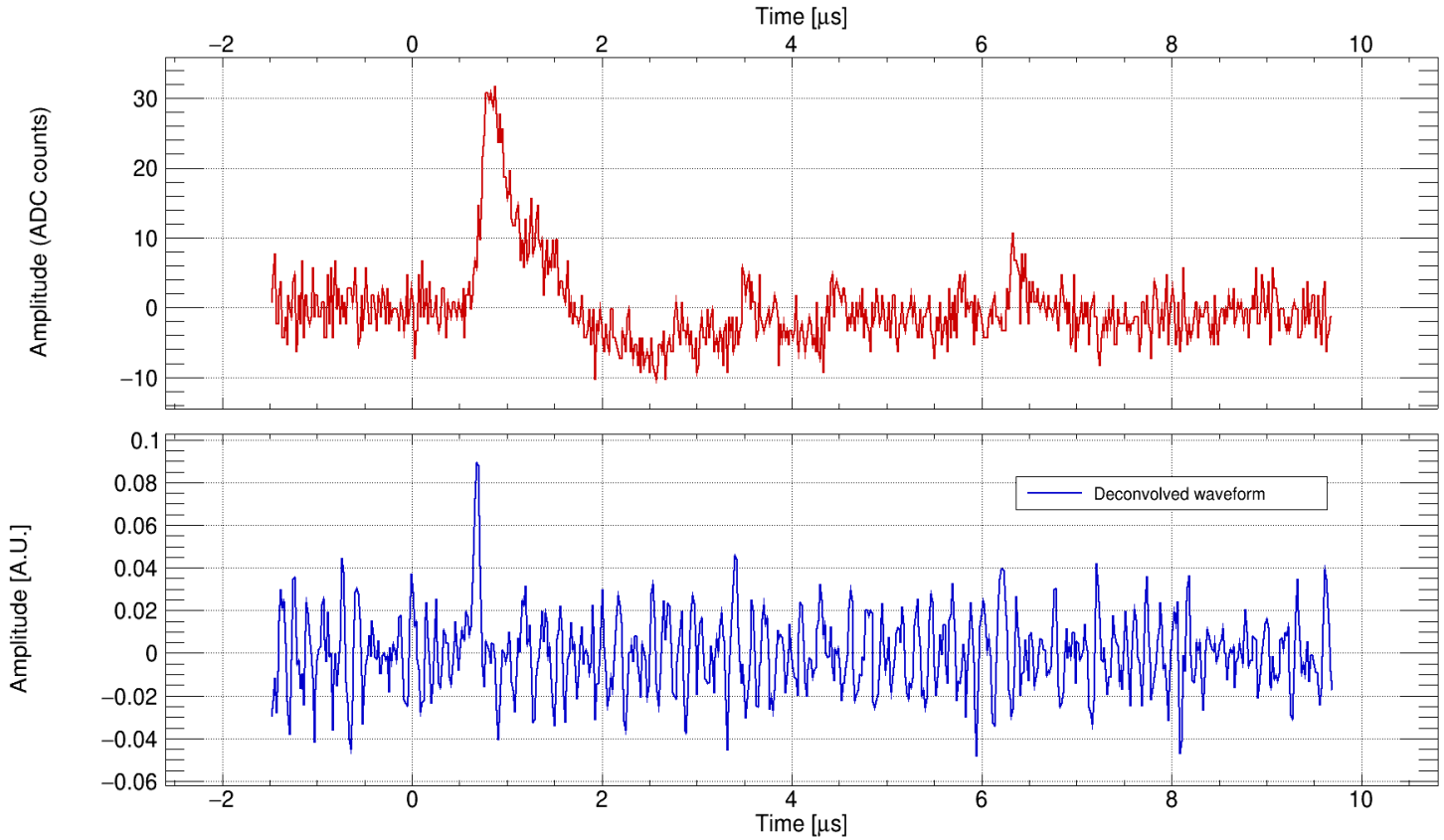


event_1_opchannel_270_waveform



Deconvolution is done with the Wiener deconvolution filter .

event_1_opchannel_200_waveform



Deconvolution is done with the Wiener deconvolution filter .

Next steps:

1. The deconvolved signals are stored in the product recob::OpWaveform. (Created by Tingjun Yang)

2. Ophit module to analyze the waveforms:
- Find the photon time distribution, and the number of photons per channel.
- DAPHNE:What is the appropriate length of the output waveform?

THANKS