Pulse-shape Analysis of the Prototype Neutron Detectors for LAMPS at RAON

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1. OUTLINE[1]

Introduction & Motivation

⦿ High Energy LAMPS

⦿ Neutron Detector Array

Data Collection

✸ Experimental Set-up

Data Analysis

◎ Typical Pulse Shape

◎ Position Dependence of Pulse Shape

◎ Pulse Height and Integrated ADC

◎ Time and Position Information

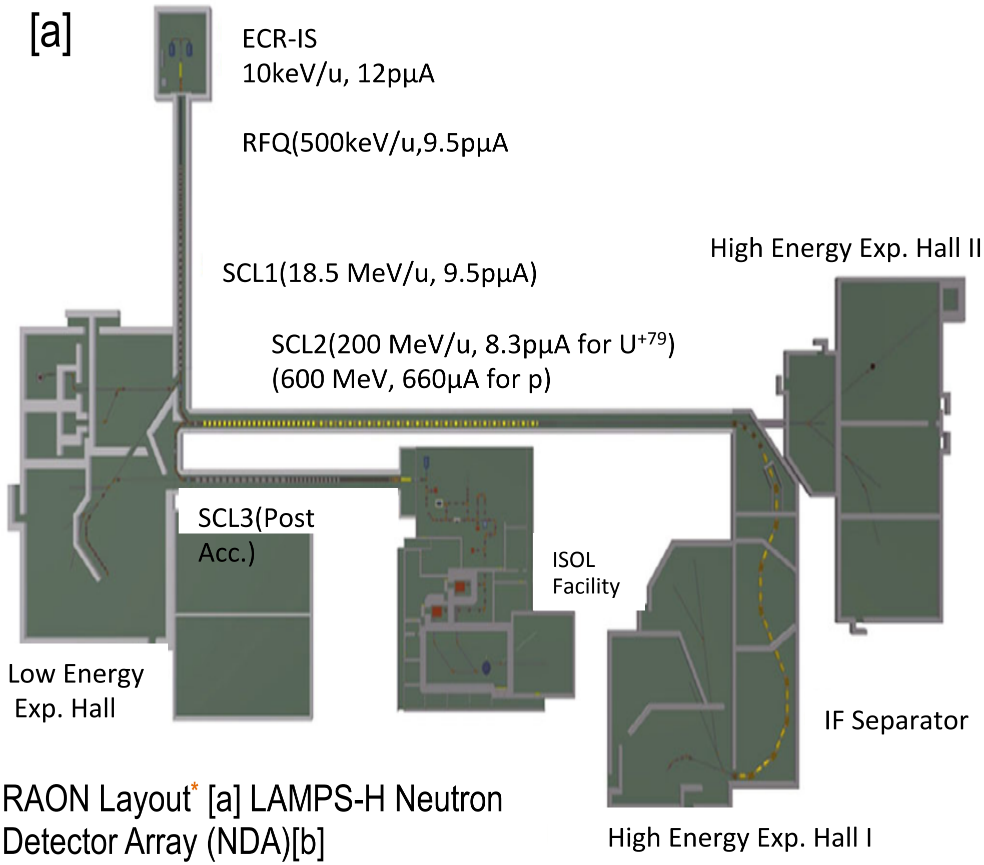
Summary & Prospect

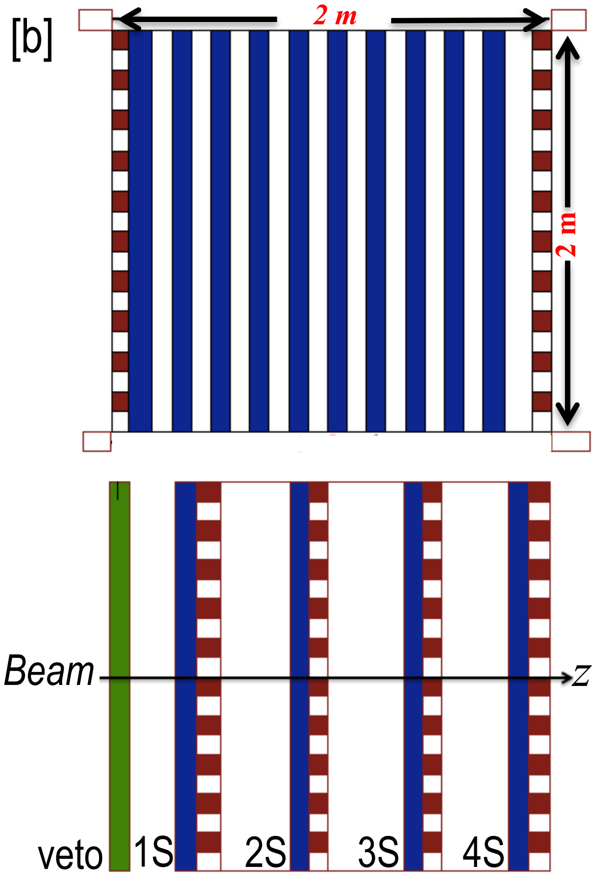
2. Introduction & Motivation[1]

- High Energy LAMPS (LAMPS-H)
- Neutron Detector Array (NDA)

→ RAON

JKPS, Vol. 65, No. 7, October 2014*

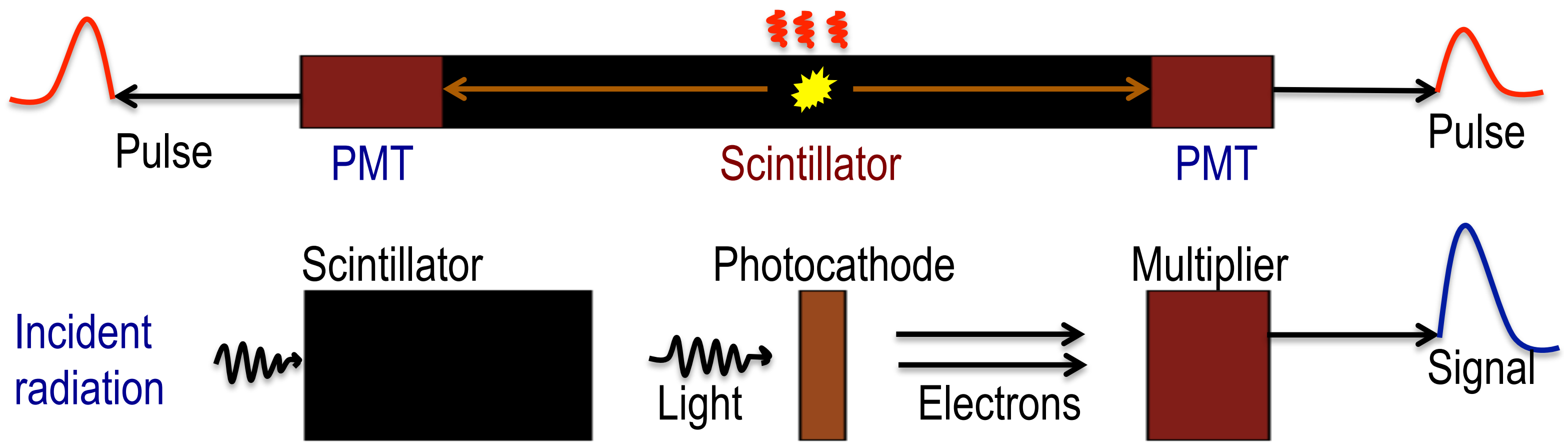




RAON Layout* [a] LAMPS-H Neutron Detector Array (NDA)[b]

2. Introduction & Motivation[2]

Typical Plastic Scintillation Detector

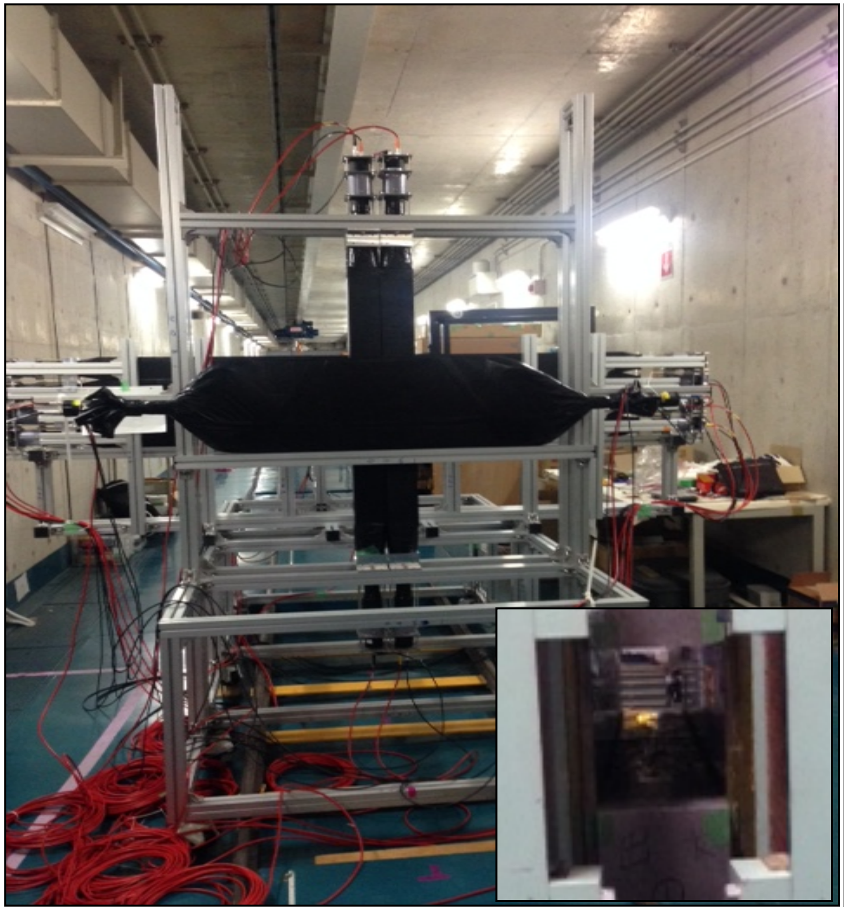


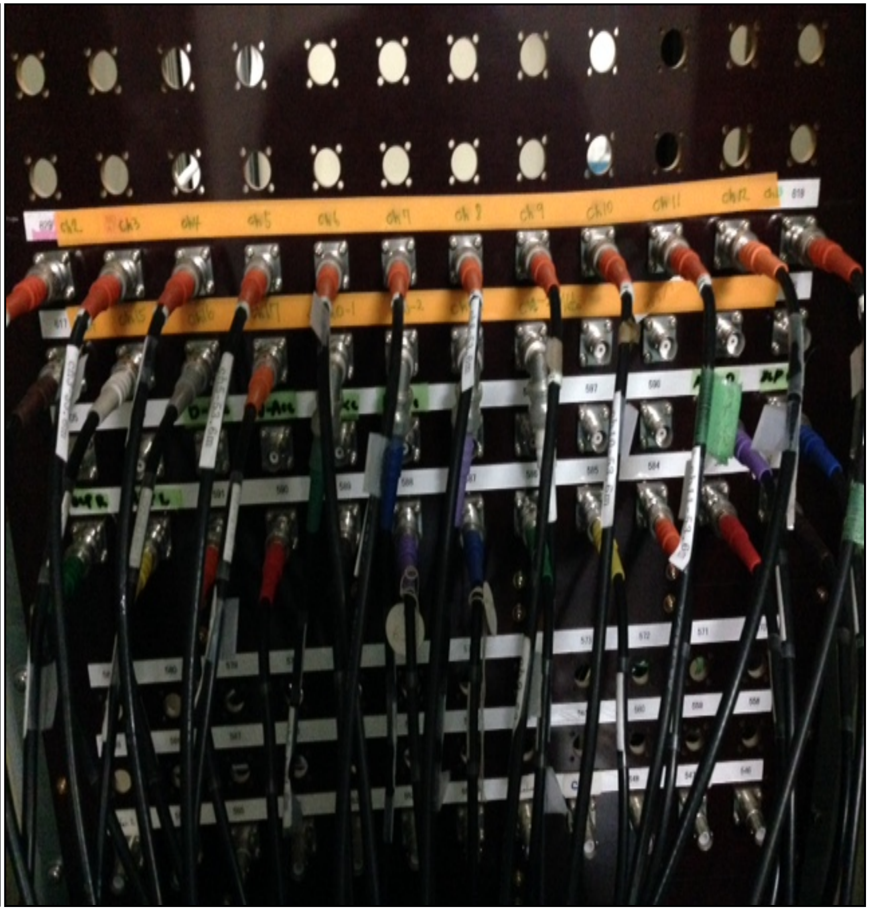
$N_{\gamma sci} \propto E_{abs}$	$N_{photoel} \propto E_{abs}$	$q_{pulse} \propto E_{abs}$

Signal Processing

3. Data Collection[1]

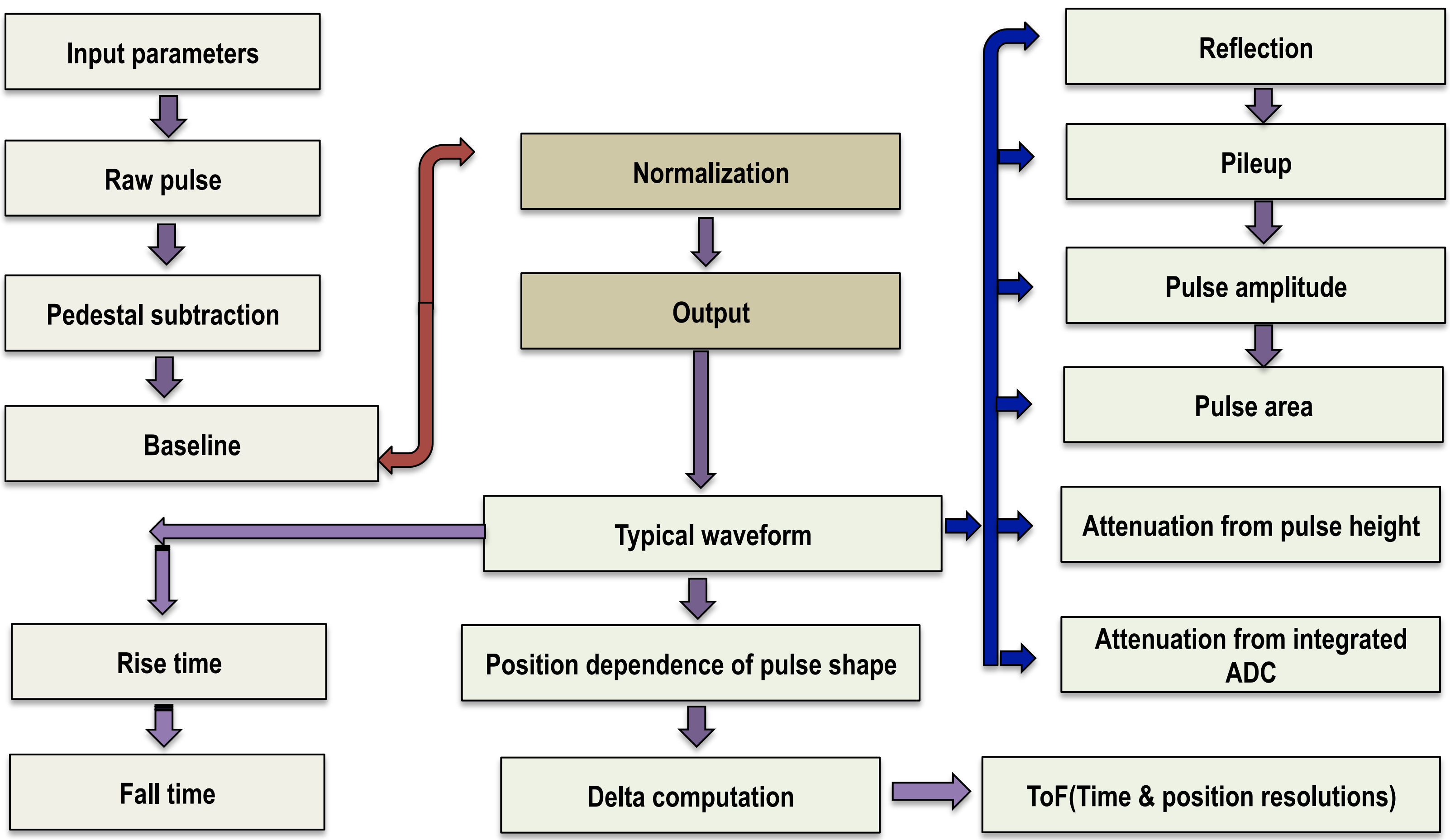
Experimental Setup



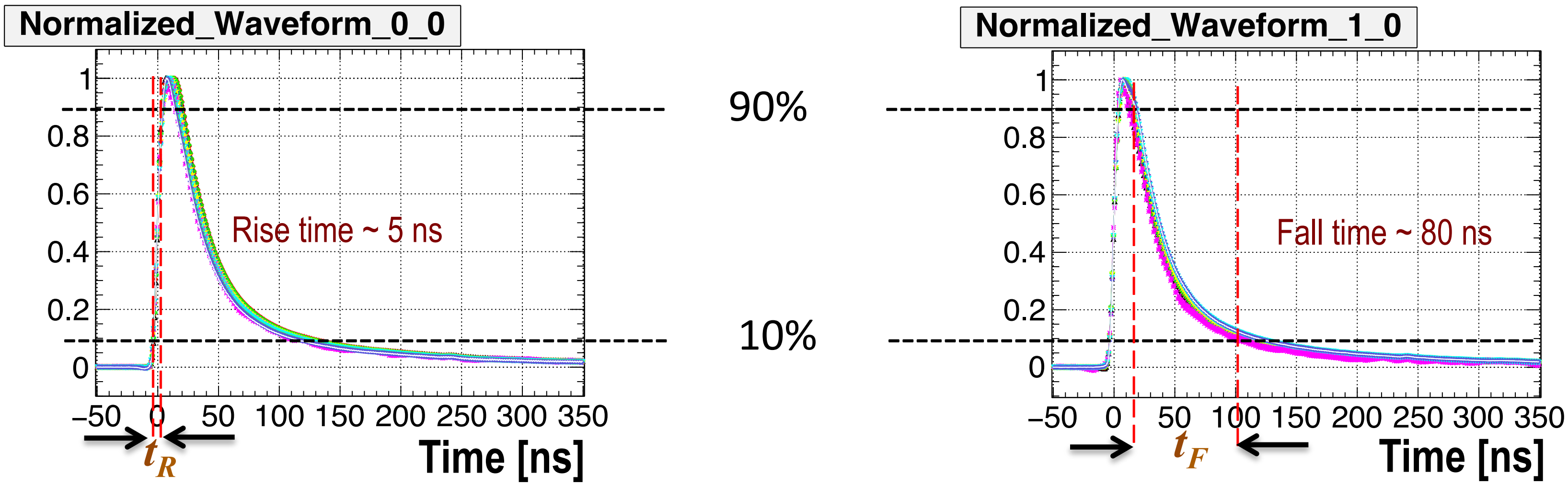


4. Data Analysis[1]

⌘Pulse Shape Analysis Routines – Program Flowchart



4. Data Analysis[2]

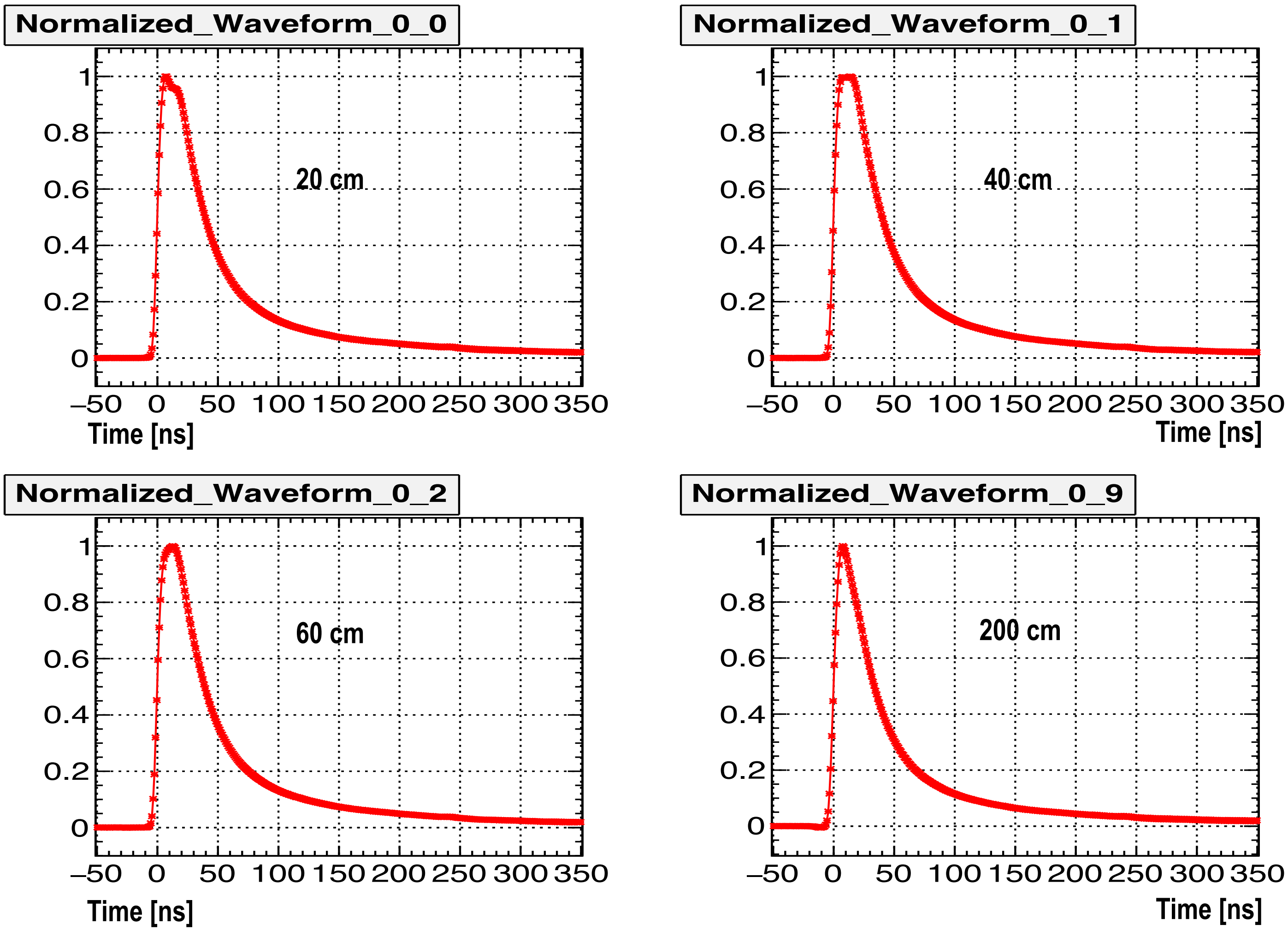


Rise Time (t_R) and Fall time (t_F)

- Rise time is time required for a signal to rise from 10% to 100% of the height of the signal.
- Fall time is the time needed for the signal to fall from 90% to 10% of the maximum height.

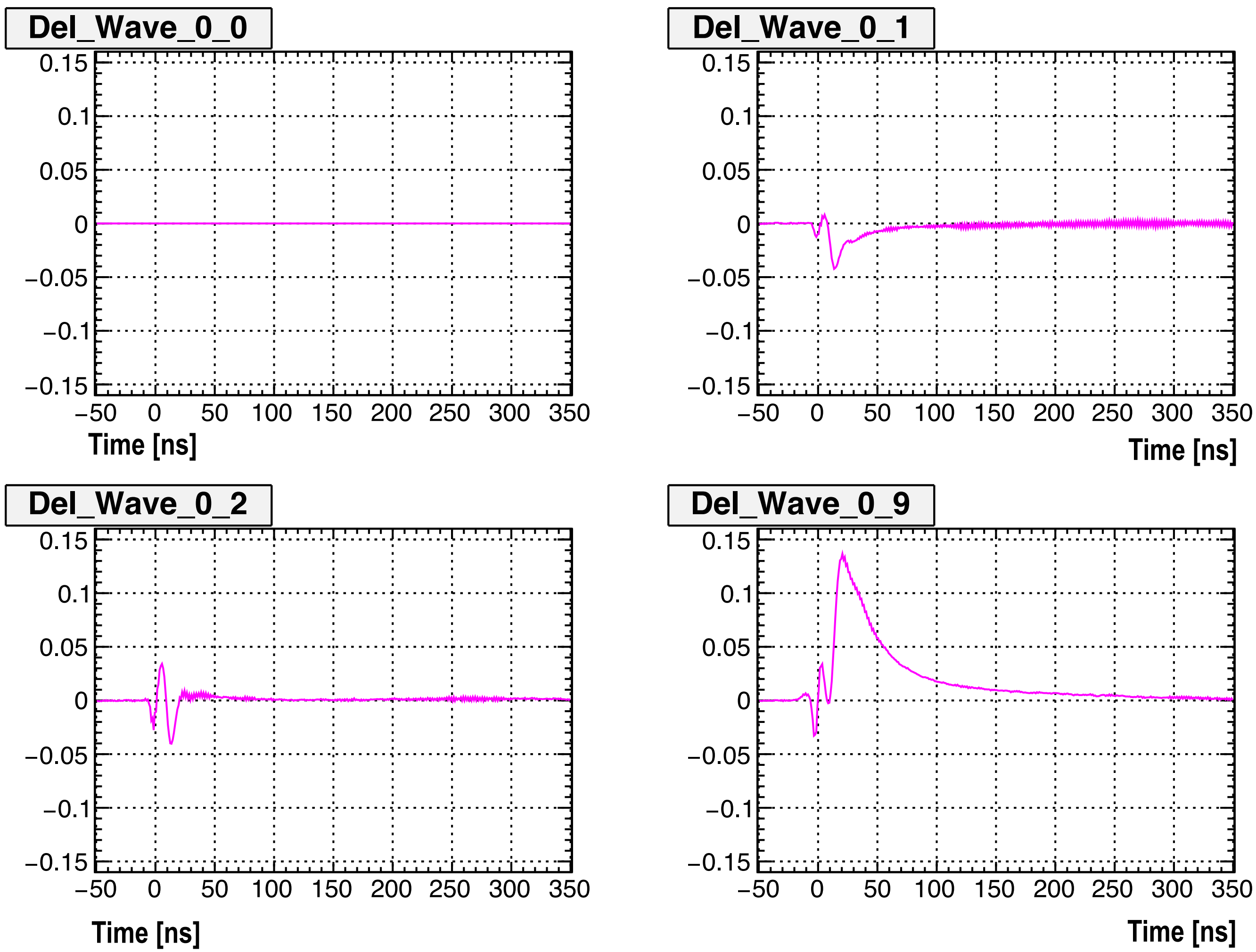
4. Data Analysis[3]

Study of Waveform by Position along the Scintillator's Length



4. Data Analysis[4]

Waveform Delta between two pulses along the Scintillator's Length



4. Data Analysis[5]

Pulse Height and Integrated ADC

- Both pulse height and integrated ADC methods were applied in understanding the attenuation length of the prototypes.

- Attenuation length is understood as the distance in the material where the intensity of the beam has dropped to 1/e, or about 63% of the particles have been stopped.

- This is Beer-Lambert law:

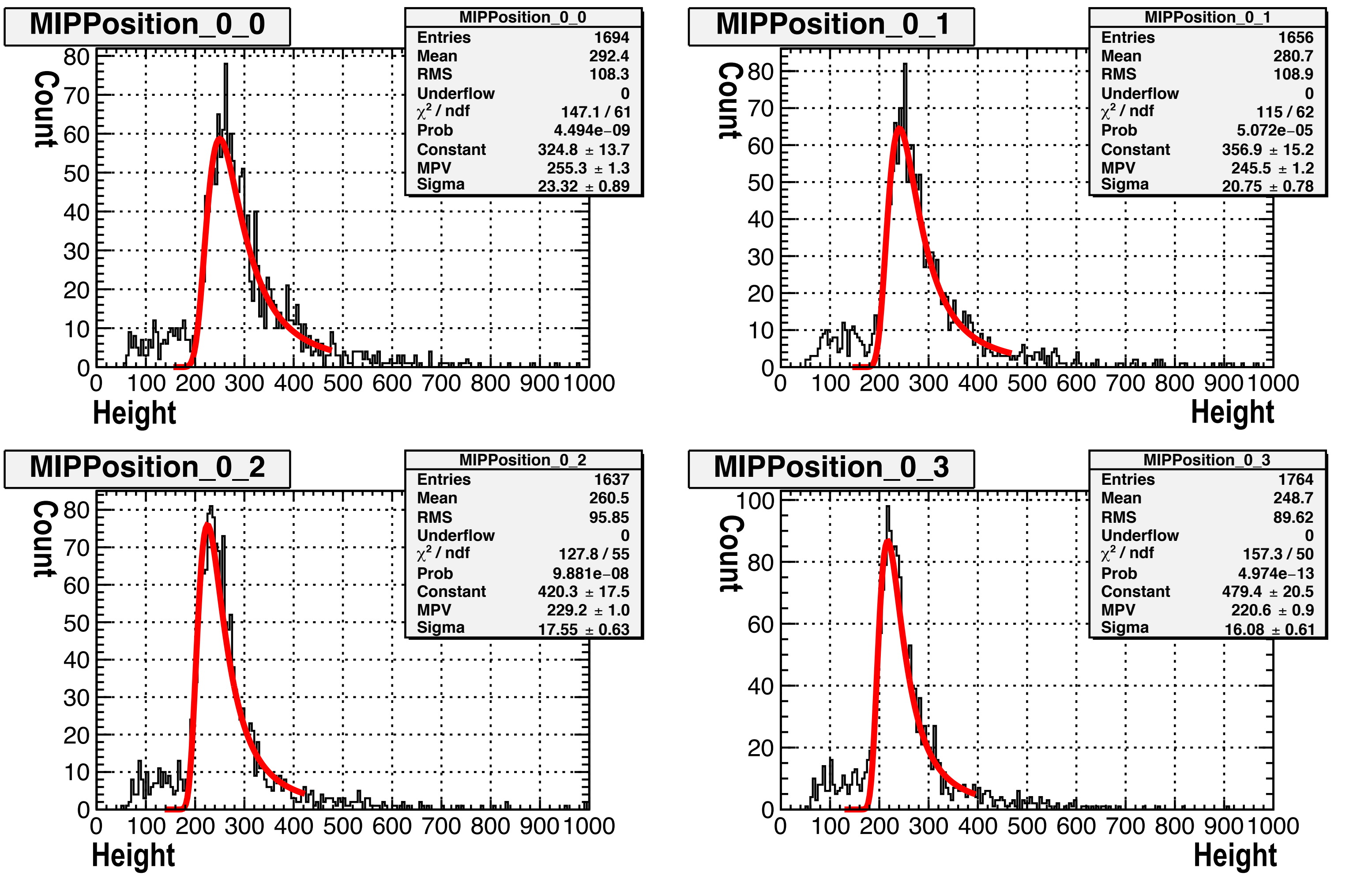
$$P(x) = P_o e^{-x/\lambda}$$

Where;

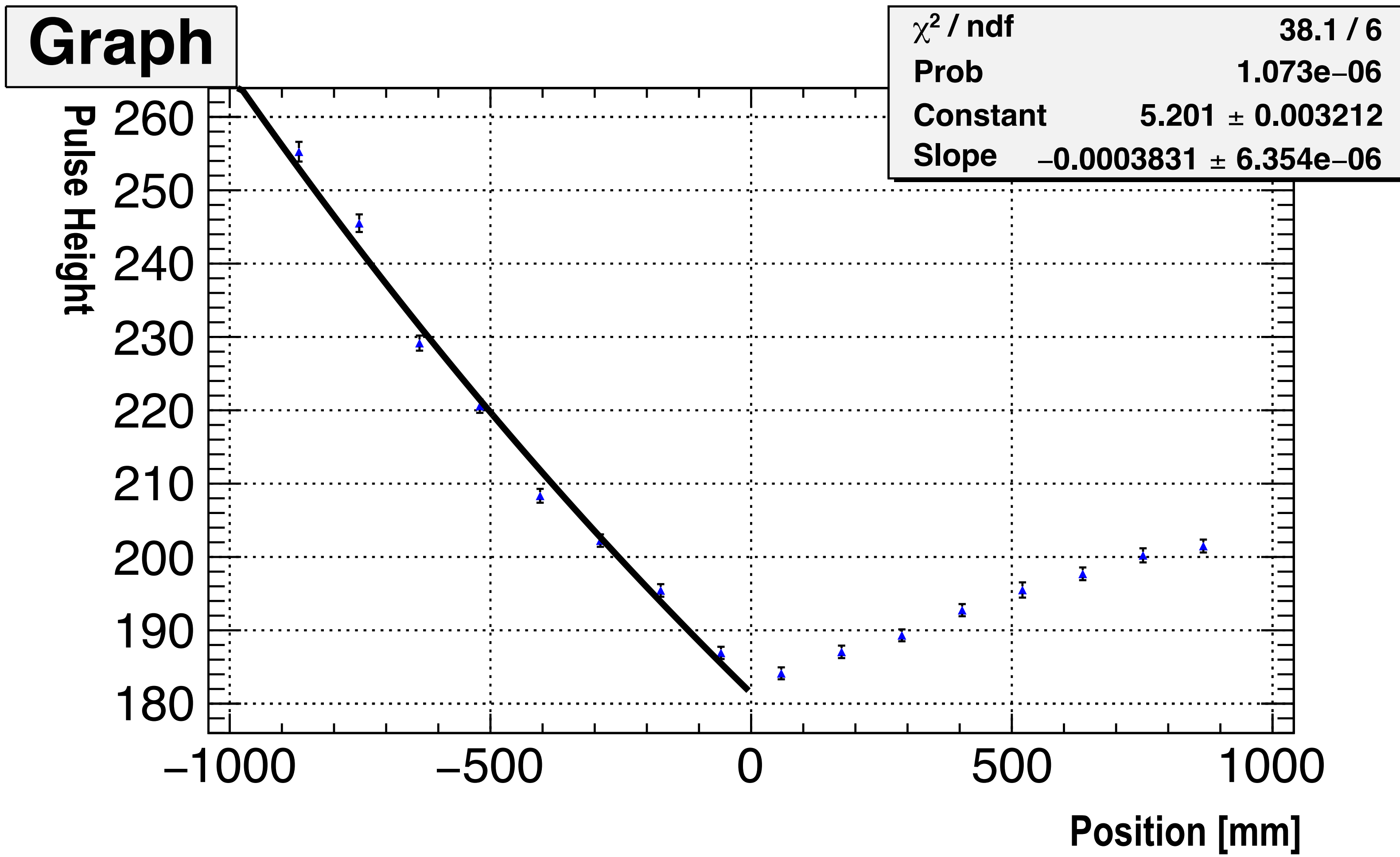
- $P(x)$ is the number of incident radiation.
- P_o is the number of photons reaching the PMT (ADC value.
- x is the path length of the scintillating material.
- λ is the attenuation length and depends on the material and energy.

4. Data Analysis[6]

Pulse Height From Cosmic Muons



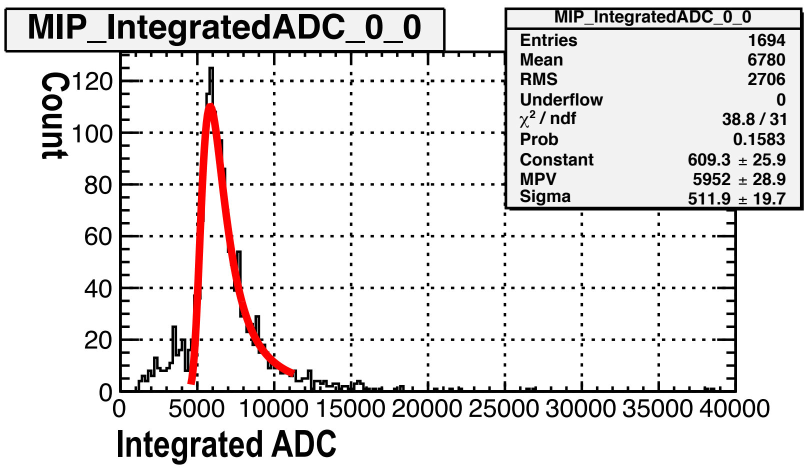
4. Data Analysis[7]

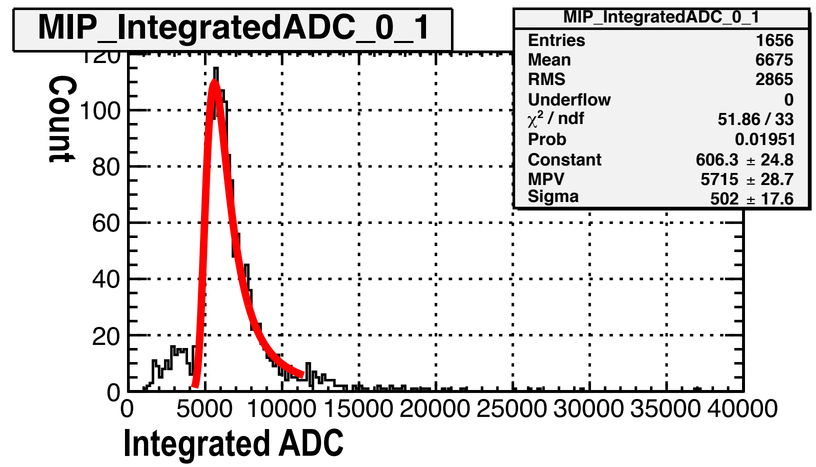


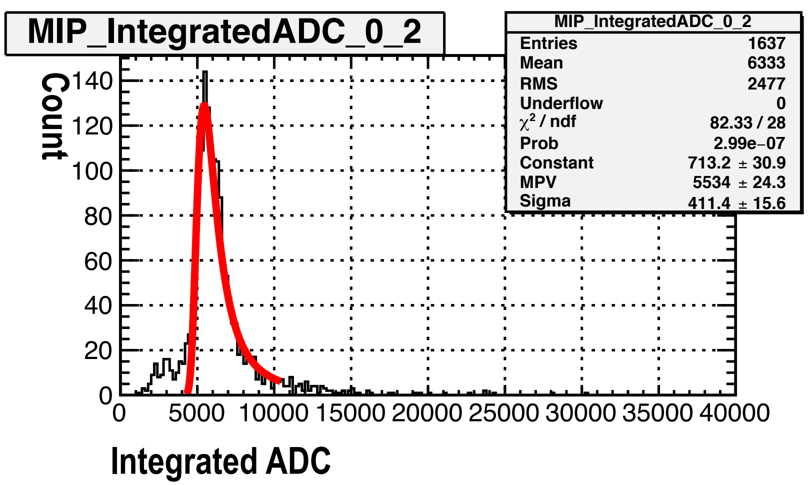
Exponential fit function with λ = 1/slope = 1/0.0003831 = 261 cm = attenuation length

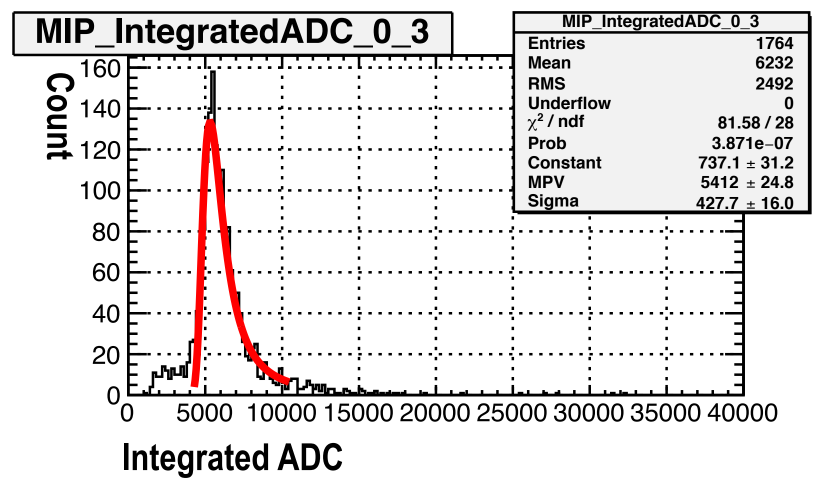
4. Data Analysis[8]

Integrated ADC From Cosmic Muons



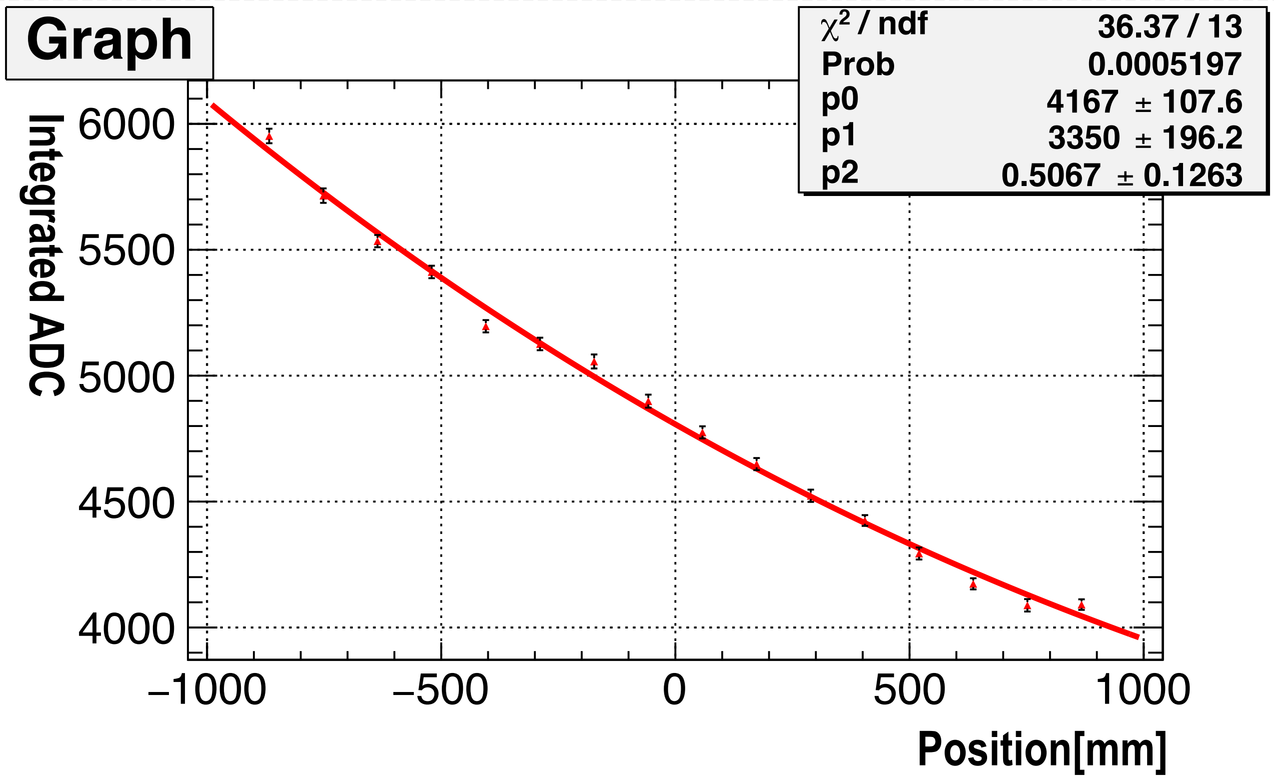






4.Data Analysis[9]

Integrated ADC From Cosmic Muons



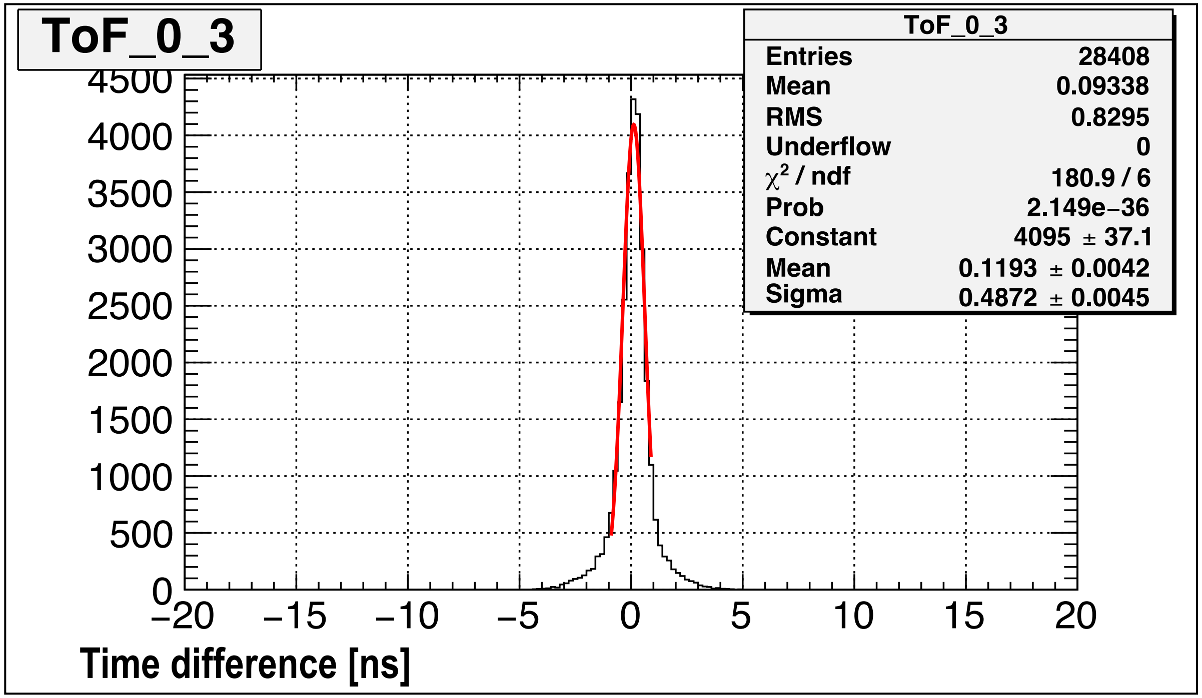
$$P = P_0 e^{-\frac{x}{P_1}} + P_2^{-\left(\frac{2L-x}{P_1}\right)}$$

Fitting function for integrated ADC

- Po = PMT photons
- P1 = Attenuation Length
- P2 = Reflectivity

4.Data Analysis[10]

Timing Information



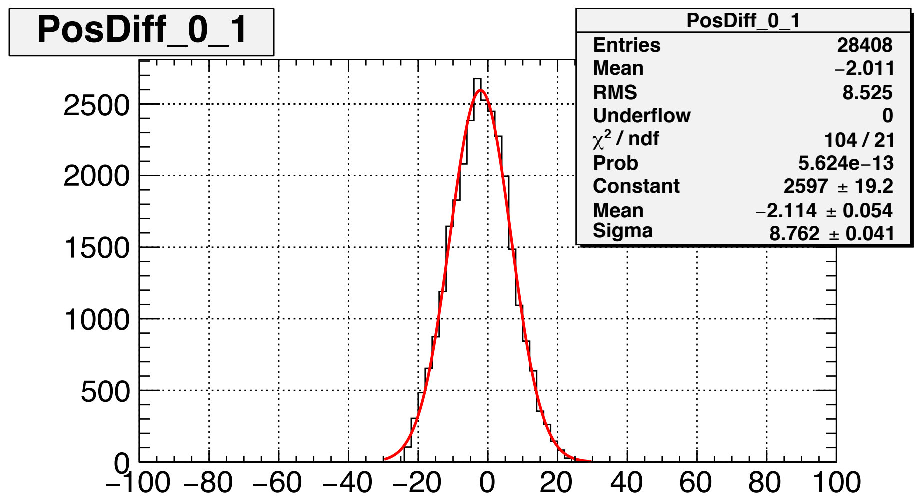
Timing distribution of muons plotted as a function of the time difference between two timing information from two different 2m long prototypes in the second station.

- Arrival time for each prototype detector is averaged value of two signals from left and right PMTs.
- The red distribution depicts the fitted Gaussian function.
- Sigma from the Gaussian fit is 487 ps so that time resolution for each prototype is 344 ps.

4.Data Analysis[14]

Position Information

Position distribution for the difference between extrapolated hit position of one prototype and direct hit position in the same prototype.
Sigma for this difference was found to be 8.76 cm.



◎ Sigma for one prototype is found from the difference between extrapolated hit position of any bottom prototype and its hit position by applying:

$$\sigma_x = \sigma\left(x_{bp,ext} - x_{bp,hit}\right)/1.87 = 8.76/1.87 = 4.7 \text{ , with } \sigma_x = \sigma\left(x_{bp,ext} - x_{bp,hit}\right) = \sigma_{dist} = 8.76$$

◎ And the relation between extrapolated position of muons in bottom prototype and hit position can be obtained by:

$$x_{bp,ext} - x_{bp,hit} = \left(1.5x_{tp,hit} - 0.5x_{tmp,hit}\right) - x_{bp,hit}$$

5. Summary & Prospect[1]

Summary

◎ Waveform changes by position as the pulse traverses the scintillating material from the interaction point to either side of the photomultiplier tubes. This change affects the time and position resolutions of the detector.

◎ The attenuation length computed from pulse height and integrated ADC is of the order of the detector's length and therefore the detectors are suitable for time of flight experiment since the radiation can be stopped within the detector's active volume.

◎ The time resolution of our current detector is estimated to be 344 ps and position resolution of 4.7 cm

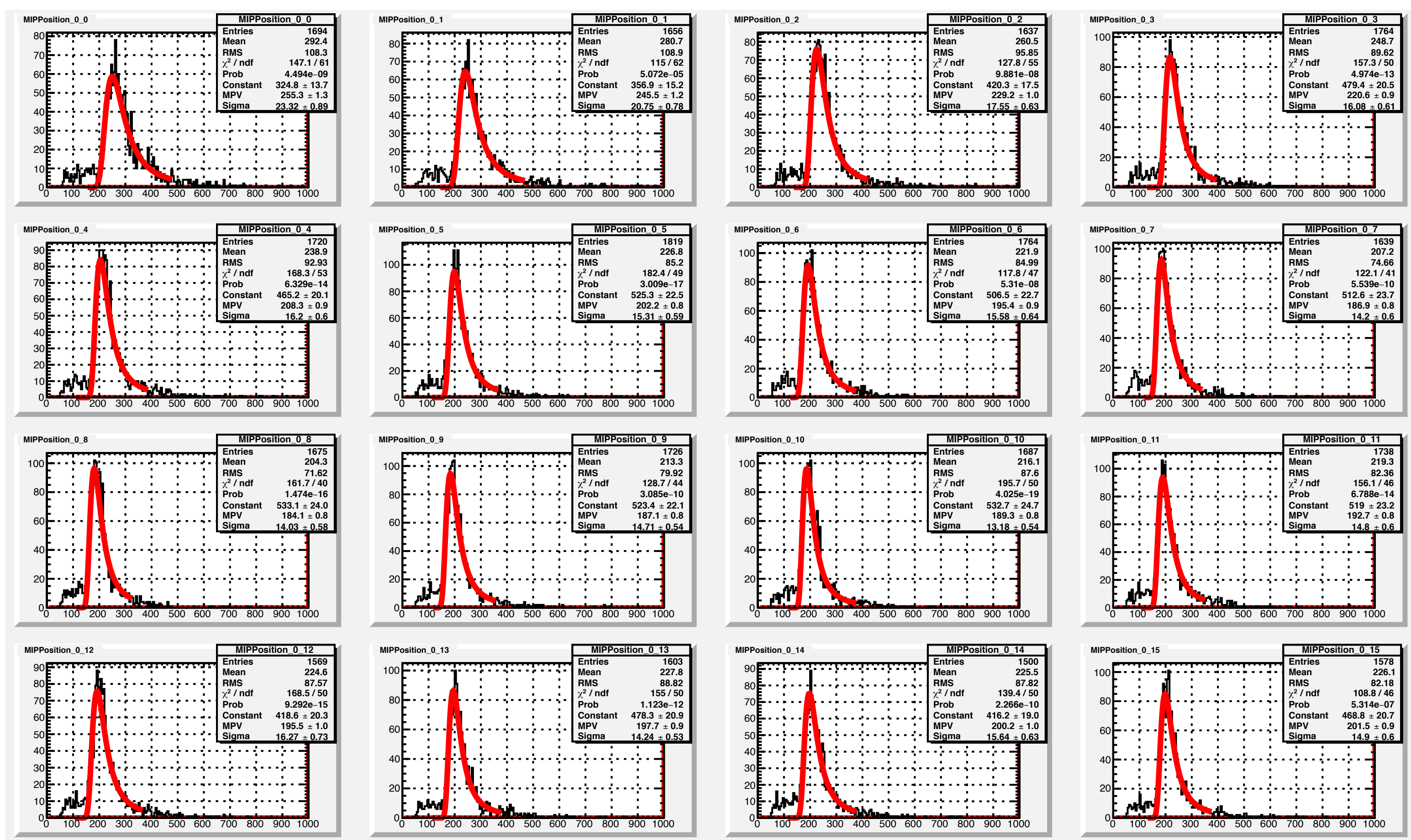
Prospect

⌘ Plan to setup an experiment to determine the velocity of the scintillator at different points since the calculation of attenuation length in this analysis assumes the effective velocity to be constant throughout the scintillator.

⌘ Analyze pulse pileup and reflection further as these distort the amplitude of the pulse and hence affect the measurement of the energy deposited in the detector.

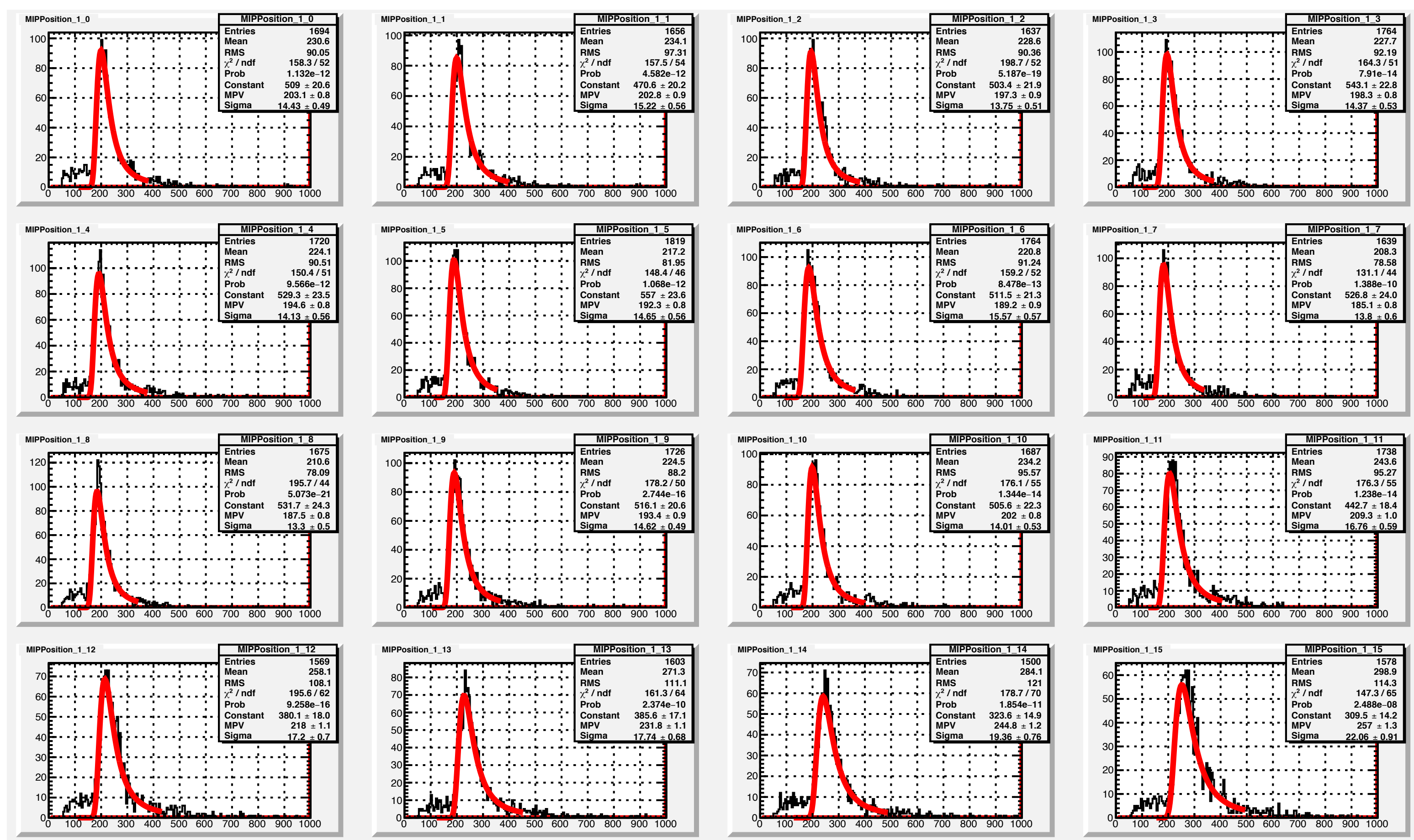
6.BACKUP[1]

Pulse Height From Cosmic Muons



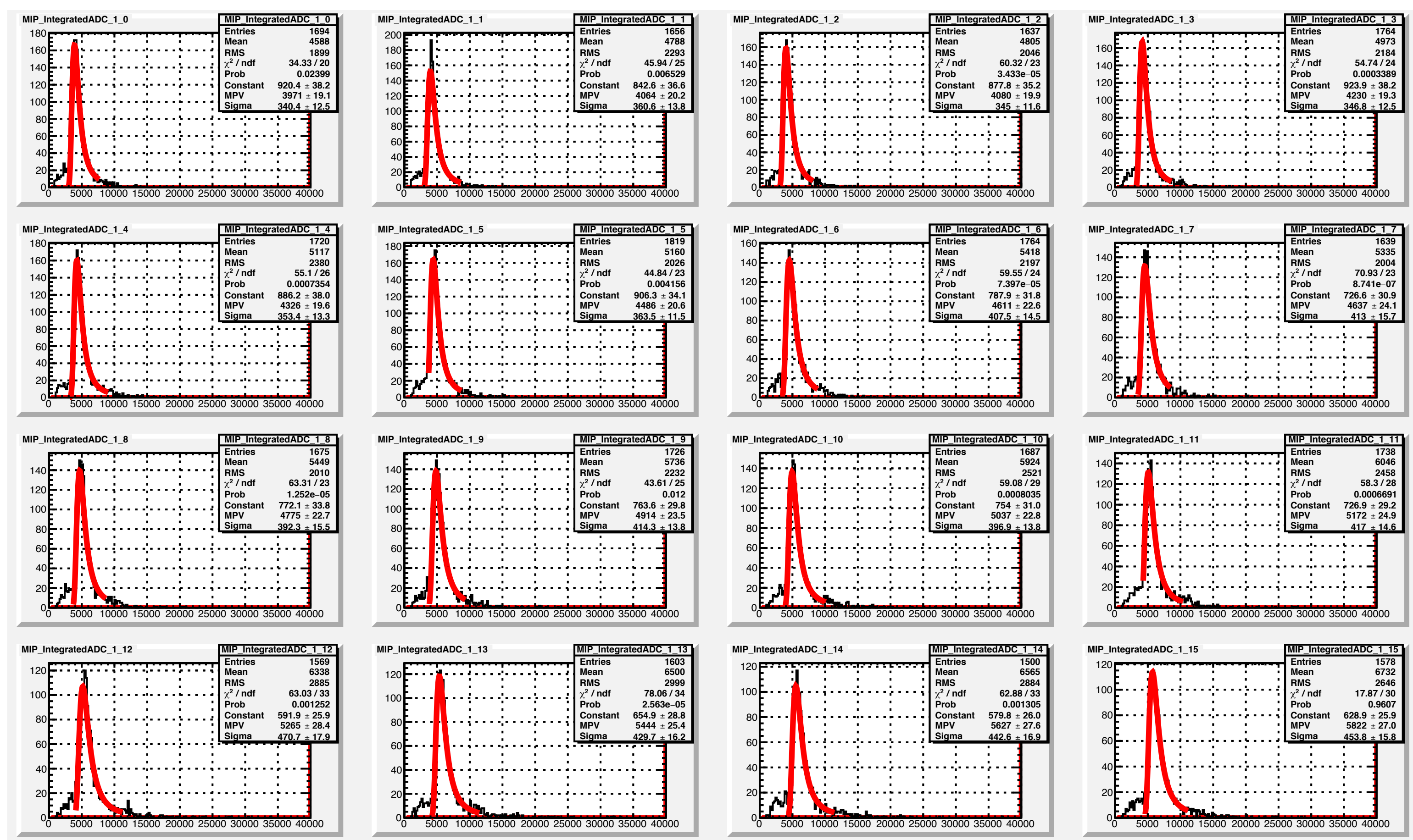
6.BACKUP²

Right PMT Pulse Height



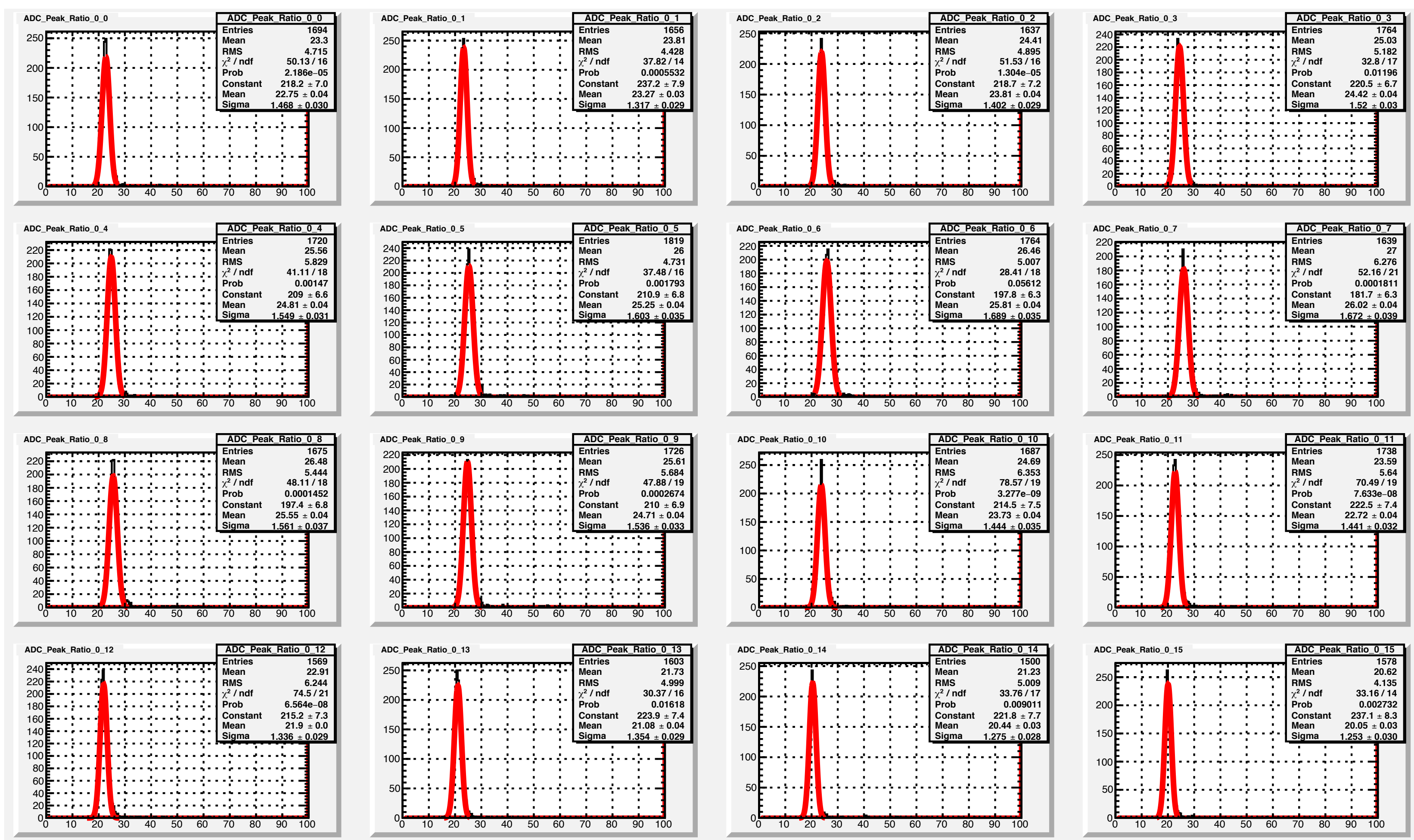
6.BACKUP[3]

Right PMT Integrated ADC



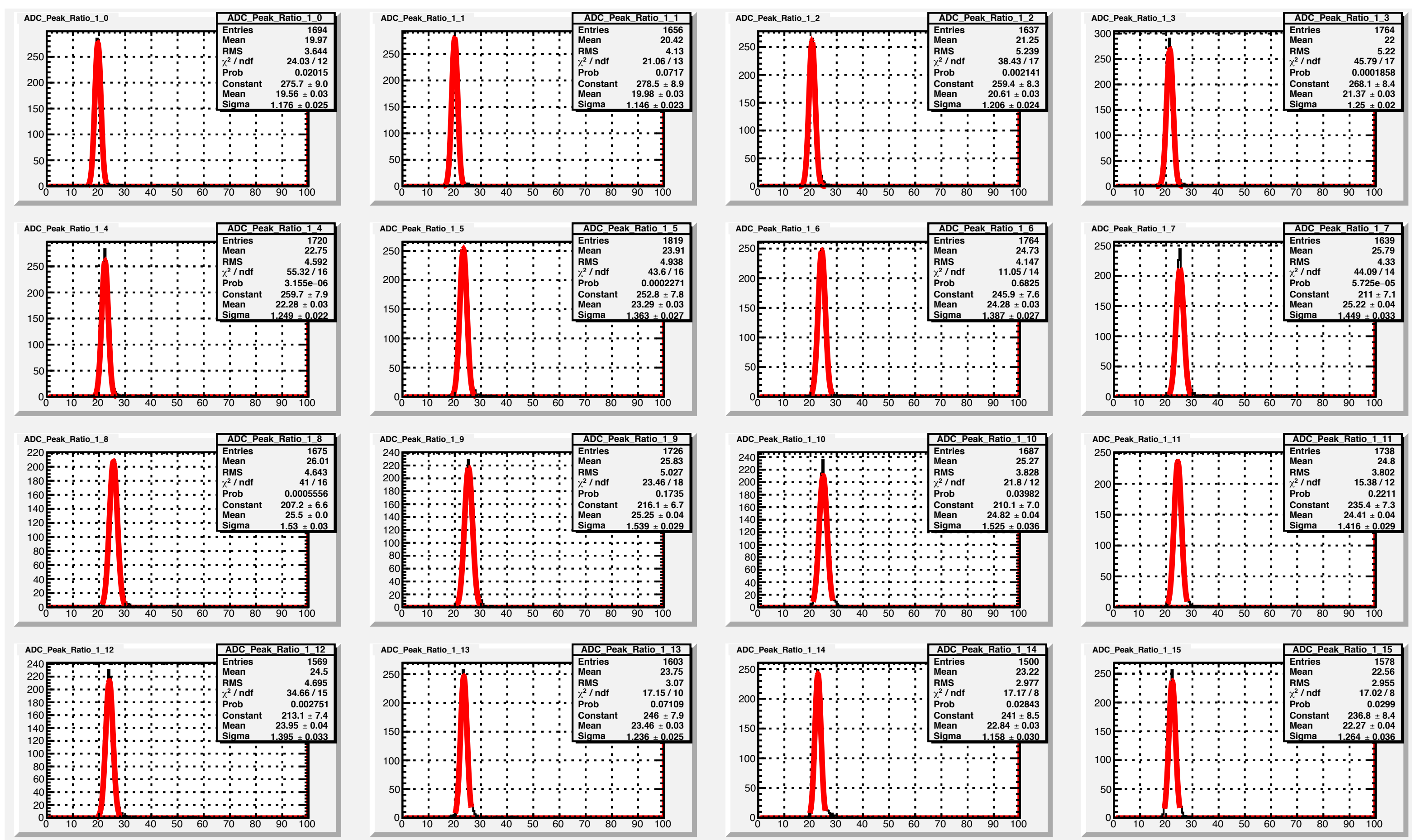
4. BACKUP[4]

MIP Integrated ADC to Pulse Peak Ratio



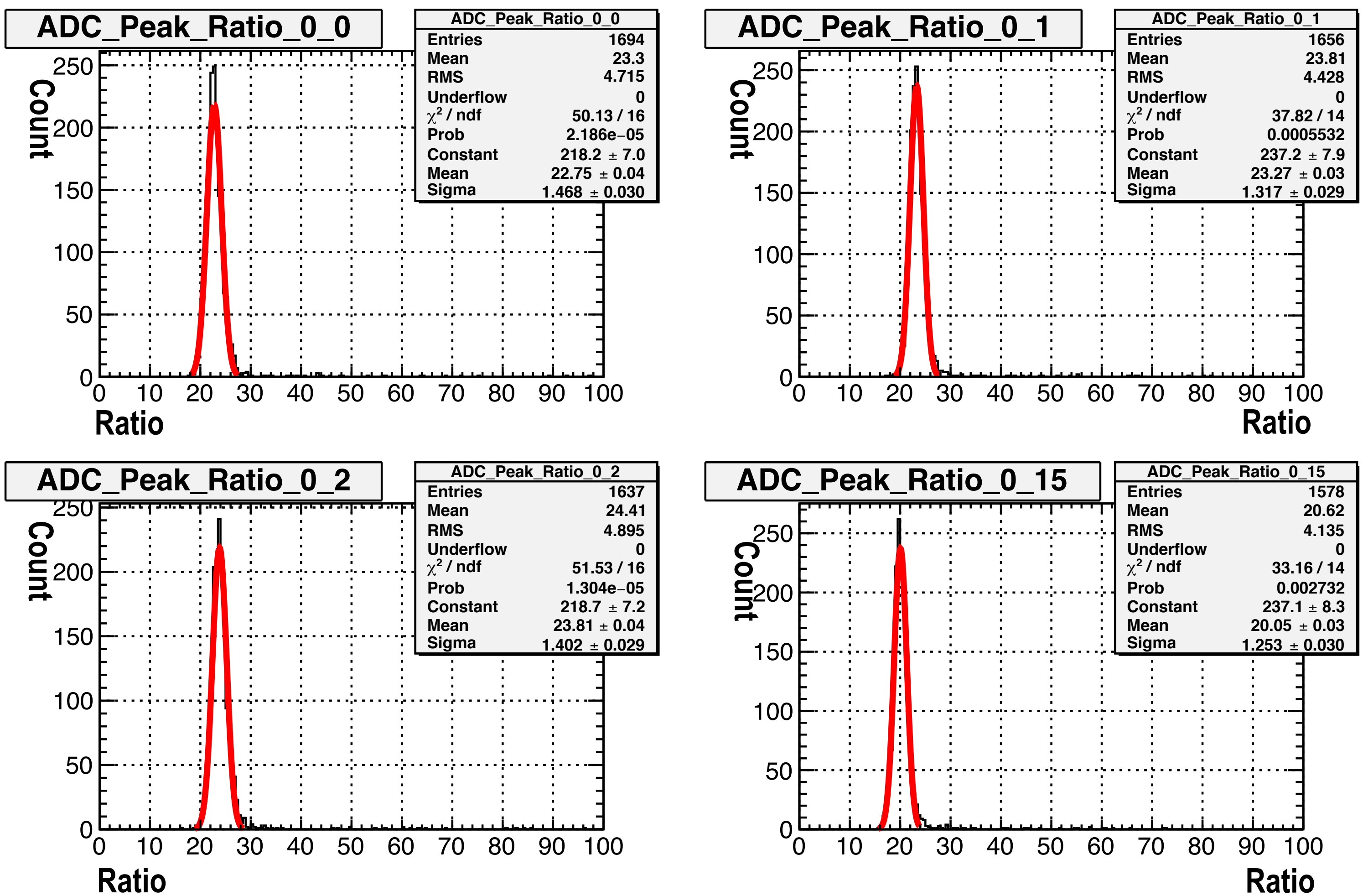
6.BACKUP[5]

Right PMT Integrated ADC to Pulse Peak Ratio

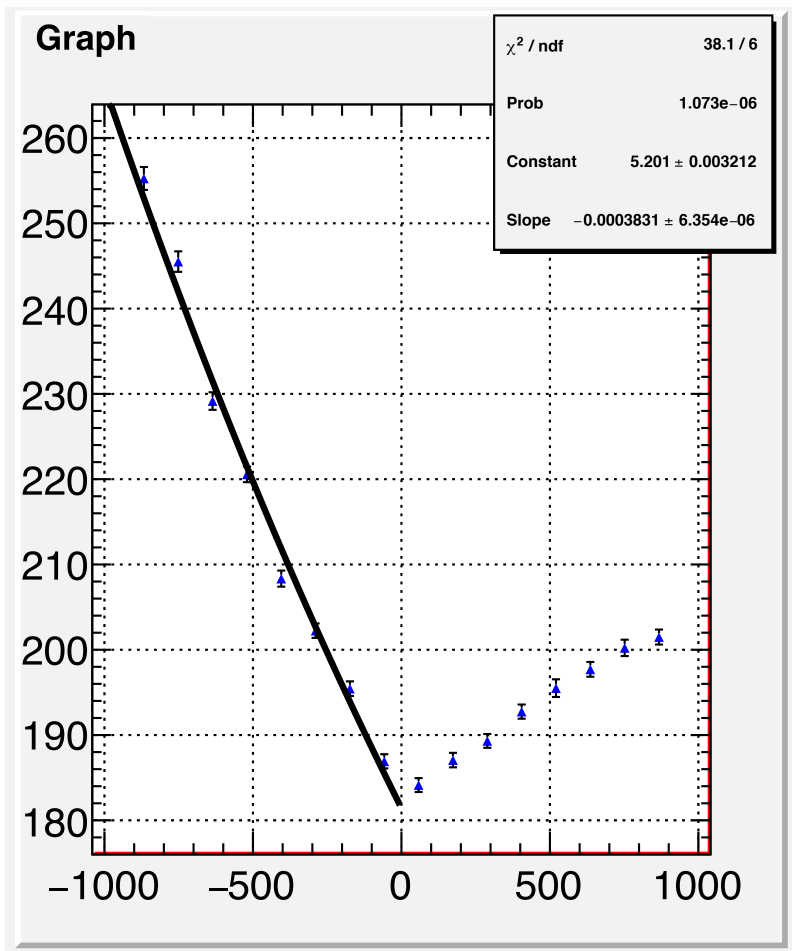


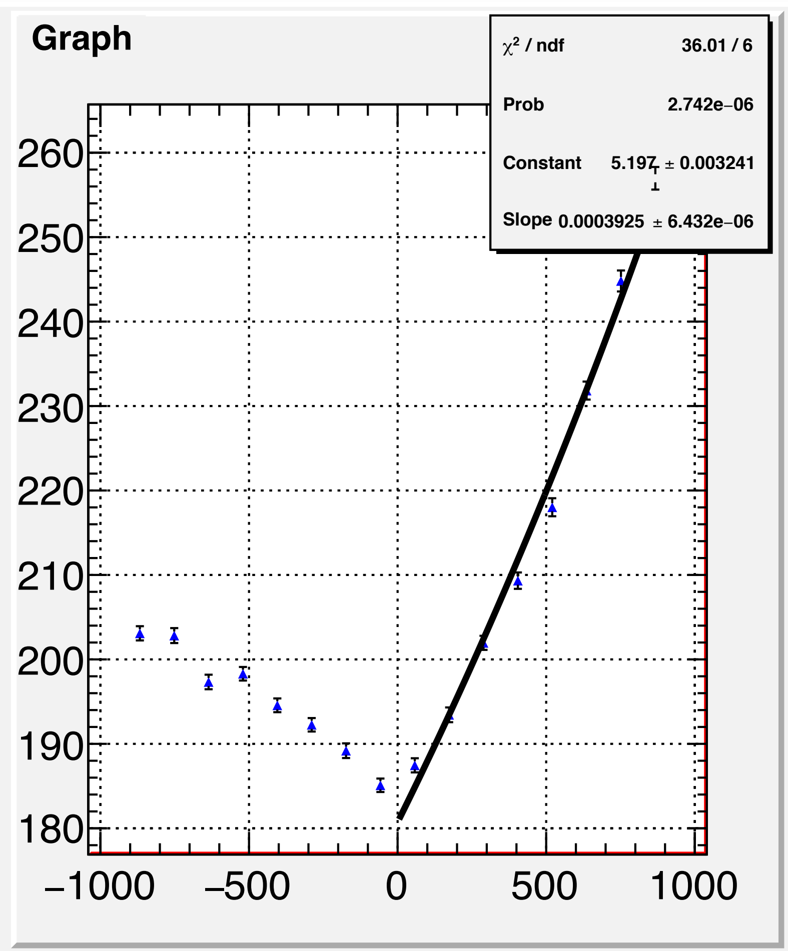
4. Data Analysis[6]

MIP Integrated ADC to Pulse Peak Ratio



4.BACKUP[7]



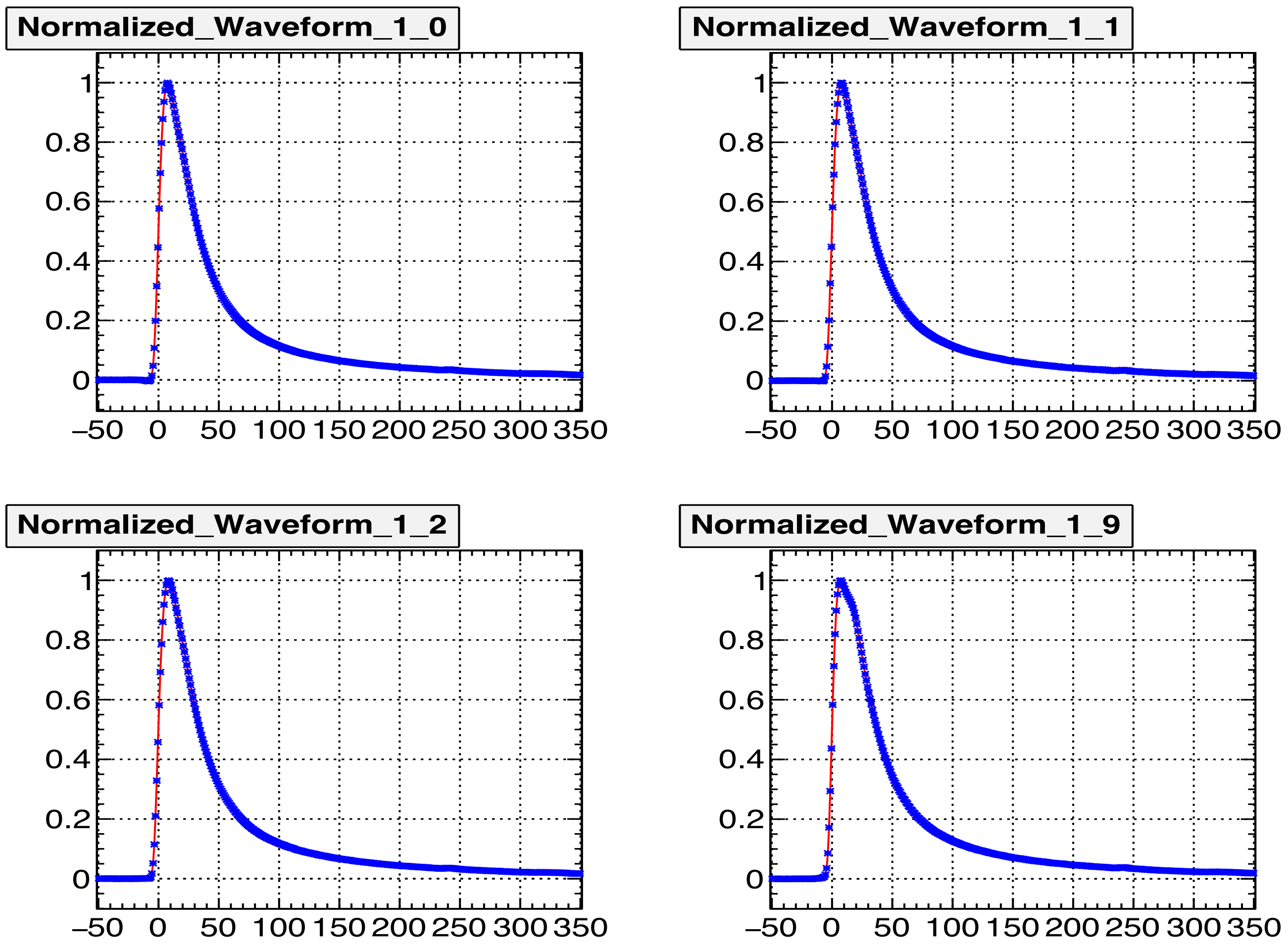


$$P = p_o e^{-\frac{x}{\lambda}}$$

Fitting function with λ = 1/slope = attenuation length

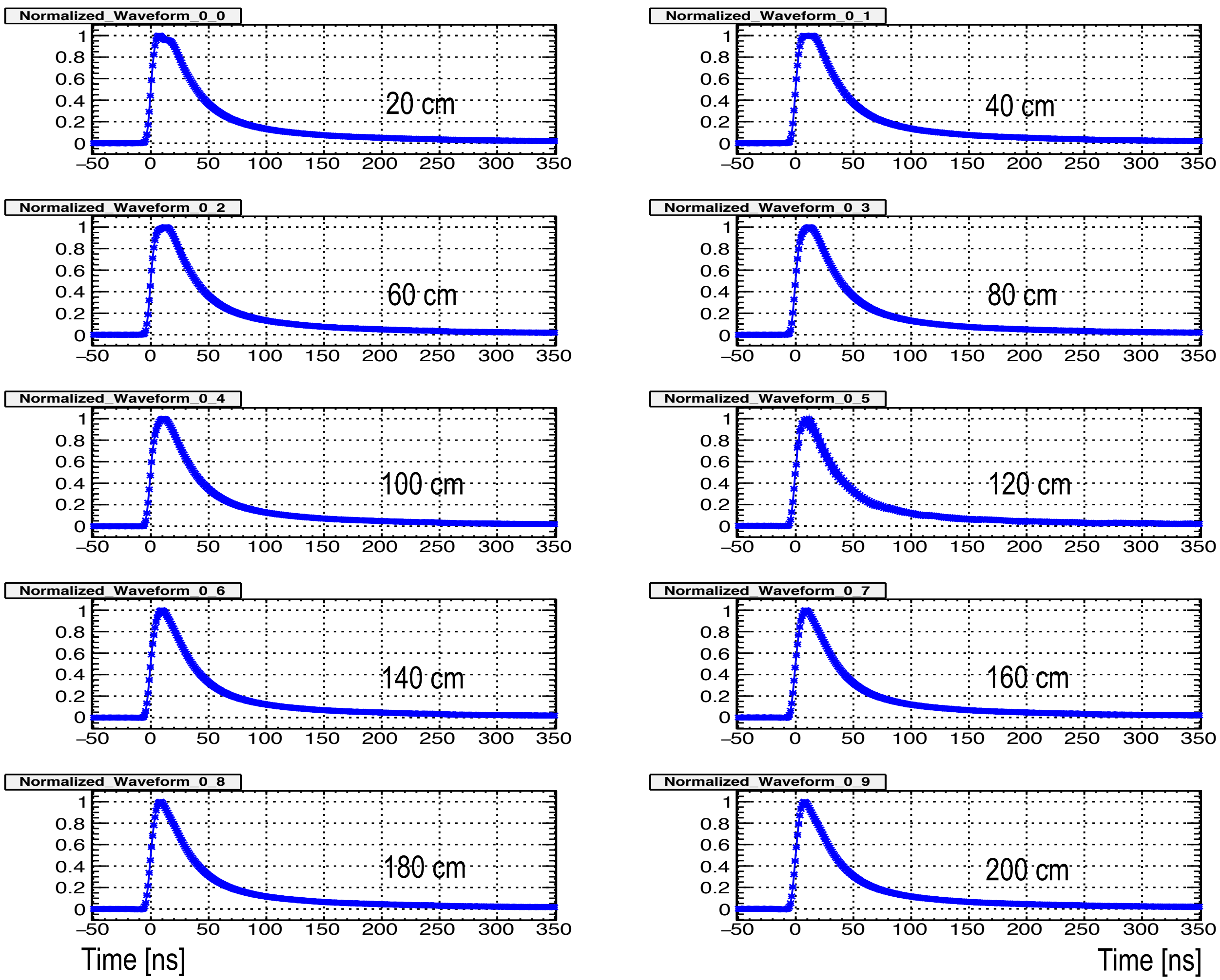
4.BACKUP[8]

Waveform by Position along the Scintillator's Length Right PMT



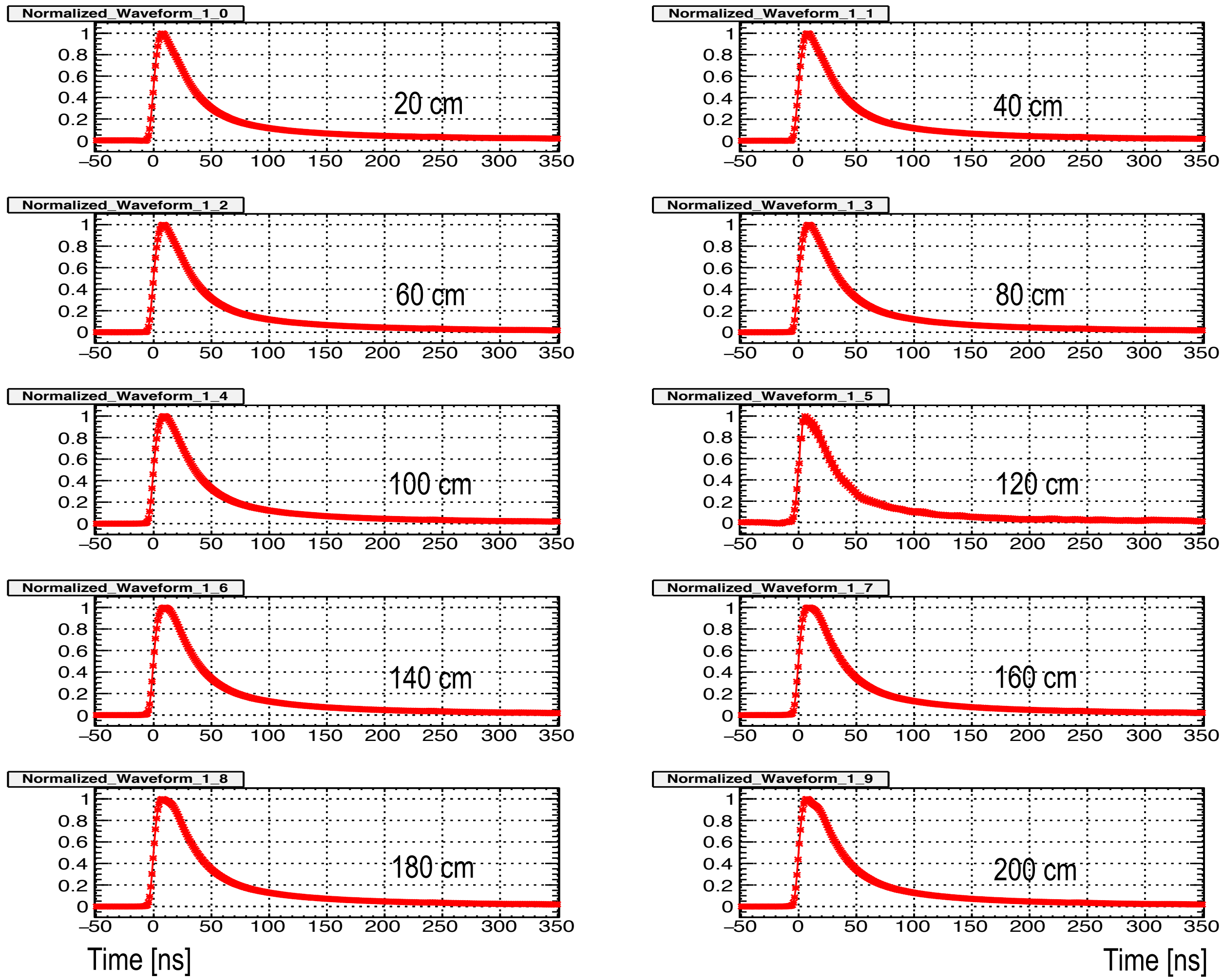
4.BACKUP[9]

Waveform by Position along the Scintillator's Length Left PMT



4BACKUP10

Waveform by Position along the Scintillator's Length Right PMT



4.Data Analysis[11]

Waveform Delta along the Scintillator's Length Right PMT