Waveform fitting

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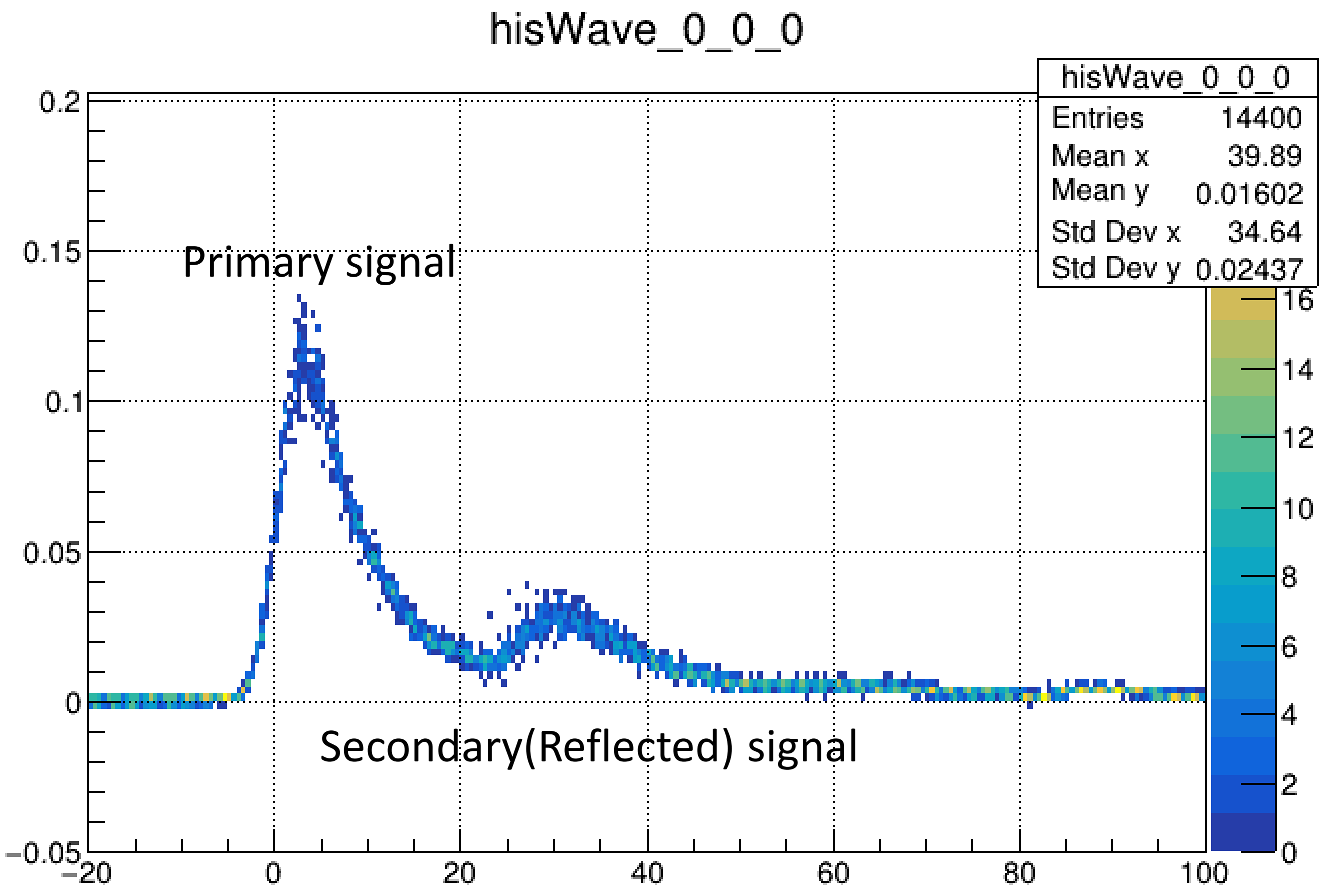
LAMPS

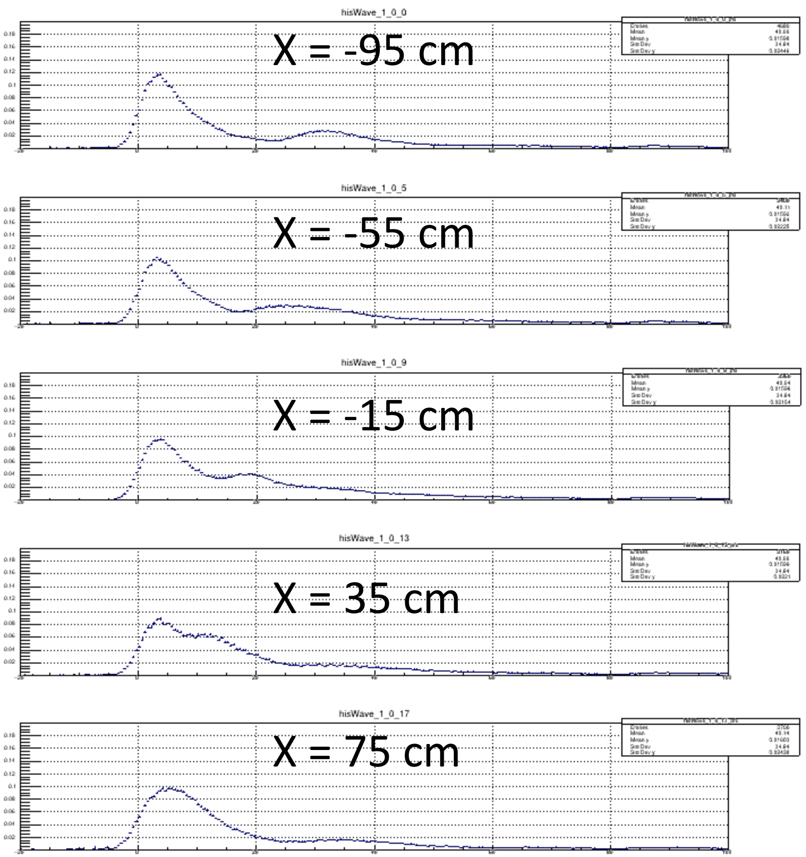
CENuM

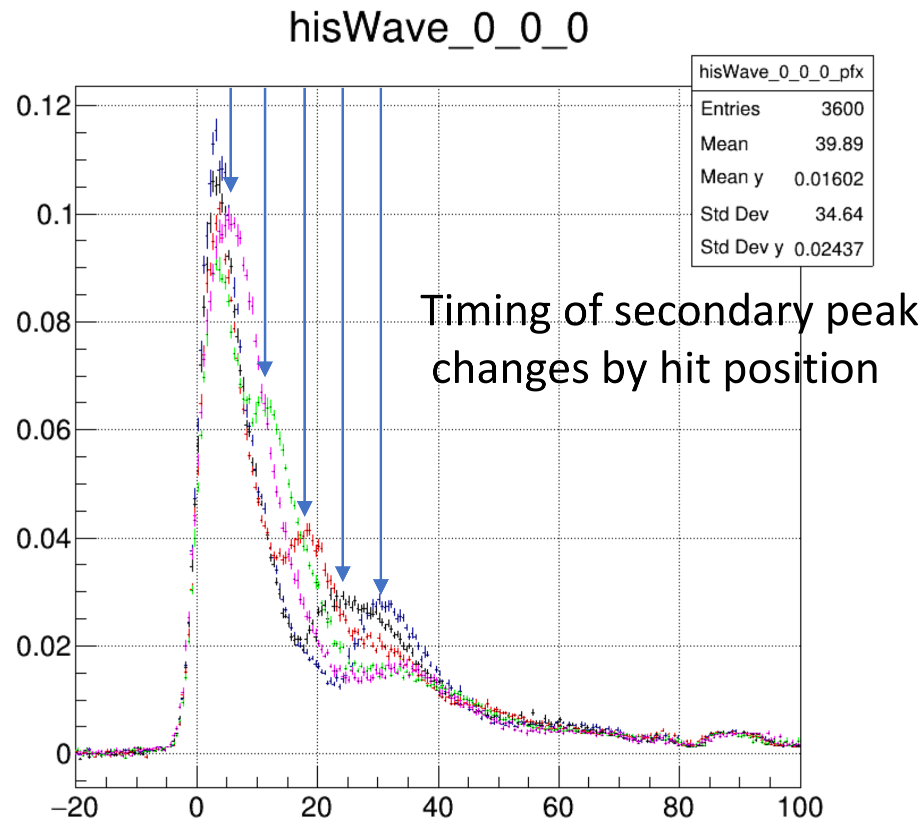
Typical waveform of neutron detector by position

- Normalize waveform with its area and move in x(time).
- Get typical waveform from 2D histogram's profile.



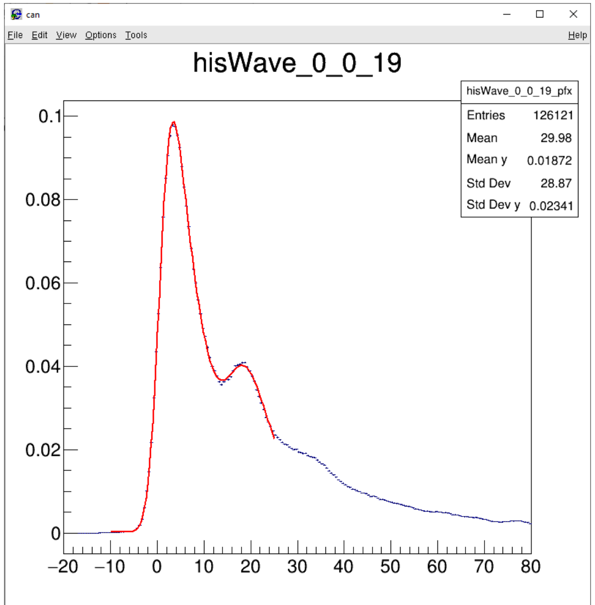
Typical waveforms by position

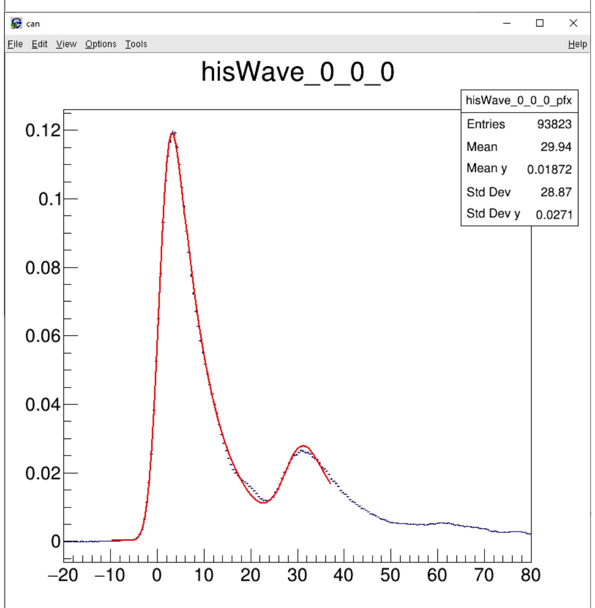




Can we describe waveforms with some function?

Neutron detector waveform fitting



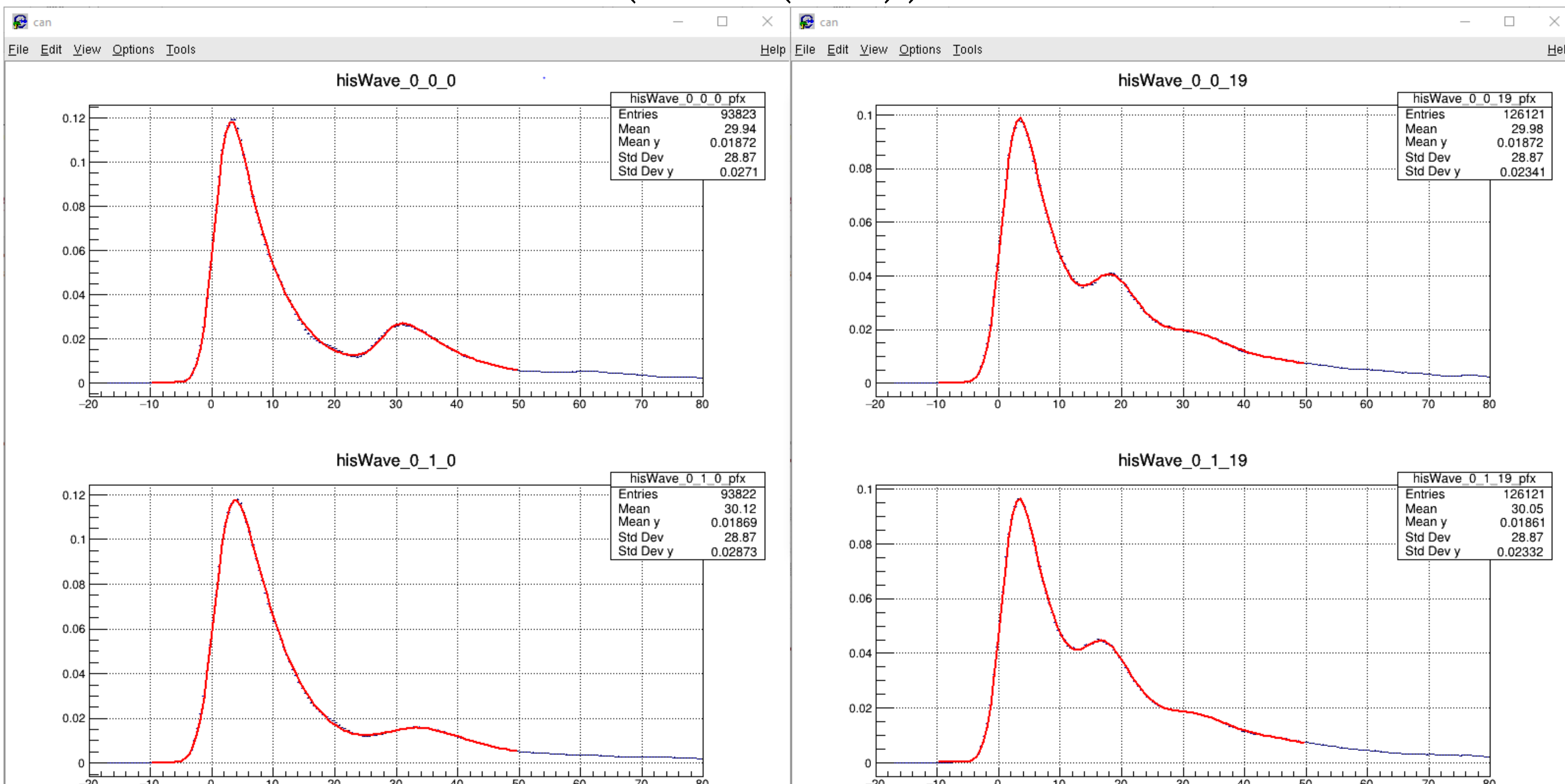


- Fitting with two function
  - Make typical waveform by 5 cm width.(41 waveforms for single channel)
  - Looks good, some wave did not fit well.
  - Fitting is affected small components at 20~50 ns region.
  - The components changes by hit position.
  - But timing is same.
  - Additional wave from light reflected two times? (4.x m difference)

New fitting function ver. 2

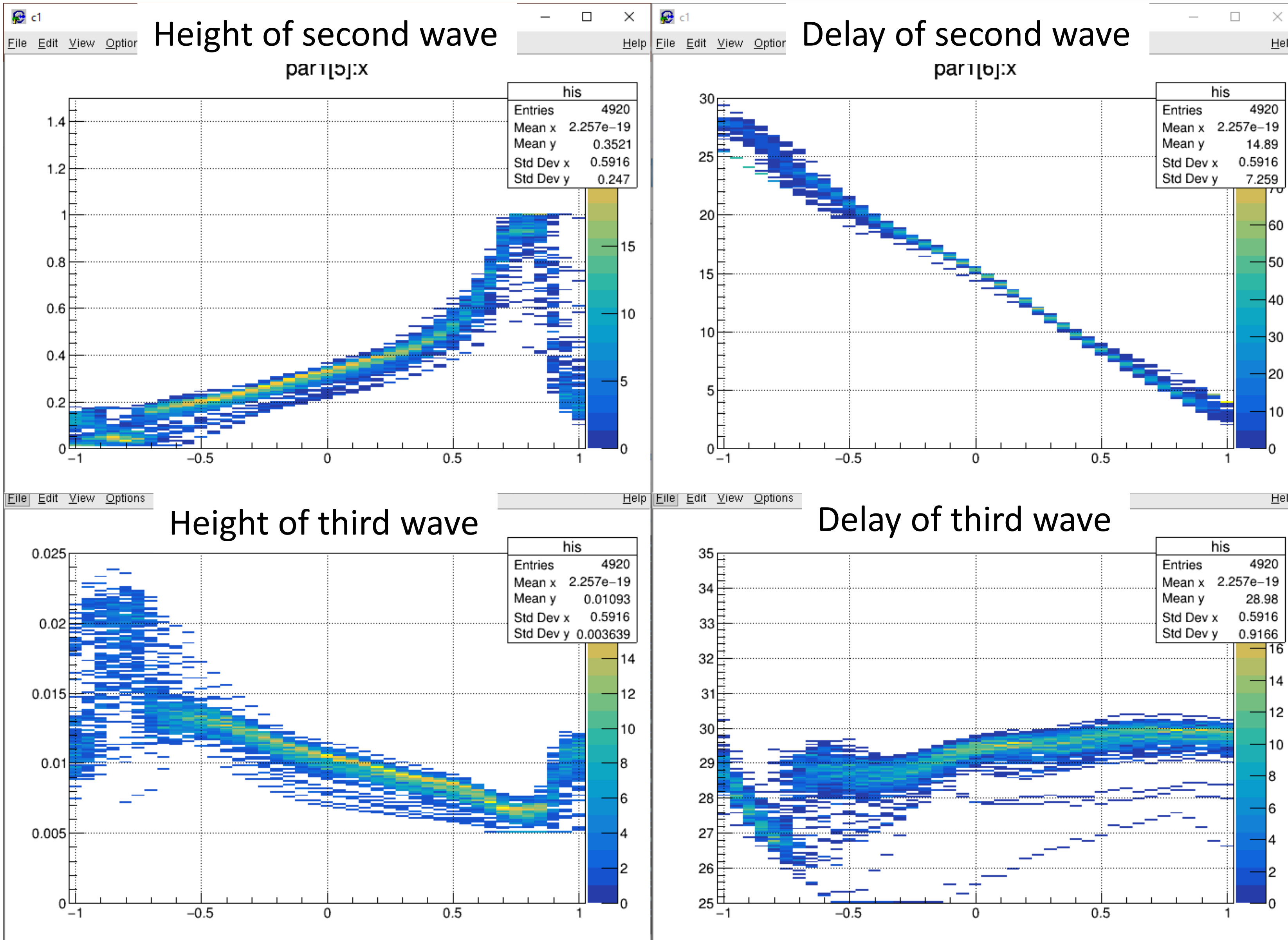
$$H \times \{ f(x, t, \sigma_r, \sigma_d) + h' f(x, t + t_d, \sigma_r', \sigma_d') \}$$
$$\underline{+H' \times \{ f(x, t + t_4, \sigma_r + \Delta, \sigma_d + \Delta) + h' f(x, t + t_4, \sigma_r + \Delta, \sigma_d + \Delta) \}}$$

$$f(x, t, \sigma_r, \sigma_d) \coloneqq \left(1 + \mathrm{erf}\left(\frac{x - t}{\sigma_r}\right)\right) \exp\left(-\frac{x - t}{\sigma_d}\right)$$



Fitting result checked for 41x120x2 waveforms

Fitting parameter distributions by x (120 modules)



Fitting function ver. 3

Change Δ as function of delayed time (= Wave packet spreads by spread length).

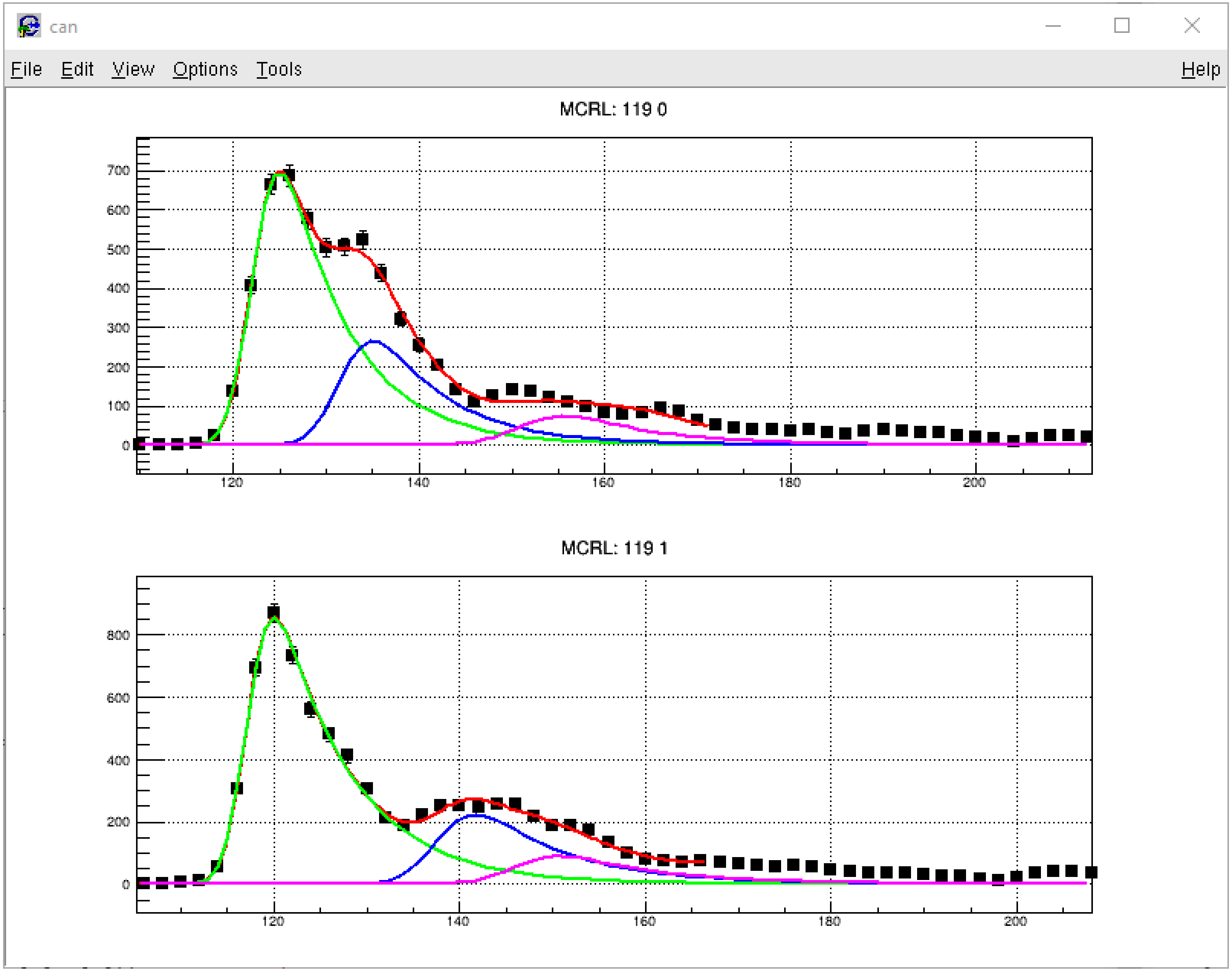
$$
\begin{aligned}
&H \times \{ f(x, t, \sigma_r, \sigma_d) + h' f(x, t + t_d, \sigma_r', \sigma_d') \} \\
&+H' \times \{ f(x, t + t_4, \sigma_r + \Delta \times t_4, \sigma_d + \Delta \times t_4) \\
&+h' f(x, t + t_d + t_4, \sigma_r + \Delta \times (t_d + t_4), \sigma_d + \Delta \times (t_d + t_4)) \}
\end{aligned}
$$

$$
f(x, t, \sigma_r, \sigma_d) \coloneqq \left(1 + \mathrm{erf}\left(\frac{x - t}{\sigma_r}\right)\right) \exp(-\frac{x - t}{\sigma_d})
$$

For further analysis, some parameters were modified.
H’ -> H*Attenuation(t_d)*(reflectivity)
h’ -> H*Attenuation(t_d+t_4)*(reflectivity)(reflectivity)

```
const Double_t AttbyTime = 33.451417;
Double_t f8( Double_t *x, Double_t *p ){
  Double_t AttRef = TMath::Exp(-p[6]/AttbyTime );
  Double_t Att4m  = TMath::Exp(-p[9]/AttbyTime );

  Double_t value = p[0]
    + p[1]*                 (TMath::Erf((x[0]-p[2]          )/(p[3]                   )) +1 )*TMath::Exp(-(x[0]-p[2]          )/p[4]   )                 // Primary
    + p[1]*p[5]*AttRef*     (TMath::Erf((x[0]-p[2]-p[6]     )/(p[3]+p[7]*p[6]         )) +1 )*TMath::Exp(-(x[0]-p[2]-p[6]     )/(p[4]+p[8]*p[6]))   // Secondary
    + p[1]*p[5]*p[5]*Att4m* (TMath::Erf((x[0]-p[2]-p[9]     )/(p[3]+p[7]*p[9]         )) +1 )*TMath::Exp(-(x[0]-p[2]-p[9]     )/(p[4]+p[8]*p[9]))   // 4m delay, Primary
    + p[1]*p[5]*p[5]*Att4m*AttRef*(TMath::Erf((x[0]-p[2]-p[6]-p[9])/(p[3]+p[7]*(p[6]+p[9]    ))) +1 )*TMath::Exp(-(x[0]-p[2]-p[6]-p[9])/(p[4]+p[8]*(p[6]+p[9])));// 4m delay, Secondary
  return value;
}
```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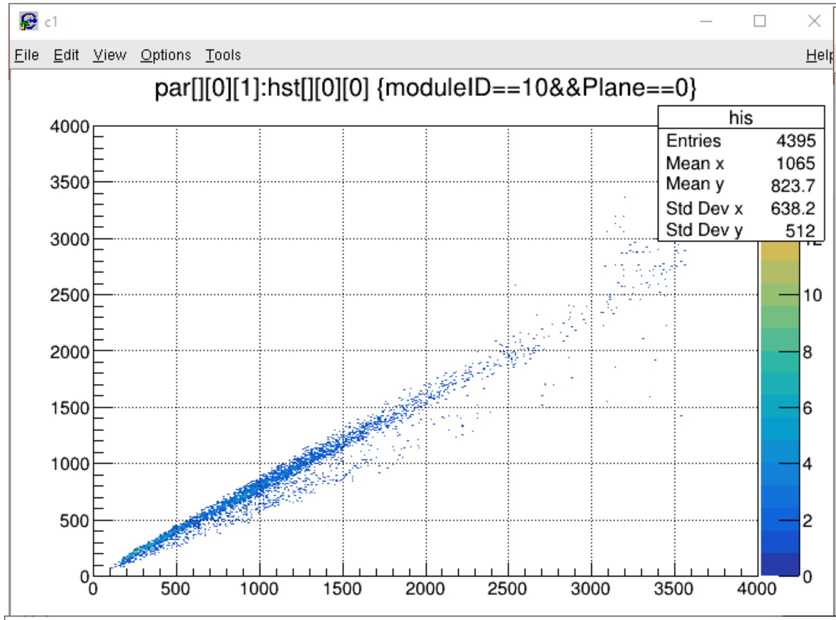
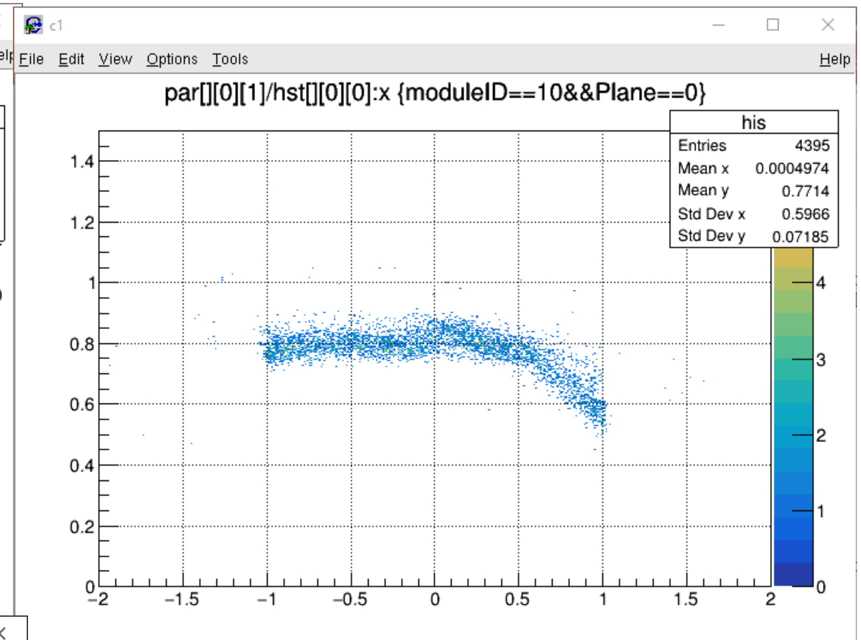
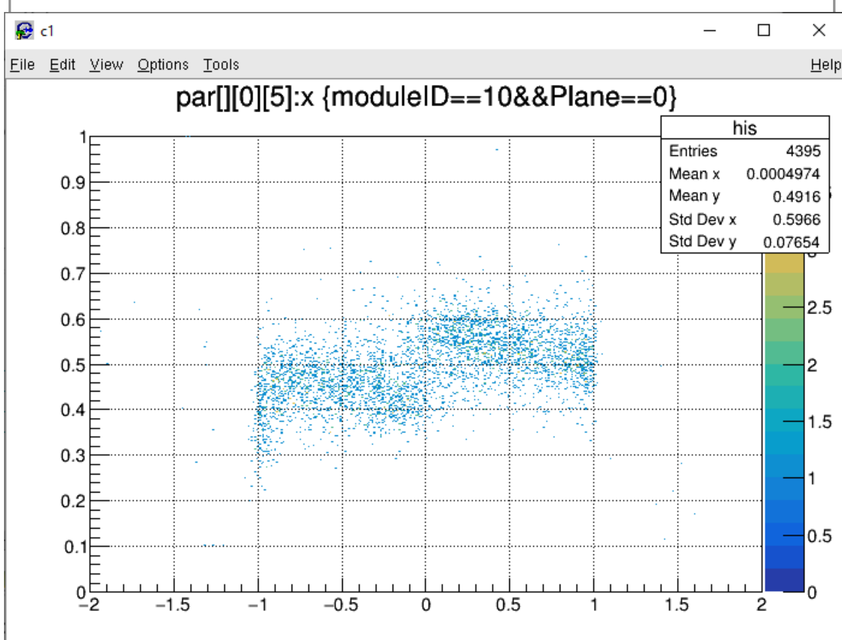
Fitting results(1) – Height & Reflectivity

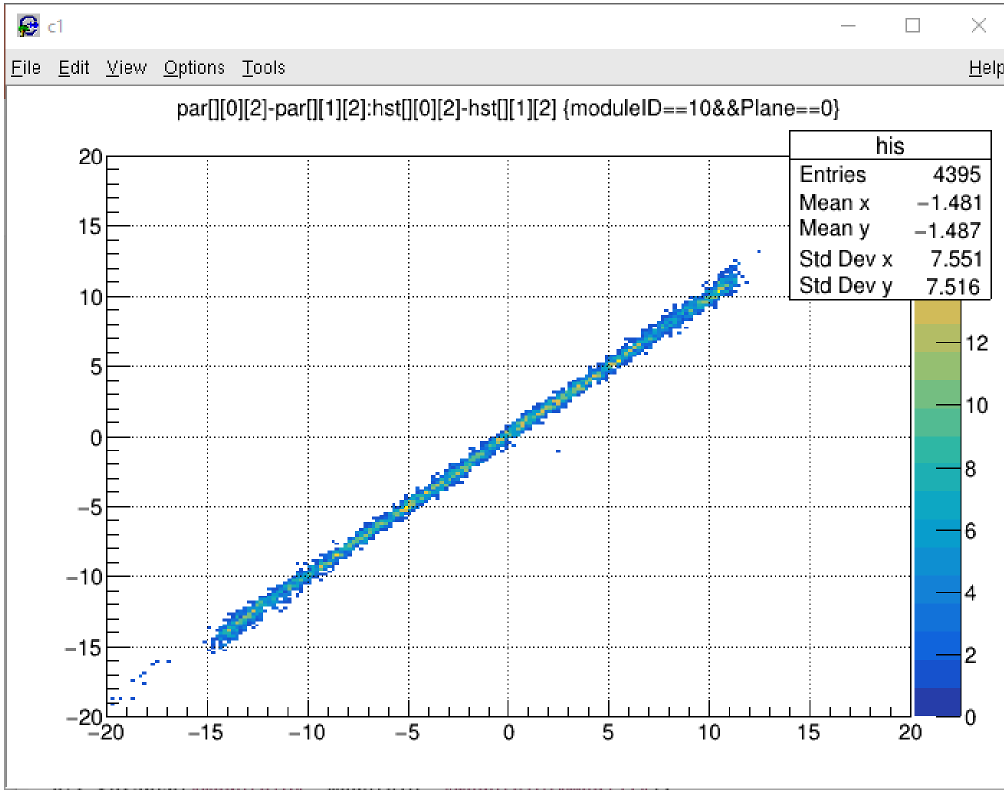


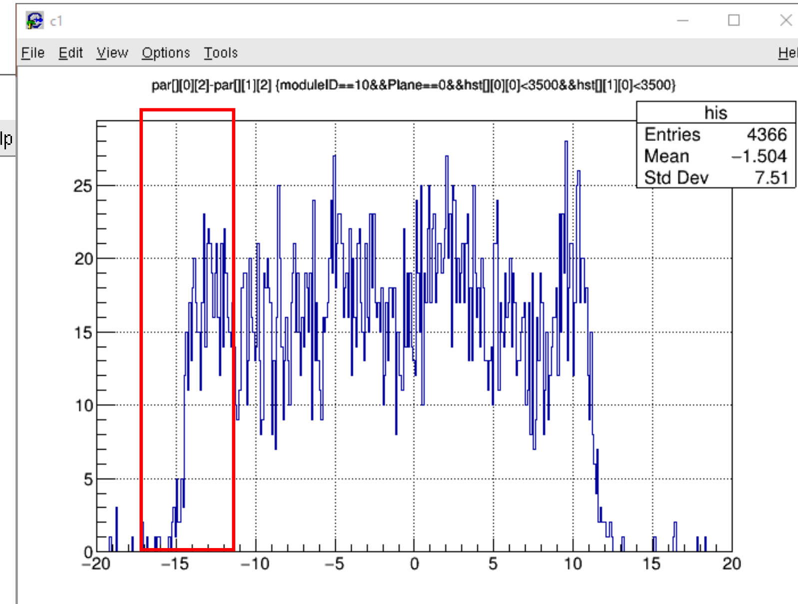


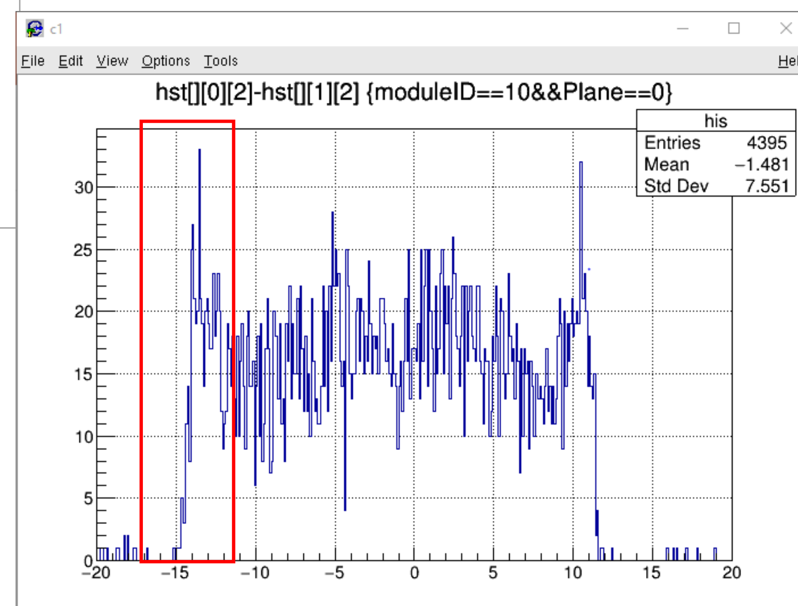


Height of function is proportional with height of waveform.
(Height of function)/(Height of waveform) shows shoulder effects at x>0.5 m.

Fitting result(2) - Timing

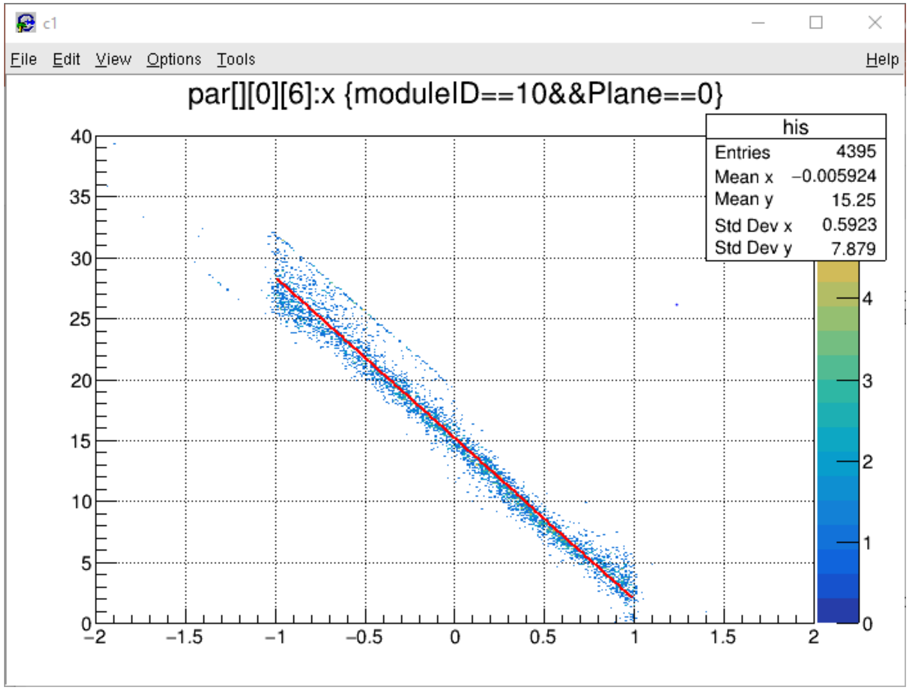


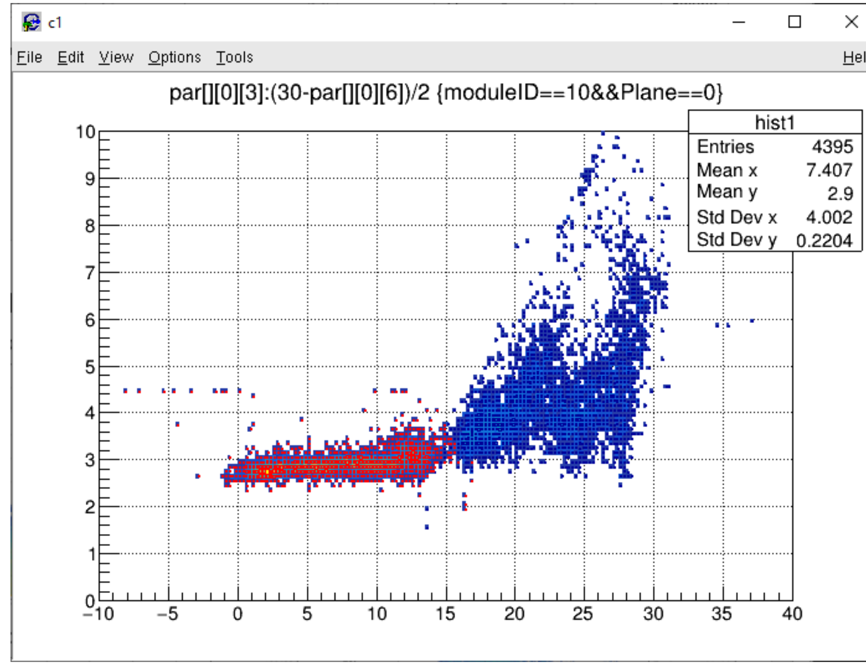




Peaks at end points were disappeared.

Fitting result(3) – Timing delay & Rising Slope





Fitting with pol1.
$F(x) = 15.18 - 13.21x$
$F(1) = 1.93$ ns ->Offset by light guide

X axis : Propagation time
Y axis : Rising slope of function
Red dots : Rising slope of Primary
Blue dots : Rising slope of Secondary