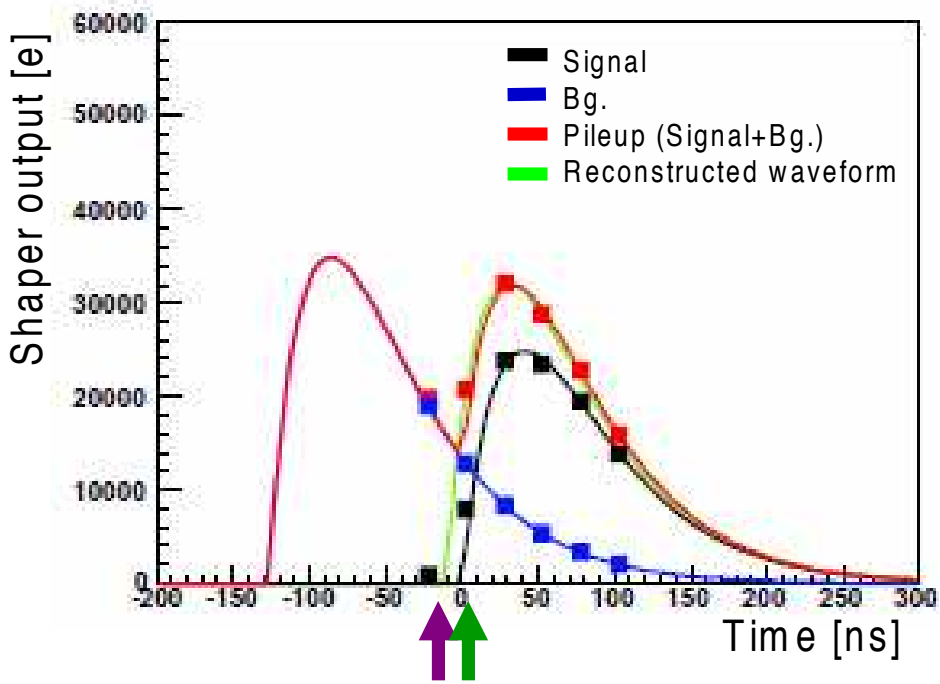
Pulse pileup

- We are concerned with the sum $f_{sum}(t)$ of two pulses — signal pulse $f_{sig}(t)$ with peak height A_{sig} and hit time t_{sig}, background pulse $f_{back}(t)$ with peak height A_{back} and hit time t_{back}
- For $t < max(t_{sig}, t_{back})$, we see only the first of the pulses
- But the sum of two shaping curves fits exactly to a shaping curve with different height and hit time



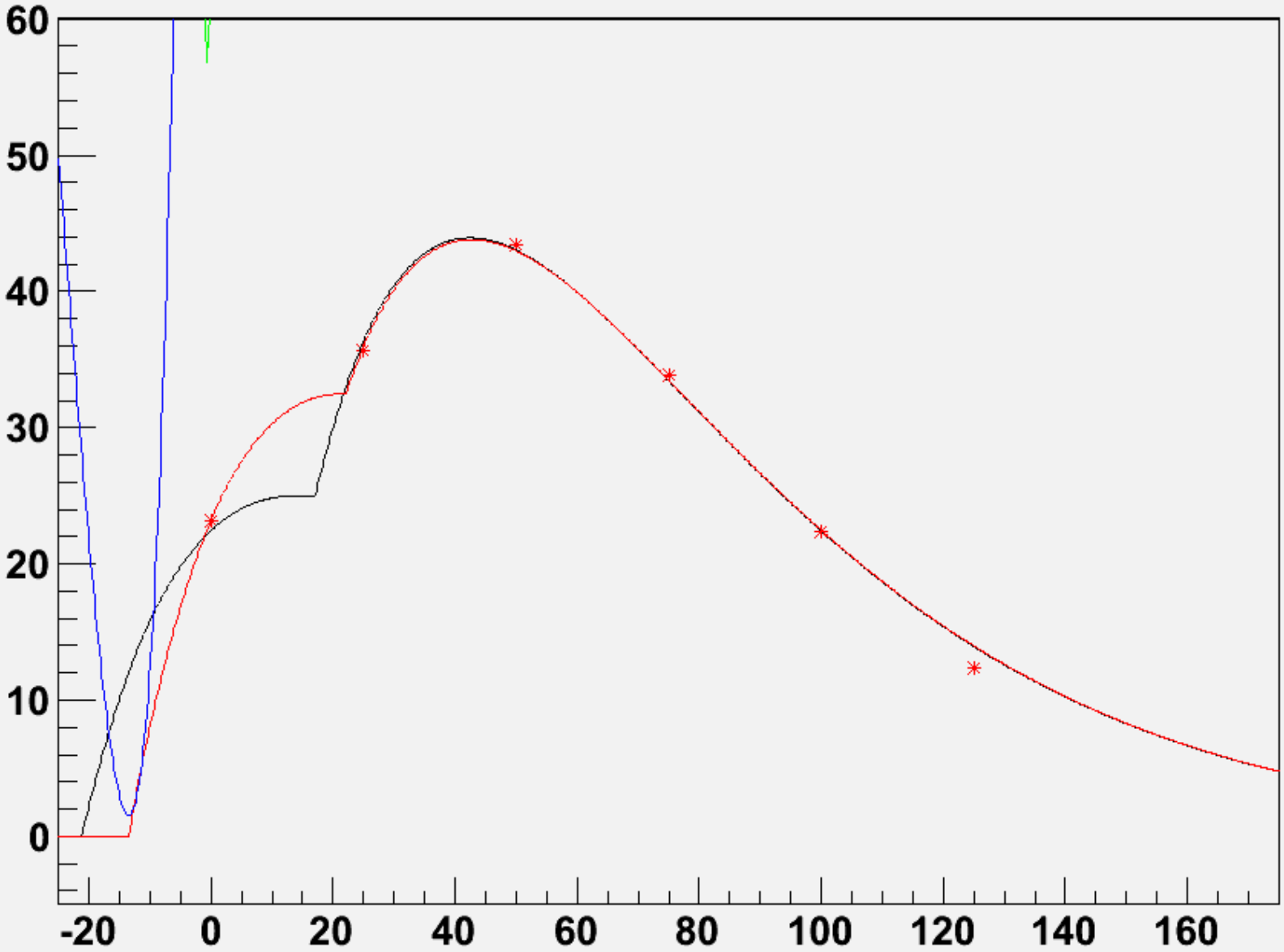
Effects of pileup

- $t_{sum} = \frac{A_{sig} t_{sig} e^{t_{sig}/T} + A_{back} t_{back} e^{t_{back}/T}}{A_{sig} e^{t_{sig}/T} + A_{sig} e^{t_{sig}/T}}$
- $A_{sum} = e^{-t_{sum}/T}(A_{sig}(t_{sum} - t_{sig} + T)e^{t_{sig}/T} + A_{back}(t_{sum} - t_{back} + T)e^{t_{back}/T})$
- This causes the fitted time to be "pulled" by the background hit time:
  $t_{sum} - t_{sig} = (t_{back} - t_{sig}) \frac{A_{back} exp^{(t_{back} - t_{sig})/T}}{A_{sig} + A_{back} exp^{(t_{back} - t_{sig})/T}}$
- If we can get the background peak height and time, we can correct for this

Cases

- Signal and background fall in the same clock cycle $\rightarrow$ no samples before pileup
  - No way to identify this; can estimate error based on background rate and height distribution
- Signal and background are one clock cycle apart $\rightarrow$ 1 sample before pileup
  - Can't fit exactly (relative heights of the two pulses is undetermined), but at least we know there's background
- Signal and background are more than clock cycle apart
  - If we have at least 2 samples above threshold before pileup, and 2 after, we can fit everything
  - 3 after pileup is ideal (lets us know if there's more than one background pulse)

One cycle apart

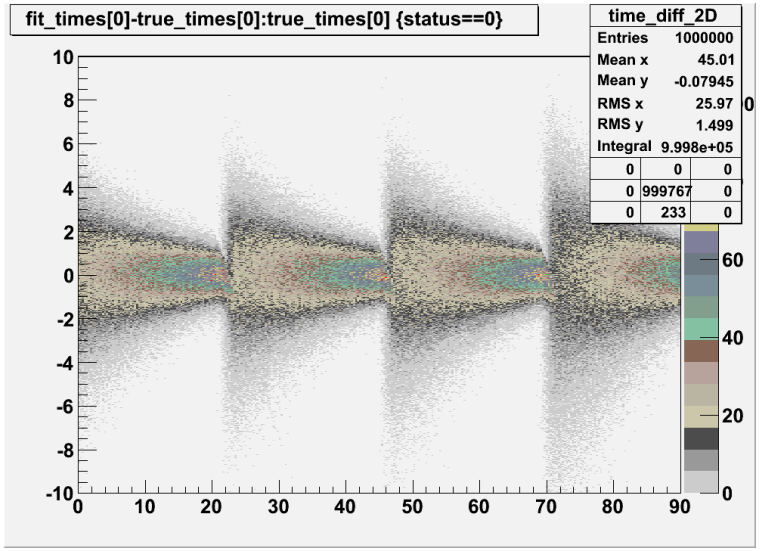


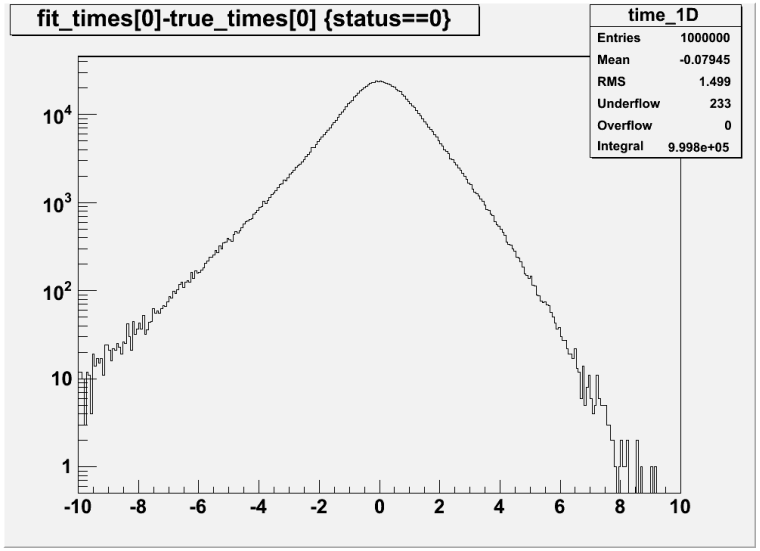
The fitter

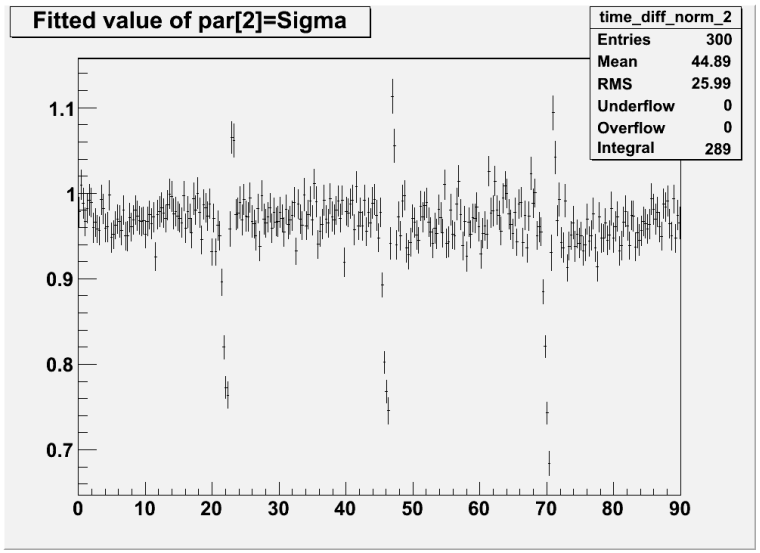
- Three approaches:
  - Fully nonlinear: use Minuit to fit times and heights
  - Partly analytic: analytic fit for heights, given times; use Minuit for times
  - Fully analytic: analytic fit for everything (assumes perfect CR-RC shaping)
- These results are from fully analytic fitter
  - Step 1: fit sections of samples to CR-RC curves (i.e. samples 0-2, samples 3-5)
  - Step 2: use formulas to subtract background pulses
  - Step 3: Return the fit with the best χ^2

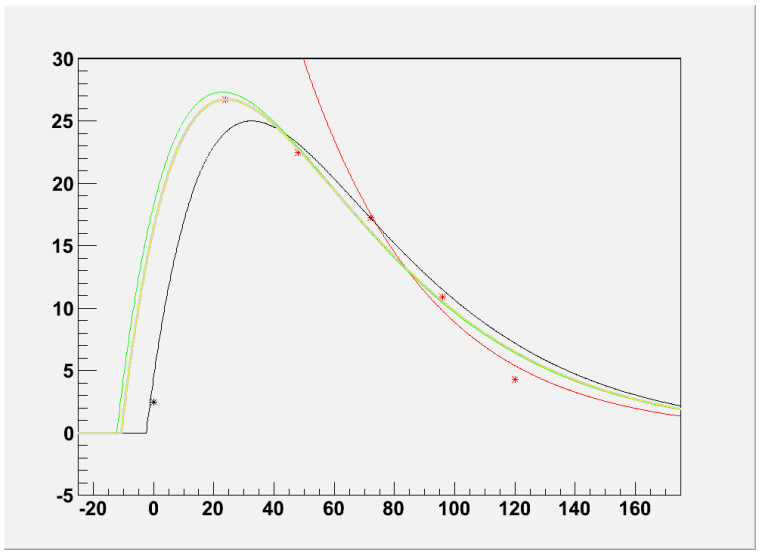
Single-peak timing

- Generate one pulse — height 25, Gaussian noise with $\sigma = 1$

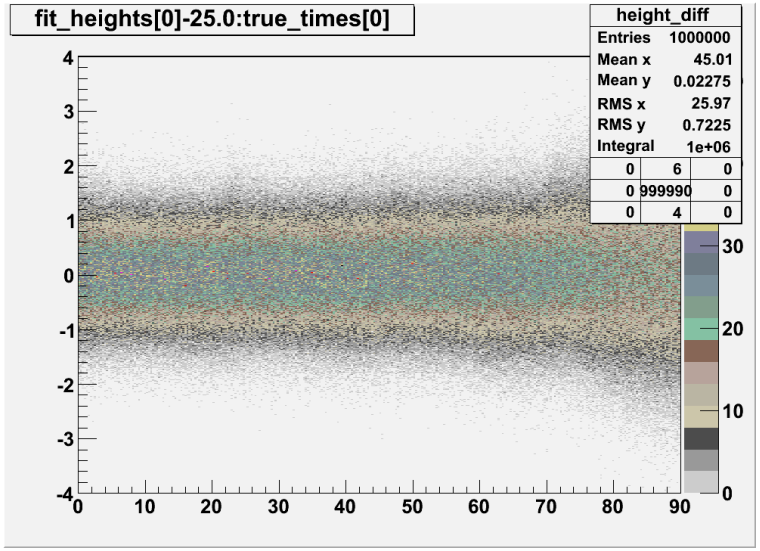


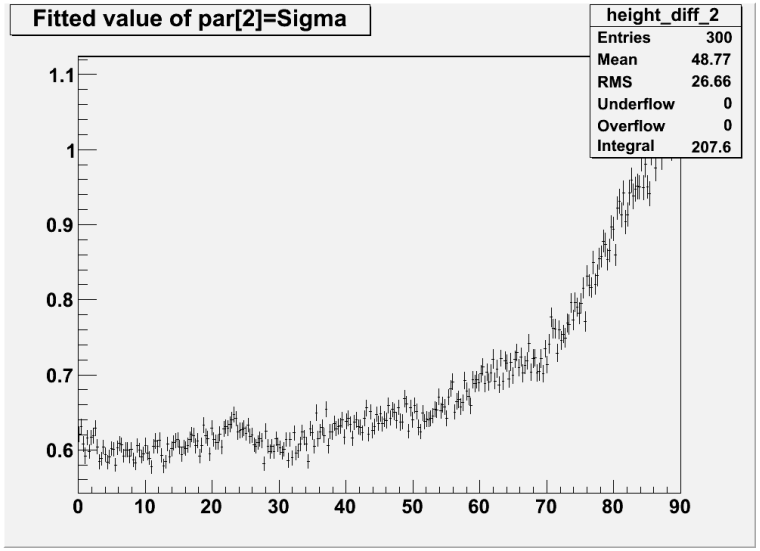




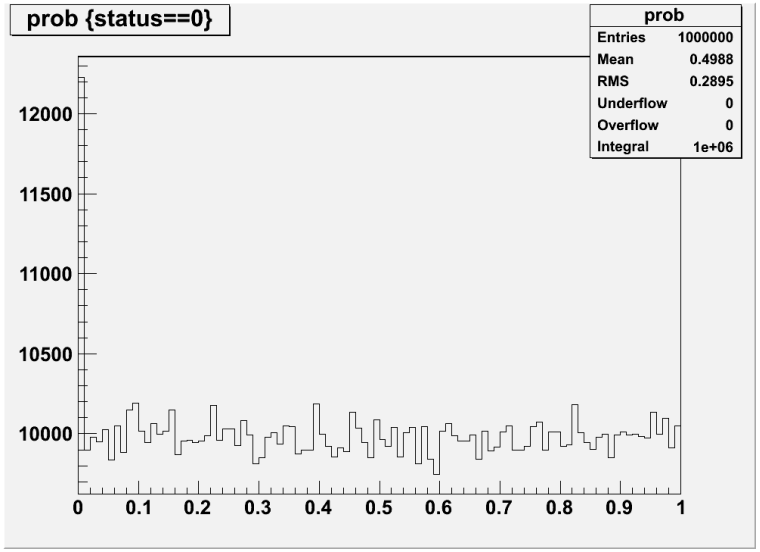


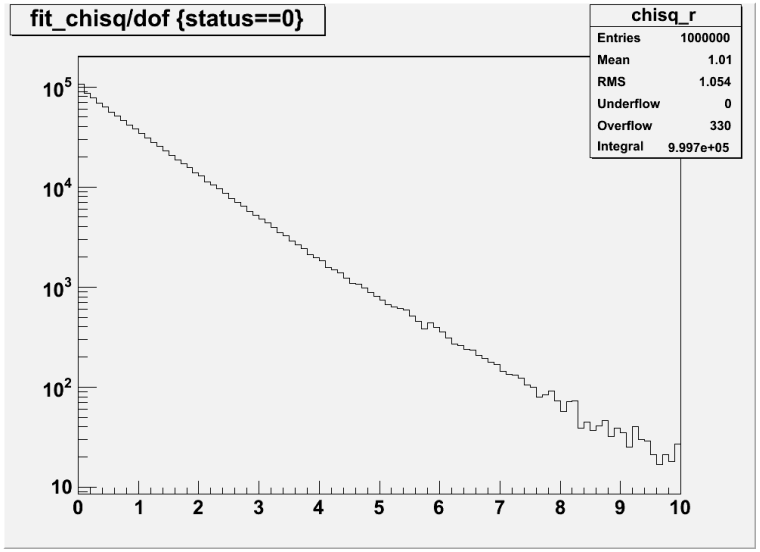
Single-peak height

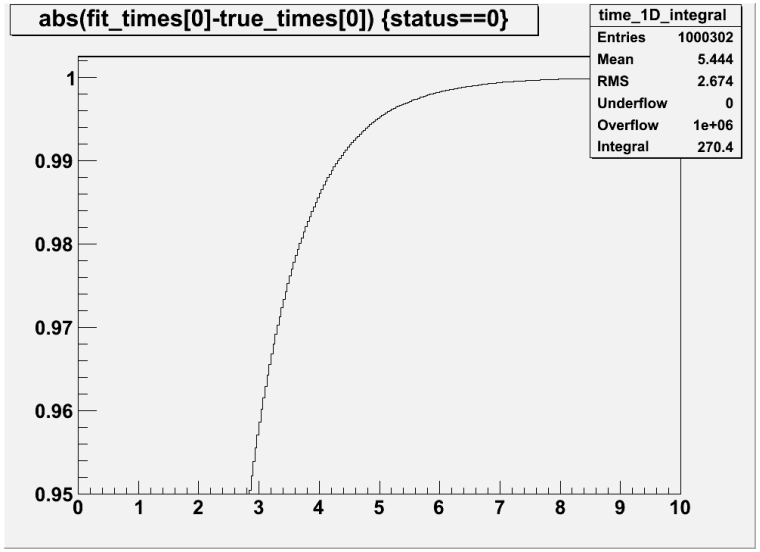


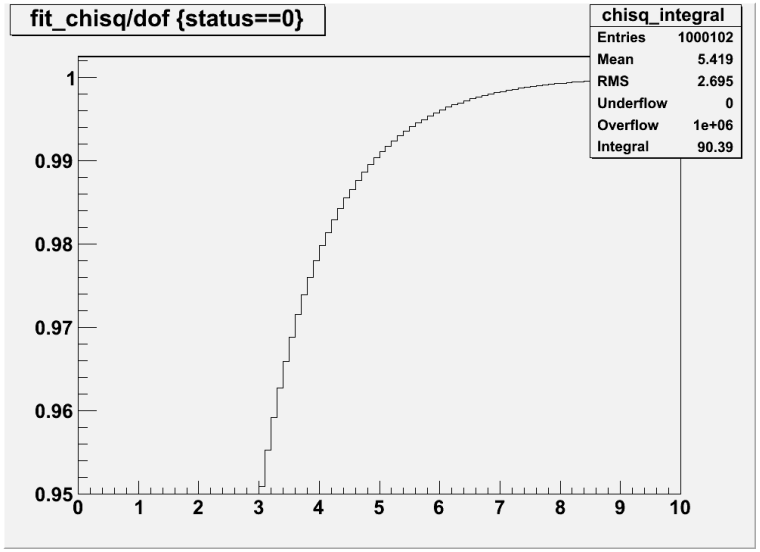


Single-peak cut efficiency



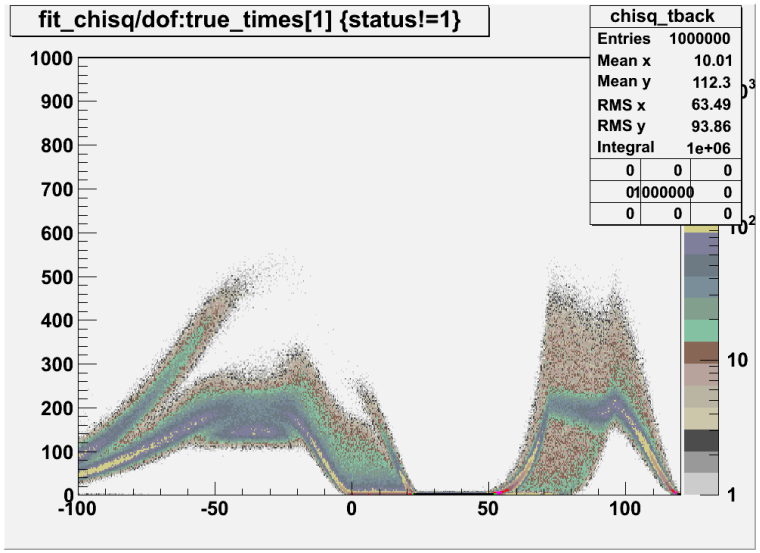


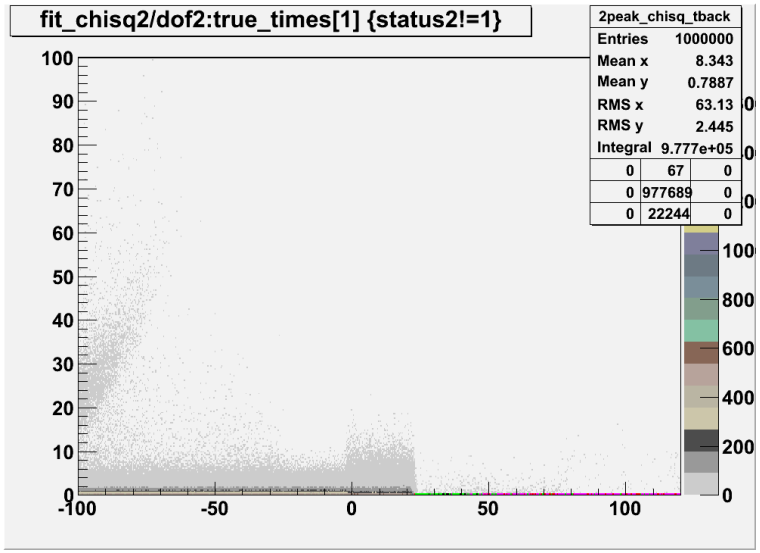


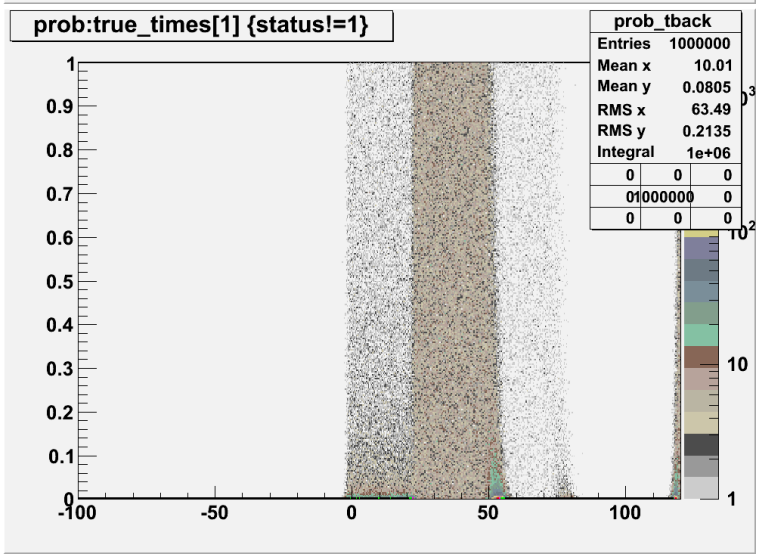


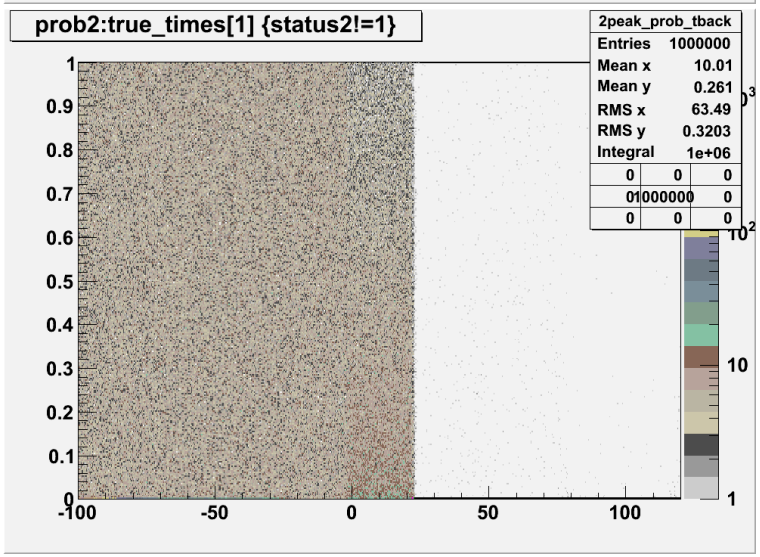
Two-peak fit

- Generate two pulses — $t_{sig} = [24, 48]$, $t_{back} = [-120, 100]$









Two-peak timing