PMT Non-Uniformity Test

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Outline

- Background
  - 8-inch MCP-PMT in Jinping Neutrino Experiment
- Test platfrom layout
- Waveform preanalysis
- Preliminary analysis
  - Relative detection efficiency
  - Transit time spread
- Summary

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Background

- Jinping Neutrino Experiment, focus on ~MeV neutrino events
  - Energy resolution
  - Time resolution

- Micro-channel Plate PMTs (MCP-PMTs)
  - Smaller transit time spread compared with dynode PMTs
  - Key parameters need to be measured   *A. Zhang, et al.*
  - ***Non-uniformity?***

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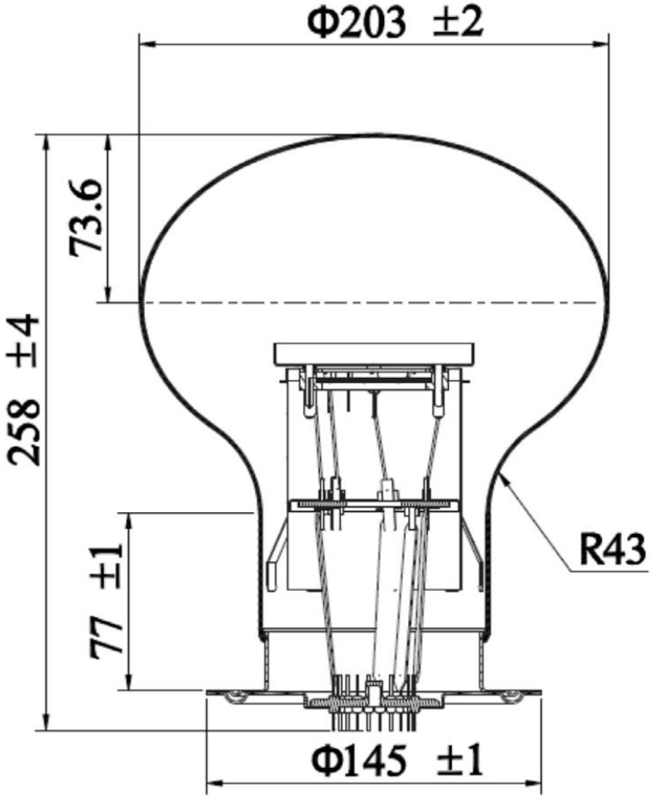
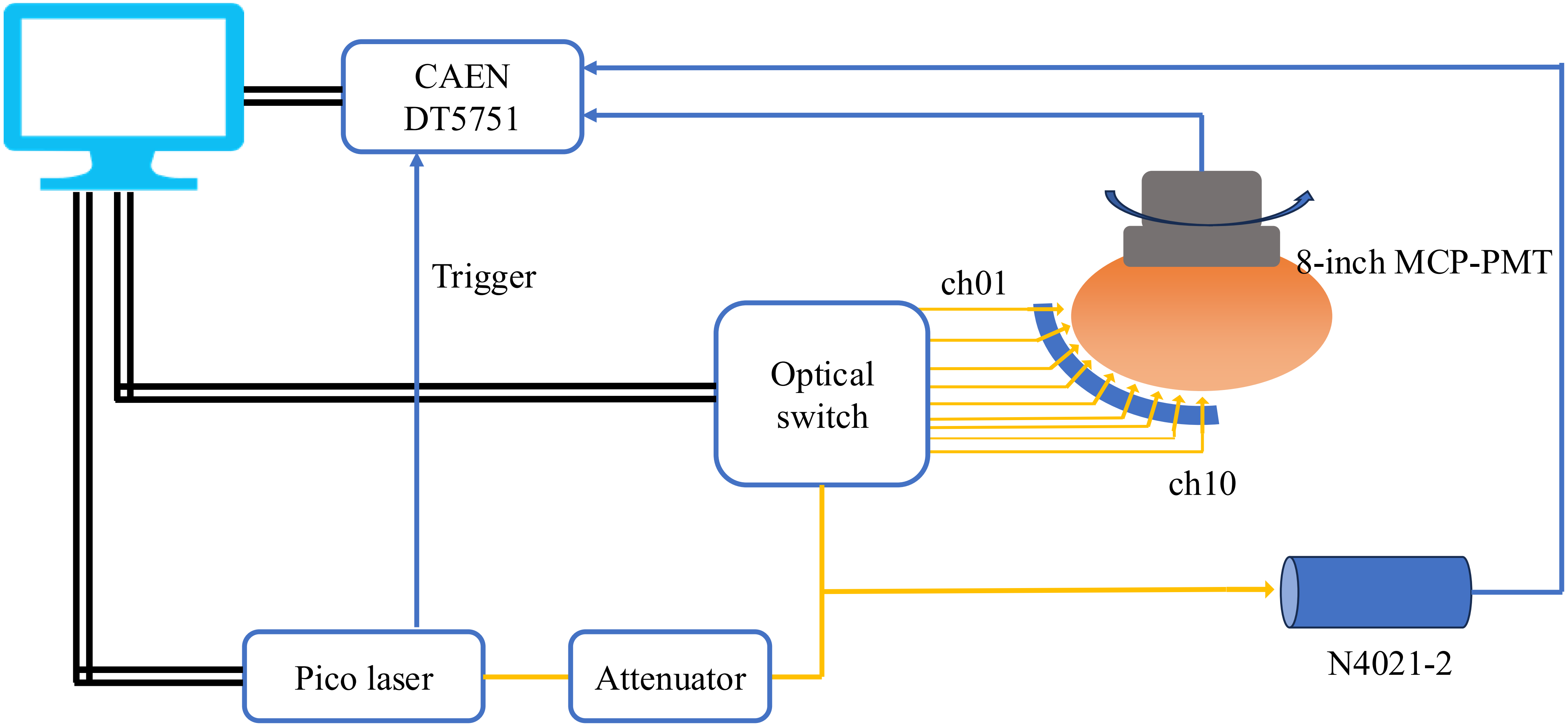
Tested PMT Models



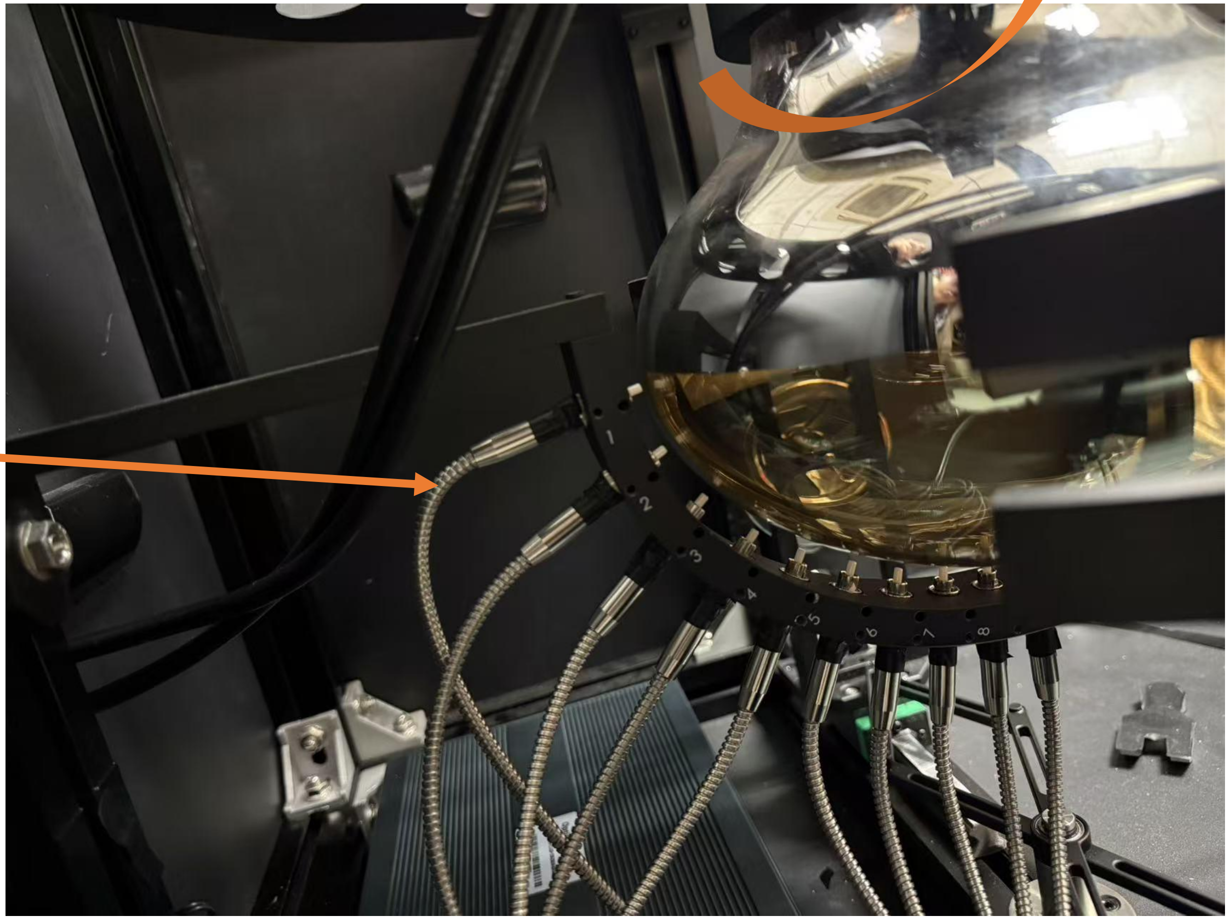
GDB-6082 MCP-PMT, produced by NNVT

Test Platform Layout



Photograph of the Test Platform

Optical fibers



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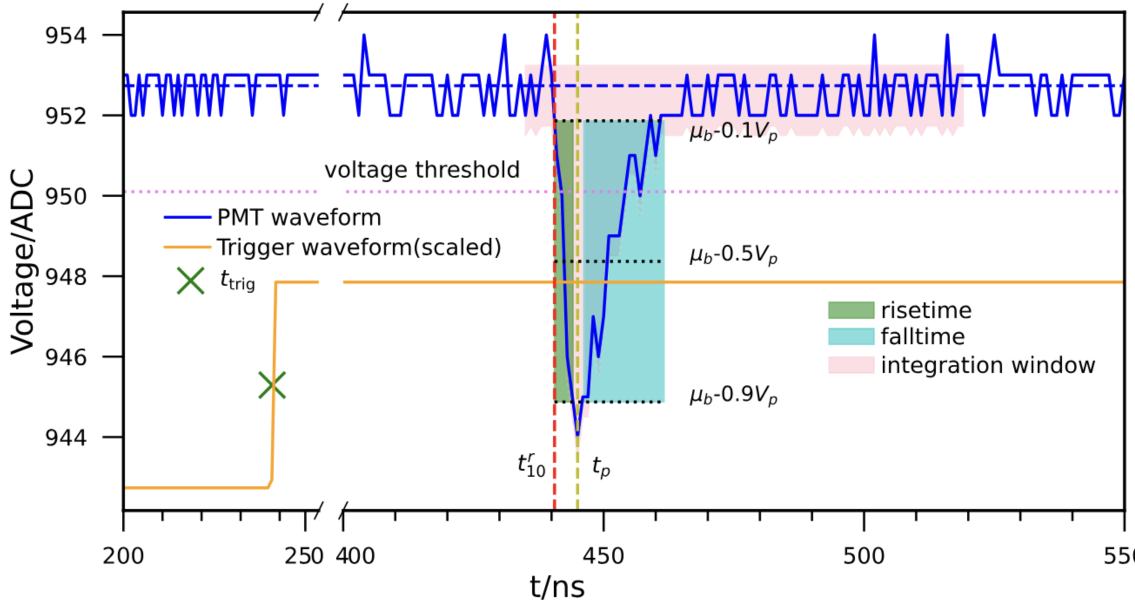
Waveform Pre-analysis *A. Zhang, et al.*

1. ~5% occupance to obtain single PE events

2. Find peak time t_p in a preliminary time window

3. Estimate baseline in window [-200ns, -10ns] relative to t_p



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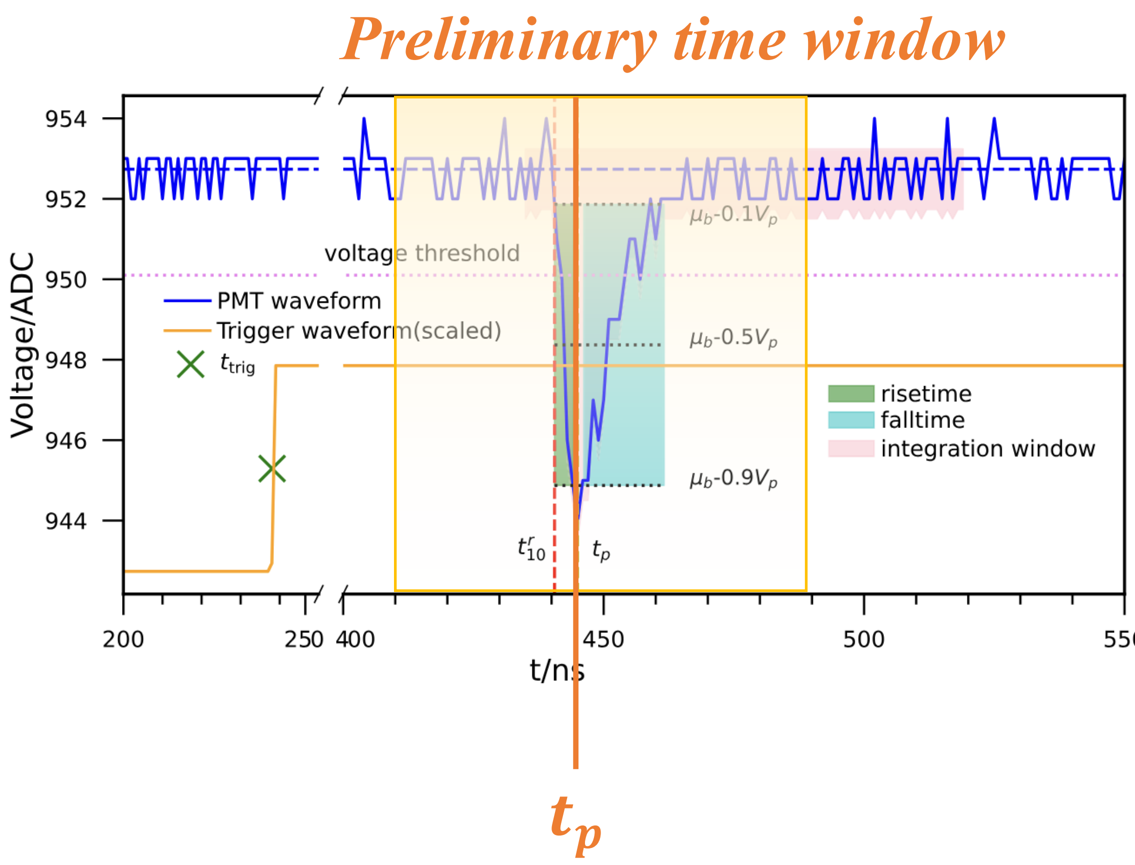

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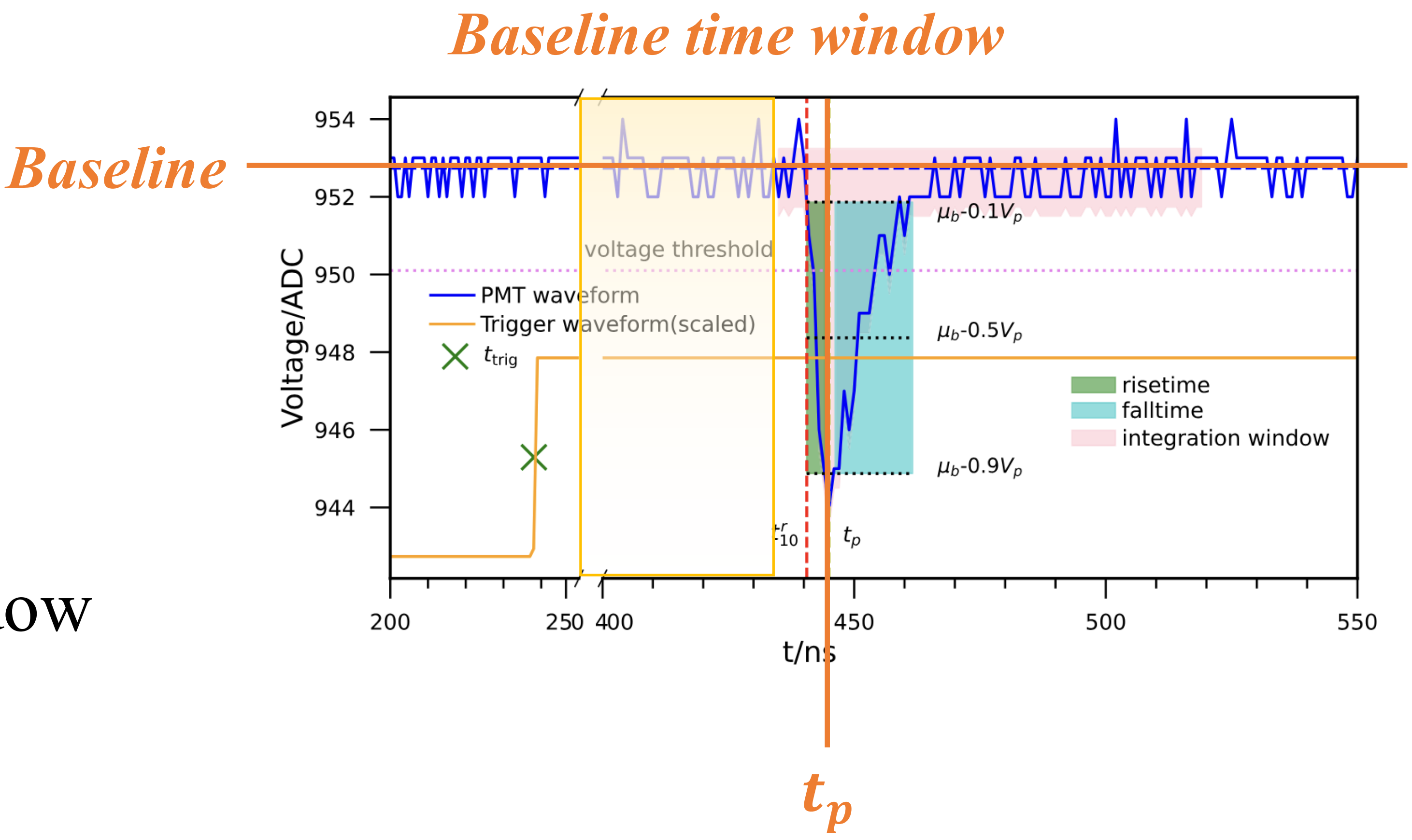
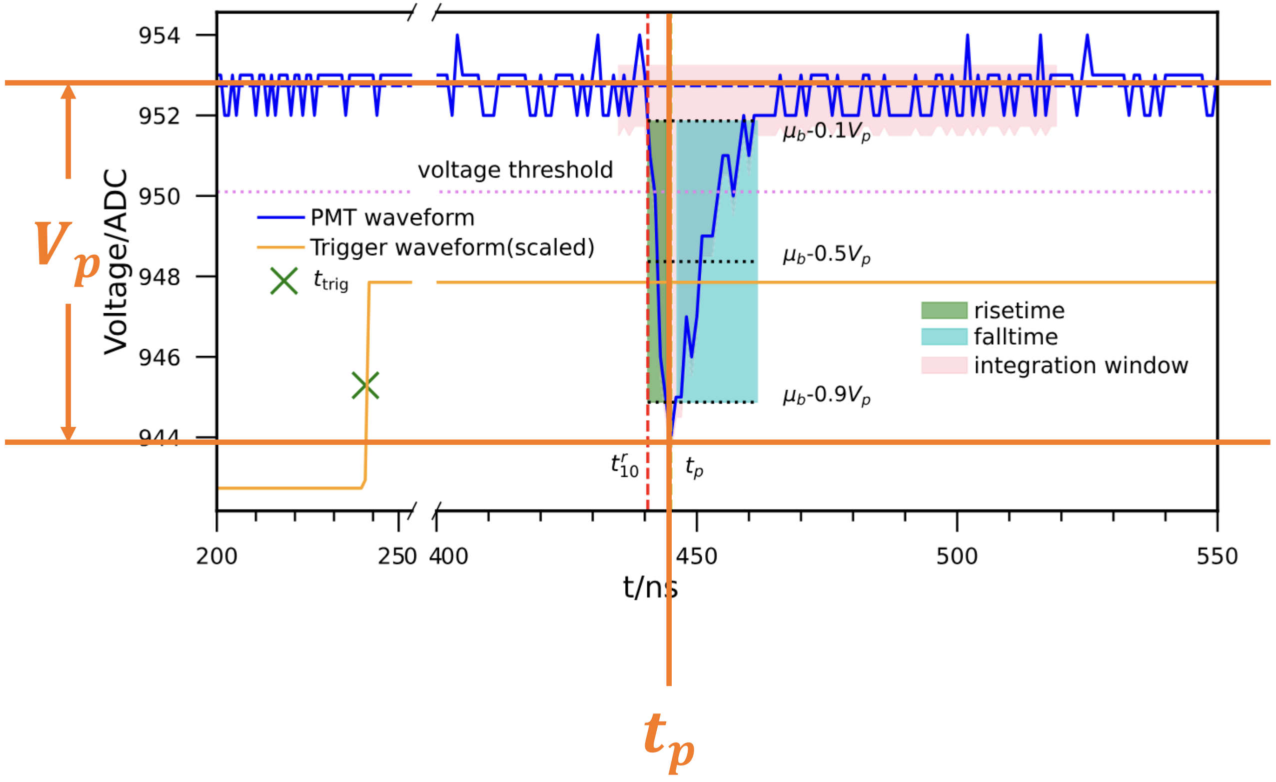


Waveform Pre-analysis *A. Zhang, et al.*

4. Obtain peak voltage V_p

5. Calculate relative rising edge time for events with $V_p > 5\text{mV}$

$$t_{\text{edge}} = t_r^{10\%} - t_{\text{trigger}}$$



Waveform Pre-analysis

A. Zhang, et al.

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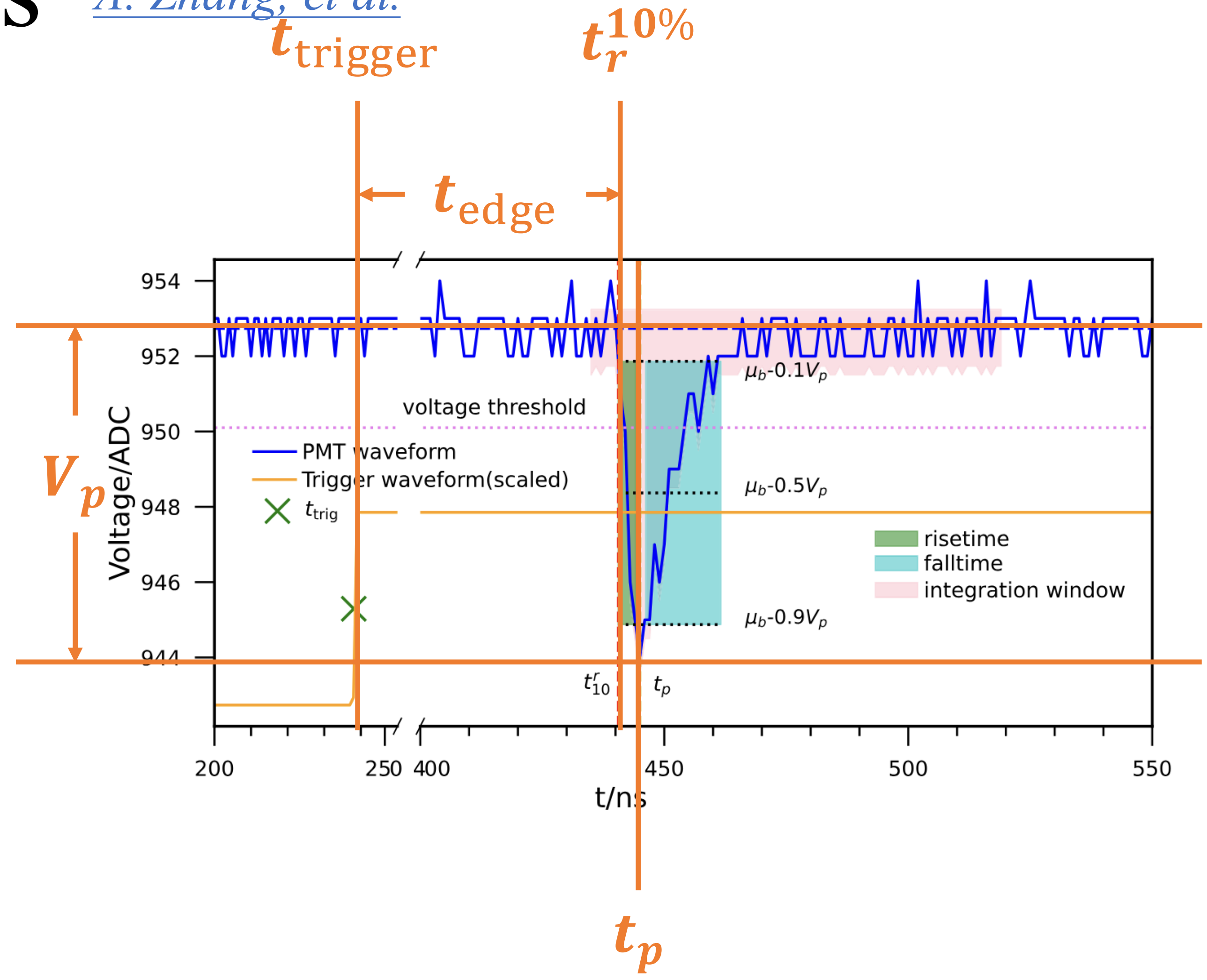

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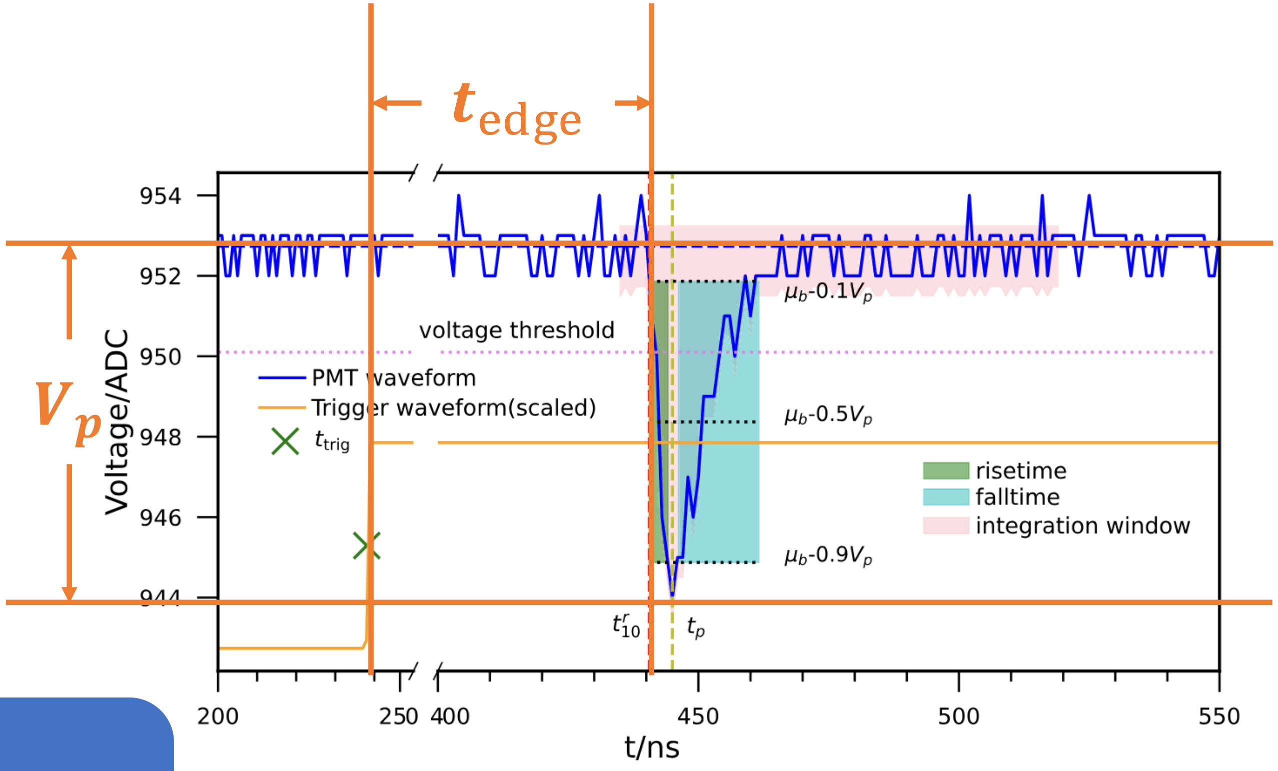

V_p and t_{edge} are obtained, used in subsequent analysis

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Occupency & Relative Detection Efficiency

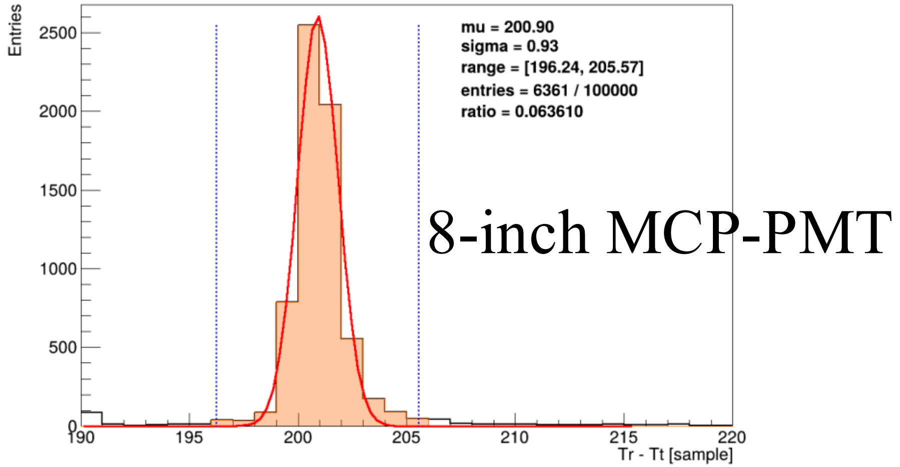
- Fit with a Gaussian $f(t;\mu,\sigma)$
- Calculate signal occupency

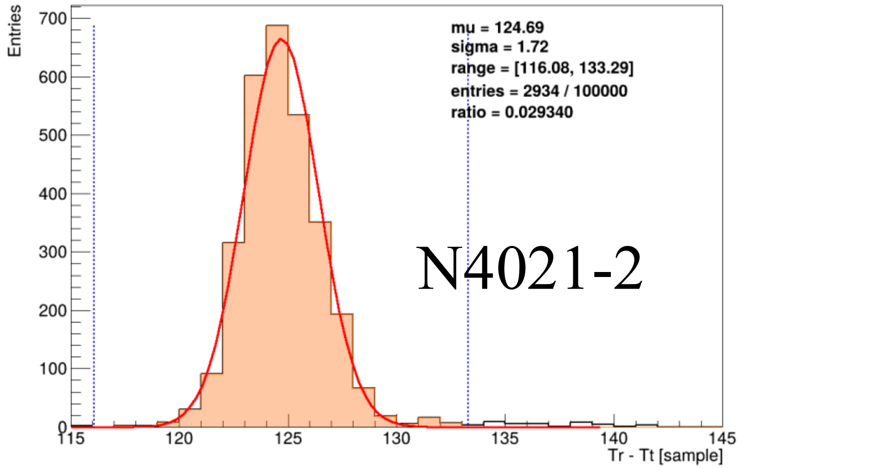
$$\Omega = \frac{N(V_p > 5\text{mV} \,\&\, \mu - 5\sigma < t_{\text{edge}} < \mu + 5\sigma)}{N}$$

- Detected photon number $n \sim \text{Poisson}\ (\lambda)$
- Relative detection Efficiency

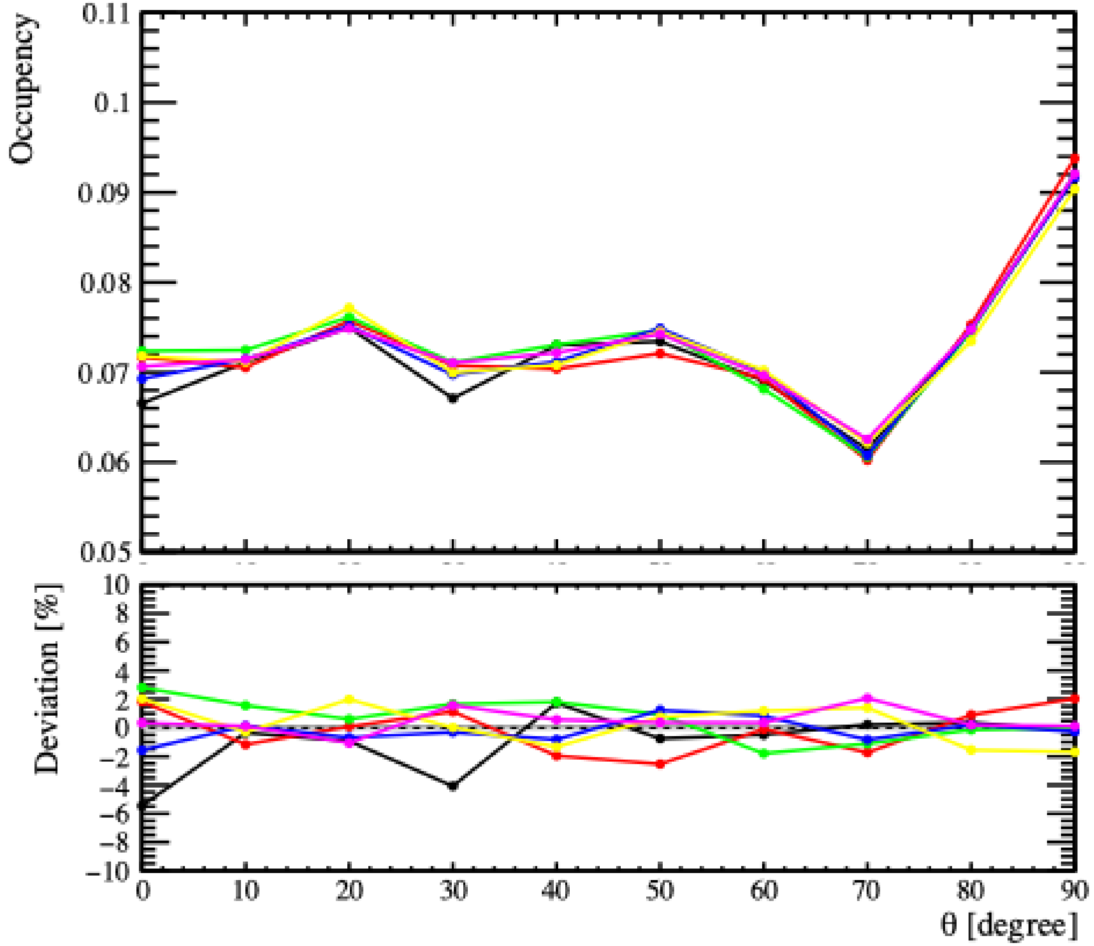
$$\epsilon_{\text{rel}} = \frac{\lambda_{\text{test}}}{\lambda_{\text{monitor}}} = \frac{\ln(1-\Omega_{\text{test}})}{\ln(1-\Omega_{\text{monitor}})}$$

Calibration needed, in progress now



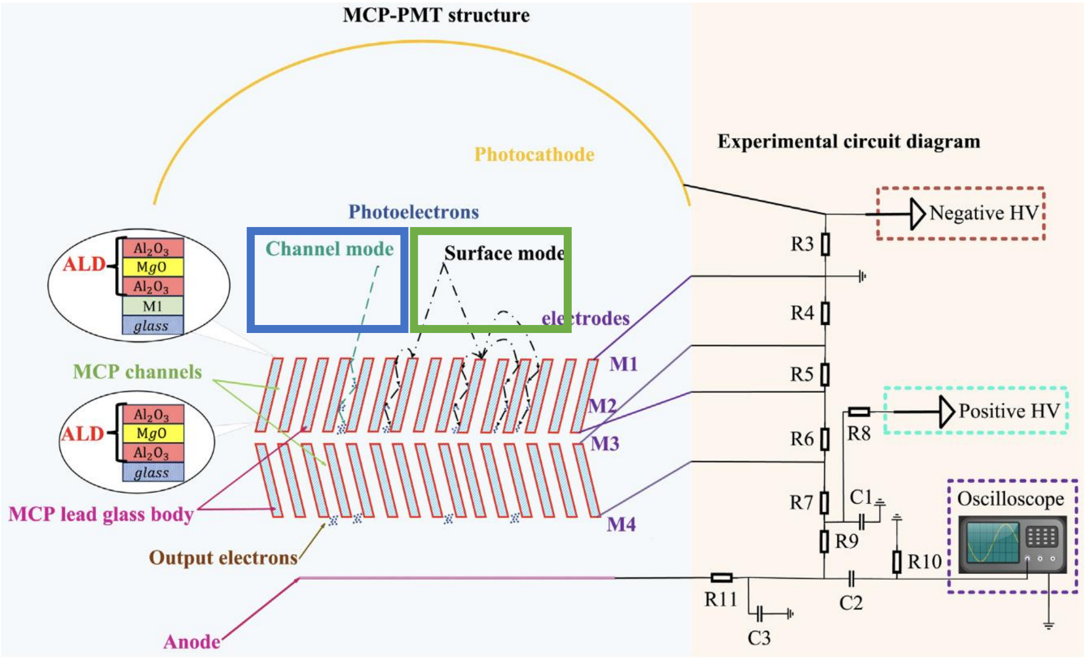


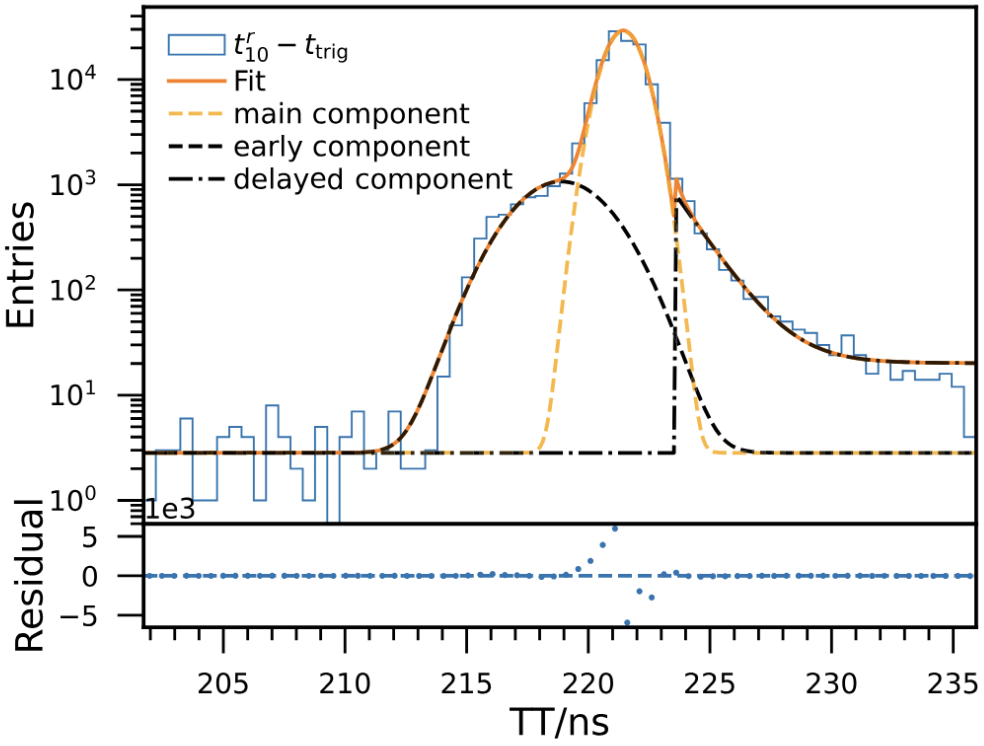
Optical Switch Stablity Test



- 6 repeated measurements, scanning signal occupancy from $\theta = 0°$ to $\theta = 90°$
- Relative deviation < 5%

Transit Time Spread





$$B + \boxed{N_1 f_1^N(t;\mu_{TT},\sigma_{TT}^2)}$$

TTS

$$+ \boxed{N_2 f_2^N(t;\mu_K,\sigma_K^2)}$$

(High kinetic energy photoelectron)

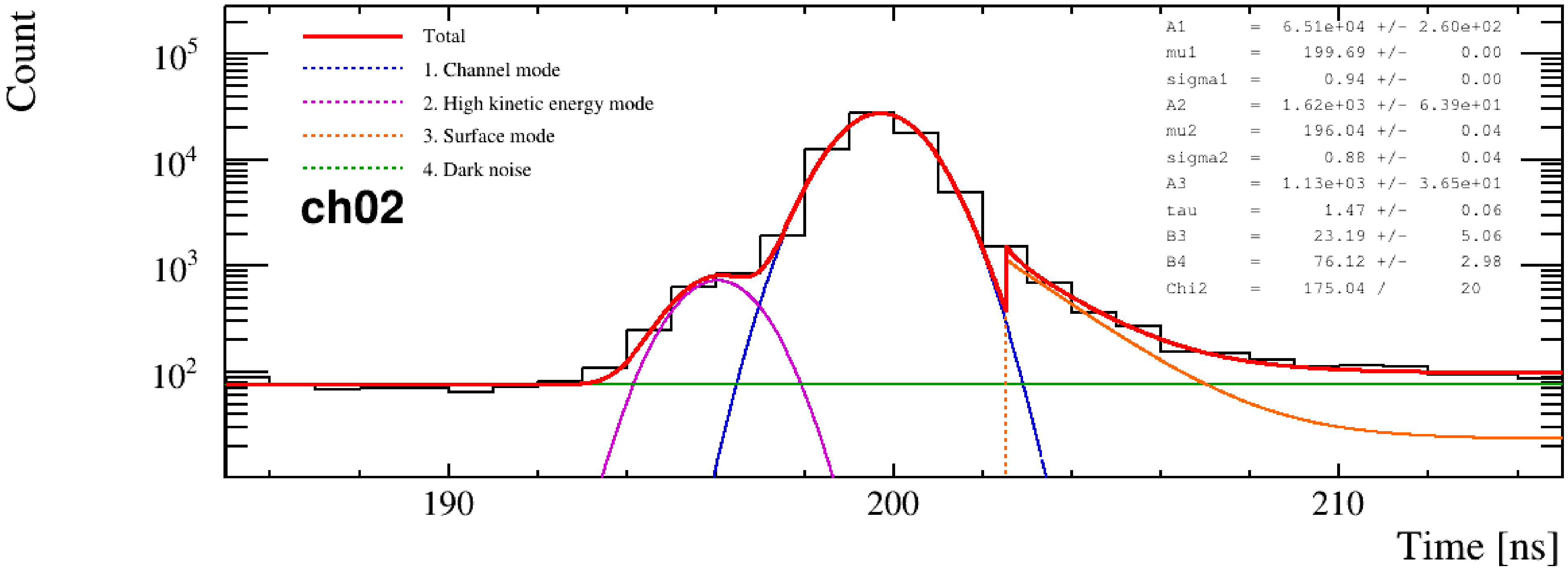
$$+ \boxed{b_S H(\mu_{TT}+3\sigma_{TT}) + N_S f^{\mathrm{Exp}}\left(t-(\mu_{TT}+3\sigma_{TT}); \frac{1}{\tau_S}\right)}$$

(surface mode)

A. Zhang, et al.

Transit Time Spread

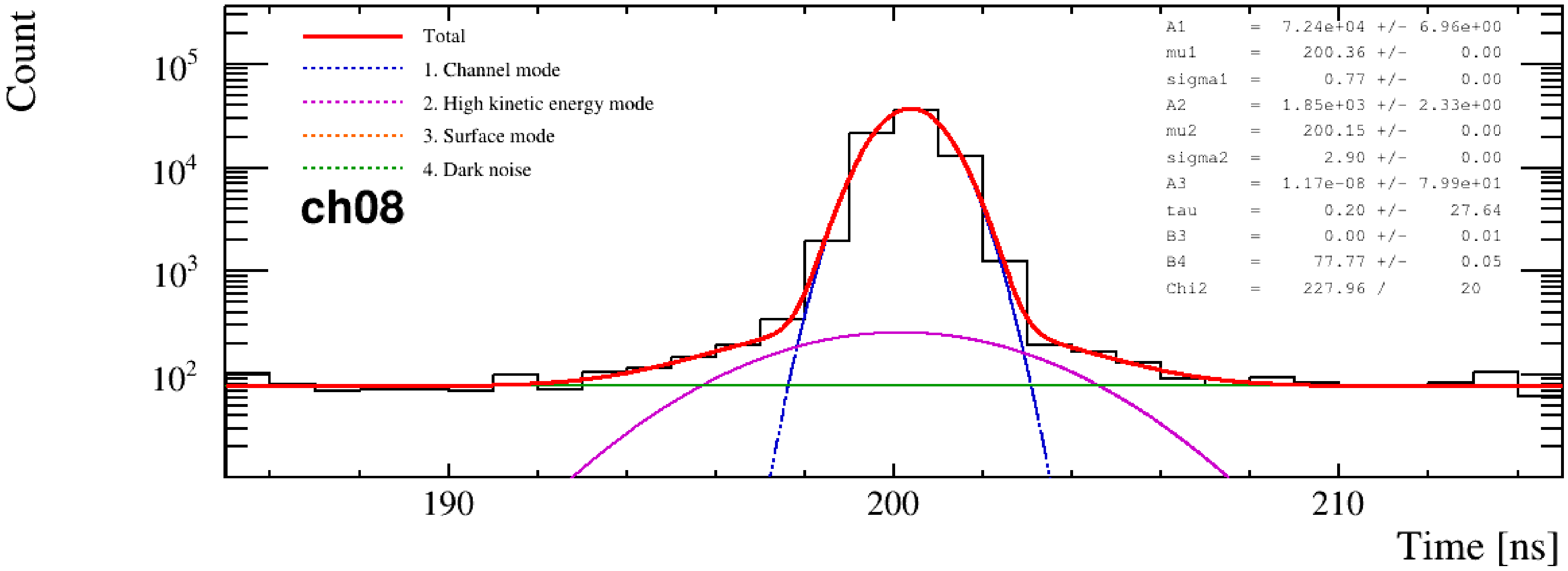
(Ω~5%)



Fit result for ch02($\theta = 80°$), TTS(FWHM) $= 2.21$ ns

Transit Time Spread

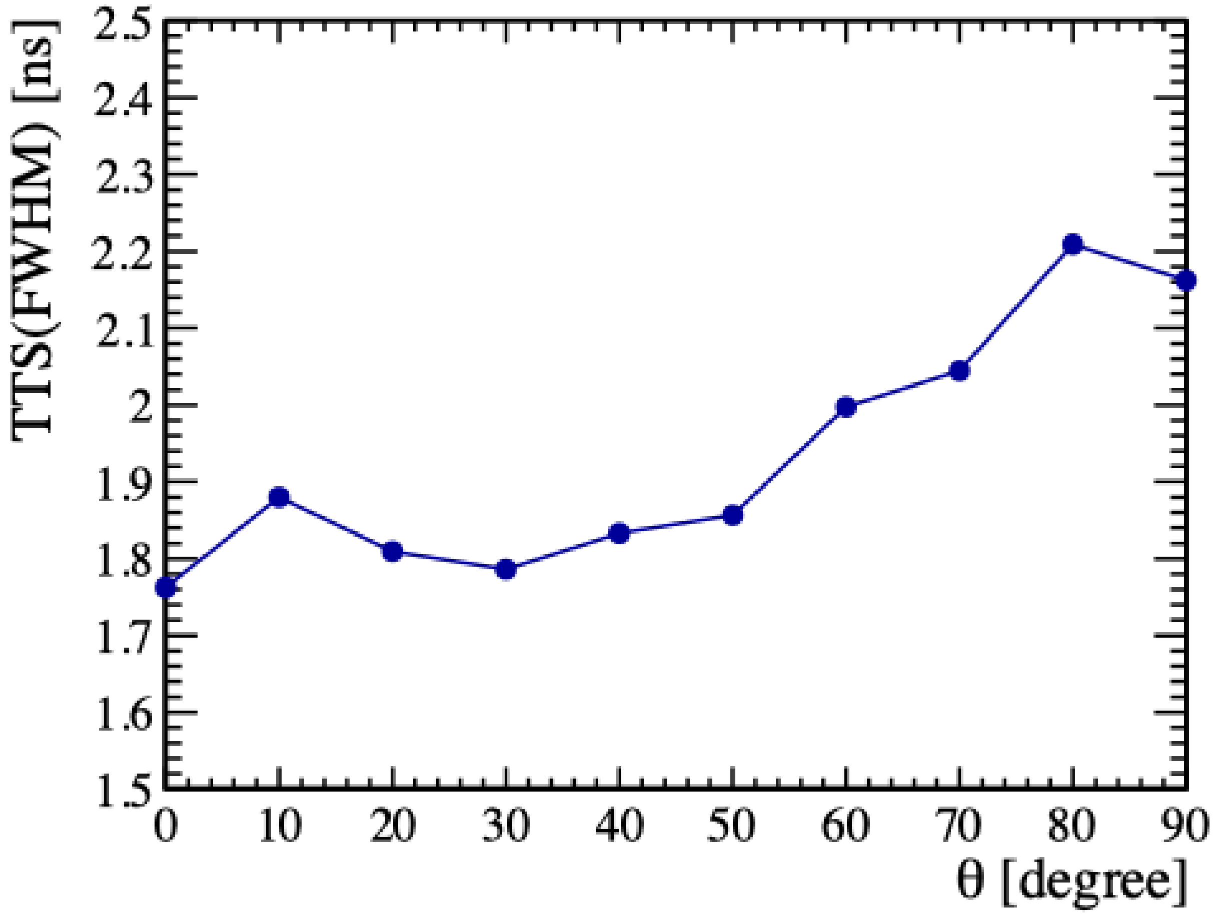
(Ω~5%)



Fit result for ch08($\theta = 20°$), TTS(FWHM) = 1.81 ns

Structure seems different, not clear currently.

TTS vs Zenith Angle θ



As the zenith angle increases, the flight path of photoelectrons becomes longer, leading to an increase in TTS.

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- An angle-adjustable test platform for 8-inch PMT non-uniformity was built.
- Synchronized data taking of tested and monitor PMTs was performed
- Preliminary studies on detection efficiency and TTS were conducted

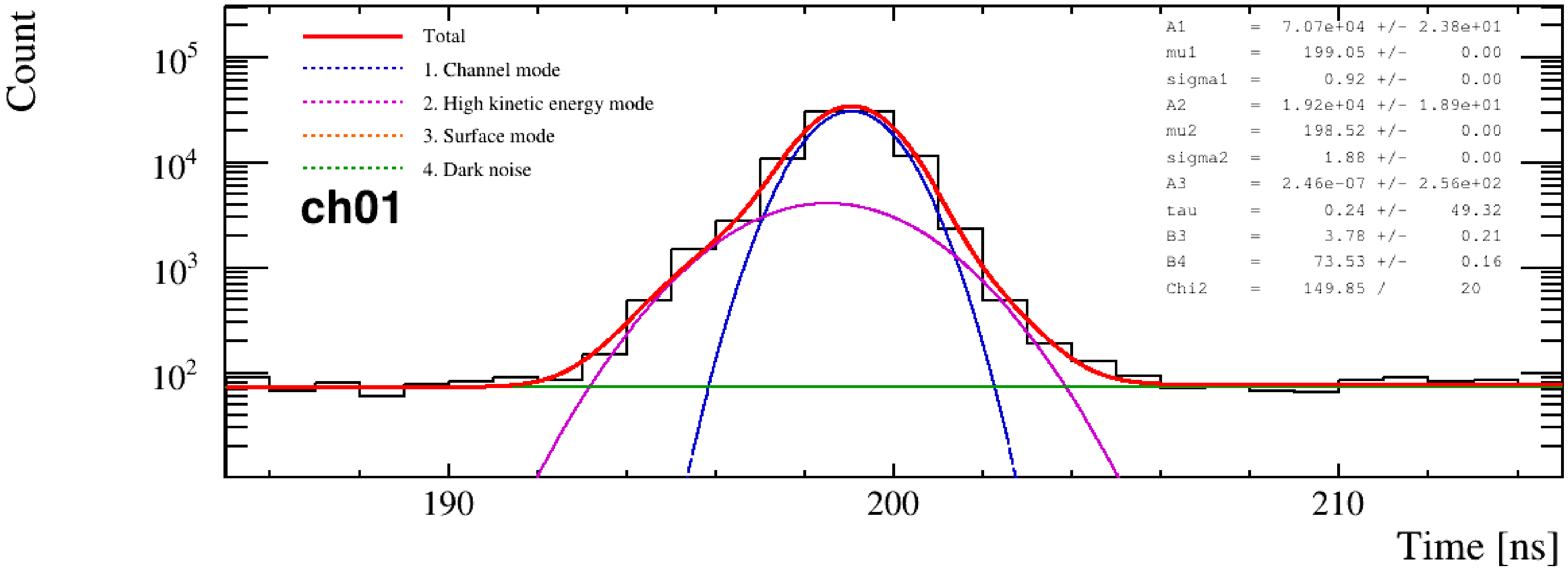
- The fibers' intensity require calibration
- More PMT samples are required in subsequent research

Thanks!

Backup

Transit Time Spread

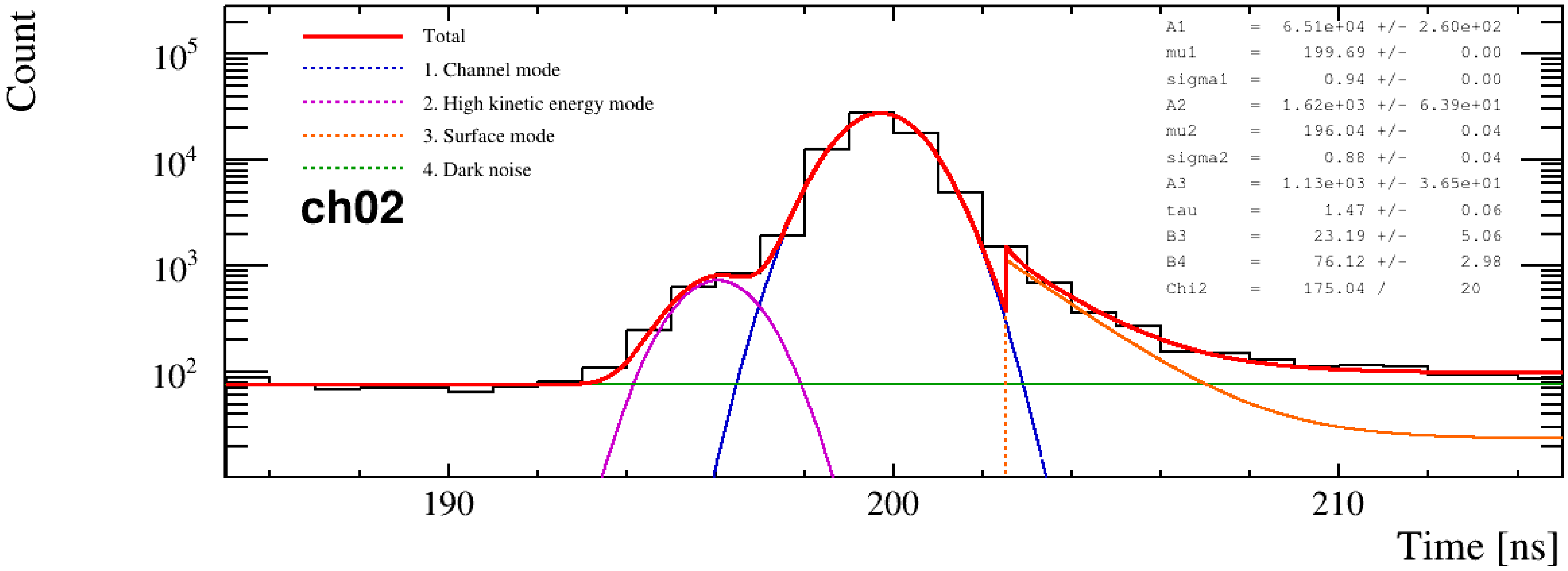
(Ω~5%)



Fit result for ch01($\theta = 90°$), TTS(FWHM) $= 2.17$ ns

Transit Time Spread

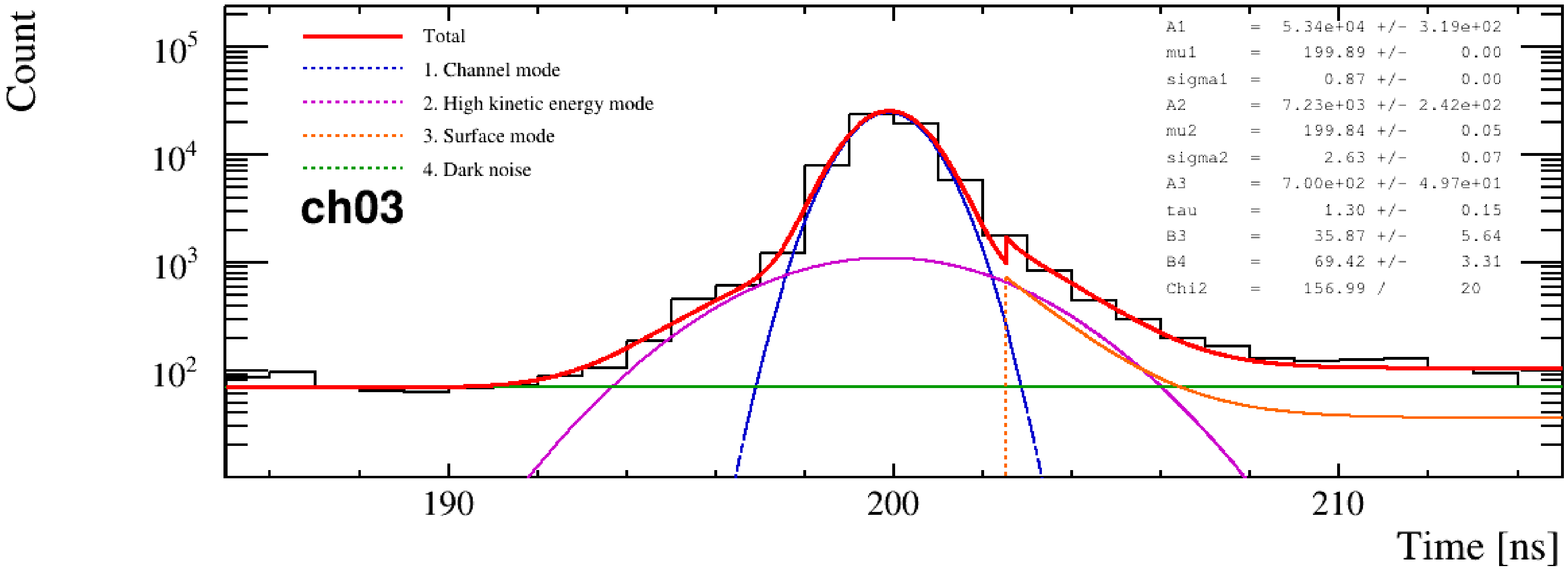
(Ω~5%)



Fit result for ch02($\theta = 80°$), TTS(FWHM) $= 2.21$ ns

Transit Time Spread

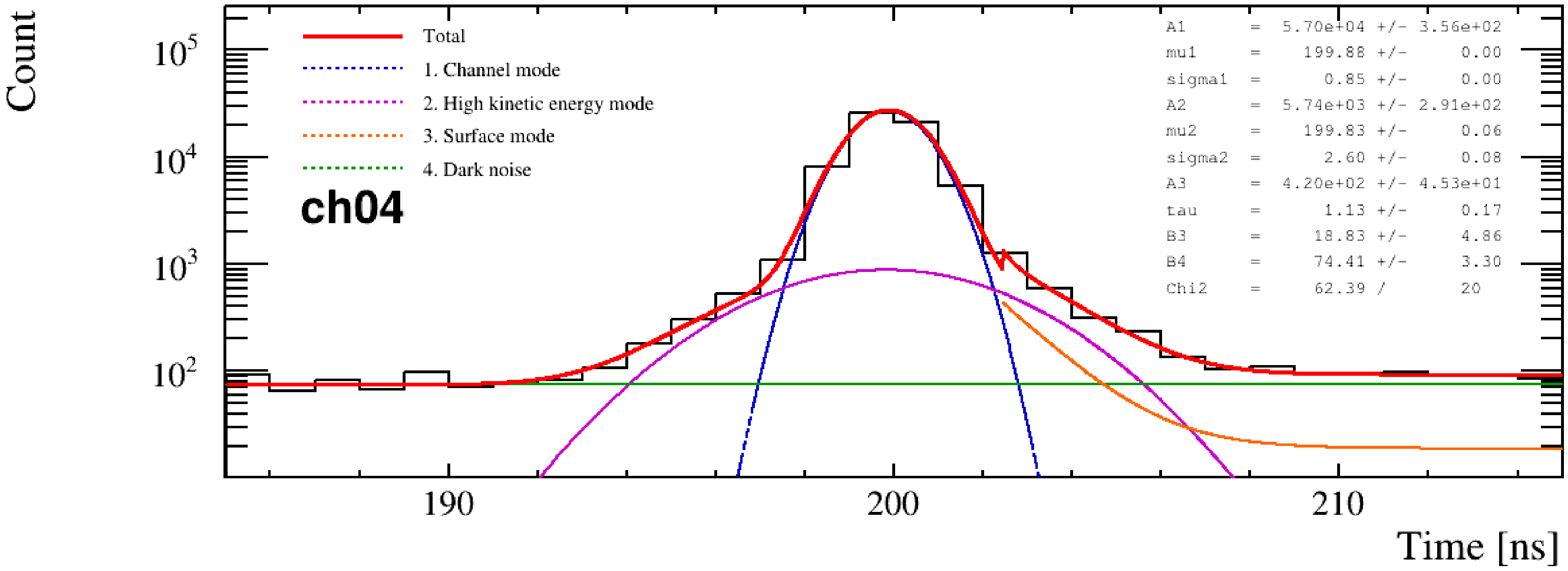
(Ω~5%)



Fit result for ch03($\theta = 70°$), TTS(FWHM) $= 2.04$ ns

Transit Time Spread

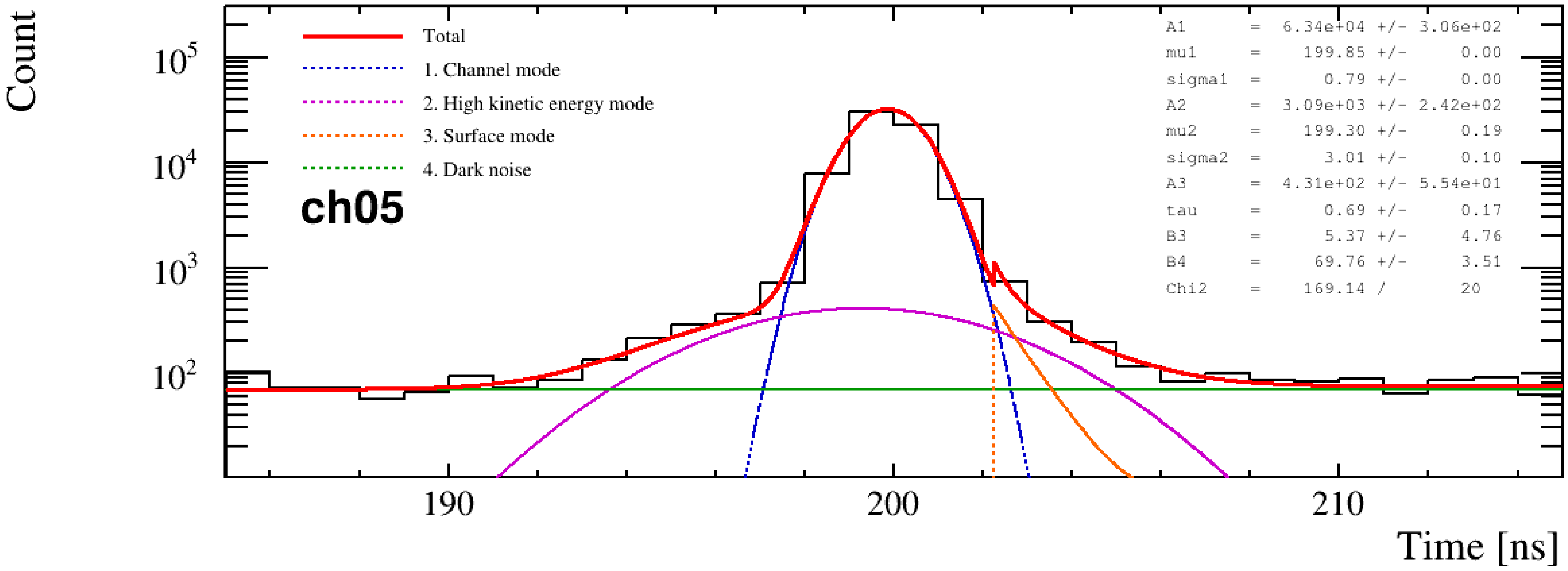
(Ω~5%)



Fit result for ch04($\theta = 60°$), TTS(FWHM) $= 2.00$ ns

Transit Time Spread

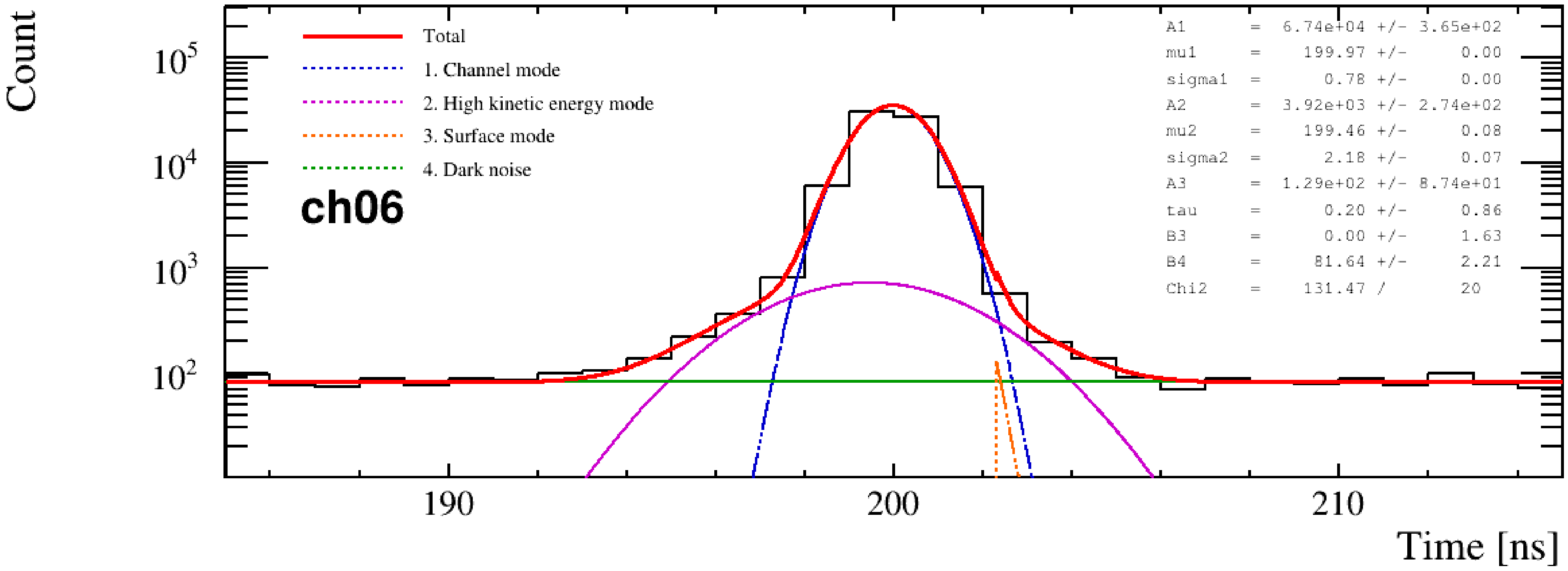
(Ω~5%)



Fit result for ch05(θ = 50°), TTS(FWHM) = 1.86 ns

Transit Time Spread

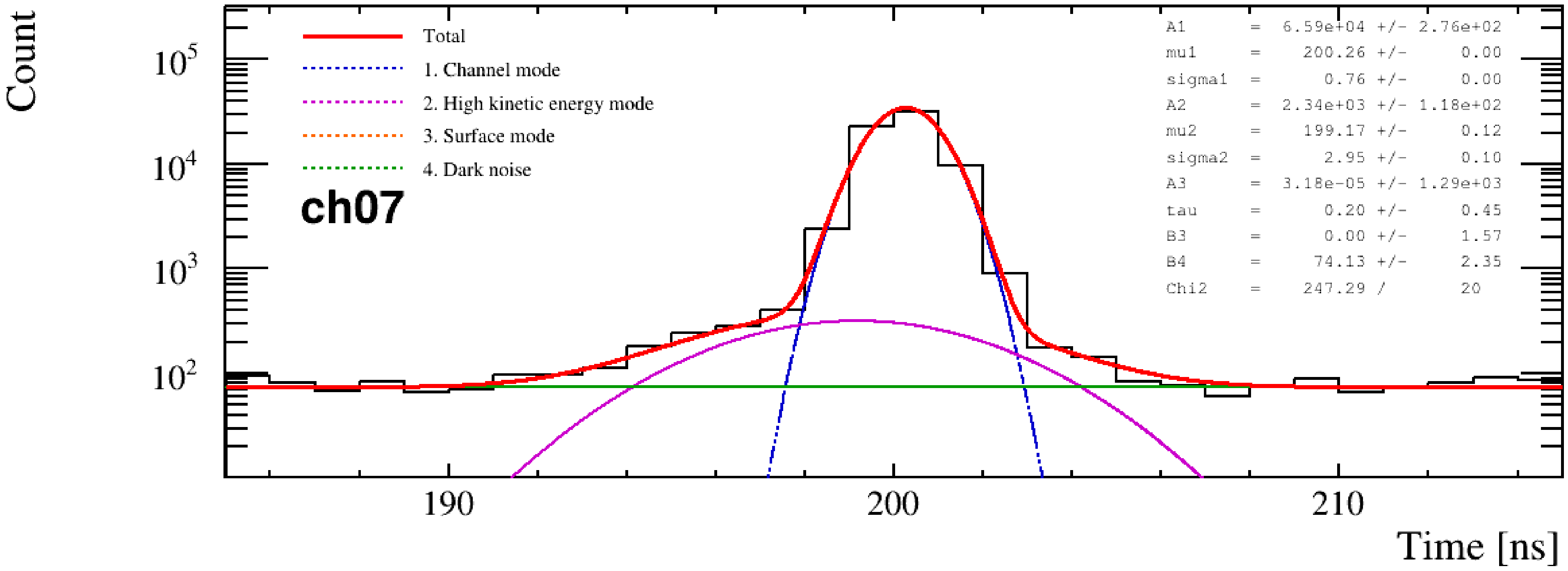
(Ω~5%)



Fit result for ch06($\theta = 40°$), TTS(FWHM) $= 1.83$ ns

Transit Time Spread

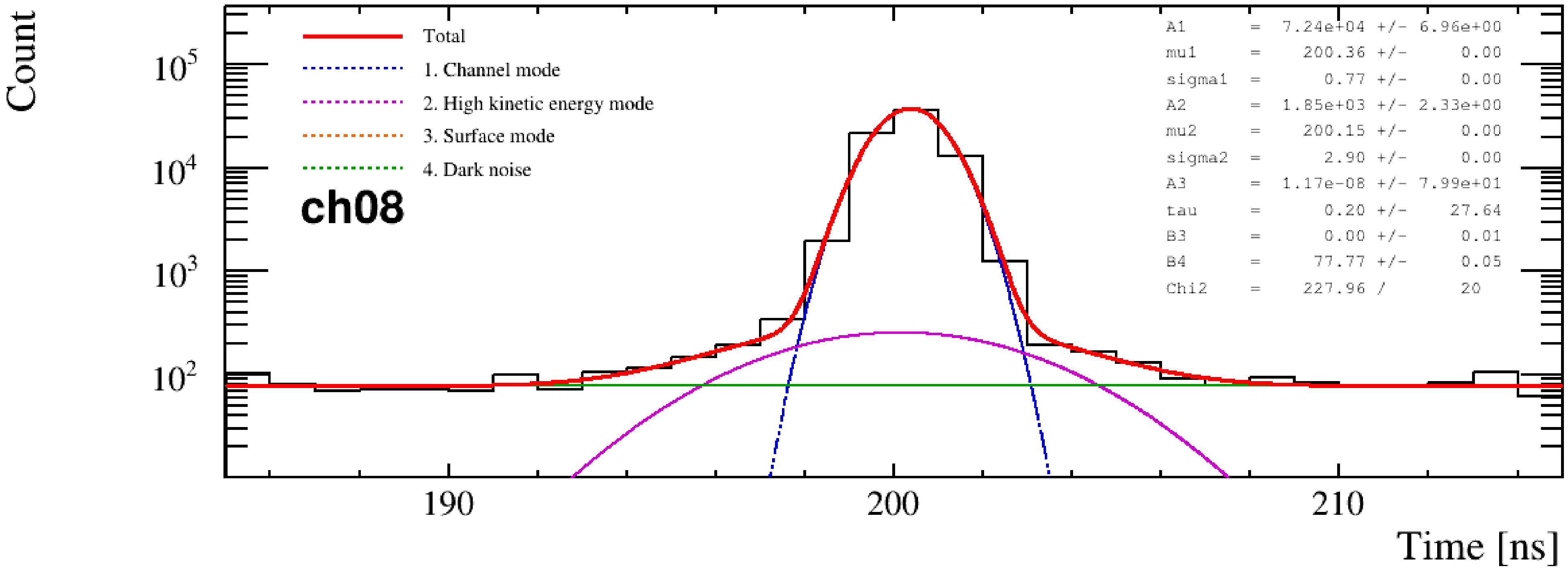
(Ω~5%)



Fit result for ch07($\theta = 30°$), TTS(FWHM) $= 1.79$ ns

Transit Time Spread

(Ω~5%)



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Transit Time Spread

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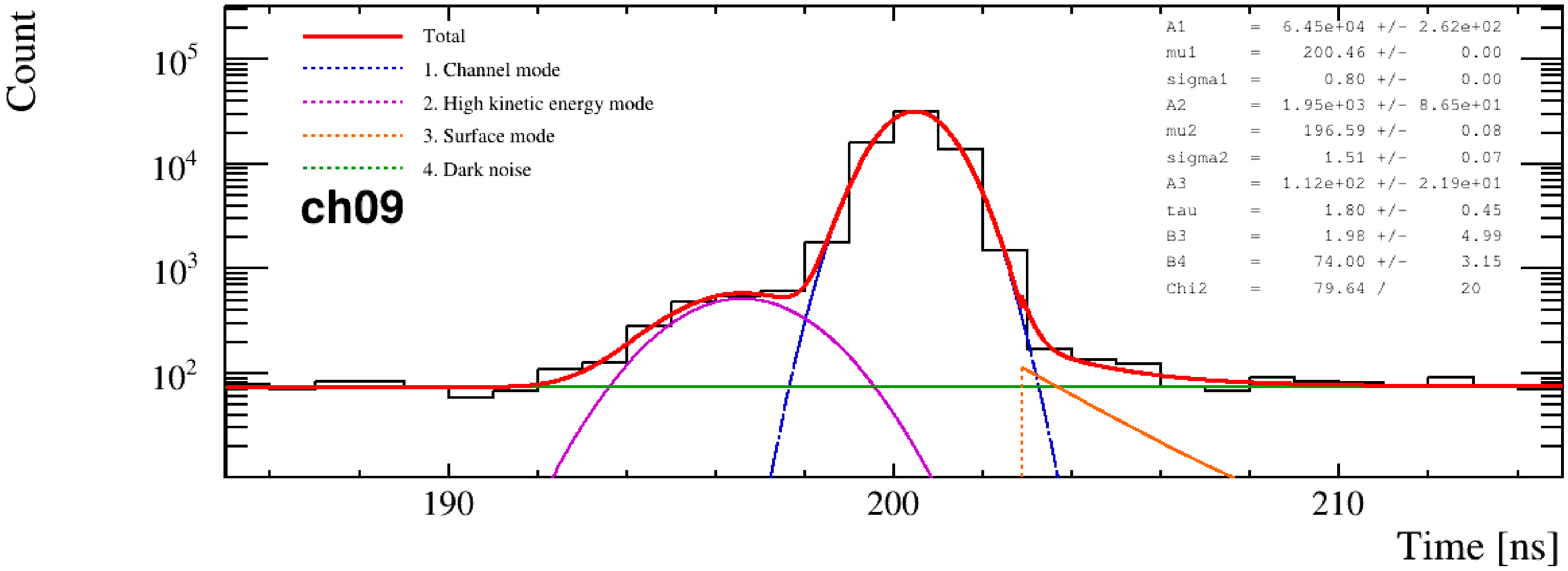
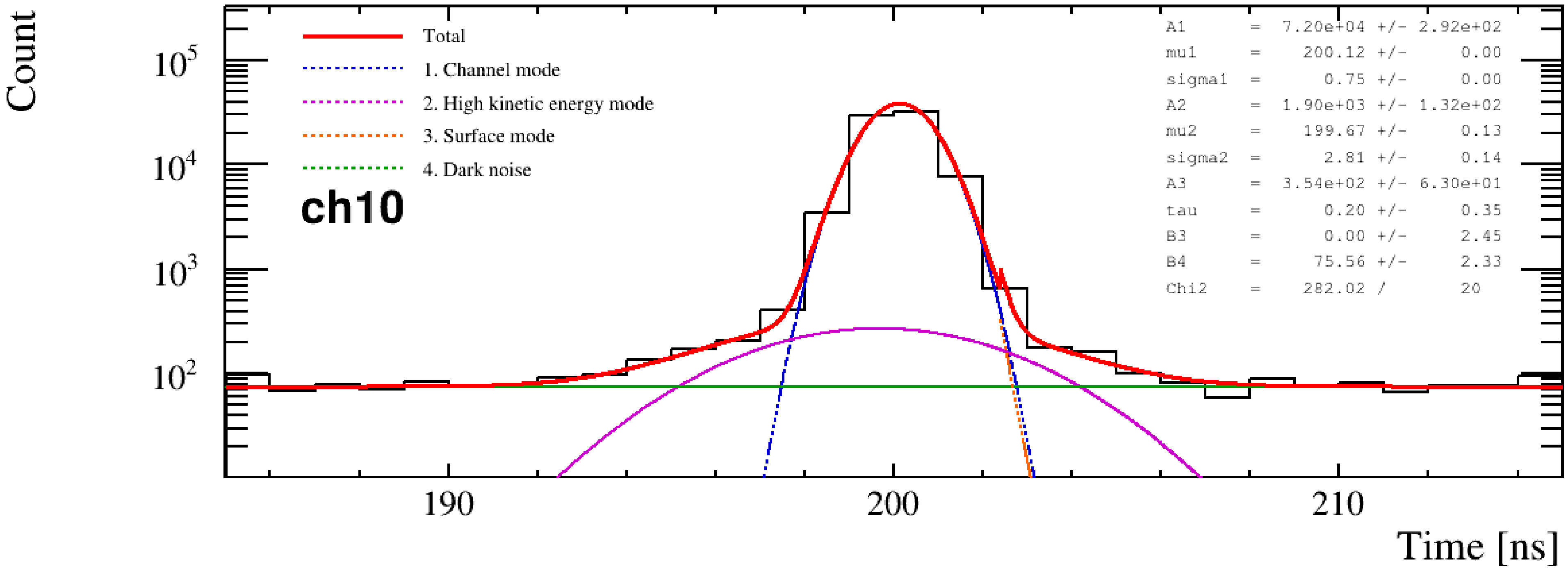


Fit result for ch09($\theta = 10°$), TTS(FWHM) $= 1.88$ ns

Transit Time Spread

(Ω~5%)



Fit result for ch10($\theta = 0°$), TTS(FWHM) $= 1.76$ ns