Scintillation time distributions of $ZnWO_4$ signal for electrons and low-energy protons

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On behalf of the GRAiNITA group:
CERN; IJClab; ISMA; LPCA; TSNUK

Introduction

- The goal is to present the preliminary beam test results of the $ZnWO_4$ scintillation pulse and pulse shape discrimination.
- Outline:
  - Beam Test setup;
  - Scintillation signal modeling;
  - Fit results;
  - Pulse shape discrimination with $ZnWO_4$;
  - Conclusions.

Scintillator characteristic [1]	$ZnWO_4$
Effective Z	61
Density (g/cm^3)	7.87
Refractive index	2.0-2.3
Light yield (photons/MeV)	~9000
Peak emission wavelength (nm)	480
Decay time (μs)	20
Radiation length (cm)	1.2
Moliere radius (cm)	1.98

[1] Barsuk, S. et all. “First characterization of a novel grain calorimeter: the GRAiNITA prototype”, 2024 JINST 19 P04008. DOI 10.1088/1748-0221/19/04/P04008

Beamtest setup

- Electrons are measured from a beta source $^{90}Sr+^{90}Y$.

- Signal from low-energy (~10 - ~25 MeV) protons was measured in April with the Cyrce cyclotron at Strasbourg.

- Scintillation photons were measured with two wavecatchers:
  - slow - 100 ns sample rate (covering time up to ~ 100 us);
  - fast - 2.5 ns sample rate (covering time up to ~ 2560 ns).

- A common trigger was used for both wave catchers.

- An RC filter with τ_{rc}=25 ns was used to smooth pulses from PMT.

Scintillation signal modeling

- The scintillation pulse was modeled with four exponents:

$$f(x) = \sum_{i=1}^{4} \frac{Q_i\left(e^{-\frac{t}{\tau_i}} - e^{-\frac{t}{\tau_{rc}}}\right)}{\tau_i - \tau_{rc}}$$

- τ_i parameters are assumed to be dependent only on scintillator material and to be the same for electrons and protons of different energies.
- Using the same τ_i parameters justified by simplifying the fit of Q_i. The difference in pulse, fitted with τ_i, is small compared to the PSD effect.
- Two stages of fit (slow + fast wavecatchers data on both):
  - combining the proton data of various energies to fit τ_i parameters;
  - fine-tuning of Q_i parameters for each energy of protons for electrons, performing separate fits.

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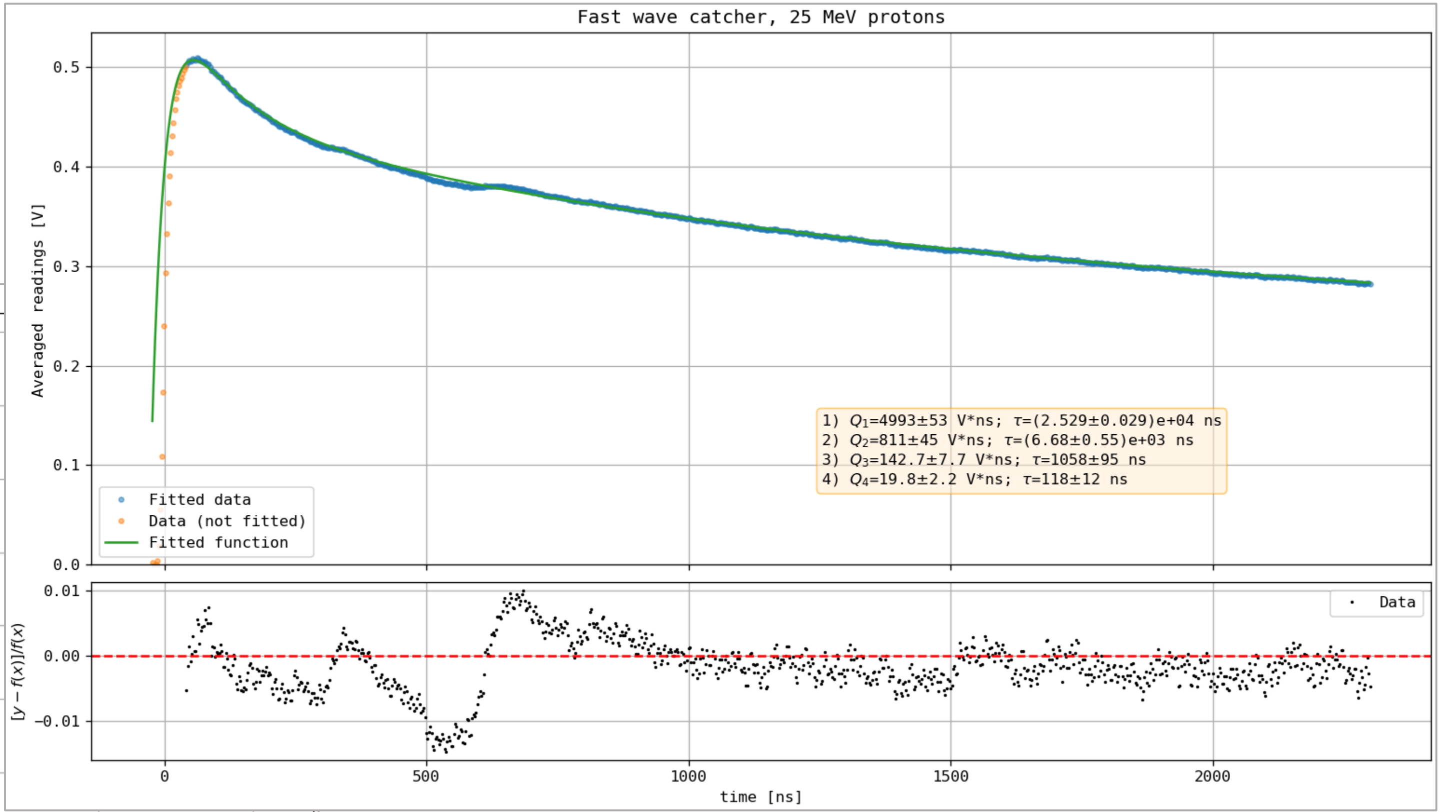
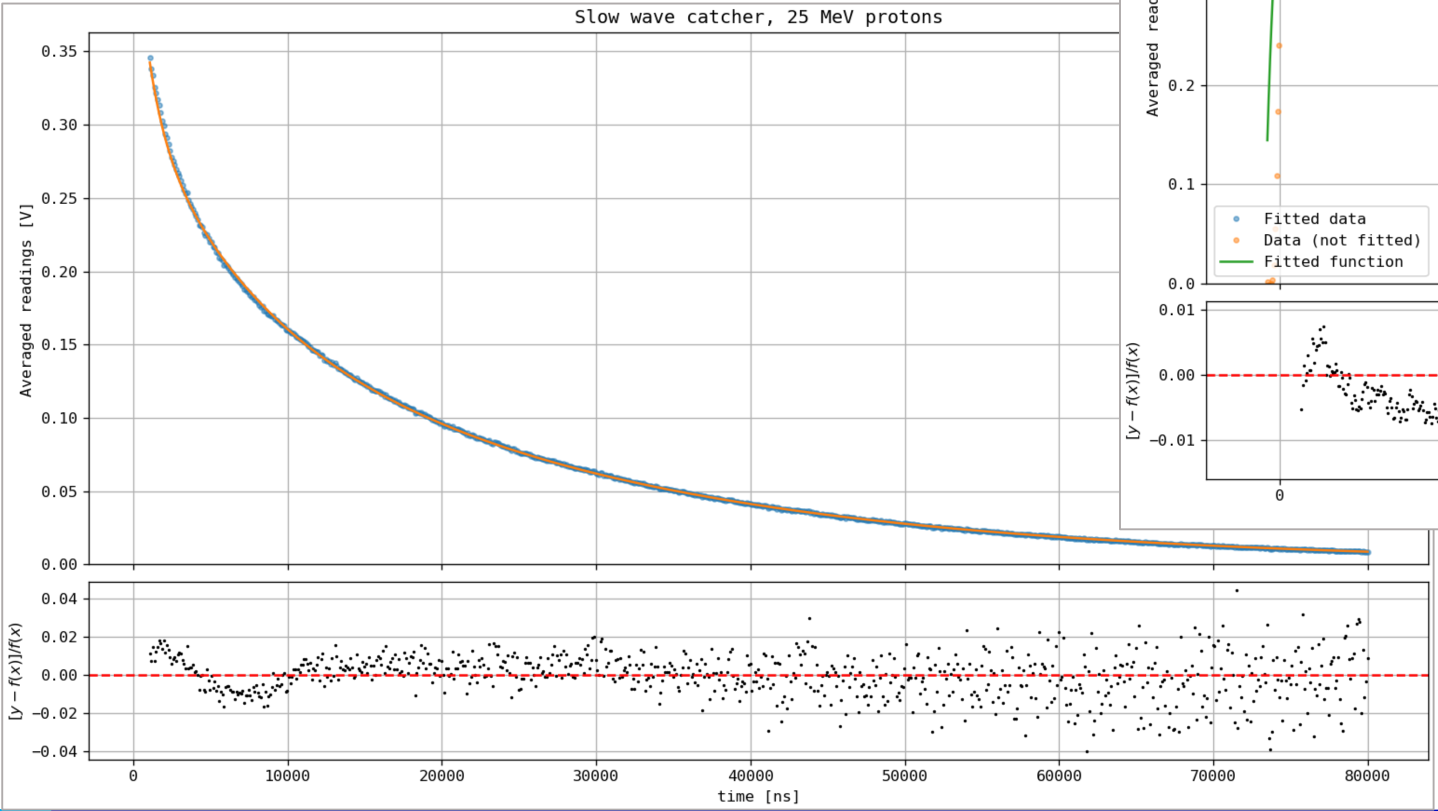
Fitted functions (25 MeV protons example)

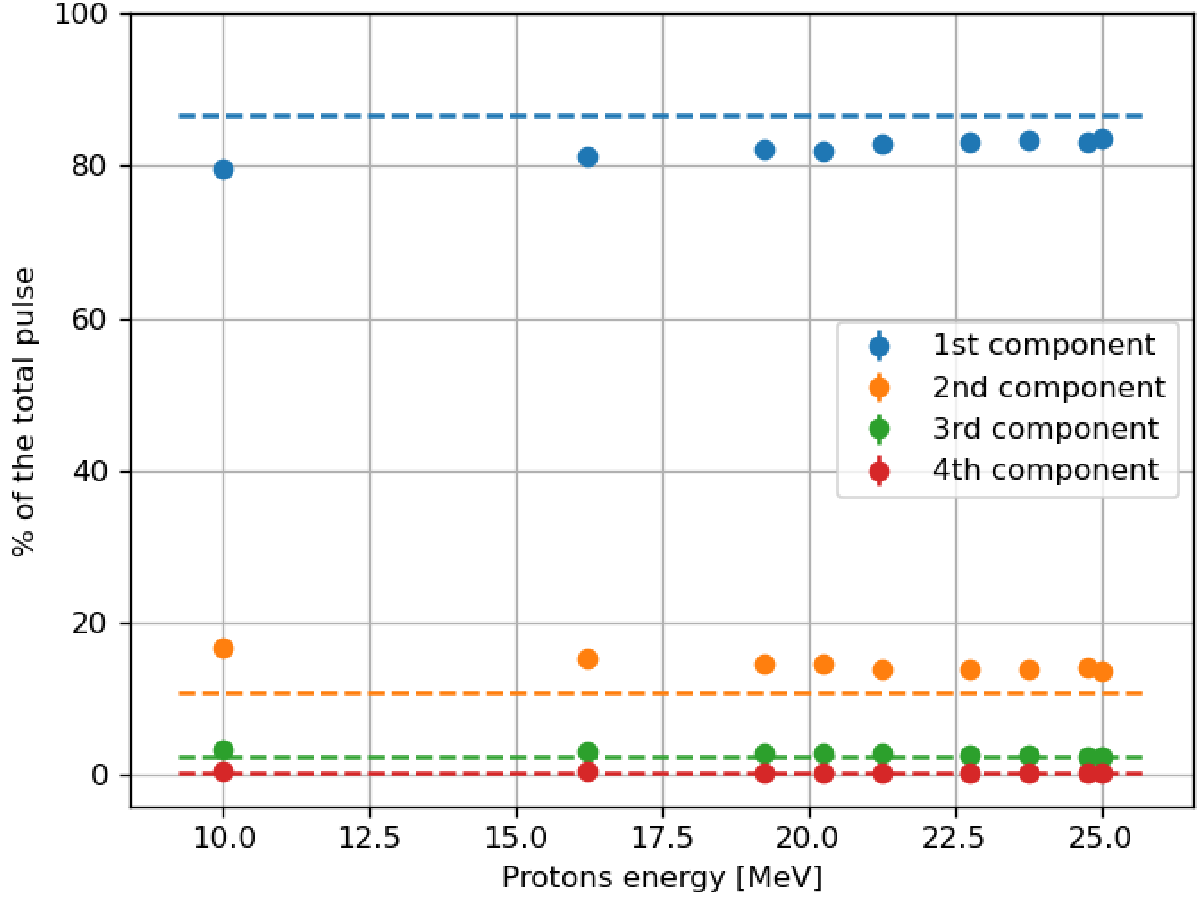




Charge components Q_i

Parameter	Value
τ_1	25300 ± 30 ns
τ_2	6700 ± 550 ns
τ_3	1060 ± 100 ns
τ_4	118 ± 12

- The relative charge components $\frac{Q_i}{\sum_{j=1}^{4} Q_j}$ are presented in the plot.
- The values for electrons are given in horizontal lines.
- Difference in Q_j leads to different pulse shapes, giving the possibility to do discrimination of the particles.



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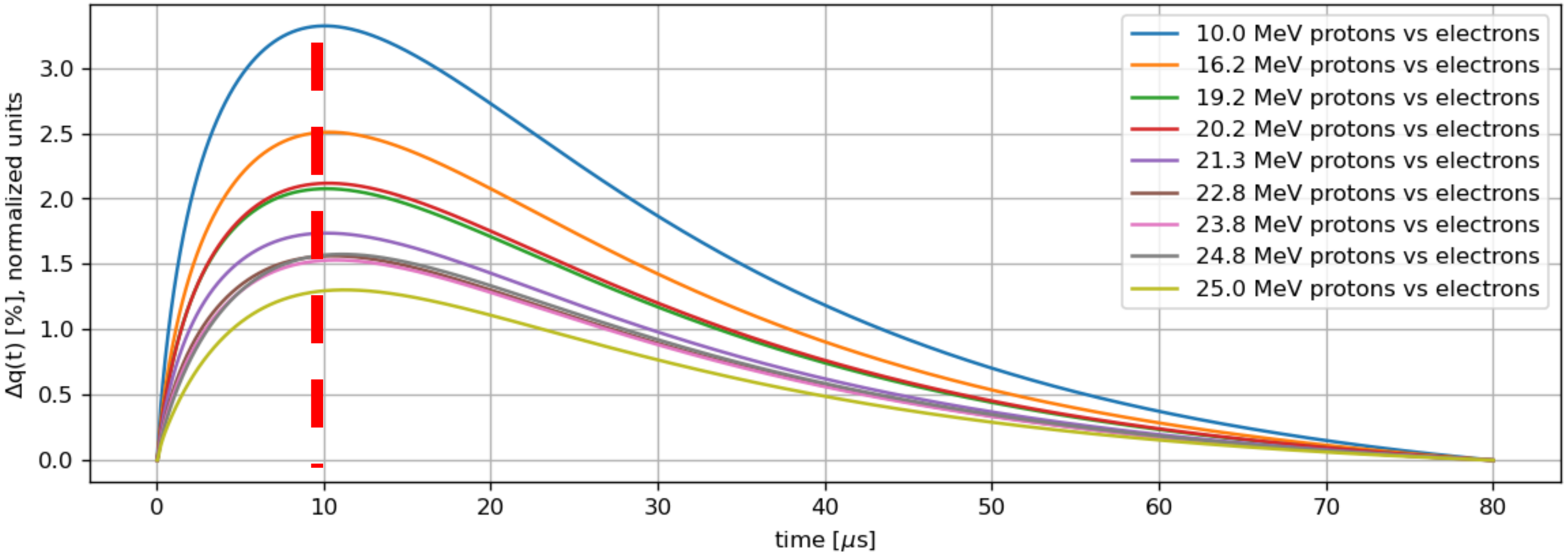
Accumulated charges

- The accumulated charge can be measured using

$$q(t) = \frac{1}{Q_a}\int_0^t f(x)dx$$

$$Q_a = \int_0^{80\ \mu s} f(x)dx$$

$$\Delta q(t) = q_{prot.}(t) - q_{el.}(t)$$



- $\Delta q(t)$ has the maximum at 10 us (threshold for separation).

$$Q_f = \int_0^{10\ \mu s} f(x)dx$$

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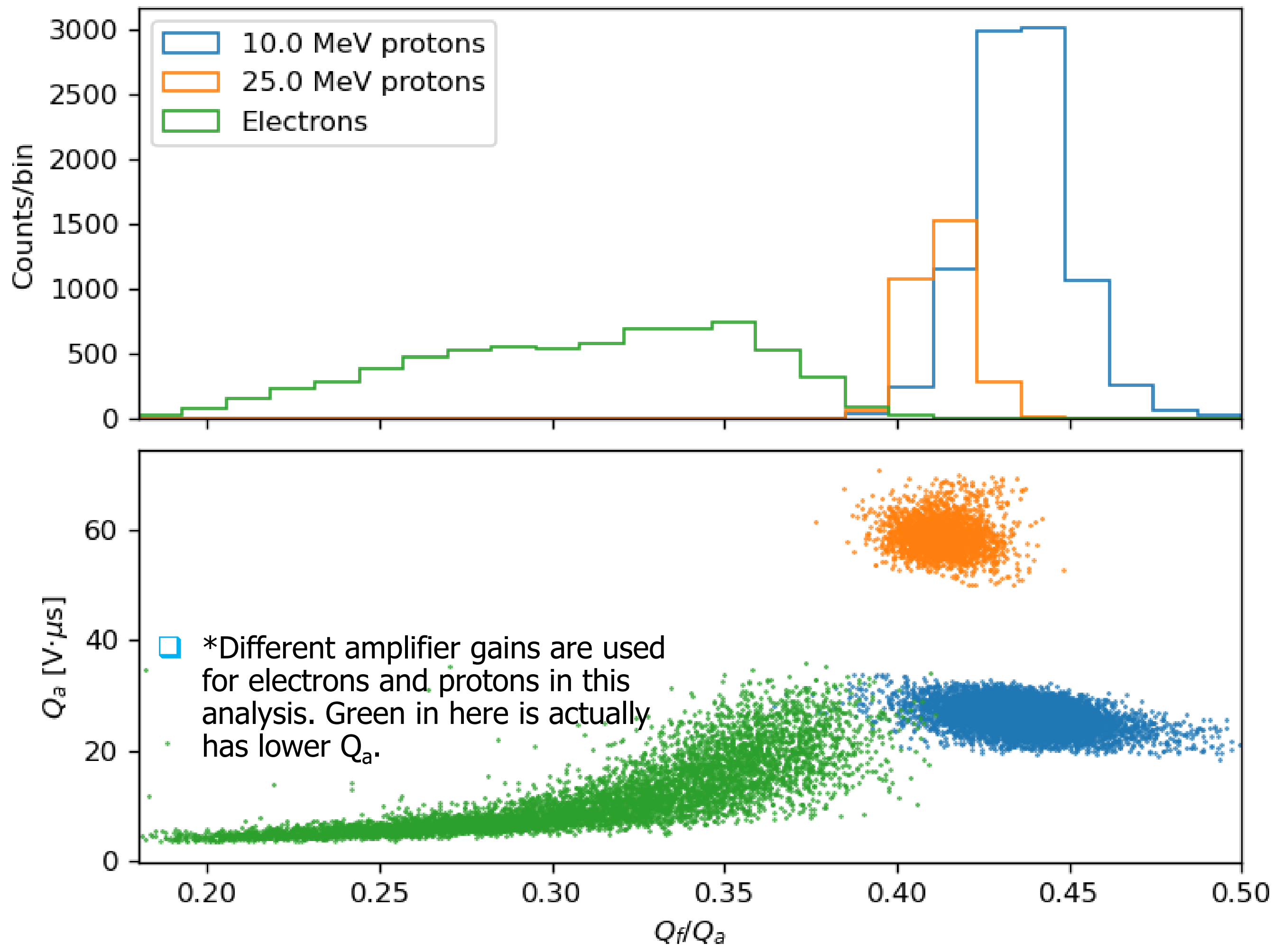
Pulse shape discrimination

- Different particles can be distinguished by comparing ratio $\frac{Q_f}{Q_s}$ with 0,4.

- The histogram of $\frac{Q_f}{Q_s}$ actually characterizes separation.

- The results are similar across different proton energies and differ from electrons.



Conclusions

- The scintillation pulses from ZnWO4 were measured with electrons and low-energy protons, capturing fast components and slow tails with two wavecatchers.

- The fitted different charge fractions Q_i show pulse shape dependence on particle type.

- Analysis shows the possibility of doing pulse shape discrimination between low-energy protons and electrons, with the fast charge threshold being at 10 µs, and a separation value of $\frac{Q_f}{Q_s}$ being at 0,4.

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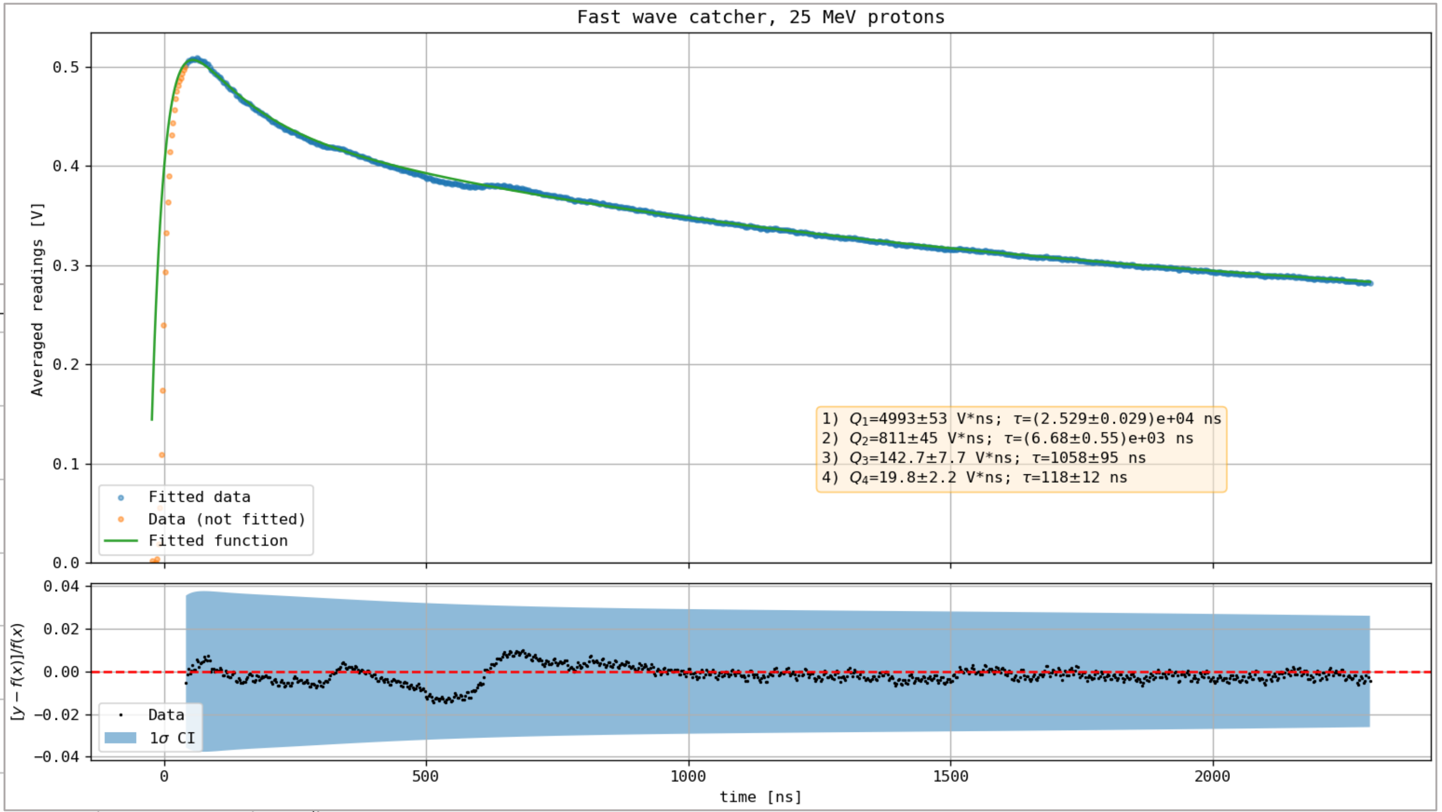
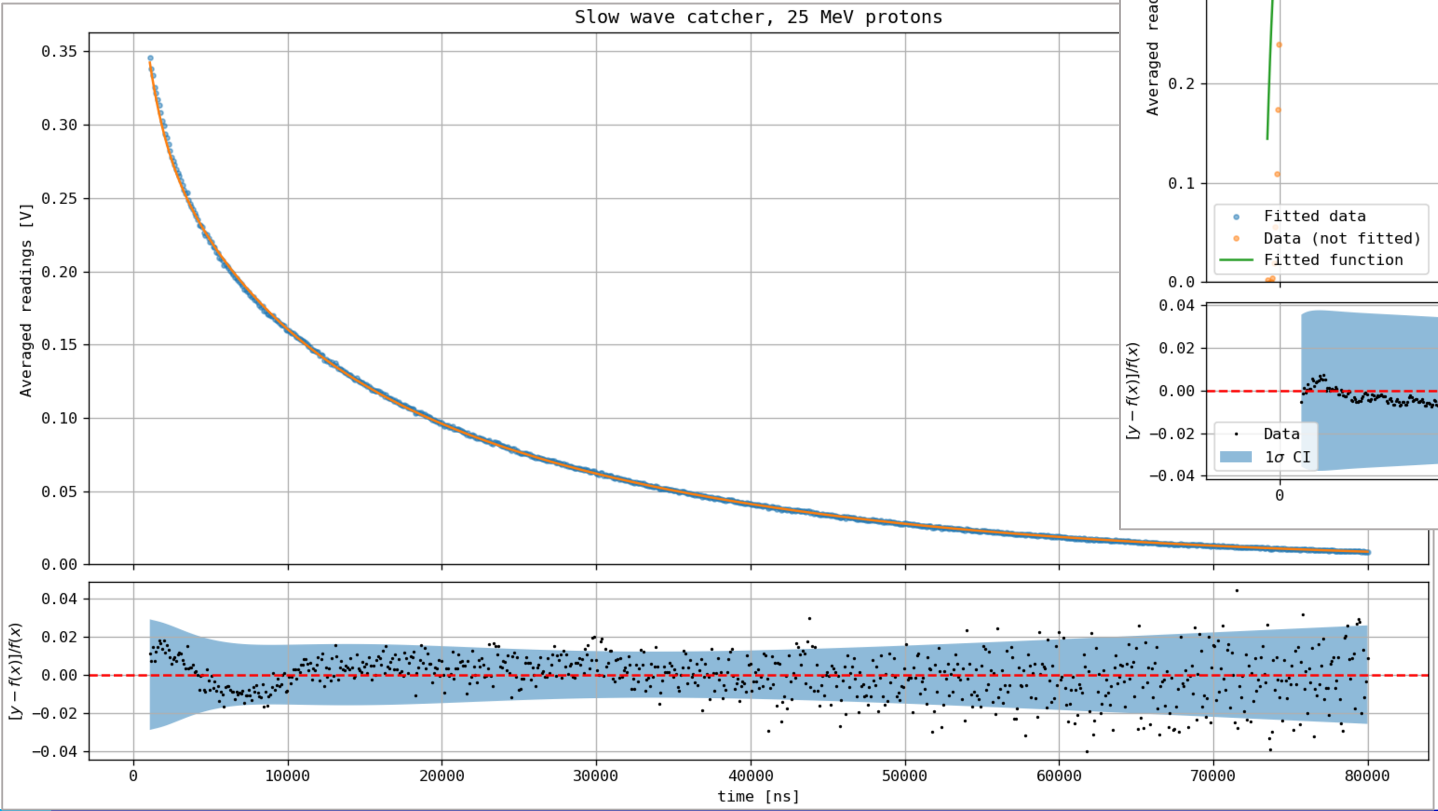
Thank you for your attention

Backup slides

Fitted functions (25 MeV protons example)

- Uncertainties estimated via the Hesse algorithm and propagated for the fitted function.





Ratio of pulse curves