Optimization of PSD technique on charge integration ratio to improve neutron/gamma discrimination for EJ-276 plastic scintillation detector

#176

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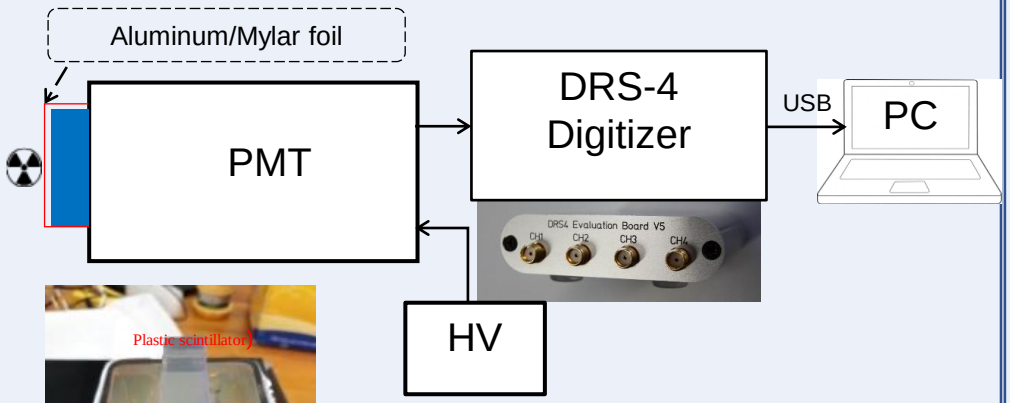
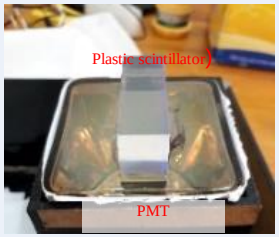
Experiment set-up and Materials



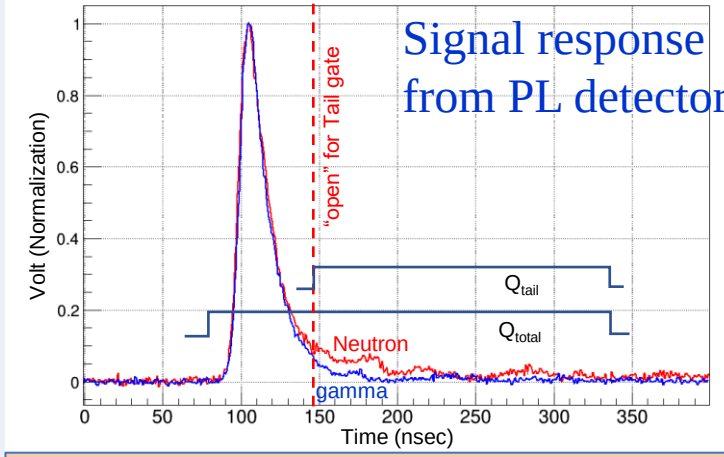


Scintillator: EJ-276, Eljen Technology. **size: (14x14x40)mm^3**
PMT: R6236-01, Hamamatsu. **Size: Square: 6cm x 6cm.**
DRS-4 digitizer, Paul Scherrer Institute.
RI source: Gamma (Co-60) and Neutron/gamma (Cf-252)

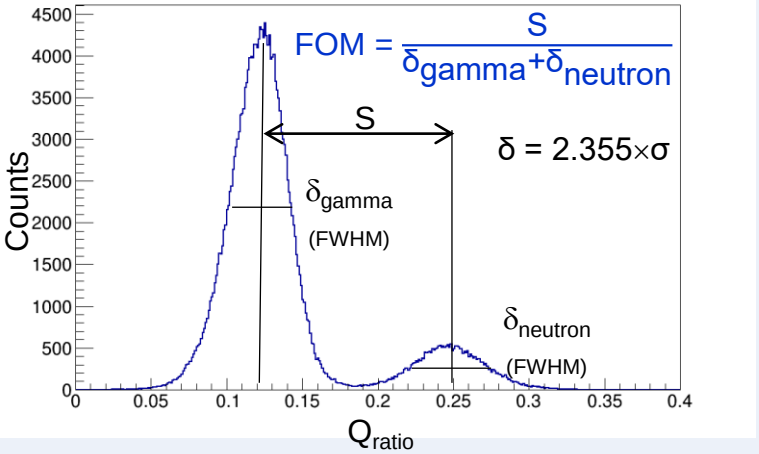
Purpose

Optimization of Q_{ratio} means FOM largest.
→ Optimize the Q_{tail}
→ Theoretical evaluation is studied in this work and compare to previous study.

Q_{ratio} and FOM

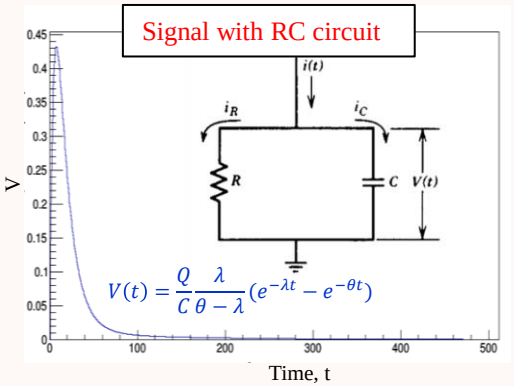


Q_{ratio} technique: $Q_{ratio} = \frac{Q_{tail}}{Q_{total}}$



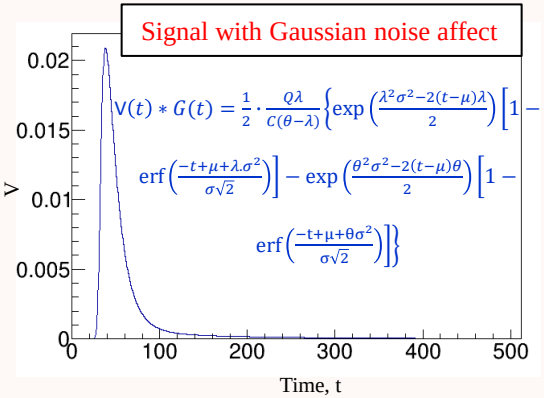
Calculation of signal response of a scintillation detector with 3 decay components

Signal with RC circuit



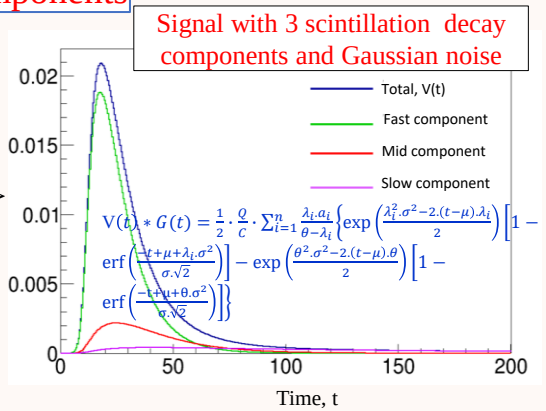
$$V(t) = \frac{Q}{C}\frac{\lambda}{\theta-\lambda}(e^{-\lambda t} - e^{-\theta t})$$

Signal with Gaussian noise affect



$$V(t) * G(t) = \frac{1}{2}\cdot\frac{Q\lambda}{C(\theta-\lambda)}\left\{\exp\left(\frac{\lambda^2\sigma^2-2(t-\mu)\lambda}{2}\right)\left[1-\operatorname{erf}\left(\frac{-t+\mu+\lambda\sigma^2}{\sigma\sqrt{2}}\right)\right] - \exp\left(\frac{\theta^2\sigma^2-2(t-\mu)\theta}{2}\right)\left[1-\operatorname{erf}\left(\frac{-t+\mu+\theta\sigma^2}{\sigma\sqrt{2}}\right)\right]\right\}$$

Signal with 3 scintillation decay components and Gaussian noise



$$V(t) * G(t) = \frac{1}{2}\cdot\frac{Q}{C}\cdot\sum_{i=1}^{n}\frac{\lambda_i a_i}{\theta-\lambda_i}\left\{\exp\left(\frac{\lambda_i^2\sigma^2-2(t-\mu)\lambda_i}{2}\right)\left[1-\operatorname{erf}\left(\frac{-t+\mu+\lambda_i\sigma^2}{\sigma\sqrt{2}}\right)\right] - \exp\left(\frac{\theta^2\sigma^2-2(t-\mu)\theta}{2}\right)\left[1-\operatorname{erf}\left(\frac{-t+\mu+\theta\sigma^2}{\sigma\sqrt{2}}\right)\right]\right\}$$

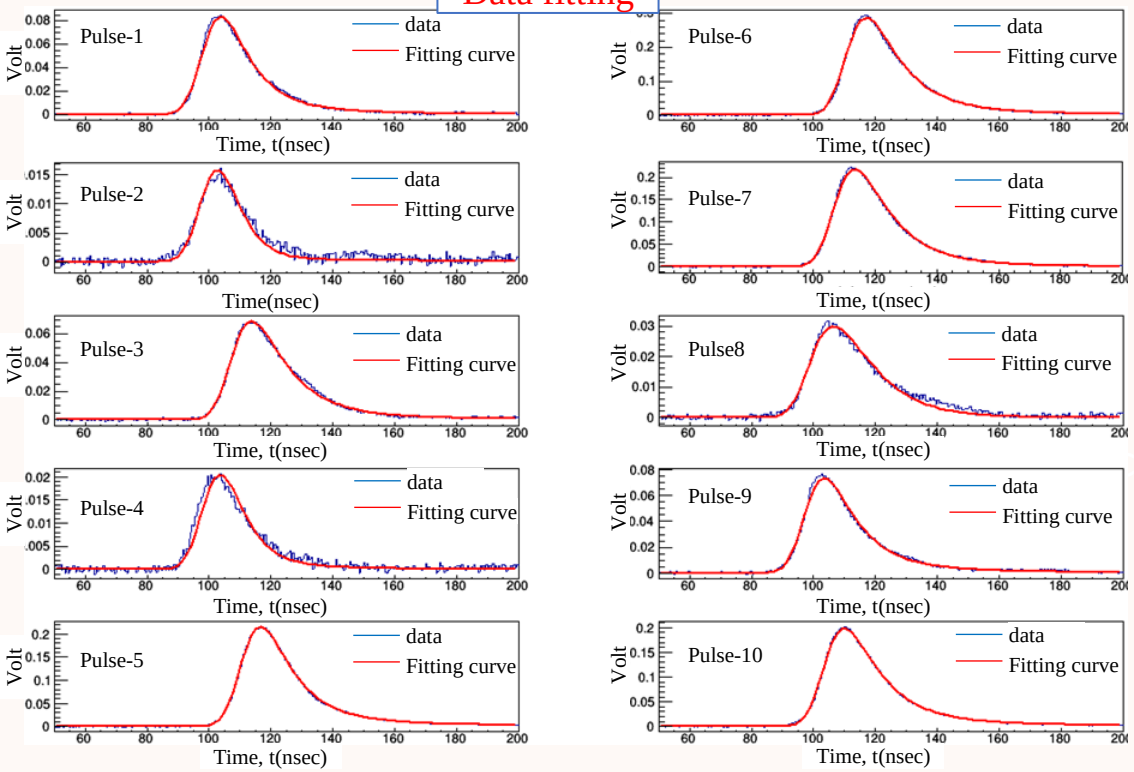
λ: Decay constant

$$G(t) = \frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{(t-\mu)^2}{2\sigma^2}}$$

$$\theta = \frac{1}{RC}$$

$$\operatorname{erf}(x) = \frac{2}{\sqrt{\pi}}\int_0^x e^{-u^2}du$$

Data fitting



Fitting formula:

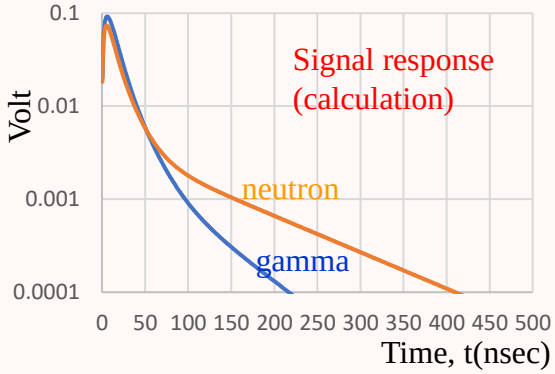
$$V(t) = \sum_{i=1}^{3} A_i\left\{\exp\left(\frac{\lambda_i^2\sigma^2-2(t-\mu)\lambda_i}{2}\right)\left[1-\operatorname{erf}\left(\frac{-t+\mu+\lambda_i\sigma^2}{\sigma\sqrt{2}}\right)\right] - \exp\left(\frac{\theta^2\sigma^2-2(t-\mu)\theta}{2}\right)\left[1-\operatorname{erf}\left(\frac{-t+\mu+\theta\sigma^2}{\sigma\sqrt{2}}\right)\right]\right\}$$

Fitting parameters: A_1, A_2, A_3, θ, λ_1, λ_2, λ_3, σ, μ.

From measurement data for Co-60 and Cf-252

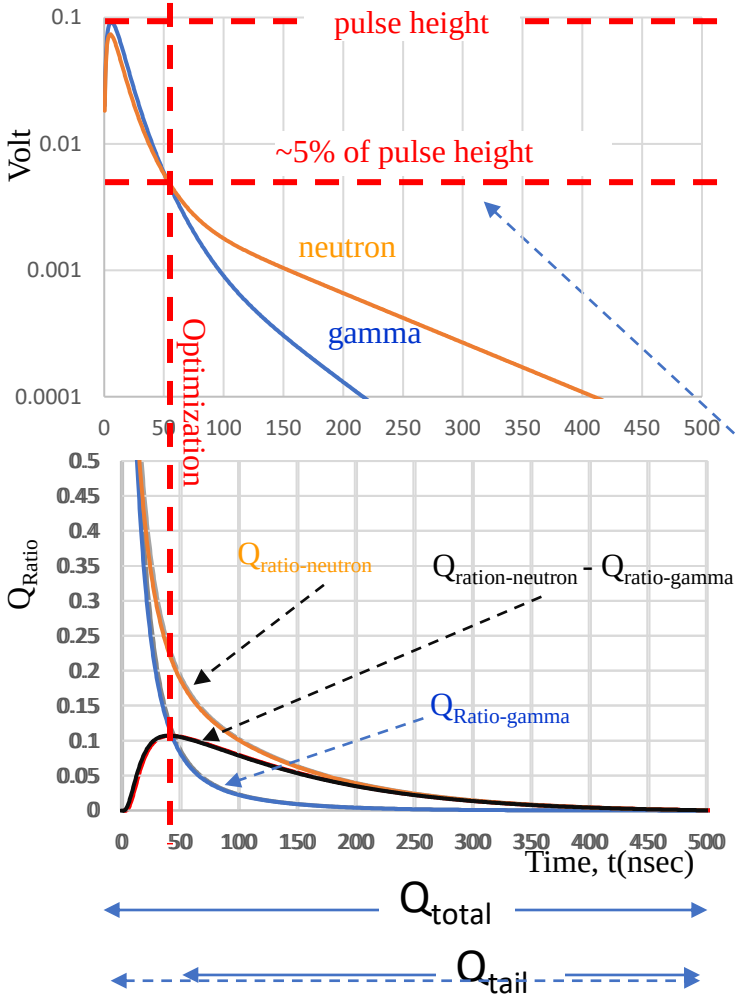
Fitting

Fitting parameters	Gamma	Neutron
θ	0.124 ± 0.034	0.142 ± 0.048
λ_1	0.266 ± 0.075	0.328 ± 0.073
λ_2	0.055 ± 0.019	0.059 ± 0.019
λ_3	0.016 ± 0.010	0.009 ± 0.005



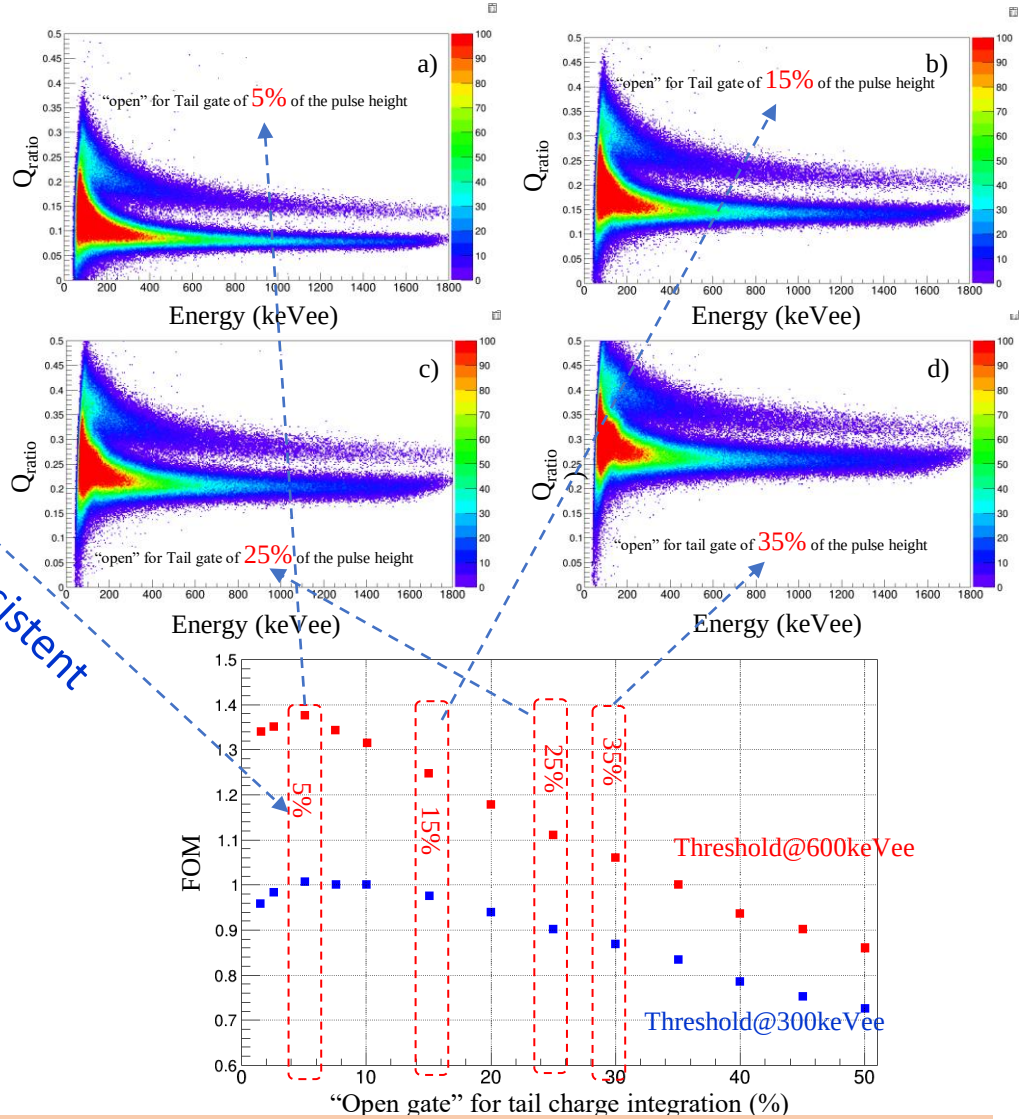
Data analysis

This work



consistent

Previous work [#717, RT Conf. 2018]



SUMMARIZE

- Equation to describe the pulse response for the EJ-276 scintillation detector with 3-decay components and gaussian noise.
- Determine characteristic parameters OF scintillation detector from measured data.
- Optimization of Q_{ratio} technique for neutron/gamma discrimination.