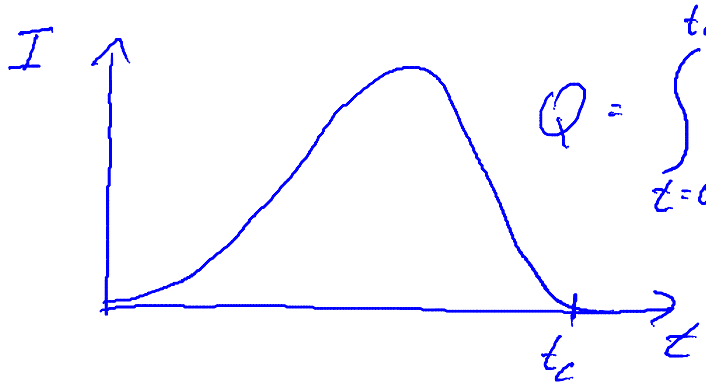
2. General characteristics of detectors

Particle with energy E_0 produces A interactions in the detector.

$$A = E_0 / w$$

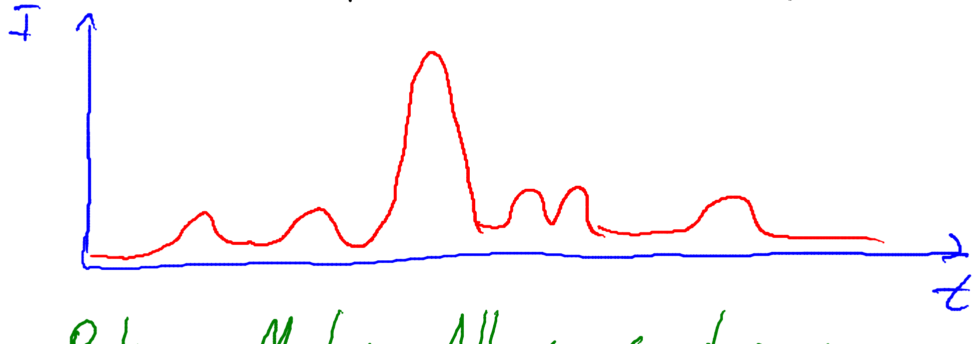
w = average energy to produce one ionization / excitation

→ Net result is usually a charge Q



$$Q = \int_{t=0}^{t_c} I \, dt$$

- Many subsequent pulses:
  Arrival of pulses is governed by Poisson statistics

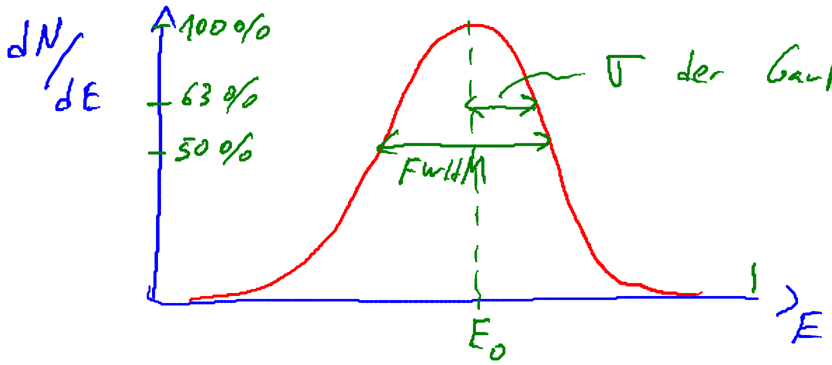


Pulse Mode: Allows spectroscopy

Current Mode: Averaging over several pulses

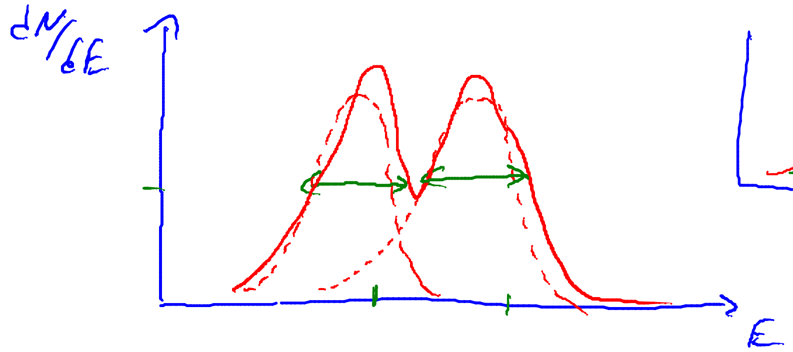
2.1 Energy resolution

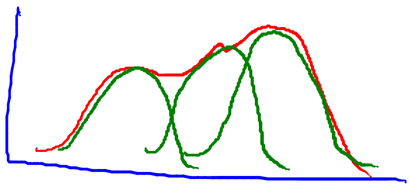
Various parts contribute to a finite energy resolution.



ΔE usually given in Full width at half maximum

$$FWHM = 2{,}35 \cdot \sigma$$





The precision how good an energy is determined from a spectrum is much better than FWHM.

ⓐ Fluctuations in the number of excitations/ionizations $\Rightarrow$ number of events A varies

$$\sigma_A = \sqrt{A} \quad \text{(if Poisson distributed)}$$

$$\text{Resolution} \quad R = \Delta E_{FWHM} / E \quad \text{(usually in \%)}$$

with: $A = E_0 / w$ and $FWHM = 2{,}35 \cdot \sigma$

$$\Rightarrow \quad R = 2{,}35 \cdot \frac{\sqrt{A}}{A} = 2{,}35 / \sqrt{A}$$

For good energy resolution w should be as small as possible $\rightarrow$ semiconductor detectors

- In ... detectors the A events are

- In many detectors the A events are somehow correlated

$\hookrightarrow$ FANO FACTOR $F = \dfrac{\text{observed variance in } A}{\text{Poisson prediction } (= A)}$

(VARIANCE $= \sigma^2$)

(b) Other sources for limited energy resolution
- electronic noise (test with pulser)
- (thermal) drifts

2.2 Detector efficiency

- Absolute detection efficiency

$$\varepsilon_{abs} = \frac{\text{number of pulses recorded}}{\text{number of radiation quanta emitted}}$$

due to

- ε_{geom} : finite size of detector

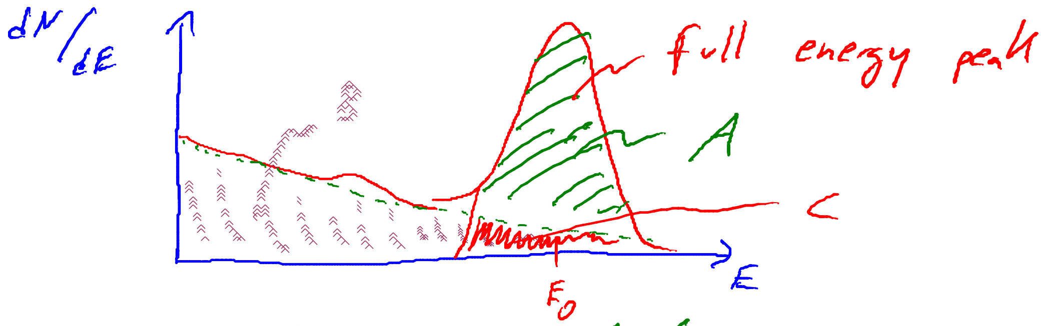
$$\varepsilon_{geom} = \Omega / 4\pi$$

- ε_{int} : intrinsic efficiency (depending on E)

$$\varepsilon_{int} = \frac{\text{number of pulses recorded}}{\text{number of radiation quanta incident on detector}}$$

$\hookrightarrow$ $\varepsilon_{abs} \simeq \varepsilon_{geom} \cdot \varepsilon_{int}$ (if independent)

- Typical response function



Peak-to-total ratio: $A/_{B+A}$

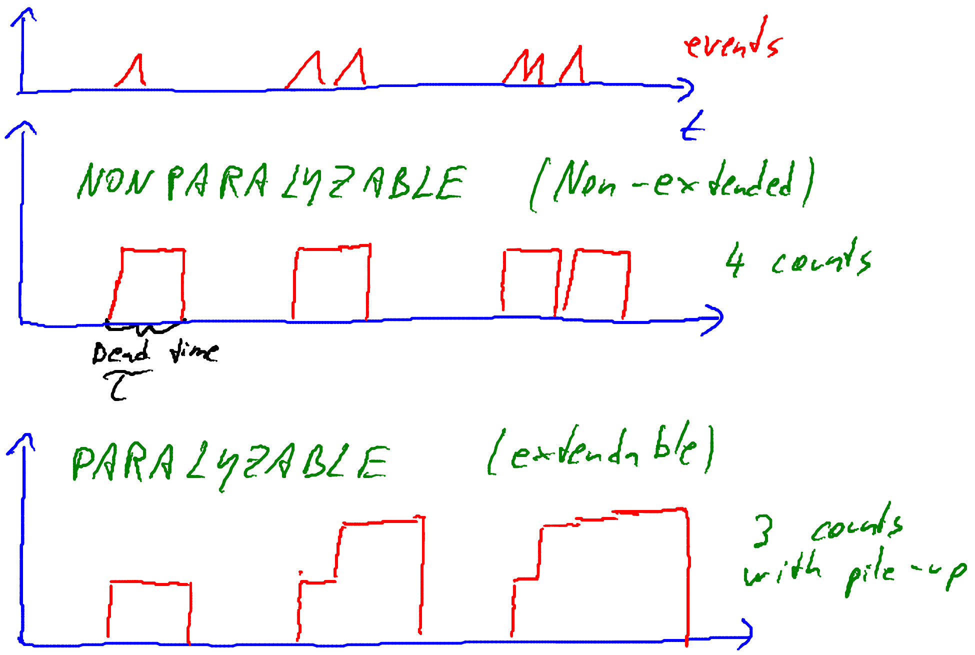
peak-to-background ratio: $A/_{C}$

2.3 Dead time

A minimum amount of time between two pulses is necessary to be able to separate them

→ DEAD TIME

- Two (simplified) models for dead time behavior



(i) non-paralyzable

- fraction of time that the detector is dead $= m \cdot \tau$

$m :=$ recorded interaction rate
$\tau :=$ dead time
$n :=$ true interaction rate

(z.B. $m = 10^6/s$ $\tau = 0{,}1\,\mu s$ $\Rightarrow m\cdot\tau = 0{,}1 = 10\,\%$)

- rate of true events which are lost $= n\,(m\cdot\tau)$

$$\Rightarrow\ n - m = n\,(m\cdot\tau)$$

$$\Rightarrow\ n = \frac{m}{1-m\tau}$$

(ii) paralyzable

distribution of intervals between subsequent events:

$$\underbrace{P_1(t)\,dt}_{\text{Prob. to observe an interval with length } t \pm dt} = n\cdot e^{-nt}\,dt \quad \text{(from Poisson)}$$

$\Rightarrow$ Probability of intervals large than dead time τ:

$$P_2(\tau) = \int_{t=\tau}^{\infty} P_1(t)\,dt = e^{-n\cdot\tau}$$

$$\Rightarrow\ m = n\cdot e^{-n\tau}$$ (no direct solution $\rightarrow$ iteration procedure)

- How to determine the dead time of a system?   6.5.09

1. Two source method

↳ Two source method

source 1: n_1 source 2: n_2 } all including background

combined sources: n_{12}

background n_b

↳ $n_{12} - n_b = (n_1 - n_b) + (n_2 - n_b)$

$\Leftrightarrow n_{12} + n_b = n_1 + n_2$

assume non-paralyzable model

↳ $$\frac{m_{12}}{1 - m_{12} \cdot \tau} + \frac{m_b}{1 - m_b \cdot \tau} = \frac{m_1}{1 - m_1 \tau} + \frac{m_2}{1 - m_2 \tau}$$

↳ $$\tau = \frac{X\left(1 - \left(\sqrt{1 - Z}\right)\right)}{Y}$$

$X := m_1 \cdot m_2 - m_b \cdot m_{12}$

$Y := m_1 m_2 (m_{12} + m_b) - m_b \cdot m_{12} (m_1 + m_2)$

$$Z := \frac{Y \cdot (m_1 + m_2 - m_{12} - m_b)}{X^2}$$

Very time consuming measurement because differences of rates come into play.

- Dead time of electronics can be measured with oscillators (pulsers)