Scintillation uses

- The primary interaction
- The detection modes
- What kind of information can be obtained?

the primary interaction

The interaction depends on the particle type and

photon $\neq$ massive particles.

- If photon (x,γ) $\rightarrow$ absorption or transmission
  $\rightarrow$ Photoelectric-Compton
  $\rightarrow$ pair creation (if E>2x511keV)
- If massive charged particle
  $\rightarrow$ energy loss function (-$\frac{dE}{dx}$)

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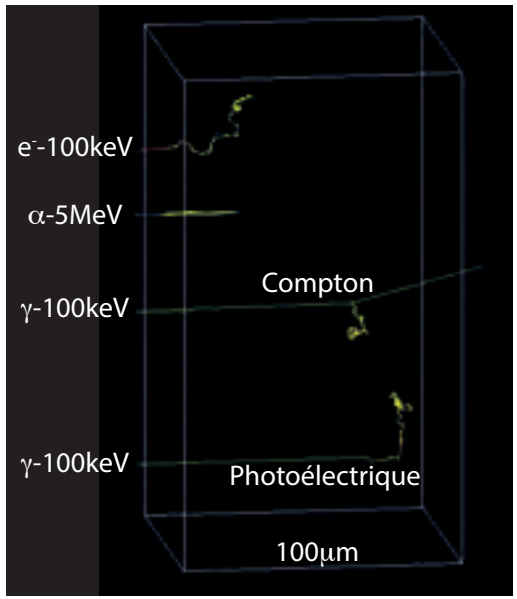
- α: $M_\alpha \gg M_{e^-}$, Bethe-Bloch formula (same for protons)
- electrons (β^-): inelastic scattering or Bremsstrahlung (X-ray emission)

Simulation with GEANT4



example with NaI:Tl

the primary interaction

Interactions with neutrons are different (restricted to detection)

- **Fast neutrons:** energy transfer through collisions with nucleus of similar mass (H) (The reason why plastics are preferred)
  Then the proton interacts as charged massive particle $\rightarrow$ light

the primary interaction

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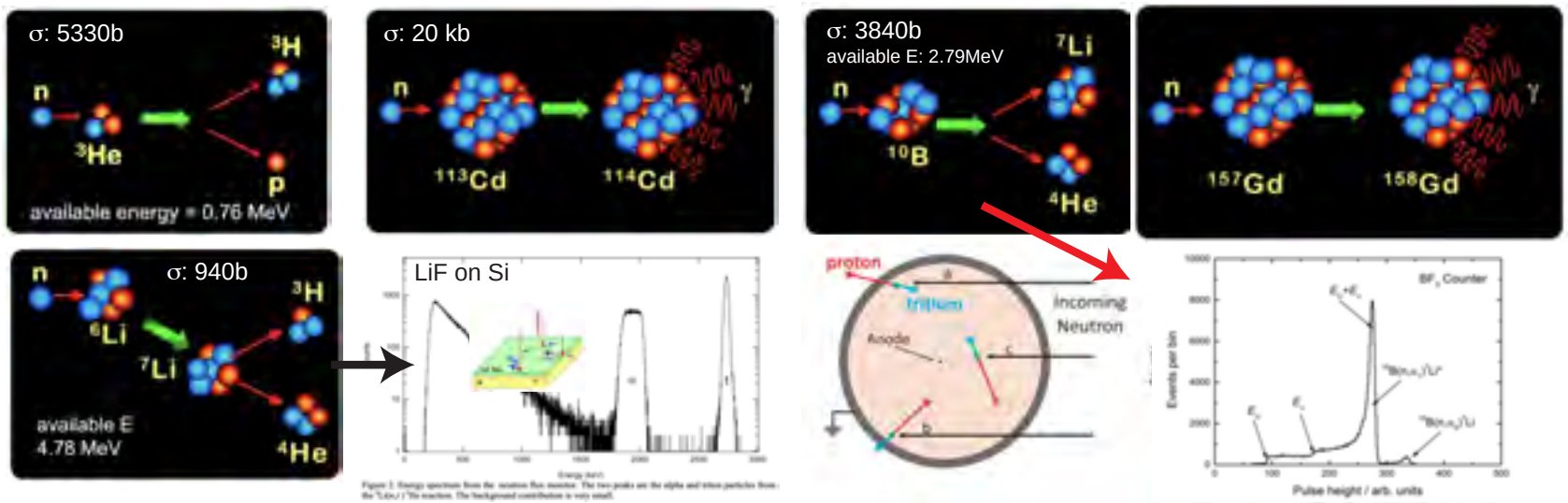
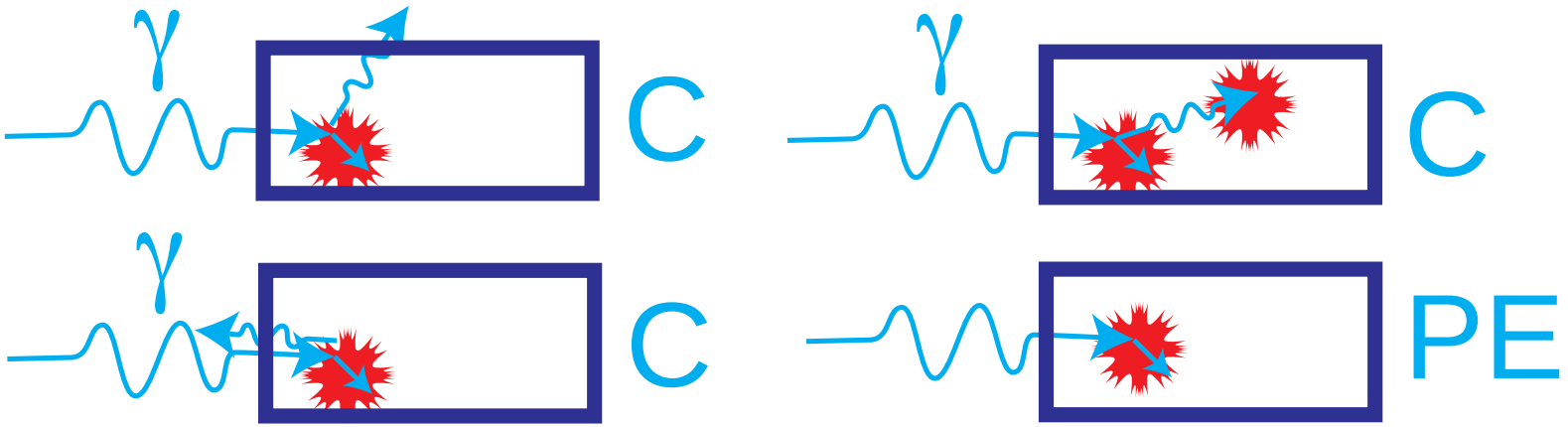
- **Thermal neutrons:** capture by nucleus with high thermal neutron capture cross-section



It can lead to a very complex pulse height spectrum

interaction with photons (E<2x511keV)

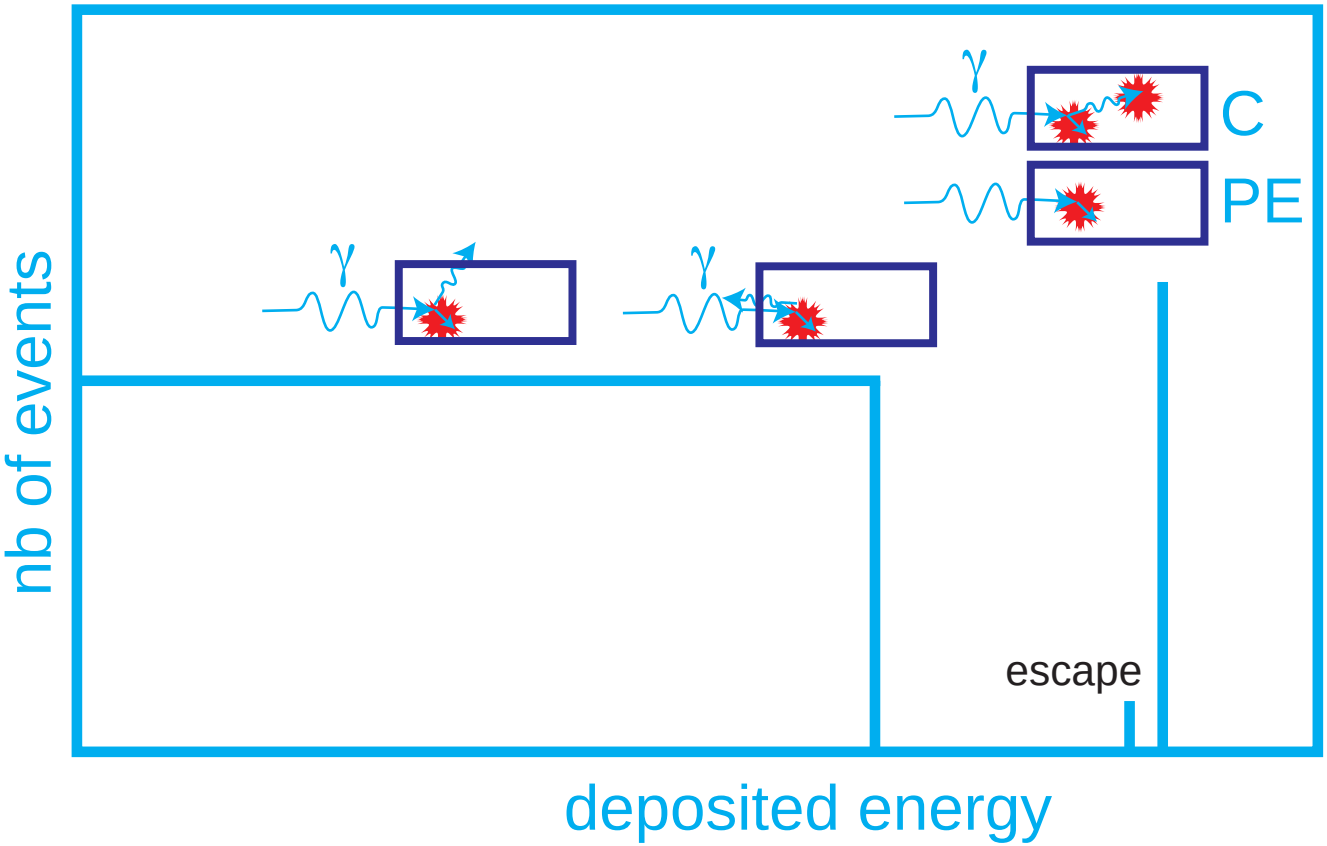


Compton and Photoelectric effects occur

- It generates a fast electron (which will generate the light at the end)
- In the case of Compton scattering, a γ photon generally escapes from the crystal and the full energy of the incoming γ is not deposited in the crystal. The energy deposition depends on the scattering angle.
- In some cases (top - right), the secondary γ is absorbed by the crystal, it appears like a photoelectric event from the energy deposition point of view

interaction with photons (E<2x511keV)

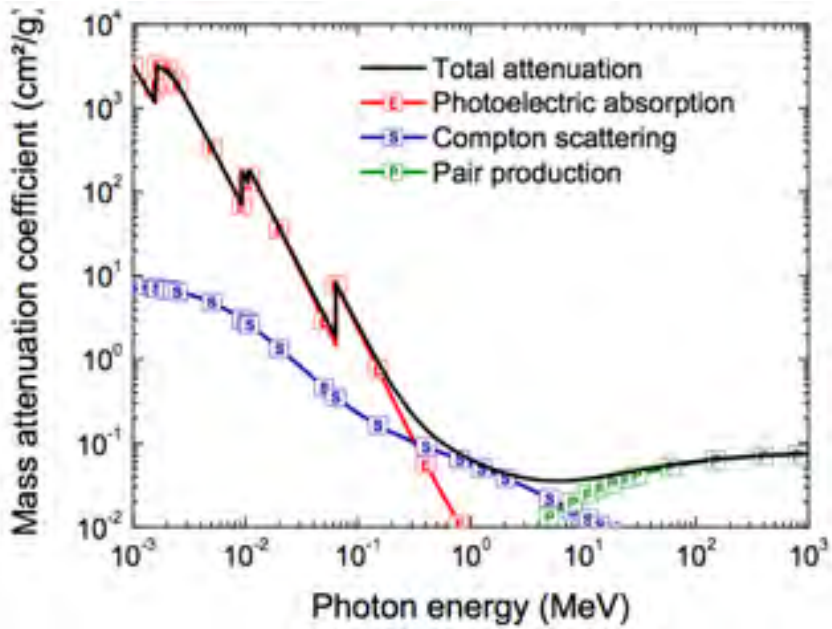
As a result, the statistics of the energy deposition following the interaction with a photon leads to this schematic histogram



Crucial to understand the spectroscopy, the energy resolution and the light yield measurement

about absorption

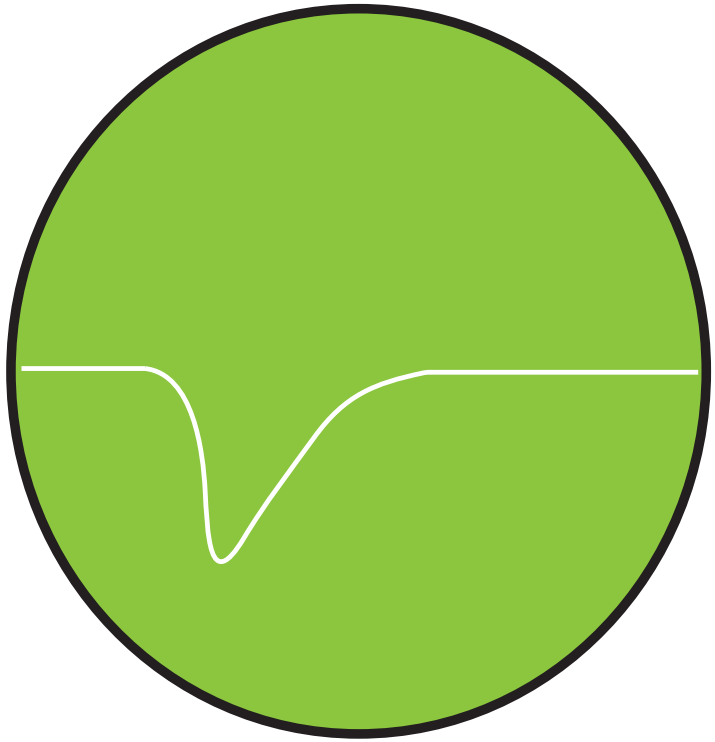
- Linear probability of interaction: $\mu = \frac{n_e . \sigma_e}{Z_{eff}}$
- with n_e the density of electrons
- $Z_{eff} = W_A Z_A + W_B Z_B + W_C Z_C$ the effective atonic number of compound $A_X B_Y C_Z$ and W_i the mass fraction
- $\sigma_e = \sigma_{pe} + \sigma_c + \sigma_{pp}$ (various interaction cross sections)
- $\sigma_{pe} \alpha \frac{Z_{eff}^5}{E_\gamma}$ (+ effect of K, L, M... edges)
- $\sigma_c \alpha \frac{Z_{eff}}{E_\gamma}$



Mass attenuation of LuAG (curve from PhD thesis of K.Pauwels)

What kind of information can be obtained?

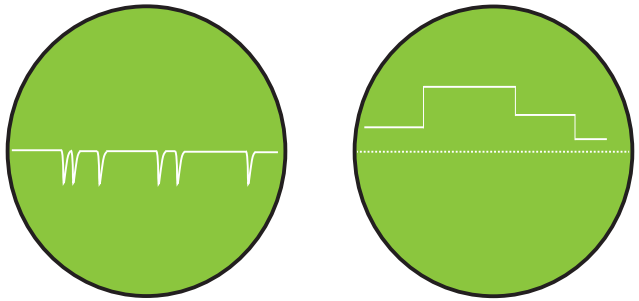
Counting mode



BIP - BIP: there are some radiations → GEIGER type detector

What kind of information can be obtained?

Counting and Integrating mode

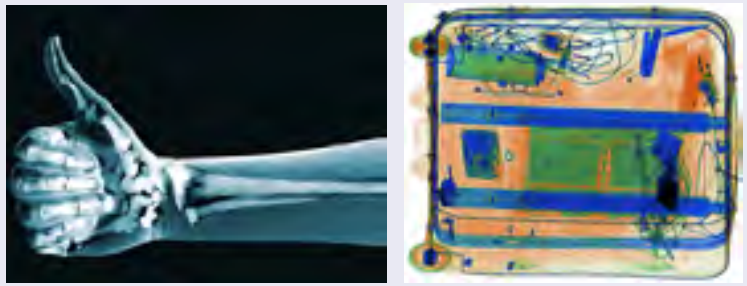


Real time dosimetry

(from https://icohup.com)

With pixelated photodetector

Imaging

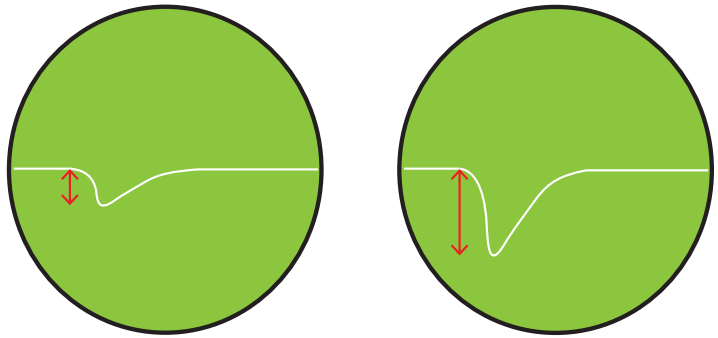


(from https://www.nema.org & https://www.securityprousa.com)

+ 3D images, even videos

What kind of information can be obtained?

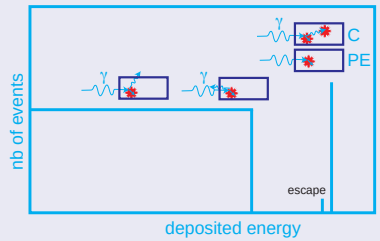
Counting mode



Information on the energy deposited during the event: 2 situations

The source is known

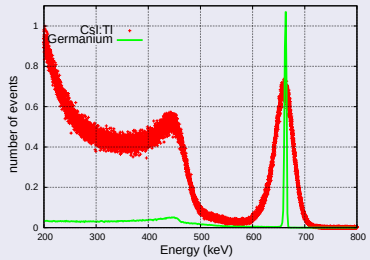
The event should belong to the predicted energy distribution



→ it says if the event is photo-electric or Compton

The source is NOT known

It requires to accumulate to form a spectra for nature identification

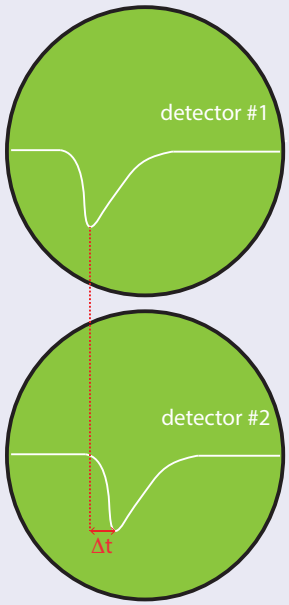


→ it says that it is ^{137}Cs ! (easy situation)

What kind of information can be obtained?

Counting mode
Information on the timing between 2 events in 2 detectors

Timing

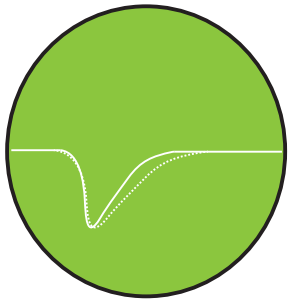


Why?

- Are the events are in coincidence or not?
- Can we obtain time of flight capabilities?
- →Positron emission tomography, high energy physics...

What kind of information can be obtained?

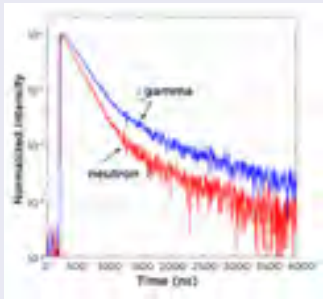
Counting mode

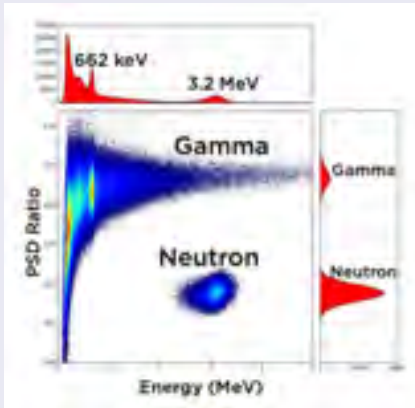


Particle identification

- In some cases, the nature of the interaction changes the time response
- $\rightarrow$ It allows to distinguish various particles nature (neutrons & photons for ex.)
- called PSD: Pulse Shape Discrimination

Illustrations with a real signal





(from www.crystals.saint-gobain.com)

Used a lot with plastic scintillators as well