



Escuela José Antonio Balseiro 2016

Nuevas Tendencias en Investigación en Física Médica

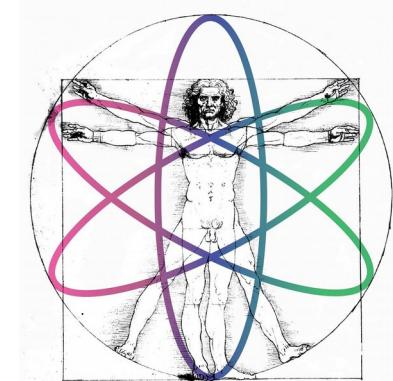
Introducción a muchas cosas

Viernes: Aceleradores y Detectores

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**Laboratorio Detección Partículas y Radiación
Centro Atómico Bariloche**



Clases en

<https://github.com/asoreyh/intro-nuclear-fisica-medica>

 asoreyh Clase 01 lista	Latest commit db0d282 2 days ago
 clases Clase 01 lista 2 days ago	
 README.md Commit inicial 4 days ago	

 README.md



Curso de Introducción a Física Nuclear y Detectores

Escuela José Antonio Balseiro - Nuevas Tendencias en Investigación en Física Médica

Octubre 2016 - Centro Atómico Bariloche e Instituto Balseiro

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Aceleradores



Radio de giro

- La componente magnética de la fuerza de Lorentz es perpendicular a la dirección de movimiento:

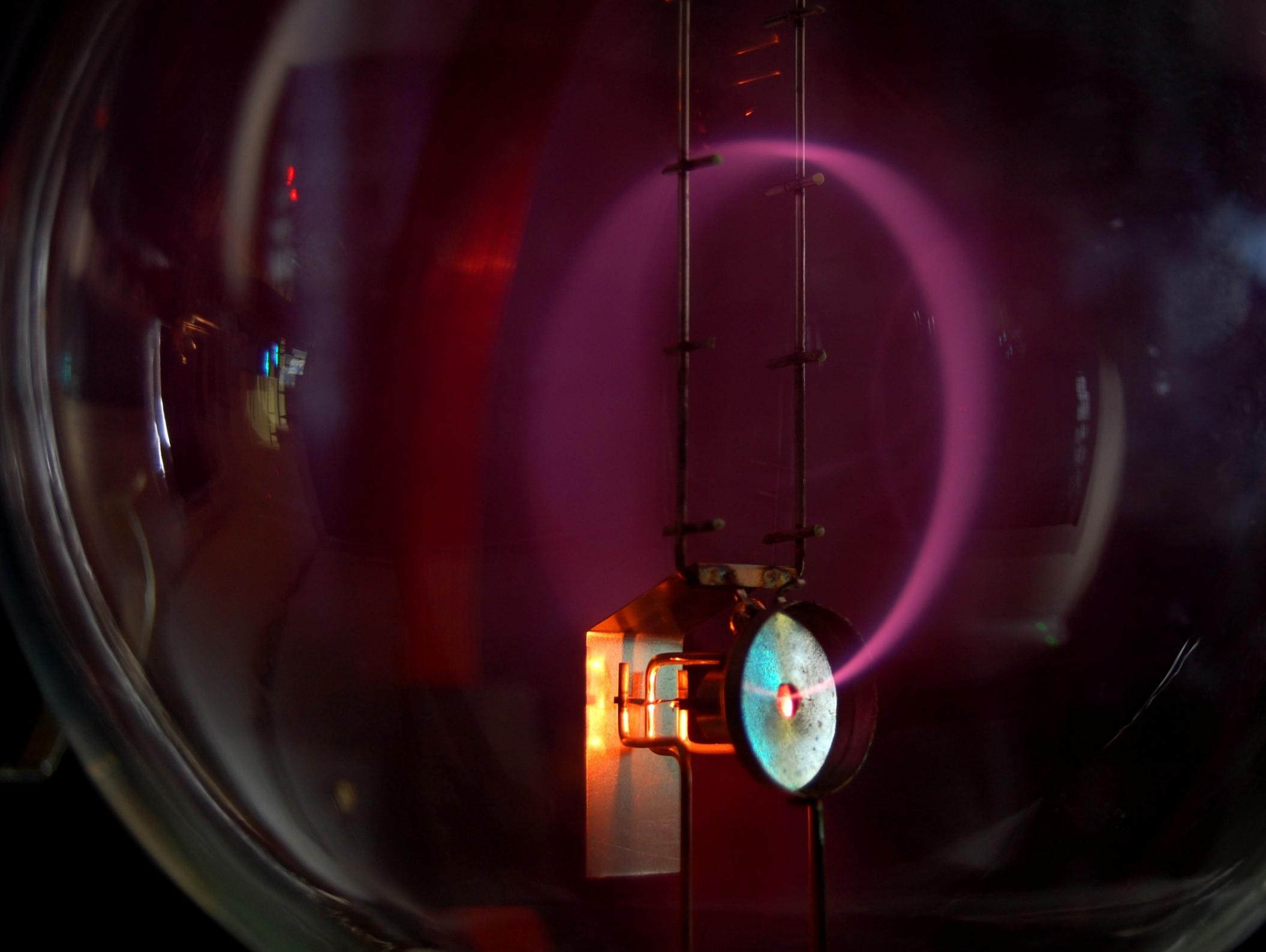
$$\vec{F} = q(\vec{v} \times \vec{B})$$

- Movimiento circular, aceleración centrípeta (¡usar γm para el caso relativista! Gracias Feynmann)

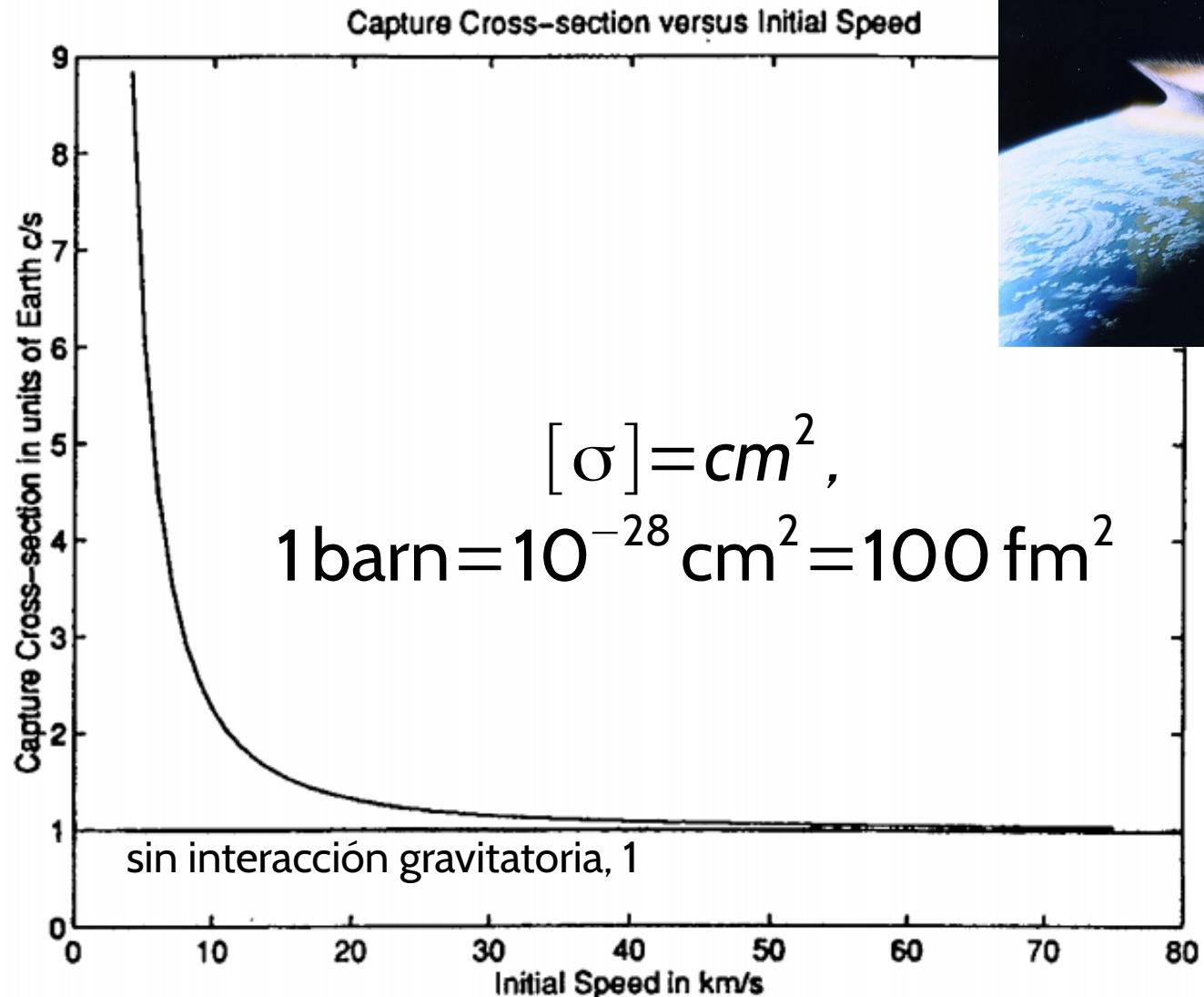
$$r_g = \left(\frac{\gamma m}{|q|} \right) \left(\frac{v_{\perp}}{B} \right)$$

- El período es entonces:

$$t_g = \frac{2\pi\gamma m}{|q|B}$$



Sección eficaz de captura de asteroides



Luminosidad de un acelerador

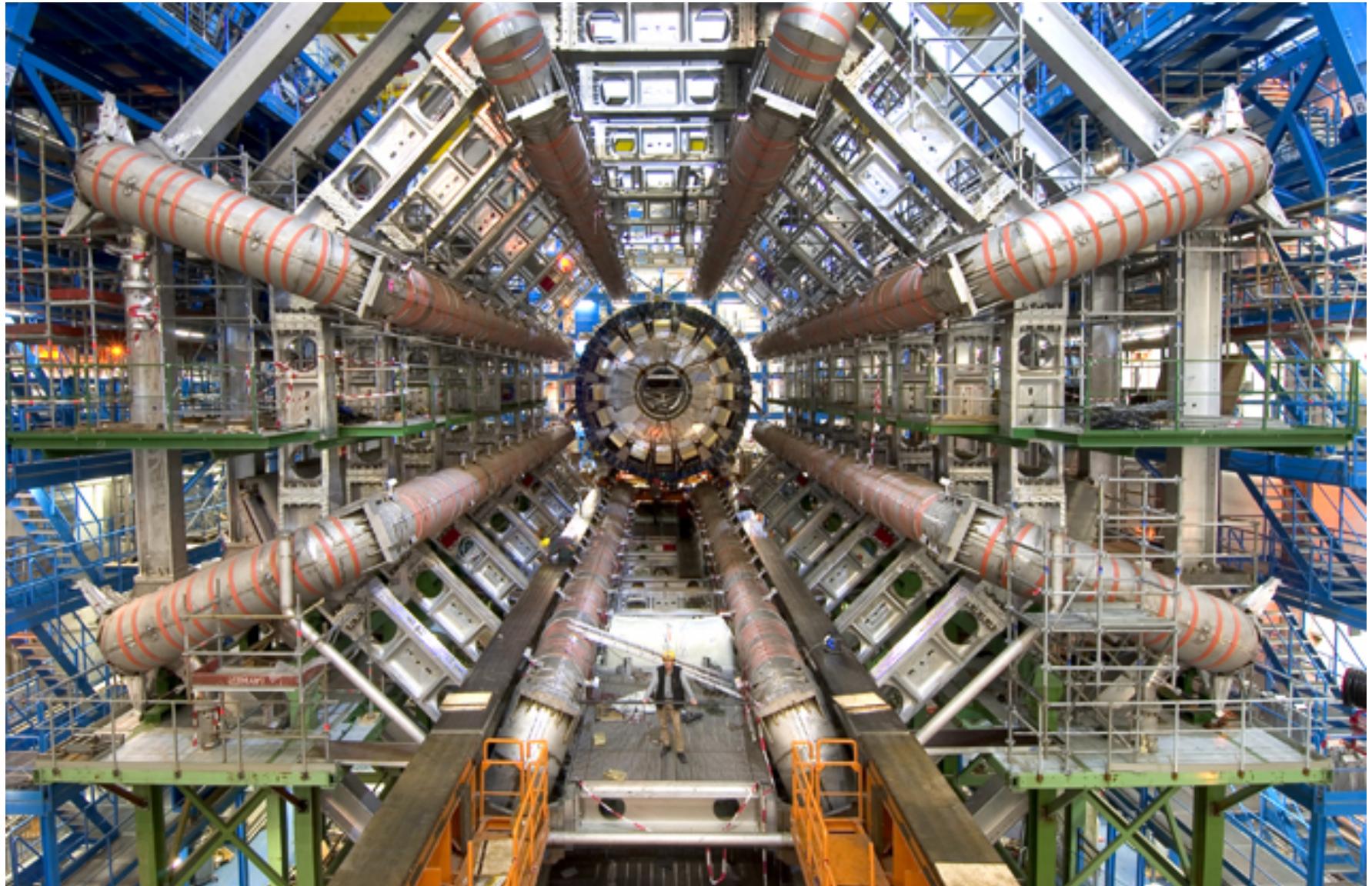
- Número de eventos **detectados** (N) como en un cierto tiempo (t) respecto a la sección eficaz de interacción (σ)

$$L = \frac{1}{\sigma} \frac{dN}{dt}, \quad [L] = \text{cm}^{-2} \text{s}^{-1}$$

- La luminosidad integrada es la integral en el tiempo:

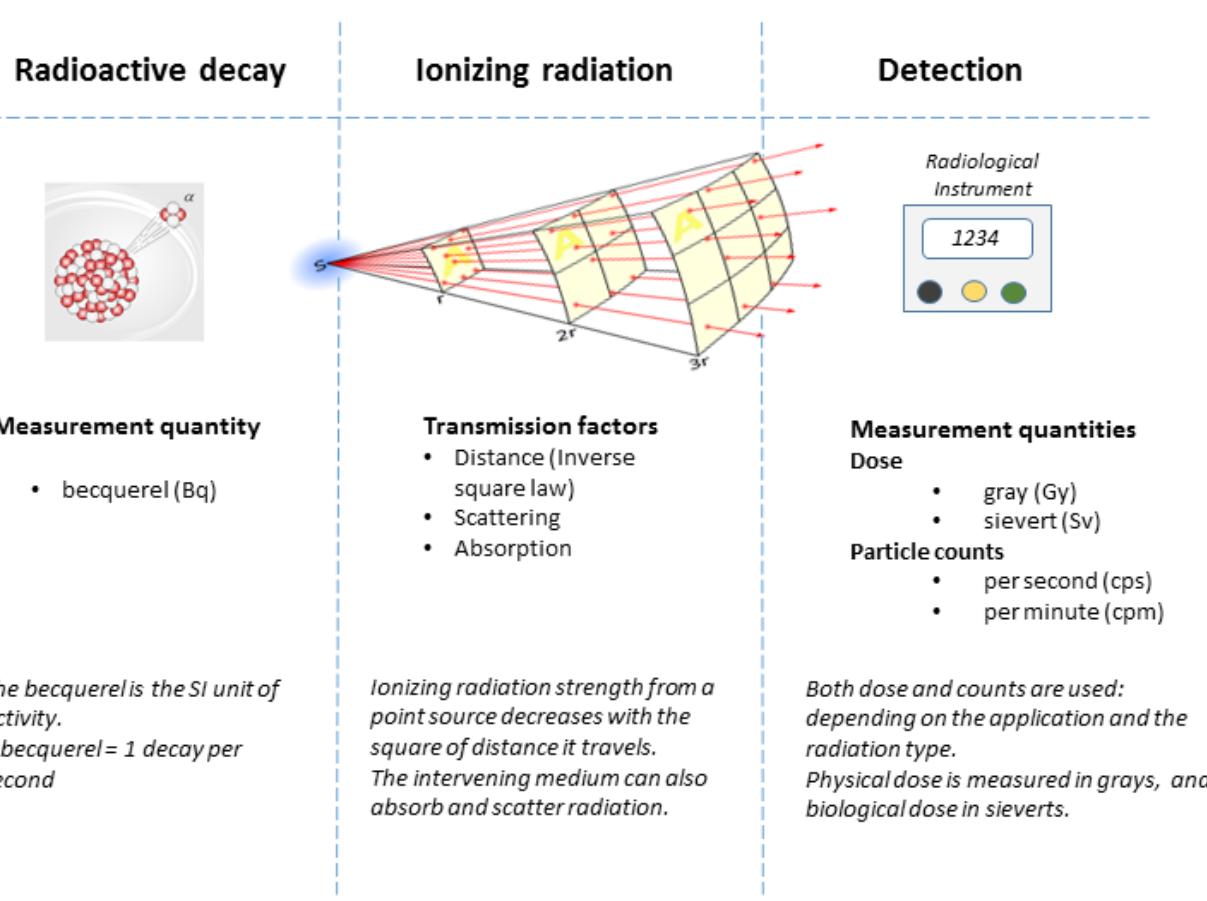
$$L_{\text{int}} = \int L dt, \quad [L_{\text{int}}] = \text{cm}^{-2}$$

Detectores, porque medir es interactuar



Radiación y Unidades

Radioactivity and Ionizing Radiation



- **Dosis efectiva, H**
considera el efecto sobre los distintos tipos de tejidos

- **Dosis absorbida, D**
Energía recibida en forma de radiación ionizante por un medio
 $[D_{R,T}] = \text{J/kg} = \text{Gy (gray)}$
(1 rad = 0.01 Gy)

- **Dosis equivalente, H_T**
Incluye el efecto biológico de los distintos tipos de radiación ionizante:

$$H_T = w_R D_{R,T},$$
$$[H_T] = \text{Sv (sievert)}$$
$$(1 \text{ rem} = 0.01 \text{ Sv})$$

Poder de frenado

- Es igual a la **energía perdida (por partículas cargadas) por unidad de camino recorrido** en el medio

$$S(E) = -\frac{dE}{dL}, \quad S(E) > 0, \text{ y } [S] = \text{MeV cm}^{-1}$$

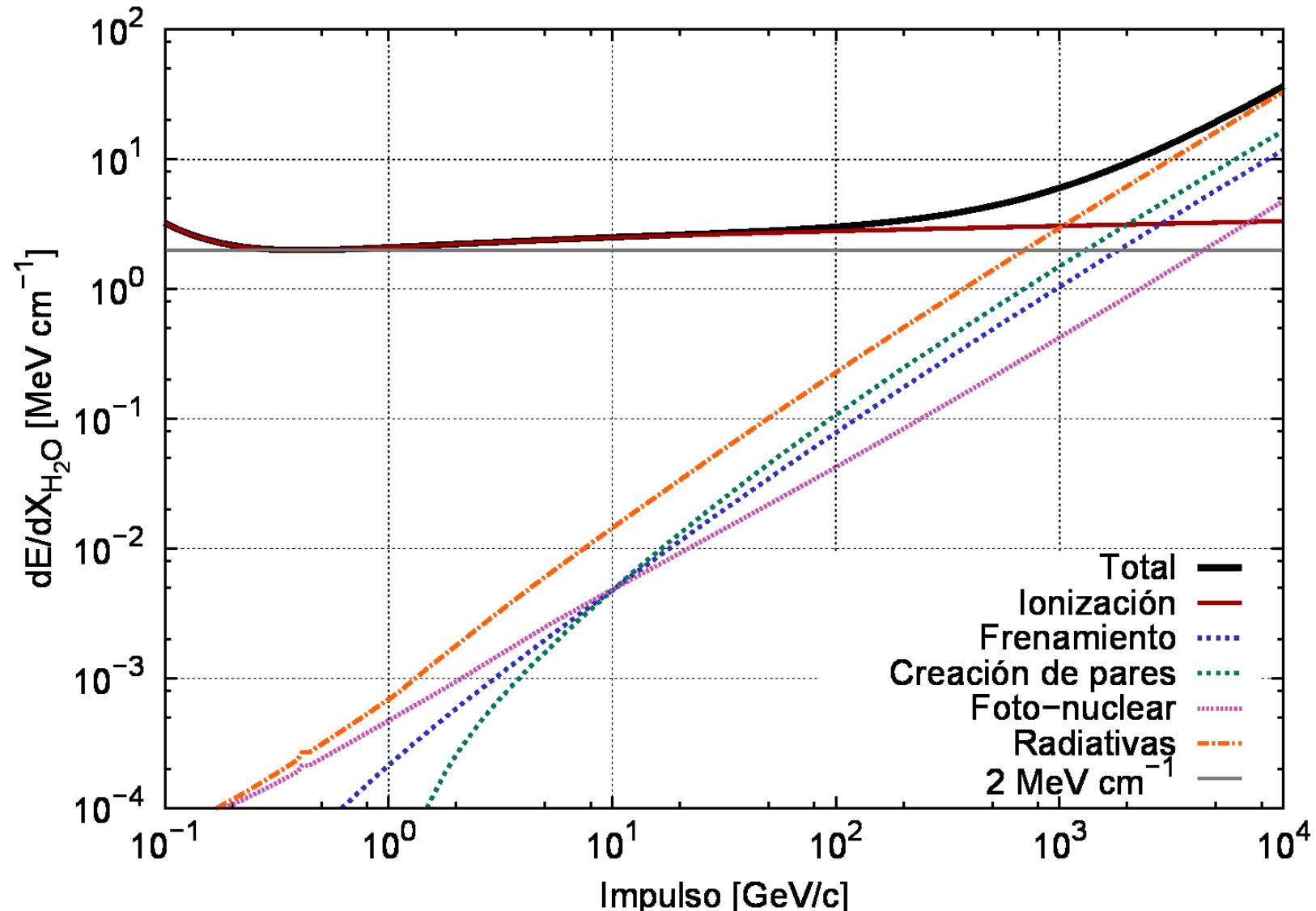
- Luego el **rango** recorrido depende de la energía inicial E_0 (CSDA: continuous slowing down approximation)

$$R(E) = \int_0^{E_0} \frac{dE}{S(E)}$$

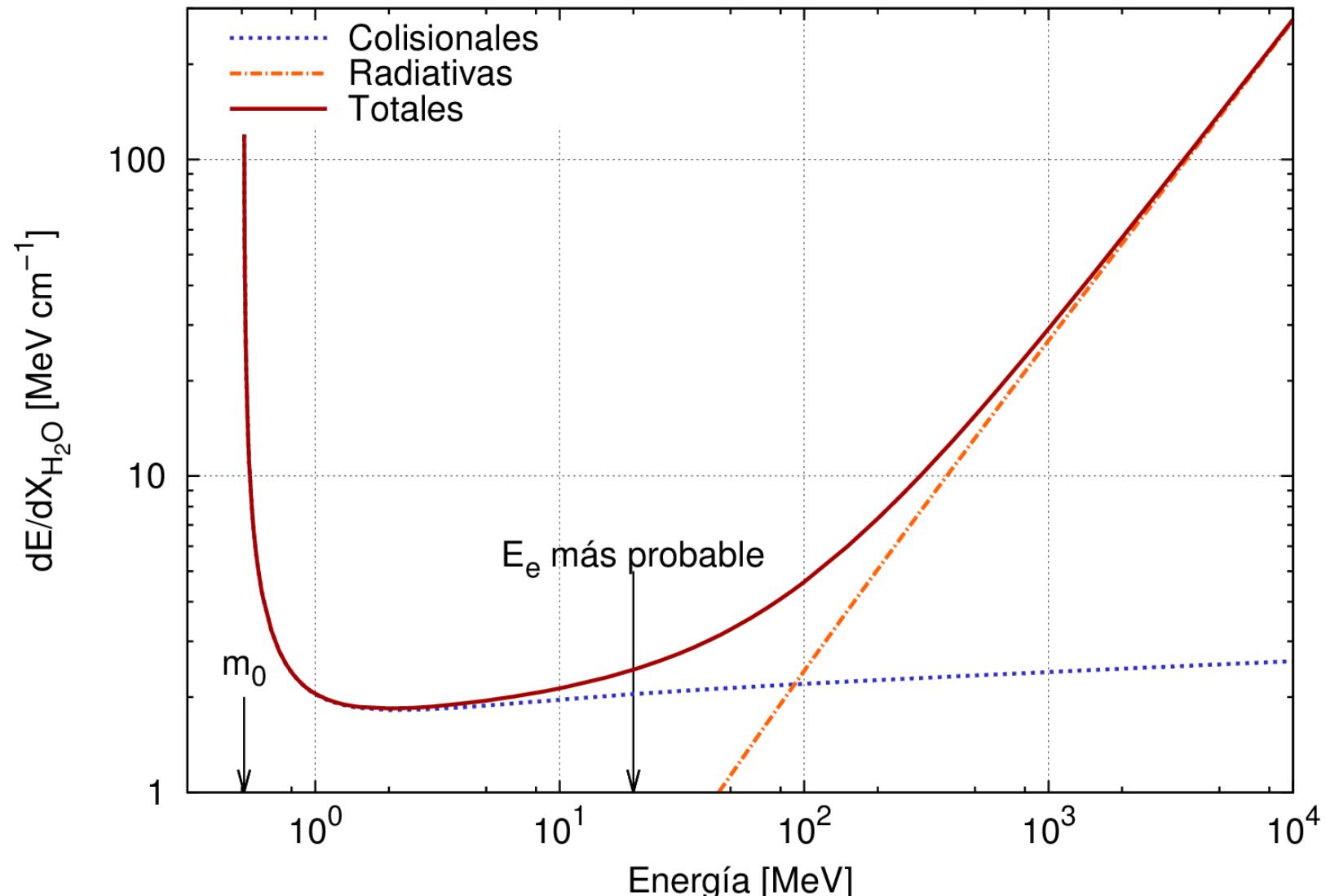
- X:

$$X = \int_0^L \rho(l) dl, \text{ si } \rho \text{ cte, } X = \rho L \quad [X] = \text{g cm}^{-2}$$

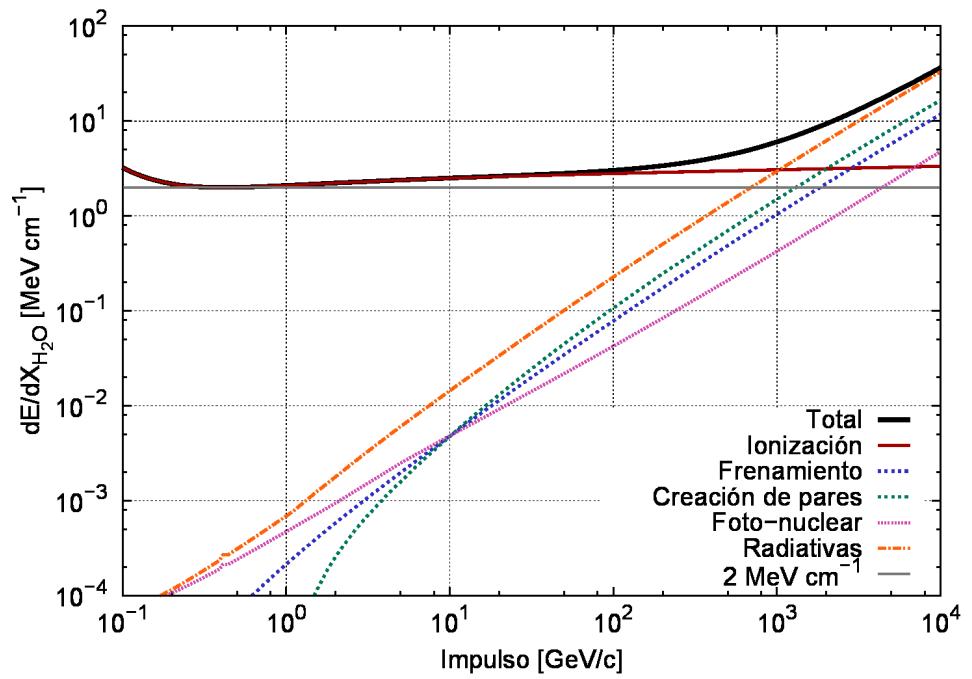
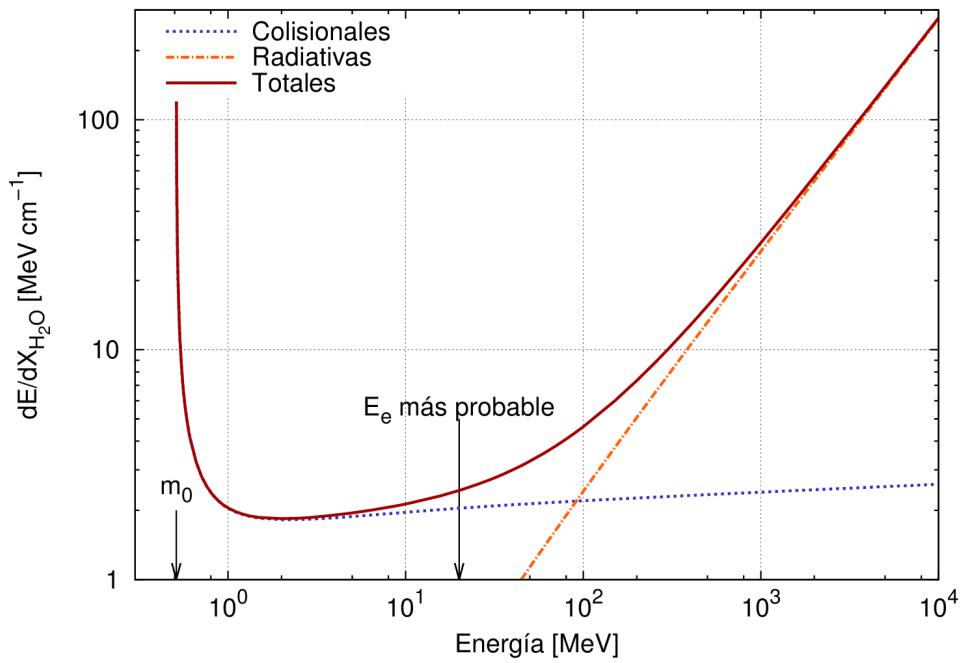
dE/dX muones en agua



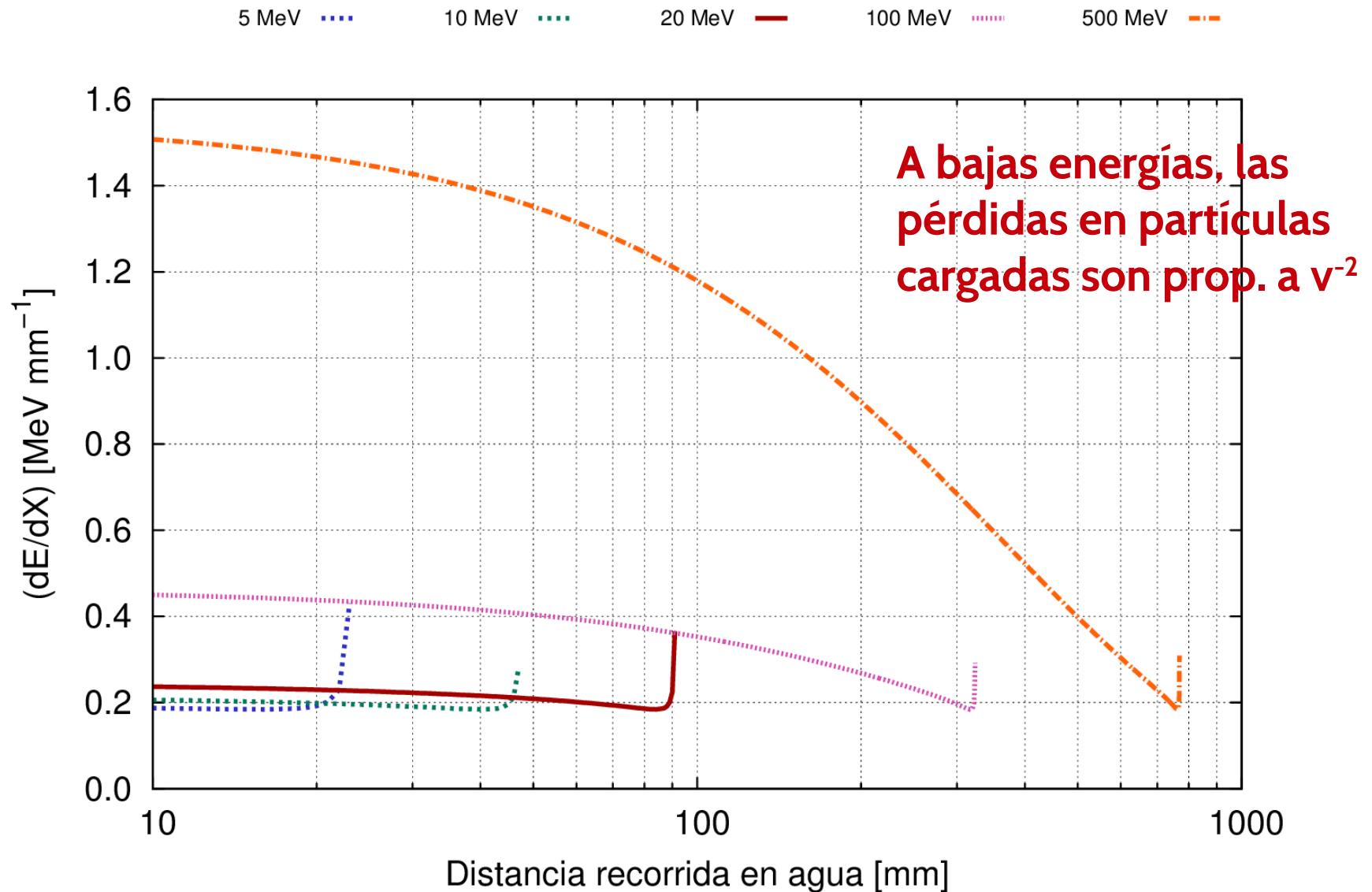
dE/dX electrones en agua



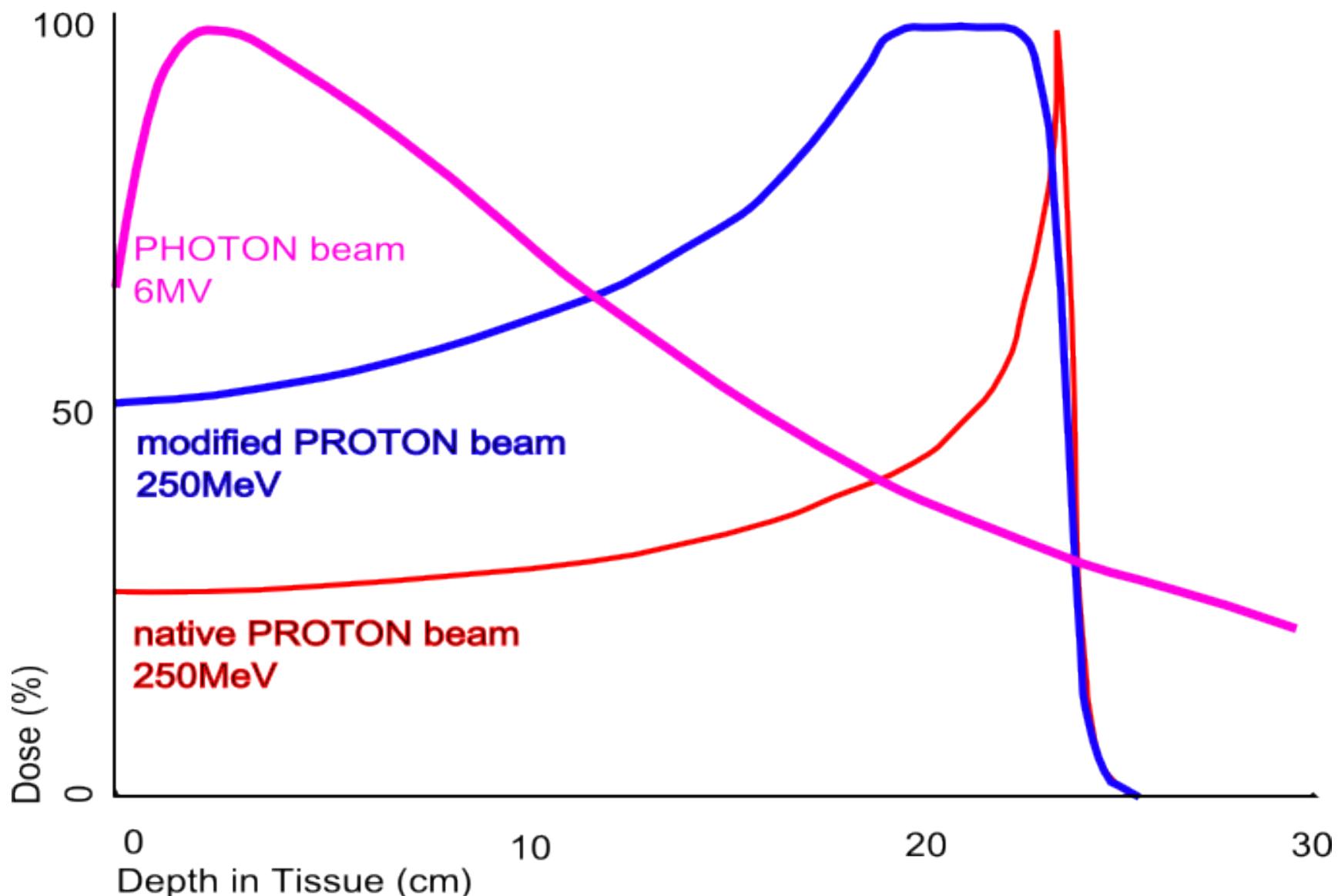
dE/dX electrones vs muones en agua



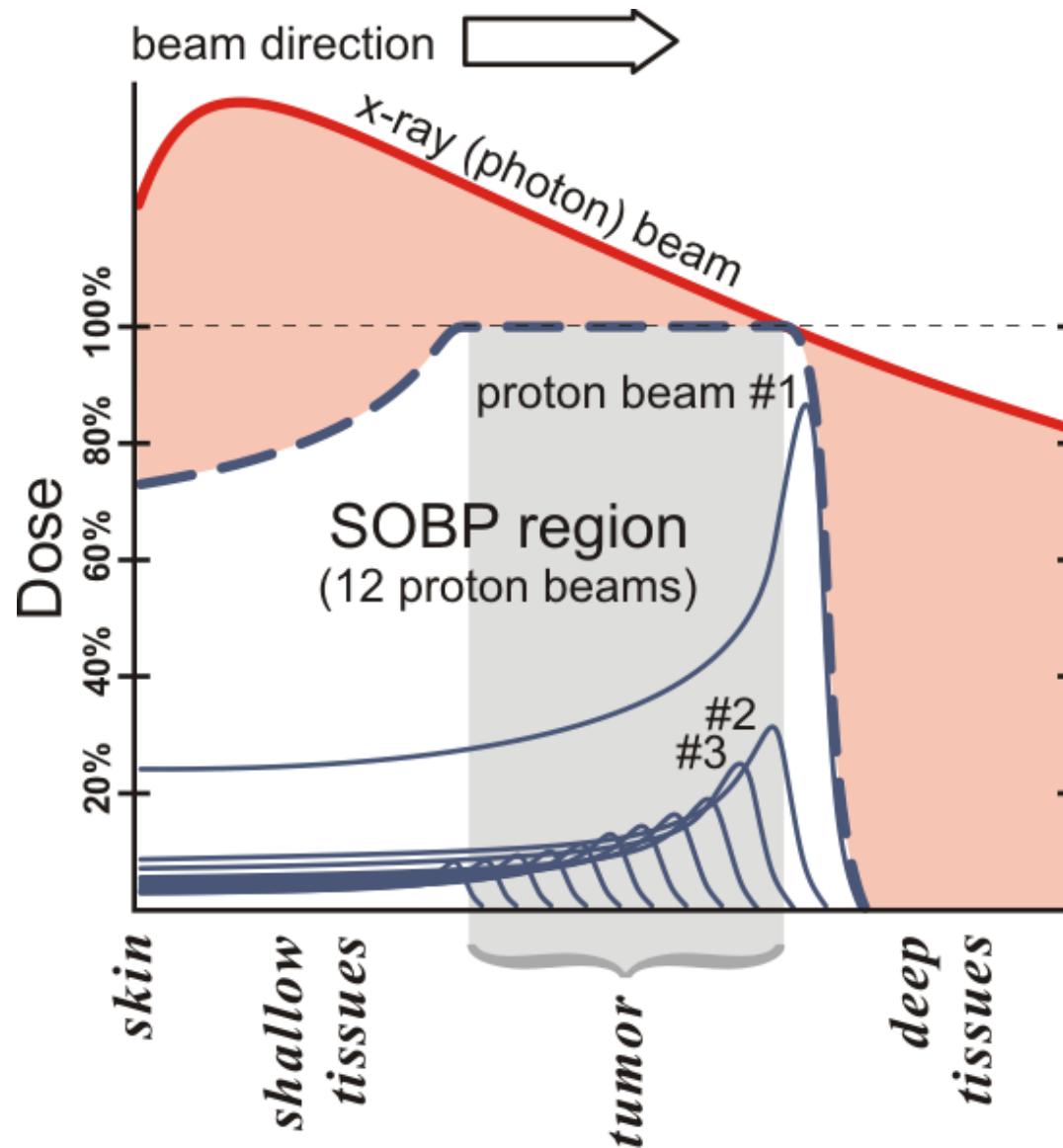
Pico de Bragg



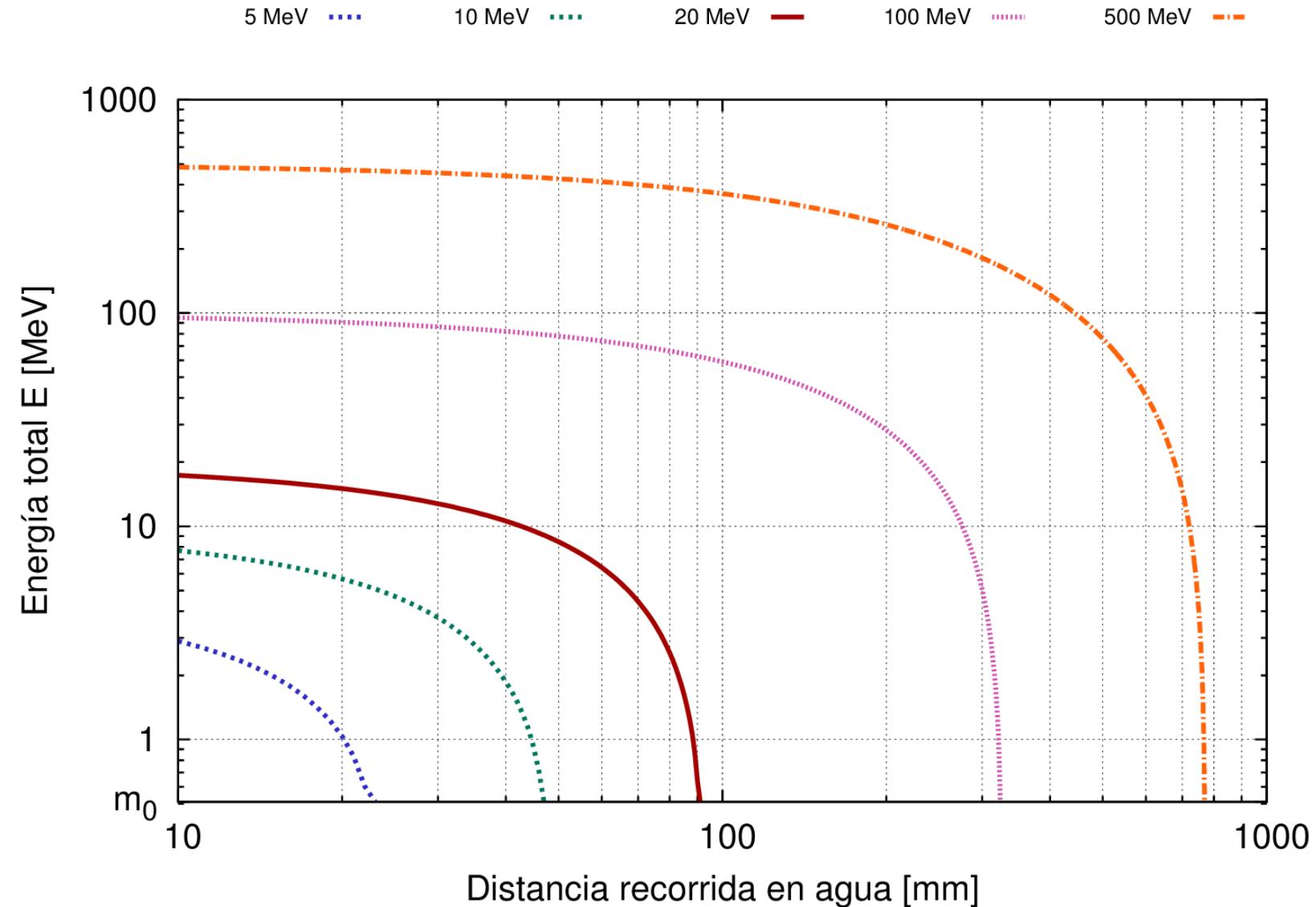
Pico de Bragg



Pico de Bragg, haces múltiples

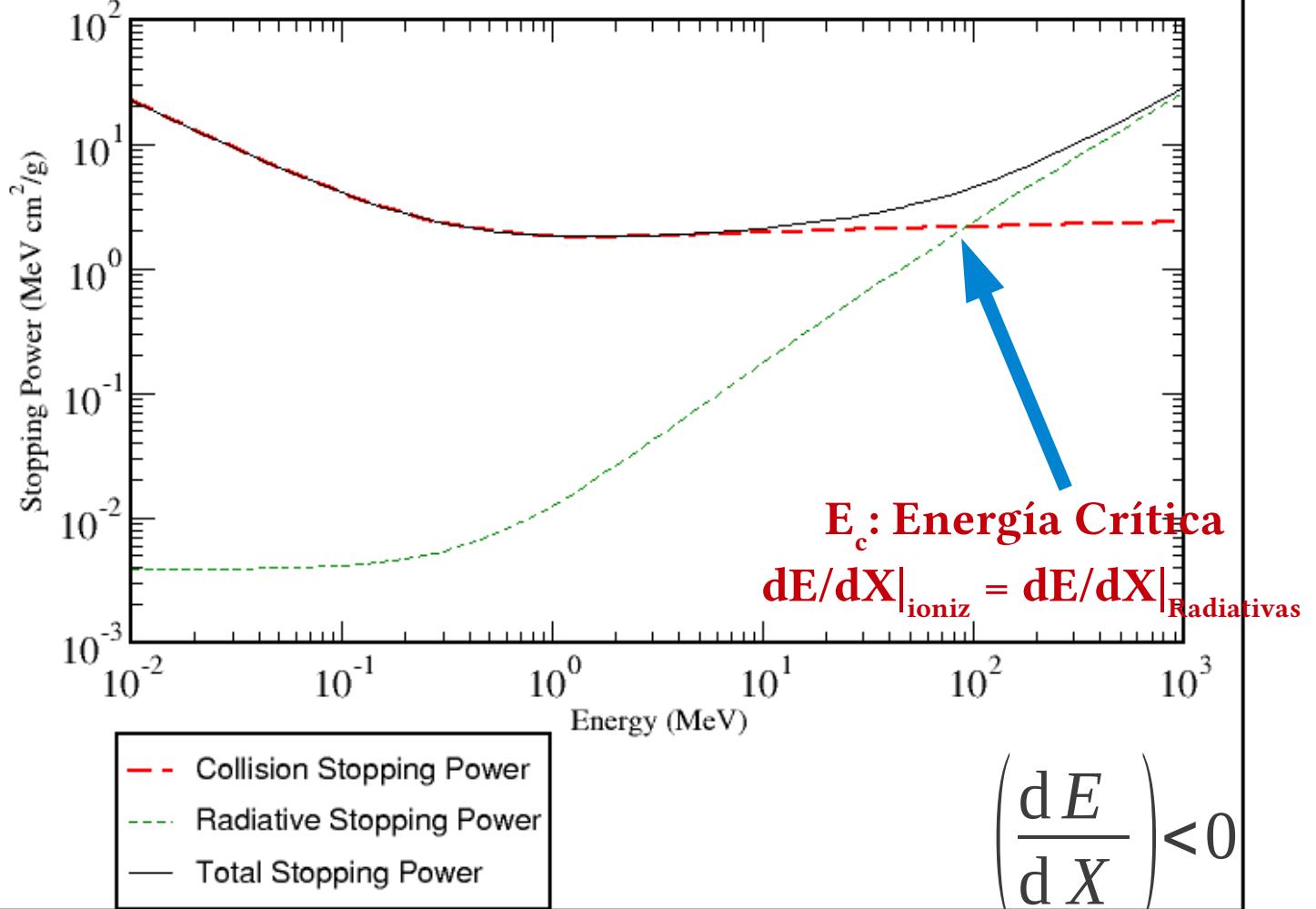
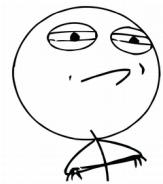


Rango de electrones en agua



Poder de frenado

CHALLENGE ACCEPTED



Si $E > E_c \rightarrow$ Nuevas partículas

Si $E < E_c \rightarrow$ Absorción en el medio

Oct, 2016

$$E_c^{EM} \approx \frac{710 \text{ MeV}}{Z + 0.92} = 86 \text{ MeV}$$

estar/pstar/astar/XCOM

NIST
National Institute of
Standards and Technology
Physical Meas. Laboratory



The ESTAR program calculates stopping power, density effect parameters, range, and radiation yield tables for electrons in various materials. Select a material and enter the desired energies or use the default energies. Energies are specified in MeV, and must be in the range from 0.001 MeV to 10000 MeV.

[Help](#)

[Text version](#)

[Material composition data](#)

Select a common material:

Muscle, Skeletal

or enter a [unique material](#)

Graph stopping power:

- Total Stopping Power
- Collision Stopping Power
- Radiative Stopping Power

Graph density effect parameter

Graph CSDA range

Graph radiation yield

No graph

Additional Energies (optional):

Use energies from a file*

[Choose File](#) No file chosen

or

Use energies entered below (one per line)

Include default energies

Note: Only stopping powers and the density effect parameter will be calculated if additional energies are used.

[Submit](#)

[Reset](#)

* Your browser must be file-upload compatible.

<https://www.nist.gov/pml/stopping-power-range-tables-electrons-protons-and-helium-ions>

Longitud de interacción X_{EM}

- A medida que la partícula avanza, pierde energía
 - Ionización → Colisiones
 - Radiativas → Producción de nuevas partículas
- En general, se define:

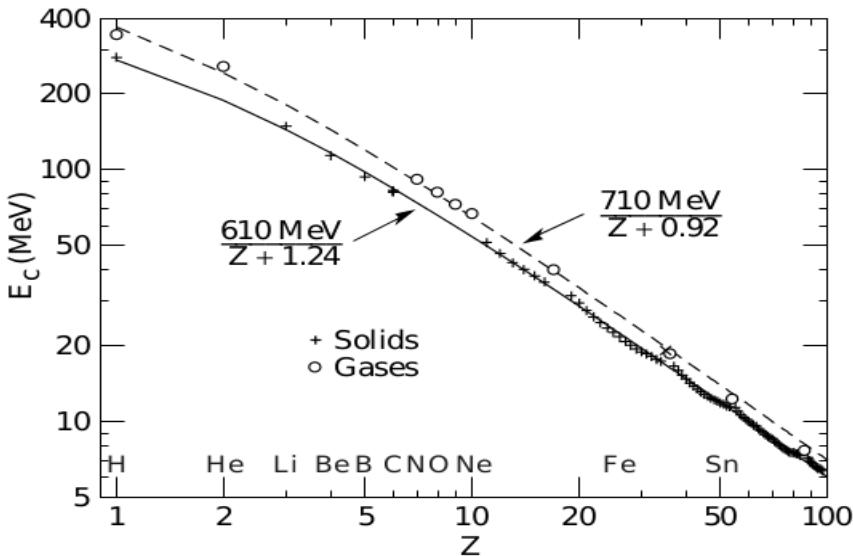
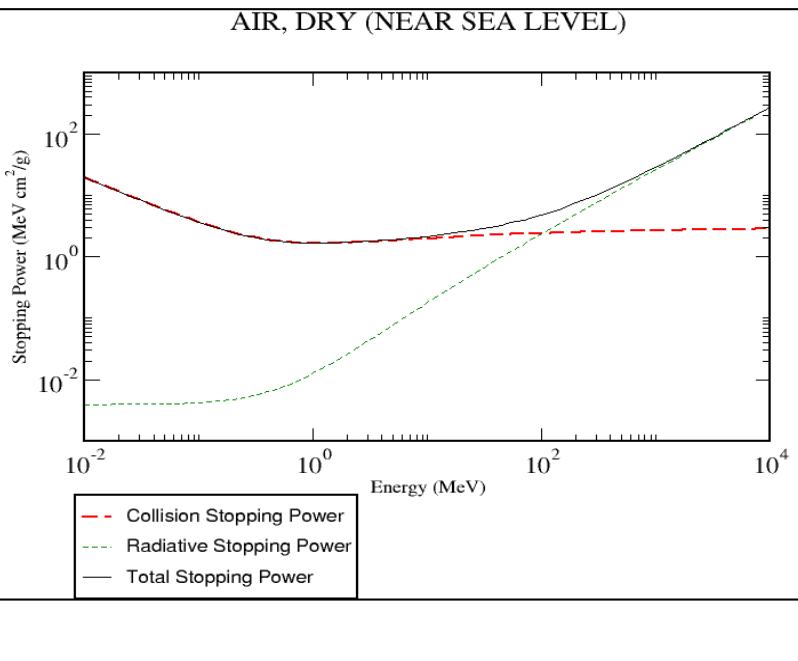
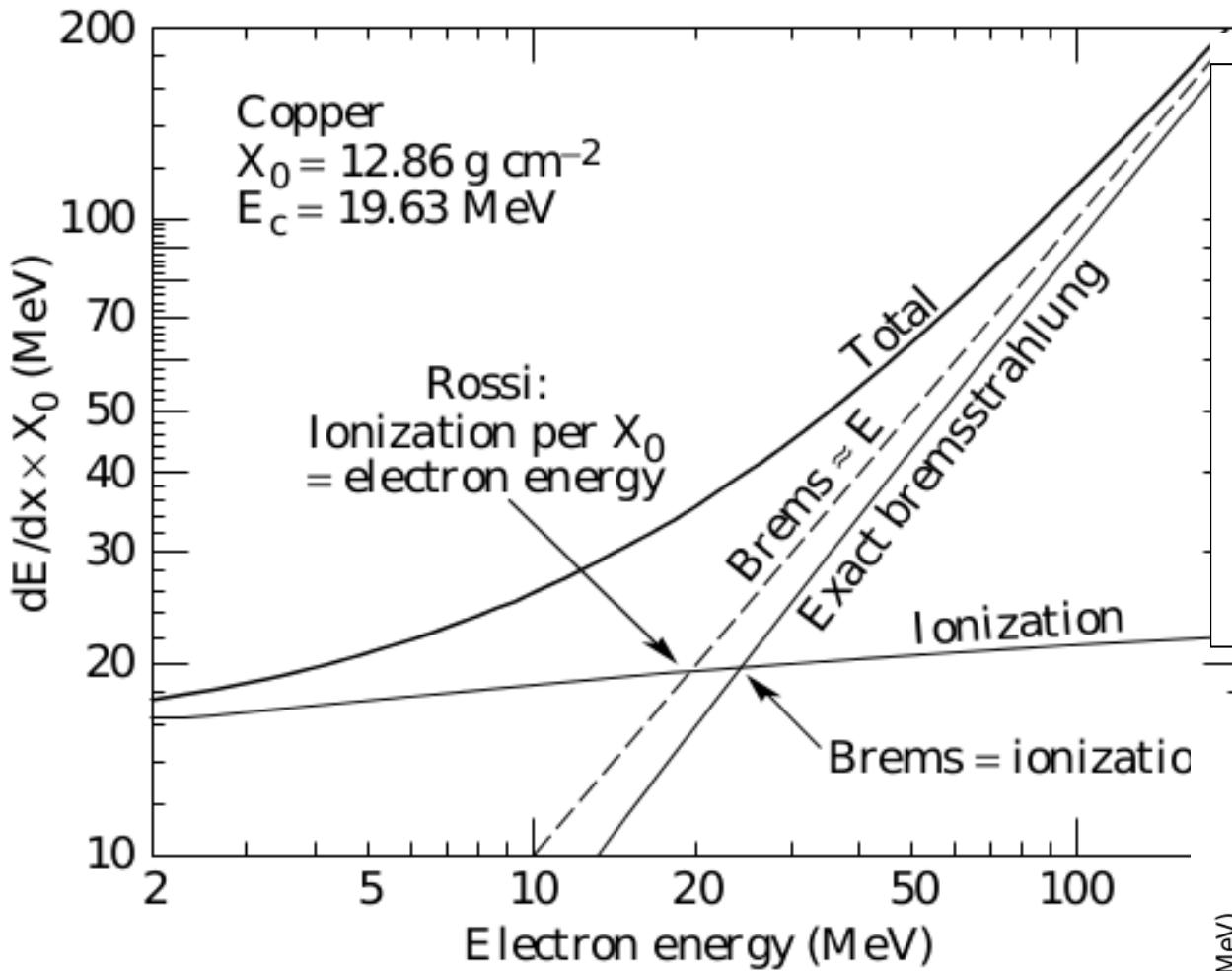
“Longitud interacción de electromagnética X_{EM} ”

- Cantidad de materia atravesada (en g/cm²) cuando un electrón pierde una fracción $1-e^{-1}$ (~63%) de su energía original
- 7/9 del camino libre medio de producción de pares para un fotón

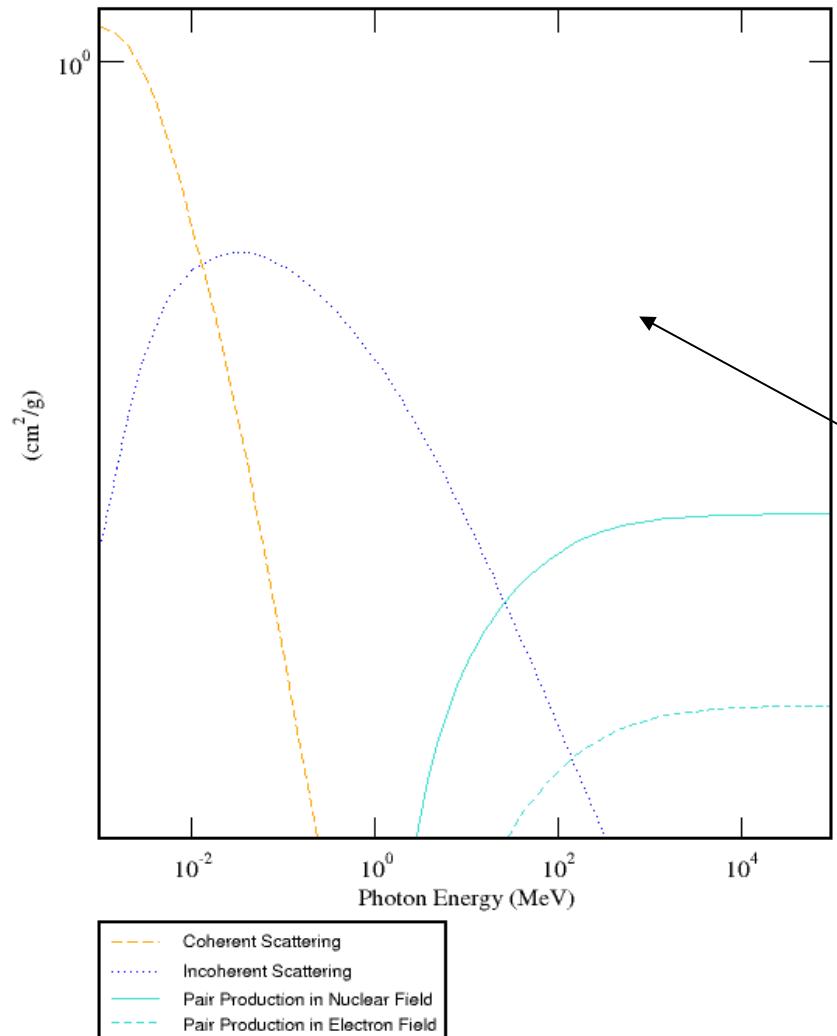
Energía Crítica

- Energía crítica es la energía a la cuál las pérdidas por ionización luego de recorrer una longitud de interacción son iguales a la energía del electrón
ó
- Energía a la cuál las pérdidas por frenado se igualan a las pérdidas por ionización

Energía crítica para electrones



¿Qué pasa con los fotones?



Partículas sin carga

Pero hay dos efectos adicionales:

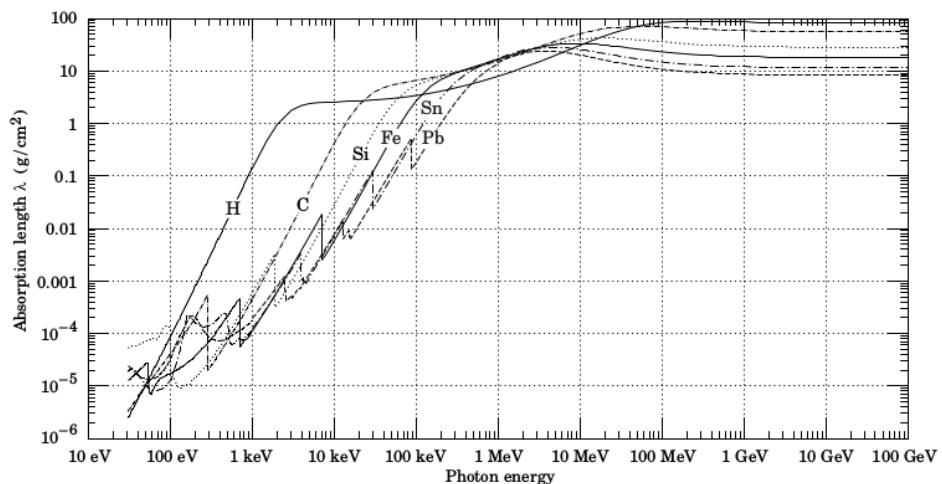
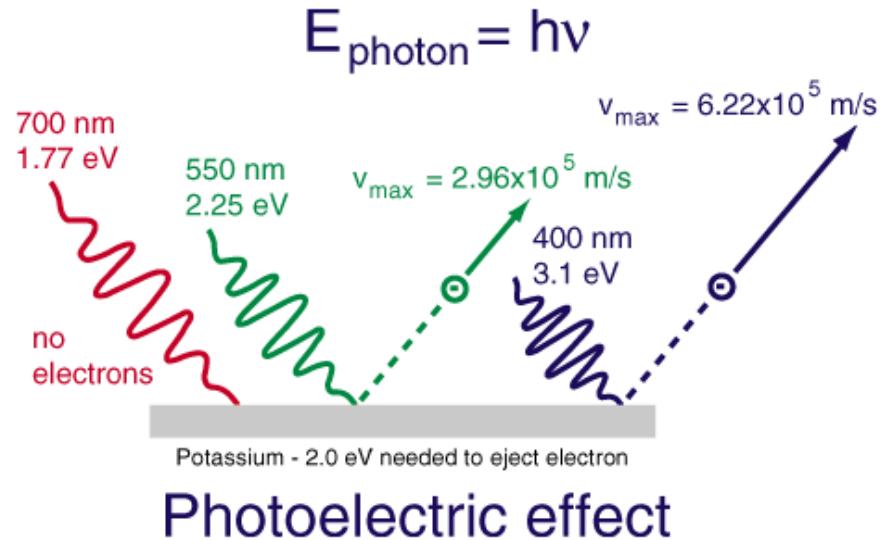
- 1) Producción de pares: un fotón puede producir un par que produzca señal
- 2) Compton: por scattering compton un electrón puede ser promovido

Efecto fotoeléctrico

- Interacción de baja energía
- La energía máxima del electrón emitido es:

$$K_{\max} = \frac{1}{2} m_e v_{\max}^2 = \frac{hc}{\lambda} - \varphi$$

- La función trabajo depende del material
- Es posible identificar la energía de ligadura de las capas atómicas

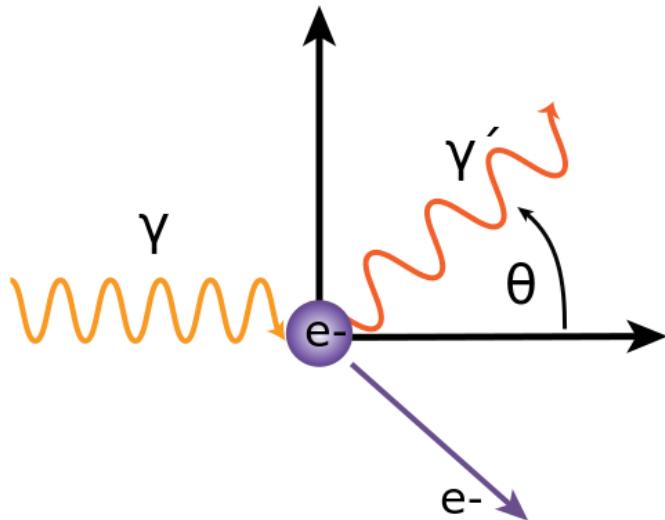


Efecto Compton

- Dispersión inelástica de fotones con partículas cargadas libres (la dispersión de Thompson es elástica):

$$\lambda' - \lambda = \frac{h}{m_e c} (1 - \cos \theta)$$

$$E'_\gamma = \frac{E_\gamma}{1 + (1 - \cos \theta) \left(\frac{E_\gamma}{m_e c^2} \right)}$$

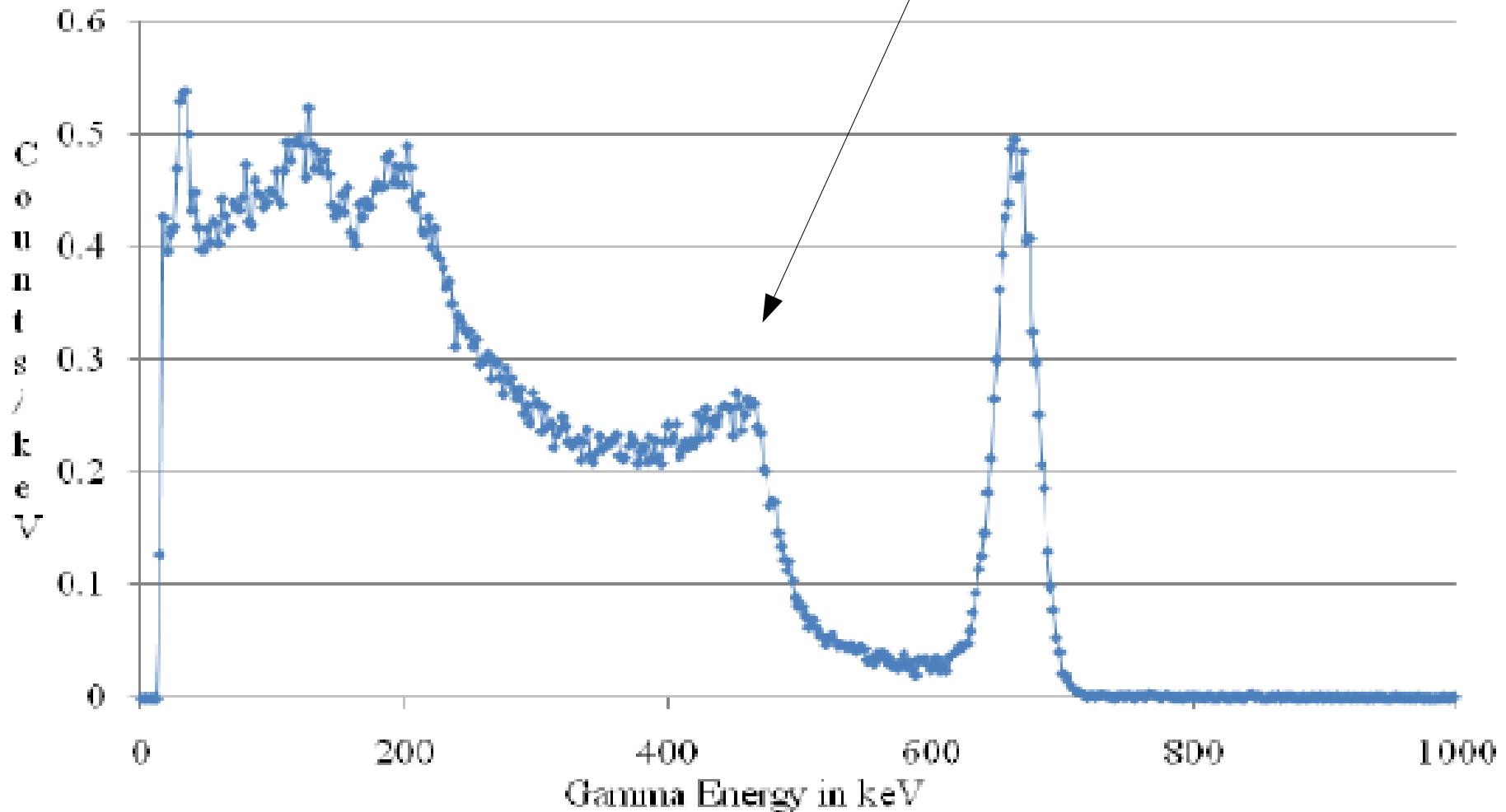


- La energía transferida depende de θ , máximo:

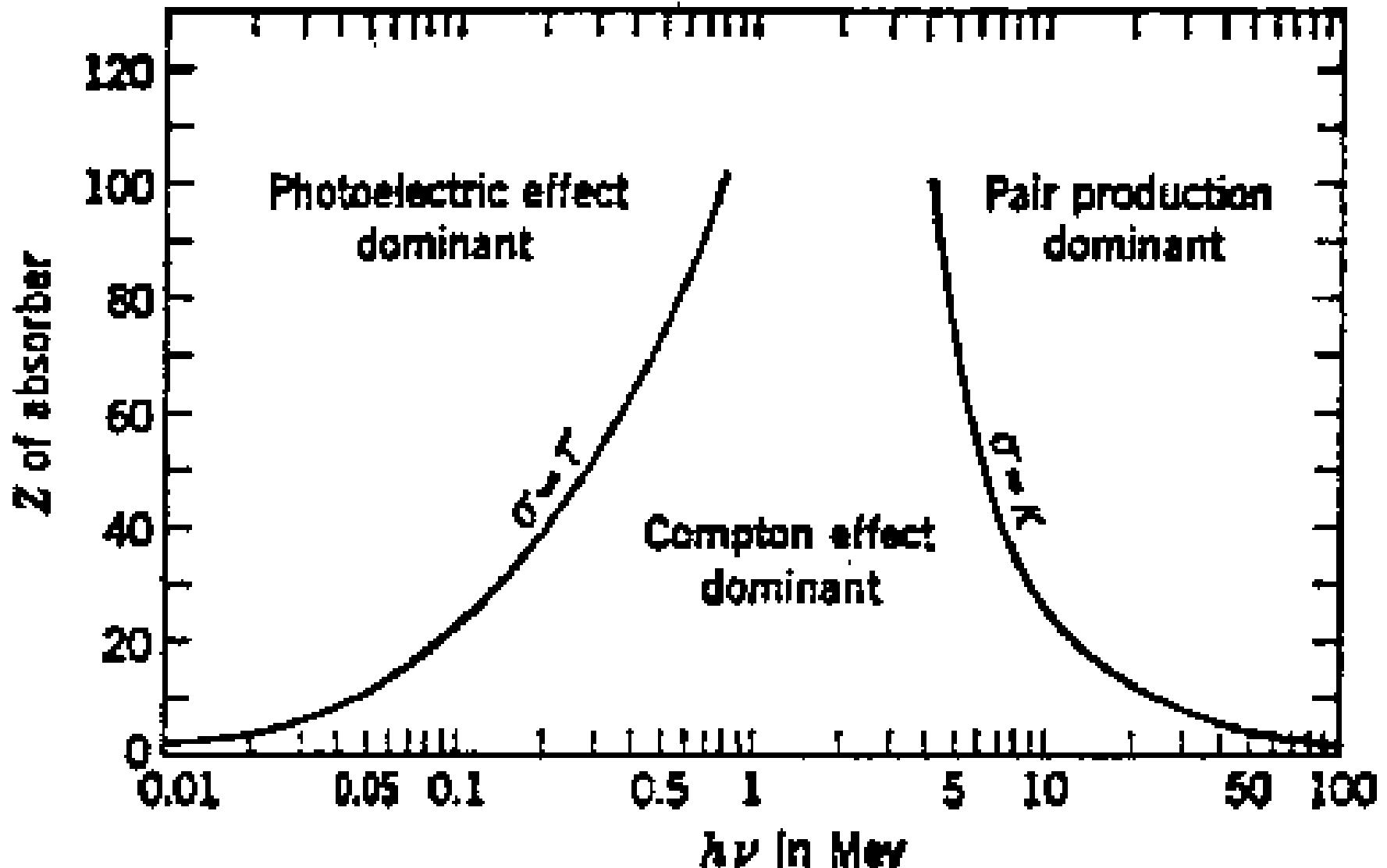
$$E'_\gamma = \frac{E_\gamma}{1 + \left(\frac{2E_\gamma}{m_e c^2} \right)}, \text{ si } \theta = \pi$$

Talón de Compton (*Compton edge*)

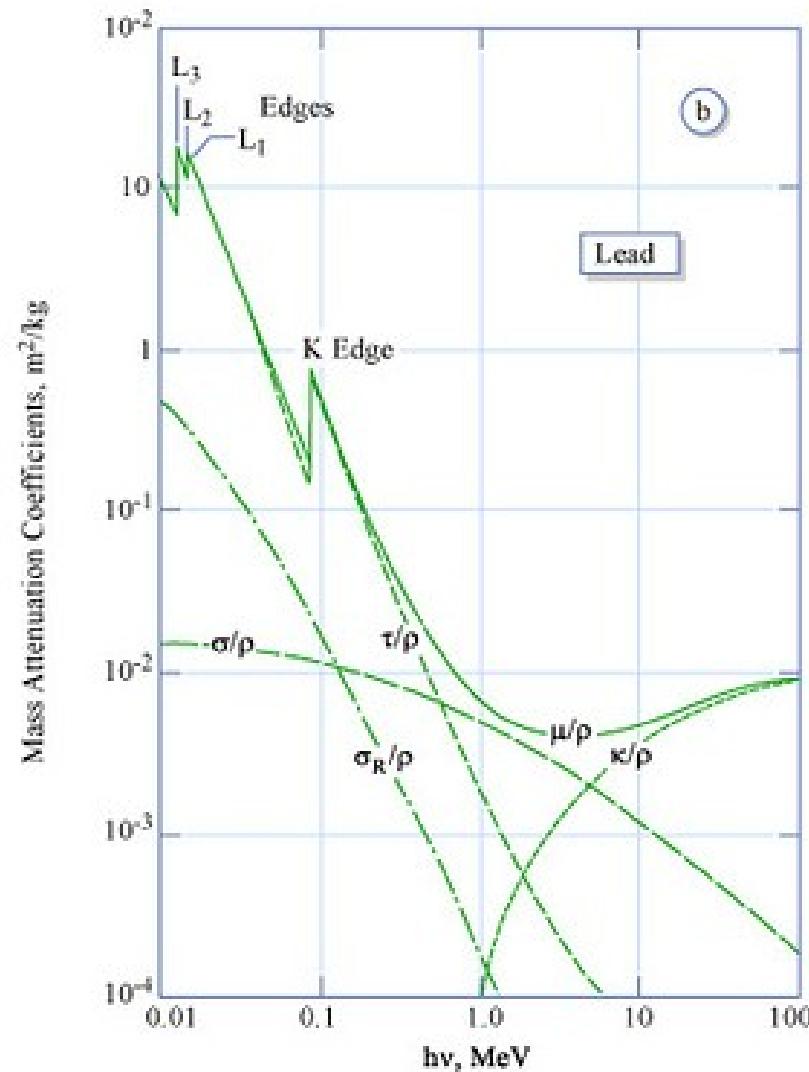
Cesium - 137 Photopeak and Compton Edge



Importante!

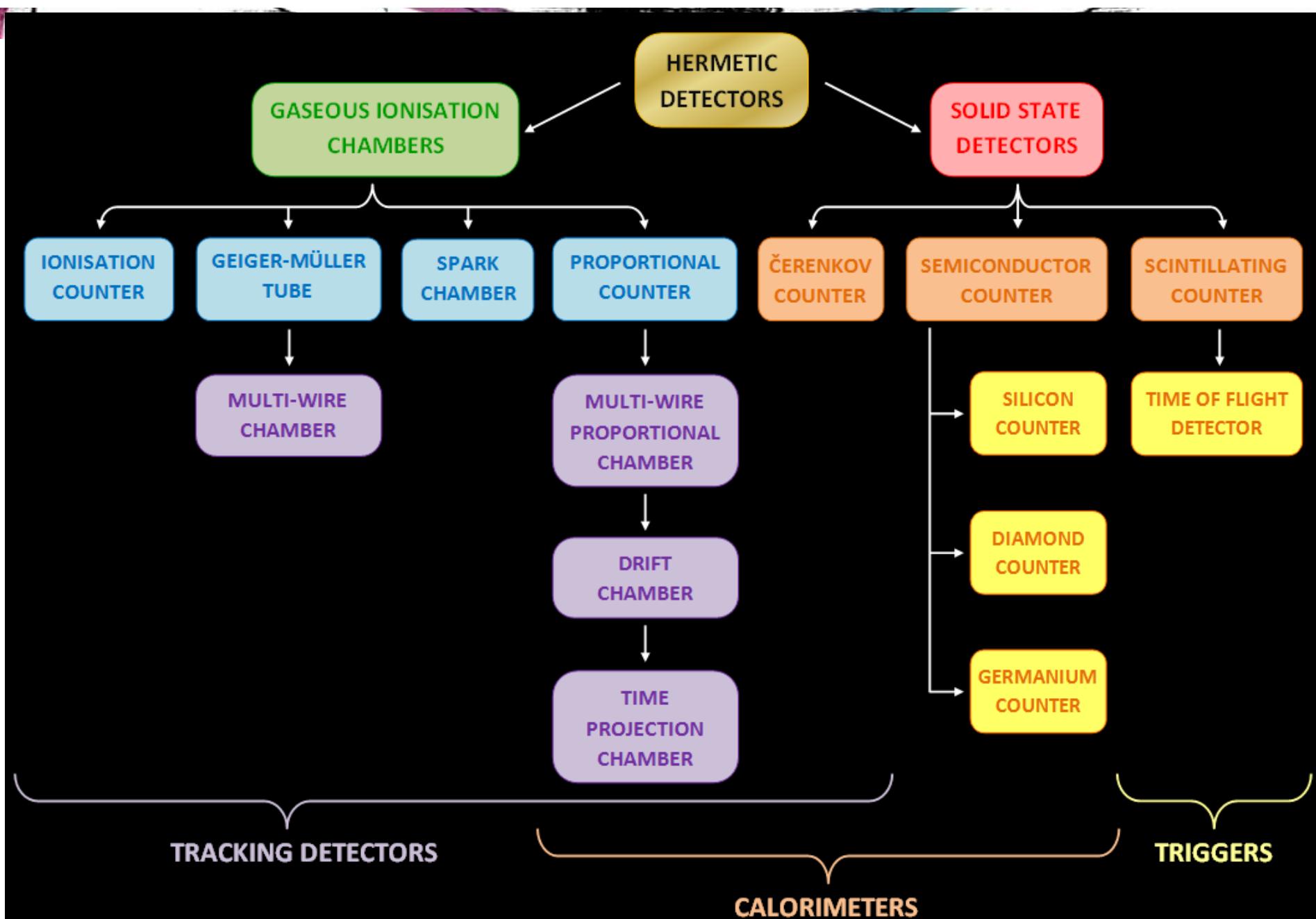


F. De atenuación

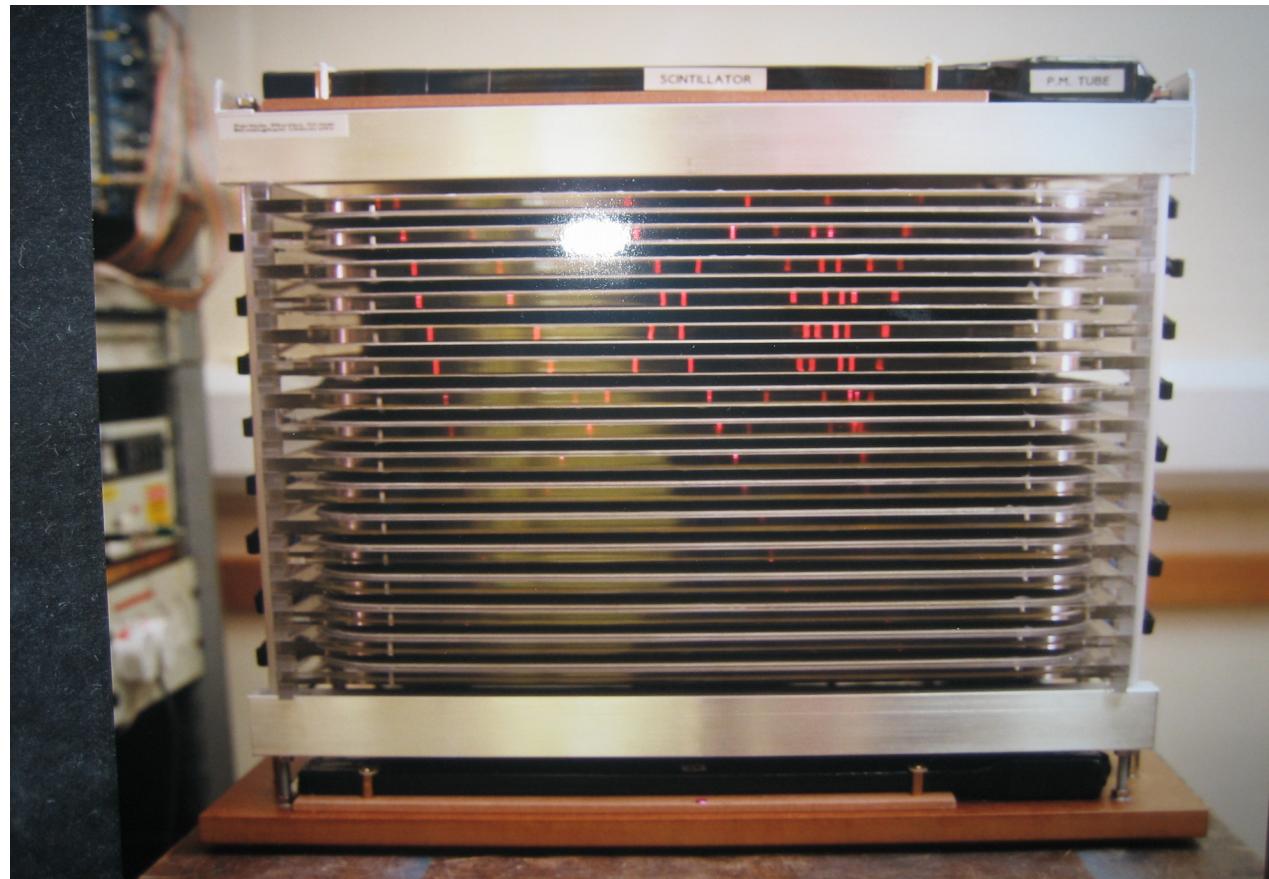
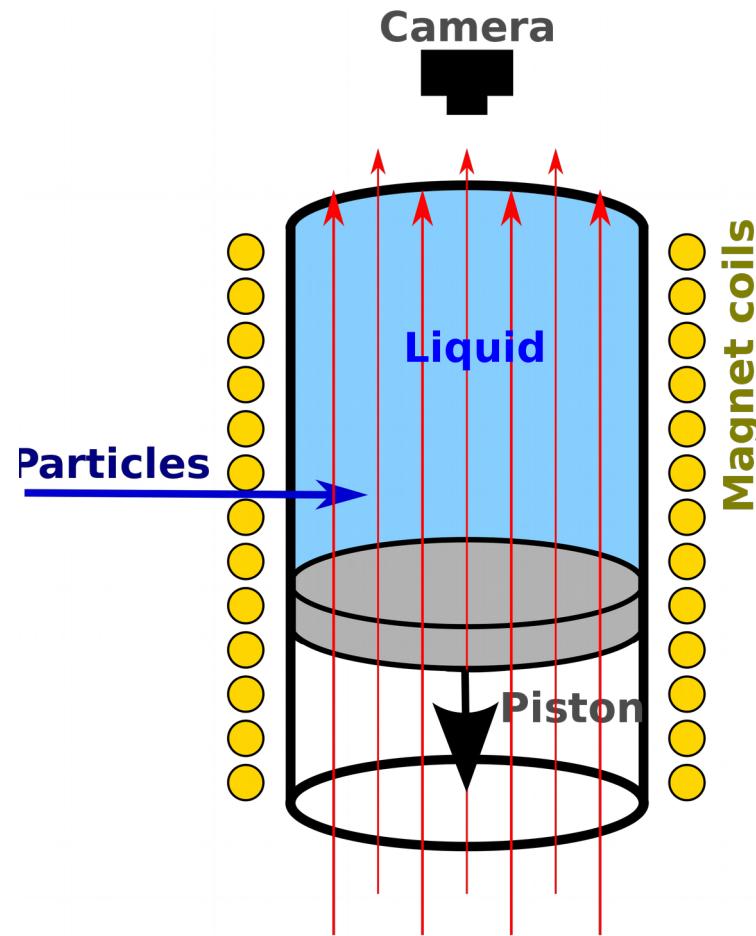


Mass attenuation coefficients for carbon (a) and lead (b). τ/ρ indicates the contribution of the photoelectric effect, σ/ρ is that of the Compton effect, κ/ρ that of pair production, and σ_R/ρ that of Rayleigh (coherent) scattering. μ/ρ is their sum, which is closely approximated in Pb by the τ/ρ curve below $h\nu = 0.1$ MeV.

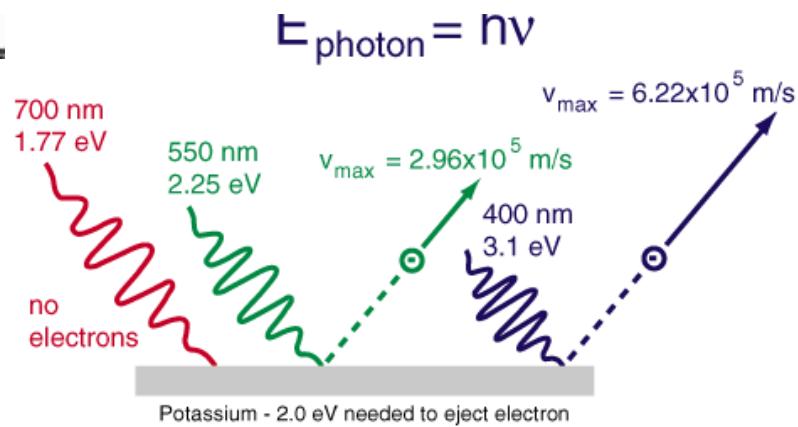
Detectores de radiación y partículas



- Registro o inferencia de
 - Posición, tiempo de arribo, Tipo (carga, masa), Energía



Fototubo, alias “PMT”



Photoelectric effect

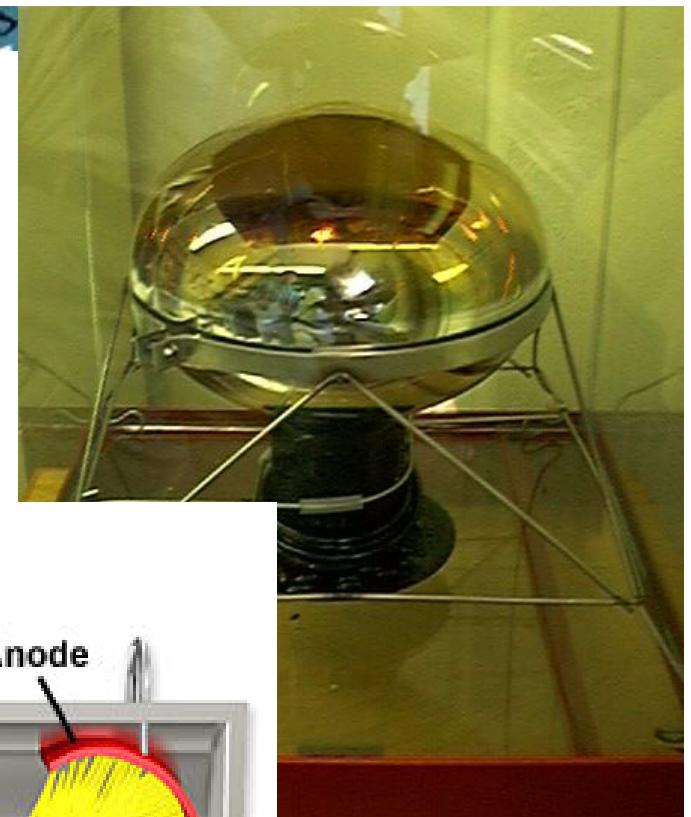
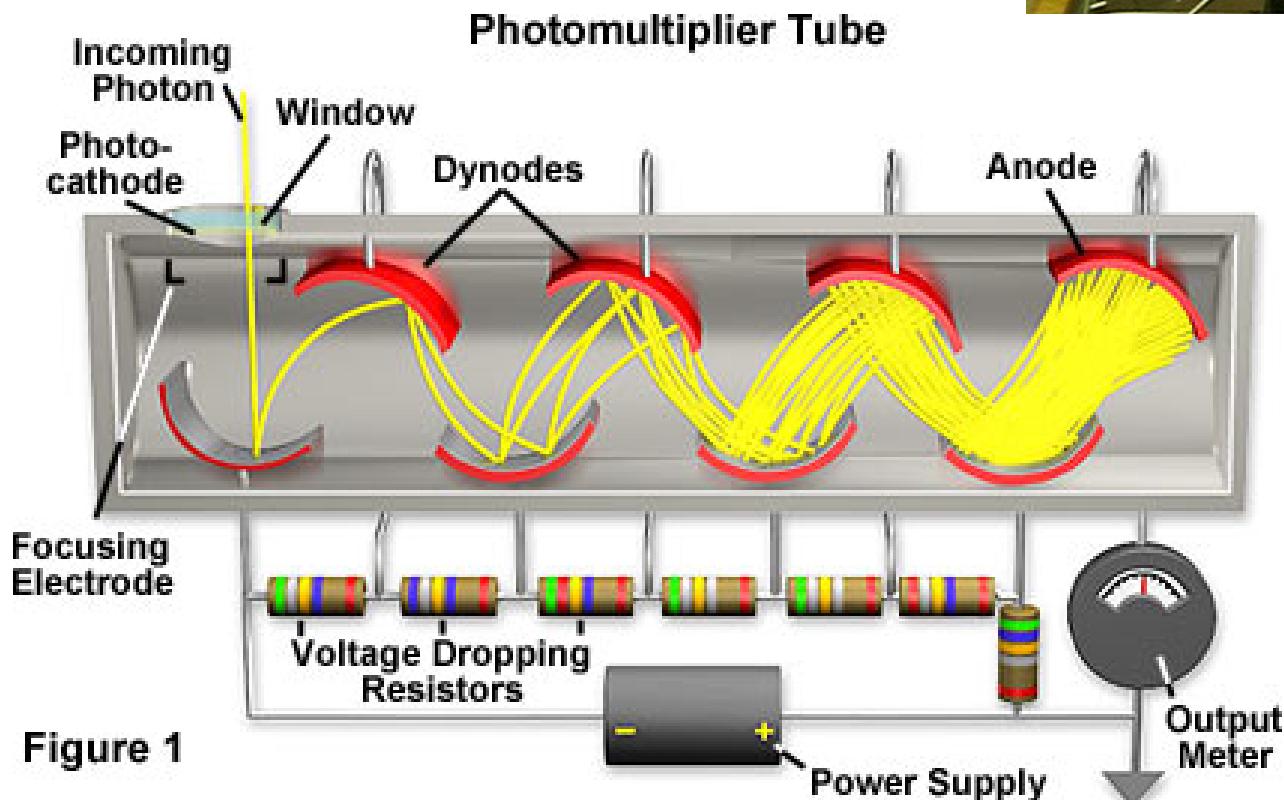
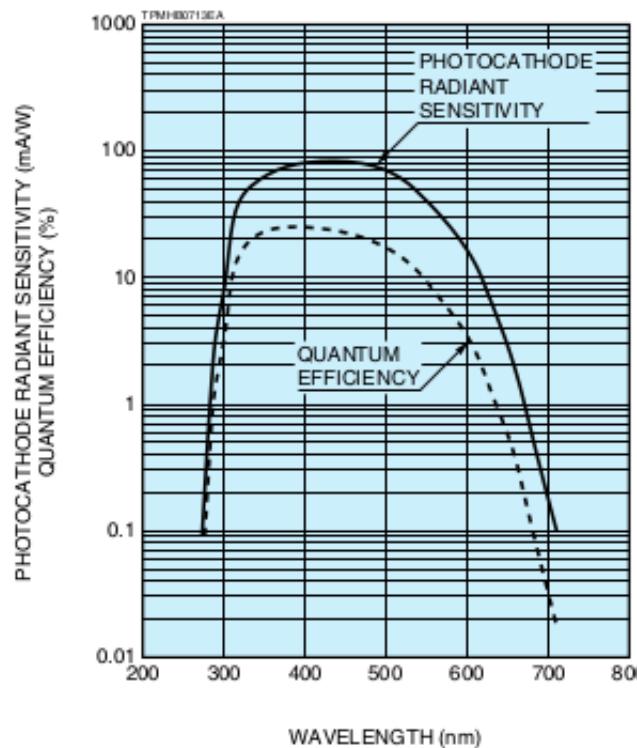


Figure 1

Hamamatsu R5912

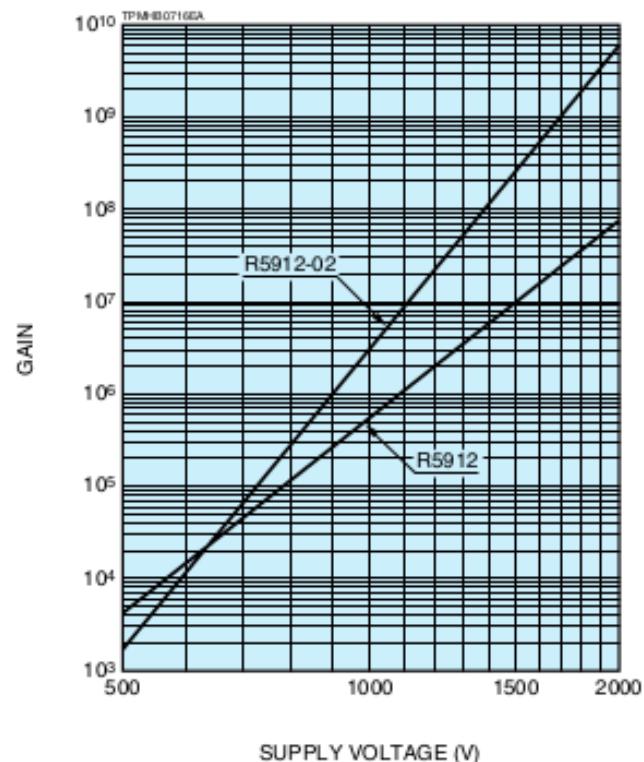
SPECTRAL RESPONSE

- R5912, R5912-02
- R7081, R7081-20



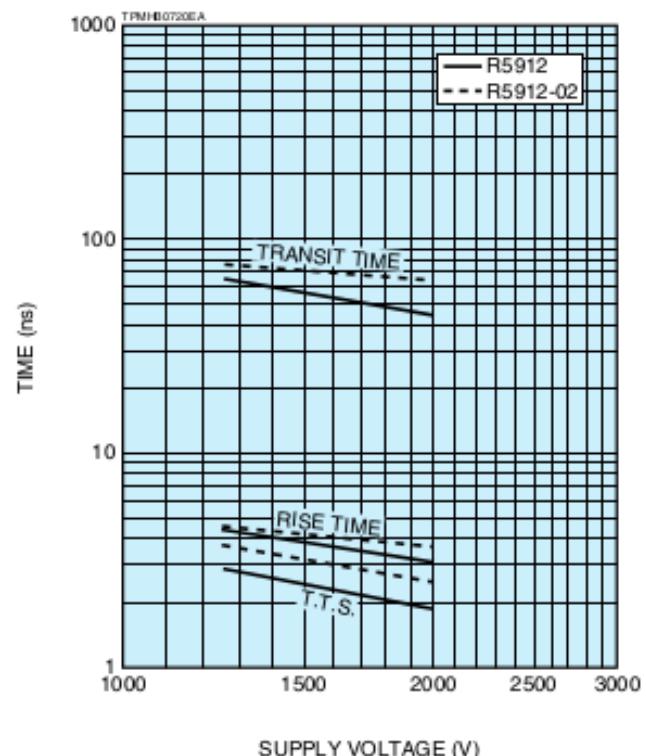
GAIN

- R5912, R5912-02



TYPICAL TIME RESPONSE

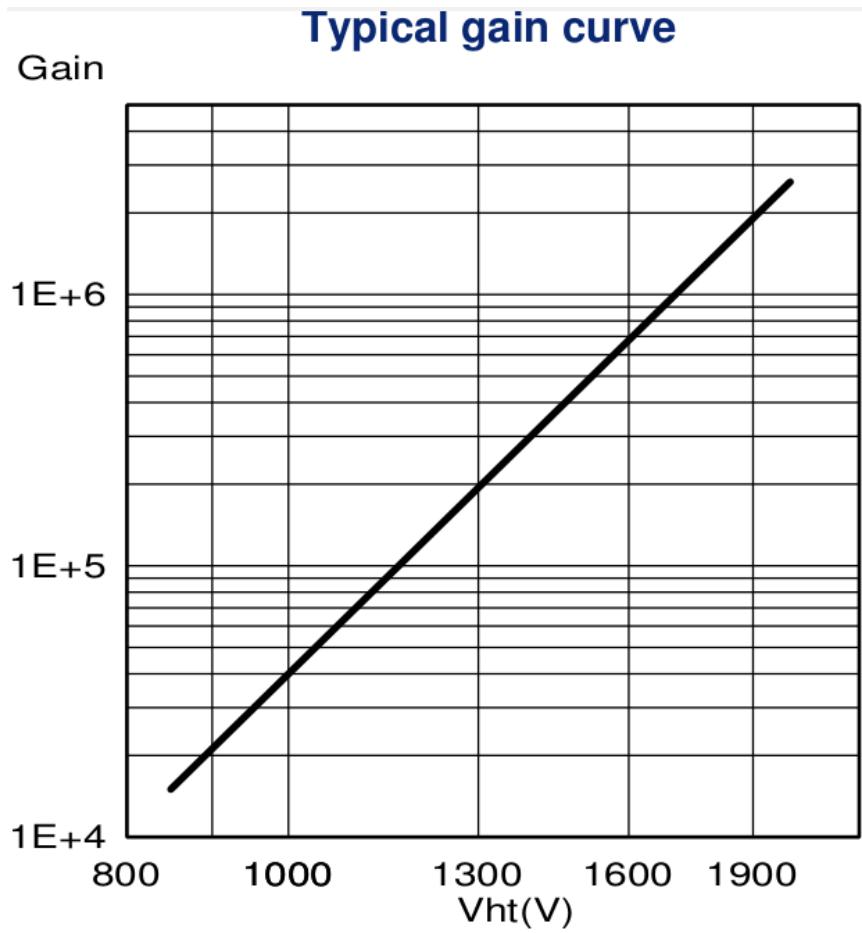
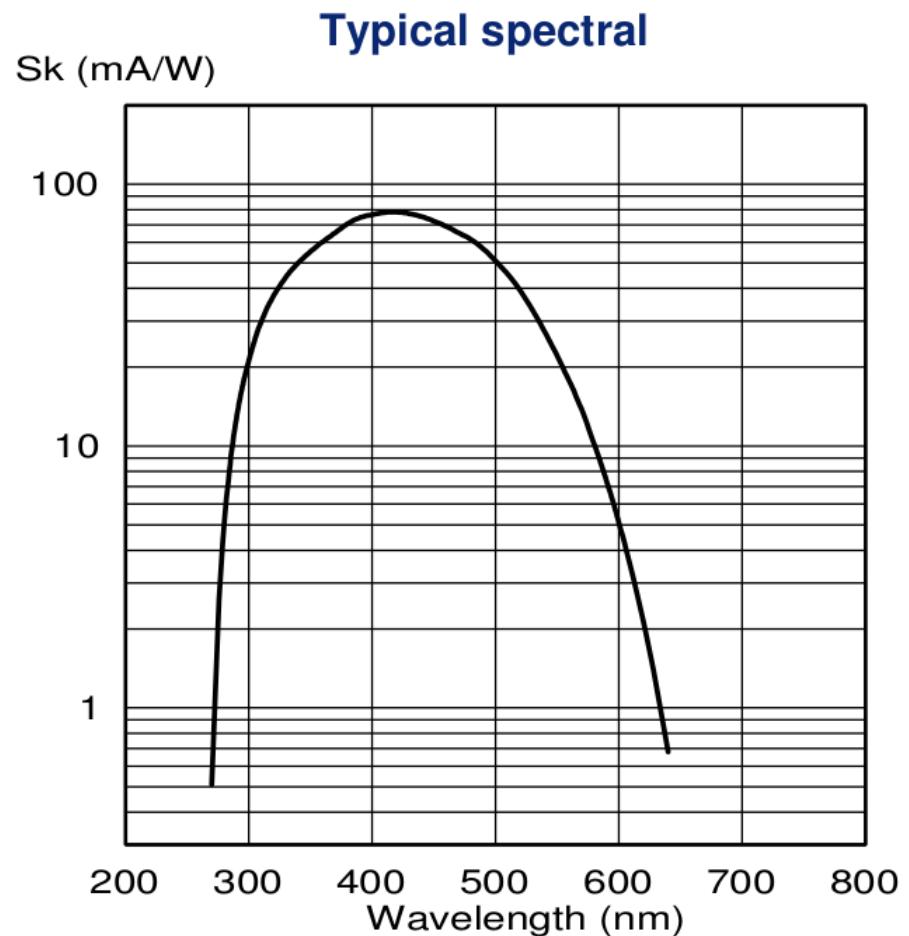
- R5912, R5912-02



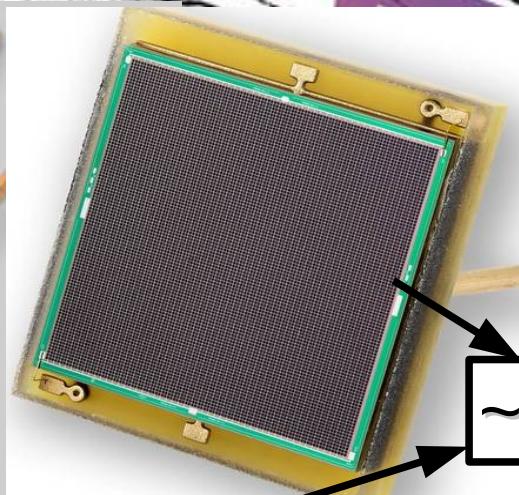
SPECIFICATIONS

Type No.	Diameter (mm) / (inch)	Minimum Effective Area (mm)	Surface Area		Dynode		Weight (g)
			Min. (cm ²)	Typ. (cm ²)	Structure	Number of Stages	
R5912	202 / 8	φ190	330	380	Box & Line	10	approx. 1100
R5912-02	202 / 8	φ190	330	380	Box & Line	14	approx. 1100

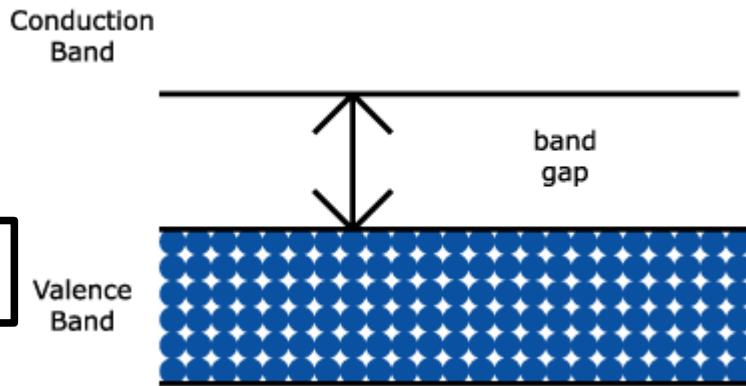
Photonis XP-1805, 202 mm diámetro



Silicon PhotoMultiplier (SiPM)



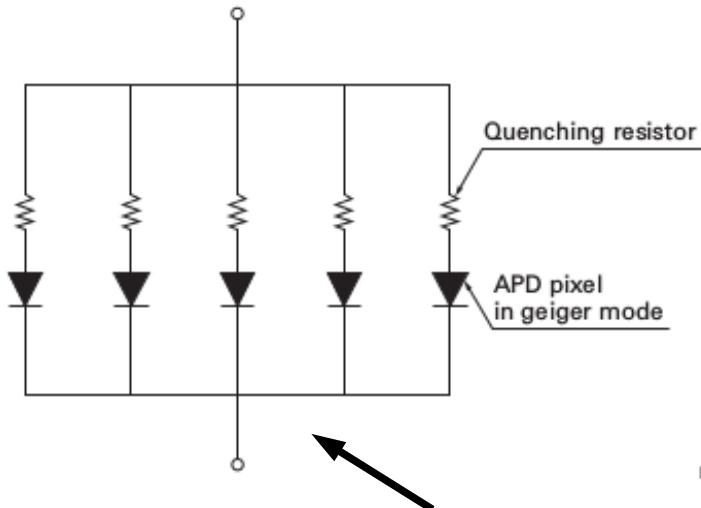
- Semiconductor



- Muchas celdas

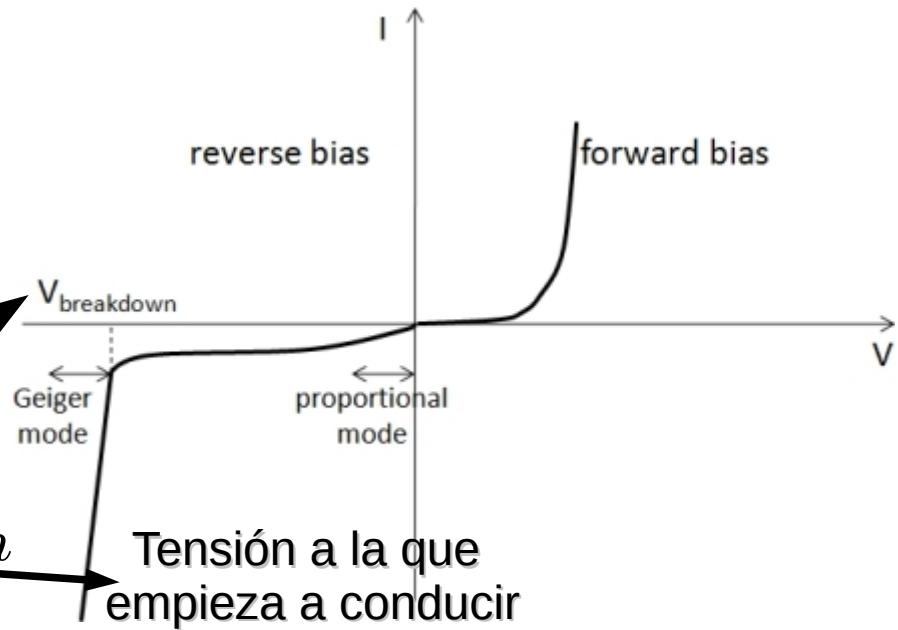
(50 μ m)

- Diodo polarizado en inversa



$$v_{overvoltage} \equiv v_{bias} - v_{breakdown}$$

Tensión aplicada al SiPM

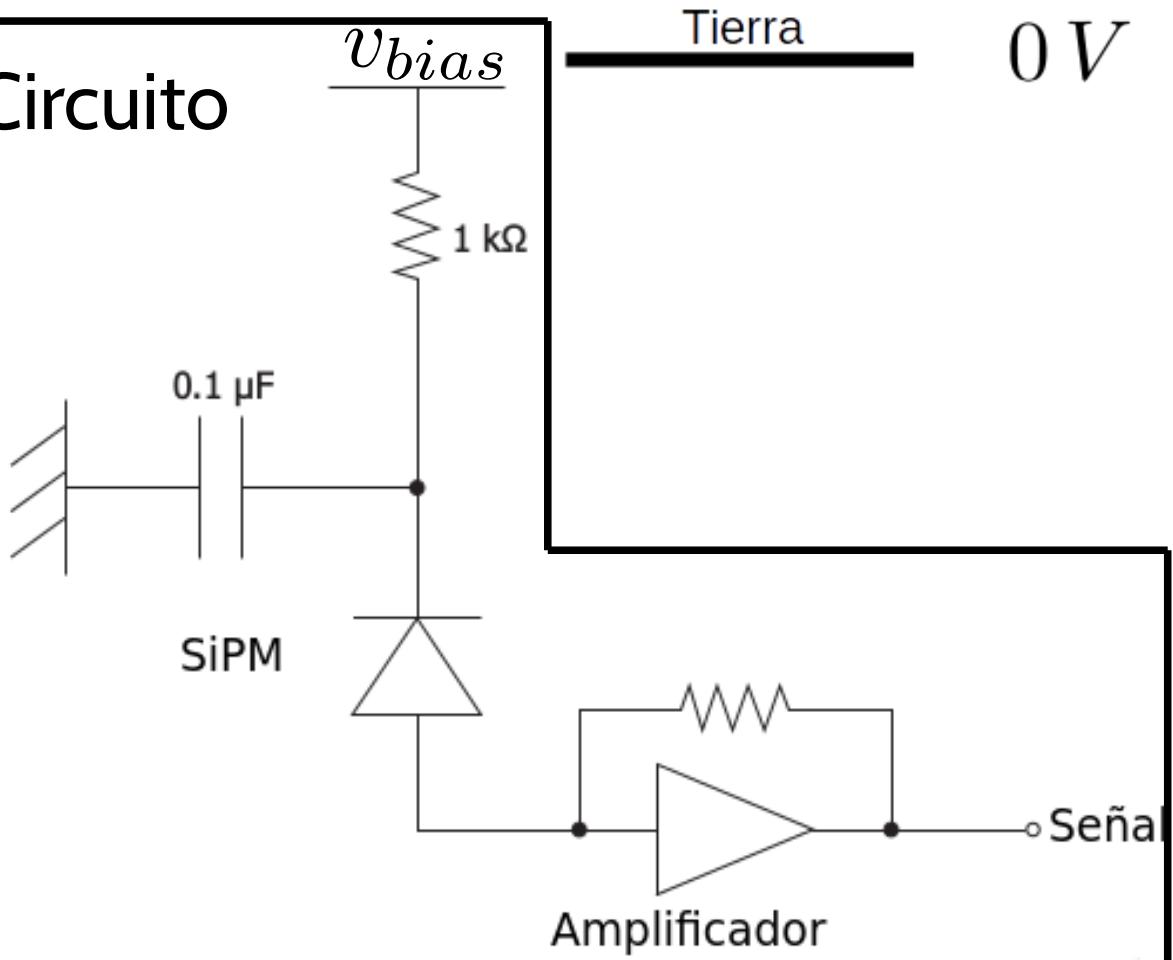


Electrónica

Aplicada
Conduce

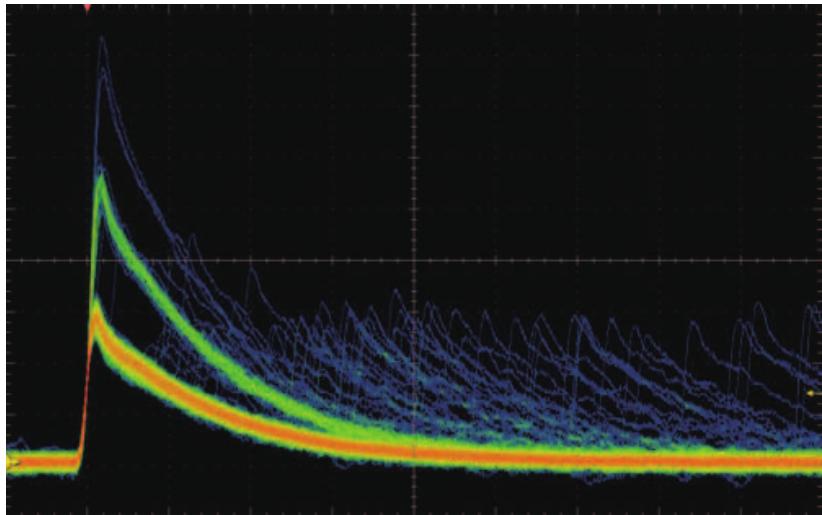
$$\left. \begin{array}{l} v_{bias} \sim 60 V \\ v_{bd} \sim 55 V \end{array} \right\} v_{ov} \sim 5 V$$

Circuito



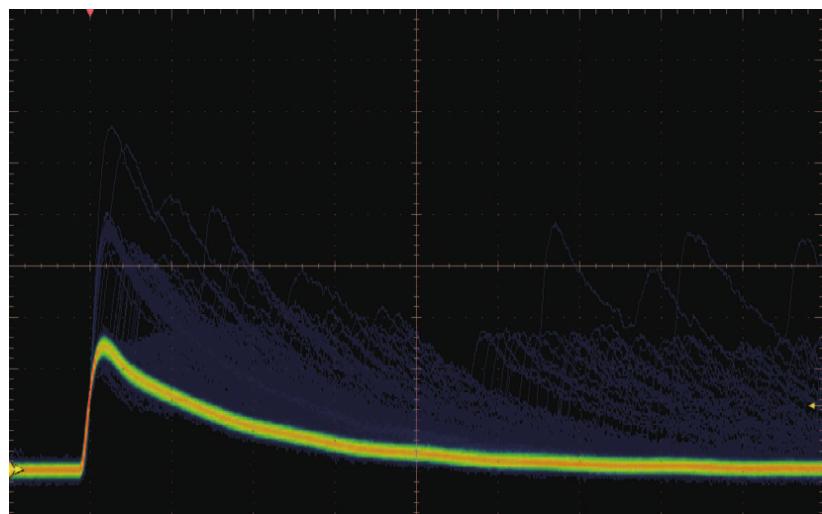
Output: Pulsos

- S11



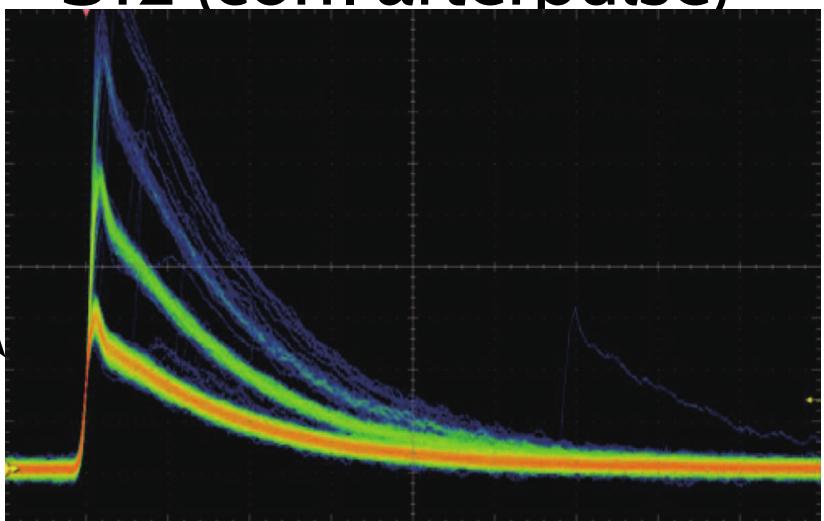
Datasheet

- S13 (corr. crosstalk)

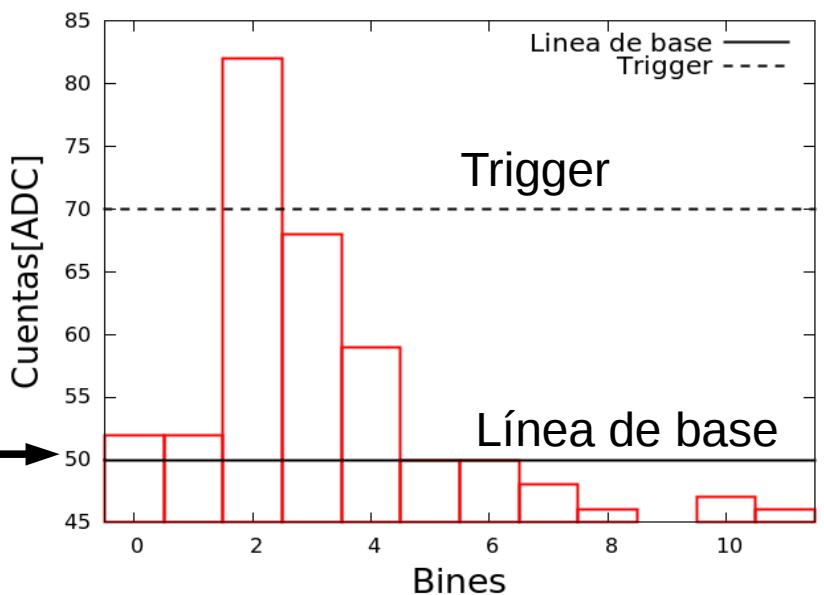


Datos

- S12 (corr. afterpulse)

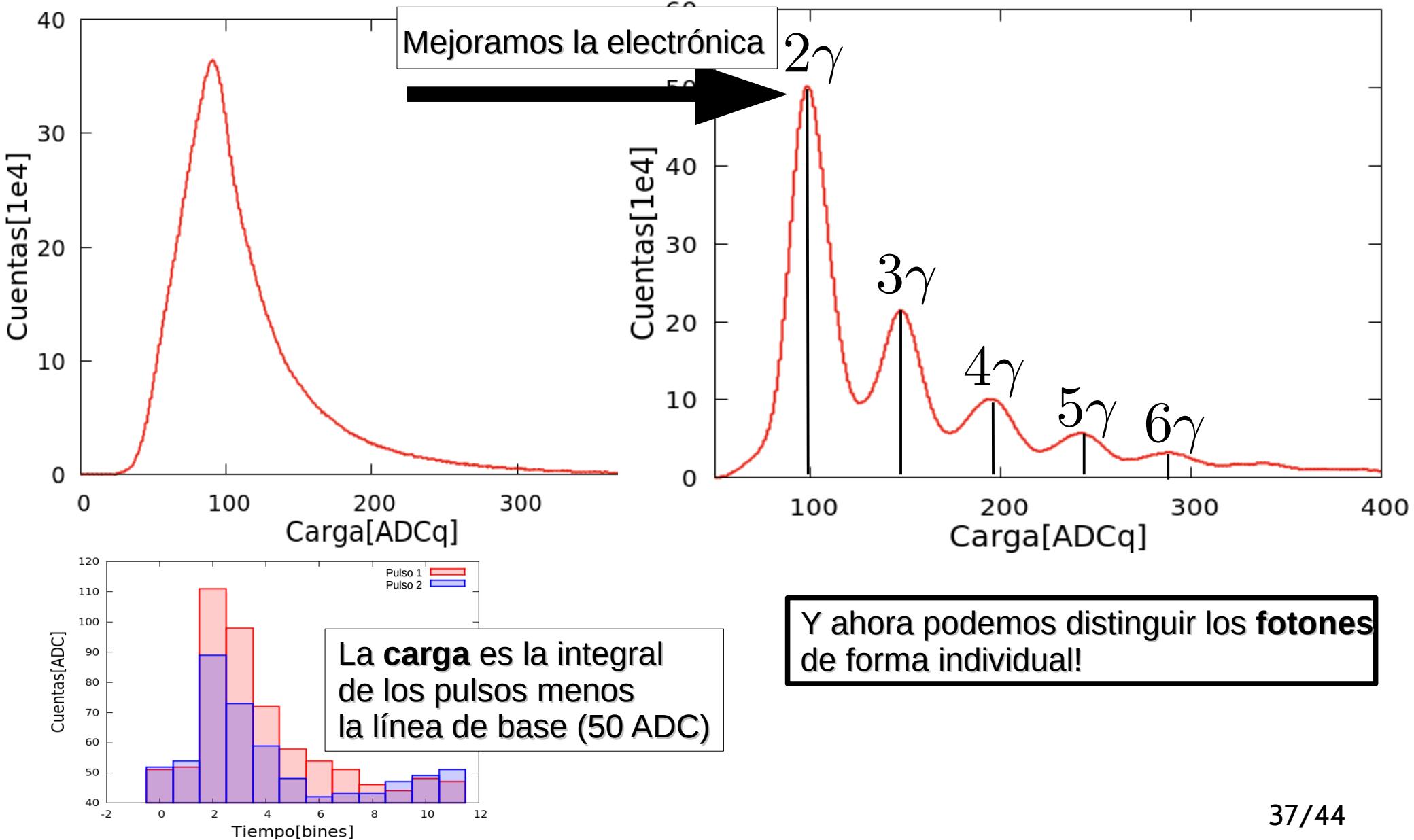


- Discretizado

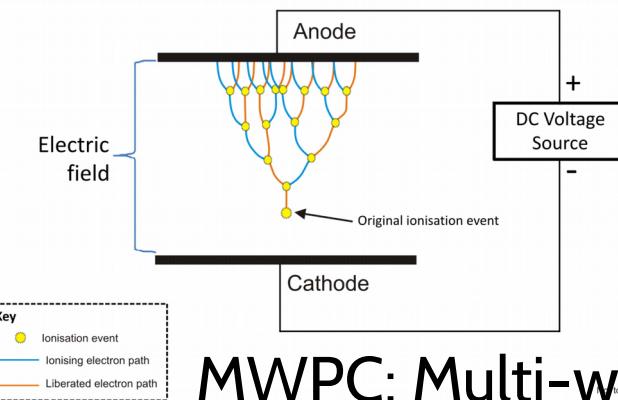


(Salieron al mercado en 2015)

Histogramas de carga: Serie S12

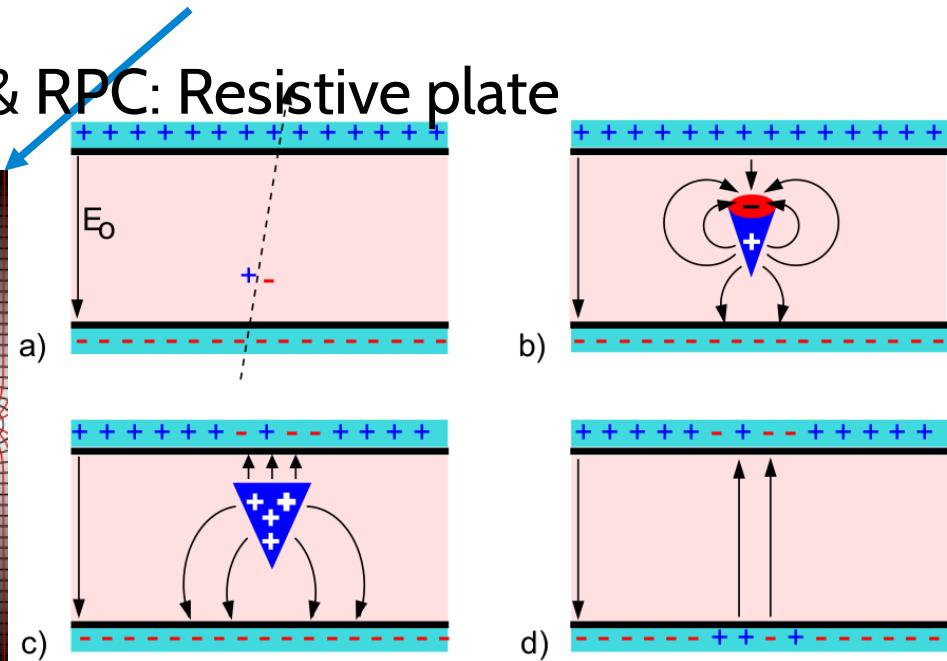
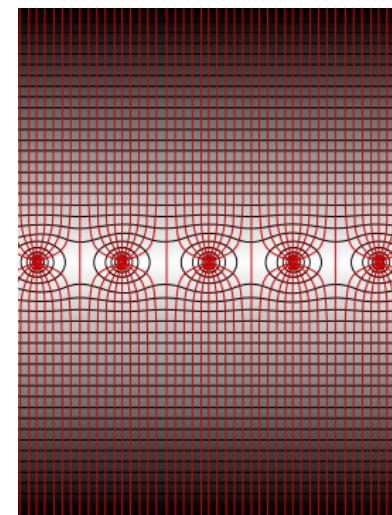
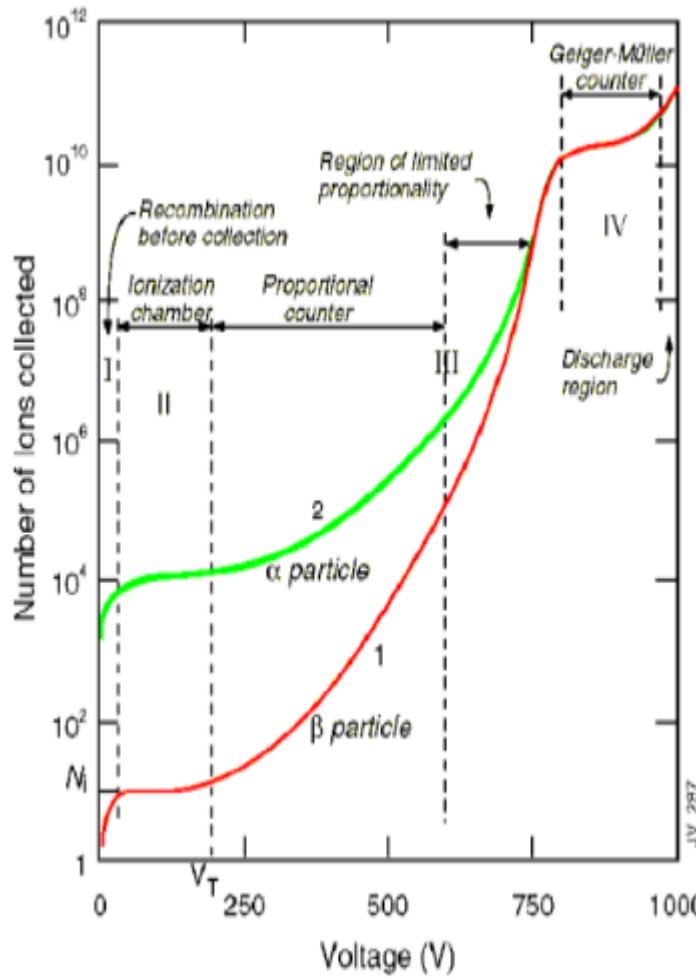


Visualisation of a Townsend Avalanche

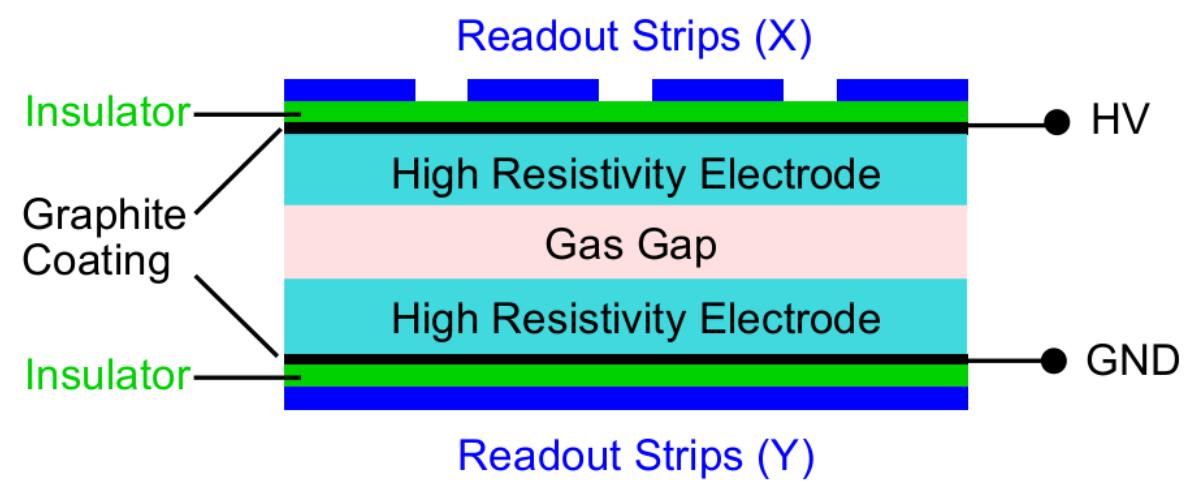


chambers

MWPC: Multi-wire proportional & RPC: Resistive plate



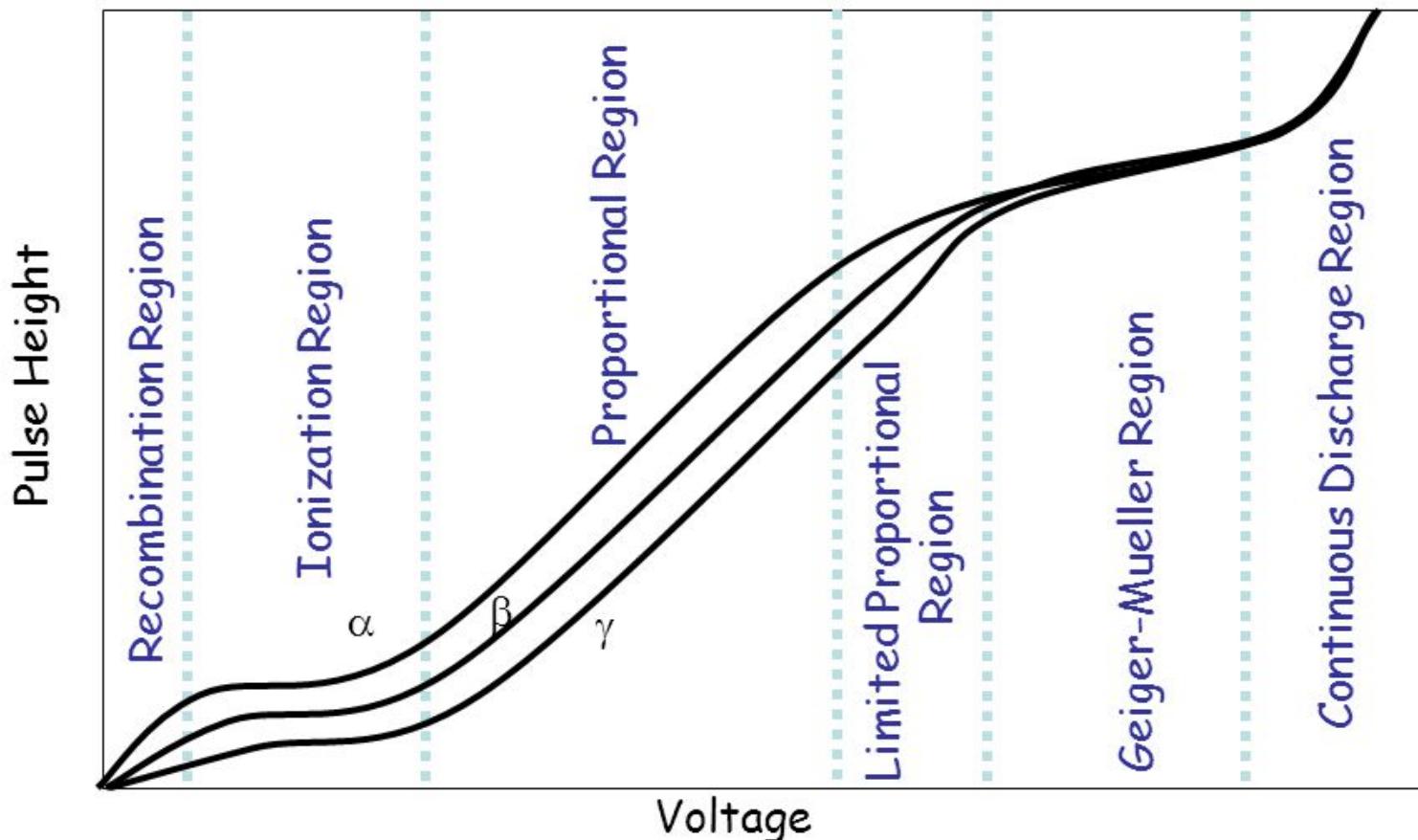
- Bals



Readout Strips (Y)

Ionización, reonización, avanlancha

Operating Regions of Gas-Filled Detectors



Centelladores plásticos

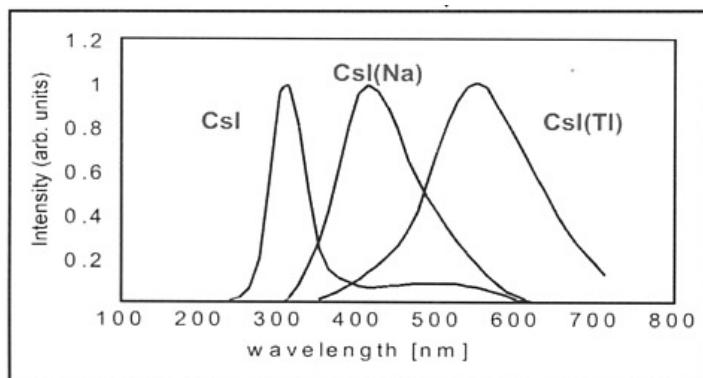
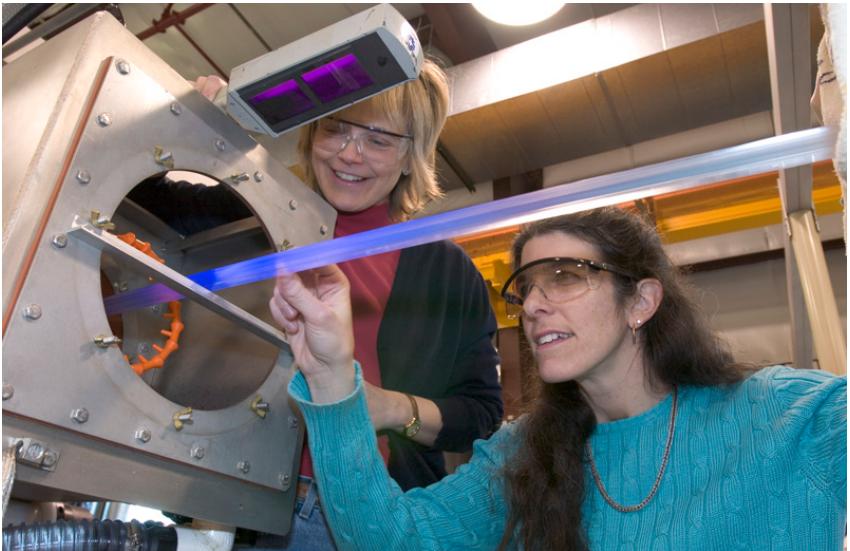
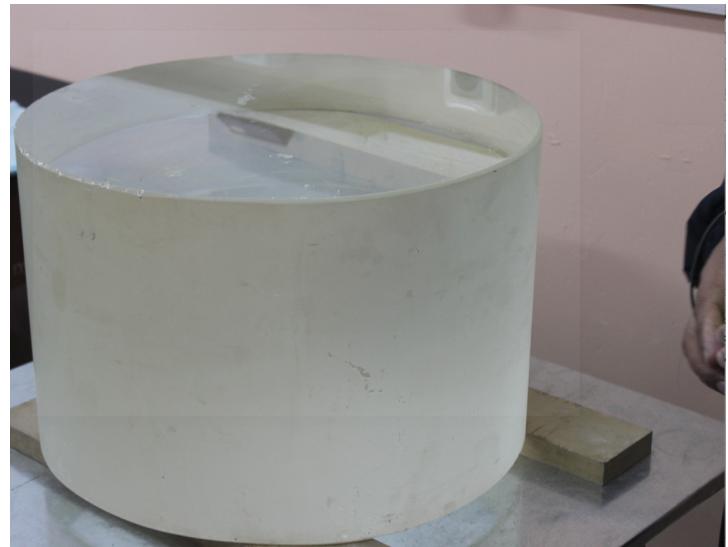
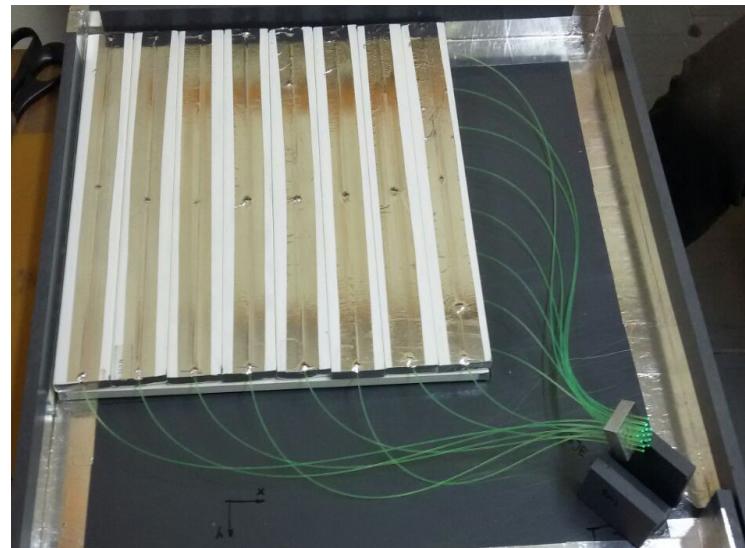
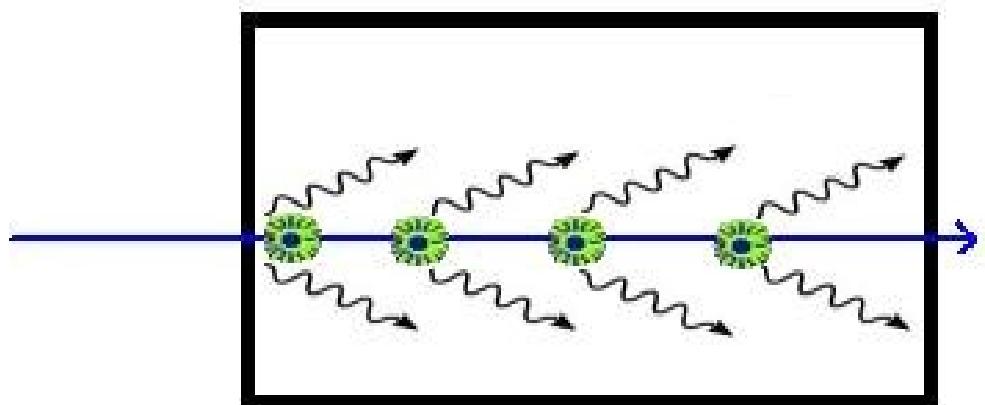
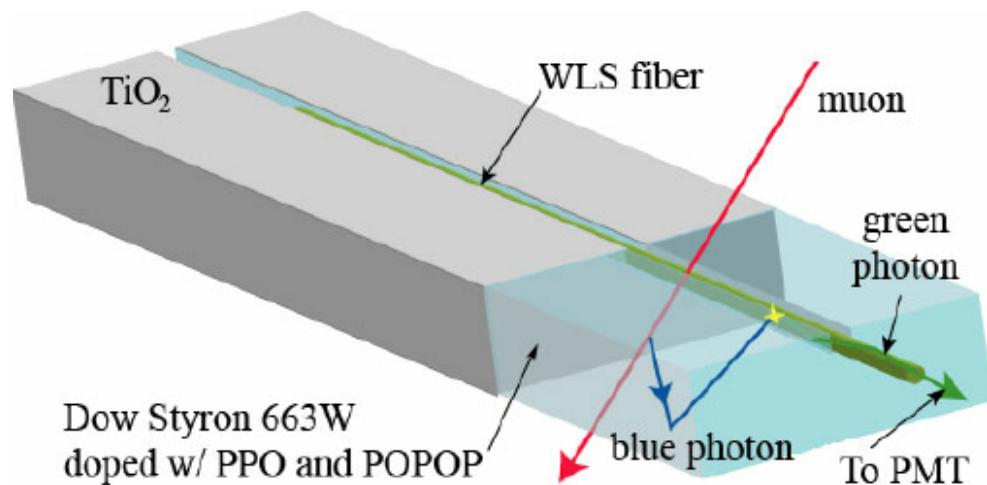


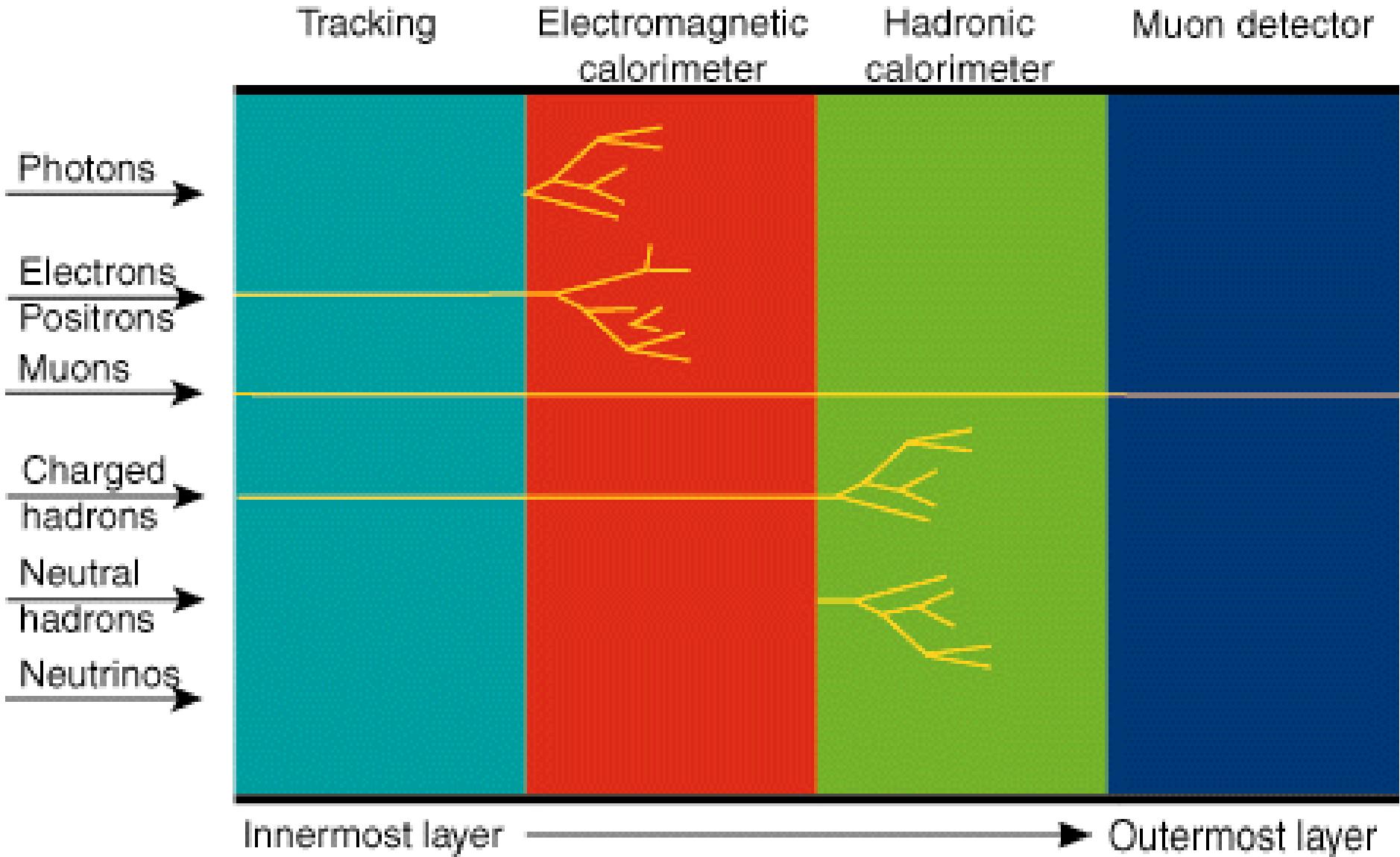
Fig. 3.2 Emission spectra of CsI, CsI(Na) and CsI(Tl) scaled on maximum emission intensity. Also a typical quantum efficiency curve of a bialkali photocathode is shown.



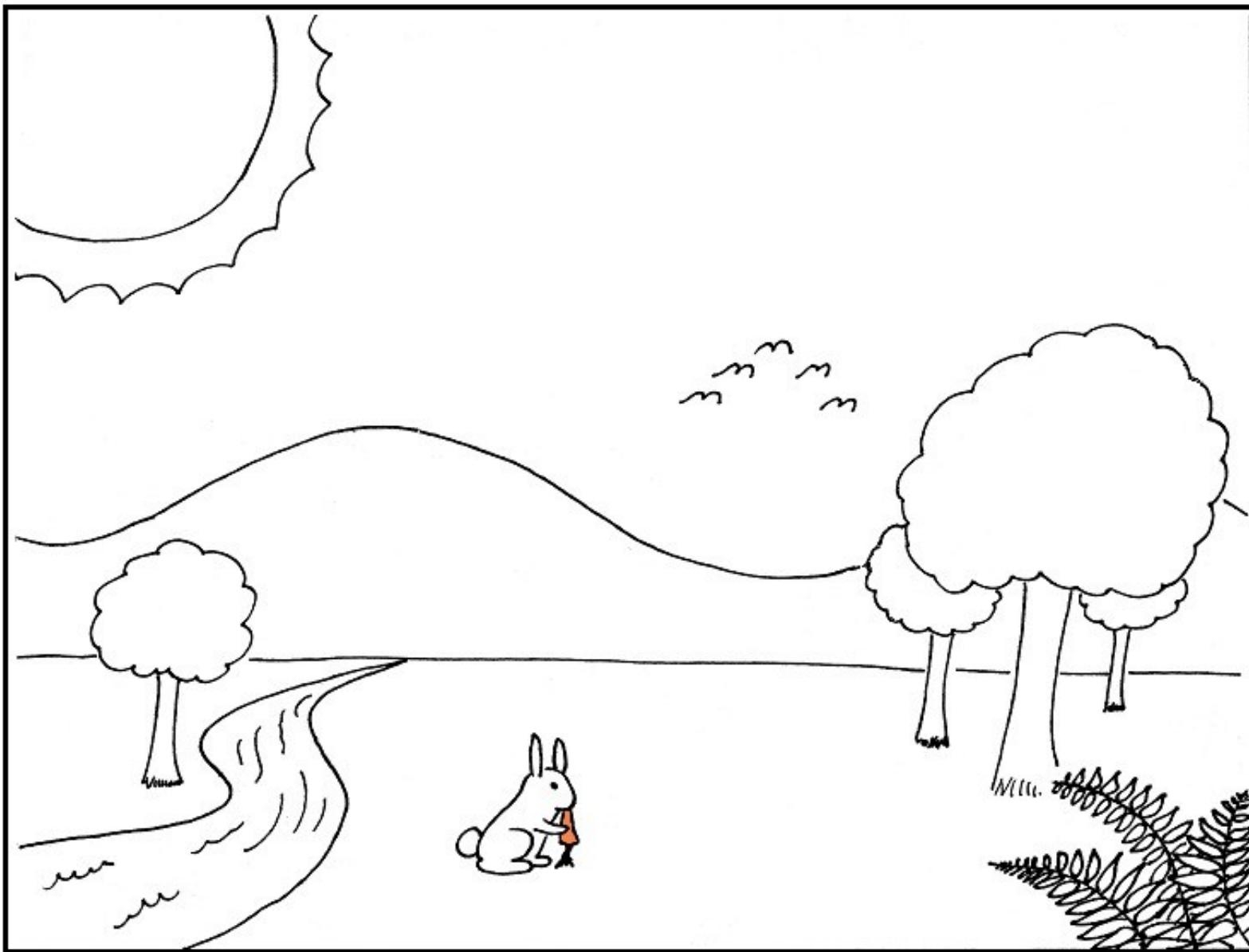
Centelladores plásticos



calorímetros



Tratamos de describir la naturaleza



Hacemos lo que podemos

