

ESPECTROSCOPIA GAMA

Alunos:

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Conteúdo Histórico

1895 – Antonie Henri descobre a emissão de uma radiação invisível do urânio

1896 – Marie S. Curie e Pierre Curie descobrem que certos minérios emitiam uma radiação desconhecida dando posteriormente o Nobel em 1903



P. Curie

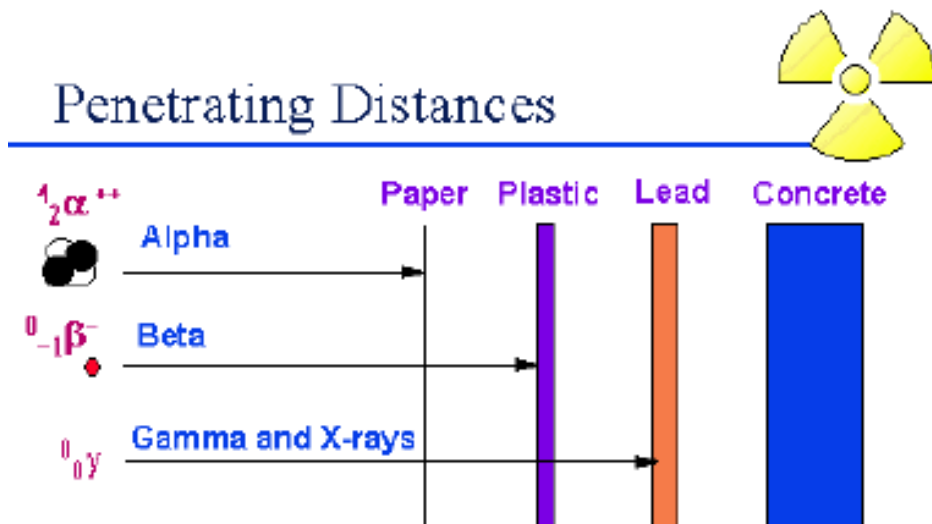
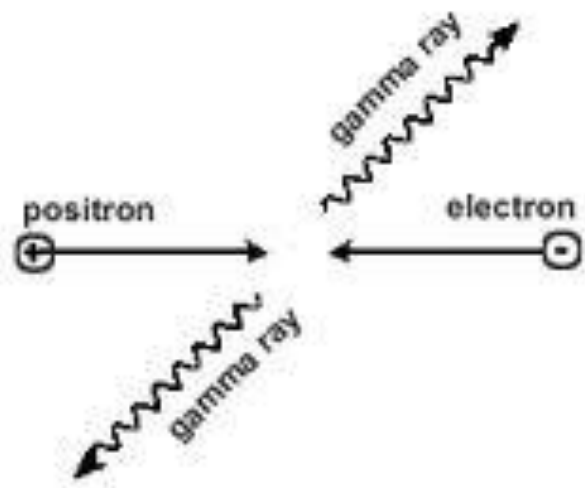


M. Curie

Teoria

Radiação gama, denotada pela letra grega, γ (gamma) é uma radiação eletromagnética de alta frequência com energia $\sim 100\text{KeV}$. Alta penetração resultando em aplicações.

São produzidos por interação de sub-partículas, tal como aniquilação elétron-pósitron, decaimento de nêutron por pión, decaimento radioativo, fusão ou fissão.



Resultados Esperados

Taxa de decaimento

$$\frac{dN}{dt} = -\lambda \cdot N(t)$$

$$N(t) = N_0 e^{-\lambda t}$$

$$\frac{N(T_{1/2})}{N_0} = \frac{1}{2} = e^{-\lambda T_{1/2}}$$

$$T_{1/2} = \frac{\ln(2)}{\lambda}$$

Nº de Contagem

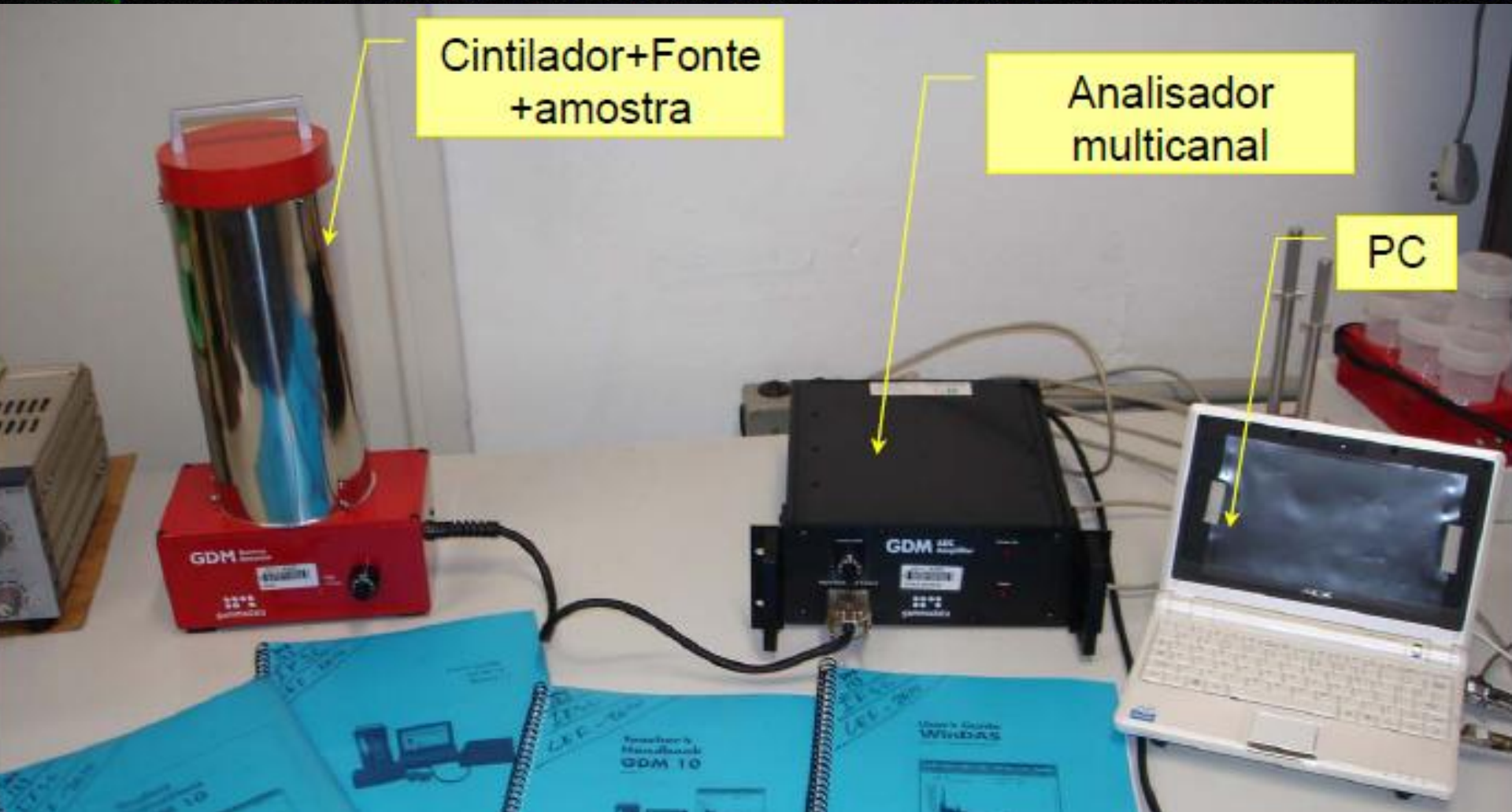
$$dN_c = f \cdot \lambda \cdot N(t) \cdot dt$$

$$N_c = f \cdot \lambda \cdot \int_{t_1}^{t_2} N(t) \cdot dt$$

$$N_c = f \cdot \lambda \cdot N_0 \cdot e^{-\lambda t} \cdot \Delta t$$

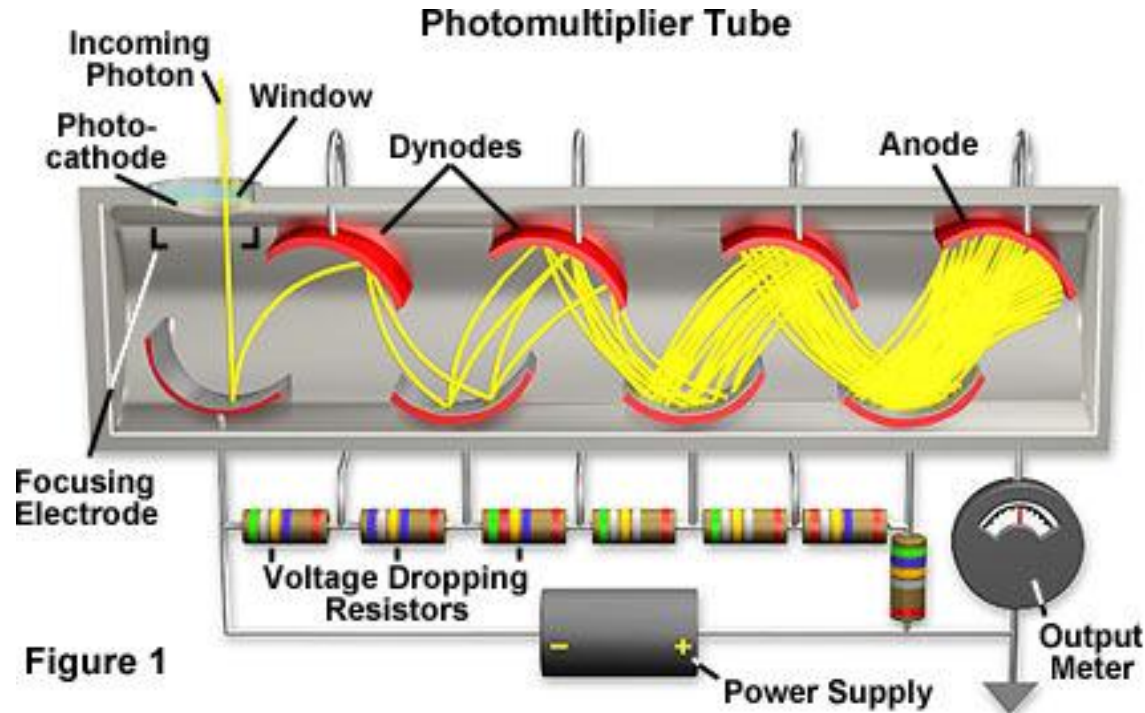
$$\ln N_c = \ln(f \cdot \lambda \cdot N_0 \cdot \Delta t) - \lambda t$$

Aparato experimental



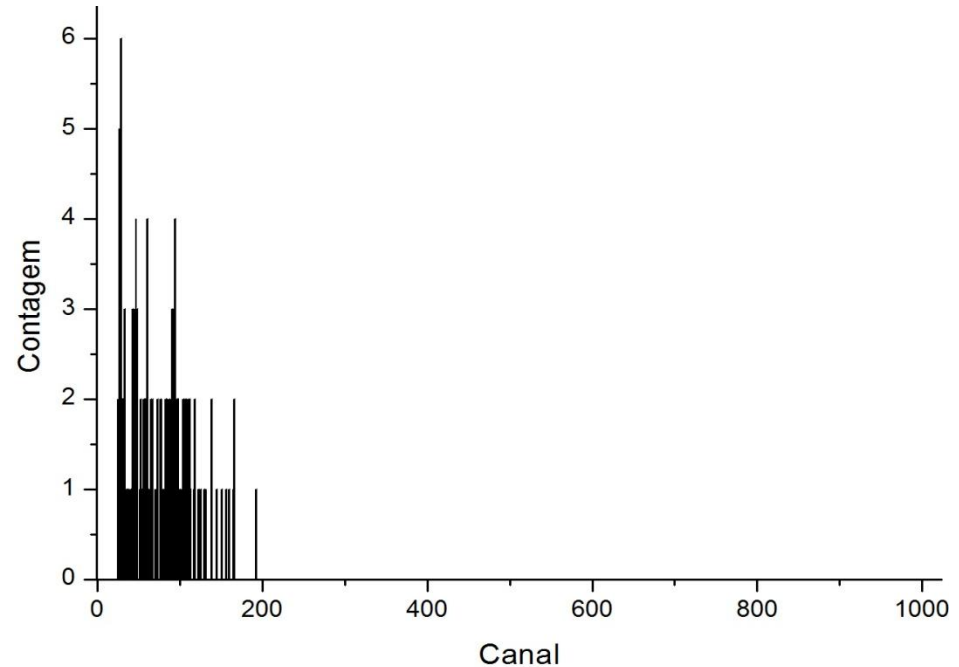
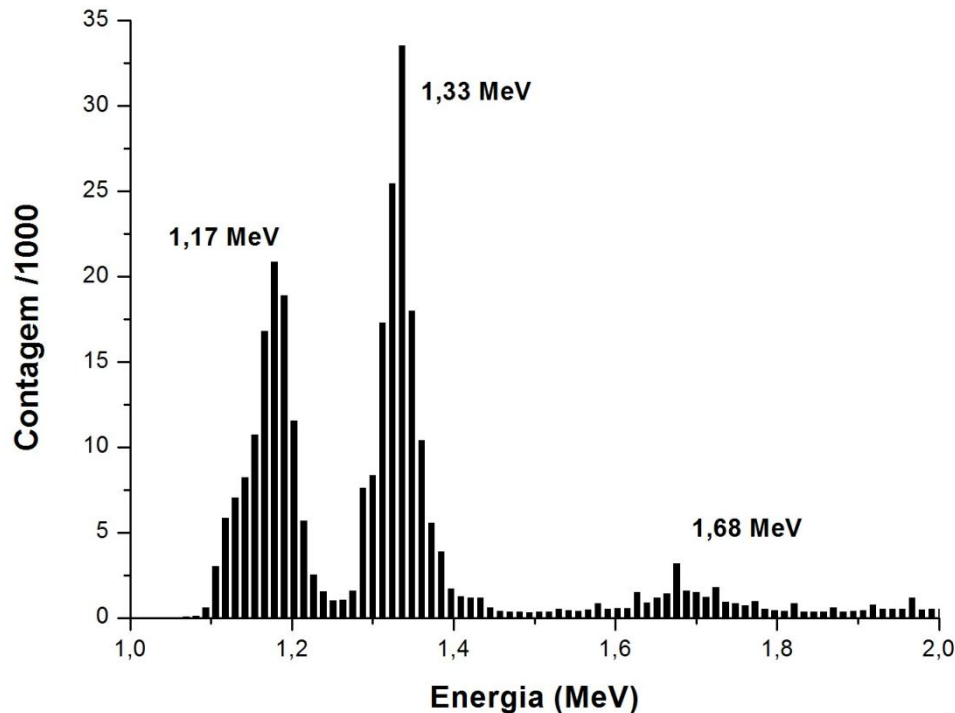
Aparato: Fotomultiplicadora

- Radiação atinge o cintilador.
- Cintilador emite fótons.
- Intensidade do sinal proporcional à energia da radiação.
- Fóton desprende elétrons do metal.
- Elétrons são acelerados por ddp.



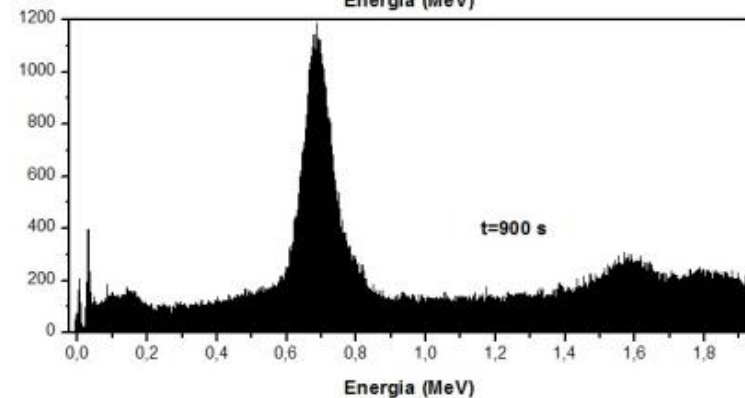
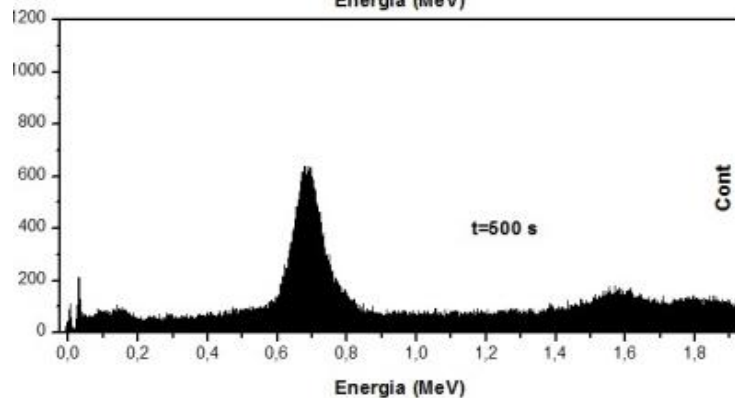
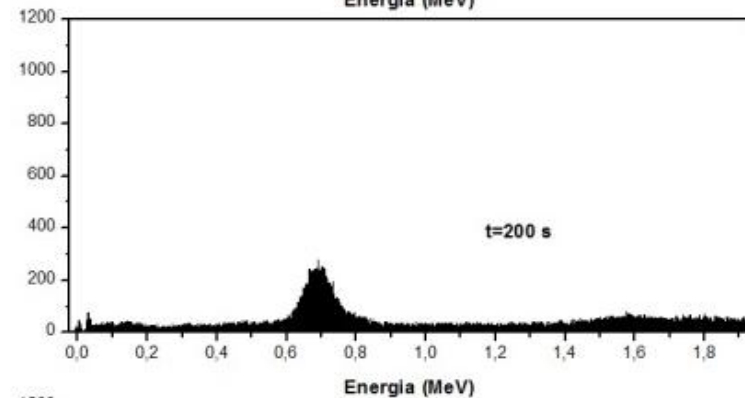
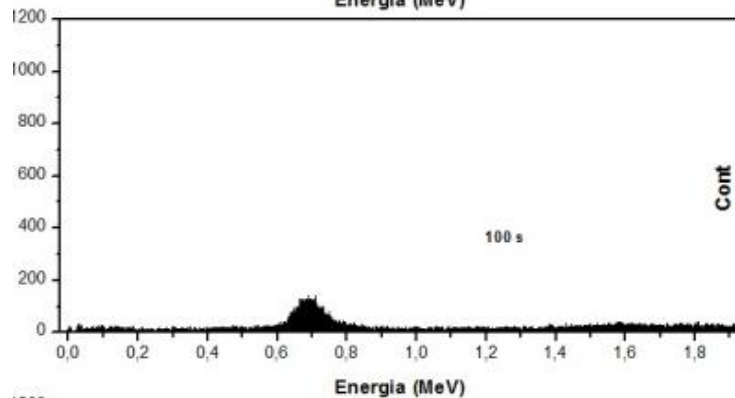
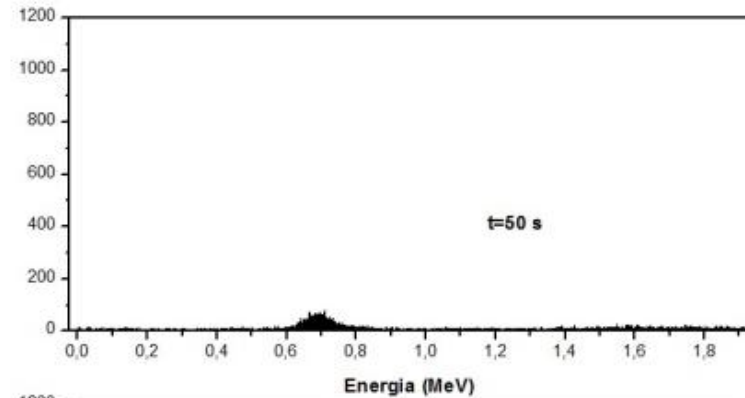
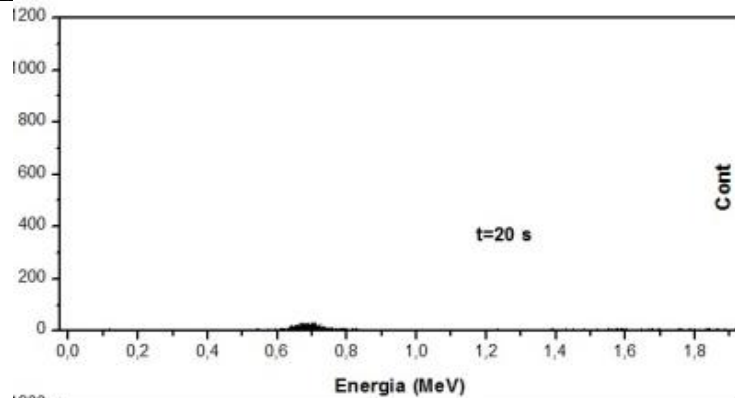
Procedimento experimental

- Obtemos um histograma do número de partículas detectadas em cada canal.
- Quanto maior o canal, mais energética foi a partícula incidente.
- Necessário fazer calibração da energia

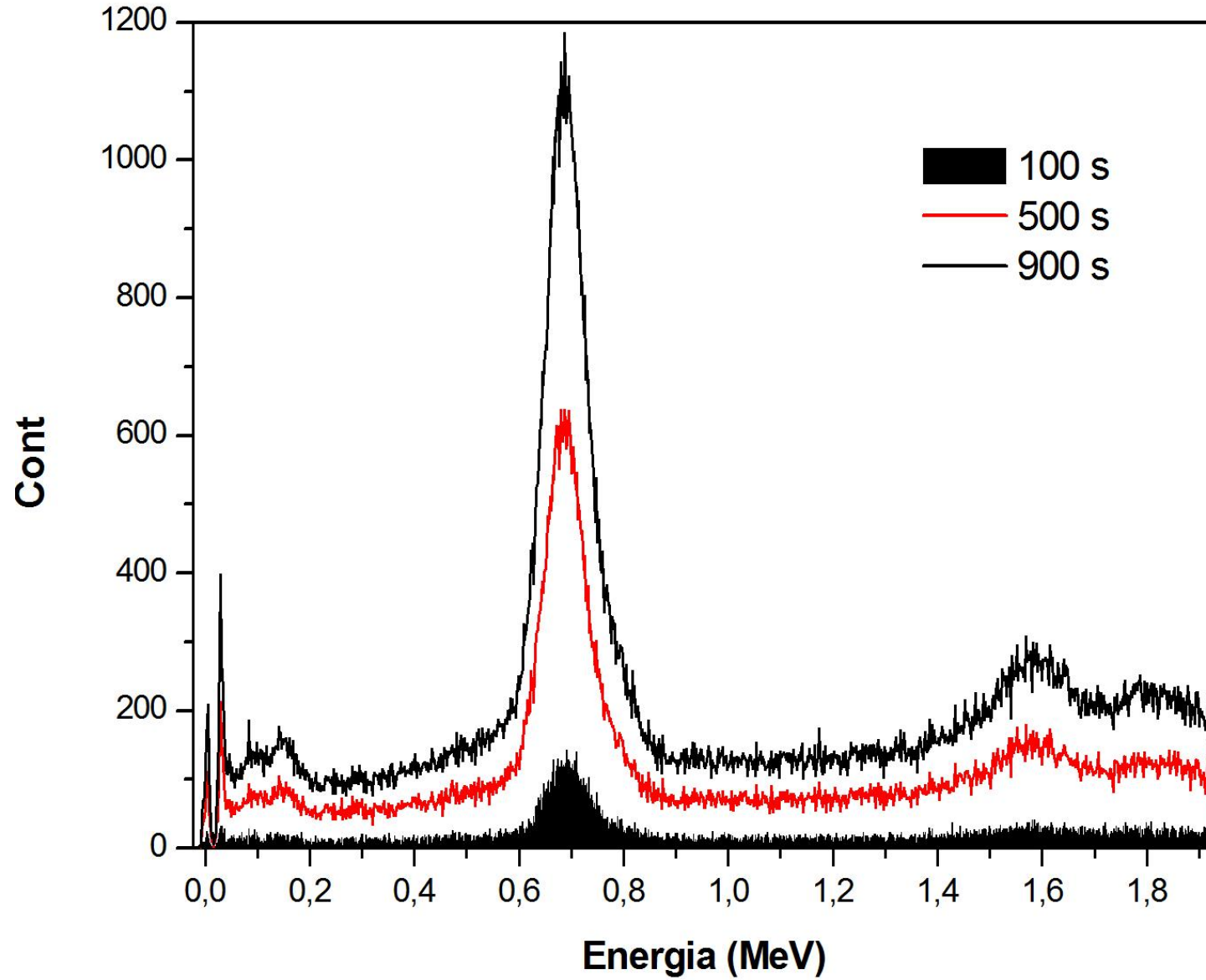


- Precisamos de um espectro com dois picos para os quais as energias sejam conhecidas.
- Para calibração, usamos os picos 1,17 e 1,33 MeV do Co-60

Resultados : Tempo

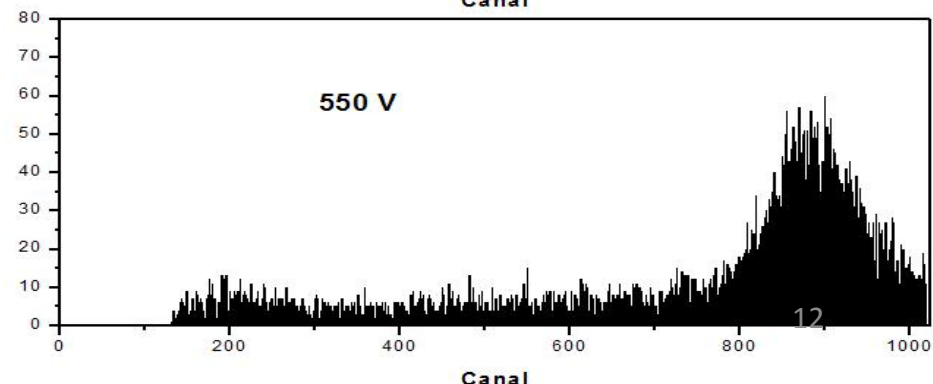
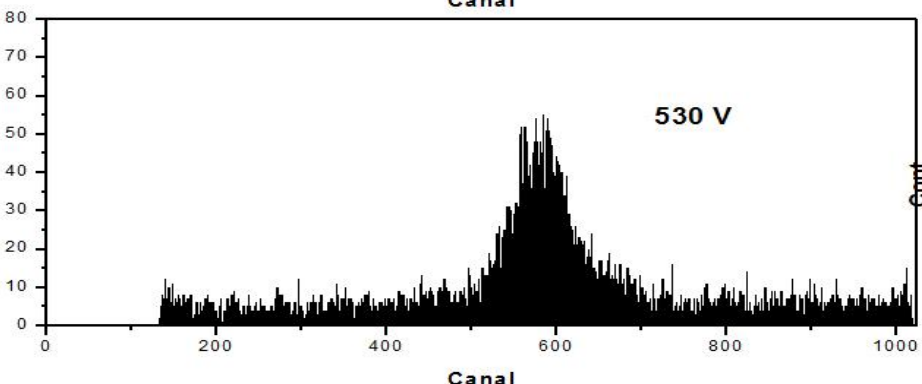
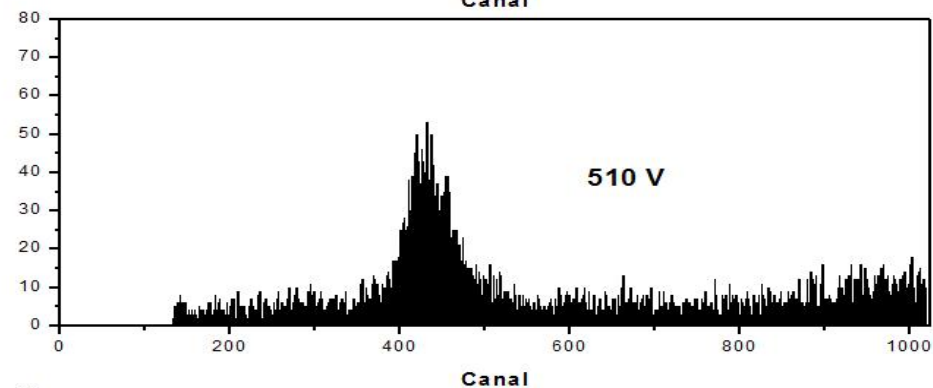
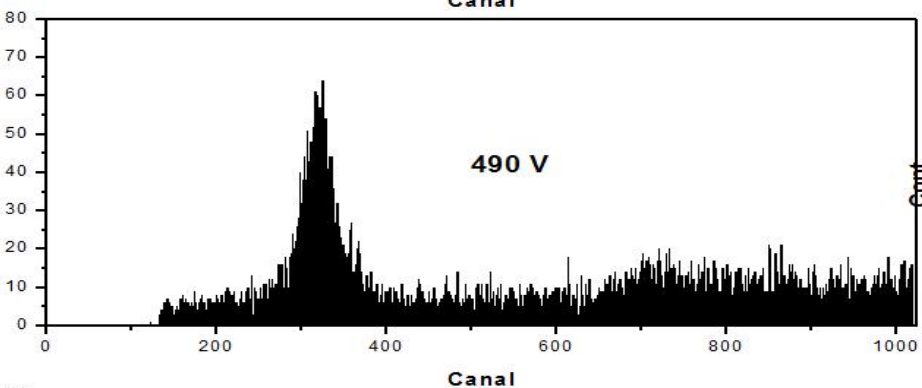
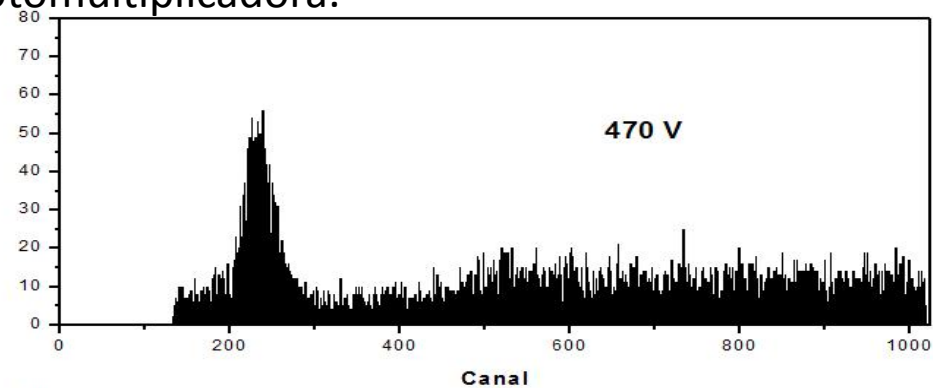
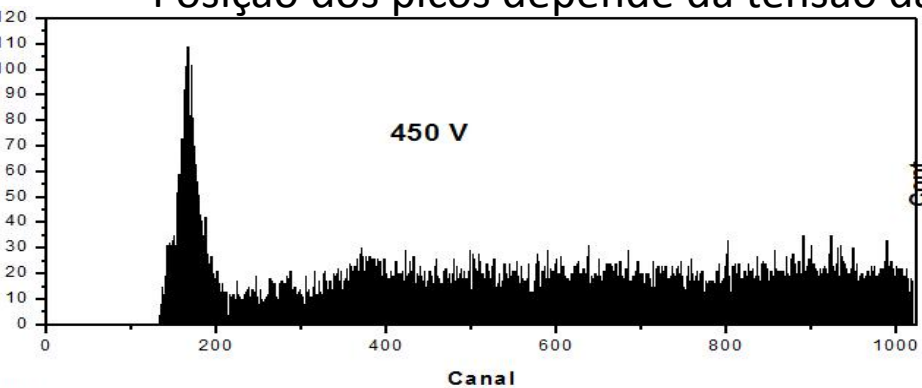


Resultados : Tempo



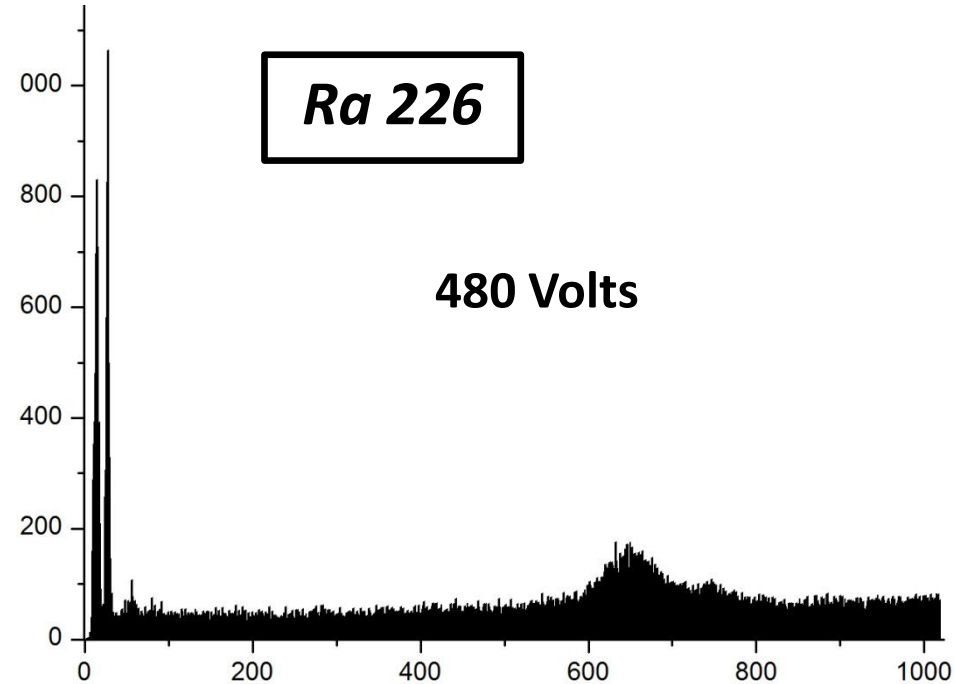
Calibração da energia: Cs¹³⁷

- Posição dos picos depende da tensão da fotomultiplicadora.

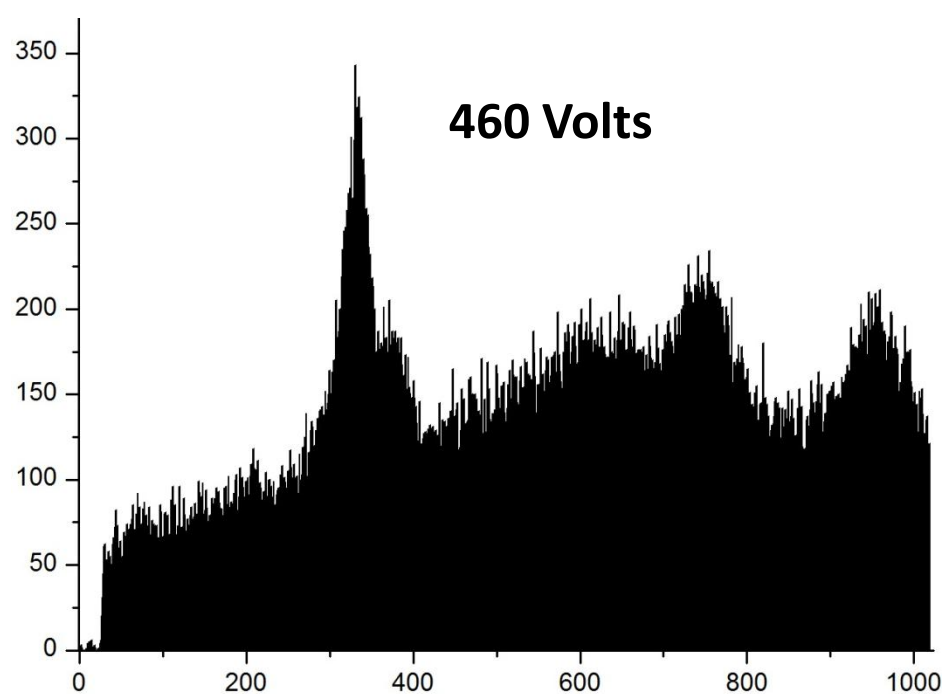


Ra 226

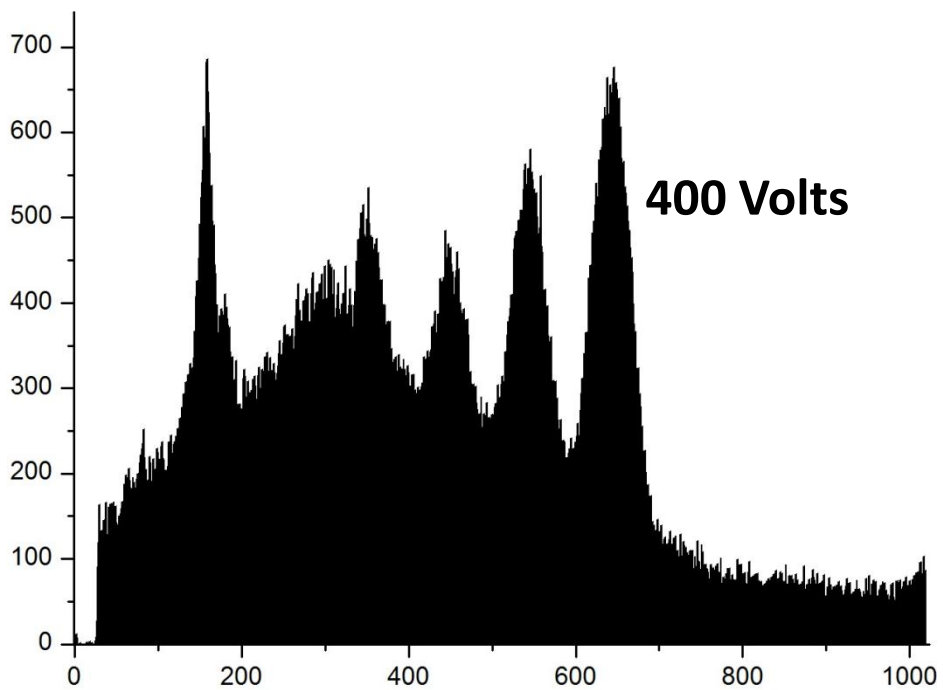
480 Volts



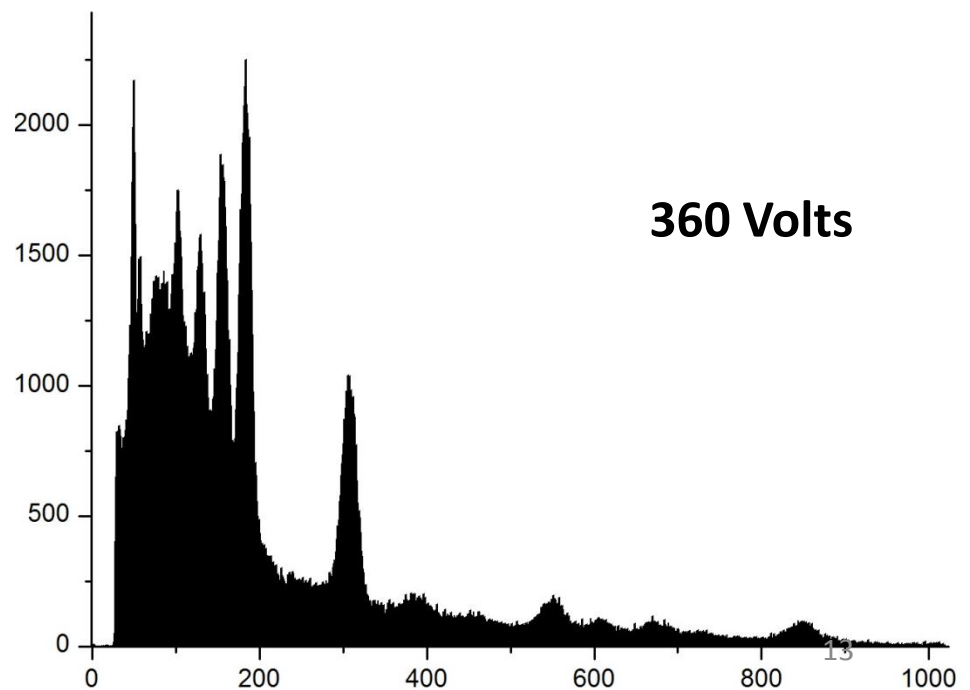
460 Volts

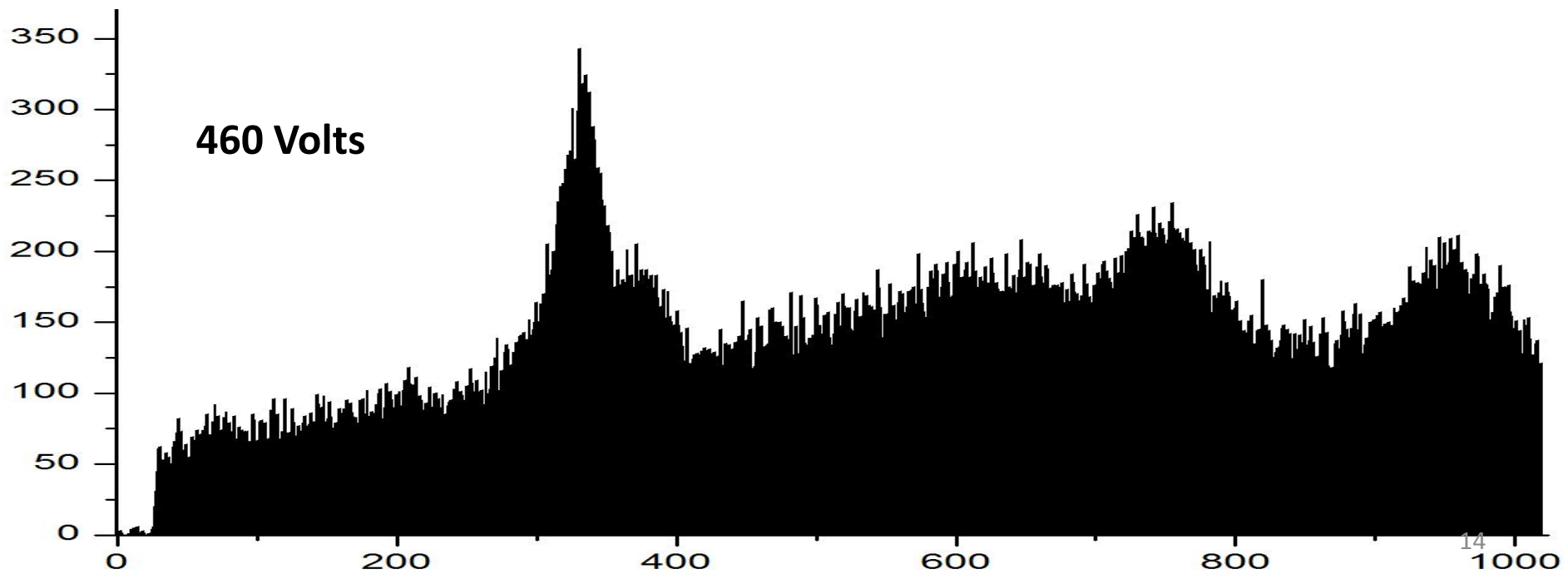
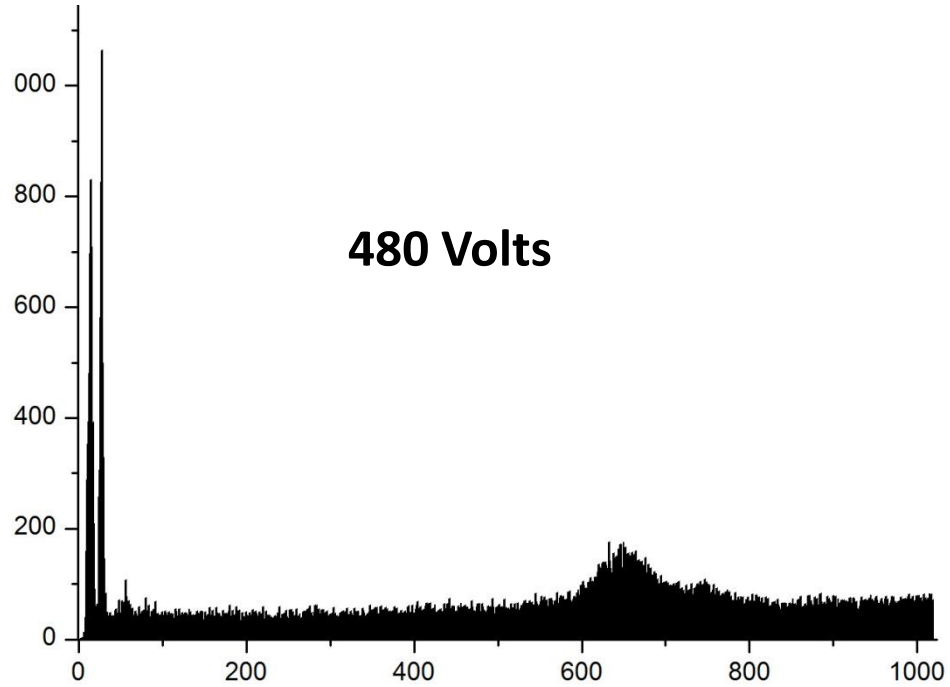


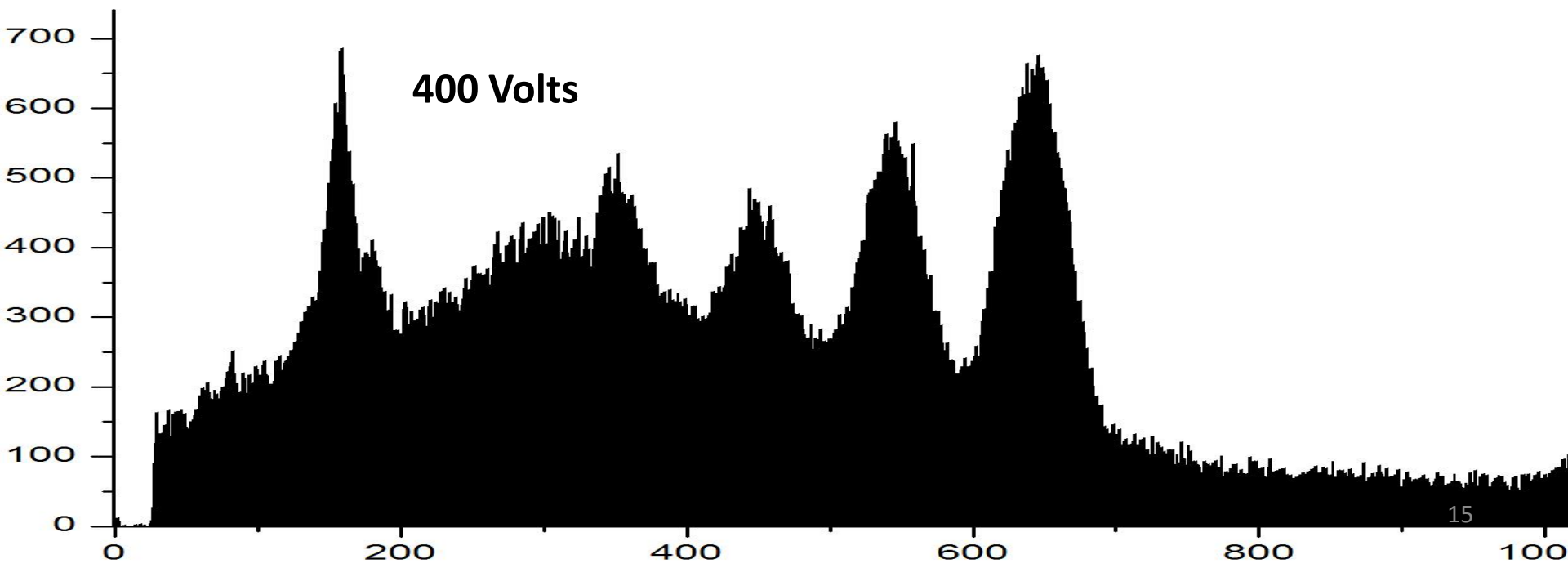
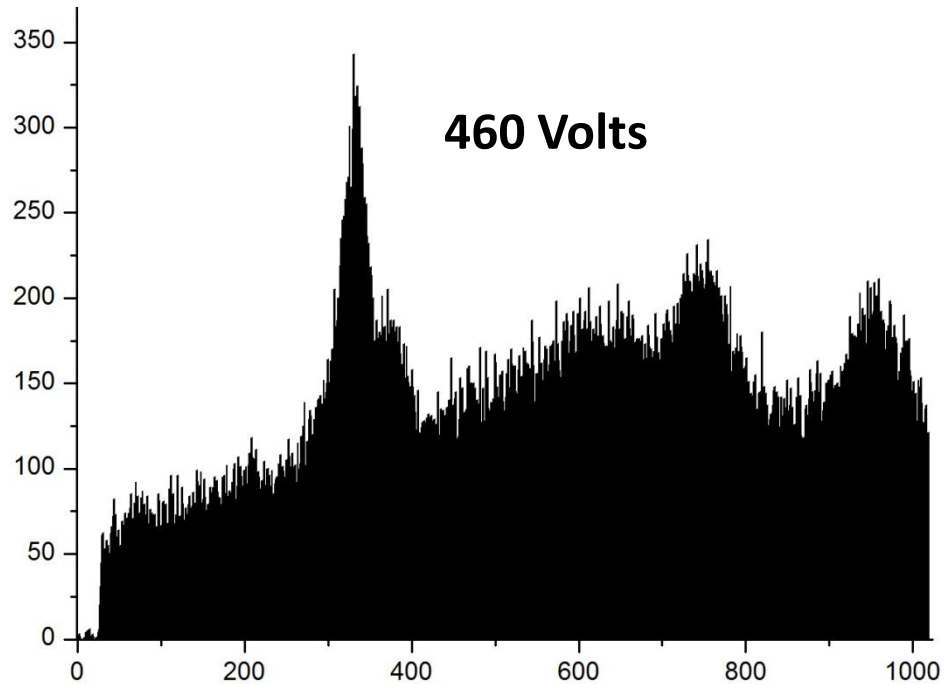
400 Volts

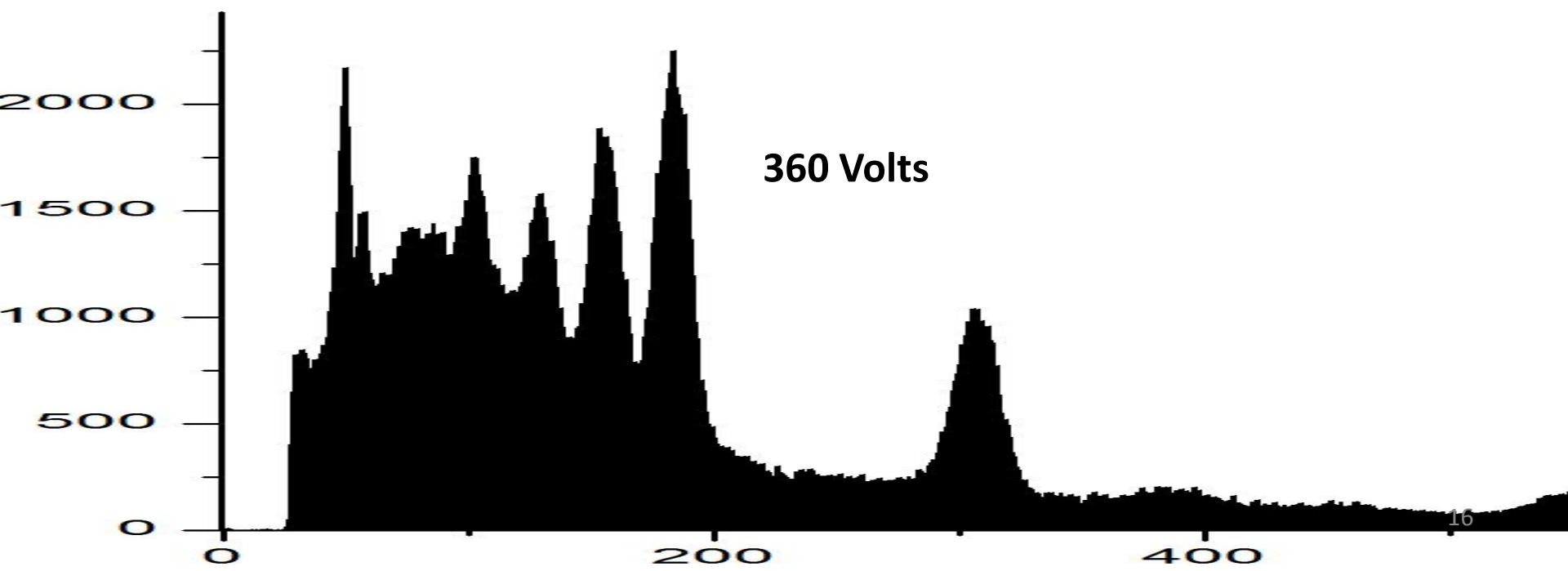
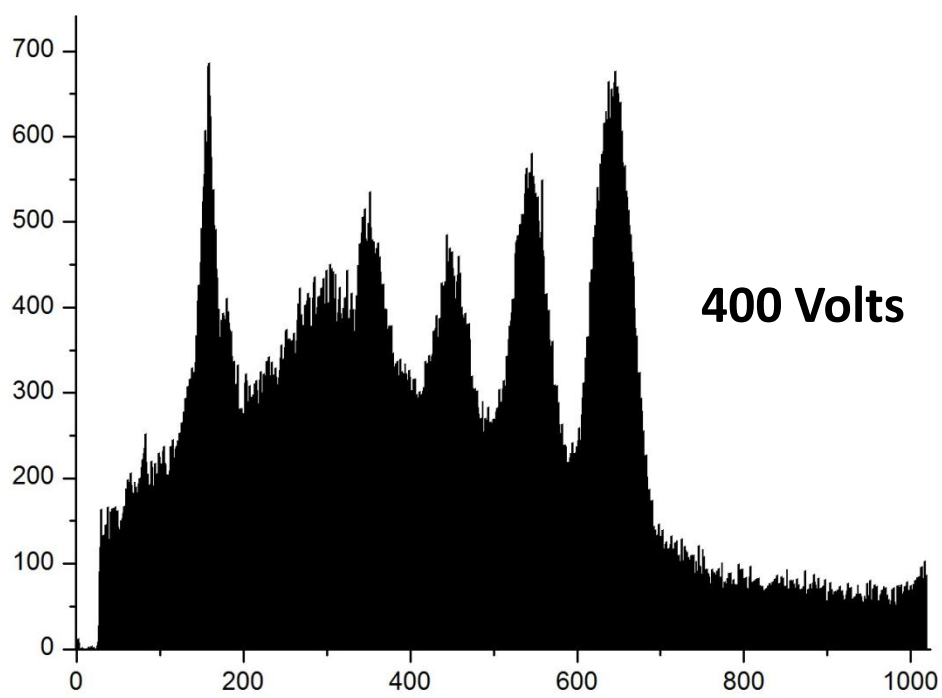


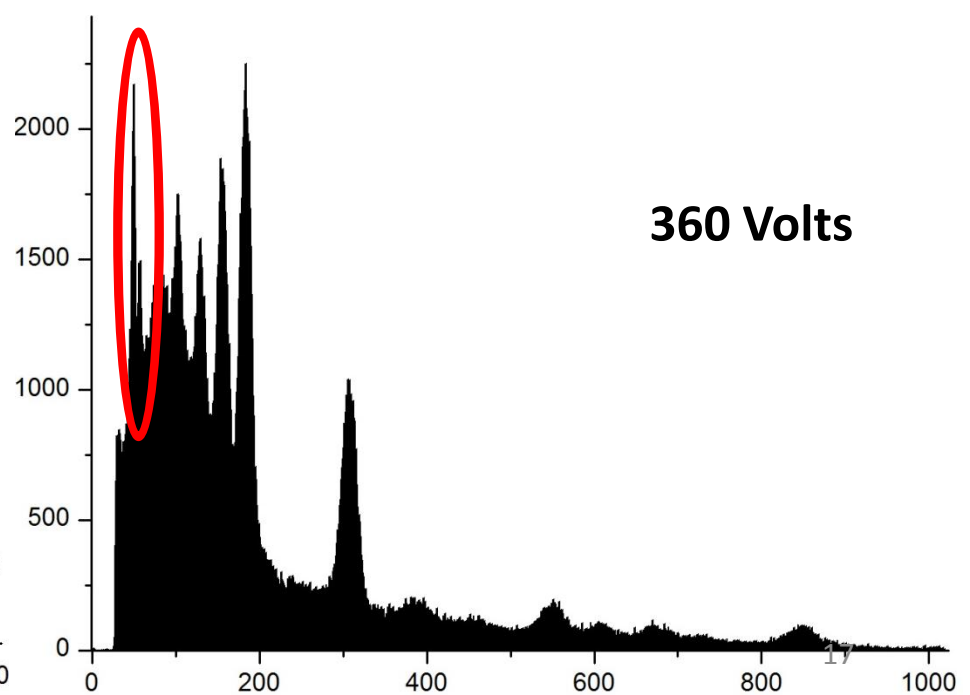
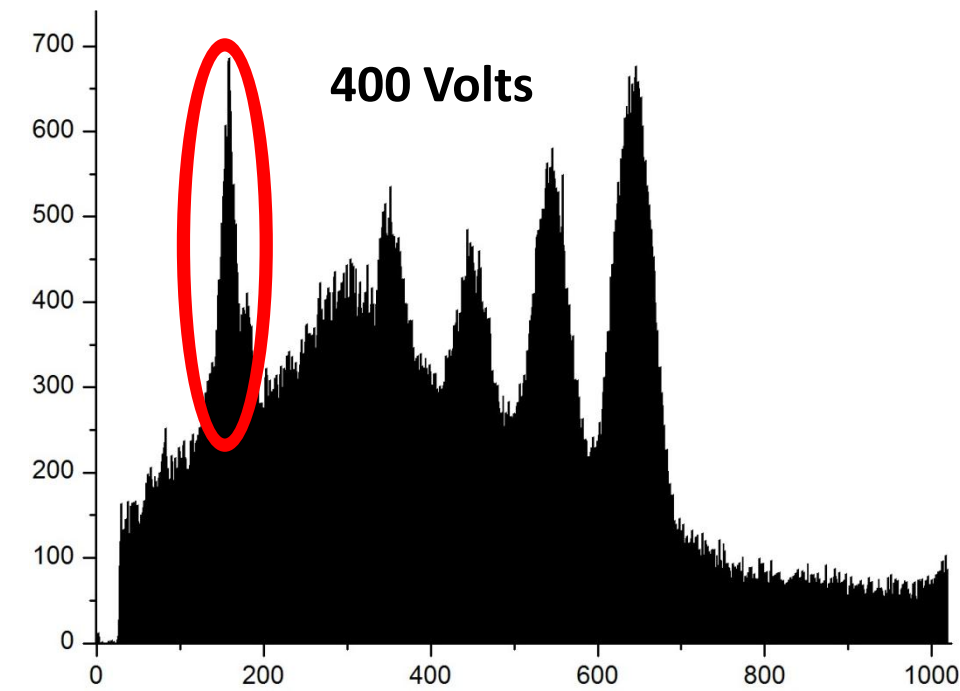
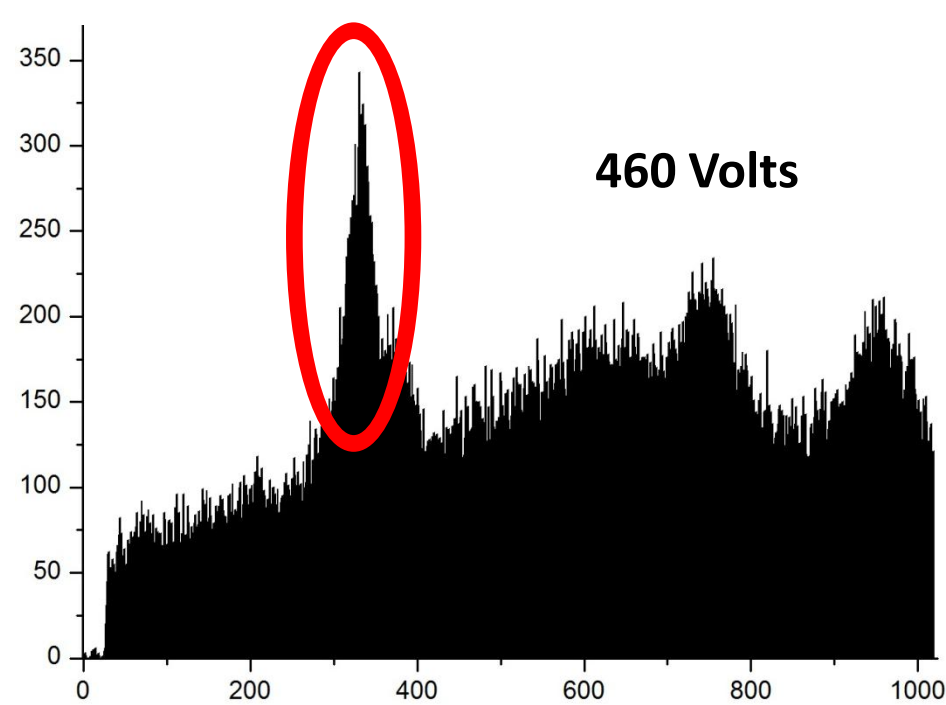
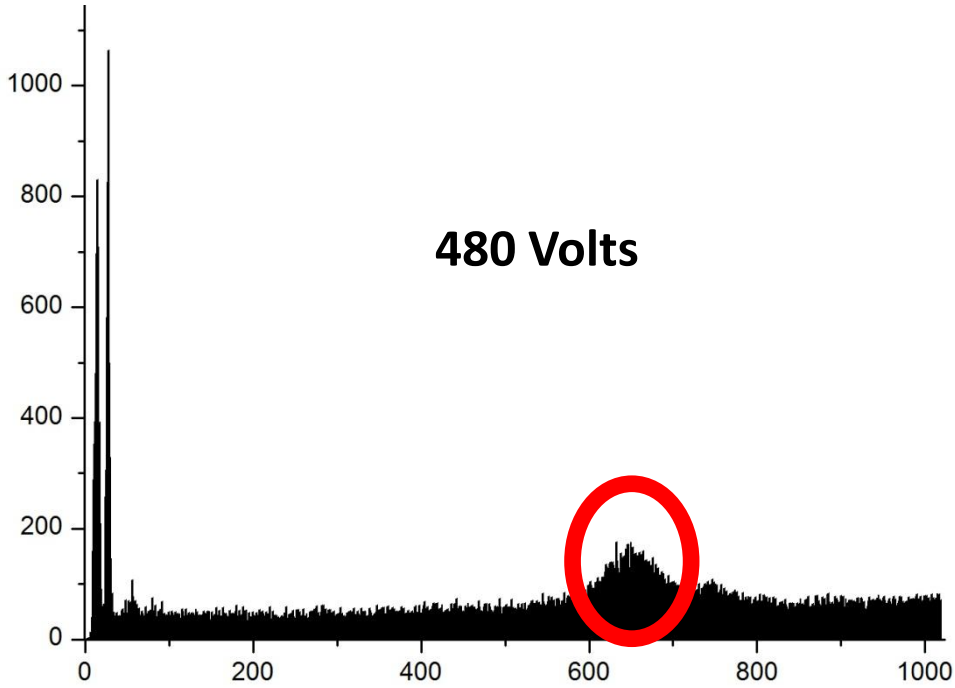
360 Volts



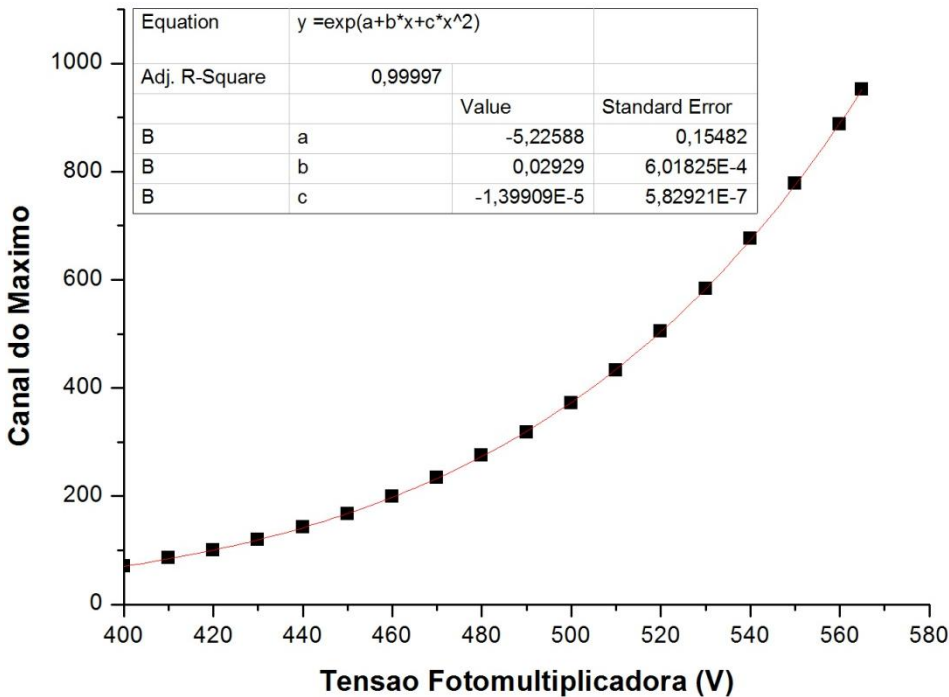




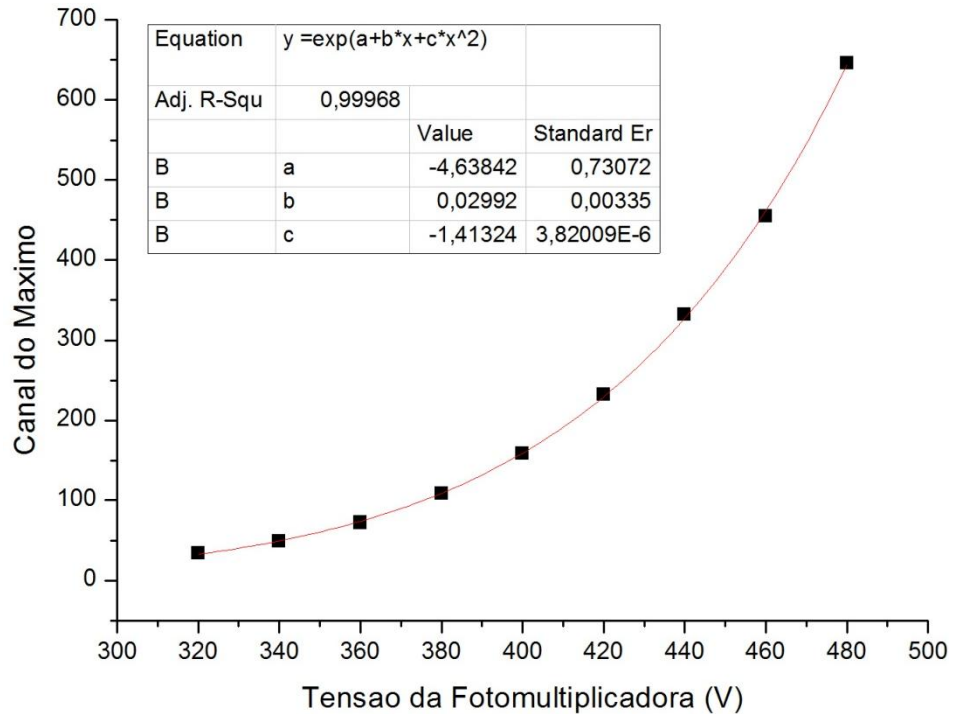




Calibração da energia: Cs¹³⁷



- Pico de 0,661 MeV do Cs-137

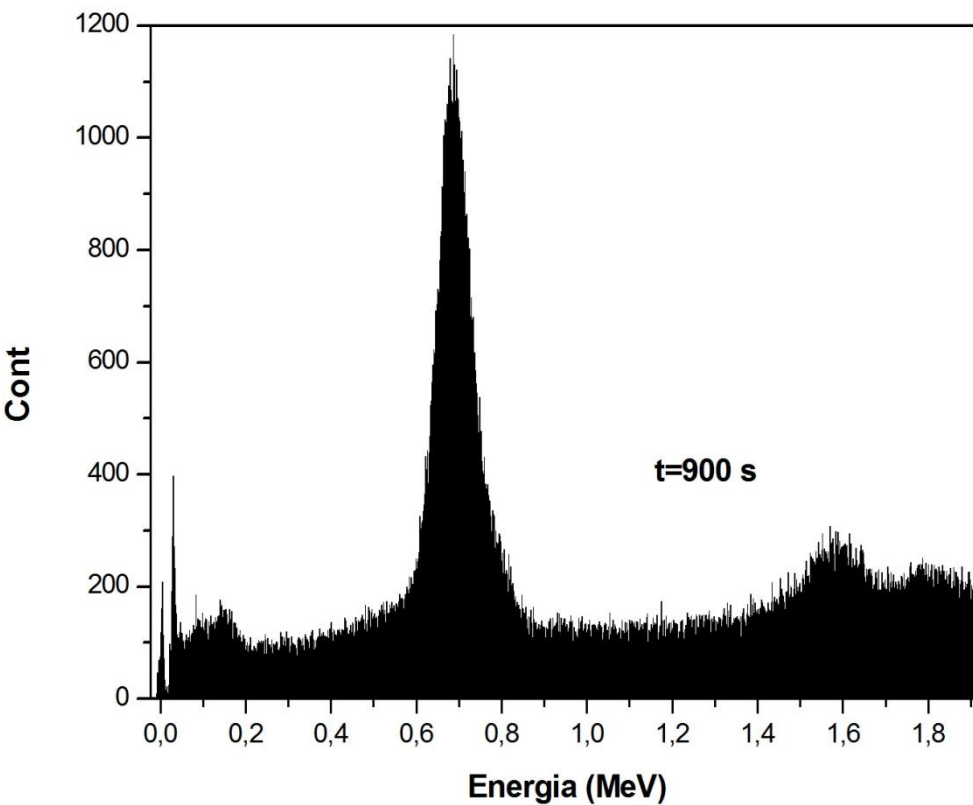


- Pico de energia não calibrada Ra-226

Não obtivemos sucesso em obter uma relação entre os canais da energia com a tensão da fotomultiplicadora.

- *Relação com a atividade da amostra?*

Resultados : Cs¹³⁷ baixa atividade



¹³⁷Cs emissions

Element: Cesium/Césium (Z=55)

Daughter(s): (β^-) Ba-137

Half-life ($T_{1/2}$): 30.05 (8) a

Decay constant (λ): 7.309E-10 s⁻¹

Mass activity (A_m): 3.213E+12 Bq.g⁻¹

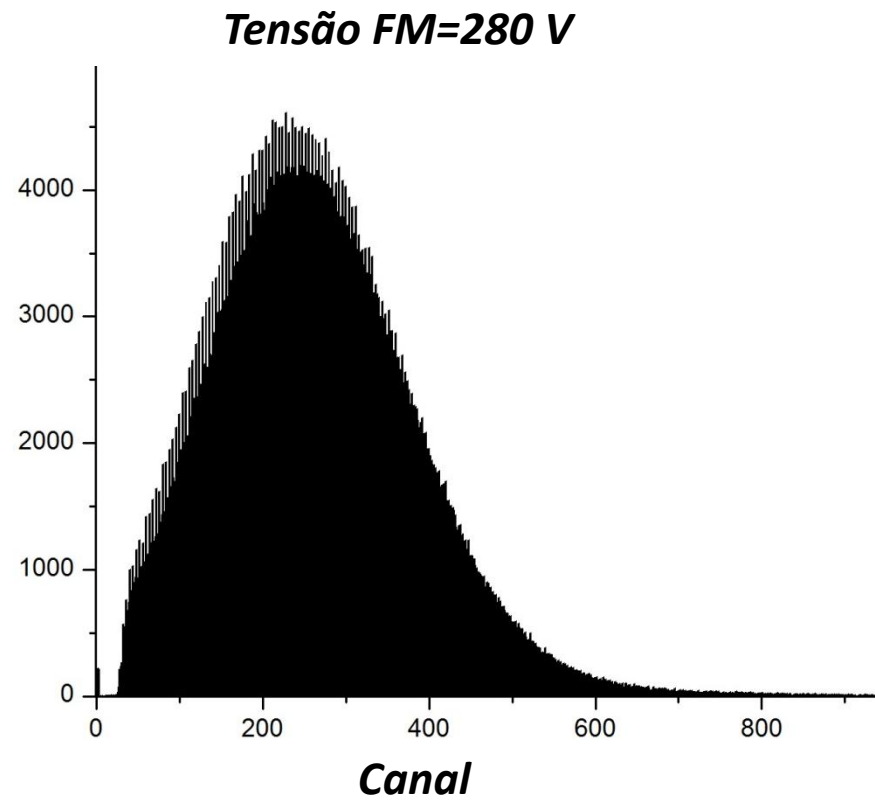
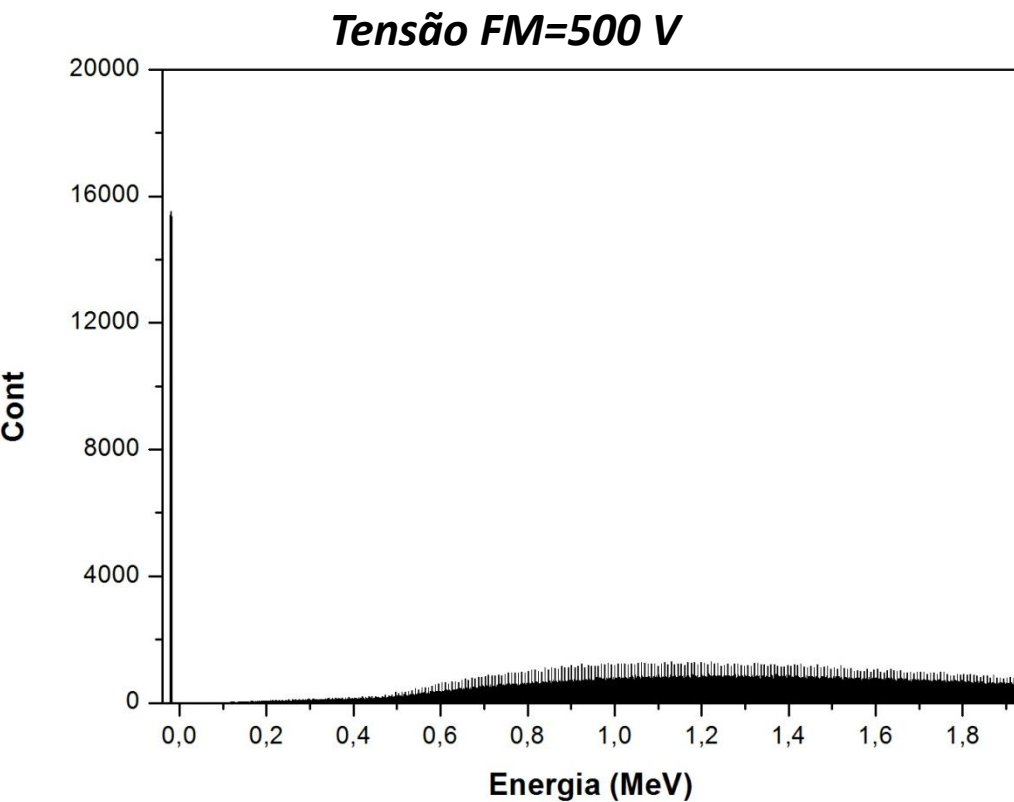
Reference: INEEL, KRI - 2006

Data evaluation files: [Table](#) - [Comments](#) - [ENSDF](#)

Gamma emissions (7 lines)

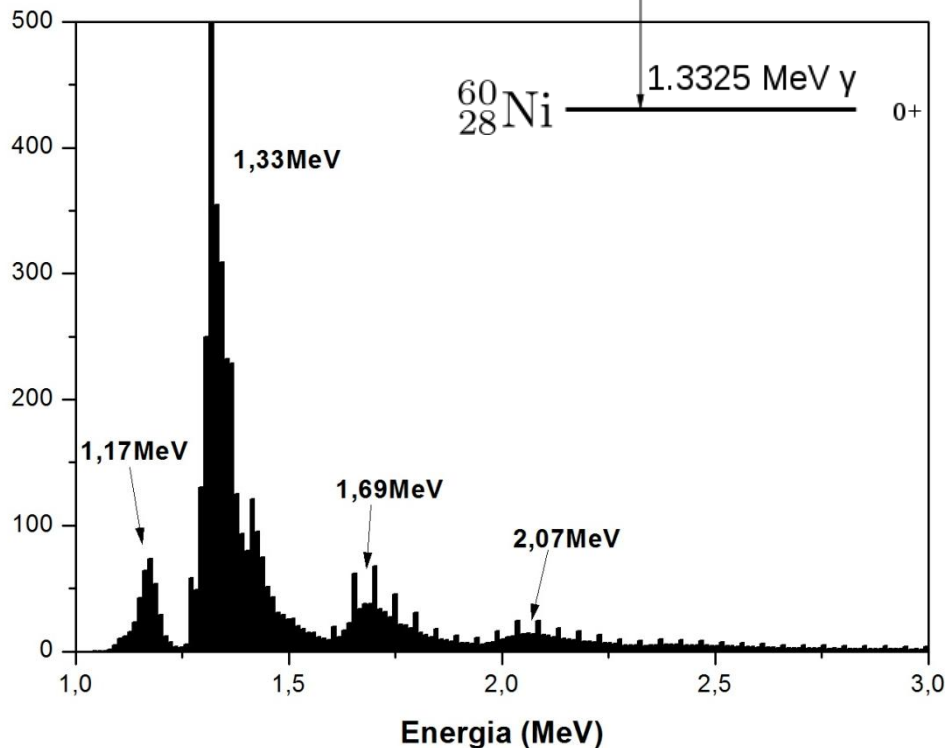
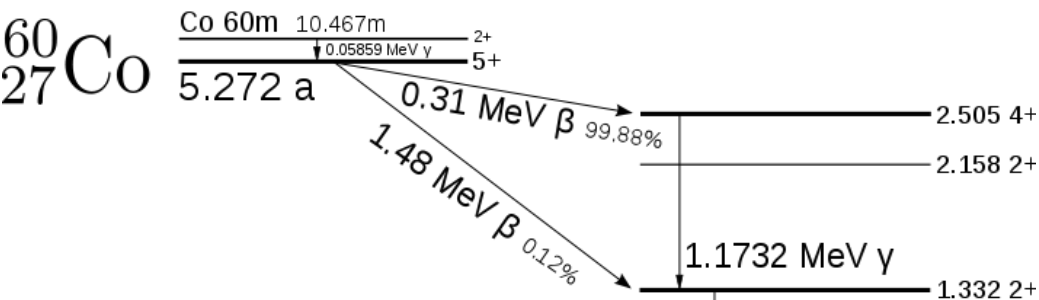
Energy (keV)	Intensity (%)	Type	Origin
4.8815 (-)	0.90 (5)	X _L	Ba-137
31.8174 (-)	1.95 (4)	X _{Kα2}	Ba-137
32.1939 (-)	3.59 (7)	X _{Kα1}	Ba-137
36.4457 (-)	1.055 (22)	X _{Kβ1}	Ba-137
37.3317 (-)	0.266 (8)	X _{Kβ2}	Ba-137
283.5 (1)	0.00058 (8)	γ	Ba-137
661.657 (3)	84.99 (20)	γ	Ba-137

Resultados : Cs¹³⁷ Alta atividade



Canal do pico não corresponde ao previsto com os dados do Cs de baixa atividade

Resultados : ^{60}Co



^{60}Co emissions

Element: Cobalt (Z=27)

Daughter(s): (β^-) Ni-60

Half-life ($T_{1/2}$): 5.2710 (8) a

Decay constant (λ): $4.167\text{E}-09 \text{ s}^{-1}$

Mass activity (A_m): $4.183\text{E}+13 \text{ Bq.g}^{-1}$

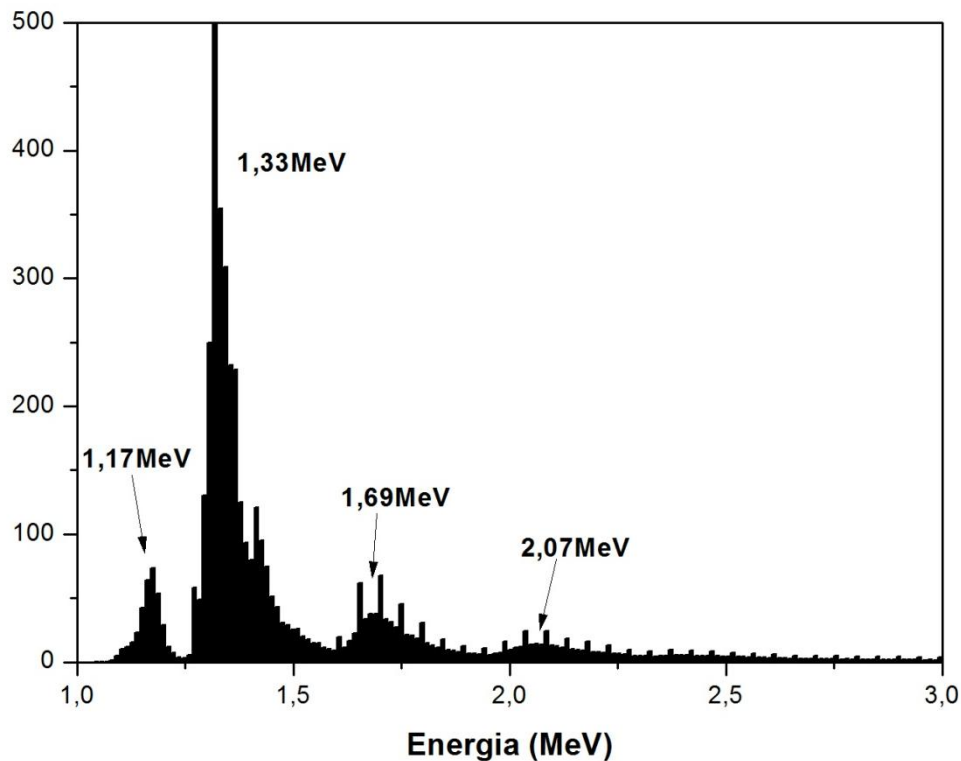
Reference: INEEL - 2006

Data evaluation files: [Table](#) - [Comments](#) - [ENSDF](#)

Emissions (10 lines)

Energy (keV)	Intensity (%)	Type	Origin
0.84 (-)	0.0002 (-)	X_L	Ni-60
7.46097 (-)	0.00334 (12)	$X_{K\alpha 2}$	Ni-60
7.47824 (-)	0.0065 (3)	$X_{K\alpha 1}$	Ni-60
8.2967 (-)	0.00136 (5)	$X_{K\beta 1}$	Ni-60
347.14 (7)	0.0075 (4)	γ	Ni-60
826.10 (3)	0.0076 (8)	γ	Ni-60
1 173.228 (3)	99.85 (3)	γ	Ni-60
1 332.492 (4)	99.9826 (6)	γ	Ni-60
2 158.57 (3)	0.0012 (2)	γ	Ni-60
2 505.692 (5)	0.0000020 (4)	γ	Ni-60

Resultados : Co^{58}



^{58}Co emissions

Element: Cobalt (Z=27)

Daughter(s): (β^+ , ϵ) Fe-58

Half-life ($T_{1/2}$): 70.83 (10) d

Decay constant (λ): $1.133\text{E-}07 \text{ s}^{-1}$

Mass activity (A_m): $1.176\text{E+}15 \text{ Bq.g}^{-1}$

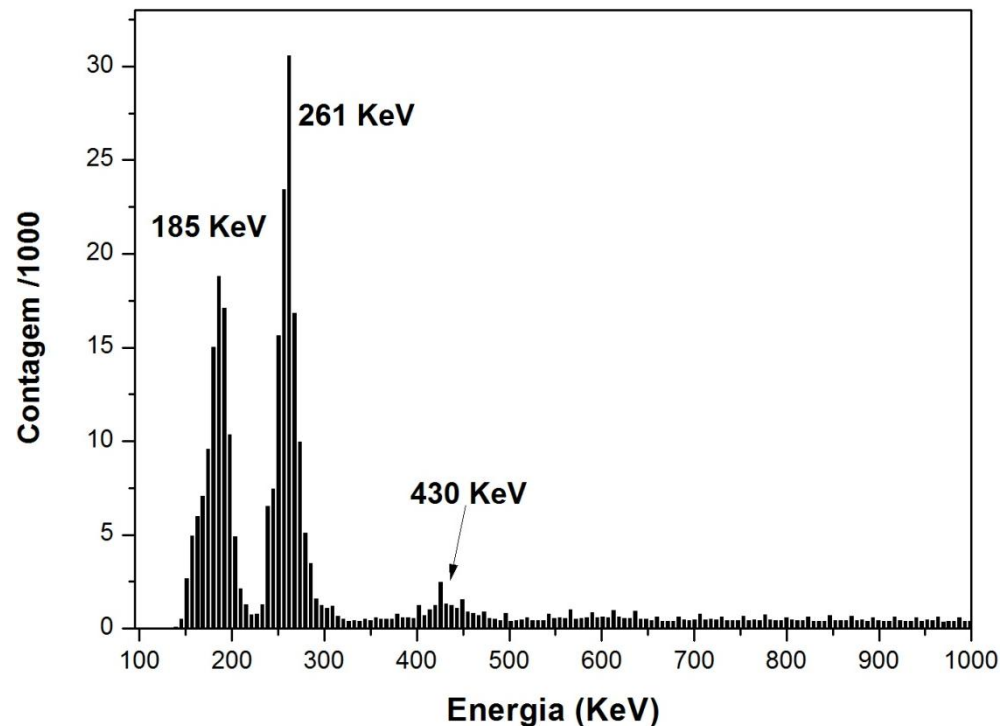
Reference: CEA/LNE-LNHB - 1998

Data evaluation files: [Table](#) - [Comments](#) - [ENSDF](#)

Emissions (8 lines)

Energy (keV)	Intensity (%)	Type	Origin
0.7025 (-)	0.73 (7)	X_L	Fe-58
6.39091 (-)	7.9 (2)	$X_{K\alpha 2}$	Fe-58
6.40391 (-)	15.6 (2)	$X_{K\alpha 1}$	Fe-58
7.0832 (-)	3.2 (1)	$X_{K\beta 1}$	Fe-58
511 (-)	30.0 (4)	γ^\pm	Fe-58
810.759 (2)	99.45 (1)	γ	Fe-58
863.951 (6)	0.69 (1)	γ	Fe-58
1 674.725 (7)	0.52 (1)	γ	Fe-58

Resultados : Ra²²⁶



²²⁶Ra emissions

Element: Radium (Z=88)

Daughter(s): (α) Rn-222

Half-life ($T_{1/2}$): $1.600 (7) \cdot 10^3$ a

Decay constant (λ): $1.373E-11$ s⁻¹

Mass activity (A_m): $3.658E+10$ Bq.g⁻¹

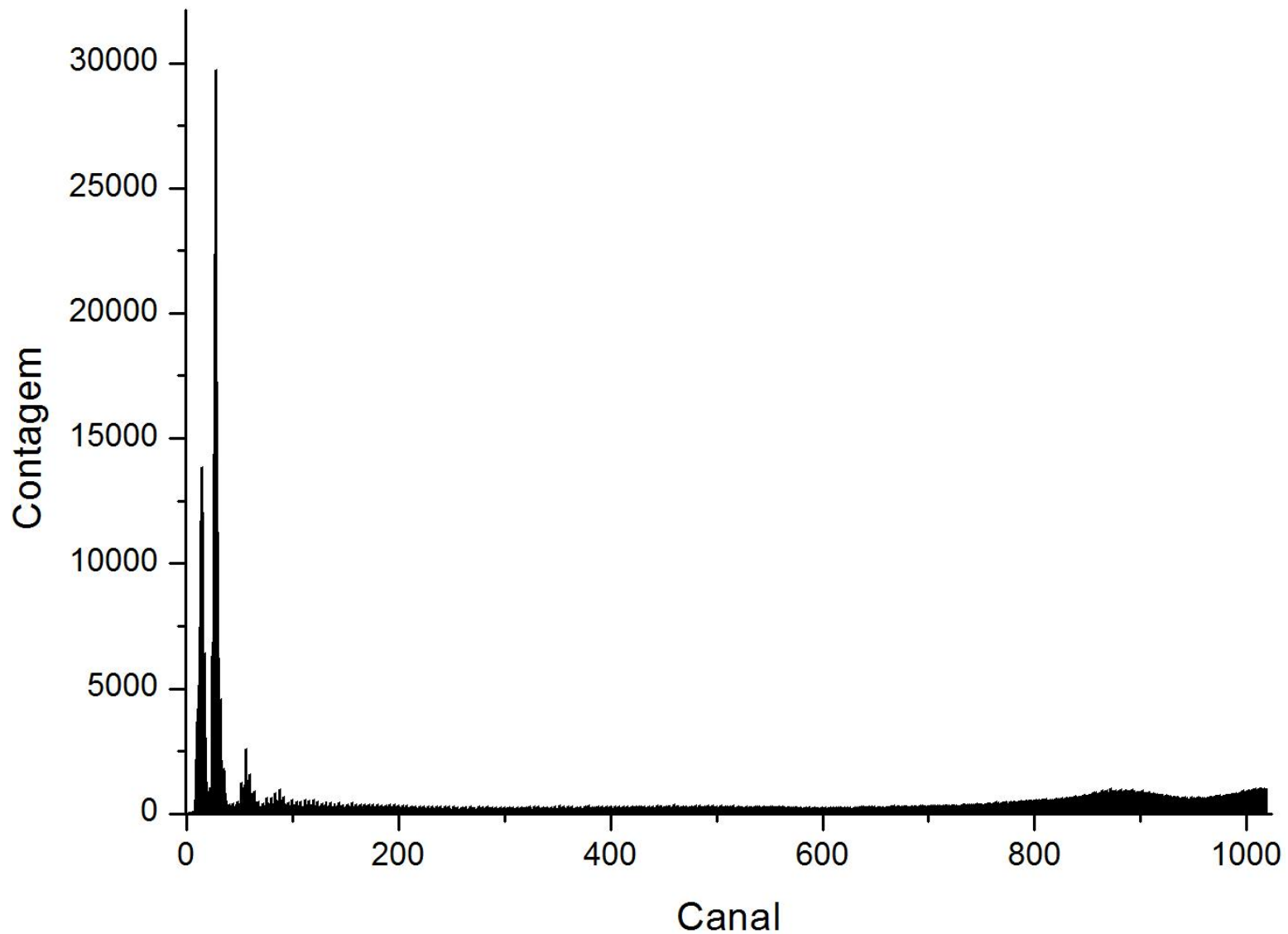
Reference: CEA/LNE-LNHB - 2006

Data evaluation files: [Table](#) - [Comments](#) - [ENSDF](#)

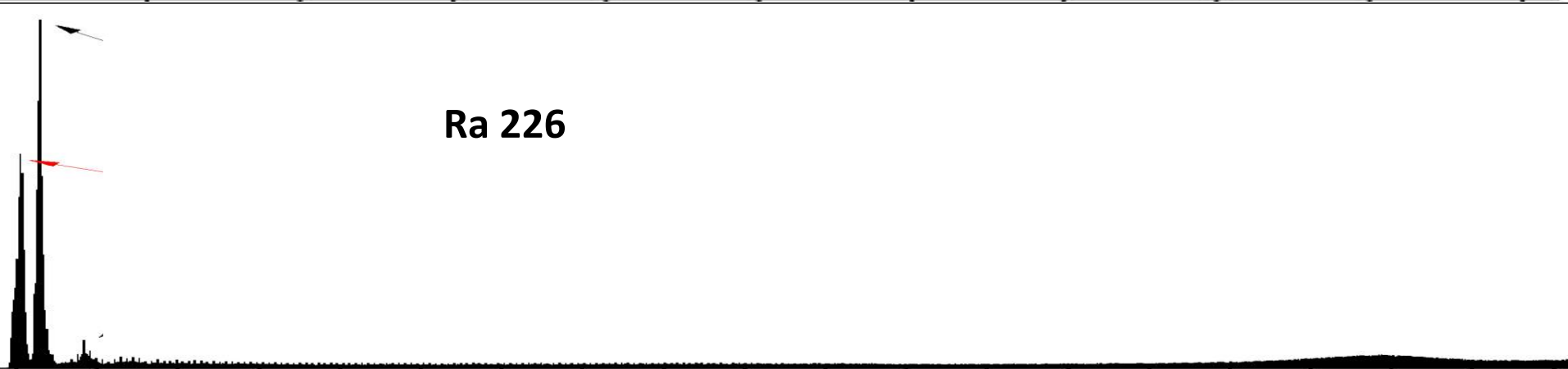
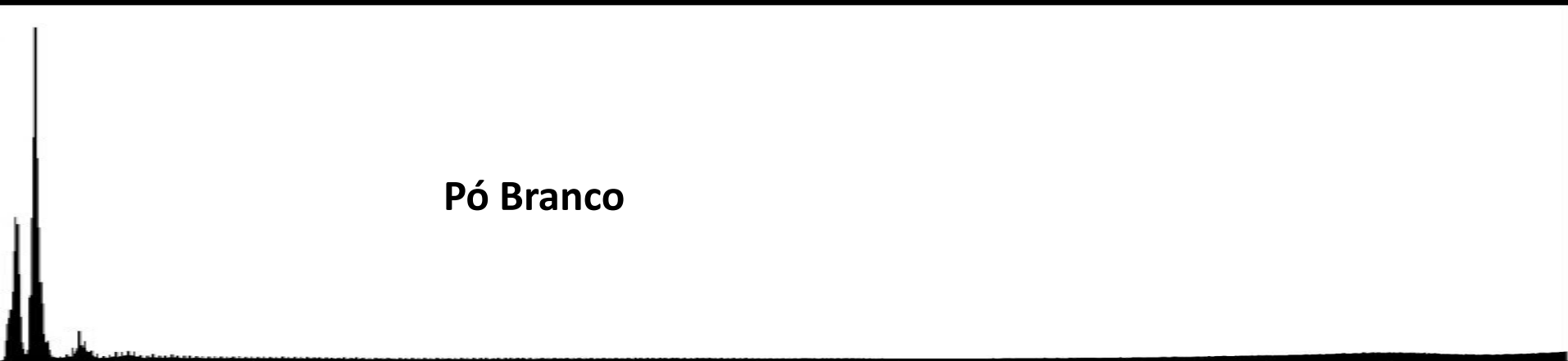
Gamma emissions (10 lines)

Energy (keV)	Intensity (%)	Type	Origin
13.7 (-)	0.807 (14)	X _L	Rn-222
81.07 (-)	0.192 (4)	X _{Kα2}	Rn-222
83.78 (-)	0.317 (6)	X _{Kα1}	Rn-222
94.8547 (-)	0.1098 (25)	X _{Kβ1}	Rn-222
97.8967 (-)	0.0351 (10)	X _{Kβ2}	Rn-222
186.211 (13)	3.555 (19)	γ	Rn-222
262.27 (5)	0.0055 (18)	γ	Rn-222
414.60 (5)	0.0003 (-)	γ	Rn-222
449.37 (10)	0.0002 (-)	γ	Rn-222
600.66 (5)	0.0005 (-)	γ	Rn-222

Resultados : Pó Branco



Amostra de Pó Branco: FM-500 V

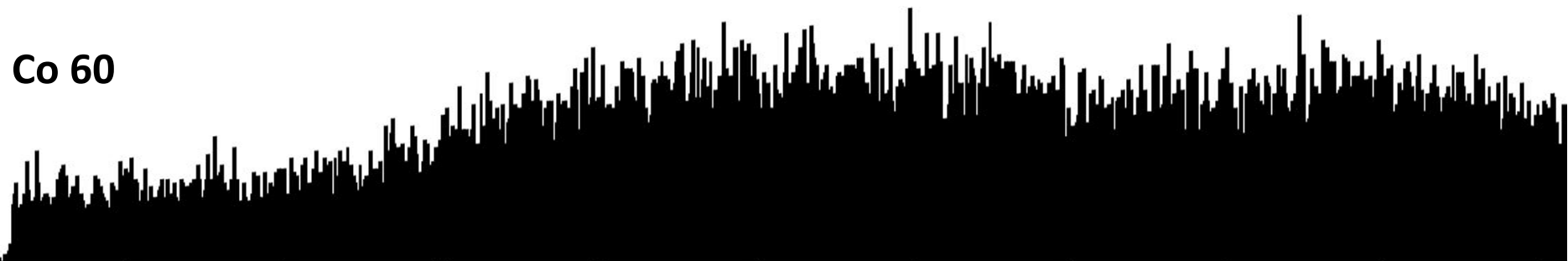


Amostra de Pó Branco: FM-440 V

Pó Branco



Co 60



Ra 226



Conclusão



Embora possua uma resolução relativamente baixa (espectro dividido em 1024 canais), ela é suficiente para diferenciar amostras radioativas e obter seus espectros.

Os valores obtidos para os picos de emissão das amostras foram coerentes com os valores obtidos na literatura.

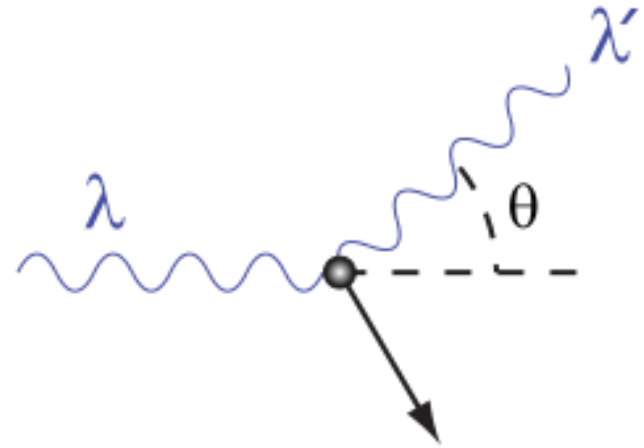
Não foi possível encontrar alguma função que descreva a energia de cada canal em função da tensão da fotomultiplicadora.

Bibliografia

- Apostilas e manuais Windas
- <http://nucleardata.nuclear.lu.se/NuclearData/toi/nucSearch.asp>
- <http://laraweb.free.fr/>

Efeito Compton

Espalhamento Compton ou Efeito Compton é o nome que se dá quando um fóton com certa energia colide inelasticamente com um elétron, transferindo momento(energia) para este que é/pode ser ejetado do material/átomo. O que obriga, pela conservação da energia um aumento no comprimento de onda.



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