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Title: Beta Emission and Bremsstrahlung

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Beta Emission & Bremsstrahlung

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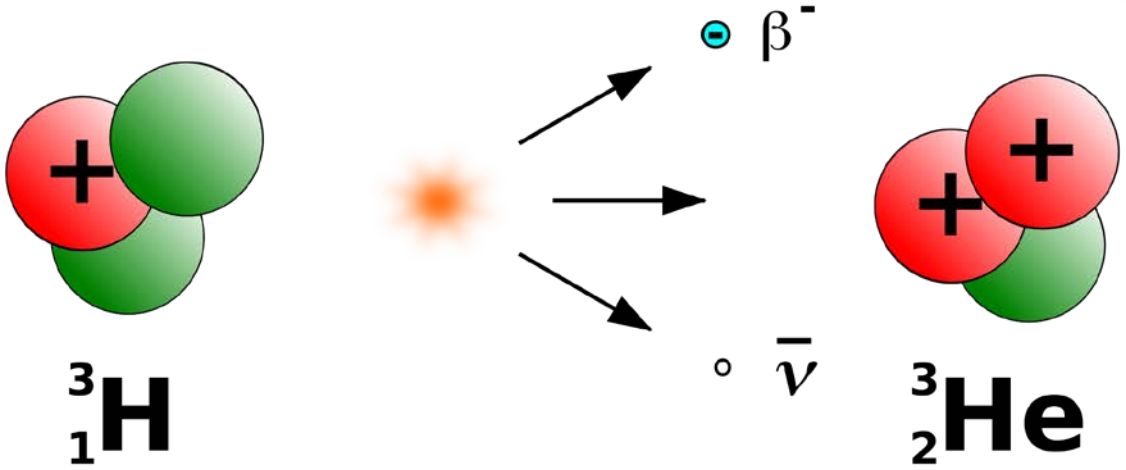
Introduction

- When a nucleus has too many protons or neutrons it may undergo beta decay
  - Too many neutrons → β^- decay
  - Too many protons → β^+ decay
- β^- and β^+ particles are the same as electrons and positrons respectively
- β^+ particles quickly undergo pair annihilation but β^- particles will radiate a continuous range of photons as they decelerate in various media.

Beta Decay

Here we see tritium decaying to He-3. A third particle given off in this reaction is called an anti-neutrino. It is undetectable by typical radiation/search detectors.



$E = mc^2$ ⇨ **Mass-Energy difference of ^{3}H and ^{3}He in MeV*:**

2809.449895 - 2809.431302 = 0.018593

This is the "endpoint energy of the emitted β particle"

* atomic masses

“Pure” β^- Emitters

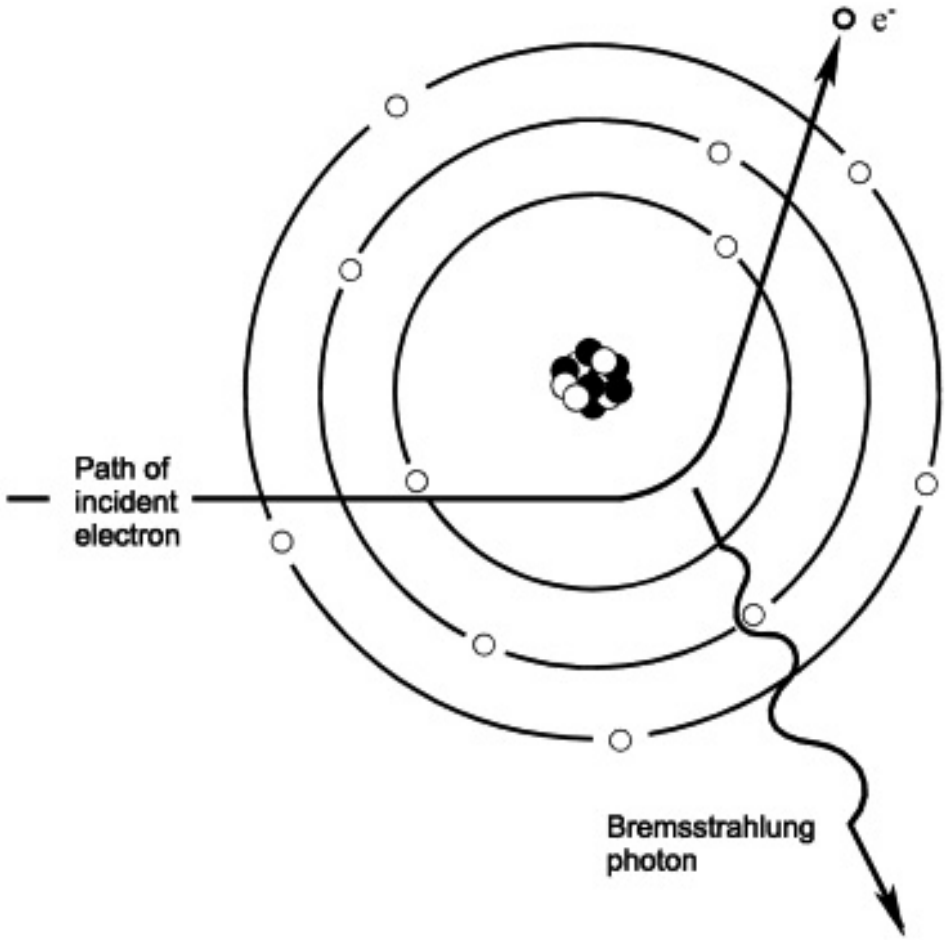
Nuclide	Half-Life	End Point Energy (MeV)
H-3	12.26y	0.0186
C-14	5730y	0.156
P-32	14.28d	1.71
P-33	24.4d	0.248
S-35	87.9d	0.167
Cl-36	3.08E+05y	0.714
Ca-45	165d	0.252
Ni-63	92y	0.067
Sr-90/Y-90	27.7y/64h	0.546/2.27
Tc-99	2.12E+05y	0.292
Pm-147	2.62y	0.224
Tl-204	3.81y	0.766

Bremsstrahlung

When a free charged particle undergoes acceleration (either positive or negative) it radiates photons.

Free electrons slowed by the electromagnetic field of a nucleus emit photons in a continuous range of energies (up until some maximum or “endpoint”)

Bremsstrahlung is German for “braking radiation”



β^- Energy Loss

- Collisional (produces no photons)
- Radiative:

$$-\frac{dE}{dx_r} = \frac{NEZ(Z+1)e^4}{137m_0^2c^4}\left(-\frac{4}{3}+4\ln\frac{2E}{m_0c^2}\right)$$

N: number density of absorber atoms

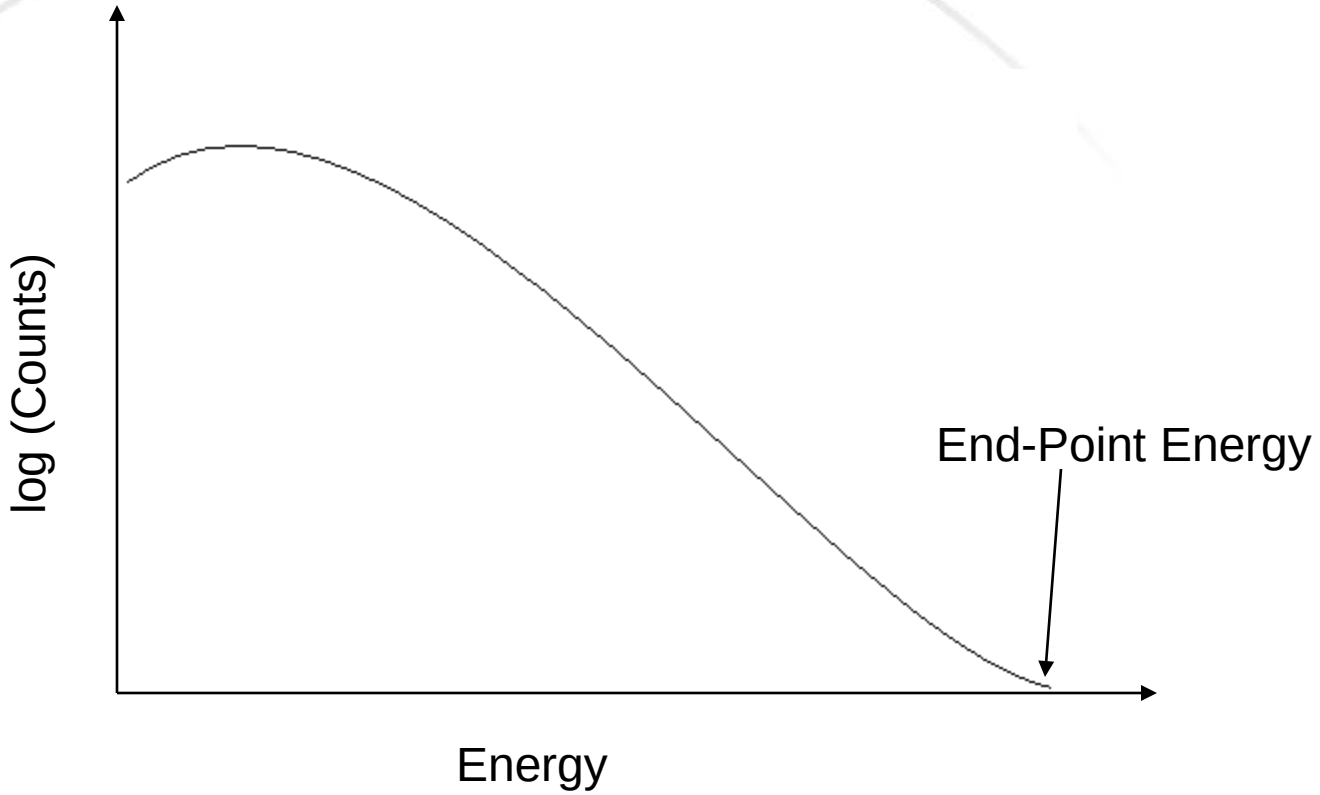
E: β^- energy

Z: absorber atomic number

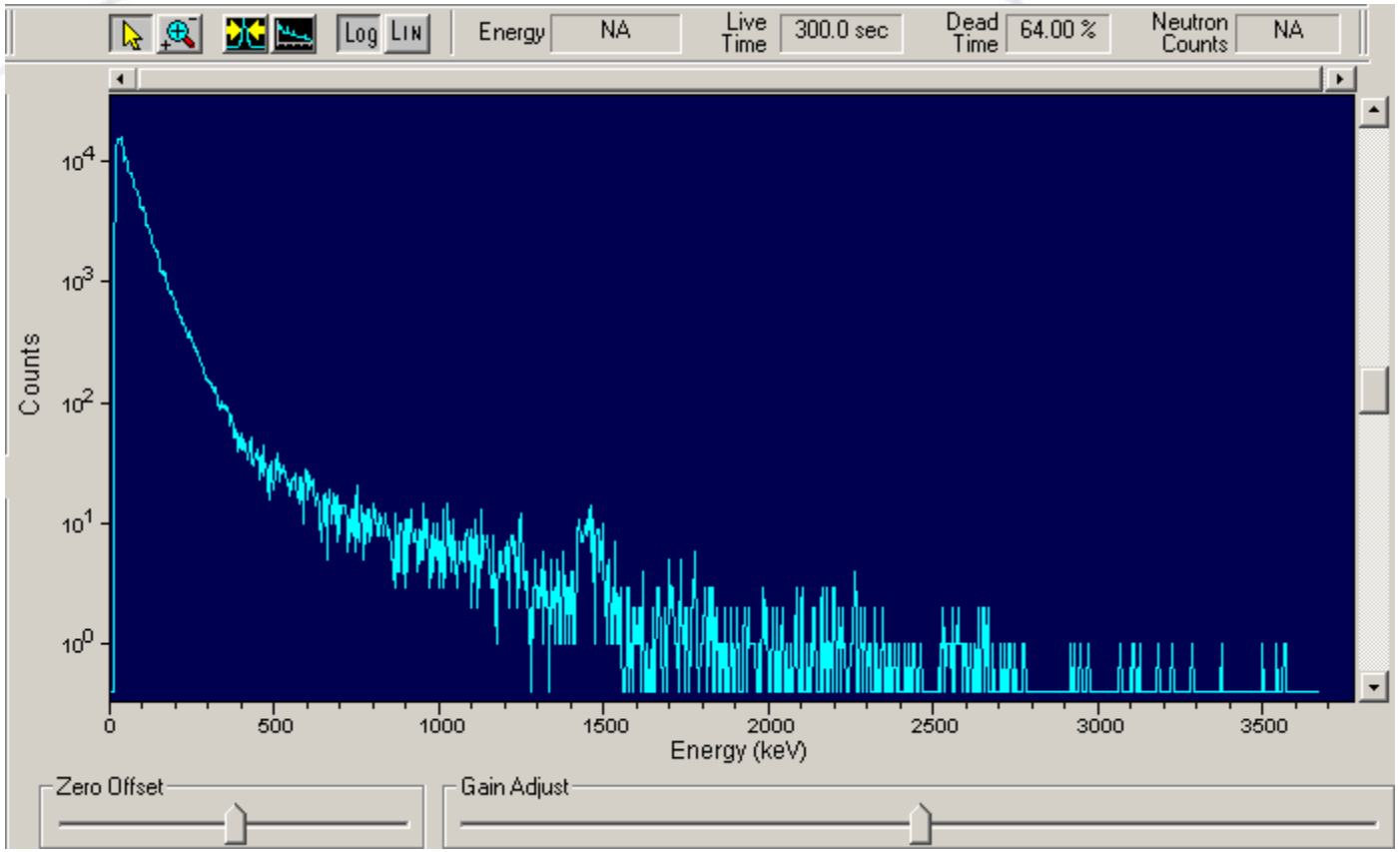
e: electron charge

m_0: electron rest mass

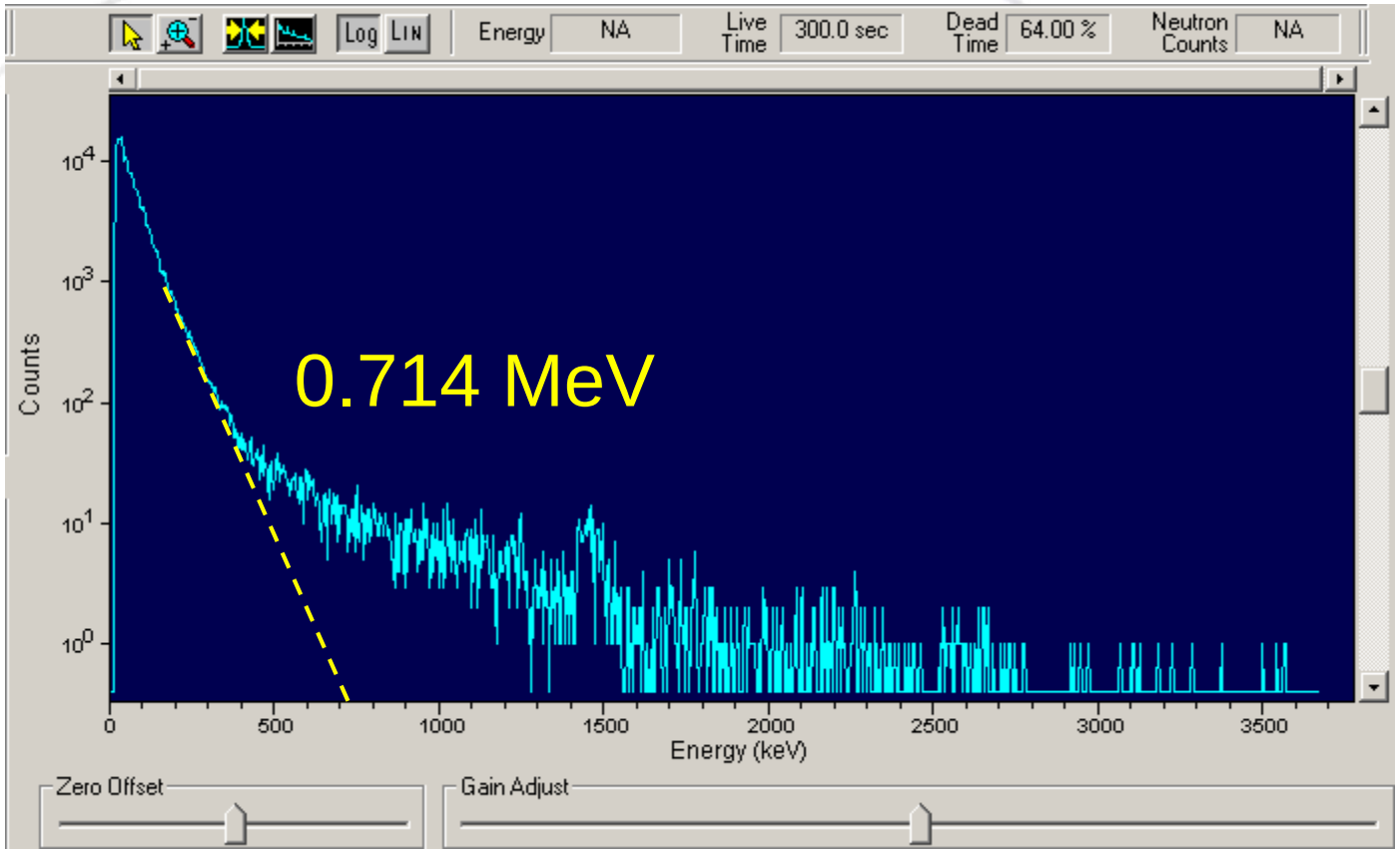
Idealized β^- Spectrum



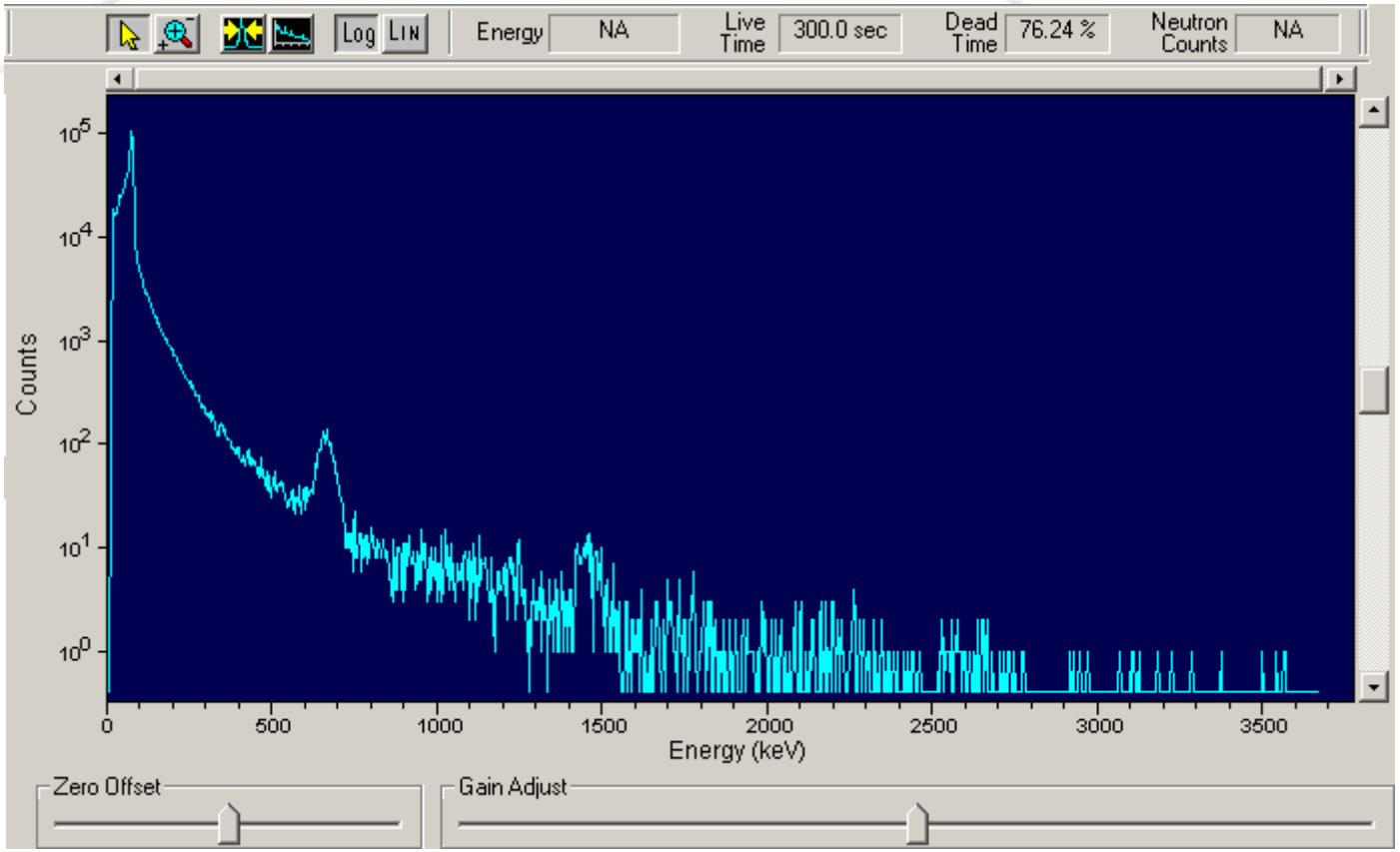
Bremsstrahlung from Cl-36



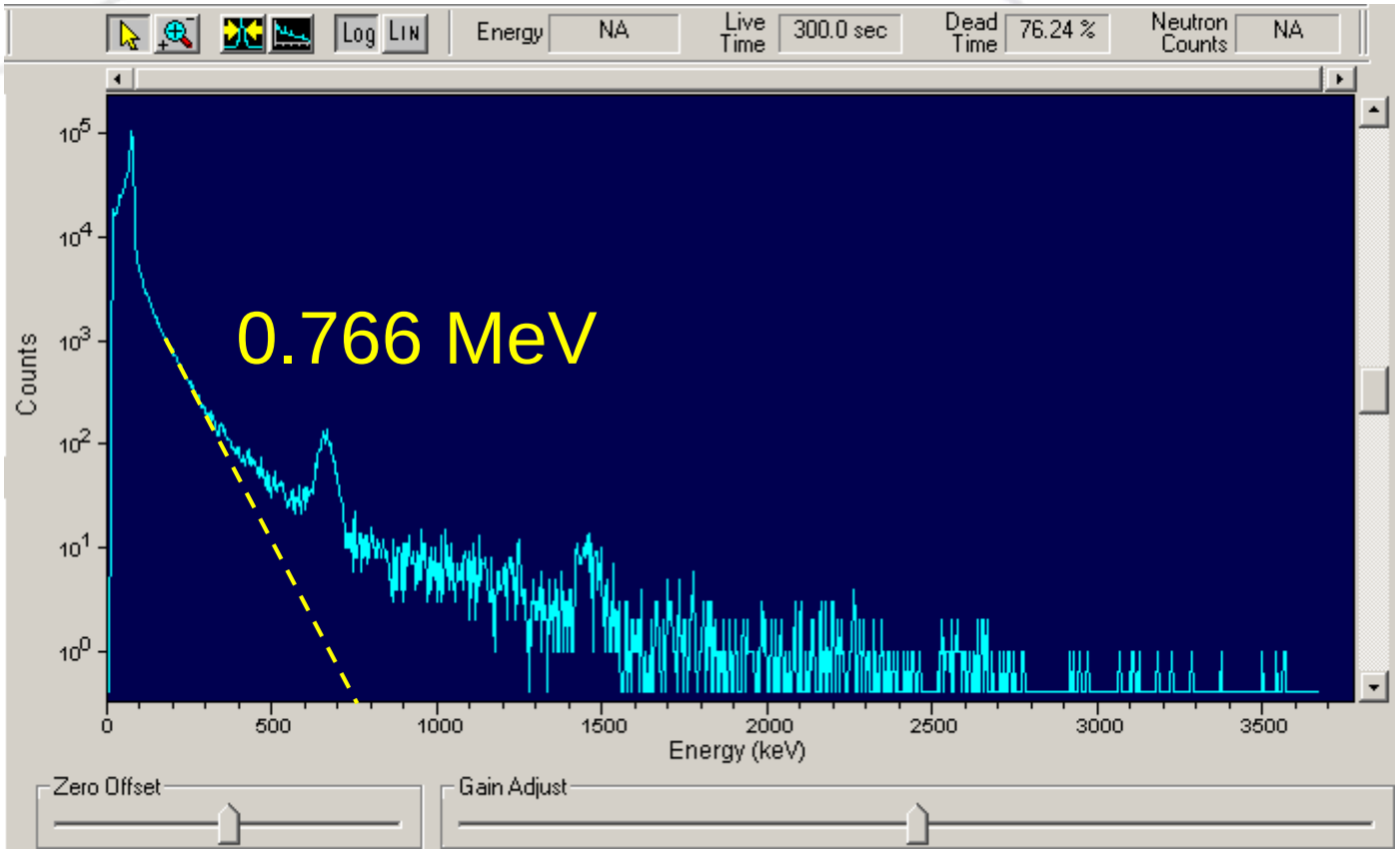
Bremsstrahlung from Cl-36



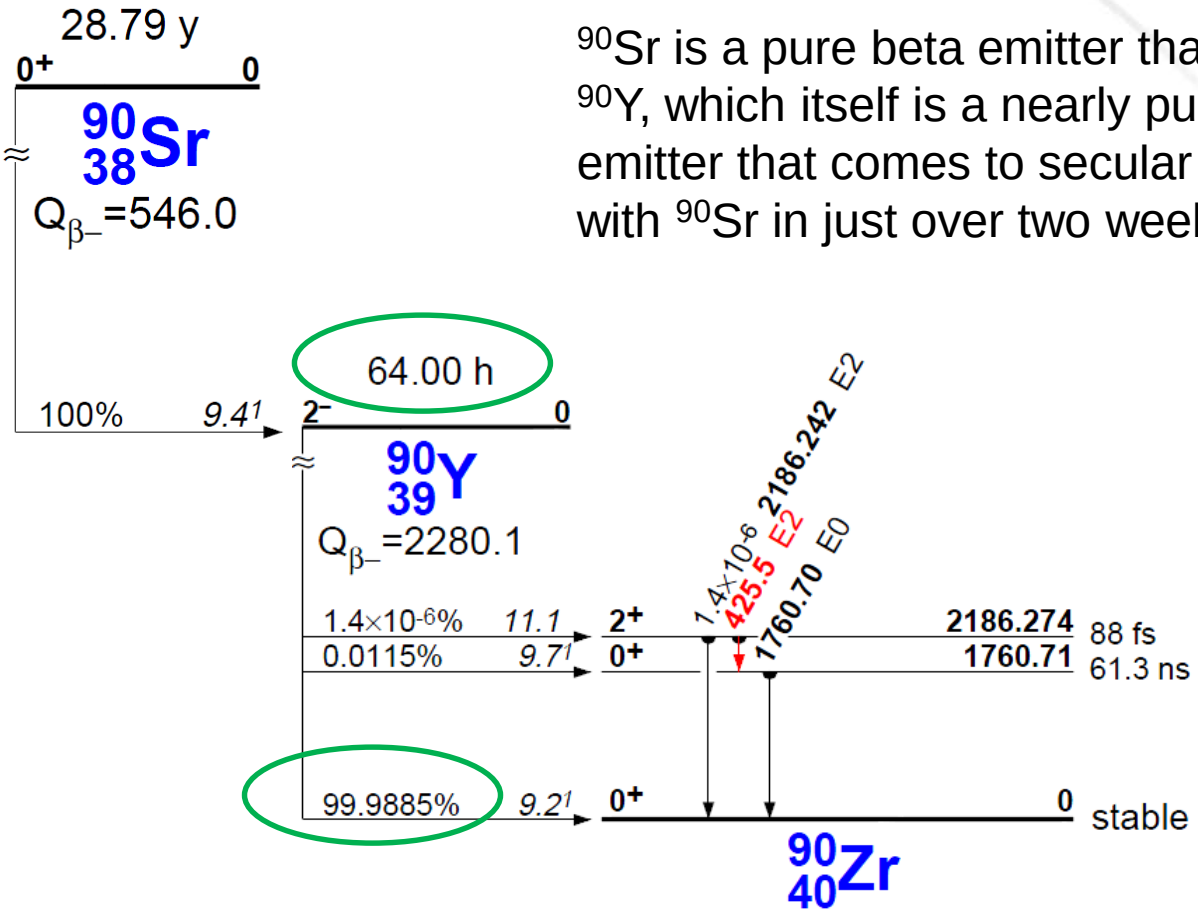
Tl-204 Bremsstrahlung + Cs-137



Tl-204 Bremsstrahlung + Cs-137

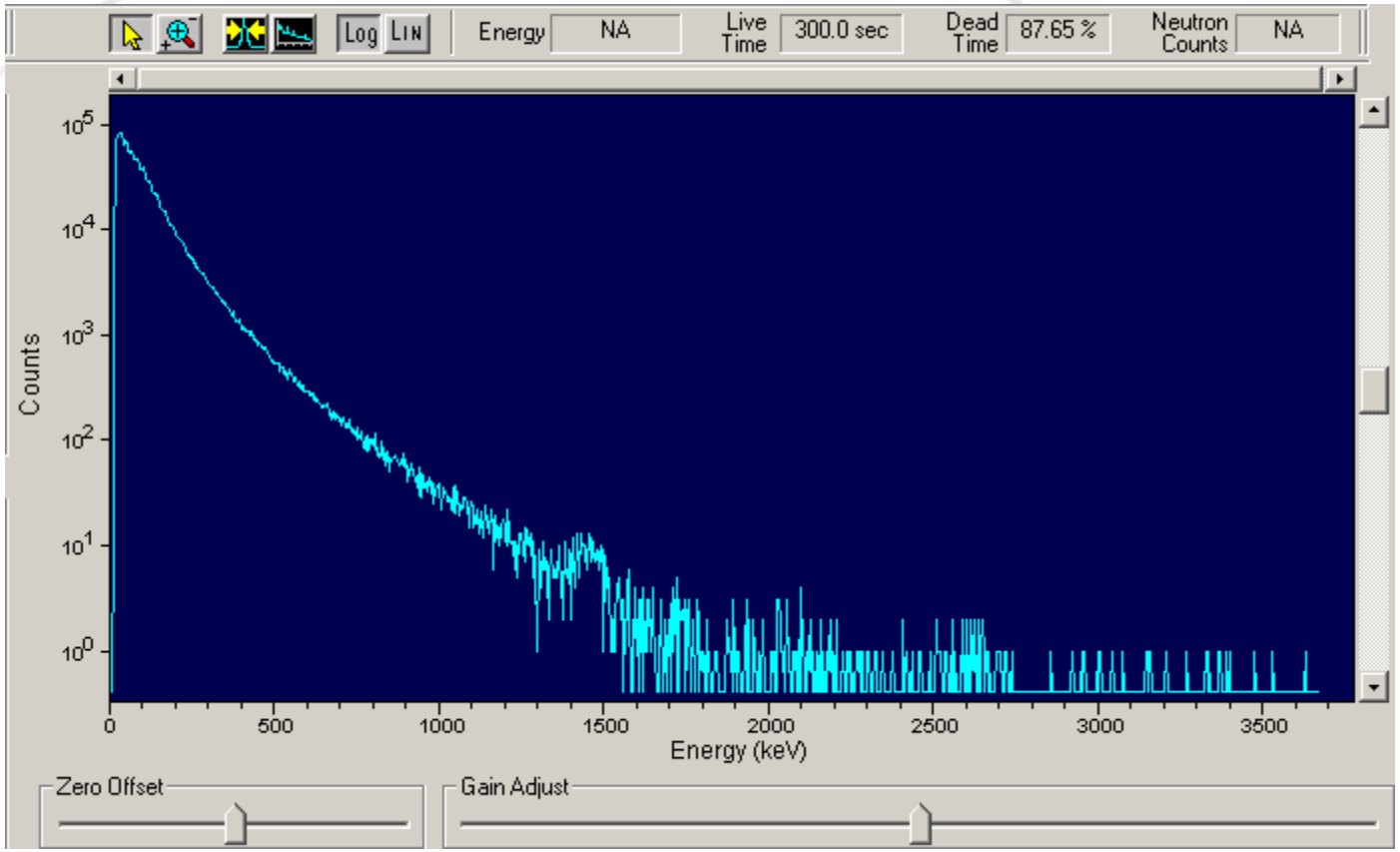


^{90}Sr / ^{90}Y Level Scheme

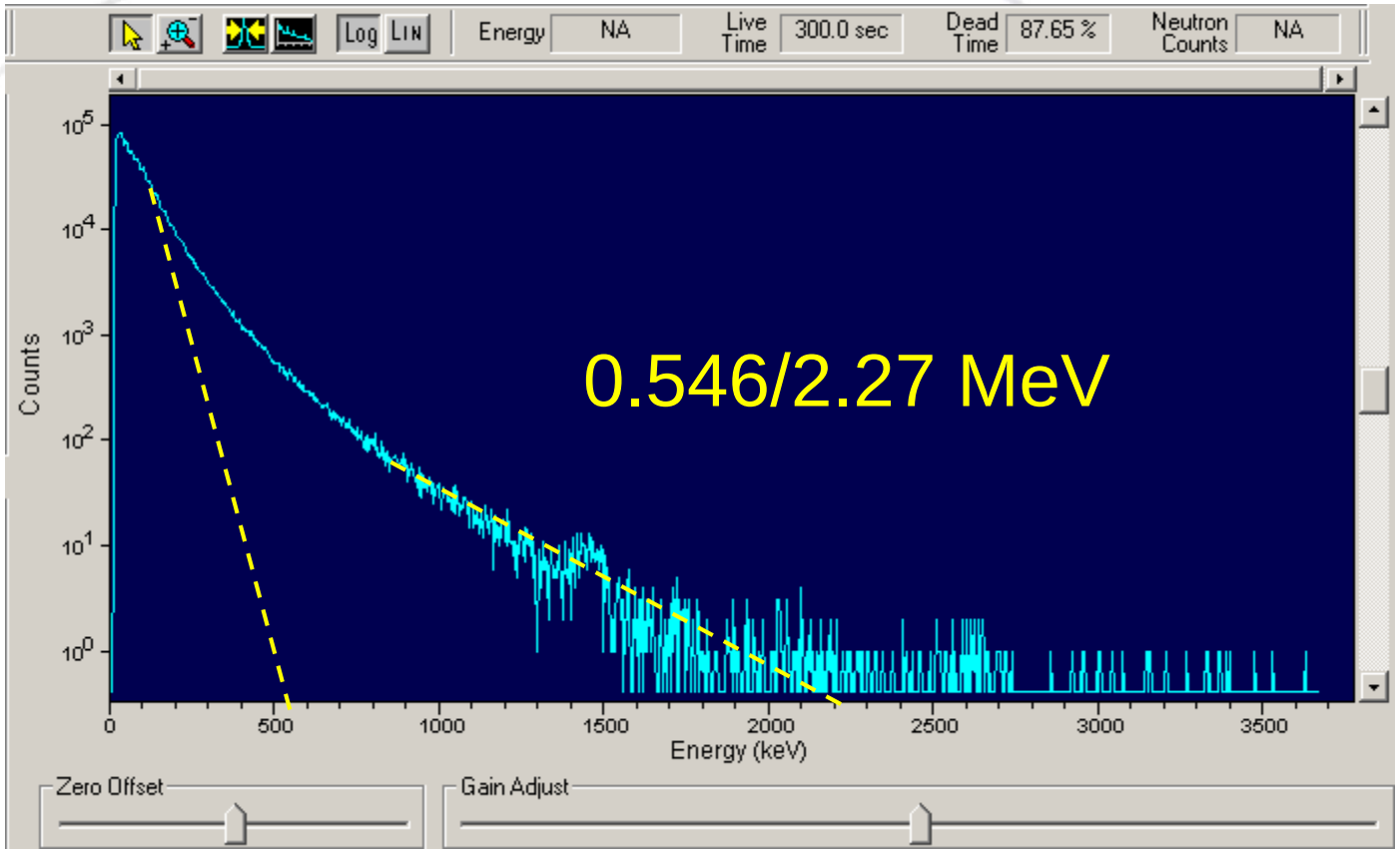


^{90}Sr is a pure beta emitter that decays to ^{90}Y, which itself is a nearly pure beta emitter that comes to secular equilibrium with ^{90}Sr in just over two weeks.

Bremsstrahlung from Sr/Y-90



Bremsstrahlung Sr/Y-90



Summary

- Bremsstrahlung is continuous radiation produced by beta particles decelerating in matter
- Different beta emitters have different endpoint energies
- High-energy betas interacting with high-Z materials will more likely produce bremsstrahlung
- Depending on the data, sometimes all you can say is that a beta emitter is present

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