β particles and Internal Conversion

Christopher Lotz, C'20
Faculty Mentor: Randolph Peterson
Department of Physics and Astronomy, The University of the South

SEWANEE
THE UNIVERSITY OF THE SOUTH

Abstract

Beta particle spectroscopy is and interesting and curious phenomenon, because unlike alpha particles or gamma particles, betas do not have a set energy. The energy is distributed between three particles upon decay. With my equipment I am able to analyze this distribution and determine the maximum possible energy these particles can have and in doing so determine the most likely. Now while that's tricky enough sometimes internal conversion peaks appear in the spectrum and that is where it gets interesting. Internal conversion is caused by gamma particles giving their energy to an electron, which is then picked up by the detector.

What they are and what they're uses are

First off we need to understand what Beta particles are, this answer is more simple, Beta particles are either an electron or a positron(a positive electron) depending on if the decay process is Beta Plus or Beta Minus(fig.4). What I focused on was Beta Minus, where the Atomic Number stays constant and a neutron is converted into a proton and in the process the daughter element is formed and releases an electron and an antineutrino. In Beta Plus, a proton becomes a neutron and a neutrino and positron are emitted. Now these particles are extremely useful due to the specific energies of the Betas released by different decay chains. They are used in a number of radiation therapies for treating Bone or eye cancer, one of the most common elements used for this that decays is Sr-90. Beta particles are also a fission product of spent fuel rods in nuclear reactors and create a blue light called Cherenkov radiation where the beta travels faster than the speed of light through water and gives off blue light(fig.5)

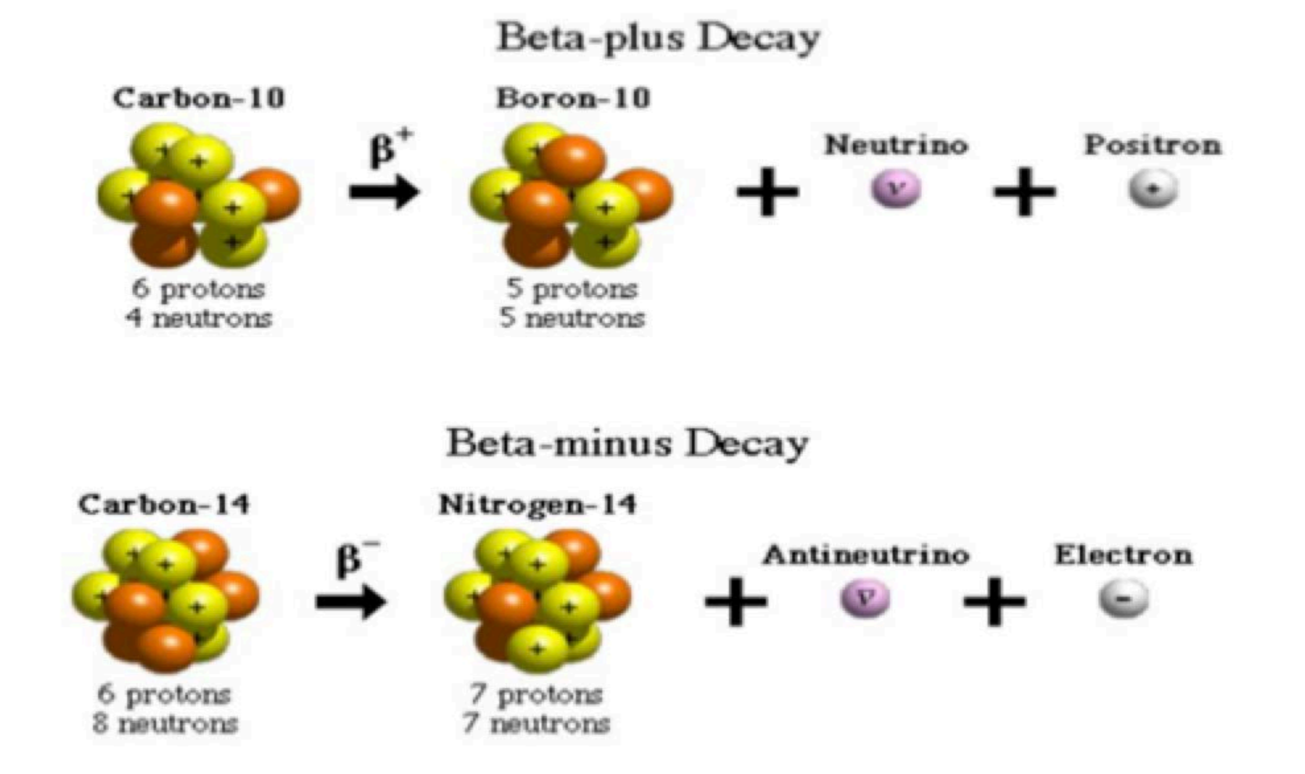


Figure 4: diagram for Beta plus and Beta minus decay

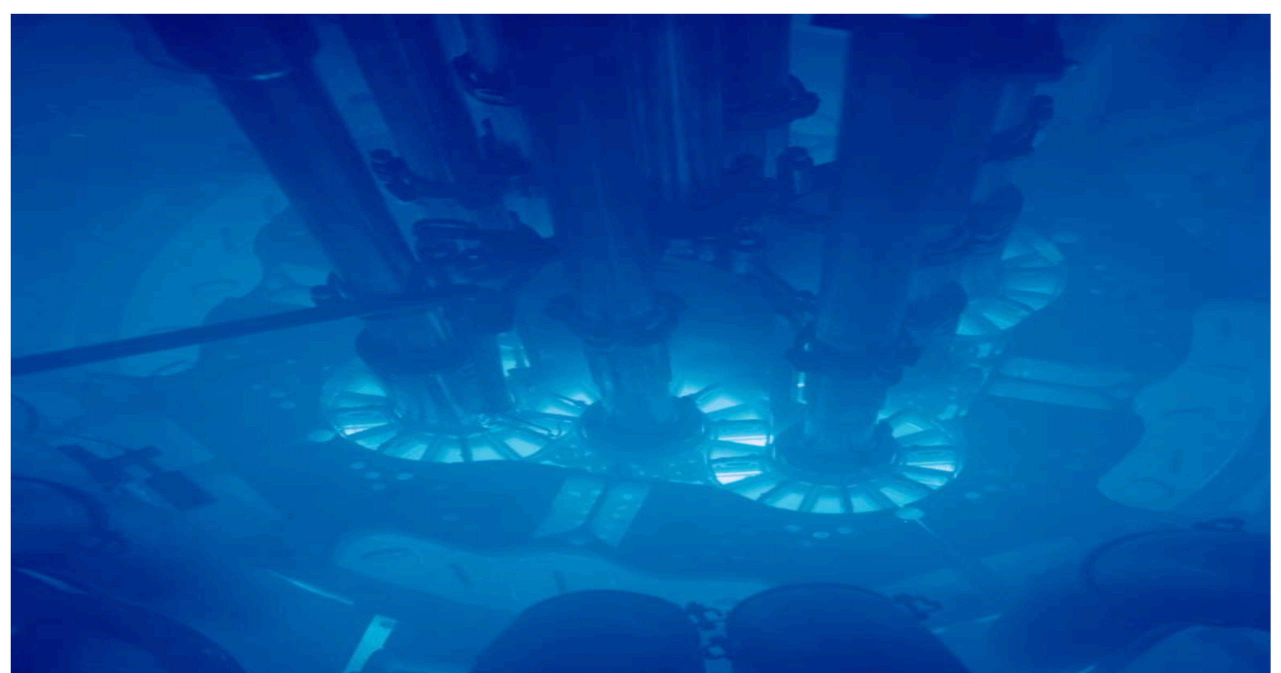


Figure 5: Cherenkov radiation

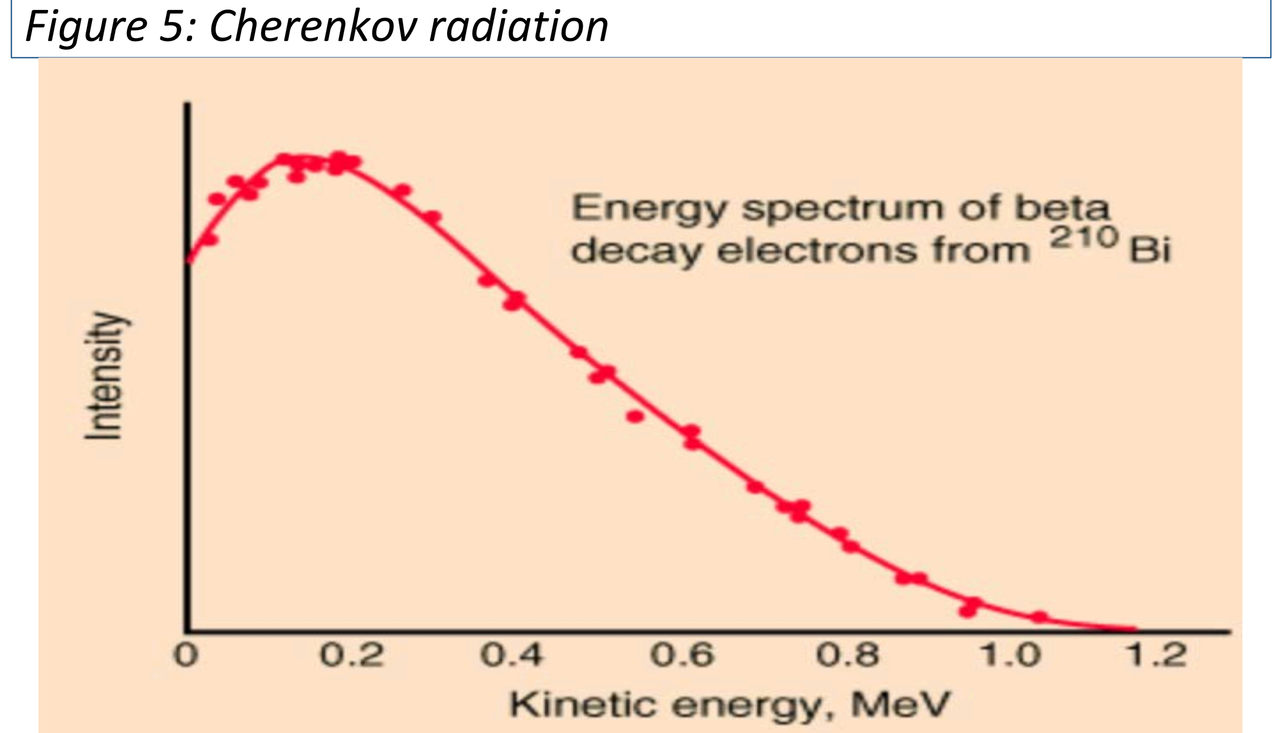


Figure 6: example of a Beta particle distribution spectrum

The distribution peak

The interesting thing about the spectra for Beta particles is that there is no specific peak as we see with gamma or alpha emissions. The reasoning behind this is that the energy used in the decay is spread between the daughter, the antineutrino, and the Beta. This means there is a distribution of values that are available for each beta (as seen in fig. 6-8). The equations for determining the maximum Beta energy is done by taking the difference between the parent and daughter element in AMU and multiplying it by a constant to get maximum energy in MeV (fig9.)

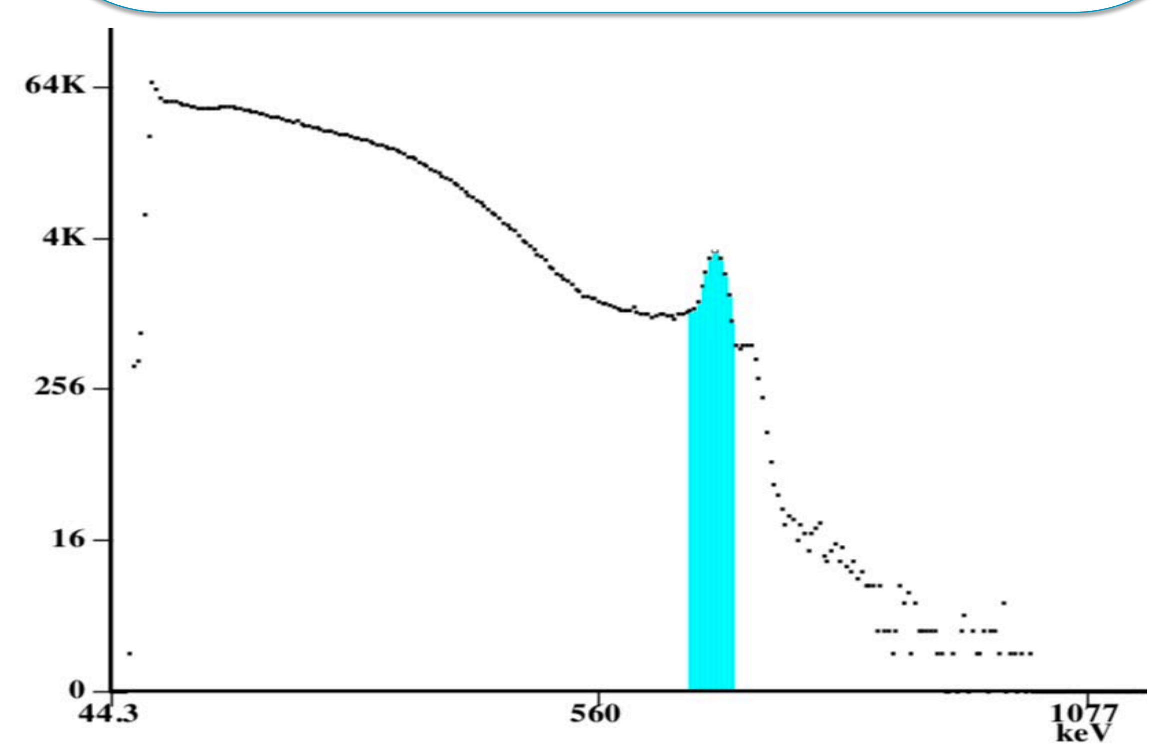
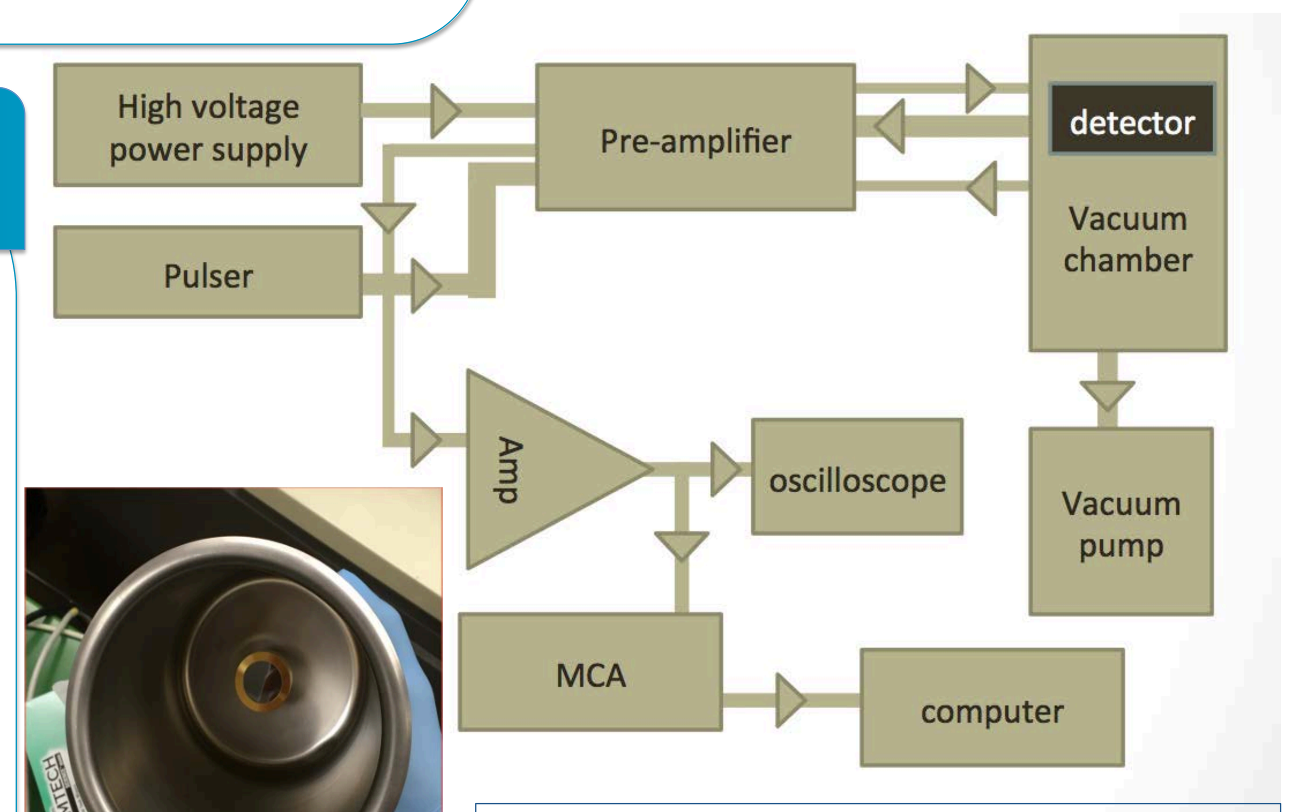
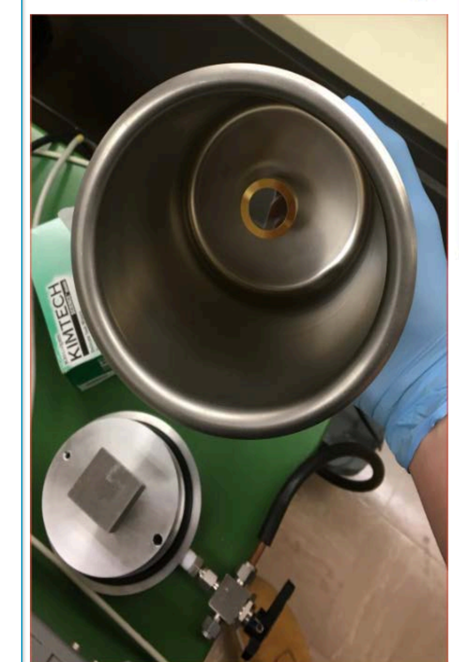


Figure 7: Cs-137 spectra

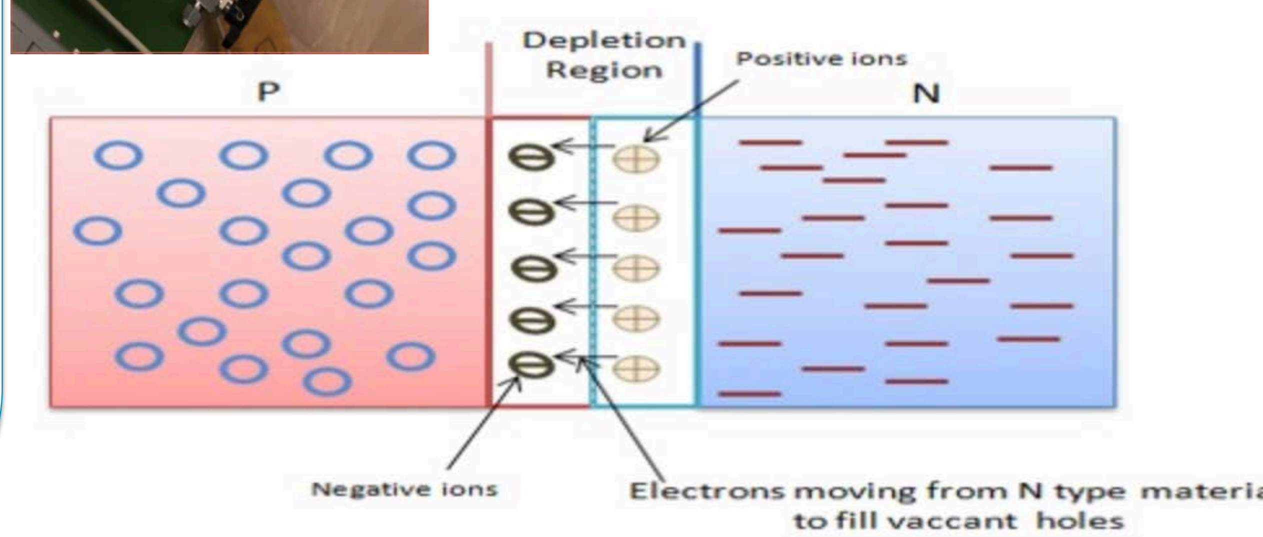
Detecting β particles and internal conversion peaks

Beta particles need to be measured in a vacuum chamber as to get the most accurate reading for their energy values. They are picked up by Solid State Silicon Surface Barrier detector that consists f a thin gold film over a wafer of SiO_2.The contacts on this detector form a P-N junction (a diode). How this ends up working is that each side is doped with a different material to give it an impurity which allows one side to have electron holes (pos.) and the other has more electrons (neg.). When a voltage is applied in reverse bias it creates an E-field which forms a depletion region where there is no free charges, the size of the region is determined by the voltage. The particles enter the detector and are stopped in the depletion region and they form electron hole pairs, the electric field sends the holes to one terminal and the electrons flow to the other. This flow is then turned into a pulse that appears on the computer screen after going through the amplifier and multichannel analyzer to boost and analyze the signal. (see figures 1-3).





Figures 1(above), 2(left), 3(below): show the setup of how I measure the emissions and the Solid Surface Barrier detector I used



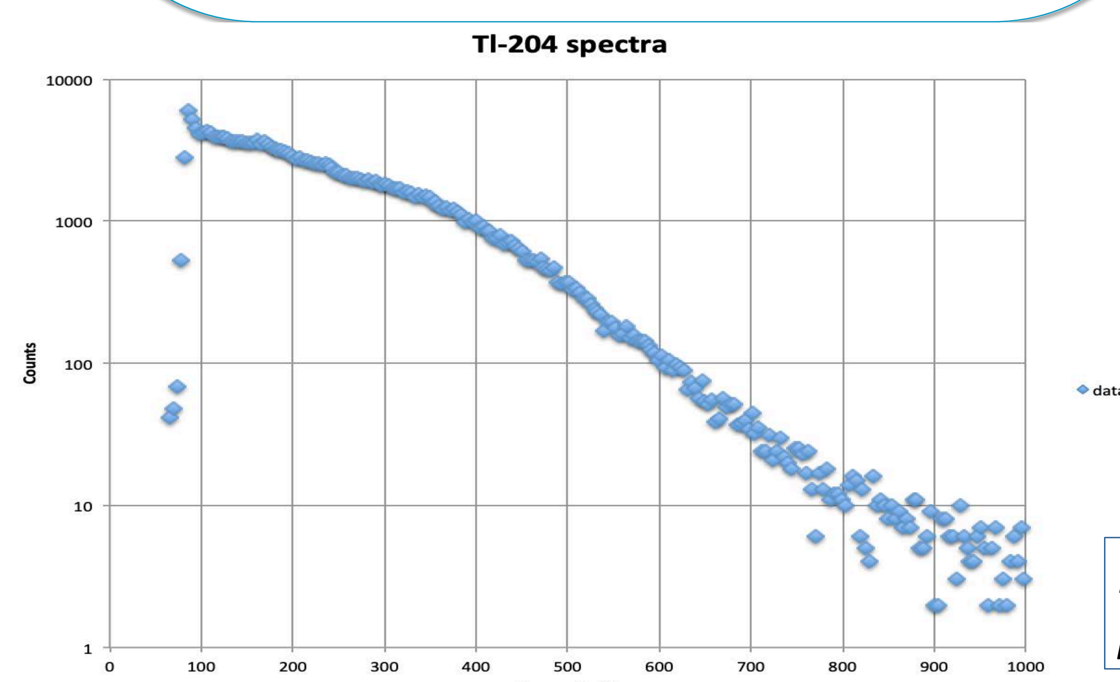


Figure 8: Spectra for Tl-204

$$\Delta E = \Delta m * \frac{931.5\text{MeV}}{c^2}$$

Figure 9: equation for determining max. Beta Energy

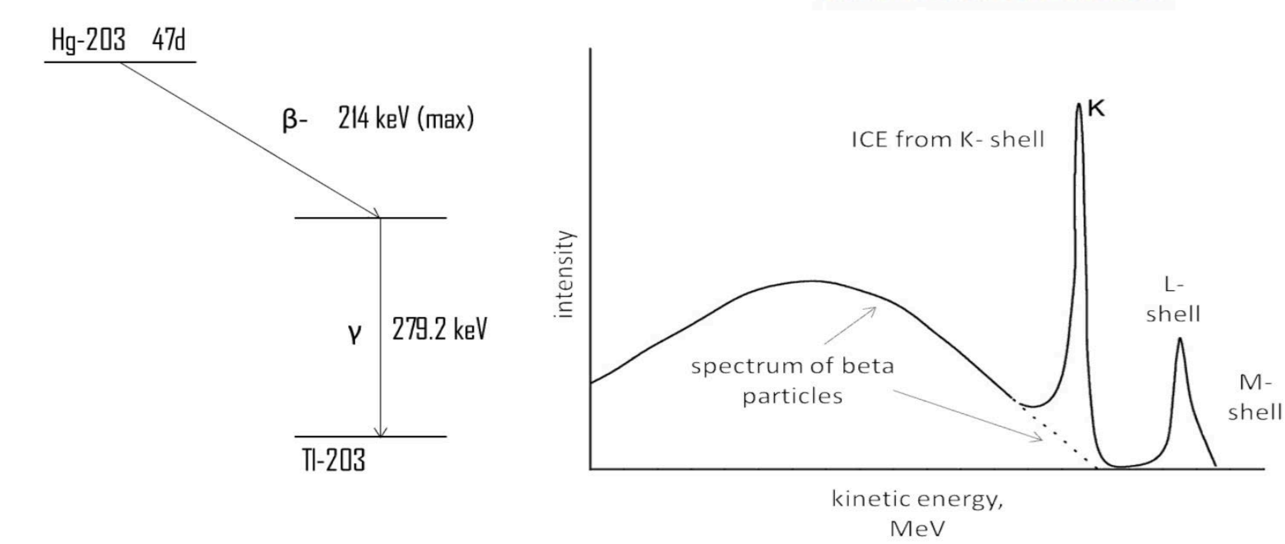


Figure 10: example of excited state decay and internal conversion peaks

emitted gammas	observed gai	probability
31keV		0.97%
35keV		22.60%
53keV		2.00%
79.6keV		3.00%
81keV		34.00%
276.4keV	233keV	7.00%
302keV	265keV	18.00%
356keV	315keV	62.00%
383.9kev	346kev	9.00%

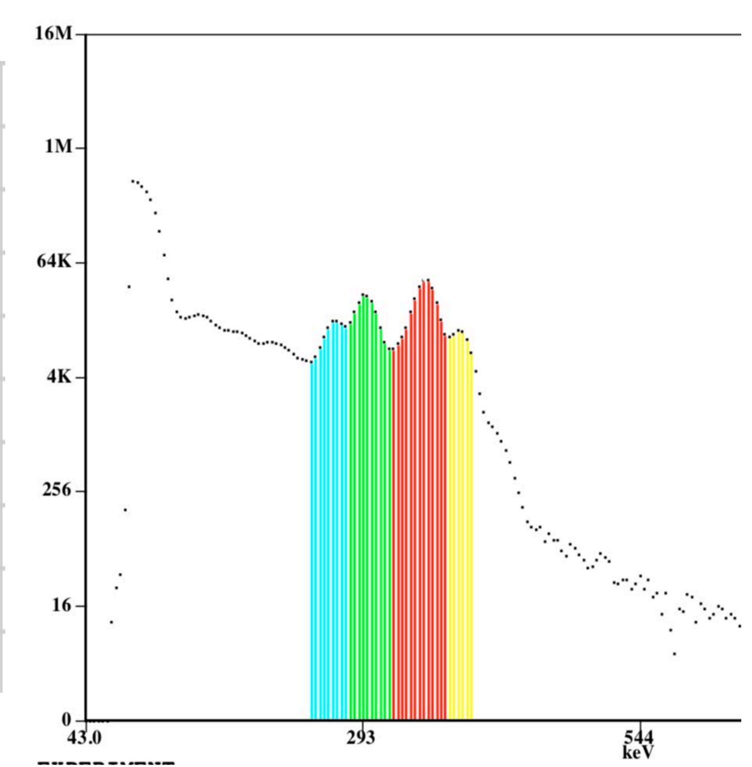


Figure 11: This is the spectra taken of Ba-133 which has multiple internal conversion peaks

Internal conversion

Internal conversion is a very interesting phenomenon where Beta decay leaves the daughter particle in an excited state, now where this would normally emit a gamma particles the gamma interacts with an electron and imparts its energy to it allowing the electron to overcom its binding energy and be ejected form the atom, which is the energy peak that is depicted in contrast with the distribution of energy. This process is possible whenever gama decay can occurunles the atom is fully ionized. Now when the electron ejects it leaves a hole which is filled by electrons from outer shells, the transitioning of which creates xrays. Most often when this process occurs the electrons that the gamma interacts with are K-shell electrons (from the 1S orbital). Exmples of internal conversion can be found in fig. 7,10,11.