Physics with Mathematica Fall 2019 Exercise #8 23 Oct 2019

Finding the half life of the metastable state in ^{137}Ba

The radioactive nucleus ^{137}Cs decays to an excited state in ^{137}Ba. This excited state is "metastable", which means that it has an anomalously long half life, in this case a few minutes. The state decays by emitting a 667 keV gamma ray.

The file "Class08_Data.dat" contains data from an undergraduate laboratory experiment which measured counts in a gamma ray detector, following the chemical separation of barium from a ^{137}Cs source. The data is in two columns. The first is the time bin and the second is the number of counts in the detector. Each time bin is 20 seconds long.

The goal of this exercise is to fit the data and determine the half life of the ^{137}Ba metastable state. You are also to determine the "goodness of fit", and come up with a pictorial representation of this notion.

Download the data file from the course website, and start a notebook by reading the file. Sort the columns into "time" and "counts", and convert the time to minutes. Use ListPlot to plot the data points, as counts versus time, and see that they represent some kind of decaying exponential plus what appears to be a constant level of background.

Now define a function $f(t)$ that describes a decay in time along with a constant background. (Hint: There are three free parameters.) Use FindFit to find the values of these parameters which best describe the data. How well does your measured half life agree with the accepted value of 2.552 minutes?

The statistical uncertainty σ on some number of counts n is just $\sqrt{n}$. Calculate χ^2 using

$$\chi^2 = \sum_i \left[\frac{n_i - f(t_i)}{\sigma_i}\right]^2$$

and compare this to the number of degrees of freedom N_{dof}, that is, the number of data points minus the number of parameters. For a good fit, they should be close to equal, in other words χ^2/N_{dof} should be about equal to one.

Finally, use ListPlot to plot the "pulls" as a function of time. These are the individual values used in the sum for χ^2, namely $[n_i - f(t_i)]/\sigma_i$. These points should be randomly scattered above and below the axis, most between ± 1, and there should be no evidence of any systematic deviations. Does the fit look good to you?

Send the grader an email with your notebook as an attachment.