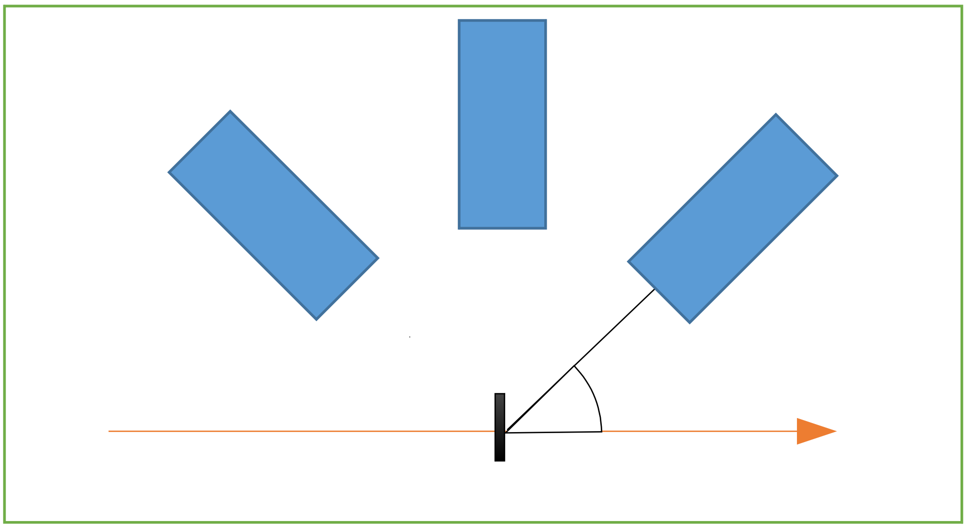
Data Analysis Tutorials

The Experiment

Data are taken with an array consisting of 3 gamma-ray detectors positioned around a target position on an accelerator beam line. The 3 detectors are positioned, with respect to the target and beam, at angles of 45,90,135 degrees.



Data are stored in root “trees”, effectively long lists of individual events; an event being a single moment in time, in which the data acquisition computer detected an input and recorded all data from detectors during a short time window.

A series of .root data files are provided from the experiment:

Run1 – A source of ^{60}Co at the target position
Run2 – A source of ^{152}Eu at the target position
Run3 – A source of ^{133}Ba at the target position
Run4 – An A=36 beam with an energy of 250 MeV impinging on a thin A=40 target.
Run5 – A decaying source feeding the nucleus observed in Run4

Exercise 1 – Determine Array Efficiency

The file BlankEffCal.C will draw data points for the relative efficiency of the array as a function of energy, calculated from a ^{152}Eu source.

Modify the script to fit the curve with the following function, with N=2

$$y = e^{\left(\sum_{n=0}^{n=N} P_n log(x)^n\right)}$$

A) What is unphysical about this initial function?

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B) The data are in ns so Run1.root last 333 s. The activity of the ^{60}Co source is 5.4 KBq. What is the absolute efficiency at 1332 keV?

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C) What is the absolute efficiency at 400 keV?

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Exercise 2 – Determining Fit Uncertainties

ROOT's TMinuit fitting functionality can calculate uncertainty bands for you. Use the following command (directly after fitting) to evaluate the uncertainty of your efficiency function at a series of points:

(TVirtualFitter::GetFitter())->GetConfidenceIntervals(hist,interval);

"hist" should be a pointer to a histogram with binning defining the points at which to calculate (a TGraphErrors can also be used as per example https://root.cern/doc/master/ConfidenceIntervals_8C.html) and interval should be a number giving the desired central probability interval.

Now the histogram has the fitted function values as the bin contents and the confidence intervals as bin errors.

Retrieve the data and plot the error bands alongside the ^{152}Eu data

D) What is the % uncertainty of the array efficiency at 1000 keV?

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Exercise 3 – Kinematic Correction

Sort Run4.root, which is data from a simulated experiment in which an A=36 beam with an energy of 250 MeV impinges on a thin A=40 target.

You should immediately see the spectrum is worse than those seen before.

E) Why is the spectrum poor?

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In such an experiment the energy is sufficient to overcome Coulomb repulsion and the fusion of the beam and target occurs. A small number of protons and neutrons are subsequently evaporated (a fusion-evaporation reaction). This leaves an excited compound-like nucleus which subsequently gamma-decays.

Due the relativistic energy there is energy difference between the frame of the compound nucleus and the lab frame.

The relationship (for a photon) is given by:

$$E' = \frac{E(1 - \beta \cos \theta)}{\sqrt{1 - \beta^2}}$$

Where E is the lab frame energy, E' the nuclear frame energy and theta the angle between the photon and the relative frame velocity beta.

F) Why is there one narrow peak observed?

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Using the information and data available, fill in the Kinematic Information at the start of Sort3.C and produce an improved spectrum.

We wish now to explain every feature observed under 3 MeV. You may attempt to begin now, but will need to follow the next exercises to complete this.

Exercise 4 – Coincidences

As multiple hits may occur approximately simultaneously, such as in a cascade, it is advantageous to look not only at the singles spectrum (the 1D histogram of all gamma-rays) but also at coincident hits in multiple detectors.

To produce a 2 dimensional histogram (sometimes refereed to as a matrix) of coincidence events uncomment the lines in Sort3.C

The matrix has been diagonalised, so $M_{ij} = M_{ji}$ so that all coincidences across the matrix can be viewed without bias due to data ordering.

Now by projecting along one axis of this histogram at a given energy, you can see all the gamma-rays that were coincident with a gamma-ray of that energy.

Use the TH2 functions: ProjectionX, ProjectionY, SetShowProjectionX and SetShowProjectionY

The latter 2 being useful for looking at multiple projections in the GUI by moving the mouse. Beware as many arguments are taken in bin number, which depending on your chosen binning may not have a 1:1 correspondence with energy.

Look at the coincidences of the largest peaks

G) What coincidence do you observe that is surprising?

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Use the function Hit::GetTime() and produce a 1D histogram showing the time between coincident hits.

H) Explain the features of the time spectrum?

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