Gamma Spectroscopy,

Goals and Tasks  (A is required, but with the advice and consent of the instructor, pick among the other tasks.)
A. Calibrate the gamma-ray spectroscopy system in terms of gamma energy.

B. Study the effect of varying the distance between the source and the detector on the received signal. (Basically this is to look for a $r^{-2}$ dependance.)

C. Study the effect on the received signal of introducing material of various thicknesses between the source and the detector. (Basically look for the exponential attenuation or absorption of the gammas by different material.)

D. Understand the gamma-ray spectroscopy system including the NaI detector, the photomultiplier tube (PMT), the amplifier, the multichannel analyzer (MCA), and the associated software.

Readings:

A.C. Melissinos, *Experiments in Modern Physics*,
Radiation safety, p.143-147.
Nuclear line spectra, p 52-56
Related equipment, p. 194-208
Compton Scattering, p 252-265

Wall Chart of the Nuclei
Compton booklet
Manual for the MCA hardware and software

Additional handouts to receive:
Nuclear Instruments handouts
MCA, what to know handout
Radiation Safety and Units handout
Official Compton Scattering Protocol

Procedure:

During the semester leave the NIM BIN turned ON and leave high voltage turned ON, so that everything is in thermal equilibrium.

Before making a serious calibration, observe effect on line position, of changing high voltage (HV) by 1, 10, 25, 50 Volts up and down.

Before making a serious calibration observe, effect on line position, of slightly changing gain of the amplifier.

Source on plastic holder directly in front of NaI detector. Toggle on MCA into acquire ON.

Save each good run. (make your own private directory)
Convert to spreadsheet format each good run

Energy Calibration procedure:

Calibration is basically finding the relationship between the energy of the emitted gammas and the channel number of the full energy peak. For as many sources as available take a spectrum and determine the MCA channel number of the full energy peak. Plot the MCA channel number against the known energy. Make a least squares fit.

This process is very similar to that used for the Rowland grating experiment.

What is the best method to find peak location and estimate the uncertainties?

Using structure (for example, the Compton edge) in spectra to get more than one calibration pair from one spectral line.
**Figure 1** Block diagram of the gamma spectroscopy system

**Figure 2** A typical gamma spectrum taken with a detector using NaI (Sodium Iodine) crystal. All of the structure in the spectrum is associated with gamma ray that when initially emitted all had the nearly same energy.
What to Learn about the MCA Program Used in Gamma Spectra

I. Getting Started
   A. To start the program at: \texttt{c:}\textbackslash{}> type \texttt{mca}
   B. Use the key associated with highlighted letter to select a menu item.
   C. Use the ESCAPE key to move up a menu tree.
   D. On the plot, the horizontal scale is channels. Each channel is associated with a small range of heights of the incoming pulse and for an NaI detector this pulse height is proportional to the energy deposited in the NaI crystal by the incident gamma. The vertical scale is number of event in a given channel.
   E. Move markers with left and right arrow keys, Faster movement with CTRL and arrows, and read marker position in upper right. Counts at marker position see Status Page 3 (Change status page using \texttt{page up/down})
   F. Use the function key overlay chart to learn what shortcuts are available from the function keys.
      \begin{itemize}
       \item F1 to toggle Start and Stop of acquiring data
       \item Shift F2 to erase current data
       \item F4 to cycle through vertical scaling method.
      \end{itemize}
   G. To quit program from menu select \texttt{EXIT}.
   H. The input range is 0 to +8 volts.
   I. To change the directory into which data is saved use:
      \begin{verbatim}
      Util Command cd "directory path"
      \end{verbatim}
      Please make your own directory under \texttt{c:}\textbackslash{}mca\textbackslash{}students using \texttt{md \"me\"}

II. Important parts of the manual to read.
   A. Chapter 3 Introduction ALL OF IT
   B. Chapter 4 Getting Acquainted
      \begin{itemize}
       \item 4-4 Display spectrum from file
       \item 4-5 Status pages
       \item 4-16 Controlling the Display
       \item 4-17 Changing the vertical scale
      \end{itemize}
   C. Chapter 7 is a break down of the functions available from the menu tree.
      \begin{itemize}
       \item 7-1 Acquire On-OFF
       \item 7-2, 3 Presets Live, Real Total, Markers
       \item 7-10 Calibrate\textbackslash{}Manual\textbackslash{}Energy
       \item 7-15 to 26 Display
       \item 7-17 overlap
       \item 7-17 vscale
       \item 7-20 expand
       \item 7-24 cursor, Markers
       \item 7-25 ROI
       \item 7-27 Move\textbackslash{}Data VERY IMPORTANT for saving data
       \item 7-54 to 58 Util\textbackslash{}Dir, Print,
       \item 7-58 MENU VERY IMPORTANT because this is the access key to the data manipulation and analysis programs described in Chapters 10 to 19
D. Chapters 10 to 19 Basic Spectroscopy Programs
10-1 to 5 Introduction

19-1 to 13 LOTCNV (convert data files from binary to text form)

VERY IMPORTANT for converting saved data files into spreadsheet readable form.

III Need to be able to:
B. Set Preset to stop data collection for a set Real Time, Live Time or Number of Counts. From menu Acquire \ Preset. Set possible presets that are not used ones to zero. See Manual pages 7-2,3.

D. Save and retrieve data. From Menu: Move \ Data \ Use From RRH which is the display To filename.dat use defaults for header and eff files. See Manual page 7-27.

E. Convert saved (binary) datafiles to something a spreadsheet can read. From Menu UTIL \ Menu then Reports from groups (left column, use page up/down to select) then Convert Data to Lotus Format (center column, use arrows). Use F2 to execute the program, then give name of binary and name of new file to create. To return to MCA screen use F10. See Manual pages 19-1 to 13.

G. To get DOS Prompt from menu Util \ System Then can issue DOS commands like: dir to see list of files
cd to change directories
del filename.ext to delete file
copy old_name.ext new_name.ext to copy files
Note data acquisition continues while you are at the DOS prompt.
Type EXIT to return to MCA program.

H. To adjust the Lower Level Discriminator from the menu use Setup \ ADC \ Coarse LLD or Fine LLD. Also of use Setup \ ADC \ Zero and Setup \ ADC \ ULD
Discriminators, Single Analyzers and Multichannel Analyzers

In nuclear and high energy physics most experiments depend on its associated the electronics. Usually, an electrical pulse is created by a detector when a particle is detected. These pulses may contain information about the detection event such as when it occurred, where on the detector the event occurred, or the energy of the detected particle. Small signals are made larger with an amplifier. The shape, and duration of a signal pulse may also be changed by special amplifiers (by integration or differentiation of the signal). In most cases, there is some level of electrical noise on the signal wires and the real signals must be sort out from the noise. Frequently discriminator, an single channel analyzer (SCA) is used for separating the signal from the noise.

If after an amplifier, pulses associated with real events are about 2 volts in peak amplitude, and the noise is 0.07 volts in amplitude, then separating the signal from the noise seems simple enough-- just pay no attention to pulses less than a volt high. This is basically what a discriminator or single channel analyzer does. One defines what a valid input is and every time the input pulse meets this selection criteria, an output pulse is produced. This output pulse carries only the information: “A valid event just happened.” This output pulse is often a + 5 Volt pulse similar to a digital logic TTL pulse. In addition to the existence of a valid pulse, there is the information as to when the pulse occurred. There are several ways of synchronizing the output to the input so that the relative timing remains the same.

When using a discriminator, one defines the minimum voltage level for a valid pulse. That is you set the discriminator level to 1.4 volts, and any pulse with a peak height of 1.4 volts or greater results in an output pulse. Many discriminators delay the output signal slightly so that is set out a set delay after the pulse reaches a set fraction of its peak height (NOT the discriminator level). These are called constant fraction discriminators (CFD’s).

A single channel analyzer is like a discriminator with added features. One can set the SCA to the Integrate mode (INT) where it will operate like a discriminator. When using the Window mode one has the added feature of defining both a maximum acceptable peak height as well as the minimum. This would be useful if the detector was detecting two types of events with different pulse peak heights and you were interested in counting the number of events associated with the smaller pulses. You would then put the SCA window around the signal of interest. That is you would set the lower level (LL) of window above the noise but below the height of the signal of interest. Next you would set the upper level (UL) of the window between the two pulse heights (often using a knob labeled Window or UL).

Often on an SCA, one actually specifies a lower level and the height of the upper level above the lower level. This is useful in analyzing a complex spectrum of signal pulse heights. For example, if you break the spectrum form 1 to 10 volts into a number of “channel” each 0.2 volts wide by set the height of the window at 0.5 volts, and then counting for a minute for each of the following lower level settings: 1.0, 1.5, 2.0, 2.5, . . . 9.5 volts. Plotting the number of counts recorded as a function of the lower level setting will yield a histogram of the incoming signals pulse height.

If you need to do a lot of this, the counting gets rather tedious, especially if the window height is something like only 0.05 Volts. Fortunately, someone invented the multichannel analyzer (MCA). This device looks at all of the “channels” at once. That is it break its input range into a number of pulse peak height ranges (channels) and counts the number of pulses falling into each range. Usually an MCA will display the resulting histogram and allow some numerical manipulation of this data. Note that often the pulse peak height is associated with the energy of a single quanta of some incident radiation and thus the histogram is an energy spectra of the incident radiation.