# Instructor's Manual

Safety Information

The power supply outputs high voltages that are carried through cables to the detectors. The power supply produces only very low current, so it should not seriously harm you if you get shocked, but it would still be quite painful. The ends of the power cables are designed to be unable to shock you, so the only way to get shocked is if a cable is damaged. If you see a damaged cable, do not turn on the power supply.

These experiments use lead for shielding purposes. Lead is a toxic metal. Either use gloves when handling lead or wash your hands afterwards.

These experiments also use radioactive sources. The sources used are small enough that they are unlikely to hurt you even with very long exposure times. Nevertheless, you should keep your doses as low as reasonably achievable. Don't keep sources on your person for extended periods of time and don't ingest sources.

Setup of the Lead House

The lead house is built from four big lead blocks (8"x4"x2"), four collimator blocks (4"x2"x1") and two Na-22 sources. The two sources are taped together with their positron-emitting sides facing each other so that no positrons escape. Two images of the lead house follow:
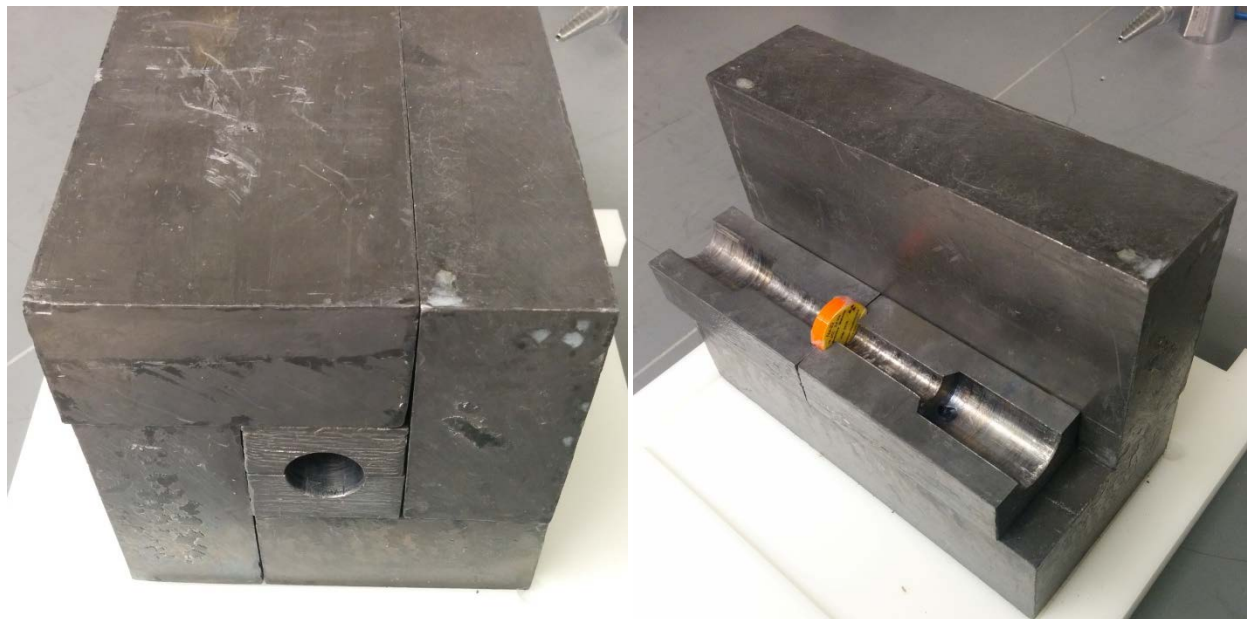
CAD drawings of the lead house and its components can be found in CADDrawings.zip (files *LeadHouse.SLDASM, BigLeadBlock.SLDPRT, LeadHouseInternalBlock.SLDPRT*). The collimator blocks are machined from the small lead blocks (file *SmallLeadBlock.SLDPRT*).

Driver and Software Installation

The Data Acquisition program requires installation of either LabVIEW 2015 (which requires a LabVIEW license) or the free LabVIEW Run-Time Engine 2015, which is available at http://www.ni.com/download/labview-run-time-engine-2015/5507/en/

Communication with the oscilloscope requires installation of the Pico Technology PicoSDK version 10.6.10.22 (32-bit), which is available at https://www.picotech.com/download/software/sr/PicoSDK_32_10.6.10.22.exe

Note that the PicoSDK is an older version because newer versions are incompatible with the Data Acquisition software.

The Data Acquisition program comes either as a modifiable LabVIEW project (requiring LabVIEW 2015 to run) or as an executable program (requiring the LabVIEW Run-Time Engine). To run the LabVIEW project, open Data Acquisition.lvproj, double click on Data Acquisition.vi, then click the white arrow in the upper left corner. To run the executable program just double click on Data Acquisition.exe.

Setup and Initial Calibration of the Detectors and Power Supply

The detectors used here operate at about -2000 V DC. Power should be connected from the power supply to the –HV connector. The signal from the detector comes from the Anode (not the Dynode) and should be directly connected to the oscilloscope. When the detectors are connected to the power supply and to the oscilloscope, turn on the power supply and let it run for several minutes so that its output stabilizes.

To initially calibrate the power supply for the detectors, group them around a Na-22 source label side up. Run the Data Acquisition program. Enable all four trigger conditions and set each of them to one of the detectors (A, B, C, D). Start data acquisition and go to the Energy Plots panel. Change the calibrated view to Uncalibrated and expand the plot limits to 0-70000. Make sure that Override Automatic Settings is disabled. Adjust the power supply voltages so that each detector has a peak at about 23000 and a peak at about 55000 (corresponding to the 511 keV and 1275 keV peaks). This will require repeatedly stopping and restarting data acquisition so that the histogram resets. When you've finished, go to the Calibrate panel and press the Run Calibration button. This will run an automated calibration procedure. If it is successful, the 511 keV

calibration values should be about 23000 and the 1275 keV calibration values should be about 55000. Keep in mind that the power supply and detectors may drift over time, so the automated calibration procedure should be run each day.

The power supply is custom-built. Parts and CAD drawings can be found in *PartsList.pdf*. As an alternative, commercial benchtop PWM power supplies can be used. Examples of these can be found at:

http://www.sens-tech.com/Products/HV-bench-top-power-supplies/

and

http://www.ortec-online.com/products/electronics/power-supplies-and-nuclear-instrument-module-nim-bins/556-and-556h

Tips for Experiments

PET Scanning:

The data rate calculated by the program saturates at about 1000 counts per second. Additionally, the calculated rate is unstable for the first few seconds of a data run and is calculated as (Total counts)/(Total time), so when the source is moved the data acquisition should be restarted and given a moment to stabilize.

Compton Scattering:

The detectors have some physical size and also are not calibrated at energies below 511 keV, so the energies reported will not match theoretical predictions as well as might be expected.

Positron Lifetime Spectroscopy:

Many of the positrons emitted by the source will go into the disk of the source and annihilate there. This gives a lifetime signal corresponding to the material of the disk. Additionally, the long timing resolution of the detectors means that the signal will be an exponentially modified Gaussian distribution instead of a simple exponential decay. Students may wish to fit the sum of several exponentially modified Gaussian distributions to the data.

Three-Gamma Events:

It can be difficult to distinguish three-gamma events from spurious coincidences or scatterings. It will help to make a scatter plot of the energy observed from one detector versus the sum of the energies of the three co-planar detectors. A cluster observed at 1022 keV for the sum of energies and less than 511 keV (vertically centered around 341 keV) for the single-detector (not including Detector D) energy gives a nice indication that the signals are in fact from three-gamma events. An example is given below.
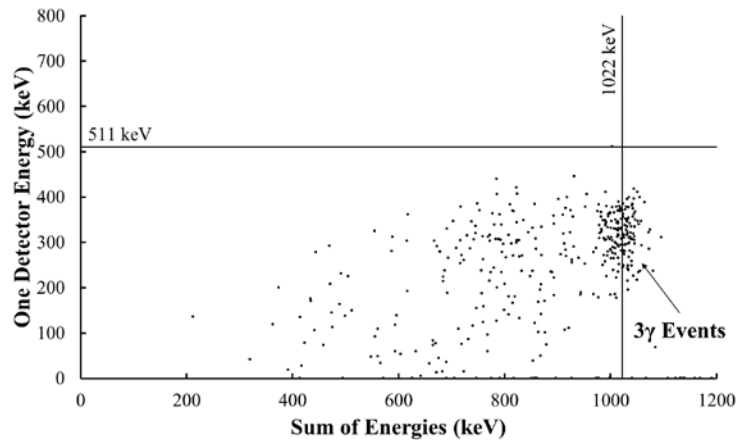
Polarimetry:

Make sure to put lead shielding between the top two detectors; leaving it out results in many counts from gamma-rays being scattered between the two detectors.

Running this experiment over several hours provides the opportunity to collect more data and to narrow the accepted energy range (resulting in a better calculated ratio).

You can achieve higher data rates at the cost of greater uncertainty in scattering angle by using longer aluminum scatterers.