Third Year Project

Dr Lee Thompson

The Binding Energy of the Deuteron

Aims and Objectives

This is an experimental project with a significant proportion of laboratory work. The apparatus consists of a high-intensity neutron source in which the deuterons will be created. The photon (or gamma ray) given off when the deuteron is formed will be measured with a combination of scintillator, and photomultiplier tube ('PMT' or 'phototube') and associated electronics. During the project the student will develop an understanding of terms such as *scintillator, phototube, calibration* and *binding energy.*

Method

Following preparatory background reading the student will be introduced to the experimental apparatus to be used for this project. The apparatus will not come pre-assembled for the project and the first main tasks will be to become familiar with all the components of the experimental equipment, to connect them together (with help from the supervisor where and if necessary), and cross-check that all the equipment is working.

On successful completion of this part of the project the next task will be to *calibrate* the experimental apparatus which involves making a series of measurements with elements and compounds which emit gamma-rays at a specific, *well-known* energy.

Once calibrated, the apparatus can be used to determine the binding energy of the deuteron.

If time permits, it will be possible to use the calibrated equipment to investigate the atomic content of a number of different materials according to the observed photon (gamma-ray) spectra observed when they are irradiated with a high dose of neutrons.

References and Suggested Reading

- Krane, K.S., Introductory Nuclear Physics;
- Leo, W.R., Techniques for Nuclear and Particle Physics Experiments;
- Cohen, B.L., Concepts of Nuclear Physics

In order to aid the student, the project is sub-divided into tasks with an approximate timescale allocated to each task. It is assumed that the project will start in week 3 (project allocations having taken place in week 2) and that the project will terminate in week 10, allowing 2 weeks for the project to be written up and handed in before the end of week 12.

Task 1: Introduction and Background Reading (week 3)

Using the references listed above, along with other resources (such as the CERN Web site: **www.cern.ch**), develop an understanding of:

- The different ways of measuring the binding energy of the deuteron and which one we are using here;
- How a scintillator works;
- How a photomultiplier works;
- How a pulse height analyser works;
- The neutron source that you are using is a 1 Curie Americium-Beryllium (Am-Be) source, make sure that you understand the nuclear processes involved when these two elements are used to make neutrons;

Task 2: Introduction to the apparatus (week 4)

The next step is to develop an understanding of the various pieces of apparatus that will be used in the project. When putting together an experiment of this kind it important to bear in mind that whilst often several pieces of apparatus can be connected together and work first time it is often the case that this doesn't happen! It will be necessary to test individual pieces of apparatus to check that they are working OK (often very simple checks are the best) – this is part of the project!

The main components of the experiment are:

- The photomultiplier tube – the one used in this experiment is a 9813K, a 2" phototube made by EMI (now ETL);
- A disk of NaI(Tl) scintillator;
- A linear "spectroscopy" amplifier (optional);
- A Multichannel Analyser (MCA) – the model used here is a LeCroy 3001;
- A Printer and Display interface module – the model used here is a LeCroy 3517;
- A printer unit which interfaces to the LeCroy 3517 above (optional);
- A NIM crate to house the electronics above;

Task 3: Interfacing the Multi-Channel Analyser to a PC (weeks 5 and 6)

The optional printer unit listed above connects to the LeCroy 3157 module via a parallel interface and a ribbon cable. It should be possible to use the same interface to connect the 3517 module directly to a PC. In this case then the data transferred to the printer unit for printing will, instead, be able to be sent to a PC file suitable for reading into a spreadsheet package such as Excel.

In order to interface the MCA to a PC it will be necessary to explore the best method of connecting the two (probably via the PC's parallel interface). Software will need to be used to "capture" the data coming through the interface to the PC, almost certainly such software already exists. It will be necessary to understand the data stream coming to the interface – for example, how individual elements of data are coded (binary, hexadecimal, etc.) and how difference pieces of data are separated or "delimited".

Task 4: Verify the apparatus using simple checks (week 7)

This part of the project involves checking the different parts of the experimental apparatus using standard techniques. The main tests are:

- To test the photomultiplier tube (and, possibly amplifier) by exposing the scintillator to gamma-rays of a known energy and looking at the pulse shape (timing) and pulse height (charge collected and hence energy deposited in the scintillator) with an oscilloscope. This procedure will also help to determine the best working conditions for the phototube in terms of the HV applied and hence the gain of the tube.
- To test the correct functioning and response of the MCA by injecting pulses of a known height, shape and duration into the system using a mercury reed relay switch.

By the end of week 7 you should have all the apparatus assembled, checked and ready to start calibration.

Task 5: Calibrating the equipment in the lab (week 8)

Using radioactive sources the emit gamma rays of a known energy (e.g. ^{60}Co and ^{137}Cs) it will be possible to calibrate the apparatus, that is, to determine the relationship between energy in and counts recorded at the MCA. This relationship will be specific to a certain PMT gain (as optimised in Task 4 above). It will be necessary to consider how much data needs to be taken with each source in order to get an accurate and reliable calibration.

Task 6: Moving the equipment to the neutron source, cross-check of calibration (week 9)

At this point the apparatus can be transferred to the neutron source. After this move is will be worthwhile to quickly cross-check that the equipment continues to function as it did in the lab and to cross-check that the calibration of the system hasn't changed dramatically.

Task 7: Measurement of the deuteron binding energy (week 10)

Project Supervision

- Dr Lee Thompson, Room E41, l.thompson@sheffield.ac.uk
- Dr. John McMillan, Room D28 or D42, j.e.mcmillan@sheffield.ac.uk
- 2nd year lab technicians (for help on electronics interfacing), 2nd year laboratory