

## 7. EXPERIMENTS with use of CdZnTe DETECTOR

In recent years CdZnTe detectors are used in nuclear spectroscopy, medical imaging, x and gamma ray detection, nuclear safety/fission materials and uranium measurements in the field. CdZnTe detectors among the wide-band semiconductor detectors have relatively higher energy resolution compared to that of scintillation detectors. This is one of the main reasons for good candidate for X- and gamma-ray spectrometric measurements. Additionally they have high stability and good response to the photons in a specific range, high sensitivity. The wide band gap ( $E_g \approx 1.65\text{eV}$ ) allows to operate them in the room temperature. In this experiment, a coplanar grid  $\text{Cd}_{0.9}\text{Zn}_{0.1}\text{Te}$  detector having  $15 \times 15 \times 7.5 \text{ mm}^3$  crystal volume, will be used. Note that if the crystal volume is different for the above one, the detector's operating voltage will also be changed. The detector crystal and its preamplifier circuit is housing in a Al enclosure case in which it has two preamplifiers to provide the signal due to electrons. While switching on the system, first be sure the proper high voltage supply unit and correct polarity. Before applying the detector bias voltage, switch on NIM crate and observe the polarity led ( LED should turned on **NEGATIVE**), then the switch on the power supply and increase the bias voltage very slowly in the first voltage. After ensuring the polarity and the right connections, the required bias high voltage should be set to operating voltage **-1000 V for this detector** by turning the knob clockwise.

**WARNING:** FIRST HIGH VOLTAGE POWER SUPPLY SHOULD BE CHECKED IF IT IS SET ZERO. THE POLARITY OF THE HIGH VOLTAGE POWER SUPPLY SHOULD DEFINITELY BE NEGATIVE AND THE APPLIED HIGH VOLTAGE SHOULD NOT EXCEED -1000 V.

When operation voltage is reached to the required value, then run on the computer **Genie** software from the desktop. From the **File** menu, click on **Open Datasource** submenu. On the window, select **Detector** and from the list select **DET01** detector then click on **Ok**. In this way the pre-known information about the detector can be loaded on Genie software. A spectrum will be seen because of previous measurements. Delete this spectrum by clicking on **Clear** button placed on the left of the screen. Count time can be preset before or spectrum can be stopped anytime during the measurements if you have selected preset=0. After this setup configuration, the present gamma counting system is ready for measurements.

Note that in order to shutdown the system, first the software should be closed then the high voltage should be decreased gradually to zero and done again gently to protect the whole detector. When it is zero, first the HV switch off, then the switch off the NIM crate.

### 7.1. Energy Calibration

Every digitized count to the incoming pulse are sorted via ADC and stored in terms of histograms to acquire a pulse height spectrum. The digitized counts are recorded in the specific channels of MCA. The stored spectrum are displayed on the screen. Every channel corresponds to the measured gamma ray energy. But pulse heights may be changed with the differences in high voltage and the gain of the amplifier. This change effects the energy

values per channel. For this reason, when in a specific operation voltage, an energy calibration shall be made to know the accurate gamma-ray energies interacted with the detector. Energy calibration is also necessary to determine unknown gamma energies from the calibration curve.

For energy calibration, standard calibration point sources with known energies, such as  $^{241}\text{Am}$  (59,6 keV),  $^{57}\text{Co}$  (122,1 keV),  $^{109}\text{Cd}$  (88 keV) and  $^{137}\text{Cs}$  (661.66 keV) can be used for the interested energy region. Calibration can be done in two ways. In the first simple technique, one channel is assumed to be equal to one keV energy. A calibration source with a known energy is placed in front of the detector and the spectrum is acquired in a suitable live time period. During the acquisition, the gain of the amplifier is changed in order to make the channel of the photopeak equal to the energy of the source. In this step, observe the spectrum on this display screen.

In the second technique, the gain of the detector is set to a specific value and it is not changed during the measurements. Then standard calibration sources are placed in front of the detector acquire the spectrum for a period of time, and the channel numbers of photopeaks of the in which maximum counts are observed should be noted. A calibration curve on the graph of should be obtained by plotting the channel numbers (horizontal axis) versus the energies of those photopeaks (vertical). Generally this curve is expected to be linear. In order to see the non-linearity, this curve should be fitted to a polynomial function by using at least three experimental points.

#### 7.1.1. 1 Channel = 1 keV Energy Calibration (Method 1):

1. On the computer from the **MCA** menu click on **Acquire Setup** submenu and adjust **Input Size** to 2048 and **Live Time** is preset to 0 seconds.
2. **In the MCA** menu click on **Adjust** submenu and do the following settings:  
Conv. Gain: 2048  
  
LLD: %0,7  
ULD: %110
3. Set the amplifiers shaping time as 1 $\mu$ s.
4. Place  $^{109}\text{Cd}$  source in a shelf close to the detector and start the acquisition.
5. At the same time by changing the **Coarse gain** and **Fine gain** settings, try to adjust photopeak to the 88<sup>th</sup> channel (the gamma ray energy of  $^{109}\text{Cd}$  is 88 keV).

#### 7.1.2. Energy Calibration with Constant Gain Settings (Method 2):

1. Set **Coarse gain** to 20 and **Fine Gain** to 1.5 and count time (live time) to 600 seconds.
2. Place the  $^{241}\text{Am}$  source in a shelf close to the detector and start the acquisition.
3. When the acquisition is finished, move the cursor to the photopeaks peak (where the maximum count is) and note the channel number.
4. Repeat the step 2 and 3 for  $^{109}\text{Cd}$ ,  $^{57}\text{Co}$ ,  $^{137}\text{Cs}$ ,  $^{54}\text{Mn}$  and  $^{60}\text{Co}$ .

### EVALUATION

1. Plot the energy (keV) versus channel number on the graph.
2. Fit these values to a first order function such as  $E(x) = mx + n$  by using a suitable fitting or another program such as in a MS Excel sheet.

- From the **Calibrate** menu, click on **Energy Only Calibration** submenu. Here fill the table with the energies and corresponding channel numbers and click on **Accept** every time. The data that you fill will be seen on the left of the screen. After you fill all data click on **Show** and make the energy calibration with a two order polynomial form. Compare the results with the one that you obtain in step 2.
- In this experiment, energy calibration is done with two different ways. Taking into account the steps that are done compare these two methods. What are the advantages and disadvantages of these two methods? Interpret your results in your report.

### 7.2. The change in energy resolution with the increasing energy

To understand the change of energy resolution with increasing the energy in a detector.

The full width half maximum (FWHM) of a photopeak is an indicator of the detectors energy resolution, R. The energy resolution at a given energy can be calculated as follows:

$$R\% = \frac{FWHM}{E_0} \cdot 100$$

Where  $E_0$  is the gamma ray energy of the measured radionuclide.

### METHOD

- Preset the count time to 600 seconds.
- Place  $^{60}\text{Co}$  source in front of the detector and start the acquisition.
- When the measurement is done, place the right and left cursors to the sides of photopeak at by taking into account the beginning and ending points of a photopeak.
- Write down the FWHM value as keV from the screen.
- Calculate the energy resolution from this value.
- Repeat step 3 to 5 for  $^{241}\text{Am}$ ,  $^{109}\text{Cd}$ ,  $^{57}\text{Co}$ ,  $^{137}\text{Cs}$  and  $^{54}\text{Mn}$ .

### EVALUATION

- Determine the energy resolution for whole energies and fill the Table 1.

Table 1

Isotope	Energy (keV)	FWHM(keV)	Resolution (	R(%)
$^{241}\text{Am}$				
$^{109}\text{Cd}$				
$^{57}\text{Co}$				
$^{137}\text{Cs}$				
$^{54}\text{Mn}$				
$^{60}\text{Co}$				

2. Plot the Energy(keV) versus R% on a graph and explain the change with the reasons. How energy resolution changes with the increasing energy? Interpret that whether the energy resolution is worsened or improved with increasing photon energy for a photon detector.
3. Compare the energy resolution of CdZnTe detector with the NaI(Tl) detector.