EXPERIMENTAL MANUAL
MCA WITH ANUSPECT

🏛 **CENTER FOR MEDICAL RADIATION PHYSICS** 🏛

CONTENTS

CHAPTER -1
INTRODUCTION

Nal Scintillation detector based gamma ray spectroscopy system with 8K/ 4K / 1K MCA consists of the following consistent units.

MINBIN with power supply (MB403)

High Voltage (HV501)

Spectroscopy Amplifier (SA524) or Linear Amplifier (LA520)

8K / 4K / 1K Multi channel Analyzer with processing software

Nal Scintillation detector (2"x2" / 3"x3" Flat / Well type) Lead shielding (40mm)

Personal computer system

Gamma Reference Sources Set

This system finds wide applications in Gamma Ray Spectroscopy measurements. Highly recommended for various Health Physics Labs of Nuclear Power Plants, Environmental survey labs & other labs for basic & applied research purposes. System also can be used in teaching labs of Nuclear Sciences & Engineering.

Multi-Channel Analyzer (MCA) is an important part of nuclear spectroscopy system. The major requirement of MCA is for nuclear pulse height analysis in energy spectroscopy. The USB-MCA presented here, incorporates state of art technologies like FPGA, USB bus interface and precision analog electronics to meet the stringent system requirements in nuclear pulse spectroscopy. The resolution supported by the USB-MCA ranges from 256 channels to 8K channels selectable via software, making it suitable for all spectroscopy applications from low resolution (e.g. Nal-PMT) to high resolution (e.g. HP-Ge) systems.The USB bus interface of the MCA provides an excellent connectivity with most of the new PCs and lap-top computers. The Anuspect application software provided with the USB-MCA, seamlessly integrates with the hardware, featuring a range of standar functions required for analysis and acquisition.

FEATURES :

- Excellent MCA performance in terms of DNL: +/- 1%; INL : +1- 0.05% of F.S. resolution etc.
- Supports both PHA & MCS modes of operation.
- Universal connectivity to a wide range of PCs and notebook computers.
- Gamma Ray Spectroscopy System uses Spectroscopy Amplifier or Linear Amplifier, HV module andScintillator Detector including instrumentation BIN & power supply.
- Excellent processing software features.
- System can be used with different sizes of Nal scintillation detectors.

CHAPTER - II

DESCRIPTION AND SPECIFICATION OF THE CONSTITUENT UNIT

1. MINIBIN AND POWER SUPPLY (MB 403)

MINI BIN : Accommodates SIX / EIGHT single bit modules or combination of multiple widths witT Amphenol connectors. Minibin is primarily designed with the objective of conserving bench space and to achieve significant saving in cost of the Minibin based systems. Bussed wiring is provided to the power connectors to distribute +1- 12V and +/24V. A control panel with ON/OFF switch, low voltage test sockets is provided on the right extreme side of the bin.

Minibin Dimensions : 11.75'%width X 11.00 depth (upto connectors) X 8.75" height.
Power supply : This is either two and half bit module or a compact box type enclosure fitted at the back of this bin, which generates highly regulated D.C voltages.
Input : (230V + 10%) A.c, 50Hz.
D.C Output : +12V @ IA, -12V @ IA, +24V @ o.5A, -24V @ 0.5A 48 watts maximum.
Regulation : Better than +1- 0.1%
Noise & Ripple : Less than 3 mV
Stability : +1- 0.5% after a 24 hr warm-up at constant line, load & ambient temp.

2. HIGH VOLTAGE UNIT (HV 501) :

a.   Output voltage variable continuously from OV to 1500 volts
b.   Output current (max) 1mA
c.   Load & Line regulations : Better than 0.005% of full scale
d.   Indefinite over load & short circuit protections and self recovery
e.   Output ripple less than 20 mv.
f.   Dimensions : Single / Two bit module

3. SPECTROSCOPY AMPLIFIER (SA524) :

Spectroscopy Amplifier is a high performance nuclear pulse shaping amplifier, ideally suited for use with all types of detectors such as germanium, silicon surface barrier and Si(Li) detectors. This is a single width NIM module with pile-up rejector (PUR), gated baseline restorer (BLR), auto threshold, diode limited unipolar output, BUSY and count-rate output as some of the key features designed into it. Some of the main applications of spectroscopy amplifier involve nuclear pulse height spectroscopy, nuclear timing spectroscopy, Counting Systems etc.

The input to SA524 can be either positive or negative signal from a detector preamplifier. The output pulses, 0 to 10V for unipolar pulse and ±10V for bipolar pulse.

A. PERFORMANCE

Gain Range : Continuously variable from Χ4 to Χ 1500.
Pulse Shaping : Quasi-gaussian and quasi-triangular.
Shaping time : 0.5, 1, 2, 3, 6 and 10 µsec
Input Noise : 5 mv r.m.s with 3 ms shaping time
Overload : Recovers to within 2% of baseline in 15x shaping time from x200 overload.
Integral Non-Linearity : < 0.05% from O to IOV.

B. CONTROLS

FINE GAIN : Front panel 10 turns precision potentiometer provides a continuously adjustable gain factor from 0.5 to 1.5.

COARSE GAIN : Front panel six-position switch selects gain factors of X20, X50, X 100, X200,X500 and X 1000.

PZ : Screwdriver adjustment of the PZ cancellation using 20-turn potentiometer on the front panel.

POS/NEG : Front panel toggle switch for selecting either positive or negative input signals.

ATN : A front panel toggle switch select an input attenuation factor of X1 or X2.5

SHAPING : Front panel six position switch for selecting shaping times of 0.5 , 1, 2, 3, 6 and 10 µsec .

4. MULTI-CHANNEL ANALYZER (8K MCA) : Multi-Channel Analyzer (MCA) is an important part of the nuclear spectroscopy system. The major requirement of MCA is for nuclear pulse height analysis in energy spectroscopy. The USB-MCA presented here, incorporates state of art technologies like FPGA,USB bus Interface and precision analog electronics to meet the stringent system requirements in nuclear pulse spectroscopy. The resolution supported by the USB-MCA ranges from 256 channels to 8K channels selectable Via software, making it suitable for all spectroscopy applications from low resolution (e.g. NaI-PMT) to high resolution (e.g.HP-Ge) systems.

The USB bus interface of the MCA provides an excellent connectivity with most of the new PCs and lap-top computers. The PHAST application software provided with the USB-MCA, seamlessly integrates with the hardware, featuring a range of standard functions required for analysis and acquisition.

SPECIFICATIONS :

Hardware features:

- MCA resolution. 256, 512, 1K, 2K, 4K and 8K channels.
- Spectrum memory : 128K bytes single port SRAM.
- Max counts / channel: 31 bit (2 Giga counts).
- Pulse processing time . 7 us including ADC conversion time of 5 us.
- Pile up rejection: Active high TTL input from spectroscopy amplifier
- DNC: +/- 1%
- INL +/- 0.05% F.S.
- MCA Input: Single channel, O to +10 volts
- Power requirement: 5V, —500 mA through USB cable directly (No external power supply required)

Software features : Important software features include * spectrum display in two windows * marker selection (two) for ROI Detection & bracketing the peaks of interest, multiple ROI selection, delection of ROIS etc.,

File Handling: Involves storing, loading of complete spectrum.0

Print: Print of Total graph, selective graph, peak report

Acquisition: With pause option

Erase: Erasing spedrum from memory

Spectrum Analysis: Find peak, Shape calibration, Energy calibration, Approx Calib, Efficiency Calibration, Activity Calculation, etc.,

**Spectrum smoothing:** 3,5,7,9 &11 point smoothing functions have been provide

ROI Option: Insert, Delect, Hide Etc.,

Scale: X-axis can be chosen as Channel number (or) Energy axis (in Kev) & Y - axis has range from 256 to 64M in binary steps with auto scaling option. Y-scale can be linear or log LLD, ULD& base line are soft selectable In built Isotope library for isotope selection & matching.

5. SCINTILLATION DETECTORS

Nucleonix Systems offers wide range of Nal Scintillation Detectors of different sizes both With flat & well type crystals, to meet the requirements of wide range of users for Gamma ray spectrometry measureμsecments.

Scintillation detectors offered include 2"x2" & 3"x3" Nal integral assemblies with built-in pre-amplifiers.These detector assemblies give excellent stability, superior performance & good resolution in the range of 8.0 to 9.5% for Cs-137. Scintillation detectors of other size can be offered against user specific requirements also.
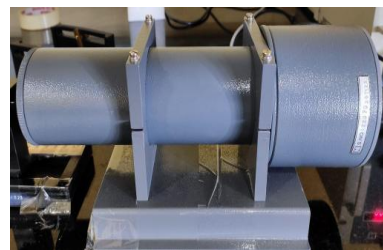
Important Specifications	Detector Type
Flat/Well type Nal crystal	SD 152/SD152 W
Crystal Sizes	2"x 2"
a. Flat crystal b. Well Size (applicable for	0.656" dia x 1.546" deep
Photo multiplier	EMI 9557 or 9266 or its equivalent
Resolution (Better than)	8.5%
Pre-amplifier	Built - in
Gain (Approx)	25
Noise (RMS. Referred to input)	Less than 50 μV
Operating Voltage	700 to 900 V
Output	Positive Tail Pulse
Output impedance	90 Ohms
Power Requirement (Typical)	-12V @ 12 mA

6. GAMMA REFERENCE STANDARD SET (GS290) :

Gamma Reference Standard Set Type: GS290 consists of a set of FIVE Gamma sources evaporated & sealed on 25mm dia x 5mm plastic disc covering SIX photopeak energies in the range of 3 to 5 micro curie. A reference chart for this is given below. The accuracy of these sources is in the range of +1-10%. All these dics sources are enclosed in a box made of acrylic sheet and supplied.

Gamma Isotope	Energy Mev	Nominal Activity	Half life
Co-57	0.123	111 kBq	273 Days
Ba-133	0.36(Main)	150 kBq	7.5 years
Cs-137	0.662	111 kBq	30 years
Co-60	1.17 ; 1.33	155 kBq	5.3 years
Na-22	0.511 ; 1,280	115 kBq	2.6 years

Note : BRIT is not able to supply this Mn-54 at present. In view of this we are able to give only 5 sources in the Gamma Reference set.
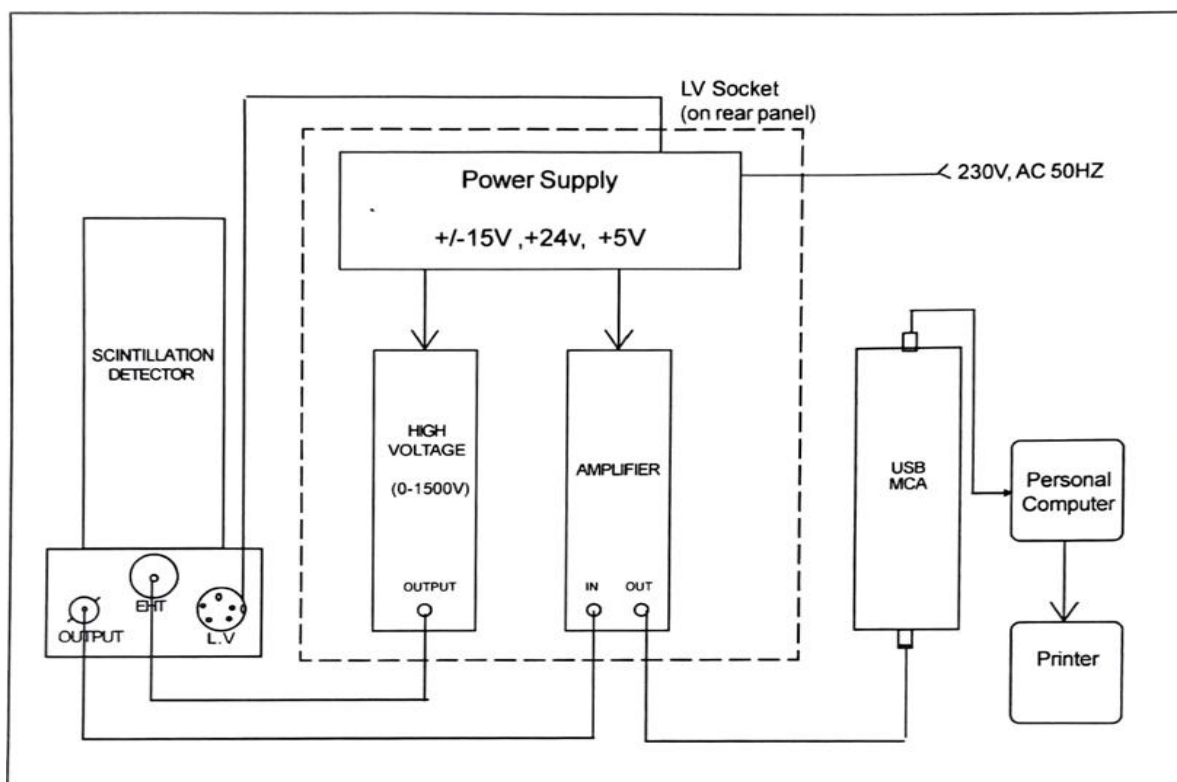
CHAPTER - III
PROCEDURE FOR OPERATION OF MULTI CHANNEL ANALYSER

Fig.l. Block diagram USB MCA

- Make the interconnections as shown in the table given below & also in above in Fig. 1.Switch on PC & Gamma Ray Spectrometer.
- Invoke the 'ANUSPECT' software on PC by double clicking on the 'ANUSPECT' icon on the desktop
- Then the main screen that appears at the start of the program is shown below in Fig.2.

Table showing system interconnection details

Sl.No.	Name of the connecting cable	Connection from	Connection to
1	BNC to BNC co-axil cable	Scintillation detector	Spectroscopy amplifier INPUT
2	UHF to MHV cable	-do-	High voltage unit
3	LV cable	-do-	Instrument bin with power

|			supply MB404 rear panel
4	Spectroscopy amplifier output	MCA(USB) module input	
5	USB cable	MCA module	Personal computer
6	Printer cable	PC	printer

HOW TO SET HARDWARE SETTINGS:

1. Go online Analysis Menu
2. Click the Hardware Setting Drop as shown
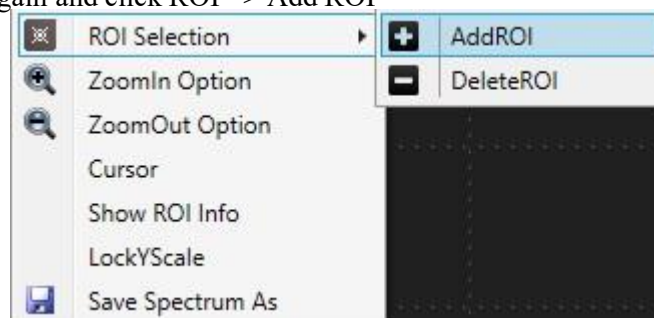3. We can save sample data at any desired location by clicking Brows
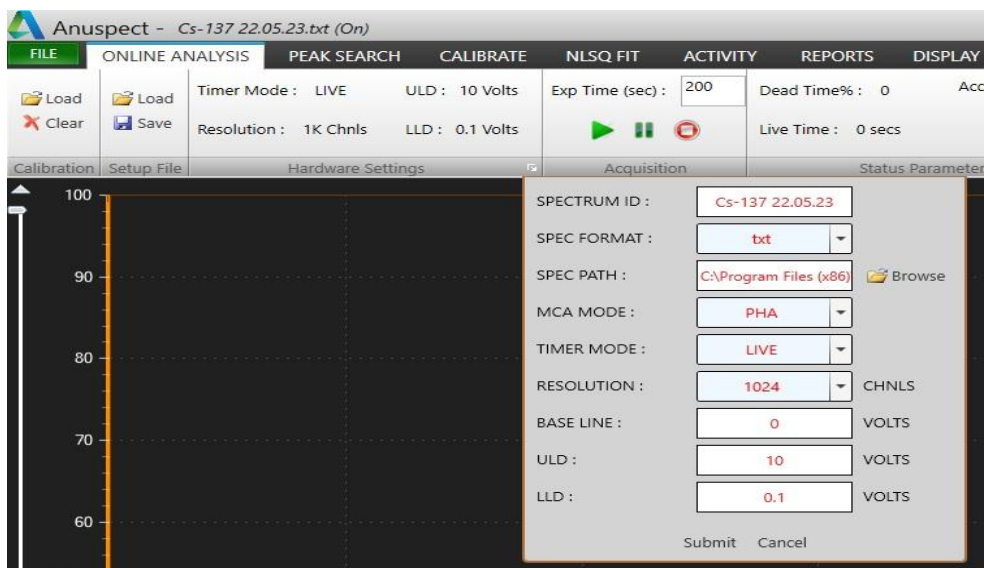
How to generate ROI

- Go to file menu=>spectrum
- Open the desired file
- Go to Peak Search Menu
- And search the peaks
- Right click on the spectrum and select cursor option
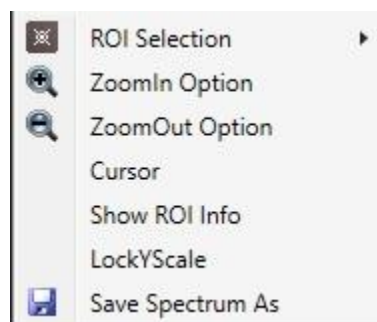
- Right click again and click ROI => Add ROI

- Adjust the limits by dragging the green bars
- If you want to delete the ROI
- Select the ROI and right click ROI => Delete ROI

CHAPTER - IV
EXPERIMENT WITH ANUSPECT SOFTWARE

EXPERIMENT - 1

ENERGY CALIBRATION OF GAMMA RAY SPECTROMETER (LINEARITY STUDY)

(DIRECT METHOD-FROM SOFTWARE)

PROCEDURE:
1. Make the system interconnections & default settings so as to get Cs-137 peak approximately at channel 300.
2. Place different Energy source on the detector 2cm away. (minimum 3 energies are required for Energy Calibration)
3. Acquire the spectrum to get a fine spectrum after giving the default setting and file name
4. Click file menu, spectrum and load the spectrum to be calibrated energy shape
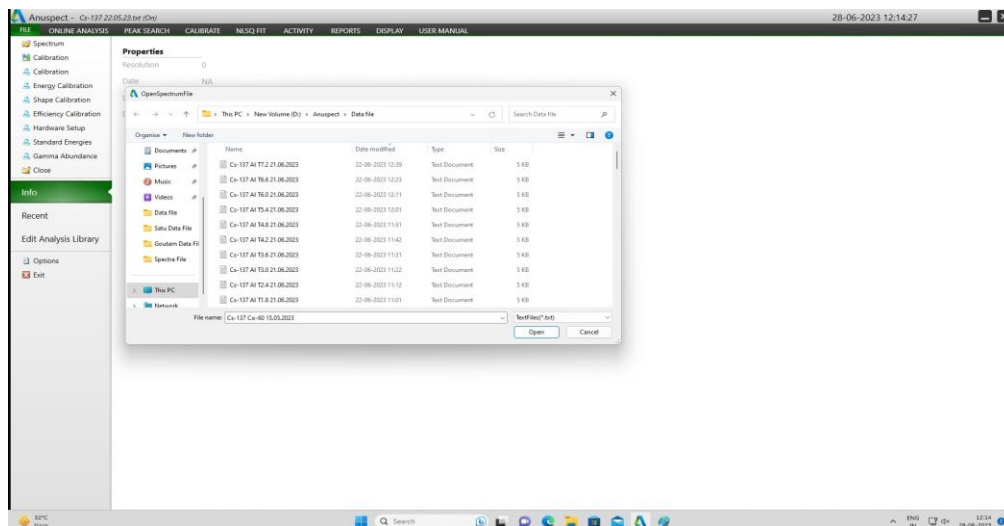
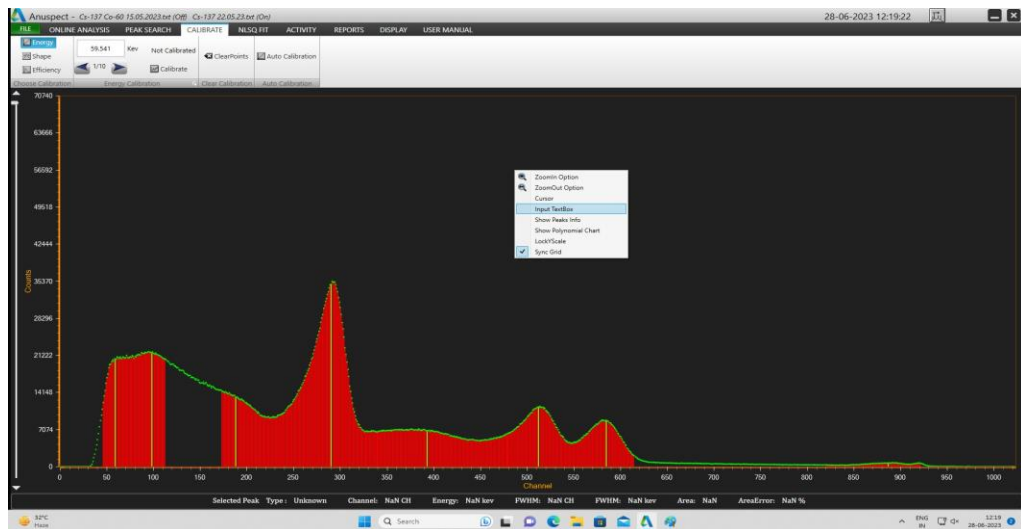5. Click NO for loading Previous Calibration.
6. Click Peak search menu, search now all the peaks will be detected in the acquired spectrum
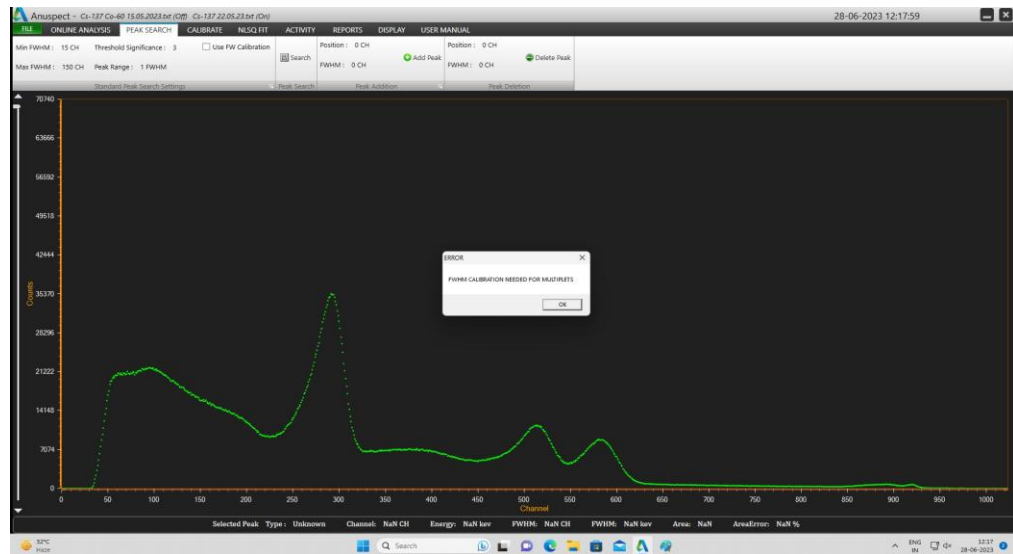
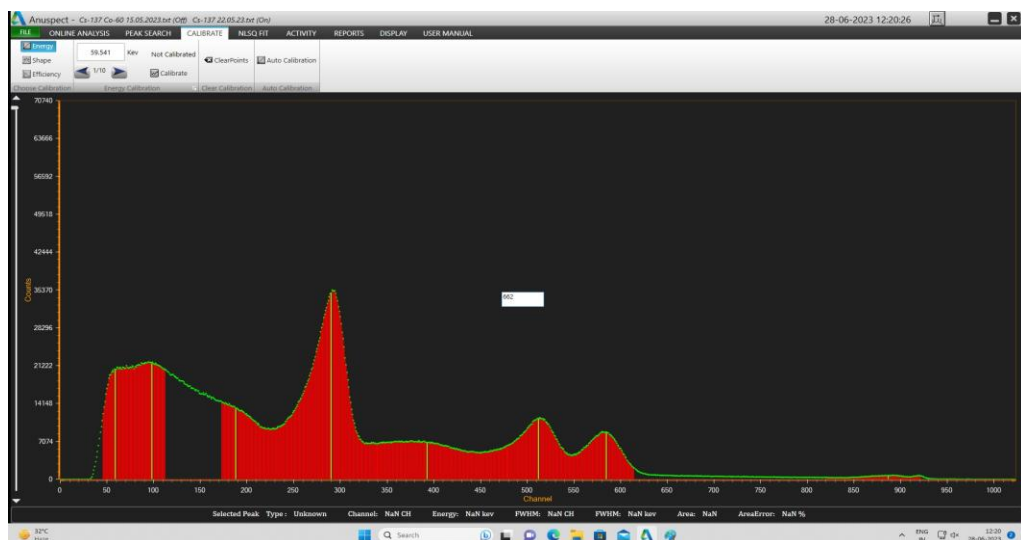7.   Go
                                                                                                                                                    to

Calibrate menu & click on energy after that right click on the spectrum, click input text box

8. Enter the energy in it, and drag it to the corresponding peak
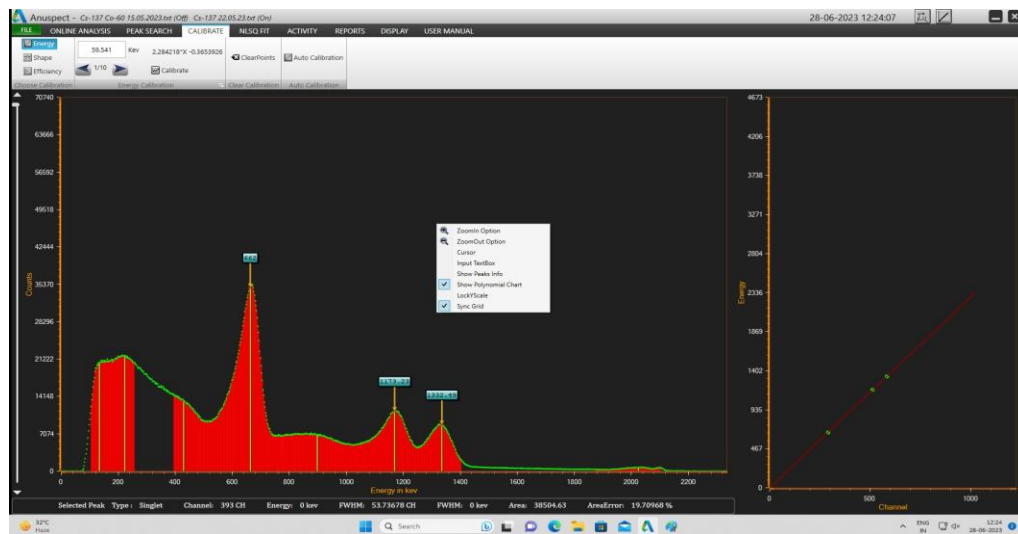
.

9. Repeat it for two more peaks

10. Click on Calibrate
11. We can see the polynomial equation & we can use this equation to find out the energy of unknown sample

12. To see the polynomial chart, right click on the spectrum, select show polynomial chart.

EXPERIMENT - 2

UNKNOWN ENERGY OF A RADIOACTIVE ISOTOPE

PROCEDURE:
1. This experiment should be followed by the previous experiment.
2. Now acquire the spectrum for the unknown sample for the same experiment set up.
3. Load that spectrum and click on the peak channel (where the height of the photo-peak is maximum) and Note down the peak channel no.
4. Now extrapolate this channel no. On to the Energy Linearity Graph to calculate the energy of the unknown peak.
5. The energy thus obtained should be matched for a known radioactive standard source

EXPERIMENT -3

PLOT THE GRAPH BETWEEN THE EFFICIENCY AND ENERGY FOR THE GAMMA RAY SPECTROMETER (Efficiency Calibration)

PROCEDURE:
1. Do the energy and shape Calibration and save the calibration with an appropriate Name
2. **Shape Calibration :**

This type of calibration is used to plot the relationship between FWHM and Energy of the Gamma Ray Spectrometer . Hence we can get proper area under the curve at any energy .

Click on "shape" in calibrate menu.

3. Right click on the spectrum and select show peaks information.
4. Select minimum three strong energy peaks from the table shown.
5. Click on calibrate to do shape calibration.
6. We can see the polynomial chart and equation by right click option
7. Click on NLSQ fit menu, to apply shape calibration to the whole spectrum by clicking" Fit" (Model Fit).
8. **Efficiency Calibration:**

Acquire the spectrum, for different radioactive source individually acquire for longer time in order to have a fine spectrum.
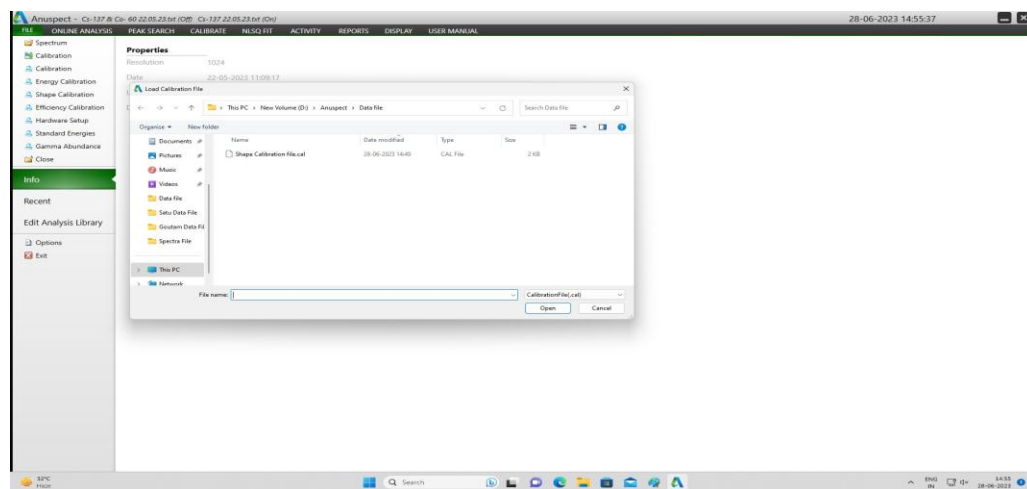Ex: Cs-137, Co-60, Mn-54 , Zn-65 etc.
9. Click file menu , spectrum, select and load the individual spectrum to do calibration (Ex. Ba-133).
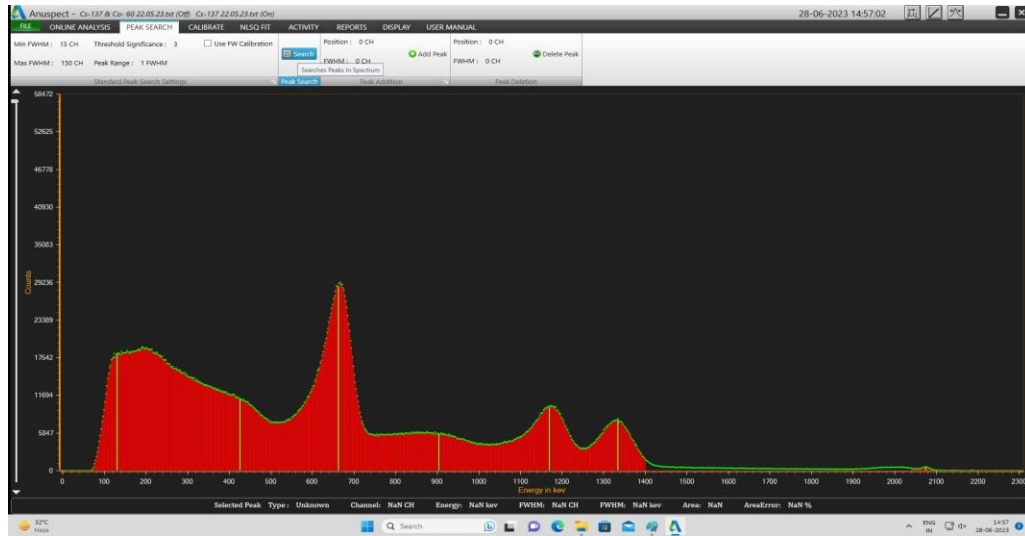10. Click No, to reject load previous calibration.
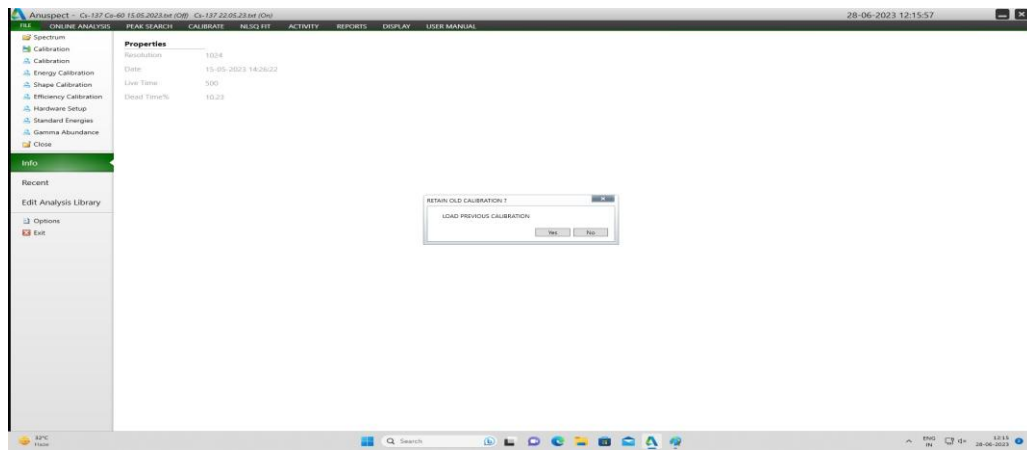
11. If the calibration file already copied in root folder, press "Yes" (for the same settings of setup).
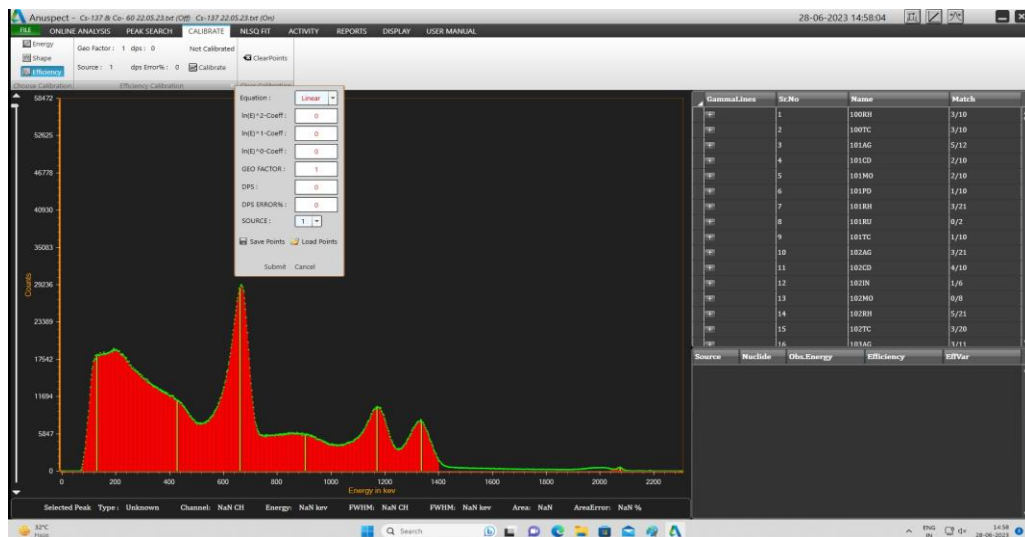
12. Otherwise load the calibration from file menu.

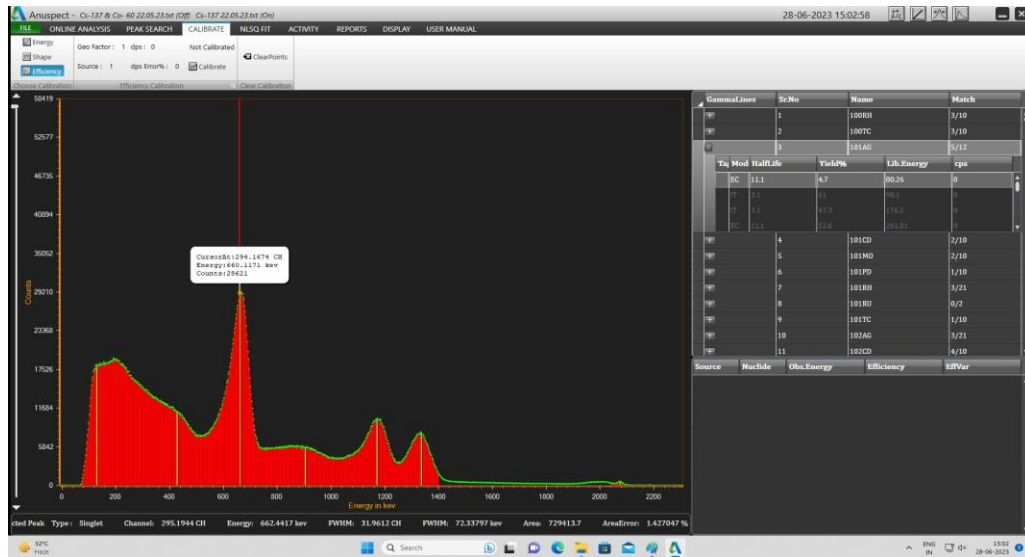13. Search peaks by selecting use FW calibration.

14. Click on the calibrate menu, efficiency calibration-sub menu enter the DPS, DPS error % and submit for Ba-133.
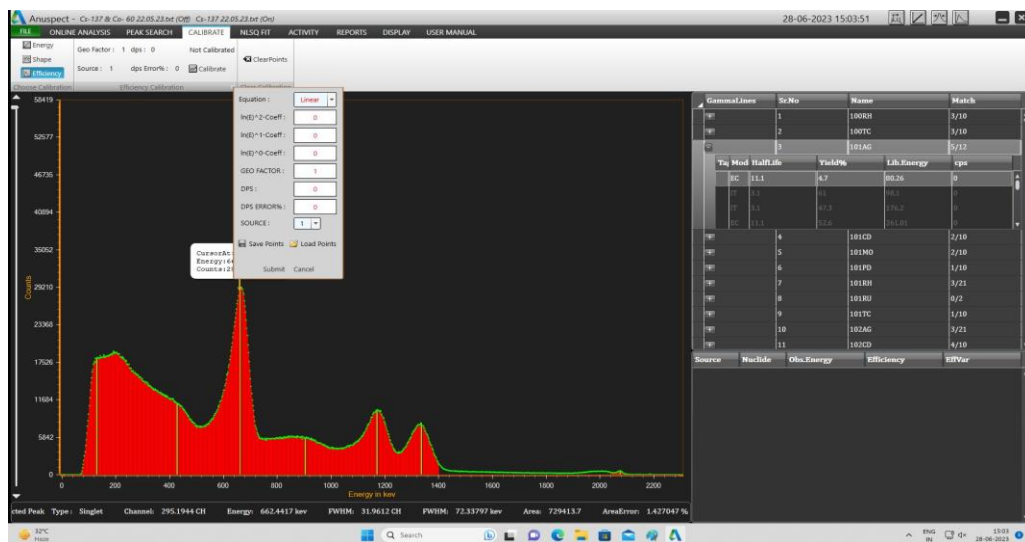

15. Click on (+) gamma line corresponding to Ba-133, **select and drag** the most matching energy level, which is having maximum yielding of gamma line , to the selection window.
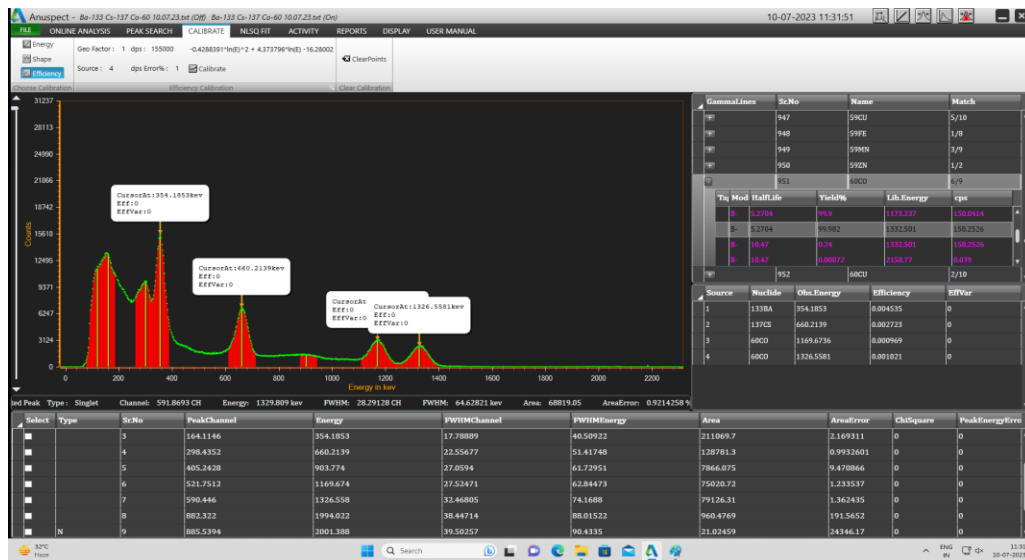
16. Go to efficiency calibration sub menu , select source 1 (1 source data) from drop down and save the points. (Ex. Ba-133 effiCalib).
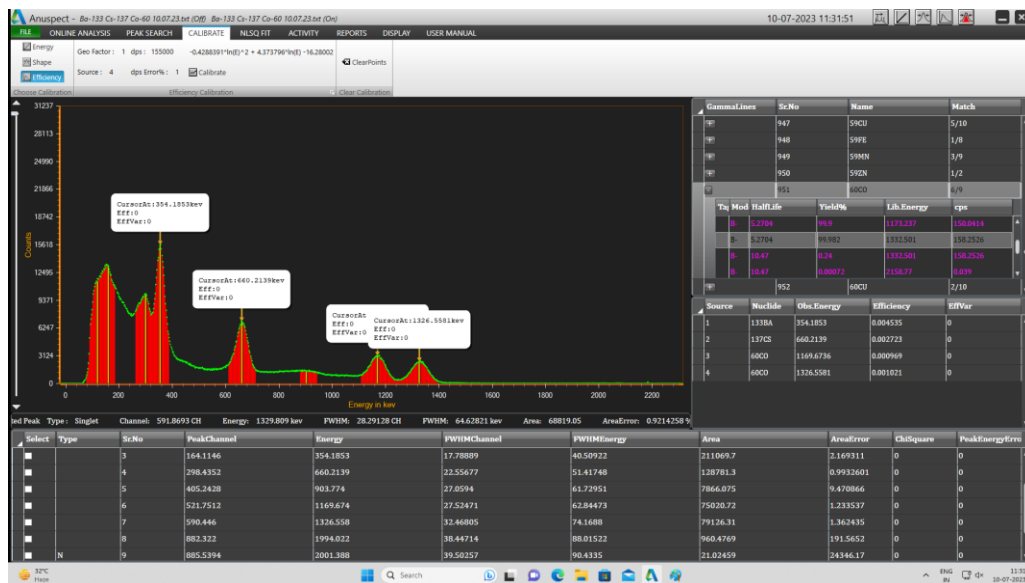

17. Repeat above steps for Co-60, Zn-65, Mn-54 and save points as source 2,3,4 data.

18. Now load the saved points from efficiency calibration sub menu.

19. To remove the wrongly loaded point, double click that point in the selection table
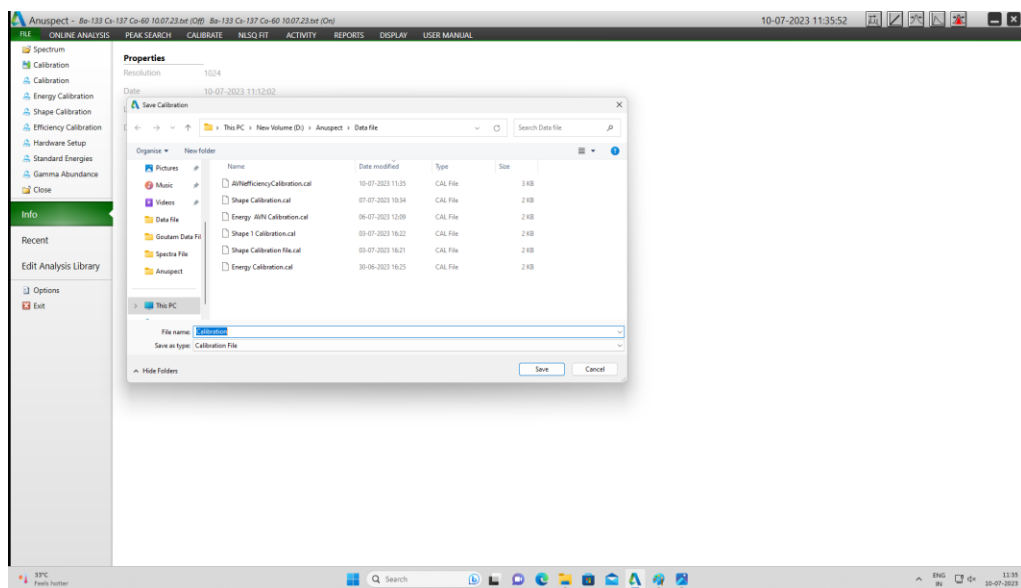20. Click on calibrate menu.

21. Polynomial equation will be shown.
22. After that right click on spectrum and select show polynomial chart to see the graph.
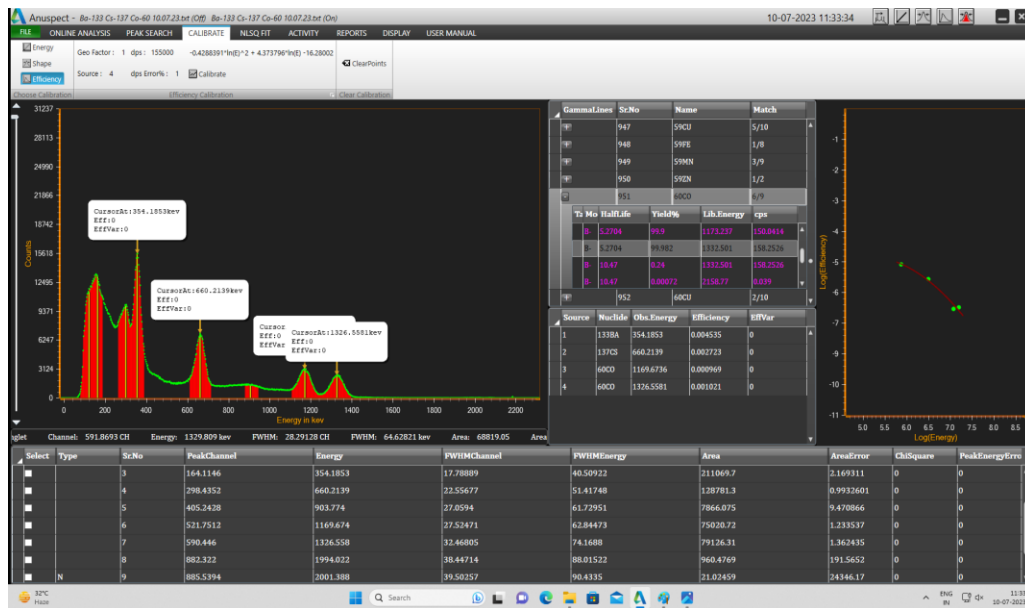
23. Now **save the calibration** by clicking calibration in the file menu.

24. We can this calibration to another spectrums for the same hardware setting to calculate the activity of unknown sample

25. This calibration data will be saved as three separate child files with the same parent name . (Ex. if we save the calibration as fullcalibration.cal then it will also saved as **fullcalibration.enca**l, **fullcalibration.shpca**l and **fullcalibration.effcal**. We can also import the energy/shape/efficiency calibration data alone from the above child files with different prefixes)

EXPERIMENT - 4

ACTIVITY CALCULATION OF UNKNOWN SOURCE.

PROCEDURE:
1. Make the same system interconnections & default settings , those used at the time of calibration of the system.
2. Do the energy, shape & efficiency calibration as explained previously.
3. Save the calibration with an appropriate file name .
4. **Activity Calculation:**

Now acquire the spectrum for the given sample (acqure for long time if it is low active).
5. Load the spectrum from file menu , spectrum .
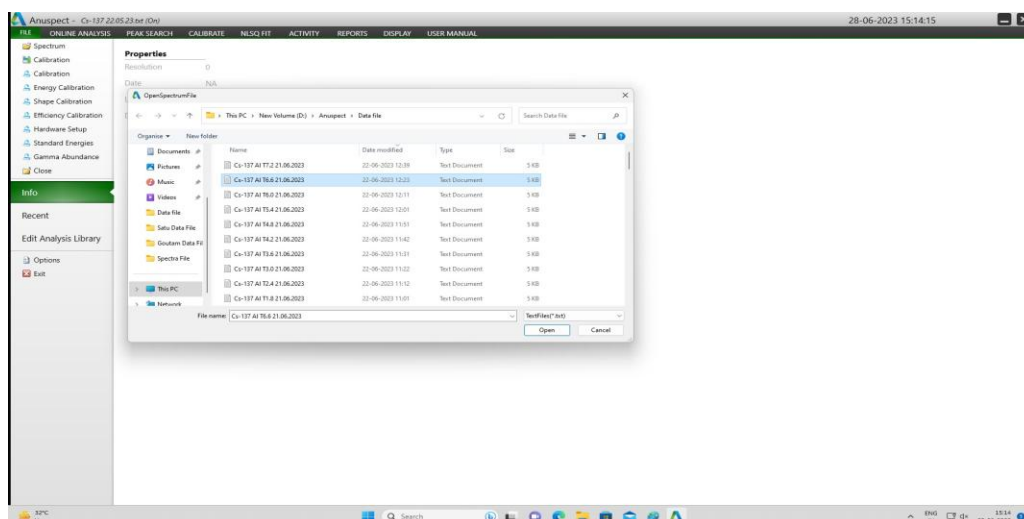
6. Load the appropriate calibration from the file menu.

7. Search the peaks by selecting "USE FW Calibration",
8. Fit the spectrum in NLSQ fit (model fit)
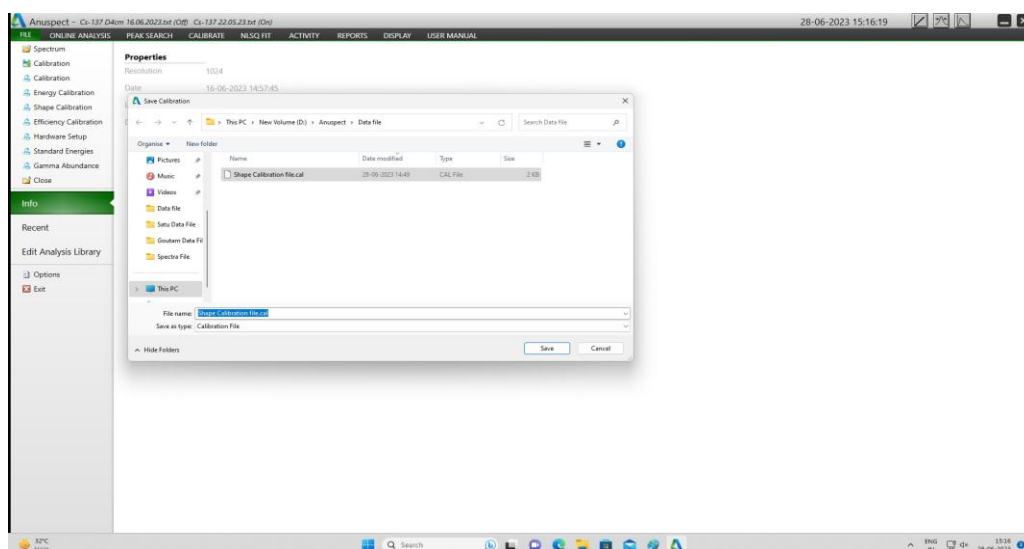9. Enter sample volume and unit in activity menu, source selected sub menu.
Sample volume: It is defined as the portion/percentage of the volume using for the calculation activity w.r.t standard volume used at the time of calibration.
Ex. 5ml of std. Source are used for calibration and we to find out the activity of 1 ml unknown sample activity.
Then sample volume should be entered = sample vol./std. Volume
$$i.e = 1/5 = 0.2$$
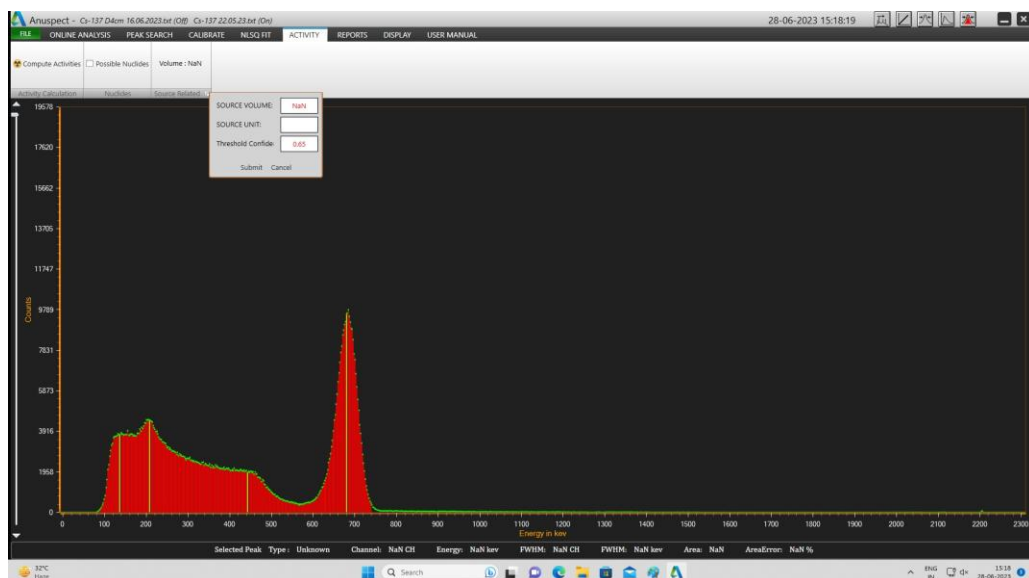
10. Click on compute activities.
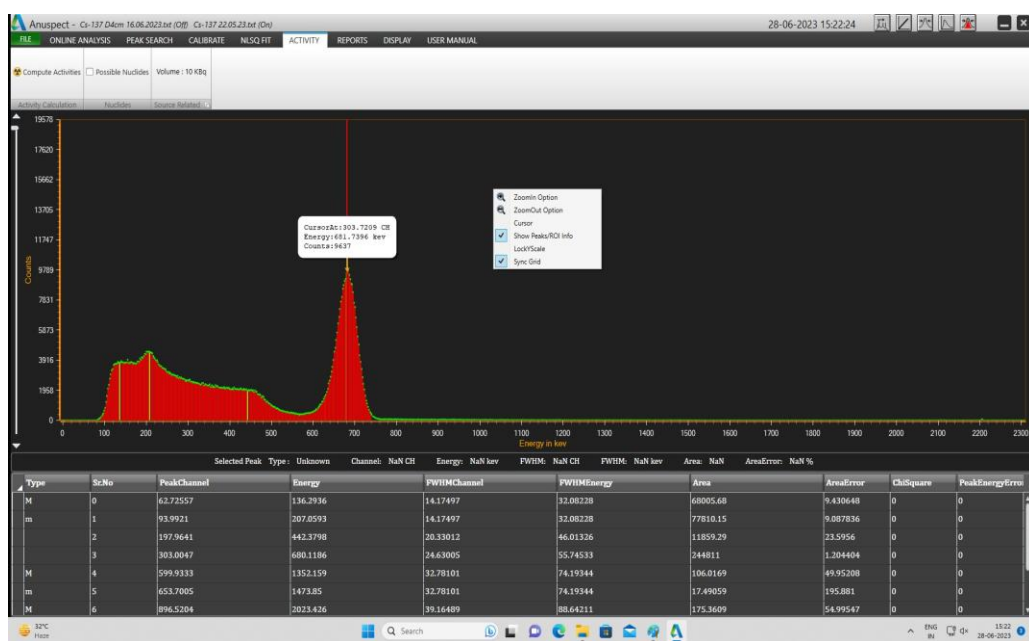
11. Right click on spectrum, select "**ROI/Show peak info** " and we can see the activities of the sample .

EXPERIMENT - 5

DETERMINATION OF MASS ABSORPTION COEFFICIENT

PROCEDURE:

1. Make system interconnections and default settings.

2. set HV to **550 volts**
3. Adjust the amplifier gain such that the photopeak of **662 Kev** gammas will appear at approximately **channel 300**.
4. Set a live time of **250 Sec**.
5. Insert the first piece of copper absorber (2mm thick) between source and detector. Acquire the spectrum.
6. Repeat with additional pieces of copper absorber in increments of 2mm until the gross area under the 662 keV photopeak falls upto 2000. Acquire spectrum for each thickness of lead absorber.
7. Obtain the background spectrum for the set live time of 250 Sec.
8. Take ROI reports pertaining to 662 keV peak of Cs- 137, for the respective absorber thicknesses.
9. From the ROI reports, obtain the gross counts pertaining to 662 keV peak, against each absorber thickness.
10. Obtain the gross background counts from the ROI report pertaining to background.
11. Calculate the net counts for each absorber thickness. (net counts = gross counts – background counts).
12. Tabulate the data as shown in the following Table -7.

DATA :   Table-7 (FOR COPPER)

Background counts for 250 sec = 2741

Data for Mass Absorption Coefficient of Copper		
Thickness (mm)	**Gross Counts**	**Net counts**
0	48249	45508
2	43348	40607
4	39120	36379
6	35981	33240
8	32102	29361
10	29183	26442
12	26492	23751
14	23764	21023
16	21394	18653
18	19700	16959
20	17661	14920

EXERCISE A : (FOR COPPER)

- Plot the Net Counts versus Absorber thickness in 'mm' as shown in Fig. 22 and determine the Half Value Thickness or Half Value Layer (HVL) in terms of thickness (mm) from the Curve.
- The Half Value Layer (HVL) is also expressed in terms of Density thickness (gm/cm). Density

  thickness is the product of density in gm/cm times the thickness in cm.

- Determine the HVL in gm/cm and calculate the Mass Absorber Coefficient m from Eq. 10. How does your value compare with the accepted value of 0.105 cm/gm

For Copper

Fig. 22 Graph showing variation of counts with Copper absorber thickness

Computation & Result :

The observed value of HVL from the graph is 13.3mm or 1.33cm.

Density Thickness = 1.33 x 8.96 = 11.92 gm/cm^2. (Density of copper = 8.96 gm/cm^3).

Hence mass absorption coefficient

m = 0.693 / HVL

=0.693 /11.92

=0.058cm^2/gm

The calculated value of Mass absorption coefficient for copper is 0.058 cm^2/gm.

EXERCISE B: (FOR ALUMINIUM)
Procedure :

1. The experiment is repeated with steel absorbers in the same manner as was done with lead absorbers, except that the Cs-137 source is kept at a distance of 8 cm from the face of the detector.

2. In this experiment, the steel absorbers are incremented in the steps of 4 mm till a maximum thickness of 60 mm is reached.

3. Thickness Vs net counts are tabulated the following Table-8

DATA :

Table-8 (FOR ALUMINIUM)

Background counts for 250 sec = 2077

Data for Mass Absorption Coefficient of Aluminium		
Thickness (cm)	Gross counts	Net counts
0	48967	46890
0.6	43746	41669
1.2	39846	37766
1.8	35967	33890
2.4	32861	30784
3.0	29243	27166
3.6	26744	24667
4.2	24180	22103
4.8	22071	19994
5.4	19986	17909
6.0	18578	16501
6.6	16832	14755
7.2	15388	13311

- Plot the Net Counts versus Absorber thickness in 'mm' as shown in Fig. 23 and determine theHalf Value Thickness or Half Value Layer (HVL) in terms of thickness (mm) from the Curve.
- The Half Value Layer (HVL) is also expressed in terms of Density thickness (gm/cm2). Density thickness is the product of density in gm/cm times the thickness in cm.

- Determine the HVL in gm/cm and calculate the Mass Absorber Coefficient m from Eq. 10.
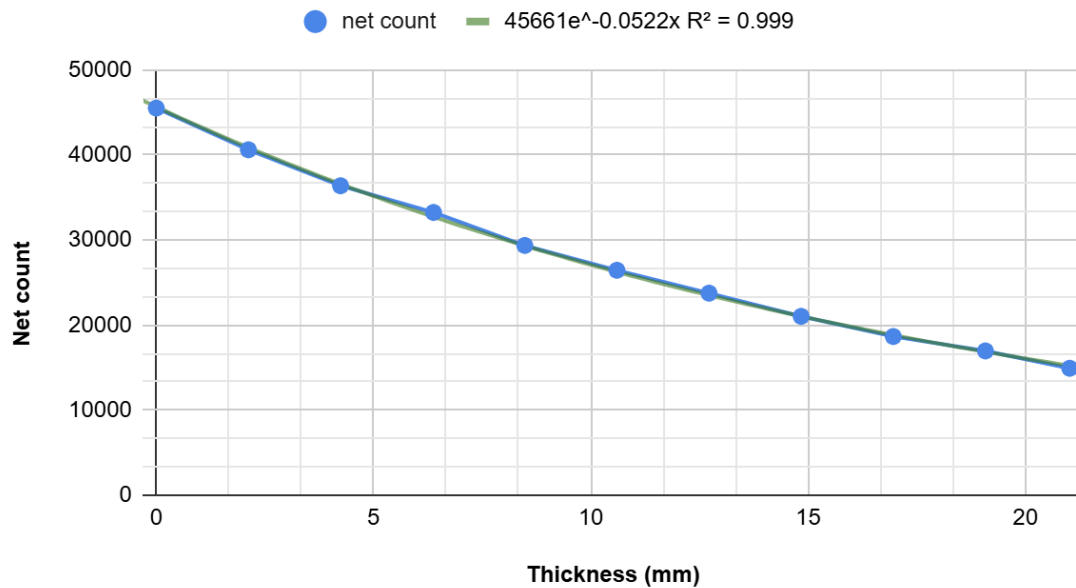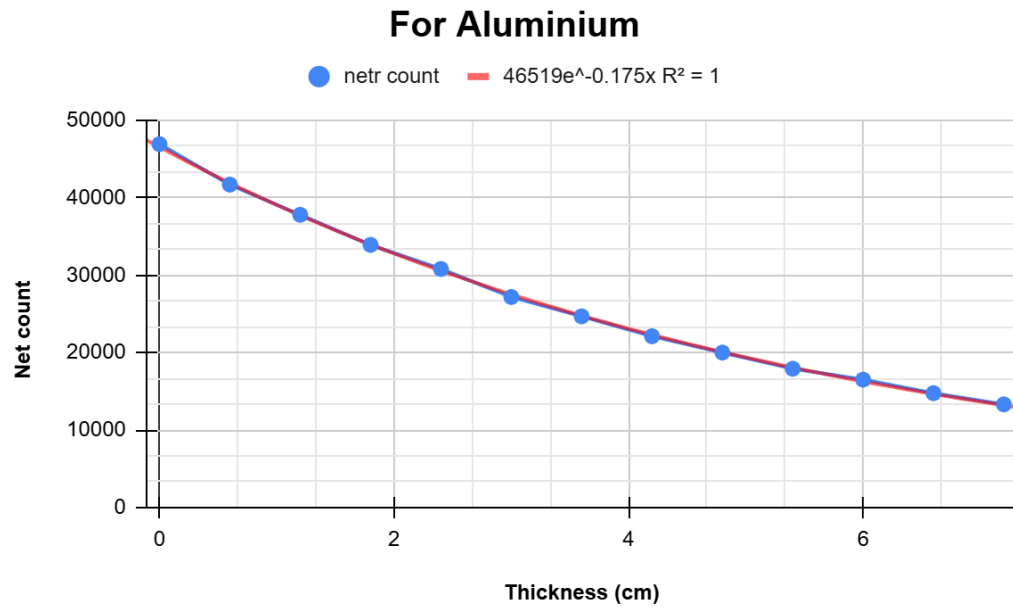
For Aluminium

Fig.23 Graph showing the variation of counts with Aluminium absorber thickness

Computation & Result :

The observed value of HVL from the graph is 4 cm.

Density Thickness = 4 x 2.7 = 10.8 gm/cm^2. (Density of Aluminium = 2.7 gm/cm^3).

Hence mass absorption coefficient

m = 0.693 / WL
= 0.693 / 10.8
= 0.064 cm^2/gm

The calculated value of Mass absorption coefficient for aluminium is 0.064 cm^2/gm.

EXPERIMENT - 6

BACK SCATTERING OF GAMMA RAY

Backscattering of gamma photons refers to the phenomenon where gamma photons, upon interacting with a material, scatter back in the direction from which they came. This process is primarily a result of **Compton scattering** (*A process where a gamma photon collides with a free electron, loses some of its energy, resulting in change in direction*). The scattered photons energy (hν') is depend on incident photon energy (hν), angle of scattering (θ) as shown in formula below-

$$h\nu' = \frac{h\nu}{1 + \frac{h\nu}{mc2}(1 - cos\theta)}$$

Where mc^2 represents electron rest mass energy (0.511MeV). The above equation signifies when scattering angle i.e θ is 180^0 which is the case for backscattering photons, the scattered photon transfers maximum of its energy to the electron and it gets backscattered with a minimum amount of energy. For fixed gamma ray energy, scattering angle, experimental environment and density of material of interest, the intensity of backscatter gamma photons depends on thickness of the material. If C is backscattered gamma count rate, μ and μ' are linear attenuation constant for incident and scattered gamma radiation beam, and t is thickness of target material then all are related with expresion as -

$$C = K\{1- exp[-(\mu + \mu')t] \}$$

Where K is a constant. Up to a certain thickness called saturation thickness, the number of counts increases, eventually reaching saturation. The information regarding thickness and density of material can be obtained by gamma backscattering technique. The gamma backscattering method is very useful for estimating the thickness of hot objects, unclean and corroded surfaces when ultrasonic methods fail to work.

PROCEDURE:

1. Make system interconnections and default settings.
2. Set HV to **550 volts**
3. Adjust the amplifier gain such that the photopeak of **662 keV** gammas will appear at approximately **channel 600**. **(Note: Course gain - 0.2, Fine gain - 540)**

4. Set a live time of **300 Sec**.
5. Make a proper arrangement of as shown in **fig. 24**.
6. Take a minimum of 2 spectra as background spectra.
7. Put the **Co-60** source in the source holder (facing opposite to detector).
8. Take two spectra for zero thickness (without any perspex slab).
9. Put the first slab of perspex (Acrylic sheet) and take two spectra.
10. Now increase the slab thickness one by one by 1cm to 10cm and take a minimum of two spectra for each thickness.
11. Prepare the table as given below.
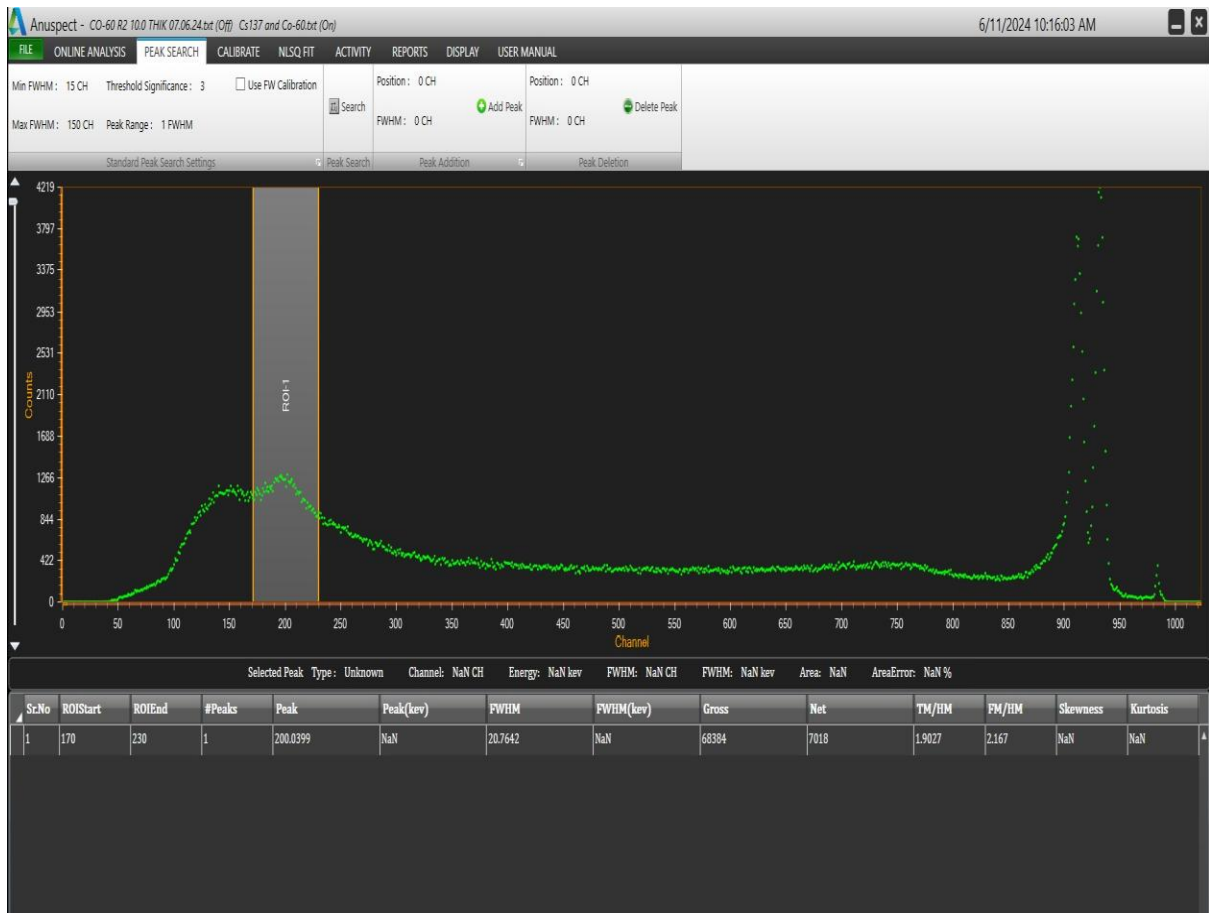
Source: Co-60   Preset Time: 300sec.

Activity: 155kBq   ROI: 170 - 230ch

Avg. BKG = 13106

Sr.No.	Prx Thickness in cm	Gross Counts in ROI		Avg Gross Count	(Avg.Gross - BKG)	Corrected Gross Count*
		Count 1	Count 2			
1	0	63894	64852	64373	63894	—-
2	1	66014	66230	66122	66014	1749
3	2	66404	66814	66609	66404	2236
4	3	67396	67443	67419.5	67396	3046.5
5	4	67513	67963	67738	67513	3365

Sr.No.	Prx Thickness in cm	Gross Counts in ROI		Avg Gross Count	(Avg.Gross - BKG)	Corrected Gross Count*
		Count 1	Count 2			
6	5	67896	68247	68071.5	67896	3698.5
7	6	68398	67751	68074.5	68398	3701.5
8	7	68186	68362	68274	68186	3901
9	8	68225	68282	68253.5	68225	3880.5
10	9	68420	68838	68629	68420	4256
11	10	68713	68384	68548.5	68713	4175.5

★ :Corrected gross count = (Avg. Gross Count - BKG) - zero thickness count

Thickness vs BKG Subtracted Gross Count

Thickness vs Corrected Gross Count