Institute for Nuclear Physics, University of Cologne

Practical Course M

experiment no. 3.5

Anti-Compton Spectroscopy

date: 29th October 2013

Contents

1 Introduction **2**

2 ACS detectors **3**
2.1 Plastic scintillators 3
2.2 NaI scintillator 4
2.3 The Photomultiplier 5
2.4 HPGe detector 5

3 ACS electronics **7**
3.1 Scintillator signals 7
3.2 HPGe-detector signal 8
3.3 The veto circuitry 8

4 Definition of „peak-to-total“ and „peak-to-Compton“ **11**

5 Experimental procedure **12**
5.1 NaI Spectra 12
5.2 Simple energy calibration of the HPGe detector 12
5.3 Measurement of room background 13
5.4 CS dependance on the scintillators used in the setup 13
5.5 CS dependance on the source distance(geometry) 14
5.6 Precise energy- and relative-efficiency- calibration of the HPGe detector . . 14
5.7 Gamma-spectroscopy identification of unknown source 14

6 Appendix **16**
6.1 Laboratory sources 16
6.1.1 Properties of the sources 16
6.1.2 Gamma-energies and relative γ-intensities of the ^{152}Eu source . . . 16
6.1.3 Level Schemes 17
6.2 Detector Datasheets 17

1 Introduction

Gamma-spectroscopy is a very efficient way of studying the nuclear structure. But the measured γ spectra do not contain only the energies of the nuclear γ transitions. There is a number of Compton-continua which are overlaid for energies below the photoabsorption peaks (photopeaks). Therefore, weak photopeaks could easily be missed in the background. Ideally one would like to have a spectrum containing only the photopeaks.
This laboratory exercise introduces you to the so-called "Anti-Compton Spectroscopy"(ACS) or also "Compton-suppression spectroscopy"(CSS). Originally, this exact set-up was developed in the 1970's at the University of Fribourg, Switzerland, and represents one of the first ACS set-ups used in experiments in Europe. Until late 1990's it was used for in-beam ACS experiments. Later, thanks to Prof. J. Jolie, it was saved from destruction and moved to Cologne. Since the year 2006 it is a part of the Advanced practical course (practical course M) at the IKP, University of Cologne.
In this practical exercise you will measure ^{60}Co, ^{137}Cs, ^{152}Eu and some "unknown" laboratory γ sources.
The goal is to determine the peak-to-total (P/T) and peak-to-Compton (P/C) with and without Compton suppression (CS) of the experimental set-up. You will study the effects of the geometry and detectors used in the set-up on the CS. In addition, you will perform a simple and advanced energy and efficiency calibration of a HPGe detector and use γ spectroscopy as a tool to identify an "unknown" source.
The basics γ-ray interaction with matter and γ spectroscopy could be found in the manuals (Praktikum B Versuch K.2 und FP Versuch Nr.4) for „γ spectroscopy using HPGe detector“ and in a number of textbooks (e.g. Knoll, Leo, etc.).

Key words/Questions:

- Interaction of gamma-rays with matter?

2 ACS detectors

Let us start with the question what characteristics should modern Anti-Compton shields possess? Firstly, they should be build out of a material with good photoabsorption, i.e. high effective Z. Secondly it should be possible to manufacture the detectors with the required geometry for the AC shields. Nowadays, for AC-spectroscopy the so-called „BGO-shields“, crystals of $Bi_4Ge_3O_{12}$ (Bismuth Germanite) with photomultipliers which surround the Ge-detector, are often used. These have a poor energy resolution, but a fast timing response of about several nanoseconds and high effective Z.
The setup used in the practical exercise is built up from the following detectors: plastic and NaI scintillators and a HPGe detector (see Fig. 1).

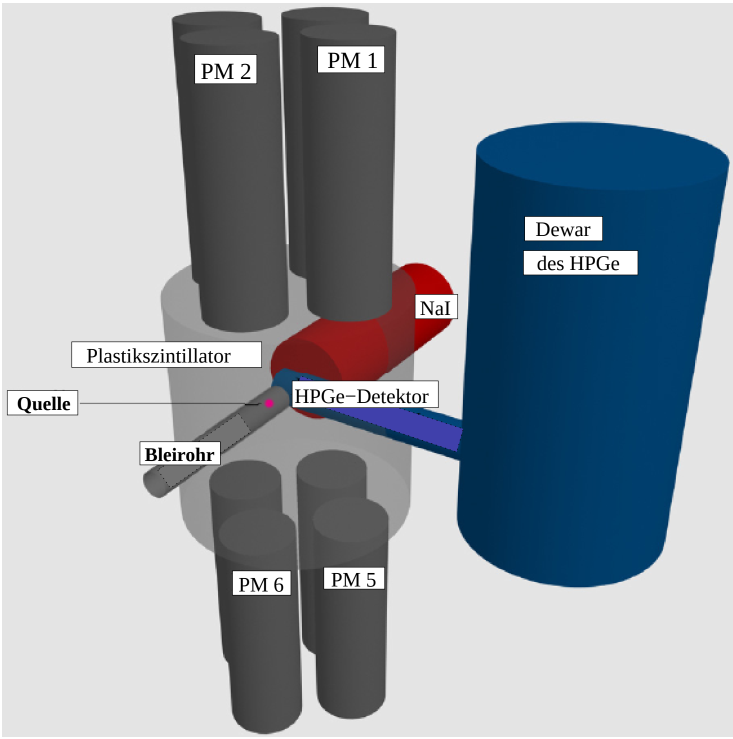


Figure 1: *Schematic figure of practical setup.*

2.1 Plastic scintillators

Plastic scintillators belong to the group of the organic scintillators. It has a π-electronic molecular structure. An example of such π-structure and its energy levels is given in Fig. 2. The plastic scintillators have the advantages of easy forming and machining, inexpensive production and quick time response. But the energy resolution is rather poor. Table 1 shows characteristics of the Polystyrene material.

Density $[\frac{g}{cm^3}]$	1.00
Luminescence efficiency (rel.)	14 %
Signal decay time [ns]	5

Table 1: *Polystyrene characteristics*

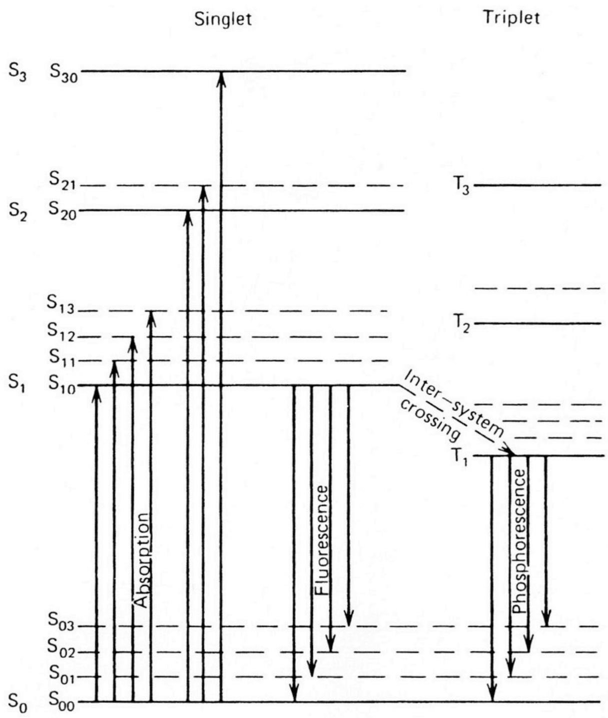


Figure 2: *Energy levels of organic molecule with π-electronic structure*

2.2 NaI scintillator

NaI scintillators are made of single NaI crystals which have isolator properties. From the point of the electronic band model this corresponds to a filled valence band, separated from the empty conduction band by a band gap of more than 5 eV. The scintillator crystal transfers the absorbed γ energy in proportional amount light(scintillations). The NaI scintillator has a high efficiency due to the high cross-section for atomic(internal) photoelectric effect on the Iodine nucleus. Compared to the plastic scintillator the NaI has a much better energy resolution (see Table 2). The disadvantages of the NaI are that it is hygroscopic and therefore has to be packed up airtight, it has worse timing characteristics than the plastic scintillator, limited formability and higher price.

Key words/Questions:

- Which nuclear and atomic physics properties determine the efficiency and the time response, and thus define the application range of the scintillators?

Density [$\frac{g}{cm^3}$]	3.67
Luminescence efficiency (rel.)	100 %
Signal decay time [ns]	230

Table 2: *NaI characteristics*

2.3 The Photomultiplier

Figure 3 shows schematically the assembly(design) and the function of a photomultiplier. It has a photocathode, electron optics, electron multiplier with dynodes and an anode. It is used to multiply the weak light signal signal so that a further processing becomes possible. This is done by converting a light pulse of only several hundred photons into an electrical signal without adding much of noise.
Its function is based on the electric photo electric effect and the secondary electron emission effect. The light emitted by the scintillator hits the photocathode and via photoelectric effect releases electrons. These are then accelerated by the voltage between the cathode and the first dynode. When these first electrons hit the first dynode they produce secondary electrons, which are further accelerated to the second dynode and so on until they reach the anode. Thus typically a signal containing about 10^7–10^{10} electrons is created. The applied voltage ranges from several hundred to several thousand Volts, and which value could be used to adjust the multiplication factor.
Obviously, the output electric signal is the photomultiplier is proportional to the input photo signal, and could be processed further.

Key words/Questions:

- External photoeffect
- How does the amplitude of the output signal depend on the HV applied to the photomultiplier?
- What determines the shape (form) of the output signal?

2.4 HPGe detector

→ See the manual for „γ spectroscopy using HPGe detector“ (Praktikum B Versuch K.2 und FP Versuch Nr.4) and in a number of textbooks (e.g. Knoll, Leo, etc.).

Key words/Questions:

- Differences in the working principles of the scintillator and semiconductor detectors; energy resolution and efficiency.

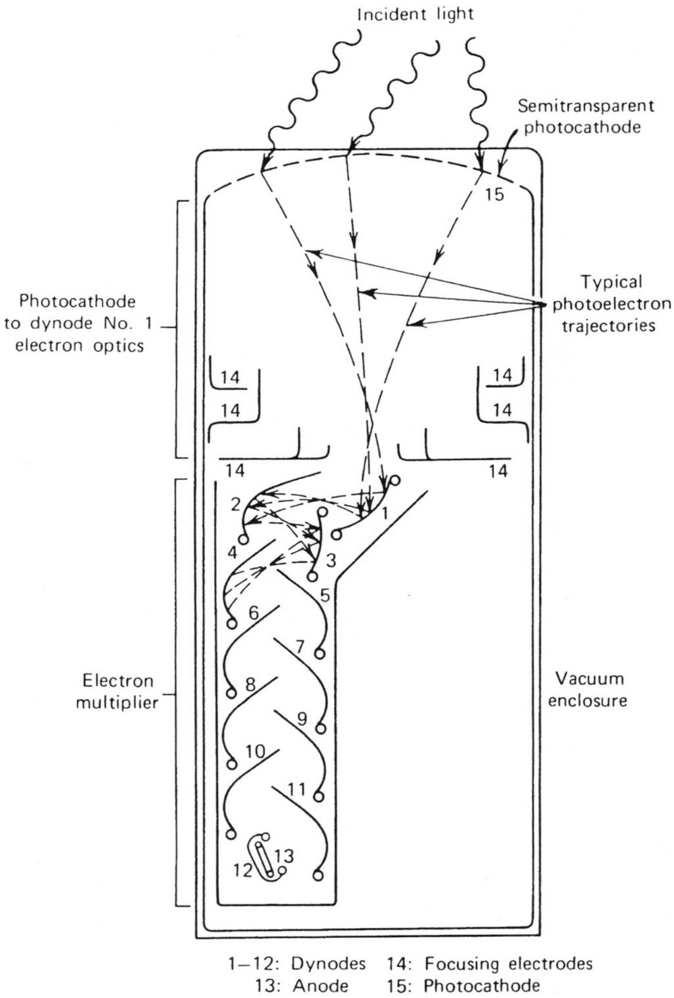


Figure 3: *Principle scheme and function of a photomultiplier*

3 ACS electronics

Since the anti-Compton spectrometer is built out of different types of detectors, the timing of their signals differs and one needs to take care about their time-synchronization. The light signal from a plastic scintillator follows within 2.4 ns after the "detected" γ-ray, while the same process in NaI scintillator takes about 0.23 μs. Additional delays come from the times needed by the electrons in the photomultipliers. Much slower is the HPGe-detector signal, since the electrons(holes) created in the semiconductor crystal need time to drift to the electrodes and to create a signal. This introduces delays of the order of several hundred of nanoseconds.

3.1 Scintillator signals

The size of the plastic scintillator makes necessary the usage of several photomultipliers. In this practical setup eight photomultipliers are used each having a diameter of 127 mm. These could be operated at a maximal voltage of +3000 V and have a high sensitivity of photocathode. A common continuous high-voltage (HV) power supply is used for all eight photomultipliers, and the separate channels HV is defined via a voltage devider, which allows the changes of separate channels in the range of several hundred volts. The output signal of the photomultipliers is fed directly into two fourfold discriminators with adjustable threshold. These discriminators produce a 50 ns wide logical NIM signalonce the input signal is over the threshold.

The outputs of the discriminators are connected to a coincidence unit, which for negative signals operates in an "OR" modus and produces a negative signal of 50 ns length, when one of the photomultipliers' signals is over the threshold.

The photomultiplier of the NaI scintillator is operated at +900 V and its output signals have a maximum level of 2 V. But the long rise time of the signals requires a special processing in order to have a good timing. The signal is first sent to a Timing-Filter Amplifier (TFA) which is similar to a normal amplifier and beside the amplification of the signal, has a filtering part with a CR high-pass filter, which differentiates the signal, and has a RC low-pass filter, which integrates the signal. This improves the signal-to-noise ratio as the unnecessary frequencies in the signal are suppressed. On the other hand compared to the normal amplifier the TFA allows for a individual selection of the differentiation and integration time-constants, which are shorter than normal ranging from 5 to 500 ns. The amplified and filtered signal is then sent to a Constant-Fraction-Discriminator (CFD).

Then the signals from both scintillators (plastic and NaI) are delayed in an octal Gate-Generator (GG8000) such that signals corresponding to one and the same event are simultaneous (i.e. electronically synchronized). When synchronizing an attention is payed mostly to the difference in the response times and the different electronic circuits of the detectors. Finally the synchronized signals are input into a coincidence unit.

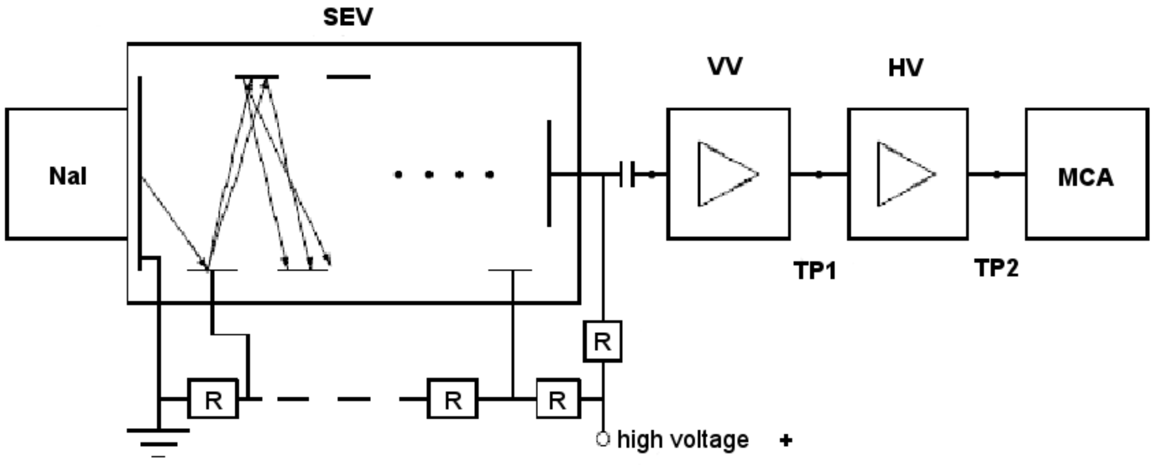


Figure 4: *Electronic block diagram of a NaI-spectrometer,*
(NaI: the scintillator crystal, SEV: photomultiplier, VV: preamplifier, HV: main amplifier, R: resistor, MCA: Multi Channel Analyzer)

3.2 HPGe-detector signal

The HPGe detector from the AC setup is biased at -2000 V. The signal is split after the preamplifier into two branches one of which is used for the timing chain and the second one for the gamma-energy determination. The split signal although originally the same is processed differently in the different chains.
The energy signal goes directly to a main amplifier which not only linearly amplifies the signal but also filters it. The goal is not to spoil the good resolution of the HPGe-detector with an electronic noise. The internal electronic scheme and the signal processing in the main amplifier is shown in the manual for the practical exercise Nr. 4.
Typically there are four integrations which help to create an output signal nearly identical with a Gauß curve. The time it takes for the signal to reach its maximum is $4 \cdot \tau$ or generally $n \cdot \tau$.

3.3 The veto circuitry

The γ-quanta which scatter out of the HPGe-detectors create signals also in the surrounding detectors. If these signals are coincident with a signal in the HPGE-detector, then we should not accept the HPGe signals. Therefore we say that the scintillator signals in this setup are "veto"-signals and could be used to the reduce the background in the HPGe-spectrum caused by the Compton scattered quanta which leave only part of their energy in the Ge detector. In the high-resolution γ-spectroscopy one uses high-efficiency multi-detector arrays of HPGe-detectors which cover a large solid angle ($\rightarrow$ *Euroball, Gammasphere*). These are often equipped with multitude of scintillator detectors to measure and suppress Compton-scattered γ-rays.

The processing and time pickoff of the detectors' signals produces fast timing signals related to the gamma-rays detected in the Germanium and scintillator detectors, correspondingly. Using the fast timing signals one can build up a logic to decide which energy signals from the HPGe are to be acquired. Therefore it is important to pay attention for the timing characteristics of the different detectors. In addition, it is known that the HPGe-detectors is position sensitive. This means that the signal's shape and delay depend on the position of the interaction of the ionizing radiation (gamma-rays, particles, etc.) with the crystal. The reason for this is the relatively small drift velocity of the electrons and holes ($\sim$ several cm/ns) in the semiconductor. In addition the electrons have a different drift velocity then the holes and therefore the signal rise time is also dependent on the interaction point.
In this setup a coincidence time window of 400 ns is chosen. For this one takes the veto-signal of the scintillator detectors and using a "Gate Generator" produces an inverted 400 ns long time signal, such that a coincident time signal of the germanium detector is coming within this time window. The signal resulting from the logic addition of these two signals is then used to make TTL (Transistor-Transistor-Logic) signal as long as the energy signal of the Germanium detector's main amplifier. A "Linear Gate" module is then letting the energy signals of the HPGe detector, which are coincident with the TTL signal, through to the MCA (**M**ulti **C**hannel **A**nalyser) which sorts the signals into histogram channels corresponding to different amplitudes of the energy signal. This allows plotting the acquired date in spectrum (counts per channel). One can calibrate the spectrum in Energy[keV] using known total-absorption (photopeak) lines.
Figure 5 shows the summary of the electronics circuit diagram.

Key words/Questions:

- Explain the function of the single electronic components!
- How are the HPGe signals suppressed by the "veto" signals?

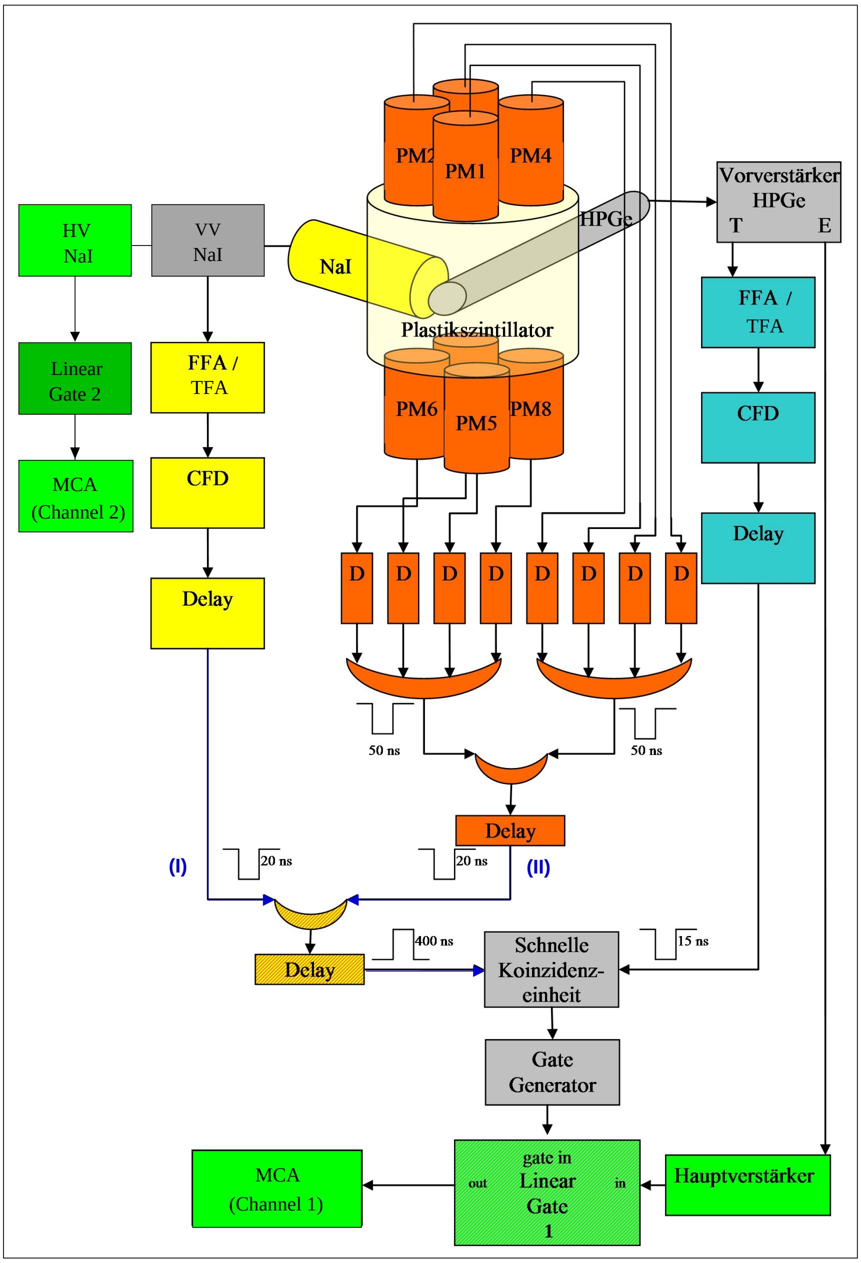


Figure 5: *Schematic circuit diagram of the Anti-Compton spectrometer setup*

4 Definition of „peak-to-total“ and „peak-to-Compton“

The „peak-to-total“ ratio is the quotient of the sum of (i) the integrated area under the 1173.2 and 1332.5 keV (for ^{60}Co) or 661.7 keV (for ^{133}Cs), and (ii) the total integrated area in the spectrum. The integration means adding up the contents of all the respective channels.

The „peak-to-Compton“ ratio is sometimes quoted as a feature of the germanium detector gamma-ray spectra. This is defined as the ratio of the count in the highest photopeak channel to the count in a typical channel of the Compton continuum associated with that peak. The latter is officially defined as the interval from 1040 to 1096 keV for the 1332.5 keV gamma rays of ^{60}Co, and the interval from 358 to 382 keV for the 661.7 keV gamma rays from ^{137}Cs [4].

5 Experimental procedure

Warning: The cabling and applying of the High Voltage to the HPGe detector is allowed only for the supervisor of the exercise or an expert. **!!!**

- Log in as user **fp** (Password **„effpee“**) on the laboratory PC. Make you own subdurectory under **/home/FP/Versuch10/** using the command
  mkdir *[Date]-[Groupnumber].*
  Warning: Take care that the spectra are saved exactly in your Subdirectory, since the software may sometimes reset the save default and the user **fp** has restricted write permissions.
- Get acquainted with the set-up components.
- After opening the programm „SADHU“ or „mca_viewer“ change the Channels to 8 K for the measurements with the HPGe detector and to 2 K or 4 K for the measurements with scintillator detectors.
- The measurement durations given in the following are only guide values. Depending on the source intensity it maybe necessary to measure longer then originally required. Please take care that you have appropriate statistics to allow for analysis. In case you are not sure ask the supervisor.
- Use the supplied manuals for working with the programs **tv** and **SADHU**. In case these are missing from the working place ask the supervisor.
- Please take complete notes (exp. protocol) of the performed exercises and measurements. These notes sheets have to be readable and ought to be submitted together with the complete analysis of the practical exercise (complete protocol).

5.1 NaI Spectra

Before you acquire spectra with the NaI detector, please ask the exercise supervisor to pull out the HPGe detector (partially) out! (Q: Why should we do this?)

- measure NaI spectra of ^{60}Co and ^{137}Cs sources for 5 min long each. Using the **tv**-program (or similar) try to make a proper fit and determine the positions of the peaks and their Full-Width-at-Half-Maximum (FWHM) in %.

5.2 Simple energy calibration of the HPGe detector

- Calibration of the HPGe-detector by using ^{137}Cs and ^{60}Co sources:
  Acquire spectra of ^{137}Cs and ^{60}Co for a short time (2-3 min) each, in which you can clearly see the respective photopeaks. Using the channel positions of two (or all

three) peaks, determine the linear calibration coefficients ($E[keV] = a + b \cdot$[Channel]). Give the values for a and b with errors.

- What is the energy resolution for E_γ = 1332.5 keV (^{60}Co) and E_γ = 661.7 keV (^{137}Cs)? Give your results in keV as well as in % (FWHM/energy).
- Compare the theoretically expected and experimentally determined positions of the Compton-edges and the Backscattered peak(s) and mark their positions in the spectra. Discuss shortly your results.
- Compare the spectra of the semiconductor and the scintillator!

5.3 Measurement of room background

(Hint: The long measurement of the room background can be performed at a later stage of the practical exercise, for example during a lunch break.)

- measure the room background with Compton Suppression (CS) for about 30 min and comment shortly on the origin of the lines in the spectrum.
- (only for FP) compare this measurement (spectrum) with the room background measure in exercise 4 and comment.

5.4 CS dependance on the scintillators used in the setup

- For a fixed position “far” of the ^{60}Co source collect the following spectra, each one for 15 min.: (Hint: disconnect one or another scintillator veto signal as needed and reconnect it afterwards.)
  i) without CS,
  ii) with CS only by NaI scintillator,
  iii) with CS only by plastic scintillator,
  iv) with CS by both scintillators.
  (Hint: use spectra i) and iv) “far” to compare peak-to-Total and peak-to-Compton of ^{60}Co in exercise 5.5 for positions “far” and “close”).

- Calculate and compare the peak-to-Compton (1332.5 keV) and peak-to-total ratios for i) – iv). Discuss shortly the CS “effect” of one or the other scintillator taking in mind the geometry of the setup. In the case of the peak-to-total, consider the full area only above the CFD threshold visible in the spectrum with CS.

- Calculate the energy that a 1.0 MeV gamma-ray would leave in the HPGe if Compton-scattered under ($\theta = 10°$).

5.5 CS dependance on the source distance(geometry)

- Position the ^{60}Co source at two different places in the lead collimator ("close" and "far" from the HPGe detector). In the position "close" acquire one spectrum with and another spectrum without Compton-Suppression (CS) for 3 min each. In position "far" repeat the measurements with and without CS but this time 15 min each. (4 measurements in total) (Hint: You can skip measurements at position "far" and use data collected in i) and iv) of 5.4.)

- Position the ^{137}Cs source at two different places in the lead collimator ("close" and "far" from the HPGe detector). In the position "close" acquire one spectrum with and another spectrum without Compton-Suppression (CS) for 3 min each. In position "far" repeat the measurements with and without CS but this time 15 min each. (4 measurements in total)

- Determine the necessary numbers by fitting and integrating, and calculate the peak-to-Compton ratios (1332.5 keV and 661.7 keV) and peak-to-total ratios (^{60}Co and ^{137}Cs) for "close" and "far" with errors.

- Comment your results.

5.6 Precise energy- and relative-efficiency- calibration of the HPGe detector

- Acquire the CS spectrum of ^{152}Eu for 10 min. Use first the simple calibration (see 5.2) to identify the peaks ^{152}Eu. Determine the positions of the ^{152}Eu peaks with adequate fitting using the **tv**-Programm (or simmilar) and make an advanced linear energy calibration with error calculation:

$$E\ [keV] = a + b \cdot [\text{Channel}].$$

  Determine the FWHM values in keV. Plot the FWHM as a function of energy and check the dependance

$$\text{FWHM} \propto E^{1/2}.$$

- Use the peak areas for transitions with $I_{rel} > 10\%$ (see Table 6.1.2) to calculate with the relative efficiency of the HPGe (setup) for the respective energies and plot the results.

5.7 Gamma-spectroscopy identification of unknown source

- Like in a real experiment, measure for some time (depending on the source activity) the CS spectrum of an "unknown" source (will be set by the exercise supervisor).

- (if necessary, make a background correction.) And determine the energies and the intensities of all clearly visible lines in HPGe spectrum. Explain the origin of these lines and determine the radiationsource(s). (Hint: During the β^+-decay of an external source, one of the e^+e^--annihilation γ-quanta (which energy do these have?) can escape the source and be detected in the HPGe thus producing a line in the spectrum.)

6 Appendix

6.1 Laboratory sources

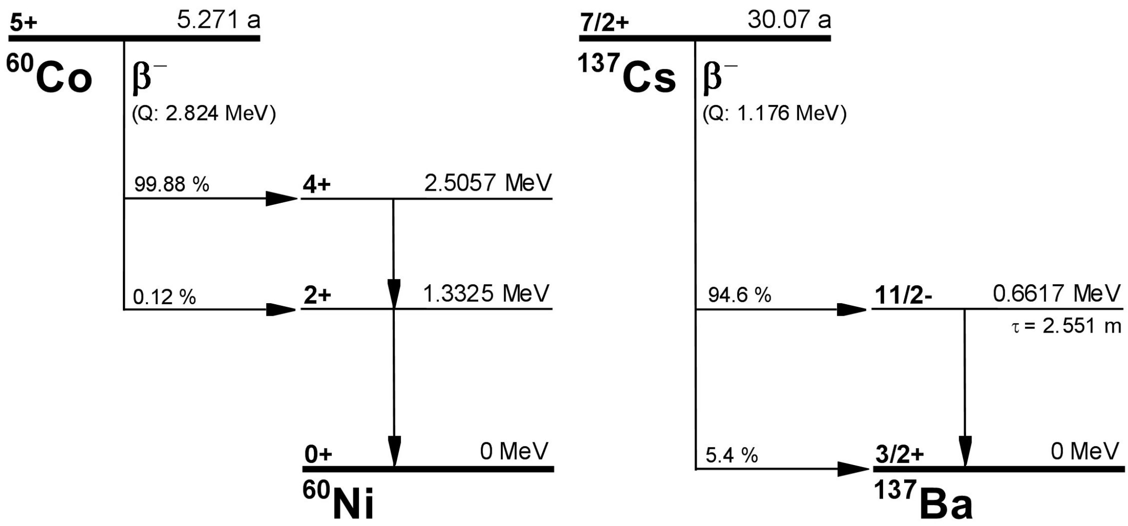
6.1.1 Properties of the sources

source	half-life	γ energy [keV]	rel. intensity	activity	date
^{152}Eu 7092	13.2 years	see Table 6.1.2		28.5 kBq	01.04.2006
^{137}Cs KM957	30.07 years	30 661.657	7 85.1	337 kBq	01.04.2006
^{60}Co KM955	5.2714 years	1173.228 1332.490	99.857 99.983	218 kBq	01.04.2006

6.1.2 Gamma-energies and relative γ-intensities of the ^{152}Eu source

γ energy [keV]	rel. intensity [%]	γ energy [keV]	rel. intensity [%]
121.78	136.2	867.34	19.9
244.69	35.8	919.40	2.1
295.94	2.1	964.13	69.2
344.28	127.5	1005.28	3.1
367.79	4.1	1085.91	46.5
411.12	10.7	1089.70	8.2
443.98	14.8	1112.12	64.9
586.29	2.2	1212.95	6.7
688.68	4.0	1299.12	7.8
778.90	61.9	1408.01	100.0
810.46	1.5	1457.63	2.3
841.59	0.8		

6.1.3 Level Schemes



6.2 Detector Datasheets

Plastic scintillator

HV:	CAEN PS 35-100 BM plus Voltage divider
Plastic height:	400 mm
Plastic ⌀:	400 mm
Voltage:	-2550 bis -2600 V global; nur PM 1: -100 V
PM ⌀:	127 mm

NaI scintillator

HV:	High Voltage Supply ORTEC
NaI height:	127 mm
NaI ⌀:	127 mm
Voltage:	+900 V

HPGe detector

HV:	5kV BIAS SUPPLY ORTEC
Voltage:	-2000V
HPGe Volume:	115 cm^3

References

[1] Bethge, Klaus:

Kernphysik

Springer Verlag, 2001

[2] Firestone, Richard B. *et al.*:

Table of Isotopes

Wiley-Interscience, 1999

[3] Hänsel, Horst & Neumann, Werner:

Physik - Atome, Atomkerne, Elementarteilchen

Spektrum, 1995

[4] Knoll, Glenn F.:

Radiation Detection and Measurement

Wiley, 2000

[5] Krane, Kenneth S.:
Introductory Nuclear Physics
Wiley, 1987

[6] Musiol, Gerhard *et al.*:

Kern- und Elementarteichenphysik

Harri-Deutsch, 1995

[7] Morinaga, Haruhiko & Yamazaki, T.:

In-Beam Gamma-Ray Spectroscopy

North Holland Publishing Company, 1976

Safe work instructions for electric powered equipment in the rooms for the practical course

Danger for people

Burns or death by high electric currants

Safety measures:

Pay attention that cables and plugs are not damaged and use them only in the way they are designed for.
In case of damage, or if you have the suspicion that they are damaged inform immediately your supervisor, do not try to repair anything yourself.
Use at maximum one extension cord and only for low powered equipment.
For equipment with large power consumption only wall outlets should be used.

In case of emergency:

Draw the mains plug.
In case of fire: Switch of all electrical equipment as far as possible

First aid:

People who can give first aid are Endres, Görgen, Rolke, Rudolph, Zell
In case of shock call immediately an emergency physician Tel. **01-112** (from any telephone in institute, or mobile **112**)
Hospital for accidents: evangelisches Krankenhaus Weyertal.
In case of all accidents also the managing director of the institute has to be informed.
In case of a working inability of 3 or more days an accident report form available from the secretary has to be filled.
The first aid box can be found in the inner stairwell.

23.07.2010
Zell

Universität zu Köln	**Safety work instructions**	**Nr.:** **Date:** 26.05.2010 Signaturet:

for the rooms of the practical course / institute for nuclear physics

IDENTIFICATION OF SUBSTANCE

Lead bricks
Lead bricks packed in plastic foil can be touched without precautions.
They are very heavy, **put them only in places where they can not drop on your feet!**
If the foil is damaged please pay attention to the following instructions:

DANGER FOR PEOPLE AND INVIRONMENT

Danger

Warning

May cause harm to the unborn child.

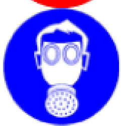
May cause damage to organs through prolonged or repeated exposure.

Very toxic to aquatic life with long lasting effects

Do not breathe dust/fumes/gas /mist /vapours/spray

Avoid release to the environment

SAFETY MEASURES AND RULES

Do not touch any lead brick with a damaged protective foil. If the foil is damaged or if you suspect that it is damaged please inform immediately your supervisor

Breathing equipment: In case of fire toxic metal oxide smoke can be released. Wear self contained breathing apparatus.

Protective equipment: If the protective foil is damaged, lead brick must be touched only with protective gloves**.**

IN CASE OF ACCIDENT

Fire brigade 01-112 from any phone, mobil 112

Leave the contaminated area and inform your supervisor. If lead dust has to be removed wear always safety glasses, protective gloves and in case of large quantities a breathing apparatus.
Fire extinguishing measures have to be taken according to the surrounding materials.
In case of a fire dangerous fumes are generated. Please take actions according to the emergency action plan. Call the fire brigade. Lead must not get in the sewage system.

FIRST AID

emergency physician 01-112, mobil 112

After eye contact: Rinse opened eye for several minutes under running water. Then consult doctor.
After skin contact: Instantly wash with water and soap and rinse thoroughly.
After swallowing: Seek immediate medical advice.
After inhalation: Supply fresh air. If required provide artificial respiration. Keep patient warm. Consult doctor if symptoms persist.

First aid can provide**: Endres, Görgen, Rolke, Rudolph, Thiel, Zell**

DISPOSAL

Do not put lead in the sewage or the dust bin. Disposal has to be made via Dr. Zell or Bereich 02.2

Safe work instructions for High voltage equipment in the rooms for the practical course

Danger for people

Instantaneous death by ventricular fibrillation

Safety measures:

Pay attention that cables and plugs are not damaged and use them only in the way they are designed for.
In case of damage, or if you have the suspicion that they are damaged inform immediately your supervisor, do not try to repair anything yourself.
Switch on the high tension only after the cables have been connected and switch it of before disconnecting.

In case of emergency:

Switch of the high tension
In case of fire: Switch of all electrical equipment as far as possible

First aid:

People who can give first aid are Endres, Görgen, Rolke, Rudolph, Zell
In case of shock call immediately an emergency physician Tel. **01-112** (from any telephone in institute, or mobile **112**)
Hospital for accidents: evangelisches Krankenhaus Weyertal.
In case of all accidents also the managing director of the institute has to be informed.
In case of a working inability of 3 or more days an accident report form available from the secretary has to be filled.
The first aid box can be found in the inner stairwell.

23.07.2010
Zell

Universität zu Köln	**Safe work instructions for liquid nitrogen**	**Nr.:** **Stand:** 26.05.2010 Unterschrift:

Institute for Nuclear Physics (rooms for the practical course)

GEFAHRSTOFFBEZEICHNUNG

Liquid nitrogen (cryogenic)

The semiconductor detectors are cooled by liquid nitrogen. If the container is tilted the liquid nitrogen may flow out. For this case you should know the risks and rules given here:

DANGER FOR PEOPLE

Cryogenic nitrogen can cause burns, spits can damage your eyes.
The evaporation of large quantities can cause suffocation by a lack of oxygen.

SAFETY MEASURES

The cooled detectors must not be moved by students

IN CASE OF EMERGENCY

Fire brigade 01 112 (mobil 112)

Please leave the room immediately and inform your supervisor, if liquid nitrogen flows out.

The supervisor should work in the region of the spilt nitrogen only with protective glasses and gloves and should look for an efficient ventilation.

In case of a fire the fire brigade should be alarmed. Any extinguishing measures should be taken according to the surrounding material.

Hospital for accidents: evangelisches Krankenhaus Weyertal.

FIRST AID

Notruf 01 112

The first aid box can be found in the inner stairwell.
People who can give first aid are Endres, Görgen, Rolke, Rudolph, Zell

Damages of the skin should be covered with a compression bandage.
In case of an injured eye both eyes should be covered and somebody should accompany the victim to a doctor.

In case of shock call immediately an emergency physician Tel. 01-112 (from any telephone in institute, or mobile 112)
Hospital for accidents: evangelisches Krankenhaus Weyertal.

In case of all accidents also the managing director of the institute has to be informed.
In case of a working inability of 3 or more days an accident report form available from the secretary has to be filled.

DISPOSAL

Just wait until the liquid nitrogen is evaporated.

Radiation protection directive for the handling of radioactive sources in the practical courses of the Institute of Nuclear Physics of the University of Cologne.

Issued September 17th 2010

1. Admission restrictions

Persons under the age of 18 years are not allowed to work in the practical course.

Pregnant women must not work with radioactive sources or in rooms in which radioactive sources are located.

Only students who have filled the registrations sheet and participated in the radiation protection instructions are allowed to carry out experiments with radioactive sources in the rooms of the practical course under the instruction of a supervisor. Visitors must not enter the rooms of the practical course when radioactive sources are located there.

2. Handling of radioactive sources

The radioactive sources are put in the experimental setup or in the lead shielding nearby by a radiation protection officer or an instructed person before the beginning of the practical course. These people document the issue in the list which is placed in the storage room (see appendix B). If radioactive sources have to be transported to other Physics institutes of the University of Cologne a list according to appendix A has to be attached to the transporting container.

When the practical course is finished the same people bring the radioactive sources back to the storage room.

A sign „Überwachungsbereich, Zutritt für Unbefugte verboten" which means „monitored in-plant area, admission only for authorized personal" has to be attached to the door of a room of the practical course when radioactive sources are inside.

It is not allowed to remove radioactive sources from the rooms of the practical course without contacting the radiation protection officer before.

During the practical course the radioactive sources must only be located at the place necessary for the measurements or behind the lead shielding nearby the experimental setup.

If you leave the rooms of the practical course make certain that doors are locked and windows are closed, even if you only leave for a short time.

Alpha-Sources are built in the experimental setup and students are not allowed to take them out.

Beta-Sources must only be handled by protective gloves or tweezers.

3. What to do in case of emergency

Any damages or suspected damages of radioactive sources must immediately be reported to the supervisor or the radiation protection officer. It is not allowed to continue work with such a source. Contaminated areas should be cordoned off immediately.

In case of fire, explosion or other catastrophic events besides the managing director and the janitor a radiation protection officer must be called in.

4. Radiation protection officers

Radiation protection officers for radioactive sources in the Institute for Nuclear Physics of the University of Cologne are

Name	Zell	Fransen	Dewald
Responsibity	Practical course	Experimental halls work with radioactive Sources except of the practical course	Work in other institutes Transport of radioactive sources accelerator