Institute for Nuclear Physics, University of Cologne

Practical Course Master

experiment no. 3.6
Lifetime Measurement

as at October 14, 2019

Abstract

The lifetimes of nuclear excited states are important observables in nuclear physics. Their precise measurement is of key importance for developing and testing nuclear models as they are directly linked with the wave functions of the nuclear system. Lifetimes in nuclear physics cover a wide range, from 10^{15} years to resonant states which have lifetimes $< 10^{-22}$ s. For lifetimes from the μs region down to the few ps region, the electronic fast-timing technique is most widely used. This technique provides a direct lifetime measurement by means of time-difference measurements between the γ rays which feed and decay from an excited state. Very fast LaBr$_3$(Ce) scintillator detectors with good energy resolution will be used to detect and select the γ rays. The analog energy signals of the detectors are connected to a digital acquisition system for a real-time digital pulse-shape analysis. The data are acquired in a time-ordered listmode format for coincidence analyses, such as the generation of γ-γ time-difference spectra. The lifetimes of the first excited 2^+ states in ^{152}Gd and ^{152}Sm as produced in the decay of ^{152}Eu will be measured. This practical course also delivers insight into modern digital data acquisition systems which make it possible to perform complex experiments, as are actually done at the 10 MV Tandem Accelerator of the IKP.

1   Introduction

After a certain process, i.e. a nuclear reaction or a decay of a radioactive isotope, the nucleus produced can be left in an exited state. This nuclear excited state is unstable and decays to other states with lower energy, most often via γ-ray emission. As a statistical process, γ-ray emission follows the radioactive decay law:

$$N(t) = N_0 e^{-\lambda t}, \tag{1}$$

where λ represents the γ-ray transition probability and is often called the decay constant. The mean lifetime of the nuclear excited state is given by the invers of the decay constant, hence: $\tau = 1/\lambda$.

Depending on the lifetime regime, different measurement techniques are used. For lifetimes in the region 10^{-6} - 10^{-11} s, the electronic *fast-timing technique* is well suited. This technique is based on the measurement of the time difference between the population of a given state and

its depopulation. An event through which a given nuclear excited state is populated is called 'feeder' and the event through which the state is depopulated is known as 'decay'. The main idea behind the γ-γ fast-timing technique is the selection of the feeder and the decay γ rays and use the time difference between these events to extract the lifetime of the state as a *direct method*. The elements of the standard γ-γ fast-timing setup presented in Fig. 1 are briefly described in the next section. Note that a 1.5-cm thick lead (Pb) shield is used to suppress inter-detector Compton scattering which introduce false coincidence events.
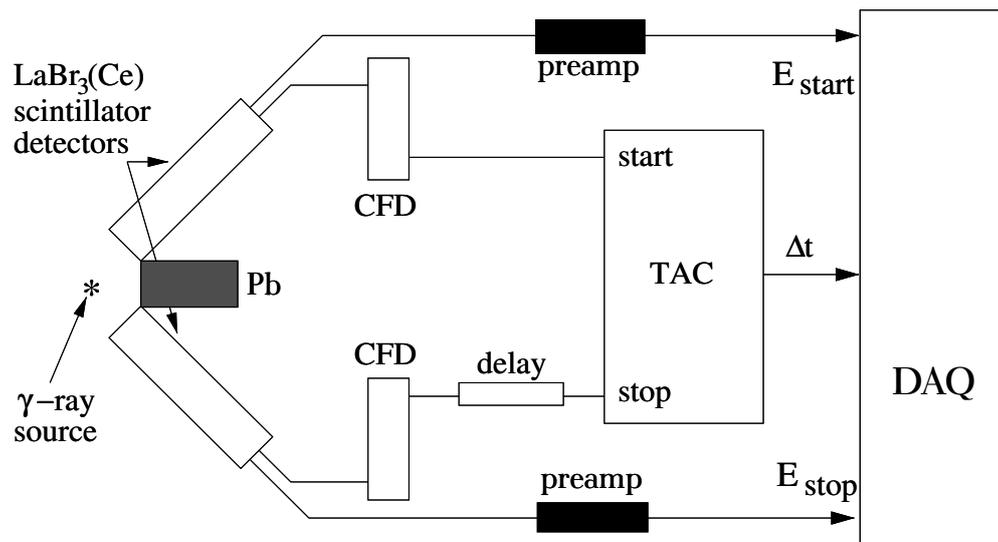
Figure 1: *The standard γ-γ fast-timing setup as used in this practical course.*

Keywords to be contained in the protocol:

- *Radioactive decay law*

- *Nuclear decays and γ-ray transitions, mean lifetime*

- *γ-ray interactions with mater*

- *Scintillators and Photomultiplier Tubes (see Ref. [3])*

- *True, false and random coincidences*

- *Electronic components (see Ref. [3]): Constant Fraction Discriminator (CFD), Time-to-Amplitude Converter (TAC), time-walk characteristics*

- *What are the sources of systematical errors?*

1.1   Shape and analysis of the time-difference spectra

The measurements are carried out with a coincidence-spectrometer consisting of two LaBr$_3$(Ce) scintillator detectors, each of them provide simultaneously a timing and an energy signal (see Fig. 1). The positive dynode pulse of the photomultiplier tube (PMT) is used for energy determination. The negative anode pulse, which has a larger amplitude compared to the dynode pulse, is used for the timing branch.

In the timing branch, the logic timing signal related to the detector signal is achieved by an analog constant fraction discriminator (CFD). The CFD produces a timing signal when the signal from the detector crosses a certain trigger level. This level is not fixed but is defined as *constant fraction* of the height of the detector signal. The energy dependency of this constant-fraction time pick-off method is minimized as compared to the case where the *leading edge* discriminator with a fixed trigger level is used. This non-linear energy dependency of the time pick-off is known as the *electronic time-walk characteristics* and needs to be taken into account when performing lifetime measurements using the fast-timing technique. The logic output signals of the CFDs are used as a *start* and a *stop* signal of a Time-to-Amplitude Converter (TAC). In order to ensure that the stop signal always arrives after the start signal an additional delay is added before the stop input of the TAC. The amount of the delay and the TAC range is chosen based on the lifetime to be measured. The height of the TAC output pulse is proportional to the time difference and is stored by the data acquisition system (DAQ), together with the amplitudes of the energy signals.

For a given feeder-decay combination, the γ-γ fast-timing set-up produces two *independent* time spectra, the delayed "d" and the anti-delayed "a" ones. The delayed spectrum is produced when the feeding γ-ray transition is selected as the start signal and the decay transition as the stop signal. The anti-delayed spectrum is produced vice versa.

In the simple case where no background is present, the delayed time distribution $D_d(t)$ is given as the convolution of the *prompt response function* (PRF) of the set-up $P(t)$ with an exponential decay:

$$D_d(t) = n\lambda \int_{-\infty}^{t} P(t_0 - t')e^{-\lambda t'}\,dt', \tag{2}$$

where n is the number of counts in the time spectrum and t_0 the position (centroid) of the PRF. The anti-delayed time spectrum $D_a(t)$ is given by simply inverting the time in this equation, which is equivalent to reversing the γ-ray selection of the detectors (see Fig. 2). The PRF is the time distibution of the fast-timing set-up related to a *prompt* coincidence. Two coincident events are considered as prompt if they occur simultaneously, e.g the two 511-keV γ rays produced in an electron-positron annihilation, or when the time difference is smaller then the time-resolving power of the system (around 1 ps in our case). It is important to note that both the centroid position and the full width at half maximum (FWHM) of the PRF depend on the amplitudes (energies) of the start and stop signals. The non-linear energy dependency of the centroid

(centre of gravity C^P) of the PRF is called the *experimental time-walk characteristics*. Depending on the lifetime τ to be measured, there are two methods to analyse the time spectra.
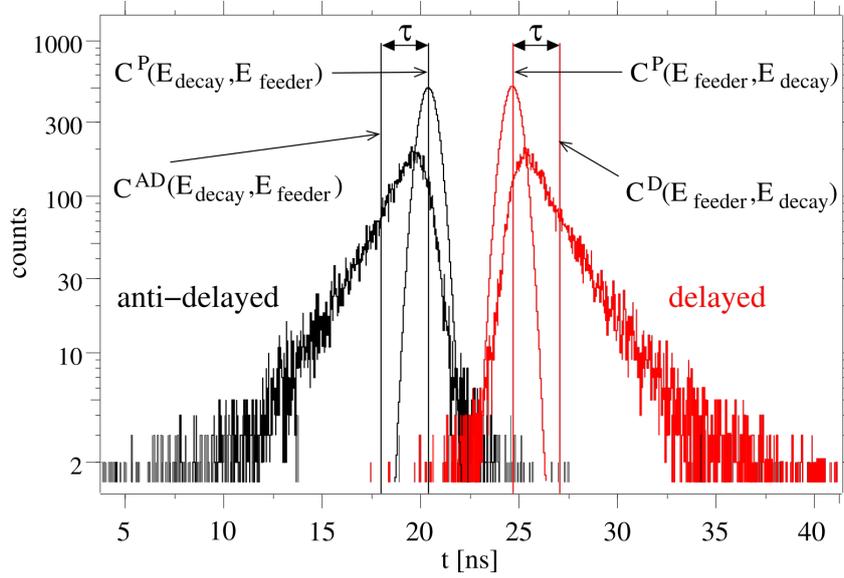
Figure 2: *The delayed and anti-delayed γ-γ time-difference spectra. The assumed Gaussian PRFs were separately deconvoluted from the spectra using Eq. 2. Note that in general: $C^P(E_{feeder}, E_{decay}) \neq C^P(E_{decay}, E_{feeder})$.*

1.1.1   The Slope Method

If $\tau \gg$ FWHM of the PRF, the time distribution is asymmetric with an exponential tail on the decay side of the time distributions. Usually, the time spectrum is presented in a semi-logarithmic plot where the decay is seen as a straight line, as illustrated in Fig. 2. Fitting an exponential decay to this tail yields the lifetime of interest, according to Eq. 1, which is true for the region where $D(t) > P(t)$. There however, the random (time) background needs to be taken into account as a constant value b (not as a variable) for the fit using:

$$f(t) = ae^{-\lambda(t-t_0)} + b. \tag{3}$$

1.1.2   The Centroid Shift Method and the Centroid Difference Method

In order to determine lifetimes which are similar to or shorter than the FWHM of the PRF, the centroid shift method is used. The centroid of the time distribution $D(t)$ is defined as the mean value of the time over the time distribution:

$$C(D(t)) = \langle t \rangle = \frac{\int_{t_{\min}}^{t_{\max}} t \cdot D(t)dt}{\int_{t_{\min}}^{t_{\max}} D(t)dt}. \tag{4}$$

In any fast-timing experiment, also random coincidences (time differences) are recorded. To avoid possible systematic errors related to the uniformly distributed random background, the integration limits should be set just at the beginning and the end of the time distribution.

The statistical error is given by the variance of $D(t)$:

$$\delta C = \sqrt{var[D(t)]} = \sqrt{\langle t^2 \rangle - \langle t \rangle^2}. \tag{5}$$

In the ideal case where no time-correlated Compton background contributes, the lifetime τ is determined by the centroid shift between the delayed and the corresponding prompt time distributions as:

$$\tau = C(D_d(t)) - C(P_d(t)), \tag{6}$$

or for the anti-delayed case:

$$\tau = C(P_a(t)) - C(D_a(t)), \tag{7}$$

where $C(P_{d/a})$ is the centroid of the PRF measured under the *same conditions* as $D_{d/a}$. Precise knowledge of the time-walk characteristics of both detectors is needed. This requires a complicated calibration procedure that is not praticable and also provide two additional sources of uncertainties. However, equations 6 and 7 can be combined into one equation to obtain two new quantities:

$$\Delta C(E_{decay}, E_{feeder}) = PRD(E_{decay}, E_{feeder}) + 2\tau. \tag{8}$$

By convention, the *centroid difference* is defined as:

$$\Delta C = C(D_d(t)) - C(D_a(t)) \tag{9}$$

and the *prompt response difference* (PRD) as:

$$PRD = C(P_d(t)) - C(P_a(t)). \tag{10}$$

The PRD describes the combined γ-γ time walk of the set-up. It is dependent on both the feeder and decay energies. Its energy dependence $PRD(E_{decay}, E_{feeder})$ is called the PRD curve. The PRD is mirror symmetric, hence: $PRD(E_1, E_2) = -PRD(E_2, E_1)$. This particularly means that the PRD vanishes when the start and stop signals have the same energy.

2 Tasks

In this laboratory exercise, the well known radioactive source ^{152}Eu is used to determine lifetimes. ^{152}Eu has two decay modes - via electron capture (EC) decay to ^{152}Sm and via β^- decay to ^{152}Gd. In both cases, also highly excited states are produced after the decay (see the level schemes in the Appendix). These states decay to the lower excited states, including the first excited 2^+ state, by a γ-ray cascade which ends in the stable ground state. By selecting the γ rays which feed and depopulate the first excited 2^+ state of a certain isotope and employing the fast-timing technique, the lifetimes of this state is obtained. The completion of this experiment contains the following tasks:

- Get familiar with the analog electronic components of the set-up.

- Get familiar with the digital DAQ (pulse-shape analysis and listmode-data acquisition).

- Carefully take notes of what you are doing. The protocol is part of the report and has to be readable as well as comprehensible.

- Answer the questions given in the next sections.

- Perform energy and time calibrations.

- Determine the energy-dependent time resolution of the setup.

- Determine the lifetimes of the first excited 2^+ states in ^{152}Sm and ^{152}Gd using:

    1. the slope method
    2. the centroid difference method.

- Discuss your results in a summary.

3   Experimental procedure

Careful adjustment of all settings of the set-up is absolutely necessary for the success of the experiment. Therefore one progresses along the way of the signals and make all adjustments in sequence. Once the correct settings are found, one proceeds to the next component and leaves the settings of the previous unchanged for the rest of the adjustment process. The assistant will lead you through the installation.

3.1   Settings of the Timing Branches

The aim of this part is to adjust the voltages of the detectors to provide nearly the same amplitude vs. energy characteristics. Also the timing settings of the two CFDs should be set to the same values. This is done in order to provide nearly the same electronic timing performance of the two detectors.

3.1.1   Anode Signals of the Detectors

Have a look at the anode pulse of the PMT using the oscilloscope. The largest γ-ray energy delivered by the ^{152}Eu source is 1408 keV. For both detectors, the PMT voltage should be adjusted in order to set the pulse height of the 1408-keV signal to approximately -1 V.
Advise: use the trigger level of the oscilloscope to isolate the 1408-keV signal.

Question: How fast is the anode pulse (rise time and decay constant)?

3.1.2   Constant Fraction Discriminator and Time-to-Amplitude Converter

Connect the anode signal of the PMTs to the Constant Fraction Discriminator (CFD). The shaping delay for the CFD is achieved by an external cable delay and it is set to approximately 2 ns.

Question: What is the working principle of a CFD?

As an important step, the time-difference spectrum generated by the TAC needs a time calibration. Use the *time calibrator* by connecting the start and stop outputs to the corresponding inputs of the TAC. The calibrator settings are: period - 20 ns, range - 160 ns. The TAC range is set to 100 ns. The assistant will record and store a time-calibration spectrum. Use the spectrum analyser software "tv" to measure the peak positions and perform a linear calibration to generate a 10 ps/channel time axis. Note the linear parameter of the fit.

Question: What is the time resolution of the TAC?

3.2 Digital pulse-height measurements and listmode-data acquisition

Have a look at the PMT dynode signal before and after the pre-amplifier.

Question: What is the pre-amplifier doing and why?

Connect the pre-amplified "energy signals" directly to the digitizer of the DAQ. There, the signal is digitized with a sampling frequency of 40 MHz. The pulse height of any signal is determined via real-time online digital pulse-shape analysis. For proper pulse-height determination, a set of parameters, e.g. related to the rise time and the decay constant of the input signals, need to be adjusted.
This is already done!

The assistant will explain the DAQ and "XiaStarter" to launch the listmode-data acquisition. The listmode data are stored into your personal directory in portions of 10 minutes "subruns". The listmode file comprises of a list of triples including the DAQ channel ID, the pulse height and the time of occurrence as a digital "timestamp" in units of 25 ns. The timestamp is given by the internal 40 MHz clock of the digitizer and is needed to identify time correlations (coincidences) between the detectors and the TAC.

- Start the DAQ for a two-hours trigger-less listmode-data acquisition.

3.3 Preparation of the listmode data

The lifetimes will be determined offline, after calibrations and coincidence conditions are introduced to the listmode data. Configuration files will be implemented with calibration and time correlation parameters. This is done to reduce the data size to be analysed by around 95% and thus to remarkably speed up the analysis. For this purpose, the first subrun of the listmode data is used to generate and analyse spectra. This is done by using the "soco2" sorting software, already after 10 minutes of the data acquisition.

3.3.1 Energy calibration

Change to your main directory and produce "singles" spectra without any condition using the command:

> soco2 dump -s -o singles 152Eu/Run01/listmode/*0001.lst

Change to the singles directory and use "tv &" to analyse the spectra which are stored according to their channel ID. Perform a linear calibration using the 122-keV and 779-keV full-energy peaks (FEP) of the spectrum. The calibration parameters must be stored in your main directory, in the following way:

channel ID   constant parameter   linear parameter

Use the editor "gedit &" and store the file as "calibration.conf". Also include the time calibration parameters of the TAC determined earlier (use only the linear parameter and fix the constant one to 0).

3.3.2   Coincidence analysis

Due to the limited γ-ray efficiency, most of the recorded γ rays in one of the detectors have no time correlation (coincidence) to γ rays detected by the other detector. True coincidences are seen as a time peak in the timestamp-difference spectra. In order to remarkably reduce random coincidences, two signals are considered to be time correlated if those time-difference is smaller than the size of a *coincidence time window*. When the set-up consists of more than two signals, e.g. the TAC output, the time peak for different signal combinations may be displaced by some OFFSET. The aim of this analysis is to align the timestamp peaks of the different combinations and to determine the optimum size of the coincidence time window.

To create the timestamp-difference spectra, the listmode data are presorted with a relatively large coincidence time window to ensure the true coincidences to be recorded. For this purpose, a DAQ-channel configuration and an appropriate coincidence requirement need to be defined. These configuration files are in your main directory: **channel.conf** and **requirement.conf**. The channel.conf includes the OFFSET parameters given in units of "ticks" (1 tick equals 25 ns).

1. Build the coincidence events with time window of 100 ticks for the first subrun using:
   > soco2 event -c channel.conf -r requirement.conf -o events 152Eu/Run01/listmode/*0001.lst -w 100

2. Generate the coincidence spectra without energy condition (gate) using:
   > soco2 gate -c channel.conf -C calibration.conf -o gatedspectra events/*0001.evt

3. Check the timestamp-difference peaks of the *.time.spc spectra using "tv &" in the gatedspectra directory and correct the OFFSETs in the channel.conf (use the editor "gedit &").

4. If the OFFSET has to be changed, repeat the procedure starting with point 1 until good overlap is achieved.

Question: How large is the optimum coincidence time window?

After fine tuning of all the parameters, more sophisticated coincidence analyses can be performed. First of all, the coincidence events of all the data have to be build using:

> soco2 event -c channel.conf -r requirement.conf -o events 152Eu/Run01/listmode/*.lst -w <optimum window size>

4 Lifetime determination

Originally, coincidence analyses are performed to identify γ-ray transitions which are in coincidence with other γ-ray transitions in order to build up the level scheme of a certain isotope. A narrow energy window (gate) is set on the FEP of a γ ray to generate a gated coincidence spectrum, that ideally only includes the FEPs of a subsequent cascade of few γ rays. For lifetime determination, two gates need to be defined in order to generate the picosecond-sensitive time-difference spectrum (the TAC spectrum) of the γ_{feeder}-γ_{decay} cascade. The gate width should correspond to about the FWHM of the FEP seen in the energy projections of the LaBr$_3$(Ce) detectors. The projections can be generated without gate using:

> soco2 gate -c channel.conf -C calibration.conf -o gatedspectra events/*.evt

- Save the calibrated γ-ray projections for your report.
- Create in the main directory the file "gate.conf" with following information:

channel ID   min E [keV]   max E [keV]

To generate energy-gated spectra, just add the "-g gate.conf" option to the "soco2 gate" command line. Any spectrum can be analysed using "tv &". Most importantly for your report is to save the relevant spectra in ASCII format. The following command has to be given in the root of tv:

> s w specname.txt'32k.txt <index>

where <index> is the tv index of the spectrum. A list of tv commands will be provided by the assistant.

4.1 Determination of the lifetime of the first excited 2^+ state in ^{152}Gd

In order to properly define the energy gates, the coincidence projection should be examined for the strong 344-keV $2_1^+ \rightarrow 0_1^+$ FEP. Define the 344-keV gate in the gate.conf file and proceed as follows:

Note: Any line in the configuration files can be out-commented with a "#"

1. Generate the 344-keV gated coincidence γ-ray spectrum for each detector and save them for your report. Define the 411-keV and 779-keV gates. What else than the FEPs are seen at these energies? What are the relative energy resolutions at 411 and 779 keV? Why is it dependent on the energy?

2. Select start and stop gates to produce the delayed time spectrum (TAC spectrum) of the 779-344-keV cascade and save it for your report. All time spectra have to be presented in a semi-logarithic plot.

3. Generate the anti-delayed 344-779-keV time spectrum and also the two time spectra of the combination 411-344 keV (save the spectra).

4. Question: How large is the FWHM (related to the time resolution) of the fast-timing set-up? Why is it dependent on the energy?

5. Determine the centroids of the four time spectra according to Eq. 4 using tv (ask the assistant).

6. Calculate the centroid differences $\Delta C(344, E_{feeder})$ using Eq. 9 and plot the two values at the corresponding energy of the feeding γ rays in the $E_{ref.}$ = 344-keV centroid-difference diagram. Fit the two values with a straight line and extract the lifetime from the extrapolated value at $E_{ref.}$ = 344 keV, according to Eq. 8.

7. Compare the result with the literature value and discuss possible systematic errors of the method.

4.2   Determination of the lifetime of the first excited 2^+ state in ^{152}Sm

The first 2^+ state in ^{152}Sm is about 2 ns and therefore, the TAC-spectrum resolution can be reduced to 100 ps per channel. This is simply achieved by dividing the linear parameter of the TAC calibration by factor 10 (calibration.conf file).

1. Proceed as in Section 4.1 to define the 122-keV and 244-keV gates; generate the 122-keV coicidence γ-ray spectrum for discussion in your report.

2. Generate the two time spectra of the 244-122-keV cascade with TAC-spectrum resolution of 100 ps/channel.

3. Use the Slope Method do extract the lifetime and show the result in a semi-logarithmic plot. Discuss on possible systematic errors of the method and compare the results with the literature value.

A Appendix

A.1 Decay schemes
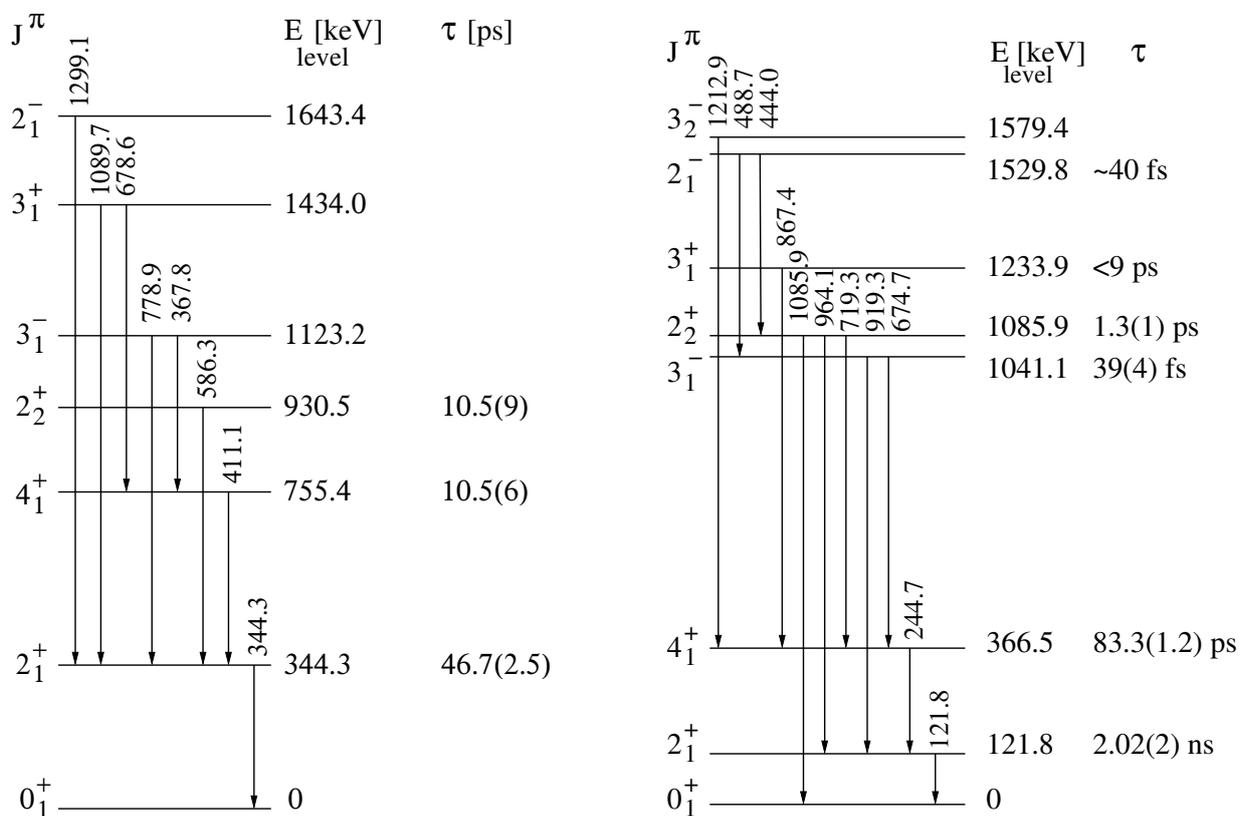
Figure 3: *Level schemes of ^{152}Gd (on the left) and ^{152}Sm. The mean lifetimes τ are from the National Nuclear Data Center; http://www.nndc.bnl.gov/ensdf/*

B Operating instructions

Operating instructions for electric powered equipment in the rooms for the practical course

Danger for people
Burns or death by high electric currents

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:
Pull 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 Görgen, Rolke, Rudolph, Thiel

In case of shock call immediately an emergency physician Tel. **01-112** (from any telephone in the 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.

13/11/2014
Blazhev

Operating 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 Görgen, Rolke, Rudolph, Thiel

In case of shock call immediately an emergency physician Tel. **01-112** (from any telephone in the 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.

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13/11/2014
Blazhev

Universität zu Köln	**O p e r a t i n g i n s t r u c t i o n s**	**Nr.:** **Date:** 13.11.2014 Signature: A. Blazhev

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

I D E N T I F I C A T I O N   O F   S U B S T A N C E

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:

D A N G E R   F O R   P E O P L E   A N D   E N V I R O N M E N T

Danger

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

Warning

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

Avoid release to the environment

S A F E T Y   M E A S U R E S   A N D   R U L E S

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**.**

I N C A S E O F A C C I D E N T	**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.

F I R S T A I D	**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: **Görgen, Rolke, Rudolph, Thiel**

D I S P O S A L

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

**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 13/11/2014

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 personnel" 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	Heinze	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

References

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