Experiment Guide:
RM3 – Neutron Activation

Introduction

In this experiment, samples are exposed to neutrons emitted from an **americium-beryllium (Am-Be) neutron source**. The resulting nuclei are beta-minus emitters. Using a **PC-controlled measurement setup**, the beta radiation is recorded at constant time intervals. From these measurements, the **half-lives and the achieved activities** of the activated samples are estimated.

The experiment consists of the following steps:

1. **Detector setup and calibration** using a known beta source (^{137}Cs).
2. **Measurement of thermal neutron fluence rate** using gold samples (one cadmium-coated, one uncoated).
3. **Activation of additional samples** (Al, Ag, V, Mn, NaCl) and analysis of their beta decay time dependence.

The goal is to **verify reaction products** by analyzing the time-dependent intensity of beta radiation.

Detector Setup and Calibration

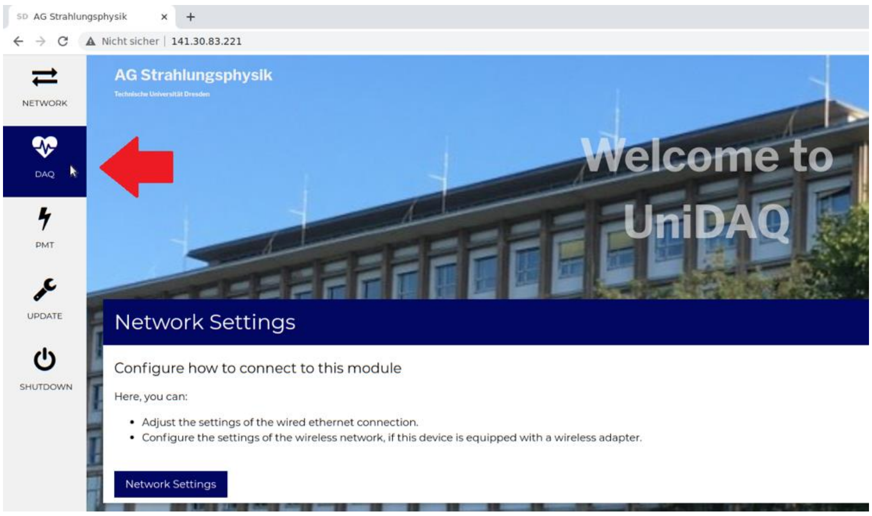
PC-detector connection

1. Connect the USB cable of the detector to PC for the power supply
2. On the digitizer of the detector, you will find the IP address (something like 141.30.83.XXX, see figure)
3. Open Google Chrome and enter the detector's IP address in the address bar.

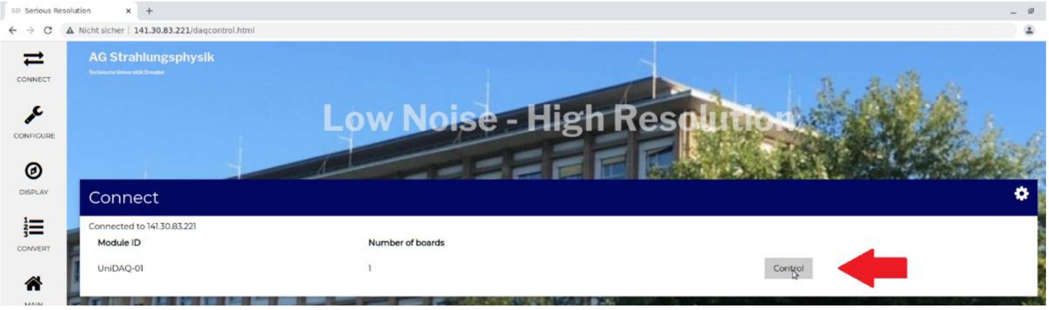
This will open the detector's **web interface**, where configurations and measurements are controlled.

Detector configuration

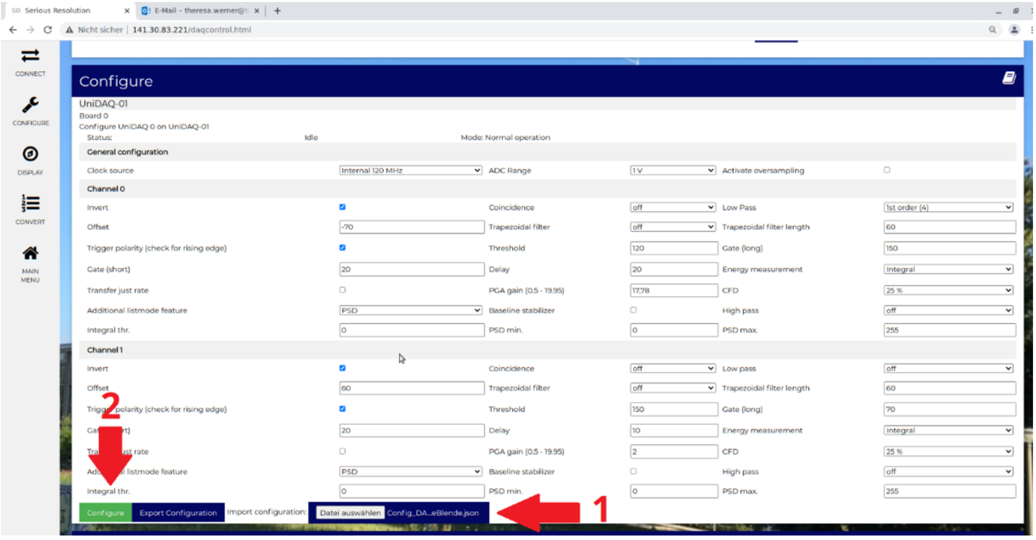
1. Click on DAQ button



2. Click on Control button



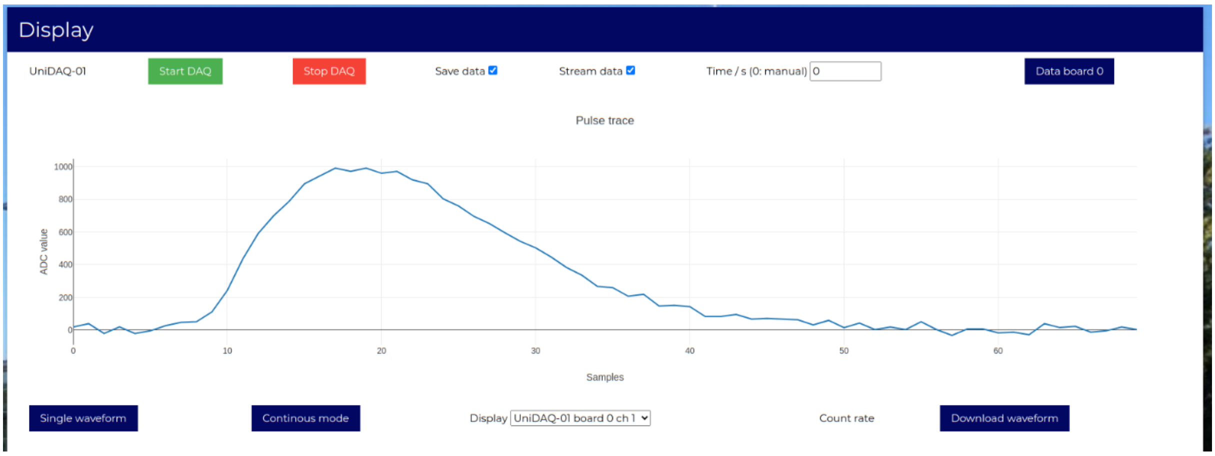
3. Click on “Datei auswählen” button and browse:
   `/Desktop/Detector_Configuration/Config_DAQ_xxxxxBlende.json`
   then Press: “Configure”



Optional: change the configuration parameter and press “Configure” again.

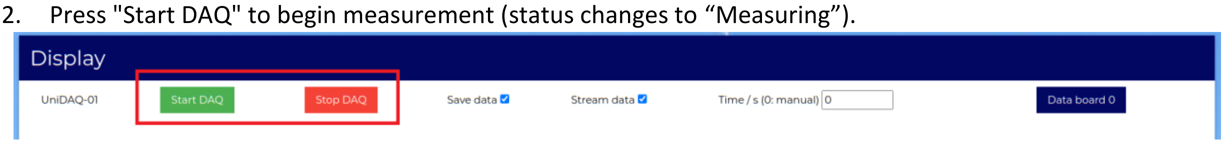
Measurement

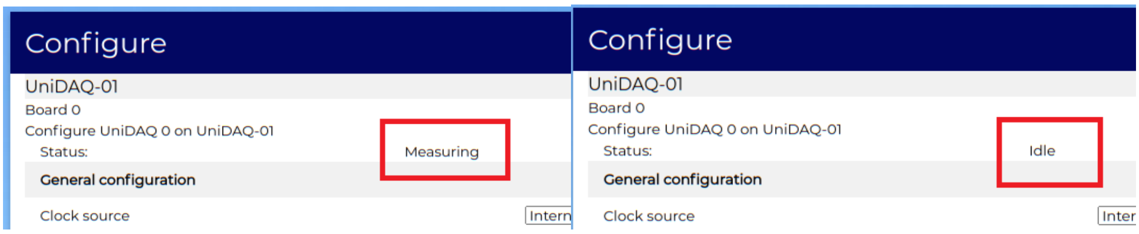
1. Click on “single waveform” or “continuous mode”



Adjust configuration settings (offset, threshold, long gate,…)

2. Press "Start DAQ" to begin measurement (status changes to “Measuring”).



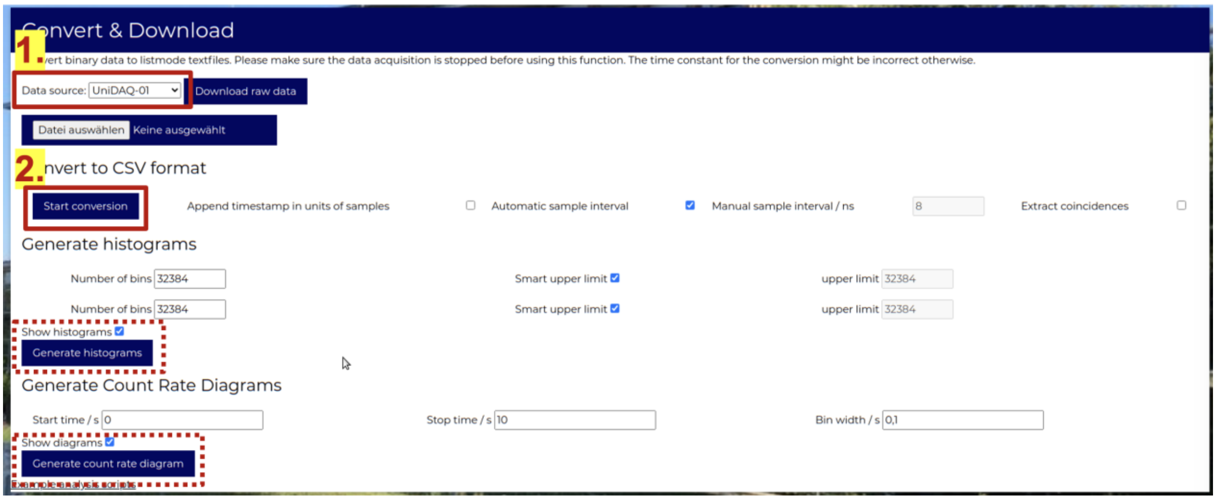


3. Press “Stop DAQ” to end measurement. (status returns to *Idle*).

Export Data

1. Click on “data board” button to save the raw (binary) data

2. Scroll down to “Convert & Download”
3. Choose data source : UniDAQ-01
4. Click on the “Start conversion” button. This generates a “xxxx.txt” file in the download folder
5. It is also possible to generate pulse or count rate histograms, use corresponding buttons



Data Format

The raw data is stored in the csv format, where the values in the row are separated with “;”. The columns are

- Channel
- time/s
- energy/channel
- PSD or risetime

```
Datei  Bearbeiten  Format  Ansicht  Hilfe
#Sample interval: 16.68302389813908 ns
#Gate length: ch0: 60 ch1: 30
#Format:
#Channel;time/s;energy/channels;PSD or risetime
0;0.0071173006420216;516;192
1;0.009708527855307564;418;0
0;0.025837446489794327;498;85
0;0.030135296021267296;6193;32
```

Instructions for Data Analysis

The measurements are stored in the Downloads folder and they can be imported into any analysis program. On the computers, SciDAVis is provided. Any other program is fine, as long as the resulting plots are of good quality. The recommendation is to work with the binned data obtained from “Generate Histograms” and “Generate count rate diagram”. Keep consistent settings when analyzing different datasets.

Task 0: Detector Calibration using ^{137}Cs beta source

Ensure the detector is correctly configured and operational before proceeding with measurements. The calibration uses a **^{137}Cs beta source** to validate the detector's response and optimize settings (threshold, voltage) for accurate data collection.

Calibration

Background Verification. Ensure the detector's **count rate without a sample** is close to zero.
If the background count rate exceeds **2 counts per second (cps)**:

Increase the threshold *or* **Decrease the voltage**.

Radiation from the source. Insert the **^{137}Cs source** and observe the spectrum.
If the spectrum appears **too compressed** (e.g., insufficient resolution):

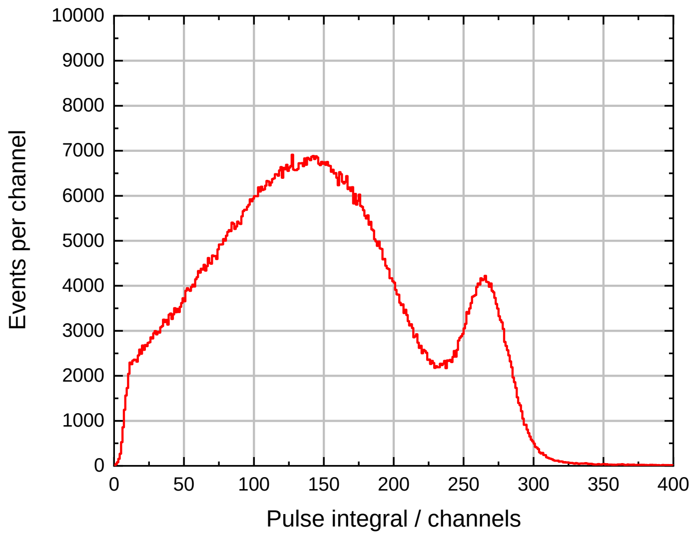
Decrease the threshold *or* **Increase the voltage**.

Iterative Adjustment. Repeat the process until:

- The **background count rate is minimal** (< 2 cps).
- The **source spectrum is well-resolved**.

To modify the detector settings (threshold/voltage):

1. **Stop the ongoing measurement** ("Stop DAQ").
2. Adjust the parameters in the configuration file.
3. Press "**Configure**" to apply changes.
4. Restart measurements ("Start DAQ").



Sample pulse charge histogram from the ^{137}Cs source. Channel numbers can be different due to different high voltage and amplifier settings.

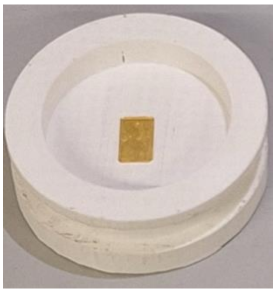
Report

In your final report, include:

1. Detector Parameters: Applied **voltage** and **threshold** values.
2. Source Measurements
   - **Count rate** (cps) of the ^{137}Cs source.
   - **Pulse charge histogram** (energy spectrum).
3. Compare your measured spectrum with the **known beta energy spectrum of ^{137}Cs** (Nudat3 database)

Taks 1: Measurement of Thermal Neutron Fluence Rate

This task aims to measure the thermal neutron fluence rate. We will use gold for this purpose, as it is particularly easy to activate due to its large effective cross-section.



While gold readily captures thermal neutrons, it's important to note that activation occurs through both thermal and higher-energy neutrons (as evident from resonance peaks in the cross-section curve). To isolate the thermal neutron contribution, we use a differential measurement technique using two identical pure gold samples:

1. A cadmium-shielded sample (cadmium absorbs all neutrons with energies >0.5 eV)
2. An unshielded reference sample

Both samples have been irradiated to saturation activity prior to the lab and should be ready to be taken out.

Procedure

1. Insert each activated gold sample into the detector, maintaining identical positioning for both measurements
2. Record beta activity from each sample for a duration of 10 minutes
3. Ensure consistent detector geometry and configuration for both measurements

Provided Data

- Sample mass: 1 g (for both samples)
- Thermally averaged cross-section for the reaction $^{197}\mathrm{Au}(\mathrm{n},\gamma)^{198}\mathrm{Au}$: (98.65 ± 0.09) b.
- Saturation activity of unshielded gold (determined for this sample using a coincidence measurement): (57.4 ± 0.2) kBq
- Nuclear properties of ^{198}Au (to be researched):
    - Beta decay half-life
    - Electron emission probability
    - Mean beta energy
    - Associated photon emissions

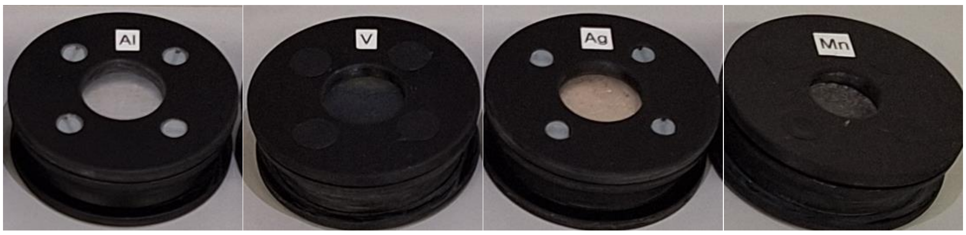
Report

Your final report must include:

1. The calculated fraction of activity attributable specifically to thermal neutrons.
2. The derived thermal neutron flux density.
3. The detector efficiency for the gold samples
4. (Optional) Comparison of activity measurements between the top and bottom surfaces of the unshielded gold sample

All calculated values must be reported with uncertainties.

Task 2: Time Dependence and Detector Efficiencies of Various Samples



In this task, we will study how different materials respond to neutron radiation by measuring their beta decay over time. We want to confirm that the radiation patterns match what we expect based on the principles of nuclear physics.

You will work with these sample options:

- Aluminum (Alloy 7075, smooth surface): 3.5 grams
- Aluminum (Alloy 7075, grooved surface): 3.6 grams
- Pure silver: 6.27 grams
- Pure vanadium: 0.21 grams
- Pure manganese: 0.37 grams
- Sodium chloride (table salt): 0.5 grams

Procedure

1. Choose at least two different materials to test.
2. Plan Your Experiment:
    - Identify what nuclear reaction will occur for each sample
    - Calculate how long to expose each sample to reach 95% of maximum activity
    - Decide how long to measure each sample's radiation
3. Run the Experiment:
    - Place your sample in the neutron source
    - When it reaches the target activity, quickly move it to the detector
    - Begin measuring immediately to track how the radiation changes over time

Coordination within the group is important for the experiment. Start recording data exactly when you remove the sample from the neutron source (this will be time zero in your measurements).

Data

The mass and composition of samples is provided above.

For each sample you choose, research:

- The specific nuclear reaction that occurs
- The average energy of the beta particles
- Half-life, emission probability and cross-section

Report

The following measurements should be included in the final report:

- Time dependence of Count rate. Verify whether these measurements are consistent with the expected reaction products
- Achieved activity after irradiation. Use the neutron flux density values obtained in Task 1 for these calculations
- Detector efficiency estimation. Determine and report the detector efficiency for each sample

Additionally:

- Compile and summarize the detector efficiencies for all tested samples (including gold from Task 1)
- Analyze and discuss how these efficiencies depend on:
    - Sample geometry
    - Average beta energy of the decay products

All reported values should include proper uncertainty analysis.