Atomic and nuclear physics

Nuclear physics

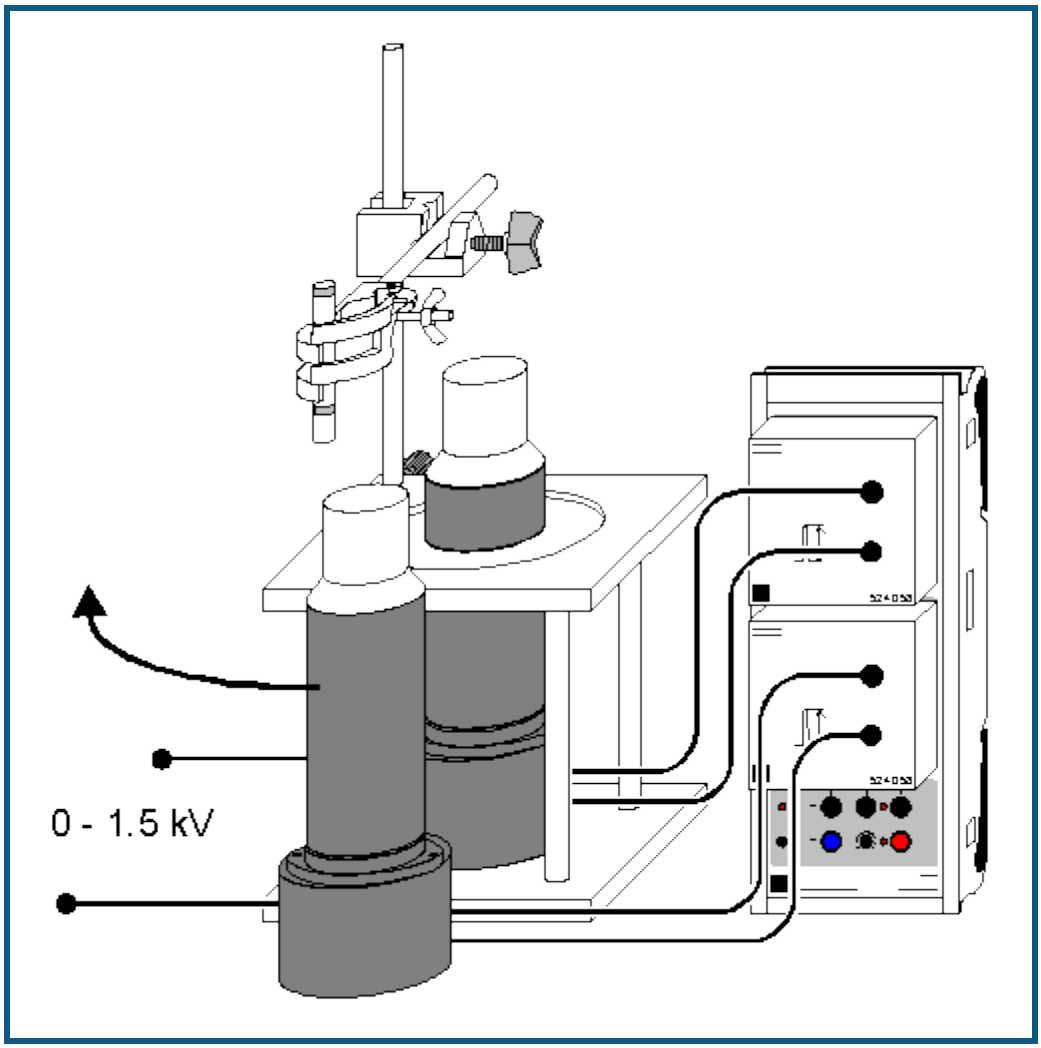
γ spectroscopy

Coincidence and γ-γ angular correlation in positron decay

Description from CASSY Lab 2

For loading examples and settings, please use the CASSY Lab 2 help.

Coincidence and γ-γ angular correlation in positron decay



Safety note

When handling radioactive preparations, in addition to the radiation protection regulations, state-specific requirements and the regulations of the educational authorities are also to be observed, e.g. in the Federal Republic of Germany at the very least the radiation protection regulations (StrlSchV - Strahlenschutzverordnung) and the directives on safety during school lessons. The preparations used in this experiment are type approved according to StrlSchV (2001) or they are below the exemption limit and do not require approval. For this reason handling without express permission is possible.

Since the used preparations produce ionizing radiation, the following safety rules must nevertheless be kept to:

- Prevent access to the preparations by **unauthorized persons**.
- Before using the reparations make sure that they are **intact**.
- For the purpose of **shielding**, keep the preparations in their safety container.
- To ensure **minimum exposure time** and **minimum activity**, take the preparations out of the safety container only as long as is necessary for carrying out the experiment.
- To ensure **maximum distance**, hold the preparations only at the upper end of the metal holder.

Experiment description

The spatial coincidence of the two γ quanta in electron-positron pair annihilation is demonstrated. The conservation of momentum requires emission of the two quanta at an angle of 180°, which is visualized in the experiment. Selective measurement of a coincidence spectrum leads to the suppression of non-correlated lines.

Equipment list

1	Sensor-CASSY	524 010 or 524 013

1	CASSY Lab 2	524 220
2	MCA boxes	524 058
1	Na-22 preparation	559 865
1	Set of 3 radioactive preparations	559 835 or 559 845
2	Scintillation counters	559 901
2	Detector output stages	559 912
2	High-voltage power supplies 1.5 kV	521 68
2	Sockets for scintillator screening	559 891
1	Stand rod, 47 cm	300 42
1	Leybold multiclamp	301 01
1	Universal clamp, 0...80 mm	666 555
1	PC with Windows XP/Vista/7/8	

Experiment setup (see drawing)

The output stages of the scintillation counters are connected to the MCA boxes and to the high-voltage power supplies. Both MCA boxes must be plugged in the same CASSY. The preparation is placed near one scintillation counter with the stand material so that the other detector can be moved around the setup, in order that the angle detector 1 - preparation - detector 2 can be varied.

Carrying out the experiment

- Load settings
- Select the display **Energy calibration**
- Use the two detectors to record the normal Na-22 spectrum each with
- In the Settings NA calibrate input A, and in the Settings NB calibrate the detector at input B
- Select the display **511 keV**
- In the Settings NA set the measurement to the **Coincidence trigger for the other box** and adjust the coincidence window to the 511 keV line (mark with two vertical lines)
- Place the movable detector so that the preparation is located between the detectors. Record the coincidence spectrum with .
- Place the movable detector so that it is located perpendicularly to the connecting line preparation - other detector. Record the coincidence spectrum with .
- Select the display **1275 keV**
- In the Settings NA set the coincidence window to the 1275 keV line (reset the old window by pressing → **0** ← and mark the new window by means of two vertical lines)
- Record the coincidence spectrum at 180° and at 90° each with .
- Select the display **Cs-137 and Na-22**
- In the Settings NA set the coincidence window to the 511 keV line (reset the old window by pressing → **0** ← and mark the new window by means of two vertical lines)
- Fix the Cs-137 preparation together with the Na-22 preparation between the detectors, place the movable detector so that the preparations are located between the detectors. Record the coincidence spectrum with .
- Record the normal MCA spectrum of this arrangement.

Evaluation

The normal Na-22 spectrum consists of a line at 1275 keV and the pair annihilation radiation at 511 keV. The two 511 keV quanta are correlated in time and space (emission under 180°). The 1275 keV quanta are correlated with the 511 keV quanta in time as the delay of 3.7 ps cannot be detected with this setup. This emission is not correlated in space.

In the normal MCA spectrum both lines are visible. At 180° coincidence, the 511 keV line clearly stands out because the other components of the spectrum (1275 keV line, Compton distribution) are correlated in time only and not in space so they are weakened by the solid angle of the second detector relative to the 511 keV line, which is correlated in space. Thereby the absolute counting rate of the 511 keV line drop according to the detection probability of the second detector.

If the detector is swivelled out of the 180° direction, the 511 keV line disappears, whereas those components that are not correlated in space remain unchanged.

If the measurement is made in coincidence to the 1275 keV line, there is no correlation in space. Therefore the spectra look the same at different angles. Since there is only one 1275 keV quantum per decay, no 1275 keV line is observed in coincidence.

In order to show the suppression of quanta that are not correlated in time, two preparations are used at the same time. Cs-137 provides a non-correlated background, which is only visible in the coincidence measurement because of accidental coincidence, whereas it is clearly visible without coincidence measurement.

Remark

The time window for coincidences has a fixed default value of 4 µs.