GEIGER-MÜLLER
IONIZING RADIATION SENSOR
DESCRIPTION D029BT

Figure 1. The GM - Ionizing Radiation Sensor

Short description

The Geiger-Müller Ionizing Radiation sensor detects low level beta and gamma radiation. It is possible to detect background radiation, as well as low level radiation, emitted by radioactive sources, like potasium fertilizers or a gas lantern mantle.
The sensor can be used as a counter to monitor counts (or counts per interval) from a radiation source (BT connector) or to measure the operating voltage applied to the GM tube (4-mm yellow output).
The power required by the sensor is supplied by the 5V-power supply on an interface.

The GM sensor is delivered with a BT-plug and can be connected to the following interfaces (with a counter input):

- UIA/UIB through the Measuring console (via 0520 adapter)
- CoachLab II.

An adapter (art. 0520) is available to connect sensors with BT-plugs to 4-mm inputs.

How the GM sensor works

The sensor contains a halogen quenched GM-counter tube which detects beta and gamma radiation with energies above 0.4 MeV.
Each count event is accompanied by a short positive pulse (5V, 0.265 ms) on pin 1 of the BT connector. Each event is indicated visually by a flash of the LED on the sensor and accustically by a 3 kHz beep of 84.5 ms.

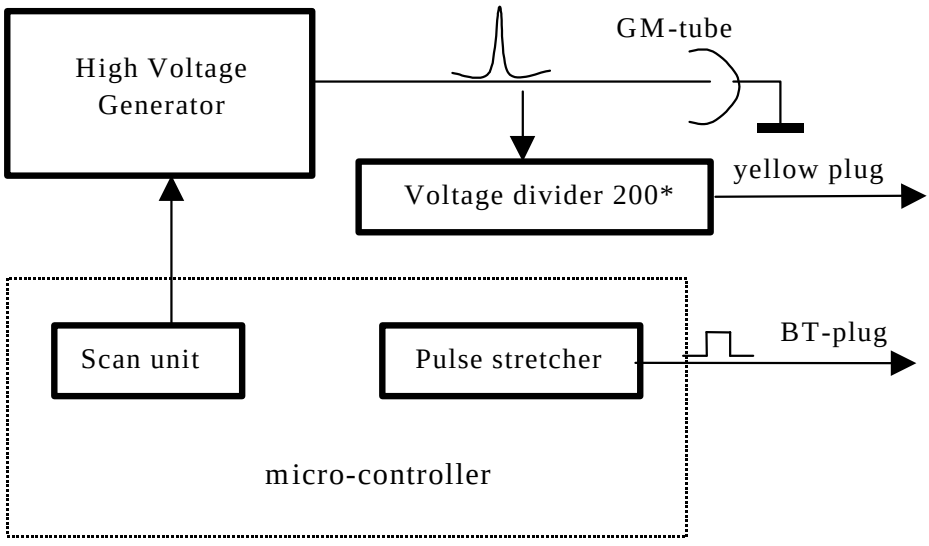

Figure 2. Circuitry of the GM-sensor.

By default the GM tube of the sensor operates at approximately 500V. The high voltage (operating voltage) applied to the GM tube can be varied. By pressing the red button on the sensor the operating voltage range between 300 and 650V is automatically swept. The low-level light of the sensor LED visualizes this operation mode. The sweep time is 10 minutes[1].
This mode allows investigating the characteristic of the Geiger-Müller tube. The applied operating voltage can be measured precisely. For such measurements the yellow output (HV Monitor), at the left side of the sensor should be connected to an analog input of the interface (see figure 4).
On the yellow output the operating voltage is scaled down by a factor 200 (to the range from 1.5 to 3.25V at impedance of 1.5 kΩ) (see figure 2.).
When the operating voltage increases significantly above the nominal 500 V level (during the sweep mode), the GM tube may generate series of pulses for each particle.

Suggestion for experiments

The CMA Geiger-Müller Ionizing Radiation sensor allows to:
- detect the presence of a radiation source;
- monitor the background radiation;
- measure radiation of common radioactive materials such as potassium salts or lantern mantels etc;
- investigate the Geiger-Müller tube characteristic (measuring counts per interval (rate) from a beta or gamma radiation source as a function of the operating voltage of the GM tube);
- determine the half-life value for short lived nuclides;
- monitor counts per interval (rate) as different thickness of a shielding are placed between the GM sensor and a beta or gamma source;
- compare the effects of different types of materials to shield beta or gamma radiation;
- monitor counts per interval (rate) from a beta or gamma radiation source as a function of the distance between the source and the GM sensor.

Example of experiments

Detailed description how to perform the example experiments with Coach 5 can be found in the appendix 'Coach 5 Activities for the Geiger-Müller sensor'.

Monitoring the background radiation and radiation of radioactive materials

If the GM sensor is set up far away from any radioactive sources it still detects pulses occasionally. This is due to the so-called 'background' radiation that is a result of radiation that occurs naturally from cosmic radiation, geophysical radiation, inherent material radiation, etc. The level of background radiation is usually very low, but it

[1] For some sensors this sweep time can be 8.6 minutes.

does vary from place to place.
Since the background radiation is present in all experiments, it should be measured and subtracted from the experimental readings for these to be reliable.
Measurement of the background radiation illustrates another feature of the counting of pulses from radioactive sources: the background radiation is emitted randomly and the experimentally collected data shows this "randomness".
Since all radioactive sources emit randomly, the same phenomenon appears in all measurements of the radiation level. The only way to increase the accuracy is to measure more events (i.e. to choose a long running time).

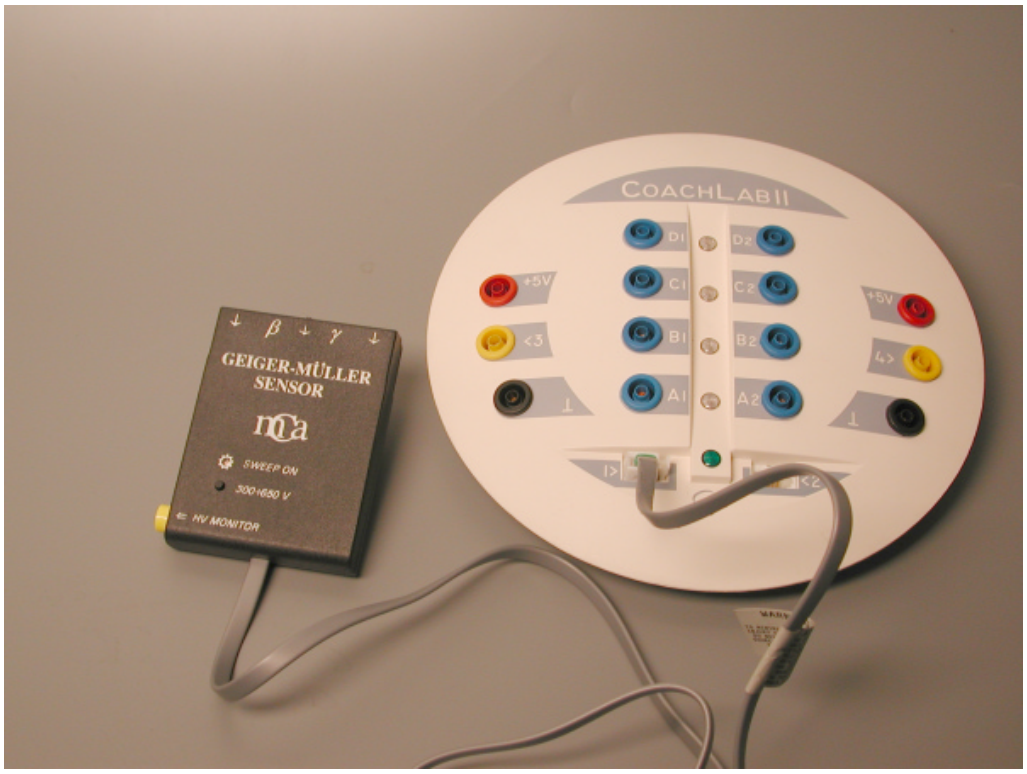

Figure 3. The GM sensor connected to the analog input 1 of the CoachLab II interface.

Characteristic of the Geiger-Muller tube (relation between operating voltage and number of count events)

For this experiment the BT connector of the GM sensor has to be connected to a counter input of the interface. Through this input pulses from the GM tube are detected. The yellow 4-mm output, at the left side of the sensor, should be connected to an analog input of the interface. Through this input the operating voltage applied to the GM tube is measured. By pressing the red button the operating voltage range is automatically swept (in 10 minutes). It is recommended to average several individual runs. To improve the quality of the data the background radiation should be subtracted.

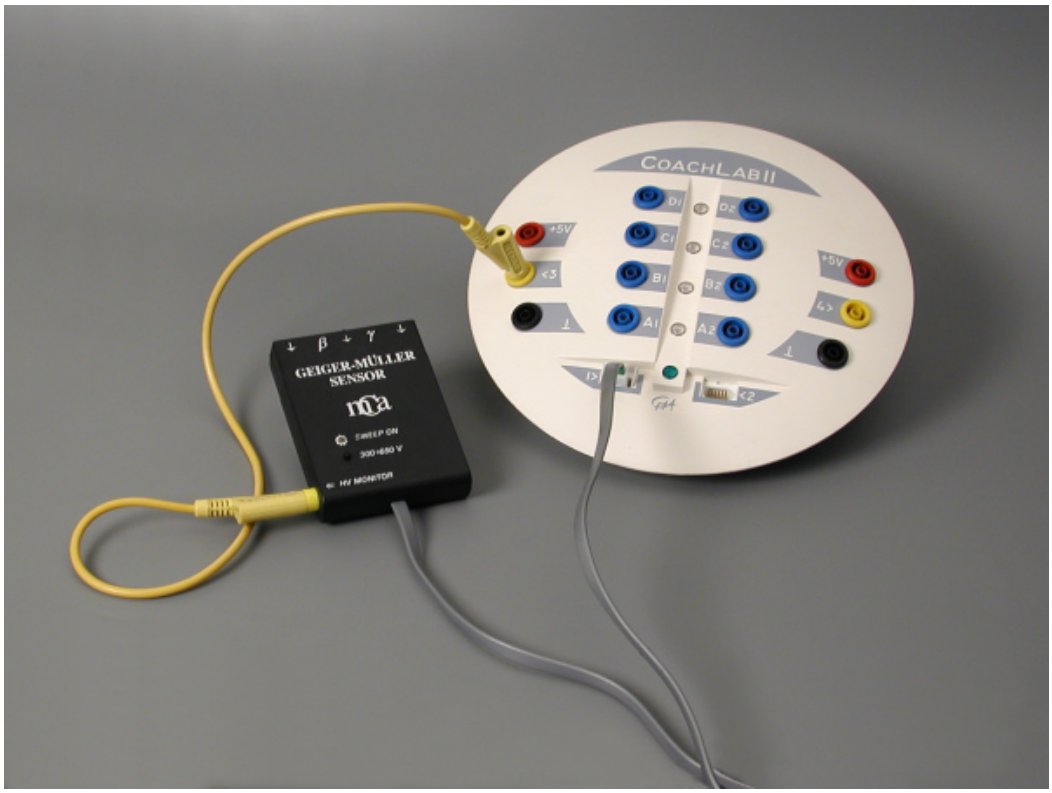

Figure 4. The operating voltage applied to the GM tube is measured through input 3 (4-mm yellow cable) and the number of counts per interval is measured through input 1 (BT connector).

Radioactive decay and half-life determination

The GM sensor gives the possibility to measure radioactive decay rate and half-life. Radioactive decay can be expressed with the following formula:

$$N(t) = N_0 e^{-lt}$$

where λ is the decay rate constant. The decay constant is characteristic for a given radioactive species and isotope, and can thus be used to identify the contents of a radioactive sample.

The half-life is the time required for half of the atoms present to decay.

A linear plot of the natural log of the decay rate versus time can be used to determine the half-life of an isotope.

$$\ln \frac{N}{N_0} = -lt$$

if $t = t_{1/2}$ then $N = N_0/2$ and

$$\ln 2 = l t_{1/2}$$

Protactinium, with its half-life time of just 72 seconds, makes an ideal radioactive material for this experiment (the source should be strong enough at the beginning).
To improve the quality of the data the background radiation should be subtracted.

Investigation of radiation level at different distances from a source

In this experiment, the radiation level is measured at different distances from a source. The distance from the sensor to the source is determined with a ruler.
The radiation values (in counts per interval) at those distances are measured and the distance values are entered via the keyboard. Further one can investigate whether the inverse square law is followed.
Some lantern mantles i.e. those containing Thorium 232 nuclei, can be used as a radioactive source in this experiment.
To improve the quality of the data the background radiation should be subtracted.

Radiation level versus shielding

In this experiment the radiation level is recorded as the absorber of different thickness is placed between the GM sensor and radiation source.
As absorber an aluminum sheet(s) for beta radiation or a lead sheet(s) for gamma radiation) can be used.
The intensity of the radiation I diminishes according to the exponential relation

$$I = I_0 e^{-md}$$

where I_0 is the incident intensity, d is thickness of a shielding sheet and μ is a constant known as the 'linear absorption coefficient'.
During the experiment the radiation (counts per interval) for different thickness' of an absorber (different number of sheets) is detected. The thickness values are entered via the keyboard.
To improve the quality of data the background radiation should be subtracted.
In this experiment you can also compare the effect of different types of materials to shield beta or gamma radiation.

Predefined sensors in the Coach Library

The name of the Geiger Müller ionizing radiation sensor icon in the sensor library of Coach 5 is **Geiger-Müller sensor (029&bt) (CMA) (0..1000).**
For measuring the operating voltage, the sensor icon **Geiger-Müller Operating Voltage sensor (029&bt Voltage)**[2] should be used.

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[2] Range (300…800V) for the older type of the GM sensor and range (300 to 650V) for the newer type of the GM sensor.

Technical data

Tube	Neon-halogen quenched GM-tube with Fe/Cr cathode
Wall density	30 mg/cm^2
Sensitive to	Beta and gamma > 0.4 MeV
Counter output	Pin 1 of the BT connector
Pulse height	5V
Pulse width	0.265 ms
Default high (operating) voltage	≅ 500 V
Default low voltage on 4-mm output	2.5 V
LED flash and acoustical beep	84.5 ms
Dead time	Effective 0.33 ms
Sweep Range Sweep time	300-650V 10 minutes (in some GM sensors could be 8.6 minutes)
Sensor box	Length=8 cm; width=9 cm; height=2 cm
Automatic sensor Identification value	1 kΩ ~ 5% to ground pin
Connections	 BT (British Telecom) plug 4-mm output (output voltage 1.5 - 3.25V) for measuring of the Operating Voltage applied to the GM tube. To measure the actual value of operating voltage the measured voltage value should be multiplied by factor 200.

Note:
GM tube operating voltage is proportional to the sensor supply voltage, values specified above apply when supply voltage is at nominal 5 V level.
This product is to be used for educational purposes only. It is not appropriate for industrial, medical, research or commercial applications.

APPENDIX: COACH 5 ACTIVITIES FOR GEIGER-MÜLLER SENSOR

Experiment 1.
Monitoring a background radiation and radiation of radioactive materials

The GM sensor can be used for measurement of the background radiation and radiation of beta and gamma radioactive sources. For this experiment the BT connector of the GM sensor has to be connected to a counter input of an interface[3]. Pulses detected by the GM tube are counted. To find out the radiation level the number of counts per time interval should be obtained by means of a Delta formula.

Coach 5 settings

- Activity type: Time based measurement.
- Sensor icon: the icon **Geiger-Müller sensor (029&bt) (CMA) (0..1000)** should be placed on the same input on the screen panel as the real sensor is connected to the interface.
- Measurement settings (depend on the strength of your source), for example: Measuring time = 10 minutes, Measurement frequency = 3 per minute.
- Table settings:

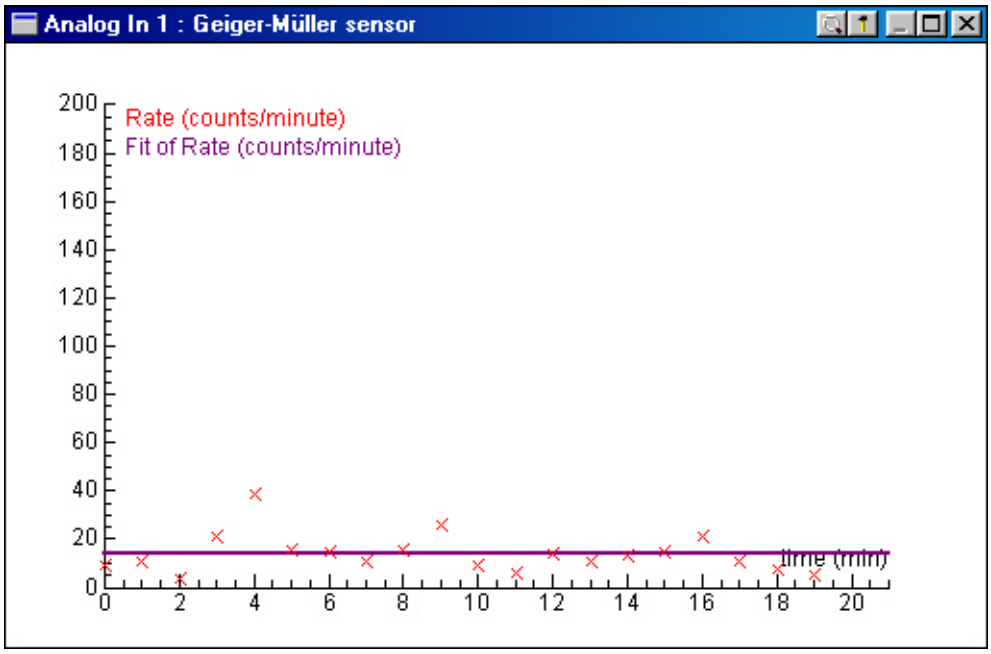
Data range	Connection	Quantity	Unit
C1	Clock	Time	Minutes
C2	Analog In: Geiger-Muller sensor	N	Counts
C3	Formula: Delta(N)/Delta(time)	Rate	Counts/minute
Data range C2 can be made invisible			

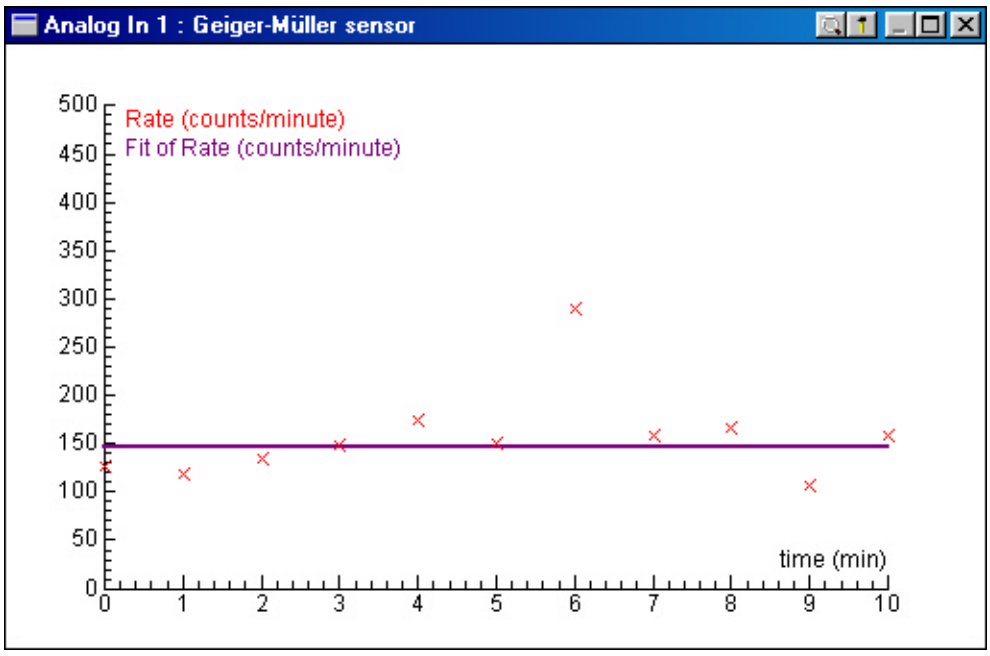
Measurement procedure

- Connect the BT connector of the GM sensor to a counter input of an interface.
- Open a Coach activity with settings for this experiment.
- Start the measurement by clicking the green button.
- Analyze the measured data.

[3] For the CoachLab II interface any analog input from 1 to 4 can be used as a counter input.

Example of measured data





The radiation rate (counts per minute) measured with the GM sensor.
The upper diagram shows the background radiation; the bottom diagram shows the radiation of the gas lantern mantle. In this experiment the random nature of the background radiation can be observed. In both diagrams the mean value of the radiation rate is found by fitting the measured data with the straight line. This value can be also found by plotting a graph of the number of times each count was obtained against the recorded radiation values. For such experiment a long run time should be chosen.

Experiment 2.
Characteristic of the Geiger-Muller tube (relation between the operating voltage and the number of count events)

For this experiment the BT connector of the GM sensor has to be connected to a counter input of an interface. Through this input pulses from the GM tube are counted. The yellow 4-mm output, at the left side of the sensor, should be connected to an analog input of an interface. Through this input the operating voltage applied to the GM tube is measured.

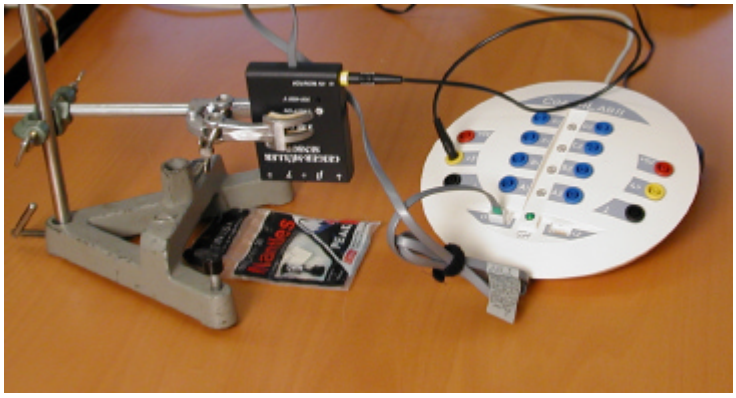


Figure 1. Experimental set-up with the CoachLab II interface. The BT connector of the GM sensor is connected to Input 1; the 4-mm connector is connected to Input 3.

Coach 5 settings

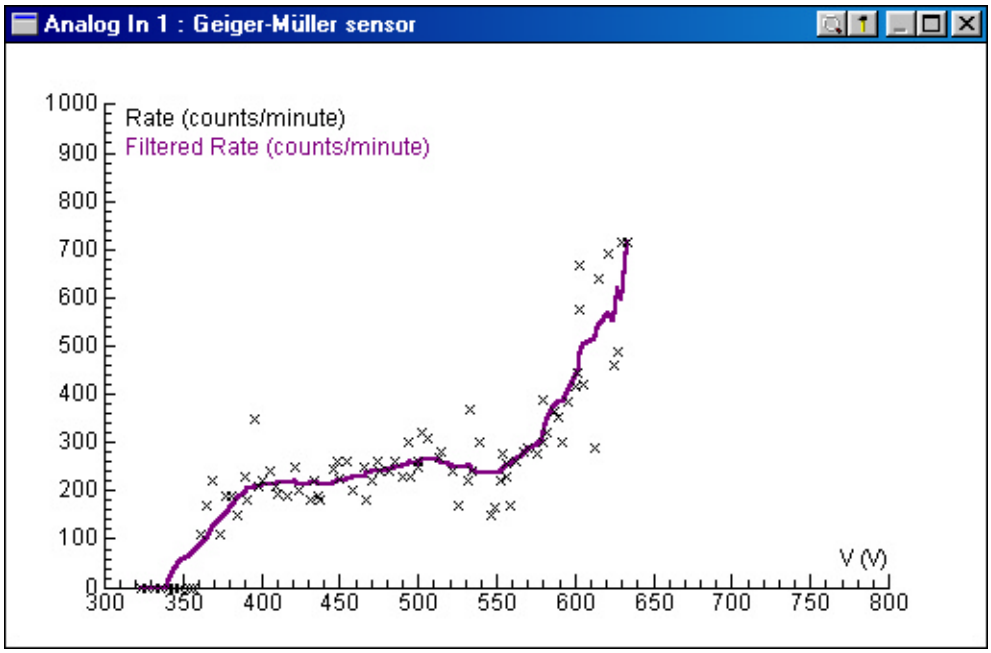
- Activity type: Time based measurement.
- Sensor icons:
  - the icon **Geiger-Müller sensor (029&bt) (CMA) (0..1000)** should be placed on the same counter input on the screen panel as the real sensor (BT connector) is connected to the interface.
  - the icon **Geiger-Müller Operating Voltage sensor (029&bt Voltage) (300..650V)** should be placed on the same analog input on the screen panel as the real sensor (4-mm connector) is connected to the interface.
- Measurement settings:
  Measuring time = 10 minutes, Measurement frequency = 10 per minute.
- Table settings:

Data range	Connection	Quantity	Unit
C1	Clock	Time	Min
C2	Analog In: Geiger-Muller sensor	N	Counts
C3	Analog In: GM Operating voltage sensor	V	V
C4	Formula: Delta(N)/Delta(time)	Rate	Counts/min
Data range C1 and C1 can be made invisible			

Measurement procedure

- Connect the BT connector of the GM sensor to a counter input of an interface.
- Connect the yellow 4-mm output, at the left side of the sensor, to the analog input of an interface.
- Open a Coach activity with settings for this experiment.
- Press the sweep (red) button to start the automatic sweep mode.
- Start the measurement by clicking the green button.
- To improve the quality of your data you can subtract the background radiation.
- Analyze the measured data.

Example of measured data



Relation between the operating voltage applied to the GM tube and the number of count events per minute (source: gas lantern mantle).
Crosses: the data collected during the experiment.
Line: the data filtered with Interval = 7.
From this graph the GM tube plateau and the voltage at which the GM tube should be operated can be found.

Experiment 3.
Radioactive decay and half life determination

The GM sensor gives possibility to measure a radioactive decay rate and half-life.
A Protactinium generator is a good source for this experiment.
This generator consists of a small plastic container hermetically sealed by a thin-walled plastic cap.
A container consists of an aqueous solution of uranyl nitrate in the lower layer and an organic phase (ketton) in the upper layer.
By shaking the generator is activated: the two phases are mixed and are allowed to separate again.

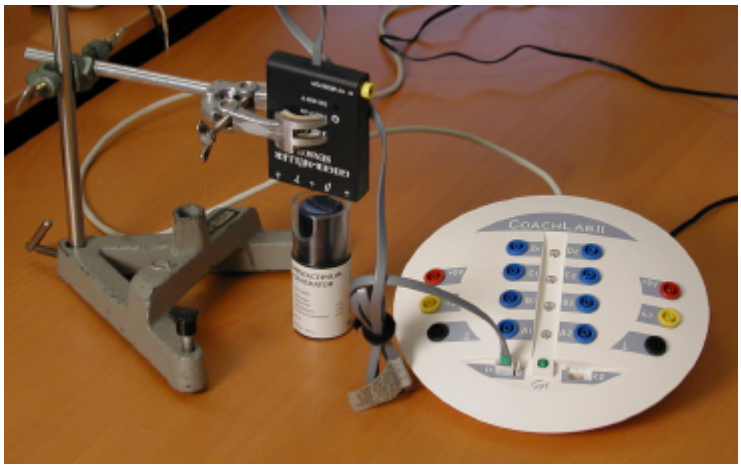


Figure 2. Experimental set-up with the CoachLab II interface. The Protactinium generator is used as the decaying source.

Due to the better solubility of the short-lived Protactinium in organic solvents, the isotope is enriched in the ketton phase. The fade away of the nuclide can be followed using the GM sensor.

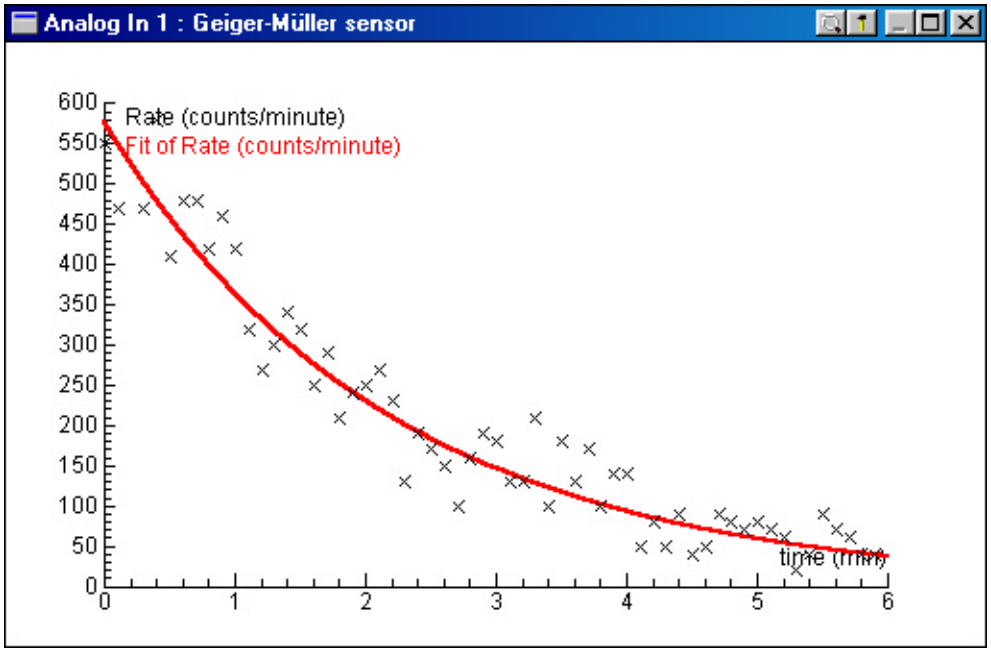
Coach 5 settings

Coach 5 settings are near the same as for the Experiment 1 with:
Measuring time = 6 minutes and Measurement frequency = 6 per minute.

Measurement procedure

- Connect the BT connector of the GM sensor to a counter input of an interface.
- Open a Coach activity with settings for this experiment.
- When you use Protactinium generator give it a shake.
- Start the measurement by clicking the green button.
- To improve the quality of your data you can subtract the background radiation.
- Analyze the measured data.

Example of measured data



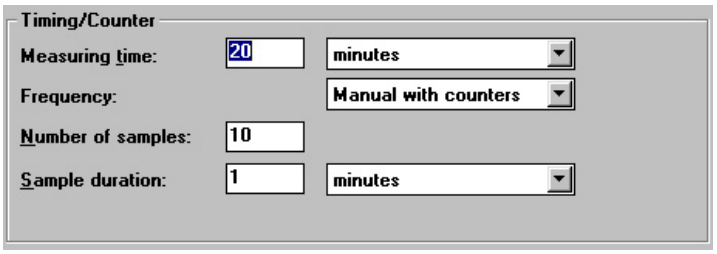
Plot of the rate (counts per minute) versus time for Protactinium generator.
It is usual for the results to look noisy. The best way to handle it is fitting a function to the result and finding the half-life from that.

Experiment 4.
Investigation of radiation level at different distances from a source

In this experiment, the radiation level is measured at different distances from a source. The distance from the sensor to the source is determined with a ruler.
The radiation values (in counts per interval) at those distances are measured and the distance values are entered via keyboard. Further investigations whether the inverse square law is followed can be done.

Coach 5 settings

- Activity type: Time based measurement.
- Sensor icon: the icon **Geiger-Müller sensor (029&bt) (CMA) (0..1000)** should be placed on the same counter input on the screen panel as the real sensor (BT connector) is connected to the interface.
- Measurement settings:
  Measuring time = 20 minutes,
  Measurement frequency = Manual with counters
  Number of samples = 10
  Sample duration = 1 minute



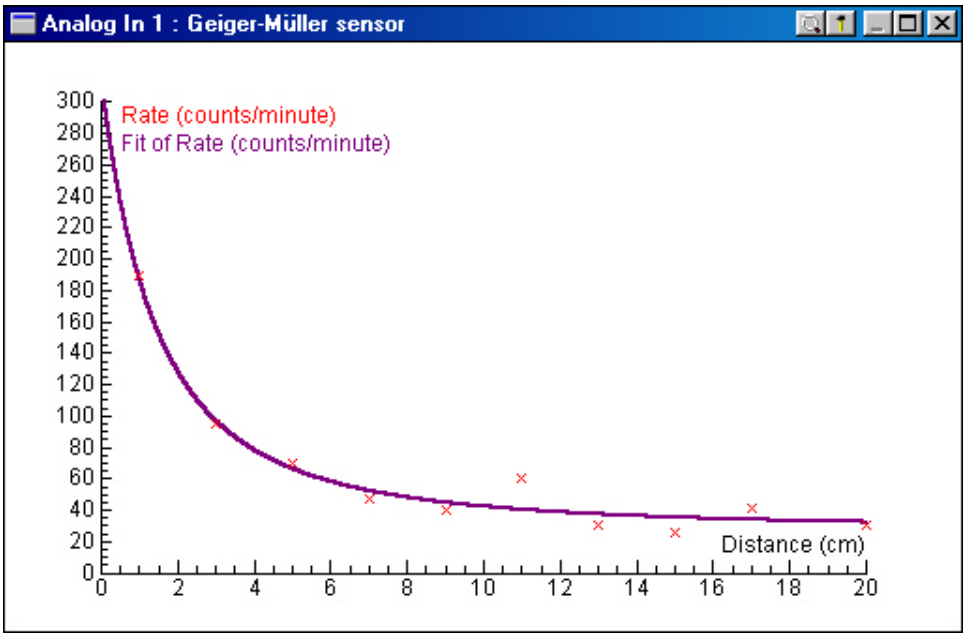
- Table setting:

Data range	Connection	Quantity	Unit
C1	Manual input	Distance	Cm
C2	Analog In: Geiger-Muller sensor	N	Counts/min

Measurement procedure

- Connect the BT connector of the GM sensor to a counter input of an interface.
- Open a Coach activity with settings for this experiment.
- Click the green button.
- Place the GM sensor 2 cm from a radiation source (e.g. gas lantern mantle).
- Start the measurement by clicking the green button with number '1'.
- Coach counts the number of pulses in 1-minute period.
- When the sampling is finished, type in the distance between the sensor and the radiation source.
- Repeat the measurements for different distances from the radiation source. Every time you are ready to start the sampling click the green button with '1'.
- The settings are prepared for 10 samples. You can stop the measurement any time by clicking the red button.
- To improve the quality of your data you can subtract the background radiation.

Example of measured data



Relation between radiation level (counts per minute) and distance to the radioactive source (gas lantern mantel).
Crosses: the data collected during the experiment.
Line: the data fitted with the inverse square function.

Experiment 5.
Radiation level versus shielding

In this experiment the radiation level is recorded as the absorber of different thickness is placed between the GM sensor and radiation source.
As absorber an aluminum sheet(s) for beta radiation or a lead sheet(s) for gamma radiation) can be used.
During the experiment the radiation (counts per interval) for different thickness of an absorber (different number of sheets) is detected. The thickness values are entered via keyboard.

Coach 5 settings

- Activity type: Time based measurement.
- Sensor icon: the icon **Geiger-Müller sensor (029&bt) (CMA) (0..1000)** should be placed on the same counter input on the screen panel as the real sensor (BT connector) is connected to the interface.
- Measurement settings (example):
  Measuring time = 20 minutes; Measurement frequency = Manual with counters
  Number of samples = 8; Sample duration = 1 minute
- Table settings:

Data range	Connection	Quantity	Unit
C1	Manual input	Thickness	Cm
C2	Analog In: Geiger-Muller sensor	N	Counts/min

Measurement procedure

- Connect the BT connector of the GM sensor to a counter input of an interface.
- Open a Coach activity with settings for this experiment.
- Click the green button.
- Place the absorber sheet between the GM sensor and the radiation source.
- Start the measurement by clicking the green button with number '1'.
- Coach counts the number of pulses in 1-minute period.
- When the sampling is finished, type in the thickness of the absorber sheet.
- Repeat the measurements for different number of sheets.
  Every time you are ready to start the counting click the green button with '1'.
- The settings are prepared for 8 samples. You can stop the measurement any time by clicking the red button.
- To improve the quality of your data you can subtract the background radiation.
- In this experiment you can also compare the effect of different types of absorbing materials to shield beta or gamma radiation.

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