Atomic and nuclear physics

Quantum physics

Particles

Detection of Muons

Description from CASSY Lab 2

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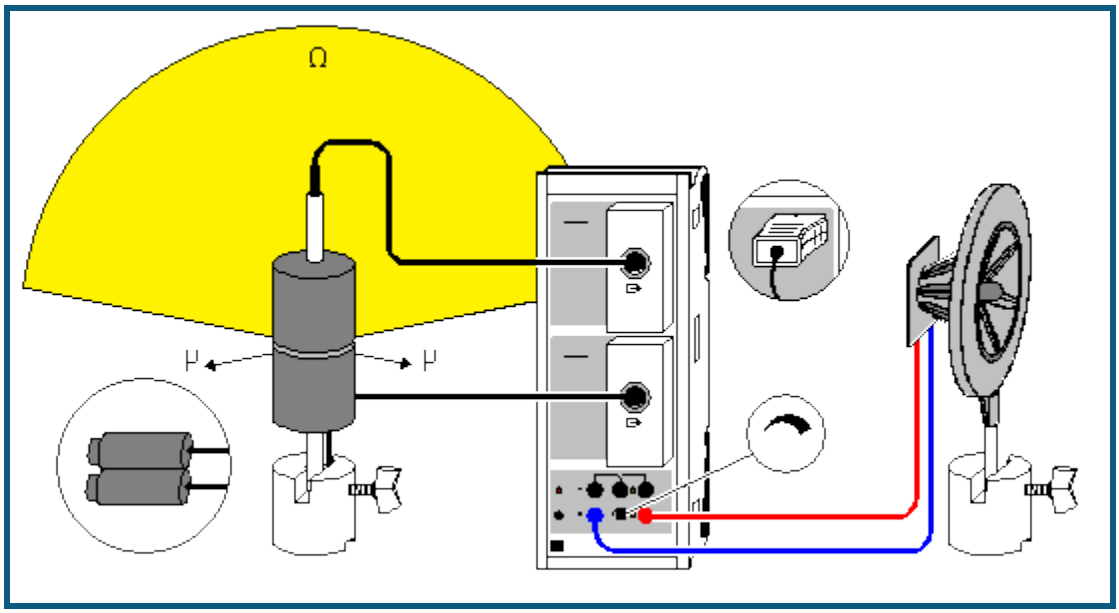
Detection of muons



Experiment description

Primary cosmic radiation is a high-energy particle radiation (predominantly protons) that interacts with the Earth's atmosphere upon impact. This produces a secondary radiation that can be detected on the Earth's surface (predominantly muons).

Muons (μ^-) and antimuons (μ^+) are charged particles classified as leptons. They are about 200 times heavier than electrons and have an average life of only about 2 µs. The fast muons (nearly at the speed of light) nevertheless make it to the Earth's surface by relativistic time dilation. The muons there still have a flow of about 1 muon per cm^2 per minute.

A counter tube can record muons very reliably (detector efficiency close to 100 %). Their very good material penetration is also useful to distinguish muons from other counter tube results (e.g. α, β and γ rays). If two counter tubes react virtually at the same time, then a muon has most likely traveled from above through both tubes. No muons come from below, because the Earth absorbs them. The drawing shows the solid angle Ω, from which a muon µ must come, to reach both counter tubes. If the two counter tubes are distant from one another, then the solid angle becomes smaller.

This also shows the muons' dependence on the crown angle, which arises from the fact that a muon from above must penetrate less atmosphere and therefore is absorbed more seldom or decays more seldom on its quickest path. Therefore the flow of muons is the greatest from above.

This experiment disregards the detection of muon showers (different muons reach different counter tubes virtually at the same time).

Equipment list

1	Sensor-CASSY	524 010 or 524 013
1	CASSY Lab 2	524 220
2	GM boxes with	524 033
2	Pancake GM tubes and	559 012
1	Saddle base or	300 11
2	End-window counters	559 01
	or	
2	GM counter tubes S	524 0331
1	PC with Windows XP/Vista/7/8	

Optional sound output

1	Tweeter	587 07
1	Saddle base	300 11

1 Pair of cables, 50 cm, red and blue 501 45

Experiment setup (see drawing)

Connect the GM counter tubes to the Sensor-CASSY with two GM boxes.

Position pancake GM tubes face-to-face.

Position small counter tubes side-by-side.

Carrying out the experiment

Load settings

- As the case may be, adjust the measurement period and interval in the Measuring Parameters (Window → Show Measuring Parameters). The measuring interval determines the gating time in this experiment.
- Start the measurement series with . The measurement stops at the end of the given measurement period or with .
- If desired, align counter tubes with another crown angle and repeast the measurement. For a more precise crown angle, the two counter tubes should be distant from one another.

Evaluation

Practically every muon that penetrates both counter tubes is recorded.

The pancake GM tube (559 012) has an effective surface of about 15 cm^2. If the two counter tubes are close to each other, almost the entire solid angle is detected (see drawing). This enables a muon pulse rate of about 12 muons per minute with two coinciding pancake GM tubes.

The farther from each other the counter tubes are, the smaller the solid angle is, from which the muons are detected, and the lower the pulse rate drops.

The muon pulse rate is also reduced if neither counting tube points up with the same solid angle. If the counting tubes are positioned one above the other, the hemisphere's range goes over the horizon, from which only few muons come. If the counting tubes are positioned side-by-side, the hemisphere's range goes over those, from which most muons come.

A **frequency distribution** also represents the measured pulse rates.

Remarks

The small counting tube (559 01) has an effective surface of about 5 cm^2 (side). Even if the two counting tubes are tightly placed one on top of the other, the solid angle Ω detected is significantly smaller as with the two pancake GM tubes, because they are farther apart from each other. Both effects reduce the measured muon pulse rate to about 1 muon per minute.

The time window for coincidences has a fixed default value of 10 µs.