Manual for Muon Observatory

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Every second, each square meter of the Earth is hit by some hundred particles originating from the cosmic radiation. Most of these are muons produced in the uppermost part of the atmosphere, where even more energetic particles collide with air molecules.

The purpose of the muon observatory is to facilitate the study of these particles.
See below concerning necessary accessories.

The development of the instrument took place in a single-storey building with a normal (light) roof. It must be assumed that a location one or more floors below the roof could affect the results - but it could of course be part of an experiment to investigate whether there is evidence of such relationship.

A few facts about muons

Muons occur as both positively and negatively charged particles. A muon is approx. 200 times heavier than an electron. Muons are unstable with a half-life of 2.197 µs.

The muons that reach down to sea level has an average energy of approx. 4 GeV.

Muon energy loss by ionization is relatively constant at 2 MeV per g/cm^2. Atmospheric thickness is approx. 1000 g/cm^2, meaning that muons are produced with an average energy of approx. 6 GeV.

Operation

Shower Mode

The particles from the cosmic radiation often spread out their energy in a shower of secondary particles, which in special cases can be enormous and hit an area of several square kilometers of land surface.

In the shower mode setup, a shower is recorded as a coincidence event from three GM tubes arranged in a triangle. This geometry ensures that no single particle can be detected in all three tubes. Production of showers may be facilitated by allowing the radiation to pass through something that is slightly "thicker" than air - that is a number of steel plates.

Telescope mode

In telescope mode two (or three) GM tubes are arranged in a line, and if a muon passes through all tubes in the setup, a pulse is output from the coincidence box. Placing steel plates between the tubes ensures that only very high-energy radiation is recorded. The third GM tube is used if you want additional suppression of random coincidences. The telescope can be set at different angles relative to vertical.

Measurements

To register coincidence between two or three GM tubes, a 1538.00 coincidence box is required. The output from the coincidence box goes to a counter (e.g. 2002.50), which is set to count with manual start and stop. (Take note of the dates and times.)

Alternatively, a stable computer can be used with appropriate datalogging equipment, which enables you to analyze any correlations with other parameters later. For example the electronic counter 2002.50 may be controlled from the free Windows program Datalyse via the serial port.
(www.datalyse.dk)

Since the measurements take a long time, it is important to take detailed and accurate notes on the measurement situation.

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Applications

In shower mode you will typically align the muon observatory vertically (absorber plates lying horizontally). Three GM tube are placed in the special holder, with a distance of for example 6-7 cm to the nearest absorber. The tubes are used without the protection caps. Starting with air you can now place more and more absorber plates over the GM tubes and record the coincidence counting rate for all three tubes. Measurement periods of approx. a day would be appropriate.

You will observe that the counting rate in the beginning will grow with the increased thickness of absorber material to a maximum is reached (after a few centimeters) then the count rate slowly decreases again. Interpretation: The thickness at the maximum is roughly equivalent to range of the particles in a shower.

In telescope mode it is possible to detect the angular distribution of the muons. Most muons are counted when the telescope is oriented vertically.
Virtually no coincidences are registered when it is horizontal. Muons may collide with air molecules on their way through the atmosphere, and on the way into they may decay (primarily electrons, positrons and neutrinos). The muon flux turns out to be proportional to $\cos^2(\theta)$ where θ is the angle from vertical.

In this application it is not strictly necessary to use more than two GM tubes, but a third will not hurt. The tubes are placed perpendicular to the unit's axis. The distance between the two tubes that are furthest apart, defines the angular resolution. For the sake of counting rates, one should not aim for too precise angles.

Also in telescope mode it is possible to place absorbers between the GM tubes. One can thus demonstrate the large range of muons in solids.

If you measure with a fixed geometry for a long period of time, you will be able to observe a negative correlation between count rate and barometric pressure. The explanation is again that a thicker atmosphere increases the likelihood of decay and collision.

A similar effect can be detected due to variations in atmospheric temperature.

Even if you are not currently investigating these effects, it is good laboratory discipline to record outdoor temperature and barometric pressure along with the other experimental parameters.

Required accessories

5138.00 Coincidence box

3 Large Area GM tubes 5125.25 *or* 3 Large area GM sensors 5135.65.

Use *identical* detectors.

2002.50 Electronic Counter

You may want to add extra absorber plates - up to a maximum total of 40:

5142.10 (pack of 5 pcs. 148 x 148 x 3 mm steel plate)