Investigating the effect of Zenith and Azimuth angles on the decay rate of Cosmic ray muons

jags
Queen Mary University of London

Background

We have been investigating cosmic ray muons. Cosmic rays are highly energised particles travelling through space. When these Cosmic rays reach the Earth's atmosphere they collide with the nuclei of atoms, this in turn creates more particles. One of these particles, the pion, swiftly decays into muons. Muons do not interact strongly with matter, and therefore can be detected at ground level. Muons along with neutrinos are the most abundant particles produced by interactions of primary Cosmic rays.

Why are muon decays important?

Experimenting to find muon decays is important as it has shown that special relativity (from Einstein's work) exists. The muons should have a very short lifetime however, they are travelling at very high speeds so they experience time dilation and therefore they appear to have a longer lifetime.

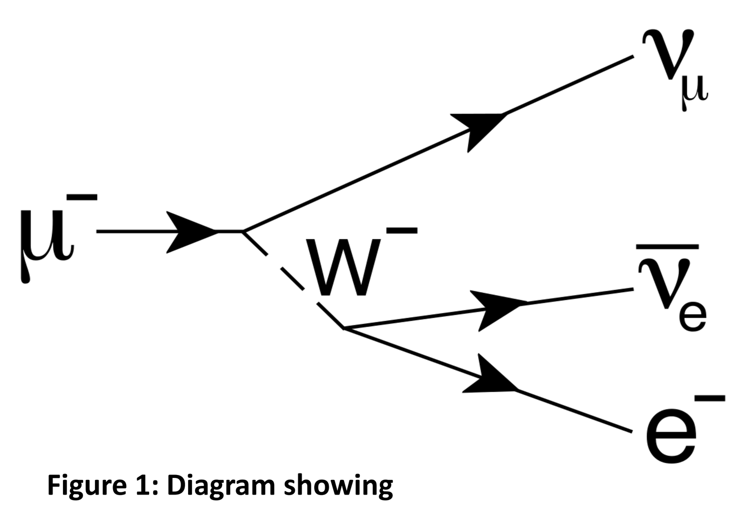


Figure 1: Diagram showing the studied muon decay

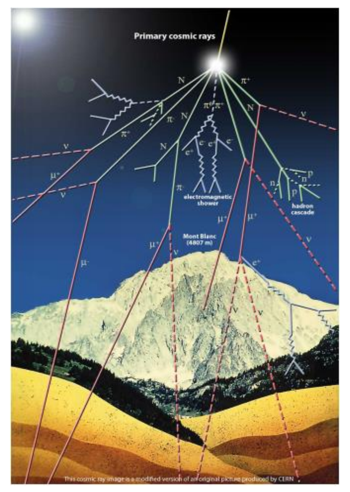


Figure 2: a graphic of cosmic ray muons

How does the detector work?

Muons are stopped in a large block of scintillator, the scintillator is made out of a material which emits a photon when hit by a charged particle. The photomultiplier tube when hit by the photon emits an electron, the photomultiplier amplifies this, producing enough electrons to produce a current (see figure 3). The current is sent through a cable and detected by the computer as a signal. As some unstable muons will decay into another electron or positron, the detector records this too.
Muon decay time is the time difference between initial detection of the muon and second detection of the charged particle it has decayed into.

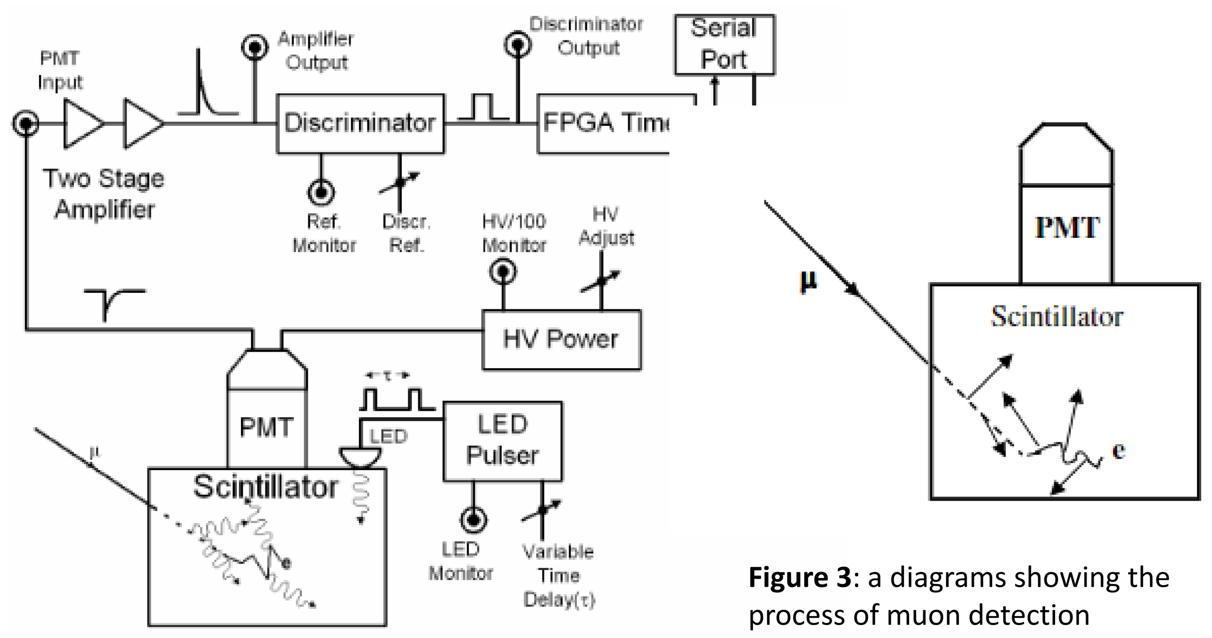


Figure 3: a diagrams showing the process of muon detection

Hypothesis

Muons with large zenith angles traverse a longer path and lose more energy compared to ones with lower zenith angles, thus, we expect the count rate to decrease with increasing zenith angles, and the decay rate to increase.

Method

1) Set up experiment as shown in figure 4
2) Find magnetic north using a compass. Line up the detector so that the top of it is facing magnetic north. This is called the azimuth angle 0 (as it is a bearing) see figure 3
3) Start recording the muon count rate and decay rate on the computer. Stop after exactly 2 hours. Halve the data (so that it is the data for 1 hour and it reduces error). Record results.
4) Repeat but increase the zenith angle with increments of 30 degrees using set up shown in figure 3. You can calculate the height needed for these angles using trigonometry (see figure 5 and 6). Take recordings for the zenith angle at 0, 30, 60, 90 degrees. Repeat all these angles twice
5) Turn the detector around facing East (azimuth angle- 90 degrees) and repeat steps 2 and 3
6) Turn the detector around facing South (azimuth angle- 180 degrees) and repeat steps 2 and 3
7) Turn the detector around facing West (azimuth angle- 270 degrees) and repeat steps 2 and 3
8) Plot a graph of the decay rate against azimuth and zenith

Nb. When analysing data on excel, we ignored any decay times over 40000 (ns) as these are not muon decays.

Errors in calculation of zenith angle:
Length of plank $\pm 0.002m$
Height raised along clamp stand $\pm 0.002m$

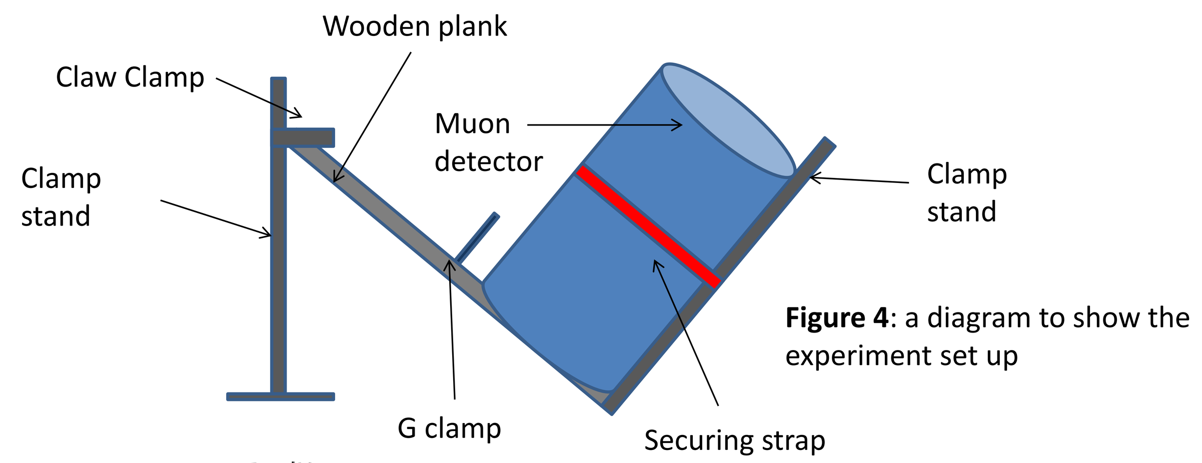


Figure 4: a diagram to show the experiment set up

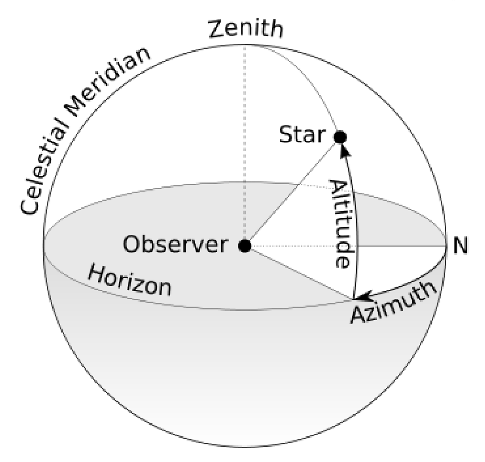


Figure 5: a diagram showing how to calculate the azimuth and zenith angles

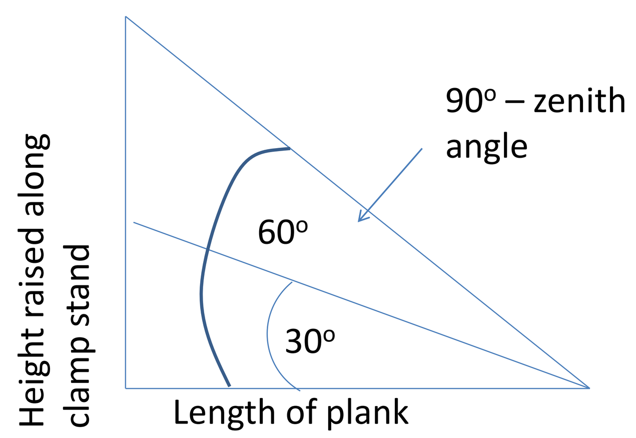


Figure 6: a diagram to showing how to calculate height for zenith angles

Results

Our results showed that there is an average decrease in decay rate from 0-30 degrees, and an average increase in decay rate from 30-90 degrees. Some of our results appear to go against this trend, but the majority follow it. This weakly confirms our hypothesis. The azimuth angle appeared to have no distinct effect on the muon decay rate.

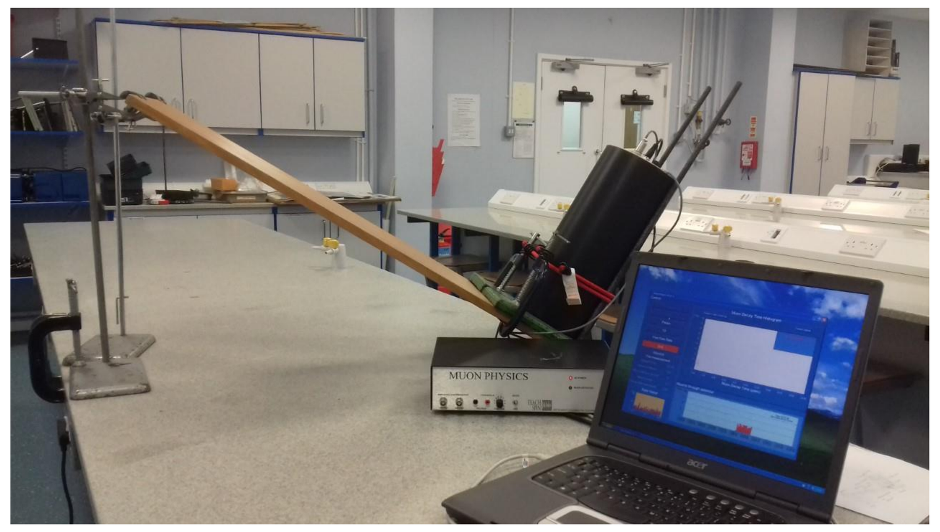
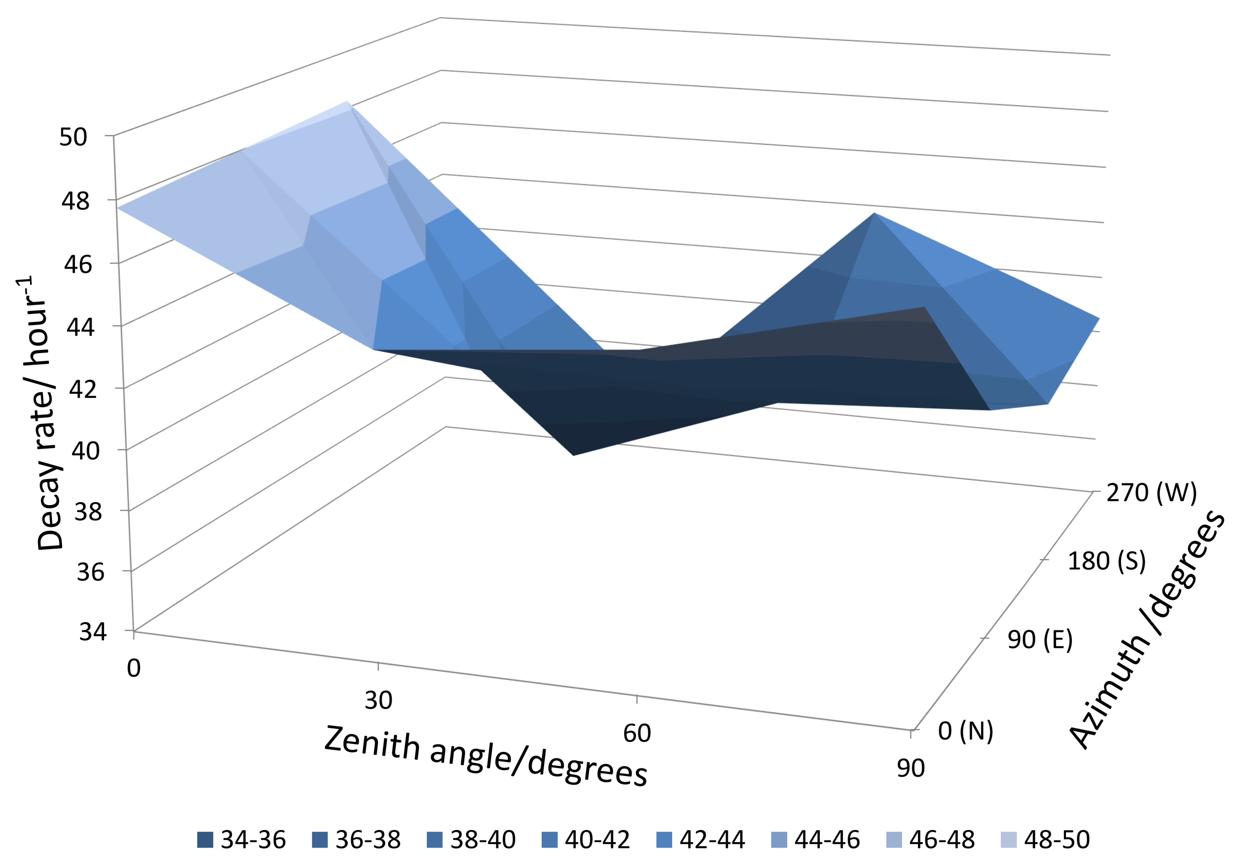


Figure 7: photograph showing our setup

3D surface graph showing the effect of zenith and azimuth angles on muon decay rates



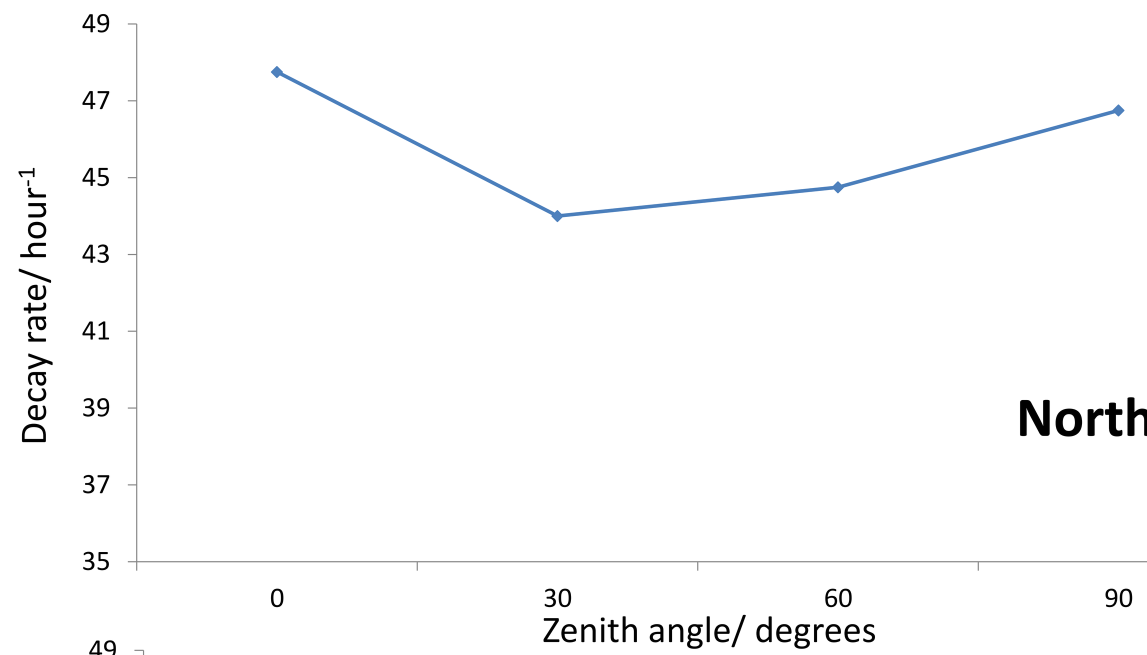
Possible improvements

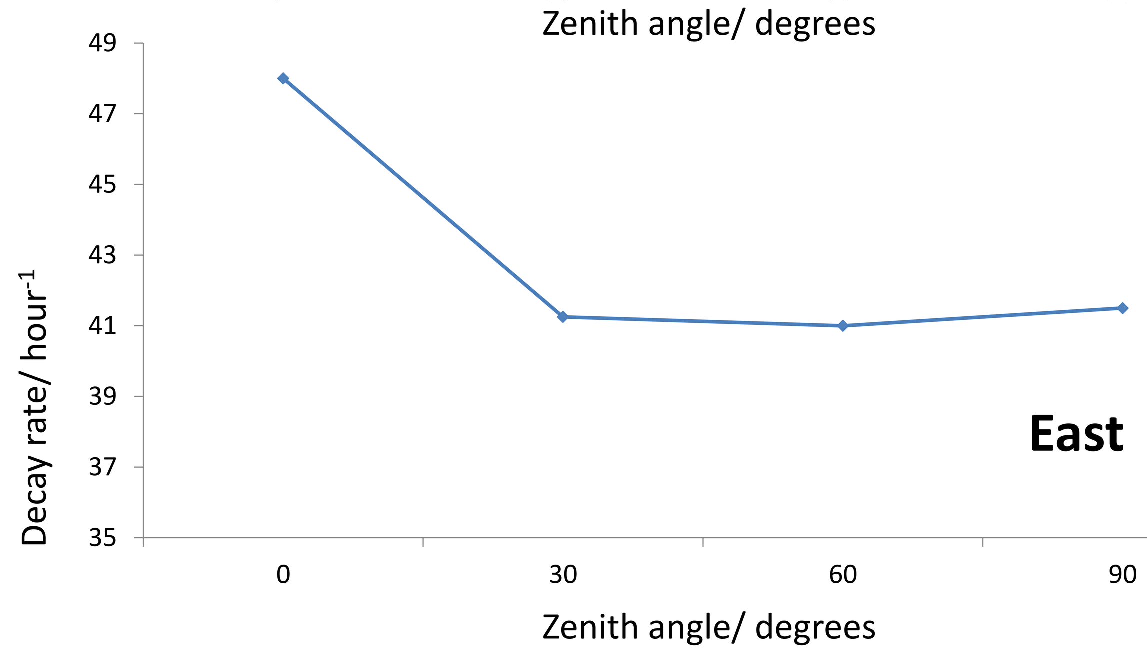
- Increase the recording period for each angle (to decrease uncertainty)
- Make more repeats on each angle
- Further investigation into the effect of azimuth angle on muon decays.

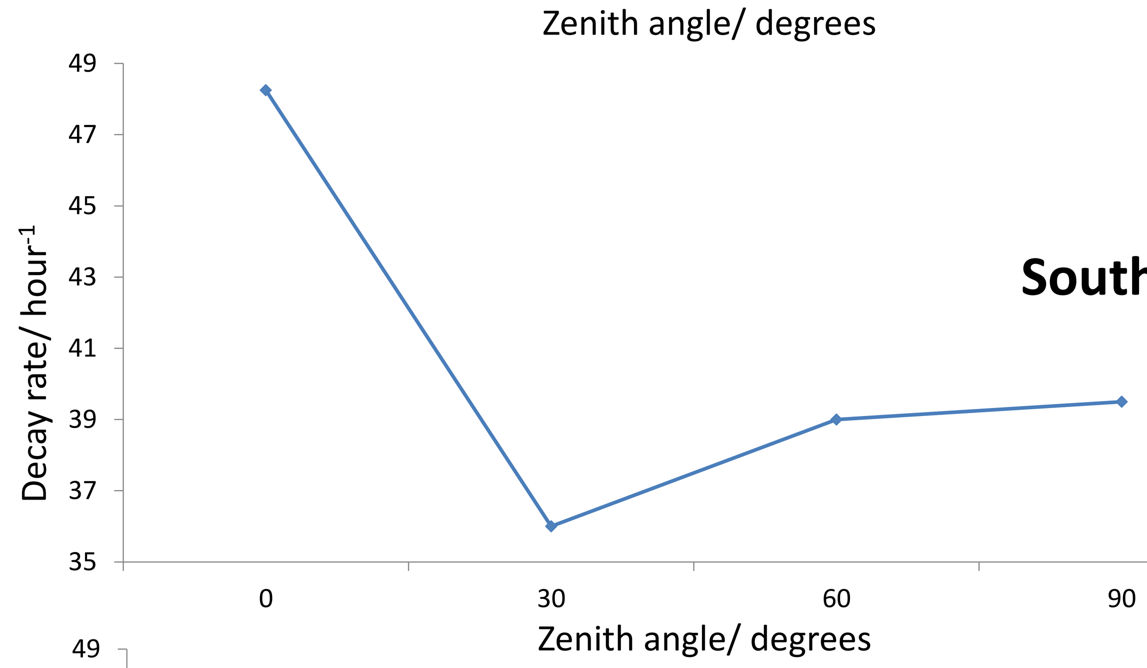
Open questions

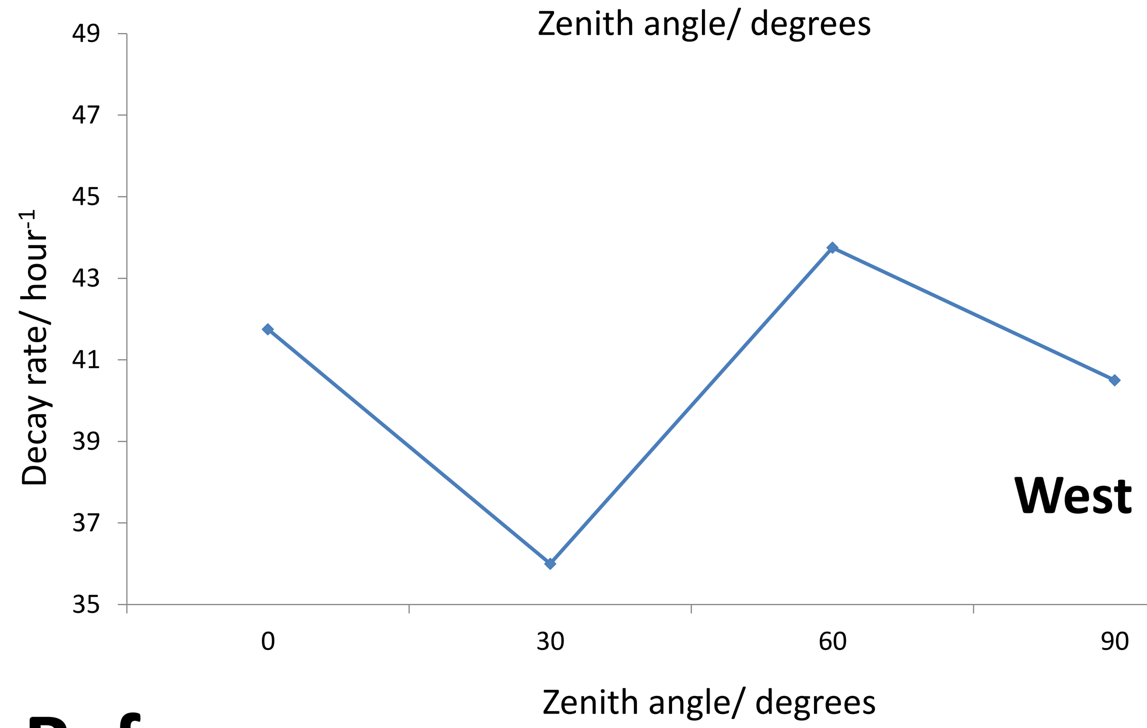
- What is the effect of the azimuth angle on muon decays/count rate?
- What effect does the earth's magnetic field have on muon decays/ count rate?

Graphs showing the effect of zenith angles on muon decay rates









References

- *Cosmic rays muon textbook, University of Washington, Interlake High school, Chunyang Ding, June 12,2015*
- *Understanding muon decay, Thommaso Dorigo, March 2010*
- *Particle at the University of Rochester, Department of Physics and Astronomy, University of Rochester*
- *Horizontal coordinate system, Wikipedia*