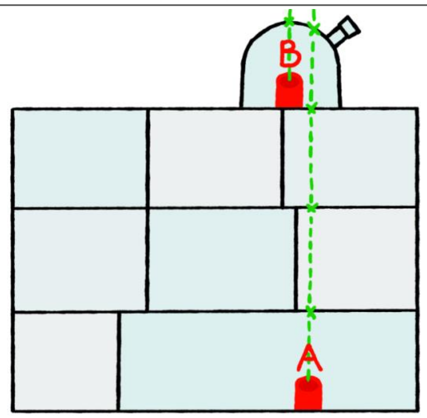
INVESTIGATING THE RATIOS OF MUONS TO ANTIMUONS

The scintillator measures the number of charged particles passing through it, and if that particle decays within the scintillator then it also records the time from that charged particle entering to when it decays. Due to the muon decay time within the scintillator being the tail end of the exponential curve of muon decay times, plotting a graph of decay times of muons within the scintillator will give the same gradient as plotting a graph of overall muon decay time. If the threshold is set at the right level then only muons and anti-muons should be detected as lighter particles such as electrons will not register.

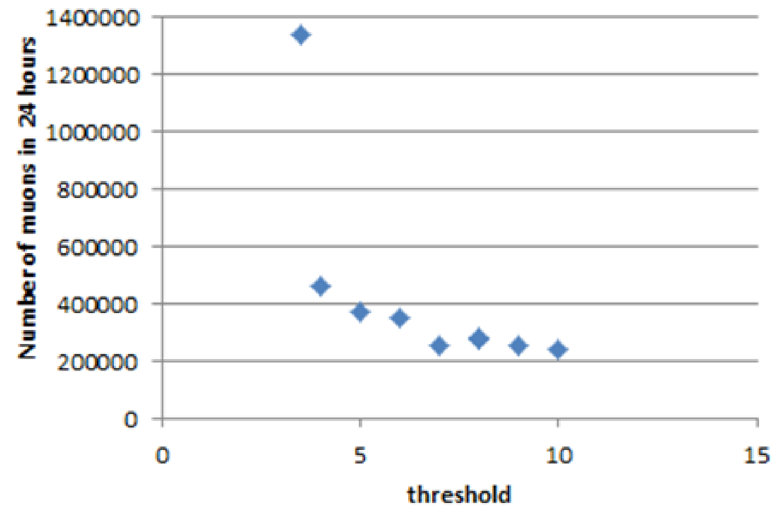
We used the muon scintillator to take data in two different locations within our science building. These are represented on the diagram as A and B. B was in the observatory on the roof of the science building, whereas A was in a physics lab on the ground floor of the building. We then made a python script to process the data in order to find values for the lifetime of muons at A and B and values for the muon flux at A and B. The reason for doing this is because, by calculating the muon flux at the two different locations, we can find the impact on muon flux of the process of passing through matter. This should give some indication of proportion of muons to anti-muons.



Left: Diagram of the scintillator positions in the science block, along with assumed pathway for muons and anti-muons. The points where the path intersects with a floor are where we assume muons will be captured

Science building with observatory

Group at observatory



We chose to use a threshold of 8 based off of results from last year, which had determined it to be one of the optimum values to use.

The accepted lifetime for free-space muons and anti-muons is 2.1969811±0.0000022μs. Since anti-muons, which are positively charged, do not interact with matter the lifetime for anti-muons, τ^+, is the same as the lifetime of free-space muons. The lifetime for negatively charged muons in carbon, τ_c, is 2.043±0.003μs which is similar to the lifetime of muons in our plastic scintillator, τ^-, as this is made with hydrocarbons. Our observed lifetime for muons, τ_{obs}, was …. We want to calculate the proportion of muons to anti-muons incident on our detector, ρ. To do this we can use the equation: $\rho = -\frac{\tau^+}{\tau^-}\left(\frac{\tau^- - \tau_{obs}}{\tau^+ - \tau_{obs}}\right)$.

Therefore we calculated ρ to be: ….

To expand on this project we hope to use the data we have for the number of muons and anti-muons per unit time at A and B. We can use our calculated value for rho to find the number of negatively charged muons per unit time at B and then subtract this from the number of muons per unit time at A. This would give us the number of muons per unit time at both A and B. We can then calculate the difference between these and use an estimate for the interaction length between A and B which is the length passed through multiplied by the density of the material passed through. We can then use this to find the impact of passing through matter on negative muons. The distance between A and B is minimal so a negligible number of muons would decay between A and B.

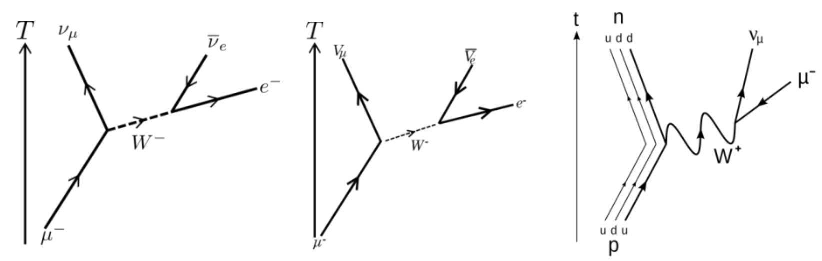
The decay paths for muons (μ^-) and anti-muons (μ^+) are shown here:

$$\mu^- \rightarrow \nu_\mu + \bar{\nu}_e + e^-$$
$$\mu^+ \rightarrow \nu_e + \bar{\nu}_\mu + e^+.$$

However there is an alternative interaction path which only works for muons, which are negatively charged. When muons pass through matter muon capture can occur if a muon gets bound by an atomic nucleus into an s orbital which allows the muon to react with the proton:

$$p + \mu^- \rightarrow n + \nu_\mu.$$

This cannot happen for anti-muons as they have the same charge as the atomic nucleus, and so can't be captured. As a result, anti-muons will have a longer predicted lifetime than their negatively charged counterparts since muons have a greater range of options for decay / interaction which means the observed lifetime appears to be shorter.



Muon decay path

Anti-muon decay path

Alternate muon decay path