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Lunar/Solar Effects on Muon Flux

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The purpose of our experiment was to determine if the moon has any effect on the amount of cosmic rays that reach the ground. We hypothesized that the moon would act as a shield for a small amount of the rays; thereby decreasing the amount of muons we counted. After further research, we discovered that our results would be inconclusive because millions of counts are needed to determine a deficit as a result of the moon because it takes up such a small angle in the sky. Low-energy cosmic rays can also be swept by earth's magnetic field.

Introduction

The moon, which orbits earth, subtends about .5 degrees of the sky. If you hold your arm out, this is around the width of your pinky. Having to travel through mass shortens the lifetime of muons; therefore cosmic rays that have to travel through the moon should have a shorter lifetime, and less of them will make it to the surface of the earth. We were interested in if the moon has an effect on the number of cosmic rays, and therefore muons that make it to the earth's surface.

Procedures

The moon only takes up a one-half degree of the sky, so our first task was to overlap the scintillators so that they formed the smallest acceptance angle possible. After doing the math, we discovered that the most reasonable angle was about four degrees when the top and bottom scintillators were placed six feet apart. We then set our monitor to a three-fold coincidence so that only the muons that made it through all three scintillators were counted. The moon moves approximately 1.5 degrees every ten minutes, so we had to adjust our structure accordingly. We also took data when our board was pointed at the sun in order to compare the results with that of the moon's count.

Results

We were unable to determine the moon's effect on cosmic rays because muons come in at every angle and will usually fill in any noticeable gaps. This means that the deficit in counts due to the moon is so small that we would need millions of counts to be able to identify a "moon shadow."

Discussions and Conclusions

If we had a longer time to observe the moon, we could take data during multiple cycles of the moon, and we could get counts closer to 100,000,000 so that we could see if our data showed conclusively that the moon did or did not have an effect on the amount of muons making it to the earth's surface.

Also, we could have made a larger structure so that the acceptance angle was half of a degree in the sky, only covering the area of the moon. An apparatus could also be made that continually shifts the altitude and azimuth of the structure so that it is constantly exactly following the path of the moon.

Muon Lifetime Study

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We used multiple scintillators and a circuit board (data acquisition) to determine the lifetime of a muon particle. We formed a right trigonal prism with two scintillators on the outside of the box and a third diagonally placed inside the box. The topside of the prism had an additional scintillator attached. We took continuous 24-hour runs of data for air and packing peanuts as materials of varying density within the box. We determined the lifetime of a muon by measuring the window between the muon's entrance and the resulting electron's ejection. From fitting exponential decay curves to the data for air and packing peanuts of decay length vs. number of decays and graphing the decay length vs. the natural logarithm of the number of decays, we determined the average muon lifetime as 4.61 and 7.64 microseconds, respectively, which are actually considerably higher than the expected value of 2.2 microseconds.

Introduction

Most naturally occurring muons are created by cosmic rays, which consist mainly of protons, but also consist of neutrons, neutrinos, and alpha particles (helium nuclei). When cosmic ray protons impact atomic nuclei in the upper atmosphere, pions are created. These hadron-hadron impacts form pion showers, which decay quickly to muon showers. A muon falls through the atmosphere with an equal probability of decaying at all times. When it travels through the top two scintillators, the measurement of the lifetime starts. The muon decays into an electron, electron antineutrino, and muon neutrino, by the weak force. Of these, the electron is the only one that is relatively easy to record. It is ejected and runs into one of three scintillators. The window between the muon's entrance and the electron that is ejected determines the lifetime of a muon. Most of the muons actually just fall straight through our apparatus. These counts have windows on the order of nanoseconds and are filtered out of our data. The muon has a reported mean lifetime of 2.2 μs. A muon does not emit much bremsstrahlung radiation (electromagnetic radiation produced by the deceleration of a charged particle when deflected by another charged particle). Because of this, it penetrates further into matter. When passing through matter, a muon loses kinetic energy. When passing through matter, it is possible that negative muons can form muonic atoms by replacing an electron in ordinary atoms. However, a muon's orbital is smaller and far closer to the nucleus than the atomic orbitals of the electrons. Our research question was: Does the experimental value for muon lifetime change if its trajectory is stopped by materials of varying density? Our hypothesis was that the lifetime will vary, and the packing peanuts will reflect the muon lifetime.

Procedures

First, the scintillators had to be calibrated, which mainly involved plotting a graph of counts (Hz) versus voltage (V). We set one detector that was to count at around 40 Hz and slowly turned up another detector's voltage from around 0.5 V to 1.5 V in 0.05 V increments until the data displayed a plateau, or a portion of a graph that exhibits little to no change. The optimal voltage, the voltage to which we calibrated the detector, was calculated one-third of the way from the beginning of the plateau. We then used this detector to calibrate all the others. To set up the scintillators, a cardboard box was surrounded by two scintillators duct taped on adjoining sides, with another scintillator duct taped on the inside of the box and touching the edges of the outer scintillators, forming a right trigonal prism. Yet another scintillator was on top of the topside scintillator. After the scintillators were set up, data was collected with different filler material in the box: no filler material and packing peanuts.

Results

The optimal voltages for detectors A, B, C, and D were determined to be 0.799 V, 0.758 V, 0.802 V, and 0.718 V, respectively. From fitting exponential decay curves to the data for air and packing peanuts of decay length vs. number of decays and graphing the decay length vs. the natural logarithm of the number of decays, we determined the average muon lifetime as 4.61 and 7.64 microseconds, respectively, which are actually considerably higher than the expected value of 2.2 microseconds.

Discussions and Conclusions

We need to test more materials before concluding on an optimal density for measuring muon lifetime. The density of the material—through which muons pass—did affect the experimental lifetime. This makes sense because a denser material will have more atomic nuclei per unit volume, resulting in a larger chance of muon to atom collisions.

Muon Telescope Flux Study

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We wanted to determine whether the count rate of muons per hour would be affected if we changed the angle that our muon telescope pointed at. We used three detectors offset about a meter apart and shifted horizontally to minimize the acceptance angle. First, we started at 90 degrees (pointing straight up) and then measured every 15 degrees until the telescope was parallel to the ground (at 0 degrees). We repeated with each of the cardinal directions. Our results were that the count rate became higher when the angle was at or close to 90 degrees, and the count rate did not differ significantly when the cardinal direction was changed.

Introduction

Cosmic collisions happen approximately 15 kilometers up in the atmosphere. Based on our results, we should be able to see whether the muons created in these collisions fall straight down or in all different directions. We hypothesize that the muons will hit our detector most frequently when it is pointed straight up, since the muons that come at angles will have to go through more of the atmosphere and will most likely decay in the process.

Procedures

We used three scintillators and put them on parallel planes but slightly shifted them to reduce the largest angle of acceptance to .2007 radians (11.5 degrees).

We took the telescope up to the roof of the parking garage so the muons could not be affected by surrounding materials.

We started with the telescope pointed straight up and timed it for an hour. Then we changed the angle by 15 degrees and went all the way to 0 degrees in each cardinal direction.

Results

As the angle changed and became closer to 0 degrees, the amount of muons going through all three detectors significantly decreased. At 90 degrees, the count in one hour was 578 muons while the average count for 0 degrees was close to 14 muons. The cardinal direction the telescope pointed did not significantly affect the muon count.

Discussions and Conclusions

Because the count rate decreased as the angle of the telescope became close to 0 degrees, we can assume that most of the muons that are created during cosmic ray collisions fall straight to the ground, or that the muons that come at angles must fall through more atmosphere and decay in the process. Our graphs could not be uploaded to the QuarkNet website.

Study of Magnetic Fields on Incoming Muons

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Our experiment tested the effects of a magnetic field on the path of muons. Four 1.2T magnets were used to achieve our field. All testing was done indoors, away from windows. Two scintillator boards were aligned vertically but offset horizontally above the magnets to narrow the angle of incoming muons. Two boards were then stacked on top of each other and placed near the magnets (far enough to not be affected by the magnetic field but close enough to ensure the counts). Because of the placing of the last two boards, we were able to have a zero-degree angle of acceptance. However, even with our zero-degree acceptance angle, we still had significant counts when the magnet was not in play. Interestingly, when we tested with the magnet, we got fewer counts with it than without. This counters a magnetism project done two years before which found more counts with the magnets than without. We are still unsure of (a) why we had "ghost counts" at the zero-degree acceptance angle and (b) why our results prove opposite to the previous experiment.

Introduction

We knew that muons had a charge of 1, and that they interact with a magnetic field. That naturally roused the question: How is the path of an incoming muon affected by a magnetic field? We decided to test with the magnets above and beside our magnets so that we could be sure of a straighter incoming path of the muon, and that the muons would hit the magnetic field.

Procedures

In the process of looking around, we found that a project had been done two years before that did a similar magnetism experiment. The difference in ours is the placement of the boards over the magnets, narrowing our acceptance angle, and the strength of our magnets. We had two scintillator boards aligned vertically 60 cm apart and offset horizontally to provide us with a narrow angle of acceptance. We then had the magnets positioned 60 cm under the bottom scintillator in the line of the muon acceptance angle. The last two scintillator boards were stacked on top of each other to the side of the magnet so that it was out of line with the acceptance angle, thus providing us with a zero-degree angle of acceptance overall. We set the DAQ to record a four-fold coincidence. We tested with and without the magnetic field in place. We also changed the position of the field so that it was turned at 90, 180, and 270 degrees from the original position. We also raised the magnet to see if the height difference could provide a difference in the count.

Results

When we tested the zero-degree angle of coincidence without the magnetic field as a control, we found that we were still getting counts. Over 4,391 minutes, we got a count of 5,326, resulting in a rate of 2.17 counts/minute with an error range of ±0.03. Using that value as a control, we tested with the field for 4,391 minutes, getting 9,532 counts. The result is 2.15 counts/minute with an error range of ±0.03. Thus, the results for without the field and with the field in the original position, is within error. With the field reversed, 2.15 ± 0.13 counts/minute were acquired. The count/minute rate for the field at 90 and 270 degrees were the same at 2.18 ± 0.04 counts/minute. When the field was raised 2.5 cm, 2.18 ± 0.04. (Due to technical difficulties, we were unable to upload any graphs. Our apologies.)

Discussions & Conclusions

Contrary to the project prior to us, we failed to find an increase in the rate of muons with the magnetic field in play versus without; rather, we found a slight decrease; however, it was still within error. We have determined that our precision is not high enough to conclude that our data is complete. Our count rates neither increased nor decreased much from the control after the magnet was added. A possible reason could be that because we used a permanent magnet, our field may be inconsistent, resulting in not curving the muons as greatly as our calculations suggested. The next step of this experiment would be to collect more data to shrink the error bars, as well as test different field positions and heights to see the different curving effects. A more uniform field would be another next step, possibly created by an electromagnet.