International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 9 (2018) pp. 7037-7041

Study of the Scintillation Detector Efficiency and Muon Flux

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Abstract

In this research we used scintillator detector that is coupled to the photo multiplier tube PMT to detect the charged particle, which is a Muon, the particle that reach the earth from the cosmic ray which is atomic nucleus or other particles with very high energy that travel in the space at a speed almost same as the speed of light of light and we calculated the efficiency of the detector as a function of the supplied voltage. Then we found the muon flux as a function of polar angle as found it depends on the incident angle. Then we found that the Moun distribution is consistent with the $\cos^2\theta$ and the efficiency of the detector plot is consistent with the error function, which is the integral of the Gaussian distribution. All of that have been made for the scintillator detector that assembled at the laboratory

Keywords: cosmic ray, Mune, Scintillator, Flux, Photomultiplier

INTRODUCTION

As we know that our atmosphere is filling by many different particles as: charged, neutral, stable, and unstable particles. These particles can be fundamental or campsite. The fundamental particles are fermions such as leptons, anti-leptons, quarks, and anti-quarks, which could be matter particles or antimatter particles, and gauge bosons or Higgs boson, which are known by the force careers that mediate the interaction between fermions. And the composite particles are any particles that made up from the fundamental particles like proton, neutron, pion, and many other different particles. And the figure (1) shows the fundamental particles. And most of the particles in our atmosphere are generated from the cosmic rays that have been coming and originating outside the solar system. So when the cosmic rays, which are a very high energy radiations, inter our atmosphere they will interact with atoms and molecules present , and they will produce secondary particles that will decay to another particles and these new particles may decay to another particles and so on, and this process known by shower of lighter particles . These showers of the particles contain many different particles such as staple and unstable as shown in the figure (2). The shower will be rich of the Muons that have relatively long life time than other unstable particles and can rich the earth surface. Therefore, we worked in this research by using the detector that designed to detect the Muons. And we found the Moun flux as a function of polar angle and the efficiency of the detector.

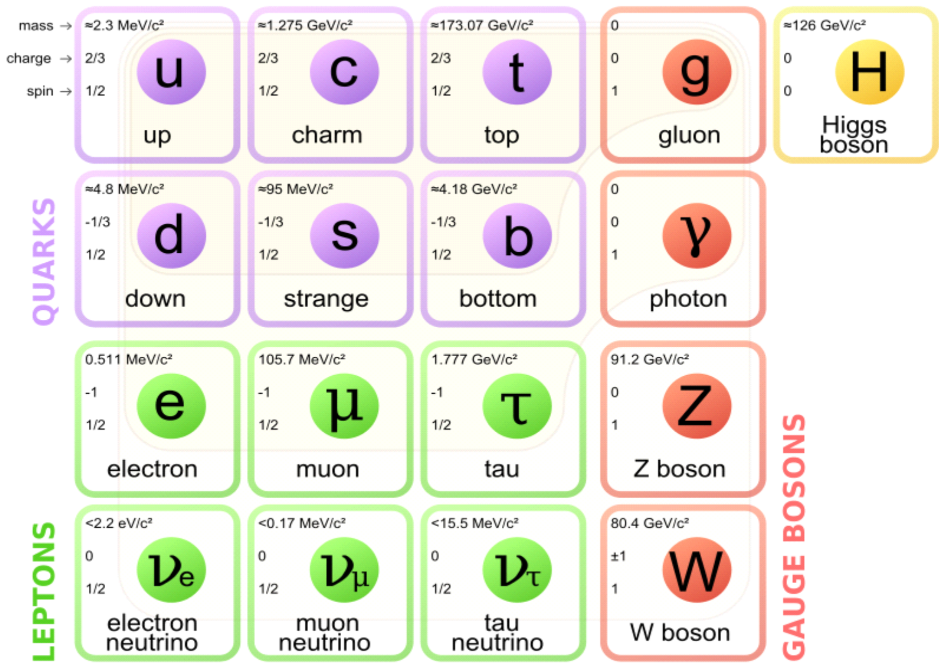

Figure 1. The fundamental particles [1]

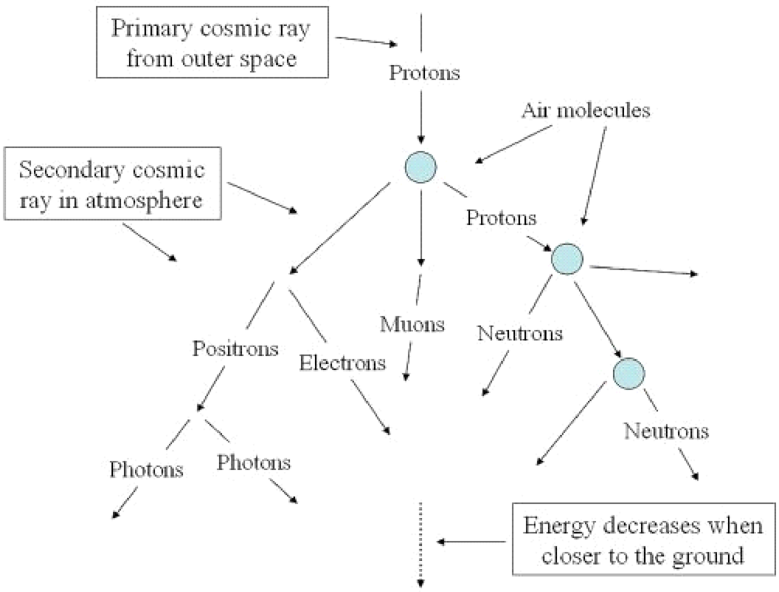

Figure 2. The cosmic ray shower

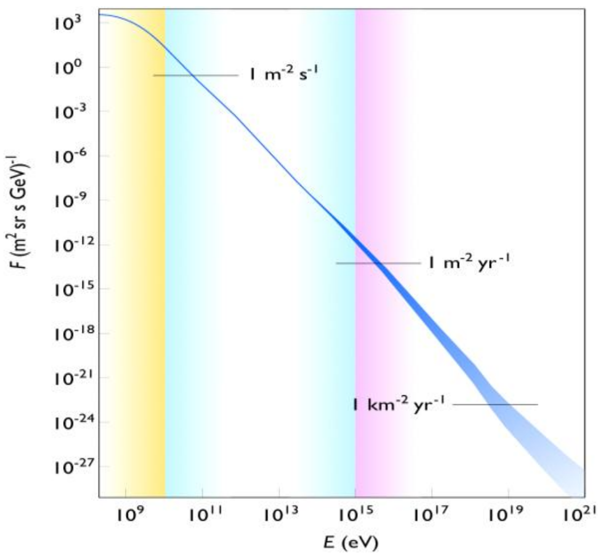

Figure 3. Cosmic rays flux and particles energy [2]

THEORY

Cosmic ray Muon

The cosmic rays consist different percentage for each kinds of particles such that 90% protons, 9% helium nuclei, and 1% of some other heavier elements and electrons. And each particles in cosmic rays are energy dependent as shown in the figure (3)[3]. However, the Moun particles are the most energetic charged particles at the sea level, because the Moun has relativity long life time and the other reasons is when the cosmic rays" protons "inter the atmosphere will decay in to Pions or Kaons, which they have very small lifetime, and in to the some other particles as shown in the decay figure (2), then the Pions and Kaons will decay to the Muon as in the decay (1) below. Therefore the Muon can reach the surface of the earth in significant way. The Moun has a mass about 105.7 GeV/c^2 with -,+ charged and ½ spin life time about 2.2 microsecond. So when the Muon reach the surface where the detector located it will be easy to detector them bu using our detector.

$K^{\pm} \rightarrow \pi^0 + \mu + \upsilon$ $\quad$ $\pi^- \rightarrow \mu^- + \upsilon_\mu$ $\quad$ $p \rightarrow n + \pi^+$

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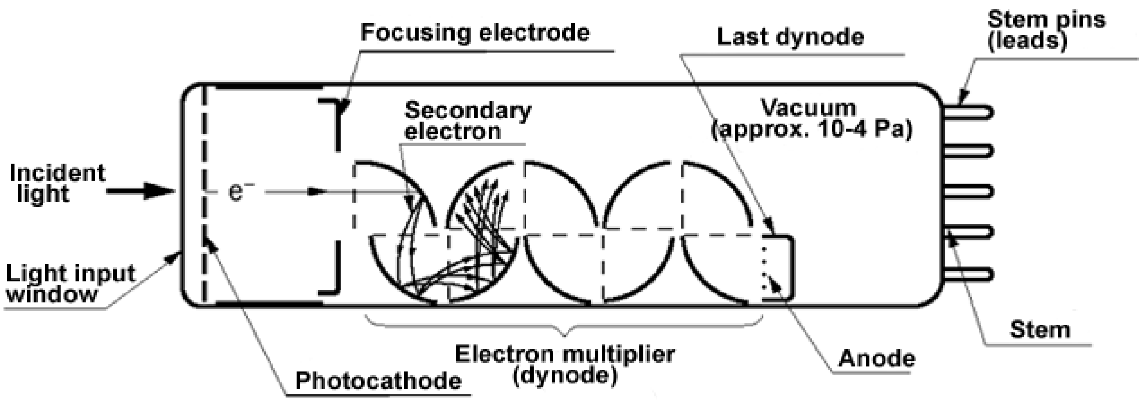

Figure 4. The PMT[4]

THE DETECTOR

The detector that we used in this research has four Scintillators layers each layer is connected to a photomultiplier. The Scintillators are a materials that made from a special kinds of plastic called poly-vinyl toluene (PVT) so when the charged particles, which are Muons, go through the scintillator layers they will excite the electrons in the PVT molecules to the higher energy level and then the electrons will drop back down by emitting photons and this photon will totally internally reflect because the PVT is designed in such a way that makes the light inside the plastic is totally internally reflected, the light will continuously reflect inside the scintillator until the end where the photomultiplier are connected. So we can see that the scintillator will not detect the Muons directly however, the muon will interact with scintillator crystal and emit photons, these lower energy photons are subsequently collected by photomultiplier tubes, which will give as a signal when the photon excite the electron in the PMT.

THE PROCEDURE AND THE RESULT

The PMT output signals

First, we site the voltage of the PMT to 2000 volts and then connected the output of the PMT to the input Chanel of the oscilloscope to see the shape of the signals as in Figure(5) and we measured the rise and fall times, 2.5 ns and 7ns restrictively, and we saw that the fall times is longer than the rise times , and to make the signal clearer we used the octal discriminator to eliminate any signal that its amplitude is lower than the threshold , which is already site in this research, and we saw that the output signal with smaller rise and fall time, 1.05ns and 5.7 ns respectively, as shown in the Figure (6)

Efficiency Measurement

The efficiency is the probability that the charge particles will go the detector and give a signal. In our detector there are four layers and we chose detector layer one and two to found the efficiency for them. Since the efficiency of detector layer one and two we have to find the ratio between the particles that went through the four detectors and the particles that went through the three detectors except the one that we want to find its efficiency, as indicate in the equation(1), and then we changed the supplied voltage for the layer that we want to find its efficiency from 1600 volts to 2000 volts by using the Zener divider.

$$\epsilon_2 = \frac{C_{1234}}{C_{134}} \qquad \text{eq (1)}$$

Where is the count number of detected particles that went through the four layers and we can get this by using the quad coincidence and is the count number of the particles that went through the four layers except layer number two, and we can find it by using the triple coincidence.

After that we took the data , the counting rate for the end , from the counter and recoded the counting rate for the once the reaches 500 counts and we saw how the counts changed with the voltage and the we plot the data as shown in the figure(5a) and we repeat the other steps to find the efficiency for the detector layer three except we relapsed the input for the AND gate by in order to get and we found the efficiency for layer three as shown in the figure(5b).

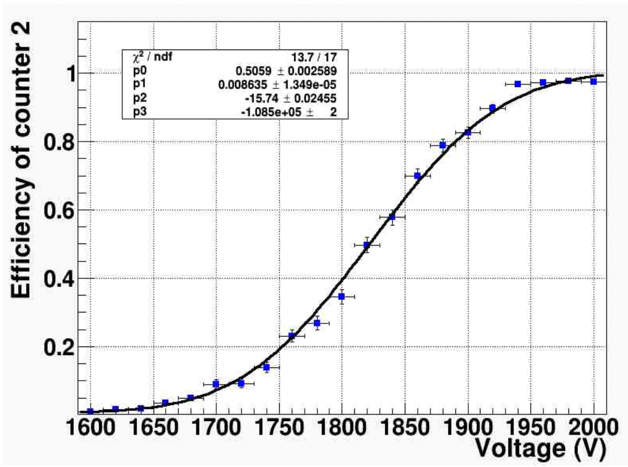

Figure 5a. The efficiency for layer two

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 9 (2018) pp. 7037-7041
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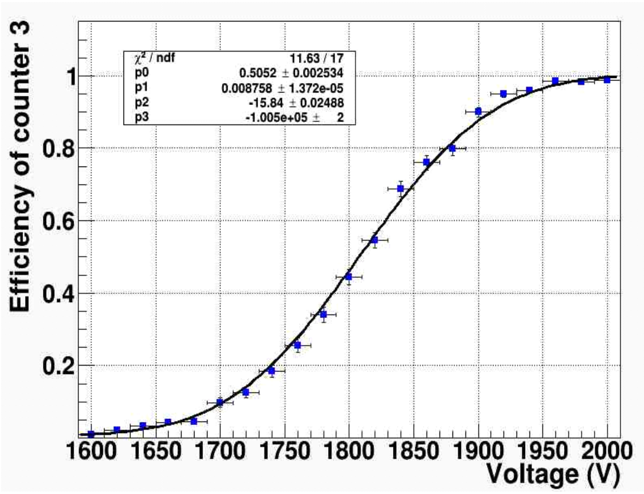

Figure 5b. The efficiency for layer three

As a result we found that the efficiency for layer number two and three. As we can see from figures (5a and 5b)that the efficiency for layer three a little bit higher than the efficiency for layer two the reason for that is the width for the detector layer number three is wider than the width of the layer two and this will make the probability of the Muon goes through layer three bigger and hence the efficiency. Also the fitting function is the error function because the response of the dynode system to the photoelectrons is approximated to Gaussian distribution, which is given by the equation (2)

$$G(x) = \frac{1}{\delta\sqrt{2\pi}} exp \frac{(x-Q^2)}{2\delta^2} \qquad \text{eq (2)}$$

Where the x is the variable charge, Q is the average charge at the PMT, δ is the standard deviation of the charge distribution. And since the error function is the integral form of the Gaussian, the error function is the best fit for the efficiency.

Flux Measurement

The flux is the rate of particles per unit area per unit solid angle. We found the muon flux as a function of a polar angle. To find the flux we set the PMTs to a certain voltage, which is the voltage that the efficiency begins to plateau, and then we hooked the output of the quad coincidence to the counter. After that we counted the rate for 10 minutes for each angle , from 60 degree to -60 degree, and then we found the flux by using the equation(3).

$$\varphi = \frac{Rd^2}{A_{top}A_{bottom}} \qquad \text{eq(3)}$$

where the is the distance between the top and bottom layers, R the rate per 10 minutes, is the area of the top layer, is the area of the bottom layer. Then we plot between the muon's flux and the polar angel and we fitted with three different functions as shown in the figures (6,7,8)

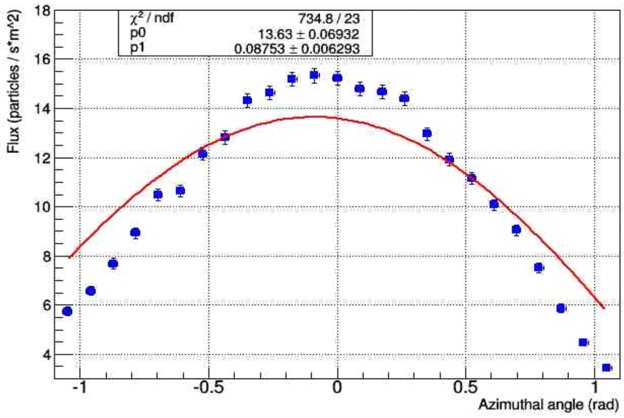

Figure 6. Fitting muon flux with a cosine function

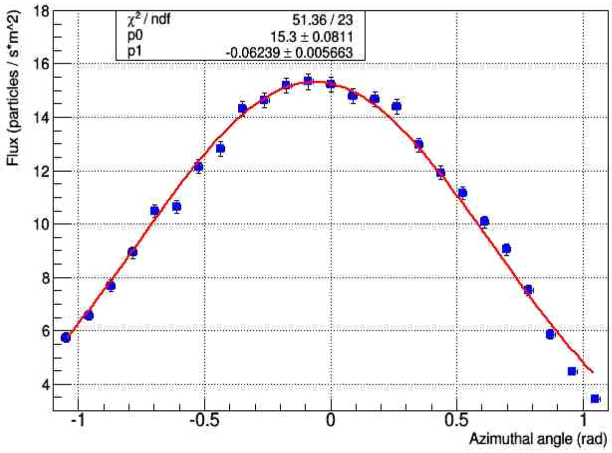

Figure 7. Fitting muon flux with a Gaussian function.

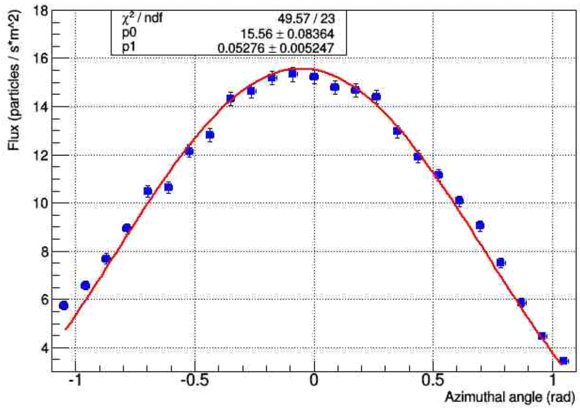

Figure 8. Fitting muon flux with a cosine square function.

We found the Muon flux as function to the polar angle, and we see that the Muons arrive at sea level with an average flux of about 1 muon per square centimeter per minute. and then plotted and fitted with three different functions as shown in the figures (6,7,8) and the best fit was by using cosine square because the chi square, appendix A, has smallest value , and there are other reasons to choose the cosine square function to fit. The first one is the muons that come with different angles (theta) from the vertical will have increases in the path length, and this assume that the earth is flat and the moun will not decay during this path. Therefore we expect the flux will vary with the angle theta however the distribution is proportion to cosine square so this a difference, cosine and cosine square, is 0% at theta equal zero and increases as the theta increases unit reach and this increment could be due to the muons decay during the path length.

The second reasons is the earth's magnetic field will deflect the cosmic rays from its surface so the cosmic rays flux is apparently dependent on latitude, longitude and azimuth angle [5]. Also as we can see that our fitting function doesn't centered at the zero the reason for this could be related to the quantum efficiency of the PMT, which is the ratio of photoelectrons per photon

SUMMARY AND CONCLUSION

In this research we have found the efficiency of the detector that we assembled at the laboratory and fitted the graph by using the error function, which is the integral of the Gaussian distribution. Finally, we found the muon flux as a function to the polar angle and we notice that the best fitting graph is cosine square function.

REFERENCES

[1] http://en.wikipedia.org/wiki/Elementary_particle

[2] http://en.wikipedia.org/wiki/Cosmic_ray

[3] http://en.wikipedia.org/wiki/Cosmic_ray

[4] Photomultiplier Tubes Basics and Applications , third edition

[5] http://en.wikipedia.org/wiki/Cosmic_ray