Secondary neutron and photon production in lead

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Introduction

Earth is constantly bombarded with the cascade of neutrinos and cosmic rays. As a result of their interaction with the molecules in the atmosphere, they produce a number of secondary particles like pions and kaons. These secondary mesons can decay to muons. The probability of this decay is as shown below .

$\pi^{\pm} \longrightarrow \mu^{\pm} + \nu_{\mu} \sim 100\%$

$\kappa^{\pm} \longrightarrow \mu^{\pm} + \nu_{\mu} \sim 63.5\%$

Unlike neutrinos which undergo only weak interaction, muons can interact in different ways. And thus their study is very important for conducting particle physics experiments which demand very low background.

In this paper, we report the study of interactions of cosmic ray muons with a lead block and the characteristics of secondary neutrons and photons produced as a result of this. The significance of the study comes because these particles especially neutrons can't be tagged while conducting the experiment. They mimic the original signal and thus pose a challenge to the experimenter. We aim to find a solution to reduce this background for low energy experiments.

Secondary neutron and photon production due to cosmic muons in lead

Secondary neutrons are produced by cosmic ray muons through the following processes; interaction of muons with the nuclei through virtual particles, elastic scattering of muons with the bound neutrons, and photo-nuclear interactions. Whereas secondary photons are produced mainly by Bremsstrahlung.

Because of their chargelessness, these neutrons and photons often mimic the original signal. We have used GEANT4 [1] software package to simulate the medium to study the process. A lead block of fixed length and breadth with dimension 50cm and variable thickness direction is used for the present study.

We have passed cosmic ray muons through the lead block with three different flux corresponding to power law($E^{-2.7}$) and realistic muon flux on earth $(4.28 + E)^{-3}$ [2] with and without angular dependance in the energy range 0.3 GeV to 100 GeV . The different characteristics of the secondary neutrons and the secondary photons produced inside the lead block are analyzed. For the present report, we focused on the multiplicity of these particles as well as the kinetic energy.

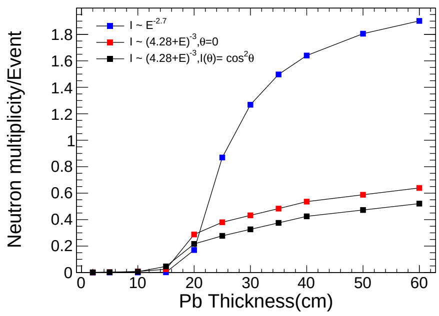

FIG. 1: Multiplicity per event of secondary neutrons due to cosmic muons in lead block.

Figure 1 and 2 show the multiplicity and average kinetic energy of neutrons produced from incident cosmic ray muons in lead. In fig. 1 it can be seen that with the increase in thickness the neutron production also increases for all input muon fluxes producing almost same number of neutrons till 20 cm of lead. Beyond 20 cm, there is a non-linear increment with

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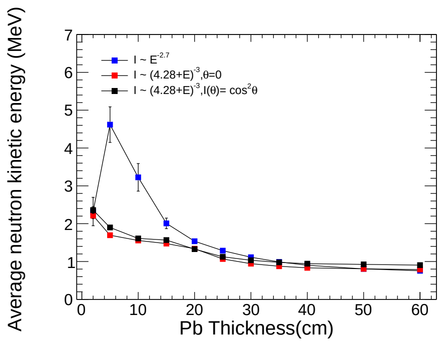

FIG. 2: Average kinetic energy of secondary neutrons due to cosmic muons in lead.

the increase in lead thickness. But there is a huge increase in neutron production for power law distribution. While the kinetic energy is showing not much variation except for small thickness and for power law distribution.

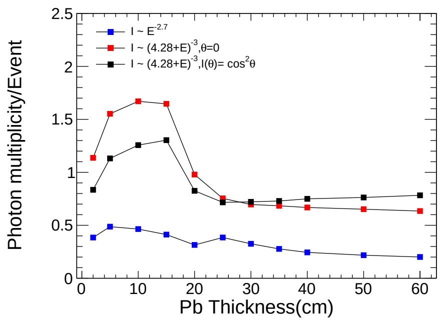

FIG. 3: Multiplicity per event of secondary photons due to cosmic muons in lead block.

Figure 3 and 4 show the multiplicity and average kinetic energy of the secondary photons produced inside the lead block. As in the previous case, in fig. 3, we can observe a different trend of photon production till 20 cm of lead. Beyond 20 cm the multiplicity is almost a constant. It is quite evident from fig. 4 that the average kinetic energy doesn't change much with the thickness of the block as same as in the case of neutrons, which is quite understandable as flux has no effect on the energy of the particle. Where as the multiplicity is dependant on the type of incident

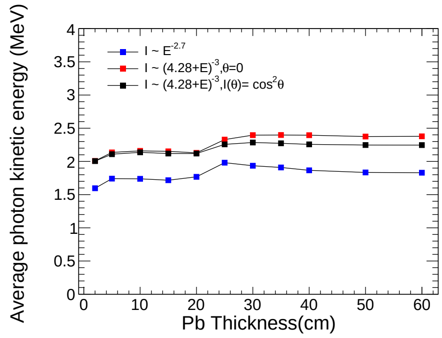

FIG. 4: Average kinetic energy of secondary photons due to cosmic muons in lead.

muon flux as in the previous case.

Conclusions

In this paper we have studied the secondary neutron and photon production from cosmic ray muons in a lead block with variable thickness. We have observed that the kinetic energies of the particles produced remains almost the same or without appreciable change regardless of the distribution of the incident cosmic muon flux. But the multiplicity is having a variable form with change in flux upto a lead thickness of 20 cm.

References

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[2] Prashant Shukla, Sundaresh Sankrith, *Energy and angular distributions of atmospheric muons at the Earth*, arXiv preprint arXiv:1606.06907 (2016).