Muon Tomography via GEANT4

A. Burkan BEREKETOGLU

Advisor: Prof. Dr. Ali Murat GULER

Abstract

Muon Tomography is an imaging approach which is initiated around 70's by a team led by Prof. Alvarez to find secret rooms in pyramids of Egypt [1-3]. The first nuclear emulsion based that uses films in muography pioneered by Tanaka and Niwa to use μ for imaging volcano in Japan and first images taken around 2007 [3]. This technique is a promising technique to be used, due to abundance of μ and not requiring continuous monitoring with considerable time limitation to fill silver grain tracks in emulsion plate to be used for high resolution imaging in experiment[1-2]. We have developed such a simulation tool via GEANT4 to detect different materials via detecting muon scattering in emulsion detectors and excerpting the μ count difference before and after the material to be analyzed in different emulsion films [4]. As μ particle distribution gaussian distribution with cosine law angular distribution selected between 100 GeV to 1 TeV μ to get our results [5].

Method

→ Detector positions are set and detector geometries, dimensions with their structures are defined

→ Particle definition, mechanics (physics lists), beam geometry, beam angular (max 70 deg) and energy distribution (mean = 550 GeV with deviation of 180 GeV) and beam position are defined

→ Run, Event, Step actions are defined.

→ Sensitive Detector is selected (Emulsion) and defined to save appropriate data,

→ Visualization and initializations for simulation are defined.

→ Recorded parameters and experiments are analyzed to check if there exist any error in data collection and experimentation.

$$-\frac{dE}{dx} = Kz^2\frac{Z}{A}\frac{1}{\beta^2}\left[\frac{1}{2}\ln\left(\frac{2m_\mu c^2\beta^2}{I(1-\beta^2)}\right)-\beta^2\right]$$

- dx: Energy loss per unit distance
- K: Constant
- z: Charge of the incident particle
- Z/A: Atomic number to mass ratio of the medium
- β: Velocity of the incident particle in units of the speed of light
- m_μ:Muon rest mass
- I: Mean excitation potential of the medium

$$\Phi = \Phi_0 \cdot e^{-\frac{h}{H}}$$

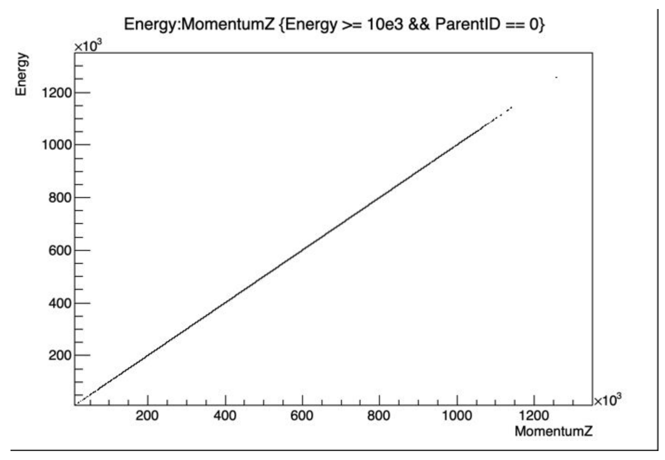
- Ø = Muon flux at a given depth.
- $Ø_0$ = Muon flux at the surface.
- h: Depth of underground.
- H = Attenuation length of muons in the material.

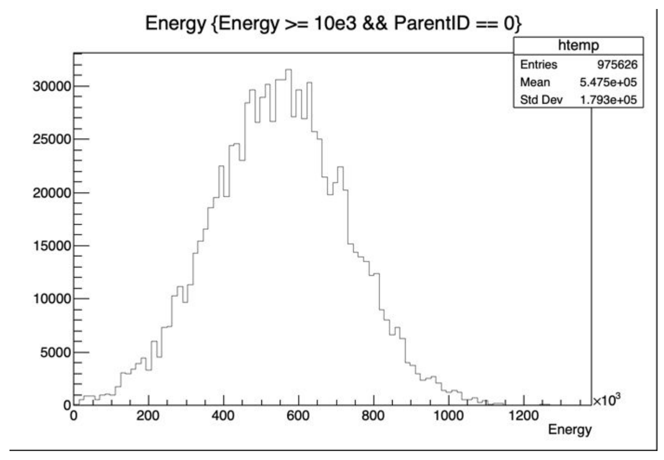
Introduction

To be able to detect μ^- interactions with high spatial resolution of the trajectories , also to make nuclear emulsions with silver grains for tomography via tracing muon tracks, due to nature and the composition of the emulsion cloud chamber, we can via tracking scatterings of muon from various materials with a sensitive detector constructed from emulsion cloud chambers we can create high resolution images, identification systems, and geological scanning. This project aimed to make such system for Turkish Historical Landscapes. For to implement such tracking system and generating particle + collecting data GEANT4 is used to make such simulation tool.

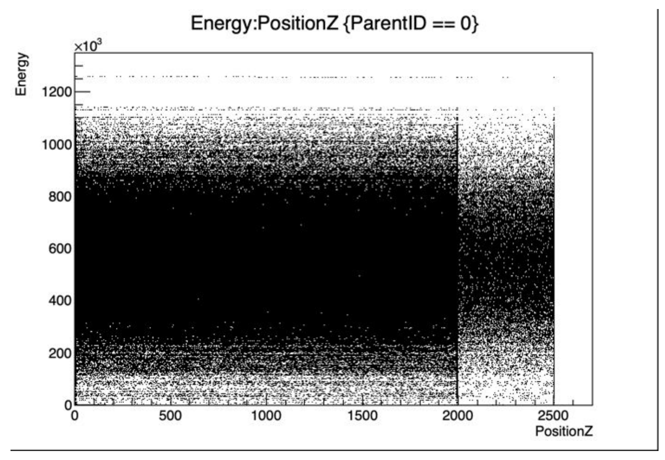
Results

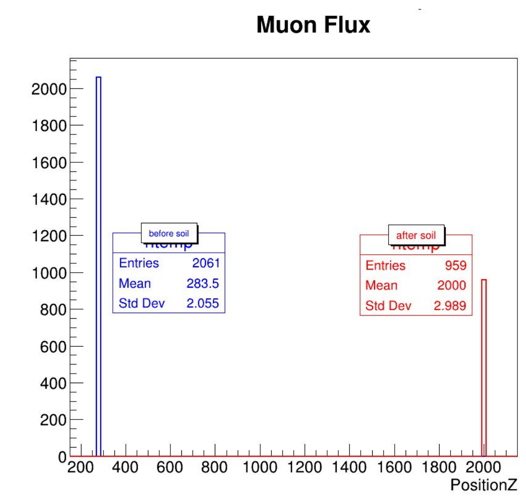
Initial distribution of energy and momentum at position 0



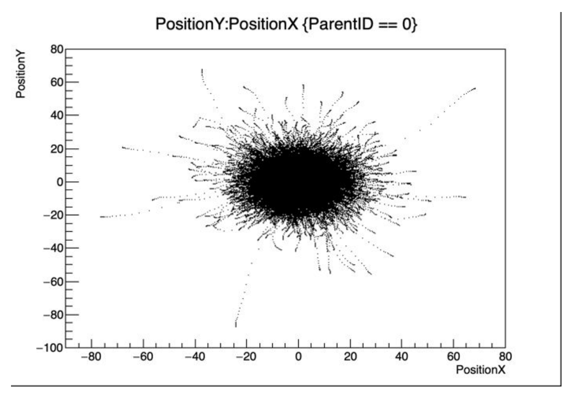


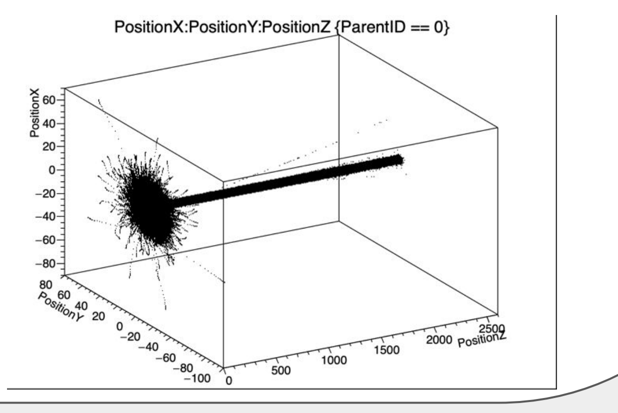
Flux Plots





Z Direction and Transverse Plots





Conclusion

- In this experimentation it is seen that μ is defined in a range that has specific characteristics in energy and angle which enables μ to penetrate through Earth's crust and help us to see what is underneath.
- 100 GeV to 1 TeV Gaussian distributed μ with cosine-law angle distribution with spherical beam shape can penetrate earth's crust defined as 99.438 cm.
- It can also be used to identify various materials from their corresponding density.
- Emulsion film based on Bromide and Silver grains can be used as sensitive detector to detect ø at different positions.

Acknowledgment

Author acknowledges that guidance of Dr. Mehmet Oğlakçı, Prof. Aysel Kayis Topaksu and Matsuo Group from Nagoya University for sharing their knowledge in muon tomography.

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Middle East Technical University
Department of Physics