Preliminary simulation study of Galeras Volcano structure using Muon Tomography.

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Abstract

Muon radiography is based on the observation of the absorption of muons in matter, as the ordinary radiography does by using X-rays. The interaction of cosmic rays with the atmosphere produce Extensive Air Showers (EAS), which provide abundant source of muons. These particles can be used for various applications, in particular to study the internal structure of different volcanoes edifice. [1].
Using GEANT4 [2], we present a simulation of the volcanic cone and a scintillation detector that has been calibrated with a radioactive source. Subsequently, the scintillation detector was placed at a previously studied point on the GV, and the production of muon flux was realized as a function of the zenith angle and to different energies that cross the Geological structure and hit the scintillation detector.

Introduction

The Galeras Volcano (GV) with a height of 4276 m a.s.l., located in San Juan de Pasto city with an estimated age of 4.500 years, is one with the highest activity in Colombia with important records of eruptions in the past. The increasing of population in higher risk areas around the volcano has motivated to develop special techniques of monitoring the volcano activity, especially for its records respecting to pyroplastic flux generated.
The tomography with muons help us to understand the internal volcano structure and its dinamics present during a eruptive process[[3].
Muons generated by EAS, interact weakly with atmosphere, losing minimal energy, allowing to get a muon flux with different zenith angles (**Fig 1**), which arrive to the terrestrial surface (**Fig. 2**). Using SOLIDWORKS, FASTRAD and GEANT4[2], We simulated the volcanic profile and a muon scintillation detector as tools for GV tomography.

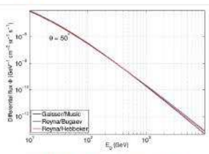
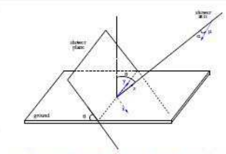


Fig 1: Muon flux model. $\theta : 50°$.



Rain plane.(Perpendicular to the rain axis) **Fig 2:** the terrestrial surface and coordinate system.[4].

Scintillation detector of atmospheric muons in GEANT4[2]

In the radiation-matter program GEANT4[2], was designed and simulated a scintillation detector of Polyvinyltoluene bars C_9H_{10}, predetermined material in GEANT4 [2](**Fig. 3**). The chosen shape of the bars is based on the experiment MINERvA[5], which allow us to observe how interact the muons when cross the detector, the physical processes involved, the energy that they deposit in it and as their tracks are affected. (**Fig. 4**).

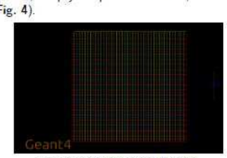


Fig. 3: Front view of the detector.

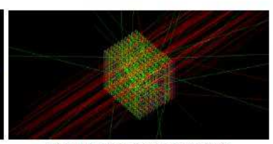


Fig. 4: Simulation of muon interaction with a scintillation detector

GV Geometry in GEANT4[2]

For the implementation of the GV in GEANT4[2] We used different softwares, in order to include the coordinates of the level curves provided by the Colombian geological service[6],and build the solid volcanic complex which was exported to a GDML format[7] that can be read by GEANT4[2].The simulation of the geometry of the GV (**Fig. 5**)is composed of standard rock and his crater of air (**Tables 1 and 2**).

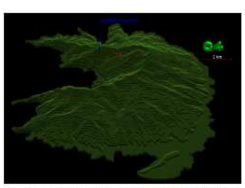


Fig 5: Simulation of Galeras Volcano in GEANT4.

Características del Volcán	
Diametro del cráter	320m
Altura	1100m
Profundidad cráter	320m

Tabla 1: Características del volcán

Composición	Porcentaje en la tierra
O	46.6
Si	27.7
Al	8.3
Fe,Ca,Na,K,Mg	17.4

Tabla 2: Composición química de la roca estándar

Calibration of scintillation detector

For the calibration of the scintillation detector was used a source of Co_{60}.
Co_{60} is artificially produced by activation of Co_{59} isotope neutron. Co_{60} decays by the disintegration beta of Ni_{60} stable isotopes (**Fig. 6**).The activated nickel nucleus emits two gamma rays with energies of 1.17 and 1.33 MeV.
In order to the detector can get a detection of the decays of the source of Co60, was added and modified new classes to the program, such as: "GammaPhysics", "PhysicList", "EmStandardPhysics" and get a graph of the characteristic peaks of gamma radiation. (**Fig. 7**).

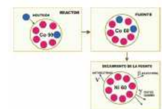


Fig. 6:A neutron hits over a core of Co_{59} which becomes in Co_{60} (unstable)

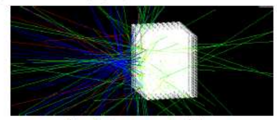


Fig. 7:Co_{60} source simulation

Ideal location of scintillation detector on Galeras volcano

The two geometries (GV and the detector with its characteristics), are implemented in the GEANT4 simulation. The location of detector is an aspect of great importance when applying muongraphy on geological bodies, because the distance that muons cross through the structure, depends of the topography of the place and the location of the area of interest. The best location points are indicated on the map.(**Fig. 8**)

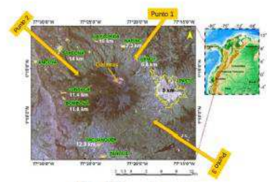


Fig. 8: Convenient points to the disposition of muon detector[6].

Fig. 9: Location on which the simulation is performed[6].

To place the location point at the simulation (**Fig 9**) We transformed the geographical coordinates of the volcano and the detector to Cartesians coordinates (X,Y,Z). After,a translation was made to the origin of the coordinate system in GEANT4.

Simulation's results in GEANT4

We used ROOT[8] for the analysis of data obtained of the simulation.
We simulated 2000 events of interactions of Co_{60} source with the scintillation detector. In **Fig 10** you can see the decays of the Co_{60} source and in **Fig. 11** the characteristic peaks of gamma radiation registered by the scintillation detector.

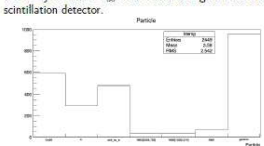


Fig. 10: Co_{60} decay.

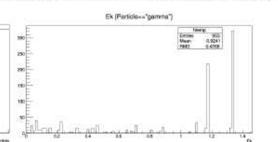


Fig. 11: The characteristic peaks of gamma radiation.

We are working with an extraordinary geometry and many events of interaction, so that the GV simuation has been scaled to units of "mm". To observe the location point of the scintillation detector in the graphical interface, the simulation has been performed with a considerable size detector. The results can be seen in **Fig. 12** and **Fig. 13**.

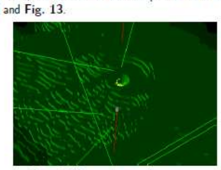


Fig. 12: Muon crossin volcanic cone and the scintillation detector

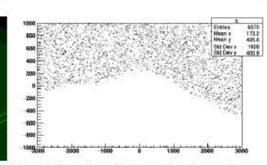


Fig. 13: Muon flux which arrived to the test detector.

Conclusions

-Next step we will calculate the atmospheric profile for Pasto city
-We will develop a real size simulation
-We will do a preliminary measurement of muon flux with the prototype detector in the three locations and the possibility to doing a measurement with the detector which has the high energies investigation group of UNIANDES.

Referencias

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