Study of secondary cosmic ray through extensive airshower (eas) simulation

Science, Physics

Introduction

Galactic Cosmic Rays (GCR), which aremainly originated outside the solar sys-tem, propagate through the galactic mediumwith relatively weak magnetic field and in-teract with the medium and magnetic field.

While in the heliosphere they interact withthe electromagnetic field carried by the solarwind, which effectively modify their flux in-tensity up to the energy of several GeVs. TheCosmic Rays (CRs) has a wide energy rangefrom sub-GeV to about 1021 eV and the inten-sity decrease rapidly for higher energies. GCRare composed mostly of fully ionized nuclei ofH (~ 85%), He (~ 12%), other heavy nuclei (~1%), and a small component of electrons (~2%). There is also very small contribution (~ 0. 1%) of positron and antiprotons whichare likely to be produced in secondary reac-tions with the interstellar medium. The earth's magnetic field provides a shield-ing from these cosmic ray particles. Depend-ing on their rigidity, cosmic rays penetrate themagnetic field of the earth and reach the topof the atmosphere. The CR flux at this pointdepends on the earth's magnetic field distribu-tion and as well as on the solar activity whichin turn modulates the magnetic field distribu-tion surrounding earth.

The CRs interact with the atmospheric nu-clei through several processes to produce sec-ondary particles which decay or interacts fur-ther to produce other particles and radiation. These secondary cosmic rays are observed by comground-based and balloon born detectors.

The study of the secondary CR particleshower has its manifold importance. Such as the proper reconstruction of the primary CR particle from the ground based observations, understanding the background environment for the detectors on board satellites and balloons, radiation mitigation to protect the electronics system for the satellites and aviation, radiation protection for humans in space expeditions, aviation or on earth surface, correlations with solar activities and terrestrial rainfall etc.

Here in this current work we study the sec-ondary CRs generated in the earth's atmo-sphere due to the interactions of the GCRsby means of Monte Carlo simulation. Procedure of EAS simulationTo study the interaction of the GCR parti-cles in the earth's atmosphere we considder afull 3D model of the atmosphere and magne-tosphere using Geant4 simulation toolkit.

The atmosphere surrounding the earth is de-fined by considering the NRLMSISE-00 standard atmospheric model parameters up to100 km from the earth surface. For earth'smagnetic field we consider 12th generation IGRF model (for internal magnetic field) and Tsyganenko Model (for external magneticfield). Some samples of the magnetic fieldline distribution are shown in Fig. 1. The primary CR spectra modified by the so-lar activity can be represented by the modifiedpower law. In our simulation we use the power law index α = 2. 83 (for H) and 2. 77 (forHe) respectively to generate primary cosmic ray proton and helium as they are the most powerful.

The solar modulation parameter φ is fixed at 650MV considering the time of the simulation, ason 11th May, 2016 at around 5: 35 UT. We con-sidered the energy of the primary CRs in 100MeV to 800 GeV.

Results and discussions

A prominent modulation of the primary flux comes from the low-energy cutoff due to geo-magnetic field. This modulation is inherentlyachieved in the simulation by the incorpora-tion of geomagnetic field. The generated primary flux of the H and He and the correspond-ing modulated flux due to the geomagnetic cutoff is shown in Fig. 2.

The graycurve represented original primary flux, while thepoints below the curve presents the same fluxesafter geomagnetic cutoff. The upward and downward proton flux atthe satellite height (400 km) due to H andHe particle interactions in the Field Of View (FOV) of 35◦ arround zenith and nadir direc-tions are shown in the Fig. 3.

Conclusion

We simulated the primary GCR interactionsin the earth’s atmosphere to produce the sec-ondary particles. Though here we have pre-sented the results for the secondary protonsat the satellite height which have been verifiedwith the observed proton flux from the satel-lite based mesurements such as by AMS02, we can study the distribution of other sec-ondary products of the CR shower and theirflux variation at different height through theatmosphere.