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Report :

Electromagnetic and hadronic extensive air shower identification using muon detector of TAIGA experiment :-

The TAIGA astroparticle observatory is under the construction at Tunka valley close to the Baikal Lake. The TAIGA experiment is searching for new intergalactic and extragalactic informations from high energy astroparticles which carrying energy in the range of 1TeV to several PeV. Up to now it consists of 2 imaging air Cherenkov telescopes, about 100 wide-angle optical detectors, and 19 stations with 342 scintillation detectors. In 2019, the existing system of scintillation detector stations was extended with 3 stations of the new type Taiga-Muon counters. Each station contains 16 counters, with 8 surface and 8 underground counters.

New Taiga-Muon station as an extension of Grande experiment which will take it into a new level. Taiga-Muon experiment is looking forward to study about extensive air shower in the range of energy greater than 100TeV. The counter and station positioning has been studied using specially developed Monte Carlo simulation program based on of CORSIKA and GEANT4 software packages. This simulation study is concentrated on the ultrahigh energy extensive air showers (EAS) induced by gamma-quanta or proton in the range from 1 PeV to 10 PeV and zenith angle ranging 0° - 45°.

The Taiga-Muon detector is totally different with Grande detector. A Taiga-Muon counter contains 11 parts with dimension of 1m x 1m. 4 parts have 2cm thickness and other 7 parts have 1 cm thickness. Each counter contain one PMT and a wavelength shifter. The scintillator plates are covered with thin aluminum sheets for insulating it from moisture. The dimension of a Grande counter is 80Cmx80cmx4cm. Polyvinyl toluene (NE102A) is used as the scintillator material in Grande, which is covered with duraluminum. On the other hand Polystyrene plastic is used as scintillator in Taiga-Muon. From the programing point of view this detector construction was the major part. The soil test data is used to build the realistic model. The Monte Carlo simulation of this experiment has four parts. Shower creation, selection of particle by means of area of interest, interaction of particle with detector, and result analysis by using ROOT software package. All simulation and analysis are programed in C++ and in addition to that shell script is used for data management.

The extensive air shower with 100TeV, 300TeV, 1PeV, and 3PeV energy of both gamma quanta and proton are created by using Corsika package. In Corsika simulation 1000 primary particle shower events are created with various theta angle such as 0, 30, and 45 degrees. The quark gluon string model(QGSJET-II-04) is used to create the shower in all cases with FLUKA(fluctuating kascade) library. High energy hadronic interaction programed in QGSJET-II-04 and low energy hadronic interaction are explained by FLUKA. The coast library package is used to create the input particle for Geant4 simulation. The Selection of particle from the output data of Corsika simulation is based on the detector position at the trigger level and particle momentum coordinates. All selected particle data given as input to GEANT4 program and which gives the results as energy deposition created by different particles.

The trigger efficiency is calculated for Grande stations by using combination of simple shell script and C++ program. Odd even combination of counters are used to calculate the trigger efficiency of Grande stations. In the case of Taiga-Muon trigger efficiency is calculated by checking the signal at least two counters. The underground detector of Grande station is placed inside a tunnel at 1.5m below the soil. Geant4 simulation is studied to identify the electromagnetic shower and hardronic shower from the simulated extensive air shower data. The Geant4 input particle data set which are present in the area of interest are selected in several manner by changing the depth of soil. First of all by changing the depth of soil in the case of Grande station is studied. Then compared with the simulation result of Taiga-Muon station, by placing the underground cluster at 2m deep in the soil. Then for better understanding and optimization Taiga-Muon station is placed in same position of Grande station and execute the program with several soil depth. From the output data it is clear that the optimum depth should be more than 1.5m.
The simulation results are analyzed with the help of neural network. For this work, a new set of air showers was created by CORSIKA. The list of useful secondary particles at the ground level is produced using the COAST library package. The interaction of secondary particles with the soil and detectors was simulated with GEANT4 package. It is known, that the lateral distributions of particle density in gamma-quanta and proton EAS are different at the ground level. Also the density of muons is different. To use both these characteristics for separation of gamma-quanta from proton we suggest using a neural network. The method called binary cross entropy was studied. Amplitudes in surface and underground counters of each station were given as input data. The air shower having energy ranging 2.25 - 3.5 PeV shows more than 90% of identification efficiency for proton by keeping identification efficiency of gamma around 50%.
The construction of Taiga-Muon counters is progressing at Educational and Scientific Laboratory for New methods of Ionizing Radiation Registration, Novosibirsk State University. First Taiga-Muon station will be installed in this summer and five more stations are planning to build in nearest future. At present the distance between two Grande stations is nearly 200m. The Muon stations are planning to build around 100m apart. Which could give more information with better accuracy.

Now we are planning to joint study with HiSCORE optical detectors and scintillation array. For this purpose we are using same software packages for simulation.

List of publications :

1) Optimization of electromagnetic and hadronic extensive air showers identification using muon detectors of TAIGA experiment
2018, Nucl.Instrum.MethodsPhys.Res.A Vol-952, 161730, ISSN 0168-9002,
DOI : 10.1016\j.nima.2018.12.045

2) An approach for identification of ultrahigh energy extensive air showers with scintillation detectors at TAIGA experiment
2020,Journal of Instrumentation 15(09):C09037-C09037,
DOI: 10.1088/1748-0221/15/09/C09037

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