29th International Cosmic Ray Conference Pune (2005) **6**, 65–68

RUNJOB emulsion chamber simulating with ECSim code

O.V. Bondartsova[a], V.V. Galkin[b], S. N. Nazarov[a] and T.M. Roganova[a]

(a) D.V. Skobeltsin Institute of Nuclear Physics, M.V. Lomonosov Moscow State University, Moscow, Russia
(b) Physics Department, M.V. Lomonosov Moscow State University, Moscow, Russia
Presenter: T.M. Roganova (rgn@dec1.sinp.msu.ru), rus-roganova-T-abs1-he11-poster

Emulsion chamber simulation code ECSim is presented based on GEANT 3.21 and QGSJET nucleus-nucleus collision generator. The results of RUNJOB-99 simulation are reported on protons and helium efficiency estimation and interaction depth distribution. The results are compared with experimental data.

1. Introduction

Any emulsion chamber experiment needs a detailed simulation of a process of passage of high energy cosmic rays through a chamber and a process of detection of radiation by sensitive layers in order to design a chamber and interpret the results of an experiment. One should rely on such a simulation while dealing with some vital problems as chamber detection efficiency calculation or testing primary particle parameter (energy, arrival direction, etc.) determination methods. We introduce here a computer code we use to interpret the data of Russian-Japanese balloon experiment RUNJOB [1].

2. Simulation method

A new method of emulsion chamber simulate can be used to solve different problems including chamber detection efficiency calculation and testing of primary particle parameter determination methods. Emulsion chamber experiment usually incorporates two stages: chamber exposure to cosmic ray flux (i.e. accumulation of real event statistics) and emulsion layer development and processing in order to extract data on particle cascades. In hight energy computer experiment the most of processor time is spent on tracking of numerous cascade particles through the detector that is why it makes sense to carry it out only once keeping its detailed results for later utilization while solving a number of problems. This means one is to conduct a computer experiment, like a real one, in two acts: firstly, one accumulates a database on high energy particle cascade development in an emulsion chamber and their interaction with its sensitive layers; secondly, the database is used to solve certain problems. Depending on the problem, the second step could be made many times using different methods.

In order to carry out such a computer experiment a computer code was developed on the basis of a well-known three dimensional Monte-Carlo simulation tool GEANT [2]. We modified a part of GEANT source code responsible for nuclear interaction simulation. Standard GEANT uses, depending on hadron energy, either GHEISHA code or FLUKA code as a hadron interaction generator. Both codes are not intended for nucleus-nucleus interaction simulation at very high energies (up to 10 PeV) which is our case. We have choosen QGSJET as an up-to-date nucleus-nucleus interaction generator for very high energies but it is inapplicable at hadron energy below 80 GeV. An interface was developed between GEANT and GQSJET which provides a call to GHEISHA if particle energy is lower than (80 GeV/nucleon for nuclei) and a call to QGSJET otherwise. GHEISHA does not consider nuclear interaction of nuclei heavier than alpha-particles but, as a matter of fact, such nuclei of energy lower than 80 GeV/nucleon never appear in our simulation with realistic nuclear fragmentation option of QGSJET.

QGSJET was extracted from CORSIKA [3] simulation package. Besides QGSJET, the package includes

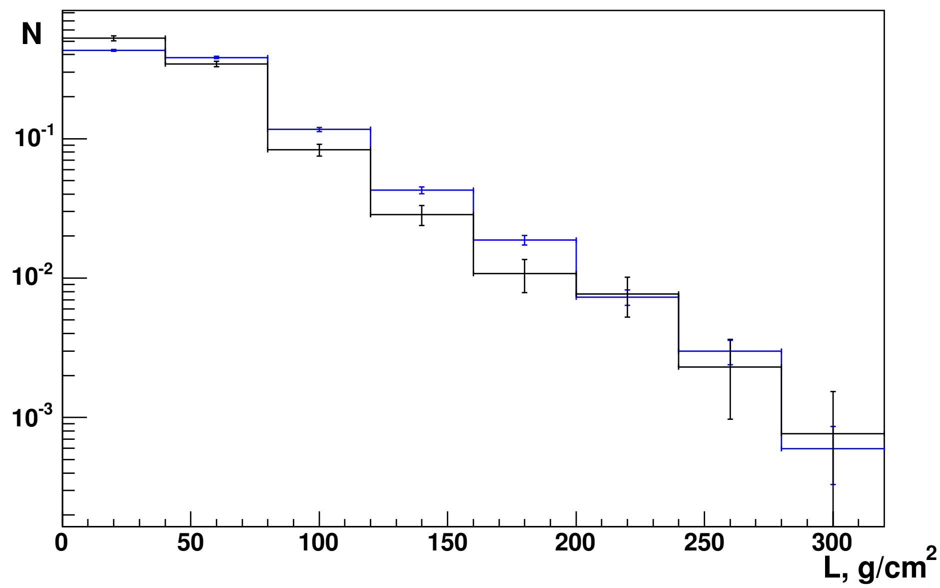

Figure 1. Distribution of vertex points for proton(black) and helium(blue) primaries normalize to unity.

other nucleus-nucleus interaction generators: VENUS, HDPM, SYBILL, DPMJET, NEXUS. Thus, with our GEANT-QGSJET interface we can easily use any of them in case we need it.

Primary and secondary particle parameters (particle type, initial coordinates and momentum components) are stored as a result of simulation of an event. To avoid of storing unnecessary information only coordinates of particles with energy above treshold E_{thr} found within a circle of radius r_{thr} about the cross point of the primary particle direction with the layer under consideration are subject to such a storage.

Besides, while simulating a nuclear interaction only secondary particles with energy above E_{thr} are subject to further tracking. The choice of threshold energy E_{thr} is particularly important for secondary γ-quanta because, on one hand, tracking of electromagnetic cascades takes the most part of simulation time and, on the other, too high values of E_{thr} result in partial loss of data which is of interest to us.

We calculated nuclear interaction point distribution and the efficiency with the help of new method.

3. Interaction point distribution

Proton and helium vertex point distributions for the RUNJOB-99 chamber are presented in the Fig. 1. Chamber matter thickness is expressed in g/cm^2. Vertical chamber depth amounts to 30 cm or 54 g/cm^2. The upper boundary of the target block is located at a depth of 2 g/cm^2 from the top.

Simulated events analysis shows that 30% particles interact in the target and 70% in the calorimeter. Such correlation of target and calorimeter events is ruled mainly by trigger conditions and conforms to the experimental data (25% for target events and 75% for calorimeter ones) within the statistical errors.

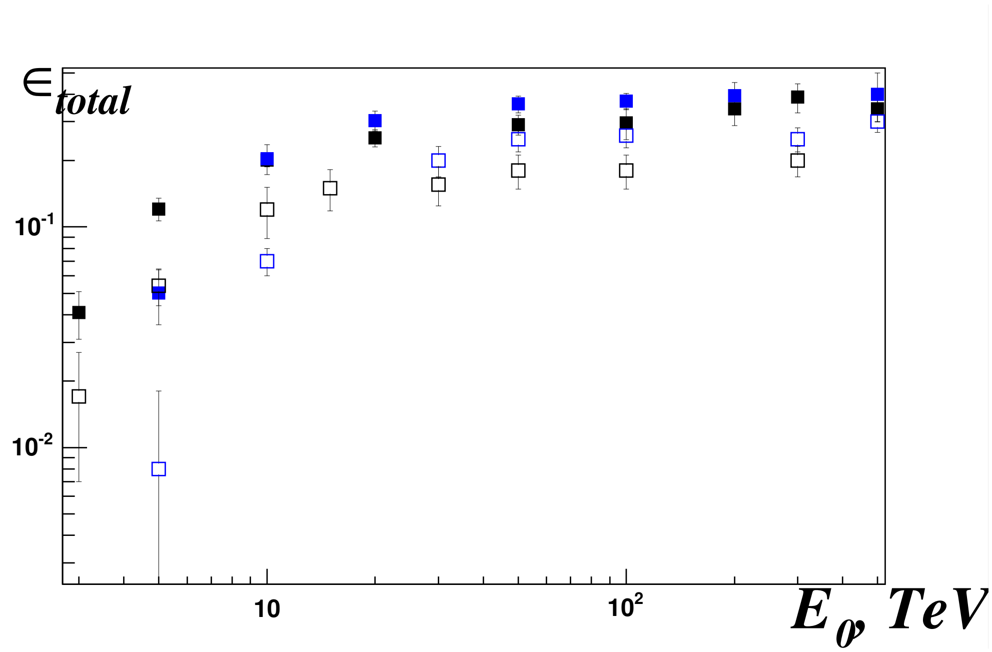

Figure 2. Efficiency of proton(black) and helium(blue) detection in RUNJOB-99(filled squares) and RUNJOB-96(empty squares) chamber structure.

4. Detection efficiency

We determine efficiency as

$$\epsilon(E_0) = N_{obs}(E_0)/N_{incident}(E_0).$$

Here $N_{incident}$ is the number of primaries that hit the chamber and N_{obs} is the number of events (=interacted primaries) that generated cascades which satisfied the trigger conditions.

Fig. 2 shows proton and helium efficiency dependence on primary energy E_0 resulting from the processing of event samples of fixed primary energy.

Total depth of the chamber is less than one mean interaction length λ_{int} even for iron nuclei which leads to the characteristic values of efficiency of less than unity. High energy edge (asymptotic) values of the efficiency for different primaries are ruled by the corresponding λ_{int} values while low energy bend of efficiency curves are greatly influenced by trigger conditions.

Detection efficiency was estimated for RUNJOB chambers of different structure (1996 and 1999 flights). Fig. 2 demonstrates qualitative agreement of efficiency curves for the two designs.

Asymptotic efficiency values for RUNJOB'99 chamber are 0.3 for protons and 0.4 for helium. The corresponding values for the case of RUNJOB'96 chamber are 0.2 and 0.27. Substantial differences between the efficiency values for different chamber design indicate the necessity of careful account of chamber structure by simulation tool. It is even more important for the low energy bends of efficiency curves.

5. Conclusions

Emulsion chamber Monte-Carlo code ECSim is presented which main purpose is simulations of super high energy cascades in emulsion chambers or other stratified detectors. Code output data structures are optimized to provide all necessary information for the solution of many common problems such as chamber detection efficiency calculation or testing primary particle parameter (energy, arrival direction, etc.) determination methods. Examples of the code application to the simulation of RUNJOB chambers are shown.

References

[1] Apanasenko A.V., Sukhadolskaya V.A., Derbina V.A. et al., Composition and energy spectra of cosmic ray primaries in the energy range 10^{13}-10^{15} eV/particle observed by Japanese-Russian joint balloon experiment. //Astropart. Physics. 16(2001). 13-46

[2] CERN/ASD Group. GEANT Detector Description and Simulation Tool, CERN Program Library W5013. CERN, 1994

[3] Knapp J., and Heck D., Extensive Air Shower Simulation with CORSIKA: A User̀s Manual, Kernforschungszentrum Karlsruhe KfK 5196 B (1993)