MONTE CARLO EVALUATION OF THE ENERGY DEPOSITED BY LEPTONS IN THE KASCADE GRANDE DETECTORS*

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Received December 21, 2004

The energy deposited by electrons, positrons and muons in the KASCADE GRANDE detectors is evaluated with a simple and quick Monte Carlo method. This method works faster than the method based on the Geant package. The time economy is important because the number of particles involved is large, *e.g.* 10^9 particles in one high energy air shower.

Key words: Monte Carlo simulation, KASCADE GRANDE experiment.

1. INTRODUCTION

The KASCADE GRANDE experiment [3] is an array of plastic scintillators of large collecting area that operate jointly with the KASCADE multi-detector experiment measuring the energy spectrum of the primary cosmic rays around and above the "knee" region. The array set up at Forschungszentrum Karlsruhe in Germany provides comprehensive observations of primary particles with energies up to 10^{18} eV.

The aim of the KASCADE GRANDE experiment is the observation of the "iron-knee" in the cosmic ray spectrum at around 10^{17} eV which is expected following recent KASCADE observations [2] where the positions of the knees of individual mass groups suggest a rigidity dependence. The reconstruction of the energy spectra of various mass groups will provide a complete picture of the physics around the "knee" region. Additionally, the validity of hadronic models used in CORSIKA Monte Carlo simulations will be tested. The existing KASCADE multi-detector experiment consists of three, nearly independent parts: the detector array, the central detector system and the muon tunnel.

The KASCADE experiment was extended to KASCADE-GRANDE by installing a large array of 37 stations consisting of 10 m^2 scintillation detectors, with an average spacing of 137 m. These detectors are sensitive to all charged

* Paper presented at the 5th International Balkan Workshop on Applied Physics, 5–7 July 2004, Constanța, Romania.

particles. The main observables measured with the Grande detectors are the particle density of charged particles, total number of charged particles and the time of arrival of the particles. Presently there is no experimental possibility to separate the different types of charged particles with these detectors. This is in contrast to the KASCADE field array which allows to determine the muon contribution and to present a partial muon number.

The concept of KASCADE-Grande is the measurement of as many as possible observables of air showers to perform multi-parameter analyses determining the primary energy and mass. Basic shower observables like the core position, angle of incidence or total number of charged particles are provided by the Grande detectors. The estimation of energy and mass of charged particles is based on a combined investigation of the charged particles, electron and muon components provided by the Grande detectors and the KASCADE array.

The experimental results are compared with air showers reconstructed by simulations of the air shower development in the atmosphere.

2. AIR SHOWER RECONSTRUCTION

The air shower reconstruction involves detailed simulation of the air shower development, evaluation of the detector response and reconstruction of the observables experimentally available.

The simulation of the development of the air shower is made using the CORSIKA [5] program. CORSIKA is a detailed Monte Carlo program to study the evolution and properties of extensive air showers initiated by high energy cosmic particles. The CORSIKA program allows to simulate interactions and decays of nuclei, hadrons, muons, electrons, and photons up to energies of some 10^{20} eV. It gives type, energy, location, direction and arrival times of all secondary particles that are created in an air shower and pass a selected observation level.

The standard method of evaluation of the detector response is based on the Geant package [6] from the CERN library. The Geant package allows to simulate the trajectory of a particle in complex experimental installations taking into account the hadronic and leptonic interactions, the disintegration of particles and deflections by electromagnetic fields. The simulation of the detector response using the Geant package can be time consuming especially if the particles involved are high energy hadrons.

In a previous paper the energy deposited by protons in the detectors was calculated with a method that involves simply fitting the Geant based distributions with simpler functions. In this work the method was applied for electrons, positrons and muons.

Extensive simulations for leptons with energies from 100 MeV to 10.000 GeV and angles of incidence from 0 to 90 degrees were made using the

Geant package taking into account the dimensions and chemical composition of the detectors. The distributions were fitted with linear and Landau-Vavilov functions using the PAW program from CERN library.

CORSIKA simulations have shown that most of the particles in an air shower have low energy and small angles of incidence and therefore it is important that the energy deposit for these particles is evaluated with good precision.

The Geant simulations have shown (Fig. 1) that the energy deposit spectra for all leptons are very resembling. This is a consequence of the fact that all this particles interact only electromagnetic and weak. For all the particles a

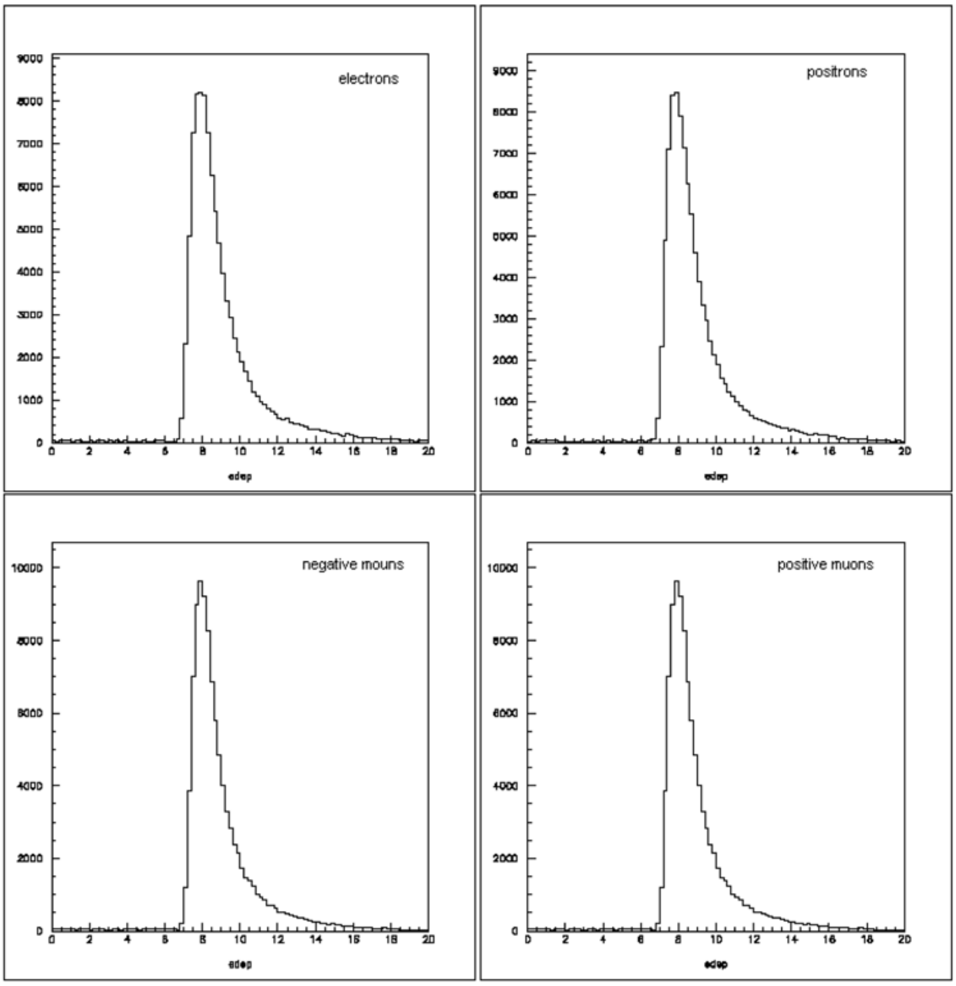

Fig. 1. – Energy deposit of various leptons with E = 10 GeV and θ = 0.4 rad evaluated with the Geant package.

combination of Landau-Vavilov and linear functions were used for fitting the spectra obtained with Geant. The Landau-Vavilov distribution is the distribution of the energy loss of a charged particle in a thin layer of a material. But because the particles involved are light, the energies are quite high and the density of the detectors is small the Landau-Vavilov distribution describes well the energy loss of air shower leptons in the detectors. The energies mentioned in the figures include the rest mass of the particles.

The energy deposited by leptons in the detectors is proportional with the length of the particle trajectory in the detectors. This reflects the fact that for the energies involved the energy loss per length of trajectory is constant. The parameters of the spectra follow a linear law in respect to 1/cos(θ). At large angles of incidence the energy spectrum suffer large fluctuations due to large number of particles that escape from the detector after the first interaction (Fig. 2).

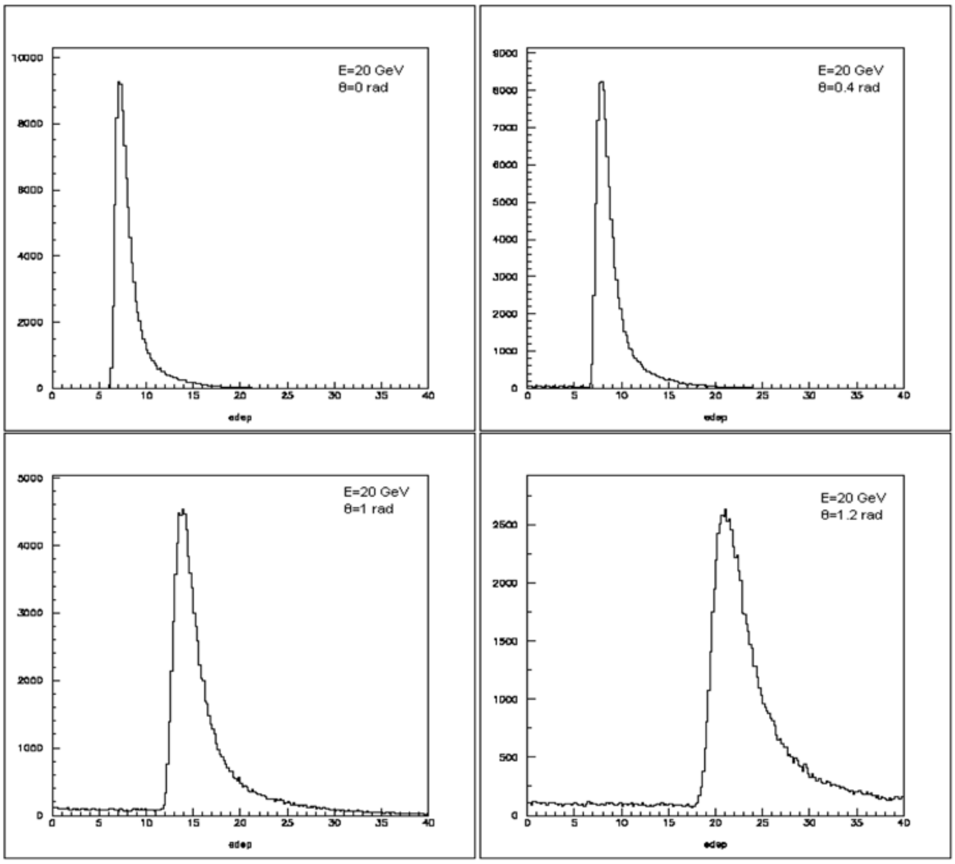

Fig. 2. – Energy deposit of positrons with $E = 20$ GeV at various angles of incidence evaluated with the Geant package.

Fig. 3 shows a comparison between the energy deposit spectra obtained with the Geant package and the new method. The new method reproduces with accuracy the energy deposit spectra in a fraction of the time needed for the Geant evaluation.

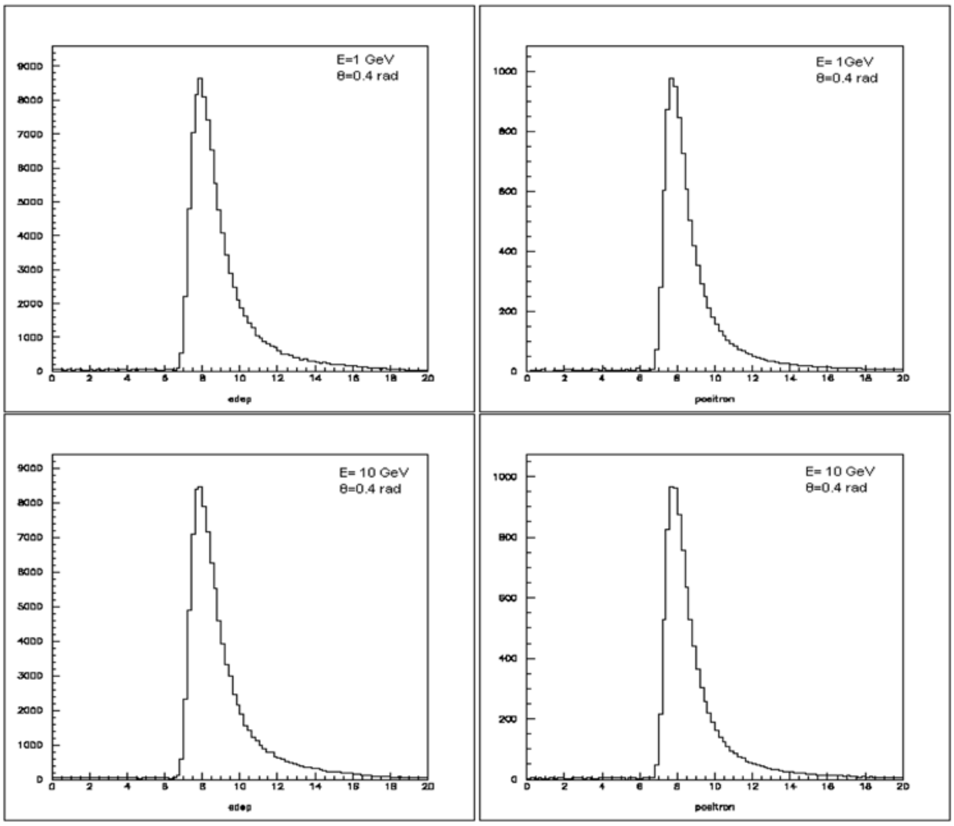

Fig. 3. – Comparison between energy deposit spectrum obtained with the Geant package (left) and the new method (right) for positrons.

4. CONCLUSIONS

Results for leptons show that this method reproduces the Geant energy deposit spectrum with accuracy. But the most important is the time economy achieved with this method. As an example the time necessary for calculating the energy deposit with the Geant program for 10^5 particles varies between 1 minute and 4 hours and with the new method is about 1 second. The time needed for a simulation with this method does not depend on the type, energy or angle of incidence of the particle.

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