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Effects of the new hadronic interaction models on the reconstruction of KASCADE-Grande observables

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In previous studies based on CORSIKA EAS simulations with the QGSJet-II-02 hadronic interaction model, the observables S(200) and S(500) (the charged particle densities at 200 m and 500 m from the shower axis) were found to be good candidates for mass discrimination and energy estimation. In order to study the effects of new hadronic interaction models on the reconstruction of EAS from the KASCADE-Grande experiment, a set of CORSIKA simulated showers was computed using the QGSJet-II.04 and EPOS-LHC models. Lateral Energy Correction Functions (LECF) are obtained for the Grande array using a Geant4 simulation code containing a realistic geometry of the Grande station. The LECFs are used to reconstruct the charged particle densities from the energy deposits in the Grande stations. We are using the real and reconstructed lateral distributions of charged particles in order to find corresponding observables for mass discrimination and energy estimation.

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1. Introduction

In parallel to the $N_\mu - N_{ch}$ energy and mass estimation procedure used in the KASCADE-Grande Experiment [1], the study of the lateral density of charged secondary particles from an EAS can provide sufficient information in order to be used in the development of an alternative reconstruction method. From the analysis of CORSIKA [2] EAS simulations based on the QGSJet-II.02 hadronic interaction model, the charged particle densities at 500 m (S(500) parameter[3]) and 200 m (S(200) parameter [4, 5]) from the shower core, were proven to be good candidates for energy estimation and mass discrimination.

Due to the difficulties in preparing a large number of CORSIKA simulations at energies greater than $10^{16} eV$ (computing time, size of the output files), and shower fluctuations, it is a challenge to have good statistics. A set of CORSIKA simulations for proton, iron and carbon primaries (180 events for each) with $\theta = 20^\circ \pm 2^\circ$ and energy range of $E_0 = 10^{16} - 10^{17} eV$ was computed for the study of the lateral density of the charged secondary particles. The QGSJet-II.04 and EPOS-LHC hadronic interaction models were used in order to test the validity of the S(500) and S(200) observables in the context of the new hadronic interaction models.

2. S(500), still a good observable for energy estimation

By comparing the charged particle density for the two hadronic interaction models in the 400 m - 600 m range, it was found that the charged particle density at 500 m practically does not depend on the mass of the primary particle.

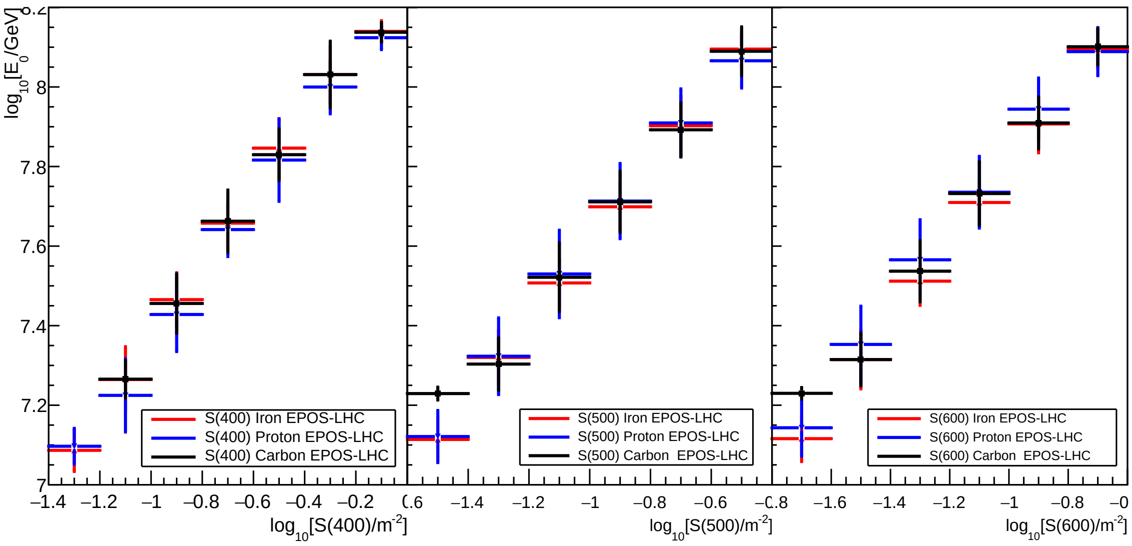

Figure 1: The charged particle density at 400 m(left), 500 m (center) and 600 m (right) for EPOS-LHC simulations for proton, carbon and iron primary particles

If we compare the averaged S(500) values for the two hadronic interaction models (Fig.3), we observe that the number of charged particles produced using the EPOS-LHC model is slightly

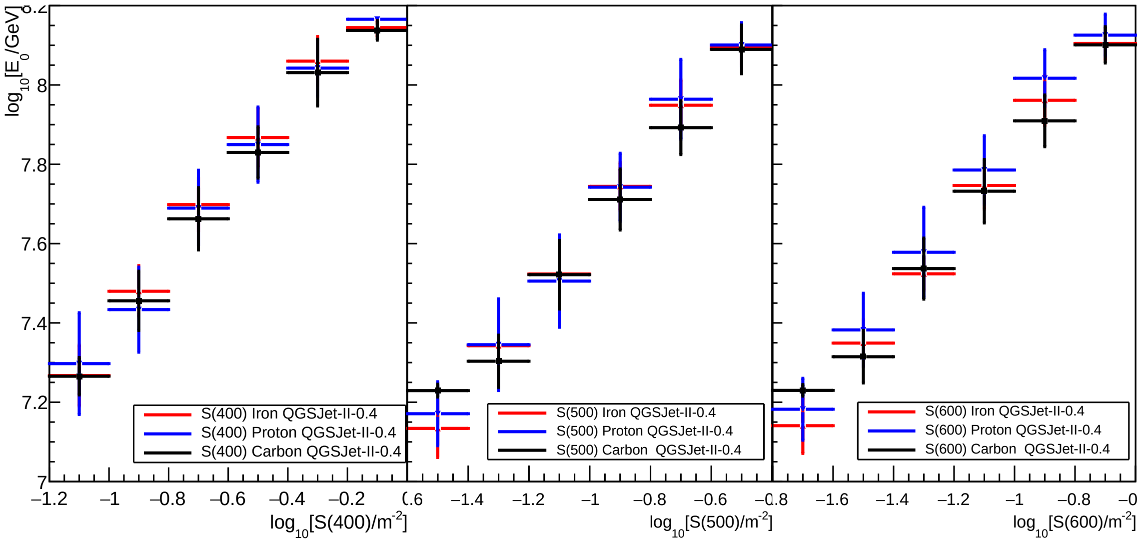

Figure 2: The charged particle density at 400 m (left), 500 m (center) and 600 m (right) for QGSJet-II-04 simulations

greater than the one obtained with QGSJet-II.04. As a result, a higher energy will be reconstructed from the same experimental data using QGSJet-II.04 than using EPOS-LHC. These effects will be the subject of future work.

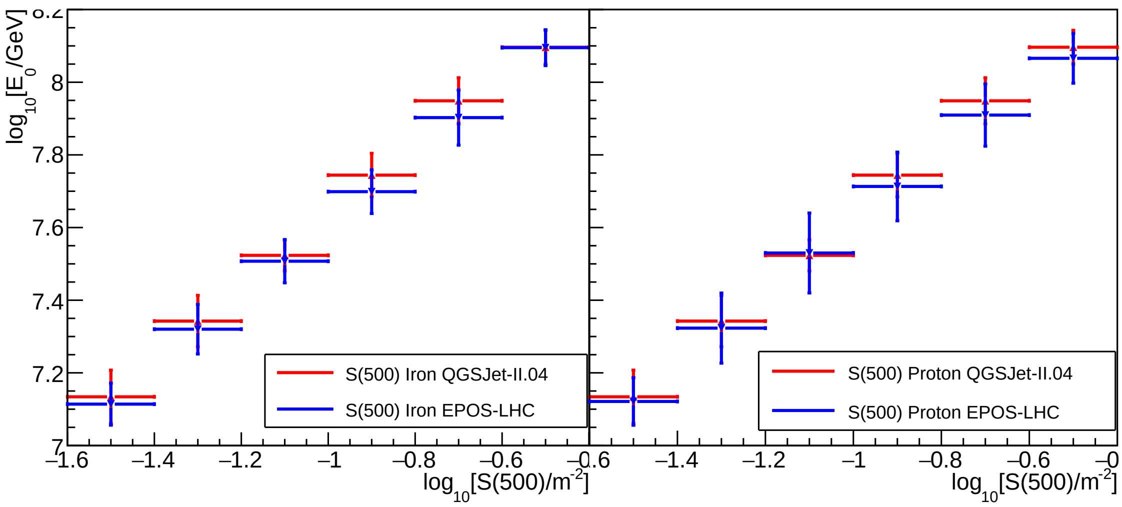

Figure 3: The charged particle density at 500 m for EPOS-LHC and QGSJet-II.04 simulations

3. S(200) - An observable of mass discrimination

Previous studies of CORSIKA simulations (using the QGSJet-I hadronic interaction model) showed that the charged particle density close to the shower core is mass dependent. The charged particle density at 100 m, 200 m and 300 m from the shower core obtained for the new set of simulations is presented in Fig.4 and Fig.5.

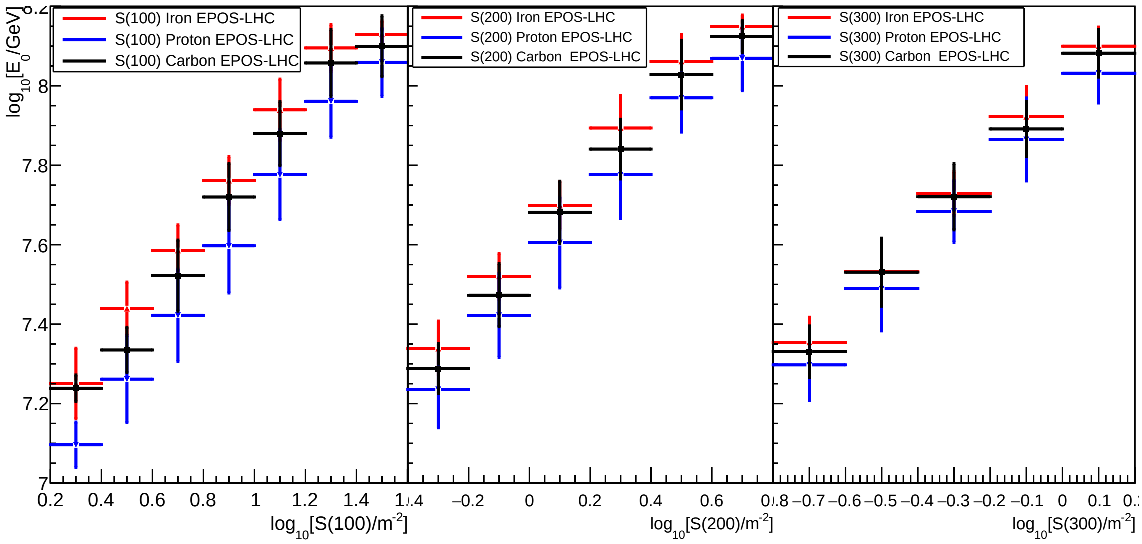

Figure 4: The charged particle density at 100 m (left), 200 m (center) and 300 m (right) for EPOS-LHC simulations

Due to the large number of charged particles in the region of 100 m from the shower core (in particular for EAS with $E_0 > 10^{17} eV$) detector saturation may occur. For that reason, the charged particle density at 200 m from the shower core (S(200) observable) seems to be a good candidate for mass discrimination.

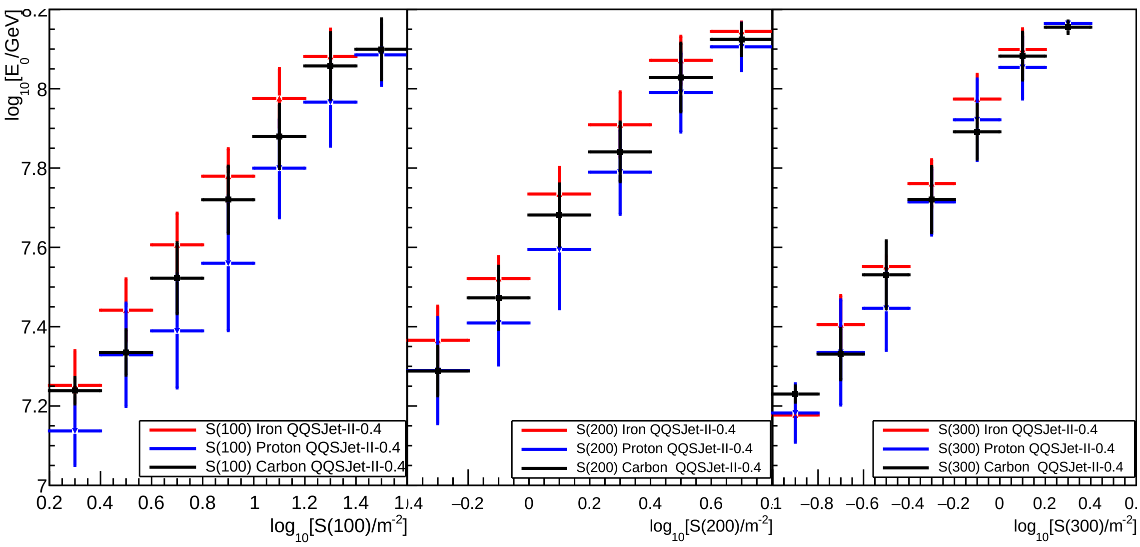

Figure 5: The charged particle density at 100 m (left), 200 m (center) and 300 m (right) for QGSJet-II-04 simulations

4. Perspectives

The experimental energy deposits measured with the Grande array are converted into charged particle densities using the Lateral Energy Correction Function (LECF). The LECF represents the energy deposited in the Grande station by all the secondary particles in a shower divided by the number of charged particles and calculated for the position of the detector relative to the shower core.

The standard reconstruction procedure uses a fixed, mean value for the LECF (Fig.6), and does not include corrections for different energies and incidence angles of the secondary shower particles interacting with the detectors. The standard LECF was computed using GEANT3 and a schematic geometry of the Grande stations.

We intend to obtain more realistic LECF functions including all the details of the Grande station (Fig.7) in simulations carried out with Geant4.10 [6]. The distribution of the secondary particles impinging on the stations will be obtained using CORSIKA simulations including QGSJet-II.04 and EPOS-LHC. In order to take into account the azimuth dependence of the LECF, a very dense array of Grande stations (800 x 800 m^2 with 10 m distance between stations) will be implemented in the simulation.

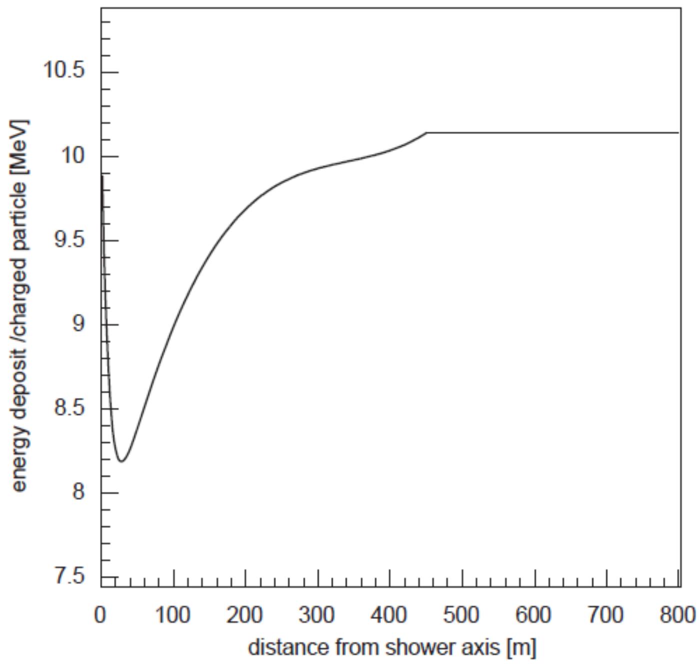

Figure 6: Standard LECF used at the KASCADE-Grande experiment

The set of LECFs that will be obtained will be used in the reconstruction of the charged particle density for simulated and experimental data. The primary particle's energy and mass will be evaluated using the S(500) and S(200) observable.

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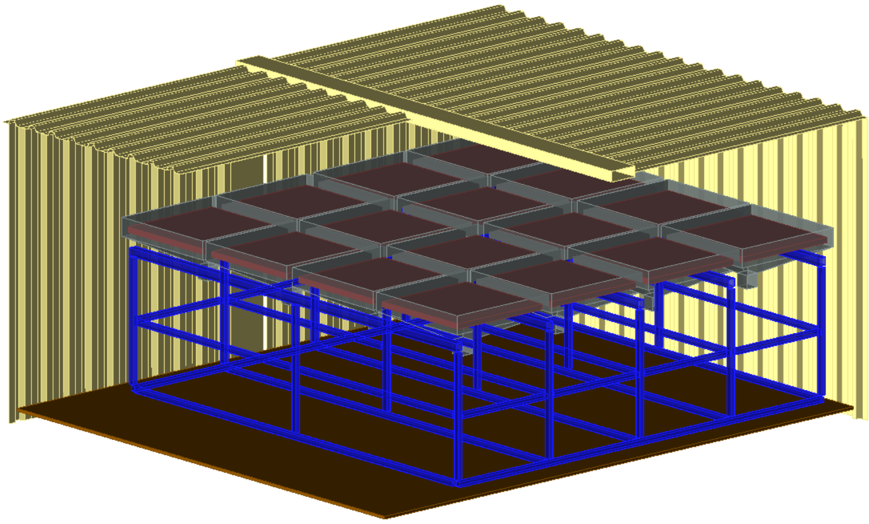

Figure 7: Grande station geometry used in the Geant4 simulation

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