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SUPPLEMENTS

On the Accuracy of the Primary Energy and Nuclei Determination at Mountain Altitudes and Sea Level

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The information carried by EAS of the energy range $10^{14} - 10^{17}$ eV is limited by significant fluctuations of the shower development, insufficient experimental sampling and uncertainties of the detector response. Additional uncertainties arise from different simulation procedures and statistical methods used for inferring the results. We propose to combine an advanced EAS simulation program like CORSIKA with the ANI multivariate statistical analysis package for an event-by-event analysis and for a standardization of the inference from EAS data. We illustrate the technique for simulated results of two different detector locations: ANI at a mountain altitude and KASCADE at sea level.

1. Introduction

The interpretation of the EAS data suffers from two different types of uncertainties, the uncertainty of energy and type of the primary particle and the nature of the hadronic interaction. For this reason, the usual analysis of cosmic ray data aim at the test of integral hypotheses, asking to what extent the data are compatible with a particular hypothesis about energy spectra, composition and scaling violation e.g.

In ref. [1-4] a new methodology for solving incorrect inverse problems has been developed for the physical inference from cosmic-ray experiments. Thereby each event representing a point in the multidimensional space of the EAS parameters is analyzed. The method combined with the model-independent estimation procedure for the primary energy [5] enables to obtain estimates of energy and nature of the primary particle, in a way compatible with the analysis of accelerator experiments.

The method is applied to simulations for the ANI [6] and KASCADE [7] detector installations using the Monte Carlo code CORSIKA [8] and the ANI statistical analysis package [9].

2. Variable Selection

Figure 1 one indicates that one-dimensional distributions of simulated EAS parameters (numbers of electrons and muons, age and electron density at a distance of 120 m from the shower core position) for different primaries (5 groups of primaries from proton to iron were used) overlap significantly. Thus, for the multivariate analysis the key for determination of the elemental composition is the availability of a large number of measured EAS parameters. The feature selection problem is solved by implementing one-dimensional, correlation and multidimensional selection procedures [10]. In figure 2 the three-dimensional plots of EAS parameters are apparently distinct for iron and proton showers (altitude 3200 m above sea level). The comparison of accuracies achievable at mountain and sea level experiments reflect the obvious fact that shower fluctuations just after reaching the maximum are significantly lower than at the end of the development. Recently, for the ANI experiment a new directly measurable parameter (the electron density at a distance of 120 m from the shower axes) has been introduced that enables the energy estimation independent from the primary. The correlation of this parameter with energy is larger

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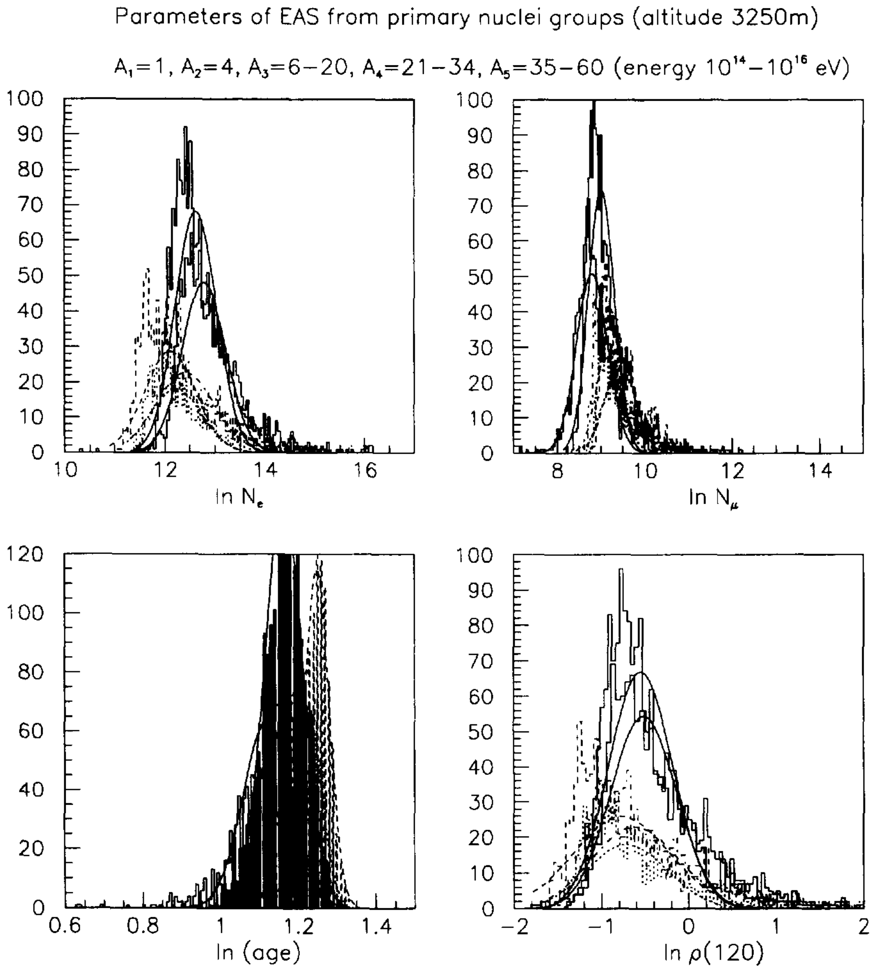

Figure 1. One-dimensional distributions of EAS parameters

than that of the number of electrons and muons. The use of this parameter with others like age leads to improved accuracy (see figure 3).

The present results for primary mass estimates are based on the Bayesian decision rules, which is one of the three nonparametric techniques, implemented in ANI package.

3. Results

Simulated samples (1000 per each primary) have been used, for checking of the probability of misclassification. Figure 4 shows the classification probabilities deduced from the simulated data. The results show clearly the advantages at mountain altitudes. For sea level two modes are presented in the case of "known" primary energy, to enable a direct comparison with mountain altitudes and a realistic case, where only numbers of electrons and muons can be estimated.

Acknowledgments

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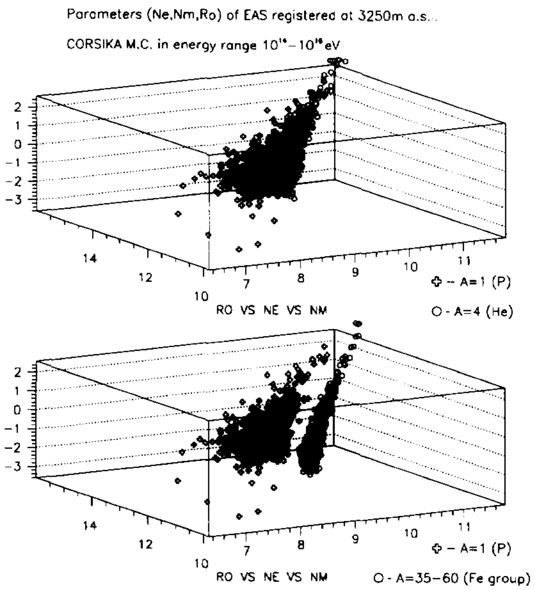

Figure 2. Three-dimensional scatter plots of selected EAS features

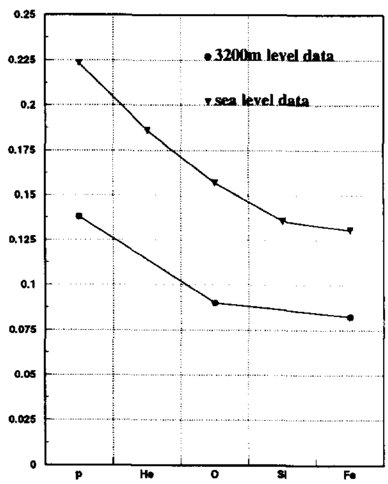

Figure 3. The Accuracy of energy estimation using nonparametric regression method (sea level and 3200 m level data)

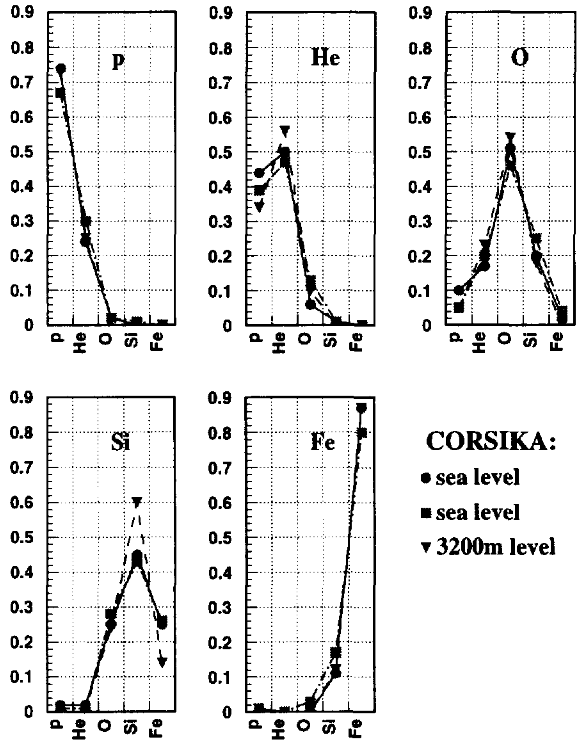

Figure 4. Primary nucleus classification by Bayesian method (sea level and 3200m level data)

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