Detailed studies in high energy ranges about ⟨Xmax⟩ and RMS of extensive air showers

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ABSTRACT

There are three fundamental pieces of information that could be obtained from a cosmic ray experiment: the energy of the incident particle, its arrival direction and its identity. With these basic quantities we can reconstruct many statistically significant quantities: (a) the energy spectrum, (b) the angular distribution function of arrival directions or anisotropy, and (c) the composition as a function of energy. The study of depth of shower maximum, Xmax, has crucial importance in the estimation of the energy and of mass composition of cosmic rays. The RMS of the ⟨Xmax⟩ distribution has been also shown to be an important and independent composition parameter. In this study, we will use CORSIKA and CONEX simulation programs to run around 2.000.000 showers in the energy range from 10^{17} to $10^{20.5}$ eV in steps of 0.1 in log(EeV) and for several primary particle types. For the low energy we will use FLUKA-INFN model and for the high energy the models QGSJETII-04, SIBYLL2.3d and EPOS-LHC will be used. We will calculate the ⟨Xmax⟩ parameter as its RMS as a function of primary composition and energy for different hadronic interaction models. A detailed comparison and parameterization for different simulation models is also going to be studied.

TARGETS

The main target of this project is to update two papers which are base for our studies: (JOSE; VITOR DE SOUZA; JOSE ALFREDO BELLIDO, 2013)[1] and (ARBELETCHE; VITOR DE SOUZA, 2020)[2]. This work will consist of the simulations of cosmic rays of various types in order to better understand their ⟨Xmax⟩ and it's RMS and with this information produce adjustment functions for longitudinal distributions and parametrizations of Xmax. Another important aspect of the work is to use the high energy models QGSJETII-04, SIBYLL2.3d and EPOS-LHC and the low energy model FLUKA-INFN. Great part of the time will be spent learning the use of high-performance clusters, the simulation codes and the management of the simulations, which are necessary to hit all targets cited.

METHODS

For the raw simulations both CORSIKA and CONEX will be used, CORSIKA is more detailed as it's simulated in three dimensions, CONEX has a parametrization after it's first particle decay, as such the data is less reliable, but much faster. The intention is to simulate all showers at a 60º inclination for stable isotopes with 1 to 56 nucleons. The energy range studied will be of 10^{17} to $10^{20.5}$ eVin steps of 0.1 in log(EeV). For the analysis of the data C, C++, Python and the ROOT package will be used.

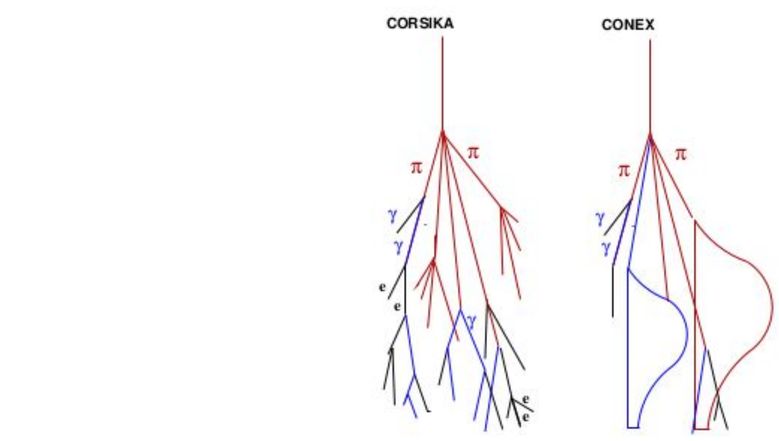


Figure 1: Differences between CORSIKA and CORSIKA. Figure by Tanguy Pierog.

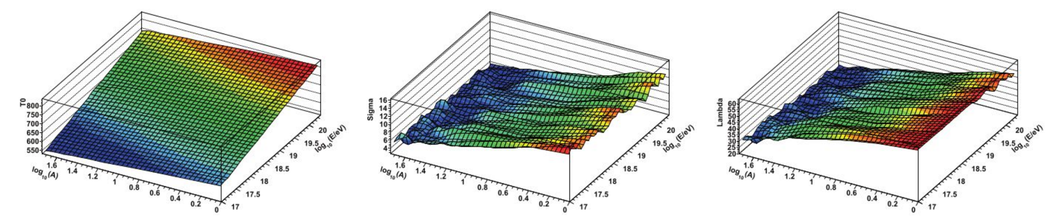
To find the possible stable isotopes to be used on the study the NUBASE2020 [3] was used, the data was filtered with Python and will be a guide to our work among other studies about elemental abundances in cosmic rays.

RESULTS

Because we are still in the beginning of our studies, there aren't enough shower simulations to analyze the data from. But we expect to obtain results close to what was seen before but with upgraded precision given by updated energy models.

We expect to obtain a parametrization following a convolution of a Gaussian curve with a exponential or an evolution of it.

$$\frac{dX_{\max}}{dN} = N_f \exp\left(\frac{t_0 - t}{\lambda} + \frac{\sigma^2}{2\lambda^2}\right) Erfc\left(\frac{t_0 - t + \sigma^2/\lambda}{\sqrt{2}\sigma}\right)$$



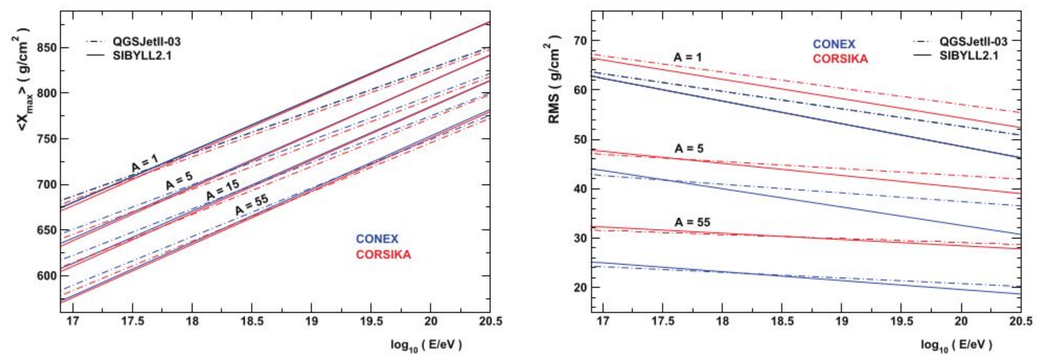
(a) t_0 (b) σ (c) λ

Fig. 10. Parametrization of the $X_{\max}$ distribution. CONEX – SIBYLL2.1. These figures show the general behavior of the three parameters used to describe the $X_{\max}$ distributions as a function of energy and mass.

Image taken from (JOSE; VITOR DE SOUZA; JOSE ALFREDO BELLIDO, 2013)[1]

CONCLUSIONS AND PERSPECTIVES

Our perspective to this study is to obtain updated and added information, as we will be using not only the updated models, we will use new models as well. This way we will be able to compare different models and utilize their data as a whole to get better statistics.



(a) $\langle X_{\max}\rangle$. (b) RMS($X_{\max}$).

Fig. 13. Comparison of $\langle X_{\max}\rangle$ and RMS($X_{\max}$) for CORSIKA and CONEX as a function of energy.

Image taken from (JOSE; VITOR DE SOUZA; JOSE ALFREDO BELLIDO, 2013)[1]

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