Hybrid simulations of extensive air showers

Jaime Alvarez-Muñiz, alvarez@bartol.udel.edu Ralph Engel T.K. Gaisser Jeferson A. Ortiz [Also at] Instituto de Física “Gleb Wataghin”, Universidade Estadual de Campinas 13083-970 Campinas-SP, Brazil. Todor Stanev [Also at] Laboratoire de Physique Corpusculaire et Cosmologie

Bartol Research Institute,

abstract We present a fast one dimensional hybrid method to efficiently simulate extensive air showers up to the highest observed energies. Based on precalculated pion showers and a bootstrap technique, our method predicts the average shower profile, the number of muons at detector level above several energy thresholds as well as the fluctuations of the electromagnetic and hadronic components of the shower. We study the main characteristics of proton-induced air showers up to ultra-high energy, comparing the predictions of three different hadronic interaction models: SIBYLL 1.7, SIBYLL 2.1 and QGSjet98. The influence of the hadronic interaction models on the shower evolution, in particular the elongation rate, is discussed and the applicability of analytical approximations is investigated.