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All-particle cosmic ray energy spectrum measured with 26 IceTop stations

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ABSTRACT

We report on a measurement of the cosmic ray energy spectrum with the IceTop air shower array, the surface component of the IceCube Neutrino Observatory at the South Pole. The data used in this analysis were taken between June and October, 2007, with 26 surface stations operational at that time, corresponding to about one third of the final array. The fiducial area used in this analysis was 0.122 km^2. The analysis investigated the energy spectrum from 1 to 100 PeV measured for three different zenith angle ranges between 0° and 46°. Because of the isotropy of cosmic rays in this energy range the spectra from all zenith angle intervals have to agree. The cosmic-ray energy spectrum was determined under different assumptions on the primary mass composition. Good agreement of spectra in the three zenith angle ranges was found for the assumption of pure proton and a simple two-component model. For zenith angles $\theta < 30°$, where the mass dependence is smallest, the knee in the cosmic ray energy spectrum was observed at about 4 PeV, with a spectral index above the knee of about −3.1. Moreover, an indication of a flattening of the spectrum above 22 PeV was observed.

1. Introduction

100 years after the discovery of cosmic rays, their sources and acceleration mechanisms still remain mostly unknown. The energy spectrum of cosmic rays as measured by various experiments follows a relatively smooth power law with spectral index $\gamma \approx -2.7$ up to about 4 PeV, where it steepens to $\gamma \approx -3.1$ [1]. While this feature in the spectrum called "knee" is well established, its origin remains controversial [2]. Most models to explain the knee involve a change in chemical composition of cosmic rays in the energy region above the knee. Such a change has been observed by various experiments [3] but systematic uncertainties are too large to discriminate individual descriptions. Features in the all-particle cosmic ray energy spectrum and their chemical composition bear important information on the acceleration and propagation of cosmic rays. The measurement of the cosmic ray energy spectrum and composition is the main goal of the IceTop air shower array.

IceTop is the surface component of the IceCube Neutrino Observatory at the geographic South Pole [4]. Installation of IceCube and IceTop was completed at the end of 2010, with 86 IceCube strings and 81 IceTop stations deployed covering an area of about 1 km^2

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