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Measurement of cosmic-ray air showers with the Tunka Radio Extension (Tunka-Rex)

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ABSTRACT

Tunka-Rex is a radio detector for cosmic-ray air showers in Siberia, triggered by Tunka-133, a co-located air-Cherenkov detector. The main goal of Tunka-Rex is the cross-calibration of the two detectors by measuring the air-Cherenkov light and the radio signal emitted by the same air showers. This way we can explore the precision of the radio-detection technique, especially for the reconstruction of the primary energy and the depth of the shower maximum. The latter is sensitive to the mass of the primary cosmic-ray particles. In this paper we describe the detector setup and explain how electronics and antennas have been calibrated. The analysis of data of the first season proves the detection of cosmic-ray air showers and therefore, the functionality of the detector. We confirm the expected dependence of the detection threshold on the geomagnetic angle and the correlation between the energy of the primary cosmic-ray particle and the radio amplitude. Furthermore, we compare reconstructed amplitudes of radio pulses with predictions from CoREAS simulations, finding agreement within the uncertainties.

1. Introduction

Despite much progress in cosmic ray physics during the last century, many questions, especially regarding the sources and mass composition of high-energy cosmic rays, remain unanswered. Established detection techniques have principal restrictions and current detectors already span over large areas and approach economical limits. To overcome these problems, new detection principles are explored. One promising candidate is the radio technique. Already in the 1960s [1,2] it was shown that the radio emission of air showers can be detected with antennas operating in the MHz frequency range. But due to technological restrictions at that time the interest in the technique faded quickly afterwards. Then, it experienced a renaissance during the last decade due to the fast advance and cheap availability of digital electronics and methods of signal processing [3–6].

With an advancing theoretical understanding of the radio emission, time-varying transverse currents, caused by geomagnetic deflection of charged particles in the atmosphere, were established as the dominant emission mechanism in air showers [7]. In addition, there is a contribution to the signal from the varying net charge, called Askaryan effect [8–11].

To evaluate the possible performance of a radio detector as a stand-alone device for measuring air showers or as part of a hybrid detector in future projects, its properties and especially the achievable precision have to be investigated in detail.

The Tunka Radio Extension (Tunka-Rex) is a radio detector for cosmic-ray air showers, which started data taking in October 2012. It is situated in Siberia, close to Lake Baikal, at the coordinates 51°48′35″N, 103°4′2″E at an altitude of 670 m, on the same site as Tunka-133 [12], an air-Cherenkov detector for air showers above 10^{16} eV. Furthermore, the TAIGA experiment for gamma astronomy [13] is currently built at the site. It consists of multiple detectors, from

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