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The Tunka radio extension (Tunka-Rex): Radio measurements of cosmic rays in Siberia

F.G. Schröder [a,*], P.A. Bezyazeekov [b], N.M. Budnev [b], O.A. Gress [b], A. Haungs [a], R. Hiller [a], T. Huege [a], Y. Kazarina [b], M. Kleifges [c], E.N. Konstantinov [b], E.E. Korosteleva [d], D. Kostunin [a], O. Krömer [c], L.A. Kuzmichev [d], N. Lubsandorzhiev [d], R.R. Mirgazov [b], R. Monkhoev [b], A. Pakhorukov [b], L. Pankov [b], V.V. Prosin [d], G.I. Rubtsov [e], R. Wischnewski [f], A. Zagorodnikov [b]

[a] *Institut für Kernphysik, Karlsruhe Institute of Technology (KIT), Germany*
[b] *Institute of Applied Physics ISU, Irkutsk, Russia*
[c] *Institut für Prozessdatenverarbeitung und Elektronik, Karlsruhe Institute of Technology (KIT), Germany*
[d] *Skobeltsyn Institute of Nuclear Physics MSU, Moscow, Russia*
[e] *Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia*
[f] *DESY, Zeuthen, Germany*

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ABSTRACT

The Tunka observatory is located close to Lake Baikal in Siberia, Russia. Its main detector, Tunka-133, is an array of photomultipliers measuring Cherenkov light of air showers initiated by cosmic rays in the energy range of approximately $10^{16}-10^{18}$ eV. In the last years, several extensions have been built at the Tunka site, e.g., a scintillator array named Tunka-Grande, a sophisticated air-Cherenkov-detector prototype named HiSCORE, and the radio extension Tunka-Rex. Tunka-Rex started operation in October 2012 and currently features 44 antennas distributed over an area of about 3 km^2, which measure the radio emission of the same air showers detected by Tunka-133 and Tunka-Grande. Tunka-Rex is a technological demonstrator that the radio technique can provide an economic extension of existing air-shower arrays. The main scientific goal is the cross-calibration with the air-Cherenkov measurements. By this cross-calibration, the precision for the reconstruction of the energy and mass of the primary cosmic-ray particles can be determined. Finally, Tunka-Rex can be used for cosmic-ray physics at energies close to 1 EeV, where the standard Tunka-133 analysis is limited by statistics. In contrast to the air-Cherenkov measurements, radio measurements are not limited to dark, clear nights and can provide an order of magnitude larger exposure.

1. Introduction

The amplitude of the radio emission by cosmic-ray air-showers is roughly proportional to the energy of the primary particle [1]. This calorimetric sensitivity yields complementary information compared to the detection of secondary air-shower particles on ground. During dark nights with clear sky similar complementary information is available by measurements of air-Cherenkov and air-fluorescence light. Despite the higher energy threshold of about 10^{17} eV, the radio technique would be an interesting alternative due to its full-time availability, provided that the cost and precision is at least comparable.

The main scientific goal of Tunka-Rex is the cross-calibration of radio and air-Cherenkov measurements of the same air showers, to test the achievable precision and real potential of the radio technique experimentally. For this purpose, Tunka-Rex is built as extension of the Tunka-133 photomultiplier array in Siberia [2] (Fig. 1), which measures the air-Cherenkov light of showers in the energy range of approximately 10^{16}–10^{18} eV. The antennas are read out in parallel with the air-Cherenkov detector which provides the necessary hybrid measurements for cross-calibration.

2. Detector description

Since the radio emission of air showers is strongest at wavelengths of a few meters, Tunka-Rex measures in the effective band of 35–76 MHz, similar to other antenna arrays, like LOPES [1],

* Corresponding author.
E-mail address: frank.schroeder@kit.edu (F.G. Schröder).

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