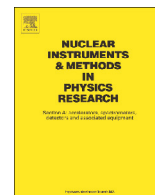




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## The Tunka radio extension (Tunka-Rex): Radio measurements of cosmic rays in Siberia

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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  $3\text{ km}^2$ , 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  $1\text{ EeV}$ , 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.

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### 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],

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