Tunka-Rex: the Tunka Radio Extension

Frank G. Schröder for the Tunka-Rex Collaboration
Tunka-Rex: Partners and Location
Layout of Tunka-Rex

- 25 antennas for Tunka-133
  - Started 2012
  - Trigger by PMTs

- 19 antennas for Tunka-Grande
  - Start 2014
  - Trigger by scintillators

Array layout
- 200 m spacing
- 1 km² inner area
Properties of Tunka-Rex

- Shared data-acquisition with Tunka-133 / Tunka-Grande
  - Radio antennas as slave detector (externally triggered)
  - Automatically hybrid measurements for same air-showers
  - Ideal for cross-calibration of different methods

- Economic design
  - 500 $ per antenna including all analog electronics, cables, etc.
  - Approx. 3 man-days per antenna for production and deployment

- Based on experience of other experiments
  - Usual 30-80 MHz bandwidth
  - Using known algorithms for data processing and reconstruction
Events of first season (2012/2013)

- 78 events
- 40 events

in 450 hours
Detection efficiency

All events with good Tunka-133 reconstruction vs. radio events with good signal in at least 3 antennas
Example event: lateral distribution

- Simple exponential fit function
- Ignore:
  - Asymmetries
  - Flattening towards shower core
- Advantage
  - Requires only 3 antennas
  - Sufficient for energy reconstruction
Energy reconstruction

- Energy ~ amplitude at 100 m / \sin (\text{geomagnetic angle})
- Spread corresponds to Tunka-133 precision (~ 15%)
Next steps

- $X_{\text{max}}$ reconstruction and cross-calibration with Tunka-133
  - Shape of lateral distribution and of wavefront
  - More complicated, maybe more antennas necessary

- Semi-blind analysis to experimentally determine precision
  - Radio reconstruction tuned to Tunka-133 data of 2012/2013
  - But energy and $X_{\text{max}}$ of Tunka-133 blind for season 2013/2014
  - Will be revealed only after radio prediction for energy and $X_{\text{max}}$

- Cosmic-ray physics with scintillator trigger
  - 10 times higher statistics for the last energy bins around $10^{18}$ eV
Conclusion

- **Tunka-Rex**
  - Economic radio extension for Tunka-133 and Tunka-Grande

- **Scientific Goals**
  - Cross-calibration with air-Cherenkov measurements
  - Determine radio precision for energy and $X_{\text{max}}$
  - Hybrid measurements with scintillators can increase accuracy

- **TAIGA-Rex**
  - Tunka-Rex concept scaled to 10 km²
  - Radio brings additional benefits $\sim 10^{18}$ eV for low additional costs
Example event

![Graph showing amplitude vs. distance to radio shower axis](image)

![Graph showing signal vs. time](image)
## Technical Data

<table>
<thead>
<tr>
<th></th>
<th><strong>Tunka-Rex</strong></th>
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<tbody>
<tr>
<td><strong>Trigger and DAQ</strong></td>
<td>Tunka-133 / Tunka-Grande</td>
</tr>
<tr>
<td><strong>Antennas: number type</strong></td>
<td>44 (2 channels each) SALLA</td>
</tr>
<tr>
<td><strong>Alignment</strong></td>
<td>NW-SE and NE-SW</td>
</tr>
<tr>
<td><strong>Spacing</strong></td>
<td>~ 200 m</td>
</tr>
<tr>
<td><strong>Area</strong></td>
<td>1 km² + outer stations</td>
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<tr>
<td><strong>Frequency band</strong></td>
<td>30 – 80 MHz</td>
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<tr>
<td><strong>Sampling: rate</strong></td>
<td>200 MHz</td>
</tr>
<tr>
<td><strong>trace length</strong></td>
<td>1024 samples (~ 5 µs)</td>
</tr>
<tr>
<td><strong>Approx. cost per antenna</strong></td>
<td>~ 500 $</td>
</tr>
<tr>
<td><strong>Analysis software</strong></td>
<td>Offline (with kind permission by the Pierre Auger Collaboration)</td>
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<td><strong>Energy range</strong></td>
<td>&gt; $10^{17}$ eV</td>
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Helmholtz Russia Joint Research Group HRJRG-303
Measurements of Gamma Rays and Cosmic Rays in the Tunka-Valley in Siberia by innovative new technologies

High energy $\gamma$ (GeV / TeV / PeV):

- **HiSCORE**
  - Cherenkov light cone

Ultra-high energy CR (PeV - EeV):

- **HRJRG-303**:
  - Resolve open questions of cosmic rays with innovative methods
  - Cherenkov
  - Radio

- **Tunka-Rex**