Tunka-Rex: Status and Results of the First Measurements

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May 24th 2013
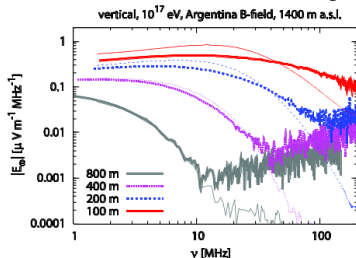
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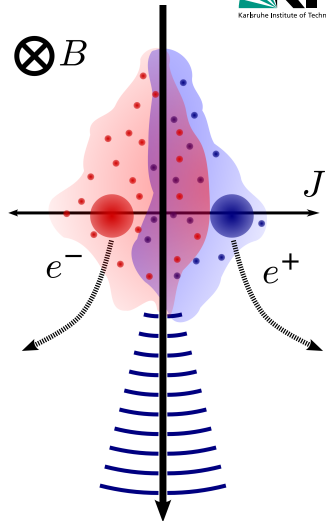
Outline

1. Radio emission from cosmic rays

2. Tunka-Rex

3. Data analysis and first events

4. Reconstructed events

5. Conclusions

Radio emission processes

- Geomagnetic deflection of charged particles: dominant effect, signal mainly EW polarized

- Variation of net charge excess: second-order effect, signal radial polarized
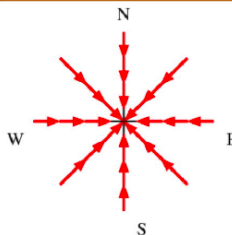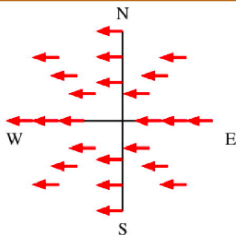
- Radio emission in MHz range

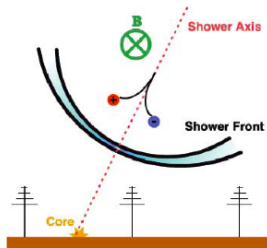vertical, 10^{17} eV, Argentina B-field, 1400 m a.s.l.

800 m
400 m
200 m
100 m

$|E_\omega|$ [μ V m^{-1} MHz^{-1}]

ν [MHz]

T. Huege et. al.

$\otimes B$

J

e^-

e^+

M. Ludwig

Radio emission processes

H. Schoorlemmer

Comparison of methods

Current status	Particles at ground	Fluor. / Cherenkov	Radio
Angular resolution	+	◦ / +	+
Energy	◦	+	+
Primary mass	◦	+	+ (?)
Exposure	+	◦	-
Duty cycle	$\sim 100\%$	$\sim 10\%$	$\sim 95\%$
Energy threshold, eV	10^{13}	$10^{17} / 10^{12}$	10^{17}

- Already shown: principle feasibility with radio (e.g. LOPES)
- Still to show: precision + large scale application

Cosmic ray energy spectrum
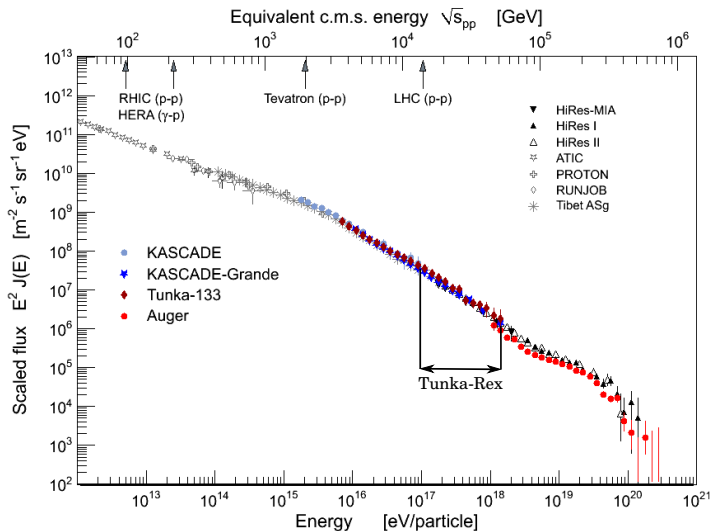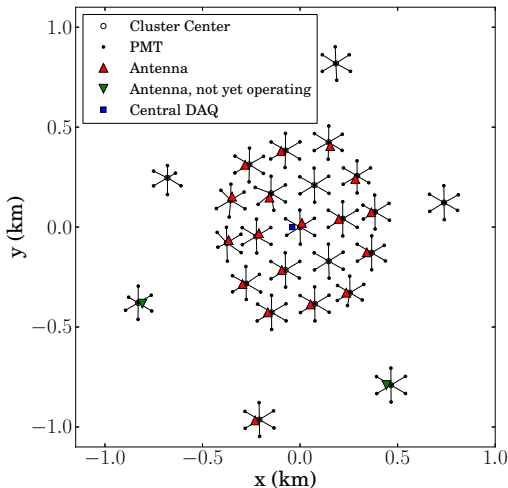
Tunka-Rex Collaboration
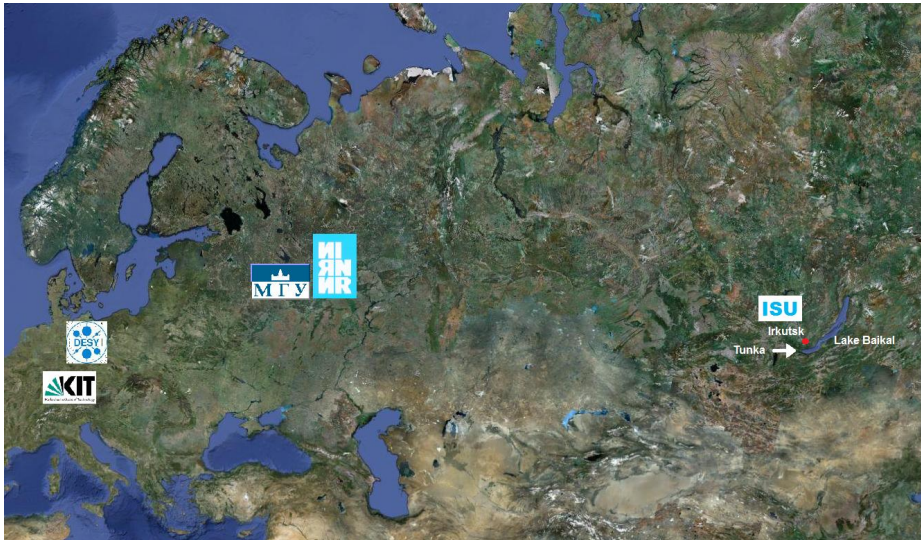
Tunka Radio Extension

- Radio extension to Tunka-133
- SALLAs connected to cluster center
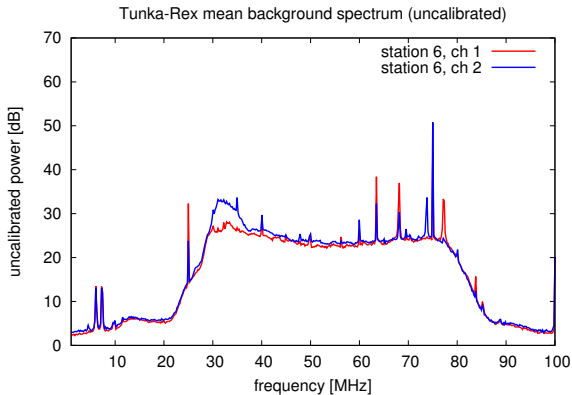- Externally triggered by Tunka-133

Tunka-Rex detector

- 18 antennas on the 1 km^2 area started data taking since Oct. 2012 ($\sim$ 30 antennas will be after full deployment)
- Existing DAQ
- Trigger and information from air-Cherenkov detector
- Radio quiet rural location

- Capabilities of joint operation
- Determine precision of reconstructed shower parameters by radio

Tunka-Rex station

LNA

SALLA
Ø1.2m

Filter
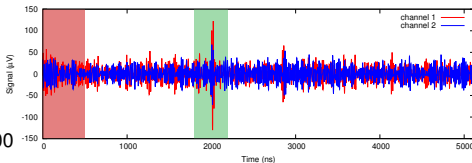
Cluster
Box

ADCs

RG213 30m

Digital filtering
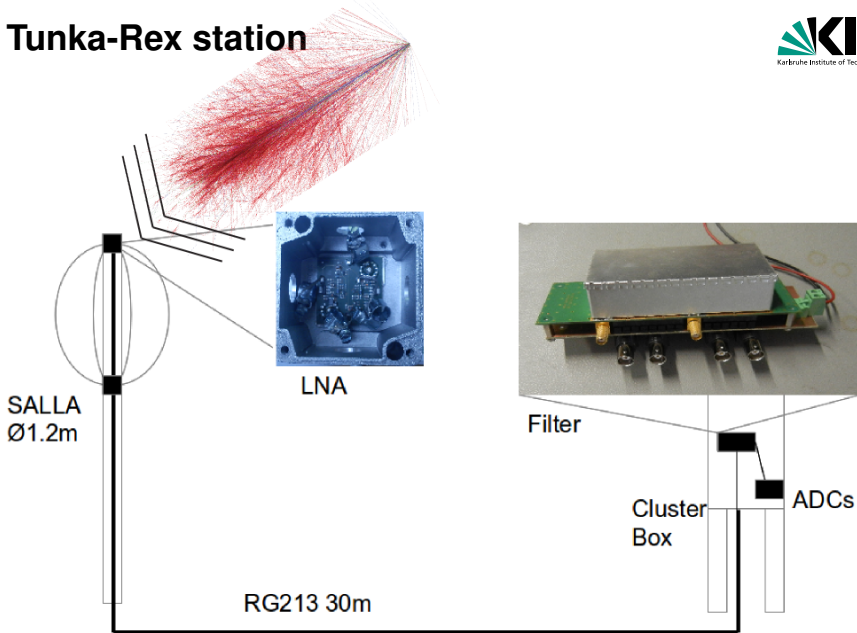
For the data analysis we use use the radio modules of the Auger Offline software[1]

Tunka-Rex mean background spectrum (uncalibrated)

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[1] Pierre Auger Collaboration, NIM A 635 (2011) 92

Sample event

$$A(r) = A_0 \exp\left(-\frac{r-d}{R_0}\right)$$

$$\eta = 1/R_0$$
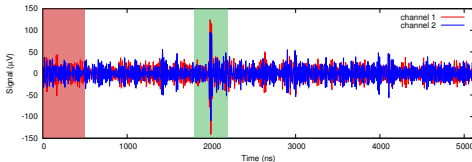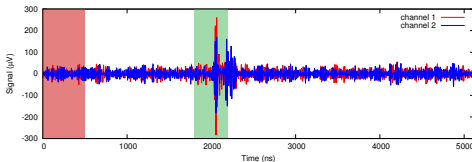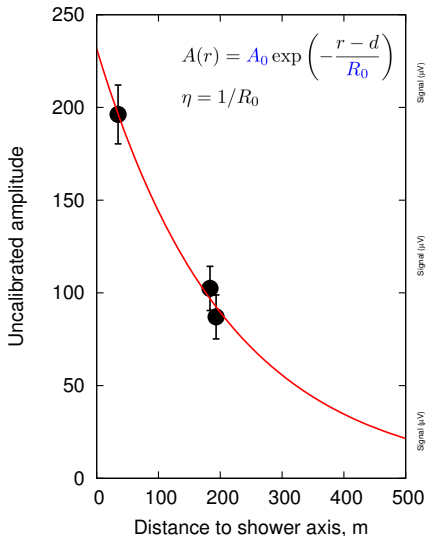
Reconstructed events

Total time of measurements $\approx$ 450 hours

Cherenkov reconsructed provided by Tunka-133 Collaboration

- Reconstructed direction, energy, shower maximum with $\theta \leqslant 50°$
- Direction reconstruction for events with $\theta > 50°$

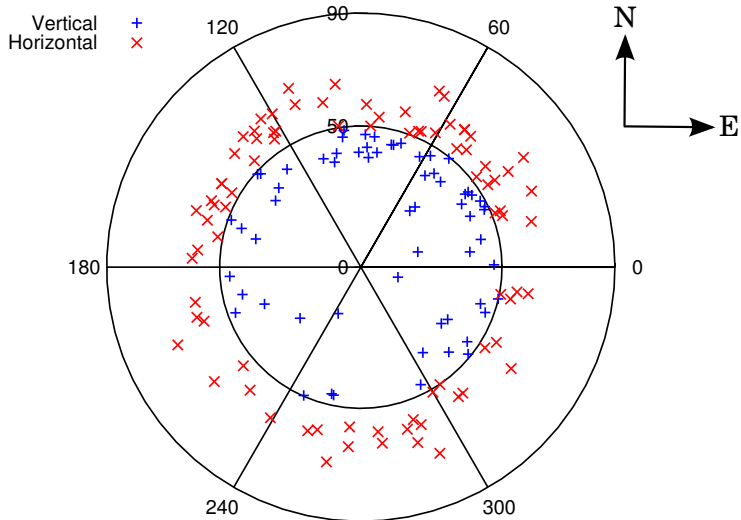Reconstruction cuts

- Angle between shower axes reconstructed by Cherenkov and radio detectors less than $5°$
- Taking core position from Cherenkov reconstruction only for events with $\theta \leqslant 50°$
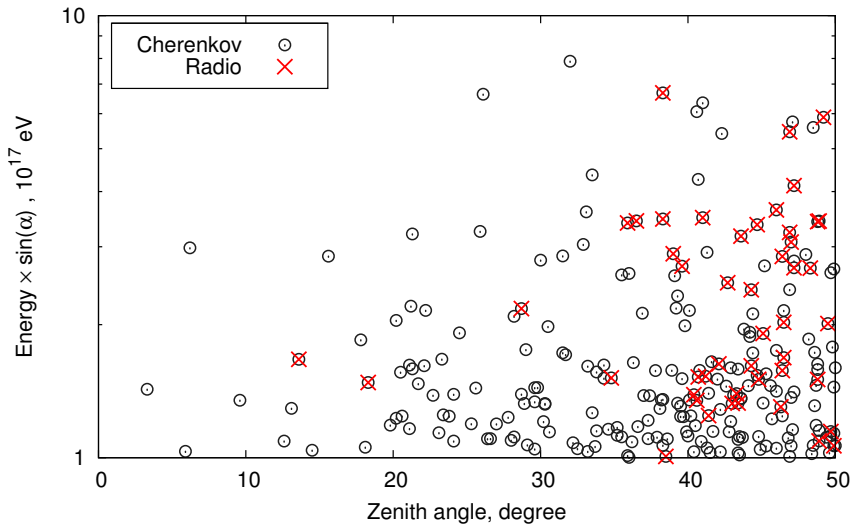- Lateral distribution function fitting, cuts for the slope parameter (η)

Total reconstructed events: 146

- Reconstructed 62 events with $\theta \leqslant 50°$
- Reconstructed 84 events with $\theta > 50°$

Angular distribution of Tunka-Rex

Detector efficiency

Correlation with shower parameters

Left plot:
$\eta \times 100$ m = 0.22±0.05
A(100) = 87.54±7.95
X_{max}=515±30 g/cm^2
E=(1.78±0.27)×10^{17} eV

Right plot:
$\eta \times 100$ m = 0.66±0.06
A(100) = 163.95±17.65
X_{max}=682±30 g/cm^2
E=(4.17±0.63)×10^{17} eV

Both plots: Uncalibrated amplitude vs Distance to shower axis, m
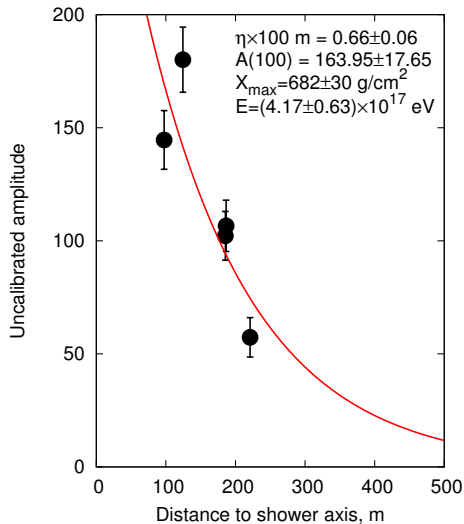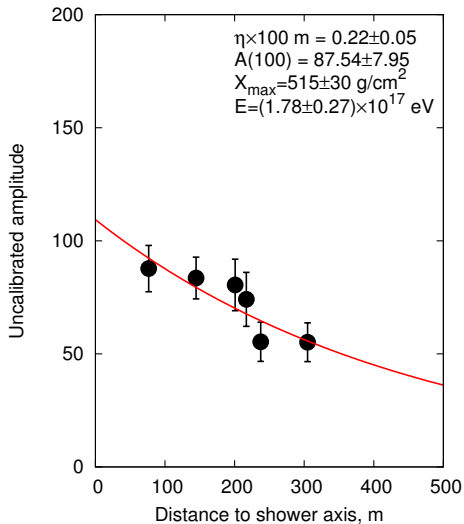
Correlation with amplitude

Conclusions

- First radio events were identified, direction reconstruction consistent with Cherenkov data.
- We confirm detection of very inclined ($\theta > 50^\circ$) showers based on Cherenkov trigger.
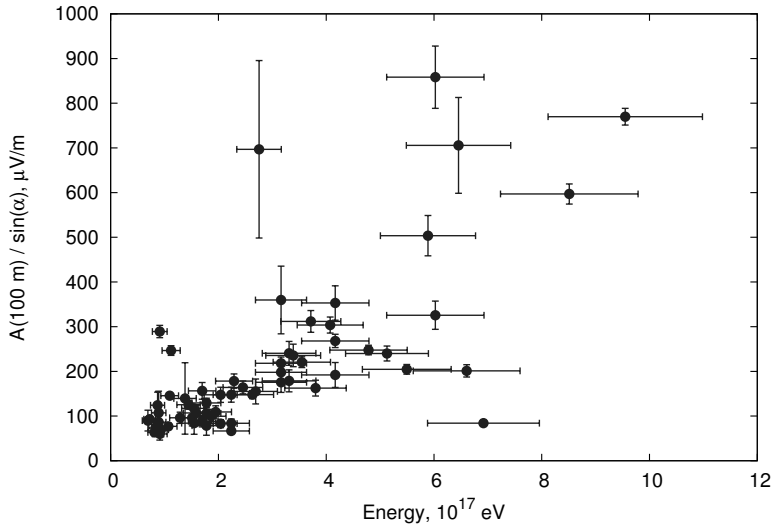- We see the correlation between initial energy and signal strength.
- Correlation between shower maximum and lateral slope is under investigation.
- Tunka scintillator extension would provide more effective trigger operating 24 hours.

Tunka-Rex Collaboration

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Data acquisition and event merging

- Every run local clocks set to zero
- Cluster centers have independent triggers (more than 2 simultaneous signals from PMT consider as event)
- Delays in optical fibers are taken into account. Event time is
  $T = \text{local time} + \text{fiber delay}$
- We merge separate events with $\Delta T \leqslant 7000$ ns into one
- UTC time sets for each event in DAQ center and then data reader choses one for merged event.

$T2 = t2 + dt2$

$T1 = t1 + dt1$