Karlsruhe Institute of Technology

Tunka-Rex

The Tunka Radio Extension: latest analysis results

Dmitriy Kostunin for the Tunka-Rex Collaboration

3rd September 2014

Helmholtz Russian Joint Research Group 303

INSTITUT FÜR KERNPHYSIK

Outline

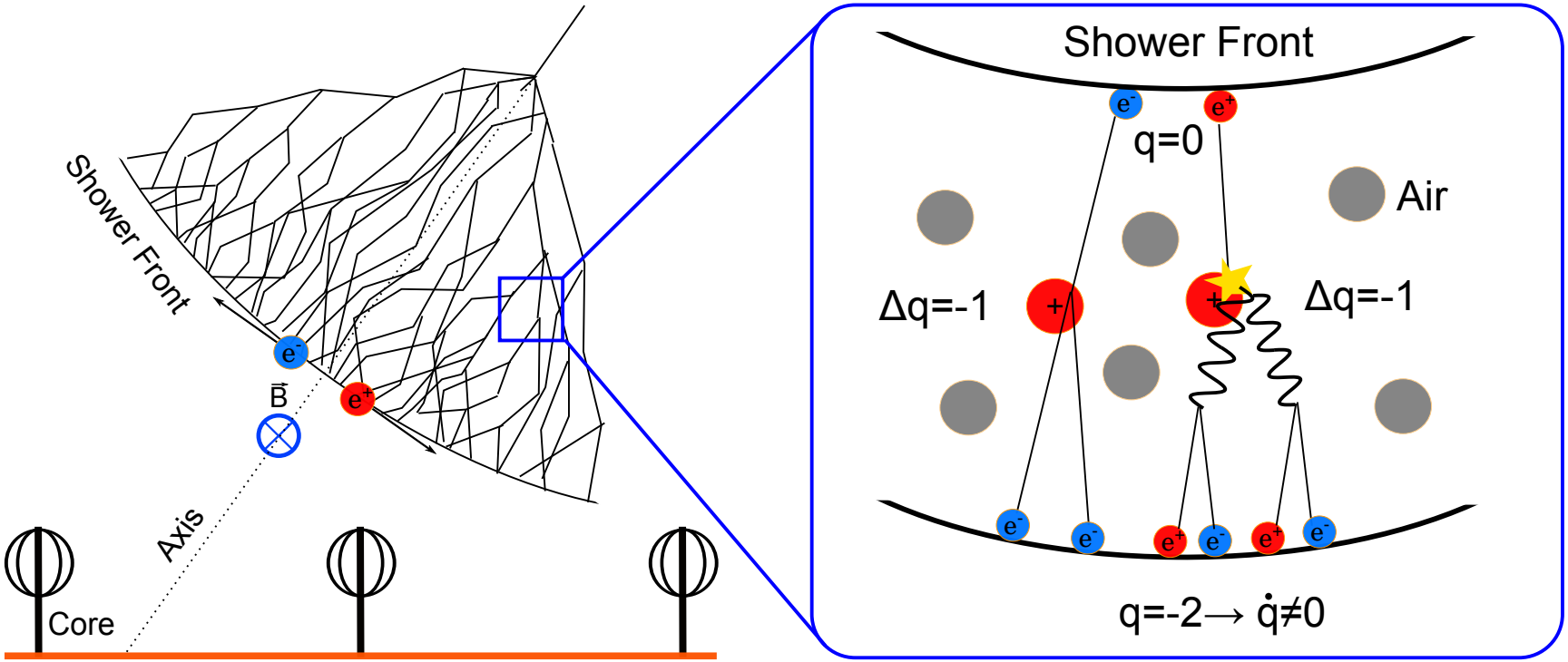
Radio emission processes

Geomagnetic effect

- Time-varying transverse currents
- East-West polarisation
- Dominant effect ($\sim \sin\alpha$)

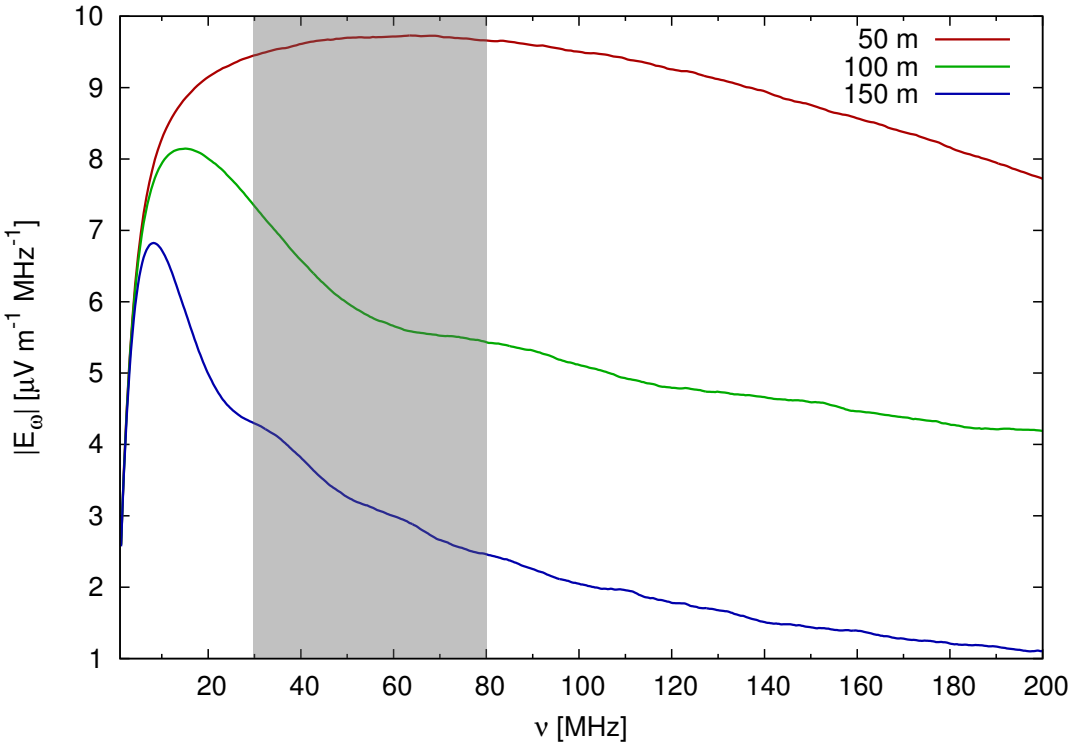
Askaryan effect

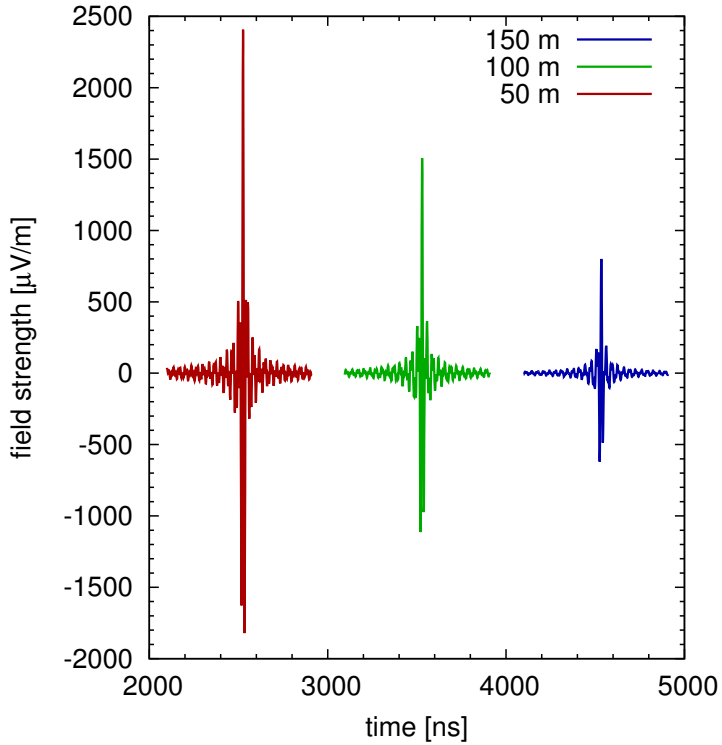
- Time-varying net charge
- Radial polarisation
- Second order effect ($\approx 10\%$)



Radio emission from cosmic rays

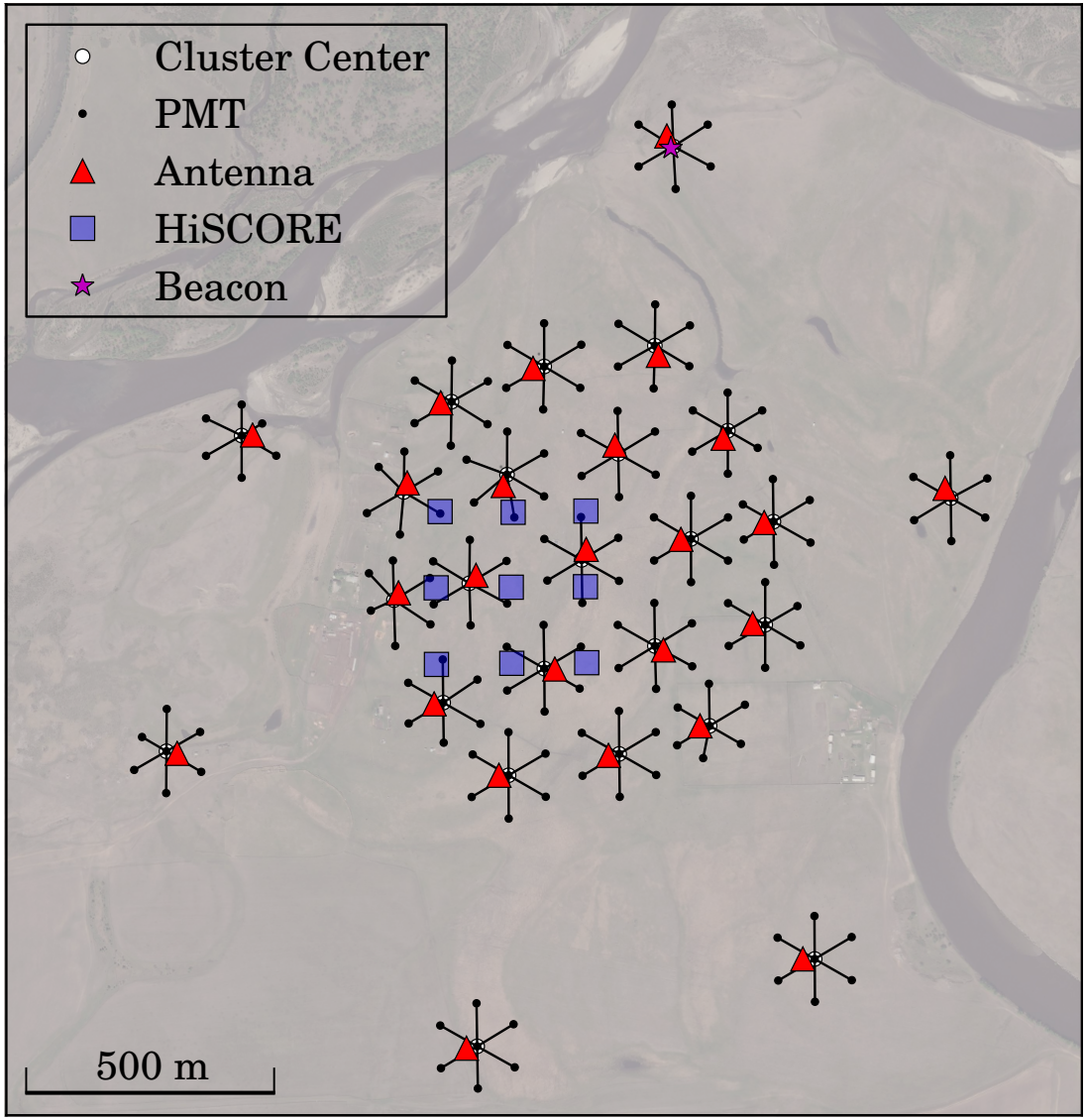
- Radio emission in MHz–GHz range
- Tunka-Rex: 30-80 MHz band, not used commercially





Vertical EeV air-shower simulated with CoREAS v1.0

Tunka facility



- Tunka-133 air-Cherenkov detector
- **Tunka Radio Extension** (Tunka-Rex)
- HiSCORE gamma ray detector
- Particle detectors
- IACT

Tunka facility

Tunka-Rex Collaboration

Tunka-Rex detector

- 25 antennas on 1 km^2 area
- Existing DAQ of Tunka-133
- Trigger and information from air-Cherenkov detector

- Radio quiet rural location
- Strong geomagnetic field ($\approx$ 60 μT)

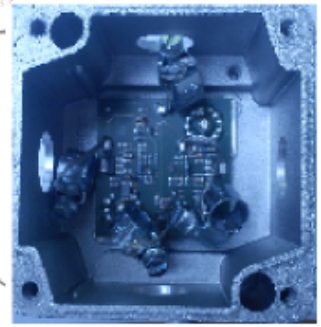
- Joint operation of radio and air-Cherenkov detectors
- Goal: precision of radio reconstruction for shower parameters (energy and shower maximum)

Tunka-Rex station

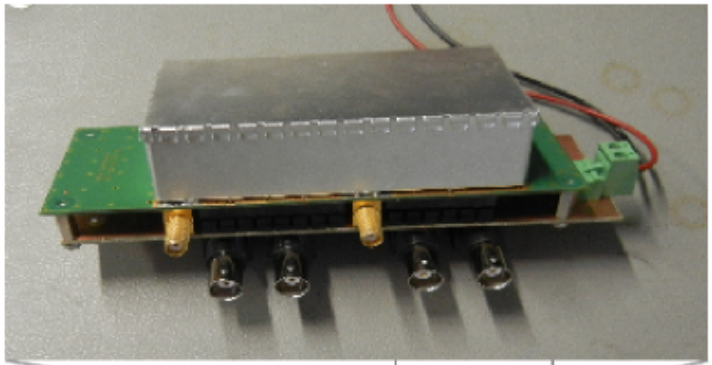
see poster **S8-455** (in the INS section)

"The Amplitude Calibration of the Tunka Radio Extension (Tunka-Rex)"

by Roman Hiller



LNA



Filter

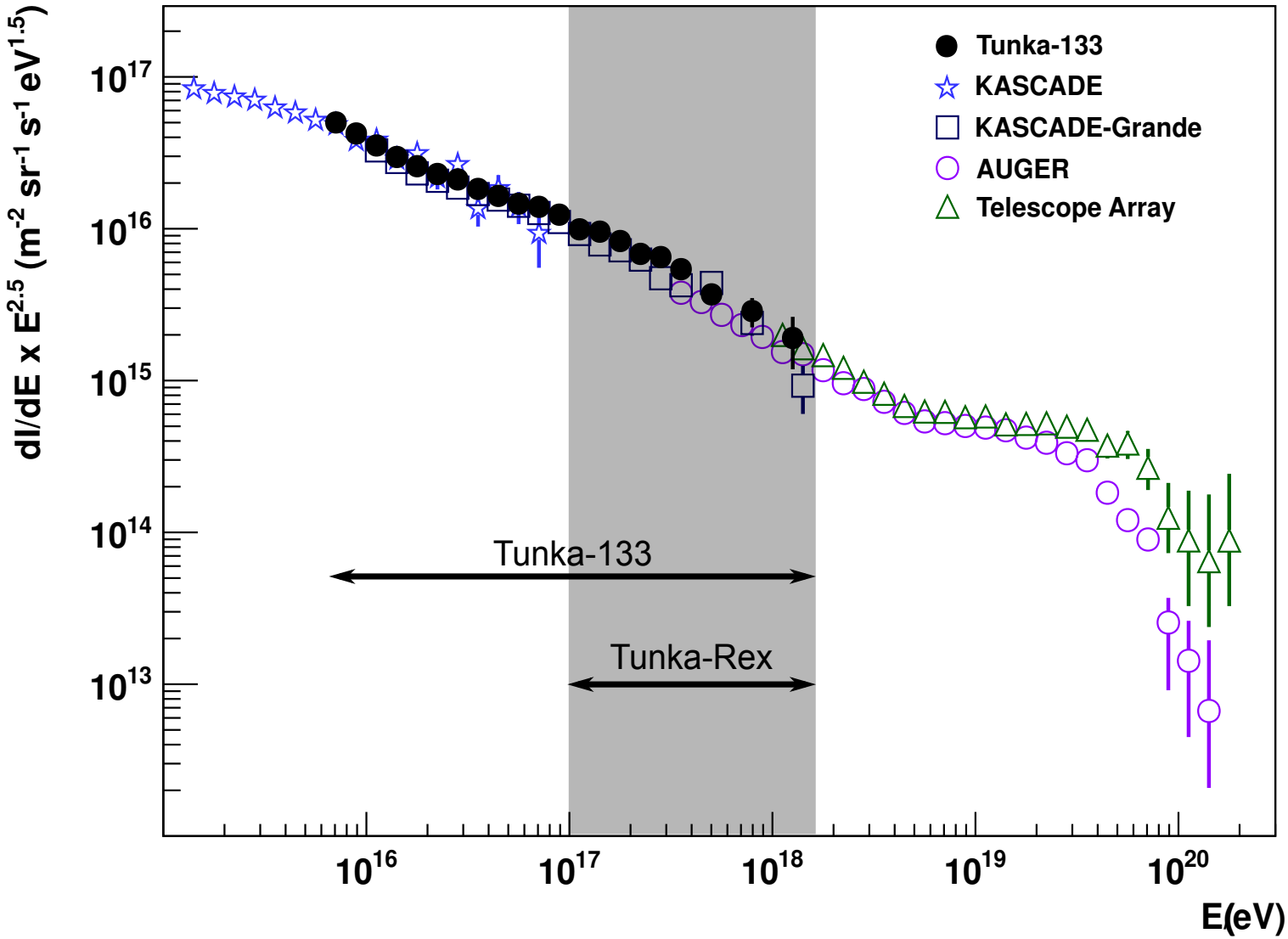
SALLA
Ø1.2m

Cluster
Box

ADCs

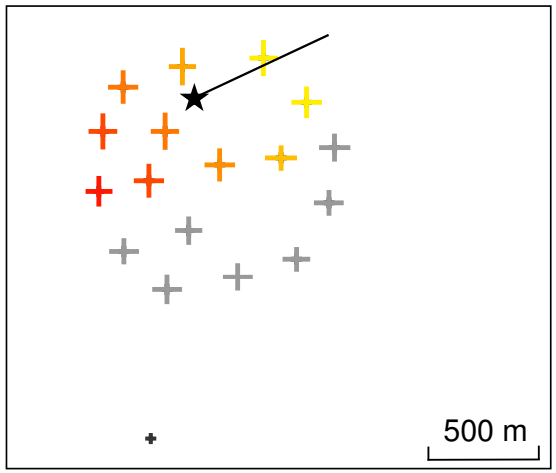
RG213 30m

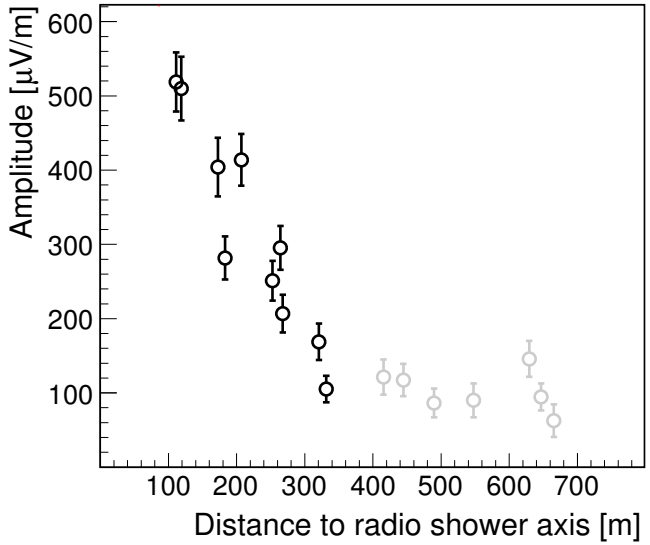
Cosmic ray energy spectrum

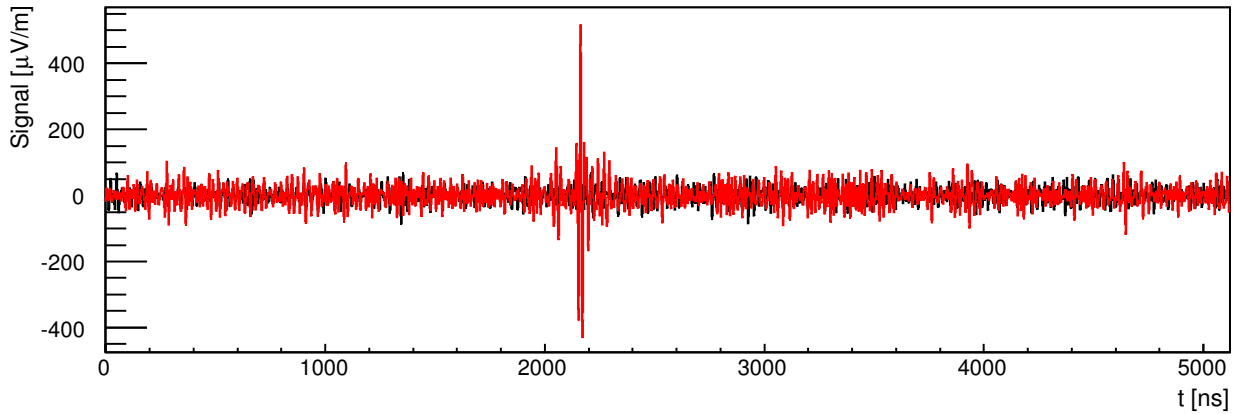


Tunka-Rex example event

For analysis we use the radio part of the Auger Offline software[1]







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

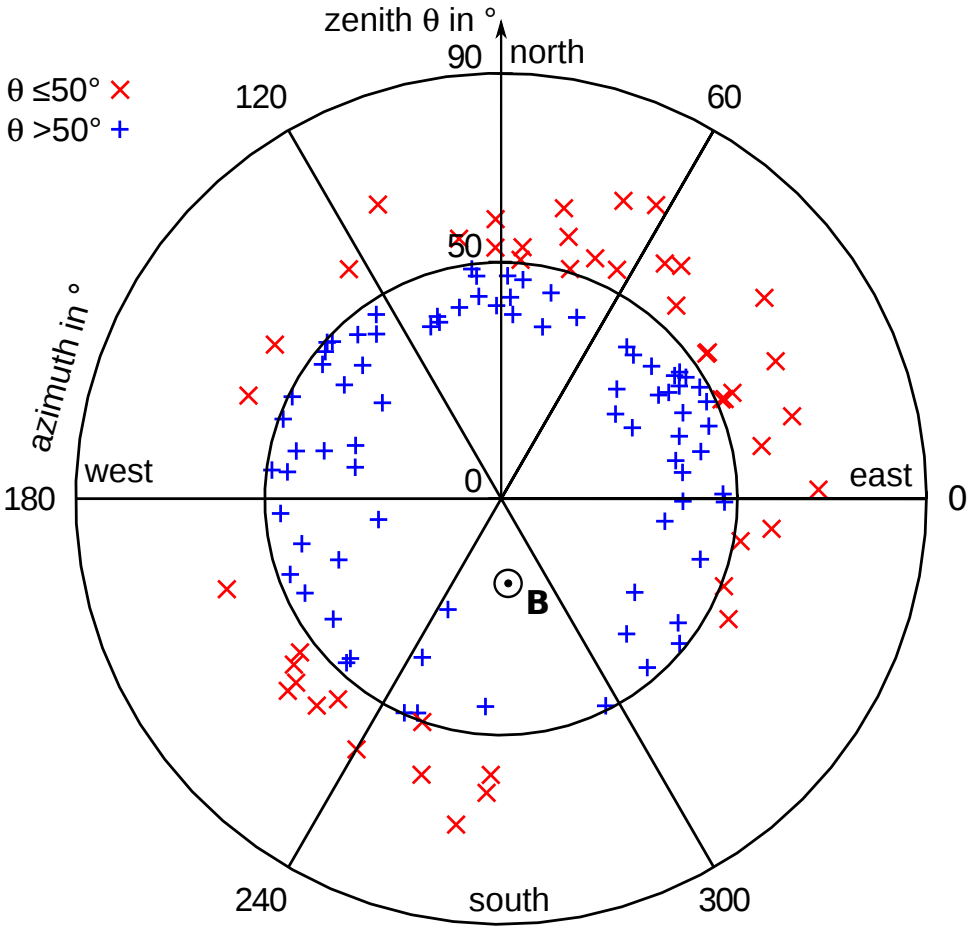
Reconstruction chain

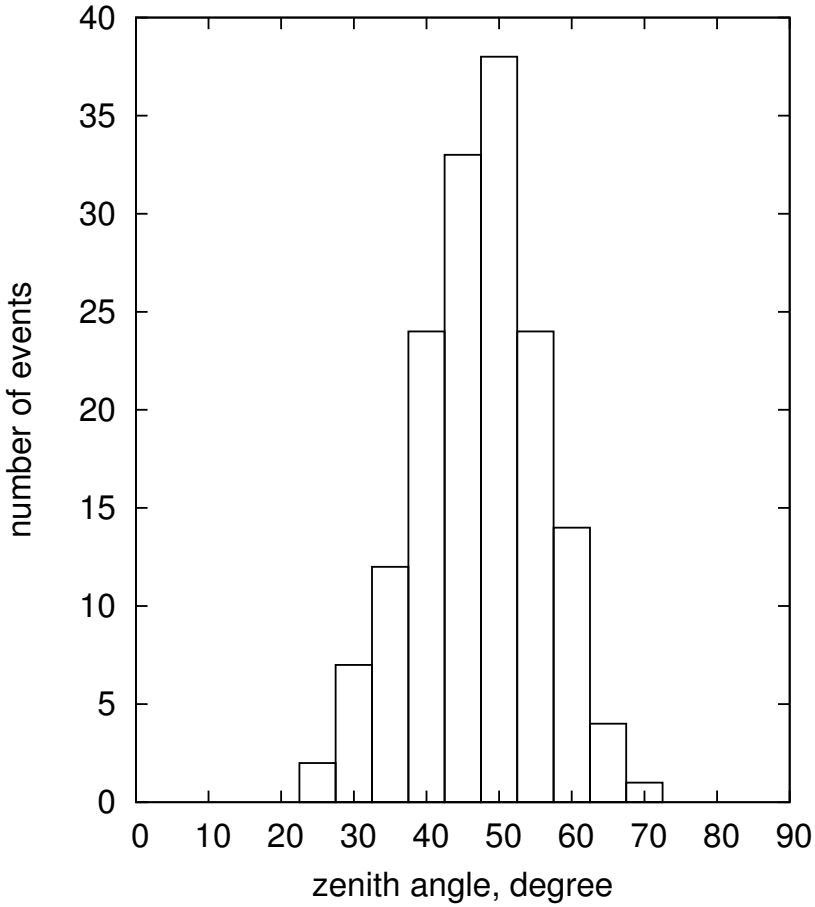
Non-blind analysis for season 2012/2013

Total time of measurements $\approx$ 450 hours

- Searching of the signal in power trace
  - Digital filtering
  - SNR$\geq$8
  - $N_A \geq 3$
  - **200 events found**
- Arrival direction check
  - Reconstruction of arrival direction with plane fit
  - Comparison with Cherenkov reconstruction ($\Delta\Omega < 5^\circ$)
  - **96 events found**
- Quality cuts
  - Rejecting outliers from the LDF
  - LDF fitting ($\chi^2/\mathrm{NDF} \leq 8$)
  - **78 events found**

Arrival directions





North-South asymmetry observed

LDF treatment

- Core position from Cherenkov reconstruction for events with $\theta \leqslant 50^\circ$
- LDF fitting

LDF ansatz

$$\varepsilon(r) = \varepsilon_{r_0} \exp\left[f(r - r_0)\right],$$

$$f(x) = \sum_{k=1}^{n} a_k x^k,$$

$n = 1, \ldots;\ r_0 \approx 100$ m

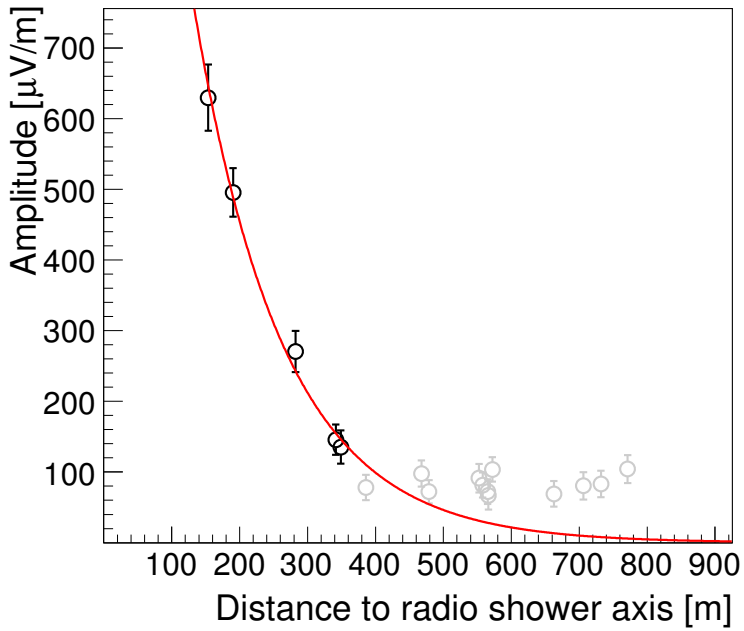
Shower parameters

$$E_{\mathrm{pr}}(\varepsilon_{r_0}) = \kappa \varepsilon_{r_0}$$

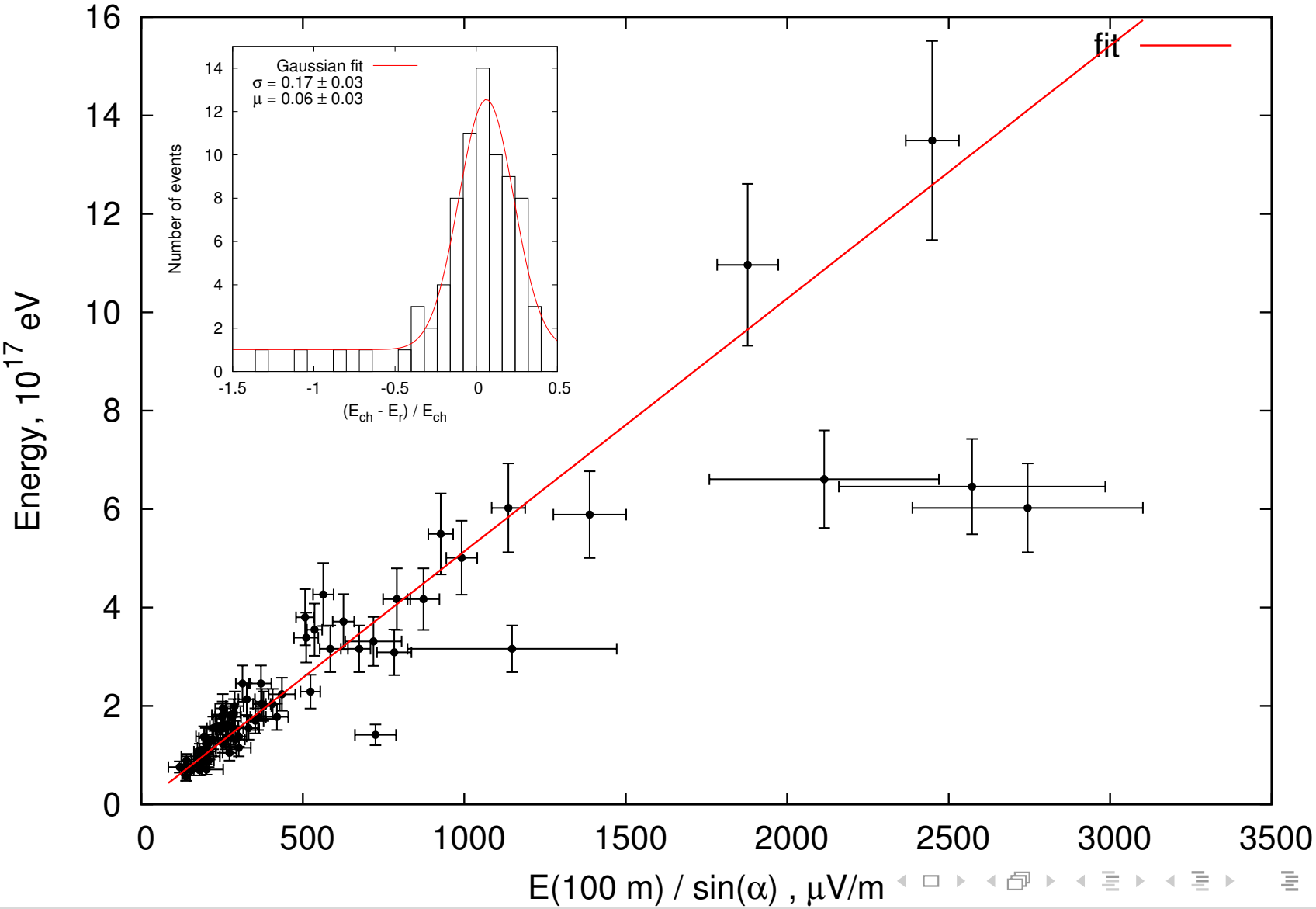
$$X_{\max}(f) = \ ?$$

$n = 1$ (exponential)

$$\varepsilon(r) = \varepsilon_{r_0} \exp\left[-\eta(r - r_0)\right]$$

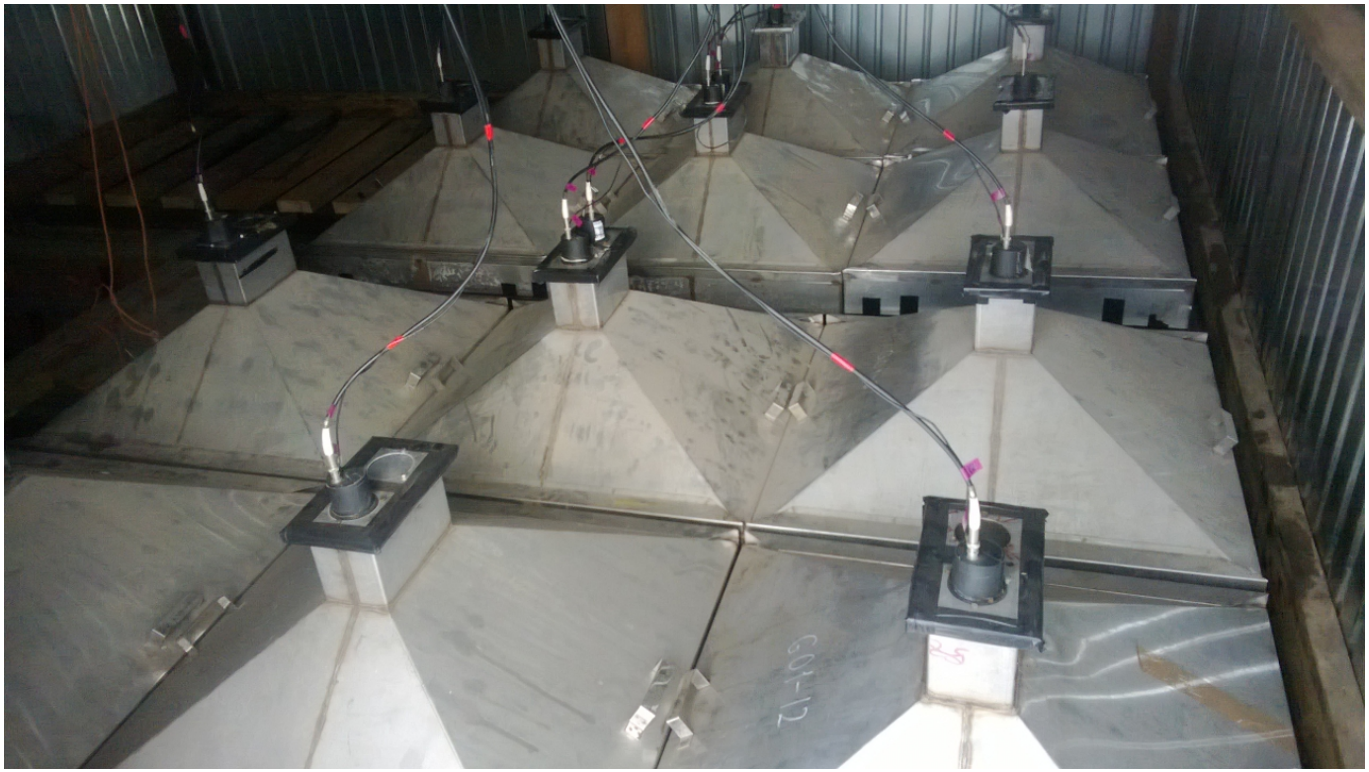


Correlation with amplitude



Future plans

- KASCADE-Grande scintillators installed at Tunka: electron and muon measurements
- $\sim$ 20 new antennas will be conntected to particle detectors in 2014 (increasing duty cycle up to 100%)



Conclusions

- Results of the 2012/2013 season have shown that Tunka-Rex detects the radio emission from extensive air-showers.
- After quality cuts strong correlation between amplitude and energy.
- Sensitivity to shower maximum is under investigation.
- Tunka-Rex has high sensitivity to inclined air-showers.
- Extension with scintillator trigger planned for this year.

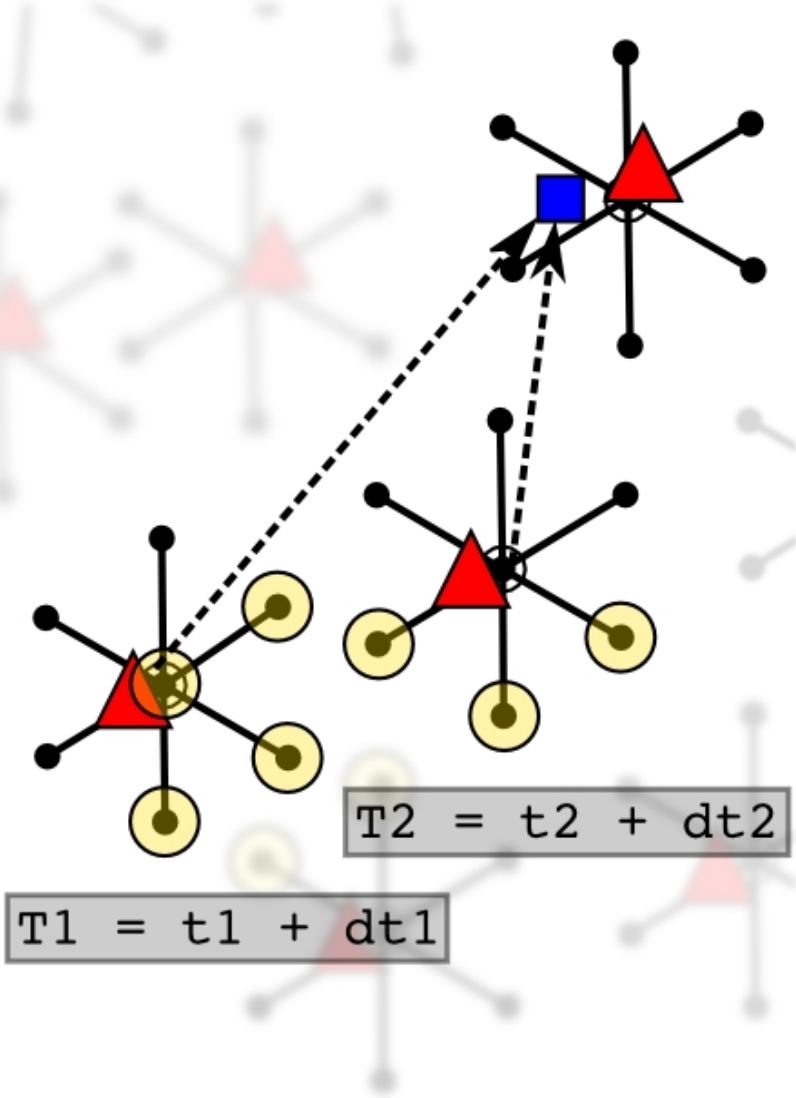
BACKUP

Tunka-Rex Collaboration

P.A. Bezyazeekov[1], N.M. Budnev[1], O.A. Gress[1], A. Haungs[2], R. Hiller[2], T. Huege[2], Y. Kazarina[1], M. Kleifges[3], E.N. Konstantinov[1], E.E. Korosteleva[4], D. Kostunin[2], O. Krömer[3], L.A. Kuzmichev[4], R.R. Mirgazov[1], L. Pankov[1], V.V. Prosin[4], G.I. Rubtsov[5], C. Rühle[3], F.G. Schröder[2], R. Wischnewski[6], A. Zagorodnikov[1]

[1] Institute of Applied Physics ISU, Irkutsk, Russia
[2] Institut für Kernphysik, Karlsruhe Institute of Technology (KIT), Germany
[3] Institut für Prozessdatenverarbeitung und Elektronik, Karlsruhe Institute of Technology (KIT), Germany
[4] Skobeltsyn Institute of Nuclear Physics MSU, Moscow, Russia
[5] Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia
[6] DESY, Zeuthen, Germany

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.