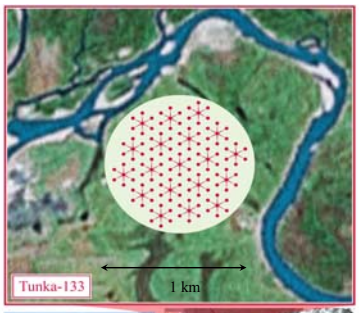
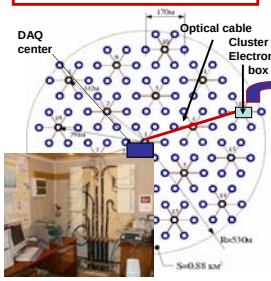
Tunka-133: the New EAS Cherenkov Light Array for Study of the Cosmic Rays in the Energy Range 10^{15} – 10^{18} eV

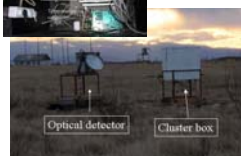


Tunka Valley:
φ = 051°48'47" .5 N
λ = 103°04'16" .3 E
h = 675 m a.s.l.
= 953 g/cm²

Tunka-133: 19 clusters,
7 detectors in each cluster



PMT
EMI 9350
Ø 20 cm



Tunka Collaboration:

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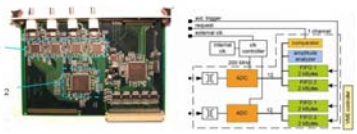
Main parameters:
- Energy threshold ~ 10^{15} eV;
- Time synchronization accuracy between different clusters ~ 10 ns;
- Energy resolution ~ 15%;
- Core location accuracy ~ 6 m;
- X_{max} EAS maximum depth accuracy ~ 25 g·cm^{-2};

The new EAS Cherenkov light array Tunka-133, with about 1 km^2 geometric area, has been installed in the Tunka Valley (50 km from Lake Baikal). The array provides a detailed study of cosmic ray energy spectrum and mass composition in the energy range of 10^{15} – 10^{18} eV. The total array consisting of 19 clusters each composed of 7 optical detectors has started data taking since October 2009.

Claster recording electronics

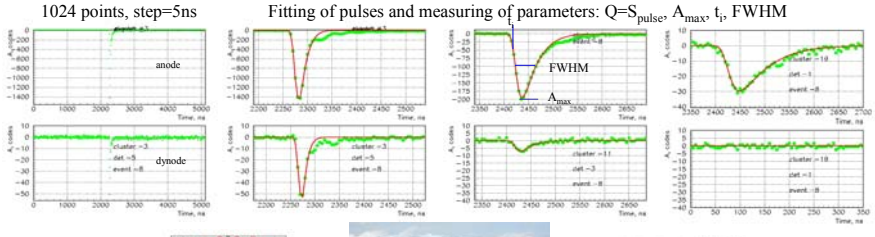


1. ADC AD9430, 12 bit, 200 MHz
2. FPGA XILINX Spartan-3

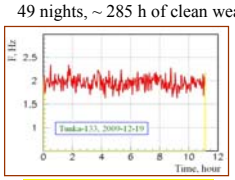
Two channels for each detector:

1024 points, step=5ns

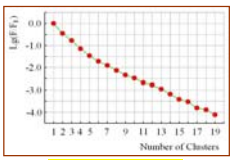
Fitting of pulses and measuring of parameters: Q=S_{pulse}, A_{max}, t_i, FWHM



The first winter season of data taking: 25.10.2009 – 17.03.2010:
49 nights, ~ 285 h of clean weather, ~2·10^6 events

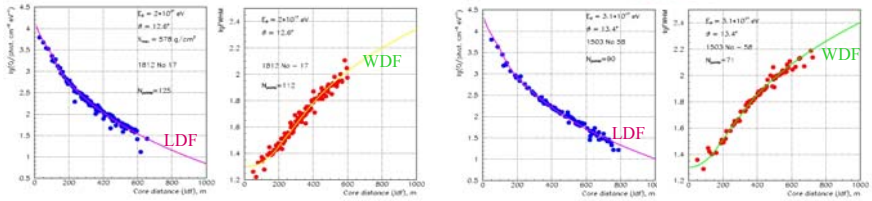


Single night Counting Rate



Cluster Multiplicity

Examples of the experimental reconstructed events.
R_{circle} ~ lgQ
Green cross – EAS core by LDF
Blue cross – EAS core by WDF



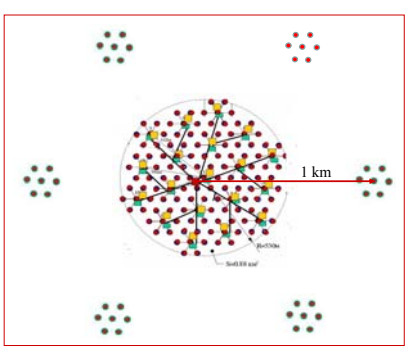
EAS parameters reconstruction using both traditional LDF method and the new WDF (width vs distanse function) methods.

The better accuracy in experimental FWHM has been obtained using $\tau_{eff} = Q/A_{max}$

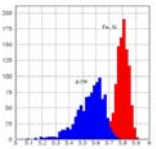
$$FWHM = \tau_{eff}/1.24$$

The array development in 2011-2012:

1. Adding of 6 outside clusters to enlarge the internal effective area to 4 times for EAS with $E_0 > 3 \cdot 10^{17}$ eV
2. Deployment of 19 muon detectors with S = 10 m^2
3. Installing of >20 radio antennas
4. Proto-type of the SCORE array of the area 0.1 – 0.2 km^2
5. Image detectors with mirrors of 1.5 – 2 m in diameter

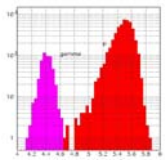


Simulation of common N_μ and Cherenkov light measurement to analyse the mass composition.
Expected errors: $\delta N_\mu / N_\mu = 10\%$, $\delta X_{max} = 20$ g/cm^2



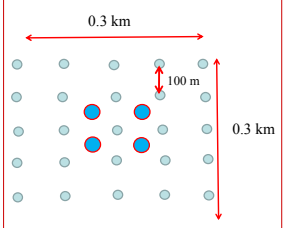
$lgN_\mu^{corr} = lgN_\mu - (X_{max} - 600)/1500$

Separation of γ from protons using N_μ



$lgN_\mu^{corr} = lgN_\mu - (X_{max} - 600)/1500$

SCORE prototype and image detectors



SCORE Cerenkov light detector (M.Tluczykont et al., arXiv: 0909.0445)

Mirror image detector (V.I. Galkin et al., 2009)

Registration of EAS radio emission

Choosing the type of antennas: Now 2 types of antennas are installed at Tunka Array

Log-periodic antenna (D. Besson et al. University of Kansas, USA)

Short Aperiodic Loaded Loop Antenna (SALLA) (A.Haungs et al. Institute fur Kernphysick, Forschungszentrum, Karslruhe, Germany

Antennas are connected to the free FADC channels of Tunka-133 cluster electronics

2010-2011: Net of 20 antennas

CONCLUSIONS

- Tunka-133 started data taking in October 2009.
- The first results show the array parameters to be in good agreement with expected ones. Recording of pulse waveform in each detector provides more reliable measurement of X_{max} and the possibility to reconstruct EAS cores outside the array.
- The upgrading of Tunka-133 with the day-time operating detectors (radio-antennas and scintillation counters) and "far" clusters has started.