Tunka-Grande array for high-energy gamma-ray astronomy and cosmic-ray physics: preliminary results.

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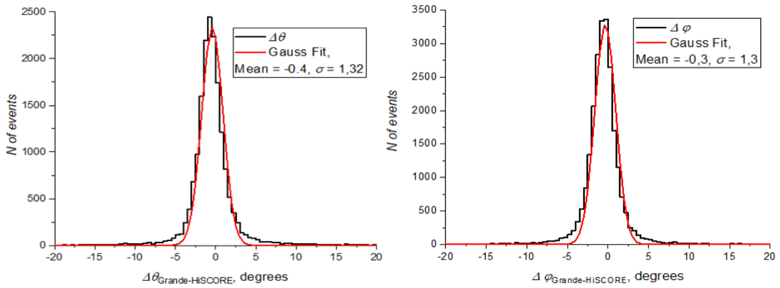
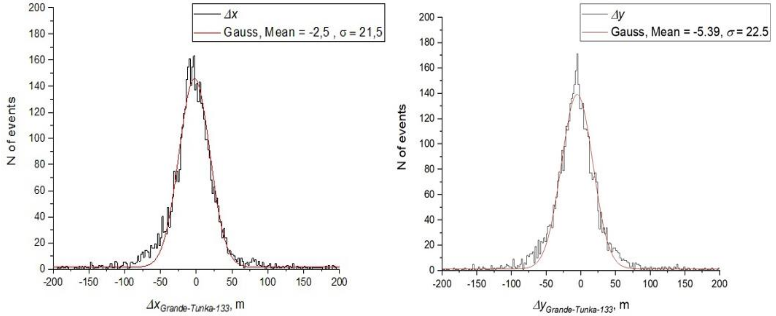
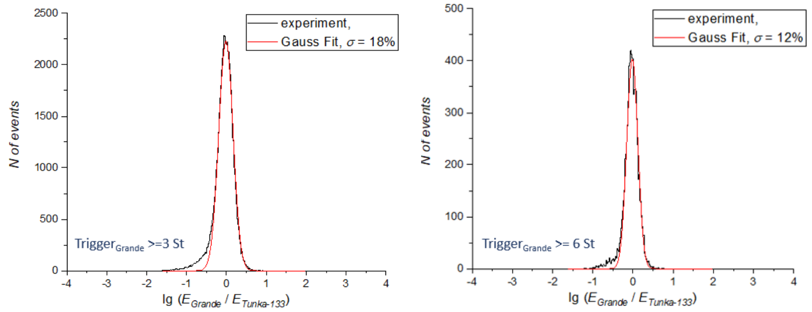
Estimating the accuracy of the main EAS parameters experimentally



The accuracy of the arrival direction reconstruction by the Tunka-Grande array in comparison with data of TAIGA-HiSCORE array.



The accuracy of the arrival direction reconstruction by the Tunka-Grande array in comparison with data of TAIGA-HiSCORE array.



The accuracy of the energy reconstruction by the Tunka-Grande array in comparison with data of Tunka-133 array.

Tunka-Grande array:

19 **Scintillation Stations** on area ≈ 0,5 km^2.
Scintillation Station =
Surface detector + **Underground detector** ;
Surface detector =12 scintillation counters;
Underground detector = 8 scintillation counters.

- Scintillation counter area – 0.64 m^2.
- Surface detector area ~ 8 m^2.
- Underground detector area ~ 5 m^2.
- Distance between stations ~ 175 m.
- Altitude of 669 m a.s.l.

Reconstructing EAS parameters

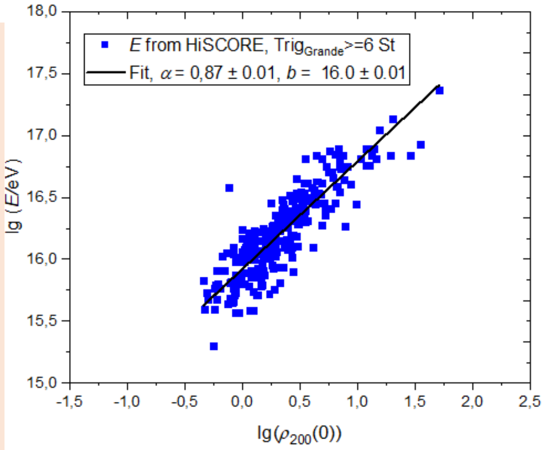
The shower arrival direction is determined by fitting the measured pulse front delay using a curved shower front formula, which is obtained in a Kascade-Grande experiment [1]: **Ti – Tth =a(1 + Ri/30)^b**, where Tth is the theoretical delay time for a flat shower front, Ri is the perpendicular distance from the shower axis in meters.

As a measure of energy, we use the charged particles density at a core distance of 200 meters – ρ_{200}. The parameter ρ_{200} is rescaled to the vertical direction relative to the measured zenith angle as: $\boldsymbol{\rho_{200}(0) = \rho_{200}(\theta)\cdot e^{\left(\frac{x_0}{\lambda}\cdot(\sec\theta - 1)\right)}}$,

where x_0 = 960 g/sm^2 is the atmospheric depth from sea level for the Tunka Valley, λ = 206 g/sm^2 – obtained from experimental data average value of absorption path length.

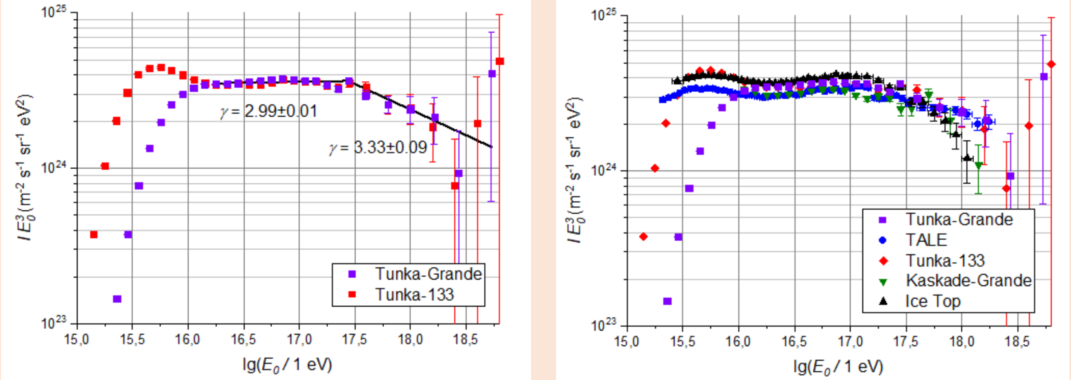
The value of $\rho_{200}(0)$ relative to the energy can be rescaled as: $\boldsymbol{E_0 = 10^b \cdot (\rho_{200}(0))^a}$, where $a = 0.87 \pm 0.01$, $b = 16.0 \pm 0.01$.

Correlation $\rho_{200}(0)$ with the primary energy is determined using the experimental results of TAIGA-HiSCORE array.



Correlation $\rho_{200}(0)$ with the primary energy from the TAIGA-HiSCORE experimental data

Energy Spectrum from 3 seasons of observation



To plot the energy spectrum according to the results from processing the data collected by the Tunka-Grande facility, events with zenith angles θ ≤ 45° and axial positions in a circle with radius R < 400 m were selected for energies E_0 < 10^{17} eV, and in a circle with radius R < 800 m for showers with energies $E_0 \geq 10^{17}$ eV. A comparison of the spectra for the circle with radius R < 400 m and ring with inner radius R > 400 m and outer radius R < 600 m showed them to coincide within the limits of error, starting with the energy 10^{17} eV and up. The events with energy E_0 >10^{17} eV detected in the ring were naturally 1.25 times more numerous than in the circle. The efficiency of event selection was approximately 100% for energies E_0 > 20 PeV. The total number of events with energies higher than this was around 350000. Some 8070 events had energies over 10^{17} eV.

[1] R. Glasstetter et al. *Shower Size Reconstruction at KASCADE-Grande*, 29th International Cosmic Ray Conference Pune, **6** (2005), 293-296

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