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Primary Energy Spectrum and Mass Composition Determined with the Tunka EAS Cherenkov Array

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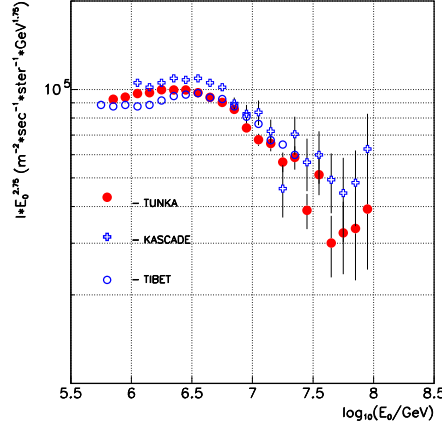
New results of 300 hours of operation of the Tunka array are presented. An improved parametrization of the Cherenkov light lateral distribution function (LDF), based on CORSIKA Monte Carlo simulations and the experiment QUEST, has been used for the reconstruction of EAS parameters. The corrected energy spectrum in the knee region is obtained. The mean depth of the EAS maximum has been derived both from the analysis of LDF steepness and the FWHM of Cherenkov light pulse. The mean mass composition around the knee is estimated.

Keywords: energy spectrum; mass composition; EAS Cherenkov light.

Experimental Differential Energy Spectrum.

The TUNKA EAS Cherenkov array is located in Tunka Valley, at an altitude of 675 m a.s.l., and was described in [1]. The new fitting function (LDF) for the EAS Cherenkov light lateral distribution, derived from CORSIKA code simulation [2], has been applied to TUNKA data. The primary energy $E_0 [TeV]$ has been obtained from the measured Cherenkov light flux at a distance 175 m from the shower core $Q_{175} [photon \cdot cm^{-2} \cdot eV^{-1}]$ with CORSIKA simulated relation: $E_0 = 370 \cdot Q_{175}^{0.96}$. The absolute energy calibration is based on the results obtained with the QUEST experiment [3]. A Monte Carlo simulation of the experiment has shown that the energy resolution is better than 18%.

The spectrum is derived from data taken in 300 hours, spread over 51 clear moonless nights, with a trigger rate of about 1.8 Hz. To construct a spectrum with energy threshold 10^{15} eV, showers with zenith angles $\theta \leq 25^\circ$ and a core position inside the geometrical area of the array have been selected. For the range from

2 *Korosteleva*Fig. 1. *Differential energy spectrum.*

$6 \cdot 10^{14}$ to 10^{15} eV, events with zenith angles $\theta \leq 12^\circ$ falling inside a 5 times smaller area around the array center have been selected.

Estimation of Primary Mass Composition

Lateral and time distributions of EAS Cherenkov light provide two independent methods to estimate the maximum depth. The simulation shows, that the LDF steepness $P = Q(100)/Q(200)$ is related to the linear distance (in [km]) from the array to the EAS maximum position: $H_{max} = 10.62 - 0.12 \cdot (P + 2.73)^2$.

The Cherenkov light pulse FWHM [ns] at distances larger than 200 m from the EAS axis is related to the relative position of the EAS maximum by $\Delta X = X_0/\cos\theta - X_{max}$ [g/cm²], where X_0 is the total depth of the atmosphere and θ is the zenith angle of the shower. This relation depends only on the distance to the EAS axis. For example, for distance of 250 m: $\Delta X = 1677 + 1006 \cdot \log_{10}(FWHM)$. This method gives a better theoretical accuracy, than the first one. Moreover, the X_{max} estimate does not depend on assumptions about the primary nucleus.

Figure 2 presents the mean depth of the EAS maximum, derived with the two methods described above, as a function of primary energy. It is seen that the threshold of the FWHM method is higher than that of the LDF steepness method, but the mean depths, obtained with the two different methods are in good agreement.

The mean values of X_{max} from fig.2 can be easily transformed to the mean logarithmic mass $\langle \ln A \rangle$ of primary particles. Figure 3 represents the result. A slight correction, derived from MC simulations of the experiment (assuming a 4-group mass composition, p:He:CNO:Fe = 0.3:0.3:0.2:0.2) has been applied. According to these data the mass composition has almost no energy dependence in the range from 10^{15} to 10^{16} eV and is compatible with the hypothetical composi-

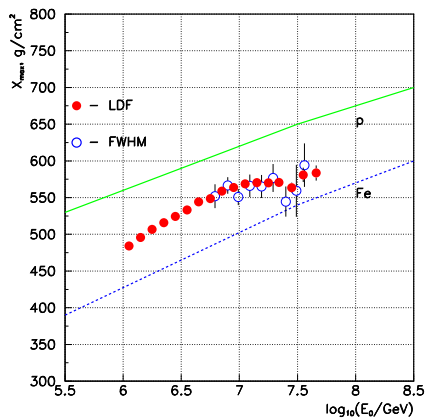


Fig. 2. Mean X_{max} vs primary energy E_0 . Curves are CORSIKA/QGSJET simulations.

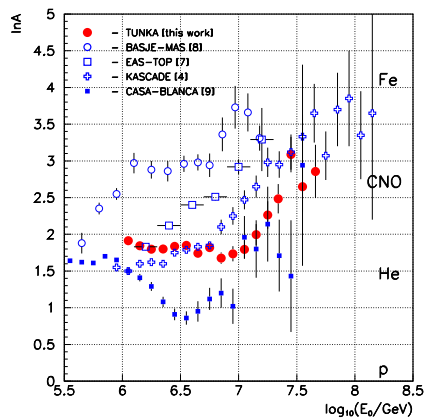


Fig. 3. Mean $\langle \ln A \rangle$ vs primary energy.

tion with $\langle \ln A \rangle = 1.75$ mentioned above. At energies above 10^{16} eV, however, a steep increase of the average mass is observed. A similar increase in average mass is observed in almost all experiments. Points of the present work coincide with KASCADE data [4] at the energy of the knee.

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References

1. N.Budnev et al., *Proc. 27th ICRC, Hamburg* **2**, 581 (2001).
2. E.Korosteleva, L.Kuzmichev, V.Prosin, and EAS-TOP COLLABORATION, *Proc. 28th ICRC, Tsukuba, Japan* **1**, 89 (2003).
3. E.Korosteleva et al. and EAS-TOP COLLABORATION, *International Journal of Modern Physics A* **this volume**, ? (2004).
4. M.Roth et al., *Proc. 28th ICRC, Tsukuba, Japan* **1**, 139 (2003).
5. The Tibet AS_γ Collaboration, *Proc. 28th ICRC, Tsukuba, Japan* **1**, 143 (2003).
6. EAS-TOP Collaboration, *Astropart. Phys.* **10**, 1 (1999).
7. S.Valchierotti on behalf of the EAS-TOP Collaboration, *Proc. 28th ICRC, Tsukuba, Japan* **1**, 151 (2003).
8. S.Ogio et al., *Proc. 28th ICRC, Tsukuba, Japan* **1**, 131 (2003).
9. J.W.Fowler et al., *Astropart. Phys.* **15**, 49 (2001)