Some characteristics of age parameter for Yakutsk array data

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Abstract
In this paper some characteristics of age parameter(s) are studied on the basis of showers from Yakutsk array data [1] having energy ranging from $10^{18}$ eV to $10^{19}$ eV.

Keywords: extensive air shower, age parameter, zenith angle, primary energy

1. Introduction
Age parameter(s) is an important parameter to describe the longitudinal development of an Extensive Air Shower. The important characteristics of age parameter are studied by different group up to primary energy of $10^{17}$ eV [2]. Age parameters are determined adopting the method developed by Idenden [3]. The basic method of Idenden is modified assuming Capdevielle Lateral Distribution Function. Capdevielle et al., put forward a LDF of electron component for proton primary as well as iron primary [4] but in this paper, available data of Giant Air Shower laboratory viz., Yakutsk are analyzed with the help of NKG LDF [5] because the NKG LDF [5] have one free parameter for fitting the lateral distributions with function.

2. Calculation and Results
We have used two different correlations [6, 7] between shower size ($N_e$) and primary energy(E) to calculate shower size for every shower

$$E = 1.22 \times 10^{13} (N_e)^{0.56}, \quad (1)$$

$$E = 3.9 \times 10^{15} \left( \frac{N_e}{10^6} \right)^{0.9}. \quad (2)$$

Then we have fitted the values of density and NKG LDF [5] to obtain the best age parameter for every shower. The mean values for showers are shown in table 1. (s- $N_e$) curves for $20^\circ < \theta < 40^\circ$ are shown in figure 1, 2. Such that figure 1 is drawn using formula (1) and figure 2 is drawn using formula 2. [6, 7].

(s- $E_p$) curves for $\theta < 30^\circ$ are shown in figure 3, 4 by using formula (1, 2) [6,7] respectively. In this curve the data that obtained by fitting is compared with the theoretical curve obtained from Fenyves model after extrapolation. The data that we calculate by fitting cannot be explained with any of the theoretical curves.

(s- $\sec \theta$) curves are shown in figure 5, 6 by using formula (1, 2) [6, 7] respectively. It is seen that s decreases with $\sec \theta$. s must increase with $\sec \theta$ due to increase in thickness of the atmosphere with $\sec \theta$ but we conclude an unusual characteristic for age parameter. Since we research in ultra high energy EAS, it is possible that the unusual conclusion is due to the mass compositions of primary particles in ultra high energy EAS.

3. Discussion and Conclusion
If we consider the values of $N_e$ obtained by applying formula (2), the average of age parameter, s, becomes as 1.8 times as the value of $N_e$ obtained by applying formula (1).

The characteristics of age parameter for $E_p$ from $10^{18}$ eV to $10^{19}$ eV from fitting the density data with the NKG LDF [5] by using the different $N_e$ are:

i) s decreases with $N_e$
ii) s decreases with $\sec \theta$

Furthermore, we have studied the correlation which is expressed as a double quadratic form and is valid for primary proton and heavy nuclei [8].
Table 1. Values obtained by using formula (1, 2).

<table>
<thead>
<tr>
<th></th>
<th>$N_e$</th>
<th>$\bar{s}$</th>
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<tbody>
<tr>
<td>Values obtained by using formula (1)</td>
<td>$3.45 \times 10^{11}$</td>
<td>0.657</td>
</tr>
<tr>
<td>Values obtained by using formula (2)</td>
<td>$2.17 \times 10^{10}$</td>
<td>1.21</td>
</tr>
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**Figure 1.** $(s-N_e)$ curve for $20^\circ < \theta < 40^\circ$ by using formula (1).

**Figure 2.** $(s-N_e)$ curve for $20^\circ < \theta < 40^\circ$ by using formula (2).

**Figure 3.** $(s-E_p)$ curve for $\theta < 30^\circ$ by using formula (1).

**Figure 4.** $(s-E_p)$ curve for $\theta < 30^\circ$ by using formula (2).

**Figure 5.** $(s-\sec \theta)$ curve for $\theta > 22^\circ$ by using formula (1).

**Figure 6.** $(s-\sec \theta)$ curve for $\theta > 22^\circ$ by using formula (2).
\[
\frac{E_p}{N_e} = 38.063 \times (s - 1.187)^4 + 1.63 \quad s \leq 1
\]
\[
\frac{E_p}{N_e} = 266.345 \times (s - 0.924)^4 + 1.67 \quad s > 1
\]

The correlation is not valid for the values of age parameter that we obtained. So, in the range of energy that we used it is not possible for proton and heavy nuclei, as primary particles, to exist.

References