Characteristics of Age Parameter for Giant Air Showers

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Abstract

The shower age is an important parameter to describe the longitudinal development of an EAS. The important characteristics of age parameter are studied by different groups upto primary energy of $\sim 10^{17}$eV. In this paper, a study of the characteristics of age parameter for giant air showers is presented. Results obtained are compared with those at lower energies.

1. Introduction

A number of lateral distribution function (LDF) of the electronic component of EAS have been developed on the basis of shower age (s) which is an important parameter to describe the longitudinal development of an EAS. The validity of these theoretical LDFs has been tested by the experimental groups upto primary energy $E_p \sim 10^{17}$eV. A preliminary work on the studies of experimental lateral distribution (LD) of the electronic component of giant air showers ($E_p > 10^{18}$eV) on the basis of age parameter was first carried out by the cosmic ray group of the Gauhati University (Saikia J, Datta P *et al.* 1993)

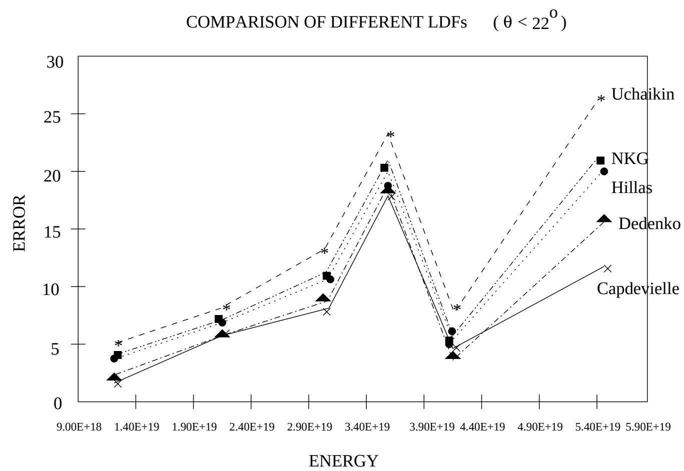

Figure 1:

One important characteristics of age parameter obtained by a number of groups is that for shower size $N_e = 2.5 \times 10^5$ to $\sim 2 \times 10^6$, s decreases and for $N_e = 2 \times 10^6$ to $\sim 10^8$, s increases with N_e.

This range of N_e showing the change in slope of s vs N_e curve coincides with the knee region of primary energy spectrum. The decreasing trend of s with N_e is quite physical but the increasing trend of s with N_e needs further theoretical explanation (H. Sakuyama *et al.* 1995).

Fenyves *et al.* (Fenyves E.J. *et al.* 1988) made an attempt to identify the primary particle on the basis of age parameter for showers with E_p upto $\sim 10^{16}$eV but the results obtained were discouraging.

In this paper, an attempt is made to study the properties of Giant air showers on the basis of s i.e. to study the characteristics of s associated with giant air showers.

2. Method

In this study, data of the following giant air showers laboratories are used.

1. Yakutsk lab of Russia (Effimov N.N. *et al.*, 1988).
2. SUGAR lab of Sydney, Australia (M.M. Winn *et al.*, 1986).
3. Volcano Ranch lab of New Mexico (Linsley J., 1980).

The experimental LD for each E_p is compared with the LDFs of Capdevielle, NKG, Hillas, Dedenko & Uchaikin (Saikia J., Datta P. *et al.* 1993). For each LDF, by introducing different s, $\chi^2_{\rm min}$ is found out for each E_p and a graph is drawn between $\chi^2_{\rm min}$ and E_p. From this comparative study, Capdevielle LDF is found to be most suitable for representing the LD of electrons for giant air showers.

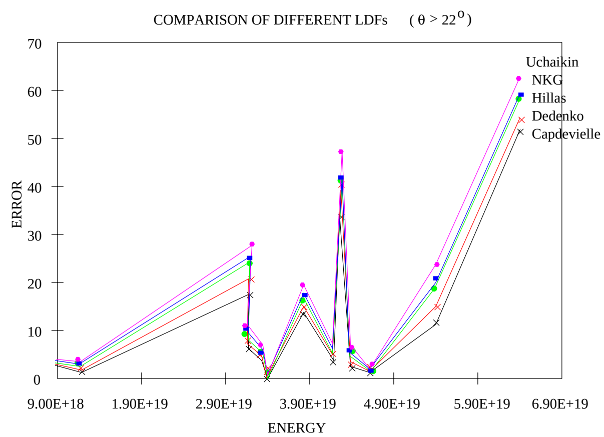

Figure 2:

Age parameters are determined adopting the method developed by Idenden (Idenden 1990). The basic method of Idenden is modified by assuming Capdevielle LDF.

Fenyves model (Fenyves E.J. *et al.* 1988) for determining s for different primary particles (photon, proton & iron nuclei) developed for E_p upto $\sim 10^{16}$eV is extrapoloated to E_p in the range $\sim 10^{18} - \sim 10^{20}$eV.

3. Results

$(\chi^2_{\rm min} - E_p)$ curves are given in fig 1 and 2 for $\theta < 22^o$ & $\theta > 22^o$ respectively. $(s - \sec\theta)$ curves are shown in fig 3 for different bins of N_e. The fitted equations to these curves are

$s = 0.89765 \sec\theta + 0.30875$ for $N_e = 4 \times 10^7 - 4 \times 10^8$

$s = 0.83304 \sec\theta + 0.28379$ for $N_e = 4 \times 10^8 - 4 \times 10^9$

$s = 0.77571 \sec\theta + 0.2613$ for $N_e = 4 \times 10^9 - 1.1 \times 10^{10}$

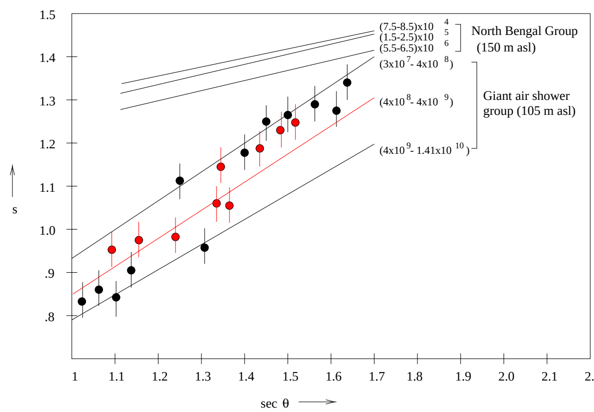

Figure 3:

$(s - N_e)$ curves for different zenith angle (θ) bins are shown in fig 4, 5, 6.

$(s - E_p)$ curves for $\theta < 30^o$ is shown in fig 7. In this figure the experimental curve is compared with the theoretical curve obtained from the Fenyves model after extrapolation. The experimental data cannot be explained with any of the theoretical curves.

4. Discussion and conclusion

From fig 3, it is seen that s increases with $\sec\theta$. This is due to increase in thickness of the atmosphere with $\sec\theta$. The curves obtained at the North Bengal University lab (Bhadra A, 1996) which has almost the same observation level as that of Yakutsk, SUGAR & Volcano Ranch are also shown in fig 3 for comparison. Fig 3 clearly demonstrates that s decreases with N_e which is also obtained from the figures 4, 5 and 6.

Hence, it is concluded that for giant air showers ($E_p > 10^{18}$eV),
(i) Capdevielle LDF gives the best fit for the LD of electronic component
(ii) s increases linearly with $\sec\theta$ and
(iii) s decreases with N_e.

From the conclusions (ii) and (iii), it is seen that for $E_p > 10^{18}$eV, showers have the usual characteristics for age parameter. It may be mentioned here, that for $E_p > 10^{20}$eV (super-giant air showers), the LPM effect will cause air showers to develop slowly (Stanev T, Vankov C *et al*, 1982). But for photon initiated super-giant air shower, due to interaction of the high energy photon in the earth's magnetosphere (Karukula, S. *et al.* 1995), energy of the particles of the electron photon cascade as they enter the earth's atmosphere will be $\sim 10^{15} - 10^{16}$eV or less and hence LPM effect will not be effective in case of photon-initiated super-giant air showers. Thus, the super-giant air showers having usual characteristics of age parameter may be photon-initiated.

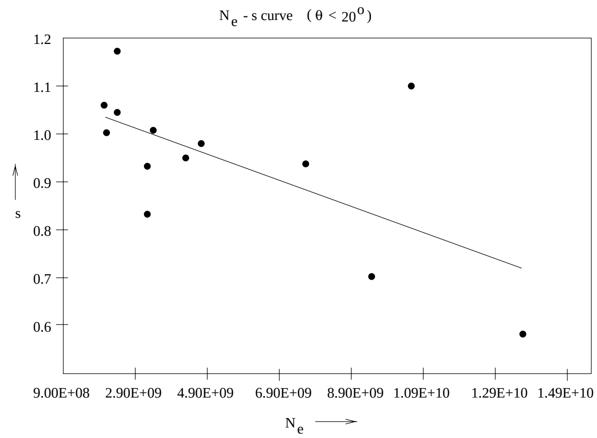

Figure 4:

Hence, for proton or iron-nuclei-initiated super-giant air showers , there may be some change in the usual characteristics of age parameter due to LPM effect. To draw a definite conclusion regarding this, super-giant air shower data will have to be compared with the theoretical model developed on the basis of electron-photon cascading of primary photon in earth's magnetosphere (Karukula S. *et al.* 1995). Encouraging results may be expected as more super-giant air shower data will be accumulated in the next few years.

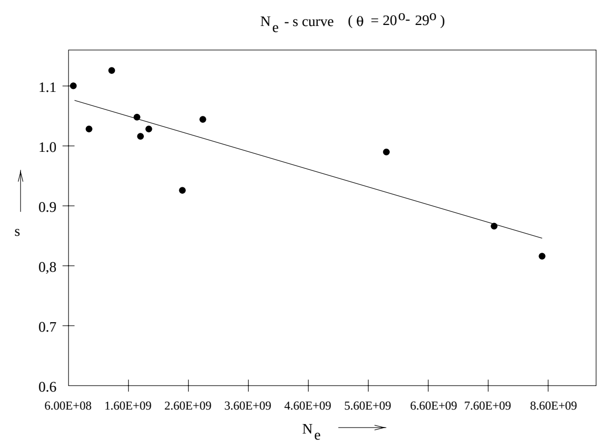

Figure 5:

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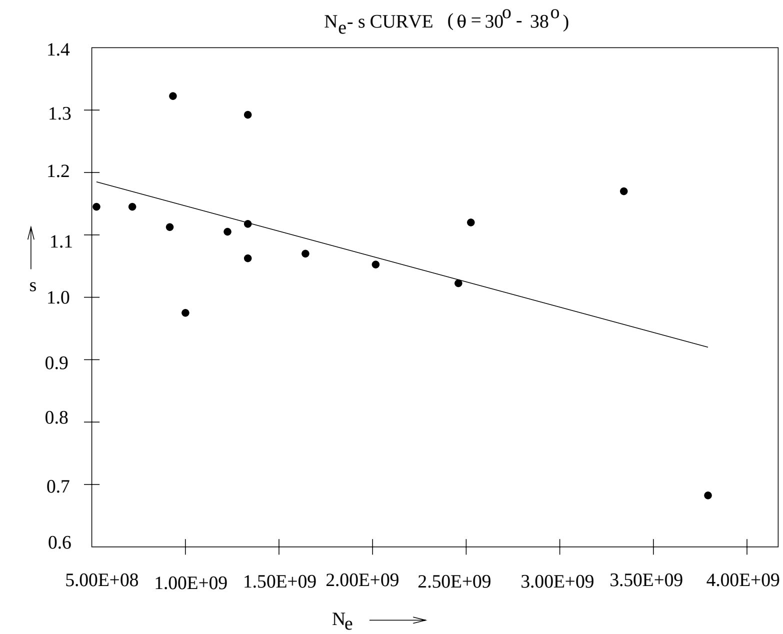

Figure 6:

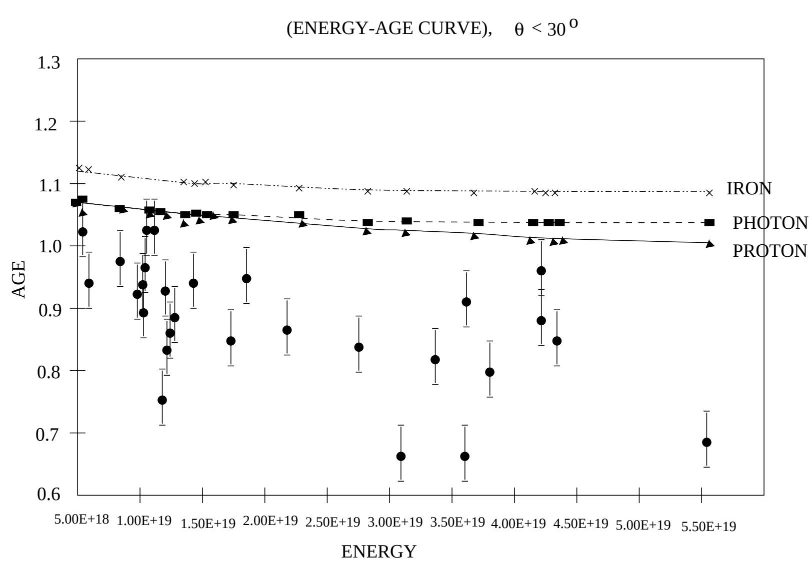

Figure 7: