Universality of the lateral and angular distributions of electrons in large extensive air showers

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Abstract
Based on shower simulations we show that the electron energy distributions depend on the shower primary and age s only; they do not depend on the energy or mass of the primary particle. Moreover, they can be described by a simple, universal function for any shower age. (5) We studied there (5) the distributions of electron's radial angles, but integrated over the tangential angles, i.e. those in the plane perpendicular to the lateral vector and gave an analytical description of them for any electron energy E and lateral distance r.

Introduction
It was already shown (1, 2) that the electron energy distributions depend on the shower primary and age s only; they do not depend on the energy or mass of the primary particle. Based on shower simulations we show that the electron distribution (6)

**The Aim of this paper is:**

- To show that any electron distribution in a large shower is universal in the sense that it is independent of the primary particle and of the shower to shower fluctuations.
- To give a full description, in a possibly compact form, of the state of electrons in a shower.

Universality of electron distributions

The state of electrons in a shower is uniquely determined by the numbers $\Delta N_i$:

$$\Delta N_i(\theta, \phi, E, s) = N_i(\theta, \phi, E, s) - N_i(\theta, \phi, s)$$

where $\Delta N_i(\theta, \phi, E, s) = f_i(\theta, \phi, E, s) \delta N_i(\theta, \phi, s)$

Distributions $f_i$, $f_\theta$, and $f_\phi$ are normalised to unity and $s$ is in g cm$^{-2}$.

The energy distributions at various ages $f_i(E, s)$ have been found already [1] and parametrised by Nerling et al. [2]. The lateral distribution $f_i(r, E, s)$ has also been shown to be universal [3, 4]. Moreover, in [5] it was shown that $f_i(r, \phi, E, s)$, a function of three variables, can be represented as a function of only one variable. Yet it remains to be shown that the last two angular distributions are universal.

**Figure 1**

**Figure 2**

**Figure 3**

**Figure 4**

**Figure 5**

**Figure 6**

**References**


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