Thinning Effects on The Simulation of Charged Particles and Their Lateral Distribution in EAS

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Abstract

To characterize the features impact of thinning energy, the lateral distribution of charğed particleș within an air shower was looked at by an effect among a thinning energy of various cosmic ray particles. AIRES system version 19.04.0, an air shower simulator, was used to simulate a lateřal distribution. At extremely high energies (10^{16}, 10^{17}, 10^{18}, and 10^{19} eV), the lateral distribution of charged particles, including the electron, positron, gamma, and every other charged particle, was simulated. We considered the impact of energies, zenith angle (θ), primary particles, and thinning energy on the lateral distribution of charged particles generated within the EAS. A rapprochement of the lateral distribution of a charged particle as gamma particle with the experimental measurements from Yakutsk EAS array, which showed reasonably agreement for proton and iron at 10^{19} eV for slanted showers at $\theta=10^{\circ}$.

Keywords: *AIRES system; Extensive air showers; Lateral distribution; Thinning energy*

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1. INTRODUCTION

In order to learn more about their origin and acceleration processes, it is crucial to accurately understand main source of cosmic rays spectra and the composition of the mass in region surrounding a knee [1, 2]. Victor Hess discovered the cosmic rays CRs in 1912[3]. As soon as a main cosmic ray interacts atoms' nuclei reside within the air,, a cascade of electromagnetic radiation and ionized particles known as extensive air showers is created; these particles include X-rays, electrons, neutrons, muons, alpha particles, and many others [4]. The EAS was discovered in 193,0 by French scientist Pierre Victor Auger by increasing the amount of particles in the atmosphere [5]. The maximum of shower development is this level of shower growth [6,7]. Since most measurements of cosmic radiation on Earth are obtained based on EAS$_s$ observations, knowledge of a lateral distribution in EAS$_s$ is the amount of charged particles necessary [8]. Electromagnetic and hadronic showers combine to form the complex development of the EAS. Completing an in-depth numerical simulation of the EAS is crucial in order to deduce the main characteristics of the radiation that generate them [9]. The models are a crucial tool for challenging this scenario from an amount charged particles within ultra high energy, EAS may ever large, possibly surpassing 10^{10} eV. [10]. Prior to the age of extremely fast computers, Heiťlēr made an extremely basic as a prototype to a growth of each cascade electromagnetic [11]. Heiťlēr, Roșši, and Ğaișser created more advanced logical instruments at the time that took into account additional physical factors [12,13]. Cotzomi examined a few findings regarding the charged particle LDF with energies more than 10^{17} eV in 2008. [14]. Tapia (2013) estimated the nature of the EAS_s particles' chemicals in order to study age as a lateral structural parameter [15]. In 2018, Ivanov conducted research on the dispersion of cosmic ray showers' zenith angles observed via the Yakũtsk array and their use in equatorial coordinate analysis for arrival direction analysis. [16].

The present computations' outcomes have shown the impact of thinning energy via simulation of $particles_s$ and their distributed laterally in EAS through the AIRES code for elementary particle's as proton and iron primary in area of high energy, (10^{16} - 10^{19}) eV about various zenith angles (0°, 10°, 30° and 45°). The aim of this research is to study The impact of thinning energy on variations the particles of charged particles and their distributed laterally when EAS make it to earth's surface, such as positron, gamma, electron, charged particles initiated by the elementary particles for proton and iron primary at extremely high energies and comparing it with the Yakutsk EAS observatory's experimental data, which produced a great compatibility at the energy level of 10^{19} eV, [13, 14].

2. LATERAL DISTRIBUTION IN EAS

The charged particle's lateral dispersion in the Earth's Atmosphere System EAS is a necessary amount for measuring cosmic radiation on Earth and an essential amount of ground-based cosmic radiation monitoring, which is primarily obtained from the EAS measurable data [17]. The study of EAS can be carried out experiments on the ground's surface, below ground, and numerous mountains peaks by measuring certain values of Lateral distribution, which is the shower core distance-dependent density of charged particles started in EAS_s or, in another sense, the cascade's shower structure at different atmospheric depths [6]. An electromagnetic cascade's lateral distribution may be described by the NKG feature that is offered via the forum [18].

$$\rho_e(R) = \frac{N_e}{2*3.14*R_M^2} * C(s) * \left(\frac{R}{R_M}\right)^{(s-2)} * \left(\frac{R}{R_M} + 1\right)^{(s-4.5)} \ldots\ldots. (1)$$

Where is the density of particles at, r-distance from the shower core, isthe total quantity of electrons in the shower, =118 m is Molier radii, is the parameter of age shower, and is the element that normalizes 0.366 $s^2 * (2.07 - s)^{1.25}$ [19].

3. THINNING MODEL

The EAS cascade simulation on the secondary particles was utilized to apply the thinning procedure if the criteria was met [20].

$$E_o\, \varepsilon_{th} > \sum_{j=1}^{n} E_j \text{----------} (2)$$

Where E_j is the energy of secondary particle; E_o is a thinning level and energy of the fundamental particle meeting the relationship $\varepsilon_{th}= E_j/E_o$. Only secondary particle i can survive in this condition. The likelihood of surviving is:

$$P_i = E_i / \sum_{j=1}^{n} E_j \text{ ………... } (3)$$

In contrast, if the total number of secondary particles, n, exceeds a thinning energy threshold, i.e.:

$$E_o\, \varepsilon_{th} < \sum_{j=1}^{n} E_j \text{ ……….. } (4)$$

When the energy of secondary particles smaller than the thinning energy threshold, the likelihood is reported as follows:

$$P_i = E_i / E_o\, \varepsilon_{th} \text{…………… } (5)$$

4. RESULTS AND DISCUSSION

4.1 The lateral distribution is simulated by utilizing the AIRES$_s$ algorithm

AIRES$_s$, an abbreviation much expanded simulation of air showers itis described as an collection that of tools additionally scripts which manage all output-related data while simulating EAS particle cascades, which started when fundamental cosmic radiations interacted high energy levels in the atmosphere. AIRES offers an accurate simulation of Particle propagation in space-time inside a medium that includes the curvature, geomagnetic field, and atmosphere of Earth [21]. When there is a many particles present in the showers, a thinning algorithm (statistical sampling step) is utilized. As a result, Samples from statistics are never alter the mean values of the output measurements when using the localized thinning algorithms used in AIRES. Several particles are considered in AIRES system simulations, including: “gammas, Positrons, electrons, and every other charged particle”. A main proton, an iron nucleus, or one of the additional main specified in the AIRES guidance paper via an extremely high basic energy that might surpass 10^{21} eV might be the incident's fundamental particle in the EAS$_s$. [21]. As Figure 1 illustrates the simulated lateral density of numerous secondary particles based on how far the Earth's surface is from a shower axis using AIRES$_s$ system with a thinning energies (ϵ_{th}=10^{-4}, 10^{-5} , 10^{-6} and 10^{-7}) for proton and iron primary, In that order. The main energy' impact (10^{16}, 10^{17}, 10^{18} and 10^{19}eV) at various zenith angles (θ = 0, 1,0, 30, and 45) about a density of secondary particles of charge created accounted for in the EAS$_s$. Figure 1 illustrates the lateral density diminishes for many secondary particles the greater the distance from the axis of the shower. Ultimately, when the thinning energy is reduced, the statistical fluctuations in the lateral density of many secondary particles diminish.

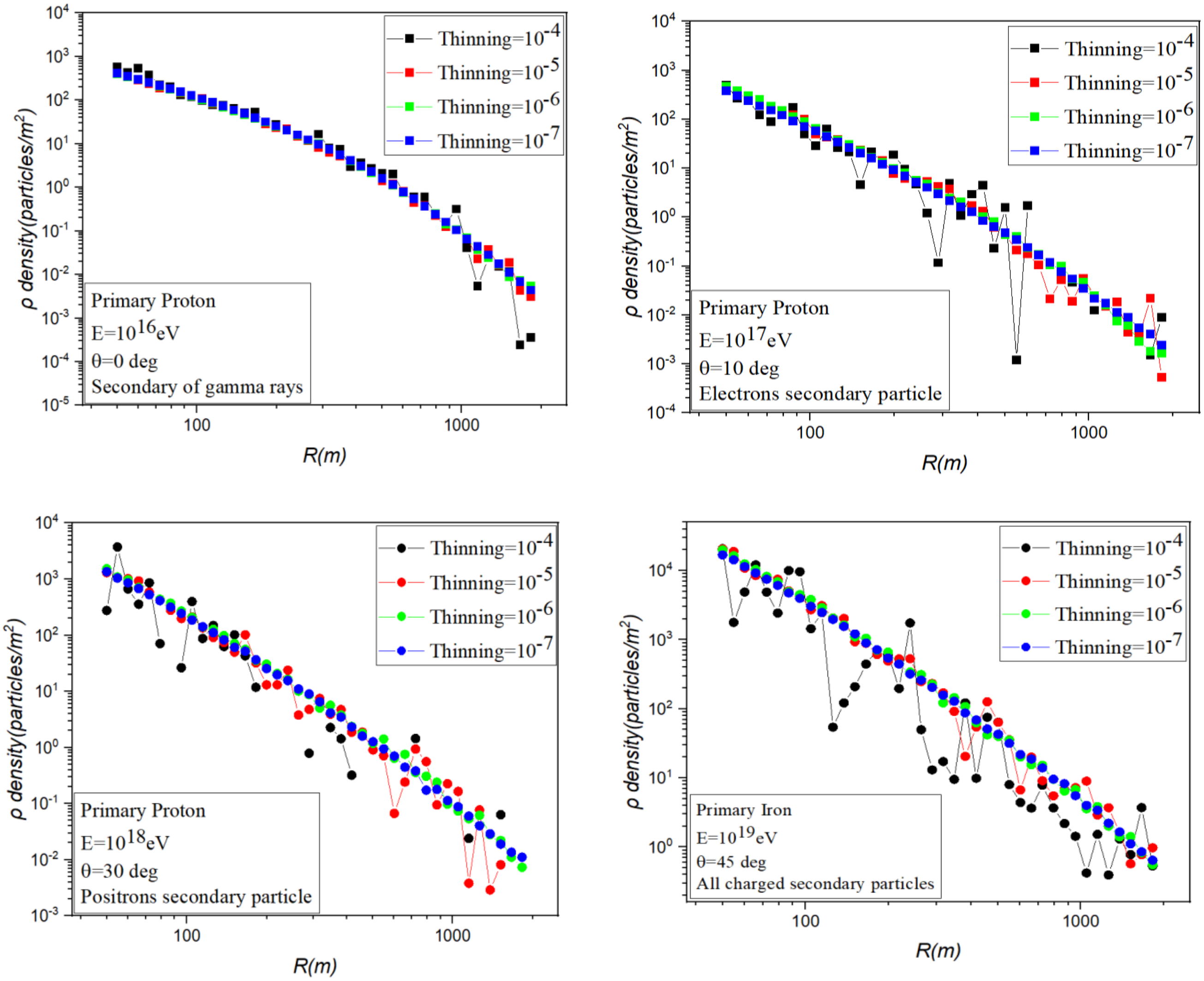

Figure 1 illustrates how the thinning energy affects the secondary particle densities of p and, Fe primary and energies, 1016, 1017, 1018, and 1019, eV , at various zenith angles (θ = 0, 1, 0, 30, and 45).

Figure 2, Compares the main proton's simulated lateral distribution with that of iron nuclei using the AIRES algorithm with energies of thinning ($\epsilon_{th}=10^{-4}$,$10^{-5,}10^{-6}$ and,10-7). Fig2, displayed a point of great importance that the lateral distribution of the secondary particles, including all charged particles and gamma, electron, and, positron that were launched by proton and iron primary at energies (10^{16}, 10^{17},10^{18} and 10^{19}eV) and various zenith angle (θ = 0°, 1’0°, 30° and 45°)’ are rather next to one another.

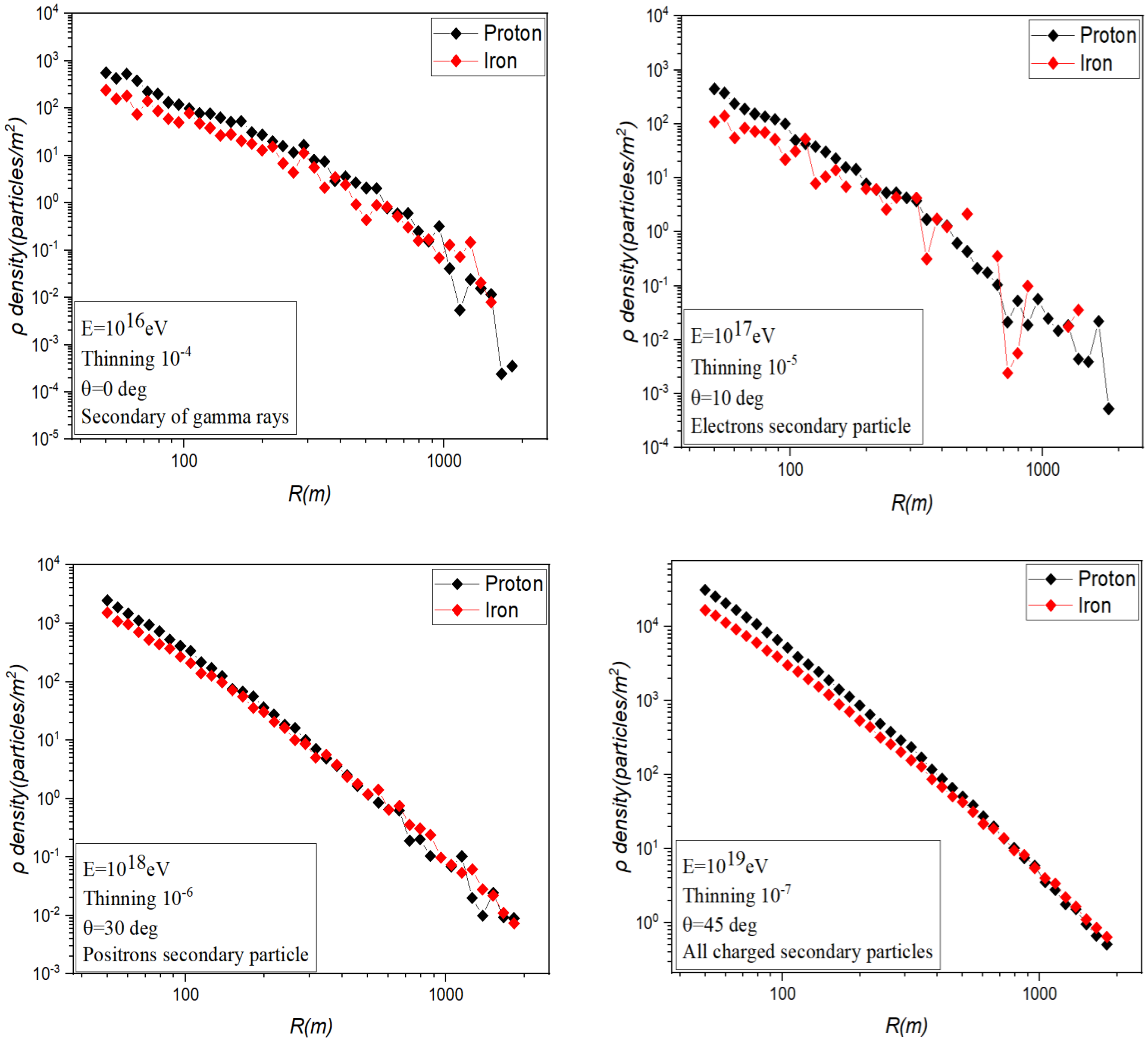

Fig 2. At various energies (1016, 1017, 1018, and 1019 eV) at the main level, the simulated lateral density of the proton (p) is compared to that of iron nuclei (Fe) for various zenith angle (θ = 0̊, 1’0̊, 30̊, and 45̊)’

4.2 Comparison with the experimental data obtained by Observatory Yakut's

Fig. 3. Shows the contrast between the current outcomes of lateral distribution that simulation carried out by AIRES ("solid lines") with experimental data obtained via Yakutsk Observatory ("triangle symbols") [21]. At energy level 10^{19}eV of the vertical showers EAS with energy of

thinning 10^{-7}, the good compatibility demonstrated in this form by the secondary particles launched by the proton and the elementary iron nuclei.

High-energy cosmic rays, which are a common occurrence in the field of astrophysics, a significant area of physics, are studied by the Yakutsk array EAS. The Yakutsk Observatory's (EAS) construction has two major objectives. The first is to look into elementary particle cascades in the atmosphere that are started by primary cosmic rays. Reconstructing the astrophysical properties of fundamental particle, like their "mass composition, spectrum of energy, intensity and place of origin," is a second objective [22]. Fig. 3 compares the current findings with the experimental information that the Yakutsk Observatory collected. [22]. A curves shown through the figure gave decent compatibility to the secondary gamma particles started by the proton and iron nuclei elementary at the energy level 1019eV for the inclined EAS showers with $\theta = 0^o$.

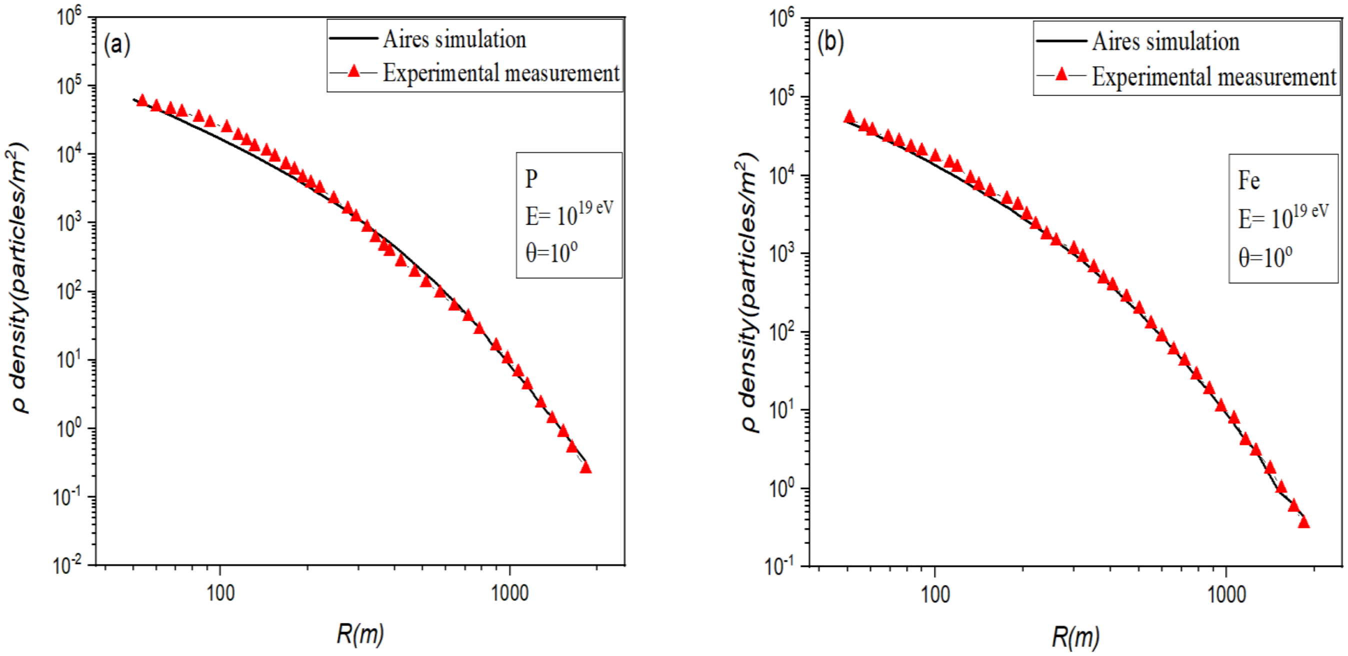

Fig.3 comparing the current outcomes of simulated lateral distribution via AIRESs algorithm to acquired experimental data via Observatory Yakut's [21,22] with θ = 0o at fixed primary energy 1019 eV for gamma secondary particles and with distinct fundamental particle: (a) proton and, (b) iron primary.

5. CONCLUSIONS

In a current study, the AIRESs system was utilized to model lateral distribution out of charged particles for two fundamental particles (iron and proton nuclei) at various ultrahigh energies of 10^{16}, 10^{17}, 10^{18}, and 10^{19} eV. The capacity to discriminate between the main particle of cosmic rays and their energy may be seen in simulations of the lateral structure of a charged particle. When the thinning energy decreases, the statistical fluctuations in the lateral distribution of various secondary particles also diminish. The establishment of a library of lateral structural samples for analysis of actual EASs things that have happened discovered and listed in the arrays of EASs is a significant aspect of the current study. The results from the AIRES system are corroborated by the experimental data from Yakutsk, demonstrating those AIRES algorithm offers an environment, ideal of researching cosmic rays with extreme energy. Thus charged, particles that reach The surface of the Earth has a variety of consequences on the environment, including weather and human health.

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