ENERGY SPECTRUM AND COMPOSITION OF PRIMARY COSMIC RAYS ABOVE 10^{18} eV

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Abstract

The spectrum of the extensive air showers (EAS) producted by protons in the depth of atmosphere, the returning knee of EAS at the primary energy $\sim 10^{17}$ eV, the generation of the big lot of EAS by protons at $E_0 > 10^{15}$eV, at $E_0 > 10^{17}$ eV and at 10^{19} point out the tenfold underestimation of the cosmic ray intensity at 10^{19} eV.

1 Introduction:

The report touches on the main astrophysical problem of the experimental investigations of the cosmic rays in the next decade and the many projects of the future installations of the area in hundreds and thousands km^2 were discussed on the last conferences. As a rule the estimations of energy of the primary cosmic rays are based on the extrapolation of some assumed processes of the generation and the development of the extensive air showers. However the accumulated experimental data exclude the knee (or a break) in the energy spectrum of the primary cosmic rays as one of two explanations of the knee in the spectrum of EAS by the number of the electrons in the shower.

The upper curve Fig. 1 includes the showers with the absorption lengh of electrons $\lambda \leq 90$ g/cm^2 in the shower, which observed with the equale frequency at defferent altitudes (720 and 960 g/cm^2). The lower curve includes EAS with $\lambda > 160$ g/cm^2, that generated by the primary nuclei ($S > 1.05$). One can see, that the spectra of EAS generated by the primary nuclei ($S > 1.05$) and by the primary protons but passing in the depth of the atmosphere ($S \leq 0.75$) have no knee.

The observation of the showers with $S < 1$ is connected with the reliable determination of the lateral distribution of the electrons at a distance $r < 80$ m from the shower axis. It means the necessity to know the density of the electrons at the distance from the axis $r < 10$ m. It is necessary in its turn to distribute of the shower detectors with the distance between the detectors < 10 m on all area, were one has to search the shower cores. The realization of this condition gives a possibility to observe the young EAS and to do not let pass the reverse knee in the EAS spectrum (J.Khristiansen et al., 1973; L.Vildanova et al., 1994). Fig. 1 shows, that the reverse knee is connected with the young showers, because such showers prevail in the shower flux above the EAS with the number of electrons above $2 \cdot 10^7$.

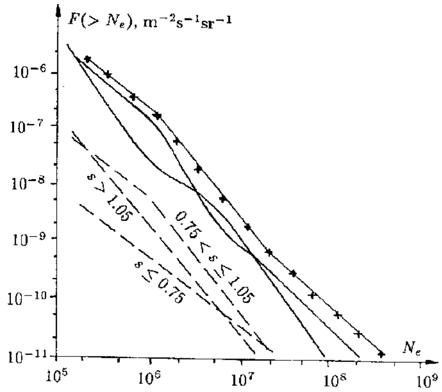

Figure 1: The dotted spectra with varions S for atmospheric depth 960 g/cm^2.The spectrum of the total number of EAS with the different number of the electrons in shown by the crosses (L.I.Vildanova, 1994).

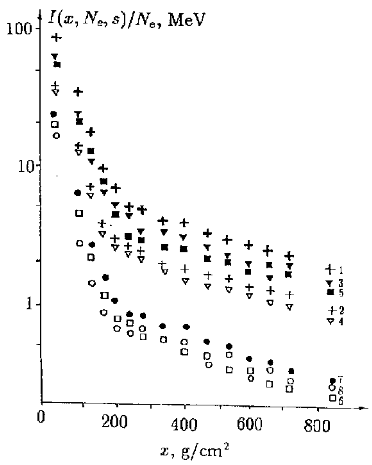

Figure 2: The absorption of the EAS cores in the lead for the different number of the N_e electrons in EAS $(1, 2 - N_e(1.8 - 3.2) \cdot 10^5, 3, 4 - N_e(1.8 - 3.2) \cdot 10^6, 5, 6 - N_e(3.2 - 5.6) \cdot 10^6, 7, 8 - N_e(5.6 - 7.5) \cdot 10^6)$ and for the different age parameter S (1,3,5,7 - $S < \bar{S}$ and 2,4,6,8 - $S > \bar{S}$).

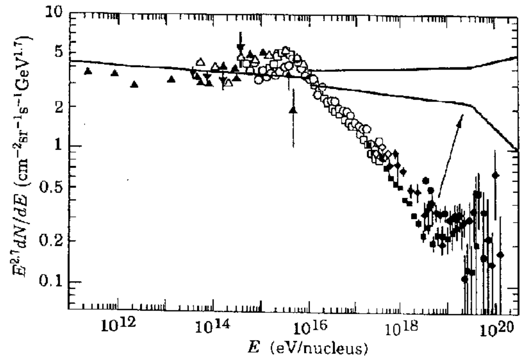

Figure 3: Primary spectrum of the cosmic rays (T.K.Gaisser, 1996), the straight line is the primary energy spectrum obtained in the satellite experimen ts (V.S.Murzin, 1979).

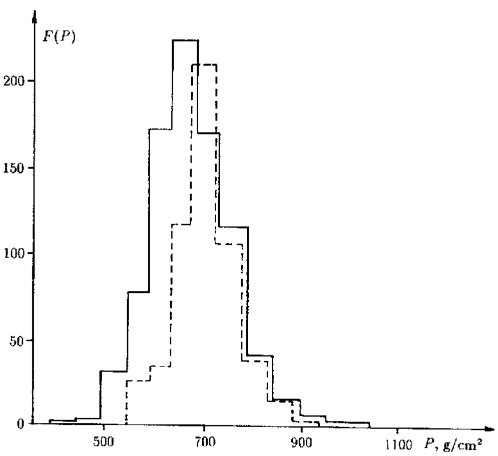

Figure 4: The distribution of altitudes of the maxim um dev elopmen t of EAS with primary energy $5 \cdot 10^{17}$ eV (solid line). The dustribution for EAS with energy $5 \cdot 10^{18}$ eV standardized to the distribution at $5 \cdot 10^{17}$ eV in proton part (M.N.Dy akonov, 1990).

The knee in the shower spectrum at $N_e \simeq 10^6$ is created with the primary protons, which generates the showers in the upper atmosphere. This showers change their own absorption from the length < 90 g·cm^{-2} up to > 160 g·cm^{-2}, it is from the absorption length of the primary protons up to the absorption of the hadron-electron cascade in the atmosphere as the EAS produced by the nuclei. Such change is observed in the interval of the showers with $10^6 - 10^7$ electrons (Fig. 1). It is impossible to suppose a substitution of the primary protons by the nuclei. It is more probable a change of the number and energy spectrum of the secondary hadrons in the inelastic nucleon collisions with the cross section more than $0.3\sigma_{inel}$ in interval of the electron number in the EAS $3 \cdot 10^6 < N_e < 6 \cdot 10^6$ as it can see in Fig. 2: at first the relative flux of an energy decreases four times in the showers which are generated close to upper border of the atmosphere ($S > \bar{S}$), then in the all showers. One can suppose a resonance in the multiparticle production of hadrons, in the result of which the multiplicity of the secondary hadrons increases in eight-twelve times. The secondary hadrons, the energy of which is comparable with the energy of the primary proton have to disappear in such proton-nucleon collisions. The fluctuations in the subsequent development of this hadron-electron cascades have to disappear also.

The very odd experimental data about the peculiarities of the hadron interactions give the variegated properties of the inelastic hadron interactions at energies $> 6 \cdot 10^3$ GeV in the centre mass sistem: the increase of transverse impulses (Romakhin, 1979), the distinct energy threshold of the new hadron inelastic collisions (Fig. 2). The excessively variety of the picture of the initial development of the hadron-electron cascades in atmosphere, was observed by means of X-ray emulsion chambers. One was observed the events of the hadron multiproduction without neutral pions ("Centauros") (C.M.G.Lattes, 1973) and the events with the predominant production of the electron-proton cascades with "halo" (I.P.Ivanenco, 1977). However the most part of the unusual events in the X-ray emulsion chambers is not determined by the primary energy and the height of the generation.

A harsh energy threshold for the new properties of the inelastic collisions, the prevailing formation of the high energetic electron-proton jet in the comparison with hadron-electron cascades, the complanar emissions (J.N.Capdevielle, 1995; A.Borisov, 1995) – all this new properties prompt the more serious changes of the inelastic collision at the energies 3–6 TeV in s.c.m. of colliding nucleons, the cause of which one can suppose in the existence a heavy hadron boson with mass 0.5–1 TeV/c^2 and the resonance multiproduction of the hadrons at the most energies. The possible mode of decay of H-boson in the gauge bosons has to explain the events with large transverse momenta, the coplanar emission(an alignment) and the predominance of the electron-photon "halo" events.

2 Energy Spectrum of Cosmic Rays above 10^{16} eV:

The supposition of the knee in the energy spectrum of the primary protons for the explanation of the EAS knee at the number of electrons$\sim 10^6$, the use of the standard models of the hadron inelastic collisions in the unknown energy region, the loss of the young EAS, the contribution of which increases with the rise of the primary energy of the showers and which are lost by the installations with the wide distributed detectors

(Fig. 1).

There are two indications on an underestimation of the energy and accordingly the intensity of the primary cosmic rays at the energies more than 10^{18} eV.

1. Many experiments with the delivered detectors of the electrons do not allow to observe the young showers and accordingly the return knee at the number of the electrons $N_e \simeq 2 \cdot 10^7$ (Fig.1). and no one is surprised, why the break of the energy spectrum of the primary protons do not exclude the determination of the attenuation length of protons in the atmosphere at energy $10^{17} - 10^{18}$ (M.V.Dyakonov, 1990). However the full loss of the showers from behind underestimation of the electron number is not possible at the number of electrons in EAS more than $3 \cdot 10^9$, at which the lot of the young showers arrives at 0.9 from the full flux of the EAS and one can see the return knee in the all experimental data (black points at $E > 10^{18}$ eV in Fig. 3).

2. If the distribution of the depths for the maximum development of the showers (M.V.Dyakonov, 1990) one makes agree the proton part of this distributions for the EAS with the primary energies $\bar{E} \simeq 5 \cdot 10^{17}$ eV and $\bar{E} \simeq 5 \cdot 10^{18}$ eV, then one has to reveal an absence of the EAS generated by the nuclei at energies $> 3 \cdot 10^{18}$ eV (Fig. 4). The nuclear disintegration of the nuclei in the collisions with the relic photons have to display at the energies more than $3 \cdot 10^{19}$ eV with cross-sextion for the disintegration significant larger than for the pion production by the collisions of the relic photons with the protons of cosmic rays.

If one takes into account of the underestimation of the primary energy for the EAS with the number of electrons $N_e > 10^6$ as a result of use of the standard model for the estimation of the primary energy of the showers and the loss of the young EAS in the measurements by the installations with the delivered detectors then the data of the satellite measrements of the primary spectrum of the cosmic rays can be extraplated up to 10^{20} eV (Fig. 3).

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