CALCULATION OF INTENSITY OF HIGH ENERGY MUON GROUPS OBSERVED DEEP UNDERGROUND

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ABSTRACT

The intensity of narrow muon groups observed in Kolar Gold Field (KGF) at the depth of 3375 m.w.e. has been calculated in terms of quark-gluon strings model for high energy hadron - air nuclei interactions by the method of direct modeling of nuclear cascade in the air and muon propagation in the ground for normal primary cosmic ray composition. The calculated intensity has been found to be $\sim 10^4$ times less than one observed experimentally.

1. Introduction. The observation of narrow muon groups at the depth of 3375 m.w.e. in KGF was reported in /1/. The radius of group was ~ 0.5 m for majority of muons and the number of muons in the group was $\gg 8$. In the work /2/ we have made an attempt to calculate the intensity of these groups in terms of simple model of hadron interactions. It was shown that in principle the narrow high energy muon groups (the thresold energy $\simeq 1.5$ TeV) can appear as a result of ordinary fluctuations. But quantitatively we must be careful in this estimation. At first, the simple model of hadron interactions does not take into account all possible fluctuations in these interactions. At the second, the Coulomb scattering of muons in the ground also was't taken into account. At last, it was considered that the group of muons had passed through the apparatus if in the limits of upper and lower plans of the apparatus there were the sections of the cylindre with radius 0.5 m and the axis, coinci-

dent with the EAS axis. In the present work we utilized the development of quark gluon strings model of interactions of hadrons with nuclei of the air /5/. Fluctuations in hadrons interactions, the muon scattering in the ground and their deflection in the Earth magnetic field have been taken into account also. The direct modeling of muon trajectories permits one to take into consideration the geometry factor of the apparatus correctly.

2. Model of interaction and the calculation method. The quark-gluon strings model describes the large number of experimental data about multiple production of hadrons in nucleon-nucleon interactions /3,4/. In the present paper we have used the development of this model in application to hadron-air nucleus interactions, developed in /5/. The mean lengths for nucleon, pion and kaons interactions were taken in accordance with /5/. The inelasticity coefficient for nucleons and incident pions and kaons were taken in accordance with inclusive spectra, calculated in /5/.

The ratio of kaon to total number of charged particle was 12%. The decays of pions and kaons were considered in the usual way. The transverse momenta distribution was taken in the form $f(p_\perp)dp_\perp \sim \exp(-B X_\perp)\, dp_\perp^2$, where $B = 2.85$; 7.15 and 6.9 for nucleons, pions and kaons correspondingly. For nucleons in the exponent $P_\perp$ was taken instead of $X_\perp$. The interactions of primary nucleus were taken into account in accordance with superposition hypothesys. The secondary particles energy spectrum was taken in accordance with /5/. The chemical composition and energy spectrum of primary cosmic radiation was taken as in /6/.

It was taken, that magnetic field of the Earth has the meridian direction component $H = 0.4$ G /7/.

The method of calculation consists of direct modeling of all processes. At first for some thresholds of the energy of the primary particles in accordance with the primary spectrum the real energy of primary particle was simulated and then its atomic weight according to accepted chemical composition was sampled. Then in the limit of 30° to the vertical the zenith angle of primary particle and its azimuth and coordinates in the upper plan of the array were simulated. Then the points of interactions, the inelasticity coefficients, multiplicity and another parameters of all secondary particles were simulated. The acts of interaction of the hadrons were simulated in such a way that the conservation laws of energy, electric charge and transverse momentum and strangeness were conserved. The Coulomb scattering of muon in the ground was considered in accordance with the known Fermi formula which takes into account the correlation of the angle and the deflection in the fixed plane. The method of the calculation of the scattering was taken as in /8/. The energy losses for bremstrachlung and photonuclear interaction with ground nuclei were simulated with fluctuations taken into account. Ionization losses and losses for the e^+e^- pair creation were taken as continuous. We take into account not only Coulomb scattering of muon but also its scattering as a result of inelastic interactions with nuclei in the ground. The cross sections of muon energy losses were taken in accordance with /10-14/.

<u>3. The result of calculation and conclusions</u>. The tresholds of primary energy were chosen equal to $3.16 \cdot 10^{15}$, 10^{16} eV and so on. For each value of energy thresholds the simulated number of events in accordance with the primary spectrum /6/ were 500, 150, 70, 20 and 50 events correspondingly. The number of narrow muon groups, as it was determined above was 0, 0, 0, 0, 2 for threshold energies $3.16 \cdot 10^{15}$, 10^{16}, $3{,}16 \cdot 10^{16}$, 10^{17}, $3{,}16 \cdot 10^{17}$ eV correspondingly. Comparing these data with the intensity of primary cosmic radiation and the intensity of groups /1/ it can be shown that the intensity of the calculated groups is approximately $\sim 10^4$ times less than experimental one. /1/ This conclusion implies the not trivial appearance of the narrow multiple muon groups.

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