Supervision of double extensive air showers

V Yakovlev

L P N Lebedev Physical Institute RAS, Leninsky pr. 53, Moscow, 119991 Russia

E-mail: yakovlev32@mail.ru

Abstract. Double extensive air showers were investigated at Tien-Shan high mountain scientific station of P.N. Lebedev Institute by means of two various installations. One installation registered electron-photon air shower component, another – Vavilov-Cherenkov radiation. On both installations the double showers divided by a time interval of ~100 nanoseconds have been registered. In the present work frequency of occurrence of such showers in each of installations is analysed, and is shown that at supervision of vertical showers (zenith angle $\Theta$ <60°) these frequencies coincide.

1. Introduction

Double extensive air showers (D-EAS) were for the first time registered in 1984 by Japan physicists M. Toshida, Y. Toyoda, T. Maeda [1]. In this work the showers delayed for the period of an order of 100 nanoseconds relatively the basic shower, have been registered simultaneously in several scintillator detectors. Later D-EAS have been registered also by other authors [2-3], however only authors [1] have come to conclusion that the delayed showers are formed by heavy particles with mass in some tens GeV and life time $\sim (5 \times 10^7 - 2 \times 10^6)$ s. Other authors abstained from such estimations.

2. Experiment-1

In 2005 by means of four-channel digital oscillograph TDS-2014 at Tien-Shan station also there have been begun researches of D-EAS [4-5]. The detector represented FEU-49 on which photocathode was located scintillator, in the thickness of 5 cm and diameter of 15 cm. The operating system selected six-fold coincidence between central and five peripheral detectors located on a circle in radius of ~65 m. During ~5000 hours installation has registered 2117 events with number of particles above $10^7$, from them in 98 events the showers which are "late" for a time from 40 to 600 nanosecond with density of shower particles $\rho > 283$ m$^{-2}$ have been registered. In 14 cases "late" signals have been registered in two and more detectors, in six cases – in three and more detectors, and in three cases – in four detectors. The example of registration of a late shower in 4 detectors is resulted in figure 1.

If to assume that the late shower grows out of casual coincidence to a small local shower, or to any other casual coincidence the probability of registration such "D-EAS" in one detector is equal: $98/2117 = 0.046(\pm0.00568)$. The expected number such casual "D-EAS", registered simultaneously in two detectors, will make $(0.0462 \times 2117 = 4.36$, in comparison with 14 registered (4.4 $\sigma$). The expected number of the events registered by three detectors simultaneously, makes 0.21 in comparison with 6 observed.
At last, the expected number of the events registered simultaneously by four detectors, is equal 0.0097 in comparison with 3 registered (30 \( \sigma \)). In papers [4-5] it is shown that the mass of the heavy particle forming the late shower, should be \( \sim 10^5 \) GeV. Such estimation has been received on the basis of two reliably measured parameters: (1) speed of a late shower (using experimentally measured average time of a delay between two showers, equal 109±6 nanosecond, and length of a way of a shower in atmosphere), and from here the lorents-factor \( \gamma \sim 15 \), and (2) energy \( E \) of a late shower (using number of particles \( N \sim 10^7 \) in a late shower). The estimated weight of a particle has appeared too big, in this connection 2 hypotheses about the nature of such late showers have been stated. According to the first, such showers can be formed by set of low energetic hadrons born, for example, at liberation a quark-gluon plasma. The second hypothesis assumes that the late shower is formed by usual hadrons, moving with a velocity of light, and the advancing shower is formed by tachyon, born in interaction of a primary particle, and having the speed exceeding a velocity of light. Losing energy, tachyon accelerates, and a shower formed by it, advances a shower formed by usual hadrons. According to T. Alväger work [6] charged tachyon quickly loses almost all energy on Vavilov-Cherenkov radiation. From Tamm and Frank’s classical work [7] follows that losses on this radiation on way unit make

\[
dE/ds = -4\pi^2Z^2e^2\left(\gamma - c^2/\gamma^2n^2\right)\nu\,d\nu/c^2.
\]

From here it is visible that with growth of tachyon speed, rate of losses of its energy increases, and it leads to occurrence of an advancing shower. In this case it is natural to assume that the shower formed by charged tachyon, will not contain muons. Detection such muon free advancing showers would be an evidence tachyon origins of advancing showers.

3. Experiment-2

In other experiment in which double showers at Tien-Shan were studied, showers were registered by means of the photo multiplier placed in focus of a parabolic mirror with diameter of 150 cm [8]. Under various zenith angles flashes of radiation of Vavilov-Cherenkov were registered. Some sessions of such supervision have been spent up to angles 80° in which double showers (and even one threefold), with a delay between showers in 100 and more nanoseconds have been registered. Examples of such showers are shown on figures 2-3.
The analysis of frequency of occurrence D-EAS in both installations has shown that at registration of vertical showers ($\Theta < 60^\circ$) these frequencies coincide (figure 4 where by circles the data on Vavilov-Cherenkov radiation is shown, and an asterisk – on scintillator array is seen).

At increase in a zenith angles the share of double showers quickly enough grows that can be connected with increase of this share with growth of energy of interaction. However the statistics of such events while is small. Originally in this experiment there were no the detectors registering shower accompany. In 2008 under the offer of the author of article the installation registering radiation of Vavilov-Cherenkov, has been added by two scintillator detectors of the area 1 m$^2$ everyone. Scintillators were located at distance of 10 m from a mirror and have been inclined at an angle 40° to horizon. There are begun joint measurements. In part of events, at registration under angles from above 70° Vavilov-Cherenkov radiation and the charged particles are registered simultaneously. Because of a supervision was deep in the atmosphere ($\geq 1991$ g/cm$^2$) it is possible to consider with high degree of probability that these charged particles are muons.
4. Discussion
Nova days, the theory applying for an exhaustive explanation of all phenomena in the physic of elementary particles, the theory of strings [9-10] is. In particular, tachyon it is quite entered in the boson theory of strings. This theory assumes that boson strings have space-temporary dimension equal 26. However, this variant of the theory doesn't describe fermions. The theories describing simultaneously as bosons, so and fermions, are called as theories of superstrings. Such theories now are five. Application of a principle of duality allows establish that these theories can be coordinated with each other. They are various limiting cases of the uniform fundamental theory which have received the name of the M-theory. All five theories have the dimensions equal 10, and exclude existence tachyon out of vacuum. For this reason we have tried to explain nature D-EAS from other positions. When we "beat out" one quark or a gluon, he tries to take off, but can't make it as pulls behind itself "string" which contains a bag of virtual particles. This "string" stretches between the observable taken off object and the projectile. After string rupture both its parts receive identical, but an opposite on a sign impulse. Thus there is also the sling effect arise. Possibly, it also is at the bottom of why both showers from pair D-EAS fly with slightly various speeds.ootnotes should be avoided whenever possible. If required they should be used only for brief notes that do not fit conveniently into the text. Please read appendix A ‘Inserting footnotes with Microsoft Word’ for guidelines on working with Word’s footnote facility.

It is necessary to underline that D-EAS weren't observed at energies E <10^{16} eV. At such energies the phenomenon alignment of the most vigorous particles produced wasn't observed also at interaction of primary particles of cosmic radiation. This phenomenon was revealed in the big experiment with the X-ray chambers, executed by collaboration "Pamir" [11], and also in some other experiments [12-13]. It is possible to assume with high degree of reliability that two phenomenon, found out at identical energies, have the general nature [14]. Studying of their nature is one of priorities of research of a role hadron components in formation and development D-EAS and the aligned events at ultrahigh energies.

References
[1] Yoshida M, Toyoda Y and Maeda T 1984 *J. Phys. Soc. Jpn.* 53 1983
[2] Vedeneev O, Nechin Yu et al 1986 *VANIT Ser: Technics of physical experiment* 3 29  47
[3] Ambrosio M, Aramo C, Colesanti L and Erlykin A 1997 *Nuclear Phys. B Proc. Suppl.* 52B 234
[4] Yakovlev V, Vildanova M, Vildanov N 2007 *Letters in JETP* 85 111
[5] Yakovlev V, Vildanova M et al 2010 *Physics of Atomic Nuclei* 73 785
[6] Alväger T, Kreisler M 1968 *Phys. Rev.* 171 1357
[7] Tamm I, Frank I 1937 *Dokl. Akad. Nauk SSSR* 14 109
[8] Bejsembaev R, Vavilov Yu et al 2011 *Izv. Russian Academy of Sciences, ser.phys.* 75 № 3 383
[9] Kaku M 1999 *Introduction to Superstrings* (Verlag: Springer)
[10] Greene B 2003 *The elegant Universe* (New York: NORTON)
[11] Pamir collaboration 1986 *Proc. of 4-th ISVHECRI*, Beijin
[12] Xue L et al 1999 *Proc. of 26-th ICRC*, Salt Lake City 1 127
[13] Apanasenko A et al 1997 *Proc. of 17-th ICRC*, Plovdiv 7 220