Anomalously delayed particles in extensive air shower core according to results of the new plant

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Abstract

Investigation of the particles delayed for some hundreds of microseconds found in the extensive air showers (EAS) which belong to the above-the-knee region of primary cosmic ray spectrum is continuing at Tien-Shan mountain station of P.N. Lebedev Physical Institute at the altitude of 3340 m. To check the reliability of our previous results and to study the attenuation of anomalous EAS component in the atmosphere a new registration point at the height $1700m$ a.s.l. has been created which consists of a neutron monitor and a detector of EAS electrons and γ-quanta. The data obtained confirm the fact of the existence of peculiar events in the common flow of registered showers which have the anomalously prolonged time distributions both of the EAS hadron and e/γ -component.

1. Introduction

The fact that prevailing majority of elementary particles constituting an extensive air shower (EAS) have relativistic energies and moving with speed of light, intersect the shower installation of usual sizes during the time intervals, which belong to nanosecond range, is nowadays generally accepted. Accordingly, all installations which have been used so far for the investigation of nuclear interaction of extra high energy cosmic rays (ionization calorimeters, scintillation detectors, Cherenkov and Geiger counters) have a registration time with characteristic duration of the order of several microseconds. However, the experiments, being carried out at Tien-Shan mountain station recent years, give reasons for a principal change of our views on the passage of EAS particles through the atmosphere.

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2. Methods

A modified NM64 type neutron supermonitor is operating as a part of the installation "Hadron" at Tien-Shan mountain station for EAS studies. [1]. Measurements of number of delayed secondary neutrons born by EAS hadrons were held on this monitor during 1995- 1999. It has been found that in the core region of EAS with power $Ne \geq 10^5$ particles it is observed that neutron component delays for $300 - 500mcs$ relatively to the common shower front. [2]

The further analysis with the use of the data from shower installation of the Tien-Shan station has shown that practically all the events having the value of neutron multiplicity (total number of neutrons registered by a monitor unit) above 1000 are accompanied by the EAS with number of particles $Ne \geq 10^6$ [3].

To specify more exactly the properties of the discovered effect an investigation of the electron-photon component of the EAS accompanying the anomalous neutron events was made. For this purpose our neutron monitor was supplemented with a detector of charged particles based on the SI5G type proportional counters capable to measure intensities of the shower electrons in the time range $300 - 3500mcs$ relatively to the moment of EAS front passage. The use of SI5G counters is due to their relatively low sensitivity for the γ-quanta and neutrons.

The events in the monitor accompanied by EAS were involved in the analysis. The results of the experiment - time distributions of the charges particles intensity - qualitatively repeat analogous distributions for neutrons. The impulse intensity reaches $10^5 c^{-}1$ in the events with $M > 1000$ which is 50 times higher than the background level; its maximum is delayed for $500 - 1000mcs$ relatively to the shower front.

To verify reliability of our earlier results and to study attenuation of the anomalously delayed EAS component in the atmosphere a new shower particles detection point is created at the Intermediate station which is placed at the height $1700ma.s.l.$ and $14km$ apart from the Tien-Shan mountain station. This detection point includes a neutron monitor and detectors of EAS charged particles.

The neutron monitor NM-01 consists of two identical units $2 \times 1m^2$ in size each. Each unit consists of the following parts:

1. Six proportional boron counters of the SNM-8 type having the sizes $3.5 \times 100cm^2$ which permit to register the thermal neutrons thanks to reaction $B^{10}(n,a)Li^7$ .The counters are placed inside a $2.5cm$ thick paraffin cylinders designed to slow down the evaporation neutrons.

2. A $5cm$ thick lead generator. Interacting with lead nuclei of it, high- energy hadrons generate evaporation neutrons having the energies up to $10MeV$.

3. A30 cm thick paraffin reflector screening the monitor's interior from the slow neutrons coming from outside and provides slowing neutrons born in

the lead down to thermal energies.

Pulse intensities from each neutron counter are measured separately in 85 subsequent time intervals having duration $60mcs$.

For registration of EAS electron-photon component a SI5G counters based detector, overlapping the space above the monitor, is used. The total sensitive area of counters is $6m^2$.

Zero point of time scale in each event coincides with the moment of the passage of relativistic shower particles through the monitor and proportional counters.

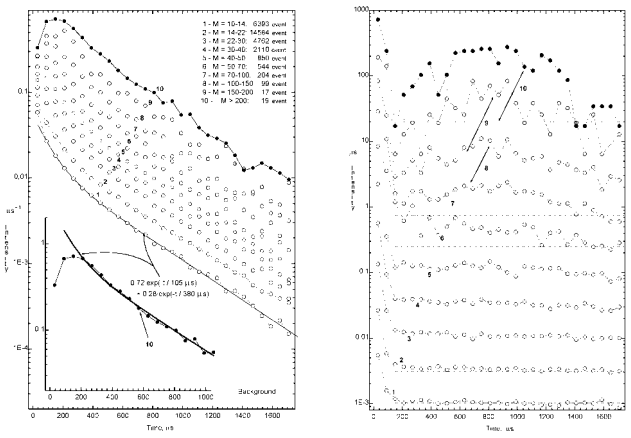
Below are presented results obtained in the measurements held in the winter season 2001-2002 at the new detection point of the Intermediate station.

3. Results

Time distributions of the neutron signal intensities being registered from the neutron monitor of the intermediate station in various diapasons of the total neutron multiplicity M are shown in Fig.1a. Since the neutron multiplicity M is connected with he energy deposit of the hadronic component in the monitor [4] and latter, in its turn - with the size and the core distance of the accompanying EAS, the selection of the neutron events accordingly to the value of M is equivalent to the selection of the EAS which belong to various ranges of the shower size N_e whose axes travel in the nearest vicinity (of the order of $2-3m$) of the monitor.

As it seen form Fig.1a, in the events with a low neutron multiplicity values the time dependence of the neutron intensity may be well described by a sum of two exponents correspondingly to the diffusion process of the thermal neutrons in two layers of light substance inside the monitor: in the inner paraffin cylinders surrounding each neutron counter particularly (the exponent with shorter life time value) and in the common outer reflector which covers a monitor unit from the outside (the exponent with shorter life time value). In the events which belong to the range of higher multiplicities (approximately $M > 70-100$) a significant difference is observed between the experimental neutron intensity distributions those predicted by the simple diffusion model; the maximum of experimental intensity distribution being displaced from the moment of EAS front passage to $100-200mcs$. It is the same phenomenon which was observed earlier at Tien-Shan station and was the reason for the hypothesis about the existence of anomalously delayed particles in EAS

Fig.1b demonstrates the time distributions of signals from the EAS electromagnetic component detectors, which are observed in the neutron events of different ranges of multiplicities.



a b

Fig. 1.

4. Conclusions

We see that in the low multiplicity events any signal from detectors SI5G is absent everywhere except the short excess in the moment of EAS from passage through the installation. In the events having high M values the shape of the time distributions is qualitatively different: together with the short intensity outburst around zero time moment a broad secondary maximum is seen delayed for some hundreds of microseconds. The pulse intensity during the secondary maximum remains an order of the amplitude higher than the corresponding background level. the same picture has been observed earlier both at Tien-Shan station and in experiments carried out by the other groups.

Therefore, the data obtained at the Intermediate station, do confirm existence of the anomalously delayed time distribution effect.

5. References

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