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Modernized Tian-Shan installation for the study of anomalous delayed E.A.S. component.

A. P. Chubenko[1], V. A. Antonova[2], S. V. Kryukov[2], M. M. Kokobaev[3], R.A. Mukhamedshin[4], N. M. Nesterova[5], T. Kh. Sadykov[5], A. L. Shepetov[1], L. A. Vildanova[3], and G. B. Zhdanov[1]

[1]P.N. Lebedev Physical Institute of RAS, Leninsky pr. 53, Moscow 117924, Russia
[2]Ionosphere Institute, Kamenskoye plato, Almaty 480068, Kazakhstan
[3]Tian-Shan Mountain Cosmic Ray Station Mitina st. 3, Almaty 480020, Kazakhstan
[4]Institute for Nuclear Research of RAS, pr. 60-letiya Oktyabrya 7a, Moscow 117312, Russia
[5]Almaty 480068, Kazakhstan

Abstract Tian-Shan cosmic ray installation including a NM64 type neutron supermonitor was essentially upgraded in 2000 year. New monitor's configuration permits to study the effect of anomalous delayed signals from E.A.S. particles, which was observed earlier, not only for neutron counters but also for electron and γ-ray detectors giving an opportunity to trace the delayed signal intensity in dependence on the absorber's depth. Preliminary results obtained during 2300 observation hours are presented.

1. Introduction.

An unusual phenomenon is studying now in experiments being carried out at Tian-Shan mountain cosmic ray installation. One of the basic features of this installation is the use of a standard NM64 type neutron supermonitor (Simpson et al., 1953) for the detection of EAS's hadronic component. The phenomenon being under investigation reveals itself through the generation of a large amount (some thousands) of neutrons inside the monitor in some rare events (Chubenko et al., 1993). Amazing peculiarity of these events is the absence of typical for the NM64 type monitor exponential neutron intensity decrease with life time τ~650 mcs. The decrease of neutron intensity is absent in at least 3.5 milliseconds, i.e. during 4–5 relaxation periods after the EAS passage. Another characteristic feature of anomalous events is that they are generated only in the nearest vicinity (some meters) to the cores of EAS with sufficiently large sizes ($N_e>10^6$, i.e. after the knee of primary spectrum) (Antonova et al., 1997).

Our further investigations have shown that the anomalous neutron events are followed by the signals from the detectors of γ- and electron component of EAS surrounding the monitor (Antonova et al., 1999). The temporal intensity distributions of electrons and γ-quanta are similar to those registered by neutron detectors, prevailing up to 10–20 times above the background until 2000–3000 mcs after the passage of EAS front. If these signals are really connected with shower particles then their existence obviously contradicts to the common model of EAS development.

Three hypotheses have been supposed in last years to explain the observed effect:

1. All delayed signals are caused by the slow background neutrons with thermal energies being generated by intensive hadron flows of EAS cores outside of monitor and subsequently diffusing in its nearest environment during some hundreds of microseconds. Gamma-quanta originating in the captures of these neutrons could be accounting in such a case for the delayed signals from electron and γ-detectors.
2. There exists in the core region of EAS with $N_e>10^6$ some unusual EAS component consisting of the particles delayed for hundreds of mcs relative to the main shower front.
3. Intensive particle flows being present in the cores of EAS of mentioned sizes are able to induce a relatively long process of chained nuclear disintegrations inside the heavy monitor's absorber resulting in production of evaporation neutrons and γ–quanta during some hundreds of mcs.

The data obtained from various groups of electron and γ-detectors placed in the vicinity of neutron monitor units permits to exclude the first of the mentioned hypotheses as fully unlikely (Shepetov, 2000). To make a resolute choose between the remaining two it seems to be necessary to distinct if the delayed particles are coming into our detectors mostly through the upper, bottom or lateral surface of the monitor, or they are originating inside of it.

2. Multi-layer neutron monitor.

An additional, fourth, unit of Tian-Shan neutron monitor was created in summer of 2000. New unit is placed immediately under the one of the existing (unit "D" in Fig.1).

Correspondence to: A.L. Shepetov
shepetov @sci.lebedev.ru

The multi-layer detectors of electrons and γ-radiation are put on the both units too. Such a layout of experimental equipment makes it possible to trace the distribution of delayed signals of both hadronic and electromagnetic origin over the depth of absorber and to obtain in this way the answer on the question formulated above.

The following groups of radiation detectors are installed in monitor units “B” and “D”:

1. The standard for a NM64 monitor SNM15 type neutron counters having the size $\varnothing$15x185 cm^2 and the characteristic relaxation time of neutron signals intensity about 240 mcs.
2. Additional “internal” neutron counters of SNM18 type placed inside the unit “B” (so as inside the “A” and “C” units). The size of these counters being only $\varnothing$3x32 cm^2 the neutron intensity relaxation time (defined by the size of surrounding polyethylene moderator) is decreased down to 30–40 mcs providing much better temporal resolution in these channels.

   Both the SNM15 and the “internal” SNM18 counters register the thermal neutrons being born by cosmic ray hadrons inside the monitor lead absorber and slowing down the thermal energies in monitor’s inner and outer polyethylene layers.
3. The “external” SNM18 neutron counters surrounded by it’s own paraffin moderator which are laid on the upper surface of the all four monitor units. These detectors are destined to measure the fluxes of low energy neutrons which are supposed to be present in the EAS core region.
4. The boxes of electron and gamma detector situating above all monitor units. Each detector module contains 20 SI5G type ionization counters with the size $\varnothing$60x560 mm^2. Electromagnetic radiation detectors placed on the “B” and “D” monitor units consist of two layers permitting to estimate the energy of registered γ-quanta according to their attenuation in the walls of detector boxes.

Output pulses from the all mentioned detectors are connected to a multi-channel time scanning system which measures the signal intensities in a set (50–85) of short (30–150 mcs) subsequent time intervals after the moment of EAS passage (which is defined according to the trigger signal provided by Tian-Shan station’s scintillation shower system). The temporal resolution of the all used detectors is strictly controlled during the measurements and maintained at the level not worse then 1–2 mcs in neutron channels and 6–8 mcs in the channels of electromagnetic radiation detectors.

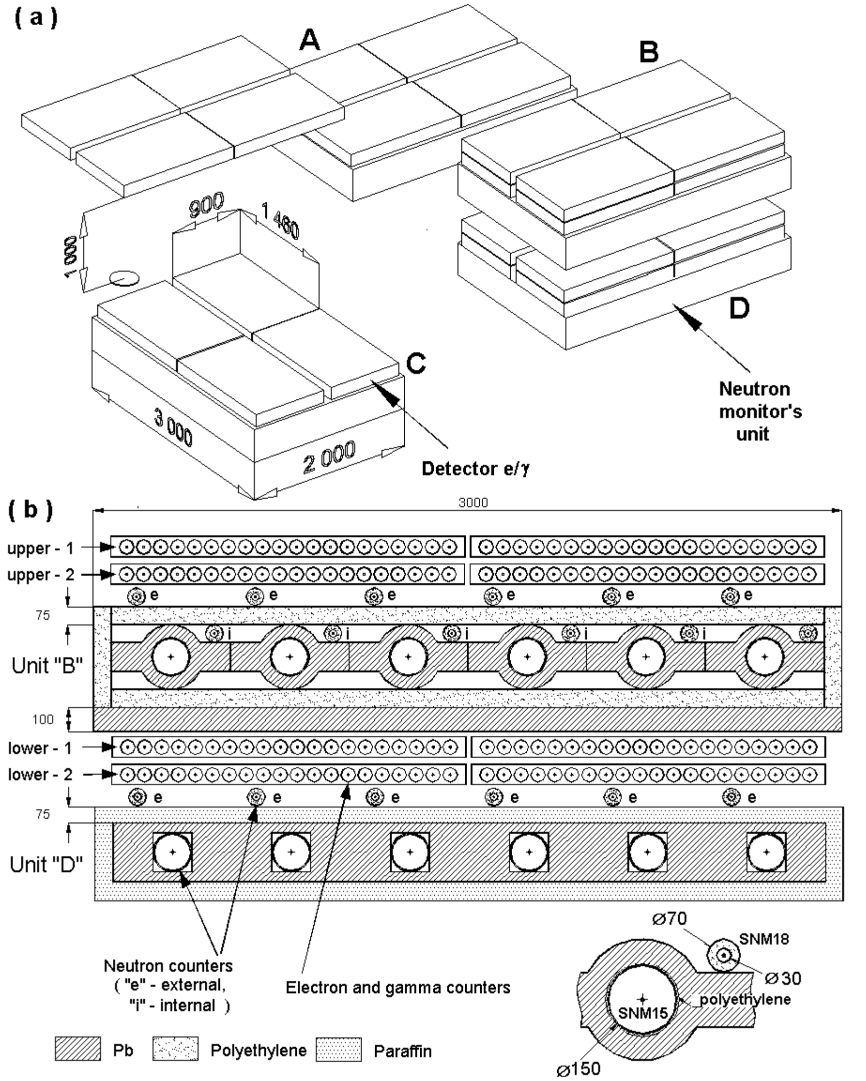

Fig. 1. General layout of the four neutron monitor’s units (a) and the cross-section of units “B” and “D” (b).

3. Preliminary results.

Neutron multiplicities. Fig.2 presents the comparison of the neutron multiplicity spectra measured before and after the discussed modernisation. (Under the neutron multiplicity M in our experiment is meant an amount of pulses obtained from the 6 SNM15 type neutron counters of a monitor unit during 3400 mcs after the trigger pulse). It is seen, that both spectra have a similar shape, decreasing nearly as $M^{-3.5}$ with the growth of neutron number. The “new” spectrum, however, has the absolute intensity 30– 40 % higher than the “old” one. This feature is connected with the registration of an additional flux of neutrons being originated inside the lead absorber placed now under the bottom of "B" unit. Such an explanation is confirmed too by the fact that the intensity of background pulses from the "B" unit has increased up to 10% after our modernisation was completed.

It should be noted that the additional neutron flux through the bottom surface of the "B" unit must be determined mostly by the fast, not thermalized, neutrons during the first tens of microseconds after each event's beginning. Afterwards, when all the outside neutrons have only the thermal energies, they are effectively absorbed and scattered by the outer polyethylene reflector of the monitor and can not reach it's interior.

Temporal distributions of neutron intensity. The averaged over the EAS events temporal intensity distributions registered by various groups of neutron counters installed inside the "B" and "D" monitor units are shown in Fig.3. The following conclusions may be done from this figure:

1. The existence of sufficient difference between the theoretical exponential function (which corresponds to the simple diffusion of low-energy neutrons inside the monitor's moderator layers) and the shape of the real temporal distributions of neutron intensity in high multiplicity events (M>700–1000) is confirmed by the new data.
2. According to the relation between the numbers of pulses obtained from the external and internal SNM18 detectors, the neutron fluxes going outside of neutron monitor unit are approximately to 10 times less intensive than the fluxes inside of it. The life time of "outside" neutrons is appreciably shorter, being nearly 300 mcs in comparison with 650 mcs of "inside" ones. Consequently, the main part of the delayed signals being registered by the internal neutron detectors in our experiment is connected with the neutrons born inside the monitor but not with the "outside" neutrons originating in the atmosphere or monitor's neighborhood.
3. There exists a drastic change in the shape of temporal intensity distributions registered by SNM15 neutron counters of the "D" monitor unit which takes place in high multiplicity events. The probable cause of this effect now seems to be related with some distortions of the true neutron intensities due to the features of registering equipment. This problem is under our investigation just now.

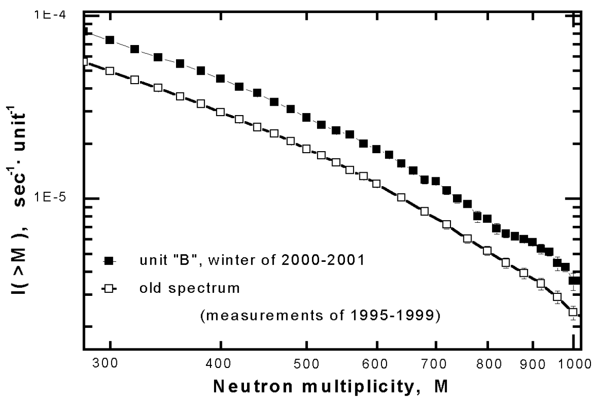

Fig. 2. Integral neutron multiplicity spectra: solid points – unit "B", present measurements; open points – spectrum observed before modernisation (published in (Aushev et al., 1997)).

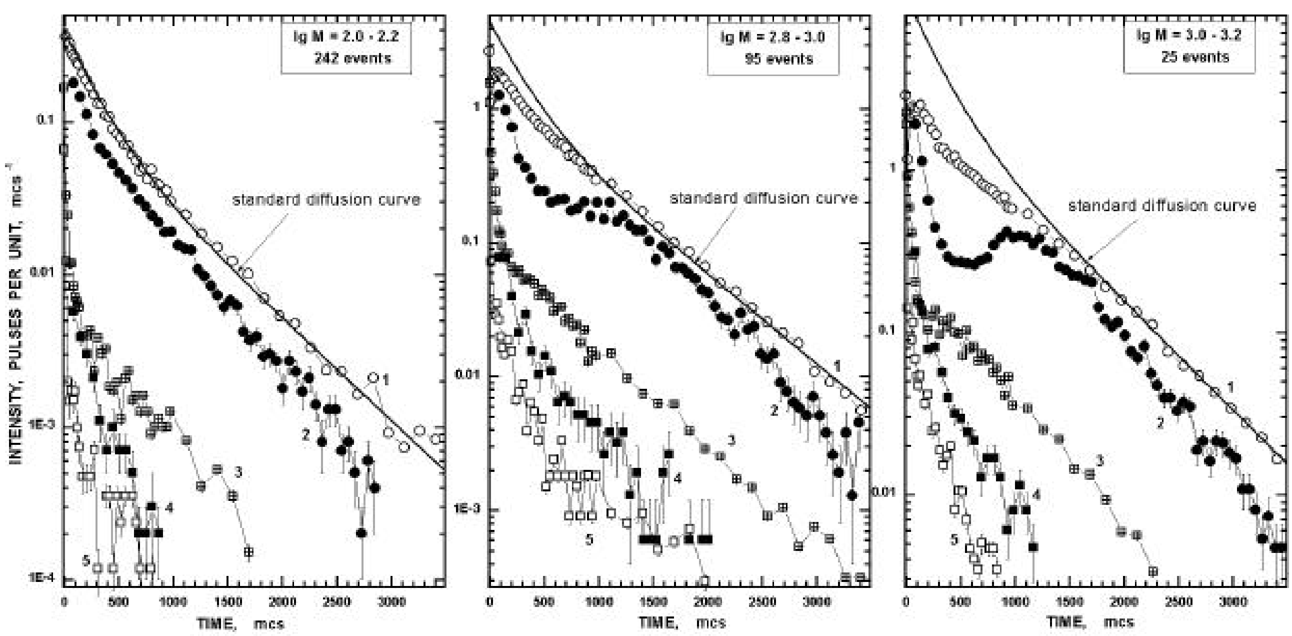

Fig. 3. Averaged temporal intensity distributions of pulses registered from the neutron detectors of "B" and "D" monitor units. From top to bottom: 1 – SNM15 neutron counters of the "B" monitor unit, 2 – SNM15 of unit "D", 3 – internal SNM18 counters of unit "B", 4 and 5 – external SNM18 of units "D" and "B" correspondingly.

Temporal distributions of the electromagnetic radiation. Distributions of the signals from the electron and γ–quanta detectors registered in high multiplicity events are shown in Fig.4. (To avoid overlapping, the curves are normalised to various powers of ten).

As it is seen, both the "upper" and the "lower" detectors register a noticeable flux of particles which has a characteristic intensity maximum at the times 400–500 mcs after the event's beginning, decreasing afterwards nearly exponentially with relaxation time of about 700–800 mcs.

According to the intensity of coincidence signals between the two layers of the upper and lower detectors one may conclude now that the total flux of particles being registered by the detectors of electromagnetic radiation in our experiment consists mostly of the γ-quanta, the share of which exceeds 80 %, but has also a little mixture of electrons.

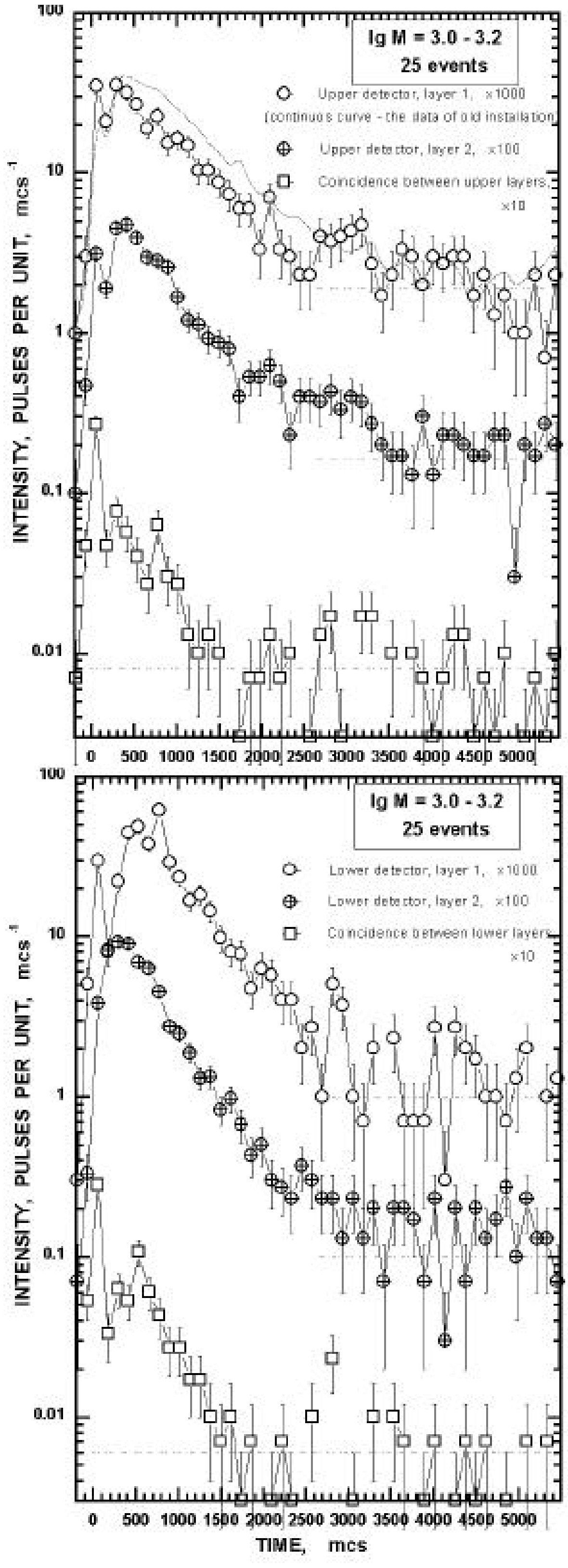

Fig. 4. Averaged temporal intensity distributions of the signals from the e/γ -detectors installed in the vicinity of "B" and "D" monitor units. Dotted lines correspond to the background intensity for each detector group.

4. Conclusion.

The investigation of anomalous "prolonged" neutron events is continuing at Tian-Shan neutron monitor. Special modernisation of the standard monitor's configuration permits to explore some new features of the considered phenomenon

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