УДК.537.53

Monitoring of the neutron flux during thunderstorms at Tien-shan

B.A.Ryabov [1]***,Wai Myo Thu*** [2]

[1]P.N. Lebedev Physical Institute of RAS, Moscow 119991, Russia
[2]Moscow Institute of Physics and Technology (State University), Moscow 117303, Russia

Introduction

At present, evidence of neutron flux enhancement in lightning discharges of the atmosphere has been obtained in a number of experiments at sea level [1], high elevations [2 - 5], and even in near space [6]. These experiments led to observations of a neutron flux excess over the cosmic background during thunderstorm activity. In this work the possibility to identify the neutron flux enhancement in the 10 s monitoring mode in the period of thunderstorm activity is demonstrated [7 - 8].

The experimental complex "Thunderstorm" is designed for investigation of the high-energy radiations which accompany the lightning development in thunderclouds. It is situated at the scientific cosmic-ray station in the mountains of Northern Tien-Shan, 3340 m above sea level, just at an altitude which corresponds to the local altitude of thunderclouds movement. Detectors used for investigation of thunderstorm neutron flux enhancements were located in two points: the Station itself – Station point, and the Hill point. The Hill point is situated 160 m above the common level of the Station; the distance between Hill point and the Station point is about 1 km. At the Station point we used the neutron monitor (NM) as well as three low-energy ^{3}He neutron detectors and two ^{3}He detectors were used at the Hill point.

At present time, "Thunderstorm" complex comprises the following facilities:

-an EAS registering system,

-the system of NaI scintillation detectors for registration of the gamma- and X-ray emission in atmosphere,

-the multi-layer ionization detectors of energetic charged particles,

-the neutron super monitor for registration of the high-energy hadronic component of cosmic rays,

-a set of the detectors of low-energy (thermal) neutron background,

-two independent radio systems,

-and electrostatic detectors of the local electric field and its high frequency component.

Instrumentation

Detectors used for investigation of thunderstorm neutron flux enhancements were located in two points: the Station itself – *Station point*, and the *Hill point*. The Hill point is situated 160 m above the common level of the Station; the distance between Hill point and the Station point is about 1 km. At the Station point we used the neutron monitor (NM) as well as three low-energy ^{3}He neutron detectors and two ^{3}He detectors were used at the Hill point. An external detector is placed outdoors inside plywood housing at the distance 15 m from other detectors. The internal detector is placed in the same room with the NM. The underfloor detector is placed under the wooden (4 cm) floor of the same room and is additionally shielded from the top by a 9 cm thick layer of rubber.

The low-energy neutron detectors are the 1.2 × 0.84 m^2 boxes of 2 mm thick aluminum each containing six 1 m long, 3 cm in diameter proportional ^{3}He neutron counters. The pressure in the counter tube is 2 atm. These counters are not surrounded by any moderator material, and thus they are mostly sensitive to the low energy range ($\lesssim$ 1 keV) neutrons. The placement of three ^{3}He detectors situated at the Station point (*external*, *internal* and *underfloor*) is shown in Fig. 2.

Two neutron detectors were installed at the Hill point. The *Hill-free* detector is of the same type as those at the Station point. The *Hill- shielded* detector is surrounded with moderator polyethylene tubes of 0.5 cm wall thickness increasing the detector efficiency. Efficiencies of detectors situated at the Station and Hill points are presented in Fig. 3.

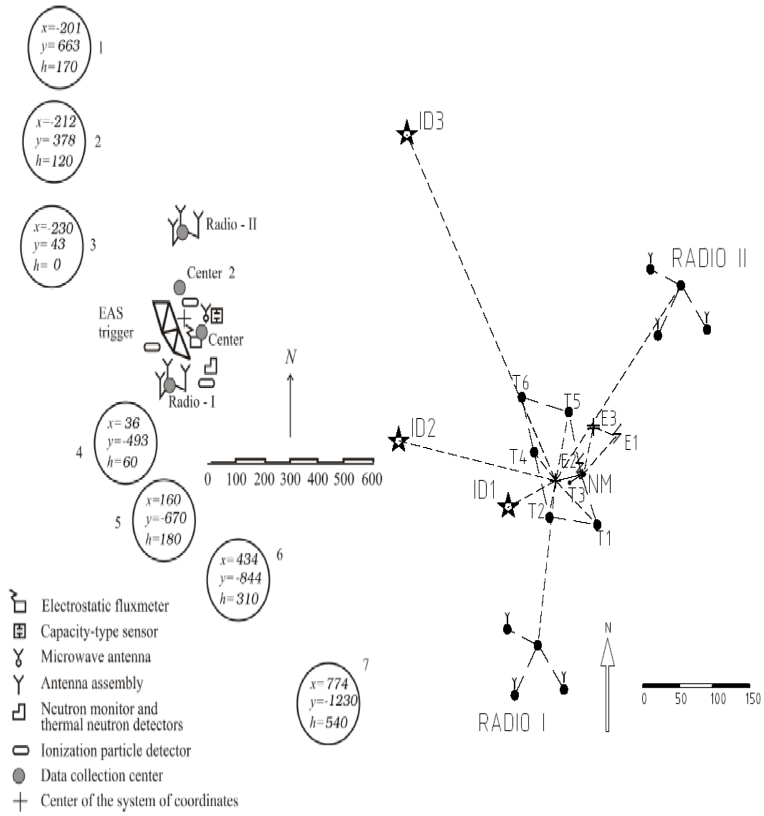

Fig. 1. The experimental complex "Thunderstorm"

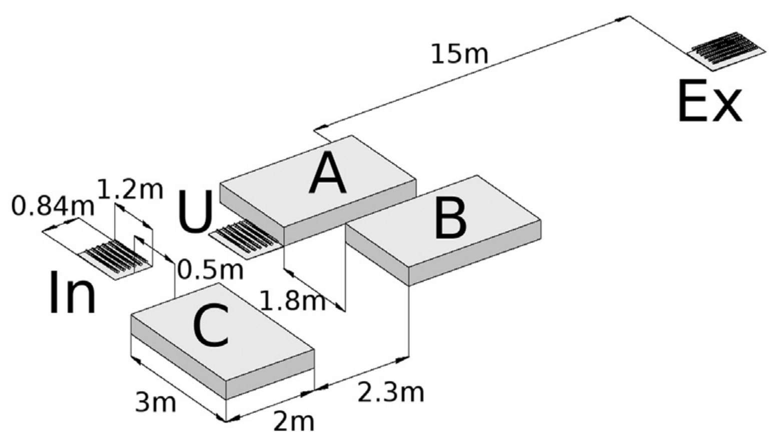

Fig. 2. Arrangement of ^{3}He detectors and NM at the Station point. Ex, In and U — the external, the internal and the underfloor detectors correspondingly. A, B, C — three standard 6- counter units of the NM64 type supermonitor.

Simultaneously, the signals from all neutron detectors are connected to another set of digital counters which continuously measure the number of pulses with a raw time resolution of 10 s, without binding to any external trigger. In this monitoring mode we also have used two field- mill type detectors to measure the electric field and two NaI scintillation detectors to register the gamma-ray flux. One electric field detector and one NaI detector were placed at the Station point, another pair of these detectors — at the Hill point.

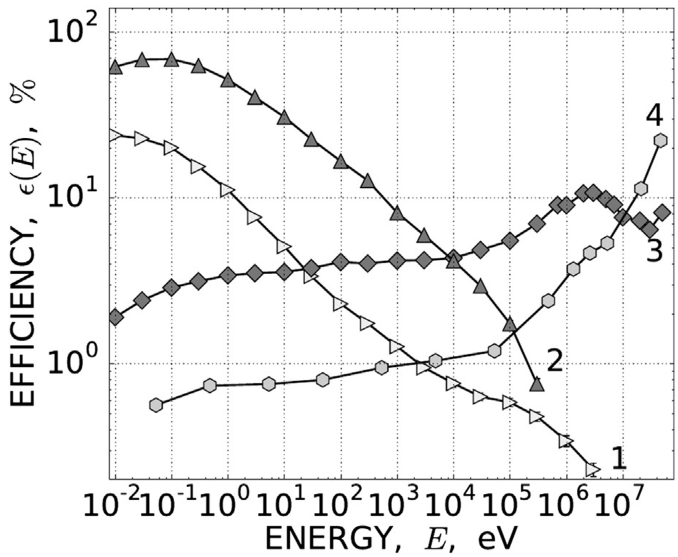

Fig. 3. Efficiencies of neutron detectors calculated with the use of GEANT4 toolkit (Geant4 Collaboration, 2003). ^{3}He counters: 1 — without moderator (external, internal and Hill-free detectors), 2 — with polyethylene moderator (Hill-shielded detector); and 3 — underfloor detector; while evaluating it's efficiency the placement (4 cm wooden floor and the 9 cm ribbon layer above the detector) was taken into account. 4 — the neutrons monitor.

Observational results

Thunderstorm neutron enhancement observations were fulfilled in 2013 on the Tien-Shan Station.

The main result of the monitoring is that the neutron enhancements are observed in the periods of thunderstorm activity only. It is illustrated in Figs. 4–6. In Fig. 4 the 10 s monitoring data obtained during July 13 and July 21, 2013 are presented. It is determined by low energy cosmic ray. The distributions of neutron flux intensity are normalized to the number of detector pulse signals which was accepted during the standard 10 s monitoring time. As it is clearly seen from the figure, the neutron background flux at all the detectors is very stable during the whole day. For the long time period of 10 s monitoring mode observations, the intensity of neutron burst cannot be seen clearly in some detectors Fig(4).

In more details the monitoring data obtained during the storms are presented at Fig. 5. The noticeable neutron enhancements were observed within the storm period when the intensive electric field variations and gamma- ray emission are present. The prominent neutron count rate enhancements are seen on July, 13 and 21 during the thunderstorm which lasted for 60 min in this figure. Two enhancements are presented in Fig. 6 with a time scale zoomed in relative to that of Fig. 5. Panels are the same as in Fig. 4. Zero points mark the middle of a 10-s interval containing the intensive signal. It is seen that the duration of every separate enhancement is not longer that 10 s. This statement is right for all registered neutron count rate enhancements.

Conclusions

In this work the time structure of neutron flux enhancements are observed in the periods of thunderstorm activity.

We can see that the intensity of neutron burst presented in a very short time and lightning could be diagnosed by its neutron emission in 10 s monitoring. The 10 s monitoring mode results can only indicate the specific time which can examine the actual intensity of neutron flux enhancement in short-time triggering mode.

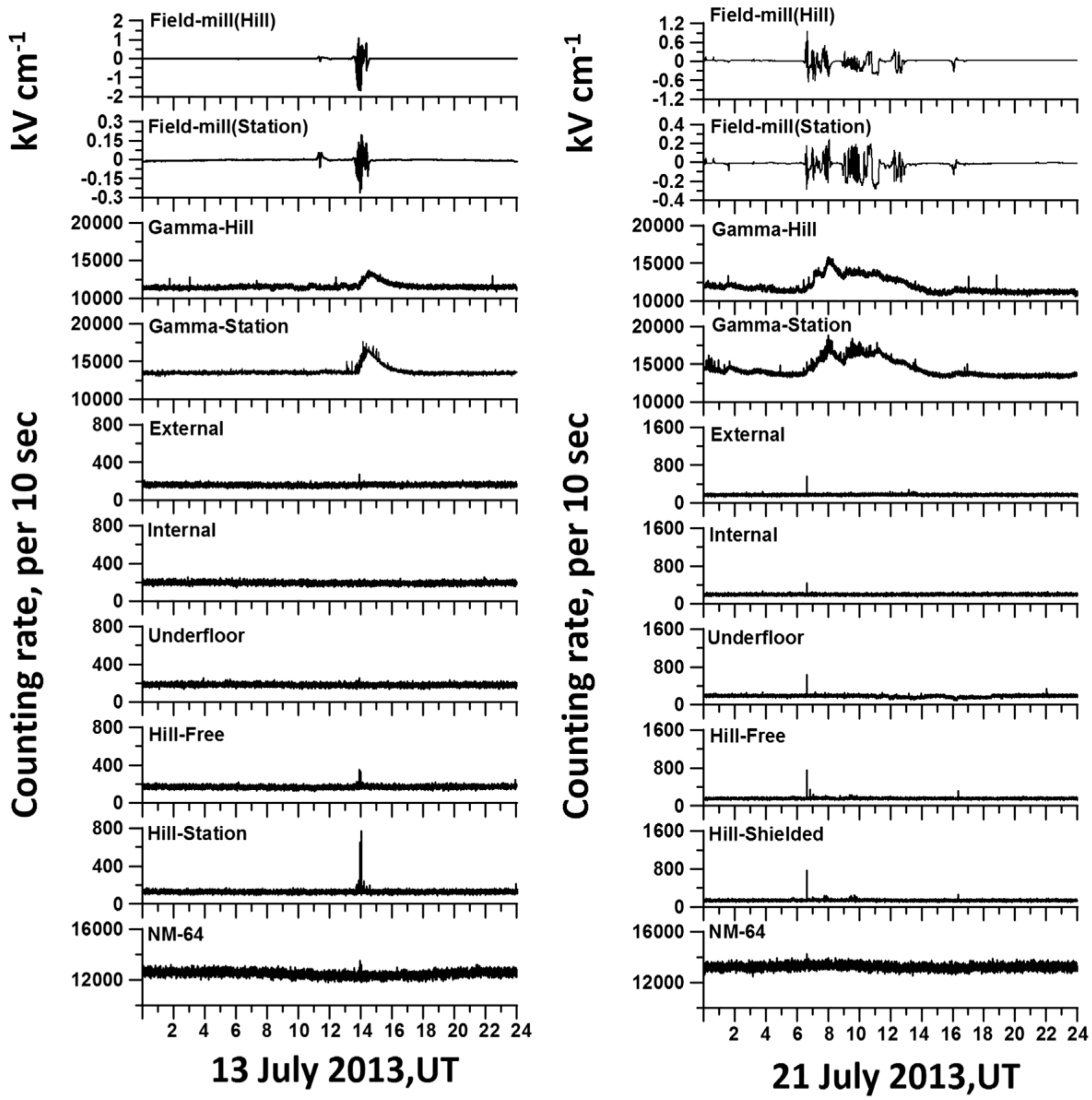

Fig. 4. 10s monitoring mode results during July 13 and 21, 2013. Detectors are marked in the panels.

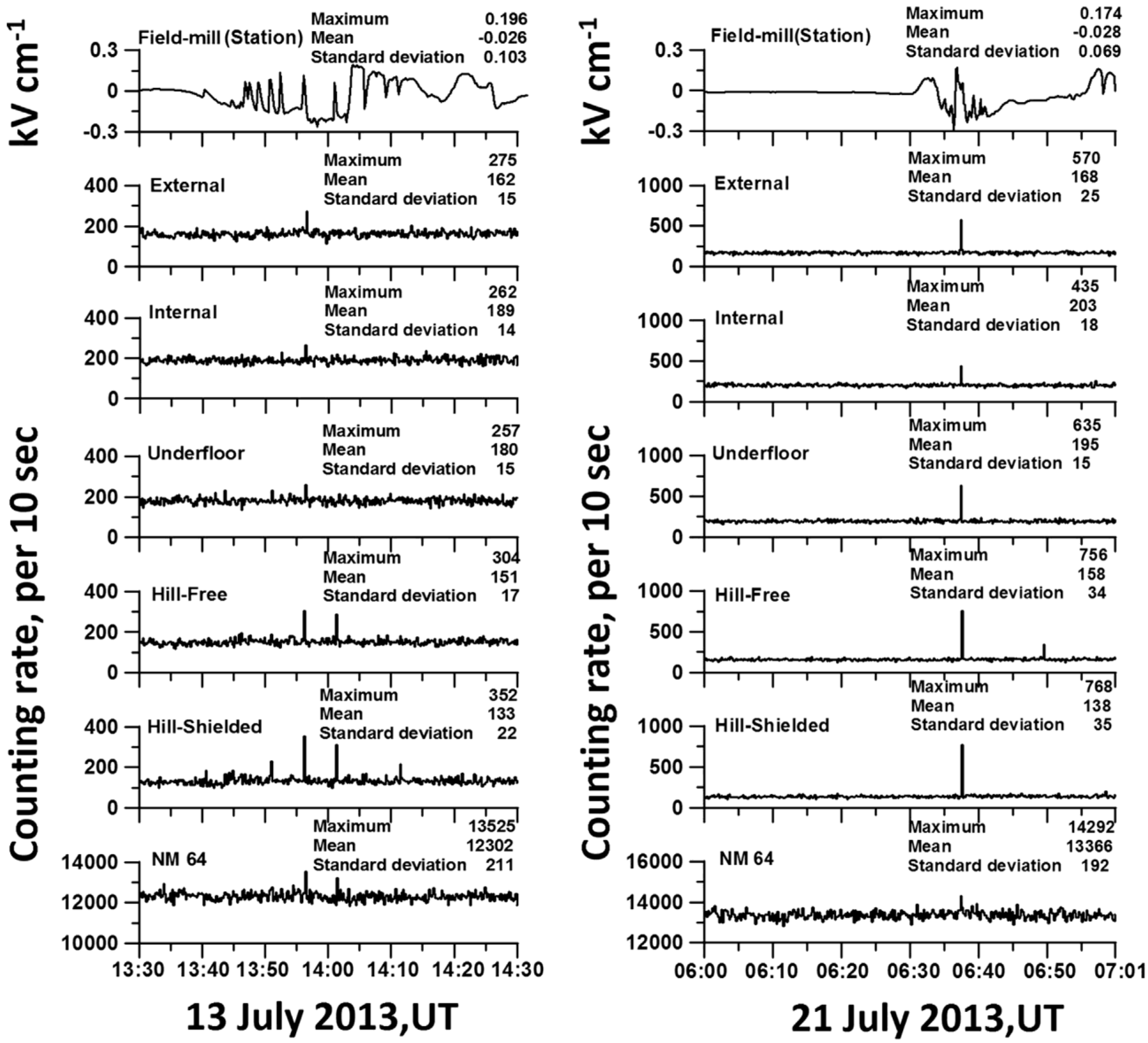

Fig. 5. Monitoring mode results for (60) minutes during thunderstorms on July 13 and 21, 2013. Upper panel — electric field as measured by the field-mill detector placed at the Station point and lower panels — count rates in different neutron detectors marked in the panels

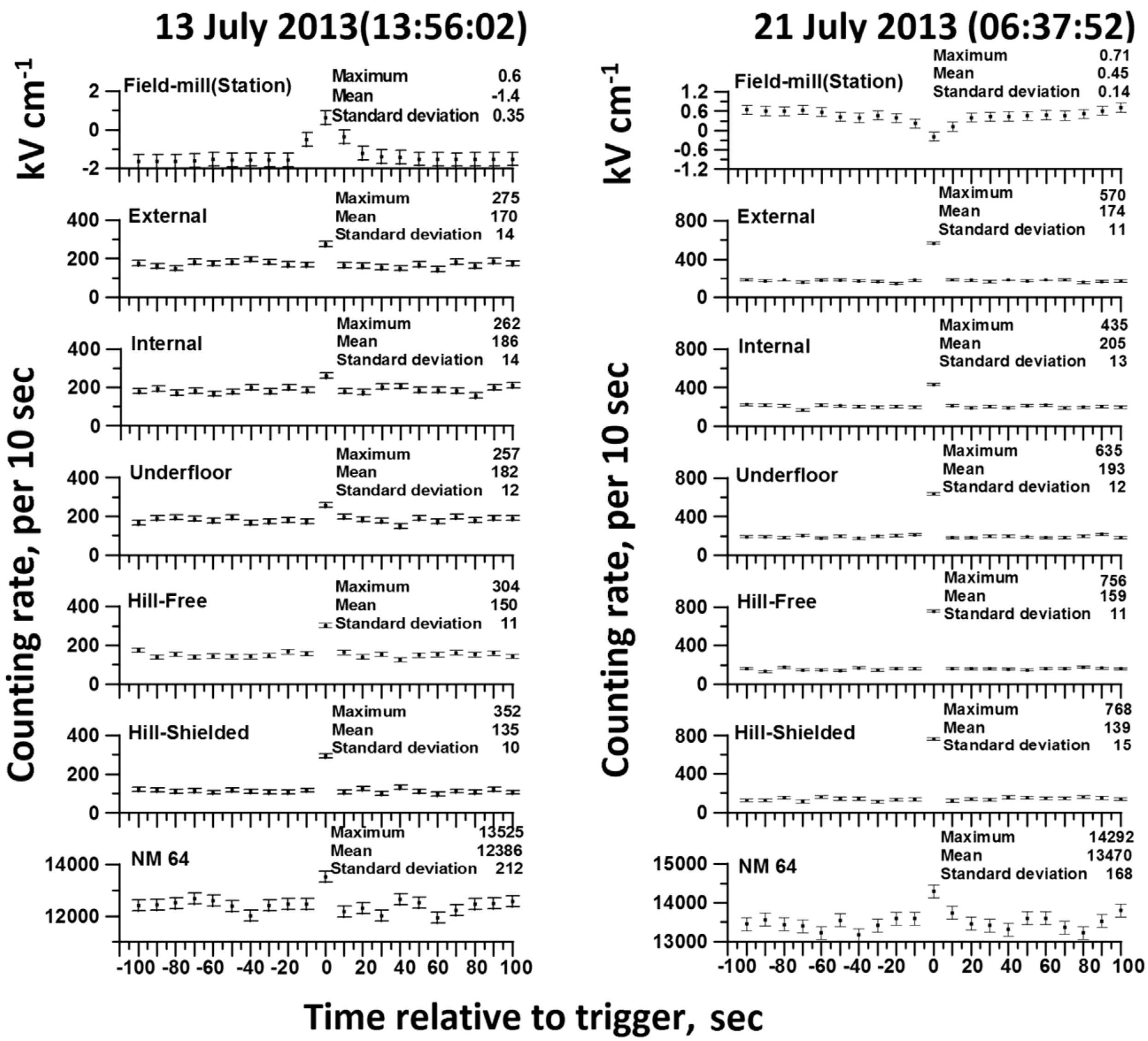

Fig. 6. Same distributions of neutron flux stretched around the time of intensive signal.

References

1. Martin I. M. and Alves M. A., J. Geophys. Res. 115, A00E11 (2010)
2. Shah G. N., Razdan H., Bhat G.L., and Ali Q.M., Nature (London), 313, 773 (1985)
3. Gurevich A.V., Antonova V. P., Chubenko A. P. et al.,Phys. Rev. Lett. 108, 125001 (2012)
4. Chilingarian A., Bostanjyan N., and Vanyan L., Phys. Rev.D 85, 085017 (2012).
5. Tsuchiya H., Hibino K., Kawata K.,et al., Phys. Rev. D 85, 092006 (2012).
6. Bratolyubova-Tsulukidze L. S, Grachev E. A, et al., Adv. Space Res. 34, 1815 (2004).
7. Gurevich A.V., Antonova V.P, Chubenko A.P, et al., Atmospheric Research, 164–165, 339 (2015).
8. Gurevich A.V., Antonova V.P, Chubenko A.P, et al., Physics review D. 94, 023003 (2016)