Proceedings of ICRC 2001: 205 © Copernicus Gesellschaft 2001

ICRC 2001

Registration of signals coming 500–1000 microseconds after the main EAS front

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Abstract. We have made an attempt to register in Lodz air shower array signals up to 1.2 miliseconds after the main EAS pulse. Special electronic arrangement has been set up for registrations of delayed signals from Geiger-Müller counters. Statistically significant excess of number of signals from muon detector has been found in 500–1000 microsecond period after the main front in about 30% EAS with muon content (muon energy $\geq$ 0.5 GeV) larger than $1.5 \cdot 10^5$.
Photomultiplier signals from two 0.5 m^2 scintillation detectors separated by about 30 m were registered in the digital oscilloscope triggered by the EAS. We have found EAS events when 2–3 signals from each scintillator were observed simultaneously from both detectors in 500–1000 microsecond period after the EAS (when expected muon background is 0.05).
Lodz air shower array setup, results and up to date interpretation of the effect is presented.

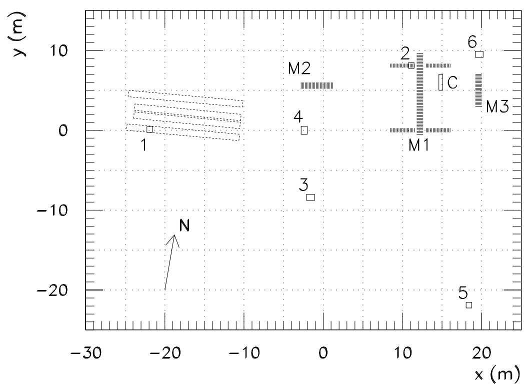

Fig. 1. Schematic plan of the Lodz air shower array. Scintillation counters are denoted by numbers.

1 Introduction

Simultaneous observations of extensive air showers (EAS) and neutrons have been performed by A.P. Chubenko et al. in Tien Shan experiment (Aushev et al., 1997; Antonova et al., 1999), where the standard neutron monitor worked together with the air shower array. Anomalous time distributions of neutrons registered in boron counters of the neutron monitor and in additional helium counters placed above the monitor have been obtained. The neutrons have been registered in the period of up to 3.5 miliseconds after the main EAS front, but only for showers of primary energy greater than $3 \cdot 10^{16}$ eV when the shower core was near to the neutron monitor. In such cases the number of registered neutrons exceeded the expected value.
Similar observations have been performed also on the Baksan air shower array, supporting the results obtained by the Tien Shan group (Voevodsky, 1998).

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Experiment of this kind has been also performed in Mexico (Stenkin et al., 1999), with boron counters of the standard neutron monitor and 4 m^2 scintillator counters placed above and under the neutron monitor. Observed in some cases great number of counts in boron counters and in scintillators, and their time distribution can be explained by the production of large number of neutrons in the shower and can be interpreted as a result of slowing down and absorption of neutrons in the monitor and surrounding matter. Signals in scintillators were caused by gammas emitted in the process of thermal neutrons capture by the nuclei of surrounding matter.
This effect may possibly indicate existence of a new physical process or give a new method of studies of the hadronic component of EAS. So we decided to add to our Lodz air shower array an electronic device which can register number of signals from Geiger–Müller counters every 100 microsec-

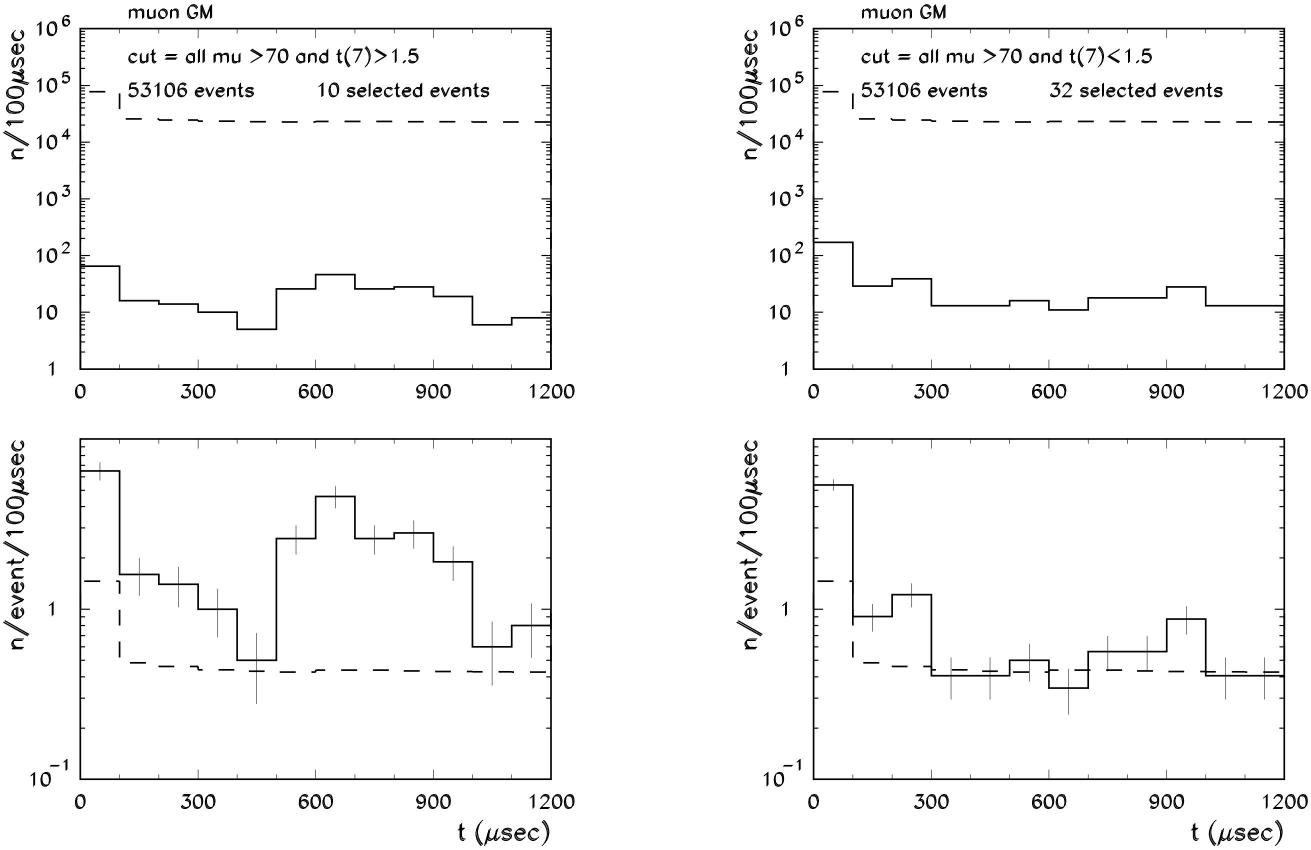

Fig. 2. Time distributions of the number of hit G-M counters: broken line – all events, solid line – events with the threshold of 70 hit muon blocks. Upper figures are histograms, lower are recalculated per 1 event. Solid lines on left figures with 2 or more signals in 600–700 μs interval, on right figures – with 0 or 1 signal in the same interval.

onds in the period up to 1.2 miliseconds after the main EAS front.

2 Experimental array

Schematic plan of our experimental array is shown in the Fig. 1. Scintillation counters 1,2 and 5 have an area of 0.5 m^2, counters 3,4 and 6 – area of 1 m^2. Coincidence of scintillators 1,2,4 and 5 triggers the array. The muon detector consists of 104 blocks of muon counters divided into 3 parts: M1 – central part built of 56 muon blocks, and M2, M3 – two side parts built of 24 blocks each. Each block contains 5 Geiger-Müller counters logically joined together. Effective area of the block equals 0.135 m^2. All muon counters are placed under the 30.5 cm layer of lead and 12.5 cm layer of iron. The threshold energy of registered muons is equal to 0.5 GeV. The central part of the muon detector (M1) is equipped with electronics counting the number of signals in 100 microsecond intervals beginning from the 2^{nd} microsecond after EAS front up to 1.2 miliseconds. Formed impulses from G-M counters have length of 100 nsec and their start coincides with the front of unformatted G-M signal.

3 Results

The total time of registrations was equal to $4.55\cdot10^6$sec (52.7 days). In this period we have registered 53106 EAS. In 182 cases of shower registration more than 50 muon blocks were hit, in 42 cases more than 70 muon blocks were hit. Threshold of 50 blocks corresponds to muon density of 4.4 μ/m^2, and threshold of 70 blocks – 7.4 μ/m^2 at the detector position. From the lateral distribution of muons (Greisen, 1960) the lower limit of total number of muons (E$\geq$0.5 GeV) in EAS can be obtained: it is equal respectively $1.5\cdot10^5$ and $2.5\cdot10^5$. All events above the given threshold number of hit muon blocks have been divided into two groups:
1) with number of signals 2 and more in the interval 600–700 μs,
2) with number of signals 0 or 1 in the same interval.
In the first group we observe an excess in the count rate in the interval 500–1000 μs as compare with background. Time distributions of all events and events with the threshold of 70 hit muon blocks are shown in the Fig. 2. According to the work Stenkin et al. (1999) the excess can be described by the

Table 1. Parameter values for eq. 1. k_{th} is the threshold number of hit muon boxes in the event, m is the number of signals in 600–700 μs interval and N denotes the number of events registered. Last column shows the sum χ^2 for the fit to k bins.

k_{th}	m	N	C	τ, μs	T_0, μs	$\chi^2/$ $k(\Delta t)$
50	2,3,...	48	324±26	229±15	442±5	6.78/8
50	0,1	134				
70	2,3,...	10	122±15	212±20	449±4	2.60/8
70	0,1	32				
80	2,3,...	9	107±14	224±23	448±5	2.56/8
80	0,1	16				

formula:

$$n(t) = C \cdot \left[exp\left(\frac{t - T_0}{\tau}\right) - exp\left(\frac{2 \cdot (t - T_0)}{\tau}\right)\right] + bg, \quad (1)$$

where the background $bg = 0.43\cdot$ (number of events) and other parameters are shown in the table 1.

4 Discussion

We observe the effect of registrations of signals delayed by 500-1000 microseconds after EAS front (maximum for around 600 microseconds) that significantly outnumber the predicted background. The effect occurs only for big showers (it is not observed in most of registered events). For one month we have also carried registrations of delayed signals from scintillation detectors. Digital oscilloscope TDS3032 steered from PC computer has been used for registration of signals from two scintillation counters for times between 600 μs before EAS and 1200 μs after EAS. We have found events of EAS registration with short series of signals occurring at 500 - 700 μs after the coincidence signal. Amplitudes of these signals are smaller than typical signals coming from single muons. We are not able to explain this effect. Three possible scenarios can be considered:
a) artificial effect connected with gas counters,
b) registration of neutrons produced in the interactions of EAS hadrons,
c) hypothetical generation of non-interacting EAS component.
We plan further experimental work in this direction.

References

Aushev, W. M., Zhdanov, G. B., Kokobaev, M. M., Piskal, W. W., Romakhina, N. S., Chubenko, A. P., Shepetov, A. L., Izvestija RAN, ser. phys., 61, 486, 1997.

Antonova, V. A., Chubenko, A. P., Kokobaev, M. M., Shepetov, A. L., Vildanova, L. A., Zhdanov, G. B., Nuclear Phys. B. (Proc. Suppl.), 75A, 333, 1999.

Voevodsky, A. V., private communication, 1998.

Stenkin, Y. V., Valdés-Galicia, J. F., Villaseñor, L., Hurtado, A., Musalem, O., 26th ICRC, Salt Lake City, Utah, USA, 1, 252, 1999.

Greisen, K., Annual Review of Nuclear Science, 10, 63, 1960.