acta phys. slov. 27. (1977), No. 4

# THE NEUTRON SUPERMONITOR 4-NM-64 WITH CONTROL OF THE LONG TERM STABILITY OF MEASUREMENT

JURAJ DUBINSKÝ*, JOZEF ILENČÍK*, MICHAL SEMAN*, Košice

The properties of the neutron supermonitor are investigated from the point of view of the long term stability and the comparability of measurement. The special unit controlling the whole aparatus is described. With the help of the unit the counting rate in the individual channels, the contents of the multiplicity counters together with the time information, values of barometric pressure, high voltages applied to the proportional counters and values of the discrimination levels on the preamplifiers are recorded on paper tape.

## НЕЙТРОННЫЙ СУПЕРМОНИТОР 4-NM-64, СЛЕДЯЩИЙ ЗА ДЛИТЕЛЬНОЙ УСТОЙЧИВОСТЬЮ ИЗМЕРЕНИЯ

В статье исследуются свойства нейтронного супермонитора с точки зрения устойчивости и соизмеримости измерения. Описан специальный блок, следящий за всей аппаратурой. С помощью этого блока запосываются на бумажную ленту данные о скорости счёта в отдельных каналах, о содержании множественности счётчиков совместно с информацией о времени, значениях барометрического давления, высоког напражения, приложенного к пропорциональным счётчикам, и о значениях разрешающих уровней на предварительных усилителях.

## I. INTRODUCTION

The measurement of the nucleonic component of the cosmic rays intensity was begun on Lomnický štít in the International Geophysical Year with the help of the "SIMPSON" type neutron monitor. Later, when the large NM-64 monitor was designed by Carmichael [1] for the IQSY, we began along with other laboratories the study of the macrovariations of the cosmic rays intensity with amplitudes ~0.5 %, using the mentioned monitor.

In spite of many satellite experiments the ground level measurements by the neutron supermonitor make still an important contribution to our knowledge of the interplanetary space.

* Institute of Experimental Physics, Slovak Academy of Sciences, Moyzesova 11, CS-040 01 KOŠICE.

The continuous multiplicity measurements with the help of the neutron supermonitor give information about the spectral character of the primary cosmic radiations; the worldwide distribution, the continuity, the reliability and the general availability of data are the great advantages of the neutron supermonitor, considering the unpredictability of the sun.

## II. THE DETECTOR DESCRIPTION

The main parts of the neutron supermonitor installed on Lomnický štít are shown in Fig. 1.

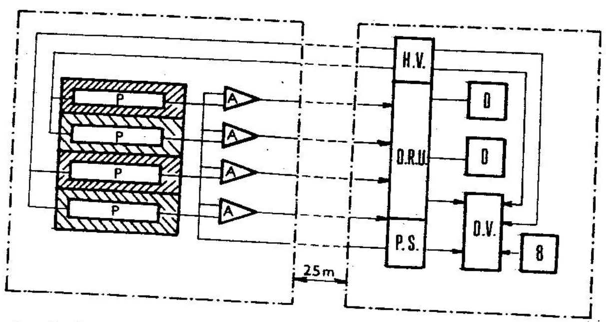
The detector with preamplifiers is placed separately in the measuring house. It is composed of four identical parts — sections. The arrangement of the supermonitor section is shown in Fig. 2.

The used proportional counters are filled with $BF_3$ enriched up to more than 80 % by $B^{10}$ at a 200 mm Hg pressure. The plateau length is more than 200 V and the working voltage for the different counters is in the range 2 600—2 800 V.

To increase the detection efficiency of the proportial counter the latter is surrounded by a polyethylen layer, the function of which is to moderate neutrons generated in the lead producer, thus increasing the probability of their capture in the boron trifluoride. A neutron captured by a $B^{10}$ nucleus induces the exothermic reaction

$$B_5^{10} + n \rightarrow Li_3^7 + He_2^4 .$$

n 94 % of the reactions the nuclei Li and He have the total kinetic energy of 30 MeV, in the remaining 6 % 2.78 MeV. As the counter is operated in the roportional region, it is possible to discriminate between relatively small pulses roduced by the passage of other charged particles through this counter.



1. Main parts of the neutron supermonitor: P — proportional counter, A — preamplifier, - puncher, B — barometer, HV — high voltage power supply, PS — power supply, DRU — driving and recording unit, DV — digital voltmeter.

The thickness of the polyethylen moderator (3 cm) was determined experimentally as the thickness giving the maximal counting rate, with the other conditions unchanged (Fig. 3), and is in agreement with the result of [2].

Lead as the local producer of neutrons is used in the form of rings with an inner diameter of 24 cm and an outer diameter of 36 cm. Lead has been chosen since the average number of neutrons produced by the nucleon interactions increases with

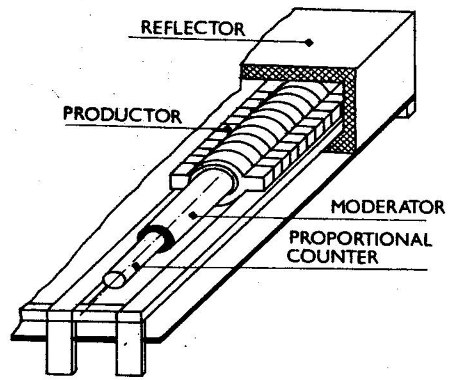


Fig. 2. Arrangement of the supermonitor section.

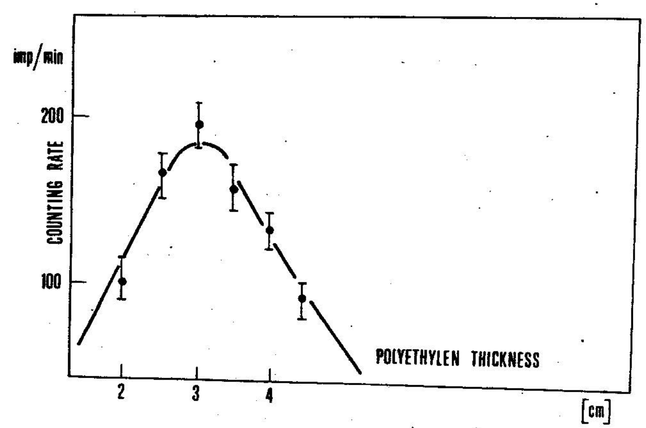


Fig. 3. Counting rate as a function of the polyethylen thickness.

the atomic mass of the producer and lead has moreover a relatively low thermal neutron absorption cross section (0.17 barn). The rings are placed along the whole counter. The distance between the axes of the adjoining rings is ~50 cm. The thickness of the lead producer represents approximately 0.75 of the inelastic mean free path of nucleons in lead, thus ~50 % of the incident nucleons carry out at least one interaction in the producer. A further increase in the producer thickness at given geometry will cause only a small change in the neutron flux through the proportional counter.

The outher part of the detector, a polyethylen layer with a thickness of 7.5 cm, reflects the neutrons produced within the monitor and simultaneously isolates the detector from neutrons generated around it. As shown in [3], the reflector with a thickness of 5 cm is adequate, since a negligible number of neutrons thermalized beyond this thickness in the reflector will diffuse back to the counter. A further increase of the reflector thickness will decrease the counting rate because of the absorption of the soft nucleonic component of cosmic rays and the absorption of neutrons produced outside the monitor. The chosen thickness is a compromise between the sensitivity of the monitor to low energy cosmic rays neutrons and the insensitivity to neutrons produced outside the monitor. The contribution of the latter to the total counting rate is in this case ~5 %.

The detector formed by four such sections has the total counting rate ~800 000 imp/hour.

## III. STABILITY OF MEASUREMENT

From the long term continuity of measurements there arise requirements as regards the stability of the whole apparatus. At a counting rate of ~2000 000 imp/hour and at the mentioned level of enrichement by $B^{10}$, the properties of the used proportional counters remain stable for ten years.

The increase in the plateau of the proportional counters (~3 %) necessitates a high stability of the used high voltage power supplies. Their long term stability is greater than $5\times10^{-3}$. Moreover, values of HV measured by the digital voltmeter are recorded every five minutes on a paper tape, providing the possibility of correcting the registered counting rates, the working characteristic of the proportional counter being known.

The long term stability of the measurement is influenced also by the stability of the preamplifier discrimination level. The circuit diagram of the preamplifier constructed on IC K243 AG1 is shown in Fig. 4. The sensitivity of the discrimination level to temperature changes in the interval from +4 °C to 60 °C is 0.2 %/°C. Since the temperature in the measuring house is stabilized within 1.0 °C, the stability of the discrimination level is mostly defined by the stability of power supplies (better than 0.1 %). The total change in the discrimination level is less than 0.5 %. The analog output of the preamplifier makes the proper choice of the discrimination level possible.

The barometric pressure measured by a barometer (accuracy ±0.1 torr) with an electric output is recorded through the digital voltmeter on paper tapes in five minute intervals, together with the other information. When processed by the



computer, the necessary corrections in the counting rate depending on the barometric pressure changes are made.

The long term continuity and stability of the measurement depends on the reliability of the controlling unit. The block diagram of the unit is shown in Fig. 5. Pulses from individual proportional counters are registered by scalers, each having the capacity of $10^6$ pulses. In this way the four relatively independent channels of the monitor are formed.

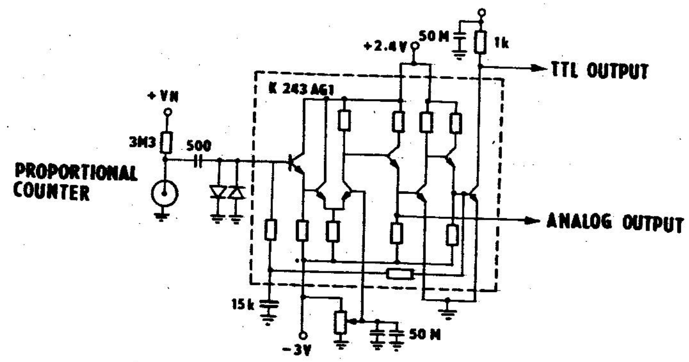



Fig. 4. Circuit diagram of the preamplifier.

At the previously mentioned counting rate the dead time of electronics practically does not introduce any error into the registered count, since the recovery time of the preamplifiers after a relatively big inpunt pulse (220 mV) is 200 µsec and the dead time of the scalers is ~50 nsec.

As mentioned before, the neutron supermonitor is divided into four electronically independent channels. The response of the channels to the changes in the intensity of the nucleonic component of the cosmic rays should be the same, so that comparing the counting rates in the individual channels we can control internally the stability of the monitor. At the proper function of the monitor the ratio of the counting rates in the individual channels must be constant within statistical fluctuations. The detailed analysis of the monitor stability is perfomed while processing by the computer the information from the day before. Since a malfunction of the monitor at such a control can be found with a delay of up to 24 hours, the driving unit includes a module controlling the difference between channels, thus identifying in a relatively short time an improperly working channel. In spite of the lower sensitivity, compared with the control of the ratio of the counting rates, the difference between channels is controlled because of the much simpler electronics and as shown in Tab. 1 at relatively small variations in the intensity (±20 %), a sufficient sensitivity to detect the malfunction of channel results.

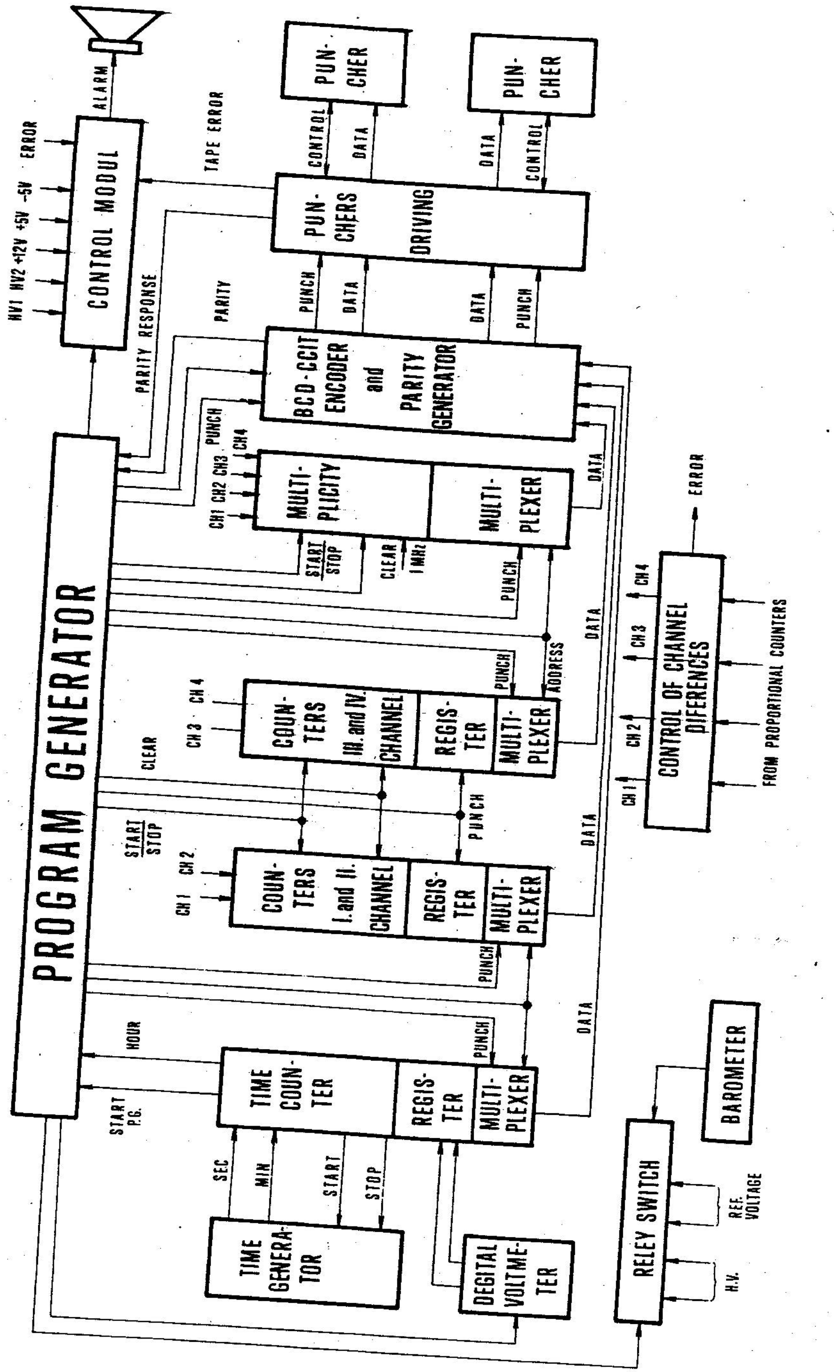



Fig. 5. Block diagram of the driving and recording unit.

Table 1

| | Probability of error indication for various values of $N$ | | |
|---|---|---|---|
| | $N = 16\ 000$ imp/min | $N = 20\ 000$ imp/min | $N = 24\ 000$ imp/min |
| At deviation from proper 4 % function of | 0.61 | 0.912 | 0.9398 |
| 5 % the channel | 0.912 | 0.995 | 0.9999 |
| 6 % | 0.9898 | 0.9999 | ~1 |
| Because of statistical fluctuation | $4 \times 10^{-7}$ | $4.3 \times 10^{-6}$ | $2 \times 10^{-5}$ |

The module controls successively every five minutes the differences between one of the channel couples (1—2, 1—3, 1—4). If the difference in the counting rates exceeds the chosen interval, the same couple is controlled again within the next five minutes interval. An error shows if the same couple is continuously controlled during four intervals and always with a difference exceeding the chosen interval. The allowed values of difference are within the interval

$$N_i - N_j \pm 2\sigma_{N_i - N_j} ,$$

where $\sigma_{N_i - N_j} = \sqrt{\sigma^2_{N_i} + \sigma^2_{N_j}}$ is the mean square deviation of the difference $(N_i - N_j)$ and $N_i$ and $N_j$ are the mean values of the counting rates in the individual channels (~20 000 imp/5 min.), at the average intensity of the nucleonic component of cosmic rays, and $\sigma_{N_i}$, $\sigma_{N_j}$ are the mean square deviations of $N_i$, $N_j$.

Using this interval of the allowed values for the difference, it is possible to detect with much probability deviations greater than 4 % from the proper function of any channel not later than in 30 minutes. Simultaneously the probability to simulate a malfunction of the monitor because of statistical fluctuations is very low. These probabilities are shown in Tab. 1 for various deviations from the proper function of a channel.

## IV. MULTIPLICITY MEASUREMENT AND INFORMATION RECORDING

The study of the variations in the energy spectrum of the primary cosmic rays through the multiplicity measurement is made possible with the help of the module, the principal diagram of which is shown in Fig. 6. Many authors [4—6] have shown that the mean multiplicity, i. e. the average number of neutrons generated by the nucleon of the cosmic rays in the producer increases with the energy of the incident nucleon. A change in the energy spectrum of the primary cosmic rays causes a change in the multiplicity distribution, and from the continuous measurement of the multiplicity distribution we can deduce a change in the energy spectrum.

Apart from measuring the multiplicity (MODE 1) the module is designed to measure the time distribution of the captured neutrons (MODE 2). From this distribution one can find the mean life time of the neutrons in the monitor.

In the first mode, the first neutron from a multiplicity event triggers the bistale multivibrator KO, thus opening gates V1 and V2. A signal with the frequency of 1 MHz proceeds to the input of the counter C1. Counter C2 counts the first as well as the all following pulses generated by the subsequent neutrons incoming within a given gate time. The events with the multiplicity $=7$ are counted together.

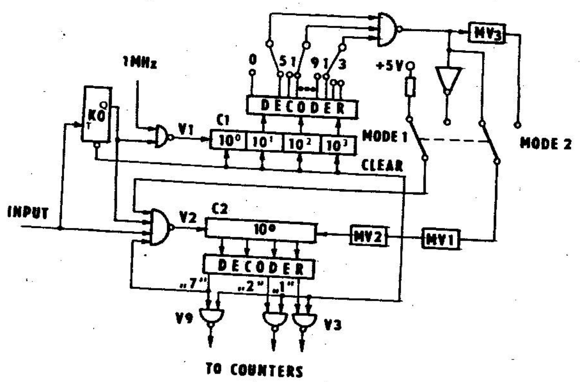



Fig. 6. Block diagram of the module for multiplicity and neutron life time measurement.

A desired gate time from 0.05 msec to 3.95 msec is set by the selector logic. After this time the pulse produced by the univibrator MV1 clears counter C1 and through one of the gates V3—V9 the content of the scaler is increased, which registers the events with the just detected multiplicity. Simultaneously the bistable multivibrator KO is reset and by the pulse from the univibrator MV2 the counter C2 is cleared, thus the whole logic of the multiplicity meter is reset to the initial state.

In the second mode of operation the gate V2 is not opened after the detection of the first neutron from the event. It is opened at the end of the time chosen by the selector logic for 50 μsec. After this time the univibrator MV2 activates the univibrator MV1 and similarly as in mode 1, the number of the incoming neutrons is registered and the whole logic is reset to the initial state.

The recording of the obtained information is initiated by the time counter in five minute intervals under the control of the program generator (Fig. 5). First the time information is recorded (day, hour, minute), then the values of the barometric pressure, the values of high voltages applied to the proportional counters and the



values of the reference voltages defining the discrimination levels on the preamplifiers. Then there follows the recording of the contents of the multiplicity counters together with the value of the chosen gate time.

Two paper tape punchers are used to record the information, one in five minute intervals, the other in one hour intervals. The last information is used for the regular processing, while the five minute data are used when interesting short time variations of the cosmic rays intensity are studied.

Each punched character is checked on the parity. In the case of an error, the recording of the information is interrupted by the signalization of the error type. After the source of the error is removed, the record can be repeated without any loss of information, since this is stored for five minutes in the registers.

## REFERENCES


[1] Carmichael H., *Cosmic Rays*, 1964 IQSA Instructions Manual, No 7.
[2] Simpson J. A., Fonger W., Treimann S. B., Phys. Rev. *90* (1953), 93.
[3] Hatton C. J., Carmichael H., Canad. J. Phys. *42* (1964), 2443.
[4] Griffiths W. K., Harman C. V., Hatton C. J. Maraden P. L., Ryder P., Canad. J. Phys. *46* (1968), 1044.
[5] Blomster K. A., Tanskanen P. J., Acta Phys. Acad. Sci. Hung. *29* (1970), Suppl. 2. 627.
[6] Hughes E. B., Marsden P. L., Journ. Geophys. Res. *71* (1966), 1435.
[7] Fujii Z., Kodama M., Wada Y., Sci. Papers of the Ins. of Phys. and Chem. Research *66* (1972), 1.


Received May 5th, 1976