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Observing Multiplicity Effect during December 13, 2006 event on the Barentsburg Neutron Monitor

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Abstract: The neutron multiplicity changes on the neutron monitor in Barentsburg (Spitsbergen) during the GLE December 13, 2006 has been studied. The neutron monitor in Barentsburg was put into operation on April, 2003. In 2006 it has found the complete configuration 18-NM-64. The new data collecting system based on a digital ADLINK 7233 card allows to register both pulses, and intervals between them. On the basis of this device the multiplicity recorder is realized to register the count rates on multiplicities (2-10). During the GLE a significant increase of the count rates of multiplicities from 2 up to 4 was detected. The multiplicity spectrum changes are compared with the solar proton spectrum dynamics during event. The spectra of relativistic solar protons was derived by modeling technique from the worldwide neutron monitor network.

1. Introduction

The source of pulse clusters in a neutron monitor is multiple neutrons generated in inelastic interaction by incident atmospheric secondaries (mainly neutrons).The number of multiple neutrons (multiplicity) carries the information on a spectrum of primary cosmic rays. The studies of multiplicities in latitude survey are described in [1]. In [2] the distribution of elapsed time interval between multiple neutrons during the GLE of 20 January, 2005 are studied. At present paper the way of measurement of multiplicity, realized on the neutron monitor in Barentsburg is described. The multiplicity registrars of the past years were designed on the basis of the discrete logic electronics. In our system a multiplicity registrar is realized by an only programming way. The multiplicity with different numbers during the GLE of December 13, 2006 has been obtained and their dynamics studied.

2. Data collecting system

The data acquisition system (Fig.1) is based on an ordinary PC equipped with two extension cards. One of them is ADLINK PCI-7233H, which is a high-speed 32-channel digital input card. The other is ADLINK PCI-8554, 12-channel counter/timer card. The collecting computer runs under DOS. The specially written collecting software runs continuously. It captures the data registered by the two cards and stores the data to the hard disk. The PCI-7233H card registers pulses from all 18 channels of the neutron monitor, while PCI-8554 collects pulses from atmospheric pressure and temperature sensors.

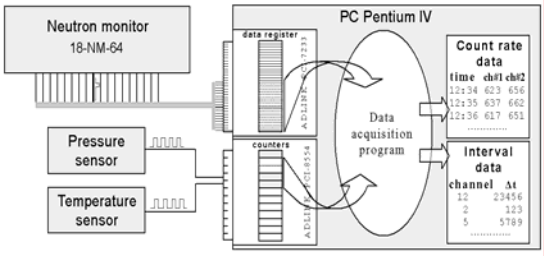

Fig.1. The new data collecting system in the neutron monitor in Barentsburg.

Pulses from all 18 counters of a neutron monitor come to PCI-7233H. Each alternate pulse produces a hardware interrupt. The collecting program registers this pulse: it increments a count for corresponding counter tube channel and measure a time elapsed since a previous pulse. In a database each pulse enters with the information on a

number of a counter tube and a time, elapsed since a past pulse (in any of 18 channels). With this information, it is possible then to obtain distributions of elapsed times between pulses in one channel or any chosen group of channels (for example, a section of the neutron monitor).

For accurate determination of elapsed time interval the program uses a high-frequency counter (Time Stamp Counter) internal to any Pentium (and its clones) processor. The frequency of TSC is equal to a processor's frequency (2-3 GHz on modern computers). So it is possible to determine time intervals with a very high precision.

The next limiting factor in a system is an interrupt processing procedure. The measured hardware and software delays during this procedure are ~6 μs. This "dead time" is less than the fixed dead time of the counting circuit equaled 10 μs. Thus the dead time of a whole our data acquisition system is 10 μs. The collecting program forms two kinds of data files. The first file contains a standard count rate data, i.e. number of pulses per minute in each channel (including pressure and temperature channels). The second file consists of three-byte records on each pulse: 5 bits for channel number and 19 bits for a number of microseconds elapsed since a previous pulse. The size of a daily file is 40-50 MB. However, hard disks of modern computers are large enough to keep the data for rather long periods.

To keep a correct time on the collecting computer a GPS receiver is connected to a serial port of the computer. Once per hour the collecting program reads GPS data and corrects computer's clock. Every 10 minutes both count rate and pulse data are copied from collecting computer to a server via a local network. The server publishes the real-time count rate data in the Internet.

3. Neutron monitor multiplicity records.

Fig.2 shows a distribution of the time intervals between pulses of a one six-counter tube section of the neutron monitor in Barentsburg averaged over the 24 quiet days during October-December 2006. The distribution of the elapsed time δT is similar to presented in [1,2], except that our distribution is truncated at the low end at 10 μs. In [1,2] this value is 95 μs.

Our simulation shows that the δT distribution can be represented as a sum of three exponential functions (curves 1,2,3 in Fig.2).The time constants of these exponents are respectively: 130, 465, 7350 μs. Physically it may be interpreted as contribution in the δT distribution of three independent distributions for corresponding particle populations.

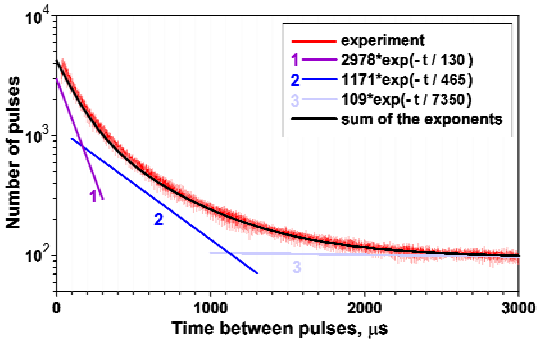

Figure 2. Distribution of the elapsed time intervals between pulses of NM Barentsburg averaged over 24 quiet days during October-December 2006 (red curve). The black line is result of simulation representing the distribution for δT by the sum of three exponential functions (1, 2, 3). The time constants of these functions are: 130, 465, 7350 μs.

An exponential distribution with a fixed time constant is characteristic for the events randomly distributed in time. Such particles, for instance could be the not interacting single neutrons coming outside. Curve 3 in Fig.2 is suitable approximation for these events. The break in the δT distribution separating single uncorrelated events from multiplicity events found in [1] at δT~ 2 ms (at low geomagnetic cutoff) is close to the similar value in Fig.2.

The time constants of 130 and 465 μs are of order of average time of life of neutrons inside the neutron monitor (326 μs) [3,4]. However, as shows our analysis with the high temporary resolution, the time constants of 130 and 465 μs may belong to distinct processes of neutron generation producing the separate population of particles. Such processes may be well known two stages of nuclear interaction in Pb [1]. During the first stage, knock-on neutrons are generated. Some part of these knock-on neutrons after slowing down could be a source of a distribution with δT~130 μs. The second exponential distribution with (δT ~ 465 μs) could belong to the evaporating neutron component. It is believed, however,

that the energy of knock-on neutrons is too high to be slow down and detecting by a counter tube [1]. Summarizing it is possible to conclude.

The δT distribution probably demonstrates presence of three populations of neutrons detected by counter tubes of a neutron monitor: 1) knock-on neutrons produced in the n-Pb nuclear interaction 2) evaporating neutrons produced in the process of deexitation of a wounded nucleus of Pb, 3) single non interaction neutrons getting into a neutron monitor from atmosphere.

Fig. 3 shows the data of continuous registration of multiplicities on the neutron monitor in Barentsburg during the period from October, 2006 to March, 2007. The daily averaged multiplicity values with numbers from 1 to 6 are shown. The 27-daily variation is well visible which can be traced up to multiplicity M5. Forbush-effects can be traced up to multiplicity M4, and the GLE effect up to multiplicity M3.

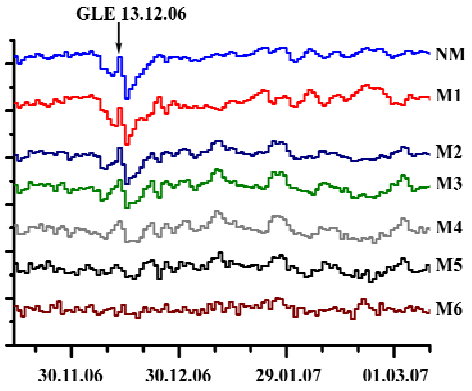

Fig. 3. The daily-average profiles of the total counts the Barentsburg neutron monitor (NM) and the multiplicities with a number 1,2...6 (M1,M2...M6) respectively. The width of a "time gate" is 150 microsecond.

4. Multiplicity records during GLE on 13.12.2007.

The ground level enhancement (GLE) on December 13, 2006 was related to the parent flare X3.4/2B with heliocoordinates S06 W24. The type II onset was reported at 02.26 UT. Increase onset on the NM Barentsburg was fixed at 02:59. Detailed description of the GLE and its modeling analysis can be found in [6]. Fig. 4 shows increase profiles of multiplicities of different numbers during the December 13, 2006 GLE. In the insert the increase profile of the total count rate of the NM Barentsburg is shown. The values of multiplicities of different numbers are obtained from hourly files of the neutron monitor data at a window width of 150 μs. The distinct increase is observed in multiplicities up to the number 3. The duration of increase has made more than 7 hours: from 3.00 to 10.00 UT (Fig.4). A spectral exponent of the rigidity spectrum has changed from 4 at 3.00 to 7 at 4.00 UT [6].

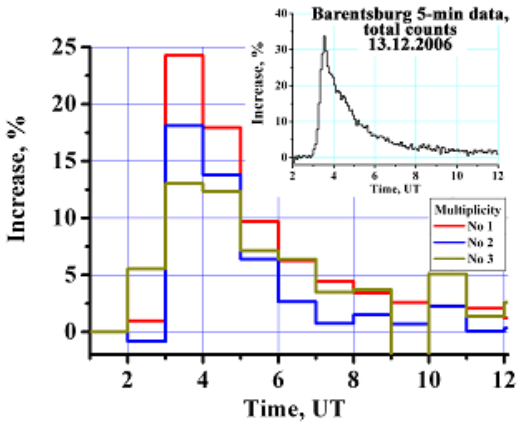

Fig. 4. Multiplicity profiles registered by the Barentsburg neutron monitor during the GLE on 13.12.06. The "time gate" width is 150 μs.

Despite of a strong softening of a spectrum the multiple neutrons were still observed for a long time. The results of multiplicity measurements clearly demonstrate evolution of a spectrum of relativistic solar protons on the data of a single neutron monitor.

For obtaining parameters of a spectrum of solar protons from the multiplicity data the specific yields for each of multiplicity is needed. In absence of these we consider definition of a spectrum of primary SCR as a task for future studies.

Results

With the help of the new developed registrar of multiplicities on the neutron monitor in Barentsburg the increases of count rate of multiple neutrons from relativistic solar protons during the GLE of December 13, 2006 are measured. The data collecting unit is developed on a basis of programming high speed digital cards ADLINK

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PCI-7233H and PCI-8554. The registrar of multiplicities is realized by an only programming way. With its help it is possible to investigate any multiplicities with any time gate and any combination of counting tubes of the neutron monitor.
The distinct increase is observed in multiplicities up to the number 3. The duration of increase has made more than 7 hours: from 3.00 to 10.00 UT. The such long increase of multiple neutrons testifies to presence at a spectrum of primary SCR of rigid enough particles.

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