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The underground neutron calorimeter for registration of the neutron-bearing cosmic ray component at Tien-Shan

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Abstract: Detector of a new type - the thick neutron calorimeter for the study of the muon-induced neutron events - is created in the underground room of the Tien-Shan mountain station (3340 m above the sea level) under a 2000 g/cm^2 thick rock absorber.

Installation consists of the two separate parts: the "vertical" calorimeter with 152 "Helium-2" type neutron counters placed in two rows in a vertical plane and a "horizontal" one, with 18 SNM-15 type neutron counters placed in two horizontal layers. As a neutron generator is used the lead (35 t in the "vertical" and 20 t in the "horizontal" calorimeter) and as a moderator - the hydrogen-enriched rubber and wood. Determination of the directions muon passage succeeds by a telescopic system of plastic scintillation detectors. The control system permits to register the temporal distributions of the signals from the each neutron detector in a time interval up to 4 ms.

Introduction.

Finding of the unexpectedly numerous events in the underground neutron monitor of Tien-Shan mountain station has given rise to creation of the new facilities for a more precise study of these phenomena. First of all, it seems timely now to check the hypothesis of the muonic origin of these events, which meets some difficulties in their explanation [1]. Correspondingly, the underground installation has been modernized, it's new status being a subject of the present report.

Experimental set-up.

A key to the problem of the nature of underground neutron events may be found in exploration of the penetrative properties of cosmic ray component responsible for them. It is convenient to carry such a study through investigation of the depth dependence of the intensity of neutron signals in a thick monitor-like installation consisting of a number of neutron detectors interlayered with heavy absorber. Hence, we have to change the traditional configuration of neutron monitor to that of *neutron calorimeter*, with an enhanced thickness of absorber substances inside. Also, a check of the origin of underground neutron events from the bremsstrahlung γ-quanta of the muons [1] may be obtained in comparison of the events intensity, registered both in the horizontally and vertically oriented detectors, with the characteristic angular distribution of the energetic muons deep underground. These reasons were put on the basis of the considered modification of underground neutron monitor.

The newly-build underground neutron detector is shown in the upper picture of figure 1. Detector is made on the basis of the "Helium-2" type ionization neutron counters, located in four vertical planes, 19 rows per 2 counters (placed one af-

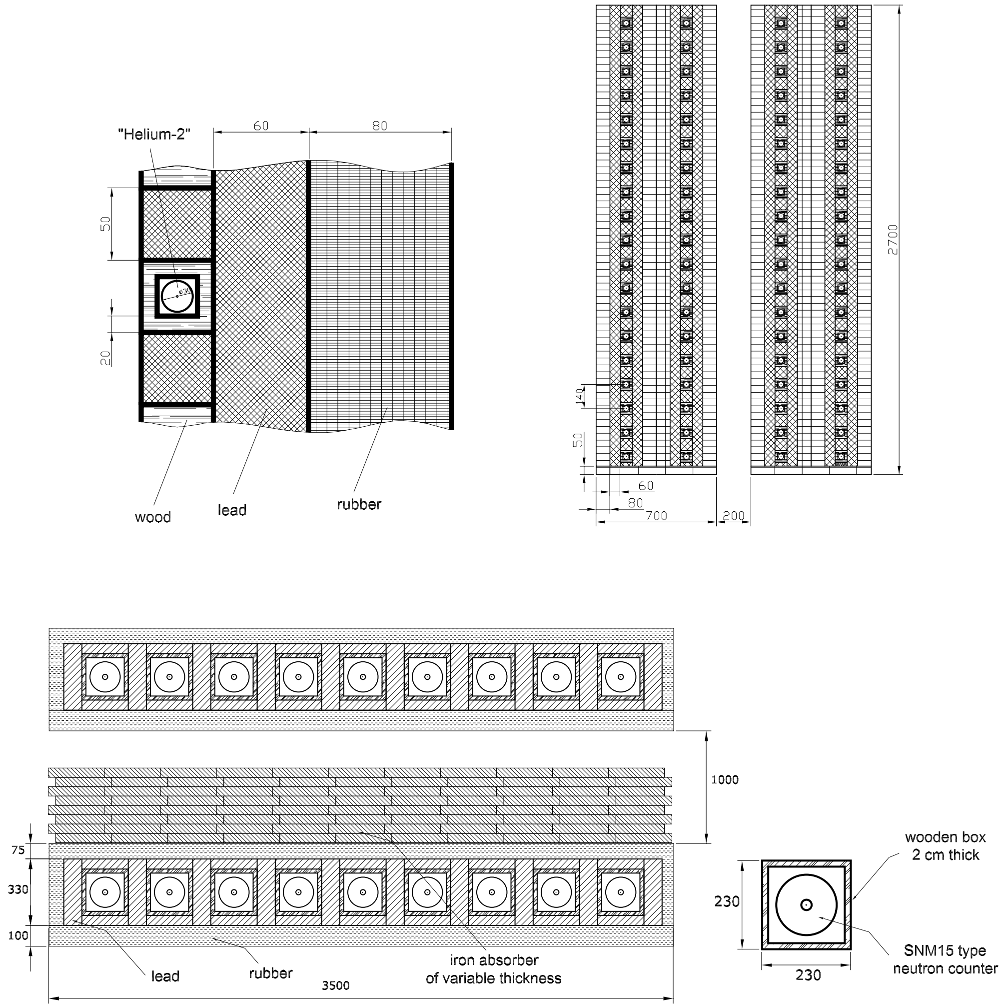

Figure 1: Internal set-up of the "horizontal" (above) and "vertical" (below) parts of the underground neutron calorimeter. Dimensions are shown in mm.

ter another) in the each. The ^3He-filled counters are ⊘30x1000 mm long, neutron registration succeeds by the nuclear reaction $n(^3He, p)^3H$. Each counter, put inside a wooden box, the walls of which play a role of a neutron moderator, is surrounded by a thick lead absorber, where the evaporation neutrons are to be born in interactions of cosmic ray particles. From the outside, lead assemblages are covered by the layers of hydrogen-enriched rubber, which also serves as a neutron moderator and simultaneously shields the installation's interior from the background low-energy neutrons.

The whole mass of the lead absorber inside the installation is about 35 t.

Four planes of neutron detectors constitute a *horizontally*-oriented neutron calorimeter, which — under condition of proper triggering — may be used for the study of neutron production by cosmic ray particles penetrating the underground room in nearly horizontal direction.

The already-existed underground neutron monitor, which is based on the big SNM15-type neutron counters (⊘150x2000 mm, neutron registration is due to reaction $n(^{10}B, \alpha)^7Li$ with boron nuclei put into counter's gas filling) [1], has been also reconfigured. To study the properties of the neutron-bearing component passing installation in the *vertical* direction, two of the underground monitor units are mounted above each other, a heavy filter being placed in the gap between them (see figure 1, below). The thickness of the filter, which consists of separate iron rods, may be progressively changed, permitting to study the neutron production in an up to 1 m thick absorber. (The third neutron monitor unit mentioned in [1] is mounted on the surface of Tien-Shan station and data taking about the multiplicity spectrum of neutron events is now going on; afterwards comparison of this spectrum with that of the standard NM64 supermonitor, which is also operating at Tien-Shan, will give an absolute calibration of the non-standard neutron set-ups used underground).

Internal arrangement of the units of underground monitor is described in [1]; it is similar to that of the ”horizontal” neutron calorimeter. Evaporation neutrons are born by cosmic ray particles inside a lead absorber, the sum mass of which in two units of ”vertical” calorimeter is about 20 t.

Trigger conditions and operation of neutron signals.

The planned operation procedure of the signals from neutron detectors of underground installation is the same as that which has been used before both in the underground neutron monitor [1] and in other neutron experiments at Tien-Shan.

Usually, in the neutron monitors is applied the scheme with negative polarity of the high voltage feeding: the –2.5 kV voltage is connected to the counter's body and its anode thread remains under potential of the earth. An advantage of such connection is the absence of the separating capacitor with high operation voltage between the anode and the first cascade of amplifier. However, the impossibility to ground the body of the counter results in a significant influence of external electromagnetic interferences on the anode signal. For the feeding of the newly build neutron installations was designed another scheme with the positive polarity of the high-voltage power source, the voltage being connected to the anode and the body of the counter being grounded for the all high-frequency signals through a large capacity electrolytic condenser (a small negative voltage is connected to the body to prevent the metal corrosion).

The low-noise pre-amplifiers of neutron signals are mounted inside the metal caps put on the ends of the counters. Their $1-3\mu$s long pulses may be transmitted without distortions through the coaxial cables of some tens of meters in the length to the data registration center where the final amplifiers, discriminators and the shapers of standard pulses are mounted.

The threshold of pulse discriminators in registration channels is 10 mV at the neutron counter's anode for SNM15 counters and 1-2 mV for the counters of ”Helium-2” type. Discriminators together with the subsequent generators of the standard rectangular signals generate the pulses with a fixed length of 1μs. These pulses come to the pulse scaler schemes, the outputs of which are connected to the random access storage buffer with a ring organization. Each scaler counts the number of pulses obtained at its input during a fixed time interval (some tens of microseconds), these numbers being stored into the buffer memory. When a signal comes which marks the beginning of a neutron event — the trigger — the system terminates operation giving a signal to the control computer about its readiness for data output. Capacity of the memory buffer is enough to remember 50-70 subsequent neutron counts for the each separate neutron detector in the underground installation (i.e. 152 ”Helium-2” and 18 SNM15 neutron counters). Hence, it is anticipated registration of neutron signals with a rather high temporal and spatial resolutions (particularly in the ”horizontal” calorimeter with its rather thin neutron detectors).

As for the trigger to pick out the events in underground installation, the same selection algorithm of the short-time neutron bursts inside the monitor which described in [1] could be used for the porpoise. However, the advantages of the multi-layered calorimetric structure may be used in a full measure, when a trigger should mark the moments of the passages of cosmic ray particles in direction nearly perpendicular to that of the neutron counter layers (i.e. vertical or horizontal, correspondingly to the calorimeter's part). To achieve that, both parts of the underground installation will be equipped with a two sets of the new plastic

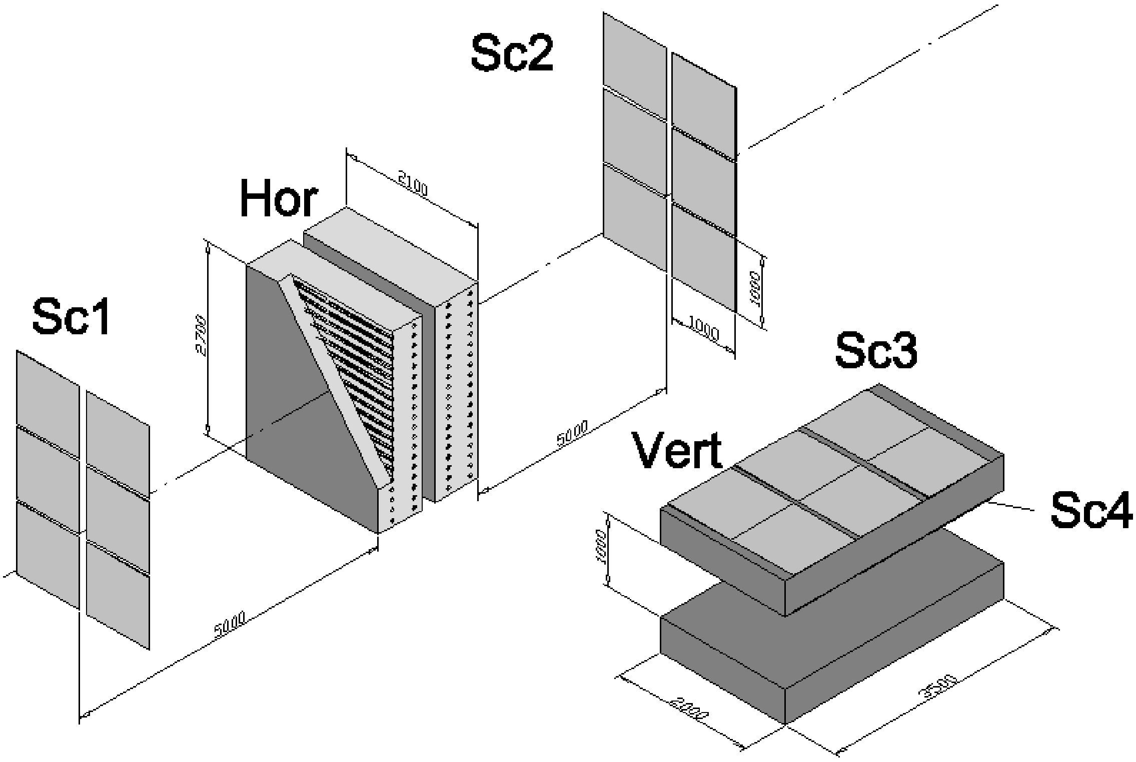

Figure 2: The muon trigger system of scintillation sets $Sc1 - Sc2$, $Sc3 - Sc4$.

scintillation detectors [2] of charged particles. Coincidences between the counterpart detector pairs of these sets should give a trigger signal and also may be used for a more precise reconstruction of the particle's trajectory. The planned placement of trigger scintillators is illustrated by the figure 2. It is supposed, that the scintillation coincidence triggers will control the data registration system together with the old "neutron" ones (from the scaler schemes of neutron bursts selection, see [1]).

Besides the production of trigger coincidences, analogue pulses from plastic scintillators, which accompany the neutron events, are to be digitized by the in-build amplitude-to-digital converters [2] and stored together with neutron counts. This information (which concerns the ionizing characteristics of initial particles) would also be useful for determination of the kind of neutron producing cosmic ray component underground.

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