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**ABSTRACT**

This report consists of 24 pages, 1 book, 5 figures, 6 sources and 2 applications.

Key words: NEUTRONS, HADRONS, AIR SHOWERS, NEUTRON DETECTORS, GAS DISCHARGE COUNTERS.

Research objects: air showers, neutrons, hadrons, neutron detectors, gas discharge counters.

Goal of research: Creation of a detectors system for collecting data of the neutron-forming component of powerful air showers with a low energy detection threshold, based on gas-discharge counters of 3He.

Research methods: informational, experimental, computer.

Results of work and their novelty:

We created and tested a system of detectors based on gas-discharge counters of 3Hе in the amount of 10 pieces for registration of the neutron-forming component of air shower. We developed software for the operation of neutron detectors based on 3He gas discharge counters. The detector system based on PD631 counters has noticeable detection efficiency in the energy range, which starts from thermal values and continues up to (0.1–0.3) keV. In this case, such a detector turns out to be the most sensitive to neutrons with energies En ≃ (0.01–0.1) eV.

The results obtained during the reporting period demonstrate a high stability of the functioning of the software and hardware complex.

Creation of neutron detectors based on gas-discharge counters 3He makes it possible to study previously unrecorded fluxes of thermal neutrons in the region of the air shower trunk.

Field of application: Experimental physics of cosmic rays.

Cost-effectiveness or value of work:

Information of the neutron-forming component of air shower, obtained on a new system for collecting data from neutron detectors, which based on gas-discharge counters 3He, makes it possible to carry out a comparative analysis with the known results of previous experiments on the Tien Shan supermonitor 18NM64.

Predictive assumptions about the development of the research object:

The experimental data obtained during the implementation of the project can be used in the analysis of fundamental problems in the physics of hadronic processes.

**CONTENTS**

|  |  |
| --- | --- |
| INTRODUCTION………………………………………………………………...………. | 7 |
| GENERAL SECTION OF REPORT……………………………………………………… | 9 |
| 1 Creation of a detectors system for registration of neutrons, based on gas discharge counters 3He.......................................................................................................................... | 9 |
| 2 Testing of a detectors system for registration of neutrons, based on gas discharge counters 3He.......................................................................................................................... | 12 |
| 3 Software engineering for operating of gas discharge counters………………………….. | 15 |
| CONCLUSION……….………………………………....………………………………… | 19 |
| REFERENCES…………………...……………...………………………………………… | 20 |
| APPENDIX А List of publications………………………………………………………... | 21 |
| APPENDIX В Calendar plan…...……………...………………………………………… | 22 |

**TERMS AND DEFINITIONS**

In this report, the following terms with appropriate definitions are used.

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| Air shower | – cascade of elementary particles produced due to interaction of primary cosmic ray particles (protons and nucleus) with nucleus of atmospheric atoms.  |
| Neutron | – an unstable particle with no electric charge, the part of the nucleus of an atom. |
| Hadrons | – a class of composite strong interacting particles.  |

**LIST OF ABBREVIATIONS AND SYMBOLS**

In this research report, the following abbreviations and symbols are used.

|  |  |  |
| --- | --- | --- |
| ADC | – | Analog-to-digital converter |
| eV | – |  electronvolt |
| GeV | – | 109 electronvolt |
| MeV | – | 106 electronvolt |
| CR | – | Cosmic ray |

**INTRODUCTION**

Assessment of the current state of the solving scientific and technical problem

The history of the study of cosmic rays in the range of primary energies of 1015 – 1017 eV is about half a century old, but, despite this, much remains unclear about their properties. First of all, such unclear questions should include the nature of the so-called break in the primary spectrum of cosmic rays, the so-called sharp change in the exponent in the power-law spectrum of cosmic rays at a primary energy of about 1015 eV. In addition to the break, a number of other effects were discovered in the same range of values, which have not yet been explained. The excessive generation of neutrons produced in the interaction of cosmic radiation hadrons with matter should be attributed to such unclear questions.

One of the supposed channels for the transfer of interaction energy during the development of air showers belonging to the energy range above the break in the primary spectrum may be the process of generating a large number of particles-products of low energy, which turn out to be below the detection threshold of detectors used in conventional experiments. In such a situation, the unique advantages of the neutron technique, namely the low energy threshold and a wide dynamic range of measured energy releases, are of particular importance for carrying out shower experiments. The results of a number of experiments carried out over the past two decades at the Tien Shan high-altitude scientific station can be interpreted as the observation of intense fluxes of low-energy hadrons.

Motivation of the research work

Over the past three decades, at the Tien Shan high-altitude station, the research group, within the framework of the "Hadron" experiment, systematically studied air showers by the method of detecting neutron signals, which is aimed at studying the characteristics of nuclear interactions in the range of primary energies of 1014 – 1017 eV.

It should be noted that the use of the neutron technique makes it possible to use the same detector to study nuclear reactions in the interactions of cosmic rays belonging to a very wide energy range.

Under performing one of the tasks of the scientific and technical program: BR05236291 "Perspective fundamental research in physics, astrophysics of cosmic rays at the Tien Shan high-mountain scientific station" at the shower facility of the Tien Shan station, evidence was obtained of an abnormally high multiplicity of evaporative neutrons that are generated inside the monitor when the trunks of air showers hit it. As a result, the question arose about the behavior of the low-energy component of the neutron flux accompanying the passage of an air shower. Therefore, to register low-energy neutrons, along with a neutron monitor as part of the complex installations of the high mountain station, it is proposed to use special neutron detectors built on the basis of gas discharge counters.

Information about the planned research level of project

All the problems considered in the Project "Creation of a detectors system for recording the neutron-forming component of powerful air showers with a low energy detection threshold" refer to a high level of development.

Project relevance and novelty

The step by step development of the Tien Shan high-altitude station detector complex has led to the creation of a multifunctional installation suitable for experimental research at the intersection of particle physics, astrophysics, cosmic ray physics, atmospheric physics, physics of solar-terrestrial communications, and geophysics. New particle detectors of the shower facility make it possible to study in detail the spatial structure of the flux of charged particles of air shower with E0 ≃ 1014 ~ 1017 eV, including inside their central region (at a distance of ≲1 m from the axis), which previously remained unattainable due to the limited dynamic range of the detectors. To study various air shower components, a large-area calorimeter was created at the station, in which, along with the traditional registration of ionization from the interaction products of cosmic ray particles, for the first time, the use of neutron detectors is provided, which makes it possible to qualitatively expand the dynamic range and information content of measurements. The shower facility includes a large number of neutron detectors of various types, which are systematically used to register previously unexplored air shower components and the products of interaction of cosmic ray particles with environmental matter.

Goal of the project

Creation of a detectors system for collecting data of the neutron-forming component of powerful air showers with a low energy detection threshold, based on gas-discharge counters.

Interim annual report for 2020 “Creation of a detectors system for recording the neutron-forming component of powerful air showers with a low energy detection threshold”, inventory No. 0220RK01575.

Calendar plan for the reporting period of 2021 is presented in Appendix B.

**GENERAL SECTION OF REPORT**

Key results for 2020

For the reporting period of 2020, a system of detectors was developed for recording the neutron-forming component of an EAS, based on gas-discharge counters 3He. The amplitude spectra of neutron counters were obtained using a pulsed analog to digital converter circuit.

**1 Creation of a detectors system for registration of neutrons, based on gas discharge counters 3He**

The system for collecting data from low-threshold neutron detectors is based on microprocessor-controlled electronic boards that generate pulse signals and measure their rate of arrival for each neutron counter. Figure 1 shows a schematic diagram of the preamplifier boards that are used to connect gas discharge neutron counters at the Tien Shan science station.



Figure 1 – Preamplifier of signals for gas discharge neutron counter

This type of borders provide high-voltage power supply to the anode filament of the counters, receive from the anode output pulse signals that correspond to the neutrons registered inside the counter, and amplify these pulses in amplitude and power to the value required for their transmission through cable communication lines. Each neutron counter has its own individual pre-amplification board, which is installed in close proximity to the counter, as well as an individual cable line for transmitting its output signals. The board is mounted inside a metal cap, which is installed on the end of the counter from the side of the anode outlet. A high-voltage power supply of positive polarity with a voltage of (2100–2900) V is supplied to the anode thread of the counter through a resistance-capacitance (RC) filter. The RC filter is necessary to suppress high-frequency noise that is present on the power supply lines. In this case, a constant negative voltage of −24 V is additionally applied to the metal body of the counter, which plays the role of a cathode. The voltage to power the neutron counters is generated by means of high-voltage converters, which are built according to the Cockcroft-Walton scheme [1]. Each inverter serves only one specific counter. This circumstance makes it possible to individually independently adjust the operating modes of the neutron detector in all information channels of the installation. Pulse output signals of negative polarity with an amplitude in the range of ∼ (5–30) mV are received from the anode filament of the counter through a high-voltage capacitor and fed to a preliminary amplification stage, which is assembled on an operational amplifier K554UD2 [2]. As a result of a small amplification in amplitude, these signals are transmitted through the coaxial cable through an emitter follower on a high-power transistor T1 for subsequent processing in pulse shaping circuits.

Figure 2 shows amplitude discrimination circuit which is used for operating with signals from neutron counters.



Figure 2 – Amplitude discriminator of analog pulse signals for a neutron counter

The presented circuit shows that the discrimination channel consists of three functional units: the main amplifier of the input signal on the elements D1/D2, the discriminator on the integrated circuit D3 and the output pulse generator-single-shot on the microcircuit D4. The amplifier cascade D1/D2 is based on integrated circuits of operational amplifiers of the K554UD2 type. It provides (15–20)× amplification of the input pulse amplitude. Two options for the construction of this node, which are shown in Figure 2, are designed to be connected to the discriminator of input pulses of both negative and positive polarity, so that the signals at the output of this amplifier always turn out to have negative polarity. The amplitude discrimination unit is built on a two-channel microcircuit of the K597SA3 type [2], which contains two identical Schmidt triggers. The discriminators generate a rectangular pulse of negative polarity with amplitude of ∼ (6–8) V at the moment when the voltage of the pulse signal at their information inputs is lower than the reference level at the comparison inputs. The amplitude of the resulting rectangular pulse at the discriminator output is determined by the difference between the supply voltage levels at pins 12 and 13 of the same microcircuit. The amplitude threshold of the discriminator is equal to the potential difference at the information and reference inputs of the K597SA3 microcircuits. This value is set by the Zener diode VD2 and is regulated by the potentiometer Rp so that the potential at the information inputs IN1 is higher than at the inputs IN2. Discriminator response thresholds in information channels are set individually for each counter. In discriminators that work with signals from counters, the threshold value is usually set in the range (0.2–0.4) V. This level of discrimination ensures stable registration of neutron pulses and insensitivity of the information channel to external electromagnetic interference. Through the emitter follower on the transistor VT1, the output signal of the discriminator starts the one-shot on the И-НЕ elements of the D4 microcircuit of type K155LA3 [3], which produces a standard pulse with a constant duration of ∼1 μs, compatible in amplitude with TTL digital microcircuits. Through a flat cable with alternating signal and screening cores, standard pulses from the output one-shot of all six channels of the monitor section are transmitted to the intensity recorder board, which is mounted in close proximity to the discriminator unit.

For all neutron detectors, simultaneous registration of two types of data is provided: regular measurements of the neutron count rate with a constant period of the order of several seconds (usually, when monitoring the neutron background with a low energy threshold, a periodicity of 10 s is adopted) and precise recording of the form of the time distribution of signal intensity over a certain period after the passage of the front of air showers. In this case, the registration of temporal distributions is performed with a resolution of the order of tens and hundreds of microseconds and is synchronized with the arrival of an external air shower trigger from the Tien Shan shower facility.

**2 Testing of a detectors system for registration of neutrons, based on gas discharge counters 3He**

To study the characteristics of the neutron detector, which correspond to different conditions of the experiment, three series of model calculations were carried out during the reporting period. In the calculations of the first series, the initial position of all primary neutrons at the beginning of each draw was set directly on the surface of the cylindrical wall of the "open" counter, and their impulse was always directed towards the internal space of the counter, along the normal to its surface. The purpose of these calculations was to determine the energy dependence of the efficiency of one individually taken PD631 neutron counter, which was considered regardless of any external environment.

In the second series of calculations, several such counters were combined into a single model of a neutron detector (these conditions are met by most of the experiments at the Tien Shan station). In this version of the calculations, random points on the outer surface containing a set of counters in the aluminum box were used as the initial position of the primary neutrons. The direction of the vector of the initial impulse for primary particles was set by playing the values of its direction cosines in a uniform distribution on the interval [0,1]. Such tinctures of the primary configuration correspond to the variant with a detector placed in an isotropic flux of incident neutrons. In this case, the effect on the total efficiency of the neutron detector, characteristic of its design, of anisotropy, which is associated with the fundamental separation of the direction along the axis of the counters, is automatically taken into account. Thus, it is obvious that the presence of spatial gaps between individual counters in a composite detector, which is considered as a whole, as well as a random distribution of the directions of motion of primary particles in this version of calculations should lead to the fact that the total efficiency of neutron registration for such a detector should be noticeable lower than in the case of the initial configuration of the primary neutron beam for a single counter.

In the third series of calculations, it was necessary to take into account the specific conditions of measurements that are carried out at the installations of the Tien Shan high-altitude station. Since the main purpose of such installations is to register particles of air shower, it is expected that among the flux of neutrons incident on the detector, particles moving in a vertical direction may prevail. In this case, instead of calculations with a completely isotropic initial distribution of primary particles, it may turn out to be more acceptable modeling, in which the position of primary neutrons is set randomly on the surface of only one of the sides of the model detector, and the distribution of their primary momenta is strictly fixed. This initial distribution of primary neutrons was adopted in the third series of model calculations.

The results obtained by simulating the neutron registration process for all three detector configuration options are shown in Figure 3.



1 – neutron counter without moderator (first version); 2 and 3 – configuration of the detector perpendicular to its surface and in an isotropic neutron flux; 4 – simulation for configurations of the neutron supermonitor NM64

Figure 3 – The efficiency of neutron registration by detectors of various configurations based on the results of model calculations

Line (1) in the upper graph of Figure 3 shows the energy dependence of the efficiency of the PD631 counter in relation to the registration of neutrons under the most favorable initial conditions (a primary neutron located directly on the counter surface with a pulse directed along the normal to its surface). It can be seen from the presented figure that in this version of the calculations, which plays the role of the upper limit for the possible efficiency, the resulting distribution reaches almost 100% in the range of thermal energies, decreases to 50% at an energy of ∼1 eV, and to 1% in the range of several keV. In a more realistic version of the calculations, with an isotropic initial distribution of the positions and momenta of primary particles, the results of which are shown by line (2) in Figure 3, the dependence of the total efficiency of the detector from several PD631 counters separated by gaps retains its maximum in the thermal energy region, but the magnitude of this maximum decreases to a level of ∼20%. Practically the same values of efficiency turn out to be in the case of a uniform distribution of primary particles over the upper side of the detector, as shown in Figure 3 (line (3)). Thus, according to the data of the model calculation, it can be concluded that the probability of registering neutrons in the detector is practically independent of the type of angular distribution of the neutron flux incident on the detector. The results obtained mean that the detector itself on the PD631 counters has a noticeable efficiency, with a neutron detection probability of 1%, in the energy range, which starts from thermal values and continues up to (0.1–0.3) keV. In this case, such a detector turns out to be the most sensitive to neutrons with kinetic energies En ≃ (0.01–0.1) eV, and in the region of higher energies its efficiency decreases in inverse proportion to √En. For comparison, line (4) of Figure 3 shows the energy dependence of the neutron detection efficiency, which was obtained by simulating neutron interactions for the NM64 supermonitor configuration in the low-energy region of the incident particle. As follows from this dependence, the efficiency of a neutron supermonitor exhibits behavior directly opposite to that of a low-threshold detector. The efficiency remains insignificant up to the energy En ≃ (0.1–1) MeV, and then begins to grow as the multiplicity of evaporative neutrons increases, which are formed during nuclear reactions initiated by energetic hadrons inside the heavy absorber of the monitor. Thus, we can conclude that the neutron supermonitor and detectors based on neutron counters not shielded by any substance complement each other in their capabilities.

**3 Software engineering for operating of gas discharge counters**

The software part of the information system consists of the following functional modules. The STM32F407 microprocessor of the autonomous measuring subsystem, to which the output signals of neutron counters are directly connected, operates under the control of the s02 registration program integrated into it. During a measurement session, this program performs the functions of the operating system of the microprocessor, ensuring its adequate response to external events: registration of pulse signals arriving at the input lines of the internal GPIO port, and processing these signals according to the algorithms embedded in the program; formation of voltage levels on the output lines of the port, which are necessary for control indication by LEDs; interaction with the central data collection system via the lines of the asynchronous serial interface (UART) built into the microprocessor. The basic functionality of the s02 program provides for the registration of pulse input signals with the calculation of the total number of pulses received by each information channel during a fixed period of time. The data obtained as a result of these measurements make it possible to calculate the current counting rate of signals from all neutron detectors, on the constant measurements of which, in fact, regular monitoring of the intensity of cosmic rays is based.

Figure 4 shows schematic diagram of program complex which is used in the system for collecting data from neutron detectors of the Tien Shan high-altitude scientific station.

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Figure 4 – Schematic diagram of the software for control measurements at the Tien Shan Scientific Station

The duration of the time interval during which the input signals are counted - the exposure duration - can be determined both by the s02 program itself, which uses one of the internal timers built into the microprocessor for this purpose or set externally by commands from an external (central) data acquisition system. Typical exposure times with regular monitoring of the intensity of neutron signals are units and tens of seconds.

Along with the basic functionality, the existing versions of the s02 program allow to continuously monitor the current flow of input signals and conduct its analysis in real time according to a number of additional algorithms included in the program: registration of the moments of arrival of input signals and construction in the local memory of the microprocessor of their intensity distributions in time with high (microsecond) resolution; generation of an internal (logical) and processing of an external trigger signal to synchronize temporal distributions of intensity measured with a high resolution (which, thus, can be recorded with reference to various external events, for example, to the passage of air showers, in contrast to the basic regular measurements of the monitoring type); internal formation of coincidence signals between input pulses and registration of their intensity with both low and high temporal resolution; internal formation of events with different "multiplicity" of neutron pulses according to a number of arbitrary, embedded in the program, algorithms, and registration of the intensity of these signals.

The s02 is programmed in *C* using the libopencm3 open program library [4]. The latter is used for programming a low-level part of the hardware interface that depends on the characteristics of a particular processor type and is necessary to support systems that are built on microprocessors of the ARM Cortex architecture (in particular, the STM32F407 microcontroller used in the information system under consideration belongs to this type of processors). The source code of the s02 program is converted into a machine-specific, for a given processor, binary code using a set of development tools, which is built on the basis of a free open source C compiler (the arm-gcc program) [5]. The resulting compiled binary file with machine code, which is intended for direct execution by the microprocessor, is loaded into the internal memory of the latter using the ST-Link interface chip built into the STM32F4Discovery board. A public program from STMicroelectronics [6] is used to control the download interface.

Through the asynchronous serial interface built into the microprocessor and (external to the microprocessor) UART↔USB line converter, the autonomous subsystem interacts with the central computer, which provides general control of the data collection process: setting the configuration of the measuring system; starting and stopping registration programs; reception, necessary processing and display of measurement results. All information exchange between the central computer and the autonomous subsystem of data collection takes place in the form of an exchange of simple text messages of the form <parameter name> = <value>, which, in the simplest case, allows initial configuration and control of the operation of an autonomous microprocessor system using standard terminal programs of the general purpose without resorting to any specialized means of controlling the measuring installation. The central computer, to which all autonomous microprocessor boards are connected, runs under the free Linux operating system, which provides the launch of specialized data collection programs and the necessary interaction with external machines (database server, Internet server) via network communication lines. Information exchange through communication lines with autonomous subsystems, which are connected to the USB port of the central computer, is provided through the USB driver included in the Linux operating system. Due to the use of this driver, for the programs running on the central computer, the interface with each of the autonomous subsystems is represented as a file open for writing and reading (/ dev / ttyUSB0 and / dev / ttyUSB1), so that data exchange between the programs of the central computer and the built-in microprocessor the s02 program can be done by standard system requests read, write, addressed to these files. On the part of the control computer, the v05001 program launched on it interacts with the external microprocessor system, which serves to transmit configuration commands to the autonomous subsystem when initiating the next measurement session; constant monitoring of the current state of the autonomous subsystem; sampling, if necessary, of the data accumulated in the internal memory of the autonomous subsystem and storing this data in a local file on the disk of the central computer. Periodically, another program, v05002, is activated on the control computer, which selects the information records accumulated in the local file and sends them over the network to an external database server. Ultimately, the results of all measurements are concentrated in two database tables: in the varitien table, where measurements of the number of signals received from neutron counters are written, which are made regularly with a minute periodicity and are used to study variations in the global flux of cosmic rays, and in the shshower table, where records on the distribution of the intensity of neutron signals in time after the passage of air shower, measured with a high temporal resolution (tens and hundreds of microseconds) and synchronized with the trigger of the shower facility. The database of the Tien Shan high-altitude station provides long-term storage of this information and access to it by third-party programs for processing and visualizing neutron data.

The r09007 program is intended for work with the distributions of neutron signals that were measured with a high temporal resolution after the passage of air shower and are stored in the shshower table of the database. In addition to its main functionality - visualization of time distributions in text or graphical form for viewing and manual editing, this program provides connection of external modules r09007exe, which are used to process information in automatic mode. Each such module is an autonomous program that implements one of the specific data processing algorithms: filtering registered events by some criterion, constructing time distributions averaged over many shower events, calculating the total multiplicity of neutron signals in individual events, etc. operations. Examples of displaying information related to the registration of neutron signals at the Tien Shan scientific station using the programs listed above are shown in Figure 5. The results obtained show a high stability of the functioning of the software and hardware complex for a long time.



Figure 5 – Continuous recording of variations in the intensity of cosmic rays and events of various multiplicity for the period 2020-2021

**CONCLUSION**

Brief conclusions based on the results of research for 2020-2021

2020: For the reporting period of 2020, a system of detectors was developed for recording the neutron-forming component of an EAS, based on gas-discharge counters 3He. The amplitude spectra of neutron counters were obtained using a pulsed analog to digital converter circuit.

2021: During the reporting period, a system of detectors was created and tested for recording the neutron-forming component of air shower, based on 3He gas discharge counters. We developed software for the operation of neutron detectors based on 3He gas-discharge counters.

It was found that the probability of detecting neutrons in the detector is practically independent of the type of angular distribution of the neutron flux incident on the detector. Therefore, it can be concluded that the detectors themselves, created on the basis of PD631 gas discharge counters, have a noticeable efficiency, with a neutron detection probability of 1%, in the energy range, which starts from thermal values and continues up to (0.1–0.3) keV. In this case, such detectors turn out to be the most sensitive to neutrons with kinetic energies En ≃ (0.01–0.1) eV, and in the region of high energies, its efficiency decreases in inverse proportion to √En.

For all neutron detectors, simultaneous recording of two types of data is provided: regular measurements of the neutron count rate with a constant period of the order of several seconds and precision recording of the form of the temporal distribution of signal intensity for a certain period after the passage of the front of air showers.

During the reporting period, we developed software that is used in the system for collecting data from neutron detectors of the Tien Shan high-altitude scientific station. The results obtained demonstrate a high stability of the functioning of the software and hardware complex. This, in turn, was maintained continuously for a long time.

Assessment of the completeness of solutions to the assigned tasks

The planned target for 2021 under the program was completed in full and in accordance with the calendar plan and technical specification.

1 young specialist took part in the Project.

Recommendations for the specific use of the results

The results of the work will be applied in further research.

Assessment of the scientific and technical level of research and development in comparison with the best achievements in this area.

The scientific and technical level of research and development work is at the proper height and corresponds to the achievements of modern world science in the field of high energy physics and cosmic rays.

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**APPENDIX A**

**Publications for 2021**

List of publications in journals indexed by Web of Science, Scopus foreign information resources

1.S. B. Shaulov, L. I. Vil'danova, E. A. Kupriyanova, V. A. Ryabov, A. L. Shepetov. Scaling violation in interaction of cosmic ray hadrons and the nature of the 3 PeV knee in the spectrum of primary cosmic rays // Submitted to: J. Phys. G: Nucl. Part. Phys. (in the press)

2. Shepetov A., Antonova V., Kalikulov O., Kryakunova O., Karashtin A., Lutsenko V., Mamina S., Piscal V., Ptitsyn M., Ryabov V., Sadykov T., Saduev N., Salikhov N., Shlyugaev Y., Vildanova L., Zhukov V., Gurevich A. The prolonged gamma ray enhancement and the short radiation burst events observed in thunderstorms at Tien Shan. // Atmospheric Research. - 2021.-Vol. 248, 105266 (Scopus percentile 94% Q1, IF = 4.676 in Web of Science) https://doi.org/10.1016/j.atmosres.2020.105266

List of publications in Kazakhstan editions recommended by the Committee for Control in the Sphere of Education and Science of the Ministry of Education and Science

3. Vildanova L.I., Novolodskaya O.A., Sadykov T. Kh., Kantarbaeva D.O. Efficiency of registration of low-energy neutrons by neutron detectors based on gas-discharge counters 3Hе // News of the national academy of sciences of the republic of Kazakhstan physico-mathematical series. - 2021.-Volume 2, Number 336.- p. 152 - 156.https: //doi.org/10.32014/2021.2518-1726.35 (KKSON MES RK IF = 0.484)

**CALENDAR PLAN**

1. **LLP “Institute of physics and technology”**
	1. Priority: Scientific research in the field of natural sciences.
	2. Subpriority: Fundamental and applied research in the field of physics and astronomy
	3. Project name: IRN APO8955730 “Creation of a detectors system for recording the neutron-forming component of powerful air showers with a low energy detection threshold”.
	4. Total amount of the project is 5 000 000 (five million) tenge, including by year, according to point 3:
* 2020 – amount of 3 000 000 (three million) tenge;
* 2021 – amount of 2 000 000 (three million) tenge;
1. **Characteristics of scientific and technical products by qualification parameters and economic indicators**
	1. Direction of the project: Fundamental research.
	2. Application area: Natural sciences.
	3. Final result:
* For 2020: We will develop detectors system for neutron registration based on 3He gas discharge counters.
* For 2021: We will create and test a detectors system for neutron registration based on 3He gas discharge counters. We will develop programs for operation of gas discharge counters.

As a result of the Project, we will publish 1 (one) scientific paper published in a peer-reviewed scientific journal in the scientific direction of the project, included in 1 (first), 2 (second) or 3 (third) quartile of Web of Science base or having not less than 50 (fifty) percentile in CiteScore base and 1 (one) scientific paper, published in foreign journal or in domestic journal with non-zero impact factor (recommended by the Committee for Control in the Sphere of Education and Science).

* 1. Patentability: patentable.
	2. Scientific and technical level (novelty): Creation of the detectors system based on 3He counters gives possibility to explore previously non-investigated fluxes of thermal neutrons in the area of the trunk of air shower. This will qualitatively expand the dynamic range and information measurements of hadron component.
	3. The use of scientific and technical products is carried out by: executor.
	4. Type of use of the result and (or) scientific and technical activity: The obtained results will be published in scientific journals, patented, presented in international conferences and presented in mass media.
1. **Name of work, Execution period and results**

|  |  |  |  |
| --- | --- | --- | --- |
| Number of the work | Name of the work, according to agreement and general stages of their execution\* | Implementation period\* | Expected result\* |
| beginning | end |
| **2020** |
| 1 | Development of detectors system for registration of thermal neutrons based on 3He counters | January 2021 | April 2021 | We will develop a detectors system for registration of thermal neutrons based on 3He counters. |
| **2021** |
| 2 | Creation of detectors system for registration of thermal neutrons based on 3He counters in the amount of 10 pcs. | April 2021 | July 2021 | We will create the detectors system for registration of thermal neutrons based on 3He counters in the amount of 10 pcs. |
| 3 | Testing of detectors system for registration of thermal neutrons based on 3He counters in the amount of 10 pcs. | April 2021 | July 2021 | We will test the detectors system for registration of thermal neutrons based on 3He counters in the amount of 10 pcs. |
| 4 | Software engineering for operating of gas discharge detectors | July 2021 | October 2021 | We will develop software for operating of gas discharge detectors. We will publish 1 (one) scientific paper published in a peer-reviewed scientific journal in the scientific direction of the project, included in 1 (first), 2 (second) or 3 (third) quartile of Web of Science base or having not less than 50 (fifty) percentile in CiteScore base and 1 (one) scientific paper, published in foreign journal or in domestic journal with non-zero impact factor (recommended by the Committee for Control in the Sphere of Education and Science). |

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| By customer:Chairman of Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan:**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Kurmangalieva Zh.D.** | By executor:Director of LLP “Institute of Physics and technology”\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**Serikkanov A.S.]**Acknowledged by:Project manager\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**Vil’danova L.I.**(signature)  |
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