E13-2020-35

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RADIATION MONITORING OF THE SLOW CONTROL ELECTRONIC EQUIPMENT OF THE **NICA-MPD** DETECTOR

Presented at XLVI IEEE–SPIE Symposium 2020, August 31 – September 6, 2020, Wilga, Poland

Submitted to "Photonics Applications in Astronomy, Communications, Industry, and High Energy Physics Experiments"

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Банцер А. и др. E13-2020-35

Радиационный мониторинг электронного оборудования системы медленного контроля детектора NICA-MPD

Одним из компонентов ионного ускорительного комплекса NICA, сооружаемого в ОИЯИ (Дубна), является MPD (Multi-Purpose Detector). Его работа отслеживается и управляется системой медленного контроля. Электронное оборудование этой системы размещено в телекоммуникационных серверных шкафах рэкового типа, расположенных на поддерживающей многоэтажной механической конструкции. Проект под названием «Прототип дозиметрической системы для электронного оборудования системы медленного котроля в экспериментах на комплексе NICA» начат для разработки прототипа дозиметрической системы постоянного мониторинга электронных устройств в составе системы медленного контроля оборудования MPD и его защиты от ионизирующих излучений. Система будет оснащена средствами оповещения для информирования уполномоченного персонала о пересечении безопасного порога излучения, выше которого оборудование может выйти из строя. В статье описывается актуальное состояние этой системы и планы ее усовершенствования. Более подробно показана логическая структура управляющей программы и ее функционал.

Работа выполнена в Лаборатории физики высоких энергий им. В. И. Векслера и А. М. Балдина ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна, 2020

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Radiation Monitoring of the Slow Control Electronic Equipment of the NICA-MPD Detector

One of the components of the Nuclotron-based Ion Collider fAcility (NICA) Complex being built at JINR (Dubna) is Multi-Purpose Detector (MPD). Its work is monitored and controlled by the Slow Control system. The electronic equipment of this system is placed in the racks located on the multilevel mechanical support construction. “The prototype dosimetry system to protect NICA Slow Control electronic equipment” project was started to design a prototype dosimetry system for continuous monitoring of the MPD Slow Control electronic devices to protect it against accidental ionizing radiation. The system will be fitted out with alarming features to inform the chosen persons about crossing a safe threshold of the radiation above which the electronics will be possibly destroyed by the irradiation. The article describes the actual state of this system and the plans for its upgrading. Logical structure of the control program and its functionality are shown in detail.

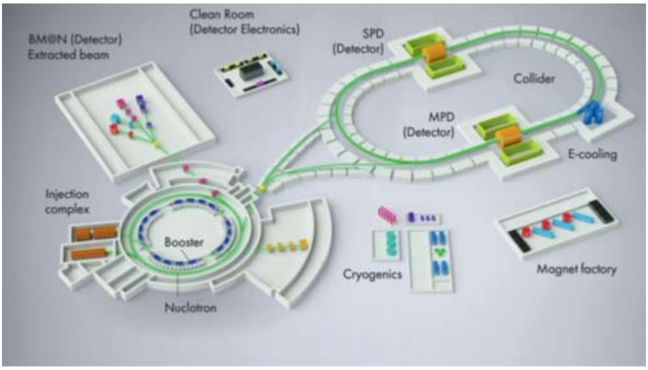
The investigation has been performed at the Veksler and Baldin Laboratory of High Energy Physics, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna, 2020

1. NICA COMPLEX AND MOTIVATION

A failure can always happen. But when we are aware of a failure type, we are able to minimize its effects. A new collider complex, called the Nuclotron-based Ion Collider fAcility (NICA) is built at the Joint Institute for Nuclear Research (JINR) in Dubna [1] (Fig. 1, top). Its purpose is to study properties of dense baryonic matter.

The Multi-Purpose Detector (MPD) [2] with additional cosmic ray detector (MCORD) [3, 4] is a part of the NICA Complex. It is located in the specially prepared concrete room. The work of the MPD must be permanently monitored and controlled remotely. It is achieved by a specially designed set of the electronic equipment called Slow Control. All these electronics will



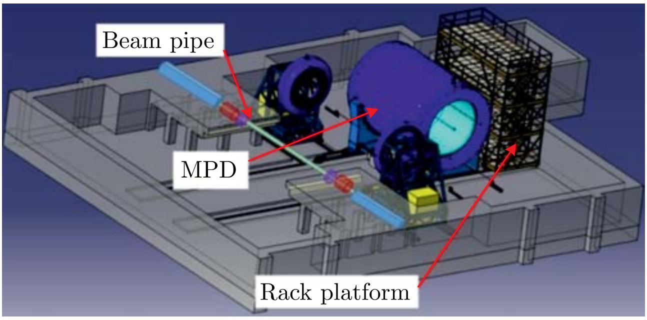


Fig. 1. Top: NICA complex; bottom: room for the MPD detector

be placed in the racks intended for this purpose (Fig. 2). The racks will be located on the mechanical support designed for this aim and standing very near of the MPD (see Fig. 1, bottom). Finally, the Slow Control devices can occupy 32 racks on this support.

Fig. 2. Example of the racks for the Slow Control electronic equipment

The radiation exposure in the MPD chamber can occur in case of any NICA's failure or its abnormal functioning. The radiation may penetrate the detector walls and irradiate the Slow Control electronics. That can destroy the devices in some cases and the NICA control would be lost. This can lead to an unexpected behavior of the MPD and even cause some accidents. In some cases, when analyzing the experimental data, it may be necessary to explain unexpectedly strange results. One of the factors influencing the stable operation of the detector control electronics is the level of radiation. The possibility of checking offline the level of radiation in the vicinity of this electronics by using the data stored in the database will make it possible, for example, to exclude radiation as a possible disturbing factor. A special dosimetry system should be designed and built, dedicated to the Slow Control electronics (Fig. 1, bottom). It must meet the following requirements:

- continuons monitoring of radiation level;
- radiation level read in fixed time intervals;
- alarming when radiation doses are too high;
- displaying of last radiation dose values on the computer monitor and writing all data to dedicated file in CSV format and to the Equipment Database (EqDb);
- informing responsible persons in case of crossing respective safety radiation level;
- reviewing of the historical data to locate the radiation leakage source.

More information about MPD Slow Control system can be found in [5].

2. SYSTEM DESCRIPTION

2.1. Hardware. The dosimetry system we build should constantly monitor the ionizing radiation on the Slow Control racks [6, 7] and start the alarm when the permissible dose is exceeded. It is expected that mostly it will be gamma radiation.

We plan to use two probe types: first for the low and medium radiation levels (EKO-C) and the second for low, medium and high radiation levels (EGM-104). Both of them use Geiger–Müller counter as a detector — the first has one counter, the second three counters. The detailed technical data of the components can be found in [5, 8–10]. The master computer communicates with them via RS-485 interface. The chosen dosimeters can be connected together in one RS-485 bus. The bus is connected to a computer with USB-RS485 converter which, in the future, will be replaced with a CompactRIO device. The connection schematic of dosimetry probes, CompactRIO and computer is shown in Fig. 3. We plan to use one EGM-104 probe and minimum one of EKO-C probes on each level of the mechanical support. The computer must be equipped with Ethernet card to communicate with EqDb to store the measurement data. More detailed information about EqDb can be found in [11].

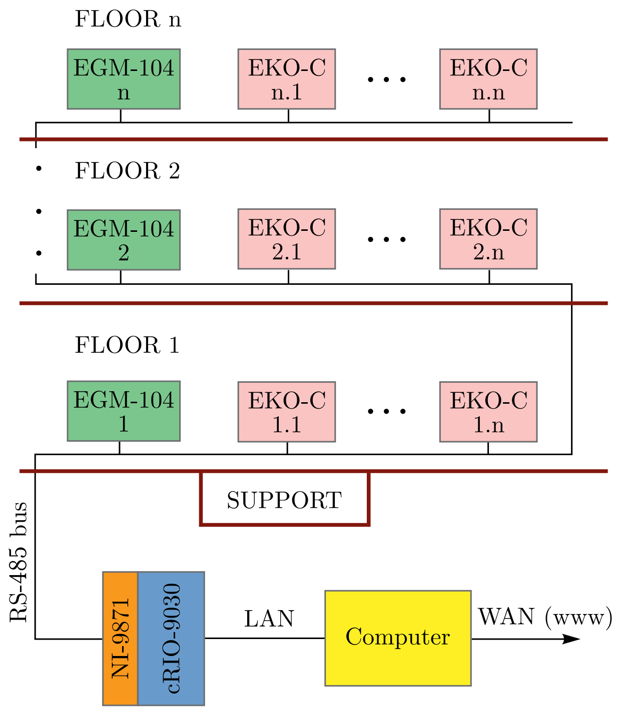


Fig. 3. The schematic of the prototype dosimetry system

2.2. Software. The dedicated software environment for the National Instrument's devices is the LabVIEW™ suit [12]. It is used for controlling the dosimetry system, data taking, visualizing and archiving. The software tasks are described in [5]. The Graphical User Interface (GUI), written in LabVIEW™, consists of three tabs:

• Run Panel — for reviewing data only, the user cannot change anything in the software or hardware configuration from this level;

• Test Panel — reviewing data, changing the system settings in limited range;

• Service Panel — full access granted for data reviewing, archiving and changing the settings of the dosimetry system (hardware and software).

The first preliminary version of the Run Panel (Fig. 4, top) and example of the Service Panel (Fig. 4, bottom) are ready so far as two different programs, not gathered yet together into one program in two tabs. It will be done in the future. All the collected data using dosimetry system are written into CSV file. This file has a special structure. It is for easily reviewing the data and creating charts from it. The file structure is as follows (Fig. 5):

• first record is a header;

• the rest lines are the collected data values;

• each line (record) ends with ⟨CR⟩⟨LF⟩.

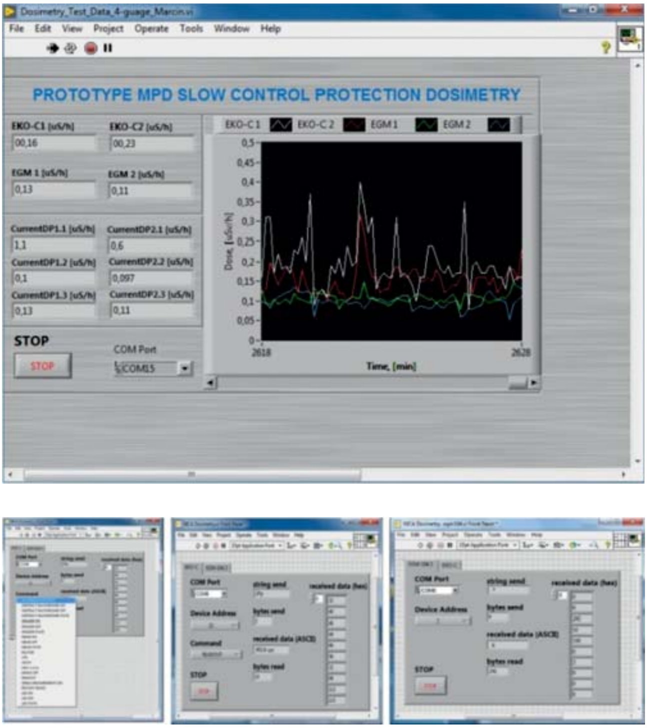
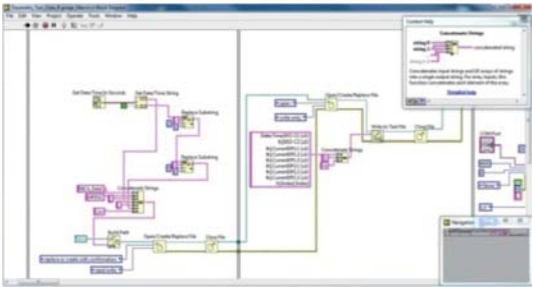


Fig. 4. Top: Run Panel GUI; bottom: Service Panel GUI (3 screenshots)



Date	Time	EKO-C1 [uS/h]	EKO-C2 [uS/h]	CurrentDP1.1 [uS/h]	CurrentDP1.2 [uS/h]	CurrentDP1.3 [uS/h]	CurrentDP2.1 [uS/h]	CurrentDP2.2 [uS/h]	CurrentDP2.3 [uS/h]	Index1	Index2
04.10.2019	11:05:07	0,1	0	0	0,423576	0	0	0	0,129262	0	0
04.10.2019	11:05:17	0,21	0,18	0	0,12547	0,08278	0	0,077575	0,097612	0	0
04.10.2019	11:05:27	0,16	0,1	0	0,133448	0,096163	0	0,132755	0,11779	0	0
04.10.2019	11:05:37	0,2	0,15	0	0,136317	0,110398	0	0,102153	0,123187	0	0
04.10.2019	11:05:47	0,16	0,14	0	0,137659	0,109052	0	0,099034	0,110193	0	0
04.10.2019	11:05:57	0,11	0,19	0	0,148868	0,102568	0	0,086948	0,106939	0	0
04.10.2019	11:06:07	0,12	0,22	0	0	0,041078	0	0,078804	0,125602	0	0
04.10.2019	11:06:17	0,13	0,23	0	0,07809	0,072013	0	0,065554	0,107654	0	0
04.10.2019	11:06:27	0,15	0,19	0	0,083558	0,082134	0	0,08148	0,123085	0	0
04.10.2019	11:06:37	0,09	0,16	0	0,068648	0,080118	0	0,08815	0,111769	0	0
04.10.2019	11:06:47	0,07	0,11	0	0,060971	0,084789	0	0,098703	0,110193	0	0
04.10.2019	11:06:57	0,12	0,13	0	0,066579	0,107165	0	0,107361	0,106941	0	0
04.10.2019	11:07:07	0,14	0,16	33,025238	0	0,08868	0	0,105905	0	0	0
04.10.2019	11:07:17	0,14	0,12	3,632849	0,031196	0,113918	0	0,112696	0,081709	0	0
04.10.2019	11:07:27	0,23	0,16	1,922145	0,058742	0,115382	0	0,114797	0,078956	0	0
04.10.2019	11:07:37	0,12	0,14	1,306782	0,085522	0,114032	0	0,116621	0,081719	0	0

Fig. 5. LabVIEW™ program example and data file structure

The flowchart (block diagram) of the Dosimetry System LabVIEW™ software is presented in Fig. 6.

The CSV file is opened at first with fixed name. The file name starts with the acronym MPDSC (MPD Slow Control) and afterwards is the date and time the file was created. The file extension is CSV which points that it is a Comma Separated Value text file with the data records. The data record fields are separated by semicolons. Each record ends with the Windows end of line (CR, LF). The data files are stored on C: disk in the NICA_Data folder. The example of the content of the file and a record structure is shown in Fig. 5, bottom.

After creating the file the COM Port is opened, and initialization of the EKO-C and EGM-104 probes starts. When initialization is finished, the Data Acquisition Loop begins. At first, the EKO-C probes are read and then the EGM-104 probes. The collected data are formed into a record and the data file is opened and the record is appended to it. Subsequently, the file is closed and after the fixed delay new Data Acquisition Loop starts.

The program can be terminated by pressing the STOP button (Fig. 4, top). It stops the data acquisition and closes the COM Port. When during the program running an error occurs, the error number and its short description are presented in the Simple Error Handler, which helps to investigate what went wrong.

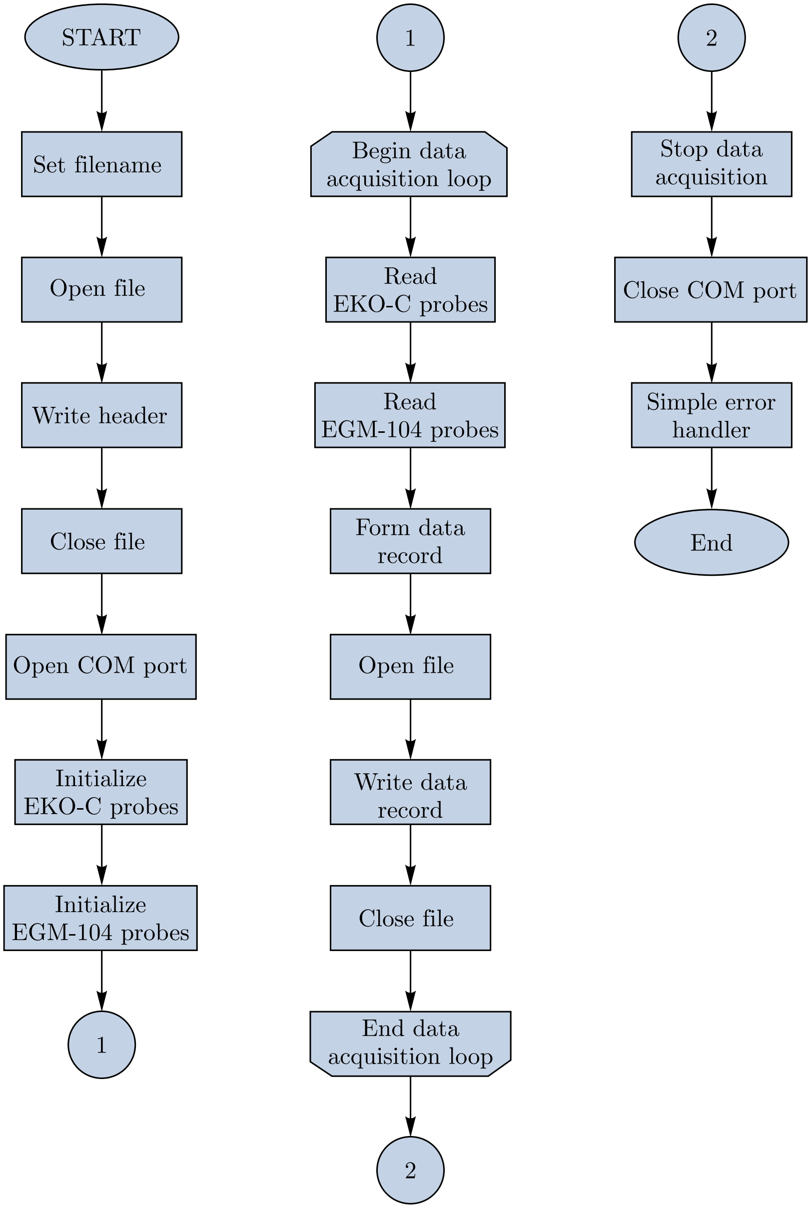


Fig. 6. LabVIEW^{TM} program flowchart

3. TESTS AND RESULTS

The test stand with prototype dosimetry system shown in Fig. 7 was established at the Joint Institute for Nuclear Research in Dubna, Russia. After performing the tests, we divided it into two identical parts and one was transported to the National Centre for Nuclear Research in Swierk, Poland. This allows one to work independently in Poland and Russia and exchange the necessary information.

The test stand was complied with the following rules:

- all dosimeters were connected to the half-duplex RS-485 bus;
- the transmission parameters are: 8-bit data, 9600 baud rate, no parity, one stop bit;
- RS-485 bus was connected to the PC computer with USB-RS485 converter;
- special connectors were made based on RJ-50 connector type;
- with these special connectors the RS-485 bus is easily expandable;
- the Run Panel GUI was displayed on an additional monitor for better view of displayed data;
- the RS-485 bus signals were tested and displayed using 4-channel oscilloscope.

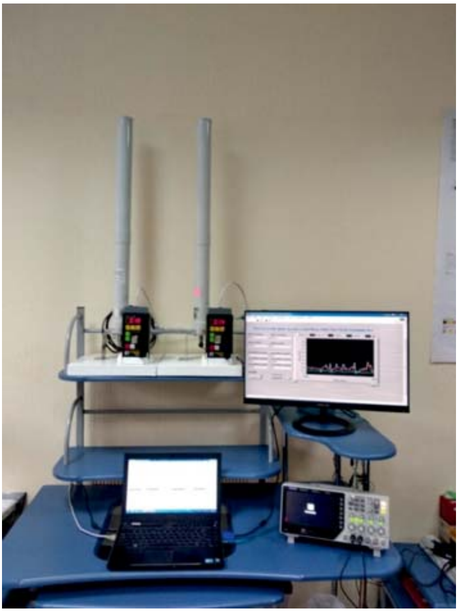


Fig. 7. Test stand at JINR

The EKO-C probes were equipped with the new RS-485 connector which is more stable and reliable than the original one. The manufacturer of this device expanded it by adding an RS-485 controller and software modifications based on our requirements and test measurement results. It uses one RJ-50 connector and the housing was printed on a 3D printer with PCV filament. The special T-branch connectors were used for connecting the probes to the bus. This construction enables to expand RS-485 with new devices. It uses three RJ-50 connectors and was printed on a 3D printer with PCV filament. This connector (RJ-50) and its cables allow one to connect the 12-V power supply into RS-485 bus. This supply is necessary for powering all the probes being on the bus. The USB-RS485 converter is connected to RS-485 bus with the use of RJ-50 connector.

In the construction of the hardware of the dosimetry system the self-made parts were applied. These parts are presented in Fig. 8 (power supply, cables, connectors and the EKO-C dosimeter base).

Fig. 8. The part of the dosimetry system. Left: the way of connecting power supply and RS-485 bus signals from USB-RS485 converter; center: T-branching signals on the RS-485 bus; right: new EKO-C connector

Figure 4 shows Run Panel GUI where the last collected data from measurements of radiation level (left side) and charts of all probes data collected during last 10 min are presented. The two upper-left fields are the data from the EKO-C probes and the next two fields beneath are the data from the EGM-104 probes. Because the EGM-104 consists of three chambers, the measured values of two EGM-104 probes are also shown. There is also the STOP button which stops the measurement loop. Next to it is the virtual COM port number to which the RS-485 converter is connected via a USB port. The collected data are written to the data CSV file. The data from this file can be easily loaded to the Microsoft Excel for better reviewing or sorting.

The described test stand was presented to the MPD project and engineering managers. They approved the proposed system and made the suggestions for adding new features and expanding the system in the future.

4. SYSTEM EXPANSION PLANS

We plan to continue the work on developing of the prototype dosimetry system adding some new features. The first step is to extend the system with neutron detector, as the present measuring system is not sensitive for a neutron at all. One of the available commercial solutions is a Thermo Fisher FHT6020 Wendi-2 Wide-Energy Neutron Detector [13], featuring high sensitivity and an excellent energy and angular response. This detector has RS-485 communication and can be integrated into the present system. Monitoring of the neutron flux is important because neutrons can activate the housing material (e.g., steel), which will generate persistent radiation, even for several hours after turning off the beam. After connecting new detectors to RS-485 bus, it is also necessary to modify the managing software to include the support for new devices. The second new feature is to add to the Run Panel GUI some new fields: the maximum radiation dose during last day and the mean radiation dose for the last day. It will give more detailed information on radiation for the user.

There are still some tasks left to accomplish:

• investigation of ionizing radiation influence on the different types of electronic devices;

• defining of the exact level of radiation dose triggering an alarm informing supervisor and other people;

• replace USB-RS485 converter with cRIO and make appropriate software modifications.

The Programmable Automation Controller (PAC) from National Instrument called CompactRIO in conjunction with NI-9871 4-port RS-485 interface C module [14] will be used to control the probes, read out the measured data and archive them. We will use the NI cRIO-9030 [15] which has the miniDisplayPort connector for connecting a display monitor directly to it.

5. SUMMARY

The paper describes the idea and construction of the dosimetry system which has been created as a part of the project "The prototype dosimetry system to protect NICA Slow Control electronic equipment" financed by the Joint Institute for Nuclear Research in Dubna, Russia. It presents its actual status and the plans to upgrade the hardware and software.

The system consists of four probes now: two EKO-C (for the low and medium radiation levels) and two EGM-104 (for low, medium and high radiation levels) connected together with RS-485 bus. Thanks to such a set of various measurement probes, the system covers a wide spectrum of gamma radiation and becomes less sensitive to erroneous readings and false indications.

The data collection is handled by the software written in LabVIEW™. The tests were done and the results are shown. The system is still under development and the directions for its expansion have been given.

The presented state of work on the system and the description of its functioning show that the designed system meets the assumptions and will become an important element improving the safety of the control electronics for the NICA-MPD detector unit. This was confirmed by the MPD project and engineering management after presenting them the working dosimetry system.

Acknowledgements. This research was supported by the Research Program for the research group at JINR and research centres in Poland by the grant of Polish Plenipotentiary to the Joint Institute for Nuclear Research Nos. Pr. 254 p. 2 (26.04.2018), Pr. 129 p. 2 (28.02.2019) and Pr. 75 p. 3 (3.02.2020).

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Received on December 1, 2020.

Редактор *Е. И. Крупко*

Подписано в печать 06.12.2021.
Формат 60 × 90/16. Бумага офсетная. Печать офсетная.
Усл. печ. л. 1,0. Уч.-изд. л. 0,86. Тираж 200 экз. Заказ № 60320.

Издательский отдел Объединенного института ядерных исследований
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www.jinr.ru/publish/