***Project (LRIP subproject) report form***

**PROJECT REPORT**

**1. General information on the project** **/ LRIP subproject**

**1.1. Scientific field**

Particle physics

**1.2. Title of the project / LRIP subproject**

SPD

 **1.3. Project (LRIP subproject) code**

02-0-1065-2007/2023

**1.4. Theme / LRIP code**

**1.5. Actual duration of the project/ LRIP subproject**

2019-2032+

**1.6. Project / LRIP subproject Leader(s)**

A. Guskov

**2. Scientific report**

**2.1. Annotation**

The Spin Physics Detector (proto-)collaboration proposes to install a universal detector in the second interaction point of the NICA collider to study the nucleon spin structure and other spin-related phenomena with polarized proton and deuteron beams at the collision energy up to 27 GeV and the luminosity up to 1032 cm-2 s-1. In the polarized ptoton-proton collisions the NICA SPD experiment will cover the kinematic gap between the low-energy measurements at ANKE-COSY and SATURNE and high-energy measurements at the Relativistic Heavy Ion Collider and the planned fixed-target experiments at LHC. Possibility for NICA to operate with polarized deuteron beams at such energies is unique.

**2.2. A detailed scientific report**

2.2.1. Description of the mode of operation and functioning of the main systems and equipment

(for the LRIP subproject).

2.2.2. A description of the conducted experiments (for experimental projects).

During the reporting period, the SPD project went through the following stages: revision of the scientific programme of the experiment, preparation and defence of the conceptual design (CDR), preparation of the technical design (TDR). The conceptual design of the facility was presented to the ProgramAdvisory Committee (PAC) for Particle Physics in January 2021 and was approved by the PAC after review by the International Advisory Committee for the SPD detector in January 2022. In January 2023, the first version of the technical design (TDR) was submitted to the PAC. In June 2021, the international SPD Collaboration was formed, its main bodies (Collaboration Board, Executive Board, Technical Board, etc.) were formed and the process of signing a Memorandum of Understanding (MoU) with the participating institutes was started.

2.2.3. A description of the research undertaken and the results obtained.

The SPD is planned to operate as a universal facility for comprehensive study of the unpolarized and polarized gluon content of the nucleon at large Bjorken-*x*, using different complementary probes such as: charmonia, open charm and prompt photon production processes. The experiment aims to provide access to the gluon helicity, gluon Sivers and Boer-Mulders functions in the nucleon, as well as the gluon transversity distribution and tensor PDFs in the deuteron, via the measurement of specific single and double spin asymmetries These functions reflect the fundamental properties of the nucleon but the most of them are poorly known at the moment. The results expected to be obtained by the SPD will play an important role in the general understanding of the nucleon gluon content and will serve as a complementary input to the ongoing and planned studies at RHIC, and future measurements at the EIC (BNL) and fixed-target facilities at the LHC (CERN). Other polarized and unpolarized physics, such as spin effects in elastic and inelastic p-p and d-d collisions, multiquark correlations and states, charm production near the threshold, hyperon polarization, etc., is possible especially at the first stage of NICA operation with reduced luminosity and collision energy of proton and ion beams.

2.2.4. A list of the main publications of the JINR authors, including associated personnel on the results of the project (list of bibliographical references).

[1] A. Arbuzov *et al.*, *On the physics potential to study the gluon content of proton and deuteron at NICA SPD Prog. Part. Nucl. Phys. 119**(2021), 103858* [hep-ex/201115005]

[2] V. V. Abramov *et al.*, *Possible studies at the first stage of the NICA collider operation with polarized and unpolarized proton and deuteron beams* [hep-ex/210208477] Physics of Particles and Nuclei volume 52, pages 1044–1119 (2021)

[3] V. M. Abazov *et al.* [SPD Collaboration], *Conceptual design of the Spin Physics Detector* [hep ex/210200442].

[4] SPD Collaboration, *Technical design of the Spin Physics Detector http://spd.jinr.ru/wp-content/uploads/2023/03/TechnicalDesignReport\_SPD2023.pdf*

2.2.5. A complete list of publications (electronic annex, for journal publications with journal impact factor).

*1) A. Arbuzov et al., On the physics potential to study the gluon content of proton and deuteron at NICA SPD Prog. Part. Nucl. Phys. 119**(2021), 103858 [hep-ex/201115005]* **IF 12.30**

*2) V. V. Abramov et al., Possible studies at the first stage of the NICA collider operation with polarized and unpolarized proton and deuteron beams [hep-ex/210208477] Physics of Particles and Nuclei volume 52, pages 1044–1119 (2021)* **IF 0.71**

*3) N. Barlykov, et al., MiniSPD Stand for Testing Si-Detectors, Nonlin.Phenom.Complex Syst. 25 (2022) 3, 254-265* **IF 0.47**

*3) V. Bautin, et. al., VMM3 ASIC as a potential front end electronics solution for future Straw Trackers, NIM A 2023, 167864* **IF 1.36**

*4) A. P. Potylitsyn, B. A. Alekseev, A. V. Vukolov, M. V. Shevelev, A. A. Baldin, V. V. Bleko, P. V. Karataev, A. S. Kubankin, Monochromatic Optical Cherenkov Radiation of Moderately Relativistic Ions in Radiators with Frequency Dispersion, JETP Letters, 115, 8, 439-443, 2022* **IF 0.57**

*5) M. Baznat, et. al., Cascade Models in Simulation of Extended Heavy Targets Irradiated by Accelerated Proton and Deuteron Beams, Physics of Particles and Nuclei Letters, 53, 5, 1219, 2022* **IF 0.57**

*6) P. G. Filonchik, M. V. Zhabitsky, Fast way to determine pp-collision time at the SPD experiment, submitted to PEPAN Letters* **IF 0.57**

*7) H.G. Khodzhibagiyan et. al., Solenoid for Spin Physics Detector at NICA from the Nuclotron-Type Superconducting Cable, Phys.Part.Nucl.Lett. 19 (2022) 4, 397-401* **IF 0.57**

*8) В.М. Абазов, et. al., СТЕНД ДЛЯ ИЗМЕРЕНИЯ НАТЯЖЕНИЯ ПРОВОЛОК В ПРОВОЛОЧНЫХ КАМЕРАХ, Письма в ЭЧАЯ. 2022. Т.19, № 5(244). С.398–404* **IF 0.57**

*9) V. Alexakhin, A. Guskov, Z. Hayman,et al. On the Study of Antiprotons Yield in Hadronic Collisions at NICA SPD. Phys. Part. Nucl. Lett. 18 (2021) 196–201* **IF 0.57**

*10) V. Dormenev et al., Multipurpose Ce-doped Ba-Gd silica glass scintillator for radiation measurements, Nucl. Instrum. Meth. A 1015 (2021) 165762*

*11) V.M. Abazov et al. , SPD Range (Muon) System, Phys. Part. Nucl. 52 (2021) 797–800* **IF 0.71**

*12) V.F. Andreev et al., Software for Tracks and Primary Vertex Reconstruction for the SPD Experiment, Phys. Part. Nucl. 52 (2021) 793 – 796* **IF 0.71**

*13) V.N. Azorskyi et al., Electromagnetic Calorimeter for the SPD Experiment, Phys. Part. Nucl. 52 (2021) 772-778* **IF 0.71**

*14) V.E. Kovtun, T.V. Malykhina, CALCULATION OF THE MOLIÈRE RADIUS FOR VARIOUS CONFIGURATIONS OF AN ELECTROMAGNETIC SAMPLING CALORIMETER ECal SPD NICA, VANT 133 (2021), 3, 86-90* **IF 0.31**

*15) O.P. Gavrishchuk, V.E. Kovtun, T.V. Malykhina, EFFECT OF ENERGY LEAKAGE ON THE ENERGY RESOLUTION OF E.M. SAMPLING CALORIMETERS, VANT 133 (2021), 3, 76-80* **IF 0.31**

*16) A. Guskov, Physics with prompt photons at SPD, J. Phys.: Conf. Ser. 1435 (2020) 012035* **IF 0.48**

*17) I. Denisenko at al., Physics with charmonia at the SPD experiment, J. Phys.: Conf. Ser. 1435 (2020) 012034* **IF 0.48**

*18) V.F. Andreev, Comparison of Algorithms for Reconstructing the Primary Interaction Vertex for the SPD Experiment, Bulletin of the Lebedev Physics Institute 48 (10, 2021): 301-306* **IF 0.45**

*19) O.P. Gavrishchuk, V.E. Kovtun, T.V. Malykhina, Simulation Study of Energy Resolution of the Electromagnetic Shashlyk Calorimeter for Different of Layers and Absorber Combinations, East European Journal of Physics 3 (2020) 73-80* **IF 0.37**

2.2.6 List of talks given at international conferences and meetings (electronic annex).

*1) A. Datta, Quarkonium Physics at SPD NICA, Quarkonia as Tools 2022, 9-15 January 2022, Aussois, France, remote talk*

*2) A. Zhemchugov, Применение метода максимального правдоподобия для оценки параметров траекторий элементарных частиц в задаче реконструкции внутреннего детектора эксперимента SPD NICA, Information and Telecommunication Technologies and Mathematical Modeling of High-Tech Systems 2022*

*3) V. Bautin, VMM3a ASIC as a potential front-end electronics solution for future Straw Trackers (ITTMM 2022), Moscow, Russia, April 18-22, 2022*

*4) E. Kokoulina, MiniSPD stand for testing Si-detector, XXIX International Seminar Nonlinear Phenomena in Complex Systems, Minsk, Belarus, June 21-24, 2022*

*5) E. Kokoulina, Study of soft photons at SPD/NICA setup, XXIX International Seminar Nonlinear Phenomena in Complex Systems, Minsk, Belarus, June 21-24, 2022*

*6) Yu. Uzikov, Possible Physics Studies at the First Stage of the NICA SPD Programme, LXXII International Conference “Nucelus-2022: Fundamental problems and applications”, Moscow, July 11-16, 2022*

*7) A. Guskov, Gluon physics at SPD (JINR), Correlations in Partonic and Hadronic Interactions (CPHI2020), 07-10 March 2022, Duke University, Durham, NC, remote talk*

*8) A. Guskov, NICA-SPD project, International Workshop on Hadron Structure and Spectroscopy 2022 (IWHSS-2022), Geneva, Switzerland*

*9) I. Denisenko, SPD experiment at JINR, 9th International Conference on Quarks and Nuclear Physics (QNP2022), 5-9 September 2022. Conference center Gustav Stresemann Institute, Bonn, Germany, remote talk*

*10) Yu. Uzikov, Suggestions for studies at the first stage of the NICA SPD physical programme, The IV International Scientific Forum “Nuclear science and Technologies”, 26-30 September 2022, Kazakhstan, Almaty*

*11) A. Datta, Spin Physics Detector (SPD) at NICA, The 6th International Conference on Particle Physics and Astrophysics (ICPPA-2022), (from the 29th of November to the 2nd of December, Moscow, Russia*

*12) E. Kokoulina, MiniSPD test bench for testing of SPD detector prototypes, The 6th International Conference on Particle Physics and Astrophysics (ICPPA-2022), (from the 29th of November to the 2nd of December, Moscow, Russia*

*13) A. Allakhverdieva, Detector description and GeoModel, The 6th International Conference on Particle Physics and Astrophysics (ICPPA-2022), (from the 29th of November to the 2nd of December, Moscow, Russia*

*14) T. Enik, Straw detectors in the future experiments, The IV International Scientific Forum “Nuclear science and Technologies”, 26-30 September 2022, Kazakhstan, Almaty*

*15) V. Bautin, Online Gas Gain Monitoring System, The XXVI International Scientific Conference of Young Scientists and Specialists (AYSS-2022), 24-28 October, Dubna*

*16) D. Rusov, Deep tracking for the SPD experiment, The XXVI International Scientific Conference of Young Scientists and Specialists (AYSS-2022), 24-28 October, Dubna*

*17) A. Guskov, SPD detector at NICA, XVIII Mexican Workshop on Particles and Fields, November 21-25 2022, Puebla city, Mexico, remote talk*

*18) A. Zhemchugov, Spin Physics Detector at NICA, Sixth Biennial “Workshop on Discovery Physics at the LHC” (Kruger2022), 5-9 December 2022, Kruger National Park, SAR*

*19) V. Ladygin, Spin Physics Detector at NICA, 24-th International Spin Symposium, SPIN2021, 18-22 October 2021, Matsue, Japan*

*20) O. Gavrischuk Simulation Studies of the Moliere Radius for EM Calorimeter, XXVII-th INTERNATIONAL CONFERENCE ON CHARGED PARTICLE ACCELERATORS, September 21–24, 2021, Kharkiv, Ukraine*

*21) A.Datta, Probing of the Gluon Helicity Distribution at SPD, LXXI-st International Conference “Nucleus-2021. Nuclear physics and elementary particles. Nuclear technologies”, 20-25 September 2021, St.Petersburg, Russia*

*22) V.Kim, Physics with the SPD experiment at NICA collider, LXXI-st International Conference “Nucleus-2021. Nuclear physics and elementary particles. Nuclear technologies”, 20-25 September 2021, St.Petersburg, Russia*

*23) A.V. Tishevsky et al., Scintillation detector prototype for Beam-Beam Counter at NICA SPD, LXXI-st International Conference “Nucleus-2021. Nuclear physics and elementary particles. Nuclear technologies”, 20-25 September 2021, St.Petersburg, Russia*

*24) A. Guskov, Spin Physics Detector project at JINR, 22-nd PANIC21 Conference, 5-10 September 2021, Lisbon, Portugal*

*25) A. Guskov, Spin Physics Detector project at JINR, 20-th Lomonosov Conference on elementary particle physics, 19-25 August 2021, MSU, Moscow, Russia*

*26) E. Tomasi, The NICA-SPD project: a new tool to investigate the hadron structure, 19-th International Conference on Hadron Spectroscopy and Structure in memoriam Simon Eidelman (HADRON2021), 26-31 July 2021, Mexico City, Mexico*

*27) A. Zhemchugov, Offline Software and Computing for the SPD experiment, The 9th International Conference “Distributed Computing and Grid Technologies in Science and Education” (GRID’2021), 5-9 July, 2021, Dubna, Russia*

*28) V. Andreev, Offline Software and Computing for the SPD experiment, The 9th International Conference “Distributed Computing and Grid Technologies in Science and Education” (GRID’2021), 5-9 July, 2021, Dubna, Russia*

*29) A. Gribovsky, Status of Spin Physics Detector at NICA, 5-th TIPP2021 Conference, 24-28 May 2021, Vancouver, Canada*

*30) L. Afanasyev, DAQ at Spin Physics Detector, XXVIII International Workshop on Deep-Inelastic Scattering and Related Subjects, Stony Brook, 12-16 April 2021*

*31) A. Korzenev, SPD experiment at NICA, International Conference on Deep-Inelastic Scattering and Related Subjects, 12-16 April, 2021, Stony Brook, NY, USA*

*32) I. Denisenko, Physics with charmonia at the SPD experiment, Quarkonia as Tools 2021, 22-26 March 2021*

*33) A. Tishevskiy, Study of the 16-channel scintillation detector prototype with SiPM readout, XXIV International Scientific Conference of Young Scientists and Specialists (AYSS-2020), 9-13 November 2020, JINR, Dubna, Russia*

*34) K. Salamatin, The system for parameters of working gas monitoring at MiniSPD stand, XXIV International Scientific Conference of Young Scientists and Specialists (AYSS-2020), 9-13 November 2020, JINR, Dubna, Russia*

*35) V. Burtsev, Mini-SPD test stand at JINR, XXIV International Scientific Conference of Young Scientists and Specialists (AYSS-2020), 9-13 November 2020, JINR, Dubna, Russia*

*36) E. Kasyanova, GEANT4 modeling of the mini-SPD test stand, XXIV International Scientific Conference of Young Scientists and Specialists (AYSS-2020), 9-13 November 2020, JINR, Dubna, Russia*

*37) A. Tishevskiy, Development of the scintillation detector prototypes with SiPM readout for SPD at NICA, 5-th International Conference on Particle Physics and Astrophysics (ICPPA2020), 5-9 October 2020, Moscow, Russia*

*38) L. Afanasiev, Planned free running DAQ for SPD experiment at NICA, COMPASS Front-End, Trigger and DAQ Workshop, 2-3 March 2020, CERN*

*39) V. Frolov, Disk IO Server Performance, COMPASS Front-End, Trigger and DAQ Workshop, 2-3 March 2020, CERN*

*40) A. Guskov, Gluon structure of hadrons with prompt photons at COMPASS-AMBER and NICA-SPD, Workshop on Correlations in Partonic and Hadronic Interactions (CPHI-2020), 3-7 February 2020, CERN*

*41) I. Denisenko, Physics with charmonia at the SPD and AMBER experiments, Workshop on Correlations in Partonic and Hadronic Interactions (CPHI-2020), 3-7 February 2020, CERN*

2.2.7. Patent activity (if any)

**2.3. Status and stage (TDR, CDR, ongoing project) of the project (subproject) (including percentage of implementation of the declared milestones of the project (LRIP subproject)** *(if applicable)*

TDR update

**2.4. Results of related activities**

2.4.1. Research and education activities. List of defended dissertations.

PhD Thesis by Reham Ibrahim Sayed Ibrahim. Production of Antiprotons inInteractions of Light Nuclei and theSearch for Dark Matter in Space Experiments, Cairo 2021

2.4.2. JINR grants (scholarships) received.

2.4.3. Awards and prizes.

2.4.4. Other results (expert investigation, organizational, outreach activities).

**3. International cooperation**

Actually participating countries, institutions and organizations

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Organization** | **State** | **City** | **Participants** | **Type of agreement** |
| **PNPI** | **Russia** | **Gatchina** |  | **MoU** |
| **Samara University** | **Russia** | **Samara** |  | **MoU** |
| **Lebedev Physical Institute of RAS** | **Russia** | **Moscow** |  | **MoU** |
|  **SPbSU** | **Russia** | **St-Petersburg** |  | **MoU** |
|  **SPbTU** | **Russia** | **St-Petersburg** |  | **MoU** |
| SINP MSU | **Russia** | **Moscow** |  | **MoU** |
| INR RAS | **Russia** | **Troitsk** |  | **MoU** |
| **AANL** | **Armenia** | **Yerevan** |  | **MoU** |
| Institute of Nuclear Physics (INP RK), | **Kazahstan** | **Almaty** |  | **MoU** |
| **MEPhI** | **Russia** | **Moscow** |  | **MoU\*** |
| **Belgorod University** | **Russia** | **Belgorod** |  | **MoU\*** |
| **ITEP** | **Russia** | **Moscow** |  |  |
| **IHEP** | **Russia** |  **Protvino** |  |  |
| Tomsk State University | **Russia** | **Tomsk** |  |  |
| Institute of Applied Physics of NAS | **Belorussia** | **Minsk** |  |  |
| Research Institute for Nuclear Problems of BSU | **Belorussia** | **Minsk** |  |  |
| SAPHIRE | **Santiago** | **Chilie** |  |  |
| Universidad Andres Bello | **Santiago** | **Chilie** |  |  |
| China Institute of Atomic Energy | **Beijing** | **China** |  |  |
| Tsinghua University | **Beijing** | **China** |  |  |
| **InSTEC** | **Havana** | **Cuba** |  |  |
| **iThemba** | **Cape town** | **RSA** |  |  |
| **Cairo University** | **Cairo** | **Egypt** |  |  |
| University of Belgrade, Institute of Physics | **Belgrad** | **Serbia** |  |  |

**4. Analysis of planed vs actually used resources: manpower (including associated personnel), financial, IT, infrastructure**

**4.1 Manpower** (actual at the time of reporting)

|  |  |  |  |
| --- | --- | --- | --- |
| **No.** | **Personnel category** | **JINR staff,****amount of FTE** | **JINR associated personnel,****amount of FTE** |
| 1. | research scientists | 66 |  |
| 2. | engineers | 10 |  |
| 3. | specialists | ~~4~~ |  |
|  | **Total:** | **80** |  |

**4.2 The actual estimated cost of the project/ LRIP subproject**

|  |  |  |  |
| --- | --- | --- | --- |
| **№№****п/п**  | **Names of costs, resources, funding sources**  | **Cost** **2020-2022****K$** | **Expenditure for the year previous to the reporting (2022)****K$** |
| 1. | International cooperation | **50** | **21** |
| 2. | Materials  | **701** | **320** |
| 3. | Equipment, Third-party company services  | **943** | **249** |
| 4. | Commissioning | **0** | **0** |
| 5. | R&D contracts with other research organizations  | **259** | **131** |
| 6. | Software purchasing | 27 | **0** |
| 7. | Design/construction | 0 | **0** |
| 8. | Service costs (*planned in case of direct project affiliation)* |  | **0** |
| **TOTAL:** | **1980** | **721** |

**5. Conclusion**

**6. Proposed reviewers**

**Theme / LRIP Leader**

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**Project leader (project code) / LRIP subproject**

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**Laboratory Economist**

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