Questionnaire
for HADES project prolongation (2022-2024).

A. Scientific merit

1. Goals of the experiment:

1a. The physics motivation for HADES includes the investigation of in-medium modification of light vector mesons as well as the study of dilepton continium in the warm (T<100MeV) and dense(up to $3\rho_0$) hadronic matter at SIS18, GSI. Due to good hadron identification the studies of the strange particles including so-called multistrange hyperons (Λ, Ξ, Ω) and hypernuclei are possible. Recent upgrade of HADES by electromagnetic calorimeter allows to measure the yield of photons and neutral mesons. The HADES strategy is the systematic di-electron and hadron measurements in NN, AA, pA, πN and πA collision.

1b. HADES physics program focuses on the high-statistics studies of the rare probes like di-leptops and strangeness, which provide the information on the early stage of the strong interaction in the energy range of 1-4.5 A GeV. The energy range is unique and cannot by covered by BES-II at STAR at RHIC BNL or NA61 at SPS CERN at the moment, and by BM@N and MPD at NICA JINR and CBM at FAIR in future. The theory predicts fast change of the di-lepton spectra slope in heavy ion collisions in the energy range of HADES that makes such measurements extremely important. The uniqueness of HADES measurements is the possibility to study not only proton-proton, but also neutron-proton and pion-proton collisions as the reference for heavy ion collisions and key input for the theory.

B. Achievements

2.Contributions of the JINR group:

2a. The contributions of the JINR group in hardware is the second plane of multiwire drift chambers (MWDC-II) and associated front-end electronics (FEE) based on the use of ASD-8 chip and maintenance of this equipment during data taking and between the runs. JINR participates in the upgrade program of HADES, namely, in the replace of MWDC FEE on new one based on the PASTTRECK chip. JINR group participates in the software developments for the tracking in MWDCs and momentum reconstruction, Cherenkov rings recognition in RICH, tracking in Forward Detector for the high occupancy case. JINR focuses on the study of elementary reactions at HADES in neutron-proton, proton-proton and pion-proton collisions and the theoretical interpretation of the results.

2b. The responsibilities of JINR group members within the management structure of the HADES collaboration:
V.P.Ladygin- member of Collaboration Board.
O.V.Fateev – responsible person for MWDC-II plane.

3.Publications (2019-2021):

[1] J.Adamczewski-Musch et al. (HADES Collaboration), Probing dense baryon-rich matter with virtual photons, **Nature Phys. 15 (2019) 1040.**

JINR participated in preparation and maintenance of MWDC-II during data taking, alignment procedure and MWDC data analysis.

[2] J.Adamczewski-Musch et al. (HADES Collaboration), Charged-pion production in Au+Au collisions at √sNN=2.4 GeV, **Eur.Phys.J.A 56 (2020) 10, 259.**

JINR participated in preparation and maintenance of MWDC-II during data taking, alignment procedure and MWDC data analysis.

[3] J.Adamczewski-Musch et al. (HADES Collaboration), Identical pion intensity interferometry in central Au + Au collisions at 1.23 A GeV, **Phys.Lett. B795 (2019) 446**.

JINR participated in preparation and maintenance of MWDC-II during data taking, alignment procedure and MWDC data analysis.

[4] J.Adamczewski-Musch et al. (HADES Collaboration), Identical pion intensity interferometry at √sNN=2.4 GeV: HADES collaboration, **Eur.Phys.J.A 56 (2020) 5, 140.**

JINR participated in preparation and maintenance of MWDC-II during data taking, alignment procedure and MWDC data analysis.

[5] J.Adamczewski-Musch et al. (HADES Collaboration), Directed, elliptic and higher order flow harmonics of protons, deuterons and tritons in Au+Au collisions at √sNN=2.4 GeV, **Phys.Rev.Lett. 125 (2020) 262301.**

JINR participated in preparation and maintenance of MWDC-II during data taking, alignment procedure and MWDC data analysis.

[6] J.Adamczewski-Musch et al. (HADES Collaboration), Proton-number fluctuations in √sNN=2.4 GeV Au+Au collisions studied with the High-

Acceptance DiElectron Spectrometer (HADES), **Phys.Rev.C 102 (2020) 2, 024914.**

JINR participated in preparation and maintenance of MWDC-II during data taking, alignment procedure and MWDC data analysis.

[7] J.Adamczewski-Musch et al. (HADES Collaboration), Sub-threshold production of K0s mesons and Lambda hyperons in Au+Au collisions at √sNN=2.4 GeV, **Phys.Lett. B793 (2019) 457**.

JINR participated in preparation and maintenance of MWDC-II during data taking, alignment procedure and MWDC data analysis.

[8] J.Adamczewski-Musch et al. (HADES Collaboration), Strong absorption of hadrons with hidden and open strangeness in nuclear matter, **Phys.Rev.Lett. 123 (2019) 022002.**

JINR participated in preparation and maintenance of MWDC-II during data taking, alignment procedure and MWDC data analysis.

[9] J.Adamczewski-Musch et al. (HADES Collaboration), Two-Pion production in the second resonance region in π−p collisions with HADES, **Phys.Rev.C 102 (2020) 2, 024001.**

JINR participated in preparation and maintenance of MWDC-II during data taking, alignment procedure and MWDC data analysis.

[10] J.Adamczewski-Musch et al. (HADES and PANDA Collaborations),Production and electromagnetic decay of hyperons: a feasibility study with HADES as a Phase-0 experiment at FAIR, **Eur.Phys.J. A57 (2021) 4, 138.**

JINR paricipated in the simulation for Forward Detector for high occupancy case.

[11] J.Adamczewski-Musch et al. (HADES Collaboration), Correlated pion-proton pair emission off hot and dense QCD matter, e-Print: 2012.01351 [nucl-ex], to be published in **Phys.Lett. B.**

JINR participated in preparation and maintenance of MWDC-II during data taking, alignment procedure and MWDC data analysis.

[12] J.Adamczewski-Musch et al. (TRB Collaboration), Efficiency and temporal response of p-terphenyl based wavelength shifting films on

H12700 multi anode photomultipliers, **Nucl.Instrum.Meth. in Phys.Res. A952 (2020) 161867.**

JINR is responsible for the development of the Cherenkov ring recognition.

[13] J.Adamczewski-Musch et al. (TRB Collaboration), Status of the CBM and HADES RICH projects at FAIR, **Nucl.Instrum.Meth. in Phys.Res. A952 (2020) 161970.**

JINR is responsible for the development of the Cherenkov ring recognition.

[14] A.V.Belyaev et al., On the initial approximation of charged particle tracks in detectors with linear sensing elements, **Nucl.Instrum.Meth. in Phys.Res. A938 (2019) 1.**

JINR is fully responsible for the development of the track finder algorithm based on the solve of the G.Schubert problem for 4 straight lines.

Total number of papers published in 2019-2021 is about 20.

4. PhD theses:

There is no PhD theses defended by JINR peoples.

5.Talks:

Due to Covid-19 pandemy number of talks from HADES collaboration were significantly reduced, especially, in 2020.

5a. There was no invited plenary talks.

5b. Parallel talk:
[1] G.Lykasov and A.Jerusalimov, Hadron and Dielectron Production in Pion-Nucleon Collisions, talk at the XXXV-th HADES Collaboration Meeting, 11-15 March 2019, GSI, Darmstadt, Germany.

C. Plans and requests

6.Plans

The plans of the JINR group for the period of time of the requested extension.
The main direction of HADES activity in 2020-2024 is the data taking at SIS18 using proton, deuteron, pion and Au beams. 5 proposals on SIS18

beam time requests were submitted to GSI PAC in 2020:
A) Production and decay of hyperons, and inclusive hadron and dilepton production in p+p reaction at 4.5 GeV.
B) Searching for critical behavior and limitations of the universal freeze-out line (Au+Au collisions at 0.2A-0.8A GeV).
C) Studying medium effects in proton induced reactions (p+Ag reactions at 4.5 GeV).
D) Scrutinizing iso-spin effects in N+N bremsstrahlung and dibaryon d*(2380) formation in N+P collisions.
E) Baryon coupling to mesons and virtual photons in the third resonance region: vacuum and cold matter studies (Pion induced reactions on CH2, C and Ag targets).
Proposal A has been fully approved and supported by 80 8hours shifts in 2022. Only 42 shifts were delivered for realization of the proposal B in 2022. HADES collaboration plans to resubmit to GSI PAC other proposals to obtain beam time in 2023-2024. Therefore, the plans on the data taking in 2022 are fixed.

1. JINR group will participate in the preparation and technical support of MWDC-II during the beam time, the software support during data taking and DST production.
2. JINR group is planning to take a part in the analysis of the p+p data at 4.5 GeV. The major goal is to study di-electron and hadronic observables. Also the JINR group is traditionally involved in the studies of the hadronic probes in elementary reactions. The physics includes multi-pion production in different reactions and their azimuthal correlations. Also the theoretical interpretation of HADES data will be continued. JINR group is especially interested in pion- and deuteron- induced reaction. Hopefully, SIS18 beam time will be delivered in 2023-2024.
3. JINR will take part in HADES upgrade program and physics simulation for SIS100 at FAIR. JINR team is participating in MWDC upgrade including new FEE program and software development for tracking in MWDC and Forward Detector, RICH. JINR group is planning to make a second stand on the FEE for MWDC at VBLHEP.

7. Group size, composition and budget.

7a. List the JINR personnel involved in the project and their FTE.

No	Name	Status	FTE	Duty
1	Belyaev A. V.	researcher	0.5	Software development: tracking and kin.refit
2	Fateev O.V.	researcher	0.1	MWDC maitenance and upgrade, management
3	Ierusalimov A.P.	researcher	1.0	Software developments in tracking and simulation
4	Ladygin V.P.	researcher	0.1	Physics, management
5	Reznikov S.G.	researcher	0.2	MWDC maitenance, FEE upgrade project
6	Troyan A.Yu.	researcher	0.5	Computing, simulation
7	Zinchenko A.I.	researcher	0.1	Software developments in tracking: vector finding algorithm
8	Ivanov V.V.	researcher	0.1	Software developments for RICH
9	Lebedev S.A.	researcher	0.5	Software developments for RICH, data taking
10	Lykasov G.I.	researcher	0.1	Theoretical interpretation
			3.2	

Total number of the peoples in the collaboration 120.

7b. JINR group budget is 90k$ for the period of 2022-2024 or 60k$ for the period of 2022-2023.

Expenditure items	Full cost*	2022 y.	2023 y.	2024 y.
Direct expenses for the Project				
1. Accelerator, reactor	-	-	-	-
2. Computers	-	-	-	-
3. Computer connection	-	-	-	-
4. Design bureau	-	-	-	-
5. Experimental Workshop	-	-	-	-
6. Materials	24	8	8	8
7. Equipment	21	7	7	7
8. Construction/repair of premises	-	-	-	-
9. Payments for agreement-based research	-	-	-	-
10. Travel allowance, including:	45	15	15	15
a) non-rouble zone countries	45	15	15	15
b) rouble zone countries	-	-	-	-
c) protocol-based				
Total direct expenses	90	30	30	30

* - from JINR-BMBF grant and JINR-Czech Republic Scientific Cooperation Program

PROJECT LEADER

LABORATORY DIRECTOR

LABORATORY CHIEF ENGINEER-ECONOMIST

7c. JINR is planning to use the JINR computing resources (LHEP farm) for the analysis of the data obtained at LHEP stand for new MWDC FEE based on PASTTRECK chip.