**Questionnaire (for projects seeking continuation):**

**A. Scientific merit**

1.   Goals of the experiment:

1a. Give a short description of the goals of the experiment

The Baryonic Matter @Nuclotron (BM@N) experiment will be upgraded to investigate heavy-ion collisions at beam energies of 2 – 4 AGeV, where the fireball is predicted to be compressed to 2-5 times saturation density. The goal of the experiment is to investigate both the equation-of-state (EOS) of nuclear matter at high baryon density, and to explore the degrees-of-freedom of this matter, including the search for new phases of high-density matter, which possibly feature characteristic structures like critical points.

1b. Explain what the project adds to the international scenario:

Constrain parameters of the equation of state (EOS) of symmetric and asymmetric nuclear matter at high baryon density exceeding 2-5 times saturation density:

► Measurement of collective flows of identified particles and fragments and sub-threshold production of multi-strange hyperons of Ξ- (dss), Ω- (sss) and anti-hyperons in heavy nucleus-nucleus collisions in order to constrain the incompressibility factor of high density isospin symmetric matter;

► Measurement of sub-threshold and near threshold production of particles with opposite isospin I3=±1: Σ\*+(uus)/Σ\*-(dds) as well as measurement of proton vs neutron collective flows at different beam energies in order to constrain the symmetry energy (difference between binding energy in isospin symmetric and asymmetric nuclear matter, see Fig.1) at high baryon densities;

► Search for phase transition from hadronic to partonic matter:

measurement of the excitation function of multi-strange hyperons in heavy nucleus-nucleus collisions in order to explore the onset of equilibration of multi-strange hyperons at high baryon densities; study transition to scaling of collective flow of mesons / hyperons with number of quarks (partonic matter);

► Measurement of yields, life times and masses (binding energies) of light hyper-nuclei

in order to constrain potentials of Λ-N and Λ-NN interactions

 

Figure 1: Different versions of the equation of state for isospin-symmetric nuclear matter (lower curves) and for asymmetric neutron matter (upper curves).

**B. Achievements**

2.   Contributions of the JINR group:

2a. List of the specific contributions of the JINR group in hardware (including use of JINR computing resources for the project), software development and physics analyses.

* Development of the BM@N detectors (see Fig.2 for details): Si beam profilers, Si beam tracker, beam counters, trigger Barrel and Si multiplicity detectors, Central tracker: system of forward Si detectors FwdSi, system of silicon STS detectors, system of GEM detectors, Outer tracker: system of cathode strip chambers CSC, time of flight systems ToF-400 and ToF-700, Electro-magnetic calorimeter ECAL, analyzing magnet, infrastructure of the experimental zone, data acquisition and trigger systems, slow control system
* Performing technical runs in deuteron, carbon, argon and krypton beams to prove the BM@N detector performance and record experimental data for physics analyses
* Development of the BmnRoot software framework for the event reconstruction, simulation and physics analysis
* Preliminary BM@N results on Lambda hyperon production in carbon-nucleus interactions
* Reconstruction of signals of Lambda hyperons and identification of charged kaons, pions, protons and light nucleus fragments in argon-nucleus interactions

2b. List of the responsibilities of JINR group members within the management structure of the collaboration, if any, giving the name of the JINR member, the managerial role and the appointment period.

M.Kapishin – spokesperson since 2018, leader of the BM@N project at JINR since 2014

A.Maksymchuk – project manager since 2018

Members of the Executive Committee since 2018:

N.Zamiatin, K.Gertsenberger, D.Dementiev, A.Zinchenko, V.Slepnev

3.   Publications:

List the papers published in the refereed literature (no conference proceedings) in which the JINR group had a major contribution (e.g. author of the analysis, promoter of the experiment, corresponding author, realization of a key equipment etc.). Give title of paper, reference and describe in 1-2 sentences the JINR contribution. Only papers published since the last approval of the project should be listed.

Mention the total number of papers published by the project in the same time period.

12 papers were published in the refereed journals:

M. Patsyuk (Dubna, JINR) et al., BM@N Collaboration,``Unperturbed inverse kinematics nucleon knockout measurements with a 48 GeV/c carbon beam,'' e-Print: 2102.02626 [nucl-ex], accepted by Nature Physcs, 2021

S.E. Vasiliev (Dubna, JINR), A.V. Galavanov (Dubna, JINR and Moscow Phys. Eng. Inst.), M.N. Kapishin (Dubna, JINR), V.Yu. Karjavine (Dubna, JINR), E.M. Kulish (Dubna, JINR) et al.,

‘’Characterization of GEM Detectors in the BM@N Experiment’’,

DOI: 10.1134/S1547477119060542, Published in: Phys.Part.Nucl.Lett. 16 (2019) 6, 859-865

P. Senger (Darmstadt, GSI and MEPhI), D. Dementev (Dubna, JINR), J. Heuser (Darmstadt, GSI), M. Kapishin (Dubna, JINR), E. Lavrik (FAIR, Darmstadt), Yu. Murin (Dubna, JINR), A. Maksymchuk (Dubna, JINR), H.R. Schmidt (Darmstadt, GSI), C. Schmidt (Darmstadt, GSI) and A. Senger (Darmstadt, GSI),

``Upgrading the Baryonic Matter at the Nuclotron Experiment at NICA for Studies of Dense Nuclear Matter,'' DOI: 10.3390/particles2040029, Published in: Particles 2 (2019) 4, 481-490

D. Baranov ([Dubna, JINR](https://inspirehep.net/institutions/902780)), M. Kapishin ([Dubna, JINR](https://inspirehep.net/institutions/902780)), E. Kulish ([Dubna, JINR](https://inspirehep.net/institutions/902780)), A. Maksymchuk ([Dubna, JINR](https://inspirehep.net/institutions/902780)), T. Mamontova ([Dubna, JINR](https://inspirehep.net/institutions/902780)), G. Pokatashkin (Dubna, JINR), I. Rufanov(Dubna, JINR), V. Vasendina (Dubna, JINR), and A. Zinchenko (Dubna, JINR), ‘’First Results from BM@N Technical Run with Deuteron Beam’’, doi:10.1134/S1547477118020036, Published in: Phys.Part.Nucl.Lett. 15 (2018) 2, 148-156

M.N.Kapishin (Dubna, JINR), for the BM@N Collaboration, ‘’The Fixed Target Experiment for Studies of Baryonic Matter at the Nuclotron (BM@N)’’, DOI: [10.1134/S1063778817100027](https://doi.org/10.1134/S1063778817100027) , Published in: Phys.Atom.Nucl. 80 (2017) 10, 1613-1619, Yad.Fiz. 7 (2016) 6, 543-550

M. Kapishin ([Dubna, JINR](https://inspirehep.net/institutions/902780)) for the BM@N collaboration.‘’The fixed target experiment for studies of baryonic matter at the Nuclotron (BM@N)’’, DOI: [10.1140/epja/i2016-16213-0](https://doi.org/10.1140/epja/i2016-16213-0) Published in: Eur.Phys.J.A 52 (2016) 8, 213

D. Suvarieva (Dubna, JINR), K. Gudima and A. Zinchenko (Dubna, JINR),

``A Monte Carlo Study of Lambda Hyperon Polarization at BM@N,'' Phys. Part. Nucl. Lett. 15, no.2, 182-188 (2018)

 Alexandrov E., Alexandrov I., Degtyarev A., Gertsenberger K., Filozova I.,- all from JINR, Dubna, Klimai P., Nozik A., Yakovlev A. ‘’Design of the event metadata system for the experiments at NICA’’, accepted for publication in Physics of Particles and Nuclei Letters, 2021

Gertsenberger K., Chebotov A., Alexandrov I., Filozova I., Alexandrov E. – all from JINR, Dubna, ‘’Design of the Condition Database for online and offline data processing in experimental setups of the NICA complex’’, Izvestiya SFedU. Engineering Sciences, 2020. No. 7 (217). pp. 172-180. ISSN 1999-9429, 2311-3103. DOI 10.18522/2311-3103-2020-7-172-180.

Alexandrov E. I., Alexandrov I. N., Gertsenberger K. V. et al. – all from JINR, Dubna, ‘’Information Systems for Online and Offline Data Processing in Modern High-energy Physics Experiments’’, International scientific journal «Modern Information Technologies and IT-Education», 2019. Vol. 15, No. 3, pp. 645–650.

K.Gertsenberger, S.Merts, O.Rogachevsky and A.Zinchenko, - all from JINR, Dubna,

``Simulation and analysis software for the NICA experiments,''

Eur. Phys. J. A 52 (2016) no.8, 214, doi:10.1140/epja/i2016-16214-y

K.V.Gertsenberger (JINR, Dubna),

``The unified database for the fixed target experiment BM@N,''

Phys. Part. Nucl. Lett. 13 (2016) no.5, 634-639

doi:10.1134/S1547477116050228

4.   PhD theses:

List the PhD theses completed within the last 3 years, or expected to be completed within one year, by JINR students within the project, giving the student name, thesis title and graduation year.

5.   Talks:

5a. List the invited plenary talks given by members of the JINR group at international conferences, workshops… since the last approval of the project: give name and date of the Conference,  title of talk and speaker name.

Speaker: M.Kapishin (JINR, Dubna) for the BM@N Collaboration,

``BM@N First Results'', plenary talk at 18th International Conference on Strangeness in Quark Matter SQM-2019, proceedings in Springer Proc. Phys. 250 (2020), 21-27

doi:10.1007/978-3-030-53448-6\_3

Speaker: M. Kapishin (JINR, Dubna),

``Heavy Ion BM@N and MPD Experiments at NICA,'', plenary talk at 3th International Conference on Nucleus-Nucleus Collisions (NN 2018)

JPS Conf. Proc. 32 (2020), 010093, doi:10.7566/JPSCP.32.010093

Speaker: M. Kapishin (JINR, Dubna),

``Studies of baryonic matter in the BM@N and MPD experiments at Nuclotron/NICA,'', plenary 18th Hellenic School and Workshops on Elementary Particle Physics and Gravity (CORFU2018), proceedings in PoS CORFU2018 (2019), 188, doi:10.22323/1.347.0188

Speaker: M. Kapishin (JINR, Dubna) for the BM@N Collaboration,

``Studies of baryonic matter at the BM@N experiment (JINR),'' talk at 27th International Conference on Ultrarelativistic Nucleus-Nucleus Collisions (Quark Matter 2018), proceedings in Nucl. Phys. A 982 (2019), 967-970, doi:10.1016/j.nuclphysa.2018.07.014

M.Kapishin, K.Alishina, P.Batyuk, D.Baranov, I.Gabdrakhmanov, L.Kovachev, A.Maksymchuk, V.Plotnikov, I.Rufanov, Yu.Stepanenko, V.Vasendina, N.Zamiatin, A.Zinchenko – all from JINR, Dubna, M.Zavertiaev (Lebedev PhI RAS, Moscow),

“Study of production of hyperons, strange mesons and search for hypernuclei in interactions of the carbon, argon and krypton beams in the BM@N experiment”, plenary talk at Conference "RFBR Grants for NICA", 2020, proceedings to appear in Phys. Part. Nucl. v.52 (2021) no.4

Speaker: M.Kapishin (JINR, Dubna)

Speaker:D.Dementiev (JINR, Dubna)

‘’Fast data-driven readout system for the wide aperture silicon tracking system of BM@N experiment’’, plenary talk at Conference "RFBR Grants for NICA", 2020, proceedings to appear in Phys. Part. Nucl. v.52 (2021) no.4

Speaker: Gertsenberger K. (JINR, Dubna)

‘’Development of the Information Systems for online and offline data processing in the NICA experiments’’, talk at the Conference "RFBR Grants for NICA", 2020, proceedings to appear in Phys. Part. Nucl. v.52 (2021) no.4

M.Kapishin, G.Pokatashkin, I.Rufanov, D.Suvarieva, V.Vasendina and A.Zinchenko – all from JINR,Dubna,

``Lambda hyperon reconstruction at the BM@N experiment and prospects for polarization studies'', plenary talk at Conference DSPIN – 2019, proceedings in J. Phys. Conf. Ser. 1435, no.1, 012052 (2020)

Speaker: A.Zinchenko (JINR, Dubna)

J.Gornaya (MEPhI,Moscow), M.Kapishin, V.Plotnikov, G.Pokatashkin, I.Rufanov, V.Vasendina and A.Zinchenko (all from JINR, Dubna),

``Hyperons at the BM@N experiment: first results'', plenary talk at 24th International Baldin Seminar on High Energy Physics Problems : Relativistic Nuclear Physics and Quantum Chromodynamics (ISHEPP 2018), proceedings in EPJ Web Conf. 204, 01006 (2019)

Speaker: G.Pokatashkin (JINR, Dubna)

D.Suvarieva (JINR,Dubna), K.Gudima and A.Zinchenko (JINR, Dubna),

``Lambda polarization feasibility study at BM@N,'', plenary talk at Conference ISHEPP – 2016, proceedings in EPJ Web Conf. 138, 08003 (2017)

Speaker: D.Suvarieva (JINR, Dubna)

5b. Give a similar list for parallel talks.

**BM@N detector and physics program:**

Speaker: M.Kapishin (JINR, Dubna) for the BM@N Collaboration,

``The fixed target experiment for studies of baryonic matter at the Nuclotron (BM@N),'' 6th International Conference on New Frontiers in Physics (ICNFP 2017)

EPJ Web Conf. 182 (2018), 02061, doi:10.1051/epjconf/201818202061

Speaker: G.Pokatashkin (JINR, Dubna) for the BM@N Collaboration,

``The BM@N experiment at JINR: status and physics program,'', talk at 2017 European Physical Society Conference on High Energy Physics (EPS-HEP 2017), proceedings in

PoS EPS-HEP2017 (2017), 657, doi:10.22323/1.314.0657

Speaker: D. Dementev (JINR,Dubna) for the BM@N Collaboration,

“The heavy-ion program at the upgraded Baryonic Matter@Nuclotron Experiment at NICA”, talk at the 19th International Conference on Strangeness in Quark Matter SQM-2021, 17-22 May 2021.

**Feasibility studies and detector upgrade:**

A.Zinchenko, M. Kapishin, V. Kireyeu, I. Rufanov, V. Vasendina (all from JINR, Dubna)

“Performance evaluation of the upgraded BM@N setup for the strangeness production studies”, talk at Conference "RFBR Grants for NICA" , proceedings to appear in Phys. Part. Nucl. v.52 (2021) no.4

Speaker: A.Zinchenko

A.Zinchenko (JINR, Dubna), T.Mamontova(MEPhi) and M.Kapishin (JINR,Dubna)

``Realistic Simulation of BM@N GEM Detectors: Model Implementation and Testing,'', talk at3rd International Conference on Particle Physics and Astrophysics (ICPPA 2017), proceedings in KnE Energ. Phys. 3 (2018), 385-390, doi:10.18502/ken.v3i1.1771

Speaker: A.Zinchenko (JINR, Dubna)

**Trigger detector development:**

N. A. Lashmanov, S. A. Sedykh, V. I. Yurevich (all from JINR, Dubna), ‘’Study of interaction trigger and fragmentation of beam ions for Au + Au collisions in BM@N experiment’’, talk at Conference NUCLEUS-2020, proceedings to appear in Phys. Part. Nucl. , last volume in 2021

Speaker: N.A.Lashmanov (JINR, Dubna)

V.I.Yurevich, S.A.Sedykh, S.V.Sergeev, D.N.Bogoslovski, V.Y.Rogov, V.V.Tikhomirov and N.A.Lashmanov (all from JINR,Dubna),

``Development of scintillation detectors with SiPM readout for the NICA project'', talk at International Conference on Applications of Nuclear Techniques CRETE-19, proceedings in Int. J. Mod. Phys. Conf. Ser. 50 (2020), 2060008, doi:10.1142/S2010194520600083

Speaker: V.I.Yurevich (JINR, Dubna)

V.I.Yurevich, G.N.Agakichiev, S.V.Sergeev, D.N.Bogoslovski, V.Y.Rogov, S.P.Lobastov, G.S.Averichev, V.V.Tikhomirov and A.A.Timoshenko (all from JINR, Dubna),

``Cherenkov and scintillation detectors with MCP-PMT and SiPM readout for MPD and BM@N experiments at JINR,'' talk at 8th International Conference on New Developments in Photodetection (NDIP17), proceedings in Nucl. Instrum. Meth. A 912 (2018), 294-297

doi:10.1016/j.nima.2017.11.092

Speaker: V.I.Yurevich (JINR, Dubna)

N.A.Lashmanov, S.A.Sedykh and V.I.Yurevich (all from JINR, Dubna),

``Study of the trigger on nucleus-nucleus interactions for the BM@N experiment using a Geant4 + QGSM software package,'', talk at MPPT-2019 Conference, Moscow

J. Phys. Conf. Ser. 1439 (2020) no.1, 012004

doi:10.1088/1742-6596/1439/1/012004

Speaker: N.A.Lashmanov (JINR, Dubna)

V.I.Yurevich, G.N.Agakichiev, S.V.Sergeev, D.N.Bogoslovski, S.P.Lobastov, V.Y.Rogov, G.S.Averichev, V.V.Tikhomirov, A.A.Timoshenko (all from JINR, Dubna) and O.I.Batenkov,

``Development of trigger and start detectors for experiments with high-energy heavy ions at the Joint Institute for Nuclear Research,'', talk at International Conference on Applications of Nuclear Techniques CRETE-17, proceedings in Int. J. Mod. Phys. Conf. Ser. 48 (2018), 1860122, doi:10.1142/S2010194518601229

Speaker: V.I.Yurevich (JINR, Dubna)

**Software development:**

D.Baranov, P.Batyuk, K.Gertsenberger and S.Merts (all from JINR, Dubna)

``Track Reconstruction in the BM@N Experiment,'', talk at Mathematical Modeling and Computational Physics (MMCP 2019, proceedings in

EPJ Web Conf. 226 (2020), 03003, doi:10.1051/epjconf/202022603003

Speaker: S.Merts (JINR, Dubna)

E.Akishina, E.Alexandrov, I.Alexandrov, I.Filozova, K.Gertsenberger, V.Ivanov, D.Priakhina and G.Shestakova (all from JINR, Dubna),

``Development of the Geometry Database for the BM@N Experiment of the NICA Project,'', talk at Mathematical Modeling and Computational Physics (MMCP 2019), proceedings in

EPJ Web Conf. 226 (2020), 03001, doi:10.1051/epjconf/202022603001

Speaker: I.Alexandrov (JINR, Dubna)

K.Gertsenberger, S.Merts, I.Gabdrakhmanov, I.Filozova, I.Alexandrov, E.Alexandrov, A.Moshkin and A.Chebotov, (all from JINR, Dubna)

``Software Development for the BM@N Experiment at NICA: Challenges and Status,''

talk at Mathematical Modeling and Computational Physics (MMCP 2019), proceedings in

EPJ Web Conf. 226 (2020), 03008, doi:10.1051/epjconf/202022603008

Speaker: K.Gertsenberger (JINR, Dubna)

P.Batyuk, K.Gertsenberger, S.Merts and O.Rogachevsky (all from JINR, Dubna),

``The BmnRoot framework for experimental data processing in the BM@N experiment at NICA,'' talk at Mathematical Modeling and Computational Physics (MMCP 2019), proceedings in EPJ Web Conf. 214 (2019), 05027, doi:10.1051/epjconf/201921405027

Speaker: K.Gertsenberger (JINR, Dubna)

I.R.Gabdrakhmanov and S.P.Merts (JINR, Dubna),``Development of the BM@N Web Monitoring,'', talk at Mathematical Modeling and Computational Physics (MMCP 2019), proceedings in EPJ Web Conf. 226 (2020), 03007, doi:10.1051/epjconf/202022603007

Speaker: I.Gabdrahmanov (JINR, Dubna)

The International Conference "Mathematical Modeling and Computational Physics", Stara Lesna, Slovakia ***Event Reconstruction in the BM@N Experiment***, , 2019

Speaker: Sergei Merts

The 5th International Conference on Particle Physics and Astrophysics (ICPPA-2020), National Research Nuclear University “MEPhI”, Moscow, Russia ***Primary vertex reconstruction in the BM@N experiment****,* 2020

Speaker: Sergei Merts

LXX International conference "NUCLEUS-2020. Nuclear physics and elementary particle physics. Nuclear physics technologies", Saint Petersburg State University, Saint Petersburg, Russia ***Global tracking in the BM@N experiment****,* 2020

Speaker: Sergei Merts

The Conference "RFBR Grants for NICA", Joint Institute for Nuclear Research, Dubna, Russia ***Global track and vertex reconstruction in the BM@N experiment****,* 2020

Speaker: Sergei Merts

**Detector development:**

K. Alishina, L. Kovachev, V. Plotnikov, Y. Petukhov, M. Rumyantsev (all from JINR, Dubna) “Charged particle identification by the time–of–flight method in the BM@N experiment”, talk at NUCLEUS-2020 Conference, proceedings to appear in Phys. Part. Nucl. last volume in 2021

Speaker: K. Alishina (JINR, Dubna)

Speaker: A.Maksymchuk (JINR, Dubna),

 “BM@N Experiment for Studies of Baryonic Matter at the Nuclotron”, talk at 27th International Symposium on Nuclear Electronics and Computing (NEC`2019), JINR, CERN, Budva, Becici, Montenegro

A.Galavanov, M.Kapishin, V.Karjavine, S.Khabarov, Y.Kirushin, E.Kulish, N.Kuzmin, V.Lenivenko, A.Makankin and A.Maksymchuk, et al. (all from JINR, Dubna)

``Status of the GEM/CSC tracking system of the BM@N experiment,'', talk at International Conference on Instrumentation for Colliding Beam Physics (INSTR20), proceedings in

JINST 15 (2020) no.09, C09038, doi:10.1088/1748-0221/15/09/C09038

Speaker: E.Kulish (JINR, Dubna)

A.Galavanov, M.Kapishin, V.Karjavine, S.Khabarov, E.Kulish, V.Lenivenko, A.Makankin, A.Maksymchuk, R.De Oliveira (CERN) and S.Piyadin (JINR,Dubna) et al.``Large area BM@N GEM detectors,'', talk at 6th International Conference on Micro Pattern Gaseous Detectors (MPGD2019), proceedings in J. Phys. Conf. Ser. 1498 (2020), 012043

doi:10.1088/1742-6596/1498/1/012043

Speaker: A.Maksymchuk (JINR, Dubna)

M.Kapishin, V.Lenivenko, V.Palichik, G.Pokatashkin, I.Rufanov, V.Vasendina, N.Voytishin and A.Zinchenko, (all from JINR, Dubna)

``Tracking system performance of the BM@N experiment,'', talk at 23rd International Conference on Computing in High Energy and Nuclear Physics (CHEP 2018), proceedings in EPJ Web Conf. 214 (2019), 02021, doi:10.1051/epjconf/201921402021

Speaker: N.Voitishin (JINR, Dubna)

A.Galavanov, M.Kapishin, V.Karjavine, S.Khabarov, Y.Kirushin, A.Kolesnikov, E.Kulish, V.Lenivenko and A.Makankin (all from JINR, Dubna) et al.

``Performance of the BM@N GEM/CSC tracking system at the Nuclotron beam,'', talk at 24th International Baldin Seminar on High Energy Physics Problems : Relativistic Nuclear Physics and Quantum Chromodynamics (ISHEPP 2018), proceedings in EPJ Web Conf. 204 (2019), 07009, doi:10.1051/epjconf/201920407009

Speaker: E.Kulish (JINR, Dubna)

D.Baranov, M.Kapishin, T.Mamontova(MEPhi), G.Pokatashkin, I.Rufanov, V.Vasendina and A.Zinchenko, (JINR, Dubna)

``The BM@N Experiment at JINR: Status and Physics Program,'', talk at 3rd International Conference on Particle Physics and Astrophysics (ICPPA 2017), proceedings in KnE Energ. Phys. 3 (2018), 291-296, doi:10.18502/ken.v3i1.1757

Speaker: G.Pokatashkin (JINR, Dubna)

S.Bazylev, M.Kapishin, V.Karjavine, S.Khabarov, A.Kolesnikov, E.Kulish, V.Lenivenko, A.Makankin and A.Maksymchuk, et al., (JINR, Dubna)

``Triple GEM Tracking Detectors for the BM@N Experiment,'' talk at 3rd International Conference on Particle Physics and Astrophysics (ICPPA 2017), proceedings in

KnE Energ. Phys. 3 (2018), 268-274, doi:10.18502/ken.v3i1.1753

Speaker: E.Kulish (JINR, Dubna)

M.Kapishin, V.Karjavin, E.Kulish, V.Lenivenko, A.Makankin, A.Maksymchuk, V.Palichik and S.Vasiliev, (JINR, Dubna)

``GEM Detector Performance Assessment in the BM@N Experiment,'', talk at International Conference “Mathematical Modeling and Computational Physics, 2017” (MMCP2017), proceedings in EPJ Web Conf. 173 (2018), 04007, doi:10.1051/epjconf/201817304007

Speaker: V.Lenivenko (JINR, Dubna)

D.Baranov, S.Bazylev, M.Kapishin, K.Kapusniak, V.Karjavine, S.Khabarov, A.Kolesnikov, E.Kulish, V.Lenivenko and A.Makankin et al., (JINR, Dubna)

``GEM tracking system of the BM@N experiment,'' talk at International Conference on Instrumentation for Colliding Beam Physics (INSTR17), proceedings in

JINST 12 (2017) no.06, C06041, doi:10.1088/1748-0221/12/06/C06041

Speaker: E.Kulish (JINR, Dubna)

**C. Plans and requests**

6.   Plans

Describe the plans of the JINR group within the project, in physics analysis, data taking, software development. detector R&D, detector operation and maintenance, upgrade activities… for the period of time of the requested extension.

The JINR group makes major contributions to the upgrade of the BM@N experiment:

* Development, assembly, installation and operation of all the detectors (except ZDC and a fragment hodoscope in front of ZDC) of the BM@N experiment (see Fig.2 for details): Si beam profiler, Si beam tracker, beam counters, trigger Barrel and Si multiplicity detectors, Central tracker: system of forward Si detectors FwdSi, system of silicon STS detectors, system of GEM detectors, Outer tracker: system of cathode strip chambers CSC, time of flight systems ToF-400 and ToF-700, electro-magnetic calorimeter ECAL, analyzing magnet, infrastructure of the experimental zone, data acquisition and trigger systems, slow control system,
* Major role in detector operation and maintenance, support of data bases, software development for online monitoring, track and event reconstruction and data taking.



Figure 2. Schematic view of the BM@N setup for the heavy ion program (without vacuum beam pipe). .

The JINR group makes major contributions to the realization of the BM@N physics program:

* Measurements of centrality, event plane, identification of nucleus fragments (together with the group from INR RAS, Moscow)
* Measurements of collective flow of protons, mesons and light fragments as a function of the transverse momentum pT and rapidity y in heavy ion collisions (beams from Kr,Xe to Au,Bi) as a function of the beam energy (2 – 4 AGeV)
* Measurements of Ξ- (dss) and Ω- (sss) hyperons: yields, spectra, pT vs. y from Au+Au and C+C collisions as a function of the beam energy (2 – 4 AGeV)

Aims:

►Extraction of the incompressibility factor K of high density symmetric matter by comparison results of the measurements with model predictions based on different K values;

►Search for phase transition from hadronic to partonic matter: transition to deconfinement in excitation function of Ξ- (dss), Ω- (sss) and transition to scaling of collective flow of mesons / hyperons with number of quarks (partonic matter)

* Measurements of particles with opposite isospin I3=±1: Σ\*+(uus)/Σ\*-(dds): yields, spectra, pT vs. y from Au+Au collisions in the beam energy range of 2 – 4 AGeV
* Measurements of proton vs neutron collective flows in the beam energy range of 2 – 4 AGeV (need to develope highly granulated neutron detector)

Aim:

►extraction of symmetry energy Esym (difference between the binding energy in isospin symmetric and asymmetric nuclear matter, see Fig.1) at high baryon density by comparison results of the measurements with model predictions based on different Esym values

* Measurement of hypernuclei: yields, lifetimes, masses of 3ΛH, 4ΛH, 5ΛH, 4ΛHe, 5ΛHe

Aim:

►constrain potentials of Λ-N and Λ-NN interactions by comparison with model predictions

The BM@N plans to start the first physics run with Xe beam. Expected statistics of hyperons collected per second and for 800 hours ( 33 days) of data taking is given in the Table below. The results take into account multiplicities from the PHSD model for impact parameter range b<10 fm, and the following beam and detector parameters: 4 AGeV Xe+Cs collisions, the beam intensity of 5 ∙105/s, the data acquisition rate of 0.5∙104/s, the accelerator duty factor of 0.25 and the hyperon reconstruction efficiency ε estimated from simulation. EthrNN is the kinematical threshold for the hyperon production. The hyperon statistics corresponds to 3.6∙109 interactions, 3.6∙1011 beam ions.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Particle | EthrNNGeV | Mb<10 fm | ε % | Yield/sb<10fm | Yield / 800 hours b<10 fm |
| Λ | 1.6 | 1.5 | 3 | 220 | 1.6⋅108 |
| Ξ- | 3.7 | 2.3⋅10-2 | 1 | 1.1 | 8⋅105 |
| Ω- | 6.9 | 2.6⋅10-5 | 1 | 1.3⋅10-3 | 900 |
| Anti-Λ | 7.1 | 1.5⋅10-5 | 3 | 2.2⋅10-3 | 1600 |

In the following years we foresee 2000-3000 hours of BM@N data taking per year (see the Table below). We assume the parallel operation of the Booster-Nuclotron for the BM@N experiment during data acquisition in the MPD experiment at the NICA collider.

The expected statistics of hyperons to be collected per second and for 2200 hours (3 months) of data taking is given in the last two columns of the Table below. In the Table below M(central) and M (m.bias) are the yields of hyperons per central / min bias event in Au+Au interactions at the kinetic beam energy of 4 AGeV predicted by the statistical model, ε is the estimated hyperon reconstruction efficiency, The event data acquisition rate is assumed to be 104 Hz and the accelerator duty factor is taken as 0.25. Taking into accout model predictions for hyper-nuclei yields per event and a1% reconstruction efficiency,the expected yields of hyper-nuclei ΛH3 andΛΛH5 for three months of data taking are 106 and 100, respectively. The hyperon / hyper-nuclei statistics corresponds to 2∙1010 interactions, 2∙1012 beam ions.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Particle | EthrNNGeV | Mcentral | Mm.Bias | ε % | Yield/sm. Bias | Yield / 2200 hours m. Bias |
| Ξ- | 3.7 | 1⋅10-1 | 2.5⋅10-2 | 1 | 2.5 | 5⋅106 |
| Ω- | 6.9 | 2⋅10-3 | 5⋅10-4 | 1 | 5⋅10-2 | 1⋅105 |
| Anti-Λ | 7.1 | 2⋅10-4 | 5⋅10-5 | 3 | 1.5⋅10-2 | 3⋅104 |
| Ξ+ | 9.0 | 6⋅10-5 | 1.5⋅10-5 | 1 | 1.5⋅10-3 | 3⋅103 |
| Ω+ | 12.7 | 1⋅10-5 | 2.5⋅10-6 | 1 | 2.5⋅10-4 | 5⋅102 |

7.   Group size, composition and budget.

7a. List the JINR personnel involved in the project, including name, status (e.g. PI, researcher, post-doc, student, engineer, technician…) and  FTE. Mention the total number of people in the collaboration.

The present number of participants in the author list of the BM@N Collaboration: 234

The number of participants from JINR in the author list of the BM@N Collaboration: 111

LIST OF PARTICPANTS FROM JINR:

Joint Institute for Nuclear Research – JINR (Dubna), FTE = 82

K. Abraamyan (PhD,leading scientist,0.4), P.N.Alexeev (engineer,0.5), S.V.Afanasiev (leading scientist,0.4), G.N.Agakishiev (PhD,leading scientist,0.3), I.N. Aleksandrov (PhD,leading scientist,0.3), E.I. Aleksandrov (scientist, 0.3), K.A. Alishina (PhD sudent,1.0), T.V.Andreeva (technician,1.0), T. Atovullaev (PhD student,1.0), ), N.I.Azorskiy (leading engineer,0.3), V.A.Babkin (senior scientist,0.2), V.P. Balandin (PhD,consultant,1.0), N.A.Balashov (engineer-programmer,0.2), D.A.Baranov (engineer,1.0), A.Baskakov (engineer,0.4), P.N.Batyuk (senior scientist,1.0), M. Baznat (leading scientist,0.3), S.N.Bazylev (senior engineer,0.6), V.I.Bekirov (laborant,0.5), M.G.Buryakov (engineer,0.5), D.N.Bogoslovsky (senior scientist,0.5), Yu.T.Borzunov (leading engineer,0.7), V.E. Burtsev (engineer,0.5), S.G. Buzin (engineer,0.3), A.I. Chebotov (engineer-programmer,0.5), A.E.Cheremukhin (senior scientist,0.5), B.Dabrowska (scientist,0.2), D.V. Dementev (scientist,0.7), A.V.Dmitriev(scientist,0.1), D.K.Dryablov (scientist,0.3), B.V.Dubinchik (engineer,0.5), P.O. Dulov (scientist,0.2), D.S.Egorov (engineer,0.8), V.V. Elsha (leading engineer,1.0), A.A.Fediunin (programmer,0.3), Yu.Fedotov (engineer,0.3), I.A.Filippov (engineer-programmer,0.6), A.Galavanov (junior scientist,1.0), I.R. Gabdrakhmanov (scientist,1.0), M.A.Gaganova (engineer,0.2), Gandzhelashvili (engineer-programmer,0.4), O.P.Gavrischuk (PhD,leading scientist,0.1), K.V.Gertsenberger(PhD,senior scientist,1.0), V.M.Golovatyuk (PhD,leading scientist,0.2), M.N.Kapishin (DrSc,1.0), V.Yu.Karjavin (PhD,leading scientist,0.1), L.A.Kartashova (engineer,0.7), R.R.Kattabekov (scientist,1.0), V.D.Kekelidze (Prof,0.1), S.V.Khabarov(senior scientist,1.0), P.I.Kharlamov (engineer,0.3), A.Khvorostukhin (PhD,senior scientist,0.3), D.I.Klimansky (senior engineer,0.8), Yu.T.Kiryushin (PhD,leading scientist,0.1), A.A.Kolozhvari (engineer,1.0), Y.A.Kopylov (engineer,0.4), V.A.Kosinov (engineer,0.3), Yu.S. Kovalev (senior scientist,1.0), L.D.Kovachev (junior scientist,1.0), E.M.Kulish (scientist,1.0), S.N.Kuklin(PhD,engineer-programmer,0.4), A.S.Kuznetsov(engineer,0.7), V.V.Kutergina (engineer,1.0), E.A.Ladygin(PhD,leading scientist,0.1), N.A. Lashmanov (junior scientist,1.0), V.V.Lenivenko (scientist,1.0), A.N.Livanov (leading engineer,0.2), E.I.Litvinenko(PhD,senior scientist,0.1), A.M. Makan'kin (senior engineer,0.5), V.I.Maksymenkova (technician,0.4), A.I.Maksymchyuk (senior scientist,0.8), A.I.Malakhov (Prof,0.1), D.G.Melnikov (programmer,0.8), G.J.Musulmanbekov (PhD,leading scientist,0.3), M.M.Merkin (PhD,leading scientist,0.2), S.P.Merts (PhD,senior scientist,1.0), Yu.I.Minaev (leading engineer,0.3), A.N.Morozov (PhD,consultant,0.7), Yu.A.Murin (PhD,leading scientist,0.5), R.V.Nagdasev (engineer-programer,1.0), S.M.Nepochatykh (engineer,0.5), D.N.Nikitin (scientist,1.0), S.V.Novozhilov (engineer,1.0), D.A.Oleynik (leading programmer,0.3), V.V.Palchik (PhD,leading scientist,0.3), V.A.Pavljukevich (technician,0.3), M.A.Patsyuk (PhD,senior scientist,1.0), Yu.P.Petukhov (PhD,leading scientist,1.0), A. Petrosyan (leading programmer,0.1), S.M.Piyadin (senior scientist,0.6), V.A.Plotnikov (scientist,1.0), D.Podgainy (PhD,leading scientist,0.1), Yu.K.Potrebenikov (PhD,leading scientist,0.1), S.V.Reshetova (engineer,1.0), V.Yu.Rogov (leading electronic,0.5), I.A.Rufanov (senior scientist,0.5), M.M.Rumyantsev (scientist,0.5), D.G. Sakulin (engineer,0.2), S.A.Sedykh (PhD,leading scientist,1.0), T.V.Semchugova (technician,1.0), S.V.Sergeev (PhD,leading scientist,0.5), A.D.Sheremetev (engineer,0.6), A.V. Shchipunov (engineer,0.5), M.O.Shitenkov (engineer,1.0), R.Shindin (senior scientist,0.2), A.V.Shutov (senior scientist,0.7), I.V.Slepnev (senior scientist,0.6), V.M.Slepnev (leading scientist,0.3), I.P.Slepov (programmer, A.V.Smirnov (senior engineer,0.3), A.S.Sorin (DrSc,0.1), V.N.Spaskov (PhD,leading scientist,1.0), A.V.Stavinskiy (DrSc,0.6), Yu.Yu.Stepanenko (PhD,researcher,1.0), E.A.Streletskaya (engineer,0.5), O.I.Streltsova (PhD,senior scientist,0.2), N.V.Sukhov(engineer,1.0), N.A. Tarasov(engineer,0.4), O.G.Tarasov (senior engineer,0.5), A.V.Terletsky (engineer,0.7), V.V.Tikhomirov(senior scientist,0.5), A.A. Timoshenko (engineer,0.5), B.L. Topko (yunior scientist,0.5), Yu.Topko(junior scientist,0.5), I.A.Tyapkin (DrSc,0.1), S.V.Udovenko (engineer,0.2), V.A.Vasendina (scientist,0.4), A.A.Vinogradova (technician,0.3), A.V.Vishnevskiy (PhD,leading scientist,0.5), A.L.Voronin(engineer,0,5), N.Voytishin, V.I.Yurevich (DrSc,0.5), N.I.Zamiatin (PhD,leading scientist,0.6), M. Zavertyaev (DrSc,0.4), Al.I.Zinchenko (PhD,leading scientist,0.5), V.N.Zhezher (senior scientist,0.3), E.V.Zubarev (leading engineer,0.7), M.I.Zuev (scientist,0.2).

7b. Present the JINR group budget for the period of time of the requested extension, specifying the main budget items (equipment, computing, salaries, common funds, travel…)

**Estimated expenditures for the Project**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Expenditure items | Total cost / resources | 1 year2022 | 2 year2023 | 3 year2024 | 4 year2025 | 5 year2026 |
| Direct project expences |  |
| 1. Accelerator, hours | 14000 | 2000 | 3000 | 3000 | 3000 | 3000 |
| 2. Computing (proc\*hours) / mln |  100 |  15 |  15 |  20 |  25 |  25 |
| 3. Laboratory workshop, hours | 2600 | 600 | 600 | 600 | 400 | 400 |
| 4. Laboratory design buro, hours | 1500 | 500 | 300 | 300 | 200 | 200 |
| 5. Equipment, materials, kUSD | 2670 | 1250 | 430 | 350 | 330 | 310 |
| 6.Research carried out under contracts, kUSD | 250 | 50 | 50 |  50 |  50 |  50 |
| 7.Traveling allowance, kUSD, including: a) non-ruble zone countriesb) ruble zone countriesc) protocol-based | 750 250250250 | 150505050 | 150505050 | 150505050 | 150505050 | 150505050 |
| Total direct expenses, kUSD | 3670 | 1450 | 630 | 550 | 530 | 510 |

7c. Indicate the use or needs of JINR computing resources for the group and for the project if any.

 The requested JINR computing resources in millions of processor\*hour are given in the Table above.