Appendix 1
Form №24

Physics research with ATLAS detector at the LHC Run-III
(JINR participation)

ATLAS. Physical researches at LHC
02-0-1081-2009/2024

DLNP: Batusov V., Bednyakov V., Boyko I., Budagov Y., Chelkov G., Chizhov M., Chubinidze Z., Davydov Y., Dedovich D., Demichev M., Elkin V., Ershova A., Gladilin L., Glagolev V., Gongadze A., Gongadze I., Gongadze L., Gostkin M., Huseinov N., Ivanov Y., Kalinovskaja L., Karpov S., Karpova Z., Kharchenko D., Khramov E., Kostyukhina I., Koval O., Kruchonak U., Kultchitsky Y., Lyabline M., Lykasov G., Lyubushkin V., Lyubushkina T., Malyukov S., Minashvili I., Minashvili I.(jr.), Nefedov Y., Plontikova E., Potrap I., Prokoshin F., Rusakovich N., Sadykov R., Sapronov A., Shiyakova M., Tsiareshka P., Turchikhin S., Yeletskikh I., Zhemchugov A., Shalyugin A., Stepenenka Y., Usov Y., Usubov Z., Vasyukov A.

LIT: Alexandrov E., Aleksandrov I., Gromova N., Iakovlev A., Kazymov A., Mineev M., Oleinik D., Petrosyan A., Shigaev V., Zrelov P.

VBLHEP: Ahmadov F., Cheplakov A., Javadov N., Kukhtin V., Ladygin E., Manashova M., Soloshenko A., Zimin N., Fillipov Y., Shaykhatdenov B., Turtuvshin T.

THE PROJECT LEADER Bednyakov V.A.
DEPUTY PROJECT LEADERS Khramov E.V. and Cheplakov A.P.

DATE OF SUBMISSION OF PROPOSAL OF PROJECT TO SOD ______________

DATE OF THE LABORATORY STC 04 April 2019 DOCUMENT NUMBER 2019-4

FIRST PROJECT APPROVAL DATE 2009

Приложение 1
Форма № 24

Физические исследования на детекторе АТЛАС на БАК в третьем периоде набора данных
(участие ОИЯИ)
АТЛАС. Физические исследования на БАК
02-0-1081-2009/2024

ЛЯП: Батусов В.Ю., Бедняков В.А., Бойко И.Р., Будагов Ю.А., Васюков А.О., Гладилин Л.К., Глаголев В.В., Гонгадзе А., Гонгадзе И.Б., Гонгадзе Л.А., Госткин М.И., Гусейнов Н., Давыдов Ю.И., Дедович Д.В., Демичев М.А., Елецких И.В., Елкин В.Г., Ершова А.В., Жемчугов А.С., Иванов Ю.П., Калиновская Л.В., Карпов С.Н., Карпова З.М., Костюнина И., Коваль О.А., Кручонок В.Г., Кульчицкий Ю.А., Лыкасов Г.И., Любушкин В.В., Любушкина Т.В., Ляблин М.В., Малюков С.Н., Минашвили И., Минашвили И.(мл.), Нефедов Ю.А., Плотникова Е.М., Потрап И.Н., Прокошин Ф.В., Русакович Н.А., Садыков Р.Р., Сапронов А.А., Степаненко Ю.Ю., Терешко П.В., Турчихин С.М., Усов Ю.А., Усубов З.У., Харченко Д.В., Храмов Е.В., Чижов М.В., Чубинидзе З., Шалюгин А.Н., Шелков Г.А., Шиякова М.М.

ЛИТ: Александров Е.И., Александров И.Н., Громова Н.И., Зрелов П.В., Казымов А.И., Минеев М.А., Олейник Д.А., Петросян А.Ш., Шигаев В.Н., Яковлев А.В.

ЛФВЭ: Ахмадов Ф.Н., Джавадов Н.А., Зимин Н.И., Кухтин В.В., Ладыгин Е.А., Манашова М., Солошенко А.А., Филиппов Ю.А., Шайхатденов Б.Г., Туртувшин Т., Чеплаков А.П.

РУКОВОДИТЕЛЬ ПРОЕКТА: Бедняков В.А.
ЗАМЕСТИТЕЛИ РУКОВОДИТЕЛЯ ПРОЕКТА: Храмов Е.В. и Чеплаков А.П.

ДАТА ПРЕДСТАВЛЕНИЯ ПРОЕКТА В НОО _________
ДАТА НТС ЛАБОРАТОРИИ 4 апреля 2019 НОМЕР ДОКУМЕНТА 2019-4
ДАТА ПЕРВОГО УТВЕРЖДЕНИЯ ПРОЕКТА 2009

Appendix 2
Form № 25

PROJECT APPROVAL LIST

Physics research with ATLAS detector at the LHC Run-III
(JINR participation)

ATLAS. Physical researches at LHC
02-0-1081-2009/2024

Vadim Bednyakov

	SIGNATURE	DATE
APPROVED BY JINR DIRECTOR		
ENDORSED BY		
JINR VICE-DIRECTOR		
CHIEF SCIENTIFIC SECRETARY		
CHIEF ENGINEER		
HEAD OF SCIENCE ORGANIZATION DEPARTMENT		
LABORATORY DIRECTOR		
LABORATORY CHIEF ENGINEER		
PROJECT LEADER		
PROJECT DEPUTY LEADERS		
ENDORSED		
RESPECTIVE PAC		

Приложение 2
Форма № 25

ЛИСТ СОГЛАСОВАНИЙ ПРОЕКТА

Физические исследования на детекторе АТЛАС на БАК в третьем периоде набора данных

АТЛАС. Физические исследования на БАК
02-0-1081-2009/2024

Бедняков Вадим Александрович

	ПОДПИСЬ	ДАТА
УТВЕРЖДЕН ДИРЕКТОРОМ ОИЯИ		
СОГЛАСОВАНО		
ВИЦЕ-ДИРЕКТОР ОИЯИ		
ГЛАВНЫЙ УЧЕНЫЙ СЕКРЕТАРЬ		
ГЛАВНЫЙ ИНЖЕНЕР		
НАЧАЛЬНИК НОО		
ДИРЕКТОР ЛАБОРАТОРИИ		
ГЛАВНЫЙ ИНЖЕНЕР ЛАБОРАТОРИИ		
РУКОВОДИТЕЛЬ ПРОЕКТА		
ЗАМ. РУКОВОДИТЕЛЯ ПРОЕКТА		
ОДОБРЕН		
ПКК ПО НАПРАВЛЕНИЮ		

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Abstract

The main purpose of the international ATLAS experiment is to investigate proton-proton interactions at unprecedented energies at the LHC collider (from 7 to 14 TeV center-of-mass energy). In particular, detailed study of the Standard Model, its application limits, search for answers to the key problems in particle physics and astrophysics, such as origin of elementary particles masses, nature of the dark matter in the Universe, existence of extra dimensions, are carried out with the ATLAS detector.

Absolutely new and unique data will be obtained based on multifaceted and comprehensive studies of the proton-proton scattering processes. These data analyses will allow to address several fundamental problems in particle physics. Within current project, scientists from JINR are going to participate in these analyses.

Scientists from JINR will obtain new results leading to publications in all mentioned above areas. The most important tasks include studies of the proton structure and of hadron spectra, tests of the Standard Model at the LHC energies, searches for Supersymmetry, searches for new heavy particles and new interactions. Apart from new physics searches, JINR scientists will work on the precision frontier and will measure with greater accuracy the properties of known elementary particles, such as W and Z bosons, top quark, and heavy baryons.

During the 2015 – 2019 period of the project, 29 papers with significant participation of JINR staff were published, more than 20 talks at international conferences and meetings excluding working meetings within the Collaboration were delivered.

The requested project budget is 2950 kUSD for 2020-2024.

Аннотация

Главная цель международного эксперимента ATLAS – это изучение протон-протонных взаимодействий при рекордных энергиях коллайдера LHC (от 7 до 14 ТэВ). В частности, с помощью установки ATLAS уже ведется тщательная проверка современной Стандартной модели физики частиц, определяются границы ее применимости, ищутся ответы на ключевые вопросы современного этапа развития физики и астрофизики, такие, например, как происхождение масс у элементарных частиц, природа темной материи во Вселенной, наличие дополнительных пространственных измерений и т.п.

На основе многопланового и всестороннего исследования процессов рассеяния протонов будут получены совершенно новые и уникальные экспериментальные данные. Анализ этих данных даст возможность решить ряд наиболее фундаментальных физических проблем. Сотрудники ОИЯИ в рамках данного проекта примут участие в решении ряда таких проблем.

Планируется получить совершенно новые данные и опубликовать статьи по всем отмеченным выше физическим задачам, за которые отвечают сотрудники ОИЯИ. Наиболее важные из них – исследование структуры протона и спектра адронных состояний и проверка Стандартной модели физики частиц при энергиях LHC, поиск и исследование проявлений суперсимметрии, поиск свидетельств существования новых частиц и новых взаимодействий. Помимо этого сотрудники ОИЯИ получат новые результаты, которые позволят уточнить свойства уже известных элементарных частиц, таких как W- и Z-бозоны, топ-кварк, тяжелые барионы и другие.

На этапе работ по данному проекту в 2015–2019 гг было опубликовано с решающим участием сотрудников ОИЯИ 29 работ и сделано более 20 выступлений на различных конференциях и митингах, не считая рабочих совещаний в рамках коллаборации ATLAS.

Бюджет проекта составляет 2950 тыс. долларов США на 2020-2024 гг.

"ATLAS expects to remain at the energy frontier of High Energy Particle Physics for the next 10-15 years"

P.Jenni
2009

Introduction

The ATLAS international collaboration was established more than 25 years ago to carry out a new-generation multipurpose experiment designed to study fundamental properties of matter in proton-proton collisions at the center-of-mass energy of 14 TeV at the Large Hadron Collider (LHC). Nowadays, the Collaboration includes 1786 authors and overall 8128 participants from 221 institutes in 41 countries. During these 25 years, very complex ATLAS detector systems were designed, constructed, commissioned, and used to successfully investigate a variety of physics phenomena, including a long-awaited Higgs boson discovery in 2012.

JINR contribution to this achievement looks very remarkable compared to other institutions. It is worth to mention that the following very important works has been carried out at JINR in full compliance with the responsibilities imposed upon JINR by the ATLAS collaboration:

1. Design, production and commissioning of the detector modules for Muon Spectrometer, Liquid argon and Tile Calorimeters, and for the Inner Tracker.
2. Calibration of the ATLAS calorimeters and preparation for data-taking.
3. Participation in the development on the ATLAS Trigger DAQ (TDAQ).
4. Creation of the ATLAS GRID at JINR (one of the best in Russia).
5. Modeling and optimization of the ATLAS magnet system.
6. Design, production and assembly of elements of the ATLAS magnet system

It is remarkable that *only Italy, USA, CERN and JINR* have contributed to all main subsystems (TileCal, Muon, LAr, ID, TDAQ) of the ATLAS detector. In 2009, JINR ATLAS project leaders explicitly stated (when the first part of the project was approved) that *the outstanding JINR contribution to design, construction, assembly and commissioning of the ATLAS detector systems should not have been in vain for JINR.* Therefore in 2015-2019 the main goal of JINR ATLAS management was to transform the above-mentioned JINR achievements into exciting physics results obtained by (or with important contribution of) the JINR scientists. Despite several complications, this goal was successfully achieved. The extended report on the JINR ATLAS team contribution to ATLAS operation and physics results during 2015-2019 is under preparation for publication.

In short, during these 5 years in the scope of the project the JINR team strongly participated in ATLAS physics results preparation including data taking, data preparation, Monte Carlo simulation and data analysis. The team took relevant part in obligatory ATLAS Common Operation Tasks, including shifts in the CERN-ATLAS and JINR-remote-ATLAS control rooms, on-call expert jobs, data quality control (remote), etc. Standard ATLAS maintenance and operation (M&O) support was supplied by JINR experts over these years. JINR has upgraded the JINR LHC computing Grid facilities and supplied computing resources which allowed successful exploitation of the JINR-based Tier-2 ATLAS Grid fragment. The JINR team has also defined its participation scope in the general ATLAS upgrade program for the HL-LHC.

Furthermore, during realization of the ATLAS project at JINR in 2009-2019, the JINR ATLAS management has carried out its inner reorganization. The reason was a general change from construction, assembly and commissioning of the ATLAS detector sub-systems (Tile and LAr Calorimeters, Muon systems, inner TRT detectors, etc) to the ATLAS detector operation via new Common Operation Tasks (OT) like, for example, shifts in ATLAS control room, on-call expertise, data preparation, data quality tests and physics analysis. These new requirements forced some optimization of the ATLAS author list as well. Currently, participation in both Operation Tasks and Physics analyses is (as a rule) obligatory for an ATLAS author (from JINR). To strengthen responsibility of JINR people and to enhance the JINR contribution in the ATLAS project it was necessary to impose a new requirement for a membership in the JINR-ATLAS team. To fulfill it, one first had to become "visible" at the general ATLAS collaboration level before becoming an official ATLAS author. The main practical goal of this rule was to create at JINR a new efficiently working ATLAS team which can solve ambitious problems at a level of the whole ATLAS collaboration. JINR ATLAS management believes that during 2015-2019 the goal was reached in general. In particular, the JINR team contributed substantially to ATLAS physics output on the main topics of the Standard Model, QCD, searches for Higgs boson and Supersymmetry, and general study of physics beyond the Standard Model (Exotics physics). Several new directions for physics research were proposed and put into development by JINR team members.

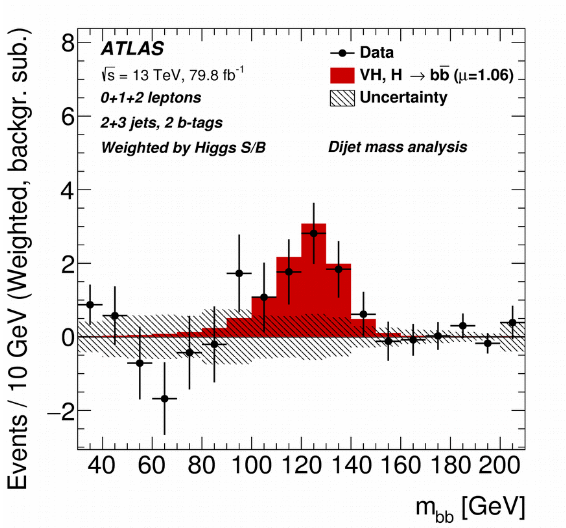
Upgrade of the ATLAS detector

It is also worth to mention that JINR provides important contribution to the upgrade of the ATLAS detector. In the Phase-I (2014-2020) of the ATLAS upgrade program the JINR team of 44 people (27 FTE) is involved in the upgrade of the ATLAS calorimeters and the muon spectrometer. In particular, we are responsible for the development of the "off-detector" electronics for the Tile calorimeter and trigger electronics for the liquid argon calorimeter. The JINR has supplied the radiation hard scintillators for replacement of MBDT modules in the transition area between the barrel and endcap cryostats. We also designed the baseplane for the new readout crate of the LAr calorimeter and developed several prototypes of the preshaper for the analog part of the LAr Trigger Digitizer Board. The most significant contribution of the JINR team in the Phase-I ATLAS upgrade project is mass production of the quadruplets for the New Small Wheel of the muon spectrometer. A special workshop was built at the Institute for production of all the outermost modules of the NSW: a total of 64 readout micromegas panels and 32 quadruplets will be made by the end of 2020.

The LHC luminosity upgrade to $7.5\times10^{34}cm^{-2}s^{-1}$ corresponding to an average μ=200 inelastic *pp* collisions per beam-crossing will allow comprehensive measurements of the Higgs boson properties in all its production and decay modes, as well as improved measurements of all relevant Standard Model processes and searches for phenomena beyond the SM. For example, one of the most important results in the ATLAS experiment in 2018 was observation of the Higgs decay into a pair of *b*-quarks and VH production. The members of our group are working in the analysis team for many years and will continue this activity in the future. A combination of Run 2 results searching for the Higgs boson produced in association with a vector boson yields an observed (expected) significance of 5.3 (4.8) standard deviations with uncertainty above 10% for signal strength value.

Models with an extended Higgs sector, like SUSY, predict deviations of the Higgs couplings from SM predictions that can be arbitrary small if Higgs states in SUSY are very heavy. That is why the increase of statistics (and better accuracy of the measurements) is very important for the future progress of this study. Dedicated analysis showed that statistical significance value for H→bb channel of 7.1 could be obtained for the integrated luminosity of 300 fb^{-1}, and 10.7 could be obtained for 3000 fb^{-1}.

Therefore to meet this unprecedented value of the luminosity is crucial for all aspects of the future physics analysis and software development.



The distribution of m_{bb} in data, as obtained with the dijet-mass analysis after subtraction of all backgrounds.

JINR participation in the ATLAS physics and software development in 2020-2024

For the next 5 years three main research directions are planned for the JINR group:

1. Participation in Running of the ATLAS experiment (M&O, Shifts, Common Operation Tasks, etc)
2. Physics research and data analysis.
3. Participation in the software maintenance and development.

As already noted since 2013 the JINR participation in the ATLAS and LHC Upgrade program is a separate project within the ATLAS theme in the JINR Topic Plan (leader A.Cheplakov).

Participation in the ATLAS detector operation

JINR will continue its participation in the ATLAS Common Operation Tasks. It includes shift work of JINR people in the CERN-ATLAS control rooms, fulfillment of on-call expert jobs, and data quality control, etc. Standard ATLAS maintenance and operation (M&O) support will be supplied by JINR over these years as well. In particular, JINR will continue participation in the running of the **Hadronic Tile Calorimeter** (Irakli Minashvivli (JINR) and Stano Nemecek (Prague) are the two main leaders of the Tile Calorimeter detector Maintenance). The LAr JINR ATLAS team will continue exploitation and support of the **Liquid Argon hadronic calorimeter**. The JINR M&O obligations include refurbishment of the electronics blocks, repairing and put in order electronic blocks, monitoring of quality of read-out channels, participation in shifts as “expert-on-call” and “HEC local expert”, etc. In the future 5 years some members of JINR ATLAS team will continue supporting the systems of ATLAS **Distributed Computing** (including Grid, etc). Also it is planned to increase the participation in the detector maintenance and operation via the software development.

JINR will continue to participate in ATLAS **Safety control** efforts. In particular JINR members (V. Batusov, I. Kostyukhina, M.Shijakova) will work as SLIMOS (Shift Leader in Matter of Safety). In addition they will take duties of the Radiation Gate Monitors in order to prevent any leak of radioactive materials from the ATLAS cavern.

JINR in the ATLAS Physics

The strategical idea of JINR participation in the ATLAS physics program is “visibility” of the JINR-team contributions. Contrary to the previous stage of the project (2015-2019, *with so-called JINR-based ATLAS preliminary activities)* any local activity in the field of ATLAS physics will not be supported at JINR if it has no clear plans to be considered, accepted and supported for development within the whole ATLAS Collaboration (or relevant ATLAS working groups).

By taking this approach, the JINR group is planning a strong participation in the following for the period of 2020-2024:

1. Study of the Standard Model applicability and verification of its predictions, study of the proton structure at ultra-high energies (PDFs), tuning and improvement of relevant computer codes and events generators etc.

2. Search for the chiral Z*/W* bosons in the two-jet decays as well as in process with more complex topology of their associative production including heavy b and t quarks.

3. Search for (supersymmetric) *charged Higgs* bosons via their specific decay modes (3-leptons, etc).

4. Analyses of associated productions of the SM Higgs with $t\bar{t}$ pair and search for Higgs production with single top.

5. Search for a valence-like nonperturbative component of heavy quarks in the proton (*intrinsic heavy* quarks) via specific final state topology in the *pp*-interactions.

6. Search for new hadrons and baryons containing heavy c- and b-quarks.

7. Measurement of the Drell-Yan triple-differential cross section and effective leptonic weak mixing angle in Z-boson decay.

8. A new comprehensive study of the *gluon* structure of the proton.

9. Search for quantum black holes in lepton+jet channel at 13 TeV.

10. Participation in the event triggers indexing infrastructure development.

11. Maintenance and development of the TDAQ system.

It is important to note that many of this topics were initiated by JINR group in the ATLAS.

JINR in the ATLAS Standard Model Working group

SANC-group

Within this WG JINR is visible thanks to the international SANC Project (Support of Analytical and Numerical Calculations for Experiments at Colliders, site: http://brg.jinr.ru/). The work on application of the SANC results to LHC physics has been carried out since 2004 (under leadership of D.Yu.Bardin). The SANC group at JINR (D. Bardin, A. Arbuzov, S. Bondarenko L. Kalinovskaya, R. Sadykov, A. Sapronov, et al.) works very successfully in the ATLAS Collaboration over the years.

They develop and apply theoretical predictions for practically all three-particle and many four-particle processes of the Standard Model at the one-loop accuracy level. The main aims of SANC are preparation for very accurate physical analysis (including loop corrections), for example of single top quark production in pp collisions at LHC within SANC. Implementation of the SANC products into the ATLAS analysis software is of highest importance for JINR.

In 2020--2024 the SANC group plans to continue theoretical support with calculation of the electro-weak and QCD (EW&QCD) NLO corrections to the Drell-Yan-like processes for ATLAS data. In particular it concerns high-order EW-corrections for Drell-Yan neutral current events; fit of the Standard Model effective parameters and related Monte Carlo simulation; implementation of the impact of the photon-induced subprocesses in the generator and investigation of the effect on the final results.

A development of the SANC/PHOTOS software for ATLAS is also planned by A. Arbuzov, R. Sadykov, and Z. Was. They plan to start from careful comparison of

SANC/PHOTOS calculations off- and on-resonance cases and study the production of light fermion pairs.

Other members of the team will upgrade the famous HERAFitter code for ATLAS purposes, so that in particular the evolution of photonic PDFs will be included.

In addition, the members of the group (leader A.Sapronov) plan to deal with the following topics:

1. Measurement of the parameters of the Standard Model based on data on the longitudinal asymmetry of the lepton decay modes of a single Z-boson. Existing calculations of electro-weak corrections in the approximation of NLO, implemented in the form of a Monte Carlo integrator MCSANC, permit, together with the approximation of the parton distributions of the proton, to measure a number of parameters of the electro-weak SM. The latter include the effective Weinberg angle, the so-called rho-parameter, and, in the long term, the effective coupling constants.

2. Analysis of the Drell-Yan-like processes in the context of QCD. The purpose of this analysis is to clarify the parton distribution functions based on experimental data of proton-proton collisions. Application of HERAFitter code for data of Run-I allows to get more information on the densities of momentum distributions of s-quark at small values of *x* and gluons at large *x*. The research will continue for wider kinematic ranges and higher statistics of Run-II.

Nowadays the SANC's mashinery for ATLAS Run-I data analysis is developed. It is necessary for the Run-II to adopt the code of the interface for the new format and extend the code functionality.

Study of the proton structure

In the years 2020-2024 it is planned to continue the study of the structure of the proton in experiment ATLAS. It is supposed to test the JINR born hypothesis of existence of the valence-quark states in the proton, the so-called intrinsic charm and strangeness, in the pp processes with direct production of photons or vector bosons (W, Z), accompanied by the c- or b-jets.

The hypothesis will be checked by comparing the spectra of direct photons and vector bosons obtained from the data of Run-I and Run-II and taken from the theory [V.A. Bednyakov, M.A. Demichev, G.I. Lykasov, T. Stavreva, M. Stockton, hep-ph/1305.3548, Phys.Lett.B 728 (2014) 602].

Experiments at the LHC can be interpreted as "the factory of gluons" because at energies of several TeV, in pp collisions, the transfer momenta are so large that a large number of gluons is produced which manifest itself experimentally as jets of hadrons, mostly heavy, c- and b-jet.

It was shown by JINR team that from ATLAS data on the spectra of hadrons at small and large transverse momenta one can extract information about the distribution of gluons, which depend on the internal longitudinal and transverse momenta as well as the transfer squared four-momentum in pp collisions.

From the analysis of ATLAS data on the spectra of light charged hadrons, π- and K-mesons produced in pp collisions in the central rapidity region and the wider range of initial energies (from SPS until the LHC), the gluon distribution function at small internal transverse momenta was found for the first time [V.A.Bednyakov, A.A. Grinyuk, G.I. Lykasov, M.Poghosyan, Intern. J. Mod.Phys., A 27 (2012) 1250042; A.A. Grinyuk, A.V. Lipatov, G.I.Lykasov, N.P. Zotov, Phys.Rev. D87, 074017(2013); G.I. Lykasov, A.A. Grinyuk, V.A. Bednyakov, Phys.Part.Nucl. 44 (2013) 568-572; A.V. Lipatov, G.I. Lykasov, N.P. Zotov, hep-ph/1310.7893, Phys.Rev.D, 89 (2014) 014001].

It is planned to conduct a detailed analysis of ATLAS data on the production of heavy hadrons containing b- and c-quarks, and heavy jets in pp collisions by using QCD calculations in order to find the form of the gluon distribution at medium and large transverse momenta.

In other words, we plan to monitor of the gluon density in a wide range of variables on which it depends, using a set of ATLAS data obtained during the 2015-2018 period.

Heavy hadrons and baryons

One of the important research directions at the LHC is investigation of baryons containing c- and b-quarks. It is not possible to do at the B-factories, and the majority of baryons with two (and/or three) heavy quarks have not yet been observed. In the period of 2019 – 2024 JINR team plans the following:

1. Study of semi-leptonic and hadronic Bc decay modes in data of RUN-II, in particular for searching for a vector states $B_c^* \to B_c+\gamma$ (earlier it was not observed in other experiments), and also for searching for possible reproducing the analysis of RUN-I for searching of $B_c^*(2S)^+$ in semi-leptonic B_c decay mode, as in Run-I, but aiming on more precise measurement of $B_c^*(2S)^+$ production cross section using higher statistics.
2. Search for a double-charged tetraquark state decaying to B_c^+ and π^+.
3. Measurement of the relative B_c^+/B^+ production cross section.
4. As the next step of the analysis performed during previous project (Phys.Lett. B751 (2015) 63-80) it is planned to measure the helicity amplitudes and parity violating asymmetry parameter α_b for $\Lambda_b^0 \to J/\Psi\ \Lambda^0$ and $\Lambda_b^0 \to \Psi(2S)\ \Lambda^0$ decay channels. It is expected that polarization effects for the $\Lambda_b^0 \to \Psi(2S)\ \Lambda^0$ decay channel will be measured for the first time.
5. Search for various exotic states in $\Lambda_b^0 \to J/\Psi\ \varphi\ \Lambda^0$ or/and $\Lambda_b^0 \to J/\Psi\ K_S^0\ \Lambda^0$ processes. For example, the $(J/\Psi,\Lambda^0)$ mass spectrum can be used to search for the hidden charm pentaquark with S=-1 in the mass range 4.35 – 4.55 GeV
6. Study of exotic structures $X \to J/\Psi\ \varphi(1020)$ in $B^+ \to J/\Psi\ \varphi\ K^+$ decays.
7. Measurement of $B_c \to J/\Psi\ D$ decays. Totally five decays, with $D = D_s^+$, $D^*{}_s^+$, D^+, D^{*+}, $D_{s1}(2536)^+$. First two were observed in Run-I, a more precise measurement is possible with Run-II. The other decays have not been observed yet.

To study the decays with J/ψ in the final state the existing trigger will be used after its adaptation to the increased luminosity of the LHC. JINR team is going to continue maintenance and development of the package for one- and di-muon trigger efficiency and scale-factors measurement, in particular for the analysis on B^+ cross section measurement.

Measurement of a Z boson produced in association with b- or c-jets

Such measurements provide an important test of perturbative quantum chromodynamics (QCD) at next-to-leading order (NLO) calculations. These processes are sensitive to heavy flavor quarks in the initial state. Two schemes are generally employed in perturbative QCD (pQCD) calculations containing heavy flavor quarks. One is the four-flavor number scheme (4FNS), which only considers parton densities of gluons and of the first two quark generations in the proton. The other is the five-flavor number scheme (5FNS), which allows a b-quark density in the initial state and raises the prospect that measurements of heavy flavor production could constrain the b-quark parton density function (PDF) of the proton. In a calculation to all orders, the 4FNS and 5FNS methods must give identical results; however, at a given order differences can occur between the two. NLO calculations combining the 4 and 5 flavor number schemes for initial state partons still carry large uncertainties.

Furthermore, the V + b(anti-b) signal forms a dominant background to many other processes with smaller cross sections, from top production, to searches for the Standard Model Higgs Boson, and many beyond the Standard Model processes including SUSY and other exotica.

JINR team is going to participate in finalizing of the analysis based on Run-I data and move to the full Run-II analysis.

Bose-Einstein correlations

Studies of the dependence of BEC on particle multiplicity and transverse momentum are of special interest. They help to understand the multiparticle production mechanism. The size of the source emitting the correlated particles has been observed to increase with particle multiplicity. This can be understood as arising from the increase in the initial geometrical region of overlap of the colliding objects: a large overlap implies a large multiplicity. While this dependence is natural in nucleus–nucleus collisions, the increase of size with multiplicity has also been observed in hadronic and leptonic interactions. In the latter, it is understood as a result of superposition of many sources or related to the number of jets. High-multiplicity data in proton–proton interactions can serve as a reference for studies of nucleus–nucleus collisions. The effect is reproduced in both the hydrodynamical/hydrokinetic and Pomeron-based approaches for hadronic interactions where high multiplicities play a crucial role. The dependence on the transverse momentum of the emitter particle pair is another important feature of the BEC effect. In nucleus–nucleus collisions the dependence of the particle emitter size on the transverse momentum is explained as a “collective flow”, which generates a characteristic fall-off of the emitter size with increasing transverse momentum while strong space–time momentum–energy correlations may offer an explanation in more “elementary” leptonic and hadronic systems where BEC measurements serve as a test of different models (Eur. Phys. J. C75 (2015) 466; Phys. Lett. B 758 (2016) 67).

JINR team is going to continue measurements of the BEC in one- and three-dimensional cases as well as investigations of charged-particle distributions in Run-II/III data.

JINR in the ATLAS Higgs Working group

VH process study with Higgs to bb decay

The results of this study were briefly presented in the "ATLAS Upgrade" chapter. Working together with our colleagues from the "Higgs to complex states" working group we will complete soon this analysis on the full dataset from Run-2. The present analysis is based on the so called "Simple template" approach, but more complicated multivariable methods will be applied once higher statistics will be available in Run-3.

ttH measurements in multilepton channel

The study of the origin of electro-weak symmetry breaking is one of the key goals of the LHC. In the Standard Model, the symmetry is broken through the introduction of a complex scalar field doublet, leading to the prediction of the existence of one physical neutral scalar particle, commonly known as the Higgs boson. The discovery of a Higgs boson with a mass of approximately 125 GeV by the ATLAS and CMS Collaborations was a crucial milestone. Measurements of its properties performed so far are consistent with the predictions for the SM Higgs boson.

JINR team in collaboration with IEAP Czech Technical University in Prague is going to continue ttH study with full Run-II dataset:

1. Fake Lepton Analysis in the Same-sign Lepton+Tau hadronic Channel (2lSS+1τ had)
2. Contribution to Group Framework 1 (GFW1)
3. Upgrade the ABCD Fake factor method for fake lepton estimation

4. Apply Template Fit for fake estimation and compare with results of updated FF method

5. Contribution to combination of channels

tH production

The Higgs boson production in association with a single top-quark (tH) is searched using Higgs decays into b quark pairs. In the Standard Model the cross-section of this process is predicted to be an order of magnitude smaller than for the Higgs production with a pair

of top quarks (ttH). Due to the very small event yield, the SM tH process can not be discovered with the Run-II statistics, only an upper limit can be set. On the other hand, this channel is sensitive to the sign (or, more generally, to the complex phase) of the top Yukawa coupling. In particular, in the BSM model with inverted top coupling (ITC) the cross-section is enhanced by more than an order of magnitude. The Run-II statistics is sufficient to observe the ITC tH channel, or to rule out this model.

So far, a generator-level Monte-Carlo study of the tH channel has been undertaken by the JINR team. A brief summary can be found O.A.Koval, I.R.Boyko and N.Huseynov, EPJ Web Conf., 201 (2019) 04003. The further plans are:

1. Improve the event selection by applying a Neural Network instead of the event selection by sequential cuts;

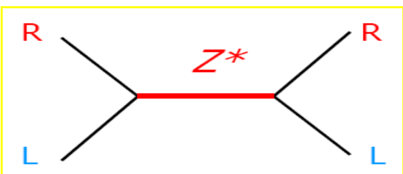
2. Analyze the Full Simulation Monte-Carlo using the experience gained with the generator-level study;

3. Study the tH (H→bb) channel using the ATLAS Run-II data and set limits if no signal is observed

JINR in the ATLAS Exotics Working group

Prospects for the search for Z*/W*

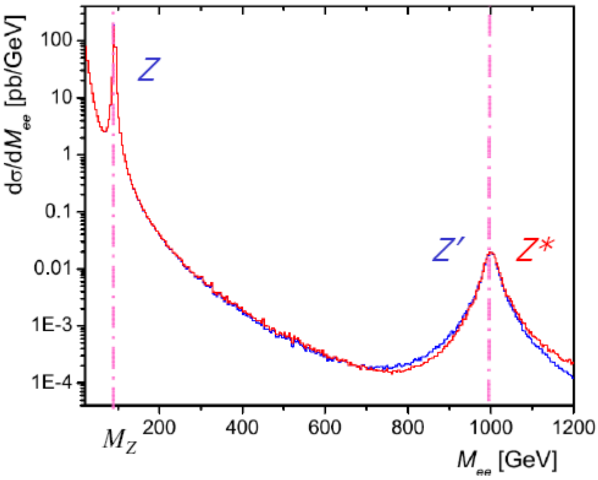
The existence of excited bosons has been suggested in the early papers of M.V. Chizhov [Mod. Phys. Lett. A 8 (1993) 2753], at present a senior researcher at Dzhelepov Laboratory of Nuclear Problems. The project for their search at the LHC has been proposed in [Phys. Atom. Nucl. 71 (2008) 2096; Nuovo Cim. C 33 (2010) 343] also by scientists of Dzhelepov Laboratory: M.V. Chizhov, V.A. Bednyakov and J.A. Budagov. The project has been accepted by the ATLAS Collaboration in 2009.

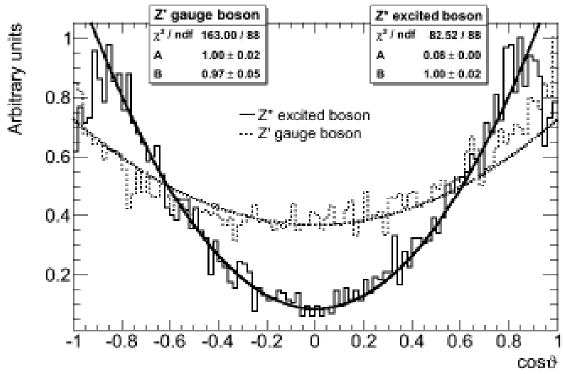


excited Z^* :

$$\mathcal{L}_{\text{exited}} = \frac{g}{\sqrt{2}\Lambda}\left(\bar{\ell}\sigma^{\mu\nu}\ell + \bar{d}\sigma^{\mu\nu}d\right)\partial_\mu Z^*_\nu$$

JINR team (Leader M.V.Chizhov) together with ATLAS team from St.Petersburg INR (Leader O.Fedin) within Lepton+X Exotics WG have carried out research on general topic "Search on inclusively produced chiral Z* bosons via their decay into lepton-antilepton pairs". The obtained data is collected at special Twiki page https://twiki.cern.ch/twiki/bin/view/AtlasProtected/ZstarEleEle. In general, the Z* analysis is very similar to the Z' analysis. However, the peculiar features of the excited bosons result in many differences in comparison with the Z' results (**Figure below**). This will help to distinguish them an ambiguously from the other neutral resonances with different spins.



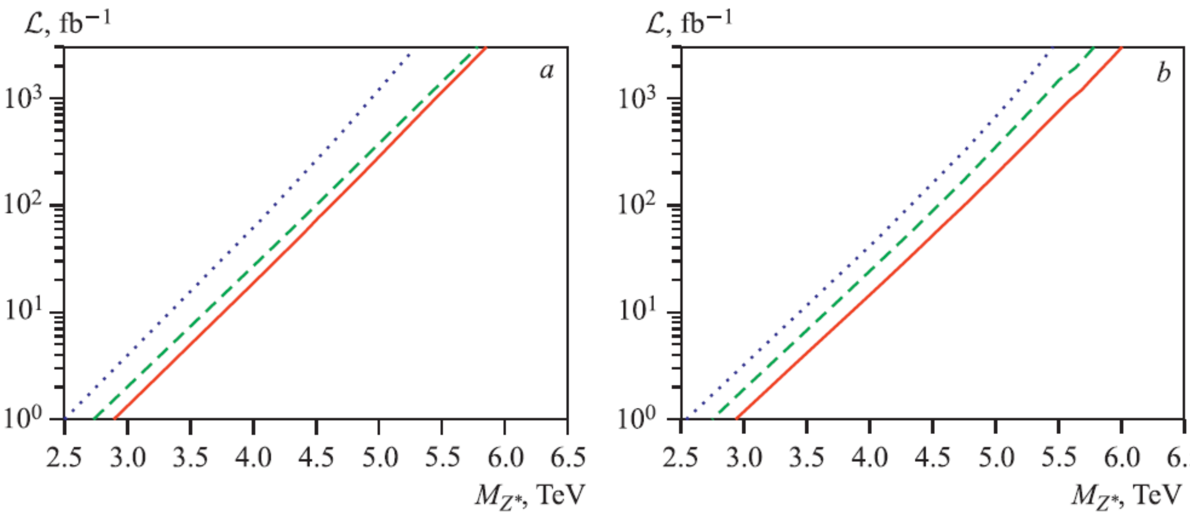


$$A + B\cos^2 \vartheta_{CS}$$

Experimental searches for these heavy excited bosons with ATLAS detector in the first period of the LHC data analysis were based on proton-proton collision energies of 7 (8) TeV and integrated luminosity of 5(20) fb-1, respectively. The results of these studies were the new upper limits for the cross sections and the masses of the new bosons. The observed mass limits Z*(W*) are 2.85 (3.21) TeV.

Prospects for further Z*, W* searches related, are based primarily on the plans to increase the energy of the proton-proton collisions at the LHC to 13-14 TeV and increase the luminosity of proton beams. Expected number of events with Z*, W* increases proportionally integrated luminosity of the collider, and for large masses of the new bosons significantly increases with the energy of the colliding beams.

The **figure below** shows the dependence of the integrated luminosity necessary for detection (left) or exclusion (right) with a confidence level of 95% of the Z* boson depending on its mass for energy of pp collisions 13 TeV.



*The integrated luminosity of the proton-proton collisions with energy 13 TeV required for detection (left) or exclusion of the existence (right) of the boson Z * depending on the mass of the latter.*

It should be noted that the increase in energy collision greatly increases the potential for the search of the new physics. For instance, for the pp-collisions with energy of 14 TeV the integrated luminosity smaller than 1fb^{-1} is required to improve the existing restrictions on the Z* mass in required, while the analysis of 100 fb^{-1} data will test the hypothesis of Z* existence up to it mass of 4.5 TeV.

The next 5 years the JINR team will continue searches for the Z* boson. Then the search will start for charged chiral W* boson, produced inclusively and decaying into electron-neutrino pair (pp→W*→μν). Due to the missing neutrino energy this analysis seems more complicated. We plan to attract our PhD students for its fulfillment.

JINR team holds leading positions in this analysis direction and attracts for cooperation the others ATLAS members. The leaders of the research (M.V.Chizhov and G.Dvali) have recently showed a deep connection between introduced chiral bosons and fresh ideas beyond the SM, such as SUSY and physics of extra dimensions.

Therefore, during 2020 – 2024 JINR team plans to continue the search for the excited bosons not only in the dilepton channels, but also in the dijets final states as well as in associated production with the heavy quarks [M.V. Chizhov, V.A. Bednyakov, J.A. Budagov, Phys. Atom. Nuclei 75 (2012) 90; ATLAS Collaboration, Phys. Rev. D 91, 052007 (2015); M.V. Chizhov, V.A. Bednyakov, Phys. Atom. Nucl. 79 (2016) 721]. To prepare for the full Run-II, new Monte-Carlo simulations of productions of the excited bosons should be done in the ATLAS software framework for different channels. This task is a direct responsibility of our Institute. JINR group plans to continue also the data analysis in the muon channel.

Mixing and mass of Z' bosons from resonant di-boson searches

Neutral vector bosons Z are among the best motivated scenarios of physics beyond the Standard Model (SM). Many new physics models beyond the SM, including superstring and left-right-symmetric models, predict the existence of such bosons. They might actually be light enough to be accessible at current and/or future colliders. The search for such neutral Z' gauge bosons is an important aspect of the experimental physics program of present and future high-energy colliders.

Depending on the considered theoretical model, Z' masses of the order of 4.5 TeV [3,4] and Z-Z' mixing angles at the level of 10^{-3} are already excluded. These constraints come from the very high-precision Z pole experiments at LEP and the Stanford Linear Collider (SLC), including measurements from the Z line shape, from the leptonic branching ratios (normalized to the total hadronic Z decay width) as well as from leptonic forward-backward asymmetries. While these experiments were virtually blind to Z' bosons with negligible Z-Z' mixing, precision measurements at lower and higher energies (away from the Z pole) attainable at TRISTAN and LEP2, respectively, were able to probe the Z' exchange amplitude via its interference with the photon and the SM Z boson. However, as was shown, at the LHC at nominal collider energy of $\sqrt{s}$ = 14 TeV and integrated luminosity of $L_{int} \approx 100$ fb^{-1} a high potential exists to improve significantly on the current limits on the Z-Z' mixing angle in the di-boson channel: pp → ($Z_2 \to W^+ W^-$) + X.

In contrast to the Drell-Yan (DY) process pp → Z' → $l^+ l^-$ + X, with l = e, μ, the di-boson process is not the principal discovery channel, but can help to understand the origin of new gauge bosons.

The JINR team plans are:

1. Set limits on W-W' mixing angle in the WZ-bosons production processes in Run-I/II

2. Set limits on Z-Z' mixing angle in the di-boson production processes in Run-II

3. Perform a search for resonant and interference effects of the new calibration bosons, the di-lepton production processes and to set limits on the dynamical parameters and masses in Run-II

V/H(→ jet-jet)+gamma resonances

Many proposals for physics beyond the Standard Model (SM) include the prediction of new massive bosons. Examples are Technicolor or little Higgs, as well as extensions to the SM Higgs sector such as including an additional electro-weak singlet scalar. Decay modes of these new bosons include final states with a Z or a W boson and a photon. In addition, decays of heavy spin-1 bosons to the 125 GeV Higgs boson and a photon present an interesting search channel. JINR team participates in a search for massive neutral and charged bosons decaying to a photon and a Z, W, or Higgs boson with subsequent hadronic decay of these bosons. The search will use the Run-II dataset of proton-proton (pp) collision data at a center-of-mass energy $\sqrt{s}$ = 13 TeV as well as Run-III data to be collected in 2021 – 2023 period.

Quantum Black Holes

Models for physics beyond the SM, such as the ADD-model, postulate the existence of extra dimensions which could lead to an energy scale of quantum gravity in the TeV region. And also Randall Sundrum-1 (RS1) model postulates the existence of extra dimensions leading to low gravity at the TeV scale. Quantum black holes are predicted in low-scale gravity models which offer a possible solution to the mass hierarchy problem of the SM by lowering the scale of gravity (MD) from the Planck scale (~ 10^{16} TeV) to a value of about 1-10 TeV. Here MD is the multi-dimensional Planck scale. The multi-dimensional paradigm has been developed into models such as that proposed by Arkani-Hamed, Dimopoulous and Dvali (ADD-model). In models with large extra spatial dimensions, like the ADD model, only the gravitational field is allowed to penetrate the n extra spatial dimensions, while all the SM fields are localized in the usual four-dimensional space-time. The model used in this note includes the following features. QBHs have masses above MD and have spin=0. The production and decay needs to conserve total angular momentum, color and electric charge. The QBH decay into two particles final states. In other words, the QBHs show quasi-particle behavior in contrast with semi-classical black holes that decay via Hawking radiation to a large number of particles. In these models baryon and lepton numbers can be violated in the QBH production.

JINR team going to finalize analysis using Run-II data and after re-optimizations and some preparation work start to analyze Run-III data.

JINR in the ATLAS SUSY Working group

SUSY related charged Higgs search (complex final states)

JINR has very strongly motivated plans to continue study of discover possibility of charged Higgs boson from MSSM. To prove SUSY discovery one coherently has to find as many SUSY particles as possible, and the charged Higgs boson is one of the main “player” of SUSY. This search will be carried out via charged Higgs boson decay into SUSY final states, charginos and neutralinos. Such final states allow one to search for and discovery the charged Higgs boson when all other his decay channels into ordinary SM particles (non-SUSY) are forbidden. This SUSY decay channel assumes rather large mass of this Higgs boson (large than 250 GeV/c^2), where associate charged Higgs and top quark production dominates. All neutralino-chargino Higgs decay channels are considered, where one can find in the final state three charged leptons, two neutral stable invisible neutralinos and some neutrinos.

Preliminary study has shown good prospects of the selected process for discovery of the charged Higgs boson predicted for rather wide parameter space of tan β and $m_{H\pm}$. Nevertheless it is possible only for well defined values of the other important MSSM parameters μ and M_2. Therefore, JINR team plans first to study the 4-dimension MSSM parameter space to select the best search strategy on the basis of simulated samples generated for benchmark SUSY points by the ATLAS Higgs WG. First real low luminosity ATLAS data will be used for real background determination (including SUSY backgrounds), later with increase of data first signal search are scheduled (Leader A.P.Cheplakov, F.Ahmedov. A.A.Soloshenko).

JINR work and plans on charged Higgs search are approved by HSG5 WG and were discussed at two Workshops of the WG (2010 and 2011) in Dubna.

In general, a study of SUSY with ATLAS detector, discovery of SUSY and coherent (SUSY) solution of the dark matter problem are between the primary goals of JINR participation in the ATLAS experiment.

JINR in the ATLAS software development

Events indexing

The EventIndex is a complete catalog of all ATLAS events, keeping the references to all files that contain a given event at any processing stage. It takes event information from various data sources, such as CERN and Grid sites. It is also checks data for corruption and consistency, provides information about overlap of events or datasets by different trigger chains as well as fast data overview. JINR team during next 5 years is going to participate in development and support of the control system of the data indexing on the GRID servers, system parameters and production monitoring and as well as full support of the EventIdex system. It is also planned to develop EventIdex system using BigData technologies for the Run-III datataking period.

TDAQ system

JINR team will participate in support of components of the real time TDAQ system, development of the operational monitoring systems and networks monitoring. It is also planned to participate in the development and maintenance of the TDAQ system for the Run-III.

Human Resources

A total number of personnel in the JINR group participating in the ATLAS Physics program is 32 including 6 professors, 12 postdocs and 14 young scientists, students engineers. The whole Team provides 29 FTE.

Besides the participation in the analysis itself members of the ATLAS-JINR Team were also playing managerial roles in the Collaboration. In the recent period we were taking responsibilities of conveners and sub-conveners of the ATLAS Working Groups (WG) as well as technical contacts persons with others Working Groups, such as Standard Model WG, B-Physcs sub-group, Trigger Performance etc.

Major part of them is engaged in the project for many years. They have well recognized reputation within the Collaboration and beyond, solid background and necessary skills to fulfill all our obligations.

	Title	Paritcipants	FTEs	1st year 2020	2nd year 2021	3rd year 2022	4th year 2023	5th year 2024
1	SANC generator	Prof. L. Kalinovskaya PhD R. Sadykov PhD A. Sapronov	1 1 1	<--->				
2	Chiral Z*/W* bosons	Prof. M Chizhov	1	<--->				
3	Charged Higgs	PhD A. Soloshenko	1	<--->				

		M.Sc. T. Turtuvshin	1		
4	Intrinsic charm + proton PDF	Prof. G. Lykasov PhD A. Lipatov PhD st. A. Prokhorov	1 1 1	<-->	
5	B-physics	Prof. L. Gladilin PhD S. Turchikhin PhD V. Lyubushkin Eng. T. Lyubushkina	0.5 0.6 1 1	<-->	
6	VH(→bb)	M.Sc. F. Ahmadov B.Sc. M. Manashova	1 1	<-->	
7	BSM→V/H(→J) +γ	PhD E. Khramov	1	<-->	
8	Quantum black holes	PhD S. Karpov PhD Z. Karpova	1 1	<-->	
9	Z+b/c x-section	PhD S. Turchikhin	0.2	<-->	
10	Penta/ tetraquark	PhD I. Yeletskikh B.Sc. A. Vasyukov	0.5 0.5	<---------------->	to be defined
11	ttH	PhD N. Huseynov	0.8	<---------------->	to be closed
12	tH	PhD I. Boyko M.Sc. O. Koval PhD I. Yeletskikh	0.5 0.5 0.5	<-->	
					<---------------------------->
		PhD N. Huseynov	0.2	<---------------->	
			1		<---------------------------->
13	Bose-Einstein Correlations	Prof. Y. Kultchitsky M.Sc. P. Tsiareshka M.Sc. E. Plotnikova	1 1 1	<-->	
14	Events Indexing	PhD F. Prokoshin PhD I. Alexandrov M.Sc. E. Aleksandrov M.Sc. A. Kazymov M.Sc. M. Mineev	1 0.2 0.1 0.1 0.1	<-->	
15	TDAQ	PhD I. Alexandrov M.Sc. E. Aleksandrov M.Sc. A. Kazymov M.Sc. M. Mineev	0.2 0.1 0.1 0.1	<---------------->	to be defined
16	Athena MT dev.	PhD I. Yeletskikh PhD S. Turchkhin B.Sc. A. Vasyukov M.Sc. Z. Chubinidze	0.5 0.2 0.5 0.5	<---------------->	to be defined

SWOT Analysis

The approach developed by our colleagues from the ATLAS-JINR Upgrade Team was used as a good starting point for the present analysis.

Strength

1. Participation in a large and challenging international projects in a competitive and high-tech, internationally oriented, research arena

2. Excellent scientific publication and citation records

3. Collaborations with groups at the leading international scientific center (CERN) in particle physics and other physics laboratories

4. Large interest of the general public and media

Weaknesses

1. The growing age of staff scientists and engineers

- The efforts are undertaking to attract young students to join the project
- JINR and CERN are the founder of the Russian Physics Teacher Programme

2. Many analyses in the ATLAS Collaboration have publication deadlines due to the high class conferences date. This is especially important for the search analyses. But nonetheless, it is rather hard to precisely predict and therefore perform the definite plan of the analyses work, publications and expenses for working trips.

Opportunities

1. LHC shows huge discovery potential which attracts scientists at all levels (master students, PhD students, postdocs and staff physicists)

2. JINR experiments often require completely new and challenging analysis methods, data acquisition and production requirements and ATLAS offers all those possibilities and contacts with new research and analysis communities

3. The experience gained in the ATLAS experiment is shared with our colleagues from the other projects of the Institute

4. The Big Grid - e-science grid–project JINR-LCG2 - provides researchers at JINR with state-of-the-art computing services and an opportunity to establish contacts and/or collaborations with many other research disciplines.

Threats

No threats are identified

Maintenance and operation responsibilities

According to the decision of the ATLAS Management the following procedure for sharing of ATLAS Operation Tasks is established for 2010 and thereafter:

1. Operation Tasks (OTs) are regrouped into three categories:

– Class 1: ACR shifts - Central and Detector Shifts in ATLAS Control Room at Point-1.

– Class 2: Other shifts - Additional shifts, including shifts in satellite control rooms, computing shifts, remote shifts, on-call shifts.

– Class 3: Expert operation tasks - Operation tasks involving experts on systems, data preparation, computing, software.

2. Institutions are expected to contribute to each of the three classes according to their OT share. As of 2015 Class 1 and Class 2 are combined in OT one can therefore do either. Activities of one class cannot be freely substituted for activities of another class. For example, Class 3 OTs (expert operation tasks) cannot be substituted for Class 1 OTs (ACR shifts) or Class 2 (On-call shifts).

During the 2015-2018 period JINR has successfully secured all requested OTs of Class 1 and 2 providing:

1. 1.47 FTEs with 1.39 FTEs requested in 2015
2. 1.38 FTEs with 1.38 FTEs requested in 2016

3. 1.23 FTEs with 1.18 FTEs requested in 2017
4. 1.37 FTEs with 1.20 FTEs requested in 2018

The main task is participation in the ATLAS SLIMOS/TI - Safety shifter and we would like to continue to cover this kind of shifts in that way.

At the beginning of the 2015-2018 period the Class 3 shifts were covered at the level of ~30%.

1. 3.81 FTEs with 9.86 FTEs requested in 2015
2. 4.14 FTEs with 9.43 FTEs requested in 2016
3. 4.36 FTEs with 8.83 FTEs requested in 2017
4. 4.62 FTEs with 8.87 FTEs requested in 2018

This coverage was mainly due to "Grid Data Processing & Analysis" and "DAQ/HLT Control & Configuration" and authorship qualification tasks. There are several minor tasks usually provided by JINR Team members in the detector sub-systems

Till the beginning of the 2017 the lack of the FTEs in this Class shifts from JINR was not a cause for concern. But the experience over the past years has shown that there is a shortage of person power in the so-called operation and service areas. It was decided to implement so-called Institutional Commitments: when ATLAS institutions commit to carry out certain tasks on a long-term basis and to provide service or certain deliverables to detector operation or to the other activity areas (Trigger, Data Preparation, Computing & Software, and Physics). The ATLAS-JINR Team management introduced special requirements to secure Class-3 shifts quota. First, each postdoc and young scientist of our physics analysis team should take responsibility for at least 0.25 FTEs. It was done by participation in the TileCal software development, B-physics trigger efficiency calculation, optimization and its software maintenance. Also in 2018 on the base of JINR the team for the "Event Indexing" task. Initially there were four participants working partially and they provided ~1.5 FTEs, and since 2019 one more participant with 1 FTE has joined this team. In addition this year the team of four participants has got ATLAS software development grant and we expect that they will participate at the level of ~2 FTEs.

For the 2019 the JINR quotas are 0.48 FTEs of Class 1 and 2 shifts and 8.05 FTEs of the Class 3 shifts.

List of publications

In this section the complete list of publications with significant contrubution of the ATLAS-JINR Team members is presented for the period of 2015 – 2019.

Journal publications

1. A. Sapronov et al, Precision measurement and QCD analysis of inclusive $W\to\ell\nu$ and $Z/\gamma^*\to\ell\ell$ production cross sections with the ATLAS detector, Eur. Phys. J. C 77 (2017) 367

2. A. Sapronov et al, Measurement of the Drell-Yan triple-differential cross section in pp collisions at $\sqrt{s}$ = 8 TeV, JHEP 12 (2017) 059

3. A. Sapronov et al, Precision studies of observables in pp→W→lνlpp→W→lνl and pp→γ,Z→l+l−pp→γ,Z→l+l− processes at the LHC, Eur.Phys.J. C77 (2017) no.5, 280

4. A. Arbuzov et al, Update of the MCSANC Monte Carlo integrator, v. 1.20, JETP Lett. 103 (2016) no.2, 131-136

5. G.I. Lykasov et al, Employing RHIC and LHC data to determine the transverse momentum dependent gluon density in a proton, Phys.Rev. D98 (2018) no.5, 054010

6. A.V. Lipatov et al, Hard production of a Z boson plus heavy flavor jets at LHC and the intrinsic charm content of a proton, Phys.Rev. D97 (2018) no.11, 114019

7. G.I. Lykasov, Self-consistent analysis of hadron production in pp and AA collisions at mid-rapidity, Eur.Phys.J. A54 (2018) no.11, 187

8. V. Bednyakov et al, Constraints on the intrinsic charm content of the proton from recent ATLAS data, Eur.Phys.J. C79 (2019) no.2, 92,

9. S.J. Brodsky et al, The Physics of Heavy Quark Distributions in Hadrons: Collider Tests, Prog.Part.Nucl.Phys. 93 (2017) 108

10. A.V. Lipatov et al,Probing proton intrinsic charm in photon or Z boson production accompanied by heavy jets at the LHC, Phys.Rev. D94 (2016) no.5, 053011

11. A.A. Grinyuk et al, Significance of nonperturbative input to the transverse momentum dependent gluon density for hard processes at the LHC, Phys.Rev. D93 (2016) no.1, 014035

12. S. Turchikhin et al, Study of the rare decays of B^0_s and B^0 into muon pairs from data collected during the LHC Run 1 with the ATLAS detector, Eur. Phys. J. C 76 (2016) 513

13. S. Turchikhin et al, Angular analysis of $B_d^0 \to K^* \mu^+ \mu^-$ decays in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector, JHEP 10 (2018) 047

14. S. Turchikhin et al, Study of the $B^+_c \to J/\psi D^+_s$ and $B^+_c \to J/\psi D^{*+}_s$ decays with the ATLAS detector, Eur. Phys. J. C, 76(1), 1-24 (2016)

15. V. Lyubushkin et al, Measurement of the branching ratio $\Gamma(\Lambda^0_b \to \psi(2S)\Lambda^0)/\Gamma(\Lambda^0_b \to J/\psi\Lambda^0)$ with the ATLAS detector, Physics Letters B 751 (2015) 63-80

16. Yu. Kulchitsky et al, Two-particle Bose--Einstein correlations in pp collisions at $\sqrt{s}$= 0.9 and 7 TeV measured with the ATLAS detector, Eur. Phys. J. C75 (2015) 466

17. Yu. Kulchitsky et al, Charged-particle distributions in $\sqrt{s}$=13 TeV pp interactions measured with the ATLAS detector at the LHC, Phys. Lett. B 758 (2016) 67

18. I. Yeletskikh et al, Search for high-mass new phenomena in the dilepton final state using proton--proton collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector, Phys. Lett. B 761 (2016) 372-392

19. I. Yeletskikh et al, Search for new high-mass phenomena in the dilepton final state using 36 fb^{-1} of proton-proton collision data at $\sqrt{s}$ = 13 TeV with the ATLAS detector, JHEP 10 (2017) 182

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32. I. Aleksandrov et al, The Resource Manager the ATLAS Trigger and Data Acquisition System, J.Phys.Conf.Ser. 898 (2017) no.3, 032016

33. M. Mineev et al, Experience with SPLUNK for archiving and visualisation of operational data in ATLAS TDAQ system, J.Phys.Conf.Ser. 1085 (2018) no.3, 032052

34. F. Ahmadov et al, Evidence for the $H\to bb$ decay with the ATLAS detector, ATLAS-CONF-2017-041

35. F. Ahmadov et al, Observation of $H\to bb$ decays and VH production with the ATLAS detector, ATLAS-CONF-2018-036

36. F. Ahmadov et al, Measurements of VH, $H\to bb$ production as a function of the vector boson transverse momentum in 13 TeV pp collisions with the ATLAS detector, ATLAS-CONF-2018-053

List of conferences and talks

In this section the full list of conferences where members of the ATLAS-JINR Team took part (25 talks at 18 conferences):

1. EDS-2015
   - E. Plotnikova: Measurements of particle production and their correlations at the LHC with the ATLAS detector
2. ISMD-2015
   - Yu. Kulchitsky: Bose-Einstein correlations and results on minimum bias interactions, underlying event and particle production from ATLAS
3. LHCP-2015
   - A. Cheplakov: Research and Development for the ATLAS Forward Calorimetry at the HL-LHC
   - Z. Karpova: Search for quantum black holes using pp collisions at sqrt(s) = 8 TeV and expected sensitivity at sqrt(s) = 13 TeV with the ATLAS
   - A. Soloshenko: Identification and energy calibration of hadronically decaying tau leptons with the ATLAS experiment in {\bf pp} collisions at {\bf $\sqrt{s}$}=8 \TeV
   - S. Turchikhin: ATLAS HF spectroscopy and exotic states
4. CHEP-2016

- E.Alexandrov: The Resource Manager of the ATLAS Trigger and Data Acquisition system

5. Beauty-2016
   - V. Lyubushkin: ATLAS Searches for new states (including pentaquarks)
   - S. Turchikhin: ATLAS Decay properties (Lambda_B, B_c)
6. GRID-2016
   - D. Oleynik: Integration Of PanDA Workload Management System With Supercomputers for ATLAS
7. Lowx-2016
   - Yu. Kulchitsky: Measurements of the underlying-event properties with the ATLAS detector
8. NewTrends-2016
   - I. Yeletskikh: Searches for new physics at TeV scale in dilepton final states at ATLAS experiment
   - Yu. Kulchitsky: Two-particle Bose-Einstein correlations in pp collisions at sqrt{s} = 0.9 and 7 TeV measured with the ATLAS detector
9. Quarks-2016
   - A. Soloshenko: Latest results from the 13 TeV LHC collisions from ATLAS
10. Hadron-2017
    - I. Yeletskikh: Status of exotic states at LHC
11. NEC-2017
    - D. Oleynik: Optimizing new components of PanDA for ATLAS production on HPC resources
12. QFTHEP-2017
    - S. Turchikhin: Searches for new physics with heavy flavour
13. Beauty-2018
    - S. Turchikhin: Beyond Standard Model searches in B decays with ATLAS
14. Charm-2018
    - S. Turchikhin: Prospects of Charm Physics at ATLAS
    - S. Turchikhin: Multiple charm (onium) production at the LHC
15. GRID-2018
    - E. Alexandrov: BigData tools for the monitoring of the ATLAS EventIndex
    - M. Mineev: Trigger information data flow for the ATLAS EventIndex
16. NewTrends-2018
    - G. Lykasov: Constraints on the intrinsic charm content of the proton from recent ATLAS data
17. QCD@work-2018
    - Yu. Kulchitsky: Probing QCD with the ATLAS Detector
18. QCD-2019
    - S. Turchikhin: Spectroscopy and production of quarkonia and heavy flavour at ATLAS

Theses

1. I. Yeletskikh, “Search for new Z* boson in dimuon final state in the proton-proton collision data with the ATLAS detector”, PhD thesis
2. J. Smiesko, “Intrisic charm in proton”, PhD thesis to be defended in June 2019
3. K. Alishina, “Reconstruction of the $J/\psi \to \mu^+\mu^-$, $Z \to \mu^+\mu^-$ and $H \to 2\mu^+2\mu^-$ decays”, master thesis
4. T. Atovullaev, “Reconstruction of the top quark decays”, master thesis
5. M. Manashova, ”Spin effects in the associated production processes of the Higgs and W bosons”, bachelor thesis

6. A. Vasyukov, “Search and study of tetraquarks Zc(3900), Zc(4200) in B-mesons decays at the ATLAS experiment”, bachelor thesis

Budget request

Appendices 26 and 29 contain detailed information about requested budget and we would like just to make some comments regarding two largest positions. The first one is the “ATLAS detector maintenance” with 300 kUSD per year. This amount should cover JINR contribution to the Collaboration for our 34 active authors. The second position “Working trips/Travel allowance” should cover Collaboration request for Operation Tasks of Class 1 and 2 that requires permanent presence of three shifters at CERN that is approximately 3*12*4kUSD = 144 kUSD per year. The rest ~86 kUSD of this position should cover travel expenses for coverage of the Operation Tasks of Class 3, for physics analyses purposes and for conferences.

Appendix 3
Form No. 26

Schedule proposal and resources required for the implementation of the Project PHYSICS RESEARCH WITH ATLAS DETECTOR AT THE LHC RUN-III (JINR PARTICIPATION)

<table>
<tr><th colspan="3" rowspan="2">Expenditures, resources, financing sources</th><th rowspan="2">Costs (k$) Resource requirements</th><th colspan="5">Proposals of the Laboratory on the distribution of finances and resources</th></tr>
<tr><th>1st year 2020</th><th>2nd year 2021</th><th>3rd year 2022</th><th>4th year 2023</th><th>5th year 2024</th></tr>
<tr><td colspan="2" rowspan="3">Expenditures</td><td>Main units of equipment, work towards its upgrade, adjustment etc.</td><td>5 years</td><td>1 year</td><td>1 year</td><td>1 year</td><td>1 year</td><td>1 year</td></tr>
<tr><td>ATLAS detector maintenance</td><td>1500 k$</td><td>300 k$</td><td>300 k$</td><td>300 k$</td><td>300 k$</td><td>300 k$</td></tr>
<tr><td>Computer connection etc.</td><td>50 k$</td><td>10 k$</td><td>10 k$</td><td>10 k$</td><td>10 k$</td><td>10 k$</td></tr>
<tr><td rowspan="4">resourcesRequired</td><td rowspan="4">Standard hour</td><td rowspan="4">Resources of
Laboratory design bureau;
Laboratory disks usage (Tb);
computer (CPU khours)</td><td colspan="6"></td></tr>
<tr><td>1000 h.</td><td>200 h.</td><td>200 h.</td><td>200 h.</td><td>200 h.</td><td>200 h.</td></tr>
<tr><td>1000</td><td>200</td><td>200</td><td>200</td><td>200</td><td>200</td></tr>
<tr><td>1000</td><td>200</td><td>200</td><td>200</td><td>200</td><td>200</td></tr>
<tr><td rowspan="3">Financing sources</td><td>resourcesBudgetary</td><td>Budget expenditures including foreign-currency resources.
a) Detector maintenance
b) working trips
c) salary</td><td>1500 k$
1150 k$
6520 k$</td><td>300 k$
230 k$
1030 k$</td><td>300 k$
230 k$
1190 k$</td><td>300 k$
230 k$
1300 k$</td><td>300 k$
230 k$
1430 k$</td><td>300 k$
230 k$
1570 k$</td></tr>
<tr><td rowspan="2">External resources</td><td>Contributions by collaborators:
working trips</td><td>450 k$</td><td>90 k$</td><td>90 k$</td><td>90 k$</td><td>90 k$</td><td>90 k$</td></tr>
<tr><td>Grants.
Contributions by sponsors.
Contracts.
Other financial resources, etc.</td><td colspan="6">CERN, Russian Federal programs, Grants RFBR etc.</td></tr>
</table>

PROJECT LEADER

Приложение 3
Форма № 26

Предлагаемый план-график и необходимые ресурсы для осуществления ПРОЕКТА “ФИЗИЧЕСКИЕ ИССЛЕДОВАНИЯ НА ДЕТЕКТОРЕ АТЛАС НА БАК В ТРЕТЬЕМ ПЕРИОДЕ НАБОРА ДАННЫХ (УЧАСТИЕ ОИЯИ)”

Наименование узлов и систем установки, ресурсов, источников финансирования			Стоимость(тыс. долл.). Потреб-ности в ресурсах	Предложения лаборатории по распределению финансирования и ресурсов				
				1 год 2020	2 год 2021	3 год 2022	4 год 2023	5 год 2024
Затраты	Коллайдер LHC, детектор ATLAS Обслуживание установки ATLAS		5 лет работы 1500 k$	год работы 300 k$	год работы 300 k$	год работы 300 k$	год работы 300 k$	год работы 300 k$
	Комп. связь и т.п.		50 k$	10 k$	10 k$	10 k$	10 k$	10 k$
Необходимые ресурсы	Нормо-час	Ресурсы КБ, ООЭП ЛЯП Использование дисков (Tb) Использование время (CPU, k-часов)	1000 ч. 1000 1000		200 ч. 200 200	200 ч. 200 200	200 ч. 200 200	200 ч. 200 200
Источники финансирования	Затраты из бюджета							
	а) обслуживание установки АТЛАС		1500 k$	300 k$	300 k$	300 k$	300 k$	300 k$
	б) командировки		1150 k$	230 k$	230 k$	230 k$	230 k$	230 k$
	в) Зарплата (1+2+3)		6520 k$	1030 k$	1190 k$	1300 k$	1430 k$	1570 k$
	Вклад коллаборации командировки сотрудников ОИЯИ		450 k$	90 k$	90 k$	90 k$	90 k$	90 k$
	Внебюджетные источники		ЦЕРН, Госпрограммы РФ, Гранты РФФИ и др.					

РУКОВОДИТЕЛЬ ПРОЕКТА

Appendix 4
Form No. 29

Estimated expenditures for the Project PHYSICS RESEARCH WITH ATLAS DETECTOR AT THE LHC RUN-III (JINR PARTICIPATION)

	Expenditure items	Full cost	1st year 2020	2nd year 2021	3rd year 2022	4th year 2023	5th year 2024
	Direct expenses for the Project						
1.	Computers Tb, kCPU-hours	1000, 1000	200, 200	200, 200	200, 200	200, 200	200, 200
2.	Design bureau	1000 h	200 h	200 h	200 h	200 h	200 h
3.	Computer connection, GRID	50 k$	10 k$	10 k$	10 k$	10 k$	10 k$
4.	ATLAS detector maintenance	1500 k$	300 k$	300 k$	300 k$	300 k$	300 k$
5.	Payments for agreement-based research	250 k$	50 k$	50 k$	50 k$	50 k$	50 k$
6.	Travel allowance, including:	1150k$	230 k$	230 k$	230 k$	230 k$	230 k$
	a) non-rouble zone countries						
	b) rouble zone countries	1000 k$	200 k$	200 k$	200 k$	200 k$	200 k$
	c) protocol-based	150 k$	30k$	30k$	30k$	30k$	30k$
	Total direct expenses	2950 k$	590 k$	590 k$	590 k$	590 k$	590 k$

PROJECT LEADER
LABORATORY DIRECTOR
LABORATORY CHIEF ENGINEER-ECONOMIST

Приложение 4
Форма № 29

Смета затрат по ПРОЕКТУ “ФИЗИЧЕСКИЕ ИССЛЕДОВАНИЯ НА ДЕТЕКТОРЕ АТЛАС НА БАК В ТРЕТЬЕМ ПЕРИОДЕ НАБОРА ДАННЫХ (УЧАСТИЕ ОИЯИ)”

	Наименование статей затрат	Полная Стоимость	1 год 2020	2 год 2021	3 год 2022	4 год 2023	5 год 2024
	Прямые расходы на Проект						
1.	ЭВМ: Tb, kCPU-часов	1000, 1000	200, 200	200, 200	200, 200	200, 200	200, 200
2.	КБ, ООЭП	1000 ч.	200 ч.	200 ч.	200 ч.	200 ч.	200 ч.
3.	Компьютерная связь, GRID	50 k$	10 k$	10 k$	10 k$	10 k$	10 k$
4.	Материалы и Оборудование, обслуживание Детектора	1500 k$	300 k$	300 k$	300 k$	300 k$	300 k$
5.	Оплата НИР, выполняемых по договорам	250 k$	50 k$	50 k$	50 k$	50 k$	50 k$
6.	Командировочные расходы: а) в страны нерублевой зоны б) в города рублевой зоны в) по протоколам	1150 k$ 1000 k$ 150 k$	230 k$ 200 k$ 30 k$	230 k$ 200 k$ 30 k$	230 k$ 200 k$ 30 k$	230 k$ 200 k$ 30 k$	230 k$ 200 k$ 30 k$
	Итого по прямым расходам:	2950 k$	590 k$	590 k$	590 k$	590 k$	590 k$

РУКОВОДИТЕЛЬ ПРОЕКТА
ДИРЕКТОР ЛАБОРАТОРИИ
ВЕДУЩИЙ ИНЖЕНЕР-ЭКОНОМИСТ ЛАБОРАТОРИИ