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., Davydov Y., Dedovich D., Demichev M., Elkin V., Ershova A., Gladilin L., Glagolev V., Gongadze A., 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.

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., 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

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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

Table of Contents

Abstract

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

Absolutely new and unique data will be obtained based on a multifaceted and comprehensive researches of the proton-proton scattering processes. These data analysis will allow to answer several fundamental physical problems. Within current project scientists from JINR are going to participate in these analyses.

It is expected to obtain new results and to make publications on all mentioned above tasks where scientists from JINR have responsibilities. The most important tasks are the studies of the proton structure and hadron states spectrum, probe of the Standard Model at the LHC energies, search and investigation of the Supersymmetry, search for the evidence of new particles and new interactions existence. Besides these results scientists from JINR are going to obtain new results which allow to specify properties of already known elementary particles such as W- and Z-bosons, top-quark, heavy barions etc.

During the 2015 – 2019 period of the current project it was published 28 papers with significant participation of the JINR staff, more than 20 talks at different conferences and meeting excluding working meeting within the Collaboration.

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 28 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 international collaboration ATLAS was established more than 25 years ago to carry out a new-generation multipurpose experiment aimed at studying fundamental properties of matter in collisions of 14-TeV protons at the Large Hadron Collider LHC. Nowadays the Collaboration includes 1786 authors out of 8128 participants from 221 institutes from 41 countries. During these 25 years the very complicated ATLAS detector systems were designed, constricted, commissioned and successfully allow one to investigate a variety of physical phenomena, including the long-awaiting Higgs boson discovery in 2012.

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

1. Creation, mounting and adjustment of the elements of the ATLAS Muon Detector System.
2. Creation, mounting and adjustment of the elements of the Liquid-Argon Calorimeter for the ATLAS.
3. Creation, mounting and adjustment of the elements of the Barrel Tile Calorimeter for the ATLAS.
4. Participation in the development and adjustment of the ATLAS Inner Detector.
5. Calibration of the ATLAS calorimeters and preparation for data-taking.
6. Participation in the development on the ATLAS Trigger TDAQ.
7. Creation of the ATLAS Grid at JINR (one of the best in Russia).
8. Calculation of ATLAS magnet system.
9. Preparation and planning of JINR participation in the ATLAS physics research program.

It is remarkable that *only Italy, USA, CERN and JINR* have contributed to all main subsystems (Tile-Cal, Muon, LiAr, TRT, TDAQ) of the ATLAS detector. It was clear claimed in 2009 (when the first part of the project was approved) that *the huge JINR contribution into design, construction, assembly and commissioning of the ATLAS detector systems should not be lost for JINR without a trace.*

Therefore in 2015-2019 the main efforts of management of JINR ATLAS team were to transform the above-mentioned JINR achievements into exciting physics results obtained by (or with decisive contribution of) the JINR people. Despite several complications, these efforts were successful in general. The extended report on JINR ATLAS team contribution in ATLAS physics and operation during 2015-2019 is under preparation for publication.

In short, during these 5 years under the project the JINR team strongly participated in the ATLAS Physics activities including data taking and simulations, data preparation 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 had upgraded the JINR LHC computing Grid facilities and supplied computing resources which allowed successful exploration of the JINR-based Teir-2 ATLAS Grid fragment. The JINR team has defined his field of participation in the general ATLAS upgrade programme for the super-LHC.

Furthermore during realization of the ATLAS project at JINR in 2009-2019, the JINR management of the ATLAS has carried out its inner reorganization. The reason was a general change from construction, assembly and commissioning of the ATLAS detector sub-systems (Tail 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. At the new stage both Operation Tasks and Physics analysis are (as a rule) obligatory for an ATLAS author (from JINR). To strengthen responsibility of JINR people and to enhance as a whole the JINR contribution in the ATLAS project it was necessary to impose the requirement that to be a member of the JINR-ATLAS team one first has to become “visible” at the general ATLAS collaboration level. The main practical goal of these rules was to create at JINR a new effectively 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 substantially contributed in ATLAS physics researches 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). Some Collaboration accepted new topic for physics research were proposed and put into development by JINR team members.

General physical motivation

Physical motivation for continuation of JINR participation in the ATLAS project relies on the main conceptual points in the Long-Term Plan of JINR development (the JINR Road-map). The Plan starts from description of the main developing directions of the modern Particle Physics and the urgent problems to be solved in the field. In particular, despite the Standard Model of particle physics explains to a high accuracy almost all relevant experimental observations, nevertheless, it is not a fundamental theory, but a low-energy limit of some underlying theory which originates from the very high energy scales. The main problems beyond the Standard Model can be cast into the following list (not complete):

1. What is the origin of the particle masses, are they due to a Higgs boson?
2. What is the nature of new particles and new principles beyond the Standard Model? Are there undiscovered principles of Nature – new symmetries, new laws?
3. Do all the forces of nature become one? How does gravity fit in? Is there a quantum theory of gravity?
4. Why are there so many types of quarks and leptons, and how can one understand their weak mixing and CP violation?
5. What is the dark matter that makes up about one quarter of the contents of the Universe? How can we make it in laboratory?
6. What is the nature of the dark energy that makes up almost three quarters of the Universe? How can we solve the mystery of dark energy?
7. Why is the universe as we know it made of matter, with no antimatter present? What is the origin of this matter-antimatter asymmetry? What happened to the antimatter?
8. What are the masses and properties of neutrinos and what role did they play in the evolution of the Universe? How are they connected to matter-antimatter asymmetry?
9. How did the universe form? How did the universe come to be?
10. Are there extra dimensions? String theory predicts seven undiscovered dimensions of space that give rise to much of the apparent complexity of particle physics, etc.

Addressing the above-mentioned central questions of the Particle Physics requires a broad, strongly integrated, program of theoretical and experimental research using a wide variety of modern tools and techniques that can be classify mainly into four interrelated directions – the **Energy-increasing accelerator** direction (the Energy Border); the **Intensity-increasing accelerator** direction (the Intensity Border), the **Accuracy-increasing non-accelerator** direction (the Accuracy Border) and the **Particle astrophysics** (the Cosmic Border).

At the Energy Border, using both hadron and lepton high-energy colliders, one will discover new physics of the **Terascale** (a TeV energy scale) and **directly** probe the properties of nature. At the Intensity Border, using intense beams, one will uncover the elusive properties of neutrinos and spread light on the problem of CP-violation, etc. At the Accuracy Border, investigating the rare processes by means of high-sensitivity, low-background experiments, one will observe new phenomena beyond the Standard Model and probe **indirectly** the properties of the nature far beyond any opportunities of modern and future accelerators. At the Cosmic Frontier one will reveal the natures of dark matter and dark energy and using high-energy particles from space (in particular neutrinos) one will probe the most far corners of the universe and make unique contribution in particle astrophysics. These four directions of the particle physics research join tightly together into a common framework that addresses all fundamental questions about the laws of nature and the cosmos.

Accelerators and experiments at the **Energy Border** are expected to make major discoveries. They will address key questions about the physical nature of the universe: the origin of particle masses, the existence of new symmetries of nature, extra dimensions of space, and the nature of dark matter.

In 2009 the **Large Hadron Collider (LHC)** at CERN (European Organization for Nuclear Research, Geneva, Switzerland) has achieved the highest collision energies. Significant participation in the full exploitation of the LHC has the highest priority in any national particle physics program. The LHC is the biggest and most powerful particle accelerator ever built. Colliding beams of protons generate about 1000 million collisions per second. Each proton flying around the LHC has energy of 7-14 Tera electron volts (TeV) to give proton-proton collision energy up to 14 TeV. Four major particle detectors – ALICE, ATLAS, CMS and LHCb – successfully observe the collisions during 5 years. The LHC experiments record about 1000 Gigabytes of data every day. Particle physicists are working with computer scientists around the world to develop and use **new grid networking technology**, which links computing and data storage resources from around the world into a seamless whole. The Grid is obviously inevitable for all the other modern experiments in Particle Physics, as well as for any research in all other fields of modern Science and Technology.

The future of Particle physics for decades is dominated by the LHC at CERN. JINR physicists participate in the general purpose experiments, **ATLAS** and **CMS**, which are designed to make excellent measurements of the many possible (known and unknown) products of collisions at the unprecedented centre-of-mass energy of 14 TeV. The experiments have already spread the light on the problem of particle mass genesis through the discovery of the Higgs boson, etc.Physics program of LHC experiments is, however, much more complex and it contains precision physics of CP violation, SUSY particles searches, extra dimensions and unexpected new phenomena.

Being in course of modern Particle Physics, JINR participates in generation of sources and tools for technological innovations with profound benefits for the sciences and society. Being in touch with (and/or in direct access to) a completely mystery substances as the dark matter and dark energy, JINR will take part in a science revolution, not just in particle physics but in the way human beings see the universe.

The Particle Physics near-the-corner opportunity for discovery about the fundamental nature of the universe that we never expected, the real work with unique best-level equipment and networking will make JINR very prestigious and most attractive for young generation of scientists and will allow the JINR Member States to be honest and generous with JINR financial support. This is also very attractive for rising the importance and prestige of high-quality education. Only such kind of very interesting, prestigious, front-end scientific work will attract young people in JINR and will copiously generate highly qualified personal for science industry, education, and all the other fields.

JINR, being in the course of modern Particle Physics, will inevitable participate in science international cooperation and will have access to most promising achievements and technologies (such as remote control systems, cryogenic and accelerator facilities, sophisticated power supply and control apparatuses, etc). Very good working example is the Grid – the new generation computing and networking system, which appeared at JINR due to its involvement in the LHC physics program. The future of the Grid is very difficult to overestimate.

This concludes description of advantages from (and motivation for) JINR participation in the Particle Physics development in general and in the ATLAS experiment, in particular.

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

During the next 5 years the two main directions are planned under this type of the ATLAS project:
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 under a specialized JINR-ATLAS upgrade project (leader Dr. A.P.Cheplakov).

Some words about **Participation in Running of the ATLAS experiment**

JINR will continue its taking relevant part in obligatory ATLAS Common Operation Tasks. It includes shift work of JINR people in the CERN-ATLAS control rooms, fulfilment 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 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 АТЛАС **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). Furthermore they will care on Radiation Gate Monitors, where the main problem is SLIMOS to be able to prevent people to get out if they are detected with radioactive material in the underground cavern, etc.

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).
In the light of the point, in the following directions JINR plans to strongly participate in 2020 – 2024:

1. Investigation of the applicability of *the Standard Model* and verification of SM predictions (including interactions of heavy ions), defining the structure of the proton 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 on associated productions of the SM Higgs with $t\bar{t}$ pair and search for 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*, study the properties.
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, etc.
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 stress, that many of the points were proposed for ATLAS at JINR.

JINR in the ATLAS Standard Model Working group

SANC-group

Within this WG JINR is mainly visible via the international SANC Project (Support of Analytical and Numerical Calculations for Experiments at Colliders). 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, etc) very sucessfully works in the ATLAS Collaboration over the years.

They develop and include 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 as well as the the impact of the production of light fermion pairs.

Other memebrs of the team will adopt (upgrade and development) famous HERAFitter code for ATLAS purposes, in particualar evolution of photonic PDFs will be included.

Furthermore the members of the group (leader A.Sapronov) plan to participate in the ATLAS experiment in the following extra directions.

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 electroweak 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 electroweak 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 showed that they have more information on the densities of momentum distributions of s-quark at small values of *x* and gluons at large *x*. There is a need for continued research data during Run-II using high kinematic ranges and higher statistics.

3) Together with colleagues from DESY (Hamburg) participation in the project ZeeD. The project ZeeD (analysis of Z decays to electron-positron pairs at DESY) is designed to study processes such as Drell-Yan from Z-boson decays into electronic final states.

Nowadays a hardware and software for ATLAS Run-I data analysis were both developed. For use in the analysis of the Run-II an interface is necessary to adapt this code to the new format of data and extend the code functionality.

Study of intrinsic heavy quark components in the proton

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 with ATLAS experiment the JINR-based predictions on possible observation of 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 essence of the check will be in the processing of the experimental data on the spectra of direct photons and vector bosons produced ATLAS collaboration in 2012 with the initial energy of 8 TeV and new data at an energy of 13-14 TeV, which was received during the whole Run-II (2015 – 2019).

The main purpose of such processing and Monte Carlo simulations is to get information, whether there are quark states in the proton and with what probability, from a comparison of data with theoretical predictions [V.A.Bednyakov, MA, Demichev, GILykasov, T. Stavreva, M. Stockton, hep-ph / 1305.3548, Phys.Lett.B 728 (2014) 602.]

LHC is a factory for gluons

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 and with the help of QCD calculations, to find the form of the gluon distribution at medium and large transverse momenta.

In other words, it is planned to make the monitoring of the gluon density in a wide range of variables on which it depends, using a set of ATLAS data to be obtained during the 2015-2018 period.

Heavy hadrons and baryons

One of important research direction at the LHC is investigation of baryons containing c- and b-quarks. It is because any study of such baryons is impossbile with B-factories and the majority of baryons with two (and/or three) heavy quarks have not yet beem observed. In the period 2015 – 2019 JINR team plans the following studies in this line:

1. Study of semi-leptonic and hadron Bc decay modes in data of RUN-II, in particular for searching of a vector states $B_c^* \to B_c + \gamma$ (earlier it was not observed in other experiments), and also for possible reproducing the analysis of RUN-I for searching of $B_c^*(2S)^+$ in semi-leptonic B_c decay mode, for the purpose of more precise measurement of $B_c^*(2S)^+$ production cross section using higher statistics.

2. Search of 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 the 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 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-to168 leading order (NLO). These processes are sensitive to heavy flavor quarks in the initial state. Two schemes are generally employed in perturbative QCD (pQCD) calculations containing heavy flavour quarks. One is the four-flavour 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-flavour number scheme (5FNS), which allows a b-quark density in the initial state and raises the prospect that measurements of heavy flavour 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 flavour number schemes for initial state partons still carry large uncertainties.

Furthermore, the V + b(anit-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-II data and move to the full Run-II analysis.

Bose-Einstein correlations

Particle correlations play an important role in the understanding of multiparticle production. Correlations between identical bosons, called Bose–Einstein correlations (BEC), are a well-known phenomenon in high-energy and nuclear physics. The BEC are often considered to be the analogue of the Hanbury-Brown and Twiss effect in astronomy, describing the interference of incoherently emitted identical bosons. They represent a sensitive probe of the space–time geometry of the hadronization region and allow the determination of the size and the shape of the source from which particles are emitted.

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-dimentional cases as well as investigations of charged-particle distributions in Run-II/III data.

JINR in the ATLAS Higgs Working group

ttH measurements in multilepton channel

The study of the origin of electroweak 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;

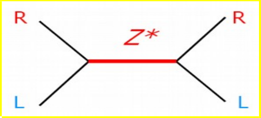
3) Study the tH (H→bb) channel using the ATLAS Run-II data and set limits if no signal is observed

JINR in the ATLAS Exotics Working group

Prospects for the search for Z*/W*

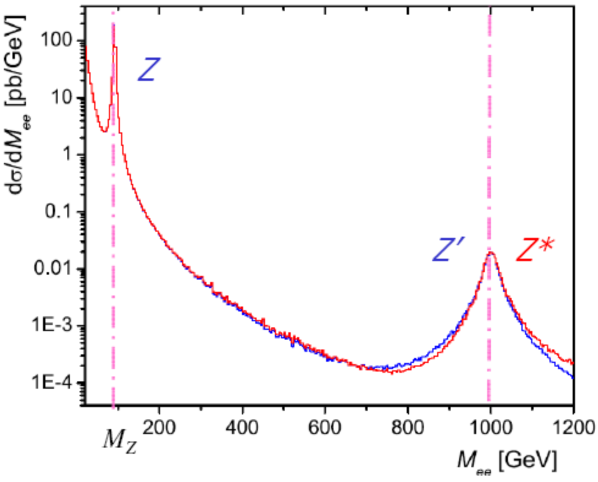
The existence of excited bosons has been suggested in the early papers of M.V. Chizhov [Mod. Phys. Lett. A 8 (1993) 2753], at present a senior researcher at Dzhelepov Laboratory of Nuclear Problems. The project for their search at the LHC has been proposed in [Phys. Atom. Nucl. 71 (2008) 2096; Nuovo 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.

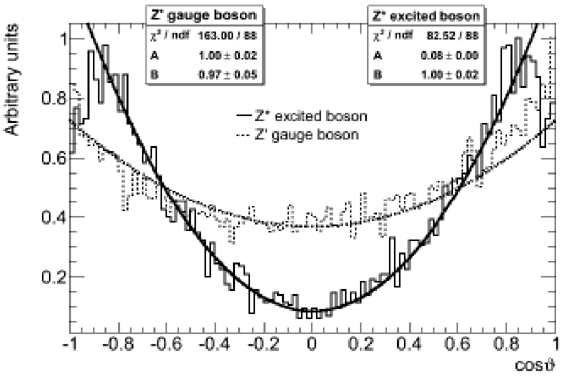
excited Z^* :



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

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 particular, it was shown that the new heavy excited Z* bosons could be even more interesting than the excited fermions for experimental searches with the data. 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’ result (**Figure below**). This will help to distinguish them an ambiguously from the other neutral resonances with different spins.





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

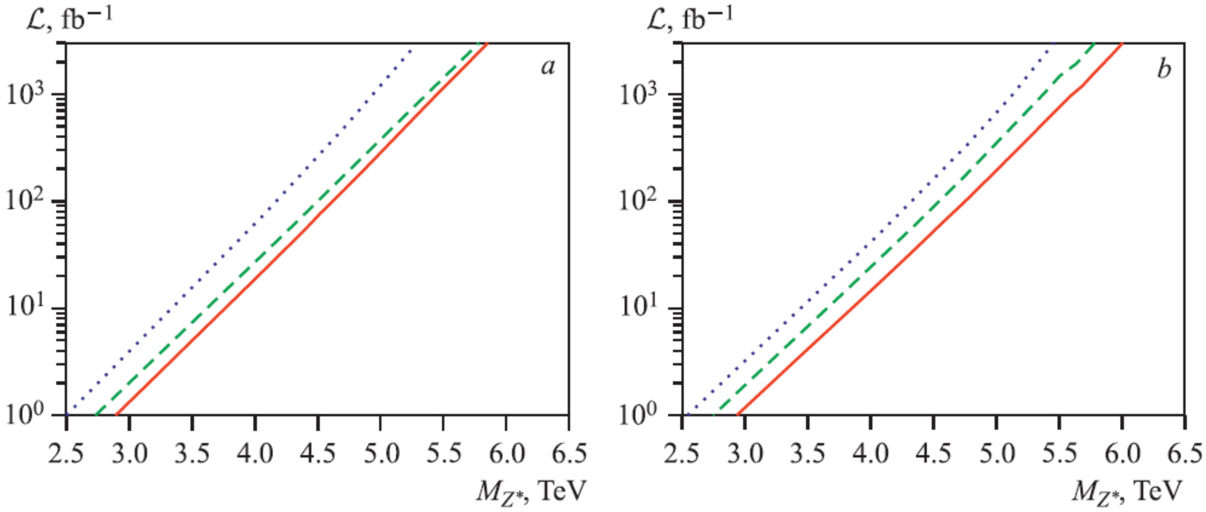
Data analysis of the first run (Run-I) of the LHC has been performed, looking for new excited bosons resonance for a first time, with the active participation of the scientists of Dzhelepov Laboratory: M.V. Chizhov, A.S. Vostrikov, I.R. Boyko, I.V. Yeletskikh, and other members of the ATLAS Collaboration. The results of the analysis have been published [ATLAS Collab., Phys. Lett. B 700 (2011) 163; JHEP 11 (2012) 138; Eur. Phys. J. C 72 (2012) 2241; Phys. Rev. D 90 (2014) 052005; JHEP 09 (2014) 037].

Up to now all searches for new physics at the LHC have not given positive results. According to the physical motivation of the existence of excited bosons [M.V. Chizhov, Gia Dvali, Phys. Lett. B 703 (2011) 593], their masses have been predicted to be in the TeV region. Therefore, the next LHC run (Run-II) at around twice higher (13-14 TeV) center-of-mass energy is highly expected. Theoretical estimations of the discovery potential for excited bosons search in the next run have been performed by JINR scientists in [M.V. Chizhov, I.R. Boyko, V.A. Bednyakov, J.A. Budagov, Phys. Part. Nucl. 45 (2014) 517.] and briefly discussed below.

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

Prospects for further Z*, W* searches related, primarily, with plans to increase the energy of the proton-proton collisions at the LHC to 13-14 TeV, as well as increasing 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 with a confidence level of 95% of the boson Z* depending on its mass for energy 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 sufficiently less 1fb^{-1} data to improve the existing restrictions on the Z* mass in required, while the analysis 100 fb^{-1} data will test the existence hypothesis Z* up to it mass of 4.5 TeV.

It should be noted that these results were obtained in the approximation of a constant reconstruction efficiency for electron and muon pairs (70% and 40%, respectively), as well as a simple linear dependence of the detector resolution on the invariant mass of the pairs. At the same time, the analysis of real experimental data shows a remarkable decrease in the efficiency of selection of muon pairs with increasing transverse momentum and increase the efficiency of selection of electron pairs. For this reason, on the one hand, it is expected that with increasing collision energy dominant contribution to the potential discovery of new resonances will be from electronic channel, and on the other hand, the increasing collision energy will require improvement of reconstruction and selection of muon pairs.

Another factor that plays a significant role in the mass region where the signal and the background are comparable in magnitude, is the quality of the simulation of background processes of the Standard Model. Systematic background uncertainty significantly affects the statistical significance of the signal. The main contribution to this uncertainty is given by the uncertainty of PDFs, inaccuracies in simulation of the SM process, inaccurate simulation of the experimental setup, etc. Therefore, one of the most important and difficult tasks of data analysis of the second period of the LHC (Run-II), is and will be improving the quality of the simulation of collision processes and reconstruction in the detector.

In general for the nearest 5 years JINR team plans, first of all to continue search for the Z* boson with Run-II data. Next, there are ideas to search 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 fulfilment.

All above-mentioned studies were dealt with the leptonic Z*-boson decay channels, the most pure channels from registration of the chiral-bosons point of view. Nevertheless with accumulation of the real data one can start to look for the chiral bosons via its hadronic decays, for example, when Z* decays into final states with bottom and top quarks. Using b-taging one can completely reconstruct both neutral and charged chiral boson decays into the heavy quarks. An analysis of such kind is rather important due to the fact that there is some class of chiral bosons which do not interact with leptons and therefore can not be found during investigation of only leptonic final states.

In above-mentioned investigations the key role plays the unique signature of the chiral boson decays, which allows one to distinguish them from any other heavy resonances with spin 0, 1 and 2. It was shown that such a signature can be indeed visible within the ATLAS detector.

Therefore JINR team holds leading positions in this direction and attracts for cooperation the other ATLAS members. Furthermore one should stress that leaders of the research (M.V.Chizhov and G.Dvali) has recently demonstrated 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 Run-II, new Monte Carlo simulations of productions of the excited bosons should be generated under the ATLAS software in 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 diboson 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} has a high potential to improve significantly on the current limits on the Z-Z' mixing angle in the diboson channel: $pp \to (Z_2 \to W^+ W^-) + X$.

In contrast to the Drell-Yan (DY) process $pp \to Z' \to l^+ l^- + X$, with l = e, μ, the diboson 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) Search for resonant and iterference effects of the new calibration bosons the di-lepton production processes and to set limit on the dinamical 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 electroweak 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 ($\sim 10^{16}$ 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, colour 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 the QBH production is supposed that baryon’s and lepton’s numbers can be violated.
JINR team is going to finalize analysis using Run-II data and after re-optimizations and some preparation work stat to analyse 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, chargios 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 neutralonos 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 catalogue 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 paticipate 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

In ATLAS the TDAQ project has primary responsibility for Level 1 Triggers, Data Acquisition System (DAQ) and High Level Trigger (HLT) infrastructure. The DAQ/HLT system interfaces to the detector readout and L1 trigger on the input side, and to the mass storage in the CERN computing centre on the output side. The ATLAS trigger system reduces the event rate in a three level architecture. After an event has been accepted by the L1 trigger it is moved from the detector specific front-end buffers via the RODs into a common readout system (ROS). From here on the L2 trigger and the Event Builder have access to the data via an Ethernet based network.

The high level trigger (L2 and the Event Filter) is implemented in software running on server computers. To avoid building full events at the L1 accept rate of at maximum 75 kHz the L2 part of the HLT uses only a subset of the data. It is guided by information that is provided by the L1 muon and calorimeter systems in the form of co-ordinates of centres of areas in η/φ space where the L1 trigger has e.g. identified tracks in the muon system or clusters in the calorimeter. These areas are referred to as “Regions of Interest”.

By requesting only data from Regions of Interest the bandwidth required for the L2 trigger is a fraction (a typical number being 5%) of the total bandwidth that would be needed for reading out the full event data.

After the L2 trigger has generated a decision the event is either discarded or built at the L2 accept rate. The full event data is passed to the Event Filter stage of the HLT, where predominantly offline algorithms are used for further event selection.

After the Event Filter has accepted an event its data are passed to the one of the data logging farm nodes running the Sub-Farm Output application that stores the data on disks.
JINR team wil 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 are 32 providing 29 FTE and 16 of them are young scientists. 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 fulfil all our obligations.

SWOT Analysis

Strength

1. Participation in a large and challenging international projects in a competitive and hightech, 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 Language Teacher Programme

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
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

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)

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

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.). Потребности 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		5 лет работы	год работы	год работы	год работы	год работы	год работы
	Обслуживание установки ATLAS		1500 k$	300 k$	300 k$	300 k$	300 k$	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

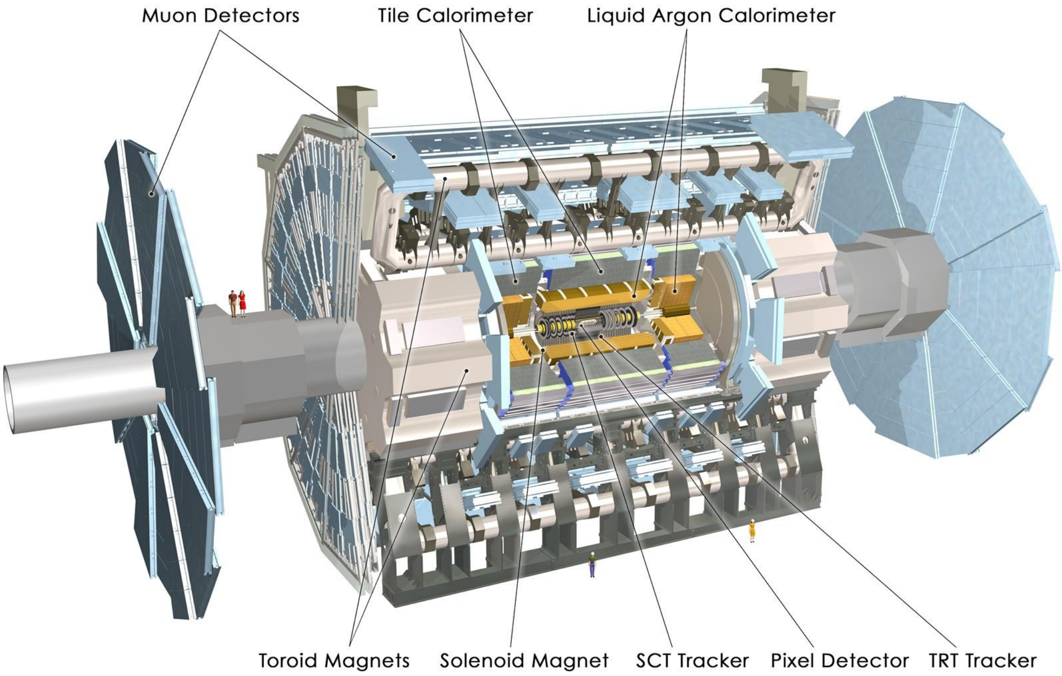
ВЕДУЩИЙ ИНЖЕНЕР-ЭКОНОМИСТ ЛАБОРАТОРИИ

Appendix

Main features of the ATLAS detector

To be complete one needs to describe here the ATLAS detector. The ATLAS (**A Toroidal LHC ApparatuS**) is one of two General Purpose Detectors at the LHC. The LHC collides protons with a centre of mass energy of 14 TeV and a design luminosity of ~10^{34} $cm^{-2}s^{-1}$. The bunch crossing time is about 25 ns and at full luminosity there will be approximately 22 proton-proton collisions per bunch crossing. The ATLAS Detector is situated at Point 1, directly opposite the CERN main entrance.

The ATLAS detector consists of four major components, the **Inner Tracker** which measures the momentum of each charged particle, the **Calorimeter** which measures the energies carried by the particles, the **Muon spectrometer** which identifies and measures muons and the **Magnet system** that bends charged particles for momentum measurement. The detector is a cylinder with a total length of 42 m and a radius of 11 m and weighs approximately 7000 tonnes. See for details [https://twiki.cern.ch/twiki/bin/view/Atlas/WorkBook].



During the long technical shutdown of the 2016 – 2017 period the Insertable B-Layer (IBL) was installed. It was placed just between the new beam pipe and the existing Pixel detector to maintain robust tracking despite effects arising from luminosity, hardware lifetime, and radiation and also to provide improved precision for vertexing and tagging. Its radius range is $31.0 < R < 40.0$ mm and it covers $|Z| < 332$ mm along the beam line ($|\eta| <3$). A Pixel sensor of the **Inner Detector** is a 16.4 x 60.8 mm wafer of silicon with 46,080 pixels, 50 x 400 microns each. The barrel part of the pixel detector consists of the 3 cylindrical layers with the radial positions of 50.5 mm, 88.5 mm and 122.5 mm respectively. These three barrel layers are made of identical staves inclined with azimuthal angle of 20 degrees. There are 22, 38 and 52 staves in each of these layers respectively. Each stave is composed of 13 pixel modules. There are three disks on each side of the forward regions. One disk is made of 8 sectors, with 6 modules in each sector. Disk modules are identical to the barrel modules, except the connecting cables. The Semiconductor Tracker (SCT) system of the Inner Detector is designed to provide eight precision measurements per track in the intermediate radial range, contributing to the measurement of momentum, impact parameter and vertex position. In the barrel SCT eight layers of silicon microstrip detectors provide precision points in the r-phi and z coordinates, using small angle stereo to obtain the z-measurement. Each silicon detector is 6.36 x 6.40 cm² with 768 readout strips of 80 micron pitch. The barrel modules are mounted on carbon-fibre cylinders at radii of 30.0, 37.3, 44.7, and 52.0 cm. The end-cap modules are very similar in construction but use tapered strips with one set aligned radially. The SCT covers range of $|\eta| < 2.5$. The outer Transition Radiation Tracker (TRT) of ATLAS is a combined straw tracker and transition radiation detector. The barrel part contains 52544 axial straws of about 150 cm length at radii between 56 cm and 107 cm. The end-caps contain a total of 319488 radial straws at radii between 64 cm and 103 cm (inner end-caps), respectively 48 cm and 103 cm (outer end-caps). The TRT provides on average 36 two-dimensional measurement points with 0.170 mm resolution for charged particle tracks with $|\eta| < 2.5$ and $p_T > 0.5$ GeV.

The **Liquid Argon** (LAr) **Calorimeter** is divided into several components: an electromagnetic sampling calorimeter with 'accordion-shaped' lead electrodes in the barrel and in the endcaps, a hadronic calorimeter using flat copper electrodes in the endcaps, and a forward calorimeter close to the beam pipe in the endcap made from copper and tungsten. In addition, pre-samplers consisting of one layer of LAr in front of the electromagnetic calorimeter help to correct for the energy loss in front of the calorimeter (mainly due to cryostat walls and the barrel solenoid).

The **Tile Calorimeter** is a large hadronic sampling calorimeter which makes use of steel as the absorber material and scintillating plates read out by wavelength shifting (WLS) fibres as the active medium. It covers the central range $|\eta| < 1.7$. The new feature of its design is the orientation of the scintillating tiles which are placed in planes perpendicular to the colliding beams and are staggered in depth. A good sampling homogeneity is obtained when the calorimeter is placed behind an electromagnetic compartment and a coil equivalent to a total of about two interaction lengths of material. The Tile Calorimeter consists of a cylindrical structure with an inner radius of 2280 mm and an outer radius of 4230 mm. It is subdivided into a 5640 mm long central barrel and two 2910 mm extended barrels. The thickness of the calorimeter in the gap is improved, which has the same segmentation as the rest of the calorimeter. The total number of channels is about 10000.

The **Muon System** of ATLAS is needed for muon measurements. In the barrel region ($|\eta| < 1.0$), which is covered by the large barrel toroid system, muons are measured in three layers of chambers around the beam axis using precision Monitored Drift Tubes (MDTs) and fast Resistive Plate Chambers (RPCs). In regions of larger pseudorapidity, also three layers of chambers are installed, but vertically. Here Thin Gap Chambers (TGCs) are used for triggering. The precision measurement of muons is again done with MDTs, except for the innermost ring of the inner station of the end caps and for $|\eta| > 2$, where high particle fluxes require the more radiation tolerant Cathode Strip Chamber (CSC) technology. In the barrel of the ATLAS muon system, the muon chambers are installed in three cylinders concentric with the beam axis at radii of about 5, 7.5 and 10 m. They are arranged to form projective towers pointing to the nominal interaction vertex. In the end caps, the distance in z from the vertex is about 7, 10 and 14 m for the three layers.

The Central Solenoid of **Magnet System** of ATLAS has a length of 5.3 m with a bore of 2.4 m. The conductor is a composite that consists of a flat superconducting cable located in the center of an aluminum stabaliser with rectangular cross-section. It is designed to provide a field of 2 T in the central tracking volume with a peak magnetic field of 2.6 T. To reduce the material build-up the solenoid shares the cryostat with the liquid argon calorimeter. The ATLAS Toroid Magnet system consists of eight Barrel coils housed in separate cryostats and two End-Cap cryostats housing eight coils each. The End-Cap coils systems are rotated by 22.5° with respect to the Barrel Toroids in order to provide radial overlap and to optimise the bending power in the interface regions of both coil systems.

Finally from the main paper of the ATLAS Collaboration [G. Aad et al., The ATLAS Experiment at the CERN Large Hadron Collider, JINST 3 (2008) S08003] one can cite that: “The broad range of physics opportunities and the demanding experimental environment of high luminosity 14 TeV proton-proton collisions have led to unprecedented performance requirements and hence technological challenges for the general-purpose detectors at the LHC. The overall ATLAS detector design is the result of a complex optimization process between conflicting requirements. These requirements can be expressed tersely as a set of four basic criteria over a large acceptance in pseudorapidity and basically full azimuthal coverage for all of the major detector systems:

- very good electromagnetic calorimetry for electron and photon identification and measurements, complemented by full-coverage hadronic calorimetry for accurate Jet- and E^{miss}_T measurements;
- high-precision muon momentum measurements with the capability to guarantee accurate measurements at the highest luminosity using the muon spectrometer alone;
- efficient tracking at high luminosity for high-p_T lepton momentum measurements, electron and photon identification, tau-lepton and heavy-flavour identification, and full event reconstruction capability;
- efficient triggering with low p_T-thresholds on electrons, photons, muons and tau-leptons, thereby providing high data-taking efficiencies for most physics processes of interest at the LHC.

After approximately fifteen years of detector design, construction, integration and installation, the ATLAS detector is now completed and almost entirely installed in the cavern. All detector teams, together with the ATLAS performance and physics working groups, have developed detailed commissioning strategies using cosmic rays, single-beams, and initial data with colliding beams. As more and more detector components become operational, detector calibrations and extensive stand-alone and combined studies with cosmic-ray events are being carried out.

List of publications

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 $pp\to W\to l\nu lpp\to W\to l\nu l$ and $pp\to\gamma,Z\to l+l-pp\to\gamma,Z\to l+l-$ 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

20) M. Chizhov et al, Search for new resonances in events with one lepton and missing transverse momentum in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector, Phys. Lett. B 762 (2016) 334

21) M. Chizhov et al, Search for a new heavy gauge-boson resonance decaying into a lepton and missing transverse momentum in 36 fb^{-1} of pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS experiment, Eur. Phys. J. C 78 (2018) 401

22) E. Khramov et al, Summary of the searches for squarks and gluinos using $\sqrt{s}$ = 8 TeV pp collisions with the ATLAS experiment at the LHC, JHEP 10 (2015) 054

23) E. Khramov et al, Search for gluinos in events with an isolated lepton, jets and missing transverse momentum at $\sqrt{s}$ = 13 TeV with the ATLAS detector, Eur. Phys. J. C 76 (2016) 565
24) E. Khramov et al, Search for heavy resonances decaying to a Z boson and a photon in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector, Phys. Lett. B 764 (2017) 11
25) E. Khramov et al, Search for heavy resonances decaying to a photon and a hadronically decaying Z/W/H boson in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector, Phys. Rev. D 98 (2018) 032015
25) F. Ahmadov et al, Search for the bb decay of the Standard Model Higgs boson in associated (W/Z)H production with the ATLAS detector, JHEP01(2015)069
26) F. Ahmadov et al, Evidence for the H→bb decay with the ATLAS detector, JHEP 12 (2017) 024
27) F. Ahmadov et al, Observation of H→bb decays and VH production with the ATLAS detector, Phys. Lett. B 786 (2018) 59
28) F. Ahmadov et al, Measurement of VH, H→bb production as a function of the vector-boson transverse momentum in 13 TeV pp collisions with the ATLAS detector, arXiv:1903.04618 (submitted to JHEP)

Other publications:

1) A. Sapronov et al, Measurement of the effective leptonic weak mixing angle using electron and muon pairs from Z-boson decay in the ATLAS experiment at $\sqrt{s}$ = 8 TeV, ATLAS-CONF-2018-037
2) A. Arbuzov et al, Computer system SANC: its development and applications, J.Phys.Conf.Ser. 762 (2016) no.1, 012062
3) G.I. Lykasov et al, Collider test of proton intrinsic charm in γ(Z)+c(b)γ(Z)+c(b) production by pp collisions, PoS DIS2017 (2018) 033
4) G.I. Lykasov et al, The physics of Heavy Quark Distributions in Hadrons: Collider Tests, DESY-PROC-2016-04
5) G.I. Lykasov et al, Significance of gluon density for soft and hard processes at LHC, PoS DIS2016 (2016) 038
6) G.I. Lykasov et al, Significance of gluon density at soft and hard processes at LHC, Int.J.Mod.Phys.Conf.Ser. 39 (2015) 1560115
10) S. Turchikhin et al, Angular analysis of the decay of B_d into K*μμ, ATLAS-CONF-2017-023
11) S. Turchikhin et al, Study of the $B_c(2S)^{\pm}$ and $B^{*}_c(2S)^{\pm}$ mesons using $B^{\pm}_c \to J/\psi\mu^{\pm}X$ decays with the ATLAS detector, CONF-BPHY-2018-06
12) S. Turchikhin, Charm physics at ATLAS, EPJ Web Conf. 202 (2019) 05001
13) S. Turchikhin, Beyond Standard Model searches in B decays with ATLAS, PoS BEAUTY2018 (2018) 048
14) S. Turchikhin, Searches for new physics with heavy flavour at ATLAS, EPJ Web Conf. 158 (2017) 02001
15) L.N. Smirnova and S.M. Turchikhin, Muon and B-physics trigger of the ATLAS experiment in Run 2, Phys.Part.Nucl. 48 (2017) no.5, 801-803, Fiz. Elem. Chast. Atom. Yadra 48 (2017) no.5, 710-713
16) S. Turchikhin, bb-hadron decays at ATLAS, PoS BEAUTY2016 (2016) 009
17) Yu. Kulchitsky et al, Charged-particle multiplicities in pp interactions at sqrt(s) = 13 TeV measured with the ATLAS detector at the LHC, ATLAS-CONF-2015-028
18) Yu. Kulchitsky, Probing QCD with the ATLAS Detector, EPJ Web Conf. 192 (2018) 00002
19) Yu. Kulchitsky, Bose-Einstein correlations and results on minimum bias interactions, underlying event and particle production from ATLAS, EPJ Web Conf. 120 (2016) 01001
20) N. Huseynov et al, Search for the associated production of a Higgs Boson with a top quark pair in multilepton final states with the ATLAS detector, ATLAS-CONF-2016-058

21) I. Yeletskikh et al, Search for resonant and non-resonant phenomena in the dilepton channel using proton-proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS Detector, ATLAS-CONF-2015-070

22) 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 at the LHC, ATLAS-CONF-2016-045

23) 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 at the LHC, ATLAS-CONF-2017-027

24) M. Chizhov et al, Search for new physics in the charged lepton plus missing transverse energy final state using pp collisions at $\sqrt{s} = 13$ TeV, ATLAS-CONF-2015-063

25) M. Chizhov et al, Search for new particles in the charged lepton plus missing transverse energy final state using pp collisions at the ATLAS detector, ATLAS-CONF-2017-016

26) E. Khramov et al, Search for squarks and gluinos in events with an isolated leptons, jets and missing transverse momentum at $\sqrt{s} = 13$ TeV with the ATLAS detector, ATLAS-CONF-2015-076

27) E. Khramov et al, Search for heavy resonances decaying to a Z boson and a photon in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector, ATLAS-CONF-2016-010

28) E. Khramov et al, Search for gluinos and squarks in events with one isolated lepton, jets and missing transverse momentum at $\sqrt{s} = 13$ TeV with the ATLAS detector, ATLAS-CONF-2016-054

29) E. Khramov et al, Distribution of the transverse mass in events with an isolated electron or muon in proton-proton collisions at $\sqrt{s} = 13$ TeV, ATL-PHYS-PUB-2015-029

30) A. Soloshenko et al, Measurement of the tau lepton reconstruction and identification performance in the ATLAS experiment using pp collisions at $\sqrt{s} = 13$ TeV, ATLAS-CONF-2017-029

31) A. Soloshenko et al, Reconstruction, energy calibration and identification of hadronically decaying tau leptons in the ATLAS experiment for run 2 of the LHC, ATL-PHYS-PUB-2015-045

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