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# DESCRIPTION OF STUDY PROGRAMME

(Text from accreditation of the study program in 2016)

| BASIC INFORMATION | |
|---|---|
| *Title of study programme* | **Doctoral study in Physics** |
| *study programme coordinator* | **Department of Physics, University of Rijeka** |
| *Study programme implementor* | **Department of Physics, University of Rijeka** |
| *Type of study programme* | **Postgraduate (doctoral) level study programme** |
| *Level of study programme* | **8.2** |
| *Academic/professional degree awarded upon completion of study* | **Doctor of Natural Sciences in the Field of Physics** |

## 1. INTRODUCTION

*1.1 Reasons for launching the study programme*

*a) Long tradition in physics education*

The Department of Physics' long tradition in physics education began in 1964, when the first four-year teacher-training study programme of Mathematics and Physics was launched within the Faculty of Pedagogy, and later continued at the Faculty of Humanities and Social Sciences, when two other double-major teacher-training study programmes were also conducted (Physics and Informatics; Physics and Polytechnics).

With the aim of integrating physics education with the scientific research in the field of physics conducted at the University of Rijeka, the University Department of Physics was founded in 2008 (hereinafter: Department), as an independent scientific and educational university constituent that organises and implements study programmes and develops scientific, artistic and professional work in a scientific field or an interdisciplinary field, and organises studies in its domain.

The Department consists of two divisions (*Division of Theoretical Physics and Astrophysics* and *Division of Experimental and Applied Physics*). The Department is led by its Head, who also represents the Department in the University Senate.

In 2005 the Department obtained the licence to carry out undergraduate and graduate level study programmes, structured according to the Bologna principles. In the following years, the Department was successfully re-accredited and obtained licences for all current study programmes. Each of the programmes was launched in the year of their initial accreditation.

- Undergraduate study programme: *Physics* (2011/2012);
- Graduate study programmes - teacher training track:
  - *Physics and Mathematics* (2012/2013),
  - *Physics and Informatics* (2012/2013),
  - *Physics and Philosophy* (2012/2013);
- Graduate interdisciplinary study programme: *Engineering and Physics of Materials* (2010/2011)
  (a joint study programme organised by the Department of Physics and the Faculty of Engineering, University of Rijeka);
- Graduate study programme – research track: *Physics* (2013/2014).
  The launch of the graduate research track programme is particularly important because of the four new modules that are offered:
  - *Astrophysics and Elementary Particle Physics,*
  - *Atomic and Molecular Physics,*
  - *Solid state Physics,*
  - *Physics and Environmental Science*.

These modules cover the main research areas at the Department.

Relocation to the new University Departments building at the University of Rijeka Campus in September 2012 and the arrival of experienced researchers to the Department gave a new impetus to the development of research and teaching activities at the Department.

*b) Research and equipment*

Successful implementation of the doctoral study in Physics is ensured by the Department's human resources.

There are 23 employees of the Department who hold a doctoral degree:

- 4 full professors
- 4 associate professors

- 8 assistant professors
- 6 senior research assistants – post-doctoral researchers
- 1 senior lecturer

Based on its personnel structure, since 2013 the Department is able to conduct procedures of appointment to scientific research grade in the area of Natural Sciences, field of Physics.

Researchers working at the Department publish their work in the most prestigious international journals, including *Nature* and *Science*. It must be noted that there has been a significant positive publishing dynamics since the Department was established in 2008. Over 90% of the papers published in the journals indexed by the Web of Science database (WoS) have resulted from international cooperation and were written in collaboration with international co-authors. In the last five years (2011-2015) the average number of works published by the researchers working at the Department is 33.2 per year (according to WoS). Since 2012 the Department of Physics has had the greatest number of citations per researcher of all University of Rijeka constituents.

Scientific research at the Department is characterised by a significant level of international networking and collaboration.

Some of the scientists working in the *Division of Theoretical Physics and Astrophysics* are members of renowned international collaborations such as MAGIC (*Major Atmospheric Gamma-ray Imaging Cherenkov Telescopes*), PLANET (*Probing Lensing Anomalies Network*), and LST (*Large Size Telescope*) within the international consortium CTA (*Cherenkov Telescope Array*). The Department is a co-owner of experimental equipment located in *Observatorio Roque de los Muchachos* at the Canary Islands (La Palma), which includes two largest Cherenkov telescopes in the world, MAGIC and MAGIC II with the accompanying hardware and a co-owner of the LST-1 telescope prototype, the first telescope of the future CTA series, which is under construction. One of the members the Division of Theoretical Physics and Astrophysics is the main observation scheduler for the MAGIC telescopes.

Some of the scientists working in the *Divison of Experimental and Applied Physics* are in responsible for the operation of parts of experiments within international collaborations that deal with measurements of high precision: CAST collaboration with the experiment at CERN in seeking answers to questions about the nature of dark matter and dark energy, and Muon g-2 collaboration with the experiment in Fermi lab, focused on explaining the current differences between the theoretically predicted and measured values of the anomalous magnetic moment of muon.

The connection with the Centre for Micro and Nano Sciences and Technologies of the University of Rijeka (CMNST) is of particular relevance for the Department's development. The Department and CMNST share personnel and access to state-of-the-art scientific research equipment. In June 2010 the University of Rijeka Senate issued a decision to establish CMNST, which has since 2013 applied for the EU project *Research Infrastructure for Campus-based Laboratories at University of Rijeka* (European Regional Development Fund - ERDF). After the contract was signed in 2014, the procurement of scientific and research equipment for the joint laboratories of the Department and CMNST began and was successfully in mid-2015. This gave a special impetus to the development of experimental physics at the Department.

The Department and the Centre for Micro and Nano Sciences and Technologies own and use research instruments and facilities that are unique in Croatia and this part of Europe, among which we highlight these state-of-the-art instruments:

- SIMS/SNMS - Secondary ion/neutron mass spectrometer
- SEM - Scanning electron microscope and the equipment for preparation of SEM samples
- ALD - Atomic layer deposition instrument
- XPS - X-ray photoelectron spectrometer
- XRF - X-ray fluorescence spectrometer
- Surface profilometer - Instrument for measuring surface roughness
- Nanoindenter - Instrument for measuring properties of materials
- AFM - Atomic force microscope and scanning tunnelling microscope

*Centre for Advanced Computing and Modelling* (CACM), located in the University Departments building is of particular relevance for the development of the Department of Physics' theoretical research related to computer simulation and numerical analyses. The University of Rijeka Senate founded CACM in 2010 and in February 2016 supercomputer Bura was released into function. Bura is based on hybrid architecture and contains 12 TB of RAM, 512 processor cores and 245 TB of local storage. The capacity of the central data storage system is 1 PB and the data archive consists of a tape library with the capacity of 2.5 PB. Bura currently ranks among the 500 most powerful computers in the world.

*c) Introduction of the 3-cycle system*

One of the basic elements of a quality research university is the organisation of all teaching through own study programmes, from undergraduate through graduate to doctoral studies, as well as postdoctoral training. The University of Rijeka aims to position itself as a research university, and accordingly requires that all its scientific and educational constituents offer appropriate doctoral studies. More specifically, the increase in the number of doctoral students is one of the fundamental objectives of the 2014-2020 University Strategy. The Department of Physics is currently the only University department that does not offer a doctoral level study programme. This is due to its earlier focus on teacher-training programmes, which primarily resulted from the lack of high-quality scientific equipment and related personnel. By implementing an active employment policy of quality staff from all resources (own graduates who completed their doctorates outside the University of

Rijeka, staff from other universities and institutes in Croatia, scientists returning from abroad), the Department has created the necessary human resources base to launch a doctoral study programme. Through active participation of its employees in EU projects, particularly through the ERDF project *Research Infrastructure for Campus-based Laboratories at University of Rijeka*, the Department has acquired the necessary research equipment for quality performance of a doctoral study in Physics in many different branches of physics.

The launch of the doctoral study in Physics is both a natural consequence and a requirement resulting from the current circumstances at the University of Rijeka. This study programme will ensure the relevance of the great efforts that the University has invested in the development of personnel structure of the Department and especially in the procurement of state-of-the-art scientific research equipment, which naturally fits with the needs of the doctoral study programme in physics. Such synergy will contribute to the development of doctoral studies, as well as to the optimal use of research equipment.

*1.2. Evaluation of purposefulness in respect to the market needs in public and private sector*

In 2015 the Department of Physics successfully underwent the international re-accreditation process of higher education institutions conducted by the Agency for Science and Higher Education in five-year cycles. The report of the Expert Panel on the re-accreditation of the Department states that the Department has *state-of-the-art facilities for teaching provision and laboratory support* and *an existant track record of high level research output*. However, one of the main disadvantages indicated in the report is the absence of a 3rd level (doctorate level) education. In the *Recommendations for improvement* section related to the *Study programmes* the report states:

- *In both the more traditional and emerging areas, the development of Doctoral Programmes should be considered a priority. It is important that the Department and University gain credit (academic and financial) for such a programme, however, and partnering with larger Universities may not be the best option. An interdisciplinary Doctoral Programme, which would integrate the divisions of the Department, and partner with other autonomous (non Faculty) Departments of the University may be the best option.*

The Department of Physics aims to implement the mentioned recommendation by launching the doctoral study in Physics. This study programme will also contribute to the attractiveness of the undergraduate and especially the graduate study programmes in Physics, as it will provide a clear educational vertical to the interested students. Increasing the number of STEM (Science, Technology, Engineering, Mathematics) students, the disciplines to which physics inherently belongs, is one of the long-term strategic goals of Croatia, as well as the EU. This is also the reason why the doctoral study programme will be open not only to the Croatian students but also those coming from other parts of the EU and the medium of instruction will, therefore, be English. Croatia is a desirable destination for all EU members and a high-quality doctoral programme in Physics offered in English is likely to be appealing to many EU students, thus ensuring direct communication between local and international students and researchers. It can be expected that such synergy is going to result in an even more rapid inclusion of the University of Rijeka in the current international scientific developments and facilitate the involvement of scientists working at the University of Rijeka in demanding EU projects.

There is a doctoral study in Physics offered by the University of Zagreb, but apart from Zagreb, our graduates continue their education at other universities abroad (Trieste, Ljubljana…), and the researchers employed by the Department of Physics obtained their doctoral degrees from many other universities worldwide.

Given the demand for doctoral graduates in the field of physics in both the public and private sectors, they are likely to find employment easily.

*1.2.1. Connection with the local community (economy, entrepreneurship, civil society)*

The doctoral study in Physics aims to prepare its graduates for finding employment in Croatia, the EU and beyond. Considering the needs of the local community, or more specifically, the economy, entrepreneurship and civil organisations in Croatia, the industries that are most likely to recruit graduates with a doctoral degree in physics include:

- *Public sector: institutes, universities, hospitals*
- *Private sector: innovative enterprises*
- *Other: companies working in the fields of environmental protection and energy efficiency; companies that develop advanced algorithms or need specific expertise related to complex processes or patterns, e.g. in the sea, air, soil, cars, ships, aircraft, in the financial sector or process optimisation; institutions using micro- and nano-technology, biotechnology, medical diagnostics, and the like.*

There are several large, medium and small enterprises in the immediate vicinity of the University of Rijeka that are interested in recruiting graduates with doctoral degrees in physics. In addition to *Clinical Hospital Centre Rijeka (CHCR)*, which is one of the partner institutions in this doctoral study programme, these entreprises include *Saipem Croatia* and *Jadran Galenski Laboratorij (JGL) d.d.*, with whom the University has signed cooperation agreements; as well as *Primorje-Gorski Kotar County Teaching Institute of Public Health*, *Alarm Automatika d.o.o.* (Rijeka), *Navis Consult d.o.o.* (Rijeka) and other (small) innovative enterprises.

It is important to note that the University of Rijeka includes two constituents that are primarily dedicated to the transfer of knowledge to the economy, both in Croatia and in the developed regions of the EU: the Technology Transfer Office and, as the only university in Croatia, the Science and Technology Park. The proposed doctoral study programme in Physics has special regulations for the protection of intellectual property realised by the doctoral candidates during the study.
Given the fact that there is a high demand for doctoral students and doctoral graduates in the field of physics in the EU and beyond, students are likely to find funding opportunities and scholarships for doctoral and post-doctoral education abroad. Therefore, in addition to the contemporary knowledge, the doctoral study in Physics will also offer its students concrete activities during the course of studies and direct them towards future occupations in the local community, thus allowing them to advance and develop in Croatia.
More specifically, should the post-doctoral researchers upon completion of the proposed doctoral study Physics be interested in multidisciplinary research that involves social sciences or humanities, they will be able to apply for the post-doctoral scholarships offered annually by the *University of Rijeka Centre for Advanced Studies – South Eastern Europe* (CAS SEE).

*1.2.2. Compliance with professional association's requirements (recommendations)*

Various professional associations in Croatia and the EU encourage the development of physics, particularly in the context of promoting the development of STEM disciplines. One of the specific goals of the project, to whose realisation the Department actively contributed, was: *Increasing the number of graduates in STEM disciplines, information and communications technology and interdisciplinary studies related to these disciplines*.
Pursuant to the *Agreement on full subsidy of the participation in the cost of study of full-time students in ac. years 2012-2013, 2013-2014 and 2014-2015* a project funded by the Ministry of Science, Education and Sport (MSES) was realised at the University of Rijeka with the aim of fulfilling the University's strategic goals.
On the national level, the EU project *Development of modern study programmes for education of computer science, technics, biology, chemistry, physics and mathematics teachers on the basis of development of the Croatian Qualification Framework – STEMp* was completed in 2016. The University of Rijeka was one of the project partners and the Department of Physics played a significant role in its realisation.
The doctoral study in Physics will certainly contribute to the number of students in STEM disciplines, which is one of the major goals of the mentioned projects.
On the EU level, there are specific EU projects that encourage the development of STEM areas, such as SCIENTIX (http://www.scientix.eu/web/guest/about), whose National contact point (NCP) for Croatia is CARNet.
The EU particularly aims to stimulate interest in STEM disciplines through its prestigious HORIZON 2020 (H2020) programmes for research and innovation, for example, through two successive calls (2014 and 2015) *Call for making science education and careers attractive for young people*. The paragraph below, which applies to all EU member states, describes what this most prestigious EU programme for research and innovation explicitly states in *Topic Description* calls:

> *The Union needs all its talents to boost creativity and competitiveness. It needs an innovative science education which shall enable todays' and tomorrows' citizens to play a more active role in the Research and Innovation process, to make informed choices and to engage in a democratic, knowledge-based society. It needs young boys and girls to pursue careers in science, technology, engineering and mathematics (STEM), while at the same time adhering to the values embedded in Responsible Research and Innovation. In such a manner, the Union will reach the objective of a R&D intensity of 3% of GDP which is essential. Yet it has been increasingly difficult to attract adequate numbers of young people, to these domains and to avoid a brain-drain of talent from Europe. Therefore, a shift to innovative and effective methods is necessary, so as to raise the attractiveness of science education and scientific careers and boost the interest of young people in STEM.*

Launching the contemporary doctoral study in Physics, conducted in English as the medium of instruction, is fully aligned with the stated EU goals.

*1.2.3. Name possible partners outside higher education system that showed interest in the study programme*

Several institutions outside the higher education system have expressed interest in the doctoral study in Physics and direct cooperation was established with two[1] important institutions:

1. *Institute of Physics in Zagreb***.** The University of Rijeka and the Institute of Physics in Zagreb signed a cooperation agreement that allowed scientists from the Institute to teach courses within the graduate study programme Engineering and Physics of Materials. The Institute also served as a teaching base where students worked with the Institute's experimental equipment. Cooperation between the two institutions was particulary strengthened through joint research projects after the Centre for Micro and Nano Sciences and Technologies and the Department procured new research instruments.
2. *Clinical Hospital Centre Rijeka (CHCR).* Given the fact that it currently employs our former graduates, CHCR is interested in the doctoral study programme, and particularly the development of medical physics. At the end of

2015, the Department took over physics teaching at the *University of Rijeka Faculty of Medicine*, as well as the staff that was employed at the *Faculty of Medicine Physics Division* and were engaged in medical physics. These changes created the conditions for the Department to establish a new *Division of Medical Physics* and encourage the development of medical physics within the doctoral study programme, which will in turn ensure the quality education of staff that is in demand in CHCR and all similar institutions.

Institute of Physics in Zagreb and Clinical Hospital Centre Rijeka have both signed the *Agreement on participation in the doctoral study in Physics*, in which they agreed to act as supporting institutions in the realisation of the doctoral study programme. The great human potential and the state-of-the-art equipment of these two institutions that are now at the Department's disposal will ensure the high-quality implementation of the doctoral programme in Physics.

[1.] The Department of Physics has offered cooperation to Ruđer Bošković Institute (RBI) as well. The Scientific Council of RBI decided to adopt a Strategy on accepting teaching responsibilities at other institutions. Considering the fact that such strategy is still pending at the time of this proposal's submission, by the decision of its Scientific Council RBI cannot be a partner institution for doctoral programmes at any other institution.

*1.3 Comparability of the study programme with similar programmes of accredited higher education institutions in the Republic of Croatia and the EU (name and explain comparability of the proposed programme with two programmes, whereas at least one of which should be from the EU (provide their web sites))*

The study programme is comparable with contemporary doctoral study programmes in physics offered by prestigious European universities.

The proposed doctoral study in Physics consists of four parts:

*(a) The scientific research project,* aimed at completion and defense of the doctoral dissertation. This is the basis of the doctoral study programme and the students are engaged with the research project from the very beginning of their studies, with the guidance of their mentors.

*(b) The programme of the doctoral study in Physics*, which provides the students with generic competences, as well as the specific ones related to the topic of their dissertation. The programme is characterised by the following:

- English is the medium of instruction, so it is available to a wide range of possible students
- courses are normally taken only in the first year of study
- there are no mandatory courses that the doctoral student has to take; courses are tailored to the specific needs of the doctoral students' scientific work.

*(c) The internationalisation of research,* aimed at promoting the involvement of doctoral students in the current scientific developments worldwide. This includes visits to renowned local and international universities and institutes, active participation in international projects and collaborations, participation in international conferences, invited lectures.

*(d) Elective activities,* aimed at promoting the visibility of students' research. These include publication of preliminary papers, scientific and professional papers in scientific and professional journals, presentations at national and international conferences, and participate in the transfer of knowledge.

The duration of the full-time study programme is four years, with the possibility of earlier completion. The extension of the study period is also possible, depending on the student's status (both full-time and part-time studies are possible) and their success in fulfilling the requirements of the study programme.

Here we list three doctoral study programmes that have a similar approach, offered by prestigious universities from three EU countries:

- *University of Bristol* (http://www.bristol.ac.uk/physics/cdtcmp/programme/)
- *Technische Universitat Munchen* ( http://www.gs.tum.de/en/doctorate-at-the-technical-university-of-munich/why-do-a-doctorate-phd/)
- *KU Leuven, Arenberg Doctoral School* ( https://set.kuleuven.be/phd/whytraining)

*Note*

*KU Leuven*'s doctoral programme in physics is part of their Doctoral school, and the similarity with this programme is a basis for the doctoral programme we propose to fit with the future Doctoral school of the University of Rijeka.

The *doctoral study programme in Physics* is also offered by the Department of Physics of the Faculty of Science at the University of Zagreb ( https://www.pmf.unizg.hr/phy/nastava/pds ). That study programme is structured somewhat differently: it has several more different tracks than the study programme proposed by the Department of Physics at the University of Rijeka. However, the structure within each track is fixed and primarily realized through mandatory general courses, with a relatively limited offer of electives. The tracks that are similar to the fields included in the doctoral study in Physics offered by the Department of Physics in Rijeka include: *Condensed Matter Physics*, *Particle Physics* and *Astrophysics*. Due to the expertise of its members, the Department of Physics in Rijeka is able to ensure a rich offer of electives in these fields so the curriculum can, to a high degree, be adapted to the needs of individual research topics of doctoral students.

Apart from the differences in the structure and organization of the two doctoral study programmes, it is important to emphasize the previously described aspects of the doctoral study in Physics offered at the University of Rijeka:

- The University of Rijeka (via the Department of Physics and the Centre for Micro and Nano Sciences and Technologies - CMNST) owns research instruments and facilities that are unique in this part of Europe, and that are used for research in the field of condensed matter physics.
- In the field of astrophysics, the University of Rijeka is, via the Department of Physics, the only university in Croatia that participates in the search for extrasolar planets in the renowned international collaboration PLANET. In addition, the research group from the Department of Physics in Rijeka has received international recognition through its activity in the renowned international astroparticle experiments and the related collaborations MAGIC and CTA, in which the Faculty of Science, University of Zagreb does not participate. Doctoral students at the University of Rijeka thus have the opportunity to work with state-of-the-art experimental equipment in this field as well.
- The University of Rijeka (within the Centre for Advanced Computing and Modelling - CACM) owns a supercomputer Bura (currently ranks among the 500 most powerful computers in the world) that enables fast computing and processing of vast sets of data, which can be crucial for solving complex problems in the field of physics.
- The medium of instruction of the doctoral study programme in Physics will be English, in order to appeal not only to the Croatian students but also high-quality candidates coming from abroad.

The University of Split offers the *doctoral study in Biophysics* ( http://split.pmfst.unist.hr/biophysics/ ), but given the fact that no members of the Department of Physics in Rijeka have expertise in this field, there are no overlaps with the mentioned programme.

*1.4. Openness of the study programme towards horizontal and vertical mobility of students within national and international higher education area*

The doctoral study in Physics is student-centred, i.e. tailored to individual doctoral student's needs and interests, as the students aim to achieve their own findings that correspond to the doctoral degree in Physics by conducting specific research projects with the guidance of their mentors and if need be, co-mentors. Therefore, typically, doctoral students cannot start a doctoral study programme at one university and then transfer to a different one.

The doctoral study in Physics ensures maximum *vertical mobility*. This means that all students who have completed appropriate graduate level programmes can be enrolled after the *Council of the Doctoral Study in Physics* reviews the applicants' previous study records, the letter of motivation and the proposed mentor, and evaluates whether the applicant will be able to successfully complete the doctoral programme.

Upon completion of the doctoral study programme, doctoral graduates have the opportunity to get a scholarship for postdoctoral training, both in Croatia and in many universities and institutes in the EU and beyond.

*1.5. Alignment with the Mission and the Strategy of the University of Rijeka*

The proposed doctoral study programme is fully aligned with the University of Rijeka 2014-2020 Strategy (http://www.uniri.hr/files/staticki_dio/strategija/Strategija_UNIRI_2014_2020_HR.pdf), which is best illustrated through the excerpts from the 2014-2020 Strategy referenced below.

*Introduction*

The University of Rijeka is a research university and in 2013 it was ranked 1143rd in global university rankings and around 450th in European rankings, based on its research productivity indexed in the Web of Science (WoS) database. Based on the Carnegie Classification of Institutions of Higher Education, the University of Rijeka is a Doctorate/Research University (DRU). In order for the University to fully inhabit its role as leader in the social and economic development, its organisation and research activities must attain RU/H (Research University – High Research Activity) levels.

*The mission*

The University of Rijeka engages in scientific, artistic and development research provides undergraduate, master's, post-master's and lifelong learning education founded on research, and stimulates the social and economic development of its region.

Among the key principles that guide the University of Rijeka is the principle of excellence and international compatibility.

*The vision*

The vision of the University of Rijeka emphasises the following:

- The University of Rijeka is a high research activity university.
- The University of Rijeka is integrated into the European Research Area.
- The University of Rijeka promotes the circulation of researchers in order to increase personal and institutional potential

*Goals and objectives*

The University of Rijeka 2014-2020 Strategy outlines the specific goals and objectives that the University aims to fulfil. Listed below are the goals and objectives from the chapters on *Research* and *Education* that relate to doctoral study in Physics, and affirm the need for such a study programme.

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*I Research*

- The University of Rijeka is a high research activity university.

| Goal/Objective | Indicator |
|---|---|
| 1. Increasing the number of doctoral degrees awarded | the number of doctoral degrees awarded per year |
| 1.1. Increasing the number of full-time doctoral students | the number of full-time doctoral students;<br>the number of scholarships/grants awarded to full-time doctoral students not employed by the University of Rijeka |
| 1.2. Increasing the number of teaching staff serving as doctoral supervisors | the number of teaching staff serving as active doctoral supervisors |
| 2. Increasing the number and quality of published academic papers | |
| 2.1. Increasing the number of published papers per researcher | the number of papers published (SCOPUS) |
| 2.2. Increasing the quality of published papers | the number of Q1 papers, the number of Exc papers (SCOPUS) |

- The University of Rijeka is integrated into the European Research Area.

| Goal/Objective | Indicator |
|---|---|
| 1. Increase research funding from EU programmes (such as Horizon, or any other programme) | the annual amount of funding from EU programmes |

- The University of Rijeka promotes the circulation of researchers in order to increase personal and institutional potential

| Goal/Objective | Indicator |
|---|---|
| 1. Increasing the number of circulating researchers | the number of person-days spent at other higher education or research institutions; the number of person-days spent at the University of Rijeka |

*II Education*

- The University of Rijeka promotes education quality and efficiency.

| Goal/Objective | Indicator |
|---|---|
| 4.2. Increasing the number of students in technology, biology, medicine, biotechnology and natural sciences, in information and communication, and in related interdisciplinary fields | the number of enrolled STEM students; the number of students completing their degrees |

- The University of Rijeka is integrated into the European Higher Education Area.

| Goal/Objective | Indicator |
|---|---|
| 2. Increasing the number of EU students from outside Croatia | the number of full-time and part-time students from other EU member countries |
| 3. Increasing the number of non-EU students | the number of full-time and part-time students from non-EU countries |
| 4. Increasing the number of master's and post-master's degree programmes taught entirely in a foreign language (including joint degree programmes) | the number of master's and post-master's degree programmes in the previous academic year that were taught entirely in a foreign language |

- The University of Rijeka increases the accessibility of higher education to all interested individuals.

| Goal/Objective | Indicator |
|---|---|

| | |
|---|---|
| 1. Providing University accommodation for students | the number of students in University accommodation |
| 2. Developing student financial aid mechanisms | |
| 2.1. Involving the private sector in the student financing system | the number of scholarships provided from the private sector |

*Key performance indicators*
The overall success of 2014-2020 Strategy implementation is measured through 10 key performance indicators, of which we single out three:

- The number of doctoral degrees awarded per year
- The number of published papers cited in the SCOPUS citation database per year
- The number of students in master's and post-master's degree programmes

*1.6. Institutional strategy for study programmes development*

The Department of Physics, as a constituent of the University of Rijeka, fully accepts and seeks to realise the mission, vision, tasks and objectives outlined in the University Strategy. Accordingly, the launch of the doctoral study in Physics is an important factor in the joint development strategy of the Department of Physics and the University of Rijeka.
In 2013, in preparation for the launch of the doctoral study in Physics, the Department accredited and launched a *research graduate study programme in Physics*, with four modules that cover the main research areas at the Department: *Astrophysics and Particle Physics, Atomic and Molecular Physics, Solid State Physics, Physics and Environmental Science*. The successful realisation of this study programme was ensured by the influx of high-quality research staff to the Department and the possibility of working with the state-of-the-art science equipment. Such intensive development of the Department can be ascribed not only to the efforts of the Department members but also to the efforts of the entire University, which is specified in Section 1.1. *Reasons for launching the study programme.*
Based on the results achieved so far, the Department considers the doctoral study in Physics a natural and necessary continuation in the development of their study programmes.

*1.7. Other important data – according to the coordinator's opinion*

- The doctoral study in Physics is a natural result of the Department's development and is vital for its further successful progress.
- The doctoral study in Physics is fully aligned with the University of Rijeka 2014-2020 Strategy (Note: All other University departments are currently participating in respective doctoral study programmes).
- The need to launch a doctoral study in Physics is particularly emphasised in 2015 report of the expert panel on international re-accreditation of the Department of Physics.
- By procuring advanced scientific equipment, the University of Rijeka has committed to putting the equipment to effective use and launching the doctoral study in Physics is the right way to ensure its successful use.
- The establishment of the doctoral study in Physics will increase the possibility of postgraduate training as well as the employment of the best students of physics in Croatia and thus reduce *brain drain*.

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## 2. GENERAL PART

*2.1. Title of study programme*

Doctoral study in Physics

*2.1.1. Type of study programme*

Postgraduate doctoral level study programme

*2.1.2. Level of study programme*

8.2

*2.1.3. Area of study programme (scientific/artistic) – indicate the title*

Area – Natural sciences; Field - Physics

*2.2. Study programme coordinator*

Department of Physics, University of Rijeka

*2.3. Implementor/s of study programme*

Department of Physics, University of Rijeka

*2.4. Duration of study programme (indicate possibilities of part-time study, long distance study)*

The duration of the full-time study programme is at least three years. The extension of the study period is possible up to a total of six years.
The duration of the part-time study programme is at least five years. The extension of the study period is possible up to a total of ten years.

*2.4.1. ECTS credits – minimal number of credits required for completion of study programme*

180

*2.5. Enrolment requirements and selection procedure*

Enrolment requirements: an appropriate graduate level degree that ensures successful completion of the doctoral study in Physics; advanced English language skills; statement of the potential mentor on the relevance of the proposed research project; applicant's statement on the sources of funding.
The selection procedure will be conducted by the *Council of the Doctoral Study* of the Department of Physics.
Applicants will be required to present their motivation for enrolment to the members of the Council of the Doctoral Study, publicly and in English, in accordance with the previously submitted *Letter of Motivation*.
Members of the Council will then further interview the applicants in order to gain insight into their abilities to successfully complete the doctoral study programme in Physics.

*2.6. Study programme learning outcomes*

*2.6.1. Competences which student gains upon completion of study (according to CROQF (HKO): knowledge, skills and competences in a restricted sense –independence and responsibility)*

*Knowledge*: creating and evaluating new facts, terms, procedures, principles and theories in the field of physics on which the doctoral dissertation focuses, which leads to advancing knowledge in the chosen field
*Cognitive skills*: using advanced, complex, original, highly specialised knowledge, skills, activities and procedures necessary for the development of new knowledge and new methods in the field of physics, as well as for the integration of different areas of physics and their relations primarily within the STEM disciplines
*Psychomotor skills*: creating, evaluating and conducting new specialised procedures and methods, instruments, tools and materials, when the doctorate involves the application of experimental methods in physics
*Social skills*: communicating with relevant researchers and institutions, via personal contacts, e-mail, social media; the popularisation of student's own findings and achievements through various media, with the aim of popularising STEM areas
*Independence:* expressing personal professional and ethical authority; managing scientific research activities; dedication to the development of new ideas a/or processes in the field of physics that is the focus of the doctoral dissertation; expanding

ideas/processes to new areas with the dissertation as the solid starting point
*Responsibility:* taking ethical and social responsibility for the successful conducting of research projects, for the social utility of findings and possible social consequences of the findings presented in the dissertation

*2.6.2. Employment possibility (list of possible employers and compliance with professional association's requirements)*

The industries that are most likely to recruit graduates with a doctoral degree in physics include:

- *Public sector: institutes, universities, hospitals*
- *Private sector: innovative enterprises*
- *Other: companies working in the fields of environmental protection and energy efficiency; companies that develop advanced algorithms or need specific expertise related to complex processes or patterns, e.g. in the sea, air, soil, cars, ships, aircraft, in the financial sector or process optimisation; institutions using micro- and nano-technology, biotechnology, medical diagnostics, and the like.*

*2.6.3. Possibility of continuation of study on higher level*

Postgraduate (doctoral) university study provides the highest level of formal education. Postdoctoral training can be viewed as the continuation of the study.

*2.7. Upon applying for graduate studies list proposer's or other Croatian institution's undergraduate study programmes which enable enrolment to the proposed study programme*

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*2.8. Upon application of integrated studies - name reasons for integration of undergraduate and graduate level of study programme*

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## 3. PROGRAMME DESCRIPTION

*3.1. List of compulsory and elective subjects and/or modules (if existing) with the number of active teaching hours required for their implementation and number of ECTS-credits.*

All courses are listed in **Study programme**

*3.2. Description of each subject.*

Course descriptions are provided in **Course description**

*3.3. Structure of study programme, dynamic of study and students' obligations*

The doctoral study in Physics consists of four parts and doctoral students must meet the minimal requirements (indicated by the ECTS credits) for each part:

- *Scientific research,* aimed at completion and defence of the doctoral dissertation.

As a precondition for the approval of the doctoral dissertation, a doctoral student is required to:
- defend *Field of research of the doctoral dissertation*, accounts for at least 5 ECTS credits
- defend *Topic of the doctoral dissertation*, accounts for at least 5 ECTS credits
- get a positive *Report on the evaluation of the doctoral dissertation*, accounts for at least 90 ECTS credits.

The doctoral student as a condition for the defense of the doctoral dissertation should have the following evidence of his *scientific research*, which are related to the topic of the dissertation:

a) At least one research paper with a dominant contribution made by the doctoral student, published in a journal categorised as Q1-Q2 in *WoS* database, in the area of Natural Sciences, field Physics
or
at least two research papers published in journals indexed in the *WoS* database, in the area of Natural Sciences, field Physics, where the doctoral student has made a significant contribution in at least one of the papers
b) At least one internationally reviewed preliminary report presented at an international conference

*Scientific research* accounts for at least 100 ECTS credits.

- *Study programme of the doctoral study in Physics*, which provides doctoral students with competences necessary for the successful completion of the doctoral study programme.

*Study programme* consists of *General study* and *Specific study*. The *Study programme* requirements should be fulfilled during the first year of the study.

- *General study* provides general (generic) research competencies.

Part of the standard competences related to doctoral studies (such as defining goals and tasks of scientific work, independently finding and using existing literature and other sources of knowledge etc.) is acquired through a mandatory course *Seminar in Physics* within the doctoral study programme in Physics. Doctoral students can further develop such competences by taking courses such as *Methodology of Scientific Research*, which is offered within several doctoral programmes at the University of Rijeka. Doctoral students can expand their knowledge in other fields as well, for example, in applied mathematics, computer science, biotechnology etc., through relevant courses within doctoral programmes offered at the University of Rijeka. Alternatively, they can acquire the necessary competences by taking appropriate courses at other universities in Croatia or abroad.

The Council of Doctoral Studies decides on the number of ECTS that are to be obtained through courses within the *General study*, based on mentor's proposal.

- *Specific study* ensures the acquisition of specific research competencies of research in physics, and is composed of *Compulsory* and *Optional* part.
- *Compulsory part* represents the fundamental research program of the doctoral study and is performed through optional (elective) courses in areas where the Department of Physics has own experts. The theme of the dissertation must fit into one of these areas, so the doctoral student must enroll at least one optional course from the compulsory part of the study; each course accounts for 10 ECTS credits.
- *Optional part* consists of specific activities necessary for the execution of the dissertation project, so the doctoral student must enroll at least one course from the *Optional part* of the study programme.

*Optional part* consists of *Specific classes* and *Physical techniques*.

- *Specific classes* are specific lectures organized to help doctoral students in mastering specific research related to the preparation of the doctoral dissertation; each course accounts for 8 ECTS credits.
- *Physical techniques* are specific techniques that are necessary to prepare the doctoral dissertation (introduction to the complex theoretical and numerical models and laboratory techniques); each course accounts for 7 ECTS credits.

Doctoral students are required to take part in *seminars* in which they discuss the study obligations, analyze the results of their research and discuss various issues with their peers. During the first year of the study, *Seminar in Physics* is a compulsory course that accounts for 5 ECTS credits.

The doctoral student through fulfillment of obligations under the *Study programme* accounts for at least 30 ECTS credits.

- *Internationalization of research*, aimed at promoting the involvement of doctoral students in the current scientific developments worldwide.

The doctoral student is required to show involvement in the exchange of scientific ideas with scientists from other reputable scientific-research institutions:

- as a resident at prestigious universities and scientific research institutions doctoral student can receive a maximum of 20 ECTS credits
- doctoral student through active participation in international projects and collaborations can get a maximum of 10 ECTS credits
- doctoral student for invited lectures can get a maximum of 10 ECTS credits
- doctoral student for participation in international meetings (conferences, summer schools, journal clubs, seminars, workshops) can get a maximum of 10 ECTS credits.

The *Internationalization of research* accounts for a minimum of 20 credits.

- *Optional activities*, aimed at promoting the involvement of doctoral students in the current scientific developments worldwide.

Doctoral students are required to publicly present their ideas, achievements and knowledge gained during the duration of the doctoral study:

- for published article cited in WOS, doctoral student can get up to 20 ECTS credits, depending on the Q-factor of the journal and the contribution of doctoral student
- for communication or poster at the symposium doctoral student can receive up to 5 ECTS credits
- for professional work published doctoral student can receive up to 5 ECTS credits
- doctoral student may participate in the transfer of knowledge (eg. as an assistant in the performance of a course or through participation in appropriate accredited program) and thus can get up to 10 ECTS credits.

The *Optional activities* account for at least 20 credits.

By satisfying the defined requirements of the doctoral study programme, the doctoral student will acquire at least 170 ECTS. In order to successfully complete the programme, the doctoral student is required to acquire at least 180 ECTS. Additional ECTS can be acquired through different activities within any of the four parts of the study programme, such as through increased scientific activity or further development of generic competences provided by the *General study*.

The decision on how the additional ECTS should be acquired is made by the Council of Doctoral Studies, based on mentor's proposal.

Upon successful fulfilment of the mentioned requirements, the doctoral student submits an *Application for the assessment of the doctoral dissertation,* thereby initiating the assessment process.

The study is completed upon a successful defense of the doctoral dissertation.

*3.3.1. Enrolment requirements for the next semester or trimester (course title)*

The doctoral study in Physics is not organised in a semester system.

In addition to the positive reports (*Doctoral candidate's annual report* and *Mentor's or advisor's annual report*), enrolment requirements for the next year of study include the submission of the following documents to the Council of the Doctoral Study in Physics:

- enrolment in the second year:
  (a) approved *Field of research of the doctoral dissertation*
  (b) certificate of completion of the mandatory course from the programme of the doctoral study, as defined by the *Contract on studying and mentorship*
- enrolment in the third year

(a) approved *Topic of the doctoral dissertation*
(b) certificate of completion of all courses from the programme of the doctoral study, as defined by the *Contract on studying and mentorship*

*3.4. List of courses and/or modules student can choose from other study programmes*

Within the study programme doctoral students can choose accredited courses in the field of physics or other fields at the University of Rijeka or other universities.
Such courses are not pre-defined. The mentor and the Council of the Doctoral Study in Physics will take under advisement and decide on individual courses chosen by students.

*3.5. List of courses and/or modules that can be implemented in a foreign language (specify the language)*

The medium of instruction of the doctoral study in Physics is English.

*3.6. Allocated ECTS credits that enable national and international mobility*

180

*3.7. Multidisciplinarity/interdisciplinarity of study programme*

The doctoral study in Physics belongs to the area of Natural sciences, field of Physics. Multidisciplinary can be achieved by choosing elective courses from other scientific areas or fields.

*3.8. Mode of study programme completion*

In order to complete the study programme, doctoral students need to submit the following documents to the Council of the Doctoral Study in Physics:

(a) a positive *Decision on the defence of the doctoral dissertation*
(b) a document certifying that all other requirements defined by the *Contract on studying and mentorship* have been fulfilled

*Note*
*Contract on studying and mentorship,* which defines the rights and obligations of the doctoral students, is elaborated in the *Regulation on the Doctoral Study Programme in Physics of the University of Rijeka Department of Physics.* The *Regulation* specifically defines the role of the mentor and the selection procedures for the members of the *Doctoral Dissertation Examination Committee, Doctoral Dissertation Evaluation Committee* and *Doctoral Dissertation Examination Committee,* in accordance with the *Regulation on Studies of the University of Rijeka:*
http://www.biotech.uniri.hr/files/Dokumenti/Pravilnik_o_studijima_-_proieni_tekst.pdf .

*3.8.1. Conditions of approval of final work /thesis and/or final/thesis exam application*

Doctoral students will publicly defend their doctoral dissertations in front of the *Doctoral Dissertation Examination Committee*. The Committee will submit a report with a proposal of the acceptance of the dissertation topic to the Council of the Doctoral Study in Physics. The Council of the Doctoral Study in Physics will then submit its proposal and the final report of the Doctoral Dissertation Examination Committee to the Department of Physics Council. The Department of Physics Council is obliged to reach a decision on the acceptance of the dissertation topic within six months from the day of application submission, and inform the candidate of its decision. Should the decision be negative, the procedure for obtaining a doctoral degree will be suspended.

*3.8.2. Composing and furnishing of final work/thesis*

Composing and furnishing of the doctoral dissertation is defined by the *University of Rijeka Regulation on composing and furnishing of doctoral dissertations.*

*3.8.3. Final work/thesis assessment procedure and evaluation and defense of final work/thesis*

Doctoral students who have fulfilled all the requirements of the doctoral study in Physics will submit an *Application for the assessment of the doctoral dissertation* to the Council of the Doctoral Study in Physics. *Doctoral Dissertation Evaluation Committee* decides on the evaluation of the dissertation by majority vote. The Committee then submits its report to the

Council of the Doctoral Study in Physics and after it has received the (final) evaluation report, the Council of the Doctoral Study in Physics submits its recommendation to the Department of Physics Council, along with the evaluation report:
- if the evaluation is positive, the Council of the Doctoral Study in Physics nominates members of the Doctoral Dissertation Examination Committee;
- if the evaluation is negative, the Council of the Doctoral Study in Physics recommends the suspension of the procedure for obtaining a doctoral degree.

If the Department of Physics Council accepts the positive evaluation of the doctoral dissertation in the same session, it will confirm the appointment of the *Doctoral Dissertation Examination Committee* members, as proposed by the Council of the Doctoral Study in Physics. If the doctoral dissertation is evaluated negatively, the Department of Physics Council will pass a decision to terminate the procedure for obtaining a doctoral degree and inform the doctoral candidate.

The doctoral dissertation can only be defended once. The protocol is defined by a University form (Protocol and minutes of the dissertation defense). Upon completion of the defense the *Doctoral Dissertation Examination Committee* makes a decision on the result of the defense which may be:
- pass by a unanimous decision of the Committee,
- pass by a majority vote of the Committee,
- fail.