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2014

MATHEMATISCH-
NATURWISSENSCHAFTLICHE
FAKULTÄT

UNIVERSITÄT ZU KÖLN

DEKANAT

MODULHANDBUCH

PHYSIK (M.Sc. Physics)

1-FACH-MASTER OF SCIENCE

VERSION [1.0]

NACH DER PRÜFUNGSORDNUNG FÜR DEN 1-FACH-MASTER-STUDIENGANG PHYSIK

M.Sc. Physics

(FASSUNG 05.06.2015)

Universität zu Köln

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Legend (Legende)

CT	Contact Time (= Time of Presence) = Kontaktzeit (= Präsenzzeit in LV)	SAoS	Secondary Area of Specialization = Nebenfach
CP	Credit Point = Leistungspunkt	SSt	Self-Study = Selbststudium
HPW	Hours per Week = Semesterwochenstunde	SuSe	Summer Semester
PAoS	Primary Area of Specialization = Schwerpunktmodul	WL	Workload = Arbeitsaufwand
PW	Preparation and Wrap-up Time = Vor- und Nachbereitungszeit	WiSe	Winter Semester

Inhaltsverzeichnis

1 The Field of Study: Physics (Das Studienfach Physik)

The physics courses at the University of Cologne aim to equip students with the knowledge and tools for independent scientific work. In the course of their studies, they gain the qualification to actively participate in the fundamental research carried out at the physics institutes at the University of Cologne.

1.1 Contents, Objectives and Requirements (Inhalte, Studienziele und Voraussetzungen)

The master courses in physics are based on the broad basic knowledge gained during bachelor studies. This knowledge of experimental and theoretical physics is deepened in the practical courses, lectures, and in intensively supervised exercise classes. In addition, students focus on individual fields of physics within the primary and secondary area of specialization. They will apply these skills to solve problems of current research.

At the end of their Master studies, the students will have acquired a number of broad and focused competencies within their area of specialization, which they will successfully apply to the different scientific and technical problems they will encounter in their following career, either within or outside academia. The master studies lead to a degree qualifying the graduate to enter a profession.

The admission regulations are given in §4 of the Examination Regulations (Prüfungsordnung). The main requirements for admission are a Higher Education Entrance Qualification and a scientific degree, which is equivalent to the Bachelor degree in Physics (B.Sc.) at the University of Cologne.

1.2 Structure and Sequence of Studies (Studienaufbau und -abfolge)

Students may begin with their studies either in the summer or the winter term. The practical course experiments and the courses for the primary and secondary area of specialization as well as the elective area can be chosen flexibly. This allows students to arrange their courses in the best order, matching their individual course choices and requirements.

In the first two semesters, students complete the practical courses, the theoretical physics module, the elective area, and the secondary area of specialization. They might also complete all courses of the primary area of specialization, except for either the advanced seminar or a specialized lecture. The advanced seminar usually takes place in the second or third semester.

The two introductory projects are conducted in the third semester.

The course is completed with the Master Thesis in the fourth semester.

The experiments for the Practical Course M will be chosen from two subjects out of the following:

- Molecular and Astrophysics
- Solid State Physics
- Nuclear Physics
- Biophysics

- Particle Physics

The course for the module theoretical physics can be chosen as either Advanced Quantum Mechanics or Advanced Statistical Physics.

The courses for the elective area module can be chosen from two different fields offered at the Faculties of Math and Natural Sciences at the Universities of Cologne and Bonn.

The primary and secondary area of specialization can be chosen from the following subjects:

- General Theory of Relativity / Quantum Field Theory
- Astrophysics
- Condensed Matter Physics
- Molecular Physics
- Nuclear and Particle Physics
- Solid State Theory / Computational Physics
- Statistical and Biological Physics

If approved by the module coordinator, fitting courses from Bonn may be credited in these modules as well. The courses passed in Bonn will be credited in Cologne according to their HPW (1 HPW = 1.5 CP).

The SAoS might also be chosen from the following modules offered in Bonn:

- Cosmology
- Experimental Hadron Physics
- High Energy Particle Physics
- Physics in Medicine
- Quantum Optics and optical Condensed Matter Physics
- Theoretical Hadron Physics
- Theoretical Particle Physics

The topic for the Master Thesis usually will be chosen from the primary area of specialization.

1.3 CP General Overview (LP-Gesamtübersicht)

The 120 CP of the Master studies split up into 66 CP for the lecture component, 24 CP for the introductory projects and 30 CP for the Master Thesis.

The two introductory projects prepare the students for the Master Thesis.

The Master Thesis completes the studies. It covers a well-defined topic of physics and is based on research conducted individually by the student. It is documented in a written thesis and presented orally in a colloquium.

CP General Overview	
Lecture Component and Introductory Projects	90 CP
Master Thesis	30 CP
Total	120 CP

1.4 CP Overview Corresponding to Semesters (Semesterbezogene LP-Übersicht)

The following table provides an overview of all modules. The first two columns indicate for which semester(s) the modules are planned for students starting either in the winter term or in the summer term.

CP Overview					
Sem. (WiSe Start)	Sem. (SuSe Start)	Module	CT	PW	CP
1	2	Advanced Quantum Mechanics or Advanced Statistical Physics	85	185	9
1	1	Practical Course M I	18	162	6
1– 2	1– 2	Elective Area	114	246	12
1– 3	1– 3	Primary Area of Specialization	179	451	21
2	1– 2	Practical Course M II	18	162	6
1– 2	1– 2	Second Area of Specialization	113	247	12
3	3	Introductory Project I	360 *		12
3	3	Introductory Project II	360 *		12
4	4	Research Module Master Thesis	900 *		30

* The distribution of the WL to CT and PW depends on the individual choice.

1.5 Calculation of the Overall Grade (Berechnung der Fachnote)

The modules contribute to the overall grade according to their individual credit points. The Master Thesis has weight 1.5; the Introductory Projects have weight 0; all other modules have weight 1. The following table provides the weighted contributions of each module.

Significance of the module mark for the overall grade		
Module	CP	Contribution to the overall grade
Advanced Quantum Mechanics or Advanced Statistical Physics	9	9/111
Elective Area	12	12/111
Primary Area of Specialization	21	21/111
Practical Course M I	6	6/111
Practical Course M II	6	6/111
Second Area of Specialization	12	12/111
Introductory Project I	12	0
Introductory Project II	12	0
Research Module Master Thesis	30	45/111

2 Descriptions and Tables of Modules (Modulbeschreibungen und Modultabellen)

2.1 Core Modules (Basismodule)

At the beginning of the Master studies, the two modules “Practical Course M” and a course from the field of theoretical physics deepen the basic knowledge gained in the bachelor studies. The theoretical physics course may be chosen as either “Advanced Quantum Mechanics” or “Advanced Statistical Physics”.

Practical Course M I

<table>
<tr><td colspan="7">Practical Course M I</td></tr>
<tr><td colspan="2">Identification number

MN-P-PraktMI</td><td>Workload

180 h</td><td>Credits

6 CP</td><td>Term of studying

1st Semester</td><td>Frequency of occurrence

Continually upon consultation, every semester</td><td>Duration

1 Semester</td></tr>
<tr><td>1</td><td colspan="3">Type of lessons

a) Preparation for experiments
b) Perform experiments
c) Analysis and Report
d) Exam</td><td>Contact times

---
15 h
---
1 h</td><td>Self-study times

45 h
---
95 h
24 h</td><td>Intended group size

Max 3 students</td></tr>
<tr><td>2</td><td colspan="6">Aims of the module and acquired skills

The course consists of advanced experiments introducing into important subfields of contemporary experimental physics. The students gain insight in relevant contemporary research by conducting experiments independently. Content of the course includes determination of experimental quantities and their errors, modern experimental physics methods, and the written presentation of scientific results.</td></tr>
<tr><td>3</td><td colspan="6">Contents of the module

Advanced methods of performing physics experiments are introduced by setting up and conducting four experiments. The experiments introduce students to modern physics research. The experiments have to be selected from one category group out of atomic physics, solid state physics, nuclear physics, or biophysics. Experiments are selected from the catalogue of laboratory set-ups offered.</td></tr>
<tr><td>4</td><td colspan="6">Teaching / Learning methods

After registration the participants will work in small subgroups of at most 3 students. Before carrying out an experiment, the student shall demonstrate to have acquired background knowledge for the experiments. For each experiment, the preparation, the measured results and the data analysis have to be documented in written form. The selected subfield of the experiments should be motivated and guided by the main focus of the selected master research fields.</td></tr>
</table>

5	**Requirements for participation** Fundamentals at the level of the bachelor courses in physics
6	**Type of module examinations** In the categories molecular and astrophysics, solid state physics, biophysics, and nuclear physics the successful preparation, measurement and analysis of each experiment is certificated, but not graded. Failed experiments may be repeated twice.
7	**Requisites for the allocation of credits** Four completed experiments are required to be admitted to an oral exam, which determines the grade of the module.
8	**Compatibility with other curricula and soft skills** As elective subject in other M.Sc. programs Teamwork, collaboration capability, time management
9	**Significance of the module mark for the overall grade** The weight of the module is 6/111 ≈ 5.4 %.
10	**Module coordinator** F. Lewen, T. Lorenz, B. Maier, P. Reiter
11	**Additional information** Alternatively to the categories listed above, experiments in particle physics may be performed in Bonn and credited in Cologne. In this case, the module examinations follow the regulations of Bonn University. Version: 05.06.2015 HK

Practical Course M II

Practical Course M II					
Identification number MN-P-PraktMII	**Workload** 180 h	**Credits** 6 CP	**Term of studying** 1st Semester	**Frequency of occurrence** Continually upon consultation, every semester	**Duration** 1 Semester

1	**Type of lessons**	**Contact times**	**Self-study times**	**Intended group size**
	a) Preparation for experiments	---	45 h	Max 3 students
	b) Perform experiments	15 h	---	
	c) Analysis and Report	---	95 h	
	d) Exam	1 h	24 h	

2	**Aims of the module and acquired skills** The course consists of advanced experiments introducing students to important subfields of contemporary experimental physics. The students gain insight into relevant contemporary research by conducting experiments independently. Content of the course includes the determination of experimental quantities and their errors, modern experimental physics methods, and the written presentation of scientific results.
3	**Contents of the module** Advanced methods of performing physics experiments are introduced by setting up and conducting four experiments. The experiments introduce students to modern physics research. The experiments have to be selected from one category group out of atomic physics, solid state physics, nuclear physics, biophysics, or particle physics. Experiments are selected from the catalogue of laboratory set-ups offered. The category chosen in this module must be different from the one chosen in Practical Course M II.
4	**Teaching / Learning methods** After registration the participants will work in small subgroups of at most 3 students. Before carrying out an experiment, the student needs to demonstrate to have the necessary background knowledge of the experiments. For each experiment, the preparation, the measured results and the data analysis have to be documented in written form. The selected subfield of the experiments should be motivated and guided by the main focus of the selected master research fields. The experiments in atomic, solid state, biophysics, and nuclear physics are performed at the University of Cologne, while the experiments in particle physics take place at the University Bonn.
5	**Requirements for participation** Fundamentals at the level of the bachelor courses in physics
6	**Type of module examinations** In the categories molecular and astrophysics, solid state physics, biophysics, and nuclear physics the successful preparation, measurement and analysis of each experiment is certificated, but not graded. Failed experiments may be repeated twice.
7	**Requisites for the allocation of credits** Four completed experiments are required to be admitted to an oral exam, which determines the grade of the module.
8	**Compatibility with other curricula and soft skills** As elective subject in other M.Sc. programs Teamwork, collaboration capability, time management
9	**Significance of the module mark for the overall grade** The weight of the module is $6/111 \approx 5.4$ %.
10	**Module coordinator** F. Lewen, T. Lorenz, B. Maier, P. Reiter
11	**Additional information** Version: 05.06.2015 HK

Advanced Quantum Mechanics

<table>
<tr><td colspan="7">Advanced Quantum Mechanics</td></tr>
<tr><td colspan="2">Identification number
MN-P-QMII</td><td>Workload
270 h</td><td>Credits
9 CP</td><td>Term of studying
1st Semester</td><td>Frequency of occurrence
Every winter term</td><td>Duration
1 Semester</td></tr>
<tr><td>1</td><td colspan="3">Type of lessons
a) Lecture
b) Problem Class
c) Preparation for exam</td><td>Contact times
56 h
28 h
---</td><td>Self-study times
84 h
84 h
18 h</td><td>Intended group size
15–20 students per
problem class</td></tr>
<tr><td>2</td><td colspan="6">Aims of the module and acquired skills
Building on the foundational exposition of quantum mechanics in the B.Sc. physics curriculum, this course teaches the parts of advanced quantum mechanics that are required knowledge for doing master thesis research in experimental or theoretical physics. In particular, the course develops the basic formalism of quantum scattering theory, arguably the main tool to analyze fundamental physics experiments at high and low energies. The part on the Dirac equation, governing all fundamental matter fields, discusses the novel features that arise when quantum mechanics is combined with the theory of special relativity; here, students learn where 'spin' comes from, and they get an outlook on the origins of quantum field theory. The part on second quantization introduces the formalism needed for the many-body physics of atomic nuclei and condensed matter systems.</td></tr>
<tr><td>3</td><td colspan="6">Contents of the module
1. Scattering theory
• differential cross section
• method of partial waves and scattering phases for systems with spherical symmetry
• optical theorem, Lippmann-Schwinger equation, Born approximation
• time-dependent scattering theory, Moeller operators
• scattering matrix, multichannel scattering
2. The formalism of second quantization
• construction of the Fock space for fermions and bosons
• second quantization of one- and two-body operators
• vacuum state and normal ordering
• quantum theory of the free electromagnetic field
3. Relativistic quantum theory
• Dirac equation, invariance properties (parity, time reversal, charge conjugation)
• hole interpretation of the positron, nonrelativistic reduction
• Pauli equation, spinors
4. Specialized topic in advanced quantum mechanics, for example, applications of group theory (theory of angular momentum and spin), the standard model of particle physics, or quantum information theory.</td></tr>
</table>

4	Teaching/Learning methods Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results.
5	Requirements for participation Classical theoretical physics (mechanics and electrodynamics), basic quantum mechanics (as taught in a one-semester theoretical physics course on quantum mechanics).
6	Type of module examinations The module is passed by passing a written exam, which is held during the semester and is offered again at the beginning of the following semester. To be accepted for the written exam, students must actively participate in the problem class, solve the homework problems and register for the exam.
7	Requisites for the allocation of credits The module is passed by passing a written exam. The grade given for the module is equal to the grade of the written exam.
8	Compatibility with other Curricula As elective subject in other M.Sc. programs.
9	Significance of the module mark for the overall grade The weight of the module is 9/111 ≈ 8.1 %.
10	Module coordinator M. Zirnbauer
11	Additional information Literature: Sakurai, Modern Quantum Mechanics (Addison-Wesley), Schwabl, Advanced Quantum Mechanics (Springer) Version: 06.11.2017 MZ

Advanced Statistical Physics

Advanced Statistical Physics					
Identification number MN-P-PN-StatPhysII	Workload 270 h	Credits 9 CP	Term of studying 1st Semester	Frequency of occurrence Every winter term	Duration 1 Semester

1	Type of lessons	Contact times	Self-study times	Intended group size
	a) Lecture	56 h	84 h	15–20 Students per
	b) Problem Class	28 h	84 h	problem class
	c) Preparation for exam	---	18 h	

2	**Aims of the module and acquired skills** This course introduces a wide range of concepts used to describe many-particle systems: Stochastic dynamics in and out of equilibrium, exact solutions of lattice models, mean-field theory, the renormalization group, and disordered systems. In particular, the renormalization group provides a unifying language across a wide range of theoretical physics: from quantum field theory and particle physics to statistical physics and condensed matter. Stochastic dynamics is a key concept to describe systems out of equilibrium, for instance transport and traffic phenomena, the dynamics of biomolecules, neural systems, or biological evolution. The course is a recommended prerequisite for the area of specialization (AoS) "Statistical and Biological Physics" and requires participation in the lecture course and in the exercise sessions.
3	**Contents of the module** 1. Macroscopic and microscopic degrees of freedom • conservation laws • fast and slow variables • elementary continuum mechanics and hydrodynamics 2. Phase transitions and critical phenomena • Universality • Landau theory • relevance of fluctuations • field-theoretic approach 3. Scaling and renormalization 4. Dynamics • Correlation- and response functions • Langevin- and Fokker-Planck equations • the Wiener integral • nonequilibrium stationary states 5. Disordered systems and glasses
4	**Teaching/Learning methods** The module consists of a lecture course, supplemented by a problem class.
5	**Requirements for participation** Classical theoretical physics; elementary thermodynamics and statistical physics.
6	**Type of module examinations** The module is passed by passing a written exam, which is held during the semester and is offered again at the beginning of the following semester. To be accepted for the written exam, students must actively participate in the problem class, solve the homework problems and register for the exam.
7	**Requisites for the allocation of credits** The module is passed by passing a written exam. The grade given for the module is equal to the grade of the written exam.

8	**Compatibility with other Curricula** As elective subject in other M.Sc. programs
9	**Significance of the module mark for the overall grade** The weight of the module is 9/111 ≈ 8.1 %.
10	**Module coordinator** J. Krug, T. Nattermann
11	**Additional information** Literature: Plischke and Bergersen, Equilibrium statistical physics (World Scientific) Goldenfeld, Lectures on phase transitions and the renormalization group (Westview Press) Chaikin and Lubensky, Principles of condensed matter physics (Cambridge University Press) Version: 24.10.2017 JB

2.2 Advanced Modules (Aufbaumodule)

n/a

2.3 Specialization Modules (Schwerpunktmodule)

The students focus on specific fields of physics from the first semester on by attending specialization modules. At the beginning, basic knowledge is gained on two subjects – the primary and the secondary area of specialization. Later the students start with active research in their PAoS in the two introductory projects, preparing for the Master Thesis.

Primary Area of Specialization General Theory of Relativity / Quantum Field Theory

General Theory of Relativity / Quantum Field Theory					
Identification number	**Workload**	**Credits**	**Terms of study**	**Frequency of occurrence**	**Duration**
MN-P-SP-GR-QFT	(540 + 90) h	21 CP	1st to 3rd semester	Details are provided online in the table “Course Offerings”.	3 semesters

1	**Types of lesson**	**Contact times**	**Self-study times**	**Intended group size**
	a) Lecture courses	These depend on the	These depend on the	15–20 students per problem class
	b) Problem classes	specific choices made	specific choices made	Individual tutoring for the seminar
	c) Advanced seminar	10 h	80 h	
	d) Exam	1 h	24 h	

2	**Aims of the module and acquired skills** The aim of the core courses to master the fundamental concepts of general relativity and/or quantum field theory, to an extent where students are able to read and comprehend original research articles in these areas. The specialized courses introduce students to an expanded range of subjects including related topics in nearby areas such as astrophysics, particle physics and physics-related mathematics. Presentation skills are acquired through the participation in an advanced student seminar. Ultimately, the goal is to prepare the candidate to do the research for a master thesis.
3	**Contents of the module** The module is subdivided into core courses, specialized courses and the advanced seminar: 1. Core courses • Relativity and Cosmology I (4+2 HPW, 9 CP): gravity as a geometric theory, Einstein field equations, Schwarzschild solution, experimental tests, gravitational waves • Relativity and Cosmology II (4+2 HPW, 9 CP): black holes, introduction to cosmology, the early universe • Quantum Field Theory I (4+2 HPW, 9 CP): second quantization and applications, functional integrals, perturbation theory, mean-field methods • Quantum Field Theory II (4+2 HPW, 9 CP): the role of correlation functions, spontaneous symmetry breaking, lattice gauge theory, topological aspects of QFT, renormalization 2. Specialized courses • Misc. courses: Quantum Aspects of Gravity (X HPW, X CP – cf. table 'course offerings') • Misc. courses: Particle– and Astrophysics (X HPW, X CP – cf. table 'course offerings') • Misc. courses: Mathematics (X HPW, X CP – cf. Table 'course offerings') • and others, including fitting courses from Bonn University, if approved by the module coordinator The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the course descriptions online. 3. Advanced student seminar (2 HPW, 3 CP) • Seminar on current topics in Quantum Mechanics, General Relativity, or Quantum Field Theory
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results. By preparing an advanced seminar, they become acquainted with a current topic of research, scientific methods and literature. They also learn to communicate in a pedagogical way on an advanced topic.
5	**Requirements for participation** The theoretical physics curriculum at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the examination, students must actively participate in the problem sessions (including the solution of homework problems) and give a talk in the advanced seminar. The grade given for the module is the grade of the oral examination.

7	Requisites for the allocation of credits The Primary AoS GR-QFT is composed of: 1. One of the core courses GR I-II or QFT I-II (lectures and exercises) 2. A second core course or specialized courses from the list above 3. Advanced student seminar
8	Compatibility with other Curricula and Soft Skills May be taken as an elective subject in other M.Sc. programs. Promotes scientific reading and presentation skills, in particular those for oral presentations.
9	Significance of the module grade for the overall grade The weight of the module is 21/111 ≈ 18.9 %.
10	Module coordinator C. Kiefer
11	Additional information Details of the course offerings and contents are given online and in the “kommentiertes Vorlesungsverzeichnis”. Version: 28.08.2015 PN

Primary Area of Specialization Astrophysics

Astrophysics					
Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-SP-Astro	(540 + 90) h	21 CP	1st to 3rd semester	Details are provided online in the table “Course Offerings”.	3 semesters

	Type of lessons	Contact times	Self-study times	Intended group size
1	a) Lecture	depending on the	depending on the	
	b) Problem class	individual choice	individual choice	15–20 Students per problem class
	c) Advanced Seminar	10 h	80 h	individual counseling for the seminar
	d) Exam	1 h	24 h	

2	Aims of the module and acquired skills The students will gain the ability to apply fundamental concepts of physics to describe astrophysical phenomena and will obtain an overview of the experimental foundations of our knowledge about the cosmos. The courses will enable them to understand the fundamental principles of the universe and its history. The courses also give an introduction to topics of active research in astrophysics and thus prepare the students towards their own research activity within the master thesis.

3	**Contents of the module** The module is subdivided into a core course, specialized courses and the advanced seminar: 1. Core course • Advanced Astrophysics (4+2 HPW, 9 CP) 2. Specialized courses • Active Galaxies (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Astrochemistry (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Data Analysis (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Experimental Methods in Astrophysics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Galaxy Dynamics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Fourier-Transform and its Applications (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Hydrodynamics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • The Physics of the Interstellar Medium (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Star Formation (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Optical/Infrared Interferometry (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Methods of Molecular Astrophysics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Observational Methods in Infrared Astronomy (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Observational Cosmology (Bonn, 2+1 HPW, 4 CP) / (2 HPW, 3 CP) • Radiointerferometry: Methods and Science (Bonn, 2+2 HPW, 6 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator 3. Advanced Seminar in Astrophysics (2 HPW, 3 CP) The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results. By preparing an advanced seminar, they become acquainted with a current topic of research, scientific methods and literature. They also learn to communicate in a pedagogical way on an advanced topic.
5	**Requirements for participation** Atomic Physics, Astrophysics and Quantum Mechanics at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems) and present a scientific talk in the advanced seminar course. The grade given for the module is equal to the grade of the oral examination.

7	**Requisites for the allocation of credits** The Primary AoS Astrophysics is composed of: 1. Core course Advanced Astrophysics (Lectures and Exercises) 2. Specialized courses (Lectures and Exercises) in Astrophysics 3. Advanced Seminar in Astrophysics
8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. Computer aided analysis of scientific data. This module prepares for topics of current research in molecular physics and astrophysics and provides the basis for the preparation of the master thesis.
9	**Significance of the module mark for the overall grade** The weight of the module is 21/111 ≈ 18.9 %.
10	**Module coordinator** P. Schilke
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”. Version: 05.06.2015 HK

Primary Area of Specialization Condensed Matter Physics

Condensed Matter Physics					
Identification number	**Workload**	**Credits**	**Term of studying**	**Frequency of occurrence**	**Duration**
MN-P-SP-CondMat	(540 + 90) h	21 CP	1st to 3rd semester	Details are provided online in the table “Course Offerings”.	3 semesters

1	**Type of lessons**	**Contact times**	**Self-study times**	**Intended group size**
	a) Lecture b) Problem class	depending on the individual choice	depending on the individual choice	15–20 Students per problem class
	c) Advanced Seminar	10 h	80 h	individual counseling for the seminar
	d) Exam	1 h	24 h	

2	**Aims of the module and acquired skills** Students shall deepen their understanding and knowledge of the main concepts (experimental & theoretical) of condensed matter physics and get familiar with some important experimental methods in condensed matter physics. In specialized courses selected up-to-date research topics of experimental condensed matter physics are discussed as applications of the main concepts and as a preparation for the master thesis. In advanced seminars, students shall acquire a comprehensive understanding of a particular topic and improve their presentation skills.
3	**Contents of the module** The module is subdivided into core courses and specialized courses: 1. Core course • Condensed Matter Physics I (3+1 HPW, 6 CP): Crystal structure and binding, Reciprocal space, Lattice dynamics and thermal properties, Free electron gas • Condensed Matter Physics II (3+1 HPW, 6 CP): Band structure, Metals and semiconductors, Transport properties, Dielectric function and screening, Superconductivity, Magnetism 2. Specialized courses • Experimental Methods of Condensed Matter Physics (2 HPW, 3 CP) • Superconductivity and Nanoscience (2 HPW, 3 CP) • Magnetism (2 HPW, 3 CP) • Semiconductor Physics (2 HPW, 3 CP) • Photons and Matter (2 HPW, 3 CP) • Physics of Surfaces and Nanostructures (2 HPW, 3 CP) • Introduction to Neutron Scattering (2 HPW, 3 CP) • Optical Spectroscopy (2 HPW, 3 CP) • Fundamentals of Spintronics (2 HPW, 3 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator 3. Advanced seminar in condensed matter physics (2 HPW, 3 CP) The contents of the specialized courses and of the advanced seminars can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results. By preparing an advanced seminar, they become acquainted with a current topic of research, scientific methods and literature. They also learn to communicate in a pedagogical way on an advanced topic.
5	**Requirements for participation** Experimental and theoretical physics at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems) and present a scientific talk in the advanced seminar course. The grade given for the module is equal to the grade of the oral examination.

7	**Requisites for the allocation of credits** The Primary AoS Condensed Matter Physics is composed of: 1. Two core courses Condensed Matter Physics I and II (2 x (3+1) HPW) 2. Two specialized courses in Condensed Matter Physics. At least one of the two has to be a course in experimental condensed matter physics, the second one can also be a course in theoretical condensed matter physics. 3. One advanced seminar in Condensed Matter Physics
8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. Computer aided analysis of scientific data. This module prepares for topics of current research in condensed matter physics and provides the basis for the preparation of the master thesis.
9	**Significance of the module mark for the overall grade** The weight of the module is 21/111 ≈ 18.9 %.
10	**Module coordinator** J. Hemberger
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the "kommentiertes Vorlesungsverzeichnis". Version: 05.06.2015 HK

Primary Area of Specialization Molecular Physics

Molecular Physics					
Identification number	**Workload**	**Credits**	**Term of studying**	**Frequency of occurrence**	**Duration**
MN-P-SP-Mol	(540 + 90) h	21 CP	1st to 3rd semester	Details are provided online in the table "Course Offerings".	3 semesters

1	**Type of lessons**	**Contact times**	**Self-study times**	**Intended group size**
	a) Lecture b) Problem class c) Practical course	depending on the individual choice	depending on the individual choice	15–20 Students per problem class individual counseling for the seminar
	d) Advanced Seminar	10 h	80 h	
	e) Exam	1 h	24 h	

2	**Aims of the module and acquired skills** Understanding of the main concepts of molecular physics, the use of computer programs for the analysis of molecular spectra (computer aided analysis of scientific data), application of molecular physics concepts to current research in fundamental physics, atmospheric physics and astrophysics including practical courses (advanced experimental skills) and advanced seminars (presentation skills).
3	**Contents of the module** The module is subdivided into core courses, specialized courses and the advanced seminar: 1. Core courses • Molecular Physics I (3+1 HPW, 6 CP): Basics of Molecular Spectroscopy, Interaction of Radiation with Matter, Chemical Bond, Born-Oppenheimer-Approximation, Rigid Rotor, Harmonic Oscillator, Electronic States, Rotational Spectroscopy, Group Theory • Molecular Physics II (3+1 HPW, 6 CP): Rotational Spectroscopy, Vibrational Spectroscopy, Group Theory, Coupling of Rotation and Vibration, Transitions and Selection Rules, Nuclear Spin Statistics, Coupling of Angular Momenta, Hund`s Cases, Fine Structure (FS), HFS 2. Specialized courses • Astrochemistry (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Introduction to Atmospheric Physics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Measurement Techniques in Atmospheric Physics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Experiments in Molecular Physics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Methods of Molecular Astrophysics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Experimental Methods in Astrophysics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Fundamentals of Molecular Symmetry (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Fourier-Transform and its Applications (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Star formation (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • The Physics of the Interstellar Medium (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator 3. Advanced Seminar in Molecular Physics (2 HPW, 3 CP) The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. Students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results. By preparing an advanced seminar, they become acquainted with a current topic of research, scientific methods and literature. They also learn to communicate in a pedagogical way on an advanced topic. In the additional lab course the students also gain insight into state-of-the-art instrumentation by conducting experiments independently.
5	**Requirements for participation** Atomic Physics and Quantum Mechanics at the level of the bachelor courses in physics

6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems) and present a scientific talk in the advanced seminar course. The grade given for the module is equal to the grade of the oral examination.
7	**Requisites for the allocation of credits** The Primary AoS Molecular Physics is composed of: 1. Two core courses Molecular Physics I and II (2 x (3+1) HPW) 2. Specialized courses in Molecular Physics, Astrophysics and Atmospheric Physics 3. Optional: advanced practical courses in Molecular Physics, Astrophysics and Atmospheric Physics 4. Advanced Seminar in Molecular Physics, Astrophysics and Atmospheric Physics
8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. Computer aided analysis of scientific data. This module prepares for topics of current research in molecular physics and astrophysics and provides the basis for the preparation of the master thesis.
9	**Significance of the module mark for the overall grade** The weight of the module is 21/111 ≈ 18.9 %.
10	**Module coordinator** S. Schlemmer
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”. Version: 23.04.2016 PN

Primary Area of Specialization Nuclear and Particle Physics

Nuclear and Particle Physics					
Identification number	**Workload**	**Credits**	**Term of studying**	**Frequency of occurrence**	**Duration**
MN-P-SP-Nuc	630 h	21 CP	1st to 3rd semester	Details are provided online in the table “Course Offerings”.	3 semesters

1	**Type of lessons**	**Contact times**	**Self-study times**	**Intended group size**
	a) Lecture	196 h	319 h	
	b) Advanced Seminar	10 h	80 h	
	c) Exam	1 h	24 h	individual counseling for the seminar

2	**Aims of the module and acquired skills** Understanding of the main concepts of nuclear and particle physics, including reaction theory and the physical principles of detectors and accelerators used in nuclear and particle physics.
3	**Contents of the module** The module is subdivided into core courses and specialized courses. 1. Core courses • Nuclear Physics II (3 HPW, 4.5 CP): Study of nuclear reactions, fission and fusion. Accelerators. • Detector Physics (2 HPW, 3 CP) Interaction of radiation with matter, scintillators, semiconductor detectors, particle detectors. • Particle Physics (3 HPW, 4.5 CP): Introduction into particle physics 2. Specialized courses • Theoretical Nuclear Physics I (2 HPW, 3 CP) • Theoretical Nuclear Physics II (2 HPW, 3 CP) • Theoretical Nuclear Physics III (2 HPW, 3 CP) • Accelerator Mass Spectrometry (2 HPW, 3 CP) • Nuclear Astrophysics (2 HPW, 3 CP) • Neutron Physics (2 HPW, 3 CP) • Selected problems in Nuclear Structure (2 HPW, 3 CP) • Heavy Ion Physics (2 HPW, 3 CP) • Tools for Particle Physics (2 HPW, 3 CP) • Selected Topics on Future Energy Supply (2 HPW, 3 CP) • Applied Nuclear Physics (2 HPW, 3 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator 3. Advanced Seminar in Nuclear and Particle Physics (2 HPW, 3 CP) The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. In discussions with others, they learn to solve challenging problems in a team and to present their approaches and results. By preparing an advanced seminar, they become acquainted with a current topic of research, scientific methods and literature. They also learn to communicate in a pedagogical way on an advanced topic.
5	**Requirements for participation** Nuclear and Particle Physics and Quantum Mechanics at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of the core courses. To be admitted to the exam, students must actively have participated in the specialized courses and have presented a scientific talk in the advanced seminar course. The grade given for the module is equal to the grade of the oral examination.

7	**Requisites for the allocation of credits** The Primary AoS Nuclear and Particle Physics is composed of: 1. Three core courses (8 HPW, 12 CP) 2. Two specialized courses in Nuclear and Particle Physics (4 HPW, 6 CP) 3. Advanced Seminar in Nuclear and Particle Physics (3 CP)
8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. This module prepares for topics of current research in nuclear and particle physics and provides the basis for the preparation of the master thesis in nuclear and hadronic physics.
9	**Significance of the module mark for the overall grade** The weight of the module is 21/111 ≈ 18.9 %.
10	**Module coordinator** J. Jolie
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”. Version: 05.06.2015 HK

Primary Area of Specialization Solid State Theory / Computational Physics

Solid State Theory / Computational Physics					
Identification number	**Workload**	**Credits**	**Term of studying**	**Frequency of occurrence**	**Duration**
MN-P-SP-THSol	(540 + 90) h	21 CP	1st to 3rd semester	Details are provided online in the table “Course Offerings”.	3 semesters

1	**Type of lessons**	**Contact times**	**Self-study times**	**Intended group size**
	a) Lecture	depending on the	depending on the	
	b) Problem class	individual choice	individual choice	15–20 Students per problem class
	c) Advanced Seminar	10 h	80 h	individual counseling for the seminar
	d) Exam	1 h	24 h	

2	**Aims of the module and acquired skills** A deep understanding of fundamental concepts used to theoretically describe solids and their excitations / ability to describe phenomena like superconductivity and magnetism / understanding of important quantum field-theoretical and computational methods / ability to translate mathematical concepts into algorithms / computational approach to problem solving with applications to many-body physics / ability to acquaint oneself with scientific questions and to present results / preparation for a master thesis in theoretical physics.

3	**Contents of the module** The module is subdivided into core courses, specialized courses and the advanced seminar 1. Core Courses • Solid State Theory (3+1 HPW, 6 CP): Concepts of solid state theory and description of excitations in solid • Computational Many-Body Physics (3+1 HPW, 6 CP): Overview of elementary numerical approaches to study many-body systems, both classical and quantum. • Quantum Field Theory I (4+2 HPW, 9 CP): Modern methods to describe solids based on functional integrals and by using diagrammatic methods 2. Specialized courses: • Quantum Field Theory II (4+2 HPW, 9 CP) • One course chosen from the specialized courses of the module Condensed Matter Physics • Hydrodynamics (2+2 HPW, 6 CP) • Advanced Topics in Solid State Theory (3+1 HPW, 6 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator 3. Advanced Seminar on topical subjects of Solid State Theory (2 HPW, 3 CP) The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets and implement computational algorithms. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results. By preparing an advanced seminar, they become acquainted with a current topic of research, scientific methods and literature. They also learn to communicate in a pedagogical way on an advanced topic.
5	**Requirements for participation** Basic knowledge in theoretical physics at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems) and present a scientific talk in the advanced seminar course. The grade given for the module is equal to the grade of the oral examination.
7	**Requisites for the allocation of credits** The following courses have to be chosen from the list given above in order to acquire the necessary credit points: 1. Two of the core courses or, alternatively, both the courses Quantum Field Theory I and Quantum Field Theory II 2. One advanced seminar 3. Further core courses, specialized courses or a second advanced seminar The module is passed by passing an oral examination covering the topics of all attended courses.

8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. This module prepares for topics of current research in solid stat theory and provides the basis for the preparation of the master thesis.
9	**Significance of the module mark for the overall grade** The weight of the module is 21/111 ≈ 18.9 %.
10	**Module coordinator** A. Rosch
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”. Version: 05.06.2015 HK

Primary Area of Specialization Statistical and Biological Physics

Statistical and Biological Physics

Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-SP-StatBio	(540 + 90) h	21 CP	1st to 3rd semester	Details are provided online in the table “Course Offerings”.	3 semesters

	Type of lessons	Contact times	Self-study times	Intended group size
1	a) Lecture	depending on the	depending on the	
	b) Problem class	individual choice	individual choice	15–20 Students per problem class
	c) Advanced Seminar	10 h	80 h	individual counseling for the seminar
	d) Exam	1 h	24 h	

2	**Aims of the module and acquired skills** Bring students to the forefront of current research in statistical and biological physics, application of concepts from physics to biological systems, understanding of complex phenomena emerging from simple systems, learn to construct models and infer model parameters from empirical observations, train interdisciplinary skills and interaction between experiment and theory, train presentation skills in advanced seminars

3 **Contents of the module**

The module is subdivided into core courses, specialized courses and the advanced seminar:

1. Core courses

- Biological Physics I: Molecules and cells (3+1 HPW, 6 CP; or 4+1, 7.5 CP): Introduction to molecular cell biology, random walks in biology, mechanical forces in molecular and cellular biology, rate equations and cellular dynamics, photophysics, electrical signals in nerve cells, biophysical methods
- Biological Physics II: Systems (3+1 HPW, 6 CP; or 4+1, 7.5 CP): Dynamical systems, dynamics of small gene regulatory networks, noise in gene expression, statistical analysis of large biological networks, biological pattern formation, reaction-diffusion systems, empirical laws in biology
- Evolutionary Biology and Genomics for Physicists (3+1 HPW, 6 CP; or 4+1, 7.5 CP): Basic concepts of evolutionary theory, introduction to molecular evolution and genomics, theory of bio-molecular networks, concepts and methods of data analysis
- Selected Topics in Statistical Physics (3+1 HPW, 6 CP; or 4+1, 7.5 CP), including Soft and biological matter, Non-equilibrium statistical physics, Statistical physics of disordered systems, information, and inference as specified annually in the “kommentiertes Vorlesungsverzeichnis”

2. Specialized courses

- Computational soft matter physics (2+1 HPW, 4.5 CP)
- Experiment and simulation on biological systems (3 HPW, 4.5 CP)
- Introduction to network science (2+1 HPW, 4.5 CP)
- Probability theory and stochastic processes (3+1 HPW, 6 CP)
- Statistical optics (2 HPW, 3 CP)
- and others

3. Advanced Seminar in Statistical and Biological Physics (2 HPW, 3 CP)

The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.

4 **Teaching/Learning methods**

Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results. By preparing an advanced seminar, they become acquainted with a current topic of research, scientific methods and literature. They also learn to communicate in a pedagogical way on an advanced topic. In the additional lab course the students also gain insight into state-of-the-art instrumentation by conducting experiments independently.

5 **Requirements for participation**

Experimental and theoretical physics at the level of the bachelor courses in physics

6 **Type of module examinations**

The module examination is by oral exam covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (as defined in the individual courses). The grade given for the module is equal to the grade of the oral examination.

7	**Requisites for the allocation of credits** The Primary AoS StatBio is composed of: 1. At least one core course (lectures and exercises) 2. Specialized courses (lectures and exercises) 3. Advanced Seminar in Statistical and Biological
8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. Interdisciplinary approach. This module prepares for topics of current research in statistical and biological physics and provides the basis for the preparation of the master thesis.
9	**Significance of the module mark for the overall grade** The weight of the module is 21/111 ≈ 18.9 %.
10	**Module coordinator** B. Maier
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”. Version: 21.06.2017 BM

Secondary Area of Specialization General Theory of Relativity/Quantum Field Theory

General Theory of Relativity / Quantum Field Theory					
Identification number	**Workload**	**Credits**	**Terms of study**	**Frequency of occurrence**	**Duration**
MN-P-PN-GR-QFT	360 h	12 CP	1st and 2nd semester	Details are provided online in the table “Course Offerings”.	2 semesters

1	**Types of lesson**	**Contact times**	**Self-study times**	**Intended group size**
	a) Lecture courses	These depend on the	These depend on the	15–20 students per problem class
	b) Problem classes	specific choices made	specific choices made	
	c) Exam	1 h	24 h	

2	**Aims of the module and acquired skills** The aim of the core courses is for the student to master the fundamental concepts of general relativity and/or quantum field theory, to an extent where she is able to read and comprehend original research articles in these areas. The specialized courses introduce her to an expanded range of subjects including related topics in nearby areas such as astrophysics, particle physics and physics-related mathematics.
3	**Contents of the module** The module is subdivided into core courses and specialized courses: 1. Core courses • Relativity and Cosmology I (4+2 HPW, 9 CP): gravity as a geometric theory, Einstein field equations, Schwarzschild solution, experimental tests, gravitational waves • Relativity and Cosmology II (4+2 HPW, 9 CP): black holes, introduction to cosmology, the early universe • Quantum Field Theory I (4+2 HPW, 9 CP): second quantization and applications, functional integrals, perturbation theory, mean-field methods • Quantum Field Theory II (4+2 HPW, 9 CP): the role of correlation functions, spontaneous symmetry breaking, lattice gauge theory, topological aspects of QFT, renormalization 2. Specialized courses • Misc. courses: Quantum Aspects of Gravity (X HPW, X CP – cf. table “course offerings”) • Misc. courses: Particle– and Astrophysics (X HPW, X CP – cf. table “course offerings”) • Misc. courses: Mathematics (X HPW, X CP – cf. Table “course offerings”) • and others, including fitting courses from Bonn University, if approved by the module coordinator The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the course descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results.
5	**Requirements for participation** The theoretical physics curriculum at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems). The grade given for the module is equal to the grade of the oral examination.
7	**Requisites for the allocation of credits** The Secondary AoS GR-QFT is composed of: 1. At least one core course (lectures and exercises) taken from the list above 2. At least one specialized course from the list above

8	**Compatibility with other Curricula and Soft Skills** May be taken as an elective subject in other M.Sc. programs. Promotes scientific reading and presentation skills, in particular those for oral presentations.
9	**Significance of the module grade for the overall grade** The weight of the module is 12/111 ≈ 10.8 %.
10	**Module coordinator** C. Kiefer
11	**Additional information** Details of the course offerings and contents are given online and in the “kommentiertes Vorlesungsverzeichnis”. Version: 28.08.2015 PN

Secondary Area of Specialization Astrophysics

Astrophysics					
Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-PN-Astro	360 h	12 CP	1st and 2nd semester	Details are provided online in the table “Course Offerings”.	2 semesters

1	**Type of lessons** a) Lecture b) Problem class c) Exam	**Contact times** depending on the individual choice 1 h	**Self-study times** depending on the individual choice 24 h	**Intended group size** 15–20 students per problem class
2	**Aims of the module and acquired skills** The students will gain the ability to apply fundamental concepts of physics to describe astrophysical phenomena and will obtain an overview of the experimental foundations of our knowledge about the cosmos. The courses will enable them to understand the fundamental principles of the universe and its history. The courses also give an introduction to topics of active research in astrophysics and thus prepare the students towards their own research activity within the master thesis.			

3	**Contents of the module** The module is subdivided into a core course, specialized courses and the advanced seminar: 1. Core course • Advanced Astrophysics (4+2 HPW, 9 CP) 2. Specialized courses • Active Galaxies (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Astrochemistry (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Data Analysis (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Experimental Methods in Astrophysics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Galaxy Dynamics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Fourier-Transform and its Applications (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Hydrodynamics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • The Physics of the Interstellar Medium (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Star Formation (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Optical/Infrared Interferometry (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Methods of Molecular Astrophysics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Observational Methods in Infrared Astronomy (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Observational Cosmology (Bonn, 2+1 HPW, 4 CP) / (2 HPW, 3 CP) • Radiointerferometry: Methods and Science (Bonn, 2+2 HPW, 6 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator 3. Advanced Seminar in Astrophysics (2 HPW, 3 CP) The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results.
5	**Requirements for participation** Atomic Physics, Astrophysics and Quantum Mechanics at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems). The grade given for the module is equal to the grade of the oral examination.
7	**Requisites for the allocation of credits** The Secondary AoS Astrophysics is composed of: 1. Core Course Advanced Astrophysics (Lectures and Exercises) 2. Specialized courses (Lectures and Exercises) in Astrophysics or an Advanced Seminar in Astrophysics

8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. Computer aided analysis of scientific data.
9	**Significance of the module mark for the overall grade** The weight of the module is 12/111 ≈ 10.8 %.
10	**Module coordinator** P. Schilke
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”. Version: 05.06.2015 HK

Secondary Area of Specialization Condensed Matter Physics

Condensed Matter Physics					
Identification number MN-P-PN-CondMat	**Workload** 360 h	**Credits** 12 CP	**Term of studying** 1st and 2nd semester	**Frequency of occurrence** Details are provided online in the table “Course Offerings”.	**Duration** 2 semesters

1	**Type of lessons** a) Lecture b) Problem class c) Exam	**Contact times** depending on the individual choice 1 h	**Self-study times** depending on the individual choice 24 h	**Intended group size** 15–20 students per problem class
2	**Aims of the module and acquired skills** Students shall deepen their understanding and knowledge of the main concepts (experimental & theoretical) of condensed matter physics and get familiar with some important experimental methods in condensed matter physics. In specialized courses selected up-to-date research topics of experimental condensed matter physics are discussed as applications of the main concepts.			

3	**Contents of the module** The module is subdivided into core courses and specialized courses: 1. Core course • Condensed Matter Physics I (3+1 HPW, 6 CP): Crystal structure and binding, Reciprocal space, Lattice dynamics and thermal properties, Free electron gas • Condensed Matter Physics II (3+1 HPW, 6 CP): Band structure, Metals and semiconductors, Transport properties, Dielectric function and screening, Superconductivity, Magnetism 2. Specialized courses • Experimental Methods of Condensed Matter Physics (2 HPW, 3 CP) • Superconductivity and Nanoscience (2 HPW, 3 CP) • Magnetism (2 HPW, 3 CP) • Semiconductor Physics (2 HPW, 3 CP) • Photons and Matter (2 HPW, 3 CP) • Physics of Surfaces and Nanostructures (2 HPW, 3 CP) • Introduction to Neutron Scattering (2 HPW, 3 CP) • Optical Spectroscopy (2 HPW, 3 CP) • Fundamentals of Spintronics (2 HPW, 3 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results.
5	**Requirements for participation** Physics at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems). The grade given for the module is equal to the grade of the oral examination.
7	**Requisites for the allocation of credits** The Secondary AoS Condensed Matter Physics is composed of: 1. The core course Condensed Matter Physics I (Lectures and Exercises, 3+1 HPW) 2. Two specialized courses (2 HPW) in Condensed Matter Physics. Alternatively, the core course Condensed Matter Physics II (3+1 HPW) can be chosen instead of the two specialized courses.

8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. Computer aided analysis of scientific data.
9	**Significance of the module mark for the overall grade** The weight of the module is 12/111 ≈ 8.9%.
10	**Module coordinator** J. Hemberger
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”. Version: 05.06.2015 HK

Secondary Area of Specialization Molecular Physics

Molecular Physics

Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-PN-Mol	360 h	12 CP	1st and 2nd semester	Details are provided online in the table “Course Offerings”.	2 semesters

	Type of lessons	Contact times	Self-study times	Intended group size
1	a) Lecture b) Problem class c) Practical course c) Exam	depending on the individual choice 1 h	depending on the individual choice 24 h	 15–20 students per problem class

2	**Aims of the module and acquired skills** Understanding of the main concepts of molecular physics, use of computer programs for the analysis of molecular spectra (computer aided analysis of scientific data), application of molecular physics concepts to applications of current research in fundamental physics, atmospheric physics and astrophysics including practical courses (advanced experimental skills) and advanced seminars (presentation skills).

3	**Contents of the module** The module is subdivided into core courses, specialized courses and the advanced seminar: 1. Core courses • Molecular Physics I (3+1 HPW, 6 CP): Basics of Molecular Spectroscopy, Interaction of Radiation with Matter, Chemical Bond, Born- Oppenheimer-Approximation, Rigid Rotor, Harmonic Oscillator, Electronic States, Rotational Spectroscopy, Group Theory • Molecular Physics II (3+1 HPW, 6 CP): Rotational Spectroscopy, Vibrational Spectroscopy, Group Theory, Coupling of Rotation and Vibration, Transitions and Selection Rules, Nuclear Spin Statistics, Coupling of Angular Momenta, Hund`s Cases, Fine Structure (FS), HFS 2. Specialized courses • Astrochemistry (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Introduction to Atmospheric Physics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Measurement Techniques in Atmospheric Physics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Experiments in Molecular Physics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Methods of Molecular Astrophysics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Experimental Methods in Astrophysics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Fundamentals of Molecular Symmetry (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Fourier-Transform and its Applications (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Star formation (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • The Physics of the Interstellar Medium (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results. In the additional lab course the students also gain insight into state-of-the-art instrumentation by conducting experiments independently.
5	**Requirements for participation** Atomic Physics and Quantum Mechanics at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems). The grade given for the module is equal to the grade of the oral examination.
7	**Requisites for the allocation of credits** The courses can be chosen from the above set in order to acquire the necessary credit points.

8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. Computer aided analysis of scientific data.
9	**Significance of the module mark for the overall grade** The weight of the module is 12/111 ≈ 10.8 %.
10	**Module coordinator** S. Schlemmer
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”. Version: 23.04.2016 PN

Secondary Area of Specialization   Nuclear and Particle Physics

Nuclear and Particle Physics					
Identification number MN-P-PN-Nuc	Workload 360 h	Credits 12 CP	Term of studying 1st to 2rd semester	Frequency of occurrence Details are provided online in the table “Course Offerings”.	Duration 2 semesters

1	Type of lessons a) Lecture b) Exam	Contact times depending on the individual choice 1 h	Self-study times depending on the individual choice 24 h	Intended group size
2	**Aims of the module and acquired skills** Understanding of the main concepts of nuclear and particle physics..			

3	**Contents of the module** The module is subdivided into core courses and specialized courses. 1. Core courses • Nuclear Physics II (3 HPW, 4.5 CP): Study of nuclear reactions, fission and fusion. • Particle Physics (3 HPW, 4.5 CP): Introduction into particle physics, accelerators and particle detectors 2. Specialized courses • Detector Physics (2 HPW, 3 CP) • Theoretical Nuclear Physics I (2 HPW, 3 CP) • Theoretical Nuclear Physics II (2 HPW, 3 CP) • Theoretical Nuclear Physics III (2 HPW, 3 CP) • Accelerator Mass Spectrometry (2 HPW, 3 CP) • Nuclear Astrophysics (2 HPW, 3 CP) • Neutron Physics (2 HPW, 3 CP) • Selected problems in Nuclear Structure (2 HPW, 3 CP) • Heavy Ion Physics (2 HPW, 3 CP) • Tools for Particle Physics (2 HPW, 3 CP) • Selected Topics on Future Energy Supply (2 HPW, 3 CP) • Applied Nuclear Physics (2 HPW, 3 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results.
5	**Requirements for participation** Nuclear and Particle Physics and Quantum Mechanics at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of the core courses. To be admitted to the exam, students must actively have participated in the specialized course. The grade given for the module is equal to the grade of the oral examination.
7	**Requisites for the allocation of credits** The secondary AoS Nuclear and Particle Physics is composed of: 1. Two core courses (6 HPW, 9 CP) 2. One specialized course in Nuclear and Particle Physics (2HPW, 3CP).

8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs.
9	**Significance of the module mark for the overall grade** The weight of the module is 12/111 ≈ 10.8 %.
10	**Module coordinator** J. Jolie
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”. Version: 05.06.2015 HK

Secondary Area of Specialization Solid State Theory / Computational Physics

Solid State Theory / Computational Physics					
Identification number	**Workload**	**Credits**	**Term of studying**	**Frequency of occurrence**	**Duration**
MN-P-PN-ThSol	360 h	12 CP	1^{st} and 2^{nd} semester	Details are provided online in the table “Course Offerings”.	2 semesters

1	**Type of lessons** a) Lecture b) Problem class c) Exam	**Contact times** depending on the individual choice 1 h	**Self-study times** depending on the individual choice 24 h	**Intended group size** 15–20 students per problem class
2	**Aims of the module and acquired skills** Comprehension of the fundamental concepts used to theoretically describe solids and their excitations / ability to describe phenomena like superconductivity and magnetism / computational approach to problem solving with applications to many-body physics			

<table>
<tr><td>3</td><td>Contents of the module

The module is subdivided into core courses, specialized courses and the advanced seminar

1. Core Courses
Solid State Theory (3+1 HPW, 6 CP): Concepts of solid state theory and description of excitations in solid
Computational Many-Body Physics (3+1 HPW, 6 CP): Overview of elementary numerical approaches to study many-body systems, both classical and quantum.
Quantum Field Theory I (4+2 HPW, 9 CP): Modern methods to describe solids based on functional integrals and by using diagrammatic methods
2. Specialized courses:
Quantum Field Theory II (4+2 HPW, 9 CP)
One course chosen from the specialized courses of the module Condensed Matter Physics
Advanced Topics in Solid State Theory (3+1 HPW, 6 CP)
Hydrodynamics (2+2 HPW, 6 CP)
and others, including fitting courses from Bonn University, if approved by the module coordinator
3. Advanced Seminar on topical subjects of Solid State Theory (2 HPW, 3 CP)

The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.</td></tr>
<tr><td>4</td><td>Teaching/Learning methods

Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets and implement computational algorithms. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results.</td></tr>
<tr><td>5</td><td>Requirements for participation

Basic knowledge in theoretical physics at the level of the bachelor courses in physics</td></tr>
<tr><td>6</td><td>Type of module examinations

The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems). The grade given for the module is equal to the grade of the oral examination.</td></tr>
<tr><td>7</td><td>Requisites for the allocation of credits

The following courses have to be chosen from the list given above in order to acquire the necessary credit points:

1. one of the core courses

2. further core courses, specialized courses or an advanced seminar

The module is passed by passing an oral examination covering the topics of all attended courses.</td></tr>
<tr><td>8</td><td>Compatibility with other Curricula and Soft Skills

As elective subject in other M.Sc. programs.

Analysis of complex problems, scientific reading and presentation skills, in particular oral presentations.</td></tr>
<tr><td>9</td><td>Significance of the module mark for the overall grade

The weight of the module is 12/111 ≈ 10.8 %.</td></tr>
</table>

10	**Module coordinator** A. Rosch
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the "kommentiertes Vorlesungsverzeichnis". Version: 05.06.2015 HK

Secondary Area of Specialization   Statistical and Biological Physics

Statistical and Biological Physics					
Identification number	**Workload**	**Credits**	**Term of studying**	**Frequency of occurrence**	**Duration**
MN-P-PN-StatBio	360 h	12 CP	1^{st} and 2^{nd} semester	Details are provided online in the table "Course Offerings".	2 semesters

1	**Type of lessons**	**Contact times**	**Self-study times**	**Intended group size**
	a) Lecture	depending on the	depending on the	
	b) Problem class	individual choice	individual choice	15–20 students per problem class
	c) Exam	1 h	24 h	
2	**Aims of the module and acquired skills** Bring students to the forefront of current research in statistical and biological physics, application of concepts from physics to biological systems, understanding of complex phenomena emerging from simple systems, learning to construct models and infer model parameters from empirical observations, train interdisciplinary skills and interaction between experiment and theory, train presentation skills in advanced seminars			

3	**Contents of the module** The module is subdivided into core courses, specialized courses and the advanced seminar: 1. Core courses • Biological Physics I: Molecules and cells (3+1 HPW, 6 CP; or 4+1, 7.5 CP): Introduction to molecular cell biology, random walks in biology, mechanical forces in molecular and cellular biology, rate equations and cellular dynamics, photophysics, electrical signals in nerve cells, biophysical methods • Biological Physics II: Systems (3+1 HPW, 6 CP; or 4+1, 7.5 CP): Dynamical systems, dynamics of small gene regulatory networks, noise in gene expression, statistical analysis of large biological networks, biological pattern formation, reaction-diffusion systems, empirical laws in biology • Evolutionary Biology and Genomics for Physicists (3+1 HPW, 6 CP; or 4+1, 7.5 CP): Basic concepts of evolutionary theory, introduction to molecular evolution and genomics, theory of bio-molecular networks, concepts and methods of data analysis • Selected Topics in Statistical Physics (3+1 HPW, 6 CP; or 4+1, 7.5 CP), including Soft and biological matter, Non-equilibrium statistical physics, Statistical physics of disordered systems, information, and inference as specified annually in the “kommentiertes Vorlesungsverzeichnis” 2. Specialized courses • Computational soft matter physics (2+1 HPW, 4.5 CP) • Experiment and simulation on biological systems (3 HPW, 4.5 CP) • Introduction to network science (2+1 HPW, 4.5 CP) • Probability theory and stochastic processes (3+1 HPW, 6 CP) • Statistical optics (2 HPW, 3 CP) • and others 3. Advanced Seminar in Statistical and Biological Physics (2 HPW, 3 CP) The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results. In the additional lab course the students also gain insight into state-of-the-art instrumentation by conducting experiments independently.
5	**Requirements for participation** Experimental and theoretical physics at the level of the bachelor courses in physics.
6	**Type of module examinations** The module examination is an oral exam covering the topics of all attended courses. To be admitted to this exam, students must actively participate in the problem sessions (as defined in the individual courses). The grade given for the module is equal to the grade of the oral examination.
7	**Requisites for the allocation of credits** The courses can be chosen from the above set in order to acquire the necessary credit points.

8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. Interdisciplinary approach.
9	**Significance of the module mark for the overall grade** The weight of the module is 12/111 ≈ 10.8 %.
10	**Module coordinator** B. Maier
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”. Version: 21.06.2017 BM

Other modules like Cosmology, Experimental Hadron Physics, High Energy Particle Physics, Physics in Medicine, Quantum Optics and Optical Condensed Matter Physics, Theoretical Hadron Physics, and Theoretical Particle Physics will be offered in Bonn and will be credited as SAoS in Cologne. The examination board decides on combinations of courses from Bonn University which are accepted as SAoS.

The courses passed in Bonn will be credited in Cologne according to their HPW (1 HPW = 1.5 CP). If students achieve more than 12 CP in the SAoS, they may choose which 12 out of these CP are to be used as weights for grading the module.

Introductory Project I

Introductory Project I					
Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-ProI	360 h	12 CP	3rd Semester	continually	3 months

	Type of lessons	Contact times	Self-study times	Intended group size
1	Lab work Oral presentation	20 h 1 h	315 h 24 h	Individual counseling

2	**Aims of the module and acquired skills** Orientation and practice in an extensive research subject of modern physics and presentation of scientific results.
3	**Contents of the module** Both introductory projects I and II provide a basis for the Master thesis and should have a topical cohesion with the latter. As a general rule, the topic of the introductory projects and the Master thesis cover an extensive research subject in the area of specialization selected by the student.

4	Teaching/Learning methods In the introductory projects, the self-study based on books and current scientific publications plays an important role. The students work individually on a problem of current research. In discussions with their supervisor and fellow students, they learn to solve challenging problems in a team and to present their approaches and results. During their research and by preparing and presenting the master thesis, they become acquainted with scientific methods and learn to communicate an advanced topic in a pedagogical way. As a general rule, the topic of the second introductory project and the master thesis will be determined by the choice of topic and advisor for the introductory project I. The introductory project I lasts approximately ca. three months. The topic and the tasks shall be defined in such a way that the project can be terminated within this period of time. An oral report is required for the completion of the introductory project I.
5	Requirements for participation Successful participation in all courses of the first year of the Master program. Sufficient knowledge in the field of specialization of the Master course.
6	Type of module examinations The introductory project is finished by the student giving a seminar talk and is graded as passed or failed.
7	Requisites for the allocation of credits The introductory project is finished by the student giving a seminar talk and is graded as passed or failed.
8	Compatibility with other Curricula None
9	Significance of the module mark for the overall grade None
10	Module coordinator The chairman of the examination board
11	Additional information This module can be started any time after consultation with the advisor of the project. The grading document has to be picked up by the student at the examination office before the seminar talk and filled after the seminar talk by the supervisor. Version: 05.06.2015 HK

Introductory Project II

Introductory Project II					
Identification number MN-P-ProII	Workload 360 h	Credits 12 CP	Term of studying 3rd Semester	Frequency of occurrence continually	Duration 3 months

1	Type of lessons Lab work Oral presentation	Contact times 20 h 1 h	Self-study times 315 h 24 h	Intended group size Individual counseling

2	Aims of the module and acquired skills Consolidation in an extensive area of research of modern physics and presentation of the corresponding scientific results.
3	Contents of the module Both introductory projects I and II provide a basis for the Mater thesis and should have topical cohesion with the latter. As a general rule, the topic of the introductory projects and the Master thesis cover an extensive research subject in the area of specialization selected by the student. The introductory project II builds on the insights gained in the introductory project I and serves as an additional consolidation in preparation of the Master thesis.
4	Teaching/Learning methods In the Introductory Project, the self-study based on books and current scientific publications plays an important role. The students work individually on a problem of current research. In discussions with their supervisor and fellow students, they learn to solve challenging problems in a team and to present their approaches and results. During their research and by preparing and presenting the master thesis, they become acquainted with scientific methods and learn to communicate an advanced topic in a pedagogical way. The advisor for the introductory project I should also be in charge of the introductory project II. The introductory project I lasts approximately ca. three months. The topic and the tasks shall be defined in such a way that the project can be terminated within this period of time. An oral report is required for the completion of the introductory project II.
5	Requirements for participation Passed examinations of all modules of the first year of the Master course, sufficient knowledge in the field of specialization of the Master course, and the contents of the previously completed introductory project I.
6	Type of module examinations The introductory project is finished by the student giving a seminar talk and is graded as passed or failed.
7	Requisites for the allocation of credits The introductory project is finished by the student giving a seminar talk and is graded as passed or failed.
8	Compatibility with other Curricula None
9	Significance of the module mark for the overall grade None
10	Module coordinator The chairman of the examination board
11	Additional information The grading document has to be picked up by the student at the examination office before the seminar talk and filled after the seminar talk by the supervisor. Version: 05.06.2015 HK

2.4 Supplementary Modules (Ergänzungsmodule)

Besides the two areas of specialization, the students gain knowledge on additional topics of natural sciences and mathematics in the elective area. Here, different courses can be chosen, adding up to a minimum of 12 CP in total. Each individual course must have at least 3 CP. Several courses from the same field form a subject (e.g. two math courses will form the subject Math).

Elective Area

<table>
<tr><td colspan="8">Elective Area</td></tr>
<tr><td colspan="2">Identification number
MN-P-WaMa</td><td colspan="2">Workload
360 h</td><td>Credits
12 CP</td><td>Term of studying
1st Sem. and 2nd Sem.</td><td>Frequency of occurrence
Depends on the individual choice</td><td>Duration
Depends on the individual choice</td></tr>
<tr><td>1</td><td colspan="2">Type of lessons
Depends on the individual choice</td><td colspan="2">Contact times
Depends on the individual choice</td><td>Self-study times
Depends on the individual choice</td><td colspan="2">Intended group size
Depends on the individual choice</td></tr>
<tr><td>2</td><td colspan="7">Aims of the module and acquired skills
Specialization in a scientific subject.</td></tr>
<tr><td>3</td><td colspan="7">Contents of the module
The module “Elective Area” covers advanced courses (usually from the choice of master courses) with a minimum of 12 CP from two subjects. In general, the courses are from topics in Natural Sciences, including the modules in physics offered by the University of Bonn. They have to differ from the Primary Area of Specialization and the Secondary Area of Specialization. Each individual subject has to cover at least 3 CP, one course has to cover at least 6 CP:
If not credited elsewhere, either of both courses “Advanced Quantum Mechanics” and “Advanced Statistical Physics” may be credited here.</td></tr>
<tr><td>4</td><td colspan="7">Teaching/Learning methods
Elective subjects are organized by the associated department (i.e. the department offering the course in their curriculum, e.g. the department of Chemistry).</td></tr>
<tr><td>5</td><td colspan="7">Requirements for participation
See module descriptions of the associated department.</td></tr>
<tr><td>6</td><td colspan="7">Type of module examinations
See module descriptions of the related special field. The failed module can be compensated once by another selection of courses.</td></tr>
<tr><td>7</td><td colspan="7">Requisites for the allocation of credits
The module is passed by passing all required individual exams.</td></tr>
<tr><td>8</td><td colspan="7">Compatibility with other Curricula
As elective subject in other M.Sc. programs</td></tr>
</table>

9	**Significance of the module mark for the overall grade** The grade for the module is the weighted arithmetic average of the grades for the individual subjects. A subject is a set of courses which will be graded in one examination. If students achieve more than 12 CP in the Elective Area, they may choose which 12 out of these CP are to be used for the weighted average. The weight of the module for the final grade is 12/111 ≈ 10.8 %.
10	**Module coordinator** The chairman of the examination board.
11	**Additional information** The courses have to be chosen from the master or advanced bachelor curricula of the associated departments. Version: 23.04.2016 PN

2.5 Master Thesis (Master-Arbeit)

The master studies are completed by the Master Thesis. The students work independently on a well-defined problem of current physics research. The topic of the Master Thesis is usually closely connected to the topics of the two introductory projects. The scientific results of this work are presented in a written thesis as well as orally.

Master Thesis

Research Module					
Identification number	**Workload**	**Credits**	**Term of studying**	**Frequency of occurrence**	**Duration**
MN-P-For	900 h	30 CP	4th semester	Depending on the individual choice	6 months

1	**Type of lessons**	**Contact times**	**Self-study times**	**Intended group size**
	Lab work	20 h	315 h	Individual counseling
	Oral presentation	1 h	24 h	
2	**Aims of the module and acquired skills** Students acquire the scientific skills that are needed to carry out a substantial research project on one of the current topics of physics. They learn to present their results in written and oral form.			
3	**Contents of the module** As an integral part of the M.Sc. program, each student works on his/her own research project. The results of the project are written up as M.Sc. thesis. The thesis work is preceded by two introductory projects which introduce the student to the theme of the M.Sc. thesis and are evaluated separately. As a rule, the introductory projects and the M.Sc. thesis research are substantial pieces of scientific work, carried out in the area of specialization chosen by the student.			

4	Teaching/Learning methods The topic to be worked on is issued by the chairman of the examination board in consultation with the student's thesis research advisor. In the research module, the self-study based on books and current scientific publications plays an important role. The students work individually on a problem of current research. In discussions with their supervisor and fellow students, they learn to solve challenging problems in a team and to present their approaches and results. During their research and by preparing and presenting the master thesis, they become acquainted with scientific methods and learn to communicate an advanced topic in a pedagogical way. They also learn to finalize a project in time and to manage their time efficiently.
5	Requirements for participation Passed examinations of all modules of the first three semesters of the Master course and the contents of the previously completed introductory projects I and II.
6	Type of module examinations The Master Thesis and the colloquium will be evaluated by two and in the exceptional case by three referees. On the day of the colloquium the referee report/reports to the master thesis have to be present. The grading of the colloquium takes place on the day of the colloquium.
7	Requisites for the allocation of credits The module is passed by successfully preparing the M.Sc. thesis and by passing the colloquium.
8	Compatibility with other Curricula None
9	Significance of the module mark for the overall grade The total grade given for the module is the 3:1 weighted average of the two grades given for the written thesis and the colloquium talk. The weight of the module is 45/111 ≈ 40.5 %.
10	Module coordinator The chairman of the examination board
11	Additional information The Master Thesis and the Master Colloquium have to be registered at the examination office. The date of issue of the master topic is to be no later than two months after the student's completing the requirements for admission to the module. Students work on the introductory projects for three months each, and then on the M.Sc. thesis for six months. The topic and the problem posed have to be of such a kind that it is possible for the student to complete the M.Sc. thesis within the allotted time. To complete the M.Sc. thesis work, the student hands in a written thesis and subsequently reports on it by way of a colloquium open to members of the faculty. The length of the thesis should not exceed 70 pages (font 12pt, baselineskip 16pt). Both English and German are permitted as a language for the written thesis and the colloquium talk. No later than 8 weeks after completion of the Master thesis the candidate reports in a colloquium on the subject of the master thesis. Presentation time should not exceed 25 minutes; time for questions is limited to 20 minutes. Version: 05.06.2015 HK

3 Studies Aids (Studienhilfen)

3.1 Model Study Plan (Musterstudienplan)

The Department of Physics recommends performing the studies according to the following plans. They are tailored to the beginning of studies either in the winter term or the summer term.

In general the study plan strongly depends on the individual choices and the selected areas of specialization. The different courses of each subject can be arranged individually. Also a number of courses is not offered every year. Therefore it is recommended to plan the courses early on. In case of major deviations from the study plan provided below, students are strongly advised to check their plan with the Student Advisory Service.

Study Plan MSc Physics (SuSe)

SuSe		WiSe		SuSe		WiSe	
1st Semester		2nd Semester		3rd Semester		4th Semester	
	CP		CP		CP		CP
Practical Courses M I + II	12	Adv. QM / Adv. Stat. Phys.	9	Introductory Project I	12	Master Thesis	30
Elective Area	6	Elective Area	6	Introductory Project II	12		
Primary Area of Specialization	6	Primary Area of Specialization	12	Advanced Seminar	3		
Secondary Area of Specialization	6	Secondary Area of Specialization	6				
Total	30	Total	33	Total	27	Total	30

Study Plan MSc Physics (WiSe)

WiSe		SuSe		WiSe		SuSe	
1st Semester		2nd Semester		3rd Semester		4th Semester	
	CP		CP		CP		CP
Practical Course M I	6	Practical Course M II	6	Introductory Project I	12	Master Thesis	30
Adv. QM / Adv. Stat. Phys.	9			Introductory Project II	12		
Elective Area	6	Elective Area	6				

Primary Area of Specialization	6	Primary Area of Specialization	12	Advanced Seminar	3		
Secondary Area of Specialization	6	Secondary Area of Specialization	6				
Total	33	Total	30	Total	27	Total	30

3.2 Subject and Exam Counseling (Fach- und Prüfungsberatung)

In addition to the services of the Student Advisory and Counseling Centre of the University of Cologne, the Department of Physics offers a special counseling for physics students (Dr. Petra Neubauer-Guenther (deputy: Dr. Harald Kierspel)). This counseling addresses bachelor students who consider continuing their studies up to the M.Sc. and master students at all stages before and during their studies.

An open consultation-hour is offered on a weekly basis during the whole year. Besides, also individual appointments can be arranged on short notice. Detailed information can also be provided via email or phone.

The counseling also addresses questions concerning examinations and their organization. Detailed questions on individual modules will be answered by the module coordinators. Detailed questions concerning examinations will also be answered by the examination office.

3.3 Further Offers of Information and Counseling (Weitere Informations- und Beratungsangebote)

Members of the BCGS honors branch will be assigned two mentors, one in Cologne and one in Bonn. These mentors will provide support for the organization and planning of the studies, as well as on subject questions.

The student’s council organized by the physics students in Cologne also provides substantial support on any questions related to the studies.

Students who aim to perform part of their studies abroad via the **Erasmus Program** may contact Prof. Jolie for further counseling.

Further counseling offers at the University of Cologne are:

Student Advisory and Counseling Centre (Zentrale Studienberatung) *http://verwaltung.uni-koeln.de/abteilung21/content/beratungsangebote/faecheruebergreifende_studienberatung/index_ger.html*	General questions concerning studies, choice of subjects, etc. (Allgemeine Fragen zum Studium, Fächerwahl etc.)

Studierendensekretariat *http://verwaltung.uni-koeln.de/studsek/content/*	Questions concerning enrolling, etc. (Fragen zur Einschreibung, Rückmeldung etc.)
Kölner Studentenwerk *http://www.kstw.de/*	Social aspect concerning the studies (Soziale Aspekte im Zusammenhang mit dem Studium)
ASTA *http://www.asta.uni-koeln.de/*	Student Representation (Studierendenvertre-tung)
Rektoratsbeauftragter für Menschen mit Behinderung *http://www.hf.uni-koeln.de/34502*	Study with disabilities (Studieren mit Behinderung)
Akademisches Auslandsamt *http://verwaltung.uni-koeln.de/international/content/incoming/studium_in_koeln/index_ger.html*	Study with migration background (Studieren mit Migra-tionshintergrund)
Zentrale Gleichstellungsbeauftragte *http://www.gb.uni-koeln.de/*	Compatibility of studies and family, gender discrimination (Vereinbarkeit von Familie und Studium, Sexualisierte Diskriminierung)