# Study plan

## Name of study plan: Jaderná a částicová fyzika

Faculty/Institute/Others:
Department:
Branch of study guaranteed by the department: Welcome page
Garantor of the study branch:
Program of study: Nuclear and Particle Physics
Type of study: Follow-up master full-time
Required credits: 0
Elective courses credits: 120
Sum of credits in the plan: 120
Note on the plan:

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Name of the block: Compulsory courses in the program
Minimal number of credits of the block: 0
The role of the block: P

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Code of the group: NMSPJCF1
Name of the group: MDP P_JČFN 1st year
Requirement credits in the group:
Requirement courses in the group: In this group you have to complete at least 10 courses
Credits in the group: 0
Note on the group: Studenti povinně absolvují alespoň jednu skupinu předmětů E, I nebo T

| Code | **Name of the course / Name of the group of courses** ***(in case of groups of courses the list of codes of their members)*** *Tutors,* ***authors*** *and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| 02KTPA1 | **Quantum Field Theory 1** *Václav Zatloukal* ***Václav Zatloukal*** *Martin Štefaňák (Gar.)* | Z,ZK | 8 | 4P+2C | Z | P |
| 02KTPA2 | **Quantum Field Theory 2** *Petr Jizba* ***Václav Zatloukal*** *Martin Štefaňák (Gar.)* | Z,ZK | 8 | 4P+2C | L | P |
| 02MTD | **Modern Detectors** *Jaroslav Adam* ***Jaroslav Adam*** *Jaroslav Adam (Gar.)* | ZK | 2 | 2P+0C | Z | P |
| 02SE1 | **Seminar 1** *Jaroslav Bielčík* ***Jaroslav Bielčík*** *Jaroslav Bielčík (Gar.)* | Z | 3 | 3S | Z | P |
| 02SE2 | **Seminar 2** *Jaroslav Bielčík* ***Jaroslav Bielčík*** *Jaroslav Bielčík (Gar.)* | Z | 3 | 3S | L | P |
| 02SZD1 | **Statistical Data Analysis 1** *Miroslav Myška* ***Miroslav Myška*** *Miroslav Myška (Gar.)* | Z,ZK | 4 | 2P+2C | Z | P |
| 02SZD2 | **Statistical Data Analysis 2** *Miroslav Myška* ***Miroslav Myška*** *Miroslav Myška (Gar.)* | Z,ZK | 4 | 2P+2C | L | P |
| 02SDSD | **Detector Systems and Data Acquisition** *Michal Broz* ***Martin Štefaňák*** *Michal Broz (Gar.)* | ZK | 2 | 2P+0C | L | P |
| 02VUJC1 | **Research Project 1** ***Jaroslav Bielčík*** *Jaroslav Bielčík (Gar.)* | Z | 6 | 6C | Z | P |
| 02VUJC2 | **Research Project 2** *Martin Štefaňák, Jaroslav Bielčík, Michal Broz, Miroslav Krůs, Petr Chaloupka, Dominika Mašlárová, Boris Tomášik, Jakub Vícha, Solangel Rojas Torres, .....* ***Jaroslav Bielčík*** *Jaroslav Bielčík (Gar.)* | KZ | 8 | 8C | L | P |

**Characteristics of the courses of this group of Study Plan: Code=NMSPJCF1 Name=MDP P_JČFN 1st year**

| | | | |
|---|---|---|---|
| 02KTPA1 | Quantum Field Theory 1 | Z,ZK | 8 |
| The lecture aims to introduce the students to both fundamental and applied parts of quantum field theory. The focus is in particular on equations of relativistic quantum mechanics, canonical quantization of scalar and bispinor field, perturbation theory (Feynmans rules) and basics of renormalization. The content of the lecture can serve as a base for further study in fields of exactly solvable models, theory of critical phenomena, molecular chemistry and biochemistry or quantum gravity. | | | |
| 02KTPA2 | Quantum Field Theory 2 | Z,ZK | 8 |
| The lecture aims at introducing the students to the Feynmans functional integral and its applications. The focus is on broadening the knowledge of modern parts of relativistic and non-relativistic quantum field theory and statistical physics. The content of the lecture can serve as a base for further study in fields of exactly solvable models, theory of critical phenomena, molecular chemistry and biochemistry or quantum gravity. | | | |
| 02MTD | Modern Detectors | ZK | 2 |
| Lectures will cover all types of detectors used in modern nuclear and particle physics. Topics include principles of construction of particular types of detectors, materials used for their construction, ways of using and constrains. Emphasis is given also to electronic detector control and voltage suppliers. | | | |

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|---|---|---|---|
| 02SE1 | Seminar 1 | Z | 3 |
| The aim of the seminar is that students get familiar with basics skills to present the own scientific results. Students get also knowledge from the fields of particle physics studied in research tasks and diploma theses of their colleagues. Participants will be informed about recent results in particle physics. | | | |
| 02SE2 | Seminar 2 | Z | 3 |
| The aim of the seminar is that students get familiar with basics skills to present the own scientific results. Students get also knowledge from the fields of particle physics studied in research tasks and diploma theses of their colleagues. Participants will be informed about recent results in particle physics. | | | |
| 02SZD1 | Statistical Data Analysis 1 | Z,ZK | 4 |
| The course is primarily focused on practical application of methods of experimental data analysis. Students obtain knowledge of different statistical methods and their usage, fitting methods, and testing of hypothesis. The course quickly recapitulates basis of mathematical probability theory but it is recommended to attend a full course of the mathematical probability. | | | |
| 02SZD2 | Statistical Data Analysis 2 | Z,ZK | 4 |
| Individual students work will include implementation and testing of a program for analysis of generated data sample. Background understanding of Monte Carlo generators for hadron collision will be explained. The course covers methods of data smearing and subsequent deconvolution of data. Basics understanding and usage of neural networks and machine learning will be covered. | | | |
| 02SDSD | Detector Systems and Data Acquisition | ZK | 2 |
| The goal of the lecture is to present knowledge of modern detector systems. We will concentrate on the aspects of construction and usage for charged-particle tracking, momentum and energy measurement as well as particle identification via various methods from time-of-flight to transition radiation. The lecture will cover also the topic of signal shaping and processing, digitalization, data acquisition and further data processing at the modern collider experiments. | | | |
| 02VUJC1 | Research Project 1 | Z | 6 |
| The research project is based on a topic approved by the administrators of the programme, department and by the dean. The student is guided by the project supervisor during common regular meetings and discussions. | | | |
| 02VUJC2 | Research Project 2 | KZ | 8 |
| The research project is based on a topic approved by the administrators of the programme, department and by the dean. The student is guided by the project supervisor during common regular meetings and discussions. | | | |

Code of the group: NMSPJCF2
Name of the group: MDP P_JČFN 2nd year
Requirement credits in the group:
Requirement courses in the group: In this group you have to complete at least 6 courses
Credits in the group: 0
Note on the group:

| Code | Name of the course / Name of the group of courses<br>*(in case of groups of courses the list of codes of their members)*<br>*Tutors,* ***authors*** *and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| 02DPJC1 | **Master Thesis 1**<br>***Jaroslav Bielčík*** *Jaroslav Bielčík (Gar.)* | Z | 10 | 10C | Z | P |
| 02DPJC2 | **Master Thesis 2**<br>*Jaroslav Bielčík* ***Jaroslav Bielčík*** *Jaroslav Bielčík (Gar.)* | Z | 20 | 20C | L | P |
| 02SE3 | **Seminar 3**<br>*Jaroslav Bielčík* ***Jaroslav Bielčík*** *Jaroslav Bielčík (Gar.)* | Z | 3 | 3S | Z | P |
| 02SE4 | **Seminar 4**<br>*Jaroslav Bielčík* ***Jaroslav Bielčík*** *Jaroslav Bielčík (Gar.)* | Z | 3 | 3S | L | P |
| 02ZQCD | **Quantum Chromodynamics**<br>*Jana Bielčíková* ***Jan Čepila*** *Jana Bielčíková (Gar.)* | Z,ZK | 6 | 3+2 | Z | P |
| 02ZELW | **Introduction to Theory of Electroweak Interactions**<br>*Jana Bielčíková* ***Miroslav Myška*** *Jana Bielčíková (Gar.)* | Z,ZK | 6 | 3P+2C | Z | P |

**Characteristics of the courses of this group of Study Plan: Code=NMSPJCF2 Name=MDP P_JČFN 2nd year**

| | | | |
|---|---|---|---|
| 02DPJC1 | Master Thesis 1 | Z | 10 |
| The master thesis is based on a topic approved by the administrators of the programme, department and by the dean. The student is guided by the project supervisor during common regular meetings and discussions. | | | |
| 02DPJC2 | Master Thesis 2 | Z | 20 |
| The master thesis is based on a topic approved by the administrators of the programme, department and by the dean. The student is guided by the project supervisor during common regular meetings and discussions. | | | |
| 02SE3 | Seminar 3 | Z | 3 |
| The aim of the seminar is that students get familiar with basics skills to present the own scientific results. Students get also knowledge from the fields of particle physics studied in research tasks and diploma theses of their colleagues. Participants will be informed about recent results in particle physics. | | | |
| 02SE4 | Seminar 4 | Z | 3 |
| The aim of the seminar is that students get familiar with basics skills to present the own scientific results. Students get also knowledge from the fields of particle physics studied in research tasks and diploma theses of their colleagues. Participants will be informed about recent results in particle physics. | | | |
| 02ZQCD | Quantum Chromodynamics | Z,ZK | 6 |
| The goal of these lectures is to acquire knowledge about basic principles of strong interaction starting from the constituent quark model and SU(3) flavour symmetry, studies of nucleon structure in deep inelastic scattering of leptons on nucleons and parton model to basics of Quantum Chromodynamics and its practical applications in the context of current experiments in high energy physics and physics of ultra-relativistic heavy-ion collisions. | | | |
| 02ZELW | Introduction to Theory of Electroweak Interactions | Z,ZK | 6 |
| The goal of these lectures is to acquire knowledge about theory of weak interaction from Fermi theory of -decay, introduction of charged intermediate vector boson to unification of electromagnetic and weak interaction in the framework of Standard model including Higgs mechanism. Short student presentations dedicated to experimental discoveries related to the topics covered in the lectures (such as first measurements of W and Z gauge bosons, Higgs boson discovery) are envisioned. | | | |

Name of the block: Compulsory elective courses

Minimal number of credits of the block: 0
The role of the block: PV

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Code of the group: NMSPJCFSE
Name of the group: MDP P_JČFN group E experimental
Requirement credits in the group:
Requirement courses in the group: In this group you have to complete at least 2 courses
Credits in the group: 0
Note on the group: Studenti povinně absolvují alespoň jednu skupinu předmětů E, I nebo T

| Code | Name of the course / Name of the group of courses *(in case of groups of courses the list of codes of their members)* *Tutors, **authors** and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| 02FUJS | **Physics of Ultrarelativistic Nuclear Collisions** *Oliver Matonoha **Jaroslav Bielčík** Katarína Křížková Gajdošová (Gar.)* | ZK | 2 | 2P+0C | L | PV |
| 02VPJRS | **Selected topics from relativistic nucleus-nucleus collisions** *Barbara Antonina Trzeciak **Martin Štefaňák** Barbara Antonina Trzeciak (Gar.)* | Z,ZK | 3 | 2P+1C | L | PV |

**Characteristics of the courses of this group of Study Plan: Code=NMSPJCFSE Name=MDP P_JČFN group E experimental**

| | | | |
|---|---|---|---|
| 02FUJS | Physics of Ultrarelativistic Nuclear Collisions | ZK | 2 |
| The goal of this subject is to introduce students the principles of physics of heavy-ion collisions at large energies. Students will gain insight into phases of a nuclear collision, properties of the created matter (quark-gluon plasma (QGP)), probes which contain information about the QGP and other phases of the collision, and knowledge that these signals brought to us based on the recent measurements at present experiments. | | | |
| 02VPJRS | Selected topics from relativistic nucleus-nucleus collisions | Z,ZK | 3 |
| The aim of the lecture is to discuss in more depth the physics of the extreme state of the nuclear matter created in relativistic nucleus-nucleus collisions. The course will cover selected topics from the physics of relativistic nucleus-nucleus collisions. The focus will be put on thermodynamic and statistical physics applications to the high-energy nuclear collisions, as well as the medium description using a hydrodynamic approach. Moreover, the in-medium parton energy loss and a related concept of the jet quenching will be discussed. The course will be complemented with computational exercises. | | | |

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Code of the group: NMSPJCFSI
Name of the group: MDP P_JČFN group I Instrumental
Requirement credits in the group:
Requirement courses in the group: In this group you have to complete at least 2 courses
Credits in the group: 0
Note on the group: Studenti povinně absolvují alespoň jednu skupinu předmětů E, I nebo T

| Code | Name of the course / Name of the group of courses *(in case of groups of courses the list of codes of their members)* *Tutors, **authors** and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| 02UC1 | **Particles Accelerators 1** *Miroslav Krůs **Miroslav Krůs** Miroslav Krůs (Gar.)* | ZK | 2 | 2P+0C | Z | PV |
| 02UC2 | **Particle Accelerators 2** *Miroslav Krůs **Miroslav Krůs** Miroslav Krůs (Gar.)* | ZK | 2 | 2+0 | | PV |

**Characteristics of the courses of this group of Study Plan: Code=NMSPJCFSI Name=MDP P_JČFN group I Instrumental**

| | | | |
|---|---|---|---|
| 02UC1 | Particles Accelerators 1 | ZK | 2 |
| Introduction to physics and technology of classical (electrostatic and radiofrequency) particle accelerators. | | | |
| 02UC2 | Particle Accelerators 2 | ZK | 2 |
| Introduction to physics and technology of modern and next generation accelerators based on laser and plasma technology. | | | |

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Code of the group: NMSPJCFST
Name of the group: MDP P_JČFN group T Theoretical
Requirement credits in the group:
Requirement courses in the group: In this group you have to complete at least 1 course
Credits in the group: 0
Note on the group: Studenti povinně absolvují alespoň jednu skupinu předmětů E, I nebo T

| Code | Name of the course / Name of the group of courses *(in case of groups of courses the list of codes of their members)* *Tutors, **authors** and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| 02GTR | **General Theory of Relativity** *Boris Tomášik **Boris Tomášik** Boris Tomášik (Gar.)* | Z,ZK | 4 | 2P+2C | Z | PV |

**Characteristics of the courses of this group of Study Plan: Code=NMSPJCFST Name=MDP P_JČFN group T Theoretical**

| | | | |
|---|---|---|---|
| 02GTR | General Theory of Relativity | Z,ZK | 4 |

The goal is to learn the basics of General Relativity theory as well as its applications, mainly in cosmology. The students will get acquainted with the starting points of General Relativity. The course includes the explanation of necessary mathematics: differential geometry. Classic results are derived, like the precession of Mercury, gravitational frequency shift and gravitational bending of light. The participants learn about Schwarzschild metrics and its solution leading to black holes. In the application part the Friedman-Robertson-Walker metrics is introduced and dynamics of the Universe is discussed.

Name of the block: Elective courses
Minimal number of credits of the block: 0
The role of the block: V

Code of the group: NMSPJCFV
Name of the group: MDP P_JČFN Optional courses
Requirement credits in the group:
Requirement courses in the group:
Credits in the group: 0
Note on the group:

| Code | Name of the course / Name of the group of courses *(in case of groups of courses the list of codes of their members)* *Tutors,* ***authors*** *and guarantors (gar.)* | Completion | Credits | Scope | Semester | Role |
|---|---|---|---|---|---|---|
| 02AQCD | **Applied Quantum Chromodynamics at High Energies** *Ján Nemčík* ***Ján Nemčík*** *Ján Nemčík (Gar.)* | ZK | 2 | 2+0 | | v |
| 02ACF1 | **Astroparticle physics 1** *Jakub Vícha* ***Jakub Vícha*** *Jakub Vícha (Gar.)* | ZK | 2 | 2P+0C | Z | v |
| 02ACF2 | **Astroparticle physics 2** *Jakub Vícha* ***Jakub Vícha*** *Jakub Vícha (Gar.)* | ZK | 2 | 2P+0C | L | v |
| 01DAS | **Data science** *Jiří Franc* ***Jiří Franc*** *Jiří Franc (Gar.)* | KZ | 3 | 1P+2C | | v |
| 02EXSH | **Extreme States of Matter** *Michal Šumbera* ***Jaroslav Bielčík*** *Jaroslav Bielčík (Gar.)* | ZK | 2 | 2P+0C | Z | v |
| 02FAJ | **Physics of Atomic Nuclei** *Jiří Adam, Petr Veselý* ***Jiří Adam*** *Jiří Adam (Gar.)* | ZK | 4 | 4+0 | L | v |
| 02BSM | **Physics beyond the Standard Model** *Zdeněk Hubáček* ***Zdeněk Hubáček*** *Zdeněk Hubáček (Gar.)* | Z | 2 | 2P+0C | Z | v |
| 02JSP | **Nuclear Spectroscopy** *Vladimír Wagner* ***Martin Štefaňák*** *Vladimír Wagner (Gar.)* | Z,ZK | 5 | 2+2 | L | v |
| 02KMP | **Quantum Many-Body Problem in the Theory of Atomic Nuclei** *Petr Veselý* ***Martin Štefaňák*** *Petr Veselý (Gar.)* | ZK | 2 | 2P+0C | Z | v |
| 02MAT | **Materials for Experimental Nuclear Physics** *Libor Škoda* ***Martin Štefaňák*** *Libor Škoda (Gar.)* | ZK | 2 | 2+0 | | v |
| 18MEMC | **Monte Carlo Method** *Jaromír Kukal, Miroslav Virius* ***Miroslav Virius*** *Miroslav Virius (Gar.)* | Z,ZK | 4 | 2P+2C | Z | v |
| 01NEUR1 | **Neural Networks and their Applications 1** *Martin Holeňa, František Hakl* ***František Hakl*** *František Hakl (Gar.)* | ZK | 2 | 2+0 | | v |
| 18OOP | **Object Oriented Programming** *Miroslav Virius* ***Miroslav Virius*** *Miroslav Virius (Gar.)* | Z | 2 | 2C | Z | v |
| 02LPA | **Particle plasma accelerators** *Miroslav Krůs* ***Miroslav Krůs*** *Miroslav Krůs (Gar.)* | ZK | 2 | 2P+0C | L | v |
| 17PRE | **Computer Control of Experiments** *Martin Kropík* ***Martin Kropík*** *Martin Kropík (Gar.)* | Z,ZK | 3 | 2+1 | Z | v |
| 02REP | **Matrix Lie group representations** *Lenka Motlochová* ***Lenka Motlochová*** *Lenka Motlochová (Gar.)* | Z | 2 | 2+0 | Z | v |
| 02ROZ3 | **Seminar on Quark-Gluon Plasma 3** *Jaroslav Bielčík* ***Jaroslav Bielčík*** *Jaroslav Bielčík (Gar.)* | Z | 2 | 2P+0C | Z | v |
| 02ROZ4 | **Seminar on Quark-Gluon Plasma 4** *Jaroslav Bielčík, Boris Tomášik, Jana Bielčíková* ***Jaroslav Bielčík*** *Jaroslav Bielčík (Gar.)* | Z | 2 | 2P+0C | L | v |
| 02ROZ5 | **Seminar on Quark-Gluon Plasma 5** *Jaroslav Bielčík* ***Jaroslav Bielčík*** *Jaroslav Bielčík (Gar.)* | Z | 2 | 2P+0C | Z | v |
| 02ROZ6 | **Seminar on Quark-Gluon Plasma 6** *Jaroslav Bielčík, Boris Tomášik, Jana Bielčíková* ***Jaroslav Bielčík*** *Jaroslav Bielčík (Gar.)* | Z | 2 | 2P+0C | L | v |
| 02SPRA1 | **Special Practicum 1** *Jan Čepila* ***Jan Čepila*** *Jan Čepila (Gar.)* | KZ | 6 | 0+4 | Z | v |
| 02SPRA2 | **Special Practicum 2** *Jan Čepila* ***Jan Čepila*** *Jan Čepila (Gar.)* | KZ | 6 | 0+4 | L | v |
| 01SUP | **Start-up Project** *Přemysl Rubeš* ***Přemysl Rubeš*** *Přemysl Rubeš (Gar.)* | KZ | 2 | 2P+0C | | v |
| 02PRF | **Selected topics from probability theory for physicists** *Michal Šumbera* ***Michal Šumbera*** *Michal Šumbera (Gar.)* | Z | 2 | 2P+0C | Z | v |

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| 02VS2 | **Workshop 2**<br>*Jaroslav Bielčík* ***Jaroslav Bielčík*** *Jaroslav Bielčík (Gar.)* | Z | 1 | 7D | Z | v |
| 02VS3 | **Workshop 3**<br>*Jaroslav Bielčík* ***Jaroslav Bielčík*** *Jaroslav Bielčík (Gar.)* | Z | 1 | 7D | Z | v |

**Characteristics of the courses of this group of Study Plan: Code=NMSPJCFV Name=MDP P_JČFN Optional courses**

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|---|---|---|---|
| 02AQCD | Applied Quantum Chromodynamics at High Energies | ZK | 2 |

This lecture is oriented to provide basic applications of quantum chromodynamicks that corresponds to understanding of the dynamics of processes in particle physics at high energies on proton and nuclear targets that are currently measured by experiments at RHIC and LHC colliders. Complementary informations to lectures of Basics of quantum chromodynamics will be provided.

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|---|---|---|---|
| 02ACF1 | Astroparticle physics 1 | ZK | 2 |

Outline of the lecture: 1. History of astroparticle physics 2. Introduction to astronomy (scales, observation windows, types of objects, contemporary problems) 3. Energy spectrum of the cosmic radiation (properties, spectral index, age) 4. Direct detection of cosmic radiation (experiments, findings) 5. Showers of cosmic radiation (expansion, Heitler-Matthews model, superposition model) 6. Composition of cosmic radiation (types of measurements, results, open problems) 7. Spreading of cosmic radiation and gamma rays through the space (interaction, magnetic fields) 8. Sources of cosmic radiation (exotic sources, acceleration mechanisms) 9. Indirect detection of cosmic radiation (experiments, overview) 10. Optical detection of showers of cosmic radiation (fluorescence and cherenkov techniques, reconstruction) 11. Surface detection of showers of cosmic radiation (types of detectors, reconstruction) 12. Detection of gamma rays (principles, experiments)

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|---|---|---|---|
| 02ACF2 | Astroparticle physics 2 | ZK | 2 |

Outline of the lecture: 1. Detection of neutral particles in the cosmic radiation data (neutrons, photons, neutrinos) 2. Radio detection of showers of cosmic radiation (Askaryans effect, experiments) 3. Detection and use of secondary mions from cosmic radiation (accelerators, tomography) 4. Models of hadronic interactions (Glaubers model, Gribov-Regge theory) 5. Cascade equation, simulation of showers of cosmic radiation (derivation, algorithms) 6. Hands-on public astroparticle data (fits data, Auger and KASCADE data) 7. Evolution of the universe (introduction to cosmology, relict radiation) 8. Nuclear processes in stars (nuclear synthesis, creation of neutrinos, final stages of stars) 9. Detection of neutrinos (principles, experiments, proton decay, double beta decay) 10. Detection of gravitational waves (principles, experiments) 11. Dark matter (theory, experiments) 12. Multimessengers (connections between detection of neutral and charged particles)

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|---|---|---|---|
| 01DAS | Data science | KZ | 3 |

Practical application of mathematical modeling methods, statistics and machine learning needs wide range of tasks from data preparation and collection to design of an appropriate method and its division into units for development and implementation into the production. Last, but not least, the cooperation in group and management of a modern data project is crucial. The actual standard of required tools will be presented on lectures. Further, these procedures will be applied during exercises with an emphasis on team collaboration, project planning. At the end of the course, students will present their results to other teams.

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|---|---|---|---|
| 02EXSH | Extreme States of Matter | ZK | 2 |

Lectures will provide basics in states of matter in extreme conditions. It deals with broad spectra of phenomena from electromagnetic plasma through phases of nuclear matter at high temperatures or densities to highly speculative forms of matter that may be responsible for initialy accelerated expansion of the Universe in its early stages (inflation) or for its current acceleration (dark energy). Lectures may also serve as a brief introduction to parts of modern cosmology connected to nuclear and particle physics.

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|---|---|---|---|
| 02FAJ | Physics of Atomic Nuclei | ZK | 4 |

Nucleon-nucleon(NN) interaction, few-body systems, G matrix, nuclear properties, nuclear models (single-particle model, collective motion, Hartree-Fock approximation, TDA method, RPA method, pairing, quasi-particles, nuclear deformations), electromagnetic and weak processes in nuclei, nuclear reactions (kinematics and mechanisms of nuclear reactions)

| | | | |
|---|---|---|---|
| 02BSM | Physics beyond the Standard Model | Z | 2 |

Standard model of particle physics is one of the most succesful physical theories. It describes the elementary particles which form the matter and their electromagnetic, weak and strong interactions. It is however an incomplete theory and there are several questions which it can not answer. The goal of the lecture is to review the missing points in the Standard model and show potential directions where the new physics beyond the Standard model could be found.

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| 02JSP | Nuclear Spectroscopy | Z,ZK | 5 |

Nuclear spectroscopy comprises several experimental techniques which are of ultimate importance for experimental nuclear physics and various applications as well. Lecture will be devoted to fundamentals of X- and gamma- ray, charged particle and neutron spectroscopy.

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|---|---|---|---|
| 02KMP | Quantum Many-Body Problem in the Theory of Atomic Nuclei | ZK | 2 |

1. Nuclear Hamiltonian and distinguishing the degrees of freedom within nuclei 2. Collective and one-body dynamics in nuclei 3. Theory of the energy density functional in nuclei 4. Theory of the energy density functional for the excited states 5. Selfconsistent mean-field model 6. Post Hartree-Fock methods 7. Tamm-Dancoff Approximation 8. Random Phase Approximation 9. Equation of Motion Phonon Method 10. Generator Coordinate Method 11. Restoration of symmetries in many-body methods 12. Coupled Cluster Method 13. Bohr collective model

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|---|---|---|---|
| 02MAT | Materials for Experimental Nuclear Physics | ZK | 2 |

This lecture is designed for students of experimental nuclear physics. The lecture gives the overview of materials physics with respect to materials frequently used in the experimental nuclear physics, particularly their construction properties and influence of the ionizing radiation on their properties and possible use in experiment.

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|---|---|---|---|
| 18MEMC | Monte Carlo Method | Z,ZK | 4 |

This courseis devoted to the numerical method Monte Carlo and to its selected applications.

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|---|---|---|---|
| 01NEUR1 | Neural Networks and their Applications 1 | ZK | 2 |

Keywords: Neural networks, data separation, functional approximation, supervised learning

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|---|---|---|---|
| 18OOP | Object Oriented Programming | Z | 2 |

This course consists of the contributions of students concerning given topics concerned on technologies uded in program development.

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|---|---|---|---|
| 02LPA | Particle plasma accelerators | ZK | 2 |

1. Introduction to laser physics and technology, CPA systems 2. Physics of plasma and plasma wave generation 3. Plasma instabilities, beam-plasma interaction 4. Plasma wave evolution 5. Methods of beam injection to plasma wave 6. Ultrashort particle bunch generation 7. Dynamics of bunch in plasma wave 8. Plasma diagnostics and plasma accelerator monitoring 9. Plasma waveguides 10. Plasma charged particle optics 11. Ultrashort bunch diagnostics 12. Handling and transport of ultrashort bunches 13. Application of ultrashort bunches

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|---|---|---|---|
| 17PRE | Computer Control of Experiments | Z,ZK | 3 |

Lectures provide information about standard interfaces of personal computers - parallel, serial, USB, LAN and special interface cards; about standalone equipment that communicate with computers via serial lines or GPIB (IEEE488) interface, further about measuring systems with VME, VXI and LXI interfaces, discuss their advantages and disadvantages. Next, lectures deal with programming of measuring systems - special dedicated software, problems of use of high programming languages and especially use of graphical oriented development tools (Agilent VEE ane LabView); data acquisition and evaluation. Finally, students prepare individual software project for data acquisition and evaluation.

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|---|---|---|---|
| 02REP | Matrix Lie group representations | Z | 2 |

1.Group theory, symmetric group, homomorphism, isomorphism, group action, direct product, semidirect product, normal group, simple and semisimple group, factor group, matrix Lie groups, SO(n), SU(n), Lorentz group, Poincaré group. 2.One-parameter group, Lie algebras, Lie group Lie algebra correspondence, exponential map. 3.Universal covering group, relation between SO(3) and SU(2). 4.Representation theory, unitary representation, regular representation, equivalent representation, irreducibility, reducibility, Schur`s lemma, Weyl`s theorem. 5.Lie algebra representation and their connection to Lie group representation, projective representation. 6.Irreducible representations of SO(3) and SU(2), raising and lowering operators, spin representation. 7.Finite-dimensional representations of Lorentz group, tensor product of representations. 8.Representations of SU(3), Gell-Mann matrices, weights and roots. 9.Young tableaux.

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|---|---|---|---|
| 02ROZ3 | Seminar on Quark-Gluon Plasma 3 | Z | 2 |
| Seminar deals with theoretical work related to problems of quark-gluon plasma. Students participate on the seminar by preparing the presentation about selected papers. | | | |
| 02ROZ4 | Seminar on Quark-Gluon Plasma 4 | Z | 2 |
| Seminar about recent experimental measurements of the properties of the QGP. Students participate on the seminar by preparing the presentation about selected papers. | | | |
| 02ROZ5 | Seminar on Quark-Gluon Plasma 5 | Z | 2 |
| Seminar about recent experimental measurements of the properties of the QGP. Students participate on the seminar by preparing the presentation about selected papers. | | | |
| 02ROZ6 | Seminar on Quark-Gluon Plasma 6 | Z | 2 |
| Seminar about recent experimental measurements of the properties of the QGP. Students participate on the seminar by preparing the presentation about selected papers. | | | |
| 02SPRA1 | Special Practicum 1 | KZ | 6 |
| Physics measurement focused on instrumental techniques that are mainly used in physics and technical professions. Topics of each parts are chosen so that students can familiarize with advanced pats of experimental physics and metrology. | | | |
| 02SPRA2 | Special Practicum 2 | KZ | 6 |
| Physics measurement focused on instrumental techniques that are mainly used in physics and technical professions. Topics of each parts are chosen so that students can familiarize with advanced pats of experimental physics and metrology. | | | |
| 01SUP | Start-up Project | KZ | 2 |
| 02PRF | Selected topics from probability theory for physicists | Z | 2 |
| Discrete and continuous probability distributions (Binomial, Poisson, negative binomial, normal, etc.) as well as the processes that lead to their origin have long played a major role in physics, biology and economics. The impetus for the further expansion of these divisions in the 20th century was their application to the description of neutron cascades, multiple particle production and the spread of infectious diseases. The generalization of the properties of these distributions has later on led to the discovery of new classes of distributions - infinitely divisible and stable distributions, which are currently widely used in physics and finance. | | | |
| 02VS2 | Workshop 2 | Z | 1 |
| Abstract: Students will participate on annual Workshop JČF, where they will present results obtained during the work on their bachelor thesis. During other presentations from students and staff, they will also get familiar with scientific topics developed at the department and with methods other colleagues use for their scientific work | | | |
| 02VS3 | Workshop 3 | Z | 1 |
| Abstract: Students will participate on annual Workshop JČF, where they will present results obtained during the work on their bachelor thesis. During other presentations from students and staff, they will also get familiar with scientific topics developed at the department and with methods other colleagues use for their scientific work. | | | |

## List of courses of this pass:

| Code | Name of the course | Completion | Credits |
|---|---|---|---|
| 01DAS | Data science | KZ | 3 |
| Practical application of mathematical modeling methods, statistics and machine learning needs wide range of tasks from data preparation and collection to design of an appropriate method and its division into units for development and implementation into the production. Last, but not least, the cooperation in group and management of a modern data project is crucial. The actual standard of required tools will be presented on lectures. Further, these procedures will be applied during exercises with an emphasis on team collaboration, project planning. At the end of the course, students will present their results to other teams. | | | |
| 01NEUR1 | Neural Networks and their Applications 1 | ZK | 2 |
| Keywords: Neural networks, data separation, functional approximation, supervised learning | | | |
| 01SUP | Start-up Project | KZ | 2 |
| 02ACF1 | Astroparticle physics 1 | ZK | 2 |
| Outline of the lecture: 1. History of astroparticle physics 2. Introduction to astronomy (scales, observation windows, types of objects, contemporary problems) 3. Energy spectrum of the cosmic radiation (properties, spectral index, age) 4. Direct detection of cosmic radiation (experiments, findings) 5. Showers of cosmic radiation (expansion, Heitler-Matthews model, superposition model) 6. Composition of cosmic radiation (types of measurements, results, open problems) 7. Spreading of cosmic radiation and gamma rays through the space (interaction, magnetic fields) 8. Sources of cosmic radiation (exotic sources, acceleration mechanisms) 9. Indirect detection of cosmic radiation (experiments, overview) 10. Optical detection of showers of cosmic radiation (fluorescence and cherenkov techniques, reconstruction) 11. Surface detection of showers of cosmic radiation (types of detectors, reconstruction) 12. Detection of gamma rays (principles, experiments) | | | |
| 02ACF2 | Astroparticle physics 2 | ZK | 2 |
| Outline of the lecture: 1. Detection of neutral particles in the cosmic radiation data (neutrons, photons, neutrinos) 2. Radio detection of showers of cosmic radiation (Askaryans effect, experiments) 3. Detection and use of secondary mions from cosmic radiation (accelerators, tomography) 4. Models of hadronic interactions (Glaubers model, Gribov-Regge theory) 5. Cascade equation, simulation of showers of cosmic radiation (derivation, algorithms) 6. Hands-on public astroparticle data (fits data, Auger and KASCADE data) 7. Evolution of the universe (introduction to cosmology, relict radiation) 8. Nuclear processes in stars (nuclear synthesis, creation of neutrinos, final stages of stars) 9. Detection of neutrinos (principles, experiments, proton decay, double beta decay) 10. Detection of gravitational waves (principles, experiments) 11. Dark matter (theory, experiments) 12. Multimessengers (connections between detection of neutral and charged particles) | | | |
| 02AQCD | Applied Quantum Chromodynamics at High Energies | ZK | 2 |
| This lecture is oriented to provide basic applications of quantum chromodynamicks that corresponds to understanding of the dynamics of processes in particle physics at high energies on proton and nuclear targets that are currently measured by experiments at RHIC and LHC colliders. Complementary informations to lectures of Basics of quantum chromodynamics will be provided. | | | |
| 02BSM | Physics beyond the Standard Model | Z | 2 |
| Standard model of particle physics is one of the most succesful physical theories. It describes the elementary particles which form the matter and their electromagnetic, weak and strong interactions. It is however an incomplete theory and there are several questions which it can not answer. The goal of the lecture is to review the missing points in the Standard model and show potential directions where the new physics beyond the Standard model could be found. | | | |
| 02DPJC1 | Master Thesis 1 | Z | 10 |
| The master thesis is based on a topic approved by the administrators of the programme, department and by the dean. The student is guided by the project supervisor during common regular meetings and discussions. | | | |
| 02DPJC2 | Master Thesis 2 | Z | 20 |
| The master thesis is based on a topic approved by the administrators of the programme, department and by the dean. The student is guided by the project supervisor during common regular meetings and discussions. | | | |

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| 02EXSH | Extreme States of Matter | ZK | 2 |
| Lectures will provide basics in states of matter in extreme conditions. It deals with broad spectra of phenomena from electromagnetic plasma through phases of nuclear matter at high temperatures or densities to highly speculative forms of matter that may be responsible for initialy accelerated expansion of the Universe in its early stages (inflation) or for its current acceleration (dark energy). Lectures may also serve as a brief introduction to parts of modern cosmology connected to nuclear and particle physics. | | | |
| 02FAJ | Physics of Atomic Nuclei | ZK | 4 |
| Nucleon-nucleon(NN) interaction, few-body systems, G matrix, nuclear properties, nuclear models (single-particle model, collective motion, Hartree-Fock approximation, TDA method, RPA method, pairing, quasi-particles, nuclear deformations), electromagnetic and weak processes in nuclei, nuclear reactions (kinematics and mechanisms of nuclear reactions) | | | |
| 02FUJS | Physics of Ultrarelativistic Nuclear Collisions | ZK | 2 |
| The goal of this subject is to introduce students the principles of physics of heavy-ion collisions at large energies. Students will gain insight into phases of a nuclear collision, properties of the created matter (quark-gluon plasma (QGP)), probes which contain information about the QGP and other phases of the collision, and knowledge that these signals brought to us based on the recent measurements at present experiments. | | | |
| 02GTR | General Theory of Relativity | Z,ZK | 4 |
| The goal is to learn the basics of General Relativity theory as well as its applications, mainly in cosmology. The students will get acquainted with the starting points of General Relativity. The course includes the explanation of necessary mathematics: differential geometry. Classic results are derived, like the precession of Mercury, gravitational frequency shift and gravitational bending of light. The participants learn about Schwarzschild metrics and its solution leading to black holes. In the application part the Friedman-Robertson-Walker metrics is introduced and dynamics of the Universe is discussed. | | | |
| 02JSP | Nuclear Spectroscopy | Z,ZK | 5 |
| Nuclear spectroscopy comprises several experimental techniques which are of ultimate importance for experimental nuclear physics and various applications as well. Lecture will be devoted to fundamentals of X- and gamma- ray, charged particle and neutron spectroscopy. | | | |
| 02KMP | Quantum Many-Body Problem in the Theory of Atomic Nuclei | ZK | 2 |
| 1. Nuclear Hamiltonian and distinguishing the degrees of freedom within nuclei 2. Collective and one-body dynamics in nuclei 3. Theory of the energy density functional in nuclei 4. Theory of the energy density functional for the excited states 5. Selfconsistent mean-field model 6. Post Hartree-Fock methods 7. Tamm-Dancoff Approximation 8. Random Phase Approximation 9. Equation of Motion Phonon Method 10. Generator Coordinate Method 11. Restoration of symmetries in many-body methods 12. Coupled Cluster Method 13. Bohr collective model | | | |
| 02KTPA1 | Quantum Field Theory 1 | Z,ZK | 8 |
| The lecture aims to introduce the students to both fundamental and applied parts of quantum field theory. The focus is in particular on equations of relativistic quantum mechanics, canonical quantization of scalar and bispinor field, perturbation theory (Feynmans rules) and basics of renormalization. The content of the lecture can serve as a base for further study in fields of exactly solvable models, theory of critical phenomena, molecular chemistry and biochemistry or quantum gravity. | | | |
| 02KTPA2 | Quantum Field Theory 2 | Z,ZK | 8 |
| The lecture aims at introducing the students to the Feynmans functional integral and its applications. The focus is on broadening the knowledge of modern parts of relativistic and non-relativistic quantum field theory and statistical physics. The content of the lecture can serve as a base for further study in fields of exactly solvable models, theory of critical phenomena, molecular chemistry and biochemistry or quantum gravity. | | | |
| 02LPA | Particle plasma accelerators | ZK | 2 |
| 1. Introduction to laser physics and technology, CPA systems 2. Physics of plasma and plasma wave generation 3. Plasma instabilities, beam-plasma interaction 4. Plasma wave evolution 5. Methods of beam injection to plasma wave 6. Ultrashort particle bunch generation 7. Dynamics of bunch in plasma wave 8. Plasma diagnostics and plasma accelerator monitoring 9. Plasma waveguides 10. Plasma charged particle optics 11. Ultrashort bunch diagnostics 12. Handling and transport of ultrashort bunches 13. Application of ultrashort bunches | | | |
| 02MAT | Materials for Experimental Nuclear Physics | ZK | 2 |
| This lecture is designed for students of experimental nuclear physics. The lecture gives the overview of materials physics with respect to materials frequently used in the experimental nuclear physics, particularly their construction properties and influence of the ionizing radiation on their properties and possible use in experiment. | | | |
| 02MTD | Modern Detectors | ZK | 2 |
| Lectures will cover all types of detectors used in modern nuclear and particle physics. Topics include principles of construction of particular types of detectors, materials used for their construction, ways of using and constrains. Emphasis is given also to electronic detector control and voltage suppliers. | | | |
| 02PRF | Selected topics from probability theory for physicists | Z | 2 |
| Discrete and continuous probability distributions (Binomial, Poisson, negative binomial, normal, etc.) as well as the processes that lead to their origin have long played a major role in physics, biology and economics. The impetus for the further expansion of these divisions in the 20th century was their application to the description of neutron cascades, multiple particle production and the spread of infectious diseases. The generalization of the properties of these distributions has later on led to the discovery of new classes of distributions - infinitely divisible and stable distributions, which are currently widely used in physics and finance. | | | |
| 02REP | Matrix Lie group representations | Z | 2 |
| 1.Group theory, symmetric group, homomorphism, isomorphism, group action, direct product, semidirect product, normal group, simple and semisimple group, factor group, matrix Lie groups, SO(n), SU(n), Lorentz group, Poincaré group. 2.One-parameter group, Lie algebras, Lie group Lie algebra correspondence, exponential map. 3.Universal covering group, relation between SO(3) and SU(2). 4.Representation theory, unitary representation, regular representation, equivalent representation, irreducibility, reducibility, Schur`s lemma, Weyl`s theorem. 5.Lie algebra representation and their connection to Lie group representation, projective representation. 6.Irreducible representations of SO(3) and SU(2), raising and lowering operators, spin representation. 7.Finite-dimensional representations of Lorentz group, tensor product of representations. 8.Representations of SU(3), Gell-Mann matrices, weights and roots. 9.Young tableaux. | | | |
| 02ROZ3 | Seminar on Quark-Gluon Plasma 3 | Z | 2 |
| Seminar deals with theoretical work related to problems of quark-gluon plasma. Students participate on the seminar by preparing the presentation about selected papers. | | | |
| 02ROZ4 | Seminar on Quark-Gluon Plasma 4 | Z | 2 |
| Seminar about recent experimental measurements of the properties of the QGP. Students participate on the seminar by preparing the presentation about selected papers. | | | |
| 02ROZ5 | Seminar on Quark-Gluon Plasma 5 | Z | 2 |
| Seminar about recent experimental measurements of the properties of the QGP. Students participate on the seminar by preparing the presentation about selected papers. | | | |
| 02ROZ6 | Seminar on Quark-Gluon Plasma 6 | Z | 2 |
| Seminar about recent experimental measurements of the properties of the QGP. Students participate on the seminar by preparing the presentation about selected papers. | | | |
| 02SDSD | Detector Systems and Data Acquisition | ZK | 2 |
| The goal of the lecture is to present knowledge of modern detector systems. We will concentrate on the aspects of construction and usage for charged-particle tracking, momentum and energy measurement as well as particle identification via various methods from time-of-flight to transition radiation. The lecture will cover also the topic of signal shaping and processing, digitalization, data acquisition and further data processing at the modern collider experiments. | | | |
| 02SE1 | Seminar 1 | Z | 3 |
| The aim of the seminar is that students get familiar with basics skills to present the own scientific results. Students get also knowledge from the fields of particle physics studied in research tasks and diploma theses of their colleagues. Participants will be informed about recent results in particle physics. | | | |

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|---|---|---|---|
| 02SE2 | Seminar 2 | Z | 3 |
| The aim of the seminar is that students get familiar with basics skills to present the own scientific results. Students get also knowledge from the fields of particle physics studied in research tasks and diploma theses of their colleagues. Participants will be informed about recent results in particle physics. | | | |
| 02SE3 | Seminar 3 | Z | 3 |
| The aim of the seminar is that students get familiar with basics skills to present the own scientific results. Students get also knowledge from the fields of particle physics studied in research tasks and diploma theses of their colleagues. Participants will be informed about recent results in particle physics. | | | |
| 02SE4 | Seminar 4 | Z | 3 |
| The aim of the seminar is that students get familiar with basics skills to present the own scientific results. Students get also knowledge from the fields of particle physics studied in research tasks and diploma theses of their colleagues. Participants will be informed about recent results in particle physics. | | | |
| 02SPRA1 | Special Practicum 1 | KZ | 6 |
| Physics measurement focused on instrumental techniques that are mainly used in physics and technical professions. Topics of each parts are chosen so that students can familiarize with advanced pats of experimental physics and metrology. | | | |
| 02SPRA2 | Special Practicum 2 | KZ | 6 |
| Physics measurement focused on instrumental techniques that are mainly used in physics and technical professions. Topics of each parts are chosen so that students can familiarize with advanced pats of experimental physics and metrology. | | | |
| 02SZD1 | Statistical Data Analysis 1 | Z,ZK | 4 |
| The course is primarily focused on practical application of methods of experimental data analysis. Students obtain knowledge of different statistical methods and their usage, fitting methods, and testing of hypothesis. The course quickly recapitulates basis of mathematical probability theory but it is recommended to attend a full course of the mathematical probability. | | | |
| 02SZD2 | Statistical Data Analysis 2 | Z,ZK | 4 |
| Individual students work will include implementation and testing of a program for analysis of generated data sample. Background understanding of Monte Carlo generators for hadron collision will be explained. The course covers methods of data smearing and subsequent deconvolution of data. Basics understanding and usage of neural networks and machine learning will be covered. | | | |
| 02UC1 | Particles Accelerators 1 | ZK | 2 |
| Introduction to physics and technology of classical (electrostatic and radiofrequency) particle accelerators. | | | |
| 02UC2 | Particle Accelerators 2 | ZK | 2 |
| Introduction to physics and technology of modern and next generation accelerators based on laser and plasma technology. | | | |
| 02VPJRS | Selected topics from relativistic nucleus-nucleus collisions | Z,ZK | 3 |
| The aim of the lecture is to discuss in more depth the physics of the extreme state of the nuclear matter created in relativistic nucleus-nucleus collisions. The course will cover selected topics from the physics of relativistic nucleus-nucleus collisions. The focus will be put on thermodynamic and statistical physics applications to the high-energy nuclear collisions, as well as the medium description using a hydrodynamic approach. Moreover, the in-medium parton energy loss and a related concept of the jet quenching will be discussed. The course will be complemented with computational exercises. | | | |
| 02VS2 | Workshop 2 | Z | 1 |
| Abstract: Students will participate on annual Workshop JČF, where they will present results obtained during the work on their bachelor thesis. During other presentations from students and staff, they will also get familiar with scientific topics developed at the department and with methods other colleagues use for their scientific work | | | |
| 02VS3 | Workshop 3 | Z | 1 |
| Abstract: Students will participate on annual Workshop JČF, where they will present results obtained during the work on their bachelor thesis. During other presentations from students and staff, they will also get familiar with scientific topics developed at the department and with methods other colleagues use for their scientific work. | | | |
| 02VUJC1 | Research Project 1 | Z | 6 |
| The research project is based on a topic approved by the administrators of the programme, department and by the dean. The student is guided by the project supervisor during common regular meetings and discussions. | | | |
| 02VUJC2 | Research Project 2 | KZ | 8 |
| The research project is based on a topic approved by the administrators of the programme, department and by the dean. The student is guided by the project supervisor during common regular meetings and discussions. | | | |
| 02ZELW | Introduction to Theory of Electroweak Interactions | Z,ZK | 6 |
| The goal of these lectures is to acquire knowledge about theory of weak interaction from Fermi theory of -decay, introduction of charged intermediate vector boson to unification of electromagnetic and weak interaction in the framework of Standard model including Higgs mechanism. Short student presentations dedicated to experimental discoveries related to the topics covered in the lectures (such as first measurements of W and Z gauge bosons, Higgs boson discovery) are envisioned. | | | |
| 02ZQCD | Quantum Chromodynamics | Z,ZK | 6 |
| The goal of these lectures is to acquire knowledge about basic principles of strong interaction starting from the constituent quark model and SU(3) flavour symmetry, studies of nucleon structure in deep inelastic scattering of leptons on nucleons and parton model to basics of Quantum Chromodynamics and its practical applications in the context of current experiments in high energy physics and physics of ultra-relativistic heavy-ion collisions. | | | |
| 17PRE | Computer Control of Experiments | Z,ZK | 3 |
| Lectures provide information about standard interfaces of personal computers - parallel, serial, USB, LAN and special interface cards; about standalone equipment that communicate with computers via serial lines or GPIB (IEEE488) interface, further about measuring systems with VME, VXI and LXI interfaces, discuss their advantages and disadvantages. Next, lectures deal with programming of measuring systems - special dedicated software, problems of use of high programming languages and especially use of graphical oriented development tools (Agilent VEE ane LabView); data acquisition and evaluation. Finally, students prepare individual software project for data acquisition and evaluation. | | | |
| 18MEMC | Monte Carlo Method | Z,ZK | 4 |
| This courseis devoted to the numerical method Monte Carlo and to its selected applications. | | | |
| 18OOP | Object Oriented Programming | Z | 2 |
| This course consists of the contributions of students concerning given topics concerned on technologies uded in program development. | | | |

For updated information see http://bilakniha.cvut.cz/en/FF.html
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