Faculty of Science

FYSC24, Physics: Particle Physics, Cosmology and Accelerators, 7.5 credits

Fysik: Partikelfysik, kosmologi och acceleratorer, 7,5 högskolepoäng

First Cycle / Grundnivå

Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2021-03-15 to be valid from 2021-03-15, autumn semester 2021.

General Information

The course is a compulsory course at first cycle level for a Degree of Bachelor in physics.

Language of instruction: English

Main field of studies	*Depth of study relative to the degree requirements*
Physics	G2F, First cycle, has at least 60 credits in first-cycle course/s as entry requirements

Learning outcomes

The course intends to give the student an overview over theories and experimental tools that form the basis for our understanding of modern particle physics. The course contains an overview over cosmology and astrophysics to answer unsolved questions concerning the composition of our Universe. The course is also linked to the part of the basic research in the technical development and how tools developed for particle physics are used in society.

Intended learning outcomes in the programme syllabus refer to the programme syllabus of Degree of Bachelor in physics at Lund's university which corresponds to qualitative target for general qualification in the Higher Education Ordinance in turn.

1-8 are milestones towards intended learning outcomes 1 in the programme syllabus

2-8 are milestones towards intended learning outcomes 2 in the programme syllabus

12-13 are milestones towards intended learning outcomes 3 in the programme syllabus

10-13 are milestones towards intended learning outcomes 4 in the programme syllabus

12-13 are milestones towards intended learning outcomes 5 in the programme syllabus

7-8, 14-16 are milestones towards intended learning outcomes 6 in the programme syllabus

7-8, 14-16 are milestones towards intended learning outcomes 7 in the programme syllabus

6-8, 14-16 are milestones towards intended learning outcomes 8 in the programme syllabus

Knowledge and understanding

On completion of the course, the students shall be able to:

1. Describe basic concepts in special relativity theory.

2. Describe the structure of matter in terms of quarks, leptons and force carriers.

3. Describe basic theories and experimental proofs that form the basis for the basic interaction in the standard model (the strong and electroweak forces).

4. Explain the basic elements in Higgs boson theory and its experimental proofs.

5. Explain the reasons that there are predicted phenomena beyond the standard model and give an account of which leading theories that can explain them.

6. Describe how particle physics, cosmology and astrophysics are connected in terms of understanding of the largest unanswered questions in the universe (e.g. dark matter).

7. Describe the most important interactions that are relevant to identify particles and measure their properties, and how this is used in modern particle detectors.

8. Explain the basic principles behind particle accelerators and their use for research and society, particularly those in Lund (MaxIV, ESS) and the Large Hadron Collider.

Competence and skills

On completion of the course, the students shall be able to:

9. Carry out quantitative calculations of reactions and decay with relativistic kinematics and use the method with 4-momentum for quantitative kinematic calculations.

10. Illustrate particle reactions and their decay with Feynman diagrams.

11. Apply conservation laws based on the standard model on reactions and decay.

12. Use an electronic detection system for muons from the cosmic radiation and measure the lifetime of the muons.

13. Carry out a simple data analysis in Python by writing a programme to measure the lifetime of the muon by means of data from experimental measurements and to generalise these lifetime measurements for the time scales for weak decays.

14. Present a report in particle physics where the students have acquired knowledge orally and in writing through working together in groups and divide up the assignments between group members.

Judgement and approach

On completion of the course, the students shall be able to:

15. Discuss why our knowledge of our Universe is incomplete and how we can search for answers through observations and experiments of particles, cosmology and astroparticle physics.

16. Evaluate critically and explain how the tools that are used to answer large questions in particle physics have importance for the society and every day phenomena.

Course content

The course consists of three different themes:

Theme 1: Special relativity

In the first part of the course the students learn about special relativity, its consequences for length and time and about the concept 4-momentum and invariant mass. By means of these theoretical tools, they learn how one calculates two particle decays for relativistic particles.

Theme 2: Theory and experimental methods in modern particle physics

In the other part of the course, the student is given an overview of elementary particles and their interactions. Reactions and decay are represented with Feynman diagrams. The standard model is described in terms of particles and interactions (strong interactions and united electroweak interactions). Finally, the Higgs-mechanism is introduced, and its discovery is discussed in popular terms. Theories beyond the standard model are explained briefly and the lecturers give an introduction to current questions in the research domain of high-energy physics. This part of the course leads to a discussion of professions in science and particle physics with regard to the technical development that is required to answer large questions in the science (for example machine learning, real time analysis, intelligent instrumentation) and their technology transfer.

Theme 3: Particle accelerators and elements in particle detectors and instrumentation

The third component focuses on instrumentation for particle physics. Interactions that are relevant for detection of particles and the methods to identify and measure the momentum of the particles are explained in connection with high energy physics experiments and are connected to other fields of physics. This part includes a laboratory course where the student measures the lifetime for cosmic muons by writing a programme in Python using Jupyter-notebooks.

Since experimental studies of subatomic systems require particle beams with high energy, the principles are described for particle accelerators in a specific part of the course acquired the principles of acceleration, mainly synchrotrons and linear accelerators and storage rings including generation of secondary jets of photons and protons as in MaxIV and ESS. This part of the course highlights the use of particle accelerators for the society in general (e.g. for medical applications and for studies of materials in physics, pharmacology, biology, chemistry). Examples are taken from the forefront of physics, such as the Large Hadron Collider at CERN, and MaxIV and ESS in Lund.

During the whole course, the students refine their transferable proficiencies in programming in the Python-language, since they practise their programming skills during the laboratory session.

The students acquire proficiencies in scientific writing during the preparation of take-home examination by answering open-ended questions about the subjects of the course. They also polish their presentation skills since they in the oral examination must prepare a short presentation about the standard model that is presented by means of whiteboard and slides.

Students can also participate (optionally) in the IPPOG Particle Physics masterclasses, where they develop their proficiencies in science communication for the public with the aim to give students additional possibilities. This is not compulsory.

Course design

The teaching consists of lectures, laboratory sessions, exercises, and a study visit in a large experimental facility. Participation in laboratory work and following the instructions is compulsory. Participation in the study visit is compulsory but can be replaced by a written project. The study visit can lead to a small cost for the student.

Assessment

Examination takes place in writing in the form of take-home examinations during the course and through an oral examination at the end of the course, and through compulsory components.

Home and oral examinations assess intended learning outcomes 1-9, and the oral examination have a special focus on intended learning outcomes 2-4 and 14-16 since students are requested to describe standard model with their own words and they must be able to answer questions about the application of particle physics in society.

The compulsory components include participation in and passed written lab report for the muonlab that mainly assesses intended learning outcomes 12-13. Participation in the visit at an experimental facility, or or a written report if the facility is also a compulsory part of the course that is not graded.

For students who have not passed the regular examination, additional occasions in close connection to this are offered.

The examiner, in consultation with Disability Support Services, may deviate from the regular form of examination in order to provide a permanently disabled student with a form of examination equivalent to that of a student without a disability.

Subcourses that are part of this course can be found in an appendix at the end of this document.

Grades

Marking scale: Fail, Pass, Pass with distinction.
To pass the whole course students are requited to have passed examinations approved laboratory report, and participation in all compulsory components (introductory lecture, the introduction lecture to the muonlab, the visit at the experimental facility/written report as compensation).

Take-home examinations and the oral examination correspond to 6 credits. The laboratory report for the muonlab corresponds 1.5 credits.

Grading scale for examinations and laboratory report are Failed, passed, passed with distinction and a percentage grade. Grading scale for study visits/compensation written report is Failed, passed.

Each take-home examination consists of different exercises. The general assessment for take-home examination is the weighted average of the individual exercises including general credits for clarity.

For the oral examination, the students' understanding of the intended learning outcomes and the clarity in the explanations when the student presents the standard model and the clarity in the answers to the teacher's questions are evaluated.

The laboratory report is classified according to the final result (whether the result of the data analysis is compatible with the value of the muon life time) and the clarity of the report. The grade is registered as a separate percentage grade worth 1.5 credits.

The examinations for take-home examinations, oral examinations and laboratory report are marked in percentage points of 100%, that then is converted to the grading scale for the faculty of natural sciences and LTH.

The equivalence between percentage points and grading scale is:

? Failed
? Passed 50% - 79%: (Pass)

? Well godkänd> = 80% (Pass with distinction)

The total mean for take-home examinations and the oral examination are on an average weighted 25% or 75% of the percentage grade to give the total 6 the hp-credits.

The final grade is then calculated as a weighted mean of the percentage grade of the take-home examination and the oral examination (6 credits) and the muonlab (1.5 credits) that are then converted to the grading scale for the faculty of natural sciences and LTH.

Entry requirements

Entry to the course requires general entry requirements and 60 credits including physics knowledge equivalent to FYSA12 Physics: Introduction to university physics with mechanics and electromagnetism, 15 credits, FYSA13 Physics: Introduction to university physics with optics, electrondynamics, and quantum physics, 7.5 credits, FYSA14 Physics: Introduction to university physics with thermodynamics, climate and experimental methodology, 7.5 credits, FYSB21 Physics: Mathematical methods for oscillations, waves and diffusion, 7.5 credits, FYSB22 Physics: Basic quantum mechanics, 7.5 credits, FYSB23 Physics: Basic statistical Physics and quantum statistics, 7.5 credits, and FYSB24 physics: Atomic and Molecular Physics, 7.5 credits and 45 credits in Mathematics equivalent MATA21 mathematics: One variable calculus, 15 credits, MATA22 Mathematics: Linear algebra 1, 7.5 credits, NUMA01 Numerical analysis: Mathematical programming with Python, 7.5 credits, MATB21 Mathematics: Multivariable analysis 1, 7.5 credits, MATB22 Mathematics: Linear algebra 2, 7.5 credits. Students who have obtained the equivalent knowledge by other means may also be admitted to the course.

Further information

The course may not be included in qualification together with FYSC14 Physics: Particle physics, cosmology and accelerators, 7.5 credits or the equivalent earlier courses.

Subcourses in FYSC24, Physics: Particle Physics, Cosmology and Accelerators

Applies from H21

2101 Examination, 6,0 hp
Grading scale: Fail, Pass, Pass with distinction
2102 Laboratory Projects, 1,5 hp
Grading scale: Fail, Pass, Pass with distinction
2103 Excursion, 0,0 hp
Grading scale: Fail, Pass