UAB
Universitat Autònoma de Barcelona

High Energy Physics

Code: 103947
ECTS Credits: 6

2024/2025

Degree	Type	Year
2500097 Physics	OT	4

Contact

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Teaching groups languages

You can view this information at the end of this document.

Prerequisites

It is highly recommended to have followed the courses Introduction to Nuclear and Particle Physics, Quantum Mechanics, Theoretical Mechanics and Non-linear Systems, and Electrodynamics and Synchrotron Radiation, Advanced Mathematical Methods, and to follow, in parallel, the course Advanced Quantum Mechanics. Otherwise, it will be more difficult to follow the course.

Objectives and Contextualisation

The main purpose of this course is to give an introduction to modern particle physics starting from the presentation of what the world is made of and finishing with the formulation of the Standard Model.

Competences

- Apply fundamental principles to the qualitative and quantitative study of various specific areas in physics
- Be familiar with the bases of certain advanced topics, including current developments on the parameters of physics that one could subsequently develop more fully
- Carry out academic work independently using bibliography (especially in English), databases and through collaboration with other professionals
- Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, and before both specialist and general publics
- Formulate and address physical problems identifying the most relevant principles and using approximations, if necessary, to reach a solution that must be presented, specifying assumptions and approximations
- Make changes to methods and processes in the area of knowledge in order to provide innovative responses to society's needs and demands.
- Take account of social, economic and environmental impacts when operating within one's own area of knowledge.
- Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
- Use mathematics to describe the physical world, selecting appropriate tools, building appropriate models, interpreting and comparing results critically with experimentation and observation

- Using appropriate methods, plan and carry out a study or theoretical research and interpret and present the results
- Work independently, have personal initiative and self-organisational skills in achieving results, in planning and in executing a project
- Working in groups, assume shared responsibilities and interact professionally and constructively with others, showing absolute respect for their rights.

Learning Outcomes

1. Analyse approaches at tree-level for electroweak and strong simple processes.
2. Analyse the limits of high and low energy for electroweak and strong simple processes.
3. Apply gauge invariance for the Lagrangian determination of electroweak interactions and quantum chromodynamics.
4. Calculate cross sections of electroweak and strong simple processes.
5. Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, in front of both specialist and general publics.
6. Establish the bases for the comprehensive formulation of Abelian and non-Abelian quantum field theories.
7. Formulate the bases for elementary particle-detection techniques.
8. From a specific initial and final state, structure and develop the strategy and calculation for the cross section of a strong or electroweak process.
9. Identify situations in which a change or improvement is needed.
10. Identify the social, economic and environmental implications of academic and professional activities within one's own area of knowledge.
11. Obtain transition amplitudes for electroweak and simple strong processes using Feynman's rules.
12. Use Feynman's rules in strong and electroweak simple processes.
13. Use Noethers theorem in quantum field theories.
14. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
15. Work independently, take initiative itself, be able to organize to achieve results and to plan and execute a project.
16. Working in groups, assume shared responsibilities and interact professionally and constructively with others, showing absolute respect for their rights.
17. Carry out academic work independently using bibliography (especially in English), databases and through collaboration with other professionals

Content

- Motivation: (Book 1 and 2 of bibliography)
- Natural units
- Scales in physics

- Symmetries: (Book 2,3,4 and 5)
- Review of group theory
- Spacetime symmetries: Poincare group
- Little group: Massive and massless particle representations
- Global symmetries

- Elementary particles: (Book 2,3,4 and 5)
- Definition of particle states
- Need for multi-particle states and anti-particles
- From particles to fields
- Fields under Lorentz transformations

- Building theories for particle interactions: (Book 3,6 and 7)
- Effective Field Theories (EFT)
- S-matrix, amplitudes and cross-sections
- Optical theorem

- Quantum ElectroDynamics (QED): (Book 3 and 6)
- massive spin-1 interactions
- massless spin-1 interactions and need for a symmetry

- Strong Interactions: (Book 4 and 8)
- Hadrons and their approximate symmetries
- Underlying dynamics: Quantum ChromoDynamics (QCD)
- Running coupling and proton mass

- Weak Interactions: (Book 4 and 8)
- Fermi Theory
- W and Z boson and the electro-weak theory
- Higgs mechanism and Higgs particle

- Standard Model of elementary particles: (Book 4-8)
- Particle content

- Gravity: (Book 6)
- massive spin-2 interactions
- massless spin-2 interactions and need for a symmetry
- Need for a UV completion

- Main problems in particle physics:
- Dark Matter, Quantum Gravity, unification of forces,…

Activities and Methodology

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Exercises	16	0.64	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 14, 15, 16
Theory Lectures	33	1.32	1, 2, 3, 4, 6, 7, 8, 9, 11, 12, 14
Type: Autonomous			
Discussion, Work Groups, Group Exercises	29	1.16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17
Study of Theoretical Foundations	60	2.4	1, 2, 3, 4, 6, 7, 8, 9, 11, 12, 14, 15, 16

Theory Lectures and Exercises.

Classwork and Homework.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continous Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Exam: 1st. Part	40%	3	0.12	1, 2, 3, 4, 6, 7, 8, 9, 11, 12, 13, 14
Exam: 2nd. Part	40%	3	0.12	1, 2, 3, 4, 6, 7, 8, 9, 11, 12, 13, 14
Homework	20%	3	0.12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17
Make-up Exam	80%	3	0.12	1, 2, 3, 4, 6, 7, 8, 9, 11, 12, 13, 14

Part 1: an exam and homework; Part 2: an exam and homework;
In order to be able to take part in the recovery exam you must have been evaluated in the two partial exams without requiring a minimum grade;
The make-up exam covers the entire subject;
You can come to the make-up exam to improve your grade. If so, your final mark will be that of this exam.

Bibliography

Bibliography:

1) "The anthropic cosmological principle", J.D. BARROW and F.J. TIPLER, OXFORD UNIVERSITY PRESS, 1986)
2) "Concepts of Elementary Particle Physics, M. Pekin, Oxford University Press, 2019
3) "Fundamentals of Quantum Field Theory", R. Luty and T. Cohen, pdf version on the campus virtual
4) "Gauge theory of elementary particle physics", T.-P. CHENG and L.-F. LI, CLARENDON PRES (OXFORD)
5) "Quantum Field Theory", L.H. Ryder, Cambridge University Press 1996
6) "Quantum Field Theory and the Standard Model", MATTHEW D. SCHWARTZ, CAMBRIDGE UNIVERSITY PRESS
7)"Introduction to quantum field theory", M.E. Peskin and D.V. Schroeder, ISBN 0-201-50397-2
8) "QUARKS AND LEPTONS: An Introductory Course in Modern Particle Physics", F. Halzen and A. D. Martin, JOHN WILEY &SONS

Software

It is recommended to use Mathematica Student Edition.

Language list

Name	Group	Language	Semester	Turn

(PAUL) Classroom practices	1	English	second semester	afternoon
(TE) Theory	1	English	second semester	afternoon