# COURSE DATA

## DATA SUBJECT

**Code:** 43300
**Name:** Experimental particle physics
**Cycle:** Master's Degree
**ECTS Credits:** 6
**Academic year:** 2025-26

## STUDY (S)

| Degree | Center | Acad. year | Period |
|---|---|---|---|
| 2150 - Master's degree in Advanced Physics | Facultat de Física | 1 | First quarter |

## SUBJECT-MATTER

| Degree | Subject-matter | Character |
|---|---|---|
| 2150 - Master's degree in Advanced Physics | Nuclear and particle physics | ELECTIVES |

## COORDINATION

FIORINI - LUCA

MORENO LLACER MARIA

ZORNOZA GOMEZ JUAN DE DIOS

# SUMMARY

The Experimental Particle Physics course presents an experimental and phenomenological approach to the physics of elementary particles. It summarizes the phenomenology of particles and their interactions, the main problems and challenges, making a description of research methods and tools used today to address them (particle accelerators, detectors, cosmic rays). It explains the Standard Model of elementary particles, and the main experiments that have been established, verify and identify their key parameters. The discovery of the Higgs boson and its implications in the Standar Model will be explained as well as search possible signatures of alternative models. The physics of the quark sector (flavor), some phenomenological aspects of the weak interaction, the CKM matrix and CP violation will be also addressed. The main topics on neutrino physicis will be covered, including oscillanions, neutrino mass, Majorana/Dirac nature, etc. A review on astroparticle physics (gamma radiation, neutrinos and cosmic rays) will be also done. We will also address the question of dark matter, explaining the evidence of its existence and the experimental efforts to detect it. The course concludes with a brief discussion of the future of particle physics and the motivation for new experiments. Special seminars about specific topics will be programmed, as well as sessions of analysis of real data of one of the LHC experiments. The course concludes with a brief discussion of the concludes with a brief discussion of the future of particle physics and the motivation for new experiments. Special seminars about specific topics will be

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## PREVIOUS KNOWLEDGE

### RELATIONSHIP TO OTHER SUBJECTS OF THE SAME DEGREE

There are no specified enrollment restrictions with other subjects of the curriculum.

### OTHER REQUIREMENTS

## COMPETENCES / LEARNING OUTCOMES

### 2150 - Master's degree in Advanced Physics

Adquirir una visión global del panorama de la Física Nuclear, Física de Partículas y Astropartículas a partir de los experimentos actuales y futuros. Conocer el tipo de estudios que realizan y sus objetivos. Familiarizarse con los aceleradores y detectores presentes y los grandes laboratorios e instalaciones a nivel mundial en Física Nuclear y de Partículas.

Analizar una situación compleja extrayendo cuales son las cantidades físicas relevantes y ser capaz de reducirla a un modelo parametrizado.

Comprender de una forma sistemática el campo de estudio de la Física y el dominio de las habilidades y métodos de investigación relacionados con dicho campo.

Comprensión teórica de los aspectos básicos de la Física Nuclear y de Partículas en lo que concierne a la estructura nuclear de la materia y los constituyentes básicos descritos por el Modelo Estándar de Física de partículas.

Concebir, diseñar, poner en práctica y adoptar un proceso sustancial de investigación con seriedad académica.

Estar en disposición para seguir los estudios de doctorado y la realización de un proyecto de tesis doctoral.

Evaluar la validez de un modelo o teoría propuesto por otros miembros de la comunidad científica.

Exponer y defender públicamente el desarrollo, resultados y conclusiones de su trabajo en el área de la Física.

Ostentar la preparación para tomar decisiones correctas en la elección de tareas y en su ordenación temporal en su labor investigadora y/o profesional.

Poseer la capacidad para el desarrollo de una aptitud crítica ante el aprendizaje que le lleve a plantearse nuevos problemas desde perspectivas no convencionales.

Realizar un análisis crítico, evaluación y síntesis de ideas nuevas y complejas en el área de la Física.

Saber interpretar los datos experimentales u obtenidos mediante simulaciones y efectuar los análisis pertinentes mediante técnicas estadísticas para la obtención de los resultados finales y las magnitudes físicas que se pretende medir en el ámbito de la Física Nuclear y de Partículas.

Saber modelizar matemáticamente los problemas físicos sencillos nuevos, conectados con problemas conocidos. Ser capaz de expresar en términos matemáticos nuevas ideas.

Saber organizarse para planificar y desarrollar el trabajo dentro de un equipo con eficacia y eficiencia.

Ser capaz de gestionar información de distintas fuentes bibliográficas especializadas utilizando principalmente bases de datos y publicaciones internacionales en lengua inglesa.

Students should apply acquired knowledge to solve problems in unfamiliar contexts within their field of study, including multidisciplinary scenarios.

Students should be able to integrate knowledge and address the complexity of making informed judgments based on incomplete or limited information, including reflections on the social and ethical responsibilities associated with the application of their knowledge and judgments.

Students should communicate conclusions and underlying knowledge clearly and unambiguously to both specialized and non-specialized audiences.

Students should demonstrate self-directed learning skills for continued academic growth.

Students should possess and understand foundational knowledge that enables original thinking and research in the field.

Utilizar con soltura aplicaciones y equipos informáticos para el tratamiento, simulación y análisis de datos experimentales en Física Nuclear y de Partículas.

## DESCRIPTION OF CONTENTS

### 1. Introduction to experimental physics at accelerators.

Overview of particle accelerators. Energy and luminosity. Linear and circular accelerators. Colliders: The LHC. Particle detectors in accelerators.

### 2. The Standard Model of Particles and Interactions

Elementary constituents of matter. The electron to the Higgs. Particle classification. The four fundamental interactions. Symmetries and conservation laws. Weak interactions. e+e-colliders (LEP). Precision Tests of the Standard Model. Measurement of the properties of the W and Z bosons.

## 3. The Standard Model: Flavor physics.

Interaction of quarks in the Standard Model. CKM matrix. Neutral mesons decay. CP violation in K and B mesons. Experiments at the energy of the Upsilon(4S) (BELLE and BABAR) and in pp colliders (LHC).

## 4. The Standard Model: QCD and hadronic physics

Hadronic colliders: LHC, TeVatron, HERA. Isospin and quarks model. High-energy hadronic interactions. Jets: definition and properties. Measurements of de Parton Distribution Functions (PDF), Underlying Event and Pile-up. Experimental measurements of hadronic parameters.
Top-quark physics: discovery, mass measurement and properties

## 5. The Standard Model: Spontaneous symmetry breaking and Higgs boson.

Electro-weak symmetry: properties and issues. Spontaneous symmetry breaking mechanism. Higgs boson properties. Search of the Higgs boson and its discovery. Measurement of the mass and properties. Prospectives for the future.

## 6. Search of New Physics beyond the Standard Model

Limitations of the Standard Model and possible solutions: supersymmetry, extra dimensions. What we know of the Higgs sector and possible extensions: additional doublets and composite models. Experimental results in the search of new physics and dark matter with colliders.

## 7. Neutrinos

Detection of neutrinos. Oscillations of neutrinos. Solares.Neutrinos atmospheric neutrinos. Neutrinos in reactors. Accelerator neutrinos. Neutrino masses. Neutrino Majorana vs. Dirac neutrinos.

## 8. Dark matter

Evidence for dark matter. Direct searches. Indirect searches. Searches in accelerators.

## 9. Astroparticle Physics

Astroparticle experiments. Origin of cosmic rays. Mechanisms hadronic vs. leptonic mechanisms. Detection of cosmic rays. Gamma-ray detection. Cosmic neutrinos

# WORKLOAD

## PRESENCIAL ACTIVITIES

| Activity | Hours |
|---|---|
| Theory | 40,00 |
| Seminar | 4,00 |
| Other activities | 7,00 |
| **Total hours** | **51,00** |

## NON PRESENCIAL ACTIVITIES

| Activity | Hours |
|---|---|
| Attendance at other activities | 0,00 |
| Individual or group project | 29,00 |
| Independent study and work | 0,00 |
| Preparation of lessons | 35,00 |
| Preparation for assessment activities | 0,00 |
| Resolution of case studies | 35,00 |
| **Total hours** | **99,00** |

# TEACHING METHODOLOGY

MD1 - Standar theory lecture.
MD2 - Problems solving.
MD3 - Problems.
MD4 - Seminars.
MD5 - Visit to external scientific facilities and companies.
MD6 - Simple studies of data of particl physics experiments.

# EVALUATION

The evaluation of the course is based on:

- Written examination on the lectures and practices: based on learning outcomes and specific objectives of each subject (from 25% up to 40%).

- Continuous evaluation of the student in the lectures and practices: participative attendance and conducting exercises in the classroom . Resolution of cuestions, problems and exercises (from 10% up to 25%).

- Oral presentation of works based on teh course content exposed in the classroom (50%).

In order to pass the subject, a minimum of 5 has to been attained, using the weights indicated above and a minium of 5 out of 10 is required in the written exam.

This evaluation system will be used for both the first and second call.

## REFERENCES


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- W.S.C.Williams; Nuclear and Particle Physics Oxford Science Publications,NY, 1992.
- B. Povh, K. Rith, C. Scholz, F. Zetsche; Particles and Nuclei Springer-Verlag Berlin , 1995.
- Sylvie Braibant, Giorgio Giacomelli, Maurizio Spurio; Particles and Fundamental Interactions, An Introduction to Particle Physics, Springer 2012
- V. Barger, D. Mafartia, K Whisnat; The Physics of Neutrino, Princeton University Press, 2012
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- R. Ellis, W. Stirling, B. Webber: QCD and Collider Physics
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- S. Guinon, H. Haber, G. Kane, S. Dawson: the Higgs Hunter Guide

- M. Sozzi: Discrete Symmetries and CP violation
- G. Cowan: Statistical Data Analysis
- F. James: Statistical Methods in Experimental Physics
- G. Bertone, Particle Dark Matter. Observations, models and searches, Cambridge University Press 2010
- M. Spurio, Probes of Multimessenger astrophysics, Springer 2018
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- G. Barr, R. Devenish, R. Walczak, T. Weidberg, Particle Physics in the LHC Era, Oxford University Press, 2016
- The state of the art of neutrino physics, Editor: A. Ereditato, Ed. World Scientific Press 2018.