VNIVERSITAT DE VALÈNCIA

# Course Guide
# 43300 Experimental particle physics

## COURSE DATA

| Data Subject | |
|---|---|
| **Code** | 43300 |
| **Name** | Experimental particle physics |
| **Cycle** | Master's degree |
| **ECTS Credits** | 6.0 |
| **Academic year** | 2021 - 2022 |

**Study (s)**

| Degree | Center | Acad. year | Period |
|---|---|---|---|
| 2150 - M.U. en Física Avanzada 12-V.2 | Faculty of Physics | 1 | First term |

**Subject-matter**

| Degree | Subject-matter | Character |
|---|---|---|
| 2150 - M.U. en Física Avanzada 12-V.2 | 4 - Nuclear and particle physics | Optional |

**Coordination**

| Name | Department |
|---|---|
| FIORINI, LUCA | 180 - Atomic, Molecular and Nuclear Physics |
| ZORNOZA GOMEZ, JUAN DE DIOS | 180 - Atomic, Molecular and Nuclear Physics |

## 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.

# PREVIOUS KNOWLEDGE

## Relationship to other subjects of the same degree

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

## Other requirements

# OUTCOMES

## 2150 - M.U. en Física Avanzada 12-V.2

- Students can apply the knowledge acquired and their ability to solve problems in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their field of study.
- Students are able to integrate knowledge and handle the complexity of formulating judgments based on information that, while being incomplete or limited, includes reflection on social and ethical responsibilities linked to the application of their knowledge and judgments.
- Students can communicate their conclusions, and the knowledge and rationale underpinning these, to specialist and non-specialist audiences, clearly and unambiguously.
- Students have the learning skills that will allow them to continue studying in a way that will be largely self-directed or autonomous.
- Students have the knowledge and understanding that provide a basis or an opportunity for originality in developing and/or applying ideas, often within a research context.
- Ser capaz de gestionar información de distintas fuentes bibliográficas especializadas utilizando principalmente bases de datos y publicaciones internacionales en lengua inglesa.
- Saber organizarse para planificar y desarrollar el trabajo dentro de un equipo con eficacia y eficiencia.
- 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.
- Estar en disposición para seguir los estudios de doctorado y la realización de un proyecto de tesis doctoral.
- 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.
- Concebir, diseñar, poner en práctica y adoptar un proceso sustancial de investigación con seriedad académica.
- Realizar un análisis crítico, evaluación y síntesis de ideas nuevas y complejas en el área de la Física.
- Analizar una situación compleja extrayendo cuales son las cantidades físicas relevantes y ser capaz de reducirla a un modelo parametrizado.
- Evaluar la validez de un modelo o teoría propuesto por otros miembros de la comunidad científica.

- Saber modelizar matemáticamente los problemas físicos sencillos nuevos, conectados con problemas conocidos. Ser capaz de expresar en términos matemáticos nuevas ideas.
- Exponer y defender públicamente el desarrollo, resultados y conclusiones de su trabajo en el área de la Física.
- 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.
- 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.
- Utilizar con soltura aplicaciones y equipos informáticos para el tratamiento, simulación y análisis de datos experimentales en Física Nuclear y de Partículas.
- 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.

At the end of the teaching-learning process the student will have learned:

1. The different aspects of the theoretical, methodological and technological aspects of the scientific development of the Nuclear and Particle Physics, their close reletionship and their applications.
2. The physical motivations, technical challenges and the historical context of some of the past, present and future experiments, key to the development of Nuclear and Particle Physics as a fundamental element of the student's research training.

## 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. The Fermi constant. e+e-colliders: LEP and SLC. 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. B meson oscillations Violation of CP. Experiments at the Upsilon(4S) energy: BELLE and BABAR. pp collider experiments: LHCb.

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

Hadronic colliders: LHC, TeVatron, HERA. Quarks model. High-energy hadronic interactions. Jets: definition and applications. 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

| ACTIVITY | Hours | % To be attended |
|---|---|---|
| Theory classes | 40,00 | 100 |
| Other activities | 7,00 | 100 |
| Seminars | 4,00 | 100 |
| Development of group work | 14,00 | 0 |
| Development of individual work | 15,00 | 0 |
| Preparing lectures | 35,00 | 0 |
| Preparation of practical classes and problem | 35,00 | 0 |
| **TOTAL** | **150,00** | |

## 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 4 out of 10 is required in the written exam.

# REFERENCES

## Basic

- Antonio Ferrer y Eduardo Ros; Física de Partículas y Astropartículas Universitat de València, 2005.
- D.H. Perkins; Introduction to High Energy Physics Addison-Wesley, 1987.
- D. Griffiths; Introduction to Elementary Particles Wiley, New York, 1987.
- A. Bettini; Introduction to Elementary Particle Physics Cambridge University Press, 2008.
- W.E. Burcham and M. Jobes; Nuclear and Particle Physics Longman Scientific & Technical, Londres, 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
- M. Spurio, Probes of Multimessenger astrophysics, Springer 2018
- E. Gardi, N. Glover, A. Robson (Editors), LHC Phenomenology, Springer 2015

## Additional

- W.R. Leo; Techniques for nuclear and particle physics experiments Springer-Verlag, Berlin, 1987.
- 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.
- C. Grupen, Astroparticle Physics. Ed. Springer, 2005.
- P.A. Zyla et al. (Particle Data Group), Prog. Theor. Exp. Phys. 2020, 083C01 (2020). https://pdg.lbl.gov/
  Book 2018: [https://journals.aps.org/prd/abstract/10.1103/PhysRevD.98.030001]
  Booklet 2018: [http://pdg.lbl.gov/2020/download/db2018r.pdf]
- R. Ellis, W. Stirling, B. Webber: QCD and Collider Physics
- V. Berger, R. Phillips: Collider Physics
- 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

# ADDENDUM COVID-19

**This addendum will only be activated if the health situation requires so and with the prior agreement of the Governing Council**

**English version is not available**