COURSE DATA

DATA SUBJECT

Code: 43301
Name: Experimental nuclear physics
Cycle: Master's Degree
ECTS Credits: 6
Academic year: 2026-27

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

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SUMMARY

The subject of Experimental Nuclear Physics focuses on present accelerator and underground facilities, and their main fields of research and their applications to various fields of science. Representative facilities of each field are presented; An introduction to nuclear reactions is given where the main concepts are studied. The measurement of cross-sections and their main sources of error are discussed. The concepts are presented in such a way that they can be easily extended to other fields such as Particle Physics, Astrophysics, Atomic, Molecular Physics and Nuclear Engineering. Some of the most representative applications of current research are also discussed: production of exotic and superheavy nuclei, relativistic and ultrarelativistic reactions and production of the quark-gluon plasma, Nuclear Astrophysics and nucleosynthesis, applications to the study of elemental analysis (RBS, PIXE, neutron activation and datation), and applications to Medicine (radiotherapy and hadron therapy). Laboratory experiments with radioactive sources and nuclear instrumentation, related to the theoretical content of the subject, are also carried out in this course in order to familiarize students with the experimental techniques employed in Nuclear Physics.

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.

Elaborar una memoria clara y concisa de los resultados de su trabajo y de las conclusiones obtenidas en el área de la Física.

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.

Know how to apply acquired knowledge and problem-solving skills in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their area of study.

Know how to communicate your conclusions (and the underlying knowledge and reasons) to both specialist and non-specialist audiences in a clear and unambiguous way.

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.

Possess the learning skills that will allow them to continue studying in a way that will be largely self-directed or autonomous.

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

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

To be able to integrate knowledge and face the complexity of formulating judgments from information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgments.

DESCRIPTION OF CONTENTS

1. Accelerator and underground facilities

-Basic description of a nuclear reactions experiment
-Cross section and related magnitudes
-Tandem van de Graaf accelerators
-Cyclotrons
-Synchrotrons
-Microtrons
-Colliders
-Neutron facilities
-Underground facilities and experiments of rare events search

2. Nuclear reactions at low energies

-Different types of nuclear reactions at low energies
-Nuclear reaction kinematics
-Classical and semiclassical cross sections
-Partial wave analysis. The quantum cross section
-Optical theorem. Inverse reactions. Identical particles
-Elastic scattering

-High Spin. Yrast lines. Superdeformed nuclei.
-Heavy ion fusion at low energy.
-Compound nucleus decay

3. Production of Exotic and Superheavy nuclei

-Exotic nuclei: Halo nuclei, Drip lines, proton and neutron rich nuclei, new magic nuclei
-Experimental methods for exotic nuclei production: ISOL and IN-FLIGHT
-Experiments for production of nuclei near the drip lines. Ion Traps. Main facilities: ISOLDE, SPIRAL,GSI-FRS
-Production of transuranic nuclei. The stability island. Main experiments for superheavy nuclei production. The new elements.

4. Nuclear reactions at relativistic and ultrarelativistic energies

-Relevant magnitudes in relativistic heavy ion collisions
-Phase transitions in nuclear matter
-The quark-gluon plasma
-Experiments to produce and study the quark-gluon plasma

5. Nuclear Physics in Astrophysics

-The big-bang theory and the early Universe
-Primordial nucleosynthesis
-Stellar nucleosynthesis:light elements
-Stellar nucleosynthesis:heavy elements
-Cosmochronology

7. Nuclear Energy

-Neutron cross sections. Fission and absorption. Nuclear chain reaction and criticality.
-Nuclear fission reactors
-Thermonuclear fusion. Effective sections.
-Nuclear fusion reactors. The ITER project.

Laboratori Experiments

The Laboratory experiments described below are offered and will be carried out in parallel in four sessions of three hours. Depending on the number of students, they will be held in groups or individually:

- Nuclear alpha decay: energy loss of alpha particles in materials (copper, nickel, gold and air). Study of

stopping power, range-energy curve, Landau distribution, convolution with detector response. Determination of the Rutherford cross section using a gold target.

- Nuclear beta decay: study of beta decay spectra and internal conversion of various sources (Bi-207, Cs-137, Sr-90, Pm-147, Cl-36), response function of the surface barrier silicon detector, Deconvolution of the spectra, Kurie Plot.

- Gamma-gamma coincidence with a Na22 or Co60 source: study of the coincidence technique with sodium iodide detectors and a gamma emitting source. Study of the angular correlation of the two gammas.

- X-ray spectroscopy: study of the emission spectra of X-rays of various materials and identification of the elemental composition of samples, verification of the Moseley law.

- Study and calibration of a multidetector of microstrips - ALIBAVA

WORKLOAD

PRESENCIAL ACTIVITIES

Activity	Hours
Theory	30,00
Seminar	3,00
Other activities	4,00
Laboratory	12,00
Total hours	**49,00**

NON PRESENCIAL ACTIVITIES

Activity	Hours
Attendance at other activities	0,00
Individual or group project	0,00
Independent study and work	0,00
Preparation of lessons	40,00
Preparation for assessment activities	0,00
Resolution of case studies	61,00
Total hours	**101,00**

TEACHING METHODOLOGY

MD1 - Lectures.

MD2 - Solution of problems.

MD3 - Laboratory experiments

MD6 - Visit to external scientific facilities and companies.

EVALUATION

SE1- Continuous assessment: 20%

SE2- Written examination of problems and questions: 50%

SE3- Laboratory experiments: 30%

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

REFERENCES

- G. R. Satchler. Introduction to Nuclear Reactions. MacMillan, 1982.
- C. E . Rolfs, W. S. Rodney. Couldrons in the Cosmos. Chicago university Press, 1988.
- Techniques for Nuclear and Particle Physics Experiments. William R. Leo. Ed. Springer Verlag, 1994.
- Apuntes de la asignatura
- H. Feshbach. Nuclear Reactions. John Wiley, 1992
- L. Csernai. Relativistic Heavy-ion collision.. John Wiley, 1994.
- Glenn F. Knoll, Radiation Detection and Measurement, John Wiley & Sons. New York, 3ª Edición, 1999.
- Krane. Introductory Nuclear Physics. Wiley, 1988.
- R. Vogt, Ultrarelativistic Heavy-ion Collisions, Elsevier, 2007