COURSE DATA

Data Subject	
Code	43301
Name	Experimental nuclear physics
Cycle	Master's degree
ECTS Credits	6.0
Academic year	2021 - 2022

Study (s)

Degree	Center	Acad. year	Period
2150 - Master's degree in Advanced Physics	Faculty of Physics	1	First term

Subject-matter

Degree	Subject-matter	Character
2150 - Master's degree in Advanced Physics	4 - Nuclear and particle physics	Optional

Coordination

Name	Department
DIAZ MEDINA, JOSE	180 - Atomic, Molecular and Nuclear Physics

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 (RD 1393/2007) // LEARNING OUTCOMES (RD 822/2021)

2150 - Master's degree in Advanced Physics

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

LEARNING OUTCOMES (RD 1393/2007) // NO CONTENT (RD 822/2021)

At the end of the teaching-learning process the student will have learned to:
1. Understand the motivation of relevant accelerator and underground facilities and their characteristics as well as the main research lines developped in them.
2. To employ the cross section as a crucial magnitude in microscopic physics. Learn the basics of measuring cross sections and to determine their source of error in various fields of physics: Nuclear Physics, Particle Physics, Atomic and Molecular Physics, Nuclear Astrophysics. Assess the quality of the data from an experiment.
3. Know the physical motivations, the technical challenges and the historical context of some key past, present and future experiments in the development of Nuclear and Particle Physics.

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

6. Nuclear Physics in Medicine

- Radiotherapy
- Survival curves
- Hadron therapy
- Radioisotope synthesis

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.

8. Nuclear Analysis Techniques

-Rutherford backscattering: surface elemental analysis
-Proton and Heavy Ions Induced X ray emission.
-Neutron activation
-Nuclear reaction analysis
-Nuclear Imaging

9. 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.

- 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

ACTIVITY	Hours	% To be attended
Theory classes	30,00	100
Laboratory practices	12,00	100
Other activities	4,00	100
Seminars	3,00	100
Preparing lectures	40,00	0
Preparation of practical classes and problem	61,00	0
TOTAL	**150,00**	

TEACHING METHODOLOGY

MD1 - Lectures.
MD2 – Solution of problems.
MD3- Laboratory experiments

EVALUATION

SE1- Continuous assessment: 40%

SE2- Written examination of problems and questions: 40%

SE3- Laboratory experiments: 20%

REFERENCES

Basic

- 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

- Krane. Introductory Nuclear Physics. Wiley, 1988.

Additional

- 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.
- R. Vogt, Ultrarelativistic Heavy-ion Collisions, Elsevier, 2007

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