COURSE DATA

Data Subject	
Code	43302
Name	Experimental techniques in nuclear and particle physics
Cycle	Master's degree
ECTS Credits	6.0
Academic year	2023 - 2024

Study (s)

Degree	Center	Acad. year	Period
2150 - M.D. in Advanced Physics	Faculty of Physics	1	First term

Subject-matter

Degree	Subject-matter	Character
2150 - M.D. in Advanced Physics	4 - Nuclear and particle physics	Optional

Coordination

Name	Department
GONZALEZ DE LA HOZ, SANTIAGO	180 - Atomic, Molecular and Nuclear Physics
YAHLALI HADDOU, NADIA	180 - Atomic, Molecular and Nuclear Physics
ZUÑIGA ROMAN, JUAN	180 - Atomic, Molecular and Nuclear Physics

SUMMARY

The course Experimental Techniques for Nuclear and Particle Physics includes a first part where we study the particle detection techniques used in the experiments of Nuclear Physics and High Energy as calorimetry, Cerenkov radiation detectors, semiconductor detectors, etc. and event reconstruction techniques and particle tracks. The second part is devoted to the techniques of analysis and treatment of experimental data and includes the study of probability distributions, error propagation, central limit theorem, fitting of experimental data, determination of parameters, hypothesis testing, introduction to the Monte Carlo methods and its applications. The course is complemented by 1.5 ECTS laboratory where the student will practice using particle detectors and where you the knowledge acquired in theory sessions is needed.

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.D. 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.
- Conocer los procesos más importantes de la interacción de la radiación con la materia, las técnicas de detección de la radiación, el funcionamiento de los detectores y la instrumentación utilizada actualmente en los experimentos de 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.

LEARNING OUTCOMES

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

1. Knowing the processes, techniques, sensors and measuring instruments in the field of Nuclear and Particle Physics.
2. Learning to design, simulate and perform an experiment.
3. Learning to manage software packages capable of simulating large-scale experiments.
4. Interpret the results obtained through simulations and perform the necessary analysis to obtain the final results and the physical quantities to be obtained.
5. Fit statistics and probability distributions to the experimental data and simulated. Extract physical quantities of the parameters obtained in the settings. Apply criteria for the goodness of the obtained data and settings.
6. Fluently use of computer applications and equipment for processing and analyzing data and for the presentation of results and reports.

DESCRIPTION OF CONTENTS

1. Detectors in High Energy Physics. Calorimetry

Detection mechanisms. Definition and interest. Classification and fundamental differences. Basic Mechanisms. Electromagnetic cascade. Rossi-Heitler model. Hadronic cascade. Signal / Power. Compensation. Energy resolution. Instrumental Effects

2. Cherencov detectors

Introduction. The techniques. Cerenkov counters. RICH detectors

3. Semiconductor detectors

Introduction. Basic characteristics. Semiconductors doped. The pn junction: formation of the desertification region. Characteristics of semiconductors as detectors Diode structure for the construction of silicon detectors. Position detectors

4. Data analysis. Preliminary concepts

Definition of probability, Random variables. Calcullus of probabilities. Bayess Theorem.

5. General properties of probability functions.

The probability density function. The cumulative distribution function. Properties of the probability density function. The characteristic function. Distributions of more than one random variable.

6. Propagation of errors

Linear functions of random variables. Change of variable. Propagation of errors. lineales de varias variables. Cambio de variable. Generalitation to several functions. Matrix notation.

7. Probability distributions

Binomial distribution. Poisson distribution. Uniform distribution. Exponential distribution. Gaussian distribution. Dstribuciones binormal and multinormal. Sampling Distributions: The distribution of -square, Student's t-distribution, the F distribution

8. Law of lareg numbers and Central Limit Theorem

Sampling. Inference. Law of large numbres. Inequality of Chebysev. Central Limit Theorem. Random generator

9. Monte Carlo methods

Introduction. Randon numbre generators. Congruent methods. Sampling distributions. Inverse transformation method. Rejection method. Composite method. Sampling discrete distributions. Poisson distribution.

10. Parameter Estimation

Introduction. Properties of estimators. Minimum variance limit. Raó-Cramér inequality.

11. The method of maximum likelihood (ML)

Maximum likelihood principle. Properties of ML estimators. Asymptotic properties. Changing variables. Variance of the ML estimators. Extended maximum likelihood method.

12. The method of least squares (LS)

Definition. Models linear in the parameters. Examples. Nonlinear Models. Least squares adjustments. Goodness of fit. Least squares with classified data.

13. Statistical errors, confidence intervals and limits

Introduction. Belts and confidence intervals. Confidence limits. Gaussian confidence intervals. Confidence intervals on the maximum likelihood method. Confidence intervals for various parameters. Limits near a physical boundary. Bayesian intervals. Poisson confidence intervals. Upper limit background existence.

14. Statistical tests

Basic concepts and properties. Hypothesis smple. Neyman-Pearson lemma. Assumptions made. Parametric test for normal variables. Goodness of settings. Chi-square test. Kolmogorov-Smirnov Tes. Consistency test and randomness. Test of independence.

15. Laboratory of experimental techniques

Students will do one of the laboratory practices described below. Depending on the number of students, they will be carried out in pairs or individually.

- Study of cosmic radiation and measurement of the half-life of the muon: Angular dependence of the cosmic ray flux. Hard and soft components of cosmic rays. Time measurements: determination of the muon half-life.

-Nuclear beta decay: study of beta decay spectra and internal conversion of various sources (Bi-207, Cs-137, Sr-90, Pm-147, Cl-37), response function of surface barrier silicon detector, deconvolution of Spectra, Kurie Plot.

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

-Study and calibration of a microstrips multidetector - ALIBAVA practice

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 - Standar theory lecture
MD3 - Problems solving
MD4 - Problems
MD5 - Seminars.
MD6 - Visit to external scientific facilities and companies

EVALUATION

The evaluation of the course is based on:

- (A) Written examination on the lectures and practices: based on learning outcomes and specific objectives of the course (40%).

- (B) Continuous evaluation of the student in the classes of theory and practice: participatory assistance, conducting exercises in the classroom, resolution of proposed problems (40%).

- (C) Evaluation of the activities of the laboratory sessions: attendance, instrumentation and handling equipment, work organization, understanding and use of the lab guides, performing calculations, analysis of results, teamwork, memories and / or reports of the the lab work (20%).

A minimun of 3,5 in (A) is required to succeed the subject.

REFERENCES

Basic

- W.R.Leo. Techniques for Nuclear and Particle Physics Experiments. Springer-Verlag, 1987, Segunda edición 1994.
- Radiation Detection and Measurement. Glenn F. Knoll. Ed. John Wiley &Sons. New York, 3ª Edición. 1999.
- R. Wigmans. Calorimetry. Energy Measurements in Particle Physics. OxfordUniversity Press. ISBN=0 19 850296 6
- J.V.Jelly, Cerenkov Radiation and Its Applications (Pergamon: London, 1958).
- A.G. Frodesen, O. Skjeggestad. Probability and Statistics in Particle Physics. Universitetsforlaget 1979.
- G. Cowan, Statistical Data Analysis, Oxford University Press
- R.J. Barlow, Statistics: A guide to the use of Statistical Methods in the Physical Sciences. John Wiley & sons
- Louis Lyons, Statistics for nuclear and particle physics. Cambridge University Press
- F. James, Statistics methods for experimental physics. World Scientific

Additional

- U. Amaldi. Fluctuations in calorimetry measurements. CERN-EP-/80-212
- C. Fabjan. Detector for elementary particle physics. CERN-EP/94-61
- T. Ypsilantis and J. Seguinot, Nulc,. Instrum. Meth. Phys. Res. 142 (1977) 377
- D. Treille, The physics potencial of the RICH, Nucl. Instrum. Meth. Phys. Res A(1996) 178
- C:J:S Damarell. Vertex Detectors: The state of the art and Future prospects. RAL-P-95-008 (Preprint).
- S. Brandt, Data Analysis: Statistical and Computational Methods for Scientists and Engineers, Springer 1999
- R.Y. Rubinstein. Simulation and the Monte Carlo Method. Ed. John Wiley and Sons Inc., Nueva York 1981
- W.T. Eadie. Statistical Methods in Experimental Physics North-Hollad P.C.
- Cosmic Rays and Particle Physics. T.K. Gaisser. Cambridge University Press. Cambridge. 1990.