UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Esperimentazioni di Fisica Nucleare e Subnucleare

2627-3-E3001Q065

Aims

1. Knowledge and understanding
By the end of the course, students will have acquired a solid understanding of the operating principles and main features of the most commonly used particle detectors in nuclear and subnuclear physics, with particular attention to radiation–matter interaction and experimental measurement techniques applied in particle physics research or radiodiagnostics.

2. Applying knowledge and understanding
Students will be able to use scientific instrumentation for the detection of ionizing radiation and to autonomously apply the knowledge acquired to the design, implementation, and optimization of laboratory experiments. This includes the statistical analysis of experimental data and a critical comparison with theoretical models.

3. Making judgements
The course will foster the development of critical thinking skills, enabling students to assess the reliability of measurements, identify the main sources of experimental uncertainty, suggest improvements to the setup or methodology, and interpret unexpected results in a constructive and well-reasoned manner.

4. Communication skills
Students will develop the ability to write clear and rigorous technical-scientific reports based on laboratory activities, and to present and discuss orally the obtained results and theoretical course contents, also within group work settings.

5. Learning skills
The course will promote the development of an autonomous scientific approach and transversal competencies useful for lifelong learning.
Students will acquire:

- methodological tools to independently learn new experimental techniques in nuclear and subnuclear physics,

- the ability to consult scientific literature, technical manuals, instrumentation documentation, and data analysis software,
- skills useful for continuing in laboratory activities, experimental thesis work, or advanced courses in experimental particle physics, radiation detection instrumentation, and related technologies.

Contents

- Introduction to the base principles for ionizing radiation detection

- Practical experiences with alpha radiation detectors for spectroscopic measurements and studies of alpha particle interactions with matter

- Practical experiences with gamma radiation detectors for spectroscopic or PET-like measurements, analysis of gamma particle interaction with matter or of Compton effect

- Practical experiences with organic scintillators for detection and characterization of cosmic rays

- Practical experiences with inorganic scintillators coupled to SiPM detectors for gamma radiation and cosmic rays detection

Detailed program

Introduction to particle detection: particle sources, dosimetry, particle-matter interaction base principles, base principles of more standard particle detectors for spectroscopy or interaction time measurement, signal processing, data acquisition and data analysis.

Practical experiences on one of the 7 experiences available in the laboratory: gamma spectroscopy, Compton Scattering measurement, alfa spectroscopy, Rutherford experiment, experience with scintillators+SiPM detectors, PET-like (2), Coscmic muons measurements.

In particular the experiences are focused on the following activities:
- Alpha, beta and gamma spectroscopy: optimization, calibration and characterization of solid state detectors; measurements of activities; measurements of the range-energy curve and of the specific ionization of alpha particles;

- Measurements of gamma rays absorption and released energy, angle and time correlations in nuclear decays, Compton effect, and measures with PET-like apparatus.

- Characterization of cosmic rays at ground: time of flight, speed and lifetime of muons using plastic scintillators and coincidence/anticoincidence/veto techniques.

- Gamma and cosmic rays measurement with inorganic scintillating crystals coupled do SiPM detectors: characterization and comprehension of the specific properties of SiPM detectors, optimization of working points and parameters for data acquisition, gamma spectroscopy measurements comparing the performances of scintillating crystals made of different compounds.

Prerequisites

- Base knowledge of root or Phyton programming for data analysis
- Base knowledge of statistical data analysis

Teaching form

- **In-person lecture-based teaching: introductory lectures:** 2-hour lectures for a total of 12 hours, held at the beginning of each semester for students who will undertake the practical part in that semester. The lectures cover the topics necessary for the performance and understanding of the laboratory experiences.

- **In-person interactive teaching: practical part:** 84 hours conducted in 4-hour sessions, held twice a week in the mornings. Students can choose to attend in either the first or second semester (subject to availability). During the 84 hours, groups of 2 or 3 students will complete one experience from the available options for the entire duration of the laboratory. Students can express their semester preference through a specific questionnaire that will be published on the e-learning page on July 30, with a deadline of September 14, after an announcement on the forum for those enrolled on the page. Actual participation in the chosen semester will depend on whether the minimum threshold is met. If the maximum number of participants is exceeded for one semester, and there is still availability in the other semester, selection will be based on the chronological order of responses to the questionnaire. Before the start of the practical part, students will be invited by the reference teacher to express their preferences regarding group composition and experience selection. The final assignment of experiences will be made by the teacher, who will take into account the expressed preferences and the practical needs of the laboratory.

Textbook and teaching resource

- Handouts and records of the introductory lessons

- Reference book: G.F.Knoll, “Radiation Detection and Measurement”

- Practical guides for each experience

- Manuals of the used instrumentation

- Gamma/beta and alpha radiation tables

- Reports from previous years' students about the practical experiences

Semester

Lectures provided at the beginning of each semester.

Practical part in the first or second semester depending on the assigned semester (see the "Teaching Methods" section for assignment procedures).

Assessment method

\ - **In itinere tests**: there are no in itinere tests but an integral part of the final evaluation is given by the observation and direct interaction of the teacher with the students in the laboratory. The following are assessed: degree of commitment and active involvement, ability to ask questions aimed at understanding and deepening what one does, aptitude to tackle problems in a critical and constructive way, exploiting all the resources made available by the teacher but also deepening, if necessary , independently.

\ - **Written test**: Final group report regarding the experience that took place during the laboratory course, to be submitted one business week before the oral examination. The report must briefly but completely illustrate the physics problem under consideration, the instrumentation used, the experimental procedure, the critical and statistical analysis of the data, the comparison with expectations and the conclusion. The report must be sent to the teacher at least one week before the scheduled date for the oral exam. This report is an integral part of the final evaluation. The following aspects will be assessed: the structure of the document, clarity, completeness of the content (without including the full theoretical background, which may be cited, but providing the minimum necessary to make the report self-contained), synthesis ability, completeness of the statistical analysis of the results, and the ability to critically interpret the results.

\ **- Oral exam**: Each student must also undergo an interview (it can also be conducted in English upon the student's request), the date of which must be agreed upon with the professor. The interviews can be conducted individually or together by the members of each group. The interview will focus on the laboratory report but also on the topics explained during the introductory lessons. The following will be assessed: the degree of knowledge, of understanding and of in-depth analysis of all aspects related to the experience carried out (subject of physics, detectors used, signal electronic reading chain and its optimization, methodology used for the measurement, data analysis and comparison with expectations), the clarity and completeness of the exposition, the critical spirit in the analysis of the results obtained and the aptitude to find explanations if they differ from expectations.

The final evaluation will take into account all three elements mentioned above, although no fixed weighting is assigned in advance.

Office hours

Everyday, after checking via email the teacher availability

Sustainable Development Goals

GOOD HEALTH AND WELL-BEING | QUALITY EDUCATION | GENDER EQUALITY