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TEACHING PRACTICAL NUCLEAR PHYSICS: A REGIONAL EXPERIENCE[1]

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Abstract

Today in México many universities are in the position to create teaching laboratories in nuclear physics, thanks to the nuclear applications developed by the National Institute on Nuclear Research (ININ) and the Physics Institute (IFUNAM). With the development of various centres of nuclear research, nuclear reactors and so on, training in experimental physics is going to be more important. In this work a teaching project developed in the Modern Physics Laboratories of the Science Faculty (FCUNAM) is described. In these laboratories the students have their first training with nuclear material and electronics. The students show a lack of information on nuclear interactions and types of radiation, dosis and units used. The different efforts to solve the above described situations are presented. The nuclear applications are growing; it therefore appears that familiarity with methods of nuclear physics should form an essential part of the physics, and sciences, student syllabus.

1. Introduction.

With the development of new methods in nuclear physics many areas have been benefitted. These areas which include radioisotope applications are medicine, biology, chemistry, and agriculture among others. The National Institute on Nuclear Research (ININ) and the Physics Institute of the National University of México (IFUNAM) are Mexican research centres where nuclear physics occupies a relevant site; the Federal Commission of Electricity (CFE) has nuclear facilities (nuclear reactors) to produceelectric energy. In the country many hospitals andindustries employ nuclear techniques (and machines) in order to obtain diagnostics in humans and in several industrial processes respectively. These institutions promoted twenty years ago the teaching of nuclear physics; as a result of these circumstances emerged the teaching project on nuclear physics in the Modern Physics Laboratories of the Science Faculty (FCUNAM). This project may be probably the first in our country. At present there are similar teaching projects in all the country, but have a recent creation.

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In spite of the important number of centres where the nuclear methods are employed, the students of scientific careers in the first year of universitary level show a lack of understanding of nuclear topics, even more, they showfear and are incredulous to when to attend to a conference or courses of these themes.

A brief description of the direction that has taken the Teaching Project on Nuclear Physics of the Laboratories of Modern Physics of FCUNAM, is given. The laboratory activities related with the nuclear physics project which are included in a pair of modern physics courses are presented. Along with this a list of general activities provided to preuniversitary students is given. Finally the origins of students misconceptions on nuclear physics are exhibited.

2. Nuclear Physics Experiments.

In this section are described practical activities where the aim is to help toclarify concepts and increase the interest of students. The other objectives are familiarize the students with the nuclear detectors and nuclear electronics, the correct handling of radioactive sources and shielding elements and the comprehension of laws and principles concerning nuclear radiations.

2.a Introductory Experiments.

In order to establish the random nature of the nuclear radiation it is firstly proposed to the students a non-nuclear exercise. With a certain initial number of dices (for example 50) and with a previously chossen number named the "emitted or dead" they proceed to put them into a vessel, stir them and next bring forth on a table. Those dices exhibiting the chossen number are eliminated of the set and counted, the survivors portion follows the same process described before until there are no more survivors. This process where a random number generator is created is employed in this case as an analog of the radioactive disintegration law. The students plot the emitted number as a function of sequencial "measurements" and are instructed to identify certain characteristic points as the ones corresponding to the "half-life", "semi-life" and the type of decaying curve. Another experience sometimes suggested is a RC circuit where it is possible to obtain similar information as before.

Elementary exercises on statistics of nuclear radiation are proposed employing a simple Geiger-Muller detector connected to a scaler and a timer. The students are questioned on class intervals, frequency and statistical distributions. In this case a fixed distance is mantained between the detector and the radioactive source which can be a beta, gamma or mixed radioactive source. This experiment can be suggested as part of a only detection stage, because yetthere is no interest on the energy spectra or other properties. Indeed there are many analogues reported in the literature that can be used depending on the available equipment or the student knowledge.

In the same order of ideas the determination of the operating voltage of a G-M can be suggested as a preliminar experience because only a radioactive source of long lived radioisotope, a scaler, the high voltage supply of the G-M and a fixed distance between detector and source (aprox. 4 cm) are needed. The applied voltage is varied and for the same time intervals the events are counted. Simultaneously the data acquired are exhibited in order to know the plateau region where the operating voltage can be assigned.

The experiences described in this section are suggested as the first contact with the nuclear physics. The students are motivated to reconigze the importance of knowing the statistical tools and the simplest manner of detecting a field of nuclear radiation with the help of a G-M, gaseous detector, despite the specific type of radiation or the absolute magnitude of radiation intensity.

Other activities recomended to essay with the students in order to fix concepts on the nuclear radiations are the is realization of exercises with the nuclide chart. The students have to identify a chossen element then proceed to write their atomic number and the atomic mass. Later they are questioned on different processes as alpha, neutron, beta and gamma decaying, paying attention to the movements realized in the nuclide chart and continuing with the construction of the decaying schemes. In this part it is convenient to try to point out for example the chart position of alpha emitters.

As later will be related, the experiments in this section can be useful for students in elementary physics courses or nonscientific areas.

2.b Basic Experiments.

The basic experiments are currently offered as part of two laboratory courses of modern physics (Laboratorio I and II) for undergraduate students in eighth or ninth semester of the physics career. The laboratory consists of typical modern physics and nuclear experiments. Due to the lack of knowledge on nuclear physics by the students, a continuos assistance is given during the semester. The students recieve an information sheet outlining in a general manner the objectives of the experiment. This information does not contain in detail the set of instructions, rather it is a brief description of the experiment with references and a brief questionnaire on theoretical and experimental aspects. The specific objectives can be modified by the instructor as a function of the experimental curiosity and the skills of the students. The instructor discusses with the students the procedures and precautions to be observed with the equipment and radioactive sources for each experiment. After this introduction to the experiment the student works more independently. The permanent large enrollment obligates to offer four or five Laboratorio I and Laboratorio II courses where the maximum student number is twelve. They are grouped in students teams with two students each. Generally a student team will perform eight experiments in the Lab I and approximately the same number in the Lab II. Four of them are nuclear physics experiments, the choice of a particular experiment depends on the students interest. After completion of the experimental work, the students team prepares a report. The instructor has a discussion with the team about the work and the revised report.

Some of the possible experiments are listed below in the following way: title plus a brief description. The proposed experiments exhibit a range of difficulty that goes from elementary to advanced, but each instructor decides when to assign a certain activity, considering the students aptitudes and past experience.

a) Geiger Muller Counter. The purpose is to study several characteristics of G-M counters such as dead time, the distance effect, radiation absorption by materials and natural radiation detection. The capability to detect beta and gamma radiation with G-M counters is considered. Interface with a PC computer is available.

b) Scintillation Detectors. The objective is to do spectroscopic analysis of gamma sources employing NaI(Tl) scintillation detectors associated to (bench or card type) multichannel analyzers. The particular features of a gamma spectra are presented. A frame of gamma radioactive sources as used for calibration is available.

c) Compton Scattering. The energy of incident and scattered gamma rays is determined using a coincidence technique with two NaI detectors. The angular dependence is stablished. The experimental arrangement employs a low intensity 2 mCi Cs-137 gamma source, nuclear electronic modules and a multichannel analyzer.

d) Positron-Electron Annihilation. The positrons emitted from the source, in this case from Na-22, are slowed down to rest in the source container and then annihilate with electrons of the material, emitting in the process two 0.511 MeV gamma rays. The conservation momentum principle requires that the two gamma rays be emited in exactly opposite direction. Two NaI detectors (with convenient slit entrance) facing each other with the positron's source in the middle are used. The following activity is suggested previously to the students. With a Na-22, source and a NaI detector the gamma spectrum is taken in the multichannel analyzer, this spectrum only exhibits one 0.511 MeV gamma peak. The student is inquired to us a conservation principle and demonstrate the directions of the gamma ray produced by the positron-electron annihilation.

e) Proportional Counter. A series of experiments with proportional counters is offered with the purpose to familiarize the student with this type of detectors. Beta and low energy gamma radiations are analyzed during this series of experiments. The instructor discusses the operation principles of proportional detectors and the differences with other gas filling detectors such as ionization cameras or G-M detectors.

f) Mossbauer Effect. The objective is to observe the nuclear resonant absorption when a beam of gamma rays strikes a target nuclei. At the present, the work is limited to studies at room temperature, but several materials are analyzed. A proportional detector, a commercial source driving device and a multichannel analyzer are used. As soon as posible a refrigeration cycle will be adapted to the Mossbauer system to study high temperature superconductor properties.

g) Range of Alpha Particles with Surface Barrier Detectors (SBD). Firstly the objective is to familiarize the student with the surface barrier detector principles of operation, later the energy lose of alpha particles in air or argon is determined. An important emphasis is devoted to distinguish electronic noise from coherent signal due to alpha particle interactions. The SBD's result convenient to use for teaching purposes because they have a reasonable sensitivity, rugged construction and low cost in comparison with hyperpure Ge and GeLi detectors.

h) Rutherford Scattering. The classic Rutherford Scattering experiment is included. In the interior of a vacuum camera there are various target materials that can be changed from the exterior. An Am alpha source with an appropiate exit slit is mantained to a fixed position while a SBD can be moved within a circular region with the purpose of detecting the scattered alpha particles as a function of the angle.

i) Solid State Nuclear Track Detectors. By their high ionization power the alpha particles produce a severe damage to materials. In materials with very low electric conductivity these damages traduce in permanent defects which can be developed by chemical or electrochemical etching methods. There is a series of experiments where the students study the features of these interactions and the track development methods.

j) Neutron Physics. There is a neutron howitzer with an Am-Be source. A series of experiments on neutron interaction is realized. The study of shielding elements, activation method with silver, the slowing down of neutrons and proportional He detectors are some experiments included in this series. An important emphasis is devoted to study the neutron interactions with plastic materials such as polycarbonate or acetates. The method to develop the tracks due to neutron interactions is the chemical etching, the same assuggested by R. L. Fleischer, P. R. Price and R. M. Walker to solid state nuclear track detectors (SSNTD).

3. The Equipment

During two decades much of the equipment had been derived from research laboratories as the ININ and IFUNAM primarily, on some cases due to regional nuclear instrumentation projects and others because the equipment was insuited to research projects. International organizations as the Organization of American States had equipment programs where it was possible to obtain some instruments. Nevertheless actually some of the equipment has been designed and constructed by the laboratory staff and instructors.

At present time, a great percentage of the nuclear equipment is less than 8 years old. It is of the same type of equipment employed in research, so the students have the opportunity to employ it in an advantageous manner during their teaching sessions. As was noted in the previous section this project has at the present nuclear modules such as amplifiers, double delay amplifiers, coincidence units, scalers, pulsers, dual sum and invert units, time to pulse height converters and high voltage supplies. Also there are multichannel analyzers (bench and cards) and calibration radioactive sources kits. These new apparatus are expensive but allow to offer a modern training program on nuclear science to undergraduate physics students. As part of the modernization of our laboratories, we are connecting experimental arrangements via interfaces to the computers, as an example G-M and X-Ray experiments are performed with the aid of the microcomputers.

4. Other Activities

In addition to the courses, other teaching and divulging activities are realized. Here we present a short description of complimentary activities that are useful to generate a most realistic attitude and intend to provide the basic elements on nuclear themes to physics and nonphysics students.

a) Open Doors. The teaching and research laboratories of the physics department are opened once during a week each year to anyone who wishes to attend. Teachers and students mount several experiments and demonstrations where the public can participate. A great number of people who attend is constituted by high school students. During these days a certain number of posters and demonstrations on radioactive sources, detectors, doses and units are mounted. The concepts are presented paying attention to the interest of public on nuclear themes.

b) Student Minicongress. Physics students adviced by the teachers participate in an internal three days congress which is carried out by the end of the school year. The projects are suggested by the students and can be on physics or interdisciplinary research. A brief memory is published after the congress and prizes (books, software) are given to the winners for the best works. Works on health, radon, ozone cycle are frequent in the recent version of this minicongress.

c) Young Students to Research. During the last four years the university has organized divulging activities in high-school level. This program includes the visit to research and teaching laboratories during two or three months for distinguished students. The purpose is to give the students the opportunity to know how the physics research is guided, and to have firsthand experiences. This program intends to motivate and generate interest toward the science and the scientific careers, because similar to other countries, the students enrollment in scientific careers has disminished in the recent years. In the project of nuclear physics teaching we have received students of this program.

d) Guided Visits. Each semester visits are organized to several research and industry centres, such as the National Institute on Nuclear Research (ININ), the Nuclear Science Institute (ICN-UNAM), the Physics Institute (IF-UNAM) and the Federal Commission of Electricity (CFE). This visits represent an interesting ocassion for the students to know different projects on pure and applied nuclear physics.

e) Learning radioactivity with computers and notes. In 1992 the university began a program on creative uses of microcomputers. We participate with a project entitled "Radioactivity: What is it, how does is behave, how is it detected, what pacific uses has it?". We have initiated a series of computer programs with text and simulations where general aspects of radioactivity are presented. Also there is a brochure, different to the practice guides, whose title is "Notes on Radioactivity and Radiological Security" (in Spanish) published in 1989 by the Faculty of Science (FCUNAM). These notes contain basic information on radioactive sources such as the ones employed in the teaching laboratories, the radiological units and the maximum permissible dosis to humans in different conditions.

We have booklets on specific topics like shielding, electronics, detectors, radioactive sources, radiation units and dosis. Also we have instruction manuals for students and teachers for every suggested experiment as well as computer programs. At present with the help of the students we are realizing videos on nuclear experiments.

5. Discussion

The nuclear physics teaching courses described here have been well accepted by the students of several generations and the faculty members. This project should be readily adapted to other geographic regions; the project does require participation of a great fraction of the faculty. We feel that a course of this type satisfies a real need in providing the students with a very useful knowledge in order to have a well understanding of nuclear fundamentals and applications. More important perhaps, is the type of understanding which incidentally will allow to eradicate misconceptions on nuclear physics. Alternative activities as mentioned here apply outside the school room that are conducted to the public, by example through TV and newspapers with an effective scientific support that can help to have more acquainted students.

Scientists have to rescue nuclear physics from all the ideas and concepts that surround it and that are recorded deep inside the human minds. When nuclear physics is mentioned, many people remember the atomic bombs of World War II orthe nuclear plants accidents or the nuclear arsenals that have the world in a permanent danger. The news that ocassionally appears in television, newspapers and radio transmissions contribute to the fear. But a very important aspect is forgotten and not mentioned: the doses, the energies, the distance and the type of particles that are generated and to which people is exposed in those circumstances. People forget or don´t know we are exposed to radiation all the days of our life, this radiation being natural (cosmic rays and the radiation from radiactive materials in the ground). One should add radiation from dental X rays, TV viewing, etc..

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