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THE ACTIVITIES OF THE PHYSICAL DATA GROUP

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THE ACTIVITIES OF THE PHYSICAL DATA GROUP

ABSTRACT

We have developed a system in which neutron interaction data are collected from nuclear physics laboratories throughout the world, organized, evaluated, and then stored for easy access in our computer network. We have also developed computer codes that use the data to solve neutron interaction problems. The system supplies reliable up-to-date data, selects specific types of data on request, provides output in a variety of forms (reports, microfiche, microfilm) and functions rapidly and efficiently.

INTRODUCTION

All matter is composed of atoms and combinations of atoms called molecules. Atoms consist of basic particles called electrons which surround a nucleus (or core) of protons and neutrons. Electrons and protons carry electrical charges; neutrons do not. In the laboratory, it is possible to produce neutrons that will interact with the nuclei of atoms, thereby causing any one of a dozen or so reactions to occur. Among the most significant:

- The nucleus may gain one neutron or lose one or more neutrons
- The nucleus may lose one or more protons
- Pure energy may be emitted in the form of radiation called gamma rays

When these reactions occur in the laboratory, physicists can make measurements that allow them to deduce what happened during the interaction. The data gained from the measurements can then serve as a basis for predicting numerical quantities associated with nuclear reactions for which there are no experimental (measured) data. Eventually, after much processing, the data can be used as a basis for designing any system in which neutrons interact with matter (e.g., nuclear reactors, nuclear weapons, biomedical diagnostic apparatus, etc.).

More than 1 600 000 measurements have been made involving the interaction of neutrons with nuclei.¹⁻¹⁷ The Physical Data Group of the Lawrence Livermore Laboratory's Theoretical Physics Division has developed a system to collect

this mass of data, organize it, evaluate it, and then make it accessible to the Laboratory's scientists. In addition, the Group is responsible for developing and testing Monte Carlo codes.* The codes have a wide variety of applications, one of which is to recognize deficiencies in the neutron interaction data. Since the Group not only processes the data, but also uses them in its Monte Carlo calculations, it get immediate in-house feedback if there are any problems with the data (or with the computer codes for that matter). The Group can then immediately act to remedy the problem. This immediate knowledge of — and reaction to — data problems differentiates the Group from almost all other data analysis organizations.

As mentioned, one of the activities of the Group is to organize the data. At present, the data are grouped as follows:

- Experimental data for neutron-induced reactions
- Experimental data for charged-particle-induced reactions
- Evaluated data for neutron-induced reactions
- Evaluated data for photon-induced reactions
- Evaluated data for nuclear structure
- Evaluated data for charged-particle-induced reactions
- Computational constants required as input for computer codes
- Standard test problems (based on experiments that approximate actual problems)
- Computer codes that produce and link the data

The heart of the system is the evaluated data: the experimental data only provide a basis for the evaluations, and the standard test problems only provide a way to test evaluated data. Most of the evaluated data have been produced within the group or in collaboration with physicists at other national laboratories.

Once the evaluated data have been produced they are stored in computer disk files. They can then be used as a data base for the computer codes that have been developed by the Group. The codes solve nuclear interaction problems that are so complex that they can only be solved on the largest computers.

* Monte Carlo is a term used to characterize a probabilistic method that simulates physical processes. It is the most successful of the neutronics/ photonics methods because it requires the least assumptions. The method requires the use of random numbers, often called "rolling the dice"; hence, the term Monte Carlo.

As the capacity and speed of computers has improved over the past two decades, our descriptions of what is happening to a material have come closer to what actually occurs in nature. However, even with the enormous increase in computer capacity, it is still usually necessary to average or otherwise modify the basic evaluated data in order to minimize the running time of the codes and maximize the number of materials that can be included in a problem. This is because it can take several tens of thousands of numbers to set up a detailed representation of the evaluated data. The large number of entries results from the fact that the energy range of neutrons, for example, varies by a factor of one billion from the least to the greatest energy.

Evaluated data are based, wherever possible, on measurements. Although more than 1 600 000 measurements^{2,3,10} have been made for the data of neutron-induced reactions, most quantities needed to provide evaluated data for neutronics calculations have not been measured. For almost all the unmeasured quantities, no adequate theoretical method exists for calculating the data. It then remains for the evaluator to use formalized empiricisms (or recipes) to provide the necessary evaluated data. This function can only be performed by qualified physicists who are familiar with the tools of evaluation; these tools include an available library of experimental data, theoretical model codes for the limited area of their applicability, and, above all, familiarity with the trends or systematics of the neutron interaction data from which empiricisms can be derived.

SYSTEM DESCRIPTION

Figure 1 shows the activities of the Physical Data Group. The first activity is to collect experimental data. Two sources provide experimental data:

- The National Nuclear Data Center (NNDC) at Brookhaven National Laboratory — The Center participates in an international effort to collect all experimental data for neutron-induced reactions through an interchange agreement with three other such centers at Obninsk, Vienna, and Paris. As data are collected by NNDC, copies of the magnetic tapes containing the data are routinely supplied to the LLL Physical Data Group.

Fig. 1. Activities of the Physical Data Group. The direct responsibilities of the group are enclosed within the continuous border. The solid arrows represent process flow while the dotted arrows represent feedback that may indicate problems with the data or codes. The numbers below the boxes are references.

- The physicists who measure the interactions of nuclear data — They frequently submit their data to us before publication.

Figure 2 shows the activities that occur before we place the experimental data in our files. Before any data, either numeric or bibliographic, are entered into the collection, a report on the experiment is obtained and checked against the numeric data for that experiment. The bibliographic data are then reproduced as microfiche and copies are distributed to the physicists who produce the evaluated data. The arrangement of the various indexes and data displays shown in Fig. 2 has proved to be the best way of ensuring that physicists have easy access to the data. These standard indexes are produced by computer, then duplicated and distributed as reports for desk-top use. In addition to the standard displays that are produced routinely, we can also retrieve or display experimental data by arbitrarily choosing anywhere from one to a dozen characteristics of the data and then specifying the range of the characteristic(s). For example, we might want to examine data concerning the energy of neutrons and might specify an energy range.

The five libraries or files of evaluated data maintained by the Physical Data Group are identified in Fig. 3 together with a schematic showing the processes used to produce the files. These files are updated routinely whenever changes — either additions or corrections — are needed. Both current and past editions of the files are readily available to LLL personnel.

A family of computer codes that updates, retrieves, and displays the evaluated data has been developed by the Physical Data Group. Using these codes we can computer-generate tables and graphs tailored to the needs of the user.

Most of the evaluations have been done by members of our group, either *in toto* or in collaboration with persons from other national laboratories. The notable exception is the nuclear structure file (Fig. 3), which has been adopted entirely from literature evaluations. The documentation for each file identifies the source of the evaluation.

SYSTEM DEVELOPMENT

The system for encoding and processing the experimental and evaluated data files was developed by the Physical Data Group over the past 20 years. At each phase of development we investigated methods and subsystems developed

Fig. 2. Input (top box) and output (bottom box) processes for the experimental data files. The numbers below the boxes are references.

Fig. 3. Process used to produce evaluated data files. The numbers below the boxes are references.

by others in an attempt to incorporate the best features into our system. Our ultimate purpose was to ensure that changes could be made easily as more detailed requirements were imposed. The system was designed such that each part would be adequate for a period of 3 to 5 years -- with the understanding that some parts of the system would then have to be modified or redesigned.

In developing the system, we assumed that the intrinsic organization of nuclear physics, as with other well-developed disciplines, dictated the design of the system (i.e., the way that the data are organized and displayed is imposed by the nature of the data). Thus, the data are tailored to satisfy the real needs of the users of the system. However, care was taken to insure that the system could be easily extended to accommodate new, but related, types of data as a need became apparent. An example is the system used for dealing with the experimental data of charged particle-induced nuclear interactions. When the system for neutron-induced interactions was designed, the design parameters were chosen such that the system would be hospitable to other inducing particles should a need arise. Such a need did arise and no redesign was necessary to accommodate the data of this closely related field.

The methods or organization of the data and the computer codes used to implement the system can be modified with relative ease to accommodate the information of another discipline. This has been done in the case of the kinetics (division) of biological cells. While the organizational methods and some of the computer codes are similar for the two fields, the two systems are disparate. A superficial case can be made for creating a "super system" that could encompass not only these two fields, but also an indefinite number of others. However, experience has shown that economy of resources (manpower and computer time) can best be achieved by tailoring each system to its own discipline.

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