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THE INTERNATIONAL EVALUATED NUCLEAR STRUCTURE DATA FILE (ENSDF)
IN FUNDAMENTAL AND APPLIED PHOTONUCLEAR RESEARCH

I.N. Boboshin, V.V. Varlamov

(Translation of a Selected Paper from Nuclear Constants 3, 1985,
Original in Russian was distributed as INDC(CCP)-252/G)

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Reference materials for the automation of data provision for scientific research are now becoming increasingly available, both in the USSR and in other countries. The establishment of new data bases, data banks and special software, the development of a reliable data analysis method and the wide-ranging use of computer technology are all conducive both to the organization of fundamental and applied research at a qualitatively higher level and to the greater effectiveness of that research.

At the present stage in the development of nuclear physics, with constantly increasing volumes of data being generated and analysed, the creation of automated information systems is a particularly urgent task. In this connection, there is a need for centres specializing in the collection, classification and processing of nuclear physics data [1, 2]. In the USSR such work is being carried out at the Atomic and Nuclear Data Centre (CAJaD) of the USSR State Committee on the Utilization of Atomic Energy (I.V. Kurchatov Institute of Atomic Energy); the Nuclear Data Centre, of the USSR State Committee on the Utilization of Atomic Energy (Power Physics Institute, Obninsk); the Nuclear Data Centre of the Leningrad Institute for Nuclear Physics of the USSR Academy of Sciences; the Centre for Photonuclear Experimental Data (TsDFEh) of the Scientific Research Institute for Nuclear Physics of Moscow State University; and other organizations.

For the purposes of international co-operation with centres in other countries, a number of nuclear data bases having both bibliographical and "factographic" contents are either being established or already in service: the Evaluated Nuclear Structure Data File (ENSDF) - (USA, USSR, France); the nuclear reaction data library in the EXFOR format (USA, USSR, France, Federal Republic of Germany); the NSR index file of bibliographical references and abstracts on nuclear physics (USA, USSR); and many others.

These data bases and computerized data libraries are distributed in the form of files recorded on magnetic tapes. For the purpose of solving specific problems on the basis of these files, the centres are establishing specialized software systems geared toward specific computer hardware. For work with the ENSDF file, for example, quite successful use is made of the software systems of CAJaD (1010V computer), of the Leningrad Nuclear Data Centre (M-4030 computer) and of the Automated Nuclear Physics Information System group at the Moscow Institute of Physics and Engineering (ES computer).

Work with the ENSDF file at the Centre for Photonuclear Experimental Data (TsDFEh) [3]

Precision research on the processes which accompany the absorption of gamma quanta by atomic nuclei and on interaction processes between other incident particles and nuclei requires accurate data both on the spectroscopic properties of the nuclear energy levels and on the characteristics of the prompt gammatransitions between them. There is great scientific interest in the reproducibility of these properties and characteristics in experiments on various types of nuclear reaction which lead to the formation of one and the same nucleus in the final state. For applied research - e.g. gamma activation analysis - it is necessary to know precisely the characteristics of the delayed gamma transitions which accompany the different types of radioactive decay.

In this connection, in order to provide the necessary nuclear physics data from the ENSDF file to those carrying out such research in the TsDFEh and co-operating organizations, it was decided to set up on an ES computer (ES-1022), a specialized software system which would satisfy the following requirements:

1. Work to be carried out using all the data sets from the ENSDF file;
2. The fullest possible information to be extracted from each data set;
3. The output of information from a data set to be accompanied by the full and detailed commentaries contained in the file, and also by a complete list of bibliographical references to the works from which the data were obtained;
4. The data output to be approximated as far as possible to the traditional representation of diagrams of energy levels and the transitions between them;
5. The software system to permit the solution of search problems on specific request, while allowing simple and efficient reorganization of the corresponding programs. Typical requests for data from the ENSDF file can be illustrated by the following examples:
 - A diagram of energy levels and the transitions between them for a specific nucleus (group of nuclei);
 - The same, but for a particular type of experiment (group of experiments, all possible experiments);
 - The same, but only for certain data sets, sorted out according to a specific indicator, such as information on the spectroscopic factor, the "uniqueness" of betadecay, the lifetimes of the energy levels, and so on;
 - A list of nuclei having certain selected distinctive energy levels, for example isomeric states with particular characteristics (in terms of energy, lifetime, etc.);
 - The same, but for nuclei formed in processes of a particular type, and so on.

We have already mentioned that the software for use with the ENSDF file created by the Automated Nuclear Physics Information System group at the Moscow Institute of Physics and Engineering, was used successfully on the ES computer. However, this software, being geared towards the solution of particular research tasks failed to satisfy the above requirements, with regard to certain parameters, and could serve only as a starting point for the creation of a software system by TsDFEh. Individual programs from the first-generation Automated Nuclear Physics Information System [4] were selected as source programs.

A brief description of the ENSDF file

The file (Fig. 1) consists of a sequence of individual data sets ($A = \dots$) for each mass chain of nuclei with a particular mass number in the range $A = 1-263$. Within each mass chain the data for the different nuclei are

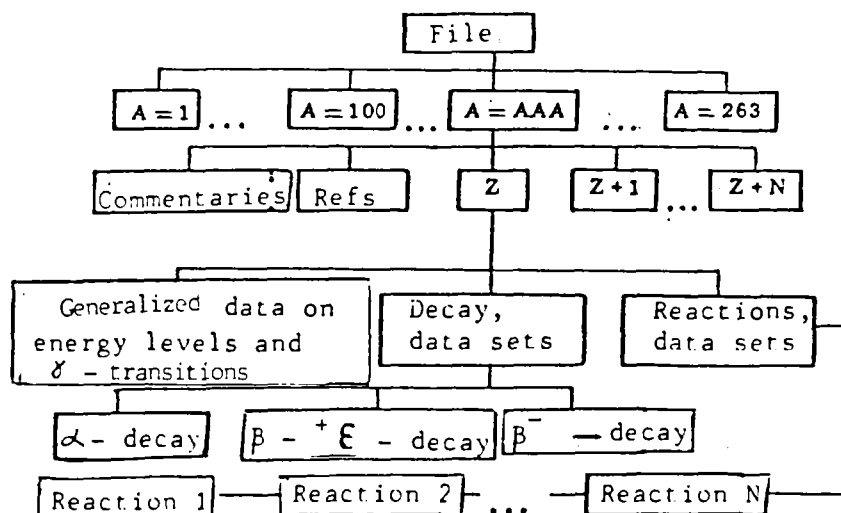


Fig. 1: General Structure of the File

arranged in order of increasing nuclear charge Z and are preceded by sets of commentaries and references.

Each data set for a nucleus with specific A and Z contains information derived from a particular experiment on radioactive decay or a nuclear reaction. Apart from such sets, there are also data sets which sum up and generalize the data for energy levels and transitions in a specific nucleus obtained from all the experiments represented in the file. Each individual data set in the file is identified according to mass number, chemical symbol and type of experiment. The information is represented in the file in the form of entries, 80 characters long.

Block diagram of the TsDFEh's software package for use with the ENSDF file

In order to meet the requirements listed above and to solve a broad class of search problems arising from specific requests relating to nuclear spectroscopic information from the ENSDF file, a branch program system was created, the general structure of which can be represented as a four-block diagram (Fig. 2). The flexibility of the system and the ease with which it can be rearranged stem from its block/modular structure. The "data reading" block shows the structure of an individual data set from the file.

The program system is organized in such a way that the acquisition of information of a particular type from the ENSDF file corresponds to a particular combination of modules within the system.

In conjunction with a particular operating module the search routine enables the user to "access" data sets, whose identification entry satisfies the prescribed conditions. These conditions may vary over a wide range, from an undifferentiated request (access to every data set) to a data set request that is strictly unique in terms of all three identifying parameters (mass number, chemical symbol and type of experiment). The selective search algorithms operate within these limits, finding mass numbers within given intervals, types of experiment or groups of similar experiments, and so on.

The unit which reads information from the data sets comprises specific modules which read from and enter into the computer memory information from individual entries, each of which describes specific physical

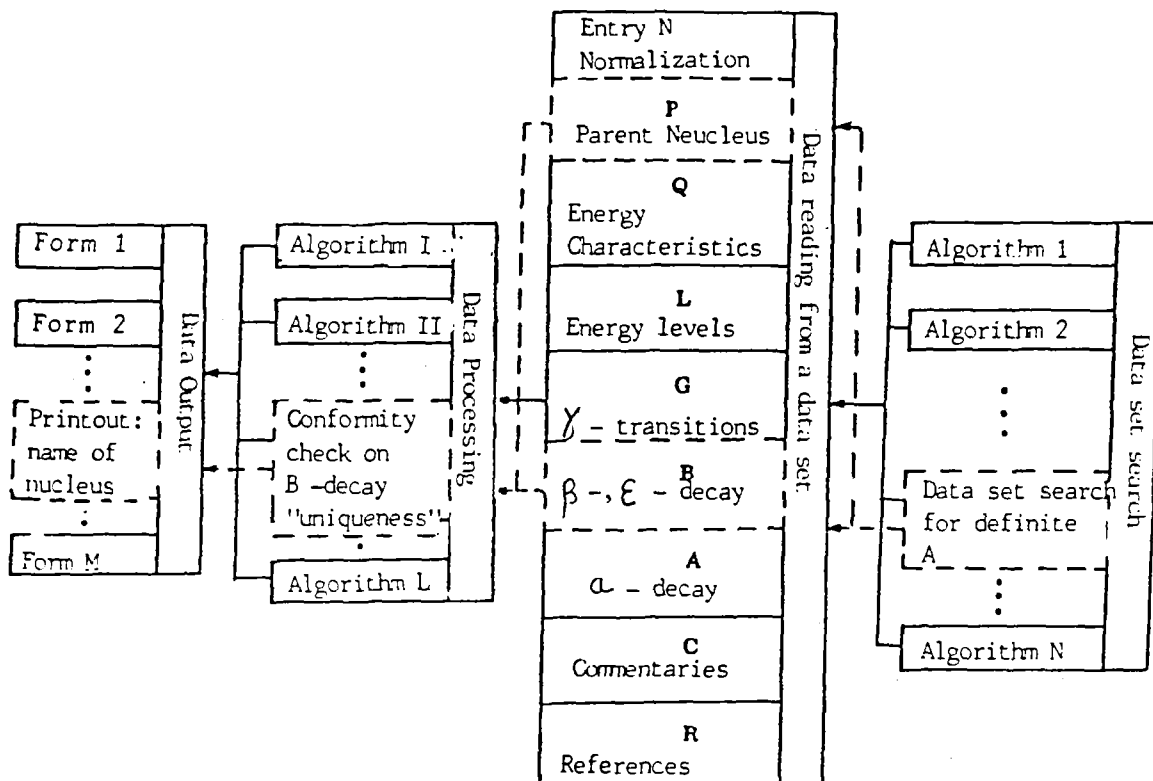


Fig. 2: General structure of the software system (dotted line signifies a combination of modules for a single specific search program)

characteristics. Choosing the necessary combination of working modules is in this case a matter of "suppressing" the reading of "superfluous" entries.

After the search routines have operated and a program, organized on the above lines has been read, a working information set is created in the computer memory in the form of variables with specific names; this makes it possible to perform different types of processing and to obtain various kinds of output of this information. The processing may include, for example, a check on the conformity between any of the characteristics of the prepared data sets and the request and search conditions. The output of information can be organized in the form that is most appropriate for the data in question. In some instances, lists of nuclei, whose properties satisfy the request conditions, or tables showing the characteristics of the corresponding gamma transitions (ordered, for example, according to energy or intensity or both, and the like) may be obtained. Thus, in the event of a request concerning information on nuclei with particular mass numbers, whose beta decay has a given "uniqueness", the program appears as shown by the broken lines in Fig. 2.

The search routine accesses only those data sets that have the mass numbers A indicated in the request (the identification by the element's chemical symbol and the type of experiment being ignored). Within the reading unit, all modules are "suppressed" except for the one which reads the characteristics of the parent nucleus and of the beta decay. If the "uniqueness" of the latter corresponds to the value requested, control is then transferred to the output unit, which produces the information in the appropriate form (in the simplest case only the name of the nucleus is printed out).

The work of the individual units of the software system can be described most fully through a detailed examination of one of the programs - the most general and comprehensive - in this package, namely the SUPER ("energy levels and transitions diagram") program.

The SUPER program

This program is characterized by the great generality of its search algorithm and the great comprehensiveness of its read unit. It generates the above-mentioned program units of the system being described.

At the input stage the program receives a request relating to the location of a uniquely determined data set of any type (generalized data, decay, reaction). At the program output, and on the basis of the information read from the corresponding data set, a diagram is presented in graphic form showing the nucleus's energy levels and the transitions (decay scheme) between them.

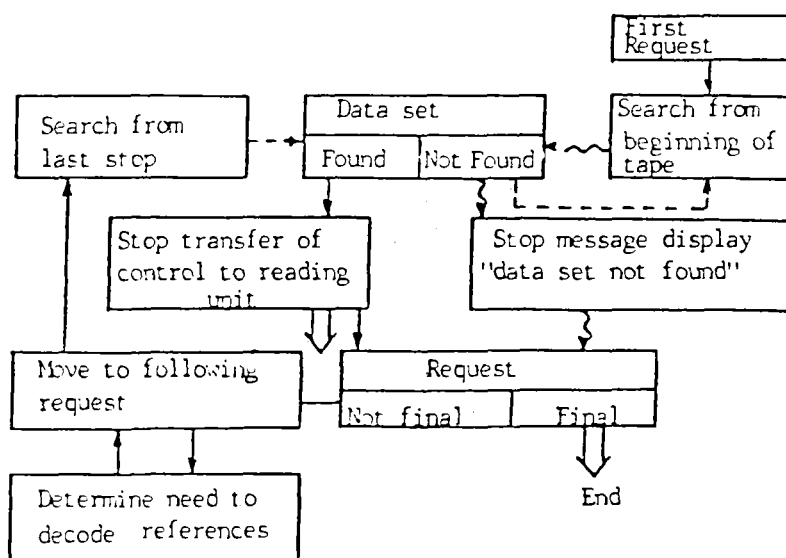


Fig. 3: Diagram showing operation of the SUPER program's data set search routine

Search for a data set: the operation of this unit of the software system when the SUPER program is being run is illustrated by the block diagram in Fig. 3. Since the ENSDF file is stored on tape and has a sequential structure, i.e. the data sets follow one another in order of ascending nuclear mass number, the SUPER program is organized in a particular manner.

When a number of successive requests are to be processed, the search for the next data set, after the one in hand has been processed, does not start from the beginning of the tape, but from the point where the previous set was found. On the diagram the "search from beginning of tape" mode is indicated by a wavy line, while a broken line is used to show the "search from last stop" mode. Logical connections, indicated by a continuous line, are made in both modes.

Thus, if the data sets in the requests come in the same order as on the tape, then all the requests will be processed with a single run-through of the tape, thereby considerably reducing the running time of the program. Upon receipt of the first request, the program begins to scan consecutively through the data sets. When it has found the required set and has read and printed

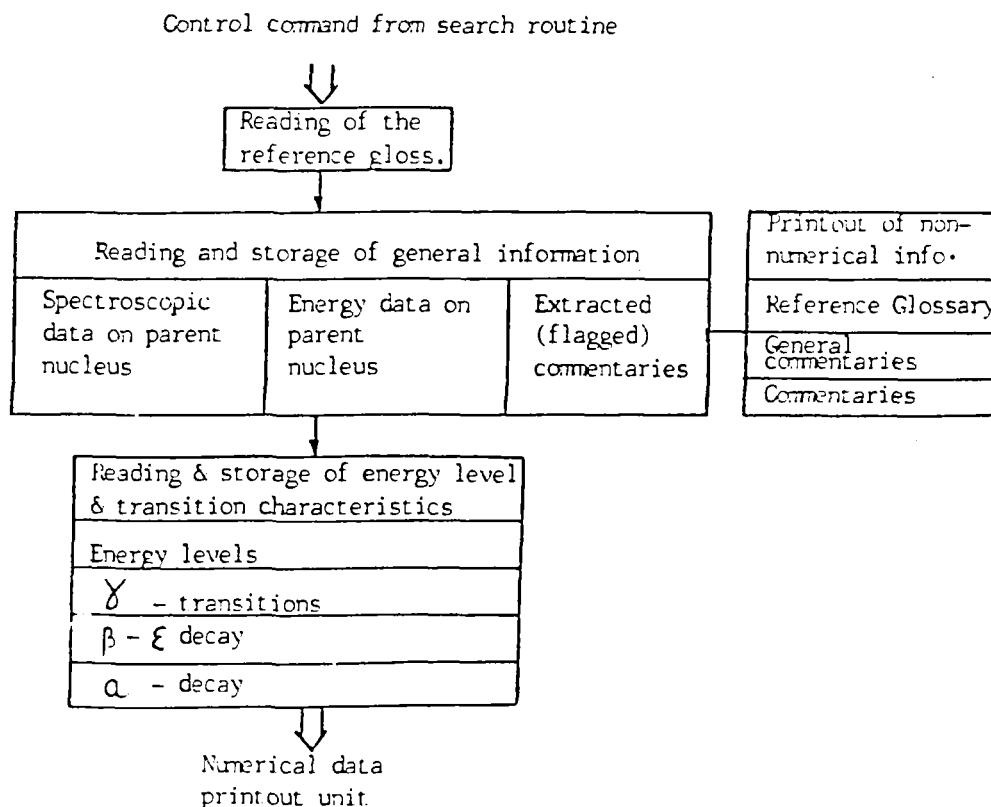


Fig. 4: Diagram showing operation of the SUPER program's unit for reading data from a data set.

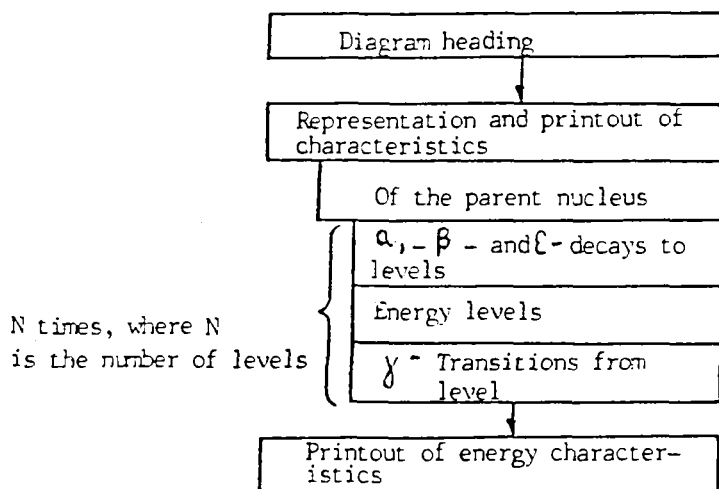


Fig. 5: Diagram showing operation of the SUPER program's data output unit

out the information from it, the program then turns to the following request and, having received it, scans further in search of the corresponding data set, and so on up to the last request. Should the programme fail to find a particular requested set (this situation typically arises when the mass number being read exceeds that requested, with no information being generated on the request involved), there are two possibilities:

- Either the regular scan-through started at a point which was known to lie beyond the required set. In this case the search is recommenced from the beginning of the tape;

- Or the scan-through is started from the beginning of the tape. Should the required set not be found, this means that it is not in the file, and an appropriate indication will be given.

Since the decoding of references is contained in the file for all nuclei with a given mass number (for the whole mass chain), this decoding is printed out only in cases where the mass number in the new request differs from that in the previous one.

Reading and processing of information from a data set: The operation of the unit for reading information from a data set (Fig. 4) is organized such that it can read from the tape and record in the computer memory all the information contained in the data sets in the file. This is important not only for determining the completeness of data in diagrams of nuclear energy levels and the transitions between them, but also for creating the above-mentioned special programs.

When the reading unit receives a control command from the search routine, the first thing that happens is that a glossary of references is read and simultaneously printed out. Then, following the output of the data set identification card, that is, of the distinctive heading which had already been read at the search stage, the following are read into the computer memory:

- The characteristics of the parent nucleus, in the case of a data set describing decay (decaying energy level, half-life, etc.);
- The energy characteristics of the nucleus, in the case of a set comprising "generalized data on energy levels" (nucleon separation energy, energy of ground-state α - and β -decays);
- Commentaries with a special marking which relates a given commentary to specific entries in a data set. Commentaries relating to the entire data set are also read and then output here. This is followed by the recording into the memory of multiply located information, i.e. characteristics of energy levels and different kinds of transition, to which end appropriate variable assays are formed. At the same time, the α -, β - and γ -transitions are referenced to the corresponding energy levels, the commentaries to the corresponding energy levels and transitions (including the previously read marked commentaries) and the commentaries are printed out.

Having organized the working set with the numerical information in the computer memory, the program moves on to the next block in the diagram, namely, the output of this information.

Information output unit: The operation of this unit (Fig. 5) is organized such as to maximize the ways in which information on energy levels and transitions can be represented (for example, according to their number), and to do this in as graphic a form as possible.

This unit prints out the traditional energy level and transition diagram. An example of such a printout is shown in Fig. 6. The levels are indicated by horizontal lines, the energy decreasing from top to bottom. Here also the characteristics of the levels are represented: spin, parity, lifetime, transferred angular momentum, spectroscopic factor, etc. The vertical arrows designate the γ -transitions from each level, together with an indication of the characteristics of the transition (energy, intensity, multipolarity, etc.) and of the level to which the transition goes. For decay

reactions it is possible to represent the parent nucleus and the observed decays together with the corresponding characteristics. In addition to this, there are special graphical symbols for levels and transitions which are identified in the file as being problematic, as well as for transitions which are part of transition cascades and for predicted but unobserved transitions. All the characteristics are output together with their symbols (for example, E for energy). The output of characteristics is organized according to the principle of non-zero output, i.e., for example, in the absence of data or energy the symbols are not produced either. The values of the standard deviations of physical quantities are given in brackets.

Technical features of the SUPER program

Type of computer	ES-1022
Operating system	OS.4.1
Interactive system of the applied program package	DUVZ
Internal memory capacity	250 kbyte
Typical run time for an ordered set of requests (with a single run-through of a magnetic tape containing data)	10-20 min

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