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INTERNATIONAL NUCLEAR DATA COMMITTEE

# First Research Co-ordination Meeting on DEVELOPMENT OF REFERENCE INPUT PARAMETER LIBRARY FOR NUCLEAR MODEL CALCULATIONS OF NUCLEAR DATA

Cervia (Ravenna), Italy, 19 to 23 September 1994

## SUMMARY REPORT

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## Table of Contents

# INTRODUCTION

The $1^{st}$ Research Coordination Meeting (RCM) on "Development of Reference Input Parameter Library for Nuclear Model Calculations of Nuclear Data" was held in Cervia(Ravenna), Italy, from 19 to 23 September 1994. The RCM was hosted by the ENEA Bologna, Italy.

The purpose of the RCM was to review current status of work in developing of the Reference Input Parameter Library and to work out detailed working programme of the Co-ordinated Research Programme (CRP) on "Development of Reference Input Parameter Library for Nuclear Model Calculations of Nuclear Data". The RCM was attended by all (nine) chief scientific investigators involved and by two local observers.

Prof. A.V. Ignatyuk of the Institute of Power and Engineering, Obninsk, Russia has been elected as a chairman of the RCM.

The agenda of the RCM included scientific and technical presentations of participants, discussion of the scope of the CRP, and discussion of future tasks and actions. The product of the CRP will be the library of numerical data that will serve as input parameters for cross section calculations of nuclear data by nuclear reaction models. Scientific background of the CRP, its scope and goals are summarized in the attached Information Sheet (see Appendix 1).

The Reference Input Parameter Library should consist of 6 segments, with additional $7^{th}$ segment proposed at this RCM. For each segment a coordinator was selected among the CRP participants. The coordinator should overview, guide and coordinate development of the particular segment of the Library. The list of segments is as follows:

I. Atomic Masses, Shell Corrections and Deformations
(Coordinator M.B. Chadwick, Livermore, USA)

II. Discrete Level Schemes
(Coordinator G. Molnár, Budapest, Hungary)

III. Average Neutron Resonance Parameters
(Coordinator G. Reffo, Bologna, Italy)

IV. Optical Model Parameters
(Coordinator P.G. Young, Los Alamos, USA)

V. Level Densities
(Coordinator A.V. Ignatyuk, Obninsk, Russia)

VI. $\gamma$ Ray Strength Functions
(Coordinator M. Uhl, Vienna, Austria)

VII. Angular Distributions
(Coordinator M.B. Chadwick, Livermore, USA)

Conclusions and recommendations of the Research Coordinated Meeting including a detailed list of actions and deadlines are given below. The agenda, the list of participants, titles and abstracts of presented papers is attached (see Appendix 2).

The procedure for transfer of files to the IAEA NDS Vax computer and their access via the electronic network Internet was agreed by the participants.

The RCM stressed close link between the current IAEA activity in developing of the Reference Input Parameter Library and the associated activity of the NEA Data Bank Paris on Nuclear Model Validation. The product of the NEA activity should be well tested and well documented nuclear reaction model codes, while IAEA should develop the library of input data for these codes for nuclear data calculations.

A special role is recognized of the ENEA Bologna for the development of the Reference Input Parameter Library. Particularly, it is expected that ENEA Bologna will host specialists' for a critical analysis of different files aimed at arriving at a recommended file of average neutron resonance parameters. A similar role of ENEA is expected in terms of level densities and discrete level schemes.

The participants strongly recommended to hold the $2^{nd}$ RCM by the end of 1995. Vienna was proposed as a venue of the meeting.

The RCM had full and efficient support of local organizers. The participants expressed their gratitude and appreciation to Dr. G. Reffo of ENEA Bologna for his excellent work as a local organizer of the RCM.

# CONCLUSIONS AND RECOMMENDATIONS

## I. Atomic Masses, Shell Corrections and Deformations

Coordinator: M.B. Chadwick, Livermore, USA

### Status

A new (1994) file of atomic masses, shell corrections, and ground-state deformation parameters produced by Möller at al. (Ref.1) has been delivered to the Agency. This work has been accepted for publication in Atomic Data and Nuclear Data Tables. The file contains tabulations of theoretical calculations, along with experimental masses from the 1989 compilation by Audi et al. Additionally, a new (1993) compilation of experimental and recommended atomic masses by Audi and Wapstra (Ref.2) has been delivered to the Agency.

CNDC Beijing has developed its MCC file (Atomic Masses and Characteristic Constants of Nuclear Ground State) and submitted it to the Agency. The file is a part of CENPL, Chinese Evaluated Input Parameter Library.

It was noted that the on-line code QCALC by T.W. Burrows (Ref.3) is now available on-line both in the NNDC (Brookhaven, USA) and IAEA NDS. This code can be used to retrieve ground-state masses.

It was noted that Audi et al. (Ref.4) are developing NUBASE, a critical compilation of the Atomic Mass Evaluation and the Evaluated Nuclear Structure Data File. NUBASE gives experimentally known nuclear properties and some that have been estimated from extrapolations for more than 2 855 nuclides in ground-state, 623 first and 60 second isomers: mass, isomeric excitation energy, half-life, spin, parity, decay modes and branching ratios.

References:


1. P. Möller, J.R. Nix, W.D. Myers and W.J. Swiatecki" "Nuclear Ground-State Masses and Deformation" (1 August 1994), accepted for publication in Atomic and Nuclear Data Tables.

2. G. Audi and A.H. Wapstra: "The 1993 Atomic Mass Evaluation", Nuclear Physics **A565**(1993)1 and **A565**(1993)66. Numerical data are available on-line in IAEA.

3. T.W. Burrows: "On-Line Q-Value Calculation Program: QCALC" (1 August 1994). The code is available on-line in NNDC and IAEA.

4. G. Audi, O. Bersillon, J. Blachot and A.H. Wapstra: "NUBASE". Under development, to be available sometime in 1995.

## Recommendations

We recommend that the Möller file be used for $B_n$, Q–values calculations, shell correction, and deformation. Where experimental values of masses exist, they should be used. In other cases the calculated values should be used. Where more detailed information is needed, and for nuclides lighter than oxygen (which were not considered by Möller), the recommended values by Audi et al. should be consulted.

## Actions

1. P. Young will supply the Agency with the README file for Möller's file.
   ** Action Young, deadline 15 October 1994*

2. The Agency will put the Möller's file into its on–line databases.
   ** Action Obložinský, deadline 31 December 1994*

# II. Discrete Level Schemes

Coordinator: G. Molnár, Budapest, Hungary

## General

Starter files containing discrete level schemes with level energies, spins, parities and gamma-ray branching ratios are or will be available from the Agency. These are the files of the

1. Nuclear Data Centre, ENEA Bologna, Italy
   (File LIVELLI, version 1993 + updates 1994)

2. Nuclear Data Center, FEI Obninsk, Russia
   (Files SEDL and SEDL–RADA, version 1993)

3. Bruyeres-le-Chatel, France
   (The Bruyeres-le-Chatel discrete level library, version 1991 + later updates)
   (Conversion of the ENSDF format, only partially available at IAEA)

4. Chinese Nuclear Data Center, Beijing, China
   (File will be delivered to IAEA)
   ** Action Su Zongdi, deadline 31 December 1994*

5. Nuclear Data Center, JAERI Tokai-mura, Japan
   (File will be delivered to IAEA)
   ** Action Fukahori, deadline 31 October 1994*)

All these files are based on data retrieved from the Evaluated Nuclear Structure Data File (ENSDF), prepared as a cooperative effort by an international network of nuclear physicists under coordination of the IAEA. These files differ in scope, format and frequency of update.

## Recommendations

1. A single recommended file has to be created, in line with the early conclusions of the 1993 IAEA Consultants' Meeting.

2. The ENSDF should remain the primary source of input data as it guarantees the high quality of evaluated data. Missing or ambiguous information should be replaced, however, by educated guesses to make the database suitable for nuclear reaction model calculations.

3. The starter file should be based on the Bologna file because

   - its data content is properly referenced

   - its format is concise yet sufficiently complete.

4. Reasonable cutoff energies should be defined for each nucleus by assessing the degree of completeness of the level scheme by means of

   - using the information from the Obninsk file, complemented with information for light ($A < 20$) nuclei from the Livermore biological file

   - inspecting the experimental methods used to obtain the ENSDF data from the viewpoint of non–selectivity.

5. The starter file should be compared with the other existing files not used for creating it.

## Actions

1. The existing data files from Bologna and Obninsk will be retrieved from the Agency's database by the Budapest group. Descriptions of the Obninsk files will be provided by Ignatyuk to the Agency. Chadwick will supply information on light nuclei along the same lines.
   ** Action Chadwick, deadline 15 October 1994*
   ** Action Ignatyuk, deadline 10 November 1994*

2. Flagging of the Bologna file in terms of cutoff energies from Obninsk and Livermore will be done at Budapest.
   ** Action Molnár, deadline 15 November 1994.*

3. Budapest will produce a code which translates ENSDF data into Bologna format.
   ** Action Molnár, deadline 1 January 1995*

4. The Budapest and Bologna groups will complement the Bologna file with all information available from ENSDF and from the CRP laboratories. Included will be new evaluated ENSDF data on level energies, spins, parities, branching ratios, as well as cutoff energies and estimates for missing experimental spin values. This work is meant to be a task for the entire CRP period of three years and should be started in November 1994 by Reffo and Molnár in Bologna.
   ** Action Molnár, deadline standing*

5. The Budapest group will survey the ENSDF level schemes of all nuclides in the mass range $50 < A < 150$ from the point of view of completeness of experimental method.
   ** Action Molnár, deadline 1 April 1995.*

6. The Budapest and Bologna groups prepare an updated version of the starter file by 1 June 1995 and circulate it via the Agency. New data from ENSDF, added to the original Bologna file, will not be flagged.
   ** Action Molnár, deadline 1 June 1995*

7. The Japanese CRP participants compare the original Bologna file with their own file and give feedback by 1 May 1995.
   ** Action Fukahori, deadline 1 May 1995*

8. The coordinator prepares the first-year report, with help from Bologna, and submits it together with the starter file to the Agency.
   ** Action Molnár, deadline 1 July 1995*

## III. Average Neutron Resonance Parameters

Coordinator: G. Reffo, Bologna, Italy

### Objective

The final objective of the activity is to make available a file of neutron resonance parameters, useful for both level density parametrization and cross section calculations. The present effort is oriented to produce a table of recommended resonance parameters which includes s– and p–wave strength functions, average resonance spacings and total radiative widths.

### Status

Presently, 3 files are available, from Obninsk, Beijing and Bologna, respectively. Obninsk file contains average resonance spacings strength functions and total radiative widths, both for s– and p–waves. Beijing file contains average s–waves resonance spacings. Bologna file contains s–wave mean resonance spacings, strength functions and total radiative widths per spin state; in particular, the number of resonances adopted for each isotope is given. The file is complemented with a short description of the statistical analysis methods adopted.

Bologna has produced comparative tables where all available information on the subject is lumped together in order to give exact map of the present situation. From these tables it appears that the Beijing file is the one which covers the largest number of isotopes. Furthermore, it appears that in most cases, within the quoted uncertainties, there is agreement among the different files. In a 15–30% of cases, however, one observes discrepancies at the limit of the uncertainty overlap interval beyond it.

**Recommendations**

1. It is generally recommended that the involved specialists from the different laboratories meet in Bologna, for a suitable length of time to solve the remaining discrepancies.

2. One person from Beijing and one person from Obninsk will join the group in Bologna Nuclear Data Center, hosted by ENEA, in the frame of the agreement engagement between the Agency and ENEA.

3. JAERI involvement in this activity would be highly welcomed.

**Actions**

1. Reffo will send the Agency for distribution the Bologna file in ASCII format complemented with a README file.
   * *Action Reffo, deadline 15 October 1994.*

2. Ignatyuk will provide to Bologna the file of neutron resonances not included in the Mughabghab compilation.
   * *Action Ignatyuk, deadline 31 december 1994*

3. Ignatyuk will complement his file with the number of resonances used in the determination of $D$. Brief description of methods will be also provided.
   * *Action Ignatyuk, deadline 31 January 1995*

4. Su Zongdi provides to Bologna the resonance schemes missing from the Mughabghab compilation.
   * *Action Su Zongdi, deadline 31 December 1994.*

5. Su Zongdi will complement the CNDC file with information on the methods adopted to derive $D$.
   * *Action Su Zongdi, deadline 31 March 1995.*

6. Su Zongdi will complement the file with the information on the number of resonances used for their analysis and uncertainties on $D$.
   * *Action Su Zongdi, deadline 31 March 1995.*

7. The recommended updated table of average resonance parameters will be prepared by Bologna for distribution by the time of the next CRP Meeting.
   * *Action, Reffo, deadline next CRP Meeting*

## IV. Optical Model Parameters

Coordinator: P.G. Young, Los Alamos, USA

Participants of the $1^{st}$ Research Coordination Meeting on Development of Reference Input Parameter Library for Nuclear Model Calculations of Nuclear Data considered the question of developing a suitable library of optical model parametrizations for the RIPL. Activities from the previous preparatory meetings were discussed, and summaries of optical model activities were given by Su Zongdi, Reffo, Fukahori, Ignatyuk, Garg, and Young concerning their respective laboratories. From this discussion, plans were formulated for accumulating optical model parametrizations from the various laboratories and for developing the required RIPL library over the period of time covered by the CRP. Preliminary discussions were held concerning possible quantities to include in the library. In addition to the standard parameters, the possibility of including dispersive and folding optical model parameters was discussed.

### Recommendations and Actions

Detailed activities planned for the next year, together with a general plan covering the three-year CRP, are given below.

1. It is recommended that computer files of optical model parameters be collected in a "working file" at the IAEA/NDS, from which a general "user file" will eventually be constructed. All participants who are willing should send their parameter files to Pavel Obložinský prior to the next CRP meeting. It was agreed that Young, Su Zongdi, Fukahori, and Garg will supply their files to the NDS by April 1, 1995, in order to facilitate development of a preliminary file by the next CRP meeting. The information to be provided (1) a data file with the required parametrizations, and (2) a "README" file that describes the contents of the data file.
   * *Action Fukahori, deadline 1 April 1995*
   * *Action Garg, deadline 1 April 1995*
   * *Action Su Zongdi, deadline 1 April 1995*
   * *Action Young, deadline 1 April 1995*

2. All participants are encouraged to provide to Young any technical references or other materials on optical model potentials that they view as useful.

3. Garg and Young agreed to develop a trial or preliminary format for the optical model parameterization library for consideration at the next CRP meeting. Garg will transform the parametrizations that are available in the NDS working library to a file of information in the preliminary format in time for discussion at the next CRP meeting. The final format, together with a clear definition of the quantities to be included in the library, should be approved at the next CRP meeting. Preparation of the preliminary working library should be complete 2 months before the next CRP Meeting.
   ** Action Garg, deadline 2 months before the next CRP Meeting*
   ** Action Young, deadline 2 months before the next CRP Meeting*

4. Following approval of the format, Garg will convert all parametrizations provided to the NDS to the final form. It is anticipated that the accumulation of parametrizations will continue in the second year of the CRP. Garg and Young will formulate a recommended subset of the parameters for the final starter file by the end of 1996. This file will be provided to the NDS for distribution and consideration by the CRP members.
   ** Action Garg, deadline 31 December 1996*
   ** Action Young, deadline 31 December 1996*

5. The final library will be assembled for discussion and approval at the final CRP meeting.
   ** Action Young, deadline the final CRP Meeting*

## V. Level Densities

Coordinator: A.V. Ignatyuk, Obninsk, Russia

### V.1. *TOTAL LEVEL DENSITIES*

Coordinator: A.V. Ignatyuk

### Total Level Densities Description

In processes of discussions it was shown that three models of the level density are used widely in practical applications: the back-shifted Fermi gas model, Gilbert-Cameron approach and generalized superfluid model. It was recommended to include in the starter file of RIPL the level density parameters for all these models. It is very important to use in any applications the parameters based on consistent set of experimental data on the density of neutron resonances and low-laying levels.

### Recommendations and Actions

1. Results of analysis of both the neutron resonance densities and cumulative numbers of low-laying levels were discussed in the reports of Obninsk, Chinese and Indian groups. The files of corresponding parameters in computer readable form are available in IAEA NDS from Obninsk only. Similar files from JAERI, ENEA, China and India useful for analysis of the parameter differences should be sent to NDS before 31 December 1994.
   * *Action Fukahori, deadline 31 December 1994*
   * *Action Garg, deadline 31 December 1994*
   * *Action Reffo, deadline 31 December 1994*
   * *Action Su Zongdi, deadline 31 December 1994*

2. After removing contradictions in the neutron resonance density analysis and updating of the average resonance parameters for corresponding nuclei the estimations of the level density parameters must be performed by Obninsk and Beijing groups independently. The results of this analysis will be discussed in Bologna with those of the Bologna group. Final conclusions will be discussed at the next CRP Meeting. The exact formulas used for the level density description must be supplied together with the parameter tables.
   * *Action Ignatyuk, deadline next CRP Meeting*
   * *Action Reffo, deadline next CRP Meeting*
   * *Action Su Zongdi, deadline next CRP Meeting*

3. An activity of Budapest group in a re-evaluation of the cumulative numbers of the low-laying levels will be welcomed for nuclei where essential contradictions of the level density parameters are obtained.
   * *Action Molnár, deadline standing*

4. Bologna will provide routine (code PARAMI) containing overall systematics used in Bologna.
   * *Action Reffo, deadline 15 October 1994*

5. A close cooperation with the NEANSC Working Party on the level density analysis for the most important constructive materials ( iron group isotopes) is recommended. The results of this analysis should be discussed at the next CRP Meeting.
   * *Action Ignatyuk, deadline next CRP Meeting*

## V.2. *LEVEL DENSITIES FOR FISSION*

Coordinator: A.V. Ignatyuk

The fission barriers compiled by Chinese group were briefly discussed. Unfortunately, this compilation is not taking into account the comprehensive systematics of the fission barriers performed by the G.Smirenkin group (Ref.1). It was noted that the new re-evaluation of the fission level densities will be reasonable only on the basis of consistent systematics of the fission barriers and new level density parameters of heavy nuclei.

References

1. G. Smirenkin: "Preparation of Evaluated Data for a Fission Barrier Parameter Library for Isotopes with Z = 82 – 98, with Consideration of the Level Density Models Used", Report INDC(CCP)-359 (IAEA, Vienna 1993)

**Recommendations and Actions**

1. The fission barriers recommended by Obninsk group can be considered as the first version of the recommended parameters for fission cross section calculations. The computer readable file of these parameters should be sent to the NDS before 31 December 1994.
   ** Action Ignatyuk, deadline 31 December 1994*

2. The analysis of these barriers by the Chinese group with an account of the Chinese Fission Barrier Library will be welcomed. The proposal on the updated fission barriers should be sent to the NDS before 1 June 1995.
   ** Action Su Zongdi, deadline 1 June 1995.*

3. The fission level density parameters based on updated fission barriers should be prepared by the Obninsk group.
   ** Action Ignatyuk, deadline next CRP Meeting*

**V.3.** *PARTIAL LEVEL DENSITIES*
Coordinator M.B. Chadwick

Partial level densities are one of the most important ingredients in preequilibrium cross section calculations. Many approaches have been developed to calculate these densities, though their determination remains an extremely difficult task. The partial level density in general depends sensitively on shell and pairing effects. With increasing excitation energy the impact of such effects varies, often in an ill-defined way, and there are few clean experimental signatures which can test the validity of different partial level density models. The Williams model (with finite well depth restrictions) is one of the simplest approaches which is widely used in preequilibrium calculations. Many more sophisticated approaches have also been developed. For instance, the Bologna model which accounts for shell effects within a Williams-type expression is particularly useful for applications since it combines a description of shell effects with ease of application. Likewise, there have been recent developments by Kalbach, among others, which account for shell effects within computationally straightforward approaches.

A wide variety of partial level density models have been used in applications, and in many cases errors in these densities are largely compensated by other parameters in the preequilibrium models which have been tuned so as to reproduce experimental data. Therefore the impact of these errors is often not as great as one might at first expect. However, there is a need for improvements in partial level density modeling to facilitate reliable calculations in new regions of parameter-space, and to enable correct interpretations of other parameters that enter into preequilibrium calculations such as residual-interaction strengths.

### Recommendations and Actions

1. To guide those involved in preequilibrium reaction calculations, we recommend that Chadwick, in collaboration with the Bologna group and other experts, develop a text file which reviews the various approaches that have been developed to determine partial level densities. This file will contain a description of the methods used and an assessment of the strengths and possible drawbacks of each approach for evaluation work. Full references will be provided, and examples of modeling calculations based on these methods described. This work should be included as a RIPL starter-file at the Agency.
   * *Action Chadwick, deadline next CRP Meeting*
   * *Action Reffo (M. Herman), deadline next CRP Meeting*

2. Based on the above work, the members of this CRP will assess whether it would be useful to collect input parameters for some of the methods described in the above work and include them in a RIPL file.
   * *Action Chadwick, deadline next CRP Meeting*
   * *Action Reffo (M. Herman), deadline next CRP Meeting*

## VI. $\gamma$ Ray Strength Functions

Coordinator: M. Uhl, Vienna, Austria

### Recommendations and Actions

We recommend the following gamma-ray strength function models for the mass range A = 100-200.

1. E1-RADIATION: An enhanced generalized Lorentzian which is characterised by 3 or 6 Lorentzian parameters and by the two enhancement parameters ($k_0$ and $\epsilon_0^\gamma$). Regarding the Lorentzian parameters we suggest to use parameters derived from photoabsorption data or, to resort to systematics if those are not available. Formulas to calculate Lorentzian parameters will be provided within short time by Su Zongdi from the Chinese Nuclear Data Center and by A. Ignatyuk from

the Institute of Physics and Power Engineering. Formulas based on the hydrodynamic model which reproduce experimental data in a wide mass range will be published by G. Reffo from ENEA Bologna. These formulas will be provided to M. Uhl, IRK Vienna.

* *Action Su Zongdı, deadlıne 31 January 1995*

* *Action Ignatyuk, deadlıne 31 January 1995*

* *Actıon Reffo, deadline immediately after publication*

For the enhancement reference energy $\epsilon_0^\gamma$ we propose to adopt the reasonable value of 4.5 MeV. The enhancement factor $k_0$ can be determined by reproducing experimental data or by simple formulas describing the trend of these quantity. Note that the enhancement factor sensitively depends on the underlying level density model. For some nuclei an E1 pygmy resonance contribution derived from a standard Lorentzian is required to reproduce the high energy end of the gamma-ray production spectra.

M1-RADIATION: A standard Lorentzian representing a spin-flip resonance with global prescriptions for the resonance energy and the width. The peak cross section should be determined from experimental strength function data derived from resonance analysis or from simple formulas describing the trend of these quantities.

E2-RADIATION: A standard Lorentzian representing the giant quadrupole resonance with global prescriptions for the Lorentzian parameters.

M2-, E3-, M3- RADIATION: The single particle model with a strength of 1 Weisskopf unit/MeV.

2. Vienna will contribute the gamma-ray strength function segment of the starter file with the following content:

   - Employed parameters for E1- and M1-strength functions for the nuclei studied so far in the mass region A=100-200 comprising:

     a) Lorentzian parameters

     b) enhancement factors $k_0$ for the E1-radiation enhanced generalized Lorentzian model

     c) level density parameters

     *Note: b) and c) will be given at least for one level density model (presumably the backshifted Fermi gas level density model)*

   - README file

   - Formulas for calculating quantities not given in the file as

     a) GDR Lorentzian parameters

b) Spin-flip resonance parameters
c) Giant quadrupole resonance parameters
d) Enhancement factor $k_0$

* *Action, Uhl, deadline 1 May 1995*

## VII. Continuum Angular Distributions

Coordinator: M.B. Chadwick, Livermore, USA

Evaluated nuclear data files usually require a description of the angular distributions of emitted particles. The Kalbach systematics, which are a phenomenological parameterization of over 900 sets of experimental measurements, very successfully characterize these distributions and have been widely used. A short computer code to compute these angular distributions (written by Kalbach) has been delivered to the Agency and includes her recent (1992) developments.

There exist a number of theoretical approaches to calculating preequilibrium angular distributions. Such approaches are of interest since they are grounded in physics and enable angular distributions to be determined in cases where the Kalbach systematics may not apply. A new theoretical approach to determine angular distributions has been developed by Chadwick and Obložinský. This approach provides a physical basis for the Kalbach systematics and allows angular distributions to be calculated in a straightforward manner.

### Recommendations and Actions

1. The Kalbach systematics are generally the most accurate way to describe continuum angular distributions. They are easy to apply computationally; apply to a wide variety of projectile/ejectile types; and they have been well-tested. Therefore we recommend their use in nuclear model calculations if an accurate result, rather than an approach based upon a physical derivation, is required.

2. At present the theoretical model by Chadwick and Obložinský has been tested successfully for a limited number of reactions involving nucleons, and a parameter to approximate quantum effects has been determined for reactions with incident energies up to 100 MeV.

   We recommend that Chadwick and Obložinský test the model against a wider set of experimental data and perform a comparison of its predictive power with that of the Kalbach systematics. Results should be presented at the next CRP Meeting.
   * *Action Chadwick, deadline next CRP Meeting*
   * *Action Obložinský, deadline next CRP Meeting*

## File Exchange and Access

The following 3-step procedure was proposed and accepted by the RCM.

1. A RIPL file should be transferred by a CRP participant into the IAEA NDS via the international computer network INTERNET. The file should be put to the open area of the IAEA NDS Vax computer, into its directory UD4:[SCR.RIPL]. This can be done by the FTP (file transfer protocol). Commands to be used:

   - ftp iaeand.iaea.or.at (alternative: ftp 161.5.2.2)
   - user ndsopen
   - cd [.ripl]
   - dir
   - put file.name
   - exit

2. Since anybody has a free access to the IAEA NDS open area (there are unrestricted read and write privileges) the file should be afterwards transferred to a protected area of the IAEA NDS Vax computer. This area will be under the directory UD4:[RIPL] with the privileges for an outside user restricted to "read only". The transfer from UD4:[SCR.RIPL] into UD4:[RIPL] will be done by the IAEA NDS staff member (P. Obložinský). Then, the original file in UD4:[SCR.RIPL] will be deleted by him.

   It seems useful that the UD4:[RIPL] be divided into sublibraries according to particular segments of RIPL, say, UD4:[RIPL.OPTICAL] etc. However, it seems that the total amount of data in the RIPL library will be of the order of 10 MB only. There should, therefore, be no particular problem with the storage of the data.

3. A CRP participant can access the protected area UD4:[RIPL] via INTERNET by using FTP. The file can be thus transferred from the IAEA NDS Vax computer to the local computer of the CRP participant for its further use. Commands to be used:

   - ftp iaeand.iaea.or.at (alternative: ftp 161.5.2.2)
   - user ripl
   - cd [.optical]
   - dir
   - get file.name
   - exit

Names of sublibraries are as follows:

I. Atomic Masses, Shell Corrections and Deformations
UD4:[RIPL.MASSES]

II. Discrete Level Schemes
UD4:[RIPL.LEVELS]

III. Average Neutron Resonance Parameters
UD4:[RIPL.RESONANCES]

IV. Optical Model Parameters
UD4:[RIPL.OPTICAL]

V. Level Densities
UD4:[RIPL.DENSITIES]
UD4:[RIPL.DENSITIES.TOTAL]
UD4:[RIPL.DENSITIES.FISSION]
UD4:[RIPL.DENSITIES.PARTIAL]

VI. $\gamma$ Ray Strength Functions
UD4:[RIPL.GAMMAS]

VII. Angular Distributions
UD4:[RIPL.ANGULAR]

VIII. Readme
UD4:[RIPL.README]

## Summary of Actions

Altogether 36 actions were specified. Given below is their brief summary.

I. Atomic Masses, Shell Corrections and Deformations
2 actions

II. Discrete Level Schemes
2 actions (General)
8 actions

III. Average Neutron Resonance Parameters
7 actions

IV. Optical Model Parameters
4 actions

V. Level Densities
5 actions (Total Level Densities)
3 actions (Level Densities for Fission)
2 actions (Partial Level Densities)

VI. $\gamma$ Ray Strength Functions
2 actions

VII. Continuum Angular Distributions
1 action

# APPENDIX

International Atomic Energy Agency

Co–ordinated Research Programme on

# "Development of Reference Input Parameter Library for Nuclear Model Calculations of Nuclear Data" (Phase I: Starter File)

*Information Sheet*

## 1. Scientific Background

A long–standing problem, how to meet nuclear data needs of the future with limited experimental resources, puts a considerable weight on nuclear model computation capabilities. Originally almost all nuclear data was provided by measurement programs. Over time, theoretical understanding of nuclear phenomena has reached a considerable degree of reliability, and nuclear modelling has become an important source of evaluated nuclear data. The nuclear measurement program could never supply all of the needed data, so results of theoretical programs have been assimilated in order to supplement the measurement results. Due to the widespread use of nuclear models in generating evaluated nuclear data there is a substantial demand for input data needed to perform such calculations. There is also an important economical argument behind this demand since theoretical calculations are much cheaper than costly and time consuming experimental procedures.

Considering neutron–induced reactions in the incident energy range up to about 30 MeV one has a set of well established nuclear reaction models that cover almost all aspects of physics involved and thus also all data of practical interest. These nuclear reaction models are optical, statistical including fission, preequilibrium/multistep and direct. Outgoing particles of major interest are neutrons, protons, $\alpha$ particles and $\gamma$ rays.

Practical use of nuclear model codes requires a considerable numerical input that describes various properties of nuclei involved. Some of these properties are in themselves model dependent. Altogether 6 major input parameter data sets were identified [1, 2]. The list consists of: (1) Atomic masses and related data, (2) Discrete level schemes, (3) Average neutron resonances, (4) Optical model parameters, (5) Level densities (total, partial, fission), and (6) Gamma–ray strength functions.

An ultimate objective of any international effort along the above lines is to develop a library of evaluated input model parameters. Considering that such a task indeed is ambitious, the objective of the proposed CRP can be only limited. It should summarize present knowledge on input parameters, whenever possible critically analyze these paramaters and to develop a single starter file of input model parameters. This data base will be of immediate practical value for a number of users and it should represent a firm basis for any future improvements and developments.

**References**


1) G. Reffo, O. Bersillon, D.W. Muir and A.B. Pashchenko: "Reference Nuclear Parameter Library for Nuclear Data Computation", Summary report of the IAEA Consultants' Meeting held in Vienna, Austria, 13–15 November 1991 (Report INDC(NDS)-266, IAEA Vienna, January 1993).
2) G. Reffo, M.B. Chadwick, A.V. Ignatyuk, J. Kopecky, D.W. Muir and A.B. Pashchenko: "Standard Input Data Sets for Nuclear Model Computations", Summary report of the IAEA Consultants' Meeting held at Sirolo (Ancona), Italy, 21–25 June 1993 (Report INDC(NDS)-282, IAEA Vienna, September 1993).


## 2. General Information on the CRP

Where it is deemed desirable that several institutes co–operate in furthering research in a given field, Co–ordinated Research Programme (CRP) represents an effective means to bring together researchers to collaborate in a well defined research topic. The role of the International Atomic Energy Agency (IAEA) is to define, co–ordinate and support the programme.

The duration of a CRP is generally 3 years, but an extension is possible, if recommended and approved by the IAEA. Research Co–ordination Meetings (RCMs) are generally convened at the beginning, in the middle and at the end of a CRP, with the purpose to define details of the programme, review the progress and formulate final report.

In accordance with the proposal from the IAEA Nuclear Data Section and with endorsement by the International Nuclear Data Committee (INDC), an advisory body for the nuclear data programme of the IAEA, the proposed CRP on "Development of Reference Input Parameter Library (RIPL) for Nuclear Model Calculations of Nuclear Data" was recommended to start in 1994.

## 3. Scientific Scope and Proposed Programme Goals

The CRP should cover 6 major parameter data sets listed below. Nuclear modelists, evaluators and practitioners from both developed and developing countries would be set together so that each item is covered by 1–3 experts. The goal of the CRP is to develop a starter file of the input model parameter library.

The following input parameter data sets should be included into the file:

- Atomic masses, shell corrections and deformations
- Discrete level schemes
- Average neutron resonances
- Optical model parameters
- Level densities (total, partial, fission)
- Gamma–ray strength functions

Expected output of the CRP is a complete starter file of input model parameters arranged in a processing–oriented format and equipped with a retrieval/processing code. This reflects an important aspect of our strategy to set up a CRP with well defined goals that can be realistically reached in 3 years time.

## 4. Participation

Due to budgetary limitations only a selected number of laboratories can participate in this CRP. Selection of participants will be based on the relevance of the current and projected work described in the proposals received from potential participants. As soon as the proposals have been evaluated all potential participants will be notified and only at that time a decision be made concerning actual participation in the CRP.

## 5. Activities

The major activities will be performed by individual participants at their home institutes. Periodically (approximately every 18 months) the IAEA will convene CRP meetings, bringing together all participants to review the status of the activities of the CRP. Between meetings participants are encouraged to inform the IAEA of all relevant work on the subject and to send copies of all papers, progress reports, etc. to the IAEA which will be distributed to all participants. At least once a year each participant must submit a progress report to the IAEA.

## 6. Research Agreements/Contracts

In order to participate in this CRP each participant must enter into a research agreement or contract with the IAEA. Participants from Developed Countries (as defined by the IAEA) must enter into a research agreement. Under a research agreement a participant does not receive from the IAEA any direct financial support for research. The only financial support received from the IAEA under a research agreement is transportation and per diem of the principal investigator or his representative to attend periodic CRP meetings. Participants from Developing Countries (as defined by the IAEA) can enter into a research contract. Under a research contract in addition to financial support to attend CRP meetings participants can also receive a small amount of financial support for research (up to US$ 5,000 per contract year). Research agreements and contracts are reviewed (based on annual reports) and, subject to approval by the Director General, renewed each year.

## 7. Duration of the CRP

The CRP will run for three years (1994–1997).

## 8. Additional Information

Additional information on the CRP may be obtained from:

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International Atomic Energy Agency

First Research Co-ordination Meeting on

# Development of Reference Input Parameter Library for Nuclear Model Calculations of Nuclear Data

Cervia (Ravenna), Italy
19-23 September 1994

# AGENDA

# ABSTRACTS

# LIST OF PARTICIPANTS

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First Research Coordination Meeting on
**Development of Reference Input Parameter Library for Nuclear Model Calculations of Nuclear Data**

Cervia (Ravenna), Italy
19-23 September 1994

# AGENDA

## 1. Timetable

**Monday, 19 September**

| | |
|---|---|
| 09:00 - 09:30 | Opening of the Meeting<br>- Host (**G. Reffo**)<br>- IAEA (**P. Obložinský**)<br>- Election of the Chairman<br>- Adoption of the Agenda |
| 09:30 - 12:00 | Presentations: Regional approaches to RIPL<br>- Talk #1 (**T. Fukahori**)<br>- Talk #2 (**Su Zongdi**) |
| 12:00 - 14:00 | Lunch |
| 14:00 - 17:30 | Presentations: Segments of RIPL<br>- Talk #3 (**G. Molnár**)<br>- Talk #4 (**G. Reffo**)<br>- Talk #5 (**P.G. Young**) |

**Tuesday, 20 September**

| | |
|---|---|
| 08:30 - 12:00 | Presentations: Segments of RIPL (continued)<br>- Talk #6 (**Su Zongdi**)<br>- Talk #7 (**S.B. Garg**)<br>- Talk #8 (**A.V. Ignatyuk**)<br>- Talk #9 (**A. Mengoni**) |
| 12:00 - 14:00 | Lunch |

| | |
|---|---|
| 14:00 - 17:30 | Presentations: Segements of RIPL (continued)<br>- Talk #10 (**M. Herman**)<br>- Talk #11 (**M.B. Chadwick**)<br>- Talk # 12 (**M. Uhl**) |

**Wednesday, 21 September**

| | |
|---|---|
| 08:30 - 12:00 | Discussions: RIPL and its Starter File<br>- General Discussion<br>- Current Status of RIPL<br>- Future scope of RIPL |
| 12:00 - 14:00 | Lunch |
| 14:00 - 17:30 | Discussions: Working plan of the CRP<br>I. Atomic Masses, Shell Corrections and Deformations<br>II. Discrete Level Schemes |

**Thursday, 22 September**

| | |
|---|---|
| 08:30 - 12:00 | Discussions: Working plan of the CRP (continued)<br>III. Average Neutron Resonances Parameters<br>IV. Optical Model Parameters |
| 12:00 - 14:00 | Lunch |
| 14:00 - 17:30 | Discussions: Working plan of the CRP (continued)<br>V. Level Densities<br>VI. $\gamma$ Ray Strength Functions<br>VII. Angular Distributions |

**Friday, 23 September**

| | |
|---|---|
| 08:30 - 12:00 | Recommendations<br>- Summary of partial coordinators<br>- Adoption of the final report |
| 12:00 - 14:00 | Lunch |
| 14:00 - 15:00 | Conclusions<br>- Conclusions and summary of the Meeting<br>- Closing of the Meeting |

## 2. Talks and Contributions on RIPL and its Segements

For more details see Abstracts.

Contributions are meant as short papers (5'-10') to be presented either immediately after related main talks or at the discussion session.

**Regional approaches to RIPL**

- Talk #1: "Database of Model Parameters and Inegrated Nuclear Data Evaluation System", T. Fukahori and T. Nakagawa, JAERI Tokai-mura

- Talk #2: "Progress and Activities on Reference Input Parameter Library for Nuclear Model Calculations of Nuclear Data at CNDC"

**Segements of RIPL**

a) Atomic Masses, Shell Corrections and Deformations
   Coordinator: none
   - Talk: none
   - Contribution Su, remark Young, remark Obložinský

b) Discrete Level Schemes
   Coordinator: G. Molnár
   - Talk #3: "Complete Spectroscopy of Discrete Nuclear Levels", G. Molnár, BNS Budapest
   - Contribution Su, contribution Reffo

c) Average Nuetron Resonances
   Coordinator: G. Reffo
   - Talk #4: "On Average Neutron Resonance Parameter File", G. Reffo, ENEA Bologna
   - Contribution Su

d) Optical Model Parameters
   Coordinator: P.G. Young
   - Talk #5: "Experience at Los Alamos with Use of the Optical Model for Applied Nuclear Data Calculations", P.G. Young, LASL Los Alamos
   - Talk #6: "Sublibrary of Optical Model Parameters", Su Zongdi, CNDC Beijing
   - Talk #7: "Optical Model and Level Density Parameters for Nuclear Data Evaluation", S.B. Garg, BARC Bombay
   - Contribution Reffo

e) Level Densities
Coordinator: A.V. Ignatyuk

- Total level densities:
  - Talk #8: "Analysis of the Neutron Resonance Densities, Low-Lying Levels and Level Density Parameters", A.V. Ignatyuk, FEI Obninsk
  - Talk #9: "Fermi-gas Parameterization and Open Problems in Nuclear Level Density Calculations", A. Mengoni, ENEA Bologna
  - Contribution Ge, contribution Herman

- Partial level densities:
  - Talk #10: "On Quasi-Particle Level Density: Proposal for the Validation of Semimicroscopic Partial Level Densities", M. Herman, ENEA Bologna
  - Talk #11: "Continuum Angular Distributions in Nuclear Model Calculations", M.B. Chadwick and P. Obložinský, LLNL Livermore and IAEA Vienna

- Fission level densities:
  - Contribution Ge

f) Gamma-Ray Strength Functions
Coordinator: M. Uhl

- Talk #12: "Gamma-Ray Strength Function Models and their Parameterization", M. Uhl and J. Kopecky, IRK Vienna and ECN Petten
- Contribution Ge, contribution Reffo

# ABSTRACTS

# A Database for Model Parameters and Integrated Nuclear Data Evaluation System

T. Fukahori and T. Nakagawa
Nuclear Data Center, Department of Reactor Engineering,
Japan Atomic Energy Research Institute,
Tokai-mura, Naka-gun, Ibaraki, 319-11 Japan

The integrated nuclear data evaluation system (INDES) is being made in order to support the evaluation work. INDES manages a database; the evaluation data file (EVLDF) storing the basic nuclear physics parameters such as optical model potential parameters, level density parameters, mass excess data, level scheme and gamma transition from excited levels, and various information, for example, names of theoretical calculation codes used in JENDL-3 evaluation work. By using EVLDF and the other databases, INDES automatically creates input data and JCL for several theoretical calculation codes for the nuclear data evaluation. A guidance system in INDES, which is called 'Evaluation Tutor (ET)', can support users in selecting a set of suitable theoretical calculation codes by applying knowledge engineering technology and the experiences of evaluation work for JENDL-3.

In the present report, the outline of INDES functions, databases in INDES, and physical quantities included in EVLDF are introduced. The format of EVLDF is also explained.

# 7 PAPERS FROM CNDC BEIJING

## Talks

1. The Progresses and Activities on Reference Input Parameter Library for Nuclear Model Calculations of Nuclear Data at CNDC
   (Su Zongdi)

2. The Sub-library of Optical Model Parameters (OMP)
   (SU Zongdi)

## Contributions

3. The Sub-Library of Atomic Masses and Characteristic Constants for Nuclear Ground States (MCC)
   (Su Zongdi)

4. The Sub-Library of Discrete Level Schemes and Branch Ratios of Gamma Decay (DLS)
   (Su Zongdi)

5. The Sub-Library of Level Density (LDL)
   (Ge Zhigang)

6. The Sub-Library of Giant Dipole Resonance Parameters for Gamma-Ray Strength Functions (GDP)
   (Ge Zhigang)

7. The Sub-LIbrary of Fission Barrier Parameters (FBP)
   (Ge Zhigang)

# COMPLETE SPECTROSCOPY OF DISCRETE NUCLEAR LEVELS

G. Molnar
Institute of Isotopes, H-1525 Budapest, Hungary

Nuclear reaction model calculations require the complete knowledge of discrete level schemes of the residual nucleus. For statistical reaction models knowledge of the discrete levels below the continuum must be known in the target nucleus as well for higher energies. Such a knowledge is also useful for the direct test of level density models describing the continuum regime. Beside level energies, spins and parities accurate gamma-ray branching information is also required, especially when isomers are present.

Completeness can be guaranteed only if a reaction statistically populating all levels in a certain energy and spin window is used for the excitation. For neutron projectiles averaged resonance capture and low-energy inelastic neutron scattering or (n,n'gamma) reaction are the best choices. For charged particles heavy ion fusion-evaporation reactions near the Coulomb barrier, typically (alpha,n) reactions, have proved most promising. In deformed nuclei the band structure should be studied in addition, with selective reaction probes.

The adopted level and decay schemes of each nucleus of practical interest should be re-examined with regard to completeness. Several examples will be shown to illustrate the capabilities of "complete" spectroscopic methods, especially neutron-induced reactions. Some conclusions will be attempted concerning the present situation.

## 7 PAPERS FROM ENEA BOLOGNA

1. ON AVERAGE RESONANCE PARAMETER FILE.
   G. Reffo (30-60) + we should allow some time for comparisons and discussions, if we intend to have a workshop on this we may need couple of hours.

ABSTRACT. Details of the methods and tools used for average resonance parameter determination are given together with an overall description of the parameter tables. An intercomparison is given of different resonance parameter determinations. Proposals for further cooperative work are made.

2. FERMI-GAS PARAMETRIZATION AND OPEN PROBLEMS IN NUCLEAR LEVEL DENSITY CALCULATIONS.
   A. Mengoni (30) + 10

ABSTRACT. A new systematic is presented based on the usual Fermi-gas model with account of collective effects.

3. ON QUASI PARTICLE LEVEL DENSITY: PROPOSAL FOR THE VALIDATION OF SEMIMICROSCOPIC PARTIAL LEVEL DENSITIES.
   M. Herman (20) + 10

ABSTRACT. A brief review of the work done at Bologna will be followed by considerations on what more can be done in terms of:
a. interpreting total level densities,
b. what can be learnt from q-p l.d. about the correct interpretation of the energy corrections accounting for residual interactions,
c. possibility of parametrizing q.p. level density.
   Proposals for future work are made.

.......................................................................

4. DESCRIPTION OF THE BOLOGNA DISCRETE LEVEL SCHEME FILE.
   G. Reffo (5-10) + 10

ABSTRACT. A description is given of the content and of the format of the discrete level scheme released to the IAEA.

5. A MINI OPTICAL MODEL PARAMETER FILE AS AN EXAMPLE AND THE SIMPLIFIED ACCESS TO IT.
   G. Reffo (5-10) + 5

ABSTRACT. An example is given of optical model parameter forms adopted at Bologna and of the simple access to it.

6. MICROSCOPIC SINGLE PARTICLE COMPONENT AND COLLECTIVE CONTRIBUTIONS TO TOTAL LEVEL DENSITY.
   M. Herman (20) + 10

ABSTRACT. Single particle component of total level density is derived from the shell model eigenvalue spectrum for the different excitation energies. Collective effects are studied from the difference of experimental a-values from the ones corresponding to the pure single particle component. Proposals for future work are made.

7. FORMULAE FOR E1-GIANT RESONANCE PARAMETER DETERMINATION
   G. Reffo (15) + 5

ABSTRACT. A semiphenomenological approach is described, based on the hydrodynamic model, for a quite accurate determination of E1-Giant Resonance Parameters. (text not ready for distribution)

Note:
Numbers after authors indicate roughly the presentation and discussion time respectively.

# EXPERIENCE AT LOS ALAMOS WITH USE OF THE OPTICAL MODEL FOR APPLIED NUCLEAR DATA CALCULATIONS

P. G. Young
Los Alamos National Laboratory

While many nuclear models are important in calculations of nuclear data, the optical model usually provides the basic underpinning of analyses directed at data for applications. An overview is given here of experience in the Nuclear Theory and Applications Group at Los Alamos National Laboratory in the use of the optical model for calculations of nuclear cross section data for applied purposes. We consider the direct utilization of total, elastic, and reaction cross sections for neutrons, protons, deuterons, tritons, 3He and alpha particles in files of evaluated nuclear data covering the energy range of 0 to 200 MeV, as well as transmission coefficients for reaction theory calculations and neutron and proton wave functions in direct-reaction and Feshbach-Kerman-Koonin analyses. Optical model codes such as SCAT and ECIS and the reaction theory codes COMNUC, GNASH, FKK-GNASH, and DWUCK have primarily been used in our analyses. A summary of optical model parametrizations from past analyses at Los Alamos will be given, together with illustrations of results from calculations using the various optical potentials and comparisons with experimental data.

# Optical Model and Level Density Parameters for Nuclear Data Evaluation

S.B.Garg, BARC-Bombay 400 085

It is now recognized that all the desired reaction cross-sections required in reactor technology and other allied sciences can not be measured in a short span of time due to various limitations. Nuclear models are, therefore, destined to play a vital role in predicting a large variety of data for meaningful technological applications. Nuclear models need some basic input parameters which determine the accuracy and acceptability of the computed data.

We plan to compile and utilize the following categories of basic input parameters:

1. Optical Model Potential Parameters: These parameters determine reaction, shape-elastic and total cross-sections of a nuclide at a given particle incident energy. The reaction cross-section is further split up into various components by including the outgoing particle channels by taking into account their transmission coefficients. Usually neutron,proton and alpha outgoing channels are considered.So,optical model potential parameters for neutron,proton and alpha-particle would be needed.These parameters would be compiled for a large number of nuclides extending up to 30 MeV energy range or more. Emphasis would be laid on spherical optical model,however, wherever possible parameters based on deformed optical model would also be compiled.

2. Level Density Parameters: The computed cross-sections show sensitivity to the level density parameters employed in the calculations. Usually parameters based on Fermi gas, Back-shifted Fermi gas and the super-fluid models are utilized. Appropriate parameters pertaining to these models together with the pairing and shell energy corrections would be compiled from the open literature. Energy dependent level density parameters would also be evaluated by including the s-wave level spacings and shell energy corrections.

# ANALYSIS OF THE NEUTRON RESONANCE DENSITIES, LOW-LYING LEVELS AND LEVEL DENSITY PARAMETERS

A.V.Ignatyuk
Institute of Physics and Power Engineering, Obninsk, Russia

ABSTRACT

Main differences of existed evaluations of the neutron resonance densities and low-lying level densities are considered. Corresponding uncertainties of the level density calculations are demonstrated for some typical nuclei. Problems of a consistent systematic of the level density parameters are discussed.

# Continuum angular distributions in nuclear model calculations

M.B. Chadwick and P. Oblozinsky
LLNL Livermore and NDS IAEA Vienna

There are a variety of different approaches for modeling the angular distribution of particles emitted in nuclear reactions. Some are based upon theoretical considerations, while others are obtained from parametrizations of experimental measurements. The most widely-used approach in evaluation work is to apply the Kalbach systematics, which account for measured forward-peaked angular distributions. These systematics have been very successful for analyzing and predicting double-differential cross sections, though their physical basis has remained obscure until recently, and they cannot be used in regions of parameter-space not included in the original parameterization.

We review the Kalbach-systematics work, and provide computer subroutines for use by evaluators. We also present our recent theoretical work, which provides a physical basis for the Kalbach-systematics by considering the momentum dependence of partial level densities. Our derivation explains the observed general forward-peaked shape of exp (cos (angle)), and theoretically predicts the extent of the forward-peaking. Some useful features of our approach are that (1) it is grounded in theory; (2) it provides angle-energy correlation for all orders of scattering; and (3) it enables angular distributions to be determined in reactions not considered by Kalbach, such as photonuclear mechanisms via the quasi-deuteron mechanism. We show some comparisons of our theory with measurements, and discuss future work that is needed for these theoretical developments to be of use to evaluators.

We recommend that linear momentum parametrization of particle-hole level densities be included into the Level Density segment of the Reference Input Parameter Library.

Gamma-ray Strength Function Models and their Parameterisation

M Uhl
Institut fur Radiumforschung und Kernphysik, University of Vienna, Austria

J Kopecky
Netherlands Energy Foundation ECN, Petten, The Netherlands

Abstract

An upgraded compilation of experimental E1- and M1 strength functions resulting from the analysis of discrete resonance data is presented. If all these strength functions are normalised to the same transition energy, 7 MeV say, the dependence on the mass number can be represented by simple expressions.

We further study the impact of models for gamma-ray strength functions $f_{XL}$ on the calculation of capture cross sections and related quantities For M1 and E2 radiation we employ strength functions derived from a standard Lorentzian with a global set of parameters. For the dominant E1 strength, however, individual Lorentzian parameters derived from photoabsorption data are used as far as possible. Besides the standard Lorentzian we apply for $f_{E1}$ also a generalised Lorentzian, which is characterised by an energy dependent width and an finite limit as the energy tends to zero. In the mass region A=100-200 a standard Lorentzian for $f_{E1}$ works only for strongly deformed nuclei. For these nuclei the generalised Lorentzian, which reasonably reproduces the data for many spherical and transitional nuclei in this mass region, fails In order to obtain an E1 strength function model for the whole mass region we propose the "enhanced generalised Lorentzian" with two parameters depending rather smoothly on the mass number.

INTERNATIONAL ATOMIC ENERGY AGENCY

First Research Co-ordination Meeting on

# Development of Reference Input Parameter Library for Nuclear Model Calculations of Nuclear Data

Cérvia (Ravenna), Italy
19 to 23 September 1994

**Scientific Secretary: Pavel OBLOŽINSKÝ**

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