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Reference Data Libraries for Nuclear Applications - ENSDF

Summary Report of Technical Meeting

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10 – 11 November 2008

November 2008

IAEA Nuclear Data Section, Wagramer Strasse 5, A-1400 Vienna, Austria

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Abstract

A Technical Meeting on "Reference Data Libraries for Nuclear Applications – ENSDF" was held on 10-11 November 2008 at the IAEA Headquarters, Vienna, Austria. All presentations, discussions and recommendations of this meeting are given in this report. The purpose of the meeting was to review and discuss possible new European input to the ENSDF database (Evaluated Nuclear Structure Data File). These inputs are comprehensive mass-chain evaluations that constitute updated recommendations for the nuclear structure and decay data of nuclides assembled on the basis of mass number. A meeting to address declining European effort was endorsed by the International Nuclear Data Committee in April 2008, and judged as essential in order to balance the share of responsibilities around the world for the maintenance of this important database.

November 2008

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Definitions of terms

Nuclear structure data: numerical values of nuclear level structure and decay parameters and associated atomic parameters of pertinence to nuclear techniques and methods.

Tabulation: systematic collection and transcription of numerical information without critical selection and manipulation.

Compilation: systematic collection and transcription of information on a given subject with collation and re-organization for optimal presentation to the users.

Evaluation: critical appraisal of all available information on a given subject and derivation of consistent best or preferred values with their uncertainties.

Mass chain: pertaining to properties of nuclides with a given mass number.

Selected/horizontal: pertaining to a particular nuclear property or properties for a range of nuclides.

1. Introduction

Proceedings were opened by Alan Nichols, Head of the Nuclear Data Section and Scientific Secretary for the meeting. He welcomed participants, and gave a few remarks concerning the nature of ENSDF (Evaluated Nuclear Structure Data File), and the need to maintain a healthy programme of work to ensure that the database is of high value to the nuclear physics community as the definitive source of recommended up-to-date data for nuclear applications and research studies. Biennial meetings of the International Network of Nuclear Structure and Decay Data Evaluators are designed to assist in this work on a multinational basis, and are held under the sponsorship of the International Atomic Energy Agency. The US National Nuclear Data Center coordinates all mass-chain evaluation efforts and is custodian of the master ENSDF database.

Dimiter Balabanski had assisted the IAEA greatly in organising the meeting, and was elected Chairman. Alan Nichols agreed to act as minutes secretary. The Agenda was adopted with minor corrections (Appendix A), and a list of participants is given in Appendix B.

2. Opening Presentations and Statements

2.1. ENSDF: Current situation (A.L. Nichols (IAEA))

Alan Nichols provided a brief introduction to ENSDF, and the reasons why this particular database should be maintained in an authoritative and comprehensive manner (see attached presentation):

(a) well-defined archives for future usage;

(b) encourages confident and constructive interplay between nuclear reaction and decay data studies;

(c) healthy impact of recommended data on developing nuclear theories;

(d) assists in the resolution of contradictory results;

(e) aids in the identification of data requirements, and stimulates new measurements;

(f) benefits in applied nuclear areas – nuclear engineering, nuclear medicine, analytical and environmental sciences, etc.

The International Network of Nuclear Structure and Decay Data (NSDD) Evaluators meets together every two years to discuss ENSDF matters of mutual interest, including various types of database requirement, and developments to software aids that speed up the production and assembly of the recommended data and test the validity and format of the resulting data sets. Mass-chain responsibilities are also agreed and assigned, and various nuclear data are discussed that might improve the final sets of recommended data (e.g. recent developments in the calculation of internal conversion coefficients). Communications between network members are also maintained in between the biennial meetings.

All evaluated data within ENSDF are essentially derived from consideration of published measurements of nuclear reaction data and decay data (although data in unrefereed laboratory reports and private communications may also have to be assessed). The Nuclear Science References (NSR) bibliographic database is the major source for all nuclear structure references, while the atomic masses of Wapstra, Audi and Thibault (Nuclear Physics, Vol. A729 (2003) 129-676) form the basis for the derivation of the resulting energy data. ENSDF is the database from which user-friendly software such as Isotope Explorer and NuDat obtain

their data, as are the origins of the nuclear structure and decay data to be found in NUBASE, MIRD, RIPL, JANIS and RADWARE. Hardcopy publications such as the Table of Isotopes, Nuclear Wallet Cards and Nuclear Data Sheets are also derived from ENSDF.

Existing long-term contributors to ENSDF include nuclear physicists from Canada, China, France, Japan, Kuwait, Russian Federation and the USA. Emerging new contributors are Australia, Bulgaria and India. However, numbers have gradually dropped over the previous 20 years, and more new evaluators are urgently required to guarantee the continued efficacy of ENSDF. As the technical coordinator of ENSDF evaluations, Jagdish Tuli (NNDC, BNL) has stated that at least 12 FTE (full-time employment) per annum are required to maintain ENSDF in a timely manner, whereas the current number is only 8.70 FTE (Table 1). The decline in numbers became significant in the 1990s, and is shown in Table 2 in a different form based on the geographical locations of the various institutes/laboratories that were and are undertaking mass-chain evaluations.

Table 1. International Network of Nuclear Structure and Decay Data Evaluators: responsible centres – November 2008: Full Time Employment, 1 FTE = one person year per annum.

Centre	FTE	Centre	FTE
CNDC, Beijing, China	0.25	NNDC, USA	2.10
Jilin, China	0.25	ORNL, USA	0.25
Bruyères-le-Châtel, France	0.20	LBNL, USA	1.70
JAEA, Japan	0.45	TUNL, USA	0.60
Kuwait	0.20	ANL, USA	0.55
PNPI, Russia	0.25	McMaster, Canada	1.50
ANU, Australia	0.20		**6.70**
IIT, India	0.20		
	2.00	**TOTAL**	**8.70**

Table 2. Multinational mass chain evaluations for ENSDF - numbers of responsible laboratories/institutes.

	Year			
	1981	**1986**	**1996**	**2008**
North America	6	6	6	6
Europe	6	5	4	1(→ 0)
Russia	2	2	2	1
Japan	1	1	1	1
China	-	-	1	2
Rest of the World	1	1	1	3
	16	**15**	**15**	**14(→ 13)**

Nichols quoted a highly-relevant statement and a related recommendation to be found in a document published recently by the OECD Global Science Forum: Report of the Working Group on Nuclear Physics, May 2008:

> page 4 - *Success in basic research and its applications relies on systematic, accurate measurements and accumulation of nuclear data in certified, reliable databases*. In some areas, such as nuclear energy, there is strong international coordination through agencies such as the OECD Nuclear Energy Agency, the IAEA, and the US Nuclear Data Program. However, the Working Group finds that gaps exist in the international plans for the coordination and oversight of these databases, *and that available resources are insufficient.*
>
> Recommendation: The national agencies should work together with international organisations, such as the OECD Nuclear Energy Agency, The International Atomic Energy Agency, and the international science community, *to create a more comprehensive international plan to acquire and curate nuclear data for the wider community.*

Nuclear physicists within Europe need to consider what might be done, and whether they wish to undertake mass-chain evaluations at a sensible level through a consortium of interested parties. A further point of note is the need for such laboratories/institutes to be already experienced and involved in nuclear structure and decay data measurements.

Finally, Alan Nichols noted that he had been invited to wrote a short editorial for the March 2009 issue of Nuclear Physics News, published on behalf of the Nuclear Physics European Collaboration Committee (NuPECC), concerning the on-going discussions and recommendations that would arise from this technical meeting, with a deadline for submission of 19 December 2008.

2.2. USA statement (J.K. Tuli (NNDC, BNL))

The sole source of US funding for ENSDF originates from the US Department of Energy (DOE), for which Nuclear Data Program budget briefings are held in February/March (see attached presentation). DOE has expressed concern about the decline in non-US contributions to ENSDF, and the observed steady decrease in European effort in particular.

Jag Tuli illustrated the significant usage of ENSDF within Europe, based on registered data extractions:

> 44% USA and Canada; **24% Europe**; 6% Japan; 4% China; ….

e-subscriptions:

> **41% Europe**; 27% USA and Canada; 25% Asia; 7% Rest of the World.

These figures are in stark contrast with recent mass-chain contributions to ENSDF:

> 78% USA and Canada; **9% Europe**; 5% Japan; ….

Tuli stressed that strong international efforts are required to sustain ENSDF. Clearly, European countries are major users of this database, and the international community would greatly appreciate their assistance in evaluating and producing recommended data for ENSDF in a timely manner. Some European research groups are interested in undertaking such work, and should be supported financially.

2.3. University of Sofia and INRNE-BAS, Bulgaria (D.L. Balabanski)

Interested institutes: INRNE-BAS and NIS of the University of Sofia; also possibly the University of Plovdiv.

Manpower: D.L. Balabanski (15%); S. Lalkovski (20%): L. Atanasova (20% to start in 2009); K. Gladnishki (20% to start in 2009); T. Venkova (declared interest).

All listed staff have already attended ICTP-IAEA NSDD workshops at Trieste, apart from T. Venkova. Interests include A ~ 130 (Balabanski and Atanasova), A ~ 100 (Lalkovski) and horizontal evaluations (1qp and 2qp, high K bands (Balabanski and Venkova)).

Support during 2004 to 2008 has already been received from the IAEA through yearly-renewed contracts, but additional financing will be required at the rate of ~20k euro per year to maintain 1 FTE.

2.4. University of Jyväskylä, Finland (H. Penttilä)

Manpower: S. Juutinen (~20%) has expressed an interest in carrying out mass-chain evaluations.

Emphasis was also placed on the importance of horizontal and regional data evaluations. Further thought should also be directed to the nature of any proposed evaluations – e.g. expert involvement in an evaluation should be speedy (highly cost-effective, and akin to the refereeing of scientific papers). When Pentillä advocated the creation of evaluation committees to review the data, Tuli pointed out that a rigorous refereeing system is already in place for ENSDF mass-chain evaluations. Pentillä also believed that the original authors of published papers should consider undertaking preparative work for the evaluation (i.e. preparation of their measured data, including proposed changes and corrections).

2.5. Universität Gießen and GSI, Germany (C. Scheidenberger)

Manpower: B. Pfeiffer (~50%) will work on atomic mass evaluations, together with Y. Litvinov (~10%) and C. Scheidenberger (~10%) – this work is dedicated to horizontal evaluations.

Work is underway to ensure the continuous and systematic collection and evaluation of atomic masses in order to develop the 2003 Audi/Wapstra database further and create the Advanced Atomic Mass Evaluation (AAME). Healthy synergies are being established between the emerging AAME database, experimentalists and theoreticians in order to benefit nuclear structure and astrophysics research centres and nuclear applications. Generally accepted that there is a clear need to maintain this activity in Europe where most atomic mass data are measured and the expertise is readily available. A start will also be made on the assembly of a nuclear reaction cross-section database (>15,000 cross sections) on the Web, constituting a combination of experimental data and calculations (metadata model).

2.6. ATOMKI, Debrecen, Hungary (J. Timár)

Manpower: J. Timár (~25%) and Z. Elekes (~25%)

Interests would focus on particular mass regions of expertise (A ~100 and 130), leading to one mass-chain evaluation per year. Existing expertise includes high-spin states, and neutron-rich light nuclei (A ~15 to 45) – shell closure, neutron decoupling and weakening of effective interactions. Funding of the order of 4k euro per year would be required to ensure the stability

of this effort. Initial purchases would include computers, and intensive training would be required through a workshop and/or mentoring process.

2.7. Poland

2.7.1. IFJ, Krakow (A. Maj)

IFJ expertise in nuclear structure involves a team of twenty nuclear physicists and six PhD students investigating the properties of neutron-rich nuclides, their high spin states, lifetimes and magnetic moments, giant resonances, and developments to the shell and modified-shell models. Mass numbers of greatest interest are 40 to 70, 150 and > 200.

Manpower: some support funding would be required to maintain 1 FTE – a particular person has been identified (recognised expert); also possibility of an additional 0.5 FTE at a later date.

Maj stated that funding would need to include 75% of salary (under such conditions, other 25% would be provided by IFJ), travel and subsistence. Specific horizontal evaluations would be envisaged as well as mass chains for ENSDF (e.g. tabulations of recommended giant resonances.

2.7.2. University of Warsaw (J. Jastrzebski)

Jastrzebski outlined the research funding arrangements in Poland through the Ministry of Science. He also noted that an appropriate letter of support from the IAEA would be most welcome and might aid the likelihood of success in obtaining a grant to carry out mass-chain evaluations. Manpower commitments within the University of Warsaw cannot be made at the present time, and would be entirely dependent on the success of appropriate applications for funding to the Polish Ministry of Science.

One statement made during the discussions of Polish intent was that the mass-chain evaluations from responsible nuclear physicists would need to be assessed and reviewed prior to release – this exercise would also require financial support. Jag Tuli (NNDC, BNL) stated that such critical reviews and refereeing have always taken place before the evaluations are accepted into ENSDF – one facet of his responsibilities was to guide and ensure that these reviews take place in a correct and timely manner.

2.8. IFIN-HH, Magurele, near Bucharest, Romania (V. Zamfir)

Zamfir emphasised the extreme importance of nuclear structure physics and applications. If evaluated nuclear structure data are unavailable, incorrect, or their quality can not be assured, many people in nuclear science research will be unable to monitor the current status of such data and could be seriously mislead. Nuclear structure evaluations in Romania can be described as three-fold: decay data evaluations for standards metrology (e.g. DDEP and the IAEA Coordinated Research Project on “Update of decay data library for actinides”); horizontal evaluations (e.g. atomic masses); and mass-chain evaluations.

Manpower: IFIN-HH can commit 1 FTE to mass-chain evaluations – other effort would be dedicated to DDEP and horizontal evaluations.

Both Zamfir and Jastrzebski noted that a major problem with such national commitments was the lack of stability in the funding process for such work. They believed that funding agreements at an international level would be required to guarantee the longer-term future,

and wondered whether the IAEA could take a more active role in such initiatives. Nichols stated that direct funding from within the Nuclear Data Section was extremely unlikely to materialise due to severe budgetary constraints. He also believed the lack of funding for available nuclear structure expertise to undertake mass-chain evaluations was predominantly a European issue, and therefore needed to be addressed in a European context.

2.9 CIEMAT, Madrid, Spain (J. Los Arcos)

Los Arcos provided a succinct description of the nuclear data work undertaken at LMRI-CIEMAT (Laboratorio de Metrología de Radiaciones Ionizantes, Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas). As the national standards laboratory, CIEMAT maintains a strong interest in recommended and evaluated nuclear structure and decay data, particularly with respect to environmental and dosimetry applications and nuclear medicine. LMRI staff undertake decay data evaluations for DDEP, and propose to extend this expertise to embrace mass-chain evaluations for ENSDF.

Manpower:

2009 – train one staff member on systematics and procedures for mass-chain evaluations;

2010-11 – 1 FTE devoted 50-50 to a combination of DDEP and ENSDF evaluations;

2012 onwards – 1 FTE devoted to mass-chain evaluations (nuclides will be extracted from this activity for DDEP submissions).

Funding options need to be explored (e.g. EC Framework Programme 7).

2.10. Turkey

2.10.1. Istanbul University (M. Bostan)

Much of the nuclear physics research at Istanbul University is carried out in conjunction with institutes and experimental facilities located outside Turkey. Nevertheless, there is a significant interest in undertaking mass-chain and horizontal evaluations.

Manpower: 0.4 FTE (0.2 FTE each by two nuclear physicists) from Istanbul University devoted to mass-chain evaluations, if suitable funding can be found.

Istanbul University can not support this work directly, and staff will have to apply to appropriate funding agencies.

2.10.2. Istanbul University and Turkish Atomic Energy Authority (M.N. Erduran)

While the Turkish Atomic Energy Authority supports fully the efforts being made to re-establish a European team of mass-chain evaluators to contribute substantially in the improvement/maintenance of ENSDF, no funds are immediately available to sustain such work within Turkey. The possibility of funding the expenses of one such position in the longer term will be explored with the Turkish Atomic Energy Authority.

2.10.3. Nigde University (S. Erturk)

Nuclear structure research activities within Turkish universities involve a total of twelve nuclear physicists, of whom two are located at Nigde University. These professors and co-

workers are heavily involved in nuclear physics measurement programmes at other institutes, and possess no previous experience in mass-chain evaluations.

Manpower: 0.6 FTE from Nigde University, and made up of inputs from two nuclear structure specialists. This commitment and continuity cannot be guaranteed – salary and infrastructure support would be required.

2.11. UK

2.11.1. University of Manchester, Dalton Nuclear Institute (J. Billowes)

The various components of and staff within the Dalton Nuclear Institute were described, along with plans to create an Applied Nuclear Physics group within the proposed Centre for Nuclear Energy Technology. Various applications for UK funding have been submitted, including a proposal to support nuclear data evaluations. Resulting interest has been limited to specific bodies within the nuclear power industry, rather than the UK funding bodies for nuclear research. More specifically, a recent bid to the UK Research Funding Council to encourage and organise nuclear data evaluations has fallen on deaf ears. Other funding options are being pursued.

2.11.2. University of Surrey (Z. Podolyak)

Nuclear structure specialists within the University of Surrey were listed, along with their specific areas of expertise. Funds are being sought from such bodies as the UK Science and Technology Funding Council and the National Physical Laboratory to work on nuclear data evaluations (and other topics). Any form of success will take two of three years to realise.

2.12. GANIL, France, and European initiatives for financial support (S Galès)

Galès stated that ENSDF was a very important source of reliable nuclear structure data, and GANIL was willing to contribute 0.5 FTE to the European evaluation effort.

NuPNET (Nuclear Physics Network) of eighteen countries and twenty-two funding agencies was the most appropriate vehicle for soliciting funding by means of the recommendations of this body to individual national governments. This network was involved in formulating and agreeing long-range plans and priorities for nuclear physics research within the Europe Union, and would guide funding on a regional basis. These arrangements do not include Turkey for the obvious reason of non-membership of the EU. As chairman of NuPNET, Galès believed that this network will take over within one to two years any European initiative to recommend financial support for mass-chain evaluations for ENSDF and equivalent work in other areas (e.g. atomic masses and other horizontal evaluations).

2.13. EC-JRC, IRMM, Geel (S. Pommé)

Pommé outlined the primary role and standards responsibilities of the European Commission Joint Research Centre, Institute for Reference Materials and Measurements (EC-JRC, IRMM), Geel, Belgium. While nuclear data measurement projects at IRMM are reasonably well supported, a suitable programme of mass-chain evaluations would prove much more difficult to implement and sustain – most IRMM researchers are only hired on temporary three-year contracts.

IRMM is funded through EURATOM, and some participants questioned whether that organisation might have a supportive role to play in a European collaboration of mass-chain evaluators. Would nuclear data evaluations match in any way the aims of EURATOM?

[*Sec. note*: full and open discussions ensued at this stage of the meeting that assisted greatly in the preparation of the material to be found in Section 5 and Tables 3 and 4, below]

3. International Evaluation Efforts

3.1. ENSDF data services (J.K. Tuli (NNDC, BNL))

Tuli provided a brief summary of ENSDF and the data services linked to the master database, which is held at and maintained by the National Nuclear Data Center at Brookhaven National Laboratory in the USA (see attached presentation). Important related facets of the main database include NSR, XUNDL, NuDat and Q-calc.

1). ENSDF: recommended nuclear structure and decay data are derived from published measurements of nuclear reaction data and decay data:

> spin-parity, half-life, angular momentum transfer, spectroscopic factor, decay branching, static moments. shell-model or single-particle configurations, and sources of experimental measurements (NSR-style references),

while evaluated radiation properties include:

> level scheme placements, energy, relative and absolute intensities, multipolarity and mixing ratios, internal conversion coefficients, *log ft* values, hindrance factors, and reduced transition probabilities (in W.u.),

with quantification of uncertainties whenever appropriate.

ENSDF can be used for the tabulation of specialized horizontal evaluations, such as *log ft* values, nuclear isomers, properties of nuclei far from the line of stability, and the assembly of limited data sets for power and research reactor calculations, homeland security, detector calibrants and nuclear medicine.

2). NSR – Nuclear Science Reference bibliographic database. NSR covers 80 journals, appropriate conference proceedings, laboratory reports, theses and private communications. A well-defined keyword system has been adopted, and the resulting retrieval process is very efficient.

3). XUNDL – see Section 3.3.

4). NuDat – see Section 4.

5). Q-calc uses the 2003 atomic mass evaluation of Audi *et al*. to calculate nuclear reaction and decay Q-values.

Statistics covering all of the NNDC databases reveal that the major growth in nuclear data retrievals from the NNDC Web site over the previous four years can be attributed almost exclusively to the attractive depiction of ENSDF data by means of the Java-based, NuDat 2.4 software.

3.2. ENSDF impact on nuclear physics research (F.G. Kondev (ANL))

Kondev provided extensive evidence for the importance of a well-evaluated and recommended set of nuclear structure data to nuclear physics research (see attached presentation) – these applications included astrophysics, energy production, homeland security and intellectual advancement. Important new radioactive ion beam facilities are in

their planning stages, and their eventual construction will provide opportunities to make major contributions to our developing knowledge of the nucleus. ENSDF represents an assembly of complex nuclear data of vital importance in ensuring that interpretative studies are made in the correct manner. However, the extensive contents of ENSDF can only be successfully maintained through the considerable efforts of a multinational networking system. No other viable alternative exists to ensure that ENSDF is comprehensive, up-to-date, accessible and reliable.

An evaluator needs to undertake critical readings of all published work on a particular nuclide, compile the results in pre-defined formats, and recommend best values for a range of nuclear properties (computer codes are available to check the data for consistency and deduce certain types of quantity), as well as assist in subsequent mass-chain peer-reviews and prepare the data for publication in *Nuclear Data Sheets*. Various examples of the impact of ENSDF on our understanding of nuclear structure were also described in detail, including the resolution of erroneous assignments (^{175}Yb nuclear levels ascribed incorrectly to ^{177}Yb), misleading definition of nuclear parameters (e.g. half-life referred to as "mean-life"), stimulation of new measurements (e.g. decay of 39/2– isomer of ^{177}Lu), and K-isomers in deformed nuclei. Various types of horizontal evaluation and topical reviews were also discussed: alpha-decay hindrance factors from even-even nuclei, nuclear moments and proton-decay data. Furthermore, new initiatives involving the development of GRETINA (USA) and AGATA (Europe) furnishes opportunities for the expansion of nuclear structure research in the future on the basis of the firm foundation created by prior measurements documented and assessed within ENSDF.

Kondev believed the time was right for nuclear structure experts within Europe to join the International Network of Nuclear Structure and Decay Data Evaluators. Their abilities and efforts would be extremely important and most welcome, as the existing membership continues to be depleted by death and retirement. Strong support within the USA comes from the DOE Office of Nuclear Physics, Office of Science, and European funding agencies need to be identified to play a similar role.

3.3. XUNDL and ENSDF – observations of an evaluator (Balraj Singh (McMaster University, Canada))

A dramatic increase in the generation of high-spin data during the 1980s and early 1990s provided the impetus for staff at McMaster University to compile this type of data with some alacrity. The net result was the evolution of XUNDL (eXperimental Unevaluated Nuclear Data List) in 1998 to provide prompt and convenient web access to current publications of experimental nuclear structure data. Singh described the contents of XUNDL in detail. Journal scans are carried out at McMaster, while the on-line retrieval system is maintained at BNL for data access only two weeks after publication. Much of the compilation work for the ENSDF-formatted data sets is undertaken by undergraduate students who are also trained in basic nuclear physics, contents of the NSR, ENSDF and XUNDL databases, and the operation of the various data checking and manipulation codes. Emphasis was placed on the developing potential of this compiled database as a repository for unpublished data due mainly to journal restrictions. Significant quantities of additional experimental data have been obtained from the original authors, and several errata have been published as a consequence of the McMaster reviews. Compiled data sets are currently available in the XUNDL database for more than 2000 recent journal publications and for about 1600 nuclei.

Atomic mass measurements have also been compiled since the issue of AME-2003. Approximately 45 primary publications were identified which contain new data reported after

the AME-2003 publication, and some of this information is accessible from an ORNL web site. Overall, about 450 new mass measurements have been made between 2004 and 2008, based mainly on highly precise Penning-trap methods for nuclei far from the line of stability.

Singh has surveyed the ENSDF database from the point of view of data currency: fifty-five mass chain evaluations are more than 12 years old, although fifteen of this number are in the process of being included in ENSDF. Thus, there exists a need to address some of these more elderly mass chains now, and acknowledge that some form of intensified effort is needed to clear this evolving back-log. Singh also proposed collaborative interactions between ENSDF evaluators and the user/measurer community. Evaluation tools could be utilized by researchers to develop and refresh their methods of data analysis. He stressed the need for mass-chain evaluators to be fully familiar with all aspects of nuclear structure experiments and statistical analyses. Such work is not technically inferior to nuclear data measurements – both forms of expertise are fully complementary.

4. International Communications and Cooperation (lead by J.K. Tuli (NNDC, BNL))

By focusing on the use of NuDat 2.4 to interrogate and present ENSDF nuclear structure and decay data in a user-friendly manner, Tuli discussed the attractiveness of multinational cooperation to develop and maintain ENSDF. NuDat portrays and provides an interactive Chart of the Nuclides as a navigation tool, and is updated regularly as new mass-chains are introduced into the ENSDF database. Various examples of access to ENSDF data through NuDat were demonstrated during the course of the presentation. Nuclear levels and decay radiations can be searched in a highly systematic manner based on these tools. NuDat constitutes an extremely powerful technique for the thorough inspection and study of the contents of ENSDF, and has proved to be very popular with all types of user.

The NSR bibliographic database contains nearly 200,000 nuclear science articles, indexed on the basis of their content. Eighty journals are covered annually, and new articles are added at the rate of 4,000 per year. These articles can be readily retrieved in a selective manner, including first author's name, any author's name, nuclide, reaction, target, measured quantity, year of publication, journal, etc. Examples were presented of various forms of retrieval that underlined the strength of the database.

Important features of the work and expertise required to compile and evaluate nuclear data for NSR, XUNDL and ENSDF were discussed in detail. During the course of this debate, a draft statement was formulated that also embraced key recommendations, actions and commitments to mass-chain evaluations for ENSDF, as brought together under Section 5 below. Commitments were sought for mass-chain evaluations, and possible short and longer-term initiatives were quantified (Table 3), along with the number of specialists requiring a crash course in ENSDF evaluation procedures (Table 4). Horizontal evaluations were also defined to provide complete estimates of the European evaluation effort.

Meeting participants agreed unanimously that the main beneficiary from the ENSDF databases is the nuclear physics research community. Discussions within NuPECC have shown that specific research institutes throughout Europe wish to become involved in the crucial evaluation process. However, the gradual loss of such expertise over the previous 20 years poses a serious problem, and will need to be carefully addressed by working together. Galès advocated the establishment of a suitable form of European collaboration to initiate this type of study, but also with the intermediate-term aim of establishing some form of DOE-EU

agreement in order to stabilize and ensure the continuity of the work. Once these arrangements had been established, incorporation into the multinational network of nuclear structure evaluators with their common interests in mass-chain evaluations would appear to be a natural progression, falling within the auspices of the International Atomic Energy Agency (IAEA) for the organisation of biennial meetings and more regular communications.

Table 3. Commitments – 1 FTE is one unit of full time employment = one person year per annum.

Country	Immediate mass-chain FTE	Horizontal evaluations FTE	Additional longer-term (> 3 years) FTE	Crash course (number of people)
Bulgaria	1.0*	-	-	1
Finland	0.2	-	-	1
France	0.5	-	-	1
Germany	?	1.0#	?	1 or 2
Hungary	0.5*	-	-	2
Poland	0.5*?	-	1.0*	1 or 2
Romania	0.2	0.5§	0.5	2
Spain	0.5	0.5§	-	1
Turkey	0.5*	-	0.5*	2
UK	-	-	?	0
TOTAL	3.9?	2.0	2.0?	12 (14)

* would require modest external funding.
# atomic mass evaluations.
§ decay data evaluation project (DDEP).

Table 4. Proposed evaluators (with course attendees underlined).

Country	Mass-Chain Evaluators
Bulgaria	Dimiter Balabanski, Kalin Gladnishki, Stefan Lalkovski, Tsanka Venkova, Liliya Atanasova
Finland	Sakari Juutinen
France	?
Germany	?
Hungary	Zoltan Elekes, Janos Timar
Poland	Kazimir Zuber?
Romania	Alexandru Negret, Aurelian Luca
Spain	Monica Galan
Turkey	Sefa Erturk, Melih Bostan, Nizam Erduran

5. Recommendations and Actions

5.1. Recommendations

While European interest in contributing to the international efforts to develop and maintain ENSDF is judged to be significant, contributions to this important goal by means of mass-chain evaluations have fallen significantly over the previous 15 to 20 years. All are agreed that this important database needs to be maintained in a timely manner by knowledgeable nuclear structure physicists so that new measurements are incorporated into the evaluation process on a regular basis to aid all research users. Europe needs to play a part in these evaluation activities commensurate with the region's world-renown technical expertise.

Consultations should be held with the main European players (Directors of national institutes/laboratories) in a concerted effort to launch a collaborative initiative to undertake mass-chain evaluations for ENSDF. A spokesman should be nominated (Dimiter Balabanski - see Actions, below) to undertake these consultations over a relatively short time period (4 months), and prepare an agreed Memorandum of Understanding. Once established, this European collaboration should be brought together with the equivalent collaborative efforts of the USA and Rest of the World under the umbrella of the International Atomic Energy Agency, to constitute co-members of the International Network of Nuclear Structure and Decay Data Evaluators. All efforts should be made to achieve these goals in 2009.

On a mid-term timescale (two or three years), the collaborative initiative within Europe should be adopted and fall within the auspices of NuPNET to recommend the necessary support from the national funding agencies, with a long-term aim to make these arrangements permanent (beyond three years).

5.2. Actions

Dimiter Balabanski and Christoph Scheidenberger (as proposed spokesman/co-spokesman for the collaboration) to explore and quantify the European interest in and viability of forming a European collaborative effort to support ENSDF through the contribution of regular mass-chain and horizontal evaluations.

IAEA Nuclear Data Section and NNDC staff to assess the feasibility of holding a one-week workshop within Europe for would-be mass-chain evaluators already possessing nuclear structure expertise. These potential participants should be prepared to undertake some prior reading so that they are familiar with the basic aspects of the ENSDF database and format. See, for example, the IAEA/ICTP April/May 2008 NSDD Workshop webpage:

http://www-nds.iaea.org/workshops/smr1939/

The host for the workshop could be IFIN Bucharest, and a proposed date is the week starting Monday, 30th March 2009.

6. Conclusions

Representatives of nuclear structure and decay data specialists from within the European community assembled for two days at the IAEA Headquarters in Vienna, Austria, in order to determine their interest and willingness to undertake mass-chain evaluations for the Evaluated Nuclear Structure Data File (ENSDF) which falls within the auspices of the International Network of Nuclear Structure and Decay Data Evaluators. Much interest and commitment was expressed in the work which was judged to be an extremely efficient means of

assembling recommended data sets for the worldwide nuclear science community. Inevitably, a major issue in moving this European commitment forward is one of financial support. NuPNET is believed to be an appropriate vehicle for aligning and generating national support for this evaluation work.

A one-week training course in ENSDF evaluation procedures needs to be held in the near future, and preparative discussions should begin immediately – people planning to attend this course also need to familiarise themselves with the ENSDF data format before attending. The International Network of Nuclear Structure and Decay Data Evaluators is scheduled to assemble at the IAEA Headquarters from 23 to 27 March 2009 for their biennial technical meeting, and arrangements should be made for committed European nuclear structure experts to attend.

APPENDIX A

International Atomic Energy Agency

Technical Meeting (TM) on

Reference data libraries for nuclear applications - ENSDF

IAEA Headquarters, Vienna, Austria
10 – 11 November 2008
Room F0817

AGENDA

Registration *Gate 1* **08:00 – 09:00**

Monday, 10 November 2008

- Introductory remarks **09:15**
- Adoption of agenda and meeting organization
- Coffee break/Administrative matters **09:30**

1. Opening statements, commitments and financial issues **10.30**

   1.1 Introductory IAEA statement [*A.L. Nichols*]

   1.2 USA statement [*J.K. Tuli*]

   1.3 Individual statements per institute
   University of Sofia + INRNE-BAS [*D. Balabanski*]
   University of Jyväskylä [*H. Penttilä*]
   Universität Gieβen and GSI [*C. Scheidenberger*]
   ATOMKI, Debrecen [*J. Timár*]
   IFJ, Krakow [*A. Maj*]
   University of Warsaw [*J. Jastrzebski*]
   IFIN-HH, Magurele, near Bucharest [*V. Zamfir*]
   CIEMAT, Madrid [*J. Los Arcos*)
   Istanbul University [*M. Bostan*]
   Istanbul University and Turkish Atomic Energy Agency [*M.N. Erduran*]
   Nigde University [*S. Erturk*]
   University of Manchester [*J. Billowes*]
   University of Surrey [*Z. Podolyak*]
   GANIL, France, and European initiatives for financial support [*S. Galès*]
   EC-JRC, IRMM, Geel [*S. Pommé*]

LUNCH **13:00**

2. International evaluation efforts **14:00 – 15:50**

   2.1 ENSDF [*A.L. Nichols*]

      2.1.1 Overview – Services [*J.K. Tuli*]
      2.1.2 Impact on research [*F. Kondev*]
      2.1.3 Observations of an ENSDF (mass chain) evaluator, and XUNDL [*B. Singh*]

   Coffee break **15:50**

   2.2 Related work on nuclear structure databases [*everyone*] } **16:10 – 17:30**
   2.3 Discussion of international cooperation [*everyone*] }

   Social Event **19:00**

Tuesday, 11 November 2008

3. Databases: Cooperation** **09:00 – 11:00**

   3.1 NSR bibliographic file [*J.K. Tuli/others*]

   3.2 ENSDF numerical file [*J.K. Tuli/others*]

   3.3 Methods of cooperation [*everyone*]

** *Coffee break as appropriate*

4. Agreed recommendations and conclusions **11:00 – 12:00**

5. Any other business

APPENDIX B

International Atomic Energy Agency

Technical Meeting

Reference data libraries for advanced nuclear applications (ENSDF)

IAEA Headquarters, Vienna, Austria
10 - 11 November 2008
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Specific Presentations

Working Links:

1. ENSDF (Evaluated Nuclear Structure Data File), Alan L. Nichols
   http://www-nds.iaea.org/ensdftm/NICHOLS.ppt

2. ENSDF Evaluation Effort: US Perspective, Jagdish K. Tuli
   http://www-nds.iaea.org/ensdftm/TULI1.ppt

3. Role of ENSDF in Nuclear Physics Research, Filip G. Kondev
   http://www-nds.iaea.org/ensdftm/KONDEV.ppt

4. XUNDL database and observations of an ENSDF evaluator, Balraj Singh
   http://www-nds.iaea.org/ensdftm/SINGH.ppt

5. NNDC Databases and Services, Jagdish K. Tuli
   http://www-nds.iaea.org/ensdftm/TULI2.ppt

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