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I N D C INTERNATIONAL NUCLEAR DATA COMMITTEE

Co-ordination of the International Network of Nuclear Structure and Decay Data Evaluators

Summary Report of an IAEA Technical Meeting

McMaster University, Hamilton, Canada

6 – 10 June 2005

Prepared by

A.L. Nichols and J.K. Tuli

September 2005

IAEA NUCLEAR DATA SECTION, WAGRAMER STRASSE 5, A-1400 VIENNA

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Abstract

The IAEA Nuclear Data Section convened the 16th meeting of the International Network of Nuclear Structure and Decay Data Evaluators at the Department of Physics and Astronomy, McMaster University, Hamilton, Canada, 6-10 June 2005. This meeting was attended by 33 scientists from 12 Member States concerned with the compilation, evaluation and dissemination of nuclear structure and decay data. A summary of the meeting, recommendations/conclusions, data centre reports, and various proposals considered, modified and agreed by the participants are contained within this document.

September 2005

ABBREVIATIONS

ANL	Argonne National Laboratory, USA.
ANU	Australian National University, Canberra, Australia.
CD-ROM	Compact disk with read-only memory.
CEA	Commissariat à l'Energie Atomique (French Atomic Energy Commission).
CNDC	China Nuclear Data Center, Institute of Atomic Energy (IAE) Beijing.
DDEP	Decay Data Evaluation Project.
DF	Self-consistent-field Dirac-Fock calculations for theoretical internal conversion coefficients.
ENSDF	Computer-based Evaluated Nuclear Structure Data File.
EXFOR	Computer-based system for the compilation and international exchange of experimental nuclear reaction data.
IAEA	International Atomic Energy Agency.
ICC	Internal Conversion Coefficients.
ICTP	International Centre for Theoretical Physics, Trieste, Italy.
INDC	International Nuclear Data Committee.
INL	Idaho National Laboratory, USA.
IP	Isotopes Project at LBNL.
JAERI	Japan Atomic Energy Research Institute, Japan.
LBNL	Lawrence Berkeley National Laboratory, USA.
NDP	Nuclear Data Project, Oak Ridge National Laboratory, USA.
NDS	Nuclear Data Sheets; journal devoted to ENSDF data.
NDS/IAEA	Nuclear Data Section, IAEA.
NNDC/BNL	National Nuclear Data Center, Brookhaven National Laboratory, USA.
NSDD	Nuclear Structure and Decay Data network.
NSR	Nuclear Science References – bibliographic file.
ORNL	Oak Ridge National Laboratory, USA.
PNPI	Petersburg Nuclear Physics Institute of the Russian Academy of Sciences.
RIA	Rare Isotope Accelerator.
RIB	Radioactive Ion Beam.
TUNL	Triangle Universities Nuclear Laboratory, USA.
USDoE	US Department of Energy.
USNDP	US Nuclear Data Program.
XUNDL	Experimental Unevaluated Nuclear Data List.

A-chain evaluation	Mass-chain evaluation: best data for the structure and decay of all nuclides with the same mass number.
Horizontal evaluation	Best values of one or a few selected nuclear parameters for many nuclides irrespective of their mass number.

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Foreword

The International Network of Nuclear Structure and Decay Data (NSDD) Evaluators holds biennial meetings under the auspices of the IAEA, and consists of evaluation groups and data service centres in several countries. This network has the objective of providing up-to-date nuclear structure and decay data for all known nuclides by evaluating all existing experimental data.

Data resulting from this international evaluation collaboration is included in the Evaluated Nuclear Structure Data File (ENSDF) and published in the journals *Nuclear Physics A* and *Nuclear Data Sheets* (NDS). The results represent the recommended "best values" for the various nuclear structure and decay data parameters. These data and bibliographic details are also available to users by means of various media, such as the World wide web, CD-ROM, wall charts of the nuclides, nuclear wallet cards and others.

US efforts are coordinated by the Coordinating Committee of the US Nuclear Data Program. While the ENSDF master database is maintained by the US National Nuclear Data Center at the Brookhaven National Laboratory, these data are also available from other distribution centres including the IAEA Nuclear Data Section.

Biennial meetings of the network are sponsored by the IAEA Nuclear Data Section, and have the following objectives:

(a) coordinate the work of all centres and groups participating in the compilation, evaluation and dissemination of NSDD;
(b) maintain and improve the standards and rules governing NSDD evaluations;
(c) review the development and common use of the computerized systems and databases maintained specifically for this activity.

This work is undertaken over a 5-day period, and this document represents a summary of the network meeting held at McMaster University, Hamilton, Canada, 6-10 June 2005. Thirty-three nuclear data specialists attended this meeting to discuss work and problems of common interest, specifically with respect to the active membership of the mass chain evaluation team for ENSDF.

The first two days were dedicated to a combination of technical reviews and discussion papers, addressing particular topics in which progress has been made and problems have been experienced over the previous 18 months (since November 2003). Specific mass chain activities and administrative issues were debated over the final three days. The list of participants is given in Annex 1, and the adopted agenda for the meeting is listed in Annex 2.

NSDD Meetings

	Place	Date	Report
1.	Vienna, Austria	29.04. – 03.05.1974	INDC(NDS)-60
2.	Vienna, Austria	03 – 07.05.1976	INDC(NDS)-79
3.	Oak Ridge, USA	14 – 18.11.1977	INDC(NDS)-92
4.	Vienna, Austria	21 – 25.04.1980	INDC(NDS)-115
5.	Zeist, Netherlands	11 – 14.05.1982	INDC(NDS)-133
6.	Karlsruhe, Germany	03 – 06.04.1984	INDC(NDS)-157
7.	Grenoble, France	02 – 05.06.1986	INDC(NDS)-182
8.	Ghent, Belgium	16 – 20.05.1988	INDC(NDS)-206
9.	Kuwait, Kuwait	10 – 14.03.1990	INDC(NDS)-250
10.	Geel, Belgium	09 – 13.11.1992	INDC(NDS)-296
11.	Berkeley, USA	16 – 20.05.1994	INDC(NDS)-307
12.	Budapest, Hungary	14 – 18.10.1996	INDC(NDS)-363
13.	Vienna, Austria	14 – 17.12.1998	INDC(NDS)-399
14.	Vienna, Austria	04 – 07.12.2000	INDC(NDS)-422
15.	Vienna, Austria	10 – 14.11.2003	INDC(NDS)-456
16.	Hamilton, Canada	06 – 10.06.2005	INDC(NDS)-0476

1. Summary

The 16th meeting of the International Network of Nuclear Structure and Decay Data (NSDD) Evaluators was held at the McMaster University, Hamilton, Canada from 6 to 10 June 2005. This biennial meeting was hosted by the Department of Physics and Astronomy, and their staff members made significant contributions towards the preparations. Thirty-three participants from twelve countries attended the meeting, representing the majority of data evaluation centres, new evaluation groups and data dissemination centres.

Profs. P. Sutherland (Dean of Science and Professor of Physics) and J.C. Waddington (Department of Physics and Astronomy) welcomed all delegates to the meeting. The Agenda was approved as listed in Annex 2. J.K. Tuli and A.L. Nichols were elected to co-chair the meeting.

Discussions over the first two days focused on specific technical issues either requiring resolution or for information. Short summaries of the various presentations can be found in Section 2 and Annex 6. A significant decision made unanimously during the course of these two days was to adopt the self-consistent Dirac-Fock model with the atomic vacancy (frozen orbital approximation) to calculate the theoretical internal conversion coefficients for ENSDF mass chain evaluations. This approach replaces the previous standard based on Hager-Seltzer calculations. Work undertaken by the ENSDF evaluation and dissemination centres over the previous two years (Annex 5) was also considered, along with their planned activities for the forthcoming two years. A list of all ENSDF evaluation centres and groups is given in Annex 3, along with their mass-chain evaluation responsibilities as assigned for 2005-2007. Status reports on other activities were also presented (see also Annex 6).

Participants discussed a wide range of technical matters, including recommendations to improve the quality of NSDD evaluations. A list of actions was also prepared for implementation during the course of the next two years (see Annex 4).

NSDD members also prepared recommendations for implementation by the IAEA and the major evaluation centres, which are aimed at improving financial and technical support towards the network. These recommendations include: the development of stronger links and understanding between key financial organizations and research facilities; planning of IAEA and ICTP workshops designed to train new NSDD evaluators; support by the major NSDD centres of the evaluation work undertaken by new groups through mentoring; and maintenance of the list of horizontal evaluations required by users or covered by on-going activities.

The next Technical Meeting of the International Network of Nuclear Structure and Decay Data Evaluators will be held in May or June 2007, most probably at Petersburg Nuclear Physics Institute.

2. Technical Discussions (Monday-Tuesday)

Prior to each of the two daily NSDD technical sessions, the opportunity was taken to listen to invited presentations by Profs. Waddington and Burke (both from McMaster University) on their thoughts and insights into future developments in experimental nuclear physics, and single- and two-particle transfer reactions, respectively. These contributions to the meeting were warmly

welcomed by an evaluation body that is most often concerned only with past measurements and their data.

2.1. Future Directions in Experimental Nuclear Structure Physics (J.C. Waddington (McMaster University))

Waddington provided participants with the opportunity to consider the consequences of studying radioactive beam reactions and RIAs, focusing on very precise measurements to address specific problems and the ability to study the properties of hard-to-reach nuclides. New equipment and techniques lead to advances in our knowledge, and also challenge evaluators as they consider how to handle the resulting data. A primary aim is to study the nucleus some considerable way from stability, resulting in the need to handle unstable target nuclides and radioactive ions (low count rates) in the creation of the desired reactions. Radioactive beam facilities are required in which experiments will have to be carried out in an entirely new manner and consequently evaluators' problems will be different:

(a) fragmentation facilities – high-energy collisions in which fragments also move;
(b) isotope separator facilities – stopped products from collisions will need to be re-accelerated.

These systems have evolved into the RIA concept (Rare Isotope Accelerator).

The ISAC facilities at TRIUMF were described, along with the need to adopt complex arrays of detectors. Waddington noted that most reaction experiments will be undertaken by means of "inverse mode", such as d(^{18}Ne, p)^{19}Ne. Some studies will require a cocktail beam (and the need to worry about impurities in the beam), and there would be the problems of low beam intensities and Döppler broadening of the γ rays. Under these circumstances, new position-sensitive Ge detectors would be highly beneficial to permit correction for Döppler broadening, and such equipment is in the process of being developed (various arrays of detectors were shown). Examples of the types of problem to be tackled include ^{30}Mg (radioactive ^{30}Mg ions to bombard a Ni target) and hyper-nuclei (^{9}Be(K^-, π^-) reaction studied using hyperball).

A large number of new nuclei will be observed for the first time in the next ten years in low count rate experiments. Waddington predicted a mixture of very precise measurements on a few special problems, and measurements of simple properties of hard-to-reach nuclei. One aim should also be to study the r-process in as much detail as possible.

2.2. Single- and Two-particle Transfer Reactions including Inverse Kinematics (D.G. Burke (McMaster University))

Burke reviewed single- and two-particle transfer reactions, along with the application of inverse kinematics. Single-nucleon transfer reactions can provide:

(a) Q-values and excitation energies;
(b) l transfers;
(c) j transfers (with polarized beams);

(d) hole or particle character (from relative pickup and stripping strengths);
(e) configuration identification and purity (from absolute cross sections).

A typical experimental set-up was considered in which the reaction products are analysed by means of a mass spectrometer. Best resolution is obtained with very thin targets (differential cross section is measured as a function of reaction angle). The reaction must be direct and involve a single-step process (i.e., neither significant compound nucleus contribution nor multi-step excitations should occur). Reaction Q-values and excitation energies of levels are obtained from the spectra in which each peak represents a level in the residual nuclide. Angular distributions of the cross sections provide l-values for transitions, and analysing power from polarised beams gives j-transfer in the reaction.

The spectroscopic factor (S) was defined that depends only on the nuclear structure. Several other definitions have been given in the literature that has caused some confusion and annoyance to NDS compilers; hence the need to compare these definitions before comparing results was stressed. “Fingerprints” can be observed in deformed nuclei in which each Nilsson state has a characteristic pattern of cross sections among the members of a rotational band – this form of pattern recognition is a powerful tool for the identification of single-proton and single-neutron configurations across a wide range of nuclei. Some reactions give the appearance of single-step processes (e.g., Coulomb excitation of ^{232}Th by ^{209}Bi beams), and are useful for populating levels that are otherwise inaccessible, but spectroscopic strengths were also considered – if transfer strength level has dominant 2QP configuration, multi-phonon character must be minor.

Two-nuclear transfer reactions in which nucleons are a time-reversed pair (e.g., (p, t) and (t, p)) were also considered. Pairing corrections that lower the ground state energy for even-even nuclei result in constructive interference of the transition amplitude, and therefore a strong ground-state population.

Inverse kinematics is defined as a reaction in which the nuclide considered as the target becomes the projectile. Radioactive ion beams (RIB) from fragmentation reactions can be used to undertake non-traditional experiments. Various examples were given that have provided information that could not have been generated any other way. RIB experiments at NSCL, Michigan, were described that are based on inverse kinematics. Data are sufficiently distinctive to determine the l-transfers, and the absolute transition intensities give reliable spectroscopic factors. Both l-transfers and strengths can only be reliably determined when the level spacing is large, and therefore the method is best suited to light nuclei (astrophysical importance) and cases near the drip line.

2.3. Network Technical Discussions

Balraj Singh introduced the Network participants to the proposition that 2005 must be close to being the 75th anniversary of the very beginnings of nuclear data evaluations, with the publication of a paper by the International Radium-Standards Commission (Curie, M., *et al*., Rev. Mod. Phys. **3** (1931) 427) on radioactive constants. This work led on to Livingston and Bethe (Rev. Mod. Phys. **9** (1937)), and the original Table of Isotopes by Livingood and Seaborg (Rev. Mod. Phys. **12** (1940)) that subsequently appeared every four years until 1958 (and the rest is history).

2.3.1 B(E2) data (W. D. Kulp (Georgia Tech))

All B(E2) data have been extracted from the available databases, and efforts made to identify systematic trends. These analyses have revealed that the global trend for all known yrast cascades in even-even nuclei match the theory for a quantum mechanical rigid rotor. Transitions from the first excited $K = 2^+$ agree with a simple tri-axial rotor model which includes band mixing and moments on inertia that are not irrotational in nature.

The studies highlighted the existence of anomalous (incorrect) data that have been rectified by means of new experimental studies. Work is now underway to provide a means of generating data for over 100 collective states that have no evaluated B(E2) data. These studies were received with interest at the meeting, and should be continued in order to identify data that do not fit accepted systematics.

2.3.2 ENSDF format (J.K. Tuli (BNL))

Tuli had previously held discussions with von Brentano (University of Cologne), in which they had agreed that confusion arose in ascertaining whether B(E2) data in ENSDF are up or down.

ACTION: Balraj Singh and Kondev to propose guidelines for appropriate configurations/labels of band assignments, define the proper quantity and symbol to represent the transition quadrupole moment for rotational bands, and related issues (see action item 34).

2.3.3 NNDC Web services (B. Pritychenko (BNL))

NNDC has been working in collaboration with staff at the IAEA Nuclear Data Section to migrate all databases from the original CODASYL-DBMS to a relational DBM system. The Web interfaces to these databases have also been upgraded to use Structured Query Language (SQL) and Java Web technologies. These facilities were launched at NNDC on 19 April 2004, and possess the following features:

- new generation of nuclear data services with hardware architecture based on robust and scaleable DELL servers that run Linux;
- relational database software (Sybase);
- new Web interfaces for CINDA, ENDF, EXFOR (CSISRS), ENSDF, NSR, NuDat, and XUNDL databases;
- Java solution;
- search by means of on-line query forms, with results presented to the user as tables and interactive plots.

Various usage statistics were presented that showed retrievals had increased overall by 66% during the course of calendar 2004 (with major increases in the recorded access to NuDat – user-friendly software for display and usage of ENSDF database). Pritychenko reviewed the relatively trouble-free operational aspects of the new facilities (e.g., minimal downtime) and proposed future directions for further improvement. An additional Web server will also be acquired to cover any downtime problems with the main server.

2.3.4 Radioactive decay data evaluations (M.-M. Bé (LNHB))

Bé described the multinational Decay Data Evaluation Project (DDEP) and demonstrated the Nucléide database and associated software that have arisen from these in-depth decay-data evaluations from the early-1990s onwards. Access to the database was demonstrated, along with detailed inspections of the DDEP data for specific radionuclides.

NSDD discussions focused on possible links between DDEP and ENSDF, and the comprehensive nature of DDEP with respect to primary and secondary decay-scheme data. While DDEP decay data cannot be blindly placed in ENSDF files, Tuli urged NSDD evaluators to consider the recommended DDEP data when undertaking their mass chain evaluations.

2.3.5 Nuclear Science References (D.F. Winchell (BNL))

NSR has seen the addition of 7248 new references from November 2003 to May 2005, to give a total of 180799 entries as of 27 May 2005. IAEA-NDS staff will begin preparing keywords for selected European journals in September 2005 to assist in these efforts. “Recent References” issue of *Nuclear Data Sheets* has been discontinued. Details of NSR search statistics were also presented.

Efforts are being made to extend the content of the NSR bibliographic database beyond decay data and related nuclear parameters. Subject indexing is under review, although non-radical changes are being proposed (e.g., multiple index values: classify one phenomenon as two quantities - ^{12}C decay, also defined as cluster decay). Other suggestions on extending the indexing system would be warmly welcomed by Winchell. These changes will be implemented in the first quarter of 2006, and will require complete regeneration of selector fields, redistribution of the database, and updating of the NSR coding manual.

2.3.6 ENSDF database (D.F. Winchell (BNL))

ENSDF and XUNDL databases have been migrated to a common relational database platform on Linux. Winchell reported that all administration programs have been modified or rewritten to work with the new database, and new Web access has been developed. ENSDF Web access includes several options for filtering and selecting the datasets by nuclide, A, Z and dataset type, reaction, decay properties, references, etc. Example selections were demonstrated, and a pie-chart breakdown of the relative popularity of these various retrieval mechanisms was shown for the period from May 2004 to April 2005.

2.3.7 Internal conversion processes - BrIcc, Band-Raman ICCs (T. Kibédi (ANU))

Tuli introduced the BrIcc studies of Kibédi and Burrows by noting that participants would be asked to make a clear decision on the basis of their recommendations at the end of the presentation, as to which type of calculational method to adopt in the future for the ICCs to be used in ENSDF mass chain evaluations. Significant debate had already taken place by e-mail during 2005, and he hoped that the additional work undertaken by Kibédi *et al.* (2005) as a result

of these exchanges of views would assist in directing the NSDD evaluators towards the most suitable choice.

Kibédi presented an extensive review of theoretical and experimental ICCs (see Annex 6) that can be summarised as follows:

Studies of theoretical internal conversion coefficients over the previous 20 years have focused on relativistic self-consistent-field Dirac-Fock (DF) calculations (Band and Trzhaskovskaya, 1993; Band *et al.*, 2002; Raman *et al.*, 2002); exact exchange terms have been used for the interaction between bound electrons and between bound and free electrons, as well as taking into account the static and dynamic effects of finite nuclear size. Raman *et al.* (2002) also assembled a set of 100 experimentally determined conversion coefficients (45 α_K and 55 α_T) derived to an accuracy of better than 5%, and compared these data with corresponding theoretical values. The comparisons have shown that the resulting DF values are in better agreement with the experimental measurements than relativistic Hartree-Fock-Slater (RHFS) values.

Theoretical internal conversion coefficients are very sensitive to the various physical assumptions when the transition energy is very close to the binding energy. One issue of contention has been whether the hole in the atomic shell from which an electron is emitted should be taken into account in such calculations. The time between filling the hole created by the emission of a conversion electron and the escape of the electron from the atom is important in ICC calculations. Most theoretical models assume either: (a) the hole is filled instantly, or (b) the hole remains unfilled as the electron is removed. Thus, Rösel *et al*. (1978) and Band *et al*. (2002) ignored the existence of the hole, whereas Hager and Seltzer (1968) and Band and Trzhaskovskaya (1993) took the hole into account in their calculations. Neglect of the hole can impact considerably at conversion-electron energies (E_k) close to the energy threshold. While this effect is negligible for low-multipolarity transitions and transitions considerably removed from the K-edge, recent measurements of the K-conversion coefficient of the 80.2-keV M4 gamma transition of $^{193}Ir^m$ have demonstrated that the hole in the atomic shell may need to be taken into account in theoretical ICC calculations (Nica *et al*., 2004).

Kibédi *et al.* (2005) have increased the experimental ICC database, extended the DF method to cover transition energies starting 1 keV above the shell binding energies to 6 MeV, and improved the accuracy of the interpolations in energy regions where the theoretical values are rapidly changing. These studies indicated that modelling the hole by means of the "frozen orbital approximation" provided better agreement with available experimental ICC data (i.e., hole is modelled, but assume that there is insufficient time for a rearrangement of the atomic orbitals prior to conversion-electron emission).

Tuli stated that nuclear structure and decay data studies for mass chain evaluations require the consistent adoption of a single appropriate set of ICCs. He urged the meeting to consider the various options - the decision was taken to adopt the "frozen orbital approximation" approach. Additional comments included the desire of mass chain evaluators to retain access to other ICC data and their calculation (e.g., Hager and Seltzer). Participants also acknowledged that further experimental studies are highly desirable in order to assess whether the "frozen orbital approximation" can be universally applied with confidence.

ACTION: Burrows and Kibédi to provide the BrIcc program for ICC calculations using the Band-Raman prescription with the frozen orbital relativistic procedure (BNIT(2)) for network use (by 1 September 2005).

2.3.8 ENSDF evaluation tools (A.A. Sonzogni (BNL))

Sonzogni provided a brief description of NuDat-2.1 for interactive searches and the plotting of ENSDF data. This powerful tool has proved to be particularly popular to users of the NNDC Web pages, and was warmly praised by the NSDD Network. Examples were presented of accessibility (with an electronic search form, and interactive chart of the nuclides), production of full decay schemes, and the links between the various data files. Retrieval statistics were also displayed in some detail.

Sonzogni was currently looking into possible ways of improving user access, and would welcome any suggestions from the NSDD Network. The creation of an ENSDF editor was discussed that would move the database away from the need to understand the relatively complex ENSDF format. This new system should be available for trial tests in September 2005.

2.3.9 Discrepant data sets – bootstrap method (V. R. Vanin (Universidade de São Paulo))

Experimental measurements of decay data parameters can be in disagreement from the point of view of their absolute values and assigned uncertainties. A description was given of such discrepancies and the recognition of outliers (any data with χ^2-value greater that the corresponding critical value, $\chi^2_{critical}$). Vanin advocated the use of the bootstrap method to analyse such data sets, and outlined the recommended procedure (see Annex 6).

2.3.10 Band structure and nomenclature in ENSDF (F.G. Kondev (ANL))

Kondev gave a brief introduction to angular momentum within nuclei, along with the assiciated confusion between the various nomenclatures adopted over the years. Both deformed and spherical nuclei were considered, with contradictory and erroneous results being made in the interpretation of their nuclear levels and resulting γ-ray cascades. Comprehensive evaluations were advocated on the basis of solid background understanding of these decay processes, rather than the simple adoption and numerical averaging of the reported data.

$\Delta J = 2$ decoupled rotational bands and $\Delta J = 1$ strongly-coupled rotational bands were described in terms of their weak and strong arguments for the derivation of γ-transition multipolarities, and various inadequacies were noted. Kondev argued that the nuclear physics research community needs suitable interrogation software to search specifically for nuclear configuration information within databases. However, one problem is the lack of consistent and unified information in the databases that can be attributed to the various NSDD documents used by ENSDF evaluators:

- Nilsson quantum numbers and their arguments are not listed;
- Nilsson quantum numbers are listed, but no arguments are given;
- some notations are meaningless.

Improvements were suggested, including the adoption of consistent set of Nilsson quantum

numbers. Although various policy documents are available, a case exists to bring all of the relevant and most suitable material together in one manual through a J^{π} policy sub-committee, and to promulgate the final set of recommendations within meetings and workshops. The Network members agreed unanimously with the need to improve band nomenclatures as proposed by Kondev.

ACTION: Balraj Singh and Kondev to propose guidelines for appropriate configurations and band assignments, define the proper quantity and symbol to represent the transition quadrupole moment for rotational bands, and propose an additional J^{π} rule for coupled bands (see action item 34).

2.3.11 Evaluation of reaction data – mainly high spin (Balraj Singh (McMaster University))

Over the previous 5 years, high-resolution γ-ray studies have revealed fine structure in hyper-nuclei – 35 hyper-nuclides are known from ^{3}H to ^{209}Bi, but mostly in the low mass region below A = 20. Seven of these nuclides have also been quantified on the basis of their level energies, lifetimes, transition probabilities, spins, etc. However, Singh noted that there are no guidelines or recommendations to include such data in ENSDF (see also action item 36).

Proposals were listed for the presentation of data from several different heavy-ion fusion reactions. There are inconsistencies in the formulation of such data within different mass chains – some A chains have one composite (HI, xnγ) dataset, even when detailed data are available from different reactions. However, combining such datasets is cumbersome, and may even create inconsistencies. All independent data for energies and intensities should be considered, and different datasets should be created for each reaction.

Singh has assessed γ-ray energy uncertainties, and found inconsistencies between different A chains. Sometimes no uncertainties are quoted (default of 1 keV for GTOL, which seems to be too large); a general statement should be given in the dataset (such as “all 0.1 keV”, or a range of uncertainties (e.g., 0.1 to 1 keV)). Singh advocated the adoption of relative γ-ray intensities and independently measured branching ratios when determined by the authors, and that values from different reactions and different beam energies in the same reaction should be combined in the same I_{γ} record. Additional observations involved the assignment of multipolarities, and the confusion engendered by some high-spin papers that do not quote uncertain multipolarities in parentheses (even when no supporting data are available). ENSDF follows the Krane-Steffen phase convention that needs to be checked in the authors’ papers. Spin and parity assigned by authors should be compared with data in the “adopted levels” dataset (formulated from the strong/weak rules).

2.3.12 Adopted data (C.M. Baglin (LBNL))

The strong J^{π} rule for proton decay was discussed in detail. Baglin declared that for spherical odd-Z, even-N nucleus, the spin and parity of a level exhibiting proton decay can be taken to be equal to a particular set of J^{π} values of the emitted proton provided that:

(a) transition reaches the ground state of the daughter nucleus;

(b) proton J^{π} values are physically reasonable (i.e., supported by systematic studies and/or shell-model calculations);

(c) calculated proton radioactivity half-life for those J^{π} values is smaller than the experimental value;

(d) calculated proton radioactivity half-lives for the other physically possible J^{π} values are far larger or far smaller than the experimental value.

These observations and proposals were accepted in full.

2.3.13 ENSDF analysis and utility codes (T.W. Burrows (BNL))

All ENSDF analysis and utility programs have been converted to Fortran95; NSDFLIB and RULER have been distributed; all others are undergoing in-house tests. Various problems are being addressed (e.g., GTOL (possible machine-dependent precision problem); HSICC (difficulties in creating new records when gamma energy is below sub-shell binding energy)). Open VMS versions will no longer be maintained or upgraded

Some network participants were particularly interested in the status of LOGFT, which is used by many people outside the Network for beta-decay calculations. Burrows reported that the program had been provided with the logic to calculate 3rd and higher-order unique forbidden transitions from the LBNL ft program; extensive testing is highly desirable before release. Following on from these tests, the program will be updated to use the electron capture data of Schönfeld and Janßen.

3. Technical Recommendations

1. Include published transition and diagonal reduced matrix elements (e.g., <||E2||>) within the Coulomb Excitation data sets. The data should be given as a comment record with corresponding key number and the assumptions used. Sometimes only a key number with appropriate comment is needed.
2. Give B(E2; I to I-2) calculated from the reduced E2 matrix elements with corresponding comment and the key number.
3. If unclear whether the matrix elements have been corrected for spin dependence (reduced matrix elements), the authors of the paper should be contacted. Results from GOSIA analysis are most often presented as the reduced matrix elements.
4. BE2UP and BE2DN should be used to remove confusion as to up or down transition.
5. Evaluation of dynamic quadrupole moments and their proper nomenclature should be explored (see action item 34).
6. Adopt Band, Raman *et al.* ICCs (BrIcc), with “frozen orbital approximation” to replace Hager and Seltzer ICCs (HSICC), as the prescription for calculation of internal conversion coefficients in ENSDF. This will be required for all new evaluations that are submitted after 1 October 2005 (Sec. note: changed to 1 November 2005).

7. Resonance data should be given for all mass regions.
    a. Adoption of resonance levels in Adopted Levels, and gammas will depend on the evaluator.
    b. Resonance level energies be given as E(excitation) or SN+E(res), depending upon the mass region.
    c. Decay data set for resonance decay can be given as needed.
8. There is a need for consistent nomenclature for band descriptors.
9. Decay evaluations done by DDEP group should be looked at by the evaluator, and taken in consideration during mass-chain evaluations.
10. Similar to the decay evaluations, other horizontal evaluations should be consulted during mass-chain evaluation.
11. Suggested that NNDC consider creating an "unpublished reports" category on their web page.
12. BNL to seek advice at the USNDP meeting in November 2005 as to whether there is a need to consider separate data sets for hyper-nuclides (see action item 36).

4. Reports from Evaluation Centres

Representatives from the individual mass chain evaluation centres presented progress reports on their NSDD studies. These status reports are brought together within Annex 5.

5. Administrative and Related Matters

5.1. Actions from Previous Network Meetings

All previous actions were reviewed in detail. Many of these actions are continuous, and are related to the monitoring of advances in NSDD to ensure that all evaluation centres are kept fully informed of various matters between biennial Network meetings. The list of actions and their current status (continuous, withdrawn and completed) can be found in Annex 4.

5.2. US Nuclear Data Programme (P. Oblozinsky (BNL))

The US Department of Energy (Office of Science, Office of Nuclear Physics) sponsors the US Nuclear Data Program (USNDP) to provide nuclear physics data for basic nuclear research and nuclear technology in the USA. Oblozinsky listed the membership of the USNDP, with a total manpower of ~ 24.5 FTE. Work programmes are identified with two standing working groups (Reaction Data; and Structure and Decay Data), and three task forces with more specific focus (Nuclear data for astrophysics; Nuclear data for and from RIA; and Nuclear data for homeland security). Major products are principally the ENSDF and ENDF databases, and nuclear structure and decay data constitutes an expenditure of ~40% of the available funding.

Oblozinsky emphasised the basic research function of ENSDF, NSR, XUNDL, etc., with sponsorship solely from USNDP, that compares with nuclear reaction activities (ENDF, CINDA, CSISRS/EXFOR,….) with significant applied technology support (and leverage). Various

manpower plots showed the unsatisfactory ENSDF ensemble – need for "new blood", and shortfall in the international contribution to ENSDF (from outside North America). While the US DoE Office of Science remains committed to ENSDF, future funding will be static (zero growth), and will effectively decrease with no compensation for inflation.

Oblozinsky believed there was an urgent need to identify and communicate with influential people in Europe, and so attract the interest of those directors able to access appropriate funding and create a healthier environment for more internationally-based efforts to undertake mass chain evaluations.

ACTION: NDS to explore and organise a 1-day meeting of 3 or 4 Directors/Heads of appropriate institutes to discuss NSDD and develop a coherent approach to EU funding.

ACTION: NDS/NNDC to invite relevant specialists/managers from appropriate institutes to attend the next NSDD meeting.

ACTION: Nichols and Tuli to write to interim Director of iThemba Labs, South Africa, to seek their involvement in NSDD (following provision of information from Stone).

5.3. IAEA Nuclear Data Programme (A. L. Nichols (IAEA-NDS))

5.3.1 Horizontal evaluations, 2003-05

A limited amount of evaluation work has continued on decay scheme studies for inclusion in the European Activation File (EAF) and JEFF-3. Decay scheme data for 36 radionuclides have been compiled and evaluated in this category (see Annex 6). Similar studies have also been completed for the 14 radionuclides within the Ra-226 decay chain, apart from Bi-214 (evaluation still underway). All of the recommended decay data have been tested for their completeness and consistency (expressed as % deviation in the tables to be found in Annex 6).

The NSDD Network urged the Agency to give further thought to extending their expertise in nuclear structure and decay data, and consider the feasibility of recruiting staff to undertake mass chain evaluations as part of their regular work programme.

5.3.2 IAEA-ICTP NSDD workshops

Outline objectives and achievements were described for all NSDD workshops sponsored by the IAEA Nuclear Data Section:

(i) NSDD Evaluation, IAEA Vienna, 18-22 November 2002;

(ii) NSDD: Theory and Evaluation, ICTP Trieste, 17-28 November 2003;

(iii) NSDD: Theory and Evaluation, ICTP Trieste, 4-15 April 2005.

The principal aims were to familiarize nuclear physicists with new experimental data that characterize nuclear structure and decay data, introduce modern nuclear models, and train participants in the methodology of NSDD evaluations and the production of evaluated nuclear structure and decay data (i.e., ENSDF mass-chain evaluations). Students became conversant with nuclear structure models, experimental data that characterize the decay properties of nuclei and

their nuclear structure, and evaluation methodologies for nuclear structure and decay data, while the co-directors sought "new blood" for the NSDD network. Workshop material was presented as lectures (mornings) and exercises (mainly afternoons), and computer exercises included on-line databases retrieval, use of ENSDF analysis and utility codes in NSDD evaluations (i.e., GTOL, LOGFT, HSICC, FMTCHK and others).

Participants attending the one-week pilot workshop in 2002 were chosen with some care, and included: Dimiter Balabanski (Bulgaria), Ashok Jain (India), Tibor Kibédi (Australia), Filip Kondev (USA), Guillermo Marti (Argentina), Ivan Mitropolsky (Russian Federation), Vito Vanin (Brazil), and Huang Xiaolong (PR China) in order to provide strong input to improve the quality of subsequent workshops. This particular course was described and assessed in INDC(NDS)-439, and all materials and computer codes were stored on file.

The two-week NSDD workshop at ICTP Trieste from 17-28 November 2003 saw several modifications based on the review of the earlier pilot programme (additional nuclear theory lectures, and the introduction of experimental studies and statistical analyses lectures). Twenty-four participants from 12 countries received training from 11 lecturers/demonstrators; participants were physicists and engineers working on a wide range of nuclear science topics, and six of them were strongly interested in becoming involved in NSDD evaluation work. A training document was prepared from the lecturers' material: INDC(NDS)-452 (also as CD-ROM).

The second two-week workshop at ICTP Trieste from 4-15 April 2005 included some minor modifications to the course (more focused nuclear theory lectures, and extension of lectures on experimental studies). Twenty-seven participants from 18 countries received training from 10 lecturers/demonstrators. This particular audience was relatively young (compared with November 2003 workshop) - participants were primarily nuclear physicists; eight participants are interested in becoming involved in evaluation work (some already working with other NSDD evaluators). An addendum training document will also be prepared from this specific workshop to include lecturers' new material (also as CD-ROM).

(a) Future ICTP-IAEA workshops

Nichols asked Network members to consider future possibilities, including the following:

(i) further two-week NSDD workshop at ICTP Trieste in early 2006;
(ii) radical changes to the contents to provide more advanced courses for trainee mass chain evaluators and/or intense course for current Network participants.

(b) Finance and training

IAEA Nuclear Data Section has placed a number of modest contracts with institutes in developing countries (Argentina, Brazil, Bulgaria and India) to encourage and support "new blood". But this funding will be finite (normally 3 years), and the Network needs to consider seriously the longer-term options to support new mass chain evaluators. Mentoring is particularly important at both the mentoring and trainee institutes – this activity needs to be re-assessed at regular intervals.

5.4. Organisation - Review (J.K. Tuli (BNL))

The current status and commitments of the mass chain evaluation centres were reviewed in detail:

		Mass chains	FTE
USA	NNDC	113	2.95
	ORNL (NDP)	9	0.25
	LBNL	43	1.85
	TUNL	19	0.45
	ANL	15	0.75
Non-USA	St. Petersburg	6	0.25
	Beijing/Jilin	12	0.5
	Bruyères-le-Chatel	11	0.25
	JAERI	12	0.5
	Kuwait	7	0.2
	Ghent	6	0.1
	McMaster University	25	1.0
	ANU	4	0.3
	IIT, India	12	0.2
TOTAL		294	9.55

Tuli estimated that at least 12 FTEs per annum would be needed to keep ENSDF in reasonably good shape.

Both ANL (Kondev) and ANU (Kibédi) are new operational evaluation centres. Specific mass chain evaluations were being undertaken by some of the new evaluators in conjunction with their mentors:

Argentina; Marti, Achtenberg and Capurro, A = 178, 191, 193, shared with the Brazilian group (Browne (LBNL), mentor);

Argentina; Abriola, A = 94 (Sonzogni (BNL), mentor).

Brazil; Vanin and Castro, A = 178, 191, 193, shared with the Argentine group (Browne (BNL), mentor).

Bulgaria; Balabanski and Lalkovski, A = 112 (De Frenne (Ghent), mentor).

India; Ashok Jain, A =165 and 218 (Singh (McMaster University), mentor);

in association with Anwesha Ghosh, A = 251 (Tuli (BNL), mentor);

in association with Sukhjeet Singh Dhindsa, A = 253 (Tuli (BNL), mentor);

Ameeya Bhagwat, A = 254-256 (Tuli (BNL), mentor);
Gopal Mukherjee, A = 88 (Sonzogni (BNL), mentor);
Mohini Gupta, A = 266-294 (Burrows (BNL), mentor).

The average time between evaluations of a particular mass chain is approximately 7 years. Tuli judged specific Network contributions to be rather fragile; research institutes need to be convinced that the work is of basic importance, and is not a secondary "fall-back" job that can be outsourced. Institutional support would appear to be waning, and is a serious cause for concern.

Both McMaster University (Balraj Singh) and BNL (Oblozinsky/Tuli) were willing to offer mentoring services and collaborative assistance to any new group in the Network. This support would be of the order of 3 or 4 weeks at the mentoring centre, supported by payment of local expenses.

A nuclide priority list is distributed once per year (list of between 150 and 200 radionuclides) that is based on the number of 'new' experimental papers that have been registered in NSR. A mass chain evaluation is deemed necessary when more than three nuclides of the same mass appear on this list. Tuli asked Network participants to contact him at the NNDC if they wished to work on a mass chain not deemed to be in their mass region of responsibility.

At this stage of the meeting, the Network agreed to invite the Indian Institute of Technology (IIT), Roorkee, Uttaranchal, India, into the NSDD Network as a new evaluation centre. An official letter of invitation will be prepared and sent to the Director of IIT, Roorkee.

6. Horizontal Evaluations

6.1. Nuclear Moments (N.J. Stone (University of Oxford))

An extensive table of nuclear magnetic dipole and electric quadrupole moments has been prepared for publication in *At. Data Nucl. Data Tables* (now with the printers). New results have been added (all NSR references), and old entries have been assigned NSR identifiers (see Annex 6). Stone stated that he is committed to providing data compilers with detailed recommendations on request that are based on the latest measurements.

6.2. Electric Monopole Strength (T. Kibédi (ANU))

Kibédi has re-assessed and updated the evaluation of E0 transition probabilities for $0^+ \rightarrow 0^+$ monopole transitions as a consequence of many experimental and theoretical studies in recent years. Recommended procedures have been proposed for the evaluation of spectroscopic information on pure E0 transitions in even-even nuclei, including q_k^2(E0/E2), X(E0/E2) and ρ^2(E0). Details of these studies are given in Annex 6 (see also *At. Data Nucl. Data Tables*, **89** (2005) 77-100). Values for these characteristic monopole transition parameters, conversion coefficients and electronic factors can be determined, and BrIcc can be used to obtain interpolated data. Thus, a major advantage of BrIcc is that conversion coefficients can be determined for electrons, electron-positron pairs and E0 transitions.

6.3. Atomic Masses (J. Blachot (CEA, Bruyères-le-Chatel))

Blachot noted the publication of the latest atomic mass evaluations and tabulations:

A.H. Wapstra *et al. Nucl. Phys.* **A729** (2003) 129-676,

and the corresponding release of NUBASE:

G. Audi *et al. Nucl. Phys.* **A729** (2003) 3-128.

The latter lists recommended nuclear and decay properties of all known ground and isomeric states. Many of these data have been adopted in the preparation of the decay data files for the JEFF-3.1 nuclear applications library.

6.4. Capture Gammas (R.B. Firestone (LBNL))

Note was taken of previous compilations and evaluations of neutron capture gamma-ray data, including Lone *et al* (1981), ENSDF (used to derive nuclear structure, and unsuitable for analytical applications), and Reedy and Frankel ((2002) mainly light elements). Firestone and co-workers have focused their attention on improving significantly these data on the basis of recent comprehensive measurements of neutron-activated prompt gamma-ray activation analyses at the Budapest Research Reactor. These studies have developed through the IAEA coordinated Research Project on "Prompt gamma-ray activation analysis" (1999-2003):

(a) preparation of literature and Budapest (n, γ) datasets for each isotope;

(b) combination of literature and Budapest datasets to produce EGAF database;

(c) test EGAF level schemes by means of γ-ray intensity balance, and compare total ground state γ-ray feedings with BNL-325 data.

The resulting EGAF database is available through the IAEA-NDS Web site:

http://www-nds.iaea.org/pgaa/

Future plans for EGAF include the following:

(a) enter new measurements and review existing database;

(b) neutron activation analysis – new IAEA CRP will be established in 2005 to extend the database to include decay data from ENSDF and k_0 data of De Corte *et al.*

(c) continuum data – calculation of statistical contribution to capture γ-ray spectrum, and determination of new $\sigma_0(\gamma)$ and J^π values;

(d) fast neutron data – average resonance and reaction data;

(e) fission data.

Known difficulties and example data for specific levels and cross sections were also presented.

6.5. Nuclear K-isomers and Multi-quasiparticle Bands (F.G. Kondev (ANL))

Plans are being made at ANL and ANU to evaluate the properties of all K-isomers in the Z = 70-102 region. Properties to be studied will include: E_x, K, J^π, half-lives, BR, ICC, B(XL) and f_ν. Multi-quasiparticle bands may also be considered (by Balabanski (University of Sofia)). ENSDF format will be adopted, and specialized codes have been developed. These evaluations will be completed within 2 years, published and made available to all NSDD centres. All are welcome to contribute to this joint effort.

6.6. Super-deformed Structures, Magnetic-dipole Bands and 3-quasiparticle Structures (Balraj Singh (McMaster University))

Various parameters associated with high-spin structures have been or are being compiled and evaluated:

(a) super-deformed structures – evaluation published in *Nucl. Data Sheets* **97** (2002) 241, and continues to be updated at McMaster University;

(b) fission isomers – Stephan Oberstedt (IRMM, Geel, Belgium) and Balraj Singh are reviewing and updating shape isomer data in the actinide region (excitation energies, decay modes, half-lives and fission barrier parameters);

(c) magnetic rotational dipole bands – first compilation was undertaken in collaboration with Ashok Jain (IIT, India) and published in *At. Data Nucl. Data Tables* **74** (2000) 283; these data are being updated, and will be re-published in the same journal;

(d) 3-quasiparticle structures in the deformed region – new data have been prepared by Ashok Jain and Balraj Singh that cover the region of A = 153-187, for publication in *At. Data Nucl. Data Tables*.

7. NSDD – Other Topics and Issues

7.1. XUNDL (J.C. Roediger (McMaster University))

The XUNDL database provides a rapid form of internet access to recent publications and pre-prints of experimental nuclear structure data that are not yet available in the ENSDF database. Over 90% of the compilation work is undertaken at McMaster University, and a status report was presented by Roediger (see also Annex 6):

> 1520 datasets from about 1250 papers, covering data for 1020 nuclides from ^{13}N to ^{288}115 within 228 A-chains; up-to-date on 20 May 2005, with much of the work carried out by undergraduate students (plus input from staff at LBNL and Grenoble).

Compilers communicate with the authors of published papers to resolve misunderstandings, inconsistencies and errors, and to acquire additional data omitted due to space limitations in the original journal publications. Roediger also noted that XUNDL datasets are regularly used by ENSDF mass chain evaluators to help speed up their evaluation efforts.

7.2. Hyper-nuclei (Balraj Singh (McMaster University))

Singh stated that high resolution γ-ray spectroscopy is revealing significant fine structure in various hyper-nuclei. About 35 such nuclides have been categorized in this manner from ^{3}He to ^{209}Bi (although most of these radionuclides reside in the low mass region below A = 20). Data handling for these hyper-nuclei needs to be assessed, and Singh noted that their decay parameters were being considered by BNL in the context of ENSDF.

ACTION: BNL/NNDC to ensure discussions take place concerning hyper-nuclei/ENSDF at the USNDP meeting in November 2005, and consider the need for a new NSDD policy.

7.3. Quality and Completeness of ENSDF (J.K. Tuli (BNL))

Tuli reminded mass chain evaluators that they are strongly advised to undertake checks of their proposed data at various stages leading up to the creation and adoption of recommended datasets, using PrePro, FMTCHK, XPQCHK and PANDORA, as well as the obligatory review system. Evaluators should also consider reviewers' comments as carefully as they can, and with due respect and courtesy. He noted that a post-review copy of the ENSDF datasets will be sent to the reviewer(s) for final approval, and stressed that additional reviewers are urgently required (with a plea for volunteers).

Future plans for *Nucl. Data Sheets* were discussed, including the proposed publication of non-ENSDF based data (e.g., DDEP and relevant IAEA CRP databases). A review board will also be formed in consultation with Elsevier. Discussions included the observation that the nuclear physics community appeared to be gradually withdrawing their subscriptions for Elsevier journals due to price increases, which implies that ENSDF administration at BNL should consider alternative publishing houses for the ENSDF databases.

7.4. Use of GTOL Code (I.A. Mitropolsky (PNPI))

Mitropolsky revealed that studies with two different versions of GTOL produce different sets of results when uncertainties in the various nuclear transitions are of the order of 1 eV. Modifications have been made to GTOL at PNPI to generate χ^2 values that monitor the quality, consistency and completeness of the proposed data describing the population/depopulation of the nuclear levels.

ACTION: Burrows to explore possible improvements to GTOL on the basis of the studies at PNPI.

8. ENSDF Customer Services

8.1. MIRD and Analysis Codes (T.W. Burrows (BNL))

Burrows reported that an entirely new interface will be prepared for MIRD as part of relational software developments. A summary was also given of the current status of various analysis codes, including program updates to FMTCHK, GTOL (number of levels increased to 1000, and number of gamma transitions increased to 4000 per nuclide), and RULER. Progress and issues

concerning the development of specific analysis codes was defined as follows:

FMTCHK	– upgraded to detect format errors;
GAMUT	– see below (Action);
GTOL	– possible machine-dependent precision problem;
HSICC	– problem of creating new records (further testing required);
LOGFT	– logic added for 3rd and higher order beta transitions;
RADLST	– calculation of sub-shell conversion and Auger electron intensities, and X-ray intensities – LOGFT changes have also been incorporated into RADLST.

Burrows stressed that VMS versions of all of these codes will no longer be upgraded or maintained.

ACTION: Firestone to provide a new version of GAMUT by the end of 2005.

8.2. NuDat (A.A. Sonzogni (BNL))

Sonzogni described specific features of NuDat-2.1:

zoom 1 image is easier to use for navigation than other options;
interactive Chart of the Nuclides – can be easily used for nuclide selection;
interactive decay scheme used to search for specific radiation;
γ-γ coincidence data can be identified much faster than before (any Z, A, N);
graphics have been improved;
new Web server is being used with faster performance (from May 2005).

Development studies are now focused on ways of improving user accessibility (make simpler and quicker). Sonzogni indicated that user requests would be most warmly welcomed during this stage of improvements to NuDat.

8.3. Nuclear Wallet Cards (J.K. Tuli (BNL))

Tuli reported that Nuclear Wallet Cards, 7th Edition (with February 2005 cut-off) has been sent to the publishers. Estimated that 10,000 copies will be printed, and copies will be distributed to APS, DNP and European Physics Societies, on request. Representatives of European/regional societies should contact Tuli with the number of copies they require.

Tuli noted that all 7,000 copies of Nuclear Wallet Cards 2000, 6th Edition, have now been dispersed – however, this edition will be maintained and archived by NNDC because the recommended half-lives have been officially defined as standards for USDoE nuclear materials inventory control.

Nuclear Wallet Cards for Radioactive Nuclides, March 2004, was also noted – contains a limited number of radionuclides (half-lives > 1 hour), and was issued for applications involving US Homeland Security.

8.4. Proposed Table of Nuclides (J.K. Tuli (BNL))

Tuli suggested the preparation and publication of a Table of Nuclides based on ENSDF (for Web and CD-ROM; preparation of DVD would also be considered). Possible contents could include "skeleton" decay schemes, adopted levels, gamma transitions and radioactive decay (basic numerical data without comments). Detailed data to be included were listed as Q-values, XREFs, BANDS, and level energies, half-lives, J^{π} values and decay modes. Gamma transition data would embrace energies, relative intensities, multipolarities, mixing ratios and internal conversion coefficients. Example data for the proposed handbook were also displayed. A possible time schedule for this activity would be to start in autumn 2005 for completion by spring 2007. Subsequent updates would be automated to match and occur in parallel with the regular ENSDF updates.

Comments and questions from Network members were many and varied, but were mainly directed towards the following charges:

was this the most effective use of ENSDF resources at BNL?

how would this electronic document differ in overall content from “Table of Isotopes”?

how would authorship be attributed and assigned?

culminating in queries concerning the real need for such a “publication”. Tuli indicated that the comments made by Network members during these discussions would be taken into consideration prior to a final decision being made concerning the proposed “tabulation”.

9. Overall Recommendations and Conclusions

1. The NSDD meeting recommended that the following group be added to the list of Network centres:
   Indian Institute of Technology, Roorkee, Uttaranchal, India.
2. Other groups will be considered for inclusion in the Network based upon the development of their evaluation programmes and involvement in NSDD evaluation activities.
3. The Network strongly endorsed the sponsorship of NSDD evaluators’ workshops, with possibly a 2-week workshop scheduled for early spring 2006 (IAEA NSDD workshop at ICTP, Trieste, Italy).
4. Evaluation centres within NSDD are encouraged to invite and provide mentoring support to new ENSDF evaluators of mass chains.
5. The Network decided to adopt the BrICC program for ICC calculations using the Band and Raman prescription, and modelling the hole by the frozen orbital approximation (see action item 35).
6. After due consideration, the Network requested the establishment of an electronic “chat site” for NSDD and ENSDF, with BNL personnel as moderator (see action item 25).
7. IAEA NDS staff were asked to seek further support for mass chain evaluations:
   - through organising a 1-day meeting of Directors/Heads from appropriate institutes to discuss NSDD and develop a coherent approach to possible EU funding,

- invite relevant specialists/managers to the next NSDD Evaluators' Network meeting (May/June 2007),
- write to Director of iThemba Labs, South Africa, to seek their involvement in NSDD activities.

8. The NSDD network urged the IAEA NDS to extend their expertise in nuclear structure and decay data through the recruitment of staff to undertake mass chain evaluations as part of their regular work programme.

9. Mass chain evaluations for ENSDF require reputable reviews by appropriate volunteers within the NSDD Evaluators' Network. More such reviewers are required from the Network to meet the current needs.

A N N E X E S

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ANNEX 2

AGENDA

Monday, 6 June 2005

08:30-09:00 Arrival

09:00-9:30 **Introduction**

- Welcome remarks
  Peter Sutherland (Dean of Science and Professor of Physics)
  Jim Waddington (McMaster)
  Alan Nichols (IAEA)
- Remarks by the organizer (Balraj Singh)
- Meeting Chairman
- Adoption of Agenda (Chairman)

09:30-10:00 **Presentation:**
Future Directions in Experimental Nuclear Structure Physics –
Jim Waddington (McMaster)

10:00-10:30 **Technical Discussions** (see list below)

10:30-11:00 *Coffee Break*

11:00-17:30 **Technical Discussions** (see list below)

12:30-14:00 *Lunch*

15:30-16:00 *Coffee Break*

17:30-19:00 *Reception* (Skylight room in Commons Building, McMaster University)

Tuesday, 7 June 2005

09:00-09:50 **Presentation**
Single- and two-particle transfer reactions including inverse kinematics –
Dennis Burke (McMaster)

09:50-17:30 **Technical Discussions** (see list below)

10:30-11:00 *Coffee Break*

12:30-14:00 *Lunch*

15:30-16:00 *Coffee Break*

Technical Discussions - Monday 10:00-17:30, and Tuesday 09:50-17:30

Discussion topics – leaders:

Transition data evaluation David Kulp (Georgia Tech)	20 mins
ENSDF format and evaluation philosophy/policies Jagdish Tuli (BNL)	60 mins
NNDC Web services Boris Pritychenko	45 mins
Radioactive decay data evaluations Marie-Martine Bé (LNHB, Saclay)	45 mins
Nuclear Science References (NSR) Dave Winchell (BNL)	30 mins
ENSDF database Dave Winchell (BNL)	30 mins
Internal conversion coefficients (BrIcc) Tibor Kibédi (ANU)	120 mins
ENSDF evaluation tools Alejandro Sonzogni (BNL)	30 mins
Discrepant data sets – Bootstrap method Vito Vanin (University of Sao Paulo)	20 mins
Band structure and nomenclature in ENSDF Filip Kondev (ANL)	30 mins
Evaluation of reaction data – mainly high spin Balraj Singh (McMaster)	30 mins
Adopted data Coral Baglin (LBNL)	30 mins
ENSDF analysis programs Tom Burrows (BNL)	60 mins
Other topics ?	
General Discussions (all)	

Wednesday, 8 June 2005

09:00-9:30 **Actions from Previous Meetings**

09:30-10:30 **Reports by Evaluation Centres**
NSDD activities and ENSDF evaluators' reports (all centers – 5-10 mins each)
NNDC
IAEA-NDS
ORNL
LBNL
TUNL
ANL

10:30-11:00 *Coffee Break*

11:00-12:30 **Reports by Evaluation Centres** *(cont.)*
NSDD activities and ENSDF evaluators' reports (all centers – 5-10 mins each)
McMaster
St Petersburg
CEN
Gent University
JAERI
Institute of Atomic Energy, China
Jilin University
Nuclear Data Project, Kuwait

12:30-14:00 *Lunch*

14:00-15:00 **Reports by Evaluation Centres** *(cont.)*
NSDD activities and ENSDF evaluators' reports (all centers – 5-10 mins each)
ANU
Others: Ashok Jain, Mohini Gupta, Gopal Mukherjee. Vito Vanin

15:00-15:30 **Administrative and Technical Items**
- Report on the US Nuclear Data Program (P. Oblozinsky, BNL)

15:30-23:00 ***Excursion to Niagara Falls*** – about 90 km from McMaster University

Thursday, 9 June 2005

09:00-10:30 **Administrative and Technical Items** (cont.)

- NSDD Network document INDC(NDS)-421, Rev. 1 (A. L. Nichols, IAEA)
- Report on the IAEA Nuclear Data Program (A. Nichols, IAEA)
  - ICTP-IAEA workshops on NSDD, November 2003 and April 2005
  - Consideration of future ICTP-IAEA workshop agenda
  - IAEA research contracts in support of new ENSDF evaluators
- New evaluation centres/new evaluators (J. Tuli, BNL)
- Training of new evaluators (B. Singh (McMaster) and others)

Organisational Review (J. Tuli, BNL):

- Activities, priorities and manpower
  - Summary of ENSDF evaluation status and activities in 2004-2005
  - Revision of NSDD membership
  - Estimated manpower of each centre for future ENSDF evaluation
  - Future evaluations: priorities
- Re-definition of responsibilities of current groups
- Preliminary mass assignments to new groups

10:30-11:00 *Coffee Break*

11:00-12:30 **Horizontal Evaluations, including Needs and Plans**

- nuclear moments – Nick Stone (Oxford)
- electric monopole strength - Tibor Kibédi (ANU)
- atomic masses – Jean Blachot (Grenoble)
- capture gammas – Rick Firestone (LBNL)
- nuclear K-isomers and multi-quasiparticle bands – Filip Kondev (ANL)/Tibor Kibédi (ANU)
- super-deformed (SD) structures, magnetic-dipole bands, 3qp structures – Balraj Singh (McMaster)/Ashock Jain (IIT, Roorkee)
- others

12:30-13:30 *Lunch*

13:30-14:30 **Horizontal Evaluations, including Needs and Plans** (cont.)
(see above)

14:30-15:30 **NSDD: Other Items**

- XUNDL (Balraj Singh/Joel Roediger, McMaster)
- quality and completeness of ENSDF (Jagdish Tuli, BNL)
- others

15:30-16:00 *Coffee Break*

16:00-17:30 **ENSDF Customer Services**

- Dissemination of ENSDF, publications and services (J. Tuli, BNL)
- MIRD (Tom Burrows, BNL)
- User-oriented database: NuDat (Alejandro Sonzogni, BNL)
- Nuclear Wallet Cards
- Table of Nuclides

19:00-22:00 *Banquet – University Club*

Friday, 10 June 2005

09:00-10:30 **Conclusions and Recommendations**
Adoption of recommendations and actions

10:30-11:00 *Coffee Break*

11:00-12:30 **Conclusions and Recommendations** (cont.)
NSDD chairman
Next meeting

12:30 *Adjournment*

ANNEX 3

ENSDF DATA EVALUATION CENTERS

a. National Nuclear Data Center

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A-Chain Evaluation Responsibility

Center	Mass Chains
a. US/NNDC	45-50,57,58,60-73(ex 62-64),82, 84-88,94-97,99,136-148,150, 152-165 (ex 164),230-240,>249
b. US/NDP	241-249
c. US/LBL	21-30,59,81,83,90-93,166-171, 180-193 (ex 188,190),210-217
d. US/TUNL	2-20
e. US/ANL	176-179,199-209
f. India	218-229
g. Russia/StP	130-135
h. PRC	51-56,62,63,195-198
i. France	101,104,107-109,111,113-117
j. Japan	118-129
k. Kuwait	74-80
l. Belgium	102,103,105,106,110,112
m. Canada	1,31-44,64,89,98,100,149, 151,164,188,190,194
n. Australia	172-175

ANNEX 4

List of Completed, Continuous and New Actions (10 June 2005).

No.	Responsible	Reason	Action
1	J. Tuli, BNL/NNDC	Quality assurance test.	Advise evaluators to run RADLST, and comment on agreement of Q-value and sum of decay energies and X-ray intensities measured and calculated. **Continuous action**.
2	J. Tuli, BNL/NNDC	Priority list evaluations: has to be updated.	Send yearly priority list for nuclide and mass chain ENSDF evaluations. Add priority list of the NSDD TM and network document. **Continuous action**.
3	J. Tuli, BNL/NNDC	Format and consistency problems could arise for certain horizontal evaluations.	Co-ordinate horizontal and A-chain evaluators by means of procedures for inserting horizontal evaluations into ENSDF. **Continuous action**.
4	T. Kibédi, ANU; J. Wood, Georgia Tech	Calculational procedures to characterise E0 transitions should be explained.	Prepare manual that describes how to handle E0 transitions in ENSDF. **COMPLETED; see Annex 6**
5	BNL/NNDC	ENSDF analysis and checking codes need to remain up to date with respect to formats, physics requirements, and the needs of the community.	Update codes for approved format changes. **Continuous action**.
6	All network participants	Results of significant horizontal evaluations are not always incorporated into ENSDF in a timely manner.	Keep abreast of activities in other areas where horizontal evaluations may be appropriate for incorporation into ENSDF. Inform J. Tuli (who will maintain a list of horizontal evaluations on NNDC-NDSDD Web site). **Continuous action**.
7	All network participants	Highly-relevant information and data from some conferences, meetings and laboratory reports are not always available to NSR compilers in NNDC.	Assist the NNDC in obtaining conference proceedings, meeting and laboratory reports for NSR. Copy of unpublished conference reports containing significant NSDD contribution should be sent to D. Winchell. **Continuous action**.
8	IAEA/NDS	Characteristics and parameters of NSDD network have to be regularly updated.	Update NSDD network document regularly as INDC(NDS) report - publish electronically according to the latest changes as defined at the network meeting. **Continuous action - updated, March 2004**.

9	BNL/NNDC	Publish versions of ENSDF are required.	Continue journal "publication" of the mass chain evaluations. **Continuous action.**
10	IAEA/NDS	Co-ordinate network activities in the lengthy period between NSDD meetings.	Nominate a chairman and deputy chairman for next NSDD meeting at the current NSDD meeting. **Continuous action**.
11	Network	Misprints and errors found in NSR and ENSDF.	Report all errors detected in NSR and ENSDF to NNDC as soon as they are found. **Continuous action**.
12	ENSDF evaluators	Accelerate the review process.	Each ENSDF evaluator should be willing to do 2 mass-chains equivalent reviews per FTE-year. Reviewing process for one mass chain should not be longer than 3 months. **Continuous action**.
13	BNL/NNDC	Researchers are not familiar with ENSDF format.	Promote the concept that researchers should supply data to the network in complete, tabular form. **Continuous action**.
14	N. Stone, University of Oxford; D. De Frenne, DSRP; J. Blachot, CEA SPN.	Decrease of NSDD manpower in Europe.	Publish in NUPECC, an informative article about nuclear data evaluations. Action continues from 1998. **WITHDRAWN.**
15	Network	Bring NSDD evaluation work to the attention of the nuclear community.	Present network activities at different conferences and meetings. **Continuous action**.
16	T. Kibédi, ANU	Simplify the data input for ENSDF, and the editing of ENSDF files.	Prepare test version of the ENSDF evaluation tool ("Editor") with brief documentation; make available for tests at the IAEA/ICTP workshop (November 2003), and distribute to network data centres. **WITHDRAWN.**
17	Network	Avoid duplication of work.	Participants should inform the network about any development of software related to NSDD. **Continuous action**.
18	J. Tuli, BNL/NNDC	Encourage specific new measurements.	Indicate in the abstract of an evaluation any critical problems in the data compared with the previous evaluation, gaps in the data, and discrepancies that could be resolved by new measurements. **Continuous action**.
19	Data centre managers	Attract young scientists to data evaluations.	Encourage evaluators to participate in research/evaluation of nuclear structure data. **Continuous action**.

20	NSDD network	Improve NSR.	Send comments and suggestions on NSR improvements (indexing) to D. Winchell. **Continuous action**.
21	BNL/NNDC	Increase the accuracy of Auger electron and continuum beta-spectra.	Improve ENSDF codes to provide more detailed presentations of Auger-electron and continuum beta spectra. **No progress to date beyond formulation of requirements.**
22	All network evaluators	Check validity of the rules.	Inform NNDC when experimental results appear to contradict the rules. **Continuous action.**
23	All network evaluators	Improve quality of evaluations.	Solicit potential non-network evaluation reserves, and send names to ENSDF manager (NNDC). **Continuous action**.
24	All network evaluators	Rule for the lowest energy of the state with isospin $T_>$.	Consider rule presented by F. Chukreev, and include in "Introductory Material" if appropriate. **WITHDRAWN.**
25	IAEA/NDS; BNL/NNDC	Improve communications with users.	Include "chat site" in the agenda of next NSDD meeting. Prepare paper on feasibility of a "chat site" (A&Q, problems and solutions, etc.). **COMPLETED: BNL to set up "chat site" or Bulletin Board, once specifications have been defined (J. Tuli to coordinate specifications).**
26	BNL/NNDC	Improve NSDD retrieval systems.	Open new relational database versions of ENSDF and NuDat to the network participants for tests and comments. **COMPLETED.**
27	T. Burrows, BNL/NNDC; T. Kibédi, ANU	Improve evaluated Internal Conversion Coefficients.	Prepare BRICC data for network usage. **COMPLETED.**
28	All network evaluators	Test BRICC tables.	Any noticeable differences with BRICC values should be reported to the ENSDF manager. **COMPLETED.**
29	IAEA/NDS	Improve low-energy ICCs.	Translate into English: Grechukhin and Soldatov paper on theoretical calculations of low-energy ICCs, and distribute to network participants. **COMPLETED – also to be issued as INDC report.** (Sec. note: now issued as INDC(CCP)-0442).

30	McMaster University; BNL/NNDC; LBNL; and other evaluation centres	Support new ENSDF evaluators.	Invite and provide local support and mentoring to new ENSDF evaluators of mass chain evaluations. **Continuous action**.
31	All network centres	Improve data service.	Keep a record of requests by customers that can not be satisfied. **Planned replacement through further implementation of Action 25.**
32	ENSDF manager	Network should be made aware of needs of NSDD users.	List of horizontal evaluation needs and on-going evaluation activities should be maintained through the NSDD network. **Continuous action**.
33	All network centres	Maintain up to date information on the Network.	Review, modify and correct the contents of INDC(NDS)-421. **Continuous action (see also Action 8)**.

New

34	Balraj Singh, McMaster; F. Kondev, ANL	Data definition.	Propose guidelines for appropriate configurations/labels of band assignments, define the proper quantity and symbol to represent the transition quadrupole moment for rotational bands, and propose an additional J^{π} rule for coupled bands, in addition to current rule #37 for other rotational bands (by 5 November 2005).
35	T. Burrows, BNL/NNDC; T. Kibédi, ANU	Preparation of new agreed data set.	Provide BRICC program for ICC calculations, using the Band-Raman prescription with frozen orbital relativistic procedure (BNIT(2)), for network use (by 1 September 2005). [Sec. note: changed to 1 November 2005].
36	BNL/NNDC	Data definition/policy.	Ensure that discussions on the inclusion of data on hyper-nuclei in ENSDF occur at USNDP meeting in November 2005, and consider whether new NSDD policy is required.
37	T. Burrows, BNL/NNDC	Improvements to codes.	Explore possible improvements to GTOL, following on from studies at Petersburg Nuclear Physics Institute.
38	R. Firestone, LBNL	Data development.	Provide network with a new version of GAMUT by end of 2005.

39	NDS/NNDC	Seek support for mass chain evaluations.	Invite relevant specialist/managers from most appropriate institutes to attend next NSDD meeting.
40	NDS	Seek support for mass chain evaluations.	Explore/organise 1-day *ad hoc* meeting of 3 or 4 Directors/Heads of appropriate institutes to discuss NSDD and develop a coherent approach to EU funding.
41	J. Tuli, BNL/NNDC; A. Nichols, NDS	Seek support for mass chain evaluations.	Following provision of information from N. Stone, write to interim Director of iThemba Labs, South Africa, to seek their involvement in NSDD.
42	J. Tuli, BNL/NNDC	Evaluation responsibilities	Send network members copy of Responsibilities table (by July 2005).
43	NSDD network	Evaluation responsibilities	Correct Responsibilities table – send all changes to J. Tuli and A. Nichols (by mid-July 2005).
44	I. Mitropolsky, PNPI	Possible venue for next NSDD meeting (May/June 2007).	Assess PNPI costs on the basis of Agency rules for external meetings.

ANNEX 5

STATUS REPORTS OF EVALUATION CENTRES

National Nuclear Data Center Activity (including Idaho Group),
Report to the 2005 NSDD Meeting at McMaster University, Canada

May 15, 2005

This report presents the status of nuclear structure, decay data, and related activities of the National Nuclear Data Center (NNDC) for the period December 2003 to May 2005. The name of the NNDC staff member who has the lead responsibility for the part of the activity is given in parentheses.

ENSDF Evaluations Activity (J. Tuli)

NNDC responsibility consists of all mass chains not assigned to any other data center. Currently, it consists of the following 166 mass chains (includes Idaho group):

A = 45-50, 57, 58, 60-73 (ex 62-64), 82-88 (ex 83, 87), 94-99 (ex 98), 136-163 (ex 149, 151), 165, 180-193 (ex 188, 190), >249

The following mass-chains were evaluated since the last meeting (11/2003):

A = 48, 70, 88 *, 153, 155, 157, 158, 160, 233 *, 266-294 *; see details below:

A.1.1. Mass		No. of Nuclides	Evaluator(s)	Status
48	13	Burrows		Pre-Review
70	12	Tuli		Published
88*	14	Sonzogni/Mukherjee		Post-Review
153	17	Helmer/Tuli		Review
155	16	Reich		Published
157	14	Helmer		Published
158	15	Helmer		Published
160	14	Reich		Review
233*	9	Singh/Tuli		Post-Review
266-294*	63	Gupta/Burrows		Pre-Review

The following mass chains are in progress:

A = 47, 67*, 94*, 95*, 150, 162, 251*, 252*, 253*, 254*

(* indicates collaboration with other evaluators)

FTE: 1.70 + 0.25 (Idaho Group)

ENSDF Evaluation Reviews (J. Tuli)

The following evaluations were reviewed:

Helmer: 70

Reich: 105, 149, 157, 185

Sonzogni: 158

Tuli: 115, 186, 205, 210, 211, 212, 217, 240, 243, 247

ENSDF Evaluation Processing (J. Tuli)

On an average there are ~23 mass chains in the production pipeline at various stages of production. Evaluations received are checked for their consistency, format and physics content. The manuscripts prepared are returned to evaluators for their approval before they are sent for review. After review, and with corrections and changes made post-review by the evaluator, the final checks are made and the manuscripts prepared for publication.

Every month processing status report is sent to the network.

One issue of Nuclear Data Sheets was sent every month to Elsevier. Since the upgrading of access via Web, publication of Nuclear Science References was stopped. Last issue devoted to recent references was the January, 2004 issue of Nuclear Data Sheets.

Evaluation Priority (J. Tuli)

A list of nuclides for priority evaluation is prepared and distributed once a year. The last distribution was on February 4, 2005.

ENSDF Maintenance (J. Tuli)

NNDC continues to maintain, update, and distribute ENSDF.

Statistics (as of May 4, 2005):

Nuclides: 2927
Datasets: 15360
Records: 1912315
Size: 153 MB
Comments Datasets: 369
Adopted Datasets: 2930
Decay Datasets: 3704
Reaction Datasets: 8083
Reference Datasets: 274

ENSDF is updated continuously. Two different versions are maintained. One in its original form as sent by the evaluator and the other after it is translated using COMTRANS. The former is

available only via the Web site www.nndc.bnl.gov/nndc/evalcorner.

ENSDF is distributed twice a year. The last distribution was on March 11, 2005. The distribution is in two modes, an update to the file as well as the full ENSDF.
IAEA, NDS, receives the full file every month.

Nuclear Wallet Cards (J. Tuli)

All printed copies (7000) of the sixth edition, January 2000, of the Nuclear Wallet Cards have been distributed.

The seventh edition, April 2005, of Nuclear Wallet Cards has been produced (10000 copies) and will soon be distributed. Although the format and content has mostly remained unchanged, it is updated to January 2005 for all the literature pertaining to decay modes and half-lives.

In March 2004, a Nuclear Wallet Cards for Radioactive Nuclides, giving half- life, decay modes, and major radiations for all naturally occurring radioactive nuclides and others with half-life > 1 h was produced (5000 copies). This was to serve mostly the needs of the US Homeland Security personnel.

Nuclear Science References (D. Winchell)

NSR highlights for the period 1-Nov-2003 to 30-Apr-2005

6992 entries added to NSR.
> 400 articles from NNDC library sent to evaluators

18 monthly distributions:
- mass-chain "recent references" to evaluators
- exchange-format update files
- special queries
- full database to IAEA

The new NSR database and Web application were successfully ported to IAEA.

In March 2005, digital object identifier (doi) information was added to over 40000 older entries using "CrossRef" service. As of May 1, 2005, almost 85000 NSR entries have doi information. This means that 61% of all journal entries have doi (85% for articles published since 2000).

NSR Web application upgrades :

- special characters (Greek symbols, etc.) added to html format
- plain-text output format added (in addition to HTML and "exchange")
- additional information added to "browse" pages
- feedback added to help user when unrecognized author, nuclide, etc. entered in search form
- "NSR for evaluators" added to NNDC evaluators corner by DW and TB

Training (J. Tuli)

Jagdish K. Tuli helped organize, and served as co-director, for two IAEA sponsored Nuclear Structure Evaluation and Theory workshops held at ICTP, Trieste, Italy. The first workshop was sponsored by the IAEA, but hosted by the ICTP, and was held during Nov 17-28, 2003. The second workshop was jointly sponsored by the IAEA and ICTP, and hosted by the ICTP, and was held during April 4-15, 2005. Jagdish Tuli and Thomas Burrows, from NNDC, lectured at these workshops and conducted hands-on training for the participants. The materials were prepared, presented and included in the IAEA report INDS(NDS)-456 for the Trieste-03 workshop. Similar report for the Trieste-05 workshop is pending.

ENSDF Analysis and Checking Codes (T. Burrows)

The ENSDF analysis and checking codes continue to be maintained and improved; recent improvements made in them and their current status is given in a separate report accompanying this contribution. Among the improvements has been the conversion of all the programs to FORTRAN 95. The FORTRAN 95 versions of NSDFLIB and RULER have been distributed and the remaining programs are undergoing in-house testing. The NNDC also participated with the Australian National University, Petersburg Nuclear Physics Institute, Russia, and Oak Ridge National Laboratory in the development of BrIcc (Band-Raman Internal Conversion Coefficients). A beta release version of the program was distributed for testing in November 2004.

NuDat 2 (A. Sonzogni)

NuDat was thoroughly redeveloped to take advantage of modern hardware and software technologies. Relational database software (Sybase) running on a fast Linux server is used to store the data. The Web interface is built with a number of Java Server Pages (JSP) files. The new version, 2.0, went online on April, 2004 . An upgrade, version 2.1, which makes extensive use of code written in JavaScript language, was released on December 2004: www.nndc.bnl.gov/nudat2.

An interactive chart of nuclei, interactive level and decay schemes, as well as a gamma-gamma search capability are among the new features incorporated in NuDat 2.

In the first year of operation, database retrievals performed from NuDat 2, showed an increase by a factor of about 3 with respect to the earlier version. This increase is fueled, in part, by the use of the interactive chart of nuclei.

With the goal to characterize NuDat's user distribution, a study of NuDat's Web logs was performed. In this exercise, the Web activity of the last 4 months in 2004 was analyzed, excluding access from Web crawlers, such as Google, and from unresolved numerical addresses. One concludes that NuDat's user distribution is large and diverse, with many world-class laboratories and universities retrieving regularly from NuDat.

Finally, NuDat 2 was featured in the **Web Watch** and **NetWatch** sections of *Physics Today* and *Science*, respectively.

NNDC Computer System (R. Arcilla)

In the first quarter of 2004, NNDC upgraded its Web services infrastructure by installing new and powerful DELL servers running the Linux operating system. These new servers, one Web server and two Sybase database servers, have been providing the much-needed processing power required by NNDC's modern Web site. They have proved to be highly reliable and have significantly improved the response time during database retrievals.

With the new servers in full operation, the aging Alpha server was decommissioned from Web services on September 30, 2004.

A wireless LAN based on Intel's Centrino technology was also installed to provide, NNDC staff and visiting ENSDF evaluators, easy access to NNDC's computing resources.

To further improve the availability of nndc's web site, sybase replication technology is currently being tested. Once implemented, updates performed on the primary sybase database server are automatically replicated to the secondary on a predetermined schedule. The secondary database server handles all data retrieval requests from the web server. In case of a severe failure on the secondary database server, all data retrieval requests would be automatically rerouted to the primary.

Web-based services (B. Pritychenko)

In April 2004, the NNDC migrated US Nuclear Data Program databases and Web services to a Java-based production environment. The new Web-based nuclear data retrieval system is based on Linux/Sybase/Apache/Tomcat solution and tightly integrated with nuclear structure evaluations and compilation efforts: www.nndc.bnl.gov.

Nuclear structure data services were significantly upgraded to improve capabilities and user friendliness for ENSDF, NSR and NuDat databases. The new ENSDF Web services substantially improve and simplify ENDSF nuclear data set retrievals. The new NuDat Web services enhance search and formatting capabilities for nuclear data, provide more convenient way to search for levels and gammas and better integration with Nuclear Wallet Cards.

The new NNDC Web services were highly appreciated by the nuclear data users. Total number of data retrievals in calendar year 2004 increased to 560.0 K versus 337.9 K in 2003. In the same period, ENSDF data retrievals grew from 60.2 K to 99.7 K and NuDat data retrievals increased from 62.6 K to 191.1 K. Three-fold increase in NuDat data retrievals is attributed to effective implementation of the latest Java and Javascript Web technologies.

During one year of operation the new NNDC Web system demonstrated better performance and reliability with a minimal down time, which is mostly due to cybersecurity upgrades. To further satisfy cybersecurity requirements, NNDC is planning in 2005 to install new Web server to Enterprise version of Red Hat Linux and Tomcat 5. During this year NNDC is planning to improve existing Web applications (MIRD, Q-value calculator) and convert Perl-based applications to Java.

Mentoring/Evaluators' Visits (J. Tuli)

Alejandro Sonzogni mentored and collaborated with Dr. Gopal Mukherjee of India (a Trieste-03 evaluators' workshop trainee) in evaluation of A=88. Alejandro also mentored and collaborated with Dr. Daniel Abriola of Argentina (a Trieste-05 evaluators' workshop trainee) in evaluation of A=94.

Thomas Burrows mentored and collaborated with Dr. Mohini Gupta of India (a Trieste-03 evaluators workshop trainee) in evaluation of A = 266-294.

Dr. Tibor Kibédi (a Vienna-02 evaluators' workshop trainee) from Australia visited NNDC (twice, September 2004 and May 2005) to collaborate with Thomas Burrows with adoption of new ICC program to replace HSICC.

Selected NNDC Publications (12/2003 – 5/2005) (ENSDF- or Web-related only)**:**

1. "NNDC Stand: Activities and Services of the National Nuclear Data Center" B. Pritychenko, R. Arcilla, T.W. Burrows, C.L. Dunford, M.W. Herman, V. McLane, P. Obložinský, A. Sonzogni, J.K. Tuli, and D.F. Winchell. International Conference on Nuclear Data for Science and Technology. AIP Conference Proceedings 769, 132 (2005).
2. "Evaluated Nuclear Structure Data File and Related Products" J.K. Tuli. International Conference on Nuclear Data for Science and Technology. AIP Conference Proceedings 769, 265 (2005).
3. "A New Tool to Interpolate Conversion Coefficients and E0 Electronic Factors" T. Kibédi, T.W. Burrows, M.B. Trzhaskovskaya, and C.W. Nestor, Jr. International Conference on Nuclear Data for Science and Technology. AIP Conference Proceedings 769, 268 (2005).
4. NuDat 2.0: Nuclear Structure and Decay Data on the Internet".A.A. Sonzogni, Proceeding of the International Conference on Nuclear Data for Science and Technology. AIP Conference Proceedings 769, 574 (2005).
5. **"**Nuclear Information Services at the National Nuclear Data Center" T.W. Burrows and C.L. Dunford. International Conference on Nuclear Data for Science and Technology. AIP Conference Proceedings 769 (2005), page 582.
6. "Nuclear Science References as a Tool for Data Evaluation" D.F. Winchell, Proceeding of the International Conference on Nuclear Data for Science and Technology. AIP Conference Proceedings 769, 570 (2005).
7. "New Web-Based Access to Nuclear Structure Datasets"D.F. Winchell, Proceeding of the International Conference on Nuclear Data for Science and Technology. AIP Conference Proceedings 769, 578 (2004).
8. "Bibliographic Databases in support of NSDD Evaluations" T. Burrows. Workshop on Nuclear Structure and Decay Data: Theory and Evaluation (Manual – Part 2). INDC(NDS)-452 (2004), page 293.
9. "Proton Radioactivity for Nuclei with Z > 50" A.A. Sonzogni, Proceeding of the International Conference on Nuclear Data for Science and Technology. AIP Conference Proceedings 769, 1269 (2004).
10. "Nuclear Structure and Decay Data: Introduction to Relevant Web Pages" T.W. Burrows, P.K. McLaughlin, and A.L. Nichols. Workshop on Nuclear Structure and Decay Data: Theory and Evaluation (Manual – Part 2). INDC(NDS)-452 (2004), page 405.

11. “ENSDF Analysis and Utility Codes” T.W. Burrows. Workshop on Nuclear Structure and Decay Data: Theory and Evaluation (Manual – Part 2). INDC(NDS)-452 (2004), page 103.
12. “Workshop on Nuclear Structure and Decay Data: Theory and Evaluation”, Trieste, November 2003. Lectures by J. K. Tuli, Summary Report, INDS(NDS)-452 (2004).
13. “Workshop on Nuclear Structure and Decay Data: Theory and Evaluation”, Trieste, April 2005 Lectures by J. K. Tuli, T. W. Burrows, Summary Report to be published.
14. “Nuclear Reaction and Structure Web Services of the National Nuclear Data Center” B. Pritychenko, A.A. Sonzogni, D.F. Winchell, V.V. Zerkin, R. Arcilla, T.W. Burrows, C.L. Dunford, M.W. Herman, V. McLane, P. Oblozinsky, Y. Sanborn, J.K. Tuli, Brookhaven National Laboratory Report BNL-73439-2004-JA, December 2004.
15. “Nuclear Data Sheets for A=60”, J. K. Tuli, Nuclear Data Sheets 100, 347 (2003).
16. “Nuclear Data Sheets for A=70”, J. K. Tuli, Nuclear Data Sheets 103, 389 (2004).
17. “Evaluated Nuclear Structure Data File”, J. K. Tuli, Bulletin of American Physical Society, October 2004, CD-003.
18. “Nuclear Data Sheets for A = 134” A.A.Sonzogni, Nuclear Data Sheets 103, 1 (2004).
19. “Next-generation Nuclear Data Web Services” A.A. Sonzogni, Proceedings of the VIII Nuclei in the Cosmos Conference, to be published.

REPORT

To IAEA Advisory Group Meeting on

NUCLEAR STRUCTURE AND DECAY DATA EVALUATORS' NETWORK

by the IAEA Nuclear Data Section

June 2005

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1. Sub-programme 1.D.1 – atomic and nuclear data

Brief summaries are given below of the various tasks within the atomic and nuclear data sub-programme of the IAEA Nuclear Data Section that are judged to be of interest to the NSDD Network:

1.01 Data services, data networks and user support

- maintain services,
- documentation and "publicity",
- multi-platform activities,
- nuclear data services in developing countries,
- CINDA/EXFOR compilations,
- INDC and A+M Subcommittee of IFRC reviews,
- NRDC (yearly) and NSDD (biennial) network meetings,
- NEA Data Bank/NDS co-ordination (also ensure no duplication),
- workshops (ICTP and IAEA),
- conference support to developing countries.

1.02 Nuclear data standards and evaluation methods

Enable users to produce evaluated nuclear data that satisfy the high accuracy and consistency demanded by emerging nuclear technologies through the production of clearly defined evaluation methods and procedures.

- CRP on "Improved Cross-Section Standards" (2002-05); 3rd and final RCM held in 2004;
- CRP on "RIPL-3" (2003-08); 2nd RCM held in 2004.

1.03 Nuclear data for radiotherapy using radioisotopes and external radiation sources

Improve data for medical isotope production, and for patient dose delivery calculations in radiotherapy.

- continuation of CRP on "Nuclear Data for Production of Therapeutic Radioisotopes" (2003-06) – 2nd RCM held in 2004;
- Web site: "Nuclear data for medical applications".

[1.04 Atomic and molecular data]

1.05 Data for Th-U fuel cycle

Strengthen energy technologies in Member States through the assessment of Th-U nuclear data needs, and develop high-quality data files relevant for Th-U fuel cycle.

- continue CRP on "Evaluation of Nuclear Data for Th-U Fuel Cycle" – 2nd RCM held in 2004;
- Web page: "Nuclear data for safeguards" – updating underway over 2005/06.

1.06 Nuclear data for reactor dosimetry and analysis

Improve the databases of differential and integral parameters, and satisfy the current needs of Member States for accurate, high-quality ion beam and neutron activation analysis data.

- CRP on "Database of Prompt Gamma Rays from Slow Neutron Capture for Elemental Analysis" – technical document, database etc completed in 2004;
- CRP on "Development of a Reference Database for Neutron Activation Analysis" (2005-2009) – 1st RCM in 2005;
- CRP on "Development of a Reference Database for Ion Beam Analysis" (2005-2009) – 1st RCM in 2005.

1.07 Nuclear data for advanced nuclear facilities

Improve Member States abilities to optimise plant design, and so reduce engineering margins

- Data for advanced systems – contracts (FENDL-2.1, ^{58}Fe, thermal scattering law, etc.);
- CRP on "Updated Decay Data Library for Actinides" (2005-2009) – 1st RCM in 2005;
- Develop and support reference library to undertake neutron transport calculations for advanced systems – TM in December 2004 (ADS).

2. Evaluated Decay Data, 2004/05

Recommended decay scheme data for 37 radionuclides have been incorporated into the European Activation File (EAF) in support of JEFF fusion studies (all files prepared in ENDF-B6 format). These radionuclides range from 32-Ge-80, through 39-Y-97 and 50-Sn-129, to 64-Gd-163 and 77-Ir-192. Full decay scheme data have also been evaluated for the Ra-226 decay chain.

Oak Ridge National Laboratory (ORNL)
Tennessee, USA

Murray Martin represented Oak Ridge National Laboratory (ORNL) at the NSDD Network meeting. Their mass chain evaluation responsibilities span from mass 241 to 249.

Isotopes Project

A.1.2. LAWRENCE BERKELEY NATIONAL LABORATORY

C.M. Baglin (Project Leader), **M.S. Basunia, E. Browne, R.B. Firestone, S.-C. Wu** (guest)

Report prepared by C.M. Baglin for the June 2005 IAEA Advisory Group Meeting at McMaster University, Canada on *Coordination of the International Network of Nuclear Structure and Decay Data Evaluators*. This report covers the period from November 2003 through May 2005.

Mass Chain Responsibility:

A = 21-30, 59, 81, 83, 90-93, 166-171, 210-240 (~520 nuclides, since Nov. 2004).

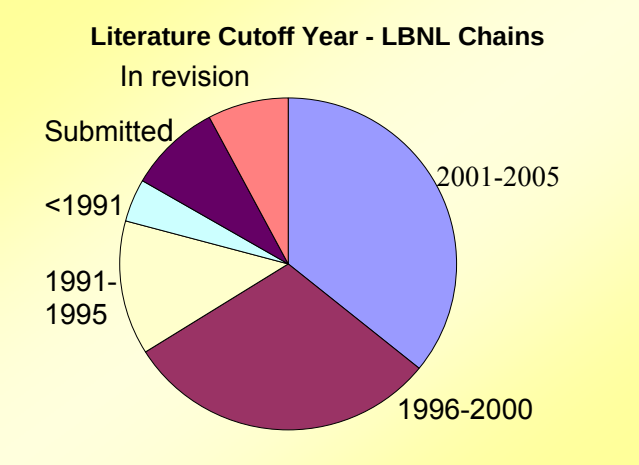
Current Levels of Effort:

Evaluation:	2.18 FTE (staff)
	0.20 FTE (guest)
Dissemination:	0.25 FTE
Management, coordination, research:	1.10 FTE
Total:	**3.73 FTE**

Collaborations with:

- Institute of Isotope and Surface Chemistry and Budapest Reactor, Hungary
- Lawrence Livermore National Laboratory
- Decay Data Evaluation Project (DDEP) participants

Status of Assigned Nuclides:



A. NUCLEAR STRUCTURE AND DECAY DATA EVALUATION

- **Mass Chain Evaluations (1.95 FTE):**
  Submitted: A=22, 169, 175, 176, 181, 185, 212 (84 nuclides).
  Published: A=21, 175, 180, 211, 212 (56 nuclides).
  Reviewed: A=73, 175, 203, 233.

- **Complete Nuclide Evaluations (0.1 FTE):**
  Unpublished; reviewed and added to ENSDF:
  ^{92}Kr, ^{171}Hg, ^{184}Bi, ^{225}Fr.

- **Decay Data Evaluation Project (DDEP) Participation (0.13 FTE):**
  - **Evaluation of 2 DDEP Radionuclides:**
    ^{56}Co, ^{243}Am
  - **Reviews of 7 DDEP Evaluations:**
    ^{56}Co, ^{108}Ag, ^{108m}Ag, ^{125}Sb, ^{233}Pa, ^{233}Th, ^{242}Cm.
  - **Coordination of program, general editorial oversight**

- **Neutron Capture Data Evaluation (0.20 FTE):**

a. Collaboration with LLNL:

Goal:

To improve the quality of information in the ENDF database by adding:

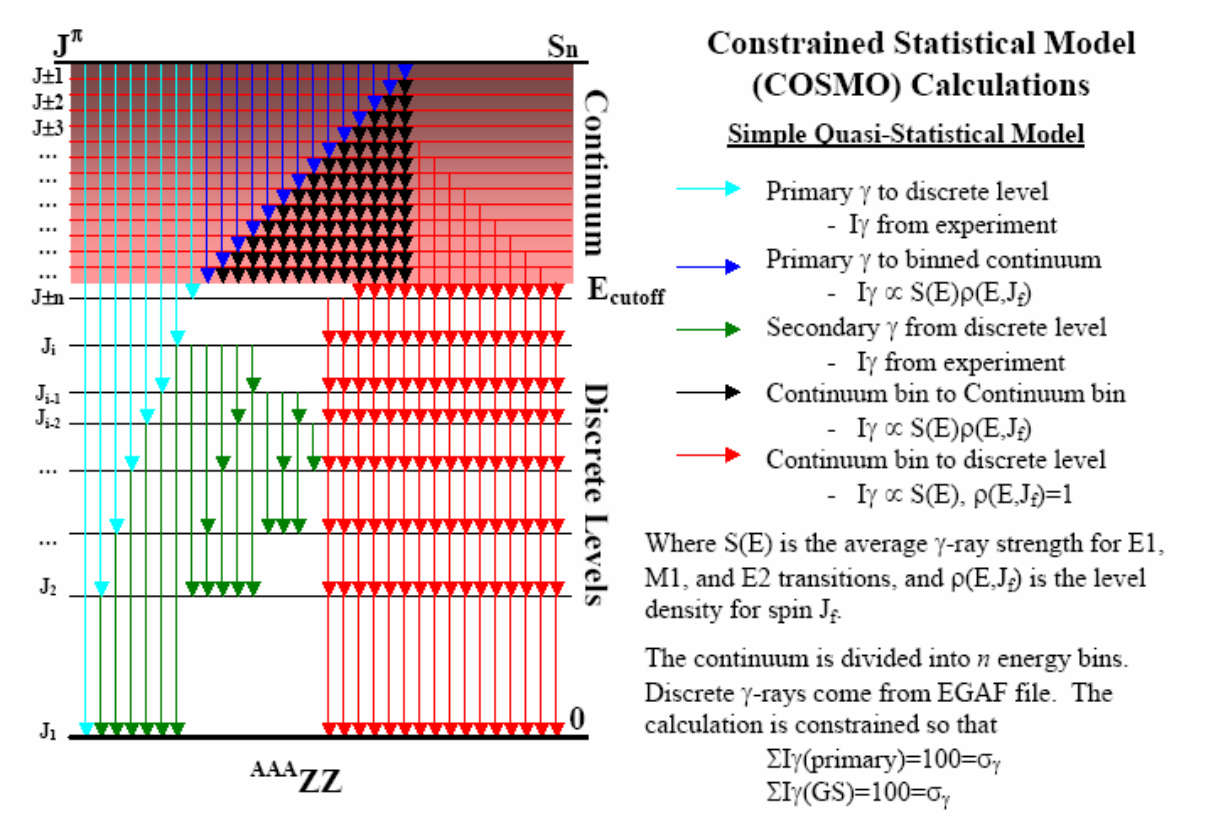
- discrete line (n,γ) information (E=thermal) from newly-completed EGAF (Evaluated Gamma-ray Activation File) database, and
- quasi-continuum photon information calculated using statistical model (with parity effects on level densities included).
-

Importance:

For use in coupled neutron-photon transport codes, including MCNP.

Progress:

- ENDF-format files for thermal-neutron capture on A=1-20 targets have been completed.
- New software, COSMO, developed (R. Firestone) to enable the necessary statistical-model calculations.



R. Firestone 5/05

b. Collaboration with Chemical Research Centre, Budapest, Hungary:

- Measured (n,γ) cross section for ^{24}Mg.
- Prepared numerous reference data appendices for 4 volumes of *Handbook of Nuclear Chemistry* (Kluwer) and for *Handbook of Prompt Gamma Activation Analysis with Neutron Beams* (Kluwer) and an (n,γ) spectrum catalog for the latter.

B. NUCLEAR STRUCTURE DATA DISSEMINATION (0.25 FTE)

- Maintained approximately 12 web pages; added interactive search capabilities for mass data and ENSDF Adopted Levels, Gammas data and extended search options for *WWW Table of Radioactive Isotopes.*
- Supported *Isotope Explorer 2* (C++, Windows) and *Isotope Explorer 3* (Java, HTML) application software developed by Isotopes Project in the 1990's and now used extensively worldwide to view ENSDF level schemes.
- Served 186K distinct hosts who downloaded ~155 Gb data in FY04.

C. RESEARCH (0.8 FTE)

- Cross-section measurements for 63Cu(α,γ) and 107Ag(α,γ) at low energies (reported at International Conference on Nuclear Data for Science and Technology, Santa Fe, Sept. 2004).
- Half-life of 108mAg (measurement in progress).
- Flux measurement for both fast and thermal neutrons from LBNL neutron generator (completed).
- Participating in IAEA CRP on New Applications of Prompt Gamma Neutron Activation Analysis; hosted Technical Meeting at LBNL in Aug. 2004. (Dec. 2002 – present).
- Evaluation of 238U cross section and 239Pu γ transition probabilities (submitted for publication).
- Measured contaminants in rare-earth material samples using prompt gamma activation analysis (submitted for publication)
- Investigations of feasibility of detecting fissile materials via neutron interrogation (three studies, one published, one in press and one ongoing).

D. PUBLICATIONS and INVITED TALKS

Mass Chain or Nuclide Evaluation Publications

Nuclear Data Sheets for A=180, S.-C. Wu and H. Niu, Nuclear Data Sheets **100,** 483 (2003).

Nuclear Data Sheets for A=175, M.S. Basunia, Nuclear Data Sheets **102**, 719 (2004).

Nuclear Data Sheets for A=211, E. Browne, Nuclear Data Sheets **103,** 183 (2004).

Nuclear Data Sheets for A=21, R. Firestone, Nuclear Data Sheets **103**, 269 (2004).

Nuclear Data Sheets for A=212, E. Browne, Nuclear Data Sheets **104**, 427 (2005).

Other Nuclear Data Related Publications

Table of Radionuclides, M.M. Bé, V. Chiste, C. Dulieu, E. Browne, V. Chechev, N. Kuzmenko, R. Helmer, A. Nichols, E. Schonfeld, R. Dersch, Bureau International des Poids et Mesures Monographie BIPM-5 (2004).

Appendices, R.B. Firestone and G.L.Molnár: *Reference Data* in Vol. 1, *Basics of Nuclear Science* and *Table of the Nuclides* in Vol 5, *Instrumentation, Separation Techniques, Environmental Issues* of *Handbook of Nuclear Chemistry*, eds. A. Vertes, S. Nagy, K. Klencsar, G.L. Molnár, Kluwer Academic Publishers, 2003.

Appendices, Reference Data, R.B. Firestone in Vol. 2, *Elements and Isotopes and* Vol. 3*, Chemical Applications of Nuclear Reactions and Radiations* of *Handbook of Nuclear Chemistry*, eds. A. Vertes, S. Nagy, K. Klenscar, and G.L. Molnár, Kluwer Academic Publishers, 2003.

Prompt Gamma-Ray Spectrum Catalog, Zs. Révay, R.B. Firestone, T. Belgya, G.L. Molnár, Chapter 7 of *Handbook of Prompt Gamma Activation Analysis with Neutron Beams*, ed. G.L. Molnár, Kluwer Academic Publishers, 2004.

Appendices: Reference Data, R.B. Firestone, G.L. Molnár, Zs. Révay, in *Handbook of Prompt Gamma Activation Analysis with Neutron Beams*, ed. G.L. Molnár, Kluwer Academic Publishers, 2004.

The Evaluated Gamma-ray Activation File (EGAF), R.B. Firestone, AIP Conference Proceedings **769**, *International Conference on Nuclear Data for Science and Technology*, eds. R. Haight, P. Talou, T. Kawano, M.B. Chadwick, p. 225 (2005).

Nuclear Data for the Present Age, Coral M. Baglin, AIP Conference Proceedings **769**, *International Conference on Nuclear Data for Science and Technology*, eds. R. Haight, P. Talou, T. Kawano, M.B. Chadwick, p. 230 (2005).

The Evaluation of Gamma Ray Emission Probabilities in the Decay of ^{56}Co, Desmond MacMahon and Coral Baglin, AIP Conference Proceedings **769**, *International Conference on Nuclear Data for Science and Technology*, eds. R. Haight, P. Talou, T. Kawano, M.B. Chadwick, p. 370 (2005).

Other Nuclear Science Publications Involving Isotopes Project Personnel

Ambient Silver Concentration Anomaly in the Finnish Arctic Lower Atmosphere, M.S. Basunia, S. Landsberger, T. Yli-Tuomi, P.K. Hopke, P. Wishinski, Y. Viisanen, and J. Paatero, Environmental Science & Technology*,* **37**, 5537-5544 (2003).

Signature of fissile materials: high-energy γ rays following fission, E.B. Norman, S.G. Prussin, R.-M. Larimer, H. Shugart, E. Browne, A.R. Smith, R.J. McDonald, H. Nitsche, P. Gupta, M.I. Frank, T.B. Gosnell, Nucl. Instrum. Meth. Phys. Res. **A 521**, 608-610 (2004).

Response to a comment on ""Signatures of fissile materials: high-energy γ-rays following fission" by Zeev B. Alfassi*,* E.B. Norman, S.G. Prussin, R.-M. Larimer, H. Shugart, E. Browne, A.R. Smith, R.J. McDonald, H. Nitsche, P. Gupta, M.I. Frank, T.B. Gosnell, Nucl. Instrum. Meth. Phys. Res. **A 534**, 577 (2004).

First PGAA and NAA Experimental Results from a Compact High Intensity D-D Neutron Generator, J. Reijonen, K.-N. Leung, R.B. Firestone, J. English, D. Perry, A. Smith, F. Gicquel, M. Sun, Bryan Bandong, Glenn Garabedian, Zsolt Révay, Laszlo Szentmiklosi and Gabor Molnár, Nucl. Instrum. Meth. Phys. Res. A 522, 598 (2004).

*The Characterization of Legacy Radioactive Materials by Gamma Spectroscopy and Prompt Gamma Activation Analysis (PGAA)***,** G.A. English, D.L. Perry, J. Reijonen, B. Ludewigt, K N. Leung, R.B. Firestone, G. Garabedian, G. Molnár, and Zs. Révay, Proceedings of the 5th International Topical Meeting on Industrial Radiation and Radioisotope Measurement Applications (IRRMA-V), Bologna, Italy, 9-14 June 2002 (to be published in Nucl. Instrum. Meth. B **213**, 410 (2004).

*The Use of Prompt Gamma Activation Analysis (PGAA) for the Analysis and Characterization of Materials: Photochromic materials***,** D.L. Perry, G.A. English, R.B. Firestone, K-N. Leung, G. Garabedian, G.L. Molnár and Zs. Révay*,* Proceedings of the 5th International Topical Meeting on Industrial Radiation and Radioisotope Measurement

Applications (IRRMA-V), Bologna, Italy, 9-14 June 2002, Nucl. Instrum. Meth. B **213**, 527 (2004).

Improved Limit on the Electron Capture Decay Branch of ^{176}Lu, E.B. Norman, E. Browne, I.D. Goldman, P.R. Renne, Appl. Radiat. Isot. **60**, 767 (2004).

Measurement of cross sections for the ^{63}Cu(α,γ)^{67}Ga reaction from 5.9 to 8.7 MeV M.S. Basunia, E.B. Norman, H.A. Shugart, A.R. Smith, M.J. Dolinski, and B.J. Quiter, Phys. Rev. **C 71**, 035801 (2005).

Measurement of Cross Sections for ^{63}Cu(α,γ)^{67}Ga, M.S. Basunia, E.B. Norman, H.A. Shugart, M. Dolinski, B. Quiter, AIP Conference Proceedings **769**, *International Conference on Nuclear Data for Science and Technology*, eds. R. Haight, P. Talou, T. Kawano, M.B. Chadwick, p. 1366 (2005).

Measurement of the ^{107}Ag(α,γ) Cross Section, C.M. Baglin, E.B. Norman, R.-M. Larimer, G. Rech, AIP Conference Proceedings **769**, *International Conference on Nuclear Data for Science and Technology*, eds. R. Haight, P. Talou, T. Kawano, M.B. Chadwick, p. 1370 (2005).

Invited Talks

The Evaluated Gamma-ray Activation File (EGAF), R.B. Firestone, International Conference on Nuclear Data for Science and Technology, Santa Fe, NM, 26 Sept. – 1 Oct., 2004.

Nuclear Data for the Present Age, Coral M. Baglin, International Conference on Nuclear Data for Science and Technology, Santa Fe, NM, 26 Sept. – 1 Oct., 2004.

Physics of Gamma-Ray Spectroscopy Measurements and *New Data and Directions for Neutron Activation Analysis,* R.B. Firestone*,* two 90-minute lectures at the ICTP (Trieste) *Workshop on Nuclear Data for Science and Technology: Materials Analysis,* 7-18 March, 2005.

ENSDF – Reaction Data, Coral M. Baglin, two 90-minute lectures at each IAEA/ICTP *Workshop on Nuclear Structure and Decay Data: Theory and Evaluation* held in Trieste, April 2005 and Nov. 2003.

ENSDF – Adopted Levels and Gammas, Coral M. Baglin, two 90-minute lectures at each IAEA/ICTP *Workshop on Nuclear Structure and Decay Data: Theory and Evaluation* held in Trieste, April 2005 and Nov. 2003.

ENSDF - Decay Data, Edgardo Browne, two 90-minute lectures at each IAEA/ICTP *Workshop on Nuclear Structure and Decay Data: Theory and Evaluation* held in Trieste, April 2005 and Nov. 2003.

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REPORT

To IAEA Advisory Group Meeting on

NUCLEAR STRUCTURE AND DECAY DATA EVALUATORS' NETWORK

TUNL NUCLEAR DATA EVALUATION PROJECT

June 2005

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I. Status of A = 3–20 data evaluation

TUNL is responsible for data evaluations in the mass range A = 3-20. Since the last NSDD/IAEA meeting in 2003, the final reviews for the masses A = 8,9,10 were published in "Energy Levels of Light Nuclei, A = 8,9,10", Nuclear Physics A745 (2004) 155. Preliminary reviews of A = 3 and A = 11, 12 are under way.

Recent Publications from the TUNL Data Evaluation Group

Nuclear Mass	Publication/Status
A = 5,6,7 [a]	Nucl. Phys. A708 (2002) 3
A = 8,9,10 [b]	Nucl. Phys. A745 (2004) 155

[a] With G.M. Hale (LANL) and H.M. Hoffman (Erlangen-Nurnberg).
[b] With D.J. Millener (BNL).

II. ENSDF

Since 2003, we have published a review of Energy Levels of Light Nuclei, A = 8-10; the corresponding ENSDF files are in progress. The ENSDF file for A = 8 was submitted in April, and files for A = 9 and 10 are nearly completed.

III. World Wide Web Services

TUNL continues to develop new WWW services for the nuclear science and applications communities. PDF and HTML documents are online for TUNL and Fay Ajzenberg-Selove reviews for 1968-present, A = 5-7 (1966) and A = 5-10 (1959). Energy Level Diagrams are provided in GIF, PDF and EPS/PS formats for the publication years 1966-present and A = 5-10 (1959). General tables that reference theoretical work related to TUNL's most recent reviews are available on our website for masses A = 5-10. Information on the TUNL web pages make extensive use of the NSR link manager. We have also begun a new effort to organize and provide information on Thermal Neutron Capture evaluated data.

IV. Related Activities

TUNL continuously maintains a substantial reference database. We make extensive use of the Nuclear Science References services at NNDC and Monthly Updates from NNDC.

Supported by the U.S. Department of Energy Director of Energy Research, Office of High Energy and Nuclear Physics, Contract Nos. DEFG02-97-ER41042 (North Carolina State University); DEFG02-97-ER41033 (Duke University).

Progress Report of Nuclear Structure and Decay Data Activities at Argonne National Laboratory*

Filip G. Kondev

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Argonne, Illinois 60439

Prepared for the 16th meeting of the *Nuclear Structure and Decay Data* Network
McMaster University, Hamilton, Ontario, Canada, June 6 - 10, 2005

Period covered: September 2003 – May 2005

I. Program overview

The Argonne Nuclear Data Program includes a variety of scientific activities carried out within the broader framework of the Coordinated Work Plan of the U.S. Nuclear Data Program. Among these are the compilation and evaluation of nuclear structure and nuclear reaction data, and the development of nuclear data measurement, analysis, modeling, and evaluation methodologies for use in basic science and technology applications. Contributions are also made to various specialized databases serving specific needs in the fields of nuclear structure, nuclear astrophysics, and applied nuclear physics.

II. Program activities

II.1 Nuclear Structure and Decay Data Evaluations for ENSDF

The main emphasis of the nuclear structure and decay data activities at Argonne National Laboratory (ANL) is on evaluations for ENSDF. At the last Nuclear Structure and Decay Data (NSDD) network meeting in Vienna, ANL became an official member of the NSDD Network and evaluation responsibilities for the A=199-209 mass chains were assigned to our program. The up-to-date status of these evaluations is presented in Table 1. During the period of time covered by this report, the evaluation of the A=205 mass chain was completed, reviewed and published in *Nuclear Data Sheets*. Work on A=203 mass chain was also completed. This evaluation was submitted to NNDC, reviewed and it is currently in press. The evaluation of A=201 mass chain is ongoing and it will be completed by early September 2005. Future plans for mass chain evaluations by our program are indicated in Table 1. The ultimate goal is to make all evaluations in this region current in the next 4-5 years. ANL is also involved in reviews of selected evaluations submitted by members of the NSDD network for inclusion in ENSDF and publication in *Nuclear Data Sheets*. Following on requests from the Editor of *Nuclear Data Sheets,* reviews of A=88 and 179 mass chains were completed. The review of A=176 is ongoing.

* This work is supported by the Office of Nuclear Physics, U.S. Department of Energy under Contract No.W-31-109-ENG-38.

Table 1. A=199-209 mass chain evaluation status

Mass	NDS publication	Evaluator	Current Status
199	NDS **72** (1994) 297	A. Artna-Cohen	being evaluated by the McMaster group
200	NDS **75** (1994) 297	M.R. Schmorak	to be evaluated during FY2006
201	NDS **71** (1994) 421	S. Rab	being evaluated
202	NDS **80** (1997) 647	M.R. Schmorak	to be evaluated during FY2006/FY2007
203	NDS **70** (1994) 173	S. Rab	completed/ in press
204	NDS **72** (1994) 409	M.R. Schmorak	to be evaluated during FY2007
205	NDS **101** (2004) 521	F.G. Kondev	completed
206	NDS **88** (1999) 29	E. Browne	
207	NDS **70** (1993) 315	M. Martin	
208	NDS **47** (1986) 797	M. Martin	being evaluated by the ORNL group
209	NDS **63** (1991) 723	M. Martin	

II.2 Specialized Decay Data Evaluation for DDEP

Argonne Nuclear Data Program is contributing to the activities of the Decay Data Evaluation Project (DDEP). An evaluated decay dataset for ^{177}Lu, a nuclide that is relevant to medical applications, was submitted to the DDEP Chairman, reviewed and published at the DDEP web site. Evaluations of decay properties of the $K\pi=16^{+}$, $T_{1/2}$=32 y isomer in ^{178}Hf and the $K\pi=23/2^{-}$, $T_{1/2}$=160 d isomer in ^{177}Lu that are of relevance for detector calibration applications are continuing. Reviews of evaluations for the ^{65}Zn, ^{204}Tl, and ^{240}Pu nuclides were also performed on requests from the DDEP chairman.

II.3 Other Activities

Argonne Nuclear Data participant attended the IAEA/ICTP organized workshop on "Nuclear Structure and Decay Data: Theory and Evaluation" that took place in Trieste, Italy in April 2005. Two lectures entitled "Experimental Nuclear Structure Methods and Techniques" and "Contemporary Nuclear Structure Physics at the Extreme" were presented at this meeting.

In collaboration with scientists from the Australian National University, the Argonne program is involved in a horizontal evaluation of properties of K-isomers in deformed nuclei. The data are compiled in ENSDF format, evaluated and processed using codes that were developed for this specific application. When completed, the evaluated data will be made available to NSDD Network members and ENSDF, and published in scientific journal. Arrangements will be made for a designated Web access through NNDC and/or other network Web sites. Further extensions aimed at compiling and evaluating properties of multi-quasiparticle bands that are associated with these isomers are also envisioned.

Our program is also involved in complementary experimental nuclear structure and decay data activities in collaboration with scientists from U.S. national laboratories and universities, and leading nuclear physics institutes overseas. The main emphasis is on studies of properties of K-isomers in a wide range of nuclei and shell-model isomers near ^{132}Sn, including decay spectroscopy of neutron-rich isotopes near A~132 that are of relevance to nuclear energy and

astrophysics applications, properties of nuclei far from the line of stability (mostly proton-rich isotopes in the Pt-Pb region) and spectroscopy of heavy nuclei. Some of the results from this effort have been already published in scientific journals and submitted to the appropriate data centers for inclusion in the ENSDF and XUNDL databases. Some unpublished data were also made available to members of the NSDD network for inclusion in ENSDF and XUNDL.

III. Nuclear Data Dissemination

Argonne continues to develop, update, and maintain the ANL Nuclear Data Measurement Report Series (www.td.anl.gov/reports), ANL Nuclear Data Information (www.td.anl.gov/NDP), and Experimental Resources for Nuclear Data Web (www.td.anl.gov/nrs) sites. Significant modifications were made to these Web sites in the past two years and extensive upgrades are planned in the future.

Status Report of the Nuclear Data Project at McMaster University
October 15, 2003 to May 20, 2005

Report prepared by B. Singh, May 20, 2005 for NSDD-2005 meeting

Status of mass chains in ENSDF for which McMaster has permanent responsibility:

A=1 (1999) (submitted March 2005)
A=31-39 (1998 by P. Endt). (A=39 submitted January 2005; A=38: being revised)
A=40 NDS, 102, 293-514 (2004)
A=41 NDS, 94, 429-603 (2001).
A=42 NDS, 92, 1-145 (2001).
A=43 NDS, 92, 783-891 (2001).
A=44 NDS, 88, 299-546 (1999).
A=64 NDS, 78, 395-546 (1996) (revision in progress).
A=89 NDS, 85, 1-179 (1998)
A=98 NDS, 98, 335-514 (2003).
A=100 NDS, 81, 1-181 (1997).
A=149 NDS, 102, 1-291 (2004)
A=151 NDS, 80, 263-565 (1997).
A=164 NDS, 93, 243-445 (2001)
A=188 NDS, 95, 387-541 (2002).
A=190 NDS, 99, 275-481 (2003)
A=194 NDS, 79, 277-446 (1996) (submitted October 2004)

Mass-chain/Nuclide Evaluations published/submitted since October 15, 2003:

A=1 B. Singh, (Submitted March 2005, pre-review stage).
A=165 A.K. Jain, A. Ghosh and B. Singh, NDS (Submitted March 2005, pre-review stage).
A=233 B. Singh and J.K. Tuli, NDS (Submitted December 2004, galley stage).
A=194 B. Singh, NDS (Submitted October 2004, review stage).
A=80 B. Singh, NDS (Submitted September 2004, post-review stage).
A=132 Yu. Khazov, A.A. Rodionov, S. Sakharov and B. Singh, NDS, **104**, 497-790 (2005)
A=240 F. Chukreev and B. Singh, NDS, **103**, 325-388 (2004)
A=40 J.A. Cameron and B. Singh, NDS **102**, 293-514 (2004)
A=149 B. Singh, NDS , **102,** 1-291 (2004)
A=73 B. Singh, NDS, **101**, 193-323 (2004)

A=267-293: Corrections made (by B. Singh) in several datasets in this mass region, in particular concerning retraction of the discovery of some of the super-heavy elements. The corrected datasets were sent to BNL in February 2004 for inclusion in ENSDF.

Nuclide updates (since October 15, 2003 to May 20, 2005)**:**
The following nuclides were evaluated and included in ENSDF:

^{32}Mg, ^{32}S, ^{89}Rh, ^{89}Ru, ^{89}Tc, ^{218}Po, ^{218}Bi

Superdeformed structures (Oct. 15, 2003 to May 20, 2005)**:** by B. Singh,
Updates of SD band data published between November 2003 to May 2005 for the following nuclides were included in ENSDF

^{88}Mo, ^{91}Tc, ^{140}Nd, ^{173}Hf, ^{174}Hf

As of May 20, 2005, the ENSDF database is current on the coverage of all the published and known SD structures in nuclei, except data from four current papers that are being evaluated.

Review of A chains (Oct. 15, 2003 to May 20, 2005):

A=21 and 22: J.A. Cameron
A=123, 134, 155, 193, 122 (first report): B. Singh

Compilation of data from recent publications (for XUNDL):

Initiated by the McMaster group in December 1998, the XUNDL project has been continuing. In earlier years the emphasis was on current high-spin papers, but since 2003 we have been compiling almost all the current low-spin papers also. Details of this work can be found in the XUNDL status report.

> From Oct. 15, 2003 to May 20, 2005, about 420 compiled new datasets and about 30 updated datasets from about 300 recent (mainly 2003-onwards) publications have been prepared at McMaster and included in XUNDL database. We are up-to-date on the coverage of all the current high-spin papers available on journal web pages. There are about 12 low-spin papers published in the last few weeks that remain to be compiled.

There is evidence that the compiled datasets in XUNDL database are being used by the mass-chain evaluators, which should potentially speed up the evaluation process.

Work in progress (as of May 20, 2005)

A=74 Full mass-chain update in collaboration with the data group in Kuwait.
The mass chain is nearly ready to be submitted to BNL, probably in May 2005.

A=38, 64, 199 Full mass-chain updates.

A=218: Full mass-chain update in collaboration with the data group at I.I.T. Roorkee, India

Superdeformed Bands: Continuous update of SD band data for all nuclides from current publication.

Compilation of recent data for XUNDL: Continued work on compilation of, primarily, high-spin data in ENSDF format from current publications. Selected low-spin (current) papers will also be compiled.

Collaborative work as a part of training/mentoring of new ENSDF evaluators:

Collaboration with Petersburg Nuclear Physics Institute, Russia: Since March 2003, McMaster group has worked closely with the team of new evaluators (Yuri Khazov, Alexander Rodionov, Sergei Sakharov) at PNPI, evaluating A=132 nuclides. The data files and comments were regularly exchanged through e-mail between the two centers. This work has now been brought to completion with the publication of A=132 chain in the March 2005 issue of the Nuclear Data Sheets. Dr. Rodionov also visited McMaster for 3 weeks in June-July 2004 for consultations and work on A=132 and 131 chains.

Collaboration with Indian Institute of Technolgy (I.I.T.), Roorkee, India: Since March 2004, McMaster group has worked closely with the team at the Department of Physics, I.I.T, Roorkee, evaluating A=165 nuclides. The mass chain was submitted to BNL in March 2005. One of the evaluators, Dr. Ashok K. Jain from also visited McMaster for 3 weeks in May-June 2004 for consultations and work on A=165 as well as to start work on A=218. Dr. Jain is visiting our group again for 3 weeks in June 2005 to work on pre-review version of A=165 and on completing A=218.

Other (data related) activities since the NSDD-2003 meeting:

Magnetic-dipole rotational (MR) bands:
Compilation of magnetic-dipole rotational structures is continuing in collaboration with the Nuclear Theory group (and data group) at IIT, Roorkee, India. Subsequent to the first publication of a table of such structures by Amita, A.K. Jain and B. Singh in Atomic Data and Nuclear Data Tables 74, 283-331 (2000), an update in 2001 was placed on NNDC website. Further update of this work covering all published data on such structures up to May 2005 has been completed and it is soon expected to be submitted for publication to the Atomic Data and Nuclear Data Tables.

3-quasiparticle structures in deformed region:
The use of large gamma-ray detector arrays during the past few years has revealed a large number of new 3-quasiparticle structures and high-spin bands. The above mentioned theory group in India have done calculations using Tilted-Axis-Cranking (TAC) model in the deformed region to explain properties of such structures. As a collaborative effort between McMaster data group and the theory group in Roorkee, India, a compilation of all the known 3-quasiparticle structures in the deformed region has been prepared covering all the literature up to January 2005. The paper by S. Singh, A.K. Jain and B. Singh has been accepted for publication in the Atomic Data and Nuclear Data Tables.

Review of Fission (Shape) Isomers in Actinide Nuclei: Subsequent to communications in 2004 between B. Singh and Dr. Stephan Oberstedt (Neutron Physics Unit, European Commission,

Geel), a detailed review and evaluation of fission (shape)-isomer data in the actinides is being prepared by Dr. Oberstedt. It is expected to be completed in 2005 for possible publication in Nuclear Data Sheets. Later the plan is to incorporate the 'recommended data' for fission isomers, based on this review in the ENSDF database.

International Network co-ordination:

In summer 2004, Dr. A.K. Jain from the (new) data center at I.I.T. Roorkee, India, and Dr. A.A. Rodionov from Petersburg Nuclear Physics Institute, Russia visited the McMaster data group for consultations and collaborative work on A-chain evaluations. Their local expenses were covered by our group. After the NSDD-2005 meeting at McMaster, Dr. Jain will be visiting the McMaster group for about 2 weeks to work on A=218 evaluation.

McMaster is hosting the IAEA-NSDD meeting from June 6-10, 2005. All the necessary arrangements, administrative matters, and website for NSDD-2005 are being handled by the data group at McMaster. The website is: http://www.physics.mcmaster.ca/~balraj/nsdd2005/

Financial Support: One FTE for evaluation + partial support for undergraduate students
(NSERC, Canada + DOE, USA)

Personnel: Jim C. Waddington (Professor, Head of the Project),
John A. Cameron (Emeritus Professor),
Balraj Singh (Research Scientist, Nuclear Data Evaluator),
Joel C. Roediger (Undergraduate student: since Feb 2004),
Roy Zywina and Michelle Lee (Undergraduate Students; until April 2004).

Meeting of the Nuclear Structure and Decay Data Network
McMaster University, Hamilton, Ontario, Canada
June 6-10, 2005

STATUS REPORT OF DATA CENTER OF PETERSBURG NUCLEAR PHYSICS INSTITUTE 2003 – 2005

I.A.Mitropolsky

General

The Data Center renewed his activity since 2000. It exists on the basis of the Nuclear Spectroscopy Laboratory which is incorporated in the Reactor Department of the PNPI. Now 5 physicists, 1 mathematician, and 2 programmers are working in the Data Center group. Only one of them is younger 50. The group is provided with the necessary equipments.

Database of the NSR

The Data Center continues refereeing of Russian publications on nuclear physics in the format NSR. Among them are the theses of the reports presented on the Russian Annual Conference on Nuclear Spectroscopy and Structure of Atomic Nuclei, preprints of Joint Institute for Nuclear Research (Dubna) and Petersburg Nuclear Physics Institute (Gatchina). This activity can be extended, if the Center will receive publications from other Russian institutes.

To support the evaluation activity in the Data Center of PNPI a local bibliographical system has been constructed on the basis of the NSR. The system contains full text references of interesting for us works.

Evaluation for the ENSDF

The area of the Data Center responsibility is nuclides with mass numbers from 130 to 135.

Mass number	Last publication	Comments
A=130	*NDS*, **93**, 2001 by B.Singh	
A=131	*NDS*, **72**, 1994	completed, planned to publication in 2005
A=132	*NDS*, **104**, 2005 with B.Singh	
A=133	*NDS*, **75**, 1995	evaluating
A=134	*NDS*, **103**, 2004 by A.Sonzogni	
A=135	*NDS*, **84**, 1998	evaluating

In 2004 we in collaboration with Dr. B.Singh finished evaluation in the A=132 chain. Now we practically completed the evaluations of A=131. We have started to work with the A=133 chain.

We plan to finish the evaluations to end of the year 2005. At the same time we are working with the A=135 chain.

Activity connected to the ENSDF

This year the Data Center of PNPI reviewed the evaluations of A=160 by C.W.Reich. We can work in such capacity more intensive.

The other side of our activity is a searching for mistakes in the ENSDF. We have developed a complex of programs for regular search of mistakes both formal, and physical. Corresponding reports have been submitted to BNL this year and the ENSDF has been in part corrected.

We have got some claims to the program GTOL connected with its accuracy and algorithm. We think our refinements of this program will allow increasing the evaluation quality in the Network.

Systematics or horizontal evaluations

We constructed the database of nuclear rotational bands on the basis of the ENSDF. The energies of rotational states were described with the «variable moment of inertia» model. The first results are published as Atlas of rotational bands in odd nuclei (in Russian, 2003, and in English, 2004). Now we have finished the similar systematics in odd-odd and even-even nuclei. The total report will be prepared for the publication in NDS this year.

In the Data Center of PNPI the compilations of resonance parameters for the reactions with neutrons and charged particles were completed and published last year (Landolt-Boernstein, Springer Verlag).

May 23, 2005

France Group Status Report

Jean Blachot
Service de Physique Nucleaire
CEA, B.P. 12
F-91680 Bruyères-le-Chatel, France

Since the beginning of the network, we have responsibility for 11 mass chains. All of the work is now done as a consultant to the laboratory of Bruyères le Chatel, CEA, France.

1. Status of publications in NDS

101	NDS 83, 1 (1998)	started April 2005
104	NDS 64, 1 (1991)	evaluated and put in ENSDF (Feb 2000)
107	NDS 89, 213 (2000)	
108	NDS 91, 135 (2000)	
109	NDS 86, 505 (1999)	review underway since April 2005
111	NDS 100, 179 (2003)	
113	NDS 104 , 791(2005)	
114	NDS 97, 593 (2002)	
115	NDS 104,967 (2005)	
116	NDS 92, 455 (2001)	
117	NDS 95, 679 (2002)	

2. Status of XUNDL

Many XUNDL files have been used for our evaluation in ENSDF.
The following files are available to update ENSDF

101 Jul 1997

101**Tc**	176YB(28SI,FG)	1999Ho10
101**Ru**	96ZR(9BE,4NG)	2002Ya13
101**Rh**	70ZN(36S,P4NG)	2001Ti08
101**Ag**	70GE(35CL,2N2PG)	1992Cr02,2001Ga49
	50CR(58NI,3PAG)	2004SO05
101**In**	50CR(58NI,PA2NG)	2002Li45
101**Zr**	248CM SF DECAY	2004UR06
	238U(A,FG)	2004HU02
101**Nb**	252CF SF DECAY	1998HW08

104 Sept 1999

104**Mo**	248CM SF DECAY	1996Gu04,2002Sm10
104**Ru**	176YB(28SI,XG	2000De33
104**Rh**	96ZR(11B,3NG)	2004VA01
104**Cd**	58NI(50CR,4PG)	1999De22
	58NI(50CR,4PG)	2001Mu19
	50CR(58NI,4PG)	2002Ro19
104**Zr**	238U(A,FG)	2004HU02

104**Ag**	76GE(35CL,A3NG)	2004DA14

107 June 1999

107**Ru**	176YB(23NA,FG)	2000Fo10
	252CF SF DECAY	2002Zh02
107**Rh**	176YB(28SI,FG)	1999Ve12
107**Sn**	107SB EC DECAY (4.0S)	2002Re14
107**Sb**	58NI(58NI,2HEPG)	2000La27
107**MO**	238U(A,FG)	2004HU02
107**TC**	248CM SF DECAY	2004UR07
	252CF SF DECAY	2004LU20
107**TE**	58NI(52CR,3NG)	2004HA59

108 June 2000

108**Rh**	176YB(28SI,XG)	2002Po11
	64NI(48CA,4NG)	2002Go03
	173YB(24MG,XG)	2003FO09
108**IN**	EC DECAY	2002Ga35
	76GE(37CL,5NG)	2001Ch71
108**MO**	238U(A,FG)	2004HU02
108**RU**	252CF SF DECAY	2004CH54
	176YB(28SI,XG)	2000DE33
108**PD**	176YB(31P,XG)	2003LA23
108**CD**	96ZR(16O,4NG)	2000KE01
	108CD(G,G')	2003GA06

111 Apr 2003

111**TC**	248CM SF DECAY	2005URAA
111**RU**	248CM SF DECAY	2004UR05
111**RH**	252CF SF DECAY	2004LU03

114 Feb 2002

114**PD**	114RH B- DECAY	2003LH01
	114RH B- DECAY	2003LH01
114**AG**	208PB(16O,XG)	2003PO11
114**CD**	114CD(N,N'G)	2003BA57
114**IN**	113IN(N,G)	2002SAZO
	113IN(D,P)	2002SAZO
	115IN(D,T)	2002SAZO

116 Feb 2001

116**PD**	238U(A,FG)	2003HU05
116**AG**	208PB(16O,XG)	2003PO11
116**CD**	116AG B- DECAY (8.6 S)	2001WA42
	116CD(N,N'G)	2003KA45
116**I**	103RH(16O,3NG)	2004MO02

117 Feb 2001

117**Ag**	252CF SFDECAY	2002Hw06
117**PD**	248CM SF DECAY	2004UR04
117**IN**	238U(12C,XG)	2002LU15

Status Report Belgian group for NSDD 2005

D. De Frenne, E. Jacobs.
Universiteit Gent, Proeftuinstraat 86
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During the last two years the mass chain A=105 was evaluated and is in now in the review stage. E. Jacobs retired last year and I will retire next year on August 1, 2005.

This means that no new evaluations of the Ghent group are planned in the future anymore. However I will help the Bulgarian group from D. Balabanski with the evaluation of mass A=112. Also a Roumanian group from D. Bucurescu showed a lot of interest in the evaluation work and I will start in Ghent the mass evaluation of mas A=106 together with A. Negret a student of Bucurescu who graduaded last May in Ghent and obtained his PhD diploma in nuclear physics.

D. De Frenne

Status Report of Japanese Activities for Nuclear Structure and Decay Data Evaluation

J. Katakura

Nuclear Data Center
Japan Atomic Energy Research Institute

1 Members

The present members of Japanese group for the evaluation of Nuclear Structure and Decay Data are following: H. Iimura, J. Katakura, M. Kanbe and S. Ohya. Most of them are part time evaluators. K. Kitao, T. Tamura, Y. Tendow and A. Hashizume are not official members of Japanese group now, but they can help us by sharing some parts of the evaluation work.

2 Mass-chain evaluation

The mass chain evaluation on which Japanese group has the responsibility is for A=118-129. The last publication of the mass chain and the status are listed in Table 1.

Table 1: Status of Mass Chain Evaluation

Mass	Last NDS publications	Evaluators	Status
118	NDS 75, 99 (1995)	Kitao	Evaluating (Kanbe)
119	NDS 89, 345 (2000)	Ohya, Kitao	
120	NDS 96, 241 (2002)	Kitao	
121	NDS 90, 107 (2000)	Tamura	
122	NDS 71, 461 (1994)	Tamura	Returned for resubmittal.
123	NDS 102, 547 (2004)	Ohya	
124	NDS 80, 895 (1997)	Iimura, Katakura, Tamura, Kitao	Evaluating (Iimura, Kitao, Wu, Katakura)
125	NDS 86, 955 (1999)	Katakura	
126	NDS 97, 765 (2002)	Katakura, Kitao	
127	NDS 77, 1 (1996)	Kitao, Oshima	Evaluating (Hashizume)
128	NDS 94, 227 (2001)	Kitao, Kanbe	
129	NDS 77, 631 (1996)	Tendow	Evaluating (Tendow)

The NDS publication after the previous meeting is for A=123. The evaluation of A=122 has been returned for resubmittal. Other evaluations are being continued. The evaluations of A=118, 124, 127 and 129 are planned to be finished in this year.

3 Other related activities on nuclear structure and decay data evaluation

3.1 Revision of the Chart of the Nuclides

The Chart of the Nuclides are regularly published almost very 4 years from 1977. The 8th edition was published in March 2005 [1] as Chart of the Nuclides 2004 and is available from Nuclear

Data Center, JAERI. The chart is characterized by inclusion of estimated values for unmeasured beta-decay partial half-life of the nuclides far from beta stability line.
Those values are based on ”Gross theory of beta decay” by Waseda University group. The estimated partial half-lives of alpha-decay are also given for heavy elements. The number of experimentally identified nuclides are 2913 until the end of year 2004. The number of the experimentally identified nuclides included in the chart is shown in Fig. 1 as a function of year.

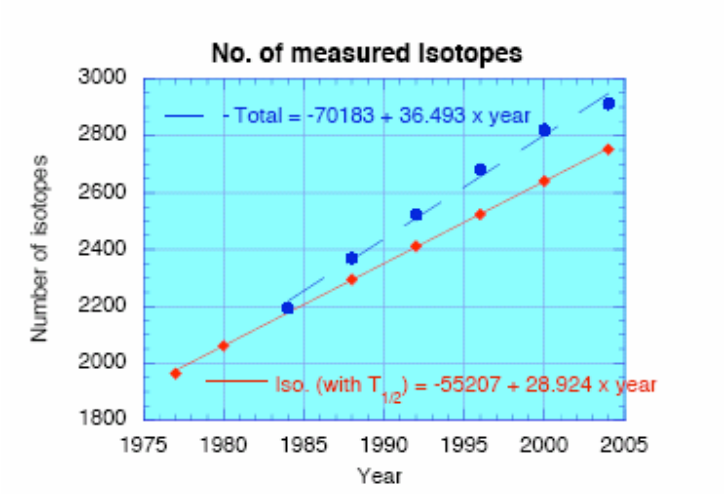

Figure 1: Number of nuclides contained in Chart of the Nuclides 2004.

As seen in this figure, about 40 nuclides are identified per year after 1984. Before the year the experimentally identified nuclides had also measured half-life. But after the year the half-life is not always measured. The number of nuclides with measured half-life steadily increases at the rate of about 30 per year from 1977, the year when the first version of JAERI’s Chart of the Nuclides was published. The chart is also seen on our web site *http://wwwndc.tokai.jaeri.go.jp/CN04/index.html*. The web chart is revised every year.

References

[1] T. Horiguchi, T. Tachibana, H. Koura and J. Katakura, “Chart of the Nuclides 2004”, Japanese Nuclear Data Committee and Nuclear Data Center, Japan Atomic Energy Research Institute (2005).

Status Report of the Nuclear Structure and Decay Data Evaluation in CNDC

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1. Mass Chain Evaluation

The nuclear structure and decay data evaluation group in China Nuclear Data Center (CNDC) has permanent responsibility for evaluating and updating NSDD for A=51,195-198; temporary for A= 61,67 and 170. The status is as follows:

Mass chain A	Status	Evaluators
51	Being evaluated	Huang Xiaolong, Zhou Chunmei
195	NDS,86,645(1999)	Zhou Chunmei
196	Being evaluated	Wu Zhendong, Zhou Chunmei
197	NDS,104,283(2005)	Huang Xiaolong, Zhou Chunmei
198	NDS,95,59(2002)	Zhou Chunmei
61	NDS,67,271(1992)	Zhou Chunmei
67	Being evaluated	(Joint with J.K.Tuli and Huo Junde)
170	NDS,50,351(1987)	Zhou Chunmei

2. Decay Data Evaluation

The evaluation of ^{233}Pa decay data was finished in 2004 and published at Appl.Radiat.Isot. in 2005.

Several data evaluation procedures were used in the analysis of the half-life data and the new measurement of Usman et al. (2000) are considered. The half-life is determined to be 26.971±0.013 days.

All known measured gamma-ray emission probabilities have been examined. And the gamma-ray emission probability of the reference gamma line of 312keV is recommended to be 38.35±0.28 % based on Schotzig et al. (2000) and Woods et al. (2000).

The new ^{233}Pa decay scheme was re-built based on Kouassi et al.(1990).

3. Other Related Activities- Nuclide Guide-3

This Nuclide Guide-3 was evaluated by China Nuclear Data Center (CNDC), Scientific Data Center, Ministry of the Russian Federation for Atomic Energy and Chinese National Committee for CODATA with English, Russian and Chinese three languages.

This Guide contains main characteristics of all stable and radioactive nuclides known by 2003. The nuclear mass, half-life, spin, parity, decay modes, energy of the strongest intensive gamma-gays and cross section of the radiation thermal neutron capture for stable and natural long-lived nuclides et al., which are evaluated by the Russian and Chinese scientists.

Status Report of the Nuclear Structure and Decay Data Evaluation for Mass Chains at Jilin University

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1. We have evaluated A-mass chains as follows:

   (1) A=52 NDS, 90, 1, 2000
   (2) A=53 NDS, 87, 517, 1999
   (3) A=54 NDS, 68, 687, 1993
       ENSDF has been updated Jan., 2001
   (4) A=55 NDS, 64, 723, 1991
       ENSDF has been updated Jan., 2001
   (5) A=56 NDS, 86, 315, 1999
   (6) A=62 NDS, 91, 317, 2000
       Joint with Dr. B. Singh
   (7) A=63 NDS, 92, 147, 2001
   (8) A=174 NDS, 87, 15, 2000
       Joint with Dr. E. Browne
   (9) A=176 NDS, 84, 337, 2000
       Joint with Dr. E. Browne

2. We are evaluating A-mass chains:

   (1) A=52 evaluating
   (2) A=54 submit to NNDC
   (3) A=55 evaluating
   (4) A=67 Joint with Drs. J. Tuli and X. Huang

IAEA Meeting on the Coordination of the International Network of Nuclear Structure and Decay Data Evaluators
McMaster University, Canada, June 6-10, 2005

Status Report
Kuwait Nuclear Data Center

Physics Department – Kuwait University
Ameenah Farhan

This report covers the evaluation activities of the Kuwaiti Group for the period (May 2003 – May 2005).

Mass Chain Evaluation:

- A=74: Ameenah Farhan worked on this mass chain in collaboration with Dr. Balraj Singh, submitted May 2005.
- A=78: Work is currently in progress on this mass chain. It will be completed and submitted by the end of summer 2005.

Personnel:

- Ameenah Farhan is working as a part-time researcher for the center (0.2 FTE)
- Prof. Ashok Jain, will be joining the Physics Department as a visiting professor for one year, starting September 2005. He will have a role in the data evaluation activities of the center.
- The Kuwait Group will continue its fruitful collaboration with Dr. Balraj Singh in order to fulfill its commitments.

Financial Support:

The research activities of the Kuwait Nuclear Data Center are funded by Kuwait University Research Administration

Status Report of the Nuclear Data Project
Department of Nuclear Physics
Australian National University, Canberra, Australia

(Nov-2003 to May-2005)

Prepared by T. Kibédi for the

16th Meeting of the Nuclear Structure and Decay Data (NSDD) Network

May 19, 2005

Electric Monopole Transitions

Electric monopole (E0) transitions, can occur between states of the same spin and parity in a nucleus enclosed by electrons. This type of nuclear transition elucidates such matters as volume oscillations (the so-called breathing mode, related to nuclear compressibility), shape co-existence, and isotope and isomer shift. The idea of this horizontal evaluation project arose while we were investigating non-yrast states in the light platinum, osmium and tungsten nuclei in relation to the evolution of shape co-existence in the $Z \leq 82$ nuclei. Realizing that the systematics of the spectroscopic information on the E0 transitions was both inconsistent and incomplete, Spear and I have carried out a project to survey E0 transitions throughout the periodic table. The study focussed on E0 transitions between 0^+ states. We have re-analyzed all experimental data and deduced 276 $B(E0)/B(E2)$ transition rates and 141 $\rho(E0)$ values for mass A=4 to A=250 nuclei. An exhaustive review article was published earlier this year (2005Ki02) and was presented at an international conference. The procedures developed for the project are now being considered for adoption by the international NSDD network.

BrIcc - Band–Raman conversion coefficients for the ENSDF

One of the actions of the 15th NSDD meeting, held in November 2003, was a decision to develop a new conversion coefficient data base and tool, based on the Band–Trzhaskovskaya–Nestor–Tikkanen–Raman tables (2002Ba85, At. Data and Nucl. Data Tables 81, 1 (2002)). The project started as an ANU–NNDC collaboration involving T.W. Burrows, and was extended to include tables of conversion coefficients for electron–positron pair formation and E0 electronic factors. Realizing that the published tables covered transition energies from 1 keV above the L1 binding energy to 2000 keV, we contacted M.B. Trzhaskovskaya (Petersburg Nuclear Physics Institute, Gatchina, Russia) and C.W. Nestor, Jr. (Oak Ridge National Laboratory, Oak Ridge, Tennessee). This collaboration resulted a much more comprehensive table, covering transition energies from 1 keV above binding energy (for all shells) to 6000 keV. The current form of the conversion data base incorporates the following tables:

TABLE I:

	Z	Shells or IPF	L	E_γ [keV]
Internal conversion coefficient α_{ic}				
[2002Ba85]	10–126	All	1–5	ε_{L1}+1–2000
This work	10–95	All	1–5	ε_{ic}+1–6000
Pair conversion coefficient α_{IPF}				
[1979Sc31]	0–100	IPF	1–3	1100–8000
[1996Ho21]	50–100	IPF	1–3	1100–8000
Electronic factor Ω(E0)				
[1969Ha61]	30–102	K, L1, L2	0	ε_K+6–1500
[1970Be87]	40–102	K, L1, L2	0	51–2555
[1986PaZM]	8–40	K, IPF	0	511–12775

A new computer program, BrIcc, has been developed which uses cubic spline interpolation to calculate all sub-shell conversion coefficients, pair (IPF) conversion coefficients and Ω(E0) electronic factors. The program can be used interactively and as an ENSDF analysis tool to generate **G** and **S G** cards. In November 2004 BrIcc was released for beta testing and can be found at the http://www.nndc.bnl.gov/nndc/evalcorner/BrIcc/ link. The feedback we have received from the NSDD network was greatly appreciated and was used for a number of improvements in the last six months. A detailed manual has been also prepared. In March 2005 a web interface was created, which can be accessed at the following link:
http://wwwrsphysse.anu.edu.au/_txk103/bricc/.

A fundamental concern in the adoption of the new conversion electron coefficient tables by the NSDD network is the exclusion of the atomic vacancy in the calculations. This question was raised by Raman et al. (2002Ra45, Phys. Rev. **C66**, 044312 (2002)). They presented two variants of the original model, based on the relativistic Dirac-Fock (DF) method, to include the effect of the hole. The debate was reignited by the precise determination of the α_K–value of the 80.236 (7) keV M4 transition of the 10.5 day isomer decay in ^{193}Ir, reported by Nica et al. (2004Ni14, Phys. Rev. **C 70**, 054305 (2004)). Earlier this year, Burrows and I have started a horizontal evaluation project to review and to extend the list of high–precision conversion coefficients used by Raman et al. to test the competing theoretical models. Two identical conversion tables have been prepared. One uses the original ”no hole” (BTNTR) approximation. The other is based on the ”frozen orbital” (RNIT(2)) approximation.

A detailed report will be presented on the NSDD2005 meeting with recommendations on the adoption of the BrIcc for the NSDD network.

A=172 mass chain evaluations

The evaluation work has been started in 2003, in collaboration with C.M. Baglin from the Isotopes Project, E.O. Lawrence Berkeley National Laboratory. This mass chain is one of the largest. Although significant progress has been made, our main priority in the last 18 months has been to complete and publish the horizontal evaluation on electric monopole transitions and to develop BrIcc.

Nuclear Data related publications

1. *Electric Monopole Transitions Between O^+ States for Nuclei Throughout the Periodic Table*
   T. Kibédi and R.H. Spear, Atomic Data and Nuclear Data Tables 89 (2005) 77-100.
   http://dx.doi.org/10.1016/j.adt.2004.11.002 (2005Ki02)
2. *The BrIcc program package (v 1.3)*
   T. Kibédi, T.W. Burrows, M.B. Trzhaskovskaya, C.W. Nestor, Jr.,
   http://www.nndc.bnl.gov/nndc/evalcorner/BrIcc/
   http://wwwrsphysse.anu.edu.au/_txk103/bricc/
3. *Electric Monopole Transitions between 0^+ States for Nuclei Throughout the Periodic Table*
   T. Kibédi and R.H. Spear, (Proc. of the International Conference on Nuclear Data for Science & Technology, published by the American Institute of Physics (AIP)) (in press).
4. *A New Tool to Interpolate Conversion Coefficients and E0 Electronic Factors*
   T. Kibédi, T.W. Burrows, M.B. Trzhaskovskaya, C.W. Nestor, Jr., (Proc. of the International Conference on Nuclear Data for Science & Technology, published by the American Institute of Physics (AIP)) (in press)

Status Report from the Indian Institute of Technology (IIT), Roorkee, India

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India

Evaluation work at the Indian Institute of Technology, Roorkee started about 2 years ago. At present this work is being carried out in collaboration with Balraj Singh (McMaster University), who is also the primary mentor of the NSDD evaluation programme in India.

The following progress has been made:

1. A=165 mass chain is complete and ready for submission. This mass chain turned out to be very large and complex, and took more time than was anticipated. From the previous evaluation, which was about 8000 lines, this mass chain evaluation has grown to almost 16000 lines.
2. A=218 mass chain evaluation has made good progress. We hope to complete and submit by the end of June 2005.
3. Several workers from India have participated in the ICTP Training Workshops held at Trieste. Among them, Dr. Mohini Gupta and Dr. Gopal Mukherjee have shown considerable interest. Both are independently pursuing mass chains and are at an advanced stage (see relevant reports in this annex).
4. Roorkee has a good infrastructure and may be ready for the status of a full NSDD Evaluation Centre – would also be able to coordinate the activities of other scientists interested in evaluation work and based in India.

Report on
ENSDF Data Evaluation for A = 266 – 294

by

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IAEA Technical Meeting on the
"Co-ordination of the International Network of Nuclear Structure and Decay Data (NSDD) Evaluators" at McMaster University, Canada, June 6 – 10, 2005

Introduction:

The evaluation for A > 265 encompasses the region of the super heavy elements where vigorous experimentation is on-going. The nuclei in this region have been synthesised by the complete fusion of heavy ions and are best detected by the in-flight separation of evaporation residues. Further selection is achieved by implanting these energetic compound nuclei in registration devices consisting of Si detectors where their subsequent decay may be observed *in-situ.* The very small number of such implants are uniquely identifiable by their nuclear decay characteristics. This is the field of 'single' atom physics.

The compound system decays by the emission of a succession of alpha particles (whose energies are detected to within a precision of ≤ 70 keV) with unique lifetimes (large uncertainties in measurements due to poor statistics). Usually these chains end in known mass regions, so that the parent nucleus may be identified with some confidence using the method of α-α correlations. The method has been used effectively in 'cold-fusion' reactions (E_x ~ 10-20 MeV) with Pb or Bi targets to create elements up to E113 (GSI, Dubna, RIKEN) following the evaporation of 1 or 2 neutrons. To reach higher Z in more neutron rich regions on the way to the 'Island of Stability' theorised to exist at N=184, targets and projectiles with greater neutron richness are required. 'Hot fusion' reactions using actinide targets (E_x ~ 30–50 MeV) with a ^{48}Ca beam (doubly 'magic' with the largest neutron excess of (N-Z)=8) have resulted in the complete fusion of compound systems leading to the synthesis of the more neutron rich isotopes of Sg, Hs and Ds, and most recently E114 to E118 (Dubna) following the evaporation of 3-5 neutrons. These decay chains however end in hitherto unknown regions thereby limiting the use of the method of α-α correlations. Additionally, spontaneous fission (SF) (in some cases possibly electron capture or β-decay) is expected to become an increasingly preferred decay mode. SF may be thus be considered to be a 'signature' for these regions. In limited cases, where decay lifetimes are around a few seconds, chemical methods may be used as a means of direct identification. The heaviest element synthesised to date is ^{294}118 at Dubna, in a hot fusion reaction following the evaporation of 3 neutrons from the compound system ^{297}118.

Current status of data:

Since the last NDS evaluation in the year 2000 (2000Fi12) over 240 alpha decay chains have been observed by many international collaborations, conducting experiments primarily at GSI (Germany), Dubna (JINR, Russia) and most recently at RIKEN (Japan). Even though these experiments are meticulously carried out and of exceptional quality, variations in data do exist. Additionally, although most experiments are carried out for the purpose of discovering a new element (resulting in comprehensive measurements), an increasing number are being done primarily to confirm earlier results (specific quantities pertaining to the element in question are measured).

Retractions of data have occurred (e.g., ^{293}118) along with re-assignments of earlier measurements to different isotopes over those originally proposed (e.g., ^{293}116). Finally, some unresolved contradictions still exist (e.g., ^{283}112).

Methodology used in arriving at the adopted data set:

Available data for a total of 29 mass chains covering 14 elements has been evaluated. We have followed the guidelines laid down by the International Union of Pure and Applied Physics and Chemistry, the Transfermium Working Group (IUPAP/IUPAC-TWG), as reinforced by the IUPAP-IUPAC Joint Working Party (IUPAP/IUPAC-JWP). Clearly, the IUPAP/IUPAC assessments are concerned with the *discovery* of a new *element* whereas ENSDF evaluations seek primarily to adopt the *best* set of data for a given *isotope.* Some of the guidelines relevant to this work are:

- Measurement of excitation functions
- Cross-bombardments
- Independent verification by another laboratory
- Redundancy and internal consistency of data (including estimates of randomness)
- Consistency of assignments of daughters:
- secured connection to known descendents
- presence of elemental signatures such as x-rays
- direct measurements of nuclei in the decay chain
- e.g. chemical studies
- $T_{1/2}$: larger statistics, better value

Also included are experiments done employing chemistry which have in specific cases become the adopted data set.

Tools used in data evaluation:

The well known Viola-Seaborg relation was extensively used with a new parameter set obtained by a fit to 65 even-even nuclei carried out at Dubna. Using this, it was possible to provide an estimate of the half-life (presumed ground state) for the adopted Q-value. In a region where the density of levels is high, around the Fermi surface, the observed event may not represent a ground-ground transition. The comparison such a method would provide is expected to be indicative.

It was also found that some of the experimenters did not quote uncertainties for measured half-lives. In other cases, when combining new data to improve statistics, it was found necessary to have a reliable way to estimate the uncertainties. We have adopted in this evaluation the methodology of 1984Sc13 to compute these quantities.

Future work proposed:

It is seen that most of the experimental groups do not attempt to calculate alpha decay hindrance factors (HF). Those that have computed this number, do so by using a variety of different methods. We have been attempting to standardise this procedure in the transfermium region by re-examining the validity of existing formalisms. This pursuit has raised questions in related areas of interest, such as the estimation of radii.

In the near future, we propose to continue with these investigations and carry them to their logical conclusions.

Topics of emerging interest included in the evaluation:

Related new developments in the field such as studies on inhibition to fusion, fusion-fission dynamics and experimental observations of quasi-fission from nascent SHE, are added in the comments section at the beginning of the paper along with some important references, for completeness. These areas of research are expected to play an increasingly important role in the future of heavy element synthesis.

Conclusions:

Keeping in mind the requirements of those working in this mass region, we have included in each data set: reaction cross-sections if quoted in the original source, excitation function measurements undertaken with the appropriate references and results from chemical studies. Also highlighted are special aspects of the experiment if any, all of the above by way of detailed comments.

With regard to future evaluations in this super-heavy element region, given the large amount of activity in this field of research resulting in more data, it will be useful and informative to show the alpha decay chains and their physical properties pictorially in the form of decay chain diagrams as they appear in the literature.

We are grateful to the physicists and chemists at the various laboratories who gave unstintingly of their time, provided us with clarifications and offered interpretations of their work, while keeping us updated on their publications and new data. One of us (MG) thanks J. K. Tuli and P. Oblozinsky (BNL); A. L. Nichols (IAEA), B. Singh (McMaster University), E. Browne (LBNL) and A. K. Jain (IIT-Roorkee). Insights and suggestions provided by the Late Y. A. Akovali (ORNL) are hereby acknowledged.

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Evaluation of Mass Chain A = 88

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1. Introduction

Experimental data on ground- and excited-state properties for all known nuclei with mass number A=88 have been compiled and evaluated. States populated in radioactive decay, as well as in nuclear reactions, have been considered. Levels and decay schemes, as well as tables of nuclear properties, are also given. This work supersedes the 1988 evaluation of Müller (1988).

One of the authors (Gopal Mukherjeee) was introduced to mass chain evaluations through his attendance at the second IAEA Workshop on Nuclear Structure and Decay Data: Theory and Evaluation, ICTP Trieste, Italy, 17-28 November 2003. Alejandro Sonzogni is based at the NNDC at Brookhaven National Laboratory, and provided appropriate mentorship.

2. A = 88

Mass chain 88 consists of 13 nuclei (from ^{88}Ge to ^{88}Ru), of which there are many new data for ^{88}Sr (N = 50), an important nucleus from a structural point of view. ^{88}Ru is another nucleus of interest because of the p-n interaction (although there are fewer new data). This work can be summarised in terms of the following: 1083 references, 841 gamma transitions, and the postulation of 717 nuclear levels (compared with only 577 in the 1988 evaluation).

The evaluation generated a number of interesting features, including the following:

(a) rotational band observed in ^{88}Ru;
(b) ground state J^{π} is questionable in ^{88}Tc ($(7^-, 8^+)$ from heavy-ion data; 3^+ or 6^+ from β-decay to ^{88}Mo);
(c) seventeen data sets in ^{88}Y and twenty-five data sets in ^{88}Sr (N = 50).

Super-deformed bands are to be found in A ~ 80-90 region, with the following features:

(a) ^{83}Sr is the first super-deformed band in this region;
(b) super-deformed minimum at N ~ 44;
(c) is ^{88}Ru a "doubly magic" super-deformed nucleus?
(d) twenty-seven super-deformed bands in 12 nuclei from ^{80}Sr to ^{89}Sr;
(e) β_2 varies from 0.26 (SD-2 ^{80}Sr) to 0.69 (^{89}Tc).

Other points of note from this set of evaluations include:

(a) level scheme of neutron-rich ^{88}Se has been developed from the deep inelastic reaction with ^{82}Se or ^{86}Kr;
(b) spectroscopy of N = Z nucleus (^{92}Pd) planned at GANIL (November 2005);
(c) J^{π} of the low-lying states in ^{88}Tc from β-decay of ^{88}Ru;
(d) search for super-deformed band in ^{88}Ru (proton decay).

3. Concluding Remarks

The mentoring process between GANIL in France (trainee) and BNL (mentor) has resulted in the A = 88 mass chain evaluation. Many new data have been reported for mass chain A = 88 since the previous study in 1988, and have all been incorporated in this new evaluation.

The evaluation efforts of this two-man team is currently focused on A = 95.

Status Report for NSDD-2005

26 May 2005
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A = 193 evaluation, in collaboration with the Sao Paulo group, was submitted to Bnl in April 2004. Datasets for the nuclides ^{193}Hg to ^{193}At have recently been revised taking into account the suggestions of the reviewer. The mass chain was resent on 13 April 2005 to the NNDC for further processing.

A = 191 evaluation: data for the nuclides ^{191}Hg to ^{191}At have been evaluated, and the respective datasets have been prepared. A final review is currently being performed. Expected that the ENSDF files for this part of the A = 191 mass chain will be sent for review to the NNDC within the next two weeks.

ANNEX 6

STATUS REPORTS OF OTHER PROJECTS AND ACTIVITIES.

BRICC Program Package
v 2.0

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(Dated: September 29, 2005)

Abstract

The BRICC program package consists of BLDBRICC and BRICC. The program BLDBRICC builds a direct access file from the tabulated electron and electron–positron pair conversion coefficients, and from the E0 electronic factors. BRICC can be used in different ways: as an interactive tool to interpolate conversion coefficients and E0 electronic factors and as an ENSDF evaluation tool. The program will prepare new ENSDF records (GAMMA and GAMMA continuation) and it also can be used to merge the new cards into existing ENSDF data sets.

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I. THE ENSDF FILE

The Evaluated Nuclear Structure Data File (ENSDF), is a computer-based file system designed to store nuclear structure information. It is maintained by the National Nuclear Data Center (NNDC) at Brookhaven National Laboratory for the international Nuclear Structure and Decay Data Network.

The ENSDF file usually contains a number of data sets, each data set refers to a particular reaction or decay mode of a nucleus. Adopted level and gamma-ray properties for each nuclide are kept in a separate data set. The data sets are composed of 80–character records. The most up–to–date description of the ENSDF files is given by J.K. Tuli [2001TuAA]. Throughout this manual we will frequently make reference to this document. Spectroscopic information is kept in predefined fields of the 80–character records. These fields are marked with bold typeface. For example the numerical value of the total conversion coefficient, stored in the **CC** field of the **GAMMA** record, is α_{tot}.

This document describes the use of the utility program, BldBrIcc (Sec VI) to generate the direct access and index files and the interactive use of the BrIcc (Sec VII) and its use as an evaluation tool (Sec VII B and VII C).

II. GAMMA TRANSITIONS RECORDS

The GAMMA and the GAMMA continuation records, designed to hold the spectroscopic information on nuclear transitions, are particularly important to the BrIcc program. A short description of the fields of the **G** records (see Table II) is given in this section. The adopted procedures, relevant to BrIcc are described in Sec III.

A. GAMMA records

Transition energy (E) and uncertainty (DE) fields: The transition energy, **E** (E_γ) and the symmetric uncertainty, **DE** (ΔE_γ) are given in keV. In a relatively small cases, asymmetric uncertainty values are given in the GAMMA continuation record using the ENSDF dictionary term, DE= with two signed, maximum two digits integer numbers. For example, E=12.4, DE=+1-2 will correspond to a transition energy of $E = 12.4^{+0.1}_{-0.2}$ keV. The asymmetric uncertainties of E_γ will be referred as ΔE_H and ΔE_L.

Photon Intensity (RI) and uncertainty (DRI): The experimental photon intensity is given in the **RI** and in the **DRI** fields. The numerical values are I_γ and ΔI_γ. Pure E0 transitions are treated differently; here **RI** is blank but the total intensity, **TI**, is given (see below).

Multipolarity (M) field: can contain a maximum of 3 multipolarities, including E0,E1,E2,...E6,M1,M2,...M6 (corresponding to electric monopole, electric/magnetic dipole, etc) or D,Q,... (dipole, quadrupole, etc.). To mark assumed, doubtful, and mixed multipolarities the following characters are used [ ] ( ) + and ,(comma). Some typical combinations are listed in Table IV. In the case of mixed multipolarity the lowest two

multipole orders will be used by the program BrIcc to calculate the conversion coefficient. *E0+M1+E2* transitions are treated differently. The *M1* or *E2* multipolarity is considered first and the **E0** is considered last. If any non-standard character is present in the **M** field, the multipolarity (and mixing ratio) will be omitted.

Mixing Ratio (MR) field: The multipole mixing ratio, δ is defined as the ratio of two absolute transition amplitudes [1974AlAA]:

$$\delta(\pi'L'/\pi L) = \frac{\gamma(\pi'L')}{\gamma(\pi L)} \tag{1}$$

The + or - character in the **MR** field indicates that the sign of the mixing ratio is known.

In some cases three multipolarities can mix and in a similar way to Eqn. 1 one can define:

$$\delta(\pi''L''/\pi'L') = \frac{\gamma(\pi''L'')}{\gamma(\pi'L')}. \tag{2}$$

Valid combination of mixed multipolarities ($0 \leq L \leq 5$) include:

	$\Delta\pi = +1$			$\Delta\pi = -1$	
πL	M1	M1	M3	E1	E3
$\pi'L'$	E2	E2	E4	M2	M4
$\pi''L''$	M3	E0	M5	E3	E5

In the case of *E0+M1+E2* transitions the **MR** field is reserved for the $\delta(E2/M1)$ mixing ratio. The *E0,E2* mixing ratio,

$$q^2(E0/E2) = \frac{I_K(E0)}{I_K(E2)} \tag{3}$$

can be specified in the GAMMA continuation record as **MRKE0/E2**. *This term is yet to be defined in the ENSDF dictionary and manual.* Conversion coefficients for mixed multipolarity transitions with E0 component (M1+E2+E0, M1+E0, E2+E0, etc.) are calculated without the monopole contribution.

Similarly, mixed transitions with three multipole components of E1-E5, M1-M5 are treated as mixed transitions with two multipole components. The correct treatment of mixed transitions with three multipole or E0 component are planned in future release of BrIcc.

Mixing Ratio Uncertainty (DMR) field: A single integer or two integers with + and - signs in the **DMR** field will be interpreted as symmetric or asymmetric uncertainty values, respectively. In some cases the **DMR** field contains *GE, GT, LE, LT* or *AP* strings indicating a limit on **MR** or that **MR** is an approximation. Some examples of the coding and interpretation of the **MR** and **DMR** field are given in Table IV. The asymmetric uncertainties of δ are only indicated if **MR** has either a + or a - sign and will be referred as $\Delta\delta_H$ and $\Delta\delta_L$.

Total Conversion Coefficient (CC) and Uncertainty (DCC) fields: If the multipolarity and mixing ratio are known, the total conversion coefficient is calculated by the BrIcc program. Numerical value of **CC** and the symmetric uncertainty is labeled as α_{tot} and $\Delta\alpha_{tot}$. **CC** will be placed onto the new **G** record if $\alpha_{tot}/(1+\alpha_{tot}) \geq 10^{-4}$, otherwise it will be placed on the **'S G'** GAMMA continuation record. If **CC** is derived purely from theoretical conversion coefficient the **DCC** field should be left blank on the **G** record. See Sec. III for the calculation method used.

Relative Total Intensity (TI) and uncertainty (DTI) fields: If the photon intensity, I_γ, and the total conversion coefficient, α_{tot} are known, the relative total intensity, I_{tot} is defined as

$$I_{tot} = I_\gamma * (1 + \alpha_{tot}). \tag{4}$$

For pure *E0* transitions I_{tot} is the sum of electron conversion (I_K, I_{L1}, ...) and pair conversion I_{IPF} intensities. Higher order effects of electromagnetic transitions are usually neglected.

If the **TI** is given, values of the K/T, L/T, *etc.* theoretical shell to total intensity ratios, are placed in the **S G** records.

B. GAMMA continuation records

Table III gives the short description of the GAMMA continuation records. There are two basic type of GAMMA continuation records.

1. '2 G' GAMMA continuation records

Any character, other than 1 or S in column 6 can be used to create a GAMMA continuation record. This record is intended to store quantities (see Table III), which are not defined in the **G** record. Quantities which will be read in by BrIcc are marked in the Table. **'2 G'** records are created by the ENSDF evaluators.

2. 'S G' GAMMA continuation records

This type of record, with a character 'S' in column 6, is a special type of continuation record which flags the Nuclear Data Sheets production code to suppress the data contained on it for the publication. BrIcc generates **'S G'** records and the data on these records are used by other programs. Conversion coefficients and uncertainties are calculated as described in Sec. III. Electron to total intensity ratios are calculated from the conversion coefficients.

The BrIcc program will scan the **'S G'** records of the input ENSDF file. A warning message will be inserted into the calculation report file if any non-standard dictionary term

is found. The non-standard quantity will be placed on a new **'S G'**. See Table III for the list of dictionary terms expected in **'S G'** records. Please note that with the exception of RadList, none of the current ENSDF utility programs extract any numerical values from the **'S G'** records.

III. CALCULATION OF CONVERSION COEFFICIENTS

Electron conversion coefficients (α_K, α_{L1}, α_{L2}, ... etc.) and electron–positron pair conversion coefficient (α_{IPF}) are calculated by BrIcc. Values for pure multipolarity transitions are obtained by a cubic spline interpolation of the tabulated values (see sec V). Input parameters, atomic number Z, transition energy E_γ and multipolarity are obtained by the program from the **IDENTIFICATION** record: **DSID**; from the **GAMMA** record: **NUCID**, **E**, **DE**, **M**, **MR** and **DMR** fields of the **G** records. The program will verify the values obtained from the above fields and will generate warning and error messages to help resolve coding errors. As this function of the program is not designed to carry out full checking of the ENSDF file, the use of FmtChk, prior to use BrIcc is highly recommended.

In some of the following cases BrIcc will not generate new **G** or **S G** (ε_{ic} denotes the binding energy for the ic-subshell):

(a) $E_\gamma + \Delta E_H < \varepsilon_{ic}$ – no calculation for that subshell but new **G** and **S G** records are generated.

(b) $E_\gamma - \Delta E_L \leq \varepsilon_{ic} + 1$ keV – no calculation for that subshell and NO new **G** or **S G** records are generated.

(c) $Z < 10$ or $Z > 95$ (outside of the range of the tabulations) - no calculations and NO new **G** or **S G** records are generated.

(d) $E_\gamma - \Delta E_L > 6000$ keV, the energy range of the tabulations (see table I) – no calculation for that subshell and NO new **G** or **S G** records are generated.

(e) For some subshells (see sec V A) the energy range of the tabulations less than 6000 keV – no calculation for that subshell but new **G** and **S G** records are generated.

For mixed ($\pi L + \pi' L'$) multipolarity transitions the conversion coefficient can be obtained from the following formula:

$$\alpha = \frac{\alpha(\pi L) + \delta^2 \alpha(\pi' L')}{1 + \delta^2}, \tag{5}$$

where $\alpha(\pi L)$ and $\alpha(\pi' L')$ are the conversion coefficients for the pure multipolarities to be mixed.

The (symmetric) uncertainty of the conversion coefficient, $\Delta\alpha$, is made up of a number of contributions. In some cases $\Delta\alpha$ uncertainty is asymmetric. In this cases the larger absolute value should be adopted for the symmetric uncertainty.

$\Delta\alpha_{\text{theo}}$ By comparing the electron conversion coefficients of Band et al., [2002Ba85] to experimental values, Raman et al., [2002Ra45] have concluded, that the accuracy of the theoretical α values is in the range of 0-1 %.

We have no knowledge of any information on the accuracy of the other data tables (α_{IPF}, $\Omega(E0)$) used by BrIcc.

Additional uncertainty may be associated to the cubic spline interpolation used in the same way for all data tables.

We adopted a relative uncertainty of 1.36% for the electron conversion and pair conversion coefficients deduced from the tables. The $\Delta\alpha_{theo}$ symmetric uncertainty incorporates both, the accuracy of the theoretical calculations and the accuracy of the interpolation. For further details see Sec V A.

$\Delta\alpha_{\text{DE\_H}}$, $\Delta\alpha_{\text{DE\_L}}$ The value of the conversion coefficient, α is obtained by interpolation at the nominal transition energy, E_γ. One can define the asymmetric uncertainties, $\Delta\alpha_{DE\_H}$ and $\Delta\alpha_{DE\_L}$, deduced from the differences in conversion coefficients obtained for E_γ, $E_\gamma + \Delta E_H$ and $E_\gamma - \Delta E_L$ energies. In the case when either $E_\gamma + \Delta E_H$ or $E_\gamma - \Delta E_L$ is outside of the energy range of the data tables, α values are calculated at the energy limit of the tabulation.

$$\begin{aligned} \Delta\alpha_{DE\_H} &= \alpha(E_\gamma + \Delta E_H) - \alpha(E_\gamma)\,, \\ \Delta\alpha_{DE\_L} &= \alpha(E_\gamma - \Delta E_L) - \alpha(E_\gamma)\,. \end{aligned} \tag{6}$$

If **DE** is a limit, new **'S G'** record will not be generated. In some cases **E** is equal to **DE**, which will be interpreted as only a limit is known for the transition energy and no calculations will be made.

$\Delta\alpha_{\text{DMR\_H}}$, $\Delta\alpha_{\text{DMR\_L}}$ In the case of mixed transitions, the uncertainties in the mixing ratio, $\Delta\delta_H$ and $\Delta\delta_L$, also contribute to $\Delta\alpha$. Depending on content of **DM** and **DMR** fields, the conversion coefficient, α and the $\Delta\alpha_{DMR\_H}$ and $\Delta\alpha_{DMR\_L}$ uncertainties associated with **DMR**, are determined in one of the following ways.

DMR *is given as symmetric or asymmetric uncertainty.* The conversion coefficient, α is calculated using Eqn. 5 and the uncertainties can be obtained as:

$$\begin{aligned} \Delta\alpha_{DMR\_H} &= \frac{[\alpha(\pi L) + \delta_H^2\alpha(\pi' L')]}{1+\delta_H^2} - \frac{[\alpha(\pi L) + \delta^2\alpha(\pi' L')]}{1+\delta^2}\,, \\ \Delta\alpha_{DMR\_L} &= \frac{[\alpha(\pi L) + \delta_L^2\alpha(\pi' L')]}{1+\delta_L^2} - \frac{[\alpha(\pi L) + \delta^2\alpha(\pi' L')]}{1+\delta^2}\,, \end{aligned} \tag{7}$$

where $\delta_H = \delta + \Delta\delta_H$ and $\delta_L = \delta - \Delta\delta_L$. For unsigned values of **DM** the program will adopt $\delta_L = Max(\delta - \Delta\delta_L, 0)$.

$\Delta\alpha_{\text{DMR\_H}}$, $\Delta\alpha_{\text{DMR\_L}}$ *Continued*

DMR *is a lower limit.*

$$\alpha = \left[\alpha(\pi' L') + \frac{\alpha(\pi L) + \delta^2\alpha(\pi' L')}{1+\delta^2}\right] \times 0.5\,,$$
$$\Delta\alpha_{DMR\_H} = \Delta\alpha_{DMR\_L} = \left|\alpha(\pi' L') - \frac{\alpha(\pi L) + \delta^2\alpha(\pi' L')}{1+\delta^2}\right| \times 0.5\,. \quad (8)$$

In this case $\Delta\alpha_{DE\_H}$ and $\Delta\alpha_{DE\_L}$ are deduced from the differences in $\alpha(\pi L)$ and $\alpha(\pi' L')$, obtained for energies of E_γ, $E_\gamma + \Delta E_H$ and $E_\gamma - \Delta E_L$.

DMR *is an upper limit.*

$$\alpha = \left[\frac{\alpha(\pi L) + \delta^2\alpha(\pi' L')}{1+\delta^2} + \alpha(\pi L)\right] \times 0.5\,,$$
$$\Delta\alpha_{DMR\_H} = \Delta\alpha_{DMR\_L} = \left|\frac{\alpha(\pi L) + \delta^2\alpha(\pi' L')}{1+\delta^2} - \alpha(\pi L)\right| \times 0.5\,. \quad (9)$$

In this case $\Delta\alpha_{DE\_H}$ and $\Delta\alpha_{DE\_L}$ are deduced from the differences in $\alpha(\pi L)$ and $\alpha(\pi' L')$, obtained for energies of E_γ, $E_\gamma + \Delta E_H$ and $E_\gamma - \Delta E_L$.

MR *is an approximate value or derived from systematics,* DMR *is empty, an approximate value ('AP'), derived from systematics ('SY'), or calculated ('CA')* The conversion coefficient, α is calculated using Eqn. 5 and $\Delta\alpha_{DMR\_H} = \Delta\alpha_{DMR\_L} = 0$. **DCC** field is set to **DMR** if it is not empty ('AP', 'SY', or 'CA').

No* MR *is given. For cases when $L \neq L'$ (for example M1+E2 or M1,E2) δ is set to 1.

$$\alpha = [\alpha(\pi L) + \alpha(\pi' L')] \times 0.5\,,$$
$$\Delta\alpha_{DMR\_H} = \Delta\alpha_{DMR\_L} = |\alpha(\pi L) - \alpha(\pi' L')| \times 0.5\,. \quad (10)$$

M *valid, but not unique multipolarity and* $L \equiv L'$ (for example M1,E1). α and $\Delta\alpha$ are calculated using Eqn 10.

M *contains dipole (D), quadrupole (Q), octupole (O), and their combinations.* No α or $\Delta\alpha$ are calculated and no new **'G'** or **'S G'** card will be generated.

A special case when the transition energy E *is an approximate value.* DE *is empty, an approximate value ('AP'), derived from systematics ('SY'), or calculated ('CA').* The conversion coefficient, α is calculated using Eqn. 5 and $\Delta\alpha_{DMR\_H} = \Delta\alpha_{DMR\_L} = 0$. **DCC** field is set to **DE** if is not empty ('AP', 'SY', or 'CA').

Combining the $\Delta\alpha_{theo}$, $\Delta\alpha_{DE\_H}$, $\Delta\alpha_{DE\_L}$, $\Delta\alpha_{DMR\_H}$ and $\Delta\alpha_{DMR\_L}$ partial values the

symmetric uncertainty of the conversion coefficient is given as:

$$\Delta\alpha = \sqrt{(\Delta\alpha_{theo})^2 + (\Delta\alpha_{DE})^2 + (\Delta\alpha_{DMR})^2} \tag{11}$$

where

$$\begin{aligned} \Delta\alpha_{DE} &= Max(|\Delta\alpha_{DE\_H}|, |\Delta\alpha_{DE\_L}|) \\ \Delta\alpha_{DMR} &= Max(|\Delta\alpha_{DMR\_H}|, |\Delta\alpha_{DMR\_L}|)\,. \end{aligned} \tag{12}$$

The **DCC** field of the new **GAMMA** record will be blank if the contribution of the $\Delta\alpha_{DE\_H}$, $\Delta\alpha_{DE\_L}$, $\Delta\alpha_{DMR\_H}$ and $\Delta\alpha_{DMR\_L}$ terms are insignificant compare to the $\Delta\alpha_{theo}$ term.

If the total conversion coefficient, $\alpha_{tot} \geq 10^{-4}$, then it will be inserted into the **CC** field of the **G** record.

The program BRICC will generate **'S G'** continuation records if the conversion coefficient can be calculated. If $\alpha_{tot} < 10^{-4}$, α_{tot} and $\Delta\alpha_{tot}$ will be put on the first **'S G'** continuation record. BRICC will append further quantities onto the **'S G'** record(s). If the total intensity field, **TI** on the **G** record is empty (i.e. I_{tot} is not given) the conversion coefficient for the major shells, α_K, α_L, α_M and α_{N+} will be listed. (α_{N+} is the sum of the α_N, α_O, α_P, α_Q, α_R and α_{IPF} conversion coefficients.) Additional **'S G'** continuation record(s) will be created to list the α_N, α_O, α_P, α_Q, α_R and α_{IPF} conversion coefficients individually.

If the total intensity, I_{tot}, **TI** is given, instead of the conversion coefficients, BrIcc will append to the first **S G** continuation record the I_K/I_{tot}, I_L/I_{tot}, I_M/I_{tot} and I_{N+}/I_{tot} intensity ratios. Additional **'S G'** continuation record(s) will be generated for intensity ratios involving the N, O, P, Q, R and S shells and electron–positron pair production. For example for the K-shell we get:

$$\frac{I_K}{I_{tot}} = \frac{\alpha_K}{1 + \alpha_{tot}}. \tag{13}$$

There is some covariance, for example between α_K and α_{tot}, which can be taken into account in the following way. Let us define the ratio, x as

$$x = \frac{a}{a + b}. \tag{14}$$

The uncertainty, Δx can be expressed as:

$$\Delta x = \frac{\sqrt{(\Delta a \times b)^2 + (a \times \Delta b)^2}}{(a + b)^2}. \tag{15}$$

Considering a case when nuclear transition involves the emission of gamma–rays and internal conversion *via* K–, L– and M–shells, to evaluate the I_K/I_{tot} we get $a = \alpha_K$ and $b = 1 + \alpha_L + \alpha_M$.

IV. CALCULATION OF E0 ELECTRONIC FACTORS

Electric monopole (E0) transitions are possible between states of the same spin and parity in a nucleus enclosed by electrons. In 1987 Firestone [1987FiAA] outlined procedures for the evaluation of E0 transition probabilities for $0^+ \rightarrow 0^+$ monopole transitions, with particular emphasis on the Wilkinson estimates of single–particle transition probabilities. There has since been much activity in the field, both theoretical and experimental; see, for example, the recent review of Kibédi and Spear [2005Ki02].

The electric monopole operator couples the nucleus to the atomic electrons, giving rise to the internal conversion process. It also couples the nucleus to the Dirac background to produce electron-positron pairs if the E0 transition energy is greater then twice the electron rest mass. Simultaneous emission of two photons is a higher order process (relative probability $\sim 10^{-3}$ to $\sim 10^{-4}$ [1986Vo07]) and for practical purposes can be neglected. Single–photon E0 transitions are strictly forbidden by considerations of angular-momentum conservation.

Here we outline the procedures relevant to evaluate pure electric monopole, E0 transitions. As it was indicated earlier (see sec. II), the procedures and the extension of BrIcc to handle mixed *E0+M1+E2* transitions is yet to be developed.

The E0 transition probability is given by the expression

$$W(E0) = \frac{1}{\tau(E0)} = W_{ic}(E0) + W_{\pi}(E0), \tag{16}$$

where $\tau(E0)$ is the partial mean life of the initial state for E0 decay. The quantities $W_{ic}(E0)$ and $W_{\pi}(E0)$ are the transition probabilities for internal–conversion electron and electron-positron pair emission, respectively. They are given by the expression

$$W_{ic}(E0) + W_{\pi}(E0) = \rho^2(E0) \times [\Omega_{ic}(E0) + \Omega_{\pi}(E0)], \tag{17}$$

where $\Omega_{ic}(E0)$ and $\Omega_{\pi}(E0)$ are electronic factors defined by Church and Weneser [1956Ch21]. They are functions of atomic number, Z, and transition energy. They can be calculated independently of nuclear properties. The quantity $\rho(E0)$ is the dimensionless monopole transition strength. It carries all the information about the nuclear structure, being related to the monopole matrix element according to the expression

$$\rho(E0) = \frac{< f|M(E0)|i >}{eR^2}, \tag{18}$$

where R is the nuclear radius. It is usually assumed that $R = r_{\circ}A^{1/3}$, where A is the atomic mass number and $r_{\circ} = 1.20$ fm.

The reduced E0 transition probability $B(E0)$ is equal to the square of the E0 matrix element, and so

$$B(E0) = \rho^2(E0)e^2R^4, \tag{19}$$

where e is the electronic charge. Clearly $\rho(E0)$ is a basic characteristic of electric monopole transitions. Because there is often an ambiguity in determining its sign, it is customary to

use $\rho^2(E0)$. Since the value of $\rho^2(E0)$ usually lies in the range 10^{-3} to 10^{-1}, reference is usually made to $10^3\rho^2(E0)$. It is evident from equation (17) that experimental determination of $\rho^2(E0)$ requires the measurement of absolute transition rates and the calculation of electronic factors. In some cases the transition rate can be determined indirectly from that of another transition de-exciting the same nuclear state, provided that the relevant branching ratio is known.

In their discussion of E0 transitions between 2^+ states, Church, Rose and Weneser [1958Ch48] introduced the quantity

$$q_K^2(E0/E2) = \frac{I_K(E0)}{I_K(E2)}, \tag{20}$$

where $I_K(E0)$ and $I_K(E2)$ represent the intensities of E0 and E2 K-conversion electron components of the $J_i^+ \rightarrow J_f^+$ transition, respectively.

The definition of $q_K^2(E0/E2)$ can be extended to the case of $0_i^+ \rightarrow 0_f^+$ transitions (which can have no E2 component) by somewhat arbitrary reference to an E2 transition from the 0_i^+ state to a 2_f^+ state [1972Al57, 1974Ha63, 1994Ki01]. Usually this is taken to be the first excited 2^+ state (2_1^+).

In some cases experimental information other than $I_K(E0)$ and $I_K(E2)$ can be used in conjunction with the relevant conversion coefficients and electronic factors to deduce $q_K^2(E0/E2)$. For example,

$$q_K^2(E0/E2) = \frac{I_\pi(E0)}{I_\pi(E2)} \times \frac{\Omega_K(E0)}{\Omega_\pi(E0)} \times \frac{\alpha_\pi(E2)}{\alpha_K(E2)}, \tag{21}$$

where $I_\pi(E0)$ and $I_\pi(E2)$ are the observed internal pair intensities for the E0 and E2 transitions, respectively, and $\Omega_{K,\pi}(E0)$ and $\alpha_{K,\pi}(E2)$ are the relevant electronic factors and conversion coefficients.

A dimensionless ratio of the E0 and E2 reduced transition probabilities was defined by Rasmussen [1960RaAA]:

$$X(E0/E2) \equiv \frac{B(E0)}{B(E2)} = \rho^2(E0)e^2R^4/B(E2). \tag{22}$$

The equivalent experimental value, considering K conversion electrons, can be deduced from the general formula:

$$X(E0/E2) = 2.54 \times 10^9 A^{4/3} \times q_K^2(E0/E2) \times \frac{\alpha_K(E2)}{\Omega_K(E0)} \times E_\gamma^5, \tag{23}$$

where E_γ is the E2 γ-ray energy in MeV.

The experimental monopole strength can be obtained directly if the partial mean life of the E0 transition, $\tau(E0)$, is known

$$\rho^2(E0) = \frac{1}{[\Omega_K(E0) + \Omega_{L1}(E0) + ...\Omega_\pi(E0)] \times \tau(E0)}. \tag{24}$$

Alternatively, if the E2 transition rate, $W_\gamma(E2)$, is known, $\rho^2(E0)$ can be obtained from the expression

$$\rho^2(E0) = q_K^2(E0/E2) \times \frac{\alpha_K(E2)}{\Omega_K(E0)} \times W_\gamma(E2). \quad (25)$$

For pure electric monopole (E0) transitions the $\Omega_K(E0)$, $\Omega_{L1}(E0)$, $\Omega_{L2}(E0)$ and $\Omega_{IPF}(E0)$ electronic factors are calculated and listed in the BrIcc report file. The accuracy of the calculated $\Omega(E0)$ values is believed to be better than 5%. The current version of BrIcc does not assign any uncertainty to the interpolated values. Part of the BrIcc calculation report file of an E0 transition is shown in Fig. 1.

FIG. 1: BrIcc calculation report for an E0 transition.

```
================================================================================================================
BrIcc v2.0 (22-Sep-2005)  Z= 40  Egamma= 1487.5 1 keV          Multipolarity= E0                    22-SEP-05

Shell   Omega(E0)
        ---------
K     1.719E+09
L1    1.812E+08
L2    1.405E+06
IPF   1.875E+08
Tot   2.090E+09

K/Tot 8.229E-01

 Compare OLD/NEW cards
    141 :  90ZR  G 1487.5    1 1.9     6 E0                                          <Old Card Kept>
```

V. DATA TABLES

The data tables, large ASCII files, have been assembled from various printed tables and electronic files. The electron conversion coefficient table (see next section) has been calculated specifically for BrIcc. The various ASCII files are converted into a single binary file (BrIccFO.icc) for quick computer access. The main features of the data tables are summarized in Table I. An additional binary file (BrIccFO.idx) contains the location of all $\alpha_i(Z)$ and $\Omega_i(E0, Z)$ data sets.

NOTE: The ScPcc, HoPcc, HsOmg, BeOmg and PaOmg data tables were produced from printed material, using a scanner and character recognition software, they may contain errors. Please report them to the authors for correction.

A. Dirac-Fock Internal Conversion Electron Coefficients (BrIccFO)

The conversion electron coefficient tables based on the model developed by Band *et al.*, [2002Ba85]. The original table, published in 2002, was calculated using the so-called *'No Hole'* approximation and had an energy range of $\epsilon_{L1} + 1$ keV to 2000 keV, covering all atomic shells in Z=10 to 126 elements. The first development version of BrIcc was based

TABLE I: Theoretical tabulations of internal conversion coefficients and electronic factors used by BrIcc.

Data Table	Reference	Z	Shells or IPF	L	E_γ [keV][a]
Internal conversion coefficient α_{ic} using the 'Frozen Orbital' approximation					
BrIccFO	This work based on the model of [2002Ba85, 2002Ra45]	10–95	All shells	1–5	ε_{ic}+1–6000
Pair conversion coefficient α_{IPF}					
ScPcc	[1979Sc31]	0–100[b]	IPF	1–3	1100–8000
HoPcc	[1996Ho21]	50–100	IPF	1–3	1100–8000
Electronic factor Ω(E0)					
HsOmg	[1969Ha61]	30–42	K[c], L_1^d, L_2^d	0	ε_K+6–1500
BeOmg	[1970Be87]	40–102	K	0	51[e]–2555
		40–102	L_1, L_2	0	51–2555
PaOmg	[1986PaZM]	8–40	K[d]	0	511–12775
		8–40	IPF	0	1430.8–12775

[a] ε_{ic} is the binding energy for the ic–shell.

[b] Used for $Z < 50$

[c] Not used

[d] Used for $Z < 40$

[e] For Z=40–58: 51.1 keV; for Z=60–82: 102.2 keV; for Z=84–96: 153.3 keV and for Z=98–102: 204.4 keV

on the same physical model. However, some modifications of the original *RAINE* program were required to extend the energy range to 6000 keV and increase the numerical accuracy of the calculations for some cases, e.g., M4–shell for Z=23, N4 and O4 for Z=21, 58, 64, *etc.* It was also noted that for certain outer shells (N6-shell for Z=59–75, and N7-shell for Z=63–75), the calculated conversion coefficients are non–monotonous values oscillating as a function of transition energy. It was assumed, that this it caused by limitation in the numerical methods used in the program. For these cases, the range of the tabulations has been reduced to about 400. It should be noted that for 400 keV transition energy in Z=59 (Praseodymium) the $\alpha_{N6}(E2)$ conversion coefficient is about 10^{-9} times smaller than the total conversion coefficient. Neglecting these shells from the evaluation of the **CC** has little or no effect.

An important question, discussed several times in the past decades, is the overall accuracy of the theoretical conversion coefficients, see for example Raman *et al.* [2002Ra45] and references therein. To answer the question, *'How good are the internal conversion coefficients now?'*, Raman *et al.* assembled a list of 100 experimental α_K and α_T conversion coefficients known to better than 5% accuracy. By comparing experiment to various theoretical values, Raman *et al.* [2002Ra45] concluded, that the best agreement with experiment can be achieved with the new Dirac-Fock model [2002Ba85] and without taking into account the effect of the atomic vacancy. Since then, an important development was the

determination of the α_K conversion coefficient of the 80.236 (7) keV M4 transition in the 10.5 day isomer decay in ^{193}Ir by Nica *et al.* [2004Ni14]. The new results clearly demonstrate that the effect of the atomic vacancies should not be neglected in the theoretical calculations.

The BrIccFO data table presented here is based on the so–called *'Frozen Orbital'* approximation, which takes into account of the effect of the atomic vacancy (hole) created during the conversion process [2002Ra45]. In this approximation the bound wave functions are calculated in the self–consistent field of a neutral atom and the continuum wave functions are calculated in an ion field constructed from bound wave functions of a neutral atom. This version of the BrIccFO data table covers Z=10 to 95 elements. In future release of the program it is planned to cover heavier elements.

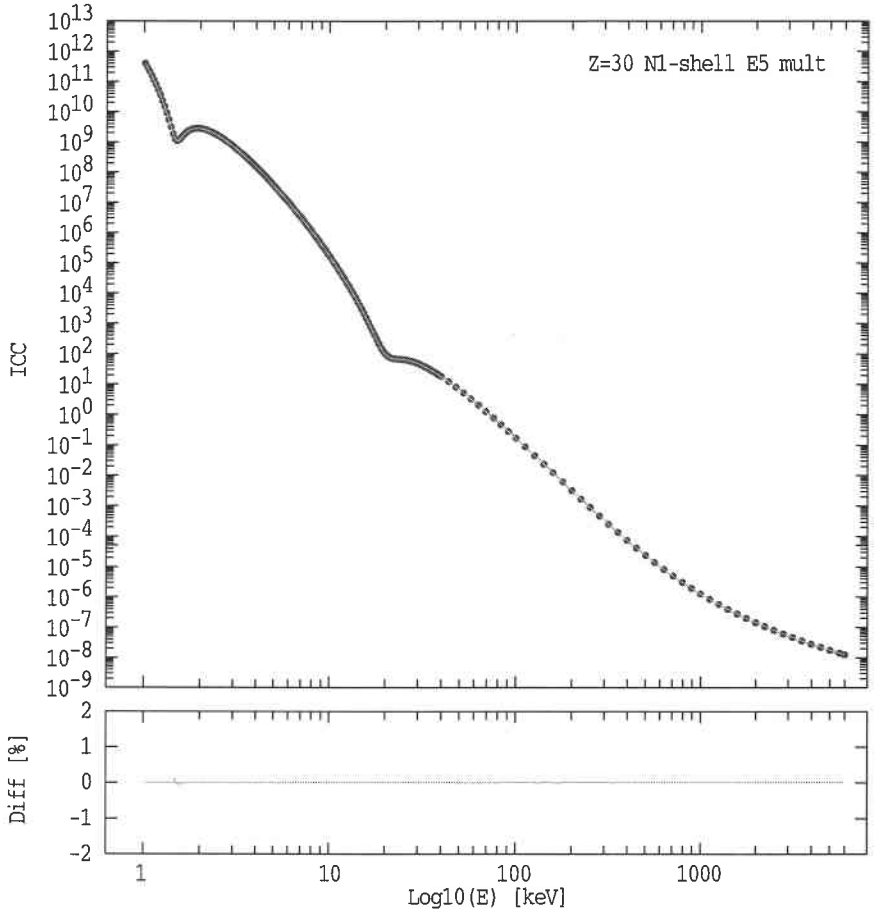

FIG. 2: E5 conversion coefficients for the N1–shell in ^{64}Zn in the 'resonance'–like region. Top panel compares the calculated values (open circles, current work and [2006KiAA]) with values obtained using cubic spline interpolation (solid curve). Bottom panel shows the differences between interpolated and directly calculated values in percentage. See text for further explanation.

Representative conversion coefficients are shown in Fig. 2. For lighter element it was suggested [2002Ba85, 2002Ra45], that the conversion coefficient for some of the $s_{1/2}$ shells

are not monotonous. It was attributed to cancelation effects of the leading matrix elements causing sharp reduction of the conversion coefficient. This so–called 'resonance'–like effect is clearly visible on Fig. 2 at 20 keV transition energy for $\alpha_{N1}(E5)$ in ^{64}Zn. Similar features can be observed for E3-E5 multipolarities for most of the lighter elements. Another type of irregularities is emerging on Fig. 2 at very low energies. This is a threshold irregularity effect and is assumed to be different in character. Both effects have been explored further in order to establish empirical relation between the position of the irregularity (the transition energy, where the conversion coefficient take the minimum value) and the atomic number Z [2005KiZW]. Fig. 3 shows the results together with the proposed empirical relations.

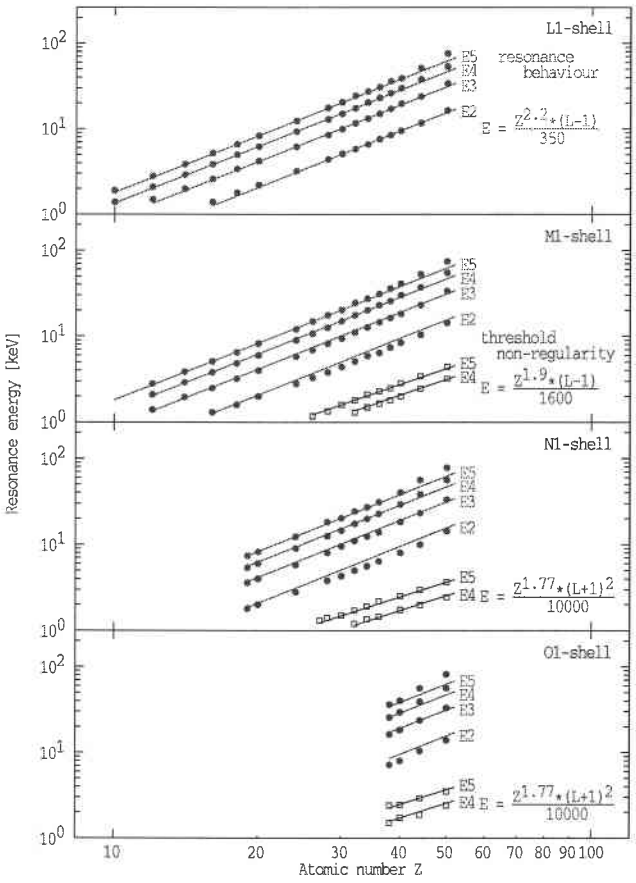

FIG. 3: Position of the 'resonance'– and threshold non–regularity regions as a function of atomic number of Z. Note the logarithmic scale on both axes. Approximate relations are also displayed.

Extra care was taken to increase the accuracy of the interpolation procedure [2005BuAA], especially in the above mentioned resonance regions. To evaluate the difference between the directly calculated and the interpolated values, we have used the

$$\Delta ICC(set1 : set2) = \frac{ICC(set1) - ICC(set2)}{ICC(set2)} \times 100 \qquad (26)$$

quantity, which gives the percentage difference between two values of set1 and set2. The bottom panel of fig. 2 shows the $\Delta ICC(Int : Calc)$ difference between interpolated (Int) and calculated (Calc) values. The difference was evaluated at the mesh points and at the middle between two mesh points for the range of the table. (Calculated values were obtained using the RAINE code for specific energies.) Evaluating the average value of $\Delta ICC(Int : Calc)$ differences over a wide range of atomic numbers, sub–shells and multipolarities, let us to establish an upper limit 0.3 % for the numerical accuracy of the interpolation procedure. It was noted that in some cases, interpolated values obtained on different computer platforms (Windows, Linux or UNIX) may be different. Closer look of the problem revealed, that the relative differences are usually at the level of $< 0.2\%$. The elimination of this problem will be one of the important improvements for future release of the program.

We have adopted the basic principles of the work [2002Ra45] to compare the calculated conversion coefficient to experimental data. In the course of this review we have re-examined the available experimental data and made several adjustments to the adopted values of high precision conversion coefficients. The present list contains about 140 α_K, α_L, $\alpha_{K/L}$ and α_T values. Comparing the experimental ICC's to the *'Frozen Orbital'* approximation gives an average difference $\Delta ICC(Exp : Frozen\,Orbital)$ of $-1.01(21)$ %, which is a lower value than previously adopted. The similar comparison to the so-called *'No Hole'* approximation gives a value of $\Delta ICC(Exp : No\,Hole) = +0.58(28)$ %, which is slightly higher than cited in [2002Ra45]. In the latter case, it is important to note, that the average difference for the K-shell (comprises about 50 % of the data), $\Delta ICC(Exp : No\,Hole) = +1.8(5)$ % and $\Delta ICC(Exp : Frozen\,Orbital) = 0.73(35)$ %. The recent meeting of international Nuclear Structure and Decay Data Network, held in June 2005 adopted the *'Frozen Orbital'* approximation for the calculated conversion coefficients for use in ENSDF evaluations.

Based on the above average differences of 0.0(3) % between calculated and interpolated values, and $-1.01(21)$ % between calculated and experimental values, we have estimated a 1.4 % symmetric uncertainty ($\Delta\alpha_{theo}$) for the accuracy for BrIccFO conversion coefficients.

B. Conversion Coefficients for Electron-Positron Pairs (ScPcc and HoPcc)

Two data sets, ScPcc for $Z < 50$ [1979Sc31] and HoPcc for $Z \geq 50$ [1996Ho21] have been assembled using the printed tables. The latter calculation takes into account the effect of the finite size of the nucleus, which is expected to be a sizable ($> 1\%$) effect in the $Z \geq 50$ elements.

The original tabulations were given up to three valuable digits and for Z=0, 10, 20, ...100 atomic numbers and energies ranging from 1100 keV to 8000 keV. To obtain $\alpha_\pi(E_\gamma, Z, \pi L)$, the pair conversion coefficient, two dimensional interpolation has to be used over the (Z, E_γ) plane. To simplify the numerical calculations, the first step, the interpolation over Z has been carried out as part of the procedure to assemble the binary data file, *BrIccFO.icc*. Typical electron positron pair conversion coefficients in Ytterbium (Z=70) are shown in Fig. 4. We have assumed the same value of 1.4 % for the $\Delta\alpha_{theo}$.

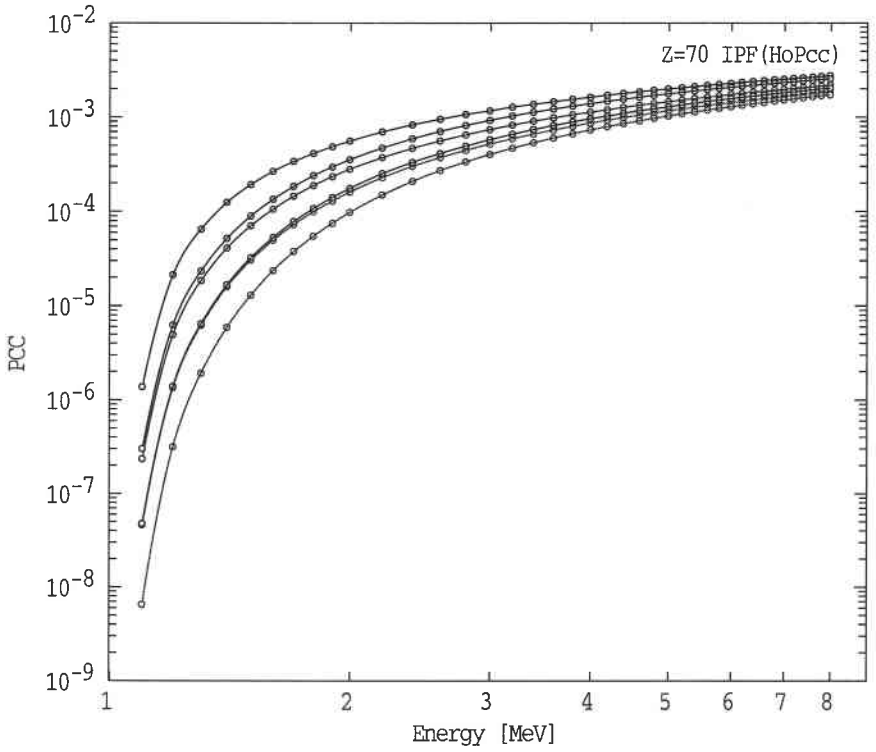

FIG. 4: Electron–positron pair conversion coefficients (α_π or PCC) in Yb. Tabulated values (open circles) taken from [1996Ho21] are compared with values obtained using cubic spline interpolation (solid curves).

C. Electronic factors for E0 transitions (HsOmg, BeOmg and PaOmg)

Three different tabulations, listed below, are partially overlapping in terms of atomic number Z, transition energy. The subset of data included in the conversion data base is indicated in each case. The original printed tables were digitized using an optical scanner and character recognition software. Please report any errors to the authors for correction.

(a) Data set label: `HsOmg`
Reference: 1969Ha61 [1969Ha61]
Z-range: 30,34,38,42 (original table). Intermediate values for Z=32,36,40 were obtained by cubic spline interpolation.

Tabulated values of $A(E0, Z, k)$ have been converted to $\Omega(Z, k)$ using the following formulae:
$\Omega(Z,k) = \frac{8\pi m_o c^2}{\hbar} A(E0, Z, k)k$.

Energy range: K-shell: 15.9(26.2)-1500 keV, L1-Shell: 7.4(9.1)-1500 keV, L2-shell: 7.2(8.8)-1500 keV
Electron shells: K, L1, L2
BrIcc data base includes: L1 and L2 shells and Z=30,32,..38.

(b) Data set label: BeOmg
Reference: 1970Be87 [1970Be87]
Z-range: 40,42,44,...102
Energy range: 51.1-2555.0 keV
Electron shells: K, L1, L2
BrIcc data base includes: all data

(c) Data set label: PaOmg
Reference: 1986PaZM [1986PaZM]
Z-range: 8,10,12,...40
Energy range: 511-12775 keV (K-shell); 1430.8-12775 (IPF)
Electron shells: K, IPF (BrIcc treats IPF coefficients in the same way as the electron shells.)
BrIcc data base includes: all data, except K-shell for Z=40

VI. BLDBRICC PROGRAM

This program reads the BldBrIcc.dat file, which contains the file names of the ASCII data files, listed in the previous chapter. It requires the 'BrIccHome' environment variable to be set to locate the data files on the various platforms (see sec IX).

BldBrIcc.dat: (input) — Contains the home directory of BrIcc and the file names of the ASCII data files, listed in the previous chapter.

BRICC.IDX: (output) — The ICC index file containing 2048–bytes records for elements from Z=1 to 126. Each record contains the atomic number, the atomic mass used to calculate the conversion coefficient, the chemical symbol and the first record number in the BRICC.ICC file where any of the 41 'shells' (α_K, α_{L1}, ... α_{R2}, α_{total}, α_{IPF}, Ω_K, Ω_{L1}, Ω_{L2} and Ω_{IPF}) is starting. The record number is set to zero if no data are available for that shell.

BRICC.ICC: (output) — The ICC data file. Each record is 44 bytes long and contains the transition energy and a maximum of 10 conversion coefficients (E1-E5,M1-M5) or just a single electronic factor.

Terminal dialog: — The program will look for and open the input file. The program will report if the sequential data files were successfully opened and will report the progress (see Fig 5).

VII. BRICC PROGRAM

This program calculates the internal conversion electron and electron-positron pair coefficients and electronic factors for E0 transitions by cubic spline interpolation on the Log-Log

```
BldBrIcc v2.0 22-Sep-2005 creating BrIccF0.idx and BrIccF0.icc files
--------------------------------------------------------------------------------
Data sets to process:
BrIccF0   \Data\BrIccF0\BrIccF0.txt
Pcc       \Data\Pcc\Pcc.txt
HsOmg     \Data\HsOmg\HsOmg.txt
BeOmg     \Data\BeOmg\BeOmg.txt
PaOmg     \Data\PaOmg\PaOmg.txt
--------------------------------------------------------------------------------
Processing data:
Created lookup file: BrIccF0.idx
Created direct access data file: BrIccF0.icc
DataSet    Z Shell   Record
--------------------------------------------------------------------------------
ScPcc      1 IPF          1
ScPcc      2 IPF         41
...
...
ScPcc      8 IPF        281
PaOmg      8 K          321
PaOmg      8 IPF        412
ScPcc      9 IPF        485
BrIccF0   10 K          525
BrIccF0   10 L1         624
BrIccF0   10 L2         796
BrIccF0   10 L3         883
ScPcc     10 IPF        970
PaOmg     10 K         1010
PaOmg     10 IPF       1101
...
...
--------------------------------------------------------------------------------
BrIccF0.idx and BrIccF0.icc files were created
```

FIG. 5: BLDBRICC terminal dialog.

scale.

'BrIccHome': The home directory of the program is defined by setting the value of the 'BrIccHome' environment variable to point to the directory, where the program is located. (See section IX for further details.)

Input files: Data files, created by BLDBRICC, are

%BrIccHome%\BrIcc.idx (ICC index file)

and

%BrIccHome%\BrIcc.icc (binary file of ICC's).

Terminal dialog: The BRICC program can be used in three different ways: (a) interactively to calculate ICC, (b) to generate GAMMA and SG records for an ENSDF file, (c) insert (merge) newly created records with existing ENSDF file.

A. BRICC – interactive use

Program execution: `BRICC<CR>`. It will invoke the program with default values of Z=70 (Ytterbium) and E_γ=279.717 keV.

Terminal dialog: The program uses 116 characters lines to report conversion coefficient for E1-E5 and M1-M5 multipolarities, see Fig. 6. Consult with the documentation of the operating system used to set the width of the terminal window accordingly. A list of interpolated conversion coefficients for all major and subshells, for electron–positron pair creation, etc.

```
Z= 70  Ytterbium          Transition energy: 279.717 keV                                    BrIcc v2.0 (22-Sep-2005)
                                                  Conversion Coefficient
Shell  E_e [keV]   E1         M1         E2         M2         E3         M3         E4         M4         E5         M5
Tot              2.367E-02 1.900E-01 9.150E-02 8.109E-01 4.258E-01 3.015E+00 2.266E+00 1.179E+01 1.250E+01 4.966E+01
K        218.38  1.989E-02 1.593E-01 6.401E-02 6.436E-01 1.910E-01 2.138E+00 5.694E-01 6.978E+00 1.740E+00 2.279E+01
L1       269.23  2.342E-03 2.191E-02 7.477E-03 1.080E-01 2.580E-02 4.547E-01 1.063E-01 1.900E+00 5.021E-01 7.981E+00
L2       269.74  3.016E-04 1.784E-03 8.317E-03 1.356E-02 1.018E-01 8.394E-02 8.120E-01 4.715E-01 5.323E+00 2.502E+00
L3       270.77  3.027E-04 2.329E-04 5.354E-03 7.571E-03 5.104E-02 1.308E-01 3.609E-01 1.249E+00 2.193E+00 9.463E+00
L-tot            2.946E-03 2.393E-02 2.115E-02 1.292E-01 1.787E-01 6.694E-01 1.279E+00 3.621E+00 8.019E+00 1.995E+01
M1       277.32  5.074E-04 4.853E-03 1.631E-03 2.463E-02 5.883E-03 1.073E-01 2.603E-02 4.644E-01 1.315E-01 2.021E+00
M2       277.54  7.192E-05 4.375E-04 2.036E-03 3.373E-03 2.540E-02 2.121E-02 2.063E-01 1.212E-01 1.377E+00 6.544E-01
M3       277.77  7.427E-05 5.792E-05 1.351E-03 1.949E-03 1.305E-02 3.462E-02 9.310E-02 3.405E-01 5.708E-01 2.657E+00
M4       278.14  1.112E-06 1.001E-06 1.102E-05 2.250E-05 1.503E-04 4.745E-04 4.054E-03 6.278E-03 6.572E-02 6.348E-02
M5       278.19  1.402E-06 8.146E-07 8.490E-06 3.852E-06 1.411E-04 1.213E-04 2.812E-03 4.201E-03 3.712E-02 7.142E-02
M-tot            6.561E-04 5.350E-03 5.038E-03 2.998E-02 4.462E-02 1.637E-01 3.323E-01 9.366E-01 2.182E+00 5.467E+00
N1       279.23  1.189E-04 1.143E-03 3.828E-04 5.840E-03 1.396E-03 2.563E-02 6.279E-03 1.118E-01 3.220E-02 4.906E-01
N2       279.32  1.635E-05 1.001E-04 4.657E-04 7.740E-04 5.834E-03 4.885E-03 4.756E-02 2.802E-02 3.188E-01 1.519E-01
N3       279.37  1.681E-05 1.315E-05 3.078E-04 4.457E-04 2.980E-03 7.969E-03 2.131E-02 7.890E-02 1.309E-01 6.196E-01
N4       279.52  2.574E-07 2.325E-07 2.559E-06 5.253E-06 3.504E-05 1.113E-04 9.507E-04 1.477E-03 1.548E-02 1.500E-02
N5       279.53  3.210E-07 1.869E-07 1.943E-06 8.836E-07 3.261E-05 2.817E-05 6.539E-04 9.822E-04 8.661E-03 1.679E-02
N6       279.71  3.233E-10 2.056E-10 1.991E-09 1.278E-09 1.744E-08 2.538E-08 2.017E-07 8.971E-07 7.373E-06 1.962E-05
N7       279.71  4.682E-10 2.459E-10 2.462E-09 1.035E-09 1.377E-08 5.023E-09 2.040E-07 1.316E-07 6.438E-06 7.161E-06
N-tot            1.526E-04 1.256E-03 1.161E-03 7.066E-03 1.028E-02 3.862E-02 7.675E-02 2.212E-01 5.060E-01 1.294E+00
O1       279.66  1.731E-05 1.666E-04 5.576E-05 8.525E-04 2.038E-04 3.747E-03 9.200E-04 1.638E-02 4.733E-03 7.198E-02
O2       279.69  1.934E-06 1.185E-05 5.514E-05 9.170E-05 6.913E-04 5.790E-04 5.638E-03 3.324E-03 3.783E-02 1.803E-02
O3       279.70  1.846E-06 1.445E-06 3.383E-05 4.904E-05 3.277E-04 8.777E-04 2.344E-03 8.701E-03 1.440E-02 6.841E-02
O-tot            2.109E-05 1.799E-04 1.447E-04 9.932E-04 1.223E-03 5.204E-03 8.902E-03 2.840E-02 5.696E-02 1.584E-01
P1       279.71  1.001E-06 9.637E-06 3.226E-06 4.932E-05 1.179E-05 2.169E-04 5.325E-05 9.479E-04 2.740E-04 4.167E-03
P-tot            1.001E-06 9.637E-06 3.226E-06 4.932E-05 1.179E-05 2.169E-04 5.325E-05 9.479E-04 2.740E-04 4.167E-03
Electronic Factor  E0
K        218.38  3.961E+10
L1       269.23  5.964E+09
L2       269.74  8.377E+07
TranEner | ChemSymb(2 char) | Z+IntValue | SUBShell | ? for help | EXIT [279.717] >
```

FIG. 6: BRICC interactive terminal dialog.

Parameter input:

Chemical symbol: Maximum of 2 characters. BrIcc will load the appropriate data set from disk.

Atomic number: Character Z followed by an integer, between 1 and 102 will be interpreted as an atomic number. BrIcc will load the appropriate data set from disk.

Transition energy: A positive number in free format, in keV. For example: 124, 124.0, 1.24E+2.

SUBShell: Will enable or disable the list of subshell ratios.

EXIT: Terminates the program execution.

Error handling: The program will reject an input string, which could not be interpreted as transition energy, chemical symbol, atomic number or subshell toggle on/off.

B. BRICC – ENSDF evaluation tool

Program execution: `BRICC` *ENSDF-file*`<CR>`.

The *ENSDF* file name is passed as program argument. A typical terminal dialog can be seen in Fig. 7.

WARNING: The input *ENSDF* file should not be modified before running the code in the MERGE mode (see sec. VII C).

NOTE: Set the working directory (path) on the Command prompt (Windows) or on the Console (Linux/UNIX) to the directory where the *ENSDF* file is. This will allow one to have all input and output files in the same directory.

Output files:

Calculation report: Complete report of calculations. Default file: *BRICC.LST*.

New G/SG records: New G/2 G records generated by the program, followed by the record number in the ENSDF input file. This is used as input to the program running as a utility to MERGE records. Default file: *CARDS.NEW*.

G/SG (New/Old) comparison report: Comparison of new and old G/2 G records. Default file: *COMPAR.LST*.

Execution control:

List conversion coefficients for all subshells (Def. N): The default is to only list the total conversion coefficients for the shell. Answering Yes (Y) will list all the subshell conversion coefficients in addition to the totals. Note that for higher atomic numbers this may be a very extensive list.

```
bricc BA1978Bo18.ens<CR>
          BrIcc v2.0 (22-Sep-2005) calculates conversion coefficients
                (for electron conversion and pair production)
                          and E0 electronic factors
                       using cubic spline interpolation
             Theoretical Dirac-Fock conversion coefficients based on
                   the so-called "Frozen Orbital" approximation

 Input & Data Files:
   Index file: C:\Program Files\BrIcc\BrIccFO.idx
   ICC file: C:\Program Files\BrIcc\BrIccFO.icc
   Input ENSDF file: BA1978Bo18.ens

 Output Files:
   Complete calculations report, (Def: BrIcc.lst):
   New G/SG records, (Def: Cards.new):
   G/SG (New/Old) comparison report, (Def: Compar.lst):

 Execution control:
   List conversion coefficients for all subshells (Def. N):
   Calculate conversion coefficients for all transitions (Def. N):

 Processing started. Please wait.

      Processing a new data set
       1 : 172YB    172LU EC DECAY (6.70 D)
     104 : 172YB  G 155.87    7 0.032   7 M1(+E2)   0.7     LT    0.90   6
     107 : 172YBS G KC=0.72 8$LC=0.139 18$MC=0.032 5$NCC+=0.0085 12
<W> Non-standard data will be over-written
     109 : 172YB  G 174.671   190.180   8
     112 : 172YB  G 348.83    220.015   11
     113 : 172YB  G 596.75    150.102   23
     114 : 172YB  G 604.65    190.050   23
     115 : 172YB  G 990.75    150.12    6 D,E2
<W> Valid but NON-unique multipolarity. Calculation could not be performed.
     ...
     ...
    1265 : 172YB  G 1932.0    2 0.0019  5
    1267 : 172YB  G 2211.4    2 0.0034  6
 BrIcc finished processing BA1978Bo18.ens
 Processed:
   #DataSets      :       1
   #AllRecords    :    1269
   #GammaRecords  :     286
   #Errors        :       0
   #Warnings      :      23
 Skipped:
   #DataSets      :       0
```

FIG. 7: BRICC – ENSDF tool terminal dialog.

Calculate conversion coefficients for all transitions (Def. N): The default is to only calculate the conversion coefficients when a definite set of conversion coefficients may be obtained; see the discussion on warnings below when BrIcc is unable to do this and Table IV for examples of when this will be done. To obtain a table of the E1-E5 and M1-M5 conversion coefficients for transitions with an unknown multipolarity or non-unique multipolarity answer Yes (Y). Note that for those transitions where a definite set of conversion coefficients may be obtained the output will remain unchanged from the default and new records will still be generated.

The program will process all data sets in the ENSDF file, except the IONIZED ATOM, COMMENTS and REFERENCES data sets. In the calculation report gamma–rays of a data set will be listed by increasing transition energy for each data set. (***NOTE:*** BrIcc will create a binary file, BrIcc.tmp to store temporarily calculation reports.)

Different type of messages are given on the console window and in the calculations report file. These messages are designed to inform the evaluator and to assist to resolve conflicts or errors in the ENSDF file.

$< I >$ For information only. Calculations of new ICC's are carried out and new **G** and **s G** cards are generated.

$< W >$ Warnings are given if the ENSDF records are correct, but some of the fields contain non-unique information or, in some cases, when calculations of the ICC values could not be carried out this is indicated in the message. For example the **M** field contains $D+Q$, or transition energy (including its uncertainty) is outside the range of BrIcc tables.

$< E >$ An error is detected either on the **G**, or **G**–continuation, or on the **IDEN**tification card. As the program progressively scans through these records, the rest of the record will not be scanned.

$< F >$ Reserved for indicating, that BrIcc encountered an internal programming error. In such a case please forward the ENSDF data set and the error message to the authors.

C. BRICC – ENSDF utility to MERGE records

This program merges the new (corrected) **G**-records with the input ENSDF data set to create an updated data set.

```
bricc BA1978Bo18.ens merge<CR>
          BrIcc v2.0 (22-Sep-2005) calculates conversion coefficients
                (for electron conversion and pair production)
                          and E0 electronic factors
                       using cubic spline interpolation
             Theoretical Dirac-Fock conversion coefficients based on
                   the so-called "Frozen Orbital" approximation

 Input & Data Files:
   Index file: C:\Program Files\BrIcc\BrIccFO.idx
   ICC file: C:\Program Files\BrIcc\BrIccFO.icc
   New G/SG cards, (Def: Cards.new):
   Output file of merged old and new cards, (Def: Cards.mrg):
 Merge operation completed!
```

FIG. 8: BRICC – ENSDF merge tool terminal dialog.

Program execution: `BRICC` *ENSDF-file* merge`<CR>`.

The ENSDF file name is passed as program argument.

WARNING: The input *ENSDF* file should not be modified before running the code in the MERGE mode.

Input file: File of new **G**-records created by BRICC. Before running the merge utility, one cane delete unwanted **G**-records. Default file: CARDS.NEW

Output files: Updated file in ENSDF format with new **G**-records inserted into the designated position. Default file: CARDS.MRG

NOTE: The ENSDF output files generated by HSICC and BRICC are not identical because (a) the conversion coefficient values are different; and (b) in the latter case a number of new quantities, for example **IPC**, are on the new **S G** cards.

Terminal dialog: (see Fig. 8)

VIII. TESTING OF THE BRICC PROGRAM PACKAGE

To provide a test of the ENSDF tool portion of BrIcc a subset of data was extracted from the ENSDF database at the NNDC in September 2004. This consisted of all IT decay data sets (total of 1773 transitions) and the $\beta-$ or electron-capture data set containing the most GAMMA records for each Z (total of 17637 γ's). It was felt that the IT data would provide a good test of the higher multipolarities and lower γ-ray energies and the $\beta-$ or electron-capture data should provide higher γ–ray energy testing. The data were processed using version 1.2 of BrIcc (September 12, 2004, using the *'No Hole'* approximation). The *Compar.lst* output from the program was parsed to obtain the original input and new output values of the total and K through NC+ shell conversion coefficients. All γ-rays where the total conversion coefficient (α_{tot}) was missing from the input or new output were excluded from further testing. The ratios of the ENSDF total conversion coefficient to the BrIcc total conversion coefficient were analyzed to identify possible problems in the BrIcc program. This consisted of looking at data for ratios that were outside the range of 0.9 through 1.1. Where available, the results from version 1.13f of HSICC (October 9, 2001) were used as an aid in the analysis. This process consisted of several parts:

1. If BrIcc and HSICC were in good agreement or there were no HSICC data, the original ENSDF data were looked at.

2. If an obvious error was found in ENSDF, the data were excluded from the comparison. If there was explicit documentation that the ENSDF conversion was anomalous, the data were retained (the largest ratio was an anomalous E1 with a value of 8.1). If no obvious errors were found in ENSDF and no problems could be identified in BrIcc, the data were also retained.

3. The BrIcc.lst output was checked if:

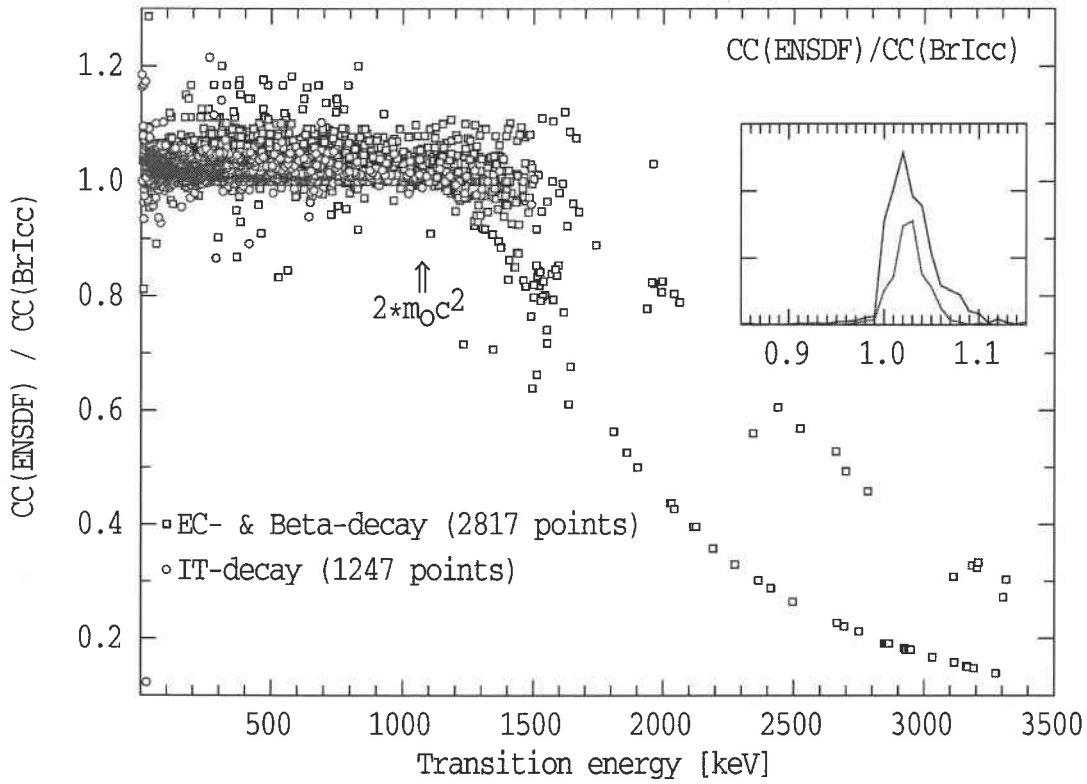

FIG. 9: Comparison of total conversion coefficients nuclear transitions of selected EC and β–decay (squares) and IT–decay (circles) data sets from the ENSDF data file compared with values calculated using BrIcc. The insert shows the frequency distribution of the CC(ENSDF)/CC(BrIcc) ratios.

(a) If BrIcc and HSICC values were discrepant.

(b) If HSICC data were not available and no obvious errors could be identified in the ENSDF data.

Identified problems were remedied in the program and were excluded from further comparison. Other cases were analyzed for some generic characteristics. Two of these are:

(a) Round-off problems. These typically occurred for M1,E2 and M1+E2 transitions with no mixing ratios resulting in an uncertainty greater than 25 in the last two significant digits and are grouped in the 1.1 to 1.2 range.

(b) Internal electron-positron pair formation. Above the pair production threshold ($E_\circ = 2m_e c^2$), the ratios started descending below 1.0 in a fairly consistent manner as a function of increasing E_γ. This appears to be caused by the internal pair coefficient becoming dominant as a function of increasing energy. Also, with a few exceptions, it was noticed that the E1 and M1 transitions were grouped

into two distinct patterns with the M1 transition ratios higher than the E1 and both decreasing in a consistent manner.

The final set of data from the above analysis is shown in Fig. 9.

IX. INSTALLATION AND DEVELOPMENT NOTES

The BLDBRICC and BRICC programs have been developed and extensively tested using Fortran 90/95 compilers on Win32 (CVF 6.6c), Linux (Lahey–Fujitsu LF95 and Intel F90) and UNIX (Digital F90) systems. Special considerations were given to avoid using system specific routines. In some places so–called compiler directive structures were used to adopt platform specific features.

External libraries used to develop the code included:

NSDFLIB library Nuclear Structure Data File Library, developed by the National Nuclear Data Center, Brookhaven National Laboratory and can be downloaded from http://www.nndc.bnl.gov/nndcscr/ensdf_pgm/nsdflib/

F2KCLI library a free implementation of the proposed Fortran F2003 command line interface, developed by Interactive Software Services Ltd. and can be downloaded from http://www.winteracter.com/f2kcli

On Windows platform the f2kcli.f90 source code has been modified, as the program failed to detect embedded blank character between double quotation (') marks. The modified version of the source code (f2kcli.f90) is now in the source directory.

X. OBTAINING BRICC V2.0

The BrIcc program package can be obtained from the following web site:
http://www.nndc.bnl.gov/nndcscr/ensdf_pgm/analysis/bricc

The BRICC distribution packages contain the following files:

BrIcc.exe - binary executable file

BrIccFO.icc - binary ICC data file

BrIccFO.idx - binary pointer (lookup) file

BrIccManual.pdf - program manual (this document)

A. Windows systems

The programs are compatible with Win9x/NT/ME/2000/XP operating systems. The self-extracting program archive will install the BrIcc program, the data files and the manual into a directory which can be selected during installation. It will create a BrIcc program group. On Windows NT, ME, 2000 and XP operating system the installation script will also set the 'BrIccHome' and 'Path' environment variables. On Windows 95 and 98 platforms the following two lines have to be added to the Autoexec.bat file:

```
set BrIccHome=<InstallDir>
set Path=%Path%;<InstallDir>
```

<InstallDir> is the directory where the program has been installed.

Due to different implementations of the command prompt, on Windows 95 and 98 systems the console buffer is limited to a maximum of 50 lines. To locate the data file the BrIcc program use the *BrIccHome* environment variable pointing to the directory, where the program and the data files are. In a typical installation, this directory is $C:\backslash Program\ Files\backslash BrIcc$. To enable the execution of BrIcc on the Command Prompt window from any working directory, the installation directory should be included into the Path variable.

To upgrade the program, please uninstall the previous version using the 'Uninstall' link provided in the BrIcc program group.

To test the program first test that the BrIccHome environment variable has been correctly set. On a Command Prompt (DOS window) to test the environment variables type

```
SET<CR>
```

and to test the path variable type

```
PATH<CR>.
```

To launch BrIcc from the *Start/Programs/BrIcc* menu or on a Command Prompt type

```
BrIcc<CR>
```

Do not forget to adjust the width of the screen to print long (117 character) lines.

B. Compaq Tru64 UNIX and Linux

The installation procedure is almost identical for both Compaq Tru64 UNIX and Linux operating systems.

Create the main directory for the programs (for example `/usr/local/bin/bricc`). then download the distribution package, a tarred, gzipped file onto that directory. Un-tar and un-zipp all program and data files into this directory. BrIcc requires an environment variable BrIccHome to be set in order to locate the data files. Use the following shell commands to set the environment variables, on Digital Unix systems:

```
setenv BrIccHome /usr/local/bin/bricc
```

and on Linux systems:

```
export BrIccHome=/usr/local/bin/bricc.
```

To test the program on the console window type $BrIcc< CR >$. Adjust the width of the screen to print long (117 character) lines.

XI. ACKNOWLEDGEMENT

The first author (TK) wishes to acknowledge the hospitality of the National Nuclear Data Center during his visits in 2004 and in 2005 and thank P.M. Davidson (Australian National University) for his continuing support to develop the Linux and Unix versions.

TABLE II: ENSDF **G** record containing information on the nuclear transitions. Taken from J.K. Tuli [2001TuAA]

Field	Name	Description
1-5	NUCID	Nuclide identification
6		Blank or continuation character
7		Must be blank
8	G	Letter G is required
9		Must be blank
10-19	E	Energy of the γ-ray in keV
20-21	DE	Standard uncertainty in E
22-29	RI	Relative photon intensity
30-31	DRI	Standard uncertainty in RI
32-41	M	Multipolarity of transition
42-49	MR	Mixing ratio, δ.
50-55	DMR	Standard uncertainty in MR
56-62	CC	Total conversion coefficient
63-64	DCC	Standard uncertainty in CC
65-74	TI	Relative total transition intensity
75-76	DTI	Standard uncertainty in TI
77	C	Comment FLAG
78	COIN	Letter C denotes placement confirmed by coincidence. Symbol ? denotes questionable coincidence.
79		Blank
80	Q	The character ? denotes an uncertain placement

TABLE III: ENSDF GAMMA continuation record. Taken from J.K. Tuli [2001TuAA]

Field	Name	Description
1-5	NUCID	Nuclide identification
6		Any alphanumeric character other than 1. ***NOTE:*** 'S' is reserved for records not shown in the Nuclear Data Sheets
7		Must be blank
8	G	Letter G is required
9		Must be blank
10-80	DATA	Allowed quantities The general form of a data entry as described on p. 33 of [2001TuAA] is: $< quant >< op >< value > [< op >< value >][< ref >]\$$ **G continuation record – any character other than 1 or S in column 6** E, DE[a], RI, DRI, M, MR[a], DMR[a], CC[a], DCC[a], TI, DTI, C, COIN, Q, BE1, BE2, ...; BE1W, BE2W, ...; BM1,BM2, ...; CE, CEK, CEL, ...; CEL1, ...; ECC[a], EKC[a], ELC[a], EL1C[a], EL2C[a], EKLC[a], EKL1C[a]...; FL, FLAG **S G records – character 'S' in column 6** BrIcc will scan the existing **'S G'** records and validate and will replace the Data entries, if they comply with the following rules: (a) **TI** not given in **G** record and **M** is known On the first **S G** record: **CC, KC, LC, MC, NC+** (electron conversion coefficients) On additional **S G** records: **NC, OC[b], PC[b], QC[b]** and **RC[b]** (electron conversion coefficients) and **IPC** (pair conversion coefficient[b]) Obsolete data entries also verified and will be removed, including: **MC+, M+** and **N+**. (b) **TI** given in **G** record and **M** is known On the first **S G** record: **CC** and **K/T, L/T, M/T, N+/T** (intensity ratios) On additional **S G** records: **N/T, O/T, P/T, Q/T** and **R/T** and **IP/T** (internal pair to total intensity ratio[b]) Obsolete data entries also verified and will be removed, including: **M+/T** and a warning will be issued. Any other data entry or text will be copied onto new **S G** records and will be inserted as new.

[a] – *BrIcc will read and interpret its numerical value.*

[b] – *To be declared in ENSDF dictionary and manual.*

TABLE IV: Typical values of the multipolarity (M), Mixing ratio (MR) and uncertainty (DMR) fields of the **G** record

M	MR	DMR	Multipolarity assignment
M1			Definite M1
(M1)			Uncertain M1
[E2]			Assumed E2
M1+E2	2.5	7	M1 plus E2, definite $\delta(E2/M1) = 2.5\,(7)$, symmetric uncertainty
M1+E2	+0.014	+15-12	Mixed M1 plus E2, definite, $\delta(E2/M1) = +0.14^{+15}_{-12}$, asymmetric uncertainty
M1+E2	2.5	LE	M1 plus E2, definite $\delta(E2/M1) \leq 2.5$, upper limit
[M1,E2]			Assumed mixed M1 plus E2, assumed $\delta(E2/M1) = 1$ with no uncertainty
E1+M2+E3	+0.012	+6-4	Mixed E1 plus M2 plus E3, definite, $\delta(M2/E1) = +0.012^{+6}_{-4}$ (E3 multipolarity component omitted)
[E1,M2,E3]			Assumed mixed E1 plus M2 plus E3, assumed $\delta(M2/E1) = 1$ (E3 multipolarity component omitted)
E0+M1+E2	+2.7	+3-1	Mixed E0 plus M1 plus E2, definite, $\delta(E2/M1) = +2.7^{+3}_{-1}$ $q(E0/E2) = 0.24\,(3)$ given in the GAMMA cont. record[a]

[a] *To be declared in ENSDF dictionary and manual.*

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Reduction of Discrepant Data Sets by a Bootstrap Method

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ABSTRACT

We discuss here the meaning of discrepant data sets from an information point of view. Reduction of these data sets can be achieved by a Bootstrap Method to obtain parameters that behave like the usual mean and standard deviations. The Bootstrap Method is also useful to define a safe bound for the standard deviation calculated by practical methods.

I. Introduction

More often than we would like, the results of experimental measurements of the same physical quantity are conflicting. Even if by its very nature this is an insolvable problem, it is possible to find objective guidelines for managing these data [1-16]. McMahon, Pearce and Harris presented a review of the problem of evaluating discrepant data sets [1]; this report addresses the characteristics of the Bootstrap Method.

II. When a data set is discrepant

Most of the time we will be dealing with a one-dimensional quantity. Therefore, the result of measurement consists of a data set formed by pairs (x_i, σ_i), where x_i is a random estimate of the quantity and σ_i measures its statistical uncertainty. The physical dimensions of both x_i and σ_i are the same; x_i measures the location of the quantity and σ_i, the dispersion in this one-dimensional physical space. Fig. 1 shows well-behaved data set. However, more often than we would expect, the data sets are like that of Fig. 2, and sometimes very discrepant, like that on Fig. 3.

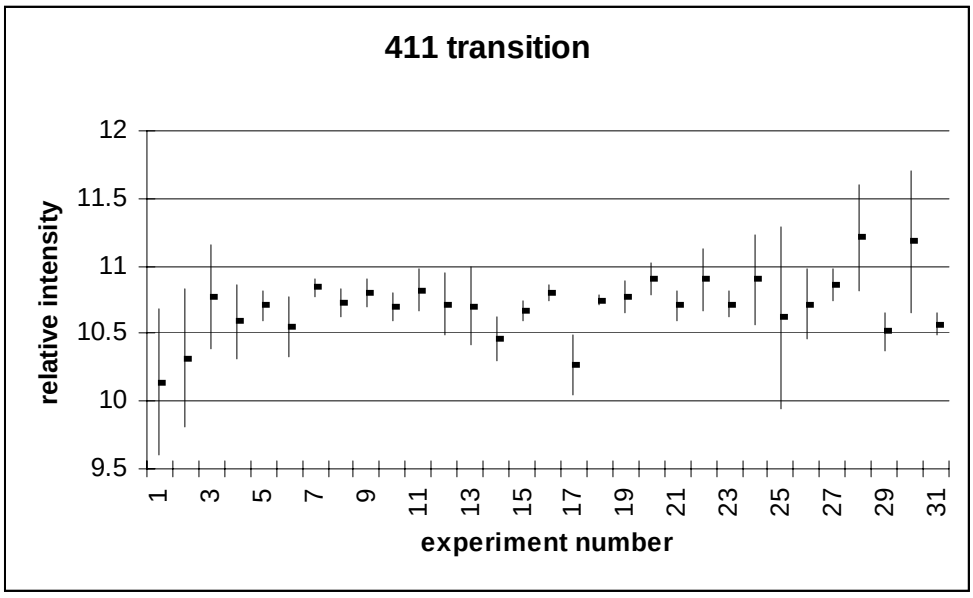

Fig. 1. Experimental values of the 411-keV gamma-ray emission probability following the decay of ^{152}Eu; average of the 31 data points shown is 10.735(20), and $\chi^2 = 29$.

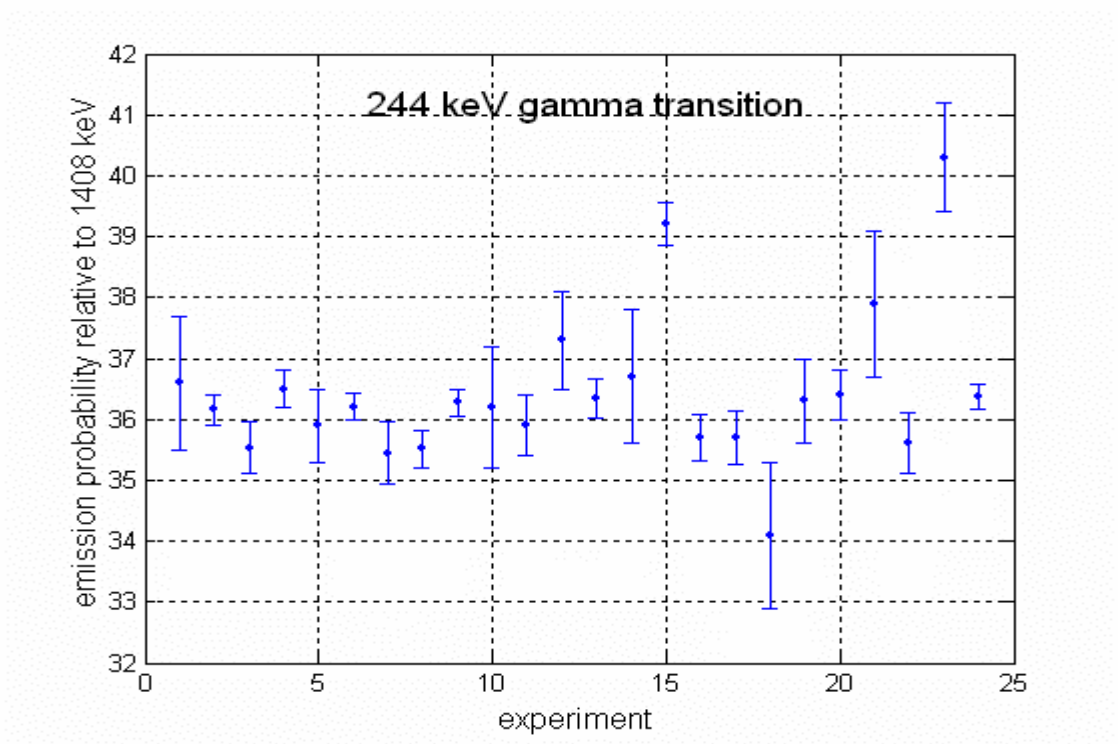

Fig. 2. Same as Fig. 1, for the 244-keV transition; weighted average of the 24 data points shown is 36.32(8), and $\chi^2 = 90$.

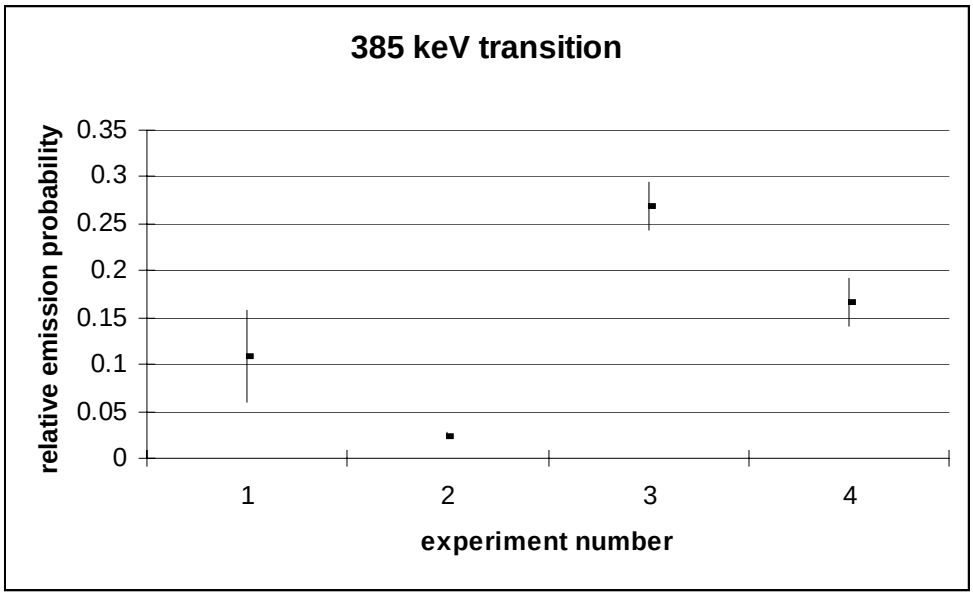

Fig. 3. Same of Fig. 1, for the 385-keV transition; weighted average of the four data points is 0.029(3) and $\chi^2 = 119$.

We say that the data sets of Figs. 2 and 3 are discrepant; the next three sections give a definition for this term.

II. 1. Weighted mean and variance

When the data set { (x_i, σ_i), I = 1,..,N } is consistent, we can calculate a best value for the mean and the standard deviation of the mean by

$$\hat{x} = \frac{\sum_{i=1}^{N} \frac{x_i}{\sigma_i^{\,2}}}{\sum_{i=1}^{N} \frac{1}{\sigma_i^{\,2}}} \quad (1)$$

$$\sigma = \frac{1}{\sqrt{\sum_{i=1}^{N} \frac{1}{\sigma_i^{\,2}}}} \quad (2).$$

II. 2. Chi-square test

The χ^2-statistics

$$\chi^2 = \sum_{i=1}^{N} \frac{\left(x_i - \hat{x}\right)^2}{\sigma_i^{\,2}}$$

assumes very different values in the two data sets, which makes it possible to attach a quantitative meaning to the quality of being discrepant. For Gaussian data, chi-square has a **p**robability **d**ensity **f**unction (pdf) that depends on N and becomes narrower (relatively) with increasing N; its average is N and the variance, 2N.

II. 3. Definition of a discrepant data set

Once a significance level for “discrepancy” is chosen, say 1%, we can say that any data set whose χ^2-value is greater than the corresponding critical value, χ^2_{critical} , is “ discrepant”.

II. 4. Occurrence frequency

In the decay data revision of the ^{152}Eu gamma-ray emission probabilities, there are about 120 γ rays observed by more than one experimentalist. This makes 120 data sets, with each one containing at least 2 values; Figs. 1 to 3 are from this revision. From these, 32 are discrepant data sets to be compared with the statistical expectation of 1.2 data sets. The conclusion is straightforward: about ¼ of the data sets contain wrong data.

However, the theoretical framework of statistics requires that the errors should be unknown and should remain unknown, only the mean square error being amenable to observation. Calling x_o the physical value of the quantity (sometimes called the *true* value, but what would be the untrue?), it is possible to write the formula:

$$x_i = x_o + \varepsilon_i \qquad \text{where } \varepsilon_i \text{ is the error .}$$

It is expected that $< \varepsilon_i > = 0$, meaning that the data are unbiased. The variance is a expectation value,

$$\sigma_i^2 = < \varepsilon_i^2 >,$$

the standard deviation being just the positive square root of the variance. It can be noted that these formulas are not intended for practical use, because they depend on unknown quantities, the error and the *true* value; however, we shall use it to give a precise framework to the discussion.

II. 5. No single estimator

Since the errors are to remain unknown, it is impossible to find what data came from mistaken measurements or data analysis. Statistics cannot help in choosing the data to discard or the standard deviations to change – necessary tasks for solving this practical problem. However, there is still some help that can be drawn from the Statistical theory of errors.

III. Discrepant data set from an information point of view

III. 1. Defining information and data reduction

The information content of a datum (x_i, σ_i) can be defined as:

$$I(x_i, \sigma_i) = \frac{1}{\sigma_i^2} ,$$

so that smaller variances correspond to bigger information contents. With this definition, and requiring that information should be an additive quantity, the overall information content of a data set is

$$I(\{(x_i, \sigma_i), i = 1,.., N\}) = \sum_i^N I(x_i, \sigma_i) = \sum_i^N \frac{1}{\sigma_i^2} ,$$

which increases therefore with the number of values in the set. Since

$I(\hat{x}, \sigma) = \frac{1}{\sigma^2}$, it is straightforward that

$$I(\hat{x}, \sigma) = \sum_i^N I(x_i, \sigma_i) ,$$

showing that the information in the mean contains all the information in the data set. If this is true, there should be nothing that we can calculate with all the values of the data set that cannot be also calculated with the mean and the standard deviation $\hat{x}, \sigma$ – indeed, this is a theorem that can be found under the heading “sufficiency” in books of mathematical statistics. It is said that the full data set can be reduced to its weighted mean and variance. Besides uniqueness, data reduction is one of the most important properties of statistical estimators.

III. 2. Dealing with a discrepant data set

It is not possible to represent a discrepant data set by its weighted mean and variance because one or some data are wrong. Obviously wrong data should be discarded, taking out terms of the sum, and incorrectly calculated variances should be enlarged, lowering the information content of the corresponding data. The realistic overall information content of the data set would be

$$I_{realistic}\left(\left\{\left(x_i,\sigma_i\right), i=1,..,N\right\}\right)=\sum_{i'}^{N} I_{realistic}\left(x_i,\sigma_i\right)=\sum_{i'}^{N}\frac{1}{\sigma_{i,realistic}^{\ 2}}\ ,$$

where the sum is to be taken only on the remaining data. Since there is not a statistical criterion for choosing the data to modify, this is an insolvable problem in the framework of Statistics. The practical approach is to perform the selection and/or variance enlargement by an expert system or person. There will not be a single procedure; therefore the uniqueness of the estimate is definitely lost.

III. 3. The statisticians' approach

The mathematical statisticians would recommend the use of a non-parametric approach, where the median replaces the mean. The median is the value that has equal probabilities of being greater than the *true* value x_o and being smaller than it,

$$P(\text{median} > x_0) = P(\text{median} < x_0) = 0.5\,. \qquad (3)$$

Calculating the estimate of the median requires that we sort the data set $\{x_i,\ I = 1,..,N\}$, hence

$$x_{[1]} \le x_{[2]} \le \cdots \le x_{[j]} \le \cdots \le x_{[N]}$$

where $x_{[j]}$ is the *j*th value of the data $\{x_i\}$ sorted in ascending order. The median is estimated as

$$x_{med} = x_{[(N+1)/2]} \qquad \text{odd } N,$$
$$x_{med} = \frac{x_{[N/2]} + x_{[N/2+1]}}{2} \quad \text{even N.}$$

The variance of x_{med} is difficult to calculate [14]:

$$\sigma^2_{\text{med (true)}} = \frac{1}{4Nf^{\,2}} \qquad (4)$$

where *f* is the probability density function (pdf) for the data set calculated at the true value of the median. Since the function *f* is unknown for discrepant data, it is not possible to estimate σ_{med} using equation (4).

The usual non-parametric approach is to determine the confidence intervals directly from the data, using only the definition of the median [equation (3)] and combinatorial analysis. For instance, in a measurement with 9 values, the probability for the median to be outside the interval $\left\lfloor x_{[1]}, x_{[9]}\right\rfloor$ is $2\cdot(1/2)^9 \sim 5\cdot10^{-3}$; outside the interval $\left\lfloor x_{[2]}, x_{[8]}\right\rfloor$ is $2\cdot9\cdot(1/2)^9 \sim 5\cdot10^{-2}$, etc.

With few data, it is not possible to reliably interpolate between the values to find predetermined confidence levels. Since the variances are required in common statistical procedures, like in the chi-square test and in least-squares fitting, an unbiased estimate of the experimental variances are generally required.

However, note the robustness of the non-parametric approach against outliers. It does not matter how far an outlier is from the median, it can pull the median just one place in the sorted data set. If the data set values are meaningful, they will cluster around the true median and this outlier will not disturb significantly the result.

III. 4. Usual approach

Most of the existing methods deal with the data and their variances until the remaining and/or modified data pass the chi-square test. Normally, we end by using all the methods listed below, ordered from the safest to the most dangerous practice, from a statistical point of view:

- LWM - try to adjust the information content by setting an upper limit for the information coming from a single experiment.
- Select data - pick up the best experiment or take the average of the better experiments. Statistics cannot help in the selection, but expertise in experimental physics does.
- Forget about the variances and take the unweighted average. Outliers make this method worse than it seems (see Section IV.3, below).
- Use the Chauvenet criterion for determining outliers.
- Multiply all the variances by a factor so that $< \chi^2 >_{\text{realistic}} = N - 1$. Be aware of this method: it assumes that all the variances are underestimated by the same factor, even if it is most unlikely that different experimentalists with different setups made the same scale factor mistake. Although this approach can be compared to healing the patient by changing the scale of the thermometer, it is a last option that should be employed if nothing else can be done.

IV. How much information can be safely retrieved?

The absolute minimum of retrievable information corresponds to the inverse of the variance of the least precise datum, which is a useless bound. Another estimate comes from the χ^2 value: the final standard deviation should be about $\sigma\sqrt{\frac{\chi^2}{N-1}}$, where σ is the standard deviation of the weighted mean. The minimum of information can also be estimated from the variance of the unweighted average. But we can try an experimentalist's approach, letting the data speak by themselves, using a bootstrap method for determining it. This method, which consists in determining the mean and variance of non-parametric statistical quantities calculated in a simulated infinite repetition of the known experiments, will be detailed in the next item. Determining the common statistical parameters from non-parametric statistics may bridge the gap between the preferred statisticians' approach and the requirements of physicists.

IV. 1. Bootstrap method

From the experimental data $\{x_i \; i = 1,..,N\}$, we define the empirical probability function with values $1/N$ at each x_i and zero elsewhere. The method is based on the medians of random samples (with replacement) of size N drawn from the experimental data set. Notice that each of these samples will have some of the data values x_i repeated and others missing. After drawing μ samples, the best value of the quantity is given by

$$\hat{x}_{med} = \frac{1}{\mu}\sum_{\eta=1}^{\mu} x_{med,\eta} \;\; ,$$

where $x_{med,\eta}$ represents the median for the ηth sample, and its variance by

$$\sigma^2_{med} = \frac{1}{\mu - 1}\sum_{\eta=1}^{\mu} (x_{med,\eta} - \hat{x}_{med})^2 \;\; .$$

The number of repetitions μ must be large enough to make negligible the fluctuations in $\hat{x}_{med}$ due to the Monte-Carlo procedure – in principle, we are looking for the mean and variance of the population of all possible sets of N experiments similar to the experiments we are analyzing. Typically, a few thousand repetitions should be sufficient.

The Bootstrap Method is based on the fact that the empirical distribution of $\{x_i\}$ approximates the true probability density function as N increases. It can be proved that $\hat{x}_{med}$ and σ_{med} approach their true values as N approaches infinity. Also, it should be noted that the Central Limit Theorem guarantees for $\hat{x}_{med}$ a Gaussian distribution with a standard deviation σ_{med} for a large value of N.

IV. 2. Examples

Table 1 shows the results of the simple statistics and the bootstrap for the data sets of Figs. 1 to 3.

Table 1. Comparison of Bootstrap Method with other statistical methods. Final result for the 385-keV transition is not in the table, and was calculated discarding two flawed experimental values.

Transition	Mean and standard deviation		
	weighted	unweighted	bootstrap
411	10.735(20)	10.71(4)	10.724(23)
244	36.32(8)	36.42(27)	36.28(8)
385	0.029(3)	0.14(5)	0.14(6)

IV. 3. Dependence on outliers

Consider a measurement that consists on N - 1data (x,s) and one datum (x', s') such data $x' - x >> \sqrt{\frac{s^2}{N} + s'^2}$. This is a discrepant data set. In the following, we define $\delta = x' - x$.

The bootstrap result can be analytically calculated in this case. When N = 2, ¼ of the sampled data sets have x as its median, other ¼, x', and the remaining ½, $x_{med} = 0.5 \cdot (x+x')$. Therefore, the mean median equals the unweighted average and the variance is 0.35 δ, which is somewhat smaller than the corresponding one of the unweighted average.

When N ≥ 3, the probabilities of the different medians can be calculated [15]. Therefore, it is possible to calculate the mean and its standard deviation by this bootstrap method. Table 2 below compares the unweighted mean to the bootstrap value. Note that the outlier looses its influence on the bootstrap mean already for N = 5, although it has some effect on the variance.

Table 2. Behavior of the bootstrap estimate and the unweighted average with the discrepant data set with one outlier presented in this section.

N	unweighted mean [variance]	**bootstrap mean [variance]**
3	x+0.33 δ [$(0.4s)^2$+$(0.33\ \delta)^2$]	x+0.63s+0.26 δ [$(0.7s)^2$+$(0.44\ \delta)^2$]
5	x+0.20 δ [$(0.4s)^2$+ $(0.20\ \delta)^2$]	x+0.31s+0.06 δ [$(0.6s)^2$+ $(0.24\ \delta)^2$]
7	x+0.14 δ [$(0.4s)^2$+ $(0.14\ \delta)^2$]	x+0.21s+0.01 δ [$(0.5s)^2$+ $(0.10\ \delta)^2$]
9	x+0.11 δ [$(0.3s)^2$+ $(0.11\ \delta)^2$]	x+0.16s+0.001 δ [$(0.4s)^2$+ $(0.038\ \delta)^2$]
11	x+0.09 δ [$(0.3s)^2$+ $(0.09\ \delta)^2$]	x+0.13s+0.0002 δ [$(0.4s)^2$+ $(0.013\ \delta)^2$]

Note that diminishing the influence of outliers may not always give the best result. It may happen that the outlier is nearer the *true* value than the remaining data. However, from a statistical point of view, it is always better to have an unambiguous behavior, and this method definitely attenuates the influence of outliers in the mean.

IV. 4. Data reduction property

The data reduction property can be tested by a method suggested by Rajput and MacMahon [8]. We take a discrepant data set and analyze it as two separate subsets. Combining these partial results must produce values consistent with those obtained by applying the Bootstrap Method to the full data set if the data reduction property is applicable. This was done by Helene et al. in the case of ^{137}Cs half-life [16] ; the same test was applied to the data set of figure 2, dividing it in two data sets with 12 points each. The result is shown in Table 3. The first two columns give $\hat{x}_{med}$ and σ_{med}, respectively, for the first subset of 12 elements. The same statistical parameters are given on columns 3 and 4 for the second subset. Columns 5 and 6 contain the weighted averages of columns 1 and 3 and their standard deviations, respectively. The corresponding partial weighted average values and their standard deviations, as well as the partial results of every subset in every random choice, are statistically consistent with the result obtained for the full data set, 36.28(8).

The test shown in Table 3 was applied also to other methods. However, we verified that the other methods failed sometimes; since they do not reduce *all* data sets, it must be assumed that they do not reduce data and the full data set must be used when updating the recommended values every time a new measurement is performed. Only the Bootstrap Method always produced acceptable results, showing that it effectively reduces the data set.

Table 3. Analysis of the data set shown in Fig. 2 - data were split in two subsets; the partial results were composed by the usual weighted average as shown in Section II.1 (see Section IV.4 for details).

First sub-set		Second sub-set		Weighted average	
36.28	0.19	36.20	0.18	36.24	0.130
36.30	0.050	35.96	0.18	36.28	0.048
36.09	0.15	36.43	0.22	36.19	0.123
35.80	0.16	36.53	0.20	36.09	0.123
36.38	0.16	35.87	0.18	36.15	0.120
36.31	0.12	36.17	0.16	36.26	0.094
36.09	0.20	36.30	0.08	36.27	0.074
36.28	0.07	36.19	0.27	36.27	0.070
36.51	0.17	36.20	0.11	36.29	0.094
36.30	0.16	36.21	0.10	36.23	0.085

IV. 5. Characteristics of the Bootstrap Method

Besides reducing the data, the most important property of the method presented here is its robustness against outliers. These properties follow from regarding the values in the data set as equally good estimates for the quantity, warranting a well-defined statistical behavior for the mean and the variance.

This Bootstrap Method does not differ substantially from other practical methods in further aspects: gives definite parameters that can be propagated in the calculations; can be easily calculated with computers; and has similar small sample properties.

Certainly the main criticism relates to the loss of information that comes from disregarding the original variances. Anyway, some loss of information is unavoidable. It is up to the evaluator choose the method according the risks she or he is willing to take when divulging (publishing) the evaluated values.

V. Conclusions

Use the Bootstrap Method to determine the minimum amount of information that can be retrieved from a discrepant data. If your special practical method determines a standard deviation greater than that calculated by the bootstrap, stick with the bootstrap estimate. When a true reduction of a discrepant data set is required, think about using the bootstrap method, which fits in the framework of the time-honored theory of statistics.

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IAEA Nuclear Data Section: Horizontal Evaluations, 2003/05

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Abstract: The decay scheme data for a limited number of radionuclides have been evaluated during 2003-05, and incorporated into the European Activation File (EAF) for fusion studies (Table 1). Similar studies have also been completed for the radionuclides within the Ra-226 decay chain (Table 2), apart from Bi-214 which has proved to be problematic because of the relatively high degree of complexity of the decay scheme. All of the recommended decay data were tested for their consistency in terms of the completeness of the resulting decay scheme (expressed as % deviation between the effective Q-value determined from the branching ratios and component Q-values, and the calculated Q-value derived from all components of decay). Good to excellent consistencies have been obtained.

Table 1: Evaluated Decay Data for European Activation File (EAF): Fusion Studies, 2003/05.

Nuclide	Half-life	Consistency (% Deviation)
32-Ge-80	27 s	-0.0204
34-Se-81	18.39 min	0.0027
34-Se-81m	57.28 min	0.1410
35-Br-72	78.6 s	-0.2821
35-Br-72m	10.6 s	0.2164
38-Sr-94	75.3 s	0.0259
39-Y-97	3.75 s	0.0105
39-Y-97m	1.17 s	-0.0227
39-Y-97n	0.142 s	-0.0264
40-Zr-99	2.2 s	-0.0510
45-Rh-110	28.5 s	0.0172
45-Rh-110m	3.2 s	0.1721
45-Rh-111	12 s	0.0125
46-Pd-113	91 s	-0.1194
46-Pd-113m	0.3 s	0.3404
50-Sn-129	2.23 min	-0.0200
50-Sn-129m	7.2 min	-0.0530
50-Sn-130	3.73 min	-0.0085
50-Sn-130m	1.7 min	0.0458
55-Cs-123	5.91 min	-0.0424
55-Cs-123m	1.7 s	-0.0020
58-Ce-149	5.3 s	0.0777
61-Pm-155	41.5 s	incomplete decay scheme
64-Gd-163	68 s	0.0550
65-Tb-146	8 s	-0.0027
65-Tb-146m	24.0 s	-0.1118
68-Er-167m	2.269 s	-0.0144
74-W-176	2.5 h	0.1347
76-Os-180	21.5 min	0.0346
76-Os-196	34.9 min	-0.0177
77-Ir-192	73.822 d	0.1323
77-Ir-192m	1.44 min	-0.0780
77-Ir-192n	241 y	0.0069
78-Pt-202	44 h	0.0000
79-Au-192		evaluation underway
79-Au-192m	0.160 s	0.3330
79-Au-192n	0.029 s	0.0100

Table 2: Ra-226 Decay Chain – 2003/05 Evaluations.

Nuclide	Half-life	Consistency (% Deviation)
88-Ra-226	5.862×10^{5} d	0.0013
86-Rn-222	3.8231 d	-0.0020
86-Rn-218	0.035 s	-0.0006
85-At-218	1.5 s	-0.0012
84-Po-218	3.098 min	-0.0014
84-Po-214	1.637×10^{-4} s	-0.0013
84-Po-210	138.388 d	-0.0014
83-Bi-214		evaluation underway
83-Bi-210	5.012 d	0.0000
82-Pb-214	26.8 min	0.0263
82-Pb-210	22.16 y	-0.4568
81-Tl-210	1.30 min	0.0191
81-Tl-206	4.202 min	-0.0050
80-Hg-206	8.31 min	0.0610

Report on horizontal evaluation March 2003 – May 2005

TABLE OF NUCLEAR MAGNETIC DIPOLE AND ELECTRIC QUADRUPOLE MOMENTS

Present status

The Table is now current to late 2004. The latest version can be obtained directly from me, although it has not been posted on the NNDC website.

Activity during the report period

Activity has focused upon preparation of the Table for publication in Atomic Data and Nuclear Data Tables. The full manuscript is now with the printers. Meanwhile new results have been entered, all with NSR references, and a considerable number of old entries have been given NSR references. Due acknowledgement is made to NNDC staff for assistance with the older material. The process of generating 'recommended values' has been started, and has given rise to considerable interest in new methods of evaluating hyperfine interactions using up-to-date computation techniques as outlined below.

Present plans for the evaluation

Currently the prime objective, in addition to keeping the Table up-to-date, is to survey all measurements and give recommended values. To this end a set of interrelated standard values for several 'reference' moments is being set up. During this process it has been realized that

a) as things stand there are incompatibilities between apparently high quality data which must limit the precision with which many derived results can be quoted.
and
b) present day computation techniques allow far more precise interpretation of, in particular, multi-electron configuration hyperfine interaction results than was possible at the time the experiments were done.

Ways in which re-assessment of data may help to resolve the incompatibilities mentioned above are being explored and this is keeping further determination of 'recommended values' on hold for the immediate future. Examples of these reassessments will be given to the meeting.

An undertaking, acknowledgement and request

Although the latest tabulation is not available at NNDC by agreement with ADNDT, I undertake to give detailed recommendations to any data compiler based on the latest measurements upon request. I thank the several compilers who have alerted me to omissions and corrections in the present Table and ask that all who find such problems be in touch with me.

N.J.Stone, Oxford, May 2005

Electric Monopole Transitions between 0^+ States

(Procedures for Nuclear Structure Data Evaluators)

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Abstract

This paper presents recommended procedures for the evaluation of spectroscopic information on $0_i^+ \rightarrow 0_f^+$ pure $E0$ transitions in even-even nuclei, including the following quantities:

(a) $q_K^2(E0/E2)$, the ratio of the K-conversion electron intensity of the $0_i^+ \rightarrow 0_f^+$, E0 transition to that of the $0_i^+ \rightarrow 2_1^+$, E2 transition,

(b) $X(E0/E2)$, the dimensionless ratio of the absolute $B(E0)$ and $B(E2)$ transition rates,

(c) $\rho^2(E0)$, the squared value of the monopole transition strength.

1

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1 Introduction

It has been known for many years that electric monopole (E0) transitions are possible between states of the same spin and parity in a nucleus enclosed by electrons. The characteristics of E0 transitions provide sensitive tests of the various models of nuclear structure. They elucidate such matters as volume oscillations (the so-called breathing mode, related to nuclear compressibility), shape co-existence, and isotope and isomer shift. Excellent surveys of monopole transitions have been given by Aldushchenkov and Voinova in 1972 [1], Lange, Kumar and Hamilton in 1982 [2], Voinova-Elseeva and Mitropolsky in 1986 [3] and Wood et al. in 1999 [4].

In 1987 Firestone [5] outlined procedures for the evaluation of E0 transition probabilities for $0^+ \rightarrow 0^+$ monopole transitions, with particular emphasis on the Wilkinson estimates of single–particle transition probabilities. There has since been much activity in the field, both theoretical and experimental, and an update is timely. To a large extent the present paper outlines procedures developed in the recent work of Kibédi and Spear [6].

The electric monopole operator couples the nucleus to the atomic electrons, giving rise to the internal conversion process. It also couples the nucleus to the Dirac background to produce electron-positron pairs if the E0 transition energy is greater then twice the electron rest mass. Simultaneous emission of two photons is a higher order process (relative probability $\sim 10^{-3}$ to $\sim 10^{-4}$ [3]) and for practical purposes can be neglected. Single–photon E0 transitions are strictly forbidden by considerations of angular-momentum conservation.

The E0 transition probability is given by the expression

$$W(E0) = \frac{1}{\tau(E0)} = W_{ic}(E0) + W_{\pi}(E0), \tag{1}$$

where $\tau(E0)$ is the partial mean life of the initial state for E0 decay. The quantities $W_{ic}(E0)$ and $W_{\pi}(E0)$ are the transition probabilities for internal–conversion electron and electron-positron pair emission, respectively. They are given by the expression

$$W_{ic}(E0) + W_{\pi}(E0) = \rho^2(E0) \times [\Omega_{ic}(E0) + \Omega_{\pi}(E0)], \tag{2}$$

where $\Omega_{ic}(E0)$ and $\Omega_{\pi}(E0)$ are electronic factors defined by Church and Weneser [7]. They are functions of atomic number, Z, and transition energy. They can be calculated independently of nuclear properties. The quantity $\rho(E0)$ is the dimensionless monopole transition strength. It carries all the information about the nuclear structure, being related to the monopole matrix element according to the expression

$$\rho(E0) = \frac{< f|M(E0)|i >}{eR^2}, \tag{3}$$

where R is the nuclear radius. It is usually assumed that $R = r_o A^{1/3}$, where A is the atomic mass number and $r_o = 1.20$ fm.

The reduced E0 transition probability $B(E0)$ is equal to the square of the E0 matrix element, and so

$$B(E0) = \rho^2(E0)e^2R^4, \tag{4}$$

where e is the electronic charge. Clearly $\rho(E0)$ is a basic characteristic of electric monopole transitions. Because there is often an ambiguity in determining its sign, it is customary to use $\rho^2(E0)$. Since the value of $\rho^2(E0)$ usually lies in the range 10^{-3} to 10^{-1}, reference is usually made to $10^3\rho^2(E0)$. It is evident from equation (2) that experimental determination of $\rho^2(E0)$ requires the measurement of absolute transition rates and the calculation of electronic factors. In some cases the transition rate can be determined indirectly from that of another transition de-exciting the same nuclear state, provided that the relevant branching ratio is known.

In their discussion of E0 transitions between 2^+ states, Church, Rose and Weneser [8] introduced the quantity

$$q_K^2(E0/E2) = \frac{I_K(E0)}{I_K(E2)}, \tag{5}$$

where $I_K(E0)$ and $I_K(E2)$ represent the intensities of E0 and E2 K-conversion electron components of the $J_i^+ \rightarrow J_f^+$ transition, respectively.

The definition of $q_K^2(E0/E2)$ can be extended to the case of $0_i^+ \rightarrow 0_f^+$ transitions (which can have no E2 component) by somewhat arbitrary reference to an E2 transition from the 0_i^+ state to a 2_f^+ state [1, 9, 10]. Usually this is taken to be the first excited 2^+ state (2_1^+).

In some cases experimental information other than $I_K(E0)$ and $I_K(E2)$ can be used in conjunction with the relevant conversion coefficients and electronic factors to deduce q_K^2. For example,

$$q_K^2(E0/E2) = \frac{I_\pi(E0)}{I_\pi(E2)} \times \frac{\Omega_K(E0)}{\Omega_\pi(E0)} \times \frac{\alpha_\pi(E2)}{\alpha_K(E2)}, \tag{6}$$

where $I_\pi(E0)$ and $I_\pi(E2)$ are the observed internal pair intensities for the E0 and E2 transitions, respectively, and $\Omega_{K,\pi}$ and $\alpha_{K,\pi}$ are the relevant electronic factors and conversion coefficients.

A dimensionless ratio of the E0 and E2 reduced transition probabilities was defined by Rasmussen [11]:

$$X(E0/E2) \equiv \frac{B(E0)}{B(E2)} = \rho^2(E0)e^2R^4/B(E2). \tag{7}$$

The equivalent experimental value, considering K conversion electrons, can be deduced from the general formula:

$$X(E0/E2) = 2.54 \times 10^9 A^{4/3} \times q_K^2(E0/E2) \times \frac{\alpha_K(E2)}{\Omega_K(E0)} \times E_\gamma^5, \tag{8}$$

where E_γ is the E2 γ-ray energy in MeV.

The experimental monopole strength can be obtained directly if the partial mean life of the E0 transition, $\tau(E0)$, is known

$$\rho^2(E0) = \frac{1}{[\Omega_K(E0) + \Omega_{L1}(E0) + ...\Omega_\pi(E0)] \times \tau(E0)}. \tag{9}$$

Alternatively, if the E2 transition rate, $W_\gamma(E2)$, is known it can be obtained from the expression

$$\rho^2(E0) = q_K^2(E0/E2) \times \frac{\alpha_K(E2)}{\Omega_K(E0)} \times W_\gamma(E2). \tag{10}$$

In assessing values of $q_K^2(E0/E2)$, $X(E0/E2)$ and $\rho^2(E0)$ from available experimental information most reviews have adopted the values of quantities as calculated by the original authors from their observed intensity data using a variety of calculated tables of internal conversion coefficients and electronic factors. It is however preferable to use original intensity data to calculate $q_K^2(E0/E2)$, $X(E0/E2)$ and $\rho^2(E0)$ in a consistent fashion using the most up-to-date published calculations of conversion coefficients and electronic factors, together with the most recent information on lifetimes and branching ratios. Restricting consideration to $0^+ \rightarrow 0^+$ transitions eliminates ambiguities and uncertainties arising in the determination of monopole parameters for non-zero initial spins due to the need to ascertain the gamma-ray mixing ratios involved.

2 Theoretical conversion coefficients and electronic factors

In order to determine values of the characteristic monopole transition parameters, conversion coefficients and electronic factors are required, possibly over a broad range of energies and atomic numbers. The ENSDF analysis tool, BrIcc [6], can be used to obtain interpolated values.

3 Determination of "Adopted Values"

Adopted values of $q_K^2(E0/E2)$ may be obtained by using equation (5) with various types of intensity data, as follows:

Method *A*: $I_K(E0)$ and $I_K(E2)$, or their ratio, are known; this provides the most direct determination of $q_K^2(E0/E2)$.

Method *B*: $I_K(E0)$ and $I_\gamma(E2)$, or their ratio, are known, and $q_K^2(E0/E2)$ has been determined using the internal conversion coefficient $\alpha_K(E2)$.

Method *E*: $I_K(E0)$ and $I_K(E2')$, or their ratio, are known, where $I_K(E2')$ is the K-electron intensity for an E2 transition other than $0_i^+ \rightarrow 2_1^+$, together with the relative intensities of the two E2 transitions:

$$I_K(E2) = \frac{\alpha_K(E2)}{\alpha_K(E2')} \times \frac{I_\gamma(E2)}{I_\gamma(E2')} \times I_K(E2') \tag{11}$$

Method *P*: Obtained from results of direct measurements of $I_\pi(E0)$ and $I_\pi(E2)$, or their ratio, and applying equation (6).

Method *Q*: As for *P*, but using measured values of $I_\pi(E0)$ and $I_\gamma(E2)$, or their ratio.

Method *S*: Obtained, particularly for the light nuclei, from relevant particle widths determined from inelastic electron scattering.

Values of $X(E0/E2)$ can be determined using equation (8).

Values of $\rho^2(E0)$ can be determined using equations (9) and (10), except that for some of the light nuclei $\rho^2(E0)$ may be determined from electric monopole matrix elements measured in inelastic electron scattering, using equation (3). Kibédi and Spear [6] have demonstrated that monopole parameters determined from inelastic electron scattering are generally in satisfactory agreement with those from more "traditional" procedures wherever comparision is possible. However, given the model-dependence of most, if not all, analyses of electron-scattering data, the traditional data are to be preferred where available.

4 Example: ^{112}Cd: $0_2^+ \rightarrow 0_1^+$ transition

In ^{112}Cd the 1224.46 *(13)* keV 0_2^+ states de-excites by a 1224.4 keV E0 transition to the ground state and a 606.88 *(15)* keV E2 transition to the first excited 2_1^+ state at 617.520 *(10)* keV. The half–life of the state is $T_{1/2}(level)$= 4.2 *(11)* ps. The value of the $q_K^2(E0/E2) = I_K(E0, 1224.4)/I_K(E2, 606.88)$ has been determined in a number of works:

1979Gi05: 0.30 *(4)*
1980Ju05: 0.33 *(5)*
1993De01: 0.30 *(4)*
1997Dr03: 0.30 *(3)*

Weighted average value: $q_K^2(E0/E2)$= 0.304 *(19)*.

Using Brlcc one can get: $\alpha_K(E2, 606.88) = 3.36 \times 10^{-3}$; $\alpha_{Total}(E2, 606.88) = 3.88 \times 10^{-3}$; $\Omega_K(E0, 1224.4) = 4.93 \times 10^{+9}$; $\Omega_{L1}(E0, 1224.4) = 5.65 \times 10^{+8}$ and $\Omega_{L2}(E0, 1224.4) = 6.24 \times 10^{+6}$. Note that $\Omega_\pi(E0, 1224.4)$ is not known and is expected to be much more smaller than $\Omega_K(E0, 1224.4)$.

Using Eqn. 8 we get: X(E0/E2) = 0.0234 *(15)*. The partial E0 half–life can be expressed as:

$$T_{1/2}(E0) = T_{1/2}(level) \times q_K^2(E0/E2) \times \frac{\Omega_K(E0)}{\Omega_K(E0) + \Omega_{L1}(E0) + \Omega_{L2}(E0)} \times \frac{1 + \alpha_{Total}(E2)}{\alpha_K(E2)} \quad (12)$$

Using Eqn. 8 we can get the value for $\rho^2(E0)$ = 0.034 *(9)*.

The corresponding records in "Adopted data set" of the ENSDF file read:

```
112CD  L 1224.46   130+               4.2 PS    11                        Y
112CD3 L XREF=ABCDEF(1228)GHJK(1220)LMNO$
112CD CL T         from BE2(1223-KEV level to 617-KEV level)=0.16 4 in double
112CD2CL COUL. EX. (1980Ju05)
112CD CL J         L(P,P')=0
112CD  G 606.88    15100       E2
112CDB G BE2W=51 14
112CD  G 1224.4                E0                                0.114      7
112CD CG           CEK(1224.4G)/CEK(606.88G)=0.304 19;
112CD2CG weighted average of 1979Gi05,1980Ju05,1993De01,1997Dr03
112CD3CG B(E0)/B(E2)=0.0234 19; RHO**2=0.037 11
112CD4CG deduced by the evaluator
```

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XUNDL Status Report (Oct. 15, 2003 to May 20, 2005)

B. Singh and J.C. Roediger (McMaster)
D.F. Winchell and T.W. Burrows (BNL)
(May 20, 2005 for NSDD-2005 at McMaster University)

XUNDL database:

Provides prompt internet access to current publications or preprints in experimental nuclear-structure data (level-schemes) that are not yet available in ENSDF database. Since 2003, the database is no longer limited to high-spin papers; current low-spin papers are also being compiled.

Provides convenient access to different viewers (LBNL's Isotope Explorer, Oak Ridge's RADWARE, BNL's on-line retrieval), and to the published article on journal webpages (if the user has valid internet access to the journal). The database is indexed by mass number, nuclide and reference keynumber.

The compilation work is done primarily at McMaster. The entry of datasets in XUNDL database is co-ordinated by B. Singh at McMaster, while the database is organized and managed by David Winchell and Tom Burrows at NNDC, BNL. This compilation work requires a consistent level of effort in keeping up-to-date with the published literature on journal websites, communication with the original authors and participation of undergraduate students.

STATUS:

Since the start of this project in December 1998, 1520 datasets have been added to XUNDL, mostly from papers published in 1995-2005. About 420 datasets have been added since the November 2003 NSDD meeting. In addition 30 previous datasets in XUNDL have been updated for newer papers. It is estimated that almost all the high-spin papers published from1998-2005; and about 50% of the high-spin papers published from 1995-97 are included.

Number of primary papers compiled for XUNDL for each year are given below:

2005: 45; 2004: 172; 2003: 132; 2002: 147; 2001: 135; 2000: 142; 1999: 118; 1998: 127; 1997: 64; 1996: 66; 1995: 53; 1994-1990: 48.

About 93% of the datasets were compiled at McMaster, using semi-automated translation procedures described in previous reports. About 7% datasets were received by McMaster group from other data centers (mainly from Berkeley and Grenoble). These datasets were reviewed and edited at McMaster, prior to inclusion in XUNDL.

Presently XUNDL has 1520 datasets from about 1250 primary papers covering data for about 1020 nuclides from ^{13}N to ^{288}115, amongst 228 A-chains (A=13 to 288). ~90% content is high-spin level schemes.

We are up-to-date (as of May 20, 2005) with the coverage of the current high-spin papers that are available on journal webpages. For current low-spin papers, only about 12 papers published in the last few weeks remain to be compiled.

A lot of actual compilation work is done by undergraduate students (Roy Zywina: June 2001-April 2004; Michelle Lee: February 2002-April 2004; Joel Roediger: February 2004-present). The students are trained in basic nuclear physics and experimental techniques in nuclear spectroscopy, retrievals from ENSDF, XUNDL and NSR databases, ENSDF formats and nuclear quantities involved, use of semi-automatic translation codes (PDF to TEXT and TEXT to ENSDF), consistency checking codes (FMTCHK, PANDORA and ISOTOPE EXPLORER), calculational codes (GTOL, HSICC and LOGFT). The students' work is checked thoroughly by B. Singh before submitting a dataset to BNL. Generally, one or two undergraduate students work full time during the summer months (May to August) and part-time (few hours/month) during the study semesters.

We continue to actively communicate with the authors of original papers to resolve data-related errors and inconsistencies, and to request additional details of data, which are often lacking in publications due to space limitations or other reasons. The response from the original authors is generally prompt. Since October 2003, about 80 such communications have taken place. In cases where we received preprints, the data-related errors pointed out to the authors were corrected prior to the actual publication of the paper. In some other cases the authors have published errata, based on our communications with them about data-related problems. Compilation of such e-mail communications containing additional information or clarification and data received from the original authors are being sent to BNL (for archival purposes) as a composite computer file as well as in print version. These private communications are not assigned NSR keynumbers. The A-chain evaluators or other users can request copies of these communications and request BNL to assign keynumbers, if deemed necessary.

As we understand, the compiled datasets in XUNDL are being used by mass-chain evaluators, which should potentially speed up the evaluation process for ENSDF. The current retrieval rate, as monitored by NNDC, is about 400/month from the NNDC website alone. There are probably other retrievals made through RADWARE and LBNL websites.

Semi-automated Procedures to Translate Tabular data in journals into ENSDF format were given in the proceedings of the 2003 NSDD meeting. Essentially the same procedures are being followed.

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