IAEA
International Atomic Energy Agency

INDC(NDS)-0793
Distr. G+AL+NC

INDC International Nuclear Data Committee

Summary Report of the Consultancy Meeting on the

Fission Product Yield Experimental Database

Tokyo Institute of Technology, Tokyo, Japan

27–30 May 2019

Prepared by

Michael Fleming
OECD Nuclear Energy Agency (NEA)

Toshihiko Kawano
Los Alamos National Laboratory (LANL)

Naohiko Otuka
IAEA Nuclear Data Section (NDS)

June 2019

IAEA Nuclear Data Section

Vienna International Centre, P.O. Box 100, 1400 Vienna, Austria

Selected INDC documents may be downloaded in electronic form from
http://www-nds.iaea.org/publications
or sent as an e-mail attachment.
Requests for hard copy or e-mail transmittal should be directed to
NDS.Contact-Point@iaea.org
or to:
Nuclear Data Section
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna
Austria

Printed by the IAEA in Austria

June 2019

INDC(NDS)-0793
Distr. G+AL+NC

Summary Report of the Consultancy Meeting on the

Fission Product Yield Experimental Database

Tokyo Institute of Technology, Tokyo, Japan

27–30 May 2019

Prepared by

Michael Fleming
OECD Nuclear Energy Agency (NEA)

Toshihiko Kawano
Los Alamos National Laboratory (LANL)

Naohiko Otuka
IAEA Nuclear Data Section (NDS)

Abstract

The Consultancy Meeting on the Fission Product Yield Experimental Database was held at Tokyo Institute of Technology, Tokyo, Japan, from 27th to 30th of May 2019, which aims to grasp the current status of experimental activities on the fission product yields (FPY), development of FPY fission modeling and data evaluation methods, and the EXFOR database compilation. The meeting brought opportunities for the participants from six different countries to discuss on our common topics of interests, such as a novel technique to measure fission-related observables, data evaluation methods by applying theoretical and/or empirical models, a consistent treatment of FPY data together with uncertainties (covariances), possible extension of the EXFOR data format to accommodate various fission-related observables, and improvement of user interface in the EXFOR web retrieving system maintained by IAEA.

June 2019

Table of contents

1 Introduction

The Consultancy Meeting on the Fission Product Yield Experimental Database was held at Tokyo Institute of Technology from 27th to 30th of May 2019, Tokyo, Japan. The primary purpose of this meeting was to share our knowledge of experimental data on the fission product yield (FPY) as well as fission-related other observables in the available databases, and to identify the issues that should be resolved to produce a brand-new evaluated FPY data library in near future. The meeting scope also covers the ongoing experimental programs, theory and modeling for the fission process, and infrastructure for the FPY data evaluation, since the experimental FPY database plays a significant role in these topics of interests. For such a very specific purpose, fifteen specialists in the relevant fields were nominated from six countries to participate in this meeting, including one IAEA staff member.

Despite recent progress in the theoretical description of the nuclear fission process and significant effort devoted to develop robust fission models, our current knowledge of fission is not yet at the level of producing the accurate FPY evaluations without guidance by experimental data, hence the quality of evaluated FPY data strongly depends on the experimental information involved. Construction of experimental database, which will be a foundation of the FPY data evaluation, is an essential process to produce the evaluated nuclear data files. The pioneers in this field (*e.g.*, Meek, England & Rider for the ENDF library in the US, Crouch for UKFY data library in the UK) carefully prepared their own experimental databases to produce the evaluated data files. The other major data library projects, such as Japanese Evaluated Nuclear Data Library, JENDL, and Chinese library, CENDL, have not been maintaining their own experimental databases; the FPY data in JENDL were evaluated based on the same database as ENDF/B-VI, and CENDL mostly relies on the available data in EXFOR. Obviously maintaining the experimental databases for the FPY evaluation at each nuclear data project is our common task, and we should share the compiled data to facilitate producing the evaluated nuclear data libraries without duplicating the burden.

In parallel to the FPY evaluation at each nuclear data library project, IAEA NDS hosted two relevant Coordinated Research Projects (CRPs) in 1990s–2000s, as well as a technical meeting in 2016 on the same subject, which evidences that NDS is aware of importance of international cooperative efforts for producing a new FPY data library. NDS also plans to start a new FPY CRP, which is scheduled for 2020. Under these circumstances, the importance of the experimental FPY database as a common basis of new libraries has been widely recognized. This was re-emphasized at the "Workshop on Fission Product Yield Experimental Data" organized by IAEA and LANL in August 2018, Los Alamos, New Mexico, USA [1].

IAEA NDS maintains a coordinating effort to bring the world experts in the FPY science, including experiment, evaluation, and theory, to explore possible improvement and extension of the EXFOR database for FPY, to survey data users' demand and request for the compilation and dissemination of the FPY data, and to centralize all the FPY-related information at the hub — evaluation of experimental data, producing evaluated nuclear data files, and theoretical research activities. Thanks to the local organizer, Prof. S. Chiba, of Tokyo Institute of Technology, IAEA NDS was able to hold this meeting as a follow up to the previous one in Los Alamos, keeping the momentum toward the same goal. Brief summaries of the presentations are given in Sec. 2, while the discussions are summarized in Sec. 3. The meeting agenda and the list of participants are given in Appendix.

Delivering the welcome address by the President of Laboratory for Advanced Nuclear Energy, Prof. K. Takeshita greeted the meeting participants, and he reiterated the high importance and impact of the FPY data in various fields of nuclear energy applications. Before starting presentations by each participant, T. Kawano of LANL was elected as the chairperson and M. Fleming of NEA Dababank was elected as the rapporteur of the meeting. The main workshop consisted of participants' presentation, which was followed by intensive discussions, and drafting the summary report and recommendations. These presentations and working papers are available at:

https://www-nds.iaea.org/index-meeting-crp/CM-FPY-2019/

Finally NDS acknowledged all the participants for their cooperation and contribution to this productive meeting.

2 Presentation summaries

2.1 M. Fleming, Centre activity at OECD-NEA

Michael Fleming presented the activities of the OECD Nuclear Energy Agency, including those both within the Databank and Nuclear Science Division. Within the Databank, the EXFOR compilation and revision work was described with the responsibility of the Databank over areas 2 and O discussed. As presented in the subsequent contribution, the compilation of the majority of the fission yield datasets identified in recent IAEA work will be the responsibility of the NEA Databank when they are included in the official allocation list. The progress of the Databank in recent years is summarised in Figure 1.

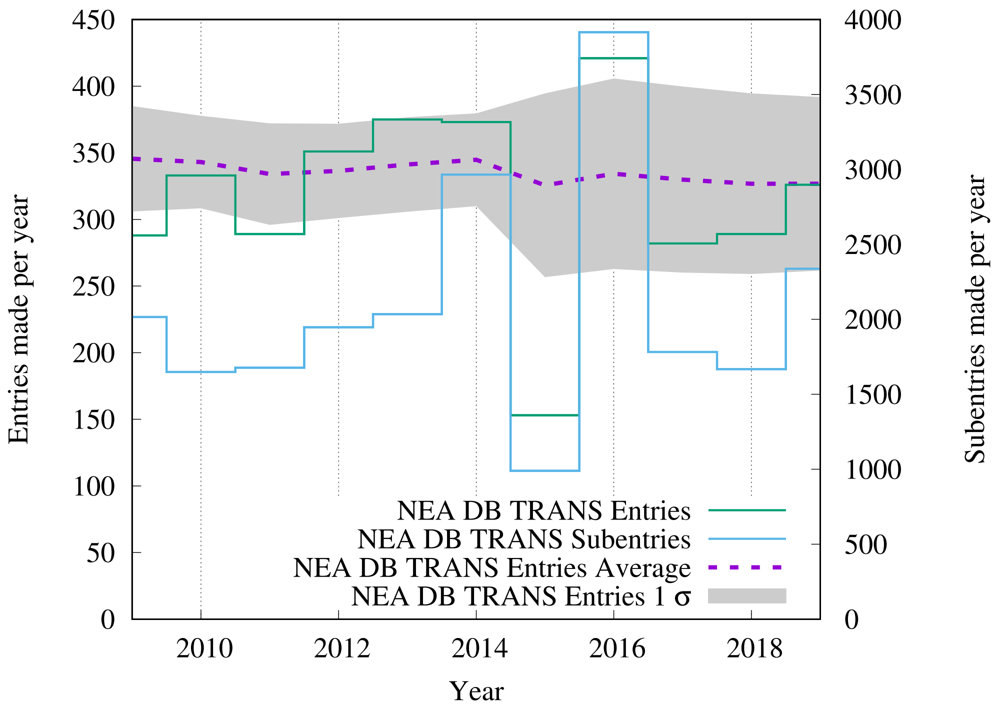

Figure 1: The total number of entries and subentries in NEA DB TRANS per year over the last decade. Note that 2019 figures include preliminary, unfinalised data in the IAEA-NDS open area as of April 2019.

In 2018 the NEA launched a new GitLab system with EXFOR compilation work as one of the first project areas. It is now used to manage the NEA DB EXFOR work, providing version control and project management tools under private repositories. Those with access permissions may visit:

https://git.oecd-nea.org/databank/nds/exfor.

This allows the EXFOR project to manage the compilation of preliminary transmissions, track issues, verify corrections and record the progress. Examples were shown with the issues raised for some recent trans.

JANIS development was discussed, with examples of the visualisation of fission quantities including prompt fission neutron spectra, fission product yields and mass yields. EXFOR was also shown, as well as the basic interface screens. These are a fraction of the capabilities of JANIS and new features are continuously in development. The release of a version 4.1 is planned for Q3-Q4 2019.

Under the NEA Nuclear Science Committee, the Working Party on International Nuclear Data Evaluation Co-operation (WPEC) enables collaboration between different evaluated nuclear data library programmes on high-priority activities. These are broken down into subgroups and expert groups that focus on specific topics/fields. The ongoing and recent activities were reviewed, including the Expert Group on Generalised Nuclear Database Structure (EG-GNDS) and two subgroups related to fission yields: SG25 and SG37. Some results from these two subgroups were discussed, including the generation of fission yield covariance matrices, of which four equivalent correlation matrices for thermal U235 are shown in Figure 2.

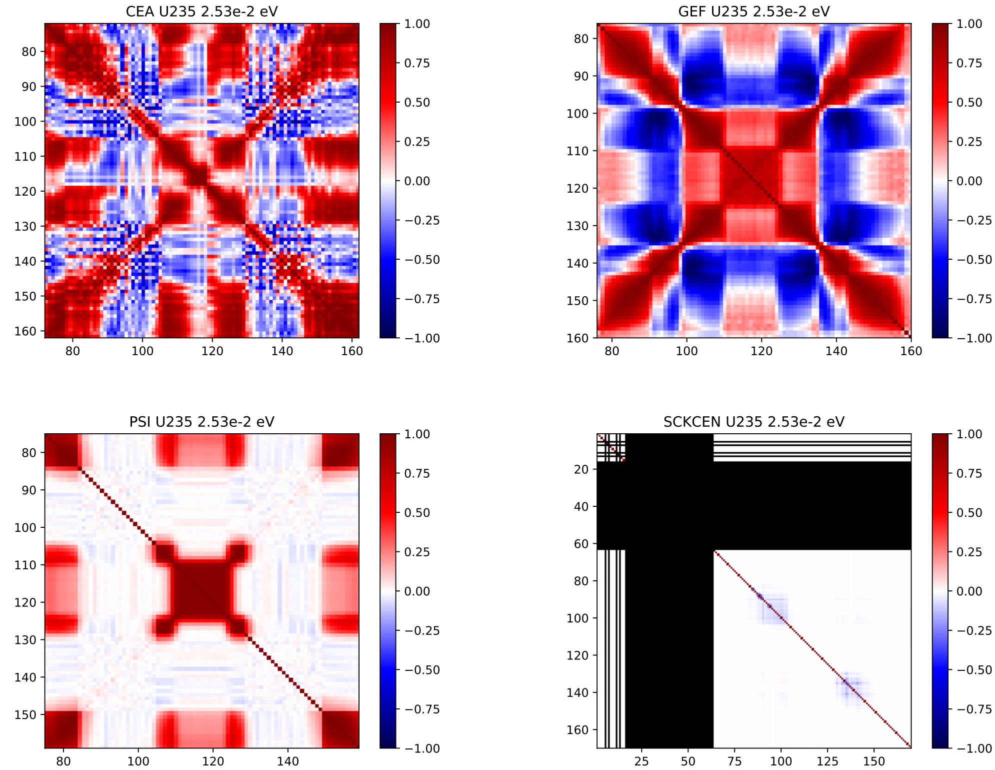

Figure 2: Correlation matrices for thermal fission mass yields of ^{235}U as calculated by four participants to the WPEC Subgroup 37 on ‘Improved fission product yield evaluation methodologies.’

2.2 S. Okumura, Completeness survey and statistics of experimental fission product yield data in EXFOR database

Shin Okumura provided an overview of the Nuclear Data Sections in IAEA, including the breakdown of work areas and staff. The fission process was reviewed and terms concerning the fission yield were defined to ensure that the participants were in agreement on basic definition of yields.

- Primary Fission Fragment Yield: The yield of the fragment formed just after scission but before prompt neutron emission.
- Independent Fission Product Yield: The yield of after prompt neutron emitted fission fragment, so called fission product.
- Cumulative Fission Product Yield: The yield of the fission product after β decay.

In order to define the nuclear reaction and its observable, EXFOR coding rule using *Reaction Code* has been established. The *Reaction Code* consitutes of 9 parameters, SF1:Target, SF2:Incident Particle, SF3:Ejectile/Process, SF4:Product, SF5:Branch, and SF6:Parameter, etc. Especially three parameters SF4, SF5, and SF6 are important to distinguish the type of FPY data and to use as a search criteria on the EXFOR web retrieval system. The three parameters defined in the EXFOR coding rule for fission product yield (FPY) are summarized in Table 1. Due to the complication of these reaction codes, users will encounter difficulties to search FPY data that they want to get. The NDS is planning to re-design new web interface to retrieve fission observables more easily and intuitively. To do this, NDS is collecting suggestions and feedbacks from user and evaluator communities.

Table 1: Types of the fission fragment/product yields (FPY) defined in EXFOR

Yield	Y(Z,A,M)	Y(A)	Y(Z)
Primary fission fragment	,PRE,FY ELEM/MASS,TER,FY ELEM/MASS,QTR,FY 1-H-1,TER,FY	MASS,PRE,FY, ,PRE,AP MASS,PRV,FY, PRV,AP	ELEM,PRE,FY, ,TER,ZP ELEM,TER/CHG,FY
Independent fission product	ELEM/MASS,IND,FY 55-CS-136,IND,FY 0-G-0,PR,FY	MASS,SEC,FY, MASS,MAS,FY, ,SEC,AP MASS,SEC/CHN,FY MASS,PR,NU	ELEM,IND,FY ,CHG,FY, MASS,,ZP,
Cumulative fission product	ELEM/MASS,CUM,FY ,42-MO-99,CUM,FY	MASS,CHN,FY	ELEM,CUM,FY

A historical review of fission yield compilation in EXFOR was provided, starting from the work of Crouch that was transmitted in 1980. Due to the ongoing and increasing work in fission yield evaluation, the IAEA have reviewed England and Rider's report[2] and Robert Mills' Ph.D. thesis from University of Birmingham[3] used in the evaluation of ENDF/B-VI the UKFY3.0, respectively. The articles used in above two works was compared with the existing EXFOR datasets to find FPY data that has not yet included in EXFOR. The result was reviewed at the NRDC-2019 meeting in April 2019 [1] alongside similar studies performed by the US NNDC

[1] Available online at https://www-nds.iaea.org/nrdc/nrdc_2019/working/wp2019-20.pdf

against NSR database. It was requested that these should be shared to the wider community by another document, potentially through an INDC report or other publication. By following the suggestion, the NDS have released the detailed procedure of this assessments as a NDRC Memo[2] after this consultancy meeting. The complete list of articles is attached in Appendix A in this report as well. Many overlaps between Ref [2] and Ref [3] were detected. It was found that nearly 200 articles have not been compiled and stored in EXFOR. The majority (approximately 90%) of the reactions incorporated in both bibliographies are neutron-induced fission and the rest are spontaneous fission. The US NNDC have done the similar completeness check against NSR database which were also reported in the NRDC memo (CP-C/444 ,445, and 446 [3]). It was found that the articles of photo-, spontaneous-, and neutron-induced fission including the various fission observable measurements which need to be compiled are 212 in total. The completeness checks done both by IAEA-NDS and NNDC are overlapped for only 33 records in neutron-induced fission.

The NDS have started to specify the C5 format for FPY and various fission related observables, since current C5 format is designed for cross sections. Universal data format is required and NDS will implement shortly, before new CRP starts.

[2]Available online at https://www-nds.iaea.org/nrdc/memo_cpd/cpd979.docx

[3]Available online at https://www-nds.iaea.org/nrdc/memo_cpc/

2.3 G. Belier, Experimental activity at CEA

Gilbert Bélier presented an overview of experimental activities carried out by or in collaboration with the CEA, including measurements at ILL in Grenoble, France, measurements carried out at the (now decommissioned) CALIBAN reactor and the SOFIA experiment at GSI in Germany. Status of the future FALSTAFF spectrometer has been done also.

At the ILL high flux reactor, two kind of experiments are performed. The first one involves the well known Lohengrin spectrometer. It allows to measure fission product individual yields thanks to an ionization chamber or γ-ray detectors. Isomeric Ratio are also measured with the γ-ray detectors, and are crucial for applying charge state changes corrections to the yields. The measurements were compared to different models, but only the FIFRELIN code could reproduce these ratios. For the second kind of experiment, cumulative fission products yields are measured thanks to the activation method. The fission rate is measured with a new kind of active scintillating target, and the activities are measured through γ-ray spectrometry with a usual Ge detector (2016 experiment) or with the new FIPPS spectrometer (end of 2018). Each time ^{235}U was irradiated. A scheduled experiment will measure ^{239}Pu in 2019 at Saclay's reactor Orphée. Beside these measurements at thermal energies, an activation experiment was also performed on the CALIBAN critical assembly. A usual fission chamber was used but thanks to a fast dedicated electronic, a large amount of ^{239}Pu (about 100 μg) could be used, avoiding the use of a second sample as is usually done. The main goal of this measurement is to determine systematic uncertainties that could be present in the J. Laurec measurement. Final result is expected in 2019.

Two SOFIA experiments were performed at GSI in 2012 and 2014. At GSI relativistic ^{238}U beam can be produced. Its fission can be studied but also numerous secondary beams can be produced. Results on ^{236}U were presented. The reverse kinematics technique is used and allow at the GSI energies to completely separate every fission fragment in Z. The mass resolution is also very good and very precise individual fission products can be obtained. In the SOFIA experiment, fission is induced through Coulomb excitation that mainly excite the Giant Dipole Resonance (GDR). Thus the fissionning compound nucleus is equivalent to the same as for the ^{235}U neutron induced fission at 8 MeV. Cumulative yields were deduced and compared to measurements performed in neutron induced fission experiment. SOFIA results represent an opportunity to obtain yield free from nuclear data, and can help to disentangle systematic uncertainties. In the future (p,2p) reaction will be used to induce fission and will allow to measure the excitation energy. The acceleration of ^{242}Pu primary beam could also allow to study plutonium isotopes, and others with masses less or equal to 242.

Finally the FALSTAFF spectrometer was presented. One arm is built and its completion in 2020 will permit to obtain individual fission product yields through the $2v$-$2E$ method. The total kinetic energy of the fragment will be also measured, and neutron multiplicity of each fragment in the case of first chance fission. Experiment will be performed at the Neutron For Science (NFS) facility at GANIL.

2.4 A. Tonchev, Experimental activity at LLNL

Anton Tonchev described work done by LLNL and LANL team at the Triangle Universities Nuclear Laboratory (TUNL) on new measurements including fission yields. This included the ability to perform time and energy dependent cumulative fission product yield (FPY) measurements not only on very long-lived cumulative FPYs with half-life of days or weeks, but also on fission products which are 5-6 precursors removed from the line of stability. The last one usually have half-lives of a few seconds or less. Measurements of these short-lived FPYs will require new experimental techniques, such as developing and commissioning a new fast transport system at TUNL, to produce complete and consistent yield sets of data for fissioning systems important for basic fission theory and applications. The available mono-energetic neutrons produced in charged-particle reactions were discussed, highlighting the limitations in the 9–14 MeV range due to contamination with breakup reactions. Prof. Chiba reminded the participants of the experimental work done decades ago identifying an additional reaction such as $^{1}H(^{11}B,n)^{11}C$ to generate monoenergetic neutrons with incident energy of about 11 MeV. The downside of this approach is the low reaction cross section.

The experimental setup was described, including the use of ToF techniques for energy discrimination and HPGe detectors for activation measurements over a wide range of timeframes up to months post irradiation. Additionally, a fast rabbit transfer system was developed to handle short cooling times and to identify additional, short-lived isotopes. These included both 1 meter rabbit system with a transfer time of 400 milliseconds and a 10 meter rabbit system with a transfer time of 1 second.

FPYs sesults were shown for a range of incident energies (0.5 – 15 MeV) and new measurements on many fission products. Several measurements were performed in order to address cases with discrepant measurements and to probe the energy dependence of some specific isotopes. The energy dependence work showed a seemingly surprising result, with dominant mass products increasing in yield as a function of incident neutron energy in the range of 1–4 MeV. At higher neutron energies, 5–14 MeV, the FPYs at the asymmetric mass distribution decrease. The unexpected trend of the FPY cannot be readily reproduced by existing, data-based phenomenological models. An even larger challenge for all fundamental theory-based models of nuclear fission is the positive slope found for high-yield fission products from neutron induced fission on ^{239}Pu and to a lesser extent on ^{238}U. This is contrary to the low-energy slop of the same FPYs from ^{235}U, suggesting different interplay between the pairing and shell effects in these fissile nuclei at low-excitation energies. It was argued whether this is corelated with trends in TKE and other measurements performed by D. Duke et al. This was questioned by some participants and it was agreed that repeated measurements in this energy range would be welcome to clarify the trends are not due to statistical fluctuations.

2.5 J. Silano, Experimental activity at LLNL

Jack Silano presented γ-ray-induced fission product yield measurements performed by the LLNL-LANL-TUNL collaboration using the High Intensity γ-ray Source (HIγS) facility at Triangle Universities Nuclear Laboratory. This work is an extension of the experimental capabilities for measuring neutron-induced fission product yields described by Anton Tonchev. A description was giving of the production of intense, monoenergetic γ-ray beams at HIγS through inverse Compton scattering of free electron laser photons by high energy electrons.

Progress was presented on experimental efforts to test using ^{A}Z(γ,f) as a surrogate experimental probe for $^{A-1}$Z(n,f) by comparing the fission product yields from ^{239}Pu(n,f) and ^{240}Pu(γ,f). The ^{239}Pu(n,f) measurements were performed at an incident neutron energy of 4.6 MeV, so the ^{240}Pu(γ,f) measurements were performed at an incident γ-ray energy of 11.2 MeV to create a compound ^{240}Pu nucleus with the same excitation energy. The comparison of these fission yields tests the combined effects of the Bohr Hypothesis for compound nuclear reactions and the spin and parity of the fissioning compound nucleus on the fission product distribution. Fission product yield measurements for both reactions were measured using the same techniques and the same detectors, putting both sets of data on the same systematic footing.

The yields from ^{240}Pu(γ,f) at an incident γ-ray energy of 11.2 MeV were remarkably consistent with the yields from ^{239}Pu(n,f) at an incident neutron energy of 4.6 MeV. Comparisons of the ^{240}Pu fission yields to the yields from ^{239}Pu for other incident neutron energies spanning the range of 0.5–14.8 MeV were all consistently in worse agreement than the 4.6-MeV data set. Additionally, the yields from ^{235}U(n,f) and ^{238}U(n,f) were also in poor agreement for all incident neutron energies in this range. Future photofission measurements on ^{240}Pu at additional γ-ray energies will test whether the good agreement with ^{239}Pu(n,f) remains at additional excitation energies. There are also plans to measure fission product yields with half lives in the 100s of ms using the fast rabbit transfer system with a 1 meter track length described by Anton Tonchev.

2.6 A. Sonzogni, Uncertainty quantification in the summation method for nuclear reactor antineutrinos

Our presentation covered several topics. First, a status report on EXFOR compilations on FY compilations, indicating that we have increased the effort from Otto Schwerer as well as bringing another EXFOR compiler, Olena Gristvay from Kiev, to contribute to this project. Second, we mention that a new postdoc, Andrea Mattera, would join BNL in July to work on obtaining recommended experimental fission yields.

Another project we have been working on is the obtention of cumulative FY correlation to deduce realistic uncertainty estimates in summation calculation. We have found that the GEF codes gives quite satisfactory independent FY correlations, which we then converted into cumulative FY correlations using the ENDF/B-VIII.0 decay data sub-library. We have applied these correlations in three areas (a) uncertainties in Inverse Beta Decay antineutrino yields from nuclear reactors, (b) total energy, prompt and delayed, release following fission, and (c) energies carried by antineutrinos following fission. In particular, for the 2nd point, we have also surveyed the values provided by the ENDF/B library and found some discrepancies, which we are exploring.

2.7 T. Kawano, Evaluation of energy-dependent FPY (LANL progress report)

Kawano summarized issues in the current evaluated fission product yield data files; discrepancies in the measured FPY of important isotopes, as well as the limited number of neutron incident energies. The new evaluation effort in the US consists of the measurements of FPY, the compilation of experimental data and recommendation of evaluated FPY, and the model code development for the evaluation. The structure is shown in Fig. 3.

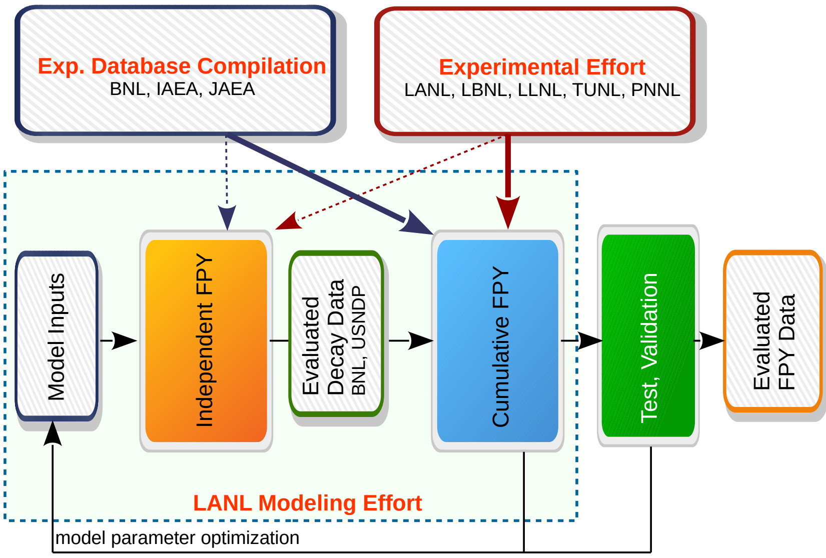

Figure 3: Multi-Laboratory effort toward the new FPY library in the US

The model-calculation based evaluation for independent and cumulative yields at LANL consists of the Hauser-Feshbach statistical decay of the excited fission fragments, and the β-decay of independent fission products. LANL is extending the model to the higher neutron-incident energies where the so-called multi-chance fission should be taken into account. Emission of the pre-fission neutron is calculated with the LANL Hauser-Feshbach code, CoH_3, by adjusting model parameters to reproduce the total fission cross section of ^{235,238}U, and the calculated average energies of the pre-fission neutron, $\langle \epsilon \rangle$ were reported. $\langle \epsilon \rangle$ is used to estimate the equivalent neutron-incident energies for the multi-chance fission, in order to decompose the measured total kinetic energies (TKE) into the chance-fission contributions. This technique suggested that the small bump in the experimental TKE seen near 6 MeV is an evidence of the second chance fission.

Kawano also briefly mentioned about some future plans of the model code development. The model will be combined with more microscopic approaches to better predict the FPY data where experimental data are scarce. The micro-macro model for fission potential energy surface will be applied to the initial fission fragment distributions, and the number projection method will replace Wahl's Z_p model. Finally a large scale model parameter optimization will be performed.

2.8 K. Tsubakihara, Evaluation activity at Tokyo Tech

Kohsuke Tsubakihara of the Tokyo Institute of Technology presented their work on development of a new semi-empirical fission yield evaluation model, which produces the independent fission product yield.

We developed a parser to convert and process experimental data retrieved from the EXFOR database directly from the *EXFOR Original* format. Statistics on the extracted data for all the fissioning systems given in EXFOR at different incident energies were shown in the presentation. An isobar distribution of the retrieved experimental data for the independent fission product $Y_I(A,Z)$ was fitted by a modified formula of the scission-point model proposed by Wilkins *et al.* [6]. It is assumed that $Y_I(A,Z)$ distribution for a given A can be expressed by the Gauss function and it is proportional to the mass yield $Y_M(A)$, where odd-even staggering $F_{\rm oe}$ is given as

$$\begin{aligned} Y_I(A,Z) &\propto \exp\left[-\frac{E_{\rm LD}(A,Z)+\Phi(E^*)\Delta E_{\rm sh}(A,Z)}{T(A,Z)}\right] \\ &= Y_M(A)\times F_{\rm oe}\times\frac{1}{\sqrt{2\pi}\sigma(A)}\int_{-0.5}^{0.5}\exp\left[-\frac{Z-Z_{\rm p}(A)+t}{2\sigma(A)^2}\right]dt \qquad (1) \\ F_{\rm oe} &= \exp\left[-\frac{\Delta E_{\rm sh}(A,Z)}{E_{\rm d}(A,Z)}\right] \quad , \end{aligned}$$

where all the physical quantities are defined in the presentation. $Y_I(A,Z)$'s for a large number of fissioning systems at the thermal and fast energies were newly calculated using Eq. (1). Results of data fitting and study on the systematics of fitting parameters were shown in the presentation. The systematics study was applied to produce $Y_I(A,Z)$ of the fissioning systems in the case where experimental data is not abundant. Since the experimental isomeric ratio data are quite limited, the Hauser-Feshbach statistical decay code, TALYS, was used to obtain the isomeric ratios. An example of schematic view of the isobaric yield distribution is shown in Fig. 4. In

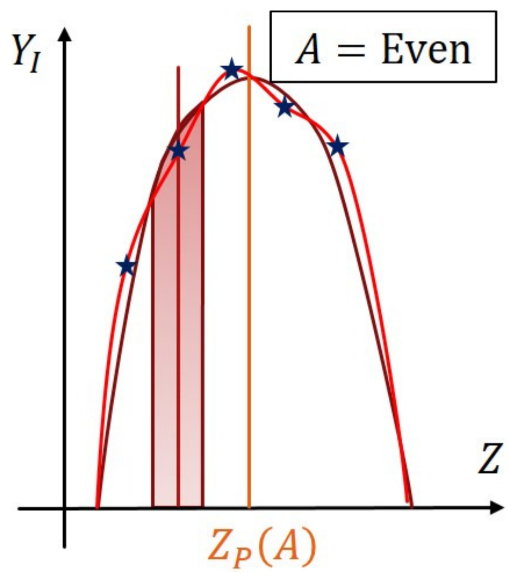

Figure 4: Schematic view of isobaric independent yield distribution. In even A isobaric distribution, the yields of odd N-odd Z (even N-even Z) fission products are smaller (larger) than the naively-expected Gaussian distribution.

the present evaluation, some experimental data that were measured as a ratio to the well-known fission yield such as ^{99}Mo, were excluded. It was suggested by the participants that the ratio data would be worthwhile to include in the evaluation, and will be taken into account in the next evaluation.

We calculated the cumulative fission product yield $Y_C(A,Z)$, decay heat and delayed neutron yields using the new $Y_I(A,Z)$ data. Some β-decay observables were shown in the presentation. It was mentioned that the isomeric ratios are essential to reproduce the experimental delayed neutron yields. The $Y_C(A,Z)$ is used for a burn-up calculation to compare the PIE data of Takahama-3 and Mihama-3. The results showed better agreements than the case where JENDL-FPY/2011 is used.

The covariance matrices for the evaluated FPYs were generated by applying the generalized least-squares method, where various fundamental constraints required in the FPY data are involved, such as the normalization of total fission product yields, as well as the constraints coming from the Z and A number conservation. To include these constraints in the evaluated covariances, the updated covariance matrices are calculated as follows,

$$V_{\mathrm{upd}} = V_{\mathrm{a}} - V_{\mathrm{a}} S^t \left(S^t V_{\mathrm{a}} S + V \right)^{-1} S V_{\mathrm{a}} \,, \tag{2}$$

where V_{a} is the prior covariance matrix, S is the sensitivity matrix, and V is the covariance matrix of experimental data. When these correlations are introduced to calculate the uncertainties on the cumulative yields, they will be comparable to the uncertainty values by England and Rider. An example is presented in Fig. 5, which is the $A = 102$ isobar yield distribution for the $^{235}\mathrm{U} + \mathrm{n_{th}}$ fission. As seen in the figure, the error-band shown by light-pink seems to conform to England-Rider's evaluated uncertainty, while the calculated uncertainties without any correlations, shown by the dark-green shaded area, are much larger.

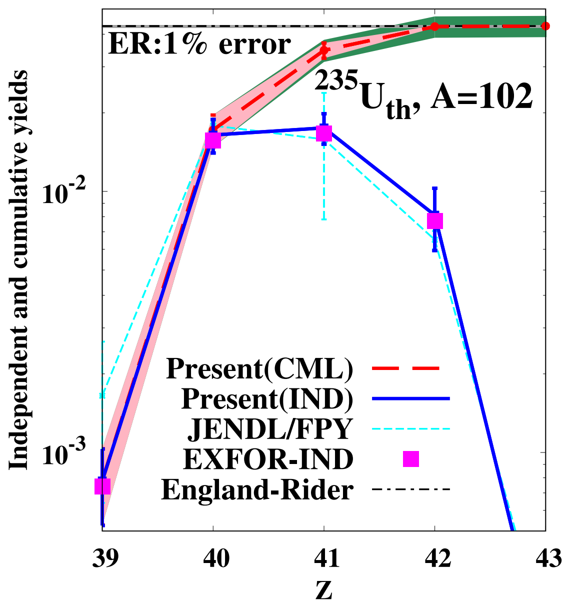

Figure 5: Isobar yield distribution at $A = 102$ for $^{235}\mathrm{U} + \mathrm{n_{th}}$ fission. Evaluated independent yields (IND) and their errors are in blue-solid line. Calculated cumulative yields (CML) and their errors are in red-dashed line.

2.9 N.C. Shu, Yield evaluation activity at CNDC

Nengchuan Shu presented an overview of the development and progress in the CENDL/FPY library project from 1987 to 2016. After the completion of CENDL-2.0/FPY in 1987, the FPY data for the neutron induced fission on ^{233}U, ^{235}U, ^{238}U and ^{239}Pu were evaluated with the Z_p model and a phenomenological model.

From 2018 a new program of development has been underway, which includes development of new theoretical models of fission, new experimental measurements, and ultimately new evaluations.

Similar to the other FPY evaluation groups, the CENDL community has extracted and developed their own local EXFOR database for use in evaluation work. This has been done in parallel to the development of the Yield Evaluation System (YES) with the version 1.0 in use. This code package uses the VisualBasic GUI, and it accepts a variety of input data formats, such as EXFOR data in EX4Comp, gamma data in XML, and yield data in MYSQL database.

With the YES package, the CENDL community is currently updating the ^{233}U, ^{235}U, ^{238}U and ^{239}Pu fission product yields. Recently, the yield ratio data including R-values in the EXFOR database were investigated for ^{99}Mo and ^{140}Ba from n+^{235}U fission, and showed they could be a several percent higher at fission energy. It needs to be carefully verified further because these two yields are often used as a standard in evaluation work.

We continue development of the YES package to include additional models, and coupling with the GEF code. This is part of the project to release a new fission yield evaluation for CENDL-3.2, as well as part of a longer-term strategy for new evaluations over the 5-year period.

2.10 F. Minato, Calculation of most probable atomic number by Skyrme HF-BCS

Futoshi Minato presented work by JAEA on new neutron-induced fission yield study. He first introduced recent activities at JAEA, then talked about his work on the fission yield. In the studies shown, the models of England and Rider were extended to consider energy dependence by utilizing an energy-dependent Z_p model. The parameterisation of the Z_p was determined by fitting to delayed neutron data. However, this kind of approaches is not capable of evaluating Z_p of fissile nuclei that have no experimental data. To seek out the solution, the presentator examined atomic number Z of two fragments calculated by a constraint Skyrme-Hartree-Fock+BCS (SHFBCS), and compared it with the evaluated Z_p of England and Rider. The SHFBCS can only give the mean value of Z_p, so that dynamical calculations like Langevin model are usually required to reproduce fission yield distribution. However, it was shown that the constraint SHFBCS reproduced the evaluated value of England and Rider within $\delta Z_\mathrm{p}= 0.6$. The results for neutron induced-fission for ^{235} and ^{239}Pu are shown in Fig 6 and 7, respectively. Note that the SHFBCS calculation was carried out with SkM* force and the mass (A) distribution of light and heavy fragments was calculated by integrating the densities. The light and heavy fragments are separated at the neck point, which is determined by searching the lowest density. It was also assumed that the scission occurs at which the mass distribution of light and heavy fragments becomes nearly constant ($Q_2 \sim 2$ barn).

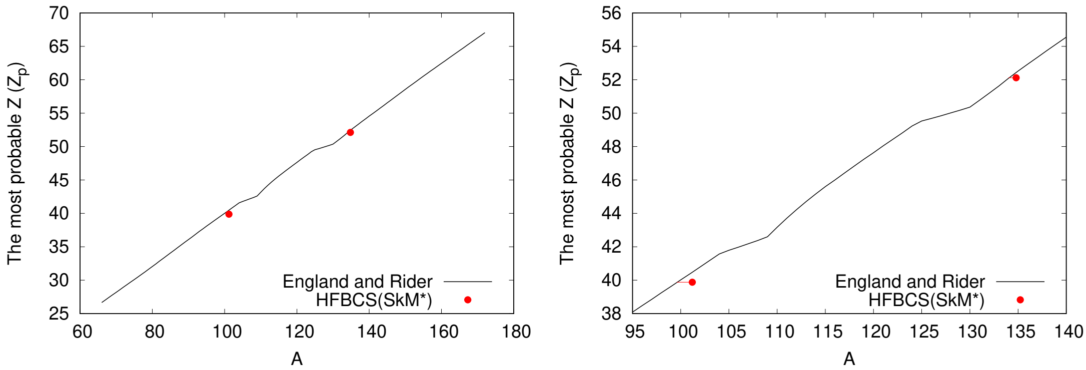

Figure 6: Z_p of England and Rider evaluation for thermal neutron-induced fission of ^{235}U(solid line). The left and right panels show different scale of A. The result of the SHFBCS calculation is also plotted (circles).

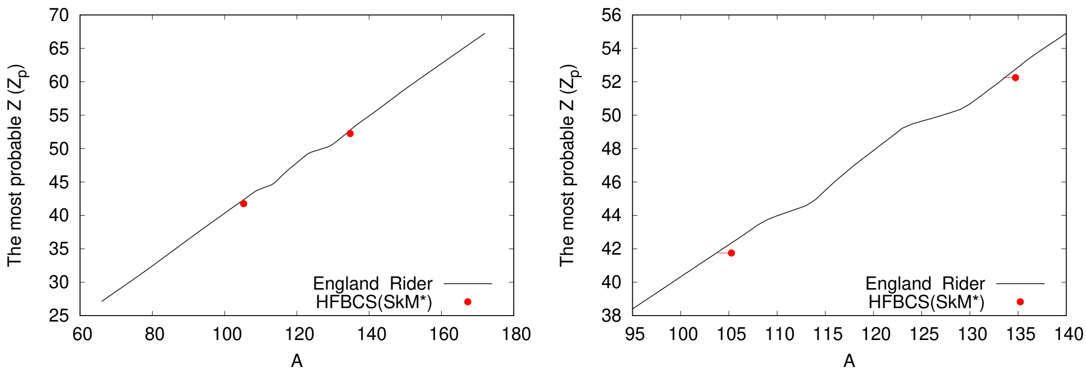

Figure 7: Same as Fig. 6, but for thermal neutron-induced fission of ^{239}Pu.

From Fig 6 and 7, Z_p evaluated by England and Rider can be approximated to have a linear A-dependence. Since the SHFBCS calculation is able to give two sets of A and Z, namely for light and heavy fragments, it was suggested that one may be able to predict the A-dependence of $Z_{\rm p}$ for fission systems that have no experimental data by drawing a line following the two points calculated by the constraint SHFBCS or other microscopic theories. It was also pointed out that the deviations between the evaluated data and the calculated result are close to the number of prompt neutron with respect to A (δA $2.5 - 2.7$). If excitation energy of two fragments would be calculated successfully by the SHFBCS, we would be able to obtain more accurate results by estimating the neutron emission from the fragments by a statistical model.

It was also presented that JAEA plans to adopt the fission product yields evaluated by Tokyo Institute of Technology for next evaluated fission yield data file, and to update the decay data including the newly evaluated delayed neutron branching ratio by IAEA CRP on β-delayed neutron as well as a new calculations of quasi-particle random phase approximation.

2.11 S. Okumura, Study on independent and cumulative fission yield calculations using fission observables taken from the EXFOR database

Shin Okumura presented work on a combination model of the Hauser-Feshbach statistical decay and β decay calculations. The Hauser-Feshbach theory has been applied to the de-excitation of fission fragments without requiring the computer resources that Monte-Carlo calculations require. The way of generations and integrations of the primary fission fragment distributions $Y_P(Z, A, M, E_{EX}, J, \Pi)$, the de-excitation, and β decay model was explained. For the energy sharing between two fission fragments, an anisothermal assumption was introduced with a parameter R_T, a ratio for nuclear temperature of the heavy and light fragments.

Various fission observables are calculated simultaneously by Hauser-Feshbach statistical decay, such as the independent fission product yield $Y_I(Z, A, Z)$ and the neutron multiplicity as a function of fission fragment mass $\overline{\nu}(A)$ (Figure 8). Important trends, such as the 'saw-tooth' structure of $\overline{\nu}(A)$, were reproduced, although specific measurements with low yields were not in precise agreement. This may be largely attributed to under-reported uncertainties and/or mass resolution issues with these data. Other calculated trends were shown, including mass distributions, and isomeric yield ratios.

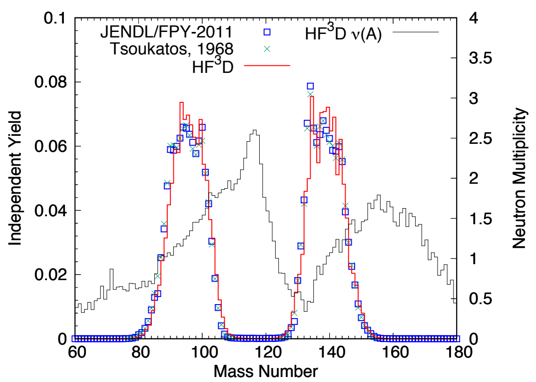

Figure 8: Neutron multiplicity and independent fission product yield as a function of fission product mass.

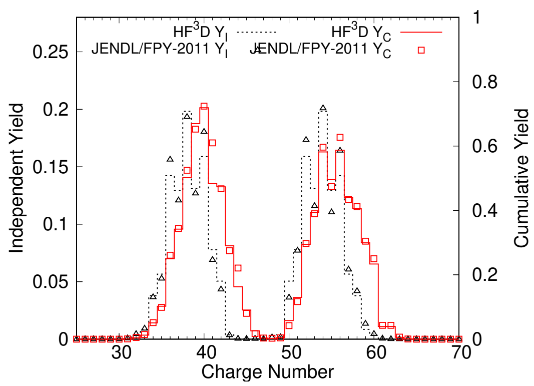

Figure 9: Independent and chain (cumulative) fission product yields as a function of fission product charge.

The neutron rich fission products undergo negative β decay. The calculated $Y_I(Z, A, Z)$ is used for β-decay and summation calculations. The cumulative fission product yield $Y_C(Z, A, Z)$, decay heat, delayed neutron yield can be obtained. Good agreement is found for several cases, such as cumulative yields (Figure 9) and decay heat, however delayed neutron data are often very sensitive to individual isotope production and this data is generally more difficult to reproduce.

This approach of the calculations of fission product yields and other observables simultaneously is extended up to 5 MeV of the incident neutron energy. The energy dependent cumulative yields for some elements is confirmed as reasonably comparable to the recent measured data by Tonchev et al. in LLNL.

2.12 S. Chiba, Needs for and requests to fission-related data compilation from theory and evaluation view points

Chiba gave an overview of the theoretical studies of fission processes done at Tokyo Institute of Technology and how this integrates with the evaluation work carried out primarily by JAEA for the Japanese Evaluated Nuclear Data Library (JENDL) and studies of astrophysical nucleosynthesis.

Examples of the astrophysical models using multiple r-process models were shown, including the need for 'Fission Recycling' to complement specific mass regions. Fission fragment mass distributions (cumulative and chain yields) were reviewed for ^{235}U thermal fission, with EXFOR data compared against each other and against simulations from different models and the evaluation nuclear data libraries. The peak at $A = 134$ was identified as an area of concern, with discontinuities and asymmetries difficult to analyze. All theories (at the time this comparison was made 3 years ago) fail to reproduce this peak, which lead to a conclusion that theories are not accurate enough to be used in data evaluation where a very high accuracy is required from reactor applications. Therefore, Tokyo Tech. group has take an phenomenological approach, which is an extension of the traditional Wahl-type method, but the even-odd and shell effects are given by the shell-correction energy of Koura *et al.* It was decided by JENDL group that outcome of the Tokyo Tech. work on fission yield will be included as the JENDL FPY data file in near future. Although the approach is rather close to traditional, it will be an important step forward modernization of the fission yield data and methodologies to achieve that.

Charge polarisation was described with the mass dependent charge polarisation systematic of Wahl questioned within the symmetric fission case. Prompt neutron multiplicity as a function of fragment mass was also discussed, as another set of important data that simulation is challenged to reproduce. Average spin of the fission fragment as a function of fragment mass number shows a saw-tooth structure similar to that of the prompt neutron multiplicity. This quantity is necessary for statistical decay calculation of fission fragments, so information like isomer ratio, which is directly connected to the spin of fission fragments, is required. Experiments as well as compilation are highly required.

Various simulation results were then shown, such as Q_{20} as a function of A, where greater deformation of the light fragments is a direct prediction from the models considered, as well as other effects. Work to simulate the excitation energy of the fission fragments is ongoing.

It was noted that TKE/mass double distribution data is important and not generally included in EXFOR. Some of this data is published only as figures and/or is available exclusively through private communication, but should be in EXFOR. It was also proposed to include pre-neutron yields into EXFOR, which is not currently done and/or is not done systematically. The use of infinite-duration cumulative data was also raised, as some evaluations include a particular time constant to control the cumulatives that are generated (*e.g.* 1000 years in the JEFF evaluations).

2.13 J. Lee, Calculation of fission fragment mass distribution by using a semi-empirical method

J. Lee gave a talk on the calculation of fission fragment mass distribution with a semi-empirical fission model developed at KAERI. Due to a short half-life, it is difficult to measure the fission product yields of the nuclides near the neutron drop line. Thus, we try to develop a semi-empirical fission model that can reproduce the fission product yields in a simple way but with a relatively good accuracy. In this study, a compound nucleus is treated as a microcanonical ensemble and it is assumed that the fission product yields are proportional to the level density of compound nucleus at the saddle point. The potential energy at the saddle point consists of the macroscopic term from the liquid drop model and the shell correction terms. They are described as a parabolic and a Gaussian functions, respectively. Among the ten model parameters, four parameters are fixed base on the previous studies and thus only six adjustable model parameters are determined by fitting.

This semi-empirical fission model is applied to calculate the mass distribution of uranium and plutonium isotopes. It was found that overall features of the fission yields are reproduced quite well. The degree of agreement between the model prediction and the ENDF data is comparable with other semi-empirical models. At present, we try to apply this model to describe the pre-neutron fission product yields in the same manner.

2.14 Y.J. Chen, Theoretical study on fission in CNDC collaboration network

Yongjing Chen presented the progress on theory and modeling study at CNDC, which is in collaboration with Peking University (PKU) and Southwest University (SWU) in China. Study on the fission dynamic at low excitation energies, which is based on the three-dimensional Langevin approach plus a constraint on the heavy fragment deformation, preliminarily shows a good agreement with the measured mass distribution; this work was performed by Lile Liu at CNDC [5]. The TDGCM based on the covariant density functional theory (CDFT) is developed at SWU, and it was applied to analyze the statical and dynamical aspects of the fission process of ^{226}Th. New calculations of 5D fission barriers for actinide nuclei are done in PKU. The nuclear shape was described with the 5D generalized Lawrence shape. The LSD model and the Folded-Yukawa potential were used to calculate the macroscopic energy and the microscopic correction energy, respectively.

3 Summary of discussion and recommendations

The participants had several discussions on fission product yields and the experimental databases, that were broadly divided into four categories. These include summaries related to (1) EXFOR data, (2) Experimental activities, (3) Evaluations and (4) Theory & Modelling.

3.1 EXFOR data

The work of the International Network of Nuclear Reaction Data Centres (NRDC), the US National Nuclear Data Center (NNDC), the OECD Nuclear Energy Agency Databank (NEA-DB), the International Atomic Energy Agency (IAEA) Nuclear Data Section (NDS) and other centres, is greatly appreciated and the progress has been impressive over the past few years in compiling new and legacy data sets.

The standard, comprehensive portal for accessing EXFOR data, https://www-nds.iaea.org/exfor/, is impressive in the breadth of quantities that can be searched. The many thousands of potential search queries that EXFOR is designed to accommodate are often overwhelming to many users who often only wish to explore a few dozen potential data types. This is such a significant issue that some experts with decades of experience in the field were unable to access essential data within the EXFOR database due to the complexity of the interface, or were simply unaware that EXFOR contained data of interest for their work.

The participants expressed their desire, personally and on behalf of the user communities that they interact with, to have a streamlined system to access EXFOR data without requiring them to use complex reaction coding and/or complex systems designed to parse the many search possibilities. The IAEA presented an effort that was targeted at this requirement and it was universally encouraged by the participants that the IAEA continues development in this direction.

Simplified user interfaces (UIs) that focus on particular data types (e.g. fission product yields) were widely appreciated by the participants and they encouraged the IAEA to make any possible progress in developing dedicated web portals to access these specific subsets of the EXFOR database. The progress that the IAEA has already made in this direction was commended by the participants.

Several systems have been developed to access and visualise EXFOR data, including, but not limited to, fission product yields, such as:

- IAEA-NDS EXFOR web retrieval system
- OECD-NEA JANIS
- US NNDC Sigma System

Several systems are in development that replicate and/or complement the functionalities of those above, including:

- CIAE-CNDC **Y**ield **E**valuation **S**ystem (YES)
- IAEA-NDS Livechart of Nuclides
- US NNDC NuDat

Although the NRDC has made great progress in adding experimental data to EXFOR for fission product yields and other fission observables, it was noted that many datasets are currently unavailable in EXFOR. These can be separated into three general cases:

- Published work that have not yet been compiled
- Unpublished work that is the subject of 'private communication' or otherwise known of but unavailable
- Work not included in digitisable format within the published work

Two studies were carried out by the US NNDC and IAEA NDS to review data that is published or unpublished but not yet included in EXFOR. The NNDC work primarily utilised the NSR database while the IAEA work studied the report of England and Rider as well as the PhD thesis of Mills. The output of this works were distributed as NRDC memos Memo CP-C/464, 465 and 466 as well as CP-D/979 [4] whose content will be included in the NRDC Allocation List[5]. Continued work to compile these into the EXFOR database and correct any remaining issues were strongly welcomed by the participants. Users are strongly encouraged to promptly report any errors that they may find in the current EXFOR and were reminded that the NRDC actively monitors and acts upon the list of reported errors in the EXFOR database[6]. The proposal made in the meeting to provide a form for submitting requests to compile new entries was supported by the participants.

For fission yields, formats such as C4 and C5 do not possess the required functionality to handle many quantities and the participants strongly encouraged the responsible maintainers to devise a solution in collaboration with the EXFOR community to address these data.

The participants noted that there are several formats for the data contained within the EXFOR database, ranging from the base EXFOR data to processed C4/C5, and others. Limitations in some of these formats have necessitated the use of new formats implemented by different participants. Various attempts to parse EXFOR data into different non-text schema were presented by different participants to the meeting or in recent conferences. It was recognised that this represents significant duplication of effort and that the current EXFOR format is maintained and designed to meet the needs of the compiler community, rather than the needs of users. A coordinated effort to design and implement a modern format for users, using an extensible schema, were strongly encouraged by the participants. This must include participants from outside the EXFOR compiler community, including experimentalists and evaluators. The Generalised Nuclear Database Structure project[7] coordinated by the OECD-NEA WPEC may offer some useful guidance based on the experience gained in the past years.

3.2 Experimental data

Experimental work for fission observables were summarised from participants from France and the US. These covered measurements carried out by CEA and the LLNL-LANL-TUNL collaboration, respectively. Several other experimental activities were noted as having recently

[4] Available online at https://www-nds.iaea.org/nrdc/memo_cpc/ and https://www-nds.iaea.org/nrdc/memo_cpd/

[5] Available online at https://www-nds.iaea.org/nrdc/alloc/

[6] Available online at https://www-nds.iaea.org/nrdc/error/

[7] More information on EG-GNDS may be found onlinen at: https://www.oecd-nea.org/science/wpec/gnds/

completed or are ongoing, including activities in China, LBNL, the Republic of Korea, although these were not presented by participants at this meeting.

From the presentations given at the meeting, it was noted that discrepancies exist between the Laurec data and US measurements for ^{239}Pu in fast 'fission-like' reactor spectra. Repeated measurements were completed and are being analysed by CEA at ILL for ^{235}U and additional measurements for ^{239}Pu are planned at Saclay. The unique capability offered by the SOFIA experiment, including excellent mass and charge resolution, provides an opportunity to obtain absolute measurements for a wide range of system. These were very complementary to the experiments carried out at HIγS, where equivalent γ-fission measurements are being carried out and may be directly cross-compared. These HIγS measurements are being performed for a range of mono-energetic gamma energies, including several carefully selected incident energies that allow direct comparison between γ- and neutron-induced fission.

The ongoing neutron-induced measurement campaigns are addressing the energy-dependence of fission product yields as well as the yields of short-lived products with half-lives down to several hundred milliseconds. The mono-energetic incident energies probed in these studies covered an impressive range but, as acknowledge by the participants, this may be enhanced by considering additional reactions, such as the ^{1}H (^{11}B, ^{1}n) ^{11}C, that the participants were reminded of [4]. The participants were extremely impressed with the progress made in these facilities and analyses and look forward to having data analysed, published and compiled into EXFOR in the very near future.

The existing evaluation libraries relied upon well-known databases such as those prepared by England/Rider and Mills. However, these are based on legacy measurements that are largely improved upon with modern techniques, such as those presented in the meeting.

3.3 Evaluation

The ENDF-6 format currently has no correlated uncertainty format for fission yields within the MF=8, MT=454 and MT=459, although it allows evaluators to include uncorrelated uncertainties. It has been routinely noted that applications using the uncorrelated uncertainties calculate propagated uncertainties that are not in agreement with many standard experimental uncertainties, including fundamental quantities such as cumulative yield uncertainties.

The participants universally requested that the ENDF-6 format be extended to allow correlations in fission yield uncertainties to be stored. The CSEWG executive chair agreed to raise this issue at the upcoming November 2019 meeting and invited the participants to attend and make the case for this format extension to the relevant committee.

There are various fission yield evaluation projects ongoing in the participants' countries, including the CIAE-CNDC programme for CENDL, the JAEA and Tokyo Institute of Technology collaboration for JENDL, the KAERI evaluation programme in the Republic of Korea, and the LANL-BNL collaboration in the US. While these projects each take different approaches, ranging from microscopic to empirical (and multiple approaches within each national programme), they all must ultimately agree with experimental data and this will require an updated and maintained experimental database akin to those employed in legacy evaluated files.

Various datatypes that have not been included in previous evaluation databases, such as the yields as a function of total kinetic energy and mass number, $Y(\text{TKE}, A)$, will play an important role in producing the next generation of evaluated nuclear data libraries, and these data should be collected in future EXFOR compilations, as well as retroactively requested for existing entries.

3.4 Theory and Modelling

The participants noted that fission modelling has benefitted from considerable research in the past years, and that more sophisticated modelling techniques are expected to play an important role in the production of improved and more predictive evaluations. Several outstanding issues, such as the application and extension of the Wahl Z_p model and even-odd effects in charge distributions, may be addressed with new microscopic theories or refinements to the existing systematics. The use of more physical de-excitation models, such as the Hauser-Feshbach approach described in this meeting, offers a more robust method for calculating isomeric ratios than the Madland and England model that has been used in previous evaluations.

As the EXFOR database covers only a limited number of the fissioning systems, for a subset of incident particle energies and (except for a select few isotopes) a few fission products, modelling is fundamentally required to produce complete evaluations including calculated results for values that have not been experimentally measured. For example fission yields at any incident energy, as well as minor actinides and other isotopes.

3.5 Next consultancy meeting

The participants agreed that this activity is still relevant after the upcoming CRP on fission yield evaluation launches, due to the importance of experimental data and its compilation into the EXFOR database. These meetings should include both NRDC delegates as well as experimentalists and evaluators to ensure that the end-users and the EXFOR compilation community are fully informed of ongoing activities.

Reference

[1] "Summary Report on Workshop on Fission Product Yield Experimental Data" LA-UR-18-28309, Los Alamos National Laboratory Report (2018).

[2] A. C. Wahl, "Systematics of fission-product yields," Technical Report LA-13928, Los Alamos National Laboratory (2002).

[3] R. W. Mills, "Fission product yield evaluation: Appendix 5," Ph.D Thesis, University of Birmingham (1995).

[4] S. Chiba, M. Mizumoto, K. Hasegawa, Y. Yamanouti, M. Sugimoto, Y. Watanabe, and M. Drosg, "The ^{1}H(^{11}B,n)^{11}C reaction as a practical low background monoenergetic neutron source in the 10 MeV region," Nucl. Instr. Methods in Phys. Research Sec. A: Accelerators, Spectrometers, Detectors and Associated Equipment, **281**, 581 – 588 (1989).

[5] Li-Le Liu, Xi-Zhen Wu, Yong-Jing Chen, Cai-Wan Shen, Zhu-Xia Li, Zhi-Gang Ge, "Study of fission dynamics with a three-dimensional Langevin approach," Phys. Rev. C **99**, 044614 (2019).

[6] B. D. Wilkins, E. P. Steinberg, and R. R. Chasman. "Scission-point model of nuclear fission based on deformed-shell." effects. Phys. Rev. C, **14**, 1832–1863, (1976).

Appendix A Fission product yield data coverage in EXFOR

Field definitions

- Mills: The reference number in the R.W. Mills's thesis[3].
- E-R: The reference number in the T.R. England and B.F. Rider's report[2].
- Author: 1st author's name.
- Reference: EXFOR format reference.
- EXFOR: Entry number is listed if the related EXFOR entry has already existed, entry number in parentheses indicates that related or partial data is already in EXFOR but without clear indication of the specified Reference, and 'new' indicates that the new entry must be created from the Reference.

Mills	E-R	Author	Reference	EXFOR
	78BYA1	A.A.Byalko+	R,INIS-SU-38,1978	40257
159	68DEL1	A.A.Delucchi+	J,PR,173,1159,1968	13232
77	70DEL1	A.A.Delucchi+	J,PR/C,1,1491,1970	13266
2092	85HAS1	A.A.Hasan+	J,ANS,49,209,1985	32667
	80NAQ1	A.A.Naqvi	R,KFK-2919,1980	21661
2044	84TEP1	A.A.Solonkin+	C,83KIEV,2,251,1983	40877
	88SOL1	A.A.Solonkin+	J,SJA,64,497,1988	40964
159	68DEL1	A.Adelucchi+	J,PR,173,1159,1968	13232
905	53PAP1	A.C.Pappas	R,MIT-REP-63,1953	13461
279	56PAP1	A.C.Pappas+	J,JIN,2,69,1956	new
906	68PAP1	A.C.Pappas+	J,JIN,30,890,1968	new
	59WAH1	A.C.Wahl	J,JIN,10,1,1959	12610
392	58WAH1	A.C.Wahl	J,JIN,6,263,1958	13450
395	55WAH1	A.C.Wahl	J,PR,99,730,1955	13388
687	72WAH1	A.C.Wahl+	J,JIN,34,2413,1972	13308
388	62WAH1	A.C.Wahl+	J,PR,126,1112,1962	13097
387	63WAH1	A.C.Wahl+	J,PR,131,830,1963	13094
	66WAH1	A.C.Wahl+	J,PR,146,931,1966	13323
331	52WAH1	A.C.Wahl+	J,PR,85,570,1952	13368
2107	66NOR2	A.E.Norris+	J,PR,146,926,1966	13043
2002	86RIC1	A.E.Richardson+	J,NSE,94,413,1986	13103
302	53STE1	A.F.Stehney+	J,PR,89,194,1953	13225
2105	80NAI1	A.G.C.Nair+	C,80WALTAI,,150,1980	new
	90NAI1	A.G.C.Nair+	J,JRN,140,215,1990	new
2022	84NAI1	A.G.C.Nair+	J,JRN,82,263,1984	33048
2023	85NAI1	A.G.C.Nair+	J,JRN,91,73,1985	30797
2016	87NAI1	A.G.C.Nair+	J,RCA,42,7,1987	30797
2016	87NAI1	A.G.C.Nair+	J,RCA,42,7,1987	30798
	75DON1	A.G.Donichkin+	C,75KIEV,5,82,1975	40459
2015	82GOL1	A.G.Golovanov+	J,SJA,53,576,1982	new
	51GOL1	A.Goldstein+	B,RCS,2,1188,1951	new
	66GRA1	A.Grau	W,GRAY,1962	13218
	74HAW1	A.H.Hawa+	R,KFK-1888,,74	21558
	80JAF1	A.H.Jaffey+	R,ANL-79-107,1980	new
	68SER1	A.I.Sergachev+	J,SNP,7,475,1968	40173
239	59KJE1	A.Kjelberg+	J,JIN,11,173,1959	new
1117	79PRI1	A.L.Prindle+	J,PR/C,20,1824,1979	10913
	41MOU1	A.Moussa+	J,PR,60,534,1941	new
789	62APO1	A.N.Apollonova+	J,SRA,4,515,1962	41072
788	62APO2	A.N.Apollonova+	J,SRA,4,631,1962	41073
	77GUD1	A.N.Gudkov+	C,77KIEV,3,192,7197	40554

1177	80GUD1	A.N.Gudkov+	J,SJA,48,418,1980	new
2046	83GUD1	A.N.Gudkov+	J,SJA,54,414,1983	40678
	85GUD1	A.N.Gudkov+	J,SNP,41,365,1985	40869
	83GUD2	A.N.Gudkov+	J,YK,,(1/50),48,1983	40677
	81GUD1	A.N.Gudkov+	R,INIS-SU-122,59,1981	new
	84GUD1	A.N.Gudkov++	C,83KIEV,2,259,1983	40878
280	58PRO1	A.N.Protopopov+	J,SJA,5,963,1958	new
269	65OKA1	A.Okazaki+	J,CJP,43,1036,1965	13076
265	71OKA1	A.Okazaki+	J,CJP,49,498,1971	13287
789	62APO1	A.P.Apollonova+	J,SRA,4,515,1962	41072
788	62APO2	A.P.Apollonova+	J,SRA,4,631,1962	41073
33	57BAE1	A.P.Baerg+	J,CJC,35,980,1957	13431
555	60BAE1	A.P.Baerg+	J,CJC,38,2147,1960	13473, 13487
1151	79RAM1	A.Ramaswami+	J,JIN,41,1531,1979	30495
1157	79RAM2	A.Ramaswami+	J,JIN,41,1649,1979	30437
1178	80RAM1	A.Ramaswami+	J,JIN,42,1213,1980	30575
	81RAM1	A.Ramaswami+	J,JIN,43,3067,1981	30495,30535,33010
	82RAM2	A.Ramaswami+	J,RCA,30,11,1982	30631
	82RAM1	A.Ramaswami+	J,RCA,30,15,1982	30629
	87RAM2	A.Ramaswami+	J,RCA,41,9,1987	30765
646	69RAO1	A.S.Rao+	J,JIN,31,591,1969	13253
2009	86SRI1	A.Srivastava+	J,PR/C,33,969,1986	30787
2035	84SRI1	A.Srivastava+	J,RCA,35,15,1984	33068
	89SRI1	A.Srivastava+	J,RCA,46,17,1989	22134
2041	87SRI1	A.Srivastava+	P,BARC-1381,51,1987	(30787)
2042	87SRI2	A.Srivastava+	P,BARC-1381,62,1987	(33062)
28	56BLA1	A.T.Blades+	J,CJC,34,233,1956	13389, 13391
28	56BLA1	A.T.Blades+	J,CJC,34,233,1956	13391
	55BLA1	A.T.Blades+	J,ZN/A,10,838,1955	13462
238	51TUR1	A.Turkevich+	J,PR,84,52,1951	13367
614	53TUR1	A.Turkevich+	J,PR,89,552,1953	13281
229	67JAD1	A.V.Jadhav+	J,NUK,9,43,1967	30948
2032	87RED1	A.V.R.Reddy+	P,BARC-1381,25,1987	new
	87RED2	A.V.R.Reddy+	P,BARC-1381,44,1987	(30981)
2040	87RED3	A.V.R.Reddy+	P,BARC-1381,47,1987	new
	71SOR1	A.V.Sorokina+	J,SJA,31,804,1972	41080
	73VEN1	A.Venezia	T,VENEZIA,1973	30964
642	66BAE1	A.von Baeckmann+	J,RCA,5,234,1966	new
332	65WYT1	A.Wyttenbach+	C,65SALZBURG,1,415,1965	new
332	64WYT1	A.Wyttenbach+	J,RCA,3,118,1964	new
	49SAK1	A.Y.Sakakura+	T,SAKAKURA,1949	13403
2092	85HAS1	Abdulhamid.A.Hasan+	J,ANS,49,209,1985	32667
229	67JAD1	Av.Jadhav+	J,NUK,9,43,1967	30948
	56PUR1	B.C.Purkayastha+	J,CJC,34,293,1956	21393
726	73PUR1	B.C.Purkayastha+	J,JIN,35,1793,1973	30958
	70KUZ1	B.D.Kuz'minov+	J,SNP,11,166,1970	40172
693	72EHR1	B.Ehrenberg+	J,PR/C,6,618,1972	30953
	69EHR1	B.Ehrenberg+	P,IA-1218,96,1970	30953
	70RID1	B.F.Rider	R,GEAP-10028-35,78,1970	13300
	72RID1	B.F.Rider	R,GEAP-13838,(H-16),1972	13306
	65RID2	B.F.Rider+	P,GEAP-4893,1965	13206
	65RID1	B.F.Rider+	P,GEAP-5060,1965	13205
	66RID1	B.F.Rider+	P,GEAP-5270,2,1966	13322
	66RID2	B.F.Rider+	P,GEAP-5403,2,1966	13256
	67RID1	B.F.Rider+	P,GEAP-5505,21,1967	13260
	64RID1	B.F.Rider+	R,GEAP-4716,1964	13204
	51FIN1	B.Finkle+	B,RCS,2,770,1951	(13395)

379	60YOU1	B.G.Young+	J,CJP,38,1,1960	13483
	72KRY1	B.Kryger	S,STI/PUB/303,77,1974	new
415	70TRA1	B.L.Tracy+	J,CJP,48,1708,1970	13277
727	73TRA1	B.L.Tracy+	J,JIN,35,2639,1973	13315
	69MOO1	B.M.Moore	R,LA-4257,1969	13250
4	57BAY1	B.P.Bayhurst	R,TID-5787,1957	13432
38	57BAY2	B.P.Bayhurst+	J,PR,107,325,1957	13453
	77MAK1	B.P.Maksyutenko+	J,SNP,25,503,1977	41085
560	69PAR1	B.Parsa+	J,JIN,31,585,1969	13252
172	69ERD1	B.R.Erdal+	J,JIN,31,2993,1969	13244
173	69ERD2	B.R.Erdal+	J,JIN,31,3005,1969	13245
	71ERD1	B.R.Erdal+	J,JIN,33,2763,1971	13324
2036	85TOM1	B.S.Tomar+	J,JRN,91,291,1985	33049
	85TOM2	B.S.Tomar+	J,RCA,39,1,1985	30911
	80SRI1	B.Srinivasan+	J,EPL,47,235,1980	12711
306	69SRI1	B.Srinivasan+	J,PR,179,1166,1969	13261
695	72KUR1	B.V.Kurchatov+	J,SNP,14,528,1972	40145
	80WEH1	B.W.Wehring+	R,UILU-ENG-80-5312,1980	10918
172	69ERD1	Br.Erdal+	J,JIN,31,2993,1969	13244
	77FEU1	C.A.Feu Alvim+	J,JPR,38,273,1977	21567
	65BIG1	C.B.Bigham+	J,ANS,8,11,1965	(13287)
	69BRA1	C.Braun+	P,IA-1190,104,1968	new
	69BRA2	C.Braun+	P,IA-1218,93,1969	30952
	73CHA1	C.Chauvin	T,FRNC-TH-470,1973	new
2018	84CHU1	C.Chung+	J,RCA,37,131,1984	30791
2010	85CHU1	C.Chung+	J,RCA,38,173,1985	32666
	62COR1	C.D.Coryell+	J,ANS,5,23,1962	(13224)
	55COR1	C.D.Coryell+	R,MIT-LNS-PR-38,1955	13465
	57CRO1	C.E.Crouthamel+	P,ANL-5789,80,1957	13433
	71CRO3	C.E.Crouthamel+	P,ANL-7887,32,1971	(12771)
	74EGG1	C.Egger+	J,RCA,21,200,1974	22059
	87LEE1	C.H.Lee.+	J,JRN,119,101,1987	new
	71PAC1	C.H.Pace	T,PACE,1971	13357
1170	80HAM1	C.Hamelin+	J,JPR/L,41,223,1980	21903
	62ORT1	C.J.Orth	W,ORTH,1962	13222
1044	77MAT1	C.K.Mathews	J,PR/C,15,344,1977	30508
721	72MAT1	C.K.Mathews+	J,CJP,50,3100,1972	13304
	88LEE1	C.Lee+	J,JRN,123,607,1988	32665
	68LEE1	C.Lee+	P,IA-1168,67,1968	30949
	86LEI1	C.Leitz+	P,NEANDC(E)-272,(5),33,1986	22016,22017
412	70LIN1	C.Lin+	J,JIN,32,2501,1970	13269
	72LIN1	C.Lin+	J,JIN,34,1479,1972	13303
891	74JEN1	C.M.Jensen+	J,ANS,19,397,1974	13329
	51DIL1	C.R.Dillard+	B,RCS,2,692,1951	new
	68RUD1	C.Rudy+	J,JIN,30,365,1968	new
	84SCH1	C.Schmitt+	J,NP/A,430,21,1984	21928
	51STA1	C.W.Stanley+	B,RCS,2,947,1951	13416
	49STA1	C.W.Stanley+	J,JCP,17,653,1949	13056
	76RIS1	Ch.Ristori+	J,ZP/A,277,1,71,1976	21556
	86CHE1	Chen Qingjiang+	J,CST,20,161,1986	30793
	84CHE1	Chen Qingjiang+	J,JRN,111,63,1987	30793
2004	87CHU1	Chien Chung+	J,JRN,109,117,1987	32668
2070	90CHU1	Chien Chung+	J,RCA,49,113,1990	32659
412	70LIN1	Chien-Chang.Lin+	J,JIN,32,2501,1970	13269
2004	87CHU1	Chien.Chung+	J,JRN,109,117,1987	32668
2010	85CHU1	Chien.Chung+	J,RCA,38,173,1985	32666

	80CHI1	Chinese Cumulative Yield Group	J,HFH,2,1,1980	32633
	80CHI2	Chinese Cumulative Yield Group	J,HFH,2,193,1980	32630
	82CHI1	Chinese Cumulative Yield Group	J,HFH,4,44,1982	30744
	84CHI3	Chinese Cumulative Yield Group	J,HFH,6,183,1984	32629
	84CHI1	Chinese Cumulative Yield Group	J,HFH,6,229,1984	32631
	85CHI1	Chinese Cumulative Yield Group	J,HFH,7,1,1985	30743
2070	90CHU1	Chung Chien+	J,RCA,49,113,1990	32659
261	65MAR1	D.A.Marsden+	J,CJC,43,249,1965	13074
21	69AUM1	D.C.Aumann+	J,JIN,31,1935,1969	13242
1069	77AUM1	D.C.Aumann+	J,JIN,39,1217,1977	21532
	78AUM1	D.C.Aumann+	J,JIN,40,9,1611,1978	21579
	81AUM1	D.C.Aumann+	J,JIN,43,2223,1981	21754
	82AUM1	D.C.Aumann+	J,RCA,30,19,1982	21917
1075	77HAR1	D.C.Harris+	J,NSE,63,504,1977	10683
305	60SAN1	D.C.Santry+	J,CJC,38,421,1960	13476
301	60SAN2	D.C.Santry+	J,CJC,38,464,1960	13486
	71SAB1	D.D.Sabu	J,JIN,33,1509,1971	13289
895	75ADA1	D.E.Adams+	J,JIN,37,419,1975	13332
	71TRO3	D.E.Troutner	J,JIN,33,4327,1971	(13299)
	70TRO2	D.E.Troutner+	J,ACS,,(23),1970	13301
632	71TRO1	D.E.Troutner+	J,JIN,33,2271,1971	13293
674	72TRO1	D.E.Troutner+	J,JIN,34,801,1972	13307
716	73TRO1	D.E.Troutner+	J,JIN,35,11,1973	13316
324	63TRO1	D.E.Troutner+	J,PR,130,1466,1963	13093
557	64TRO1	D.E.Troutner+	J,PR,134,B1027,1964	13096
484	70TRO1	D.E.Troutner+	J,PR/C,1,1044,1970	13278
691	71TRO2	D.E.Troutner+	J,PR/C,4,505,1971	13294
	63TRO2	D.E.Troutner+	P,ORNL-3488,8,1963	13068
	51WAT1	D.E.Waters+	B,RCS,3,1507,1951	new
174	52ENG1	D.Engelkemeir+	R,ANL-4927,1952	13425
760	72AND1	D.G.Anderson	T,ANDERSON,1972	13298
	82BRE1	D.G.Breederland	R,ORNL-TM-8168,1982	14095
641	65SAR1	D.G.Sarantites+	J,PR,138,B353,1965	13080
403	61VAL1	D.G.Vallis+	R,AWRE-O-58/61,1961	new
363	68GOR1	D.J.Gorman+	J,CJC,46,1663,1968	13233
	55LIT1	D.J.Littler	C,55GENEVA,5,141,1955	new
1185	81PAL1	D.K.Pal+	J,JIN,43,885,1981	10995
634	71SWI3	D.L.Swindle+	J,JIN,33,3643,1971	13292
586	71SWI2	D.L.Swindle+	J,JIN,33,651,1971	13291
588	71SWI1	D.L.Swindle+	J,JIN,33,876,1971	13290
393	56WIL1	D.M.Wiles+	J,CJC,34,227,1956	13429
68	59BID1	D.R.Bidinosti+	C,58GENEVA,15,459,1958	12010
	61BID1	D.R.Bidinosti+	J,CJC,39,628,61	13208
1183	80NET1	D.R.Nethaway+	J,JIN,43,889,1981	10994
638	65NET1	D.R.Nethaway+	J,PR,139,B1505,1965	13078
348	69NET1	D.R.Nethaway+	J,PR,182,1251,1969	13251
1076	77NET1	D.R.Nethaway+	J,PR/C,16,1907,1977	10712
	72NET2	D.R.Nethaway+	J,PR/C,6,1827,1972	13346
	72NET1	D.R.Nethaway+	R,UCRL-73937,1972	13345
398	53WIL1	D.R.Wiles+	J,CJP,31,419,1953	13375
327	54WIL1	D.R.Wiles+	J,PR,96,696,1954	13382
	81JOS1	D.T.Jost+	J,JIN,43,2629,1981	21711

	51ENG1	D.W.Engelkemeir+	B,RCS,3,1334,1951	new
	51ENG2	D.W.Engelkemeir+	B,RCS,3,1372,1951	13396
	51ENG3	D.W.Engelkemeir+	B,RCS,3,1375,1951	13397
174	52ENG1	D.W.Engelkemeir+	R,ANL-4927,1952	13425
484	70TRO1	De.Troutner+	J,PR/C,1,1044,1970	13278
363	68GOR1	Dj.Gorman+	J,CJC,46,1663,1968	13233
588	71SWI1	Dl.Swindle+	J,JIN,33,876,1971	13290
	71CRO2	E.A.C.Crouch	C,71CANT,,147,1971	new
256	55MEL1	E.A.Melaika+	J,CJC,33,830,1955	13384
256	55MEL1	E.A.Melaika+	J,CJC,33,830,1955	12086, 13384
	85AKE1	E.Aker+	C,85SANTA,,337,1985	21967
	71ALE1	E.C.Alexander+	J,SCI,172,837,1971	13279
180	54FRE1	E.C.Freiling+	J,PR,96,102,1954	13378
	71CHE1	E.Cheifetz+	J,PR/C,4,1913,1971	12691
	84DOB1	E.Dobreva+	J,JRN,81,29,1984	30767
221	63HAG1	E.Hagebo	J,JIN,25,615,1963	new
	70HAG1	E.Hagebo	J,JIN,32,2489,1970	C0325
	62HAG1	E.Hagebo+	J,JIN,24,117,1962	new
	51HOA3	E.J.Hoagland+	B,RCS,2,1035,1951	13406
	51HOA1	E.J.Hoagland+	B,RCS,2,635,1951	new
	51HOA2	E.J.Hoagland+	B,RCS,2,660,1951	new
61	61BON1	E.K.Bonyushkin+	J,SJA,10,10,1961	41070
161	60BON1	E.K.Bonyushkin+	R,AEC-TR-4682,1960	new
	65KON1	E.Konecny+	C,65SALZBURG,1,401,1965	new
	66KON1	E.Konecny+	J,AF,36,319,1966	new
1067	81VIN1	E.N.Vine+	J,JIN,43,877,1981	10996
309	70OHY1	E.Ohyoshi+	J,RRL,3,1,1970	new
	51STE1	E.P.Steinberg+	B,RCS,2,566,1951	13417
	51STE2	E.P.Steinberg+	B,RCS,2,877,1951	new
	51STE4	E.P.Steinberg+	B,RCS,2,910,1951	13414
	51STE3	E.P.Steinberg+	B,RCS,3,1378,1951	new
613	54STE2	E.P.Steinberg+	J,PR,95,431,1954	13584
	54STE1	E.P.Steinberg+	J,PR,95,867,1954	13381
	47STE1	E.P.Steinberg+	R,MDDC-1632,1947	13361
	70EBE1	E.R.Ebersole+	S,LA-4430-MS,140,1970	13355
	69YEL1	E.Yellin+	P,IA-1190,99,1969	30955
46	55BRO1	F.Brown	J,JIN,1,248,1955	new
	53BRO1	F.Brown+	J,CJC,31,242,53	13464
	81CAI1	F.Caitucoli+	J,NP/A,369,15,1981	21758
	62FRO1	F.H.Froehner	J,ZP,170,62,1962	new
582	71LIS1	F.L.Lisman+	J,JIN,33,643,1971	13285
245	70LIS1	F.L.Lisman+	J,NSE,42,191,1970	13270
	63ROB1	F.P.Roberts+	J,JIN,25,1298,1963	13212
	57ASH1	F.T.Ashizawa+	J,JIN,5,12,1958	13472
611	67WUN1	F.Wunderlich	J,RCA,7,105,1967	new
486	70COW2	G.A.Cowan+	J,PR/C,2,615,1970	10067, 13451
	76DII1	G.Diiorio+	T,DIIORIO,1976	13359
601	66GOR1	G.E.Gordon+	J,NUC,24,62,1966	13217
2029	83ENG1	G.Engler+	J,ZP/A,314,59,1983	30912
	76FIS1	G.Fischbach+	P,MAINZ-1975,108,1976	20878
	77FIS1	G.Fischbach+	P,MAINZ-1976,102,1977	new
	78FIS1	G.Fischbach+	P,MAINZ-1977,93,1978	new
661	56HER1	G.Herrmann+	J,ZN/A,11,946,1956	new
	74KIR1	G.J.Kirouac+	R,KAPL-P-4005,1974	10985
	73KIR1	G.J.Kirouac+	R,KAPL-P-4005,1974	10985
	69WAS1	G.J.Wasserburg+	J,PRL,22,1198,1969	13263
	70LUM1	G.Lum-Hee+	P,AECL-3776,96,1970	new
	81MAR1	G.Mariolopoulos+	J,NP/A,361,1,213,1981	21743

181	53FOR2	G.P.Ford	R,AECD-3597,1953	new
	65FOR1	G.P.Ford+	C,65SALZBURG,1,333,1965	(13077)
	65FOR2	G.P.Ford+	J,PR,137,B826,1965	13077
	84FOR1	G.P.Ford+	J,PR/C,30,195,1984	12895
637	53FOR1	G.P.Ford+	R,AECD-3551,1953	13370
194	56FOR1	G.P.Ford+	R,LA-1997,1956	13427
	76FOR1	G.P.Ford+	R,LA-6129-MS,43,1976	(13255, 13443, 13444, 13445, 13446, 13447, 13448)
	65FOR3	G.P.Ford+	W,FORD,1965	13221
311	64TER1	G.P.Tercho+	J,JIN,26,1129,1964	13071
	76PAF1	G.Paffrath+	P,MAINZ-1975,90,1976	20878
	51LEA1	G.R.Leader	B,RCS,2,934,1951	13409
	90RUD1	G.Rudstam+	J,RCA,49,155,1990	22161
	85RUD1	G.Rudstam+	R,NFL-42,1985	22003
	74SIE1	G.Siegert+	J,PL/B,53,45,1974	21594
949	76SIE1	G.Siegert+	J,PR/C,14,1864,1976	21605
	75SIE1	G.Siegert+	J,PRL,34,1034,1975	21562
284	55REE1	G.W.Reed	J,PR,98,1327,1955	13387
285	53REE1	G.W.Reed+	J,PR,92,1473,1953	13372
325	53WET1	G.W.Wetherill	J,PR,92,907,1953	new
	75CLE1	H.-G.Clerc+	J,NP/A,247,74,1975	21597
	75CLE2	H.-G.Clerc+	J,ZP/A,274,203,1975	21557
863	65STO1	H.A.Storms+	R,CONF-65-235-16,1965	13224
2000	88AFA1	H.Afarideh+	J,ANE,16,313,1989	22111
650	68ARI1	H.Arino+	J,JIN,30,677,1968	13351
	61LEV1	H.B.Levy+	J,PR,124,544,1961	13059
2007	85BRA1	H.Braun+	J,RCA,38,169,1985	22040
	79BRA1	H.Braun+	P,NEANDC(E)-202,(5),74,1979	21662
764	73JAI1	H.C.Jain+	J,RCA,19,90,1973	30504
2021	84JAI1	H.C.Jain+	J,RCA,37,63,1984	(new-creation)
764	71JAI1	H.C.Jain+	P,BARC-584,1971	30504
	70JAI1	H.C.Jain+	P,BARC/I-62,1970	30957
	67BOR4	H.E.Borikwa+	J,SNP,6,331,1967	40329
207	62FAR2	H.Farrar+	J,CJP,40,1017,1962	13065
209	64FAR1	H.Farrar+	J,CJP,42,2063,1964	13070
356	62FAR1	H.Farrar+	J,NP,34,367,1962	13064
	84HIC1	H.G.Hicks	P,UCAR-10062,66,1984	12925
	62HIC1	H.G.Hicks+	J,PR,128,700,1962	13091
278	54PET1	H.G.Petrow+	J,PR,96,1614,1954	13380, 13718
	49THO1	H.G.Thode+	J,RPP,12,1,1949	new
872	76GAE1	H.Gaeggeler+	J,JIN,38,205,1976	21552
1081	78GAE1	H.Gaeggeler+	J,PR/C,17,172,1978	21604
1051	77GAE1	H.Gaeggler+	J,JIN,39,1105,1977	21553
872	76GAE1	H.Gaggeler+	J,JIN,38,205,1976	21552
1051	77GAE1	H.Gaggeler+	J,JIN,39,1105,1977	21553
1081	78GAE1	H.Gaggeler+	J,PR/C,17,172,1978	21604
916	75GOE1	H.Goektuerk+	J,JIN,37,2247,1975	new
	72GUN1	H.Gunther+	J,NP/A,196,401,1972	new
2026	80MEI1	H.H.Meixler+	J,CJC,61,665,1983	20711, 21686
	76KLO1	H.Klonk	J,RCA,23,161,1976	21559
	76MEI1	H.Meixler	T,MEIXLER,1976	21686
	77MEI1	H.Meixler+	P,MAINZ-1975,113,1976	20711
	77MEI2	H.Meixler+	P,MAINZ-1976,100,1977	new
612	66MEN1	H.Menke+	J,RCA,6,76,1966	new
1080	78ERT1	H.N.Erten+	J,JIN,40,183,1978	new

	81ERT1	H.N.Erten+	J,NSE,79,167,1981	21712
	82ERT1	H.N.Erten+	J,PR/C,25,2519,1982	21805
	86NAI1	H.Naik+	J,RCA,40,175,1986	30766
2038	87NAI2	H.Naik+	P,BARC-1381,37,1987	new
629	71NAK1	H.Nakahara+	J,JIN,33,3239,1971	22064
160	69DEN1	H.O.Denschlag	J,JIN,31,1873,1969	new
	71DEN2	H.O.Denschlag+	J,JIN,33,3649,1971	22056
	78DEN2	H.O.Denschlag+	P,NEANDC(E)-192,(5),70,1978	21008
	84DEN1	H.O.Denschlag+	P,NEANDC(E)-252,(5),38,1984	21939
178	59FIC1	H.R.Fickel+	J,CJP,37,916,1959	13482
67	59FIC2	H.R.Fickel+	J,CJP,37,926,1959	13480
592	59HEY1	H.R.Heydegger+	J,JIN,12,12,1959	13470
347	69GUN1	H.R.Von Gunten+	J,JIN,31,3357,1969	13353
	67GUN1	H.R.Von Gunten+	J,PR,161,1192,1967	13230
213	67GUN2	H.R.Von Gunten+	J,RCA,8,112,1967	new
	76THI1	H.Thierens+	J,NIM,134,299,1976	21531
	80THI1	H.Thierens+	J,NP/A,342,229,1980	21651
1175	80ZWI1	H.U.Zwicky+	J,RCA,27,121,1980	21706
	78ZWI1	H.U.Zwicky+	P,NEANDC(OR)-151,7,1978	21002
722	73UME1	H.Umezawa	J,JIN,35,353,1973	22069
	66UME1	H.Umezawa	R,JAERI-1103,1966	(22069)
333	65WEI1	H.V.Weiss+	C,65SALZBURG,1,423,1965	13082
385	65WEI3	H.V.Weiss+	J,JIN,27,1917,1965	13216
	66WEI1	H.V.Weiss+	J,JIN,28,2067,1966	13083
382	68WEI1	H.V.Weiss+	J,PR,172,1269,1968	13240
404	69WEI1	H.V.Weiss+	J,PR,188,1893,1969	13264
	65SCH1	H.W.Schmitt+	J,PR,137,B837,1965	13081
	76WOH2	H.Wohlfarth	T,WOHLFARTH,1976	21054
334	66YOS1	H.Yoshida+	P,IA-1128,63,1966	30946
562	61CRO1	I.F.Croall	J,JIN,16,358,1961	21464
	61CRO2	I.F.Croall	R,AERE-R-3879,1961	(21464)
	64CRO1	I.F.Croall+	C,65SALZBURG,1,355,1965	21464
80	62CRO1	I.F.Croall+	J,JIN,24,221,1962	new
84	63CRO1	I.F.Croall+	J,JIN,25,1213,1963	21464
101	69CRO2	I.F.Croall+	R,AERE-R-6154,1969	new
	66AND1	I.O.Anderson+	J,NAT,211,618,1966	new
712	60KRI1	I.T.Krisyuk+	J,RAK,2,743,1960	new
713	60KRI2	I.T.Krisyuk+	J,RAK,2,746,1960	new
	68KRI1	I.T.Krisyuk+	J,SNP,6,669,1968	41076
	84WIN1	I.Winkelmann+	J,PR/C,30,934,1984	21983
805	63MCH1	J.A.Machugh	R,UCRL-10673,1963	13202
	51MAR1	J.A.Marinsky+	B,RCS,2,1229,1951	new
260	60MAR1	J.A.Marinsky+	J,JIN,12,223,1960	13460
558	66MCH1	J.A.Mc Hugh	J,JIN,28,1787,1966	13040
805	63MCH1	J.A.Mc Hugh	R,UCRL-10673,1963	13202
	68MCH2	J.A.Mc Hugh+	J,PR,172,1160,1968	new
	70PAN1	J.A.Panontin+	J,JIN,32,1775,1970	C0326
275	55PET1	J.A.Petruska+	J,CJP,33,640,1955	13385
276	55PET2	J.A.Petruska+	J,CJP,33,693,1955	13386
	51SEI1	J.A.Seiler	B,RCS,2,860,1951	13413
	51SEI2	J.A.Seiler	B,RCS,2,910,1951	13414
	51SWA1	J.A.Swartout+	B,RCS,2,856,1951	13421
242	61LAI1	J.B.Laidler+	J,JIN,24,1485,1962	21482
	50NID1	J.B.Niday+	R,AECD-2862,1950	13404
410	69BLA1	J.Blachot+	C,69VIENNA,,803,1969	new

654	71BLA1	J.Blachot+	C,71CANT,,13,1971	(21734)
773	74BLA1	J.Blachot+	J,JIN,36,495,1974	21590
907	75BLA1	J.Blachot+	J,JRC,26,107,1975	21592
	71BLA2	J.Blachot+	J,JRC,7,309,1971	21561
	77BLA1	J.Blachot+	P,NEANDC(E)-162,(4),42,1974	21736
904	61ROY1	J.C.Roy	J,CJP,39,315,1961	13060
222	69HAS1	J.D.Hastings+	J,RCA,11,51,1969	13247
237	59KNI1	J.D.Knight+	J,JIN,10,183,1959	13452
1190	81GIN1	J.E.Gindler+	J,JIN,43,1433,1981	10966
1189	81GIN4	J.E.Gindler+	J,JIN,43,1743,1981	12710
1181	81GIN2	J.E.Gindler+	J,JIN,43,445,1981	10967
	81GIN3	J.E.Gindler+	J,JIN,43,895,1981	10986
1077	77GIN1	J.E.Gindler+	J,PR/C,16,1483,1977	10642
304	60SAT1	J.E.Sattizahn+	J,JIN,12,206,1960	13475
603	70FAH1	J.Fahland+	J,JIN,32,3149,1970	22060
67	61BAY1	J.G.Bayly+	J,CJP,39,1391,1961	13057
78	57CUN2	J.G.Cuninghame	J,JIN,4,1,1957	new
79	57CUN1	J.G.Cuninghame	J,JIN,5,1,1957	new
77	58CUN1	J.G.Cuninghame	J,JIN,6,181,1958	new
155	53CUN1	J.G.Cuninghame	J,PM,44,900,1953	new
796	74CUN1	J.G.Cuninghame+	J,JIN,36,1453,1974	20769
1053	77CUN1	J.G.Cuninghame+	J,JIN,39,383,1977	20771
85	61CUN1	J.G.Cuninghame+	J,NP,27,154,1961	new
92	66CUN1	J.G.Cuninghame+	J,NP,84,49,1966	22053
	72CUN2	J.G.Cuninghame+	R,AERE-R-6862,,1972	20768
865	62GRA1	J.Gray Jr+	J,RSI,33,1258,1962	13218
1077	77GIN1	J.J.Gindler+	J,PR/C,16,1483,1977	10642
	79DIC1	J.K.Dickens	J,NSE,70,177,1979	10894
2061	87DIC1	J.K.Dickens	J,NSE,96,8,1987	new
1141	80DIC1	J.K.Dickens+	J,NSE,73,42,1980	10890
1180	81DIC1	J.K.Dickens+	J,NSE,77,146,1981	10961
	82DIC1	J.K.Dickens+	J,NSE,80,455,1982	12734
1173	80DIC2	J.K.Dickens+	J,PR/C,23,331,1981	10962
	81DIC3	J.K.Dickens+	J,PR/C,24,192,1981	12705
	83DIC1	J.K.Dickens+	J,PR/C,27,253,1983	12807
2011	86DIC1	J.K.Dickens+	J,PR/C,34,722,1986	13102
2012	86DIC2	J.K.Dickens+	R,ORNL-6266,1986	new
580	70KEM1	J.Kemmer+	J,RCA,13,181,1970	new
597	71KEM1	J.Kemmer+	J,RCA,15,113,1971	new
2084	49KOC1	J.Koch+	J,PR,76,279,1949	new
	69FAS1	J.L.Fasching+	P,MIT-905-154,15,1969	13246
	81LAU1	J.Laurec+	R,CEA-R-5147,1981	21707
2097	57ALE1	J.M.Alexander+	J,PR,108,1274,1957	13430
14	63CRO2	J.M.Crook+	R,IS-558,1963	13200
	51SIE1	J.M.Siegel+	B,RCS,2,549,1951	13415
253	50MAC1	J.Macnamara+	J,PR,78,129,1950	13360
	50MAC2	J.Macnamara+	J,PR,80,471,1950	13546
666	58MAL1	J.Maly+	J,CZC,23,1886,1958	new
705	72BOC1	J.P.Bocquet+	J,NP/A,189,556,1972	21734
	90BOC1	J.P.Bocquet+	J,ZP/A,335,41,1990	22143
2014	73UNI1	J.P.Unik+	C,73ROCH,2,19,1973	10642, 13454, 14298
	47ARN1	J.R.Arnold+	J,JCP,15,703,1947	11821,13052
243	69LAE1	J.R.de Laeter+	J,CJP,47,1409,1969	13248, 13481
	75DEE1	J.R.Deen	J,NT,25,416,1975	13334
782	73DEE1	J.R.Deen+	J,ANS,17,531,1973	(13334)
	82LAE1	J.R.deLaeter+	J,AUJ,35,385,1982	30650
243	69LAE1	J.R.deLaeter+	J,CJP,47,1409,1969	13248, 13481

896	75LAE1	J.R.Delaeter+	J,CJP,53,775,1975	new
	63FRA1	J.S.Fraser+	J,CJP,41,2080,1963	13067
911	75HAR1	J.T.Harvey+	J,JIN,37,2243,1975	13336
	53TER1	J.Terrell+	J,PR,92,1091(I4),1953	13374
803	73KRA2	J.V.Kratz+	C,73ROCH,2,95,1973	(20521)
578	70KRA1	J.V.Kratz+	J,JIN,32,3713,1970	22047
812	73KRA1	J.V.Kratz+	J,JIN,35,1407,1973	20521
364	68HAR1	J.W.Harvey+	J,CJC,46,2911,1968	13234
223	66HAR1	J.W.Harvey+	J,CJP,44,1011,1966	13090
	73MAN1	J.W.Mandler+	J,BAP,18,768(AB8),1973	13312
260	60MAR1	Ja.Marinsky+	J,JIN,12,223,1960	13460
1118	78KRA1	K.-L.Kratz	J,RCA,25,1,1978	21058
	77KRA1	K.-L.Kratz	P,MAINZ-1976,34,1977	21058
709	72PET1	K.A.Petrzhak+	J,SJA,33,826,1972	41081
1111	77PET1	K.A.Petrzhak+	J,SJA,42,379,1977	41087
639	70PET1	K.A.Petrzhak+	J,SNP,11,654,1970	40422, 41077
683	72PET2	K.A.Petrzhak+	J,SNP,15,482,1972	40019
1	60PET1	K.A.Petrzhak+	R,AEC-TR-4696,1961	new
554	68BAC1	K.Bachmann	J,RCA,9,27,1968	new
49	64BRO1	K.Broom	J,PR,133,B874,1964	13095
71	69BOR1	K.D.Borden+	J,JIN,31,2623,1969	13243
	67BOR2	K.D.Borden+	R,ORO-3235-12,21,1967	13220
1114	78DEB1	K.Debertin	C,78HARWELL,,229,1978	21306
757	72DEB1	K.Debertin	J,RCA,18,202,1972	22054
	77DEB1	K.Debertin	S,INDC(NDS)-87,211,1978	21624
208	69FLY2	K.F.Flynn+	C,69VIENNA,,731,1969	21496
935	75FLY4	K.F.Flynn+	J,ANS,22,677,1975	(10798)
205	69FLY1	K.F.Flynn+	J,HCA,52,2216,1969	23271
885	75FLY1	K.F.Flynn+	J,JIN,37,869,1975	10517
888	75FLY2	K.F.Flynn+	J,JIN,37,881,1975	13459
926	76FLY1	K.F.Flynn+	J,JIN,38,661,1976	13340
1047	77FLY1	K.F.Flynn+	J,JIN,39,759,1977	10979
902	75FLY3	K.F.Flynn+	J,PR/C,11,1676,1975	10516
686	72FLY1	K.F.Flynn+	J,PR/C,5,1725,1972	13454
720	72FLY2	K.F.Flynn+	J,PR/C,6,2211,1972	13302
	66FLY1	K.F.Flynn+	R,ORO-3235-12,21,1967	13220
	66FRI1	K.Fritze	J,RCA,5,57,1966	13219
193	59FRI1	K.Fritze+	C,58GENEVA,15,436,1958	13484
2017	83ROS1	K.J.R.Rosman+	J,CJP,61,1490,1983	14087
283	69PIL1	K.K.S.Pillay+	J,JRC,3,233,1969	13354
	64KIM1	K.Kimura	P,MIT-2098-64,35,1964	13203
	70KOB1	K.Kobayashi+	R,KURRI-AR-3,84,1970	20272
1118	78KRA1	K.L.Kratz	J,RCA,25,1,1978	21058
48	62BRO1	K.M.Broom	J,PR,126,627,1962	13061
49	64BRO1	K.M.Broom	J,PR,133,B874,1964	13095
	66MAR1	K.Marti+	J,ZN/A,21,398,1966	new
	82RAG1	K.Raghuraman+	J,RCA,31,65,1982	33066
	82REN1	K.Rengan+	P,UCAR-10062-81-1,111,1982	12740
182	63FAL1	K.T.Faler+	J,PR,131,1746,1963	13092
581	71WOL2	K.Wolfsberg	J,JIN,33,587,1971	13296
889	75WOL1	K.Wolfsberg	J,JIN,37,1125,1975	13338
570	65WOL1	K.Wolfsberg	J,PR,137,B929,1965	13084
	74WOL3	K.Wolfsberg+	J,ACS,,(21),1974	13467
394	60WOL1	K.Wolfsberg+	J,JIN,12,201,1960	13477
568	71WOL1	K.Wolfsberg+	J,PR/C,3,1333,1971	13295
205	69FLY1	Kf.Flynn+	J,HCA,52,2216,1969	23271
780	72BER1	L.A.Berge	T,BERGE,1972	13299

40	65BAL1	L.Balcarczyk+	J,NUK,7,169,1965	new
	67BRO1	L.C.Brown+	J,JIN,29,2133,1967	13348
	70CAR1	L.C.Carraz	J,CR/B,270,358,1970	new
151	68CIU1	L.Ciuffolotti	J,EN,15,272,1968	21483
	51GLE4	L.E.Glendenin	B,RCS,2,1092,1951	13400
	51GLE1	L.E.Glendenin	B,RCS,2,596,1951	13399
	49GLE2	L.E.Glendenin	R,MIT-TR-35,1949	13402
	60GLE1	L.E.Glendenin	W,GLENDENIN,1960	(13366, 13428)
	51GLE2	L.E.Glendenin+	B,RCS,2,793,1951	13365
	51GLE3	L.E.Glendenin+	B,RCS,2,992,1951	new
	62GLE1	L.E.Glendenin+	J,ANS,5,20,1962	13066
218	55GLE2	L.E.Glendenin+	J,JIN,1,45,1955	13455
1162	80GLE1	L.E.Glendenin+	J,PR/C,22,152,1980	10920
	70FOR1	L.Forman+	R,LA-DC-11500,1970	13267
357	70GEV1	L.H.Gevaert+	J,CJC,48,641,1970	13268
406	70NIE1	L.H.Niece+	J,PR/C,1,312,1970	13273
	63KIR1	L.J.Kirby	P,HW-77609,(3.1),1963	13201
	81KOC1	L.Koch	J,RCA,29,61,1981	21155
	77KOC1	L.Koch	P,NEANDC(E)-182,(5),47,1977	21155
	67SCH1	L.L.Schwartz+	W,SCHWARTZ,1967	13438
232	57KRI1	L.M.Krizhansky+	J,SJA,2,334,1957	new
234	58KRI1	L.M.Krizhansky+	J,SJA,4,95,1958	new
772	74YUR1	L.N.Yurova+	J,SJA,36,75,1974	40206
1143	79YUR1	L.N.Yurova+	J,SJA,47,528,1980	40489
756	73BAT1	L.R.Battles+	J,JIN,35,3075,1973	13309
337	59BUN1	L.R.Bunney+	C,58GENEVA,15,444,1958	new
34	59BUN2	L.R.Bunney+	C,58GENEVA,15,449,1958	(13214)
29	65BUN2	L.R.Bunney+	J,JIN,27,1183,1965	13214
73	65BUN1	L.R.Bunney+	J,JIN,27,273,1965	13213
	85ROB1	L.Robinson+	J,PR/C,31,1334,1985	12931
	68BEL1	L.S.Beller+	J,ANS,11,607,1968	13231
	77KEL1	L.S.Kellogg+	C,77PALOALTO,3,1307,1977	13342
561	68TOM1	L.Tomlinson+	J,JIN,30,1995,1968	new
653	71TOM1	L.Tomlinson+	J,JIN,33,3609,1971	new
	79TOP1	L.Toppare+	S,IAEA-SM-241,182,1979	21700
	82WEN1	L.Wenxin+	J,PHE,6,365,1982	30695
	51WIN1	L.Winsberg	B,RCS,2,1284,1951	13422
	51WIN2	L.Winsberg	B,RCS,2,1292,1951	13423
	51WIN3	L.Winsberg	B,RCS,2,1302,1951	13424
383	68WIS1	L.Wish	J,PR,172,1262,1968	13241
380	53YAF1	L.Yaffe+	J,CJC,31,48,1953	13376
381	54YAF1	L.Yaffe+	J,CJC,32,1017,1954	13383
	47YAF1	L.Yaffe+	J,CJR/B,25,371,1947	new
	87LI 1	Li Wen-xin+	J,PHE,11,376,1987	30785
	80LI 1	Li Wenxin+	J,HFH,2,9,1980	32634
	83LI 2	Li Wenxin+	J,HFH,5,176,1983	32628
	82LI 1	Li Wenxin+	J,PHE,6,365,1982	30695
	83LI 1	Li Ze+	J,CNP,5,226,1983	30691
	85LI 1	Li Ze+	J,CNP,7,97,1985	30751
	85LIU1	Liu Conggui+	J,CNP,7,235,1985	30788
65	59BAK1	M.A.Bak+	J,SJA,6,429,1960	new
1142	79MON1	M.A.Monzyk+	J,PR/C,20,212,1979	10897
	78ASG2	M.Asghar+	J,NP/A,311,205,1978	21544
	80ASG2	M.Asghar+	J,NP/A,341,388,1980	new
	81ASG1	M.Asghar+	J,NP/A,368,328,1981	21771
781	73BRA1	M.Brasca+	J,EN,20,691,1973	22792
361	67BRE1	M.Bresesti+	J,JIN,29,1189,1967	22791

810	66SIL1	M.D.Silbert+	J,RCA,5,223,1966	13072
	89DJE1	M.Djebara+	J,NP/A,496,346,1989	22116
	74EIC1	M.Eichor	J,JIN,36,3880,1974	13318
608	71EIC1	M.Eichor+	J,JIN,33,1543,1971	13280
	64DUR1	M.F.Duret+	C,64GENEVA,3,347,1964	new
671	71ROC1	M.F.Roche+	J,RCA,16,66,1971	13288
	68ROC1	M.F.Roche+	R,ORNL-3994,7,1966	13237
644	66BRO1	M.G.Brown+	J,RCA,6,16,1966	new
	49ING1	M.G.Inghram+	J,PR,76,1717(2),1949	13457
	50ING1	M.G.Inghram+	J,PR,79,271,1950	12106, 13352
	51FEL1	M.H.Feldman+	B,RCS,2,598,1951	13363
	51FEL2	M.H.Feldman+	B,RCS,2,654,1951	13364
	85HAD1	M.Haddad+	C,85SANTA,,353,1985	21972
2024	87HAD1	M.Haddad+	J,RCA,42,165,1987	new
	89HAD1	M.Haddad+	J,RCA,46,23,1989	22119
	73KIK1	M.Kikuchi+	J,RCA,19,54,1973	13311
	74FOW2	M.M.Fowler+	J,JIN,36,1191,1974	13321
783	74FOW1	M.M.Fowler+	J,JIN,36,1201,1974	13319
651	68NAM1	M.N.Namboodiri+	J,JIN,30,2305,1968	30950
360	67RAO2	M.N.Rao	J,JIN,29,863,1967	new
229	65RAO1	M.N.Rao+	J,JIN,27,2679,1965	30945
298	66RAO1	M.N.Rao+	J,PR,147,884,1966	13063
299	67RAO1	M.N.Rao+	J,RCA,8,12,1967	new
17	59ANI1	M.P.Anikina+	C,58GENEVA,15,446,1958	40730
	57ANI1	M.P.Anikina+	J,SJA,2,332,1957	(40730)
16	58ANI1	M.P.Anikina+	J,SJA,4,270,1958	(40730)
254	64MEN1	M.P.Menon+	J,JIN,26,401,1964	13223
917	76RAJ1	M.Rajagopalan+	J,JIN,38,351,1976	21554
924	75RAJ1	M.Rajagopalan+	J,NSE,58,414,1975	21595
657	71ROB1	M.Robin+	C,71CANT,,19,1971	22050
	51FRE1	M.S.Freedman+	B,RCS,3,1344,1951	13398
1119	78SHI1	M.Shima+	J,CJP,56,1340,1978	10864
	79SHM1	M.Shmid	R,IA-1345,1979	30961
1188	81SHM1	M.Shmid+	J,JIN,43,867,1981	30960
2028	83SHM1	M.Shmid+	J,ZP/A,311,113,1983	30915
	58ROB1	M.T.Robinson+	J,NSE,4,288,1958	new
351	68THE1	M.Thein+	J,JIN,30,1145,1968	13238, 13969
	70ROW1	M.W.Rowe	J,GCA,34,1019,1970	13275
	79WEI1	M.Weis	T,WEIS,1979	21687
1174	81WEI1	M.Weis+	J,JIN,43,437,1981	21687
	77WEI1	M.Weis+	P,MAINZ-1976,84,1977	new
	78WEI1	M.Weis+	P,MAINZ-1977,80,1978	new
	76WEI1	M.Weis+	T,VINE,1976	20878
878	75DUD1	N.D.Dudey+	J,NT,25,294,1975	13335, 13337
	51BAL1	N.E.Ballou+	B,RCS,2,675,1951	13405
	74BAL1	N.E.Ballou+	J,ACS,,16,1974	13274
	66RUN1	N.G.Runnalls	T,RUNNALLS,1966	13343
287	69RUN1	N.G.Runnalls+	J,PR,179,1188,1969	13254
408	70RUN1	N.G.Runnalls+	J,PR/C,1,316,1970	13276
287	69RUN1	N.G.Runnals+	J,PR,179,1188,1969	13254
365	67BOR1	N.I.Borisova+	J,SNP,6,331,1968	40329, 41069, 41074
	68BOR1	N.I.Borisova+	J,SNP,8,404,1968	41075
930	76IMA1	N.Imanishi+	J,NP/A,263,141,1976	20589
26	66ARA1	N.K.Aras+	J,JIN,28,763,1966	13085
300	66RAV1	N.Ravindran+	J,JIN,28,921,1966	13069
	51SUG1	N.Sugarman	B,RCS,2,1139,1951	13419
303	53SUG1	N.Sugarman	J,PR,89,570,1953	13373
741	73SKO1	N.V.Skovorodkin+	J,SJA,34,449,1973	40205

767	73SKO2	N.V.Skovorodkin+	J,SJA,35,1109,1973	40389
593	70SKO1	N.V.Skovorodkin+	J,SRA,12,458,1970	41078
408	70RUN1	Ng.Runnalls+	J,PR/C,1,316,1970	13276
30	71BIR1	O.Birgul+	J,RCA,16,103,1971	(22062)
75	69BIR2	O.Birgul+	J,RCA,11,108,1969	21731
169	69BIR1	O.Birgul+	J,RCA,12,66,1969	new
30	71BIR1	O.Birgul+	J,RCA,16,103,1971	(22062)
405	71BIR2	O.Birgul+	J,RCA,16,104,1971	22039
30	67BIR1	O.Birgul+	J,RCA,8,9,1967	new
	70MAN1	O.K.Manuel+	W,MANUEL,1970	13356
717	72ALE1	P.Alexander	J,NP/A,198,228,1972	22038
617	60STE1	P.C.Stevenson+	J,PR,117,186,1960	14063
252	68MAR1	P.del Marmol	J,JIN,30,2873,1968	new
	67MAR1	P.del Marmol+	J,JIN,29,273,1967	new
633	70MAR1	P.del Marmol+	J,JIN,32,705,1970	new
725	72MAR1	P.del Marmol+	J,NP/A,194,140,1972	22055
	71MAR1	P.del Marmol+	J,RCA,16,4,1971	new
	86DHO1	P.D‘Hondt+	S,BLG-586,43,1986	22057
	75FET1	P.Fettweis+	J,ZP/A,275,359,1975	21530
	73VAN1	P.H.M.van Assche+	R,RCN-203,95,1973	21560
	54KUR1	P.K.Kuroda+	J,JCP,22,1940,1954	new
	56KUR1	P.K.Kuroda+	J,JCP,25,603,1956	new
589	61KUR1	P.K.Kuroda+	J,NSE,10,70,1961	13058
235	57KAF1	P.Kafalas+	J,JIN,4,239,1957	13435
590	58PAR1	P.L.Parker+	J,JIN,5,153,1958	13471
2008	75REE1	P.L.Reeder+	C,75WASH,1,401,1975	13207
	85REE1	P.L.Reeder+	J,PR/C,32,1327,1985	12945
308	65STR1	P.O.Strom+	J,CJC,43,2493,1965	new
307	66STR1	P.O.Strom+	J,PR,144,984,1966	13073
	71DYA1	P.P.D‘yachenko+	J,SNP,7,27,1968	40234
1137	79PEU1	P.Peuser+	J,ZP/A,289,219,1979	21581
288	59REG1	R.B.Regier+	J,PR,113,1589,1959	13581
291	60REG1	R.B.Regier+	J,PR,119,2017,1960	14078
	77STR1	R.B.Strittmatter+	J,ANS,27,862,1977	10722
2031	79STR1	R.B.Strittmatter+	J,NIM,166,473,1979	new
	71BRI1	R.Brissot	T,BRISSOT,1971	21549
938	76BRI2	R.Brissot+	J,JPR/L,37,241,1976	21549
919	75BRI1	R.Brissot+	J,NP/A,255,461,1975	21550
1059	77BRI1	R.Brissot+	J,NP/A,282,109,1977	21549
604	71HAW1	R.C.Hawkings+	J,CJP,49,785,1971	13284
2076	72LAR1	R.D.Oldham+	P,ANL-7879,16,1972	13271
600	71DIE1	R.Dierckx+	J,JNE,25,85,1971	22058
615	60COL1	R.F.Coleman+	J,JIN,14,8,1960	new
	66NIS1	R.G.Nisle+	J,NSE,25,93,1966	new
	68NIS1	R.G.Nisle+	J,NSE,31,241,1968	13236
	68GAN1	R.Ganapathy	T,GANAPATHY,1968	13089
662	67GAN2	R.Ganapathy+	J,EPL,3,89,1967	13229
355	66GAN1	R.Ganapathy+	J,JIN,28,2071,1966	13087
609	66GAN3	R.Ganapathy+	J,JIN,28,3071,1966	13089
	67GAN1	R.Ganapathy+	J,JIN,29,257,1967	13228
	66GAN2	R.Ganapathy+	J,PR,151,960,1966	13088
225	63IYE1	R.H.Iyer+	J,JIN,25,465,1963	30947
352	64JAM1	R.H.James+	J,RCA,3,76,1964	new
2068	90HEN1	R.Hentzschel+	J,RCA,50,1,1990	22176
	91HEN1	R.Hentzschel+	P,NEANDC(E)-322,(5),63,1991	new
619	70ARM1	R.J.Armani+	J,ANS,13,90,1970	13265
2102	82SIN1	R.J.Singh+	J,RCA,31,69,1982	33002

401	55WAN1	R.K.Wanless+	J,CJP,33,541,1955	13389
45	53BAR1	R.M.Bartholomew+	J,CJC,31,120,1953	13369
44	56BAR1	R.M.Bartholomew+	J,CJC,34,201,1956	13390
31	59BAR1	R.M.Bartholomew+	J,CJC,37,660,1959	13474
574	71HAR1	R.M.Harbour+	J,JIN,33,1,1971	13282
690	72HAR2	R.M.Harbour+	J,JIN,34,2109,1972	13325
777	74HAR1	R.M.Harbour+	J,PR/C,10,769,1974	13320
758	73HAR1	R.M.Harbour+	J,PR/C,8,1488,1973	13310
598	71HAR2	R.M.Harbour+	J,RCA,15,146,1971	13283
777	73HAR2	R.M.Harbour+	R,DP-MS-73-29,1973	(13320)
263	69MUN1	R.Muenze+	J,KE,12,380,1969	new
15	57IVA1	R.N.Ivanov+	J,SJA,3,1436,1957	40730
231	54KEL1	R.N.Keller+	J,PR,94,969,1954	13379
681	72NAE1	R.Naeumann+	J,JIN,34,1785,1972	new
	57NAS1	R.Nasuhoglu+	J,PR,108,1522,1957	13436
790	74LAR1	R.P.Larsen+	J,NSE,54,263,1974	12771
	66LAR1	R.P.Larsen+	P,ANL-6900,338,1964	13226
2076	72LAR1	R.P.Larsen+	P,ANL-7879,16,1972	13271
	73LAR4	R.P.Larsen+	P,ANL-7979,7,1973	(12771)
	51MET1	R.P.Metcalf	B,RCS,2,891,1951	13410
	51MET2	R.P.Metcalf	B,RCS,2,898,1951	13411
	51MET3	R.P.Metcalf	B,RCS,2,905,1951	13412
	51SCH1	R.P.Schuman	B,RCS,2,1191,1951	new
297	65RIC1	R.R.Rickard+	J,NSE,23,115,1965	13079
226	65IYE1	R.S.Iyer+	C,65SALZBURG,1,439,1965	30944
378	66OND1	R.S.Ondrejcin	J,JIN,28,1763,1966	13062
	81SEH1	R.Sehr+	P,MAINZ-1980,76,1981	new
310	69STE1	R.Stella+	J,JIN,31,3739,1969	21412
	67STE2	R.Stella+	J,RIC,37,354,1967	new
	67STE3	R.Stella+	J,RIC,37,357,1967	new
	67VIL1	R.Villarreal	T,VILLARREAL,1967	13349
804	74PAR1	R.W.Parsons+	J,JIN,36,2392,1974	13331
787	73PAR1	R.W.Parsons+	J,RRL,15,335,1973	(13331)
	81WAL1	R.W.Waldo+	J,PR/C,23,1113,1981	12926
619	70ARM1	Rj.Armani+	J,ANS,13,90,1970	13265
297	65RIC1	Rr.Rickard+	J,NSE,23,115,1965	13079
378	66OND1	Rs.Ondrejcin	J,JIN,28,1763,1966	13062
2025	86CHI1	S.A.Chitambar+	J,RCA,42,169,1987	33003
	73CHI1	S.A.Chitambar+	P,BARC-690,134,1973	30514
688	72RAO3	S.A.Rao	J,JIN,34,2405,1972	10357
677	72RAO1	S.A.Rao	J,PR/C,5,171,1972	13305
646	69RAO1	S.A.Rao+	J,JIN,31,591,1969	13253
723	73RAO1	S.A.Rao+	J,JIN,35,1443,1973	13313
	89MAN1	S.B.Manohar+	J,NP/A,502,307c,1989	(33062)
1079	78MAN1	S.B.Manohar+	J,PR/C,17,188,1978	30516
1140	79MAN1	S.B.Manohar+	J,PR/C,19,1827,1979	30511
	73MAN2	S.B.Manohar+	P,BARC-690,132,1973	30511
	73DAR2	S.Daroczy+	C,73KIEV,3,323,1973	30267
	75DAR1	S.Daroczy+	J,AK,18,317,1976	30639
1133	78MAR1	S.F.Marathe+	J,JIN,40,1981,1978	30439
	61MAR1	S.F.Marsh+	J,AC,33,870,1961	13211
1133	78MAR1	S.G.Marathe+	J,JIN,40,1981,1978	30439
	68FRE1	S.H.Freid+	J,JIN,30,3155,1968	O0621
876	74BAL2	S.J.Balestrini+	J,PR/C,10,1872,1974	13317
910	75BAL1	S.J.Balestrini+	J,PR/C,12,413,1975	13333
1155	79BAL1	S.J.Balestrini+	J,PR/C,20,2244,1979	21641
	73BAL1	S.J.Balestrini+	R,LA-UR-73-838,1973	(13317)
912	69LYL1	S.J.Lyle+	J,RCA,12,43,1969	22062

405	70LYL1	S.J.Lyle+	J,RCA,13,167,1970	(22062)
	64LYL1	S.J.Lyle+	J,RCA,3,80,1964	new
621	68LYL1	S.J.Lyle+	J,RCA,9,90,1968	new
	76LIS1	S.K.Lisin+	J,SNP,24,570,1976	40428
	51KAT3	S.Katco	B,RCS,2,980,1951	13407
	51KAT5	S.Katcoff+	B,RCS,2,1005,1951	new
	51KAT8	S.Katcoff+	B,RCS,2,1017,1951	new
	51KAT6	S.Katcoff+	B,RCS,2,1097,1951	13408
	51KAT7	S.Katcoff+	B,RCS,2,1167,1951	new
	51KAT1	S.Katcoff+	B,RCS,2,587,1951	new
	51KAT2	S.Katcoff+	B,RCS,2,591,1951	new
	51KAT4	S.Katcoff+	B,RCS,2,982,1951	new
240	65KAT1	S.Katcoff+	J,JIN,27,1447,1965	13215
230	53KAT1	S.Katcoff+	J,PR,91,1458,1953	13371
	53KAT2	S.Katcoff+	R,BNL-1652,1953	13426
739	73TON1	S.L.Tong+	J,JIN,35,3079,1973	13314
323	69TON1	S.L.Tong+	J,RCA,12,179,1969	13262
	73DUB1	S.M.Dubrovina+	R,YFI-16,19,1973	40193
	71QAI1	S.M.Qaim+	C,71CANT,,121,1971	20513
566	70QAI1	S.M.Qaim+	J,JIN,32,1767,1970	22067
1086	78NAG1	S.Nagy+	J,PR/C,17,163,1978	10798
602	69DAN1	S.P.Dange+	C,69VIENNA,,741,1969	(33008)
	87RAM1	S.Ram+	J,NIM/B,24/25,501,1987	30768
	81HSU1	S.S.Hsu+	J,PR/C,24,523,1981	30666
2106	80RAT1	S.S.Rattan+	C,80WALTAI,,155,1980	(33007)
2019	83RAT1	S.S.Rattan+	J,RCA,33,189,1983	33007
876	74BAL2	Sj.Balestrini+	J,PR/C,10,1872,1974	13317
2078	87JIA1	Sun Jianguo+	J,JRN/L,108,347,1987	30790
	51NOV2	T.B.Novey	B,RCS,2,976,1951	new
	51NOV1	T.B.Novey+	B,RCS,2,678,1951	13405
1099	78CHA1	T.C.Chapman+	J,PR/C,17,1089,1978	10828
1172	80DAT1	T.Datta+	J,PR/C,21,1411,1980	33069
	82GAR1	T.Garlea+	P,INDC(ROM)-014,2,1982	30752
1094	78IZA1	T.I.Biran+	J,JIN,40,757,1978	30425
1074	77IZA1	T.I.Biran+	J,PR/C,16,266,1977	30425
	69ISA1	T.Isak+	P,IA-1190,101,1969	30954
616	67ISH1	T.Ishimori+	J,RCA,7,95,1967	new
	70IZA1	T.Izak	T,IZAK,1970	30956
1094	78IZA1	T.Izak-Biran+	J,JIN,40,757,1978	30425
1110	78IZA2	T.Izak-Biran+	J,JIN,40,937,1978	30425
238	57KEN1	T.J.Kennett+	J,CJP,35,969,1957	13463
663	56KEN1	T.J.Kennett+	J,PR,103,323,1956	13393
1095	78KAI1	T.Kaiser+	J,JIN,40,377,1978	21218
1107	78KAI2	T.Kaiser+	J,PR/C,17,4,1510,1978	21745
	84SEM1	T.M.Semkow+	J,PR/C,30,1966,1984	12813
648	65MO 1	T.Mo+	J,JIN,27,503,1965	13075
262	68MO 1	T.Mo+	J,JIN,30,345,1968	13235
	77NIS1	T.Nishi+	P,NEANDC(J)-51,38,1977	20848
	80NIS1	T.Nishi+	W,NISHI,1980	20848
	71MCL1	T.P.Mc Laughlin	T,MC LAUGHLIN,1971	13286
	57SUG1	T.T.Sugihara+	J,PR,108,1264,1957	C2303
262	68MO 1	Tin Mo+	J,JIN,30,345,1968	13235
	88QUA1	U.Quade+	J,NP/A,487,1,1988	22130
	79UME1	U.Umezawa+	P,NEANDC(J)-51,33,1977	20847
2044	84TEP1	V.F.Teplykh+	C,83KIEV,2,251,1983	40877
1158	79TEP1	V.F.Teplykh+	J,SNP,29,144,1979	40545
1108	77GAB1	V.Gabeskiriya+	J,SJA,43,670,1977	41084
217	61GOR1	V.K.Gorshkov+	J,JNE/A,13,198,1961	41071

212	57GOR1	V.K.Gorshkov+	J,SJA,3,729,1957	40363	
217	59GOR1	V.K.Gorshkov+	J,SJA,7,649,1961	41071	
1136	79RAO1	V.K.Rao+	J,PR/C,19,1372,1979	30496	
755	74RAO1	V.K.Rao+	J,PR/C,9,1506,1974	30496	
1108	77GAB1	V.Ya.Gabeskiriya+	J,SJA,43,670,1977	41084	
755	74RAO1	Vk.Rao+	J,PR/C,9,1506,1974	30496	
	77MYE1	W.A.Myers+	R,UCRL-80020,1977	(10821)	
877	75JAM1	W.D.James+	J,JIN,37,1341,1975	10433	
170	69DAV1	W.Davies	J,RCA,12,173,1969	22066	
	47GRU1	W.E.Grummitt+	J,CJR/B,25,364,1947	13053	
214	61GRU1	W.E.Grummitt+	J,JIN,20,6,1961	13209	
210	57GRU1	W.E.Grummitt+	J,JIN,5,93,1957	13434	
	48GRU1	W.E.Grummitt+	J,NAT,161,520,1948	13054	
	51GRU1	W.E.Grummitt+	R,CRC-470,51	13054	
264	60NER1	W.E.Nervik	J,PR,119,1685,1960	14079	
51	62BUR1	W.H.Burgus	R,IDO-16797,1962	13098	
	51BUR1	W.H.Burgus+	B,RCS,2,1184,1951	13394	
	51BUR2	W.H.Burgus+	B,RCS,2,1195,1951	13362	
179	56FLE1	W.H.Fleming+	J,CJC,34,193,1956	13392	
206	54FLE1	W.H.Fleming+	J,CJP,32,522,1954	13377	
	53FLE1	W.H.Fleming+	J,PR,92,378,1953	new	
219	53HAR1	W.H.Hardwick	J,PR,92,1072,1953	new	
	51SUL2	W.H.Sullivan+	B,RCS,2,1015,1951	new	
	51SUL1	W.H.Sullivan+	B,RCS,2,808,1951	13420	
	75ZIM1	W.H.Zimmer+	J,NT,25,289,1975	13339	
	71HOL1	W.Holubarsch+	J,NP/A,171,631,1971	new	
	49ARR1	W.J.Arrol+	J,CJR/B,27,757,1949	13055	
1092	74MAE1	W.J.Maeck	R,ICP-1050-I,1975	(13270, 13210, 10865)	13848, 13440,
871	77MAE1	W.J.Maeck	R,ICP-1050-II,1977	13469	
	80MAE2	W.J.Maeck	S,INDC(NDS)-113,68,1980	new	
	61MAE1	W.J.Maeck+	J,AC,33,235,1961	13210	
1153	79MAE2	W.J.Maeck+	R,ENICO-1001,1979	10898	
1160	80MAE1	W.J.Maeck+	R,ENICO-1028,1980	13440	
1182	80MAE4	W.J.Maeck+	R,ENICO-1046,1980	10917	
1072	77MAE2	W.J.Maeck+	R,ICP-1050,(III),1977	10723	
1134	79MAE1	W.J.Maeck+	R,ICP-1050-IV,1979	10845	
	76MAE1	W.J.Maeck+	R,ICP-1092,1976	13341	
1116	78MAE1	W.J.Maeck+	R,ICP-1142,1978	10865	
	70HEN1	W.K.Hensley+	J,JIN,32,1761,1970	new	
	80LAN1	W.Lang+	J,NP/A,345,34,1980	21689	
	70MCE1	W.N.Mc Elroy+	J,ANS,13,868,1970	13272	
	75MCE1	W.N.Mc Elroy+	J,NT,25,180,1975	new	
165	66DAN1	W.R.Daniels+	J,PR,145,911,1966	13086	
	76RUD1	W.Rudolph	T,RUDOLPH,1976	20878	
1046	77RUD1	W.Rudolph+	J,JIN,39,753,1977	20879	
	72SCH1	W.Scholtyssek	P,KFK-1272-1,1972	new	
685	72WEI1	W.Weinlaender+	J,RCA,17,18,1972	22073	
685	72WEI1	W.Weinlander+	J,RCA,17,18,1972	22073	
	85WAN1	Wang Dao+	J,HFH,7,234,1985	32632	
	82WAN1	Wang Lianbi+	J,HFH,4,44,1982	30744	
	80WAN1	Wang Yusheng+	J,HFH,2,129,1980	32635	
144	59CHU1	Y.Y.Chu	R,UCRL-8926,1959	new	

Appendix B List of participants

Consultancy Meeting on the

Fission Product Yield Experimental Database

Laboratory for Advanced Nuclear Energy,
Tokyo Institute of Technology, Tokyo, Japan
27–30 May 2019

List of Participants

China	Ms Yongjing CHEN China Nuclear Data Center (CNDC), China Institute of Atomic Energy (CIAE) China National Nuclear Corp. (CNNC), P.O. Box 275-41 Beijing, CHINA Tel: Email:cyj@ciae.ac.cn
China	Mr Nengchuan SHU China Nuclear Data Center (CNDC), China Institute of Atomic Energy (CIAE) China National Nuclear Corp. (CNNC), P.O. Box 275-41 Beijing, CHINA Tel: Email:nshu@ciae.ac.cn
France	Mr Gilbert BELIER CEA DAM DIF Service de Physique Nucleaire 91297 Arpajon Cedex, FRANCE Tel: Email:gilbert.belier@cea.fr
NEA	Mr Michael FLEMING OECD Nuclear Energy Agency (NEA) 46, quai Alphonse Le Gallo 92100 Boulogne Billancourt, France Tel: Email:michael.fleming@oecd-nea.org
Japan	Mr Satoshi CHIBA Laboratory for Advanced Nuclear Energy Tokyo Institute of Technology Ookayama 2-12-1-N1-9, Meguro-ku Tokyo 152-8550, Japan Tel:+81-3-5734-3066 Email:chiba.satoshi@nr.titech.ac.jp
Japan	Mr Takanari FUKUDA Graduate School of Advanced Science and Engineering

	Waseda University Building 51, Nishi-Waseda Campus, Okubo 3-4-1, Shinjuku-Ku Tokyo 169-8555, Japan Tel: Email:sun-village@akane.waseda.jp
Japan	Ms Chikako ISHIZUKA Laboratory for Advanced Nuclear Energy Tokyo Institute of Technology Ookayama 2-12-1-N1-9, Meguro-ku Tokyo 152-8550, Japan Tel:+81-3-5734-1168 Email:chikako@lane.iir.titech.as.jp
Japan	Mr Futoshi MINATO Nuclear Data Center, Japan Atomic Energy Agency Shirakata, Tokai-mura, Naka-gun Ibaraki 319-1195, Japan Tel: Email:minato.futoshi@jaea.go.jp
Japan	Mr Kohsuke TSUBAKIHARA Laboratory for Advanced Nuclear Energy Tokyo Institute of Technology Ookayama 2-12-1-N1-9, Meguro-ku Tokyo 152-8550, Japan Tel:+81-3-5734-1168 Email:tsubakihara.k.aa@m.titech.ac.jp
Japan	Mr Tadashi YOSHIDA Laboratory for Advanced Nuclear Energy Tokyo Institute of Technology Ookayama 2-12-1-N1-9, Meguro-ku Tokyo 152-8550, Japan Tel:+81-3-5734-1168 Email:yoshida.gonneko@gmail.com
Republic of Korea	Mr Jonghwa LEE Nuclear Data Center Korean Atomic Energy Research Institute Daedeok-Daero 111, Beon-Gil, Yuseong-gu Daejeon 305-600, Korea Tel: Email:leejh033@kaeri.re.kr
United States of America	Mr Toshihiko KAWANO Theoretical Division Los Alamos Natoinal Laboratory 87545 Los Alamos, NM, United States of America Tel:+1-5056640513 Email:kawano@lanl.gov
United States of America	Mr Jack SILANO Lawrence Livermore National Laboratory

	7000 East Avenue Livermore, CA, United states of America Tel:+1 (925)4229914 Email:silano1@llnl.gov
United States of America	Mr Alejandro SONZOGNI Brookhaven National Laboratory P.O. Box 5000 Upton, NY, United States of America Tel: Email:sonzogni@bnl.gov
United States of America	Mr Anton TONCHEV Lawrence Livermore National Laboratory 7000 East Avenue Livermore, CA, United states of America Tel: Email:tonchev2@llnl.gov
IAEA	Ms Shin OKUMURA Nuclear Data Section International Atomic Energy Agency P.O.Box 100 A1400 Wien, Austria Tel:+43 (1) 2600 21727 Email:s.okumura@iaea.org
IAEA	Mr Naohiko OTSUKA Scientific Secretary Nuclear Data Section International Atomic Energy Agency P.O.Box 100 A1400 Wien, Austria Tel:+43 (1) 2600 21715 Email:n.otsuka@iaea.org

Appendix C Agenda

Consultancy Meeting on the

Fission Product Yield Experimental Database

Laboratory for Advanced Nuclear Energy,
Tokyo Institute of Technology, Tokyo, Japan
27–30 May 2019

Agenda (Complete)

27 May 2019 (Monday)

Morning (9:30-12:30)	
Welcome address	K. Takeshita
Announcement	S. Chiba
Introduction	N. Otuka
Election of chairperson and rapporteur, adoption of the agenda, announcement	N. Otuka
Centre activity at the OECD Nuclear Energy Agency	M. Fleming
Completeness survey and statistics of experimental fission product yield data in EXFOR database	S. Okumura
Afternoon (14:00-17:00)	
Experimental activity at CEA	G. Belier
Experimental activity at LLNL	A. Tonchev
Discussion - EXFOR and experiments	All
19:00-	
Social dinner	

28 May 2019 (Tuesday)

Morning (9:30-12:30)	
Uncertainty quantification in the summation method for nuclear reactor antineutrinos	A. Sonzogni
Evaluation of energy-dependent FPY (LANL progress report)	T. Kawano
Evaluation activity at Tokyo Tech	K. Tsubakihara
Afternoon (14:00-17:00)	
Yield evaluation activity at CNDC	N.C. Shu
Calculation of most probable atomic number by Skyrme HF BCS	F. Minato
Study on independent and cumulative fission yield calculations using fission observables taken from EXFOR database	S. Okumura
Discussion - EXFOR and evaluations	All

29 May 2019 (Wednesday)

Morning (9:30-12:30)	
Needs for and requests to fission related data compilation from theory and evaluation viewpoints	S. Chiba

Calculation of fission fragment mass distributions by using a semi-empirical method	J. Lee
Theoretical study on fission in CNDC collaboration network	Y.J. Chen
Discussion - EXFOR and modelling	All
Afternoon (14:00-17:00)	
Drafting of the meeting summary report	All

30 May 2019 (Thursday)

Morning (9:30-12:30)	
Review of the meeting summary	All
Closing address	Chairman

Nuclear Data Section
International Atomic Energy Agency
P.O. Box 100
A-1400 Vienna
Austria

e-mail: nds.contact-point@iaea.org
fax: (43-1) 26007
telephone: (43-1) 2600 21725
Web: http://www-nds.iaea.org/