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Summary Report of the Workshop on

The Experimental Nuclear Reaction Data Database

IAEA Headquarters, Vienna, Austria
6 - 10 October 2014

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December 2014

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ABSTRACT

The Workshop on the Experimental Nuclear Reaction Data Database (EXFOR) was held at IAEA Headquarters in Vienna from 6 to 10 October 2014. The workshop was organized to discuss various aspects of the EXFOR compilation process including compilation rules, different techniques for nuclear reaction data measurements, software developments, etc. A summary of the presentations and discussions that took place during the workshop is reported here.

December 2014

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THE INTERNATIONAL NETWORK OF NUCLEAR REACTION DATA CENTRES

National, regional and specialized nuclear reaction data centres, coordinated by the International Atomic Energy Agency, cooperate in the compilation, exchange and dissemination of nuclear reaction data in order to meet the requirements of nuclear data users in all countries. At present, the following data centres participate in the International Network of Nuclear Reaction Data Centres (NRDC):

NNDC	US National Nuclear Data Center, Brookhaven National Laboratory, Upton, USA
NEA DB	OECD NEA Data Bank, Issy-les-Moulineaux, France
NDS	IAEA Nuclear Data Section, Vienna, Austria
CJD	Russian Nuclear Data Centre, Institute of Physics and Power Engineering, Obninsk, Russia
CNDC	China Nuclear Data Centre, China Institute of Atomic Energy, Beijing, China
ATOMKI	Charged-Particle Nuclear Reaction Data Group, Institute for Nuclear Research (ATOMKI), Debrecen, Hungary
NDPCI	Nuclear Data Physics Centre of India, Bhabha Atomic Research Centre, Trombay, Mumbai, India
JAEA/NDC	Nuclear Data Center, Japan Atomic Energy Agency, Tokai-mura, Japan
JCPRG	Nuclear Reaction Data Centre, Hokkaido University, Sapporo, Japan
KNDC	Nuclear Data Center, Korea Atomic Energy Research Institute, Daejeon, Republic of Korea
CDFE	Centre for Photonuclear Experiments Data, Moscow State University, Moscow, Russia
CNPD	Centre of Nuclear Physics Data, Institute of Nuclear and Radiation Physics, Russian Federal Nuclear Center –All-Russia Research Institute of Experimental Physics, Sarov, Russia
UkrNDC	Ukrainian Nuclear Data Centre, Institute for Nuclear Research, Kyiv, Ukraine

1. Introduction

The Workshop on The Experimental Nuclear Reaction Data Database (EXFOR) was held at IAEA Headquarters, Vienna, Austria from 6 to 10 October 2014. Eleven participants from different Nuclear Reaction Data Centres and four staff from the IAEA attended the Workshop (Appendix II)

The Workshop was organized to discuss various aspects of the EXFOR compilation process including compilation rules, different techniques for nuclear reaction data measurements, software developments, etc. At the beginning the conclusions and the recommendations of the Report NEA/DB/DOC(2014)3 "Statistical verification and validation of the EXFOR database: (n,n'), (n,2n), (n,p), (n,α) and other neutron-induced threshold reaction cross sections" were discussed. Presentations of charged-particle induced reaction cross sections, thick target yields, nuclear astrophysics data, TOF spectra in the resolved resonance region, beta-delayed neutron emission data and photonuclear data measurements provided information on the experimental technique in order to improve the quality of the EXFOR compilations. The need to compile the neutron Kerma factors, status of Kerma factors in EXFOR data library and a list of articles for compilation were discussed during the Workshop. The importance of defining the format (rules) for the compilation of neutron source spectra in EXFOR was emphasized and different proposals were discussed. Software developments related to EXFOR compilation, both stand-alone and online, were presented. In addition to discussions, several compilation and digitization exercises were carried out. The Workshop was concluded with a list of recommendations.

In the welcome address S. Simakov (IAEA) and R. Capote-Noy (IAEA) greeted participants of the Workshop on behalf of the Nuclear Data Section and its Section Head, Robin Forrest, who was not able to attend.

N. Otuka was elected Chairperson of the Workshop and B. Pritychenko Rapporteur. The agenda was discussed and adopted (see Appendix I).

During the Workshop participants gave presentations, led intensive discussions and carried out compilation exercises. The presentations and Working Papers are available at https://www-nds.iaea.org/nrdc/wksp_2014/.

The Nuclear Data Section acknowledged all participants for their cooperation and contribution to this Workshop.

2. Presentation summaries

2.1. Technical remarks on compilation, N. Otuka

Technical remarks from the reviewers were discussed. Many of them are treated as recommendations rather than (proposals of) new rules. Some of them could be further discussed and added to the manuals if appropriate. The goal is to make key information more visible in a simple and concise EXFOR database.

DECAY-DATA - $T_{1/2}$ vs isomeric flag

All half-lives coded under the keyword `DECAY-DATA` with those compiled in the Nuclear Wallet Cards were compared last year, and a list was prepared for cases where more than 50% deviation exists between EXFOR and Nuclear Wallet Cards. Each case was checked with Svetlana Babykina against the source article as well as the ENSDF library (mainly through the LiveChart of Nuclides). Some cases are for straight forward corrections, *e.g.*, simple mistake by the compiler, change in the level order (*e.g.*, 5 hr and 70 min state of ^{120}In). But our response must be discussed for some non-trivial cases (*e.g.*, half-

life reported by the author but without a corresponding state in ENSDF, isomeric flag for which its level ordering is uncertain (*e.g.*, the 17 sec and 6 min state of ^{108}Rh).

Level energies in heavy-ion binary reactions

The level energy (E-LVL) of the residual nucleus (reaction product) is sufficient to characterize the secondary energy of the binary reaction when the projectile is a light particle (*e.g.*, neutron, proton, deuteron). However, both the outgoing nucleus and residual nucleus may not be in their ground states. Therefore, the compiler should provide the level energies of both products (*e.g.*, under E-LVL1 and E-LVL2) when a partial data set is compiled for a binary heavy-ion induced reaction.

Alternative (interdependent) results

Different results for the same quantity obtained in the same experiment by two different methods of analysis (*e.g.*, two data sets obtained by off- and on-line analysis, two data sets from two flight paths.) may be coded in the (1) same subentry by using the multiple reaction formalism, or (2) separated subentries linked to each other by COREL under the keyword STATUS. However, the flags should not be used for this purpose. Also two entries must be linked to each other not by COREL but by a related reference (REL-REF) type O when they are compiled from the same article (*e.g.*, neutron data in area 1 while charged-particle in area C).

Keywords kept in deleted entries

Our current rule asks to keep REFERENCE, TITLE, AUTHOR, INSTITUTE, and HISTORY keywords in the common subentry (001) when an entry is deleted, while the decision is up to the compiler for other keywords. In order to make future maintenance of deleted entries easier (*e.g.*, replacement of a code due to dictionary update), it is recommended to delete unnecessary keywords.

Free text – *Be short and concise!*

The compiler should not perform a simple "copy and paste" operation but rather carefully identify essential key information to be kept as free text. Lengthy free text information may hide the essential free text information. Repetition of the coded information by its expansion in free text should be avoided. A coded form should be adopted instead of free text when possible. When appropriate, free text must be entered under the keyword and code to which it pertains.

Source described under ERR-ANALYS

The EXFOR Formats Manual introduces the keyword ERR-ANALYS as follows: "Explains the **sources** of uncertainties and the values given in the COMMON or DATA". The "source" in this sentence does not mean where the compiler found the uncertainties but what types of error sources are considered (*e.g.*, counting statistics, normalization). Therefore, headings should not be trivialized as "The uncertainty is reported by authors on figure". Some headings (e.g., ERR-DIG) are self-explanatory without any free text information, and it is advisable not to define such headings under this keyword.

Documentation of alterations under HISTORY

In the NRDC 2014 meeting documents, the conclusion was that (1) all important alterations must be described in each affected data subentry in addition to a short summary (*e.g.*, subentry numbers) in the common (001) subentry; (2) compilers will not be urged to document all changes under HISTORY (c.f. Conclusion 28 and Action 12 of the meeting). It is proposed that the documentation of formal corrections (*e.g.*, upper to lower cases, two digits to four digits year) should be avoided in favour of the more important alterations.

2.2. Compilation of beta-delayed neutron emission data, V. Semkova

The main characteristics of the beta-delay neutron emission, the measurement techniques and the compilation rules were discussed in accordance with the decision of the NRDC Meeting 2014 to include beta-delayed neutron spectra from specific precursors in the scope of the EXFOR compilation. The rules for the compilation of the emission probabilities have been revised in order to take into account the probability of the emission of more than one beta-delayed neutron from a precursor.

Beta-delayed neutron emission data are important in many fields of science and applications. Regarding nuclear technologies, beta-delayed neutron are essential for reactor kinetics, safety and decay heat analysis. The new developments of advanced reactors, Accelerator Driven Systems etc., considerably extend: the type of the targets; projectiles and excitation energies involved in the nuclear fission or fragmentation processes; the composition of the fission products and its dynamics during the fuel cycle. In such cases the calculations of the aggregate beta-delayed neutron characteristics based on the data for the individual precursors are more feasible than the measurements. The benchmark experiments are particularly sensitive to a beta-delayed neutron emission. In such experiments β_{eff} is used as a conversion factor between experimental results and calculations, which implies a high accuracy of the beta-delayed neutron emission data. The beta-delayed neutron emission is an important process for nuclear astrophysics. The process may shift the decay path towards lower masses. It also provides neutrons during the freeze-out stage. There is a renewed interest in the beta-delayed neutron data measurements in recent years. Consistent compilation of the beta-delayed neutron emission data measurements will provide an experimental data record in this field.

The compilers are advised to verify the ($Q_\beta > S_{Nn}$) condition for emission of beta-delayed neutrons during the compilation. This condition can be calculated using atomic masses of the isotopes involved. Such data are also available, for example, from the Live Chart of Nuclides (https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html). The decay of a precursor may be followed by a decay chain as presented in Fig. 1 [1]. Thus, the decay of some precursors can be followed by the emission of more than one beta-delayed neutron. The coding rules for the compilation of beta-delayed neutron emission from the specific precursor Z-S-A are defined in **Memo CP-C/429** as follows:

- The delayed neutron emission probability (= probability for emission of at least one beta-delayed neutron), P_n, is coded as: ,PN with units NO-DIM.
- The probability of emission of N beta-delayed neutrons, P_{Nn}, is coded as: ,NUM,PN with units NO-DIM.
- The delayed-neutron emission multiplicity, $<n> = P_{1n} + 2*P_{2n} + 3*P_{3n} + \ldots$ is coded as ,MLT,DN with units PRT/DECAY or PC/DECAY.
- The energy spectrum of delayed neutrons emitted by a specific precursor is coded as: ,PN/DE with units of dimension 1/E.

The precursors' production and separation methods applied at different experimental facilities are shown in Table 1. The following new codes for the keyword METHOD have been proposed in the WP2014- 23(Rev.) NIFIS (neutron induced fission), PIFIS(proton induced fission), HIIFR (heavy-ion induced fragmentation), LIISP (light-ion-induced spallation LCP<=4) documents.

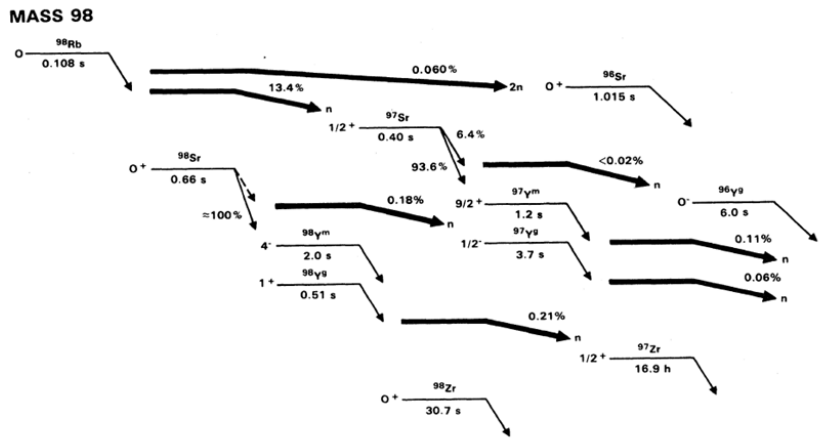


Fig.1. The mass chain beginning with ^{98}Rb and delayed-neutron branching ratios from the Ref. [1].

Determination of the branching ratios and decay characteristics is often performed by analysis of the measured growth and decay curves as presented in Fig. 2 [1].

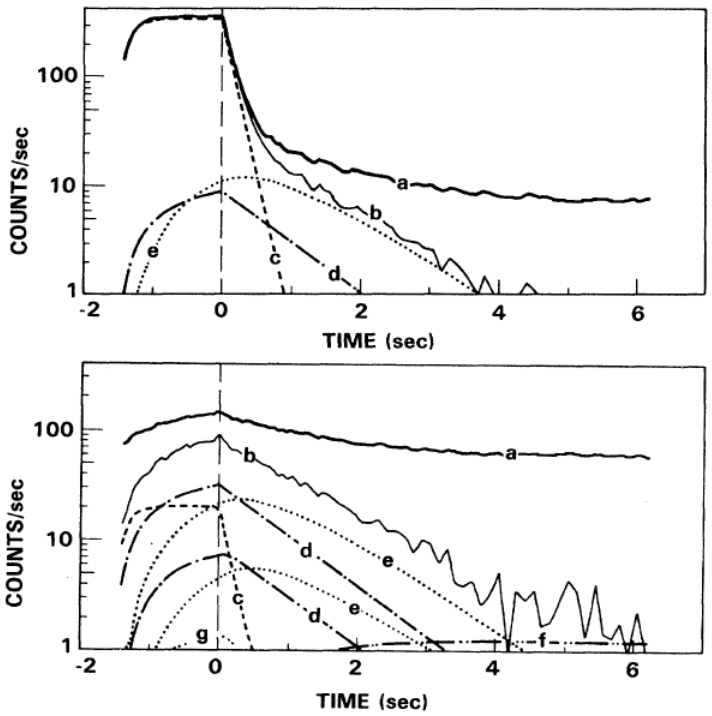


FIG. 4. Growth and decay curves at mass 98 and calculated components; the upper for the neutron, the lower for the beta. *a* denotes the experimental count rate. *b* denotes the count rate after subtraction of constant background. *c* denotes ^{98}Rb (0.108 s). *d* denotes ^{98}Sr (0.66 s). *e* denotes ^{98}Y^{g} (0.51 s). *f* denotes ^{98}Zr (30.7 s). *g* denotes ^{97}Sr (0.40 s). For the beta curve, ^{98}Sr and

Fig. 2 Growth and decay curves from Ref. [1].

Table 1. Production and separation methods of beta-delayed neutron precursors at different experimental facilities.

Facility	*bdn* precursors production reaction	precursors separation method	Compilation Codes
ILL Grenoble France	n_{th} + ^{nat}U	LOHENGRIN recoil mass separator	NIFIS
Univ. Mainz, Germany	n_{th} + ^{nat}U	Chemical separation. techniques	
Studsvik, Sweden	n_{th} + ^{nat}U	OSIRIS isotope separator	
HFBR, Brookhaven Nat. Lab., USA	n(^{56}Fe/Al and Sc/Ti filtered beam) + ^{nat}U	TRISTAN mass separator.	
CERN	p (1GeV) + ^{nat}U	ISOLDE On-line mass sep	PIFIS
GSI, Germany	^{238}U (1 GeV/u) +Be	FRB Fragment separator + (TOF+dE) isotope identification	HIIFR
Holyfield Radioactive Ion Beam Facility (HRIBF) Oak Ridge Net. Lab., USA	p (50 MeV) + ^{nat}U	IRIS-1 + IRIS2 + selective laser ionization	PIFIS
Cyclotron Lab. Of Univ. of Jyvaskyla	p (25 MeV) + Th	Mass separator + penning trap	PIFIS
RIPS at RIKEN	^{40}Ar + ^{nat}Ta	Fragment separator + (TOF+dE) isotope identification	HIIFR
TRIUMF	p (25 MeV) + ^{238}U	Mass separator + Isobar separator	

Many complex detection systems have been developed recently for the simultaneous or coincidence detection of the beta particles, neutrons, gamma rays. Improved detection and acquisition systems have been developed for beta-delayed neutron measurements. A new technique for precise studies of beta-decay using a linear radiofrequency-quadrupole ion trap is described in Ref. [2]. The recoil nucleus and the emitted particles from the radioactive decay have sufficient energy to leave the volume of the trap. After that the charged particles are guided by associated spectrometer systems towards detectors. The kinematics of the process is determined using conservation of energy and momentum.

References:

[1] P.L. Reeder and R.A. Warner, *Phys. Rev* C28 (1983) 1740.
[2] N.D. Scielzo et al., *Nuclear Instruments and Methods Phys. Res.*, A681 (2012) 94.

2.3. Results of the ^{100}Mo(p,2n)^{99m}Tc cross section measurements and possible systematic errors, S. Takacs

The nuclear medicine community is expressing concerns regarding potential shortages of ^{99m}Tc supply based on the fission production of ^{99}Mo from highly-enriched uranium (HEU) to prepare ^{99}Mo/^{99m}Tc generators. As an alternative to a reactor-produced ^{99}Mo/^{99m}Tc generator technology, the direct accelerator production of ^{99m}Tc is considered. However, the most of the available experimental cross section data for ^{100}Mo(p,2n)^{99m}Tc reaction have the same general shape while their amplitudes are different. A large difference of more than a factor of two exists between the lowest and highest datasets.

There are several error sources that could contribute to the differences among the reported datasets:

- Beam current
- Target thickness
- Detector efficiency
- Nuclear decay data
- Problematic peak analysis
- Latent cooling time error

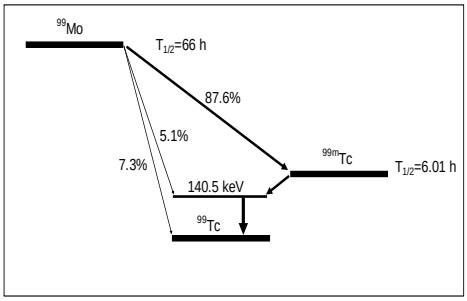


Figure 1. Simplified decay scheme of ^{99}Mo

The most important and most probable error sources are the obsolete nuclear decay data and the data evaluation methods.

The aim of this study was to determine the absolute amplitude of the excitation function of ^{100}Mo(p,2n)^{99m}Tc reaction. For determining of the cross section peaks in spectra the E_γ=140.5keV gamma photons could be used.

The E_γ=140.5keV gamma photons have four different origins, these are:

- Decay of directly-produced ^{99m}Tc (Eq.1)
- Decay of ^{99m}Tc produced during extensive irradiation by decay of ^{99}Mo (Eq.2)
- Decay of ^{99m}Tc produced after end of bombardment (EOB) by decay of ^{99}Mo (Eq.3)
- Prompt gamma radiation that follows the decay of ^{99}Mo (Eq.4)

The corresponding contributions to the total peak area T_γ acquired during a t_m measuring time after a t_b irradiation and t_c cooling time for a given Mo target foil can be described by the following four equations for the above four components respectively.

$$T_\gamma(direct)_D = \varepsilon_d \varepsilon_{\gamma_2} \varepsilon_t N_t N_b \sigma_2 \left(1-e^{-\lambda_2 t_b}\right)\frac{1}{\lambda_2} e^{-\lambda_2 t_c}\left(1-e^{-\lambda_2 t_m}\right) \quad (1)$$

$$T_\gamma(decay)_x = \varepsilon_d \varepsilon_{\gamma_2} \varepsilon_t \frac{f N_t N_b \sigma_1}{(\lambda_1-\lambda_2)}\left[\lambda_1\left(1-e^{-\lambda_2 t_b}\right)-\lambda_2\left(1-e^{-\lambda_1 t_b}\right)\right]\frac{1}{\lambda_2} e^{-\lambda_2 t_c}\left(1-e^{-\lambda_2 t_m}\right) \quad (2)$$

$$T_\gamma(decay)_y = \varepsilon_d \varepsilon_{\gamma_2} \varepsilon_t \frac{f N_t N_b \sigma_1}{(\lambda_1-\lambda_2)}\left(1-e^{-\lambda_1 t_b}\right)\left[e^{-\lambda_2 t_c}\left(1-e^{-\lambda_2 t_m}\right)-\frac{\lambda_2}{\lambda_1} e^{-\lambda_1 t_c}\left(1-e^{-\lambda_1 t_m}\right)\right] \quad (3)$$

$$T_\gamma(direct)_M = \varepsilon_d \varepsilon_{\gamma_1} \varepsilon_t N_t N_b \sigma_1 \left(1-e^{-\lambda_1 t_b}\right)\frac{1}{\lambda_1} e^{-\lambda_1 t_c}\left(1-e^{-\lambda_1 t_m}\right), \quad (4)$$

where: N_t is surface density of target atoms, [atom/cm^2]; N_b is number of bombarding particles per unit time, [proton/sec]; σ_i is activation cross sections, [cm^2]; f is decay branching ratio of ^{99}Mo to ^{99m}Tc; ε_d is detector efficiency; ε_γ is corresponding gamma intensity; ε_t is dead time correction; λ_i is decay constant, [1/sec]; t_b is bombarding time, [sec]; t_c is cooling time, [sec]; t_m is acquisition, [sec]; i is the *i=1* index refers to the ^{99}Mo parent radionuclide, *i=2* is referred to the ^{99m}Tc daughter radionuclide instead.

Following the above data, the independent experiments were performed at 38, 36 and 16 MeV proton energies. The stacked foil technique, proton activation and high resolution gamma-spectrometry methods were used for measuring the cross sections of the ^{100}Mo(p,2n)^{99m}Tc reaction using thin molybdenum foils in metallic form with natural isotopic composition as target. The 36 and 16 MeV

irradiations were new experiments, while the 38 MeV irradiation was done earlier with results published in 2003. This experiment was re-evaluated by using up-to-date decay data and upgraded recommended cross sections for the $^{nat}Ti(p,x)^{48}V$ monitor reaction.

The excitation function of the $^{100}Mo(p,2n)^{99m}Tc$ reaction determined in the three independent irradiations using analytically derived equations and the data evaluation are in perfect agreement. This agreement proves that the main discrepancy among the published experimental cross section data of the $^{100}Mo(p,2n)^{99m}Tc$ reaction could originate from the data evaluation methods.

New experimental results were cross checked by evaluating additional non-interfering reactions $^{nat}Mo(p,x)^{95m}Tc$ and $^{nat}Mo(p,x)^{96g}Tc$ reactions which are in a good agreement with the earlier published data.

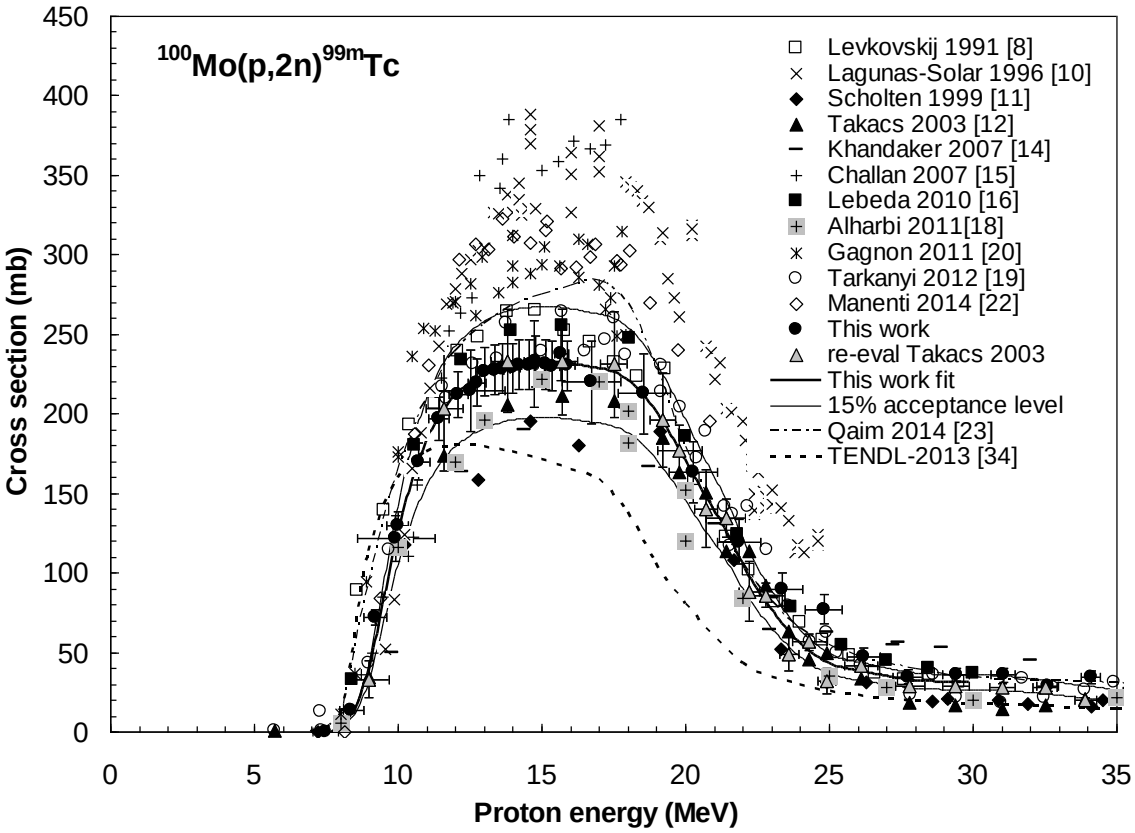


Figure 2. The newly-measured cross section data of the $^{100}Mo(p,2n)^{99m}Tc$ reaction in comparison with the data reported earlier. The thick solid line is a spline fit of the results of this work and the re-evaluated data of published in 2003. Thin lines indicate a ±15% acceptance level.

Detailed information on the experiment and the derived results will be published in Nuclear Instruments and Methods B.

2.4. Definitions of yields. Problems and confusions, S. Takacs

There is some confusion among the different definitions and use of the experimental yields of charged particle induced reactions in everyday use. Different physical quantities like production rates, EOB activity (activity at the end of bombardment) are called yield and the applied units are mixed up as well which makes proper compilation of the reported data difficult.

The yield of a nuclear reaction is defined as the ratio of the number of new nuclei formed in the nuclear reaction to the number of particles incident on the target. This yield is termed as the physical yield, *Y* and the corresponding unit is *particle/particle*.

For charged particle induced reactions the number of incident particles can also be expressed by the corresponding charge of the number of bombarding particles. So, the unit of the yield can be *particle/charge, particle/C, particle/μAh etc.* (where the μAh represents charge unit and not μA*h).

The yield is always:

- target specific
- depends on the energy of the bombarding particles
- a time independent quantity.

There are fewer problems in the compilation of yields of stable reaction products which are always expressed in terms of the number of product particles per number of beam particles or in units of electric charge in case of charged particle beam. Since the reaction products are stable, the yield is "time independent".

Although the yield of a reaction with radioactive products can be expressed in the same manner, in the every-day practice some other physical quantities such as production rate or activity are used as yield, and this is a major source of confusion. Description on definitions of the used "experimental yield" is often insufficient or even missing in the literature. For radioactive reaction products it is widely accepted that the number of produced particles is determined by the measured activity. The unit of yield then is expressed as *Activity/Charge* (MBq/C, MBq/μAh, (μAh is a charge unit). In an experiment not the yield but the number of decays is measured directly. The main problem arises from the fact that the activity is not time independent, and several time-dependent corrections should be applied to the measured activity in order to determine the proper number of the produced particles.

Experimental data of more than 800 works, which present experimental excitation functions and thick target yields were determined by measurements of activities followed by charged-particle irradiation, are already included in the EXFOR library.

In order to retrieve and analyse experimental thick target yields of a specific type from EXFOR efficiently and properly, each experimental data set must be properly tagged not only by the reaction type (*i.e.*, target, beam particle, radioisotope product), but also by the definition of the yield. However, the large variety of yield nomenclature that can be found in the literature makes compilation work difficult.

Thin- and Thick-Target Yield

Thick-target Yield is defined as the yield of a reaction measured on a target with such a thickness in which the energy of the incident beam degrades to below the threshold energy of the reaction.

Thin-target yield is defined as the yield of a reaction measured on a target with such a thickness in which the energy of the incident beam degrades less significantly and the energy of the particles passing through the target is above the threshold energy of the reaction.

Production and decay rates

For any target thickness the number of reaction product formed during irradiation can be described as follows. If the cross section to produce the isotope *i* is $\sigma_i(x)$, the **total number** of the produced isotope *i* after irradiation time *t* is *N(t)* (not considering any decay, just production).

$$\approx tI_0 \int_{E_L}^{E_0} dE \left(-\frac{dE}{\rho dx} \right)^{-1} \sigma_i(E)(S/Ze) \qquad (1)$$

$$N(t) = tI_0 y, \qquad (2)$$

where E_L is the beam energy at the exit of the sample, *-(1/ρ)(dE/dx)* is the stopping power, and *y* is the number of the isotope *i* produced by deposition of unit charge (e.g., 1 C). The quantity ***y*** *(in nuclides/C)* describes the amount of produced particles in the target per unit charge; therefore it is called **production rate**. This quantity can be defined for both stable and radioactive products and it is time independent.

If the isotope *i* is radioactive (with decay constant λ), the **total number** *N*(t)* of the radioisotope *i* present in the target after irradiation time *t* satisfies the following differential equation

$$\frac{dN^*(t)}{dt} = I_0 y - \lambda N^*(t) \qquad (3)$$

and its solution is

$$N^*(t) = I_0 y \frac{1 - e^{-\lambda t}}{\lambda}. \qquad (4)$$

Experimentally, the activity of the produced nuclides is measured and the production rate can be deduced from the measured activity *A(t)*

$$A(t) = \lambda N^*(t) = I_0 y \left(1 - e^{-\lambda t}\right) \equiv I_0 a(t), \qquad (5)$$

where *a(t)* defined as the **decay rate** or **specific activity** per unit current *(Bq/μA)* at the irradiation time *t*. The decay rate is a time dependent quantity.

The limit of equation (5) at $t \to \infty$ and its derivate at *t=0* have special importance.

For a very long irradiation time (i.e., *t* much longer than the half-lives of the reaction product) the value of the $\left(1 - e^{-\lambda t}\right) \approx 1$, and the production rate and decay rate of the reaction product are in equilibrium.

$$A(t \to \infty) = I_0 y \equiv I_0 a_{sat}, \qquad (6)$$

where a_{sat} defined as the **saturation decay rate** or **saturation specific activity** per unit current *(Bq/μA)* after a very long irradiation time.

The curve of the growing activity of the produced radionuclide versus irradiation time described by equation (5) is not a straight line. From Eq. (5), the time evolution of the activity during irradiation is described as:

$$\frac{dA(t)}{dt} = I_0 \lambda y e^{-\lambda t} \equiv I_0 \alpha(t) \qquad (7)$$

$$\alpha(t = 0) = \lambda y. \qquad (8)$$

Equation (8) describes the slope of the growing activity curve versus time. The value of $\alpha(t)$ at *t=0* has a special importance, it is the *production rate (y)* times *decay constant (λ)* which gives the decay rate at *t = 0*. This time-independent quantity with units of Bq/C is defined as the **physical yield**.

Quantities defined in EXFOR	Symbol		Typical unit
hick target product yield	y	,PY,,TT/CH	nuclei/μC, nuclei/μAh
end-of-bombardment thick target yield	a(t)	,TTY,,EOB	MBq/μA
saturation thick target yield	a_{sat} $a(t\rightarrow\infty)$	,TTY,,SAT	MBq/μA
physical thick target yield	α_{phys} a(t=0)	,TTY,,PHY	MBq/C

2.5. Neutron Kerma factors in EXFOR: actual status and missing published results, S. Simakov

KERMA (*K*) is a Kinetic Energy Released in Matter per mass unit, $K = dE/dm$. *K* accounts for the energy deposition from all charged ejectiles (*p, d, α, e*) of nuclear reaction including heavy recoils which deposit their energy locally. However, it excludes neutral reaction products (*n, γ, …*) which deposit energy non-locally, i.e. at "large" distance from collision.

The KERMA factor k_f is defined as KERMA per incident particle fluence $\Phi = N/Area$:

$$k_f = K/\Phi.$$

k_f is a product of mean ejectile energy E_j and production cross section σ_j summed over all reaction channels *j* and is normalized per target atom mass *M :*

$$k_f(E) = \sum_j k_j = \frac{\sum_j E_j\, \sigma(n, xj)}{M}.$$

Units of KERMA factors are *Energy/Mass*Area* and expressed either in *J/kg* m^2 and *Gy* m^2 (SI) or in *erg/g* cm^2 and *rad* cm^2 (CGS).

KERMA factors are used:

- In Reactor and Radiation Material Physics: Kerma factors after partitioning between electron ionization losses and atom recoils energies gives the Damage Energy that defines the number of Primary Kick-off Atoms (PKA) shifted from the lattice sites and finally the displacement-per-atom probability or dpa-cross-sections. This is, in particular, a point of interest for the IAEA CRP on "Primary Radiation Damage Cross Sections": https://www-nds.iaea.org/CRPdpa/;
- In Medicine: Neutron Kerma factors are used to predict the ionization coursed by the secondary charged particles from neutron reactions in the human tissue or in Tissue Equivalent Plastics (TEP) such as A-150;
- More generally, for the Validation of Evaluated cross section Libraries: KERMA provides additional data for confidence.

EXFOR Documents have at the moment the following information about KERMA factors:

- LEXFOR (IAEA-NDS-208, rev 2011/01) has no information about KERMA at all;
- EXFOR Basics (IAEA-NDS-206, June 2008) defines in Dictionary 236 the specific *Kerma factor* parameter in subfield SF6 as ,KER ;
- EXFOR Protocol (IAEA-NDS-0215, rev 2014/05) categories a compilation scope for Kerma as "voluntary compilation (B)" and "Kerma factors (integral data only)".

Currently EXFOR contains the measured K_f data published by following authors:

- U. Schrewe et al., Entry 22507: results from paper presented at ND-1997 Trieste for 8 elements and 3 materials (however the author' data were wrongly converted into fGy*m^2 units and likely these data have to be superseded by those published in Phys. Med. Biol. 45, 651 (2000));
- S. Benck et al., Entry 22811: (Al) and 22807.45 (Si);
- E. Raeymackers et al., Entry 22942: Bi and U, total and partial K_f;
- M.A. Lone et al. Entry D0592.003: Kerma-rates in Air at 125 cm from Be(d,xn) source.

After an overview of Kerma data available in EXFOR and published in the literature (Table), the following proposals have been made:

- compile articles with neutron KERMA factors listed in Table;
- revisit and eventually correct Entry 22507 (include data from the later publication, correct units) and Entry 22811 (correct main reference).

Table. The KERMA data published in literature but missing in EXFOR

Target Reaction	Energy	Source Lab	Reference	Recommendation
C, Mg, Fe	14.7 MeV	D-T Univ. of Kansas	C. Wuu and L. Milavickas, "Determination of the Kerma Factors in Tissue-equivalent Plastic. C, Mg, and Fe for 14.7 MeV Neutrons," **Med. Phys. 14(6), 1007 (1987)**	compile in EXFOR
C, Mg, Fe	15.0 MeV	D-T LLNL	E. Goldberg, D.R. Slaughter and R.H. Howell, "Experimental Determination of Kerma Factors at E ≈ 15 MeV", **LLL Report UCID-17789, 1978**	compile in EXFOR
C	14.1 MeV 15, 17.8 MeV 19.8 MeV	RTNS-I LLNL	P.M. DeLuca, Jr., H.H. Barschall, R.C. Haight, and J.C. McDonald, ''Kerma factor of carbon for 14.1 MeV neutrons', **Radiation Research 100, 78–86 (1984)** P.M. DeLuca, Jr., H.H. Barschall, R.C. Haight, and J.C. McDonald, ''Measured neutron carbon kerma factors from 14.1 MeV to 18 MeV,'' *Proc. of 5th Symp. Neutron Dosim., v I:* Luxembourg, 1985, **No. EUR 9762 EN, pp. 193–200**. P.M. DeLuca, Jr., H.H. Barschall, M. Burhoe, and R.C. Haight, ''Carbon kerma factor for 18- and 20-MeV neutrons,'' **Nucl. Sci. Eng. 94 (1986) 192-198**	compile in EXFOR compile in EXFOR
O, Al, Si	15, 17.5, 18.1, 19.1 MeV	RTNS-I LLNL	P.M. DeLuca, H.H. Barschall, H.H. Sun, R.C. Haight, 'Kerma factor of Oxygen, Aluminium and Silicon for 15 and 20 MeV neutrons **Radiat. Protect. Dosimetry 23 (1988) 27**	compile in EXFOR
C	14.1 MeV	D-T LLNL	R.C. Haight, S.M. Grimes et al. **NSE 87 (1984) 41**	compile in EXFOR
H C, N,O	25.8, 50.0, 63.1 MeV 27.4, 39.7, 60.7 MeV	^{7}Li(p,n) Crocker Nucl. Lab. Uni. of CA	J.L. Romero, F.P. Brady, and T.S. Subramanian, ''Neutron induced charged particle spectra and kerma from 25 to 60 MeV,'' **Santa Fe - 1985, v. 1, pp. 687–699**	compile in EXFOR

Target Reaction	Energy	Source Lab	Reference	Recommendation
C, O, Si C, Mg, Fe	18, 23, 25 MeV 18, 23, 25 MeV (Data on Graph)	T(d,n) Uni. of Wisconsin	C.L. Hartmann, P.M. DeLuca, Jr., and D.W. Pearson, 'Measurement of neutron kerma factors in C, O, and Si at 18, 23, and 25 MeV,' **Radiat. Protect. Dosim. 44, 25 (1992)** C.L. Hartmann, P.M. DeLuca Jr., D.W. Pearson, 'Measurement of C, Mg and Fe Kerma Factors and the $^{19}F(n,2n)^{18}F$ Cross Section for 18 to 27 MeV Neutrons' **ND-1991, Jülich, pp. 589-591** C.L. Hartmann, "Measurements of Neutron Kerma Factors at 18, 23 and 25 MeV", **Ph.D. Thesis, University of Wisconsin, Madison, 1991**	compile in EXFOR
Mg, Si, Fe O	25 to 85 MeV 34 to 66 MeV	WNR by ToF LANL and PSI	W.D. Newhauser, "Neutron Kerma Factor Measurements in the 25 MeV to 85 MeV Neutron Energy Range", **Ph.D. Thesis, University of Wisconsin, Madison, 1995** here **Abstract: Medical Physics 22(1995)2128**	compile in EXFOR
C C	42.5, 62.7, 72.8 MeV 26.5 - 72.8 MeV	Cyclotron Li(p,n) Louvain-la-Neuve	I. Slypen, V. Corcalciuc and J.P. Meulders, 'Kerma values deduced from neutron-induced charged-particle spectra of carbon from 40-MeV to 75-MeV' **Phys. in Med. and Biol. 40, 73–82 (1995)** I. Slypen, S. Benck, J.P. Meulders, V. Corcalciuc, 'Experimental partial and total kerma coefficients for carbon deduced from microscopic cross sections at incident neutron energies below 75 MeV" **Phys. in Med. and Biol. 45 (2000) 577**	compile in EXFOR compile in EXFOR
H, C, O, N, A-150, TE-M, TE-P, H_2O, ICRU muscle, H	3.0 to 72.8 MeV 29.0 to 72.8 MeV	Cyclotron Li(p,n) Louvain-la-Neuve	J.P. Meulders, S. Benck, I. Slypen, V. Corcalciuc, 'Experimental kerma coefficients of biologically important materials at neutron energies below 75 MeV', **Medical Physics 27, 2541 (2000)** V. Corcalciuc, S. Benck, R. Malu, J.P. Meulders, I. Slypen, "Experimental hydrogen kerma factors for incident neutron energies from 25 to 75 MeV, **Phys. in Med. and Biology 44(1999)719**	compile in EXFOR compile in EXFOR
$^{12}C(n,n'3\alpha)$	11 - 35 MeV	$^{9}Be(d,n)$ Louvain-la-Neuve	B. Antolkovic, L. Slaus and D. Plenkovic, **"**Experimental Determination of the Kerma Factors for the Reaction $^{12}C(n,n'3a)$ at E_n = 10 - 35 MeV", **Radiation Research 97(1984)253**	compile in EXFOR
$^{12}C(n,n'3\alpha)$	11.9 -19.0 MeV	D(d,n), T(d,n) PTB	B. Antolkovic, G. Dietzes and H.Klein, "Secondary Alpha Particle Spectra and partial Kerma Factors of the reaction n+ ^{12}C -> n + 3α", **Radiation Protect. Dosimetry 44(1992)31**	compile in EXFOR
C, N, O, Mg, Al, Si, Fe, Zr, AlN, Al_2O3, $Si0_2$, A-150 C and A-150 plastic	5, 8, 15, 17, 34, 44, 66 MeV 26.3, 37.8 MeV	D(d,n) T(d,n) 5-17MeV PTB $^{9}Be(p,xn)$ 34-66MeV PSI $^{9}Be(p,xn)$ PSI, Switzerland	U.J. Schrewe, W.D. Newhauser, H.J. Brede, P.M. DeLuca, "Experimental kerma coefficients and dose distributions of C, N, O, Mg, Al, Si, Fe, Zr, A-150 plastic, Al_2O_3, AlN, SiO_2 and ZrO_2 for neutron energies up to 66 MeV", **Phys. Med. Biol. 45, 651 (2000)** H. Schuhmacher, H.J. Brede, R. Henneck, A. Kunz, H.G. Menzel, J.P. Meulders, P. Pihet, U.J. Schrewe, 'Measurement of neutron kerma factors for carbon and A-150 plastic at neutron energies of 26.3 and 37.8 MeV' **Phys. Med. Biol. 37, 1265–1281 (1992)** U.J. Schrewe, H.J. Brede et al. 'Determination of Kerma Factors for A-150 plastic and Carbon for neutron energies above 20 MeV' **ND-1991, Jülich, p. 586-594**	compile in EXFOR compile in EXFOR

Target Reaction	Energy	Source Lab	Reference	Recommendation
Mg Al C	13.9, 15.0, 19.0 MeV 13.9, 15, 17, 19MeV 15, 17 MeV	T(d,n) PTB	G. Buhler, H.G. Menzel, H. Schuhmacher, 'Neutron kerma factors for magnesium and aluminium measured with low-pressure proportional counters' **Phys. Med. Biol. 31 (1986) 601** G. Buhler, H.G. Mentzel, H. Schuhmacher, S. Guldbakke, **5th Symp. Neutr. Dos., Munich, EUR-9762, p. 309 (1985)**	compile in EXFOR
C, A-150	13.9-20 MeV	T(d,n) PTB	P. Pihet, S. Guldbakke, H.G. Menzel and H. Schuhmacher, 'Measurement of kerma factors for carbon and A-150 plastic: neutron energies from 13.9 to 20.0 MeV' **Phys. Med. Biol. 37, 1957 (1992)**	compile in EXFOR
N, O, Ca	18-26 MeV	?? Ohio Univ.	M.S. Islam, R.W. Finlay, J.S. Petler, J. Rapaport, R. Alarcon and J. Wierzbicki, 'Neutron scattering cross sections and partial kerma values for oxygen, nitrogen and calcium at $18 < E_n < 60$ MeV' **Phys. Med. Biol. 33, 315 (1988)**	compile in EXFOR
C	14.6 MeV	T(d,n) RTNS-II, LLNL	J.C. McDonald, ''Calorimetric measurements for the carbon kerma factor for 14.6-MeV neutrons,'' **Radiation Research 109 (1987) 28–35**	compile in EXFOR
C total and partial	96 MeV	^{7}Li(p,n) TSL Uppsala.	B.E. Bergenwall, A. Atac and S. Kullander, 'Experimental kerma coefficients for carbon deduced from microscopic cross sections at 96MeV incident neutron energy", **Phys. Med. Biol. 49, 4523 (2004)** P. Mermod, J. Blomgren, C. Johansson, A. Ohrn, M. Osterlund, S. Pomp et al. "95 MeV neutron scattering on hydrogen, deuterium, carbon, and oxygen", **Phys. Rev. C 74, 054002 (2006)**	compile in EXFOR has to be added to 23030
C elastic and ineal k_f	E = 16.5 – 22 MeV	T(d,n) gas target University Uppsala.	N. Olsson, B. Trostell, E. Ramstroem, "Cross sections and partial KERMA factors for elastic and inelastic neutron scattering from Carbon in the energy range 16.5 - 22.0 MEV", **Int. Conf. Nucl. Data Sci. & Techn., Mito, 1988, 1045**	has to be added to 22098
?	??	???	L.S. August, P. Shapiro, R.B. Theus, Cross Sections and Yields for High Energy Neutron Source Reactions. **National Bureau of Standards Report NBSIR 77-1279, pp. 31-34, 1977**	???

2.6. Some problems of photonuclear data compilation and evaluation, V. Varlamov

Experimental photonuclear data research is a complicated problem for several reasons:

- absence of intensive monoenergetic photon beams (experimentalists are forced to use special methods for production of quasimonoenergetic photon beams or to use special mathematical methods for unfolding the results obtained using electron bremsstrahlung);
- photoneutron reaction contribution as a main part of Giant Dipole Resonance (experimentalists are forced to detect neutrons using detectors with low efficiency and not sufficient accuracy for measurements of neutron energies);
- direct methods of neutron registration frequently lead to missing contributions of accompanying protons (because of low and close values of the correspondent reaction thresholds);
- activation methods have many restrictions due to the properties of final nucleus decay.

As a result we have many data with significant systematic uncertainties obtained with the different experimental measurement methods and/or data processing procedures. Therefore, there are many problems in photonuclear data compilation and evaluation.

1. **Total reaction SF1(G,SF3)SF4,,SIG) definition**

In many sources of information a definition (γ, Sn) is used for neutron yield reaction (γ,Sn) = (γ,1n) + 2(γ,2n) + 3(γ,3n) - SF1(G,X)0-NN-1,,SIG), but in many others – for total photoneutron reaction (γ,Sn) = (γ,1n) + (γ,2n) + (γ,3n) - SF1(G,X)0-NN-1,**UNW**,SIG).

Therefore, the compiler should be very careful **(γ, Sn)**.

2. **Partial reaction SF1(G,N(2N)(3N))SF4,,SIG) definition**

In experiments with the direct identification of the reaction via final nucleus **SF4** using the method of induced activity the final nuclei are different, having different spectra of de-excitation g-quanta and, therefore, SF4 defines SF3: (γ,1n), (γ,2n), (γ,3n), etc.
In experiments using the direct neutron multiplicity sorting methods, (γ,1n) and (γ,2n) reactions are separated by detection of neutrons with different energy and therefore **SF3** defines SF4. In such cases, reactions with different outgoing particles can occur at the same energies: not (γ,1n) - SF1(G,N)SF4,,SIG) but (γ,1n) + (γ,1np) – [SF1(G,N)SF4,,SIG)+ SF1(G,N+P)SF4p,,SIG)] and possibly more [(γ,1n) + (γ,1n1p) + (γ,1n2p)], etc.

Therefore, the compiler should be very careful in partial reaction definition.

3. **Systematic disagreements of data obtained with bremsstrahlung and quasimonoenergetic annihilation photons.**

3.1"Direct" measurement versus Inverse unfolding

One can measure only the reaction yield Y – folding of a cross section investigated with continuous γ-spectrum using bremsstrahlung. The cross section is the result of solving the inverse unfolding task using one of the special mathematical methods (photon difference, inverse matrix, least structure, Penfold–Leiss, Tikhonov regularization, reduction, etc.) in accordance with the quasimonoenergetic presentation of effective γ–quanta spectrum with a definite energy resolution equal to the width of line in effective γ–spectrum.

An alternative to bremsstrahlung unfolding "direct" method of quasimonoenergetic annihilation photons is the three step difference procedure: i) measurement of reaction yield Yp with spectrum as the sum of photons from positron annihilation and bremsstrahlung, ii) measurement of yield Ye with photons from electron bremsstrahlung, iii) subtraction of second result from the first one and definition the result Yp-Ye as cross section with resolution equal to annihilation line. However, this is impossible: difference between two results with bad resolution could not produce results with good resolution. If yes – that would be the "perpetuum mobile". As a result almost all cross sections obtained using annihilation photons look like smoothed version of those obtained using the bremsstrahlung unfolding.

The difference of two yields is yield Yp-Ye = Y, not a cross section. Additional unfolding with simulated γ-spectrum leads to a cross section close to that obtained using bremsstrahlung unfolding. The real resolution of annihilation photons experiments is 4-6 time worse in comparison with annihilation line width.

Therefore, there are the problems for compilers and evaluators: if Yp-Ye is interpreted as cross section (INC-SOURE) (QMPH)) its resolution should be described as noticeably worse. If Ys-Ye = Y (not (QMPH) but not (BRST)) additional unfolding is needed.

3.2 Systematic disagreements of partial photoneutron reaction cross sections obtained using annihilation n photons in different laboratories.

The majority of partial reaction cross sections was obtained using annihilation photons at the Livermore (USA) and Saclay (France) laboratories. Both laboratories employed the same assumption that the neutron spectra of (γ, 1n), (γ, 2n) and (γ, 3n) reactions, and the methods for neutron kinetic energy measurement used for multiplicity determination are quite different. Systematic discrepancies (up to ~ 100 %) in partial photoneutron reaction cross sections are well–known: in many cases for the same nuclei the (γ, 1n) reaction cross sections are noticeably larger at Saclay, but the (γ, 2n) cross sections vice versa at Livermore.

Some objective criteria for data reliability were found out for the transitional multiplicity functions – the ratios of the definite partial reaction cross sections σ(γ, in) to the neutron yield reaction cross section σ(γ,Sn) = σ[(γ,1n) + 2(γ,2n) + 3(γ,3n) + …]. According to the definition F_2 = σ(γ,2n)/σ(γ,Sn) cannot exceed 0.50 in magnitude: larger value means a physically incorrect determination of (γ, 2n) and of (γ,1n) reactions cross sections. The regions of physically unreliable values $F_2 > 0.50$ (too large σ(γ,2n)) correlate with unreliable negative values (too small) in the σ(γ, 1n) reaction cross section. Correspondingly, F_1 should < 1.00, $F_3 < 0.33$, $F_4 < 0.25$, $F_5 < 0.20$, $F_6 < 0.17$, $F_7 < 0.14$, etc. If these functions (ratios) or Fi go beyond absolute limits mentioned that means that neutron multiplicity sorting was erroneous.

Investigations of ^{90,91,94}Zr, ^{115}In, $^{112–124}$Sn, ^{159}Tb, ^{165}Ho, ^{181}Ta, ^{188,189,190,192}Os, ^{197}Au and ^{208}Pb experimental data obtained using neutron multiplicity sorting show that as a rule of thumb they do not satisfy proposed criteria of data reliability. A new method of evaluation based on the well–tested data combined with a theoretical model of photonuclear reactions was proposed as a method of satisfied introduced criteria. Initial data include experimental neutron yield reaction cross sections σ^{exp}(γ, Sn) and neutron multiplicity sorting functions calculated in the model F_i^{theor}: $\sigma^{eval}(\gamma,in) = F_i^{theor} \bullet \sigma^{exp}(\gamma,Sn)$. That means that the competition of partial reactions (γ,1n), (γ,2n), (γ,3n),… is in accordance with equations of the model and the correspondent sum of evaluated partial reaction cross sections – $\sigma^{eval}(\gamma,Sn) = \sigma^{eval}(\gamma,1n) + 2\sigma^{eval}(\gamma,2n) + 3\sigma^{eval}(\gamma,3n)$ – is equal to the experimental σ^{exp}(γ,Sn).

Data evaluated using this approach noticeably disagree with both Saclay and Livermore data but agree with the data obtained using alternative activation method.

That means that many well-known experimental partial photoneutron reaction cross sections are not reliable and should be re-measured and/or evaluated using appropriate data reliability criteria.

2.7. Compilation of neutron data in the resolved resonance region measured by TOF method. Spectrometers' response function, V. Semkova

The nuclear data for the neutron-induced reaction in the resonance range have been extensively compiled in EXFOR. However, in many cases only the resonance parameters are reported. Some experimentalists have provided also raw data such as transmission and capture yields. The time-of-flight spectra are valuable for future analysis (reanalysis, simultaneous analysis) and compilation of them has been desired of the NRCD community for many decades. Proper analyses require additional experimental information such as sample thickness (affecting self- shielding, multiple collisions) and response function (RF). The spectrometers' response functions are needed for comparison of data measured at different experimental facilities. The resolution broadening has to be applied to evaluated data in order to compare experimental data with the evaluation. A template was developed at the Consultants' Meeting "EXFOR Data in Resonance Region and Spectrometer Response Function" that

includes all essential information for a time-of-flight measurement. The template is available at the https://www-nds.iaea.org/index-meeting-crp/CM-RF-2013/ webpage and compilers are advised to use it in order to request and compile information from the experimentalists. In addition, the main uncertainty components have to be identified and the correlated and uncorrelated components have to be reported separately, preferably based on the AGS-concept.

During the Meeting, possibilities for the compilation in EXFOR of the TOF spectrometer response functions which is required for the neutron spectroscopy applications were discussed. The broadening components and the intrinsic widths of resonances are usually non-Gaussian and, therefore, need to be taken into account by a full convolution of the corresponding distributions. The RF consists of a number of independent contributions: the distribution of the pulsed charged particle beam, serving as a start of the time-of-flight measurement; the neutron producing target and moderator ensemble; interactions in the sample and detector ensemble; electronic noise from the signal processing and data acquisition system; the widths of the data binning. In the R-matrix codes (SAMMY, REFIT), the RFs are presented by analytical expressions that contain a number of components. The parameterization for the specific facility/experiment is usually obtained by a fitting procedure. Some experimentalists have recently submitted the analytical functions and the fitting parameters for their experiments to EXFOR. For some facilities the RFs have been determined by Monte Carlo simulations. While a parameterized analytical function may in some cases be an adequate description of a RF, nowadays Monte Carlo simulations can provide the RF in a detailed way. Storage of the RF in EXFOR in numerical form or possibly even as input file for a Monte Carlo description or R-matrix analysis codes would preserve this information in a sustainable way. The following recommendations for the development of the RF compilation rules in EXFOR were discussed during the Meeting:

- Best solution for target/moderator: matrix of (En, d) (use a dense enough grid for En and for d);
- Flexibility: allow also (En, t) or even (En, E') matrices (code input is often as (En, t));
- Flexibility: allow additional components in either time (pulse width), distance, or energy;
- For existing measurements, also supply support for analytical expressions;
- Possibility to associate several RFs with a measurement (for example, target/moderator + pulse width + sample/detector);
- Define unique and informative tags for RFs, allowing for possible upgrades of a particular RF.

2.8. Neutron source spectra format. EXFOR formats and rules: present status and proposals for neutron source data storage, O. Gritzay

The following proposal for the source spectral information storage in EXFOR was suggested in INDC(NDS)-0590 to introduce into EXFOR **new special ENTRY/SUBENTRY** for neutron spectrum.

New: type of spectrum and its characteristic should be entered **in numeric data type** using **separate SUBENTRY** or **ENTRY** for neutron spectrum if the spectrum is commonly applied to measurements performed at the neutron source.

1. Use special form of **REACTION** to define the neutron source (see table below) with the proper modifier **SPD** to REACTION **SF8**.
2. Use **DATA** to enter **the numerical spectral data.**
3. **Data that are averaged** over broad incident-projectile energy spectrum and entered into the EXFOR system, should be labelled by the keyword **INC-SOURCE** with use of all relevant keywords from the Inc-Source Dictionary (#19) and **the cross-reference** to the EXFOR entry/subentry with **these numerical spectral data.**
4. This cross-reference must be coded as an eight-digit integer

Unfortunately, this proposal was not realized.

We continue to use the following rules:

LEXOR:

Spectrum Average

Cross sections averaged over a broad incident-projectile energy spectrum may be entered into EXFOR using the proper modifier to REACTION SF8. The type of spectrum and its characteristic should be entered in free text under the information-identifier keyword INC-SPECT.

The following spectrum types are defined:

1. **Maxwellian Averag**e: Modifier MXW
2. The spectrum temperature should be given, if known. For thermal Maxwellian spectrum averaged data, see **Thermal Neutron Energies**.
3. **Epithermal Spectrum Average**: Modifier EPI
4. The energy quoted will be, typically the low energy cut off.
5. **Fission-Neutron Spectrum Average**: Modifier FIS
6. For details, see **Fission-Neutron Spectra**.
7. **Fast Reactor Spectrum Average**: Modifier FST
8. **Bremsstrahlung Spectrum Average**: Modifier BRA
9. The energy quoted will be, typically, EN-MAX, or EN-MIN with EN-MAX.
10. **Average over "good resolution" Bremsstrahlung Spectrum**: Modifier BRS
11. The energy quoted will be, typically, EN with EN-RSL.
12. **Spectrum Average (unspecified Spectrum)**: Modifier SPA
13. Used for all other spectra, *e.g.*, thermal reactor spectra. Care should be taken to compile only those data that would be of value to the user of EXFOR.

EXFOR Formats Manual (Chapter 7):

INFORMATION-IDENTIFIER KEYWORDS AND CODING RULES

INC-SPECT. Provides information on the characteristics and resolution of the incident-projectile beam. See also **LEXFOR, Incident-Projectile Energy**.

1. Must be present when a spectrum average modifier (*e.g.*, MXW, SPA, or FIS) is present in REACTION SF8. See also **LEXFOR, Spectrum Average**. Otherwise its use is optional. No coded information.

However even if the data for the incident spectrum are provided in the compilation the spectrum retrieval is not easy and plotting is not possible with the current compilation rules.

Free text presentation of the incident spectrum makes the search difficult and plotting capabilities of the retrieval system cannot be applied. Such presentation is often lengthy. For example, in Subentry 22850001 it has 699 lines (from 769 lines); in Subentry 23075001 it has 230 lines (from 326 lines). The length of the text can be up to thousands of lines in case of spectra for average cross sections measured by proton recoil counters using the NFBT. If several spectra are compiled in free text it is very difficult to find where one ends and the next spectrum starts. is not convenient.

Based on the proposal given in the beginning the following revision of the LEXFOR manual is proposed:

Spectrum Average

Cross sections averaged over a broad incident-projectile energy spectrum may be entered into EXFOR using the proper modifier to REACTION SF8. The type of spectrum and its characteristic should be entered **in free text** under the information-identifier keyword INC-SPECT or **in numeric data type** using separate special SUBENTRY or ENTRY.

Data that are averaged over broad incident-projectile energy spectrum and entered into the EXFOR system, should be labelled with the code DEP under the keyword STATUS, if the spectrum is entered into the EXFOR system in numeric data type.
In these special SUBENTRY/ ENTRY
1) use a special form of **REACTION** to define the neutron source (see table below) with the proper modifier **SPD** to REACTION **SF8**;
2) use **DATA** to enter **the numerical spectral data.**

Dependent Data

Data that are deduced by a trivial operation from other data sets entered into the EXFOR System or data, that are averaged over broad incident-projectile energy spectrum entered into the EXFOR system in numeric data type (using special SUBENTRY/ENTRY) should be labelled with the code DEP under the keyword STATUS. Free text under STATUS and/or ANALYSIS should give information as to how the data were deduced. Cross reference to the EXFOR entries from which the data were deduced or to the EXFOR entries with spectrum in numeric data type must be coded as an eight-digit integer following the code.

The EXFOR rules for INC-SPECT and INC-SOURCE remain the same.
The following coding is proposed in order to define the neutron source by REACTION:
REACTION is a reaction by which neutrons are generated.
SF1 – target, SF2 – incident particle (SF2=0 for spontaneous fission),
SF3 – outgoing particle/product X (SF3=F for spontaneous fission),
SF4 – outgoing neutron 0-NN-1,
SF6 – Differential with energy of outgoing particle (neutron),
SF8 – SF8=SPD – Spectrum Description, SPD/REL Relative data (ARB-UNITS)
SF9 – CALC/EXP Calculated/Experimental data

Name of neutron source	In INC-SPECT	SF1-SF8 in REACTION in SubEntry with SF8= SPD
Alpha-Beryllium	A-BE	4-BE-9(A,X)0-NN-1,, DE,,SPD
Americium-Beryllium ns	AM-BE	4-BE-9(A,X)0-NN-1,, DE,,SPD ?
Spont. fission of Californium-252	CF252	98-CF-252(0,F)0-NN-1,, DE,,SPD
Spont. fission of Curium-244	CM244	96-CM-244(0,F) 0-NN-1,, DE,,SPD
Spont. fission of Curium-246	CM246	96-CM-246(0,F) 0-NN-1,, DE,,SPD
Spont. fission of Curium-248	CM248	96-CM-248(0,F) 0-NN-1,, DE,,SPD
Deuteron-Beryllium	D-BE	4-BE-9(D,X)0-NN-1,, DE,,SPD
Deuteron-Carbon 12	D-C12	6-C-12(D,X) 0-NN-1,, DE,,SPD
Deuteron-Carbon 14	D-C14	6-C-14(D,X) 0-NN-1,, DE,,SPD

Name of neutron source	In INC-SPECT	SF1-SF8 in REACTION in SubEntry with SF8= SPD
Deuteron-Deuterium	D-D	1-H-2(D,X) 0-NN-1,, DE,,SPD
Deuteron-Lithium	D-LI	3-LI-0(D,X) 0-NN-1,, DE,,SPD
Deuteron-Lithium 7	D-LI7	3-LI-7(D,X) 0-NN-1,, DE,,SPD
Deuteron-Nitrogen 14	D-N14	7-N-14(D,X) 0-NN-1,, DE,,SPD
Deuteron-Nitrogen 15	D-N15	7-N-15(D,X) 0-NN-1,, DE,,SPD
Deuteron-Tritium	D-T	1-H-3(D,X) 0-NN-1,, DE,,SPD
Evaporation neutrons	EVAP	13-Al-0(P,X) 0-NN-1,, DE,,SPD 74-W-0(P,X) 0-NN-1,, DE,,SPD 82-Pb-0(P,X) 0-NN-1,, DE,,SPD 92-U-0(D,X) 0-NN-1,, DE,,SPD …
Nuclear explosive device	EXPLO	Entries with SPA are absent in EXFOR. Time-of-flight method was used
Proton-Beryllium	P-BE	4-BE-9(P, X) 0-NN-1,, DE,,SPD
Proton-Deuterium	P-D	1-H-2(P, X) 0-NN-1,, DE,,SPD
Photo-neutron	PHOTO	1-H-2(G,X) 0-NN-1,, DE,,SPD 13-Al-0(G,X) 0-NN-1,, DE,,SPD 92-U-0(G,X) 0-NN-1,, DE,,SPD ...
Proton-Lithium 7	P-LI7	3-LI-7(P,X) 0-NN-1,, DE,,SPD
Polarized neutron source	POLNS	Entries with SPA are absent in EXFOR.
Proton-Tritium	P-T	1-H-3(P,X) 0-NN-1,, DE,,SPD
Plutonium-Beryllium ns	AM-BE	4-BE-9(A,X) 0-NN-1,, DE,,SPD ?
Spont. fission of Plutonium-240	PU240	94-PU-240(0,F) 0-NN-1,, DE,,SPD
Spont. fission of Plutonium-242	PU242	94-PU-242(0,F) 0-NN-1,, DE,,SPD
Reactor	REAC	92-U-235(N,X) 0-NN-1,, DE,,SPD or 92-U-0(N,X) 0-NN-1,, DE,,SPD
Thermal column	THCOL	92-U-235(N,X) 0-NN-1,, DE,,SPD
Thorium-Beryllium ns	TH-BE	4-BE-9(A,X) 0-NN-1,, DE,,SPD ?

An example of a compilation of an experiment with filtered neutron beam is given below:

```
ENTRY           32238   20140507                                                 32238 0 1
SUBENT       32238001   20140507                                                 32238 1 1
BIB                12        35                                                  32238 1 2
INSTITUTE (4UKRIJD,4UKRUKR)4UKRUKR - State Scientific-Engineering                 32238 1 3
Center for Control and Emergency Response, Kyiv                                   32238 1 4
REFERENCE (C,2012KYIV,,430,2013)                                                 32238 1 5
AUTHOR (O.O.Gritzay, A.K.Grymalo, V.V.Kolotyi, V.A.Pshenychnyi, V.P.Shakhov, V.M.Venedyktov)
TITLE Determination of total neutron cross section of 52Cr with using average energy 32238 1 9
shift method for filtered neutron beam                                           32238 1 10
FACILITY (REAC,4UKRIJD) Reactor WWR-M                                            32238 1 12
INC-SOURCE (REAC) Neutron filter installed in horizontal channel of the reactor.  32238 1 13
Filter components: S-116.53 g/cm2,                                               32238 1 14
58Ni-81.42g/cm2,V-24.44g/cm2,Al-5.4g/cm2,10B-0.5g/cm2.                           32238 1 15
The calculated energy and width of the neutron line (95% response function) after 32238 1 16
this filter are: 59 (+1.2, -6.7) keV.                                            32238 1 17
Calculated and experimental spectra after this filter are presented              32238 1 19
in 32238002 and 32238003.                                                        32238 1 20
INC-SPECT The initial neutron line with the average energy 59 keV produces at the 32238 1 21
scattering angles 15, 20 and 25 ADEG the scattered neutron lines with the average 32238 1 22
```

```
energies 55, 52, 48.4 keV and 58.6, 58.3, 58 keV if neutrons are scattered by       32238 1 23
hydrogen and carbon, respectively. Thickness of the used scattering-samples C and   32238 1 25
CH2 was 10.02+-0.01 and 4.52+-0.01 mm.                                              32238 1 26
METHOD (FNB,TRN) Transmission measurement of the scattered filtered neutrons.       32238 1 28
DETECTOR (PROPC) The proton recoil detector LND-281 (gas filling H+CH4+N2,          32238 1 30
diameter-38.1 mm length-254.0 mm, gas pressure-3240 torr)                           32238 1 31
SAMPLE 52Cr sample was made of a metal powder, loaded into aluminum container.      32238 1 33
A thickness of the 52Cr sample was 0.0173+-0.0002 atoms/barn.                       32238 1 34
STATUS (TABLE) From text                                                            32238 1 36
HISTORY (20140425) UKRNDC                                                           32238 1 37
ENDBIB           35 0                                                               32238 1 38
NOCOMMON        0   0                                                              32238 1 39
ENDSUBENT       38    0                                                           32238 199999
SUBENT     32238002   20140507                                                       32238 2 1
BIB         1        8                                                             32238 2 2
REACTION (92-U-235(N,X)0-NN-1,,DE,,SPA/REL,CALC)                                    32238 2 3
Calculated was done by FILTER-7 using JENDL-3.3 (58Ni-81.42 g/cm2, 10B-0.5 g/cm2,   32238 2 4
11B-0.088 g/cm2, 27Al-5.4 g/cm2, Vnat-24.44 g/cm2), CENDL-2(Snat-116.53 g/cm2).     32238 2 5
Calculated energy line is 58.98 keV, purity about 95%. The limits of 95% response   32238 2 7
function for the 59 keV filter spectrum were defined as 52.111 to 60.319 keV.       32238 2 9
ENDBIB               8          0                                                   32238 2 11
COMMON               2          3                                                   32238 2 12
EN-MIN     EN-MAX                                                                   32238 2 13
EV         MEV                                                                      32238 2 14
1.e-5      20.                                                                      32238 2 15
ENDCOMMON            3         0                                                   32238 2 16
DATA                 2      1201                                                   32238 2 17
E          DATA                                                                     32238 2 18
KEV        ARB-UNITS                                                                32238 2 19
40.5499    .318100E-01                                                              32238 2 20
40.6795    .370900E-01                                                              32238 2 21
…
61.5046    .689100E-01                                                            32238 2 1219
61.5322    .474500E-01                                                            32238 2 1220
ENDDATA          1203         0                                                   32238 2 1221
ENDSUBENT        1220         0                                                  32238 299999
SUBENT        32238003  20140507                                                     32238 3 1
BIB                  1         1                                                   32238 3 2
REACTION (92-U-235(N,X)0-NN-1,,DE,,SPA/REL,EXP)                                     32238 3 3
ENDBIB               1         0                                                   32238 3 4
COMMON               2         3                                                   32238 3 5
EN-MIN      EN-MAX                                                                   32238 3 6
EV          MEV                                                                      32238 3 7
1.e-5       20.                                                                      32238 3 8
ENDCOMMON           3         0                                                     32238 3 9
DATA                3       240                                                   32238 3 10
E          DATA      DATA-ERR                                                      32238 3 11
KEV        NO-DIM    NO-DIM                                                        32238 3 12
39.9696    2.8626    0.0320                                                        32238 3 13
40.0953    2.7958    0.0301                                                        32238 3 14
…
69.8826    1.0589    0.1184                                                      32238 3 251
70.0083    0.9470    0.0985                                                      32238 3 252
ENDDATA          242        0                                                    32238 3 253
ENDSUBENT        252        0                                                   32238 399999
SUBENT       32238004 20140507                                                     32238 4 1
BIB                  5       24                                                   32238 4 2
REACTION   (24-CR-52(N,TOT),,SIG,,SPA)                                           32238 4 3
INC-SOURCE (REAC)                                                                32238 4 4
STATUS (DEP,32238002)Calculated neutron spectrum after filter                    32238 4 5
       (DEP,32238003)Experimental neutron spectrum after filter                  32238 4 6
       (DEP,32238005) Scattered neutron spectrum at the angle 15 ADEG (55 keV)   32238 4 8
       calculated by the MCNP 4C code                                            32238 4 9
       (DEP,32238006) Scattered neutron spectrum at the angle 20 ADEG (52 keV)   32238 4 10
       calculated by the MCNP 4C code                                            32238 4 11
      (DEP,32238007)Scattered neutron spectrum at the angle 25 ADEG (48.8 keV)   32238 4 12
       calculated by the MCNP 4C code                                            32238 4 13
COMMENT Correction connected with existence in the neutron scattered spectrum on  32238 4 14
CH2 neutrons scattered on carbon was done. A correction on the self-shielded effect 32238 4 15
was not be done for the measured values of the total cross sections of 52Cr.     32238 4 16
The rough estimation, done by the MCNP 4C code calc., shown that the difference  32238 4 18
between the total cross sections at these energies and the observed self-shielded 32238 4 20
cross sections may rich 2-6%.                                                    32238 4 21
ERR-ANALYS Total error includes:                                                 32238 4 22
```

```
          - statistical error of the transmission measurements;                    32238 4 23
          - measurement errors of dimension and weight of the sample;              32238 4 24
          - error due to presence of impurities in the sample.                     32238 4 25
ENDBIB              24            0                                                  32238 4 27
NOCOMMON             0            0                                                  32238 4 28
DATA                 3            3                                                  32238 4 29
EN          DATA       ERR-T                                                        32238 4 30
KEV         B          B                                                            32238 4 31
48.8        5.94        0.49                                                        32238 4 32
52.         18.29       0.89                                                        32238 4 33
55.          9.27       0.51                                                        32238 4 34
ENDDATA              5           0                                                  32238 4 35
ENDSUBENT           34           0                                                 32238 499999
SUBENT       32238005    20140507                                                    32238 5 1
BIB                  1           3                                                  32238 5 2
REACTION (92-U-235(N,X)0-NN-1,,DE,,SPA/REL,CALC)                                32238 5 3 <-SPD
Scattered neutron spectrum at angle 15 deg. (55 keV) calculated by the MCNP 4C code  32238 5 4
ENDBIB              3            0                                                  32238 5 6
COMMON              2            3                                                  32238 5 7
EN-MIN      EN-MAX                                                                  32238 5 8
EV          MEV                                                                     32238 5 9
1.e-5       20.                                                                    32238 5 10
ENDCOMMON           3            0                                                 32238 5 11
DATA                2          248                                                 32238 5 12
E           DATA                                                                    32238 5 13
KEV         ARB-UNITS                                                               32238 5 14
40.006       0.108                                                                  32238 5 15
40.087       0.095                                                                  32238 5 16
…
59.969       0.065                                                                 32238 5 261
60.050       0.063                                                                 32238 5 262
ENDDATA            250          0                                                  32238 5 263
ENDSUBENT          262          0                                                 32238 599999
SUBENT       32238006   20140507                                                    32238 6 1
BIB                  1           3                                                  32238 6 2
REACTION (92-U-235(N,X)0-NN-1,,DE,,SPA/REL,CALC)                                32238 6 3 <-SPD
Scattered neutron spectrum at angle 20 deg. (52 keV) calc. by the MCNP 4C code       32238 6 4
ENDBIB              3           0                                                   32238 6 6
COMMON              2           3                                                   32238 6 7
EN-MIN      EN-MAX                                                                  32238 6 8
EV          MEV                                                                     32238 6 9
1.e-5       20.                                                                    32238 6 10
ENDCOMMON           3          0                                                   32238 6 11
DATA                2        248                                                   32238 6 12
E           DATA                                                                    32238 6 13
KEV         ARB-UNITS                                                               32238 6 14
40.006       0.116                                                                  32238 6 15
40.087       0.156                                                                  32238 6 16
…
59.969       0.038                                                                 32238 6 261
60.050       0.010                                                                 32238 6 262
ENDDATA            250          0                                                  32238 6 263
ENDSUBENT          262          0                                                 32238 699999
SUBENT        32238007   20140507                                                    32238 7 1
BIB                  1           3                                                  32238 7 2
REACTION (92-U-235(N,X)0-NN-1,,DE,,SPA/REL,CALC)                                32238 7 3 <-SPD
Scattered neutron spectrum at angle 25 deg. (48.8 keV) calc. by the MCNP 4C code     32238 7 4
ENDBIB              3           0                                                   32238 7 6
COMMON              2           3                                                   32238 7 7
EN-MIN      EN-MAX                                                                  32238 7 8
EV          MEV                                                                     32238 7 9
1.e-5        20.                                                                   32238 7 10
ENDCOMMON           3           0                                                  32238 7 11
DATA                2         309                                                  32238 7 12
E           DATA                                                                    32238 7 13
EV          ARB-UNITS                                                               32238 7 14
35.056       0.110                                                                  32238 7 15
35.137       0.115                                                                  32238 7 16
…
59.969       0.031                                                                 32238 7 322
60.050       0.014                                                                 32238 7 323
ENDDATA          311         0                                                      32238 7 324
ENDSUBENT        323         0                                                     32238 799999
ENDENTRY 7
```

2.9. Nuclear astrophysics data. Calculations of nuclear astrophysics and californium neutron cross section uncertainties using ENDF/B-VII.1, JEFF-3.1.2, JENDL-4.0 and low-fidelity covariances, B. Pritychenko

Nuclear astrophysics and californium fission neutron spectrum averaged cross sections and their uncertainties for ENDF materials have been calculated. Absolute values were deduced with Maxwellian and Mannhart spectra, while uncertainties are based on ENDF/B-VII.1, JEFF-3.1.2, JENDL-4.0 and Low-Fidelity covariances. These quantities are compared with available data, independent benchmarks, EXFOR library, and analyzed for a wide range of cases. Recommendations for neutron cross section covariances are given and implications are discussed. These findings are published in Nucl. Data Sheets 123, 119 (2015).

2.10. Structure of software on graphic data processing for the EXFOR data library, G. Pikulina, S.Taova, S. Dunaeva

The previous version of InpGraph was designed more than 10 years ago. It was developed for our internal needs only. The main advantage of this version is a special processing procedure that provides compilation of image data of old images into EXFOR format. But the old version of InpGraph demands additional training of users as a strict order of digitizing operations is needed. This fact decreases the number of its potential users.

Nowadays the user's interface requirements have radically changed. So, we have decided to follow modern trends and create a user friendly interface.

The main idea was to design an intuitively understandable interface with the convenient tools for data digitizing. We tried to implement an approach of "identical user's reactions on identical user's actions".

Also we decided to use Wizard technology as an additional helper function for step instructions and hints during digitizing.

We implemented a selection of possible values from lists, automatic searching and automatic input, automatic checking on the input stage to minimize manual data input volume and to decrease possible error quantities.

This work was taken up two years ago.

We have analyzed different digitizing software (GetData Graph Digitizer, Graph2Digit, G3Date, Grafula) including GSYS and GDgraph.

We took into account the experience of the previous version use, feedbacks and proposals of the users.

We developed a flexible structure of InpGraph, new version and its internal data. Improvement and modification of our software are simpler for implementation now.

An algorithm of image processing for the EXFOR data base is implemented as a sequence of the following steps:

1. Import image into the program environment;
2. Edit the image if it is necessary;
3. Input service information as the EXFOR format demands;
4. Set axes, their names, units, directions;
5. Digitize data curves;
6. Process data and obtain physical data values;
7. Save compiled data in the EXFOR file.

The InpGraph structure makes it possible to return at any digitizing stage and then edit the input data. This version of InpGraph does not require a strict order of operations.

We kept all advantages of the previous version of InpGraph in the new one:

- special math software compiles image data form old sources of low quality;
- digitizing and quantization errors are calculated;
- check of scale correctness is provided at the stage of data input and while creating the EXFOR file;
- traditional lens with separate points division is used for digitization:
- consequent creation of service files (AXS, SRC) with a possibility of their correction is supported;
- EXFOR-oriented data treatment including EXFOR format of the output file is implemented.

Summary of the new features of InpGraph:

- Operation of the initial data image loading is implemented in three ways: open any image format file, paste an image from clipboard or capture a part of screen.
- Input of service information has been optimized: EXFOR Dictionaries are used now.
- Procedure of data digitizing has been modified: automatic marking of axes has been implemented, editing of point positions and using of different colors and markers has been provided.
- Strict order of digitization is optional now. User can add any amount of abscissa and ordinate axes at any digitizing stage. Every axis has its own name. While digitizing curves, the user should select axes for every curve from the list available.
- Results of digitizing are stored in files with EXF extension. Service files with the extensions AXS, SRC are also created during compilation. Special edit windows are provided to make corrections (if necessary) in these files.

Thus, the new InpGraph version has all the advantages of the old one. We have tried to make it more convenient for the users. Now we are presenting the beta-version of InpGraph 3.0. Feedback and proposals from users is welcome and will all be taken into account. We are going to continue this development.

2.11. Introduction to the digitization software GDgraph, Guochang Chen (Yongli Jin, Jimin Wang, CNDC, China)

1. Introduction

GDgraph is a software for digitization. Since 1997, CNDC has been devoted to develop a software for digitization. The first version of digitization software GDGraph was developed and released in 2000 using VC++ language. Five years later, we collected much feedback information on update and bugs of this software. The 2nd version of GDGraph software was released at 2006, in which the whole software was re-written using a Perl computer language to obtain more comfortable conditions for programming and updating. The version 3.0, 4.0 and 5.0 of GDGraph was released in 2011, 2012 and 2013, respectively.

2. Main feature of GDGraph5.0

(1) Operating system: WindowsXP or the later version of Windows.
(2) Intuitive and light GUI: Provides Chinese and English version GUI.
(3) Supports image format: such as PNG, GIF, BMP and JPEG etc.
(4) The image can be automatically fit to the GUI windowwith zoom-in or zoom-out manually together

with the digitizing X, Y axis.
(5) Allows to rotate the image and set a rotation angle with degree unit.
(6) The maximum digitizing data group number is three, and the colour, size and shape of each group can be defined by user using “Settings” function.
(7) Randomly adds the digitizing point and move it by mouse or cursor keys.
(8) Output data can be saved as a data file or at clipboard.
(9) Import data function enables to reuse the former digitizing data or compare with other data group easily.
(10) X, Y axes: Select or set a unit for X, Y data by user is available. Allows to digitize X, Y error with symmetry or asymmetry mode and move it using mouse or cursor keys, and set a fix value with relative (%) or absolute mode.
(11) Magnifying glass function: magnifies the local area of the image, and the window size can be set from 200% to 800% and be moved by mouse. The partial image in the magnifying glass window can be magnified by 2 or 4 times.
(12) Setting the colour, size and shape of digitizing point, the background with or without gridding lines, output digitizing numerical data format is available.
(13) Project function: It is used to save an image, digitizing results with other settings as a project file *.GDP for checking and modification in the future.
(14) Remark function is applied to keep some marks and memo text for checking, modification and memory by user.

3. Basic Functions of GDGraph5.0

3.1. Loading an image file

There have been some options to load an image. One is using “Load Graph File” from the “File” menu in the menu bar. Select an image file (as PNG, GIF, BMP or JPEG etc.) from a file dialog box in a new window and load the image with original size as default. Another way is to directly copy an image using clipboard from other file such as MS Word, PDF, etc. If an image file is successfully loaded, the image is displayed on the main panel as shown in **Fig. 1**. It is allowed to rotate with an setting angle, zoom in, zoom out, auto fit to the GUI window and revert the image size.

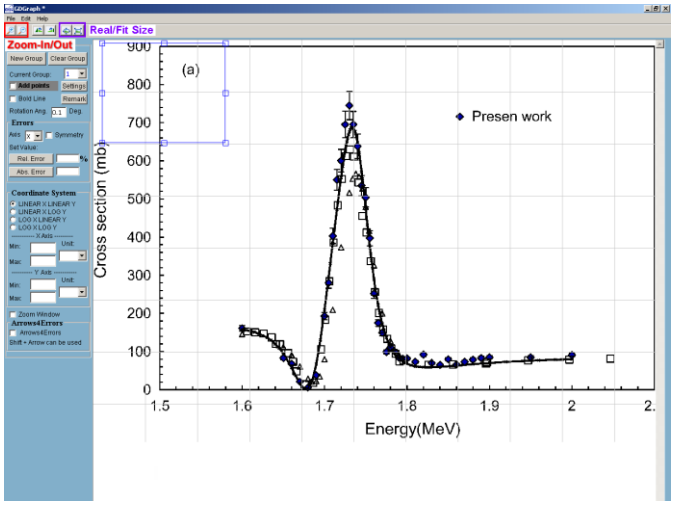


Fig. 1: An image loads on the main panel.

3.2. Setting axes

Use cross lines to set the X-Y axis, and adjust the square symbols of the starting, middle and ending positions of X-Y axis to fit the image one. Then select the X-Y axis type as Linear-Linear, Linear-Log, Log-Linear or Log-Log. According to the cross line positions, fill in the starting and ending value of X-Y axes, and select or fill in units for X-Y axes at "Coordinate System" in "Control Panel" for identifying the digitizing data in the output data file, respectively. When we set or adjust the positions of axis, there exists an orthogonal frame to assist confirmation of the position of axes. When you finish setting the axis, you will see a window as shown in **Fig. 2**.

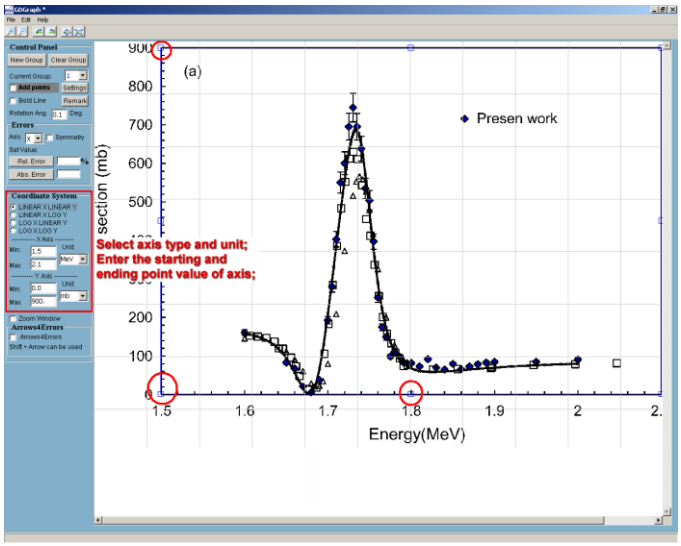
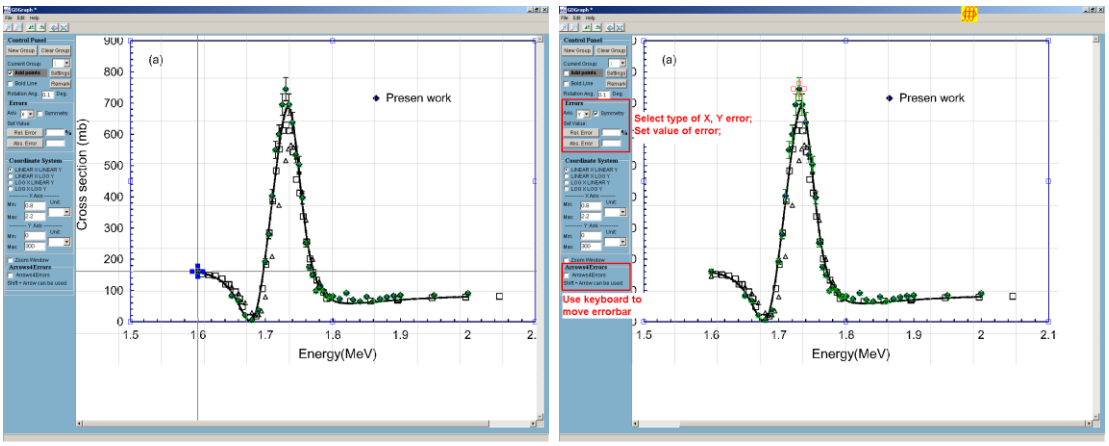


Fig. 2: Window after setting axes with squares.

3.3. Digitizing the data and their uncertainties

Activate the check box "Add points" to start digitization process. If you need to digitize more than one group points, please select which group you want to digitize or modify the original digitizing results. If you click on the image in the data input mode, a digitizing data point is added on the image. Continue to click the image until all the data points are added. When you finish adding the data points, you will see a window as shown in part (a) in **Fig. 3**.

The function of digitizing data point error is available with asymmetric or symmetric now. First of all, disable the "Add points" mode. Then, to select each error mode for X/Y with asymmetric or symmetric. The default error mode of X/Y is asymmetric. To set a symmetric error for X or Y, first select X-axis or Y-axis at "Axis" list box in "Errors" part, then click "Symmetric" check box. After that, click a data point to activate it which will make 4 red square symbols appear around it. In this mode, move data point by mouse or cursor keys or set a fix value as X-Y error. The left and right square symbols represent X-Err-/X-Err+, and the bottom and top symbols represent Y-Err-/Y-Err+. If you obtain the information of X-Y uncertainty from paper or other data sources, you can directly fill in a fixed value as X-Y uncertainty with relative (%, in percent) or absolute mode. You can directly use the mouse to pull one of four red squares to obtain X-Y error. On the other hand, you can apply "Arrows4Errors" function using cursor keys to move one of four red squares to proper position. After inputting errors, you will see a window as shown in part (b) of the **Fig. 3**. After digitizing one point, the "Pageup" or "Pagedown" key can be used to activate the previous or next data point.



(a) Reading the data points (b) Reading the data errors

Fig. 3: Window after reading the data points and errors.

3.4. Outputting the digitizing result

Select “Save Data File” from the “File” menu or directly use “Ctrl+C” to copy all digitizing results to clipboard and paste to other applications. The output data are in exponential or floating formats, and the number of digits can be set using the “Settings” function. Each data can be set as 11 columns to fit EXFOR format requirements. The output file contains the information of each group No., number of data points, name of each column and digitizing data. Each group output contains X, Y, Y-Err+, Y-Err-, X-Err-, and X-Err+ as shown in **Fig. 4**.

```
!!######group 1 ####(39 points) ############
!#     X(MeV)          Y(mb)          dY+            dY-            dX-            dX+
 1.03415E+00 5.34411E+01 2.63429E+00 2.63429E+00 0.00000E+00 0.00000E+00
 1.15063E+00 2.73492E+01 3.13606E+00 3.13606E+00 0.00000E+00 0.00000E+00
 1.17425E+00 2.24569E+01 2.38340E+00 2.38340E+00 0.00000E+00 0.00000E+00
 1.19746E+00 6.65120E+00 2.50884E+00 2.50884E+00 0.00000E+00 0.00000E+00
 1.22109E+00 1.63351E+00 1.63075E+00 1.63075E+00 0.00000E+00 0.00000E+00
 1.24430E+00 1.22961E+01 2.88517E+00 2.88517E+00 0.00000E+00 0.00000E+00
 1.26751E+00 6.41037E+01 3.13606E+00 3.13606E+00 0.00000E+00 0.00000E+00
 1.27932E+00 9.30809E+01 4.51592E+00 4.51592E+00 0.00000E+00 0.00000E+00
 1.29073E+00 1.34100E+02 6.77388E+00 6.77388E+00 0.00000E+00 0.00000E+00
 1.30294E+00 1.83274E+02 9.15728E+00 9.15728E+00 0.00000E+00 0.00000E+00
 1.31435E+00 1.99958E+02 1.00354E+01 1.00354E+01 0.00000E+00 0.00000E+00
 1.32616E+00 2.31695E+02 1.15407E+01 1.15407E+01 0.00000E+00 0.00000E+00
 1.33780E+00 2.48260E+02 1.20897E+01 1.20897E+01 0.00000E+00 0.00000E+00
 1.34937E+00 2.31569E+02 1.16661E+01 1.16661E+01 0.00000E+00 0.00000E+00
 1.36118E+00 2.12627E+02 1.07880E+01 1.07880E+01 0.00000E+00 0.00000E+00
 1.37258E+00 1.78256E+02 8.90640E+00 8.90640E+00 0.00000E+00 0.00000E+00
 1.38480E+00 1.67719E+02 8.53007E+00 8.53007E+00 0.00000E+00 0.00000E+00
 1.39539E+00 1.32093E+02 6.77388E+00 6.77388E+00 0.00000E+00 0.00000E+00
 1.40802E+00 8.37982E+01 4.26504E+00 4.26504E+00 0.00000E+00 0.00000E+00
 1.41860E+00 5.79571E+01 2.88517E+00 2.88517E+00 0.00000E+00 0.00000E+00
 1.43082E+00 4.94270E+01 2.50884E+00 2.50884E+00 0.00000E+00 0.00000E+00
 1.44304E+00 3.27432E+01 1.63075E+00 1.63075E+00 0.00000E+00 0.00000E+00
 1.45404E+00 3.60047E+01 2.13252E+00 2.13252E+00 0.00000E+00 0.00000E+00
```

Fig. 4: An example of outputting numerical data file.

4. Conclusion

Since 1997, the digitization software GDgraph has been developed to fit the requirements of evaluation, measurement and EXFOR compilation. From the old software to the present version 5.0, GDgraph does mainly fit the requirements, although some modifications and additions of new functions are needed.

2.12. Status of the compiled Neutron Spectra in EXFOR. Summary of discussions held at the Workshop and further developments, S. Simakov, N. Otuka, V. Semkova, V. Zerkin

1. History

The issue of compilation of Neutron Spectra in EXFOR was initially addressed at the IAEA Consultants' Meeting on "Neutron Sources Spectra for EXFOR" (13- 15 April 2011, IAEA), see:

- Summary Report INDC(NDS)-0590
- Presentations: *https://www-nds.iaea.org/index-meeting-crp/CM-2011_web/* .

2. Current status of EXFOR

NDS has searched the EXFOR database for Entries with Neutron and Photon Source Spectra information (energy distribution) which are collected under the keyword INC-SPECT.

The non-monoenergetic neutron sources are used for the measurements of Spectrum Averaged cross sections (SPA), fission yields and other physical quantities. This information is coded in the REACTION string, the numerical data are compiled in block DATA in the same Entry.

The results of search are summarised in Table 1 (around 17 Entries were found with the source energy distribution in INC-SPECT) and in Table 2 (no energy spectra, however with some additional information about neutron source).

Table 1. Entries with the neutron source energy distribution after keyword INC-SPECT.

INC-SOURCE	Lab First Author	n-Source description	EXFOR Entries with INC-SPECT having n-Source spectral information
Reactor facilities			
REAC	AERE, Dhaka M.S. Uddin	TRIGA Mark II LEU fuel, core	31733 http://www-nds.iaea.org/EXFOR/31733.002
REAC	KUR, I. Kimura	^{6}Li-D convertor behind C-column	22214 http://www-nds.iaea.org/EXFOR/22214.007
REAC	TOK, Tokyo H. Harada	YAYOI Reactor, Glory hole	23075 http://www-nds.iaea.org/EXFOR/23075.002
REAC	CEA, Cadarache A. Cricchio	Rapsodie fast reactor fuel pins	21816 http://www-nds.iaea.org/EXFOR/21816.002
REAC	INL, Idaho I. Glagolenko	EBR-II, control rods	31686 http://www-nds.iaea.org/EXFOR/31686.002
REAC	IPPE, Obninsk V.I. Ivanov	BR-5, PuO_2 core	40308 http://www-nds.iaea.org/EXFOR/40308.007
REAC	IPPE, Obninsk G.V. Anikin	beam from BR-5, Shapes of 6 n-lines ?	40080 http://www-nds.iaea.org/EXFOR/40080.001
Radioactive sources			
AM-BE	Bangladesh S. Qaim	Am-Be in polyethylene	31724 http://www-nds.iaea.org/EXFOR/31724.002
Accelerator based sources			
P-LI7	TIT, Tokyo T. Matsumoto	thick ^{7}Li(p,n) E_p = 1.9 – 2.3 MeV	22850 http://www-nds.iaea.org/EXFOR/22850.005
P-LI7	TIT, Tokyo K.Terada	thick ^{7}Li(p,n) E_p = 1.9, ?? MeV	23187 http://www-nds.iaea.org/EXFOR/23187.003
P-LI7	TIT, Tokyo T. Wang	thin ^{7}Li(p,n) E_p = 1.9, 2.3 MeV	23103 http://www-nds.iaea.org/EXFOR/23103.002

INC-SOURCE	Lab First Author	n-Source description	EXFOR Entries with INC-SPECT having n-Source spectral information
P-LI7	Manipal H. Naik	thin ^{7}Li(p,n) E_p = 5.6 MeV	33033 http://www-nds.iaea.org/EXFOR/33033.004
P-LI7	KFK, Karlsruhe F. Kaeppeler	thick ^{7}Li(p,n)	O1963 http://www-nds.iaea.org/EXFOR/O1963.002 this source was used to measure many (n,γ) SPA, e.g. http://www-nds.iaea.org/EXFOR/22996.003 (link to O1963 should be included ?)
P-LI7	TSL, Uppsala R. Bevilacqua	thin ^{7}Li(p,n) E_p = 179 MeV	23129 http://www-nds.iaea.org/EXFOR/23129.002 (should be comp. as separated p-Li spectrum ?)
P-BE9	WERC, Japan M.S. Uddin	Be(p,xn) E_p = 7.7 MeV	23238 http://www-nds.iaea.org/EXFOR/23238.002 (4 energy groups flux is given)
D-BE9	ANL S. Liskien	thick ^{9}Be(d,xn) E_d = 7 MeV	21857 http://www-nds.iaea.org/EXFOR/21857.002
SPALL	JINR, Dubna C. Bhatia	Pb + U blanket E_d = 1.6 GeV	41529 http://www-nds.iaea.org/EXFOR/41529.002 41565 http://www-nds.iaea.org/EXFOR/41565.002
D-D *D-T*	*FNG, Frascati* *M. Pillon*	*solid TiT, D targets* *E_d = 0.3 MeV*	23127 *http://www-nds.iaea.org/EXFOR/23127.002* *(n-spectra is available - has to be compiled)*

Table 2. Entries which do not have source energy distribution in INC-SPECT, however provide some numerical information about neutron filed.

INC-SOURCE	Lab First Author	n-Source description	EXFOR Entries with INC-SPECT having n-Source spectral information
P-LI7 P-T	IRMM, Geel E. Birgersson	^{7}LiF(p,n), T(p,n) E_p = MeV	23054 http://www-nds.iaea.org/EXFOR/23054.002 (only neutron energy resolution is given …)
D-D	Mexico E. Chavez	D(d,xn) E_d = 3.7 -5.2 MeV	31687 http://www-nds.iaea.org/EXFOR/31687.002 (only dependence of En vs. Angle is given)
REAC	ILL, Grenoble A. Letourneau	High Flux reactor, 2 channels in moder.	22941 http://www-nds.iaea.org/EXFOR/22941.002 (only total and thermal fluxes)
D-BE9	*Julich* *S. Qaim*	*thick ^{9}Be(d,xn)* *E_d=9.7,14,30,53MeV*	*There are many Entries with S.Qaim's SPA[1]* *(n-spectra have to be referred or compiled)*
D-D *D-T*	*IRRM, Geel* *M. Pillon*	*solid TiT, gas D,* *E_d = 7 - 25 MeV*	*23142* *http://www-nds.iaea.org/EXFOR/23142.002* *(only E_{min}, E_{max}, E_{mean} are given)*
REAC	*IJD, Kyiv* *O. Gritzay*	*WWR-M* *filtered n-beam*	*32216* *http://www-nds.iaea.org/EXFOR/32216.002* *(E_{mean}, and Yields of the main and satellite lines are given, shapes have to be compiled)*

Comments to Tables 1 and 2: *italic font* – incident spectra were found and compiled after Workshop.

Other Entries which have some information on the incident spectrum but do not contain energy distribution in INC-SPECT:

11467; 20139; 20436; 20534; 20735; 21812; 22007; 22089; 22105; 22340; 22392; 22658; 22661; 22748; 22794; 22837; 22838; 22858; 22882; 22903; 23027; 23067; 23078; 23105; 23222; 40063; 40476; 40924; C0228; C1516; G0002; M0536; O0291.

3. Progress of work on inclusion of Neutron Spectra in EXFOR (after Workshop)

The spectrum averaged cross sections measured by A. Zvonarev at the fast reactor assembly BR-1 (IPPE) were compiled early in *41068*. After the workshop this Entry was updated by CJD:

- 14 group energy spectrum from the authors' publication was added under INC-SPECT,
- reference to ICSBEP(*https://www.oecd-nea.org/science/wpncs/icsbep/)* was added where this assembly (including the MCNP deck for the spectrum calculation) is described as a Benchmark FUND-IPPE-FR-MULT-RRR-001.

Several Incident Neutron Spectra (Figs. 1 and 2) were received from the authors and will be included in EXFOR:

- FNG facility at Frascati, D-D and D-T n-sources (M. Pillon), Entry 23127;
- D-Be n-sources at FZJ Julich (S. Qaim et al.). The overview of spectra used in his measurements see in INDC(NDS)-0590, p. 35 and the summary prepared by NDS see in Table 3.

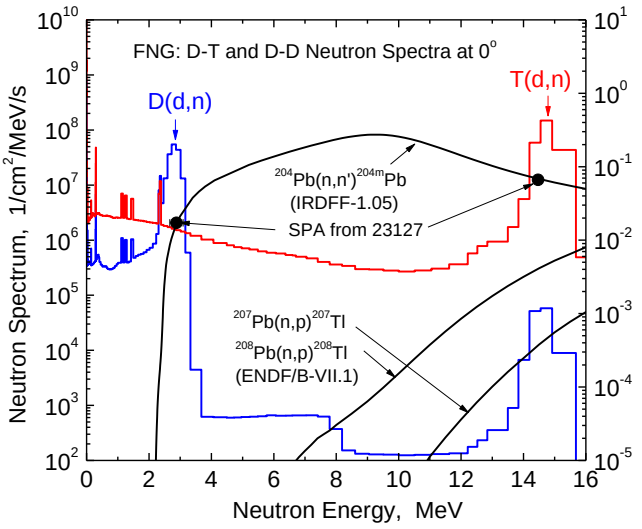


Fig. 1. Neutron spectra from D-T and D-D sources received in Nov 2014 from M. Pillon (175 groups presentation).

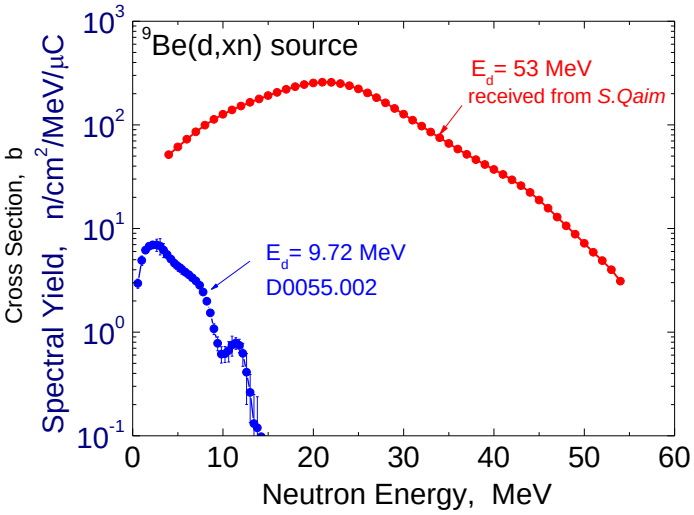


Fig. 2. Neutron spectra from D-Be sources received from S. Qaim et al. at 9.7 and 53 MeV (51 points).

Table 3. Information for the d(Be) neutron spectra applied for the spectrum average cross sections measurements performed at *Institut fur Nuklearchemie, Forschungszentrum Julich GmbH, D-52425 Julich,* Germany and corresponding EXFOR compilations.

Reference	Ed, MeV	n-Spectrum Data / Units	Incident spectrum additional information	EXFOR Entry	How n-Spectra are compiled now
NP/A,100,537,1967	53.8	Table n/(μC MeV sr)		O1924 http://www-nds.iaea.org/EXFOR/O1924.002	REACTION (4-BE-9(D,X)0-NN- „TTY/PY/DA/DE)
NP/A,329,63,1979	53.8	Text n/(μC MeV sr)	Adopted from NP/A,100,537,1967 and Phys.Med.Biol.20(1975)235 Num. data provided by S.M Qaim	21009 http://www-nds.iaea.org/EXFOR/21009.003	EN-MEAN = 22.5MEV ; EN-RSL-FW = 15.8 MEV
RCA,62,107,1993	53.8	Text n/(μC MeV sr)	Adopted from NP/A,100,537,1967 and Phys.Med.Biol.20(1975)235 Num. data provided by S.M Qaim	22708 http://www-nds.iaea.org/EXFOR/22708.002 Data compiled without SF8=SPA	EN=53 MEV
NP/A,410,421,1983	53.8	Text n/(μC MeV sr)	Adopted from NP/A,100,537,1967 and Phys.Med.Biol.20(1975)235 Num. data provided by S.M Qaim	21916 http://www-nds.iaea.org/EXFOR/21916	EN = 22.5MEV ; EN-RSL-HW = 7.9 MEV
JIN,36,3639,1974	53.8	Figure n/(μC MeV sr)	Adopted from NP/A,100,537,1967 and Phys.Med.Biol.20(1975)235 Num. data provided by S.M Qaim	20524 http://www-nds.iaea.org/EXFOR/20524	EN-APRX = 22.5 MeV
ARI,30,3,1979	53.8	Text	From NP/A,100,537,1967 Num. data provided by S.M Qaim	21878 http://www-nds.iaea.org/EXFOR/21878	EN = 22.5MEV ; EN-RSL-HW = 7.9 MEV
NP/A,295,150,1978	53.8	Text	From NP/A,100,537,1967 Num. data provided by S.M Qaim	20840 http://www-nds.iaea.org/EXFOR/20840	EN-DUMMY = 22.5 MEV
NSE,91,162,1985	17.5, 20, 22.5, 25, 27.5 30	Tables n/(cm^{2}s MeV)		21988 (Cross sections determined from the SPA measured at given d(Be) spectra) http://www-nds.iaea.org/EXFOR/21988	no information given
91JUELIC,,297,199 1	20 and 25	Text	From NSE,91,162,1985	22444 http://www-nds.iaea.org/EXFOR/22444	EN-MIN = 2 MEV
NP/A,423,130,1984	30	Figure n/(sr μCs MeV)		21934 http://www-nds.iaea.org/EXFOR/21934	EN-DUMMY 12 MeV
76GARMIS,,589,1 97606	30	Figure n/(sr μC s MeV)		20721 http://www-nds.iaea.org/EXFOR/20721	EN-DUMMY = 11.5 MEV
BNL-NCS- 51245,539,1980	30	Figure n/(sr μA s MeV)		21649 http://www-nds.iaea.org/EXFOR/21649	EN-DUMMY = 20 MeV
RCA,51,49,1990	31	Figure cm^{-1}s^{-1} rel.scale		30977 http://www-nds.iaea.org/EXFOR/30977	EN-DUMMY = 10 MEV

Reference	Ed, MeV	n-Spectrum Data / Units	Incident spectrum additional information	EXFOR Entry	How n-Spectra are compiled now
NIM/A,404,373,1998	9.72 ATOMKI	Figure n/(cm^{2}s MeV)		d(Be) spectrum compiled in D0055 http://www-nds.iaea.org/EXFOR/D0055.002	REACTION (4-BE-9(D,N)5-B-10,,TTY/MLT/DE,,REL)
				Data compiled in 31495 http://www-nds.iaea.org/EXFOR/31495.016 http://www-nds.iaea.org/EXFOR/31495.040	EN-MEAN = 4.3 MEV
	13.55 Juelich	Figure arbitrary units			
ARI,64,717,2006 RCA,92,183,2004	14	Figure arbitrary units	From NIM/A,404(1998)373	22857 http://www-nds.iaea.org/EXFOR/22857	EN-DUMMY = 3 MeV
ARI,54,655,2001	14	Text	From NIM/A,404(1998)373	22664 http://www-nds.iaea.org/EXFOR/22664.011	EN-MEAN = 13.6 MeV
INDC(GER)-049,10,2003	14	Text	From NIM/A,404(1998)373	22832 http://www-nds.iaea.org/EXFOR/22832	EN-MEAN = 14 MeV

4. Summary of the discussion at this Workshop.

Following two Alternatives for the Neutron source compilation were considered (highlighted in red - new for EXFOR).

First Alternative: use the REACTION string for incident spectrum, i.**e.**
create new special SubEntry to code the incident Spectrum as Reaction string:

REACTION (U-238-SRC(0,0),,DE,,SPD)

which will specify Spectrum for already existing SubEntry with reaction SPA cross section coded by proper spectrum code SF8 = MXA, EPI, FIS, FSR, BRA, SPA in REACTION (6-C-12(N,TOT) , , , ,SPA

Second Alternative: continue to use INC–SPECT for incident spectrum, i.e.
store spectrum information (data, reference or link to file with spectrum) after keyword

INC-SPECT *[or extended keyword INC-SPECT(DE,...) for searching, plotting etc.]*

as a free text (spectrum itself and how it was obtained), e.g.:

E	Sp	*or (E, Sp, Npoints) to be readable by retrieving system*
eV	1/eV	
10000.	.0001	
.....	.....	

or as a link to other database or file, or as a text explaining where to find data, e.g.:

- *to File with spectrum if the spectrum array is rather long;*
- *to research reactor spectra database IRDFF-2002 (https://www-nds.iaea.org/irdf2002/data/irdf2002_spectra.dat):*
  - *from G.P.Lamaze 13153, B.M.Oliver 13752 to ISNF spectrum*
  - *from A.Fabry 20948, A.Hannan 20950, I.Garlea 30452, 30568 to Sig-Sig spectrum*
  - *from Y.Harker 10218, E.P.Lippincott 13756 to CFRMF spectrum*
  - *from K.Kobayashi 21589, K.Kobayashi 20693 to YAYOI spectrum*
- *to evaluated libraries or Standards,*
  e.g. to PFNS of ^{252} C(s.f.) or ^{235}U(n,f) sources;
- *to criticals' database ICSBEP (https://www.oecd-nea.org/science/wpncs/icsbep/):*
  e.g. to Benchmark FUND-IPPE-FR-MULT-RRR-001 from A. Zvonarev 41068.

2.13. EXFOR Web Editor, V. Zerkin

A new project "Light EXFOR Web Editor" is presented, the current stage of implementation was demonstrated, the possible development is discussed. The idea of the project is to re-use existing software, such as: Web presentation of an EXFOR files as interactive tree X4± and Reference checker, and extend them by editing features. The Editor will operate on the user's side only in the Web browser; it could be used with and without Internet connection. For the moment, it is a "Pilot" project; plans and details of the project are not yet fully clarified and fixed.

Summary of the discussions
The NDS project "Light EXFOR Web Editor" was supported by NNDC (B. Pritychenko) and other participants as an alternative of EXFOR-Editor and software independent from: operating system, commercial system components, internal policy of organizations (of nuclear data centers), etc.

3. Summary of discussions and recommendations

The workshop has facilitated the best software, EXFOR compilation practices, and facilitated exchange between the different NRDC centers. This exchange will provide an increase in compilation productivity and overall quality improvements of the EXFOR library. Several presentations have led to extensive discussions, and produced valuable suggestions that are listed below in chronological order.

1. Some comments on EXFOR compilations, N. Otuka:
   1.1. Binary heavy ion case: both nuclei should have E-LVL1 and E-LVL2 tags. Compilers should not omit such information.
   1.2. N. Otuka and O. Schwerer should clarify the difference between the alternative and interdependent results and update the manual.
   1.3. Compilers are discouraged to use FLAG to distinguish the alternative results.
   1.4. Compilers are recommended to delete unnecessary keywords from the deleted entries.
   1.5. Compilers are encouraged to use concise free text statements.
   1.6. Compilers should make important alterations more visible using the keyword HISTORY.
2. Compilations of beta-delayed neutron emission data. V. Semkova:
   2.1. IAEA/Compilers should review a consistency of the old compilations with new rules for beta-delayed neutrons, and for TOF measurements.
   2.2. Substantial problems should trigger the recompilation of existing entries.
3. EXFOR compilations for CIELO project. B. Pritychenko:
   3.1. Compilers should follow the NRDC action A56, and assign a high priority for six CIELO materials UNOBT data compilations; perhaps deletion of "empty" subentries, and general cleaning of irrelevant data.
   3.2. General revision of the updated entries by the whole network.
   3.3. EXFOR compilations should be performed in close contacts with the evaluators, and experimentalists. Contacts with the CSEWG and other groups are encouraged.
   3.4. Recent problems with EXFOR editor installation on Windows 7 triggered a request for a Web-based EXFOR editor that can be implemented using the platform-independent solutions by V. Zerkin. This, complementary, editor will provide an alternative route for non-Windows compilers.
   3.5. Nuclear data community has requested the IAEA to produce two different Email distribution lists: EXFOR general and compilation-specific lists.
   3.6. NNDC strongly supports the IAEA-led effort on electronic library creation. It can be a joint project between two organizations, and include all EXFOR and NSR publications. Copyrights restrictions will represent a certain challenge for this project.
   3.7. Data transfer from EXFOR to NSR should proceed according to the NRDC action A84.
4. Results on the ^{100}Mo(p,2n)^{99m}Tc cross section measurements and possible systematic errors. S. Takacs:
   4.1. Decay data are important in EXFOR compilations: compilers should contact authors if problems are found.
   4.2. Recommended data: compilers can include author's recommendations in the compilation.
   4.3. Compilers should be aware that systematic errors are present in the experimental data.

4.4. S. Takacs & N. Otuka should revisit the definition of yields, old entries on TTY, and propose corrections for reaction codes.

5. Kerma factors in EXFOR: actual status and missing published results. S. Simakov:
   Compilers are encouraged to add 20 publications on Kerma factors, and revise 2 existing EXFOR entries 22507 and 22811.

6. Some problems of photonuclear data compilation and evaluation. V. Varlamov:
   6.1. Compilers should be careful in partial and total photonuclear reaction definition due to possible contribution of protons in photoneutron reactions and vice versa of neutrons in photoproton reactions.
   6.2. Users and evaluators should be very careful with photonuclear data because monochromatic gamma sources do not exist; this introduces additional systematic errors.
   6.3. Many photonuclear data sets need to be reexamined.

7. Compilation of neutron data in the resolved resonance region measured by TOF method. Spectrometers' response function, V. Semkova:

   ORELA data and resolution function should be recovered by the NNDC according to the NRDC action A36: B. Pritychenko.

8. Neutron source spectra format, O. Gritzay:

   O. Gritzay should prepare a new proposal for neutron spectra compilations and distribute it among the NRDC members.

9. Nuclear astrophysics data. Calculations of nuclear astrophysics and californium neutron cross section uncertainties using ENDF/B-VII.1, JEFF-3.1.2, JENDL-4.0 and low-fidelity covariances, B. Pritychenko:

   B. Pritychenko & N. Otuka should generate a nuclear astrophysics priority list for the NRDC network based on the KADONIS stellar nucleosynthesis library and other sources.

10. Structure of software on graphic data processing for EXFOR data library, G. Pikulina:
    - Software developers should make improvements to curve digitizers according to user's comments. This suggestion is applicable for all network digitizers.
    - Compilers are encouraged to eliminate error analysis correction from EXFOR compilations, per S. Dunaeva suggestion.

11. Additional presentation on EXFOR software and editing tools, V. Zerkin:
    - It will be highly-beneficial for all if the IAEA-EXFOR interface will provide a "Text Google Search" option.
    - Workshop attendees strongly support and appreciate the effort on checking codes by V. Zerkin.

Finally, several EXFOR compilations were produced, and discussed by the workshop attendees before the workshop was adjourned. The workshop organizers and attendees will continue their work at home institutions until the next NRDC meeting.

Workshop on
Compilation for Experimental Nuclear Reaction Data Base EXFOR
6 – 10 October 2014, Vienna, Austria

Meeting Room: M0E10

AGENDA

(Coffee breaks morning / afternoon as appropriate)

Monday, 6 October 2014
9:30 – 12:30

1.1	Welcome address	10 min	R. Forrest
1.2	Self-introduction	15 min	All
1.3	Announcement	5 min	K. Nathani
1.4	Objectives of the workshop	10 min	V. Semkova
1.5	Some comments on EXFOR compilation.	150 min	N. Otsuka

12:30 – 14:00 Lunch break

14:00 – 18:00

1.6	Compilation of beta-delayed neutron emission data.	60 min	V. Semkova
1.7	Compilation exercises on beta-delayed neutron emission data	180 min	All

Tuesday, 7 October 2014
9:00 – 13:00

	Review of the compilation exercise of 6th October	30 min	V. Semkova N. Otsuka
2.1	EXFOR compilations for CIELO project	60 min	B. Pritychenko
2.2	Results on the ^{100}Mo(p,2n)^{99m}Tc cross section measurements and possible systematic errors. Definition of radioisotope thick target yields.	60 min	S. Takacs
2.3	Kerma factors in EXFOR: actual status and missing published results.	60 min	S.P. Simakov

13:00 – 14:00 Lunch break

14:00 – 18:00

2.4	Compilation exercises on charged particle-induced data and Kerma factors.	240 min	All

Wednesday, 8 October 2014

9:00 – 13:00

	Review of the compilation exercises of 7th October	45 min	S. Takacs S.P. Simakov N. Otsuka
3.1	Some problems of photonuclear data compilation and evaluation.	45 min	V. Varlamov
3.2	Compilation of neutron data in resolved resonance region measured by TOF method. Spectrometers' response function.	45 min	V. Semkova
3.3	Neutron source spectra format.	45 min	O. Gritzay

13:00 – 14:00 Lunch break

14:00 – 18:00

3.4	Compilation exercises on neutron-induced and photonuclear data.	240 min	All

Thursday, 9 October 2014

9:00 – 13:00

4.1	Nuclear astrophysics data. Calculations of nuclear astrophysics and californium neutron cross section uncertainties using ENDF/B-VII.1, JEFF-3.1.2, JENDL-4.0 and low-fidelity covariances.	60 min	B. Pritychenko
4.2	Structure of software on graphic data processing for the EXFOR data library.	30 min	G. Pikulina
4.3	User's interface of a program on graphic data processing for the EXFOR data library: approaches, solutions, capabilities.	30 min	S. Taova
4.4	Introduction of digitization software GDgraph.	30 min	Chen Guochang
4.5	Digitization software GSYS.	30 min	D. Ichinkhorloo
4.6	Digitization capabilities of Origin 9.0.	30 min	B. Marcinkevicius

13:00 – 14:00 Lunch break

14:00 – 18:00

4.7	Digitization tools and compilation exercises on nuclear astrophysics data.	240	All

Friday, 10 October 2014

9:00 –

5.1	Review of the compilation exercises of 8th and 9th October		B. Pritychenko V. Varlamov N. Otsuka
5.2	Discussions.		
5.3	Closing of the meeting		

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