International Atomic Energy Agency

Presentation at NRDC 2010 Meeting

IAEA Nuclear Data Section

N. Otsuka

International Atomic Energy Agency

Fission Quantity Coding
(WP 2010-31)

N. Otsuka

EXFOR Ternary Fission Quantity

- **Fission where Light charged particle (LCP) is emitted with two fission fragments – t, α (Long Range Alpha)**

- **Inconsistency in EXFOR REACTION coding**

  ***Example*:**

  alpha yield in ternary fission

  (92-U-235(N,F),TER,FY,A) or

  (92-U-235(N,F)2-HE-4,TER,FY)

  alpha kinetic energy

  (92-U-233(N,F),TER,AKE,A,MXW)or

  (92-U-235(N,F)2-HE-4,TER,KE,,MXW)

Proposal in Memo CP-D/599

(1) <u>Yield of given fission product/particle</u>

Fragments/particle: coded in SF4 except neutron and coincidence measurement

Example:

`(92-U-235(N,F)0-G-0,FY)` : gamma fission yield

`(92-U-235(N,F)2-HE-4,TER,FY)` : α ternary fission yield

`(92-U-235(N,F)35-BR-87,FY)` : ^{87}Br fission yield

`(92-U-235(N,F),PR,NU)` : prompt fission neutron yield

`(92-U-235(N,F)35-BR-87,,FY,G)` :

γ yield measured in coincidence with 87Br fragment

Proposal in Memo CP-D/599 (cont'd)

(2) Average kinetic energy of given product/particle

Fragments/particle: coded in SF4 except neutron and coincidence measurement with KE in SF6

***Example*:**

`(92-U-235(N,F)0-G-0,KE)`: gamma average kinetic energy

`(92-U-235(N,F)2-HE-4,TER,KE)`: α average kinetic energy

`(92-U-235(N,F)35-BR-87,KE)`: ^{87}Br average kinetic energy

`(92-U-235(N,F)0-NN-1,PR,KE)`:

Prompt fission neutron average kinetic energy

`(92-U-235(N,F)35-BR-87,,KE,G)`:

Average γ kinetic energy measured in coincidence with 87Br fragment

Proposal in Memo CP-D/599 (cont'd)

(3) Average kinetic energy of a group of fission product/particles
Group of fission product/particles: coded in SF7 with AKE in SF7

***Example*:**

`(92-U-235(N,F),AKE,FF):`

Average kinetic energy of fission fragment

`(92-U-235(N,F),AKE,LF) :`

Average kinetic energy of light fragment

`(92-U-235(N,F),AKE,LF+HF) :`

Average kinetic energy of light and heavy fragment (TKE)

Proposal in Memo CP-D/599 (cont'd)

(4) Most probable mass or charge

Same as kinetic energy (3)

(5) Complicated fission quantities with two or more objects in SF7

***Example*: Average neutron kinetic energy as a function of TKE**

EXFOR 14065.007: `(98-CF-252(0,F),PAR,AKE,N/FF)`

We will code such complicated fission quantities with MSC until a consistent coding rule is established.

***Example:* Above quantity will be coded with**

`(98-CF-252(0,F)0-NN-1,PAR,KE,,MSC)`

Proposal in Memo CP-D/600

"Ternary to binary light charged yield ratio"
has been measured by Wagemans *et al*.

They often denote these quantities by
LRA/*B* (Long range alpha yield per binary fission)
t/*B* (triton yield per binary fission)
and coded by

```
(98-CF-252(0,F),TER/BIN,FY/RAT,A)
(98-CF-252(0,F),TER/BIN,FY/RAT,T)
```

However they are ratio of counting rate of LCP (α or t) to counting rate of all (ternary and binary) fission event. These are simple fission yield.

The following quantity codes should be used.

```
(98-CF-252(0,F)2-HE-4,TER,FY)
(98-CF-252(0,F)1-H-3,TER,FY)
```

Proposal in Memo CP-D/613

Proposed rule of differential fission yield:

Unit Family	FY	FYDA (Diff. angle)	FYDE (Diff. energy)	FYAE (Double Diff.)
Fission Fragment	FY	FY/DA	FY/DE	FY/DA/DE
Fission neutron	NU	NU/DA	NU/DE	NU/DA/DE

Example:
(92-U-235(N,F),2-HE-4,TER,FY/DA):
Angular distribution of fission α fragment
(92-U-235(N,F),2-HE-4,TER,FY/DA/DE):
Double differential yield of fission α fragment

END

International Atomic Energy Agency

Clarification of usage of MLT and PY in LEXFOR
(WP 2010-32)

N. Otsuka

Multiplicity and Product Yield (in EXFOR)

According to LEXFOR explanation about thick-target yield,

Multiplicity: Yield of an outgoing particle (SF3) - MLT

Product yield: Yield of reaction product (SF4) - PY

Example: **capture gamma and continuous exclusive gamma**

`(82-PB-207(N,G)82-PB-208,,MLT)`

Yield of outgoing particle (= γ)

Unit: PRT/REAC (particle per reaction) etc.

`(82-PB-207(P,X)0-G-0,,PY)`

Yield of reaction product (= γ)

Unit: PRD/INC (product per incident particle) etc.

Multiplicity and Product Yield (Tips)

SF1(SF2,SF3)SF4,SF5,SF6

Object	Quantity name	SF6	Unit
SF3	Multiplicity	MLT	PRT
SF4	Product yield	PY	PRD

Usually “product yield” is defined for inclusive measurement (i.e. SF3=X).

END

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Update of LEXFOR
“General Quantity Modifier”
(WP 2010-33)

N. Otsuka

General Quantity Modifier

A: times natural isotopic abundance

FCT: times other factor (e.g. branching ratio)

REL: shape data

RAW: Raw data (e.g. uncorrected transmission)

MSC: Unusual quantity not defined in EXFOR dict.

MXW, FIS, SPA: Spectrum average

Example:

22-TI-48(P,X)17-CL-39,,SIG,,A

^{48}Ti(p,x)^{39}Cl cross section times *a*(^{48}Ti)~73.7%

Proposal about Use of GENQ (for consistency)

1) Only one code can be chosen from `A`, `FCT`, `REL`, `RAW` and `MSC`, where righter code is more wider:

A < FCT < REL < RAW < MSC

Example:

Shape (REL) of uncorrected (RAW) neutron transmission is given for ^{235}U,

`(92-U-235(N,TOT),,TRN,,RAW)` should be used.

2) Spectrum average modifier must be <u>before</u> other GENQ.

Example:

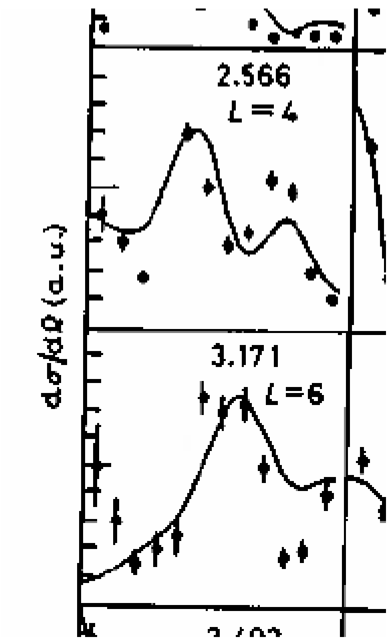
235U prompt fission neutron spectrum for reactor neutron in arbitrary unit.

`(92-U-235(N,F),PR,NU/DE,,MXW/REL)`

Many Panels of Data in Arbitrary Unit

Many panels for data in arbitrary unit
→ Do not combine data into one table

Example: **dσ/dΩ for two levels in arbitrary unit**




```
REACTION (42-MO-92(T,P)42-MO-94,PAR,DA,,REL)
ENDBIB
DATA
E-LVL    ANG     DATA   DATA-ERR
2.566    …       …      …
…        …       …      …
2.566    …       …      …
3.171    …       …      …
…        …       …      …
```

is forbidden!
(Data of two panels might have different normalization constant to mb/sr).

END

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DERIV for Data Measured by Indirect Reaction
(WP 2010-34)

N. Otsuka

Definition of Derived Data

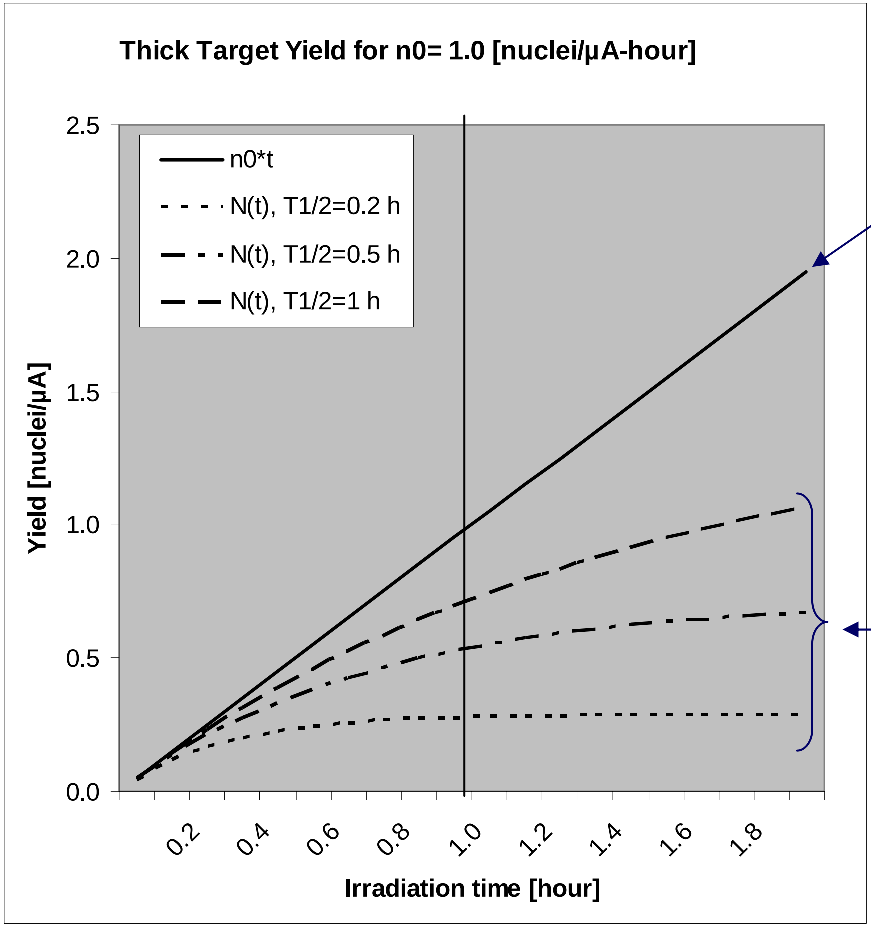
"Data that are not derived from the experimental data by <u>the most direct method</u>, but are, instead, calculated from other data obtained in the analysis of the experimental data"

<u>Derived data entered in EXFOR system</u>

- Resonance integrals derived from resonance parameters or energy-dependent cross sections
- Thermal cross sections calculated from resonance parameters.
- Angular distributions calculated from fitting coefficients.
- Cross-section values at one energy (*e.g.*, at 0.0253 eV) or spectrum averages derived from a smooth fit to measured points.
- Data calculated from the sum or difference of two or more measurements.
- <u>*Thick target yields derived from cross sections or cross sections calculated from thick target yields.*</u>
- <u>*Data calculated using measurements for an inverse reaction.*</u>
- ν calculated from fission yields.

Example: **`(92-U-235(N,G)92-U-236,,SIG,,,DERIV)`**

Physical TTY Derived from Cross Section
(not in WP2010-34)



Physical thick target yield
(usually obtained by integration of cross section from thin target measurement)

$$n_0(E_0) \equiv \frac{dN_0(E_0,t)}{dt} = \frac{1}{Ze} \cdot \int_0^{E_0} dE\,\sigma(E)\rho\left(\frac{dE}{dx}\right)^{-1}$$

Production thick target yield
(usually obtained by thick target measurement)

Saturation thick target yield
($t \rightarrow \infty$)

Integration of cross section is the most straightforward method to obtain physical thick target yield.

Physical TTY Derived from Cross Section
(not in WP2010-34, cont'd)

Derived data entered in EXFOR system

Thick target yields derived from cross sections or cross sections calculated from thick target yields.

→

Production or Saturation thick target yields derived from cross sections or cross sections calculated from thick target yields.

Conclusion:

Physical thick target yields derived from cross sections will not be treated as derived data.

Data measured by Indirect reaction

Various indirect reaction methods, for example,

Surrogate reaction

^{237}Np(n,f) data derived from ^{238}U(^{3}He,t+f) measurement

Trojan horse method

^{9}Be(p,α)^{6}Li data derived from ^{2}H(^{9}Be,α+^{6}Li)n measurement

Coulomb breakup

^{14}C(n,γ)^{15}C data derived from ^{nat}Pb(^{15}C,n+γ)^{nat}Pb measurement

These should be distinguished from data from direct measurement.

Data measured by Indirect reaction (cont'd)

Derived data entered in EXFOR system

Data calculated using measurements for an inverse reaction

→

Data calculated using measurements for an indirect reaction

Conclusion:

Data calculated using measurements for an indirect reaction will be treated as derived data.

END

International Atomic Energy Agency

REACTION for Inverse Kinematics
(WP 2010-35)

N. Otsuka

Inverse Kinematics

Example:

20Ne resonance property in 19F(p,p0)19F scattering by 1H(19F,1H)19F experiment (unstable nucleus reaction)

^{238}U(p,x) isotope production cross section by ^{1}H(^{238}U,x) experiment (online isotope separation by magnet)

Data table from authors are often unchanged under swapping of projectile and target, e.g.., given as function of

- center-of-mass energy
- incident energy per mass number
- center-of-mass angle

etc.

User Unfriendly Coding ☹

“Traditional” EXFOR compilation for GSI experiments

```
SUBENT        O1302002   20060526
BIB                  3          11
REACTION   (1-H-1(92-U-238,X)ELEM/MASS,,SIG)
…
ENDBIB              11
NOCOMMON
EN
GEV
       238.
ENDCOMMON            3

DATA                 5         254
ELEMENT    MASS       DATA        DATA-ERR1  DATA-ERR2
NO-DIM     NO-DIM     MB          PER-CENT   PER-CENT
         7.        15.        1.8        23.        22.
         7.        16.       0.44        22.        21.
```

Users cannot search this data set as p (1 GeV) + ^{238}U reaction.

(J.-C. David, WPEC SG30 meeting, NEA/NSC/DOC(2007)25)

Improved Coding ☺

```
SUBENT         O1302002   20060526
BIB                   3         11
REACTION    ((1-H-1(92-U-238,X)ELEM/MASS,,SIG)=
            (92-U-238(P,X)ELEM/MASS,,SIG))
…
ENDBIB               11
NOCOMMON
EN
GEV/A
         1.
ENDCOMMON             3

DATA                  5        254
ELEMENT     MASS        DATA        DATA-ERR1  DATA-ERR2
NO-DIM      NO-DIM      MB          PER-CENT   PER-CENT
         7.         15.        1.8        23.         22.
         7.         16.       0.44        22.         21.
```

Can be searched as proton-induced reaction data (Tautology formalism)

Incident energy expression invariant under target ⇔ projectile

Encouraged in the Consultant Meeting of Spallation Model Benchmark (Saclay, February 2010)

Tautology (…=…) for Inverse Kinematics

The tautology formalism will be always used when

- all independent variables are unchanged under swapping of projectile and target

and

- $A_{targ} \leq 4$ and $A_{proj} \geq 5$

Example:

```
((1-H-2(9-F-19,P)9-F-20,,SIG)=(9-F-19(1-H-2,P)9-F-20,,SIG)
((1-H-1(9-F-19,EL)1-H-1,,DA,P)=(9-F-19(P,EL)9-F-19,,DA,RSD)
```

END

International Atomic Energy Agency

Atomic Interaction Part of Photo-nuclear Reaction Data
(WP 2010-36)

N. Otsuka

181Ta+ γ cross section by transmission

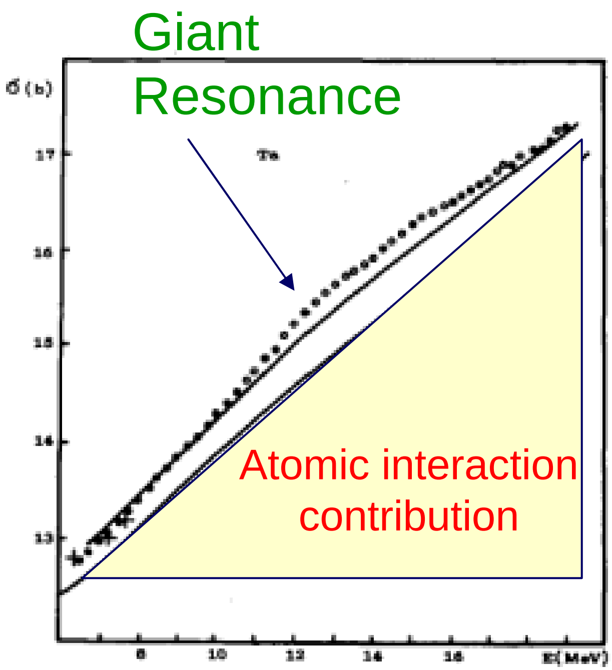
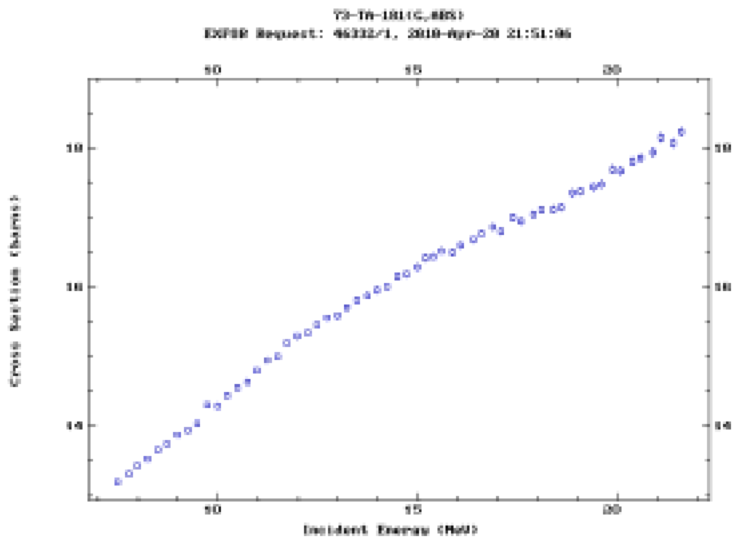


Fig. 3. A comparison between the results of this work for Ta (open circles) and the data of the experiments with monoenergetic photons [6]) (crosses). Upper curve: calculations [4]); lower curve: calculations [5]).



EXFOR M0041.009

G.M.Gurevich *et al*.,Nucl.Phys.**A338**(1980)97

σ =(1/A)log (N_0/N): Transmission cross section

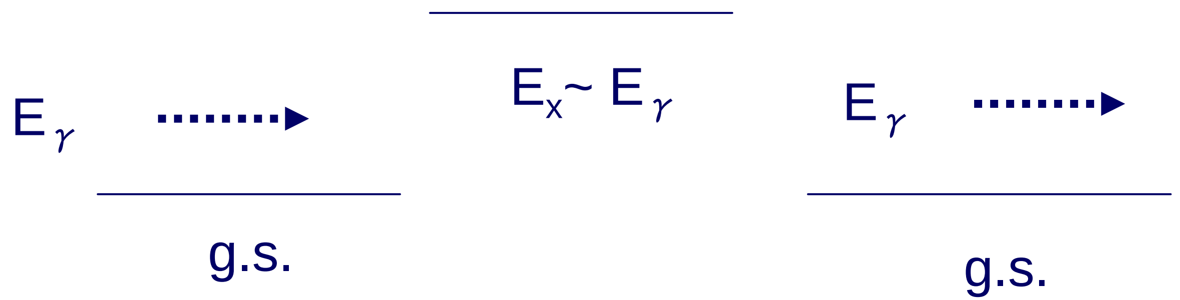
Total and Absorption of photon in EXFOR (Proposal)

(γ,tot)=(γ,n)+(γ,p)+(γ,2n)+…+(γ,f)+nucl. scat.

(γ,abs)=(γ,tot) – nucl. scat.

i.e. photo-atomic interaction contribution (e.g. Rayleigh scattering, Compton scattering, photo-ionization) will be excluded from EXFOR photonuclear reaction data.

Nuclear scattering (nuclear fluorescence)



END

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Use of Reaction Combination
(WP 2010-37)

N. Otsuka

Synonym of Same Reaction/Quantity (1)

Example:

Data for natural target =

Sum data for all contributing target nuclide

```
(46-PD-0(P,X)45-RH-105-G,CUM,SIG)
```

or

```
(46-PD-106(P,2P)45-RH-105-G,CUM,SIG,,A)+
(46-PD-108(P,X)45-RH-105-G,CUM,SIG,,A)+
(46-PD-110(P,X)45-RH-105-G,CUM,SIG,,A)
```

Synonym of Same Reaction/Quantity (2)

Example:

Inclusive cross section =

Sum of exclusive cross section

```
(40-ZR-91(P,X)0-NN-1,,SIG)
```

or

```
(40-ZR-91(P,N)41-NB-91,,SIG)+
(40-ZR-91(P,N+P)40-ZR-90,,SIG)+
(40-ZR-91(P,N+A)39-Y-87,,SIG)
```

Synonym of Same Reaction/Quantity (3)

Example:

Production =

Sum of processes

```
(46-PD-102(P,X)46-PD-101,CUM,SIG)
```

or

```
(46-PD-102(P,D)46-PD-101,CUM,SIG)+
(46-PD-102(P,N+P)46-PD-101,CUM,SIG)
```

Synonym of Same Reaction/Quantity (4)

Example:

Scattering =

Elastic scattering + inelastic scattering

```
(3-LI-7(N,SCT)3-LI-7,PAR,SIG)
```

or

```
(3-LI-7(N,EL)3-LI-7,,SIG)+
(3-LI-7(N,INL)3-LI-7,PAR,SIG)
```

Synonym of Same Reaction/Quantity (5)

Example:

Alpha value =

Capture cross section / fission cross section

```
(92-U-235(N,ABS),,ALF)
```

or

```
(92-U-235(N,G)92-U-236,,SIG)/
(92-U-235(N,F),,SIG)
```

Synonym of Same Reaction/Quantity (6)

Example:

Resonance strength (Capture kernel) $g\Gamma_n\Gamma_\gamma/\Gamma_{tot}$

(82-PB-208(N,G)82-PB-209,,WID/STR)

or

**((82-PB-208(N,EL),,WID,,G)*
(82-PB-208(N,G),,WID))/
(82-PB-208(N,TOT),,WID))**

EXFOR Formats Manual
“Reaction Combination”

the reaction combination formalism is *not* used for certain frequently occurring sums, ratios, and products for which specific quantity codes have been introduced

↓

Addition of these examples in WP2010-37 (a)-(f) to the manual is proposed.

END

Heading for Relative Energy
(WP 2010-38)

N. Otsuka

Relative Energy

Relative energy of the final channel in $1+2 \rightarrow 3+4+\ldots+n$:

$$E_{rel}(3+4+\ldots+n) = E_{cm}(1+2) + Q$$

does not depend on the system.

Two heading codes in dictionary:

- **E-RL: Relative energy of outgoing particle Lab. system**
- **E-RL-CM: Relative energy of outgoing particle, c.m. system**

!?

Only one code should be kept in the dictionary.
(I prefer to keep E-RL only.)

END

Prompt Fission Neutron Spectrum Coding
(WP 2010-39)

N. Otsuka

(For 1st RCM for Prompt Fission Neutron Spectra, April 2010, Vienna)

Statistics of EXFOR PFNS

Year	TH232	U233	U235	U238	NP237	PU239	PU240	PU242 (s.f.)	CM244 (s.f.)	CM248 (s.f.)	CF252 (s.f.)
1950-			3								
1960-			2			2		1	1		7
1970-			9	1		5					19
1980-	2	7	11	6	2	9	1(n,f)				13
1990-	2	1	3	3	1					1	13
2000-	1	1	10	2		4	1(s.f.)	1			
Total	**5**	**9**	**38**	**12**	**3**	**20**	**2**	**2**	**1**	**1**	**52**

Total = 145 subentries (52 for ^{252}Cf(s.f.))

Various Expressions of PFNS

(1) Absolute PFNS (neutrons/MeV/fission)

$\chi(E)$ $\qquad \int \chi(E)dE = \bar{\nu}$

(2) **PFNS <u>relative to the ^{252}Cf spontaneous PFNS</u>** (no dimension)

$\chi(E) / \chi_{252}(E)$ $\qquad \int \chi(E)dE = \bar{\nu} \qquad \int \chi_{252}(E)dE = \bar{\nu}_{252} \sim 3.76$

(3) **PFNS <u>relative to Maxwell distribution</u>** (no dimension)

$$C \frac{\chi(E)}{\sqrt{E}\exp(-E/T)}$$

Various Expressions of PFNS (cont'd)

(4) **"Normalized" PFNS** (1/MeV/fission)

$X(E)$

$$\int X(E)dE = 1$$

(5) **"Normalized" PFNS <u>relative to the "normalized" 252Cf spontaneous PFNS</u>** (no dimension)

$X(E) / X_{252}(E)$

$$\int X(E)dE = 1 \quad \int X_{252}(E)dE = 1$$

(6) **PFNS <u>relative to √E</u>**

$$C\frac{\chi(E)}{\sqrt{E}}$$

Absolute data, shape data, absolute ratio, shape ratio …

The current EXFOR system is not ready for this variety…

Inconsistency of PFNS in EXFOR

REACTION: **With or without PR (prompt)**

(98-CF-252(0,F),PR,DE,N)
(98-CF-252(0,F),,DE,N)

REACTION: **Variety in PFNS relative to Maxwell spectrum**

(98-CF-252(0,F),PR,DE,N,MXD)
(98-CF-252(0,F),PR,DE,N,REL)
((98-CF-252(0,F),PR,DE,N,,EXP)/(98-CF252(0,F),PR,DE,N,,CALC))
((98-CF-252(0,F),PR,DE,N)/(98-CF-252(0,F),PR,DE,N))

REACTON: **Strange quantity code defined in the EXFOR system**

PR,DE,N,RTE - Energy spectrum of prompt fission neutron * square root(E)) ***!?***

Variety in unit

1/MEV (should not be used for any type of PFNS)

PT/FIS/MEV (should be used for absolute PFNS)

NO-DIM (should be used for absolute PFNS ratio)

ARB-UNITS (should be used for shape data)

Decision of PFNS Unit by EXFOR compilers

TABLE III

The Shape of the Prompt Fission Neutron Spectrum of ^{235}U Induced by 0.53-M

(The error of the values are given in Table II. The numerical values best-fit Watt distribution are also included.)

Mean Neutron Energy (MeV)	Measured Value [$\chi(E)_{exp}$/MeV]	Fitted Value [$\chi(E)_{fit}$/MeV]
0.6250E 00[a]	0.1872E 07	0.1778E 07
0.6750E 00	0.1830E 07	0.1787E 07
0.7250E 00	0.1771E 07	0.1791E 07
0.7750E 00	0.1730E 07	0.1791E 07
0.8250E 00	0.1731E 07	0.1787E 07
0.8750E 00	0.1754E 07	0.1779E 07

Relative data (arbitrary unit)?
Absolute data (neutrons per MeV per fission)?

Summary

- Inconsistency in EXFOR (REACTION code, unit)

- Can't translate to C4 format, Can't plot on web.

- Several versions of data exist in the database
  (e.g. Starostov *et al*. NIIAR)
  → See details in Pronyaev's note (Nov. 2008)

EXFOR PFNS needs clean-up !

END

International Atomic Energy Agency

Final and Intermediate Reaction Products
(WP 2010-40)

N. Otsuka

END

International Atomic Energy Agency

Future NRDC Cooperation on CINDA
(WP 2010-21)

N. Otsuka

Previous Agreement in 2003 Meeting

- WP2003-25 Item 2 (Transmission responsibility)

NNDC → US and Canada

NEA-DB → NEA member countries

NDS → Rest of the World

- From WP2003-26

Theoretical works and reviews will *not* be entered in CINDA.

Current Situation of Compilation

- NNDC

  No compilation.

- NEA Data Bank

  Compiling European theoretical works until year 2008, and also receive CINDA batches from JCPRG and JAEA.

- JCPRG and JAEA

  Compiling experimental and theoretical works from Japanese publications

- NDS

  No compilation.

Conversion and Database Update

EXFOR to CINDA

Conversion program from EXFOR to CINDA works well at NDS.

Update of CINDA database

Old “manual” CINDA lines

+ new “manual” CINDA lines from NEA DB, JCPRG, JAEA (*minor contribution*)

+ CINDA lines translated from the latest EXFOR database

+ updated “manual” CINDA lines from NDS (correction of mistakes)

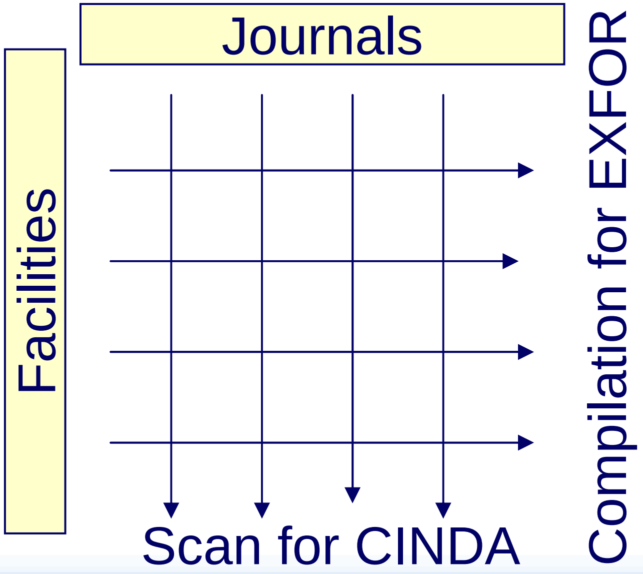
CINDA as EXFOR Coverage List

Responsibility of CINDA compilation is assigned by locations of publishers.

c.f. EXFOR compilation is assigned by locations of experimental facilities.

The idea of responsibility assignment by journal works as a double checking of EXFOR completeness.
(Actually NNDC found some Phys. Rev. C articles cannot be found by NDS.)

Each centre must scan journals of their own area (as previously agreed!)



Proposals

1) Agreement on WP2003-25 item 2 will be cancelled.

2) Theoretical works and reviews will be accepted in future transmission.

3) Centres willing to be responsible to CINDA input can continue (or start) compilation of CINDA entries after notification of their compilation scope (journal, conference, data library, experimental, theoretical etc.) to NDS.

4) Originating centres will send their CINDA entries to NDS.

5) NDS will periodically update the CINDA master file and distribute it to other centres.

Remarks (may be in proposal?)

<u>Each NRDC centre has to scan assigned journals</u> tabulated in the proceedings of NRDC2006 (INDC(NDS)-0503, page 26) for the EXFOR Compilation Control System, and send the list of articles relevant to EXFOR compilation to NDS. NDS will update the list generated from the system periodically.

INDC(NDS)-0503, page 26-27

Coverage of major journals
Coverage of major journals by data centre
(updated November 2006)

NNDC: PR/C, PRL, NSE
NDS: ARI, NP/A, CNP, NIM/A+B, PL/B
CAJAD: YF, EPJ
CNDC: CST, (NPR), PHE, HFH, NTC, CPL, CNDP, CNST, ASI, CPH
CNPD: IZV
CJD: YK
NEA: ANE, RCA
JCPRG: AEJ, NST, NSTS
ATOMKI: AHP, JRN, JRN/L

END

International Atomic Energy Agency

New LEXFOR entry - Fusion
(WP 2010-21)

N. Otsuka

END