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# Intermediate Energy Nuclear Data and Related International Collaboration

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# History of Intermediate Nuclear Data



## *1980's: beginning*

Needs of nuclear data in the intermediate energy range up to several GeV

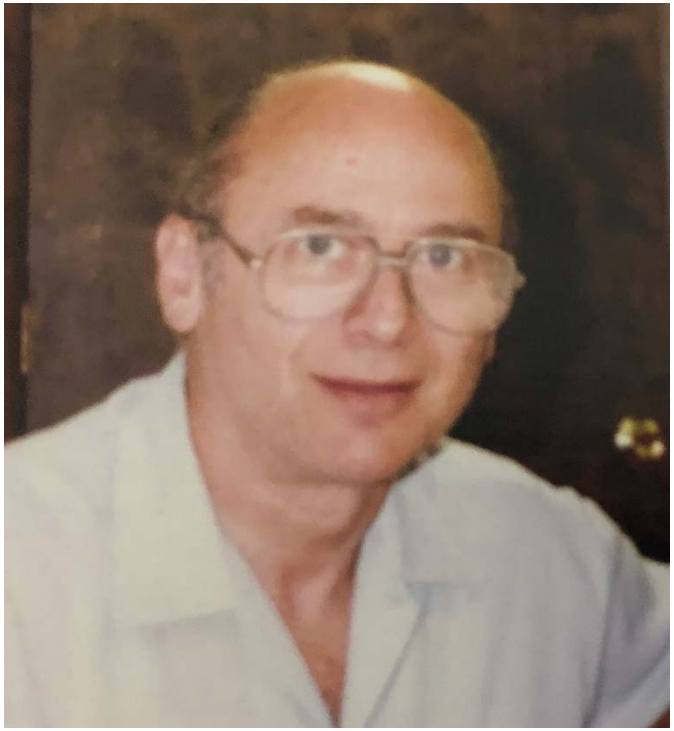
- accelerator systems used for physical researches
- radiation therapies, medical isotope productions
- radioactive waste transmutation
- space engineering: radiation effects on astronauts and their equipments
- astrophysical studies like cosmic history of meteorites and the other galactic substances.

## *1988-1999: beginning*

Staying at BNL and then;

Case studies of producing evaluated intermediate energy nuclear data libraries have been started, for example, evaluation for proton- and neutron-induced reactions up to 1 GeV on C-12, Fe-56 were compiled in the ENDF/B-VI High Energy File.

Evaluation for Pb-208 and Bi-209
→ Reported at IAEA/TM



# History of Intermediate Nuclear Data

## *1990-1995: at early time*

Japanese Nuclear Data Committee (JNDC) has started a project to produce the JENDL High Energy File (JEDNDL/HE) for the accelerator-driven radioactive waste transmutation system (OMEGA project, 1.5 GeV), the material irradiation test facility for fusion application which is called the Energy Selective Neutron Irradiation Test Facility (ESNIT, 50 MeV), etc.

and then, started activities on evaluation of intermediate energy nuclear data in Japan.

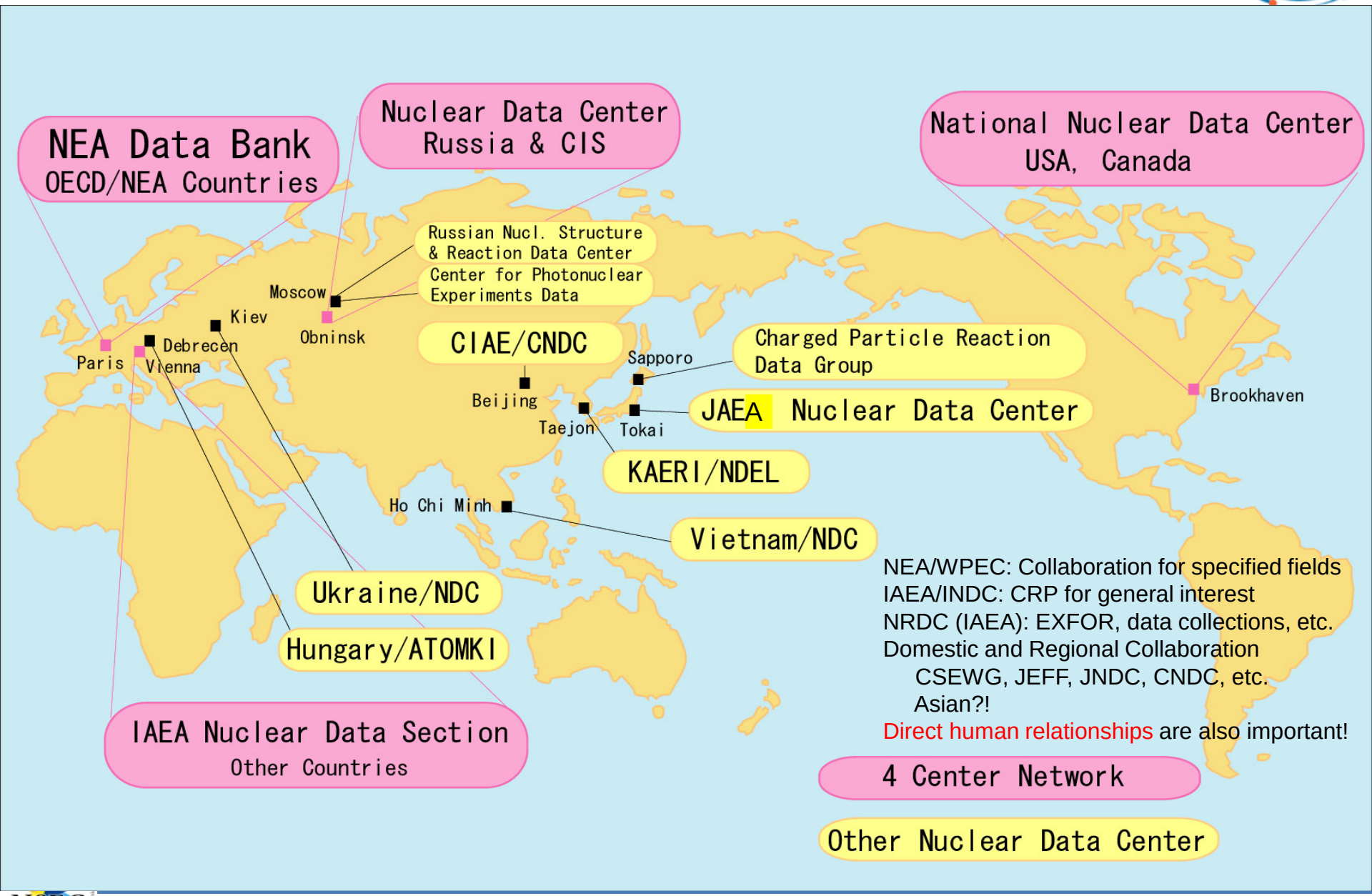
<u>Experts' Meeting on Intermediate Nuclear Data</u>

1991.10: 1st meeting

1995.01: 2nd meeting

# Trends of International Collaboration





# *OECD/NEA/NSC/WPEC Subgroups (SG)*

## Long-term subgroups

Three long-term subgroups had been created in 1993.

SG-A: Experimental Activities
← WP on Int. ND Measurement Activities (WPMA)

SG-B: Evaluated Data Formats and Processing for Application Libraries

SG-C: High Priority Request List (HPRL)
Co-ordinator: A. Plompen (EC/JRC/IRMM)

## Short-term subgroups

SG-1: Comparison of evaluated data for $^{52}$Cr, $^{56}$Fe and $^{58}$Ni (1992, C.Y. Fu)
SG-2: Generation of covariance files for $^{56,nat}$Fe (1994, H. Vonach)
SG-3: Actinide data in the thermal range (1994, H. Tellier and H. Weigmann)
SG-4: $^{238}$U capture and inelastic cross-sections (1999, M. Baba)
SG-5: $^{239}$Pu fission cross-section between 1 and 100 keV (1994, E. Fort)
SG-6: Delayed neutron data (2002, A. d'Angelo)
SG-7: Nuclear data standards (2006, A. Carlson)

## OECD/NEA/NSC/WPEC

# Report of the NEACRP/NEANDC Task Force on Evaluation Cooperation

J. Rowlands, C. Nordborg

6 October 1989

## 1 Members of the Task Force

J. Rowlands (NEANDC) chairman,
C. Nordborg (NEA) secretary,

| | | |
|---|---|---|
| C. Dunford (ENDF), | T. Fukahori (JENDL), | H. Gruppelaar (EFF), |
| S. Igarasi (JENDL), | Y. Kikuchi (JENDL), | H. Küsters (NEACRP), |
| D. Larson (ENDF), | R. McKnight (NEACRP), | T. Nakagawa (JENDL), |
| S. Pearlstein (ENDF), | M. Salvatores (JEF), | M. Sowerby (JEF), |
| H. Vonach (NEANDC). | | |

# Trends of International Collaboration

## *OECD/NEA/NSC/WPEC*

First Meeting of the

**WORKING GROUP ON INTERNATIONAL EVALUATION COOPERATION**

Oak Brook, USA, 9th October 1989

**Present:**

| | | |
|---|---|---|
| C. Dunford | (ENDF) | Chairman |
| H. Gruppelaar | (EFF) | |
| Y. Kikuchi | (JENDL) | |
| R. McKnight | (NEACRP) | |
| H. Küsters | (NEACRP) | |
| C. Nordborg | (NEA) | Secretary |
| M. Salvatores | (JEF) | |
| A. Smith | (NEANDC) | |
| M. Sowerby | (NEANDC) | |

Second Meeting of the

**WORKING GROUP ON INTERNATIONAL EVALUATION COOPERATION**

Marseille, France, 30th April and 1st May 1990

Present:

| | | |
|---|---|---|
| C. Dunford | (ENDF) | Chairman |
| E. Fort | (NEANDC) | |
| H. Gruppelaar | (EFF) | |
| Y. Kanda | (JENDL) | |
| Y. Kikuchi | (JENDL) | |
| H. Küsters | (NEACRP) | |
| D. Larson | (ENDF) | |
| E. Menapace | (JEF) | |
| C. Nordborg | (NEA) | Secretary |
| M. Salvatores | (JEF) | |
| M. Sowerby | (JEF) | |
| H. Takano | (JENDL) | |

## *JENDL/HE: early stage*

1. The file for phase I includes the data for 41 elements, which are structural materials and the other important elements for the above applications.
2. The evaluated quantities are planned to be total, elastic scattering, reaction, fission and isotope production cross sections, and double differential particle and gamma-ray emission spectra by proton- and neutron-induced reactions
3. In order to investigate the reliability of model calculations, benchmark calculations were performed for isotope production cross sections of manganese and iron below 50 MeV, and of aluminum, iron and bismuth up to 1 GeV with the codes of SINCROS-II, ALICE-F, EXIFON, MCEXCITON, HETC/3STEP and NUCLEUS.

## *JENDL/HE: early stage*

4. The statistical model with the correction of preequilibrium process is selected for the evaluations, and the intranuclear cascade model for the phase II evaluation and the break-up reaction for the lighter mass nuclei are also considered.
5. As a new method for intermediate energy nuclear data evaluation, the application of the quantum molecular dynamics (QMD) theory is investigated, which has the merits such as easy treatment of multi-fragmentation to calculate spallation product yields, inclusion of preequilibrium process in the calculation, and no requirement of particular assumption on the structures and reaction mechanisms related nuclei.
6. As a secondary file, the PKA/KERMA file, which includes the primary knock-on atom (PKA) spectra, displacement per atom (DPA) cross sections and KERMA factors for the estimation of the radiation damage in solid materials, will be processed from the JENDL High Energy File up to 50 MeV.

# History of Intermediate Nuclear Data



## *1990-2010: HE files in the world*

| Organization | Outline | Nuclides |
|---|---|---|
| BNL | **ENDF/B-VI High Energy File**.<br>Neutron and Proton up to 1 GeV | $^{12}$C, $^{56}$Fe,$^{208}$Pb, $^{209}$Bi |
| LANL | **LA150** library:<br>Neutron and proton up to 150 MeV | $^{1}$H, $^{12}$C, $^{14}$N, $^{16}$O, $^{27}$Al, $^{28,29,30}$Si, $^{31}$P, $^{40}$Ca, $^{50,52,53,54}$Cr, $^{54,56,57,58}$Fe, $^{58,60,61,62,64}$Ni, $^{63,65}$Cu, $^{93}$Nb, $^{182,183,184,186}$ W, $^{206,207}$,$^{208}$Pb |
| NRG<br>Petten | **NRG-2003** library:<br>Neutron and proton up to 200 MeV<br>TALYS code | $^{40,42,43,44,46,48}$Ca, $^{45}$Sc, $^{46,47,48,49,50}$Ti, $^{54,56,57,58}$Fe, $^{58,60}$Ni, $^{70,72,73,74,76}$Ge, $^{204,206,207,208}$Pb, $^{209}$Bi |
| FZK | Neutron up to 50 MeV<br>for IFMIF | $^{52}$Cr, $^{56}$Fe, $^{51}$V |
| IPPE<br>Obninsk | File up to 100 MeV (**WIND**)<br>Activation file up to 100 MeV<br>(**MENDL-2**) | n+$^{232\text{-}238}$U, $^{237,239}$Np, $^{236\text{-}244}$Pu, p+$^{238}$U<br>505 nuclides/reactions |
| KAERI | Neutron and proton up to 400 MeV<br>ECIS-GNASH code | $^{12}$C, $^{27}$Al, $^{56}$Fe, $^{208}$Pb |
| JAEA | **JENDL High Energy File** 2007<br>Neutron and proton up to 3 GeV | 106 Nuclides |

## *Improvement after JENDL/HE-2007*

- Remained nuclides: mainly, light mass nuclides and MA

- Tool improvement: CCONE
  multi-particle emission from preequilibrium stage
  luster particle emission (IHS model)
  JENDL/HE-2007 : $^{56}$Fe, Zr, $^{93}$Nb, W, Pb, $^{209}$Bi

- Cross section gap at 200 MeV
  important for activation calculation

## OECD/NEA/NCS/WPEC

URL: http://www.oecd-nea.org/science/wpec/

SG12: Nuclear Models to 200 MeV for High-energy Data Evaluations (1998)
SG13: Intermediate Energy Data (1998)

## *IAEA/NDS*

### Intermediate Nuclear Data

INDC(NDS)-245 (Feb 1991)  Ed. N.P. Kocherov
Proceedings of the Advisory Group Meeting on Intermediate Energy Nuclear Data for Applications, Vienna, 9-12 October 1990

INDC(NDS)-0546 (Apr 2009) K.I. Zolotarev
Evaluation of Cross-section Data from Threshold to 40-60 MeV for Specific Neutron Reactions Important for Neutron Dosimetry Applications Part 1 Evaluation of the excitation functions for the 27Al(n,alpha)24Na, 55Mn(n,2n)54Mn, 59Co(n,p)59Fe, 59Co(n,2n)58m+gCo and 90Zr(n,2n)89m+gZr reactions

INDC(NDS)-0615 (Apr 2012) S.G. Yavshits, O.T. Grudzevich
Evaluation and Compilation of Neutron/Proton-induced Fission Cross-sections for Hg, Pb, Bi, Th and U at 20 MeV to 1 GeV

## *IAEA/NDS*

### FENDL

INDC(NDS)-0547 (Mar 2009) A. Trkov and R. Forrest and A. Mengoni
INDC(NDS)-0567 (Jun 2010) M.E. Sawan
INDC(NDS)-0602 (Mar 2012) M.E. Sawan
Summary Report from the RCM on FENDL-3

INDC(NDS)-0628 (Dec 2012) R.A. Forrest, R. Capote, N. Otsuka, T. Kawano, A.J. Koning, S. Kunieda, J-Ch. Sublet and Y. Watanabe
FENDL-3 Library Summary documentation

INDC(NDS)-0645 (Dec 2013) R.A. Forrest
FENDL-3 Library Summary Report of the CRP

INDC(NDS)-0724 (Aug 2016) M. Fleming, A. Trkov
INDC(NDS)-0769 (In preparation) L. Packer and A. Trkov
FENDL: Summary report of the Consultants Meeting

## IAEA/NDS

### Photonuclear Data

IAEA-TECDOC-1178 (Oct 2000)
Handbook on Photonuclear Data for Applications Cross-sections and Spectra Final Report of a CRP 1996-1999 IAEA

INDC(NDS)-364 (Apr 1997) P. Oblozinsky
Summary Report of the 1st RCM on Compilation and Evaluation of Photonuclear Data for Applications, Obninsk, Russia, 3-6 December 1996

INDC(NDS)-394 (Jan 1999) A.V. Varlamov, V.V. Varlamov, D.S. Rudenko and M.E. Stepanov
Atlas of Giant Dipole Resonances

INDC(NDS)-409 (Feb 2000) P. Oblozinsky
Summary Report of the Third RCM on Compilation and Evaluation of Photonuclear Data for Applications, JAERI, Japan, 25-29 October 1999

## *IAEA/NDS*

### ADS

INDC(NDS)-469 (Dec 2004) A. Stanculescu and A. Trkov
Report on the IAEA Technical Meeting on Application Libraries for ADS and Transmutation, Vienna, 15-17 December 2004

INDC(NDS)-0474 (Aug 2005) D. Lopez Aldama and A. Trkov
ADS-Lib/V1.0, A Test, Library for Accelerator Driven Systems

INDC(NDS)-0585 (Dec 2010) Ed. F. Gunsing and N. Otsuka
Minor Actinide Nuclear Reaction Data (MANREAD) Summary Report of Third RCM (19-22 October 2010, Vienna, Austria)

INDC(NDS)-0656 (Dec 2013) D.L. Aldama
ADS-HE: Evaluated Nuclear Data Library up to 1 GeV for 202Hg, 208Pb, 209Bi, 232Th, 235U, 238U, 237Np, 239Pu, 242Am and

## *IAEA/NDS*

### IFMIF

INDC(NDS)-0478 (Oct 2005) R. Forrest and A. Mengoni
Summary Report of a Technical Meeting on Nuclear Data for the IFMIF, Karlsruhe, Germany, 4-6 October 2005

### FPY

IAEA-TECDOC-1168 (Dec 2000)
Compilation and Evaluation of Fission Yield Nuclear Data Final Report of CRP 1991-1996 IAEA

### Therapy

IAEA-TECDOC-992 (Dec 1997)
IAEA-TECDOC-1211 (May 2001)
Charged Particle Cross-Section Database for Medical Radioisotope Production

## *IAEA/NDS*

### Standard Nuclear Data

INDC(NDS)-368 (May 1997) A.D. Carlson and S. Chiba and F.-J. Hambsch and N. Olson and A.N. Smirnov Edited by H. Wienke
INDC(NDS)-0641 (Jul 2013) V.G. Pronyaev, A.D. Carlson and R. Capote Noy
INDC(NDS)-0677 (Oct 2015) V.G. Pronyaev, A.D. Carlson, R. Capote Noy

INDC(NDS)-0681 (May 2015) B. Marcinkevicius, S. Simakov, V. Pronyaev
209Bi(n,f) and natPb(n,f) Cross Sections as a New Reference and Extension of the 235U, 238U and 239Pu(n,f) Standards up to 1 GeV

INDC(NDS)-0716 (Aug 2016) G. Noguere and A. Trkov
Current Status and Open Issues of the U-235 Evaluation Summary Report from the Consultants' Meeting, 24-27 May 2016, Vienna, Austria

## *Current HE files in the world*

JENDL-4.0 High Energy File (JENDL-4.0/HE) : 2015.11

JENDL-4.0 + neutron and proton data up to 200 MeV
(neutron-induced: 130, proton-induced:133)

Ref.) S. Kunieda et al., "Overview of JENDL-4.0/HE and benchmark calculation" JAEA-Conf 2016-004, pp. 41-46 (2016).

download) https://wwwndc.jaea.go.jp/ftpnd/jendl/jendl40he.html

TENDL-2017 : 2017.12

TALYS results up to 200 MeV ← NRG-2003
World record on numbers of compiled nuclides

Ref.) D. Rochman, A.J. Koning, J.Ch. Sublet, M. Fleming, et al, "The TENDL library: hope, reality and future", proceedings of the International Conference on Nuclear Data for Science and Technology, September 11-16, 2016, Bruges, Belgium

download) https://tendl.web.psi.ch/tendl_2017/tendl2017.html

ENDF/B-VIII.0 : 2018.2

Miner change from LA-150

download) https://www.nndc.bnl.gov/exfor/endf00.jsp

## *Remained …*

**Fission Related Quantities** in Intermediate Energy Region

**Activation Cross Sections** in Intermediate Energy Region

- Simulation codes can not always reproduce activation cross section.
- For dose estimation and/or source of shielding calculation, certain level accuracy is required.

# Thank you for your attention!


is your good choice.