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D. Rochman

How well do we know some cross sections below 20 MeV ?

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- Do we know neutron cross sections?
- Experimental evidence of discrepancies
- Modeling uncertainties
- Conclusion







Neutron cross sections: state of knowledge

- In the following, neutron-induced reaction up to 20 or 200 MeV
- Most of the efforts were for thermal/resonance/fast range (in this order)
- Many nuclear data libraries (US, NEA, Japan, ...)
- Many dedicated libraries (fusion, dosimetry, reactor...)

Libraries: All O Selected Check Reset	
Libraries: All O Selected Check R Major Libraries 1) ENDF/B-VII.1 (USA,2011) 2) JEFF-3.2 (Europe,2014) 3) JENDL-4.0u2 (Japan,2012) 4) CENDL-3.1 (China,2009) 5) ROSFOND-2010 (Russia,2010) 6) BROND-2.2 (Russia,1992)	 Special Libraries 7) JENDL-4.0/HE, JENDL-4.0 High Energy File 2015 (neutron, proton) 8) IBA-EVAL Differential data for ion beam analysis, 2013 9) EPICS-2014 Electron and Photon Interaction Cross Sections (USA,2014) 10) TENDL-2014 (n,y,p,d,t,he3,a) (Netherlands,NRG,2014) 11) EAF-2010: European Activation File /816MAT,60MeV/, UK+Netherlands 12) ENDF/HE-VI (High Energy) 13) FENDL-3.0 Fusion Evaluated Nuclear Data Library, 2015 14) JEFF-3.1/A (Activation) 15) IRDFF (Dosimetry) 16) IRDF-2002 (Dosimetry) 17) INDL/TSL (Thermal Scattering Law) 18) IAEA-Medical (diagnostic radioisotopes prod.) 19) IAEA-Medical (therapeutical radioisotopes prod.) 20) IAEA-Standards, 2006 21) PADF-2007, Proton Activation Data File, 2007 22) JENDL/AC-2008, JENDL Actinoid File 2008 23) JENDL/AN-2005, (alpha,n) Reaction Data File 24) JENDL/PD-2004, Photoreaction Data 25) JENDL/HE-2007, High Energy (neutron, proton) 26) MENDL-2, Medium Energy, 1995-1998 27) MINKS-ACT Actinides Library (Maslov et al.)
	 25) JENDL/HE-2007, High Energy (neutron, proton) 26) MENDL-2, Medium Energy, 1995-1998 27) MINKS-ACT. Actinidas Library (Maslov et al.)
	28) Wind, U,Np,Pu (up to 100 MeV) 29) Yavshits (neutron, proton induced fission for Pb-Pu)
	O ≥ Archival O ≥ Derived





Nuclear data life cycle



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- Cross section library = measurements + modeling
- In many libraries, cross sections for the same reactions are different, why?
 - Not enough experimental data ?
 - Discrepant experimental data ?
 - Wrong modeling ?
 - Discrepant experiment/model ?
 - Different interpretation (human, processing, simulation)?
- Why many libraries ?
 - Different application field
 - Different knowledge
- Still, cross sections are unique quantities expressing probabilities (not like uncertainties)





Fe54(n,p)Mn54







Large discrepencies between JEFF-32 (=JEFF-311) and IRDFF-1.04

Impact on activation calculations

Fe54(n,p)Mn54



From JEFDOC-1593, NEA, November 2014

- IQNet



Examples on dosimetry cross sections



tions for 59 Co(n,3n) reaction and p- 7 Li source spectra [8].

From Progress in Nuclear Science and Technology 4 (2014) 591

Among the activation/dosimetry libraries: important change/differences





Examples for important reactor cross sections

• Famous ²³⁵U(n,g) cross section in the keV range



Examples for important reactor cross sections



FIG. 3: (Color online) Fitted spectra (left); and comparison of the fitted basis function with renormalised differential data (i.e. shape data) (right) displayed as ratios to a Maxwellian with temperature 1.32 MeV.

• Prompt fission neutron spectrum of ²³⁵U(n,f)



FIG. 5: (Color online) Spectrum fitted with the GANDR code, showing the uncertainties that include the normalisation uncertainty in the measured data.

Nuclear Data Sheets 123 (2015) 8

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http://www.psi.ch/stars



• ¹⁶O(n,a) cross section, long standing problem, soon resolved



From http://dx.doi.org/10.1051/ndata:07481



Modeling: another source of uncertainties

- Models and theoretical calculations are necessary for cross section evaluations
- Without experimental data, microscopic/macroscopic calculations are still too blind for the required accuracy





Modeling: another source of uncertainties

- Different models will lead to different cross sections
- Different persons with the same model will lead to different cross sections
- Current approach to express the spread of data: covariance files or TMC
 - <u>Covariance files</u>: uncertainties + correlations for cross sections
 - <u>TMC</u>: model parameter "pdf" (probability density function)
- Both approach have advantages and drawbacks







- Cross section evaluation below 20/200 MeV are based on measurements,
- Cross section evaluation below 20/200 MeV are complemented by modeling,
- Both are not well known and approximate,

- Many important cross sections are (too) uncertain,
- A current effort in the nuclear data community focusses on uncertainty estimation,
- As a conclusion, cross sections are still better represented by pdf^{*} than by unique values.





Wir schaffen Wissen – heute für morgen

