



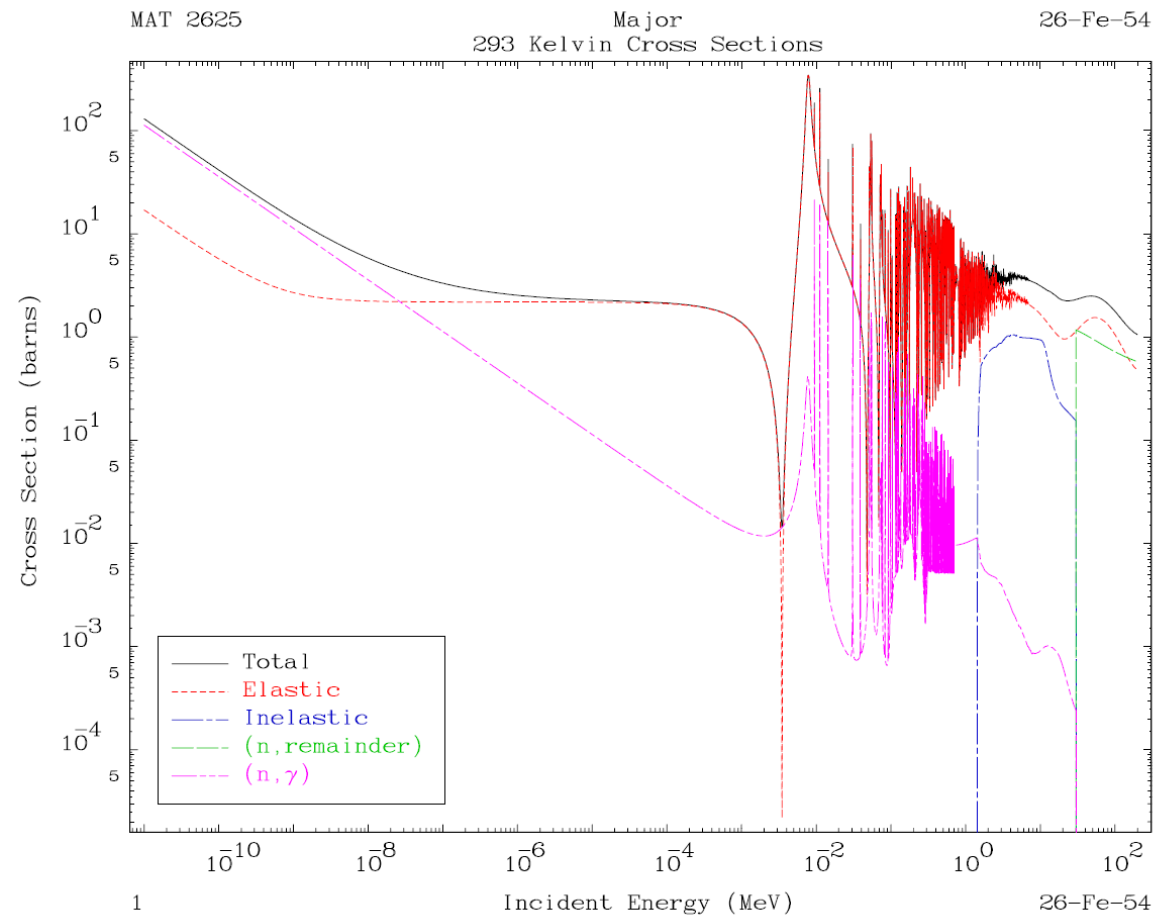
D. Rochman

How well do we know some cross sections ?

EURADOS WP 6-9-11, Karlsruhe, Germany, March 1, 2017

Summary

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



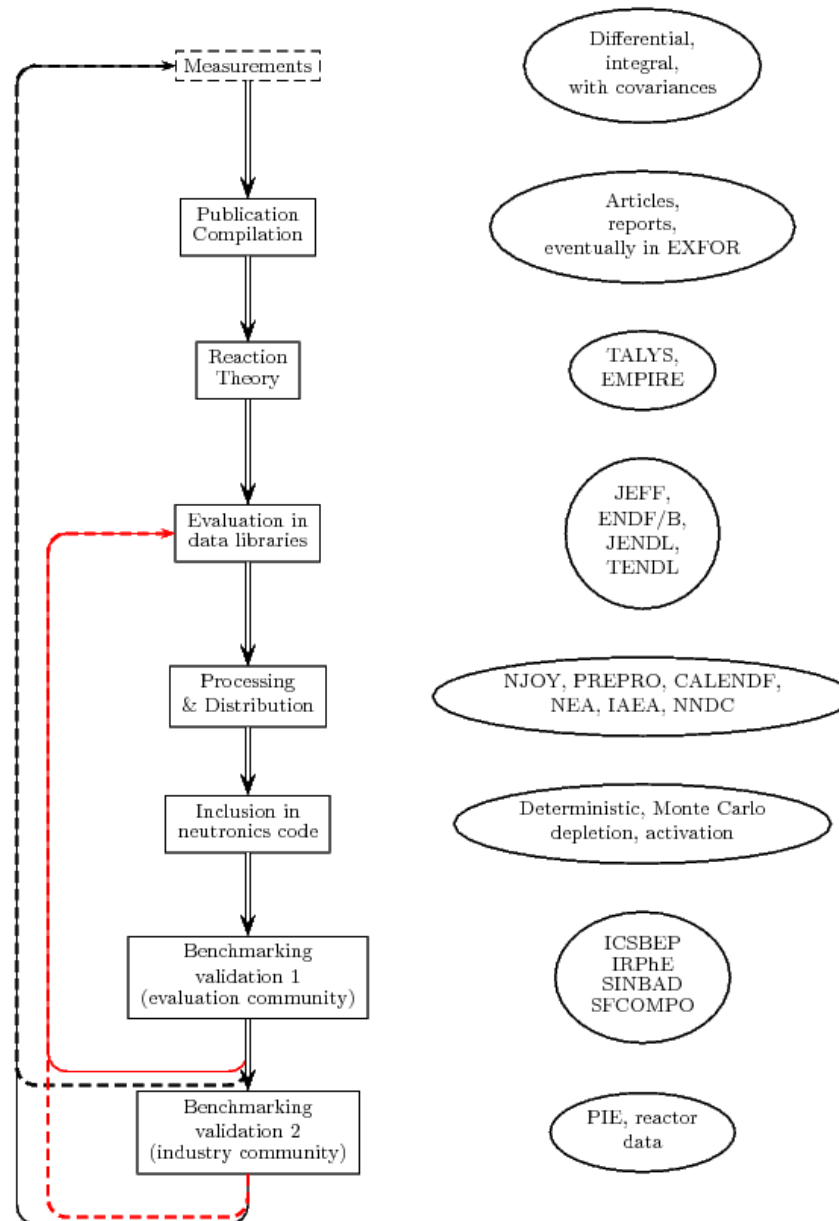
Neutron cross sections: state of knowledge

- 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 ☐ Selected [Check](#) [Reset](#)

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

Nuclear data life cycle

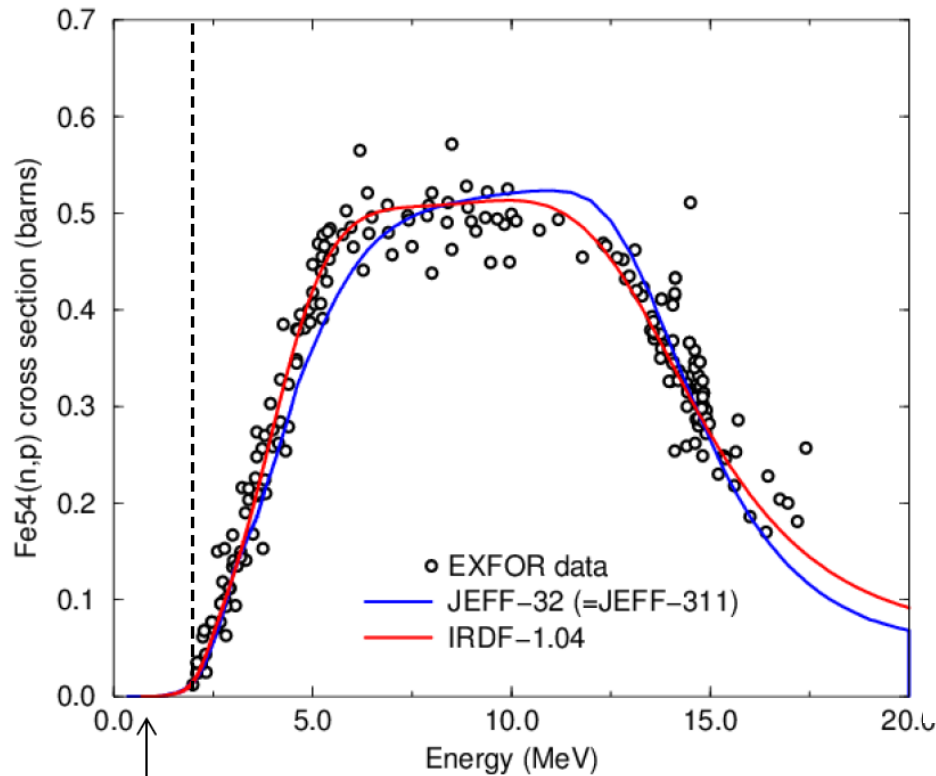


How do know that we don't know

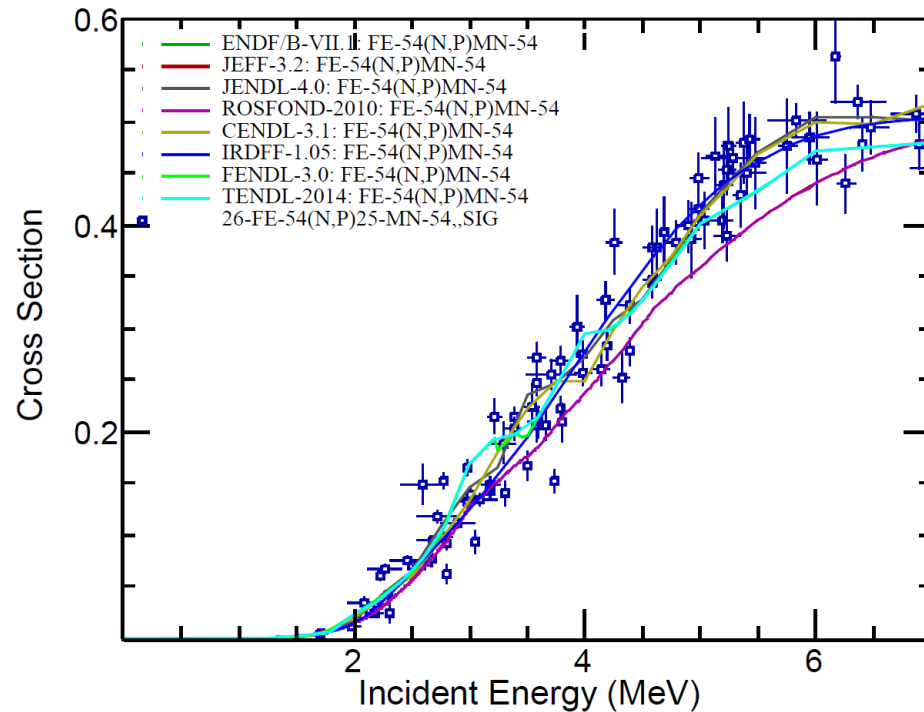
- Cross section library = measurements + modeling
- In many libraries, cross sections for the same reactions are different, why ?
 - Not enough experimental data ?
 - Discrepant experimental data ?
 - Wrong modeling ?
 - Discrepant experiment/model ?
 - Different interpretation (human, processing, simulation)?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

Examples on dosimetry cross sections

Fe54(n,p)Mn54

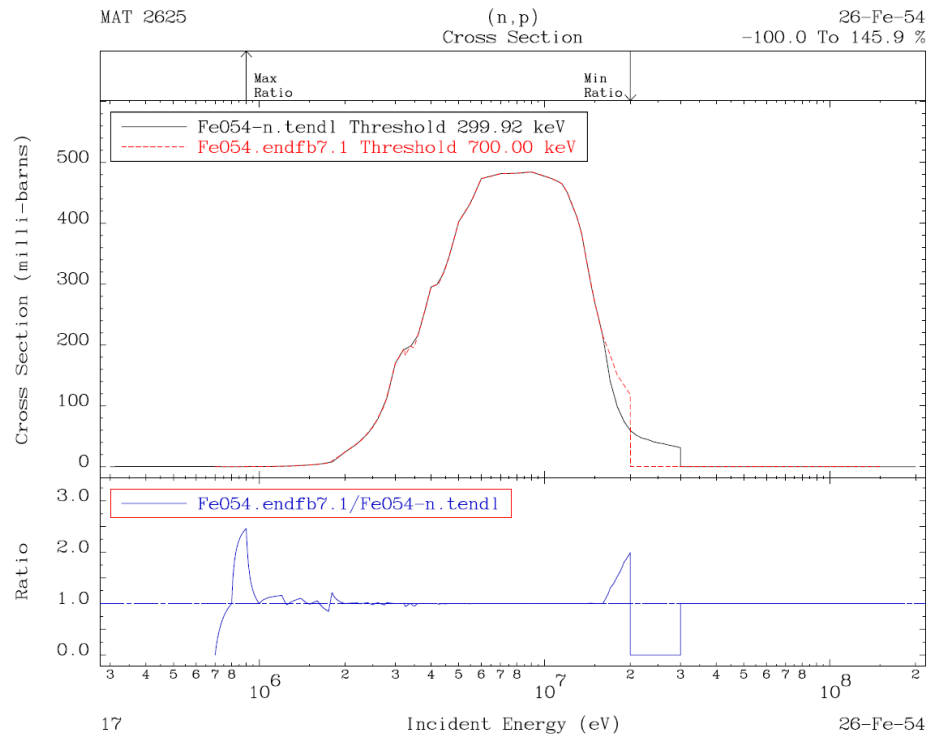


From JEFDOC-1593, NEA, November 2014

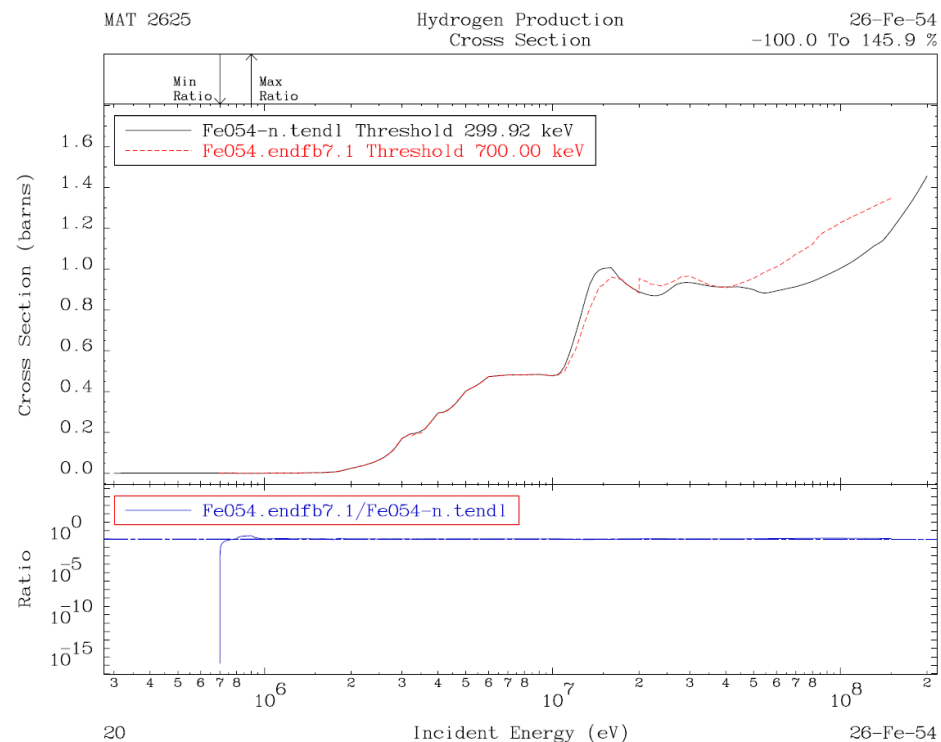


Examples on dosimetry cross sections

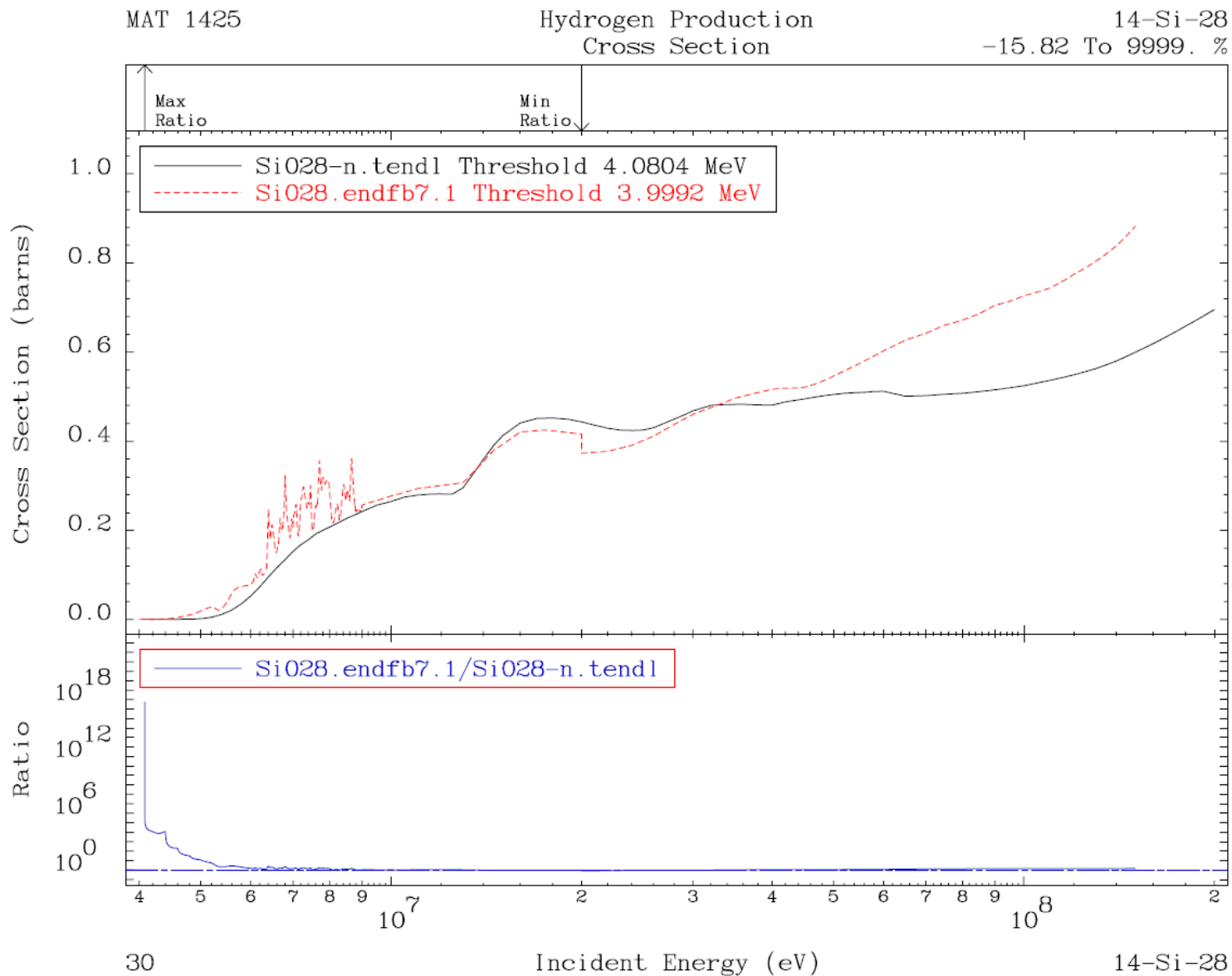
Fe54(n,p)



Fe54 p (or hydrogen) production



Examples on dosimetry cross sections: Si-28

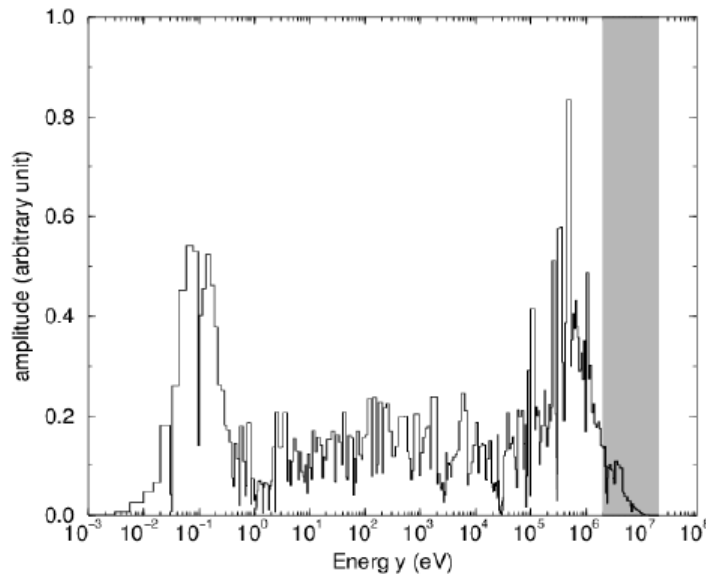


Examples on dosimetry cross sections

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

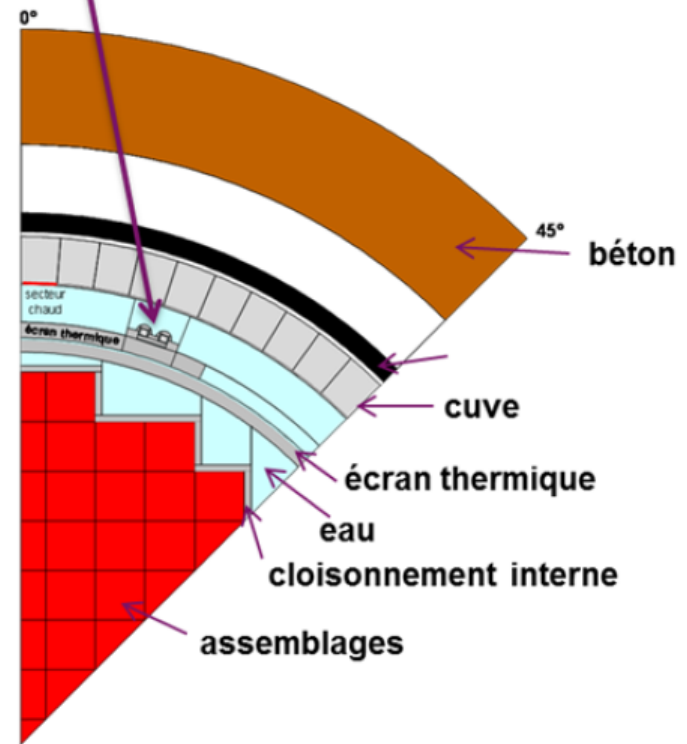
Impact on activation calculations

Fe54(n,p)Mn54



Ratio	Result
IRDFF-1.04/EXFOR	0.99(2)
JEFF-32/EXFOR	0.91(2)

Capsule



From JEFDOC-1593, NEA, November 2014

Examples on dosimetry cross sections

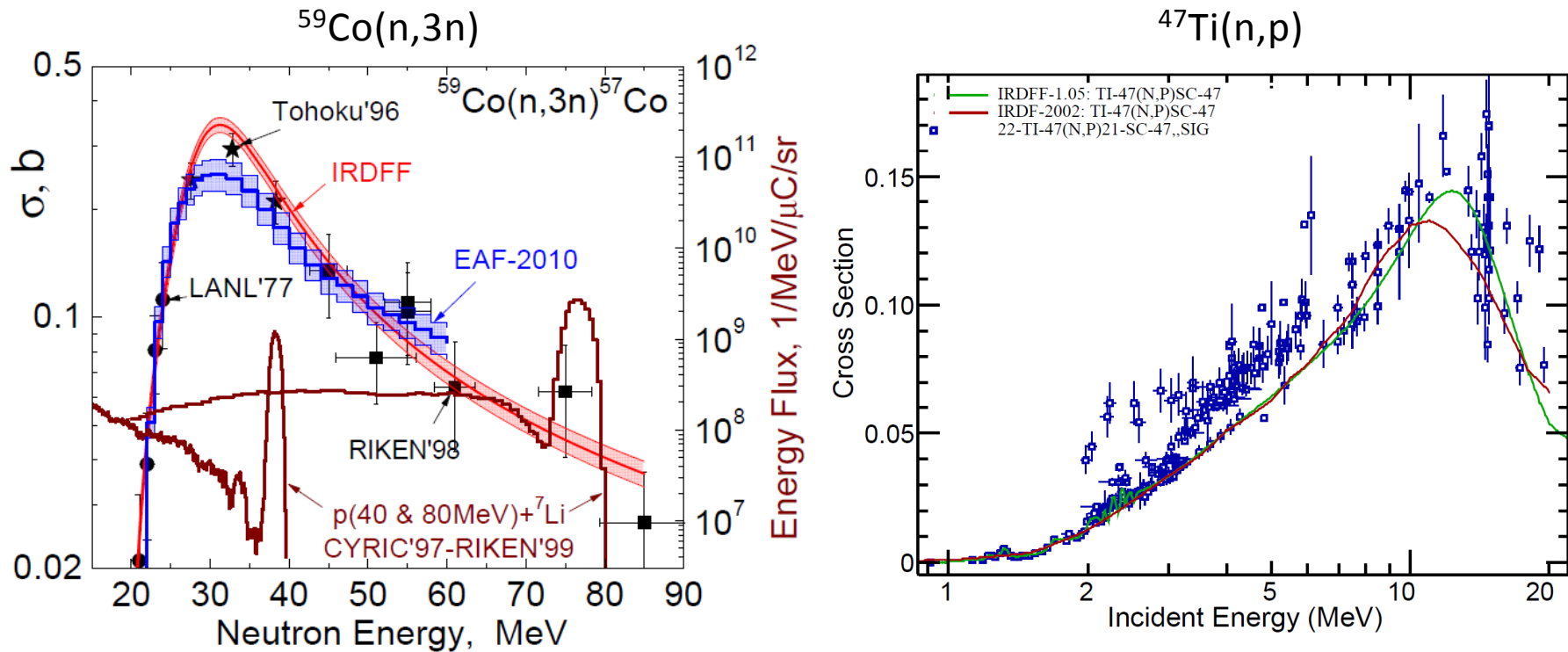


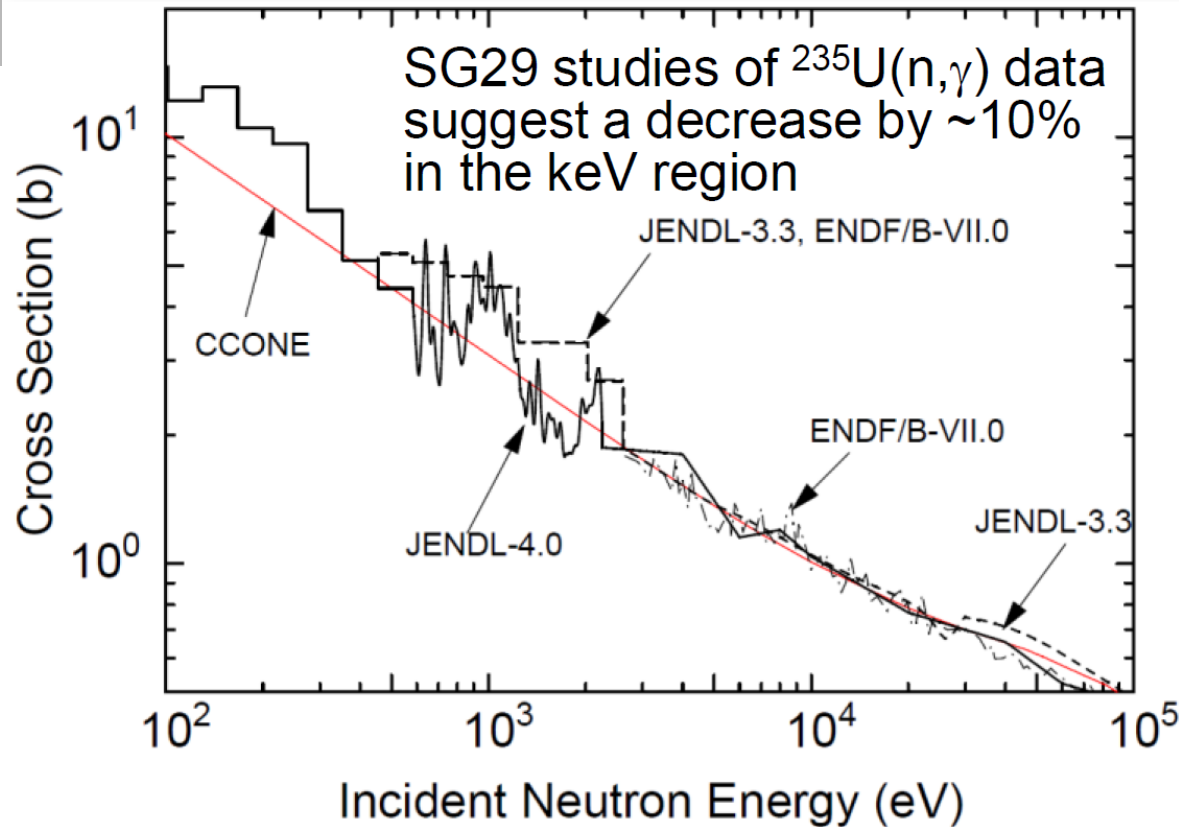
Figure 1. Experimental (EXFOR) and evaluated cross sections for $^{59}\text{Co}(n,3n)$ reaction and p- ^7Li source spectra [8].

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 $^{235}\text{U}(n,\gamma)$ cross section in the keV range



Nuclear Science
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International Evaluation Co-operation

Volume 29

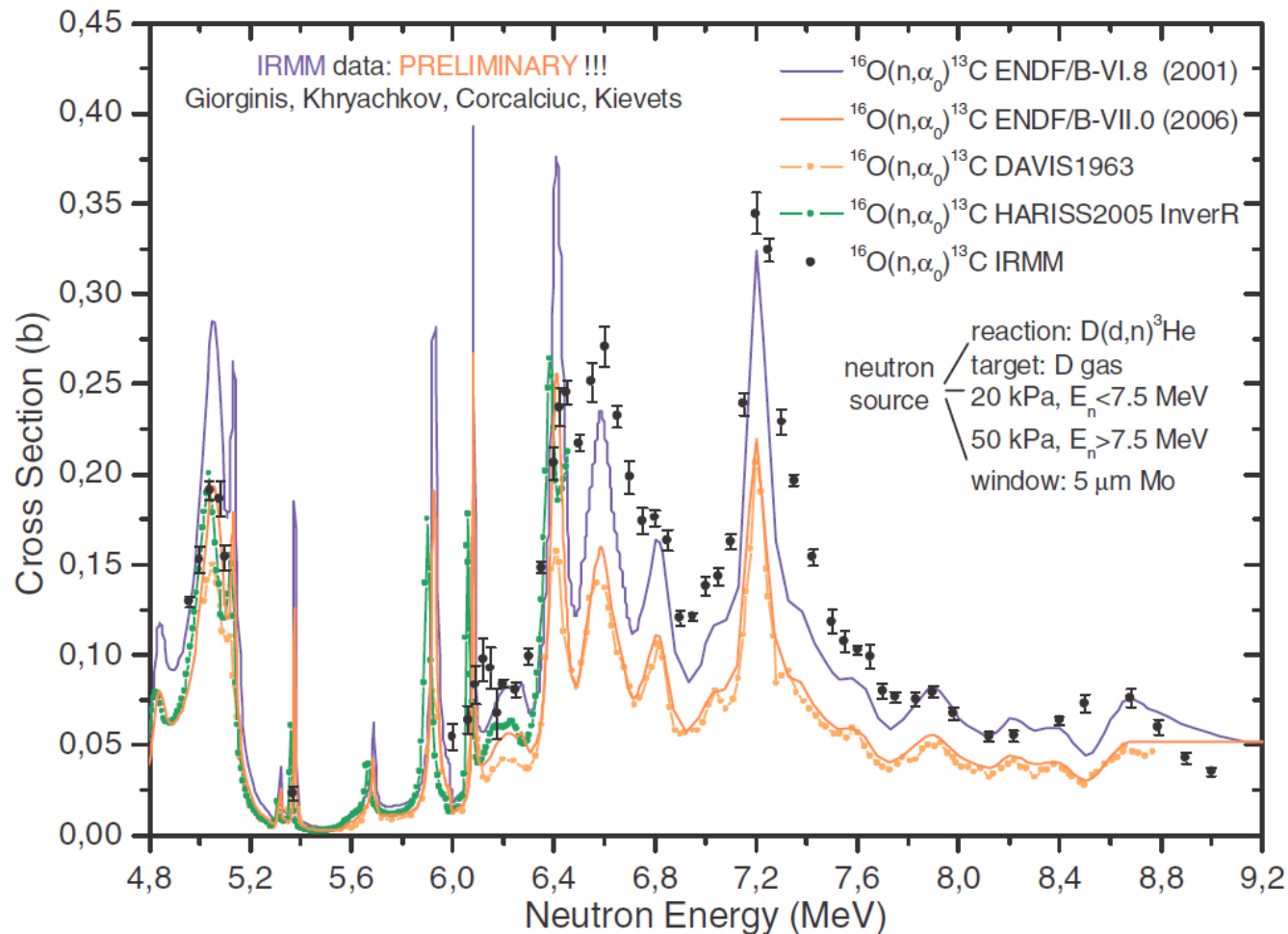
Uranium-235 Capture Cross-section
in the keV to MeV Energy Region

OECD
BETTER POLICIES FOR BETTER LIVES

NEA
NUCLEAR ENERGY AGENCY

Examples for important reactor cross sections

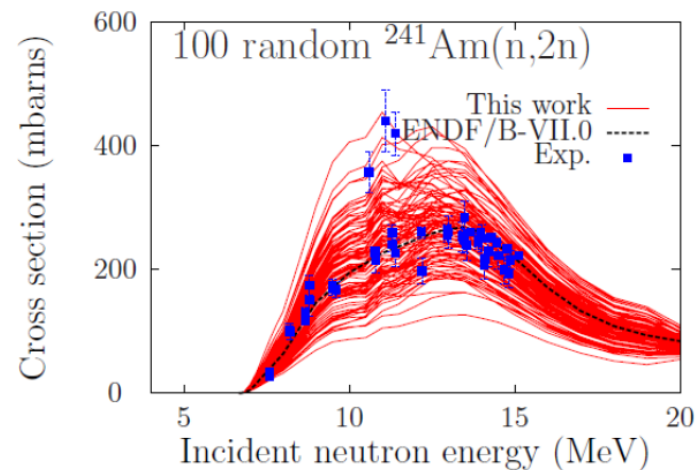
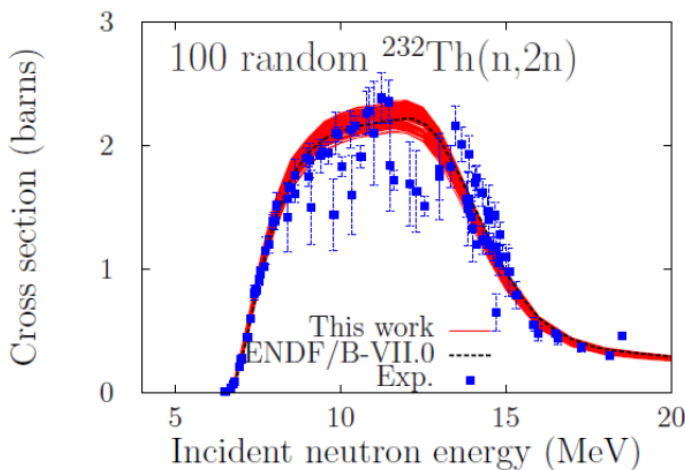
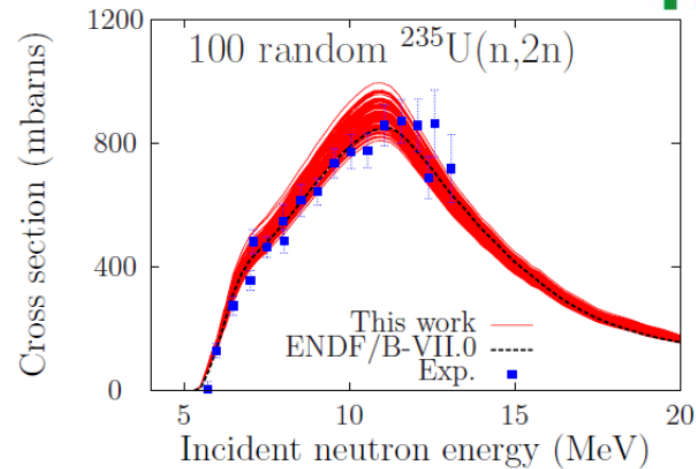
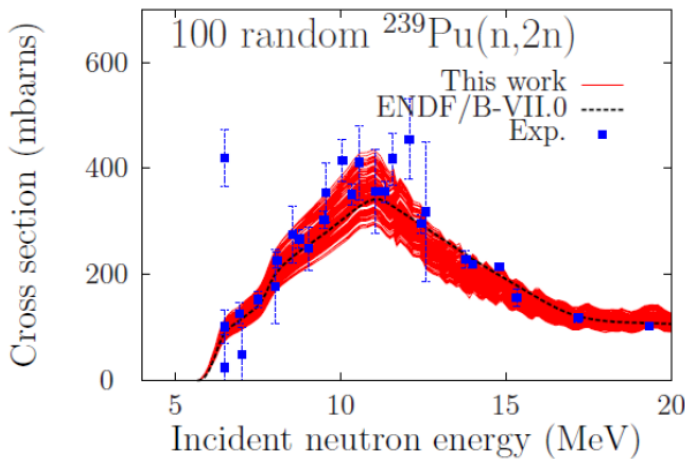
- $^{16}\text{O}(n,\alpha)$ cross section, long standing problem, soon resolved



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

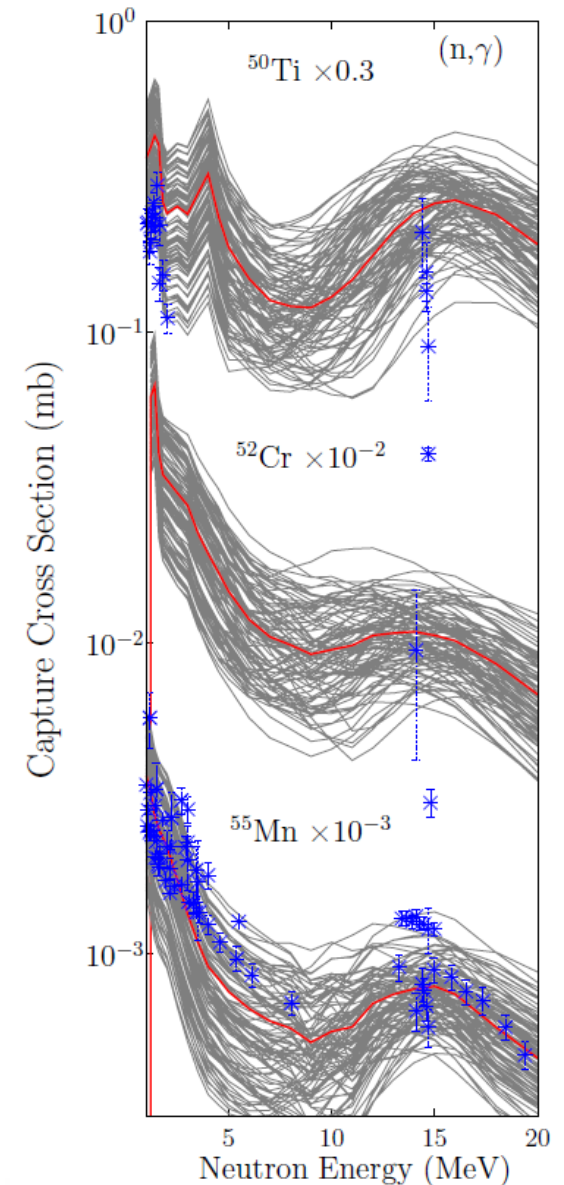
Modeling: another source of uncertainties

- 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
 - Covariance files: uncertainties + correlations for cross sections
 - TMC: model parameter “pdf” (probability density function)
- Both approach have advantages and drawbacks



Conclusion

- 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.

*pdf: probability density functions

