IAEA
International Atomic Energy Agency
Atoms for Peace and Development

GNDS, ENDF-6, HENDF, PENDF, GENDF, ANISO, ACE data forms and format

J.-Ch. Sublet
Nuclear Data Services Unit Head, Nuclear Data Section, IAEA

Consultancy Meeting – AnDFS Virtual Event 15-17 March 2021

Lexical semantics

- Global Nuclear Data Structure: GNDS
- Evaluated Nuclear Data Format: ENDF-6

} Format

- Hybrid END File >>> from PREPRO to JANIS, FISPACT-II,..
- Pointwise END File >> from NJOY, PREPRO, CALENDF,…to many codes
- Groupwise END File >> from NJOY, PREPRO,… to many codes
- ANISOtropy >> from TRIPOLI-4 to TRIPOLI-4
- A Compact Endf >> from ACER, FRENDY… to MCNP, SERPENT, OpenMC,…
- Probability tables >> from CALENDF, PURR… to FISPACT-II, MCNP, TRIPOLI,…
- PDF, CDF, TF >> from NJOY, PREPRO to MCNP, SERPENT, OpenMC, TART,…
- …..

- It is important to differentiate between:

nuclear data form, format and formalism

Lexical semantics

- Hybrid END File
- Pointwise END File
- Groupwise END File
- ANISO tropy
- A Compact Endf
- Probability Tables
- PDF and CDF
- …

Nuclear data forms

Formalisms

- Multi-Level-Breit-Wigner, Reich-Moore, R-Matrix Limited, Blatt and Biedenharn, Kalbach-Mann, Froehner, Watt, …

Lexical semantics

- Pre-processing steps: convert the ENDF-6 nuclear data into simple forms that can be interpreted
- Processing steps: processes the ENDF-6 nuclear data into complex forms useful for applications: particles transport, reactor analysis codes, etc.
- Post-processing steps: verify either of the above steps

The lexical is ancient, as the ‘tape’ the above usually modular and sequential steps I/O uses. It belongs to the dawn of the computer age, does sound a bit odd now a day, however it still works – just about

if it ain't broke, don't fix it

ENDF-6 Format Manual

- De facto the standard
- File 1-10 n-description
- File 11-15 g-description
- File 23-28 atomic data
- File 30-40 cov.-description

- 418 pages

- The majority of the World libraries are distributed in that format
- Designed, crafted by evaluator with science in mind, since May 1966

CSEWG Document ENDF-102
Report BNL-203218-2018-INRE
SVN Commit: Revision 215

ENDF-6 Formats Manual

Data Formats and Procedures for the Evaluated Nuclear Data Files
ENDF/B-VI, ENDF/B-VII and ENDF/B-VIII

Written by the Members of the Cross Sections Evaluation Working Group

Edited by
A. Trkov, M. Herman and D. A. Brown

With contributions from
N. Holden and G. Hedstrom

February 1, 2018

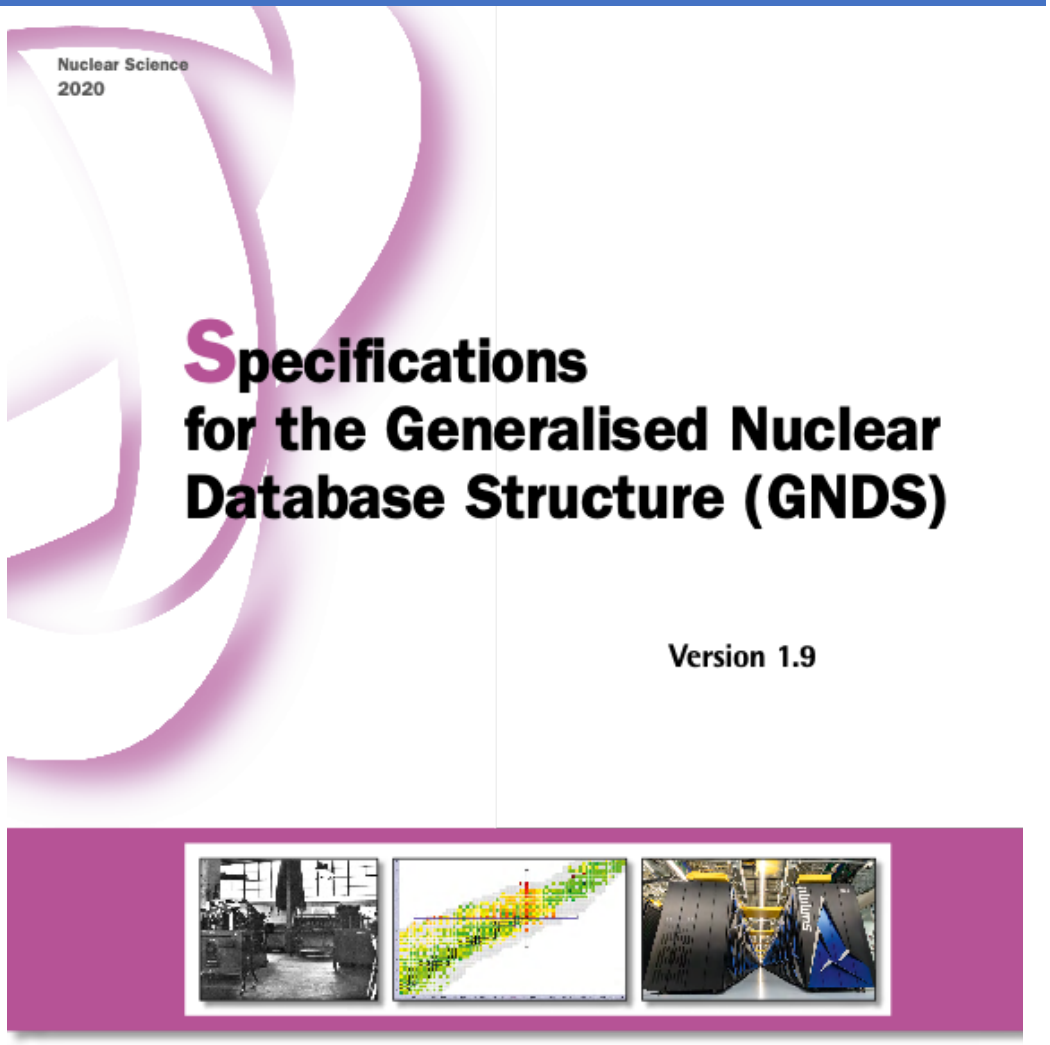
National Nuclear Data Center
Brookhaven National Laboratory
Upton, NY 11973-5000
www.nndc.bnl.gov

Generalised Nuclear Database Structure (GNDS)

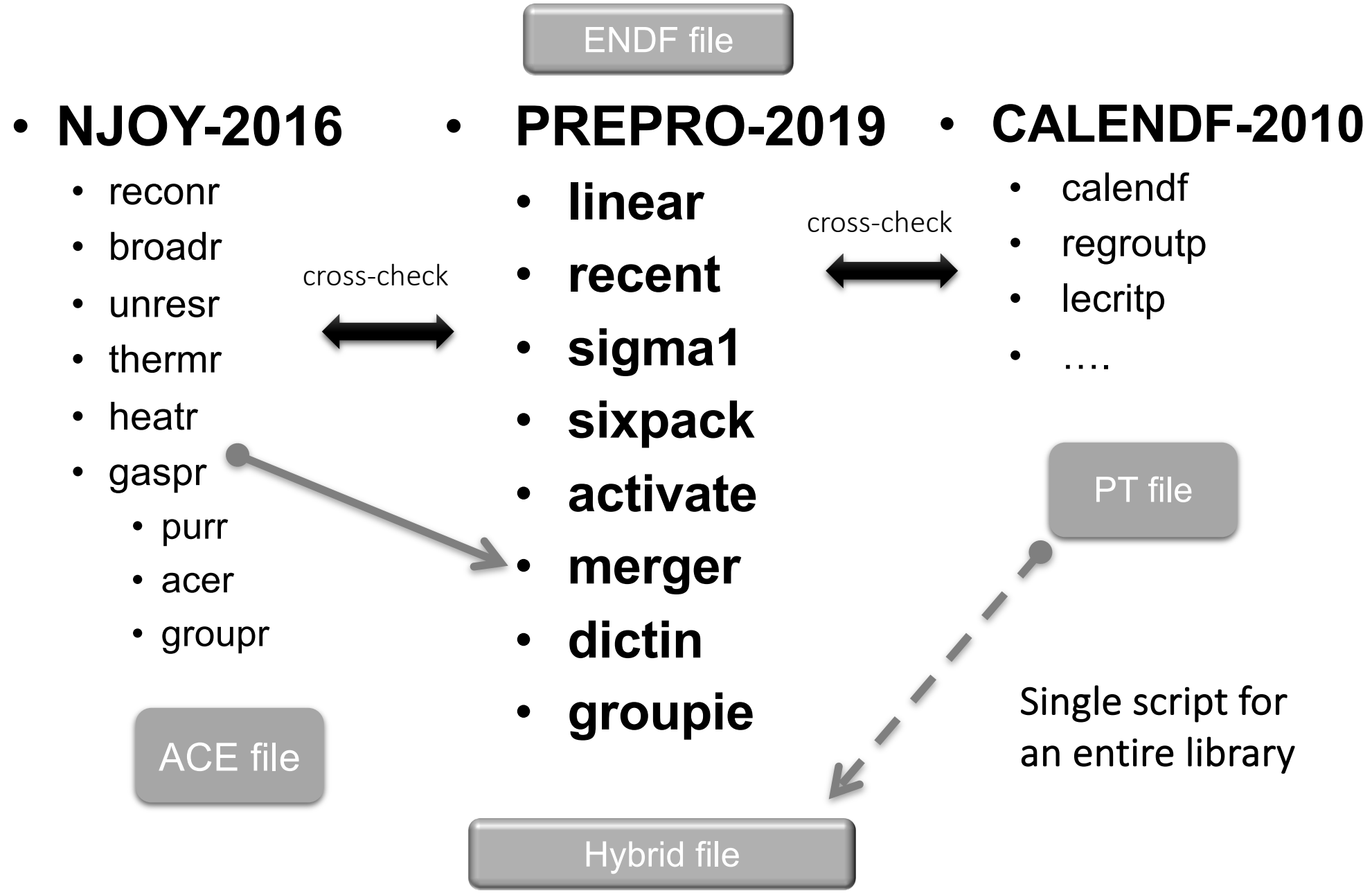
- The new reference
- A modern structure not a format
- 342 pages

- Three of the World libraries are now distributed in that format

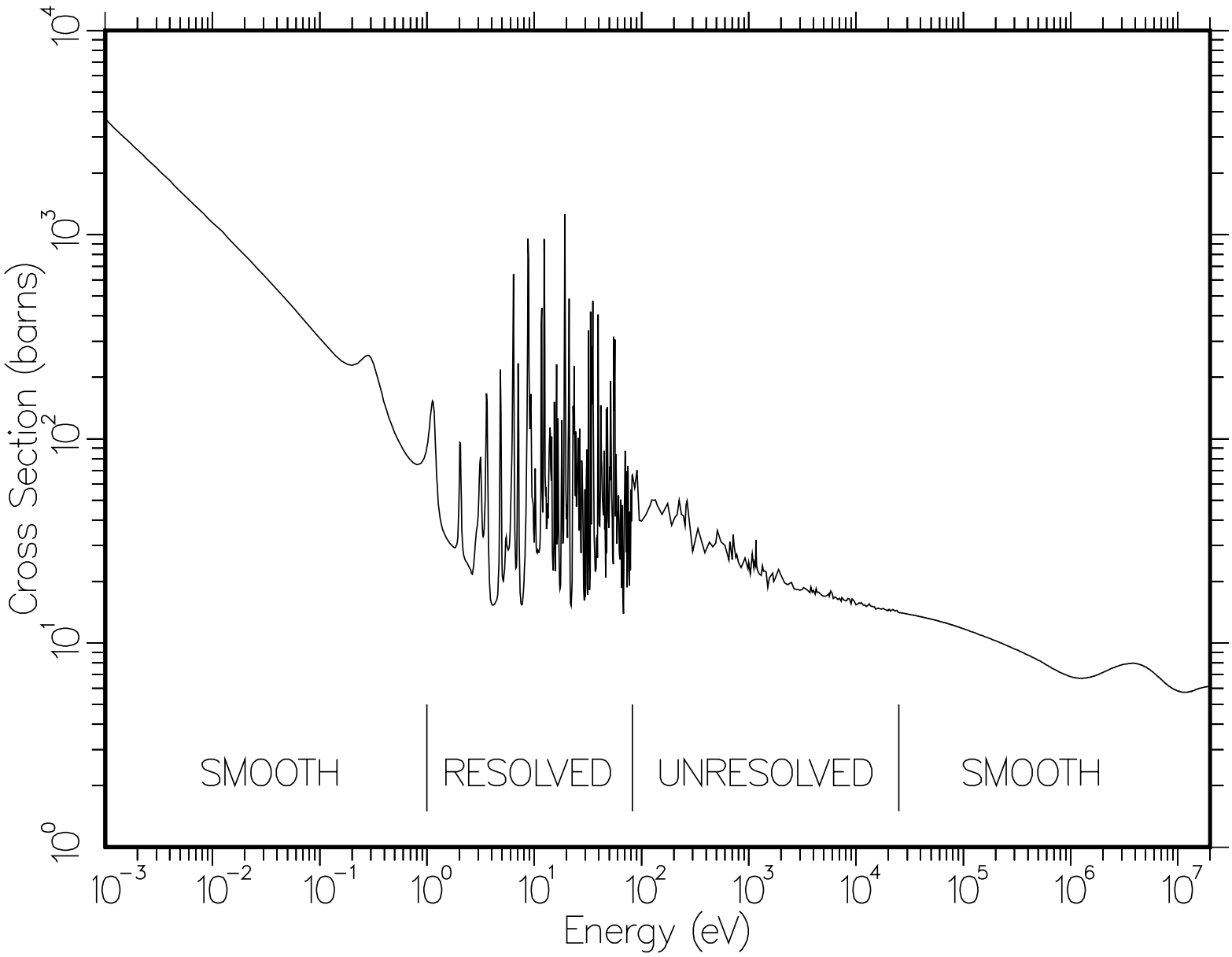
- Designed, crafted by evaluator with science and Multiphysics in mind, born with the millennia to unleash simulation's potential



Processing: an example with three codes



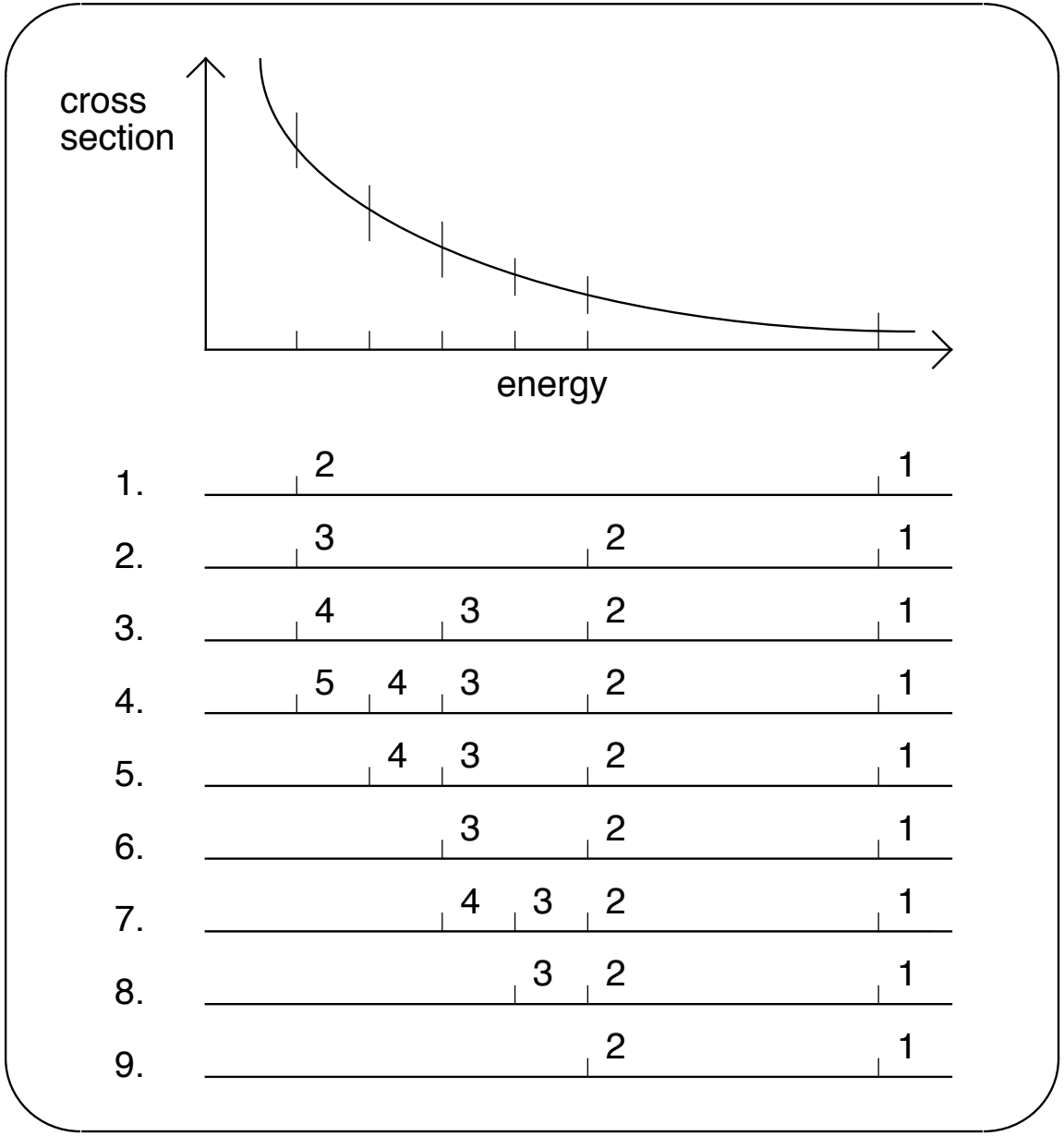
Pointwise ENDF



R. E. MacFarlane NJOY

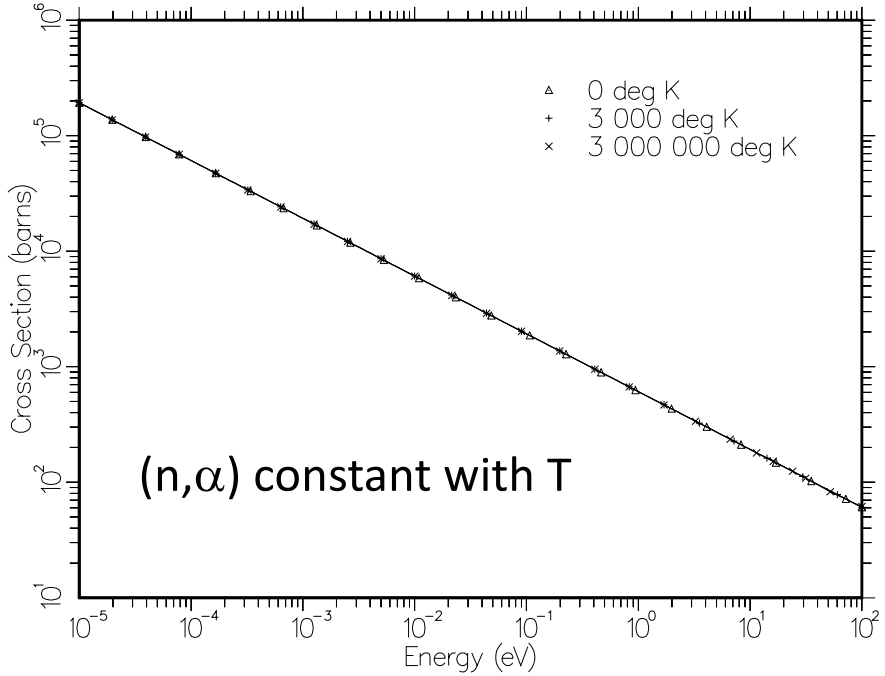
Pointwise ENDF linearisation and reconstruction

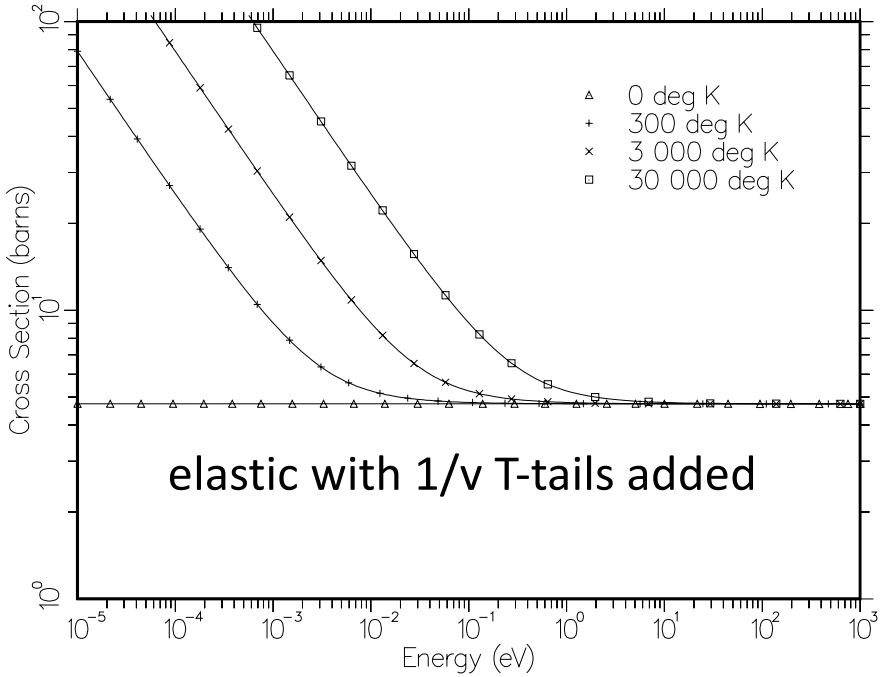
- Inverted -stack method used in RECONR
- In line 2, a new point has been calculated at the midpoint, but the result was not converged, and the new point has been inserted in the stack.
- In line 3, the midpoint of the top panel has been checked again, found to be not converged, and inserted into the stack. The same thing happens in line 4.
- etc.

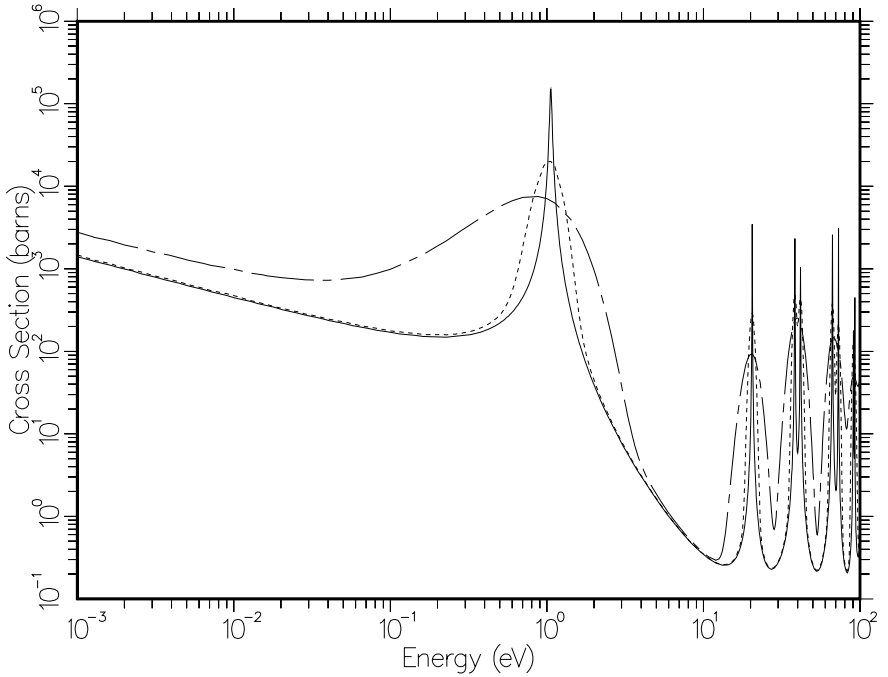


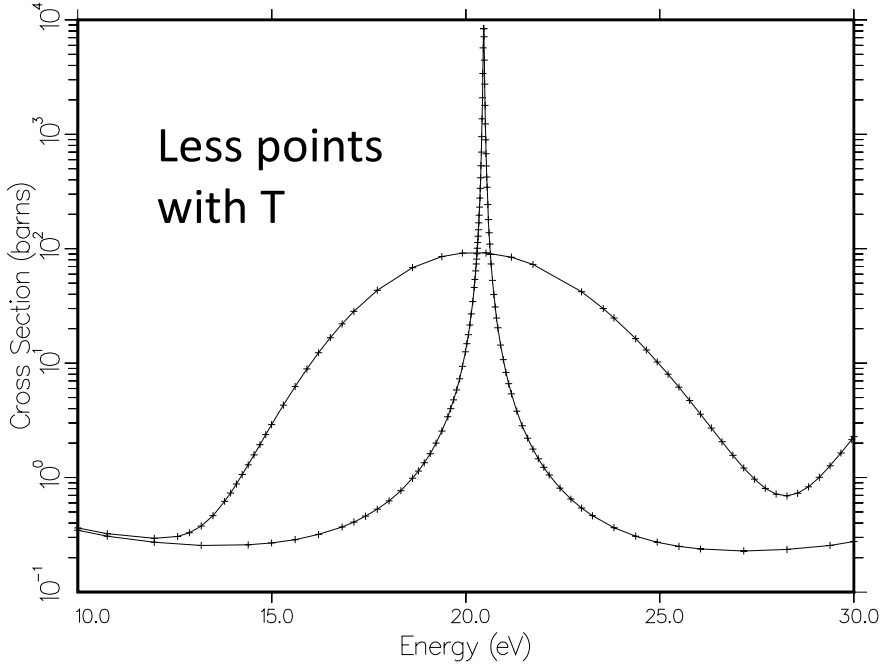
R. E. MacFarlane NJOY

Pointwise ENDF, doppler broadening in the RR



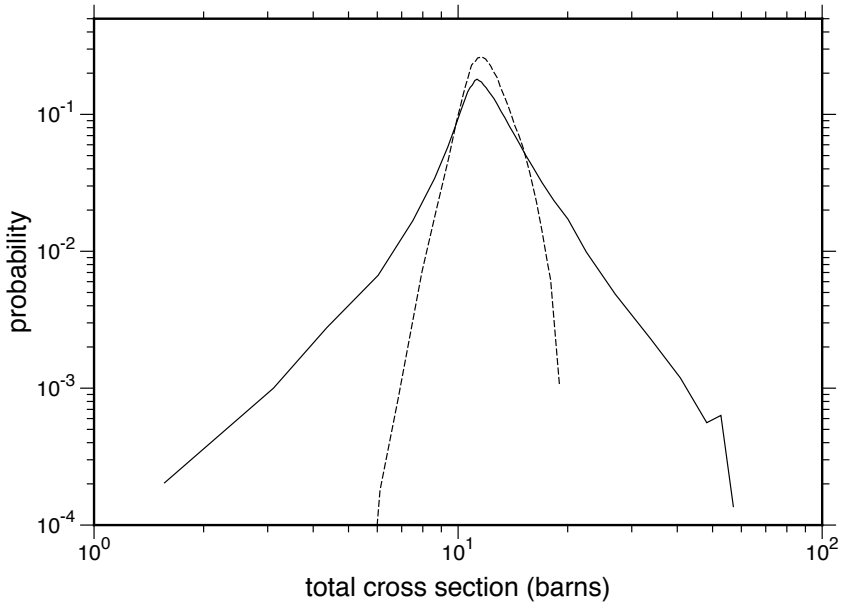




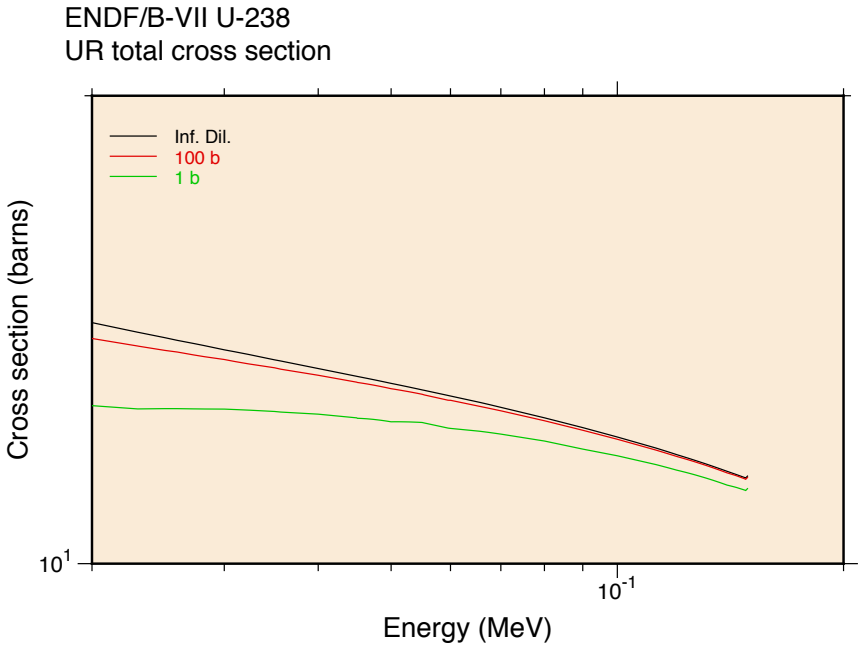


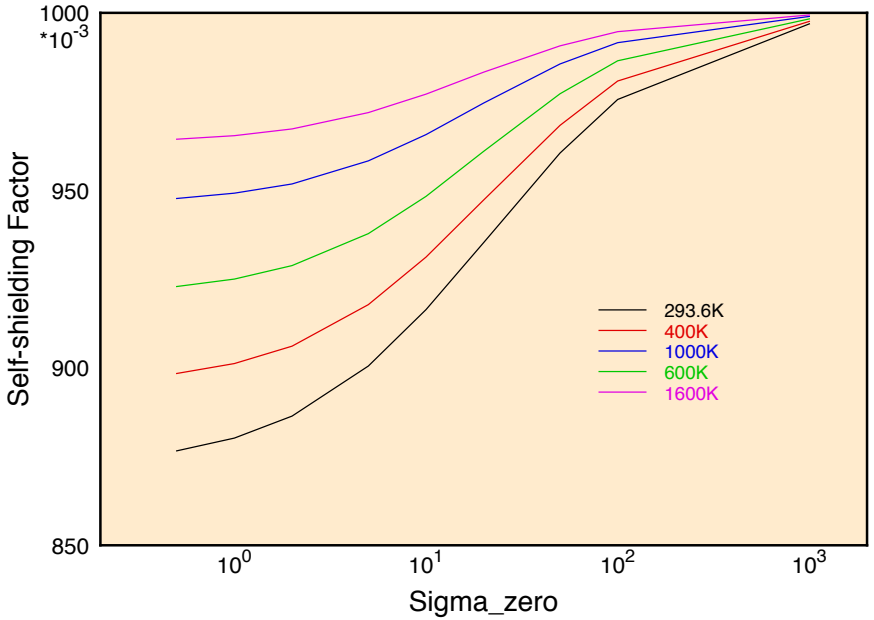
Pointwise ENDF, enhanced in the URR, PT's SSF

- PDFs @ 20 keV, dashed 140 keV



R. E. MacFarlane NJOY





Reactor physics lexical : background (dilution)

Distribution, deployment

- An efficient, elegant way to distribute processed files prototyped with TALYS based TENDL-2019 & Pointwise 2020

Reactors physics temperatures

#	List	Download
1	0° Kelvin	tarball:369Mb
2	293.6° Kelvin	tarball:317Mb
3	600° Kelvin	tarball:290Mb
4	900° Kelvin	tarball:275Mb
5	1200° Kelvin	tarball:264Mb

Astrophysics temperatures

#	List	Download
1	1 eV	tarball:101Mb
2	1 KeV	tarball:223Mb
3	5 keV	tarball:240Mb
4	30 keV	tarball:256Mb
5	80 keV	tarball:263Mb

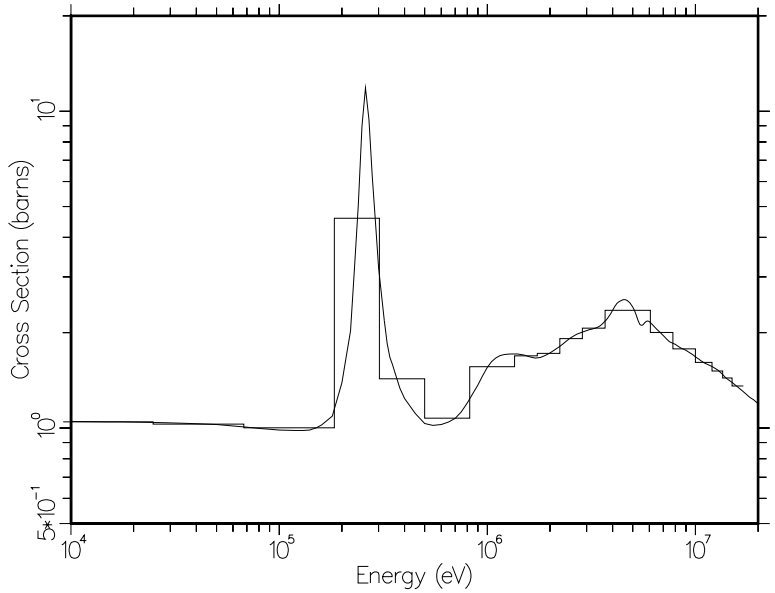
Temperatures independant

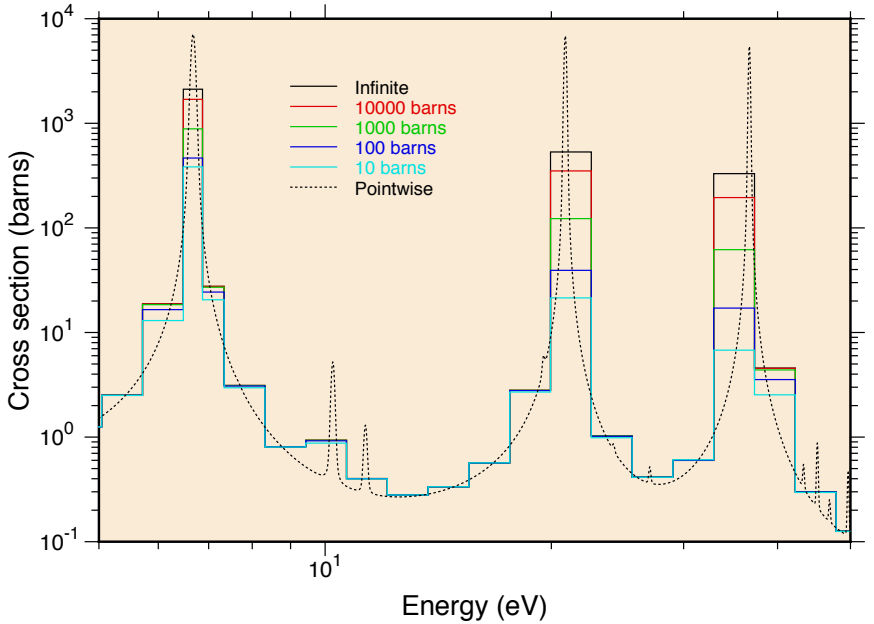
#	List	Download
1	MFOther	tarball:542Mb

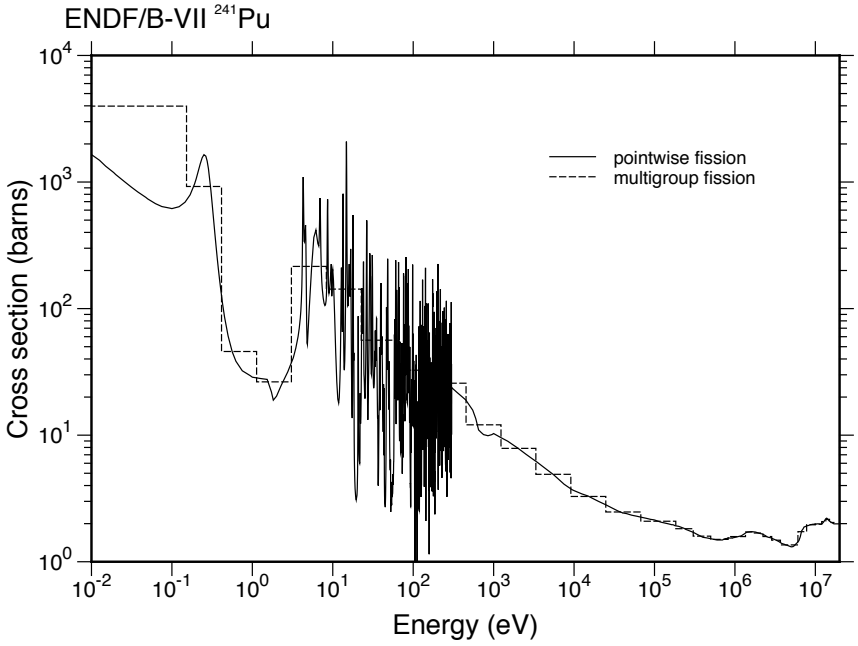
- The temperature dependent forms are supplied at 10 temperatures, whilst the temperature independent form are supplied only once:
  - Temperature dependent forms: ENDF-6 MF = 1-3
  - Temperature independent forms: ENDF-6 MF = 4-40
- PREPRO merger to re-assemble

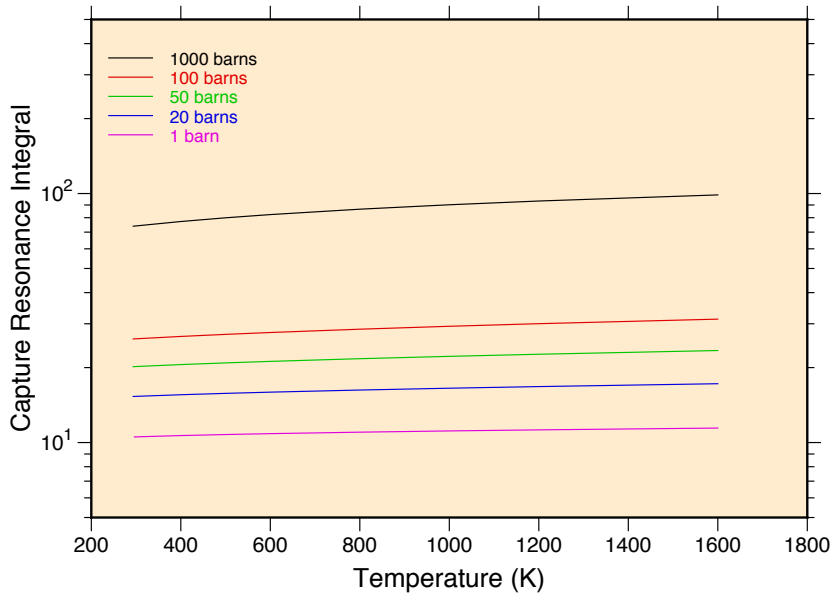
Groupwise ENDF and dilution, Bondarenko

- SSF on U^{238} first 3 resonances



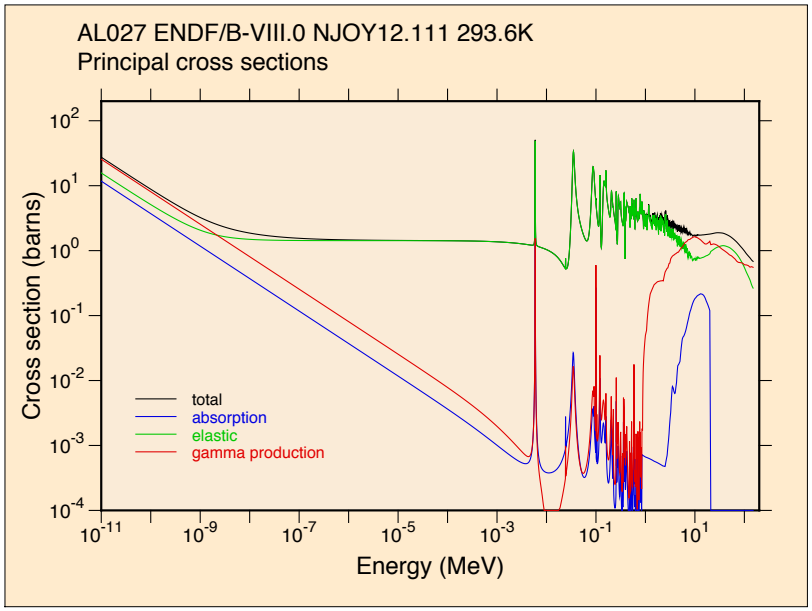


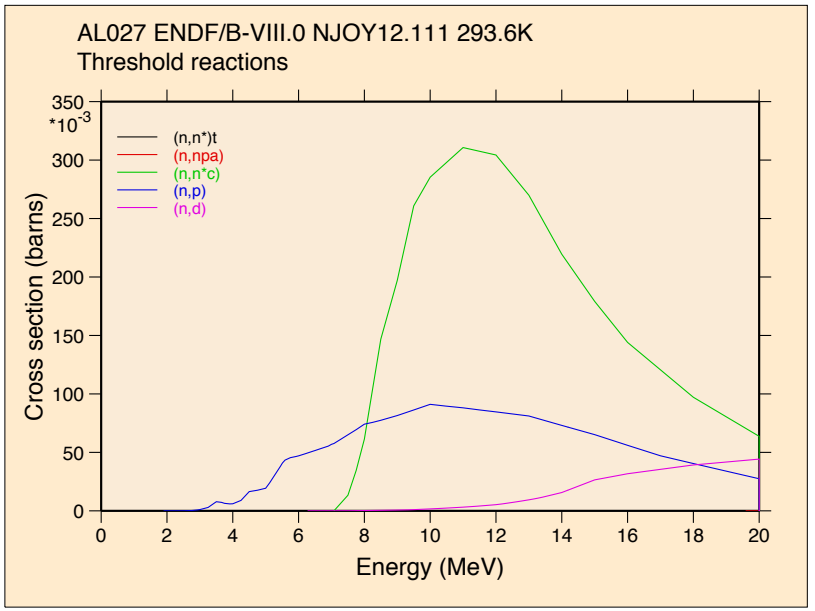


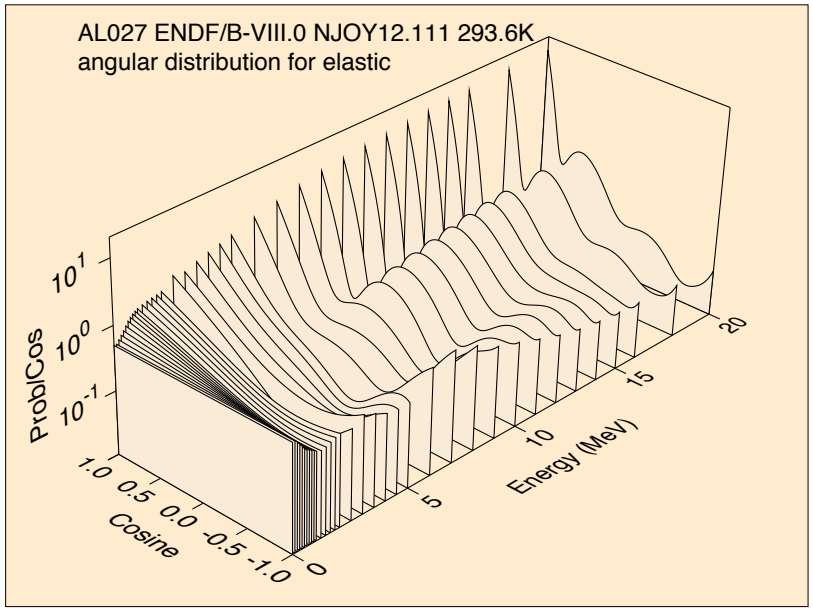


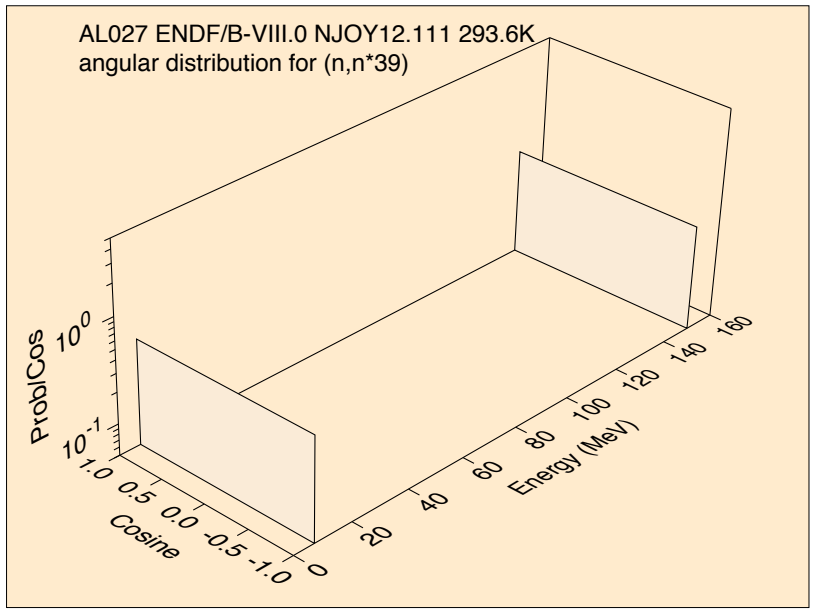
Slope with T = negative temperature coefficient

Acer output forms checks



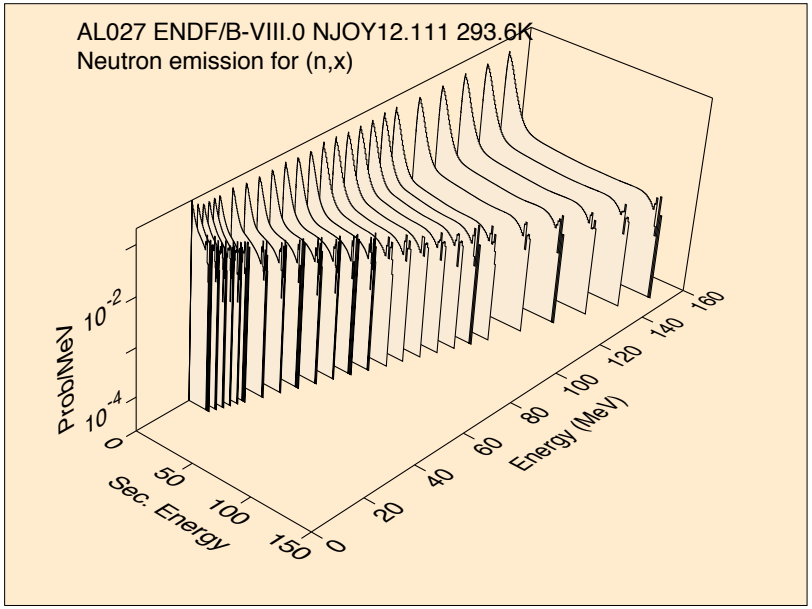


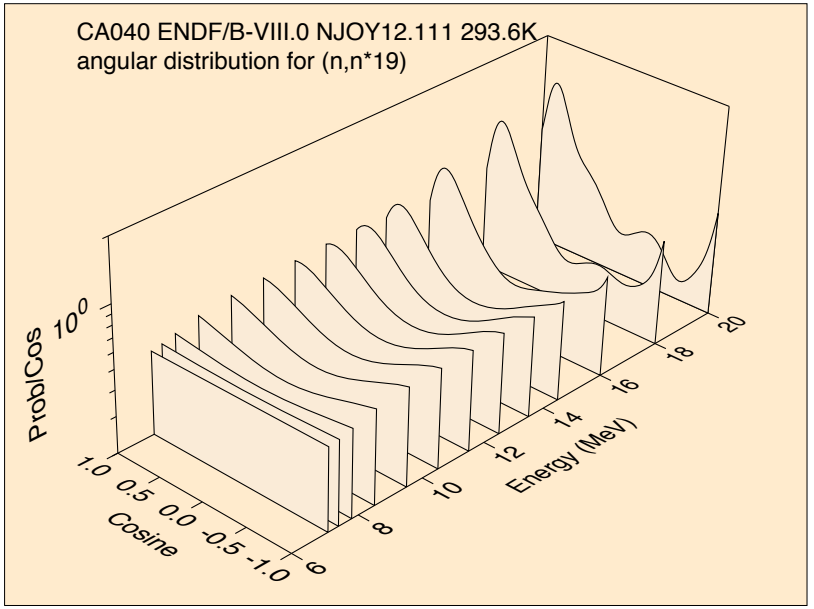


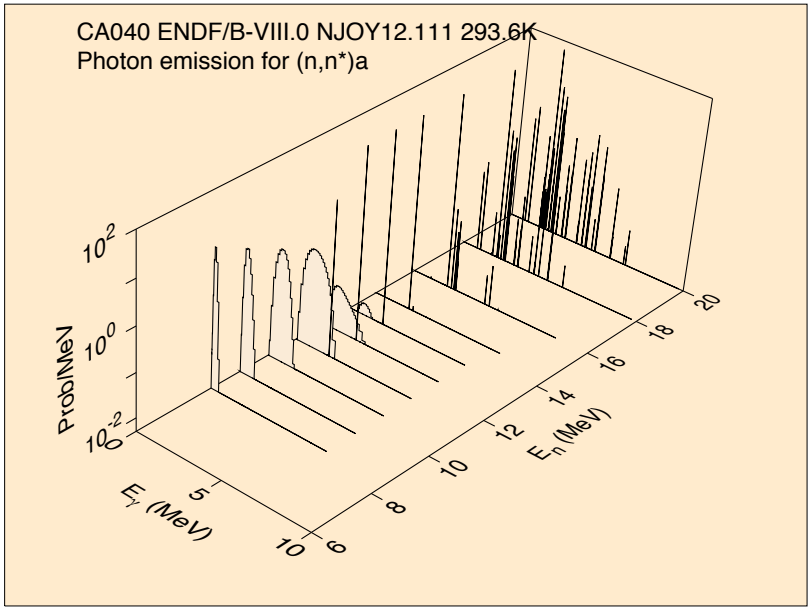


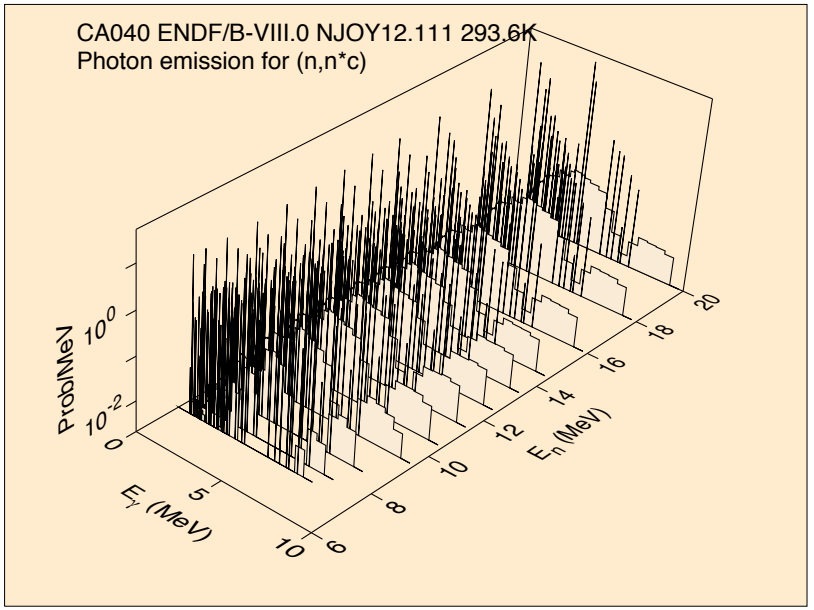
R. E. MacFarlane NJOY

Acer output forms checks





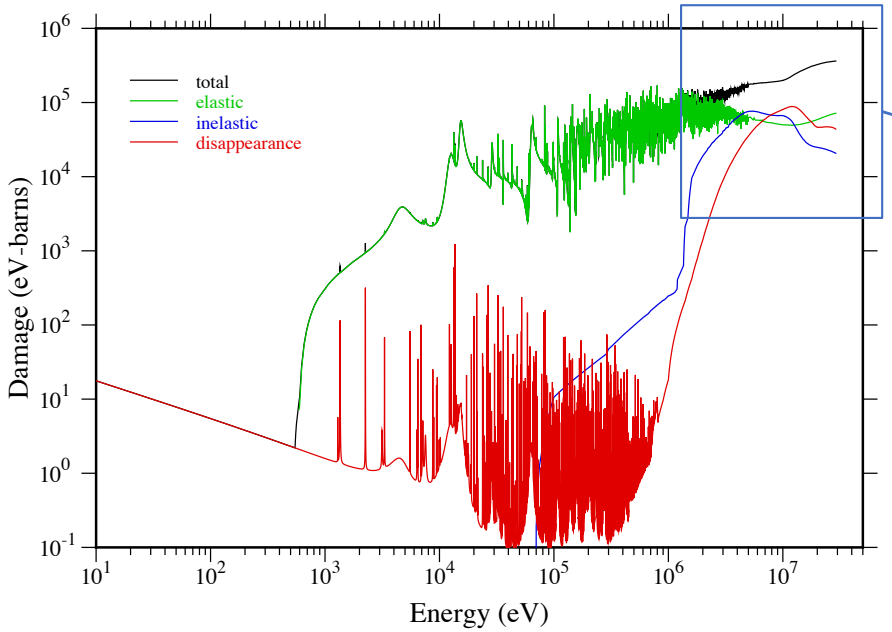


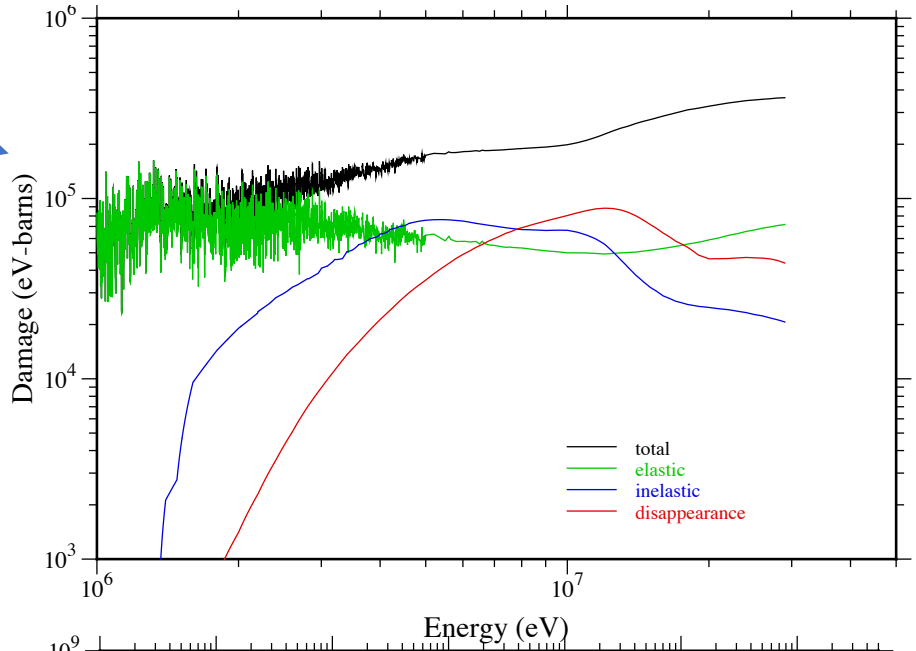


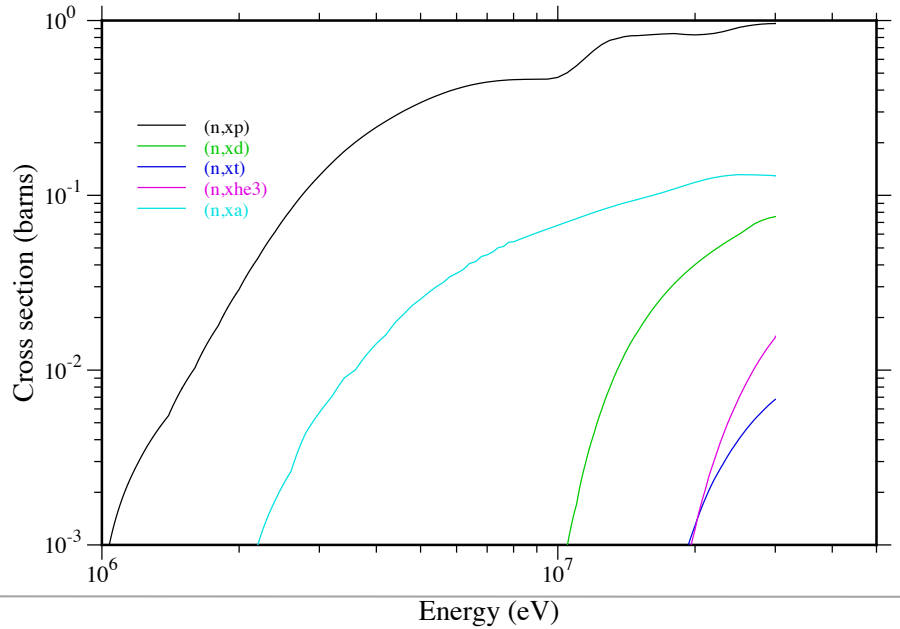
R. E. MacFarlane NJOY

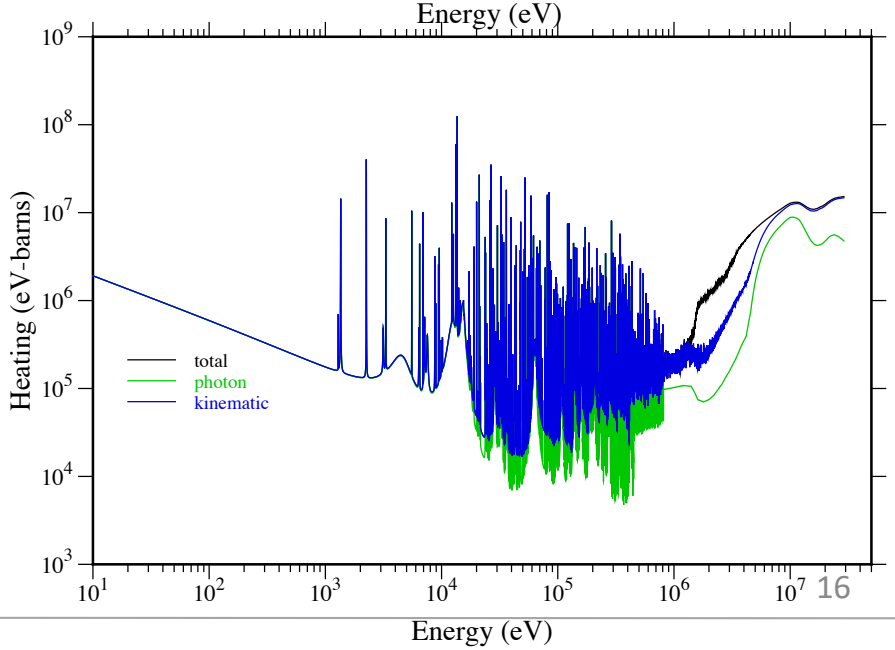
Derived nuclear data forms

- Kerma, Damage Energy, Gas Production (Ni) Elemental



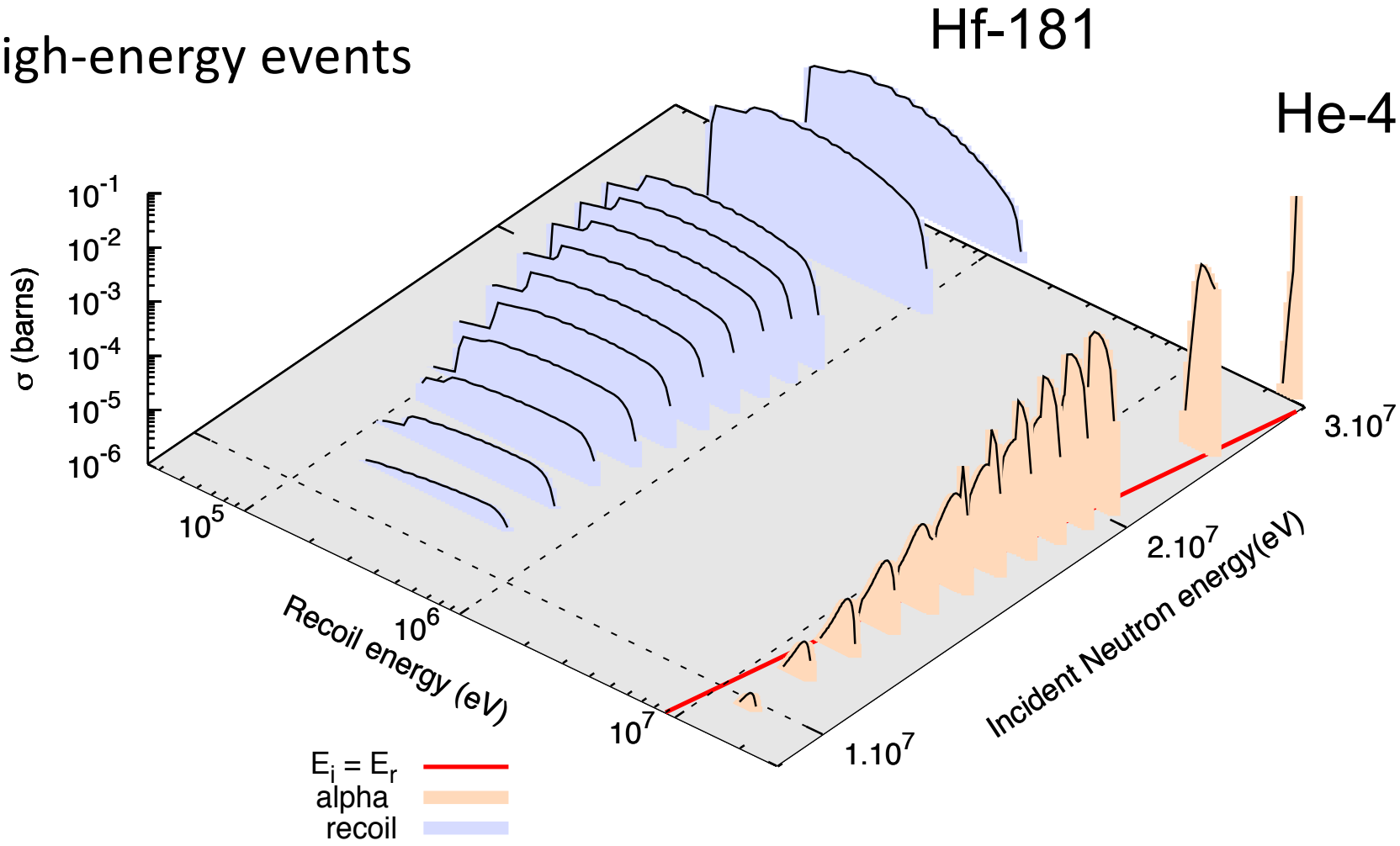






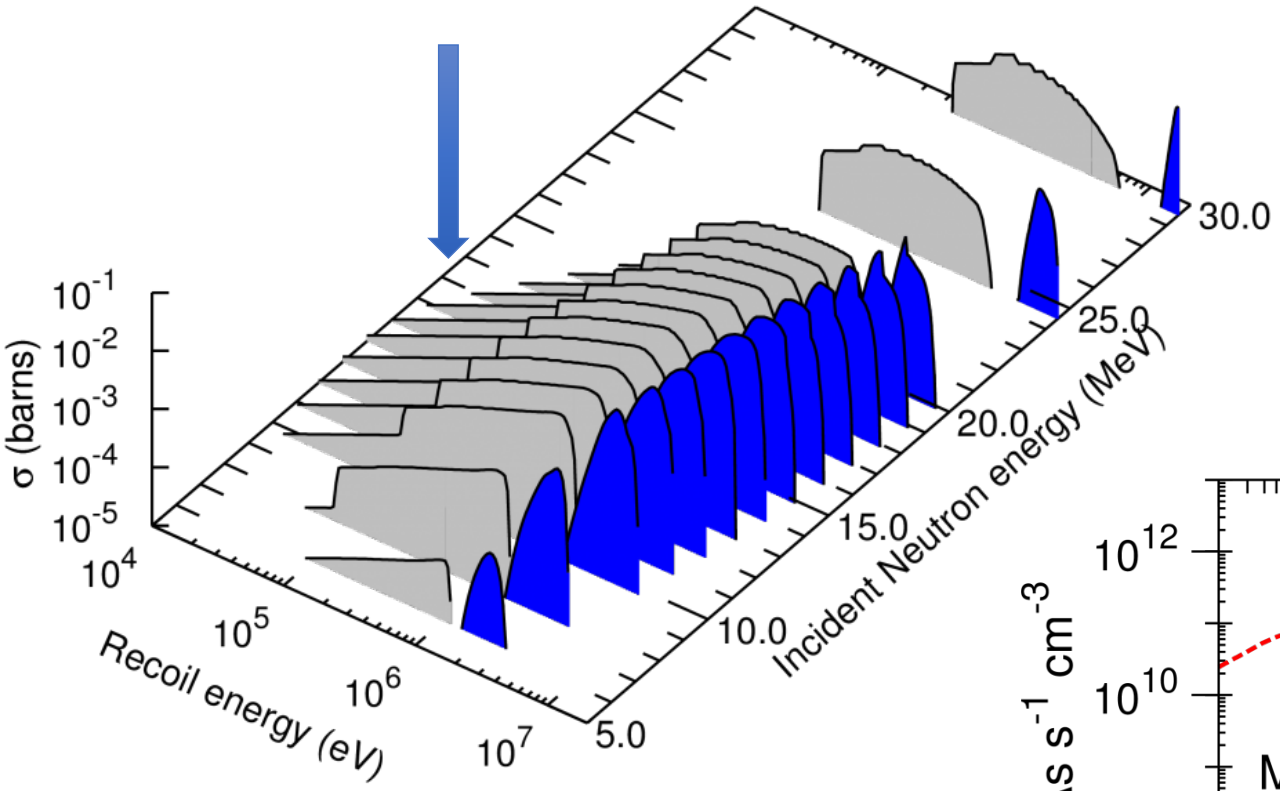
Residual and charged particles matrix

^{184}W + n: residual Hf-181 - $T_{1/2}$= 42 days, Beta- to Ta-181 (stable)



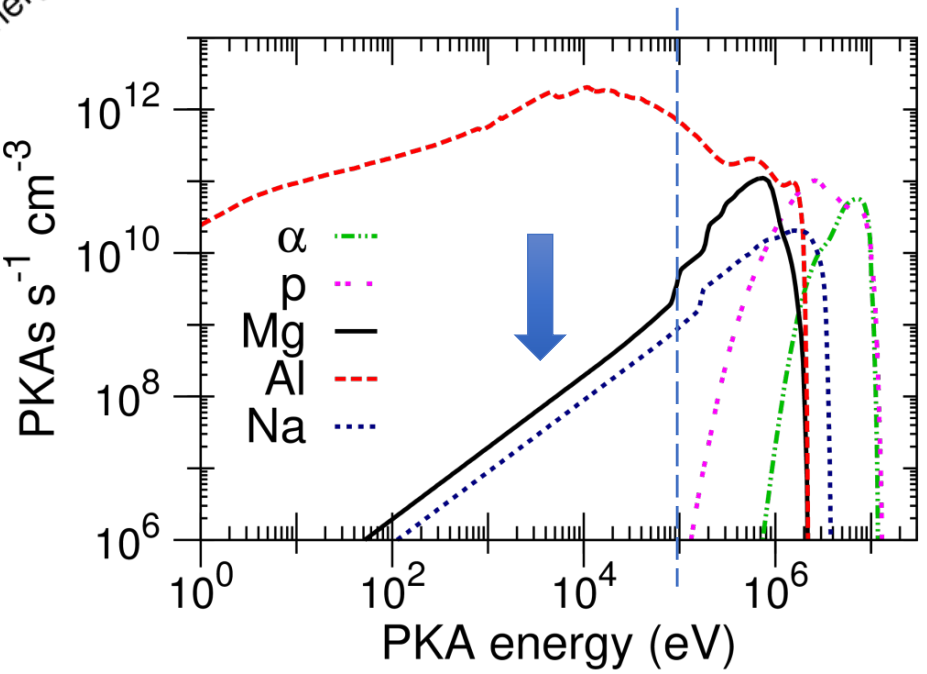
Q positive (7.3 MeV) means that the alpha energy can be much higher than the energy of the n-incident !!! At 22.7 MeV and above the secondary energy grid is truncated !!!

Matrix NJOY processing ismooth = 1



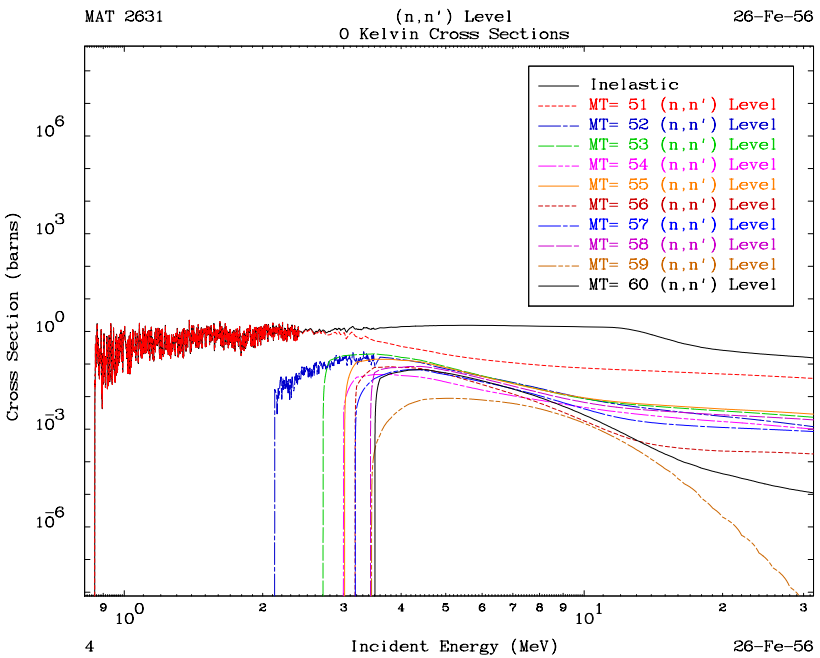
Tails are important

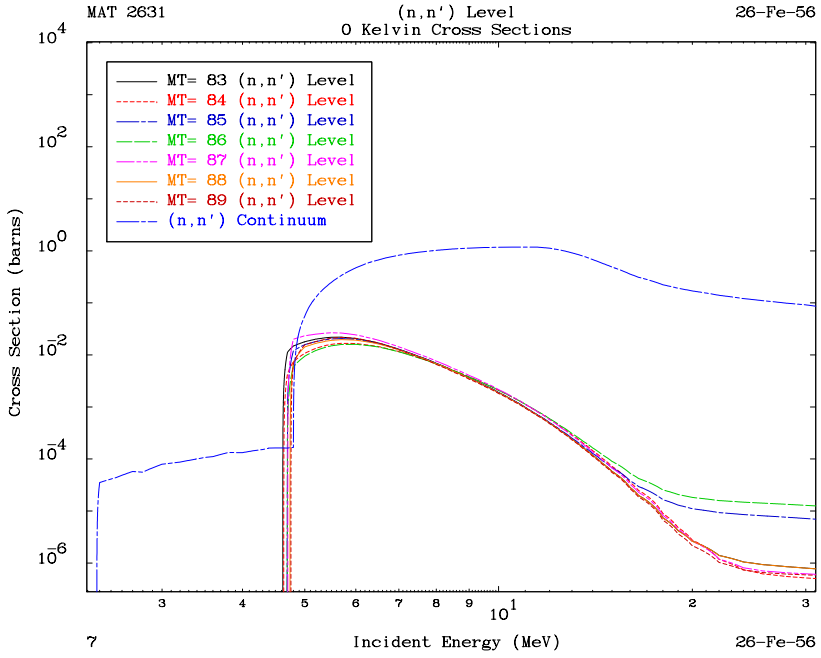
Transmuted residuals also: Mg, Na <u>not Al</u>

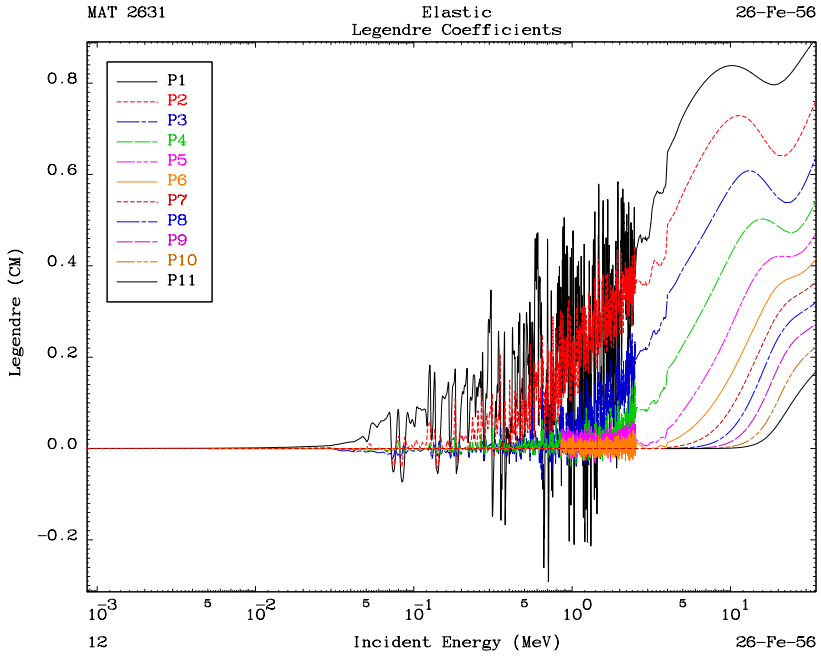


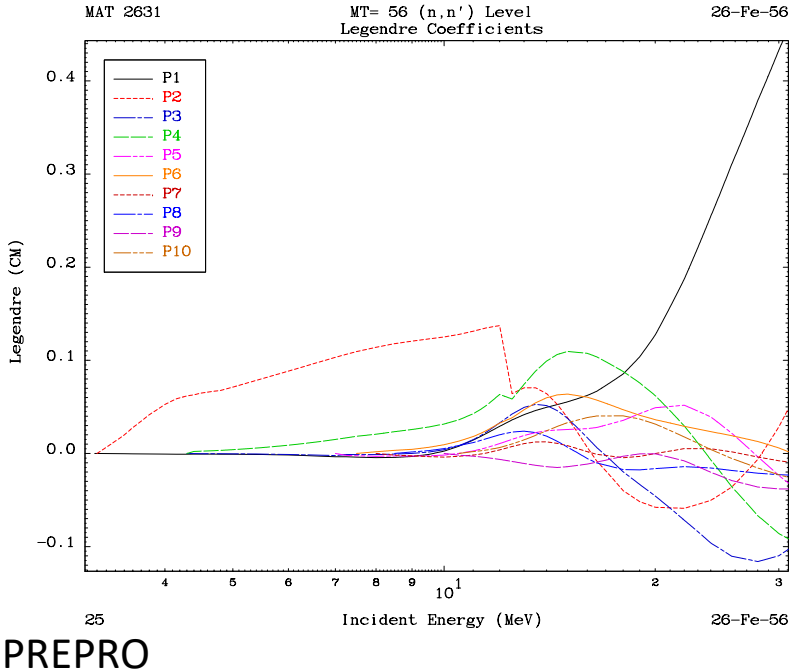
Q negative this time, but NJOY ismooth =1 ($\sqrt{E}$ shape) for when the evaluator decided to cut short the secondary energy grid of the recoil!

Partials and Legendre coefficients





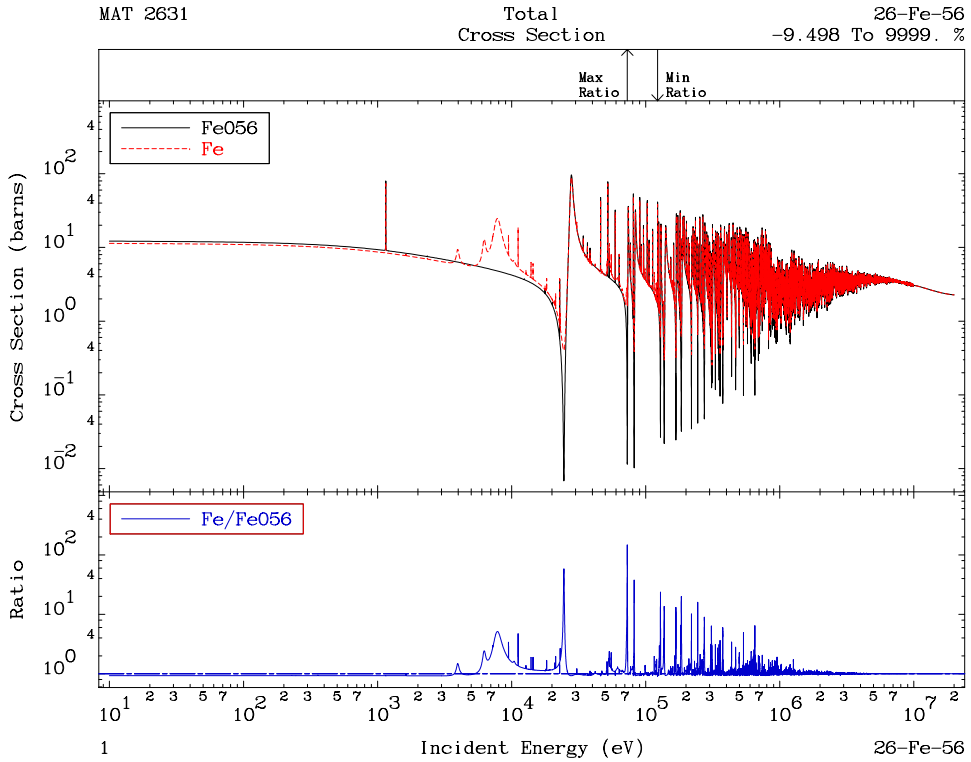


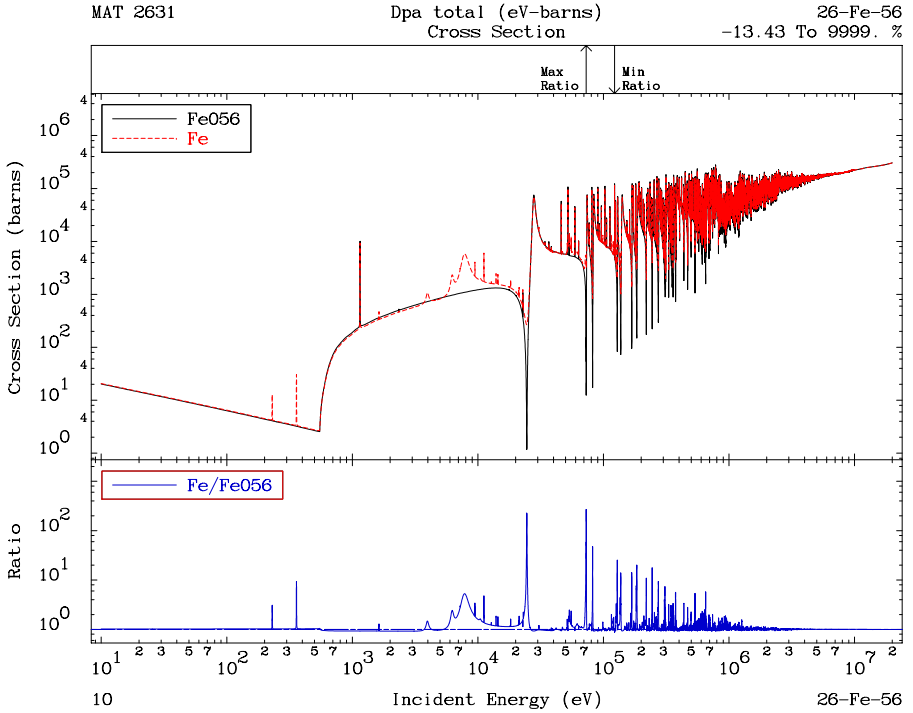


D. E. Cullen PREPRO

Total and Dpa: isotopic versus elemental

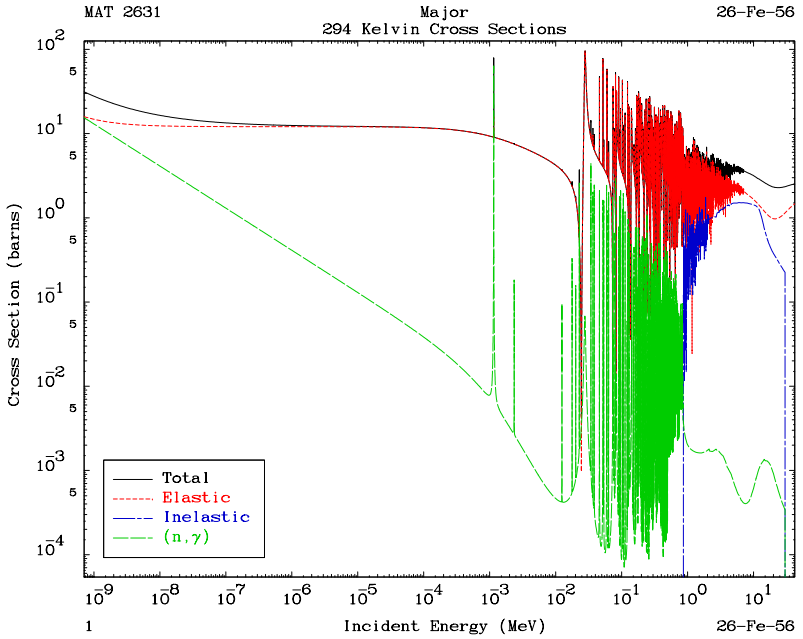
The energy range matters

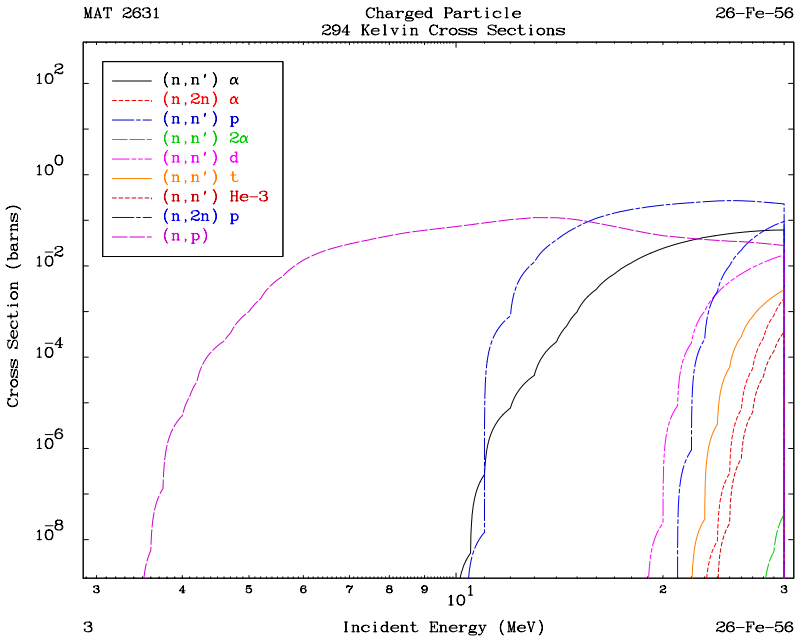


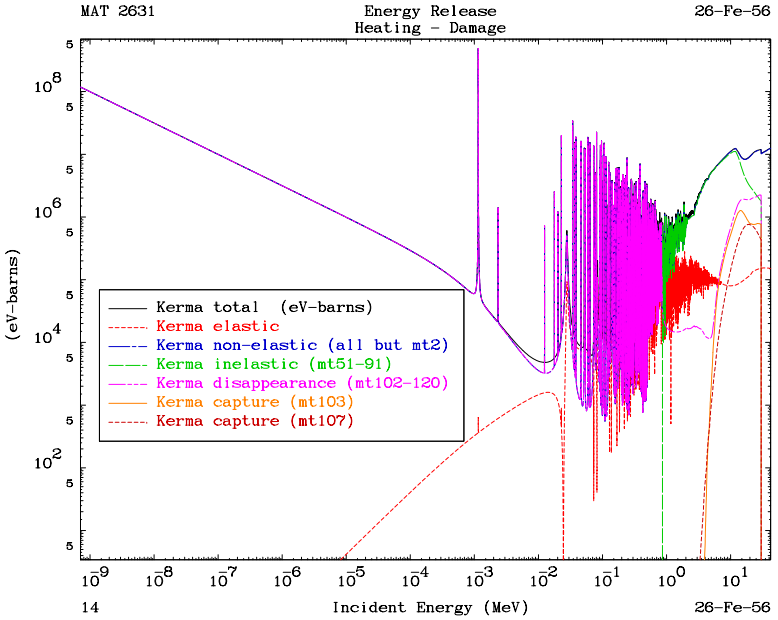


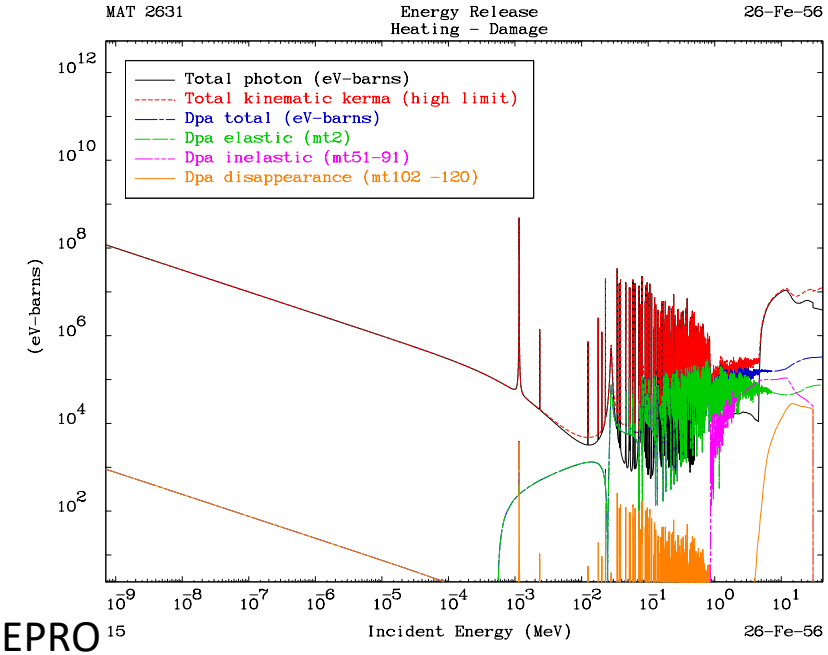
D. E. Cullen PREPRO

Major, charged particles, heating Kerma, DPA



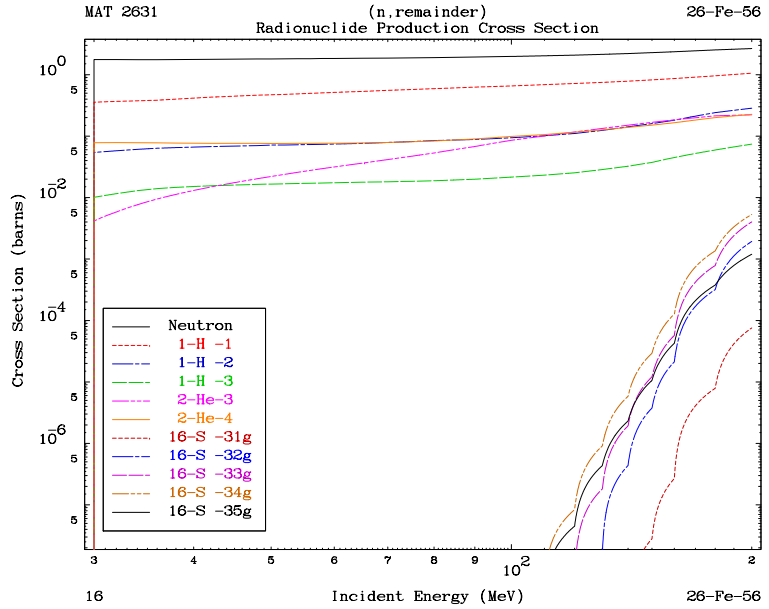




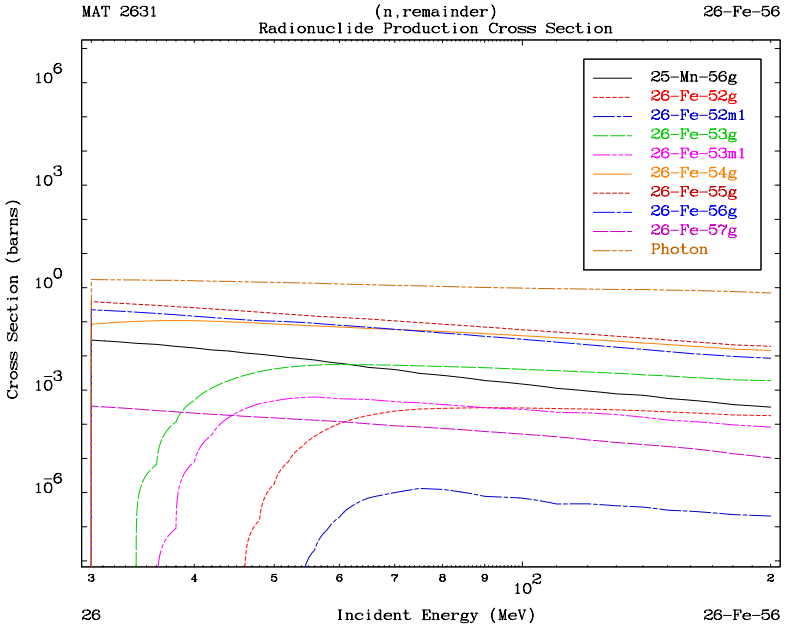


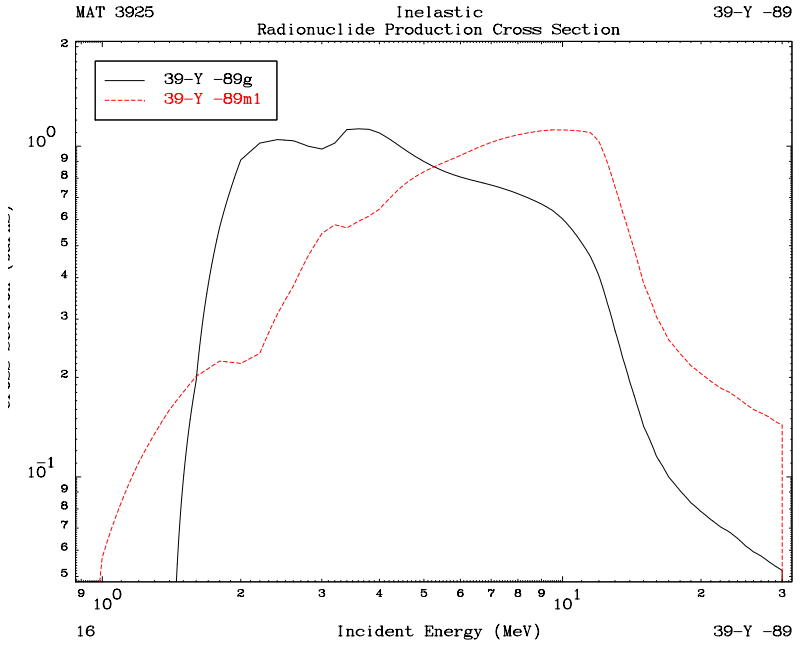
D. E. Cullen PREPRO

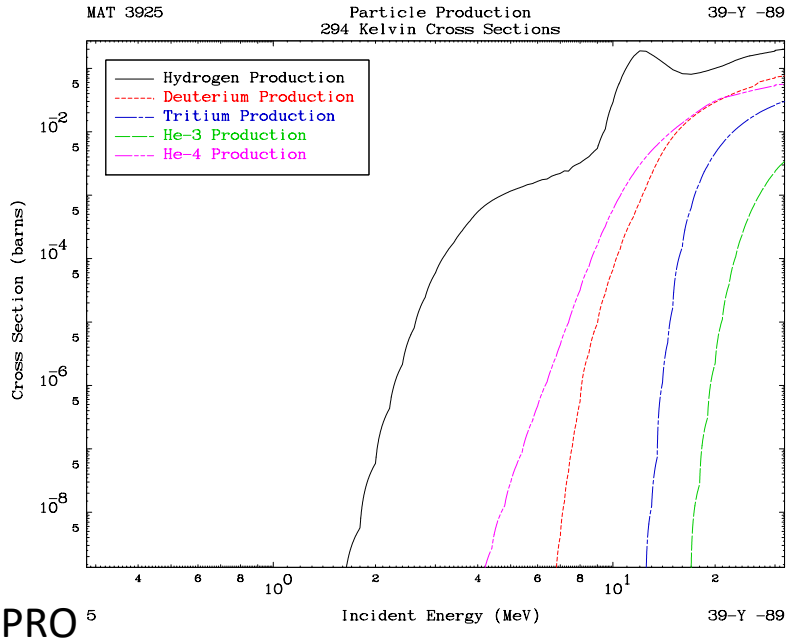
Implicit MF-3 MT-5 above 30 MeV – isomer & gas production



Hundreds of transmutation yields



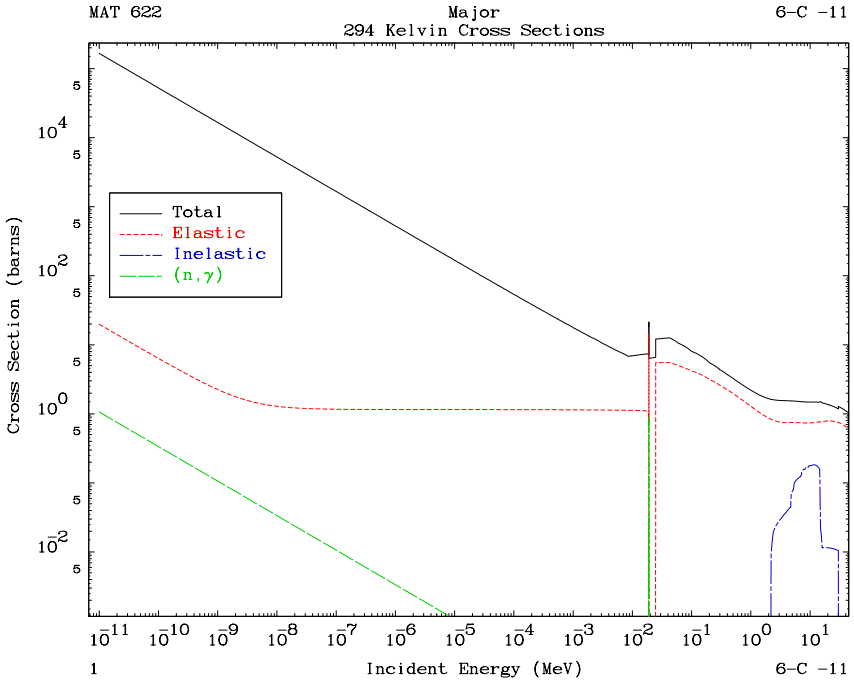


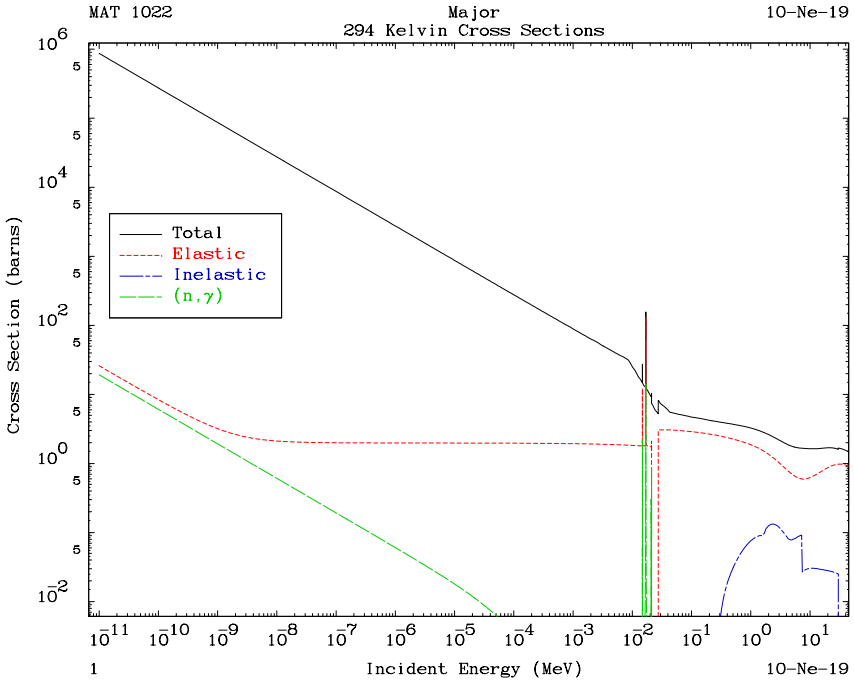


D. E. Cullen PREPRO 5

TENDL-2019 glitches C^{11}, Ne^{19}

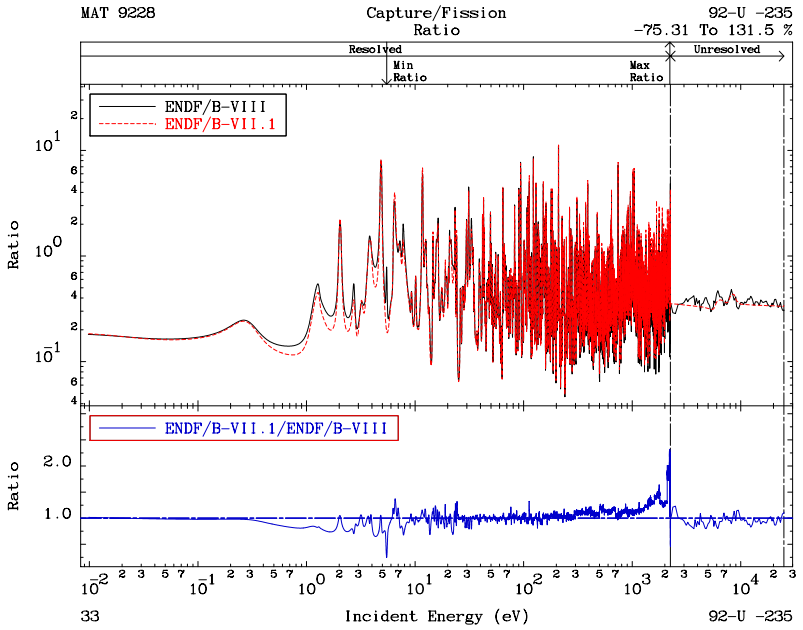
- Flagged during processing: FRENDY findings

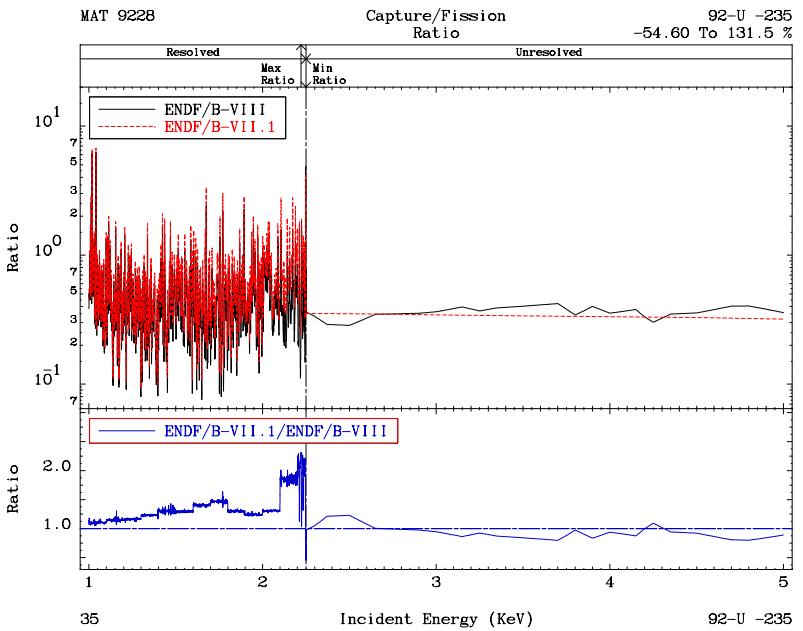


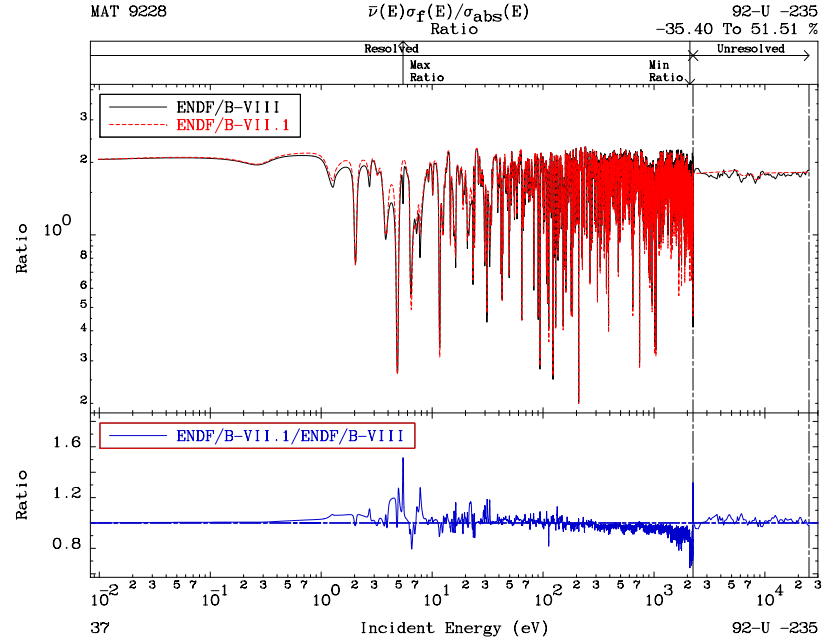


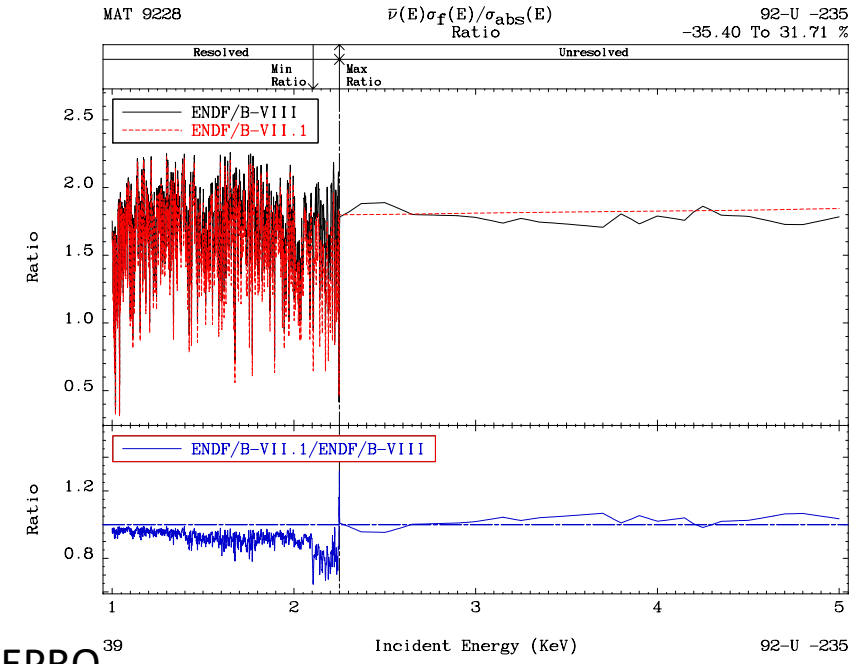
D. E. Cullen PREPRO

Derived quantities: capture/fission and alpha



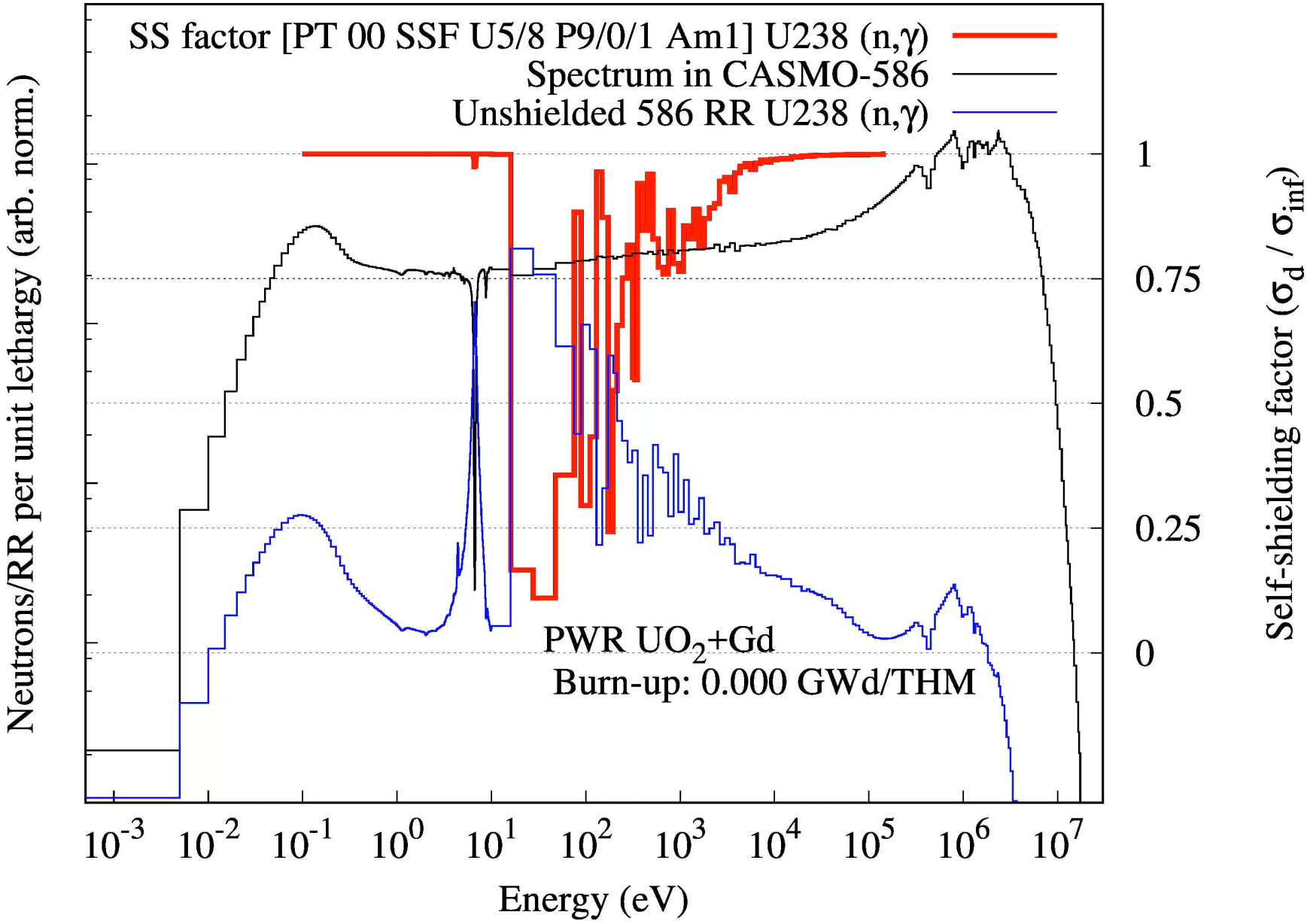






D. E. Cullen PREPRO

What for ? : neutron flux, SSF and RR



Data forms not presented

- Scattering law S(α,β) and neutron scattering in the thermal region up to 4 eV, now 10 eV and going up to 100 eV for some applications
- Variances and covariances
- Photo-atomic
- Photonuclear
- Induced charged particles
- High energy, spallation
- Fission fragments, independent and cumulative yields
- Decay data scheme
- ….

Conclusions

- Evaluated is just a commencement, although it is seen as an end to an entire community
- Processed nuclear data forms are numerous, rich, abundant, diverse. Some are observable other not, all have a specific importance for at least one applications
- Processing enhances, enriches, deepens the evaluated nuclear data forms
- NJOY plotr and viewr, PREPRO complot and evalplot are underrated verification tools. FUDGE will need the same kind of tools

Thank you for your attention!

IAEA
International Atomic Energy Agency
Atoms for Peace and Development