



IAEA

Consultant Meeting on the on Compilation of Nuclear Data Experiments for Radiation Characterization (CoNDERC)

J.-C. Sublet

UH-NDSU

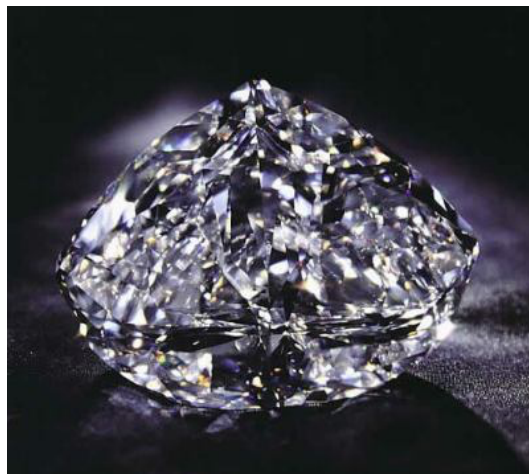
International Atomic Energy Agency

Nuclear Data Section

- The purpose of the project on Compilation of Nuclear Data Experiments for Radiation Characterization (CoNDERC) is to transfer into technology the experimental integral radiation information that can be used as part of the Validation and Verification processes of nuclear model and code systems, and to provide various schema to perform the V&V
- The IAEA will task, organize institutions to construct several of these databases based on their own extensive V&V activities associated with inventory and source term codes.

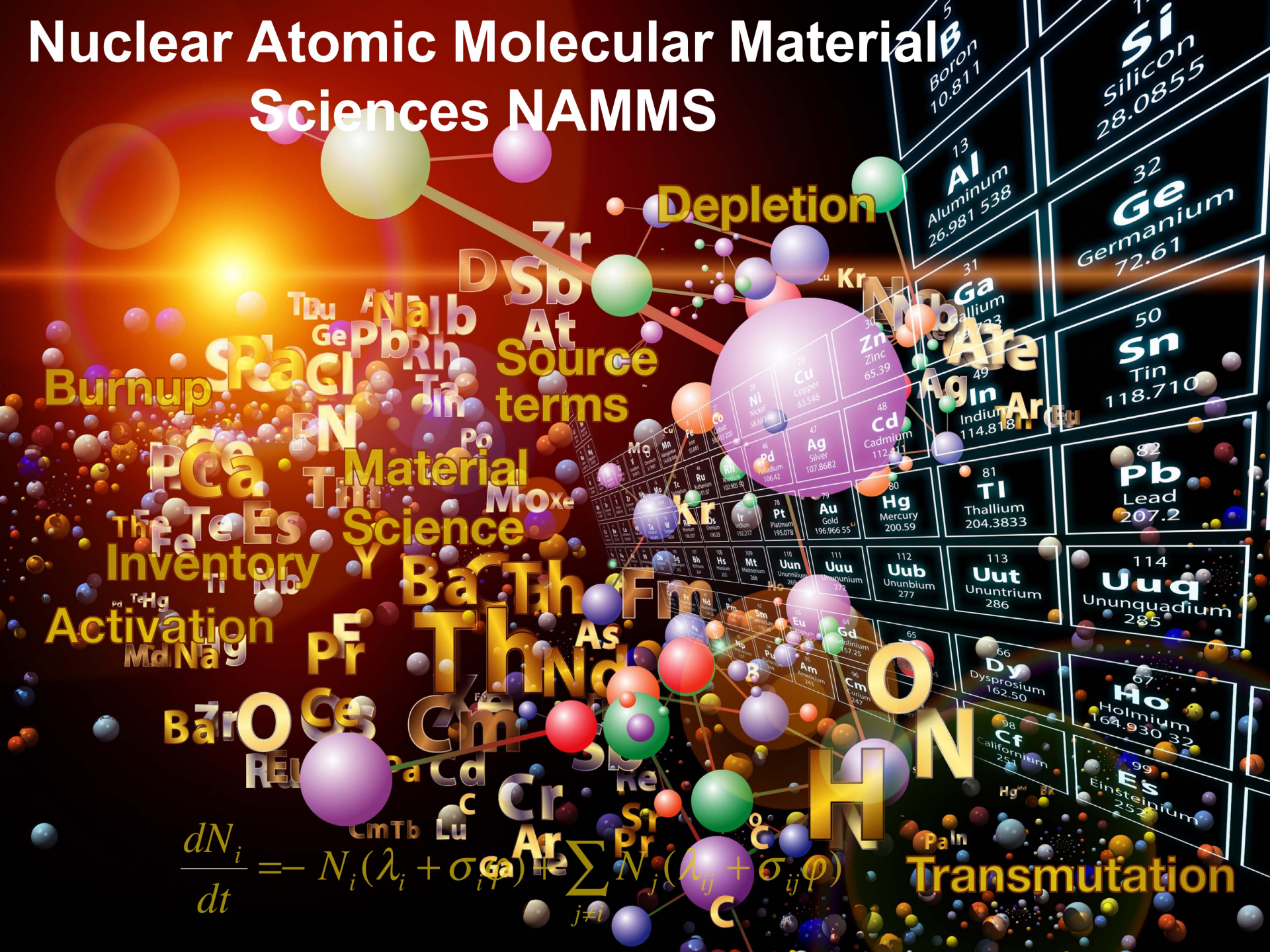
- Identify and compile a comprehensive set of experimental integral radiation characterization benchmark information: spectral indices, reaction rates, decay heat, resonance integral, particle counts and fluxes, etc...
- Evaluate the data, quantify, compute rank their overall uncertainties then compile the data into computer format for dissemination
- Perform simulations of each experiment with the suitable code system and selected nuclear libraries and produce a database/repository of the necessary input files to repeat those simulations for other nuclear data libraries.

Data mining: from raw to shaped diamond



Blue Zoe

Nuclear Atomic Molecular Material Sciences NAMMS



Depletion

Source terms

Material Science

Thermal

OHN

Transmutation

$$\frac{dN_i}{dt} = -N_i(\lambda_i + \sigma_{if}\phi) + \sum_{j \neq i} N_j(\lambda_{ij} + \sigma_{ij}\phi)$$

| | | | | | | | |
|---------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|------------------------------|----------------------------|--------------------------|
| 5 Boron 10.811 | 13 Aluminum 26.981 538 | 31 Gallium 69.723 | 49 Indium 114.818 | 81 Thallium 204.3833 | 113 Ununtrium 286 | 66 Dysprosium 162.50 | 98 Californium 251 |
| 14 Silicon 28.0855 | 32 Germanium 72.61 | 50 Tin 118.710 | 82 Lead 207.2 | 114 Ununquadium 285 | 67 Holmium 164.930 32 | 99 Einsteinium 252 | |
| 26 Iron 55.845 | 44 Ruthenium 101.07 | 74 Tungsten 183.84 | 112 Ununbium 277 | 65 Terbium 158.925 32 | 97 Berkelium 247 | | |
| 29 Copper 63.546 | 46 Palladium 106.42 | 76 Osmium 192.22 | 111 Ununium 272 | 64 Gadolinium 157.25 | 96 Curium 247 | | |
| 30 Zinc 65.39 | 47 Silver 107.8682 | 78 Platinum 195.078 | 110 Ununnilium 269 | 63 Europium 151.964 | 95 Americium 243 | | |
| 33 Arsenic 74.9216 | 48 Cadmium 112.411 | 80 Mercury 200.59 | 109 Meitnerium 268 | 62 Samarium 150.36 | 94 Plutonium 244 | | |
| 36 Krypton 83.798 | 52 Tellurium 127.603 | 84 Polonium 209 | 108 Hassium 265 | 60 Neodymium 144.242 | 92 Uranium 238.02891 | | |
| 39 Yttrium 88.9062 | 54 Xenon 132.90545 | 86 Radon 222 | 107 Bohrium 264 | 59 Praseodymium 140.90765 | 91 Protactinium 231 | | |
| 40 Zirconium 91.224 | 56 Barium 137.327 | 88 Radium 226 | 106 Seaborgium 263 | 58 Cerium 140.127 | 89 Actinium 227 | | |
| 41 Niobium 92.90638 | 58 Ce 140.127 | 90 Thorium 232.0377 | 105 Dubnium 262 | 57 Lanthanum 138.90547 | 87 Francium 223 | | |
| 42 Molybdenum 95.94 | 60 Nd 140.90765 | 92 U 238.02891 | 104 Rutherfordium 261 | 56 Europium 151.964 | 85 Astatine 210 | | |
| 43 Technetium 98.90625 | 62 Sm 150.36 | 94 Pu 239.0521634 | 103 Lawrencium 260 | 55 Cesium 132.90545196 | 83 Bismuth 208.9803987 | | |
| 44 Ruthenium 101.07 | 64 Gd 157.25 | 96 Cm 247 | 102 Nobelium 259 | 54 Xenon 132.90545196 | 82 Lead 207.2 | | |
| 45 Rhodium 102.90550 | 66 Dy 162.50 | 98 Cf 251 | 101 Darmstadtium 261 | 53 Iodine 126.90447 | 80 Mercury 200.59 | | |
| 46 Palladium 106.42 | 68 Er 167.259 | 100 Fermium 257 | 100 Fermium 257 | 52 Tellurium 127.603 | 79 Gold 196.96655 | | |
| 47 Silver 107.8682 | 70 Yb 173.054 | 102 Nobelium 259 | 99 Mendelevium 258 | 51 Antimony 121.757 | 77 Iridium 192.222 | | |
| 48 Cadmium 112.411 | 72 Hf 178.49 | 104 Rutherfordium 261 | 97 Berkelium 247 | 50 Tin 118.710 | 75 Rhenium 186.207 | | |
| 49 Indium 114.818 | 74 Ta 180.94788 | 106 Seaborgium 263 | 95 Americium 243 | 49 Indium 114.818 | 73 Tantalum 180.94788 | | |
| 50 Tin 118.710 | 76 W 183.84 | 108 Hassium 265 | 94 Plutonium 244 | 48 Cadmium 112.411 | 72 Hf 178.49 | | |
| 51 Antimony 121.757 | 78 Pt 195.078 | 110 Ununnilium 269 | 92 Uranium 238.02891 | 47 Silver 107.8682 | 70 Yb 173.054 | | |
| 52 Tellurium 127.603 | 80 Hg 200.59 | 112 Ununbium 277 | 90 Thorium 232.0377 | 46 Palladium 106.42 | 68 Er 167.259 | | |
| 53 Iodine 126.90447 | 82 Pb 207.2 | 114 Ununquadium 285 | 88 Radium 226 | 45 Rhodium 102.90550 | 66 Dy 162.50 | | |
| 54 Xenon 132.90545 | 84 Po 209 | 116 Ununhexium 289 | 86 Rn 222 | 44 Ruthenium 101.07 | 64 Gd 157.25 | | |
| 55 Cesium 132.90545 | 86 Radium 226 | 118 Ununoctium 293 | 88 Ra 226 | 43 Technetium 98.90625 | 62 Sm 150.36 | | |
| 56 Barium 137.327 | 88 Radium 226 | 120 Ununnilium 297 | 90 Th 232 | 42 Molybdenum 95.94 | 60 Nd 140.90765 | | |
| 57 Lanthanum 138.90547 | 90 Th 232 | 122 Ununium 301 | 92 U 238 | 41 Niobium 92.90638 | 58 Ce 140.127 | | |
| 58 Cerium 140.127 | 92 U 238 | 124 Ununium 305 | 94 Pu 244 | 40 Zirconium 91.224 | 56 Eu 151.964 | | |
| 59 Praseodymium 140.90765 | 94 Pu 244 | 126 Ununium 309 | 96 Cm 247 | 39 Yttrium 88.9062 | 54 Xe 132.90545 | | |
| 60 Neodymium 144.242 | 96 Cm 247 | 128 Ununium 313 | 98 Cf 251 | 38 Strontium 87.62 | 52 Te 127.603 | | |
| 61 Promethium 144.9127 | 100 Fm 257 | 130 Ununium 317 | 100 Fm 257 | 37 Rubidium 85.4678 | 50 Sn 118.710 | | |
| 62 Samarium 150.36 | 102 No 259 | 132 Ununium 321 | 102 No 259 | 36 Krypton 83.798 | 48 Cd 112.411 | | |
| 63 Europium 151.964 | 104 Rf 261 | 134 Ununium 325 | 104 Rf 261 | 35 Bromine 79.904 | 46 Pd 106.42 | | |
| 64 Gadolinium 157.25 | 106 Sg 263 | 136 Ununium 329 | 106 Sg 263 | 34 Selenium 78.96 | 44 Ru 101.07 | | |
| 65 Terbium 158.92532 | 108 Hs 265 | 138 Ununium 333 | 108 Hs 265 | 33 Arsenic 74.9216 | 42 Mo 95.94 | | |
| 66 Dysprosium 162.50 | 110 Ds 277 | 140 Ununium 337 | 110 Ds 277 | 32 Germanium 72.61 | 40 Zr 91.224 | | |
| 67 Holmium 164.93032 | 112 Cn 285 | 142 Ununium 341 | 112 Cn 285 | 31 Gallium 69.723 | 38 Sr 87.62 | | |
| 68 Erbium 167.259 | 114 Fl 289 | 144 Ununium 345 | 114 Fl 289 | 30 Zn 65.39 | 36 Kr 83.798 | | |
| 69 Thulium 168.93032 | 116 Lv 293 | 146 Ununium 349 | 116 Lv 293 | 29 Cu 63.546 | 34 Se 78.96 | | |
| 70 Ytterbium 173.054 | 118 Og 297 | 148 Ununium 353 | 118 Og 297 | 28 Ni 58.6934 | 32 Ge 72.61 | | |
| 71 Lutetium 174.967 | 120 Ts 301 | 150 Ununium 357 | 120 Ts 301 | 27 Co 58.933195 | 30 Zn 65.39 | | |
| 72 Hafnium 178.49 | 122 Uu 305 | 152 Ununium 361 | 122 Uu 305 | 26 Fe 55.845 | 28 Ni 58.6934 | | |
| 73 Tantalum 180.94788 | 124 Uub 309 | 154 Ununium 365 | 124 Uub 309 | 25 Mn 54.938045 | 26 Fe 55.845 | | |
| 74 Tungsten 183.84 | 126 Uuq 313 | 156 Ununium 369 | 126 Uuq 313 | 24 Cr 51.99616 | 24 Cr 51.99616 | | |
| 75 Rhenium 186.207 | 128 Uubk 317 | 158 Ununium 373 | 128 Uubk 317 | 23 V 50.9415 | 23 V 50.9415 | | |
| 76 Osmium 192.22 | 130 Uuqk 321 | 160 Ununium 377 | 130 Uuqk 321 | 22 Ti 47.88 | 22 Ti 47.88 | | |
| 77 Iridium 192.222 | 132 Uubk 325 | 162 Ununium 381 | 132 Uubk 325 | 21 Sc 44.955912 | 21 Sc 44.955912 | | |
| 78 Platinum 195.078 | 134 Uubk 329 | 164 Ununium 385 | 134 Uubk 329 | 20 Ca 40.078 | 20 Ca 40.078 | | |
| 79 Gold 196.96655 | 136 Uubk 333 | 166 Ununium 389 | 136 Uubk 333 | 19 K 39.0983 | 19 K 39.0983 | | |
| 80 Mercury 200.59 | 138 Uubk 337 | 168 Ununium 393 | 138 Uubk 337 | 18 Ar 39.948 | 18 Ar 39.948 | | |
| 81 Thallium 204.3833 | 140 Uubk 341 | 170 Ununium 397 | 140 Uubk 341 | 17 Cl 35.453 | 17 Cl 35.453 | | |
| 82 Lead 207.2 | 142 Uubk 345 | 172 Ununium 401 | 142 Uubk 345 | 16 S 32.06 | 16 S 32.06 | | |
| 83 Bismuth 208.9803987 | 144 Uubk 349 | 174 Ununium 405 | 144 Uubk 349 | 15 P 30.973762 | 15 P 30.973762 | | |
| 84 Polonium 209 | 146 Uubk 353 | 176 Ununium 409 | 146 Uubk 353 | 14 Si 28.0855 | 14 Si 28.0855 | | |
| 85 Astatine 210 | 148 Uubk 357 | 178 Ununium 413 | 148 Uubk 357 | 13 Al 26.9815386 | 13 Al 26.9815386 | | |
| 86 Radon 222 | 150 Uubk 361 | 180 Ununium 417 | 150 Uubk 361 | 12 Mg 24.304 | 12 Mg 24.304 | | |
| 87 Francium 223 | 152 Uubk 365 | 182 Ununium 421 | 152 Uubk 365 | 11 Na 22.98976928 | 11 Na 22.98976928 | | |
| 88 Radium 226 | 154 Uubk 369 | 184 Ununium 425 | 154 Uubk 369 | 10 Ne 20.1797 | 10 Ne 20.1797 | | |
| 89 Actinium 227 | 156 Uubk 373 | 186 Ununium 429 | 156 Uubk 373 | 9 F 18.9984032 | 9 F 18.9984032 | | |
| 90 Thorium 232 | 158 Uubk 377 | 188 Ununium 433 | 158 Uubk 377 | 8 O 15.999 | 8 O 15.999 | | |
| 91 Protactinium 231 | 160 Uubk 381 | 190 Ununium 437 | 160 Uubk 381 | 7 N 14.00643 | 7 N 14.00643 | | |
| 92 Uranium 238 | 162 Uubk 385 | 192 Ununium 441 | 162 Uubk 385 | 6 C 12.0107 | 6 C 12.0107 | | |
| 93 Neptunium 237 | 164 Uubk 389 | 194 Ununium 445 | 164 Uubk 389 | 5 B 10.811 | 5 B 10.811 | | |
| 94 Plutonium 244 | 166 Uubk 393 | 196 Ununium 449 | 166 Uubk 393 | 4 He 4.002602 | 4 He 4.002602 | | |
| 95 Americium 243 | 168 Uubk 397 | 198 Ununium 453 | 168 Uubk 397 | 3 Li 6.941 | 3 Li 6.941 | | |
| 96 Curium 247 | 170 Uubk 401 | 200 Ununium 457 | 170 Uubk 401 | 2 He 4.002602 | 2 He 4.002602 | | |
| 97 Berkelium 247 | 172 Uubk 405 | 202 Ununium 461 | 172 Uubk 405 | 1 H 1.00794 | 1 H 1.00794 | | |
| 98 Californium 251 | 174 Uubk 409 | 204 Ununium 465 | 174 Uubk 409 | | | | |
| 99 Einsteinium 252 | 176 Uubk 413 | 206 Ununium 469 | 176 Uubk 413 | | | | |
| 100 Fermium 257 | 178 Uubk 417 | 208 Ununium 473 | 178 Uubk 417 | | | | |



Verification & Validation exercises in support of radiation characterisation

J.-Ch. Sublet, M. Fleming* and M Gilbert*

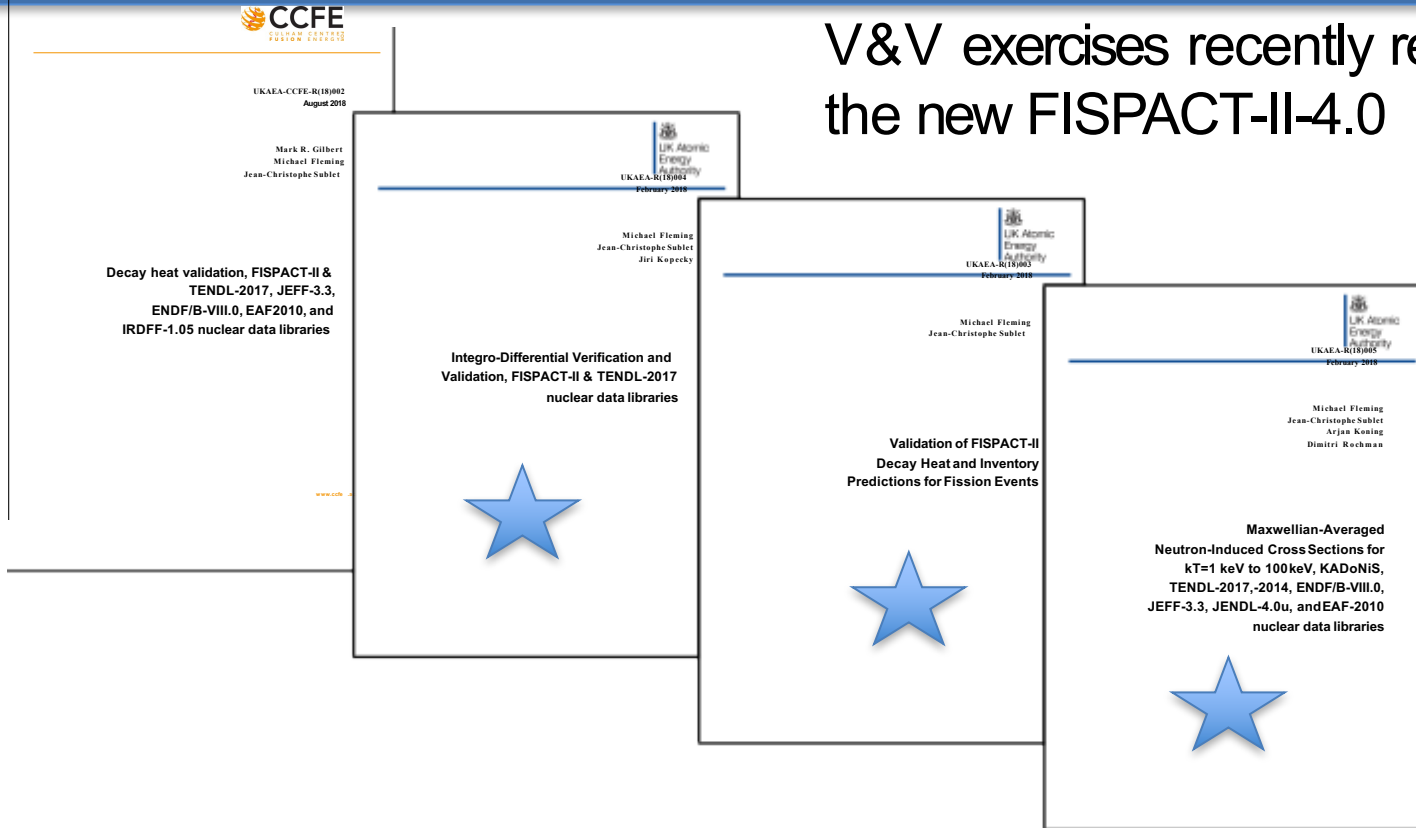
UH-NDSU

***UKAEA-OECD/NEA**

International Atomic Energy Agency

Nuclear Data Section

V&V exercises recently repeated for the new FISPACT-II-4.0



Benchmarking ENDF/B-VIII.0, JEFF-3.3, JENDL-4.0 and TENDL-2017 (and others)

Decay heat validation against (Japan-FNS) fusion experiments

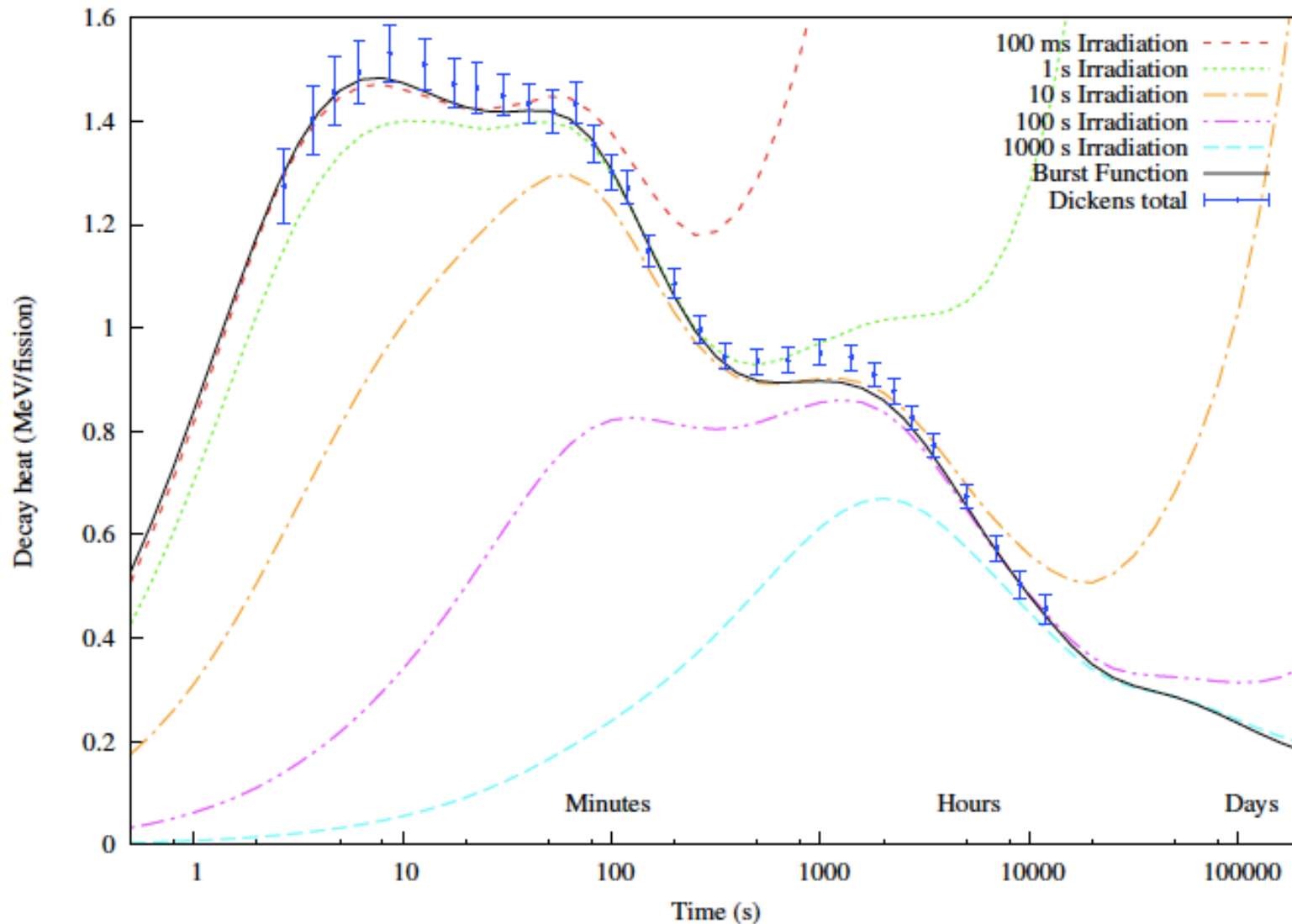
Integral & differential xs validation against EXFOR

Fission events

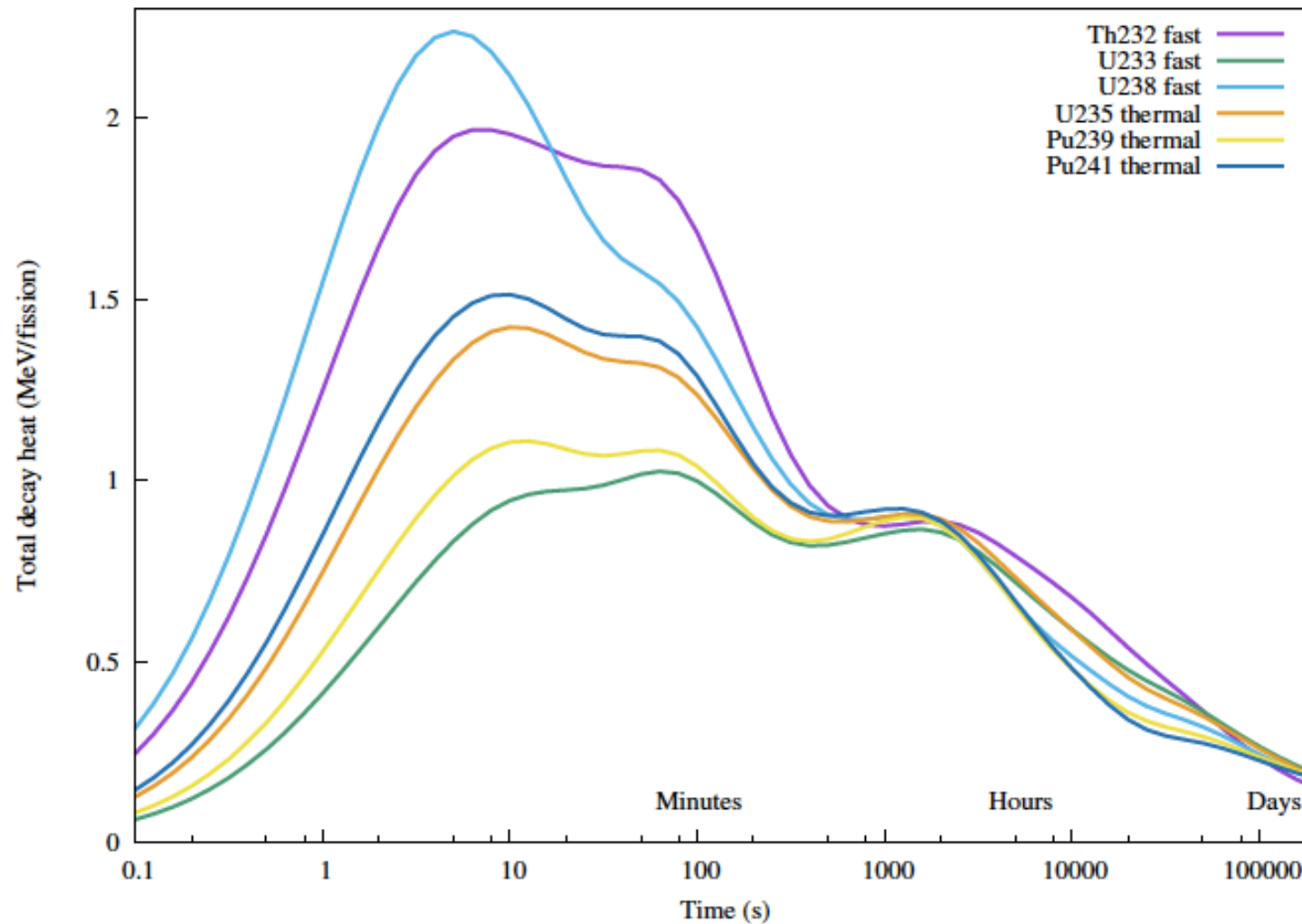
Astrophysics MACS (KADoNiS)

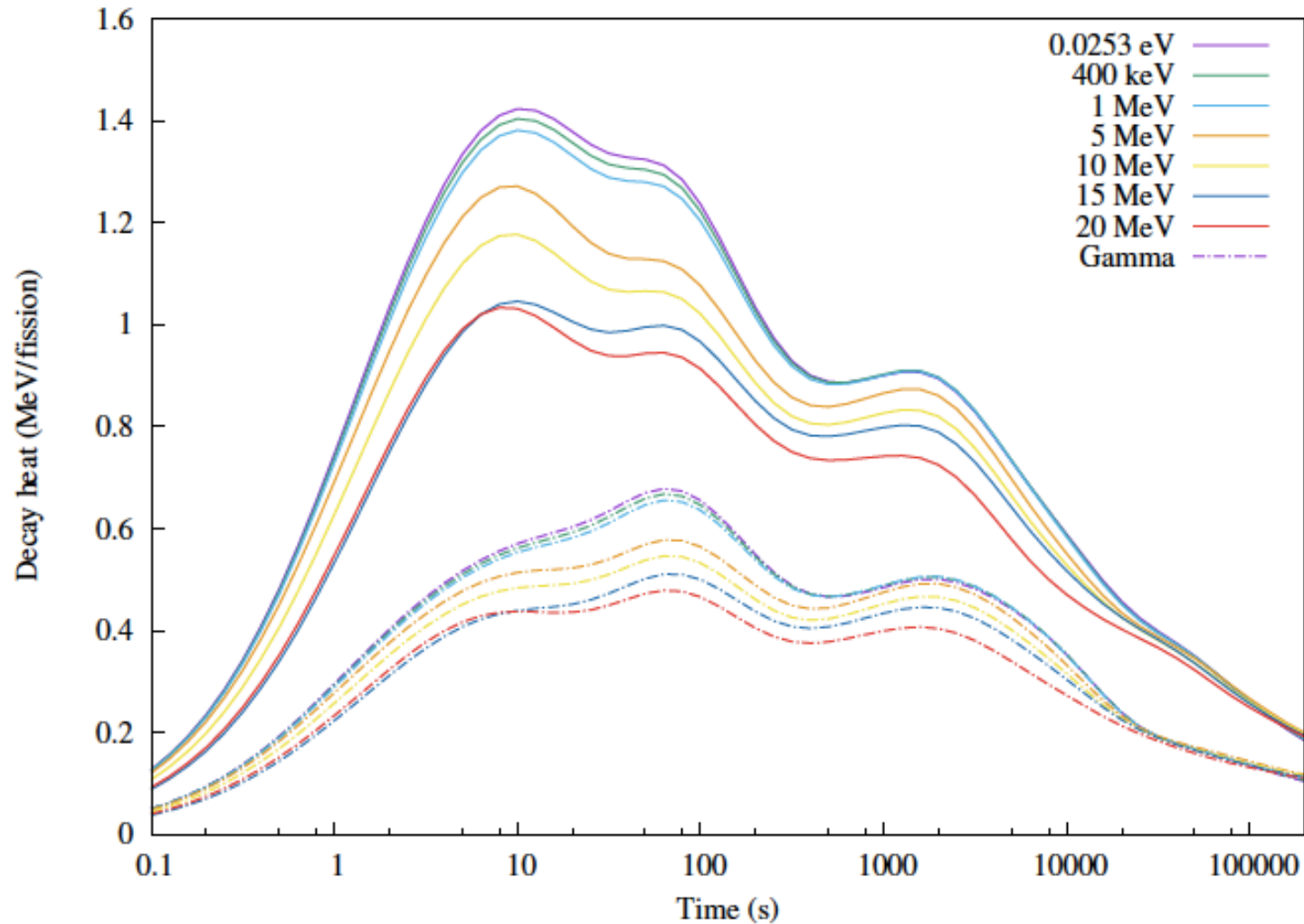
| Author, Institute | Nuclide(s) | Method | Irrad. (s) | Year |
|--------------------|--|--------------------|------------|------|
| Fisher, LANL | $^{232}\text{Th}_f$, $^{233}\text{U}_f$, $^{235}\text{U}_f$, $^{238}\text{U}_f$, $^{239}\text{Pu}_f$ | γ | < 1 | 1964 |
| McNair, UKAWRE | $^{235}\text{U}_{th}$, $^{239}\text{Pu}_{th}$ | β | 10-1E5 | 1969 |
| MacMahon, SRRC | $^{235}\text{U}_{th}$ | β | 10-1E4 | 1970 |
| Scobie, SRRC | $^{235}\text{U}_{th}$ | β | 1E4-1E5 | 1971 |
| Lott, CEA | $^{235}\text{U}_{th}$ | Total | 1E2-5E3 | 1973 |
| Yarnell, LANL | $^{233}\text{U}_{th}$, $^{235}\text{U}_{th}$, $^{239}\text{Pu}_{th}$ | Total | 2E4 | 1978 |
| Jurney, LANL | $^{233}\text{U}_{th}$, $^{235}\text{U}_{th}$, $^{239}\text{Pu}_{th}$ | γ | 2E4 | 1979 |
| Murphy, UKAEA | $^{235}\text{U}_f$, $^{239}\text{Pu}_f$ | β | 1E5 | 1979 |
| Dickens, ORNL | $^{235}\text{U}_{th}$, $^{239}\text{Pu}_{th}$, $^{241}\text{Pu}_{th}$ | γ & β | 1-100 | 1980 |
| Baumung, Karlsruhe | $^{235}\text{U}_{th}$ | Total | 200 | 1981 |
| Akiyama, JAEA | $^{233}\text{U}_f$, $^{235}\text{U}_f$, $^{238}\text{U}_f$, $^{239}\text{Pu}_f$ | γ & β | 10-300 | 1982 |
| Akiyama, JAEA | $^{232}\text{Th}_f$, $^{nat}\text{U}_f$ | γ | 10-300 | 1983 |
| Johansson, Uppsala | $^{235}\text{U}_{th}$ | γ & β | 4-120 | 1987 |
| Tobias Berkeley NL | $^{235}\text{U}_{th}$, $^{239}\text{Pu}_{th}$ | Stat. | - | 1989 |
| Schier, UM Lowell | $^{235}\text{U}_{th}$, $^{238}\text{Pu}_f$, $^{239}\text{Pu}_{th}$ | γ & β | <1 | 1997 |
| Ohkawachi, JAEA | $^{235}\text{U}_f$, $^{237}\text{Np}_f$ | γ & β | 10-300 | 2002 |

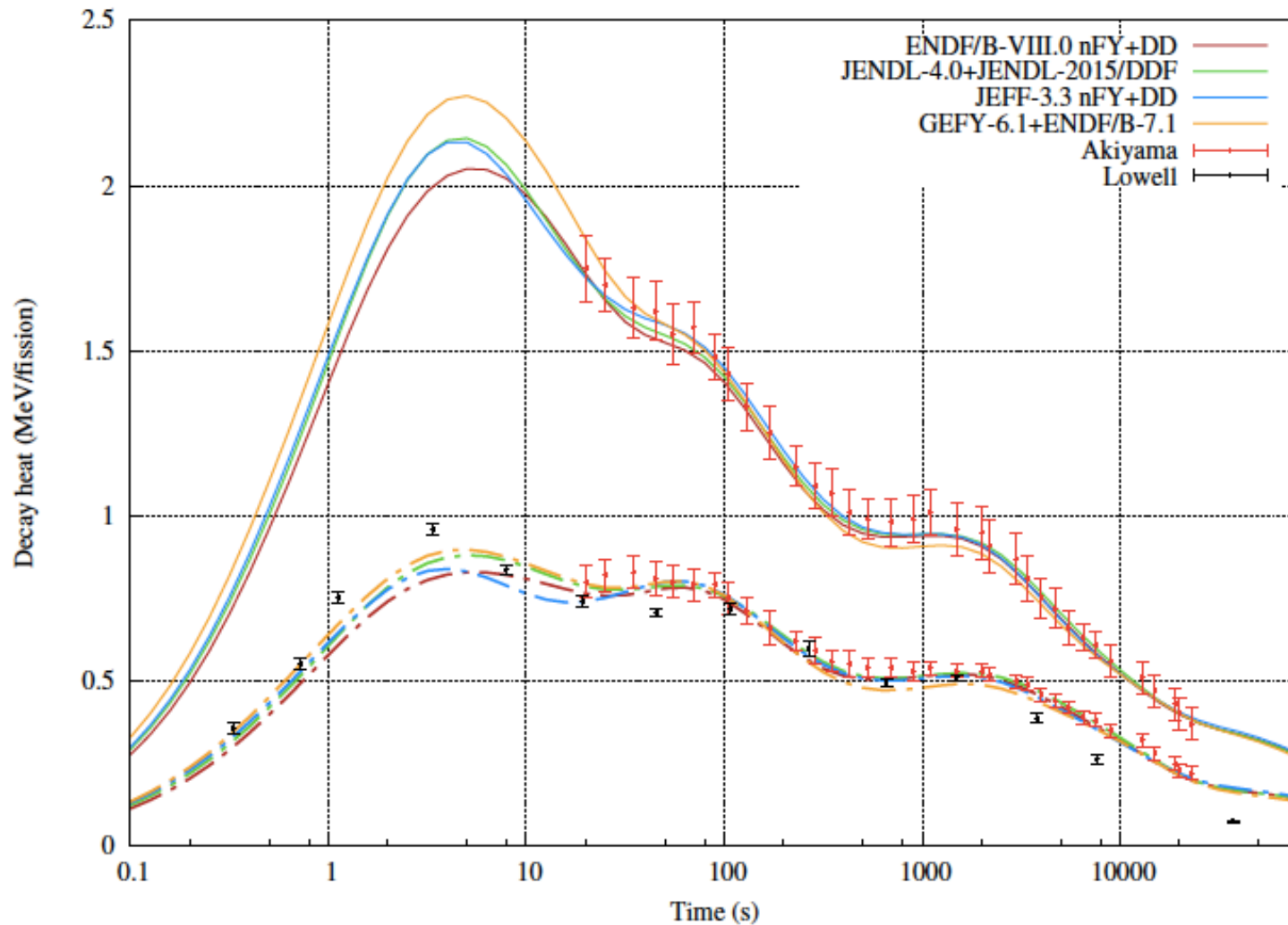
The burst function calculated using a 1E^{21} flux over 1 ns and the experimental results from Dickens are included for comparison, capture decay excluded, chain not



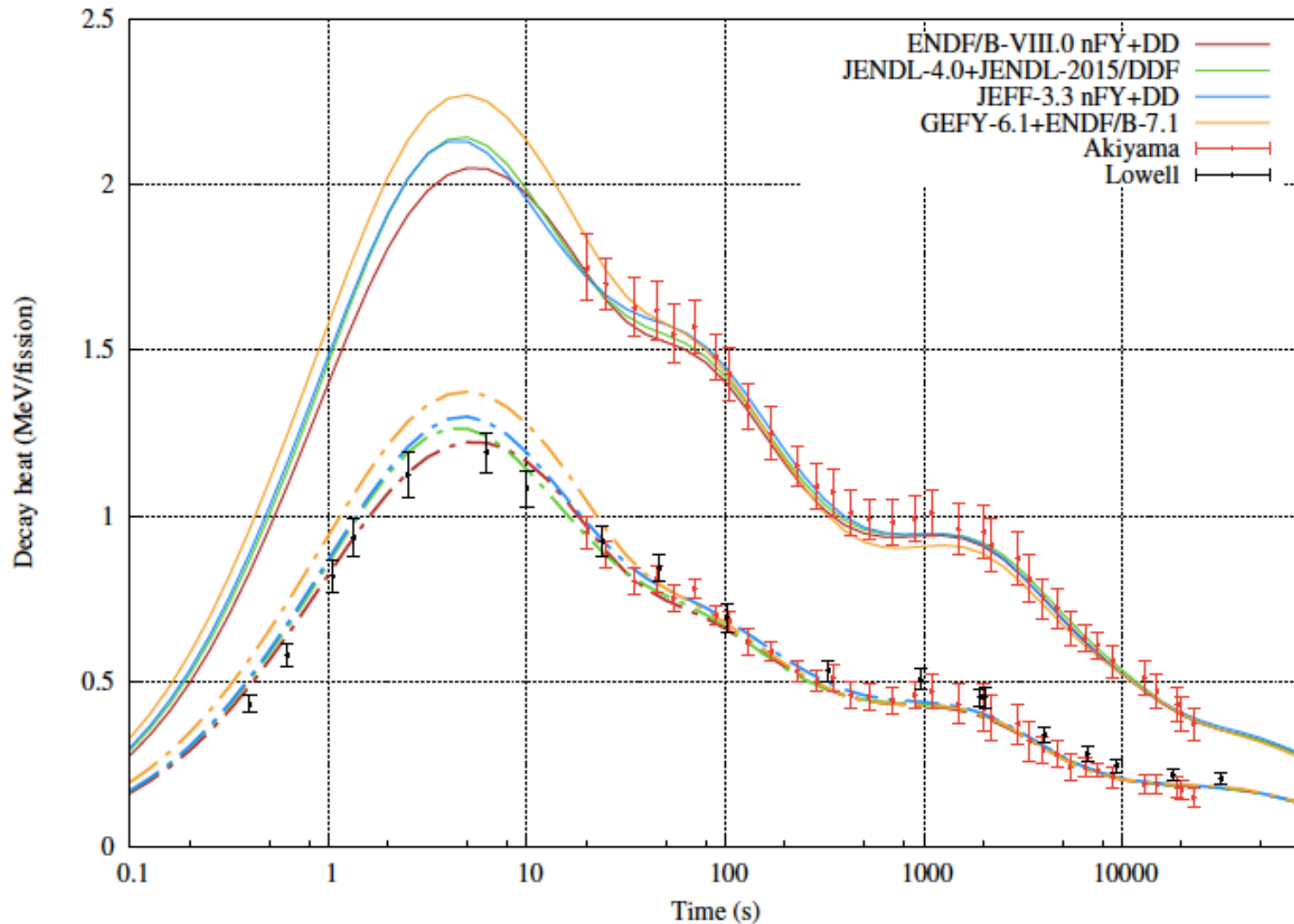
- Various fissiles, fast and thermal burst

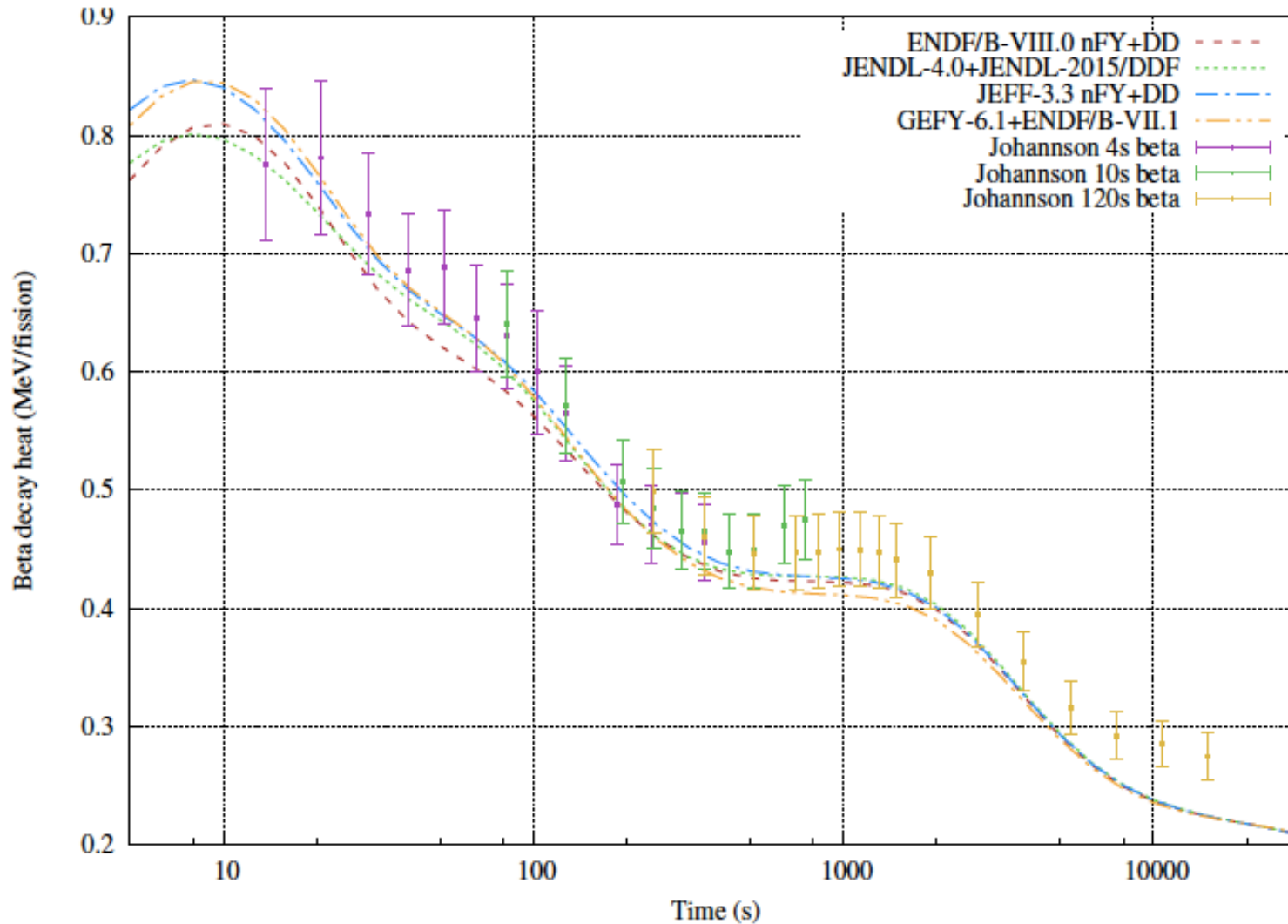


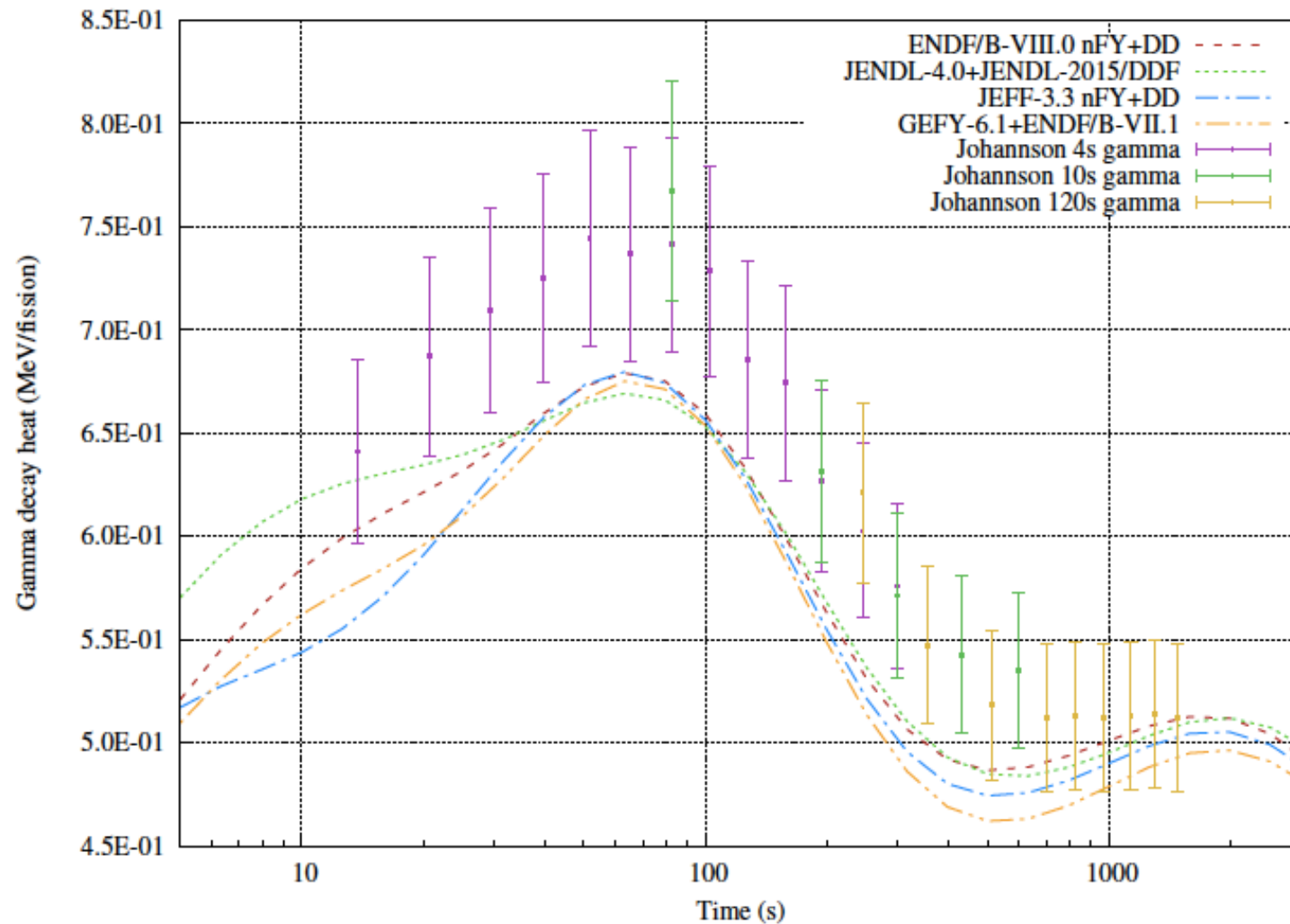
Decay heat burst functions of ^{235}U for various neutron energies

Total (solid) and gamma (dash) decay heat from fast pulse ^{238}U 

Total (solid) and beta (dash) decay heat from fast pulse ^{238}U

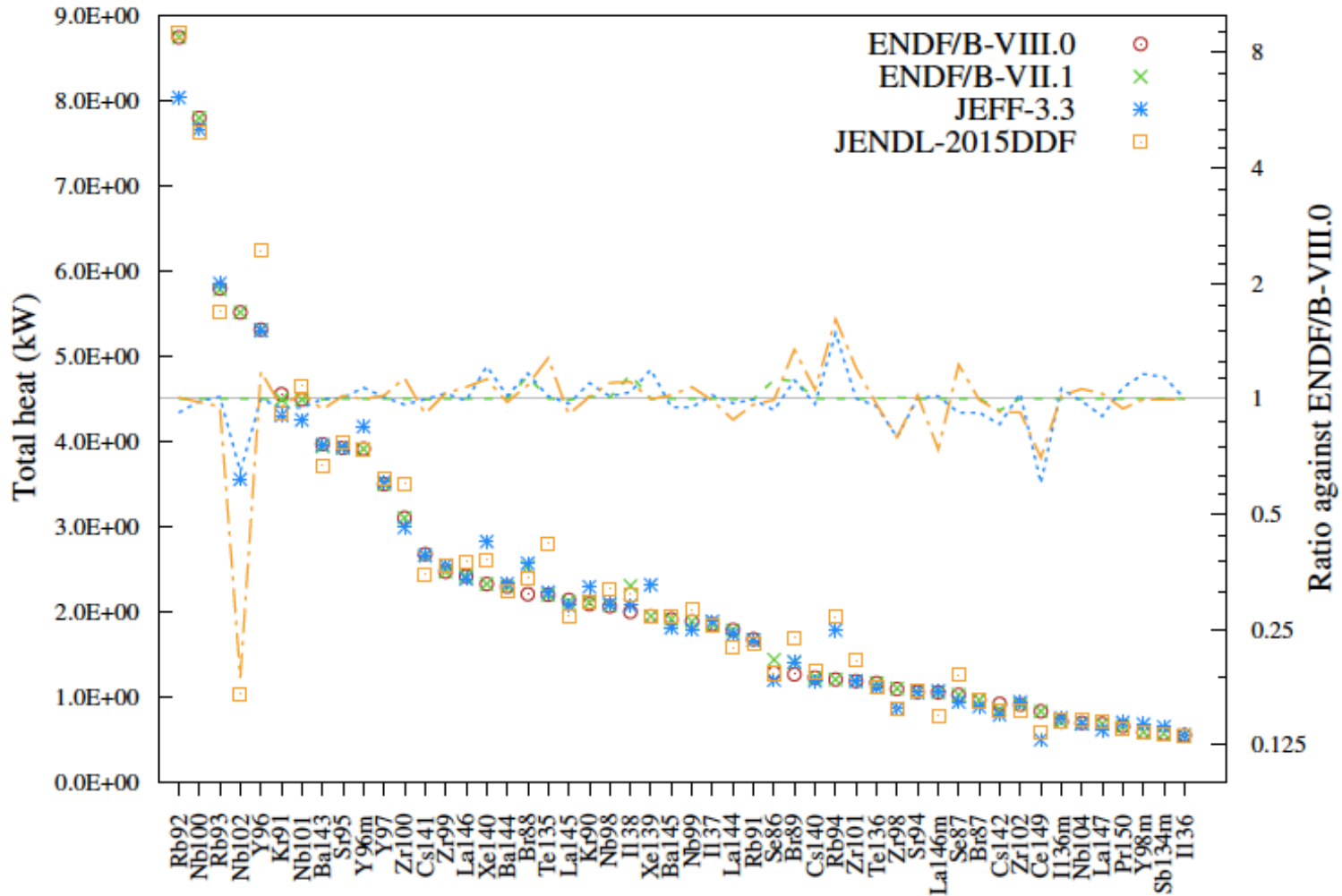


Beta decay heat from 4-120s irradiation of ^{235}U 

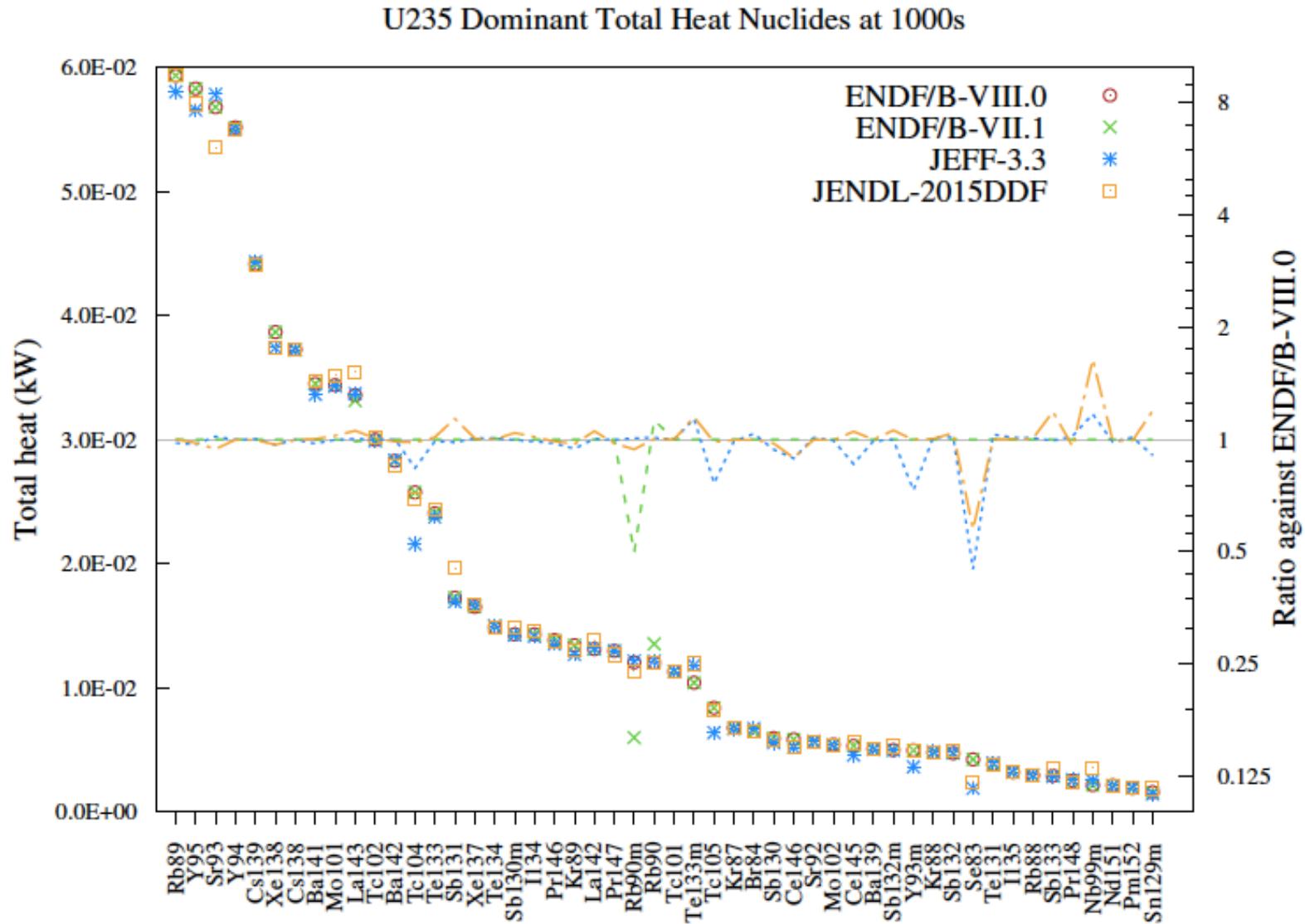
Gamma decay heat from 4-120s irradiation of ^{235}U 

- Nb102 !!

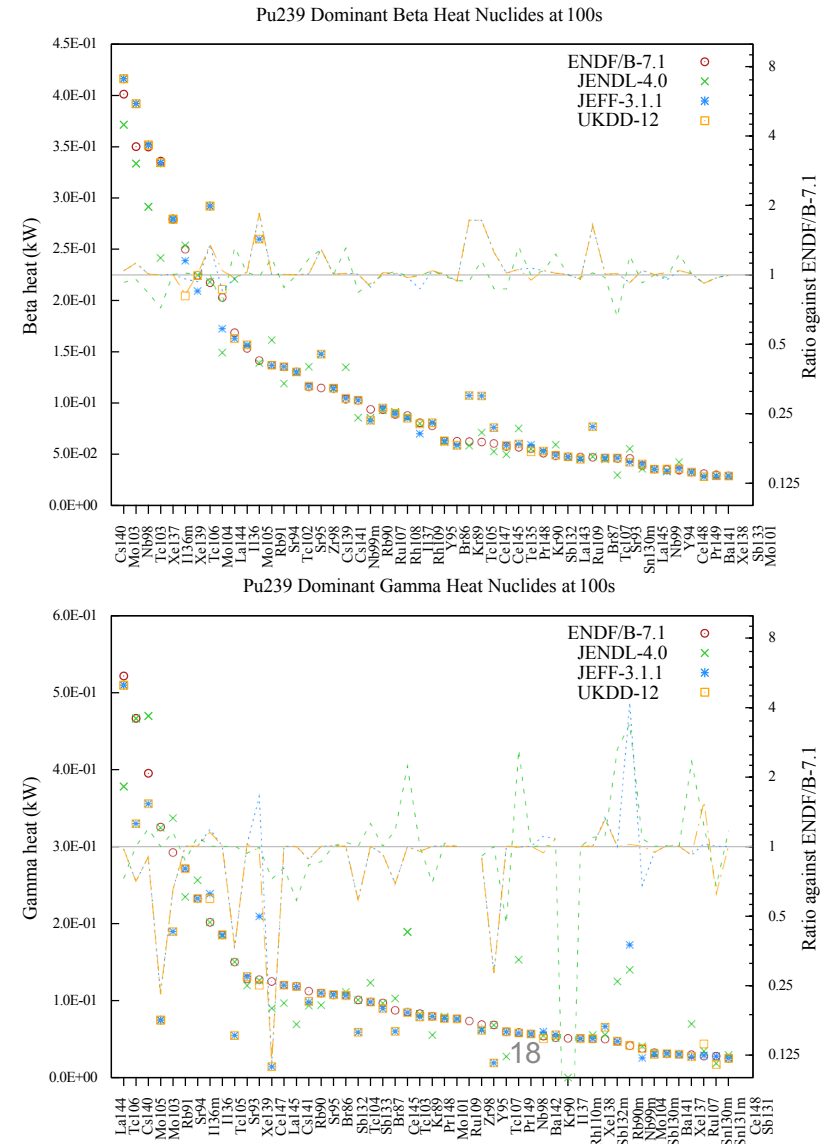
U235 Dominant Total Heat Nuclides at 10s



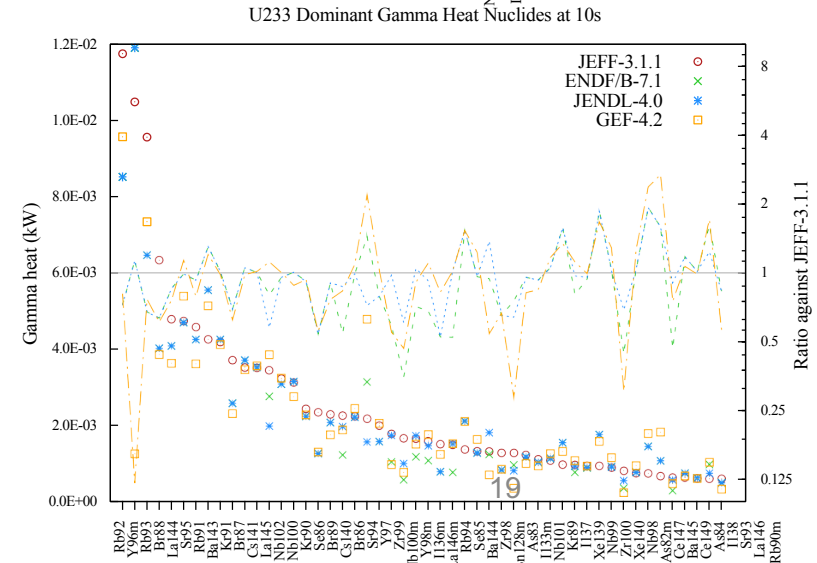
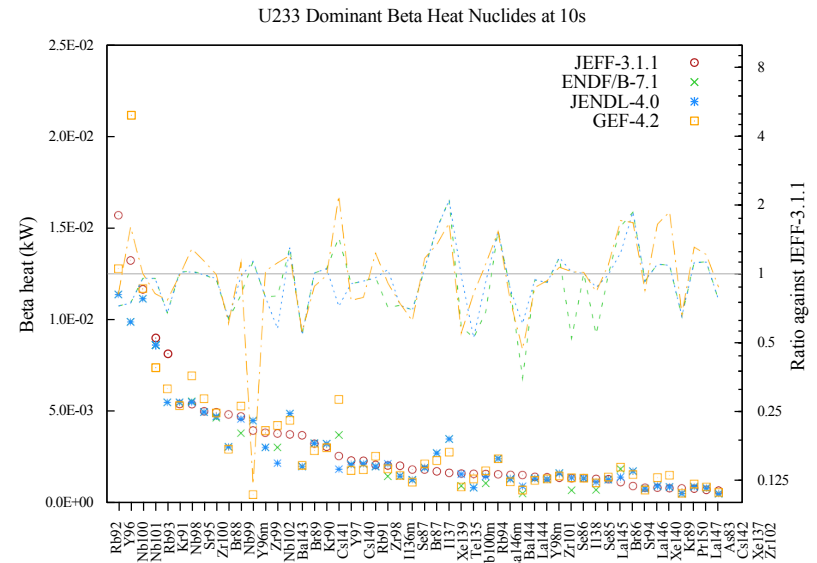
- Too perfect agreement ?? cumulative FY uncertainty



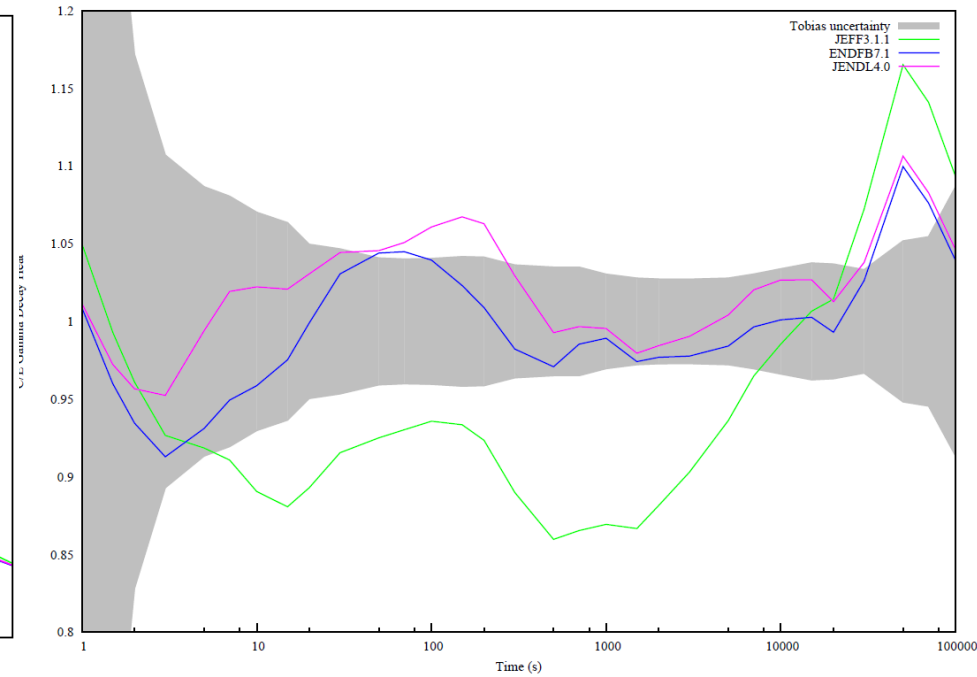
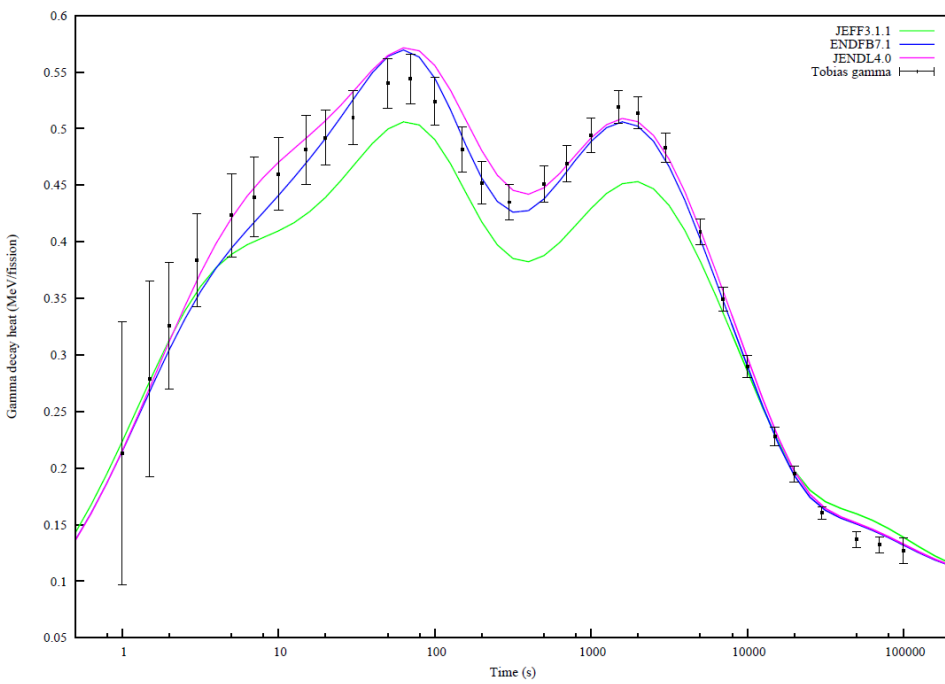
- Fix the nFY and vary the decay data to probe for differences (ENDF/B-VII.1 decay reference)
- Right: ^{239}Pu beta (top) and gamma (bottom) heat at 100 s cooling – note large variation in decay files
 - Nominal values and ratio to one, here ENDF/B-VII.1
- Useful check to see what evaluations have been performed and where some libraries lag behind (or make different evaluations)



- Other option: use the same DD and vary the nFY
- Right: ^{233}U fast fission pulse beta (top) and gamma (bottom) at 10 s cooling
 - Nominal values and ratio to an example, here JEFF-3.1.1
- This is all over the place! *Note* that the same DD is used in each simulation, but varied independent fission yields
- Minor actinides all show the same pattern

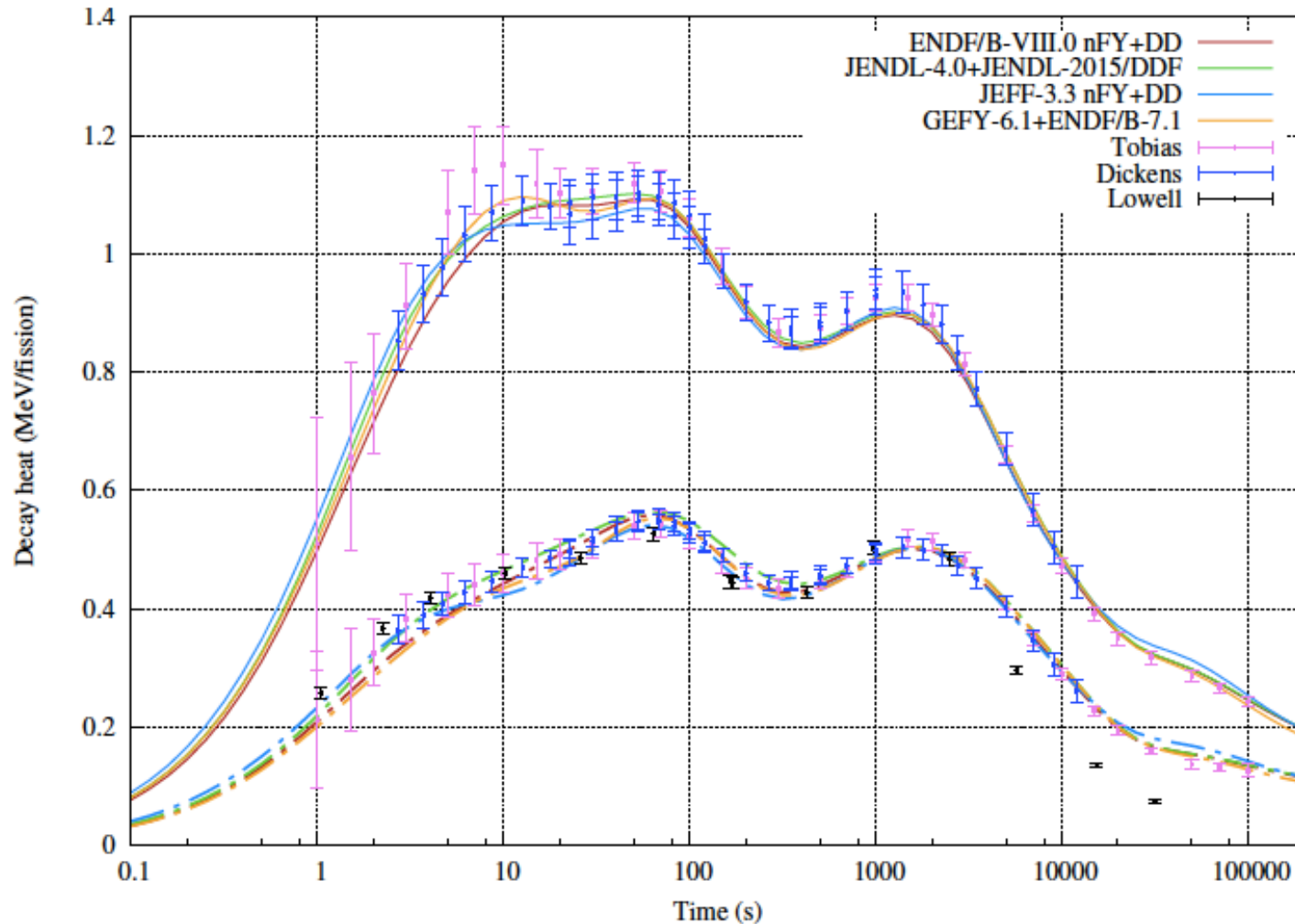


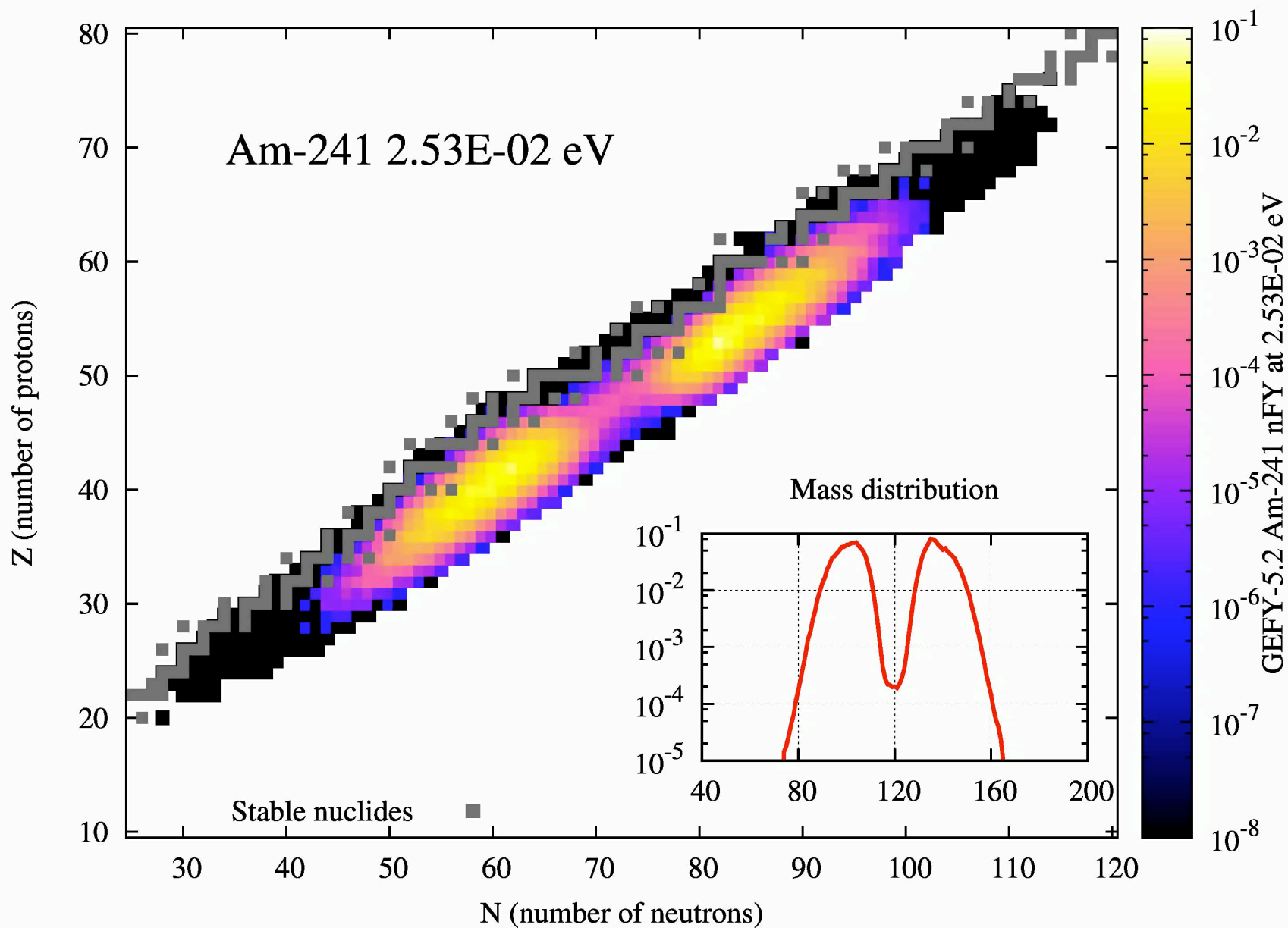
- Underestimation of high-energy gamma feeding due to poor detector efficiency: Pandemonium effect
- Better simulation with TAGS results, recently added in JENDL 4.0 and ENDF/B-VII.1, not JEFF-3.1.1 decay files !!



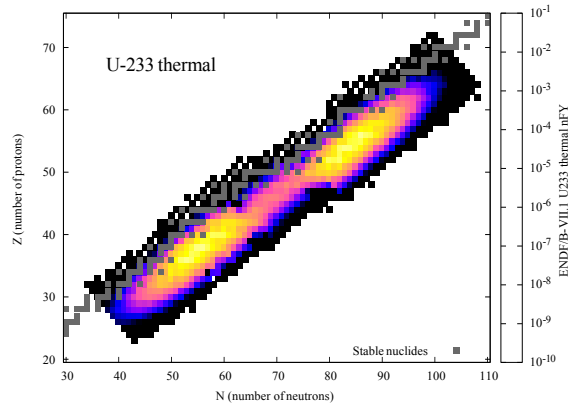
Compensation → too high beta for “fixed” total

Total (solid) and gamma (dash) decay heat from thermal pulse on ^{239}Pu . Fixed but Tobias metadata @ 1-10 seconds !!

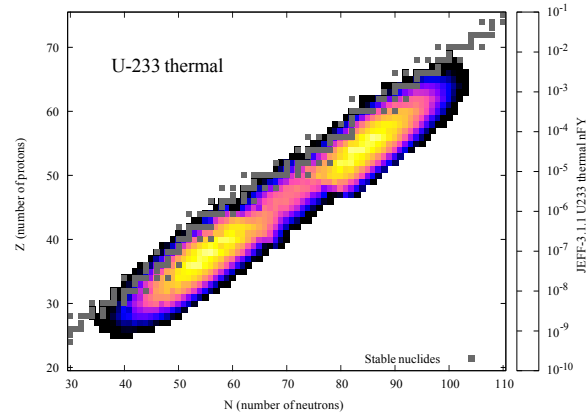




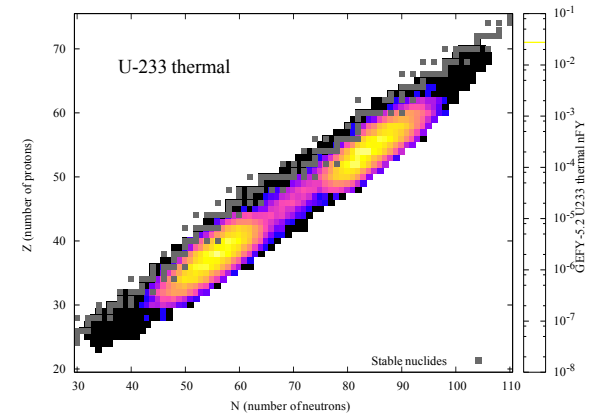
U²³³ nFy examples: yield and uncertainty



ENDF/B-VII.1



JEFF-3.1.1

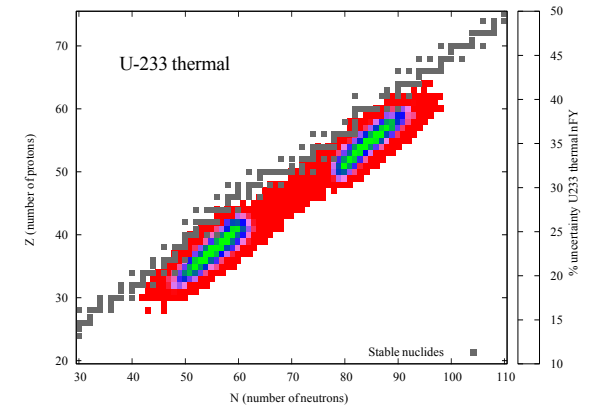
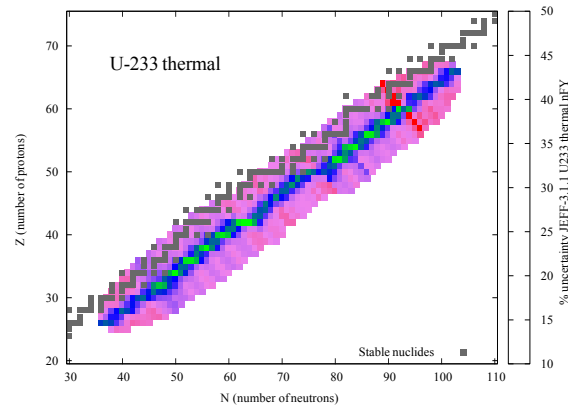
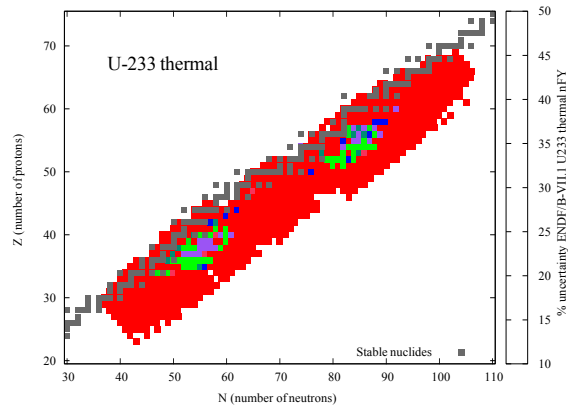


GEFY-5.2

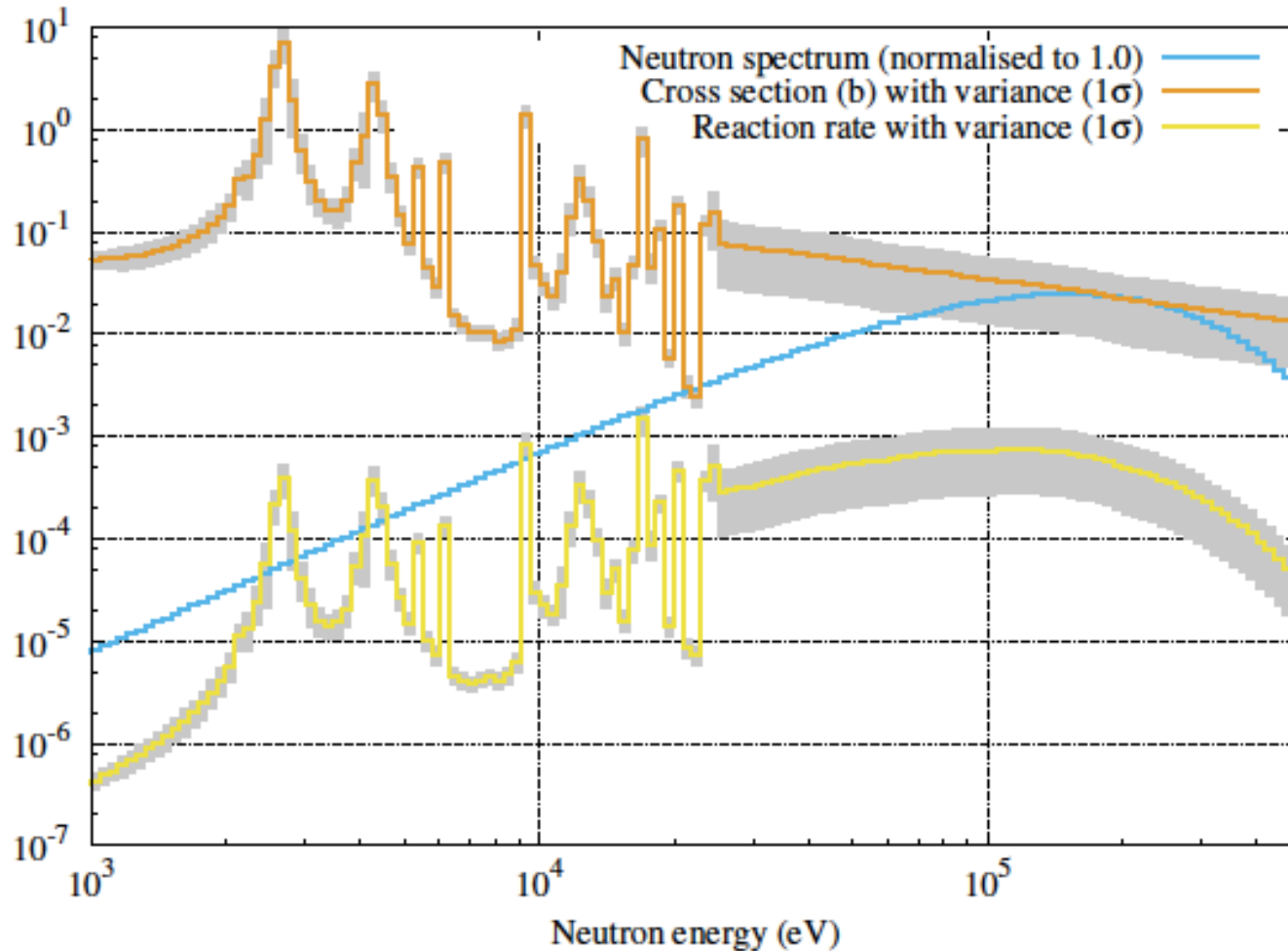
Too far? Man-made boundaries?

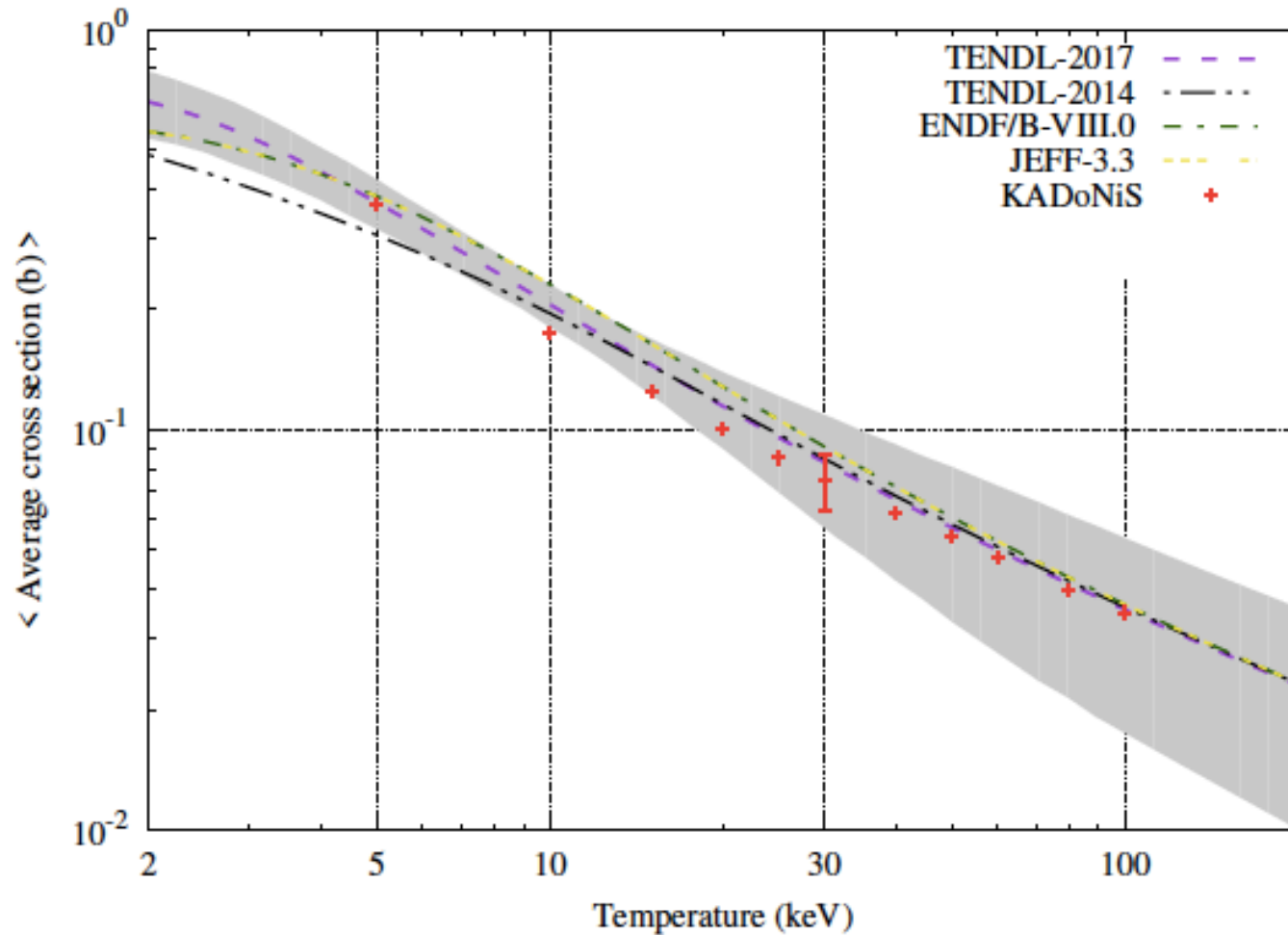
N=Z Diagonals?

Far enough?

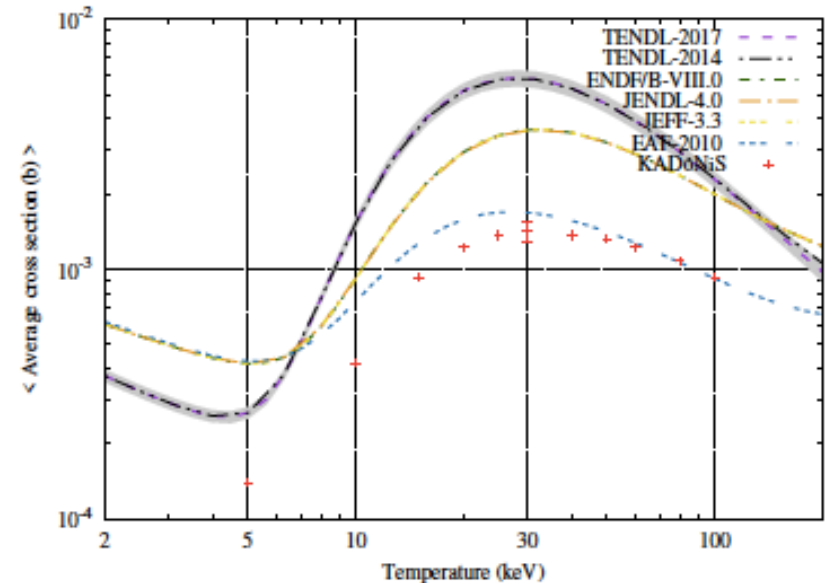
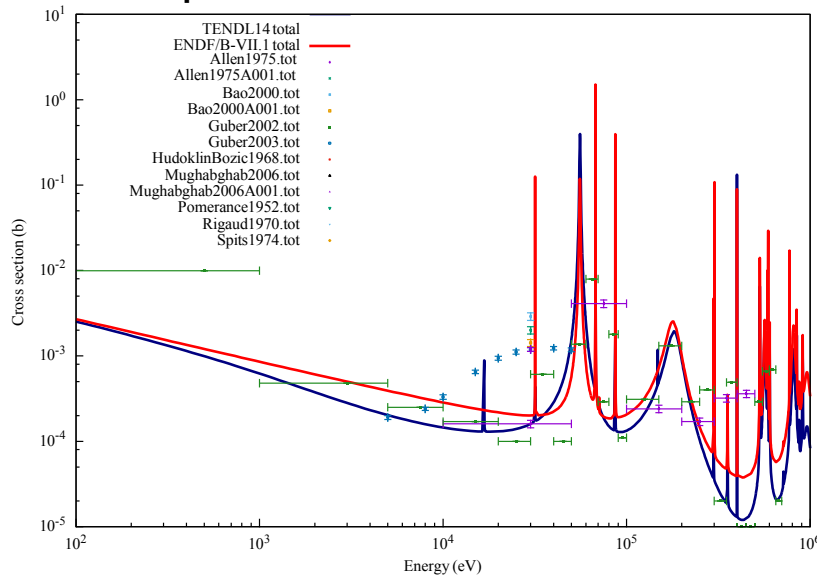
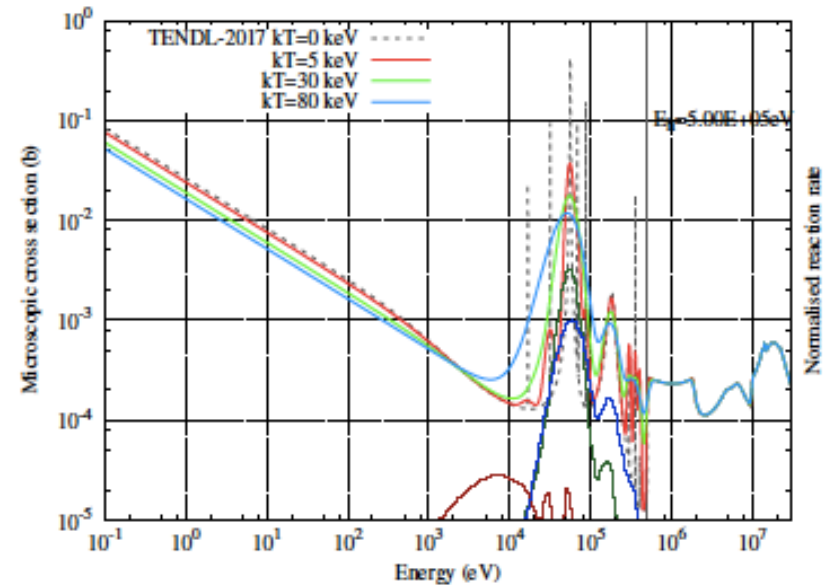


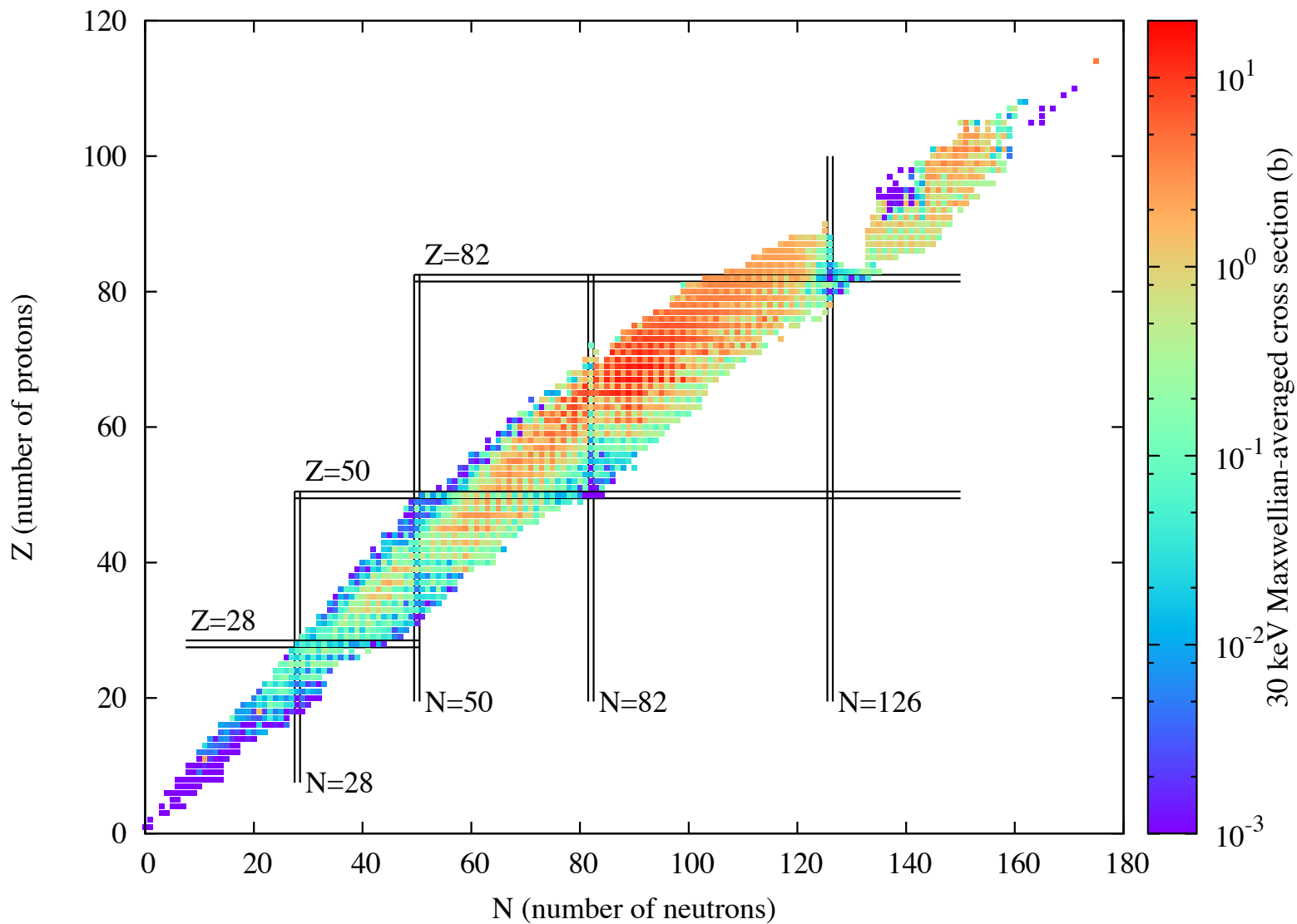
Fe55 capture 660 group differential cross sections (b) and uncertainties (variances shown) with the $kT=30$ keV Maxwellian spectrum and resulting, energy-dependent reaction rate with uncertainty



T-dependent MACS for ^{55}Fe + T-dependent uncertainty

- TENDL adds targets to fully compare against KADoNiS
- A few problematic differences, and several observations from temperature-dep studies
- Often, winner or loser resonance takes it all, ^{28}Si but in that case it is certainly the direct capture competition!!





In red statistical Kadonis

TENDL-2014: ^{21}Ne , ^{26}Al , $^{36,38}\text{Ar}$, ^{60}Fe , ^{63}Ni , $^{74,76}\text{Ge}$, ^{78}Se , ^{126}Sn

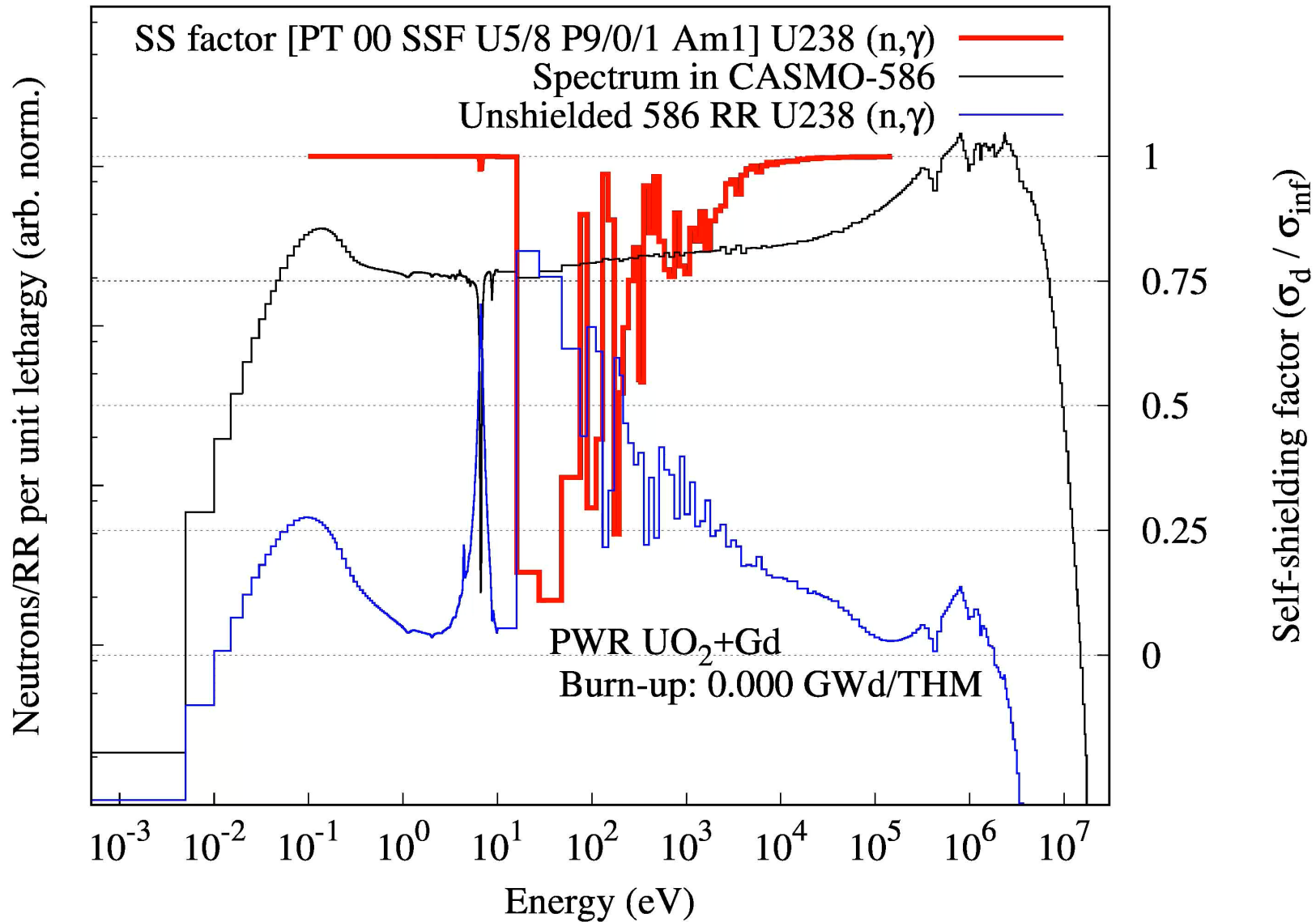
JENDL-4.0: ^{140}Ce , $^{206,207,208}\text{Pb}$

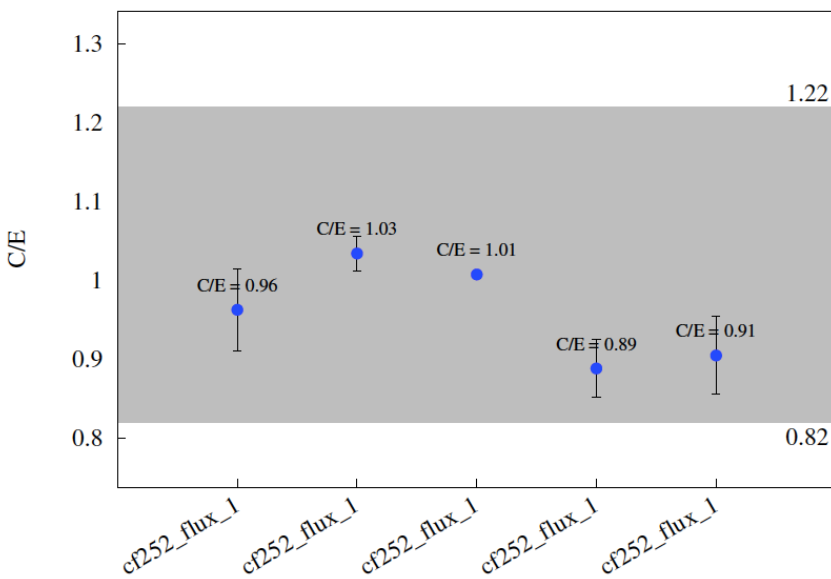
ENDF/B-VIII.0: ^{139}La , ^{205}Tl

JEFF-3.3: ^{192}Pt

EAF-2010: ^{28}Si , ^{36}S

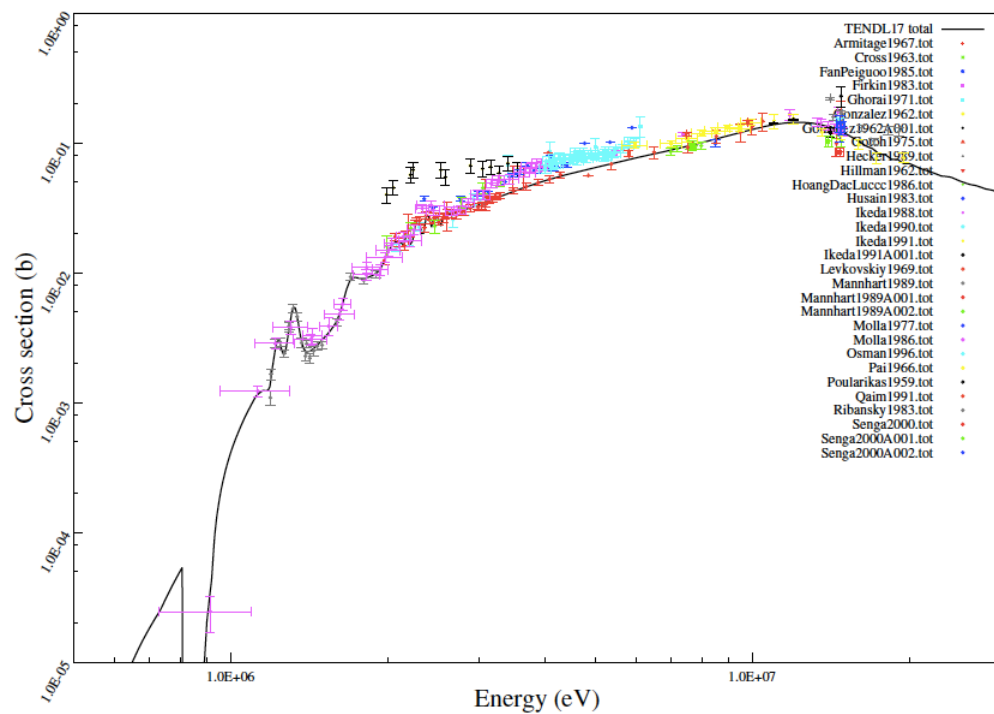
against TENDL-2017

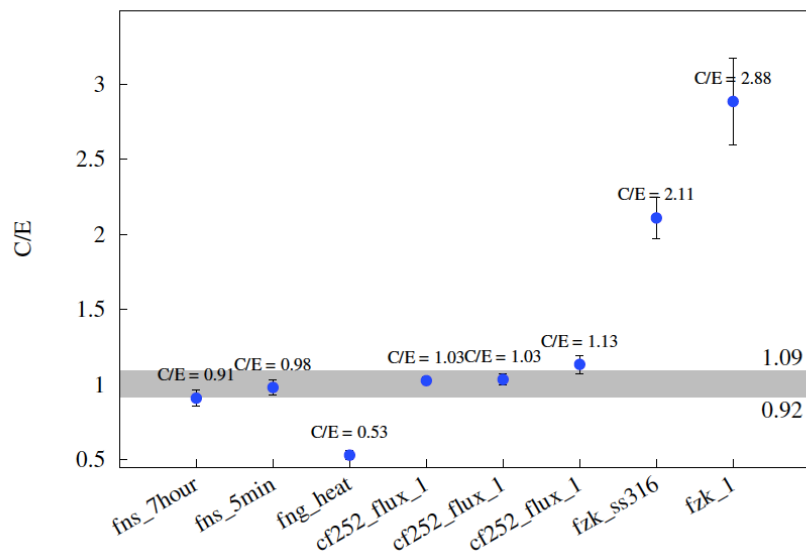




~ 450 channels
UKAEA-R18004

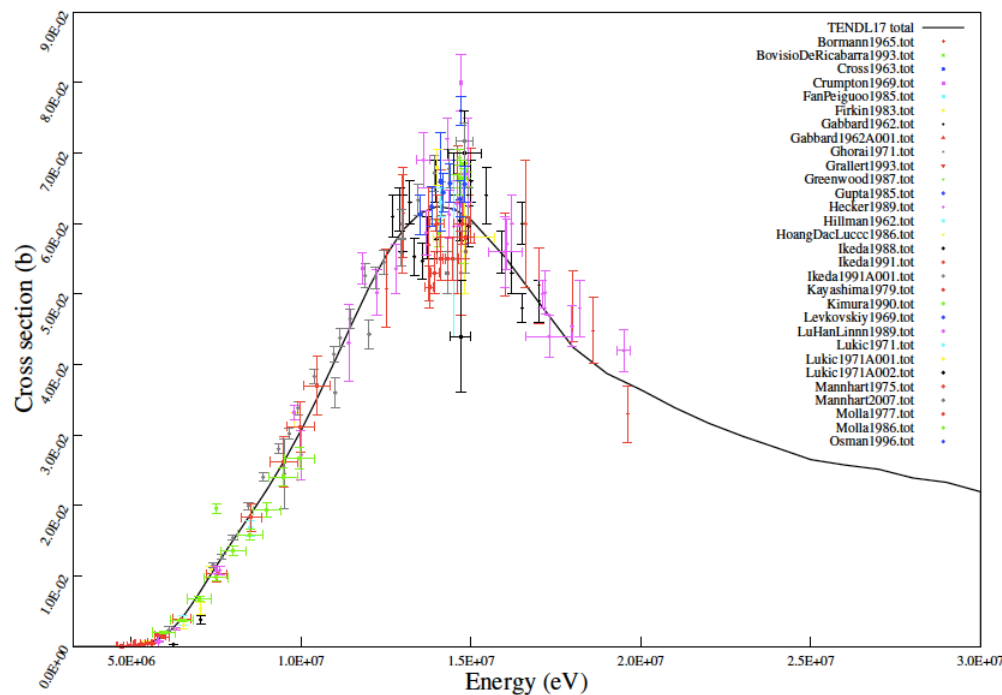
$^{47}\text{Ti} (n,p) ^{47}\text{Sc}$





$^{48}\text{Ti} (n,p) ^{48}\text{Sc}$

~ 450 channels
UKAEA-R18004



- Uniform, open set of experimental data tables
- Distributed, shared set of inputs decks

- Better, more inquisitive data analytics
- Novel, repeatable visualization techniques
- UQP, uncertainty quantification and propagation
- Open source development

- User's orientated, but shared by institutions



Spectral indices

J.-Ch. Sublet
UH-NDSU

International Atomic Energy Agency
Nuclear Data Section

- Spectral indices embodies direct measurement made in a defined environment
 - Reference source: Cf-252,
 - Experimental reactor, pile: Zoe, Minerve, ZPR, EBR-2...
 - Beam/target experiments: D-Be, D-T, D-Li, P-x,...
 - Astrophysical metrics: MACS
- Reference input spectra: 1/4 RPV, PWRs, FBRs, SMRs,...Phenix, Paluel, SGHWR, NIF,, etc.

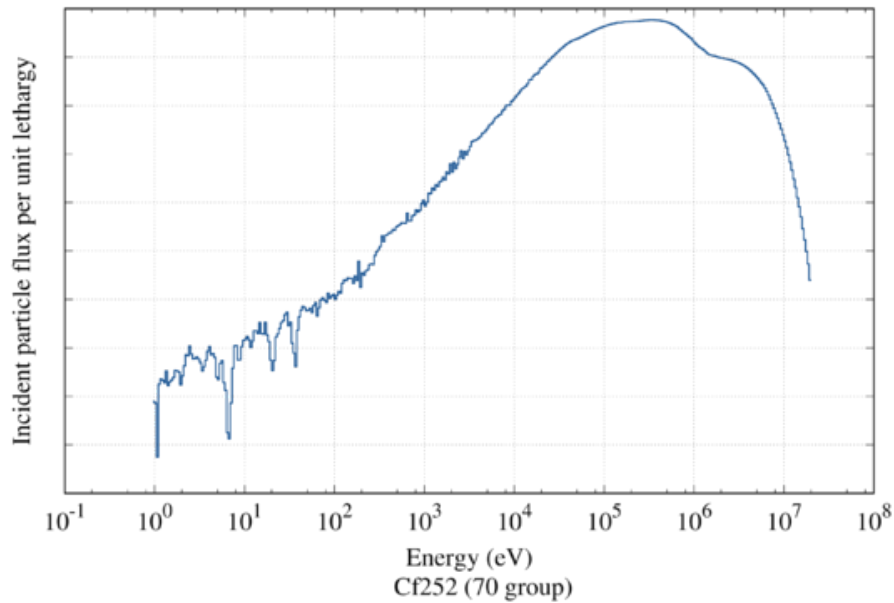
- The collapsed cross-sections depend strongly on the nature of the projectile spectra, and so it is important to use the appropriate spectrum together with the appropriately-weighted cross-section data. With the advances of modern simulation software and high resolution spectra the user is reminded of the importance of the tails, low or high-energy ones, on the reaction rates.
- In essence the particle spectrum profile, through the collapsing process, emphasises the energy region of most importance for each application. Transferring data from one application or energy range to another should be done with great care as it can easily lead to misleading and inappropriate numerical results.

http://fispact.ukaea.uk/wiki/Reference_input_spectra

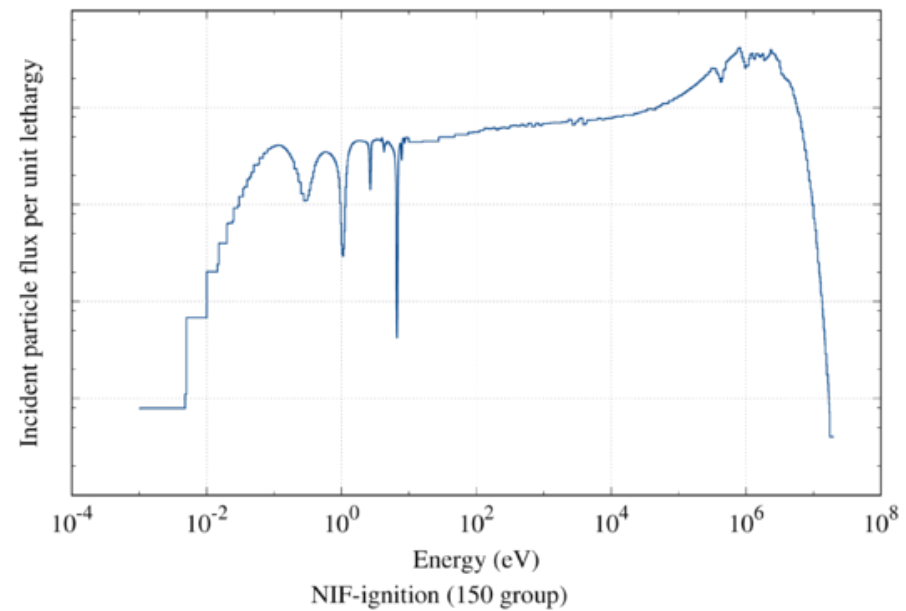
Reference incident particle spectra

| Name | Group | Particle | arb_flux file | Figure | Description |
|---------------|-------|----------|------------------------------|---------------|---|
| Bigten | 407 | n | Media:407 Bigten.txt | Bigten | International Criticality Safety Benchmark Experiment, Bigten |
| BWR-MOX-Gd-0 | 1102 | n | Media:1102 BWR-MOX-Gd-0.txt | BWR-MOX-Gd-0 | BWR MOX fuel with Gd, 0 GWd/THM |
| BWR-MOX-Gd-15 | 1102 | n | Media:1102 BWR-MOX-Gd-15.txt | BWR-MOX-Gd-15 | BWR MOX fuel with Gd, 15 GWd/THM |
| BWR-MOX-Gd-40 | 1102 | n | Media:1102 BWR-MOX-Gd-40.txt | BWR-MOX-Gd-40 | BWR MOX fuel with Gd, 40 GWd/THM |
| BWR-RPV | 198 | n | Media:198 BWR-RPV.txt | BWR-RPV | Boiling water reactor, 1/4 Thickness reactor pressure vessel |
| BWR-UO2-Gd-0 | 1102 | n | Media:1102 BWR-UO2-Gd-0.txt | BWR-UO2-Gd-0 | BWR UO2 fuel with Gd, 0 GWd/THM |
| BWR-UO2-Gd-15 | 1102 | n | Media:1102 BWR-UO2-Gd-15.txt | BWR-UO2-Gd-15 | BWR UO2 fuel with Gd, 15 GWd/THM |
| BWR-UO2-Gd-40 | 1102 | n | Media:1102 BWR-UO2-Gd-40.txt | BWR-UO2-Gd-40 | BWR UO2 fuel with Gd, 40 GWd/THM |
| CERN-H4IRRAD | 288 | n | Media:288 CERN-H4IRRAD.txt | CERN-H4IRRAD | CERN H4IRRAD experiment |
| Cf252 | 070 | n | Media:070 Cf252.txt | Cf252 | Californium-252 spontaneous fission source |
| DEMO-HCPB-BP | 616 | n | Media:616 DEMO-HCPB-BP.txt | DEMO-HCPB-BP | DEMO fusion concept He-cooled pebble bed, backplate |
| DEMO-HCPB-FW | 616 | n | Media:616 DEMO-HCPB-FW.txt | DEMO-HCPB-FW | DEMO fusion concept He-cooled pebble bed, first wall |

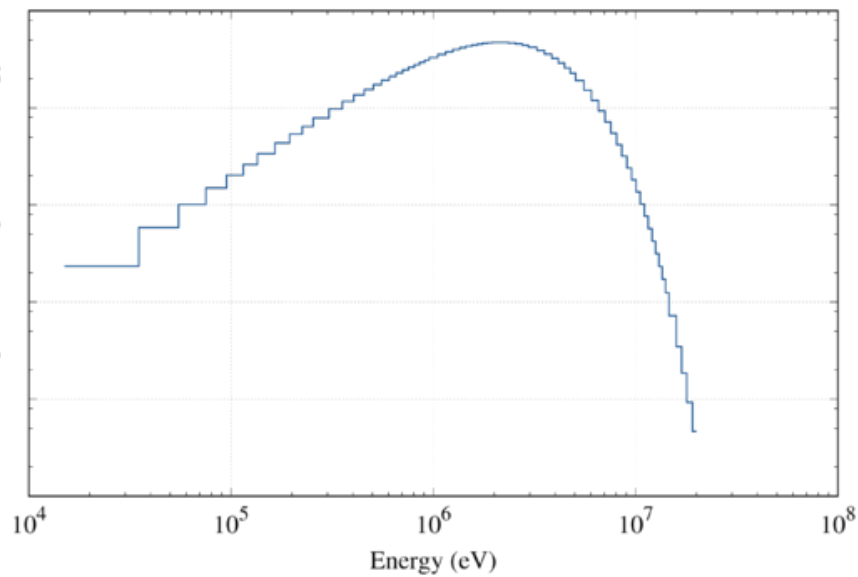
Bigten (407 group)



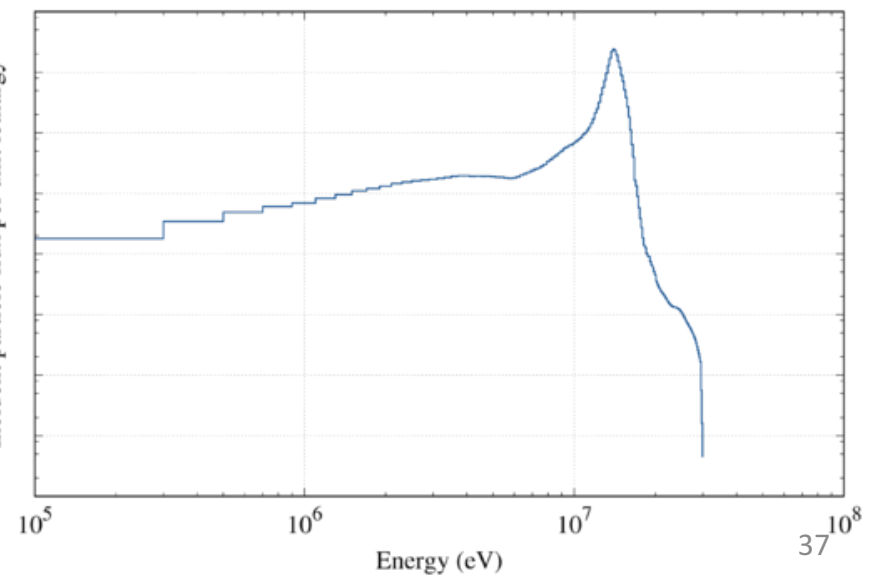
BWR-MOX-Gd-0 (1102 group)

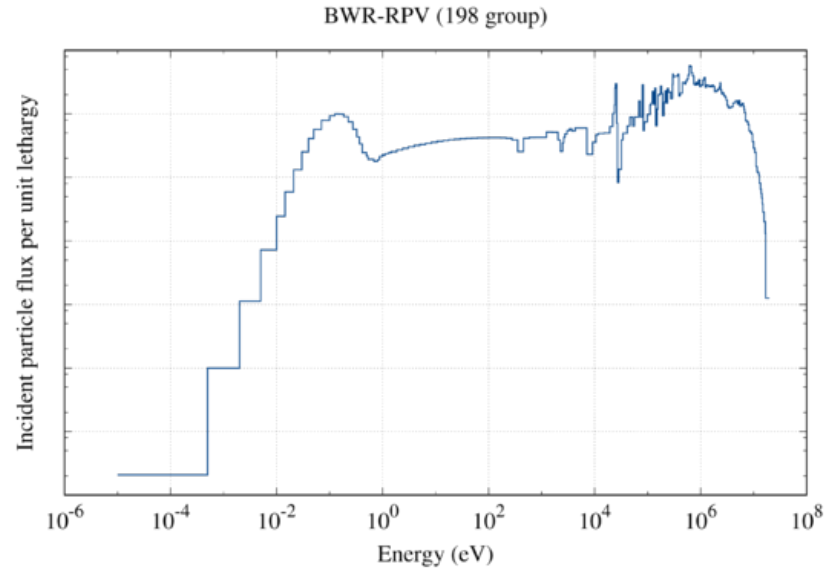
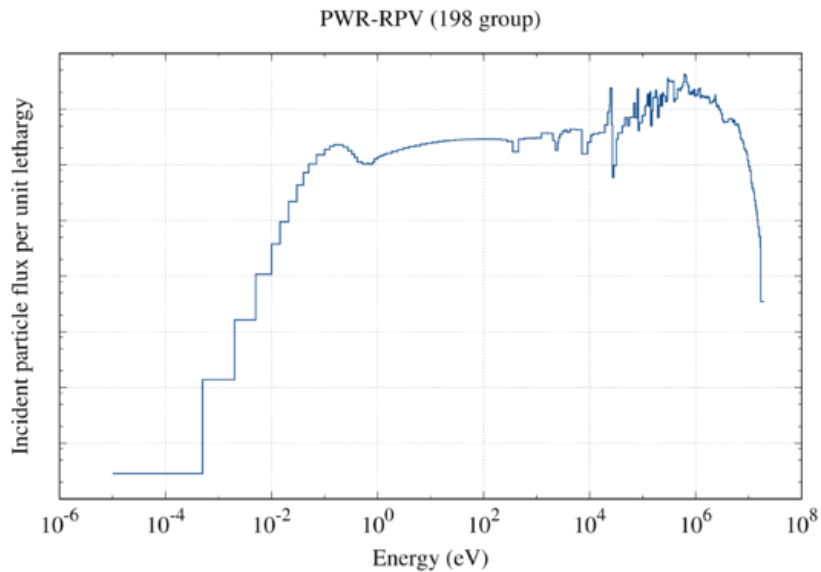


Incident particle flux per unit lethargy



Incident particle flux per unit lethargy





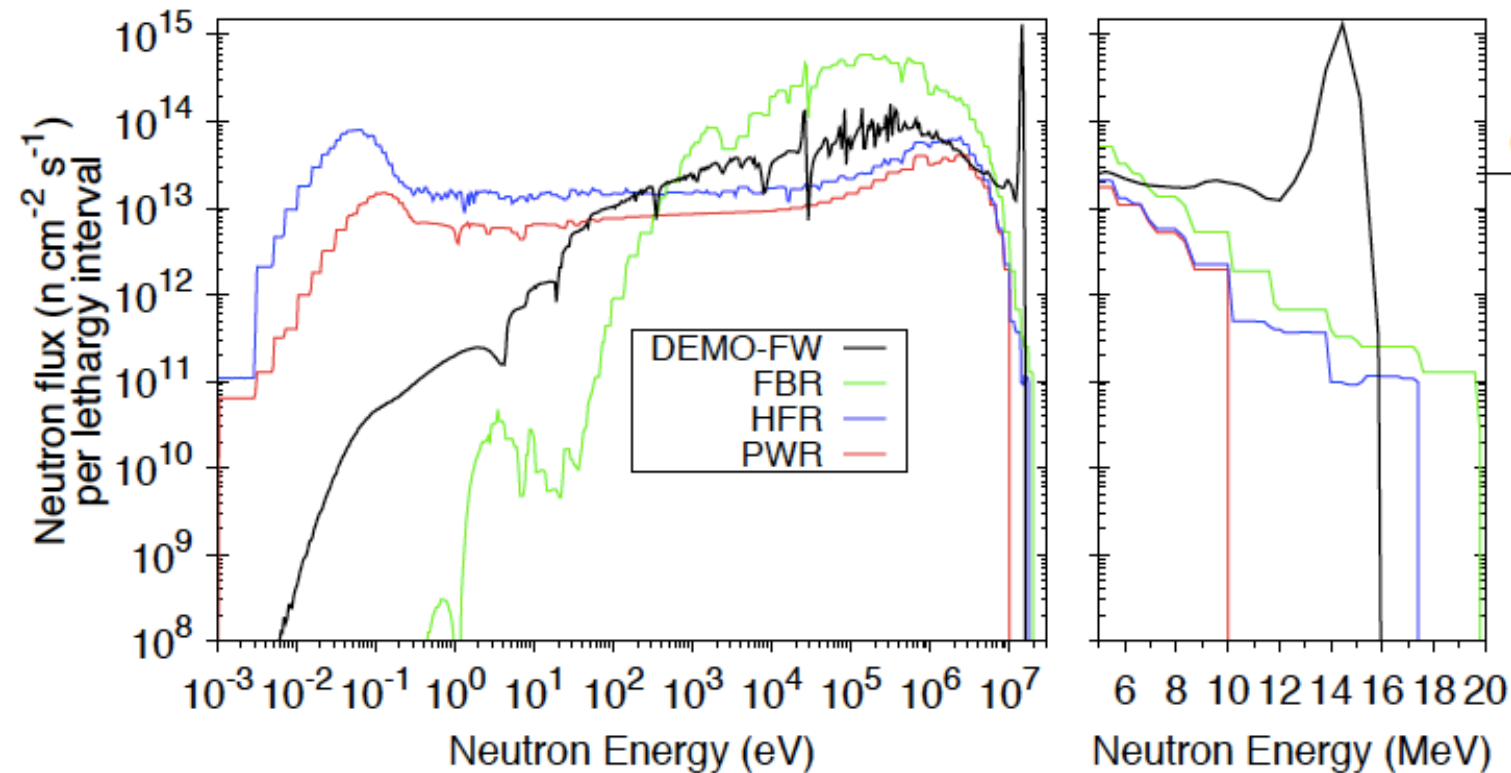
Assuming a 40-year plant operation and a load factor of 0.8, giving an effective lifetime of 32 years, FISPACT-II results

PWR $1.3\text{E-}3 \times 32 = 0.0416$ dpa, total fluence $1.136\text{E+}20$, > 1 MeV $2.387\text{E+}19$ n/cm²

BWR $2.3\text{E-}4 \times 32 = 0.0073$ dpa, total fluence $1.798\text{E+}19$, > 1 MeV $4.469\text{E+}18$ n/cm²

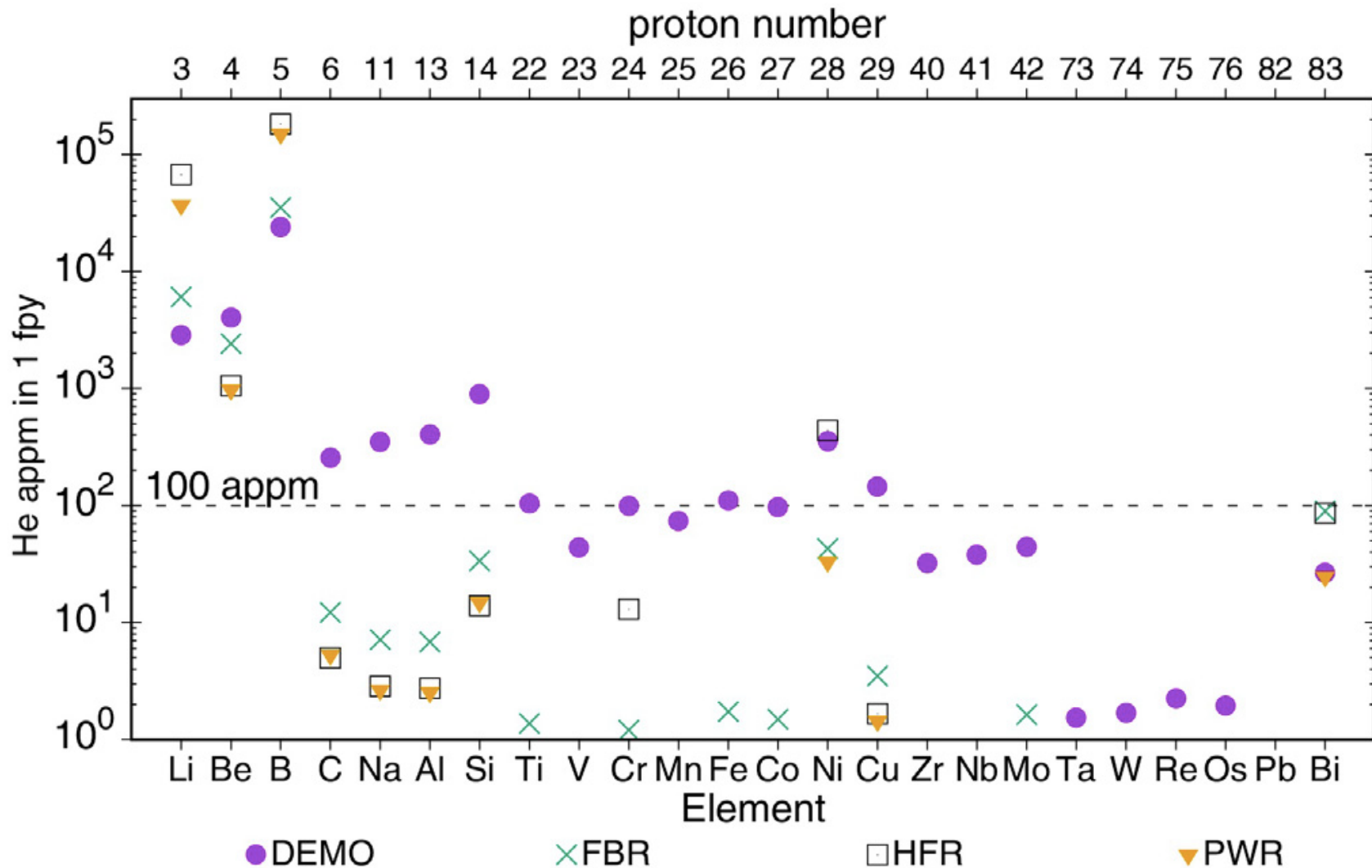
An end-of-life fluence value of $3.0\text{E+}19$ n/cm², is quoted to produce about 0.045 ± 0.05 dpa in *G. R. Odette and G. E Lucas, Embrittlement of Nuclear Reactor Pressure Vessels, JOM, 53 (7) (2001), pp 18-22*

Tails: low and high energy

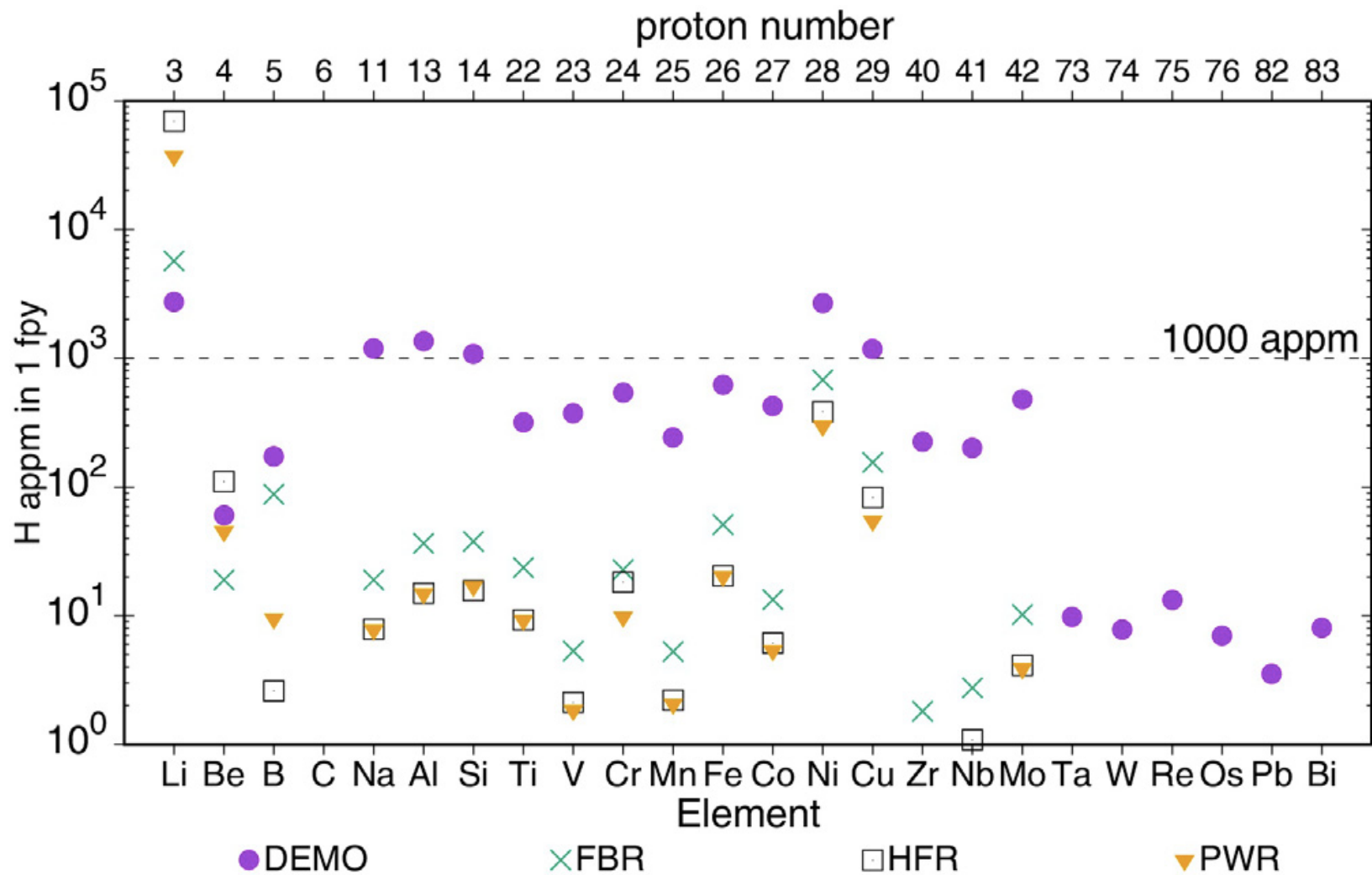


- FBR – superphenix Fast Breeder Reactor
- HFR – High Flux Reactor, Petten
- PWR – Pressurized Water-cooled Reactor

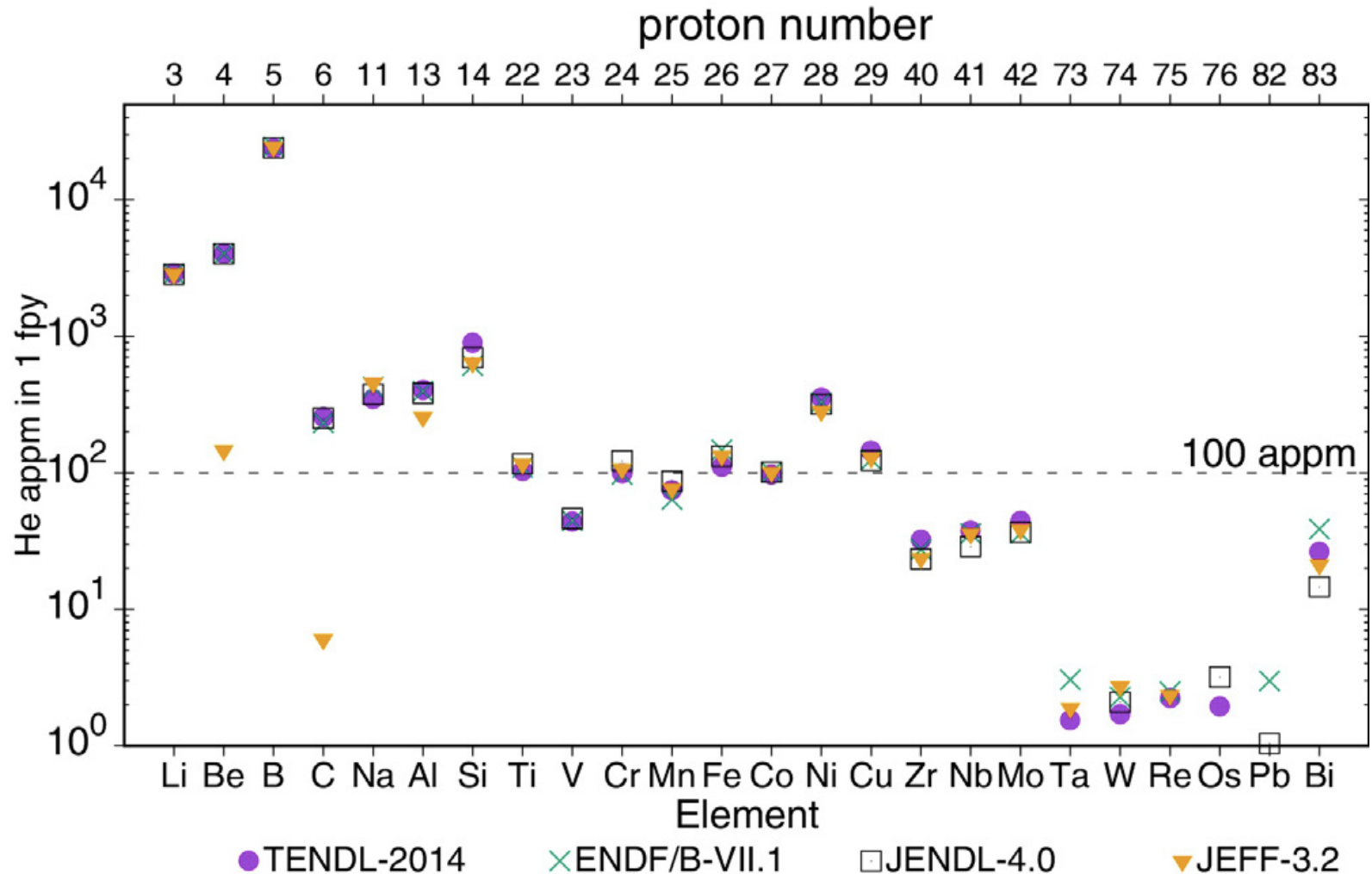
Variation in He production (in atomic parts per million or appm) per fpy as a function of element and irradiation environment



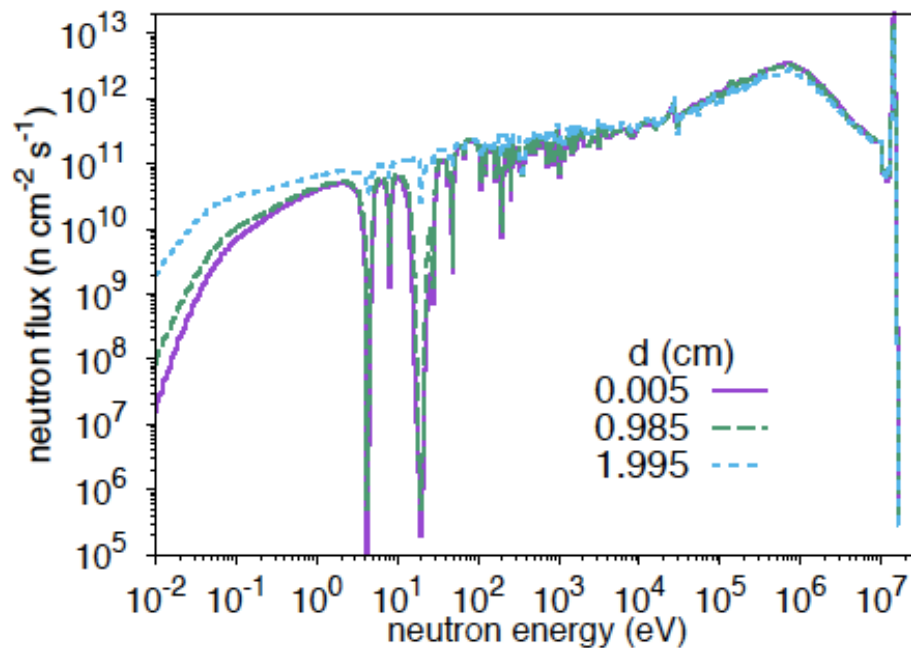
Variation in H appm per fpy as a function of element and irradiation environment.



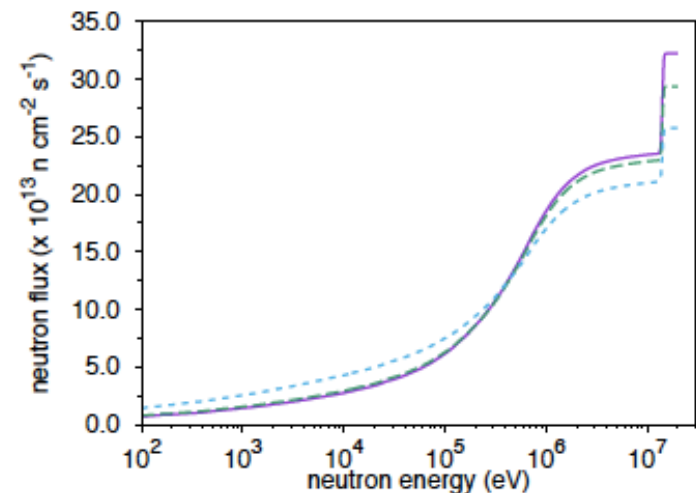
Variation in He production per fpy under the DEMO-FW spectrum as a function of element and choice of nuclear data library



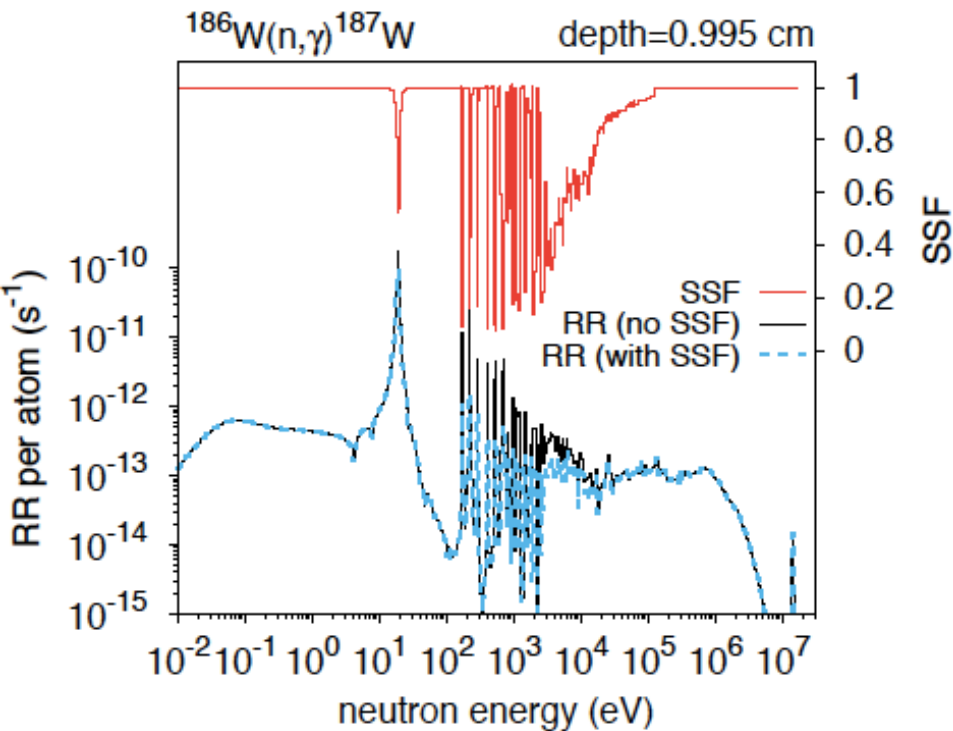
- Even in first 0.1 mm the flux depletions due to the giant resonances are present
 - ▶ suggesting that self-shielding occurs at all depths because neutron backscattering populates all neutron energies
- Flux depletions are reduced in W layers close to the moderator & thermal component of spectrum is higher
 - ▶ potential change in transmutation behaviour



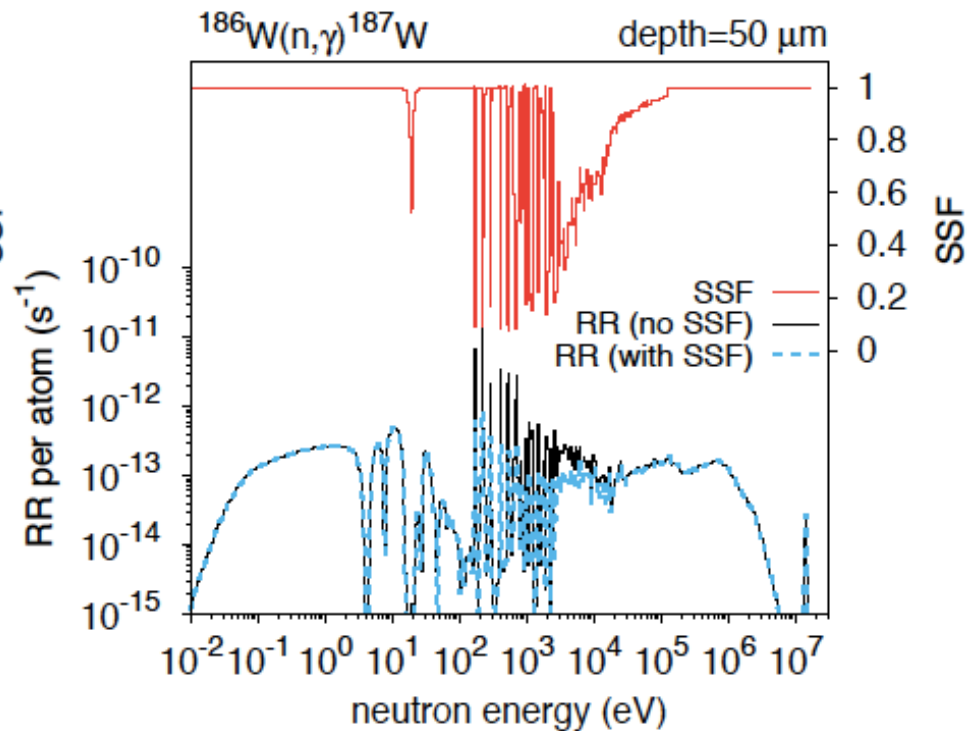
- 20% drop in total flux across 2 cm depth



- Probability Table (PT) SSFs used to account for dilution effects associated with both resolved and un-resolved ($> \sim 20$ keV) resonances

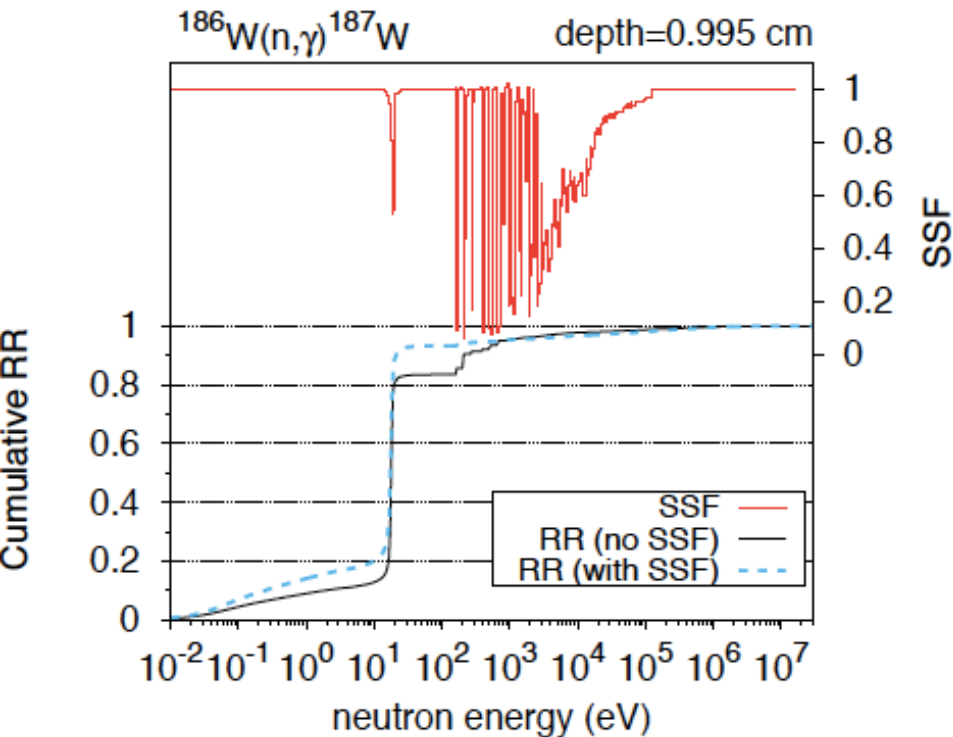


- final 0.1 mm of W
- total SSF: 0.64
- giant resonance dominates RR of $^{186}\text{W}(n,\gamma)$ (70% of RR)

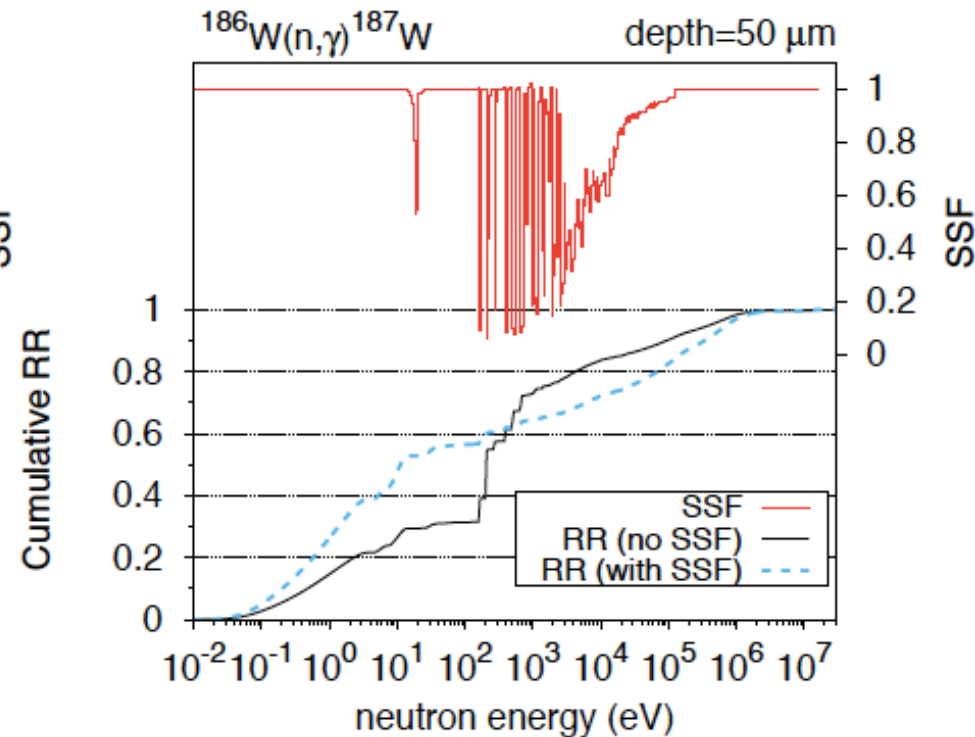


- first 0.1 mm of W
- total SSF: 0.55
- minor contribution from giant resonance

- Probability Table (PT) SSFs used to account for dilution effects associated with both resolved and un-resolved ($> \sim 20$ keV) resonances

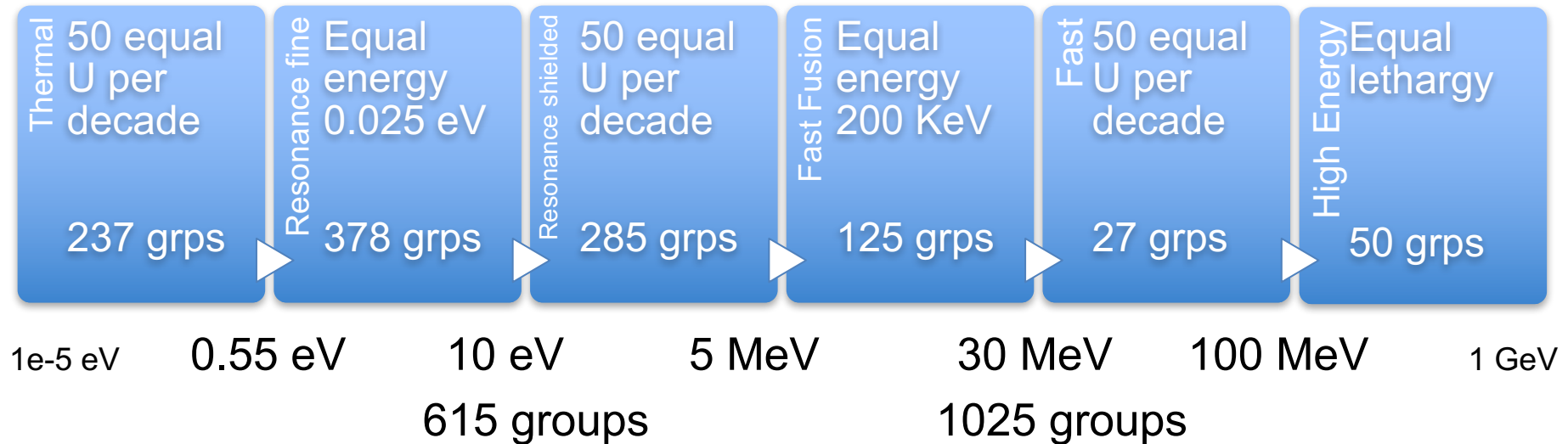


- final 0.1 mm of W
- total SSF: 0.64
- giant resonance dominates RR of $^{186}\text{W}(n,\gamma)$ (70% of RR)

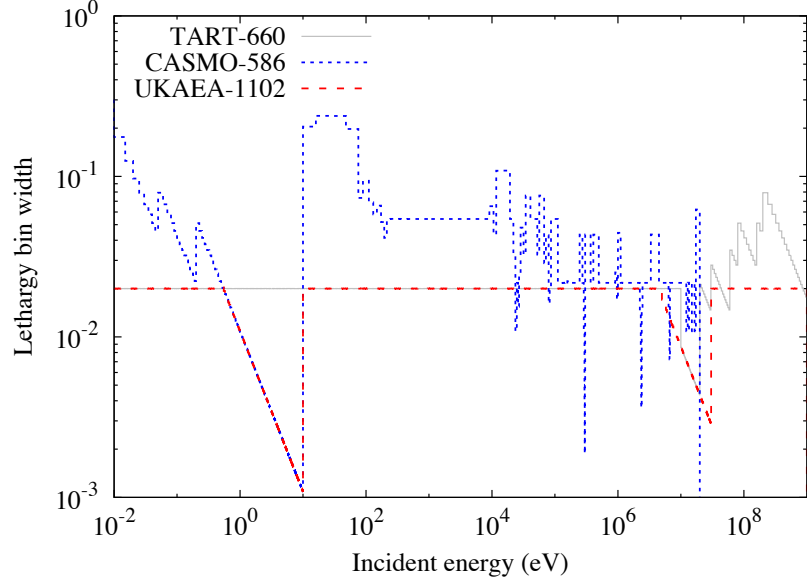
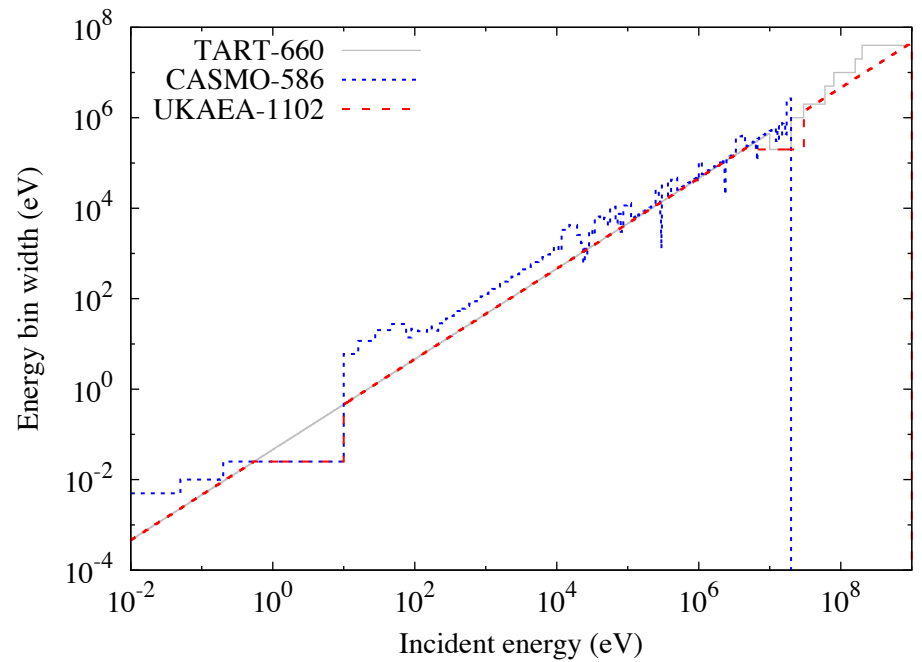
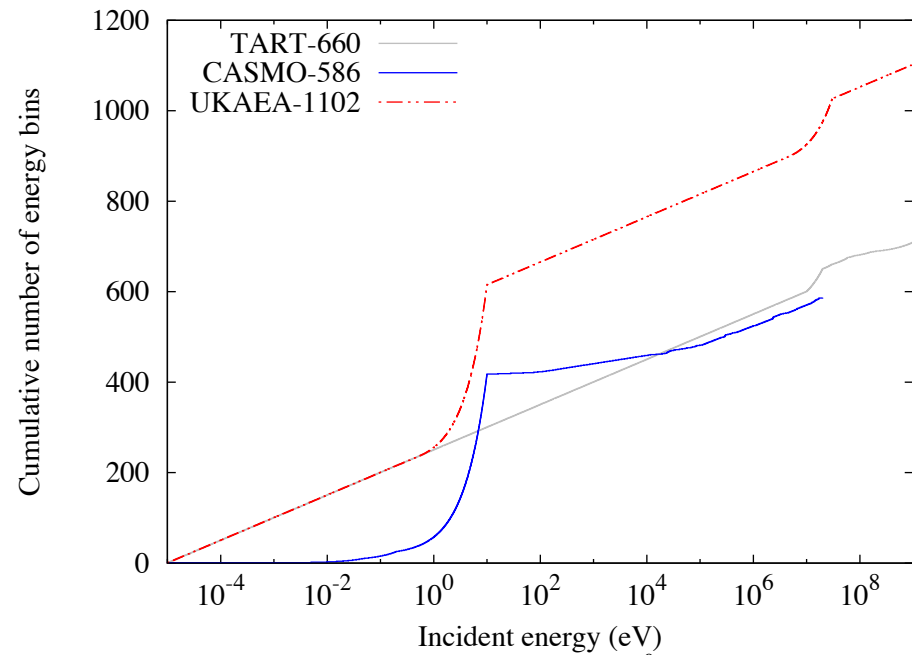


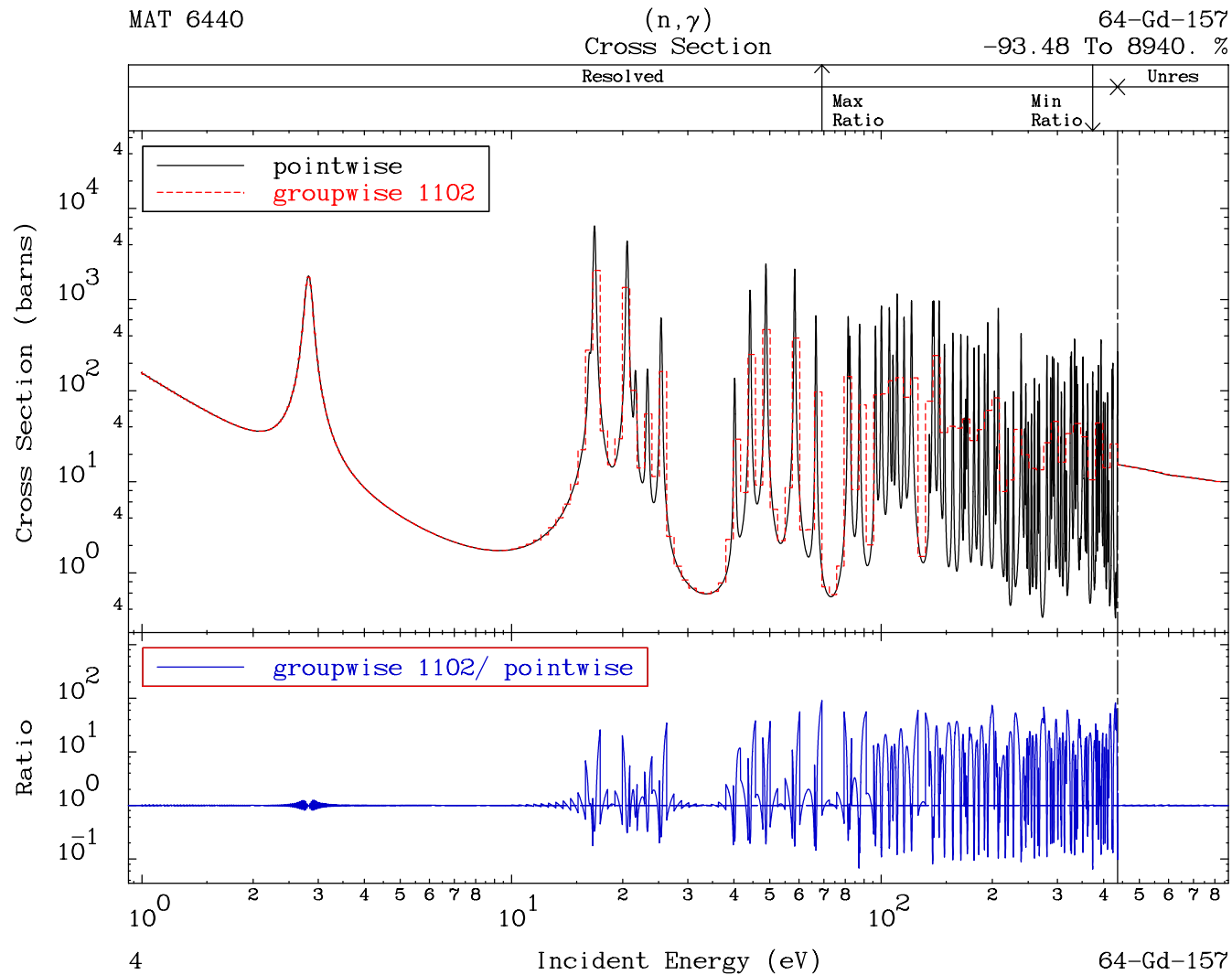
- first 0.1 mm of W
- total SSF: 0.55
- minor contribution from giant resonance

- For all target nuclides
- 1102 energy groups for all applications alike

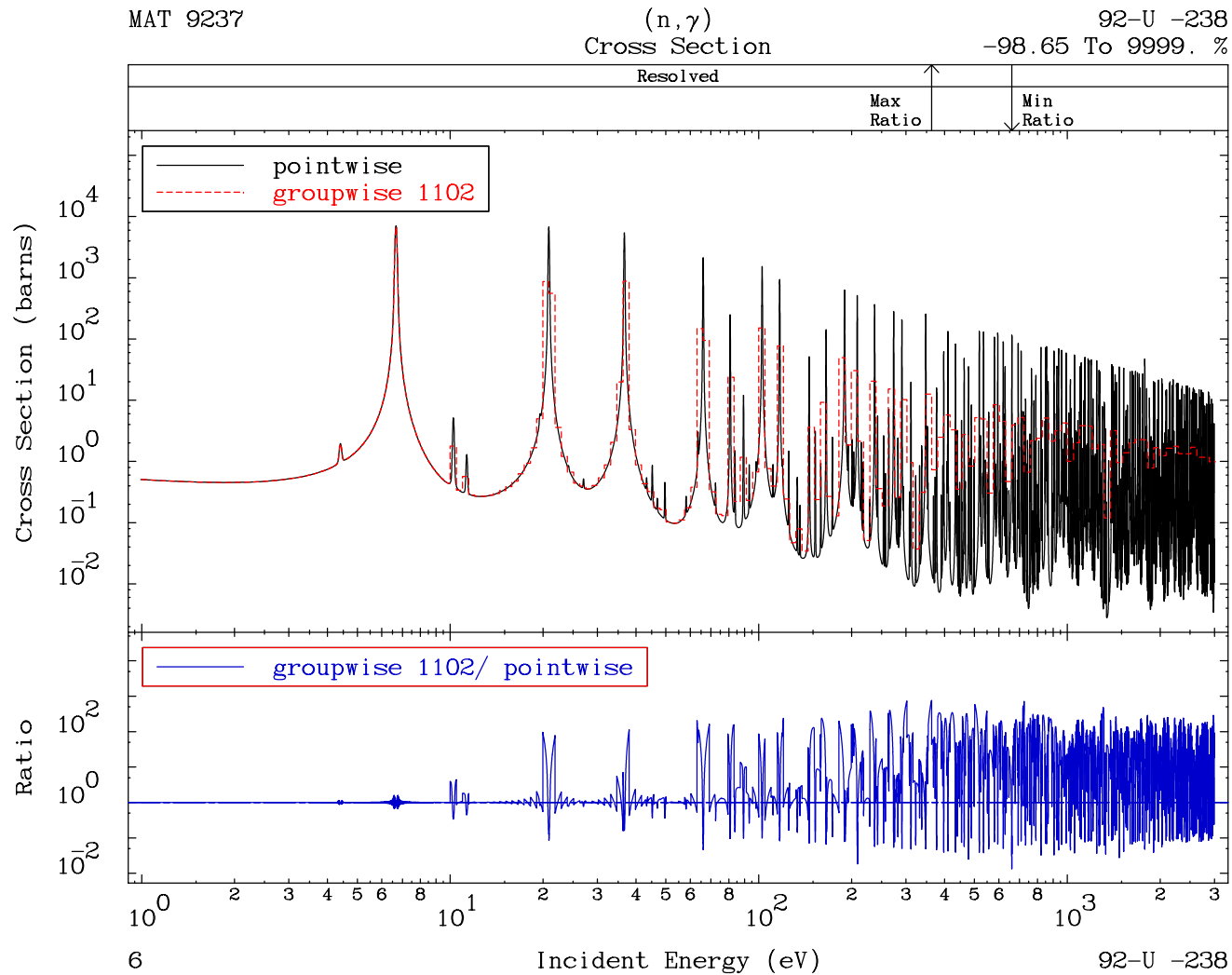


- 378 fine groups in the resonance range
- Resonance shielded data available in the RRR (0.1 eV) up to the end of the URR for all nuclides IDs
- Fast fine structure for accurate threshold reaction rate

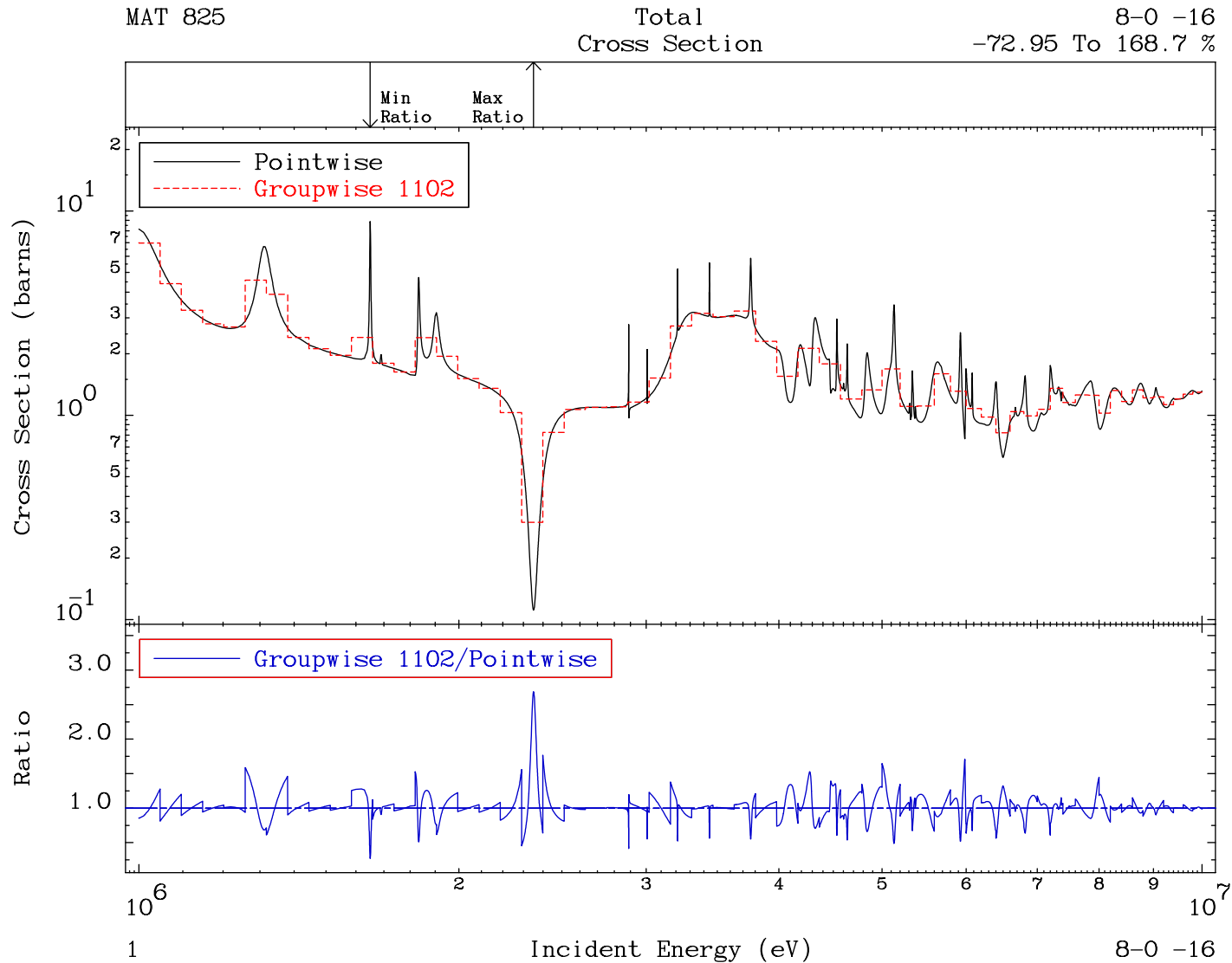




Fine group to 10 eV Resonance shielded to end of URR



Fine group to 10 eV Resonance shielded to end of URR



Peak and trough are well described

- Clearly spell out the pitfalls
 - Collapsing process
 - Flux tails, high and low, influence on RR
 - It is much more difficult to converge a RR than a K_{eff}
- Reference input spectra database
- UQP reaction rates uncertainty quantification
 - Cross section
 - Effective cross section and SSF (the forgotten factor)
 - Binned flux, standard deviation