PAUL SCHERRER INSTITUT

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Resonance form and format: inside TARES

IAEA Consultancy meeting on model code output & application nuclear data structure, 16 March 2021

Content

- TARES: developments
- TARES focus on the HFR, physical checks
- TARES outputs

- Publications: *NDS 163 (2020) 163, NDS155 (2019) 1, ANE 51 (2013) 60, NDS113 (2012) 2841*
- Acknowledgments: A. Koning, J.Ch. Sublet and J. Kopecky

TARES developments

- Started in 2008
  - Translate tabulated resonance parameters into ENDF-6 format: MF2, MF32 and MF32c
  - Based on the ATLAS-2006
  - Used in combination with TALYS for TENDL production

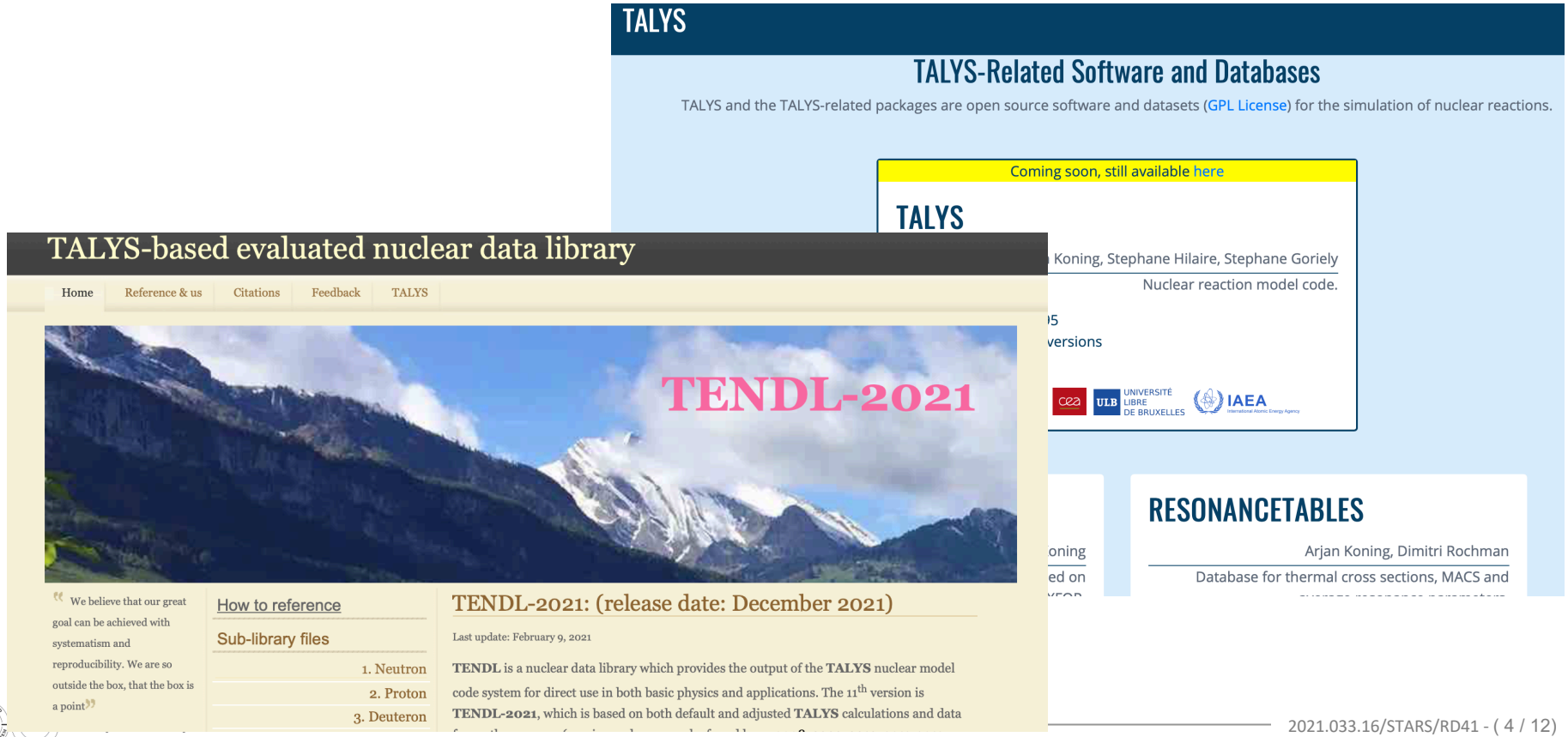
- 2012:
  - Addition of the “HFR”: generation of statistical resonances using CALENDF
  - Read the ATLAS and other libraries (JEFF, ENDF/B, JENDL)
  - Add missing information (uncertainties)

- 2015:
  - Automatic match of the thermal (n,g) points
  - Generation of MF33

- 2018:
  - Read many ATLAS versions, k0 database, some Sukhoruchtin data

TARES developments

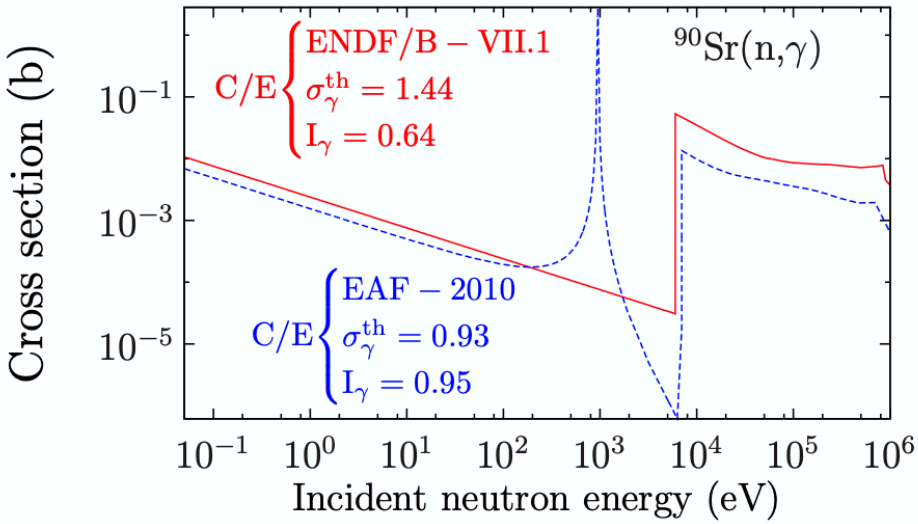
- 2008-2021
  - constant developments of the source, removal (and creation) of “bugs”
  - Update of the resonance parameter databases
  - Used for all TENDL versions, included in the T6 code package
  - Distributed on-demand, all output available here: https://nds.iaea.org/talys/ and https://tendl.web.psi.ch/tendl_2021/tendl2021.html

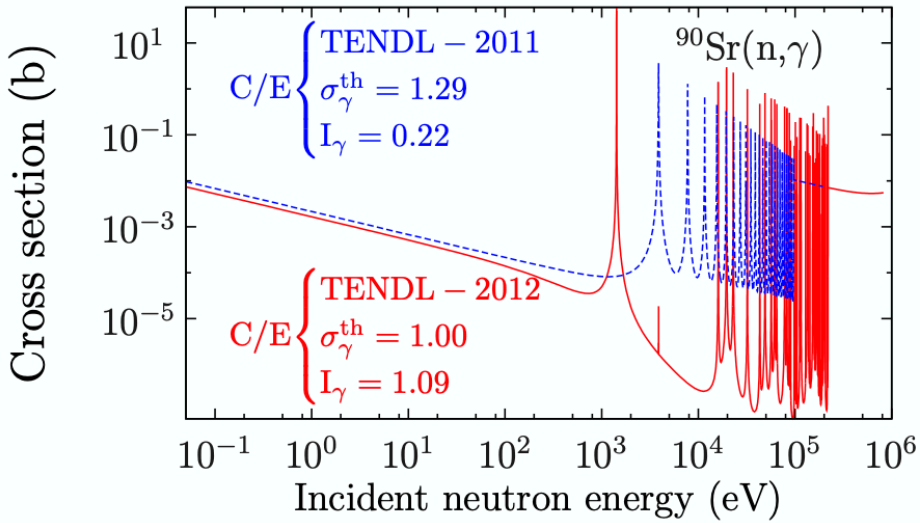


TARES focus on the "HFR"

- Started with the Single Resonance Approximation from the EAF library

Examples of different approaches for ^{90}Sr ($h_{1/2} = 28$ sec) in the low energy region.



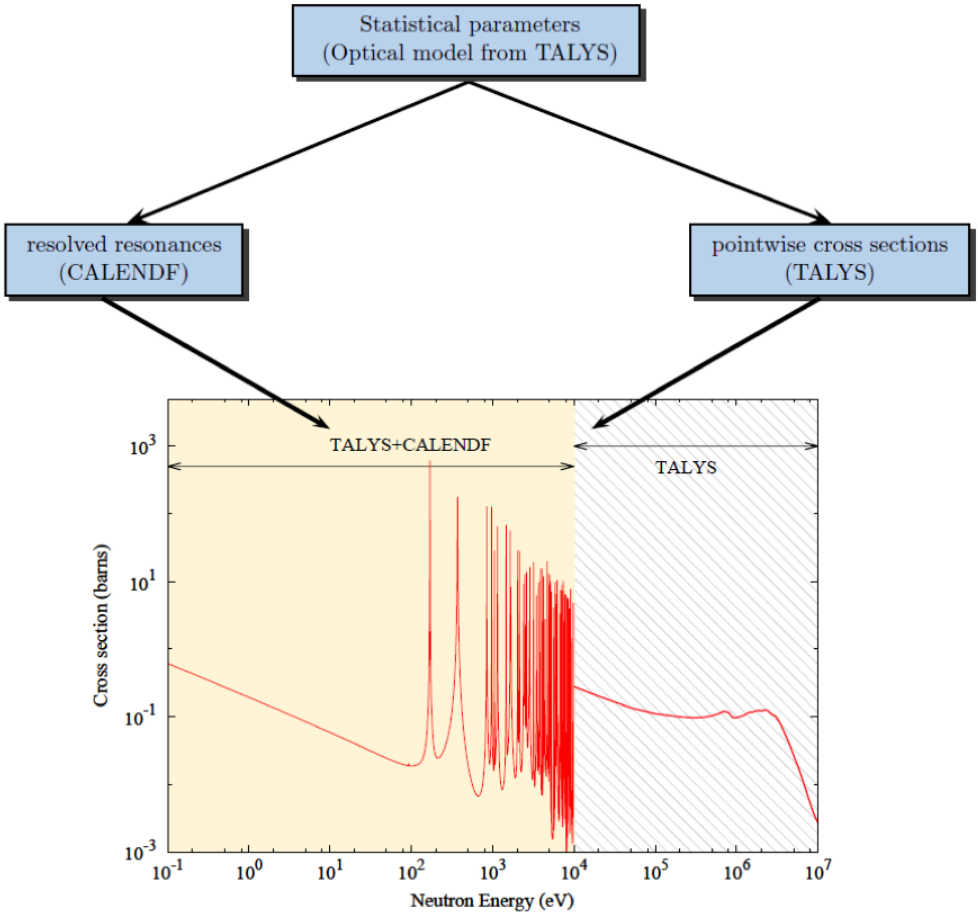


Left: basic optical model calculation for ENDF/B-VII.1 and Single Resonance Approximation (SRA) for EAF-2010. Right: multi-SRA for TENDL-2011 and the present methodology from TENDL-2012 to TENDL-2014.

TARES focus on the "HFR"

- In TENDL, all 2800 isotopes have unique resonances
  - Only about 10 % of the resonances are measured,
  - The rest comes from the HFR method (statistical resonances),

- Presented in ANE 50 (2013) 60
  - Combine the 3 previous models (ld, omp and γ-str) to produce statistical resonances
- Uses the following scheme:
  - TALYS (input: ld + omp + γ-str)
  - CALENDF (input: TALYS output)
  - Output: statistical resonances



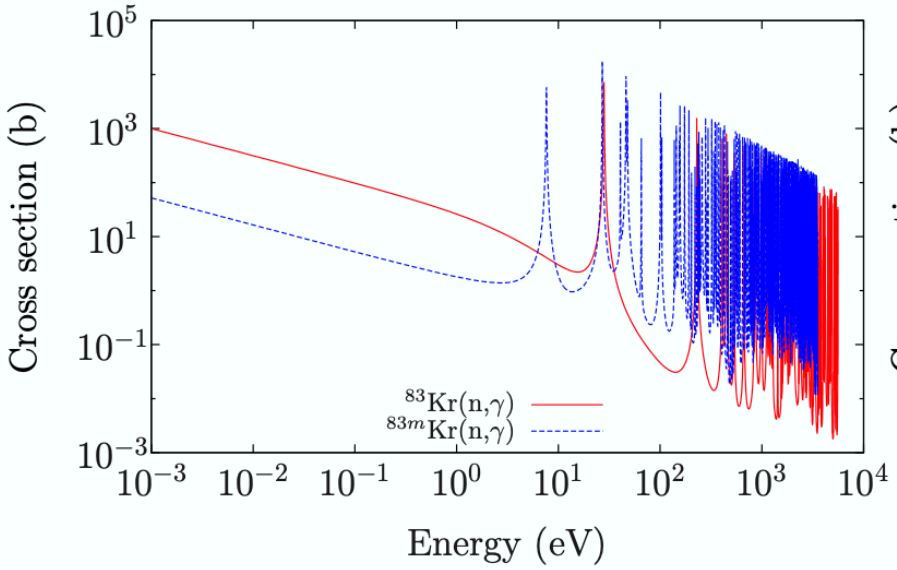
TARES focus on the "HFR"

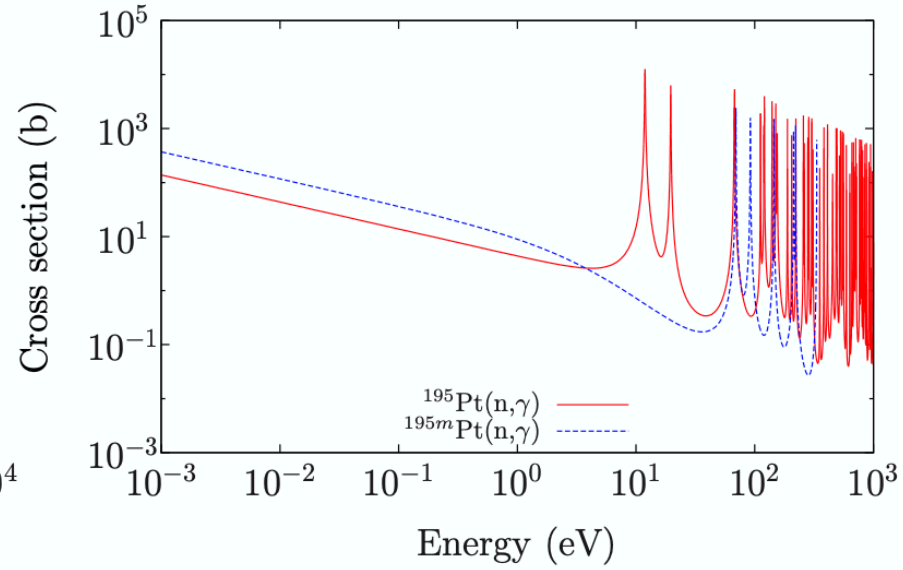
- HFR applied for ground state and isomeric states

$$\sigma_\gamma^{\text{isomer}} = \sigma_\gamma^{\text{ground}} \frac{\sum_j \frac{g\Gamma^0_{nj}\Gamma_{\gamma j}}{E^2_{0j}}}{\sum_i \frac{g\Gamma^0_{ni}\Gamma_{\gamma i}}{E^2_{0i}}}$$

$\sigma_\gamma^{\text{ground}} \Longrightarrow$ known from measurements (or systematics)

$\sum_j$ and $\sum_i \Longrightarrow$ taken (as before) from the global OMP of TALYS.





TARES: physical checks

- Spacing distribution, Wigner distribution
- Cumulative level distribution
- Average total capture width

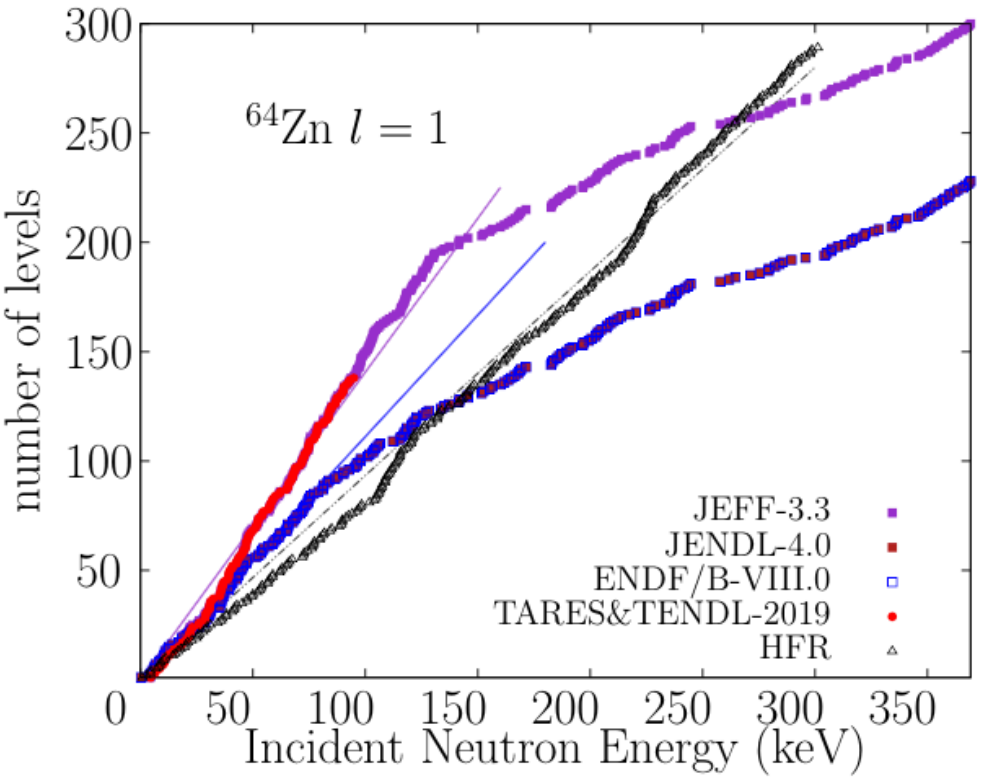
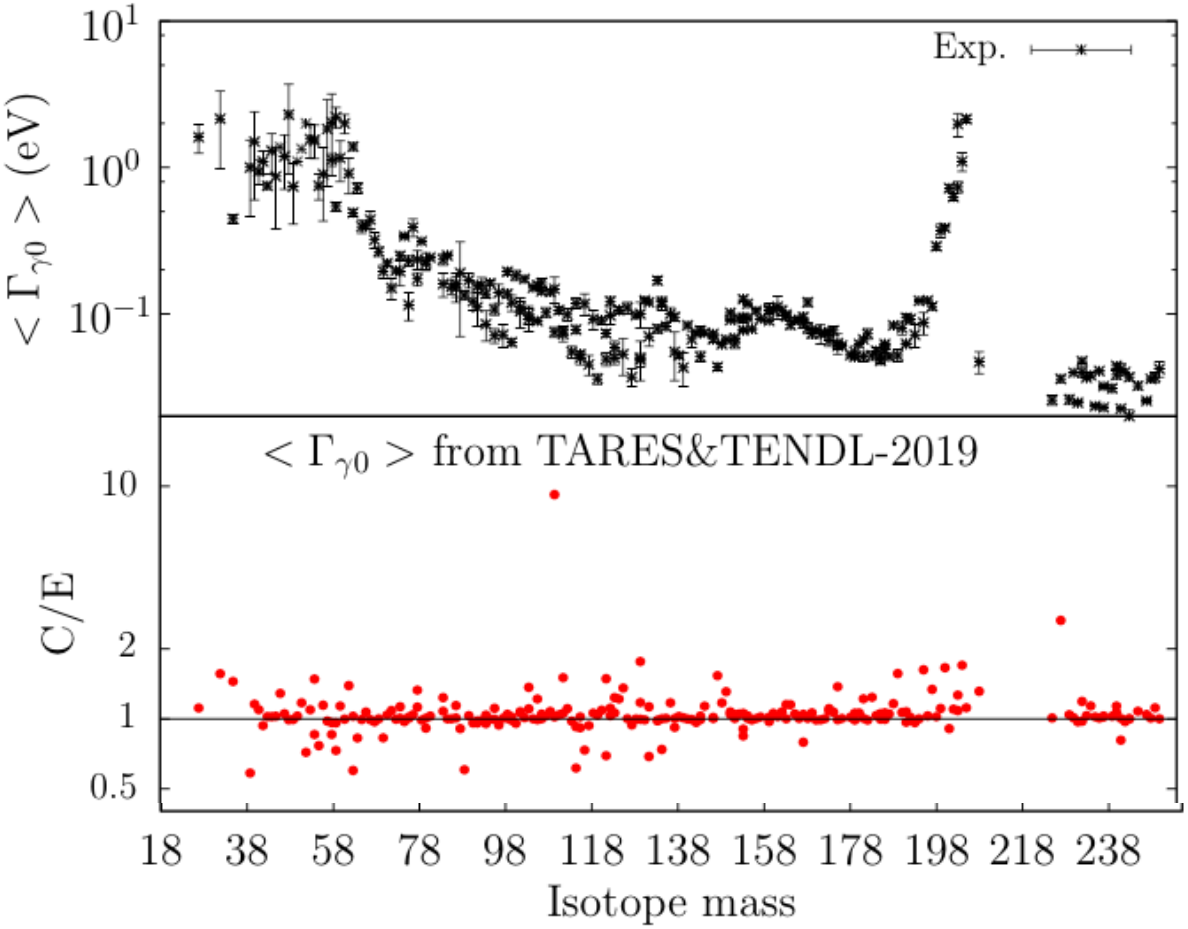


FIG. 16. (Color online) Top: cumulative level distribution for ^{120}Sn and $l = 0$; Bottom: same for ^{64}Zn and $l = 1$.

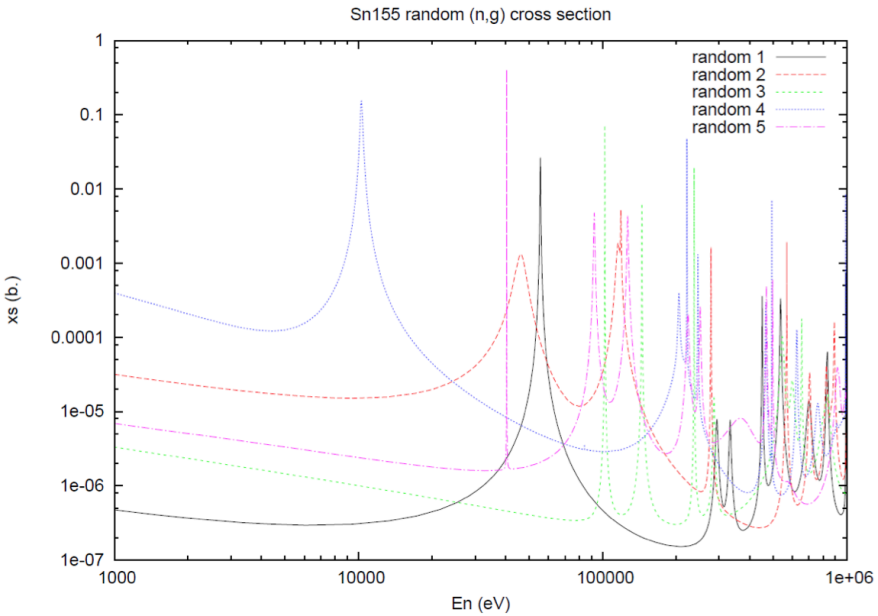
TARES: physical checks

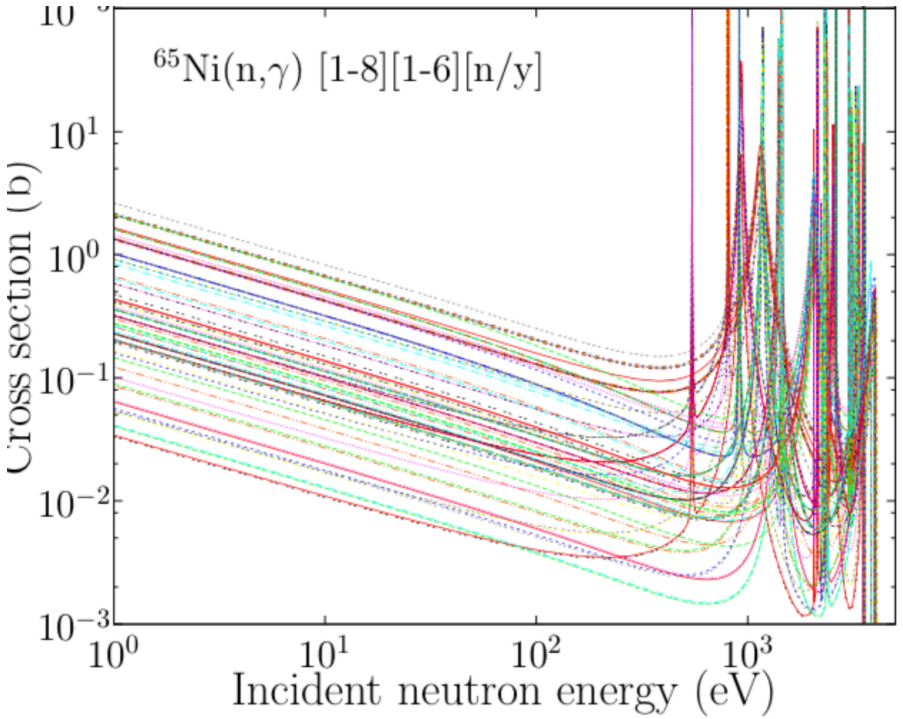
- Spacing distribution, Wigner distribution
- Cumulative level distribution
- Average total capture width



TARES: generation of MF32 and MF33

- For all resonance parameters:
  - Uncertainties are assigned to match thermal (n,g) and RI uncertainties
  - Otherwise default uncertainties are assigned
  - Sampling of parameters are performed to produce group average cross sections





TARES outputs

- For all TENDL isotopes (2800), different outputs are produced together
  - MF1, MF2, MF32c, MF33,
  - .tex, .txt, inter & psyche ouputs
  - Reconstructed pointwise and groupwise cross sections, processed covariances

```
# D. Rochman  TARES version 1.43, Villigen   , Switzerland
# Time: Wed Mar 10 06:06:06 2021
#
# Element          : Sm
# Z                : 62
# A                : 151
# I                : 0
# Data origin      : TENDL
# Formalism        : Multi-level Breit-Wigner
# Emin (RRR)       : 1e-5 eV
# Emax (RRR)       : 1.002000E+03 eV
# Emax2 (background): 1.002000E+03 eV
# Nbr. res. (<Emax) : 524
# Nbr. res. (<Emax2): 525
# Thermal  (n,g) xs : 1.514970E+04 b. (Calc.)
# Thermal  (n,g) xs : 15140 +/- 300 b. (Exp.)
# Res. Int (n,g) xs : 3.423830E+03 b. (Syst.)
# MACS 30 keV       : 4.863000E+01 b.
#
# Thermal (n,el) xs : 1.307810E+02 b. (Calc.)
# Thermal (n,el) xs : 61 +/- 3.05 b. (Exp.)
# Res. Int (n,el) xs: 1.525730E+02 b. (Calc.)
#
# Scattering radius : 5.82 fm +/- 10.00 %
#
# Ave. Gtotal   l=0 : 1.295430E-01 eV
# Ave. redu. Gn l=0 : 1.257650E-03 (Gn^0)
# Ave. Gg       l=0 : 1.019440E-01 eV
# Ave. D        l=0 : 1.919540E+00 eV (level spacing)
# Ave. S        l=0 : 3.829210E-04 eV (gamma strength function)
#
#
#
#
#
#   Energy (eV)     +/- DE (eV)       l         J          Gn (eV)       +/- DGn (eV)       Gg (eV)      +/- DGg (eV)
#<--------------><--------------><-----><----------><--------------><--------------><--------------><--------------><
  -2.200000E-01      1.000000E-03     0       +3.00      2.357140E-03    4.285710E-05    7.530000E-02    5.000000E-04
  +4.560000E-01      1.000000E-02     0       +3.00      2.199430E-05    8.571430E-07    1.000000E-01    2.000000E-03
  +1.093000E+00      2.000000E-03     0       +3.00      6.857140E-04    2.571430E-05    1.195000E-01    3.000000E-03
  +1.704000E+00      2.000000E-03     0       +3.00      3.000000E-04    5.142860E-05    9.840000E-02    1.700000E-03
  +2.036000E+00      3.000000E-03     0       +3.00      5.228570E-04    2.571430E-05    9.990000E-02    2.000000E-03
  +4.132000E+00      3.000000E-03     0       +3.00      9.171430E-04    8.571430E-05    9.590000E-02    1.000000E-03
  +6.395000E+00      4.000000E-03     0       +3.00      4.722860E-03    1.714290E-04    1.077000E-01    2.000000E-03
  +1.044800E+01      2.000000E-02     0       +3.00      1.054290E-02    4.285710E-04    1.153000E-01    5.000000E-03
```

Conclusion

- TARES is a tool dedicated to RRR and URR production and formatting
- Used for TENDL and for JEFF (and some files in ENDF/B-VIII.0)
- Tested on 2800 isotopes (more in astrophysics studies)
- Using evaluated or compiled resonance parameters
- Various consistent outputs
- Distributed with T6
- Yearly tested

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Wir schaffen Wissen – heute für morgen