UK Atomic Energy Authority

FISPACT-II

Self shielding of resonant channels

Thin and thick target yields - High fidelity resonance
Applications: beam, accelerator, isotope production

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Neutron self-shielding model

- thin and thick target yields
- accounts approximately for target geometry
- applicable to thick targets
- handles foils, wires, spheres and finite cylinders
- uses one physical length scale to represent the target: the "effective length" y

Type ID	Geometry	Dimension(s)	Y
1	foil	thickness (t)	y=1.5t
2	wire	radius (r)	y=2r
3	sphere	radius (r)	y=r
4	cylinder	radius (r), height (h)	y=1.65rh(r+h)

Epithermal Neutron Self-shielding Model

- theory of radioisotope production
- production rates and cross-sections
- saturation factors and practical yields

- model uses resonance parameters from the Resolved Resonance Range
- model includes the effects of neutron loss through radiative capture
- model includes effects of neutron energy diffusion through elastic scattering

Model development, first step (1)

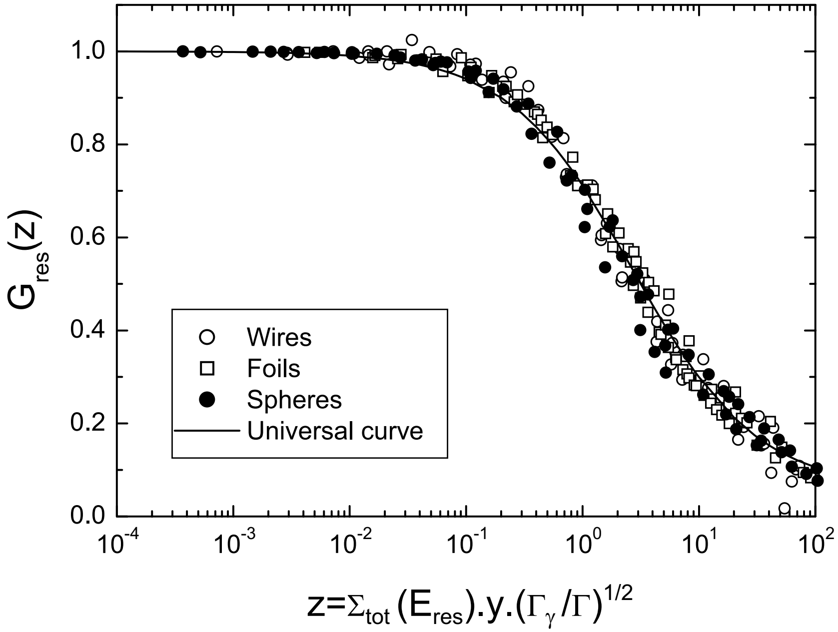
- one resonance in a pure target
- dimensionless parameter to combine the physical effective length with the nuclear parameters

$$z = \Sigma_{tot}(E_{res})\, y \sqrt{\frac{\Gamma_\gamma}{\Gamma}}$$

- where
  - $\Sigma_{tot}(E_{res})$ is the macroscopic cross-section at the energy E_{res} of the resonance peak
  - Γ_γ is the radiative capture width
  - Γ is the total resonance width
  - y "effective length"
- Self-shielding factor G_{res} is defined in terms of z only

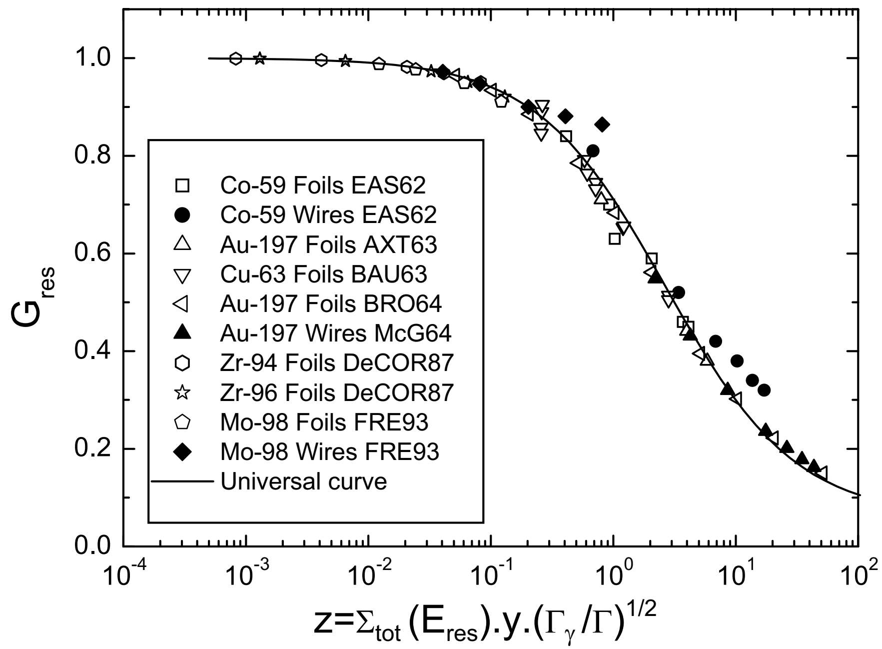
Model development, first step (1)

Baumann, 1963; Yamamoto and Yamamoto, 1965; Lopes, 1991



Target geometry

Experimental self shielding factor



Model development, first step (2)

$$G_{res}(z) = \frac{A_1 - A_2}{1 + \left(z / z_0 \right)^p} + A_2$$

- this is the "universal sigmoid curve" for the model
- the parameters have been determined empirically to be a good fit to experimental data
- preferred values are:
  - A1 = 1.000 ± 0.005
  - A2 = 0.060 ± 0.011
  - Zo = 2.70 ± 0.09
  - p = 0.82 ± 0.02

Model development, second step

- extend model to a group of separated resonances
- still considering a pure target: one nuclide
- assign a weight to each resonance

$$w_i = \left(\frac{\Gamma_\gamma}{E_{res}^2} \cdot \frac{g\Gamma_n}{\Gamma} \right)_i$$

where

- Γ_n is the neutron scattering width
- g is the statistical factor, (2J + 1)/(2(2I + 1))
- J is the spin of the resonance state
- I is the spin of the target nucleus
- form an average self-shielding factor from all resonances of interest

$$\langle G_{res} \rangle = \frac{\sum w_i G_{res}(z_i)}{\sum w_i}$$

Model development, third step

- extend $\langle G_{res} \rangle$ to form the average for resonances of a mixture of nuclides
- assume the resonances of different nuclides do not overlap significantly

- make $\langle G_{res} \rangle$ energy dependent by taking averages separately for each energy bin used for the group-wise cross-sections
- use Fröhner's simple expression for the peak cross-section of each resonance (not available from the GENDF data however, in FISPACT-II gxs application forms)

Application of the model in FISPACT-II

- universal curve model provides an alternative to probability table self shielding
- use $\langle G_{res} \rangle(E)$ to scale down energy-dependent cross-sections before cross-section collapse
- $\langle G_{res} \rangle(E)$ reduces the neutron flux, so apply it to all cross-sections
- target geometry specified with

  SSFGEOMETRY type length_1 <length_2 >
- use resonances from mixture specified with **SSFFUEL** or **SSFMASS**
- PRINTLIB 6 now generates a table of all cross-sections with $\langle G_{res} \rangle$ reduction factors

Application of the model in FISPACT-II

- The self shielding factors are calculated from the resonances of the materials specified with the SSFFUEL or SSFMASS keywords

Nuclide	Atoms percent
W 182	26.534
W 183	14.319
W 184	30.680
W 186	28.467

parent nuclide	daughter nuclide	mt	old sigma barns	new sigma barns	self shielding factor (%)
W 181	W 182	102	1.28654E-01	1.00821E-01	78.37
W 182	W 183m	102	4.88539E-04	4.37982E-04	89.65
W 183m	W 184	102	1.22719E-01	9.19139E-02	74.90
W 185	W 186	102	4.02148E-02	2.72004E-02	67.64
W 186	W 187	102	5.91903E-02	2.45217E-02	41.43
W 182	W 183	102	6.68732E-02	2.79708E-02	41.83
W 183	W 184	102	5.68988E-02	2.03099E-02	35.69
W 184	W 185	102	9.99565E-03	6.32533E-03	63.28
W 185m	W 186	102	6.51538E-02	4.98838E-02	76.56
W 187	W 188	102	5.15139E-01	4.63582E-01	89.99