II.B.3.a. Single and multilevel Breit-Wigner cross sections

The MLBW elastic (scattering) cross section may be written in the form

$$\sigma^{elastic} = \frac{\pi}{k^2}\sum_J g_J \sum_c \Bigg\{ \left(1-\cos 2\varphi\right)\left(2-\sum_\lambda \Gamma_{\lambda c}\Gamma_\lambda / d_\lambda\right) + 2\sin 2\varphi \sum_\lambda \Gamma_{\lambda c}\left(E-E_\lambda\right)/d_\lambda \qquad \text{(II B3 a.1)}$$
$$+\left(\sum_\lambda \Gamma_{\lambda c}\left(E-E_\lambda\right)/d_\lambda\right)^2 + \left(\sum_\lambda \Gamma_{\lambda c}\Gamma_\lambda / 2d_\lambda\right)^2 \Bigg\} \quad ,$$

in which the summation over c includes only incident (i.e., neutron) channels. For SLBW, the level-level interference terms in this equation are dropped; that is, the summations over λ in the last line are outside, rather than inside, the parentheses. The total width Γ_λ in Eq. (II B3 a.1) is given by

$$\Gamma_\lambda = \sum_c \Gamma_{\lambda c} + \overline{\Gamma}_{\lambda\gamma} \quad , \qquad \text{(II B3 a.2)}$$

in which the sum over c includes **all** particle channels (i.e., over all channels except the eliminated capture channel). Partial widths $\Gamma_{\lambda c}$ and $\overline{\Gamma}_{\lambda\gamma}$ are related to amplitudes $\gamma_{\lambda c}$ and $\overline{\gamma}_\lambda$, as in the Reich-Moore approximation, by

$$\Gamma_{\lambda c}^{neutron} = 2\gamma_{\lambda c}^2 P_c$$
$$\Gamma_{\lambda c}^{fission} = 2\gamma_{\lambda c}^2 \qquad \text{(II B3 a.3)}$$
$$\text{and} \qquad \overline{\Gamma}_{\lambda\gamma} = 2\overline{\gamma}_{\lambda\gamma}^2 \quad .$$

(Note that we have again adopted the convention that the gamma channel be denoted by a bar over the symbol, even though it is not really treated differently from particle channels in the Breit Wigner approximations.) The denominator d_λ in Eq. (II B3 a.1) represents

$$d_\lambda = \left(E-E_\lambda\right)^2 + \left(\Gamma_\lambda/2\right)^2 \quad . \qquad \text{(II B3 a.4)}$$

For both MLBW and SLBW, the fission cross section is given by

$$\sigma^{fission} = \frac{\pi}{k^2}\sum_J g_J \sum_c \sum_{c'} \sum_\lambda \frac{\Gamma_{\lambda c}\Gamma_{\lambda c'}}{d_\lambda} \quad , \qquad \text{(II B3 a.5)}$$

in which the sum over c includes only incident (neutron) channels, d_λ is again given by Eq. (II B3 a.4), and the sum over c' includes all exit channels. Caution: In principle, Eq. (II B3 a.5) could be used to describe any reaction channel, where term "reaction" encompasses any non-elastic, non-capture channel. However, the only reaction channel permitted in ENDF is fission; for SLBW only one fission channel is permitted, and for MLBW two fission channels may be used. In addition, ENDF allows only one neutron channel (i.e., only one entrance channel). Because SAMMY's Breit-Wigner options were created solely for use with ENDF evaluations (for comparison purposes), similar restrictions apply to the use of the Breit-Wigner approximations in SAMMY. (For the more general case involving other reactions such as inelastic, (n,p), (n,α), or fission with more than two channels, use the Reich-Moore approximation as discussed in Section II.B.1.c.)

The Breit-Wigner form for the capture cross section is

$$\sigma^{capture} = \frac{\pi}{k^2} \sum_J g_J \sum_c \sum_\lambda \frac{\Gamma_{\lambda c} \overline{\Gamma}_{\lambda\gamma}}{d_\lambda} \quad , \tag{II B3 a.6}$$

where, again, the sum over c includes only incident (neutron) channels. Total and absorption cross sections are given by the appropriate sums of the other three cross sections,

$$\sigma^{total} = \sigma^{elastic} + \sigma^{fission} + \sigma^{capture} \tag{II B3 a.7}$$

and

$$\sigma^{absorption} = \sigma^{fission} + \sigma^{capture} \quad . \tag{II B3 a.8}$$

As noted in Section IV.C, it is the u-parameters on which Bayes' equations operate. The u-parameters associated with the MLBW and SLBW resonances are defined similarly to those for Reich-Moore resonances:

$$u\left(E_\lambda\right) = \pm\sqrt{\left|E_\lambda\right|} \quad , \tag{II B3 a.9}$$

where the negative sign is chosen if $E_\lambda < 0$,

$$u\left(\Gamma_{\lambda c}\right) = \gamma_{\lambda c} \tag{II B3 a.10}$$

and

$$u\left(\overline{\Gamma}_{\lambda\gamma}\right) = \overline{\gamma}_{\lambda\gamma} \quad . \tag{II B3 a.11}$$

(The reduced-width amplitudes $\gamma_{\lambda c}$ and $\overline{\gamma}_{\lambda\gamma}$ may be either positive or negative. However, the sign is irrelevant in the Breit-Wigner equations, for which the reduced-width amplitudes enter only as squared quantities.)

The matching radius a_c may also be varied (i.e., treated as a u-parameter) with the Breit-Wigner approximations.