Appendix 1: Nuclear reaction code TALYS 1.9

TALYS includes a large number of different models. Some of them are invoked in calculation by default.

By default, for compound reaction contributions TALYS 1.9 performs calculations in the Hauser–Feshbach approach with Moldauer width fluctuation corrections.

Koning and Delaroch local parametrization for optical model was used with different models for direct reactions:

Diatorted Wave Born Approximation (DWBA)
Coupled-channels (rotational and vibrational approaches)

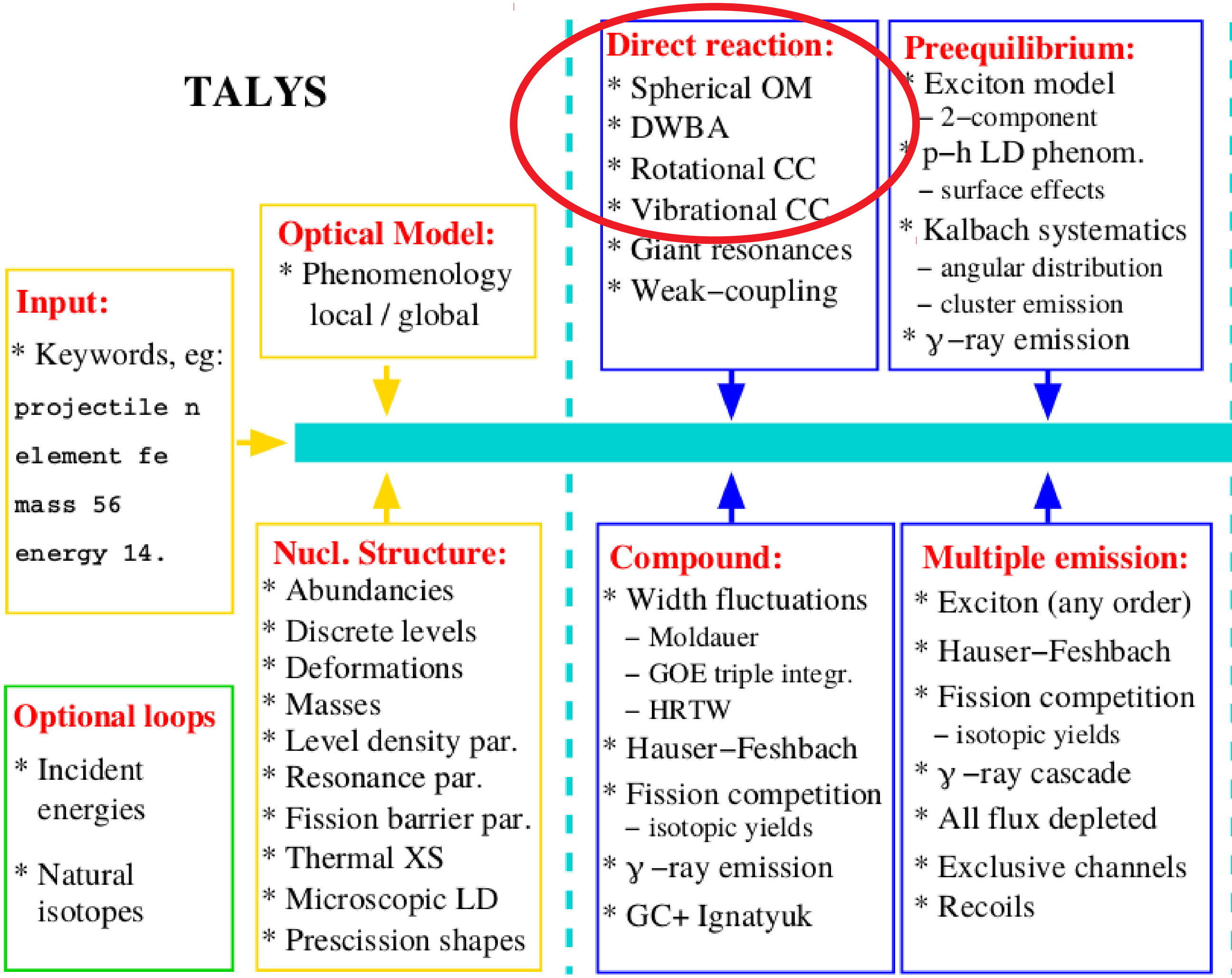

Fig. 6. Nuclear models in the TALYS program [6].

6. Koning, A., S. Hilaire, and S. Goriely. "User Manual of Talys-1.9." (2017).

Appendix 2: Optical model potential (OMP) in TALYS

Phenomenological OMP. It consists of several components:

- **Volume (real and imaginary parts: V_v, W_v)**
- **Superficial (only imaginary part: W_D)**
- **Spin-orbital (real and imaginary parts: V_{so}, W_{so})**

In this work - local parametrisation of Koning and Delaroche is used. Local parametrisation describes concrete nucleus for some energy range of the incident particle.

$$\begin{aligned} \mathcal{U}(r,E) &= -\mathcal{V}_V(r,E) - i\mathcal{W}_V(r,E) - i\mathcal{W}_D(r,E) \\ &\quad +\mathcal{V}_{SO}(r,E).\mathbf{l}.\sigma + i\mathcal{W}_{SO}(r,E).\mathbf{l}.\sigma + \mathcal{V}_C(r), \end{aligned}$$

$$\begin{aligned} \mathcal{V}_V(r,E) &= V_V(E)f(r,R_V,a_V), \\ \mathcal{W}_V(r,E) &= W_V(E)f(r,R_V,a_V), \\ \mathcal{W}_D(r,E) &= -4a_D W_D(E)\frac{d}{dr}f(r,R_D,a_D), \\ \mathcal{V}_{SO}(r,E) &= V_{SO}(E)\left(\frac{\hbar}{m_\pi c}\right)^2 \frac{1}{r}\frac{d}{dr}f(r,R_{SO},a_{SO}), \\ \mathcal{W}_{SO}(r,E) &= W_{SO}(E)\left(\frac{\hbar}{m_\pi c}\right)^2 \frac{1}{r}\frac{d}{dr}f(r,R_{SO},a_{SO}). \end{aligned}$$

$$f(r,R_i,a_i) = \left(1+\exp[(r-R_i)/a_i]\right)^{-1},$$

Appendix 3: Koning and Delaroche local optical parametrization

Calculation of components for local parameterization:

v_1, v_2, v_3, v_4, w_1, w_2, r_V, a_V, d_1, d_2, v_{SO1}, v_{SO2}, w_{SO1}, w_{SO2}, r_{SO}, a_{SO}

- **are obtained by fitting experimental data (integral and differential cross sections) for a given nucleus at different energies E_n**
- **specified in the .omp file and fed to the TALYS input**

$$
\begin{aligned}
V_V(E) &= v_1[1 - v_2(E-E_f) + v_3(E-E_f)^2 - v_4(E-E_f)^3] \\
W_V(E) &= w_1 \frac{(E-E_f)^2}{(E-E_f)^2 + (w_2)^2} \\
r_V &= \text{constant} \\
a_V &= \text{constant} \\
W_D(E) &= d_1 \frac{(E-E_f)^2}{(E-E_f)^2 + (d_3)^2} \exp[-d_2(E-E_f)] \\
r_D &= \text{constant} \\
a_D &= \text{constant} \\
V_{SO}(E) &= v_{so1} \exp[-v_{so2}(E-E_f)] \\
W_{SO}(E) &= w_{so1} \frac{(E-E_f)^2}{(E-E_f)^2 + (w_{so2})^2} \\
r_{SO} &= \text{constant} \\
a_{SO} &= \text{constant} \\
r_C &= \text{constant},
\end{aligned}
$$

Appendix 4: Default TALYS 1.9 optical parameters

	E_n	V_V	r_V	a_V	W_V	W_D	r_D	a_D	V_{SO}	r_{SO}	a_{SO}	W_{SO}
^{48}Ti	2	51.61	1.185	0.671	0.31	4.24	1.276	0.530	5.72	1.01	0.600	-0.02
	14.1	47.24	1.185	0.671	1.20	5.58	1.276	0.530	5.45	1.01	0.600	-0.07
	20	45.22	1.185	0.671	1.77	5.34	1.276	0.530	5.32	1.01	0.600	-0.10
^{52}Cr	2	51.57	1.190	0.667	0.30	4.85	1.282	0.535	5.91	1.01	0.600	-0.02
	14.1	47.20	1.190	0.667	1.11	5.70	1.282	0.535	5.63	1.01	0.600	-0.07
	20	45.18	1.190	0.667	1.65	5.35	1.282	0.535	5.50	1.01	0.600	-0.11
^{56}Fe	2	52.33	1.186	0.663	0.26	6.29	1.282	0.532	5.83	1.00	0.580	-0.02
	14.1	47.91	1.186	0.663	1.03	7.67	1.282	0.532	5.55	1.00	0.580	-0.07
	20	45.86	1.186	0.663	1.55	7.23	1.282	0.532	5.42	1.00	0.580	-0.10

Appendix 5: Radii of the OMP terms in coupled channels

- No deformation $$R_i = r_i A^{1/3}$$
- CC, symmetric rotational model $$R_i = r_i A^{1/3} \left[1 + \sum_{\lambda=2,4,\ldots} \beta_\lambda Y_\lambda^0(\Omega) \right]$$

β_λ is are permanent, static deformation parameters, Y_λ functions are spherical harmonics

- CC, harmonic vibrational model $$R_i = r_i A^{1/3} \left[1 + \sum_{\lambda\mu} \alpha_{\lambda\mu} Y_\lambda^\mu(\Omega) \right]$$

Appendix 6: TALYS default deformation parameters

^{48}Ti

22	48	4	S	B	
0	V	0			
1	D				0.269
2	D				0.150
10	D				0.197

^{52}Cr

24	52	10	R	B		
0	R	0				
1	R	0			0.22300	0.07700
2	R	0				
3	V	3	2	0	0.09500	
5	V	2	2	2	0.08000	
6	R	0				
7	V	3				
9	V	2				

^{56}Fe

26	56	10	S	B	
0	V	0			
1	D				0.23900
2	D				0.02200
3	D				0.04500
5	D				0.01500
8	D				0.06500
9	D				0.04500
10	D				0.02800
14	D				0.03800
17	D				0.03000

Each line include nuclear level number, type of level collectivity, deformation parameters β_2, β_4.