Role of ENSDF in cross section evaluations

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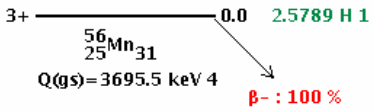
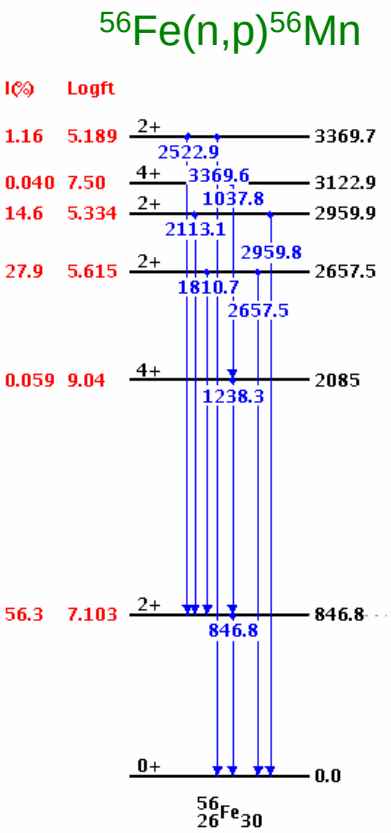
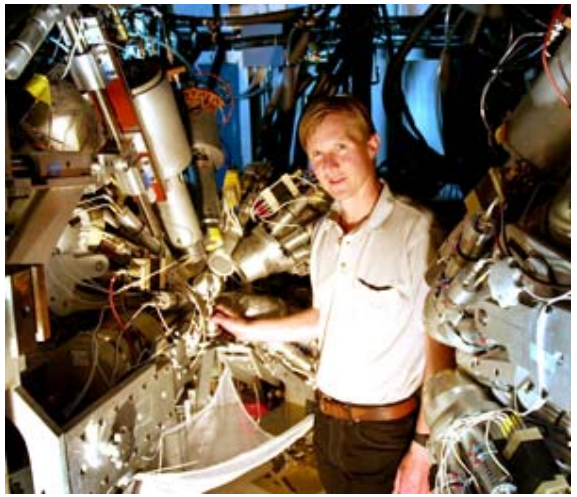
Structure data in x-sec. measurements

- Activation measurements
  - Decay modes
  - Decay schemes
  - Half lives
  - Internal conversion coefficients
- In-beam measurements (e.g., GEANIE)
  - (Decay schemes)^2
  - Internal conversion coefficients







Structure data in reaction calculations

Structure Quantity = = = = ==>		Reaction Quantity
Masses	Q-values	Reaction thresholds
		Excitation energies
Ground state deformations	Moments of inertia	Lev. dens. rotational enhancement
		Lev. dens. spin distribution
	GDR splitting	γ-ray strength function
Quadrupole moments (Q), B(E2), B(E3)	Dynamic deformations for DWBA and CC	Absorption cross sections
		Inelastic cross sections
		Transmission coefficients

Structure data in reaction calculations

Structure Quantity = = = = ==> Reaction Quantity		
Shell corrections		Level densities
		Fission barriers
Half-lives		Define isomers
Level schemes	Levels	Level densities below B_n
	Level spins (parities)	Spin (parity) distribution of level densities below B_n
	Collective levels	CC coupling, DWBA and MSD
		Vibrational enhancement of level densities
	γ-transitions	γ-spectra

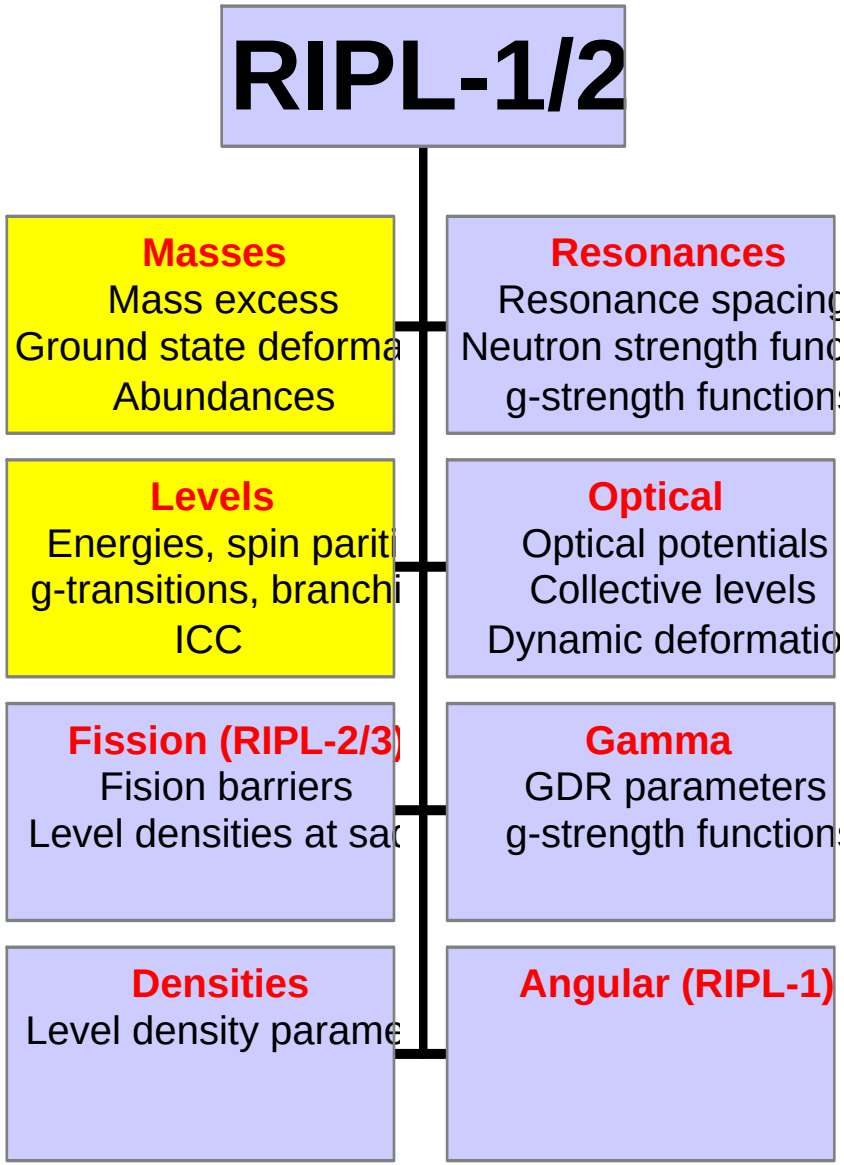
Reference Input Parameter Library (RIPL)

IAEA Coordinated Research Project

Objective: provide comprehensive library of input parameters for nuclear reaction calculations

- RIPL-1 (1997)
- RIPL-2 (2003)
- RIPL-3 (2008)

Structure data predominantly from ENSDF



RIPL: dynamic deformations

ENSDF's Q, B(E2), and B(E3) converted to β_2, β_3 using:

$$Q = Q_0 \frac{(3K^2 - 1)(I+1)}{(I+1)(2I+3)}$$

$$Q_0 = \frac{3Zr_0^2\beta}{\sqrt{5\pi}}(1 + 0.16\beta + ...)$$

$$B(E2) = \left(\frac{3R_0^2 Z\beta_2}{4\pi}\right)^2$$

$$B(E3) = \left(\frac{3R_0^3 Z\beta_3}{4\pi}\right)^2$$

$$R_0 = 0.12A^{1/3}$$

Recommended deformation parameters for 1643 collective levels (including fictitious!)

Excited-level deformation parameters

Z	A	El	Ex [MeV]	J	P	L	beta	Reference
3	7	Li	0.477612	0.5	-1	2	0.763388	ENSDF(BE2)
4	10	Be	3.368030	2.0	1	2	1.140000	Raman2
6	10	C	3.353600	2.0	1	2	0.830000	Raman2
6	12	C	4.438900	2.0	1	2	0.600000	JENDL-3.2
6	12	C	4.438910	2.0	1	2	0.582000	Raman2
6	12	C	9.641000	3.0	-1	3	0.400000	JENDL-3.2
6	12	C	9.641000	3.0	-1	3	0.831482	Kibedi
6	14	C	6.728000	3.0	-1	3	0.408090	Kibedi
6	14	C	7.012000	2.0	1	2	0.360000	Raman2
8	16	O	6.130000	3.0	-1	3	0.728519	Kibedi
8	16	O	6.130400	3.0	-1	3	0.640000	JENDL-3.2
8	16	O	6.917100	2.0	1	2	0.364000	Raman2
8	16	O	6.917100	2.0	1	2	0.400000	JENDL-3.2
8	18	O	1.982070	2.0	1	2	0.355000	Raman2
8	18	O	5.098000	3.0	-1	3	0.595131	Kibedi
8	20	O	1.673680	2.0	1	2	0.261000	Raman2
8	20	O	5.614000	3.0	-1	3	0.348769	Kibedi
8	22	O	3.190000	2.0	1	2	0.208000	Raman2

RIPL: levels segment

- Discrete level schemes, including energies, spins, parities, γ-transition branchings and conversion coefficients
- Most of the information contained in the ENSDF library, however:
  - ENSDF format is not appropriate for reaction calculations
  - unique spin and/or parity assignments are often lacking
  - conversion coefficients are missing for most of the electromagnetic transitions
- RIPL levels segment is derived from ENSDF but reaction codes don't use ENSDF

Construction of the RIPL levels segment

- Author: Tamas Belgya
- RIPL-3 database derived directly from ENSDF plus:
  - Determination of unique spins (5 cases, 2 involving statistical approach)
  - Determination of missing ICCs (modified HSICC code)
  - Determination of missing decay probabilities
- Determination of nuclear temperature for constant temperature level densities (Gilbert-Cameron)
- Determination of the cut-off energy up to which the level scheme is complete
- Number of consistency test
- Extensive verification with reaction codes (EMPIRE, TALYS)

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

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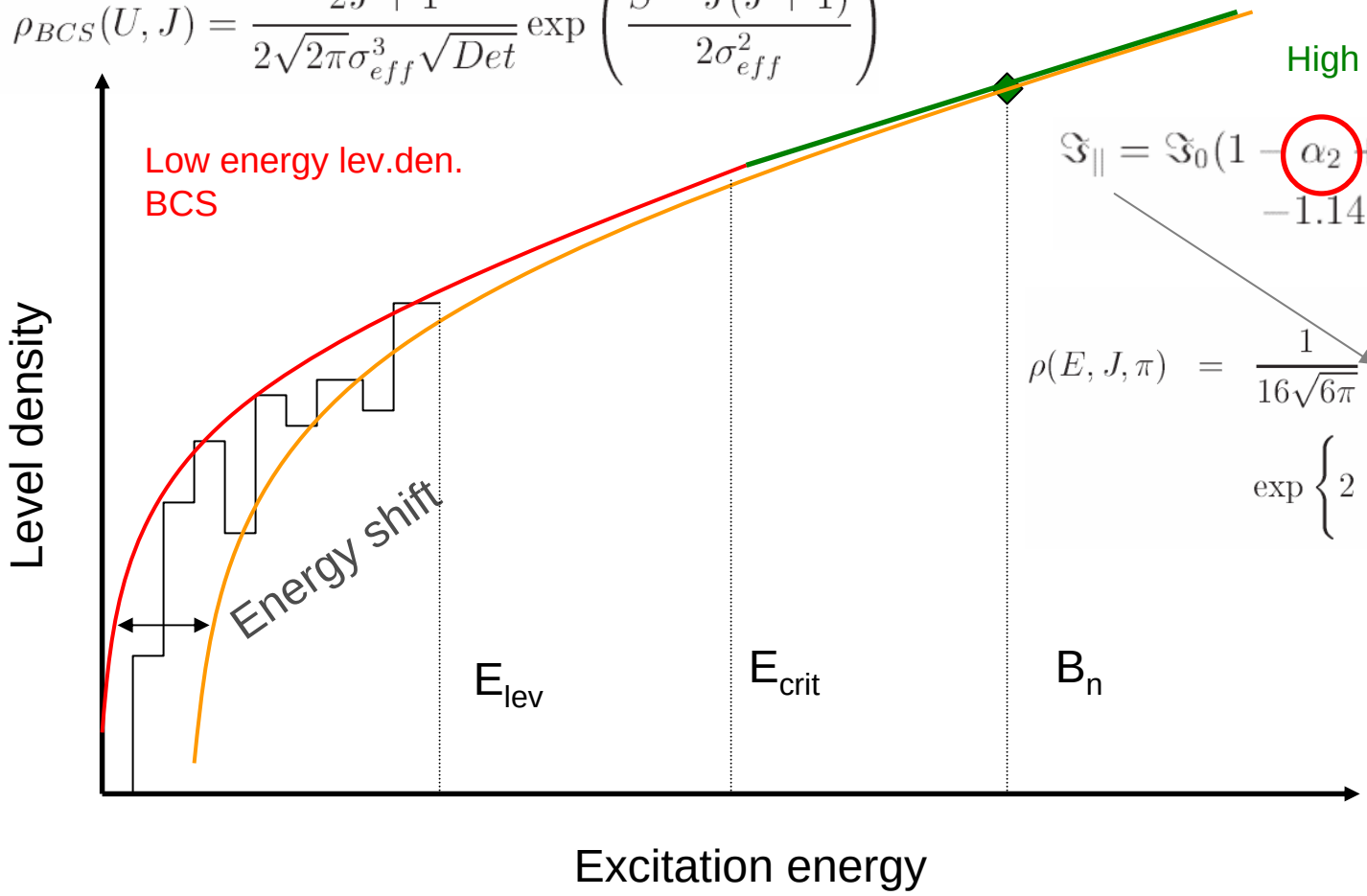
Example of the RIPL level file (^{198}Au)

```
Symbol A   Z   Nl Ng  Nc   Nk    Sn       Sp
198Au 198  79 136 876 104  13   6.512340   6.448910
Level   E     J  π    T1/2  Nd          possible spins    decay mode
  1  0.000000   2.0 -1  2.33E+05  0u              2- 1 =   100.0000 %B-
  2  0.055180   1.0 -1        1u              1- 0
                         Nf    Eg     Pg       Pe       ICC
                         1    0.055  7.407E-02  1.000E+00  1.250E+01
  3  0.091004   0.0 -1        2u              0- 0
                         2    0.036  2.581E-02  7.381E-01  2.760E+01
                         1    0.091  2.949E-02  2.619E-01  7.880E+00
  4  0.192943   1.0 -1  7.00E-10  3u              1- 0
                         3    0.102  1.048E-01  8.535E-01  7.140E+00
                         2    0.138  1.961E-02  7.882E-02  3.020E+00
                         1    0.193  4.739E-02  6.772E-02  4.290E-01
  5  0.214971   4.0 -1  4.00E-10  1u              4- 0
                         1    0.215  7.710E-01  1.000E+00  2.970E-01
  6  0.236044   3.0 -1  1.50E-10  2u              3- 0
                         2    0.181  9.132E-02  1.405E-01  5.390E-01
                         1    0.236  5.968E-01  8.595E-01  4.400E-01
  7  0.247572   1.0 -1  4.00E-10  3u              1- 0
                         3    0.157  5.098E-03  1.580E-02  2.100E+00
                         2    0.192  2.211E-01  4.798E-01  1.170E+00
                         1    0.248  3.186E-01  5.044E-01  5.830E-01
```

From discrete levels to level density

$$\sigma_{eff}^2 = \left(\Im_{\parallel}^{BCS}\right)^{1/3} \left(\Im_{\perp}^{BCS}\right)^{2/3} T$$

$$\rho_{BCS}(U,J) = \frac{2J+1}{2\sqrt{2\pi}\sigma_{eff}^3\sqrt{Det}} \exp\left(\frac{S-J(J+1)}{2\sigma_{eff}^2}\right)$$



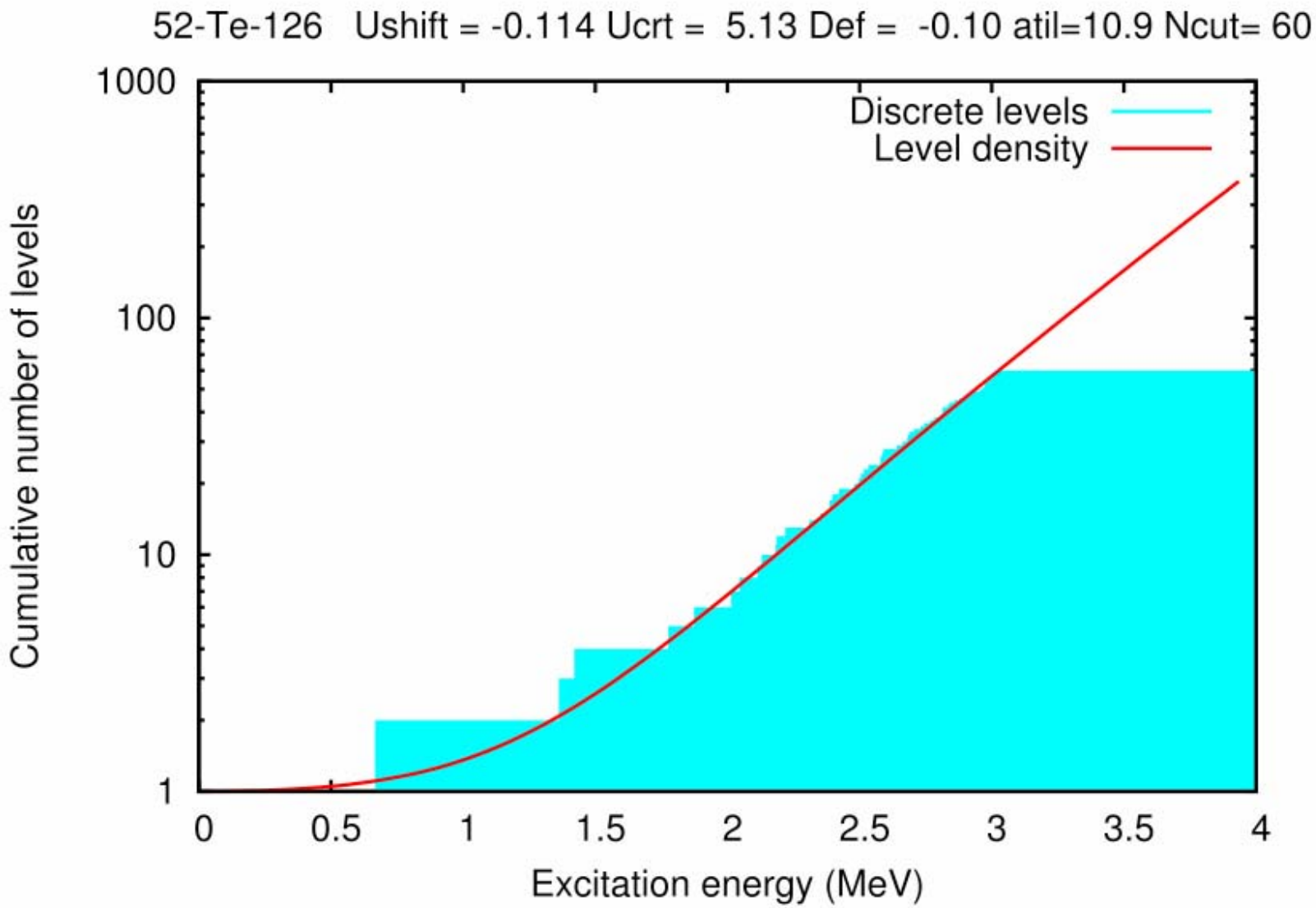
High energy lev.den.

$$\Im_{\parallel} = \Im_0(1 - \alpha_2 + 0.429\alpha_2^2 + 0.268\alpha_2^3 - 0.212\alpha_2^4 - 1.143\alpha_2\alpha_4 + 0.494\alpha_2^2\alpha_4 + 0.266\alpha_4^2)$$

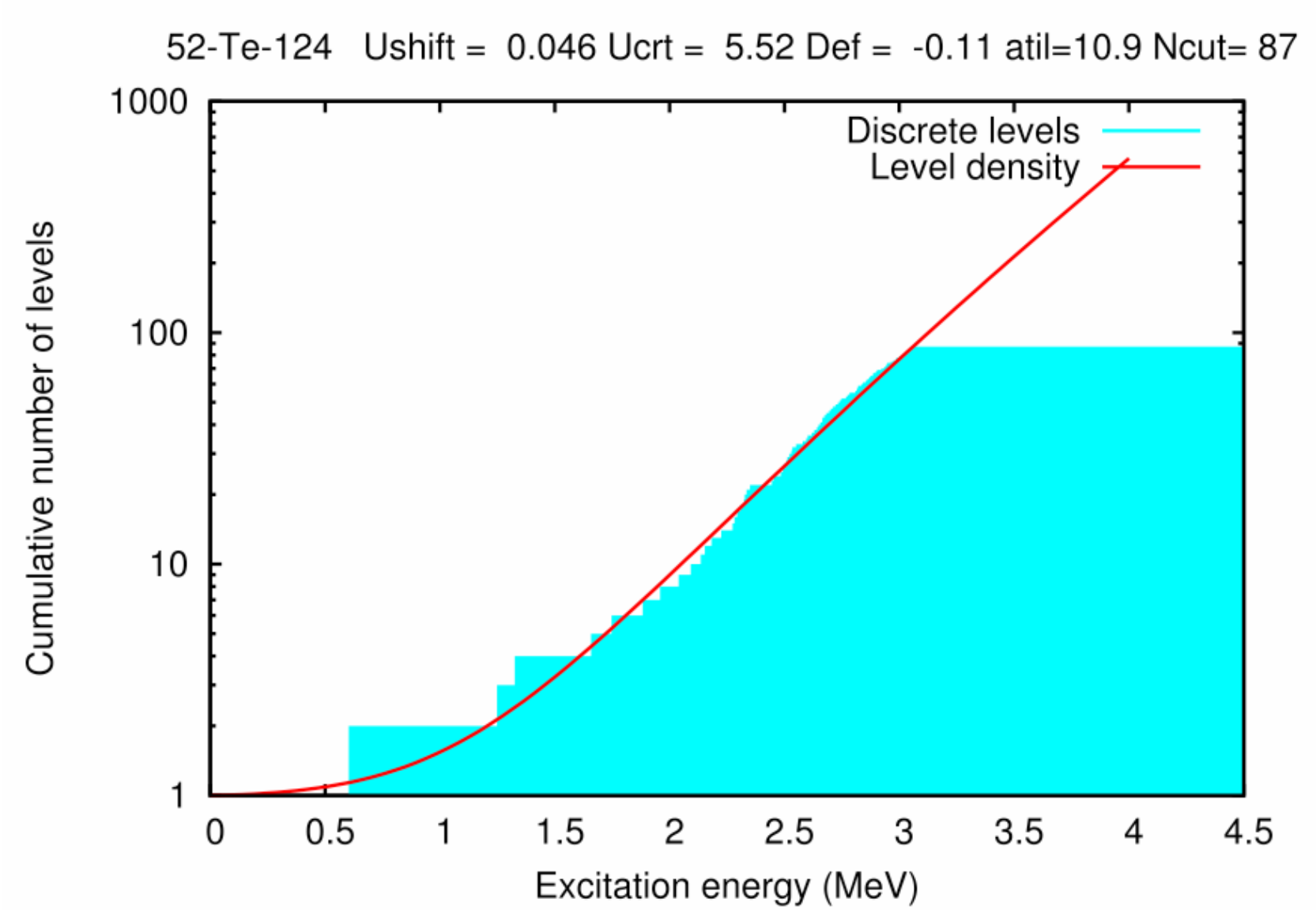
$$\rho(E,J,\pi) = \frac{1}{16\sqrt{6\pi}}\left(\frac{\hbar^2}{\Im_{\parallel}}\right)^{\frac{1}{2}} a^{1/4} \sum_{K=-J}^{J} \left(U - \frac{\hbar^2K^2}{2\Im_{eff}}\right)^{-\frac{5}{4}} \exp\left\{2\left[a\left(U - \frac{\hbar^2K^2}{2\Im_{eff}}\right)\right]^{\frac{1}{2}}\right\}.$$

$$a(U) = \tilde{a}[1 + f(U)\frac{\delta W}{U}]$$

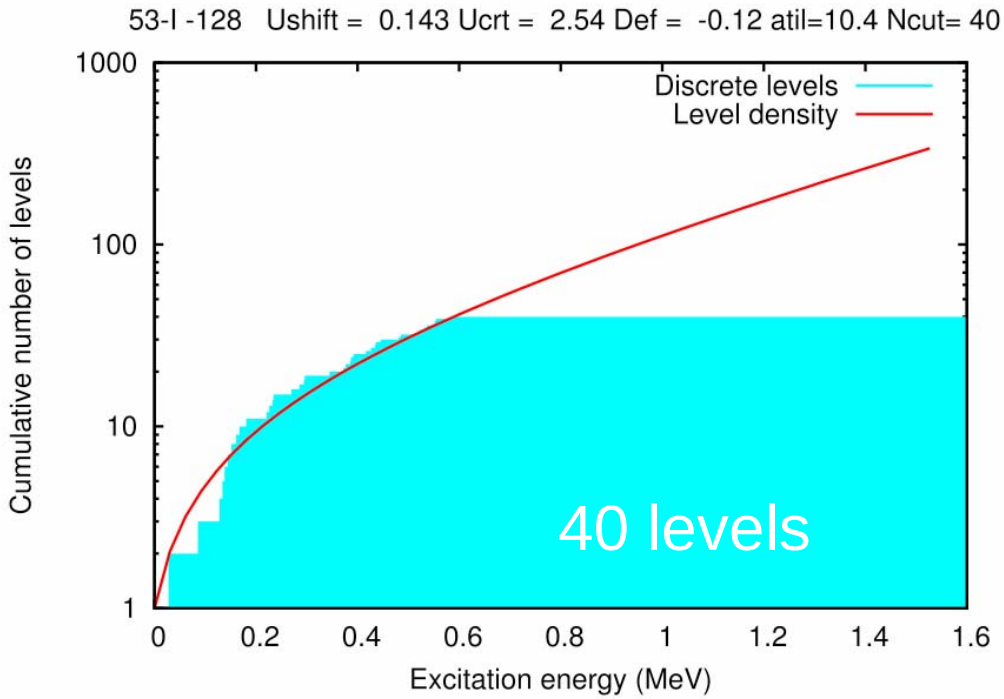
… excellent fit

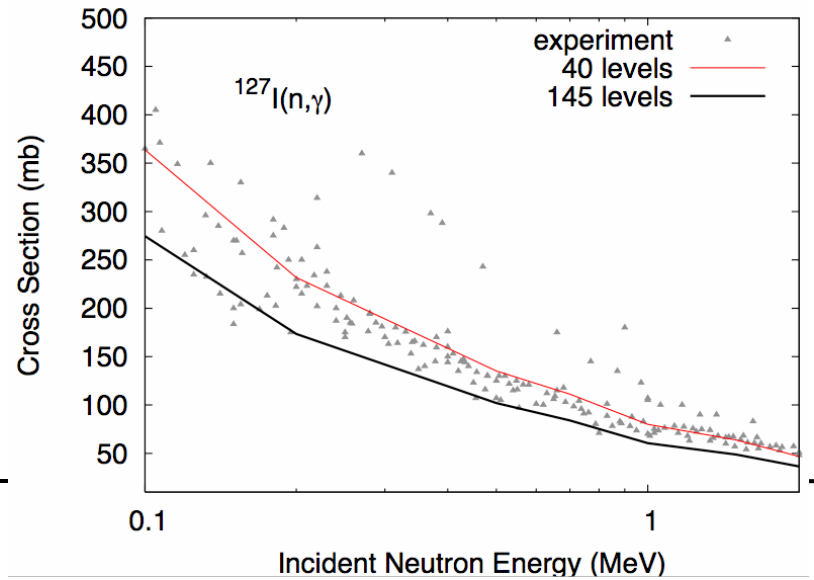


… excellent fit

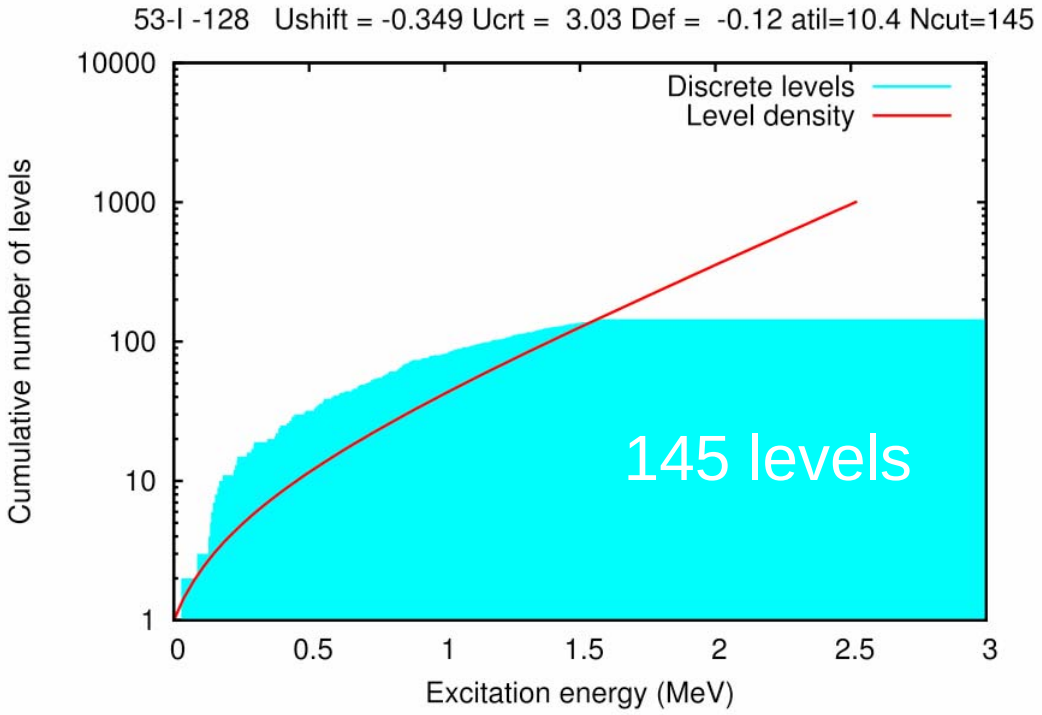


Case of ^{128}I

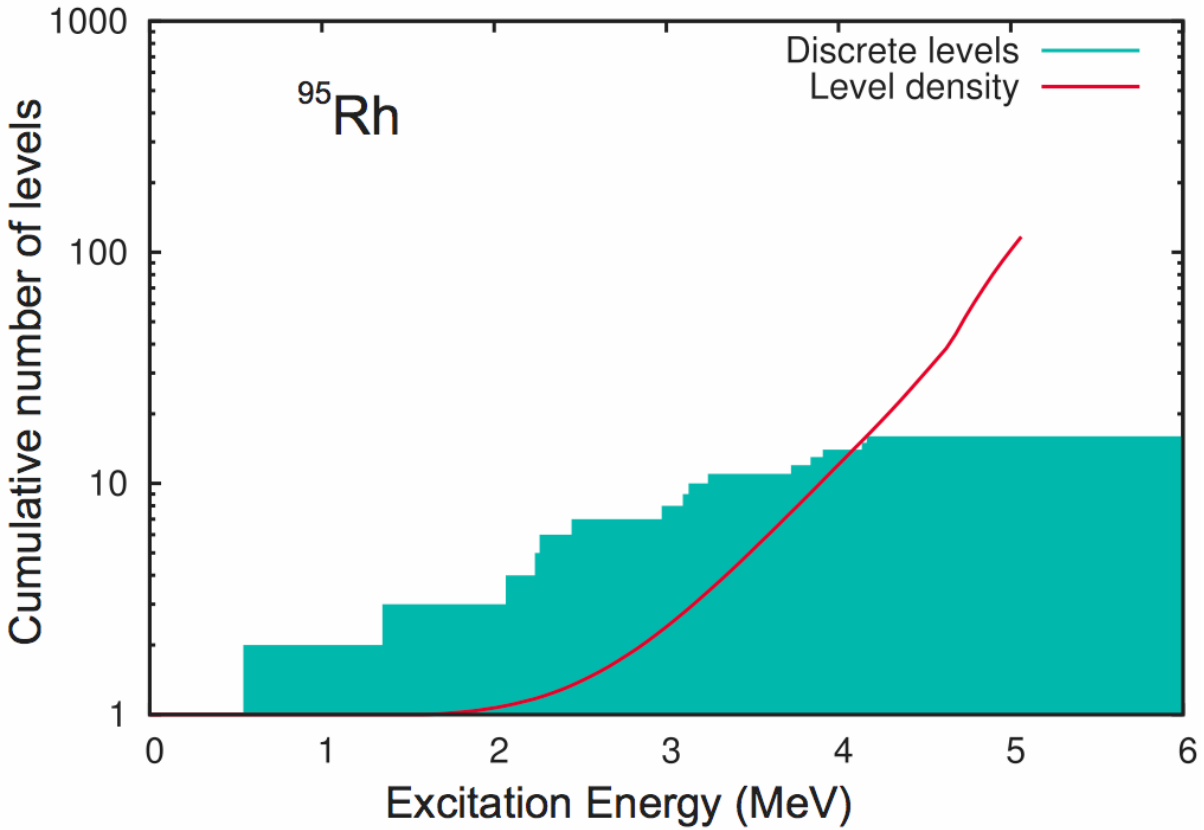


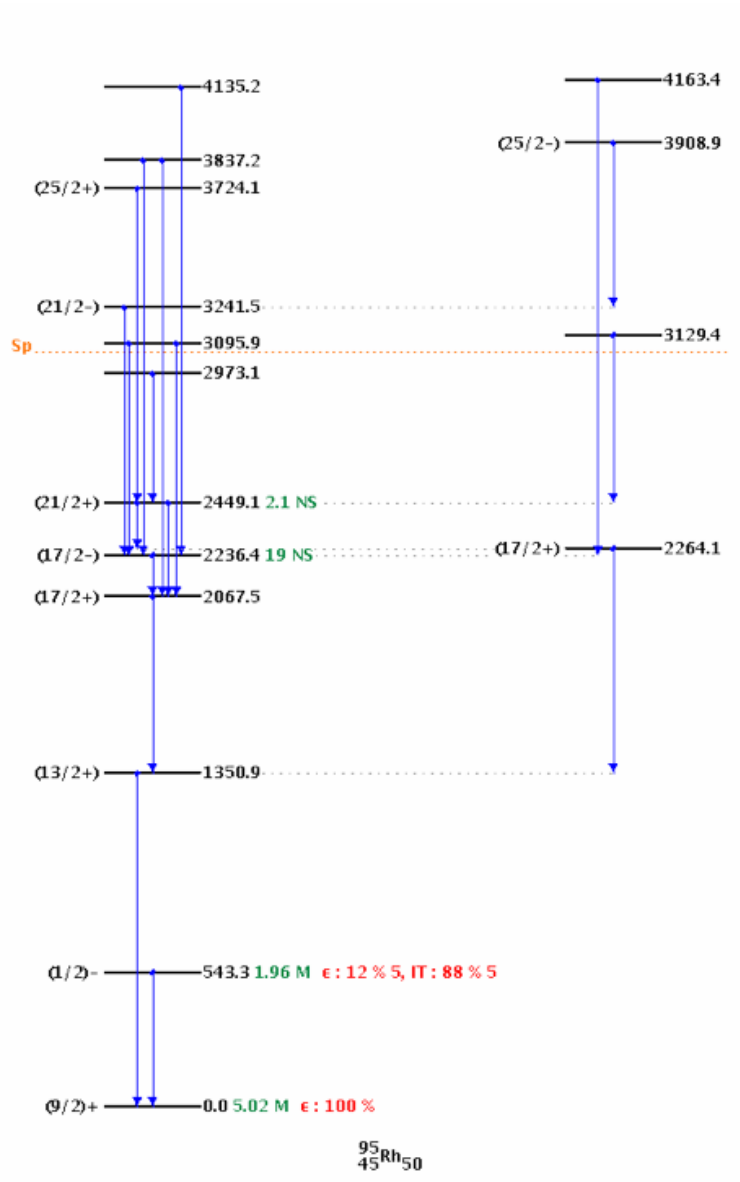


- Empire-specific level density
  - BCS below U_{crt}
  - Fermi gas above U_{crt}

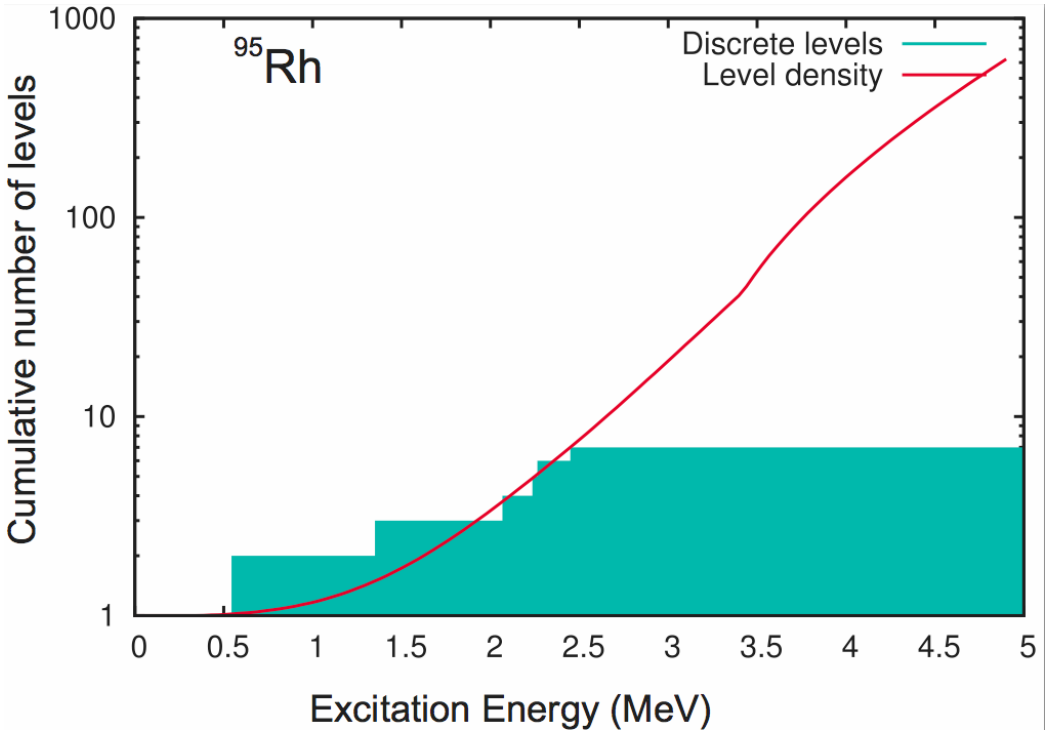


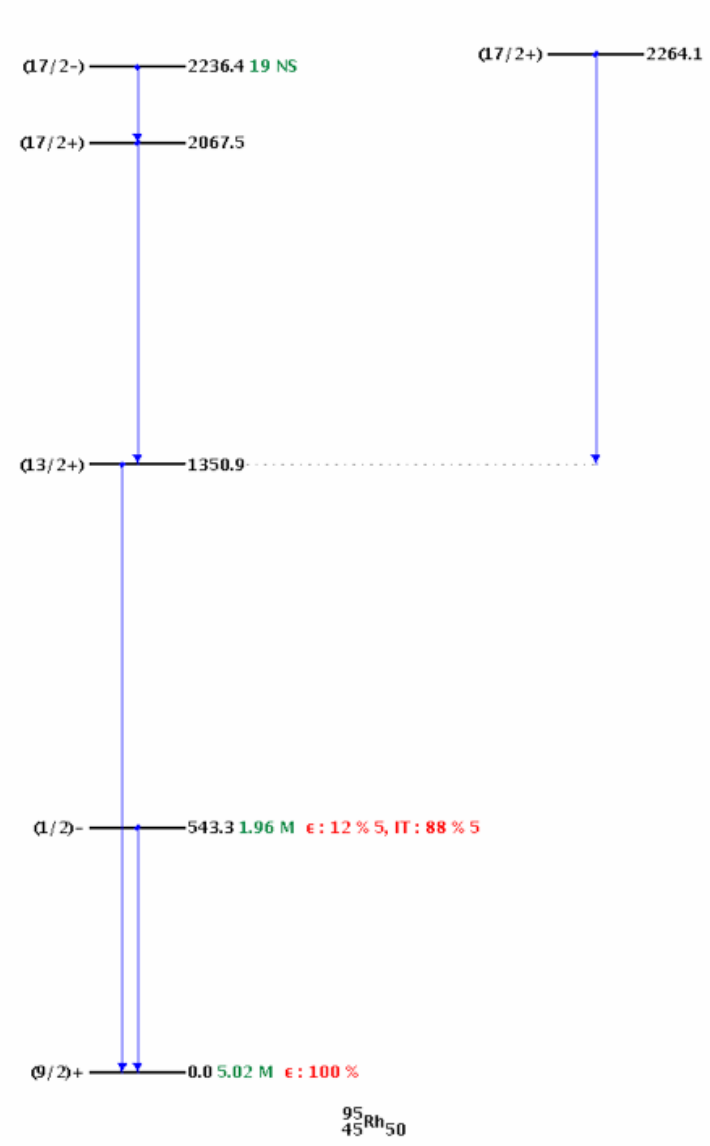
Bad fit: ^{95}Rh - 16 levels



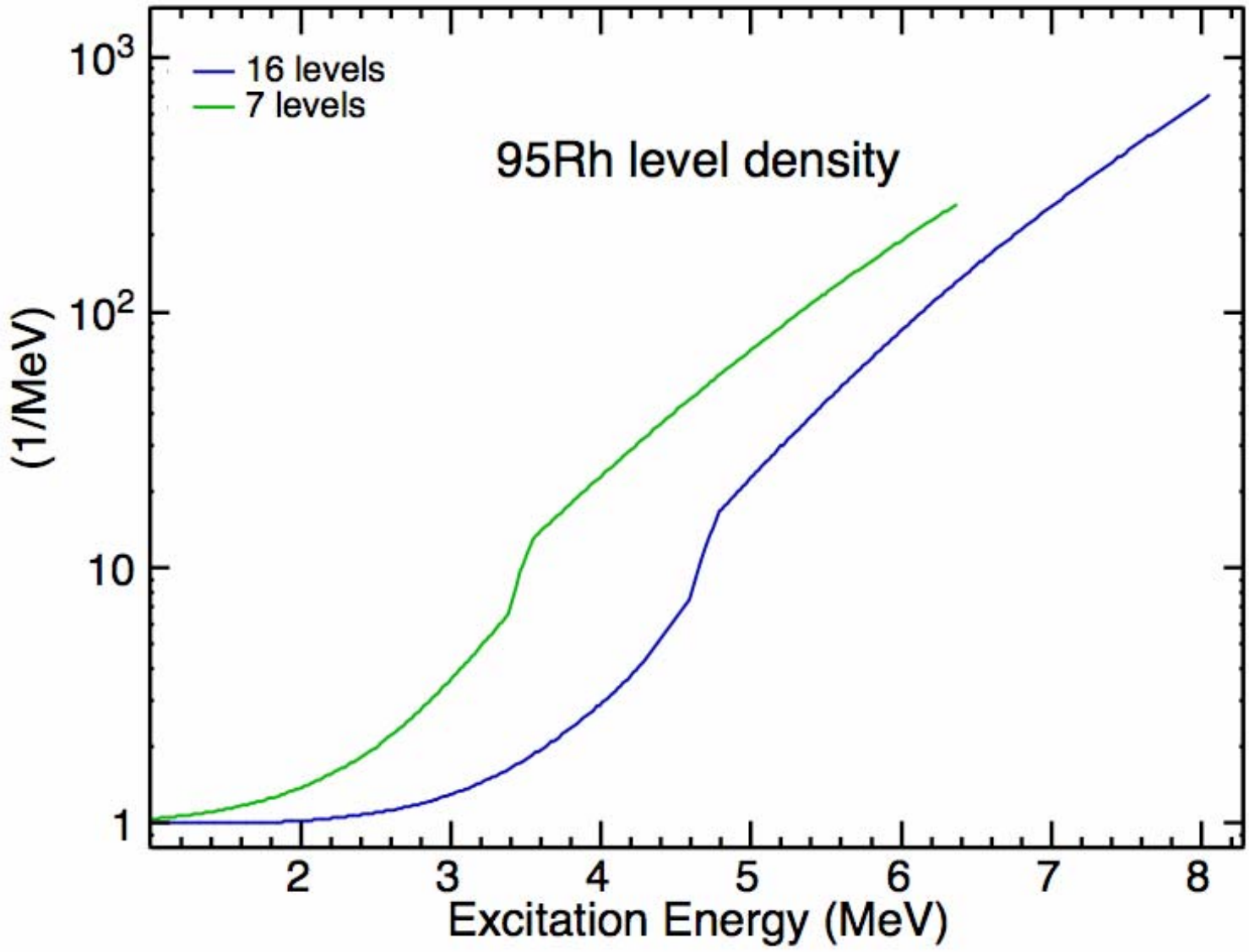


Fixed fit: ^{95}Rh - 7 levels

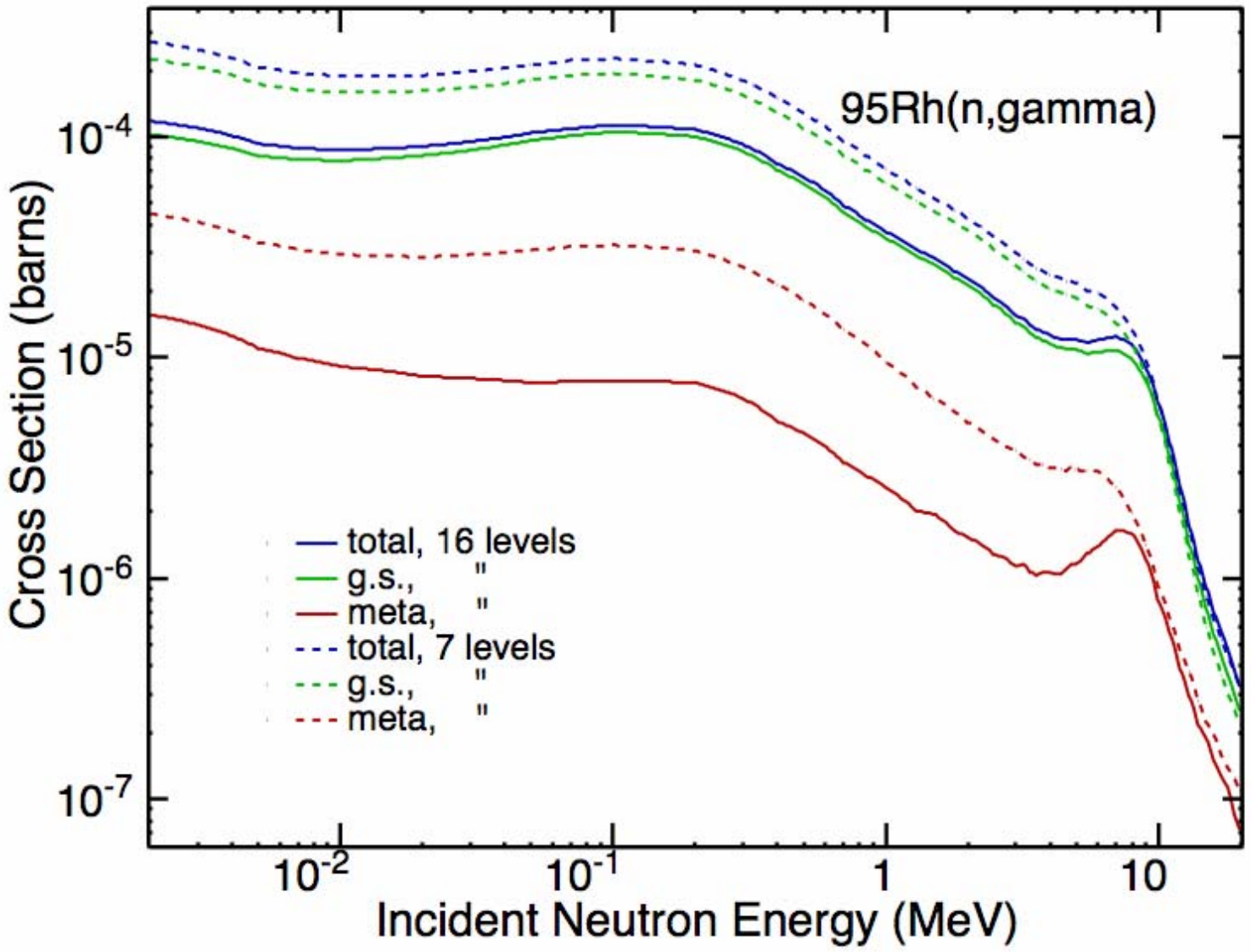




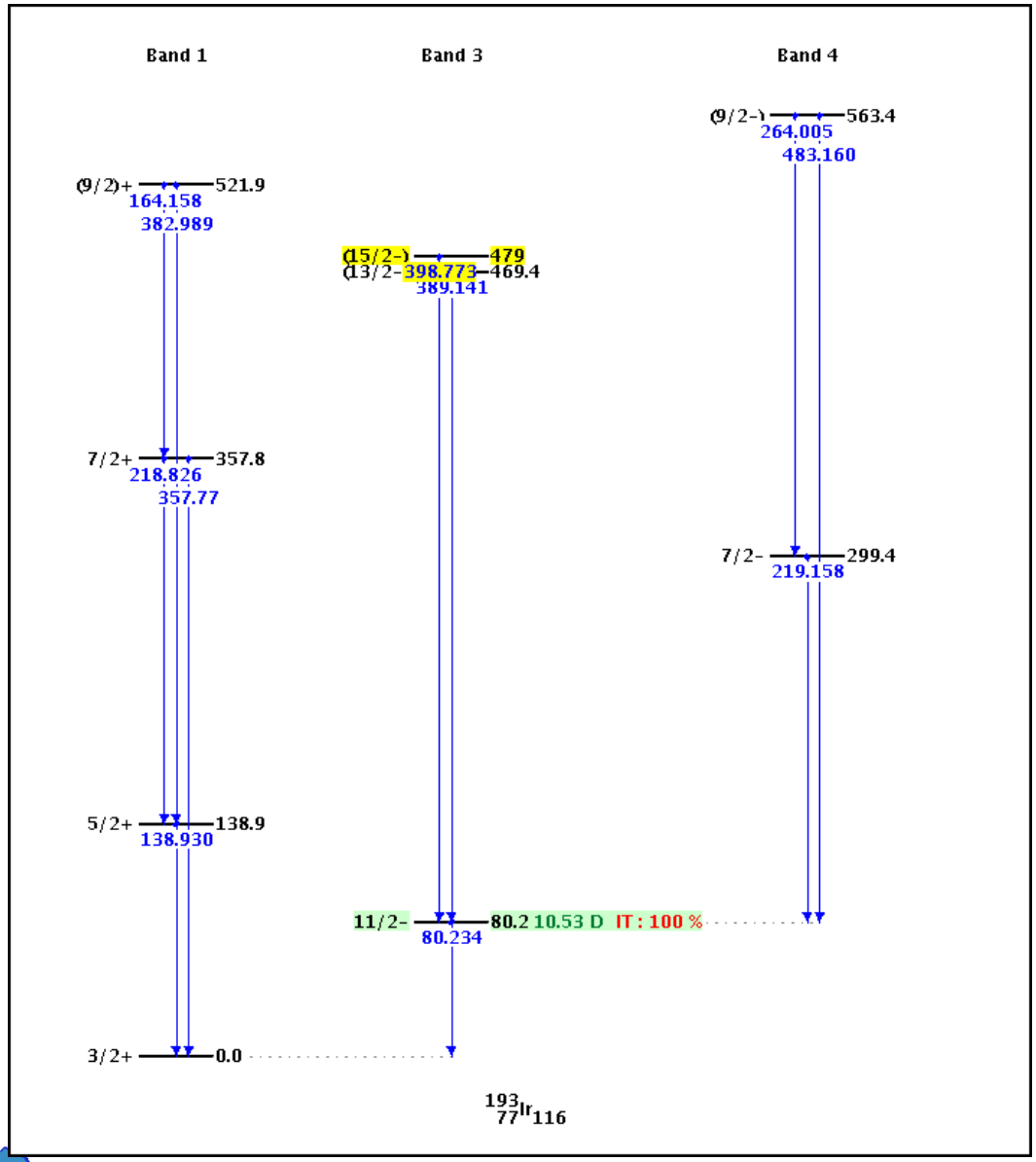
Effect on the level density



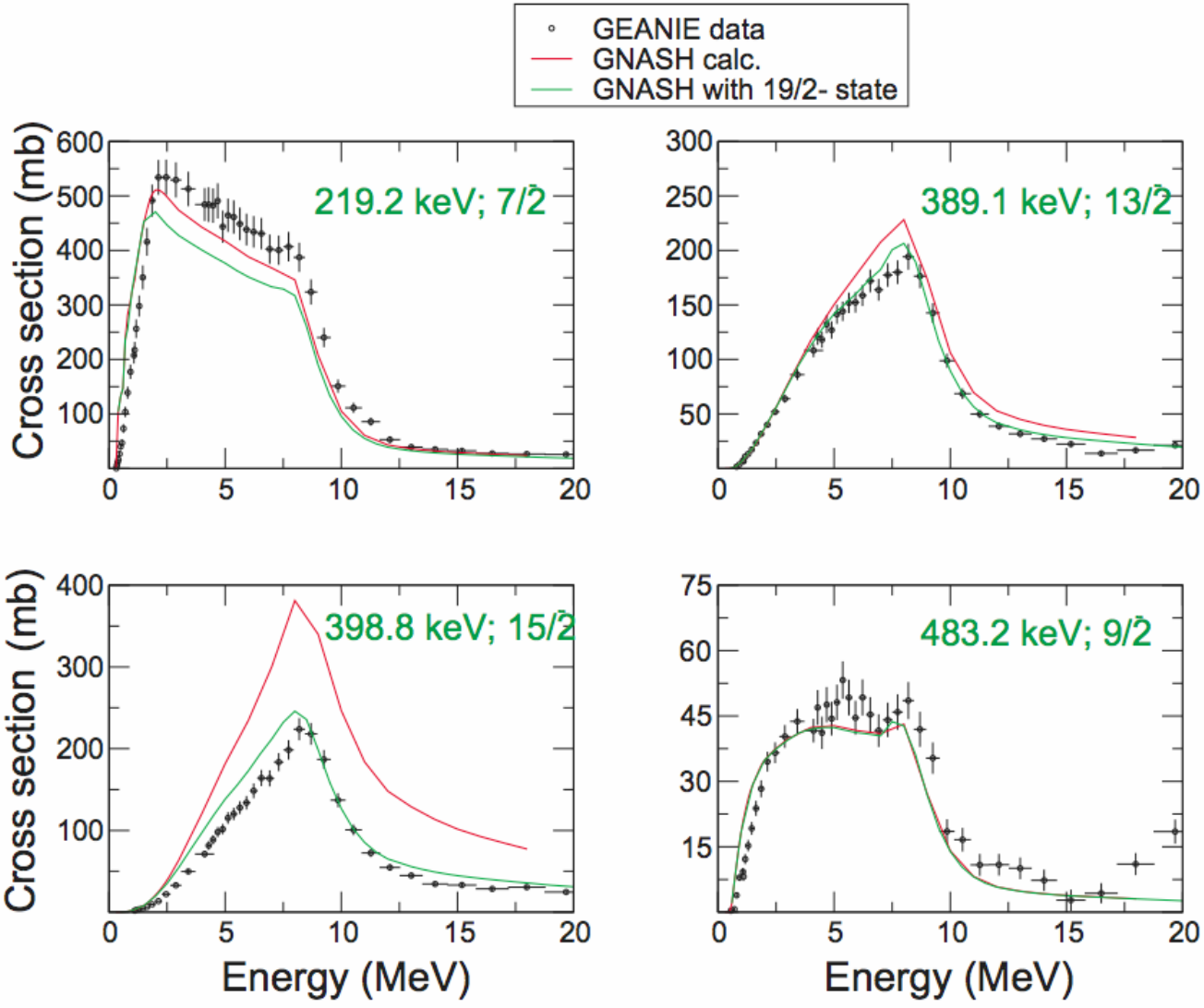
Effect on the cross sections



Spin effect


Band 1
Band 3
Band 4
(9/2)+ 521.9
164.158
382.989
(15/2-) 479
(13/2-) 398.773 469.4
389.141
(9/2-) 563.4
264.005
483.160
7/2+ 357.8
218.826
357.77
7/2- 299.4
219.158
5/2+ 138.9
138.930
11/2- 80.2 10.53 D IT : 100 %
80.234
3/2+ 0.0
193 77 Ir 116

Spin effect



Chadwick, Frankle, Trellue, Talou, Kawano, Young, MacFarlane, Wilkerson, to be published in NDS, Dec. 2007

Conclusions

- What counts most:
  - Completeness of the level scheme
  - Collective bands and their deformations (for deformed nuclei)
  - Masses => Q-values (well known inside the stability valley)
- What counts less (for total cross sections):
  - Level spins, parities and branching ratios
  - ICCs - irrelevant to cross sections; affect γ-spectra only
  - Ground state deformations
- What counts for isomeric cross sections:
  - Branching ratios (decay scheme)
  - Level spins and parities
  - Ground state deformations (spin distribution)