Quelle structure pour la désexcitation nucléaire ?

DE LA RECHERCHE À L'INDUSTRIE

Olivier Litaize, A. Chalil, V. Piau, A. Chebboubi, O. Serot, P. Tamagno

27-28 Juin 2022, Saclay

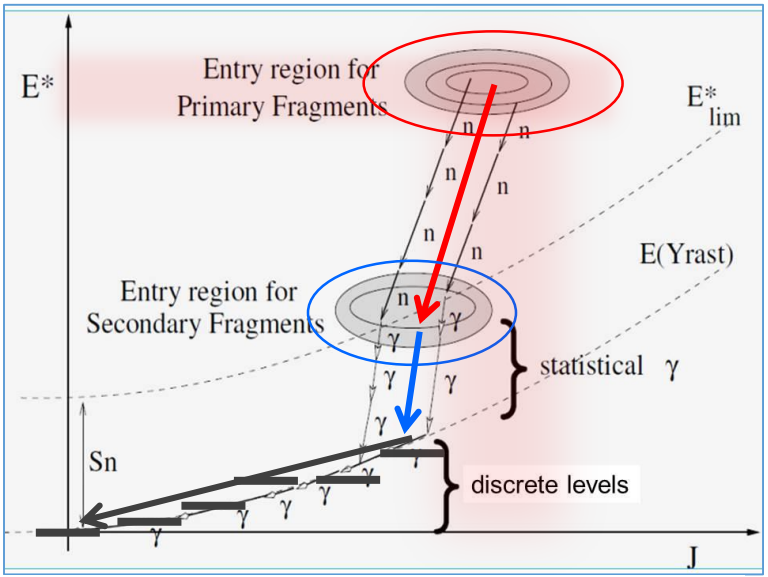
IRESNE / DER / SPRC / LEPh

Institut de recherche sur les systèmes nucléaires pour la production d'énergie bas carbone

- Désexciter un noyau: d'accord ! Mais comment ?
- Quelles données de structure pour la désexcitation nucléaire?
- Conclusion

- Désexciter un noyau: d'accord ! Mais comment ?
- Quelles données de structure pour la désexcitation nucléaire?
- Conclusion

❑ Key ingredients for the n/γ/e emission from neutron rich FFs



O. Litaize and O. Serot, Phys. Rev. C82, 054616 (2010)

Excitation energy & total angular momentum sharing for primary FF entry zone estimation

Level density models (in background) !

Neutron transmission coefficients (OMP)
T(l,j) **→ strength of neutron emission (number and energy)**

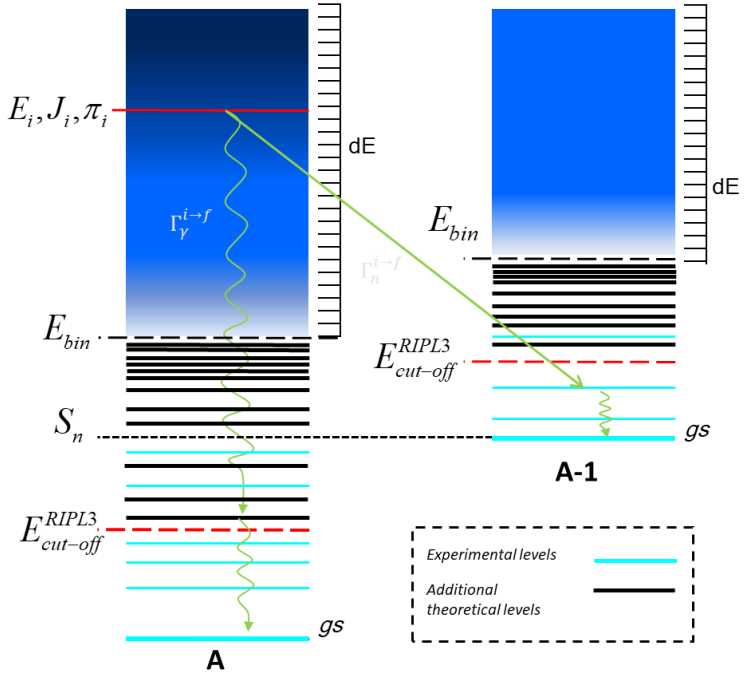
Photon strength functions (PSF)
F(X,L) **→ strength of gamma emission (number and energy)**

Internal conversion coefficients (ICC)
α(X,L) → strength of electron emission

Nuclear structure: (E,J$^{\pi}$),T$_{1/2}$, I$_{\gamma}$, ICC, …
→ strength of gamma/electron emission in the discrete region of the level scheme

Différentes applications

- ❑ Fission fragments (neutron rich nuclei = poorly known)
- ❑ Excited nuclei (n,γ) reactions



⟶ Construire des schémas de niveaux

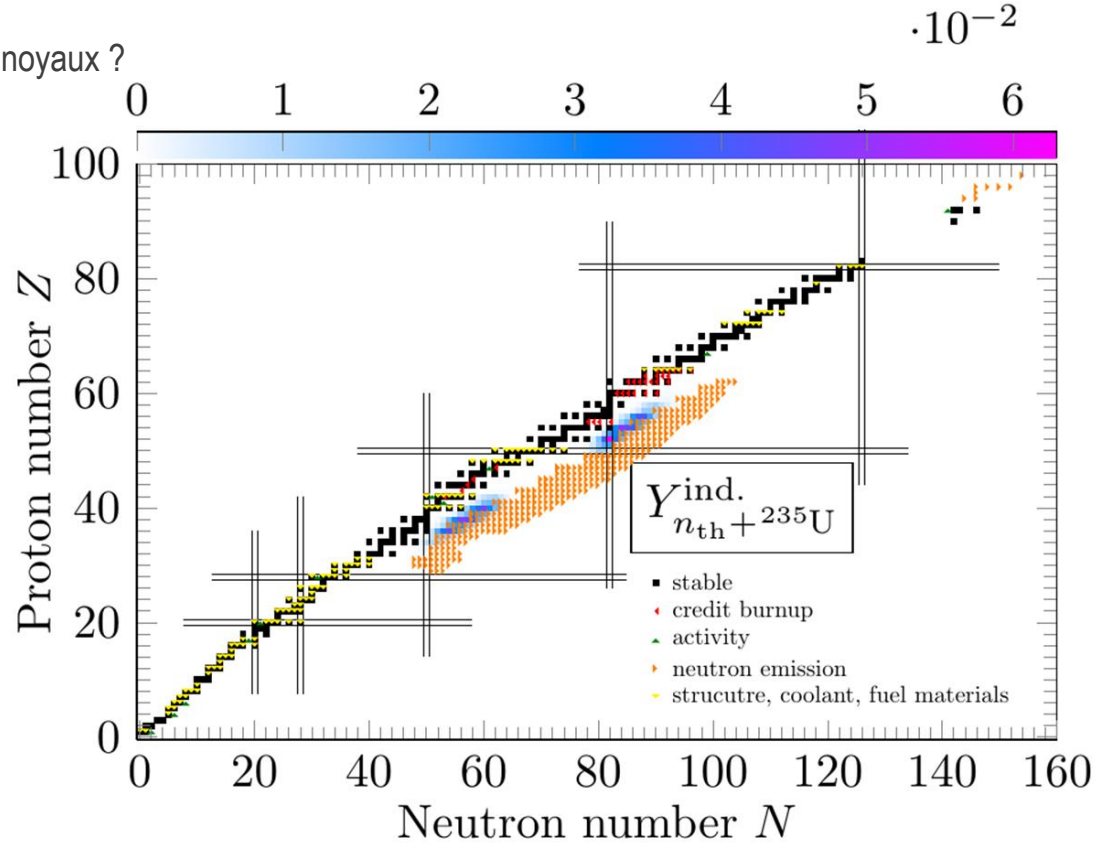
- Désexciter un noyau: d'accord ! Mais comment ?
- Quelles données de structure pour la désexcitation nucléaire?
- Conclusion

Quelles données de structure pour la désexcitation nucléaire?

Des données de structure nucléaire sont nécessaires à la construction du schéma de niveaux des noyaux (à basse énergie). Ce schema sera complété par des modèles (de densités de niveaux, de distributions de spins avec leur cortège de paramètres…).

- RIPL (pour tous les noyaux dont les fragments de fission)
  - Masses
  - Densities
  - **Levels**
  - Fission
  - …
- EGAF (pour les noyaux 'standards' en capture thermique)
  - **Levels**
- ENSDF (pour tous les noyaux)
  - **Levels**

Quels noyaux ?



Quelles données de structure pour la désexcitation nucléaire?

EGAF pour les captures thermiques (n_{th},γ).

Thermal (n,g) Target Nucleus

1H	2H	3HE	6LI	7LI	9BE	10B	12C	13C	14N
16O	17O	19F	20NE	21NE	22NE	23NA	24MG	25MG	26MG
27AL	28SI	29SI	30SI	31P	32S	33S	34S	35CL	36S
36AR	37CL	39K	40AR	40K	40CA	41K	42CA	43CA	44CA
45SC	46CA	46TI	47TI	48CA	48TI	49TI	50TI	50V	50CR
51V	52CR	53CR	54CR	54FE	55MN	56FE	57FE	58FE	58NI
59CO	60NI	61NI	62NI	63CU	64NI	64ZN	65CU	66ZN	67ZN
68ZN	69GA	70GE	71GA	72GE	73GE	74GE	74SE	75AS	76GE
76SE	77SE	78SE	79BR	80SE	81BR	83KR	84SR	85RB	86KR
86SR	87RB	87SR	88SR	89Y	90ZR	91ZR	92ZR	92MO	93NB
94ZR	94MO	95MO	96ZR	96MO	96RU	97MO	98MO	98RU	99RU
100MO	100RU	101RU	102RU	102PD	103RH	104RU	104PD	105PD	106PD
107AG	108PD	109AG	110PD	110CD	111CD	113CD	113IN	115IN	115SN
116SN	117SN	118SN	119SN	120SN	121SB	122SN	122TE	123SB	123TE
124SN	124TE	124XE	125TE	126TE	127I	128TE	128XE	129XE	130TE
130XE	131XE	133CS	134BA	135BA	136XE	136BA	136CE	137BA	138BA
138LA	138CE	139LA	140CE	141PR	142CE	142ND	143ND	144ND	145ND
146ND	147SM	148ND	149SM	150ND	150SM	151EU	152SM	152GD	153EU
154SM	154GD	155GD	157GD	159TB	160DY	161DY	162DY	162ER	163DY
164DY	165HO	166ER	167ER	168ER	168YB	169TM	170ER	170YB	171YB
172YB	173YB	174YB	174HF	175LU	176YB	176LU	176HF	177HF	178HF
179HF	180HF	180W	181TA	182W	183W	184W	184OS	185RE	186W
186OS	187RE	187OS	188OS	189OS	190OS	191IR	192OS	193IR	194PT
195PT	196PT	196HG	197AU	199HG	201HG	203TL	204PB	205TL	206PB
207PB	209BI	232TH	235U	238U					

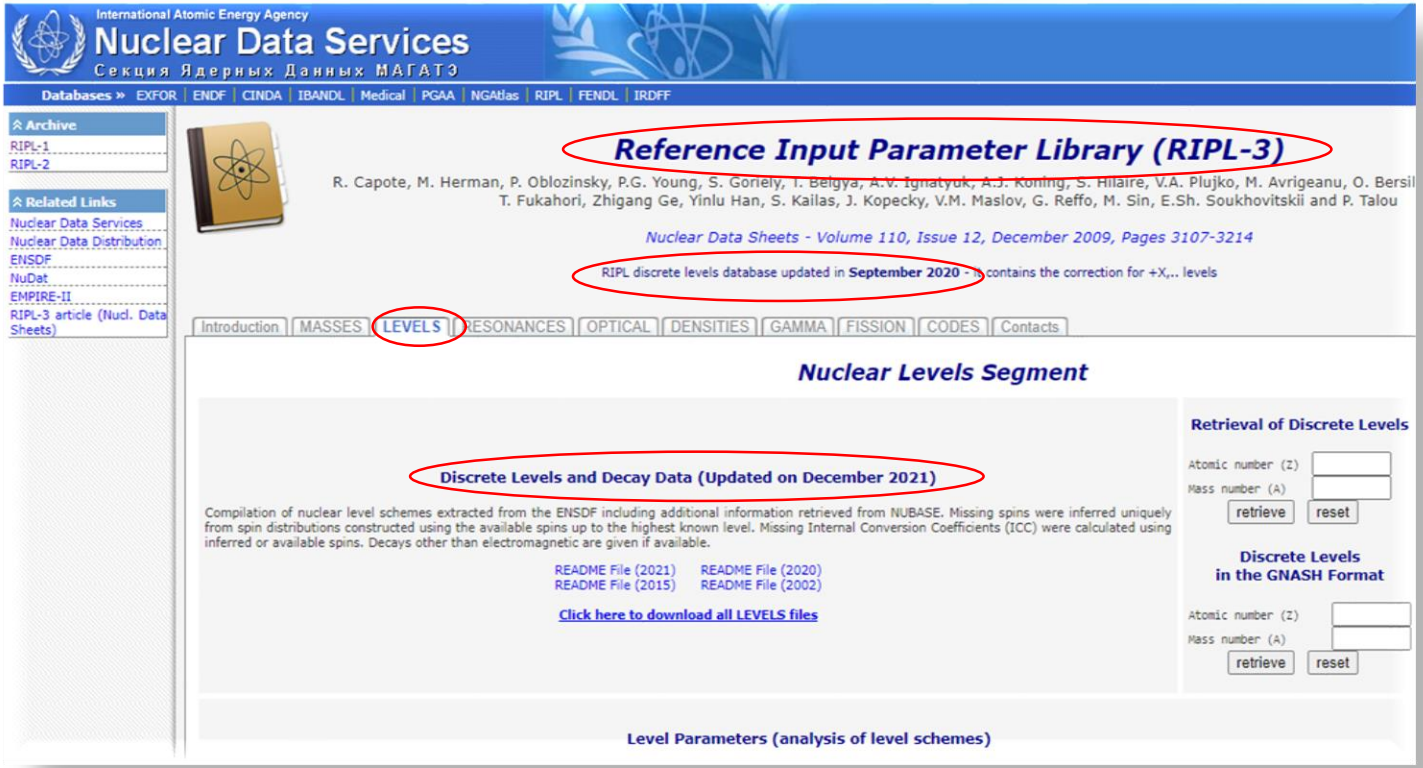
183W	L	6190.76	
183W	G	3943.10	0.281
183W	G	3955.76	0.241
183W	G	3981.77	0.228
183W	G	4014.18	1.112
183W	G	4021.20	0.122
183W	G	4026.24	0.563
183W	G	4034.00	0.118
183W	G	4064.51	0.536
183W	G	4091.91	0.228
183W	G	4132.30	0.188
183W	G	4162.34	0.375
183W	G	4201.18	0.123
183W	G	4209.50	0.002
183W	G	4246.62	1.313
183W	G	4275.60	0.055
183W	G	4289.90	0.109
.			
.			
.			
.			
183W	G	4530.00	0.095
183W	G	4557.60	0.161
183W	G	4562.87	0.804
183W	G	4578.40	0.090
183W	G	4604.80	0.094
183W	G	4634.80	0.456
183W	G	4719.86	0.536
183W	G	4727.90	0.055
183W	G	4755.90	0.013
183W	G	4881.14	0.174
183W	G	5164.50	5.239
183W	G	5256.15	0.375
183W	G	5984.51	0.006
183W	G	6144.23	5.079
183W	G	6190.66	13.936

$^{182}W+n_{th}$

Niveau à S_n

Énergie et intensité de chaque transition

RIPL pour les fragments de fission



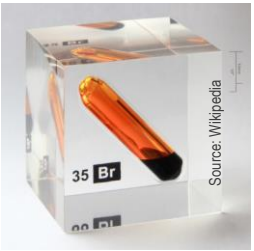
RIPL3-2021

$^{88}_{35}Br_{53}$

S_n = 4.896 MeV

S_p = 11.579 MeV (not used)

```
88Br    88    35     9    14     1     1     4.895600    11.578806
  1   0.000000    1.0 -1  1.634E+01  0                        (1-)  2 =  1.0000E+02 %B-     =  6.5800E+00 %B-N
  2   0.159200   -1.0  0             1                   (1-,2-,3-)  0
                                                 1     0.1592  9.619E-01  1.000E+00  3.960E-02
  3   0.259200   -1.0  0             1                     (1,2,3+)  0
                                                 1     0.2592  1.000E+00  1.000E+00  0.000E+00
  4   0.270100   -1.0  0  5.300E-06  1                   (3-,4-,5-)  1 =  1.0000E+02 %IT
                                                 2     0.1109  6.254E-01  1.000E+00  5.990E-01
  5   0.272700    1.0  0             2                       (1)  0
                                                 2     0.1135  1.770E-01  1.770E-01  0.000E+00
                                                 1     0.2727  8.230E-01  8.230E-01  0.000E+00
  6   0.408700    1.0  0             2                       (1)  0
                                                 2     0.2495  4.565E-01  4.565E-01  0.000E+00
                                                 1     0.4087  5.435E-01  5.435E-01  0.000E+00
  7   0.566000    1.0  0             2                       (1)  0
                                                 5     0.2933  5.076E-01  5.076E-01  0.000E+00
                                                 1     0.5660  4.924E-01  4.924E-01  0.000E+00
  8   1.903720    1.0  1             4                     (1+)  0
                                                 6     1.4950  1.529E-01  1.529E-01  0.000E+00
                                                 3     1.6445  2.676E-01  2.676E-01  0.000E+00
                                                 2     1.7445  2.852E-01  2.852E-01  0.000E+00
                                                 1     1.9037  2.941E-01  2.942E-01  6.210E-04
  9   3.154100    1.0  1             1                     (1+)  0
                                                 3     2.8948  1.000E+00  1.000E+00  0.000E+00
```



RIPL3-2021

9 known levels

Level number

```
 88Br   88   35    9   14    1    1    4.895600   11.578806
   1  0.000000   1.0 -1  1.634E+01  0                    (1-)  2 =  1.0000E+02 %B-     =  6.5800E+00 %B-N
   2  0.159200  -1.0  0             1                (1-,2-,3-)  0
                                          1     0.1592  9.619E-01  1.000E+00  3.960E-02
   3  0.259200  -1.0  0             1                 (1,2,3+)  0
                                          1     0.2592  1.000E+00  1.000E+00  0.000E+00
   4  0.270100  -1.0  0  5.300E-06  1              (3-,4-,5-)  1 =  1.0000E+02 %IT
                                          2     0.1109  6.254E-01  1.000E+00  5.990E-01
   5  0.272700   1.0  0             2                   (1)  0
                                          2     0.1135  1.770E-01  1.770E-01  0.000E+00
                                          1     0.2727  8.230E-01  8.230E-01  0.000E+00
   6  0.408700   1.0  0             2                   (1)  0
                                          2     0.2495  4.565E-01  4.565E-01  0.000E+00
                                          1     0.4087  5.435E-01  5.435E-01  0.000E+00
   7  0.566000   1.0  0             2                   (1)  0
                                          5     0.2933  5.076E-01  5.076E-01  0.000E+00
                                          1     0.5660  4.924E-01  4.924E-01  0.000E+00
   8  1.903720   1.0  1             4                  (1+)  0
                                          6     1.4950  1.529E-01  1.529E-01  0.000E+00
                                          3     1.6445  2.676E-01  2.676E-01  0.000E+00
                                          2     1.7445  2.852E-01  2.852E-01  0.000E+00
                                          1     1.9037  2.941E-01  2.942E-01  6.210E-04
   9  3.154100   1.0  1             1                  (1+)  0
                                          3     2.8948  1.000E+00  1.000E+00  0.000E+00
```

RIPL3-2021

14 transitions

```
88Br   88   35    9   14    1    1    4.895600   11.578806
  1   0.000000   1.0 -1  1.634E+01  0                    (1-)  2 =  1.0000E+02 %B-     =  6.5800E+00 %B-N
  2   0.159200  -1.0  0              1                (1-,2-,3-)  0
                                                  1  0.1592  9.619E-01  1.000E+00  3.960E-02
  3   0.259200  -1.0  0              1               (1,2,3+)  0
                                                  1  0.2592  1.000E+00  1.000E+00  0.000E+00
  4   0.270100  -1.0  0  5.300E-06  1              (3-,4-,5-)  1 =  1.0000E+02 %IT
                                                  2  0.1109  6.254E-01  1.000E+00  5.990E-01
  5   0.272700   1.0  0              2                   (1)  0
                                                  2  0.1135  1.770E-01  1.770E-01  0.000E+00
                                                  1  0.2727  8.230E-01  8.230E-01  0.000E+00
  6   0.408700   1.0  0              2                   (1)  0
                                                  2  0.2495  4.565E-01  4.565E-01  0.000E+00
                                                  1  0.4087  5.435E-01  5.435E-01  0.000E+00
  7   0.566000   1.0  0              2                   (1)  0
                                                  5  0.2933  5.076E-01  5.076E-01  0.000E+00
                                                  1  0.5660  4.924E-01  4.924E-01  0.000E+00
  8   1.903720   1.0  1              4                  (1+)  0
                                                  6  1.4950  1.529E-01  1.529E-01  0.000E+00
                                                  3  1.6445  2.676E-01  2.676E-01  0.000E+00
                                                  2  1.7445  2.852E-01  2.852E-01  0.000E+00
                                                  1  1.9037  2.941E-01  2.942E-01  6.210E-04
  9   3.154100   1.0  1              1                  (1+)  0
                                                  3  2.8948  1.000E+00  1.000E+00  0.000E+00
```

Number of transitions

Reached level (1=g.s.)

RIPL3–2021

Only 1 level is fully known (the ground state !)

```
88Br   88   35     9   14     1    1    4.895600   11.578806
  1  0.000000   1.0 -1  1.634E+01  0                    (1-)  2 =  1.0000E+02 %B-     =  6.5800E+00 %B-N
  2  0.159200  -1.0  0                1                (1-,2-,3-)  0
                                                 1     0.1592  9.619E-01  1.000E+00  3.960E-02
     .259200  -1.0  0                1                 (1,2,3+)  0
                                                 1     0.2592  1.000E+00  1.000E+00  0.000E+00
     .270100  -1.0  0  5.300E-06     1                (3-,4-,5-)  1 =  1.0000E+02 %IT
                                                 2     0.1109  6.254E-01  1.000E+00  5.990E-01
  5          1.0  0                2                    (1)  0
                                                 2     0.1135  1.770E-01  1.770E-01  0.000E+00
                                                 1     0.2727  8.230E-01  8.230E-01  0.000E+00
  6  0.408700  1.0  0                2                    (1)  0
                                                 2     0.2495  4.565E-01  4.565E-01  0.000E+00
                                                 1     0.4087  5.435E-01  5.435E-01  0.000E+00
  7  0.566000  1                   2                    (1)  0
                                                 5     0.2933  5.076E-01  5.076E-01  0.000E+00
                                                 1     0.5660  4.924E-01  4.924E-01  0.000E+00
  8  1.903720  1.0  1                4                   (1+)  0
                                                 6     1.4950  1.529E-01  1.529E-01  0.000E+00
                                                 3     1.6445  2.676E-01  2.676E-01  0.000E+00
                                                 2     1.7445  2.852E-01  2.852E-01  0.000E+00
                                                 1     1.9037  2.941E-01  2.942E-01  6.210E-04
  9  3.154100  1.0  1                1                   (1+)  0
                                                 3     2.8948  1.000E+00  1.000E+00  0.000E+00
```

Level 1 (g. s.)

Energy (0.0 MeV)

J^π (1^-)

$T_{1/2}$ (16.34s)

J^π (1^-)

$T_{1/2}$ (16.29s)

RIPL3–2015

RIPL3-2021

Second level (first excited) at 159.2 keV ...

... has unknown spin/parity

This one could be 1⁻, 2⁻ or 3⁻

as well as 3rd and 4th levels...

These one could be 1 but which parity ?

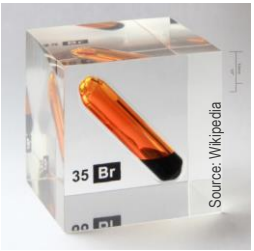
```
88Br    88    35     9    14     1     1     4.895600    11.578806
  1   0.000000    1.0 -1   1.634E+01  0                      (1-)   2 =  1                    0 %B-N
  2   0.159200   -1.0   0              1                    (1-,2-,3-)   0
                                                                  01  1.000E+00  3.960E-02
  3   0.259200   -1.0   0                                          0
                                                        1     0.2592  1.000E+00  1.000E+00  0.000E+00
  4   0.270100   -1.0   0   5.300E-06  1                        (3-,4-,5-)   1 =  1.0000E+02 %IT
                                                        2     0.1109  6.254E-01  1.000E+00  5.990E-01
  5   0.272700    1.0   0              2                          (1)   0
                                                        2     0.1135  1.770E-01  1.770E-01  0.000E+00
                                                        1     0.2727  8.230E-01  8.230E-01  0.000E+00
  6   0.408700    1.0   0              2                          (1)   0
                                                        2     0.2495  4.565E-01  4.565E-01  0.000E+00
                                                        1     0.4087  5.435E-01  5.435E-01  0.000E+00
  7   0.566000    1.0   0              2                          (1)   0
                                                        5     0.2933  5.076E-01  5.076E-01  0.000E+00
                                                        1     0.5660  4.924E-01  4.924E-01  0.000E+00
  8   1.903720    1.0   1              4                        (1+)   0
                                                        6     1.4950  1.529E-01  1.529E-01  0.000E+00
                                                        3     1.6445  2.676E-01  2.676E-01  0.000E+00
                                                        2     1.7445  2.852E-01  2.852E-01  0.000E+00
                                                        1     1.9037  2.941E-01  2.942E-01  6.210E-04
  9   3.154100    1.0   1              1                        (1+)   0
                                                        3     2.8948  1.000E+00  1.000E+00  0.000E+00
```

RIPL3-2021

$$I_{em} = I_\gamma + I_{e-} = I_\gamma(1+\alpha)$$

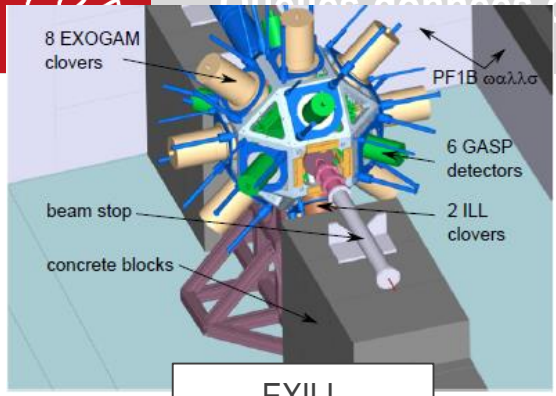
I_γ I_{em} α (ICC)

```
88Br   88   35    9   14    1    1    4.895600   11.578806
  1   0.000000   1.0 -1  1.634E+01  0                    (1-)  2 =  1.0000E+02 %B-     =  6.5800E+00 %B-N
  2   0.159200  -1.0  0             1                (1-,2-,3-)  0
                                          1     0.1592  9.619E-01  1.000E+00  3.960E-02
  3   0.259200  -1.0  0             1                (1,2,3+)  0
                                          1     0.2592  1.000E+00  1.000E+00  0.000E+00
  4   0.270100  -1.0  0  5.300E-06  1                (3-,4-,5-)  1 =  1.0000E+02 %IT
                                          2     0.1109  6.254E-01  1.000E+00  5.990E-01
  5   0.272700   1.0  0             2                   (1)  0
                                          2     0.1135  1.770E-01  1.770E-01  0.000E+00
                                          1     0.2727  8.230E-01  8.230E-01  0.000E+00
  6   0.408700   1.0  0             2                   (1)  0
                                          2     0.2495  4.565E-01  4.565E-01  0.000E+00
                                          1     0.4087  5.435E-01  5.435E-01  0.000E+00
  7   0.566000   1.0  0             2                   (1)  0
                                          5     0.2933  5.076E-01  5.076E-01  0.000E+00
                                          1     0.5660  4.924E-01  4.924E-01  0.000E+00
  8   1.903720   1.0  1             4                  (1+)  0
                                          6     1.4950  1.529E-01  1.529E-01  0.000E+00
                                          3     1.6445  2.676E-01  2.676E-01  0.000E+00
                                          2     1.7445  2.852E-01  2.852E-01  0.000E+00
                                          1     1.9037  2.941E-01  2.942E-01  6.210E-04
  9   3.154100   1.0  1             1                  (1+)  0
                                          3     2.8948  1.000E+00  1.000E+00  0.000E+00
```



Les ICC sont recalculés en amont pour chaque XL et chaque sous couche électronique (Brlcc code): $ICC_{XL}^{K,Li,Mi...}$
Lorsque ICC est donné on determine les mixing ratio et on sélectionne une multipolarité.

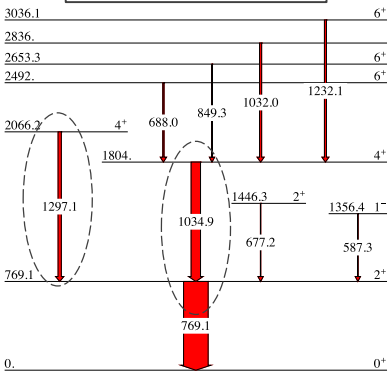
Quelles données de structure pour la désexcitation nucléaire?



10^8 collimated n.cm^{-2}.s^{-1}
10^5 fissions.s^{-1}
8 EXOGAM clovers
6 GASP HpGe
2 ILL clovers
BGO anti-compton

Influence du schéma de niveaux

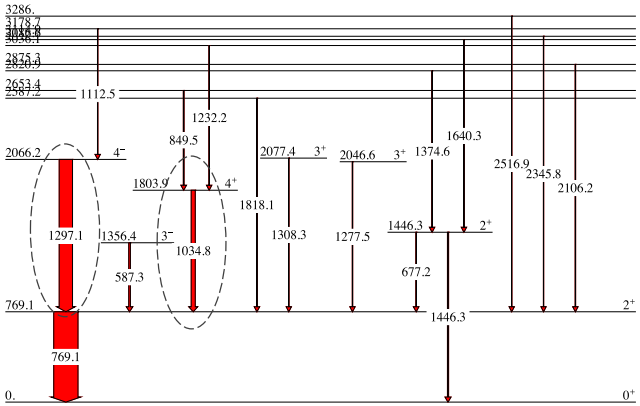
EXILL (EXOGAM@ILL)



Gamma-ray cascade in ^{92}Kr according to EXILL data [4]

(in coincidence with ^{142}Ba)

FIFRELIN / RIPL-3 (2009)



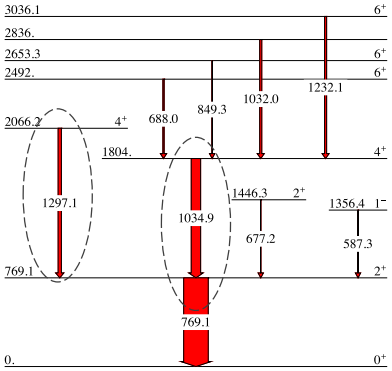
Gamma-ray cascade in ^{92}Kr according to FIFRELIN

(old RIPL-3 version, without low intensity transitions, in coincidence with ^{142}Ba)

Materna et al., EPJ Web of Conferences 146, 04041 (2017)

Influence du schéma de niveaux

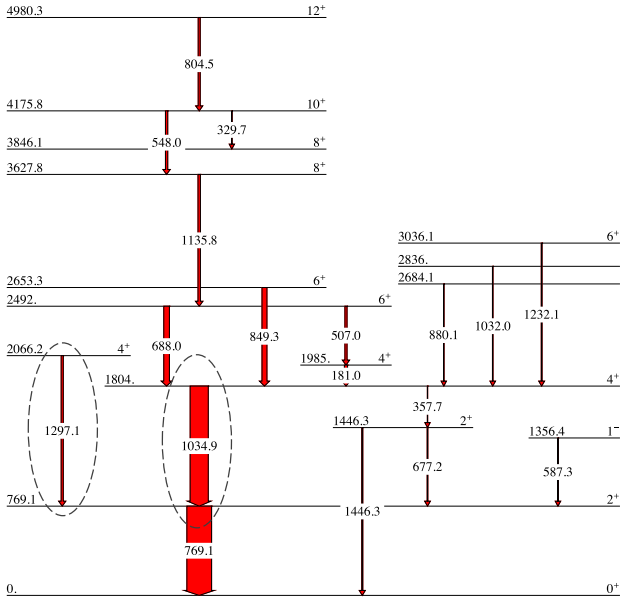
EXILL (EXOGAM@ILL)



Gamma-ray cascade in ^{92}Kr according to EXILL data [4]

(in coincidence with ^{142}Ba)

FIFRELIN / RIPL-3 (2015)



Gamma-ray cascade in ^{92}Kr according to FIFRELIN [4]

(new RIPL-3 version, without low intensity transitions, in coincidence with ^{142}Ba)

Materna et al., EPJ Web of Conferences 146, 04041 (2017)

^{139}Xe

Last 'known' level

23 1.684040 2.5 1 5 c (5/2,7/2,9/2) 0

9	0.6757	2.481E-02	2.492E-02	4.700E-03
8	1.0056	1.613E-01	1.619E-01	4.280E-03
4	1.1245	5.582E-02	5.600E-02	3.230E-03
3	1.6525	1.364E-01	1.365E-01	6.300E-04
2	1.6615	6.202E-01	6.206E-01	6.340E-04

First 'unknown' level

24 1.771430 **-1.0 0** 4

23	0.0874	1.754E-01	1.754E-01	**0.000E+00**
9	0.7633	3.509E-01	3.509E-01	**0.000E+00**
6	1.1469	3.158E-01	3.158E-01	**0.000E+00**
4	1.2122	1.579E-01	1.579E-01	**0.000E+00**

24ième niveau : - Spin et parité inconnus
- Intensités relatives connues (sans électrons) vers les niveaux 23, 9, 6 et 4.

Si ce niveau 24 est alimenté lors de la cascade, la simulation peut se poursuivre ($E\gamma$ connus) mais ni le type ni la multipolarité du rayonnement ne le sont : échantillonnage du spin et de la parité à partir de lois de densités de niveaux $\rho(E,J,\pi)$.

Impacte :

- Les correlations angulaires
- L'alimentation de ce niveau par les niveaux supérieurs
- L'alimentation de ce niveau par le noyau père via l'émission neutron

Neutron rich nuclei (pre-neutron)

139 Xe — *4.3 10^{-2}*

number of levels:	52
number of gamma-rays:	116
number of levels in a complete level scheme:	23
number of levels with assigned spin and parity:	1

140 Xe — *5.0 10^{-2}*

number of levels:	35
number of gamma-rays:	66
number of levels in a complete level scheme:	10
number of levels with assigned spin and parity:	5

141 Xe — *3.4 10^{-2}*

number of levels:	19
number of gamma-rays:	25
number of levels in a complete level scheme:	1
number of levels with assigned spin and parity:	1

142 Xe — *2.0 10^{-2}*

number of levels:	23
number of gamma-rays:	34
number of levels in a complete level scheme:	10
number of levels with assigned spin and parity:	2

143 Xe — *6.5 10^{-3}*

number of levels:	9
number of gamma-rays:	10
number of levels in a complete level scheme:	1
number of levels with assigned spin and parity:	1
neutron separation energy:	3.044552 [MeV]
proton separation energy:	12.688884 [MeV]

neutron emission

103Nb		$2.1\ 10^{-2}$
number of levels:	48	
number of gamma-rays:	94	
number of levels in a complete level scheme:	17	
number of levels with assigned spin and parity:	1	
neutron separation energy:	6.801721 [MeV]	
proton separation energy:	10.736212 [MeV]	

104Nb		$1.7\ 10^{-2}$
number of levels:	10	
number of gamma-rays:	14	
number of levels in a complete level scheme:	**1**	
number of levels with assigned spin and parity:	1	
neutron separation energy:	4.853647 [MeV]	
proton separation energy:	11.290974 [MeV]	

neutron emission

105Nb		$1.6\ 10^{-2}$
number of levels:	25	
number of gamma-rays:	54	
number of levels in a complete level scheme:	16	
number of levels with assigned spin and parity:	1	
neutron separation energy:	6.175868 [MeV]	
proton separation energy:	11.486858 [MeV]	

Z	Symbol	Mass range
35	Br	84,86,88-90
36	Kr	93
37	Rb	93-95
38	Sr	100
39	Y	102
40	Zr	103
41	Nb	102,104,105
51	Sb	133
52	Te	137
53	I	136-139
54	Xe	141
55	Cs	144
56	Ba	147

Fragments de fission primaires ($U235(n_{th},f)$) (rendement > 0.5%)

Recent improvements performed at ILL

- neutron rich krypton isotopes $^{90-95}$**Kr** located in the low Z boundary of A~100
- odd-mass neutron rich bromine isotopes $^{87-93}$**Br**

Reygadas, PhD 2021

La physique sous-jacente à l'émission de particules lors du processus de fission nécessite une meilleure connaissance de la structure nucléaire.

Composante prompte :

- Fragments de fission primaires
  = noyaux riches en neutrons
  = à l'origine du 'spectre de neutron de fission' en réacteur (PFNS)
  = avant β-

- Fragments de fission secondaires
  = toujours '*un peu*' riches en neutrons
  = à l'origine du spectre de gamma de fission en réacteur (PFGS)
  = toujours avant β-

Composante retardée :

- Voir présentation O. serot

Fragments de fission primaires (U235(n_{th},f)) - rendement > 0.5%

Z	Symbol	Mass range
35	Br	84,86,88-90
36	Kr	93
37	Rb	93-95
38	Sr	100
39	Y	102
40	Zr	103
41	Nb	102,104,105
51	Sb	133
52	Te	137
53	I	136-139
54	Xe	141
55	Cs	144
56	Ba	147

IRESNE** | **DER** | **SPRC** | **LEPh

Institut de recherche sur les systèmes nucléaires pour la production d'énergie bas carbone

Commissariat à l'énergie atomique et aux énergies alternatives - www.cea.fr

$^{92}_{36}Kr$

92Kr 92 36 37 62 16 1 5.546000 14.570001
0.0 1 1.84E+00 0 u 0+ 2 = 100.0000 %B-
2.0 1 1 u 2(+) 0
1 0.769 9.991E-01 1.000E+00 9.285E-04
3.0 -1 1 g 0
2 0.587 9.994E-01 1.000E+00 6.473E-04
4 1.446300 2.0 1 2 c (1,2+) 0
2 0.678 3.546E-01 3.551E-01 1.303E-03
1 1.447 6.448E-01 6.449E-01 1.971E-04
5 1.803900 4.0 1 2 u 4(+) 0
4 0.358 1.767E-02 1.784E-02 9.289E-03
2 1.035 9.818E-01 9.822E-01 4.051E-04
6 1.985000 2.0 1 1 g 0
5 0.181 9.066E-01 1.000E+00 1.031E-01
7 1.994200 0.0 1 0 n 0
8 2.019400 1.0 1 2 g 0
4 0.573 3.823E-01 3.831E-01 2.090E-03
2 1.250 6.167E-01 6.169E-01 2.670E-04
9 2.046600 3.0 1 1 g 0
50E-04
10 2.066200 4.0 -1 18E-04
11 2.077400 3.0 1
4 0.631 6.013E-02 6.023E-02 1.586E-03
2 1.309 9.395E-01 9.398E-01 2.425E-04
12 2.153200 1.0 -1 2 c (1,2+) 0
2 1.384 8.928E-01 8.929E-01 1.056E-04
1 2.153 1.071E-01 1.071E-01 0.000E+00
13 2.164300 2.0 -1 2 g 0
4 0.718 4.443E-01 4.445E-01 4.120E-04
2 1.395 5.554E-01 5.555E-01 1.042E-04
14 2.350800 2.0 1 3 c (1,2+) 0
3 0.994 1.036E-01 1.036E-01 2.110E-04
2 1.582 3.782E-01 3.782E-01 0.000E+00
1 2.351 5.181E-01 5.181E-01 0.000E+00
15 2.471700 2.0 -1 2 g 0
4 1.026 6.279E-02 6.280E-02 1.800E-04
2 1.702 9.372E-01 9.372E-01 0.000E+00
16 2.492000 6.0 -1 2 g 0
6 0.507 0.000E+00 0.000E+00 5.469E-02
5 0.688 0.000E+00 0.000E+00 2.804E-03

RIPL-3 (2009)

Sn + 320 keV

levels + 6

transitions + 7

Third level from 3⁻ to 1⁻

and so on…

92Kr 92 36 43 69 14 2 5.866670 14.951000
1 0.000000 0.0 1 1.840E+00 0 u 0+ 2 = 1.0000E+02 %B-
2 0.769100 2.0 1 5.000E-12 1 u 2+ 0
1 0.769 9.991E-01 1.000E+00 9.460E-04
3 1.356400 1.0 -1 1 g 0
2 0.587 9.993E-01 1.000E+00 7.000E-04
4 1.446300 2.0 1 2 c (1,2+) 0
2 0.678 3.546E-01 3.550E-01 1.200E-03
1 1.447 6.448E-01 6.450E-01 2.880E-04
5 1.804000 4.0 1 2 u 4+ 0
4 0.358 1.767E-02 1.785E-02 9.900E-03
2 1.035 9.817E-01 9.822E-01 4.730E-04
000 4.0 1 1 u (4+) 0
5 0.181 9.434E-01 1.000E+00 6.000E-02
200 2.0 -1 0 n 0
8 2.019400 2.0 -1 2 g 0
4 0.573 3.826E-01 3.828E-01 7.400E-04
2 1.250 6.170E-01 6.172E-01 2.230E-04
9 2.046600 0.0 -1 1 g 0
2
10 2.066200 4.0 1
2
11 2.077400 1.0 1
4 0.631 6.013E-02 6.022E-02 1.440E-03
2 1.309 9.395E-01 9.398E-01 2.960E-04
12 2.153200 1.0 1 2 c (1,2+) 0
2 1.384 8.926E-01 8.928E-01 2.840E-04
1 2.153 1.071E-01 1.072E-01 4.380E-04
13 2.164300 3.0 1 2 g 0
4 0.718 4.442E-01 4.446E-01 1.040E-03
2 1.395 5.552E-01 5.554E-01 2.830E-04
14 2.350800 2.0 1 3 c (1,2+) 0
3 0.994 1.036E-01 1.036E-01 2.250E-04
2 1.582 3.781E-01 3.782E-01 2.910E-04
1 2.351 5.179E-01 5.182E-01 5.680E-04
15 2.471700 -1.0 0 2 0
4 1.026 6.279E-02 6.279E-02 0.000E+00
2 1.702 9.372E-01 9.372E-01 0.000E+00
16 2.492000 6.0 1 2 (6+) 0
6 0.507 0.000E+00 0.000E+00 3.230E-03
5 0.688 0.000E+00 0.000E+00 1.330E-03

RIPL-3 (2015)