# CRL (correlation) for Detection of Fission Fragments in Coincidence

(N. Otsuka, 2012-06-11. CP-D/748)

The parameter code `CRL` (correlation) and `COR` (angular correlation) have been often used to compile quantities labeled "correlation" by authors without deep consideration of their real definition. Discussion on this problem is seen in WP2001-7. The code `COR` is now obsolete, and now used in only one entry (O0011). All `DA/CRL` quantity codes are also obsolete as reminded in Memo CP-D/429. Some `CRL` quantity codes are not obsolete, but I found many of them can be replaced with more appropriate existing quantity code. Corrections are proposed at the end of this memo. We also should remember that `CRL` was recently discussed as a typical encrypted EXFOR code [1] and should remove and avoid it.

An open question about `CRL` for me is coding of fission yields FY $(A_L,Z_L;A_H,Z_H)$ measured by J.H. Hamilton (Vanderbilt Univ., Nashville) et al. by detection of prompt gammas by gamma sphere. All `CRL` data sets in are 1 (EXFOR 13599, 13648, 13698, 13747, 13749, 13751, 13807) are from this group. To distinguish from normal fission yields FY(A,Z), e.g.,

```
(98-CF-252(0,F)ELEM/MASS,IND,FY)
```

Hamilton's yield FY$(A_L,Z_L,A_H,Z_H)$ has been coded with

```
(98-CF-252(0,F)ELEM/MASS,IND,FY/CRL,LF/HF)
```

with $A_L$ and $A_H$ under `MASS1` and `MASS2`, and $Z_L$ and $Z_H$ under `ELEM1` and `ELEM2`. A coding sample (EXFOR 13599.002) is shown below:

```
SUBENT        13599002  20030107
BIB           3         5
REACTION   (98-CF-252(0,F)ELEM/MASS,IND,FY/CRL,LF/HF)
           Yield of correlated fragment pairs.
...
COMMON               4         3
ELEM1       ELEM2     MONIT1    MONIT2
NO-DIM      NO-DIM    PC/FIS    PC/FIS
 40.         58.       1.0       2.2
ENDCOMMON            3
DATA                 4        14
MASS1       MASS2     DATA      DATA-ERR
NO-DIM      NO-DIM    PC/FIS    PC/FIS
 98.        146.       0.04      0.01
 98.        148.       0.04      0.01
…
```

A further exclusive quantity FY$(A_L,Z_L,A_H,Z_H; A_{LCP},Z_{LCP})$ is newly compiled in 14331 in PRELIM.1379. For example LCP=$^4$He case is coded as below

```
SUBENT         14331002  20120407
BIB            3         3
REACTION   (98-CF-252(0,F)ELEM/MASS,TER,FY/CRL,A)
...
COMMON               2         3
ELEM1       ELEM2
NO-DIM      NO-DIM
  58.0        38.0
ENDCOMMON            3         0
DATA                 4         9
MASS1       MASS2      DATA      DATA-ERR
NO-DIM      NO-DIM     PC/FIS    PC/FIS
 146.0       98.0       0.06      0.02
 148.0       95.0       0.08      0.02
...
```

Two and three fragments are identified in coincidence in these two examples, but the situation is not clearly seen in two REACTION codes in 13599.002 and 14331.002.

If we want to have a quick solution for 14331.002 which is consistent with 13599.002, coding of three fragments (LF, HF and A) in SF7 would be a better solution, for example

        (98-CF-252(0,F)ELEM/MASS,TER,FY/CRL,LF/HF/A)
. Another possible solution without CRL could be use of a new branch code (say, COI) in SF5. For example,

1. Independent yield where one (Z,A) is specified:
        (98-CF-252(0,F)ELEM/MASS,IND,FY)
2. Independent yield where two (Z,A) are specified (e.g., 13599.002):
        (98-CF-252(0,F)ELEM/MASS,IND/COI,FY)
3. Independent yield where three (Z,A) are specified (e.g., 14331.002);
        (98-CF-252(0,F)ELEM/MASS,IND/TER/COI,FY)

Namely, COI explains two or more particles/nuclides detected in coincidence are coded under headings ELEM1, ELEM2,… and/or MASS1. MASS2,…. It is also a question whether or not we should code (Z,A) of both fragments with COI when both fragment masses are given for primary fragments (i.e., before prompt neutron emission). For primary fragments, it is enough to specify (Z,A) of one fragment.

**Reference**
[1] S. Simakov, EXFOR difficulties, INDC(NDS)-0614, p14 (2012).

**Proposed corrections to CRL and COR entries (2012-05-18)**

| Subentry | REACTION (Current) | Remark |
|---|---|---|
| 13599.002 | `98-CF-252(0,F)ELEM/MASS,IND,FY/CRL,LF/HF` | (for discussion in this memo) |
| 13599.003 | `98-CF-252(0,F)ELEM/MASS,IND,FY/CRL,LF/HF` | (for discussion in this memo) |
| 13648.002 | `98-CF-252(0,F)ELEM/MASS,IND,FY/CRL,LF/HF` | (for discussion in this memo) |
| 13648.003 | `98-CF-252(0,F)ELEM/MASS,IND,FY/CRL,LF/HF` | (for discussion in this memo) |
| 13648.004 | `98-CF-252(0,F)ELEM/MASS,IND,FY/CRL,LF/HF` | (for discussion in this memo) |
| 13648.005 | `98-CF-252(0,F)ELEM/MASS,IND,FY/CRL,LF/HF` | (for discussion in this memo) |
| 13648.006 | `98-CF-252(0,F)ELEM/MASS,IND,FY/CRL,LF/HF` | (for discussion in this memo) |
| 13698.002 | `98-CF-252(0,F)ELEM/MASS,TER,FY/CRL,LF/HF` | (for discussion in this memo) |
| 13698.003 | `98-CF-252(0,F)ELEM/MASS,IND,FY/CRL,LF/HF` | (for discussion in this memo) |
| 13698.004 | `98-CF-252(0,F)ELEM/MASS,IND,FY/CRL,LF/HF` | (for discussion in this memo) |
| 13698.005 | `98-CF-252(0,F)ELEM/MASS,IND,FY/CRL,LF/HF` | (for discussion in this memo) |
| 13698.006 | `98-CF-252(0,F)ELEM/MASS,IND,FY/CRL,LF/HF` | (for discussion in this memo) |
| 13747.002 | `94-PU-242(0,F)ELEM/MASS,SEC,FY/CRL,,REL` | (for discussion in this memo) |
| 13747.003 | `94-PU-242(0,F)ELEM/MASS,SEC,FY/CRL,,REL` | (for discussion in this memo) |
| 13749.002 | `98-CF-252(0,F)ELEM/MASS,IND,FY/CRL,LF/HF` | (for discussion in this memo) |
| 13751.002 | `98-CF-252(0,F)ELEM/MASS,IND,FY/CRL,LF/HF` | (for discussion in this memo) |
| 13751.003 | `98-CF-252(0,F)ELEM/MASS,TER,FY/CRL,LF/HF` | (for discussion in this memo) |
| 13751.004 | `98-CF-252(0,F)ELEM/MASS,TER,FY/CRL,LF/HF` | (for discussion in this memo) |
| 13807.002 | `98-CF-252(0,F)ELEM/MASS,PRE,FY/CRL,LF/HF` | (for discussion in this memo) |
| 20220.007 | `6-C-12(N,INL)6-C-12,PAR,DA/CRL,G/N,REL` | `(6-C-12(N,INL)6-C-12,PAR,DA/DA,G/N,NCP)/` `(6-C-12(N,INL)6-C-12,PAR,DA);E->E-LVL;` Add `ANG-AZ= 0` or `90 deg.` |
| 22152.010 | `92-U-235(N,F)MASS,PRE,KE/CRL,LF/HF,MXW` | Use `PRE,KE,LF+HF,MXW` |
| 22461.003 | `98-CF-252(0,F),TER,DA/CRL,G/A,RSD` | Superseded by 22461.005? |
| 22461.005 | `98-CF-252(0,F),TER,DA/CRL,G/A,RSD` | Use `2-HE-4,TER,DA,G+FF,RSD` |
| 22461.006 | `98-CF-252(0,F)ELEM/MASS,TER,DA/CRL,G/LCP,RSD` | Use `ELEM/MASS,TER,DA,G+FF,RSD` |

| 22461.008 | `98-CF-252(0,F),TER,DA/CRL,G/A,LEG/RS` | Use `2-HE-4,TER,DA,G+FF,LEG/RSD` |
|---|---|---|
| 22461.009 | `98-CF-252(0,F)ELEM/MASS,TER,DA/CRL,G/LCP,LEG/RS` | Use `ELEM/MASS,TER,DA,G+FF,LEG/RSD` |
| 22464.012.1 | `92-U-235(N,F),PR,KE/CRL,N/HF,MXW` | For future discussion |
| 22464.012.2 | `92-U-235(N,F),PR,KE/CRL,N/LF,MXW` | For future discussion |
| 23012.005 | `94-PU-239(N,F)MASS,PRE,KE/CRL,LF/HF,MXW` | Use `PRE,KE,LF+HF,MXW` |
| 23014.002 | `92-U-233(N,F)MASS,PRE,KE/CRL,LF/HF,MXW` | (same) |
| 23014.003 | `92-U-235(N,F)MASS,PRE,KE/CRL,LF/HF,MXW` | (same) |
| 30521.002.H | `(92-U-235(N,F)ELEM/MASS,TER,FY/CRL,LCP/HF,MXW)/` `(92-U-235(N,F)2-HE-4,TER,FY/CRL,A/HF,MXW)` | Use `TER,FY,,MXW/MSC` for both numerator and denominator |
| 30521.002.L | `(92-U-235(N,F)ELEM/MASS,TER,FY/CRL,LCP/LF,MXW)/` `(92-U-235(N,F)2-HE-4,TER,FY/CRL,A/LF,MXW)` | (same) |
| 30521.002.R | `(92-U-235(N,F)ELEM/MASS,TER,FY/CRL,LCP/LF,MXW)/` `(92-U-235(N,F)ELEM/MASS,TER,FY/CRL,LCP/HF,MXW)` | (same) |
| 30544.003 | `92-U-235(N,F),PR/PAR,DA/CRL,N/N` | Use `PR/PAR,DA,N+N,,REL` |
| 30916.006 | `98-CF-252(0,F),PRE/TER/PAR,FY/CRL,A/FF,REL` | Use `PRE/TER,FY/TKE,A,REL` |
| E1974.003 | `96-CM-248(P,F)MASS,PRE,KE/CRL,LF/HF` | Use `PRE,KE,LF+HF` |
| E2089.002.2 | `92-U-238(P,F)MASS,PRE,KE/CRL,LF/HF` | Use `PRE,KE,LF+HF` |
| L0101.002 | `92-U-238(G,F)MASS,,KE/CRL,LF/HF,BRA` | Use `,KE,LF+HF,BRA` |
| M0035.011 | `2-HE-4(G,N+P)1-H-2,,DA/CRL,N/P,BRA` | Use `,DA,N+P,BRA/REL` |
| M0035.014 | `2-HE-4(G,N+P)1-H-2,,DA/CRL,P/D,BRA` | Use `,DA,P+D,BRA/REL` |
| M0035.017 | `2-HE-4(G,N+P)1-H-2,,DA/CRL,N/D,BRA` | Use `,DA,N+D,BRA/REL` |
| O0011.002 | `90-TH-232(P,F),,COR,FF/FF,,EXP` | Use `,DA/DA,FF/FF+FF`; `ANG -> ANG-RL`; add `ANG=90 deg` |
| O0011.003 | `90-TH-232(P,F),,COR,FF/FF,,EXP` | (same) |
| O0011.004 | `90-TH-232(P,F),,COR,FF/FF,,EXP` | (same) |
| O0011.005 | `90-TH-232(P,F),,COR,FF/FF,,EXP` | (same) |
| O0011.006 | `90-TH-232(D,F),,COR,FF/FF,,EXP` | (same) |
| O0011.007 | `90-TH-232(D,F),,COR,FF/FF,,EXP` | (same) |
| O0011.008 | `90-TH-232(D,F),,COR,FF/FF,,EXP` | (same) |
| O0011.009 | `90-TH-232(D,F),,COR,FF/FF,,EXP` | (same) |

| | | |
|---|---|---|
| O0011.010 | `92-U-233(A,F),,COR,FF/FF,,EXP` | (same) |
| O0011.011 | `92-U-233(P,F),,COR,FF/FF,,EXP` | (same) |
| O0011.012 | `90-TH-232(A,F),,COR,FF/FF,,EXP` | (same) |
| O0011.013 | `90-TH-232(A,F),,COR,FF/FF,,EXP` | (same) |
| T0117.003 | `6-C-12(7-N-14,D+A)10-NE-20,PAR,DA/CRL,D/A,REL` | Use `ISP/PAR,DA/DA,D/D+A,REL` |