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Memo CP-D/649

Date: 11 June 2010
To: Distribution
From: N. Otsuka
Subject: **Fission fragments measured in coincidence**
Reference: Memo 4C-4/181

Coding of fission fragments measured in coincidence is discussed in Memo 4C-4/181. Indication of all measured fragments (incl. light charged particles) under (ELEM1,MASS1), (ELEM2,MASS2) etc. would be a solution.

Here I would like to discuss how we can differentiate such quantities in REACTION code by using three subentries (13698.002, 23012.006-007). I cannot find the best solution without further analysis for each case.

1. Fission yield for triple coincidence (13698.002 in PRELIM.1364)

Alpha ternary secondary neutron-less (ν_p = 0) independent fission yield is given for ^{252}Cf spontaneous fission. Both heavy and light fragments were identified by de-excitation γ coincidence measurement.

(1) If we follow the coding sample shown in LEXFOR "Fission Yields"(without particle considered in SF7), one will obtain the following coding:

SAMPLE 1

```
SUBENT        13698002   20100608                                  13698  2    1
BIB                 3          3                                  13698  2    2
REACTION   (98-CF-252(0,F)ELEM/MASS,TER,FY/CRL)                    13698  2    3
...
ENDBIB              3          0                                  13698  2    6
NOCOMMON            0          0                                  13698  2    7
DATA                6         16                                  13698  2   11
ELEM1      MASS1      ELEM2      MASS2      DATA       DATA-ERR   13698  2   12
NO-DIM     NO-DIM     NO-DIM     NO-DIM     PC/FIS     PC/FIS     13698  2   13
 36.        92.        60.       156.        0.002      0.001     13698  2   14
 38.        96.        58.       152.        0.008      0.003     13698  2   15
 38.        98.        58.       150.        0.014      0.006     13698  2   16
...
 40.       102.        56.       146.        0.009      0.004     13698  2
...
```

(2) If we adopt the proposal in Memo 4C-4/181, one can code this quantity as follows:

SAMPLE 2

```
SUBENT        13698002   20100608                                    13698  2    1
BIB                  3          3                                    13698  2    2
REACTION    (98-CF-252(0,F)ELEM/MASS,IND/TER,FY)                     13698  2    3
...
ENDBIB               3          0                                    13698  2    6
COMMON               2          3                                    13698  2    7
ELEM1       MASS1                                                    13698  2    8
NO-DIM      NO-DIM                                                   13698  2    9
 2.          4.                                                      13698  2   10
ENDCOMMON            2          0                                    13698  2   11
DATA                 6         16                                    13698  2   12
ELEM2       MASS2       ELEM3       MASS3       DATA       DATA-ERR  13698  2   13
NO-DIM      NO-DIM      NO-DIM      NO-DIM      PC/FIS     PC/FIS    13698  2   14
 36.         92.         60.         156.        0.002      0.001     13698  2   15
 38.         96.         58.         152.        0.008      0.003     13698  2   16
 38.         98.         58.         150.        0.014      0.006     13698  2   17
...
 40.         102.        56.         146.        0.009      0.004     13698  2
```

(3) Let us denote this quantity as $FYI(Z_L,A_L,Z_H,A_H,Z_{LC},A_{LC})$, where $(Z_{LC},A_{LC})=(2,4)$ for alpha ternary fission. Because,

$$FYI(Z_1,A_1)=\sum_{Z_2,A_2,Z_3,A_3,\ldots} FYI(Z_1,A_1,Z_2,A_2,Z_3,A_3,\ldots) \qquad (1)$$

we can regard $FYI(Z_L,A_L,Z_H,A_H,Z_{LC},A_{LC})$ as a partial yield of $FYI(Z,A)$. Therefore we may introduce a new branch code (say `COI`), which will be used when two or more (Z,A) are given under (`ELEM1`,`MASS1`), (`ELEM2`,`MASS2`) to explain fission yield data sets. Below is a coding sample of the same data table with this branch code.

SAMPLE 3

```
SUBENT        13698002   20100608                                    13698  2    1
BIB                  3          3                                    13698  2    2
REACTION    (98-CF-252(0,F)ELEM/MASS,IND/TER/COI,FY)                 13698  2    3
...
ENDBIB               3          0                                    13698  2    6
COMMON               2          3                                    13698  2    7
ELEM1       MASS1                                                    13698  2    8
NO-DIM      NO-DIM                                                   13698  2    9
 2.          4.                                                      13698  2   10
ENDCOMMON            2          0                                    13698  2   11
DATA                 6         16                                    13698  2   12
ELEM2       MASS2       ELEM3       MASS3       DATA       DATA-ERR  13698  2   13
NO-DIM      NO-DIM      NO-DIM      NO-DIM      PC/FIS     PC/FIS    13698  2   14
 36.         92.         60.         156.        0.002      0.001     13698  2   15
 38.         96.         58.         152.        0.008      0.003     13698  2   16
 38.         98.         58.         150.        0.014      0.006     13698  2   17
...
 40.         102.        56.         146.        0.009      0.004     13698  2
```

Note that `COI` is not used if only (`ELEM`,`MASS`) is used in data tables.

(4) Use of SF7 for indication of all fragments under (ELEM1,MASS1), (ELEM2,MASS2) , (ELEM3,MASS3) etc. would be also possible. Below are three possibilities with SF7:

```
SAMPLE 4
SUBENT        13698002   20100608                                  13698  2    1
BIB                  3          3                                  13698  2    2
REACTION    (98-CF-252(0,F)ELEM/MASS,IND/TER/COI,FY,LCP+LF+HF)     13698  2    3
...
ENDBIB               3          0                                  13698  2    6
COMMON               2          3                                  13698  2    7
ELEM1       MASS1                                                 13698  2    8
NO-DIM      NO-DIM                                                13698  2    9
 2.          4.                                                   13698  2   10
ENDCOMMON            2          0                                  13698  2   11
DATA                 6         16                                  13698  2   12
ELEM2       MASS2       ELEM3       MASS3       DATA        DATA-ERR 13698  2   13
NO-DIM      NO-DIM      NO-DIM      NO-DIM      PC/FIS      PC/FIS   13698  2   14
 36.         92.         60.        156.         0.002       0.001   13698  2   15
 38.         96.         58.        152.         0.008       0.003   13698  2   16
 38.         98.         58.        150.         0.014       0.006   13698  2   17
...
 40.        102.         56.        146.         0.009       0.004   13698  2
```

or

```
SAMPLE 4
SUBENT        13698002   20100608                                  13698  2    1
BIB                  3          3                                  13698  2    2
REACTION    (98-CF-252(0,F)ELEM/MASS,IND/TER/COI,FY,LCP/LF/HF)     13698  2    3
...
ENDBIB               3          0                                  13698  2    6
COMMON               2          3                                  13698  2    7
ELEM1       MASS1                                                 13698  2    8
NO-DIM      NO-DIM                                                13698  2    9
 2.          4.                                                   13698  2   10
ENDCOMMON            2          0                                  13698  2   11
DATA                 6         16                                  13698  2   12
ELEM2       MASS2       ELEM3       MASS3       DATA        DATA-ERR 13698  2   13
NO-DIM      NO-DIM      NO-DIM      NO-DIM      PC/FIS      PC/FIS   13698  2   14
 36.         92.         60.        156.         0.002       0.001   13698  2   15
 38.         96.         58.        152.         0.008       0.003   13698  2   16
 38.         98.         58.        150.         0.014       0.006   13698  2   17
...
 40.        102.         56.        146.         0.009       0.004   13698  2
```

or

```
SAMPLE 5
SUBENT        13698002   20100608                                  13698  2    1
BIB                  3          3                                  13698  2    2
REACTION    (98-CF-252(0,F)ELEM/MASS,IND/TER/COI,FY,A/LF/HF)       13698  2    3
...
ENDBIB               3          0                                  13698  2    6
NOCOMMON             0          0                                  13698  2    7
DATA                 6         16                                  13698  2   12
ELEM1       MASS1       ELEM2       MASS2       DATA        DATA-ERR 13698  2   13
NO-DIM      NO-DIM      NO-DIM      NO-DIM      PC/FIS      PC/FIS   13698  2   14
 36.         92.         60.        156.         0.002       0.001   13698  2   15
 38.         96.         58.        152.         0.008       0.003   13698  2   16
 38.         98.         58.        150.         0.014       0.006   13698  2   17
...
 40.        102.         56.        146.         0.009       0.004   13698  2
...
```

(4) The same quantity is coded in 13698.002 and 007 in PRELIM.1364 as follows (IND must be added in SF5 in final transmission):

```
SAMPLE 6
SUBENT        13698002   20100608                                  13698  2    1
BIB                  3          3                                  13698  2    2
REACTION    (98-CF-252(0,F)ELEM/MASS,TER,FY/CRL,LF+HF)             13698  2    3
...
ENDBIB               3          0                                  13698  2    6
NOCOMMON             0          0                                  13698  2    7
DATA                 6         16                                  13698  2   11
ELEM1       MASS1     ELEM2      MASS2      DATA       DATA-ERR    13698  2   12
NO-DIM      NO-DIM    NO-DIM     NO-DIM     PC/FIS     PC/FIS      13698  2   13
 36.         92.       60.        156.       0.002      0.001      13698  2   14
 38.         96.       58.        152.       0.008      0.003      13698  2   15
 38.         98.       58.        150.       0.014      0.006      13698  2   16
...
 40.        102.       56.        146.       0.009      0.004      13698  2
...
SUBENT        13698007   20100608                                  13698  7    1
BIB                  3          3                                  13698  7    2
REACTION    (98-CF-252(0,F)ELEM/MASS,TER,FY/CRL,A+LF)              13698  7    3
...
ENDBIB               3          0                                  13698  7    6
NOCOMMON             0          0                                  13698  7    7
DATA                 6         16                                  13698  7   12
ELEM1       MASS1     ELEM2      MASS2      DATA       DATA-ERR    13698  7   13
NO-DIM      NO-DIM    NO-DIM     NO-DIM     PC/FIS     PC/FIS      13698  7   14
 40.        102.       56.        146.       0.009      0.004      13698  7   15
...
```

We can see the same data line is coded twice in 002 and 007 for ^{102}Zr+^{146}Ba+α ternary fission with different REACTION code. This situation shows difficulty of keeping consistency in fission fragment yield compilation.

2. TKE and ν_p as functions of fission fragment masses (23012.006-007)

Below are coding samples of two quantities which importance was recently stressed in the 1st RCM of the IAEA CRP for prompt fission neutron spectra (and also mentioned in CP-D/635). Because the sum rule shown in Eq.(1) is not valid for total kinetic energy prompt fission neutron number, parameter code CRL would be better than branch code COI.

23012.006

Total kinetic energy (KE,LF+HF) as a function of fragment (FF) mass

```
SAMPLE
SUBENT        23012006   20071203                                  23012006    1
BIB                  4          5                                  23012006    2
…
REACTION    (94-PU-239(N,F)MASS,PRE,KE/CRL,LF+HF/FF,MXW)           23012006    5
MISC-COL    (MISC) FWHM of kinetic energy distribution             23012006    6
...
ENDBIB               5                                             23012006    8
NOCOMMON             0          0                                  23012006    9
DATA                 3         79                                  23012006   10
MASS        DATA      MISC                                         23012006   11
NO-DIM      MEV       MEV                                          23012006   12
 81.         104.26                                                23012006   13
...
```

23012.007

Prompt fission neutron number (PR,NU) as a function of fragment (FF) mass

```
SAMPLE
SUBENT        23012007   20071203                                  23012007    1
BIB                  3          4                                  23012007    2
...
REACTION   (94-PU-239(N,F)MASS,PR,NU/CRL,FF,MXW)                   23012007    4
...
ENDBIB               4                                            23012007    7
NOCOMMON             0          0                                 23012007    8
DATA                 2         29                                 23012007    9
MASS       DATA                                                   23012007   10
NO-DIM     PRT/FIS                                                23012007   11
 126.       3.454                                                 23012007   12
...
```

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