New/Updated ENSDF codes: Java-RULER and ConsistencyCheck

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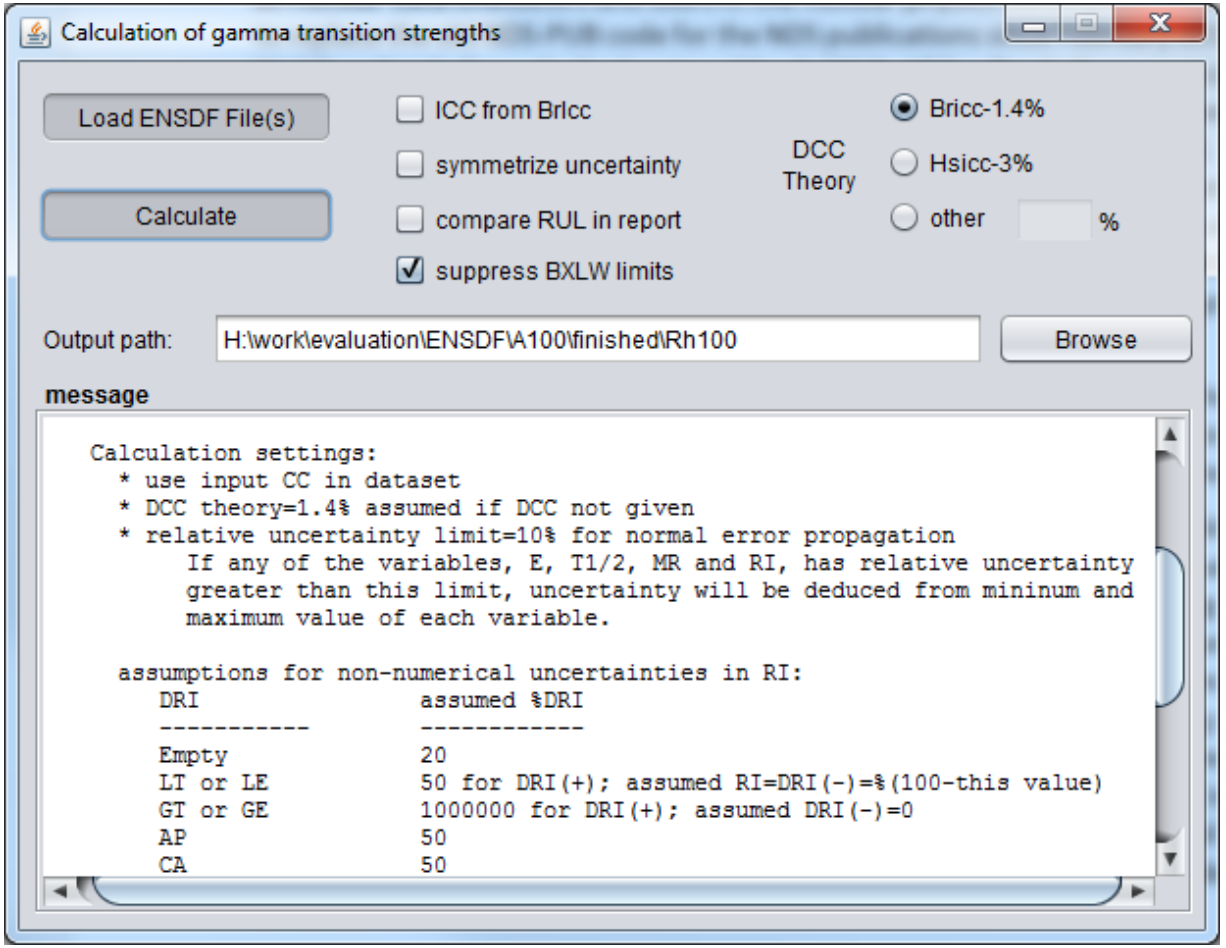
Java-RULER & ConsitencyCheck

- ***Java-RULER***
  - written in Java with all functions as in the old Fortran version
  - Solve issues with error propagations of large and asymmetric uncertainties

- ***ConsistencyCheck***
  - Check data consistency among datasets, e.g., JPI, MULT, XREF, T1/2, etc.
  - Group levels and gammas to assist in preparing Adopted dataset
  - Average EG, RI, T1/2 and generate averaging comments in ENSDF
  - Other functions: setting up evaluation folders, sorting, merging/splitting datasets, etc.

Java-RULER



Questions on proper error propagation of large/asymmetric uncertainties (e.g., in $T_{1/2}$ and mixing ratio)

Java-RULER: some assumptions

Assumptions for non-numerical uncertainties in RI:

ΔRI	assumed %ΔRI
Empty	20
LT or LE	50 for ΔRI(+); assumed RI=ΔRI(-)=%(100-this value)
GT or GE	1000000 for ΔRI(+); assumed ΔRI(-)=0
AP, CA, SY	50

(same for MR and CC except for empty DCC where theory DCC assumed)

Proposed rule for choosing methods of error propagations

all relative uncertainties <=**10%** ➡ normal error propagation

any relative uncertainty >**10%** ➡ use minimum and maximum

(**ANY** of the variables: Eg, T1/2, MR, RI, ICC)

normal error propagation for $f(x,y)$, with x and y independent:

$$\left(\frac{\Delta f}{f}\right)^2 \approx \left(\frac{\Delta x}{x}\right)^2 + \left(\frac{\Delta y}{y}\right)^2$$

valid only if $\frac{\Delta x}{x}$ and $\frac{\Delta y}{y}$ are small enough

Java-RULER: calculation reports

```
190PB  L 2614.8     8   (10)+              150 NS
190PB  G  338.6        100        E2                      0.0813
190PB  G  362.9                   [E2]                     0.0670

--->gamma#2-1: EG=338.6 5(assumed)  BR(%g)=92.48 10  BR(%g+%ce)=100.0  Mult=E2 CC=0.0813 11(assumed)

        Weisskopf single-particle B(XL)(s.p.)(down) and half-lives T1/2(s.p.) in second:
                    (uncertainties in T1/2 are from uncertainty in EG)
          L     B(EL)sp           B(ML)sp           L     T1/2(EL)sp          T1/2(ML)sp
          1     2.1304E-02        1.7910E+00        1     5.272E-15   23      5.67E-13    3
          2     6.4882E-03        5.4532E-01        2     1.960E-9    15      2.109E-7    16
          3     2.1443E-03        1.8023E-01        3     0.001110    12      0.1195      12
          4     7.4986E-04        6.3031E-02        4     932         12      1.002E+5    13

   EG=338.6 5(assumed)  BR(%g)=92.48 10  BR(%g+%ce)=100.0  Mult=E2 CC=0.0813 11(assumed)
   T1/2(partial)=1.6219E-7 17 (sec)
    BE2(DOWN)=7.839E-5 59           BE2W=0.012082 90 (RUL=1000)

   EG=338.6 5(assumed)  BR(%g)=92.48 10  BR(%g+%ce)=100.0  Mult=E2 CC=0.0813 11(assumed)
   T1/2(partial)=1.6219E-7 17 (sec)
    BE2(DOWN)=7.840E-5 66           BE2W=0.012083 102 (RUL=1000)

**** new line: 190PBB G BE2W=0.01208
**** old line: 190PBB G BE2W=0.012

--->gamma#2-2: EG=362.9 5(assumed)  Mult=[E2] CC=0.0670 9(assumed)
               intensity (IG) is not given. IG=0 is assumed.
```

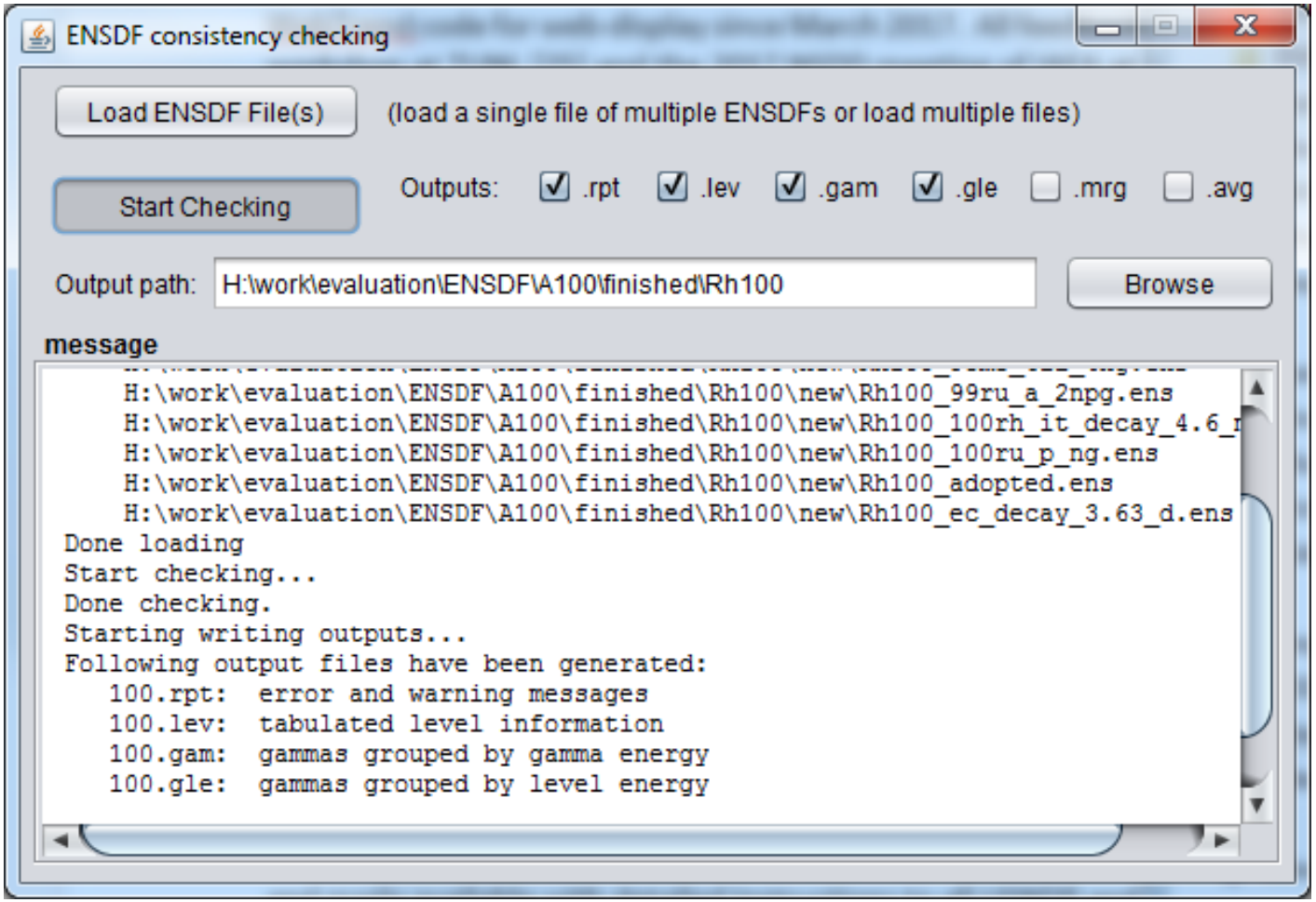
two approaches for uncertainties

ConsistencyCheck code for ENSDF evaluation (or *CheckENSDF*)

- ***Main functions for checking:***
  - **Check data consistency** among datasets (Adopted and individuals), e.g., JPI, MULT, XREF, T1/2, etc.
  - **Check data validity (physics)**, e.g., large B(XL) compared to RUL, gammas with large ΔJPI, decay branches with large ΔJPI, etc.
- ***Functions for speeding up preparation of Adopted datasets:***
  - **Group ENSDF lines of levels and gammas** (including comment lines) from individual datasets in one place for a quick view of all available data from different reactions
  - **Average EG, RI and T1/2** with uncertainties in the same group and generate averaging comments in ENSDF that can be directly copied and pasted into the Adopted dataset (copy-and-paste is not automated since human evaluation is needed here)
- ***Other useful functions:***
  - Setting up and creating evaluation folders when starting a new mass-chain evaluation
  - Sorting and merging individual datasets
  - Splitting a large file of multiple datasets into files of single dataset
  - and more

ConsistencyCheck code: user interface

check data consistency among ENSDF datasets, group levels and gammas, and average values from different datasets



ConsistencyCheck code: usage & output files

The usage is simple:

load an ENSDF file containing all datasets to be checked

or

load multiple single-dataset files at one time
(drag and release files into the message window to load files)

Output files: (e.g., for A=73)

```
73.err:  error reports
73.wrn:  warning reports
73.lev:  tabulated level information
73.gam:  gammas grouped by gamma energy
73.gle:  gammas grouped by level energy
73.mrg:  grouped lines of all datasets
73.avg:  average results of records
```

ConsistencyCheck example: grouped entries

```
----------------------------------------------------------------------------------------------------------------------------------
 LEVEL**********************************100RU  L 1741.011    8 0+               1.39 PS  GT                                  ---
                                NEW   100RUX L XREF=ABDGHIJKMPR
                                OLD   100RUX L XREF=ABDGHIJKMPR
     100TC B- DECAY (15.46 S)--->A  A     100RU  L 1740.95    10 0+                                                    A
      100RH EC DECAY (20.8 H)--->B  B     100RU  L 1740.993   11 0+
  100MO 2B- DECAY (6.9E+18 Y)--->D  D     100RU  L 1741.0        0+                                                    X  ?
                 98MO(A,2NG)--->G  G     100RU  L    1740.9911 0+
                 99TC(3HE,D)--->H  H     100RU  L 1741       20                                 (4)       0.086       D
              99RU(N,G) E=RES--->I  J     100RU  L 1741.9     7  0+
               99RU(N,G) E=TH--->J  I     100RU  L 1741.052   20 0+
                    99RU(D,P)--->K  K     100RU  L 1742       2                                                        Y
         100RU(N,N'G),(N,N')--->M  M     100RU  L   1741.074250+               1.39 PS   GT
                   101RU(P,D)--->P  P     100RU  L 1741                                                      0.0002   LT   ?
                   102RU(P,T)--->R  R     100RU  L 1742.0     2   0+                                          2.97     b
     100TC B- DECAY (15.46 S)--->A  A     100RU  B              0.066 3            6.35  2
     100TC B- DECAY (15.46 S)--->A  A     100RU cB IB$0.062 {I6} from TAGS data (2017Gu17).
      100RH EC DECAY (20.8 H)--->B  B     100RU  E                0.0090 17  0.058 10   8.9    1                0.067    12
  100MO 2B- DECAY (6.9E+18 Y)--->D  D     100RU cL                                                                 0|*10{+20} y
  100MO 2B- DECAY (6.9E+18 Y)--->D  D     100RU2cL
  100MO 2B- DECAY (6.9E+18 Y)--->D  D     100RU cL                                                                 dence level for
  100MO 2B- DECAY (6.9E+18 Y)--->D  D     100RU2cL
  100MO 2B- DECAY (6.9E+18 Y)--->D  D     100RU cL                                                                 0{+20} y (1995Ba29).
                   102RU(P,T)--->R  R     100RU cL                                                                 I5} at 15|'.
                   102RU(P,T)--->R  R     100RU2cL |s(6|')/|s(15|')>2.
 GAMMA-----------------------------------100RU  G 378.90    5   75.4  13 E2                    0.01250                  --- EG=378.90
     100TC B- DECAY (15.46 S)--->A  A     100RU  G 378.7     1 85      6  E2                    0.01252              C   *** EG=378.7
      100RH EC DECAY (20.8 H)--->B  B     100RU  G 378.79    5 69      12 E2                    0.01251              C   *** EG=378.79
  100MO 2B- DECAY (6.9E+18 Y)--->D  D     100RU  G 378.9                                                                *** EG=378.9
                 98MO(A,2NG)--->G  G     100RU  G    378.81 11100     8                                               *** EG=378.81
              99RU(N,G) E=TH--->J  I     100RU  G  379.10   10100     14                                              *** EG=379.10
         100RU(N,N'G),(N,N')--->M  M     100RU  G    378.94  375.1    11                                              *** EG=378.94
     100TC B- DECAY (15.46 S)--->A  A     100RUS G KC=0.01083 16$LC=0.001390 20$MC=0.000256 4$
     100TC B- DECAY (15.46 S)--->A  A     100RUS G NC=4.06E-5 6$OC=1.85E-6 3
      100RH EC DECAY (20.8 H)--->B  B     100RU2 G EKC=0.0012 6 (1974Ko23)
      100RH EC DECAY (20.8 H)--->B  B     100RUS G KC=0.01082 16$LC=0.001389 20$MC=0.000256 4$
      100RH EC DECAY (20.8 H)--->B  B     100RUS G NC=4.06E-5 6$OC=1.85E-6 3
      100RH EC DECAY (20.8 H)--->B  B     100RU cG E$378.93 {I4} (1974Ko23).
      100RH EC DECAY (20.8 H)--->B  B     100RU cG M$|a(K)exp in 1974Ko23 gives mult=M1,E2, but |DJ|p requires E2;
      100RH EC DECAY (20.8 H)--->B  B     100RU2cG (378|g)(1362|g)(|q): A{-2}=-0.1 {I5}, A{-4}=+0.4 {I9} (1990KeAA)
      100RH EC DECAY (20.8 H)--->B  B     100RU3cG supports E2.
 GAMMA-----------------------------------100RU  G  610.48   10           E0                      0.08     4       --- EG=610.48     FL=1130.305   JF=0+
      100RH EC DECAY (20.8 H)--->B  B     100RU  G  610.48   10          E0                      0.00009  5 E     *** EG=610.48     FL=1130.300   JF=0+
              99RU(N,G) E=TH--->J  I     100RU  G  611                  (E0)                                        *** EG=611        FL=1130.323   JF=0+
      100RH EC DECAY (20.8 H)--->B  B     100RU cG TI$from ce(K)(611|g)/ce(K)(540|g)=0.00020 {I10} (1974Ko23).
      100RH EC DECAY (20.8 H)--->B  B     100RU2cG Uncertainty of 0.00001 quoted by 1974Ko23 is probably underestimated
      100RH EC DECAY (20.8 H)--->B  B     100RU3cG since the peak is very weak in the ce spectrum shown by 1974Ko23.
      100RH EC DECAY (20.8 H)--->B  B     100RUxcG I|g<0.03 (1974Ko23).
 GAMMA-----------------------------------100RU  G 1201.503  16 100.0  11  (E2)                                         --- EG=1201.503   FL=539.5103   JF=2+
     100TC B- DECAY (15.46 S)--->A  A     100RU  G 1201.5    1 100     4                                          C   *** EG=1201.5     FL=539.48     JF=2+
```

ENSDF record lines of the same gamma from different datasets

final levels

ConsistencyCheck example: averaging reports

```
**************** Level=539.5103     Gamma=539.509 in 100RU     ******************

------ average E------
Data points of E record
*       100RH EC DECAY (20.8 H)   539.512(5)       weight=13.40%
*                 99RU(N,G) E=TH  539.508(2)       weight=83.76%
###                               in weighted average)
       100TC B- DECAY (15.46 S)   539.52(11)       weight=0.03%
   70ZN(36S,A2NG),88SR(14C,2NG)   539.7(1)         weight=0.03%
                    98MO(A,2NG)   539.509(14)      weight=1.71%
                   100MO(A,4NG)   539.7(3)         weight=0.00%
             100RU(N,N'G),(N,N')  539.506(18)      weight=1.03%
              COULOMB EXCITATION  539.6(1)         weight=0.03%

Averaging results:

                                  539.5086(19)          (internal)
                                  539.5086(14)          (external)
                                  chi**2/(n-1)=0.560
                                  539.5086(18)          (internal)
                                  539.5086(16)          (external)
                                  chi**2/(n-1)=0.785
                                  539.57(3)
                                  chi**2/(n-1)=0.007

### weighted average comment:
100RU cG E$weighted average of 539.512 {I5} from {+100}Rh |e decay (20.8 h) and
100RU                            h. Others: 539.52 {I11} from {+100}Tc
100RU                            7 {I1} from ({+36}S,|a2n|g), 539.509 {I14}
100RU                            rom (|a,4n|g), 539.506 {I18} from (n,n'|g),
100RU                            excitation

### weighted average comment (all values):
100RU cG E$weighted average of 539.52 {I11} from {+100}Tc |b{+-} decay (15.46
100RU2cG s), 539.512 {I5} from {+100}Rh |e decay (20.8 h), 539
100RU3cG ({+36}S,|a2n|g), 539.509 {I14} from (|a,2n|g), 539.50
100RU4cG E=th, 539.7 {I3} from (|a,4n|g), 539.506 {I18} from (
100RU5cG {I1} from Coulomb excitation

### unweighted average comment (all values):
100RU cG E$unweighted average of 539.52 {I11} frc
100RU2cG s                       m {+100}Rh |e decay (20.8 h), 539.7 {I1} from
100RU3cG (                       .509 {I14} from (|a,2n|g), 539.508 {I2} from (n,|g)
100RU4cG E                       m (|a,4n|g), 539.506 {I18} from (n,n'|g), and 539.6
100RU5cG {                       citation
```

unweighted comments

averaging results

weighted comments (major values)

weighted comments

for copy and paste

unweighted comments

ConsistencyCheck example: error reports

```
################################################################################
In dataset of 100RU: XB 100RH EC DECAY (20.8 H)

100RU  L 1130.300   7 0+              8.2 PS    +15-11
100RU  G 1130.3     3              E0                          0.00051  4 E
                                  *                                        <W> Check E0 transition.
100RU  L 1740.993  11 0+
100RU  G  610.48   10              E0                          0.00009  5 E
                                  *                                        <W> Check E0 transition.
100RU  G 1740.6     2              E0                          0.00019  4 E
                                  *                                        <W> Check E0 transition.
100RU  L 2099.109   8  2+
100RU  G 234.0      5  0.0023 8 [M1,E2]                0.047  16              ?
                                  *                                        <E> Mult commented from Adopted but inconsistent
                                                                                Adopted Mult= this Mult=[M1,E2]

100RU  L 2512.41    3  (4)+
100RU  E                          0.03  LT   8.7  GT              0.03     LT    ?
         *                                                                  <W> Decay branch is less likely. Please check.
                                                                                parent JPI=1- this JPI=(4)+
                                                                                spin change=3 parity change=yes


100RU  L 2516.824   6  1-
100RU  G 349.960    16 0.0379 13[E2]                 0.01614
                                  *                                        <E> Mult commented from Adopted but inconsistent
                                                                                Adopted Mult= this Mult=[E2]
100RU  G 465.15     3  0.1283 10[E1]                 0.010  9             BC
                                  *                                        <E> Mult commented from Adopted but inconsistent
                                                                                Adopted Mult= this Mult=[E1]

100RU  L 2569.908   8  (3)-
100RU  E                          0.03  LT   8.7  GT              0.03     LT    ?
         *                                                                  <W> Decay branch is less likely. Please check.
                                                                                parent JPI=1- this JPI=(3)-
                                                                                spin change=2 parity change=no

100RU  G 470.98     17 0.0037 8 [E1,M2]              0.010  8                <E> Mult commented from Adopted but inconsistent
                                  *                                             Adopted Mult= this Mult=[E1,M2]

100RU  L 2660.135   17 (1,2+)                                                <E> JPI commented from Adopted but inconsistent
                     *                                                          Adopted JPI=1,2+ this JPI=(1,2+)

100RU  L 2666.30    3  (1+,2,3+)                                            <E> JPI commented from Adopted but inconsistent
                     *                                                          Adopted JPI=(2,3) this JPI=(1+,2,3+)

100RU  L 2801.41    6
100RU  G  141.27    5  0.0028 5  [D,E2]                0.21   16              <E> Mult commented from Adopted but inconsistent
                                  *                                             Adopted Mult= this Mult=[D,E2]
                                  *                                        <W> Mult is inconsistent with JPI (one of JPIs is empty)
100RU  G 2262.1     5  0.0061 15 D+Q                                           JI= JF(2660.135)=(1,2+)
                                  *
                                                                           <W> Mult is inconsistent with JPI (one of JPIs is empty)
100RU  L 2915.542   6  2-                                                       JI= JF(539.511)=2+
100RU  G  249.25    3  0.0151 6  [D,E2]                0.03   2             C
                                  *                                        <E> Mult commented from Adopted but inconsistent
```

error and warning messages

NSCL

ConsistencyCheck: checklist

This program performs the following checks (PANDORA checks 1-5 plus some others):

1. check MS flag in column 78-79 for level record with T1/2>0.1 sec
2. check consistency of gamma-ray multipolarity with change of spin and parity between parent and daughter levels
3. check consistency of log ft value with change of spin and parity between parent and daughter levels for beta/EC decay dataset following the rule used in PANDORA:

   If 3.6<log ft<5.9, then, Ji-1<=Jf<=Ji+1, no parity change

   If log ft>=8.5 and 1U, then, Jf=Ji+/-2, with parity change
4. check consistency of HF value with change of spin and parity between parent and daughter levels for alpha decay dataset following the rule used in PANDORA:

   If mass=odd and HF<4, then, Jf=Ji, no parity change

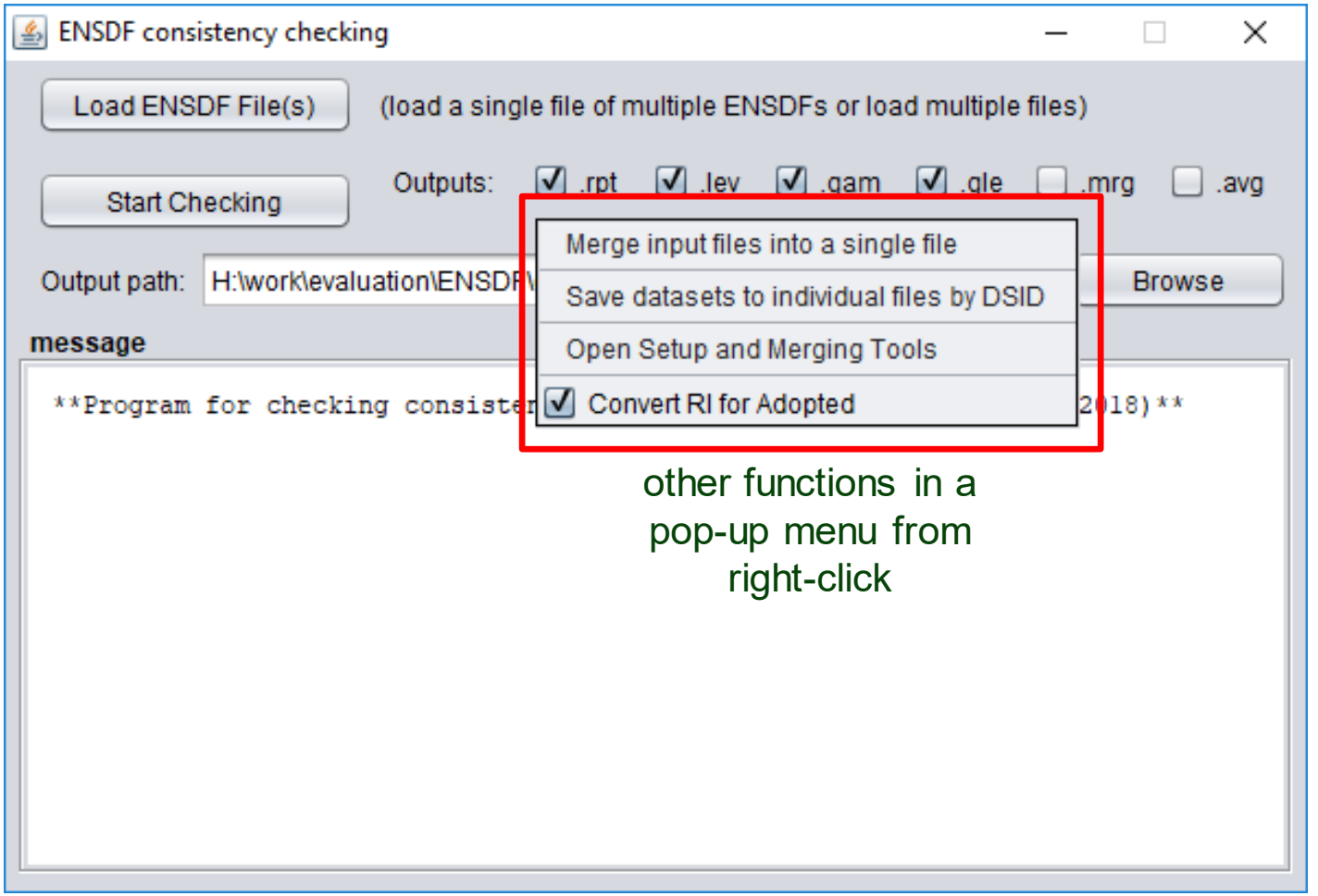
   If Jf=0 or Ji=0, then, parity change=(-1)^(Jf-Ji), with +1 for no change and -1 for change
5. check consistency of spin-parity values in Adopted Levels with those in individual datasets if there is any comment stating that they are from Adopted Levels
6. check consistency of information in parent record in decay dataset with the Adopted data for the parent nuclide, like, JPI, T1/2, Q-value

ConsistencyCheck: checklist (cont.)

7. check BXLW values in continuation records with RUL values for Adopted Level, Gammas dataset
8. check if any level from individual datasets is missing in Adopted Levels dataset or if its XREF tag is missing in the "XREF=" field of the corresponding Adopted Level
9. check if the "XREF=" field of an Adopted level has any wrong XREF tag.
10. check 0 to 0 transition, parity-change=yes should not happen
11. check if Ig is normalized to strongest=100 (PN=6) in Adopted Gammas, and that should not normalized to gamma flagged by ?, *, &
12. check decay branch with DJ>2 or (DJ==2 and parity change=no), less likely
13. check if any gamma is missing in Adopted Gammas
14. check if T1/2 as quoted from Adopted is consistent
15. check if MULT and MR as quoted from Adopted is consistent
16. check if BXLW is missing in Adopted Levels when T1/2, Ig, MUL are available

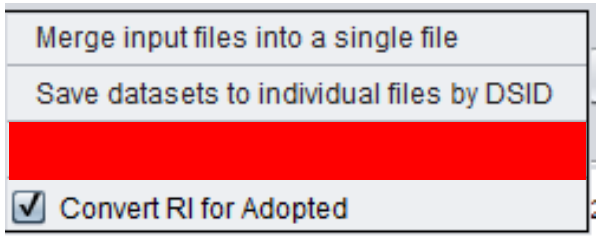
checklist is to be discussed and more items are needed

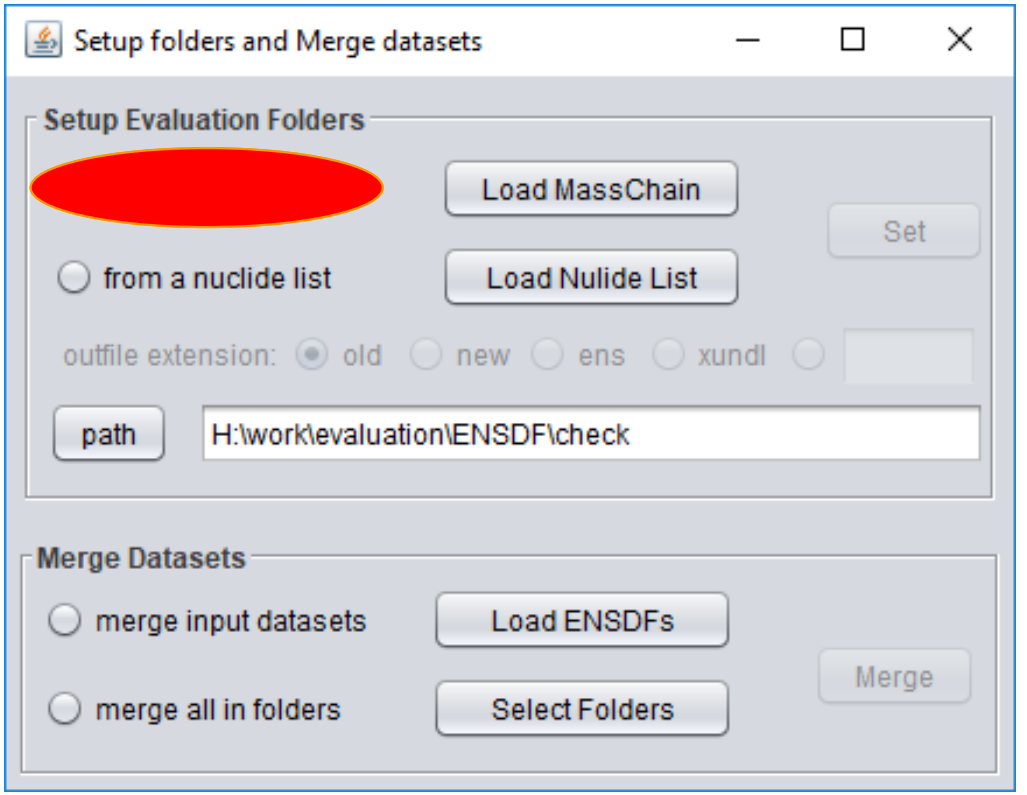
ConsistencyCheck: other functions

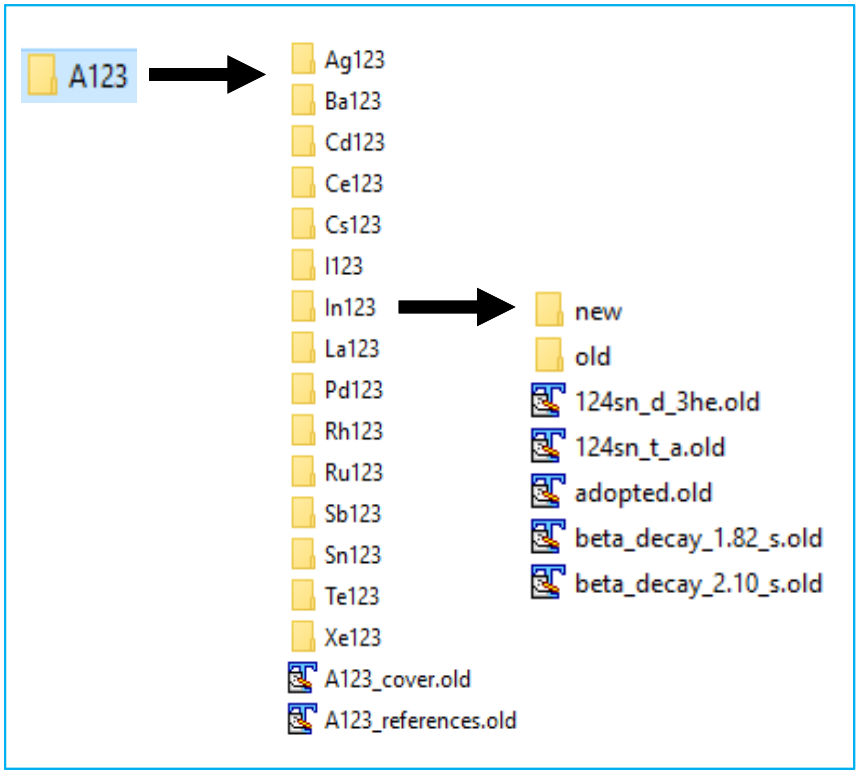


other functions in a pop-up menu from right-click

ConsistencyCheck: other functions (cont.)







An example of evaluation fodders created from an input mass-chain file, with ENSDF files of individual datasets also created from it.