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TENDL covariance files for JEFF

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Background

- In JEFF-3.2, 217 isotopes contain covariances,
- Many covariances come from TENDL-2012 (for exotic isotopes),
- But JEFF-3.2 lacks complete covariances for ^{235}U, ^{239}Pu, and ^{238}U.

- Out of 217 isotopes with covariances, 45 are original,
- In ENDF/B-VII.1, 180 isotopes, all uranium and plutonium (93 originals),
- In JENDL-4.0, 88 isotopes, all uranium and plutonium (88 originals).

- For the users, MF33 is more suitable, even if MF32 contains more physics,
- Above all, consistency and unicity of format needs to be mandatory.

Rules of thumb for JEFF-3.3 covariances

- For neutrons:
  - Validate existing JEFF-3.2 covariances (real or „fake“ benchmarks)
  - If good, keep them
  - If not good, replace them with another source (ENDF/B-VII.1, JENDL-4.0, TENDL…)
  - Make use of the latest TENDL release for all the other isotopes
  - Do not use MF32, simply MF33

- For other sub-libraries:
  - If the format exists, produce covariances (charged particles),
  - If not, provide random files, the users will produce them anyway (FY, DD, TSL…)

- For all:
  - Use the same format for all files
  - Completeness
  - Produce tabulated format

Possibilities from TENDL

- In June 2015, after the JEFF meeting, 41 JEFF-3.2 files were complemented with TENDL-2014 covariances,
- These files were sent to the NEA,
- Production based on „simple“ shell scripts (available on demand)

- $^{40,42\text{-}44,46,48}$Ca, $^{106,108,110\text{-}114,116}$Cd, ^{35}Cl, $^{151\text{-}157}$Eu, $^{155\text{-}158,160}$Gd, $^{236\text{-}242}$Pu, ^{235,236,239}U, ^{91,93,95,96}Zr

- All in MF31/33/35 formats,

- All processed with NJOY, PREPRO,

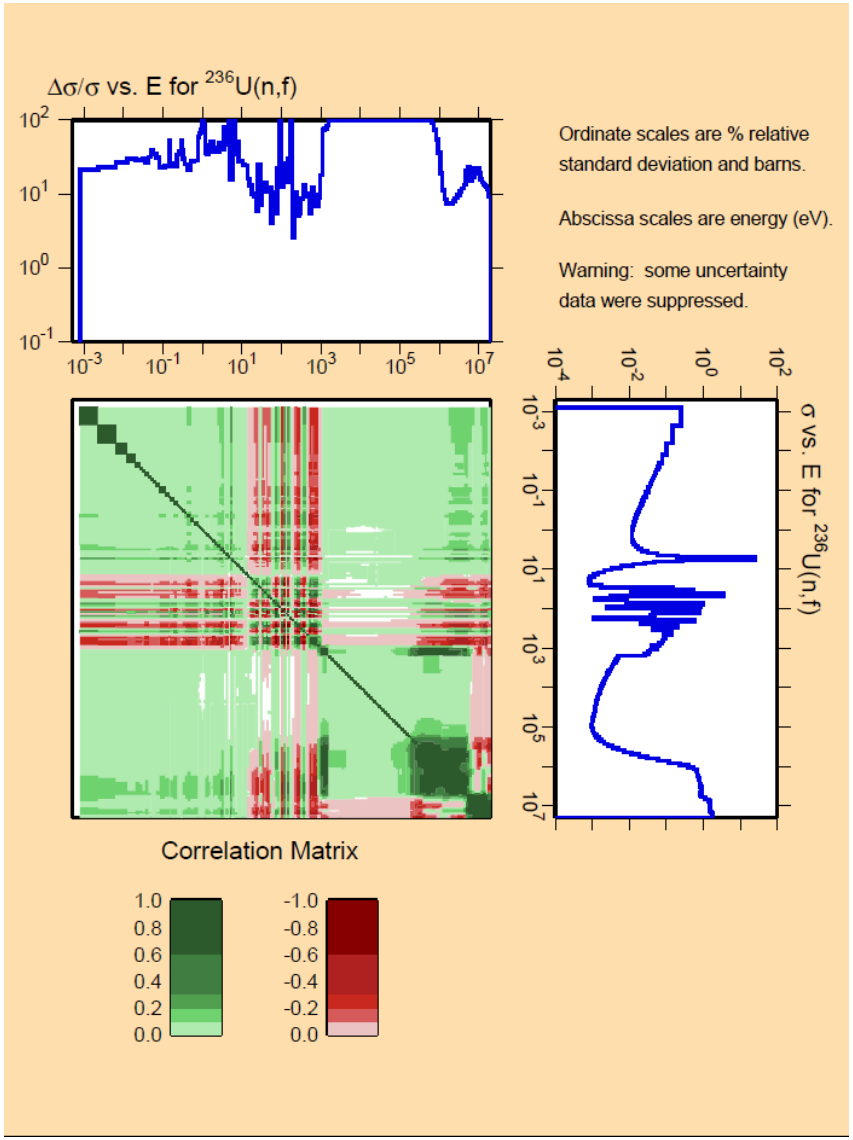
- Automatic update of MF1 with average cross sections and uncertainties,

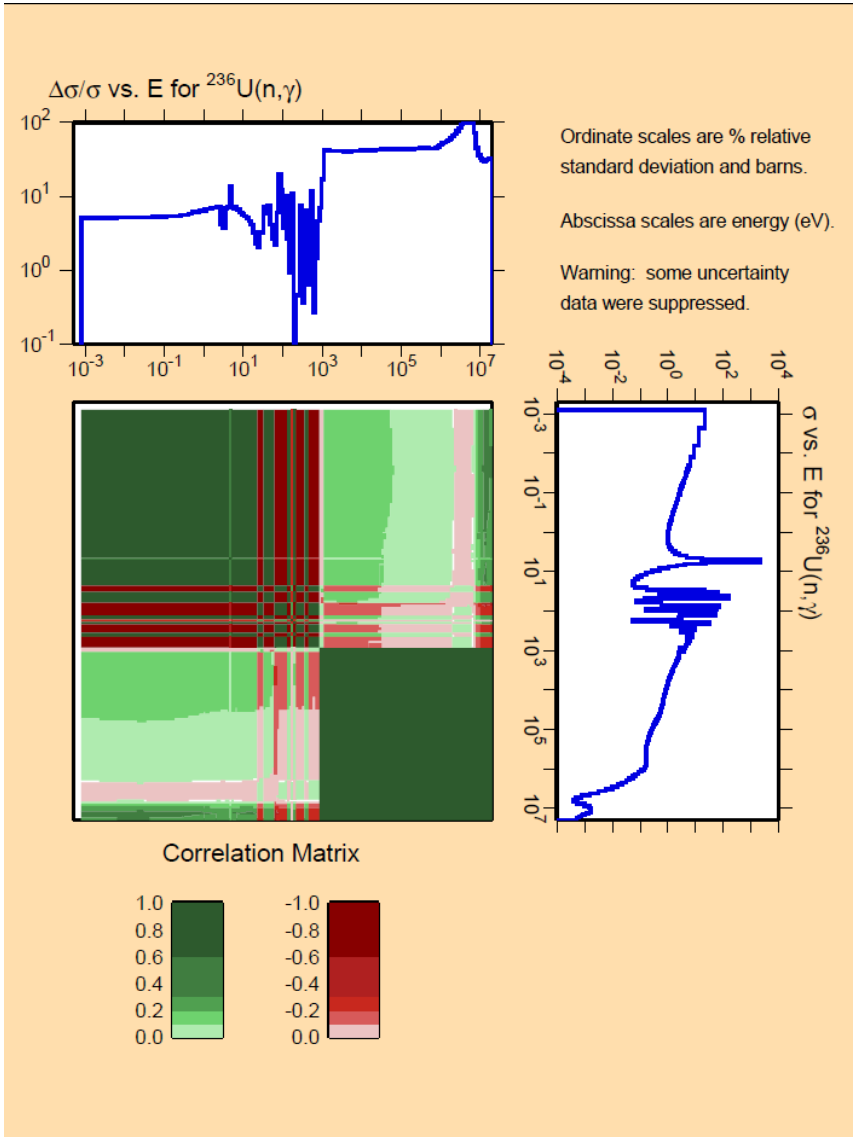
Example for ^{236}U

```
JEFF-3.3 Release - Neutron File 2015-05-17                              0  0    0
 9.223600+4 2.340178+2          1          1          2          19231 1451    1
 0.000000+0 0.000000+0          0          0          0          69231 1451    2
 1.000000+0 3.000000+7          1          0         10         329231 1451    3
 0.000000+0 0.000000+0          0          0        301        1629231 1451    4
 92-U -236 BRC        EVAL-JUL08 P. Romain, B. Morillon, H. Duarte9231 1451    5
 BRC2009              DIST-      REV1-                           9231 1451    6
----JEFF33            Material 9231         REVISION 1          9231 1451    7
-----Incident neutron  data                                      9231 1451    8
------ENDF-6 Format                                            9231 1451    9
============================  JEFF-3.3  ========================9231 1451   10
==                                                            ==9231 1451   11
==   D. Rochman, PSI                                          ==9231 1451   12
==   Automated file production based on JEFF-3.2 and TENDL-2014 ==9231 1451   13
==   performed on 2015-05-17. The covariance files from       ==9231 1451   14
==   TENDL-2014 are simply imported and added at the end of   ==9231 1451   15
==   the JEFF-3.2 file. As TENDL uses MF32, it is first used to ==9231 1451   16
==   produce random parameters, reconstruct cross sections with ==9231 1451   17
==   PREPRO (187 groups) and produce covariances. Part of the ==9231 1451   18
==   original TENDL MF33 is then added.                       ==9231 1451   19
==            ----------------------------------------        ==9231 1451   20
==   The following cross sections and uncertainties are       ==9231 1451   21
==   obtained with NJOY 99.396 and 187 groups processing.     ==9231 1451   22
==                                                            ==9231 1451   23
==               En           cross section                   ==9231 1451   24
==      (n,tot) 0.025 eV    1.37e+01 barns +/- 1.66e+01 %     ==9231 1451   25
==      (n,el)  0.025 eV    8.34e+00 barns +/- 2.75e+01 %     ==9231 1451   26
==      (n,g)   0.025 eV    5.30e+00 barns +/- 5.17e+00 %     ==9231 1451   27
==      (n,f)   0.025 eV    6.13e-02 barns +/- 2.82e+01 %     ==9231 1451   28
==                                                            ==9231 1451   29
==      (n,tot)   14 MeV    5.83e+00 barns +/- 1.64e+01 %     ==9231 1451   30
==      (n,el)    14 MeV    2.69e+00 barns +/- 3.25e+01 %     ==9231 1451   31
==      (n,inl)   14 MeV    5.99e-01 barns +/- 1.04e+01 %     ==9231 1451   32
==      (n,2n)    14 MeV    8.28e-01 barns +/- 3.11e+01 %     ==9231 1451   33
==      (n,g)     14 MeV    1.20e-03 barns +/- 2.99e+01 %     ==9231 1451   34
==      (n,f)     14 MeV    1.55e+00 barns +/- 1.34e+01 %     ==9231 1451   35
==      (n,p)     14 MeV    3.67e-04 barns +/- 6.99e-03 %     ==9231 1451   36
==      (n,a)     14 MeV    6.99e-05 barns +/- 1.18e+00 %     ==9231 1451   37
==                                                            ==9231 1451   38
==               Resonance integrals (from INTER)             ==9231 1451   39
==    Uncertainties are obtained using random files (not      ==9231 1451   40
==    covariances) in a TMC mode (looping with INTER).        ==9231 1451   41
==      (n,tot)             6.28e+02 barns +/- 2.10e+01 %     ==9231 1451   42
==      (n,el)              2.73e+02 barns +/- 1.37e+01 %     ==9231 1451   43
==      (n,g)               3.45e+02 barns +/- 1.41e+01 %     ==9231 1451   44
==      (n,f)               4.87e+00 barns +/- 2.54e+01 %     ==9231 1451   45
```

```
                                 5        455       2345          9231 1451  414
                                 6          5       1193          9231 1451  415
                                 6         16       1052          9231 1451  416
                                 6         17        584          9231 1451  417
                                 6         22       1124          9231 1451  418
                                 6         24        589          9231 1451  419
                                 6         25        287          9231 1451  420
                                 6         28        752          9231 1451  421
                                 6         37        271          9231 1451  422
                                 6         41        387          9231 1451  423
                                 6         42        179          9231 1451  424
                                 6         91       1741          9231 1451  425
                                 6        102       1370          9231 1451  426
                                12         18          4          09231 1451  427
                                13          4       1747          19231 1451  428
                                13         16       1769          19231 1451  429
                                13         17        849          19231 1451  430
                                13         22        485          19231 1451  431
                                13         24        421          19231 1451  432
                                13         25         96          19231 1451  433
                                13         28         61          19231 1451  434
                                13         37        544          19231 1451  435
                                13         41          7          19231 1451  436
                                13         42         77          19231 1451  437
                                13        102       3479          19231 1451  438
                                13        103        183          19231 1451  439
                                13        107        737          19231 1451  440
                                14          4          1          19231 1451  441
                                14         16          1          19231 1451  442
                                14         17          1          19231 1451  443
                                14         18          1          19231 1451  444
                                14         22          1          19231 1451  445
                                14         24          1          19231 1451  446
                                14         25          1          19231 1451  447
                                14         28          1          19231 1451  448
                                14         37          1          19231 1451  449
                                14         41          1          19231 1451  450
                                14         42          1          19231 1451  451
                                14        102          1          19231 1451  452
                                14        103          1          19231 1451  453
                                14        107          1          19231 1451  454
                                15         18         32          09231 1451  455
                                31        452       1179          19231 1451  456
                                33          1          7          19231 1451  457
                                33          2      12844          19231 1451  458
                                33          4        318          19231 1451  459
                                33         16         15          19231 1451  460
                                33         18       7737          19231 1451  461
                                33         51        200          19231 1451  462
                                33         91        143          19231 1451  463
                                33        102       2632          19231 1451  464
                                33        103         65          19231 1451  465
                                33        107         52          19231 1451  466
                                35         18       2121          19231 1451  467
0.000000+0 0.000000+0           0          0          0          09231 1  099999
```

Example for ^{236}U





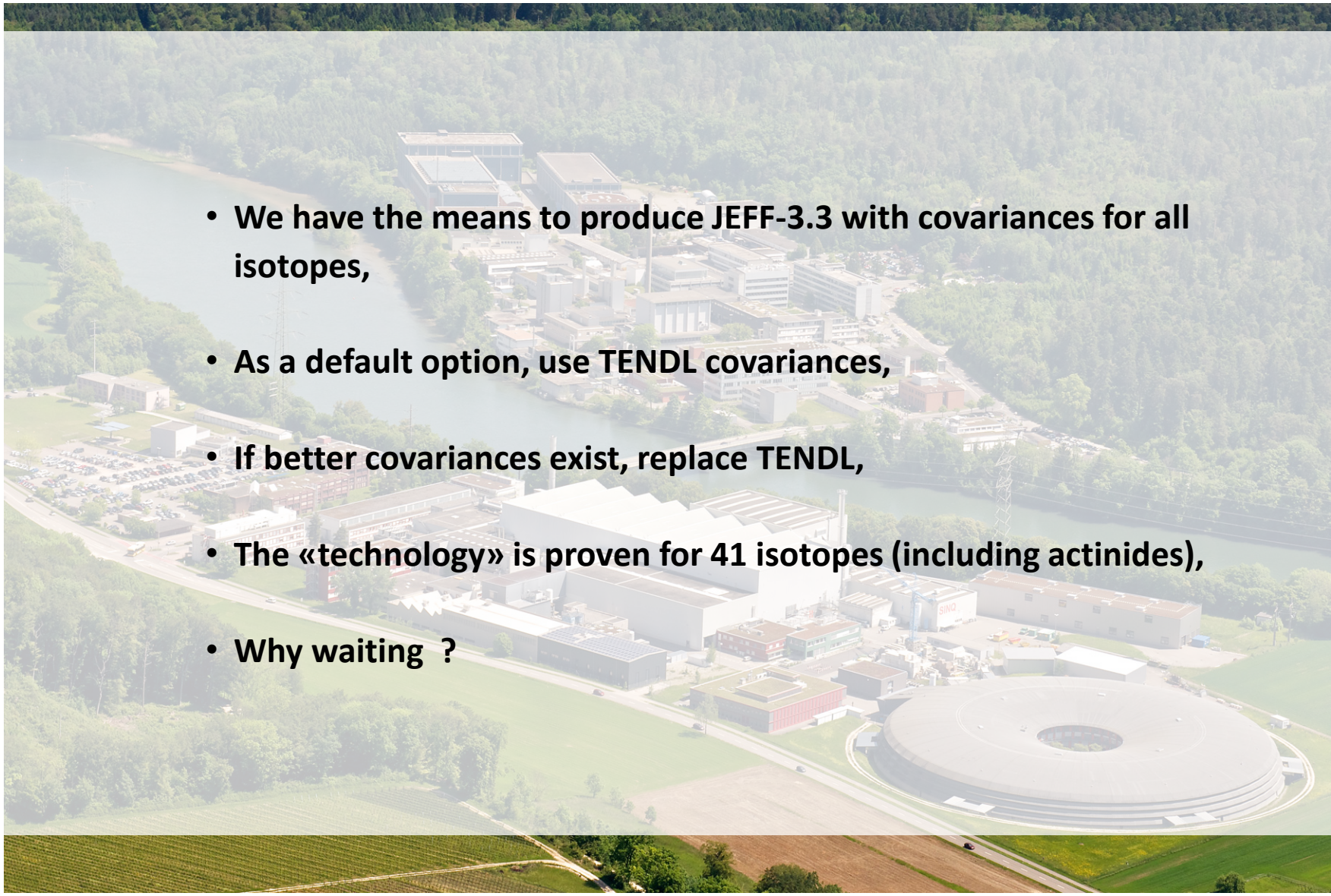
What can be done now

- For JEFF-3.3, more covariance files can be produced, for all isotopes,
- One still needs to process/verify the covariances,
- If possible, one should evaluate the impact on dedicated benchmarks (*e.g.* fake shielding benchmarks).

- Possible plan:

  1. Produce JEFF-3.2 + covariances for all isotopes,
  2. Check thermal, resonance integral, 14 MeV uncertainties,
  3. Test the covariances on real/fake benchmarks (TMC style)

Conclusion



- We have the means to produce JEFF-3.3 with covariances for all isotopes,
- As a default option, use TENDL covariances,
- If better covariances exist, replace TENDL,
- The «technology» is proven for 41 isotopes (including actinides),
- Why waiting ?