Proposal for coding of covariance data in EXFOR files

V.Zerkin, IAEA-NDS, 13-Apr-2012

"Technical Meeting Neutron Cross Section Covariances, IAEA Headquarters Vienna, Austria 27-30 September 2010":

- *The EXFOR format should be extended to accommodate the full explicit covariance matrix, if provided by the authors or, alternatively, data required by a recipe for constructing covariance matrices based on providing partial error and correlation components.*

A34 NDS:

- *Prepare a consolidated solution on the EXFOR format for covariance data coded under the keyword COVARIANCE (WP2011-32rev and WP2011-40)*

Task

Today EXFOR has very few entries having some information about experimental covariance data (47 entries from 19394 in total). Not all of them have numerical information - sometimes it is reference to the author, sometimes just general remarks. Entries with numerical covariance data describe several types of correlations including: correlations between data measured on different energies (correlations between experimental points and energy intervals); correlations between data of different reactions; correlations between Legendre coefficients of angular distributions; full and fractional, covariance and correlation matrices are given. Now covariance data are presented in EXFOR in different ways by different compilers without any agreed system, and without any software support. This paper presents a proposal for formalized rules (conventions) of coding for these types of data.

Essentially, we are going to describe and store matrices $Z_{i,j}(X_i,Y_j)$, where X and Y are given in arrays:

- Symmetric squared matrix for energy-energy data correlation: X is array with incident energies, Y is array equal to X, Z is array with correlation coefficients given as lower triangle. All three arrays are arrays of REAL numbers.

- Matrix presenting various types of correlations, where X and Y are arrays of indices or text (e.g. identifying reaction-codes or Subentries), and Z is an array of REAL numbers - correlation coefficients between data of different reactions given in different Subentries.

1. Proposal

For every array X, Y, Z the following information should be given:

1. Code: line-header with text in parentheses, starting with parenthesis and having four parameters separated by commas: (1) type and (2) length of array, (3) data type and (4) units
2. Data array: lines following the Code with real numbers separated by blanks or text lines with leading index
3. This information is placed as free text starting from 12 column under the keyword COVARINCE

Four parameters of the code:

1. Type of array: “X”, “Y”, “Z”, “XY” (when x-grid equals to y-grid), “ZP” for fractional matrix
2. Length of array: number of elements of the array following the line with the code. If X is equals to Y and LZ=(LX*(LX+1))/2, then the matrix is considered as symmetric squared matrix given as lower triangle
3. Type of data with optional data specification.
   1) Data types: “COR” – correlation matrix, “COV” - covariance matrix, “EN” - incident energy, etc.
   2) Data specification is separated by “:” from the type and used to specify type of partial information for fractional matrices, such as: name of uncertainty, incident energy for Legendre coefficients
4. Units of the following data array. It can be “PER-CENT” and “NO-DIM” for matrices, MeV for energy array. Value “N” is used as indication that the following array of X or Y will be given as text lines.

Data arrays

1. Numerical array: data values separated by space (one or more symbols ‘0x20’):
   1) length of a single data value is not fixed;
   2) number of values in one text line is not specified;
   3) decimal point “.” can be dropped
2. Text array
   1) Consists of the lines: one line for one element of array
   2) One line contains the pair: *<index> space <text>*
   3) *<index>* is sequential number from 1 to the length of array
   4) *<text>* is any text

2. Typical cases

2.1. Energy-Energy correlations

For example, we have correlation matrix for a dataset with four experimental data points measured on four incident energies. Matrix 4×4 is symmetric and given in per-cents, energy is given in MeV. This can be coded as:

```
1            (XY,4,EN,MEV)
2             0.597 0.797 0.898 0.906
3            (Z,10,COR,PER-CENT)
4             100
5             46  100
6             40  32  100
7             56  43  37  100
```

Line-1. Code `(XY,4,EN,MEV)` means: two independent variables are equal and given below as array with 4 elements; it is array with energy given in MeV.

Next line has four real numbers present 4 energies.

Line-3. Code `(Z,10,COR,PER-CENT)` means: several following lines will contain array with 10 elements which is correlation matrix given in per-cents. Comparing lengths of X, Y and Z arrays we can see that Z array is given as lower triangular matrix, 10=4*(4+1)/2. If it would be given as squared matrix, array Z would contain 16 elements.

Lines 4 to 7 contains real numbers – correlation coefficients.

Because number of values in one line and format and precision of data are not specified, equivalent presentation can be given differently, for example:

```
1               (XY,4,EN,MEV)
2                0.597 797e-3
3                0.898 0.906
4               (Z,10,COR,PER-CENT)
5                100 46 100 40. 32.0 1e2 56 43 37 1e+02
```

The same data given as full matrix and using other units:

```
1               (XY,4,EN,KEV)
2                597 797 898 906
3               (Z,16,COR,NO-DIM)
4                  1  .46 .40 .56
5                 .46  1  .32 .43
6                 .40 .32  1  .37
7                 .56 .43 .37  1
```

In the cases where we need to specify some additional information about matrix, “specification” part of the data type can be used. For example, fractional correlation matrices for different uncertainties and full correlation matrix can be coded as:

```
(ZP,45,COR:MONIT-ERR,PER-CENT)
(ZP,45,COR:ERR-4,PER-CENT)
(Z,45,COR:ERR-T,PER-CENT)
```

2.2. Reaction-Reaction correlations

Some EXFOR Entries describe correlations between data of different reactions stored in different Subentries. Such cases need another type of independent variable – different from array with real numbers as we have for description of energy grid. We need more general X and Y arrays, namely - text array, i.e. indexed text describing, for example, reactions or reaction-ratios.

```
1               (XY,6,Reaction,N)
2                 N Reaction
3                 1 Al-27(n,a)Na-24
4                 2 Mg-24(n,p)Na-24
5                 3 Ti-46(n,p)Sc-46
6                 4 Ti-47(n,p)Sc-47
7                 5 Ti-48(n,p)Sc-48
8                 6 Fe-54(n,p)Mn-54
```

Line-1. In the code `(XY,6,Reaction,N)` - `N` is used as indication that following array will contain text lines instead of real numbers.

Line-2. This is free text.

Lines 3 to 8. Every line contains index (i from 1 to 6) and Text to fill in text array X[i]=Text. Reading program should scan lines expecting leading integer number from 1 to 6 and interpret it as next element of the text array. Other lines (including line-2) should be considered as comments (really free-text).

2.3. Correlations of the Legendre coefficients

This type of correlations can be described with independent variable (number of the coefficient) in integer array and data type specification indicating incident energy:

```
1            (XY,6,NUMBER,NO-DIM)
2             0 1 2 3 4 5
3            (Z,21,COR:EN=13.33 MEV,PER-CENT)
4               100
5                 7 100
6                -1  51 100
7                 7  60  57 100
8                 4  31  50  57 100
9                 3  33  43  62  46 100
```

See other examples in Attachments 1 to 6.

3. Software support

Data preparation

Using Web-ZVView package EXFOR compiler can input matrix in almost free format, display it with various options, and produce output in several text formats including draft for EXFOR. http://nds121.iaea.org/exfor/myplot.htm

Data checking

Checking compiled EXFOR covariance data can be done using Web EXFOR Uploading system: http://nds121.iaea.org/exfor2/x4up1.htm
where user can produce plots via Web-ZVView package (see Attachement-7).

Data output for users

This part is not yet done, because there is no EXFOR files with covariance data coded with proposed rules in the EXFOR database. But since such data will be entered to EXFOR, they will be displayed by Web-ZVView package in several output formats, including simple text, html table, ENDF-MF33 and data for reading in a program including Fortran code together with data (see Attachement-8).

Conclusion

The proposed rules of coding of EXFOR covariance data are trivial, easy for programming and can be applied for all covariance data existing now in EXFOR database. The rules can be extended later if necessary. The rules do not require any modification of existing EXFOR programs. Supporting software for data input, visual checking and output for users have already been developed.

NDS agreed to present this proposal as consolidated solution on the EXFOR format for covariance data.

Example-1. Energy-Energy data correlation

Triangle symmetric matrix Energy-Energy correlation (EXFOR: 22211003)

```
123456789.123456789.123456789.123456789.123456789.123456789.123456
COVARIANCE .Covariation matrix in percent
           (XY,17,EN,MEV)
            0.597 0.797 0.898 0.906 1.01 1.098 1.117 1.193 1.376
            1.39 1.693 2.144 3.908 5.182 5.7 6.195 6.759
           (Z,153,COR,PER-CENT)
            100
            46  100
            40  32  100
            56  43  37  100
            37  29  25  34  100
            56  44  38  53  35  100
            37  30  26  35  24  35  100
            40  32  28  37  26  38  26  100
            55  44  38  51  35  52  35  38  100
            57  45  38  53  35  54  36  38  53  100
            57  45  39  54  35  55  36  39  53  55  100
            52  41  36  49  33  50  33  36  49  51  52  100
            58  45  39  54  35  54  36  38  53  55  55  51  100
            49  38  33  46  30  47  31  33  46  47  48  44  48
            100
            46  36  31  44  29  44  29  31  43  45  45  42  45
            39  100
            43  34  29  10  27  41  27  29  40  42  42  39  42
            37  35  100
            39  31  26  37  24  38  25  26  37  38  39  36  38
            34  32  30  100
```

Today in EXFOR: http://www-nds.iaea.org/EXFOR/22211.003

```
COVARIANCE .Covariation matrix in percent
           Energy,MeV
           0.597    100
           0.797     46 100
           0.898     40  32 100
           0.906     56  43  37 100
           1.010     37  29  25  34 100
           1.098     56  44  38  53  35 100
           1.117     37  30  26  35  24  35 100
           1.193     40  32  28  37  26  38  26 100
           1.376     55  44  38  51  35  52  35  38 100
           1.390     57  45  38  53  35  54  36  38  53 100
           1.693     57  45  39  54  35  55  36  39  53  55 100
           2.144     52  41  36  49  33  50  33  36  49  51  52->
           3.908     58  45  39  54  35  54  36  38  53  55  55->
           5.182     49  38  33  46  30  47  31  33  46  47  48->
           5.700     46  36  31  44  29  44  29  31  43  45  45->
           6.195     43  34  29  10  27  41  27  29  40  42  42->
           6.759     39  31  26  37  24  38  25  26  37  38  39->
           2.144       ... ... ...       100
           3.908       ... ... ...        51 100
           5.182       ... ... ...        44  48 100
           5.700       ... ... ...        42  45  39 100
           6.195       ... ... ...        39  42  37  35 100
           6.759       ... ... ...        36  38  34  32  30 100
```

Example-2. Energy-Energy data correlation: fractional correlation matrices for different uncertainties

Correlation of different components of full correlation matrix (EXFOR:23114002)

```
123456789.123456789.123456789.123456789.123456789.123456789.123456
COVARIANCE  Correlation matrix between different energy points:
            (XY,9,EN,MeV)
             8.34 9.15 13.33 16.1 17.16 17.9 19.36 19.95 20.61
            (ZP,45,COR:MONIT-ERR,PER-CENT)
              100
              43  100
              0   0   100
              0   0   6   100
              0   0   9   12  100
              0   0   9   12  100 100
              0   0   11  11  40  40  100
              0   0   11  11  40  40  100 100
            (ZP,45,COR:ERR-4,PER-CENT)
              100
              0   100
              0   100 100
              0   100 100 100
              0   0   0   0   100
              100 0   0   0   0   100
              0   0   0   0   100 0   100
              0   0   0   0   0   0   0   100
              100 0   0   0   0   100 0   0   100
            (Z,45,COR:ERR-T,PER-CENT)
              100
               35 100
               37  42 100
               38  43  53 100
               40  45  57  58 100
               41  45  57  59  84 100
               21  24  30  31  39  39 100
               30  34  44  45  58  59  51 100
               20  22  29  30  40  42  39  65 100
```

Today in EXFOR: http://www-nds.iaea.org/EXFOR/23114002

```
COVARIANCE  Correlation matrix (multiplied by 100.) between
            different energy points:
                  100
                   35 100
                   37  42 100
                   38  43  53 100
                   40  45  57  58 100
                   41  45  57  59  84 100
                   21  24  30  31  39  39 100
                   30  34  44  45  58  59  51 100
                   20  22  29  30  40  42  39  65 100
ERR-ANALYS (ERR-T) Total uncertainty.
           (MONIT-ERR) Uncertainty of monitor cross section.
           . . . . . .
           (ERR-4) Uncertainty of Am target nuclei number
```

Example-3. Reaction-Reaction correlation

Correlation between different reactions in different subentries (EXFOR: 13134)

```
123456789.123456789.123456789.123456789.123456789.123456789.123456
COVARIANCE Correlation matrix for fission cross section ratios
           (XY,9,Reaction-Ratio,N)
             N Reaction Ratio
             1 230Th/235U
             2 232Th/235U
             3 233U/235U
             4 234U/235U
             5 236U/235U
             6 238U/235U
             7 237Np/235U
             8 239Pu/235U
             9 242Pu/235U
           (Z,45,COR,PER-CENT)
             100
              57 100
              58  48 100
              69  60  62 100
              71  59  64  78 100
              68  58  58  73  73 100
              53  51  41  53  53  56 100
              52  43  50  59  62  59  36 100
              42  40  37  44  43  39  37  35 100
```

Index

Text: Reactions Ratio

Today in EXFOR: http://www-nds.iaea.org/EXFOR/13134

```
COVARIANCE Correlation matrix for fission cross section ratios
                           1   2   3   4   5   6   7   8   9
           230Th/235U 1  100
           232Th/235U 2   57 100
           233U/235U  3   58  48 100
           234U/235U  4   69  60  62 100
           236U/235U  5   71  59  64  78 100
           238U/235U  6   68  58  58  73  73 100
           237Np/235U 7   53  51  41  53  53  56 100
           239Pu/235U 8   52  43  50  59  62  59  36 100
           242Pu/235U 9   42  40  37  44  43  39  37  35 100
```

Example-4. Energy-Energy data correlation and covariance matrices

Correlation and covariance matrices are given on the same energy grid

```
123456789.123456789.123456789.123456789.123456789.123456789.123456
COVARIANCE  (XY,31,EN,MEV)
             0.98 1.17 1.28 1.38 1.46 1.62 1.66 1.68 1.77 1.89
             1.92 2    2    2.09 2.13 2.23 2.31 2.43 2.62 2.64
             2.71 2.79 2.92 3.07 3.09 3.21 3.45 3.52 3.71 5.58
             5.9
            (Z,496,COR,PER-CENT)
             100
             32  100
             50  30  100
             41  25  39  100
             48  29  46  38  100
              . . . . . . . . . . . . . . . . . . . . . . .
            (Z,496,COV,1e-6) Covariance matrix, units are 10**-6.
             55
             38  153
             38  38  55
             38  38  38  55
             38  38  38  38  55
             38  38  38  38  38  45
              . . . . . . . . . . . . . . . . . . . . . . .
```

Multiplier10^{-6} to convert to NO-DIM

Today in EXFOR: http://www-nds.iaea.org/EXFOR/40664002

```
COVARIANCE  Covariance matrix, units are 10**-6.
               1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16 17
            1  55
            2  38 153
            3  38 38 55
            4  38 38 38 55
            5  38 38 38 38 55
            . . . . . . . . . . . . . . . . . .
                    (continued covariance matrix)
                18 19 20 21 22 23 24 25 26 27 28 29 30 31
           18   43
           19   38 43
           20   15 15 41
            . . . . . . . . . . . . . . . . . .
           31   38 38 15 38 15 38 15 38 38 38 38 38 38 49
                Correlations matrix, units are 10**-2 :
              1   2   3   4   5   6   7   8   9   10  11  12  13
            1 100
            2  32 100
            3  50  30 100
            4  41  25  39 100
            . . . . . . . . . . . . . . . . . .
                 (continued)
               27  28  29  30  31
           27  100
           28   44 100
           29   47  42 100
           30   43  38  41 100
           31   44  39  42  38 100
```

Example-5. Correlations between data on energy intervals

Correlation matrix is given for energy groups with EnMin[i+1]=EnMax[i]

```
COVARIANCE .PARALLEL PROPAGATION OF CORRELATED AND UNCORRELATED
           UNCERTAINTY WITH CODE ANGELA
           (XY,16,EN,EV)
            2.485  2.691  6.874  13.77  21.75  40     80.77
            115.6  193.8  382.7  722.5  1844   6129   21020
            183200 409400
           (Z,136,COR,PER-CENT)
             100
              57 100
              73 49 100
              2 2 3 100
              9 9 22 1 100
              -6 3 26 2 28 100
              -8 -2 6 1 10  25 100
              -6 -2 2 0 5 14 6 100
             -38 -17 0 1 24 66 28 16 100
             -47 -23  -7 1 23 67 29 17 85 100
             -52 -27 -12 1 22 65 29 17 86 93 100
             -53 -28 -17 1 19 59 26 16 82 90 95 100
             -43 -23 -17 0 13 44 20 12 66 75 82 90 100
              -7 -5 -5 0 1 8 4 3 19 27 35 50 76 100
              34 18 12 0 -9 -29 -13 -7 -35 -34 -30 -18 12 58 100
              34 18 12 0 -9 -29 -13 -7 -35 -34 -30 -18 12 58 58
              100
DATA                6        866
```

One additional point added to present end of the last interval

Today in EXFOR: http://www-nds.iaea.org/EXFOR/21968

```
COVARIANCE .PARALLEL PROPAGATION OF CORRELATED AND UNCORRELATED
           UNCERTAINTY WITH CODE ANGELA
               ENERGY GROUPS(EV)
               NR      FROM          TO
                1   2.485E00    2.691E00
                2   2.691E00    6.874E00
                3   6.874E00    1.377E01
                4   1.377E01    2.175E01
                5   2.175E01    4.000E01
                6   4.000E01    8.077E01
                7   8.077E01    1.156E02
                8   1.156E02    1.938E02
                9   1.938E02    3.827E02
               10   3.827E02    7.225E02
               11   7.225E02    1.844E03
               12   1.844E03    6.129E03
               13   6.129E03    2.102E04
               14   2.102E04    1.832E05
               15   1.832E05    4.094E05
           UNCERTAINTY CORRELATION BETWEEN GROUPS
           ENERGY GROUPS/
           1/100
           2/ 57 100
           3/ 73 49 100
           4/ 2 2 3 100
           5/ 9 9 22 1 100
           6/ -6 3 26 2 28 100
           7/ -8 -2 6 1 10  25 100
           8/ -6 -2 2 0 5 14 6 100
           9/-38 -17 0 1 24 66 28 16 100
           10/-47 -23  -7 1 23 67 29 17 85 100
           11/-52 -27 -12 1 22 65 29 17 86 93 100
           12/-53 -28 -17 1 19 59 26 16 82 90 95 100
           13/-43 -23 -17 0 13 44 20 12 66 75 82 90 100
           14/ -7 -5 -5 0 1 8 4 3 19 27 35 50 76 100
           15/ 34 18 12 0 -9 -29 -13 -7 -35 -34 -30 -18 12 58 100
```

Example-6. Correlations of the Legendre coefficients

```
COVARIANCE .Correlations of the Legendre coefficients
           (XY,11,iLeg,NO-DIM)
            0 1 2 3 4 5 6 7 8 9 10
           (Z,66,COR:EN=9.41MeV,PER-CENT)
            100
             35 100
             20  65 100
              8  59  91 100
              0  33  87  94 100
              2  42  87  97  98 100
              1  30  86  91  99  97 100
              1  34  83  92  97  98  98 100
              4  26  82  84  93  92  97  96 100
              6  36  79  84  88  90  92  94  95 100
              6   9  65  57  72  67  79  76  87  83 100
           (XY,14,iLeg,NO-DIM)
            0 1 2 3 4 5 6 7 8 9 10 11 12 13
           (Z,105,COR:EN=15.20MeV,PER-CENT)
           100
            39 100
            50  74 100
            36  91  80 100
            33  61  84  84 100
            22  75  68  93  88 100
            20  48  69  76  95  90 100
            11  59  52  82  83  96  92 100
             4  29  44  60  82  82  94  92 100
             2  49  40  73  76  91  88  98  93 100
             4  31  45  62  82  82  93  91  98  94 100
             8  55  43  77  75  90  83  95  88  97  90 100

            10  32  43  58  75  74  82  81  88  84  91  88 100
             9  62  32  70  51  77  56  76  59  78  64  86 71 100
```

Specification of incident Energy

Proposal

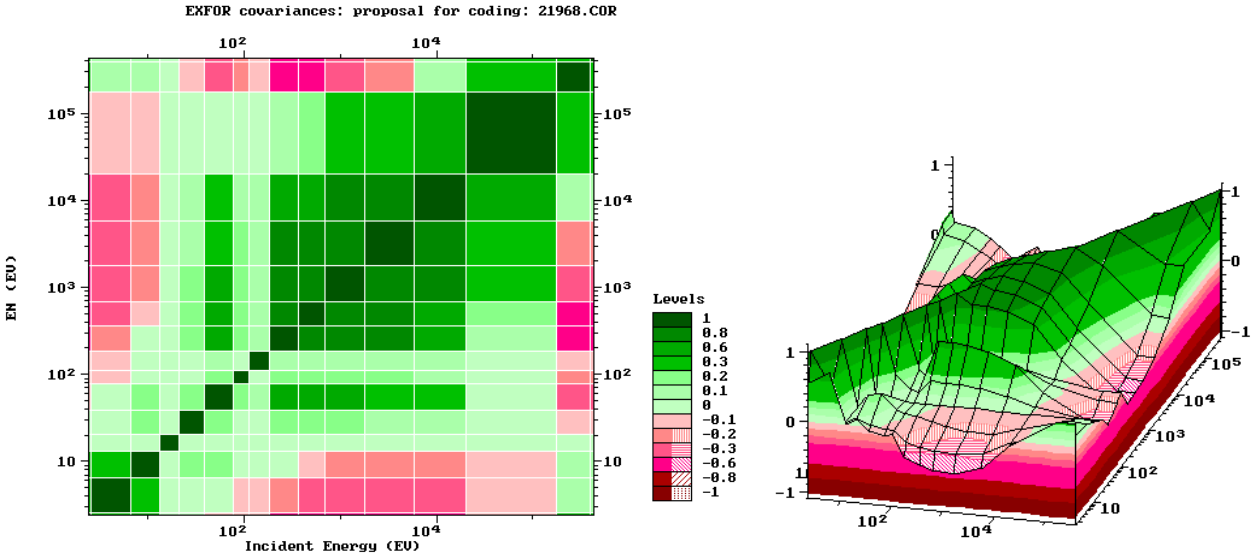
Original

Today in EXFOR: http://www-nds.iaea.org/EXFOR/22403005

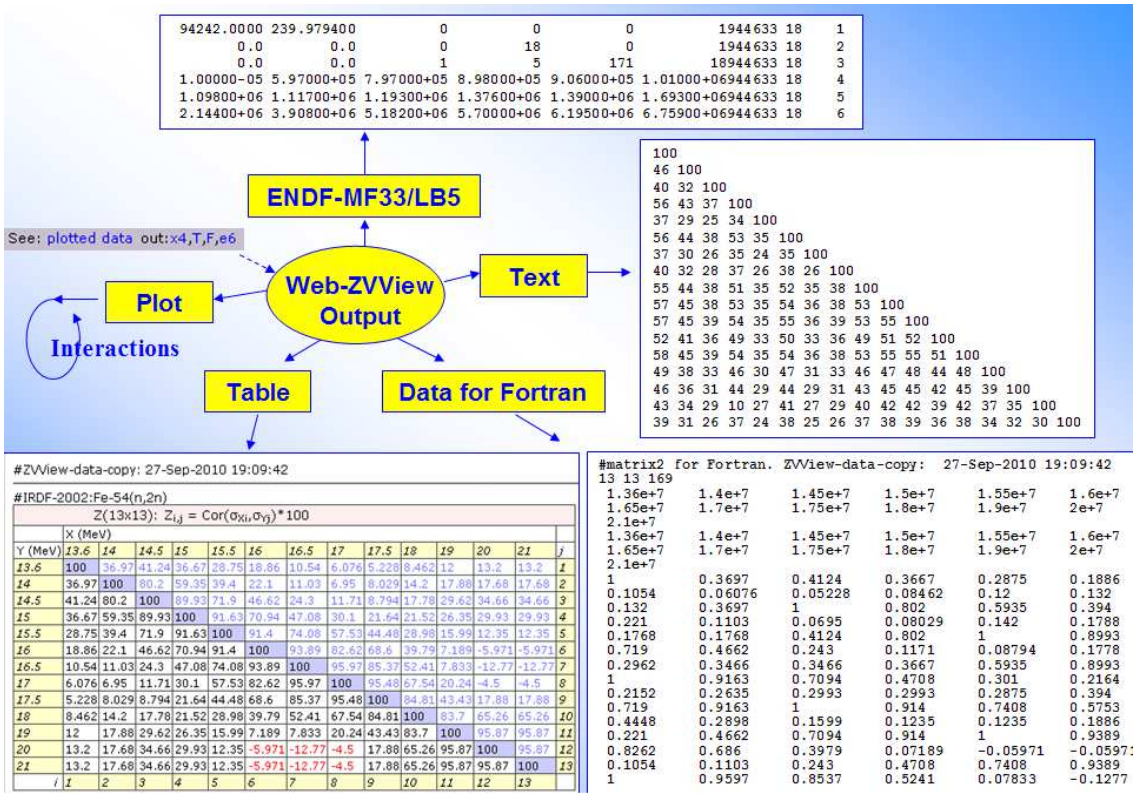
```
COVARIANCE .Correlations of the Legendre coefficients
               EN = 9.41 MEV
            l RSD(%)           correlation matrix
           -
            0   2.10 100
            1   0.13  35 100
            2   0.20  20  65 100
            3   0.33   8  59  91 100
            4   0.58   0  33  87  94 100
            5   0.97   2  42  87  97  98 100
            6   1.58   1  30  86  91  99  97 100
            7   2.30   1  34  83  92  97  98  98 100
            8   4.00   4  26  82  84  93  92  97  96 100
            9   6.29   6  36  79  84  88  90  92  94  95 100
           10  13.84   6   9  65  57  72  67  79  76  87  83 100
            ----------------------------------------------
               E-0 =  15.20 MEV
            l       RSD(%)             correlation matrix
           -
            0   2.28 100
            1   0.39  39 100
            2   0.40  50  74 100
            3   0.62  36  91  80 100
            4   0.62  33  61  84  84 100
            5   1.01  22  75  68  93  88 100
            6   1.15  20  48  69  76  95  90 100
            7   1.74  11  59  52  82  83  96  92 100
            8   2.03   4  29  44  60  82  82  94  92 100
            9   3.58   2  49  40  73  76  91  88  98  93 100
           10   6.05   4  31  45  62  82  82  93  91  98  94 100
           11  19.42   8  55  43  77  75  90  83  95  88  97  90..
           12  39.25  10  32  43  58  75  74  82  81  88  84  91..
           13 339.68   9  62  32  70  51  77  56  76  59  78  64..
           -
           ....The tail of last 3 matrix rows are given below.
           -
           11  19.42                          ... 90 100
           12  39.25                          ... 91  88 100
           13 339.68                          ... 64  86  71 100
```

Plotting with Web-ZVView package

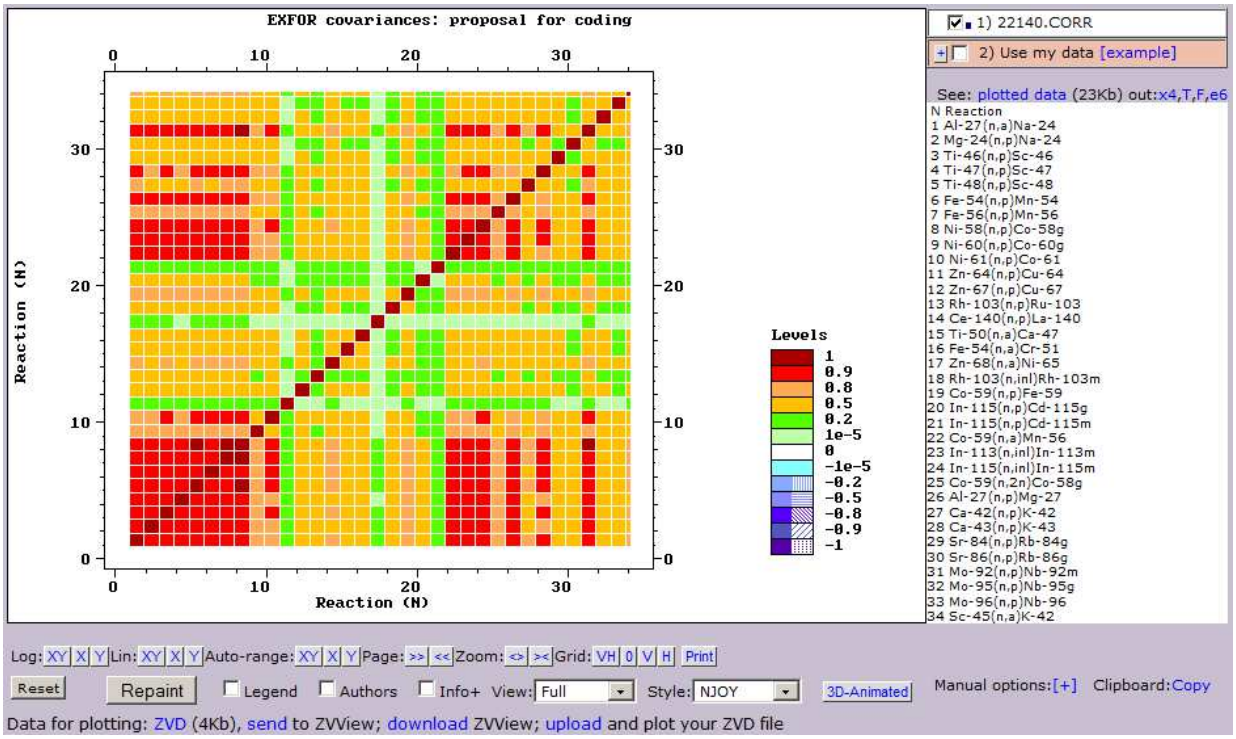
Correlation between Energy-Groups



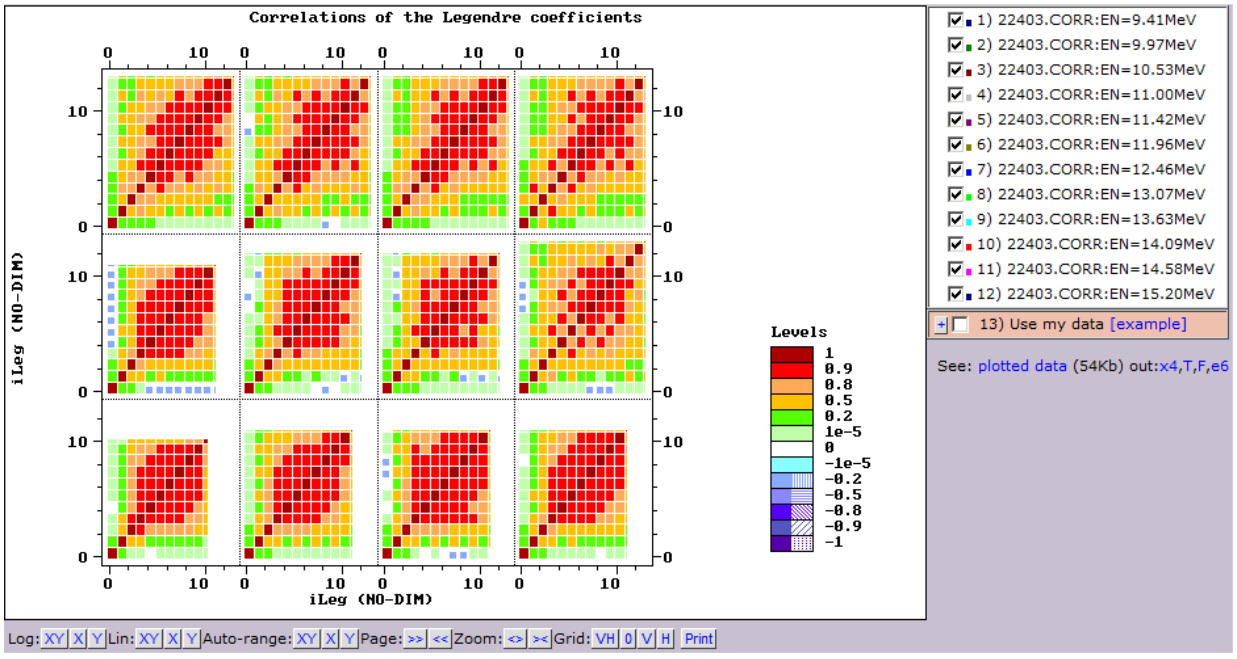
Output from Web-ZVView to text formats



Reaction-Reaction correlations



Correlations of Legendre coefficients



Web-ZVView output for Fortran users: data+code in one file

```
#matrix2 for Fortran. ZVView-data-copy:  12-Apr-2012 18:09:35
17 17 289

 597000     797000     898000     906000     1.01e+6    1.098e+6
 1.117e+6   1.193e+6   1.376e+6   1.39e+6    1.693e+6   2.144e+6
 3.908e+6   5.182e+6   5.7e+6     6.195e+6   6.759e+6

 597000     797000     898000     906000     1.01e+6    1.098e+6
 1.117e+6   1.193e+6   1.376e+6   1.39e+6    1.693e+6   2.144e+6
 3.908e+6   5.182e+6   5.7e+6     6.195e+6   6.759e+6

 1          0.46       0.4        0.56       0.37       0.56
 0.37       0.4        0.55       0.57       0.57       0.52
 0.58       0.49       0.46       0.43       0.39       0.46
 1          0.32       0.43       0.29       0.44       0.3
 0.32       0.44       0.45       0.45       0.41       0.45
 0.38       0.36       0.34       0.31       0.4        0.32
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
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 0.43       0.45       0.45       0.42       0.45       0.39
 1          0.35       0.32       0.43       0.34       0.29
 0.1        0.27       0.41       0.27       0.29       0.4
 0.42       0.42       0.39       0.42       0.37       0.35
 1          0.3        0.39       0.31       0.26       0.37
 0.24       0.38       0.25       0.26       0.37       0.38
 0.39       0.36       0.38       0.34       0.32       0.3
 1
#//---------------------------------------------------------------
#//fortran program for reading
      integer lx,ly,lz
      character*80 filename
      character*80 title
      real xx(200),yy(200),zz(40000)
      in=30
      filename='m2.txt'
      write (*,*) 'file: ',trim(filename)
      open (unit=in, file=filename, status='old')
      read (in,*) title
      read (in,*) lx,ly,lz
      read (in,*) (xx(ii),ii=1,lx)
      read (in,*) (yy(ii),ii=1,ly)
      read (in,*) (zz(ii),ii=1,lz)
      close(unit=in)
      call matrix2out(lx,ly,xx,yy,zz)
      stop
      end

      subroutine matrix2out(lx,ly,xx,yy,zz)
      dimension xx(lx),yy(ly),zz(lx,ly)
      write (*,*) ' LX=',lx,' LY=',ly,' LZ=',lx*ly
      write (*,200) (' i=',ii,' x=',xx(ii),ii=1,lx)
      write (*,200) (' j=',jj,' y=',xx(jj),jj=1,ly)
200   format(' ',a3,i3,' ',a3,g13.7)
      do jj=1,ly
        do ii=1,lx
          write (*,*) jj,ii,' x=',xx(ii),' y=',yy(ii),' z=',zz(ii,jj)
        enddo
      enddo
      return
      end
```