

DE LA RECHERCHE À L'INDUSTRIE



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2nd Research Coordinated Meeting on IRDFF validation

Progress of the CEA contribution to IRDFF
validation: experimental data and codes

CALMAR – ECORCES presentation

16th – 20th March 2015 – IAEA- Vienna | C Destouches, G. Gregoire

0 – Goal / Context of the adjustment/unfolding process

1 - Data Shaping operations : ECORCES

2 - Unfolding CALMAR code status

Goal:

- Derivation of the most likely neutron spectrum and its covariance matrix from “measured” reaction rates (saturated activities) using nuclear data (cross section), prior neutron spectrum and their respective covariance matrices.

Context :

- Nuclear Reactor spectra ($E < 20$ MeV)
- Need of integrated values (Thermal, Epithermal, Fast Fluxes, DPA,...) with realistic uncertainties ($< 10\%$)
- Cross section are considered as non modifiable Response Functions
- Adjustment/Unfolding process is considered as the best process to propagate uncertainties to the output data

ECORCES

Energy **C**omputation of **R**eaction rate
from **C**ross section & n**E**utron **S**pectrum



User friendly tool for data shaping operations:

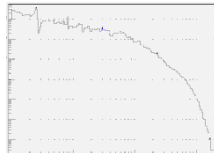
- Energy Mesh modification for neutron spectrum and Covariance Matrices
- Condensation of cross section and Covariances Matrices on a selected Energy Mesh
- Integrated Flux and Reaction Rate calculations with Incertitude derivation
- Input data preparation for CALMAR
- E max : 20 MeV, 640Grp (SANDII format)

INPUTS

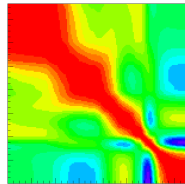
User NRJ Mesh

```
1E-11  
0.01  
0.1  
1  
5  
10  
20
```

Input Spectrum



Spectrum matrix



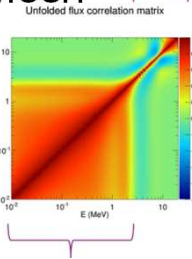
Isotopes

2	204469E+4	4	000309E+1	0	0	0	0	57550	1073	257
-1	58400E+1	1	58400E+1	0	0	1	0	183200	1403	274
210	0000E+0	0	4270E+0	1	0267E-5	5700000	0	1711330	-2523	282
240	0000E+0	0	39544E+5	2	0000000	0	0	638442	54228	143
270	0000E+0	0	000278E+4	2	001558E-4	4000000	0	0008535E+2	210	272
300	0000E+0	0	422000E+0	3	0000000	0	0	0022890E+2	2520	279
530	0000E+0	0	014258E+5	3	004481E-5	5100000	0	00003370E+2	96	318
360	0000E+0	0	011449E+0	3	0000000	0	0	0270307E+2	202	291
390	0000E+0	0	000282E+0	4	0000000	0	0	0400770E+2	222	282
430	0000E+0	0	074150E+0	4	0000000	0	0	0452767E+2	2520	293
480	0000E+0	0	052364E+5	4	0000000	0	0	0628340E+2	202	284
490	0000E+0	0	038204E+4	4	0000000	0	0	0757463E+2	210	295
670	0000E+0	0	009124E+0	5	0000000	0	0	0047370E+2	202	286
640	0000E+0	0	000492E+0	5	0000000	0	0	0044341E+2	210	287
670	0000E+0	0	130250E+0	5	0000000	0	0	0233933E+2	210	286
690	0000E+0	0	122401E+4	6	0000000	0	0	1500212E+2	210	287
670	0000E+0	0	158275E+0	6	0000000	0	0	0232890E+2	210	286
690	0000E+0	0	192485E+0	6	0000000	0	0	1952750E+2	210	287
840	0000E+0	0	222220E+0	7	0000000	0	0	2234860E+2	210	284
750	0000E+0	0	210390E+0	7	0000000	0	0	2257575E+2	210	285
780	0000E+0	0	227145E+0	7	0000000	0	0	2324850E+2	210	284
780	0000E+0	0	239541E+5	7	0000000	0	0	2409312E+2	210	286
820	0000E+0	0	212210E+0	8	0000000	0	0	2174700E+2	210	286
840	0000E+0	0	250112E+4	8	0000000	0	0	2642761E+2	210	287
870	0000E+0	0	238853E+5	8	0000000	0	0	2643097E+2	210	286
900	0000E+0	0	252038E+4	9	0000000	0	0	2679442E+2	210	289
930	0000E+0	0	259777E+5	9	0000000	0	0	2707877E+2	210	286
960	0000E+0	0	276282E+5	9	0000000	0	0	2804358E+2	210	331
980	0000E+0	0	282487E+6	10	0000000	0	0	2863193E+2	210	332
100	0000E+0	0	240002E+0	10	0000000	0	0	2312522E+2	210	331
106	0000E+0	0	251215E+5	10	0000000	0	0	2463352E+2	210	332
106	0000E+0	0	249740E+5	10	0000000	0	0	2460207E+2	210	336
110	0000E+0	0	242404E+5	10	0000000	0	0	2407480E+2	210	334
114	0000E+0	0	343731E+3	11	0000000	0	0	3053450E+2	210	337
120	0000E+0	0	333969E+3	11	0000000	0	0	3032216E+2	210	338
125	0000E+0	0	342053E+3	11	0000000	0	0	3043498E+2	210	339
130	0000E+0	0	318078E+3	11	0000000	0	0	2857911E+2	210	340
126	0000E+0	0	236230E+3	11	0000000	0	0	2481316E+2	210	312
125	0000E+0	0	298646E+3	11	0000000	0	0	2818939E+2	210	312
124	0000E+0	0	272409E+3	11	0000000	0	0	2622770E+2	210	312
136	0000E+0	0	272144E+6	11	0000000	0	0	2627130E+2	210	312
138	0000E+0	0	253889E+0	11	0000000	0	0	2487223E+2	210	316
143	0000E+0	0	212202E+5	12	0000000	0	0	2286797E+2	210	316
144	0000E+0	0	247706E+5	12	0000000	0	0	2523644E+2	210	317
147	0000E+0	0	231609E+5	12	0000000	0	0	2243410E+2	210	316
152	0000E+0	0	230945E+3	12	0000000	0	0	2257314E+2	210	316
97	0000E+0	0	740167E+0	15	0000000	0	0	7297849E+2	210	310

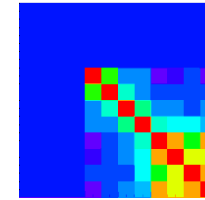
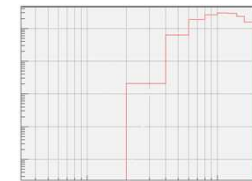
International Reactor Dosimetry File

OUTPUTS (ASCII, GRAPH)

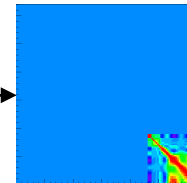
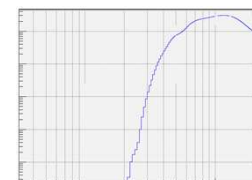
Spectrum in new Mesh



Reaction rate

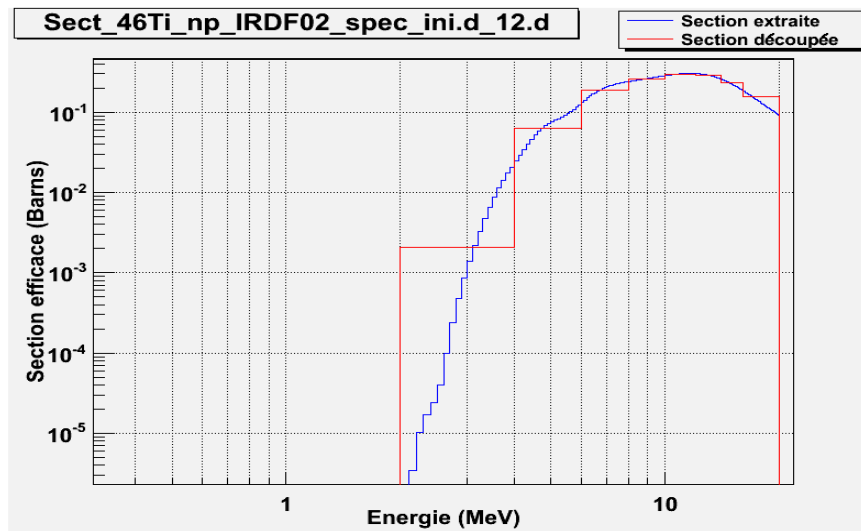
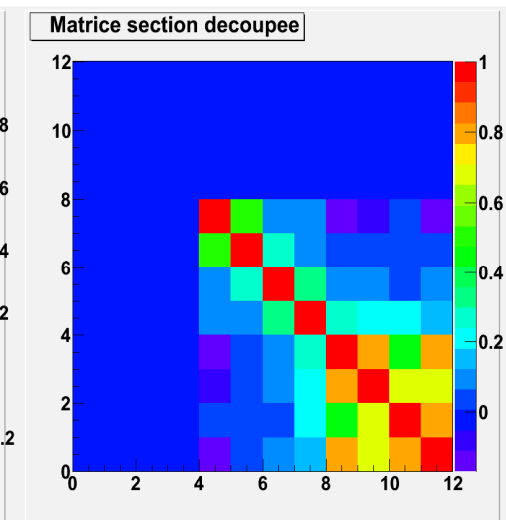
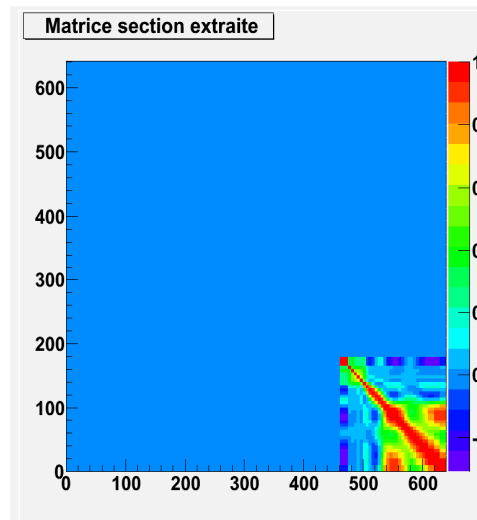
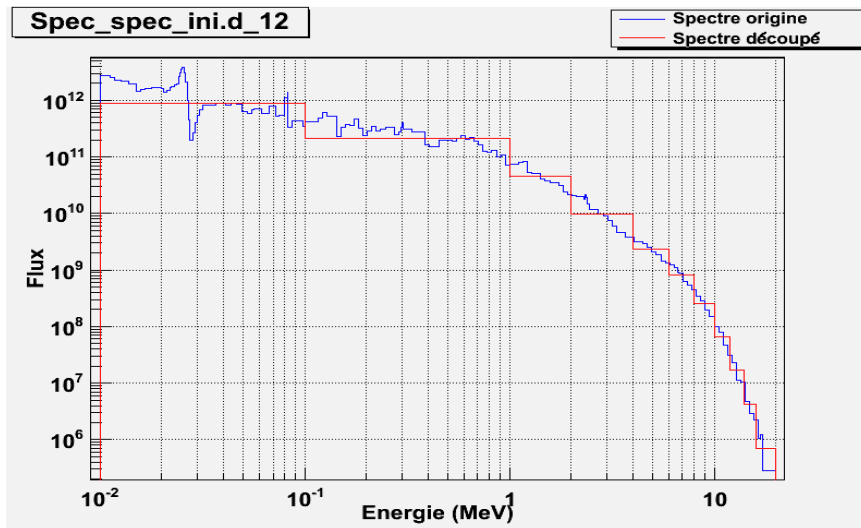


Cross section



1 - Data Shaping operations : ECORCES

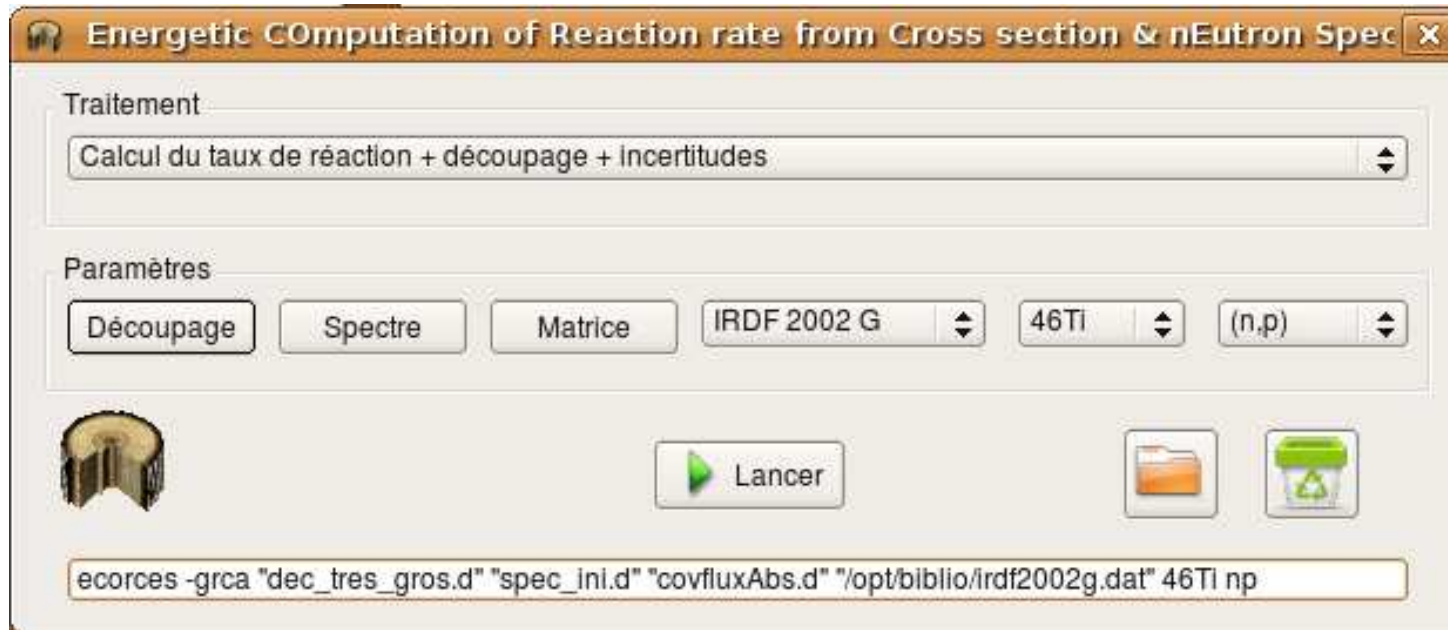
Output samples



Gr (n)	E-Inf (MeV)	Flux (n/cm ² /s)	Incert. (%)	Section (Barn)	Incert. (%)	Taux (Bq)	Incert. (%)
1	1.000E-11	0.000E+00	0.00	0.000E+00	0.00	0.000E+00	0.00
2	1.000E-02	8.116E+10	8.64	0.000E+00	0.00	0.000E+00	8.64
3	1.000E-01	1.925E+11	7.35	0.000E+00	0.00	0.000E+00	7.35
4	1.000E+00	4.616E+10	7.19	0.000E+00	0.00	0.000E+00	7.19
5	2.000E+00	1.961E+10	3.59	2.094E-03	11.70	4.107E+07	12.24
6	4.000E+00	4.636E+09	3.47	6.344E-02	3.86	2.941E+08	5.18
7	6.000E+00	1.640E+09	5.96	1.859E-01	4.58	3.048E+08	7.52
8	8.000E+00	5.184E+08	10.70	2.577E-01	2.86	1.336E+08	11.07
9	1.000E+01	1.331E+08	15.88	2.953E-01	3.04	3.930E+07	16.17
10	1.200E+01	3.377E+07	21.01	2.907E-01	2.31	9.818E+06	21.13
11	1.400E+01	8.413E+06	26.36	2.315E-01	2.48	1.948E+06	26.48
12	1.600E+01	2.808E+06	32.32	1.537E-01	3.97	4.317E+05	32.56
Total:		3.464E+11	6.33	2.381E-03	8.84	8.250E+08	6.17
Somme > 0.01MeV		3.464E+11	6.33	2.381E-03	8.84	8.250E+08	6.17
Somme < 0.01MeV		0.000E+00	0.00	0.000E+00	0.00	0.000E+00	0.00
Somme > 0.1MeV		2.653E+11	6.20	3.110E-03	8.75	8.250E+08	6.17
Somme < 0.1MeV		8.116E+10	0.00	0.000E+00	0.00	0.000E+00	0.00
Somme > 1MeV		7.275E+10	5.33	1.134E-02	8.16	8.250E+08	6.17
Somme < 1MeV		2.737E+11	8.64	0.000E+00	8.64	0.000E+00	0.00

Taux de reaction total: 8.250E+08 (Bq) 90% entre 4.001E+00 et 1.052E+01 (MeV)

1 - Data Shaping operations : ECORCES



- IHM (WINDOWS LINUX)
- Encapsulated programme
- Upgrade to 60 MeV and 725 groups possible – to be studied
- **To be proposed for publication at the NEA at the end of 2015**

PRINCIPE

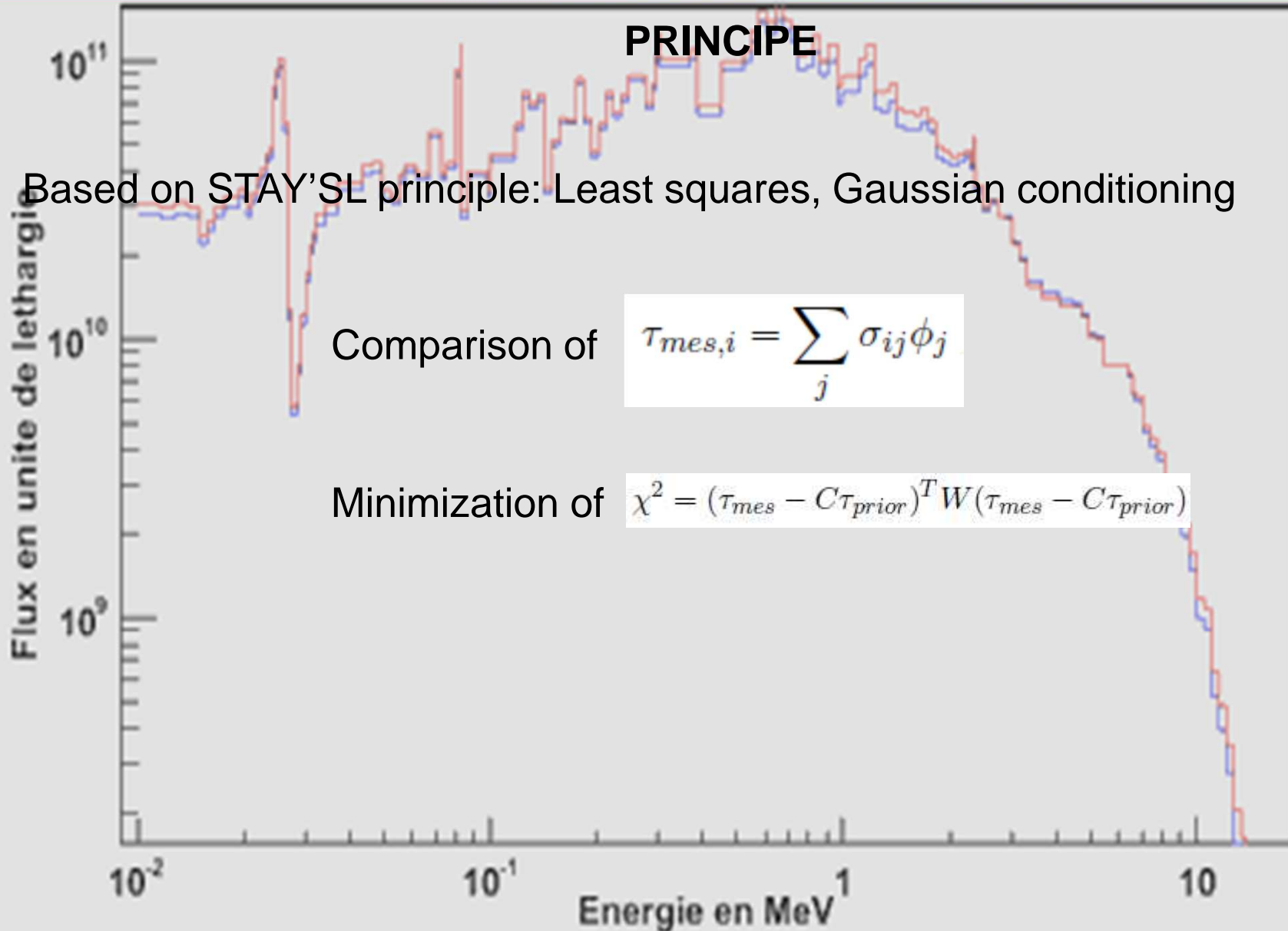
Based on STAY'SL principle: Least squares, Gaussian conditioning

Comparison of

$$\tau_{mes,i} = \sum_j \sigma_{ij} \phi_j$$

Minimization of

$$\chi^2 = (\tau_{mes} - C\tau_{prior})^T W (\tau_{mes} - C\tau_{prior})$$

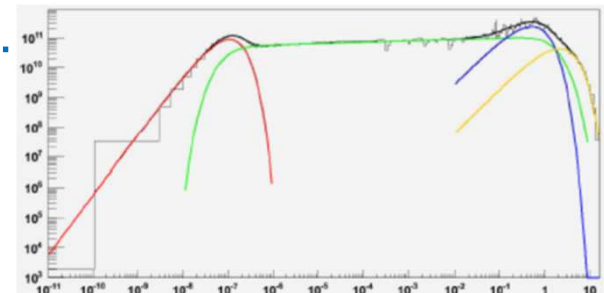


Upgrades 2013-2014

- Optimization of the process : **Parallel** iterative shape and normalization process (← MS-ITER)
- Uncertainty propagation:
 - Inclusion of the normalization
 - Complete uncertainty propagation (covariance included)
- C++ - ROOT platform coding
 - 3 possible functioning modes : Library or dll, Stand alone executable, Script/class (root)
- ASCII format data inputs : readable/portable files or BdD
- Recoding in C++ of STAY'SL, MS-ITER, GRAVEL/SANDII
 - Multi-code Analysis possible

Inputs

- “Measured” Reaction Rates
 - Output of the Activation calculation Process :
 - Analytical or DARWIN/PEPIN2
 - Corrected from self-shielding effects
 - Correlation Matrix derived from uncertainty propagation
- Cross sections and covariance Matrices condensed on the spectrum energy mesh (ECORCES + IRDFF)
- Prior neutron spectrum (representative MC code result)
 - Adapted energy mesh (Emin, Number of groups)
 - Local anti-resonance suppressed (coherence with the MatCov)
- Correlation Matrix deduced from “Williams” type Method
 - Analytical representation, MC simulation,...

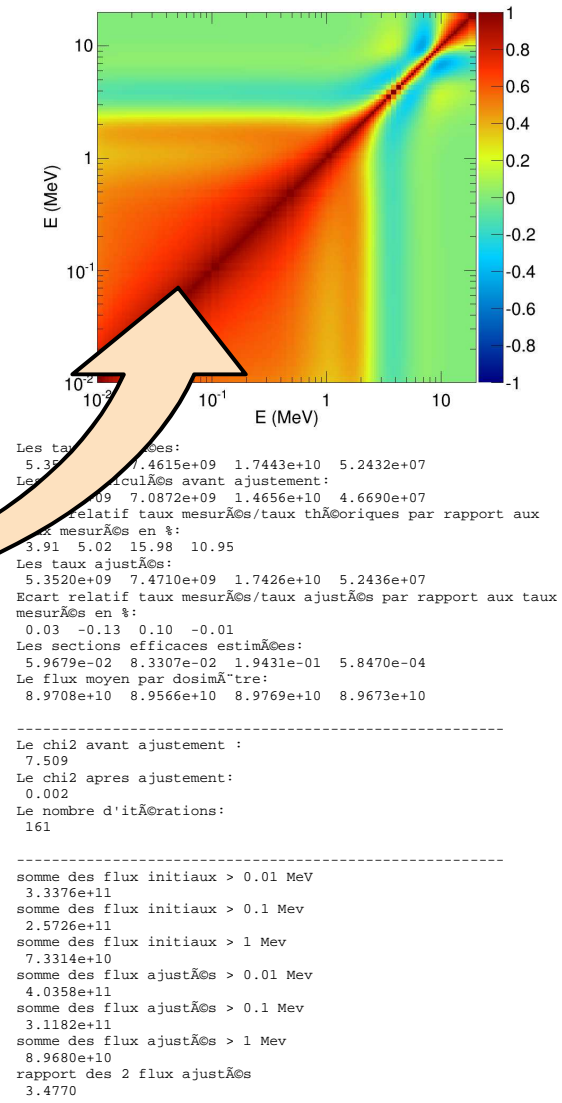
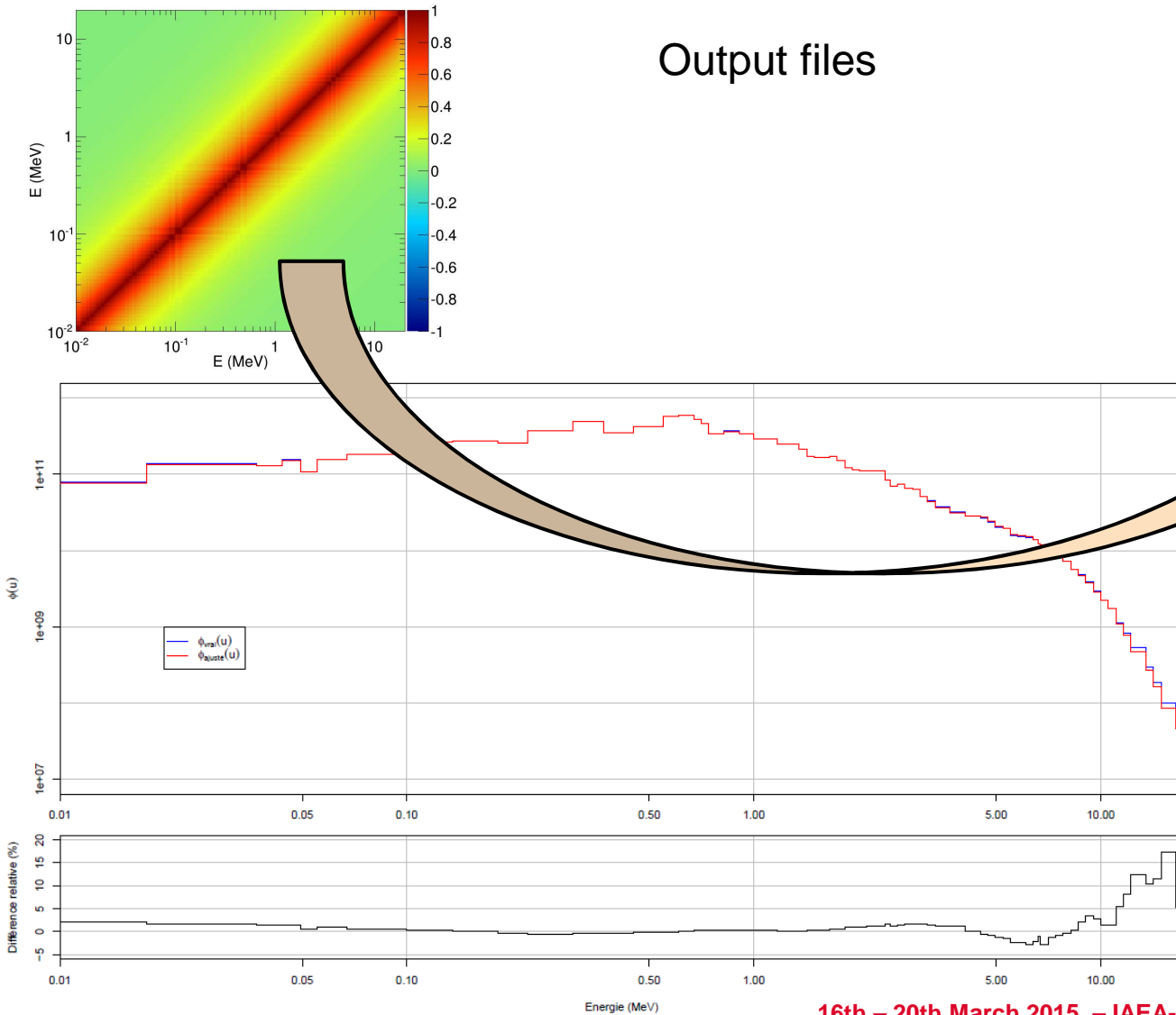


2 - Unfolding CALMAR code status

Initial flux correlation matrix

Unfolded flux correlation matrix

Output files



2015 Program

- Extension to 60 MeV, 725 groups if needed and possible

- Finalization of the code:
 - IHM, output format
 - Benchmark tests
 - Documentation

- Publication at the NEA