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

Contents

0 – Goal / Context of the unfolding/adjustment process

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 **CO**mputation of **R**eaction rate
from **C**ross section & n**E**utron **S**pectrum

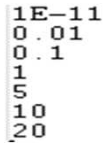
User friendly tool for data shaping operations:

- 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)

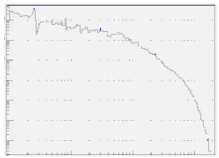
1 - Data Shaping operations : ECORCES

INPUTS

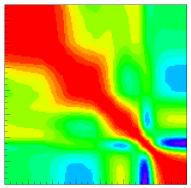
User NRJ Mesh



Input Spectrum

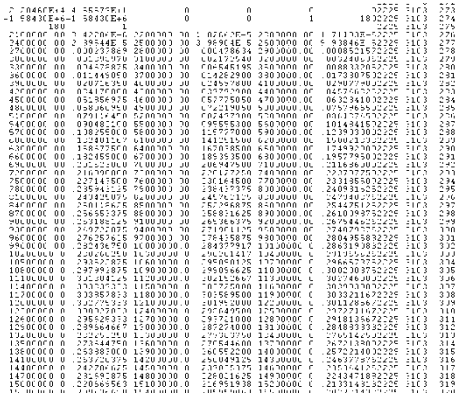


Spectrum matrix



Isotopes

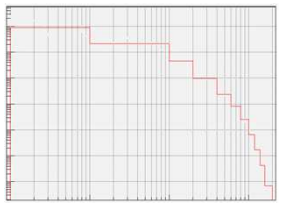
Reactions

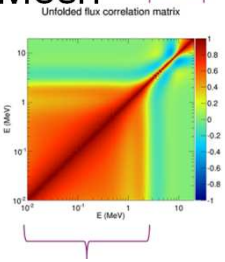


International **R**eactor **D**osimetry **F**ile

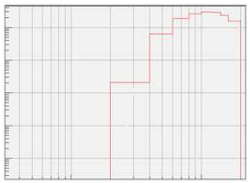
OUTPUTS (ASCII, GRAPH)

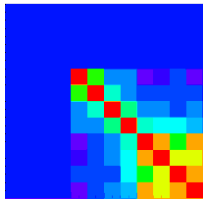
Spectrum in new Mesh



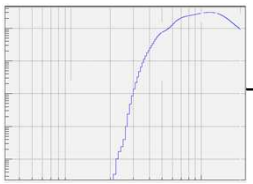


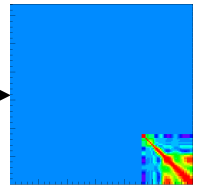
Reaction rate





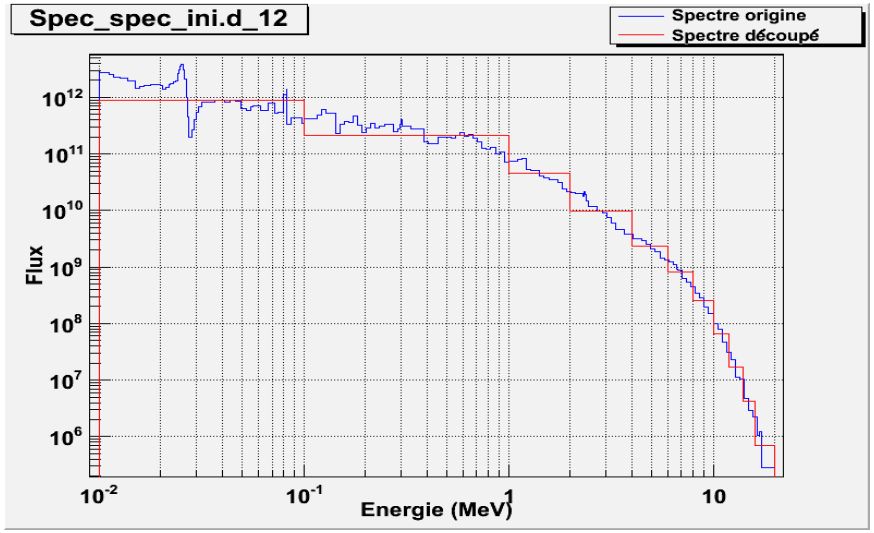
Cross section

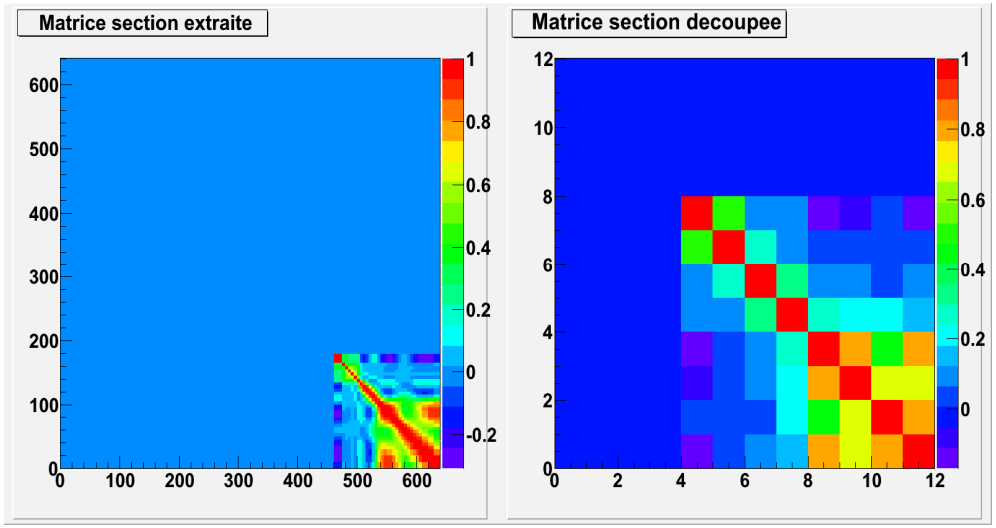


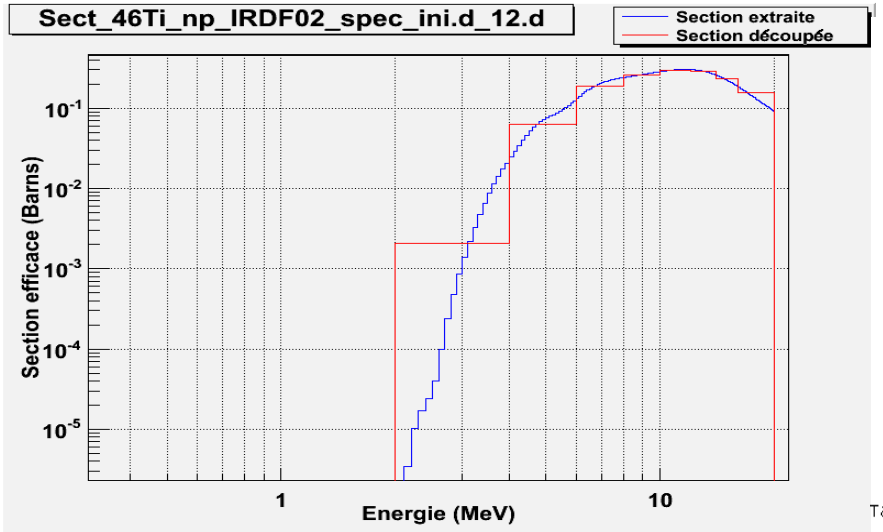


1 - Data Shaping operations : ECORCES

Output samples



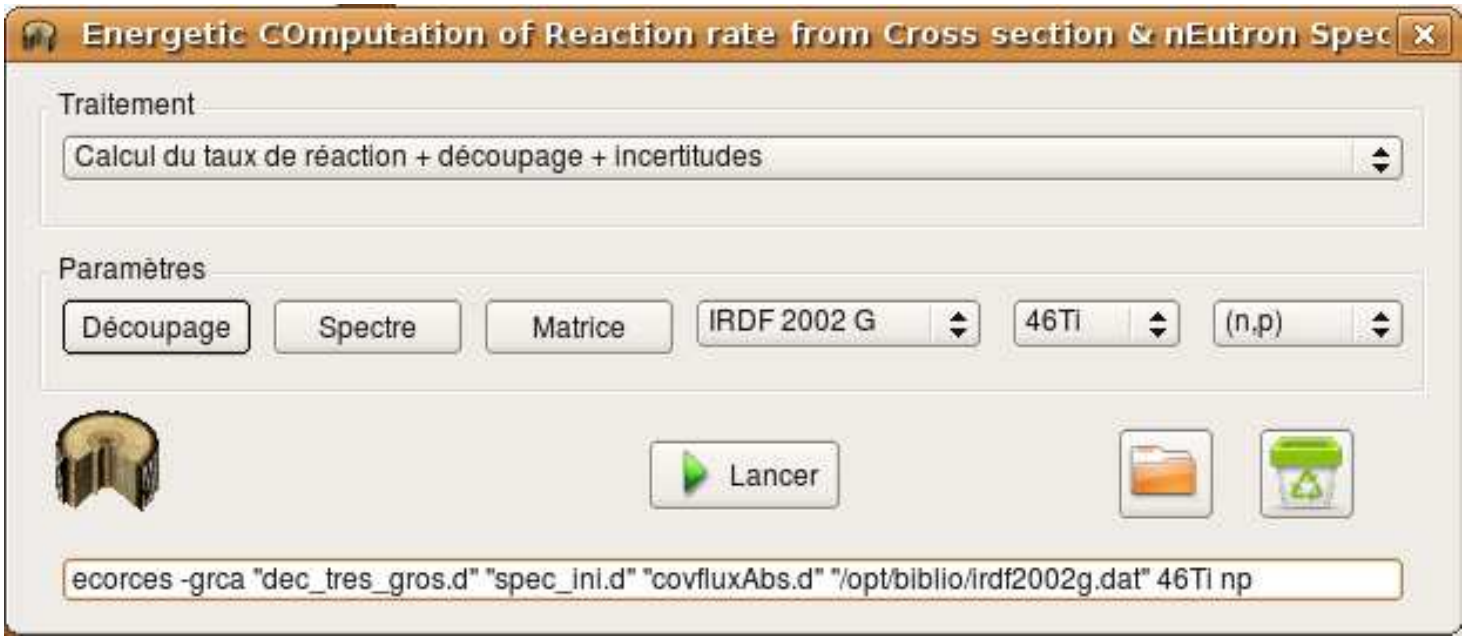




Gr (n)	E-Inf (MeV)	Flux (n/cm²/s)	Incert. (%)	Section (Barn)	Incert. (%)	Taux (Bq)	Incert. (%)
1	1.000E-11	0.000E+00	0.00	0.000E+00	0.00	0.000E+00	0.00
2	1.000E-02	8.116E+10	8.64	0.000E+00	0.00	0.000E+00	8.64
3	1.000E-01	1.925E+11	7.35	0.000E+00	0.00	0.000E+00	7.35
4	1.000E+00	4.616E+10	7.19	0.000E+00	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**

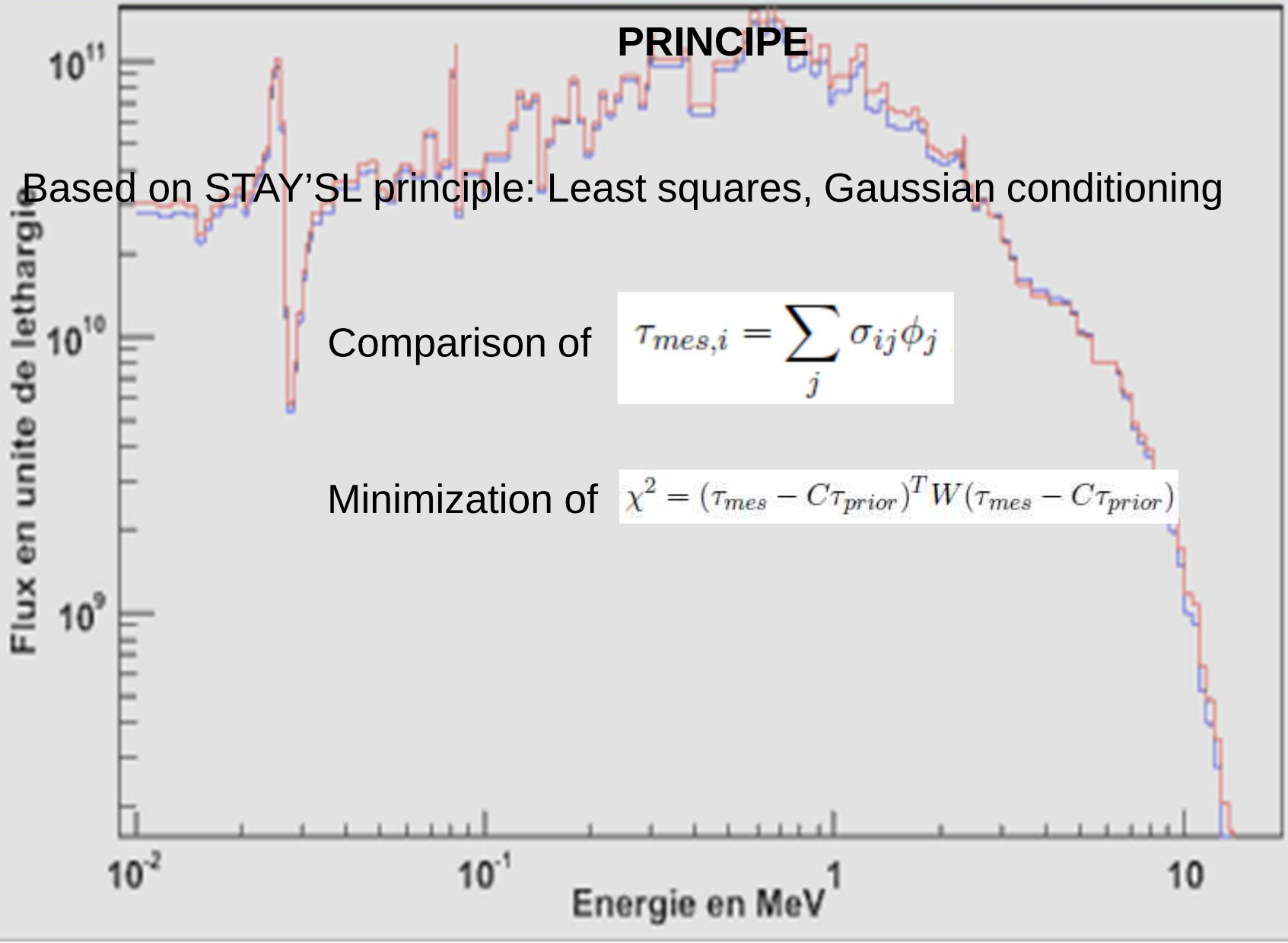
2 - Unfolding CALMAR code status

PRINCIPE

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

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

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



2 - Unfolding CALMAR code status

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

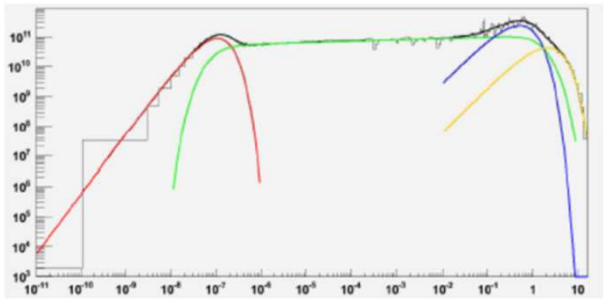
- Recoding in C++ of STAY'SL, MS-ITER, GRAVEL/SANDII
  - → Multi-code Analysis possible

Imputs

- “Measured” Reaction Rates
  - Output of the Activation calculation Process :
    - Analytical or DARWIN/PEPIN2
    - Corrected from self-shielding effects
    - Correlation Matrix derived from uncertainty propagation

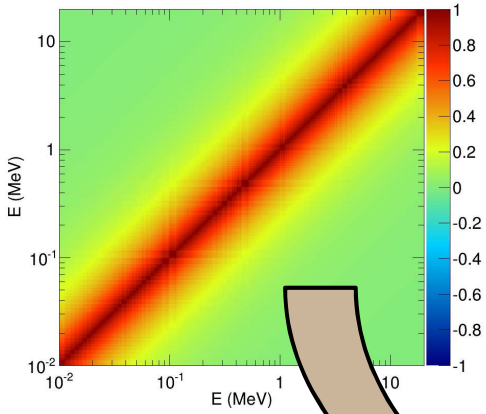
- Cross sections and covariance Matrices condensed on the spectrum energy mesh (ECORCES + IRDFF)

- 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,…

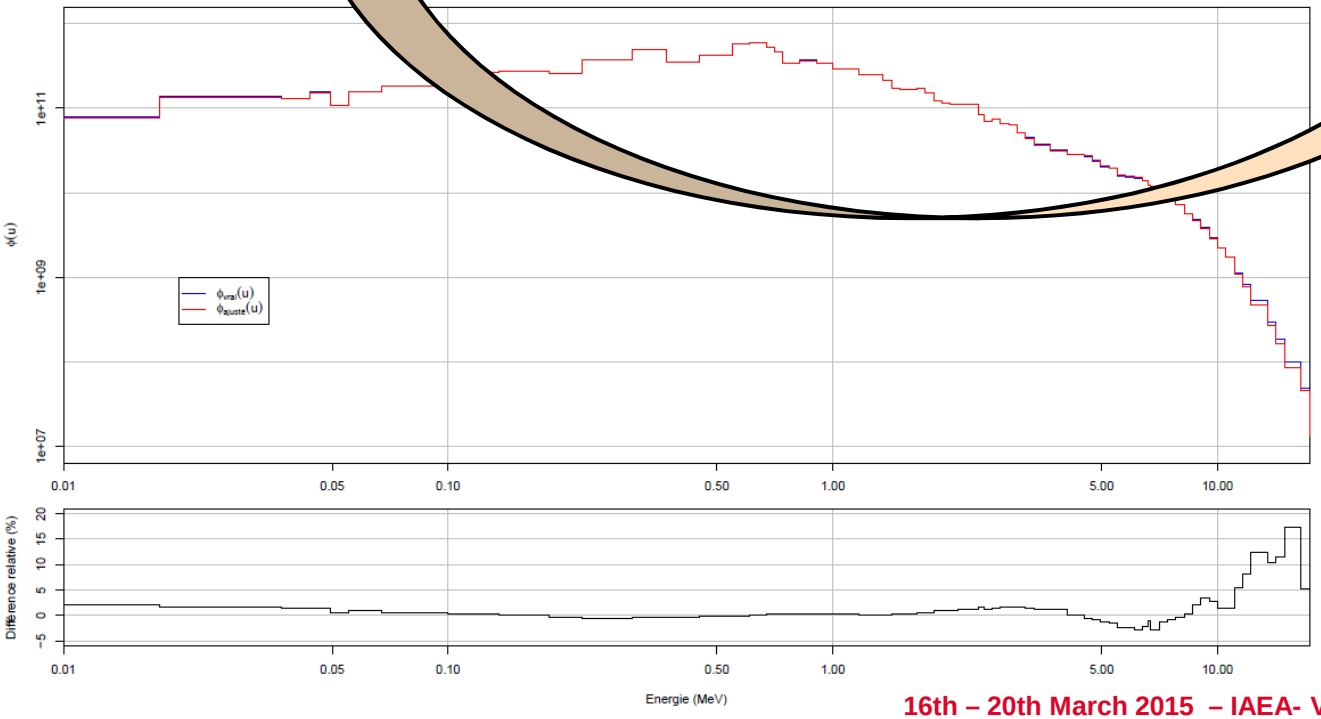


2 - Unfolding CALMAR code status

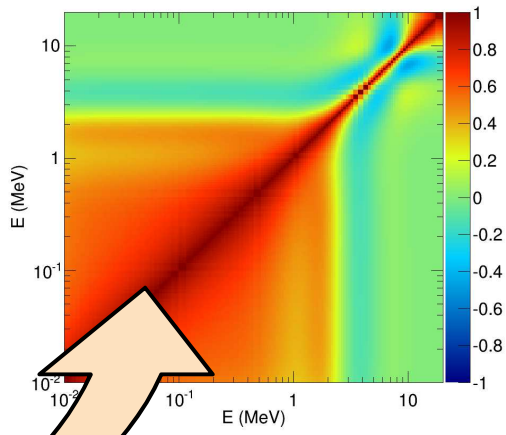
Initial flux correlation matrix



Output files



Unfolded flux correlation matrix




```
Les ta                    ©es:
 5.35                  7.4615e+09  1.7443e+10  5.2432e+07
Les                    lculÃ©s avant ajustement:
                       09  7.0872e+09  1.4656e+10  4.6690e+07
                    relatif taux mesurÃ©s/taux thÃ©oriques par rapport aux
    mesurÃ©s en %:
 3.91  5.02  15.98  10.95
Les taux ajustÃ©s:
 5.3520e+09  7.4710e+09  1.7426e+10  5.2436e+07
Ecart relatif taux mesurÃ©s/taux ajustÃ©s par rapport aux taux
mesurÃ©s en %:
 0.03  -0.13  0.10  -0.01
Les sections efficaces estimÃ©es:
 5.9679e-02  8.3307e-02  1.9431e-01  5.8470e-04
Le flux moyen par dosimÃ¨tre:
 8.9708e+10  8.9566e+10  8.9769e+10  8.9673e+10

------------------------------------------------------------
Le chi2 avant ajustement :
 7.509
Le chi2 apres ajustement:
 0.002
Le nombre d'itÃ©rations:
 161

------------------------------------------------------------
somme des flux initiaux > 0.01 MeV
 3.3376e+11
somme des flux initiaux > 0.1 Mev
 2.5726e+11
somme des flux initiaux > 1 Mev
 7.3314e+10
somme des flux ajustÃ©s > 0.01 Mev
 4.0358e+11
somme des flux ajustÃ©s > 0.1 Mev
 3.1182e+11
somme des flux ajustÃ©s > 1 Mev
 8.9680e+10
rapport des 2 flux ajustÃ©s
 3.4770
```

2 - Unfolding CALMAR code status

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