EMPIRE+KALMAN

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WPEC Subgroup 24

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Working Party on International Nuclear Data Evaluation Cooperation (WPEC)

Subgroup 24: Covariance Data in the Fast Neutron Region

Proposal

Proposal for SG24 was discussed and approved at the WPEC annual meeting, Antwerp, Belgium April 8-9, 2005.

Membership

- **Coordinator** Mike Herman, ENDF Project
- **Monitor** Arjan Koning, JEFF project
- **ENDF** M. Herman and P. Oblozinsky (BNL), T. Kawano and P. Talou (LANL), R. Capote-Noy and A. Trkov (IAEA Vienna)
- **JEFF** A. Koning (NRG Petten)
- **JENDL** T. Nakagawa (JAERI)

Charge

Develop methodology and tools for producing covariance data in the fast neutron region. Specific goals:

WPEC Subgroup 24

Develop methodology and tools for producing covariance data in the fast neutron region.

■ Specific goals:

- Develop covariance generation capabilities in nuclear reaction model codes EMPIRE, McGNASH and TALYS using:
  - KALMAN (Bayesian) method and
  - Monte Carlo sensitivity method.
- Compare results of these methods and validate the methodology against experimental covariance data.
- Address correlations between fast neutron region and resonance region (low priority goal).
- Produce covariance data for a few selected materials.

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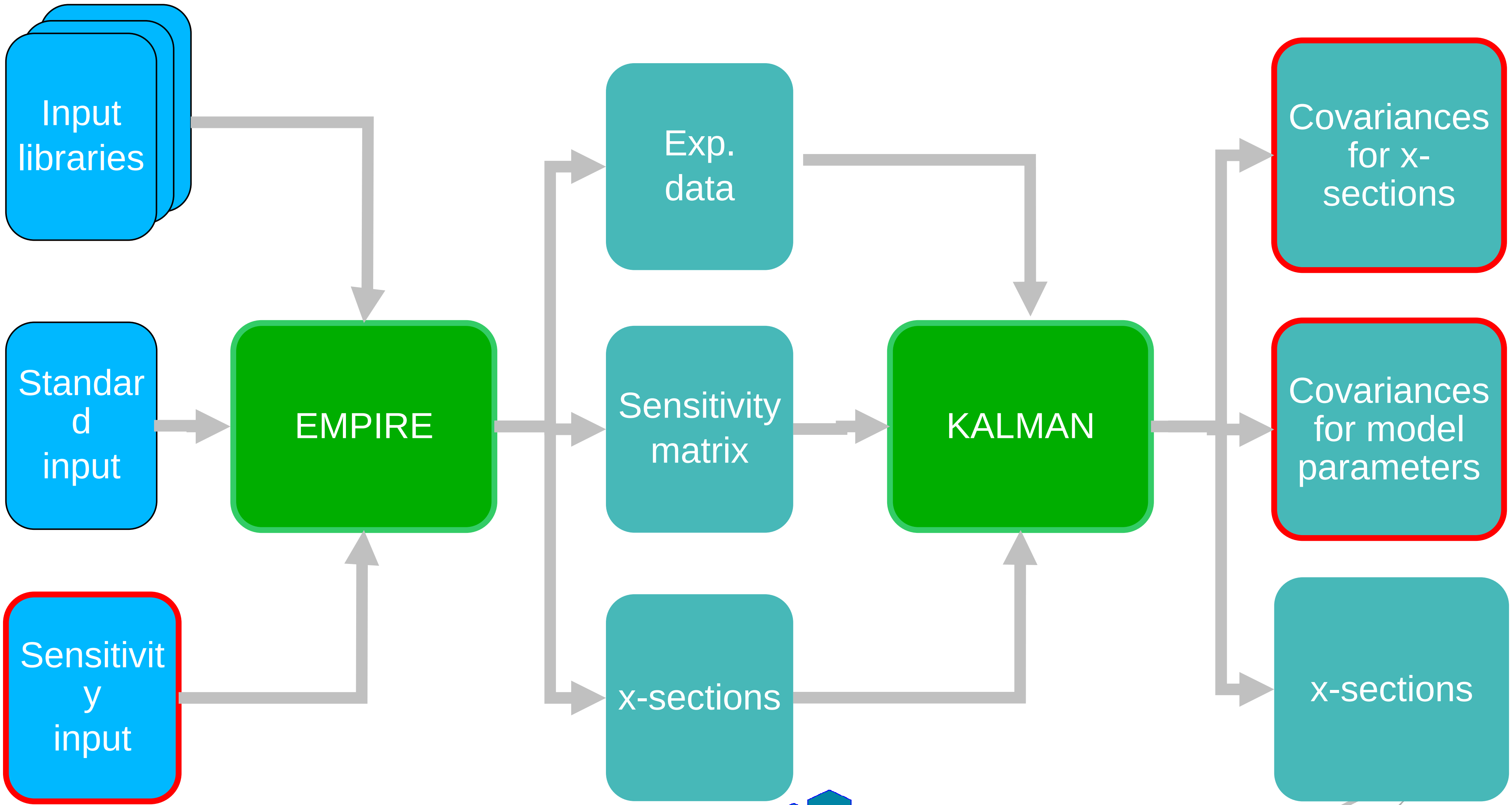

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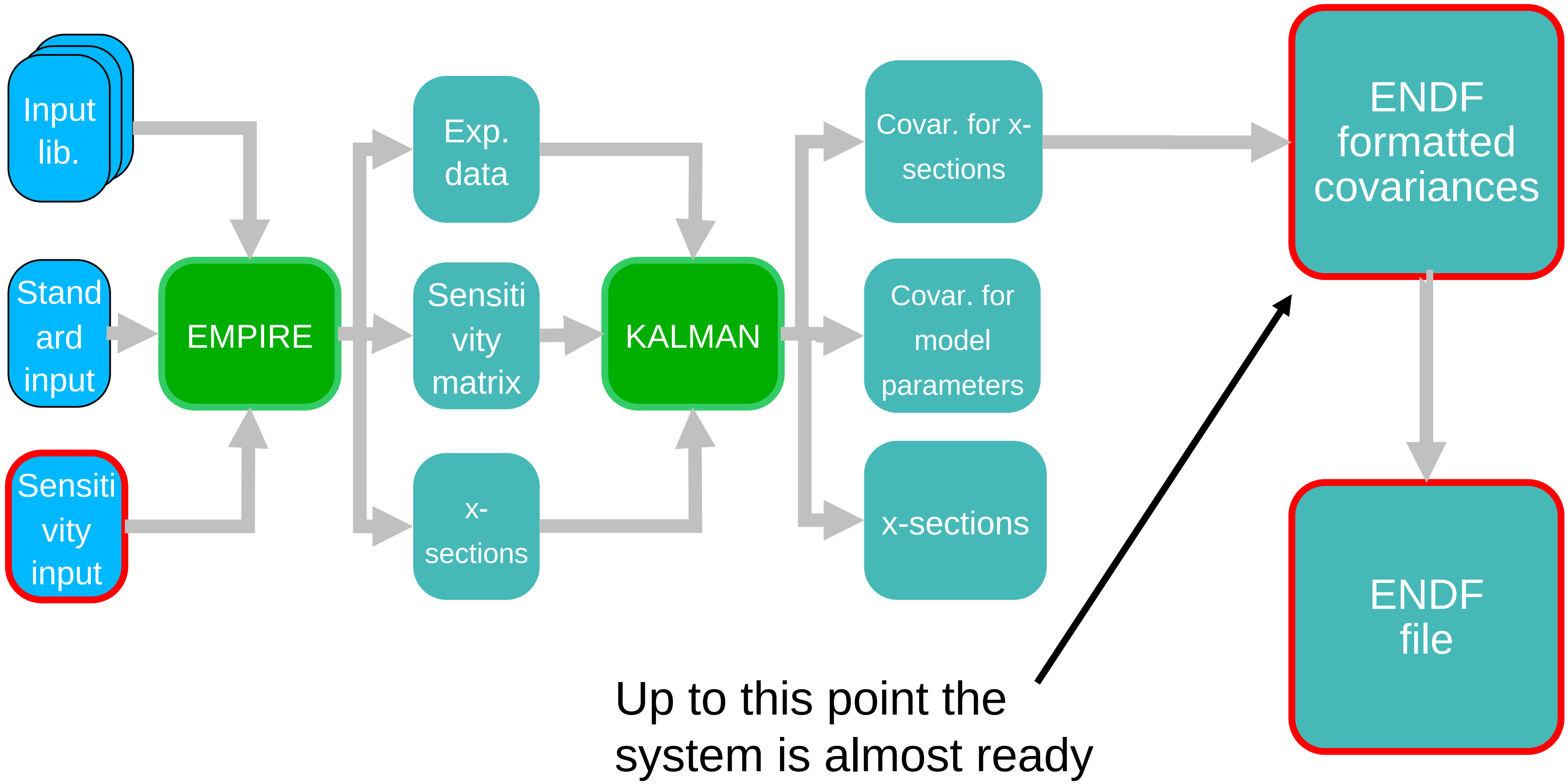


Application to Gd isotopes

- Sensitivity matrices calculated for 152,(153),154,156,157,158,160-Gd
- Nuclear models: CC, MSD, MSC, PE, HF
- Experimental data
  - Karlsruhe capture
  - Frehaut (n,2n)
- Starting from the very good agreement between calculations and experimental data
- 15 model parameters varied
  - omp real and imaginary depth
  - level density parameter for the first 4 nuclei along the neutron decay
  - emission width for γ, *n*, and *p* from the Compound Nucleus
  - Preequilibrium free path
  - MSD response functions
- Uncorrelated parameters with 10% uncertainty

Model parameters (n+Gd156)

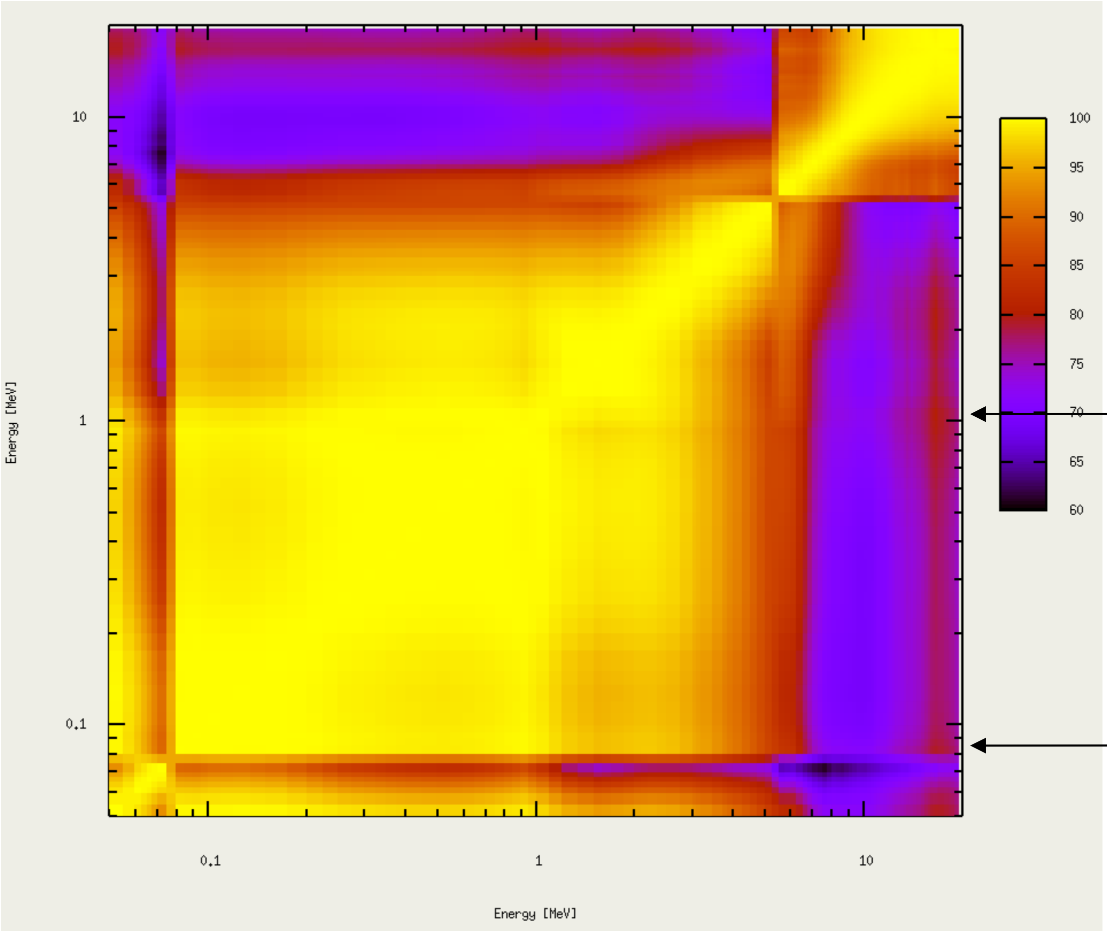
	PARAMETER	INITIAL	FINAL	ERROR
1	OMPVV (Gd156+n)	1.0	9.8466E-01	3.7 (%)
2	OMPWS (Gd156+n)	1.0	9.9756E-01	8.4 (%)
3	OMPWV (Gd156+n)	1.0	1.0000E+00	10. (%)
4	OMPVV (Gd156+p)	1.0	1.0000E+00	10. (%)
5	OMPWS (Gd156+p)	1.0	1.0000E+00	10. (%)
6	OMPWV (Gd156+p)	1.0	1.0000E+00	10. (%)
7	a(Gd157)	1.0	9.9909E-01	3.9 (%)
8	a(Gd156)	1.0	1.0000E+00	10. (%)
9	a(Gd155)	1.0	1.0000E+00	10. (%)
10	a(Gd154)	1.0	1.0000E+00	10. (%)
11	TUNE (Gd157 g)	1.0	9.9985E-01	9.2 (%)
12	TUNE (Gd157 p)	1.0	1.0000E+00	10. (%)
13	TUNE (Gd157 a)	1.0	1.0000E+00	10. (%)
14	PE mean free path	1.0	1.0000E+00	10. (%)
15	MSD resp. funct.	1.0	1.0000E+00	10. (%)

Model parameters (n+Gd156)

					1	2	3	4	5	6	7	8	9	10
1	OMPVV	156	n	9.85E-01	1000									
2	OMPWS	156	n	9.98E-01	90	1000								
3	OMPWV	156	n	1.00E+00	0	0	1000							
4	OMPVV	156	p	1.00E+00	0	0	0	1000						
5	OMPWS	156	p	1.00E+00	0	0	0	0	1000					
6	OMPWV	156	p	1.00E+00	0	0	0	0	0	1000				
7	a	157		9.99E-01	124	-65	0	0	0	0	1000			
8	a	156		1.00E+00	0	0	0	0	0	0	0	1000		
9	a	155		1.00E+00	0	0	0	0	0	0	0	0	1000	
10	a	154		1.00E+00	0	0	0	0	0	0	0	0	0	1000
11	TUNE	157	g	1.00E+00	25	-48	0	0	0	0	-961	0	0	0
12	TUNE	157	p	1.00E+00	0	0	0	0	0	0	0	0	0	0
13	TUNE	157	a	1.00E+00	0	0	0	0	0	0	0	0	0	0
14	PCROSS			1.00E+00	0	0	0	0	0	0	0	0	0	0
15	RESNOR			1.00E+00	0	0	0	0	0	0	0	0	0	0

Correlation $^{160}Gd(n,\gamma)$ Energy-Energy

-No experimental data
-No correlation between model parameters



Pre-equilibrium
(PCROSS and MSD starts
at 5 MeV) → **(n,2n)**

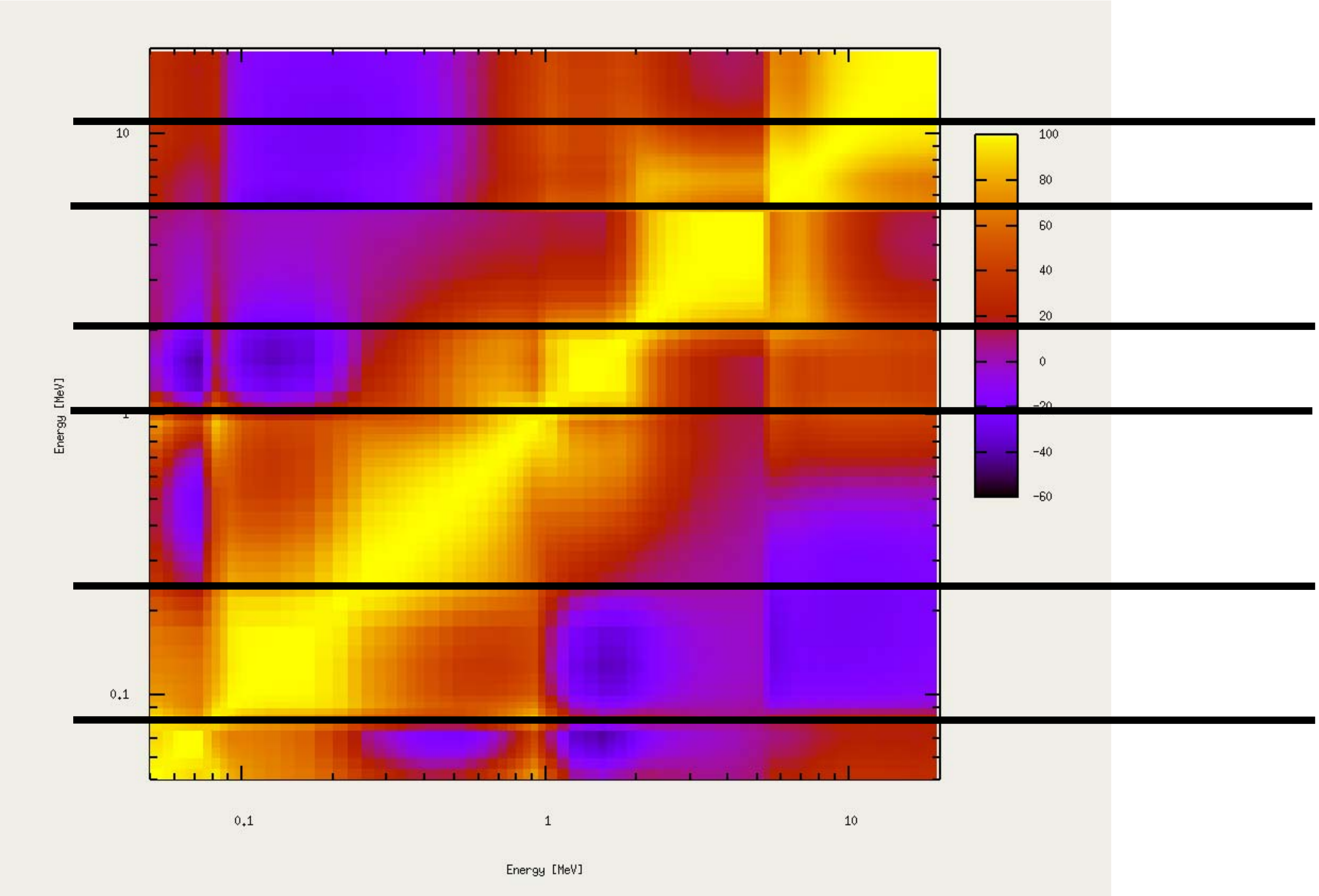
(2+) excited state

Compound nucleus and direct
→ (n,inl)

1st excited state (2+)

Correlation $^{160}Gd(n,\gamma)$ Energy-Energy

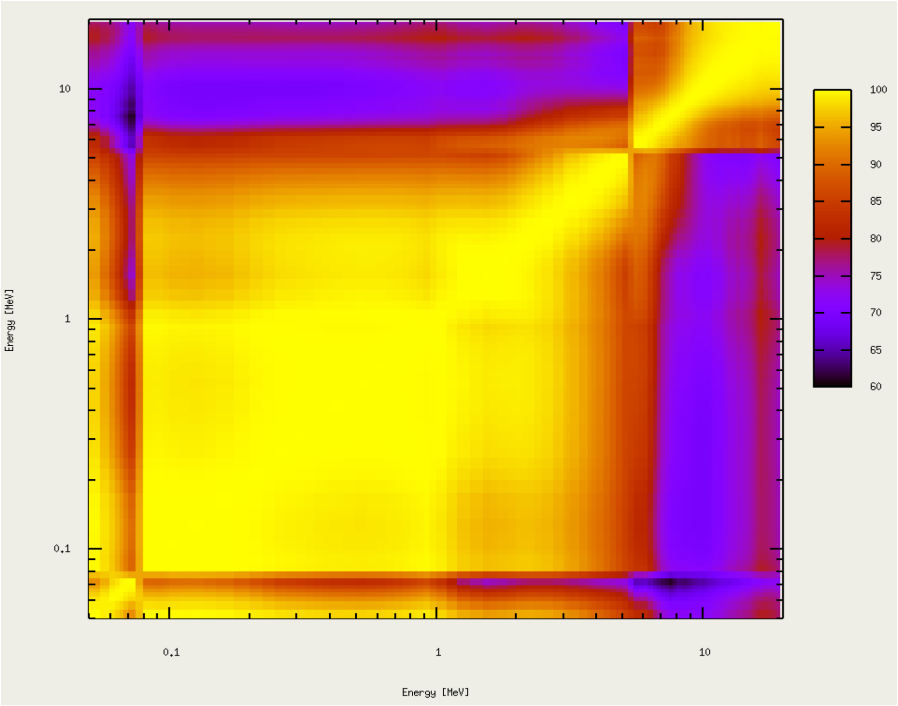
2 sets of experimental data for (n,γ), correlation: 0.20



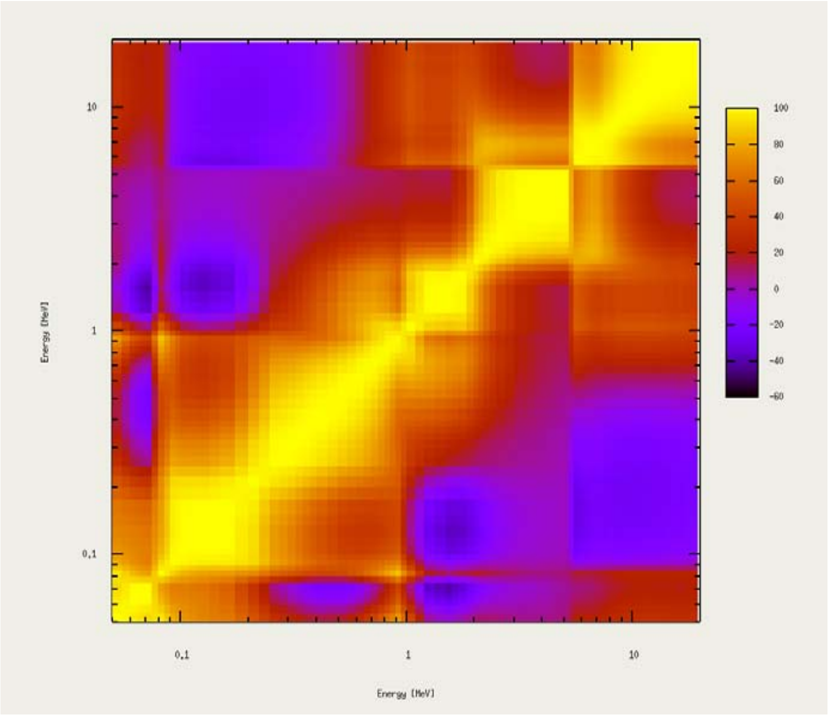
Effect of the experimental constrain

^{160}Gd(n,g) energy-energy correlation

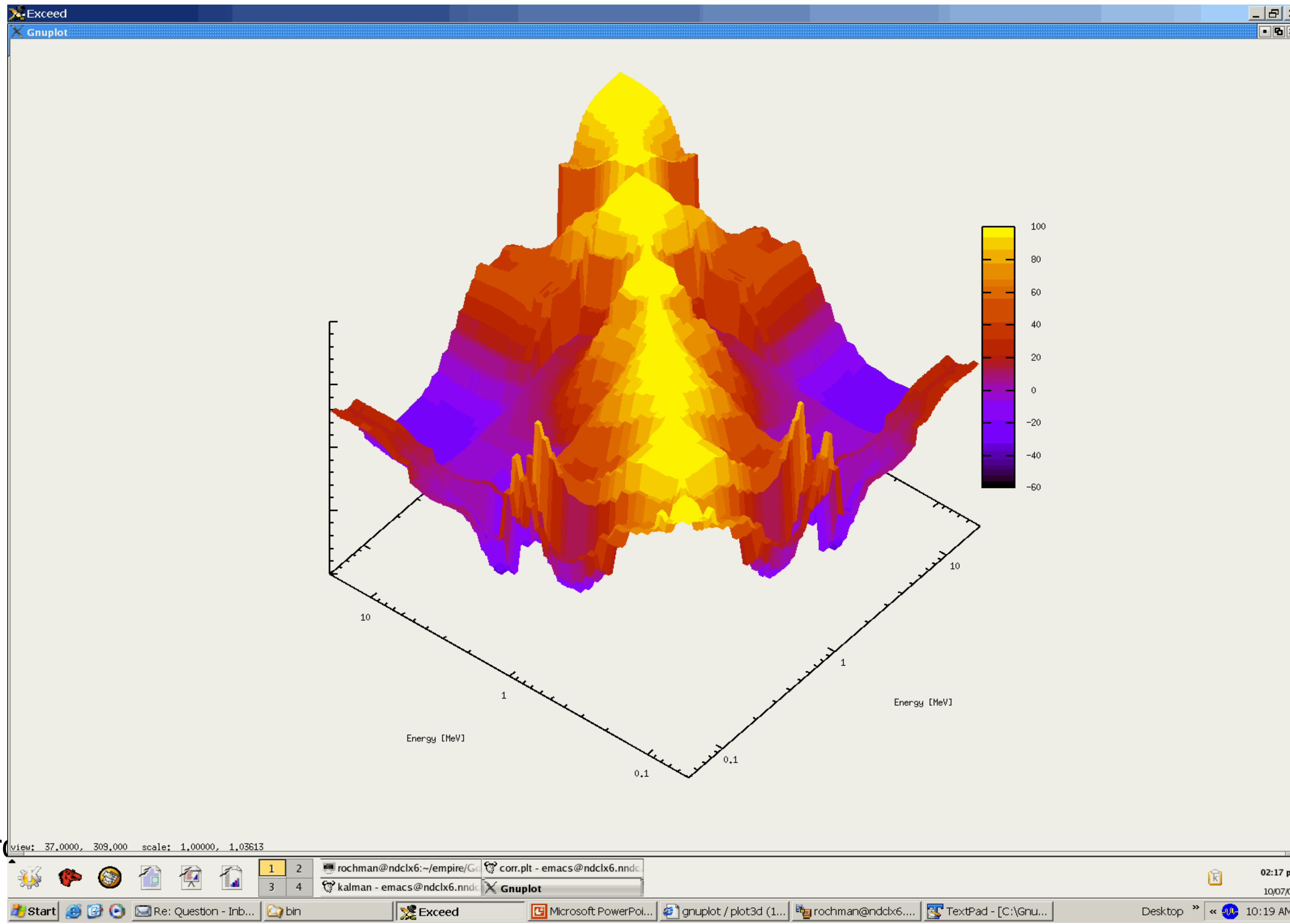
Without experimental data



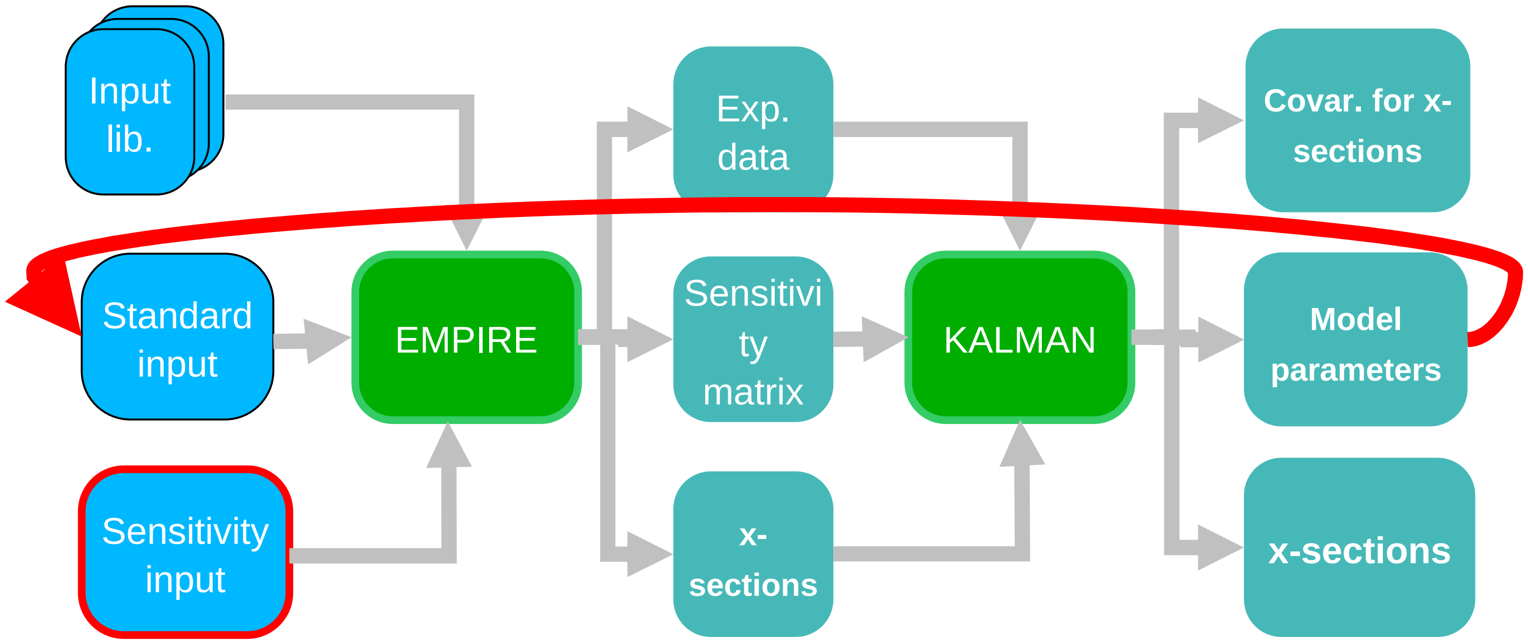
With experimental data



The monster


Exceed
Gnuplot
100
80
60
40
20
0
-20
-40
-60
10
1
0.1
Energy [MeV]
10
1
0.1
Energy [MeV]
view: 37.0000, 309.000 scale: 1.00000, 1.03613

EMPIRE+KALMAN iterative fitting



Conclusions

- EMPIRE+KALMAN system is well advanced
  - covariances can be produced for all reactions
  - automatic ENDF formatting only for capture
  - the system will be extended and improved
- Structure of the covariance matrix needs better understanding
- Intercomparison of methods and validation against experimental uncertainties (benchmarks?) should be performed
- Combination of EMPIRE+KALMAN can bring a major breakthrough in the evaluation methodology
- EMPIRE is also ready to be used for Monte-Carlo calculations (e.g., 232-Th at IAEA)