METHODODLOGY USED BY THE CEA TO ASSESS THE COMPUTATIONAL BIAS AND ASSOCIATED UNCERTAINTY DUE TO THE NUCLEAR DATA

Alain SANTAMARINA, Christophe VENARD

OVERVIEW

- INTEGRAL EXPERIMENT METHODOLOGY
- R.I.B. TOOL
- DESIGN OF NEW EXPERIMENT
- CONCLUSION

INTEGRAL EXPERIMENT METHODOLOGY

This methodology uses the information transfer from the integral experiment to the nuclear data.

It's based on :

- on the statistical adjustment method of the nuclear data,
- and the correlation between experiment and application, integral experiment representativity.

$$r_{AE} = \frac{\left(S_A^+ \cdot D_\sigma \cdot S_E\right)}{\varepsilon_A \cdot \varepsilon_E}$$

The methodology allows the assessment of :

- the bias and the posterior uncertainty on the calculated integral parameter due to the nuclear data

Used Notations

D_σ : ND covariance matrix,

A : Application, **E** : experiment

ε : experiment prior uncertainty, **S** : experimental sensitivity matrix to ND

Statistical adjustment of nuclear data

The nuclear data adjustment following integral experiments interpretation is based :

- on the Bayes' theorem
- and on the maximum likelihood principle

ND adjustment vector $$\delta\sigma = \frac{\sigma^* - \sigma_0}{\sigma_0} = D_\sigma \cdot S_E \cdot \left[S_E^T \cdot D_\sigma \cdot S_E + D_E\right]^{-1} \cdot \frac{I_m - I_0}{I_0}$$

Posterior ND correlation matrix $$D_\sigma^* = D_\sigma - D_\sigma \cdot S_E \cdot \left[S_E^T \cdot D_\sigma \cdot S_E + D_E\right]^{-1} \cdot S_E^T \cdot D_\sigma$$

Used Notations

- $\mathbf{I_m}$: measured integral parameter vector, $\mathbf{I_0}$: computational integral parameter vector
- $\boldsymbol{\sigma}$: ND vector, $\mathbf{D_\sigma}$: ND covariance matrix,
- $\mathbf{E}$: experiment, $\mathbf{D_E}$: experimental covariance matrix, $\mathbf{S_E}$: experimental sensitivity matrix to ND

Methodology of Integral Experiment Use

After the nuclear data adjustment on the representative experimental database E of the studied application A, assessment of :

– the bias $\delta I(A)$ due to the nuclear data

$$\delta I(A) = \frac{I^*(A) - I_0(A)}{I_0(A)} = S_A^T \cdot \delta\sigma$$

– its associated uncertainty ε_A* (posteriori uncertainty)

$$\varepsilon_A^* = \sqrt{S_A^T \cdot D_\sigma^* \cdot S_A}$$

R.I.B. means **R**epresentativity , Uncertainty (**I**ncertitude) and **B**ias

Main objective :

- Define the experimental validation area corresponding to the application
- Assess automatically k_{eff} computational bias and its uncertainty due to the Nuclear Data

R.I.B. is linked to the CRISTAL experimental validation database and to the CRISTAL experiment k_{eff}-sensitivity coefficient database

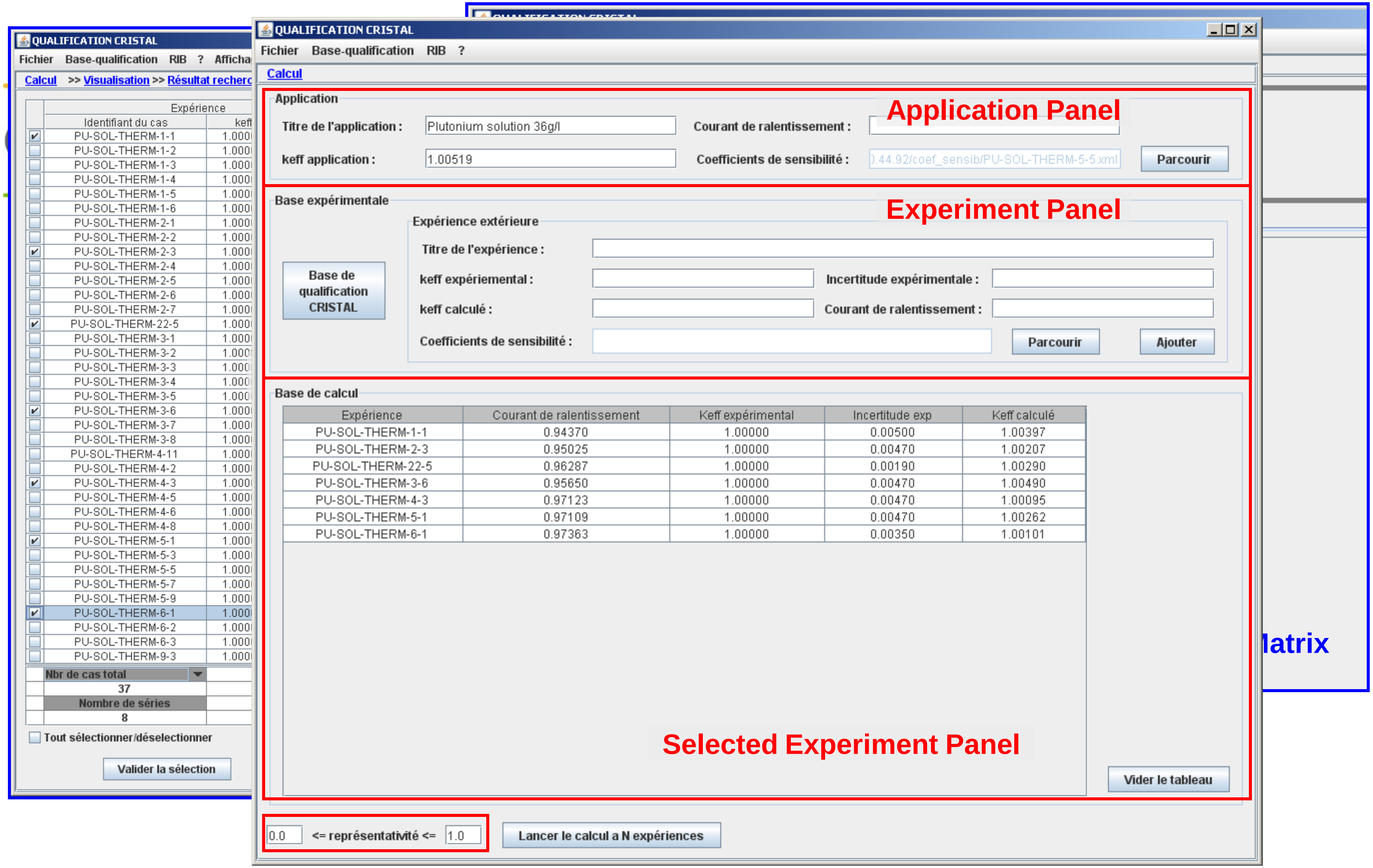
R.I.B. is developed in JAVA with a GUI

R.I.B. CODE

Its main features :

- Any energy group structure for sensitivity vectors and covariance matrix
- Selection of experiences based on descriptive criteria from CRISTAL experimental validation database or from others experiments
- Filter on experiment representativity
- Assess k_{eff} computational bias and its uncertainty due to the Nuclear Data
- Provide some other information like individual isotope contribution to the nuclear data uncertainty, physical correlation between experiments, nuclear data trend…

R.I.B. CODE – SCREENSHOTS – INPUT DATA



R.I.B. CODE – SCREENSHOTS - RESULTS

QUALIFICATION CRISTAL

Fichier Base-qualification RIB ?

Calcul >> Resultat calcul

Application :Plutonium solution 36g/l

Courant de ralentissement	Keff calculé	Incertitude a priori	Biais	Keff corrigé	Incertitude a postériori
	1.00519	0.00728	-0.00253	1.00266	0.00141

Application | Expériences | Données nucléaires

Experiences | Représentativité | Coef de sensibilité

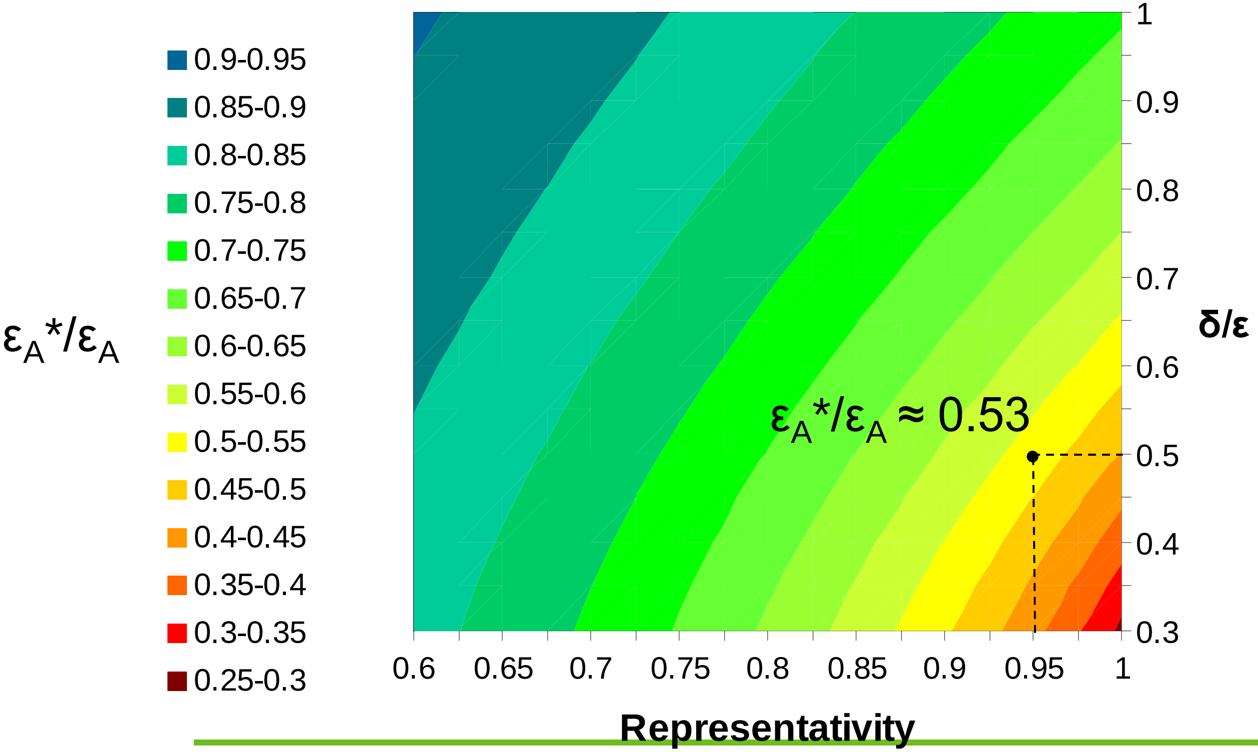
Representativite entre deux expériences — Representativite entre une experience et l'application

Exp / Exp	PU-SOL-THERM-1-1	PU-SOL-THERM-2-3	PU-SOL-THERM-22-5	PU-SOL-THERM-3-6	PU-SOL-THERM-4-3	PU-SOL-THERM-5-1	PU-SOL-THERM-6-1
PU-SOL-THERM-1-1	0.99127	0.99860	0.97262	0.99550	0.97846	0.98486	0.97671
PU-SOL-THERM-2-3	0.99860	0.99607	0.97295	0.99894	0.98757	0.99148	0.98536
PU-SOL-THERM-22-5	0.97262	0.97295	0.98096	0.97664	0.96850	0.97981	0.97653
PU-SOL-THERM-3-6	0.99550	0.99894	0.97664	0.99902	0.99335	0.99627	0.99203
PU-SOL-THERM-4-3	0.97846	0.98757	0.96850	0.99335	0.99603	0.99815	0.99877
PU-SOL-THERM-5-1	0.98486	0.99148	0.97981	0.99627	0.99815	0.99891	0.99902
PU-SOL-THERM-6-1	0.97671	0.98536	0.97653	0.99203	0.99877	0.99902	0.99623

Correlation between experiments

DESIGN OF A NEW EXPERIMENT

- For a studied application, R.I.B. tool can
  - identify a lack of experiments to validate criticality safety studies with the representativity
  - help to design a new experiment by assessing
    - its representativity with respect to the studied application
    - its contribution on the ND uncertainty reduction



$$\frac{\varepsilon_A^*}{\varepsilon_A} = \sqrt{1-\frac{r_{AE}^2}{1+(\delta/\varepsilon)^2}}$$

δ : experiment uncertainty

Σ : experiment prior uncertainty

$r_{AE} = 0.95$ and $\delta/\varepsilon = 0.5$

CONCLUSION

- Representativity method based on Integral Experiments :

  rigorous combination of differential and integral information to calibrate the computational bias and to reduce the uncertainty due to the ND

- To ease its use, the CEA has developed a java tool, named RIB, connected to the CRISTAL experimental validation database, which allows quickly calculating computational bias and its associated uncertainty due to nuclear data. This tool will be available to the next major version of the French criticality package CRISTAL V2.

- R.I.B. tool can estimate the contribution of new experiences on the reduction of the uncertainties due to the ND