First results for ^{239}Pu Consistent Data Assimilation

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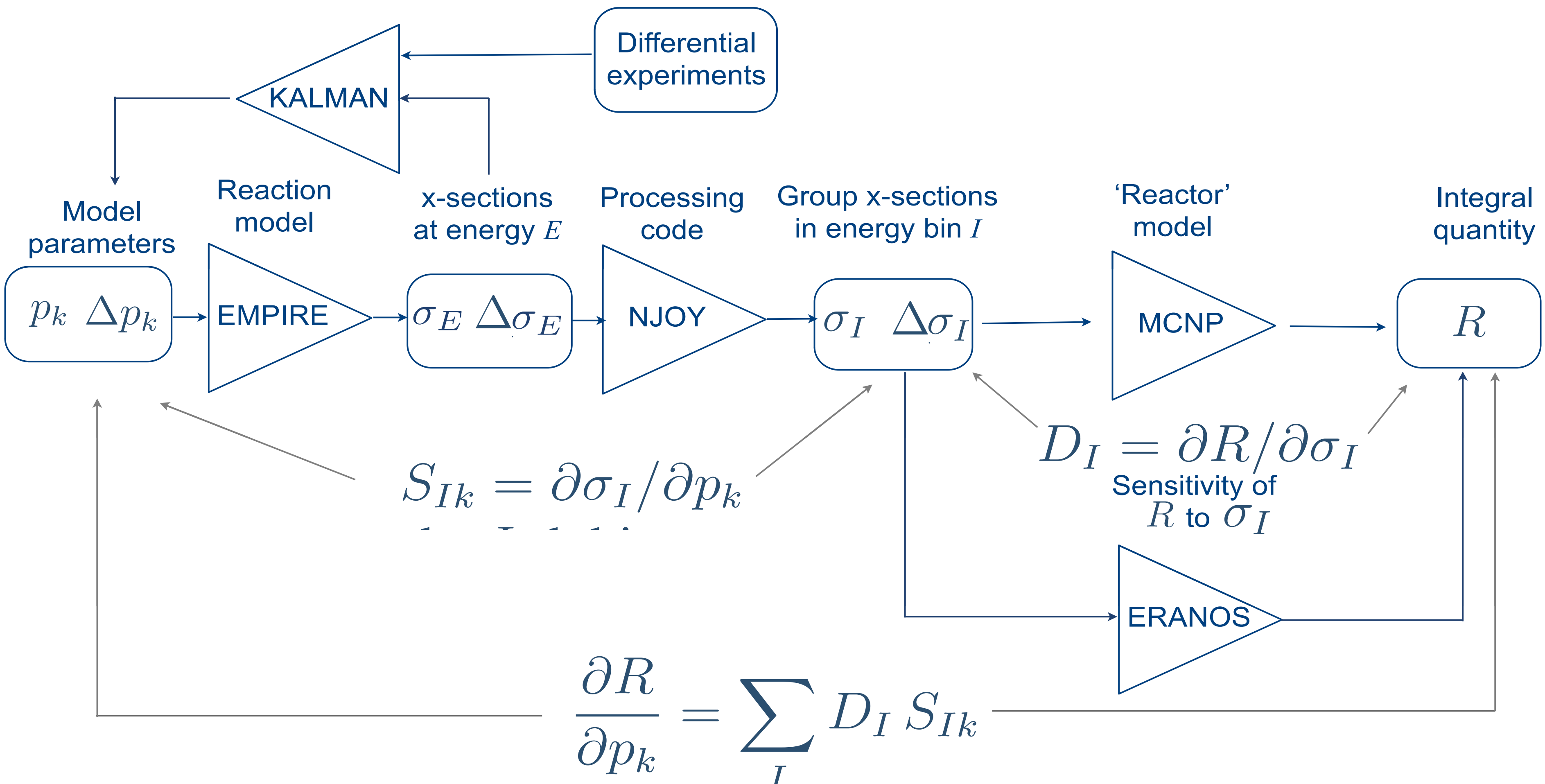
Consistent Data Assimilation

- A new approach has been developed in order to adjust physical parameters and not multigroup nuclear data, the objective being now to correlate the uncertainties of some basic parameters that characterize the neutron cross section description, to the discrepancy between calculation and experimental value for a large number of clean, high accuracy integral experiments.
- This new approach is the first attempt to build up a link between the wealth of precise integral experiments and basic theory of nuclear reactions. By using integral reactor physics experiments (meter scale), information is propagated back to the nuclear physics level (femtometers). In this way, the worlds of reactor nuclear physicists and that of nuclear physicists are bridged together.
- The classical statistical adjustment method can be improved by "adjusting" reaction model parameters rather than multigroup nuclear data. The objective is to associate uncertainties of certain model parameters (such as those determining neutron resonances, optical model potentials, level densities, strength functions, etc.) and the uncertainties of theoretical nuclear reaction models themselves (such as optical model, compound nucleus, pre-equilibrium and fission models) with observed discrepancies between calculations and experimental values for a large number of integral experiments.

Consistent Data Assimilation

Linking integral experiments with reaction model parameters



S_{Ik} **contains all restrictions imposed by differential data**

^{239}Pu Consistent Data Assimilation

- **Selected critical experiments were analyzed using MCNP.**

k_{eff} results for each sphere (experimental k_{eff} = 1.0 (±100~300pcm)).

Experiment	EMPIRE (±pcm)	ENDF/B-VII.0 (±pcm)
JEZEBEL-239	0.98567 (±8)	0.99986 (±9)
FLATTOP-Pu	0.98838 (±18)	1.00097 (±18)

C/E ratio of spectral indices at the center of JEZEBEL-239

	JEZEBEL-239	
	EMPIRE	ENDF/B-VII.0
$\sigma_f(^{238}U)/\sigma_f(^{235}U)$	0.956±0.009	0.974±0.009
$\sigma_f(^{233}U)/\sigma_f(^{235}U)$	1.000±0.017	0.986±0.017
$\sigma_f(^{237}Np)/\sigma_f(^{235}U)$	0.999±0.017	1.009±0.017
$\sigma_f(^{239}Pu)/\sigma_f(^{235}U)$	0.971±0.020	0.984±0.020

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Old and new C/E before and after adjustment for JEZEBEL experiments

Experiment	old C/E ± σ	new C/E ± σ
K_{eff}	0.9857 ± 0.002	0..9998± 0.002
Fis.^{238}U/Fis.^{235}U	0.9561 ± 0.009	0.9598 ± 0.002
Fis.^{239}Pu/Fis.^{235}U	0.9708 ± 0.020	0.9917 ± 0.003
Fis.^{237}Np/Fis.^{235}U	0.9988 ± 0.017	1.0010 ± 0.001
Fis.^{233}U/Fis.^{235}U	1.0003 ± 0.017	1.0002± 0.001

The χ^2 test after adjustment provided a normalized (to the number of degrees of freedom) value of 5.03; however, most (4.6) of the contribution to this value is coming from the ^{238}U spectral index integral parameter.

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^{239}Pu parameter variations and standard deviations obtained by data assimilation

Parameter	Variation (%)	Init. Stand. Dev. (%)	Final Stand. Dev. (%)
VA000000 [a)]	-0.141	0.134	0.121
FUSRED000000 [b)]	0.432	0.951	0.612
LDSHIF000100 [c)]	0.299	0.705	0.692
DELTAF000000 [d)]	-0.120	0.671	0.668
ATILNO000100 [e)]	-0.076	0.965	0.958
VB000000 [f)]	-0.079	0.480	0.479
ATLATF000000 [g)]	0.128	1.240	1.239
TOTRED000000 [h)]	-0.081	0.918	0.815
HA000000 [i)]	-0.155	0.474	0.471

[a)] Height of the first fission barrier hump in ^{240}Pu, [b)] Factor multiplying the reaction (fusion, absorption, compound nucleus formation) cross section, [c)] Shift of the level densities in target at the point they reach discrete levels (LDSHIFT - 1) MeV, [d)] Pairing energy used in the level densities at the saddle point in ^{240}Pu, [e)] Factor multiplying asymptotic level density parameter in the target, [f)] Height of the second fission barrier hump in ^{240}Pu, [g)] Factor multiplying asymptotic level density parameter at saddle point in ^{240}Pu, [h)] Factor multiplying total cross section, [i)] Width of the first fission barrier hump in ^{239}Pu.

^{239}Pu Consistent Data Assimilation

Contribution of the parameter variation to the relative change of the C/E of the JEZEBEL K_{eff}.

Parameter	Variation (pcm)
VA000000	630
FUSRED000000	298
LDSHIF000100	223
DELTAF000000	184
VB000000	67
ATLATF000000	48
ATILNO000100	31
HA000000	-29
TOTRED000000	-4
Total	1435

- **It is interesting to note that the new standard deviations obtained after the data assimilation produce a reduction of the evaluated uncertainty of the JEZEBEL K_{eff} of 18.7% mostly coming from the fission cross section contribution.**
- **This is already an indication of the potential gain, in terms of uncertainty reduction, that the data assimilation can produce.**
- **One should expect more reductions when other integral experiments are included in the data assimilation process**

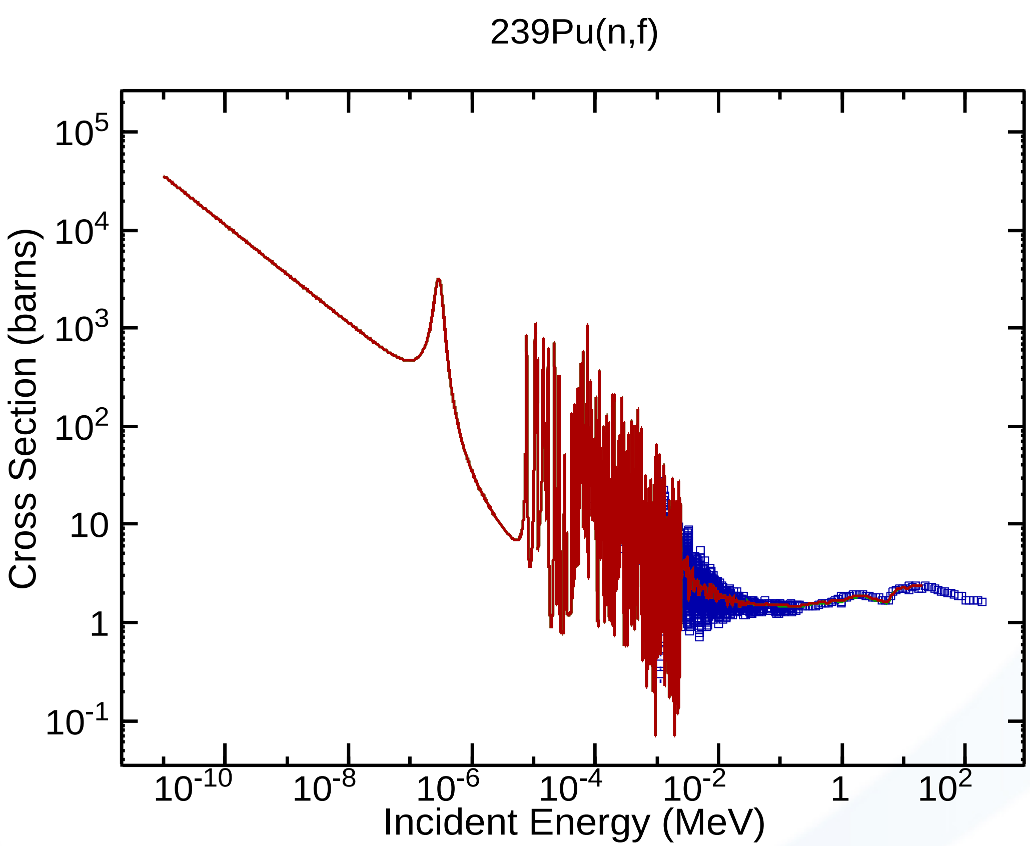
PARAMETERS

```
TOTRED    0.020  00  00  00  00  !  tuning for total xcs
ATILNO    0.020  00  00  00  00  !  level density parameter   Z   A+1 (compound)
ATILNO    0.020  00  01  00  00  !  level density parameter   Z   A   (target)
ATILNO    0.020  00  02  00  00  !  level density parameter   Z   A-1 (n,2n)
ATILNO    0.020  00  03  00  00  !  level density parameter   Z   A-2 (n,3n)
GTILNO    0.020  00  00  00  00  !  single-level density parameter   Z   A+1 (compound)
GTILNO    0.020  00  01  00  00  !  single-level density parameter   Z   A   (target)
VA        0.005  00  00  00  00  !  fission inner barrier for Z A+1 (compound)
HA        0.005  00  00  00  00  !  fission inner width   for Z A+1 (compound
VB        0.005  00  00  00  00  !  fission outer barrier for Z A+1 (compound)
HB        0.005  00  00  00  00  !  fission outer width   for Z A+1 (compound)
VA        0.005  00  01  00  00  !  fission inner barrier for Z A+1 (target)
HA        0.005  00  01  00  00  !  fission inner width   for Z A+1 (target)
VB        0.005  00  01  00  00  !  fission outer barrier for Z A+1 (target)
HB        0.005  00  01  00  00  !  fission outer width   for Z A+1 (target)
VA        0.005  00  02  00  00  !  fission inner barrier for Z A+1 (target)
HA        0.005  00  02  00  00  !  fission inner width   for Z A+1 (target)
VB        0.005  00  02  00  00  !  fission outer barrier for Z A+1 (target)
HB        0.005  00  02  00  00  !  fission outer width   for Z A+1 (target)
FUSRED    0.020  00  00  00  00  !  tuning for reaction
TUNEFI    0.020  00  01  00  00  !  tuning for fission
TUNEFI    0.020  00  02  00  00  !  tuning for fission
DELTAF    0.020  00  00  00  00  !
GAMMA     0.020  00  00  00  00  !
ATLATF    0.020  00  00  00  00  !
VIBENH    0.020  00  00  00  00  !
DELTAF    0.020  00  01  00  00  !
GAMMA     0.020  00  01  00  00  !
ATLATF    0.020  00  01  00  00  !
VIBENH    0.020  00  01  00  00  !
LDSHIF    0.020  00  00  00  00  !
LDSHIF    0.020  00  01  00  00  !
LDSHIF    0.020  00  02  00  00  !
LDSHIF    0.020  00  03  00  00  !
TUNEPE    0.020  01  00  00  00  !
TUNE      0.020  00  00  00  00  !
TUNE      0.020  00  01  01  00  !
TUNE      0.020  00  01  00  00  !
FCCRED    0.020  00  00  00  00  !
PCROSS    0.100  00  00  00  00  !
```

VA – 0.155%

FUSRED - 0.432%.

PRIOR/POST ASSIMILATION

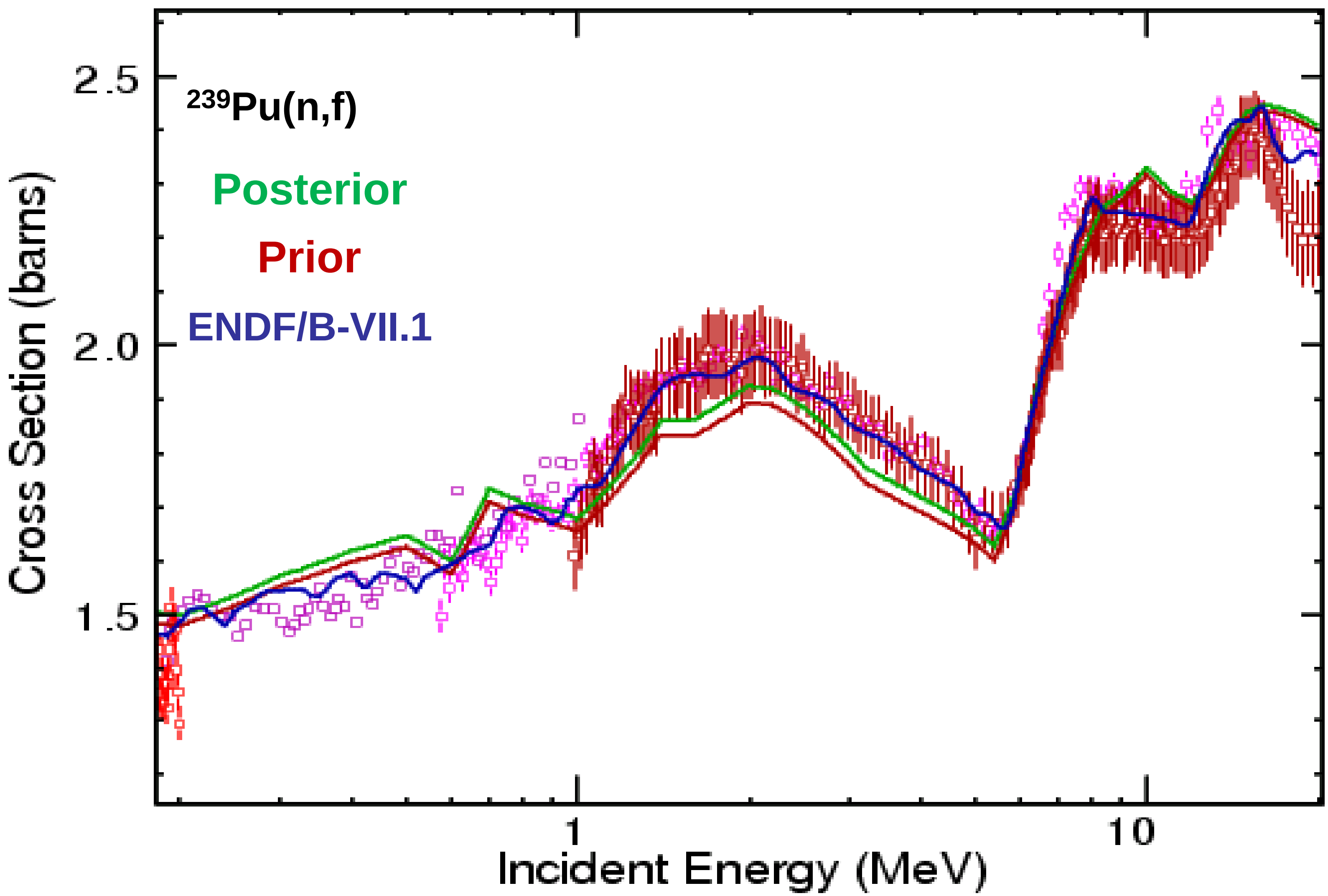


Started with ^{239}Pu files (~gforge/projects/pu-239)

Input:
Empire level densities
CC calculations

Energy dependent tuning – up to 10 MeV

RESULTS



239Pu(n,f)
Posterior
Prior
ENDF/B-VII.1
Cross Section (barns)
2.5
2.0
1.5
1
10
Incident Energy (MeV)

ASSIMILATION RESULTS

MCNP RESULTS

Calc. keff	Calc. keff
A Priori	A Posteriori
0.98540 ± 0.00008	**0.99526 ± 0.00008**

Calc. k_{eff}: EMPIRE + ENDF/B-VII.1

JEZEBEL

Calc. keff	Calc. keff
A Priori (±pcm)	A Posteriori (±pcm)
0.98567 (± 8)	**0.99986 (± 9)**

CURRENT STATUS