

# The Undergoing Work on Sensitivity and Uncertainty Analysis of Integral Parameters in CNDC

Report on Sg33

Presentation in  
OECD/NEA, Paris

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My presentation can be splitted into three parts:

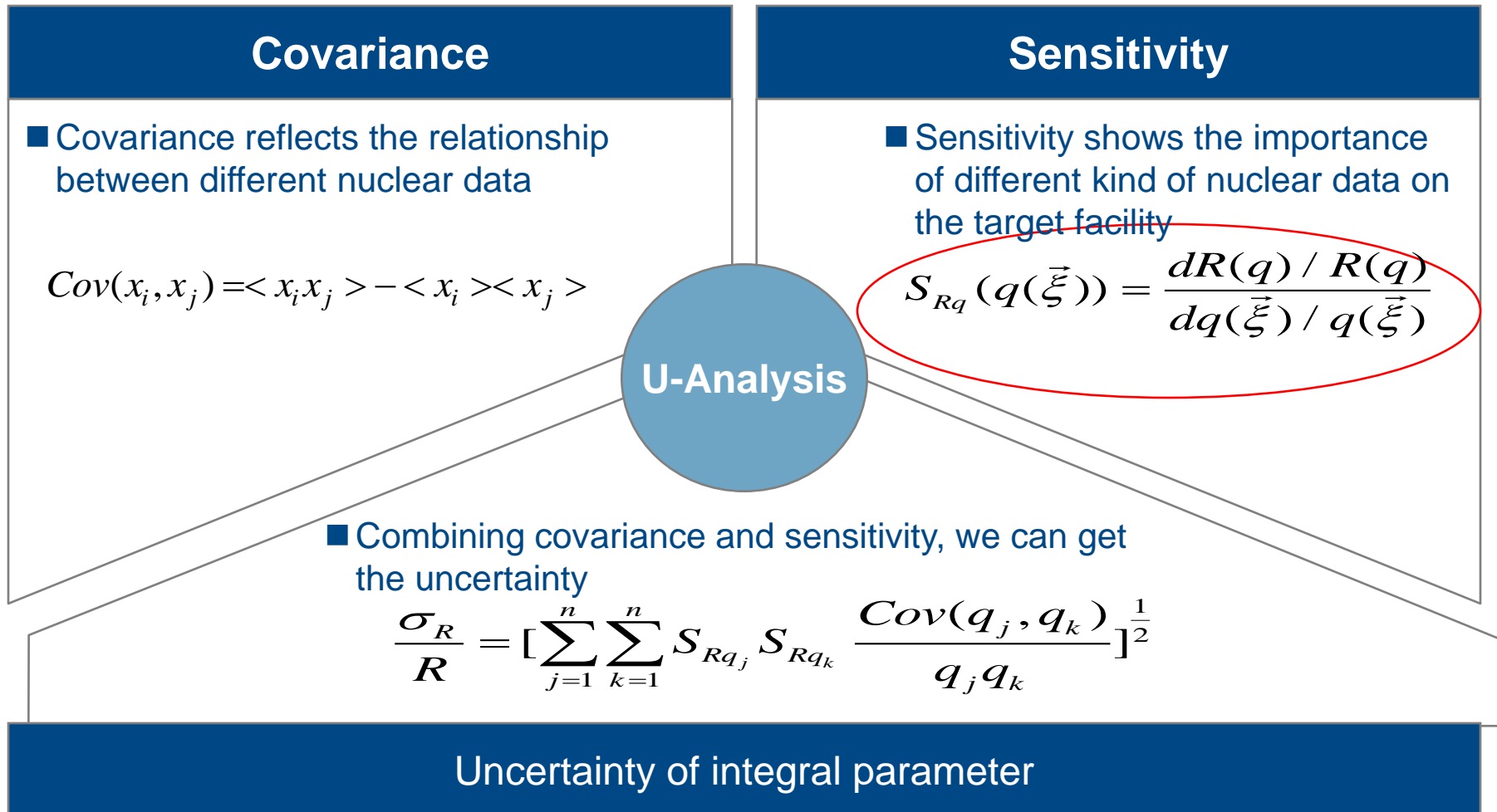
**1 What's before**

2 What's now

3 What's next

## 1 What's before

In order to get the uncertainty of interested integral parameter of the target facility, we should get the covariance and sensitivity of the nuclear data.



## 1 What's before

There are two ways to generate the sensitivity matrix, MC method and deterministic method, both of which are not perfect.

### MC Method

- Easy algorithm
- MC code is very powerful
- Nice precision

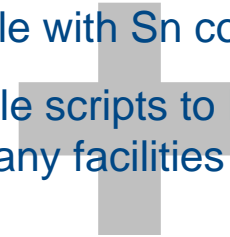


- High calculating cost
- Hard to calculate very small changing paces



### Deterministic Method

- Fast calculation
- Easy to couple with Sn code
- Easy to handle scripts to handle many nuclei and many facilities at the same time
- Able to handle very small sensitivity



- Complex theory and approximation
- Hard to handle conditions of complex geometrical



## 1 What's before

According to the perturbation theory, using forward and adjoint flux, we can deduce the sensitivity of  $k_{eff}$  over different X-S data in a simple formulae.

### The sensitivity of $k_{eff}$ (1)

Some integral parameter can be expressed as a bi-linear function,

$$k_{eff} = \frac{\langle \Phi^*(\vec{\xi}), \hat{B}(q(\vec{\xi}))\Phi(\vec{\xi}) \rangle}{\langle \Phi^*(\vec{\xi}), \hat{A}(q(\vec{\xi}))\Phi(\vec{\xi}) \rangle}$$

whose sensitivity over parameter  $q$  can be in the following form:

$$S_{kq} = q(\vec{\xi}) \left[ \frac{\langle \Phi^*, \frac{dB}{dq} \Phi \rangle}{\langle \Phi^*, A\Phi \rangle} - \frac{\langle \Phi^*, \frac{dA}{dq} \Phi \rangle}{\langle \Phi^*, B\Phi \rangle} \right] - \frac{q(\vec{\xi})}{k} \left[ \langle \Gamma^*, \frac{dL}{dq} \Phi \rangle + \langle \Gamma, \frac{dL^*}{dq} \Phi^* \rangle \right]$$

As for XS data, the sensitivity of  $k_{eff}$  over XS can be concluded in the following formulae:

$$S_{k_{eff} \Sigma(\vec{\xi})} = - \frac{\Sigma(\vec{\xi})}{k} \frac{\langle \Phi^*(\vec{\xi}), \left( \frac{dA(\Sigma(\vec{\xi}))}{d\Sigma(\vec{\xi})} - \frac{1}{k} \frac{dB(\Sigma(\vec{\xi}))}{d\Sigma(\vec{\xi})} \right) \Phi(\vec{\xi}) \rangle}{\langle \Phi^*(\vec{\xi}), \frac{1}{k^2} B(\Sigma(\vec{\xi}))\Phi(\vec{\xi}) \rangle}$$

## 1 What's before

In order to make it programmable, we can discretize the formulae to the following form, with T1,T2,T3 and D as absorption, scattering, fission and total integral factor.

### The sensitivity of Keff (2)

$$S_{k, \Sigma_{x,g,z}^i} = \frac{T_{1,x,g,z}^i + T_{2,x,g,z}^i + T_{3,x,g,z}^i}{D}$$

$$D = \frac{1}{k_{eff}} \left\langle \Phi^*(\vec{\xi}), \frac{\chi(E)}{4\pi} \int_0^\infty dE' \int_{\Omega'} \nu \Sigma_f d\Omega' \Phi(\vec{\xi}) \right\rangle$$

$$= \frac{1}{k} \sum_{i=1}^{IN} \sum_{z=1}^{RN} V_z \sum_{g=1}^{GN} (\nu_{g,z}^i \Sigma_{f,g}^i \Phi_{g,z}) \sum_{g'=1}^{GN} (\chi_{g',z}^i \Phi_{g',z}^*)$$

$$T_{1,z,g,z}^i = -\Sigma_{x,g,z}^i \left\langle \Phi^*(\vec{\xi}), \Phi(\vec{\xi}) \right\rangle$$

$$= -\Sigma_{x,g,z}^i V_z \sum_{j=0}^{JN} \tilde{\Phi}_{g,z}^{*j} \tilde{\Phi}_{g,z}^j wt(j)$$

## 1 What's before

Replay the  $\Sigma$  data with different kind of multi-group X-S data, we can get the whole sensitivity matrix of keff over different kind of X-S data.

### The sensitivity of Keff (3)

$$\begin{aligned}
 T_{2,z,g,z}^i &= \Sigma_{x,g,z}^i \langle \Phi^*(\vec{\xi}), \frac{d(\int_0^\infty \int_{\Omega'} \Sigma_s f(E' \rightarrow E, \Omega' \rightarrow \Omega))}{d\Sigma_{x,g,z}^i} \Phi(\vec{\xi}) \rangle \\
 &= \sum_{j=0}^{JN} V_z \sum_{g'=1}^{GN} \tilde{\Phi}_{g,z}^{*j} \tilde{\Phi}_{g,z}^j \Sigma_{x,g' \rightarrow g,z}^i wt(j) \\
 T_{3,z,g,z}^i &= \frac{1}{k_{eff}} \Sigma_{x,g,z}^i \langle \Phi^*(\vec{\xi}), \frac{d\left(\frac{\chi(E)}{4\pi} \int_0^\infty dE' \int_{\Omega'} \nu \Sigma_f d\Omega'\right)}{d\Sigma_{x,g,z}^i} \Phi(\vec{\xi}) \rangle \\
 &= \frac{1}{k} V_z \nu_{f,g,z}^i \Sigma_{f,g,z}^i \Phi_{g,z} \sum_{g'=1}^{GN} (\chi_{g',z}^i \Phi_{g',z}^*)
 \end{aligned}$$

## 1 What's before

Combining multi-group covariance data and calculated sensitivity matrix together, we can obtain the uncertainty of keff in the following formulae.

### The sensitivity of Keff (4)

The relative uncertainty of keff can be calculated via:

$$\frac{\sigma_{K_{eff}}}{K_{eff}} = \left[ \sum_{j=1}^n \sum_{k=1}^n \sum_{g=1}^{GN} \sum_{g'=1}^{GN} S_{\sigma_j^g}^{Keff} S_{\sigma_k^{g'}}^{Keff} \frac{Cov(\sigma_j^g, \sigma_k^{g'})}{\sigma_j^g \sigma_k^{g'}} \right]^{\frac{1}{2}}$$

Actually from the formulae above, we can define the input parameter as following:

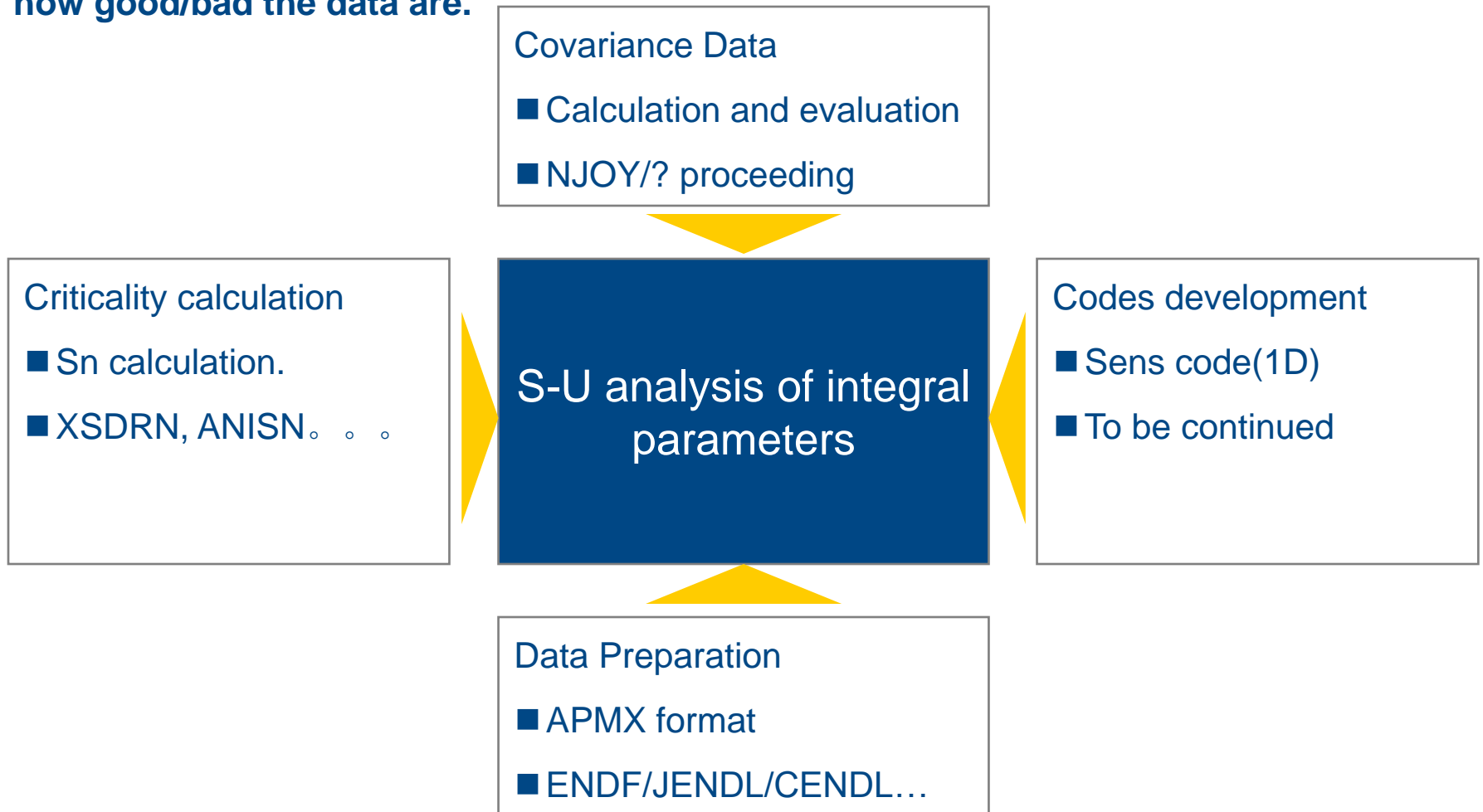
1D M-g X-S data	Fission spectrum	Averaged fission neutron number	2D scattering X-S matrix	...
Energy group structure	Components and its distribution	Geometrical shape of the target facility	Integral weighting factor	...
Forward neutron flux	Adjoint forward flux	Forward angular neutron flux	Adjoint angular neutron flux	...

My presentation can be splitted into three parts:

- 1 What's before
- 2 What's now**
- 3 What's next

## 2 What's now

The s-u analysis of macro nuclear data in CNDC has just started, which combined covariance data evaluation and benchmark calculation together in order to determine how good/bad the data are.

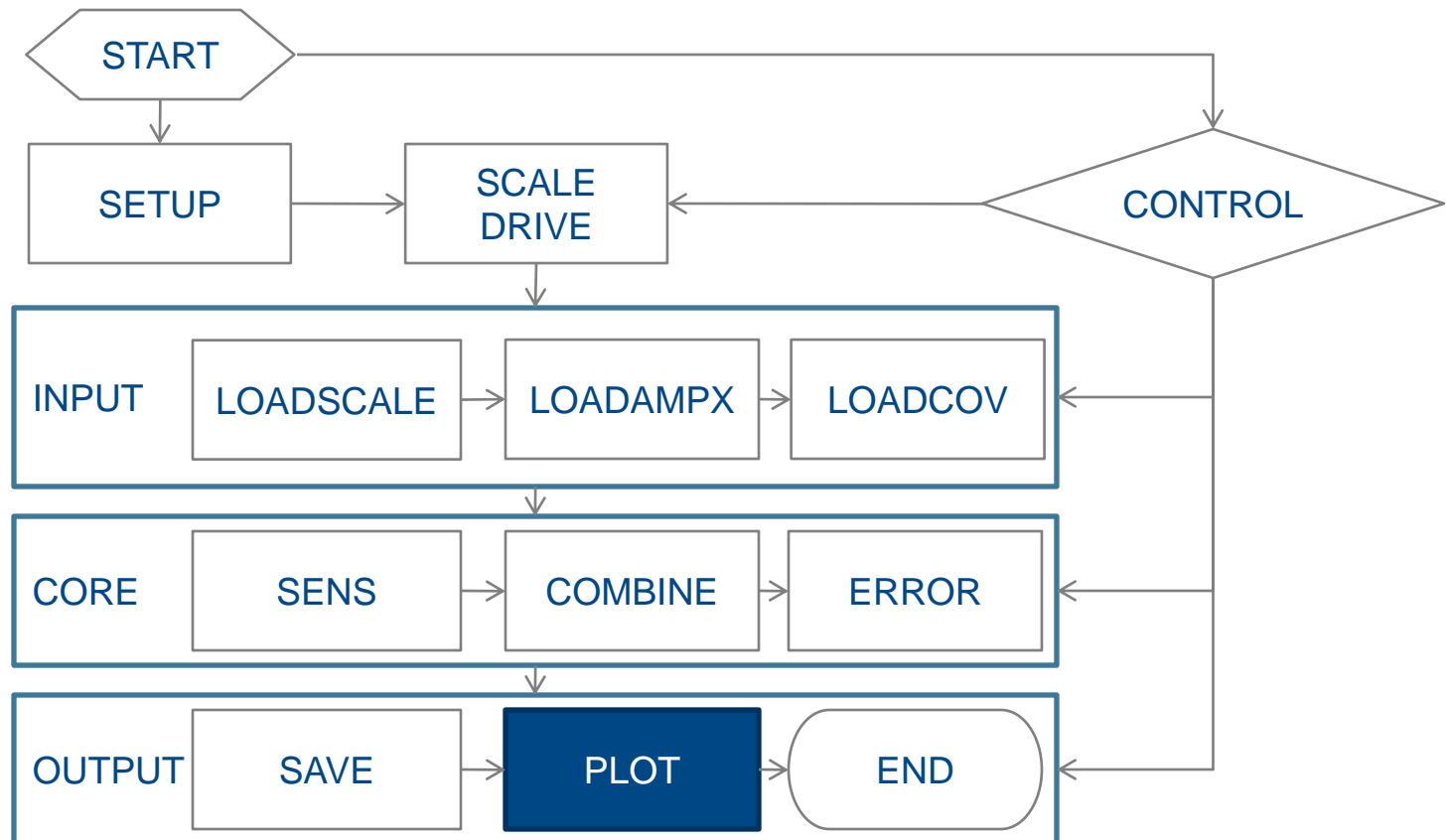




## 2 What's now

The Sens(1D) code were written in f95, including IO, flow control, driving and core s-u calculation modules, whose flows are as follows:

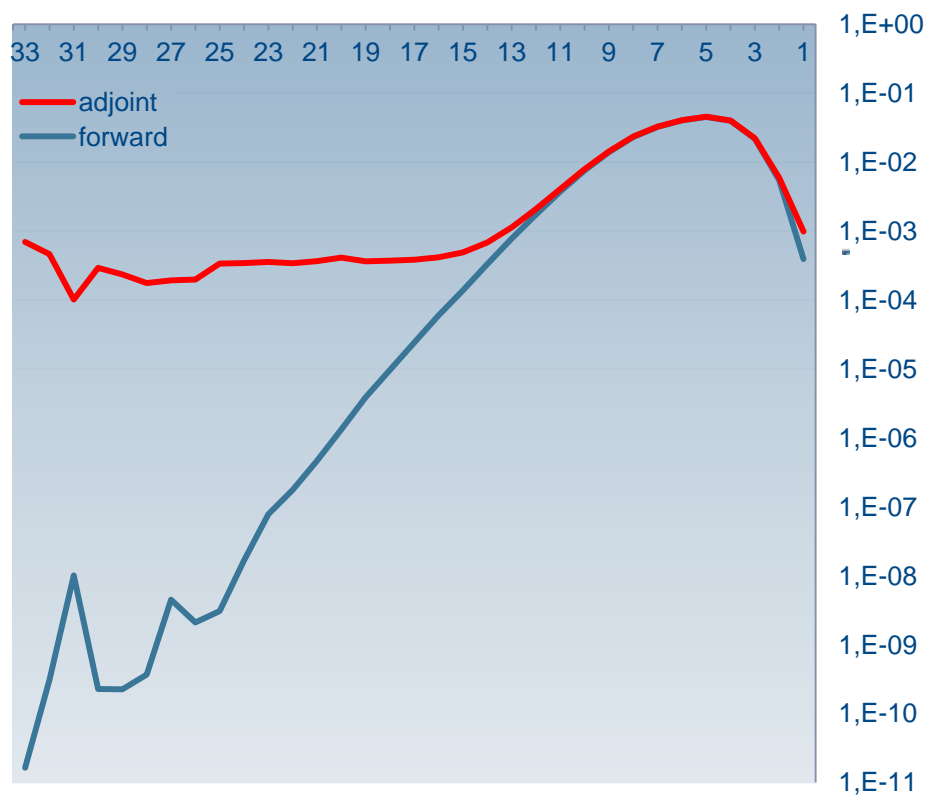
### Flow of Sens(1D) code



## 2 What's now

In order to test the sens(1D) code, we chose the Jezeble-Pu facility, with XSDRN to do the criticality calculation.

### Criticality Calculation( $k_{eff}=1.0040$ )



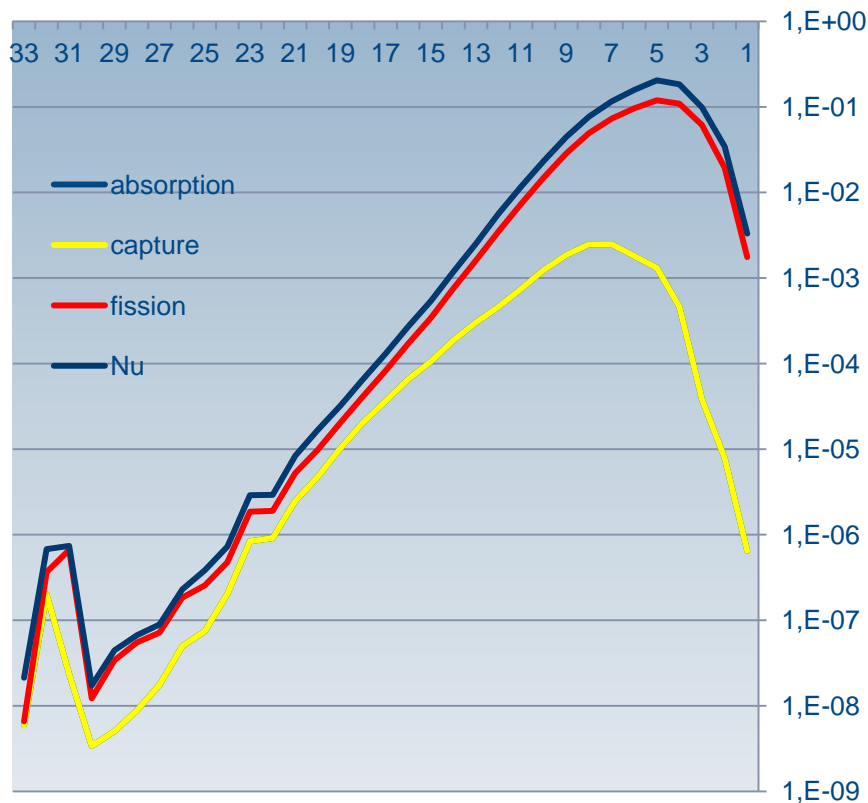
### Nuclei Components

Nuclei	Atom Density
Pu-239	3.70E-02
Pu-240	1.75E-03
Pu-241	1.17E-04
P-069	8.36E-04
P-071	5.39E-04
U-235	1.00E-12
U-238	1.00E-12
Np-237	1.00E-12

## 2 What's now

We can get the sensitivity contribution of different X-S data of different energy group (taking Pu-239 as example), which shows some reasonable conclusion.

### Sensitivity of Pu-239 data



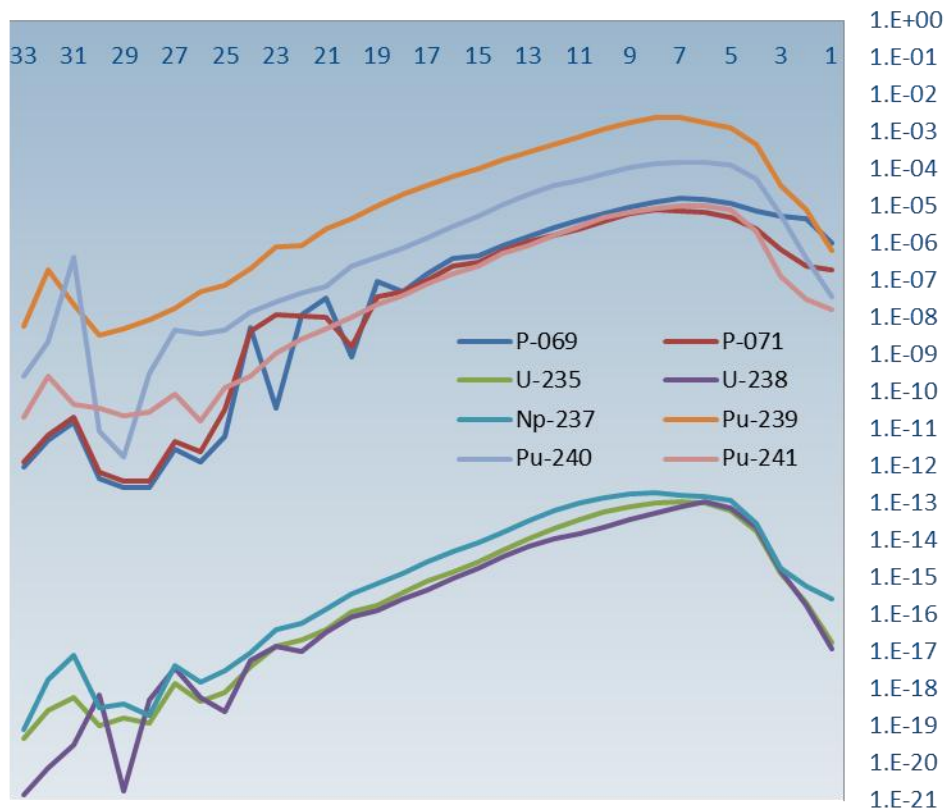
### Some Conclusion

- As for keff, the nuclear data concerning about fission shows a dominantly bigger sensitivity
- The difference between nu and fission data comes from the neutron absorption factor mentioned above
- The neutron flux distribution is proved to be a very important weighting factor for sensitivity of different energy group
- Absorption always leads to a minus sensitivity

## 2 What's now

Taking all the nuclei into consideration, we can get the total sensitivity also found some reasonable conclusion.

### Sensitivity of Different Nuclei



### Some Conclusion

- Pu-239 data shows bigger sensitivity for it's high abundance in Jezebel-Pu
- The sensitivities of different nuclear data are influence by neutron flux, nuclei density, energy structure and the nuclear data itself, which can lead to a complex shape or trend.

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## 3 What' next

Actually, the S-U analysis in CNDC is just starting to sail, there are still a long way for us to go.

### The Future Work on S-U in CNDC

- A more detailed comparison between SENS results and MCNP results as well as other deterministic sensitivity calculation codes.
- Using different data library for comparison.
- How to deal with resonance data? How to consider the influence of self-shielding process?
- Sensitivity → → → → data adjusting
- 1D → → 2D → → 3D
- Modify the formulae to consider the factor of time, or burn-up in other words.

THANK U FOR  
UR ATTENTION