CBGLIB: A multi-group neutron library for accurate neutronics simulations

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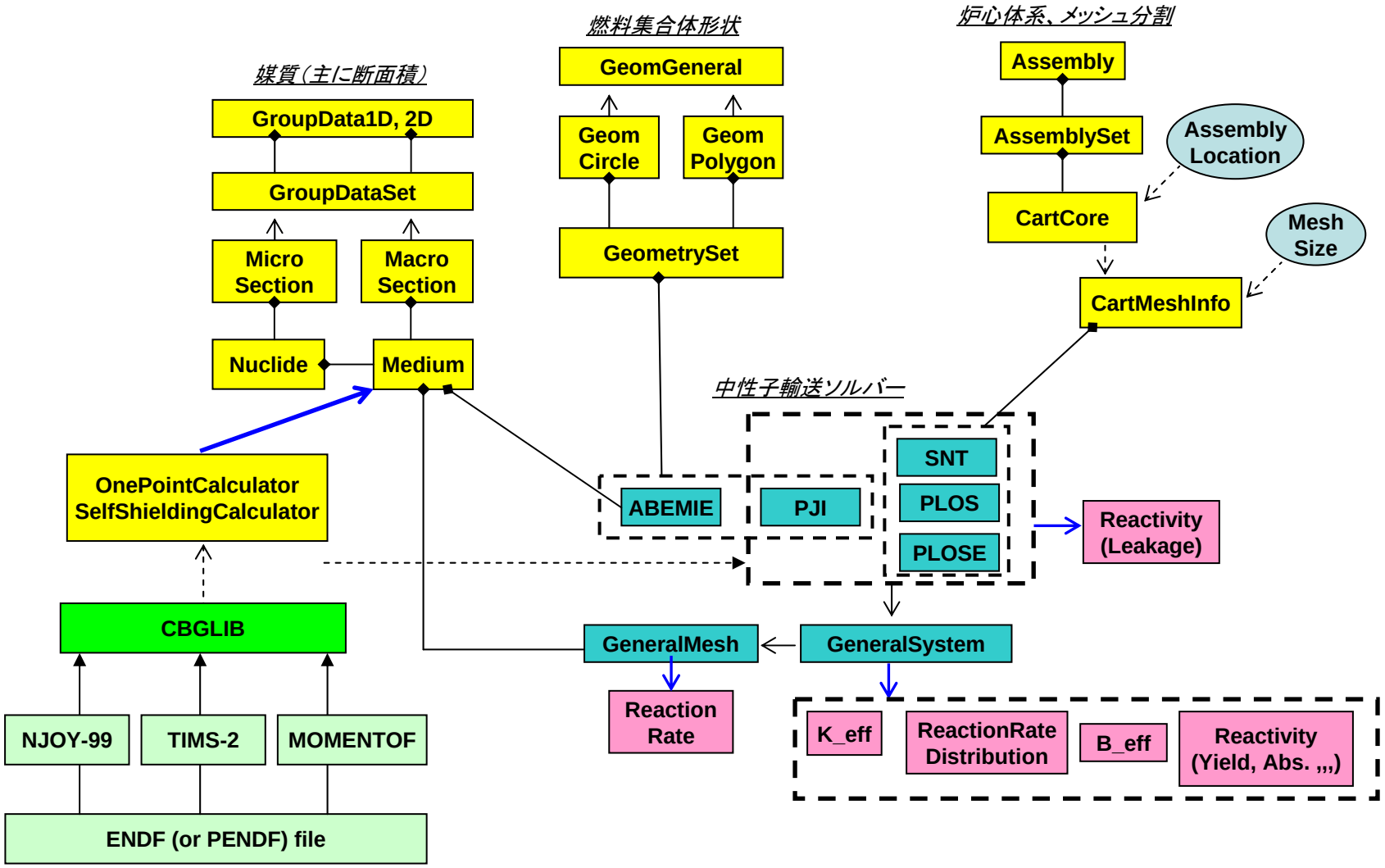
[Background]

- Accurate effective cross sections are necessary for reliable neutronics simulations.

- From a view of computational cost, coarse-group neutron library has an important role in neutronics simulations.

- How to improve an accuracy of coarse-group libraries ?

CBG : An integrated neutronics simulation code system



CBGLIB is a multi-group neutron library composed of

- Infinite dilution cross sections,
- Scattering matrices,
- Self-shielding factors,
- Probability table,

and, the following techniques are adopted to increase Its accuracy:

(1) Nuclide- and energy group-dependent Bell factor,
(2) multiple R-parameter,
(3) adjustment of Bell factor to cancel out errors induced by coarse group structure

(1) Nuclide- and energy-group-dependent Bell factor

- Bell factor is used to improve the following rational approximation:

$$P_{esc}(E) \approx \frac{a}{\tilde{l}\,\Sigma(E) + a}$$

- Neutron flux in fuel region of isolated pin-cell is (NR-based) :

(rigorous form): $$\phi_r(E) = \frac{\Sigma_{f,0}}{\Sigma_f(E)}(1 - P_{esc}(E)) + P_{esc}(E)$$

(Approx. form): $$\phi_a(E) \approx \frac{\tilde{l}\,\Sigma_{f,0} + a}{\tilde{l}\,\Sigma_f(E) + a}$$

- The value of Bell factor is determined so as to preserve the following relation for each nuclide and each energy-group :

$$\frac{\langle \sigma(E)\phi_r(E) \rangle}{\langle \phi_r(E) \rangle} = \frac{\langle \sigma(E)\phi_a(E) \rangle}{\langle \phi_a(E) \rangle}$$

[impotant!]
Integrals on both sides are calculated with probability tables.

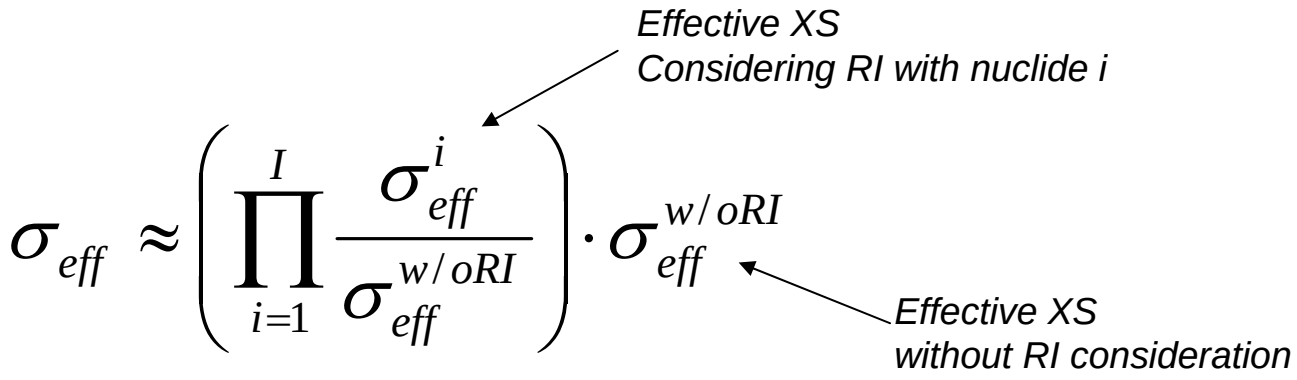
(2) Multiple R-parameter

- R-parameter is a parameter for f-table to consider resonance interference (RI).

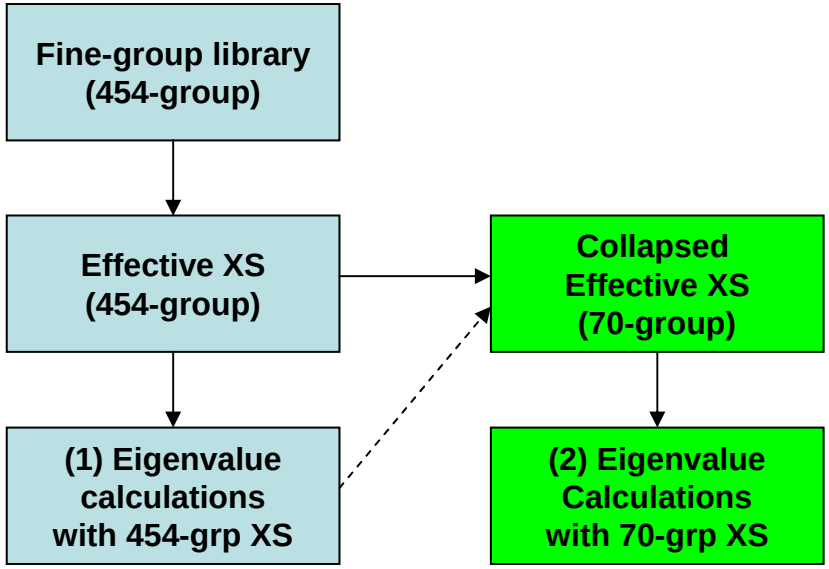
  f(σ_0, T, R) … R is defined as a ratio of the "target" nuclide density to the nuclide density of itself.

- In CBGLIB, "Target" nuclide depends on energy-group.

- When we have to consider RI with several nuclides, we treat it with the following approximated procedure.



(3) Adjustment of Bell factor



	(1)	(2)
UO2	1.47615	1.47191
MOX	1.23367	1.23172

Coarse-group calculation cannot reproduce fine-group calculation results.

$$\frac{\langle \sigma_{fine}\phi_{fine} \rangle}{\langle \phi_{fine} \rangle} \neq \frac{\langle \sigma_{fine}\phi_{fine} \rangle}{\langle \phi_{coarse} \rangle}$$

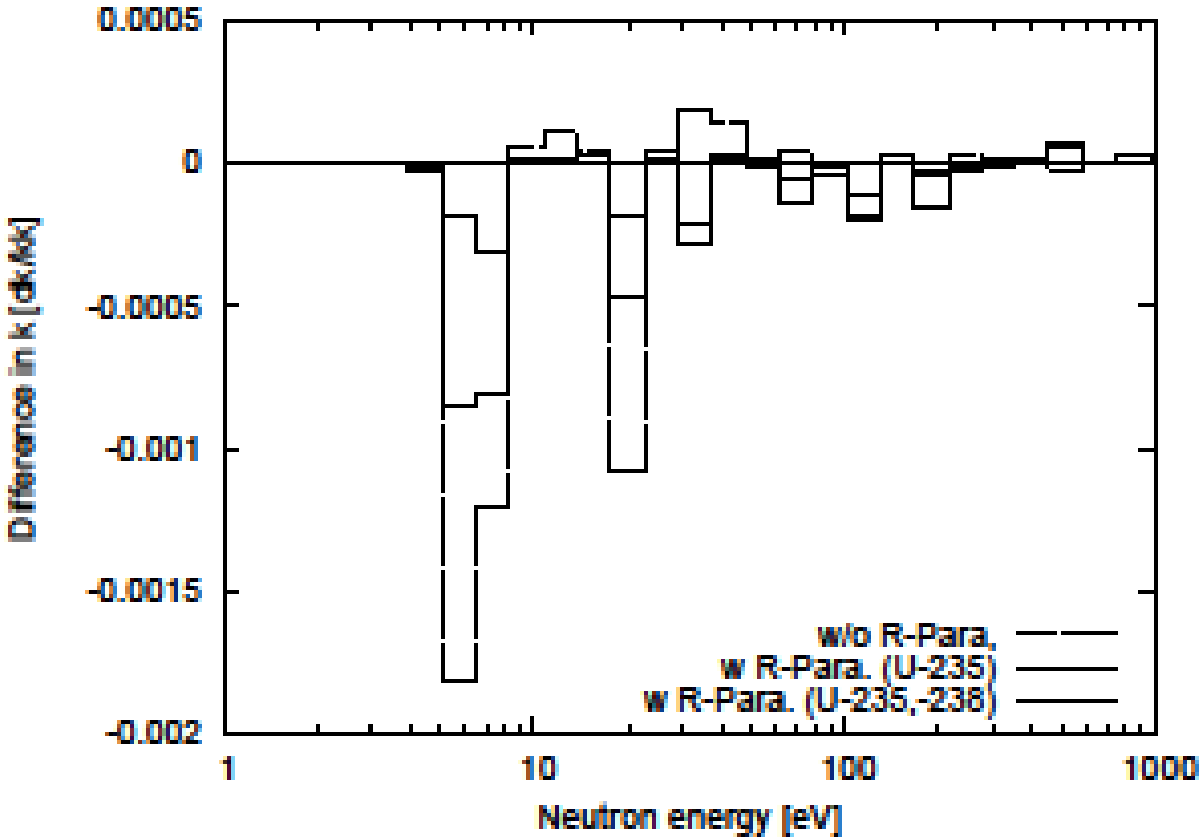
It is pointed out that the SPH-factor is necessary for group-collapsing.
(N.Sugimura, A.Yamamoto, JNST 44[7], p.958 (2007))

Instead of applying the SPH-factor, Bell factor is adjusted in CBGLIB.

Assessment of accuracy of the effective cross sections

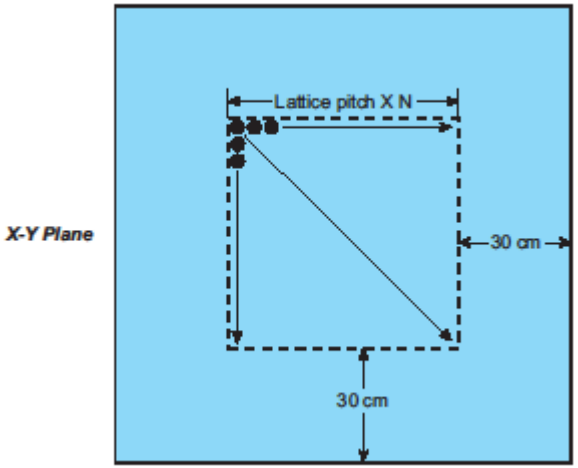
Collision probability based-perturbation theory is used.
(Reference : XS calculated with SRAC/PEACO)

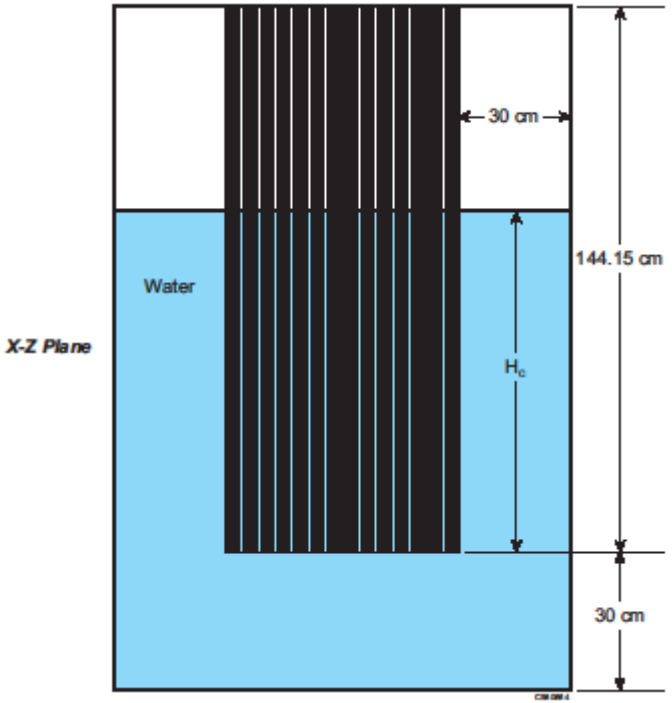
Energy-group-wise error contribution to keff (UO2 pincell)



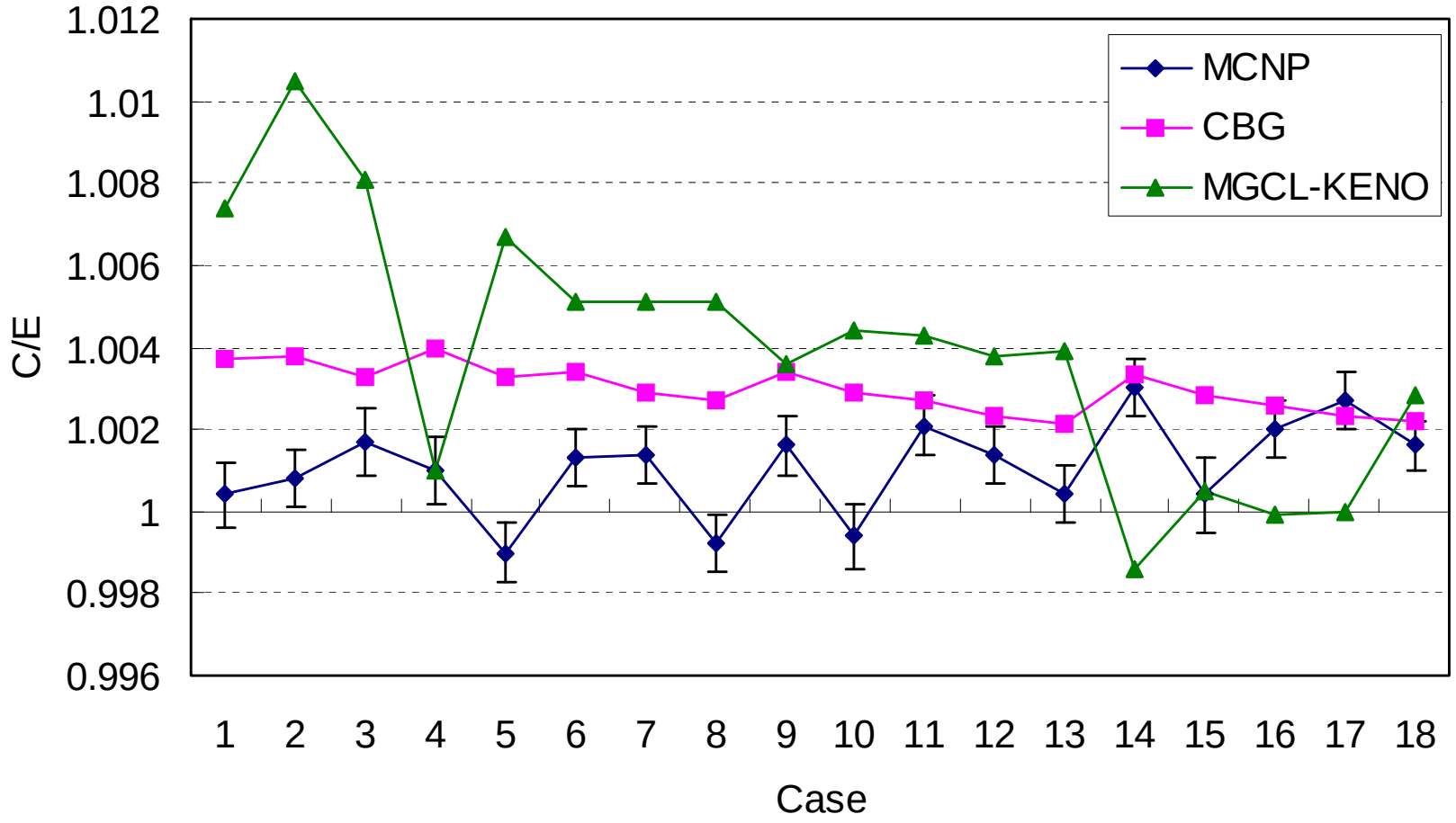
Numerical tests : TCA calculation

- 107-group CBGLIB is generated.
- It is applied to TCA calculations in the ICSBEP handbook
- Core calculations are performed with a 3D-Sn code (P1S4, 107-group)





Results (1) UO2 (LCT006)



- Results of MCNP and MGCL-KENO are from the ICSBEP handbook.
- MGCL is 137-group multi-group library for critical safety calculations.

Results (2) MOX (MCT004)