In-situ APEC Leakage Correction for Homogenized Group Constants of Baffle-Reflector Region

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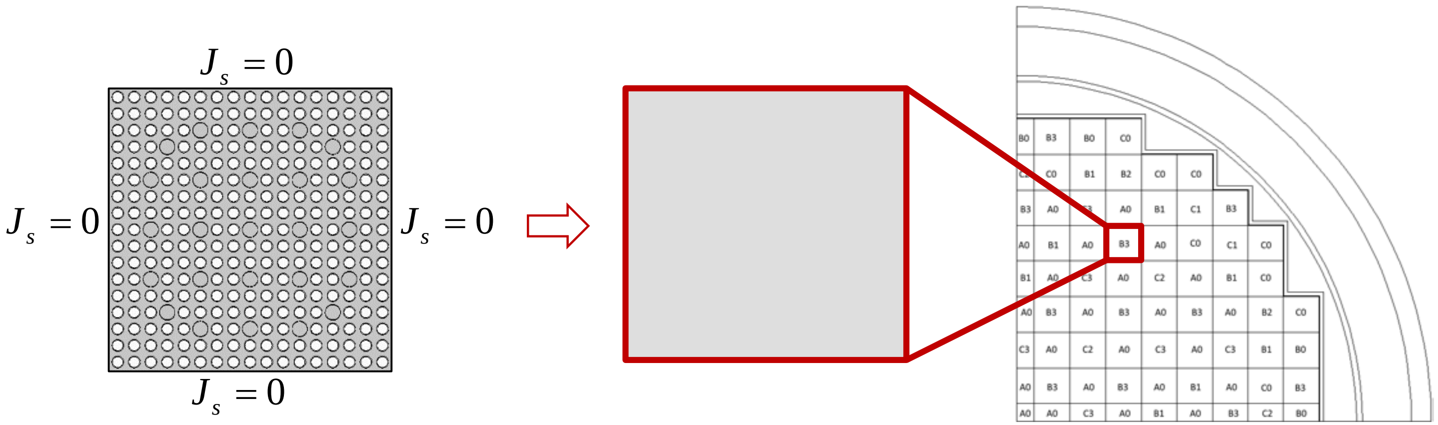
Table of Contents

Introduction (1/4)

❖ **Generalized equivalence theory (GET) for 2-step procedures**

➢ Assembly homogenization using all reflective BC (infinite lattice)

- Computing cost for whole-core transport calculation is too large.
- Very successful for the analysis of conventional LWR.



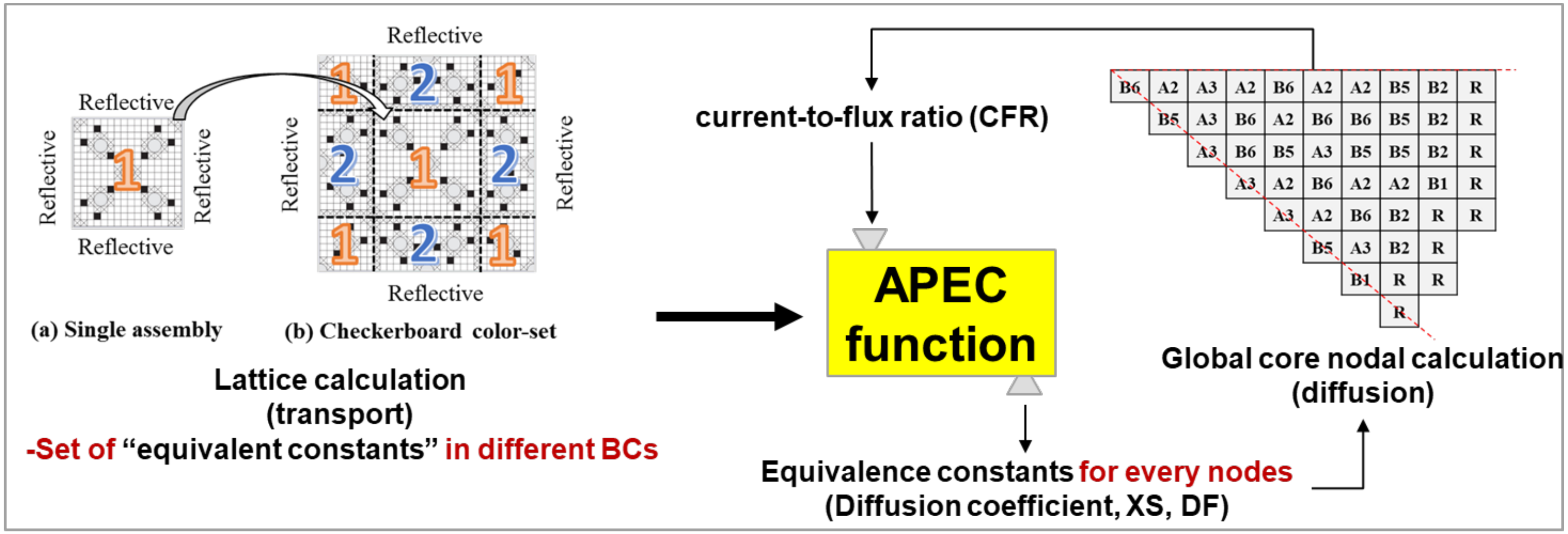
Lattice calculation (transport) | **Homogenization and condensation** | **Global core calculation (diffusion)**

➢ Limitation of conventional 2-step procedures

- Limited accuracy when the neighborhood effect is rather strong.
- The ad-hoc critical spectrum correction was used for the leakage correction.

Introduction (2/4)

❖ Albedo-corrected parameterized equivalence constants (APEC) method

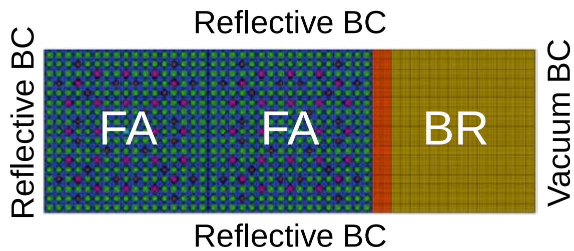


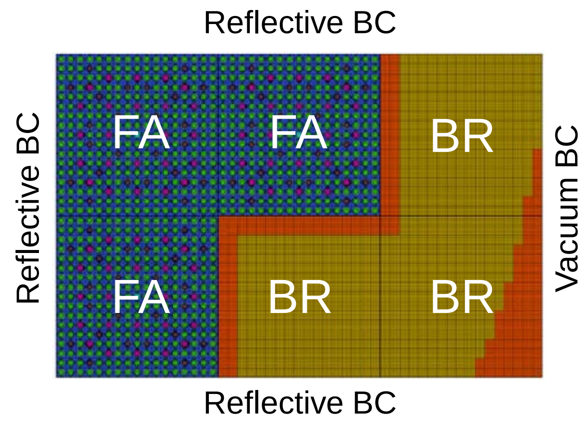
- ➢ Conventional 2-step-consistent approach for computational efficiency
  - Equivalence constants are updated during nodal calculation using actual leakage information.
  - Once determined APEC functions can be used for thousands of nodal calculations.
- ➢ Almost reproduced the transport solution of UOX loaded PWR initial core analyses: ~1 % of Max. assembly power error.
- ➢ Application of APEC leakage correction to commercial DeCART2D/MASTER code
  - Corrected group constants in the middle of a microscopic core depletion.
  - Approximated burnup-dependent APEC functions: FA of interest to be burned and that the surrounding FAs to be fresh.
- ➢ Improved APEC DF modeling

Introduction (3/4)

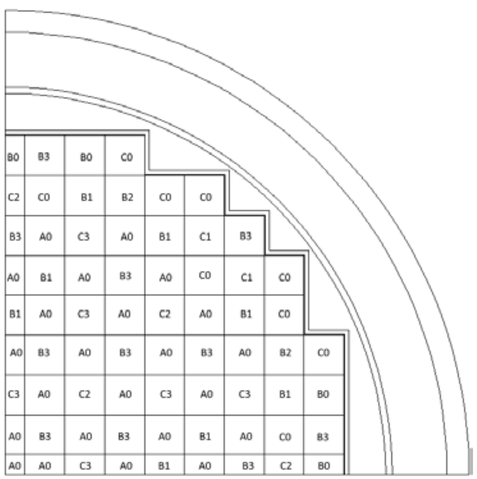
❖ **Homogenization of baffle-reflector (BR) modeling**

➢ Simplified spectral geometry

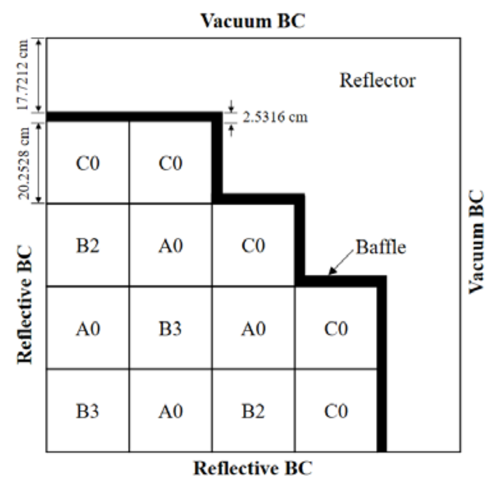




➢ Whole core calculation at the BOC



Conventional PWR



SMR

Introduction (4/4)

❖ Objective of this paper

- Application of the APEC leakage correction to the homogenized group constants of the BR region.

❖ Codes and benchmark problem

- DeCART2D code
  - MOC based 2D transport lattice code.
  - Whole-core transport calculations (reference solution).
  - Lattice and color-set calculations.

- In-house nodal code
  - Implementation of the NEM within the p-CMFD formulation.
  - APEC leakage correction for both FAs and BR region.

- Partially MOX-loaded SMR benchmark problem

Options
▹ 47-group library.

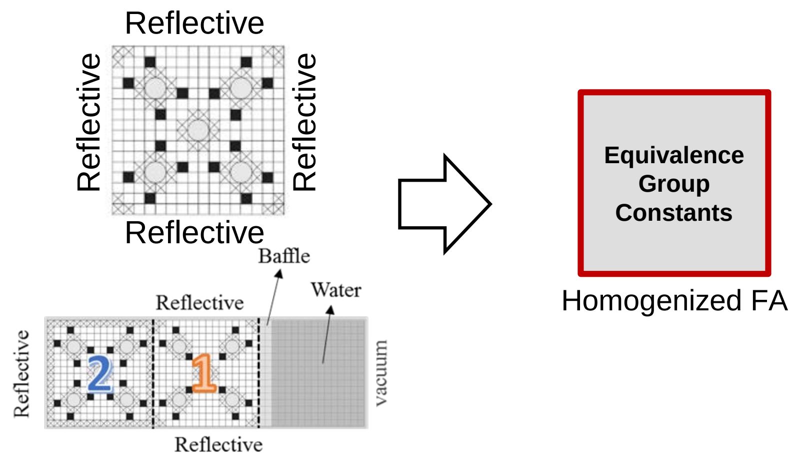
▹ Transport corrected P0 XS for anisotropic scattering treatment.

▹ Default ray tracing
- two polar angles for 90°
- eight azimuthal angles for 90°
- ray-spacing of 0.02 cm

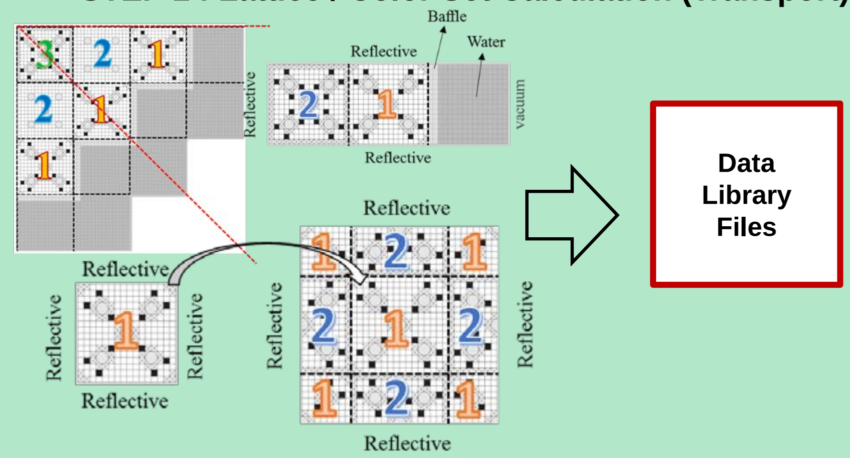
APEC leakage correction for BR region (1/7)

❖ Summary of APEC method compared to conventional 2-step method

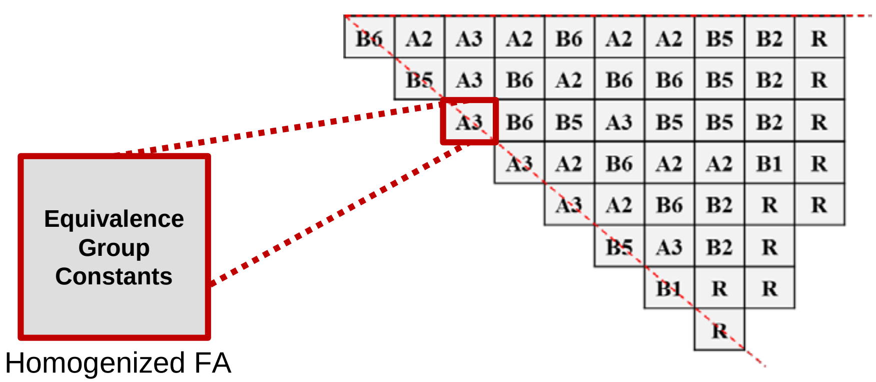
STEP 1 : Lattice / Color Set Calculation (Transport)



STEP 1 : Lattice / Color Set Calculation (Transport)

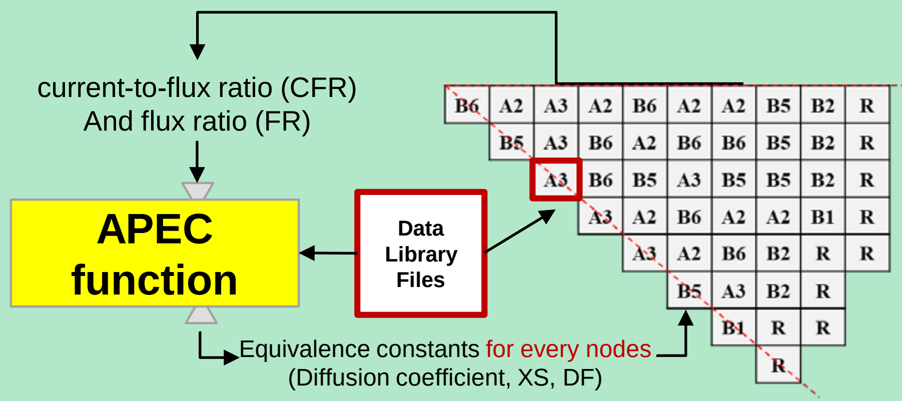


STEP 2 : Whole core nodal calculation (Diffusion)



<Conventional 2-step Method>

STEP 2 : Whole core nodal calculation (Diffusion)

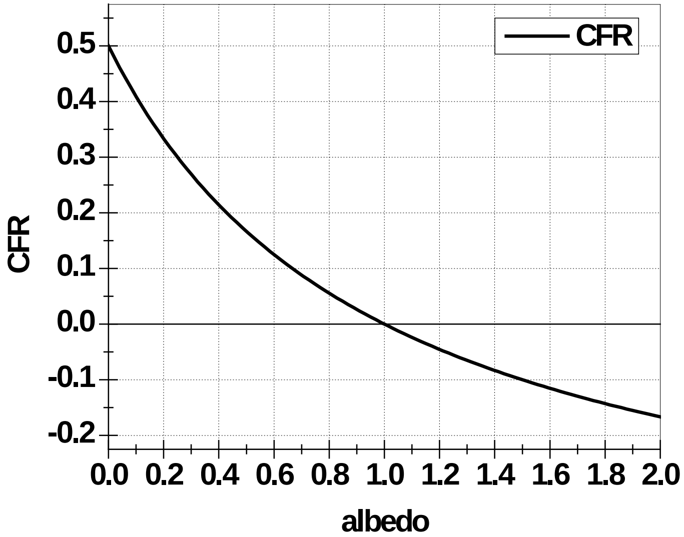


<APEC Method >

❖ **Albedo-corrected parameterized equivalence constants (APEC) method**

➢ Normalized parameter for functionalization of APEC XSs and DFs

- Current to flux ratio (CFR): normalized parameter representing a surface leakage of the FA



$$\alpha = \frac{J^-}{J^+} = \frac{\frac{1}{4}\phi - \frac{1}{2}J}{\frac{1}{4}\phi + \frac{1}{2}J}, \quad \longrightarrow \quad \frac{J}{\phi} = \frac{1}{2}\frac{(1-\alpha)}{(1+\alpha)}. \qquad (1)$$

- Assembly-surface CFR

$$CFR_{G,s} \equiv \frac{J_{G,s}}{\phi_{G,s}} \qquad (2)$$

- Assembly-average CFR

$$CFR_G \equiv \frac{\sum_s J_{G,s}}{\sum_s \phi_{G,s}} \qquad (3)$$

APEC leakage correction for BR region (3/7)

❖ Albedo-corrected parameterized equivalence constants (APEC) method

➢ APEC XS and DF Functions for FAs

- APEC XS Functions

$$\Sigma_{x,g}^{FA} = \Sigma_{s,g}^{SA} + \Delta\Sigma_{x,g}^{FA}, \quad (4)$$

$$\Delta\Sigma_{x,F}^{FA} = a_{x,F} CFR_F^N + b_{x,F} CFR_T^N + c_{x,F}, \quad (4.1)$$

$$\Delta\Sigma_{x,T}^{FA} = a_{x,T} CFR_T^N + b_{x,T} \left(CFR_T^N\right)^2 + c_{x,T}. \quad (4.2)$$

- APEC DF Functions

$$DF_{g,s}^{FA} = ADF_{g,s}^{SA} + \Delta DF_{g,s}^{FA}, \quad (5)$$

$$\Delta DF_{g,s}^{FA} = a_{g,1} FR_g^S + a_{g,2} CFR_g^S + a_{g,3} CFR_g^N + c_g. \quad (5.1)$$

where,

Σ^{SA} : single assembly HGC,

F : fast group, T : thermal group,

$J_{g,s}$: surface current, $\phi_{g,s}$: surface flux, $\overline{\phi}_g^{Avg}$: average flux,

$$c_{x,G} \begin{cases} = 0 & \text{for interior FA} \\ \neq 0 & \text{for peripheral FA} \end{cases}.$$

Assembly-averaged CFR

$$CFR_g^N \equiv \frac{\sum_s J_{g,s}}{\sum_s \phi_{g,s}}$$

Assembly-surface CFR

$$CFR_g^S \equiv \frac{J_{g,s}}{\phi_{g,s}}$$

Assembly-surface FR

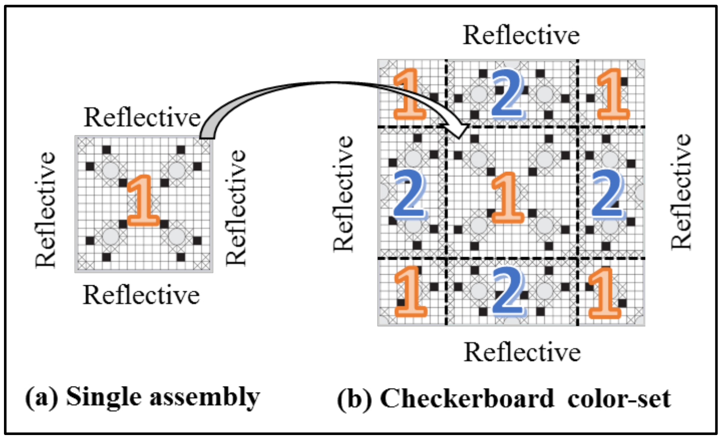
$$FR_g^S \equiv \frac{\overline{\phi}_g^{Avg}}{\phi_{g,s}}$$

APEC leakage correction for BR region (4/7)

❖ Albedo-corrected parameterized equivalence constants (APEC) method

➢ APEC XS Functions

- The procedure of determining the APEC XS functions.



Lattice calculation (transport analysis)

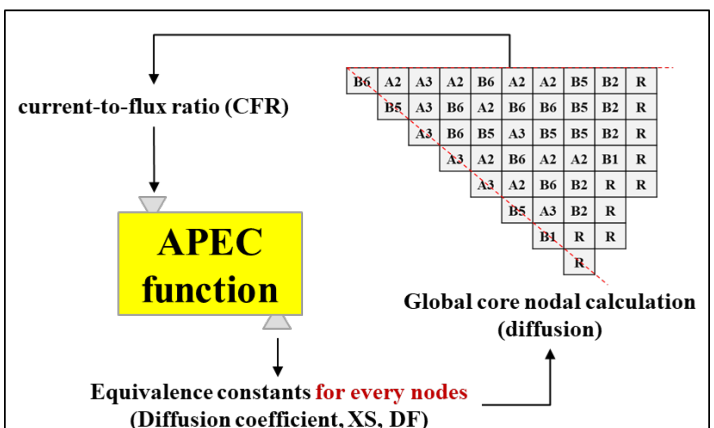
① **Arrangement of data obtained by color-set calculation**

$$a_{x,F} CFR_F + b_{x,F} CFR_T + c_{x,F} = \Sigma_{x,F} - \Sigma_{s,F}^{SA} = \Delta\Sigma_{x,F}$$

$$a_{x,T} CFR_T + b_{x,T} \left(CFR_T\right)^2 + c_{x,T} = \Sigma_{x,T} - \Sigma_{s,T}^{SA} = \Delta\Sigma_{x,T}$$

② **Determining coefficients by multiple linear regression**

$$a_{x,F}, b_{x,F}, c_{x,F} \qquad a_{x,T}, b_{x,T}, c_{x,T}$$



Nodal analysis (diffusion analysis)

③ **Updating APEC XS by corresponding CFRs**

$$\Delta\Sigma_{x,F} = a_{x,F} CFR_F + b_{x,F} CFR_T + c_{x,F},$$

$$\Delta\Sigma_{x,T} = a_{x,T} CFR_T + b_{x,T} \left(CFR_T\right)^2 + c_{x,T}.$$

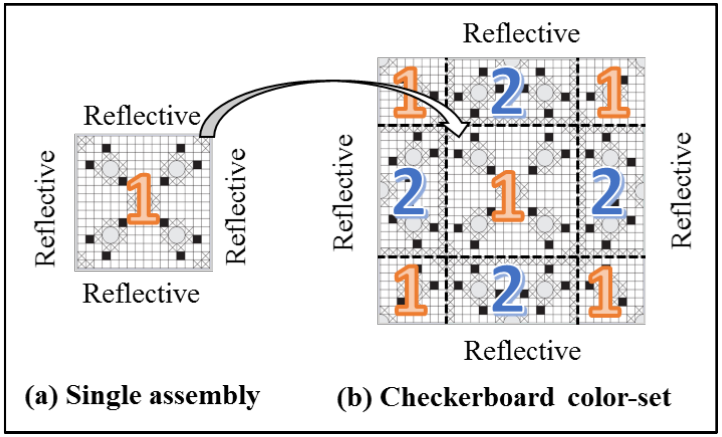
$$\Sigma_{x,g} = \Sigma_{s,g}^{SA} + \Delta\Sigma_{x,g}$$

APEC leakage correction for BR region (5/7)

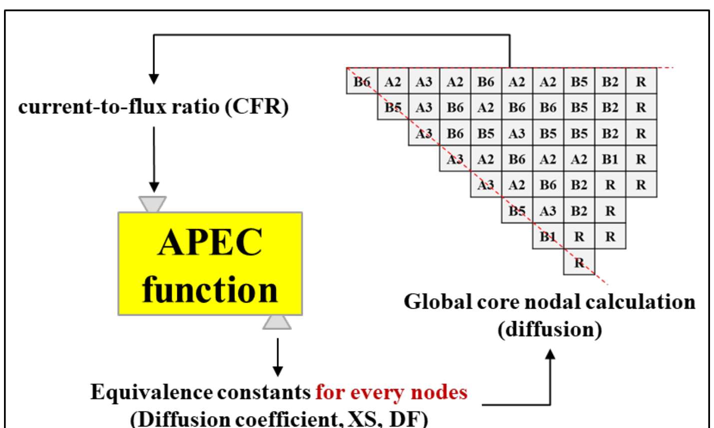
❖ Albedo-corrected parameterized equivalence constants (APEC) method

➢ APEC DF Functions

- The procedure of determining the APEC DF functions.



Lattice calculation (transport analysis)



Nodal analysis (diffusion analysis)

① Arrangement of data obtained by color-set calculation

$$a_{g,1}FR_{g,s} + a_{g,2}CFR_{g,s} + a_{g,3}CFR_{g} + c_g = DF_{g,s} - ADF_{g,s}^{SA} = \Delta DF_{g,s}$$

② Determining coefficients by multiple linear regression

$$a_{g1}, a_{g2}, a_{g3}, c_g$$

③ Updating APEC XS by corresponding CFRs

$$\Delta DF_{g,s} = a_{g,1}FR_{g,s} + a_{g,2}CFR_{g,s} + a_{g,3}CFR_{g} + c_g$$

$$DF_{g,s} = ADF_{g,s}^{SA} + \Delta DF_{g,s}$$

APEC leakage correction for BR region (6/7)

- **Albedo-corrected parameterized equivalence constants (APEC) method**
  - APEC XS and DF Functions for BRs
    - APEC XS Functions

$$\Sigma_{x,g}^{BR} = \Sigma_{s,g}^{\text{Standard}} + \Delta\Sigma_{x,g}^{BR}, \quad (6)$$

$$\Delta\Sigma_{x,F}^{BR} = a_{x,F}\Delta CFR_F^N + b_{x,F}\Delta CFR_T^N, \quad (6.1)$$

$$\Delta\Sigma_{x,T}^{BR} = a_{x,T}\Delta CFR_T^N + b_{x,T}\left(\Delta CFR_T^N\right)^2. \quad (6.2)$$

    - APEC DF Functions

$$DF_{g,s}^{BR} = DF_{g,s}^{\text{Standard}} + \Delta DF_{g,s}^{BR}, \quad (7)$$

$$\Delta DF_{g,s}^{BR} = a_{g,1}\Delta FR_g^S + a_{g,2}\Delta CFR_g^S + a_{g,3}\Delta CFR_g^N. \quad (7.1)$$

where,

Σ^{SA} : single assembly HGC,

F : fast group, T : thermal group,

$J_{g,s}$: surface current, $\phi_{g,s}$: surface flux, $\overline{\phi}_g^{Avg}$: average flux.

Assembly-averaged ΔCFR

$$\Delta CFR_g^N \equiv \frac{\sum_s J_{g,s}}{\sum_s \phi_{g,s}} - \frac{\sum_s J_{g,s}^{\text{Standard}}}{\sum_s \phi_{g,s}^{\text{Standard}}}$$

Assembly-surface ΔCFR

$$\Delta CFR_g^S \equiv \frac{J_{g,s}}{\phi_{g,s}} - \frac{J_{g,s}^{\text{Standard}}}{\phi_{g,s}^{\text{Standard}}}$$

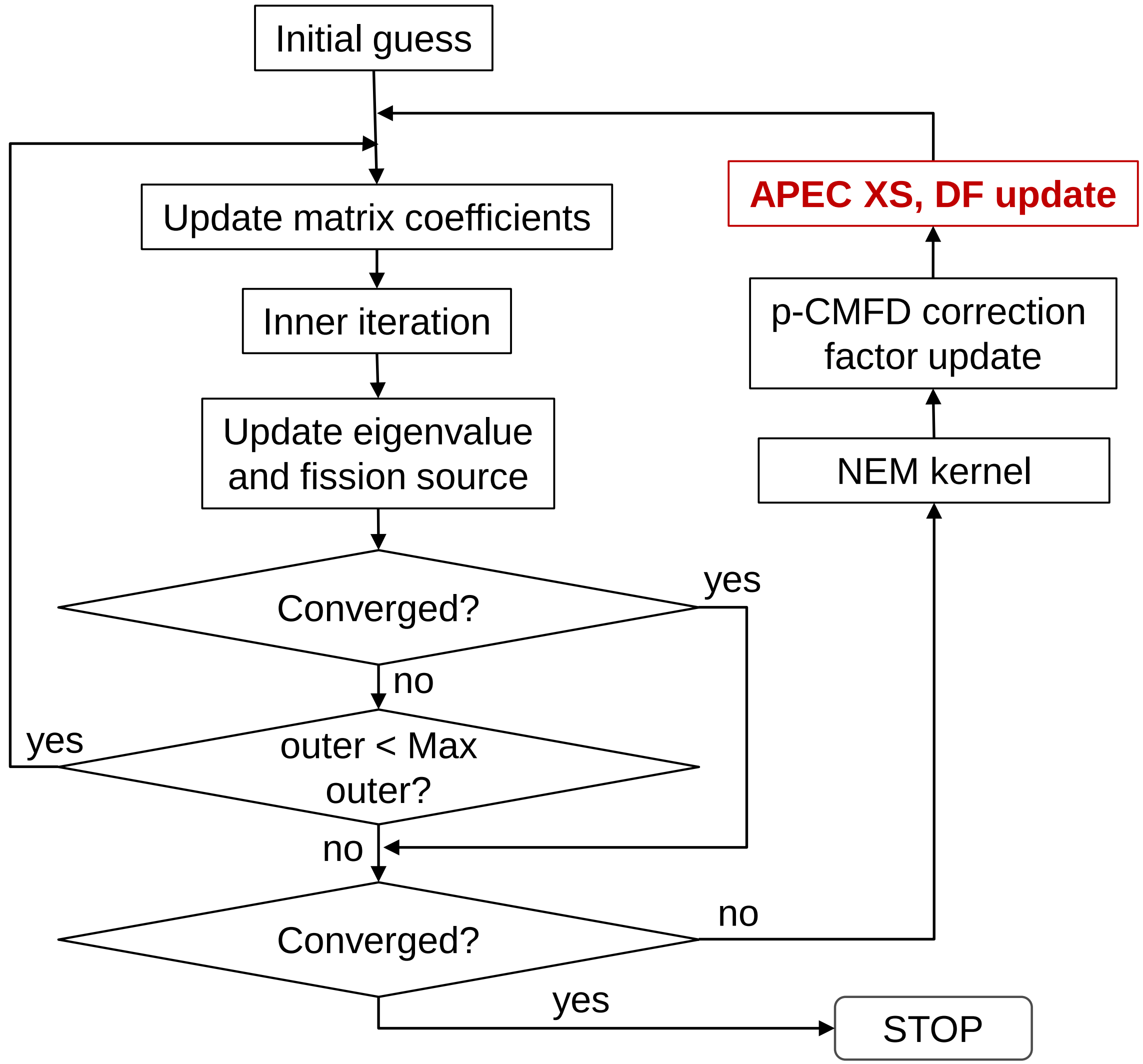
Assembly-surface ΔFR

$$\Delta FR_g^S \equiv \frac{\overline{\phi}_g^{Avg}}{\phi_{g,s}} - \frac{\overline{\phi}_g^{Avg,\text{Standard}}}{\phi_{g,s}^{\text{Standard}}}$$

APEC leakage correction for BR region (7/7)

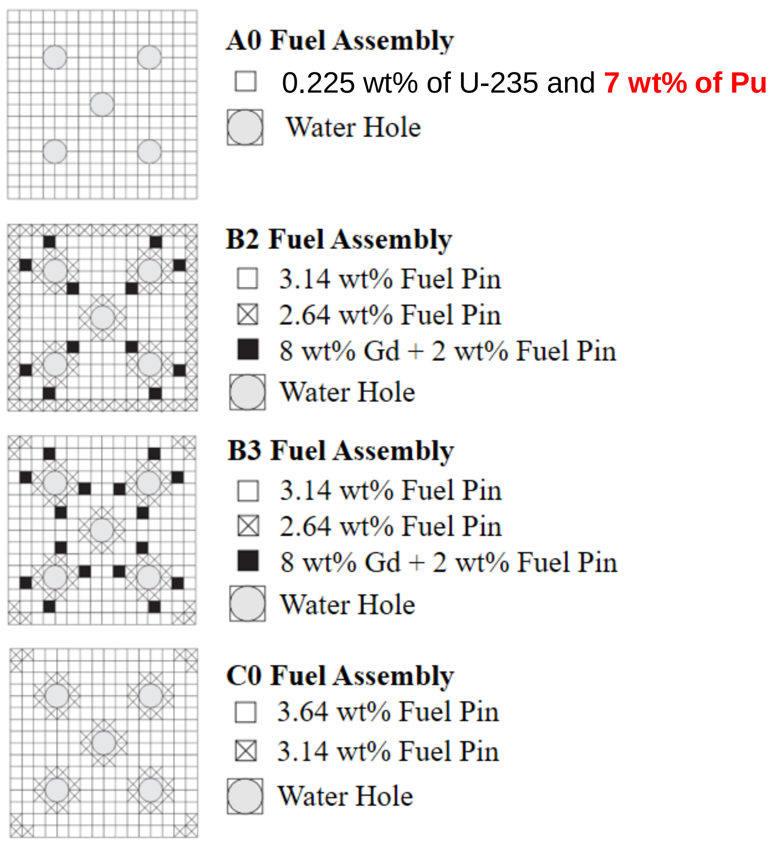
❖ Implementation to NEM nodal calculation

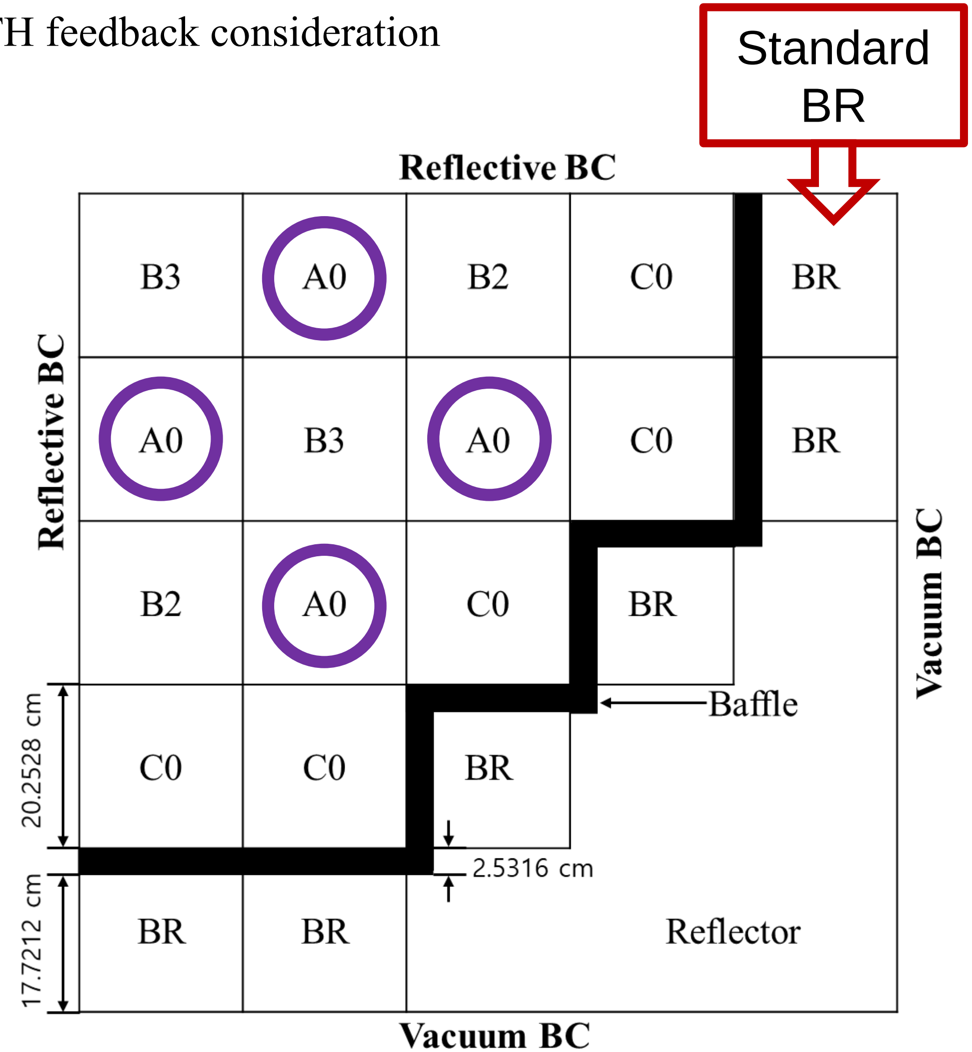
- NEM code with p-CMFD method for acceleration
- XSs and DFs are updated right after the p-CMFD correction factors are updated
- No additional iteration loop for APEC method
- Comparable convergence rate to the conventional nodal calculation



Benchmark Problem

- Partially MOX-loaded SMR problem
  - Soluble boron free condition.
  - Hot zero power (HZP) condition → No TH feedback consideration





Numerical Results (2/11)

❖ Benchmark Problem

- Partially MOX-loaded SMR problem
  - Soluble boron free condition.
  - Hot zero power (HZP) condition → No TH feedback consideration

C0	A0	C0	A0
	C0	B3	C0
		B3	

Variant 1

A0	B3	A0	C0
	B2	B2	B2
		B3	

Variant 2

B3	B2	B3	A0
	A0	C0	C0
		A0	

Variant 3

A0	B3	C0	B3
	A0	B2	C0
		A0	

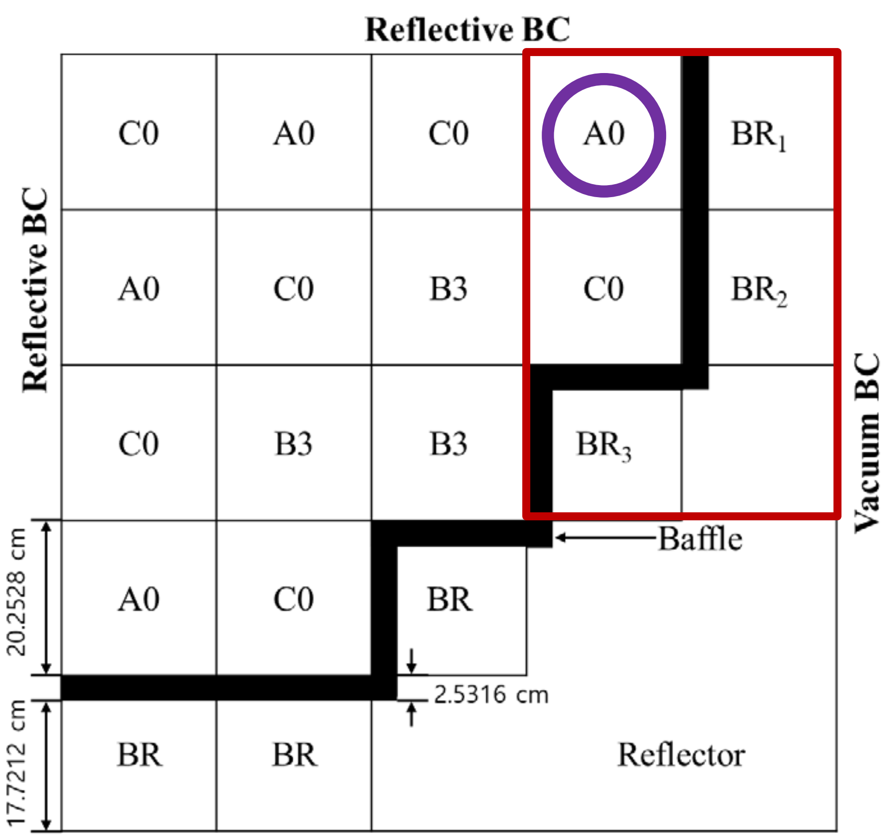
Variant 4

C0	A0	B2	C0
	B3	C0	A0
		B3	

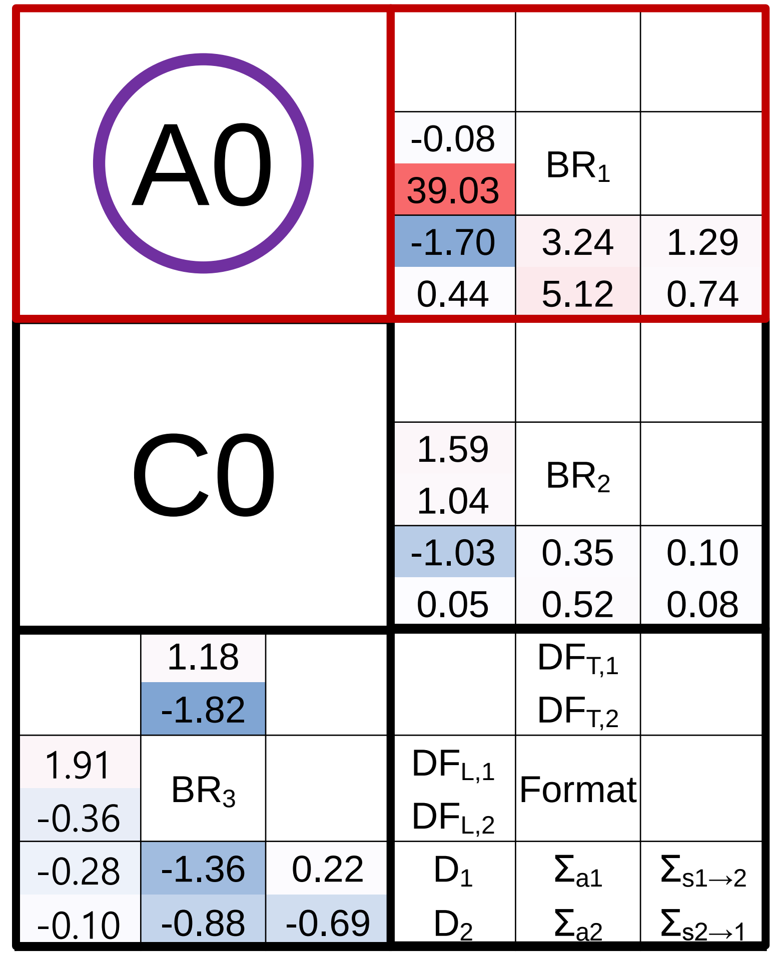
Variant 5

❖ Tendency of HGCs in BR region

- Partially MOX-loaded SMR Variant 1 problem
  - Relative error (%) of standard HGCs in the BR region.
    - → Significant discrepancies of HGCs due to the neutron spectrum change by partially MOX-loaded FA (A0).



Variant 1

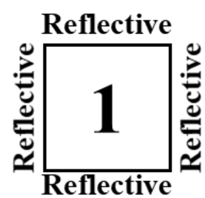


Numerical Results (4/11)

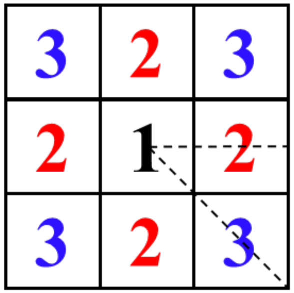
- **Preprocessing for predetermining APEC functions**
  - List of Color-set Calculation

Color-set Model	Combination of FAs
Checkerboard	(B2,B3,C0), (B3,C0,B2), (C0,B3,B2), (A0,B2,B3), (B3,C0,A0), (C0,A0,B2)
L-Shape Type1	(B2,B3,C0), (B2,C0,B3), (B3,C0,B2), (B3,B2,C0), (C0,B2,B3), (C0,B3,B2), (A0,B2,C0), (A0,C0,B3), (B2,A0,C0), (B2, B3, A0)
L-Shape Type2	(B2,B3,C0), (B2,C0,B3), (B3,C0,B2), (B3,B2,C0), (C0,B2,B3), (C0,B3,B2), (B2,B3,B2), (C0,B2,C0), (B3,C0,B3), (C0,B2,A0), (A0,B3,C0), (B2,A0,B3), (B3,B2,A0), (A0,C0,A0), (C0,A0,C0), (B3,A0,B3)

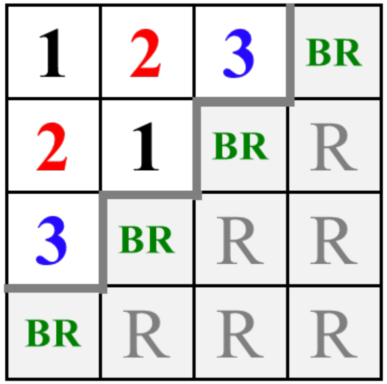
Options
- ▹ *47-group library.*
- ▹ *Transport corrected P0 XS for anisotropic scattering treatment.*
- ▹ *Default ray tracing*
  - *- two polar angles for 90°*
  - *- eight azimuthal angles for 90°*
  - *- ray-spacing of 0.02 cm*



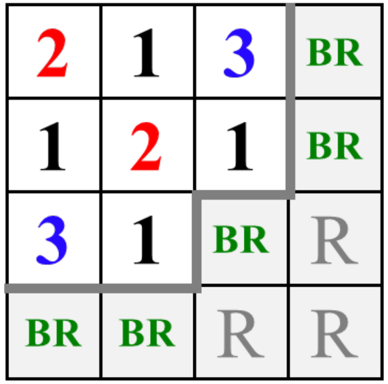
(a) Single Assembly



(b) Checkerboard color-set



(c) L-shape color-set type 1



(d) L-shape color-set type 2

❖ Generation of APEC functions for BR region

➢ APEC XS and DF Functions for BRs

- APEC XS Functions

$$\Sigma_{x,g}^{BR} = \Sigma_{s,g}^{\text{Standard}} + \Delta\Sigma_{x,g}^{BR}, \quad (6)$$

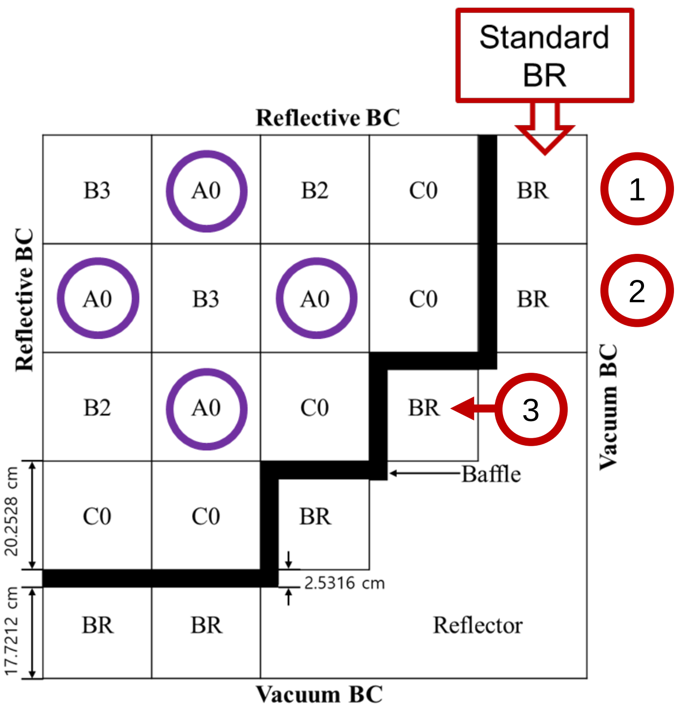
$$\Delta\Sigma_{x,F}^{BR} = a_{x,F}\Delta CFR_F^N + b_{x,F}\Delta CFR_T^N, \quad (6.1)$$

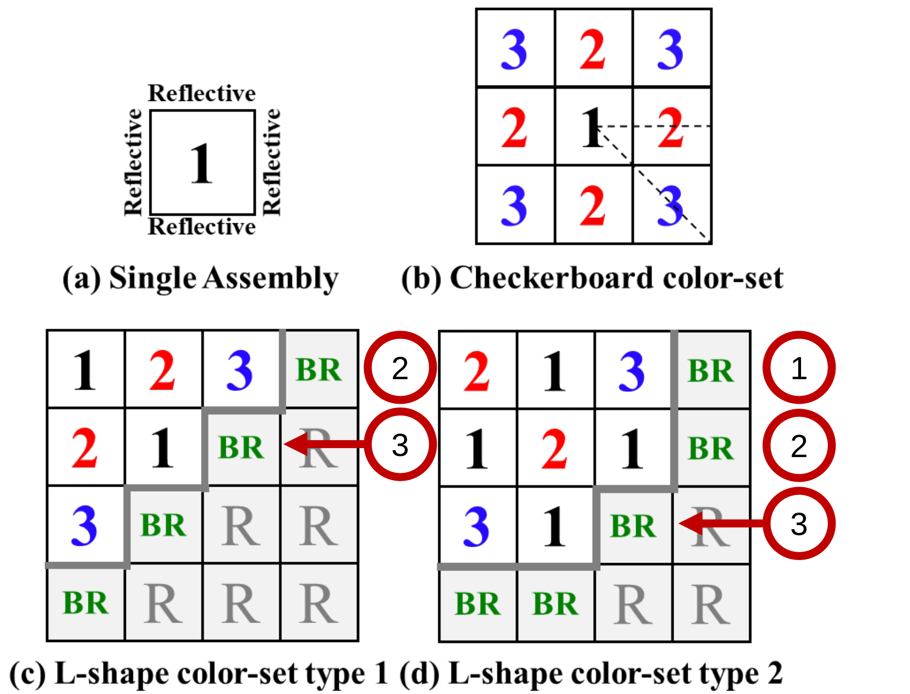
$$\Delta\Sigma_{x,T}^{BR} = a_{x,T}\Delta CFR_T^N + b_{x,T}\left(\Delta CFR_T^N\right)^2. \quad (6.2)$$

- APEC DF Functions

$$DF_{g,s}^{BR} = DF_{g,s}^{\text{Standard}} + \Delta DF_{g,s}^{BR}, \quad (7)$$

$$\Delta DF_{g,s}^{BR} = a_{g,1}\Delta FR_g^S + a_{g,2}\Delta CFR_g^S + a_{g,3}\Delta CFR_g^N. \quad (7.1)$$





❖ Results of partially MOX-loaded SMR problem

➢ Effective multiplication factors, reactivity errors, relative RMS and maximum error in assembly power

XS	DF	k_{eff}	Δρ(pcm)	RRMS[a] (%)	Max.[b] (%)
DeCART2D		1.053803			
HGC[c]	SHGC[d]	1.057638	344.06	0.980	1.859
APEC[e]	SHGC[d]	1.053974	-9.18	0.337	0.728
APEC[e]	APEC[e]	1.053645	-14.26	0.361	0.718

a: Relative root mean square error (%),

$$\text{RRMS Error}(\%) = \sqrt{\frac{1}{n}\Sigma_i^n\left(\frac{P_i^{predicted} - P_i^{reference}}{P_i^{reference}}\times 100\right)^2}$$

b: Maximum absolute relative error in assembly power (%),

$$\text{Relative Error}(\%) = \frac{P^{predicted} - P^{reference}}{P^{reference}}\times 100$$

c: HGCs generated by lattice (FWC | ADF),
d: Standard HGCs of the SMR benchmark problem,
e: APEC correction for HGCs (APEC XS | APEC DF).

- The APEC leakage-corrected HGCs should be theoretically identical to standard HGCs (SHGCs).
- The APEC leakage correction for the BR region may occur a minor discrepancy of HGCs due to the nonlinear correction during the nodal analysis.
- The results showed that the change of nodal equivalence occurred by APEC leakage correction in BR is minor.

	B3	A0	B2	C0
	1.09	1.324	1.061	0.961
	-0.780	-1.541	0.189	0.187
	-0.110	0.227	-0.009	-0.728
	-0.018	0.295	0.028	-0.718
		B3	A0	C0
		0.991	1.064	0.682
		1.241	0.000	0.997
		0.394	0.235	-0.132
		0.434	0.216	-0.308
FA Type			C0	
DeCART2D			0.737	
FA: HGC | BR: SHGC (%)			1.859	
FA: APEC | BR: SHGC (%)			0.014	
FA: APEC | BR: APEC (%)			-0.136	

Numerical Results (7/11)

❖ Results of partially MOX-loaded SMR variant problems

➢ Effective multiplication factors, reactivity errors, relative RMS and maximum error in assembly power

Variant 1

FA	BR	k_{eff}	Δρ(pcm)	RRMS* (%)	Max.* (%)
DeCART2D		1.138768	*Variant 1*		
HGC[c]	SHGC[d]	1.141329	197.08	0.895	1.072
APEC[e]	SHGC[d]	1.139281	39.53	0.527	0.962
APEC[e]	APEC[e]	1.139196	33.03	0.484	0.833

Variant 2

FA	BR	k_{eff}	Δρ(pcm)	RRMS* (%)	Max.* (%)
DeCART2D		1.035491	*Variant 2*		
HGC[c]	SHGC[d]	1.038042	237.34	0.752	1.520
APEC[e]	SHGC[d]	1.035533	3.95	0.663	1.052
APEC[e]	APEC[e]	1.053645	3.82	0.673	1.054

Variant 1 assembly power map:

	C0	A0	C0	A0
	2.506	1.669	1.212	0.499
	0.156	-1.072	0.899	0.521
	0.024	0.276	-0.446	0.962
	0.219	0.431	-0.413	-0.100
		C0	B3	C0
		1.411	0.654	0.360
		0.957	-0.933	1.056
		0.142	-0.291	-0.528
		0.269	-0.260	-0.833
FA Type			B3	
DeCART2D			0.294	
FA: HGC | BR: SHGC (%)			-1.020	
FA: APEC | BR: SHGC (%)			-0.680	
FA: APEC | BR: APEC (%)			-0.816	

Variant 2 assembly power map:

	A0	B3	A0	C0
	1.806	1.285	1.307	0.962
	-0.880	0.117	-0.191	1.372
	1.052	0.342	0.191	-0.977
	1.047	0.335	0.191	-0.904
		B2	B2	B2
		1.147	0.822	0.444
		-0.445	0.231	-0.225
		0.096	-0.292	-0.833
		0.087	-0.316	-0.878
FA Type			B3	
DeCART2D			0.408	
FA: HGC | BR: SHGC (%)			-1.520	
FA: APEC | BR: SHGC (%)			-0.907	
FA: APEC | BR: APEC (%)			-1.054	

Numerical Results (8/11)

❖ Results of partially MOX-loaded SMR variant problems

- ➢ Effective multiplication factors, reactivity errors, relative RMS and maximum error in assembly power

Variant 3

FA	BR	k_{eff}	Δρ(pcm)	RRMS* (%)	Max.* (%)
DeCART2D		1.049439	*Variant 3*		
HGC[c]	SHGC[d]	1.052795	303.78	1.636	3.317
APEC[e]	SHGC[d]	1.049892	41.12	1.063	2.438
APEC[e]	APEC[e]	1.049334	-9.58	0.509	0.844

Variant 4

FA	BR	k_{eff}	Δρ(pcm)	RRMS* (%)	Max.* (%)
DeCART2D		1.062324	*Variant 4*		
HGC[c]	SHGC[d]	1.065042	240.21	0.818	1.325
APEC[e]	SHGC[d]	1.062192	-11.69	0.813	2.341
APEC[e]	APEC[e]	1.062068	-22.68	0.521	0.918

B3	B2	B3	A0
1.004	1.103	0.966	0.685
-3.317	-1.342	-0.994	0.847
-1.215	-0.698	-0.673	1.591
-0.458	-0.100	-0.383	0.453
	A0	C0	C0
	1.437	1.382	0.723
	-1.308	1.889	1.660
	0.404	-0.130	-0.263
	0.828	-0.022	-0.719
		A0	
		0.841	
		1.558	
		2.438	
		0.844	

FA Type
DeCART2D
FA: HGC | BR: SHGC (%)
FA: APEC | BR: SHGC (%)
FA: APEC | BR: APEC (%)

A0	B3	C0	B3
1.566	1.240	1.525	0.586
-0.760	0.210	0.098	-1.177
0.613	0.056	-1.036	-0.017
0.830	0.234	-0.918	0.085
	A0	B2	C0
	1.313	0.869	0.564
	-0.990	1.013	0.479
	0.381	0.357	-0.301
	0.465	0.299	-0.479
		A0	
		0.551	
		1.325	
		2.341	
		0.417	

FA Type
DeCART2D
FA: HGC | BR: SHGC (%)
FA: APEC | BR: SHGC (%)
FA: APEC | BR: APEC (%)

Numerical Results (9/11)

❖ Results of partially MOX-loaded SMR variant problems

- ➢ Effective multiplication factors, reactivity errors, relative RMS and maximum error in assembly power

Variant 5

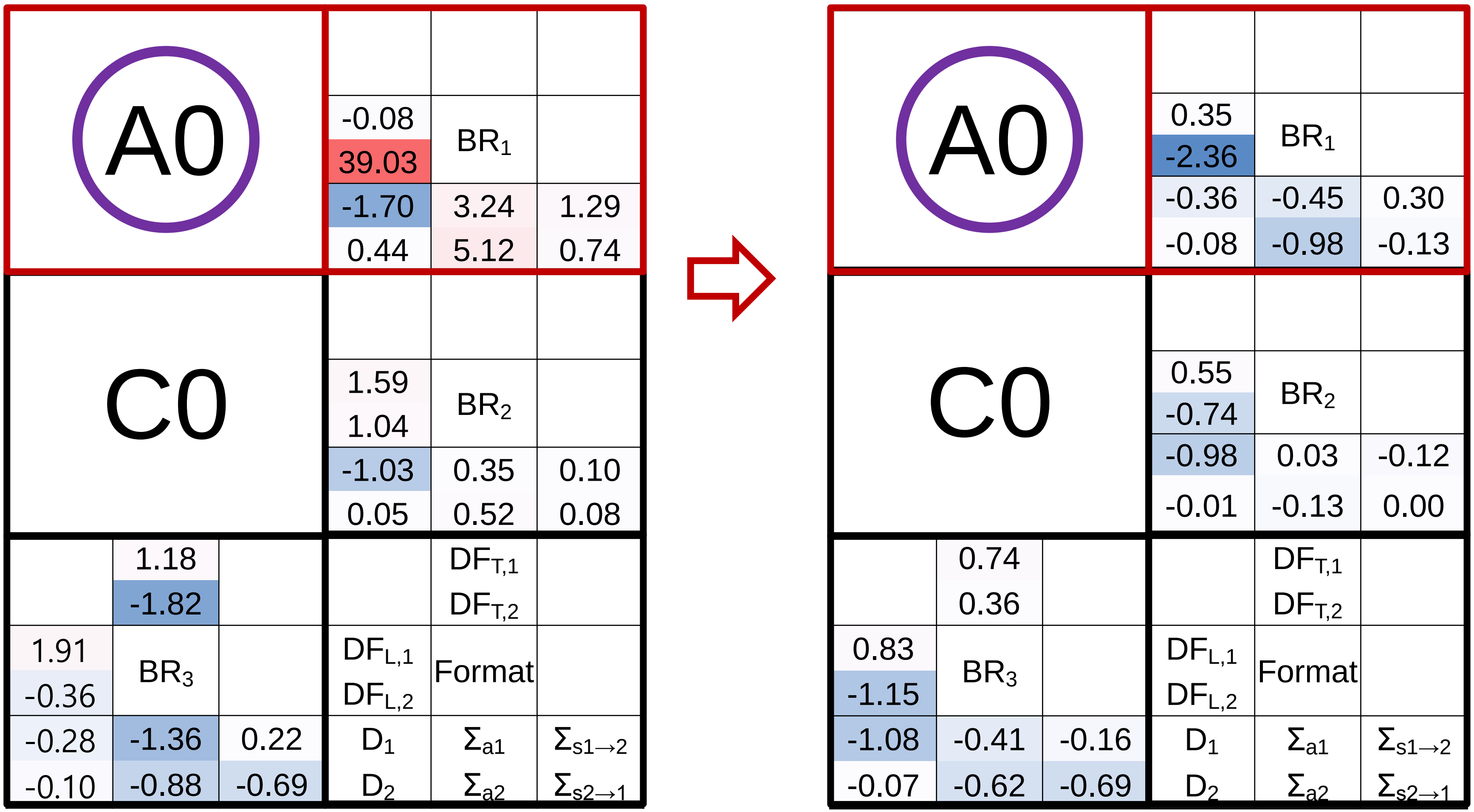
FA	BR	k_{eff}	$\Delta\rho$(pcm)	RRMS* (%)	Max.* (%)
DeCART2D		1.111130	*Variant 5*		
HGC[c]	SHGC[d]	1.113556	196.09	0.942	1.506
APEC[e]	SHGC[d]	1.111501	30.01	0.560	0.944
APEC[e]	APEC[e]	1.111404	22.17	0.651	0.890

<table>
<tr><td></td><td>C0</td><td>A0</td><td>B2</td><td>C0</td></tr>
<tr><td></td><td>2.783</td><td>1.654</td><td>0.881</td><td>0.589</td></tr>
<tr><td></td><td>0.007</td><td>-1.506</td><td>0.488</td><td>1.104</td></tr>
<tr><td></td><td>0.158</td><td>0.351</td><td>-0.250</td><td>-0.611</td></tr>
<tr><td></td><td>0.438</td><td>0.581</td><td>-0.182</td><td>-0.815</td></tr>
<tr><td></td><td></td><td>B3</td><td>C0</td><td>A0</td></tr>
<tr><td></td><td></td><td>1.031</td><td>0.911</td><td>0.371</td></tr>
<tr><td></td><td></td><td>0.854</td><td>0.922</td><td>0.701</td></tr>
<tr><td></td><td></td><td>0.252</td><td>-0.724</td><td>0.944</td></tr>
<tr><td></td><td></td><td>0.408</td><td>-0.779</td><td>-0.890</td></tr>
<tr><td colspan="2">FA Type</td><td></td><td>B3</td><td></td></tr>
<tr><td colspan="2">DeCART2D</td><td></td><td>0.375</td><td></td></tr>
<tr><td colspan="2">FA: HGC | BR: SHGC (%)</td><td></td><td>-0.828</td><td></td></tr>
<tr><td colspan="2">FA: APEC | BR: SHGC (%)</td><td></td><td>-0.214</td><td></td></tr>
<tr><td colspan="2">FA: APEC | BR: APEC (%)</td><td></td><td>-0.534</td><td></td></tr>
</table>

- The APEC leakage correction in BR region tends to improve the nodal equivalence in arbitrarily introduced variant core analyses.
- The improvements of the nodal equivalence by the APEC leakage correction in BR are substantial when the partially MOX-loaded FAs are located at the peripheral region contacted to BR.

❖ Tendency of APEC leakage-corrected HGCs in BR region

- ➢ Partially MOX-loaded SMR Variant 1 problem
  - Relative error (%) of standard HGCs in the BR region.
    → Substantial improvements in the accuracy of HGCs by APEC leakage correction in the BR region.



❖ Results of Relative RMS Error (%) of the HGCs

- HGCs from partially MOX-loaded SMR and variant cores.

	D_1	Σ_{a1}	$\nu\Sigma_{f1}$	$\nu\Sigma_{s1\to2}$	DF_1	D_2	Σ_{a2}	$\nu\Sigma_{f2}$	$\nu\Sigma_{s2\to1}$	DF_2
A0 Type FA										
Case 1[a]	0.273	0.552	0.370	0.690	0.973	0.558	1.418	1.620	5.233	**6.235**
Case 2[b]	0.092	0.196	0.121	0.231	0.558	0.035	0.146	0.166	0.283	**2.568**
Case 3[c]	0.090	0.193	0.121	0.228	0.553	0.024	0.121	0.138	0.148	**1.837**
B2 Type FA										
Case 1	0.129	0.313	0.191	0.690	0.814	0.165	0.385	0.642	2.541	1.848
Case 2	0.048	0.198	0.070	0.087	0.795	0.062	0.136	0.243	0.973	1.422
Case 3	0.030	0.063	0.074	0.107	0.731	0.008	0.072	0.089	0.160	1.193
B3 Type FA										
Case 1	0.380	0.962	0.330	1.253	0.854	0.148	0.329	0.815	2.457	2.105
Case 2	0.067	0.176	0.152	0.258	0.761	0.023	0.069	0.055	0.112	1.275
Case 3	0.067	0.175	0.152	0.258	0.761	0.023	0.069	0.054	0.110	1.275
C0 Type FA										
Case 1	0.532	1.285	0.828	2.882	1.249	0.191	0.831	0.983	2.854	2.946
Case 2	0.115	0.184	0.120	0.279	0.958	0.042	0.066	0.075	0.203	2.356
Case 3	0.116	0.184	0.120	0.282	0.958	0.042	0.065	0.074	0.205	2.337
Baffle-Reflector										
Case 1	0.751	1.636	-	0.743	0.876	0.218	2.377	-	0.563	**18.163**
Case 2	0.751	1.636	-	0.743	0.876	0.218	2.377	-	0.563	**18.163**
Case 3	0.663	0.667	-	0.629	0.496	0.054	0.488	-	0.421	**1.666**

a: FA: HGC | BR: SHGC, b: FA: APEC | BR: SHGC, c: FA: APEC | BR: APEC

Summary

❖ **Summary**

➢ APEC leakage correction for BR region

- DeCART2D code was used to whole-core, lattice, and color-set transport calculations.
- In-house nodal code was used to perform the APEC leakage correction in FAs and BR region.
- APEC functions for BR region has been introduced in terms of ΔCFR and ΔFR as below:

$$\Sigma_{x,g}^{BR} = \Sigma_{s,g}^{\text{Standard}} + \Delta\Sigma_{x,g}^{BR},$$
$$\Delta\Sigma_{x,F}^{BR} = a_{x,F}\Delta CFR_F^N + b_{x,F}\Delta CFR_T^N,$$
$$\Delta\Sigma_{x,T}^{BR} = a_{x,T}\Delta CFR_T^N + b_{x,T}\left(\Delta CFR_T^N\right)^2.$$

$$DF_{g,s}^{BR} = DF_{g,s}^{\text{Standard}} + \Delta DF_{g,s}^{BR},$$
$$\Delta DF_{g,s}^{BR} = a_{g,1}\Delta FR_g^S + a_{g,2}\Delta CFR_g^S + a_{g,3}\Delta CFR_g^N.$$

➢ Partially MOX-loaded SMR benchmark problem

- Partially MOX-loaded SMR and variant core problems were introduced for performing APEC leakage correction for FAs and BR region.

Conclusions and Future Works

❖ Conclusions

- ➢ The APEC leakage correction for HGCs of the BR region has been proposed.
- ➢ It was demonstrated that the APEC leakage correction based on the standard HGCs of BR can improve the nodal equivalence in terms of reactivity error (pcm) and relative error (%) in assembly power.
- ➢ It is concluded that the in-situ APEC leakage correction can lead to a very accurate and reliable multiplication factor and power distribution, not only in the case of FAs but also BR region.

❖ Future Works

- ➢ APEC leakage correction of BR region for the macroscopic depletion analysis.

Thank you for your attention!