

Analyses of SA sequences in the SFP of the VVER-1000 type of reactor with MELCOR 1.8.6

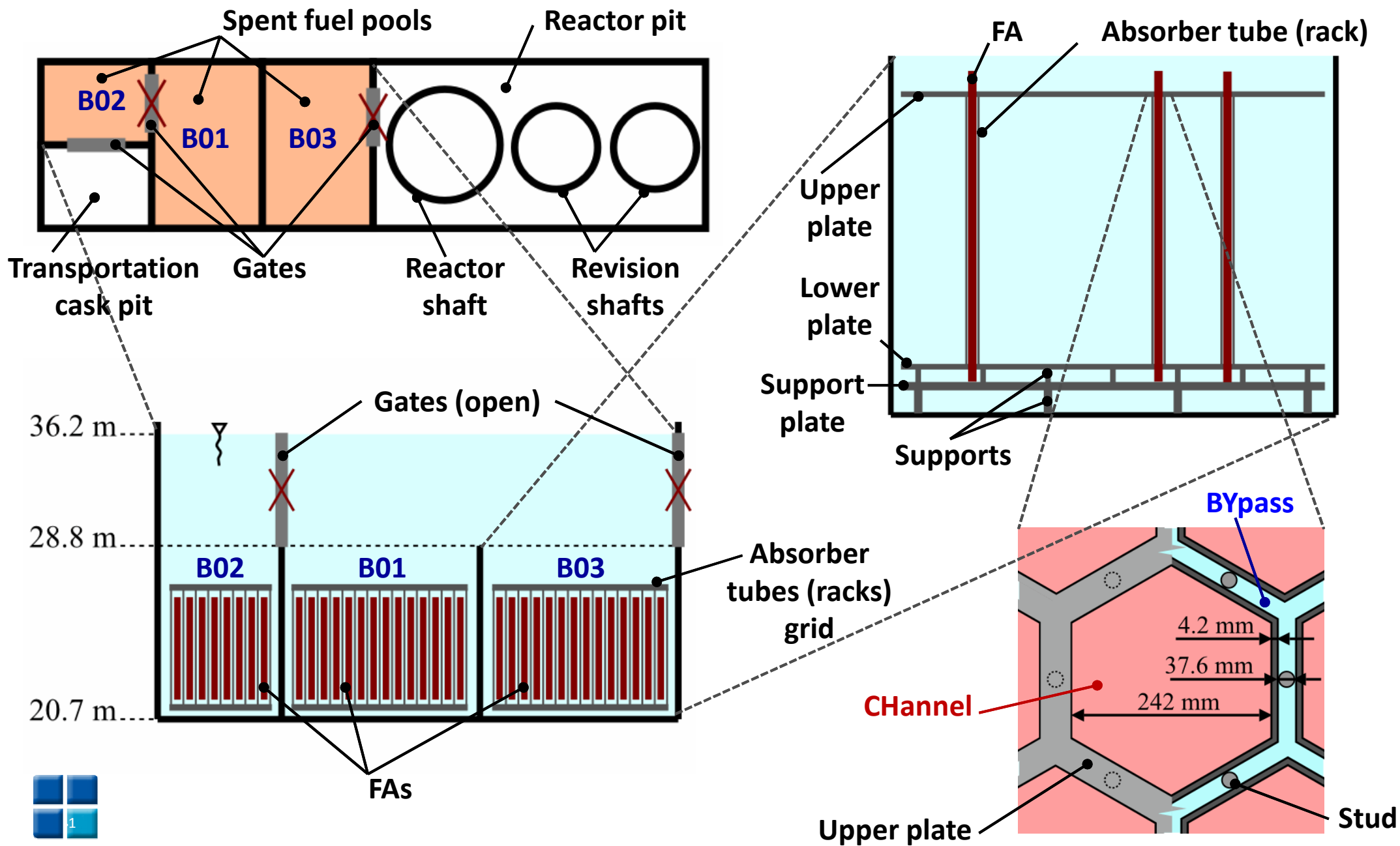
*Focus on modeling approach and encountered
problems*

Miroslav Kotouč

ÚJV Řež, a. s.

The 6th Meeting of the “European MELCOR User Group”
Bratislava, Slovakia, April 15-16, 2014

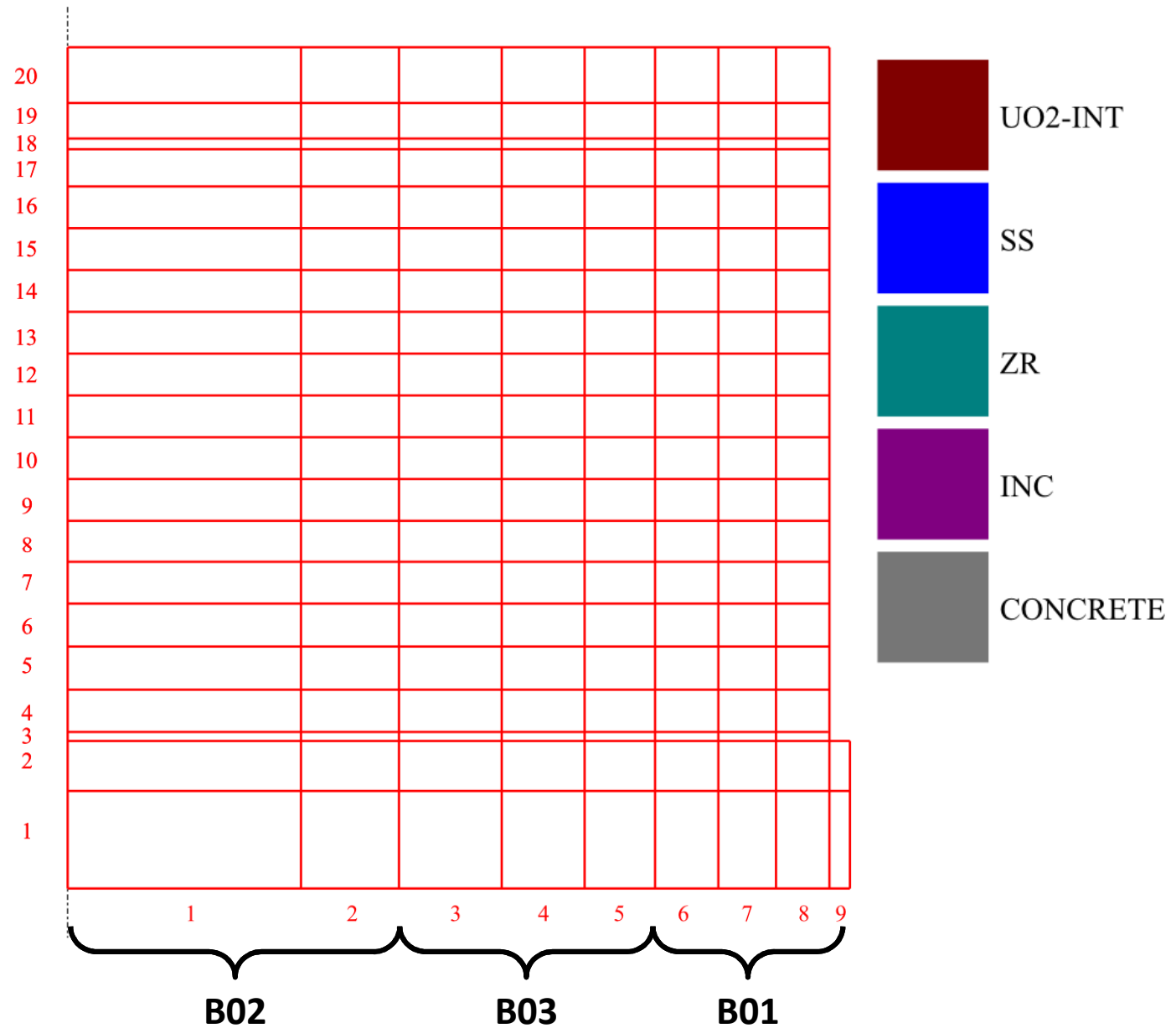
SFP layout



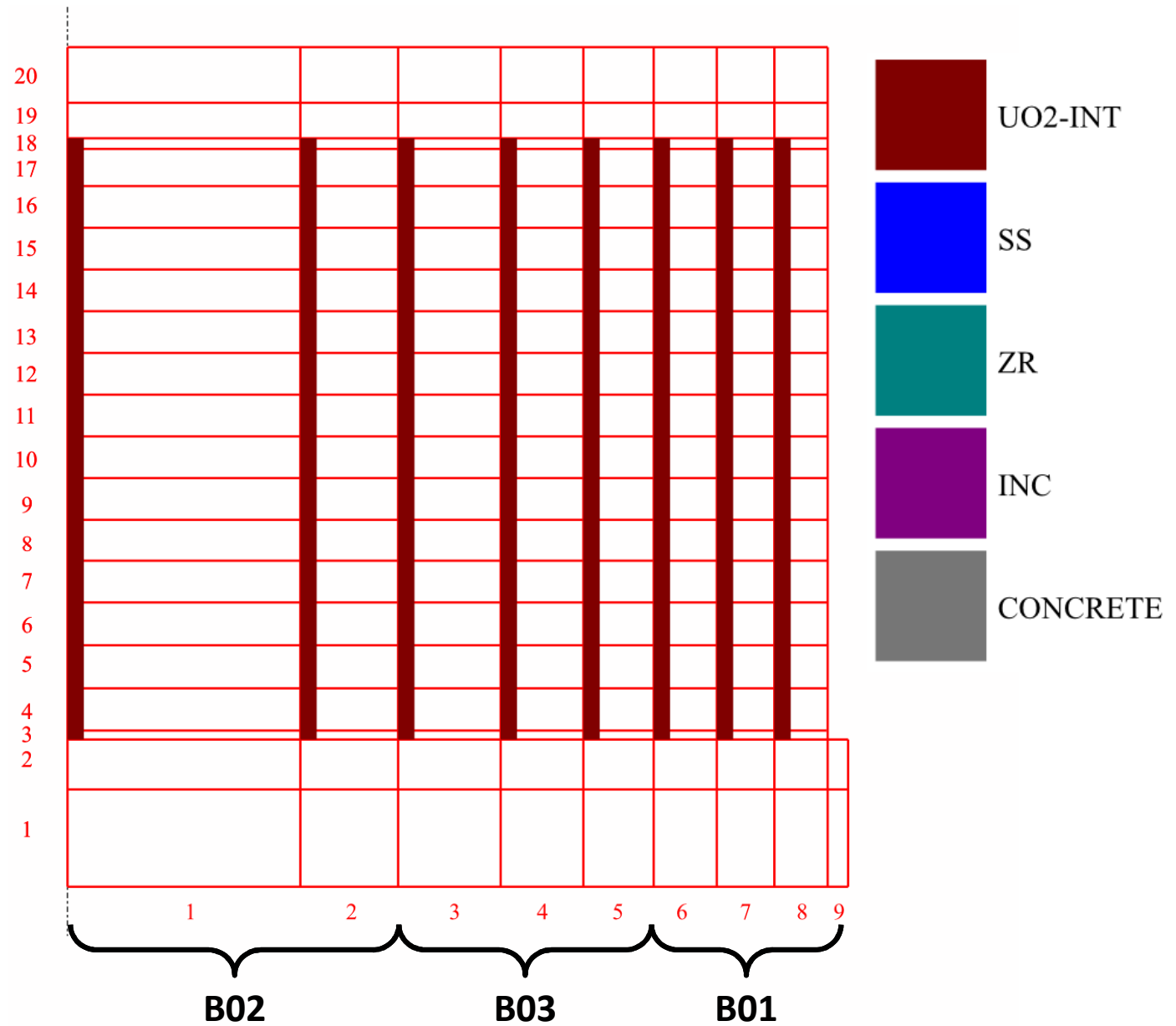
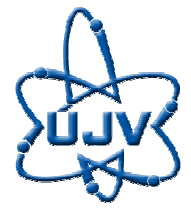
COR nodalization: COR cells



- 20 axial levels
- 9 radial rings (2 + 3 + 3)



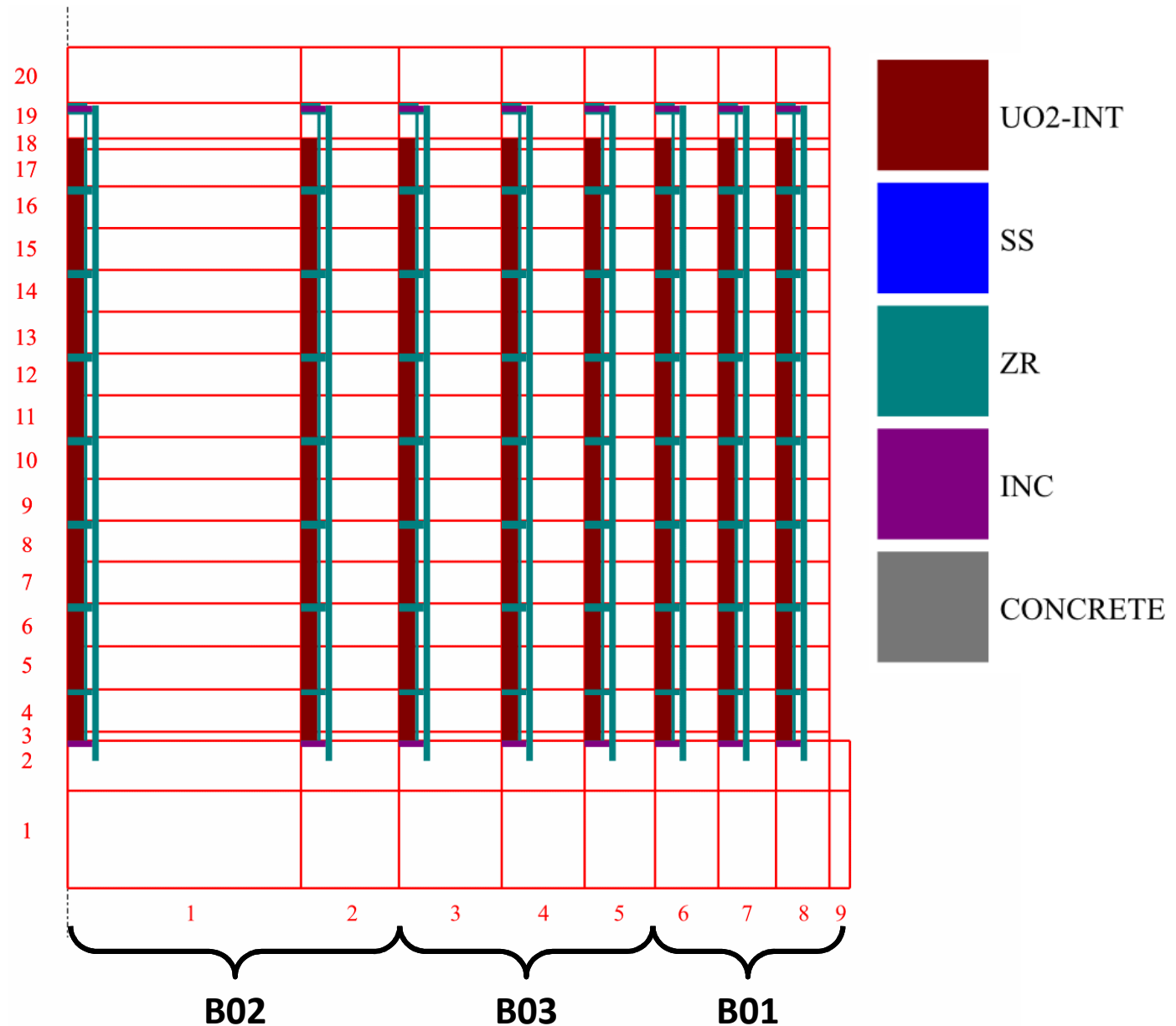
COR nodalization: + FU



COR nodalization: + CL



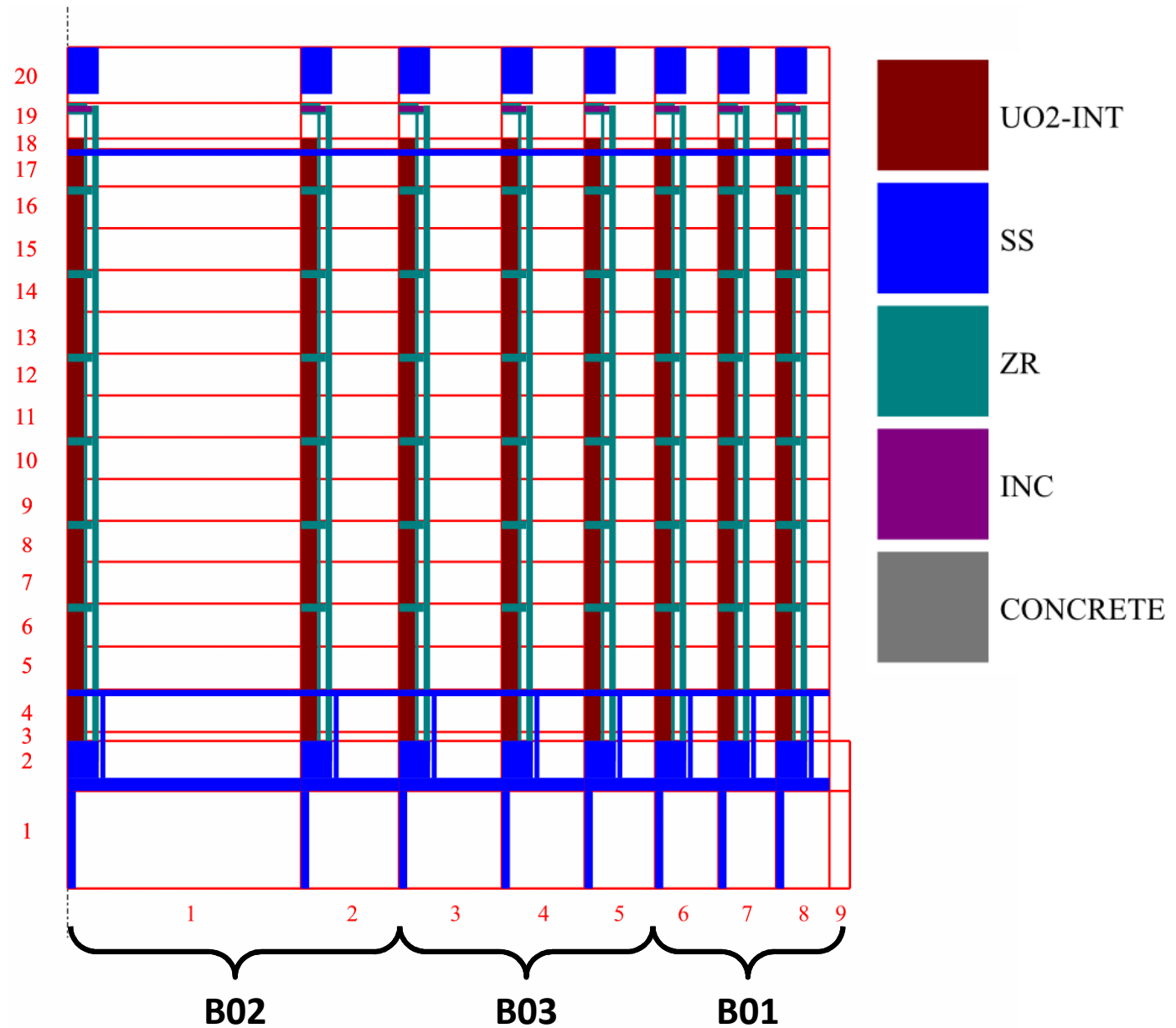
- **CL – cladding, spacer grids**
 - CORijjDX record for ‘supporting’ qualities of the grids
 - 2 Inconel grids



COR nodalization: + SS



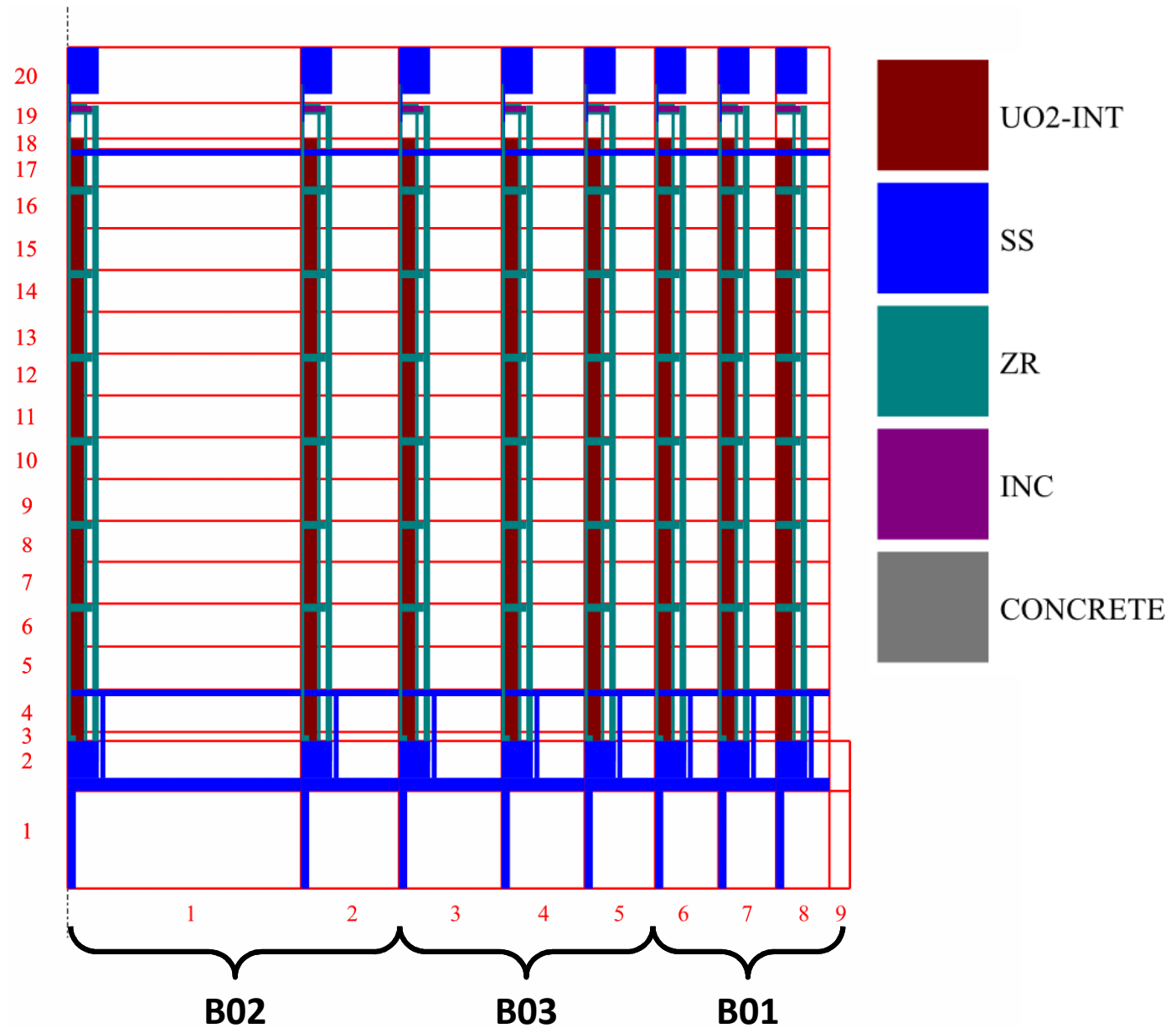
- *SS – support plate, upper & lower plate (BY), supports, FAs nozzles*



COR nodalization: + NS



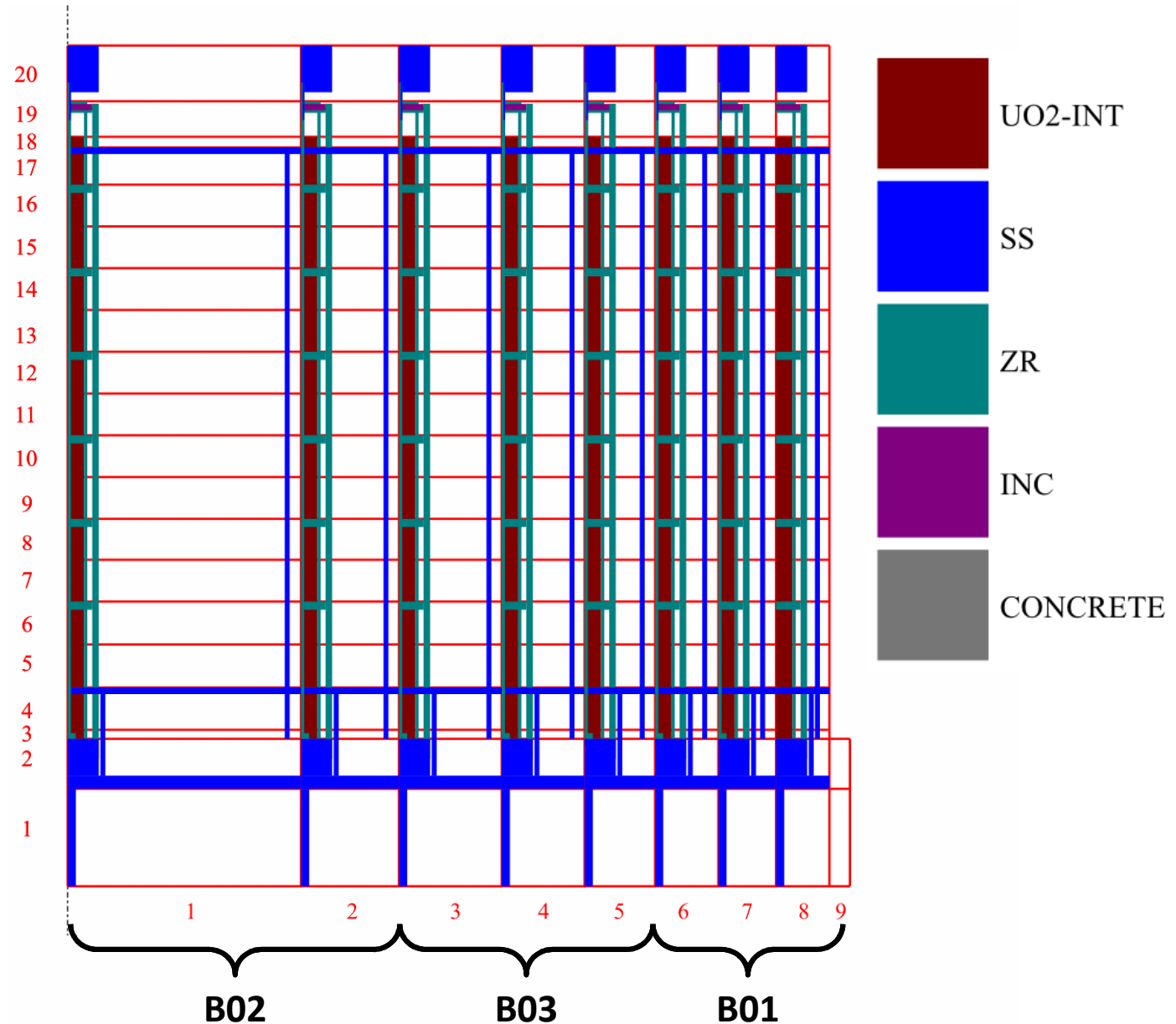
- *NS – guide & central tubes*



COR nodalization: + CN



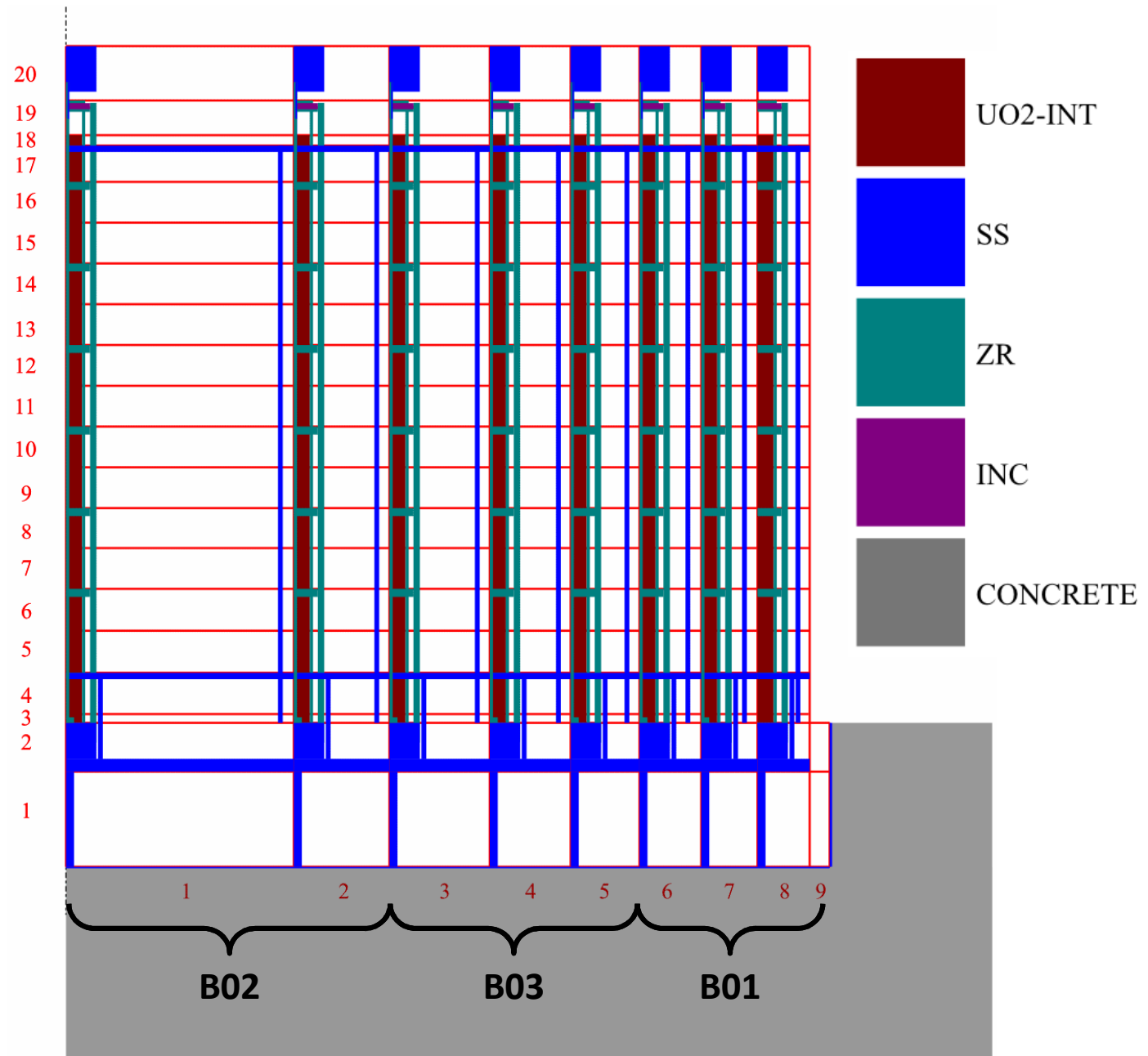
- *'BWR' type of reactor*
- *CN – absorber tubes (racks)*
- *BY where CN exists*



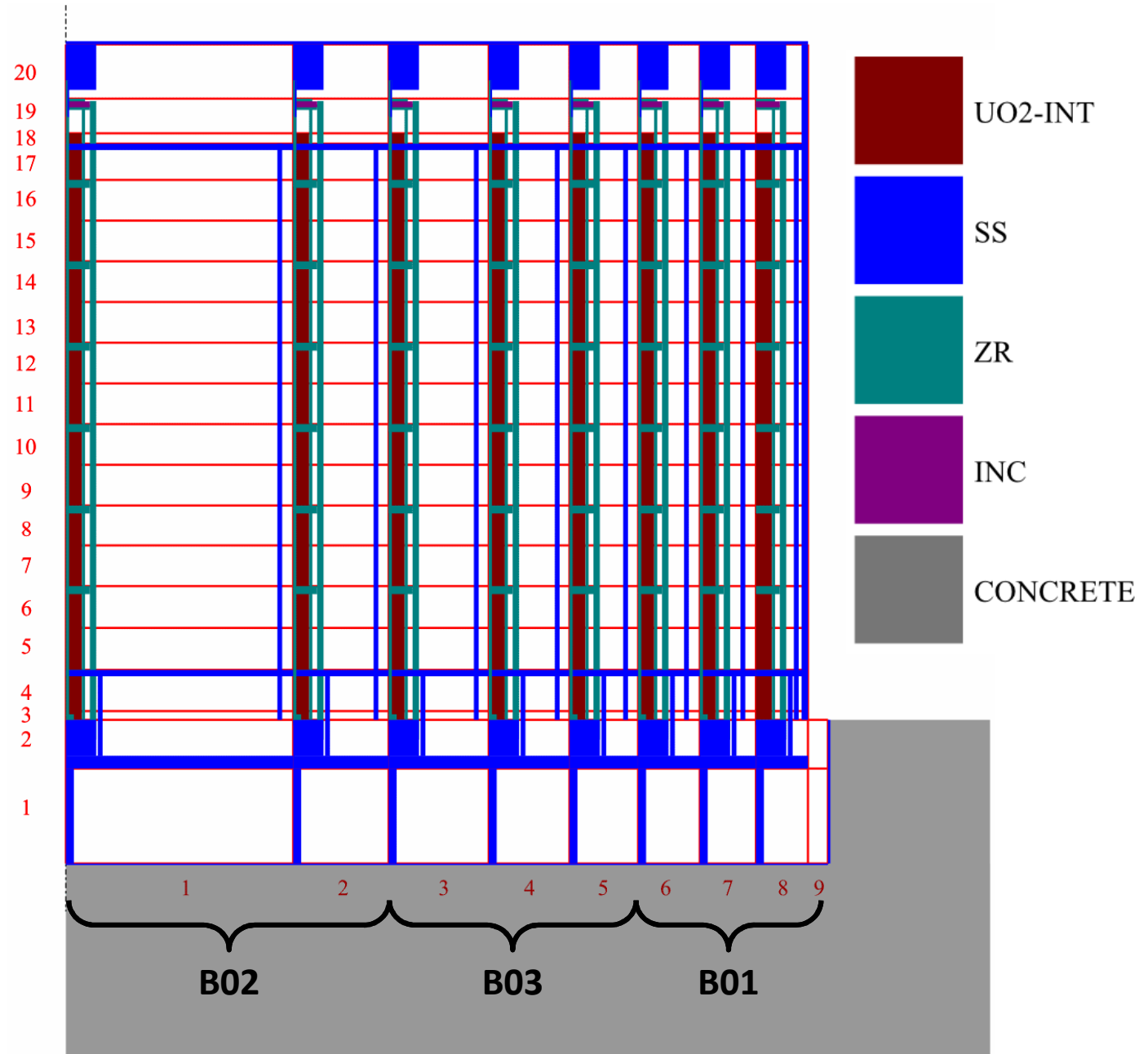
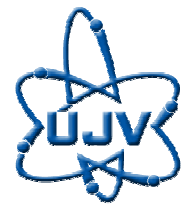
COR nodalization: + LH



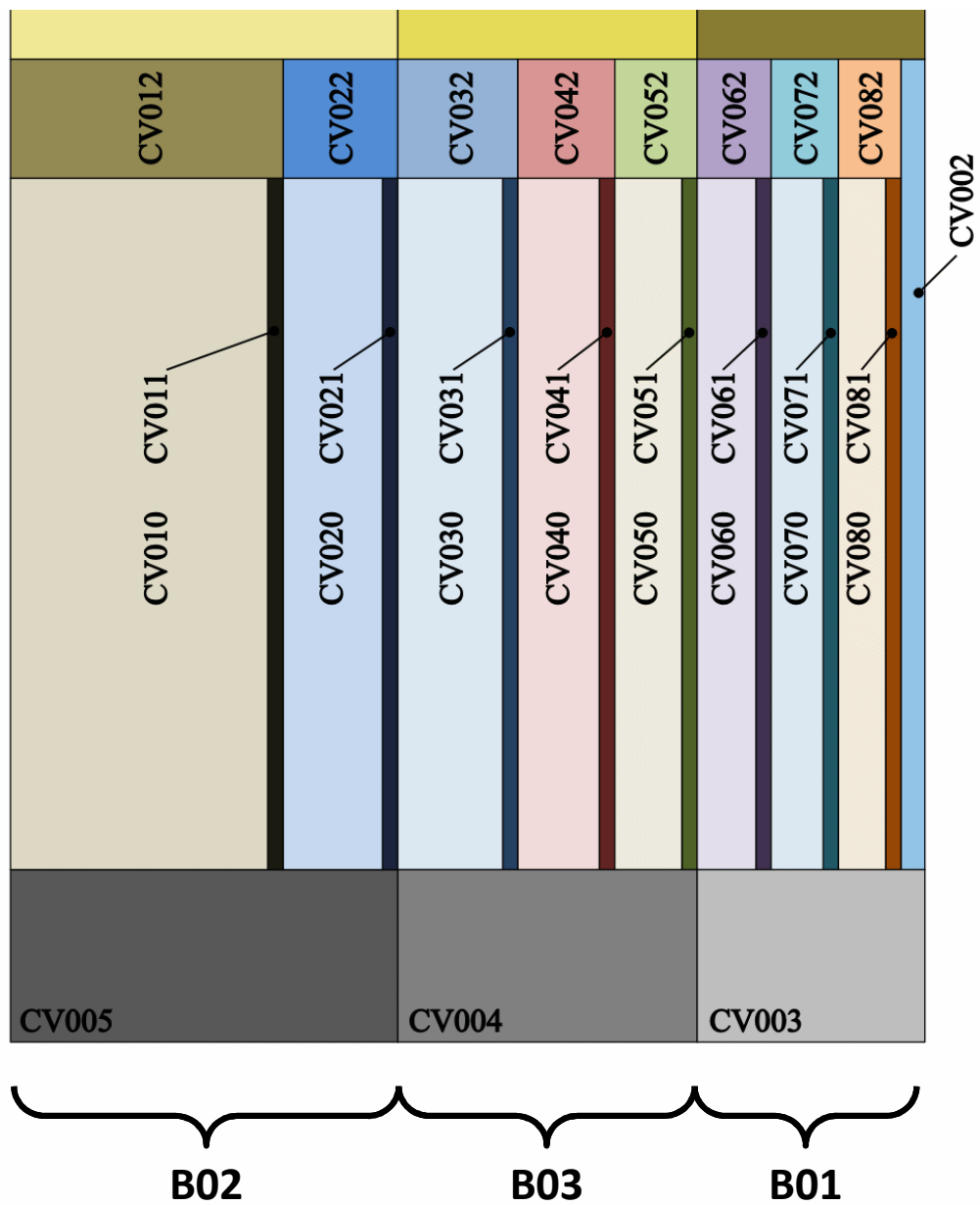
- *8 mm stainless steel*
- *8 mm carbon steel*
- *1.2 m concrete (insulation)*



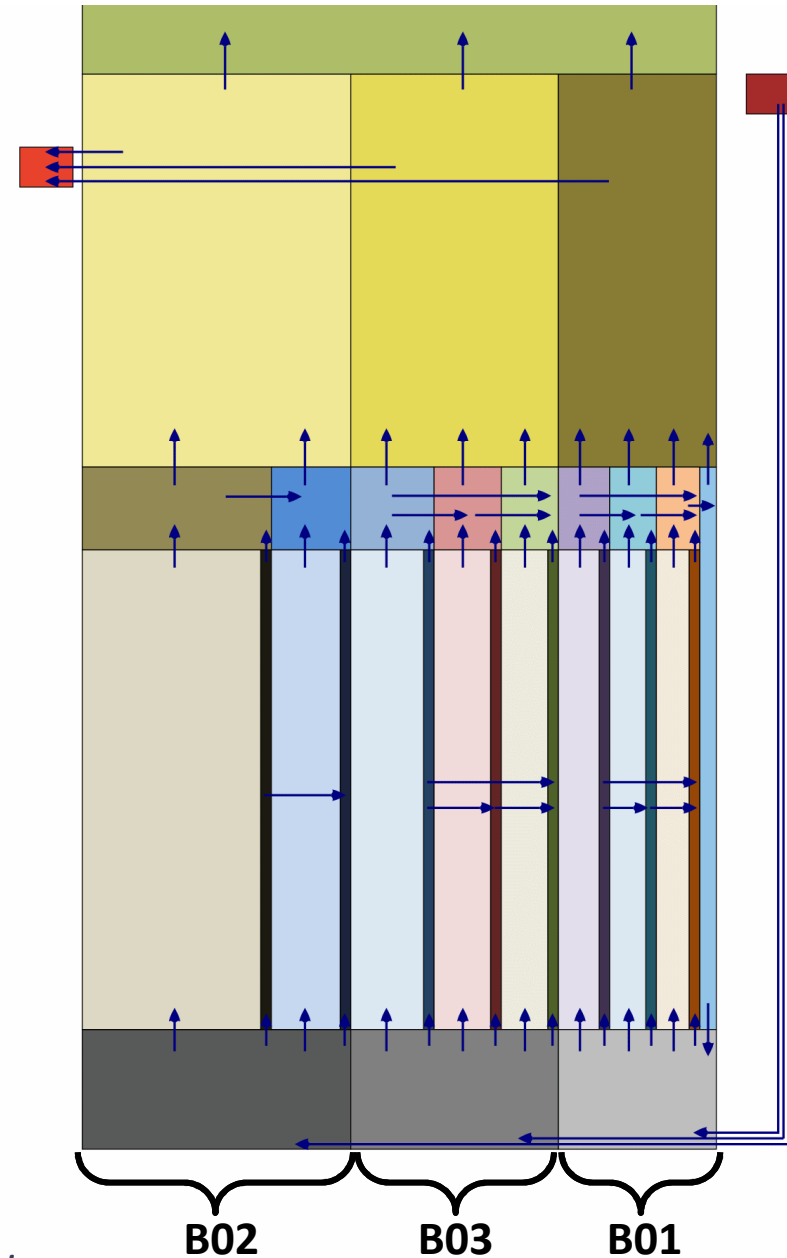
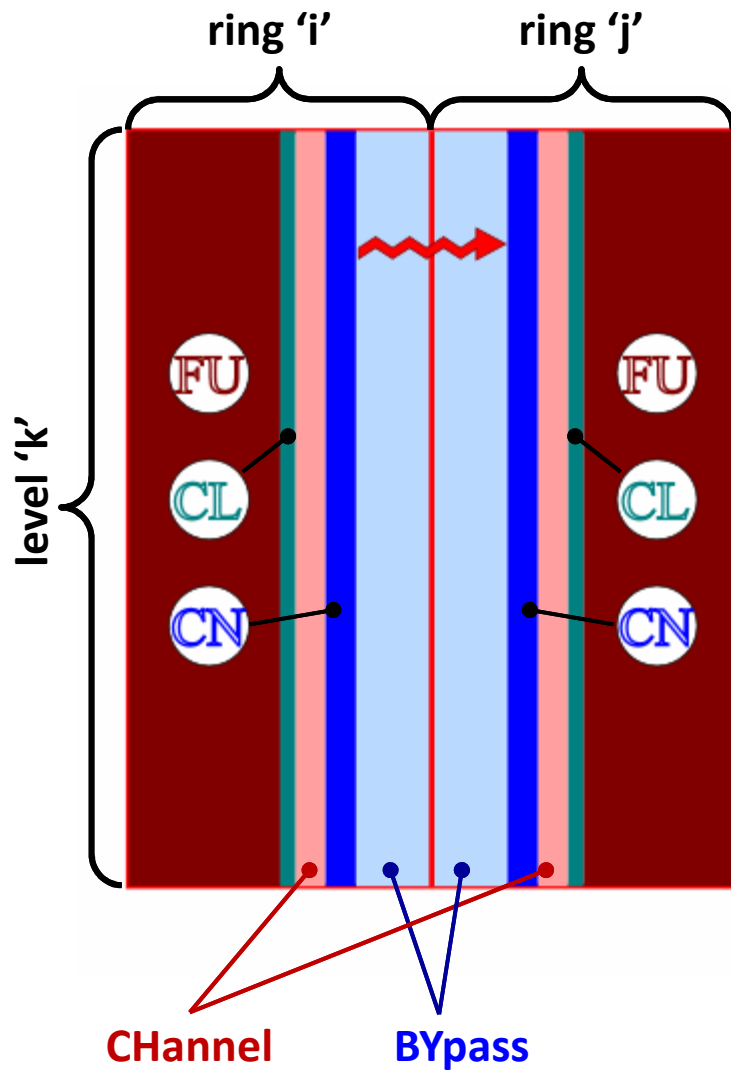
COR nodalization: + BHS



CVH nodalization: CVs

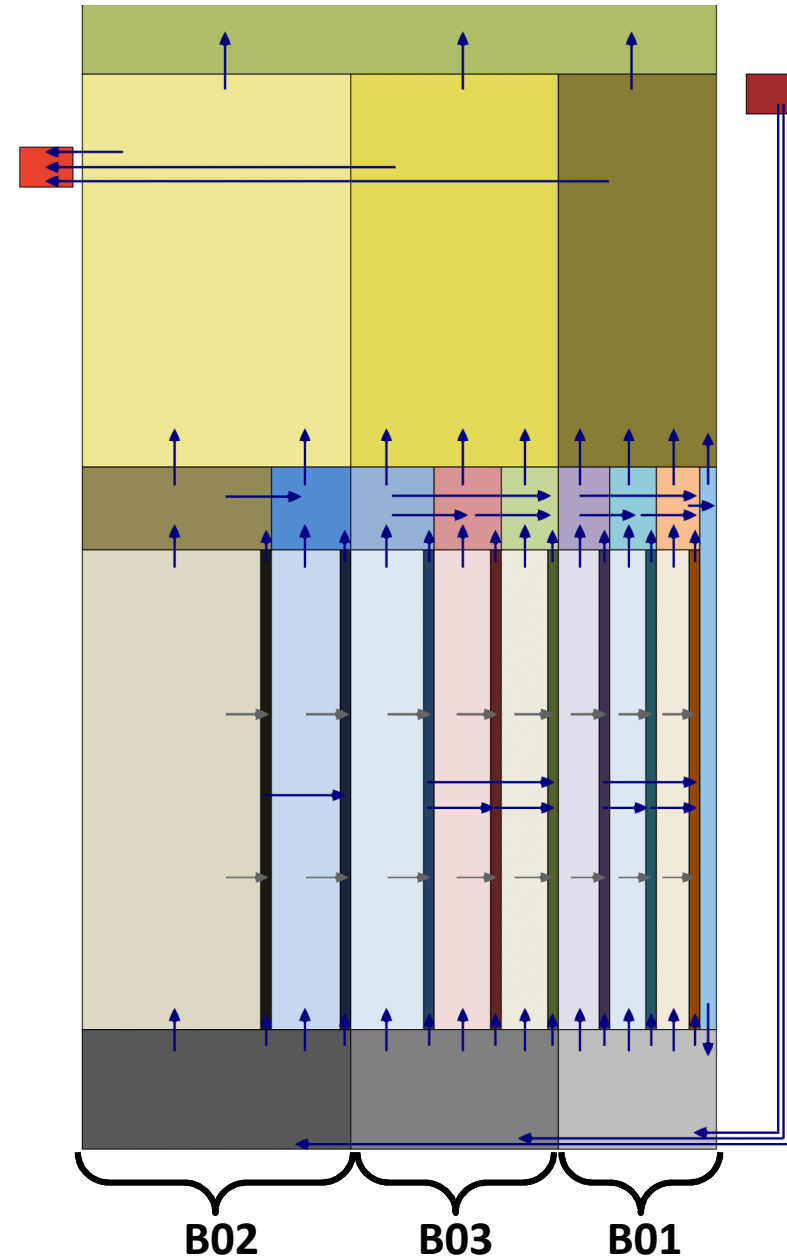
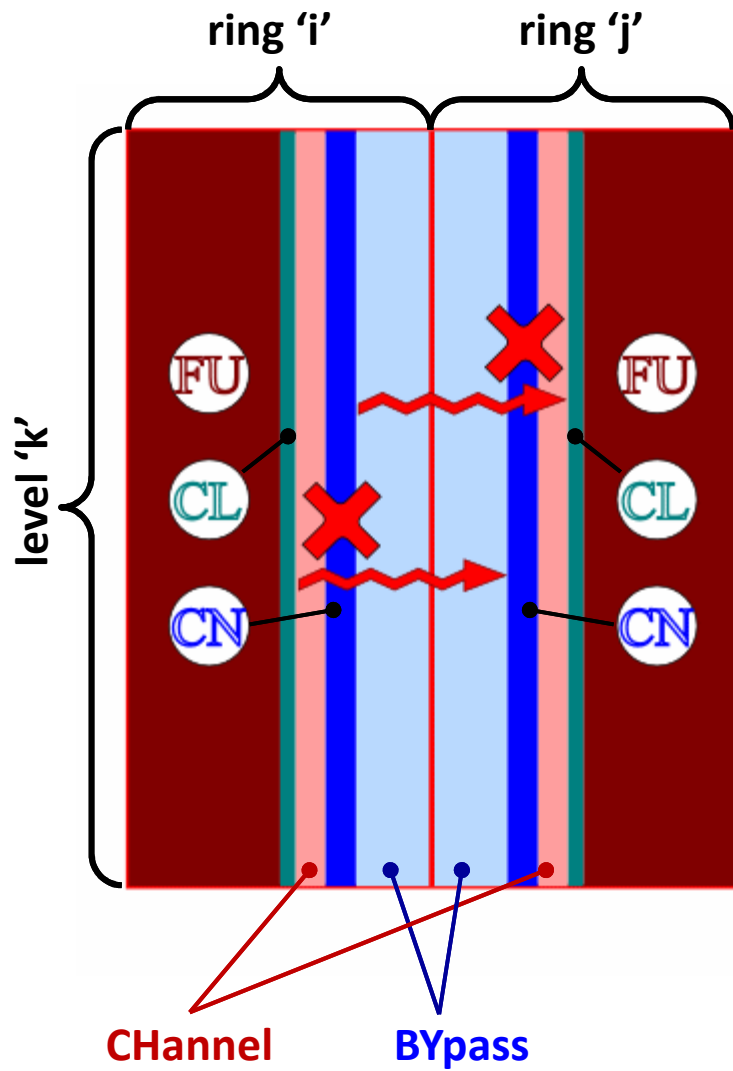
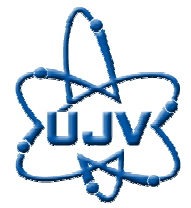


CVH nodalization: CVs + FLs

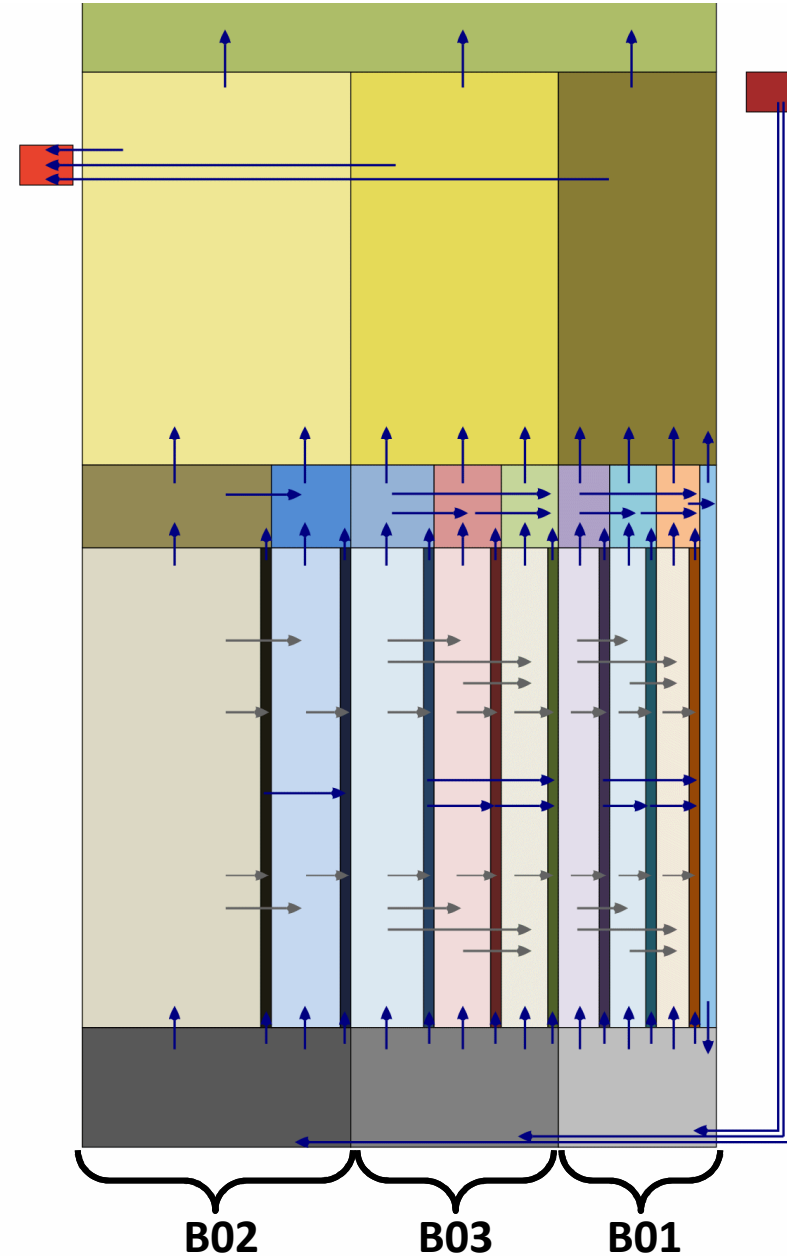
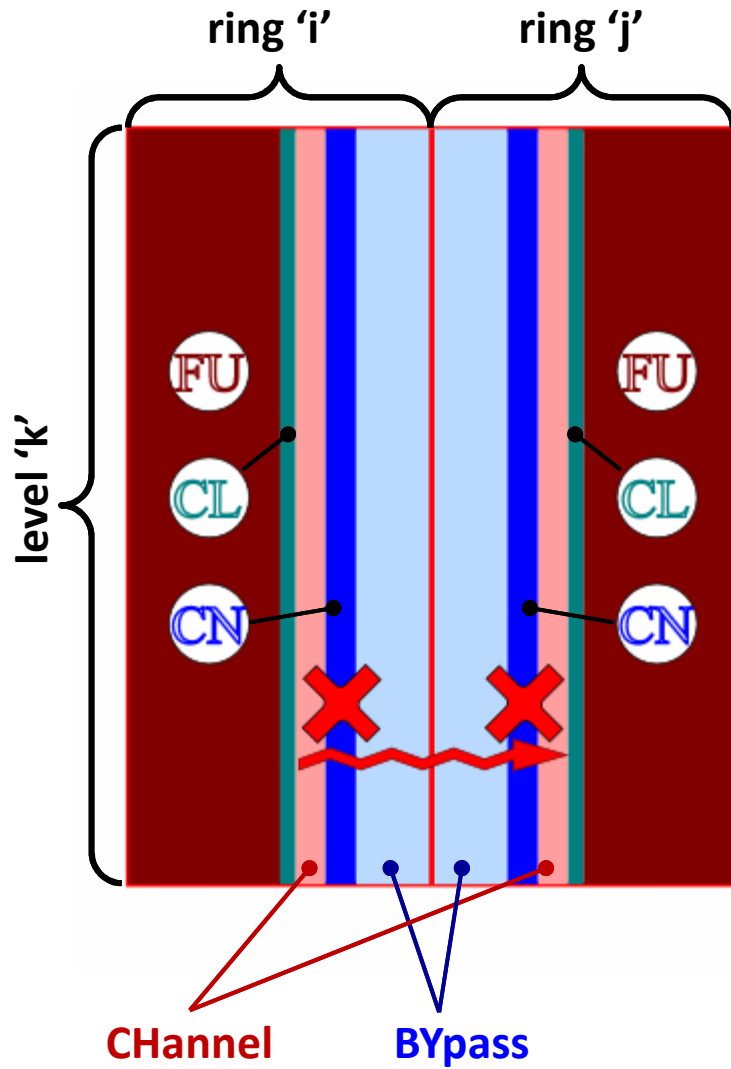
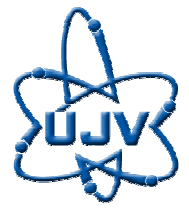


- $COR00003(FCEL R) = 0.0 \Rightarrow CORHTRxx$
- *heat exchange surface area*
- *user defined from rings' common boundaries*

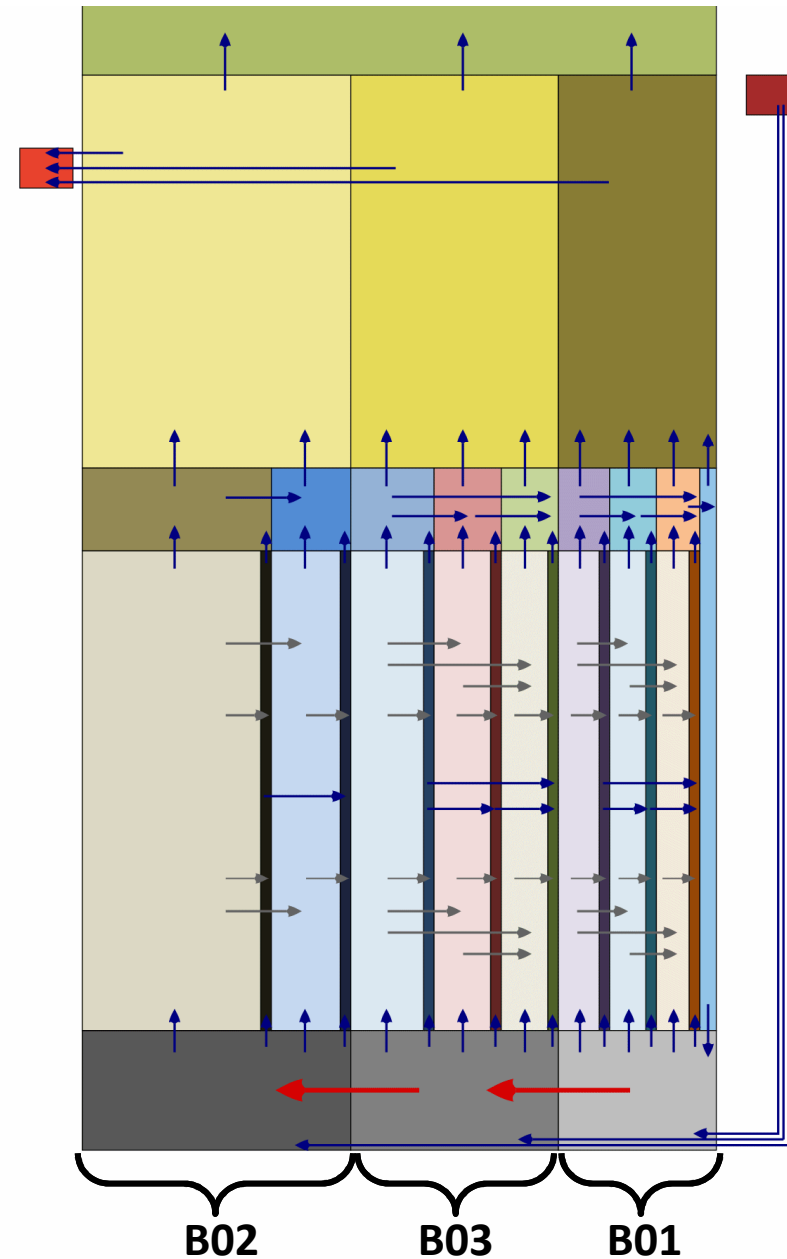
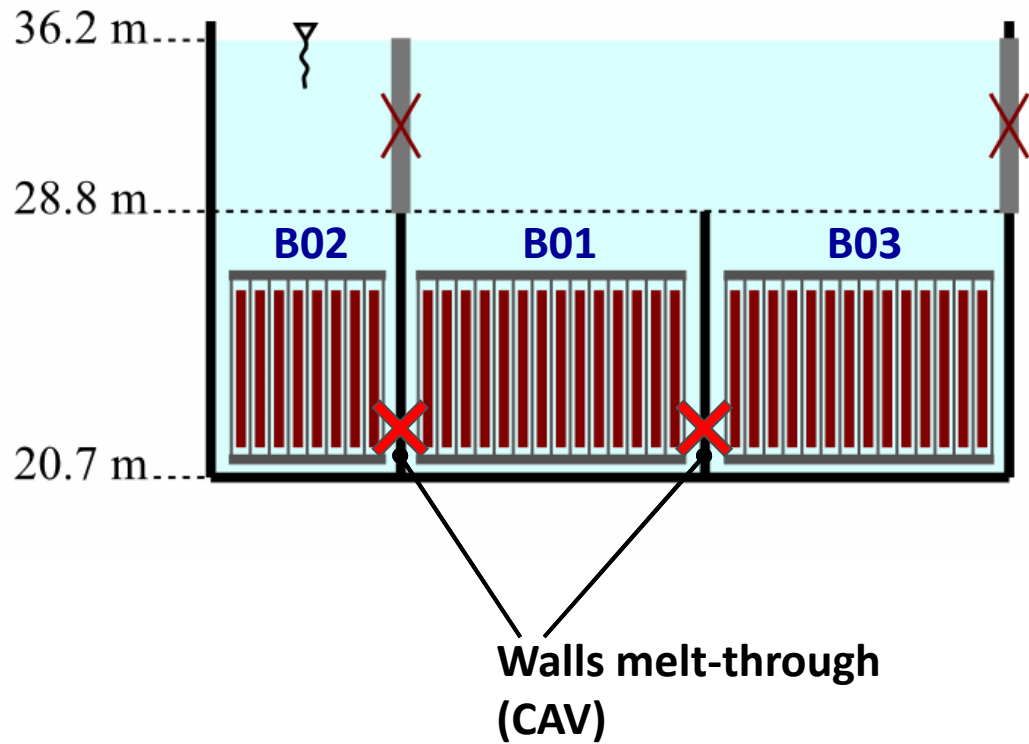
CVH nodalization: CVs + FLs (CN collapsed)



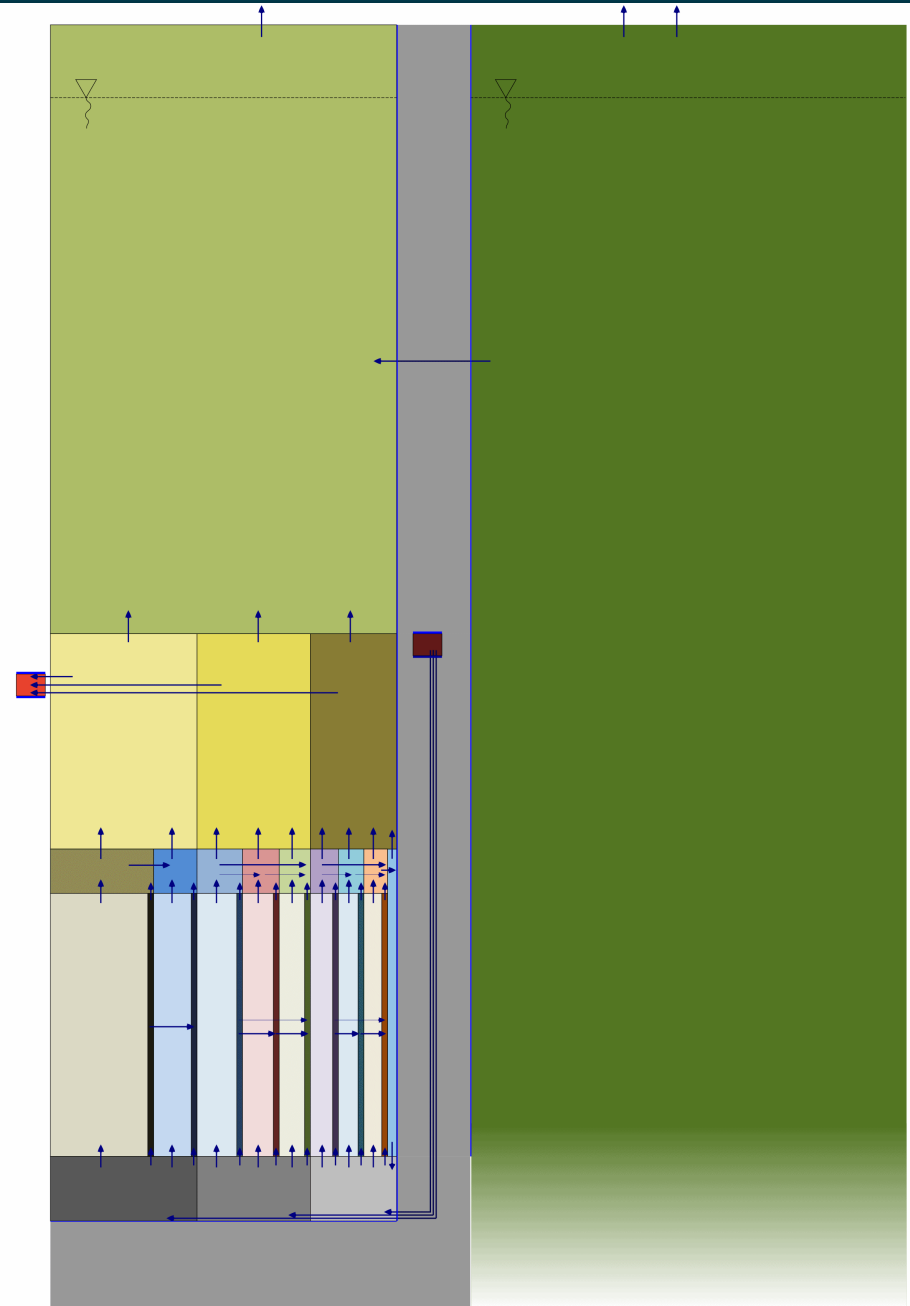
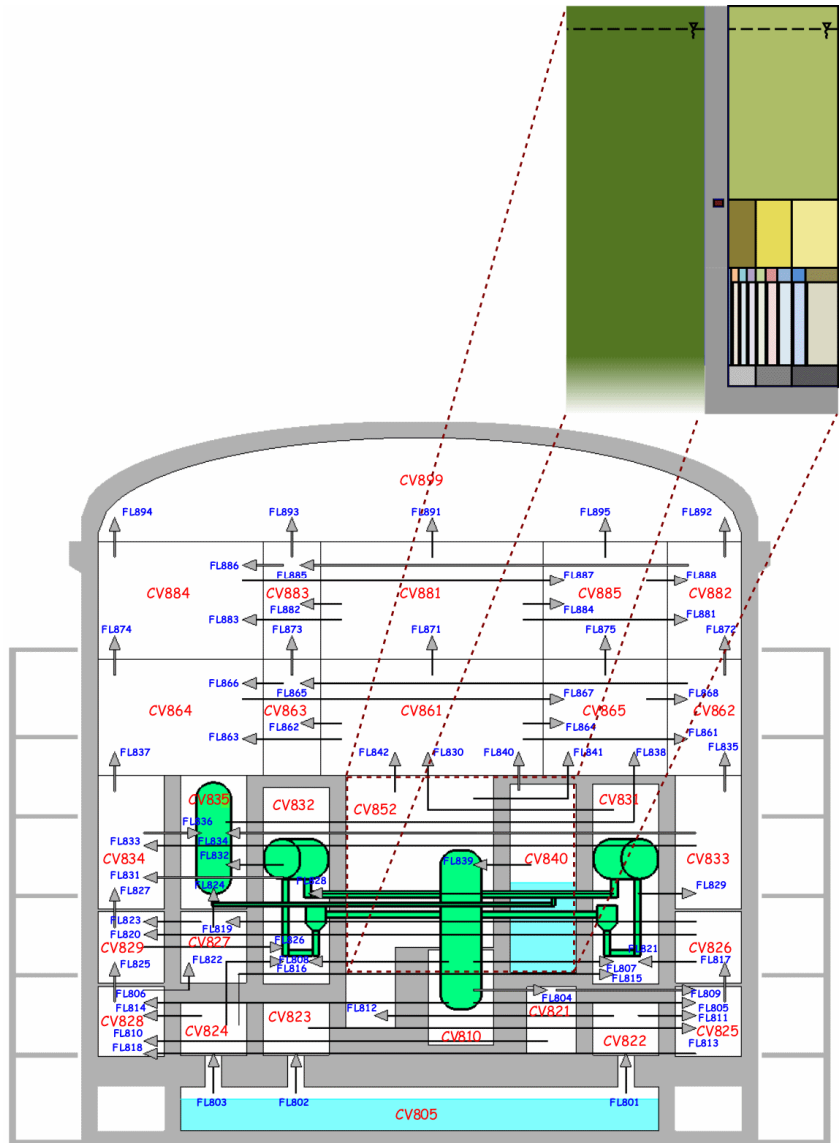
CVH nodalization: CVs + FLs (CN-CN collapsed)



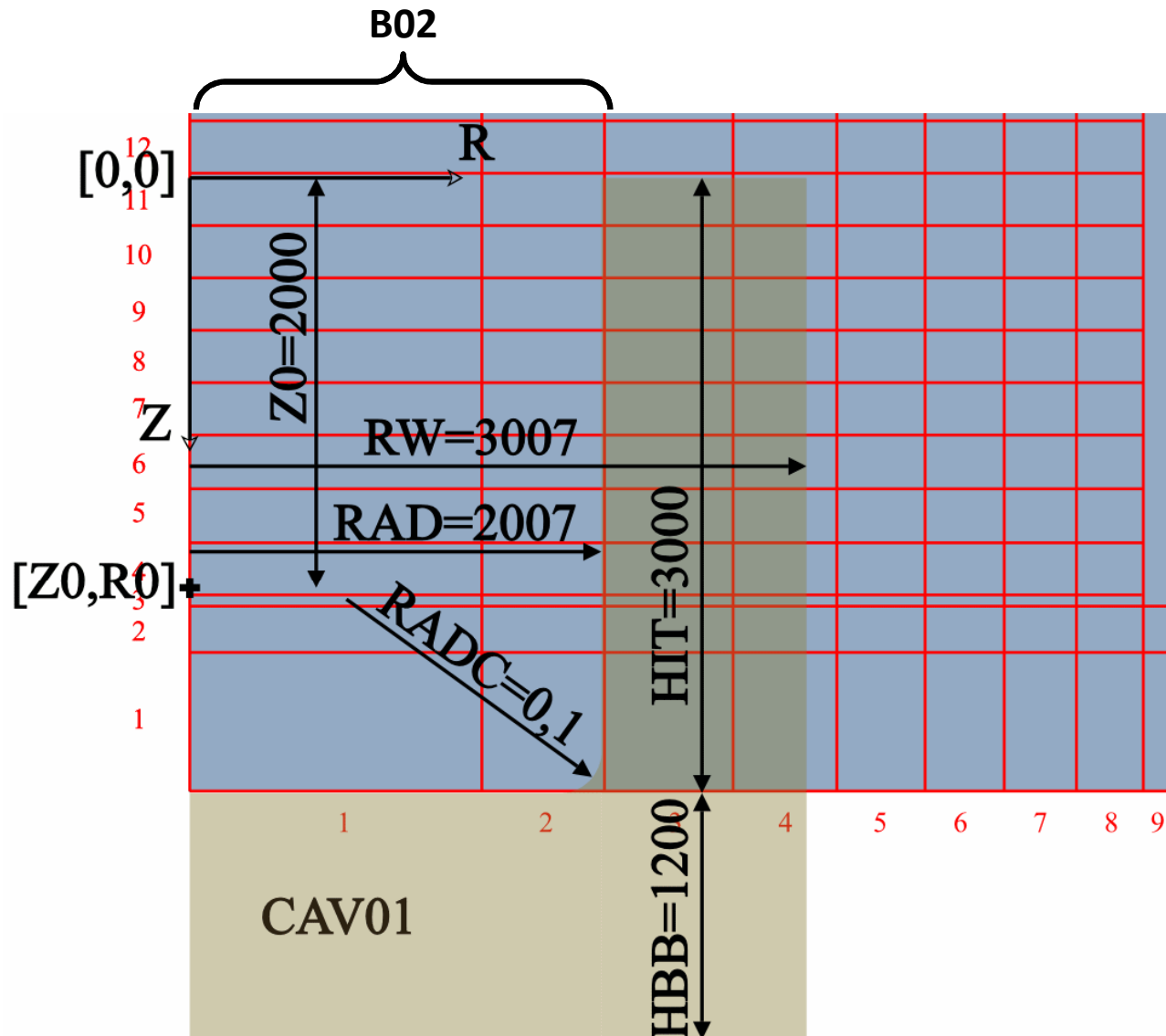
CVH nodalization: CVs + FLs (wall melt-through)



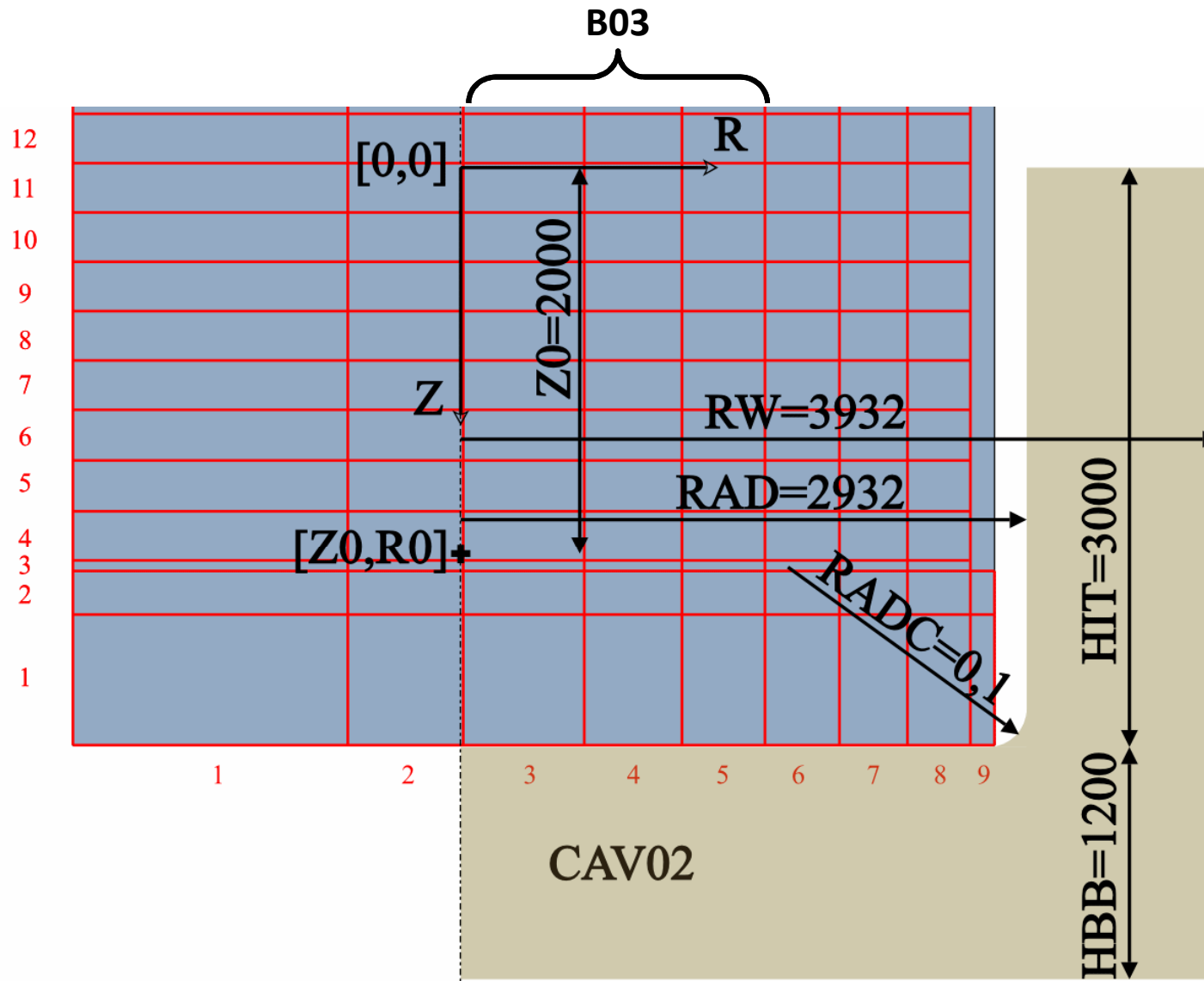
SFP nodalization: CVs + FLs + HSs



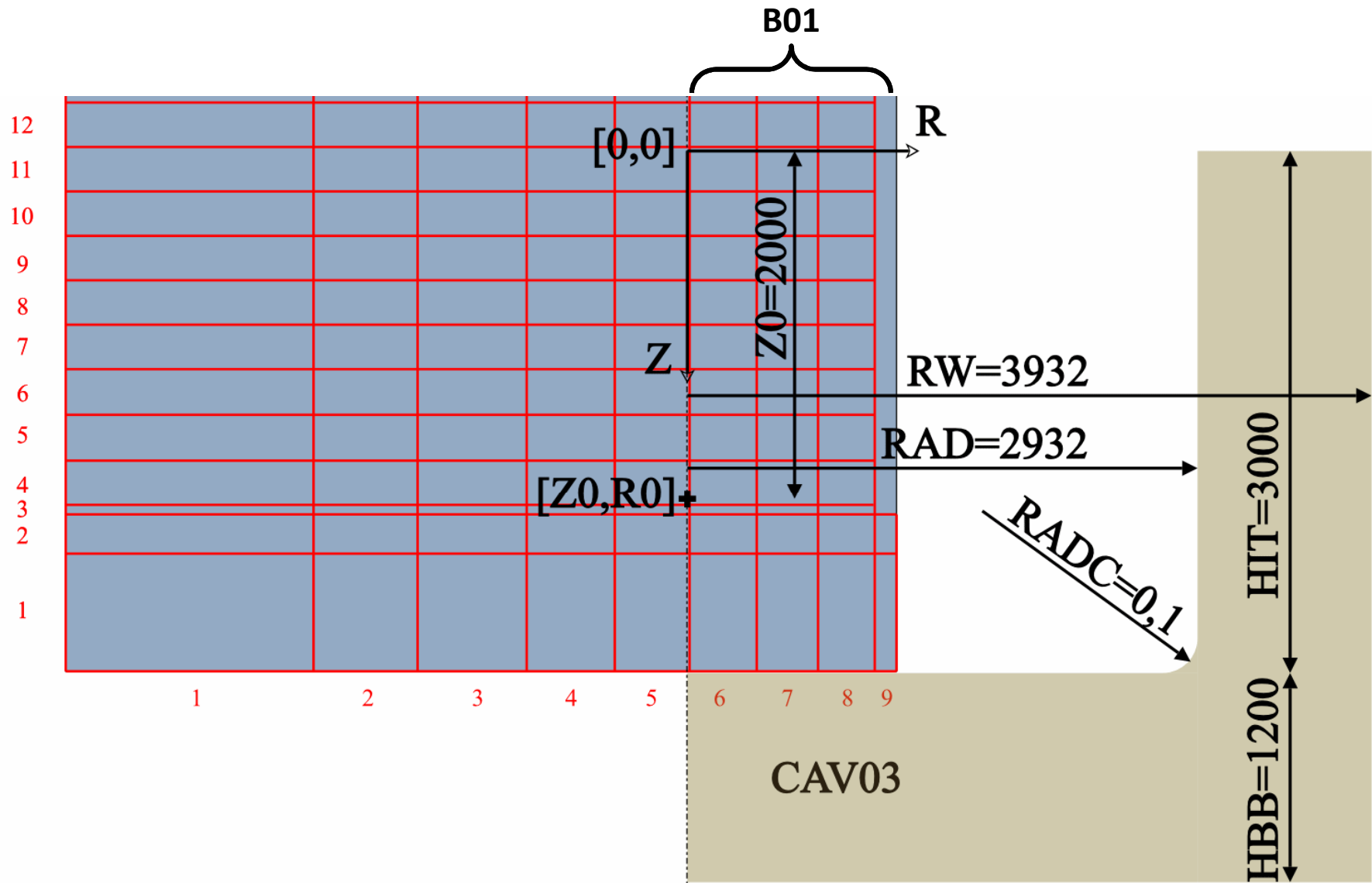
CAV nodalization: CAV01 adjacent to B02



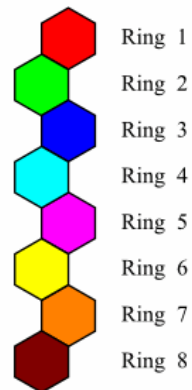
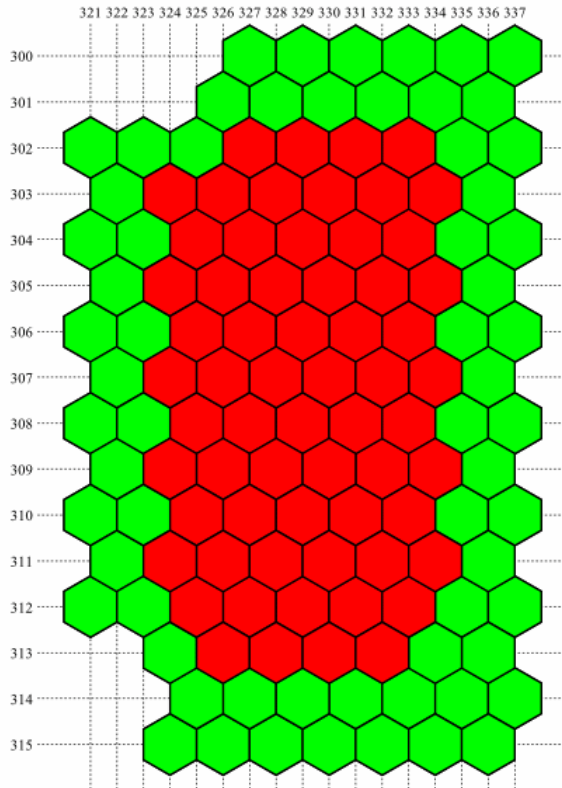
CAV nodalization: CAV02 adjacent to B03



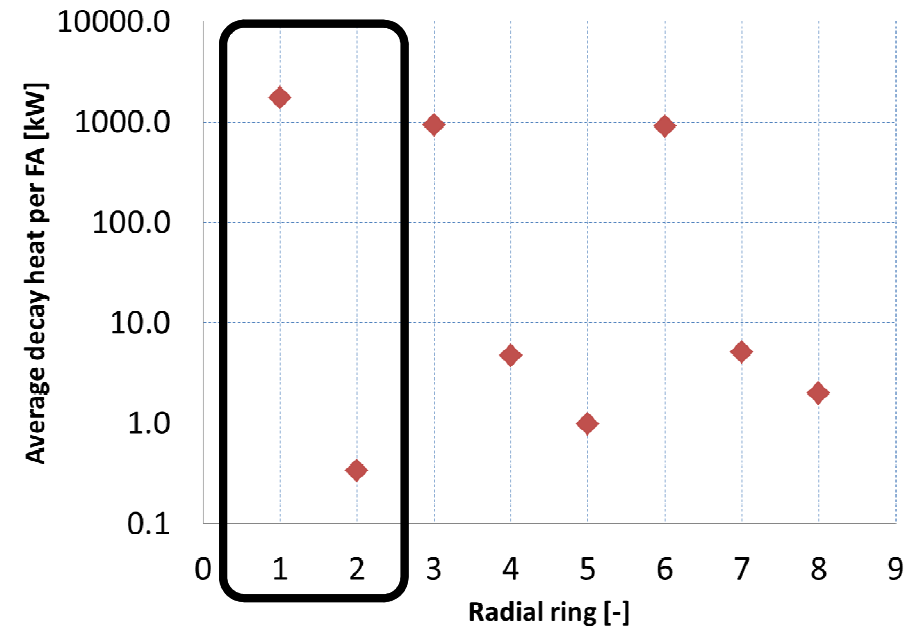
CAV nodalization: CAV03 adjacent to B01



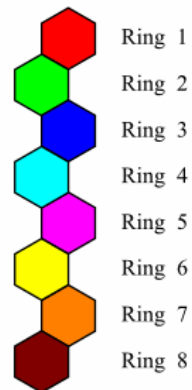
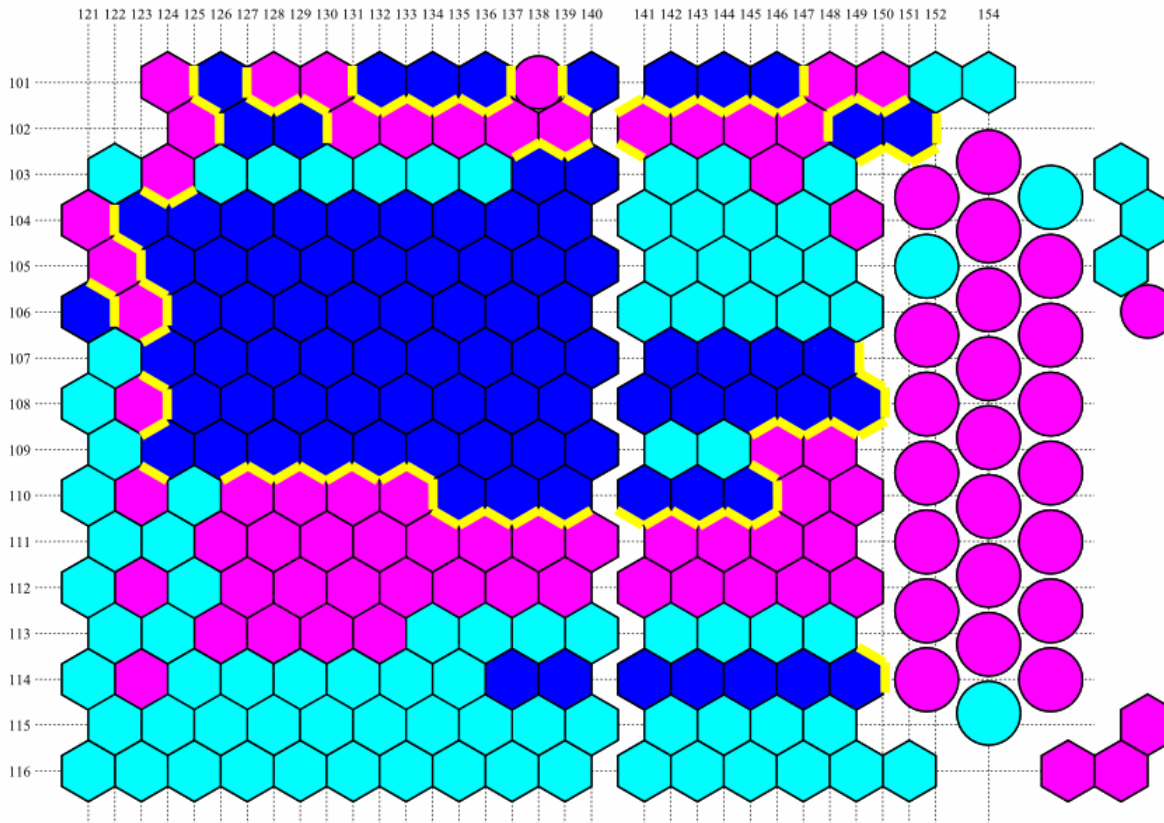
Radial rings (B02): decay power distribution



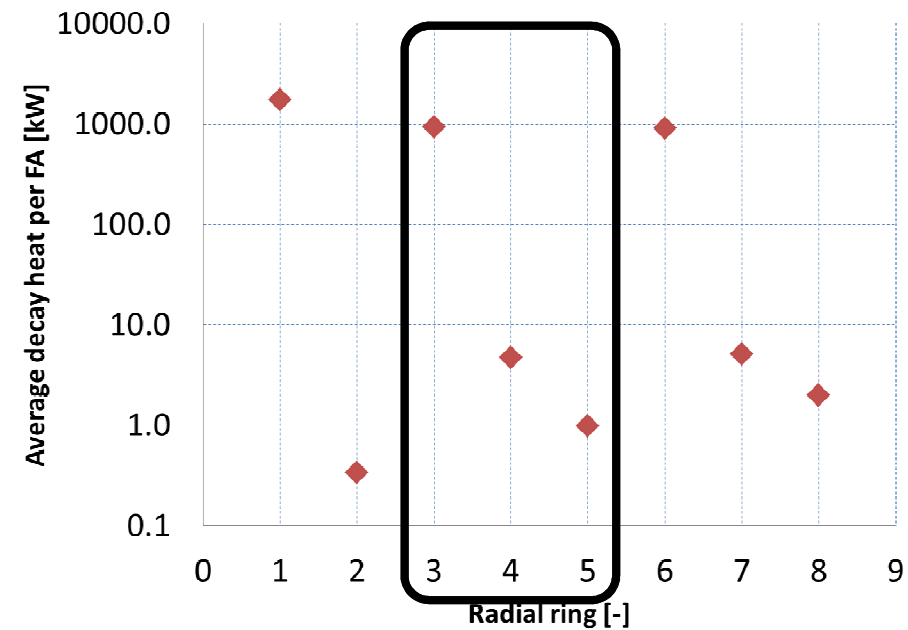
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19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
18	5.94E-03	1.15E-06	3.15E-03	1.59E-05	3.36E-06	3.04E-03	1.74E-05	6.75E-06	
17	1.96E-02	3.78E-06	1.04E-02	5.27E-05	1.11E-05	1.00E-02	5.75E-05	2.23E-05	
16	3.30E-02	6.37E-06	1.75E-02	8.87E-05	1.87E-05	1.69E-02	9.68E-05	3.76E-05	
15	3.62E-02	6.98E-06	1.92E-02	9.72E-05	2.05E-05	1.85E-02	1.06E-04	4.12E-05	
14	3.53E-02	6.80E-06	1.87E-02	9.47E-05	1.99E-05	1.81E-02	1.03E-04	4.01E-05	
13	3.39E-02	6.54E-06	1.80E-02	9.11E-05	1.92E-05	1.74E-02	9.94E-05	3.86E-05	
12	3.31E-02	6.39E-06	1.76E-02	8.89E-05	1.87E-05	1.70E-02	9.71E-05	3.77E-05	
11	3.32E-02	6.40E-06	1.76E-02	8.92E-05	1.88E-05	1.70E-02	9.73E-05	3.78E-05	
10	3.40E-02	6.55E-06	1.80E-02	9.12E-05	1.92E-05	1.74E-02	9.96E-05	3.86E-05	
9	3.55E-02	6.85E-06	1.88E-02	9.54E-05	2.01E-05	1.82E-02	1.04E-04	4.04E-05	
8	3.76E-02	7.24E-06	1.99E-02	1.01E-04	2.12E-05	1.92E-02	1.10E-04	4.27E-05	
7	3.97E-02	7.66E-06	2.11E-02	1.07E-04	2.25E-05	2.03E-02	1.16E-04	4.52E-05	
6	4.04E-02	7.79E-06	2.14E-02	1.08E-04	2.29E-05	2.07E-02	1.18E-04	4.59E-05	
5	3.60E-02	6.94E-06	1.91E-02	9.66E-05	2.04E-05	1.84E-02	1.05E-04	4.09E-05	
4	2.45E-02	4.72E-06	1.30E-02	6.57E-05	1.38E-05	1.25E-02	7.17E-05	2.78E-05	
3	9.90E-03	1.91E-06	5.25E-03	2.66E-05	5.60E-06	5.07E-03	2.90E-05	1.13E-05	
2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00



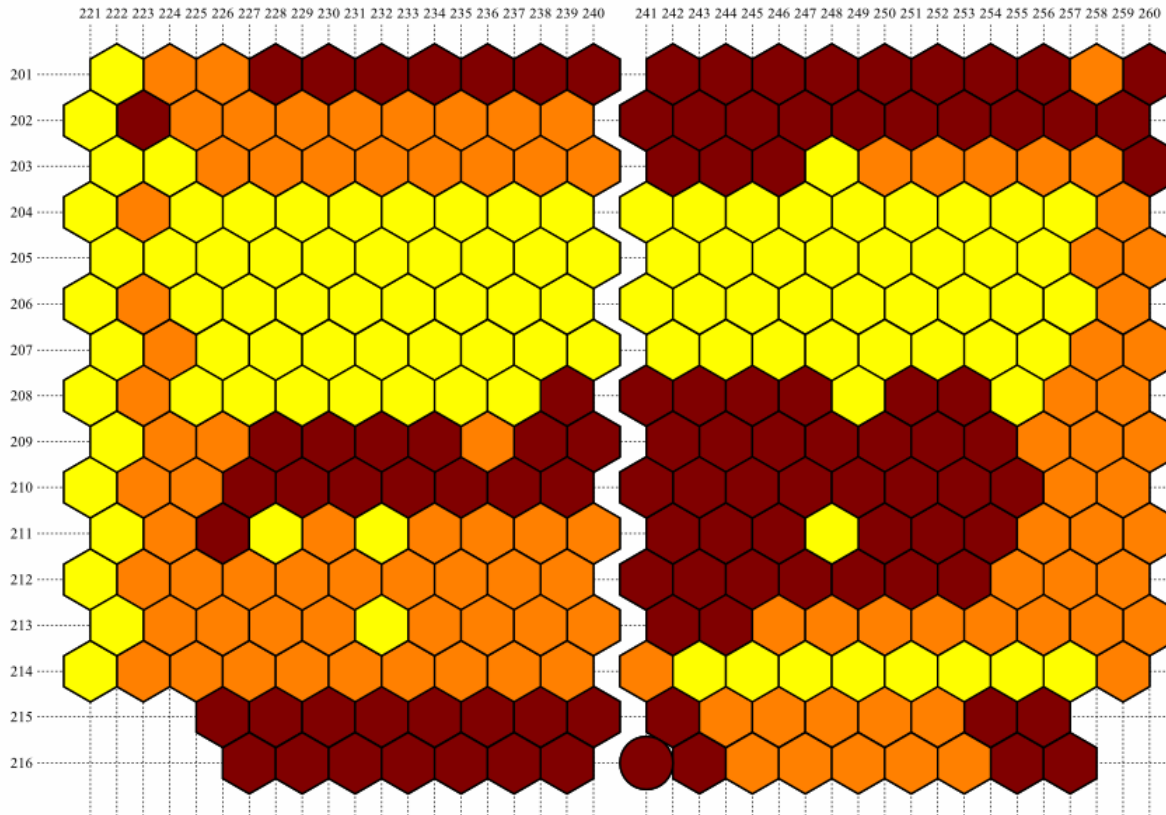
Radial rings (B03): decay power distribution



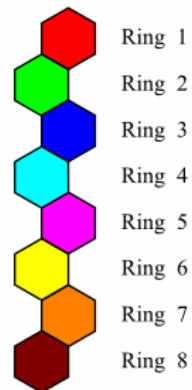
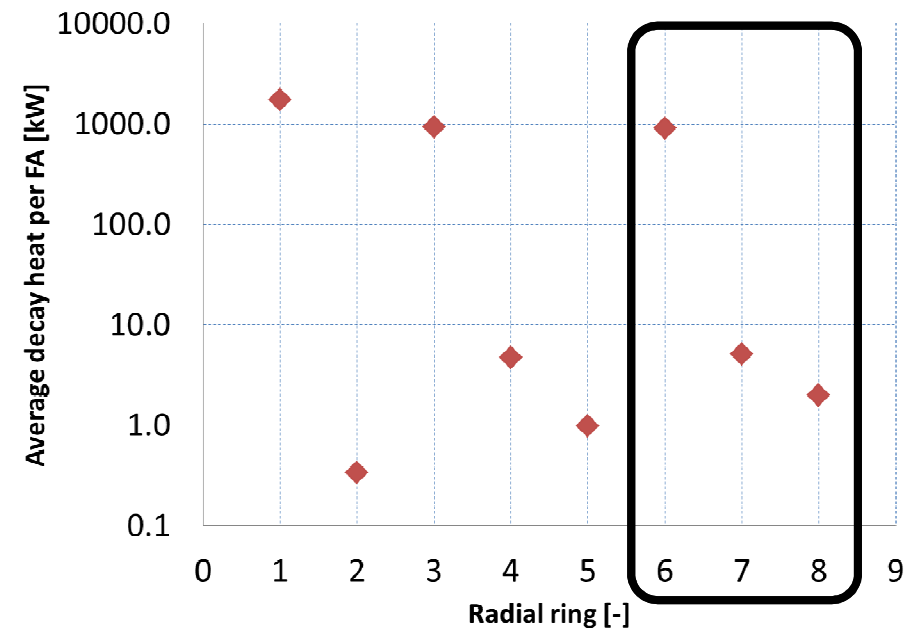
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19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
18	5.94E-03	1.15E-06	3.15E-03	1.59E-05	3.36E-06	3.04E-03	1.74E-05	6.75E-06	
17	1.96E-02	3.78E-06	1.04E-02	5.27E-05	1.11E-05	1.00E-02	5.75E-05	2.23E-05	
16	3.30E-02	6.37E-06	1.75E-02	8.87E-05	1.87E-05	1.69E-02	9.68E-05	3.76E-05	
15	3.62E-02	6.98E-06	1.92E-02	9.72E-05	2.05E-05	1.85E-02	1.06E-04	4.12E-05	
14	3.53E-02	6.80E-06	1.87E-02	9.47E-05	1.99E-05	1.81E-02	1.03E-04	4.01E-05	
13	3.39E-02	6.54E-06	1.80E-02	9.11E-05	1.92E-05	1.74E-02	9.94E-05	3.86E-05	
12	3.31E-02	6.39E-06	1.76E-02	8.89E-05	1.87E-05	1.70E-02	9.71E-05	3.77E-05	
11	3.32E-02	6.40E-06	1.76E-02	8.92E-05	1.88E-05	1.70E-02	9.73E-05	3.78E-05	
10	3.40E-02	6.55E-06	1.80E-02	9.12E-05	1.92E-05	1.74E-02	9.96E-05	3.86E-05	
9	3.55E-02	6.85E-06	1.88E-02	9.54E-05	2.01E-05	1.82E-02	1.04E-04	4.04E-05	
8	3.76E-02	7.24E-06	1.99E-02	1.01E-04	2.12E-05	1.92E-02	1.10E-04	4.27E-05	
7	3.97E-02	7.66E-06	2.11E-02	1.07E-04	2.25E-05	2.03E-02	1.16E-04	4.52E-05	
6	4.04E-02	7.79E-06	2.14E-02	1.08E-04	2.29E-05	2.07E-02	1.18E-04	4.59E-05	
5	3.60E-02	6.94E-06	1.91E-02	9.66E-05	2.04E-05	1.84E-02	1.05E-04	4.09E-05	
4	2.45E-02	4.72E-06	1.30E-02	6.57E-05	1.38E-05	1.25E-02	7.17E-05	2.78E-05	
3	9.90E-03	1.91E-06	5.25E-03	2.66E-05	5.60E-06	5.07E-03	2.90E-05	1.13E-05	
2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00



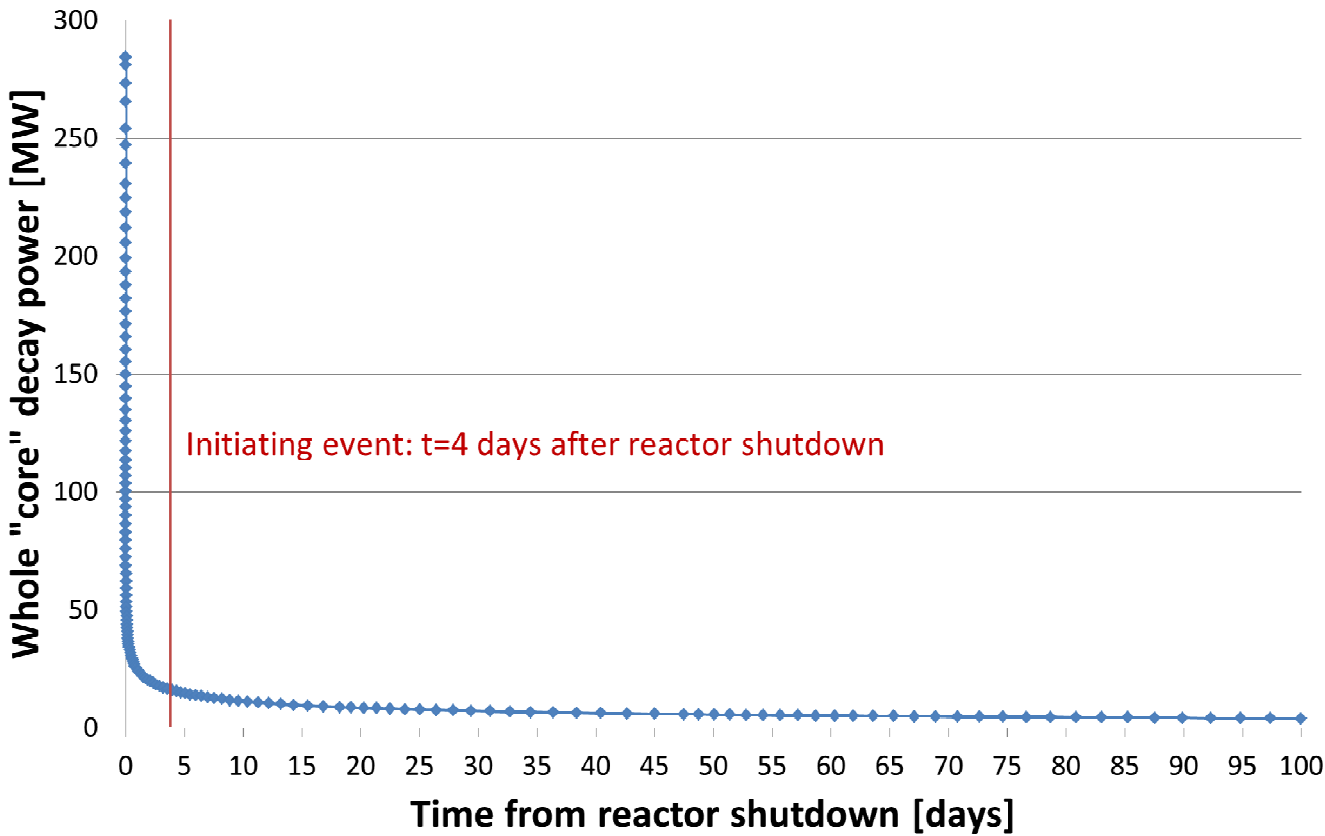
Radial rings (B01): decay power distribution



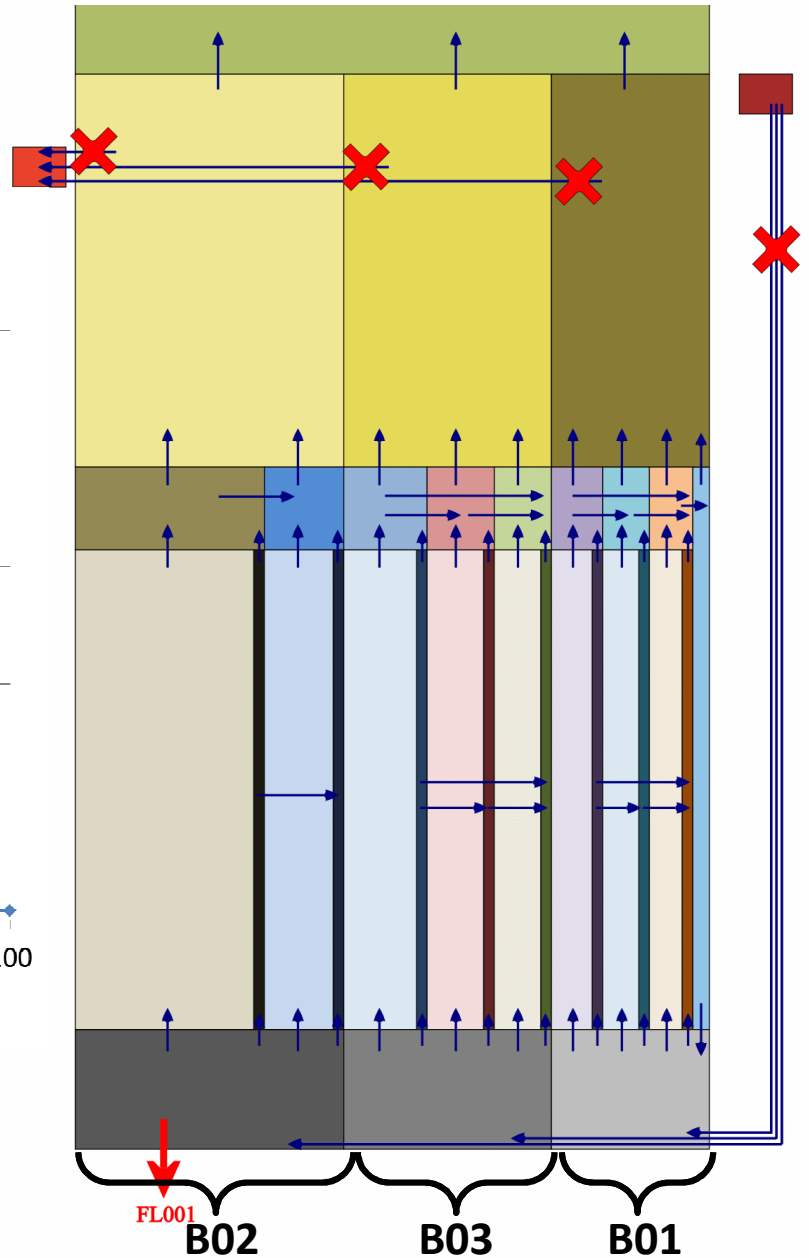
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20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
18	5.94E-03	1.15E-06	3.15E-03	1.59E-05	3.36E-06	3.04E-03	1.74E-05	6.75E-06	
17	1.96E-02	3.78E-06	1.04E-02	5.27E-05	1.11E-05	1.00E-02	5.75E-05	2.23E-05	
16	3.30E-02	6.37E-06	1.75E-02	8.87E-05	1.87E-05	1.69E-02	9.68E-05	3.76E-05	
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14	3.53E-02	6.80E-06	1.87E-02	9.47E-05	1.99E-05	1.81E-02	1.03E-04	4.01E-05	
13	3.39E-02	6.54E-06	1.80E-02	9.11E-05	1.92E-05	1.74E-02	9.94E-05	3.86E-05	
12	3.31E-02	6.39E-06	1.76E-02	8.89E-05	1.87E-05	1.70E-02	9.71E-05	3.77E-05	
11	3.32E-02	6.40E-06	1.76E-02	8.92E-05	1.88E-05	1.70E-02	9.73E-05	3.78E-05	
10	3.40E-02	6.55E-06	1.80E-02	9.12E-05	1.92E-05	1.74E-02	9.96E-05	3.86E-05	
9	3.55E-02	6.85E-06	1.88E-02	9.54E-05	2.01E-05	1.82E-02	1.04E-04	4.04E-05	
8	3.76E-02	7.24E-06	1.99E-02	1.01E-04	2.12E-05	1.92E-02	1.10E-04	4.27E-05	
7	3.97E-02	7.66E-06	2.11E-02	1.07E-04	2.25E-05	2.03E-02	1.16E-04	4.52E-05	
6	4.04E-02	7.79E-06	2.14E-02	1.08E-04	2.29E-05	2.07E-02	1.18E-04	4.59E-05	
5	3.60E-02	6.94E-06	1.91E-02	9.66E-05	2.04E-05	1.84E-02	1.05E-04	4.09E-05	
4	2.45E-02	4.72E-06	1.30E-02	6.57E-05	1.38E-05	1.25E-02	7.17E-05	2.78E-05	
3	9.90E-03	1.91E-06	5.25E-03	2.66E-05	5.60E-06	5.07E-03	2.90E-05	1.13E-05	
2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00



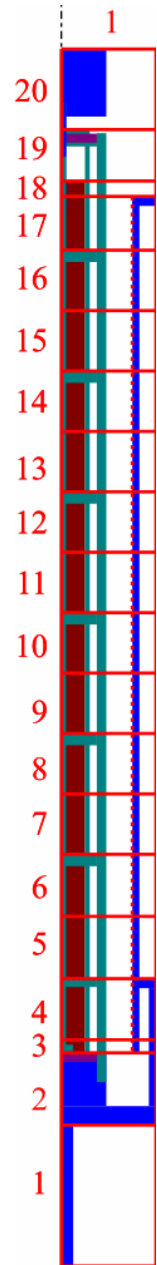
Scenario example: LOCA



■ decay heat = 16 MW at the time of initiating event



Debris exclusion: CORijjDX(FCHXRD)



Component presence

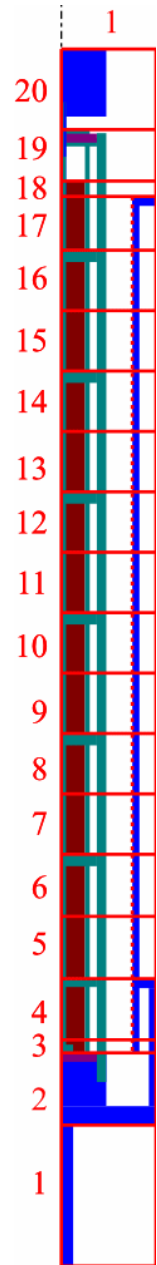
	1
20	0.0
19	1.0
18	1.0
17	1.0
16	1.0
15	1.0
14	1.0
13	1.0
12	1.0
11	1.0
10	1.0
9	1.0
8	1.0
7	1.0
6	1.0
5	1.0
4	1.0
3	1.0
2	1.0
1	0.0

Volume blocked

	1
20	0.0
19	0.5
18	0.9
17	0.9
16	1.0
15	0.9
14	1.0
13	0.9
12	1.0
11	0.9
10	1.0
9	0.9
8	1.0
7	0.9
6	1.0
5	0.9
4	1.0
3	0.9
2	0.5
1	0.0



Debris exclusion: CORijjDX(FBYXCN)



Component presence

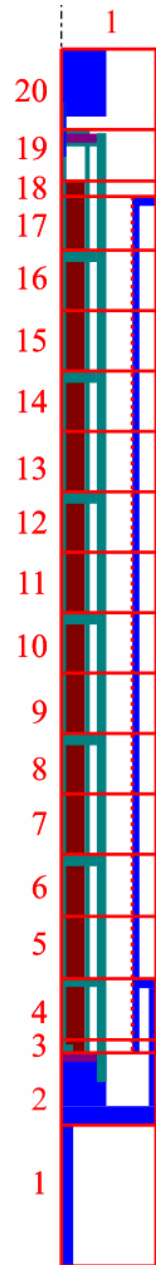
	1
20	0.0
19	0.0
18	0.0
17	1.0
16	1.0
15	1.0
14	1.0
13	1.0
12	1.0
11	1.0
10	1.0
9	1.0
8	1.0
7	1.0
6	1.0
5	1.0
4	1.0
3	1.0
2	0.0
1	0.0

Volume blocked

	1
20	0.0
19	0.0
18	0.0
17	0.3
16	0.3
15	0.3
14	0.3
13	0.3
12	0.3
11	0.3
10	0.3
9	0.3
8	0.3
7	0.3
6	0.3
5	0.3
4	0.3
3	0.3
2	0.0
1	0.0



Debris exclusion: CORijjDX(FBYXSS)



Component presence

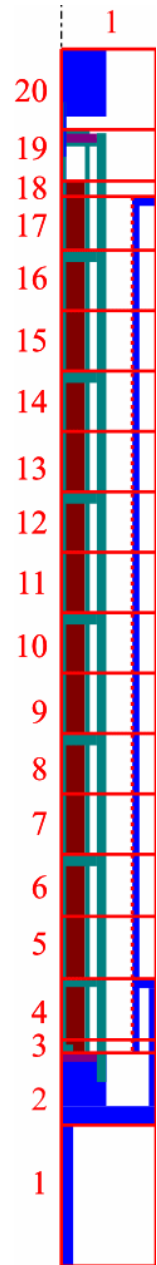
	1
20	1.0
19	0.0
18	0.0
17	1.0
16	0.0
15	0.0
14	0.0
13	0.0
12	0.0
11	0.0
10	0.0
9	0.0
8	0.0
7	0.0
6	0.0
5	0.0
4	1.0
3	1.0
2	1.0
1	1.0

Volume blocked

	1
20	0.0
19	0.0
18	0.0
17	0.7
16	0.0
15	0.0
14	0.0
13	0.0
12	0.0
11	0.0
10	0.0
9	0.0
8	0.0
7	0.0
6	0.0
5	0.0
4	0.7
3	0.0
2	0.0
1	0.0



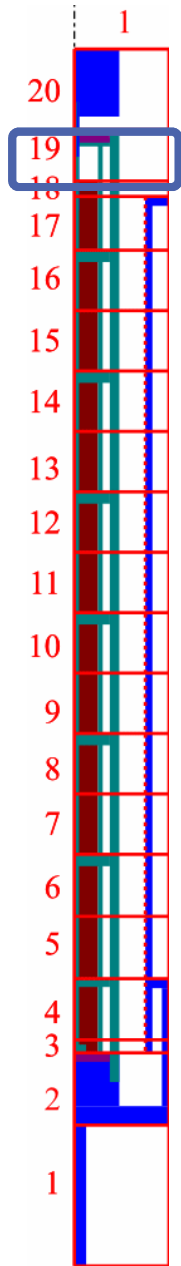
Debris exclusion: CORijjDX – all together (add?!)



Volume blocked

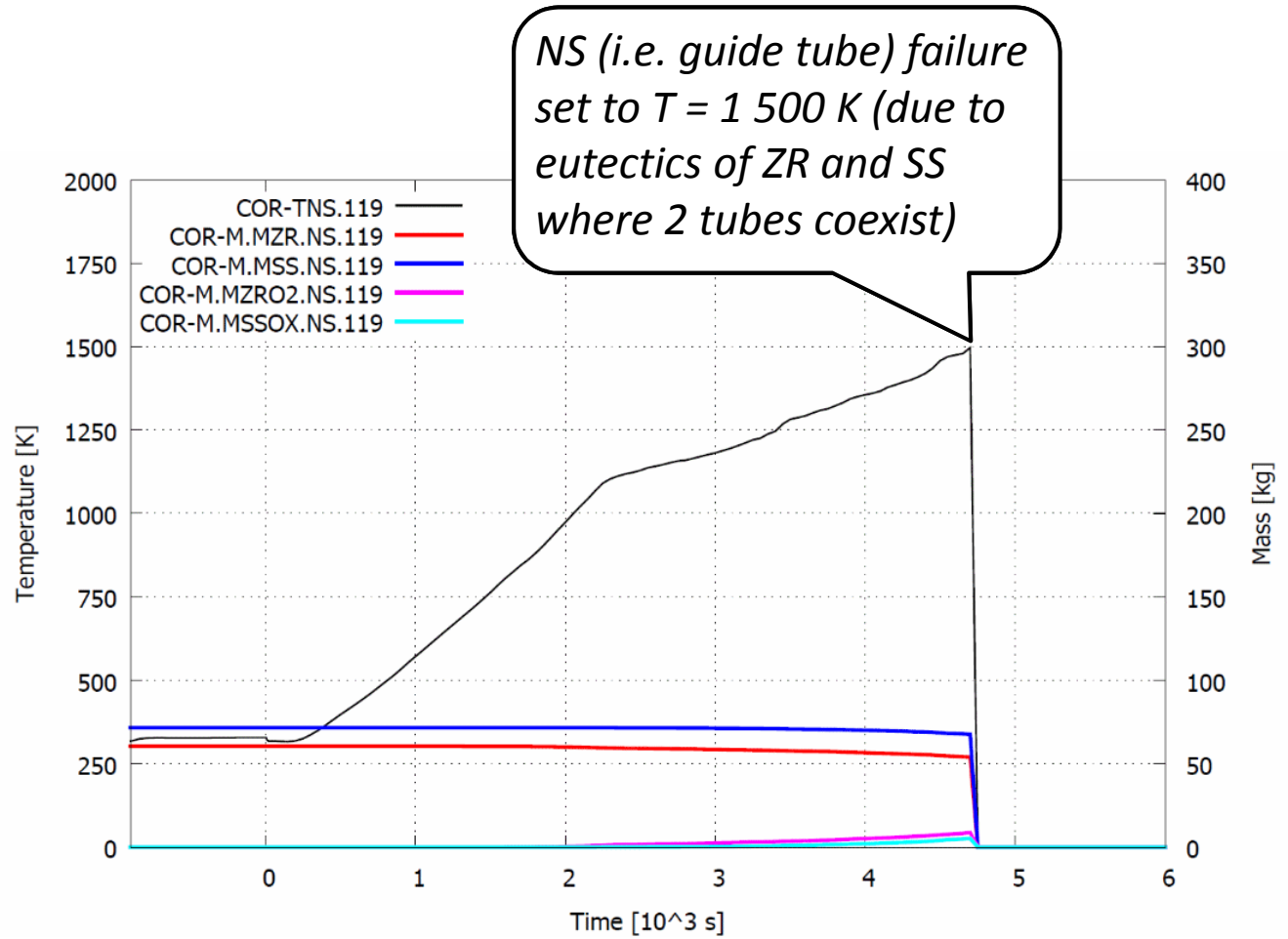
	1	
20	0.0	
19	0.5	
18	0.9	
17	0.9	1.0
16	1.0	0.3
15	0.9	0.3
14	1.0	0.3
13	0.9	0.3
12	1.0	0.3
11	0.9	0.3
10	1.0	0.3
9	0.9	0.3
8	1.0	0.3
7	0.9	0.3
6	1.0	0.3
5	0.9	0.3
4	1.0	1.0
3	0.9	0.3
2	0.5	
1	0.0	

Debris exclusion: NS fail

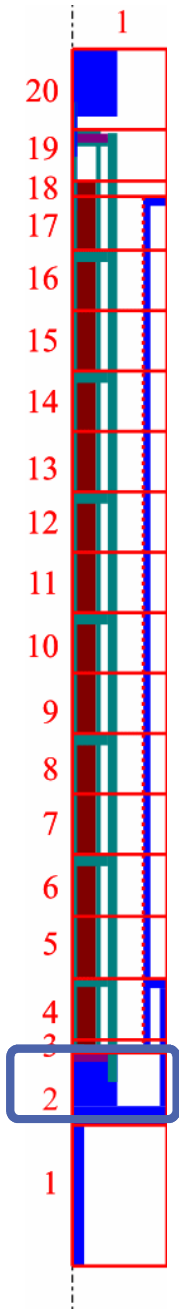


Volume blocked

	1	
20	0.0	
19	0.5	
18	0.9	
17	0.9	1.0
16	1.0	0.3
15	0.9	0.3
14	1.0	0.3
13	0.9	0.3
12	1.0	0.3
11	0.9	0.3
10	1.0	0.3
9	0.9	0.3
8	1.0	0.3
7	0.9	0.3
6	1.0	0.3
5	0.9	0.3
4	1.0	1.0
3	0.9	0.3
2	0.5	
1	0.0	

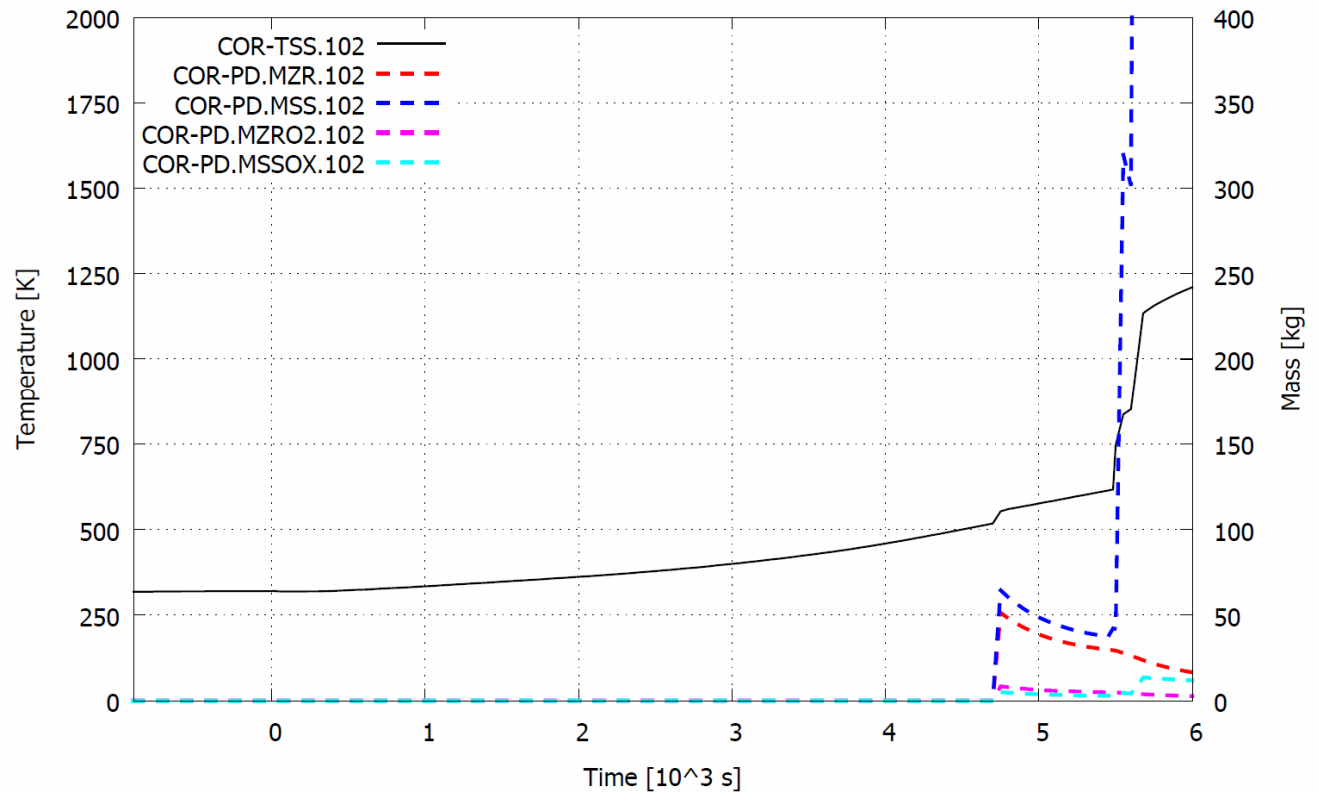


Debris exclusion: CORijjDX – all together, NS fail

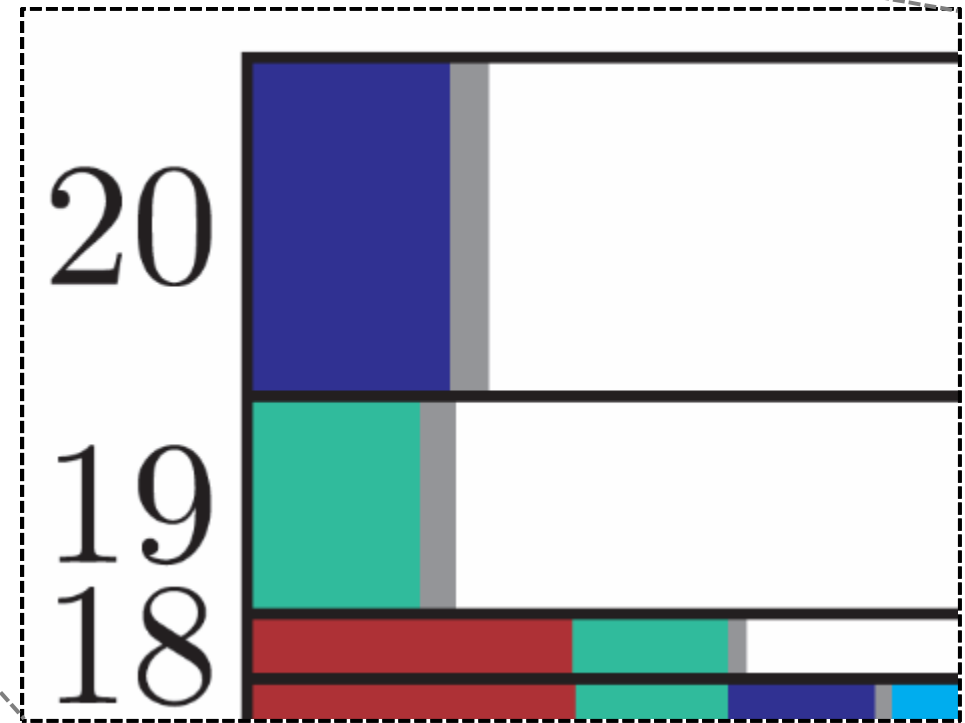
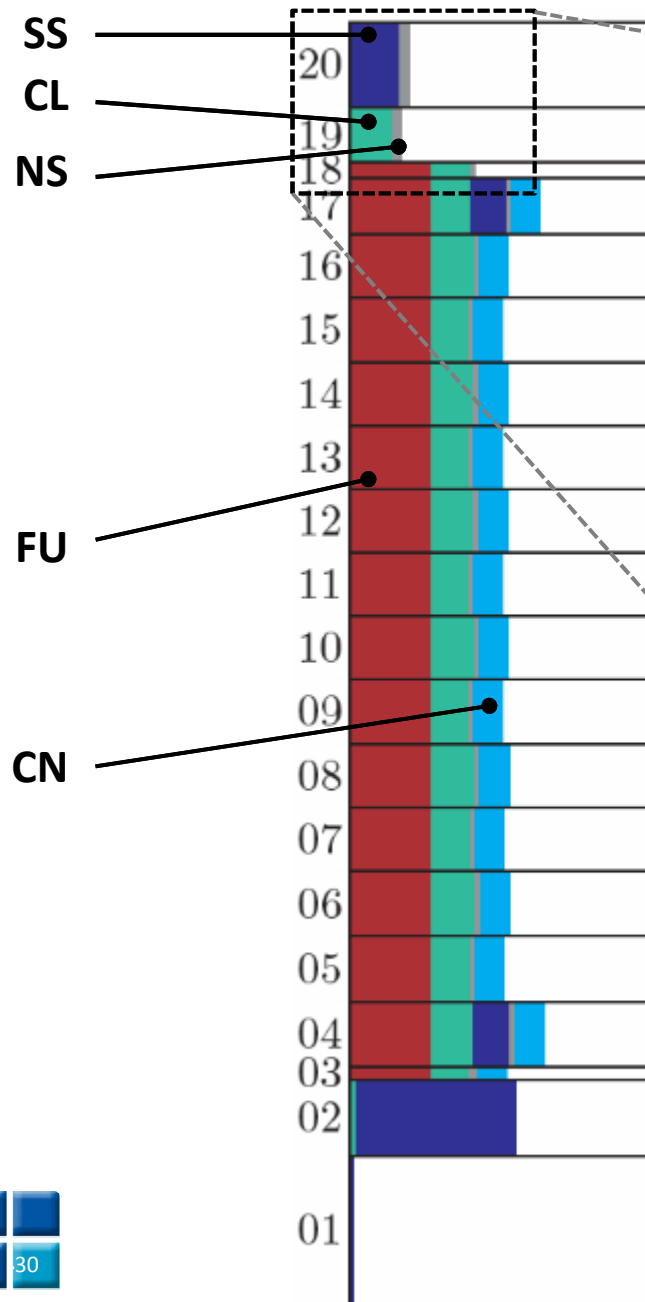


Volume blocked

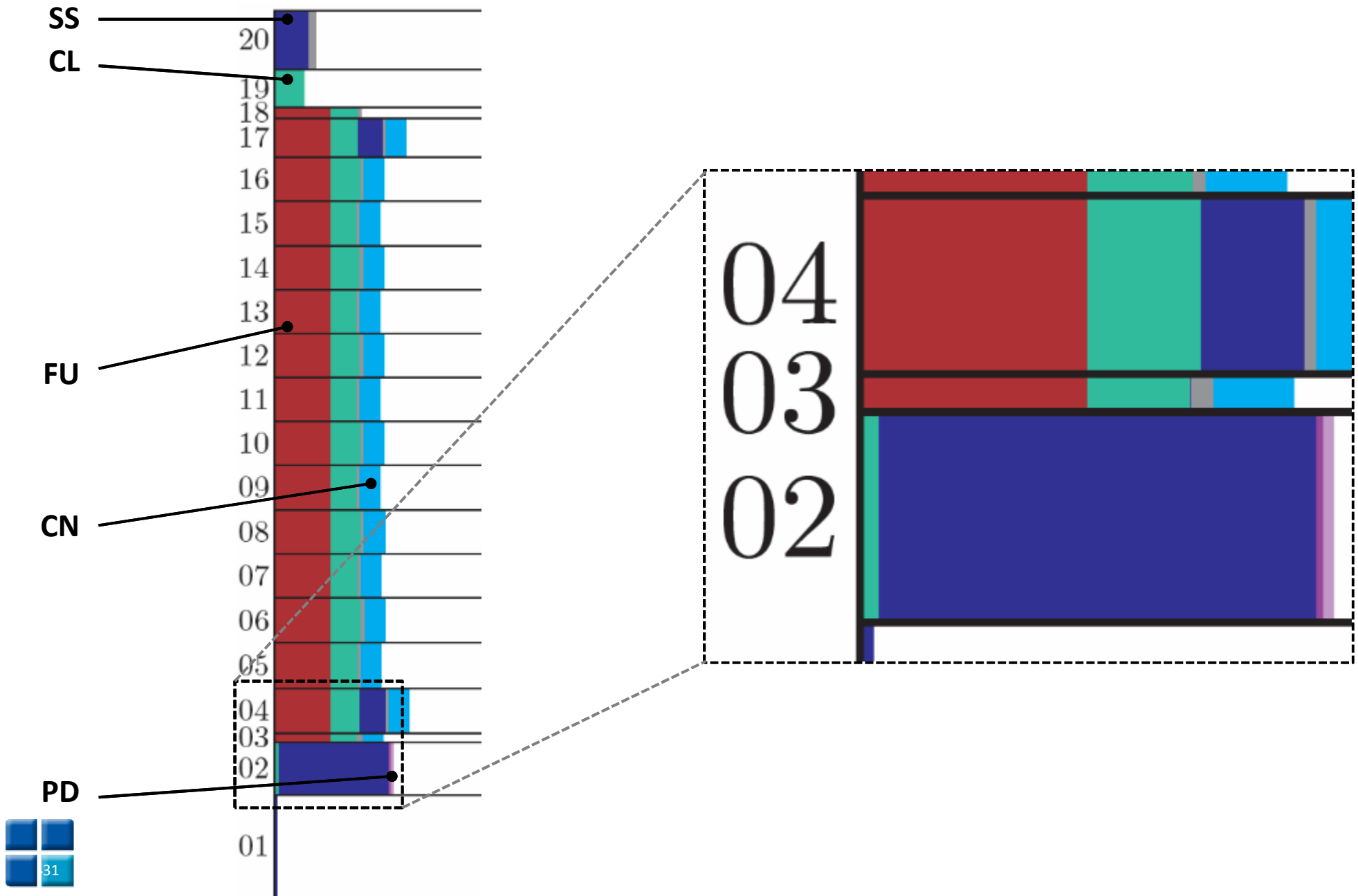
	1	
20	0.0	
19	0.5	
18	0.9	
17	0.9	1.0
16	1.0	0.3
15	0.9	0.3
14	1.0	0.3
13	0.9	0.3
12	1.0	0.3
11	0.9	0.3
10	1.0	0.3
9	0.9	0.3
8	1.0	0.3
7	0.9	0.3
6	1.0	0.3
5	0.9	0.3
4	1.0	1.0
3	0.9	0.3
2	0.5	
1	0.0	



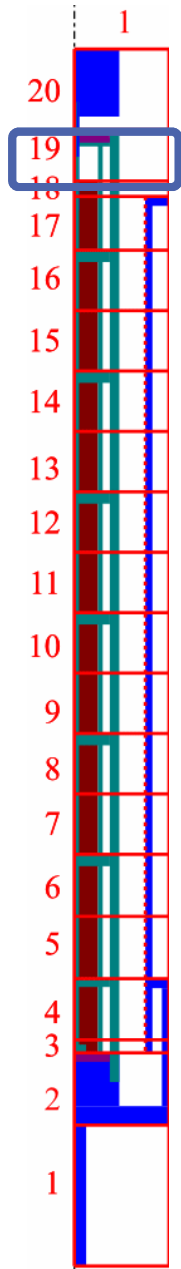
NS fail – just before failure



NS fail – just after failure

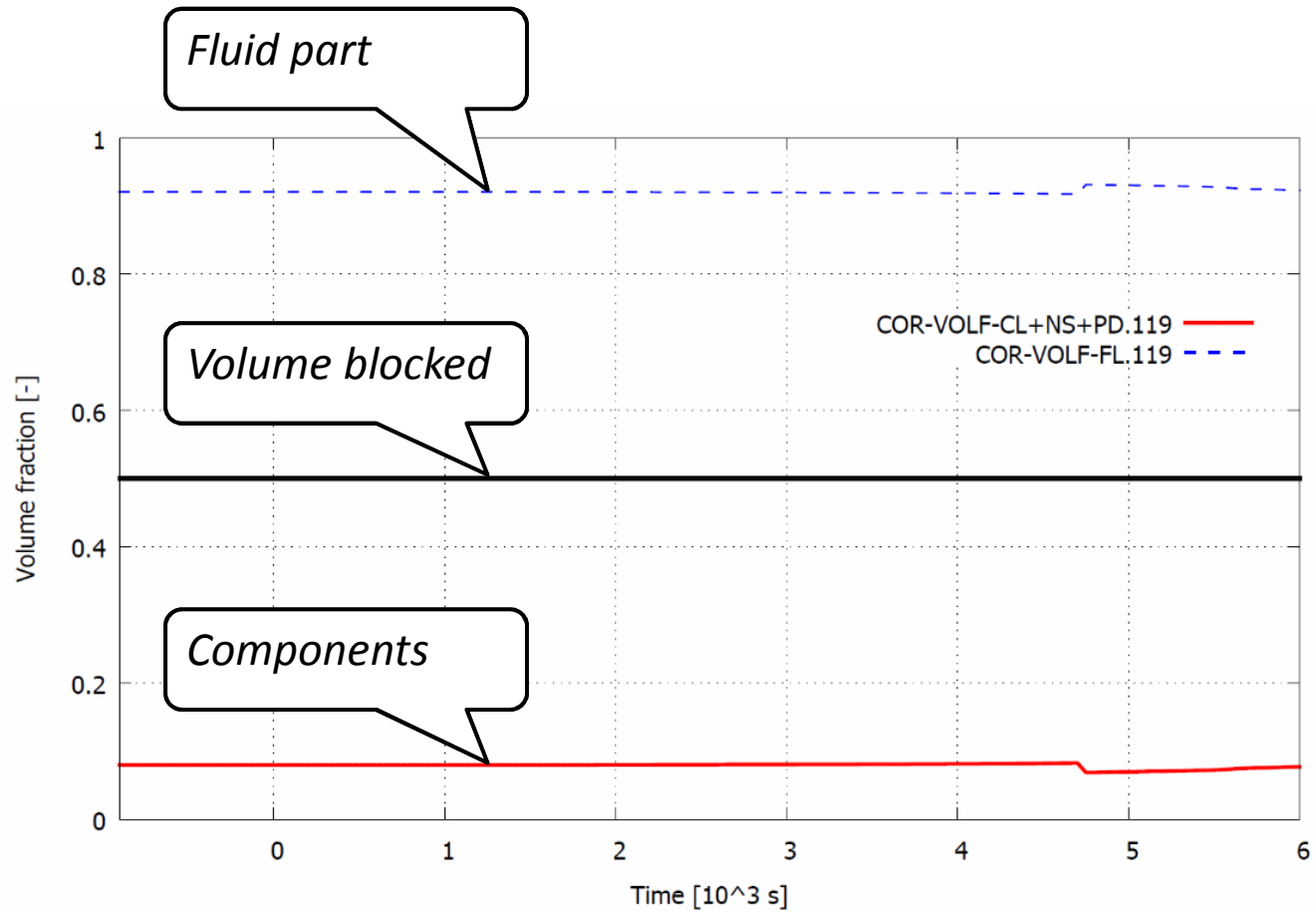


Debris exclusion: CORijjDX – COR cell #119

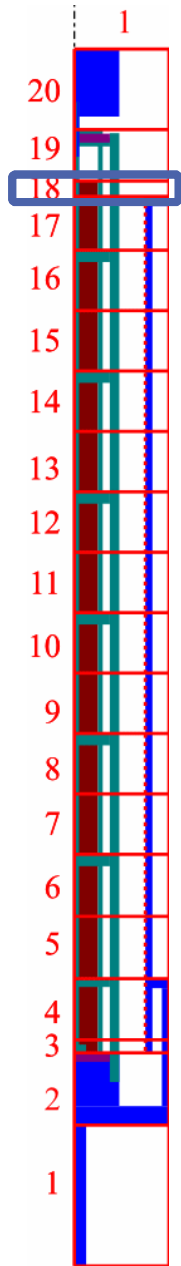


Volume blocked

	1	
20	0.0	
19	0.5	
18	0.9	
17	0.9	1.0
16	1.0	0.3
15	0.9	0.3
14	1.0	0.3
13	0.9	0.3
12	1.0	0.3
11	0.9	0.3
10	1.0	0.3
9	0.9	0.3
8	1.0	0.3
7	0.9	0.3
6	1.0	0.3
5	0.9	0.3
4	1.0	1.0
3	0.9	0.3
2	0.5	
1	0.0	

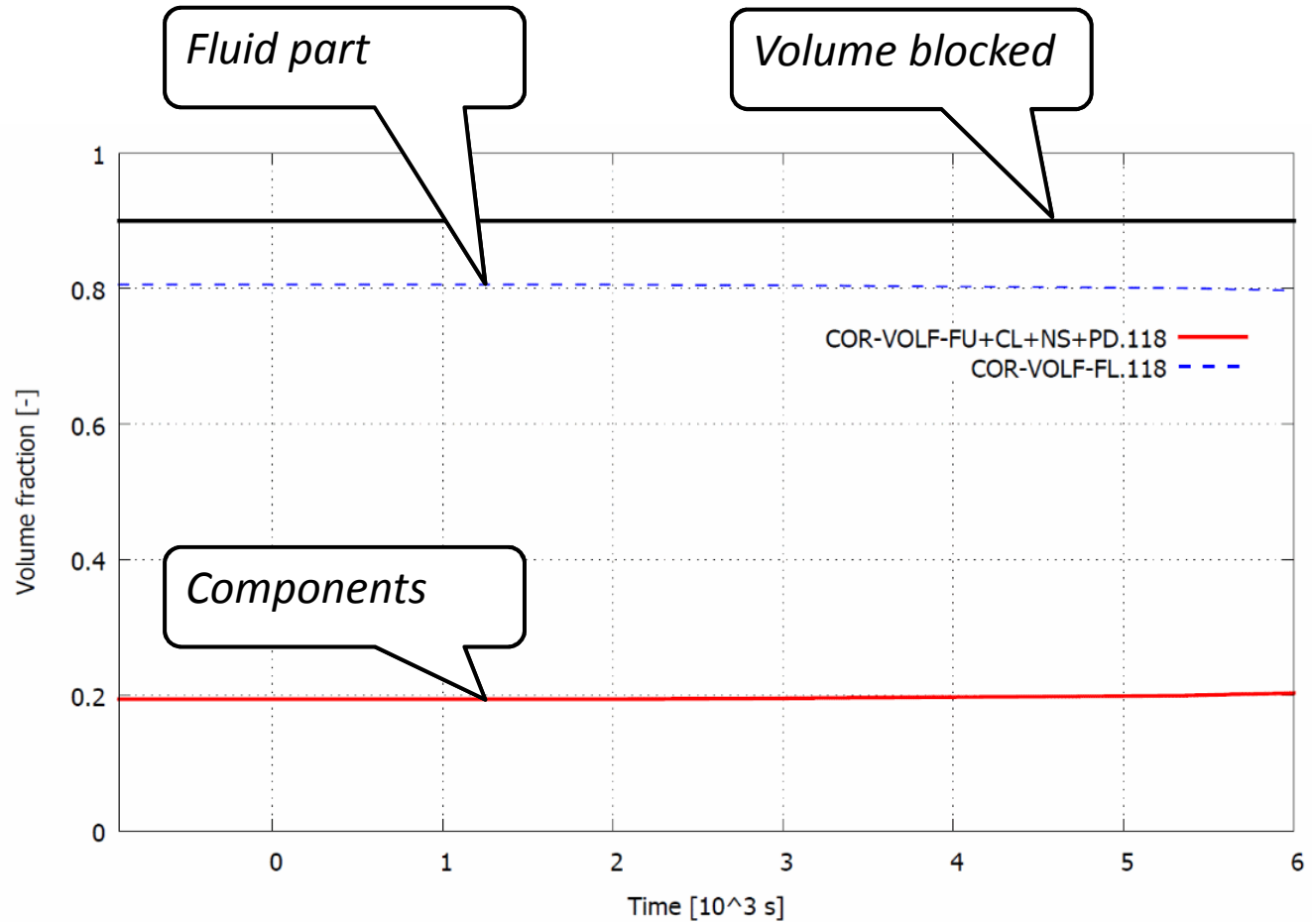


Debris exclusion: CORijjDX – COR cell #118

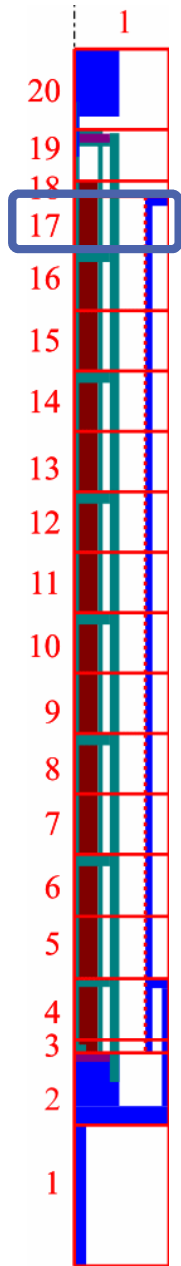


Volume blocked

	1	
20	0.0	
19	0.5	
18	0.9	
17	0.9	1.0
16	1.0	0.3
15	0.9	0.3
14	1.0	0.3
13	0.9	0.3
12	1.0	0.3
11	0.9	0.3
10	1.0	0.3
9	0.9	0.3
8	1.0	0.3
7	0.9	0.3
6	1.0	0.3
5	0.9	0.3
4	1.0	1.0
3	0.9	0.3
2	0.5	
1	0.0	

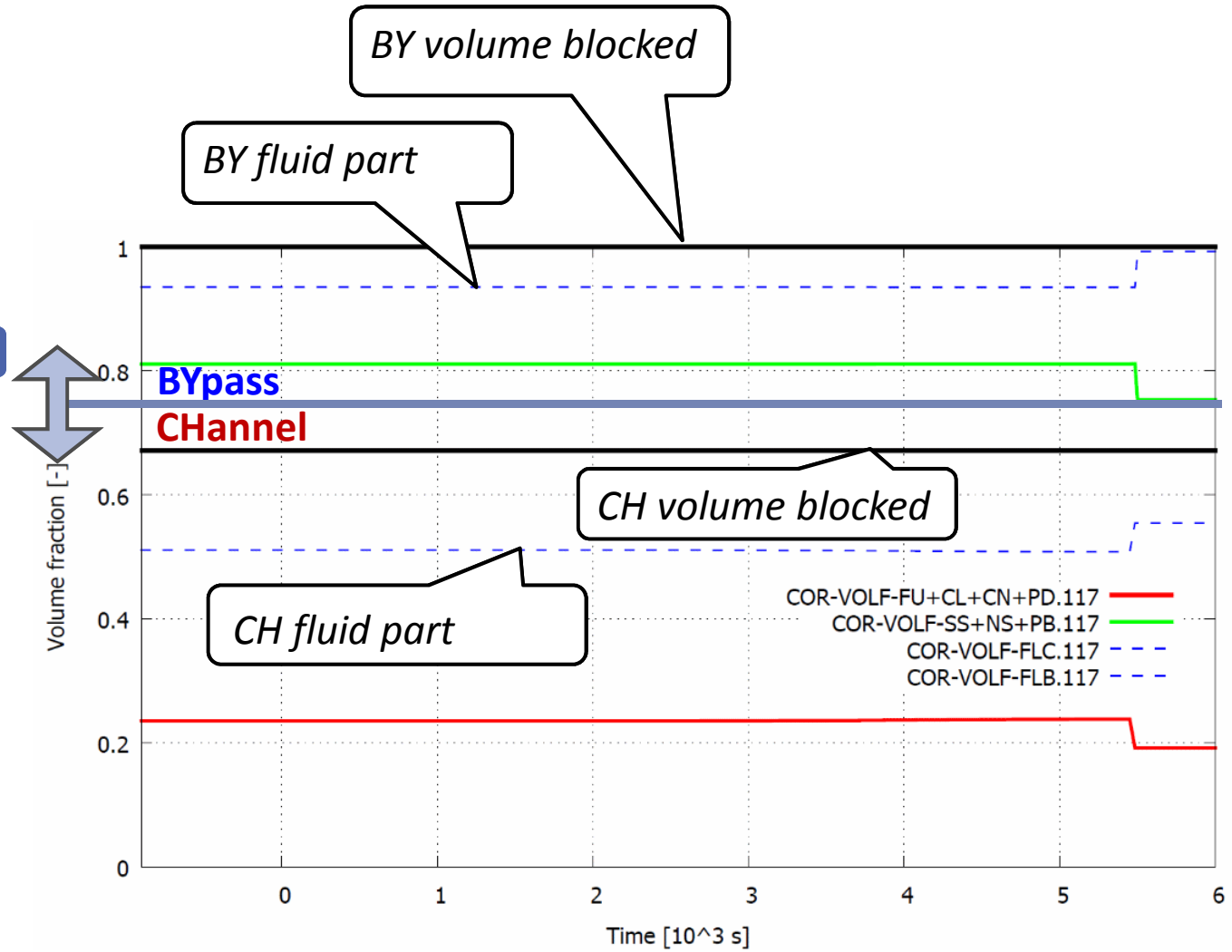


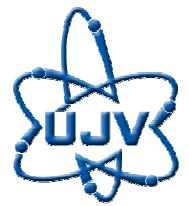
Debris exclusion: CORijjDX – COR cell #117



Volume blocked

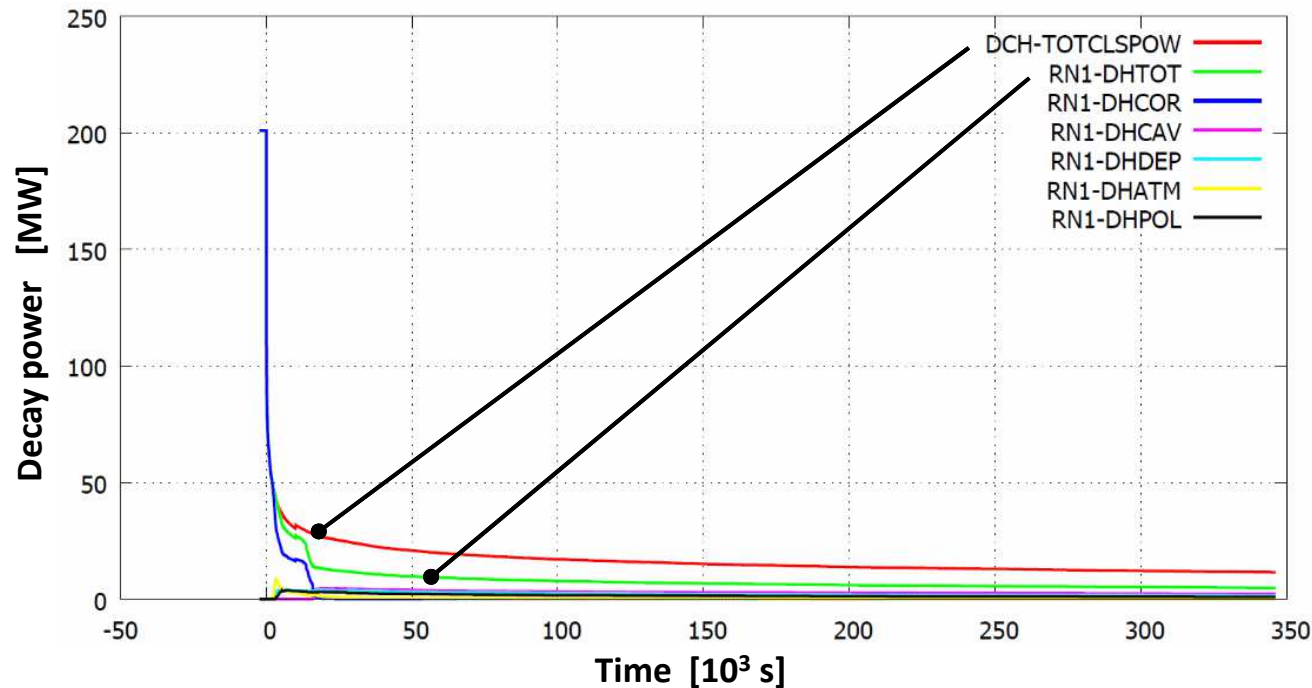
	1	
20	0.0	
19	0.5	
18	0.9	
17	0.9	1.0
16	1.0	0.3
15	0.9	0.3
14	1.0	0.3
13	0.9	0.3
12	1.0	0.3
11	0.9	0.3
10	1.0	0.3
9	0.9	0.3
8	1.0	0.3
7	0.9	0.3
6	1.0	0.3
5	0.9	0.3
4	1.0	1.0
3	0.9	0.3
2	0.5	
1	0.0	





- Use of the **CORijjDX** record for structures' supporting capabilities is unclear
- → **Supporting structure (SS)** rather to be used for spacer grids

- Total decay heat calculated by DCH and RN packages differ
 - for LB LOCA scenarios (where huge MPs exist)
 - not for SBO scenarios (MPs partially suppressed)
 - Remede: $CORTST01(IMP MOD) = 1$, $CORTST01(IMP PRT) = 1$
 - Bugzilla: #1260



- MELCOR download page down (new releases of MELCOR 2.1, ptfread)

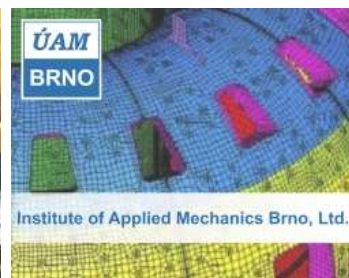


Thank You for Your Attention

UJV GROUP



Nuclear Research Institute Rez



Institute of Applied Mechanics Brno, Ltd.



EGP INVEST, spol. s r.o.



Research and Testing Institute Plzen



Research Centre Rez