Study on the Nodalization Effect of MELCOR for Simulation of Nordic BWR

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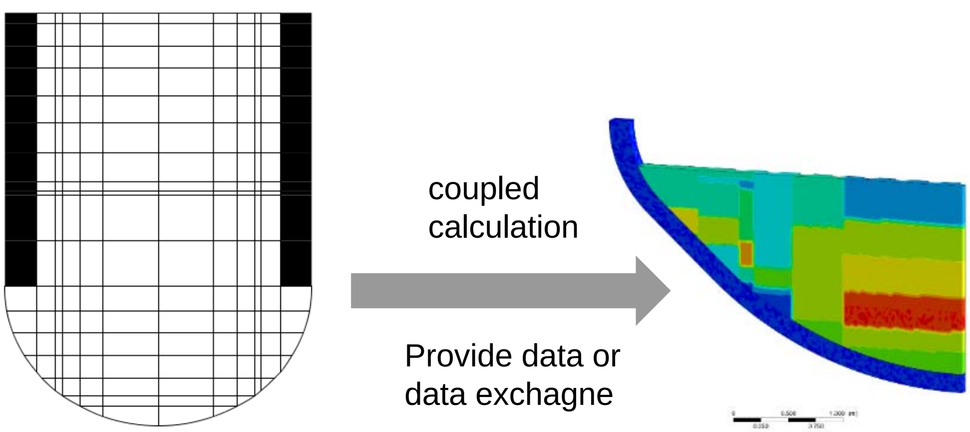
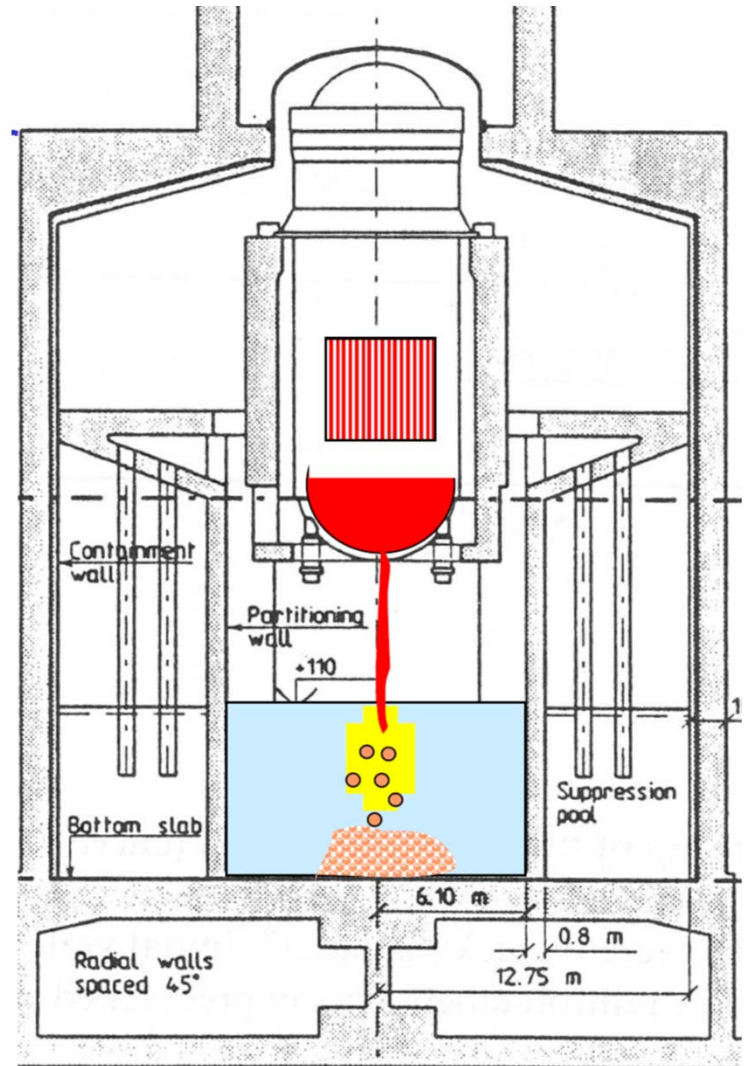
Outline

- Motivation
- Features of Nordic BWR
- MELCOR models
- Simulation results
- Concluding remarks and perspectives

Motivation

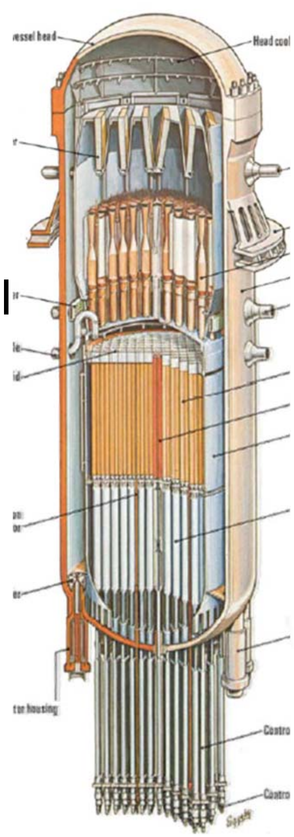
- Analysis of current SAMG of Nordic BWRs
  - Employ the cavity (lower drywell) flooding as a SAM measure to promote melt fragmentation and quenching, and formation of a coolable debris bed on the drywell floor (ex-vessel coolability).
  - MELCOR provides the initial and boudary condition for a coupled calculation

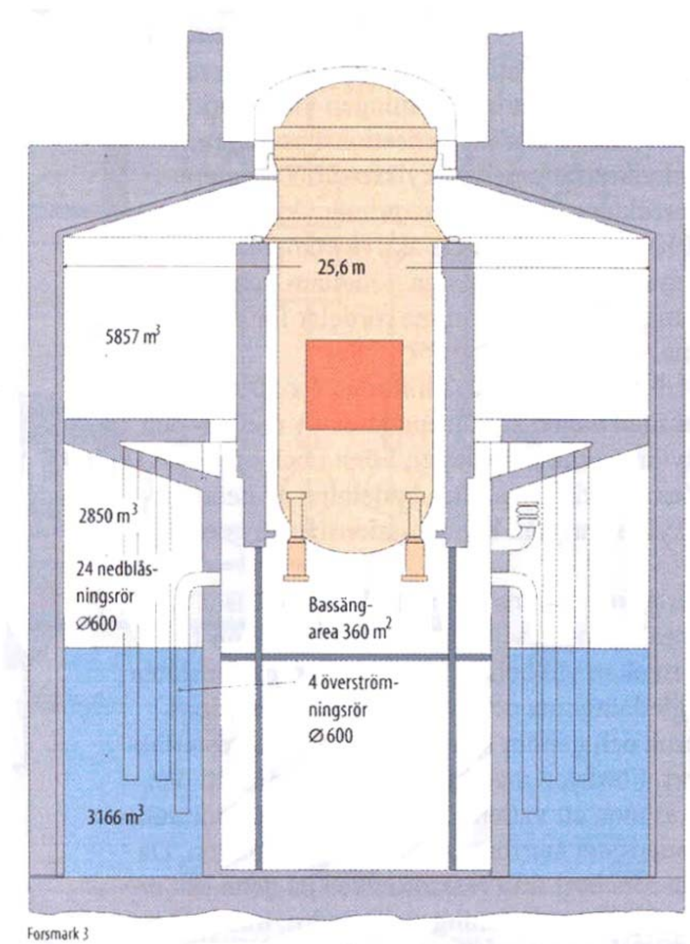




Design features of a Nordic BWR

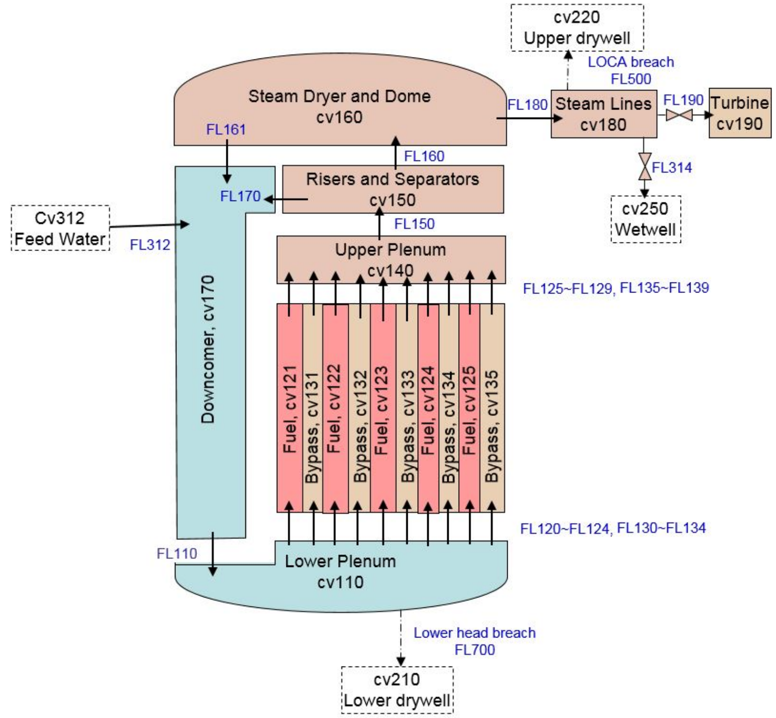
- Thermal power: 3900WMth
- Vessel diameter: 6.4m
- Small containment
  - Volume: 1/5 of that of PWR
  - Inerted with N_2 for H_2 risk
  - Pressure supression with wetwell (condensation pool)
- Forest of penetrations

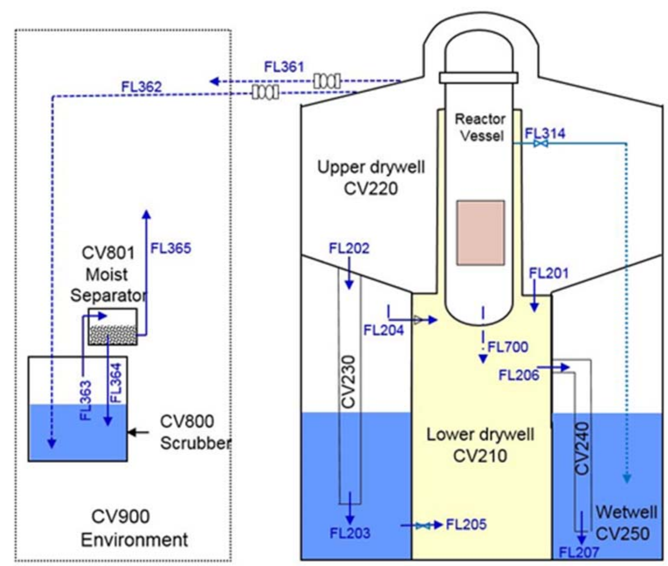




MELCOR Modelling

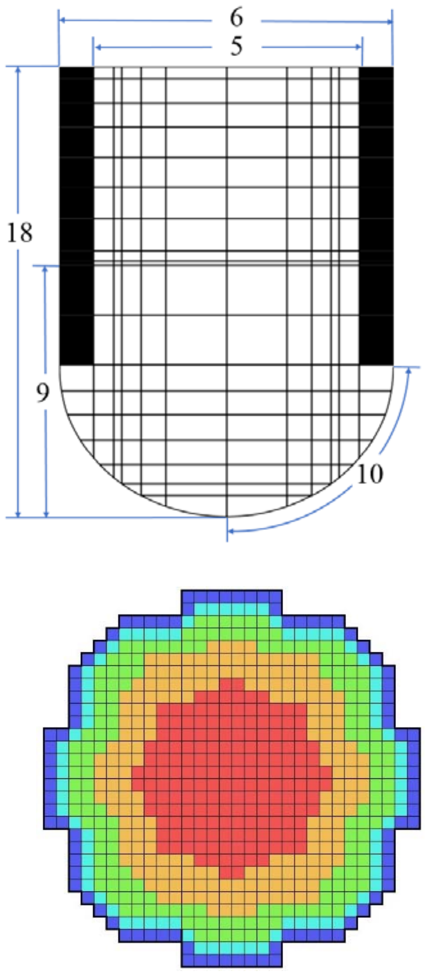
- MELCOR 2.2.9541 is used for the integral simulation of the whole plant.
- A 2D axisymmetric geometry is used to model the RPV.
- A hemisphereical shape is used to model the lower head.
- Penetrations failure deactivated.
- Scenarios: Station Blackout (SBO); SBO combined with LBLOCA.



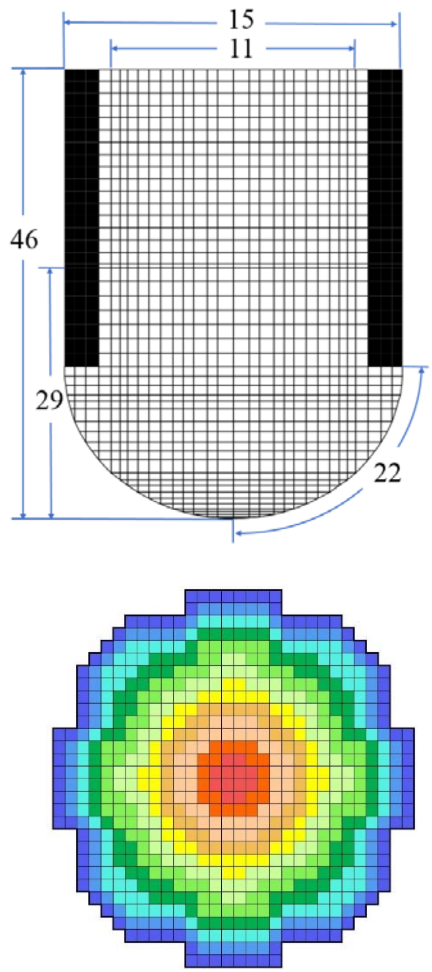


Three core meshing shemes

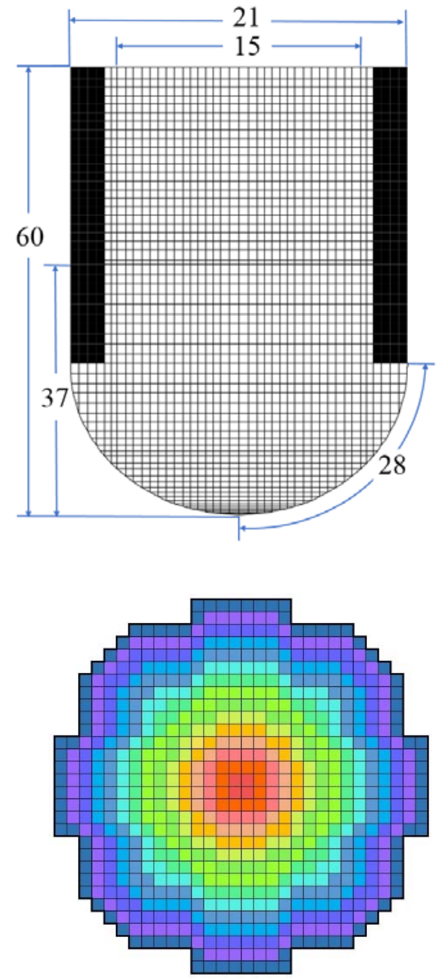
Coarse mesh
6rings X 18levels



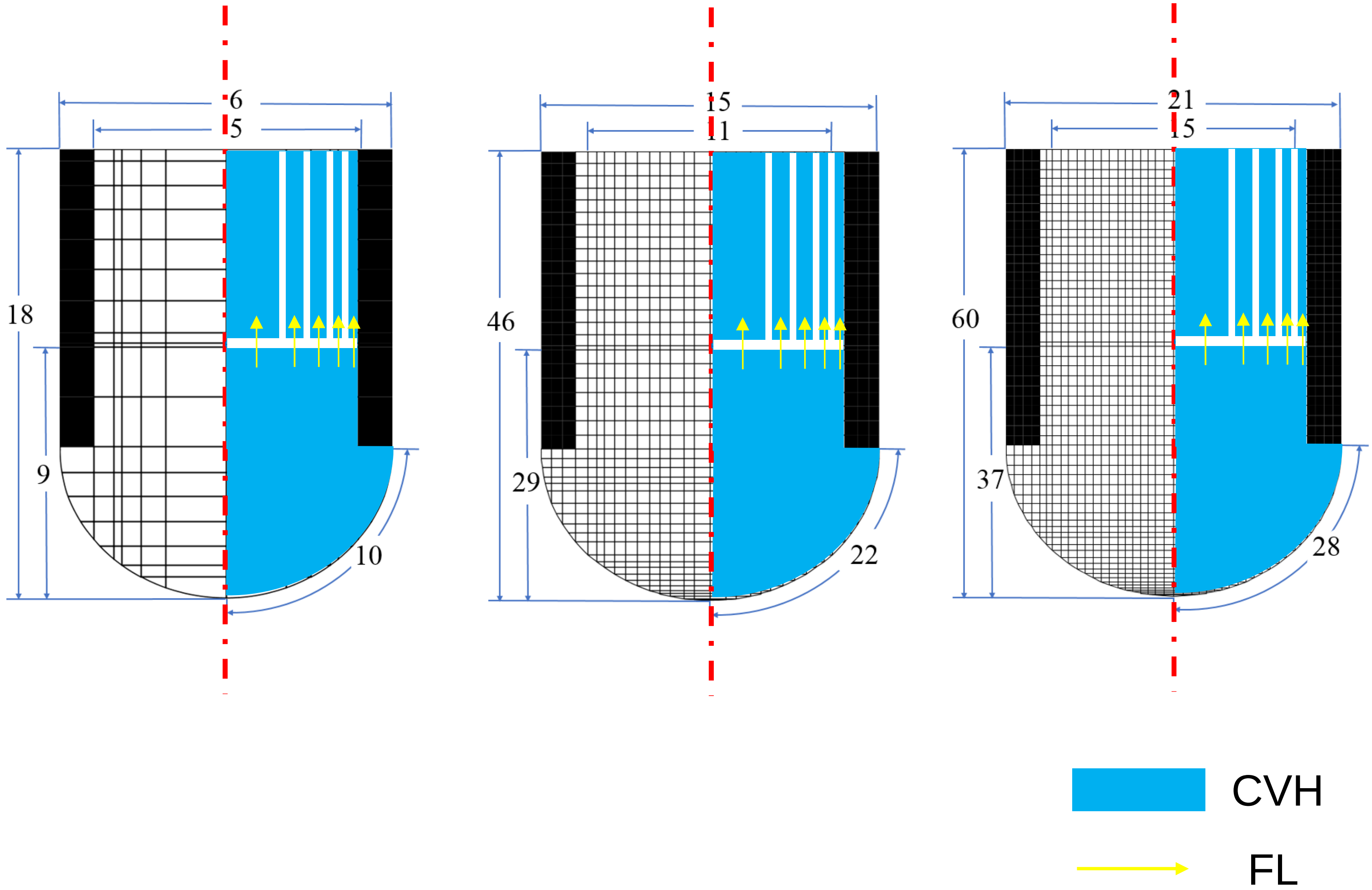
Medium mesh
15rings X 46levels



Fine mesh
21rings X 60 levels



Three core meshing shemes

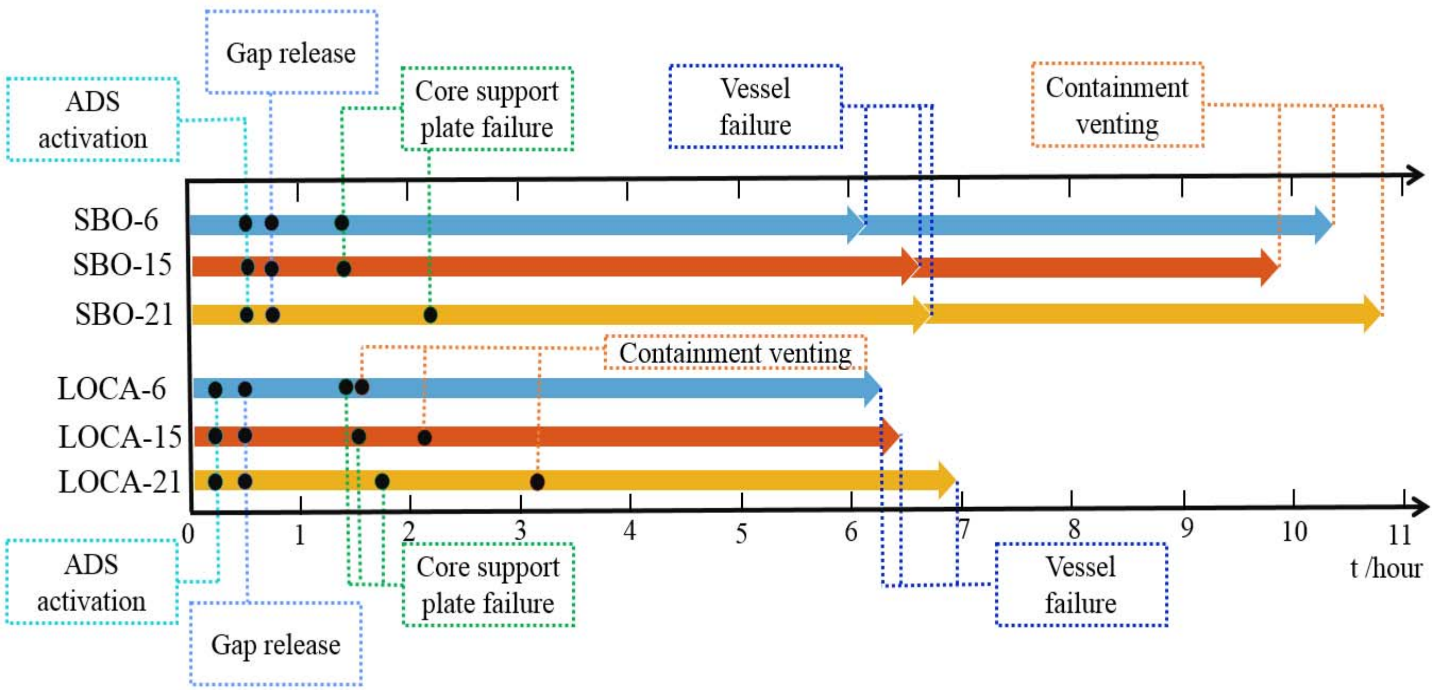


MELCOR calculation results

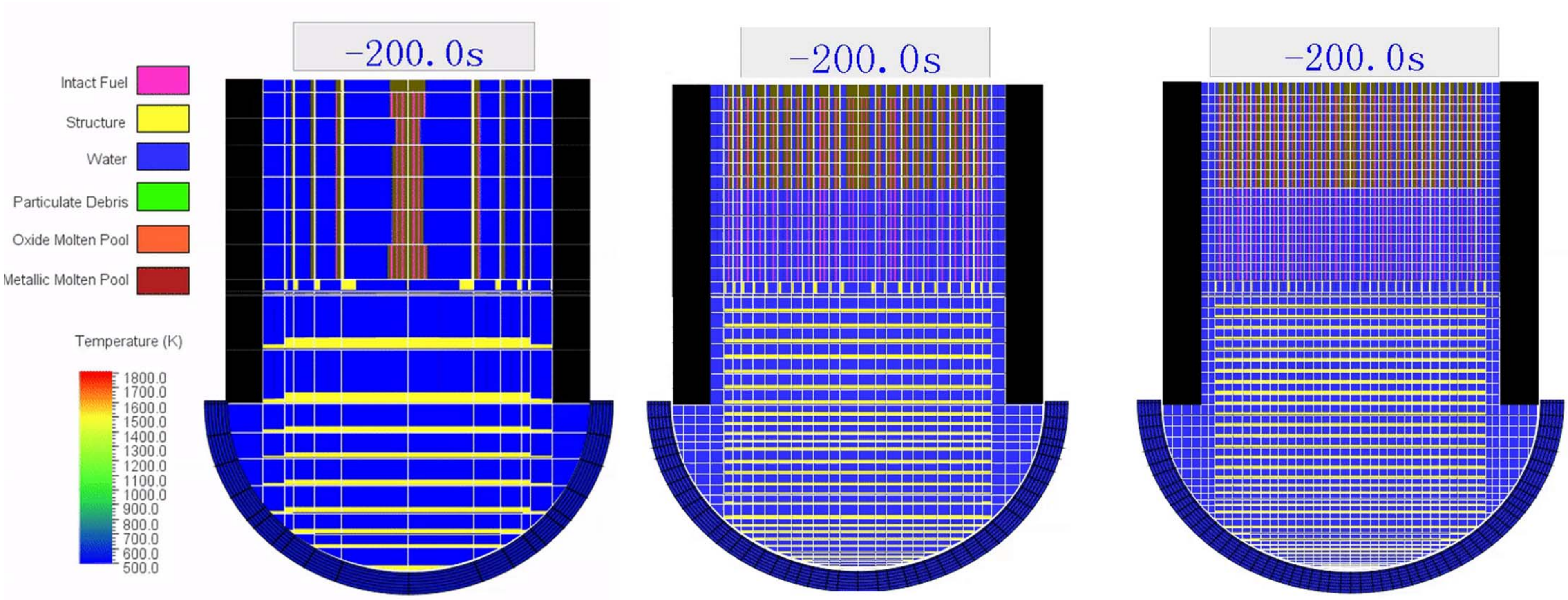
- Calculation matrix
  - ➢ Station Blackout (SBO)
  - ➢ SBO with large break LOCA at steamline with area of $0.1 m^2$

	SBO	SBO+LOCA
6-ring	SBO-6	LOCA-6
15-ring	SBO-15	LOCA-15
21-ring	SBO-21	LOCA-21

- Accident progression

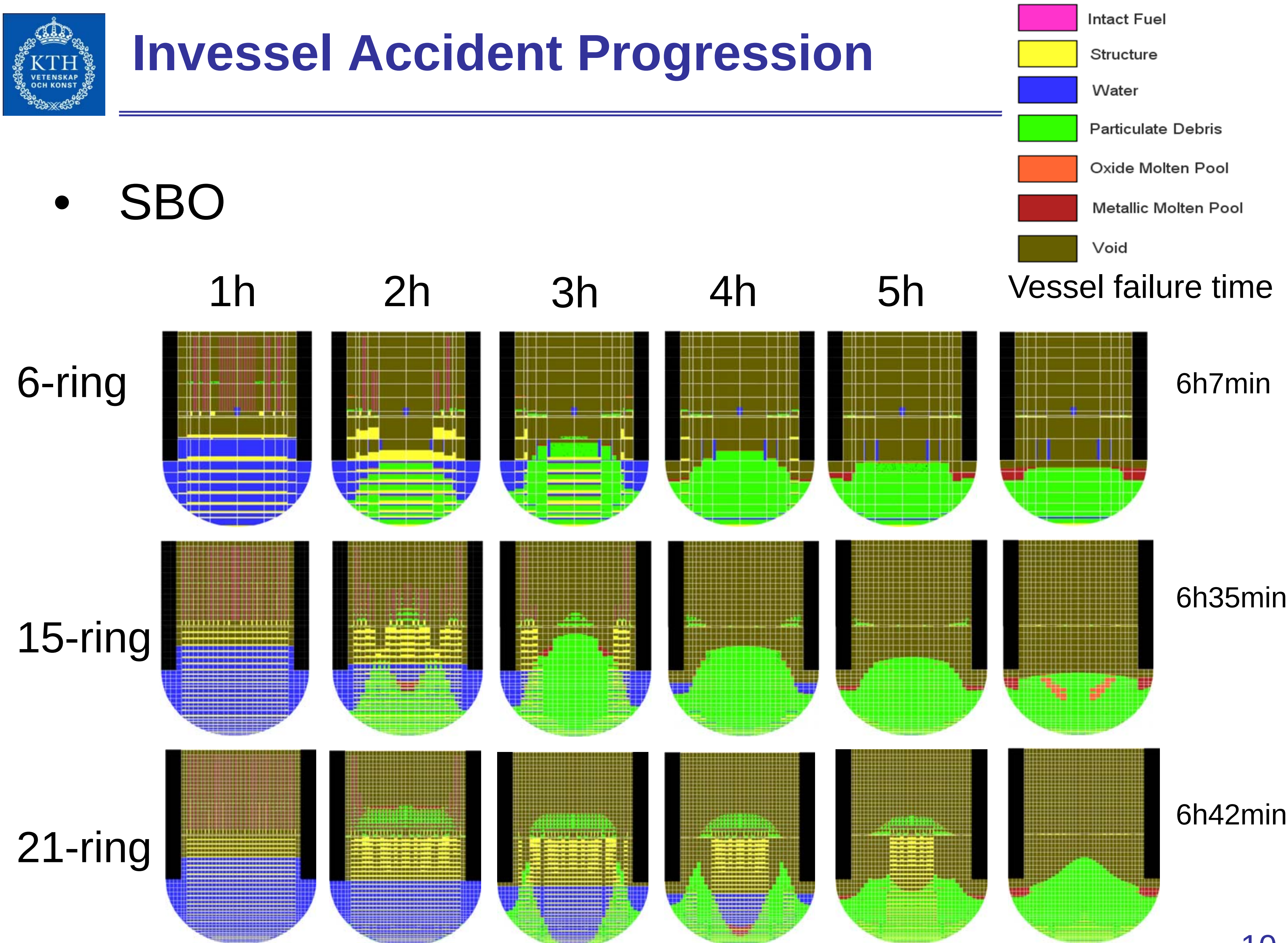


Invessel Accident Progression

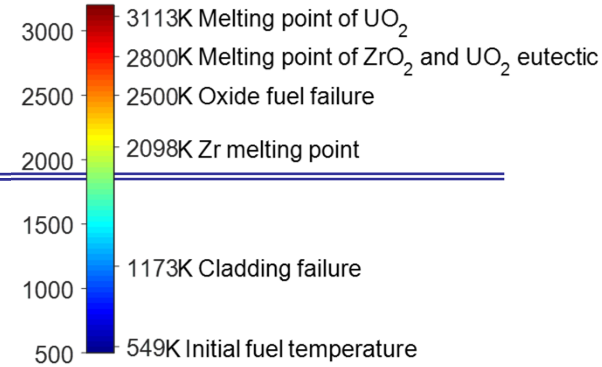


Invessel Accident Progression

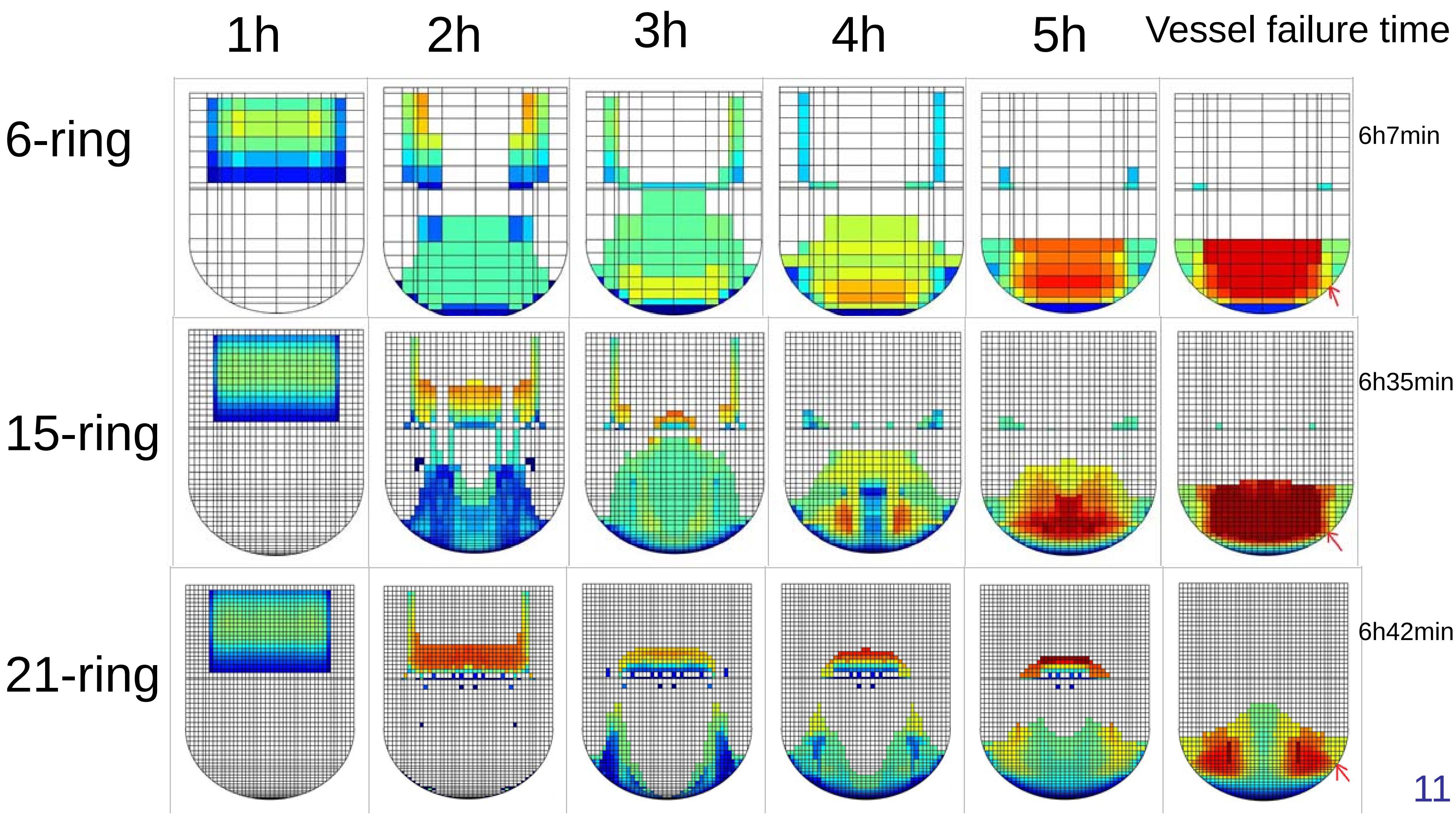
- SBO



Invessel Accident Progression

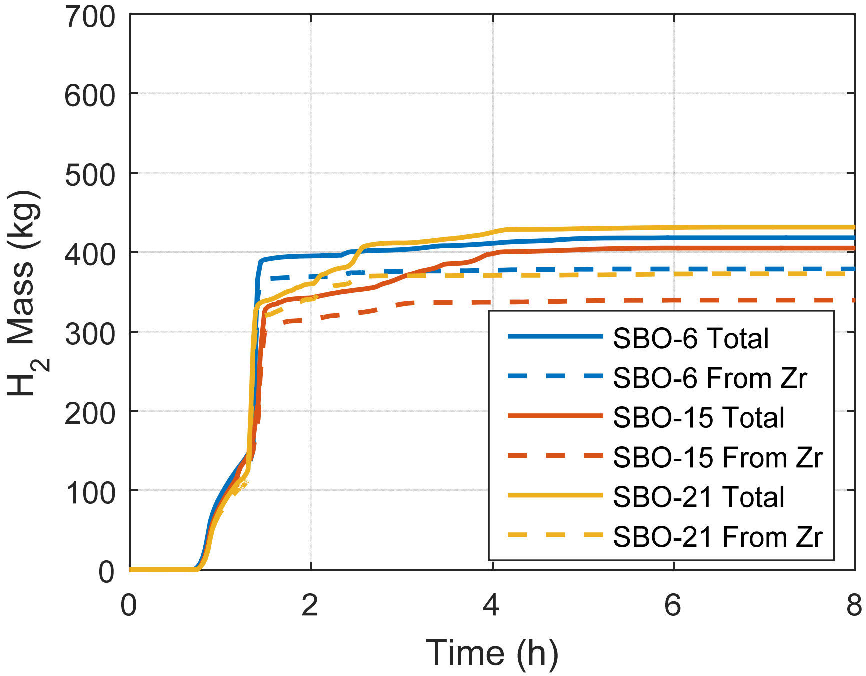


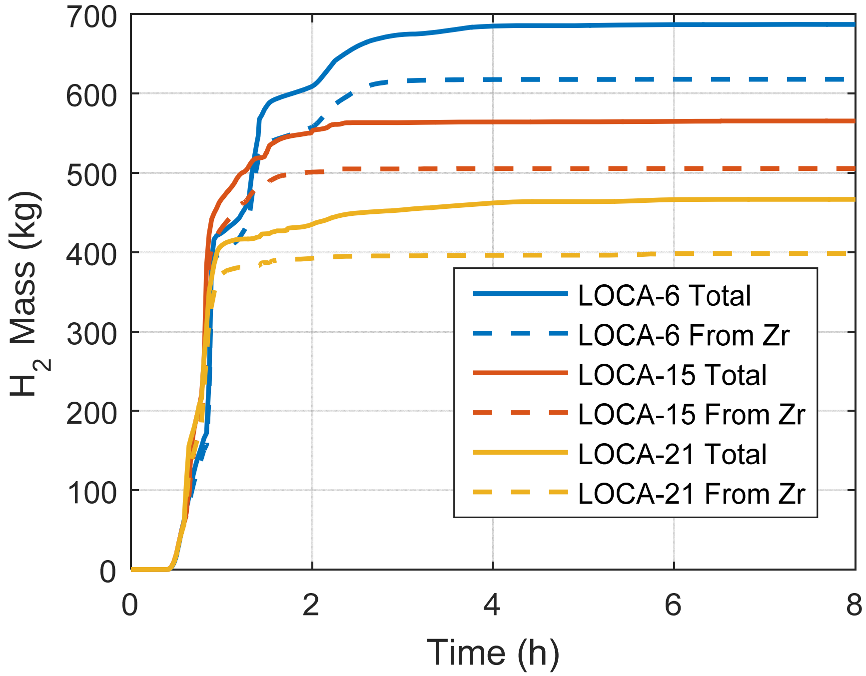
- SBO



H_2 generation

- SBO
- LOCA

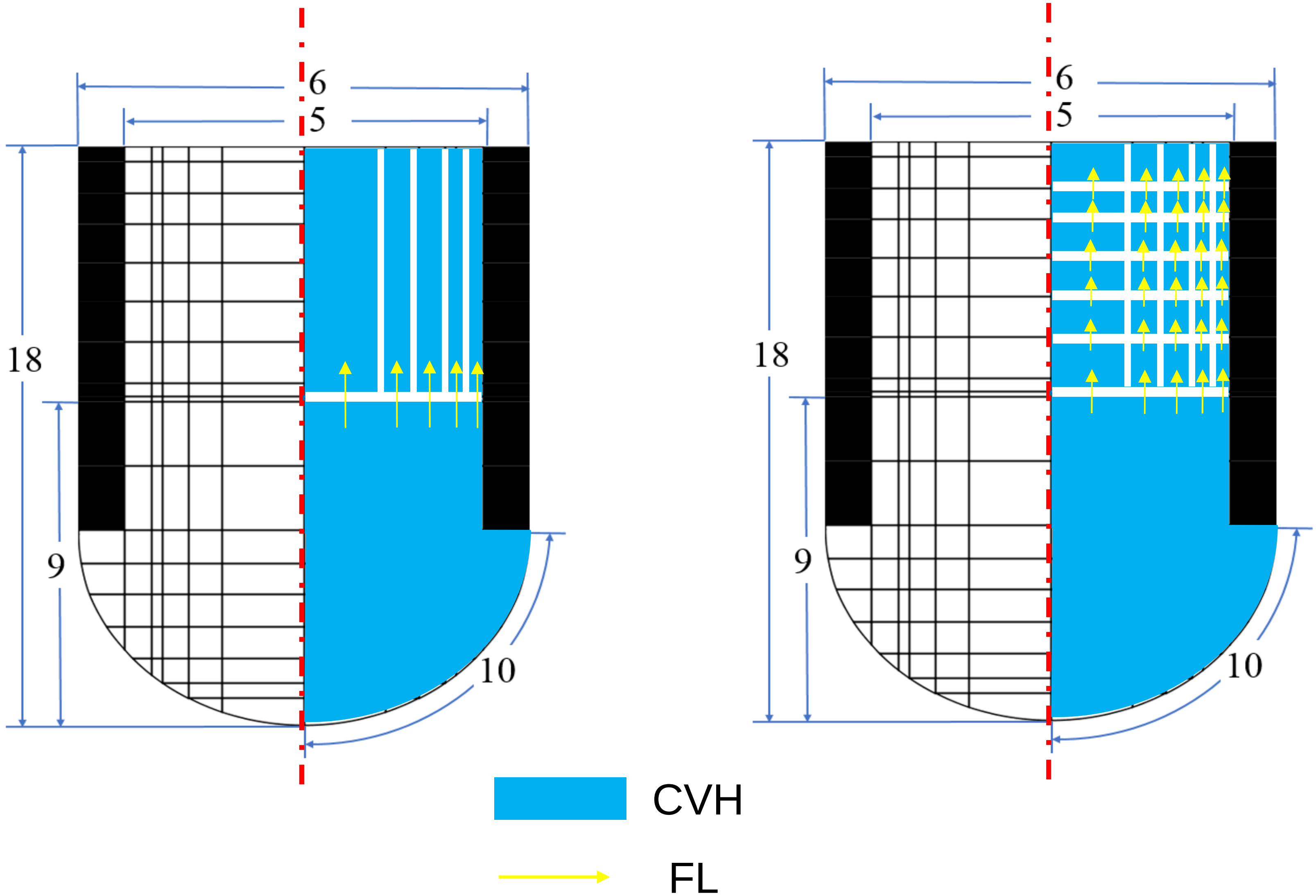




Reference:
Y. Chen, H. Zhang, W. Villanueva, W. Ma, and S. Bechta, 'A sensitivity study of MELCOR nodalization for simulation of in-vessel severe accident progression in a boiling water reactor', Nuclear Engineering and Design, vol. 343, pp. 22–37, 2019.

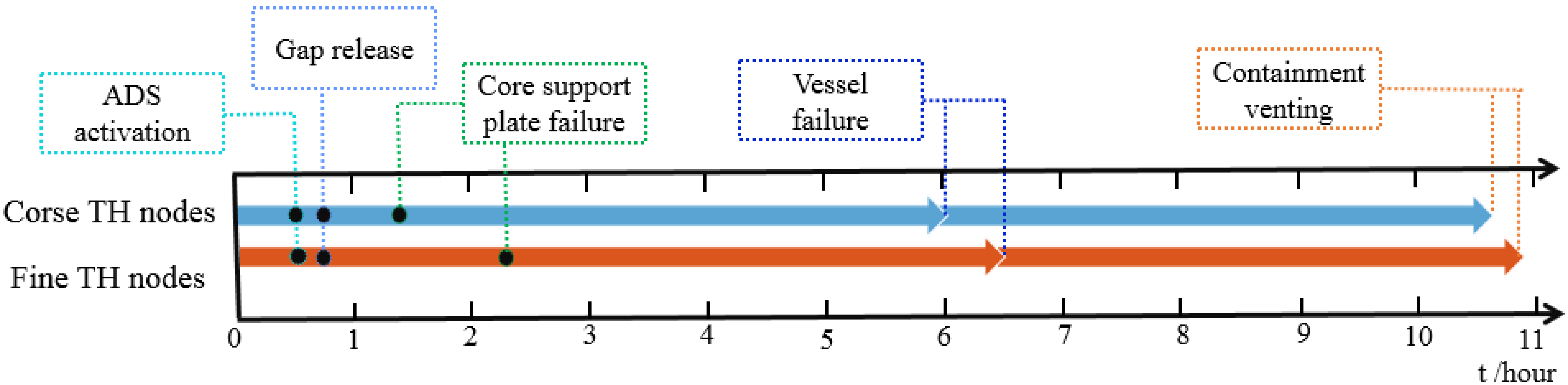
Fine TH nodalization for the core

- More axial levels



Results

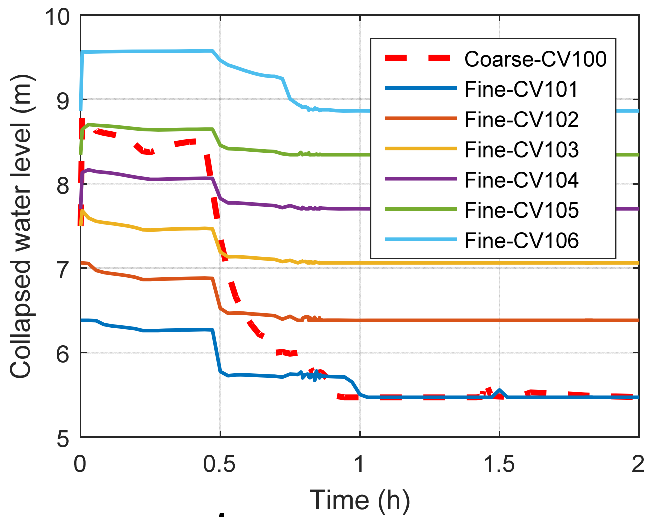
- Accident progression

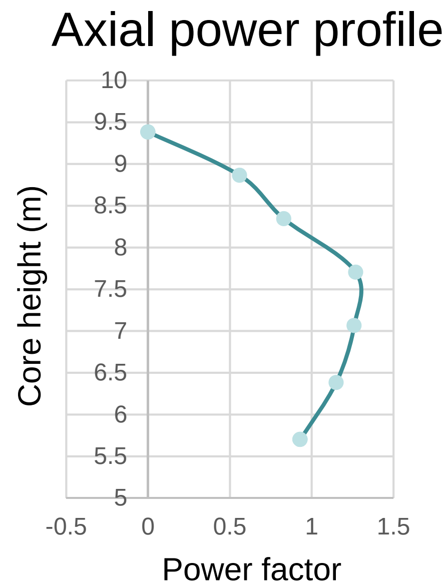


Main event	Corse nodes	Fine nodes
Initial accident	0	0
Downcommer low water level signal	0.30h	0.32h
ADS activation	0.47h	0.49h
Gap release	0.76h	0.81h
Core support plate failure	1.44h	2.20h
Vessel failure	6.07h	6.52h
Containment venting	10.75h	10.91h

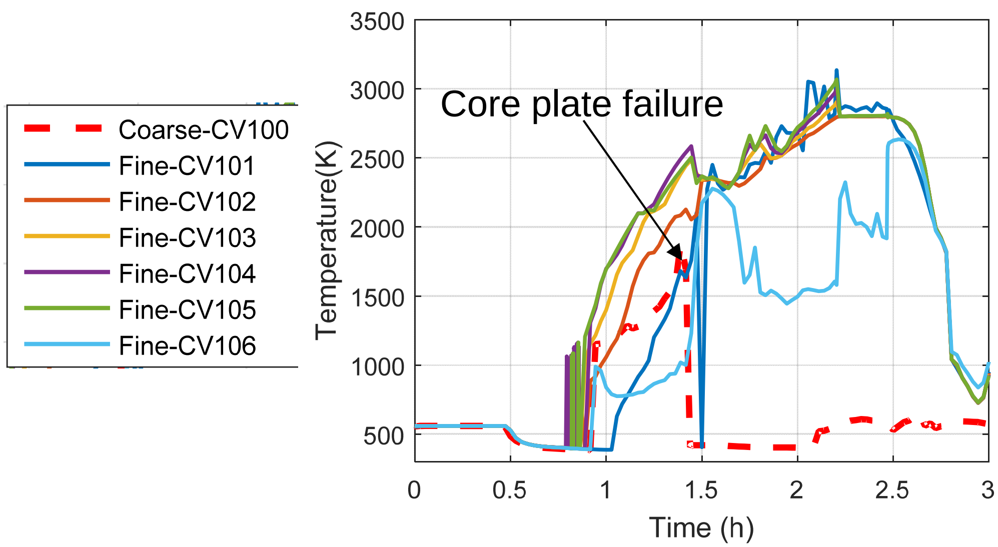
Results

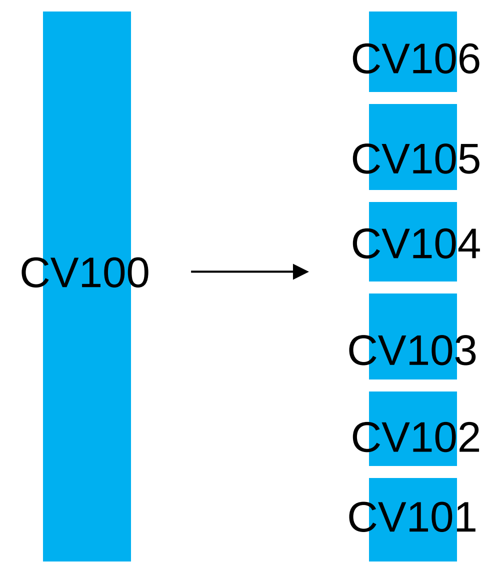
- CV Water level





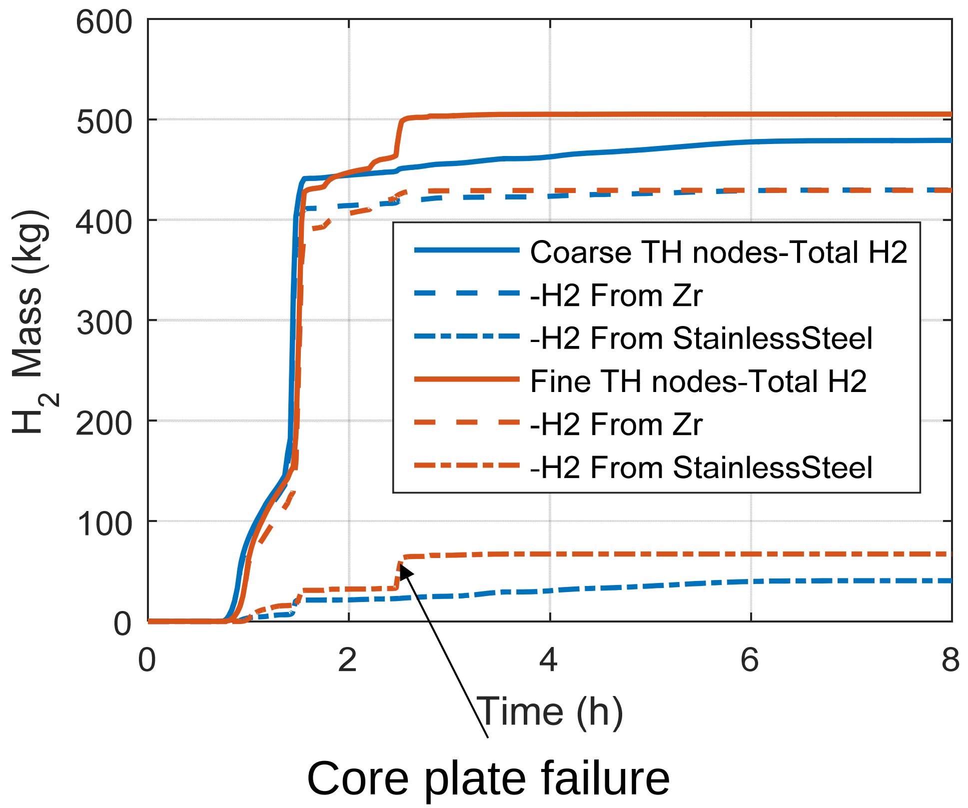
- CV Temperature





Results

- H_2 generation
  - Fine TH nodalization leads to little more H2 generation.
  - H2 from Zr oxidation is similar.
  - Difference comes from stainless steel oxidation which is intense at plate failure of fine TH node case.



Concluding Remarks

- A previous study discusses the effect of core nodalization on the in-vessel progression of a Nordic BWR
  - Three meshing schemes and two accident scenarios considered.
  - Main events during the accident progression is slightly delayed in finer mesh.
  - H_2 generation is scenatio-based.

- A continuous study taking the TH nodalization into account
  - The TH nodalization for the 6-ring core mesh case is refined axially.
  - Main events is also slightly delayed with finer TH nodalization, especially the core plate failure time.
  - The power distribution affects the water level and CV temperature for finer case.
  - H2 generation is slightly affected.

Perspectives

- Refining the TH nodalization for the 15-ring core mesh case is tried, but the calculation time step decreases to 10^{-4}s.
- The TH nodalization seems not influtiential regarding the in-vessel corium behaviour, therefore for our study interest, it may be not necessary to have finer TH nodalization for the core part.

Acknowledgment

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