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Fuel Assembly Bow DNBR Penalty for VVER-1000 reactors

Tommaso Carnicella, Akif Abdullayev, Ulf Lindelöw

Westinghouse Electric Sweden

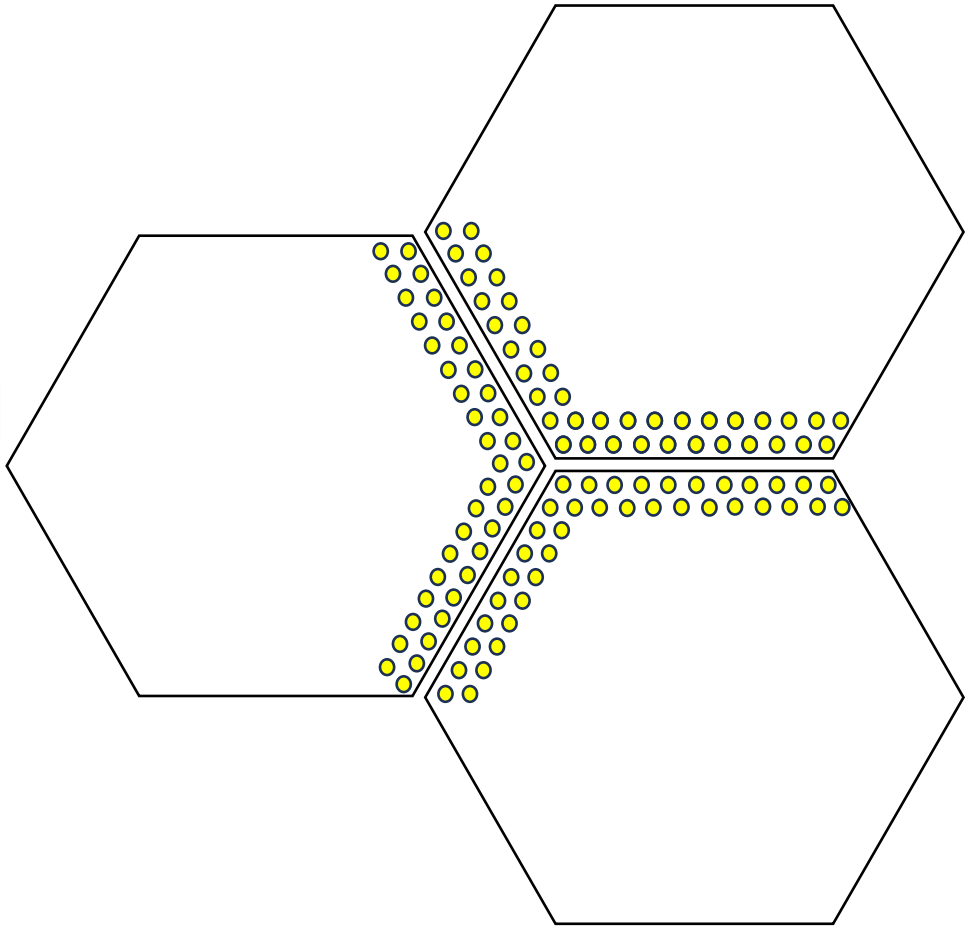
Outline

- Core modelling with increased inter-assembly gap for TH analysis
- Methodology
- Design Limit DNBR Analysis
- Verification of DL DNBR for increased gap conditions
- Results

Full Core Model with increased inter-assembly gap

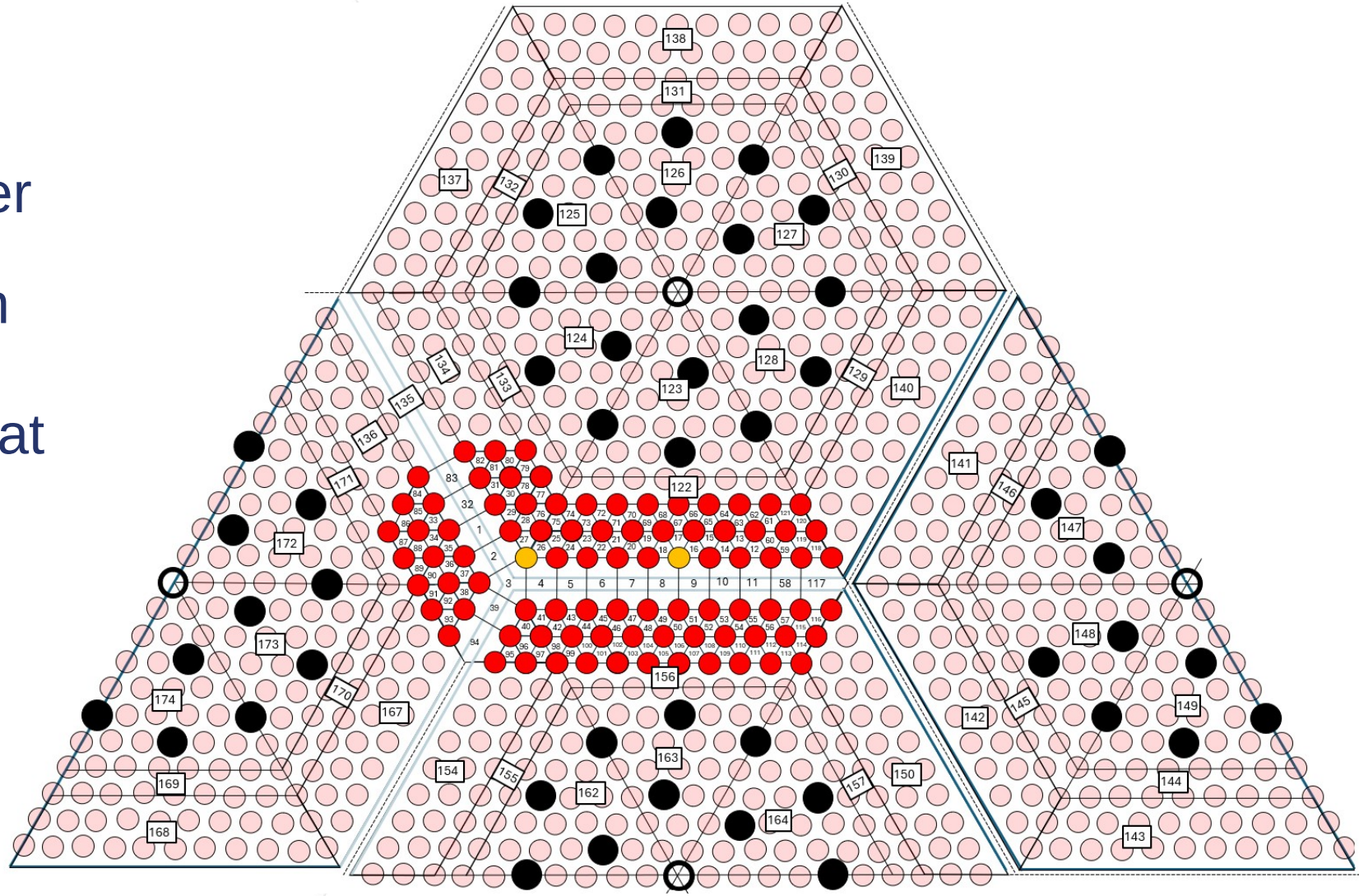
Increase of the inter-assembly gap

- Increased assembly-to-assembly gap impacts to local power and integral rod power due to over-moderation
- Impact on DNB is evaluated for hot channels located at periphery of FA (side and corner)

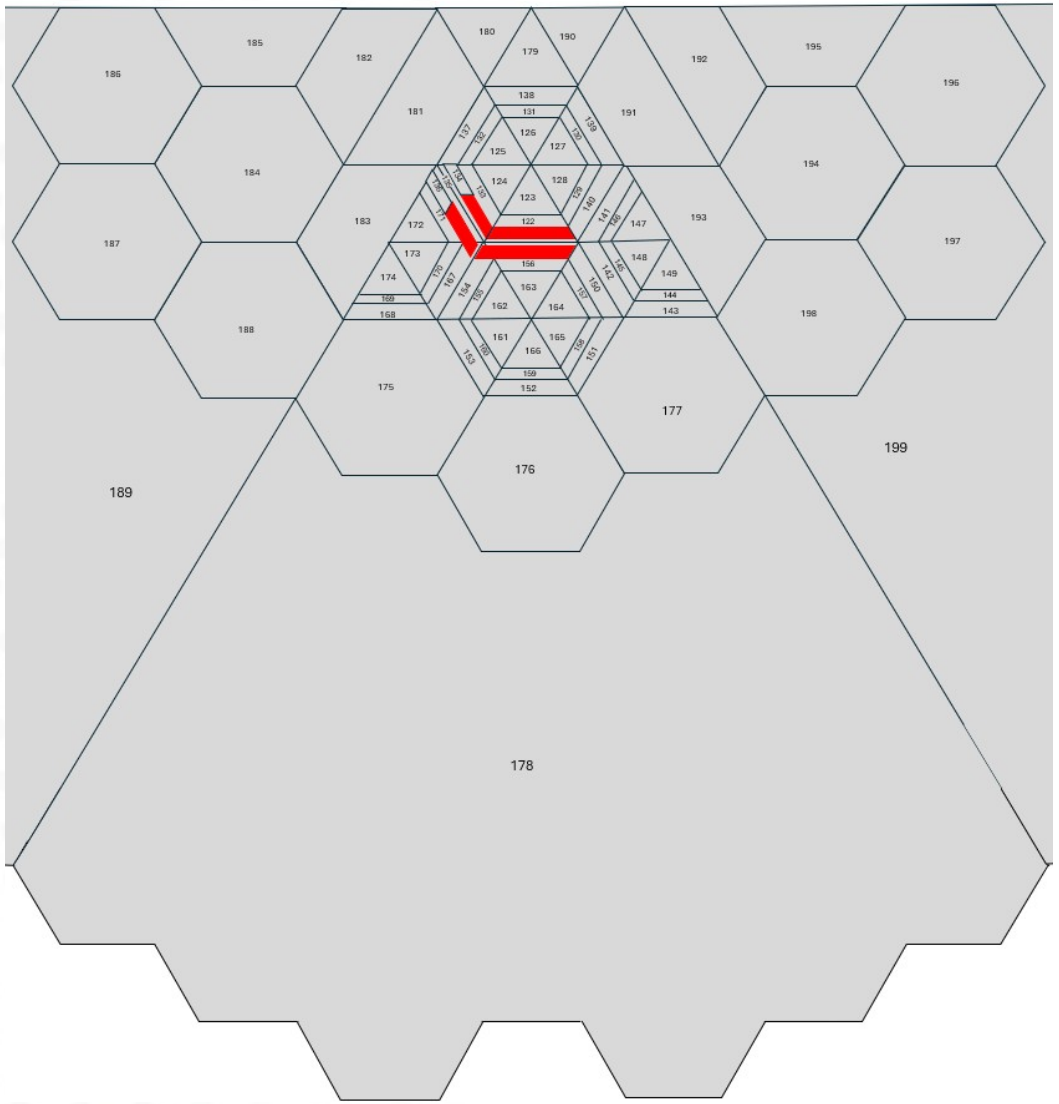


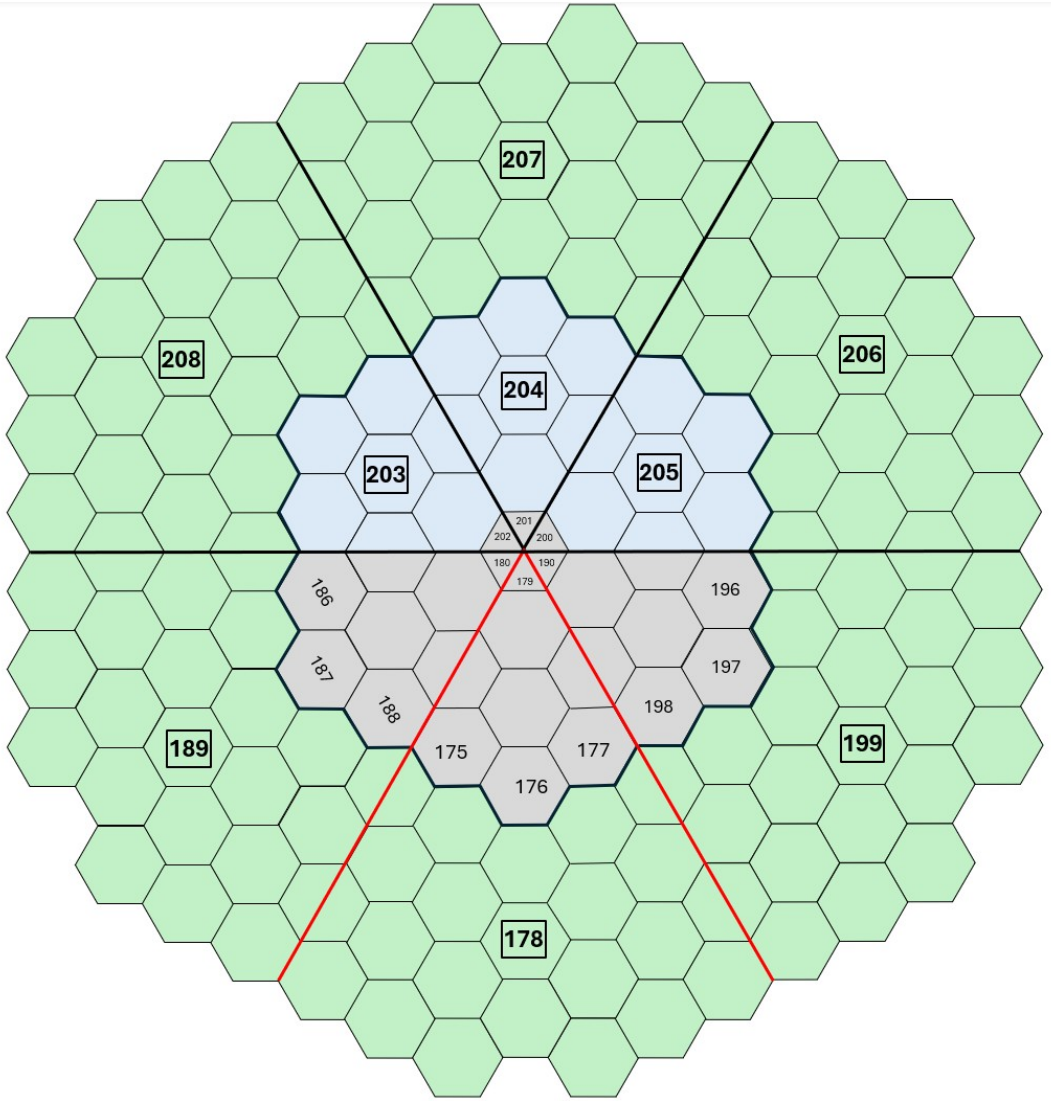
Full Core VVER-1000 Model: 208-channels VIPRE Model

- A VVER-1000 reactor core is modeled in a relatively small number of channels without losing any accuracy in DNBR predictions
- Hot channels located at periphery of FA and their adjacent region are modeled in detail, while the rest of the core is modeled as lumped channels



Full Core VVER-1000 Model: 208-channels VIPRE Model





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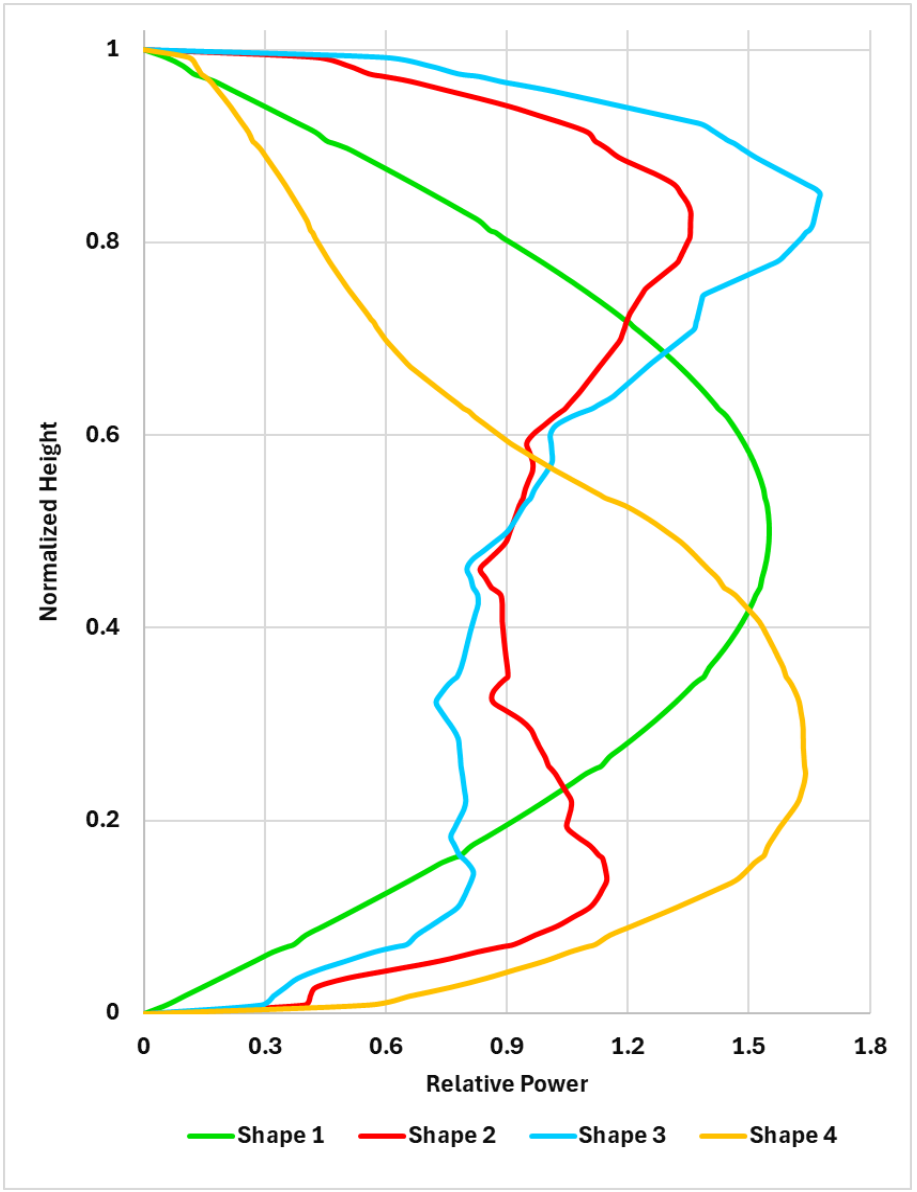
Methodology

Methodology: Statistical DNBR Analysis

Reactor Uncertainties
+
CHF corr. Uncertainty

- DL DNBR for side and corner channels.
- CHF correlation is used for grids with and without vanes
- 10 Reactor Limiting Operational Conditions.
- Power, Pressure, Inlet flow, Inlet Temperature.
- 4 different axial power shapes.
- $F_{\Delta H}^{Design}$
- Hot FAs power $F_{\Delta H}^{Design}$ /1.04 which is the highest FA power.
- $Gap_{nominal}$ = 2mm



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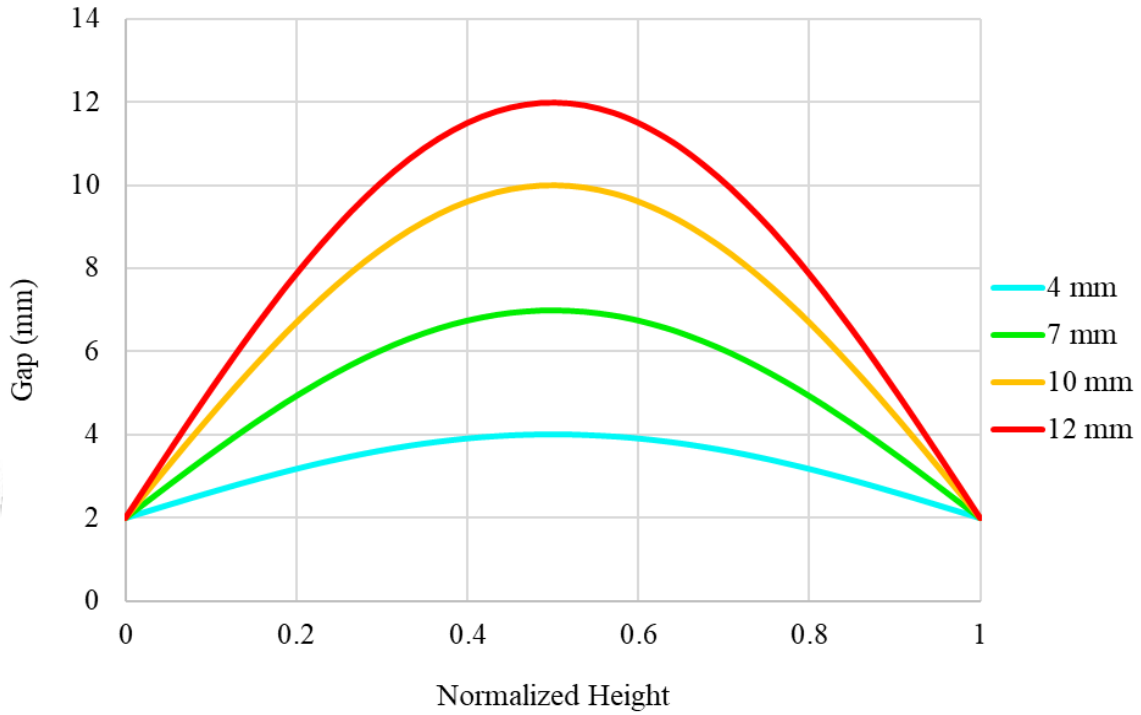
Methodology: Increase of Inter-assembly gap and rods power

- The methodology is applied to all 10 cases.
- The maximum gap has been increased at step of 1mm.
- For each value of max gap, the axial gap distribution has been evaluated as follow
- $$gap(z) = gap_{nominal} + \Delta gap_{max} \sin\left(\frac{\pi z}{H}\right)$$
- Where:

$$gap_{nominal} = 2\ mm$$
$$\Delta gap_{max} = gap_{max,j} - gap_{nominal}$$

- The gap distribution is going to impact the hydraulic parameters of peripherical cells which have been changed consequently.



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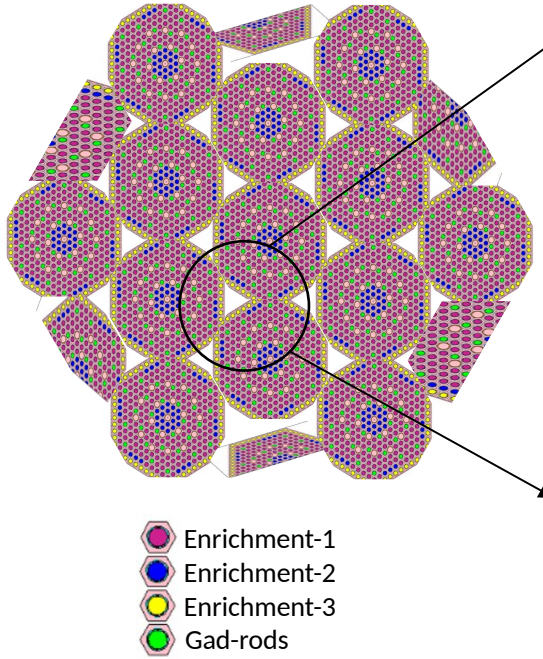
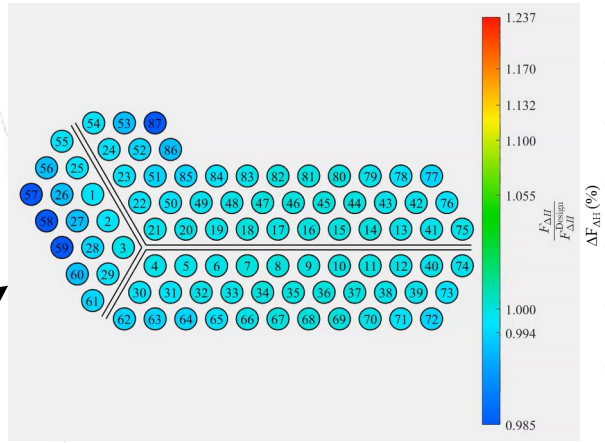
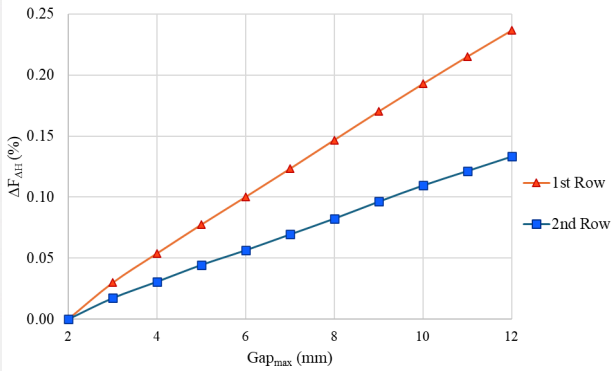
Methodology: Increase of Inter-assembly gap and rods power

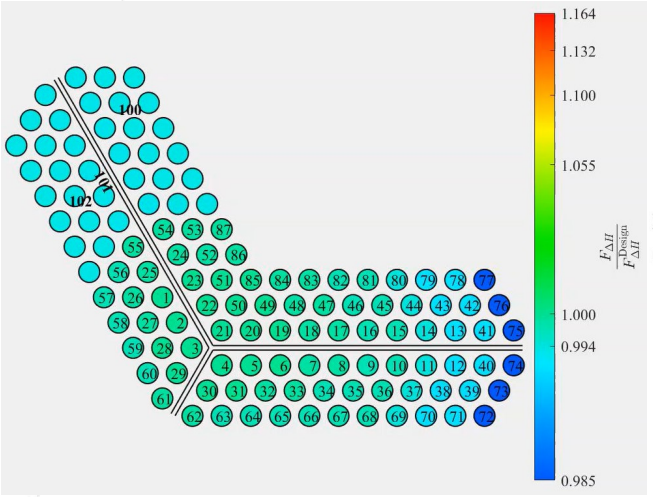
- Mini-Core with 19 FAs with highest reactivity
- Power rods is a function of inter-assembly gap
- MCNP: Monte-Carlo code

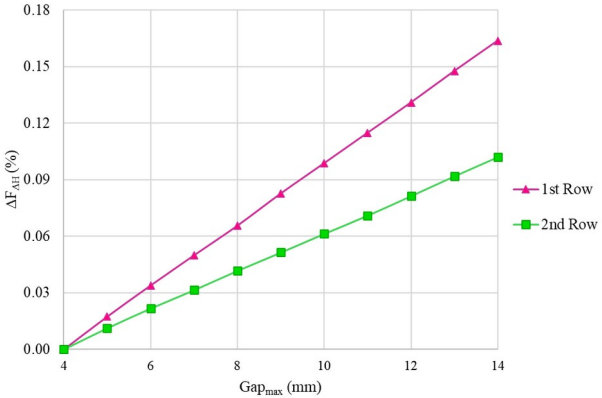






1-sided gap – distance along the normal between opposite faces of adjacent FA





2-sided gap – sum of two distances along the normal between opposite faces of two adjacent FA

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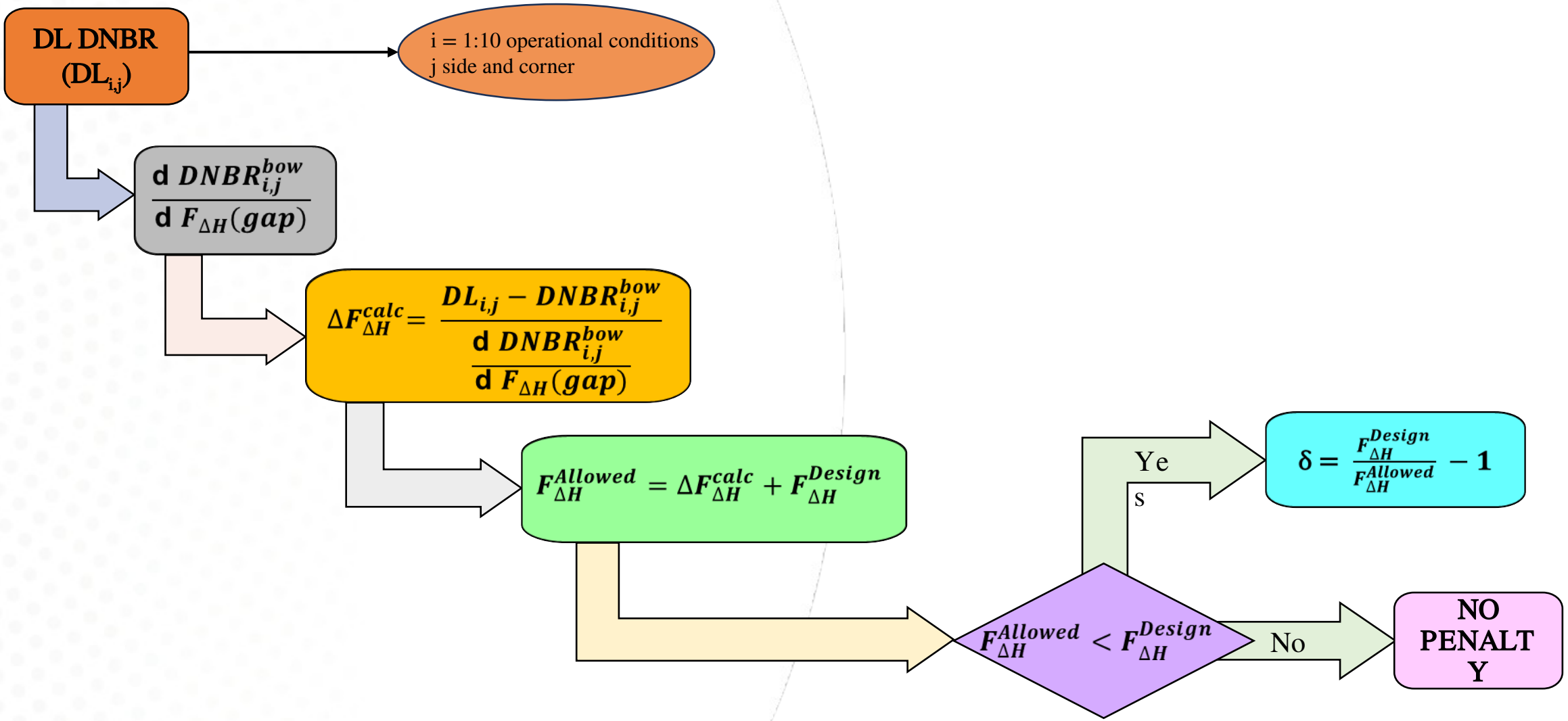
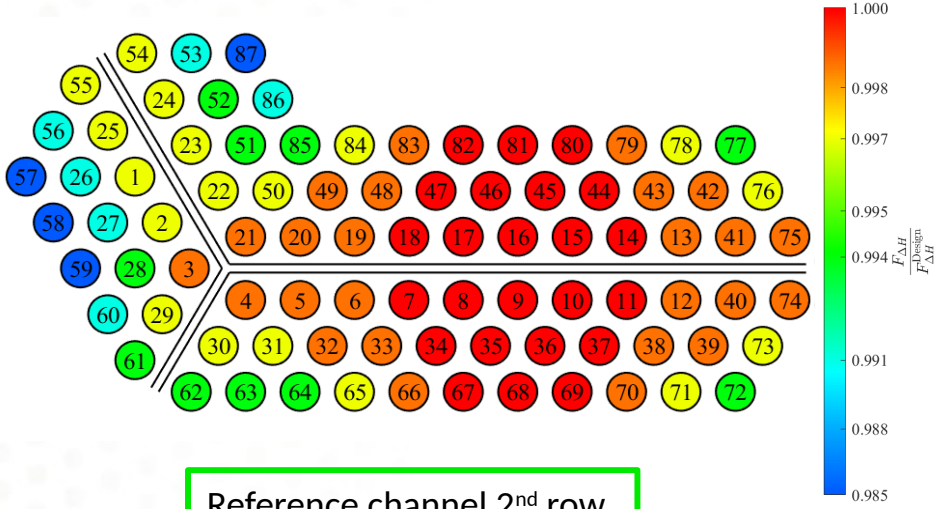
Methodology: $F_{\Delta H}$ penalty (δ)

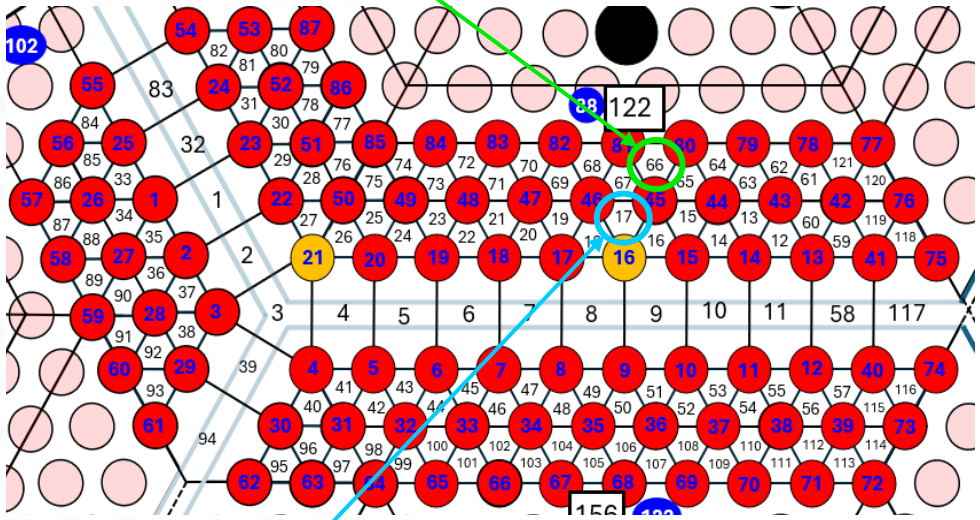


Verification of DL DNBR for increased gap conditions

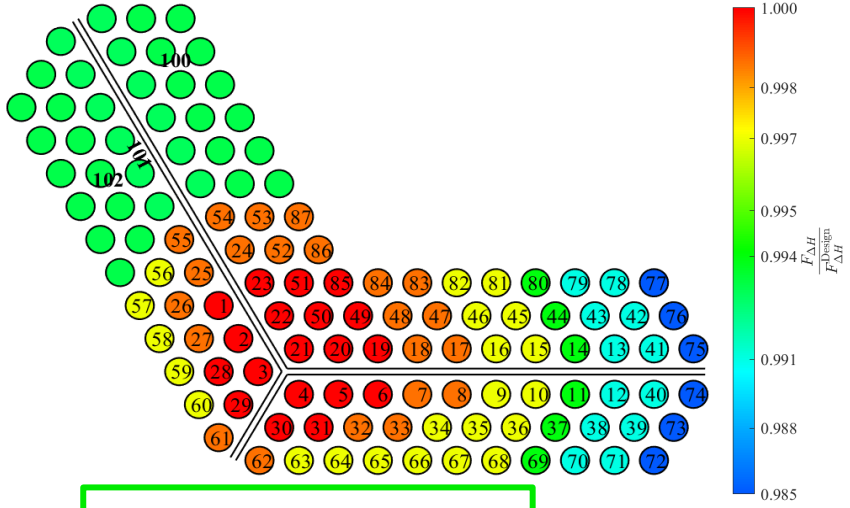
Verification of DL DNBR: Reference cases



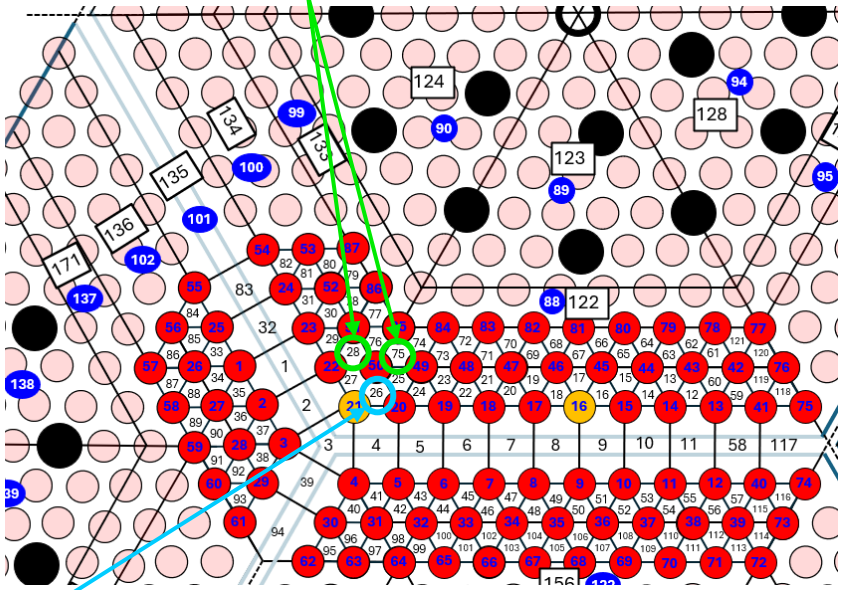
Reference channel 2nd row



Reference channel 1st row



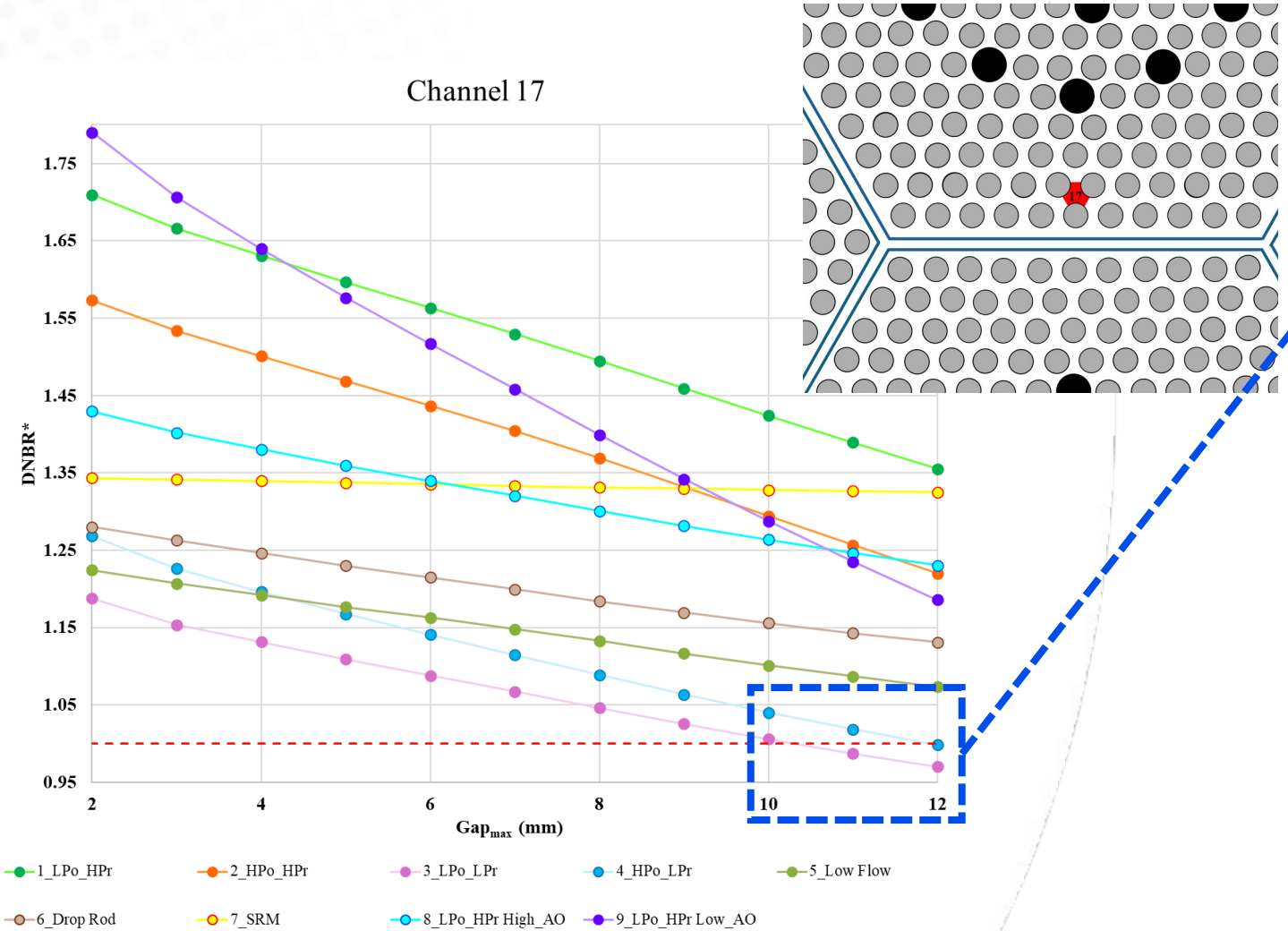
Reference channel 2nd row

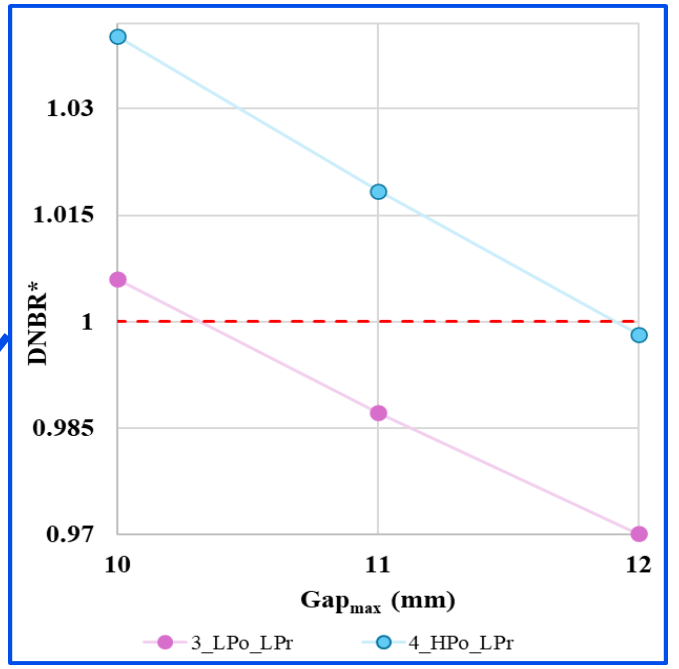


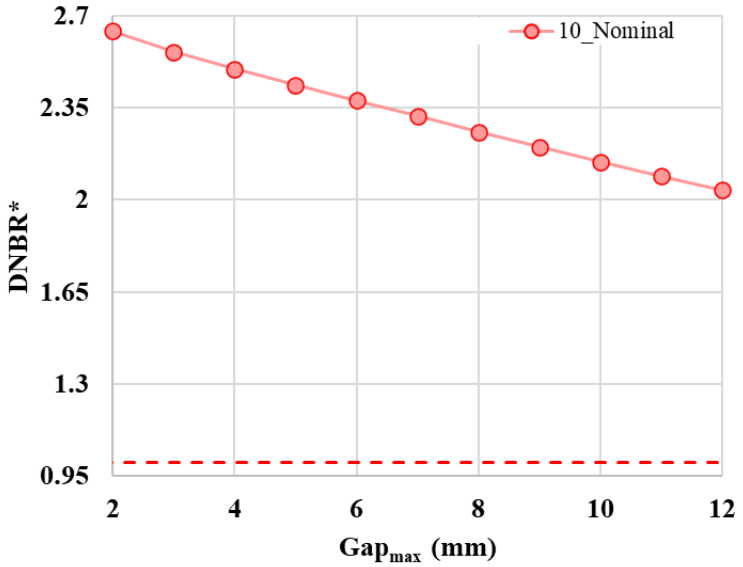
Reference channel 1st row

Verification of DL DNBR: Side 1st row

- Introduction of new variable: $DNBR^* = \frac{DNBR_{bow}}{DL\ DNBR}$







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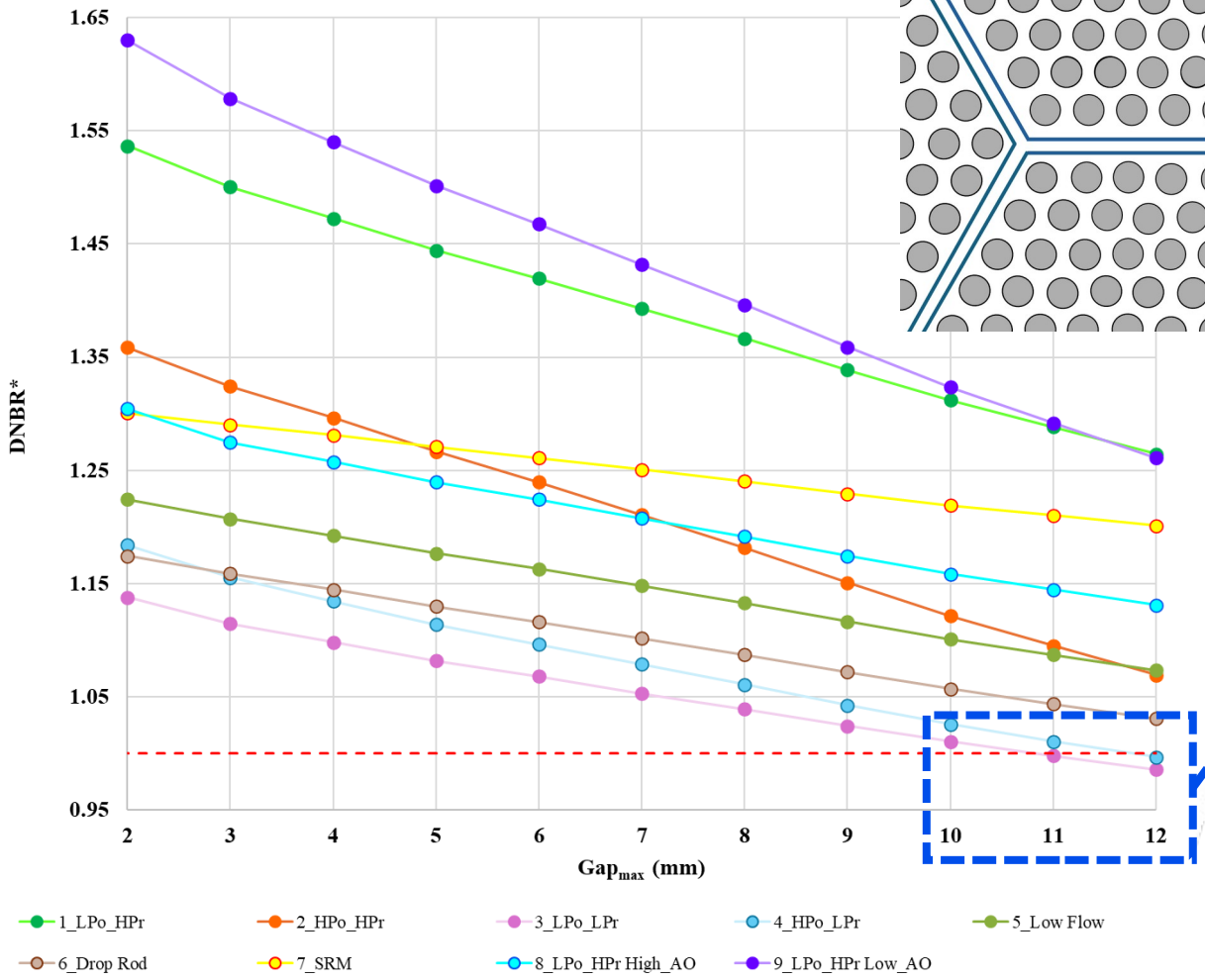
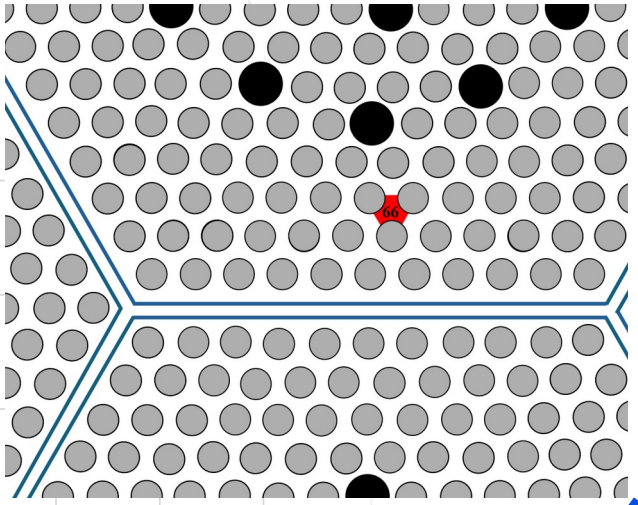
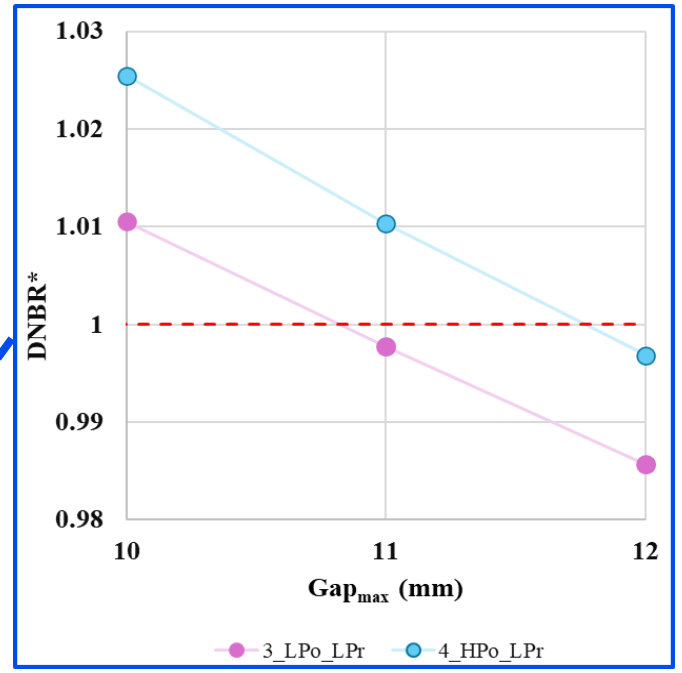
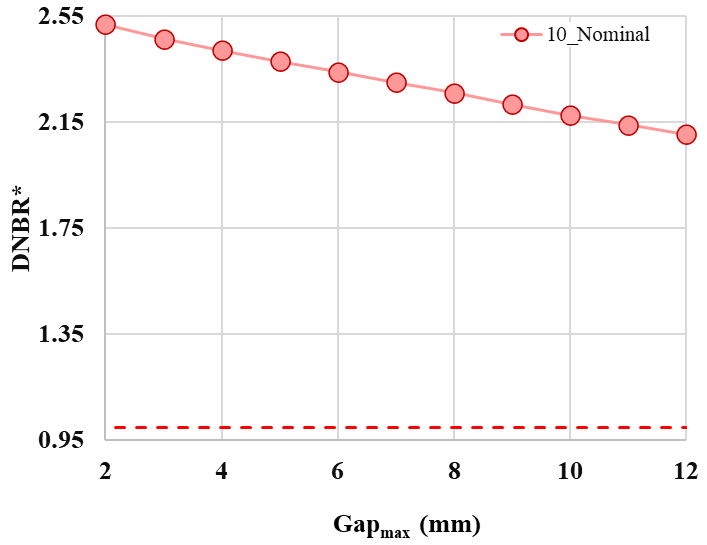
Verification of DL DNBR: Side 2nd row









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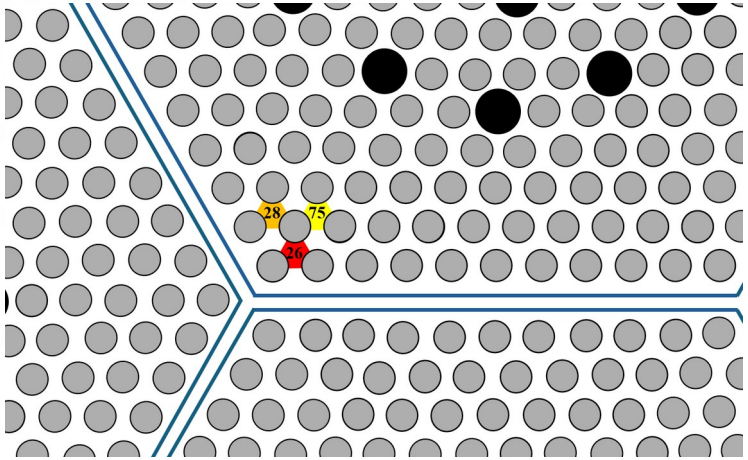
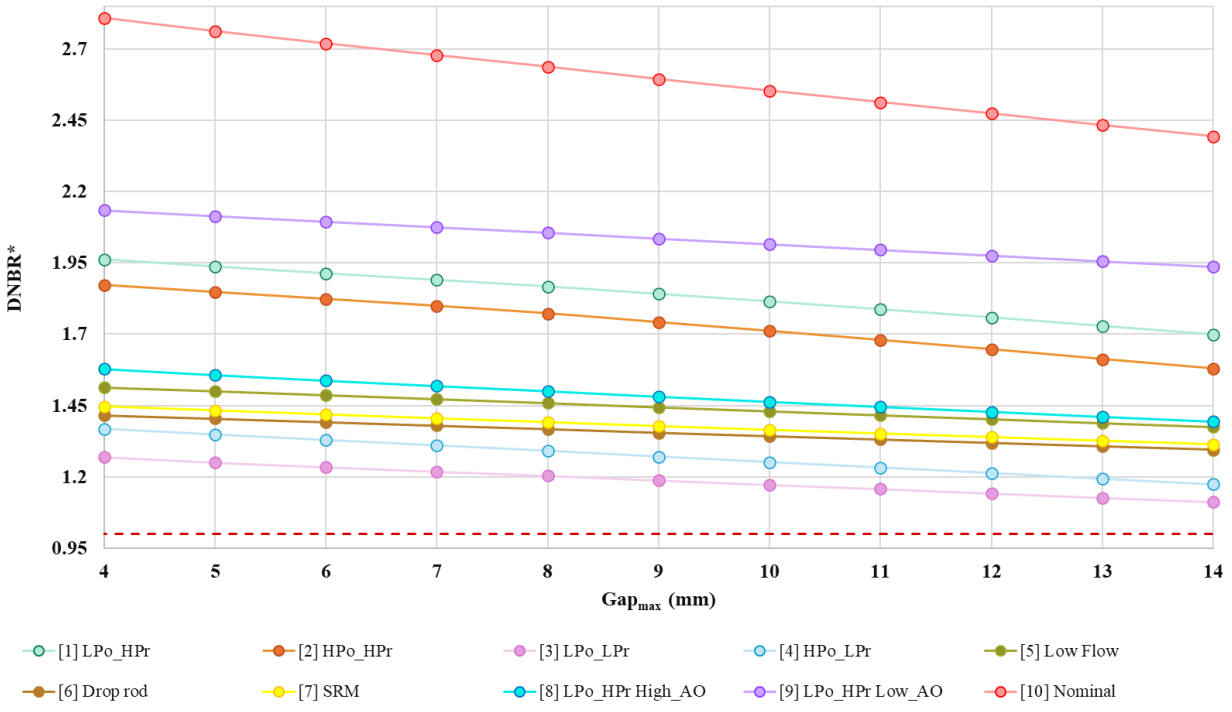
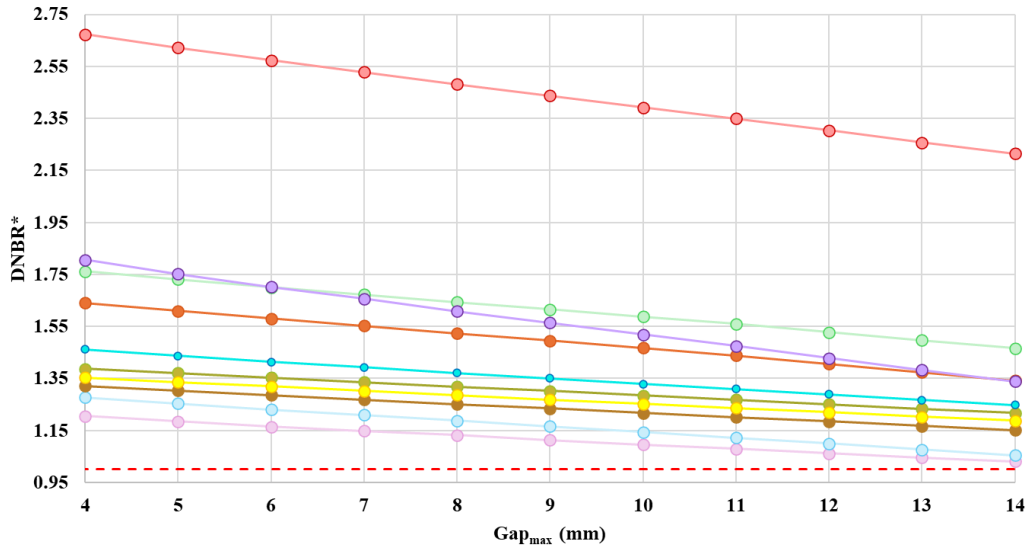
Verification of DL DNBR: Corner



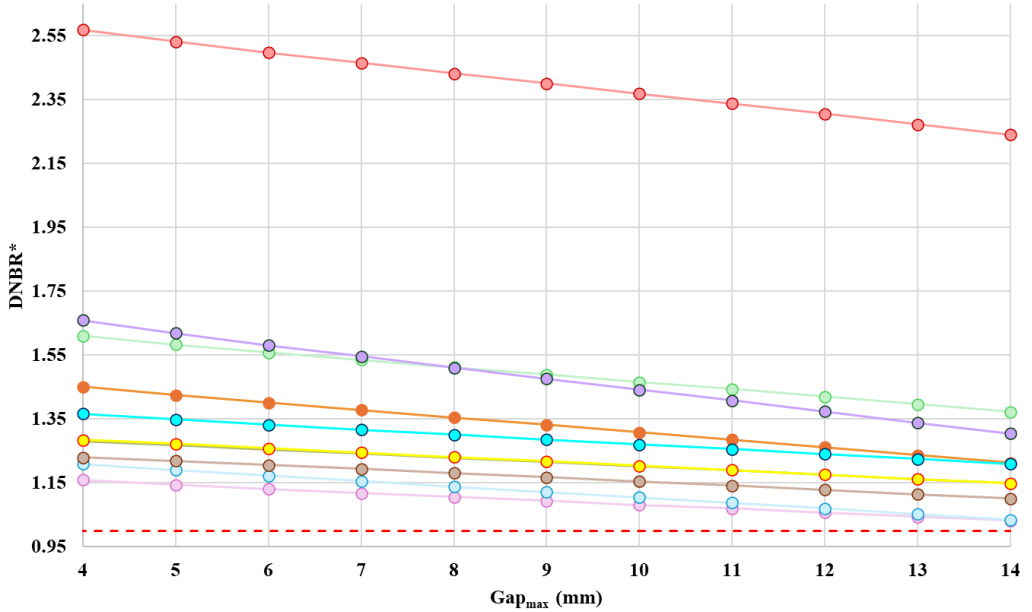
Channel 26



Channel 28



Channel 75



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Results

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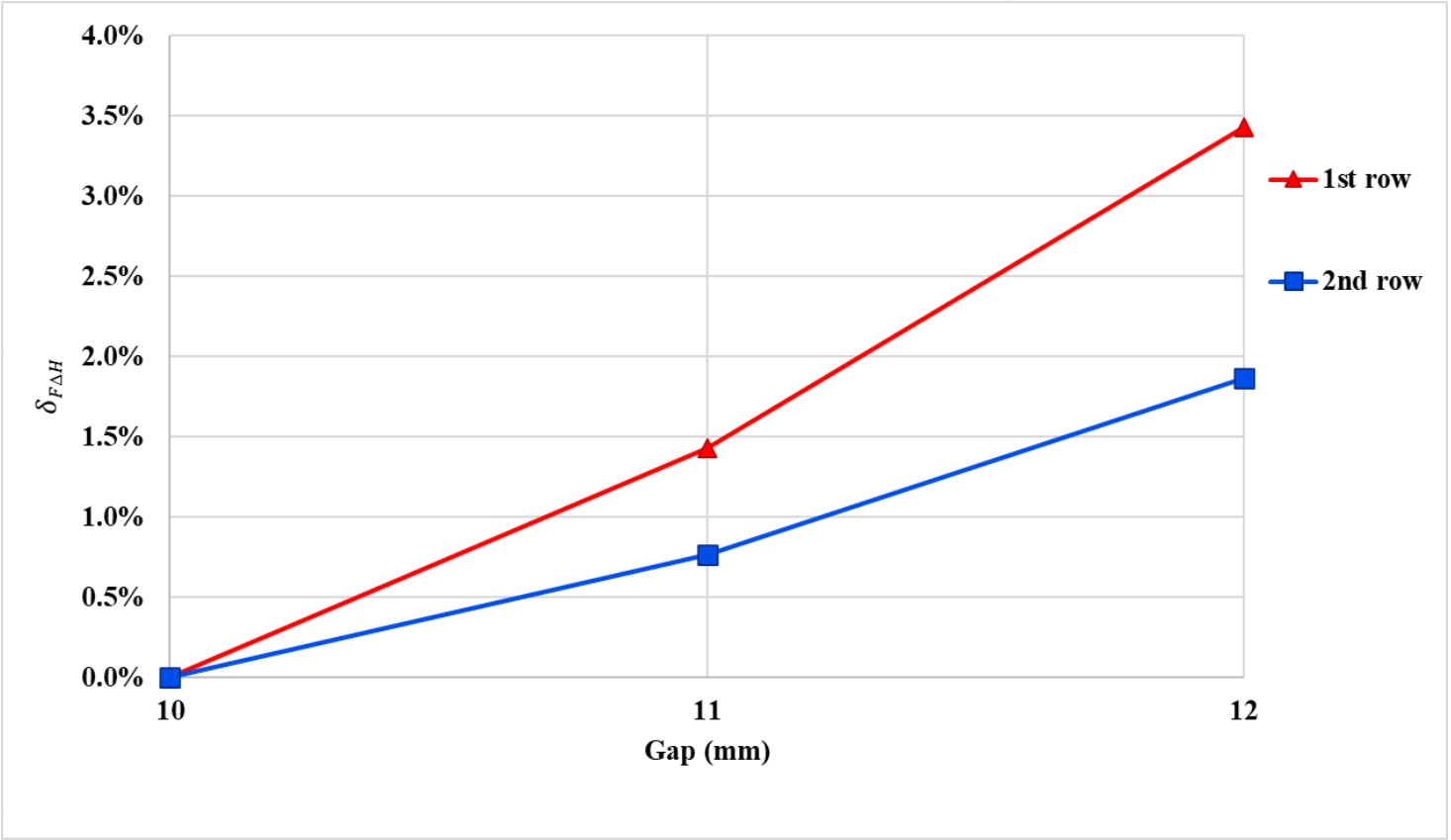
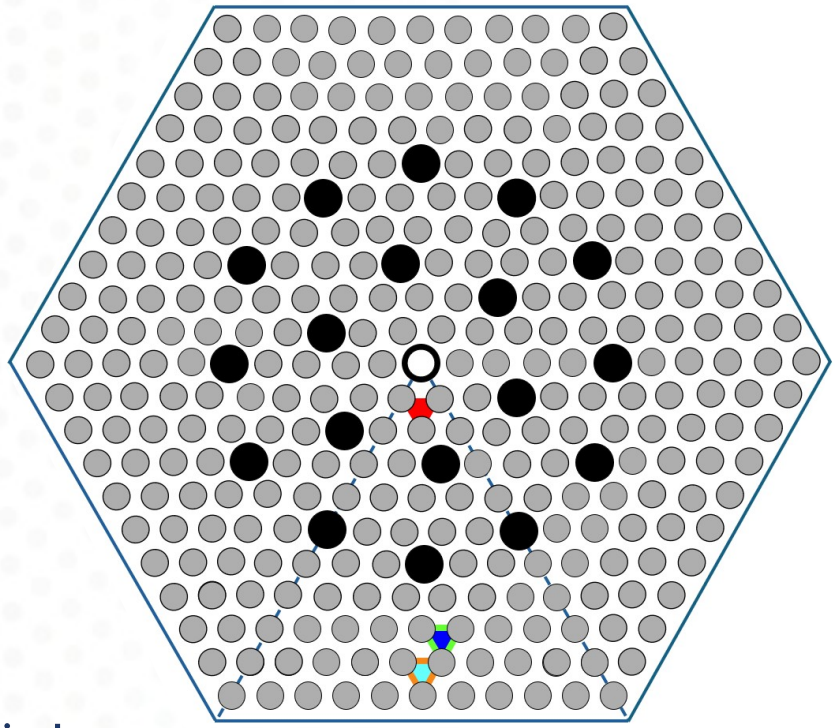
Results: $F_{\Delta H}$ penalty (δ)

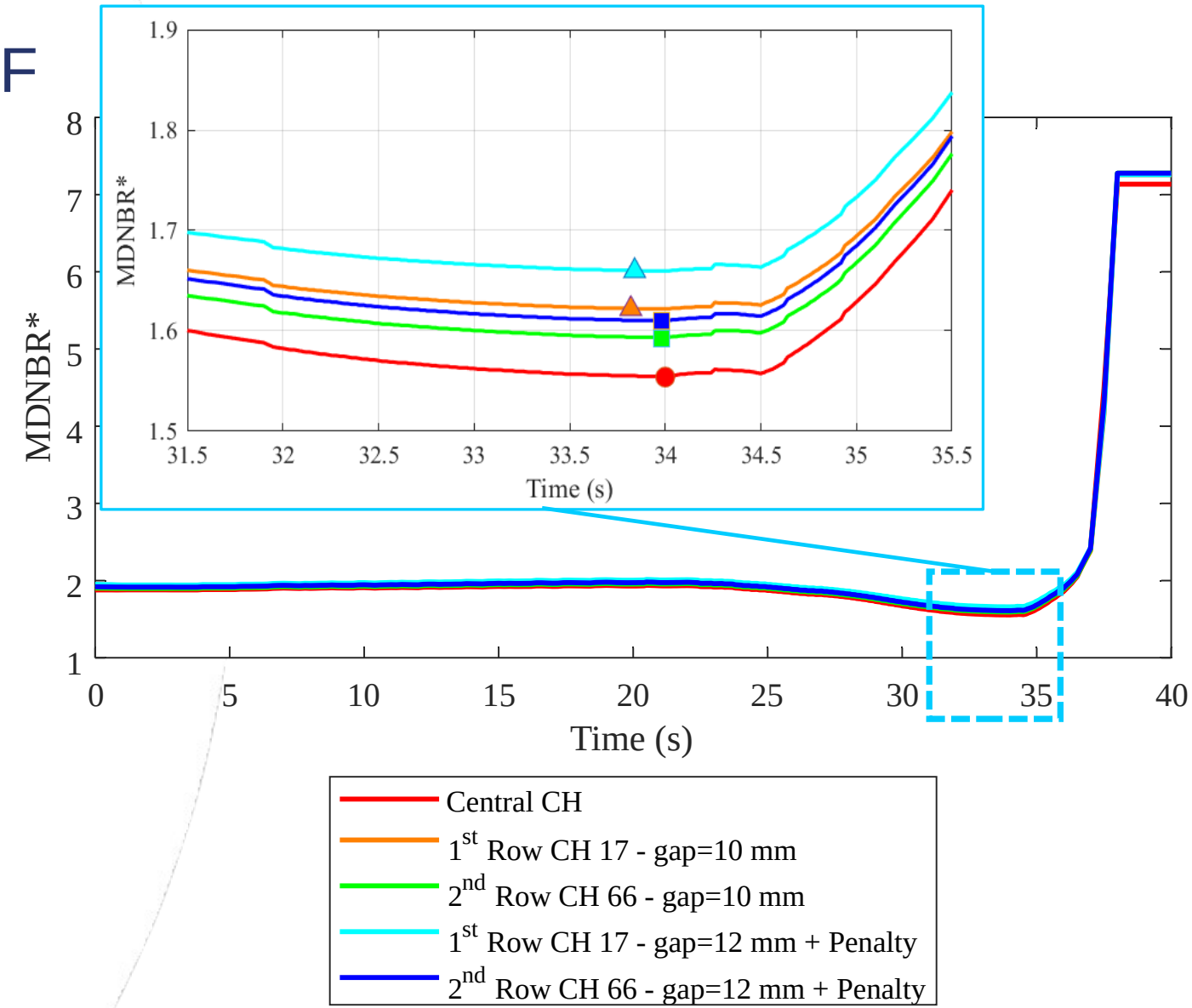
- No penalty for gap ≤10 mm
- Penalties based on the most conservative values.



Results: Safety analysis verification

- Analysis of CLOF with LONF transient for VVER-1000 shows that hot channel located in interior region remain limiting





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