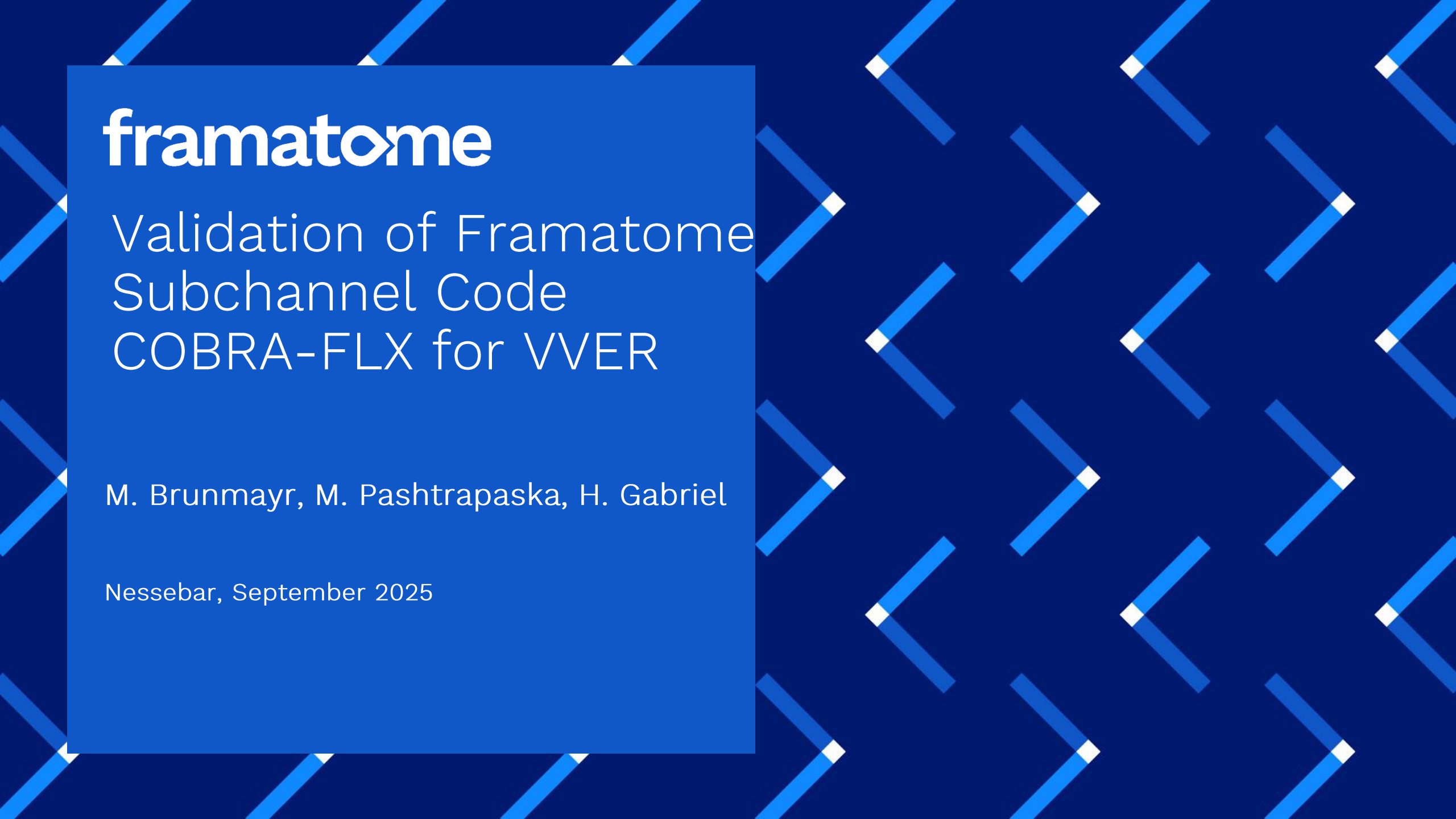




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Validation of Framatome Subchannel Code COBRA-FLX for VVER

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Nessebar, September 2025

Content

1. Framatome Code Tool chain for VVER
2. COBRA-FLX Validation & Benchmark with SUBCAL
3. COBRA-FLX Usage in VVER CHF Testing & Correlation Development
4. Conclusions

1

Framatome Code Tool Chain for VVER

Framatome Code Toolchain for VVER

Code		Software	Developer
Mechanical analyses	Normal and accidental conditions	ANSYS ABAQUS KWUSTOSS	Ansys Dassault <u>Framatome</u>
Fuel rod performance	Fuel rod code (Class I/II and postulated accidents)	GALILEE	<u>Framatome</u>
Nuclear FA design (Cross sections)	Lattice code Neutronics	HELIOS-2	Studsvik
Core Simulator	Steady-state (Burnup)	ANDREA	UJV REZ
	Transient	DYN3D	HZDR
TH code	Subchannel	COBRA-FLX	<u>Framatome</u>
LOCA	LOCA	RELAP5/mod3	US NRC

2

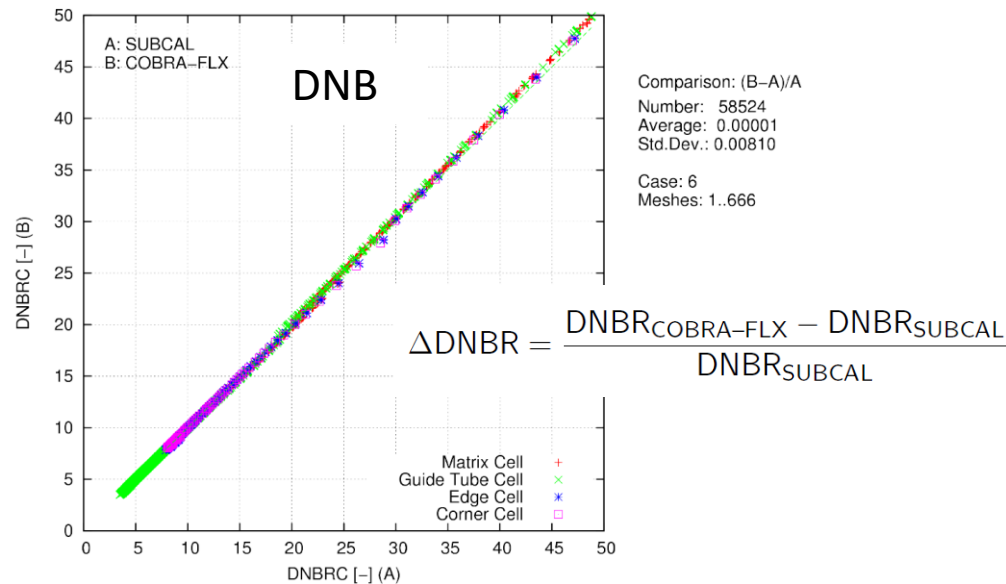
COBRA-FLX Validation & Benchmark with SUBCAL

Qualification of COBRA-FLX Subchannel Code

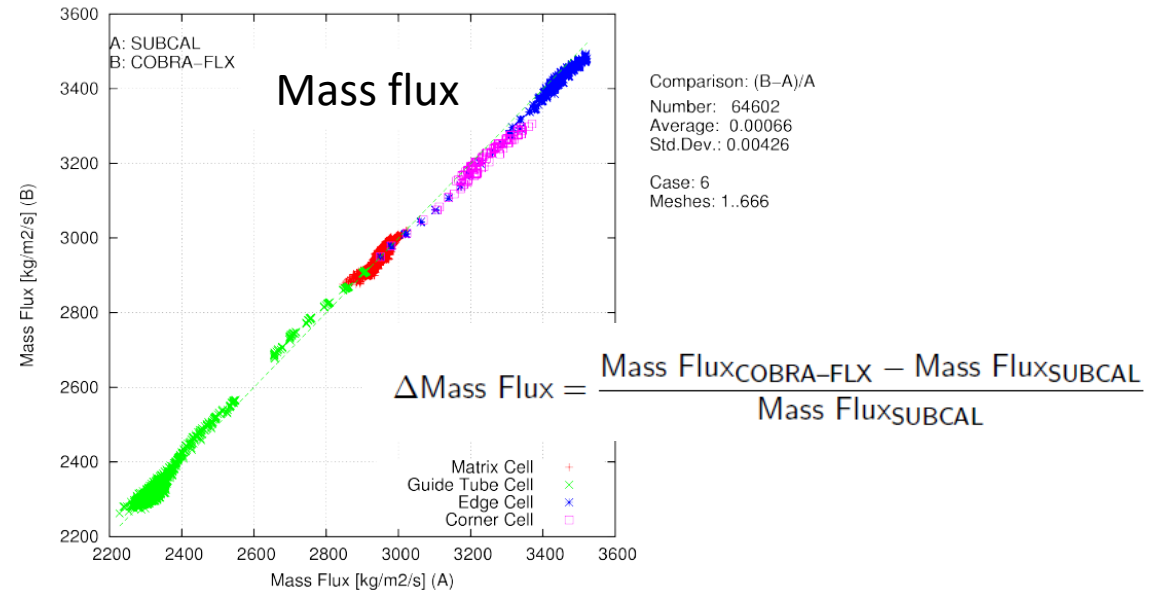
- *Subchannel code*
 - Solution of the conservation equations, e.g. flow, pressure and enthalpy/temperature for determination of minimum DNB ratios using CHF correlations, core pressure drop, guide tube boiling, crud risk assessment, ...
- *COBRA-FLX subchannel code licensed and applied in 11 countries*
 - For many purposes: PWR core design; PWR FA design; CHF correlation development; accident analysis
 - For a large range of reactor types: Framatome, Siemens, AREVA, Westinghouse, CE, B&W and research reactors; 360 to 1600 MW electrical power; 14x14 to 18x18 PWR-FA
- *SUBCAL subchannel code licensed and applied in the Czech Republic*
 - VVER core design
 - Licensing applications
 - Safety assessments of fuel cycles

COBRA-FLX – SUBCAL Benchmark 1

- Collaboration Project Framatome – UJP Praha in 2020
- Model single fuel assembly in subchannel-by-subchannel resolution and various thermal-hydraulic conditions for different CHF correlations (e.g. Bezrukov)
- DNB ratios and local TH conditions (mass velocity and steam quality) are compared

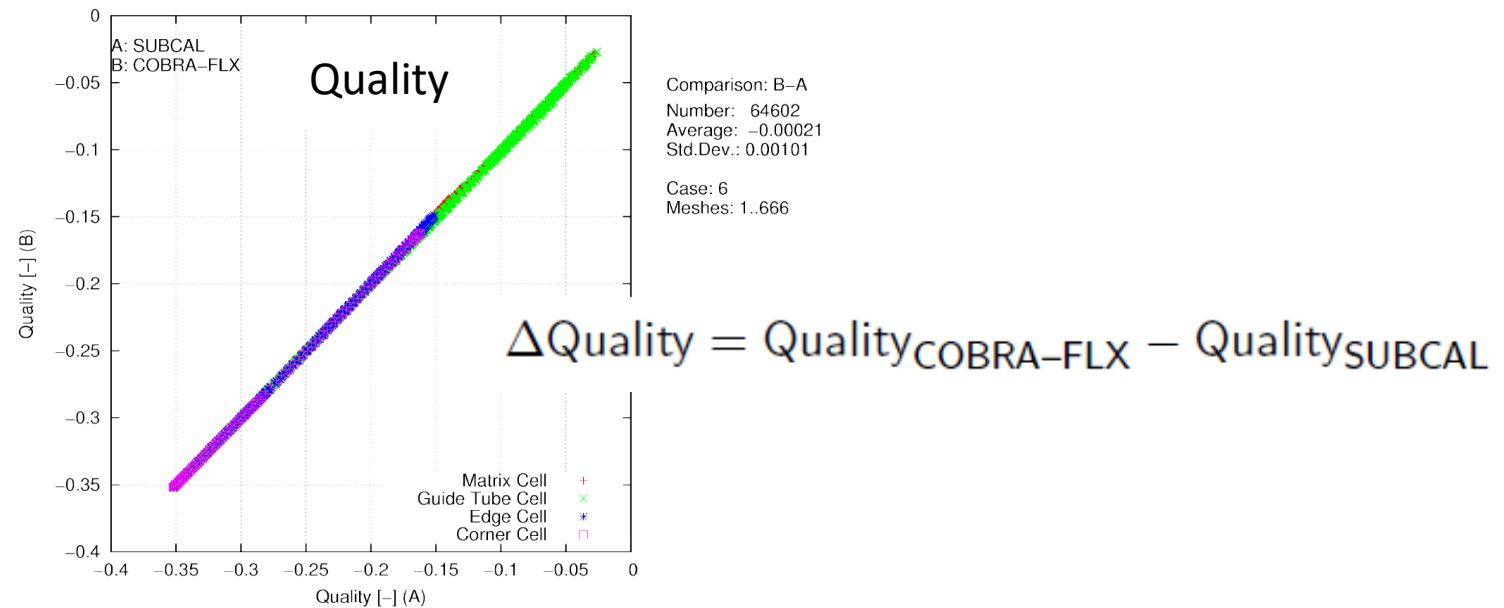


Average of the difference in the calculated values below 1%
Standard deviation less than 3%



Average of deviation less than 1%
Standard deviation below 4%

COBRA-FLX – SUBCAL Benchmark 2



Average of deviation less than 0.1%
Standard deviation 0.2%

- 
- Demonstrates ability to handle hexagonal geometries
 - Proves applicability for thermal-hydraulic (TH) design calculations for VVER reactors

3

COBRA-FLX Usage in VVER CHF Testing & Correlation Development

COBRA-FLX Use for VVER-1000 CHF Testing

Table 1: VVER-1000 Completed CHF Tests

Grid Type	AFS	Cell Type
SGR	uni	GT
SGR	cos	GT
SGR	cos	TC
SGR	uni	TC
SGR	uni	TC
MGR	cos	TC
MGR	cos	TC
MGR	uni	TC
MGR	cos	GT
MGR	uni	GT

SGR ... Spacer grid (non-vaned) ; MGR ... Mixing grid (vaned)
AFS... Axial Form Factor; uni... uniform, cos ... cosine
TC ... Typical Cell, GT ... Guide Tube

- As of September 2025, CHF test program completed for supporting the development of first CHF correlations for Framatome VVER-1000 Fuel using the Framatome “KATHY” CHF test facility*.
- COBRA-FLX used for CHF correlation development for Framatome spacer & mixing grids
- In addition, VVER-1000 triangular lattice experimental data from open literature relevant to VVER-1000 evaluated
- From 10 completed series of tests (see table), in total ca. 2000 CHF test data points evaluated & included in Framatome CHF data base using COBRA-FLX code

Supported by:



Federal Ministry
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Nature Conservation and Nuclear Safety

based on a decision of
the German Bundestag

* For CHF test loop “KATHY” see presentation P. Pohl

COBRA-FLX Use for VVER-440 CHF Testing

- Test Program for Framatome VVER-440 Fuel defined and in preparation
- First CHF tests will start in summer 2026
- COBRA-FLX is used for CHF correlation development for Framatome spacer grids
- In addition, triangular lattice experimental data from open literature will be re-evaluated for VVER-440 & further code benchmarking is planned.
- Preliminary CHF correlation to be shared with partners in the EU-funded SAVE Project, Work Package 6 to calculate the TH performance of most limiting transients & core thermal limits:

Table 2: SAVE WP6 Project Partners

								
ENERGORISK	EK		VUJE	UJP	UJV		VTT	Framatome

4

Conclusions

Conclusions

- Framatome Subchannel code COBRA-FLX is suitable for usage in VVER hexagonal geometry
- Validation by COBRA-FLX and SUBCAL benchmarking realized with UJP Praha in 2020 which shows good agreement for VVER fuel
- COBRA-FLX used for VVER-1000 Framatome Fuel CHF program with relatively large test database available to develop CHF correlations.
- VVER-440 Framatome Fuel Development will also use COBRA-FLX. Testing will start in 2026 along with collaboration with European partners

Acknowledgements

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Thank
you

Благодаря!
Köszönöm!
Děkuji!
Kiitos!
Ďakujem!
Дякую!
Tack!
Merci !
Danke!

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