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## **SAPIUM - Follow-up activities, perspectives for future development**

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# SAPIUM

## Follow-up activities, perspectives for future development

SAPIUM special session, NURETH-19, March 6-11 2022, Brussels, Belgium / Online conference

Philippe Fillion, Lucia SARGENTINI, Alberto GHIONE, Guillaume DAMBLIN

## Former OECD-NEA projects on uncertainties in thermalhydraulics

## 2004 - 2010 BEMUSE

(Best Estimate Methods plus Uncertainty and Sensitivity Evaluation)

Uncertainty propagation for a LB-LOCA → *what about the input uncertainties?*

## 2012 - 2015 PREMIUM

(Post BEMUSE Reflood Models Input Uncertainty Methods)

Inverse uncertainty quantification (IUQ) for reflooding → *important user-effect*

## 2017 - 2019 SAPIUM

(Systematic Approach for Input Uncertainty quantification Methodology)

Guideline for IUQ → *theory but no application*

**During SAPIUM project, CEA proposed application cases to demonstrate the relevance of the best-practices developed in SAPIUM**

**Several aims for these demonstration cases**

- Verify the applicability of the best-practices to several practical problems
- Verify that the issues identified during PREMIUM can be avoided by following the SAPIUM guideline
- Give a feedback on the SAPIUM conclusions and potentially suggest improvements

**A progressive approach was proposed in order to treat the key issues identified. For that, 3 cases were proposed:**

- The experimental database contains enough data and there are few influential phenomena: the problem is well posed and seems easy to treat
- Several influential phenomena but the experimental database provides enough data of different types
- Several influential phenomena but the experimental database does not contain enough varied data or few influential phenomena and not adequate database

From this ideas, a new OECD/WGAMA activity has been proposed by CEA in 2021: **the ATRIUM project**

*Application Tests for Realization of Inverse Uncertainty quantification and validation Methodologies in thermal-hydraulics*

Set a standard on uncertainty methodology applying for the first time the SAPIUM guideline on simplified exercises



Focus on Adequacy and Inverse Uncertainty Quantification

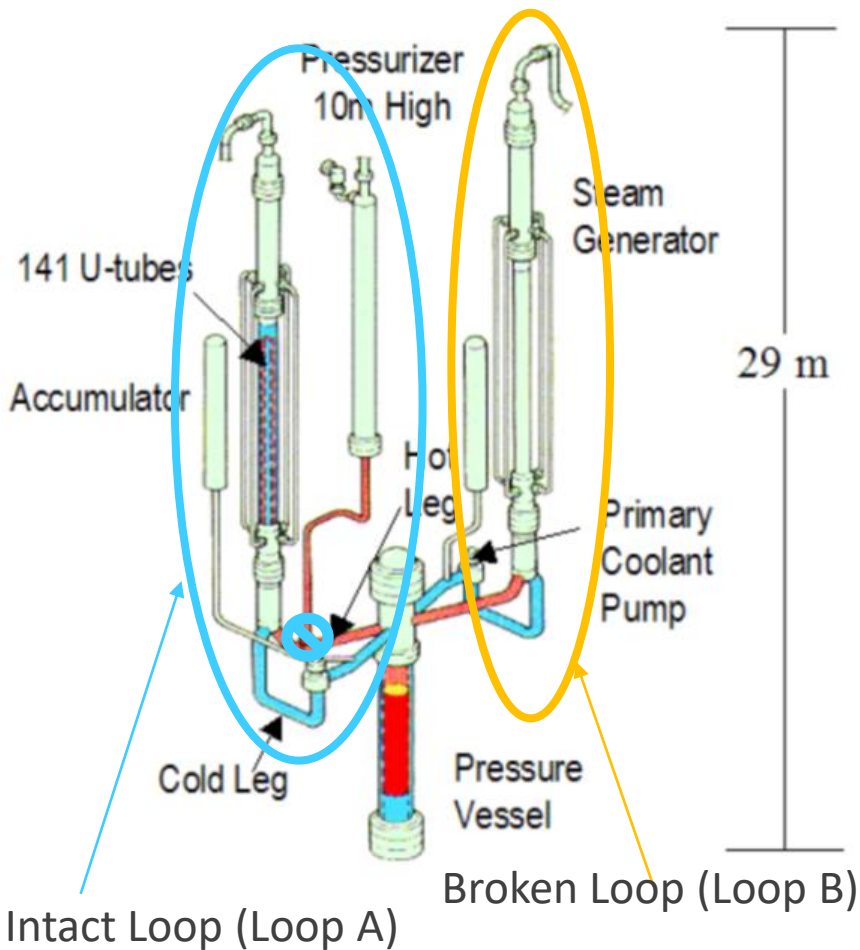
1. Definition of the accident interesting in → Intermediate Break Loss Of Coolant Accident (IB-LOCA)
2. Definition of relevant physical phenomena → PIRT analysis from M. Y. Young et al. (1998), Frepoli (2006), T. Takeda and I. Ohtsu (2018)



Among important phenomena, two of them will be addressed in the ATRIUM project:

- Critical flow at the break
- Heat transfer in the core post-CHF

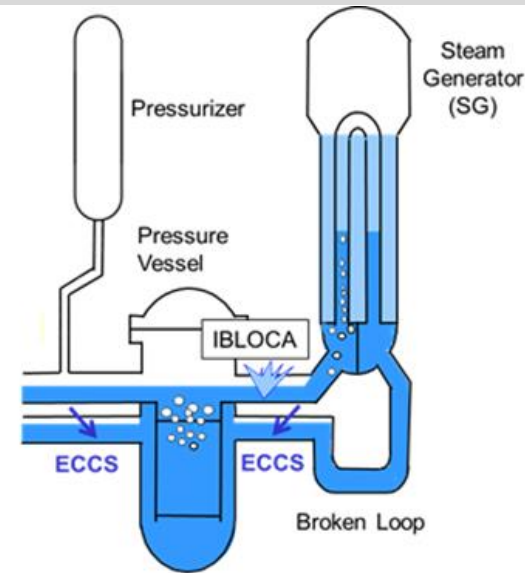
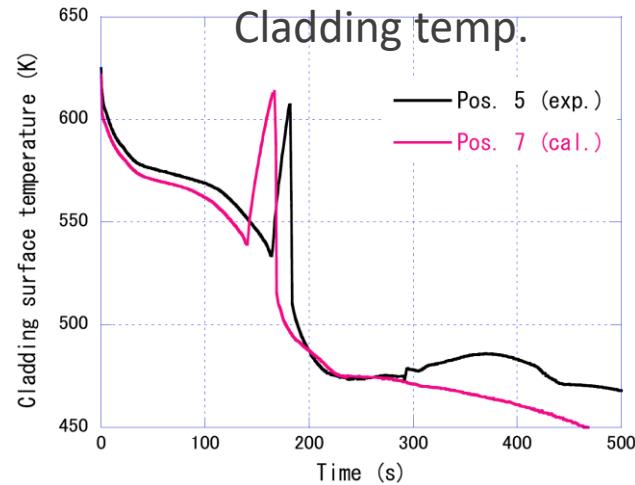
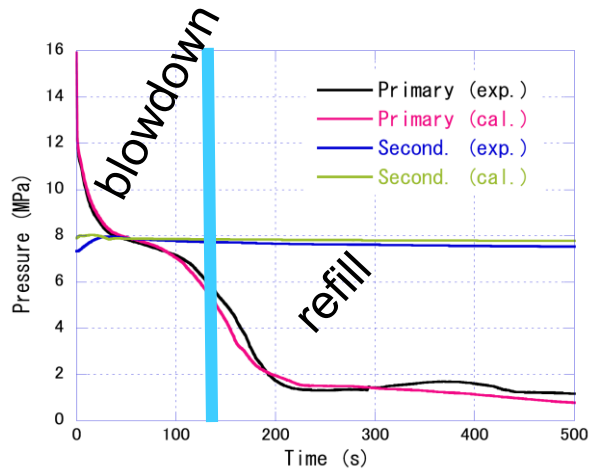
3. Definition of an Integral Effect Test (IET) for the application case → OECD/NEA ROSA-2 Project LSTF IB-HL-01



**Full-pressure and full-height two-loop integral test facility simulating an 1100 MWe four-loop Westinghouse-type PWR with a volumetric scaling of 1/48**

- Full size core rod bundle with 10 MW electrical power (14% of volumetrically-scaled core power)
- 2 equal-volume loops to simulate two-phase flows during reactor accidents and transients
- Cold/Hot legs of 207 mm inner diameter
- Around 1900 instruments for direct measurements

**Test considered in the ATRIUM project:** Intermediate Break LOCA in the Hot Leg with High Pressure Injection and auxiliary feedwater failure (Test 1)



Fast primary depressurization. The primary pressure became lower than the steam generator (SG) secondary-side pressure at about 55 s.

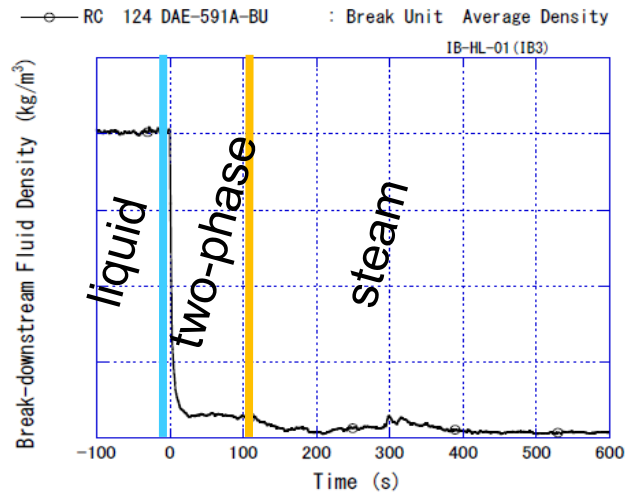


Fig. 3-8 Break-downstream averaged fluid density

Break flow turned from single-phase liquid to two-phase flow in a very short time just after the break, and to single-phase vapor simultaneously with the hot leg became empty of liquid temporarily.

The break flow rate followed the liquid level transient in the hot leg.

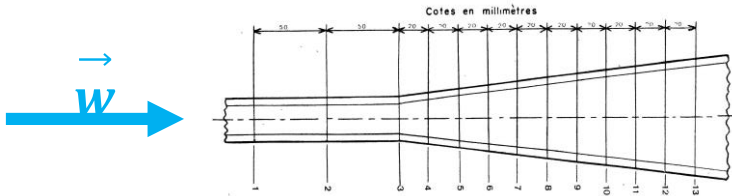
\*Source : T. Takeda, I. Ohtsu / Nuclear Engineering and Technology 50 (2018)



Two IUQ exercises with increasing complexity

For each exercise → uncertainty quantification of physical models relevant for the **critical mass flow** and the **peak cladding temperature**

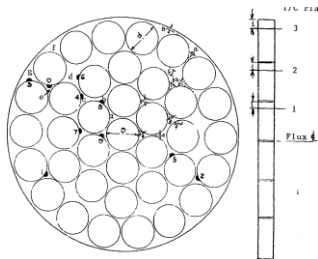
## 1<sup>st</sup> EXERCISE on CRITICAL FLOW



Available SETs/CETs:

- Super Moby-Dick Long Nozzle
- Sozzi-Sutherland Nozzles
- MARVIKEN: transient tests for validation

## 2<sup>nd</sup> EXERCISE on POST-CHF



Available CETs (to be defined precisely)

**For the two IUQ exercises:**

1. Database analysis
2. Adequacy
3. Physical models choice
4. Creation of the file for code simulations (choice of nodalization)
5. IUQ with the own methodology
6. Analysis and validation based on the **envelope band on the Figure of Merit** (critical mass flow rate and cladding temperature)

Participants must describe and justify the adequacy of the experimental databases, the modelling choices and the IUQ methodologies.

**Then: propagation on LSTF IB-HL-01 transient**



1<sup>st</sup> Exercise:  
Critical Flow

- Database analysis
- Adequacy
- Physical models choice
- Creation of the file for code simulations (choice of nodalization)
- IUQ with the own methodology
- Analysis and validation based on the enveloped band on critical flow



2<sup>nd</sup> Exercise:  
Post-CHF

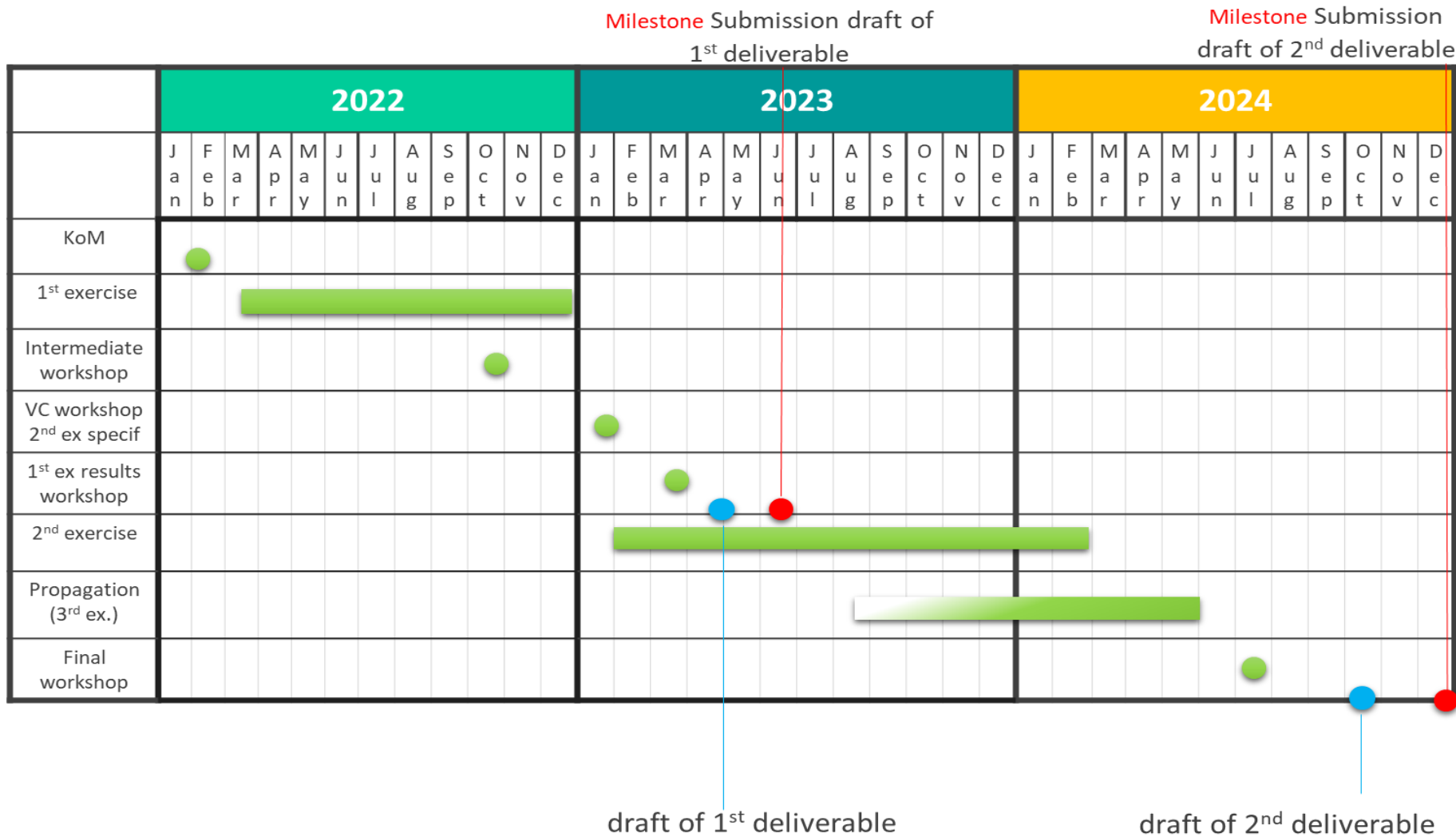
- Database analysis
- Adequacy
- Physical models choice
- Creation of the file for code simulations (choice of nodalization)
- IUQ with the own methodology
- Analysis and validation based on the enveloped band on wall temperature

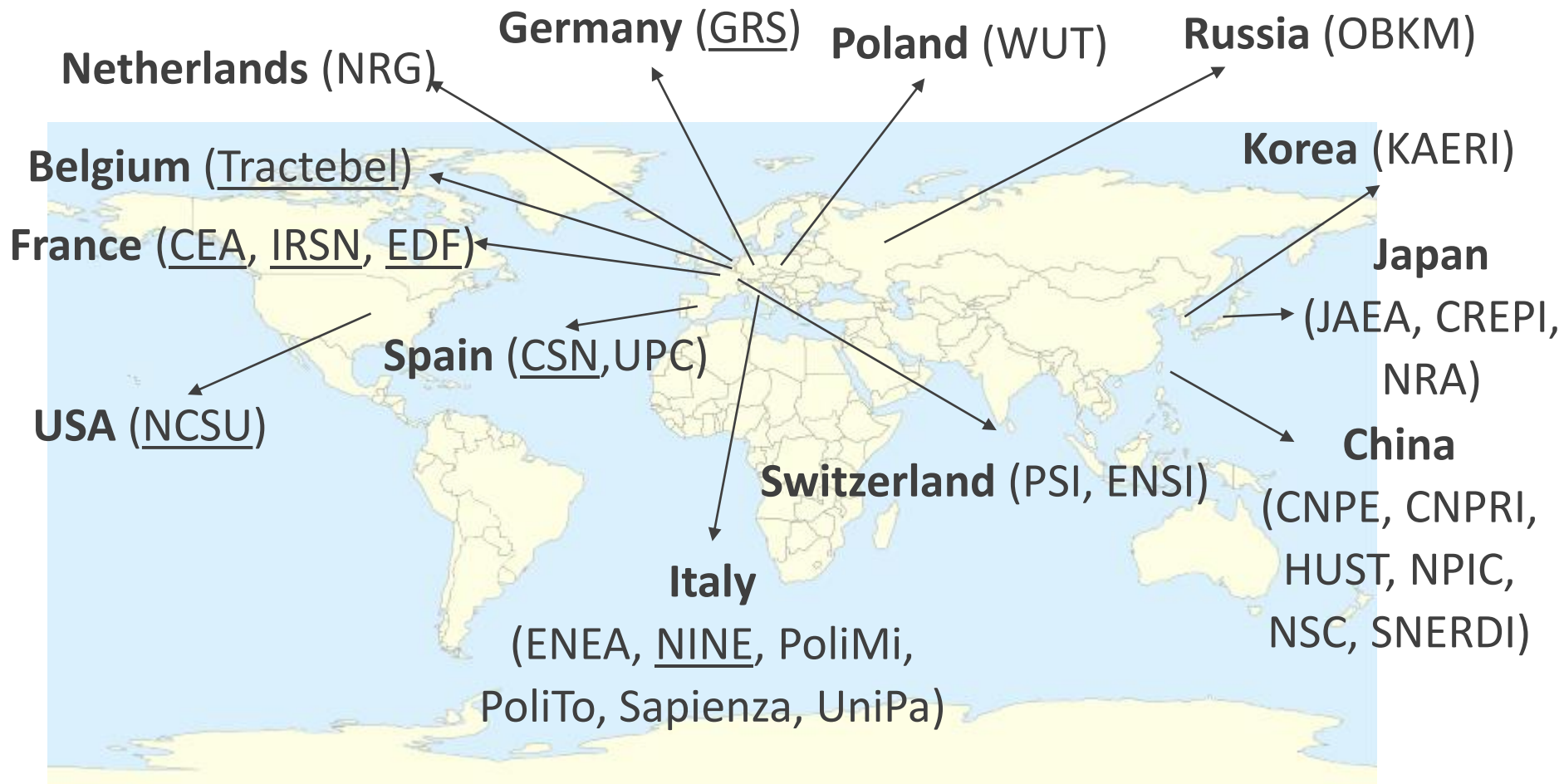


IET  
Propagation

- Interpretation of the IET experiments
- Analysis/Creation of the file for code simulations (choice of nodalization)
- Propagation
- Analysis and validation based on the enveloped band on break flow rate and cladding temperature

ATRIUM has been endorsed by OECD/CSNI in Dec. 2021 => 3 years (Jan. 2022 – Dec. 2024)





29 institutions participated to the Kick-Off meeting (7-9 February 2022)

Pilot and task leaders are underlined

Proposals for future activities in the SAPIUM project have materialized

The OCDE/WGAMA ATRIUM project consists of the application of the SAPIUM guideline:

- Two IUQ exercises with increasing complexity
- Propagation on the LSTF-ROSA IB-HL-01

This benchmark activity allows:

- Verifying the applicability of the SAPIUM guideline with practical examples in thermal-hydraulics
- Summarizing the lessons learned from the different participants, identifying the advantages and limits of the available methods and proposing possible improvements
- Promoting best-practices in IUQ to improve Best Estimate Plus Uncertainty (BEPU) methodologies for safety analysis of NPPs



**THANK YOU FOR YOUR  
ATTENTION**