REDUCTION OF RADIOLOGICAL ACCIDENT CONSEQUENCES

Title	**Work performed in uncertainty quantification**
Authors:	**R. Zimmerl, Y. Janal, B. Hrdy, W. Giannotti, N. Muellner**
Affiliation:	**BOKU University Vienna**
Event:	R2CA Final Open Workshop
When:	29-30 November 2023
Where:	IRSN Headquaters

Commission européenne

This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 847656.

Table of Contents

- Introduction
- CIAU Method
- Extension of parameters for iodine release
- Summary

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

Accuracy – Sensitivity - Uncertainty

A: It can be defined as *"the known bias between a code prediction and the actual transient performance of a real facility".*

The evaluation of accuracy implies the *availability of a calculation result and of a measured value.* The experimental error is *not* part of the definition

SA: *"what-if" analysis. "The study of how the variation in the output of a model (numerical or otherwise) can be apportioned, qualitatively or quantitatively, to different sources of variation, and of how the given model depends upon the information fed into it".*

Performed for verification purposes, for finding a) singular points, b) the factors that mostly contribute to the selected response or c) the correlation among input variables

UA: *"An analysis to estimate the uncertainties and error bounds of the quantities involved in, and the results from, the solution of a problem". Estimation of individual modeling or overall code uncertainties, representation uncertainties, numerical inadequacies, user effects, computer compiler effects and plant data uncertainties for the analysis of an individual event.*

Nuclear safety principles and concepts like defense-in-depth require to perform UA: it must be ensured that the nominal result of a code prediction, 'best-estimate' in the present case, is supplemented by the uncertainty statement in such a way that connected safety margins are properly estimated.

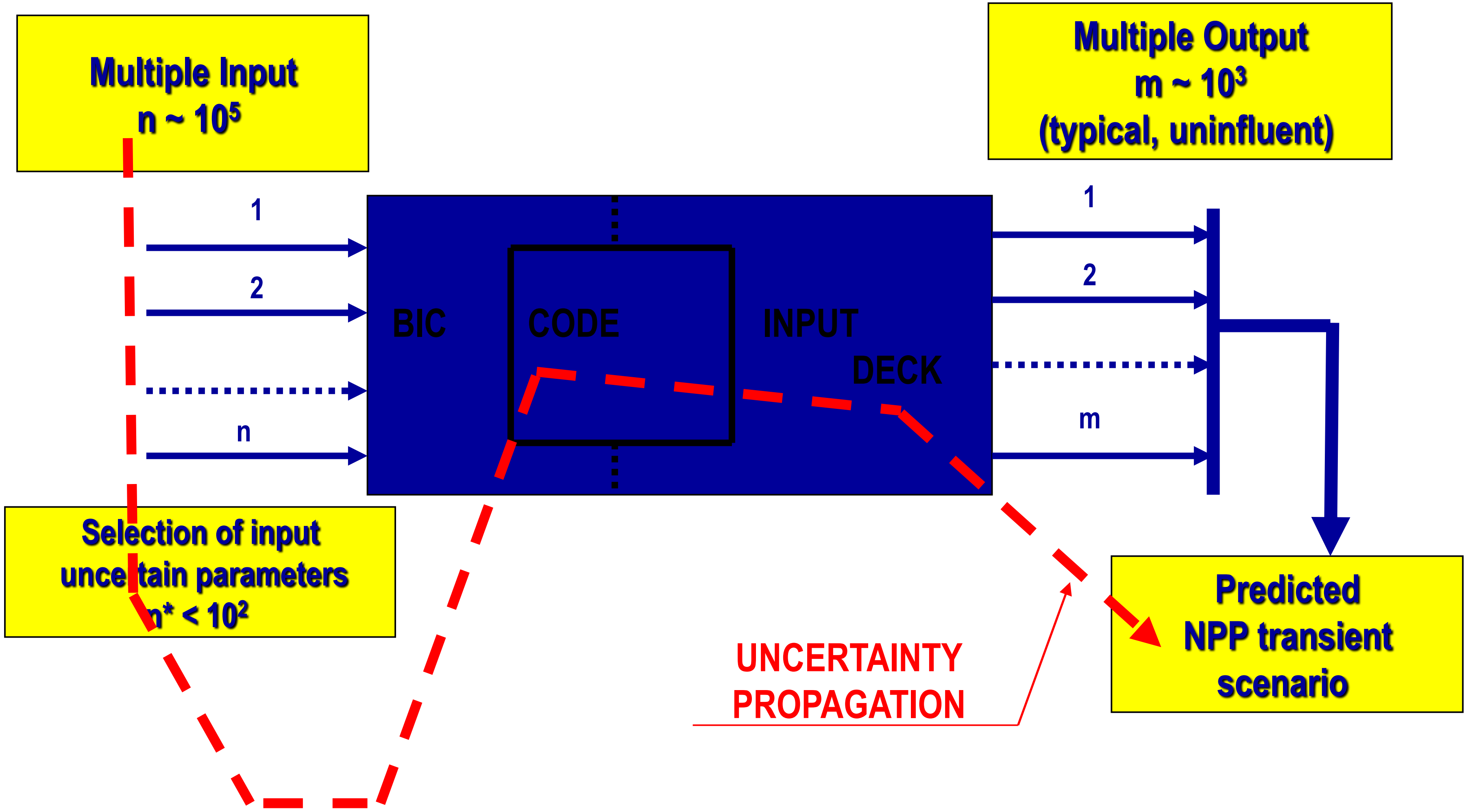
Why Uncertainty Evaluation?

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

Licensing:

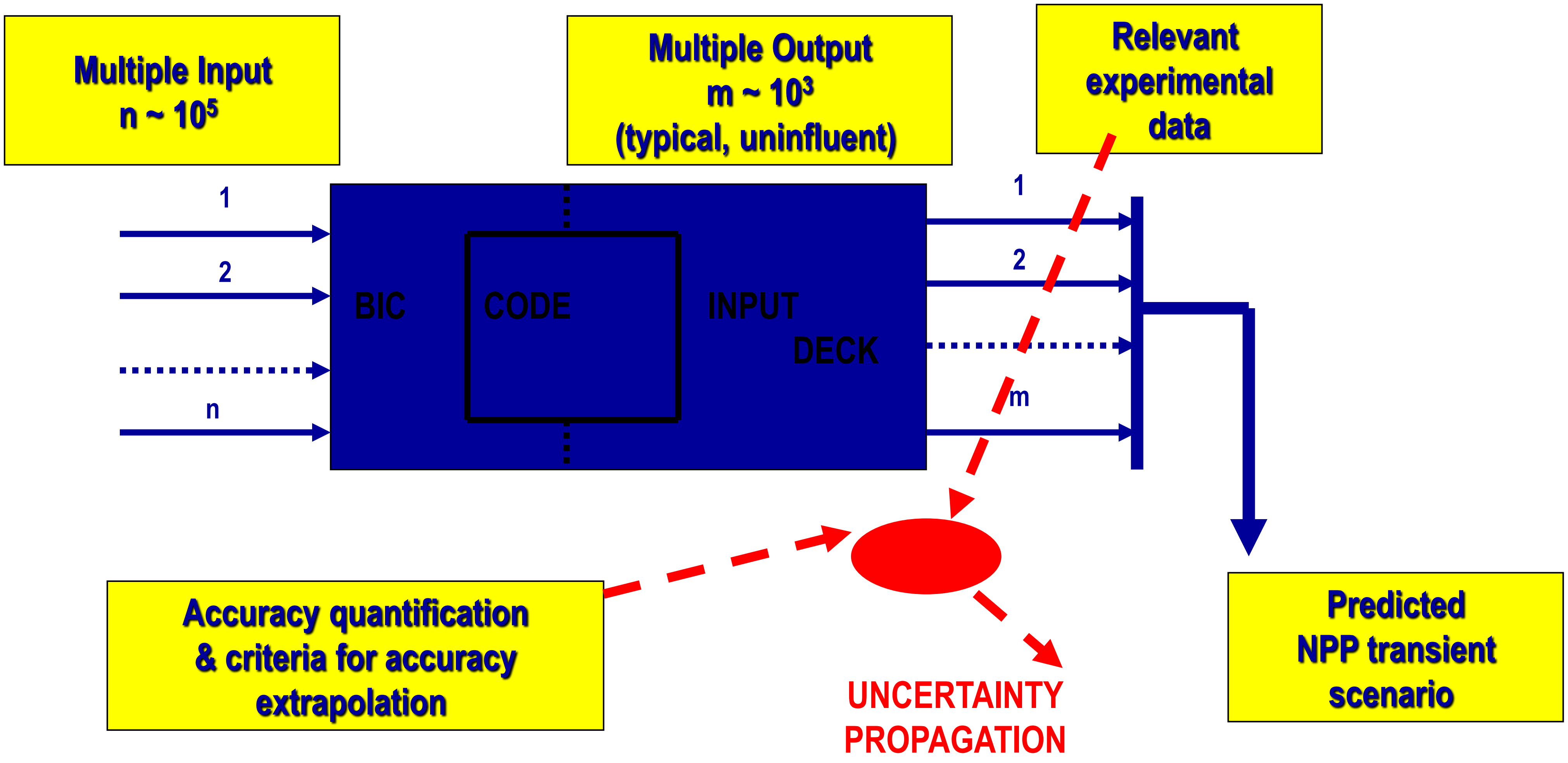
Applied codes	Initial and boundary conditions	System availability	Approach	Regulation
Conservative code	Conservative	Conservative assumptions	Deterministic	10 CFR § 50.46 (a)(1)(ii), Appendix K
Best estimate (realistic) code	Conservative	Conservative assumptions	Deterministic	Current German practice; IAEA Guide, 4.89
Best estimate code + uncertainty	Realistic + uncertainty	Conservative assumptions	Deterministic	§ 50.46 (a)(1)(i), Appendix A; IAEA Guide, 4.90
Best estimate code + uncertainty	Realistic + uncertainty	PSA-based assumptions	Deterministic + probabilistic	

Propagation of input uncertainty



UMAE & CIAU: Propagation of output uncertainty

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS



UMAE & CIAU: Propagation of output uncertainty

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

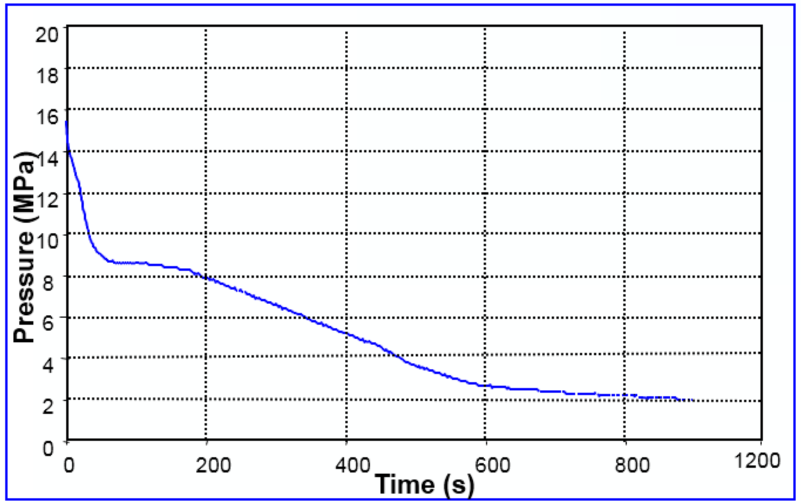
THE CIAU METHOD

CIAU = Code with the capability of Internal Assessment of Uncertainty

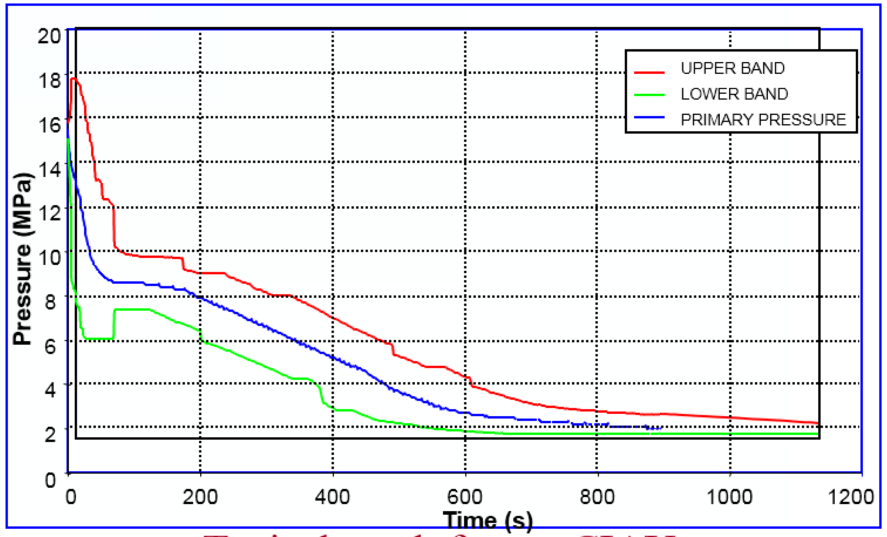
- **RELAP5** IS THE CODE
- **UMAE** IS THE COUPLED UNCERTAINTY METHODOLOGY

Any Qualified Thermal-Hydraulic System Code and Any Qualified Uncertainty Methodology can be coupled to constitute the CIAU

*THE WORDS **'INTERNAL ASSESSMENT OF UNCERTAINTY'** CAME OUT AS A NEED FOR THE SCIENTIFIC COMMUNITY DURING THE OECD/CSNI "ANNAPOLIS MEETING" ORGANISED BY US NRC AND HELD IN ANNAPOLIS (MD) IN NOVEMBER 1996*



Typical result of a thermo-hydraulic system code



Typical result from a CIAU

CIAU Parameters

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- Problem CIAU "stores" the uncertainty of three main parameters
  - Primary system pressure
  - Hot rod temperature
  - Primary system mass inventory

- Aim for R2CA – evaluate the uncertainty of iodine release to the environment during a DEC-A steam generator tube rupture event

- Approach – "uncertainty propagation" analogous to "error propagation"

Considered Event

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- At VVER-1000 320 pressurized water reactor consider “hot header break”
- Leak equivalent to 100mm Diameter from primary system to secondary system (beyond “usual” size of Steam Generator Tube Rupture, but considered at VVER as bounding case)
- Further assumption – BRU-A valve of affected loop stuck open after first opening
- Iodine transported with Relap5-3D radionuclide transport model

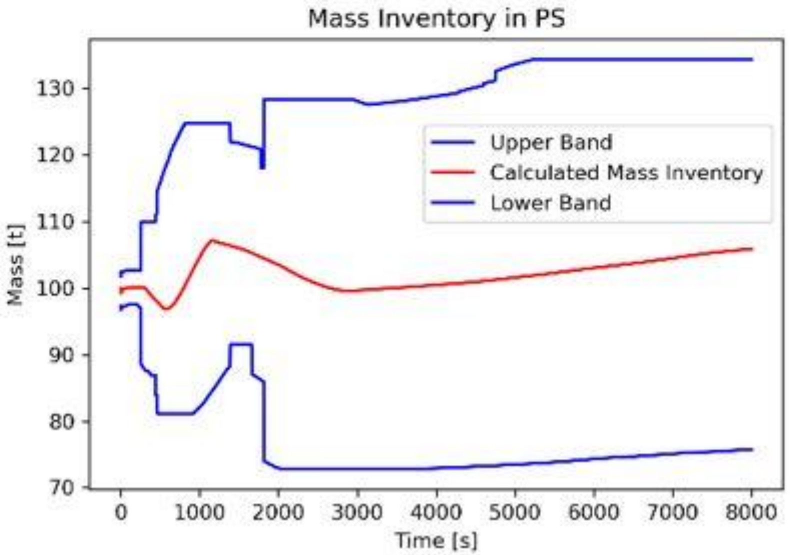
Uncertainty propagation assumptions

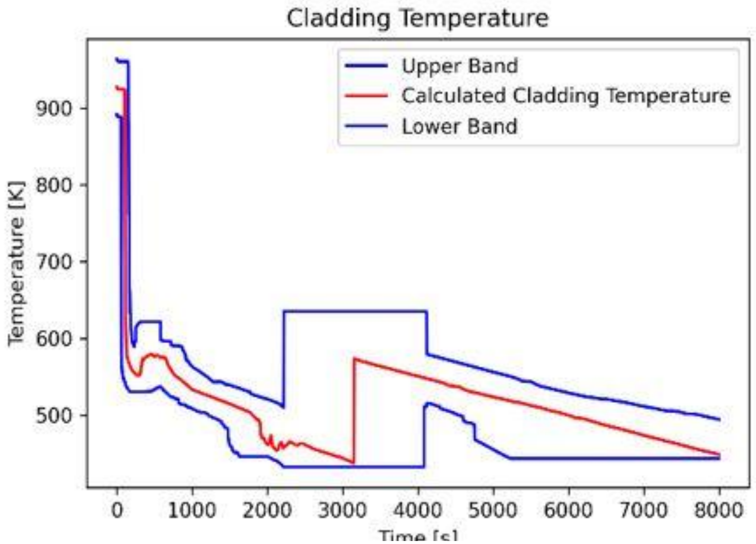
REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

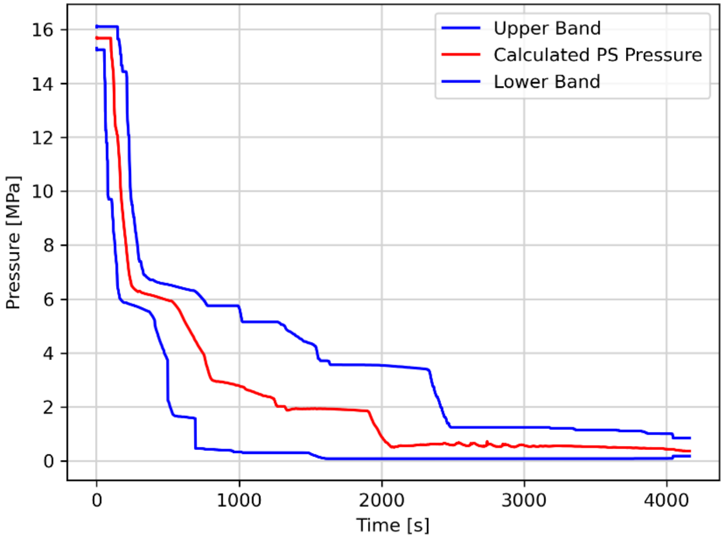
- Target – uncertainty of iodine release because of TH-SYS code uncertainty
- Iodine transported with fluid – break flow will govern the release to the environment
- Over the time simulated "choked flow" phaenomena present and Relap5-3D choked flow model applied
- Choked flow governed by sound speed, which in term is governed by void fraction and upstream pressure
- Upstream (SS) pressure uncertainty governed by primary pressure uncertainty, since systems are connected in the present case
- **Used Gauss error propagation law to propagate PS-Pressure Uncertainty to Iodine release uncertainty**
- **Uncertainty of void fraction at the valve from literatur**

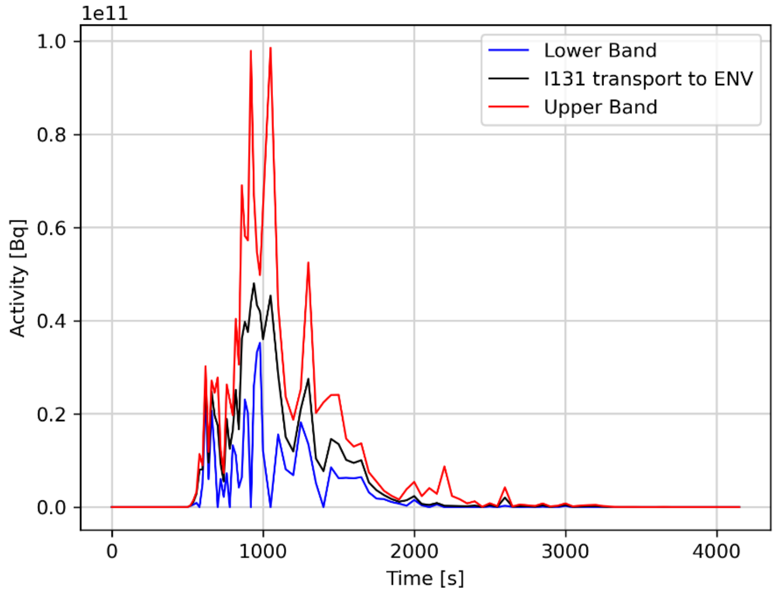
Results CIAU and propagated uncertainty

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS









Conclusion

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- One contributor of uncertainty was propagated
- Other contributors might have even larger influence
- Approach of propagation not general applicable – tight to transient and domain of parameters
- However, indication of uncertainty related to the use of TH-System code could be derived!

Thank you!

Contact: nikolaus.muellner@boku.ac.at

This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 847656.