Sensitivity analysis using the URANIE platform with subchannel codes

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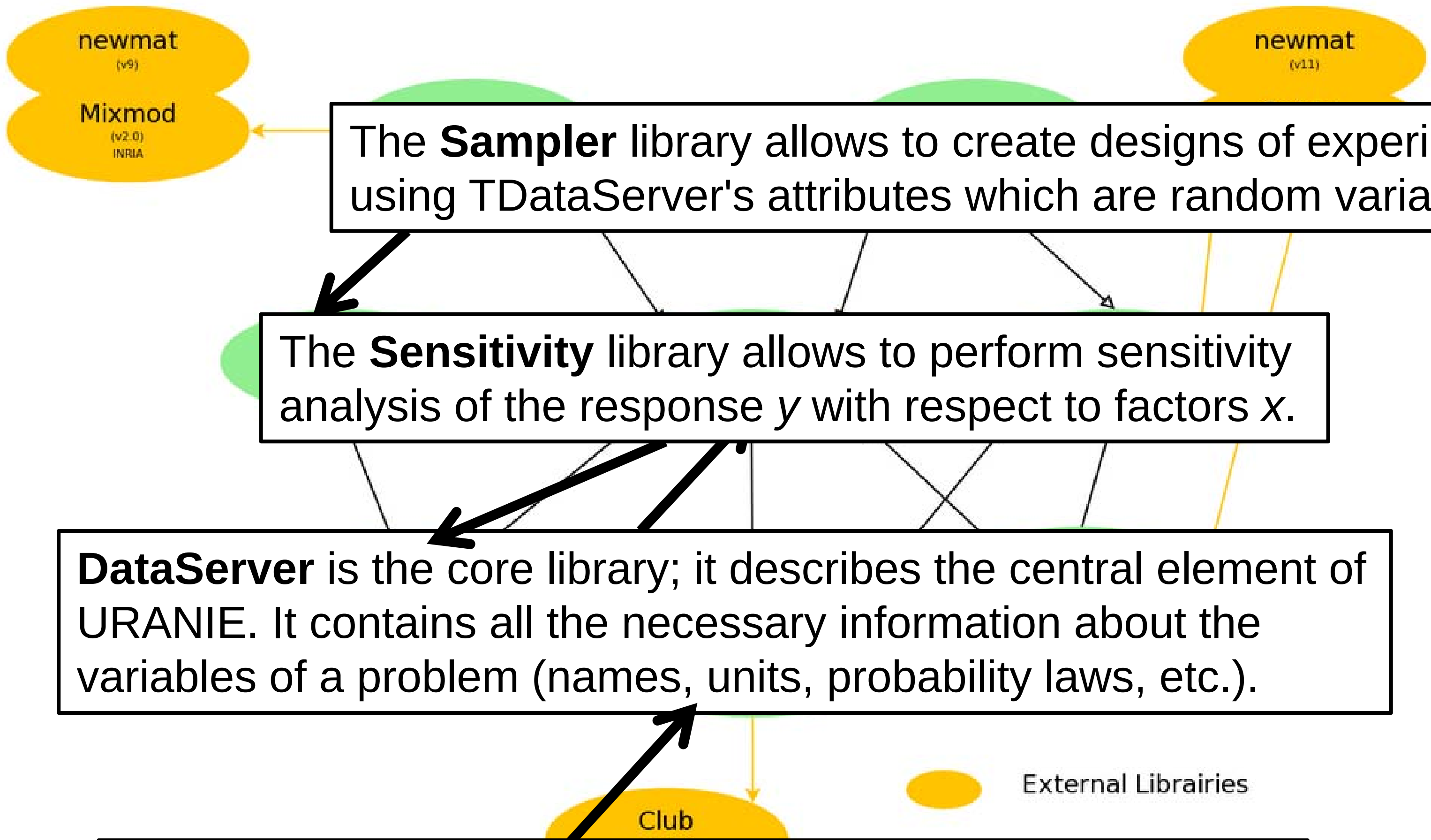
- Summary

URANIE

- URANIE is a software dedicated to uncertainty and optimization.
- It allows to perform studies on uncertainty propagation, sensitivity analysis or model calibration in an integrated environment.
- It is based on ROOT, a software developed at CERN for particle physics data analysis.
- URANIE benefits from the numerous features of ROOT, among which:
  - a C++ interpreter (CINT)
  - a Python interface (PyROOT)
  - access to SQL databases
  - many advanced data visualization features

URANIE Software Functional Diagram

Karlsruher Institut für Technologie



The **Sampler** library allows to create designs of experiments using TDataServer's attributes which are random variables.

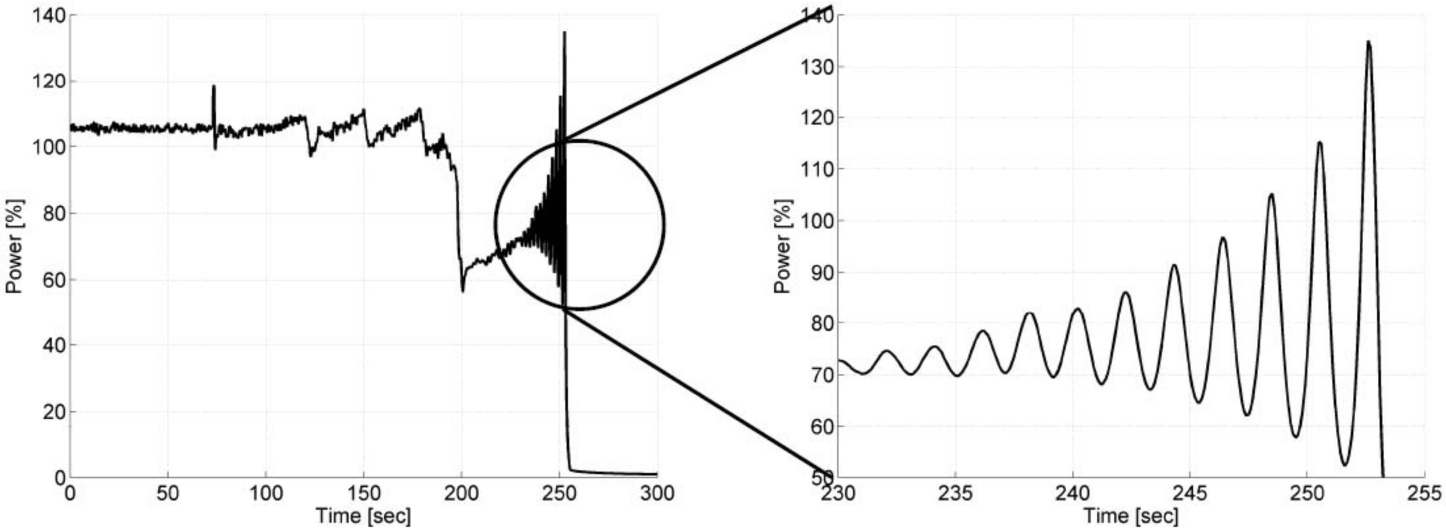
The **Sensitivity** library allows to perform sensitivity analysis of the response *y* with respect to factors *x*.

DataServer is the core library; it describes the central element of URANIE. It contains all the necessary information about the variables of a problem (names, units, probability laws, etc.).

The **Launcher** library applies an analytical function or an external simulation code on the content of a TDataServer.

Application to the O2 -1999 FW transient

- Power oscillation during the event (feedwater transient)



Oskarshamn-2 February 25, 1999 feedwater transient

- Boundary conditions taken from TRACE/PARCS calculation (KIT model with 444 channels)
- Modeling the O2 core with COBRA-TF using 444 channels

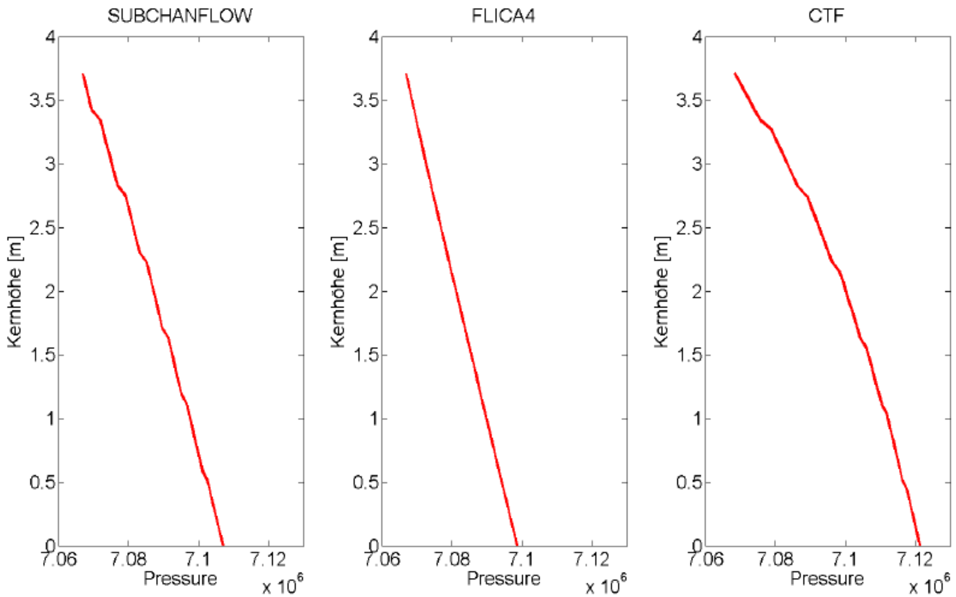
O2 Modeling with subchannel codes

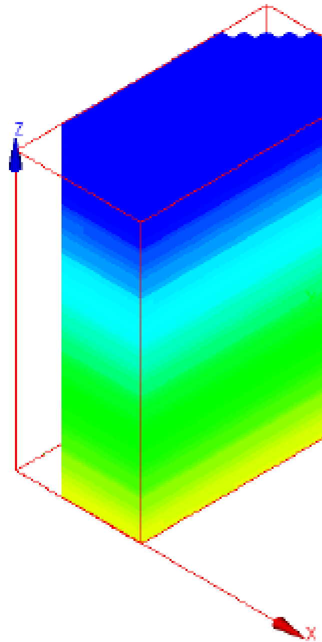
- Oskarshamn-2 Core has being modeled with COBRA-TF, SUBCHANFLOW and FLICA4
- Code versus measured data comparison

Parameter at HFP	Benchmark	SCF	FLICA4	CTF
Thermal Power (MW)	1798.6	1798.6	1798.6	1798.6
Core inlet Temperature (K)	547.30	547.30	547.30	547.30
Core Inlet Mass Flow (kg/s)	4793.50	4793.50	4793.50	4793.50
Core outlet Temperature (K)	558.48	559.63	558.2	559.25
Average void fraction (-)	0.42	0.41	0.39	0.37
Void fraction at core outlet (-)	-	0.7124	0.6698	0.7080
Presure drop in the core (kPa)	46.0	45.1	40.1	53.52
Average flow velocity in the core (m/s)		2.99	4.59 (Vap.) 2.77 (Liq.)	3.21

Results: Pressure drop

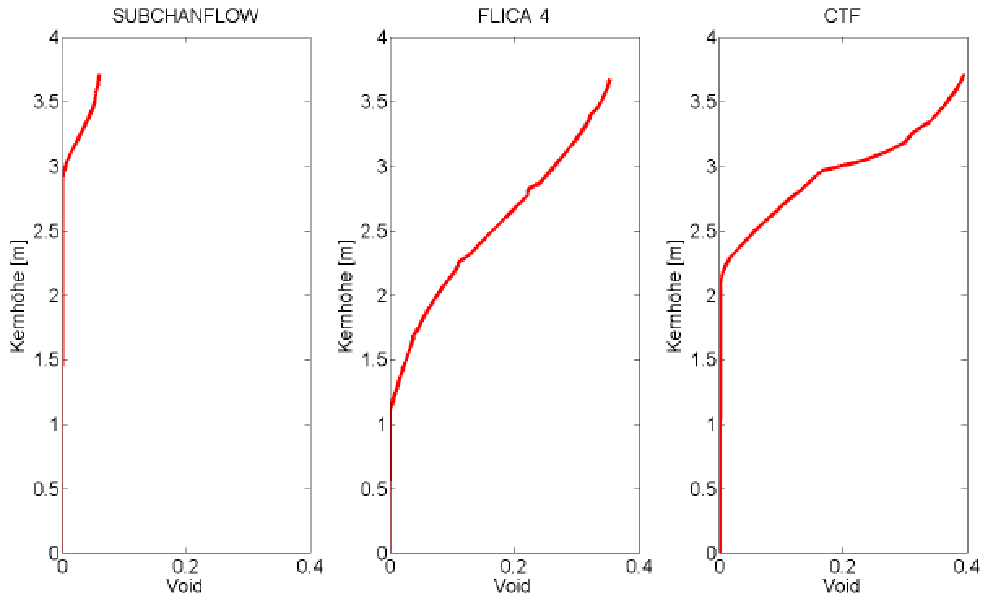
- **3D Power distribution take from converge steady state TRACE/PARCS**

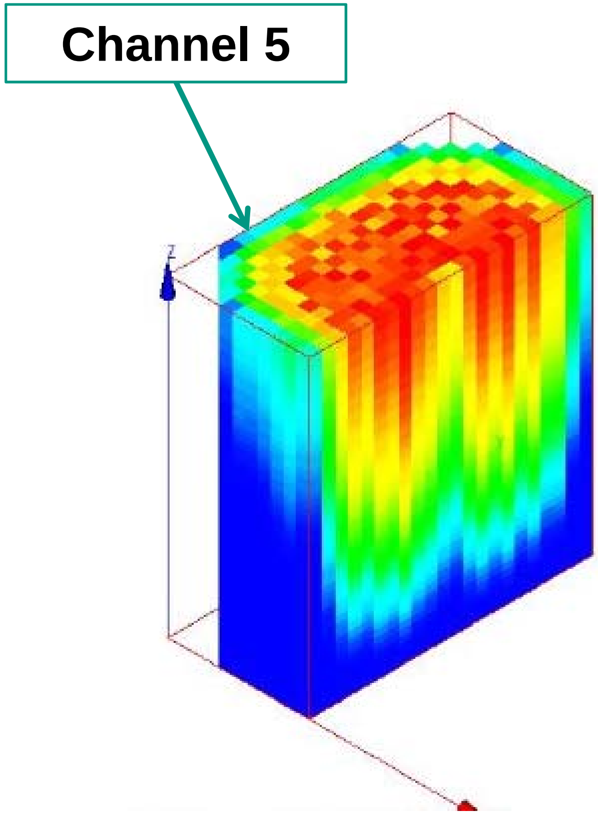




	Benchmark	SUBCHANFLOW	FLICA4	CTF
Average Pressure drop in the core (kPa)	Ref.	-1.9%	-12.8%	+16.3%

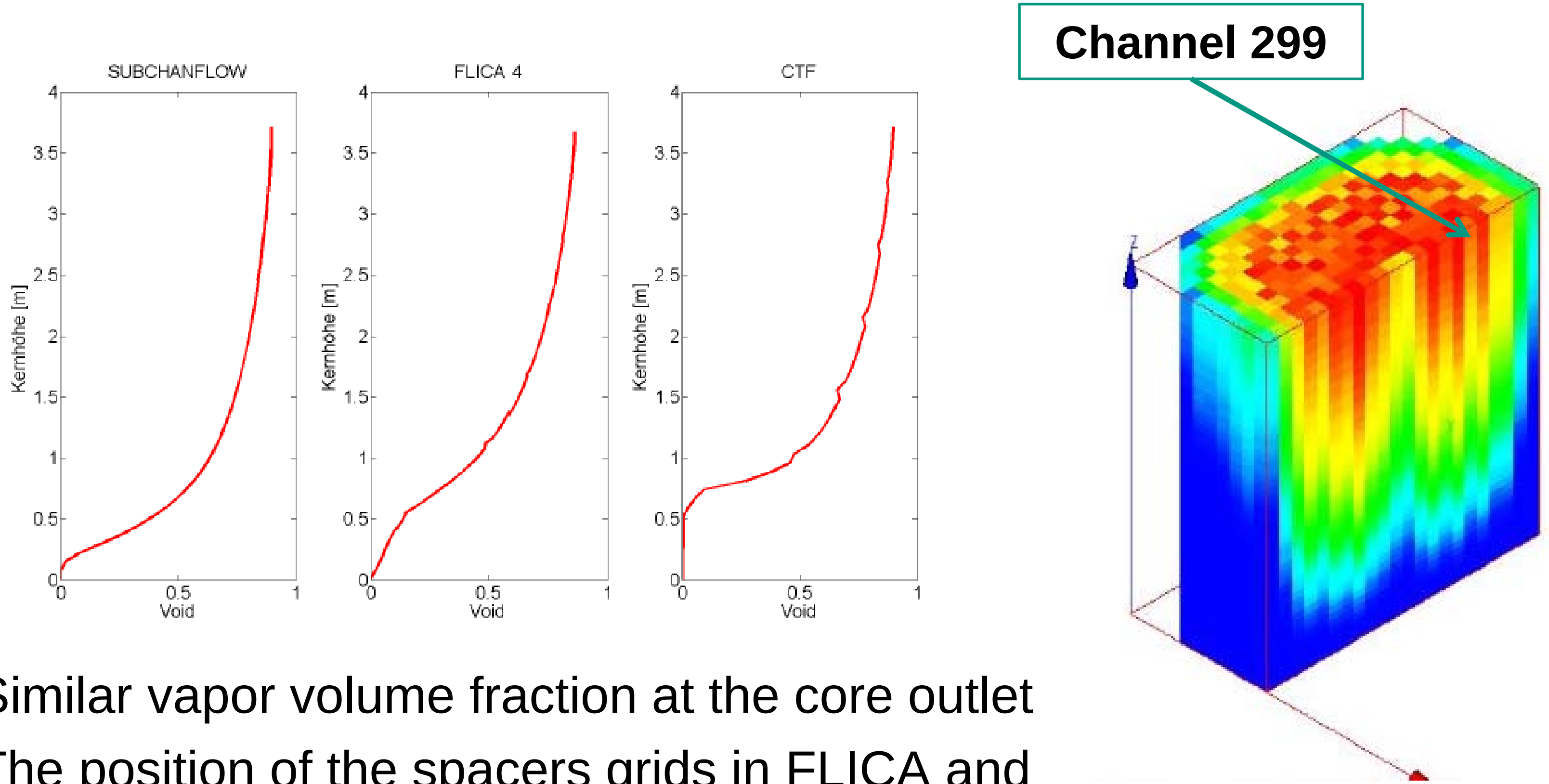
Results: Void fraction in channel 5





- Very different onset of boiling
- Effects of subcooled boiling are modeled differently

Results: Void fraction in channel 299



- Similar vapor volume fraction at the core outlet
- The position of the spacers grids in FLICA and COBRA-TF can be seen clearly

Sensitivity study

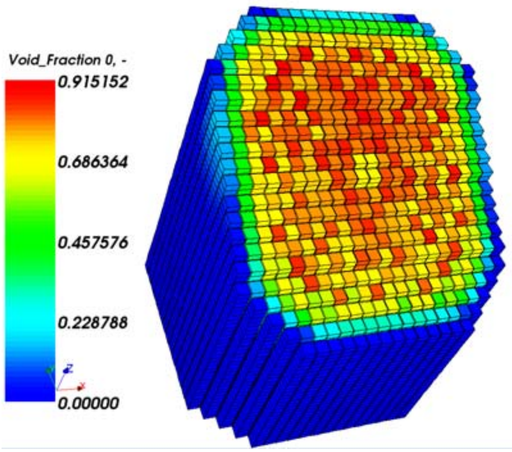
- Sensitivity analysis with parameters taken from the PhD I. Gajev
  - Power range was increased from ± 0.75% to ± 2.0%

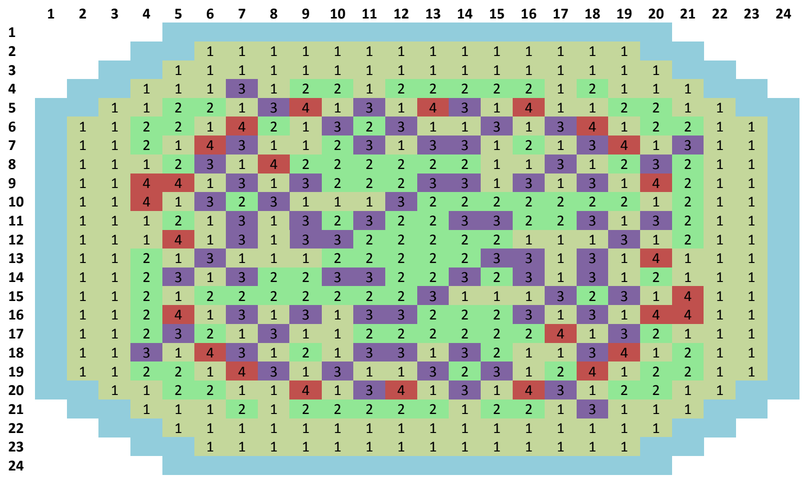
No.	Parameter	Range	Distribution
1	Outlet pressure	**± 0.5 %**	Uniform
2	Mass flow rate	**± 0.5 %**	Uniform
3	Inlet temperature	**± 2.0 %**	Normal
4	Power	**± 2.0 %**	Normal
5	Cladding Wall Roughness	**± 30.0 %**	Normal
6	Spacer grid pressure drop coefficient	**± 5.0 %**	Uniform
7	Gap Conductance	**± 35.0 %**	Uniform
8	Fuel Conductivity	**± 10.0 %**	Uniform
9	Cladding Conductivity	**± 6.25 %**	Uniform

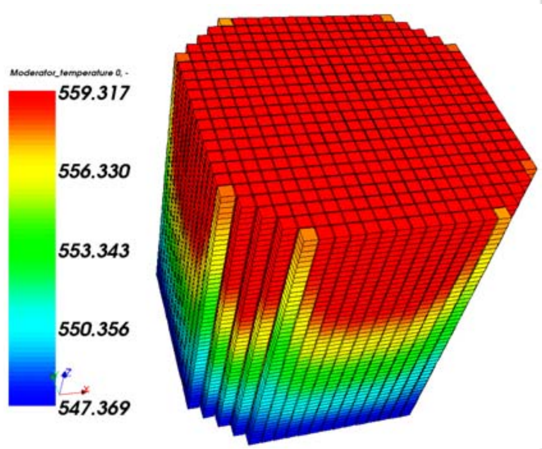
COBRA-TF O2 nominal steady state results

- *Axial pressure drop* and *Outlet void fraction* are the output parameters studied (500 runs were used).
- The computed sensitivity coefficients by URANIE corresponding to a steady state at nominal operating conditions using COBRA-TF.

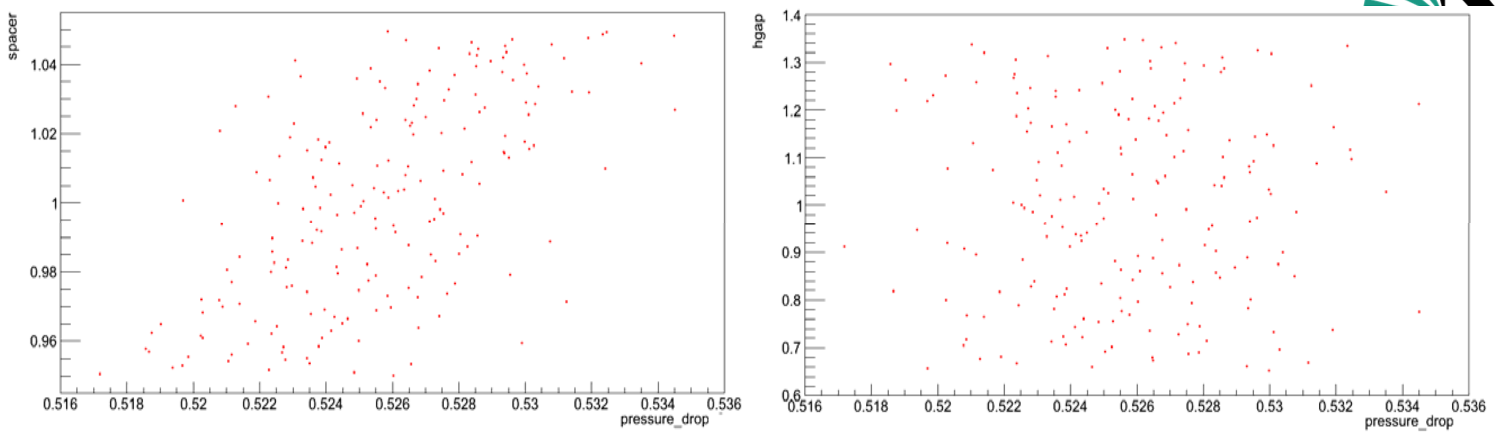
	Mass flow rate	Inlet enthalpy	Pressure	Heat flux	Spacer	Gap conductivity
Axial pressure loss	0.259488	0.384382	-0.52228	0.410298	0.597949	-0.0036
Void Fraction	-0.198526	0.673415	-0.660979	0.275753	-0.0077247	0.02582



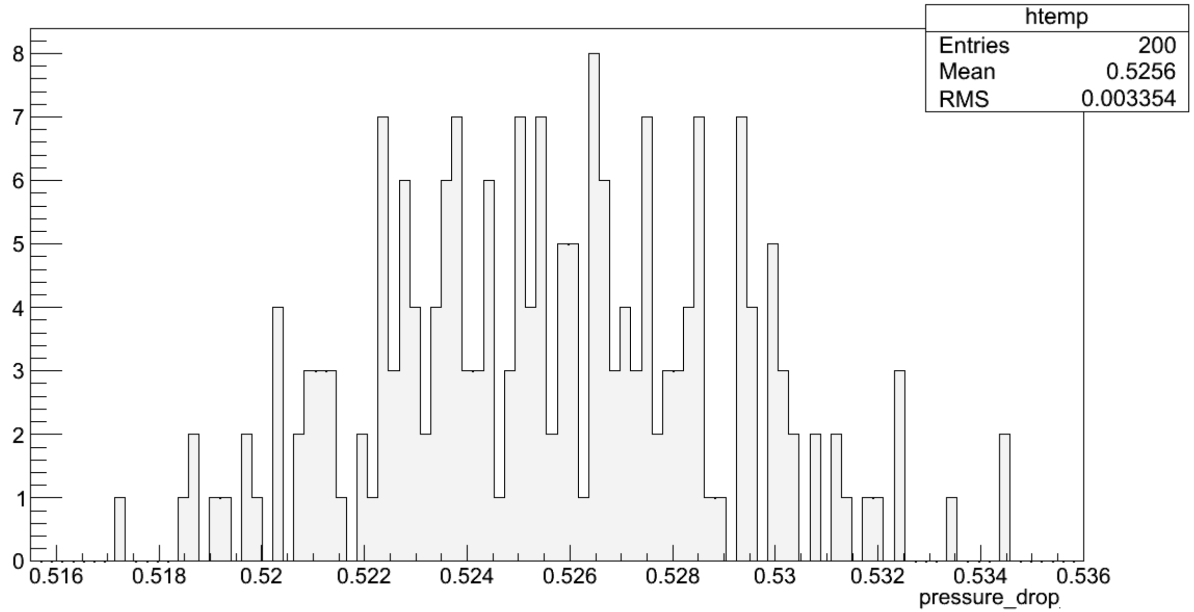




COBRA-TF O2 nominal steady state results



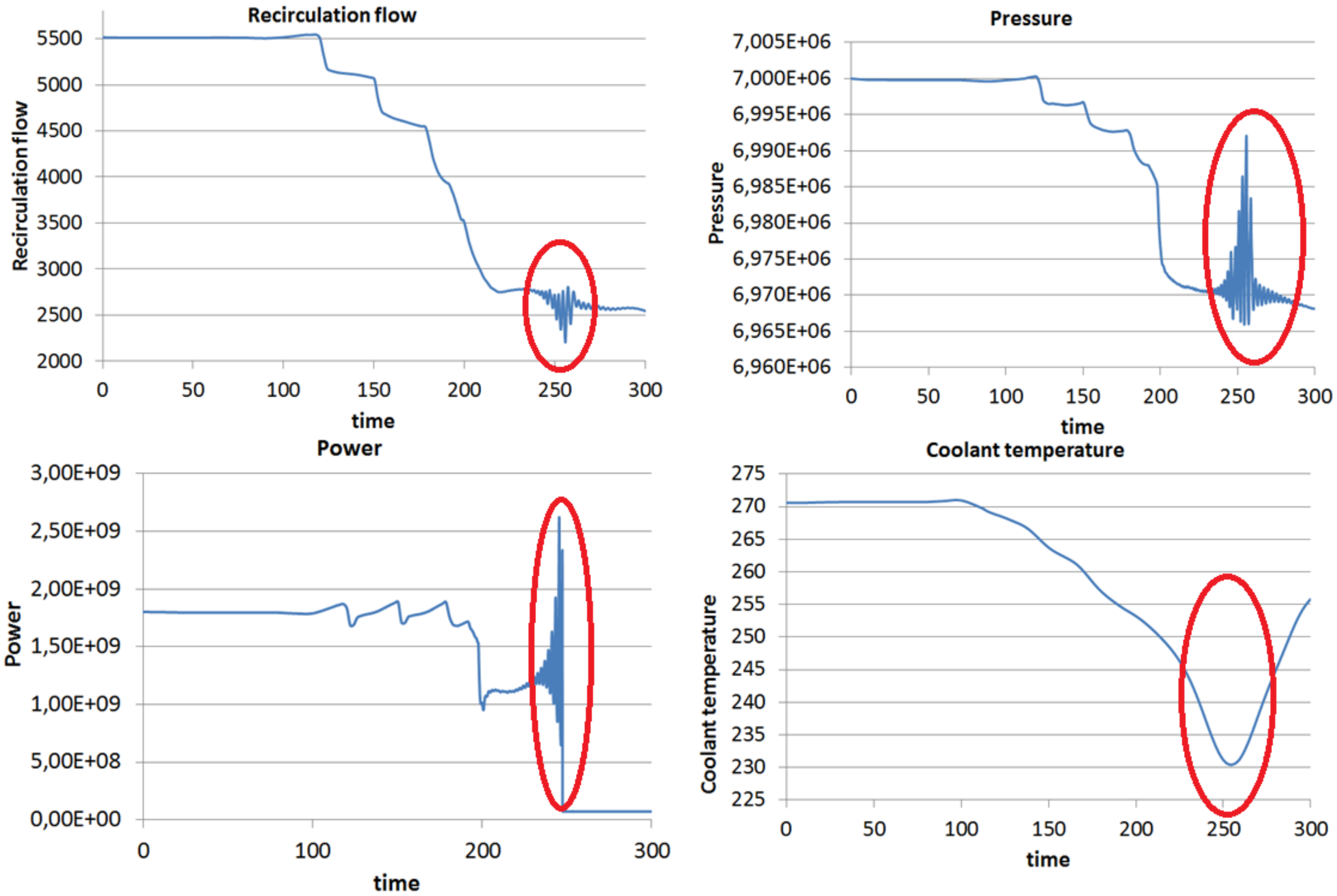
Axial pressure drop for different spacer coefficient and gap boundary conditions



Pressure drop distribution over all COBRA-TF runs

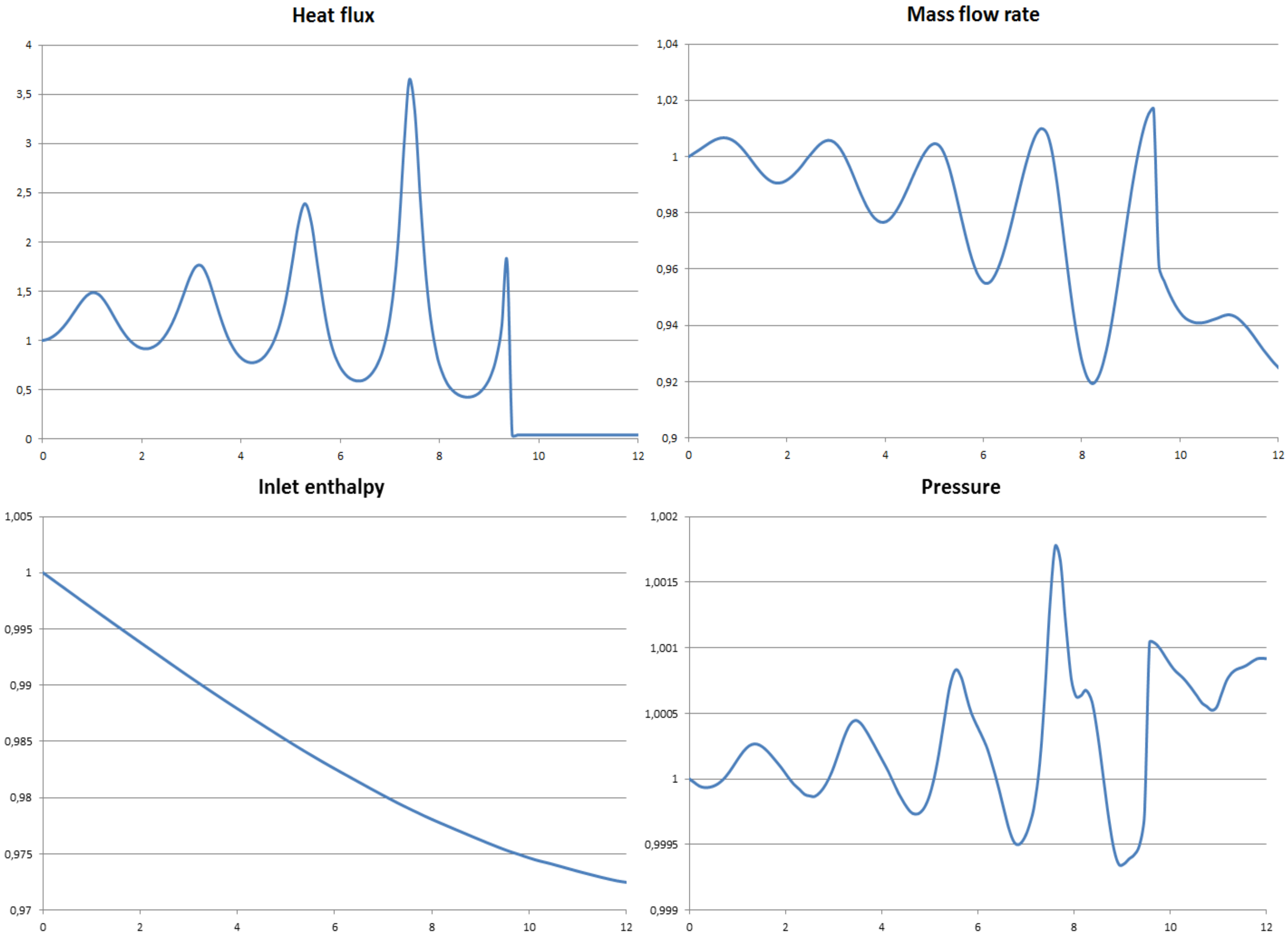
Transient Boundary Conditions applied

- The next boundary conditions were introduced into CTF for the simulation of the oscillations (only 12s are analyzed).
  - Power, inlet temperature, pressure, mass flow rate.



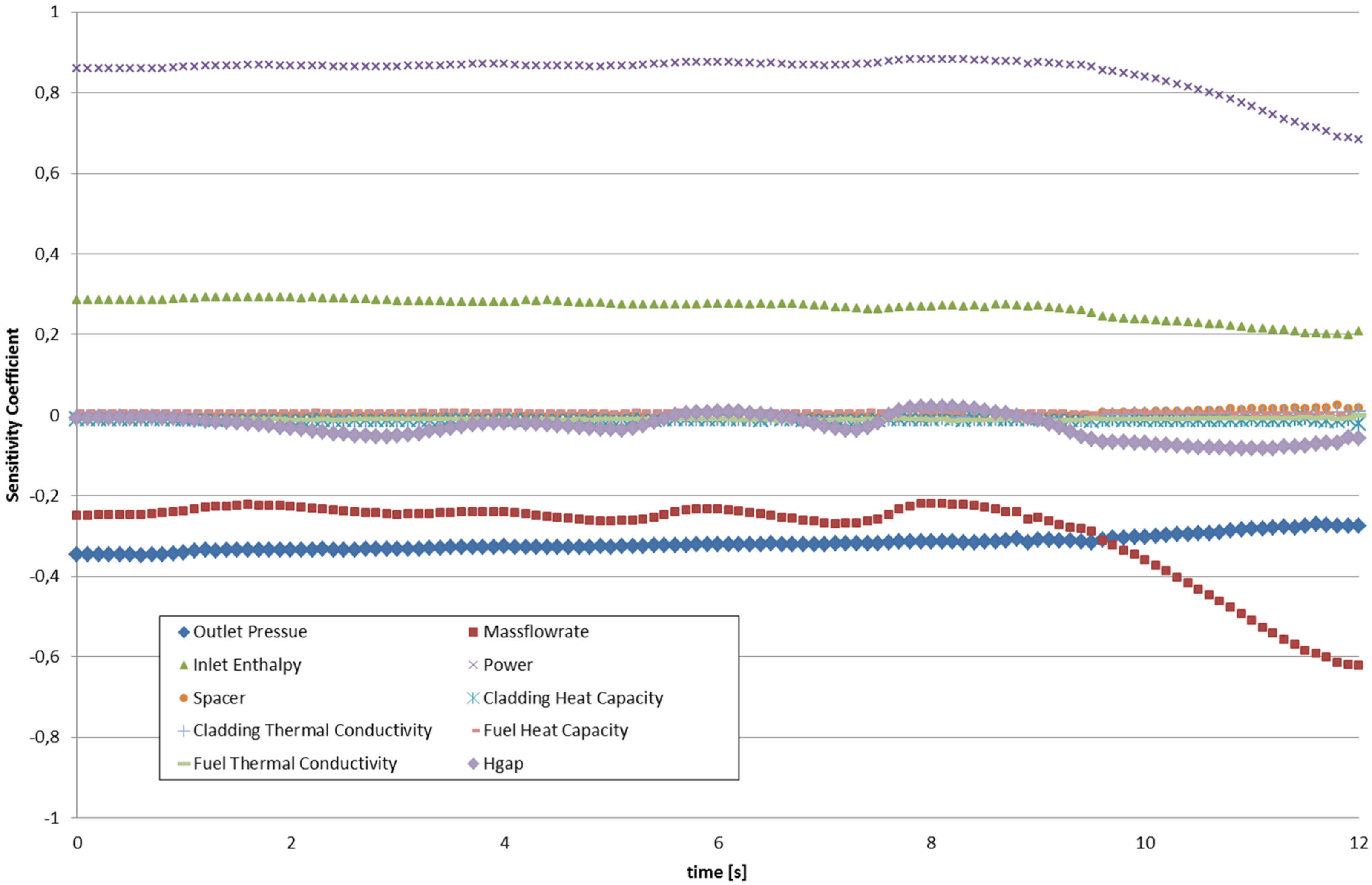
Transient Boundary Conditions applied

- Those BC are representative of a stability event.



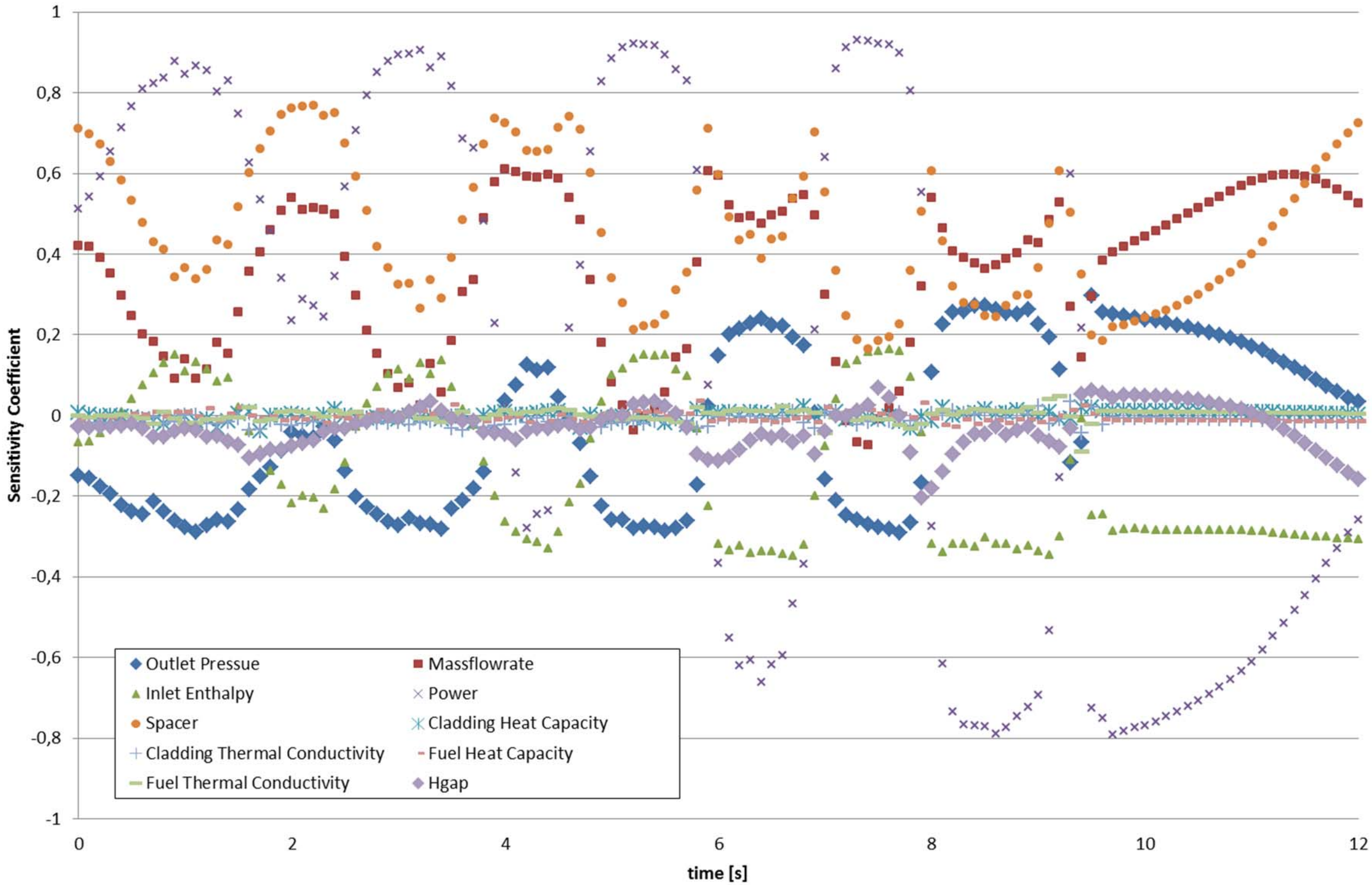
COBRA-TF Results in the zooming area

- Sensitivity coefficients of the void fraction



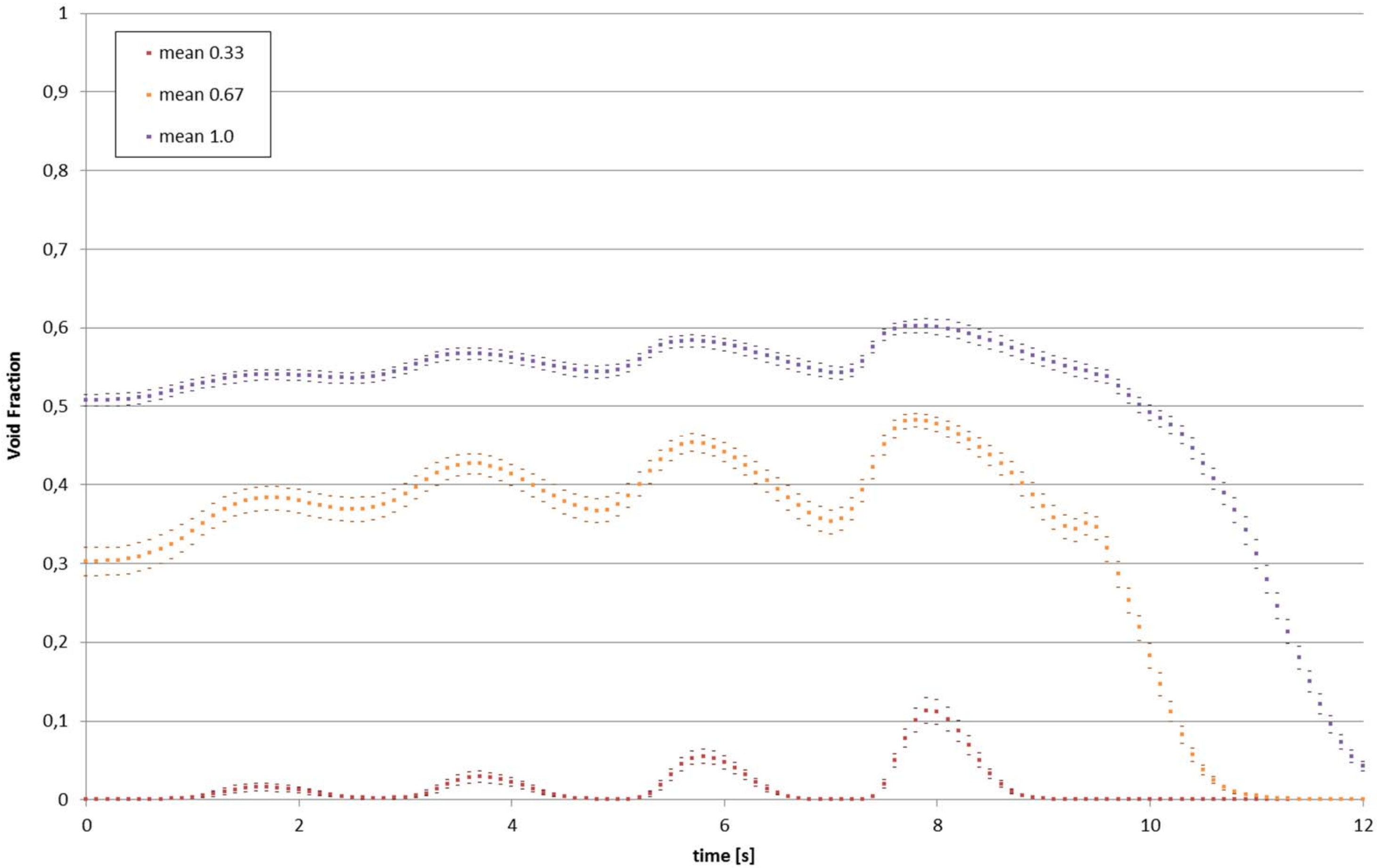
COBRA-TF Results in the zooming area

- Sensitivity coefficients of the axial pressure drop



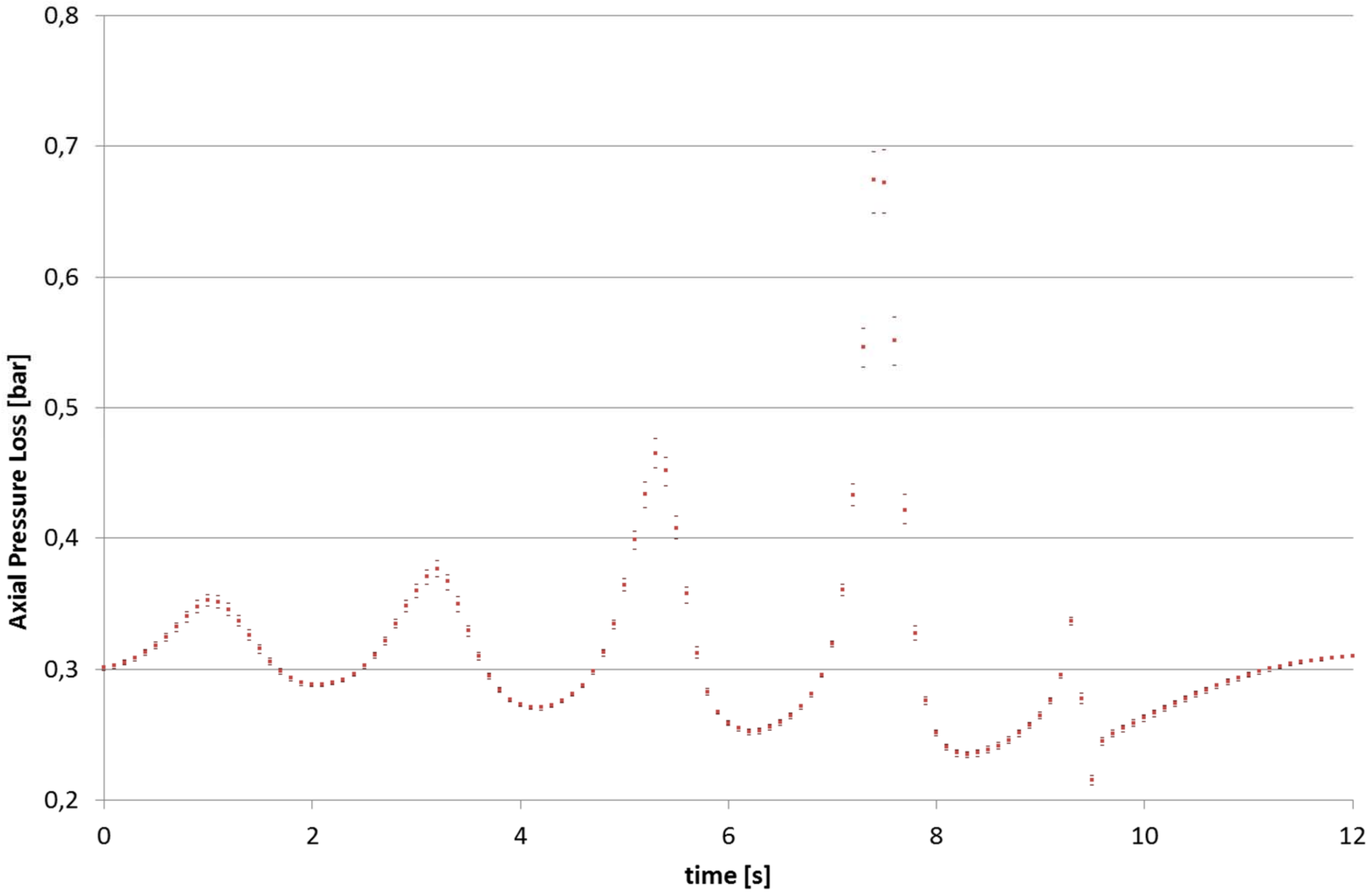
COBRA-TF Results in the zooming area

- Mean, min and max value of the void fraction at three different elevations: 1/3, 2/3 and exit



COBRA-TF Results in the zooming area

- Mean, min and max value of the axial pressure loss of the bundle average



Conclusions and Outlook

- Investigations on the use of URANIE platform for sensitivity analyses have been conducted within the framework of the NURESAFE FP7 EU project.
- COBRA-TF model for O2 core was developed
  - Good agreement between O2 reference values and predictions,
  - FLICA4 and SUBCHANFLOW models developed too.
- Studies using the COBRA-TF code on steady state and transient simulations were carried out.
- Satisfactory results, high degree of flexibility in the URANIE scripts.
- Further validation of the inputs is still needed (FLICA4 v1.11.13).
- The developed inputs could be applied in Phase 3, exercise 2 and 3 of the O2 benchmark.

Thanks for your attention