NURESAFE WP1.1
TESTBED FOR INTEGRATED COUPLING AND UNCERTAINTY QUANTIFICATION METHODS

Updates in the SUBCHANFLOW component
Support to SALOME 6 series

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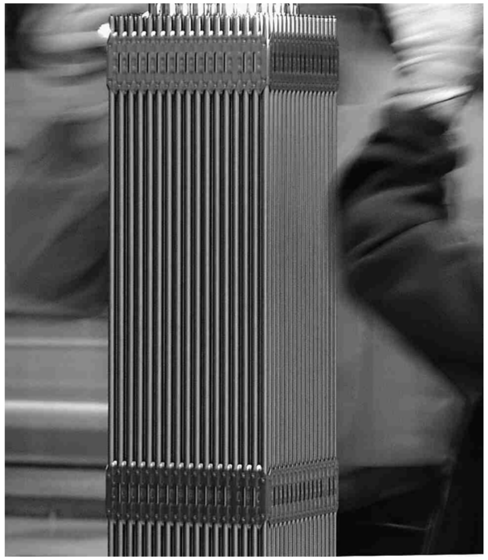
Outline

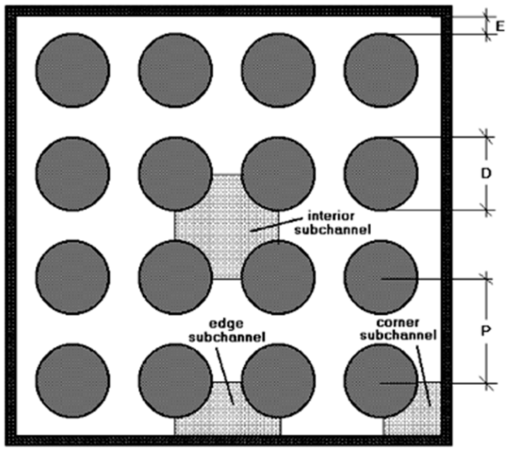
- Short review of SUBCHANFLOW code
- Updates in the SUBCHANFLOW component
- Current component capabilities
- Implementation of a plugin in the PWRDATA for input generation
- Conclusion and Outlook

SUBCHANFLOW Features

- **Description of the KIT code SUBCHANFLOW:**

- ✓ **Single and two phase (mixture) subchannel code for water, sodium, lead and gas cooled reactors.**
- ✓ **Mass, momentum, enthalpy (3)-equation solver for strictly upward flow.**
- ✓ **Fast running implicit fix-point iteration solver with axial plane wise matrix solution.**
- ✓ **Hexagonal and square bundle geometry.**
- ✓ **Stationary and transient solutions.**
- ✓ **Applicable to LWR & Innovative reactors (SFR).**
- ✓ **Capability for coupling with a system code.**





Sub-channel analysis of SUBCHANFLOW

SUBCHANFLOW Features

SUBCHANFLOW
KIT Subchannel Code

HZDR Dresden
- Simulation of single and two phase flow tests

RWTH Aachen
- INBK: Simulation of gas cooled reactors for transmutation (AGATE Project)

TÜV Nord
- LWR applications of SUBCHANFLOW (Testing Phase)

National

Use of SUBCHANFLOW at KIT
- EU NURESAFE Project
- EU THINS Project (Lead/Bismuth)
- EU CDT Project (Lead)
- Multi-physics coupling with
  - MCNP5, SERPENT
  - DYN3D-SP3 (transport)
  - COBAYA3 (Diffusion)
- International Benchmarks e.g. BFBT, PSBT
- Code improvement and validation:
  - (Internships, Bachelor, MSc, PhD)

EU JRC IE Petten
- Gen-IV reactors

UPM/ Nuclear Engineering Chair
- EU ESFR Project
- Coupling with COBAYA3

DNC / Delft
- EU HPMC Project
- SCF coupling with time-dependent Monte Carlo

CIEMAT/ Nuclear Safety Department
- SCF / MCNPX Coupling

International

Updates in SUBCHANFLOW component

- **SUBCHANFLOW component is an in-kind contribution from KIT to the project.**
- SUBCHANFLOW version 2.5 has been uploaded in the NURESAFE svn repository.
- The MEDMEM format in all the methods have been replaced by MEDCoupling, standard library in SALOME6 series.
- Nevertheless, still supporting SALOME5 series for non-regression testing purposes.
- Major changes:
  - Implementation of a thermal and fluid meshes, needed for two level coupling (hybrid runs).
  - Reorganization of the methods and clean-up: SUBCHANFLOW.cxx size decreased from 4300 to 3150 lines.
- No ICOCO interface has been developed yet.

Updates in SUBCHANFLOW component

- The next methods are available in the SUBCHANFLOW.hxx:

```
void init_SCF(const char *inputPath,
              const char *outputPath,
              const char *fileName,
              const char *debug_initialization);

void setPower_SCF(const ParaMEDMEM::MEDCouplingFieldDouble *fuel_power,
                  const ParaMEDMEM::MEDCouplingFieldDouble *coolant_power,
                  double Total_power,
                  const char *Print,
                  const char *normalization,
                  const char *transient);

double transient_SCF();
```

Initialize transient calculation

```
void set_Powermap_SCF();

void calc_SCF(int step_count,
              double time_real,
              double time_step,
              double old_time);

void END_SCF();

void StandAloneSCF();
```

Updates in SUBCHANFLOW component

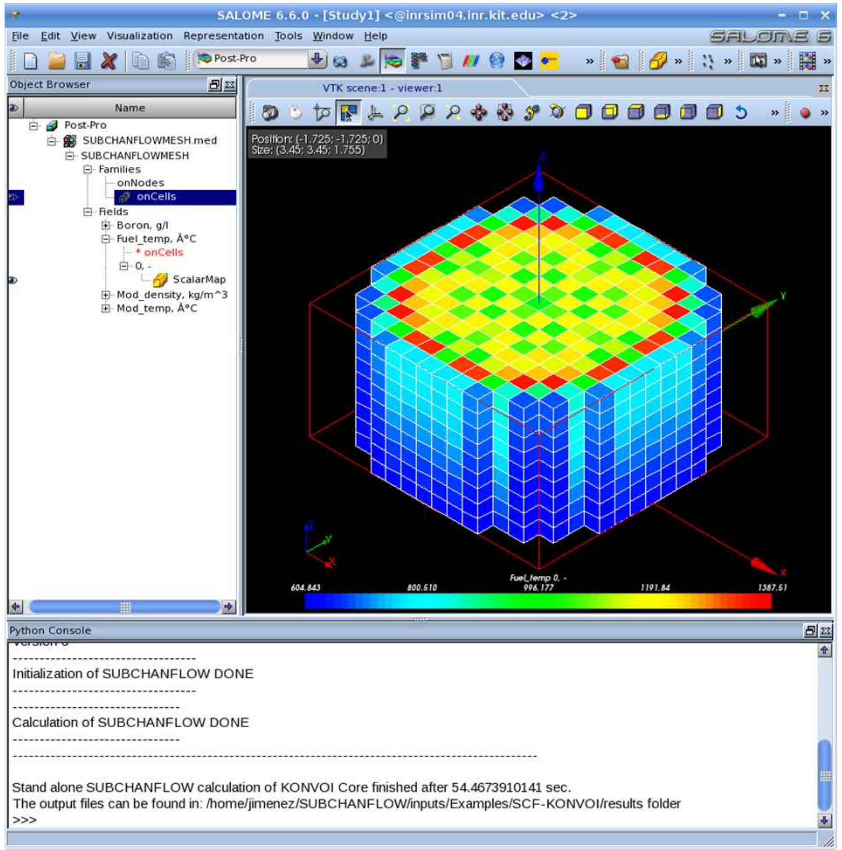
- The next methods are available in the SUBCHANFLOW.cxx:

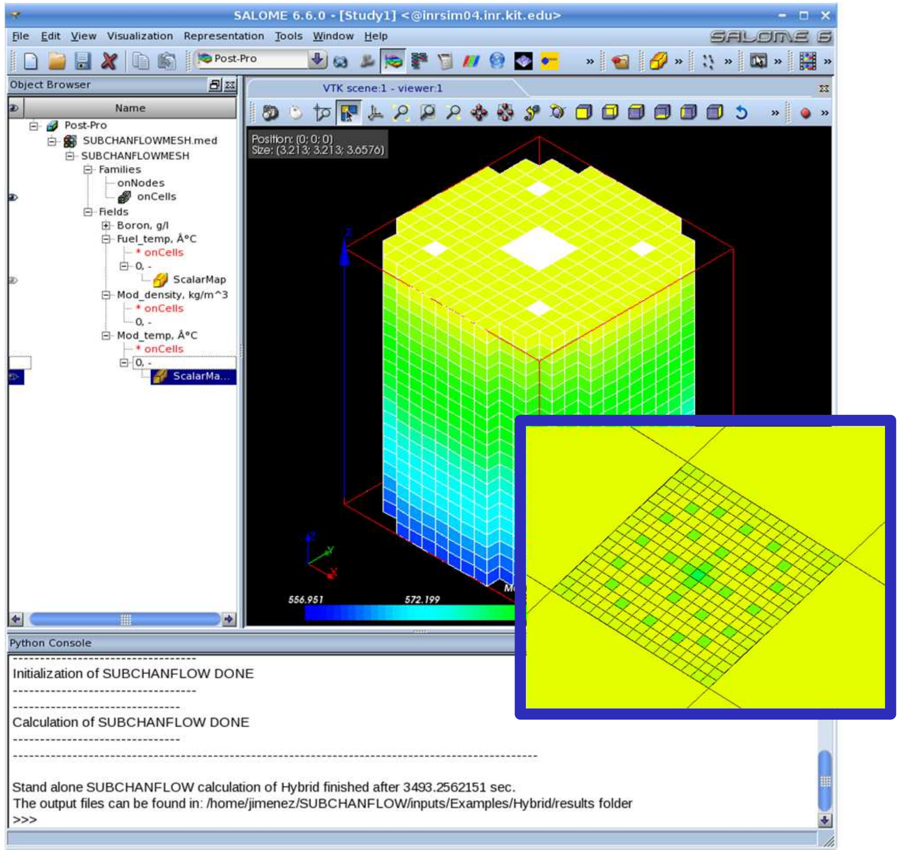
```
void Mesh_SCF(double Origin_X_m,
              double Origin_Y_m,
              double Origin_Z_m,
              int geometry);

ParaMEDMEM::MEDCouplingFieldDouble *get_outputField_SCF(const char *name) const;

ParaMEDMEM::MEDCouplingFieldDouble *getFeedback_SCF(const char *TH_variable,
                                                    double Real_time) const;

double get_TH_variable_SCF(const char *variable,
                           int channel,
                           int axial,
                           double lambda);

double get_results_SCF(double time_real,
                       int step_count,
                       const char *variable,
                       double lambda);

double TH_convergence_SCF(const ParaMEDMEM::MEDCouplingFieldDouble* field_1,
                          const ParaMEDMEM::MEDCouplingFieldDouble* field_2,
                          const char *TH_variable);
```

TFUEL,TMOD, DMOD or VOID

Current component capabilities

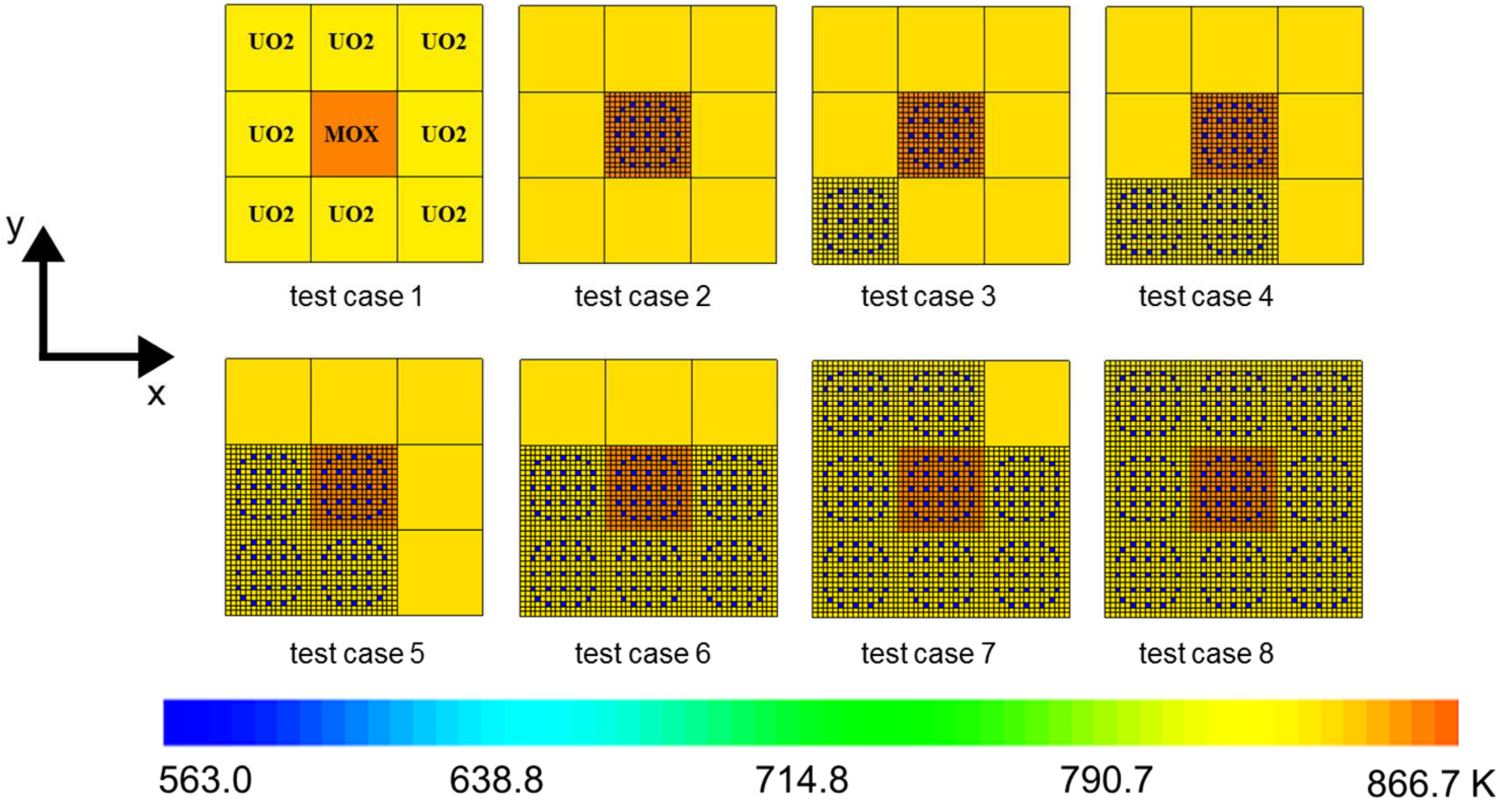
- **The next features are available: CARTESIAN GRIDS**
  - Channel level and hybrids meshes.





Current component capabilities

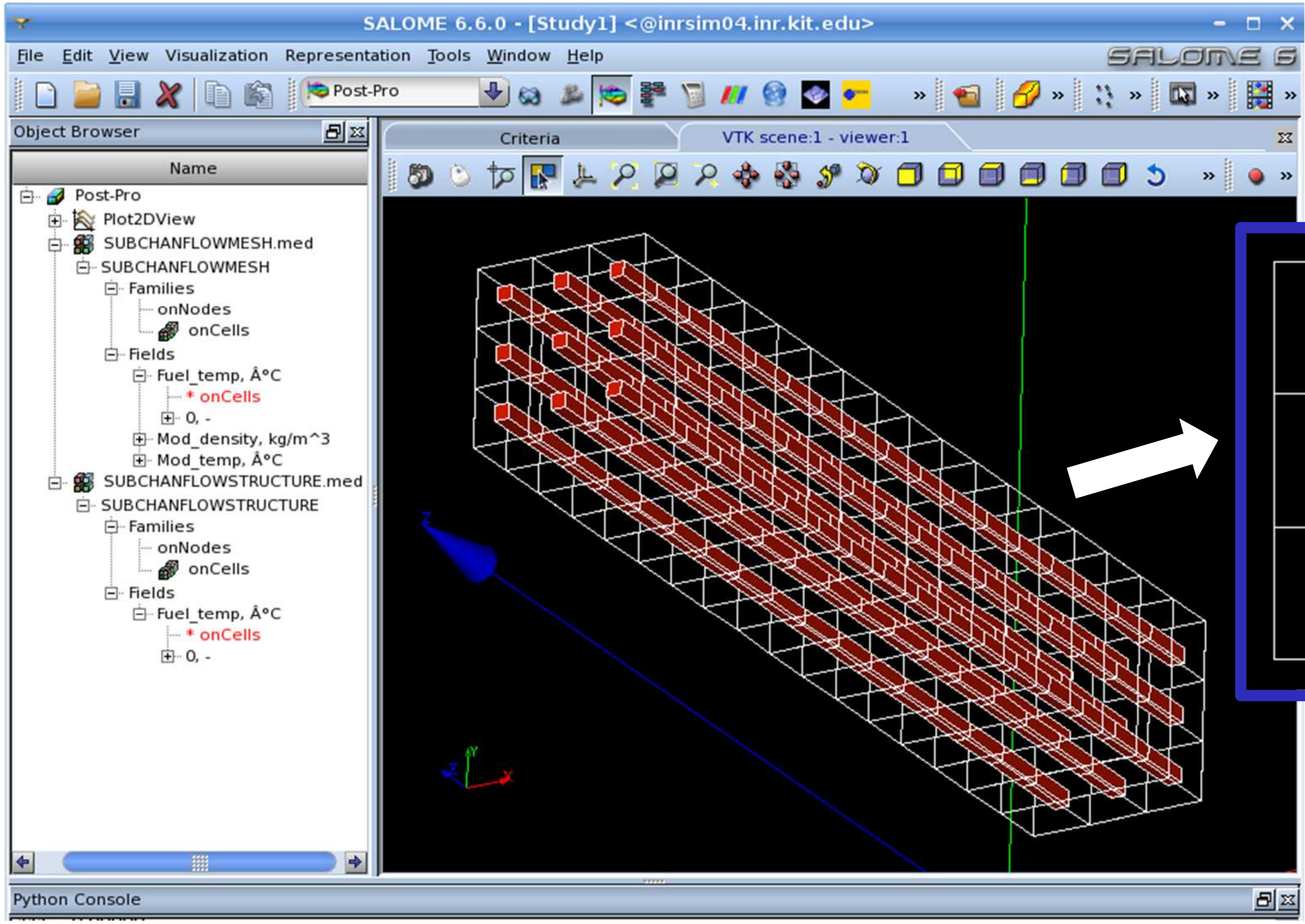
- **The next features are available: CARTESIAN GRIDS**
  - Channel level and hybrids meshes (Any number of refinements using the preprocessor).

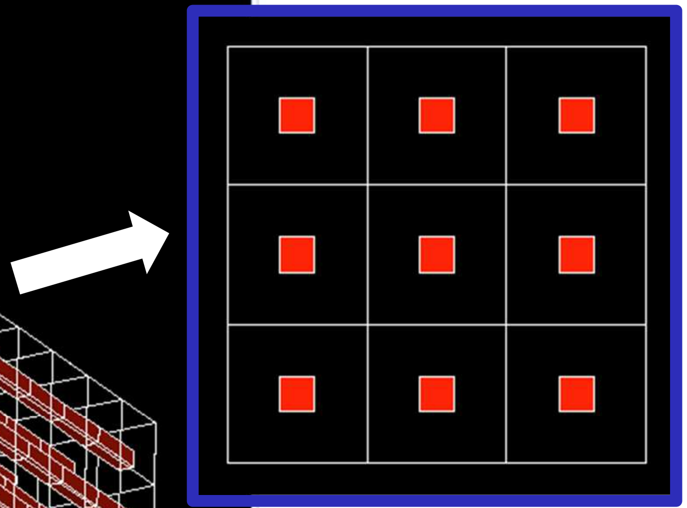


"***Implementation of Hybrid Simulation Schemes in COBAYA3/SUBCHANFLOW Coupled Codes for the Efficient Direct Prediction of Local Safety Parameters***", Calleja, M., Jimenez, J., et al., Annals of Nuclear Energy, volume 70, pages 216–229, 2014, http://dx.doi.org/10.1016/j.anucene.2014.02.028

Current component capabilities

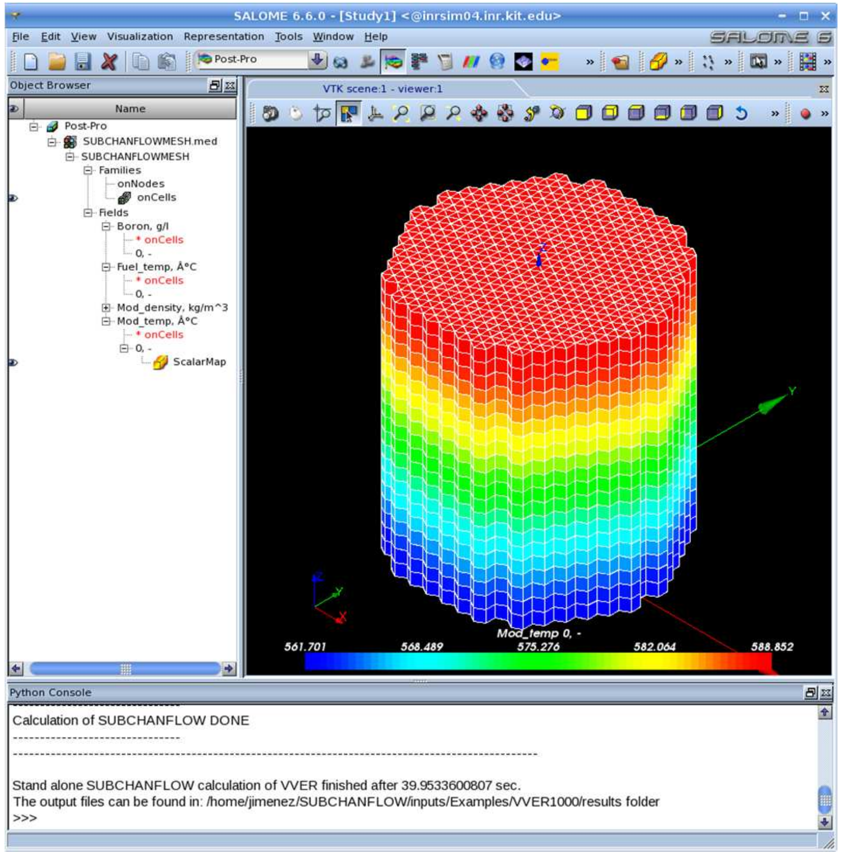
- **The next features are available: CARTESIAN GRIDS**
  - Thermal and fluid meshes for coupling with INTERP_2_5D

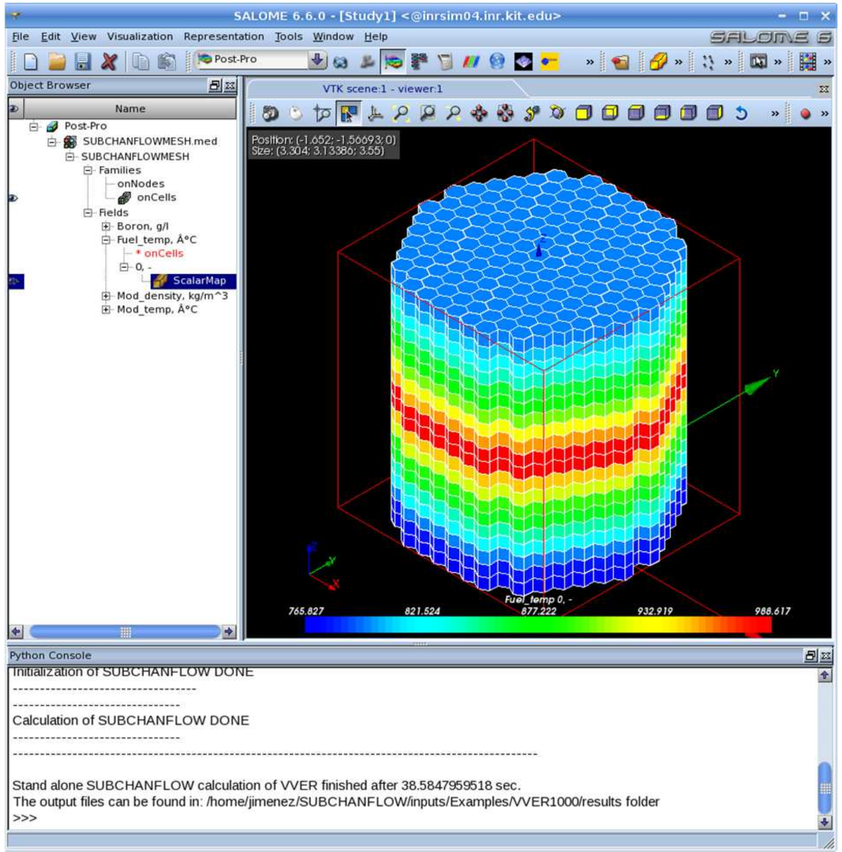




Current component capabilities

- **The next features are available: HEXAGONAL GRIDS**
  - Triangular or hexagonal based meshes.





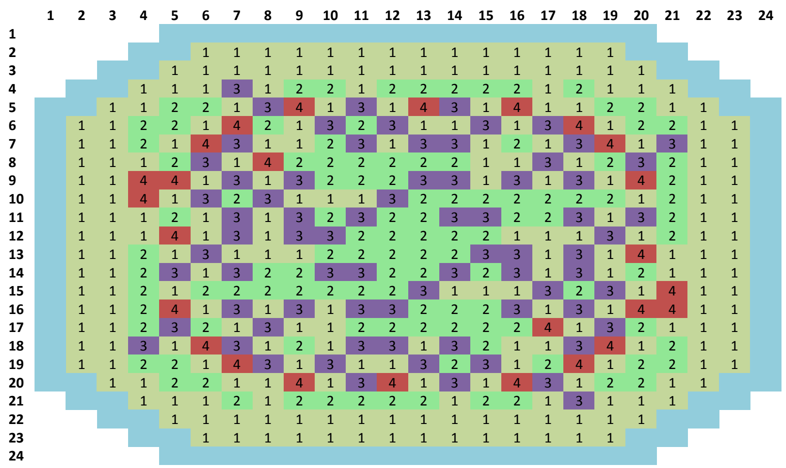
SUBCHANFLOW input decks already available

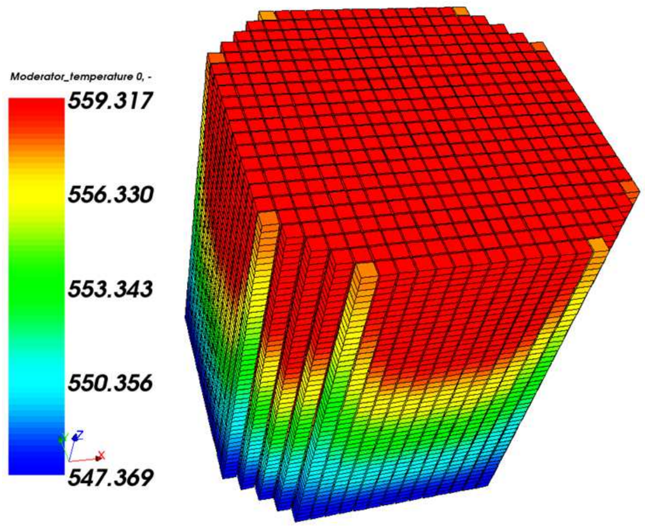
- This is the validation database of COBAYA3/SCF (PhD. M. Calleja)

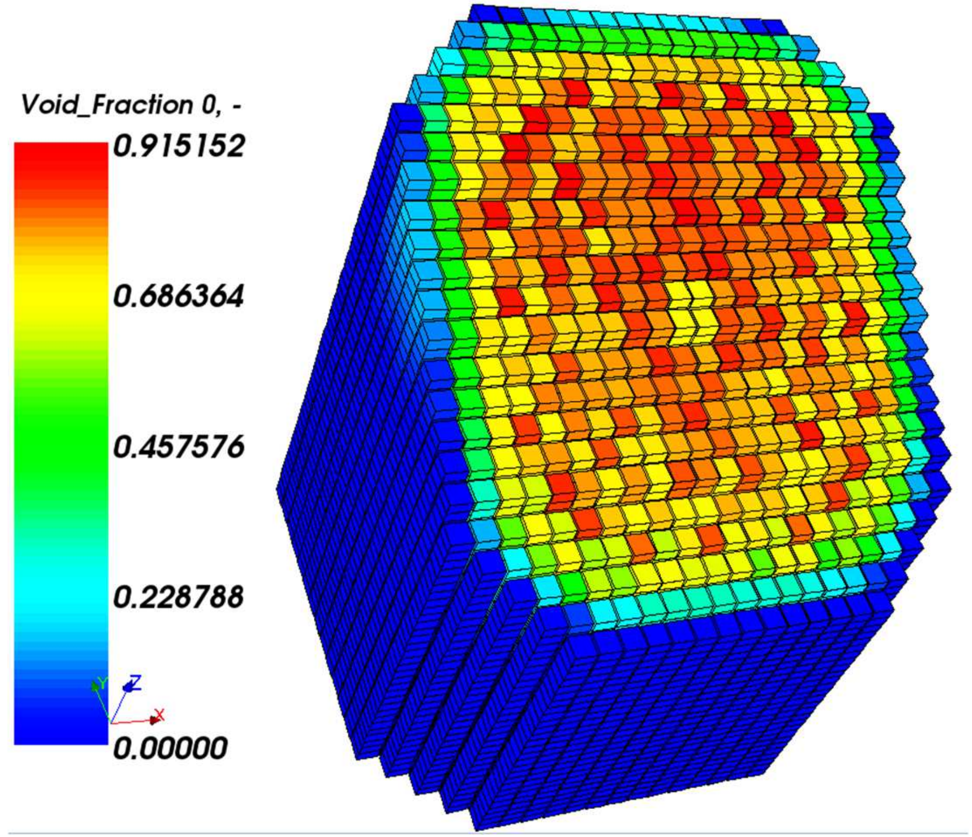
	Benchmark – Nodal Square	Case	Type	Condition
1	NEABN LWR core transient benchmark R. Fraikin, NEA-NSC 3-D PWR Core Transient Benchmark: Uncontrolled Withdrawal of Control Rods at Zero Power, OECD report no. NEA/NSC(93), 1993	A1	Steady State	HZP
		A1	Transient	From HZP
2	OECD/NEA US-NRC PWR MOX/UO2 core transient benchmark T. Downar and T. Kozowski, PWR MOX/UO2 Core Transient Benchmark, Nuclear Science, NEA/NSC/DOC, 2006	2a	Steady State	HZP/HFP
		4a	Transient	From HZP
3	PWR Main Steam Line Break Benchmark (MSLB) K. Ivanov, A. Baretta and T. Beam, Pressurized Water Reactor Main Steam Line Break (MSLB) Benchmark: Final Specifications, Nuclear Energy Agency, 1999	2	Steady State	HFP
		2a	Transient	From HFP
4	PWR MOX/UO2 boron dilution transient S. Kliem, S. Mittag, A. Gommlich and P. Apanasevich, Definition of a PWR boron dilution benchmark, A Collaborative Project NURISP report, February, 2011		Steady State	HZP
			Transient	From HZP
	Benchmark – Nodal Hexagonal	**Case**	**Type**	**Condition**
5	KALININ-3 Coolant Transient Benchmark K. Ivanov, V.A. Tereshonok, S.P. Nikonov, M.P. Lizorkin, K. Velkov and A. Pautz, KALININ-3 coolant transient benchmark: Switching off of one of the four operating main circulation pumps at nominal reactor power, OECD report no.NEA-1848/04 zz-KALININ3, 2008	3a	Steady State	HZP
		3b	Steady State	HFP
		3b	Transient	From HFP
	Hybrid coupling		**Type**	**Condition**
6	PWR MOX/UO2 - one hybrid FA (based on T. Downar and T. Kozowski, PWR MOX/UO2 Core Transient Benchmark, Nuclear Science, NEA/NSC/DOC, 2006)		Steady State	P_{tot} at 16.2 % from nominal

Last applications of SUBCHANFLOW

A core model for the Oskarshamn-2 NPP was developed and will be applied in the Phase 3 of the OECD/NEA benchmark





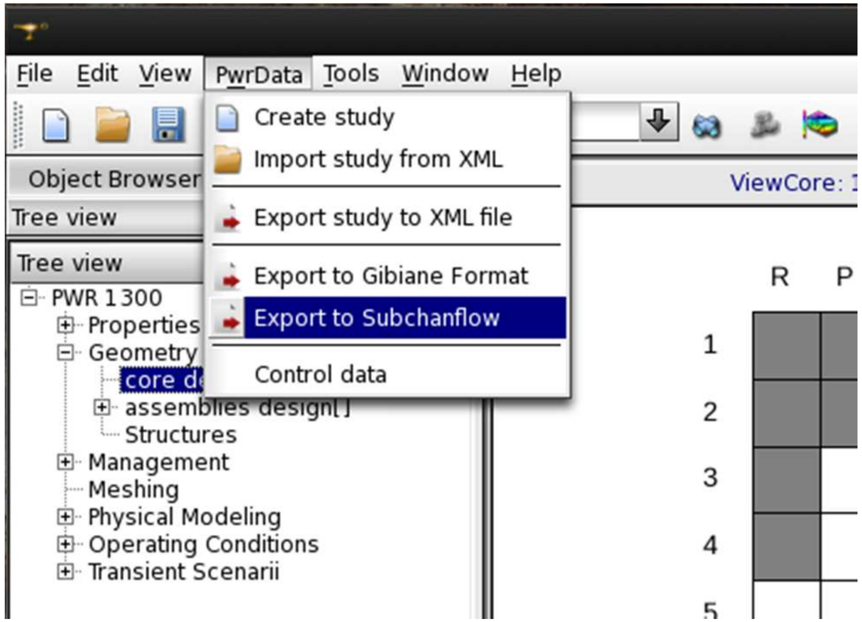


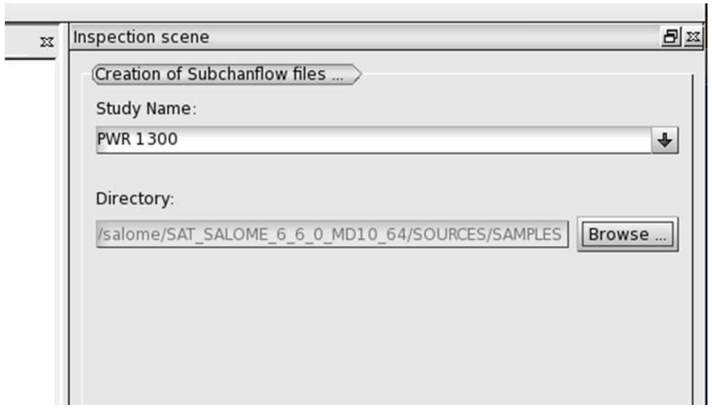
NURESAFE PWRDATA module

- PWRDATA is a Salome component for defining Pressurized Water Reactor inputs for simulations.
- It is being developed at CEA.
- Currently, it supports generation of CRONOS and FLICA input files.
- A new export option to generate SUBCHANFLOW input files is being developed at KIT-INR.

Description of the SCF export option

- Using SUBCHANFLOW export:





- Select "Export to Subchanflow" in menu
- Specify target directory
- THAT´S ALL!!

Plugin development status

- SUBCHANFLOW plugin in PWRDATA is under development.
- Minimal changes (<25 lines) to existing PWRDATA code.
- Main tables concerning geometry (channel table, neighbouring table, rod table) can be written from the general data description.
- Currently only generation of assembly-level inputs.
- Development is 60% complete.

File	Lines changed	Lines added
PWRDATAGUI.py	1	10
PWRDATADesktop.py	0	11
scfexportdialog.py	new file	113
scfexport.py	new file	348

Conclusion and Outlook

- SUBCHANFLOW 2.5 version has been updated to run in SALOME6 series using MEDCoupling libraries.
- PWRDATA plugin is currently under development. Still there are open issues but this is very promising.
  - Ready to use for work with assembly-level inputs.
  - Choice of Python (in PWRDATA) led to speedy development.

FUTURE WORK

- **In the next months:**
  - Generation of pin-level and/or hybrid inputs with the PWRDATA plugin
  - Develop of an interface with ICOCO, future coupling with other TH codes like CATHARE o ATHLET.
  - Coupling with the DYN3D component using the INTERP_2_5D tool.
  - Using Sphinx/Doxygen for html documentation of the component.

Parallel computing

- Adding the OpenMP pragmas from the SUBCHANFLOW version used in DYNSUB to the component black box library.

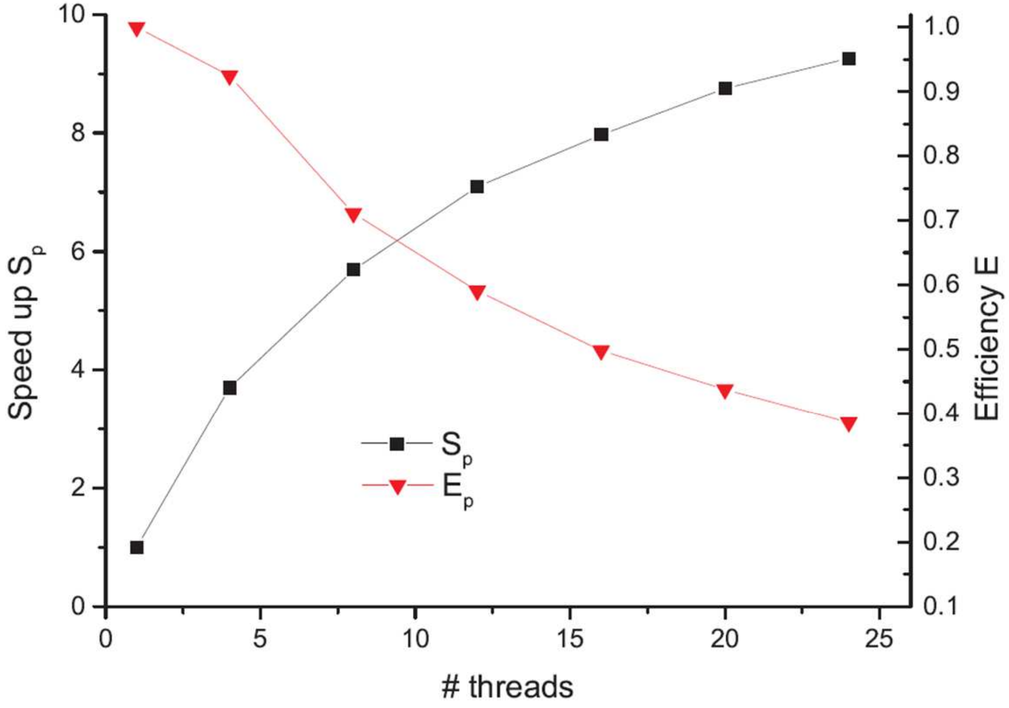


Figure 1: Parallel speed up and efficiency vs. number of threads for DYNSUB modelling of a full PWR core under HFP conditions

THANKS FOR YOUR ATTENTION