NURESAFE WP1.4
HIGHER-RESOLUTION VVER MSLB

KIT results for the Hot assembly BC problem using COBRA-TF and SUBCHANFLOW

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Outline

- **A fine mesh preprocessor for hexagonal geometry was produced and tested: Hexbundle**
  - Working for SUBCHANFLOW and COBRA-TF.
  - Operative SUBCHANFLOW MEDCoupling interface was released on 09.03.2015, generation of MED files enabled.
  - Adaptation of the MEDCoupling interface recently achieved in COBRA-TF (June 2015).
- **Calculation of hot assembly problem with provided BC is reported here.**
  - The COBRA-TF input decks plus python scripts can be found in the next folder:

https://www-svn-corpus.cea.fr/nuresafe/SAT/TEST/RESSOURCES/data/cobratf/VVER-1000/transient/KIT-HOT-CHANNEL

  - The whole SUBCHANFLOW input decks can be found in the next folder:

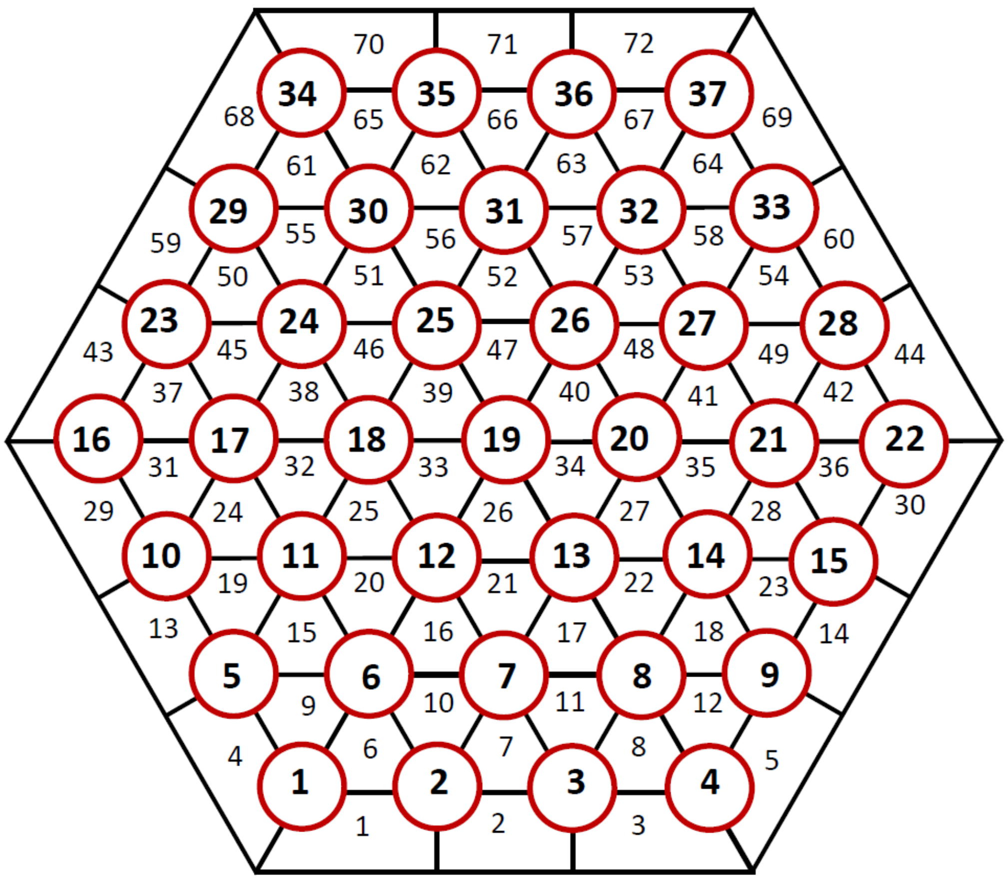
https://www-svn-corpus.cea.fr/nuresafe/SAT/TEST/RESSOURCES/data/scf/VVER_Hot_Assembly_BC_problem

- **Conclusion and Outlook**

Fine mesh preprocessor (KIT Fortran code)

- You can find it in the svn repository

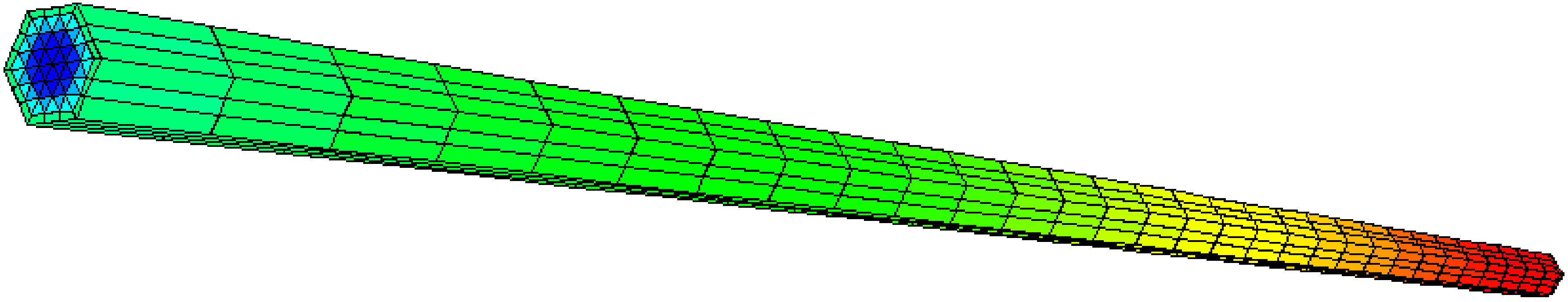
  /SAT/TEST/RESSOURCES/HexBundle



- **Fully operational for SUBCHANFLOW and COBRA-TF geometry tables generation.**
- **Inclusion of Guide tubes and instrumentation rods in SCF.**
- **MEDCoupling enabled in SCF and CTF.**
- **TO DO**
  - Extension to minicores

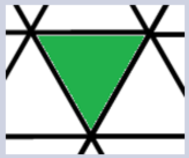
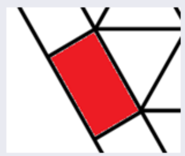
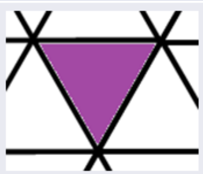
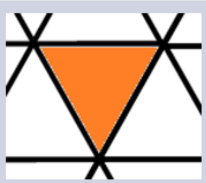
Fine mesh preprocessor (KIT Fortran code)

- **Few input parameters:**
  - Number of rods in the bundle (fuel and guide tubes). (**37**)
  - Pitch between the fuel pins. (**12.81380e-3 m**)
  - Side length of the aristae. (**47.408e-3 m**)
  - Rod diameter. (**9.1455e-3 m**)
  - Guide tube diameter. (**12.663e-3 m**)
  - Instrumentation rod diameter. (**11.256e-3 m**)



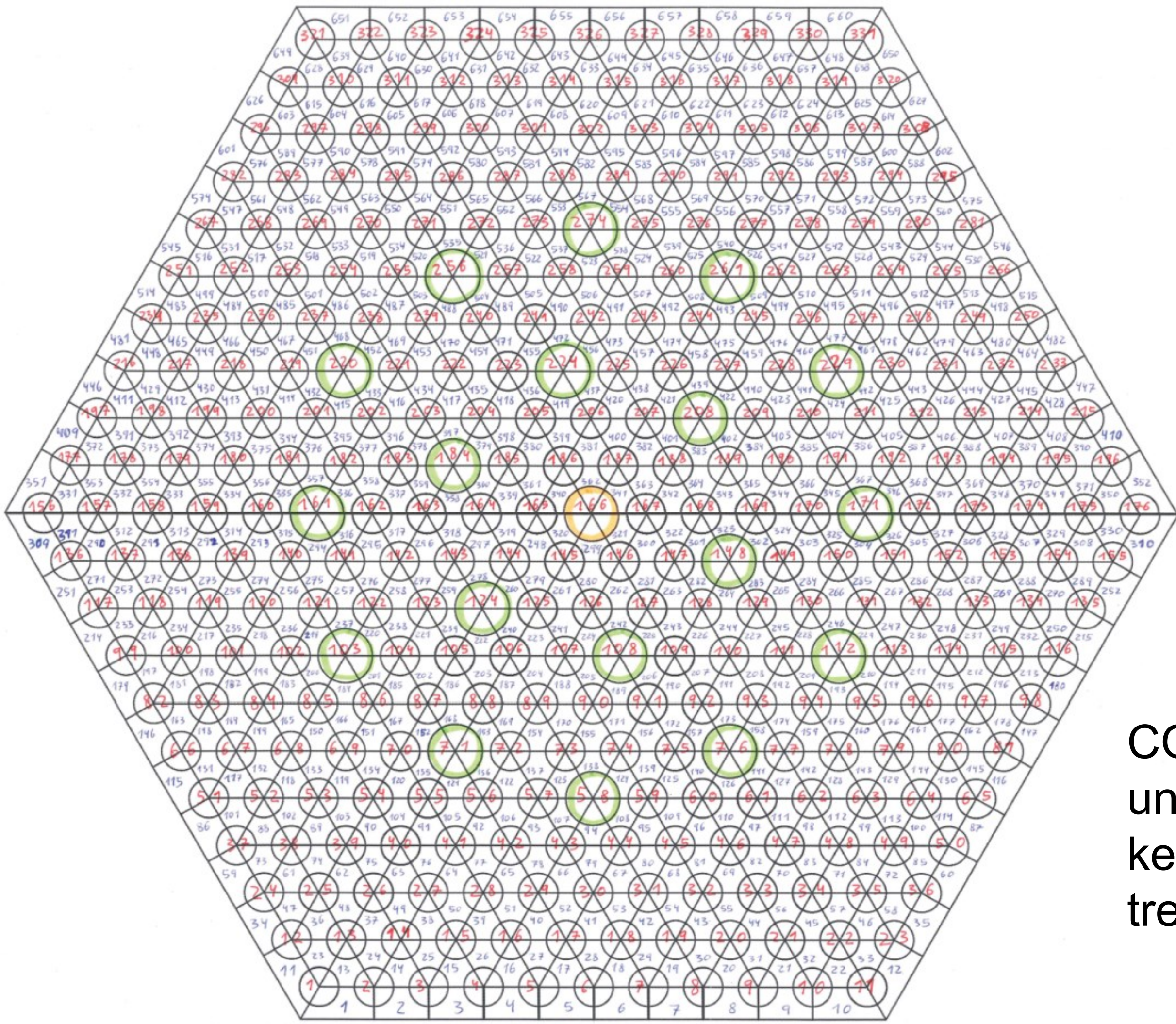
Fine mesh preprocessor (KIT Fortran code)

- ## Subchannel types are predefined:

Type (tchan)	Shape	Area	Wetted Perimeter	Heated Perimeter
1 Central subchannel		$pitch^2 \cdot \sqrt{3}/4$ - 0.5·rod_area	0.5·rod_perimeter	0.5·rod_perimeter
2 Lateral subchannel		pitchb·pitch - 0.5·rod_area	0.5·rod_perimeter	0.5·rod_perimeter
3 Corner subchannel		pitchb·pitch + 0.5·$pitchb^2$·tan(30) - rod_area·(7/12)	rod_perimeter· (7/12)	rod_perimeter· (7/12)
4 Guide tube subchannel		$pitch^2 \cdot \sqrt{3}/4$ – 1/3·rod_area – 1/6·guideT_area	1/3·rod_perimeter+ 1/6·guideT_perimeter	1/3·rod_perimeter
5 Instrumentation rod subchannel		$pitch^2 \cdot \sqrt{3}/4$ – 1/3·rod_area – 1/6·InstR_area	1/3·rod_perimeter+ 1/6·InstR_perimeter	1/3·rod_perimeter

Fine mesh preprocessor (KIT Fortran code)

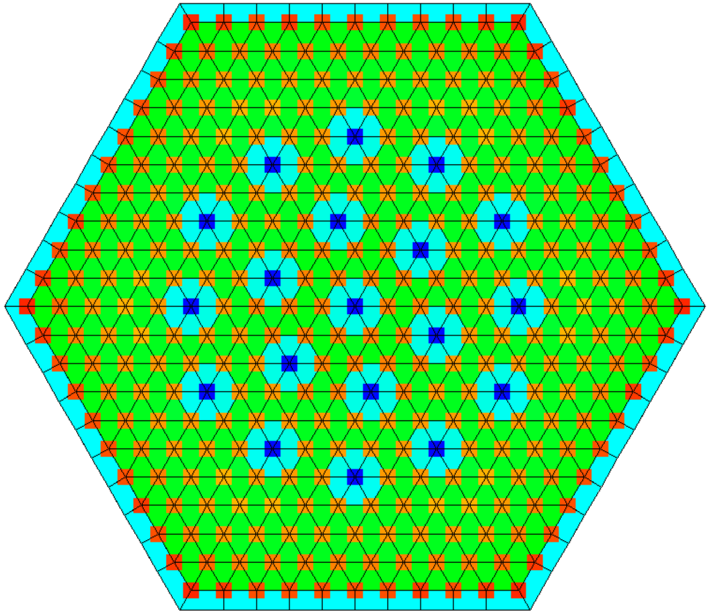
- The final goal was to be able to mesh the hot FA



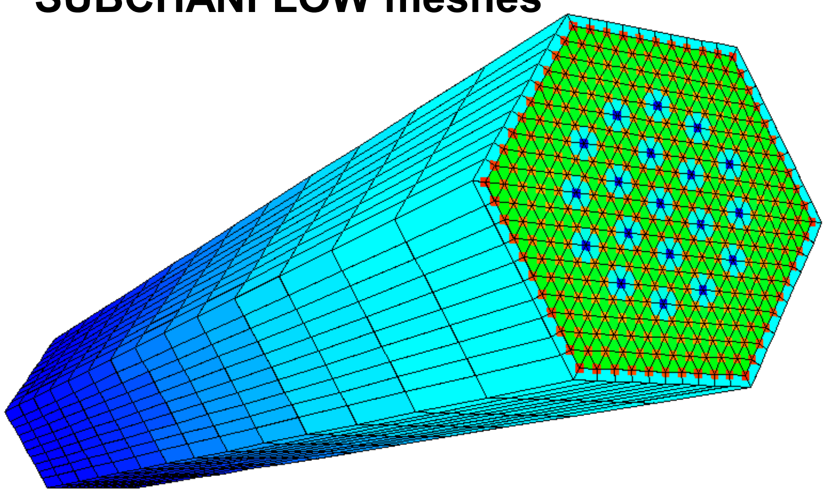
MESH DETAILS:
331 fuel rods
660 subchannels
876 gaps

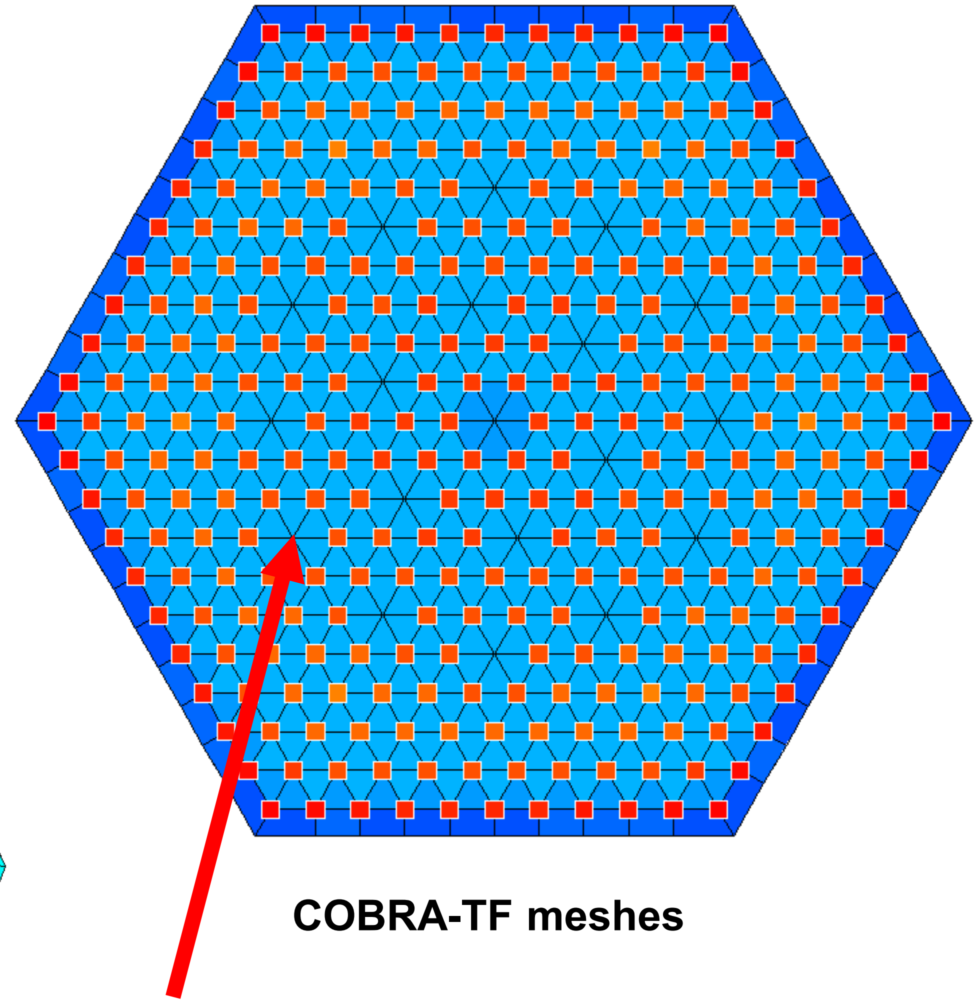
COBRA-TF deck.inp includes unheated structures ('tube' keyword), this is properly treated in the thermal mesh.

Thermal and fluid mesh visualization



SUBCHANFLOW meshes





COBRA-TF meshes

Guide tubes are not part of COBRA-TF thermal mesh

COBRA-TF MED generation

- **Changes in the CTF API were done.**
- **New method fine_triangular_mesh_external taken from SUBCHANFLOW API (July 2015).**
  - All the geometrical information could not be read from the deck.inp, natural input of COBRA-TF.
    - Channels coordinates (YES)
    - Rods coordinates (NO: arrays does not exist)
  - Coordinates are read from external files as auxiliary solution.
    - mesh_parameters.txt
    - table_rods.txt ⟵
    - table_channels.txt
    - table_levels.txt
  - Those files are also generated by the hexbundle tool.

COBRA-TF MED generation Example

cd NURESAFE_TEST/RESSOURCES/HexBundle/

./compile.sh

cd VVER-1000-FA

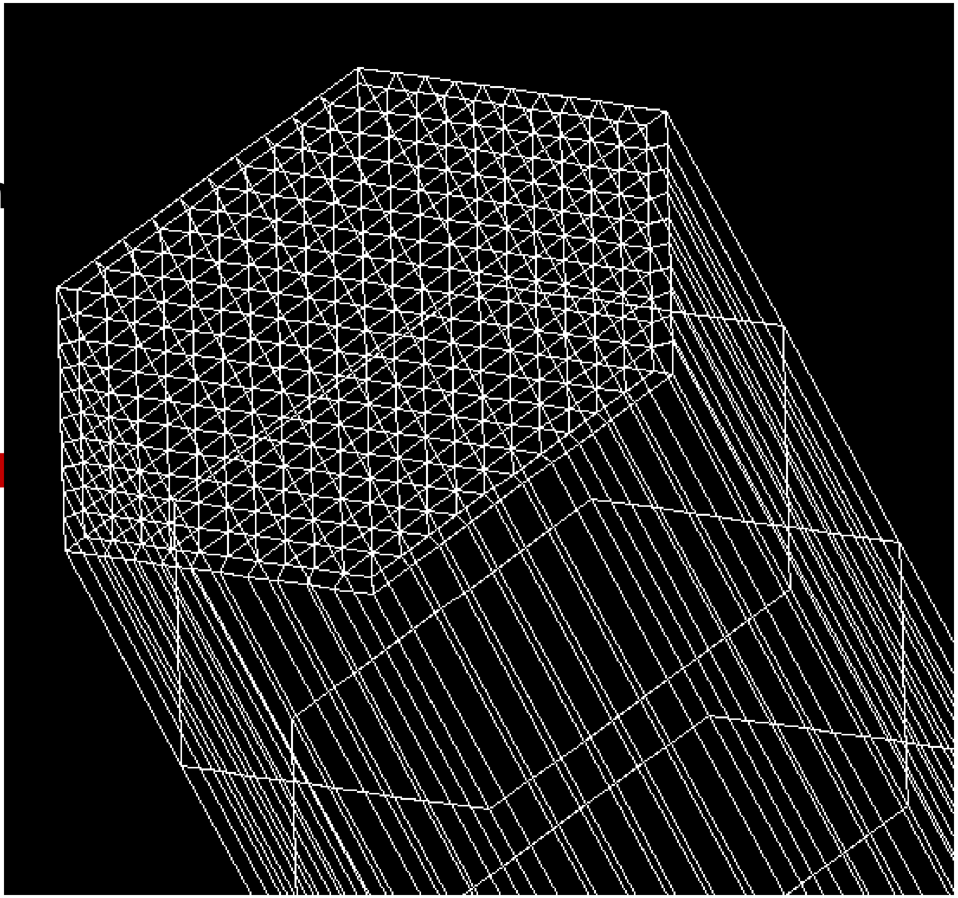
../hexbundle ! This will generate

./merge.sh ! Create the deck.in

source /your/environmental/file

python run_CTF.py

You can open the CTF_FINE_MESH
PARAVIEW

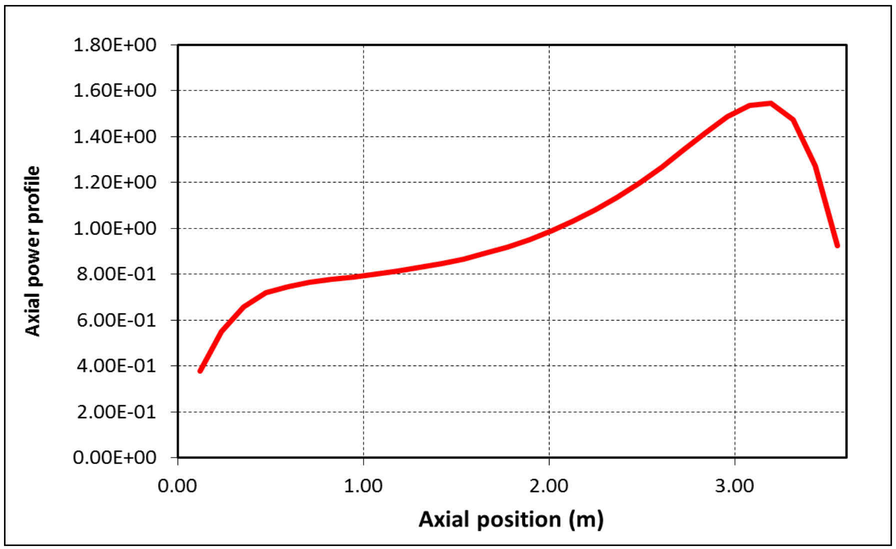


COBRA-TF API changes since June 2015

- Modification of getOutputMEDField to dump the code results in the new MEDCoupling object (GRS-KIT).
- Restructuring of mesh generation methods within COBRA-TF API (GRS-KIT, July 2015 in a 4 days stay in Garching).
- Extension of the hexbundle tool to also deal with unheated structures and generate a complete CARD 8 for COBRA-TF, new array NOSLCHC for CARD 8.5 (KIT).

MSLB Hot assembly TH BC problem

- A preliminary pin power distribution which corresponds to the HFP state was used taken from the OECD-UAM Phase II Specifications document.



Axial power distribution

- In the single assembly simulation, the lateral flow at the external boundary was assumed zero.

Radial power distribution

0.000										
1.001	1.001									
1.000	1.000	1.000								
0.998	0.997	0.000	0.998							
0.992	0.984	0.993	0.994	0.992						
0.000	0.990	0.992	0.993	0.992	0.000					
0.982	0.986	0.988	0.000	0.988	0.987	0.983				
0.971	0.973	0.975	0.985	0.985	0.975	0.973	0.971			
0.985	0.978	0.976	0.979	0.979	0.979	0.976	0.978	0.985		
1.015	1.002	0.998	0.993	0.995	0.995	0.994	0.998	1.002	1.015	
1.078	1.057	1.046	1.041	1.040	1.038	1.040	1.054	1.046	1.057	1.078

SUBCHANFLOW steady state bundle average

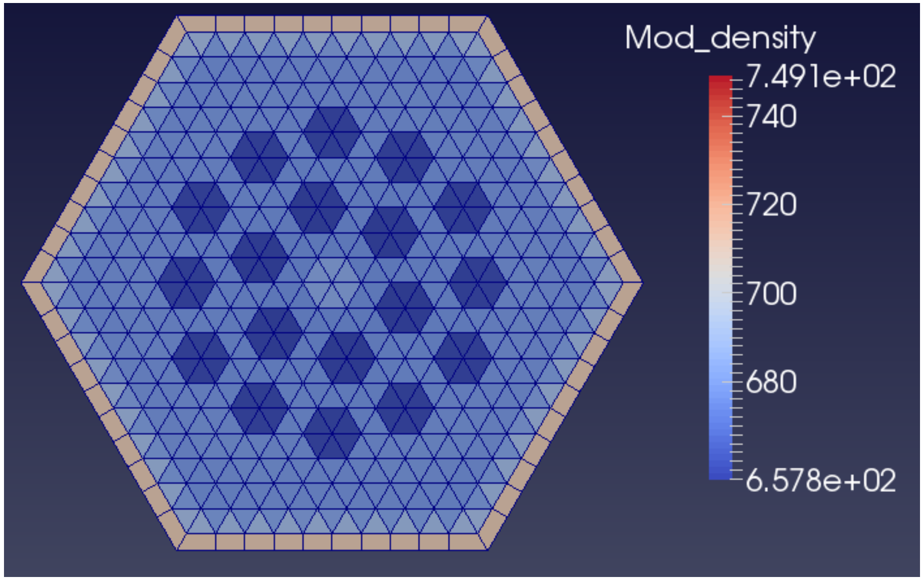
distance (m)	delta-p (pa)	temperature (c)	t_sat (c)	density (kg/m3)	equil. quality	osv quality	flow (kg/s)	velocity (m/s)	Reynolds
0.0000	90959	288.51	346.35	749.47	-0.3868	0.0000	105.61	5.5047	468970
0.1183	88179	289.1	346.33	748.37	-0.3833	-0.0087	105.61	5.5128	469630
0.2367	85400	289.69	346.31	747.26	-0.3798	-0.0123	105.61	5.5210	470680
0.3550	82049	290.41	346.30	745.90	-0.3756	-0.0149	105.61	5.5311	472040
0.4733	79272	291.19	346.28	744.39	-0.371	-0.0164	105.61	5.5422	473610
0.5917	75922	292.01	346.27	742.81	-0.3662	-0.0171	105.61	5.5541	475280
0.7100	73148	292.85	346.25	741.18	-0.3613	-0.0176	105.61	5.5663	477010
0.8283	69799	293.7	346.23	739.51	-0.3563	-0.0179	105.61	5.5789	478780
0.9467	67028	294.57	346.22	737.80	-0.3513	-0.0181	105.61	5.5917	480590
1.0650	63679	295.44	346.20	736.06	-0.3462	-0.0184	105.61	5.6050	482430
1.1833	60909	296.32	346.19	734.29	-0.3410	-0.0187	105.61	5.6185	484320
1.3017	57559	297.22	346.17	732.47	-0.3357	-0.0191	105.61	5.6325	486240
1.4200	54790	298.13	346.16	730.60	-0.3303	-0.0195	105.61	5.6469	488210
1.5383	51438	299.06	346.14	728.67	-0.3248	-0.0199	105.61	5.6618	490230
1.6567	48668	300.01	346.13	726.68	-0.3191	-0.0205	105.61	5.6773	492310
1.7750	45899	300.99	346.11	724.62	-0.3133	-0.0211	105.61	5.6935	494480
1.8933	42543	302.00	346.09	722.47	-0.3072	-0.0219	105.61	5.7104	496710
2.0117	39773	303.05	346.08	720.22	-0.3010	-0.0227	105.61	5.7282	499050
2.1300	36412	304.13	346.06	717.87	-0.2944	-0.0237	105.61	5.7470	501490
2.2483	33640	305.25	346.05	715.38	-0.2876	-0.0248	105.61	5.7670	504060
2.3667	30273	306.43	346.03	712.76	-0.2805	-0.0261	105.61	5.7883	506770
2.4850	27497	307.67	346.02	709.96	-0.2730	-0.0275	105.61	5.8110	509650
2.6033	24123	308.96	346.00	706.99	-0.2650	-0.0290	105.61	5.8355	512700
2.7217	21344	310.32	345.98	703.82	-0.2566	-0.0307	105.61	5.8618	515970
2.8400	17961	311.75	345.97	700.43	-0.2478	-0.0324	105.61	5.8901	519450
2.9583	15178	313.22	345.95	696.86	-0.2386	-0.0339	105.61	5.9203	523170
3.0767	11785	314.73	345.94	693.13	-0.2290	-0.0350	105.61	5.9521	527060
3.1950	8998.8	316.23	345.92	689.36	-0.2196	-0.0349	105.61	5.9847	531100
3.3133	6210.1	317.63	345.91	685.78	-0.2106	-0.0330	105.61	6.0160	535110
3.4317	2799.1	318.81	345.89	682.67	-0.2029	-0.0283	105.61	6.0433	538760
3.5500	0.0000	319.34	345.88	681.28	-0.1994	-0.0251	105.61	6.0557	541750

COBRA-TF steady state bundle average

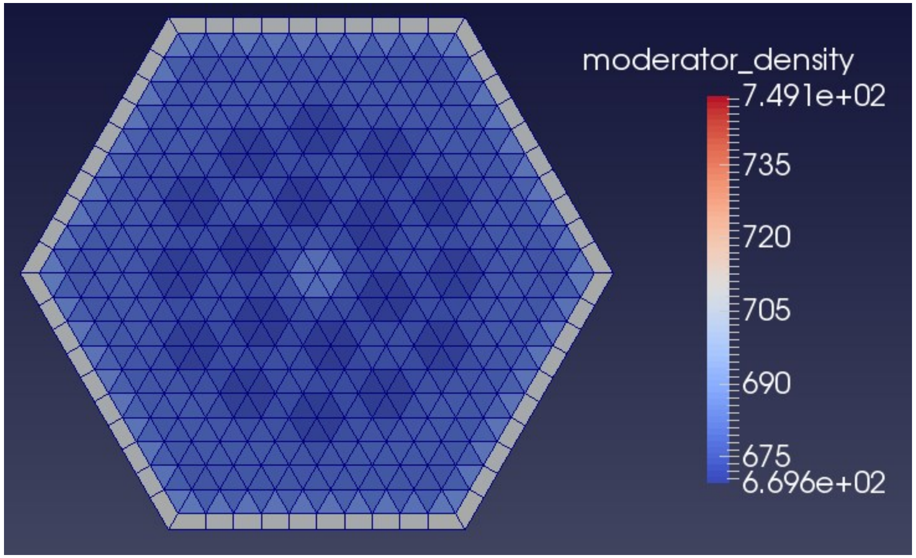
distance (m)	Vol. Frac. Liq (-)	Temperature (c)	Pressure (pa)	Enthalpy mixt (KJ/Kg)	equil. quality	flow (kg/s)
0.000	1.0	288.52	0.9182	1276.3	-0.384	105.61
0.118	1.0	288.85	0.89043	1278.0	-0.382	105.61
0.237	1.0	289.36	0.86267	1280.7	-0.379	105.61
0.355	1.0	290.03	0.82898	1284.2	-0.375	105.61
0.473	1.0	290.8	0.80099	1288.2	-0.371	105.61
0.592	1.0	291.61	0.76728	1292.4	-0.366	105.61
0.710	1.0	292.44	0.73933	1296.8	-0.361	105.61
0.828	1.0	293.29	0.70566	1301.3	-0.356	105.61
0.947	1.0	294.15	0.67778	1305.9	-0.352	105.61
1.065	1.0	295.01	0.64414	1310.5	-0.347	105.61
1.183	1.0	295.89	0.61631	1315.2	-0.342	105.61
1.302	1.0	296.78	0.58268	1320.0	-0.336	105.61
1.420	1.0	297.69	0.55487	1324.8	-0.331	105.61
1.538	1.0	298.61	0.52122	1329.8	-0.326	105.61
1.657	1.0	299.55	0.49336	1334.9	-0.32	105.61
1.775	1.0	300.52	0.46554	1340.2	-0.315	105.61
1.893	1.0	301.51	0.43183	1345.6	-0.309	105.61
2.012	1.0	302.54	0.40397	1351.3	-0.303	105.61
2.130	1.0	303.60	0.37016	1357.1	-0.297	105.61
2.248	1.0	304.70	0.34223	1363.3	-0.29	105.61
2.367	1.0	305.85	0.3083	1369.7	-0.283	105.61
2.485	1.0	307.06	0.28026	1376.5	-0.276	105.61
2.603	1.0	308.32	0.24616	1383.6	-0.268	105.61
2.722	1.0	309.65	0.21798	1391.2	-0.26	105.61
2.840	1.0	311.05	0.18368	1399.2	-0.252	105.61
2.958	1.0	312.50	0.15531	1407.6	-0.243	105.61
3.077	1.0	314.00	0.12076	1416.4	-0.233	105.61
3.195	1.0	315.52	0.09215	1425.4	-0.224	105.61
3.313	1.0	316.99	0.06352	1434.1	-0.215	105.61
3.432	1.0	318.31	0.02866	1442.1	-0.206	105.62
3.550	1.0	319.35	0.00000	1448.4	-0.200	105.62

Comparison at bundle outlet in the steady state

- Sub-channel coolant density at bundle outlet.
- Qualitatively and quantitatively both codes are very close to each other.



SUBCHANFLOW



COBRA-TF

Steady state results comparison

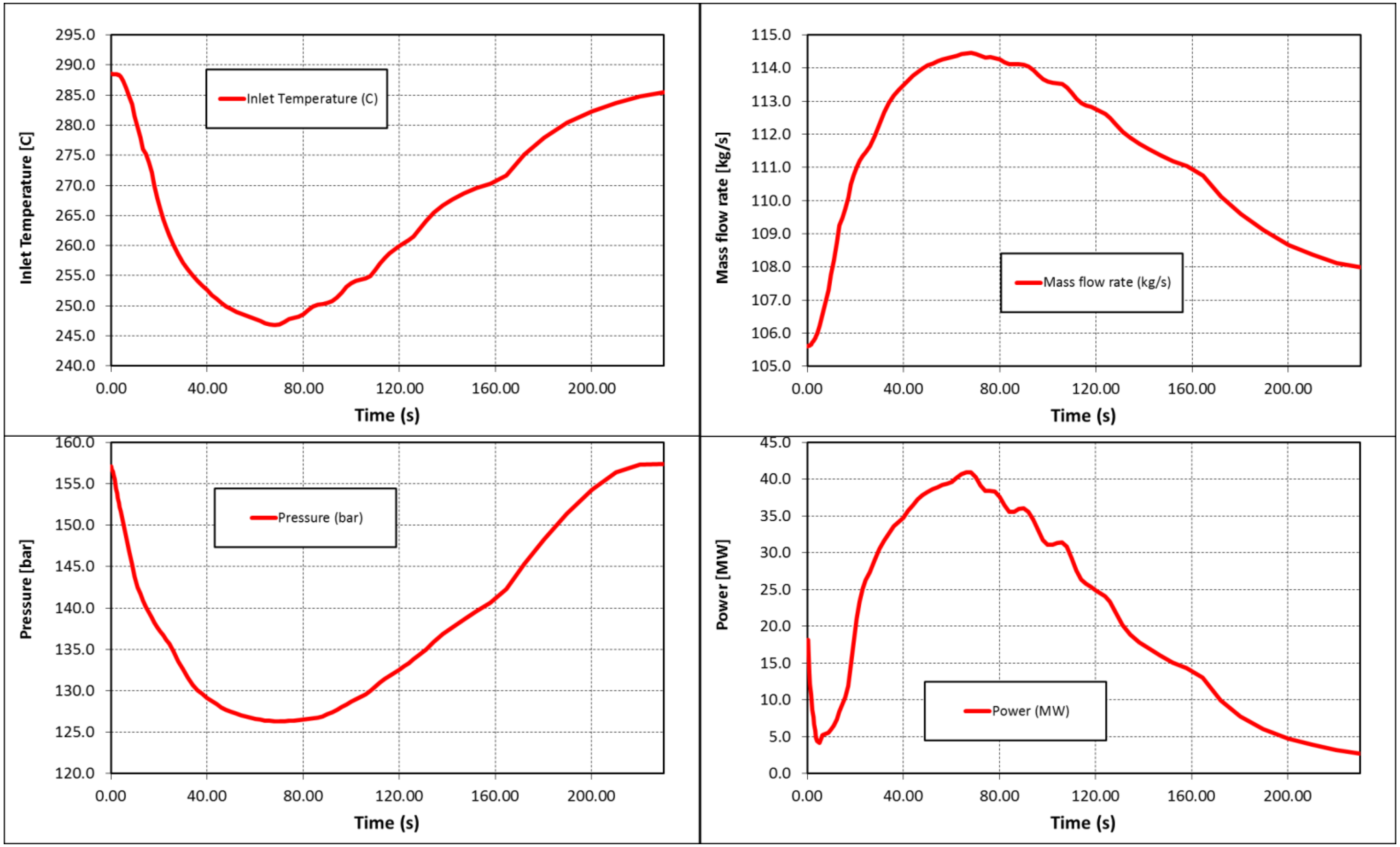
- **Predicted vs. design HFP pressure drop over the heated length.**

	Design data	FLICA4	COBRA-TF (INRNE)	SUBCHANFLOW	COBRA-TF (KIT)
dP, MPa	0.09493 ± 0.0047	0.0955	0.09459	0.090959	0.091891

- **Bundle pressure drop dependent on single phase turbulent friction factor correlation and in the spacer grids pressure loss coefficients.**
  - Used Blasius with $= 0.204Re^{-0.2}$ in both codes.
  - Used spacers grids with k= 0.0503789 value from INRNE input deck.

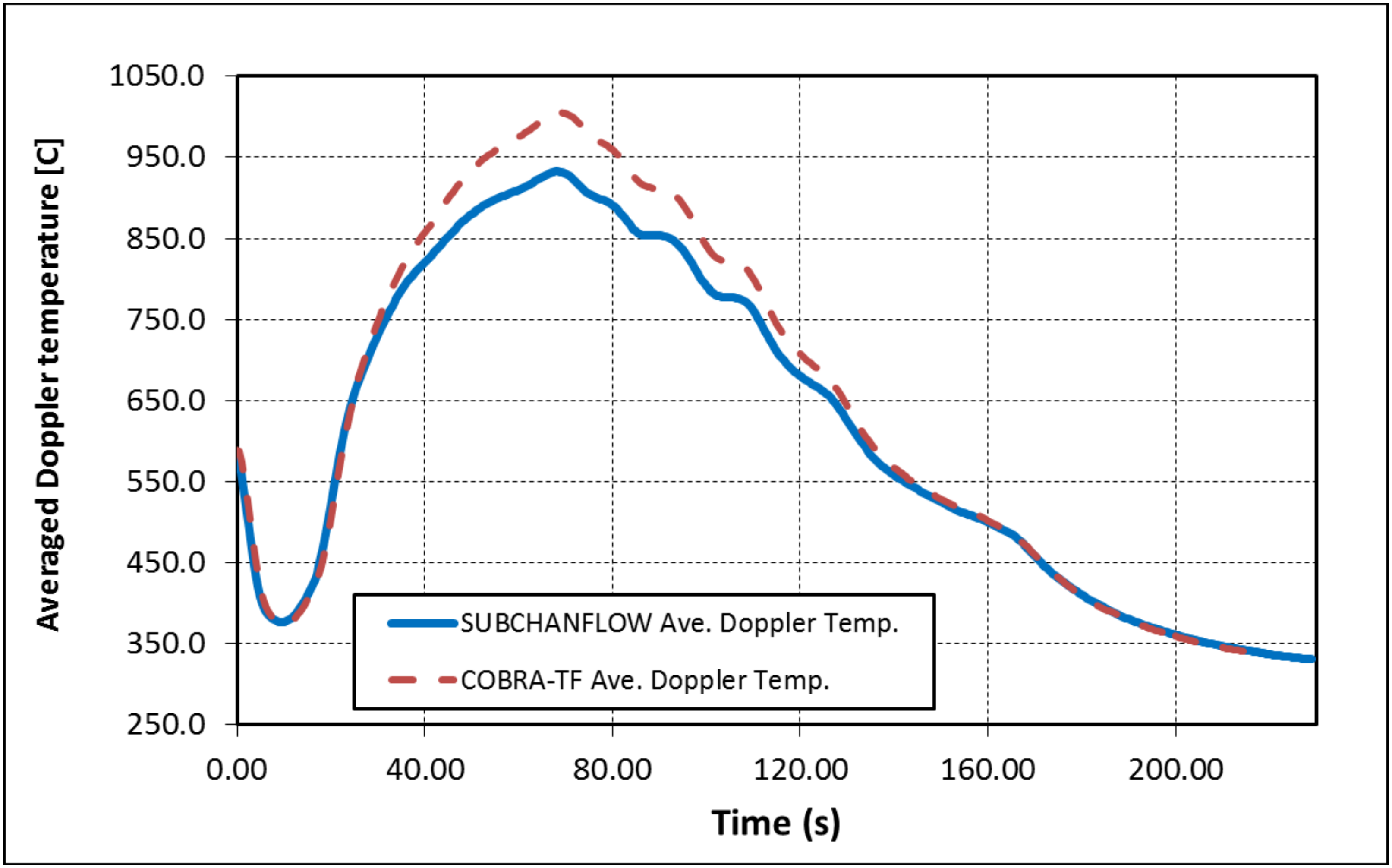
Transient problem BC

- The time dependent MSLB BCs at the assembly inlet and outlet are shown in the next figures
- The transient lasts 230 second.



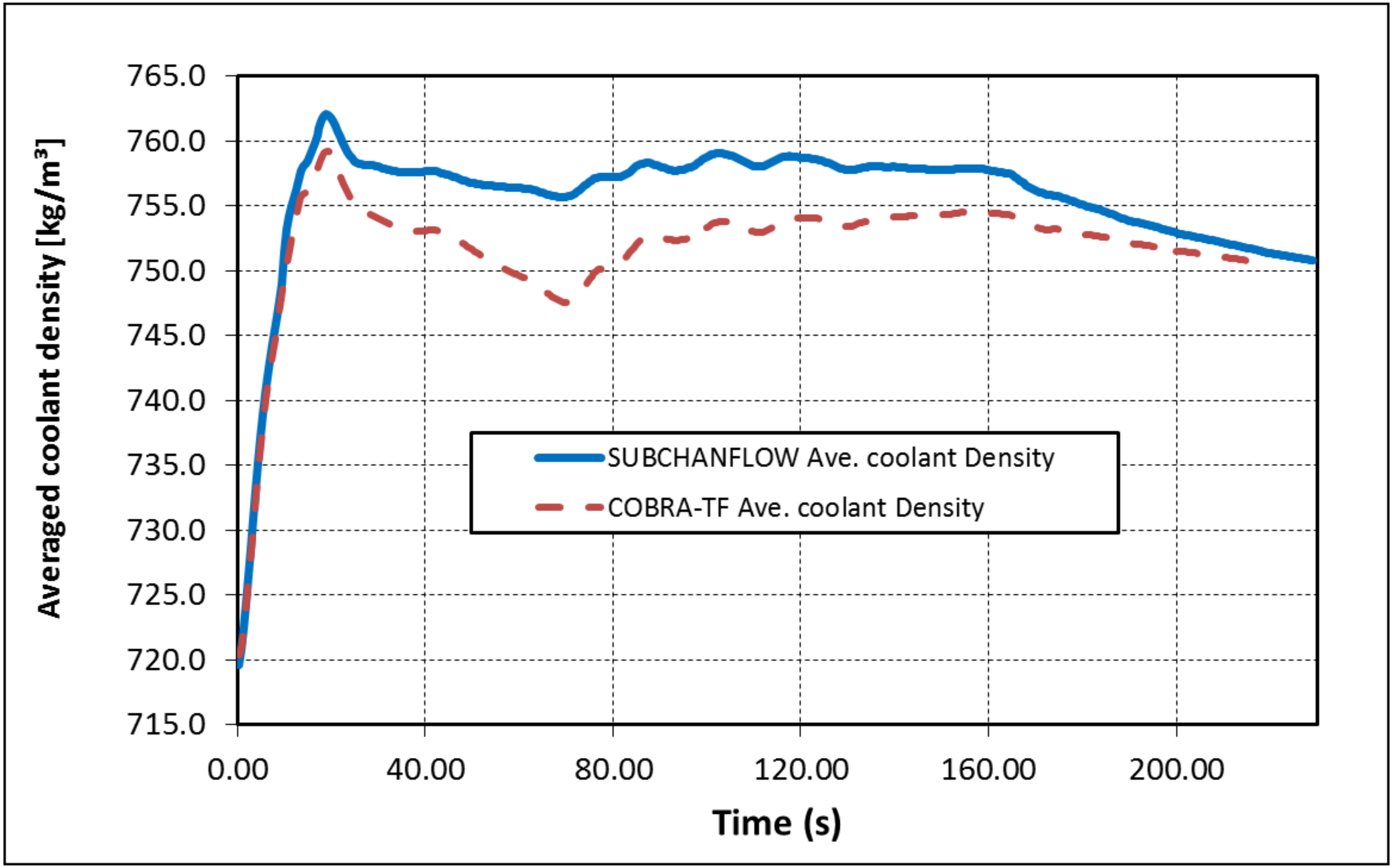
COBRA-TF vs. SUBCHANFLOW bundle average

- Averaged fuel Doppler temperature versus time.

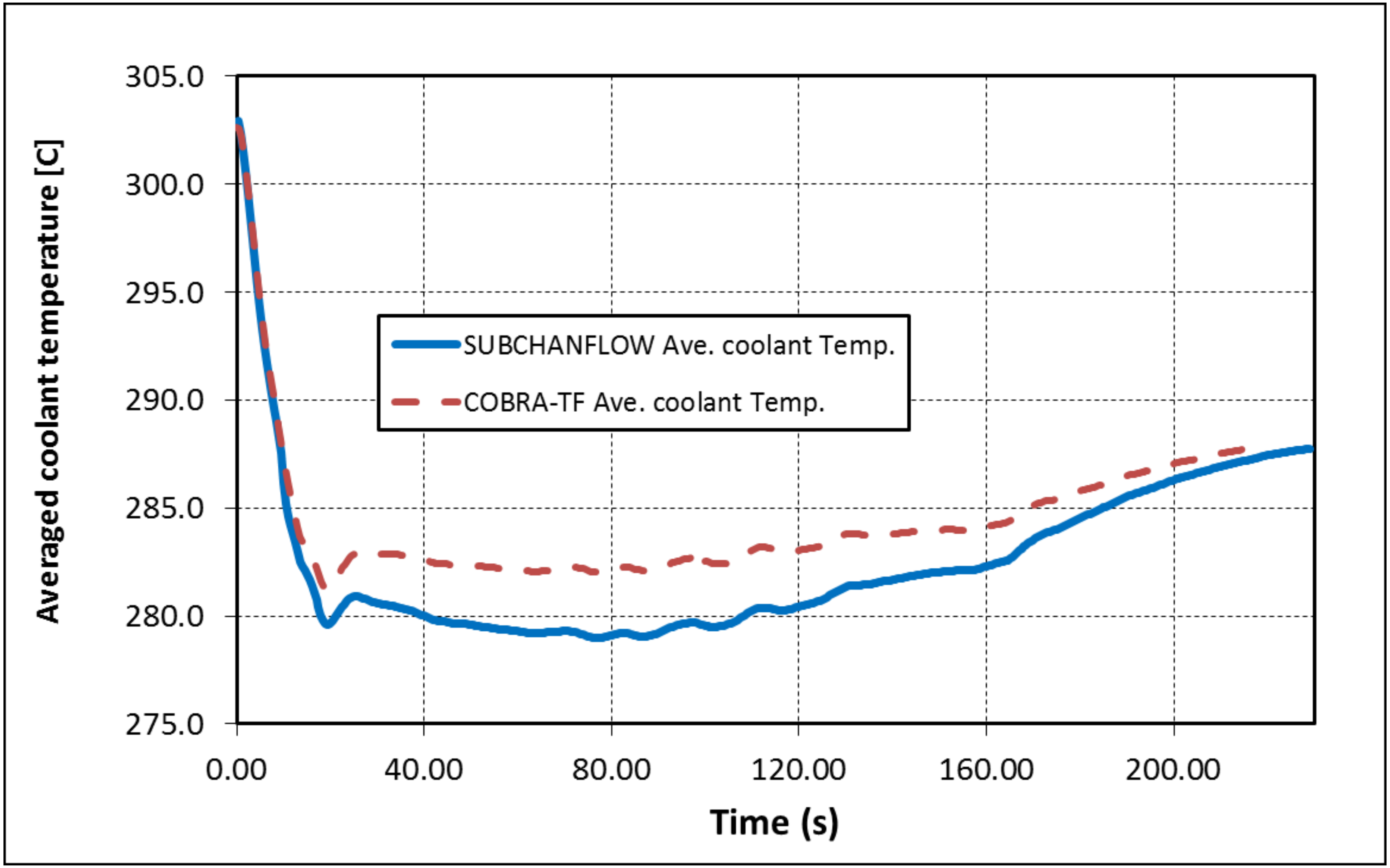


COBRA-TF vs. SUBCHANFLOW bundle average

- Averaged coolant density versus time.



- Averaged coolant temperature versus time

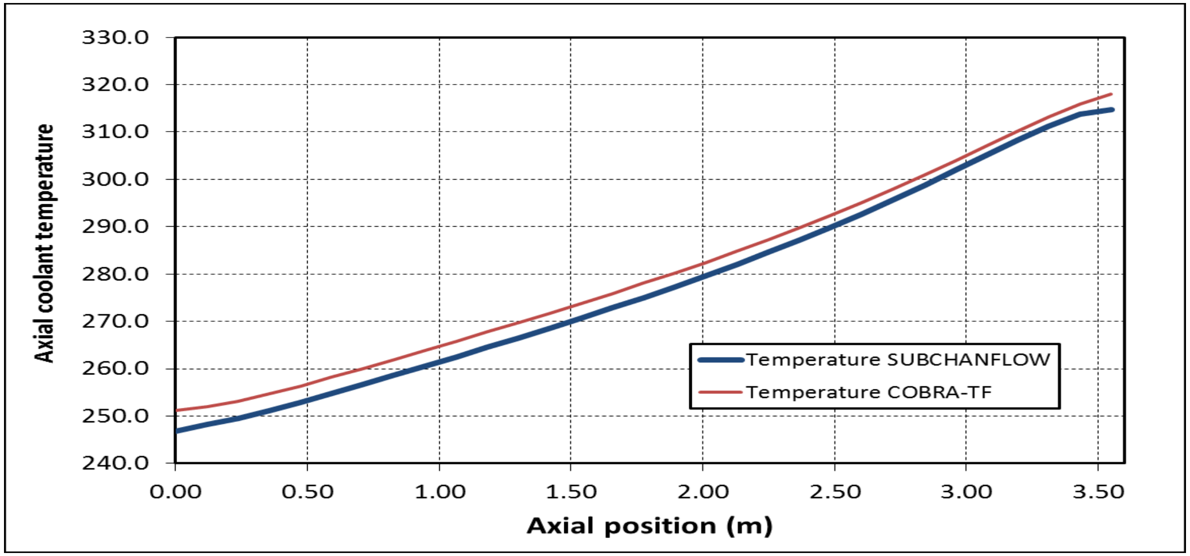


Transient results at 69 seconds

- Coolant-centered dP at time of max return to power (second 69)

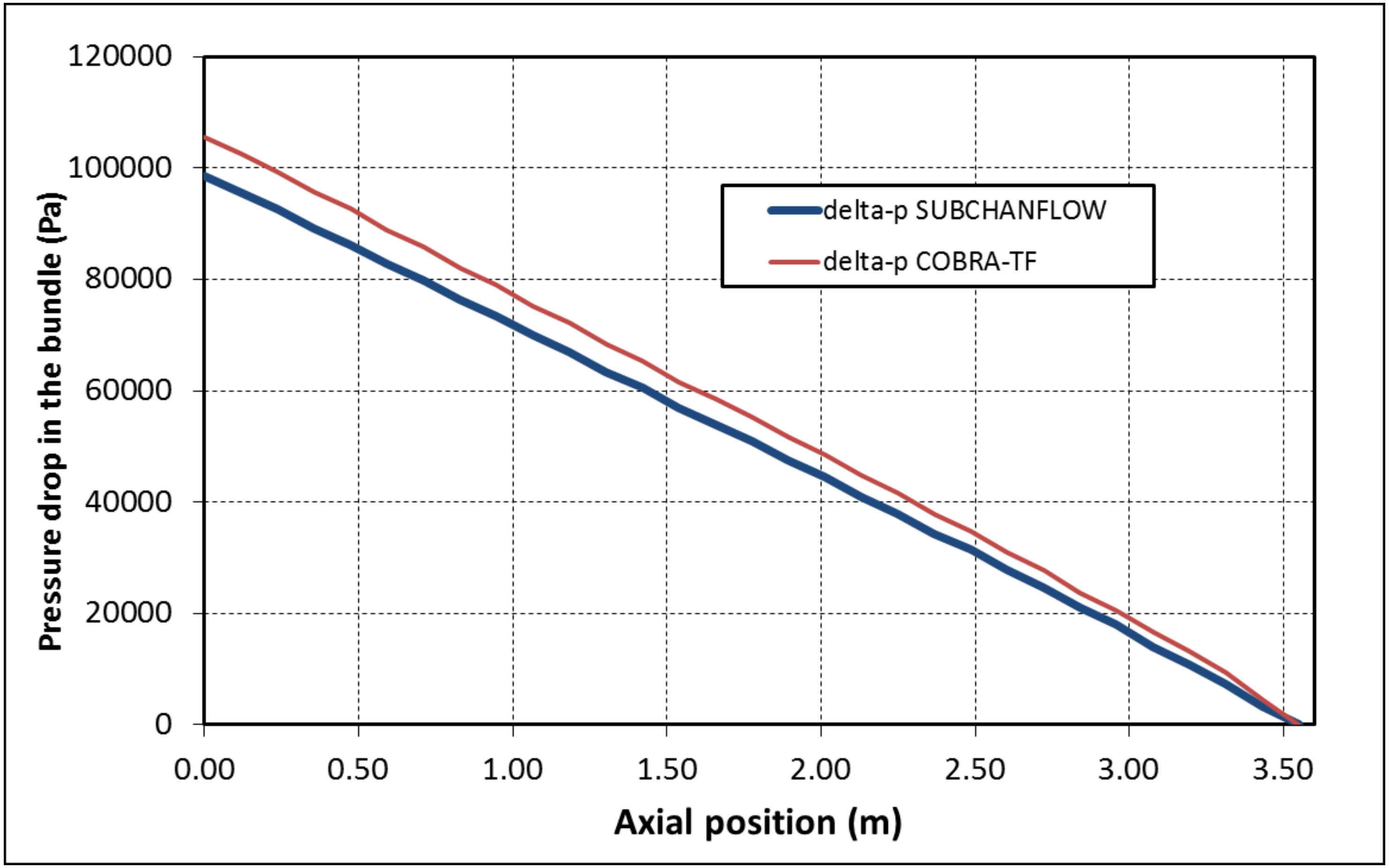
	COBRA-TF (INRNE)	SUBCHANFLOW (KIT)	COBRA-TF (KIT)
dP, MPa	0.10549 (+ 0.0109)	0.098451(+0.010004)	0.106626 (+0.014735)

- Axial average coolant temperature distribution at time of max return to power (second 69)



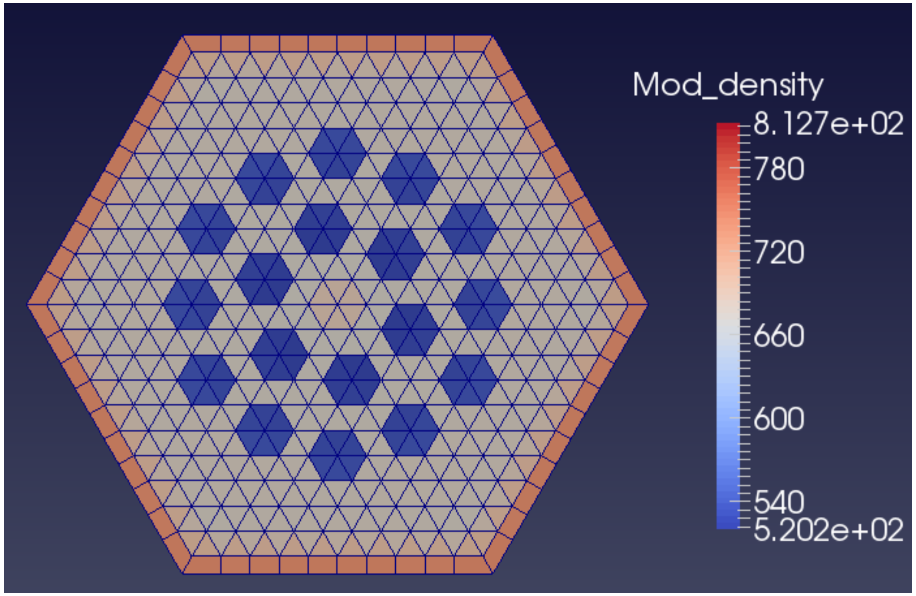
Transient results at 69 seconds

- **Axial pressure drop at time of max return to power (second 69)**

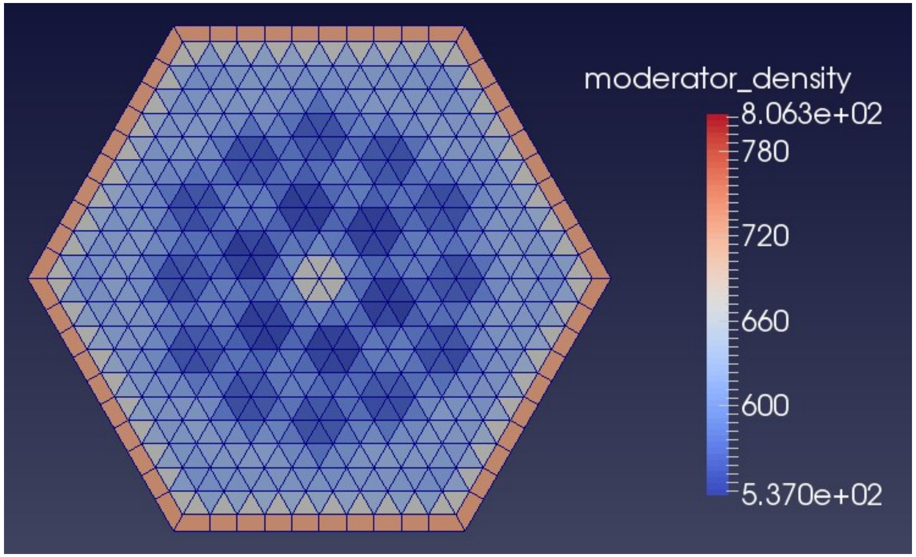


Transient results at 69 seconds

- **Comparison of the sub-channel coolant density at bundle outlet at time 69s**



SUBCHANFLOW



COBRA-TF

Conclusion

- **Development of a generic FORTRAN VVER FA preprocessor:**
  - Suitable for COBRA-TF and SUBCHANFLOW
- **Extension of the CTF.cxx API: new fine_triangular_mesh_external method taken from SCF**
  - Now the Fluid mesh can be produced to be used within INTERP_2_5D in the coupling scripts.
- **Results for the HFP steady state and transient has been produced by COBRA-TF and SUBCHANFLOW.**
  - Those inputs can be reused for the pin-by-pin coupling with COBAYA4.
- **Extension to minicores is not foreseen before the end of the project.**
- **A technical note summarizing the results presented here was sent the 21st of September to the partners.**

THANKS FOR YOUR ATTENTION