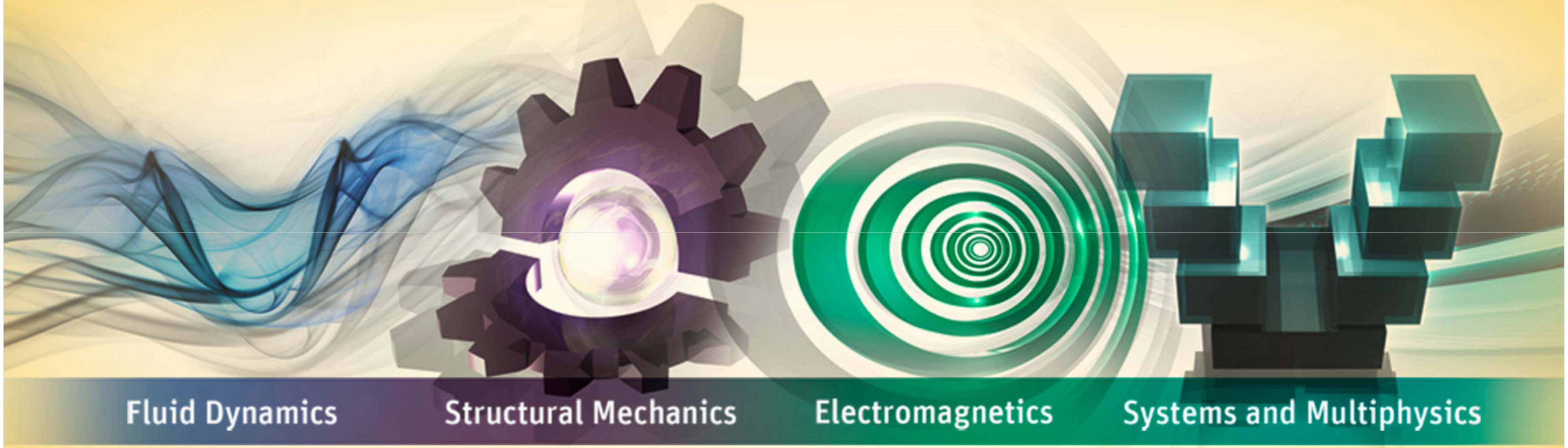
Realize Your Product Promise™

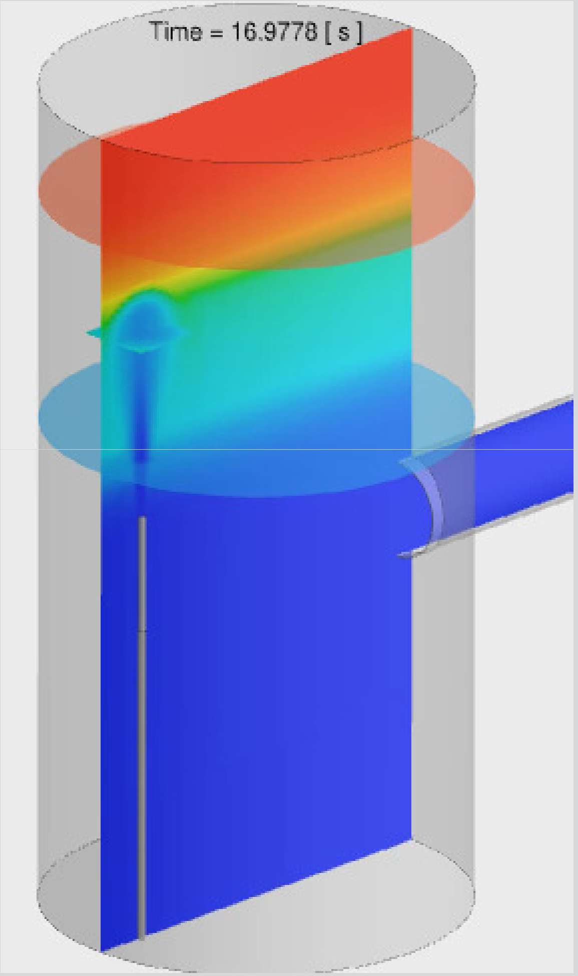
Investigation of the MiniPanda Benchmark using ANSYS CFD



Christoph Kasprzyk,
Thomas Frank,
Guillermo Zschaeck
ANSYS Germany, Otterfing

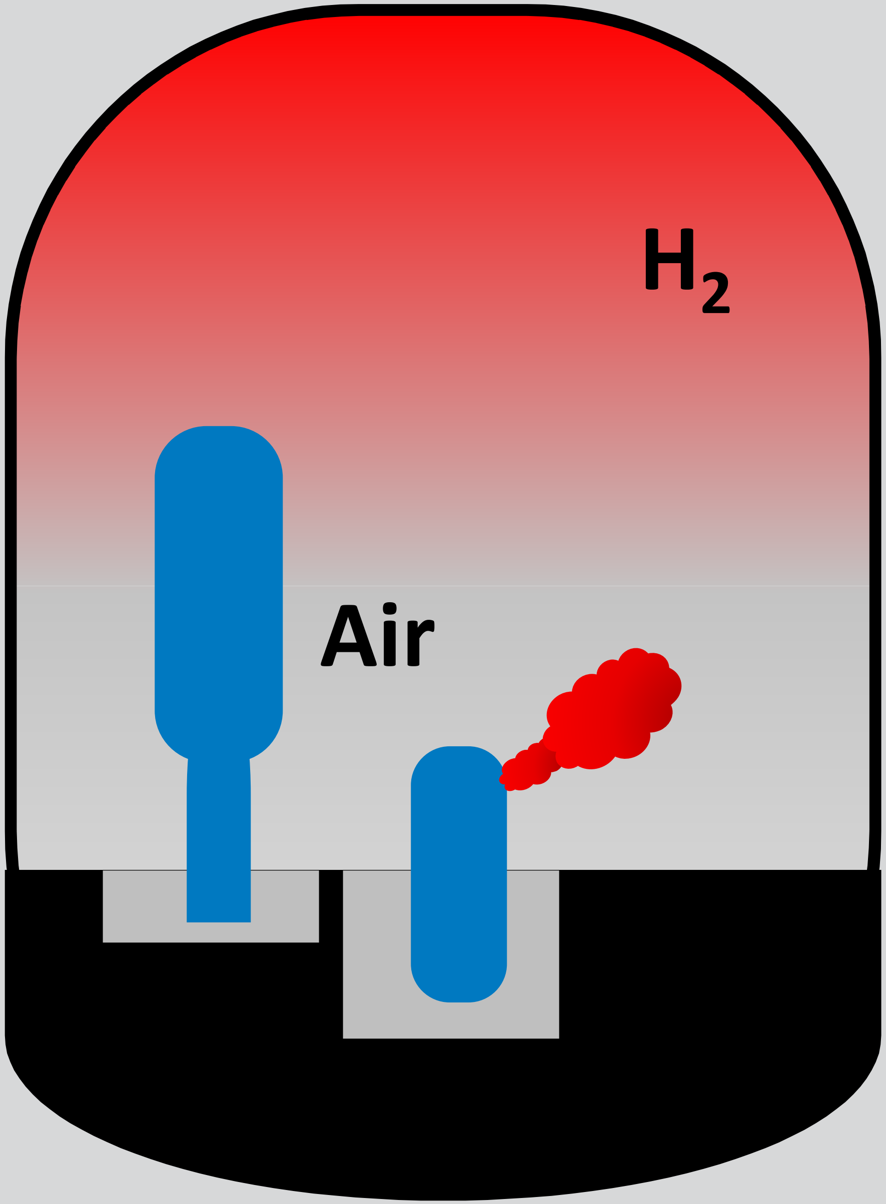
Contents

- **Motivation**
- **MiniPanda Benchmark**
  - The ETHZ / PSI experiment
  - CFD Setup
  - MPII_1 results
  - MPII_2 results
- **Conclusion**

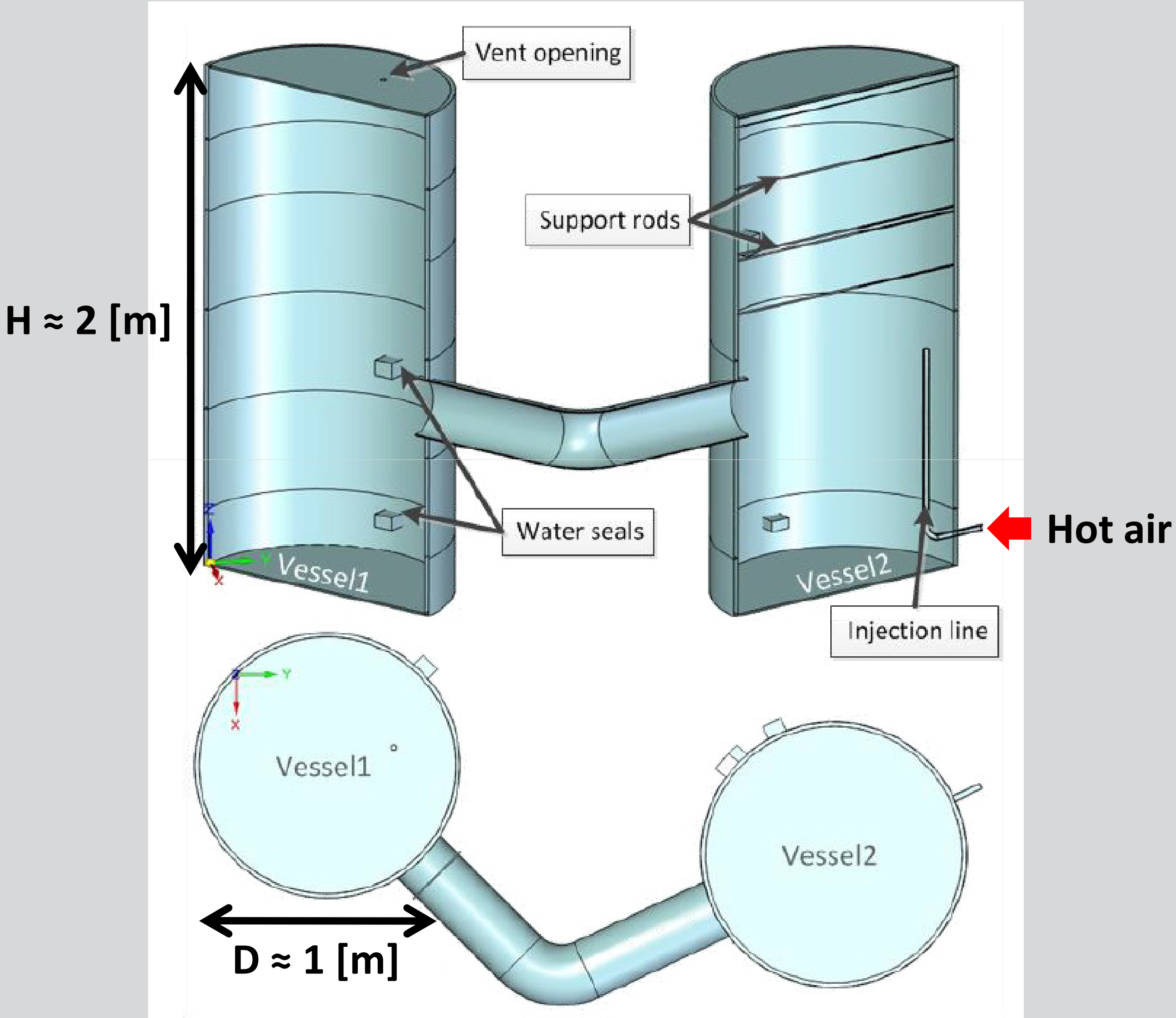


Motivation

- Nuclear reactor accident
  - Hydrogen release in containment
- Simulation tasks:
  - Prediction of containment atmosphere mixing
  - Prediction of critical H_2 concentrations
  - Pressure build-up



MiniPanda Test Facility

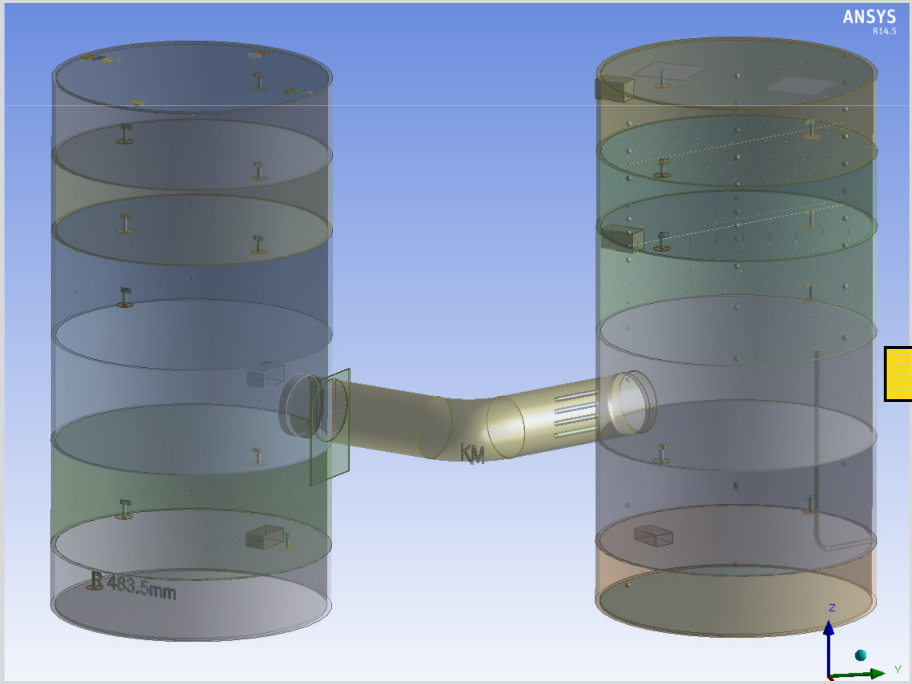


Ritterath, PSI (2011)

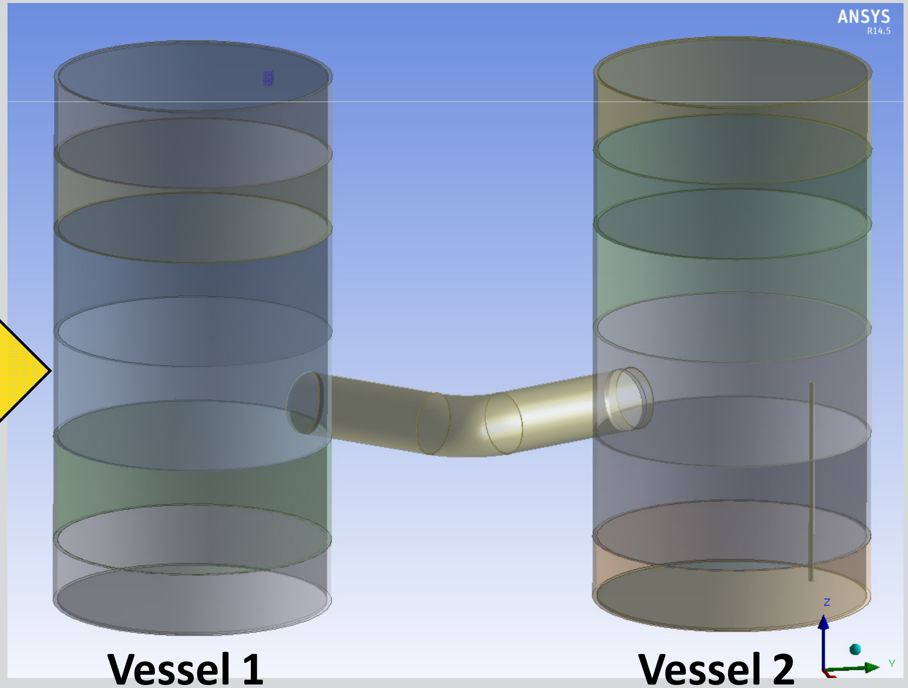
Geometry

- **CAD geometry provided by Kelm et al. (2012)**

Original



Simplified



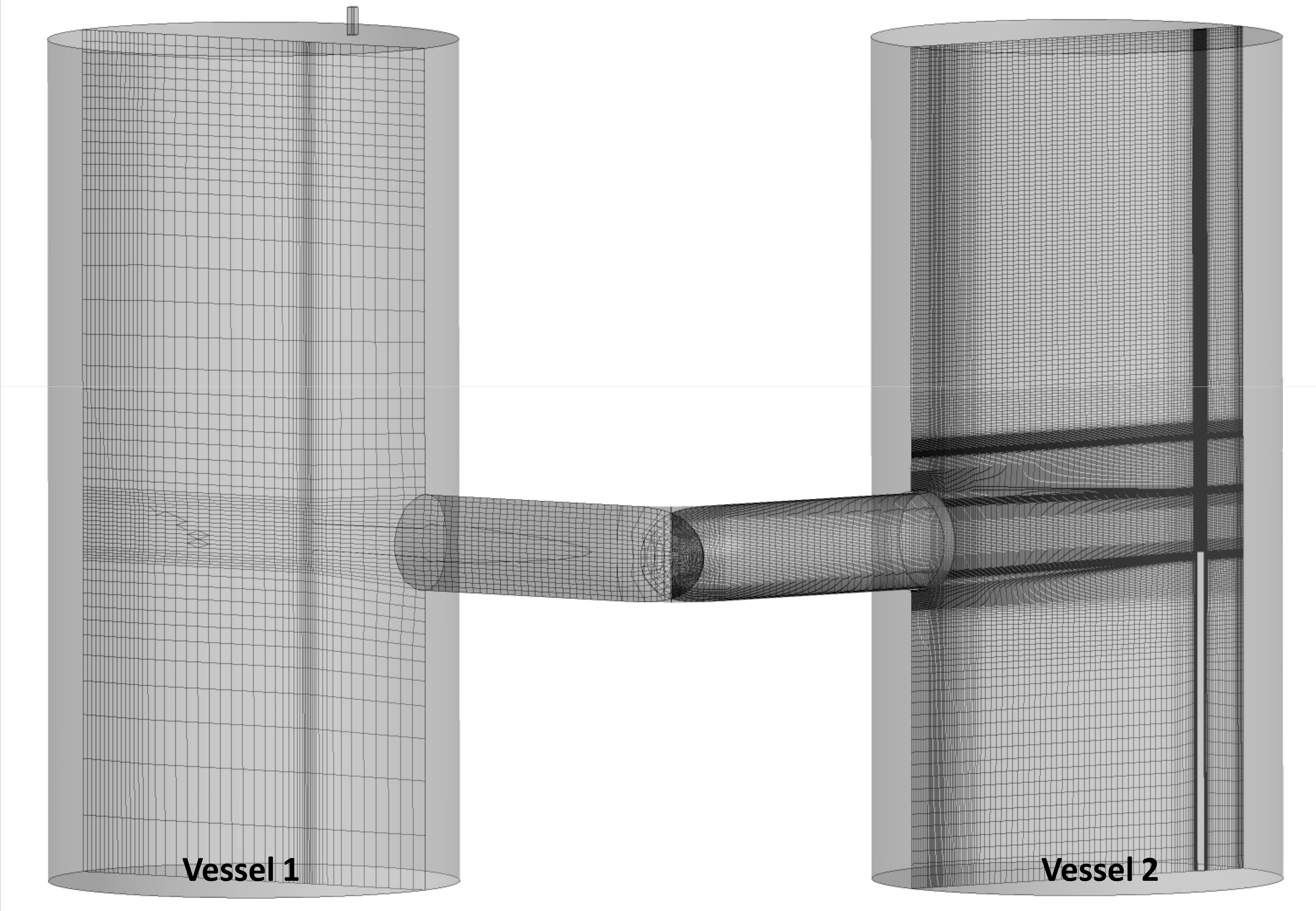
Vessel 1 **Vessel 2**

Mesh Information

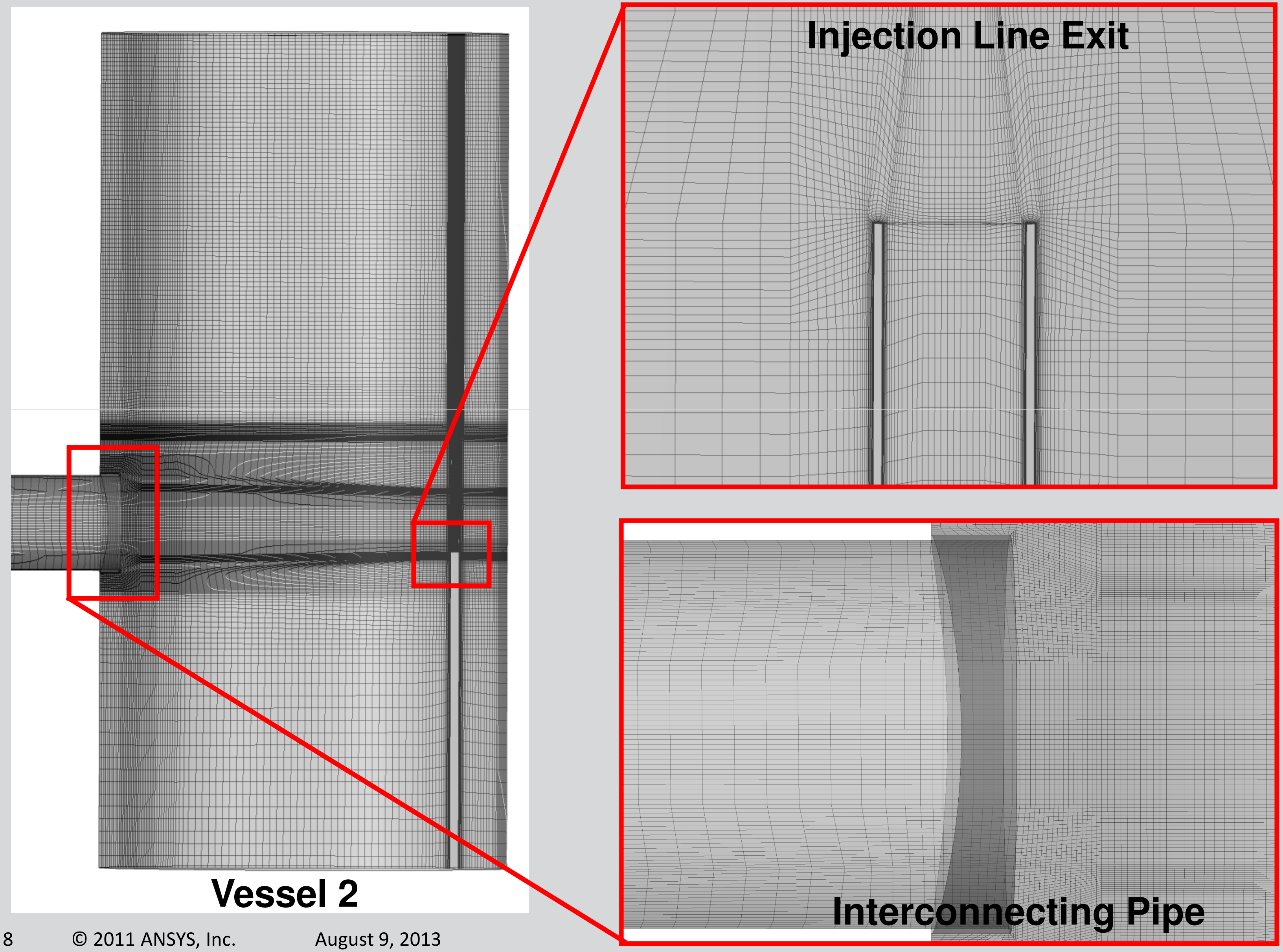
- **ANSYS ICEM CFD**
  - **Structured hexahedral mesh**

	Vessel1	**Vessel2**
Elements	176,648	5,340,238
Nodes	184,603	4,039,603
Max. Aspect Ratio	59	834
Min. Grid Angle	37.3°	29.1°
Average y^+ (t = 1500 s)	-	0.767

Mesh Information

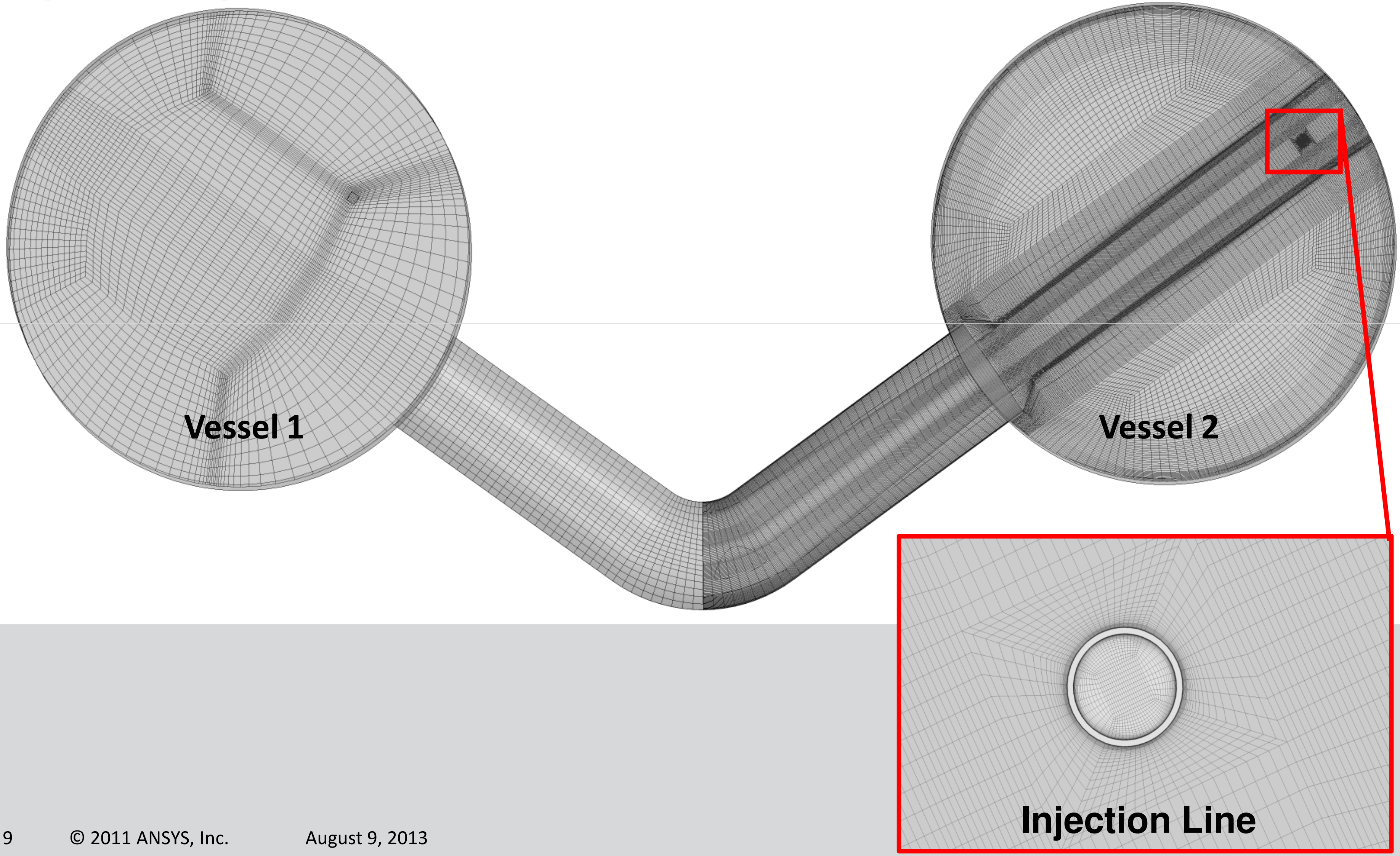


Mesh Information: Vessel2

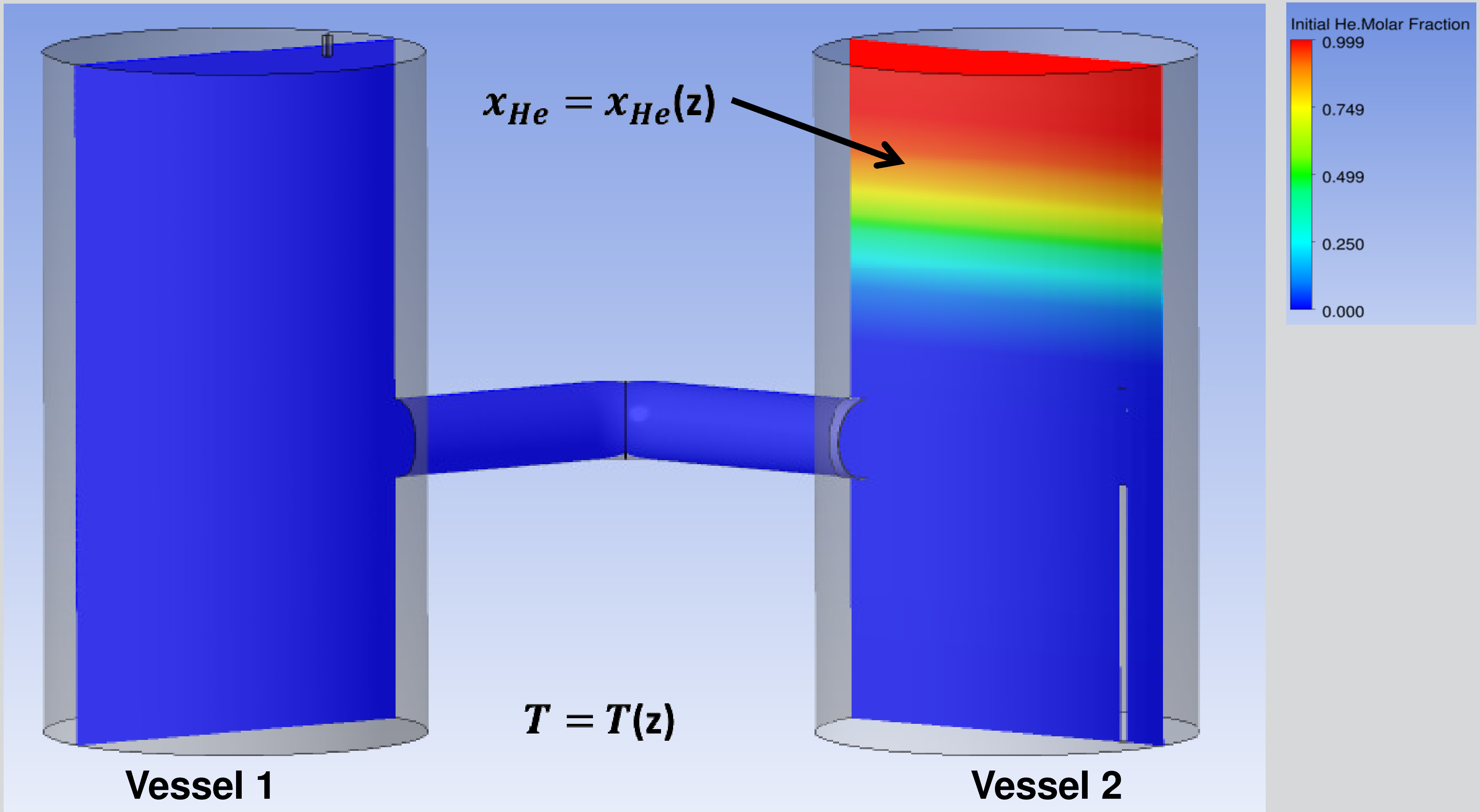


Mesh Information

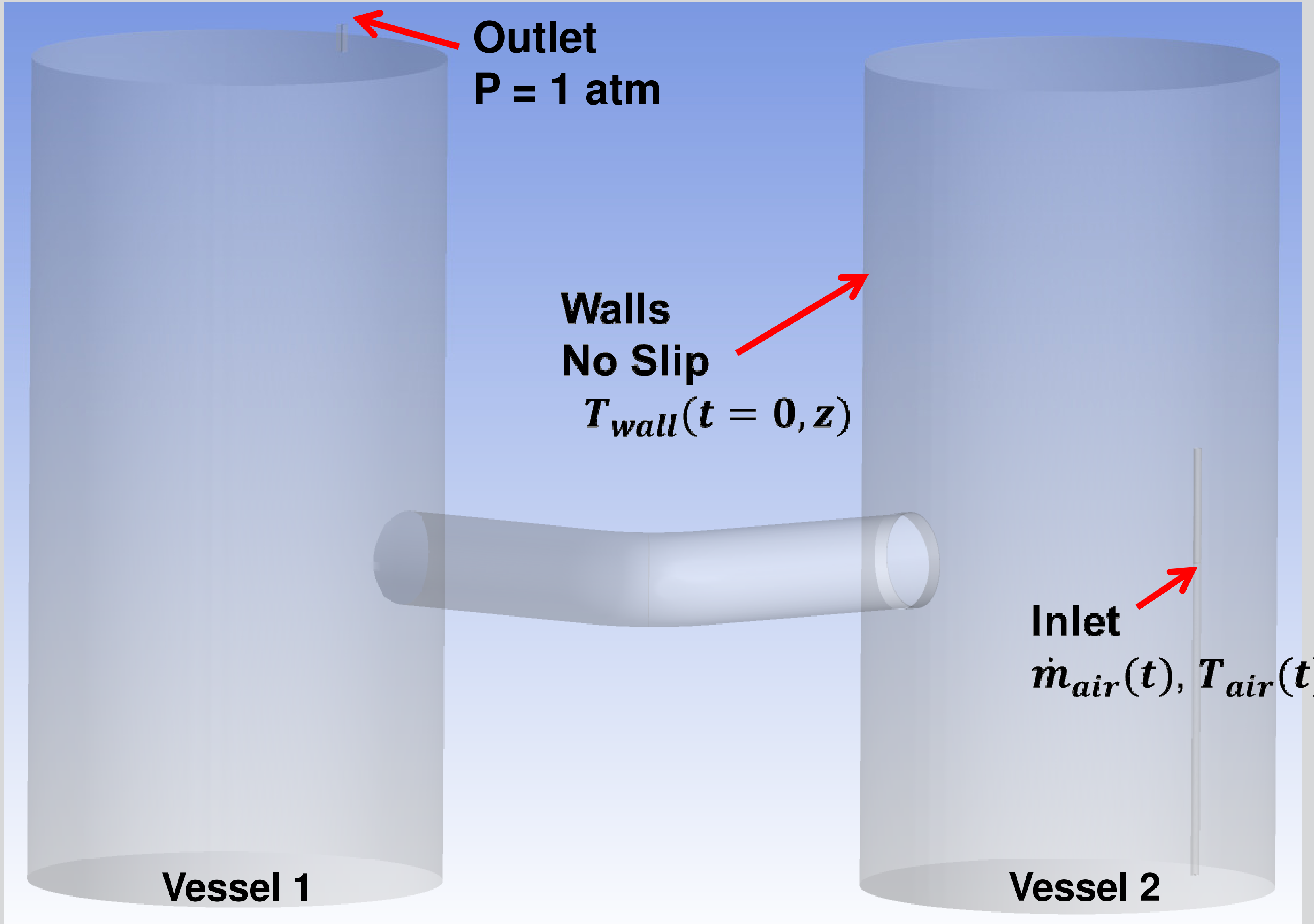
Top view on plane z = 0.8 m



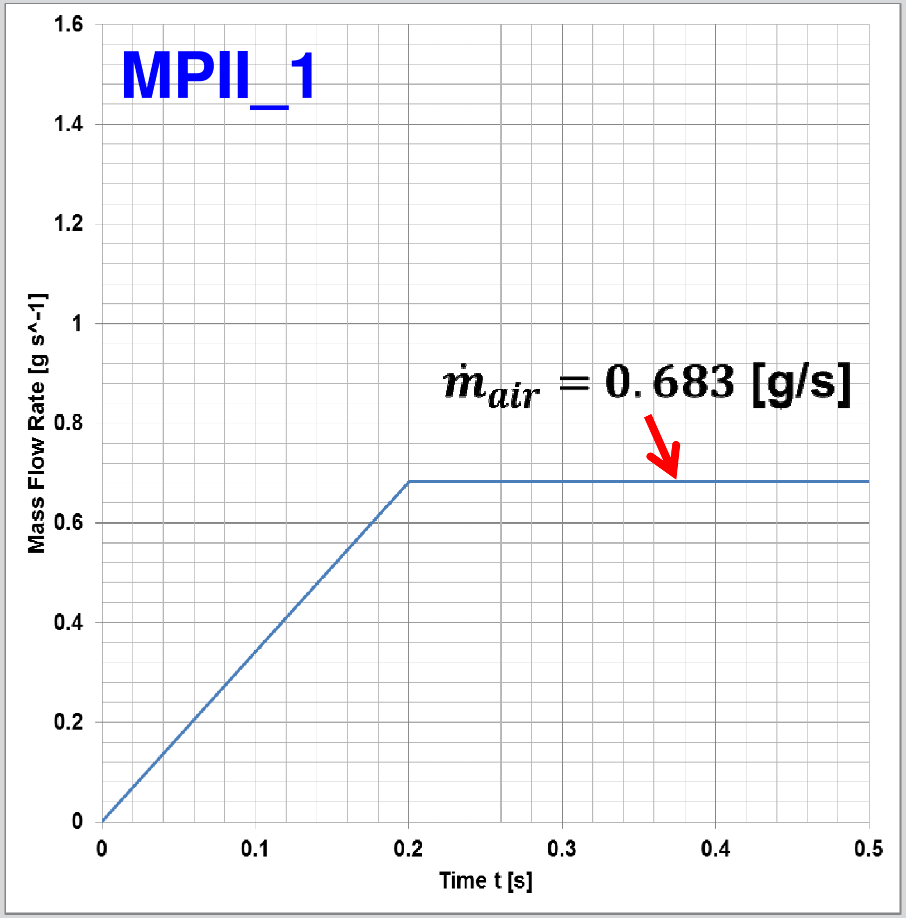
Initial Condition for He

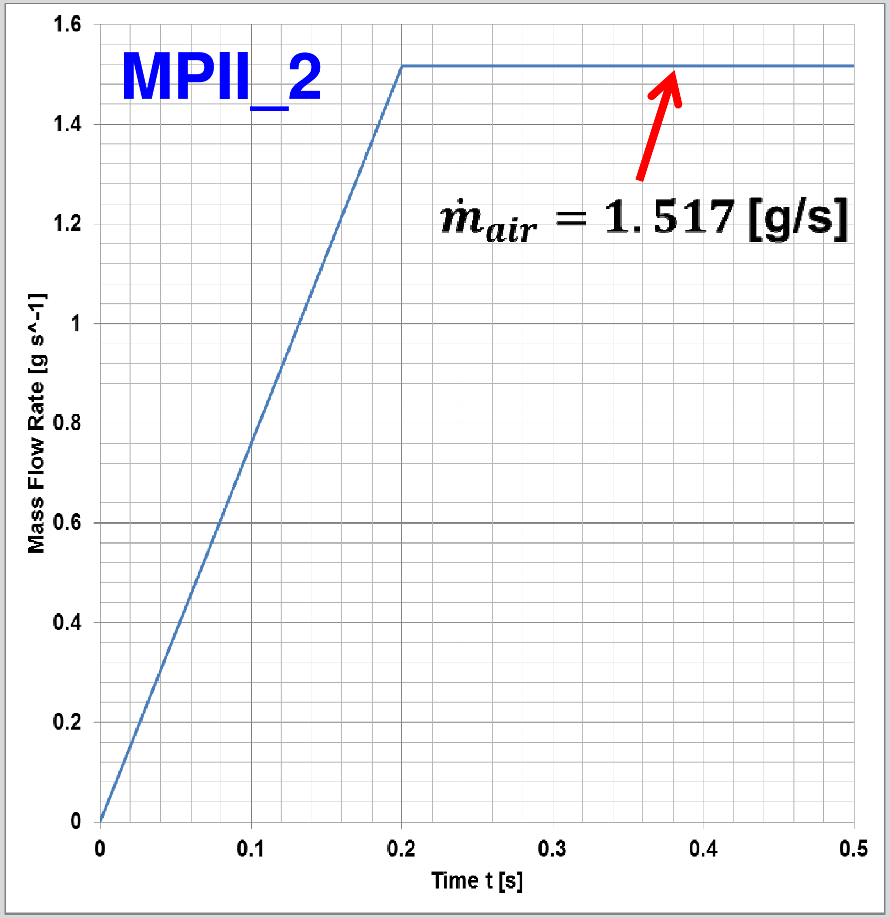


Boundary Conditions



Boundary Condition @Inlet

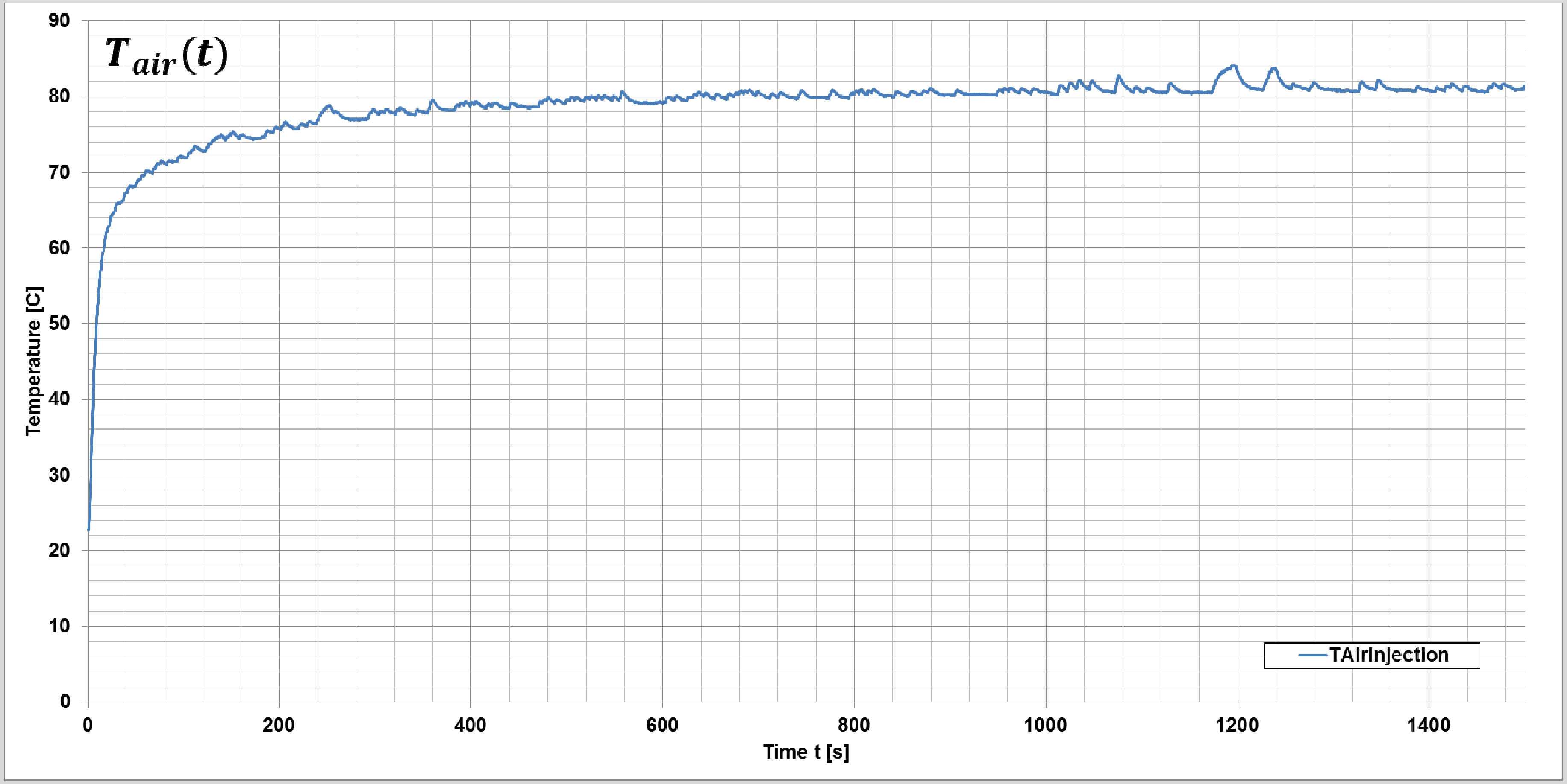




Re_{inj}=2350 ; Fr_i=0.7 ; Pe_m=530

Re_{inj}=4400 ; Fr_i=1.3 ; Pe_m=990

Boundary Condition @Inlet MPII_1

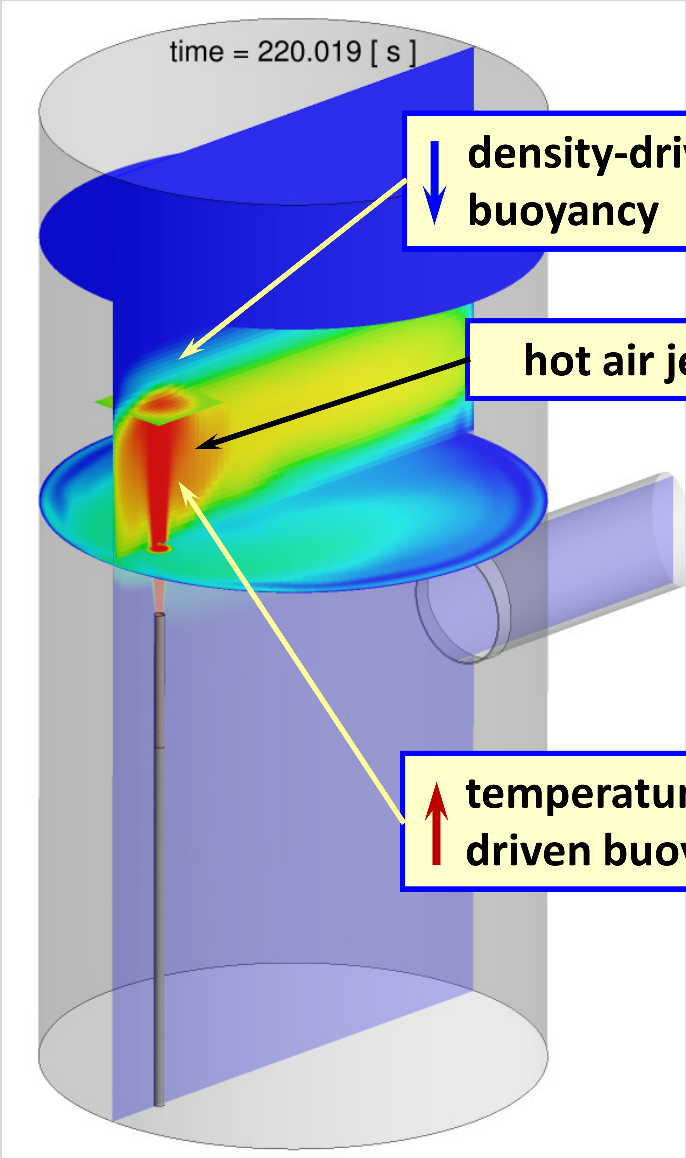


MPII_2 has approximately the same inlet temperature curve

CFD Simulation Setup

- **URANS simulation**
  - 1800s real-time
  - Multicomponent fluid mixture
    → He as the constraint material
  - SST turbulence model
  - Buoyancy induced turbulence
    → production & dissipation
  - Kinematic diffusivity law
    for Air-He mixture

- **Time discretization:**
  2nd order backward Euler
- **Advection scheme:**
  HiRes / 2nd order upwind scheme
  1st order for turbulence
- **Timestep:** $\Delta t=0.01s,...,0.05s$

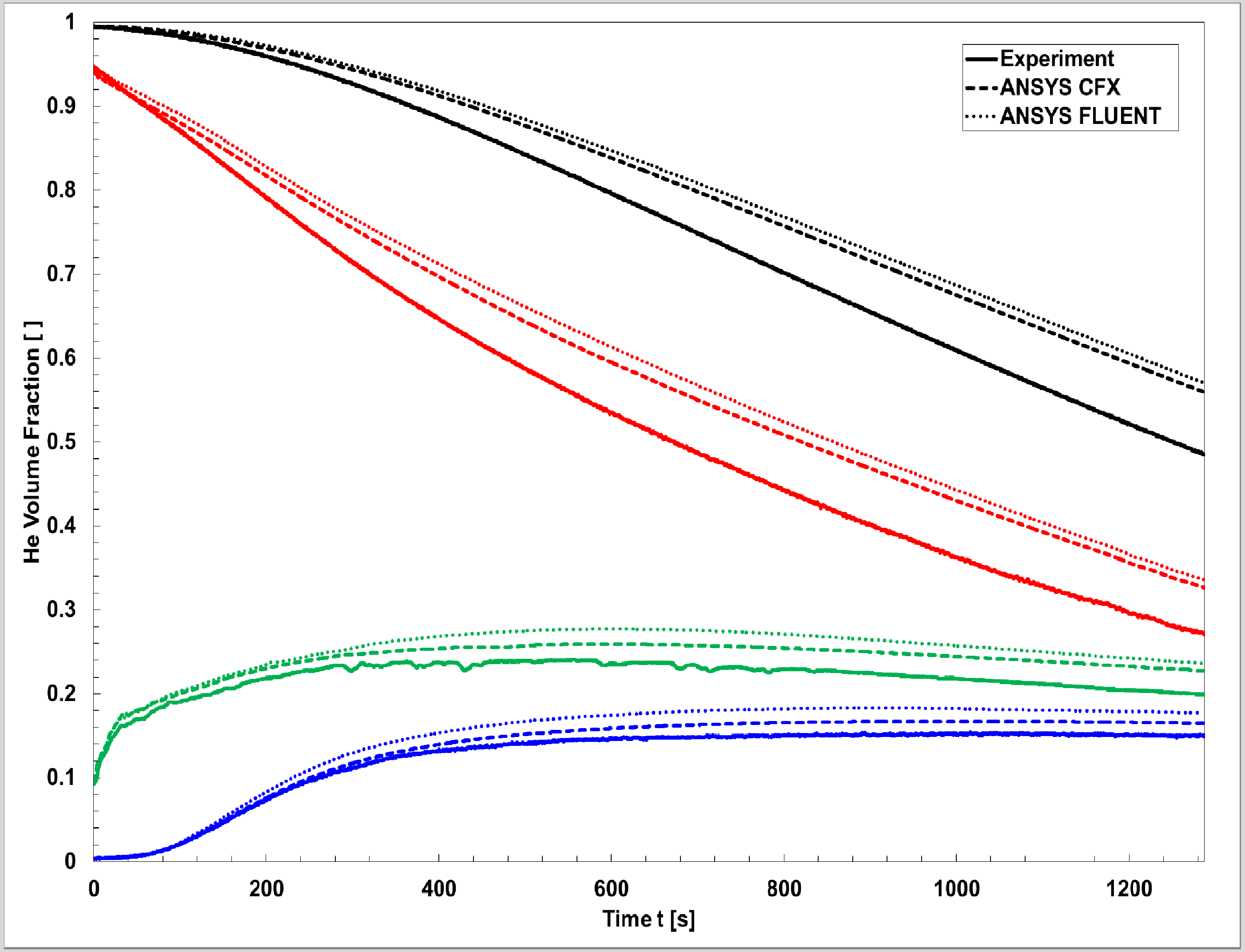


CFD Simulation Setup

- **Main aim & difficulty of MiniPanda simulations:**
  - Include all relevant physics
  - Ensure required accuracy of the CFD simulation (mesh & time resolution, convergence)
  - Reduce computational time as much as possible
  - Increase simulation time step as much as possible for a feasible advancement of the CFD simulation in real-time

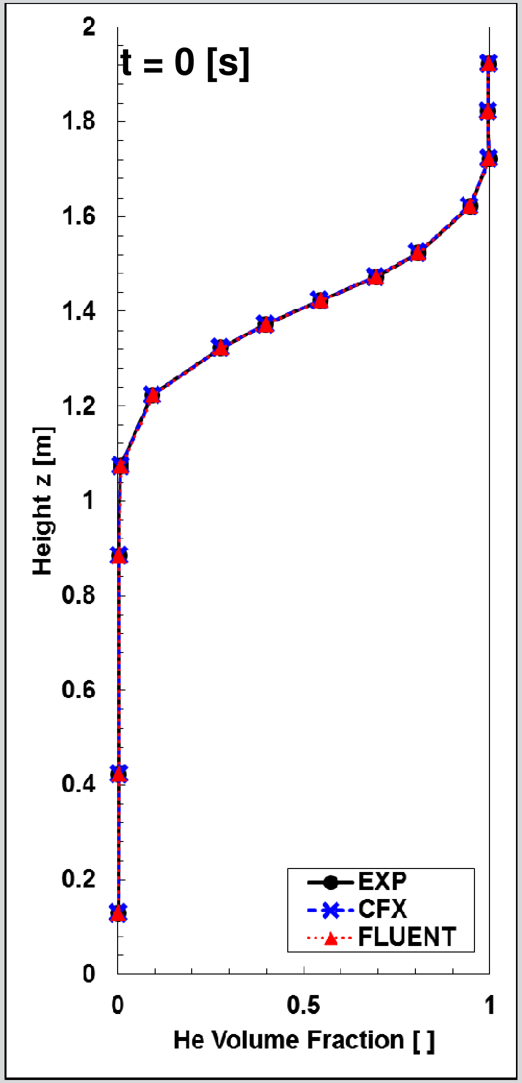
- **Due to this aim separate investigations had been carried out to determine:**
  - Grid resolution
  - Residual targets (RMS vs. MAX)
  - Convergence criteria
  - Time step

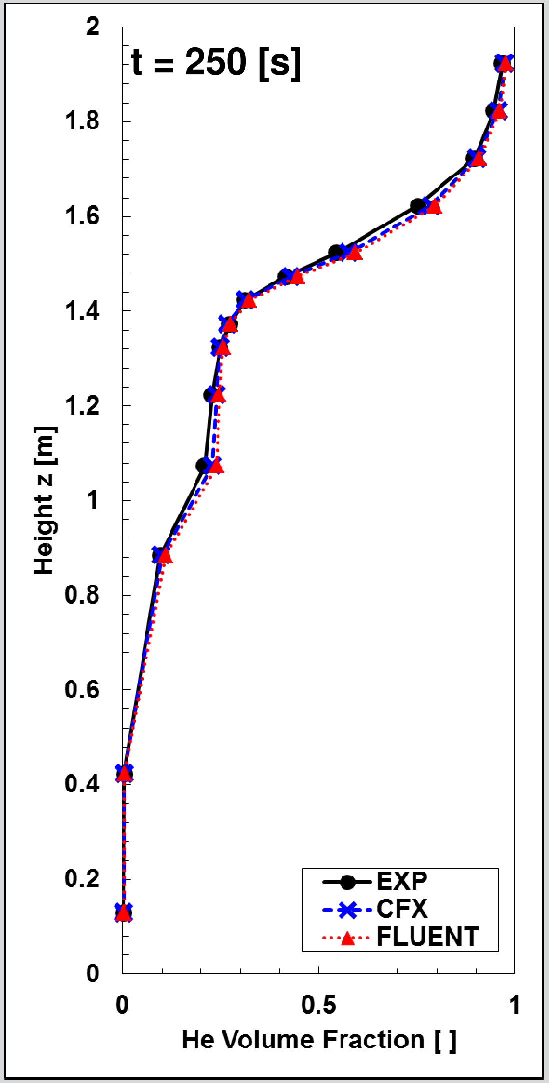
Results MPII_1

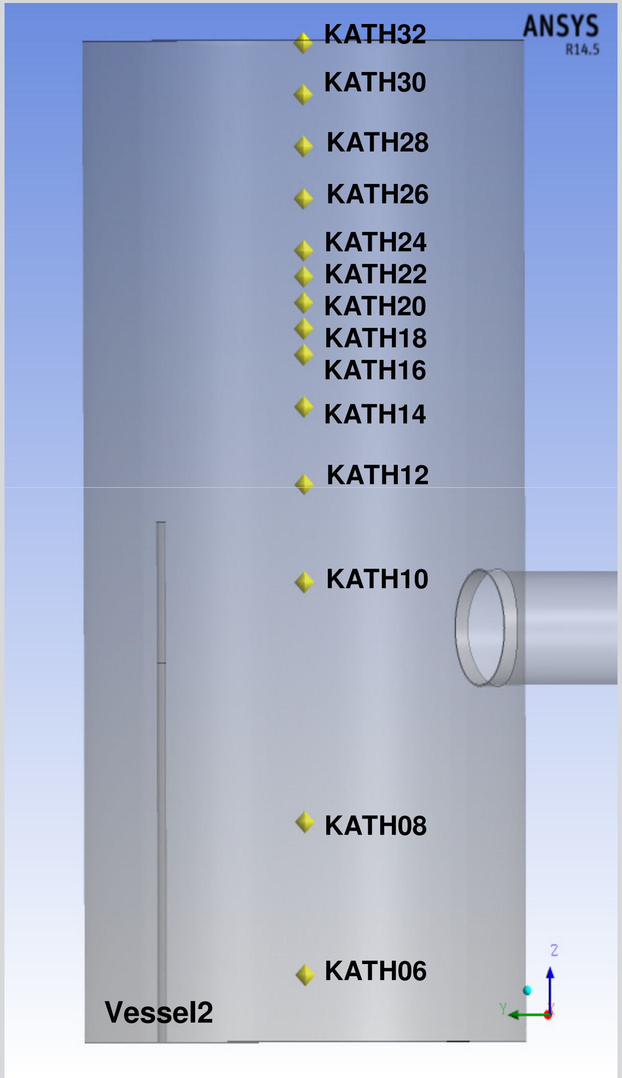


  August 9, 2013

Results MPII_1

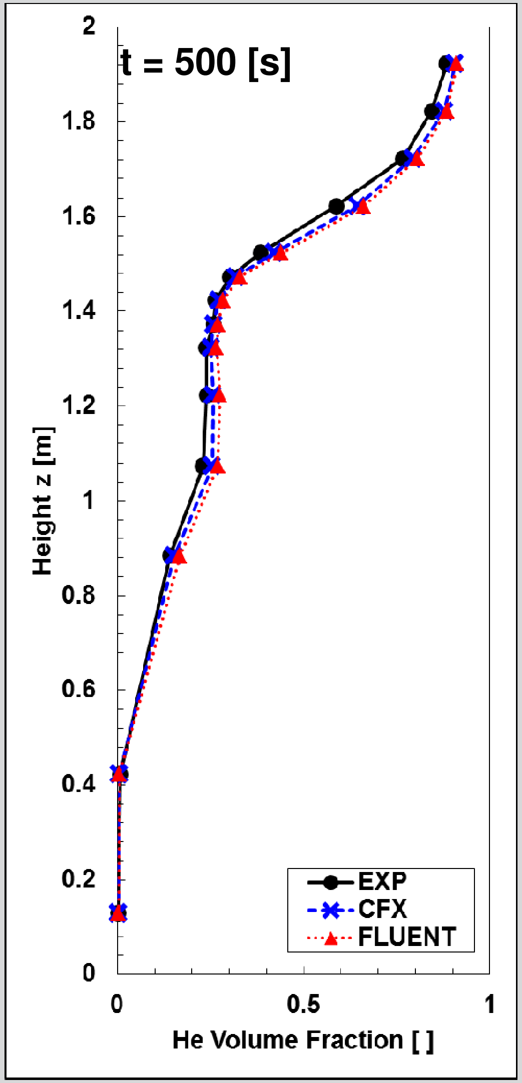


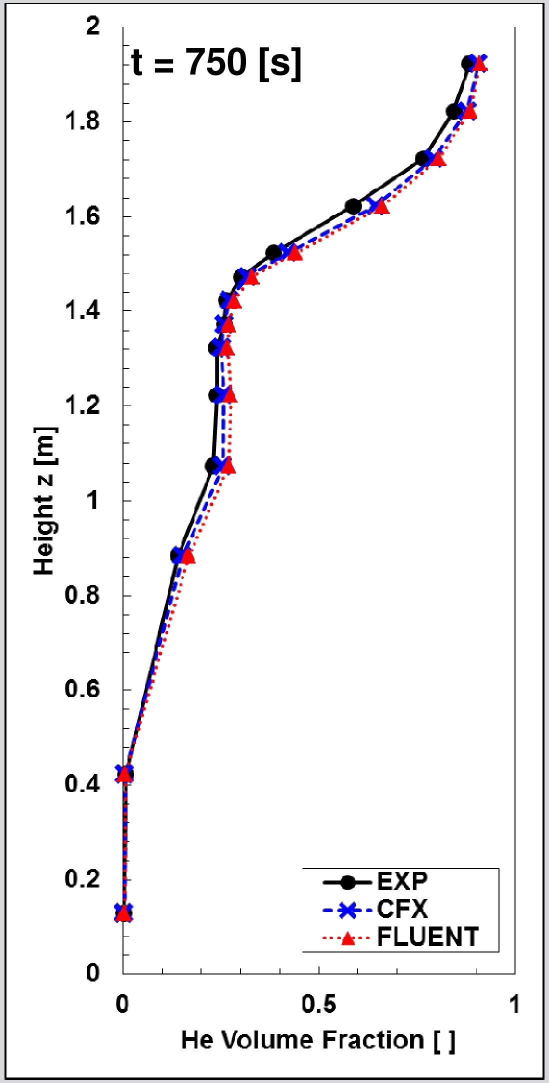


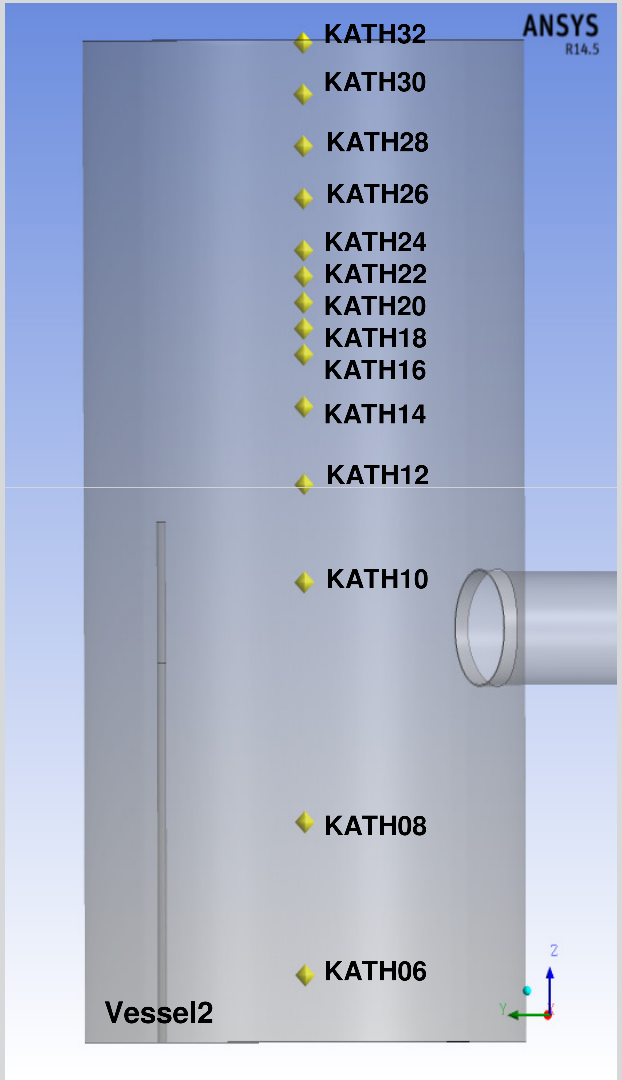


  August 9, 2013

Results MPII_1

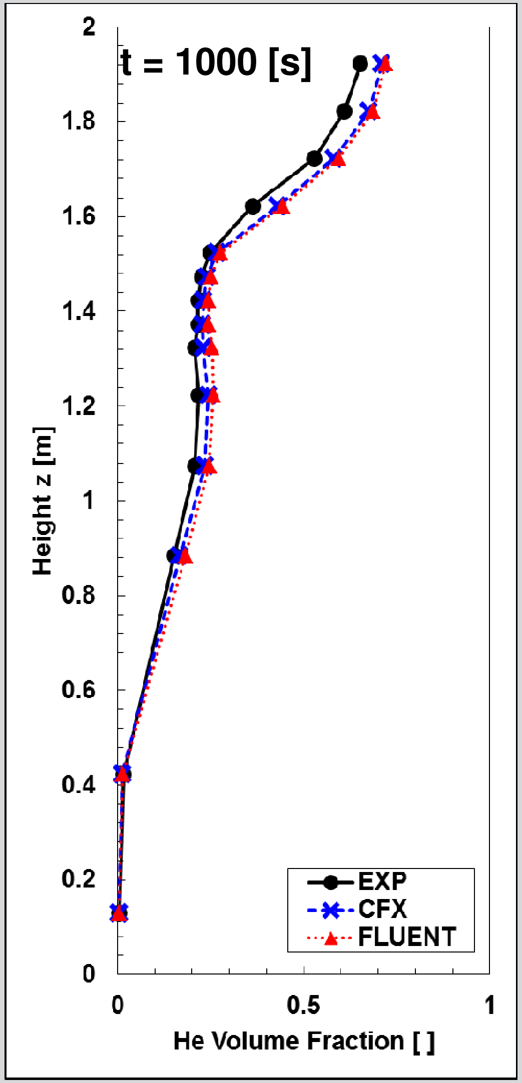


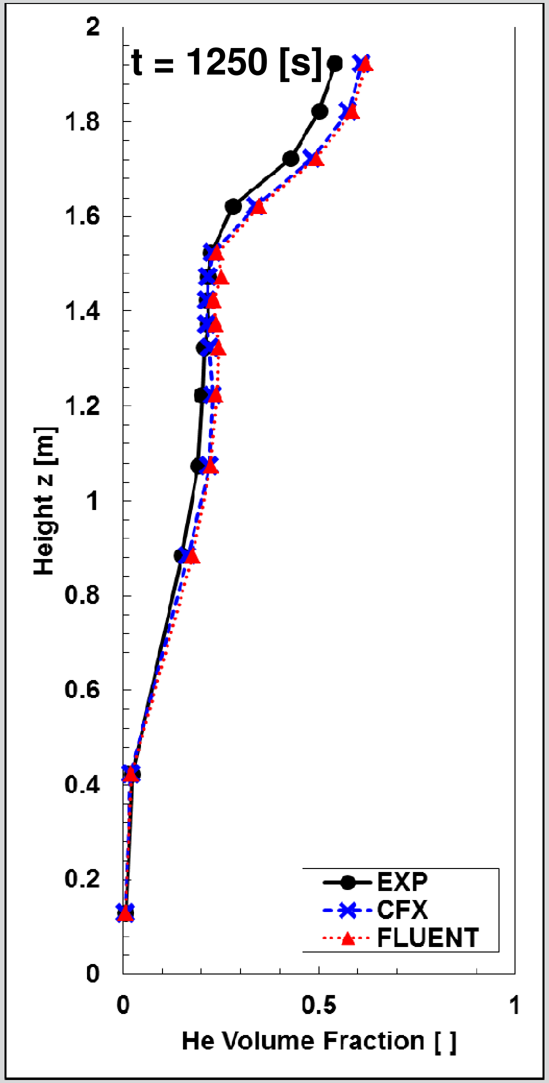


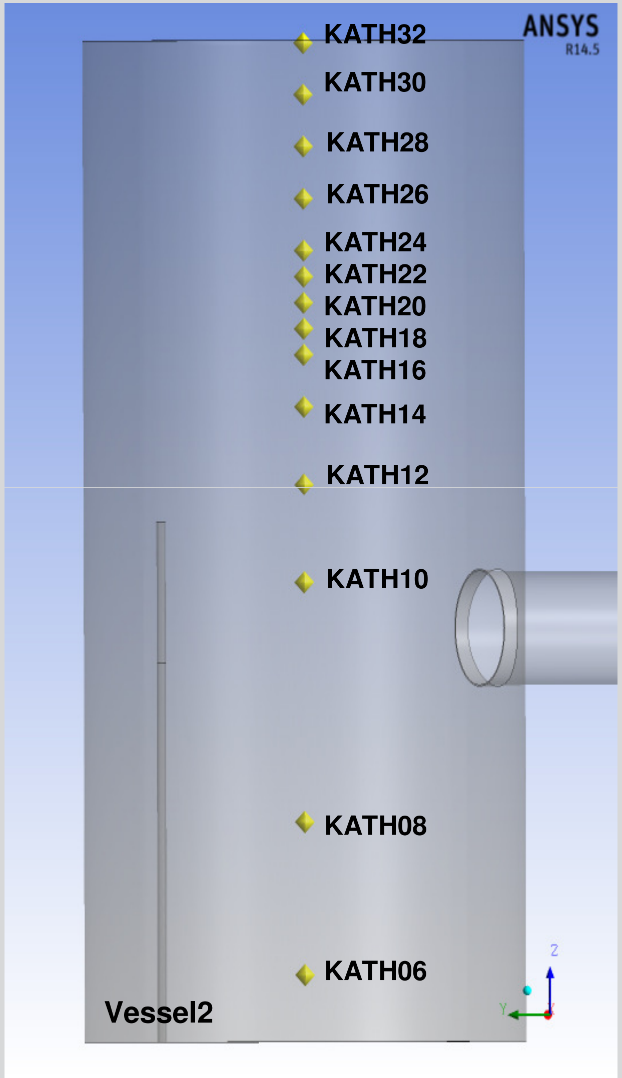


  August 9, 2013

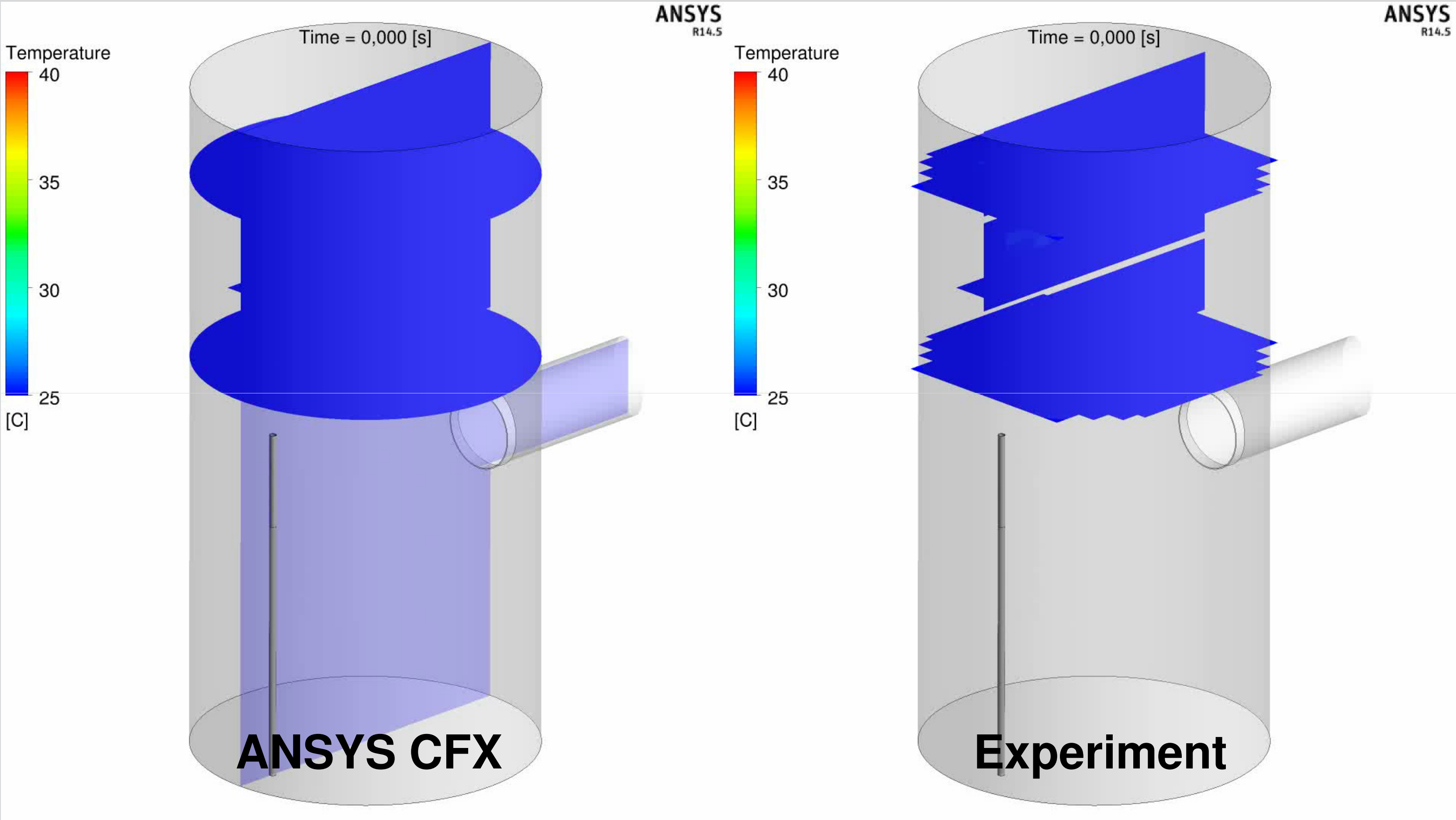
Results MPII_1



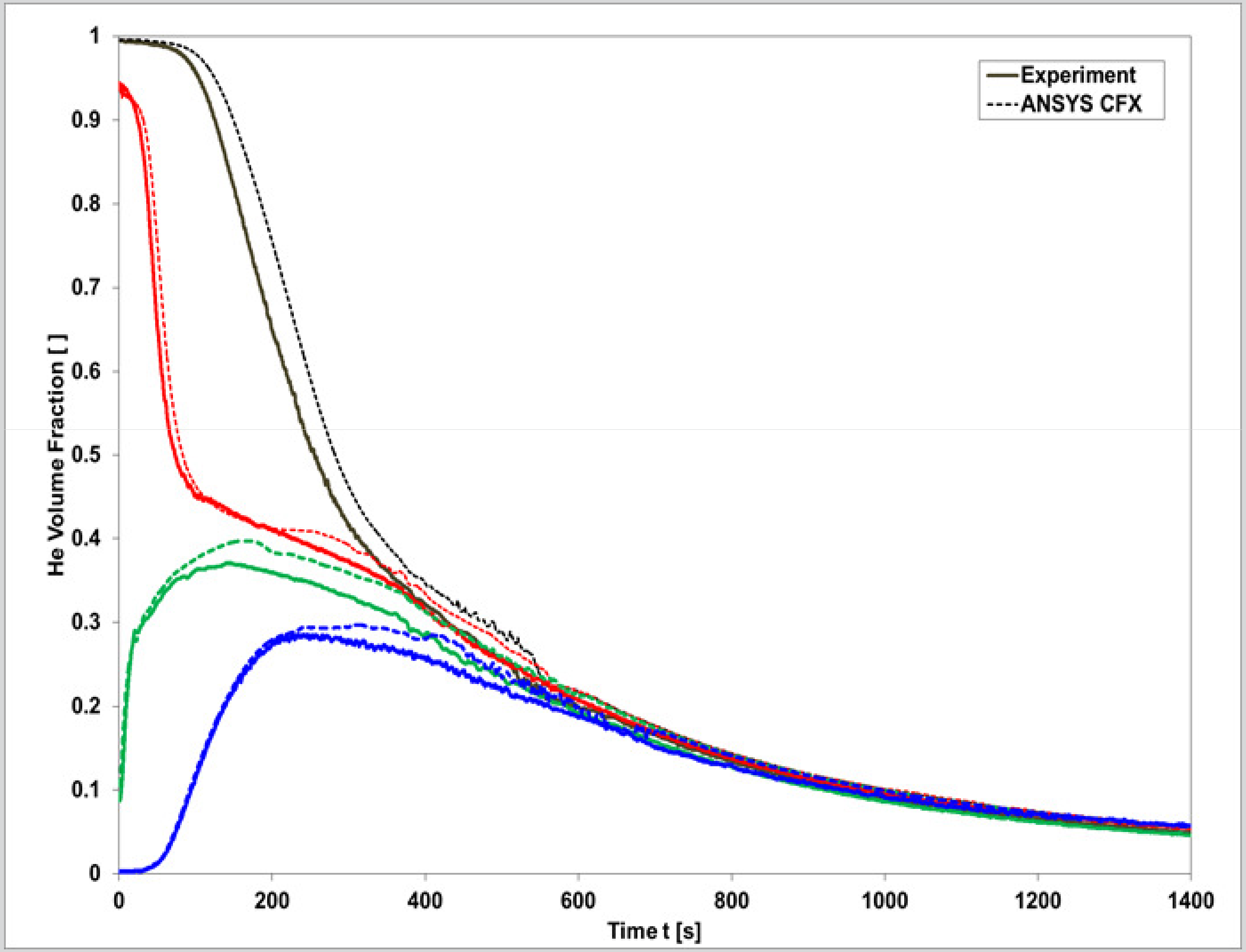




Results MPII_1

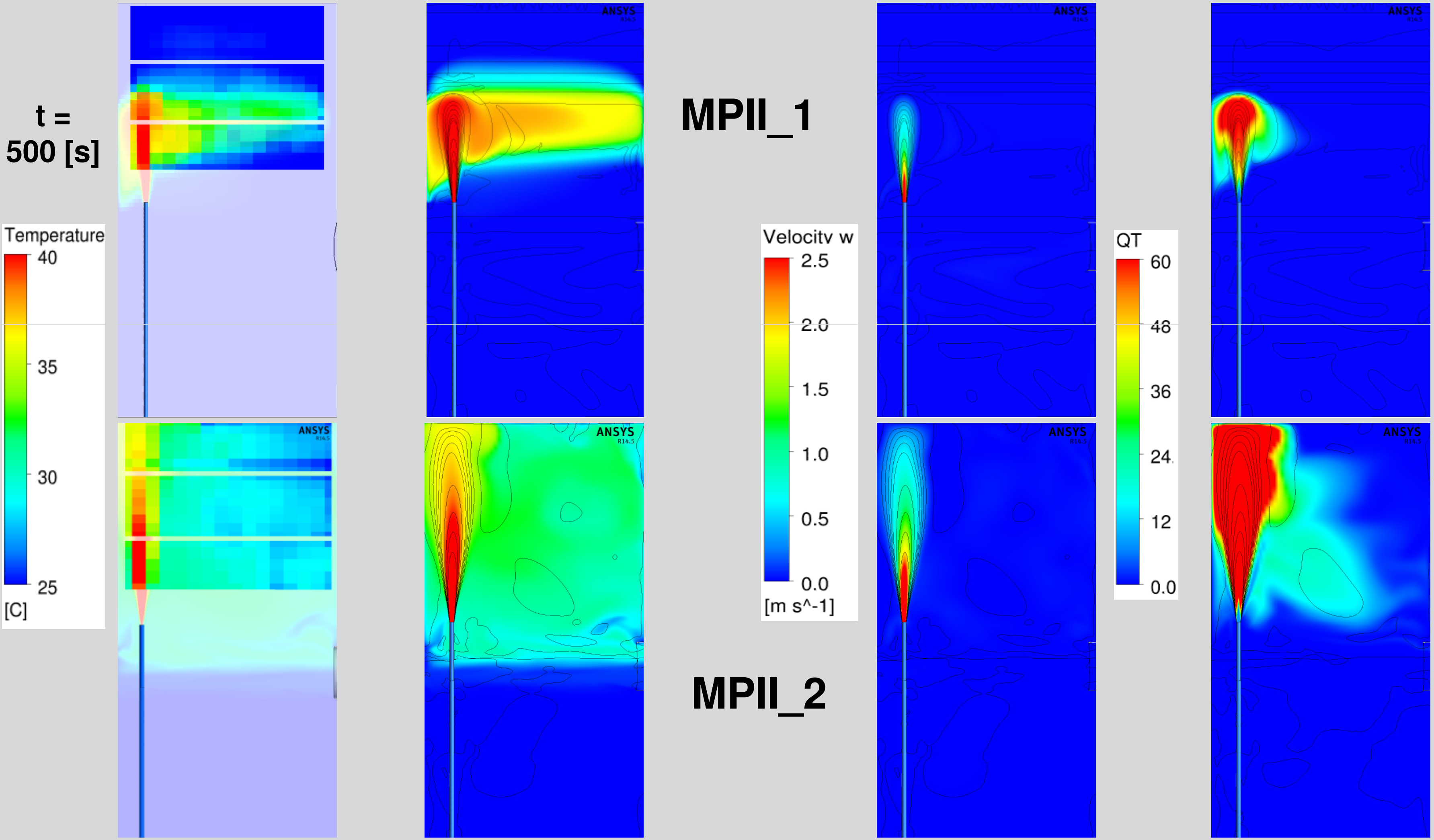


Results MPII_2



Comparison MPII_1 / MPII_2

Temperature Experiment	Temperature Simulation	Vertical Velocity Simulation	Eddy Viscosity Ratio Simulation



  August 9, 2013

Conclusion

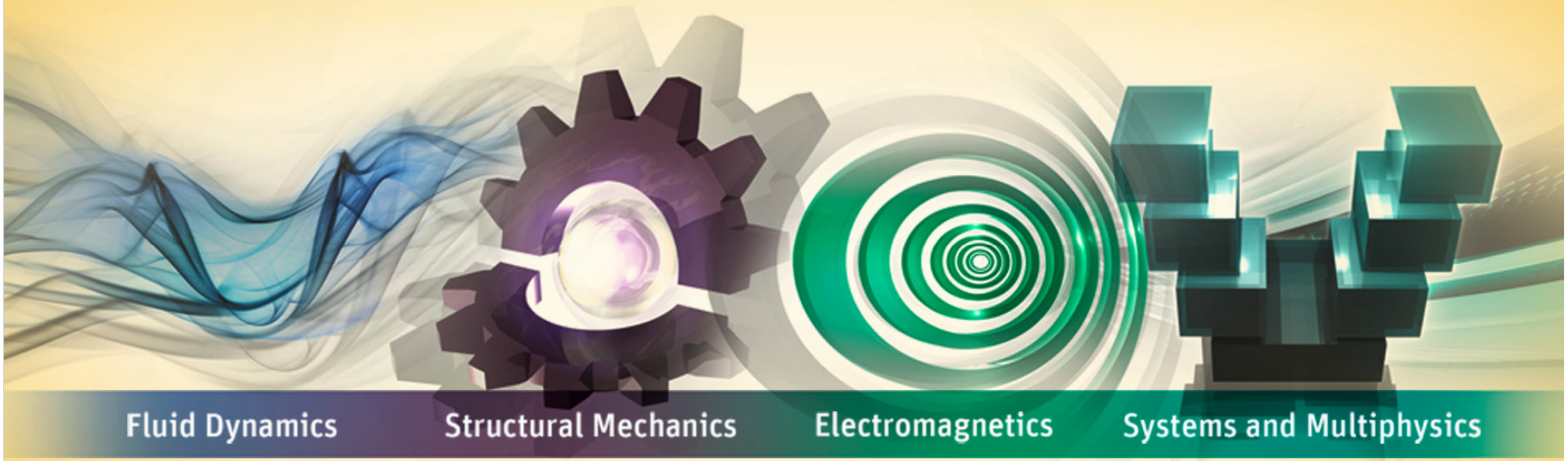
- **CFD results in good agreement with He data**
  - ANSYS CFD has the ability to predict the turbulent mixing and transport of He in density- and temperature-driven buoyant flows
  - Good agreement between ANSYS CFX and ANSYS Fluent
  - Physical modeling applicable to variation of MiniPanda test conditions, i.e. variation of Re, Fr and Pe numbers

- **Agreement with temperature data less satisfactory**
  - Uncertainties in experimental boundary conditions for injected air temperature
  - Uncertainties in thermal BC's for vessel walls (heat capacity, heat flux)

  → better controlled experiment required

Realize Your Product Promise™

References



References

1. St. Kelm, M. Ritterrath, R. Heierli, H.-M. Prasser and H.-J. Allelein “Specification and Proposal for the MiniPanda – Layer Breakup Evaluation and Code Benchmark”
2. Ritterath, M.: Instrumentation and mixing experiments on safety relevant gas flows in containments of nuclear reactors, PhD thesis, ETH Zuerich, 2011
3. Ritterath, M. et.al.: MiniPanda – A small-scale-containment test facility with novel instrumentaion is used for code validation for an air ingress scenario, NURETH-14, Toronto, Ontario, Canada, September 25-29, 2011

References

4. Studer, E. et.al.: Interaction of a light gas stratified layer with an air jet coming from below: Large scale experiments and scaling issues
5. Kelm, S., Ritterath, M. et al.: MiniPanda - Layer Breakup Evaluation and Code Benchmark, 20th German CFD Network Meeting, Garching, March 2012
6. Poling, B. et.al. "The Properties of Gases and Liquids, 5th edition", pp. 11-10: Method by Fuller et al., 2000
7. Wiki1, http://de.wikipedia.org/wiki/Luft

