Expansion of the model basis in MELCOR

Philipp Dietrich

Institute for Nuclear and Energy Technologies (IKET)

Outline

- Motivation
- Adding new models to MELCOR
  - Coupling external models
  - Direct integration of models into the source code
- Simulation of the LIVE-Facility
- Summary

Outline

- Motivation
- Adding new models to MELCOR
  - Coupling external models
  - Direct integration of models into the source code
- Simulation of the LIVE-Facility
- Summary

Motivation

- New models describing phenomena in a severe accident were and are developed
- In current system codes only specific models are integrated
- The implementation of new models in system codes is only possible by the developers
- The coupling interface for MELCOR based on the MPI-Standard is available at the IKET (Dr. Tobias Szabó)

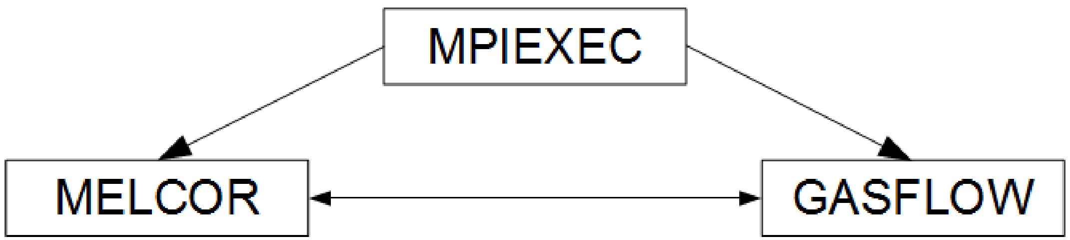
→ Coupling additional models to MELCOR

Outline

- Motivation
- Adding new models to MELCOR
  - Coupling external models
  - Direct integration of models into the source code
- Simulation of the LIVE-Facility
- Summary

Coupling external Models

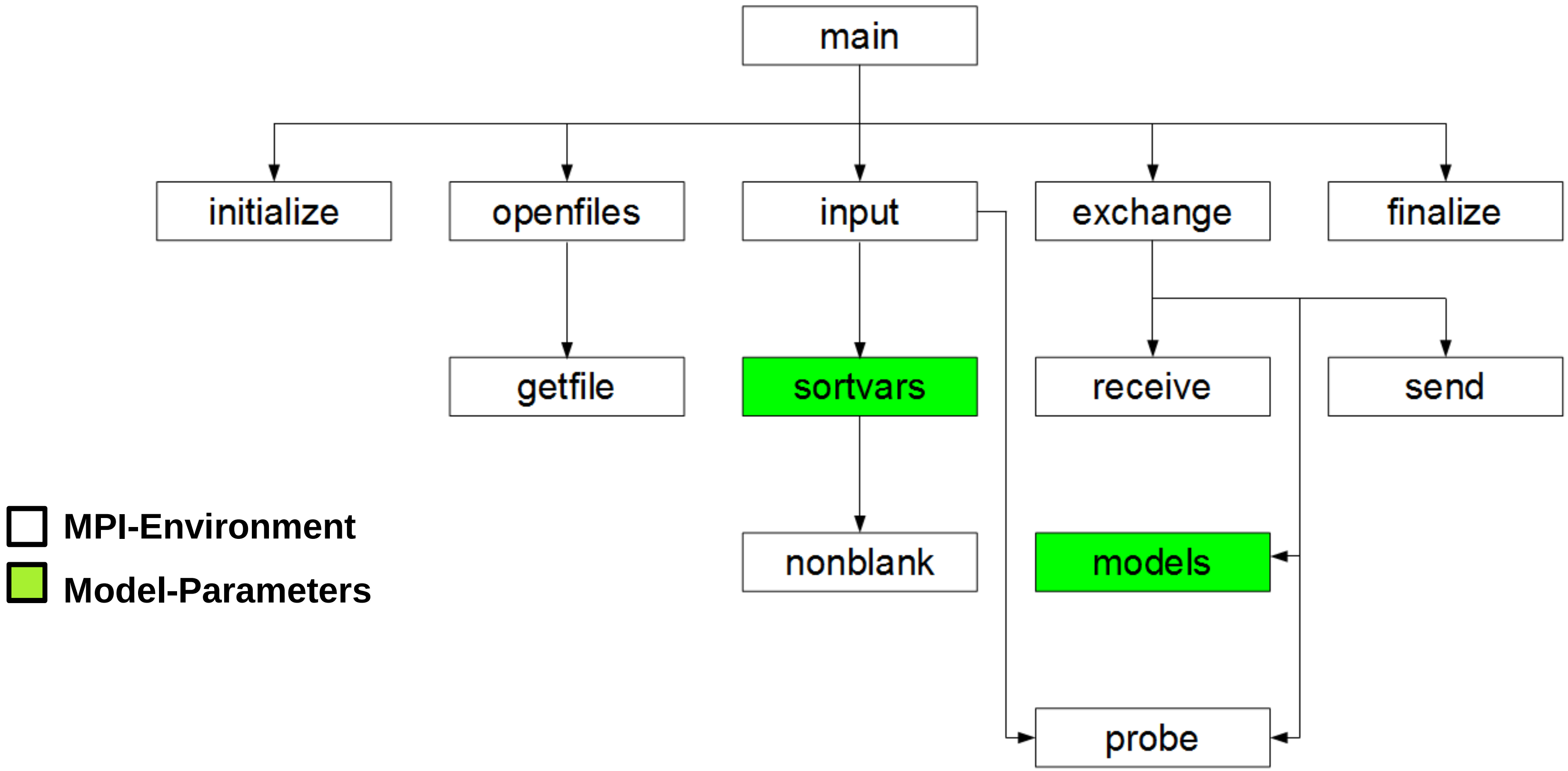
- Coupling interface in MELCOR
  - Coupling-Interface directly changes Control Functions
  - Communication program MPIEXEC (SNL) available at the IKET
  - Coupling of MELCOR ⇔ GASFLOW performed at the IKET (Dr. T. Szabó)



  - Coupling is external, explicit and asynchronous
  - Replace the GASFLOW Program by the developed external tool, which provides an interface for the definition of additional models

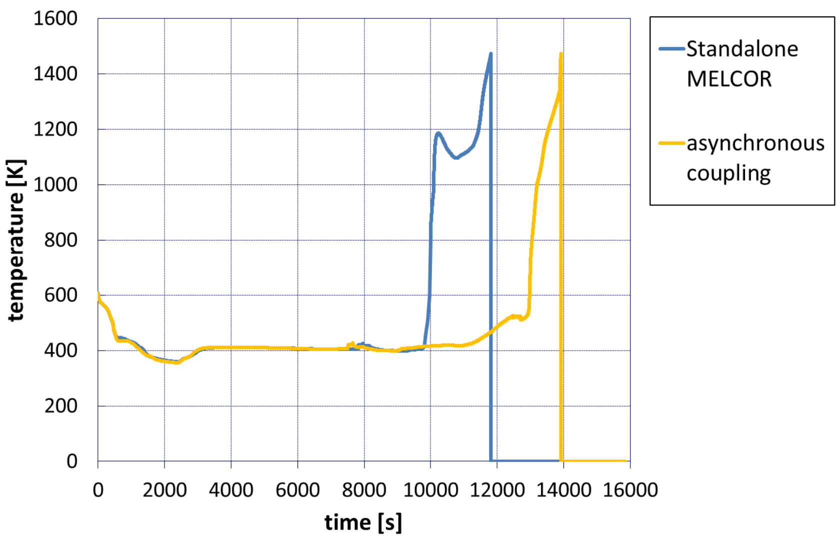
Coupling external models

- Structure of DINAMO
  - Direct Interface for Adding Models
  - Currently the only way to add external models

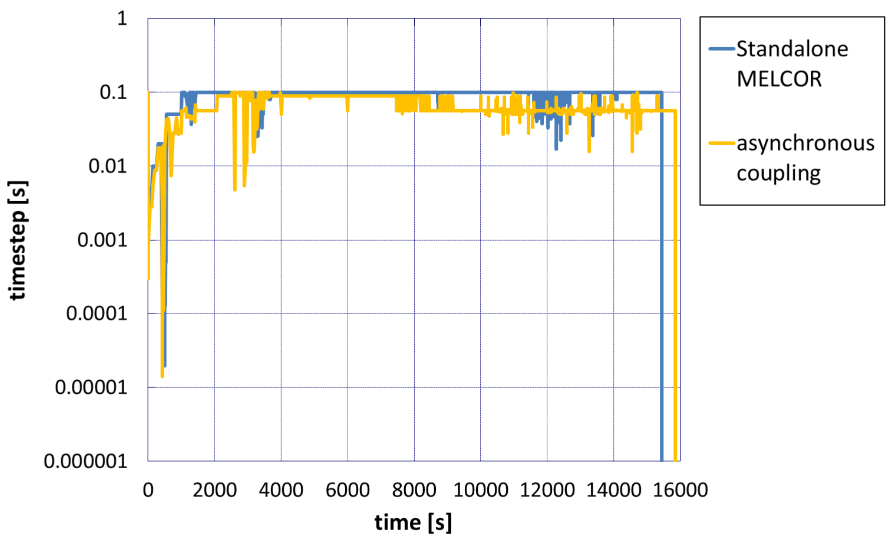


Coupling external models

- Deviations in the simulation results due to different coupling timesteps



Temperature in the
lower core support plate

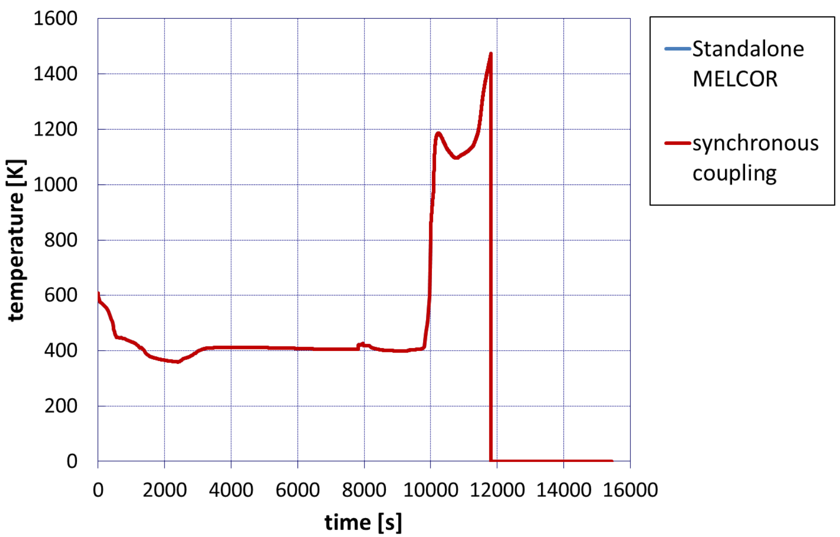


Timestep size in MELCOR
Coupling timestep: 0.2s

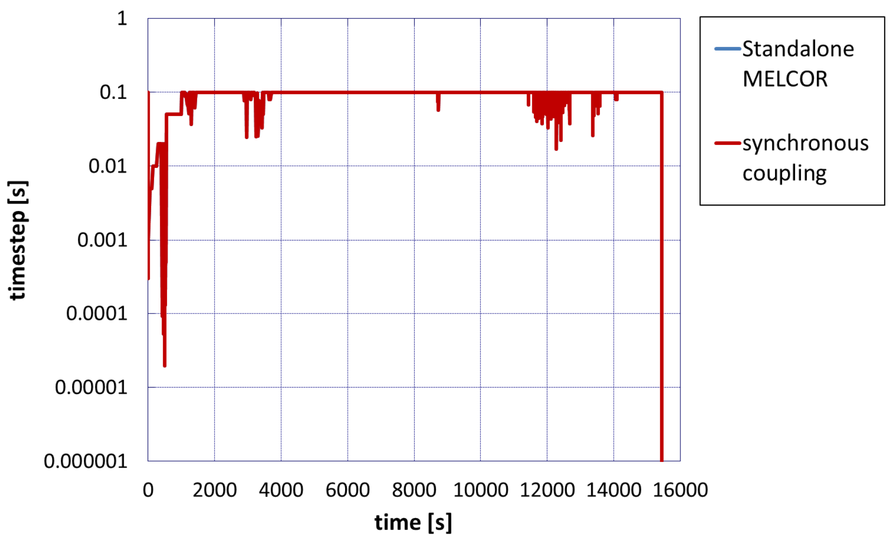
→ Method to synchronize the coupling timesteps with the MELCOR timesteps needed

Coupling external models

- Results with the synchronized coupling method



Temperature in the
lower core support plate



Timestep size in MELCOR

→ No influence of the coupling interface on the simulation results

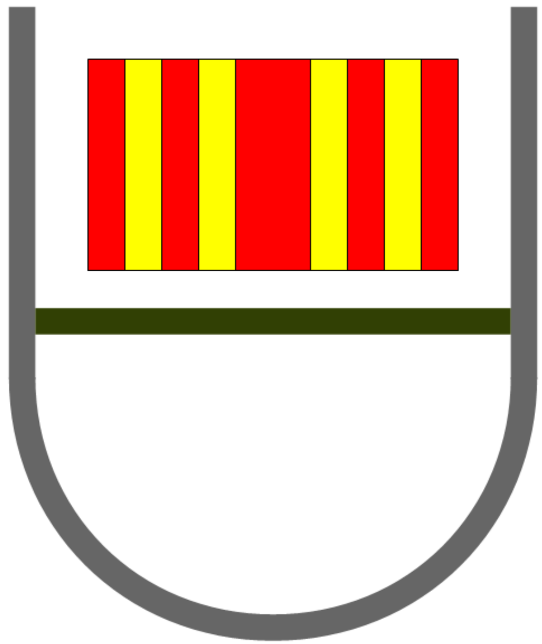
Coupling external models

- Example: Coupling of the Larson-Miller-Model
- Model to calculate the failure of a structure by creeping
  - Application to the lower core support plate
    - Existing approach:

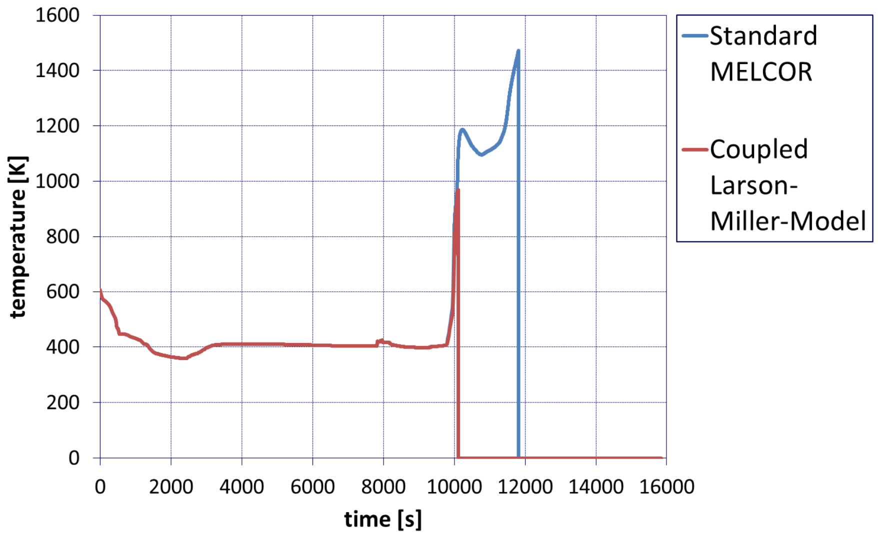
      Failure due to temperature
    - New approach:

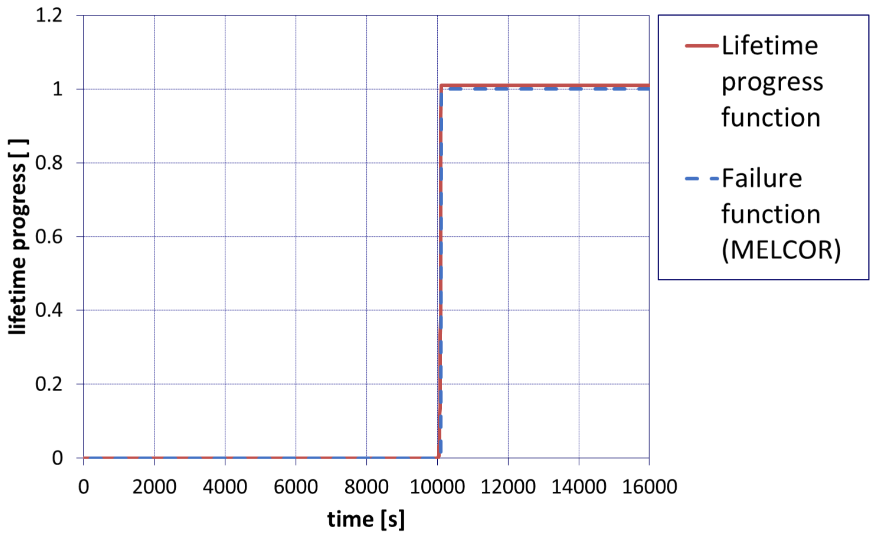
      Failure due to temperature

      and stress



Coupling external models





Temperature of the lower core support plate

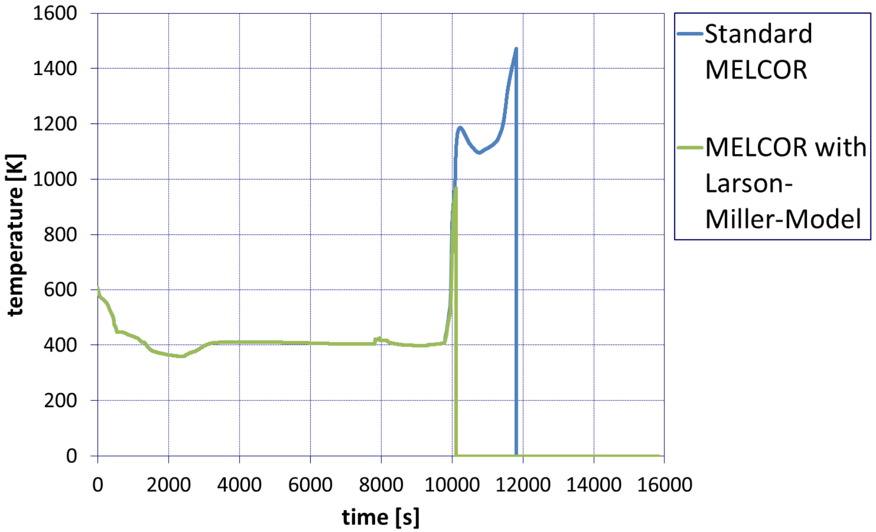
Externally calculated lifetime progress function and the corresponding failure function

Direct integration of models

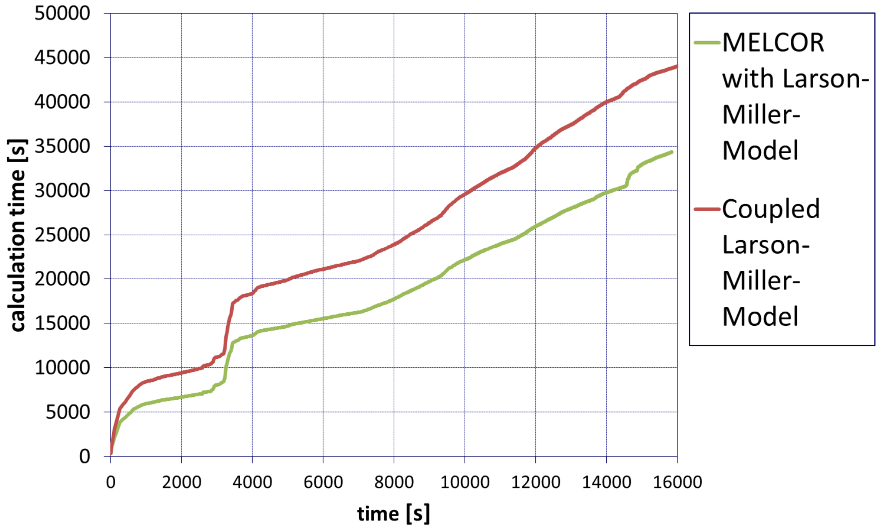
- Integration of new models via the Control-Functions-Package
- Faster calculations compared to the coupling of external models
- Knowledge of the source code is needed
- Example:

  Integration of the Larson-Miller-Model as a Control-Function

Direct integration of models



Temperature of the lower core support plate



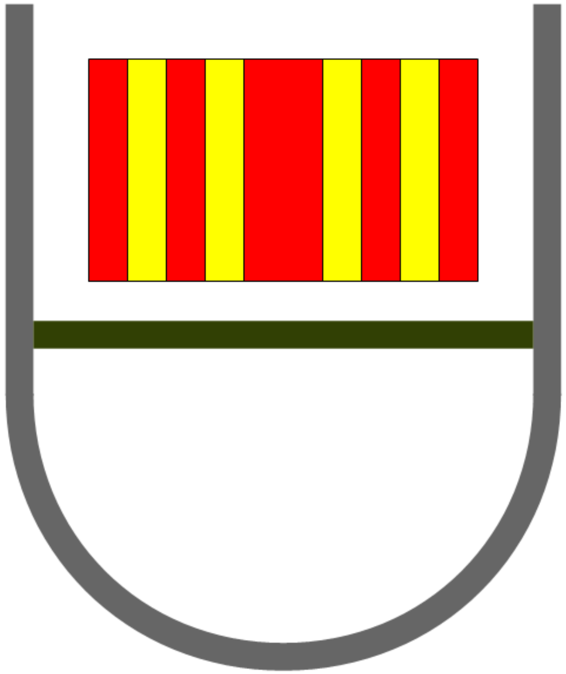
Comparison of the calculation times

Outline

- Motivation
- Adding new models to MELCOR
  - Coupling external models
  - Direct integration of models into the source code
- Simulation of the LIVE-Facility
- Summary

LIVE-Facility

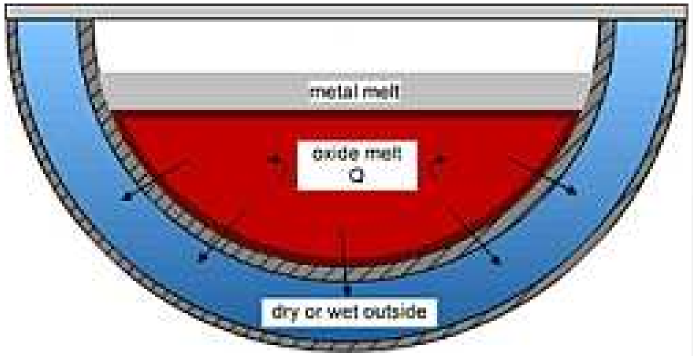
- Scenario:
  - Core-Degradation due to a severe accident in a PWR
  - Formation of a melt pool in core
  - Failure of the lower core support structure
  - Relocation of the molten pool to the lower plenum



- Objectives:
  - Illustration of the behaviour of the molten pool in the lower plenum
  - Investigation of the coolability of the reactor pressure vessel

LIVE-Facility

- Scenario:
  - Core-Degradation due to a severe accident in a PWR
  - Formation of a melt pool in core
  - Failure of the lower core support structure
  - Relocation of the molten pool to the lower plenum
- Objectives:
  - Illustration of the behaviour of the molten pool in the lower plenum
  - Investigation of the coolability of the reactor pressure vessel



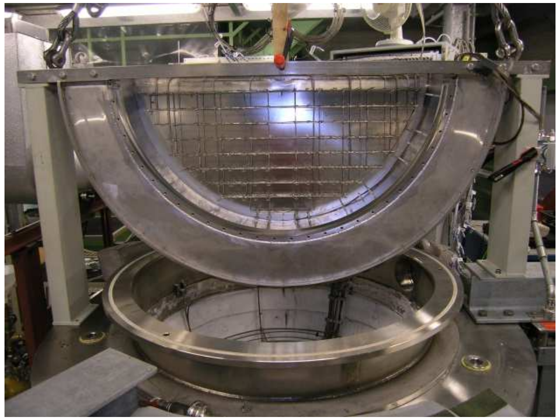
LIVE-Facility

- Setup:
  - LIVE 2D and LIVE 3D
  - Lower Plenum on scale of 1:5 (PWR)
  - External cooling by water or air
  - Atmospheric pressure
  - Molten corium

    → Salt melt (KNO_3 und $NaNO_3$) at 350°C

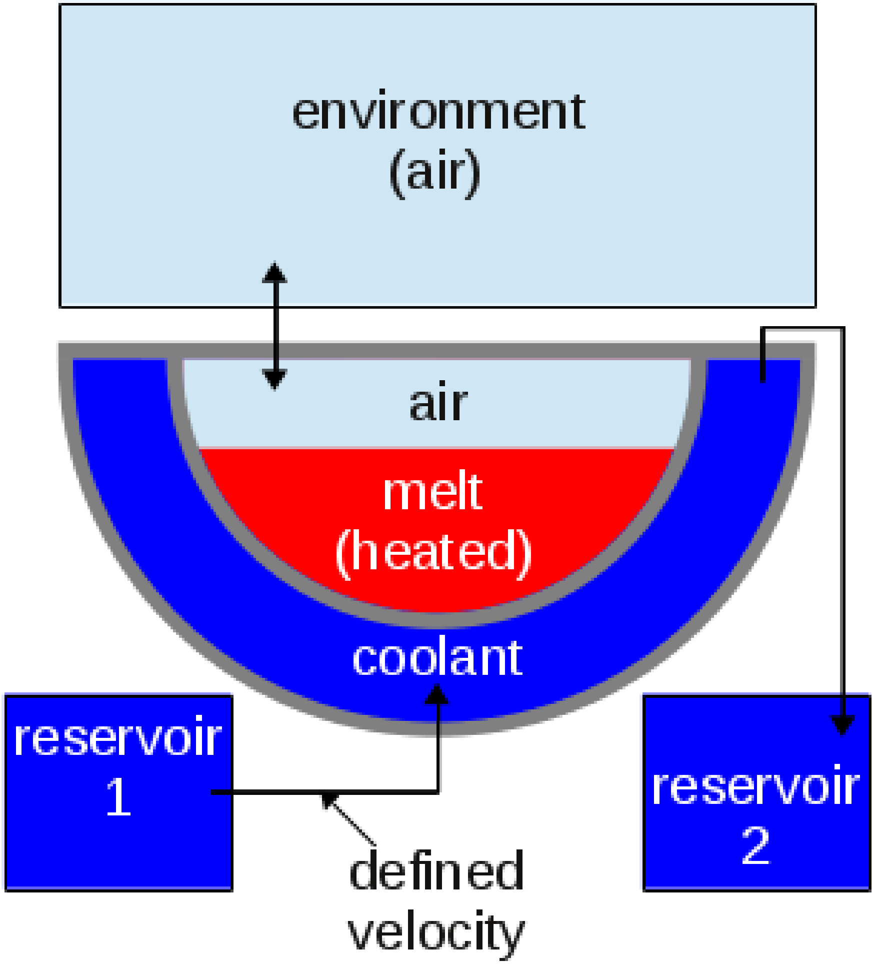
    → Water at 70°C
  - Heating helixes to model

    inner heating of the melt



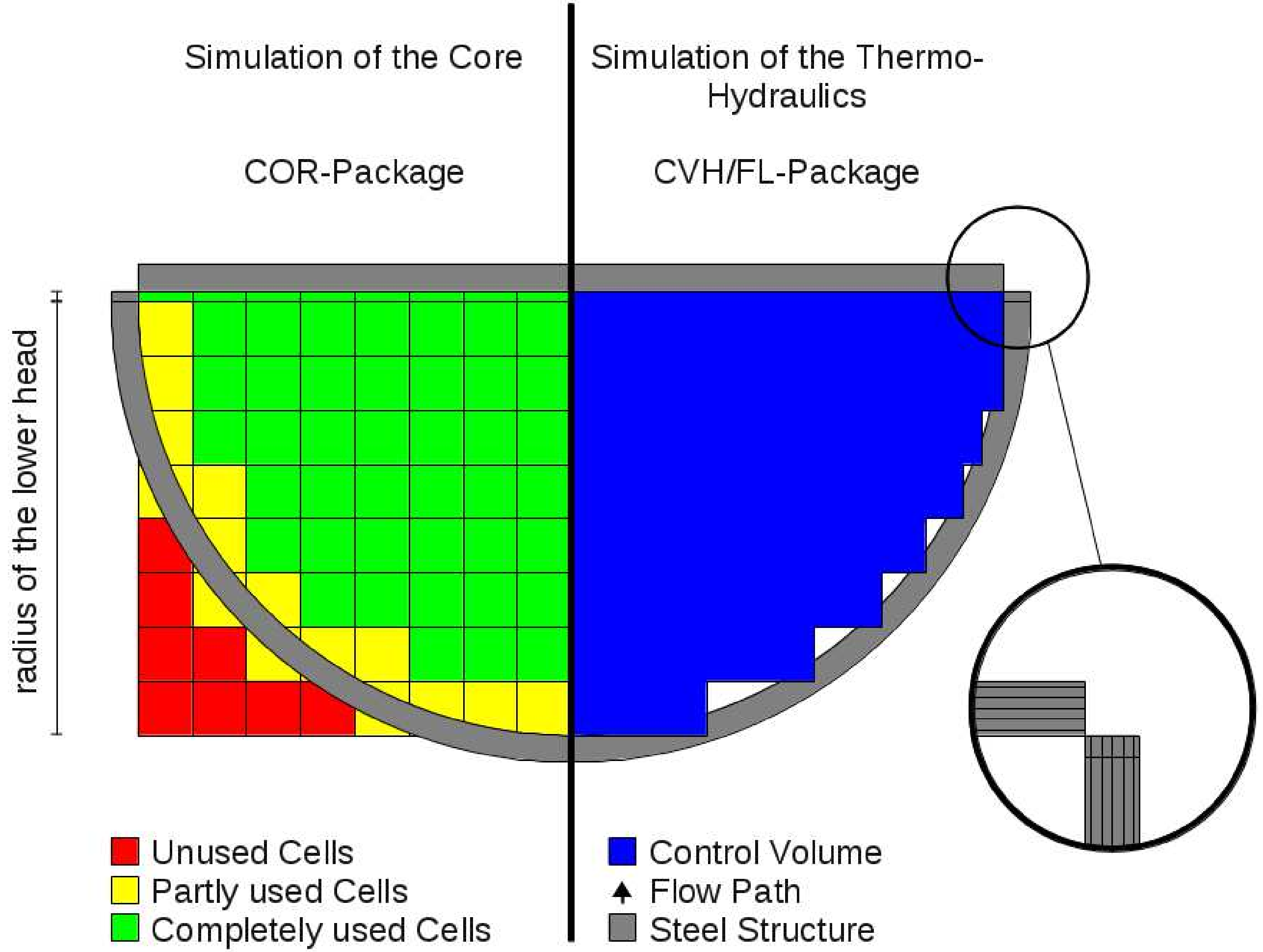
LIVE-Facility

- MELCOR-Input for the LIVE-Facility



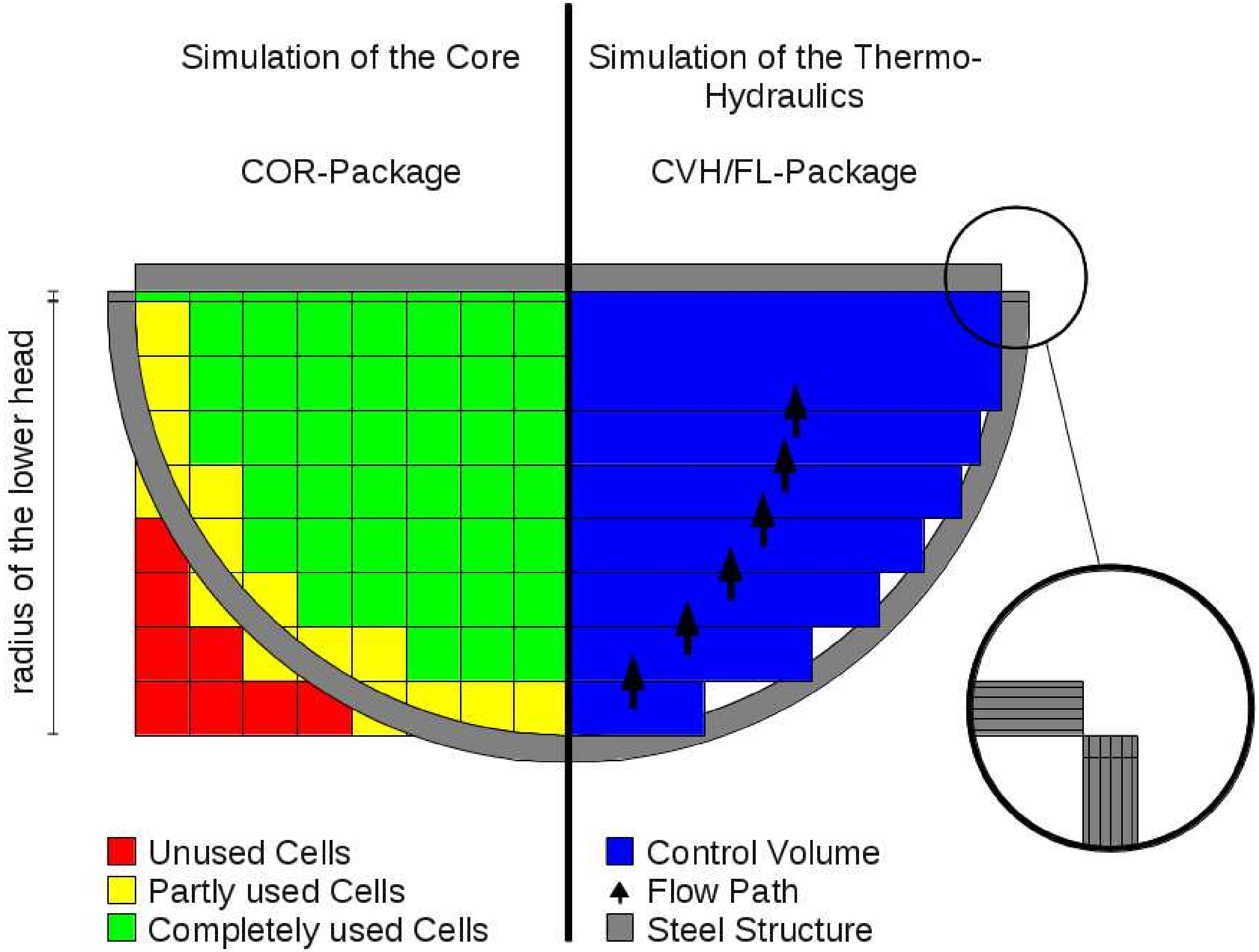
LIVE-Facility

- Nodalization of the Lower Plenum



LIVE-Facility

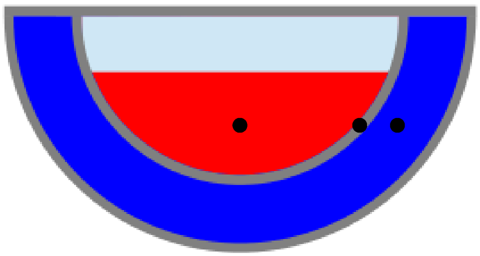
- Nodalization of the Lower Plenum



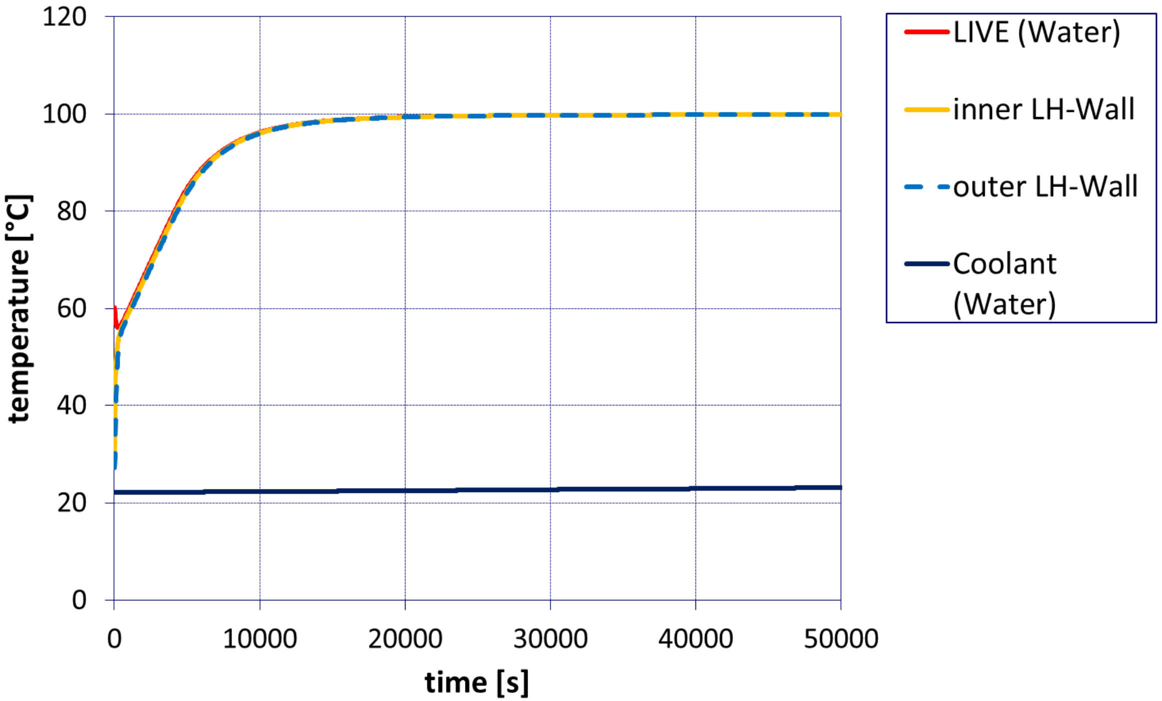
LIVE-Facility

- Simulation of water uniformly heated in the facility (LIVE-I1)

Temperatures in the LIVE-Facility



Coolant support: 10 cm³/s at 23°C

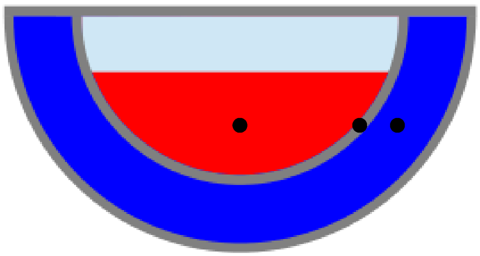


- Implemented boiling-model calculates no heat transfer to the coolant
  → New model to describe heat transfer is needed

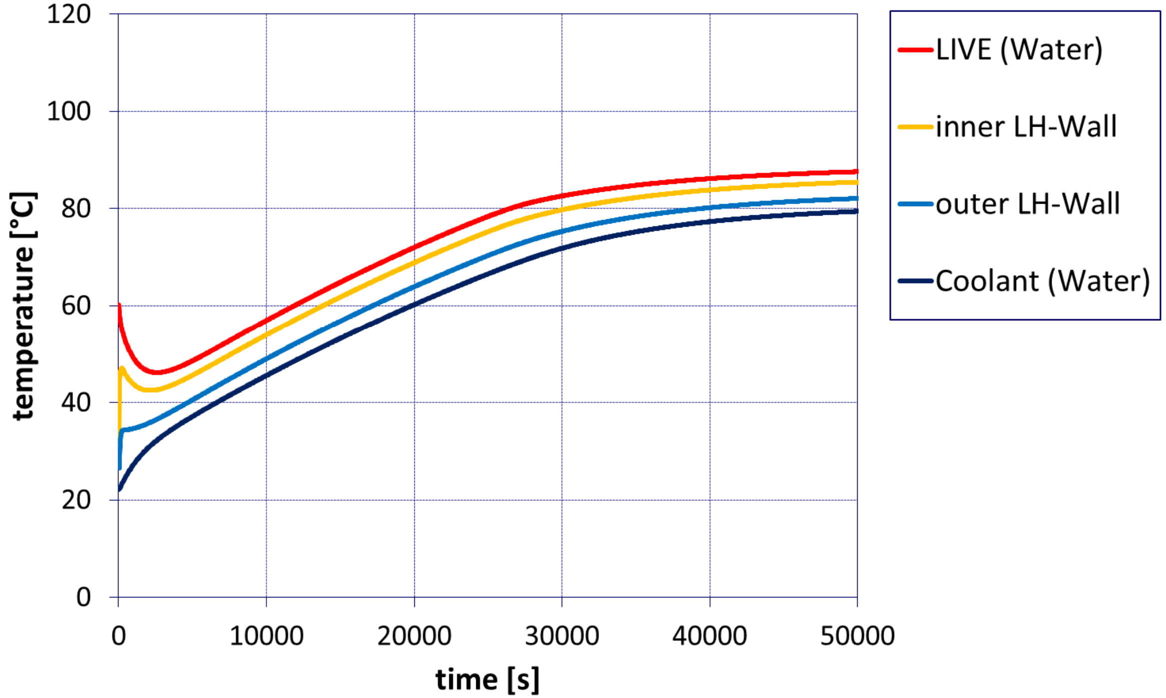
LIVE-Facility

- Simulation of water uniformly heated in the facility (LIVE-I1)

Temperatures in the LIVE-Facility



Coolant support: 10 cm³/s at 23°C



- Implementation of stationary heat transfer model calculates heat transfer to coolant

Outline

- Motivation
- Adding new models to MELCOR
  - Coupling external models
  - Direct integration of models into the source code
- Simulation of the LIVE-Facility
- Summary

Summary

- Summary
  - Development of a tool to couple external models to MELCOR (DINAMO)
  - Development of a method to implement new models directly into MELCOR using the Control-Functions-Package
  - Creation of a MELCOR-Input for the LIVE-Facility
  - Implementation of a model for the heat transfer to the coolant
- Outlook
  - Simulation of LIVE-Experiments with salt
  - Coupling of the „Effective Convectivity Model“ (KTH, Sweden)
  - Simulation of the LIVE- and SIMECO-Facility with the coupled models

Thank you for your attention

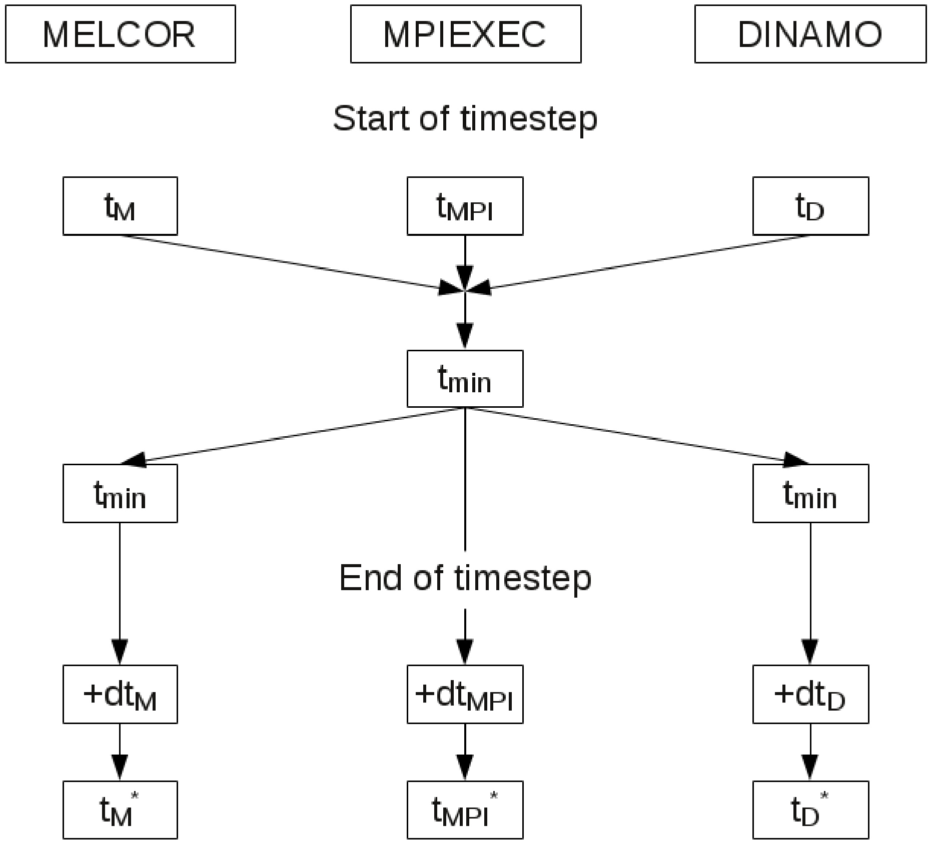
Sponsored by the

Federal Ministry of Education and Research

BACKUP

Synchronization of MELCOR and DINAMO

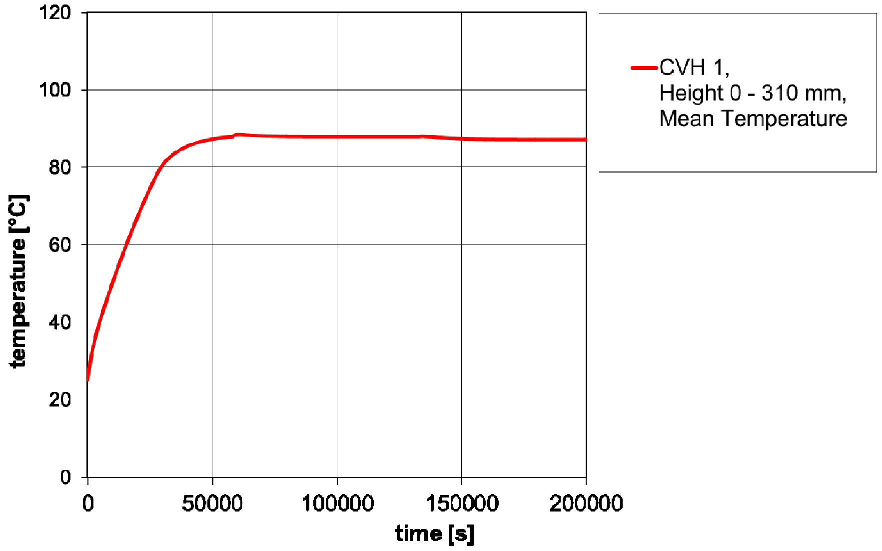
- Methodology to synchronize the programs MELCOR, DINAMO and MPIEXEC

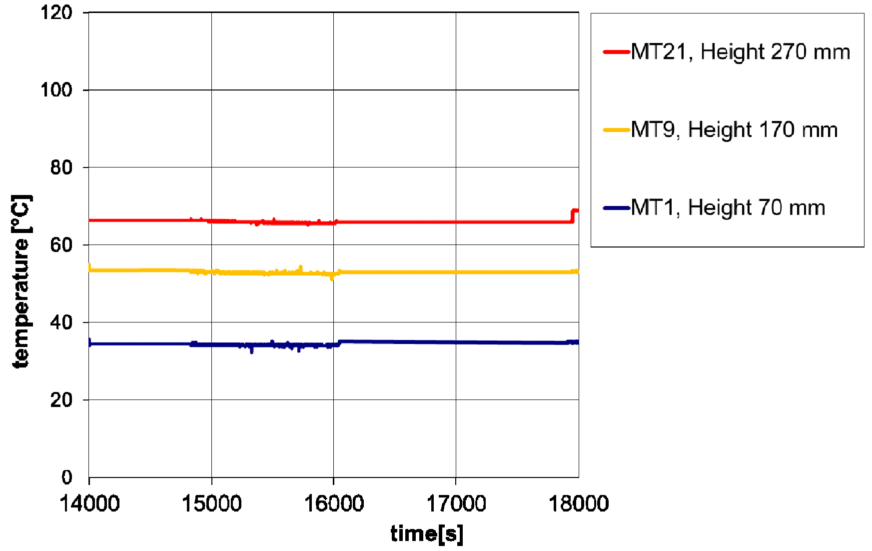


LIVE-Facility

- Comparison with the experimental data

Water Temperature in the LIVE-Facility at different elevations





Coarse Simulation
(1 CV inside the facility)

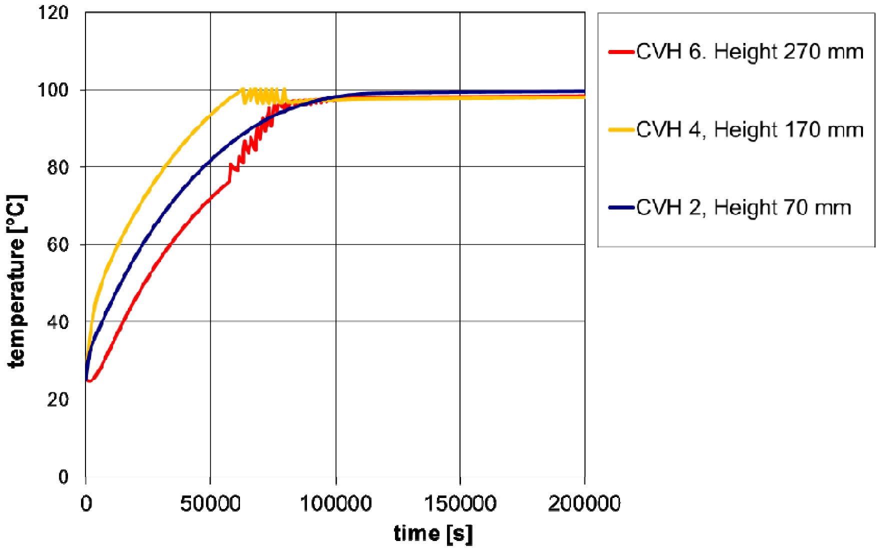
Experimental Data from LIVE-I1

("Results of the LIVE-I1 commissioning test on molten pool behaviour in the lower head of the RPV",
Miassoedov et al., Jahrestagung Kerntechnik, Karlsruhe, 2007)

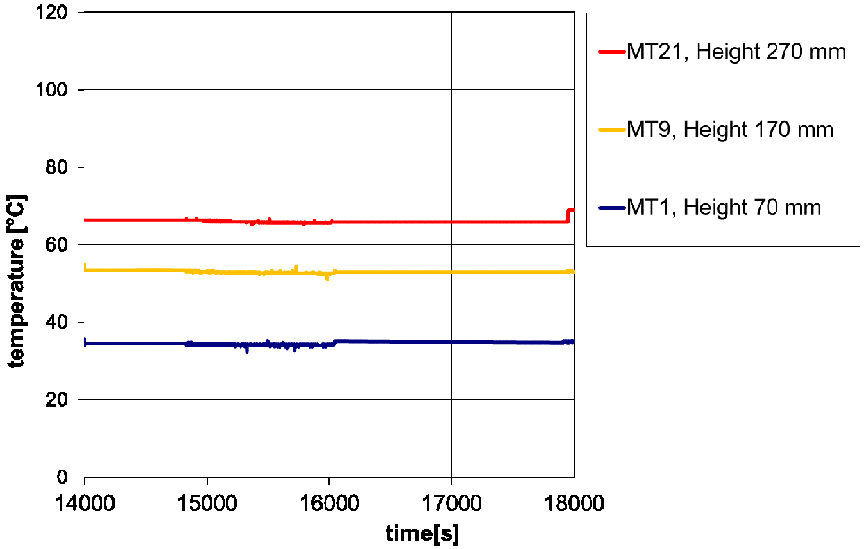
LIVE-Facility

- Comparison with the experimental data

Water Temperature in the LIVE-Facility at different elevations



Fine Simulation
(7 CV inside the facility)



Experimental Data from LIVE-I1

("Results of the LIVE-I1 commissioning test on molten pool behaviour in the lower head of the RPV",
Miassoedov et al., Jahrestagung Kerntechnik, Karlsruhe, 2007)