Coupling the PECM with MELCOR

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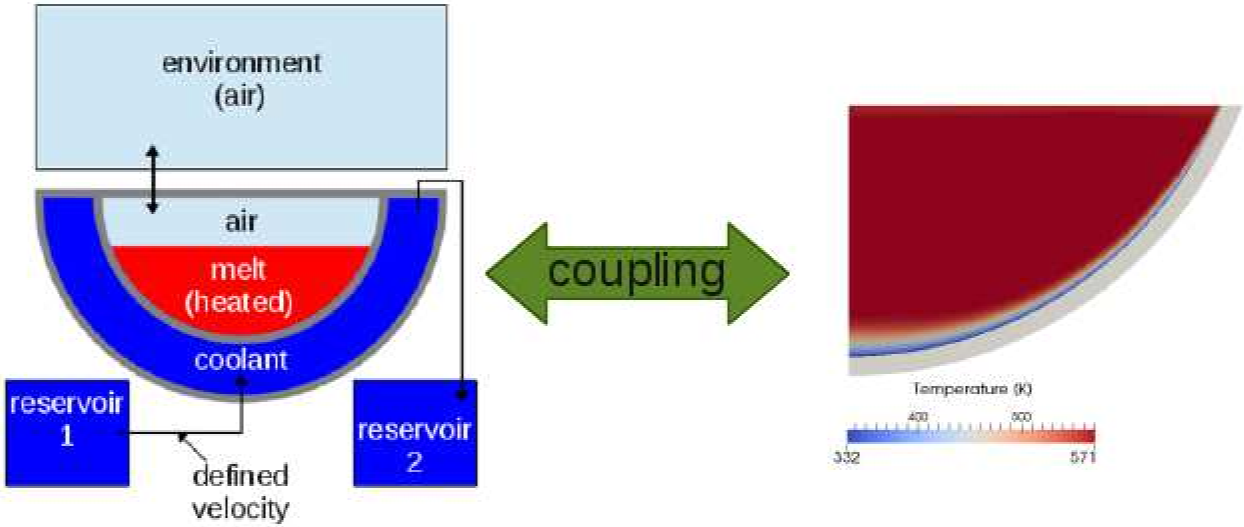

Outline

- Motivation
- Example: Adding the PECM to MELCOR
  - Coupling Interface
  - Theoretic Background
  - Coupling the PECM with MELCOR
- Simulation of the LIVE-facility
- Summary

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Motivation

- In-vessel retention an effective severe accident management strategy
- New models for IVR are available
  - Example: Phase-Change Effective Convectivity Model (PECM)
- The coupling interface for MELCOR based on the MPI-Standard is available at the IKET (Dr. Tobias Szabó)
- DINAMO (Direct Interface for Adding Models) allows coupling of new models to MELCOR

→ Improve MELCORs possibilities by new models using DINAMO

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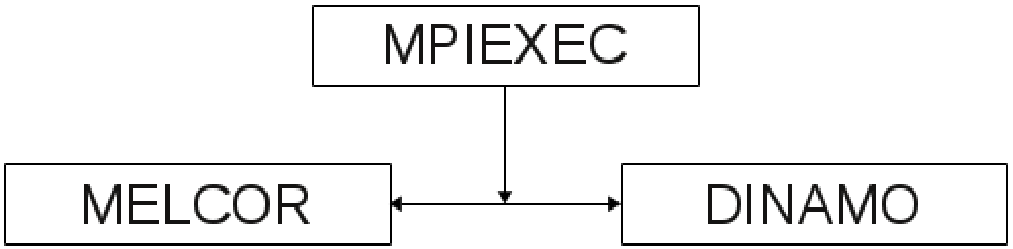
Coupling Interface

- Coupling interface in MELCOR
  - Coupling-Interface directly changes Control Functions (CF)
  - Communication program MPIEXEC (SNL) available at the IKET
  - Coupling of MELCOR ⇔ DINAMO:



  - Coupling is external, explicit and synchronous

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Theoretic Background

- MELCOR models pool as uniform continuum

  → No temperature distribution in molten material

- Fixed melting point in MELCOR

  → Only applies to eutectic material compositions

- Phase-Change Effective Convectivity Model (PECM)
  - Temperature distribution in the molten pool
  - Treatment of non eutectic solidification
  - Fast solving

→ PECM can improve the prediction of a molten core in MELCOR

Theoretic Background

- Phase-Change-Effective-Convectivity-Model (PECM)
  - Developed by Chi Thanh Tran at the Royal Institute of Technology (KTH)
  - Empirical correlations define characteristic velocities for the convective heat transfer in a molten pool
  - Temperature equation is solved on grid similar to CFD-Calculations

$$\frac{\delta T}{\delta t} + U_{char,i} \frac{\delta T}{\delta x_i} = -\frac{1}{\alpha}\left(\frac{\delta^2 T}{\delta x_i^2}\right) - Q$$

Convection modeled by the PECM as an energy source

→ PECM was implemented in CFD-Code OpenFOAM

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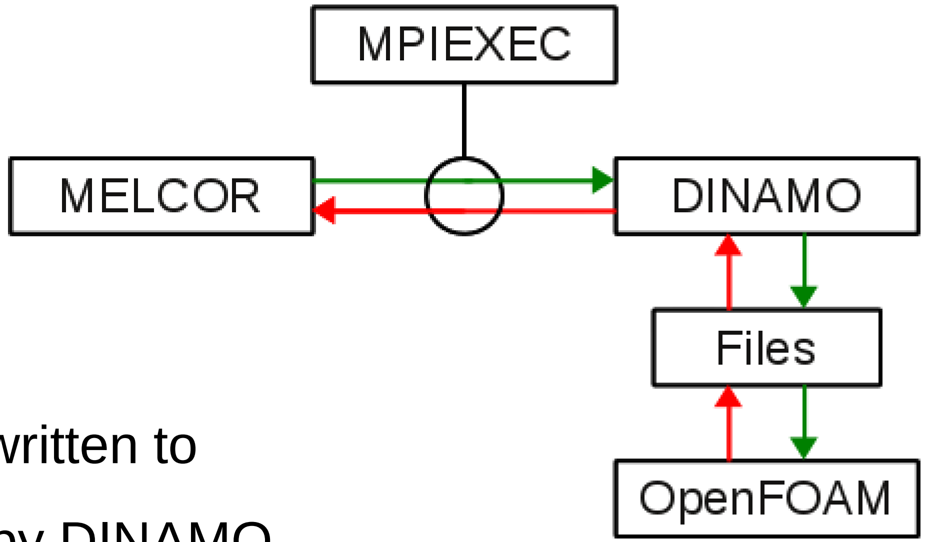
Coupling with MELCOR

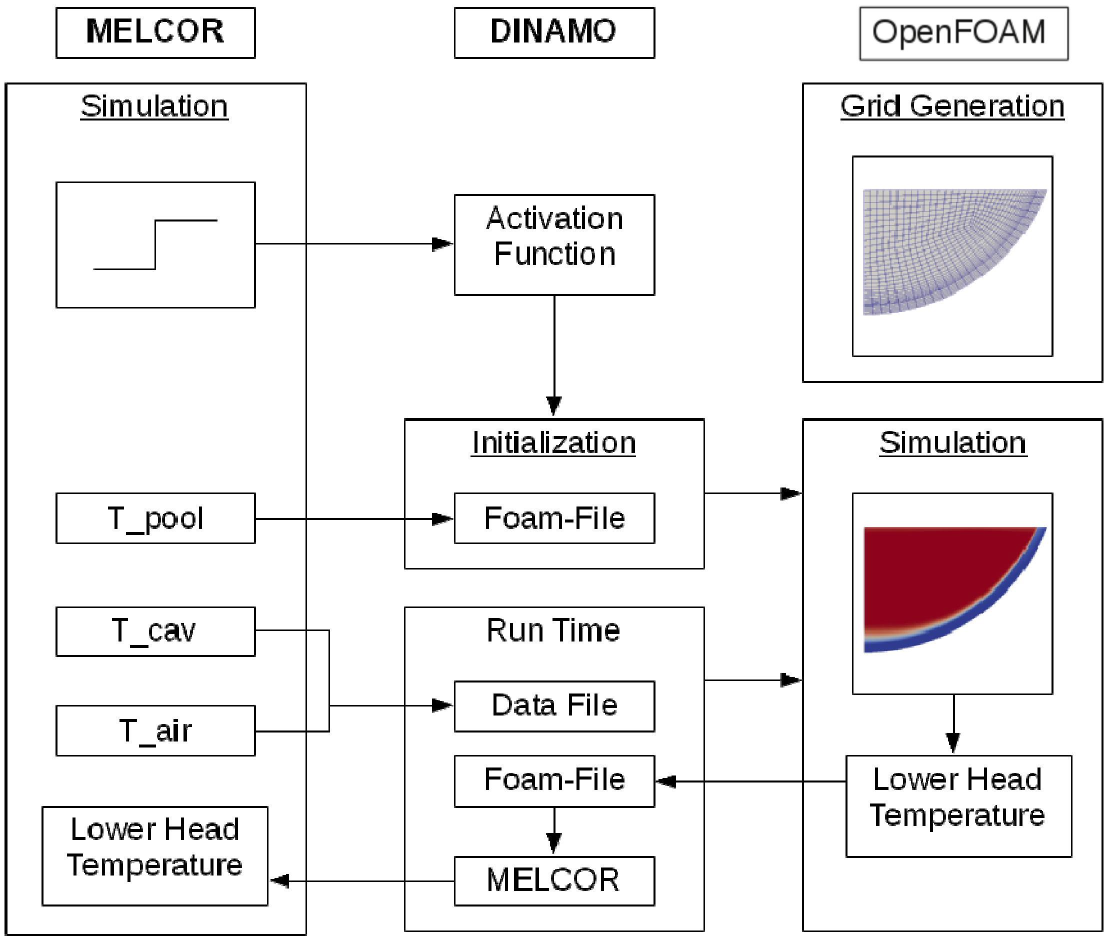
- Coupling methodology



- Data send from MELCOR is written to OpenFOAM compatible files by DINAMO
- OpenFOAM calculates the MELCOR-timestep
- DINAMO reads the OpenFOAM output and sends compatible data to MELCOR via the coupling interface

Coupling with MELCOR

- Exchanged Data



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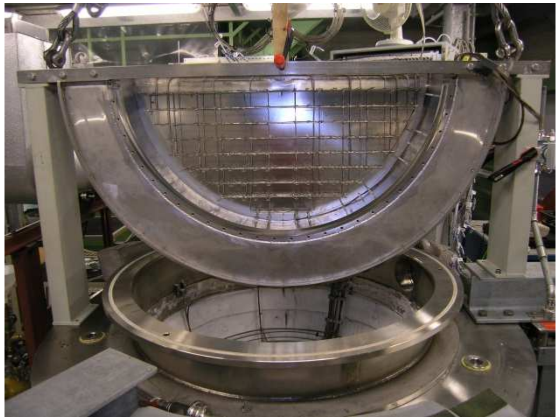
Simulation of the LIVE-facility

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

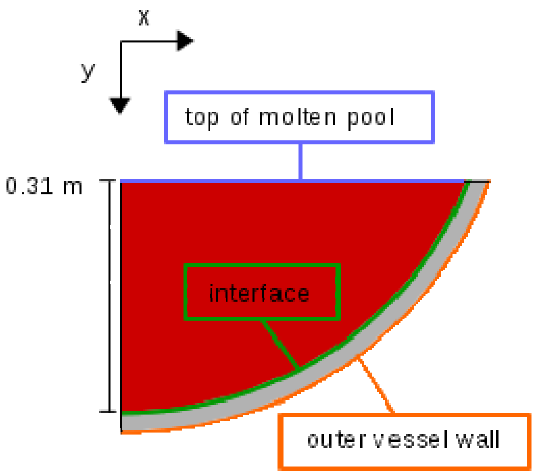
    → Salt melt (KNO_3 and $NaNO_3$)
  - Heating helixes to model

    inner heating of the melt

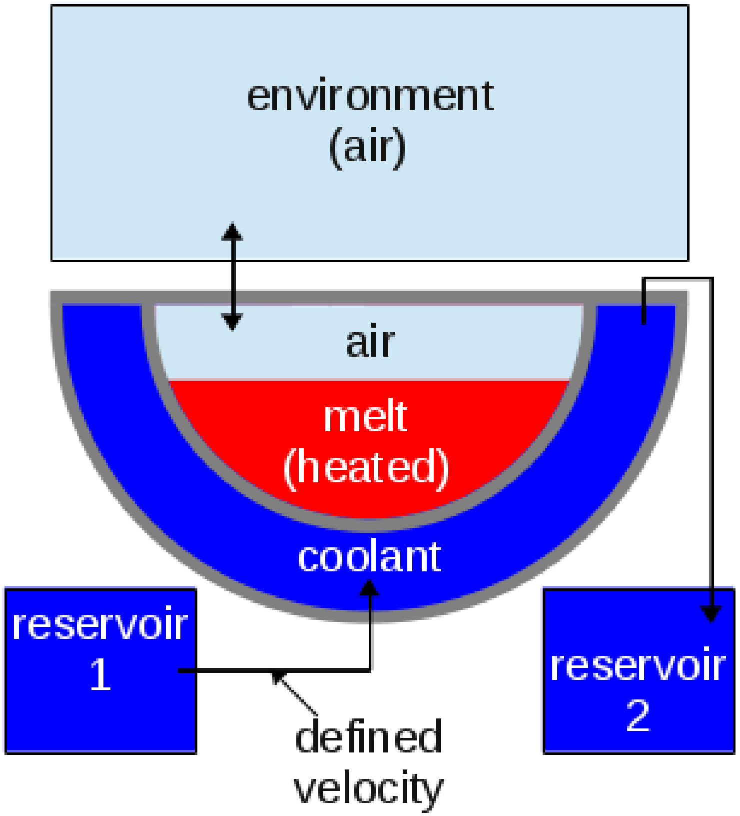


Simulation of the LIVE-facility

- Simulation setup
  - Experiment LIVE-L1
  - 120 l of salt melt in the facility
  - Volumetric heating 10 kW and 7 kW
  - Constant coolant support



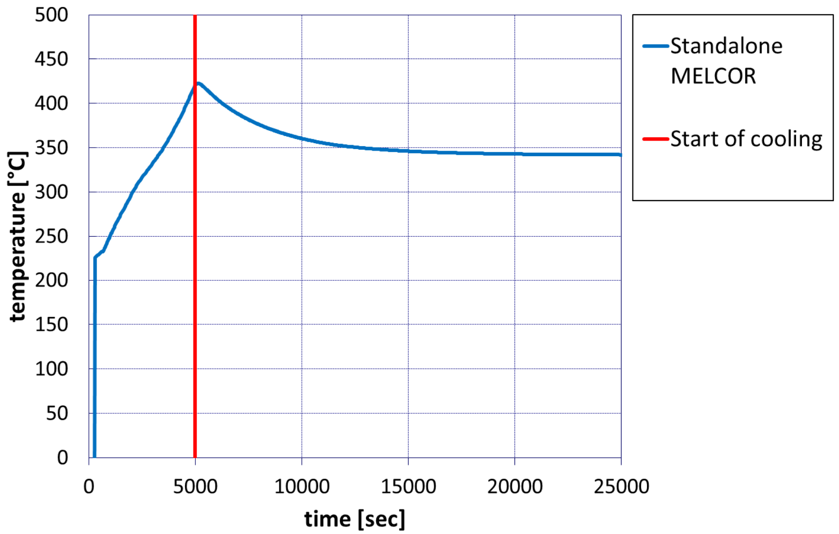
Calculation domain in OpenFOAM



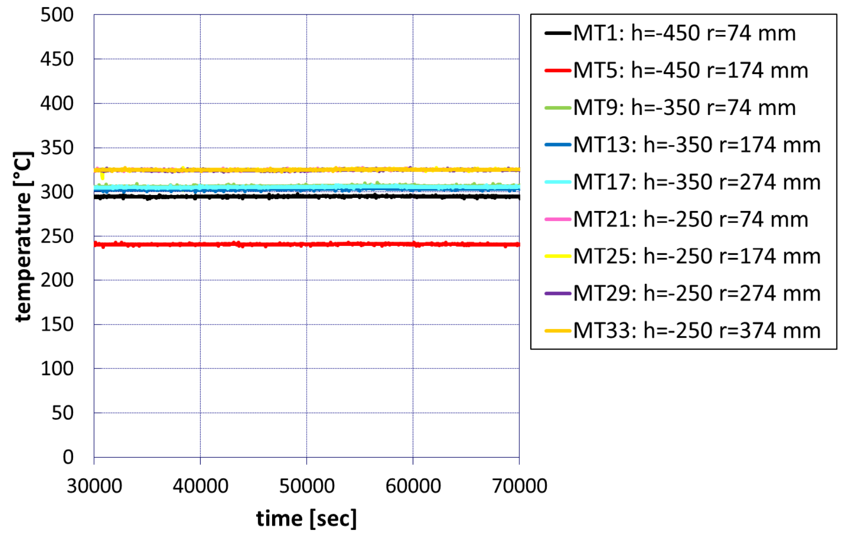
MELCOR-input for LIVE

Simulation of the LIVE-facility

- Melt temperatures at steady state with heating power of 10 kW



Melt temperatures calculated by MELCOR



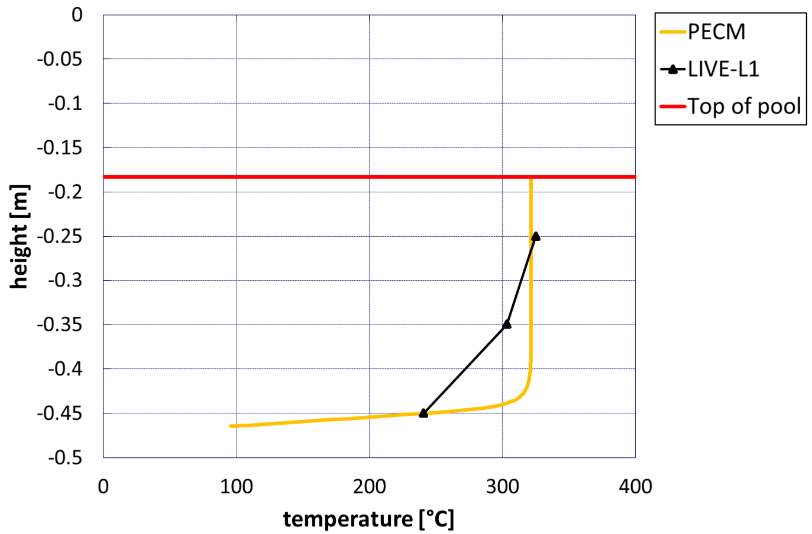
Melt temperatures in LIVE-L1

Fluhrer, B. et al., "The LIVE-L1 and LIVE-L3 Experiments on Melt Behaviour in RPV Lower Head", 2008, KIT Scientific Report 7419

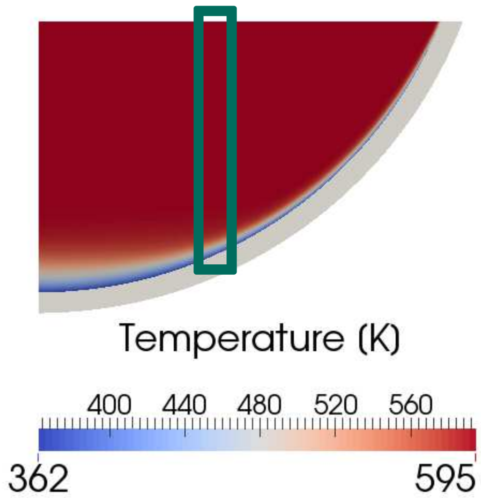
→ Temperature calculated by MELCOR higher than in LIVE

Simulation of the LIVE-facility

- Melt temperatures at steady state with heating power of 10 kW



Melt temperatures in the PECM and LIVE-L1 (vertical line at r = 0.175 m)



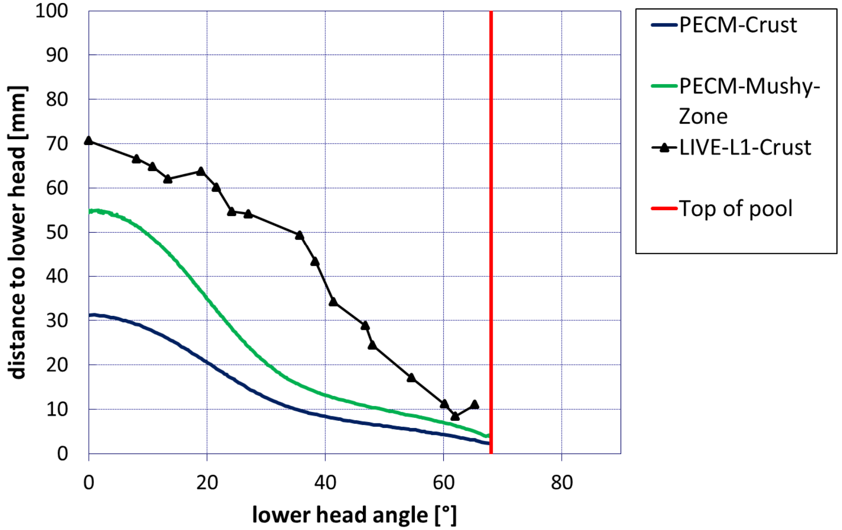
Temperature distribution in OpenFOAM with the PECM

→ Maximum temperature in LIVE-L1 matches max. temperature in the PECM

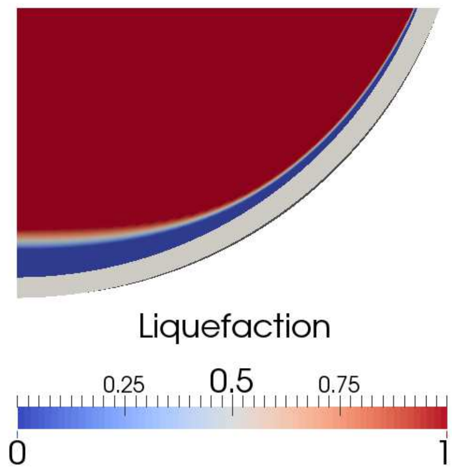
→ Resolution of local temperature distribution possible

Simulation of the LIVE-facility

- Crust development at steady state with heating power of 7 kW



Solidification process in the PECM compared to LIVE-L1



Liquefaction distribution in OpenFOAM with the PECM

→ Detection of a crust is now possible with the PECM

→ Crust calculated by the PECM is thinner than in the experiment

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Summary

- Development of the program DINAMO
- Coupling of the PECM with MELCOR
  - Cooperation with the KTH
  - Implementation of the PECM into OpenFOAM
  - Coupling between MELCOR and the PECM in OpenFOAM via DINAMO
- Simulations of the LIVE-facility with MELCOR and the coupled MELCOR-PECM-system
- DINAMO can be used to expand the possibilities of MELCOR by coupling new models

Karlsruhe Institute of Technology

Thank you for your attention

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WASA-BOSS

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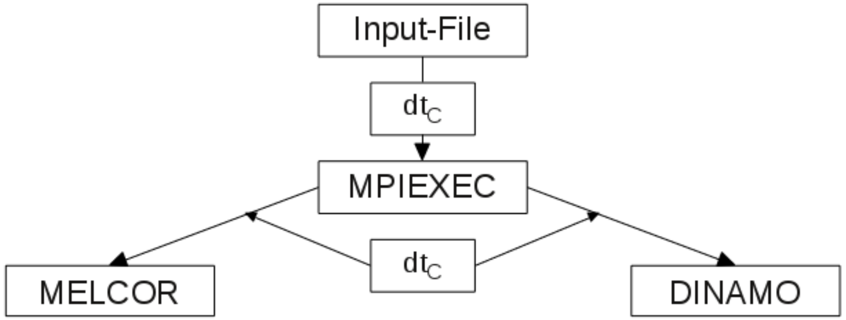
Coupling Interface

- Synchronization of the coupling interface
  - Traditional approach:



  - New approach: