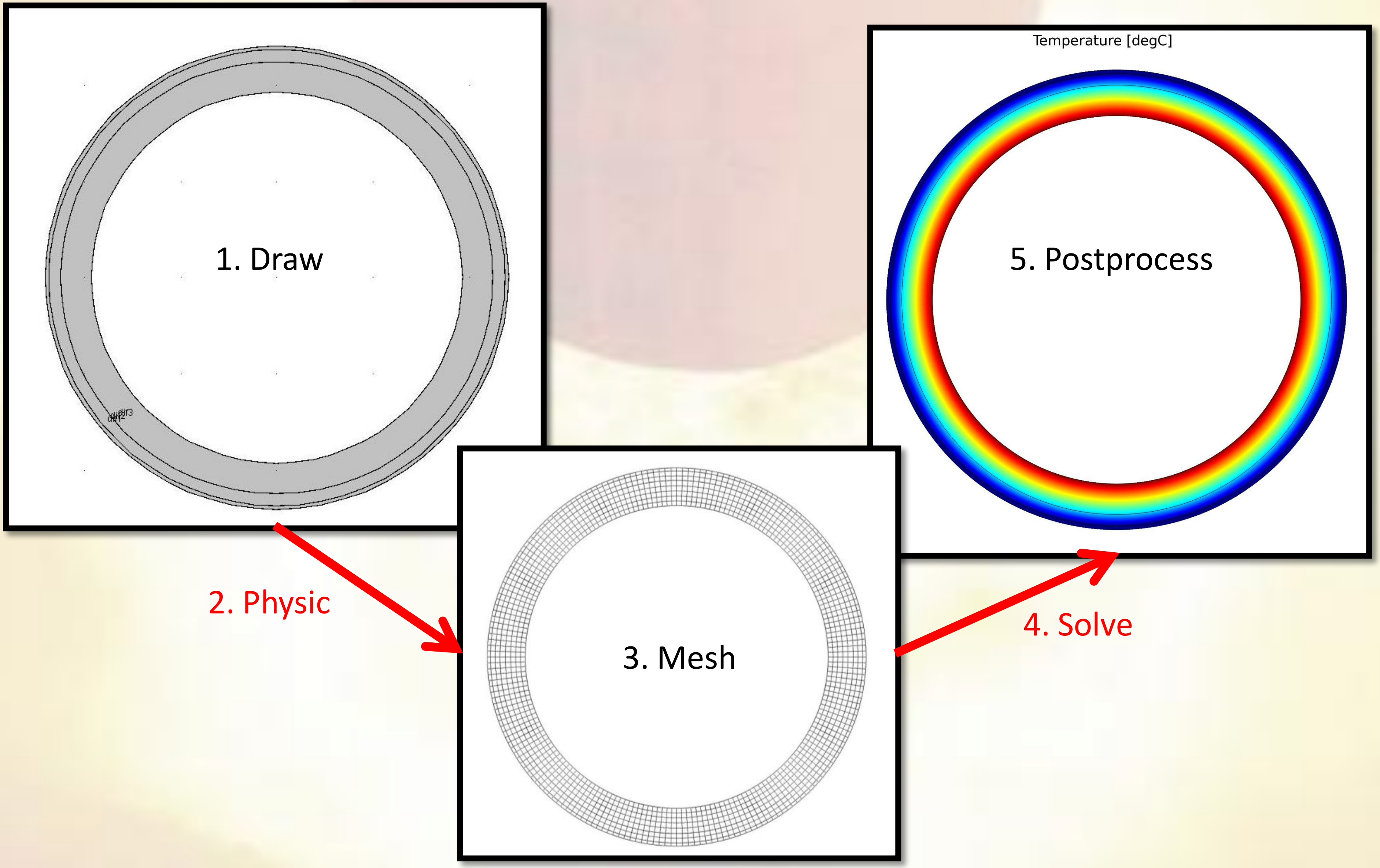
Almatis-TU Delft Seminar on

Numerical Modeling of Rotary Kilns

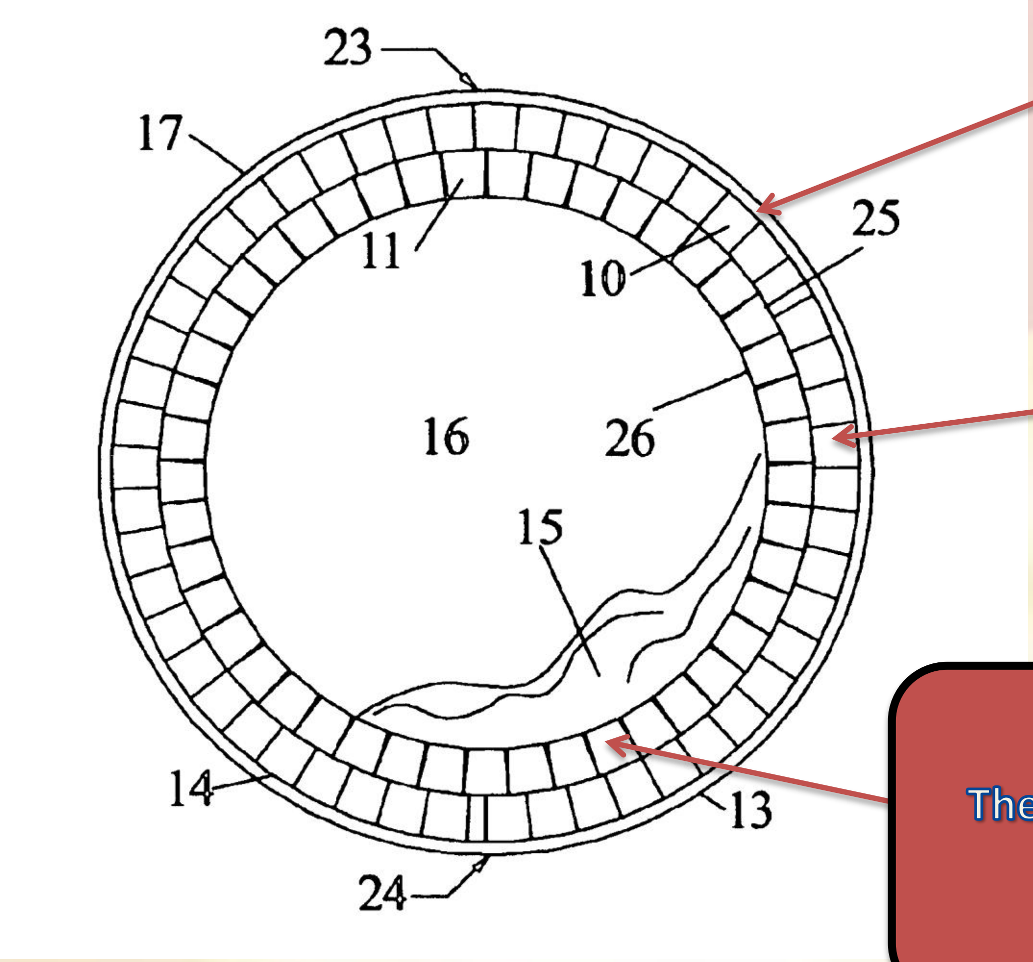
June 9, 2011

Room Vassiliadis, 16th floor, EWI Building, Mekelweg 4, Delft

Organizers: M. Pisaroni (TU Delft), R. Sadi (Almatis) and D. Lahaye (TU Delft)


1. Draw
2. Physic
3. Mesh
4. Solve
Temperature [degC]
5. Postprocess

MODEL 1: HEAT TRANSFER IN THE LINING



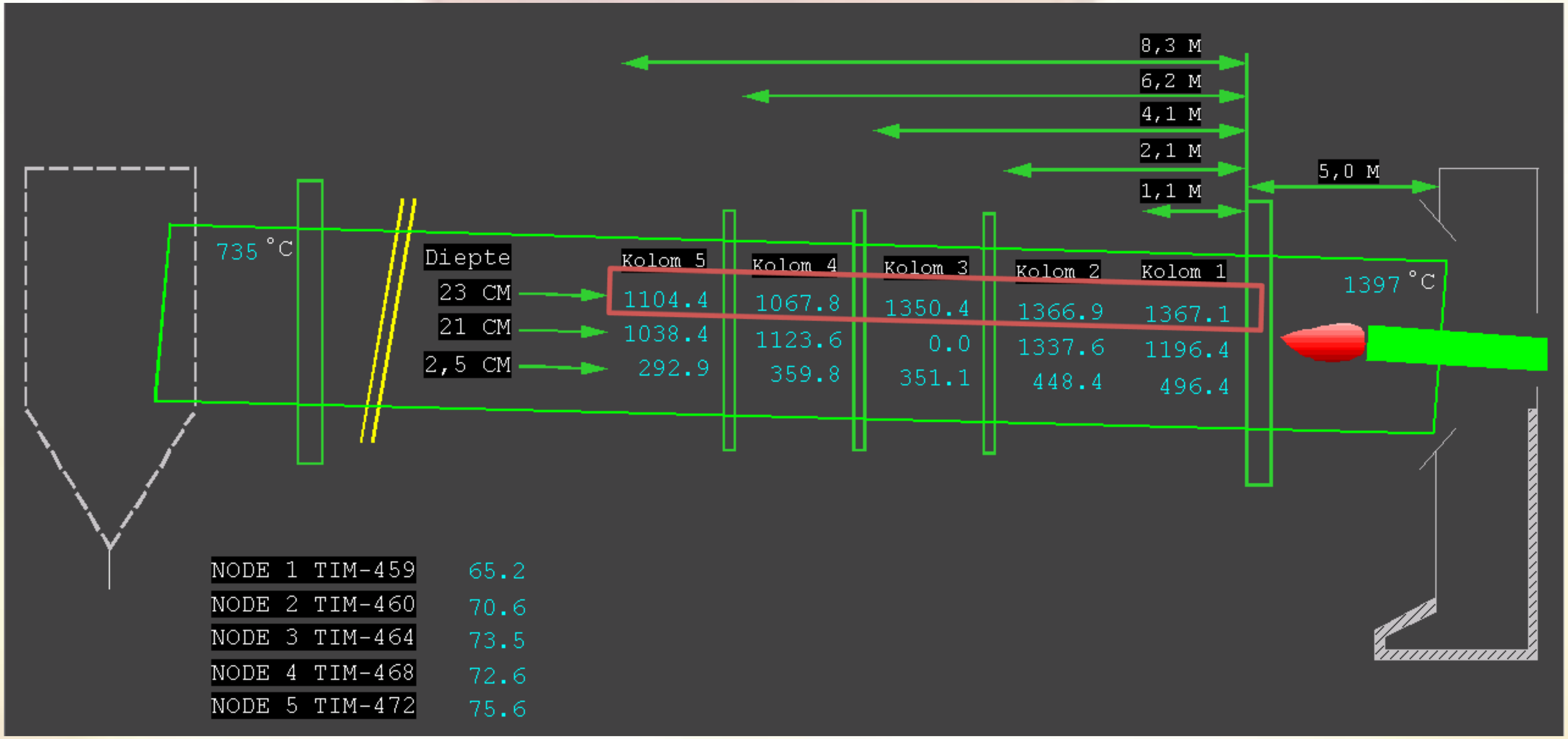
Steel 37
Thermal conductivity: 53 W/mK
Density: 7850 kg/m^3
Heat capacity: 470 J/kgK

A-Brick
Thermal conductivity: 1.38 W/mK
Density: 2150 kg/m^3
Heat capacity: 796 J/kgK

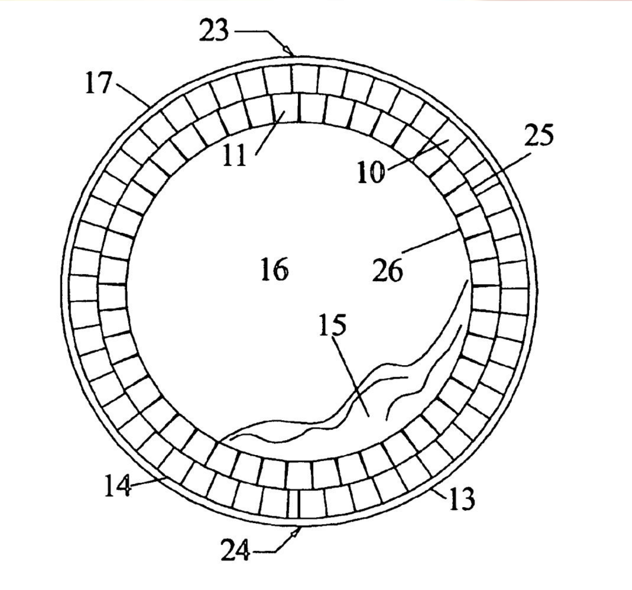
AK42(AK86)-Brick
Thermal conductivity: 1.45 (2.1) W/mK
Density: 2250 (2800) kg/m^3
Heat capacity: 800 (860) J/kgK

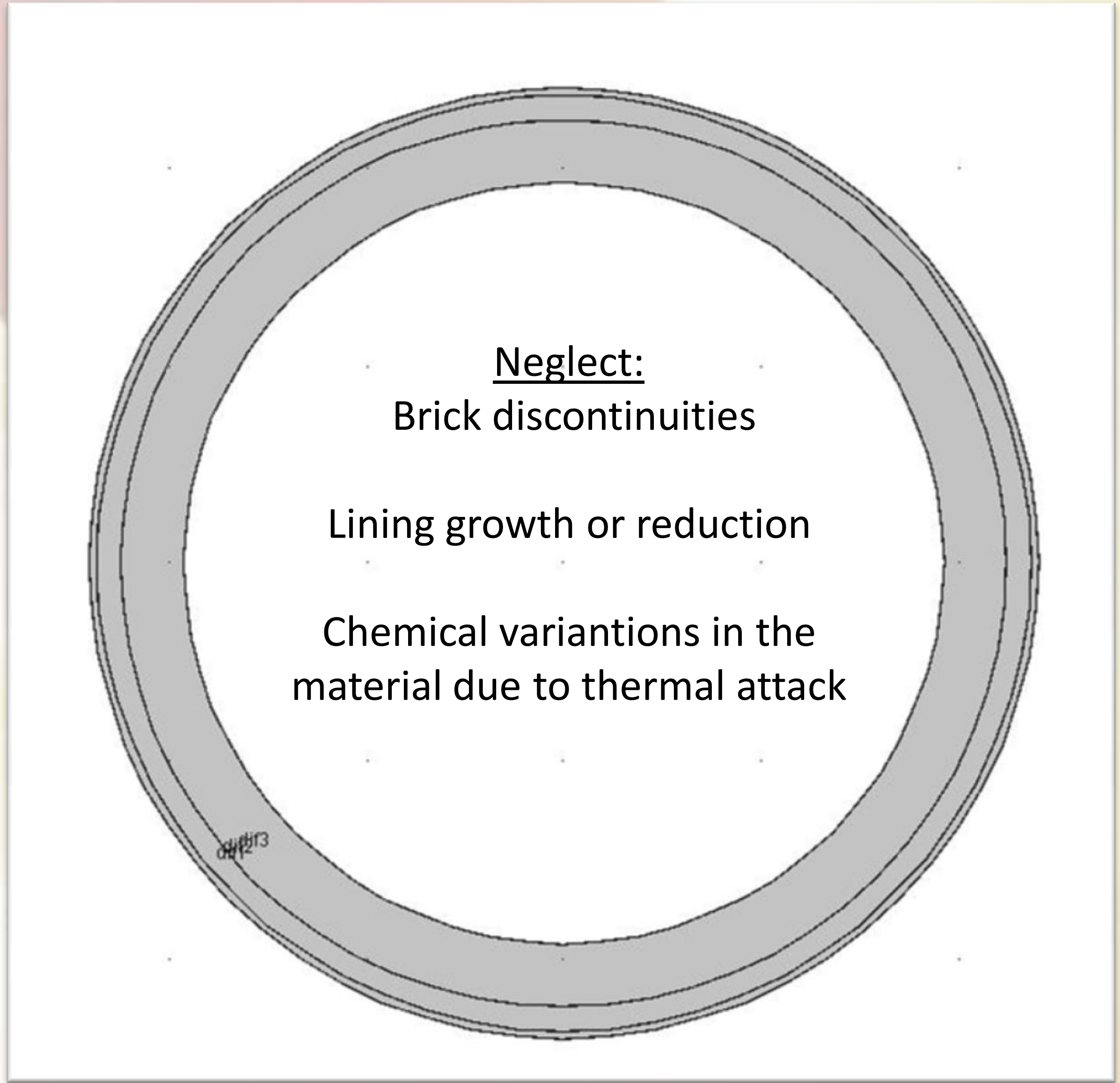
- INPUT1: thermocouples data of the interior zone
- INPUT2: dimensions and proprieties of the layers
- INPUT3: outside ambient conditions.

[PARAMETERS]



Geometry and assumptions





Neglect:

Brick discontinuities

Lining growth or reduction

Chemical variantions in the material due to thermal attack

Physical model

- Heat transfer in solids

$$\rho C_p \frac{\partial T}{\partial t} - \nabla \cdot (k \nabla T) = Q$$

- Boundary conditions

$$T = T_0$$

Prescribed temperature in the inside layer

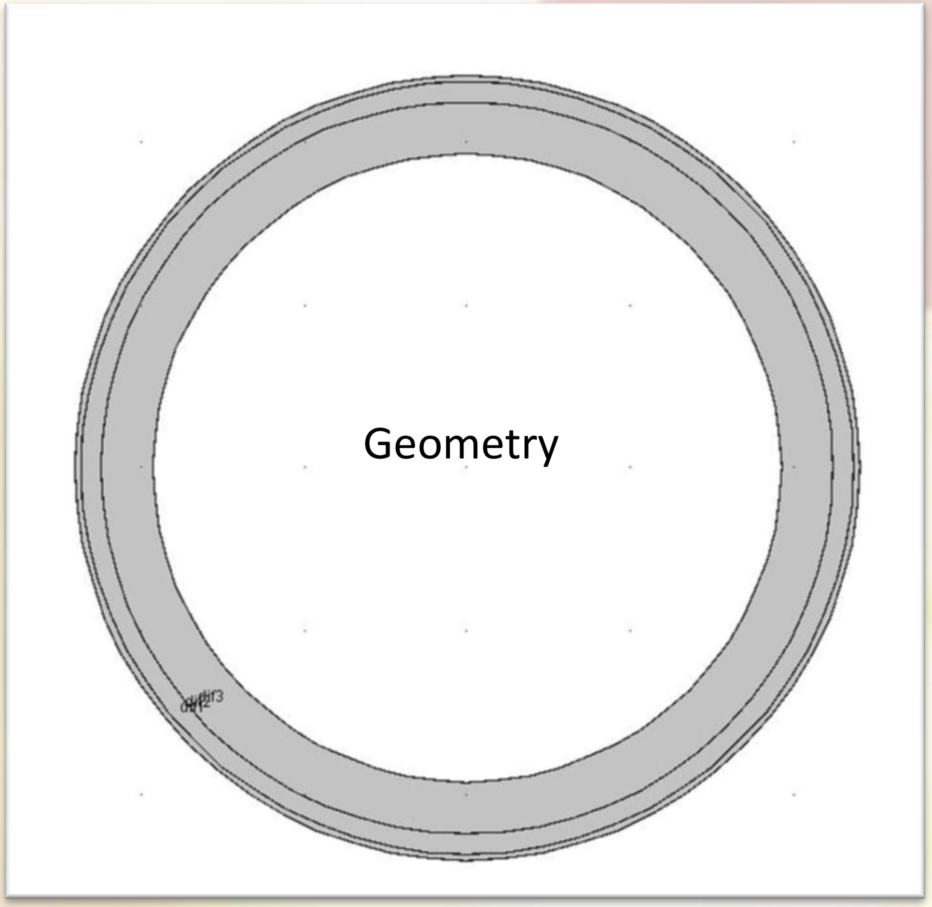
$$q = \varepsilon\sigma(T_{\mathrm{amb}}^4 - T^4)$$

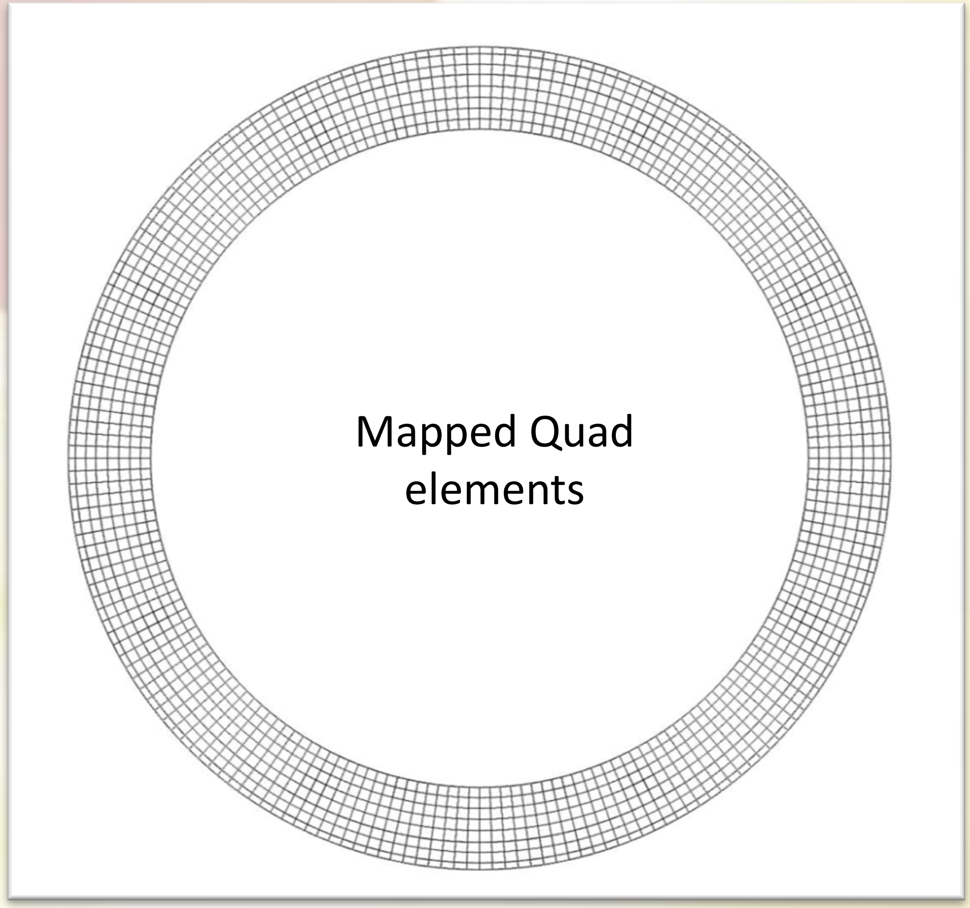
Surface to ambient radiation

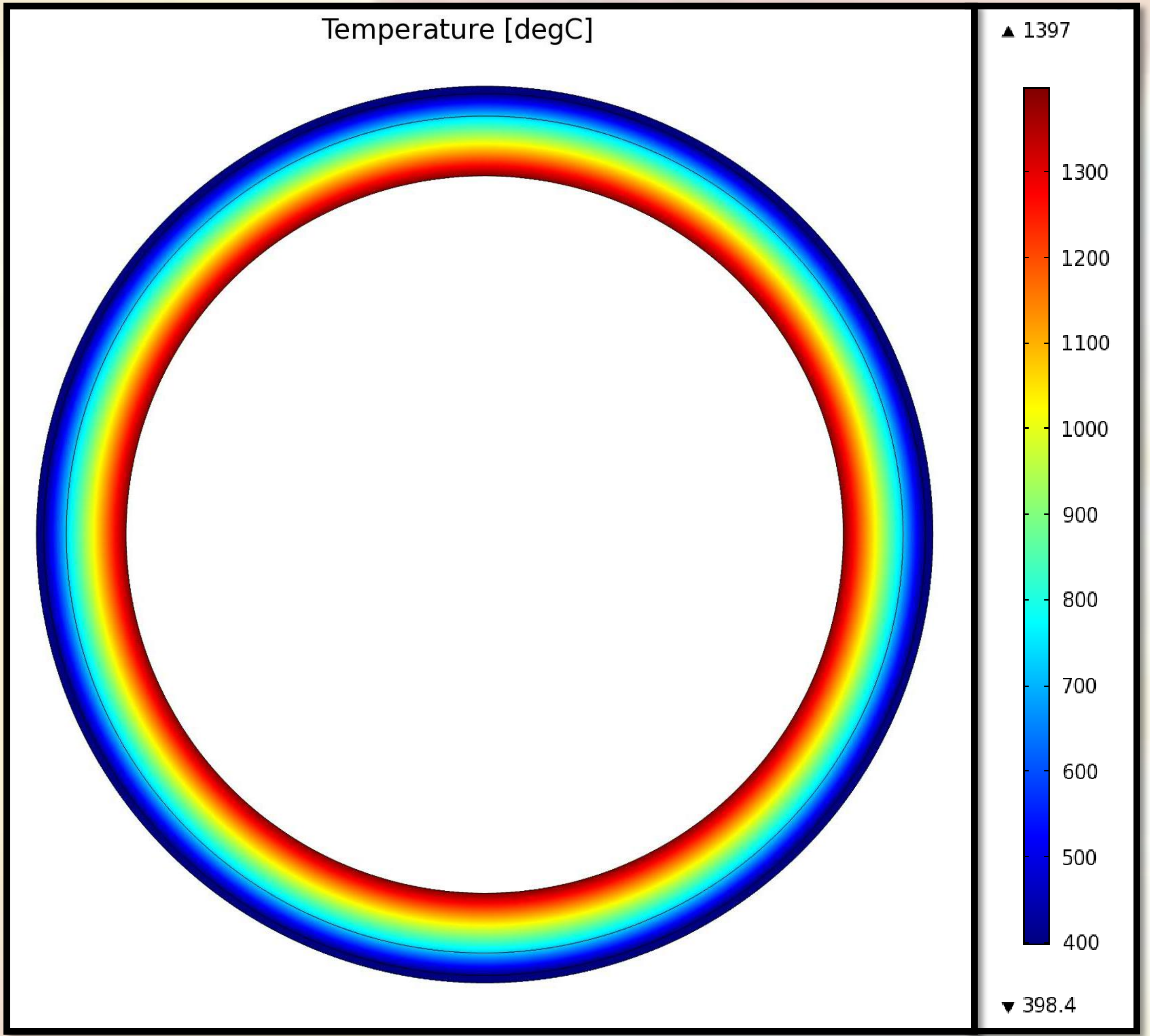
$$h(T_{\mathrm{ext}} - T)$$

Convective cooling with the air (forced)

Discretization and mesh refinement







Temperature profile at regime (24 hours).
In zone K1

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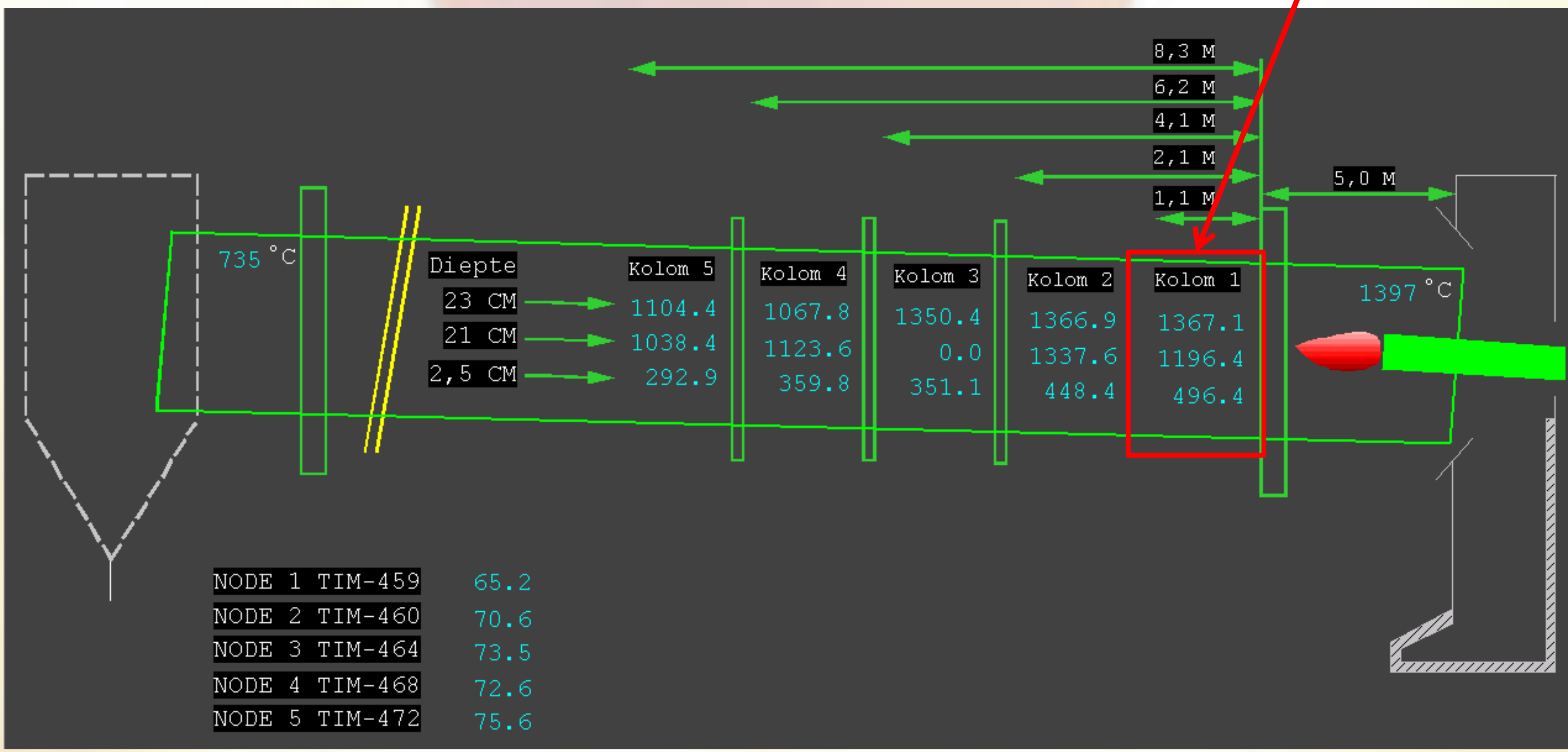
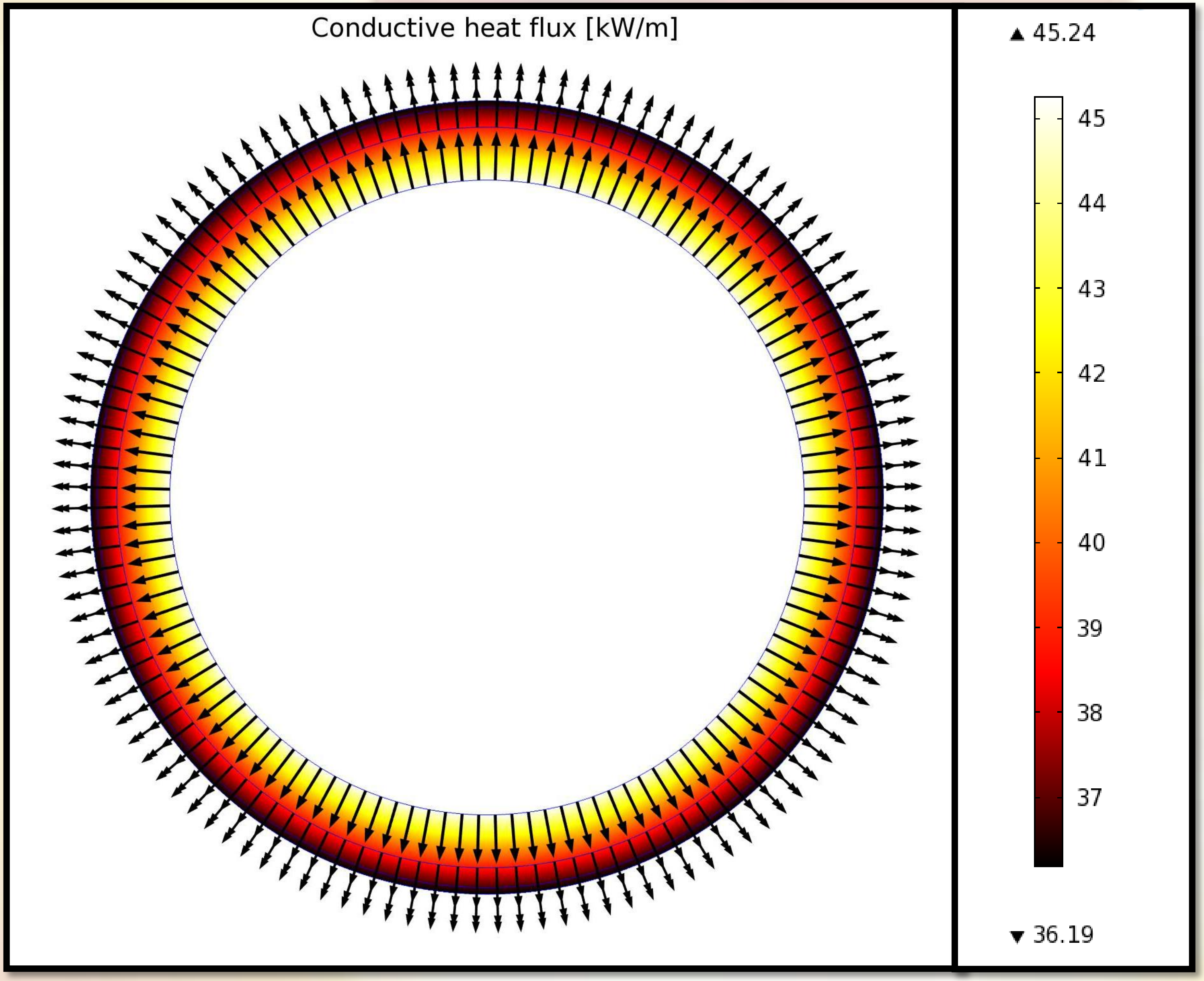
Temperature profile at regime (24 hours).
In zone K1





Conductive heat flux magnitude at regime (24 h)

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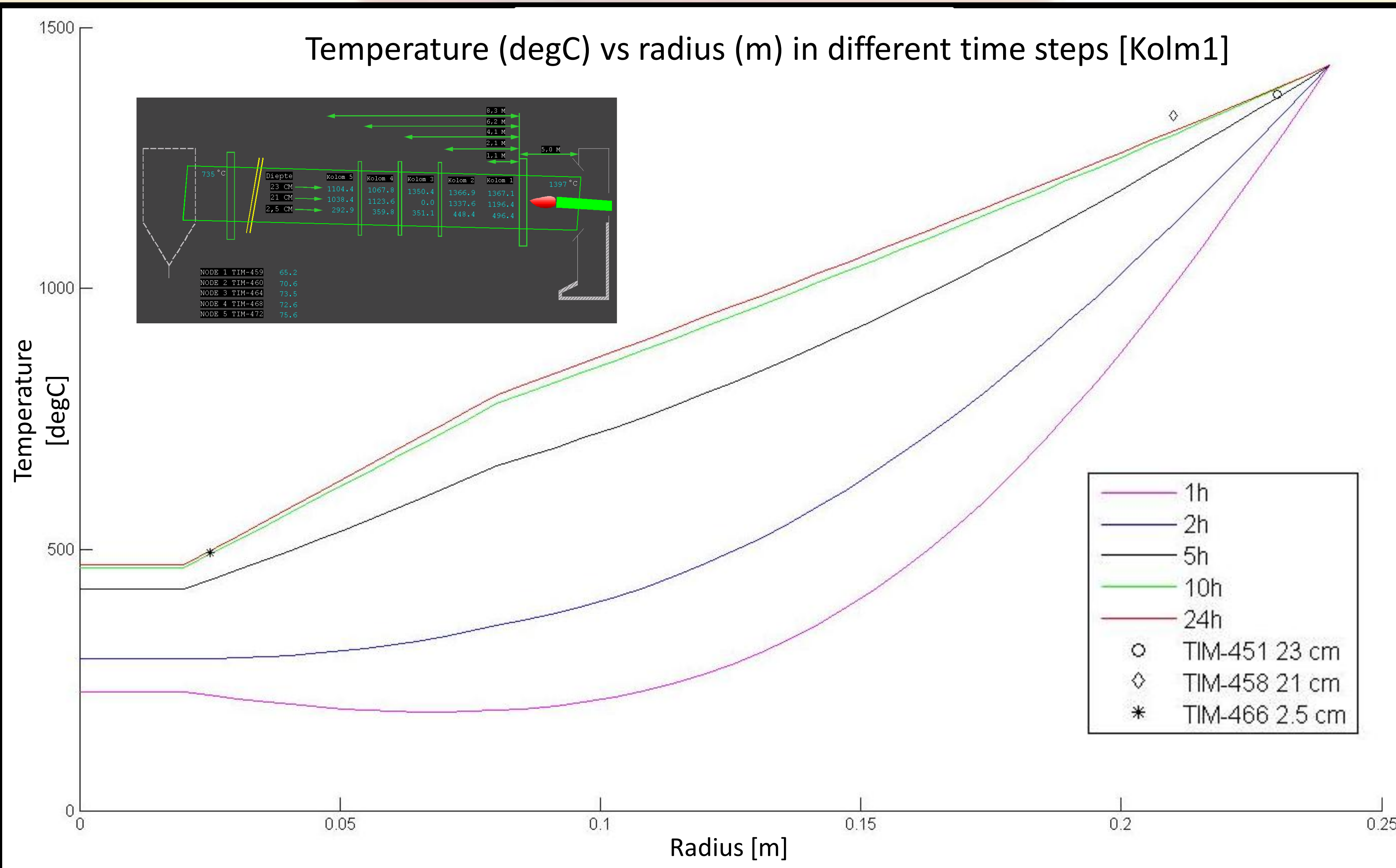

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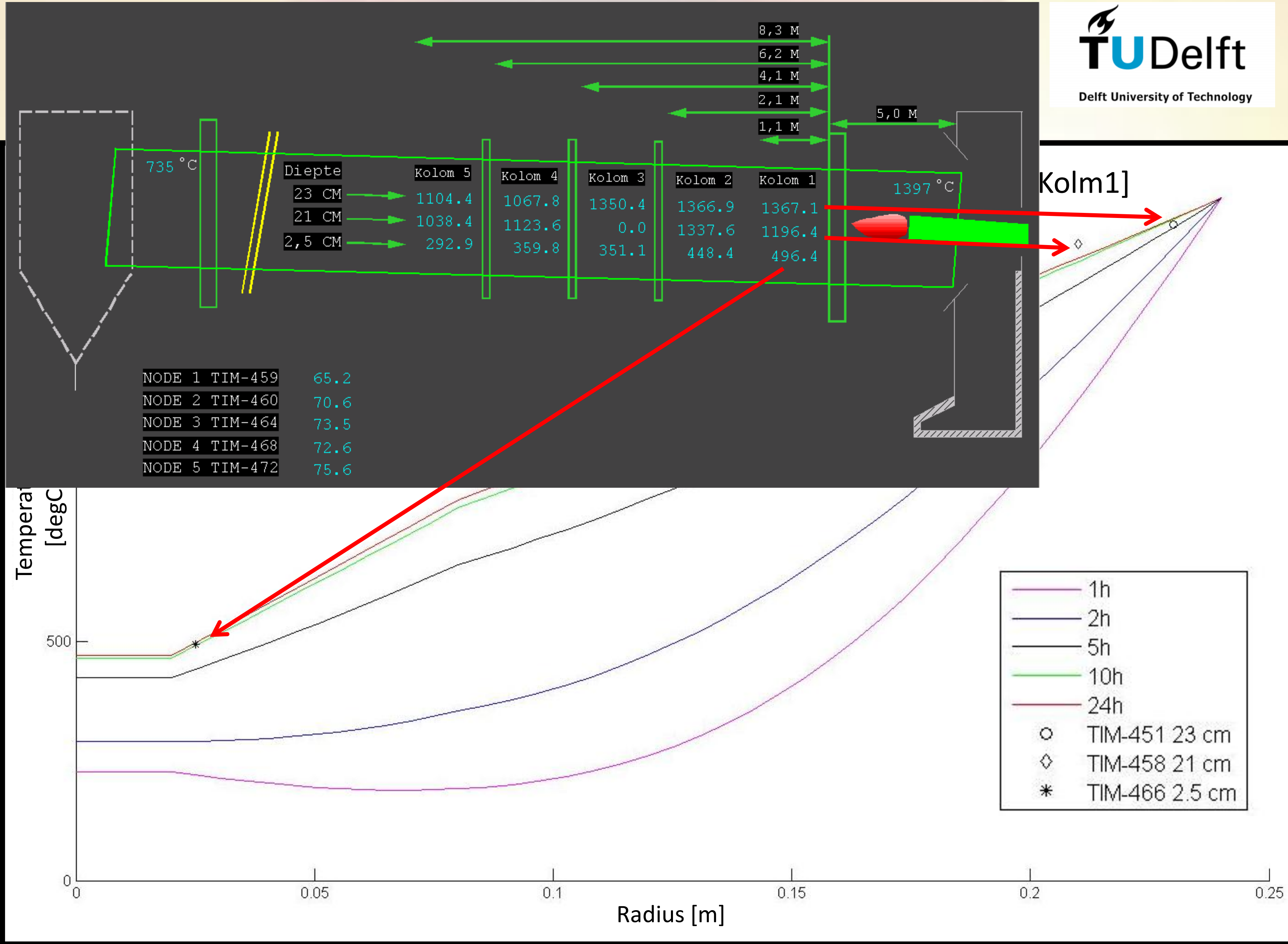


STEP1A: *Heat transfer in the lining*

- ➢ INPUT1: thermocouples data of the interior zone
- ➢ INPUT2: dimensions and proprieties of the layers
- ➢ INPUT3: outside ambient conditions.

- ✓OUTPUT1: temperature profile
- ✓OUTPUT2: time dependent simulation
- ✓OUTPUT3: conductive heat transfer profile

TEST DIFFERENT LINING MATERIALS AND THICKNESS

Time: 30 min of calculation

Memory: <100 Mb

MODEL 2: 1D COMBUSTION

- 1D simulation of a non-premixed cunterflow flame with CANTERA
    - Preliminar and fast test of different fuels
    - NOx and temperature prediction.
    - Mechanisms test
    - Air supply

Cantera is an open-source chemical kinetics software used for solving chemically reacting flows.

It is used as a third party library in external reacting flow simulation codes, to evaluate properties and chemical source terms that appear in the application's governing equations. Developed by Prof. Dave Goodwin of California Institute of Technology.

It is written in C++ and can be used from C++, Python, Matlab and Fortran

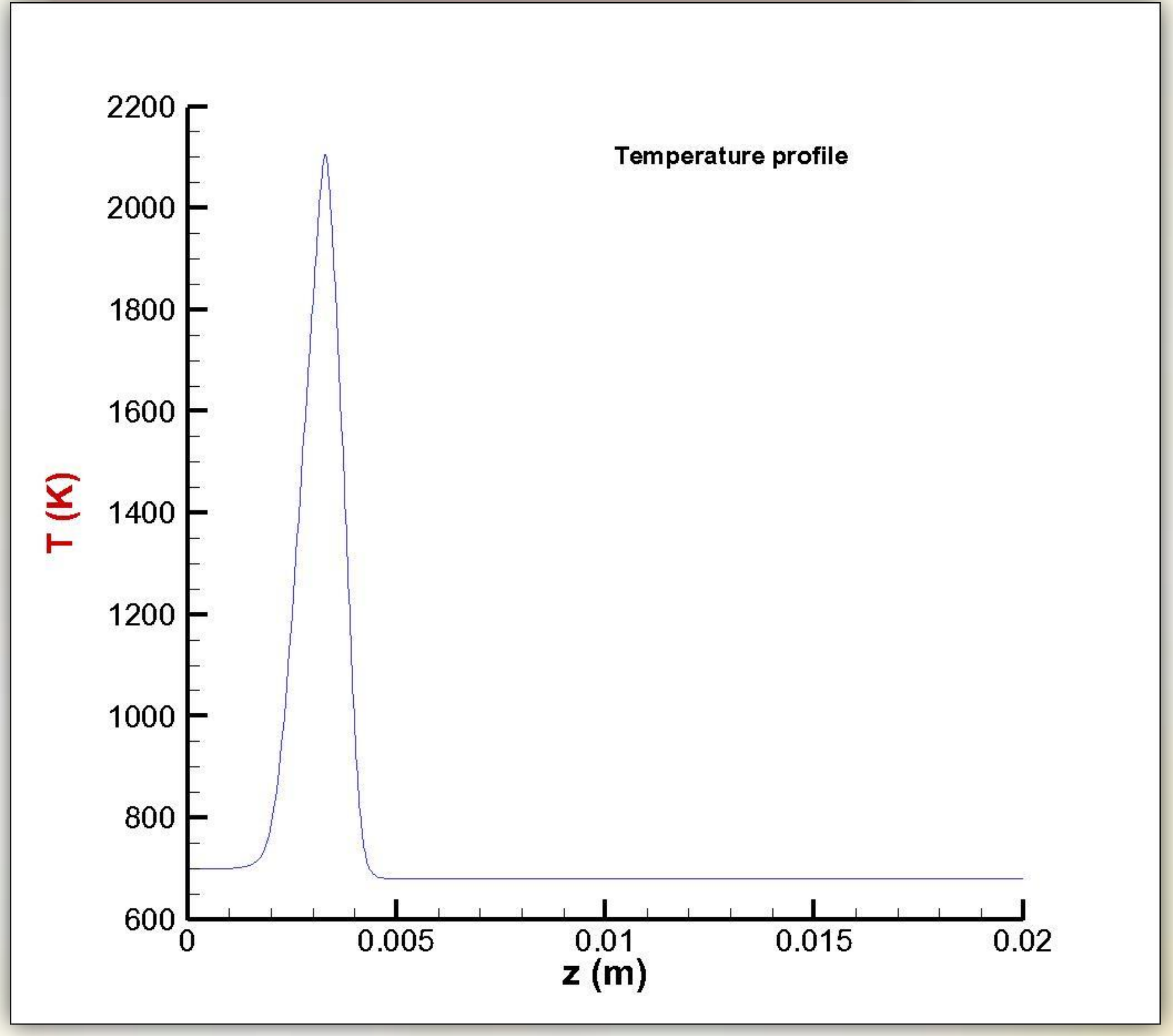
MODEL

- 1D simulation of a non-premixed cunterflow jet to create a database necessary to test the model in a CFD solver (3D simulation)

- INPUT1: Chemical/transport/thermodynamic library.
- INPUT2: Combution regimes

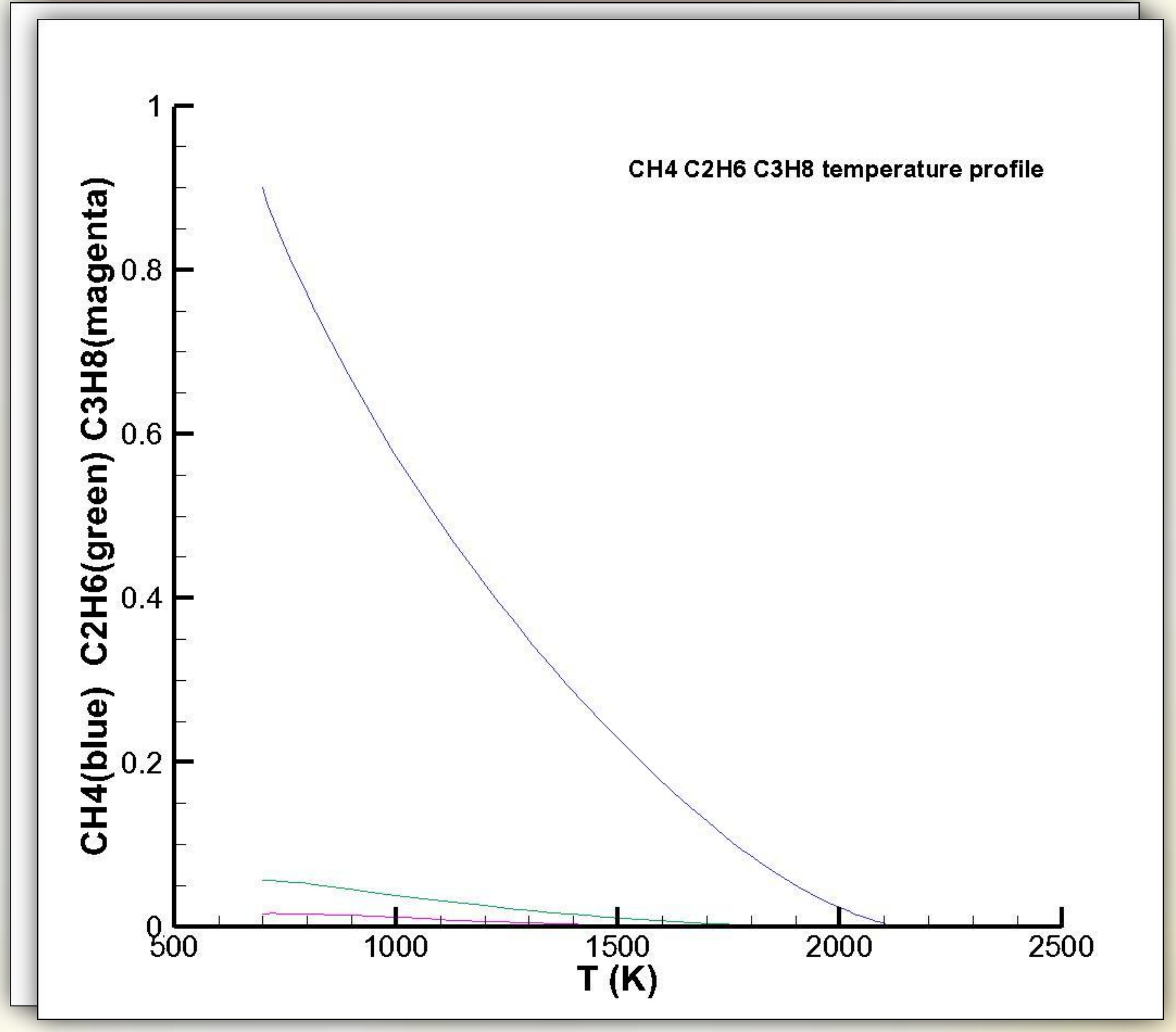
- Creation of a python script that is linked to cantera subrutines.
  - comp_o = 'O2:0.21, N2:0.78, AR:0.01';
  - comp_f = 'CH4:0.9, C2H6:0.056, C3H8:0.016, CO2:0.014, N2:0.014';
  - mdot_o = 3.93 # kg/m^2/s
  - mdot_f = 0.44 # kg/m^2/s

Results



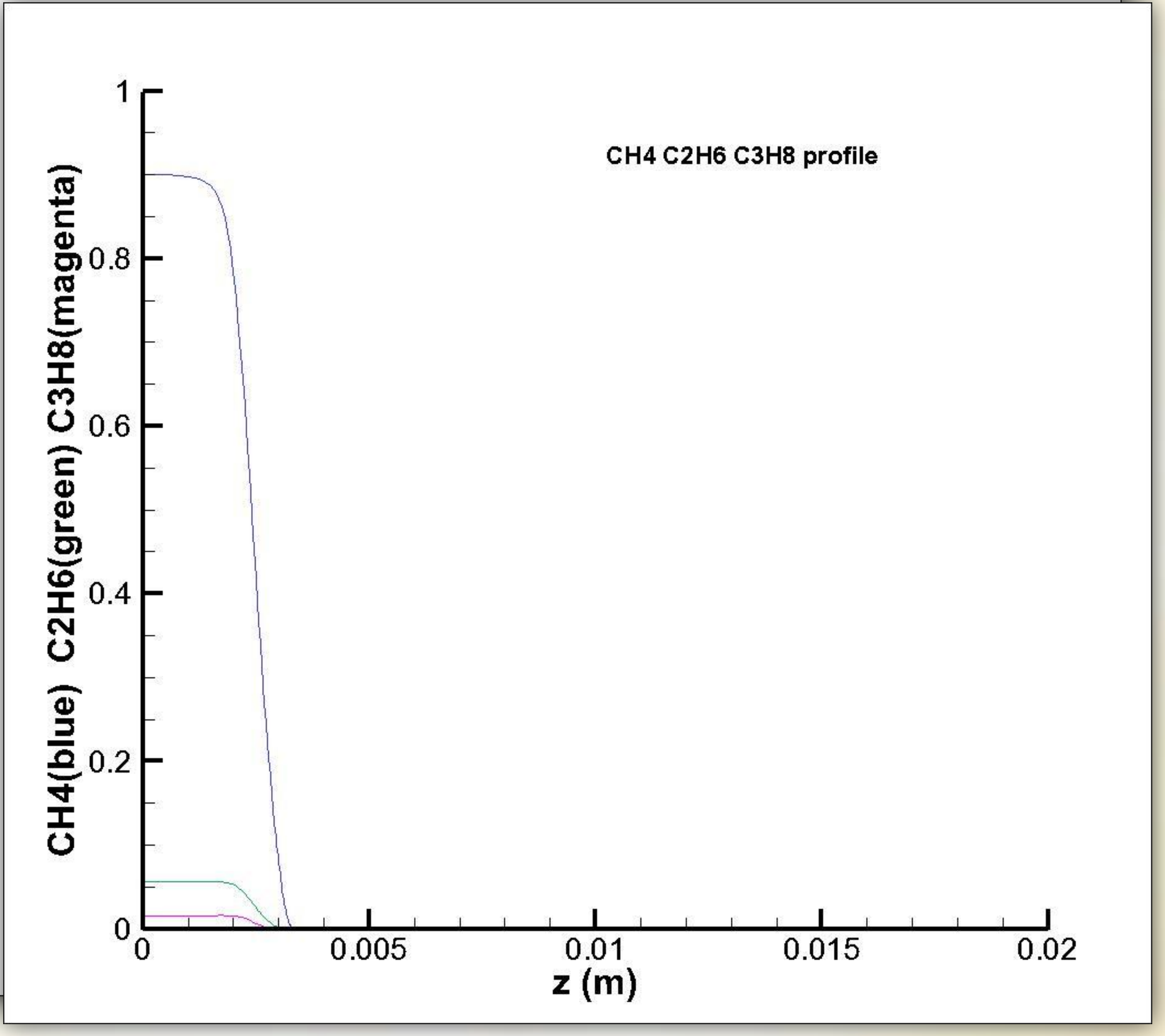
Temperature profile
T (K)
z (m)
2200
2000
1800
1600
1400
1200
1000
800
600
0
0.005
0.01
0.015
0.02

Results



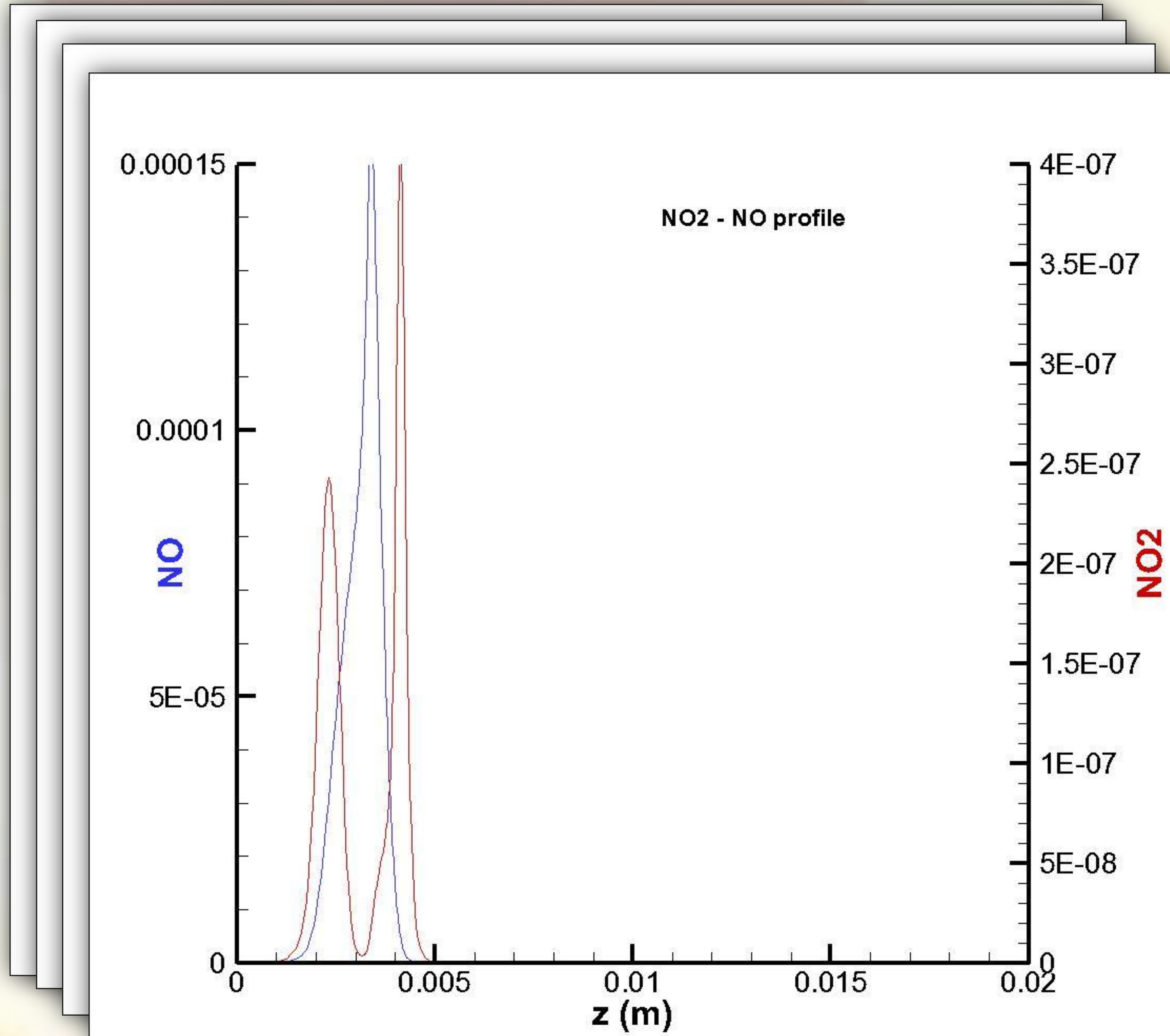
CH4 C2H6 C3H8 temperature profile
CH4(blue) C2H6(green) C3H8(magenta)
1
0.8
0.6
0.4
0.2
0
500
1000
1500
2000
2500
T (K)

Results

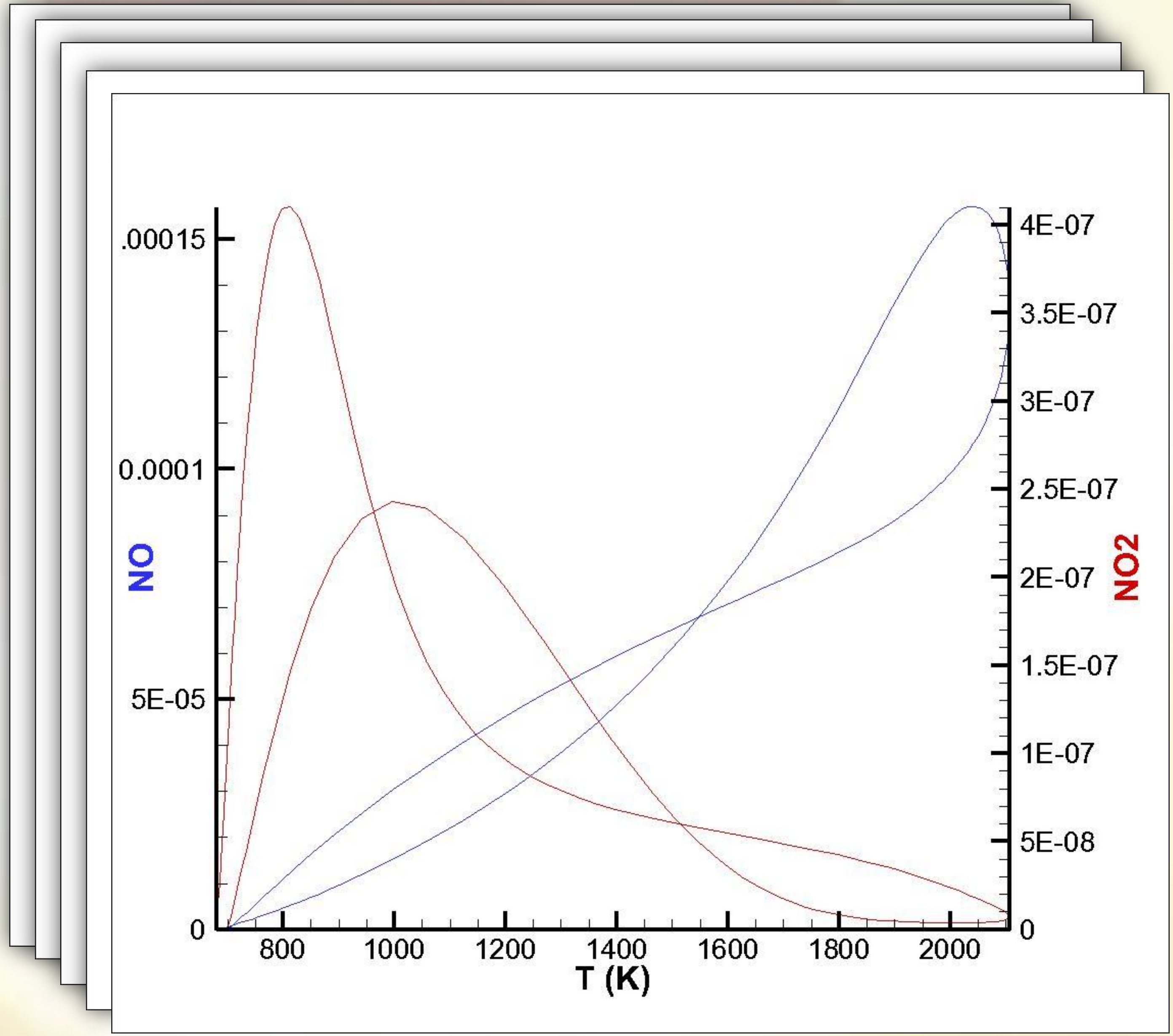


CH4 C2H6 C3H8 profile
CH4(blue) C2H6(green) C3H8(magenta)
z (m)
1
0.8
0.6
0.4
0.2
0
0
0.005
0.01
0.015
0.02

Results


NO2 - NO profile
0.00015
0.0001
5E-05
0
NO
4E-07
3.5E-07
3E-07
2.5E-07
2E-07
1.5E-07
1E-07
5E-08
0
NO2
0
0.005
0.01
0.015
0.02
z (m)

Results



.00015
0.0001
5E-05
0
NO
4E-07
3.5E-07
3E-07
2.5E-07
2E-07
1.5E-07
1E-07
5E-08
0
NO2
800
1000
1200
1400
1600
1800
2000
T (K)

STEP1B: *1D Combustion*

- INPUT1: Fuel composition
- INPUT2: Fuel/Air ratio
- INPUT3: Fuel and Air inlet temperature

- ✓OUTPUT1: Max Temperature
- ✓OUTPUT2: NOx estimation

TEST DIFFERENT FUEL AND A/F RATIO

Time: 5 min of calculation

Memory: <10 Mb