Towards Understanding of Cooling Process: Application to Spiral

Second thermal team meeting

Overview

- Project goals
- Up-to-date efforts
- Basics of heat transfer
- Overview of cooling technologies
- The current cooling system
- 2D results for spiral and impingement
  - ✓ Results of 2D spiral
  - ✓ Results of 2D impingement system
  - ✓ Comparison between the two systems
- Next steps
- Conclusion

Project objectives

- Reduction in time of cooling

- Improving product quality (dehydration, texture, flavour)

- Freezing the product

- Increasing company profitability

Up-to-date efforts and next steps

- Proposing impingement approach as an alternative

➢ Extending 2D into 3D

- Developing 3D geometry of systems

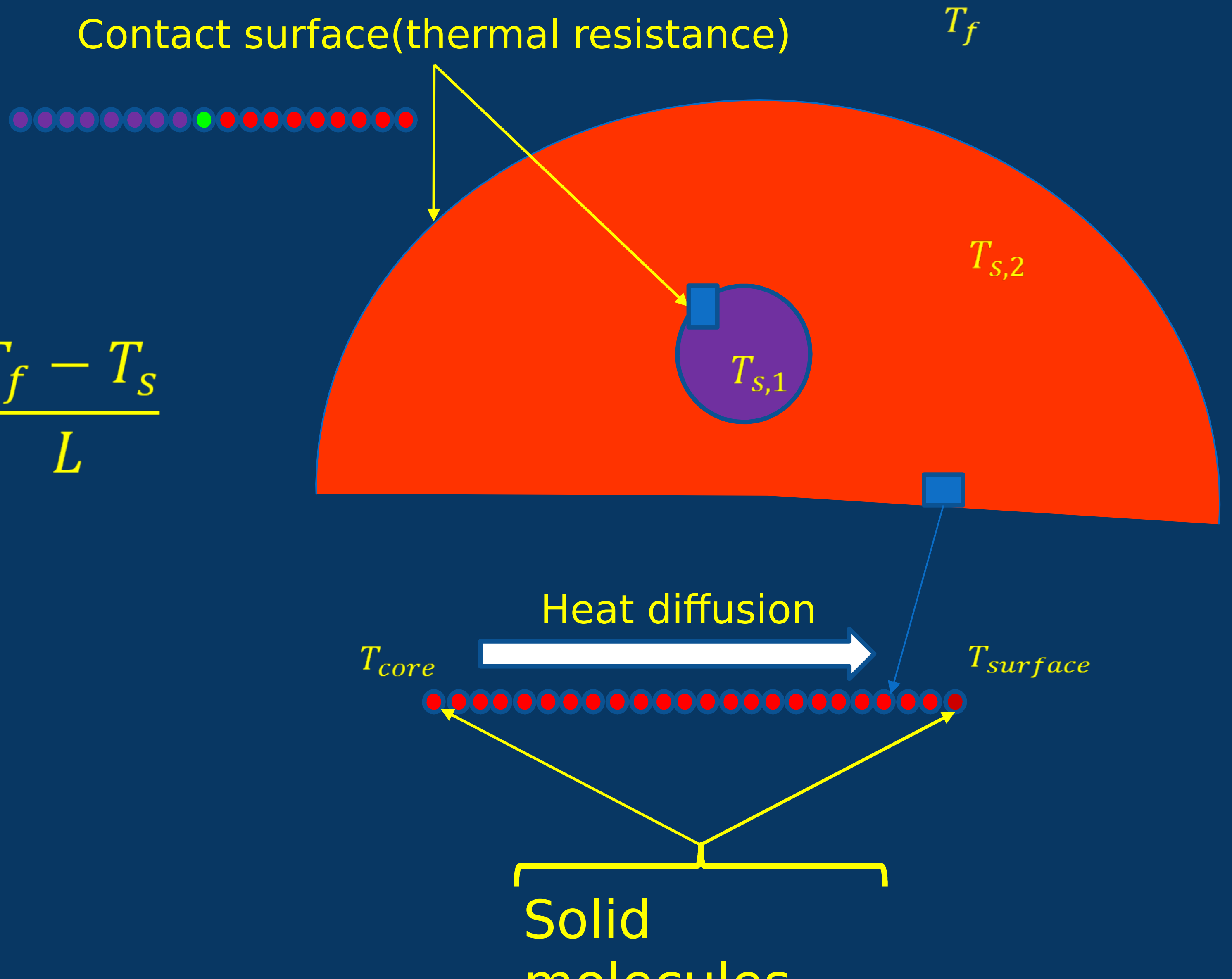
Basics of Heat Transfer

Conduction

$$Q = -k\,A\,\frac{T_f - T_s}{L}$$

Convection

Radiation



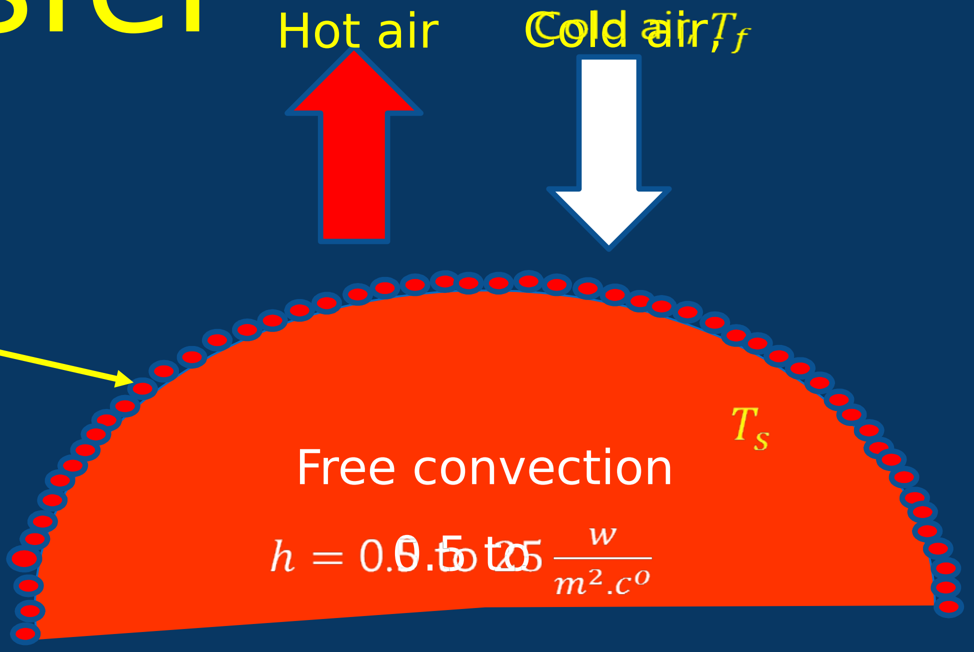
Basics of Heat Transfer

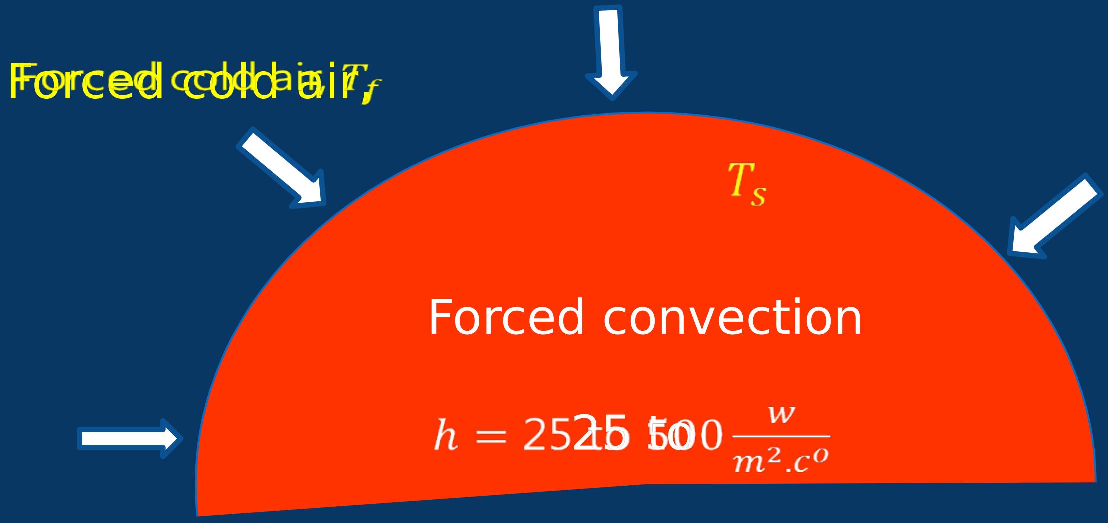
Conduction

Convection

$$Q = h\,A(T_f - T_s)$$

$$\mathrm{Nu} = \frac{Q_{convective}}{Q_{conductive}} = \frac{hL}{k}$$





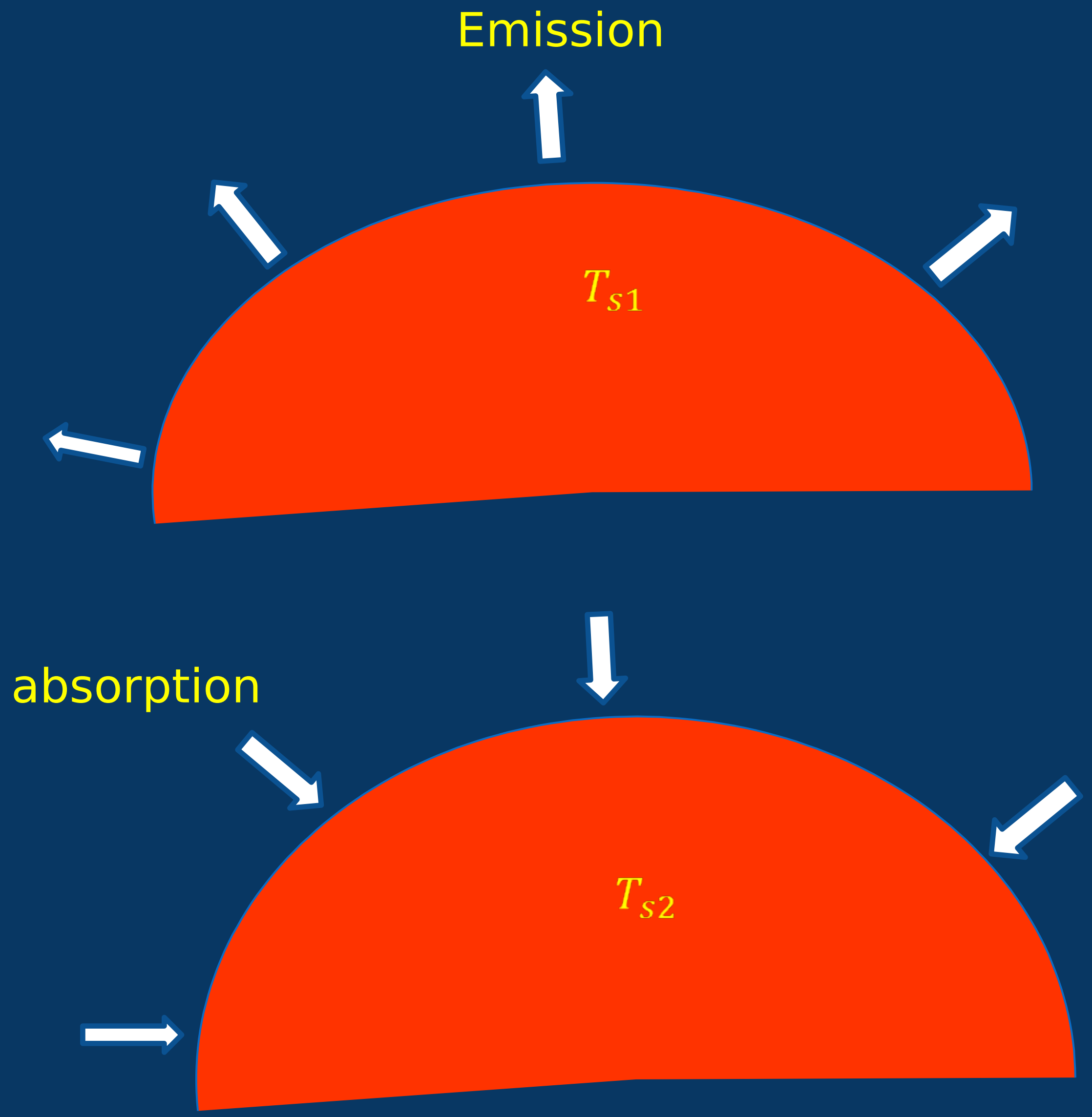
Radiation

Basics of Heat Transfer

Conduction

Convection

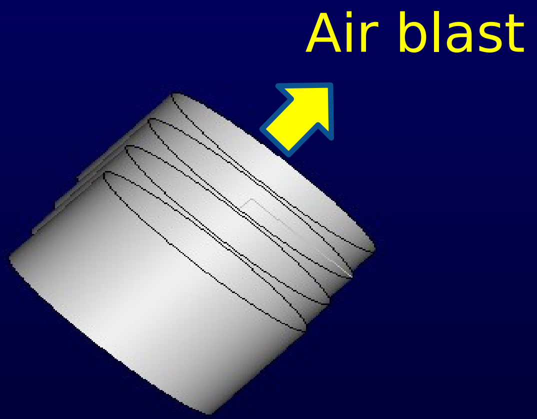
Radiation



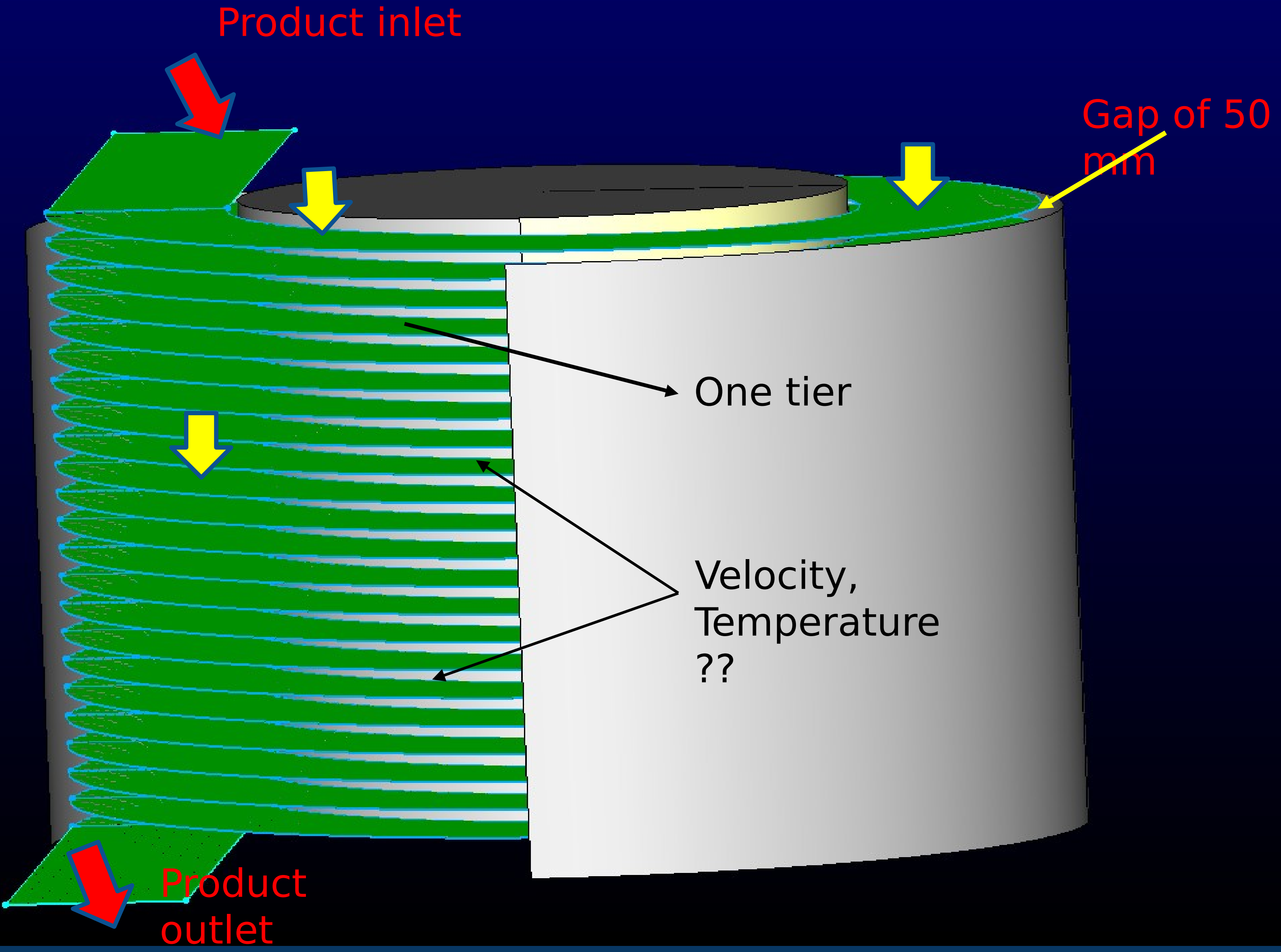
Cooling/Freezing Technologies

Mechanical	Use refrigerant (ammonia or Co2) to extract heat from the air at heat exchanger. The coolant then can be blasted into the spiral
Cryogenic	Uses substances that have high heat transfer coefficient such as liquid of Nitrogen and solid dioxide carbon. The coolant is directly applied to the product
Impingement	It is similar to the mechanical but the coolant is efficiently distributed by directly applying air the product surface.
Immersion	The product can be cooled by immersion into liquid with high heat transfer coefficient.

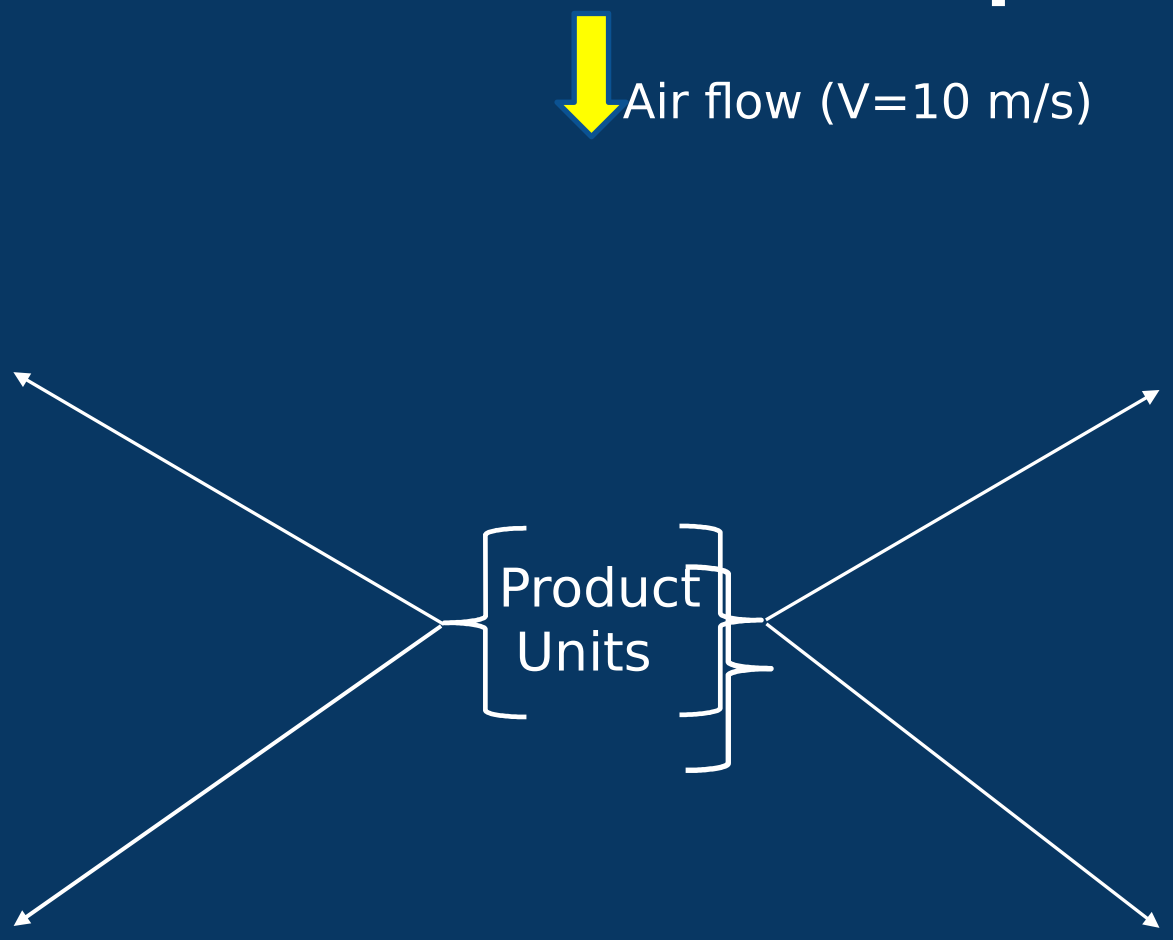
Current Cooling/Freezing System



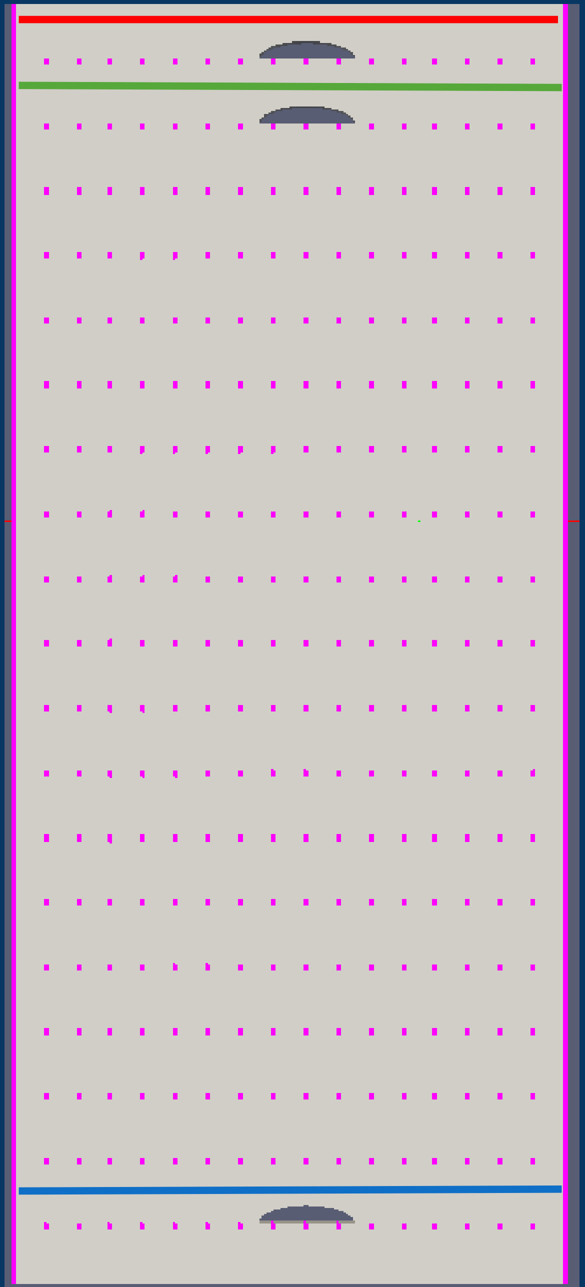
- 4x fans pump in air at $-28^o c$
- each releases ~ $9.18\ m^3/s$
- ~ 2 units per second required < $0.3\ m^3/s$

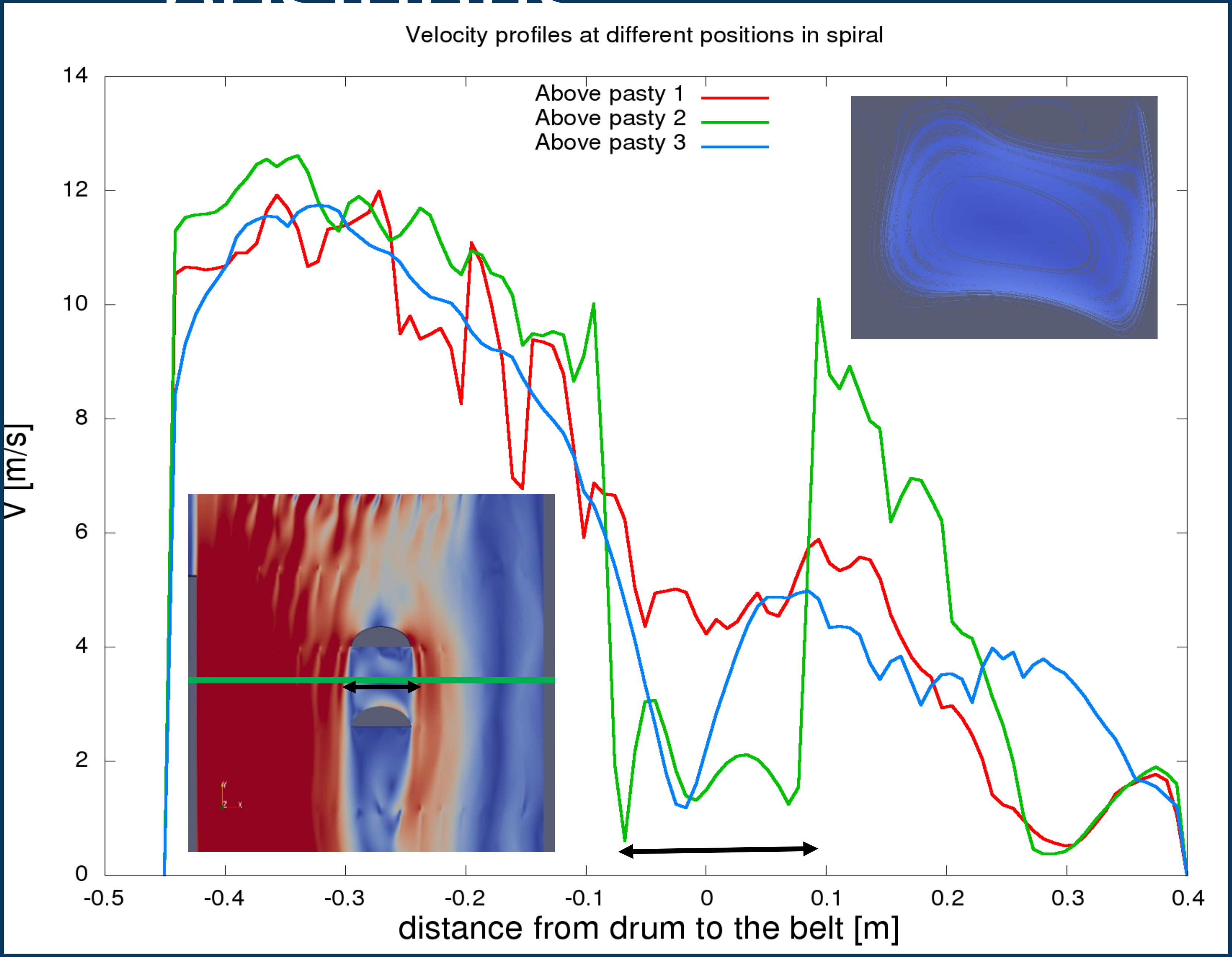


2D model of spiral

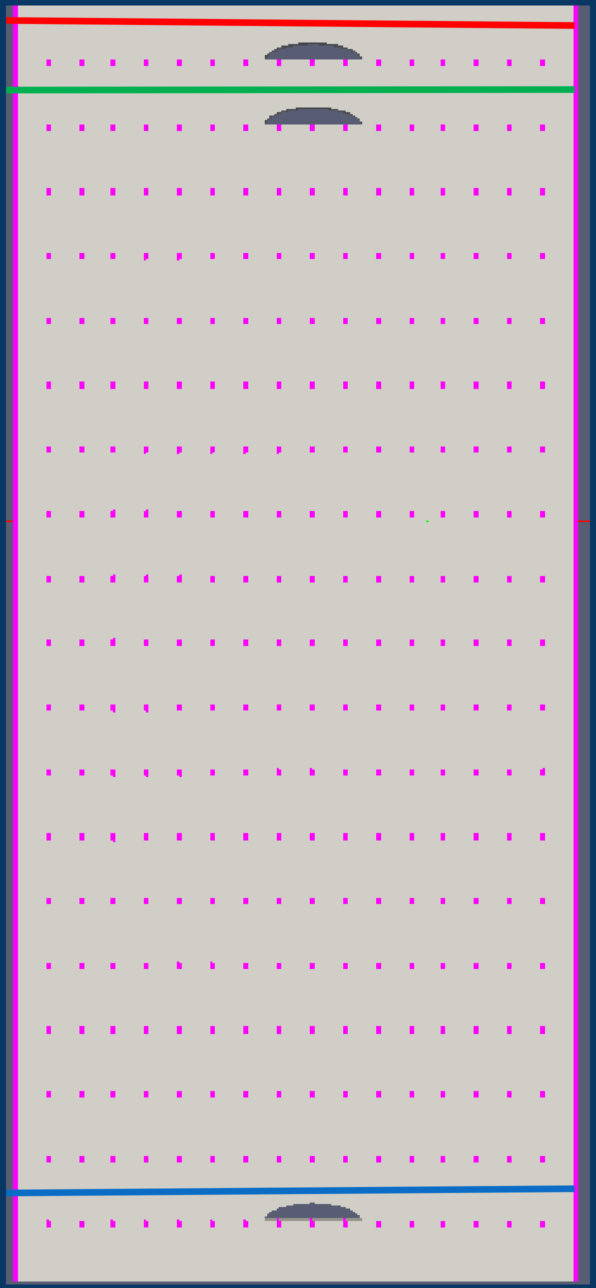


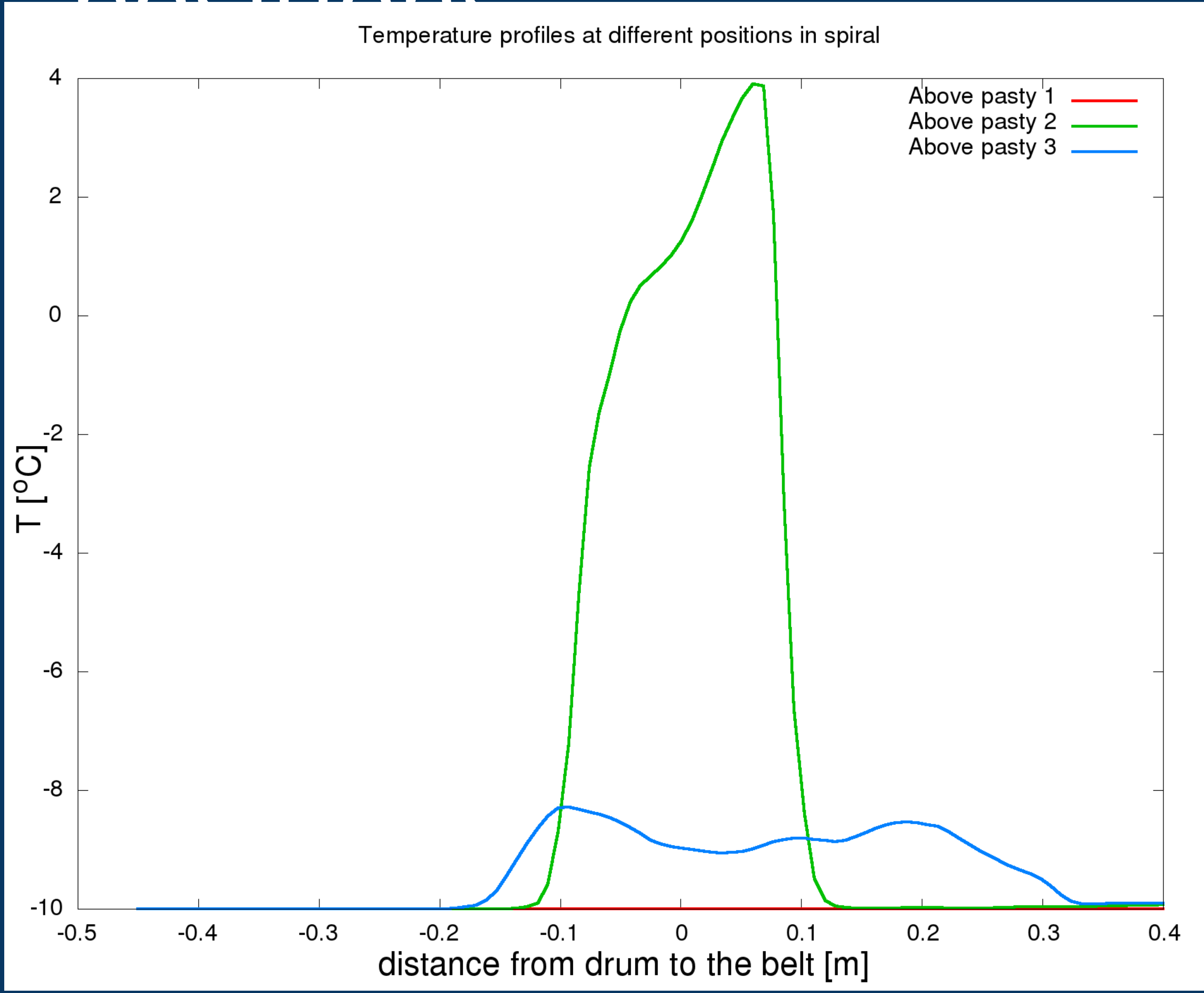
Velocity profiles at different positions



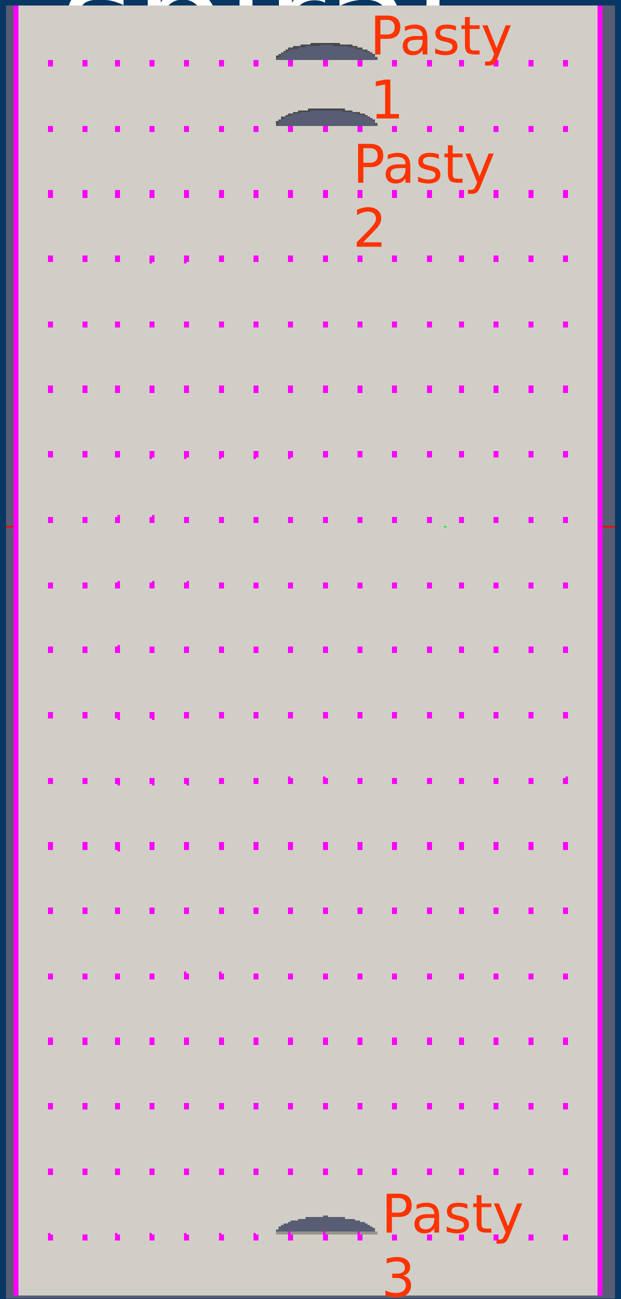


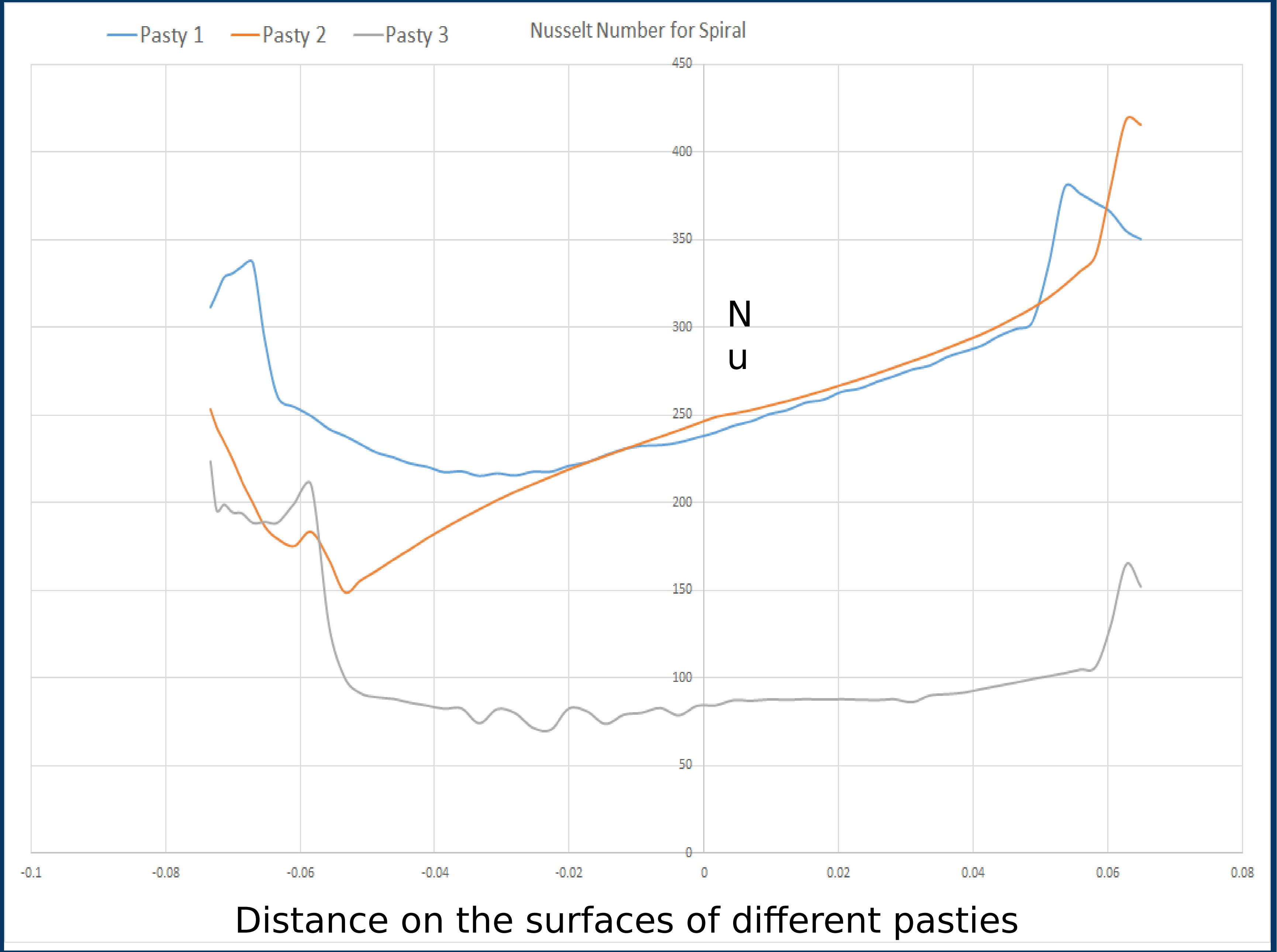
Temperature profiles at different positions





Heat extraction from pasties in spiral



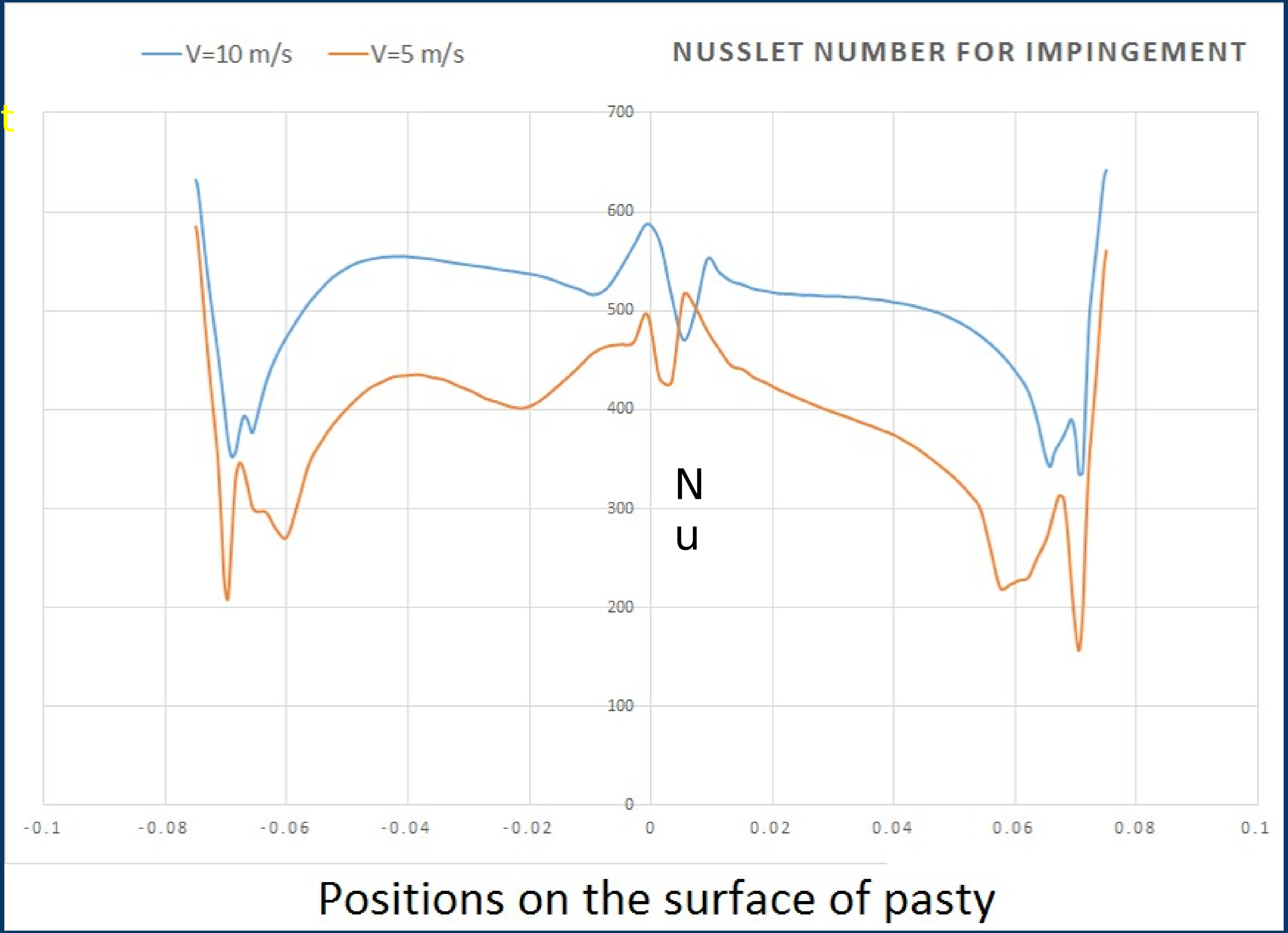


Impingement System

- Covering the whole surface
- Ensuring consistent cooling
- Efficient management of the coolant
- Improving product quality
- Possibility of energy recovering
- Reduction of cost

Effects of impingement velocity

Increase in the speed of the coolant can improve heat removal.



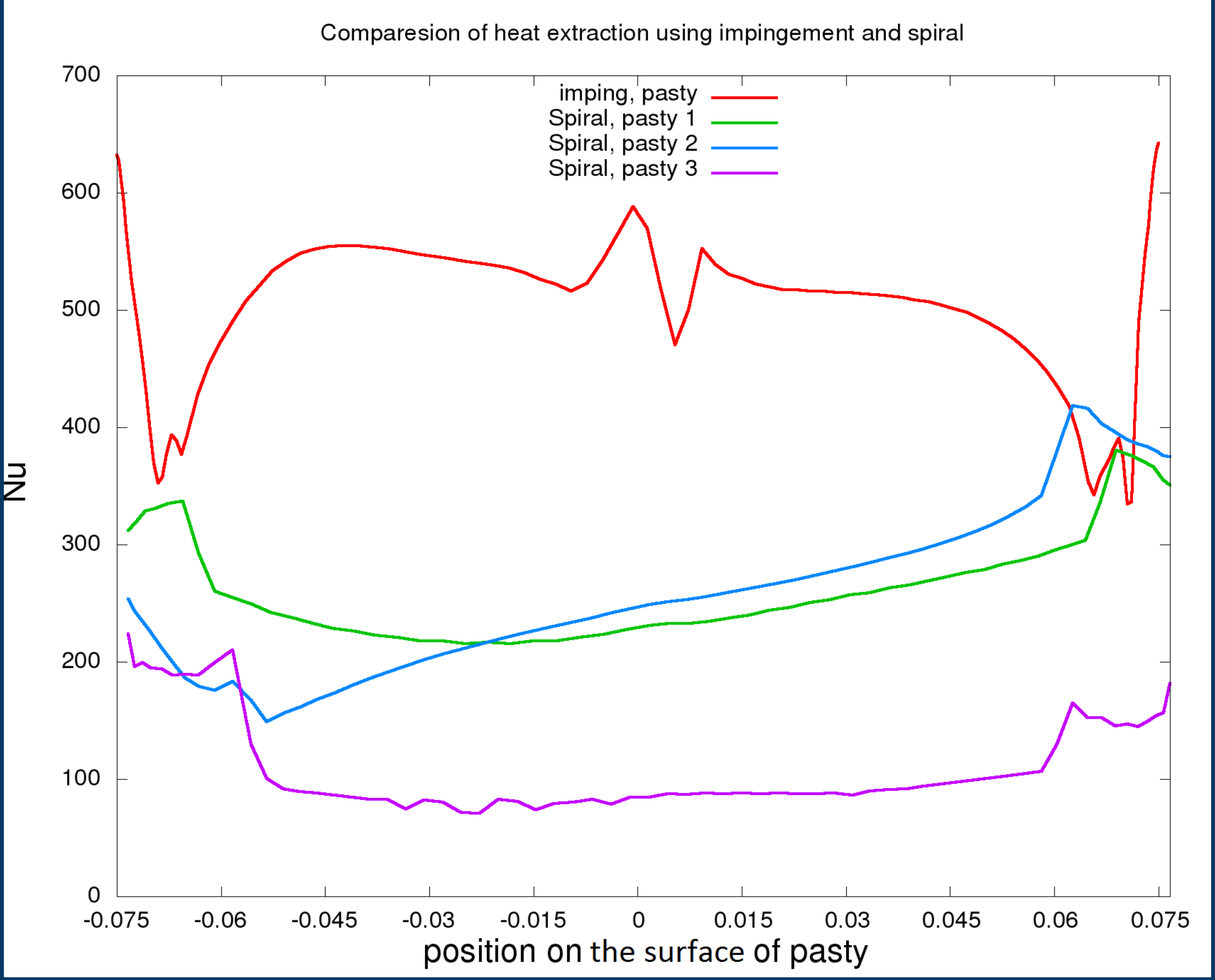
Spiral vs Impingement

Average of a single product:

✓ Impingement Nu ~ 500

✓ Spiral Nu ~ 180

The ratio of air: Spiral/impingement ~ 9.8/0.036



Next Steps

- Simulation of whole spiral
  - Monitoring air (velocity and temperature)
  - Looking at different way of pumping in the air
  - Product layout

- Simulation of 3D pasty using impingement
  - Air implementation (speed)
  - Jets: geometry, number and distance, materials
  - Effect of mass product

Conclusion

- Two different systems were numerically investigated
- Some issues were identified in spiral
- Impingement system showed a better performance
- Air jet can be a potential alternative to the spiral system
- A deep investigation on 3D systems is required

The end of presentation