Fridge Multiphase CFD & ROM

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RECAP FROM API > APPLICATION CASE

1900 Combi Bottom Frost Free Parallel Twin

Part of GENESI prgm.
Target for 2024 is to reach class C appliance (production 1000 pcs/year); D and E (90000 pcs/year)

- Frozen food cavity (Freezer): Vented
- Fresh food cavity (Fridge): Static

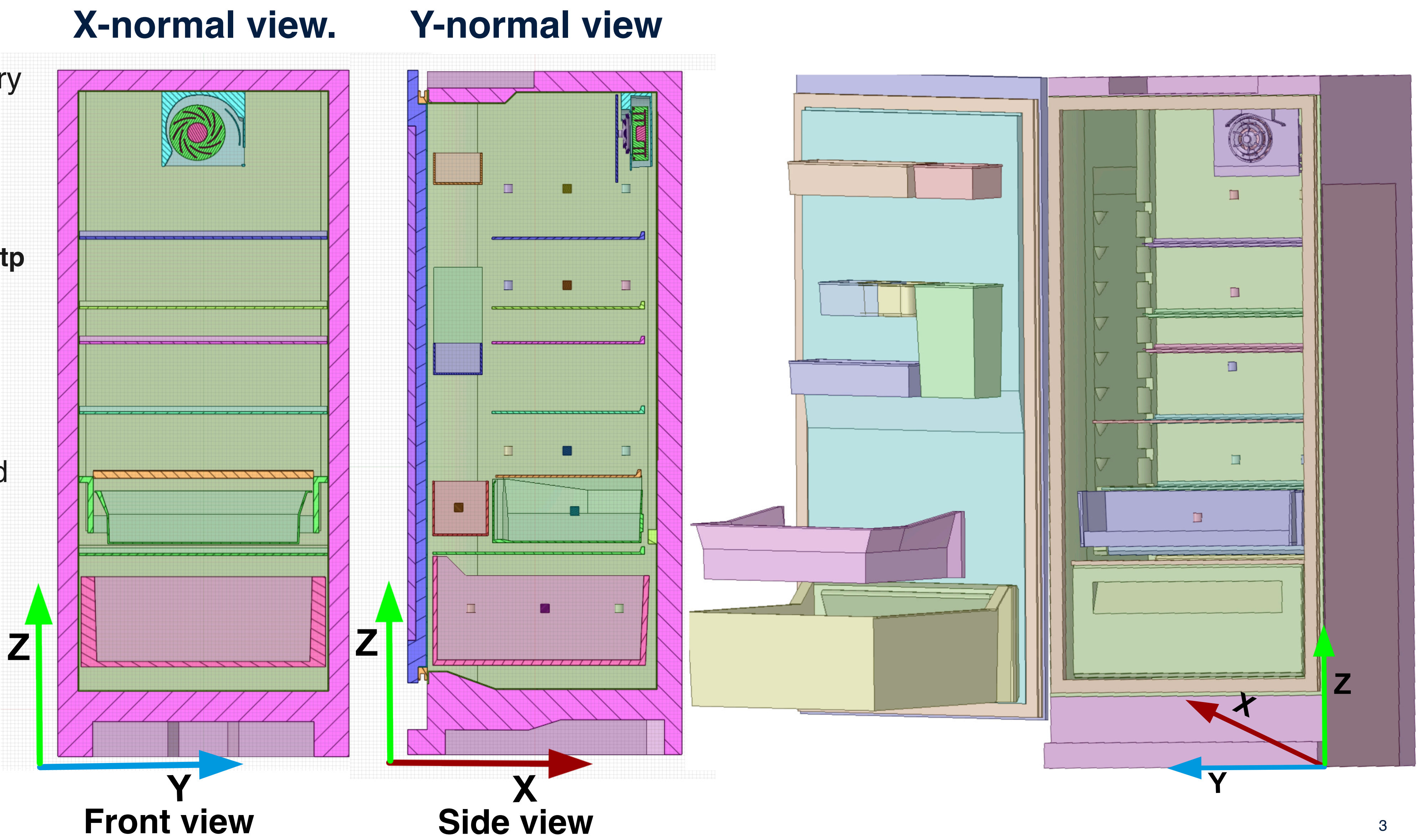
★ crisper

Fridge compartment:
110mm higher compared to 1780mm compartment.

- **High stratification**
- **Warm crisper**

2. CFD PACKAGE > MODEL-SET UP

- ECODESIGN test geometry (Empty fridge)
- Electrolux provided the geometry: **Supercombi_CFD_sept_21.stp**
- There are 51 components and more than 100 interfaces
- 2 fluid regions and 49 solid regions
- 50 interfaces between air and the component inside the fridge cabin

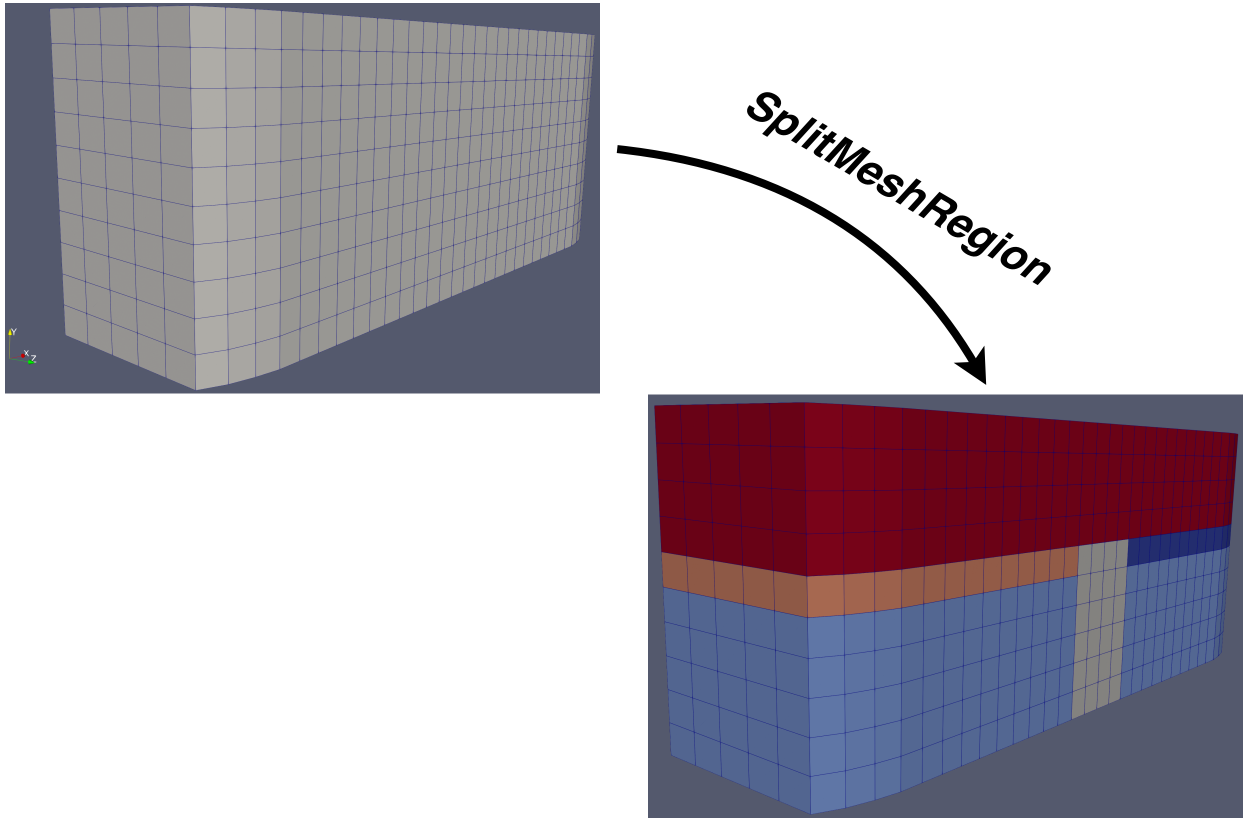


2. CFD PACKAGE : CHT Modeling

- Conjugate Heat transfer (CHT) is the problem in which heat conduction in solid, heat transfer in fluid and heat transfer between a solid and a fluid are computed together

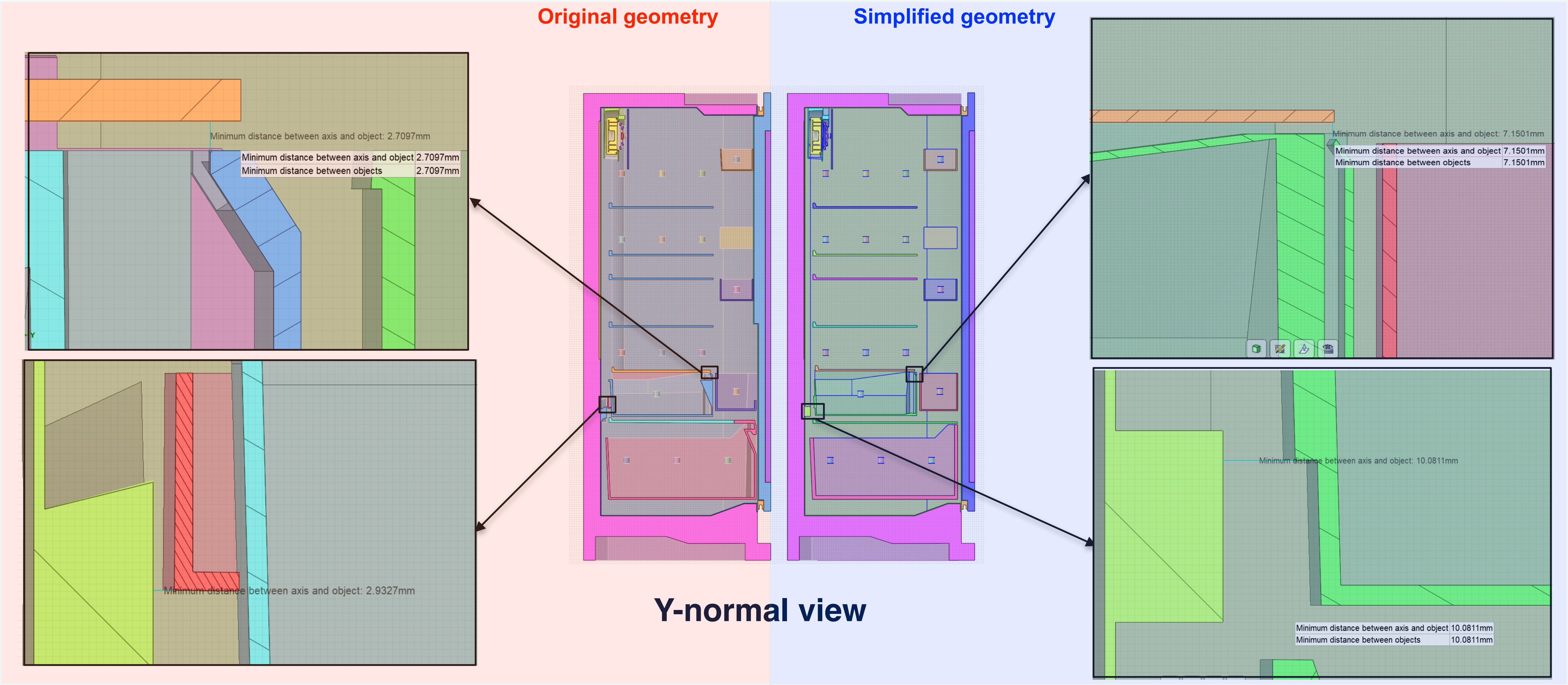
- To perform a CHT analysis, additional CAD requirements must be taken into account.
    - The model must contain distinguished solid and fluid regions. (Each closed volume,each part, is a region)
    - It is necessary to properly define interfaces between contacting regions
- In the empty fridge case, we have 51 regions among them one is fluid and the other 50 regions are solids.
- To Solve different types of equation and apply different BC for each region, we must have separate meshes for each region, to do so:
    - A cell-zone is created for each region by ***topoSet*** utility in OpenFoam. Now each component(region) has its own cell-zone.
    - ***SplitMeshRegion*** utility is used to split the obtained conformal-mesh into multi-region mesh according to their cell-zone.

- The ***chtMultiRegionSimpleFoam*** and ***chtMultiRegionFoam*** are the solvers that solve steady-state and transient conjugate heat transfer between solid and fluid regions in OpenFoam.



2. CFD PACKAGE > Geometry simplification

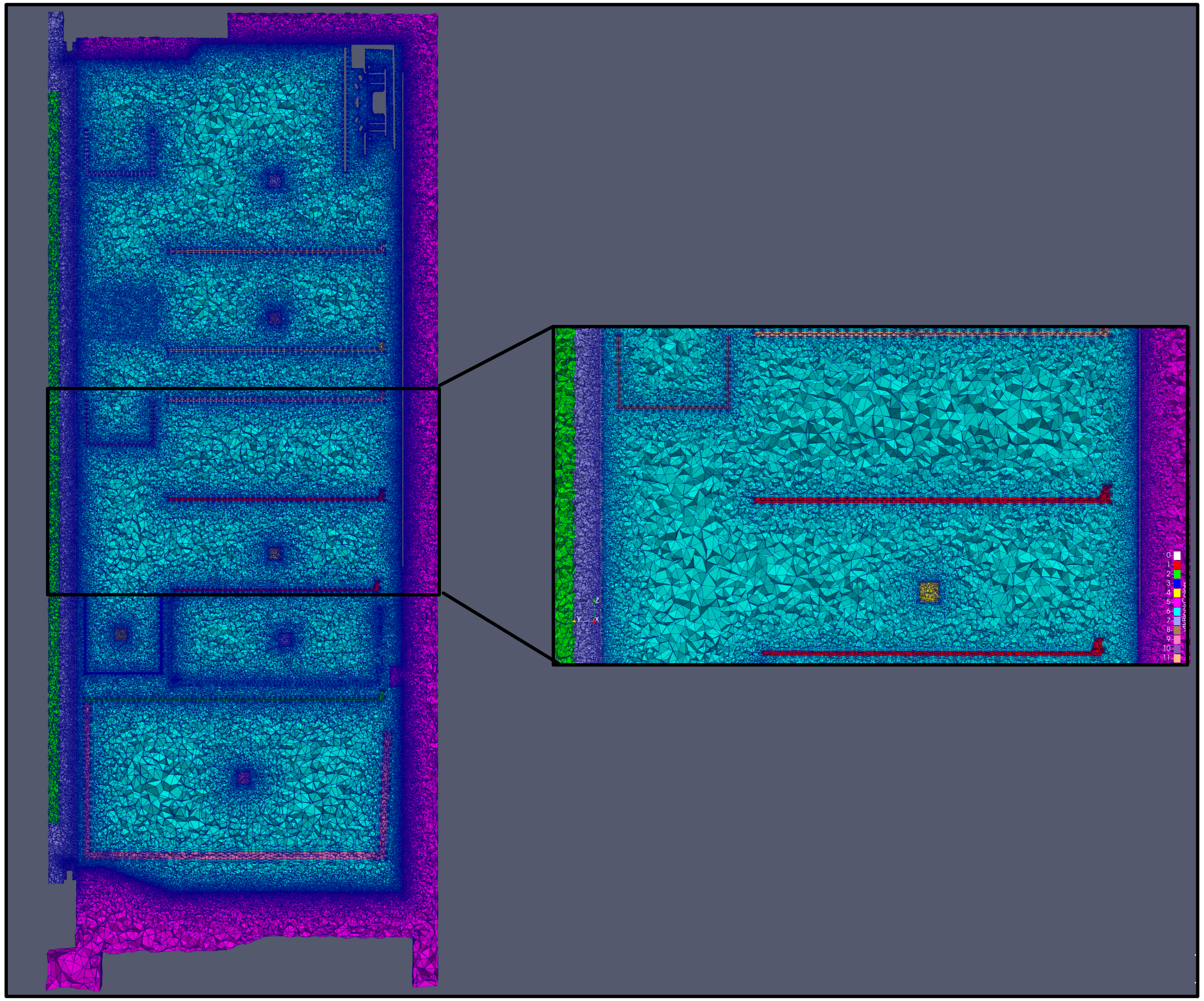
- The geometry was simplified to as much as possible to decrease complexity and consequently cell numbers
- The gap size is increased to prevent having too small elements and manage better boundary layers in these regions



2. CFD PACKAGE : Mesh Generation

- A **multi-region** mesh is required for a CHT simulation to have a clear definition of the interfaces in the computational domain.
- The exported "***.unv***" mesh from Salome can be imported into OpenFOAM. The mesh is totally compatible with OpenFOAM
- "*SALOME*" is able to generate only tetrahedral mesh for CHT cases
- Difficulty to produce high quality mesh for complex geometry in particular for CHT cases
- Local refinement and boundary layers must be managed manually
- The imported mesh is converted to polyhedral directly in OpenFoam to decrease cell numbers.
- One conformal mesh ic created for all the regions.

Side view

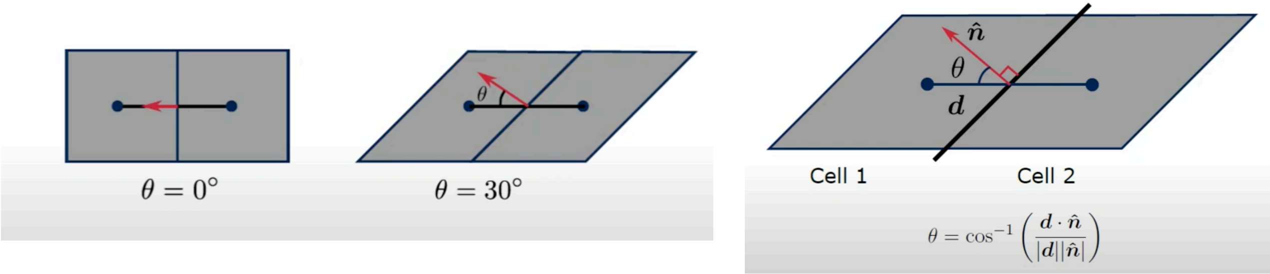


2. CFD PACKAGE : Mesh Generation

- Increase mesh quality
  - skewness
  - aspect ratio
  - Non-Orthogonality

- To do so:
  - Aspect ratio / skewness can be decreased by local refinement
  - Non-Orthogonality can be decreased by
    - Change the discretization scheme
    - Use non-Orthogonality correctors

- Non-Orthogonality: The angle between vectors **d** and **n**



$$\begin{cases} \theta = 0^o & \text{Perfectly orthogonal faces} \\ \theta < 70^o & \text{Is usually ok for OpenFOAM} \\ \theta > 70^o & \text{In general is not ok, special treatments needed} \end{cases}$$

Min Size	Max Size	Cell numbers	Boundary layers	Clock time
0.1 mm	32 mm	19’277’800(poly) 32’000’000(tetra)	3 layers for fan (t=0.01) 2 layers the rest (t=0.1)	3.5 hours

```
Checking geometry...
    Overall domain bounding box (-269.5 -475.8 505) (269.5 35.4 1782)
    Mesh has 3 geometric (non-empty/wedge) directions (1 1 1)
    Mesh has 3 solution (non-empty) directions (1 1 1)
    Boundary openness (-4.824933e-16 -7.584961e-15 -1.090027e-16) OK.
    Max cell openness = 3.832918e-16 OK.
    Max aspect ratio = 23.95116 OK.
    Minimum face area = 1.890852e-06. Maximum face area = 798.8213.
     Face area magnitudes OK.
    Min volume = 1.391212e-05. Max volume = 13184.21.
     Total volume = 3.372115e+08.  Cell volumes OK.
    Mesh non-orthogonality Max: 59.96673 average: 7.27443
    Non-orthogonality check OK.
    Face pyramids OK.
    Max skewness = 3.943425 OK.
    Coupled point location match (average 0) OK.

Mesh OK.
```

2. CFD PACKAGE : MRF Modeling

- Multiple Reference Frame (MRF) approach is used for modeling fan in the fridge

- MRF models the relative motion between the stationary and rotating regions without moving the mesh by adding a source term to NS equations.

- It is required to introduce MRF as a separate cell-zone to OpenFOAM, Although it is a part of air region. to do so, a separate cell-zone for MRF is created by ***topoSet*** utility, Consequently
  - There are two separate meshes for MRF and air after using ***SplitMeshRegion***
    - One sets of equations must be solved for them ❌
  - Two interfaces are created between them, **MRF_To_ Air** and ***Air_To_MRF***
    - There should not be any walls between them ❌

- To overcome the situation, Special treatment is adopted to model MRF.
  - ***mergeMesh*** utility is used to merge the meshes of air and MRF regions.
  - There is no internal wall in OpenFoam, So the created interfaces can not easily defined as internal wall and they should be removed. ***StitchMesh*** utility is used to merge the interfaces.

```
air_to_crisper
{
    type            mappedWall;
    inGroups        3(wall mappedPatch viewFactorWall);
    nFaces          60205;
    startFace       43304574;
    sampleMode      nearestPatchFace;
    sampleRegion    crisper;
    samplePatch     crisper_to_air;
}
```

2. CFD PACKAGE : Radiation Modeling

- Radiation is modeled by using a Surface to surface model, ***View factor model***

- This model compute the amount of radiative heat transfer leaving one surface that reaches to a second surface.

- **ViewFactorGen** Utility generate the rays between discrete faces of the surface.

- The computational time and memory requirement of the modeling is largely determined by the number of faces. In OpenFOAM, the cost can be reduced by grouping faces together using the ***faceAgglomerate*** pre-processing utility.

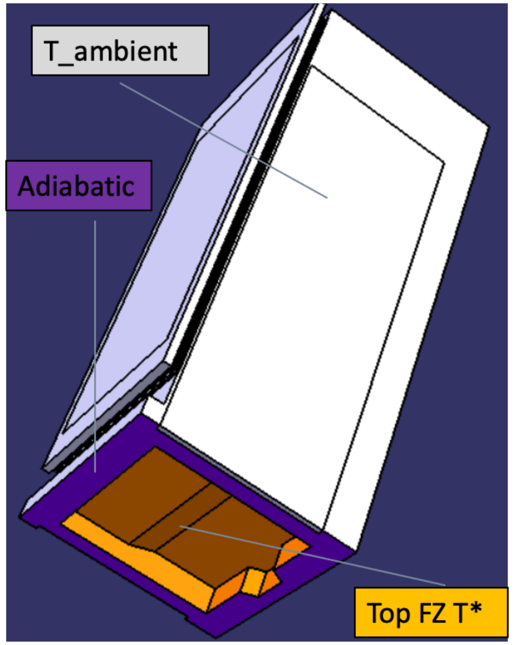
- Difficulties:
  - Particular treatment is needed to use ***View factor model*** in OpenFoam. ***viewFactorWall*** keyword must be used in a dictionary where the boundaries are defined.
  - Resolve a bug in parallel run of radiative heat transfer model.

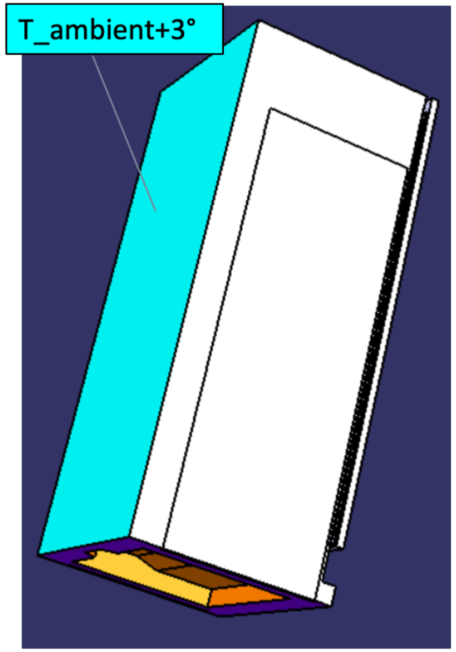
```
air_to_crisper
{
    type            mappedWall;
    inGroups        3(wall mappedPatch viewFactorWall);
    nFaces          60205;
    startFace       43304574;
    sampleMode      nearestPatchFace;
    sampleRegion    crisper;
    samplePatch     crisper_to_air;
}
```

2. CFD PACKAGE : BCs and Material Properties

- Conjugate heat transfer BC is considered as temperature BC between solid-fluid /solid-solid regions. The BCs in OF are:
  - ***TurbulentTemperatureCoupledBaffleMixed***
    - Solid/Solid CHT without radiation
  - ***TurbulentTemperatureRadCoupledMixed***
    - SolidLiquid CHT when radiation is also considered for the boundary
- No-slip BC is considered for as velocity BC for all boundaries inside the fridge cabin which are in contact with air

- Definition and material properties courtesy of CX-A Taste Fps (M.Bortolato)

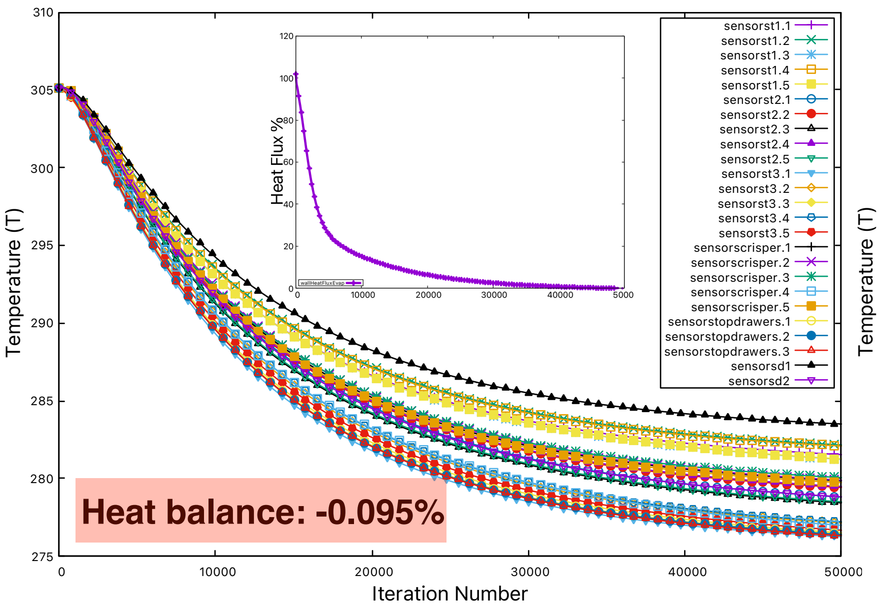




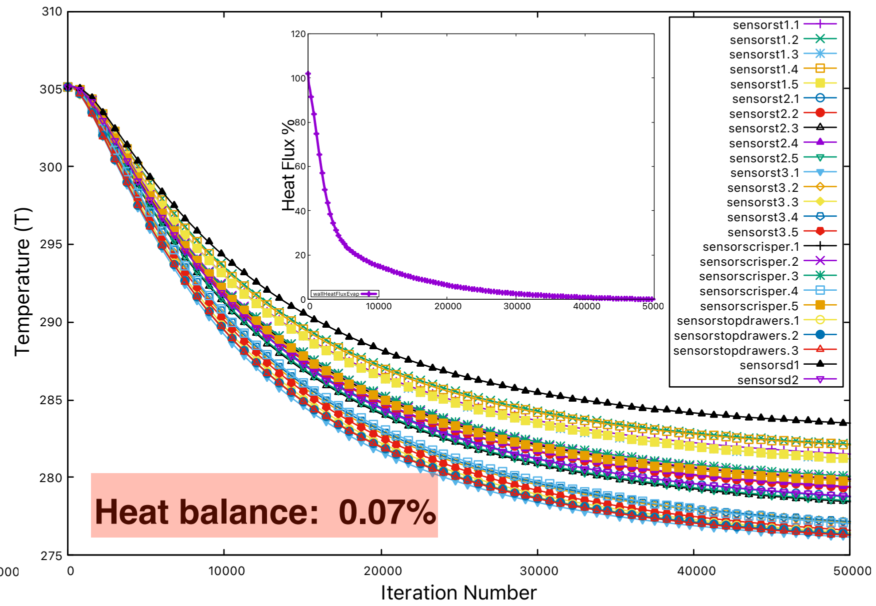
Material properties	Density [kg/m3]	Specific heat [J/(kg K)	Thermal conductivity [W/(m K)]	Parts
ABS	1049	1423,51	0,25	*Back top drawer, crisper top plastic, back top drawer glass, crisper_glass_back, fan cover front,*
Aluminium	2702	903	237	**Roll bond**
Brass	8500	376	120	**All temperature sensors**
Glass	2500	840	1,4	**Glass_1, Glass_2, Glass_3, Glass_4, glass top drawer, crisper glass**
PP	906	1800	0,195	*Top drawer, crisper,*
PS	1050	1200	0,12	**Door liner, All door bins, bottle bin, Top drawer front, right top drawer, left support top drawer, crisper front, fan housing, radial fan impeller, inner liner**
PU Foam	34	1450	Table vs T	**foam, door foam**
Soft PVC	1235	1350	0,14	**Gasket**
VIP	220	900	0,0045	**VIP door, VIP left side, VIP right side**
Thermal packs	1010	Table vs T	0,45	**Thermal packs**
Sponge	37	1020	0.04	**Sponge**

2. CFD PACKAGE : Turbulence vs. Laminar in Static Fridge

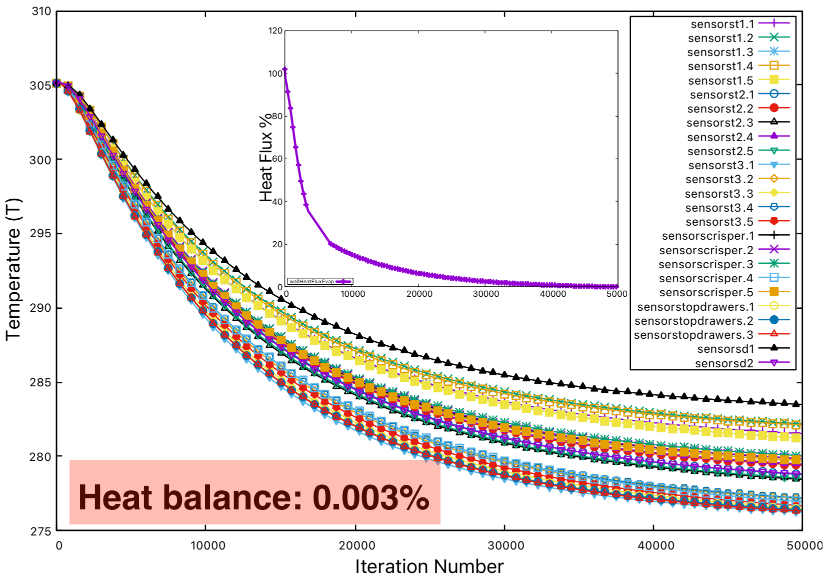
Laminar



Turbulence - KEpsilon.



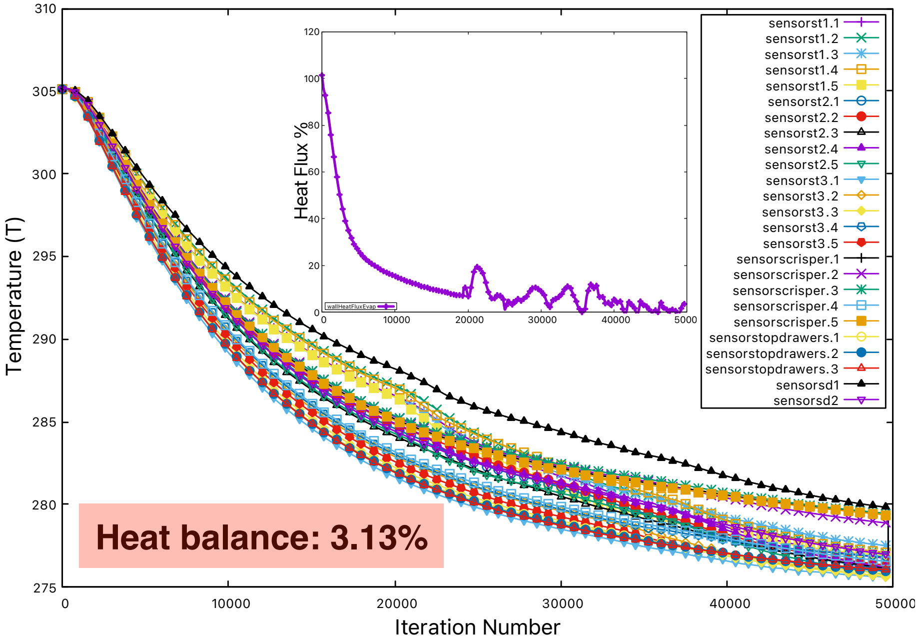
Turbulence - KOmegaSST



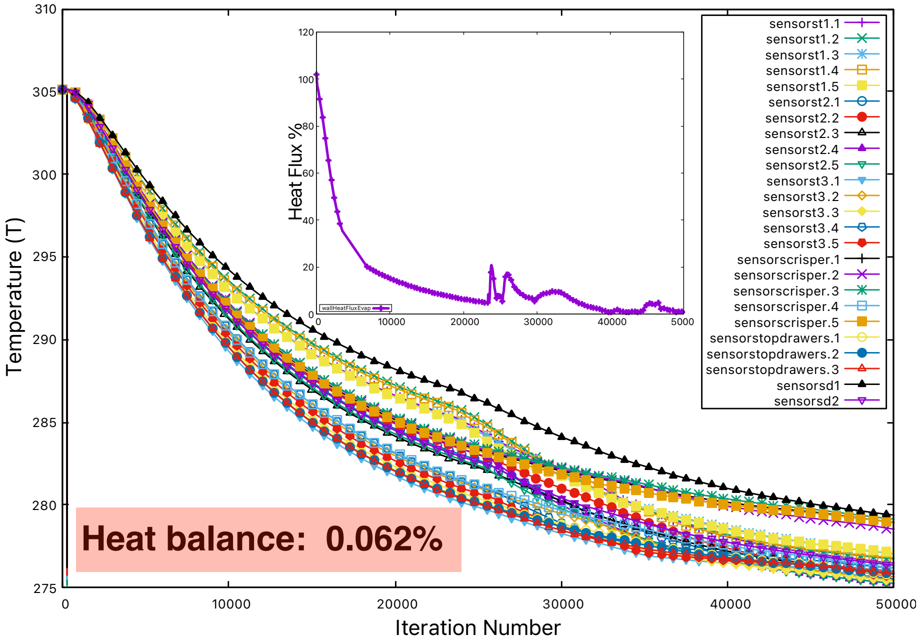
- Three models have been compared in term of Heat Balance and Temperatures in sensors to select the best approach to model the static Fridge.
- Heat Balance is the difference between heat flux entering to the system and exiting from the system. The ideal heat Balance is zero.
- According to the results, Temperature was reached to steady-state for all models but Heat balance is less for KOmegaSST model.
- **The best approach to model the static fridge is to use Turbulent regime with KOmegaSST model.**

2. CFD PACKAGE : Best Turbulence Model in Ventilated Fridge

Turbulence - KEpsilon.



Turbulence - KOmegaSST



- Two models have been compared in term of Heat Balance and Temperatures in sensors to select the best approach to model the ventilated Fridge.
- Laminar regime is out of table since the fan is activated,
- According to the results, Temperature was reached to steady-state for all models but Heat balance is less for KOmegaSST model.
- **The best approach to model the ventilated fridge is to use Turbulent regime with KOmegaSST model.**

2. CFD PACKAGE > Parallel computing with OpenFOAM

- In parallel run, geometry must be decomposed and distribute among all physical cores(MPI processes)
- Decomposition method :
  - **manual**
  - **simple**
  - **scotch**
  - …
- **Scotch** decomposition requires no geometric input from the user and tries to minimize the number of processor boundaries
- The problem is limitation on the number of processors for each region. It is not possible to Chose different number of processors for each region. NO SPEEDUP
- **Metis** decomposition method has been compiled separately allowing us to Parallelize each region with desired processor number/decomposition method.

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       dictionary;
    object      decomposeParDict;
}
// * * * * * * * * * * * * * * * * *

numberOfSubdomains  128;
method  scotch;
```

```
numberOfSubdomains  128;
method  metis;

regions
{
   foam //4067473
    {
      numberOfSubdomains  64;
      method  scotch;
    }
    innerliner //2273192
    {
      numberOfSubdomains  32;
      method  scotch;
    }
    doorfoam
    {
      numberOfSubdomains  16;
      method  scotch;
    }
    doorliner
    {
      numberOfSubdomains  8;
      method  scotch;
    }
    gasket
    {
      numberOfSubdomains  5;
      method  scotch;
    }
    topdrawer
    {
      numberOfSubdomains  4;
      method  scotch;
```

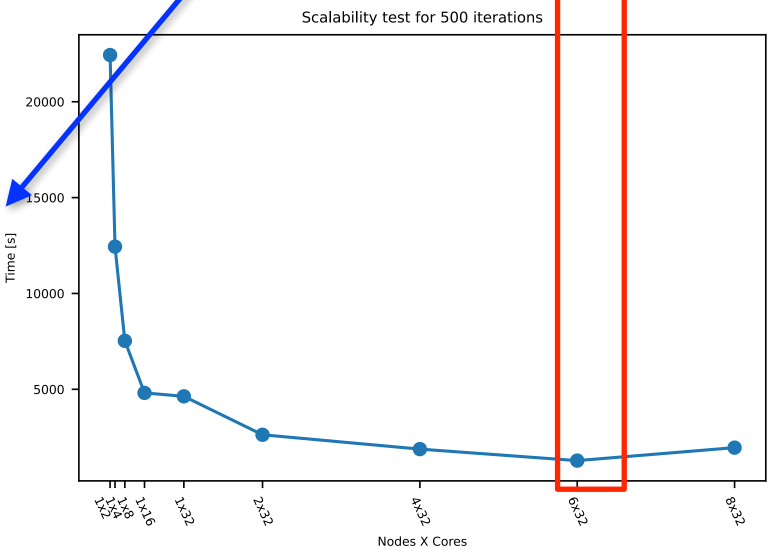
2. CFD PACKAGE > Scalability Test

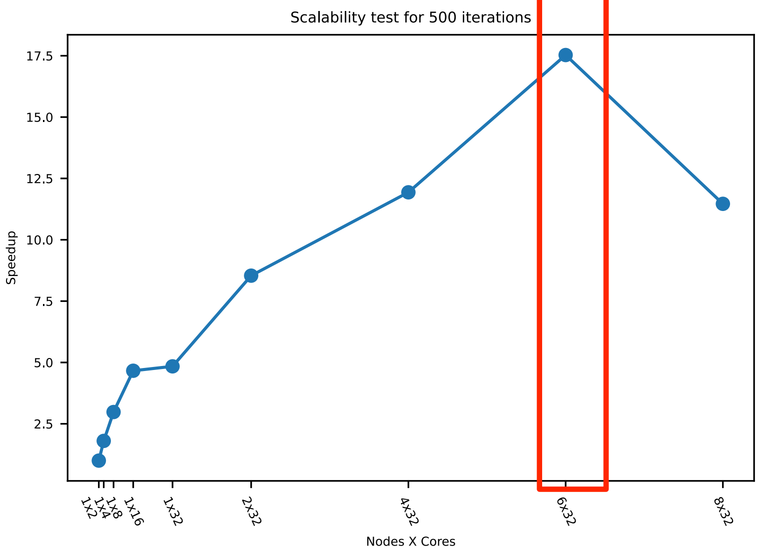
Reasonable option

- Scalability test for 500 iteration without input/output(IO) on **Ulysses** with **Metis** decomposition
- The test has been done for a case with 20 M polyhedral cells

Nodes/time	Minutes	Hours
1 Nodes / 32 cores	9268	154.5
2 Nodes / 64 cores	5256	87.6
4 Nodes / 128 cores	3760	62.7
6 Nodes / 192 cores	2560	42.7

Best option

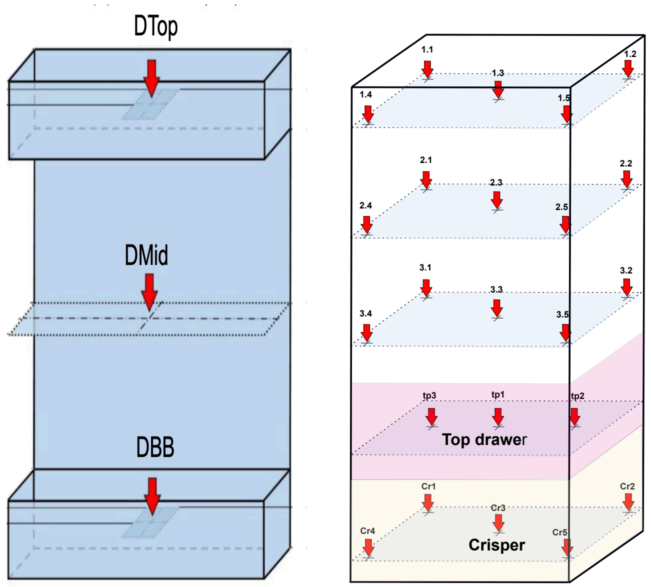


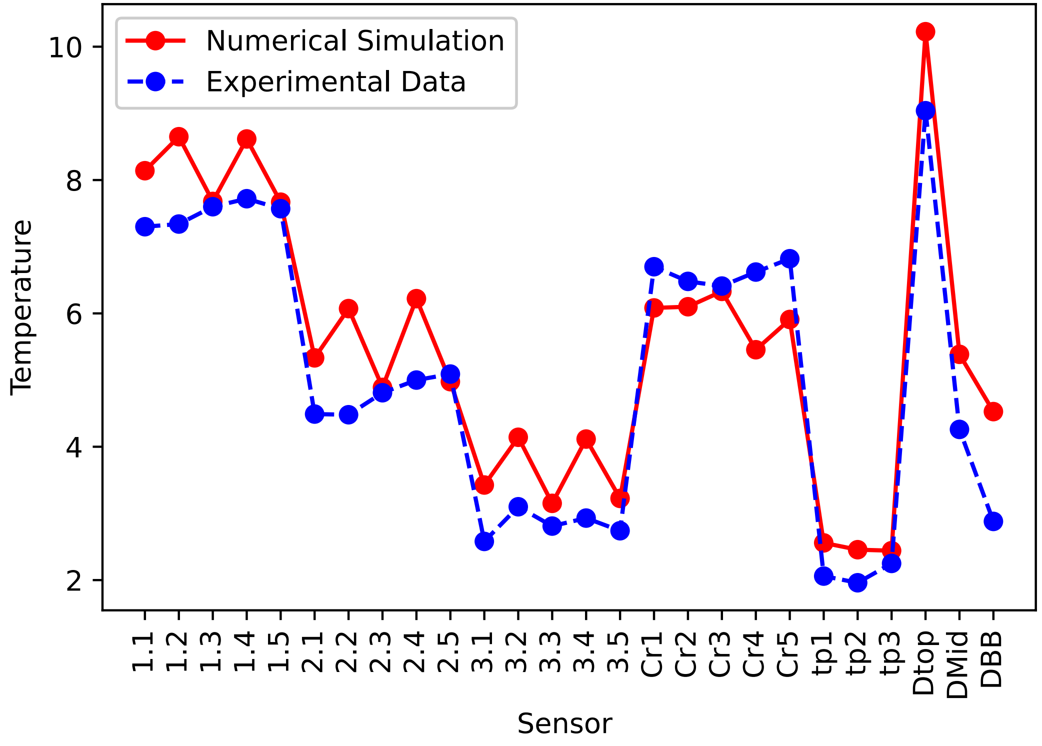


- Optimum computational resource for this case is to use 6 nodes
  - Asking 6 nodes requires normally long queue time.
  - **Best tradeoff between queue time and computational cost is using 2 to 4 nodes**
  - The results are not general, it is case/solver dependent.

2. CFD PACKAGE : Static Fridge Validation

- First CFD run on real geometry
- The numerical result and experimental data follow the same trend
- There is a good agreement between numerical results and experimental data for the sensors on the :
  - First shelf (1.1, …, 1.5)
  - Second shelf (2.1, …, 2.5)
  - Third shelf (3.1, …, 5.5)
  - Top drawer (tp1, tp2, tp3)
  - Crisper (Cr1, … , Cr5)
  - Bins (Dtop, Dmid, DBB)

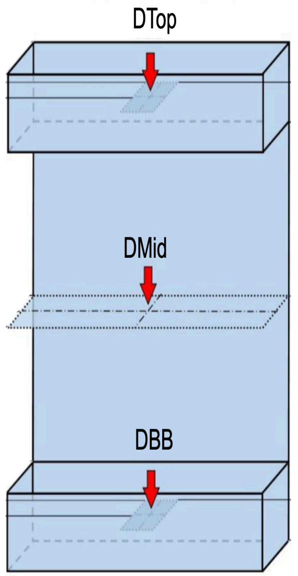


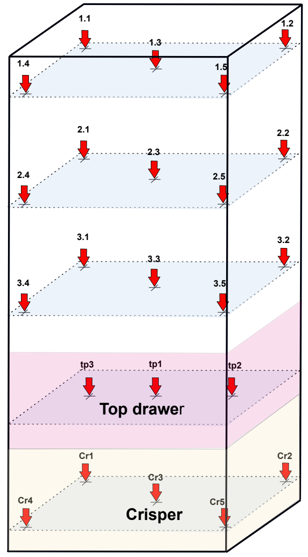


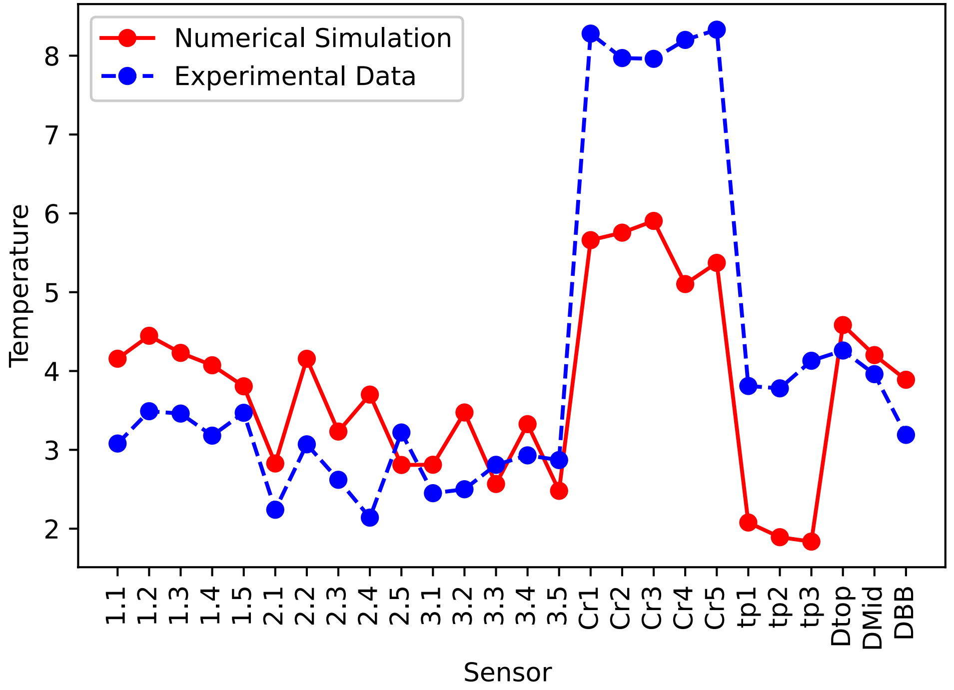
	Numerical Simulation	Experimental Data	accuracy level
Average T FF	5.75	5.04	0.71
Average T Crisper	2.48	2.09	0.49
Average T Top drawer	5.975	6.61	0.64

2. CFD PACKAGE : Ventilated Fridge Validation

- First CFD run
- The numerical result and experimental data follow the same trend
- There is an acceptable agreement between numerical results and experimental data for the sensors on the first, second and third shelves
- There is a difference between numerical and experimental data for the sensors located in top drawer and crisper ❌
- The reason might be related to CAD simplification in particular the gaps between liner and topdrawer/crisper that were oversimplified



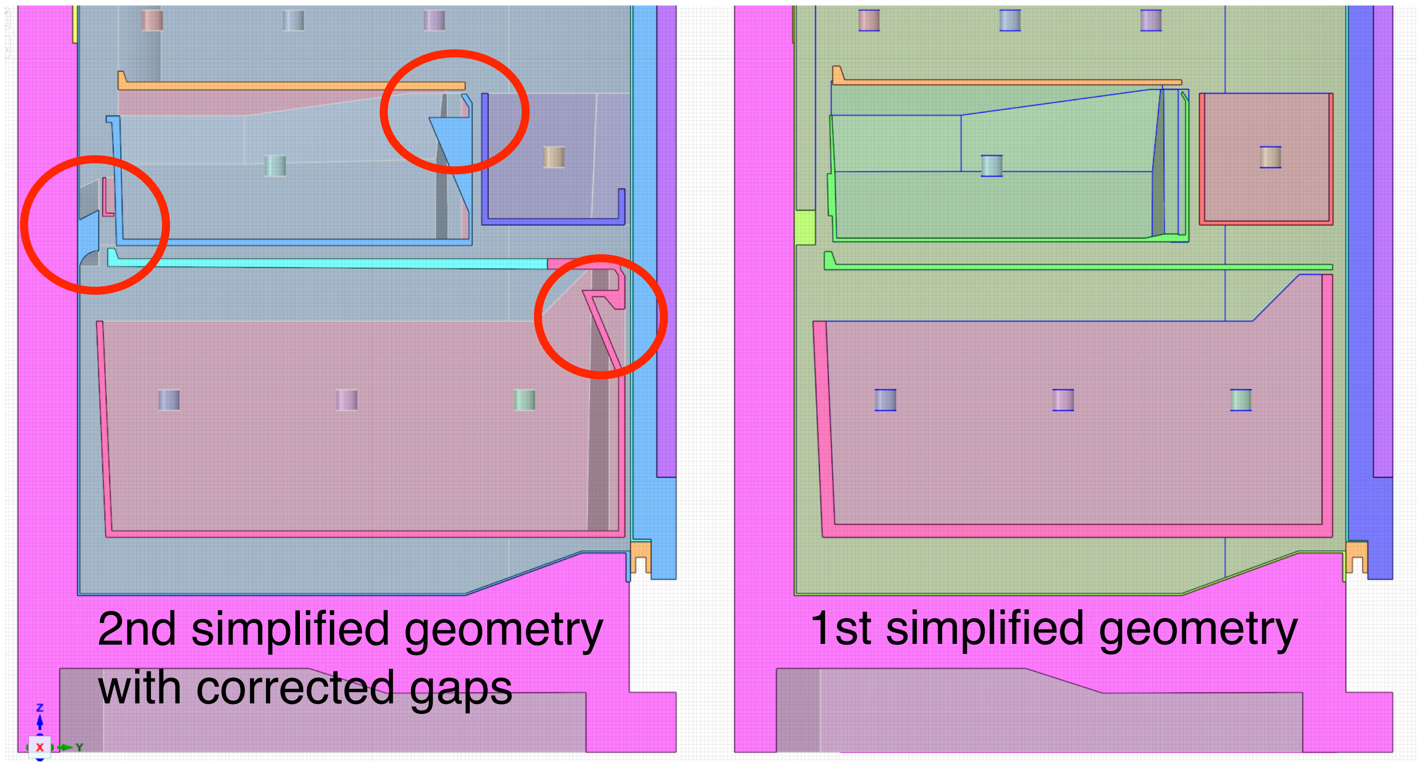




	Numerical Simulation	Experimental Data	accuracy level
Average T FF	3.47	2.9	0.57
Average T Crisper	5.55	8.15	2.6
Average T Top drawer	1.93	3.91	1.98

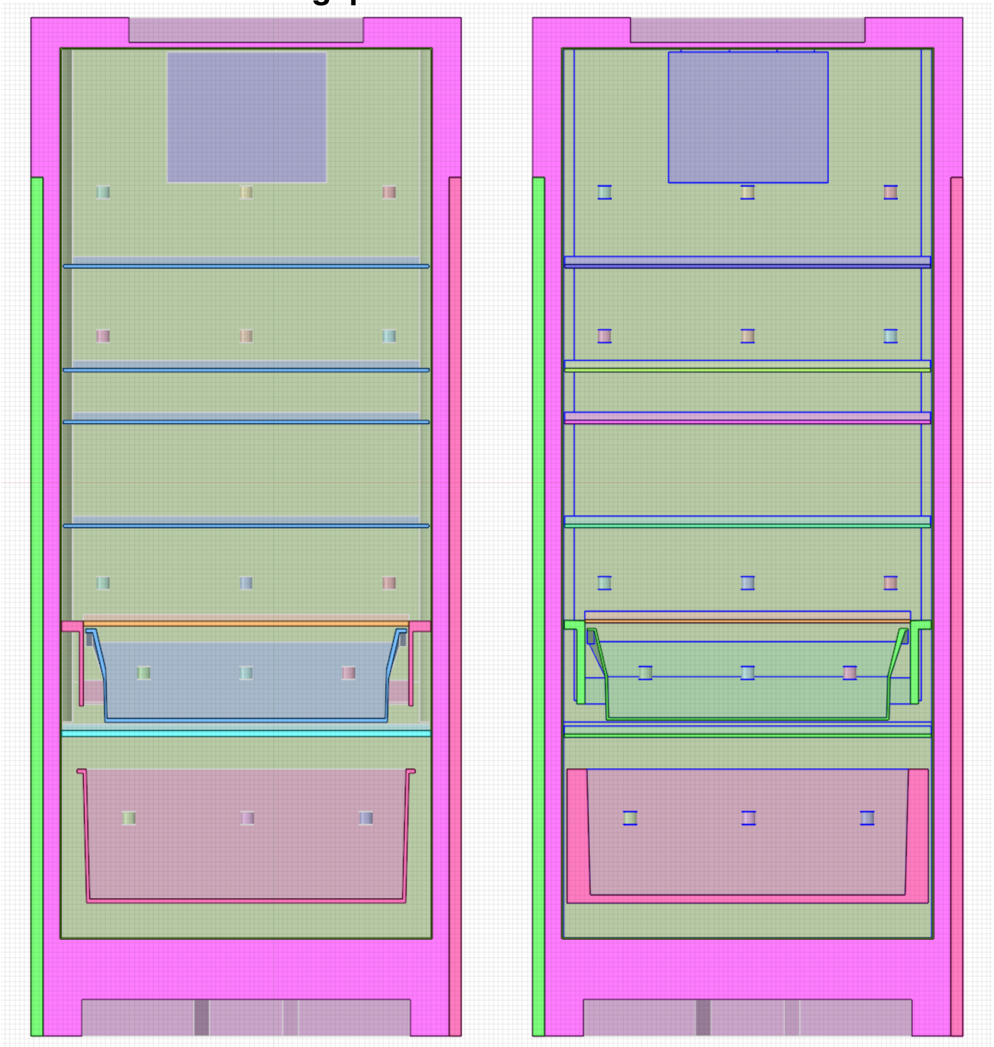
2. CFD PACKAGE > Geometry correction

- The geometry of crisper and top-drawer are back to the original shape
- The gaps between the following regions are corrected:
  - liners and top drawer
  - Liner and crisper
  - Top-drawer and top-drawer support



X-normal View

2nd simplified geometry with corrected gaps | **1st simplified geometry**



Y-normal View

2. CFD PACKAGE : Mesh Generation

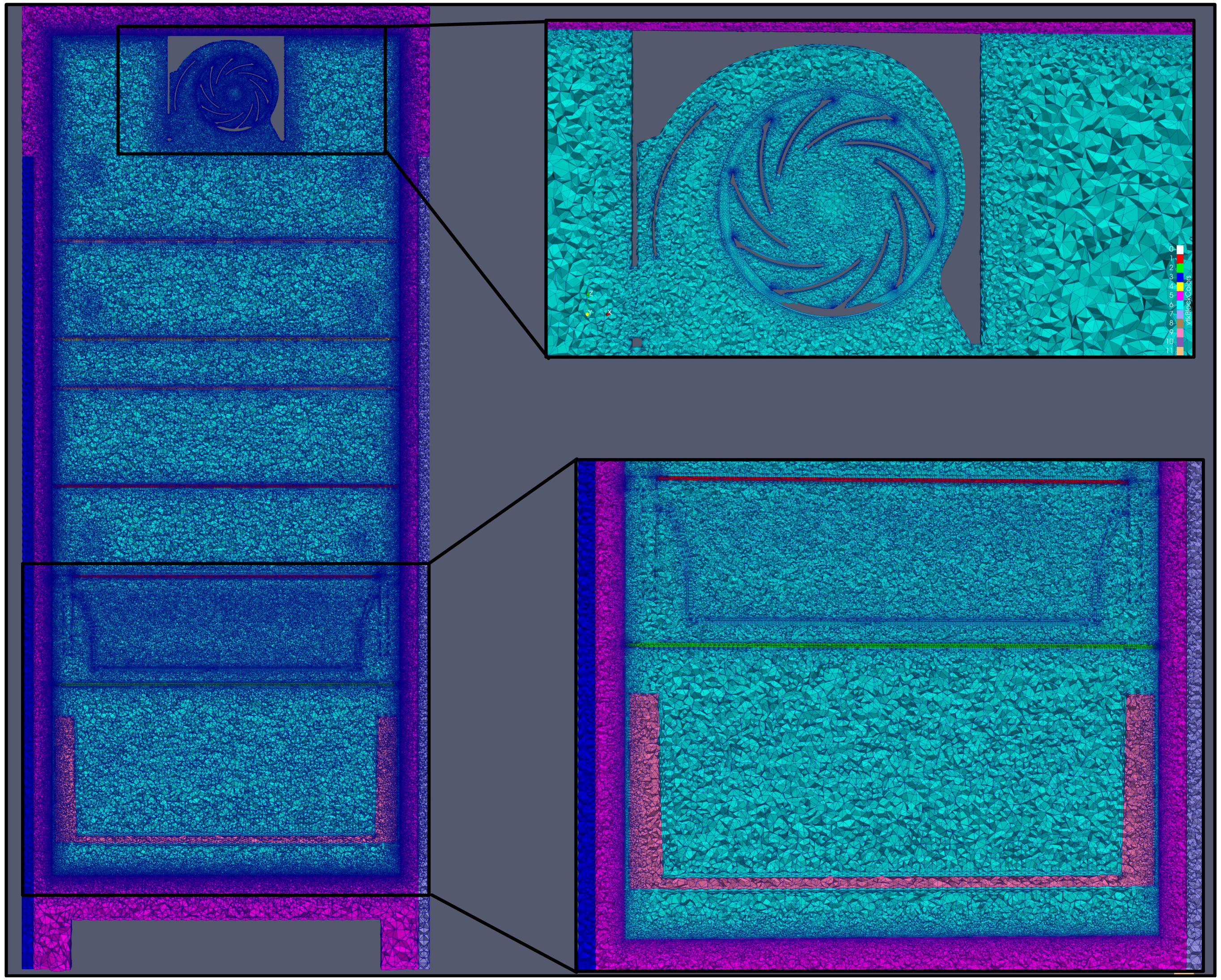
- Corrected geometry was meshed again to increase the accuracy level
- Difficulties:
    - Capture very well the small gaps
    - Boundary layer on the gaps

Min Size	Max Size	Cell numbers	Prism layers	Clock time
0.1 mm	32 mm	21’350’000(poly) 35’000’000(tetra)	3 layers for fan 2 layers the rest	3.5 hours (1 cpu)

```
Checking geometry...
    Overall domain bounding box (-0.2695 -0.4757999878 0.505) (0.2695 0.03540000153 1.782)
    Mesh has 3 geometric (non-empty/wedge) directions (1 1 1)
    Mesh has 3 solution (non-empty) directions (1 1 1)
    Boundary openness (-1.26794035239e-16 4.37297907303e-16 1.06546802246e-16) OK.
    Max cell openness = 4.62819025609e-16 OK.
    Max aspect ratio = 28.742854749 OK.
    Minimum face area = 2.68613858354e-12. Maximum face area = 0.000782856292477.
    Face area magnitudes OK.
    Min volume = 2.01757698343e-15. Max volume = 1.12629748001e-05.
    Total volume = 0.336545229921.  Cell volumes OK.
    Mesh non-orthogonality Max: 59.966160706 average: 7.43189290652
    Non-orthogonality check OK.
    Face pyramids OK.
    Max skewness = 3.78408329674 OK.
    Coupled point location match (average 0) OK.

Mesh OK.
```

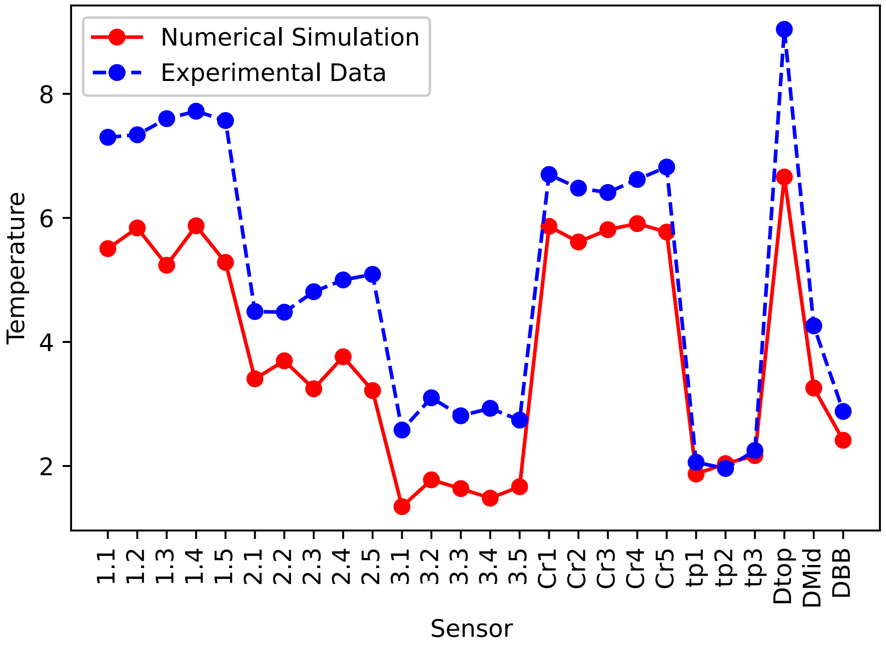
Front view



2. CFD PACKAGE > Correction on Radiation Model

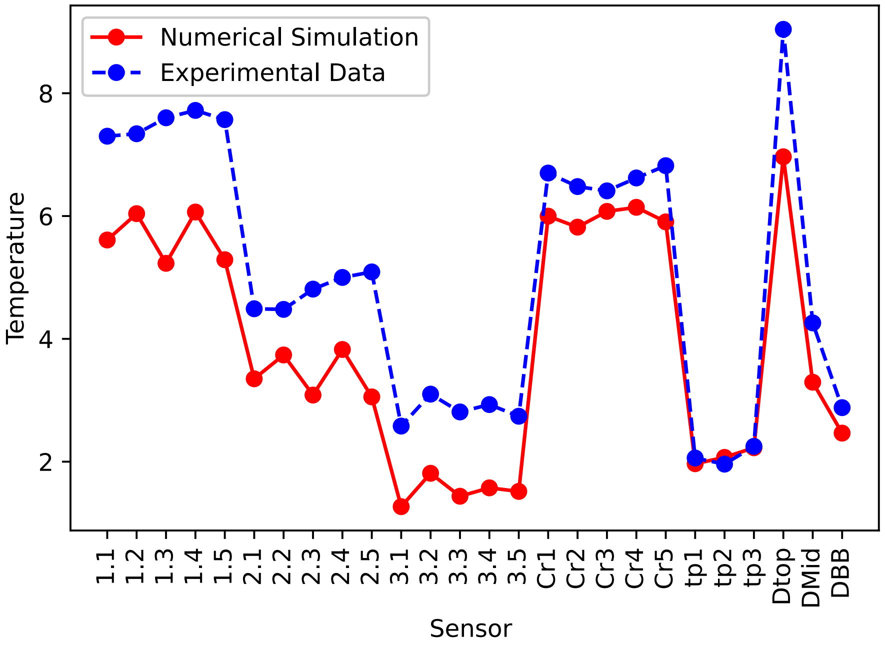
- Further correction on radiation model has been done
- Unlike the other CFD software, the value of absorptivity and emissivity are not the same in OpenFOAM
- We have used right values of absorptivity in the simulations but the the default emissivity value was zero in radiation dictionary.
- We change the default value and new configuration is compared with the old one.
- Results confirm that more accurate results obtained when these two value are equal.

Absorptivity ≠ Emissivity



	Numerical Simulation	Experimental Data	accuracy level
Average T FF	3.53	5.04	1.51
Average T Top drawer	2.025	2.09	16
Average T Crisper	5.79	6.61	0.82

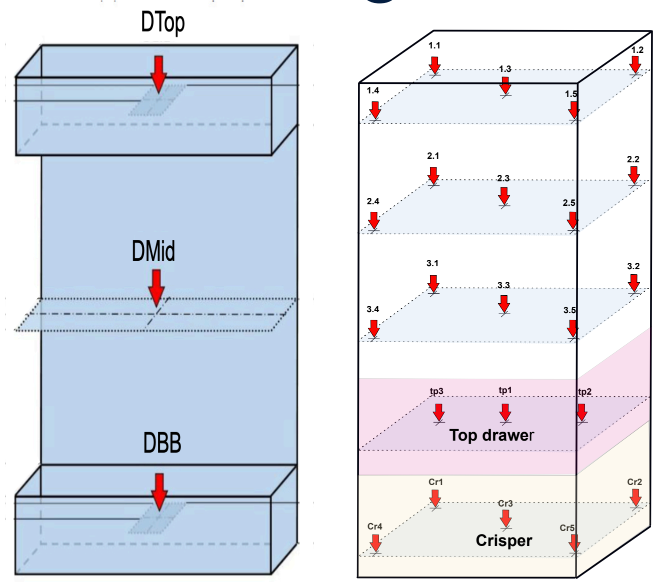
Absorptivity = Emissivity

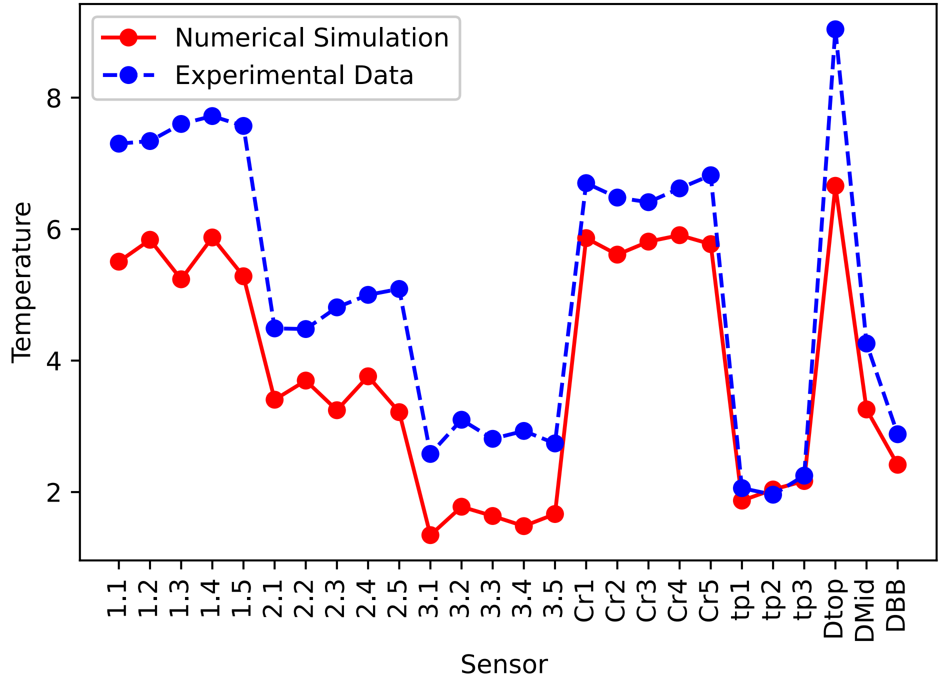


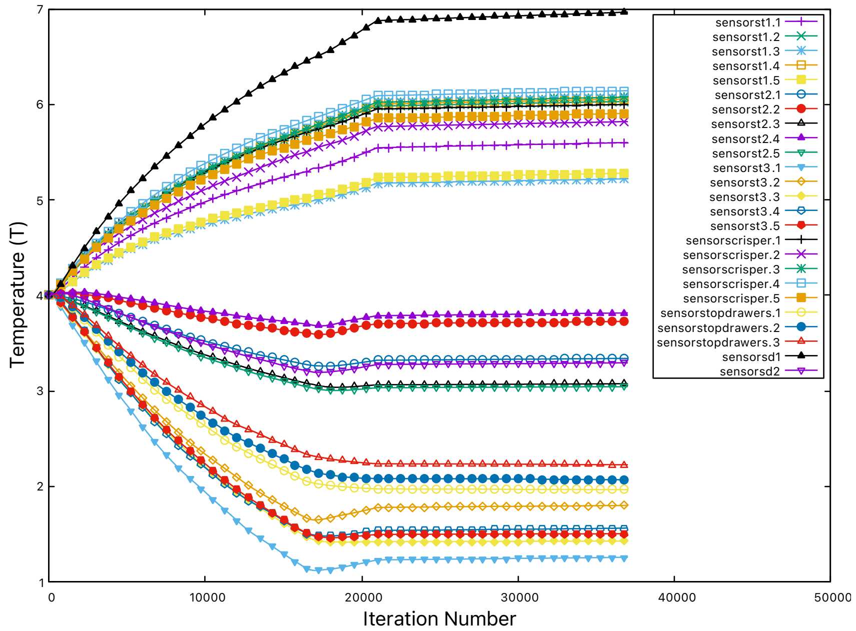
	Numerical Simulation	Experimental Data	accuracy level
Average T FF	3.8	5.04	1.24
Average T Top drawer	2.08	2.09	0.01
Average T Crisper	5.99	6.61	0.62

2. CFD PACKAGE : Static Fridge Validation

- 2nd run of static fridge on corrected geometry
- The numerical result and experimental data follow the same trend
- There is a good agreement between numerical results and experimental data for the sensors on the :





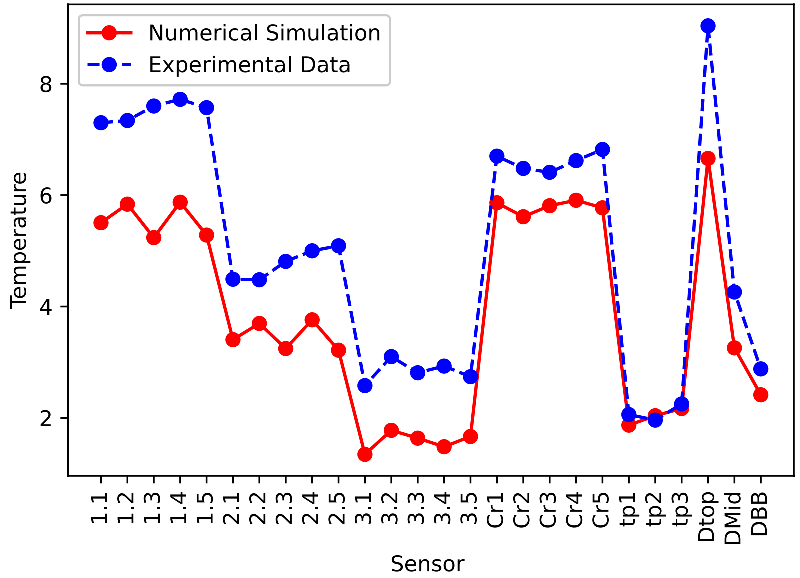


	Numerical Simulation	Experimental Data	accuracy level
Average T FF 1st floor	5.7	7.4	1.7
Average T FF 2nd floor	3.46	4.77	1.31
Average T FF 3rd floor	1.9	2.83	0.93
Average T Crisper	2.08	2.09	0.01
Average T Top drawer	5.99	6.61	0.62

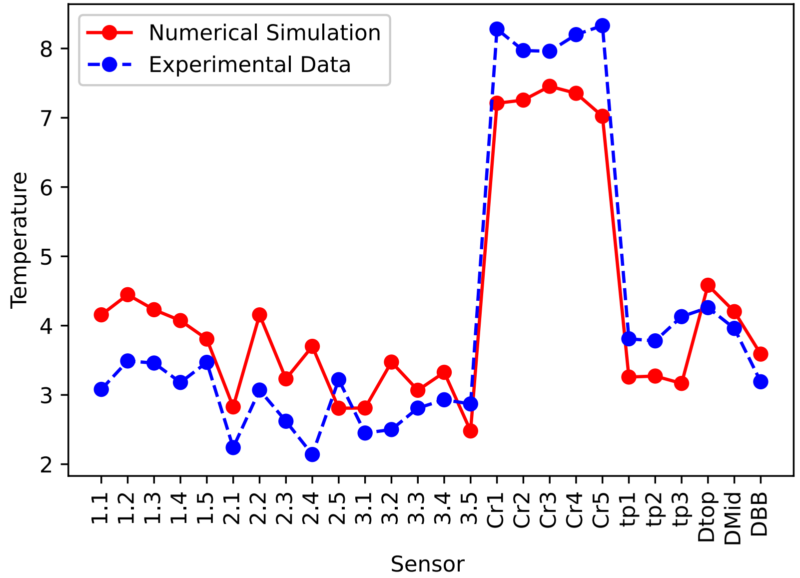
Stratification:

- Experiment= 4.57
- CFD = 3.8

2. CFD PACKAGE : Static Fridge Validation



	Numerical Simulation	Experimental Data	accuracy level
Average T FF 1st floor	5.7	7.4	1.7
Average T FF 2nd floor	3.46	4.77	1.31
Average T FF 3rd floor	1.9	2.83	0.93
Average T Crisper	2.08	2.09	0.01
Average T Top drawer	5.99	6.61	0.62



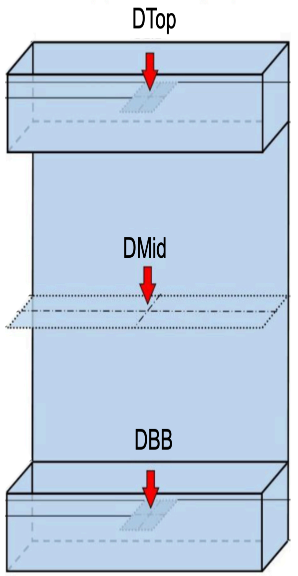
	Numerical Simulation	Experimental Data	accuracy level
Average T FF 1st floor	4.14	3.36	0.78
Average T FF 2nd floor	3.34	2.65	0.69
Average T FF 3rd floor	3.03	2.7	0.33
Average T Crisper	7.3	8.1	0.8
Average T Top drawer	3.9	3.3	0.6

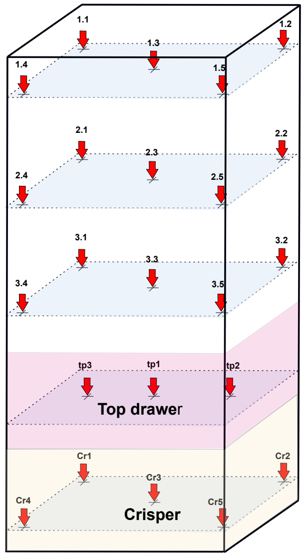
2. CFD PACKAGE : Ventilated Fridge Validation

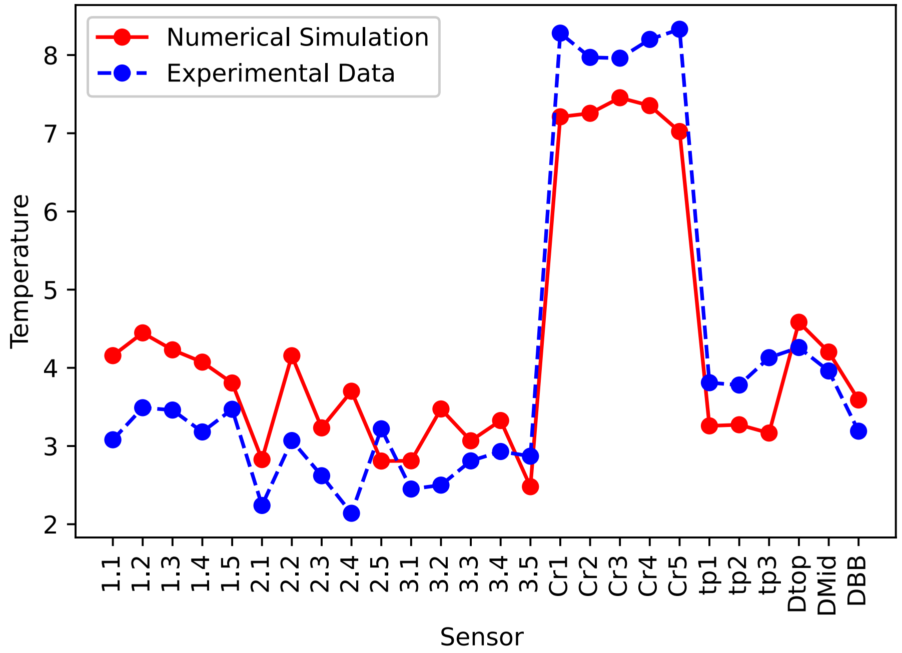
- 2nd run of static fridge on corrected geometry

- The numerical result and experimental data follow the same trend

- There is a good agreement between numerical results and experimental data for the sensors on the :







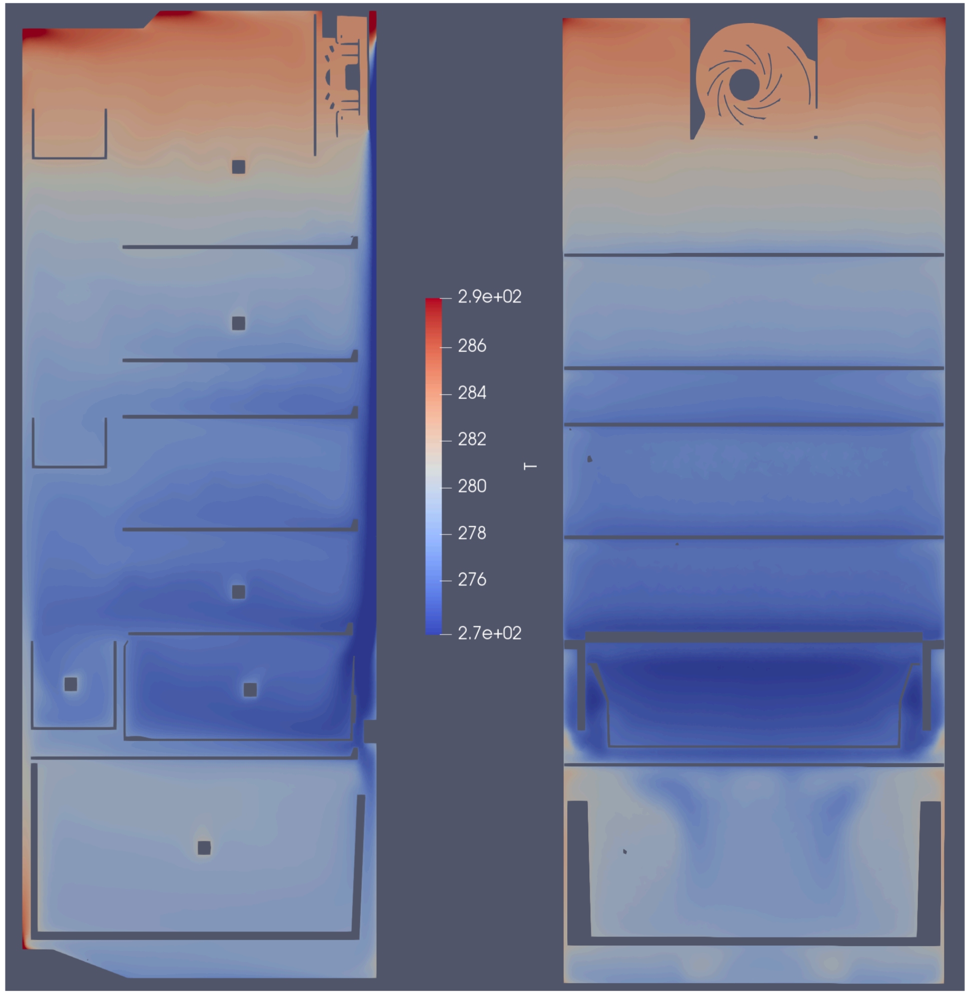
	Numerical Simulation	Experimental Data	accuracy level
Average T FF 1st floor	4.14	3.36	0.78
Average T FF 2nd floor	3.34	2.65	0.69
Average T FF 3rd floor	3.03	2.7	0.33
Average T Crisper	7.3	8.1	0.8
Average T Top drawer	3.9	3.3	0.6

Stratification:

- Experiment= 0.66
- CFD =1.1

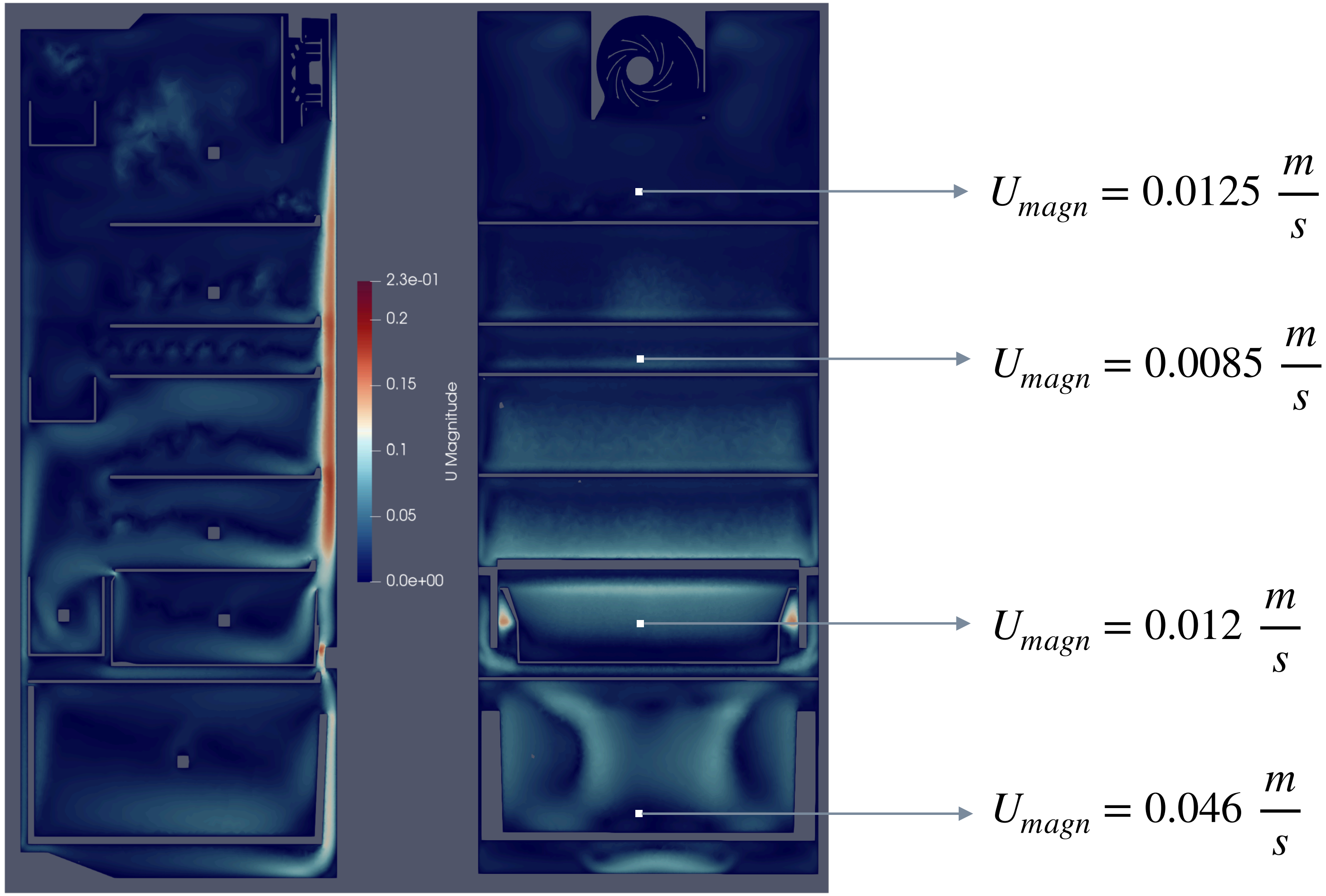
2. CFD PACKAGE > Results : static

Temperature



Side view **Front view**

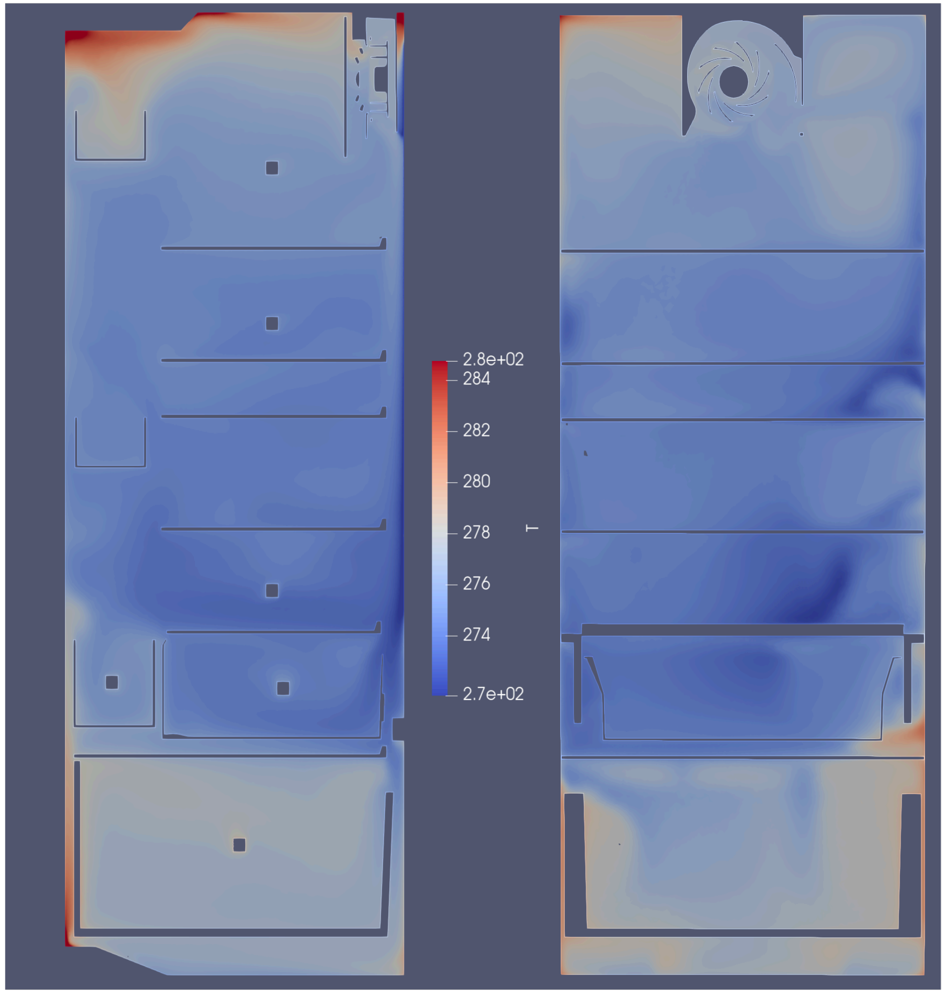
Velocity



Side view **Front view**

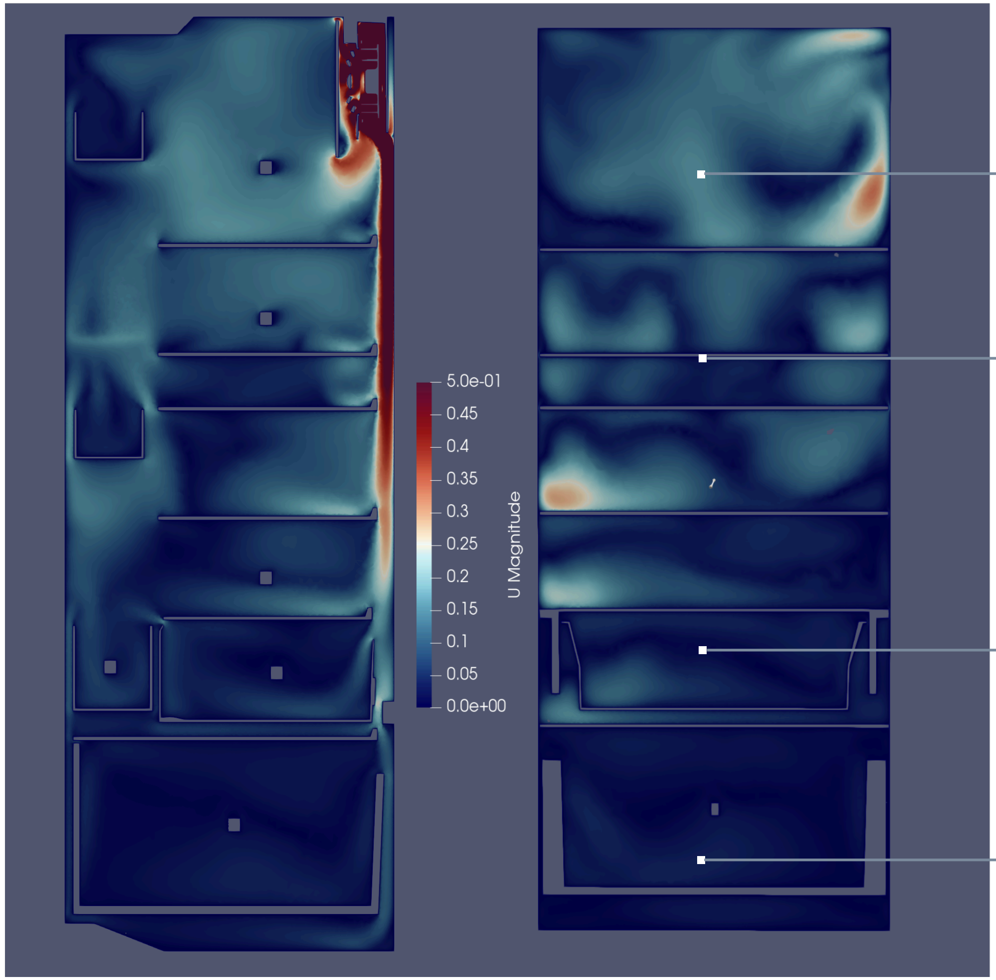
2. CFD PACKAGE > Results : ventilated

Temperature



Side view **Front view**

Velocity



$$U_{magn} = 0.65 \frac{m}{s}$$

$$U_{magn} = 0.011 \frac{m}{s}$$

$$U_{magn} = 0.03 \frac{m}{s}$$

$$U_{magn} = 0.08 \frac{m}{s}$$

Side view **Front view**

24

2. CFD PACKAGE > Transient Simulation

Strategy for transient simulations:

- Launch steady-state simulations for static and ventilated fridge
- Use stationary flow field of steady-state simulation as the initial condition for transient simulations
- The Pimple algorithm is used for transient simulation, instead of PISO, allowing us to increase CFL number and consequently **dt**

- Static fridge:
  - We have managed to increase ***dt*** to 2e-4 sec using CFL=100 without causing divergence but why?
  - It is always recommended to keep CFL number in CFD simulation below one
  - We will not run static fridge: calculations are too long (order of years)
- Ventilated fridge:
  - The Solver is modified to freeze the flow, letting us increase ***dt*** to 10-15 sec (much faster iteration)
  - We don't have constraints on CFL number

CFD PACKAGE > RUN-TIME

	STEADY-STATE	TRANSIENT
STATIC	**20000 iterations to reach convergence** (Used as initialization for the Transient CFD run) **Run time:** • 52 hours on 32 cores (1 node) • 29.2 hours on 64 cores (2 nodes) • 21. hours on 128 cores (4 nodes)	Solving all the equations: Flow, turbulence and thermal **Physical time modeled: 60min (2 cycle of 30 min)** • Time Step = 0.0002 s • Inner iterations: 5 • Iterations: 9.00 E+07 **Run time (Extrapolated)** • 26 Years on 32 cores • - • 10 Years on 128 cores
VENTILATED	**30000 iterations to reach convergence** (Used as initialization for the Transient CFD run) **Run time:** • 77.5 hours on 32 cores (1 node) • 43.8 hours on 64 cores (2 nodes) • 31.5 hours on 128 cores (4 nodes)	Solving thermal Freezing the flow-field (Flow and Turbulence) **Physical time modeled: 60min (2 cycle of 30 min)** • Time Step = 10 to 15 s • Inner iterations: 10 • Iterations: 10 **Run time** • 7.3 hours on 64 cores • - • 3.2 hours on 128 cores

On-going discussion in SISSA to get higher priority on the HW booking so as to understand availlibility for the project and build High fidelity database

ADITIONAL INFO
COST & RUN-TIME Comparison: OpenFOAM & StarCCM+

For ventilated fridges:

- OpenFOAM is 5 to 8 times more costly (HW & SW usage)
- OpenFOAM process is 20 times longer (Steady states + Transient)

For static fridges:

- With OpenFOAM: The effort (HW & SW usage) cannot be consider
- With Starccm+: The effort is still significant (1 week / 5.5k€ to 3 Weeks 15.5 k€)

		SOLVE												TOTAL CLOCK TIME		COST ESTIMATION		
		ARDWARE WORKER		STEADY				TRANSIENT										
		HW	CPUs	MODEL short description	# Iterations SteadyState	Time per iteration [h:mm:ss]	Clock Time [h:mm:ss]	MODEL short description	Physical time modeled [h:mm]	Time step [s]	Inner iteration	# Iterations Transient	Clock Time [h:mm:ss]	[h:mm:ss]	Days / Hours / Minutes	SW	HW	TOTAL
OPEN SOURCE TOOL CHAIN	1900 Combi Bottom FF ParalellTwin VENTILATED	Ulysse @ SISSA	32	CHT / MRF / RADIATION / RANS	30000	0:00:09	77:30:00	CHT / MRF / RA	1:00	15	5	1200	7:20:00	84:50:00	3 days 12 hours	€ -	€ 407	€ 407
			64	CHT / MRF / RADIATION / RANS	30000	0:00:05	43:50:00	CHT / MRF / RADIATION / RANS								€ -	€ -	€ -
			128	CHT / MRF / RADIATION / RANS	30000	0:00:04	31:03:00	CHT / MRF / RA	1:00	15	5	1200	3:12:00	34:15:00	1 days 10 hours	€ -	€ 658	€ 658
STARCCM+	1900 Combi Bottom FF ParalellTwin VENTILATED	EDISA	64	CHT / MRF / RADIATION / RANS	600	0:00:05	0:55:00	RF / RADIATION	1:00	15	10	2400	3:40:00	4:35:00	4 hours 35 Minutes	€ 92	€ 44	€ 136
OPEN SOURCE TOOL CHAIN	1900 Combi Bottom FF ParalellTwin STATIC	Ulysse @ SISSA	32		20000	0:00:09	52:00:00	CHT / MRF / RA	1:00	2E-04	5	9E+07	234000:00:00	234052:00:00	26 Year 12	€ -	€ 1,122,298	€ 1,122,298
			64		20000	0:00:05	29:20:00	CHT / MRF / RA	1:00	2E-04	5	9E+07	132000:00:00	132029:20:00	15 Year 22	€ -	€ 1,266,560	€ 1,266,560
			128	CHT / MRF / RADIATION / RANS	20000	0:00:04	21:00:00	CHT / MRF / RA	1:00	2E-04	5	9E+07	94500:00:00	94521:00:00	10 Year 12	€ -	€ 1,812,038	€ 1,812,038
STARCCM+	1900 Combi Bottom FF ParalellTwin STATIC	EDISA	64	CHT / MRF / RADIATION / RANS	600	0:00:05	0:55:00	RF / RADIATION	1:00	3E-01	10	120000	183:20:00	184:15:00	7 days 16 hours	€ 3,685	€ 1,769	€ 5,454
																lculated	Calculated	Calculated

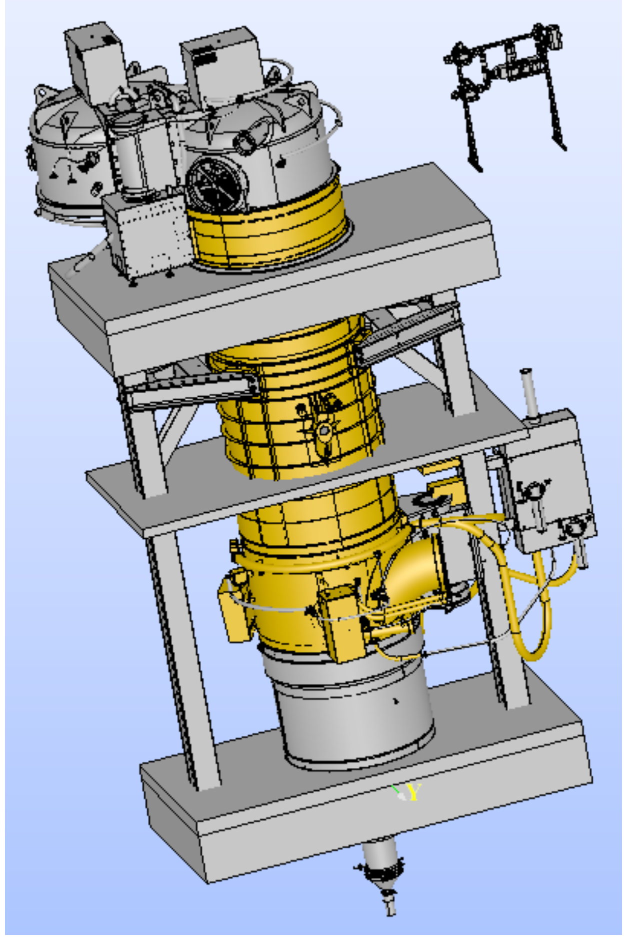
(*) Data extracted from GENSI and MIDSUMMAR project

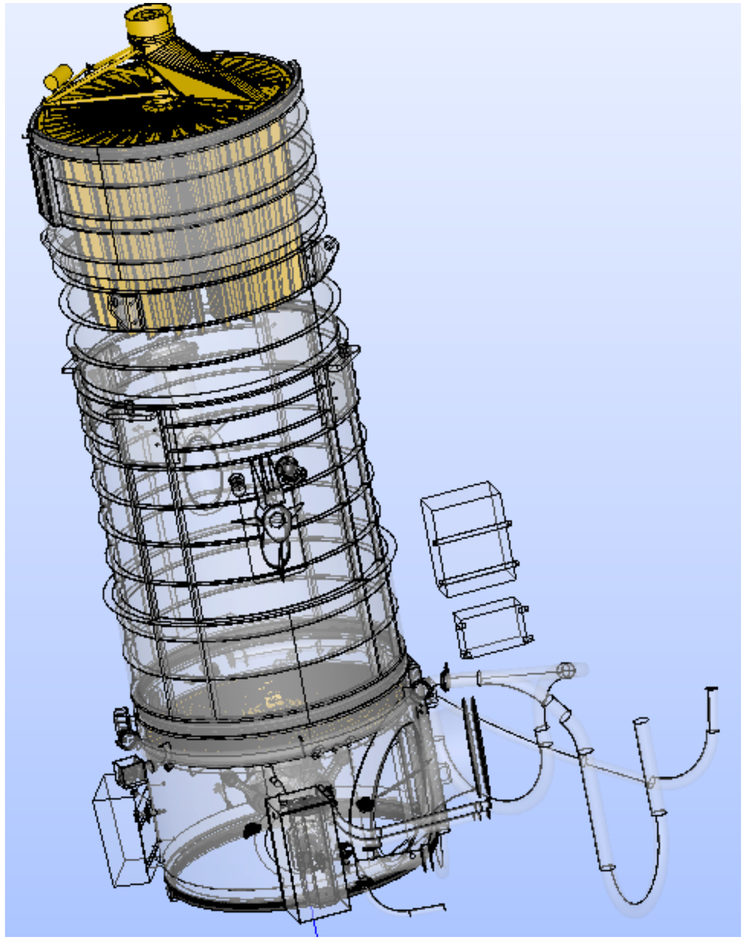
Numerical modeling of INNOJET VENTULUS V1000 granulator

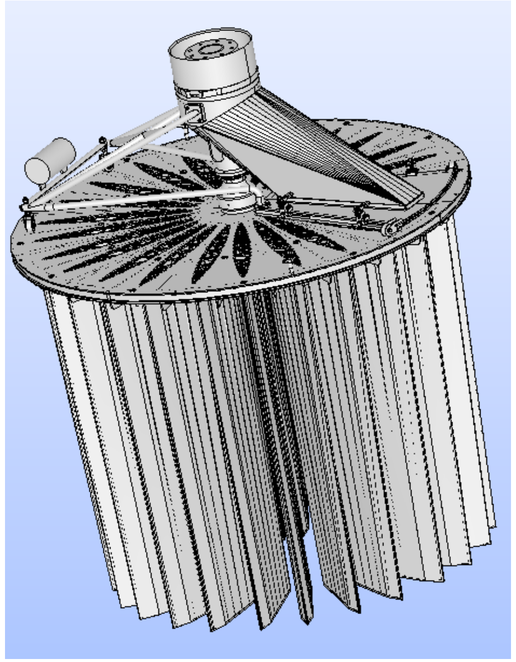
Speaker: Arash Hajisharifi

28/06/2023

Geometry simplification





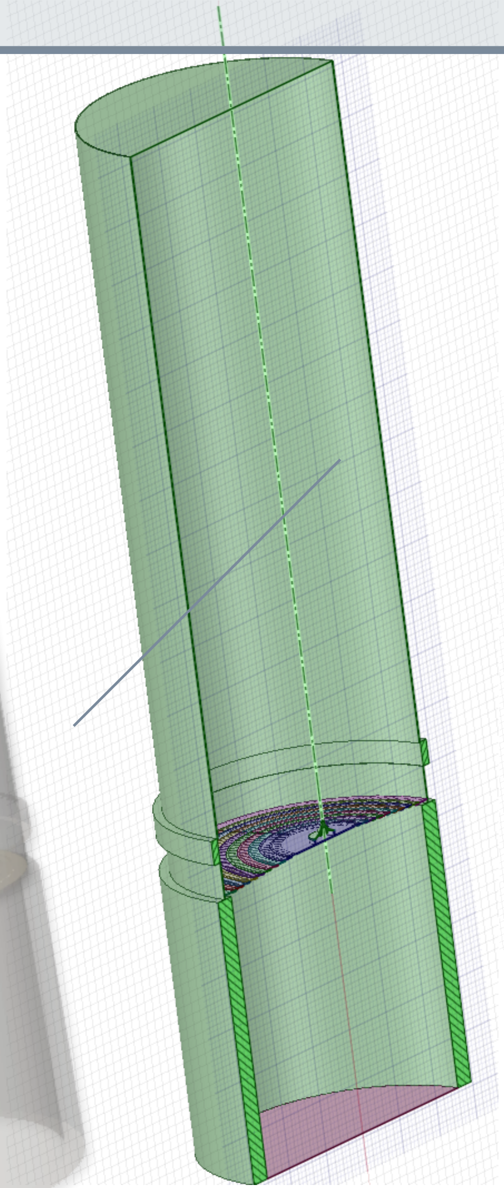


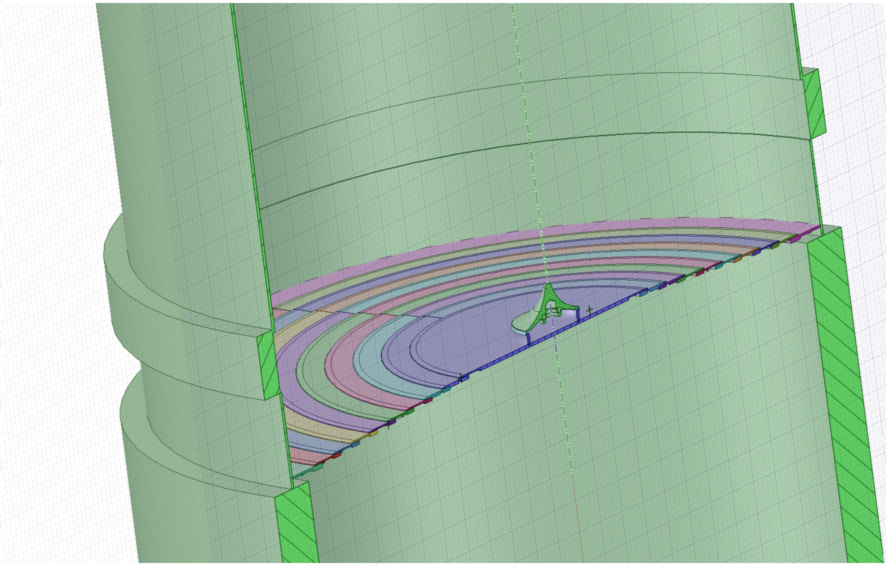
Geometry simplification

- The additional internal and external elements are removed

- The geometry was simplified first to decrease complexity and mesh numbers

- The problem is the middle plate which can not be simplified since it has a direct influence on the dynamic of the flow

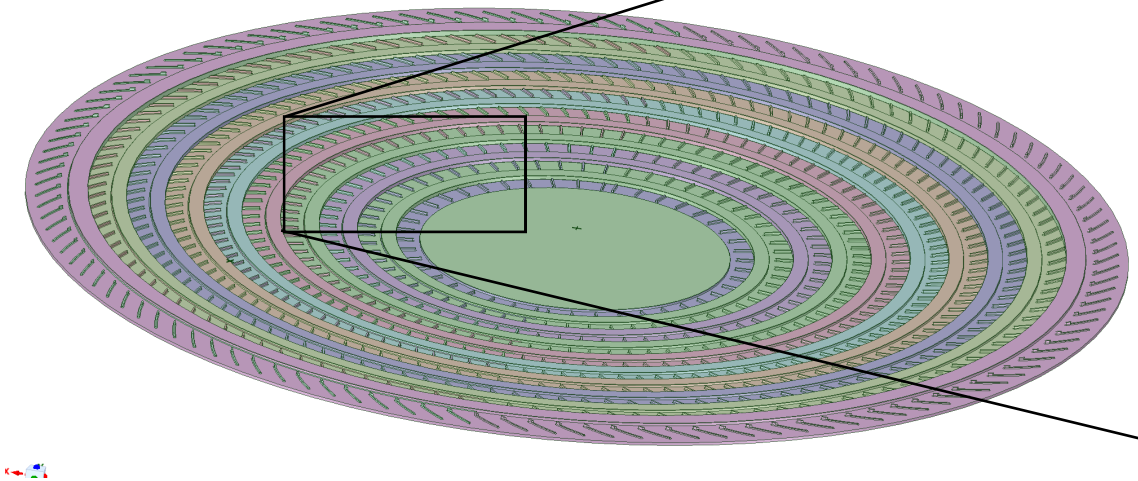


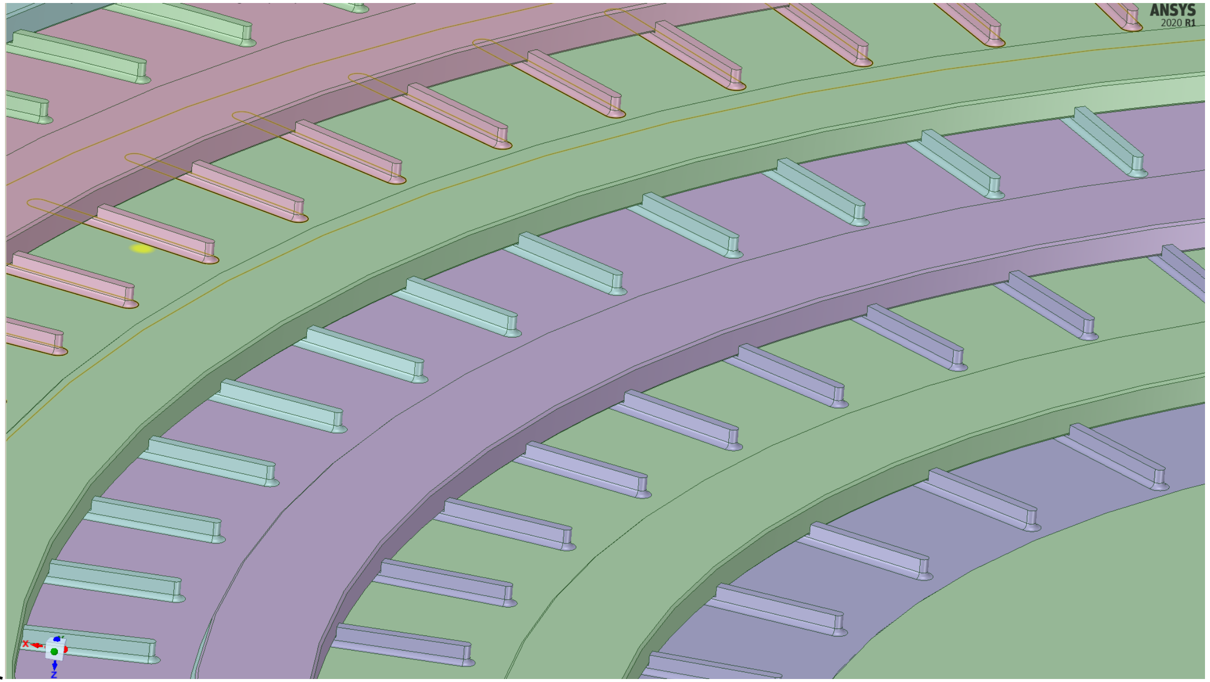


- There are elevations on the plate

- The blade that guides the fluid flow, increases the complexity of the plate

- These details can not be removed

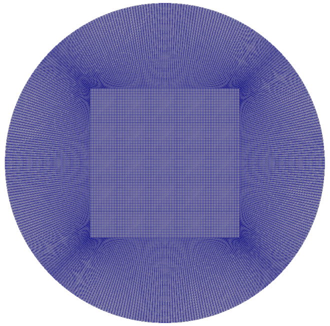


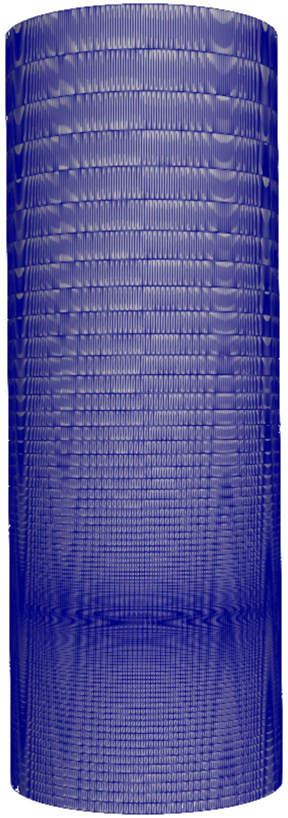


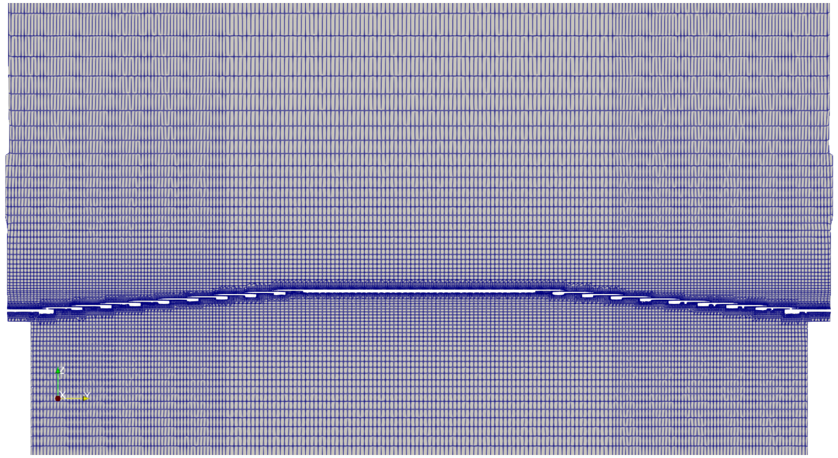
Mesh Generation

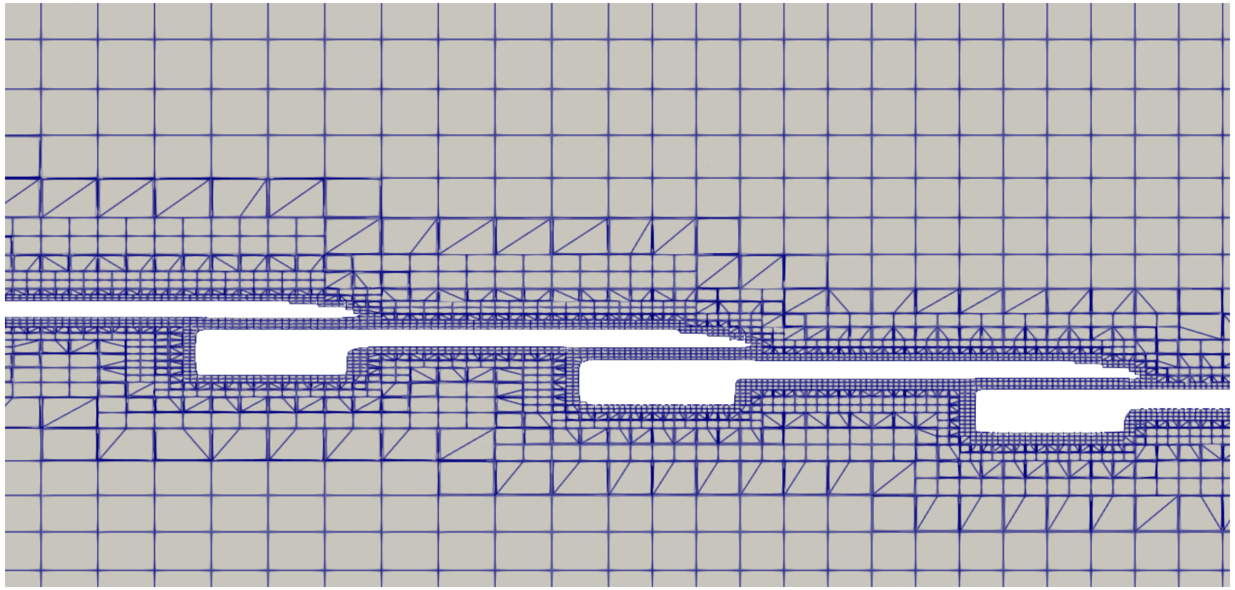
- SanppyHexaMesh was used for mesh genration
- The mesh is totally compatible with OpenFOAM
- Difficulty to produce high quality mesh for complex geometry for the fluid region within the plate
- Local refinement and boundary layers must be managed manually

Min Size	Max Size	Cell numbers	Clock time
0.05 mm	50 mm	25’560’000	3 hours



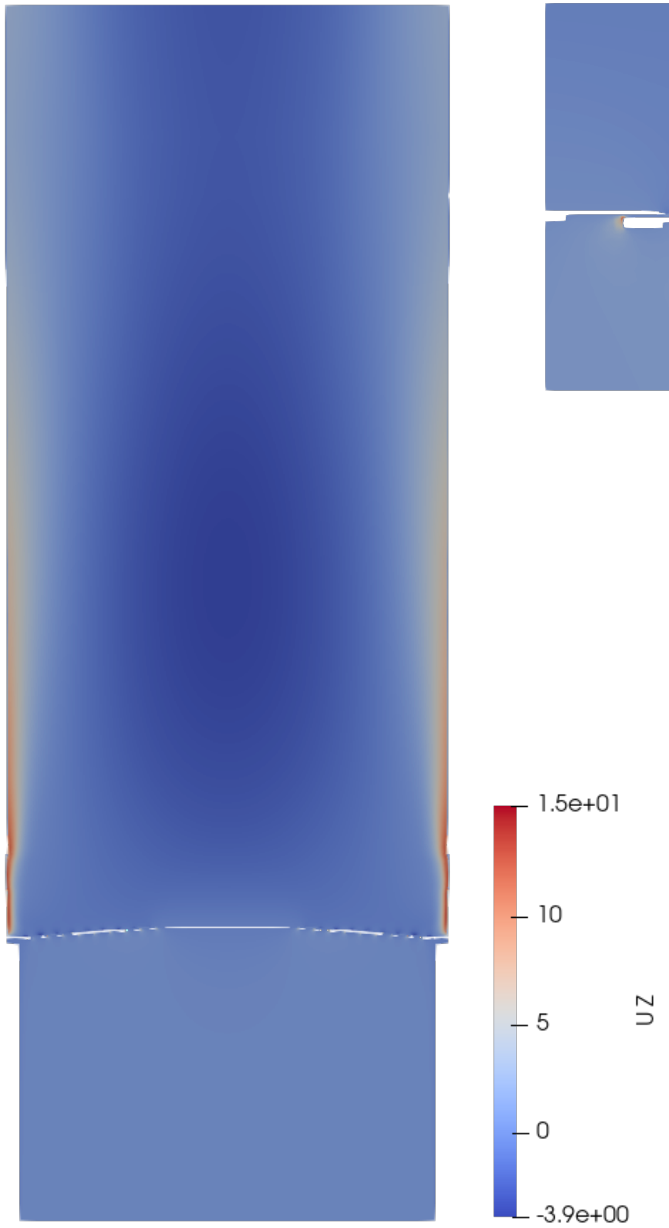


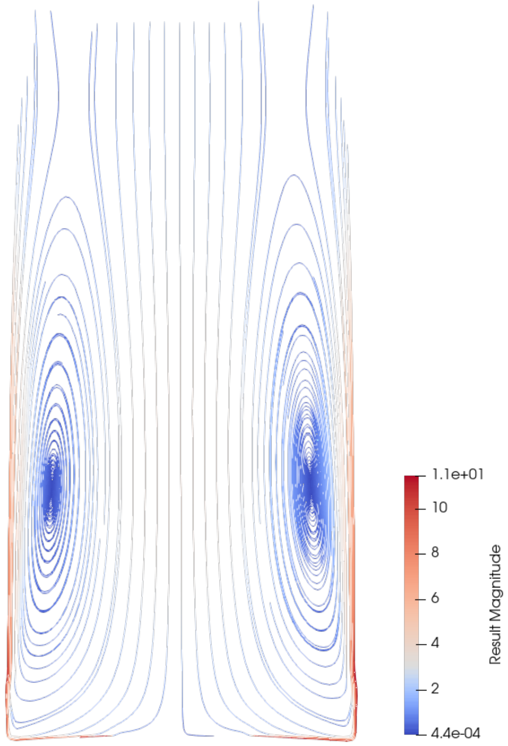




Results

- The flow on the inlet section is deflected by 90° by the orbiter and accelerated in a radial direction
- The fluid flow has a rotational motion according to the arrangement of the thin blades.
- This simulation has been continued to reach to steady-state





More simplification

- We have removed the lower part of the granulator and plate.
- We use the outflow of the steady-state simulation on the plate as the boundary condition for the upper part of the cylinder
- The mesh number is reduced from 25 M to 500 K and it is a perfectly structured mesh.
- We have launched the productive simulation on this geometry with 500k Mesh.