# Pre-design of the Performance-Based Design of the smoke management system Lausanne University Library

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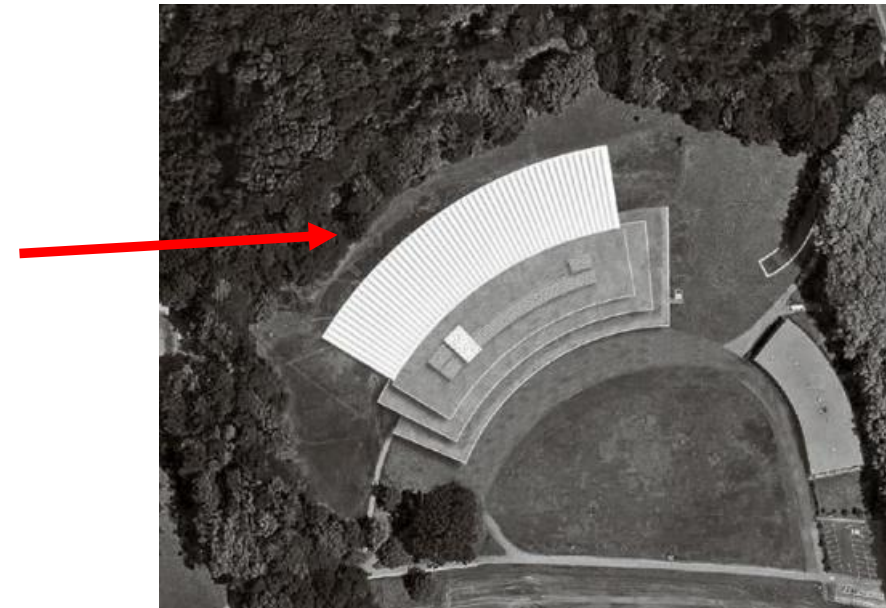
Eric **TONICELLO** – ISI - Ingénierie et Sécurité Incendie Sàrl – Lausanne – Switzerland
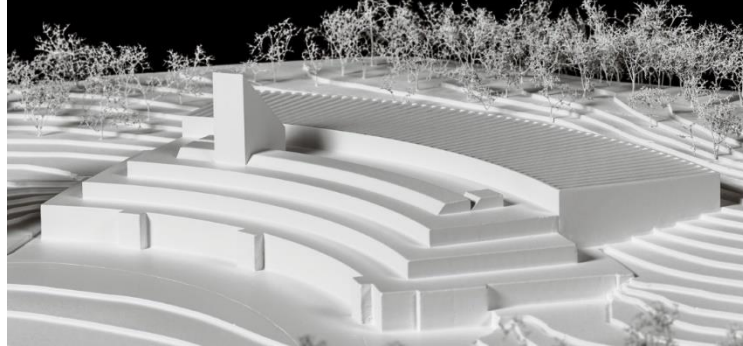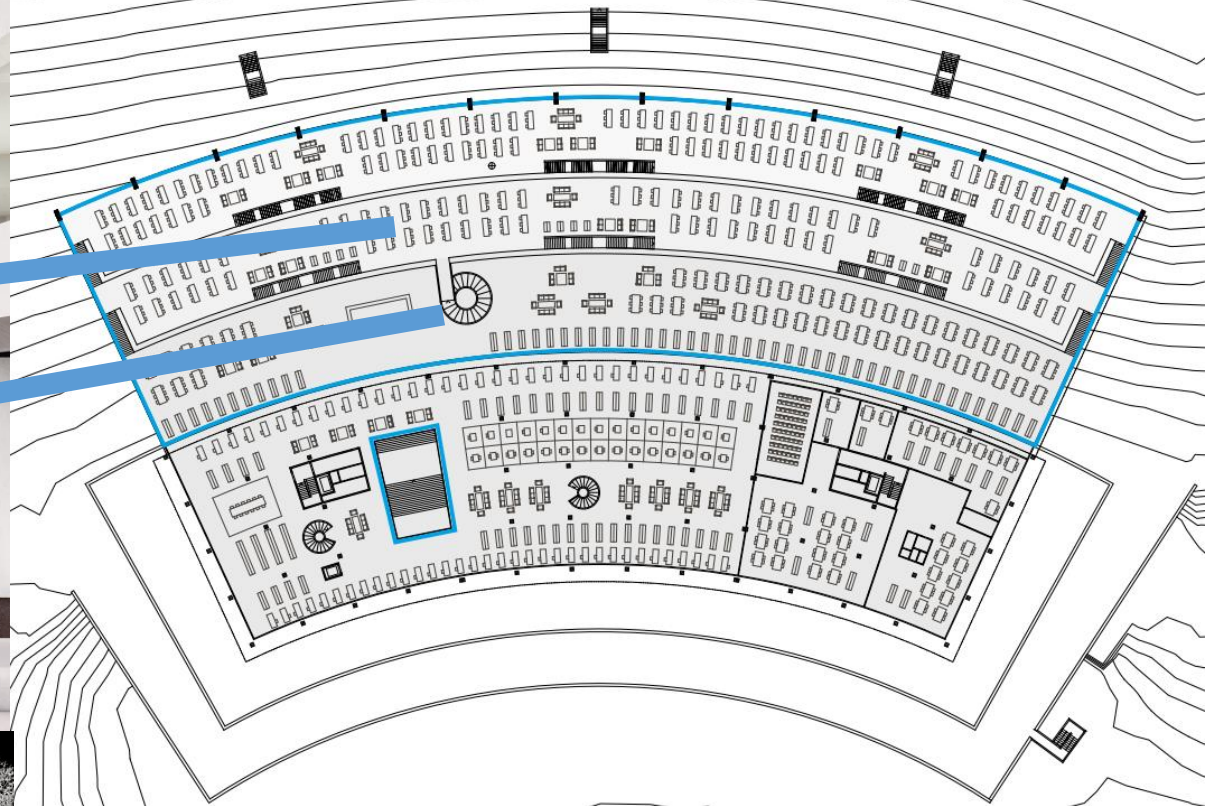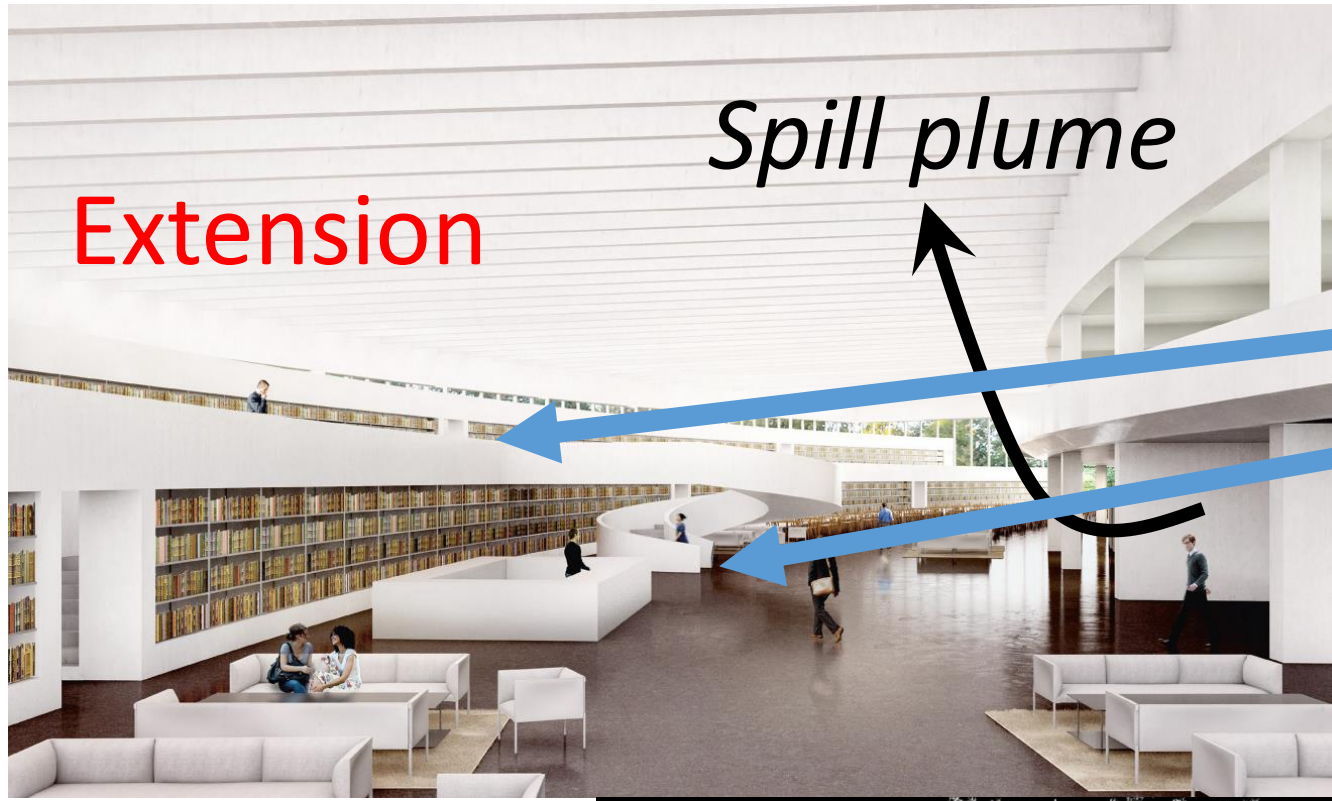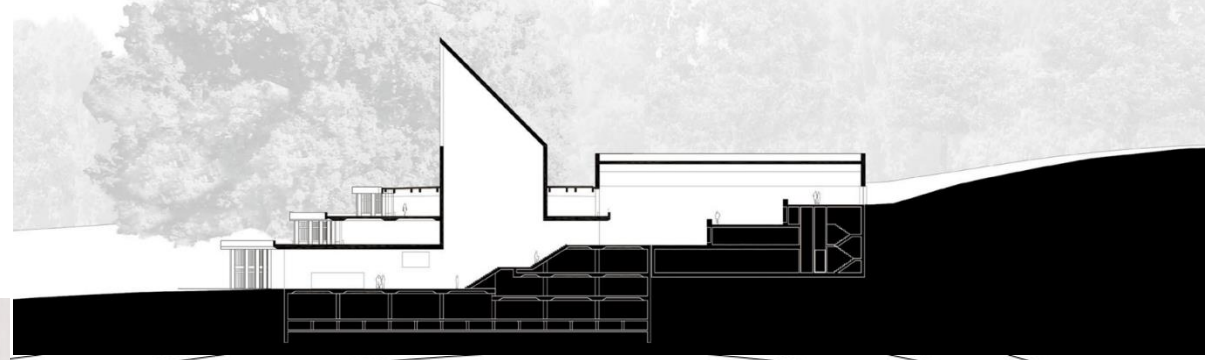
Context of the study

➢ « Bibliothèque cantonale et universitaire de Lausanne (BCUL) »

➢ Original building used since 1983

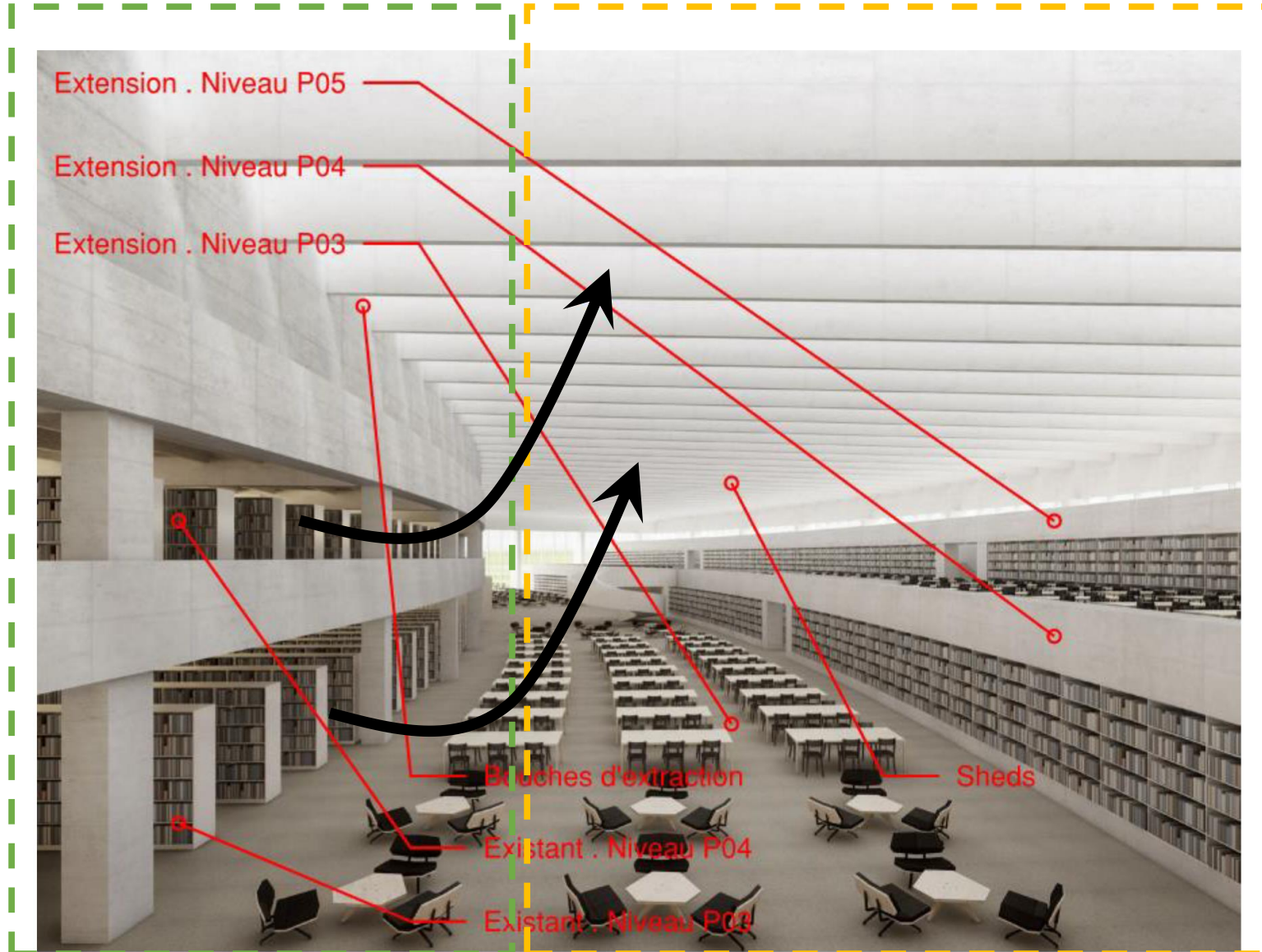➢ Increasing number of students at UNIL
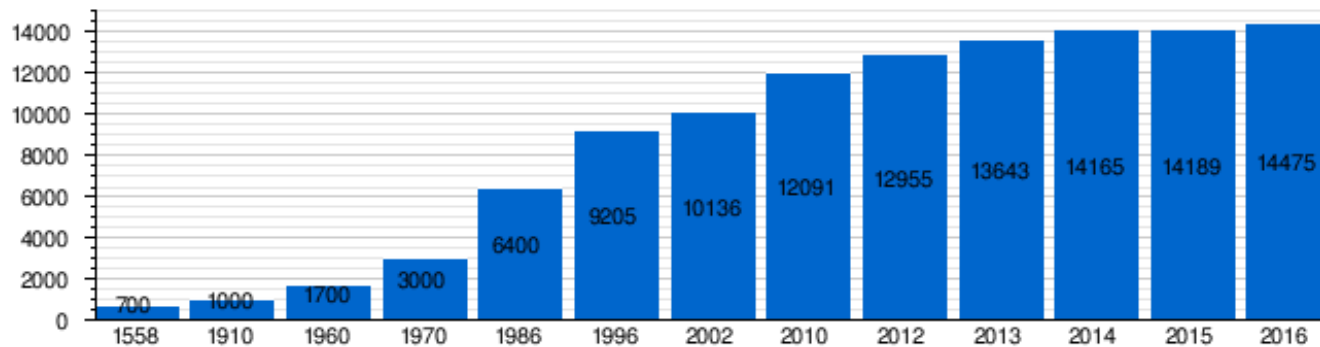
➢ Need for an extension of the building

   ➢ Seating capacity x 2 + shelving length x 2
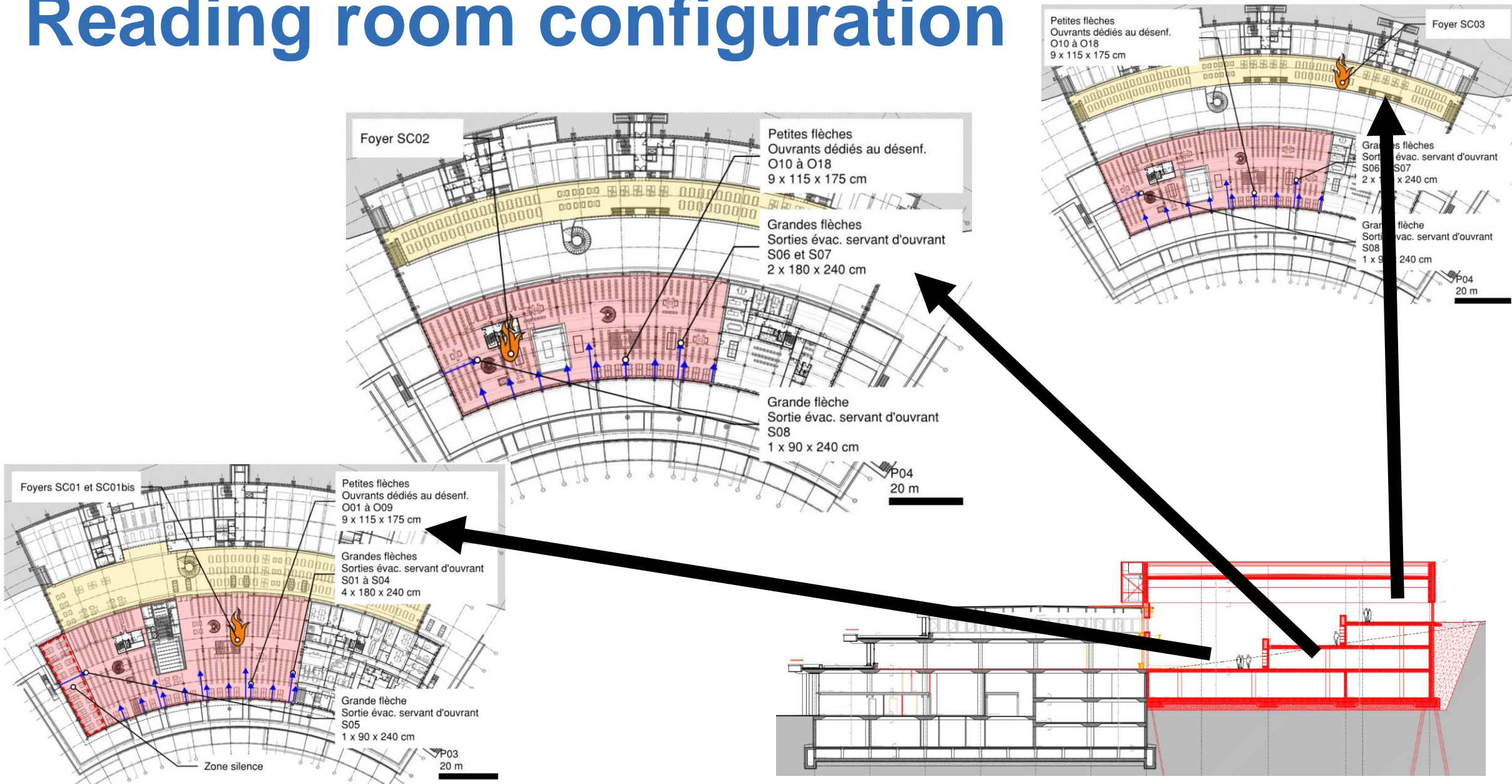
   ➢ Expansion of the restaurant (not presented)

Architectural project

Extension
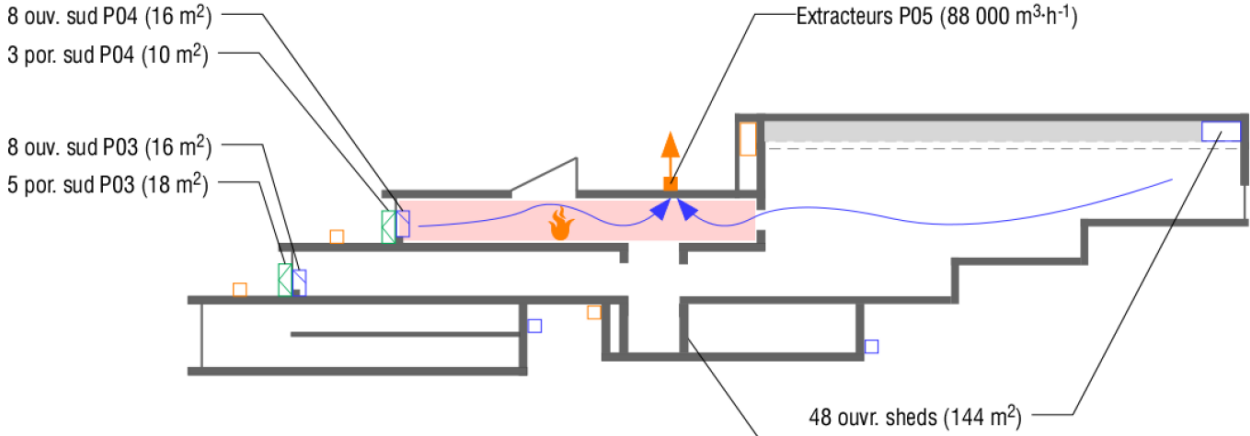
Spill plume

Architectural project

Reading room configuration

Foyer SC02

Petites flèches
Ouvrants dédiés au désenf.
O10 à O18
9 x 115 x 175 cm

Grandes flèches
Sorties évac. servant d'ouvrant
S06 et S07
2 x 180 x 240 cm

Grande flèche
Sortie évac. servant d'ouvrant
S08
1 x 90 x 240 cm

P04
20 m

Petites flèches
Ouvrants dédiés au désenf.
O10 à O18
9 x 115 x 175 cm

Foyer SC03

Grandes flèches
Sorties évac. servant d'ouvrant
S06 et S07
2 x 180 x 240 cm

Grande flèche
Sortie évac. servant d'ouvrant
S08
1 x 90 x 240 cm

P04
20 m

Foyers SC01 et SC01bis

Petites flèches
Ouvrants dédiés au désenf.
O01 à O09
9 x 115 x 175 cm

Grandes flèches
Sorties évac. servant d'ouvrant
S01 à S04
4 x 180 x 240 cm

Grande flèche
Sortie évac. servant d'ouvrant
S05
1 x 90 x 240 cm

Zone silence

P03
20 m

Fire safety issue : smoke management

➤ Strategy

8 ouv. sud P04 (16 m^2)
3 por. sud P04 (10 m^2)
8 ouvr. sud P03 (16 m^2)
5 por. sud P03 (18 m^2)
Extracteurs P07 (360 000 m^3·h^{-1})
Extracteurs P04 (106 000 m^3·h^{-1})
48 ouvr. sheds (144 m^2)
Cylindre en béton

8 ouv. sud P04 (16 m^2)
3 por. sud P04 (10 m^2)
8 ouv. sud P03 (16 m^2)
5 por. sud P03 (18 m^2)
Extracteurs P05 (88 000 m^3·h^{-1})
48 ouvr. sheds (144 m^2)

Fire safety issue : smoke management

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8 ouv. sud P04 (16 m^2)

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5 por. sud P03 (18 m^2)

Extracteurs P07 (360 000 m^3·h^{-1})

48 ouvr. sheds (144 m^2)

Cylindre en béton

Extracteurs P04 (106 000 m^3·h^{-1})

Fire safety issue : smoke management

Bouches d'extraction dans les sheds
48 x 70 x 70 cm

Extracteurs E01 à E03
3 x 230000 m3/h
raccordés aux bouches

P06
20 m

Fire safety issue : smoke management

➢Strategy

8 ouv. sud P04 (16 m^2)

3 por. sud P04 (10 m^2)

8 ouv. sud P03 (16 m^2)

5 por. sud P03 (18 m^2)

Extracteurs P05 (88 000 m^3·h^{-1})

48 ouvr. sheds (144 m^2)

Fire safety issue : smoke management

Gaine d'amenée d'air mécanique G02
20000 m³/h

Foyer SC06

Extracteurs E22 à E25
En toiture du P02
4 x 15000 m³/h

Extension

Existant

P02
20 m

Fire safety engineering study

> Fire scenarios
>> Cellulosic and plastic « mixed » fire
>>> 25 MJ/kg – 5 % soot production
>> Small « smoky » fire
>>> 25 MJ/kg – 10 % soot production
>> Several locations in the room

Heat Release Rate
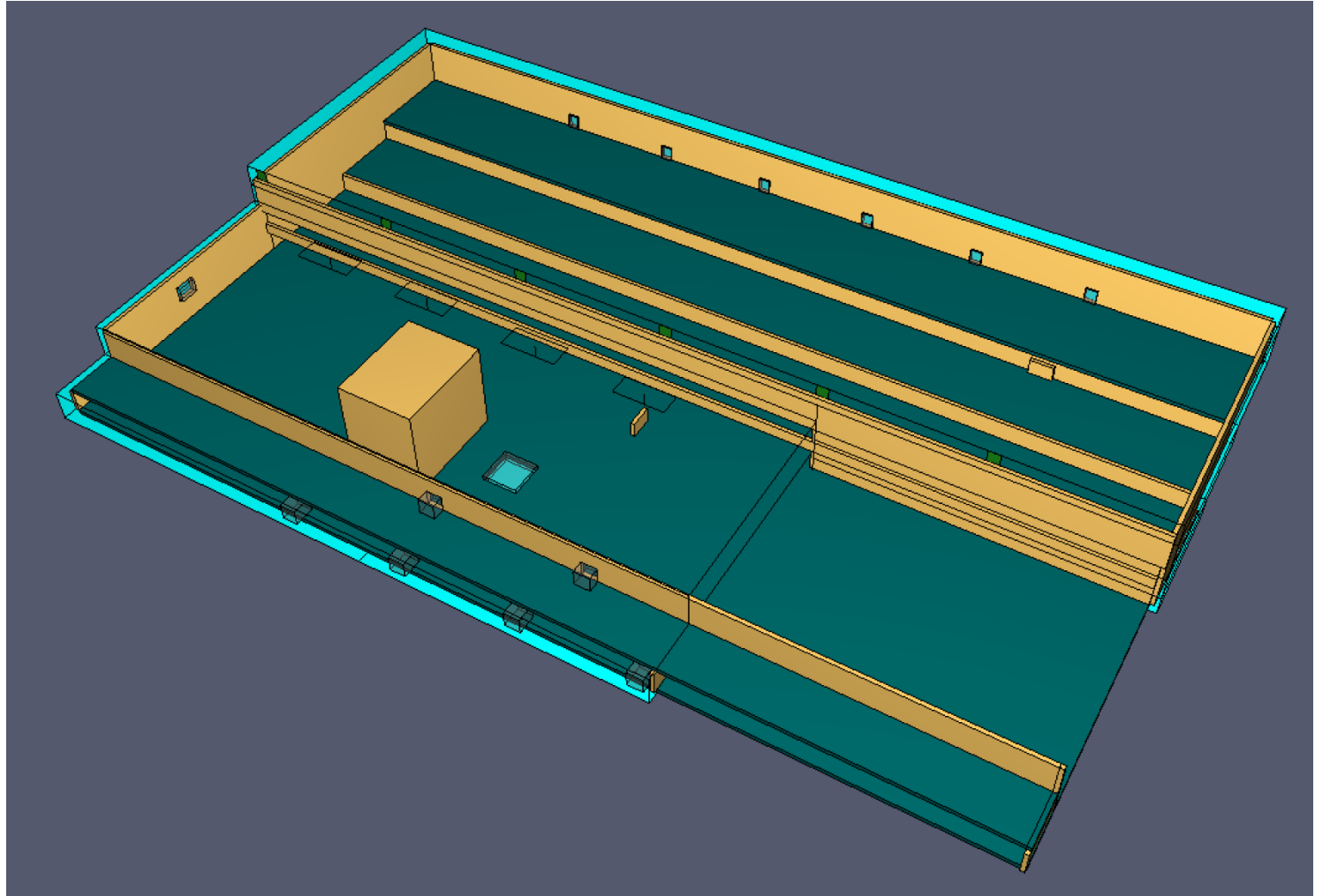

Spill plume
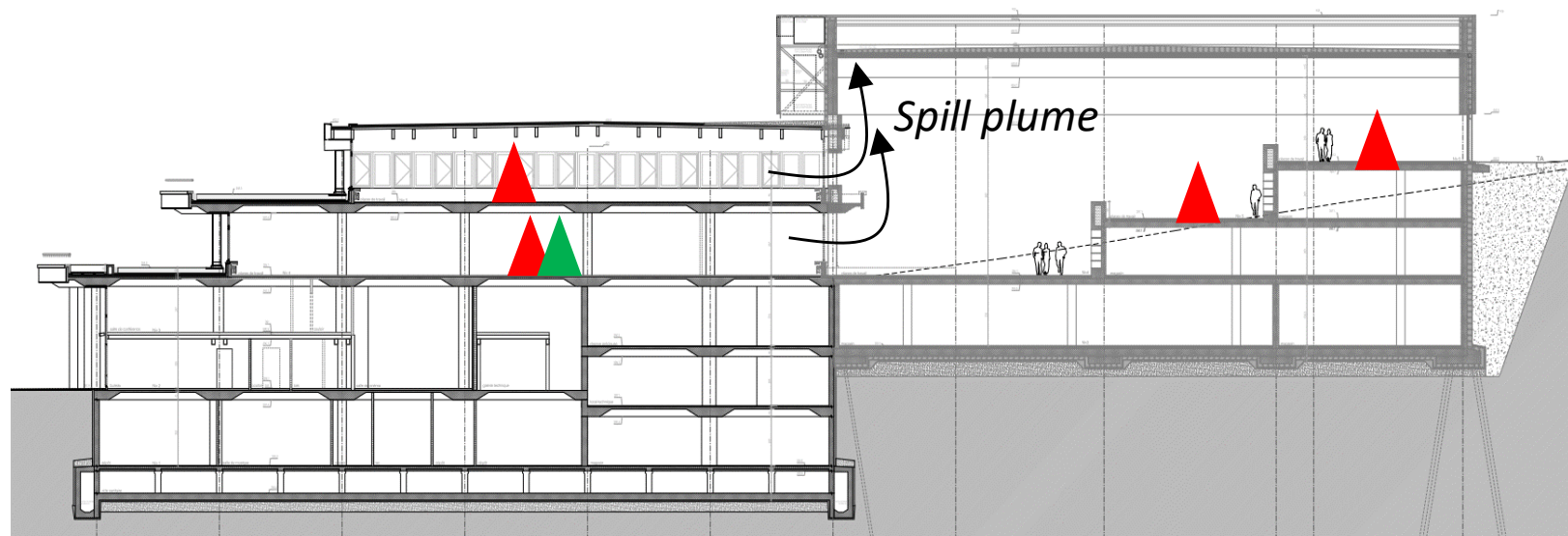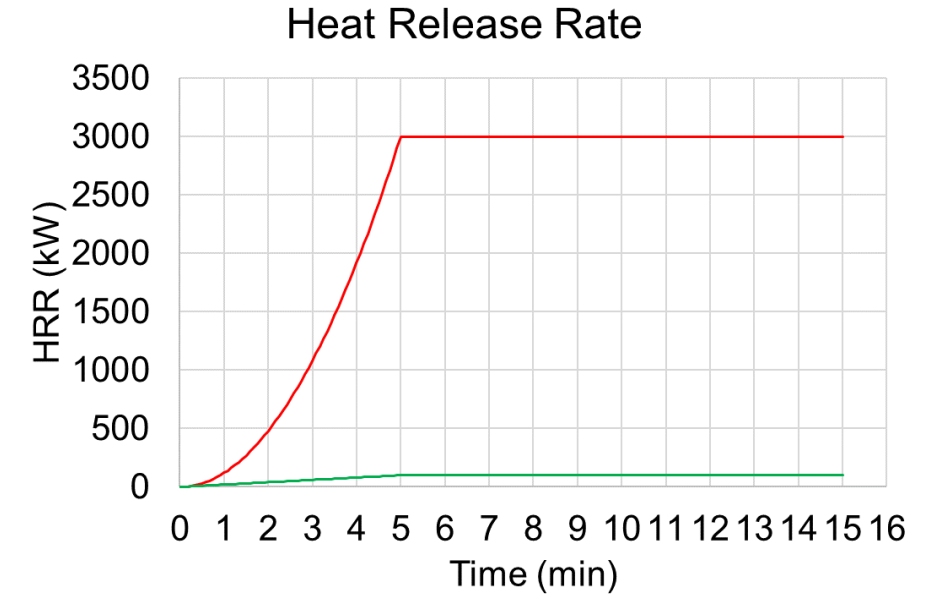
Fire safety engineering study

➢ Building modeled using FDS 6 : **13'000'000 cells with a 20cm grid**

➢ 48 meshes for efficient calculation time : 2-3 days on HPC computer
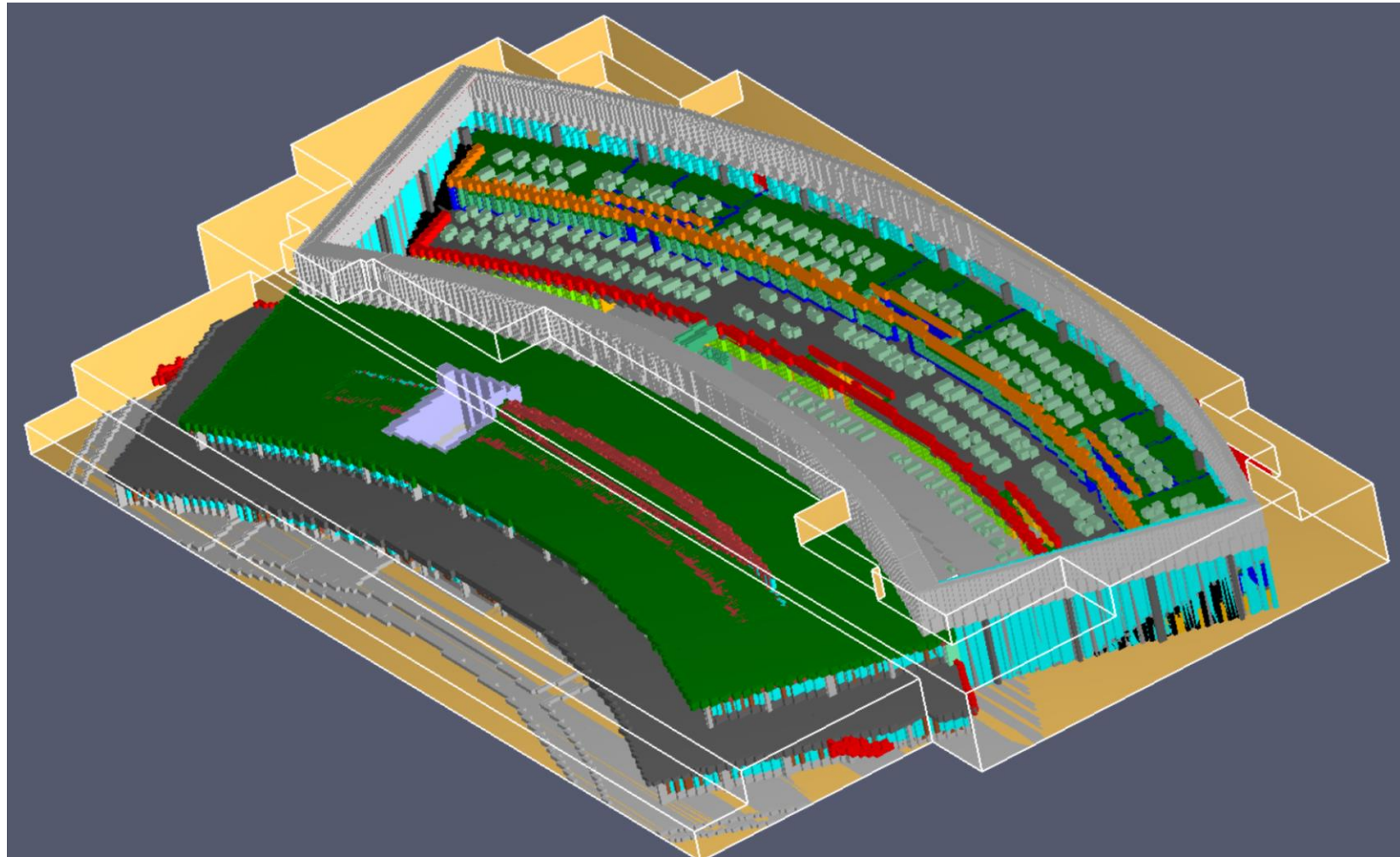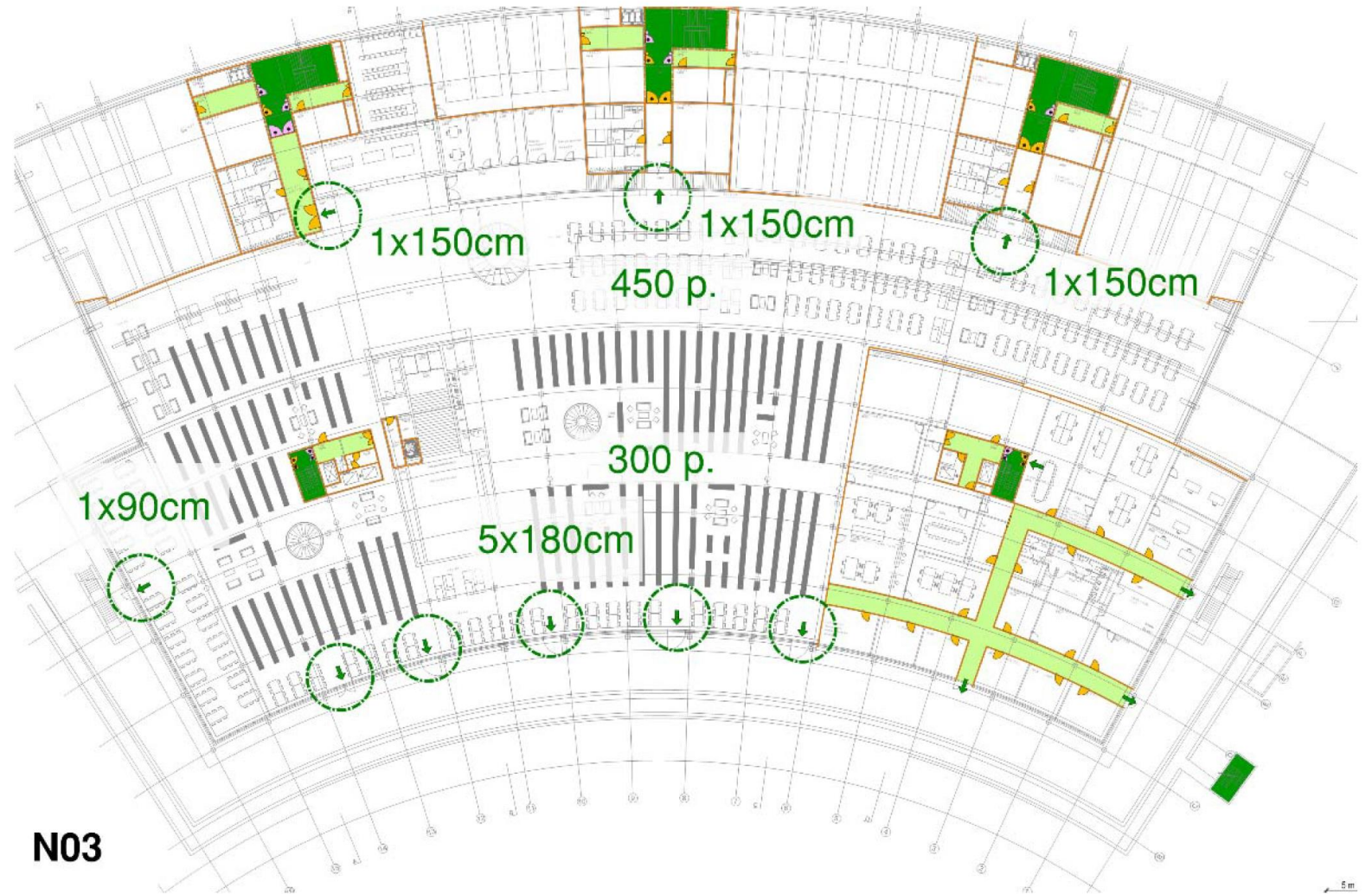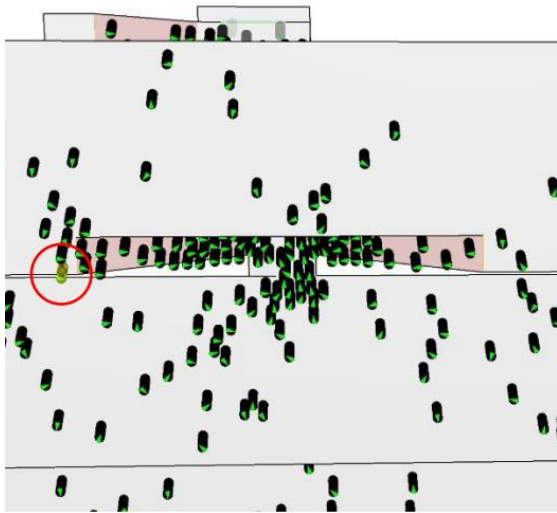
Fire safety engineering study

➤ Simplified building modeled using FDS 6 : **3'000'000 cells with a 20cm grid**

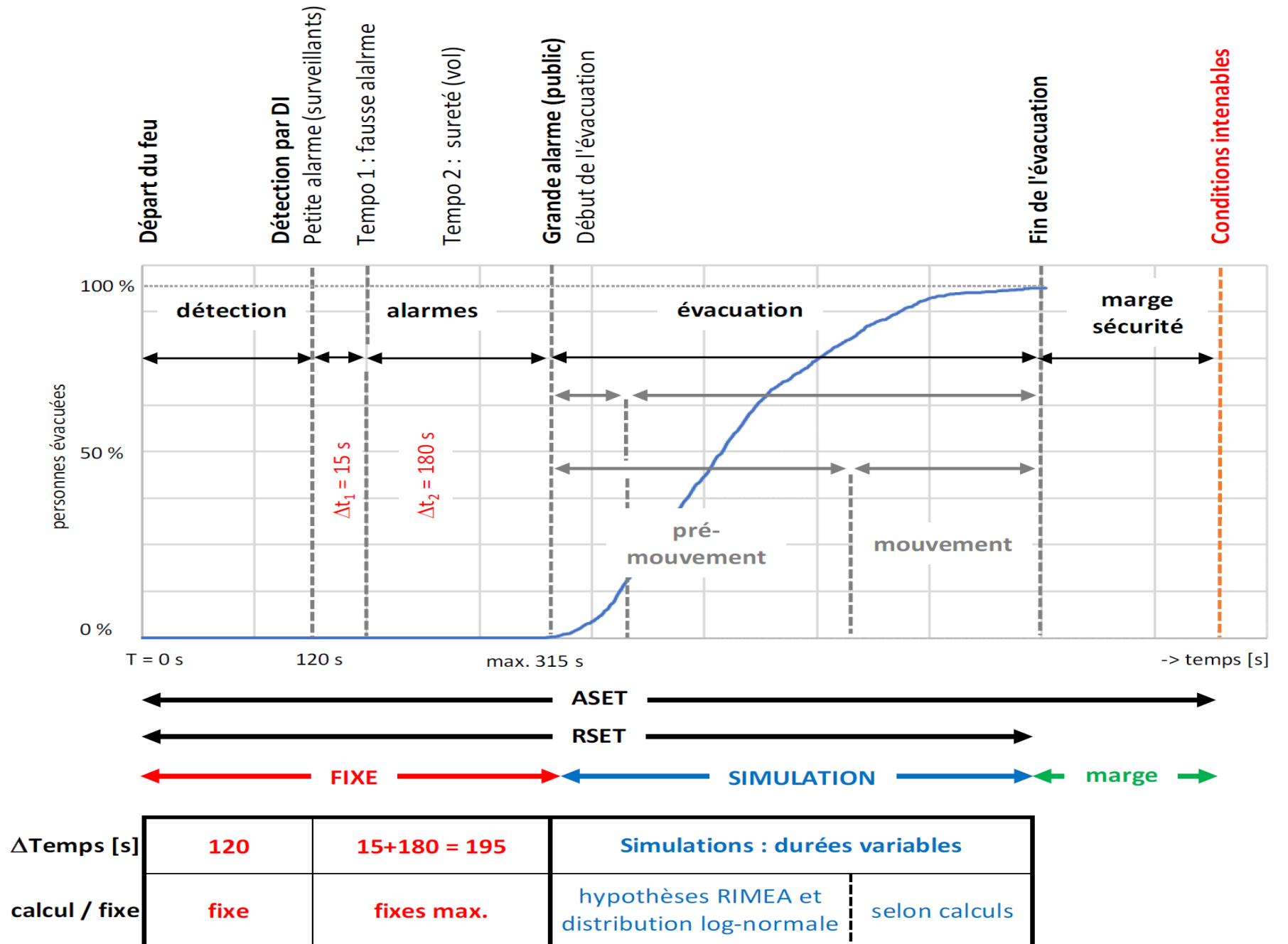➤ 16 meshes for efficient calculation time : 1 day on HPC computer

Evacuation modeling

➢Model with **Pathfinder**

- 50 up to 2000 users

1x150cm

1x150cm

1x150cm

450 p.

1x90cm

300 p.

5x180cm

N03

Evacuation modeling

Definition of the times and delay…

ΔTemps [s]	120	15+180 = 195	Simulations : durées variables	
calcul / fixe	fixe	fixes max.	hypothèses RIMEA et distribution log-normale	selon calculs

Evacuation modeling – Pre-movement times

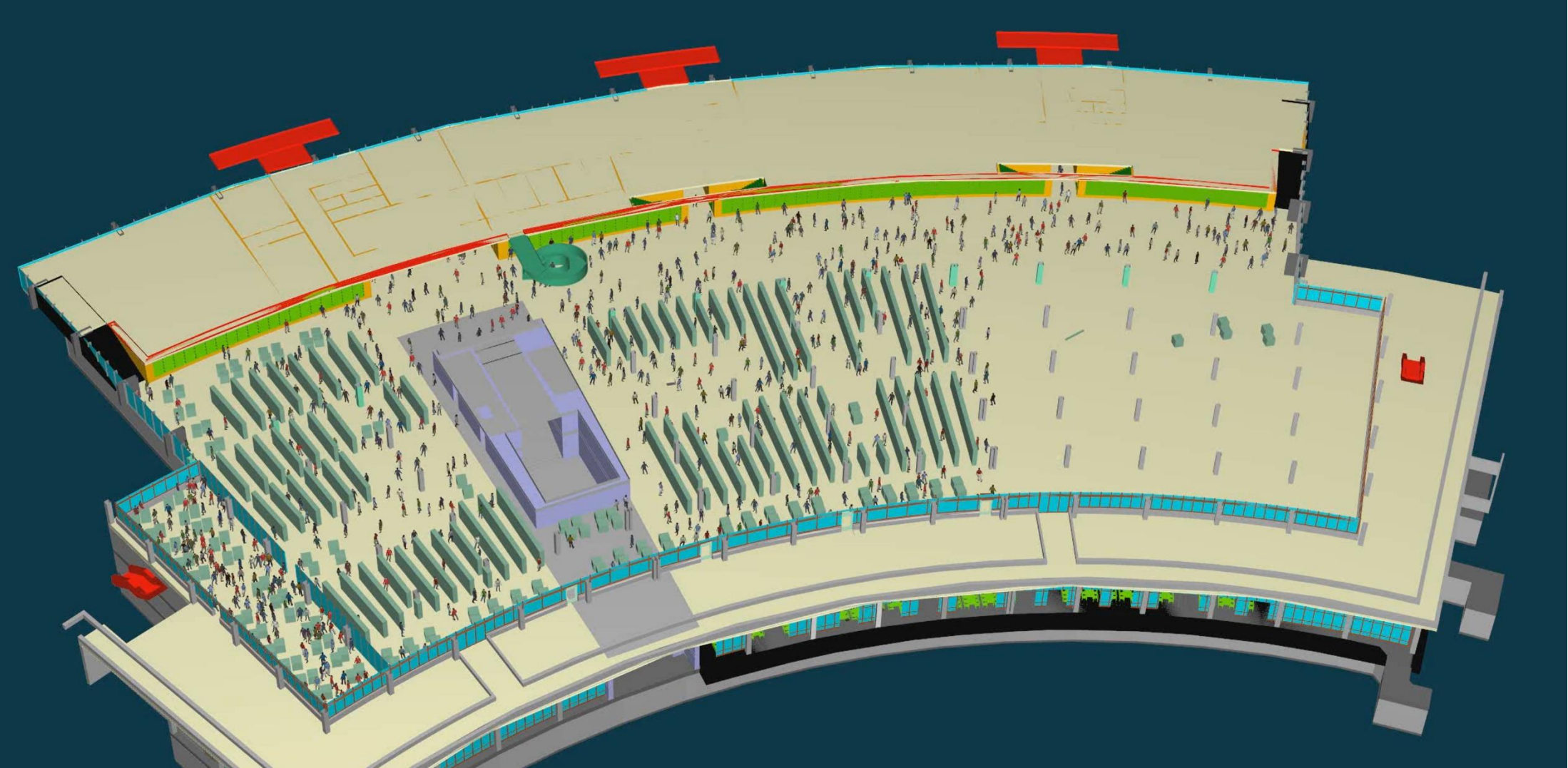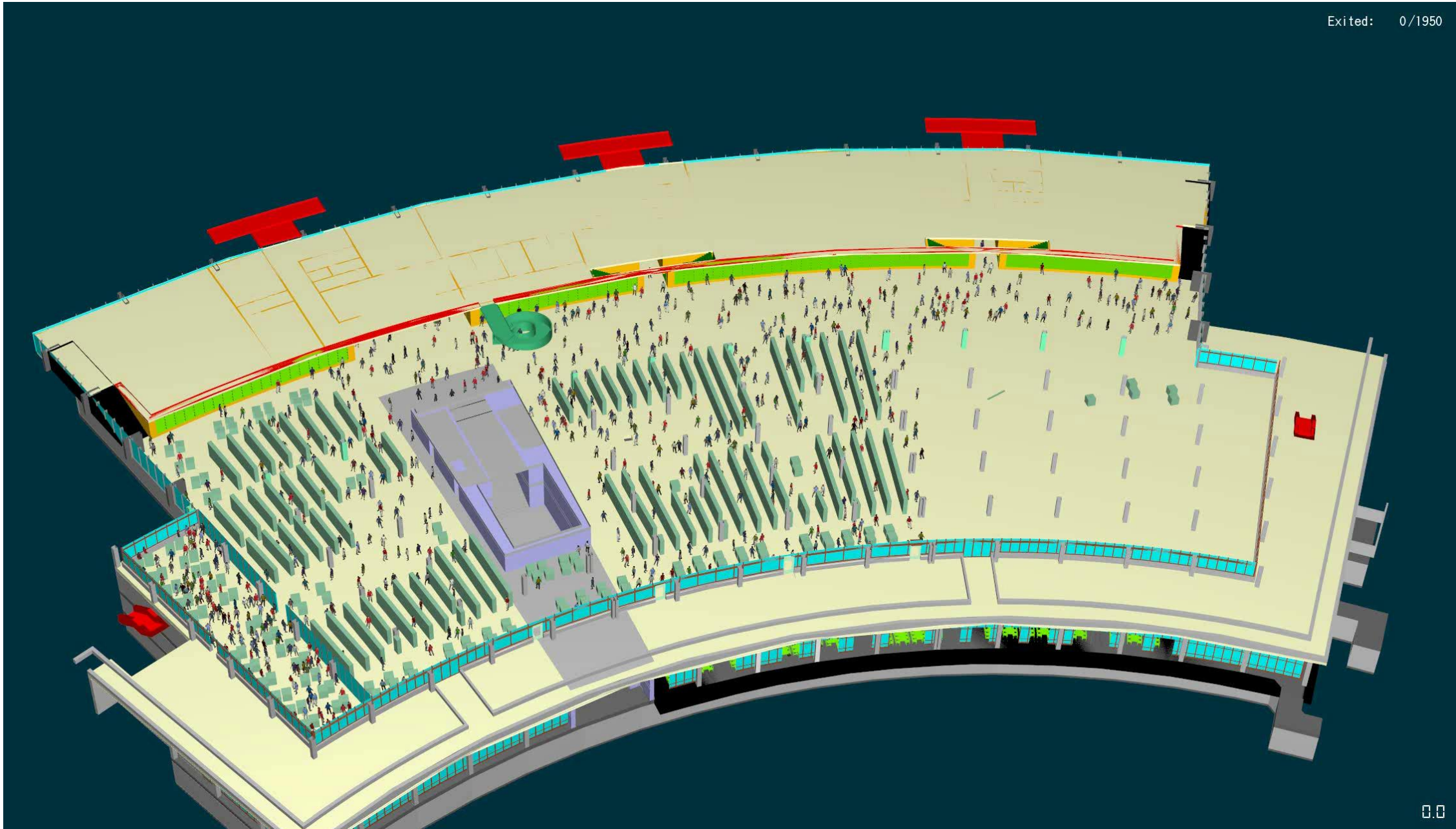| Group of persons	Mean walking speeds on stairs (m/s)			
	downstairs		upstairs	
	(1)	(2)	(1)	(2)
Under 30 years of age	0.76	0.81	0.55	0.58
30 to 50 years of age	0.65	0.78	0.50	0.58
Over 50 years of age	0.55	0.59	0.42	0.42
Persons with impaired mobility	0.42		0.32	
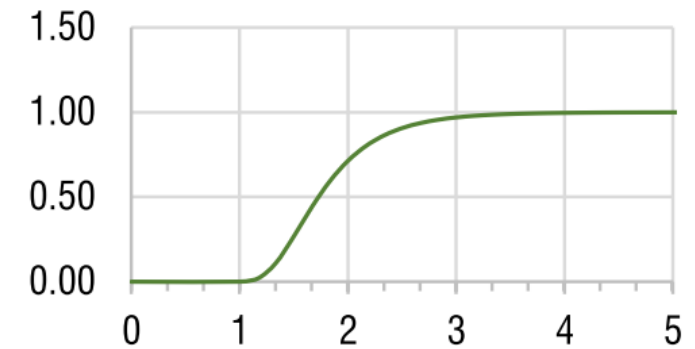
Time (min)

Evac scenarios and modeling
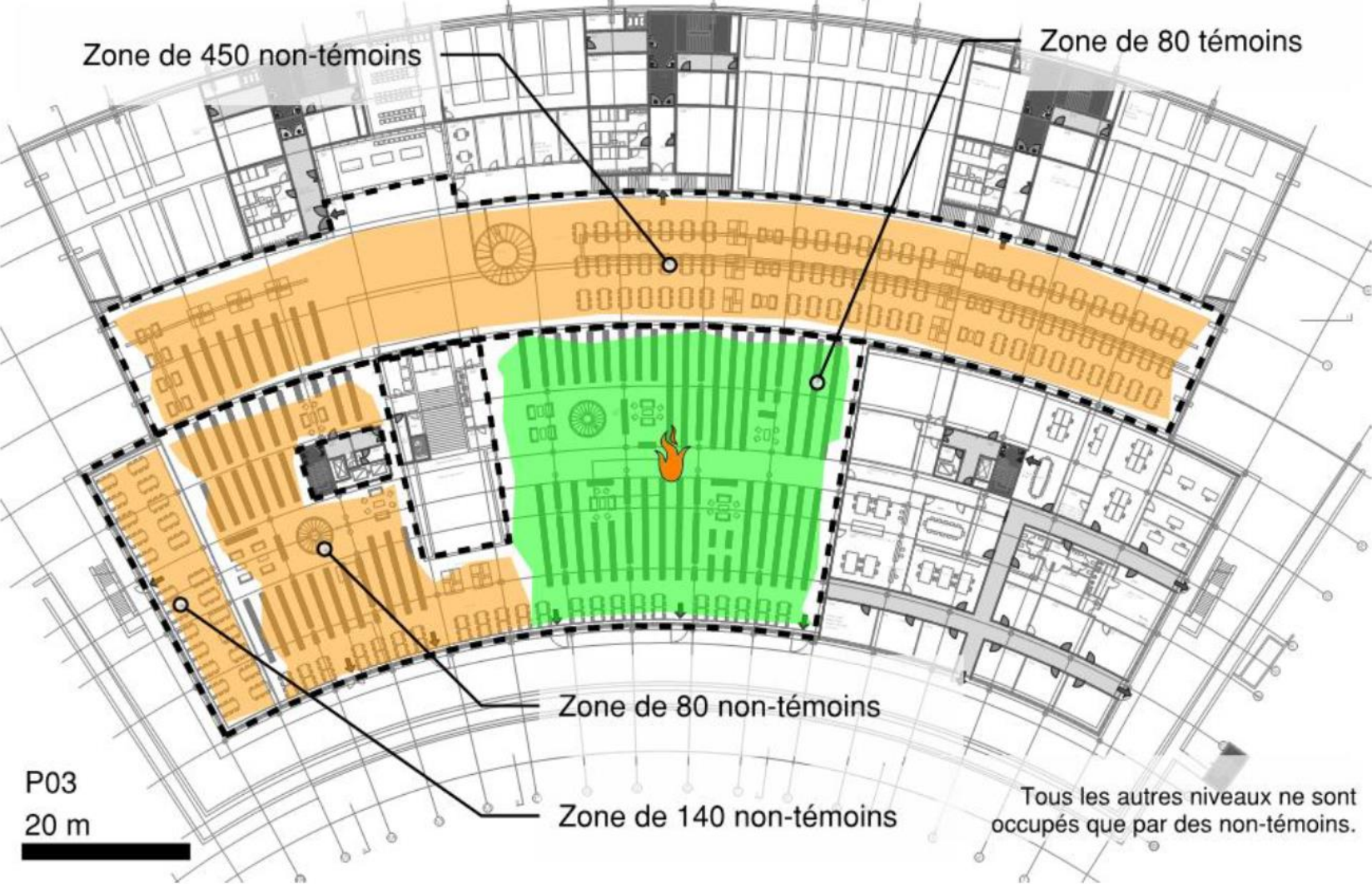
Post-processing

0.0

Post-processing

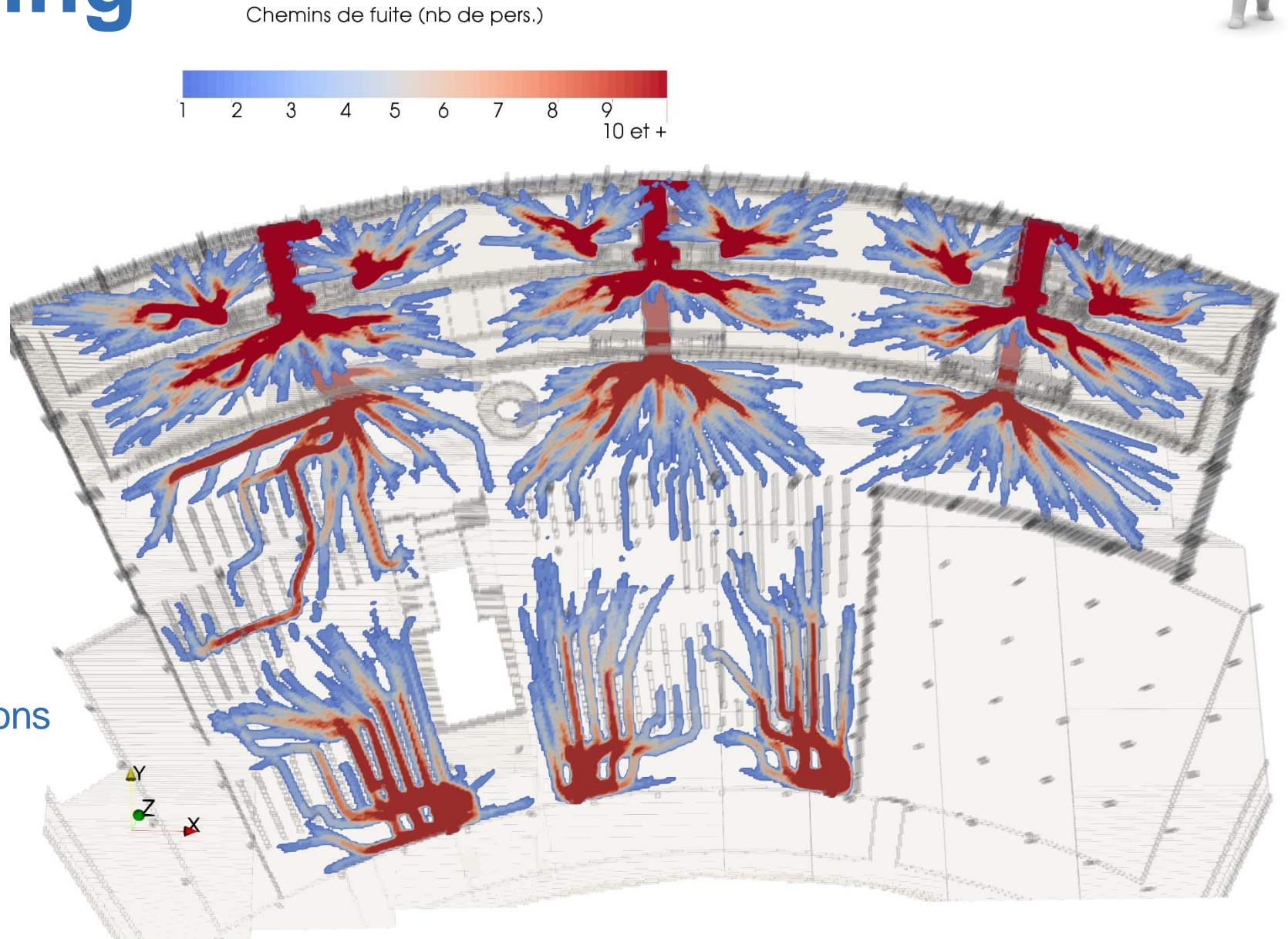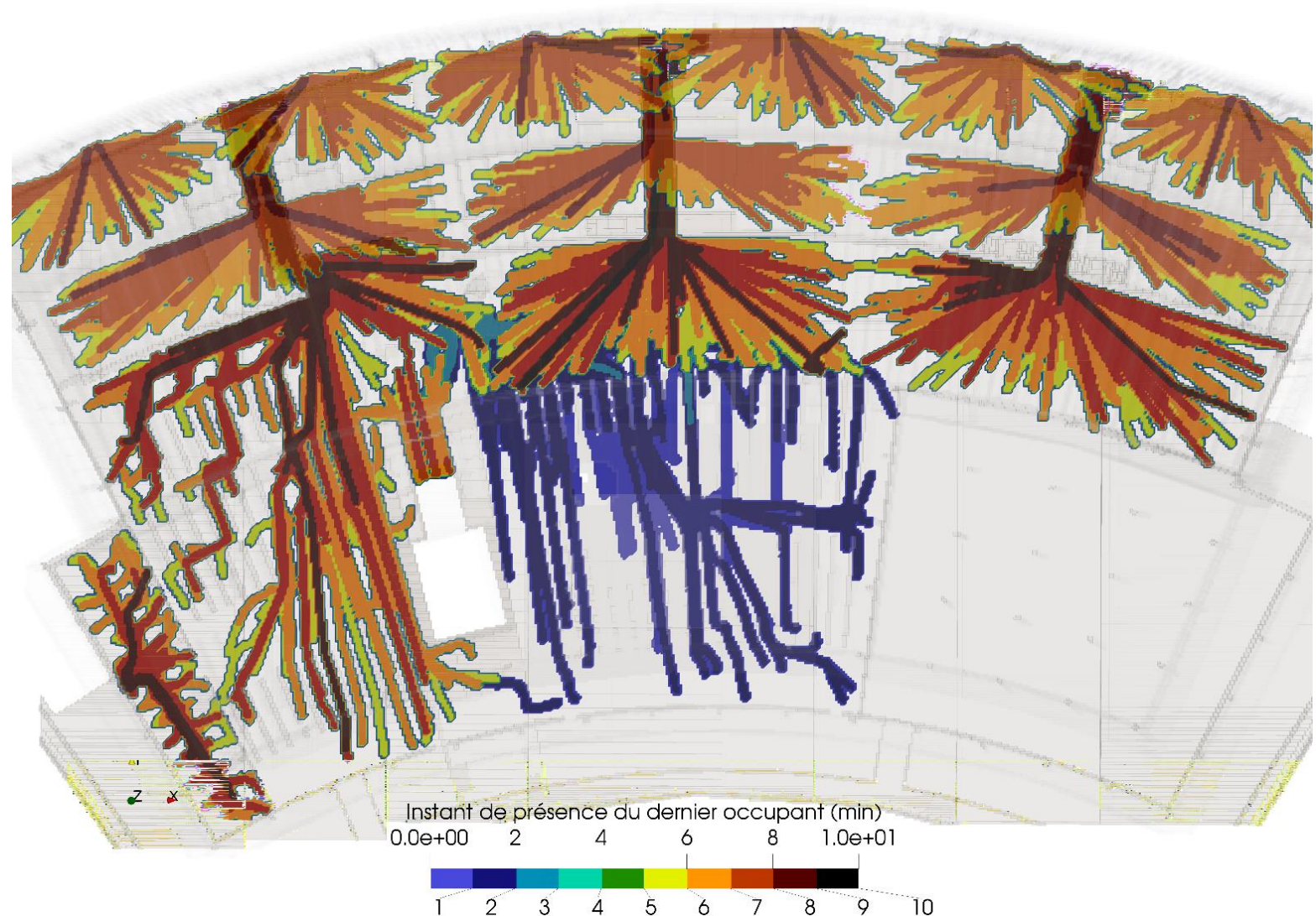> Pathways to exits

> **Special development (not a Pathfinder output):**

>> Analyse X/Y position of occupants vs. Time
>> Cumulated density over all simulation :
>> **find critical zones**

>> Number of occupants who have been there at each location
>> This is where good conditions have to be maintained

Chemins de fuite (nb de pers.)

1 2 3 4 5 6 7 8 9
10 et +

Post-processing egress

- **Special development (not a Pathfinder output):**

- Time of last occupant within the room
    - Defines the local RSET for the simulation
    - Several simulations are performed to get significant values

Instant de présence du dernier occupant (min)

0.0e+00   2   4   6   8   1.0e+01

1   2   3   4   5   6   7   8   9   10

Post-processing FDS results

Plot3d
ext_coef
1/m

0.20
0.20
0.20
0.20
0.20
0.20
0.20
0.20
0.20
0.20
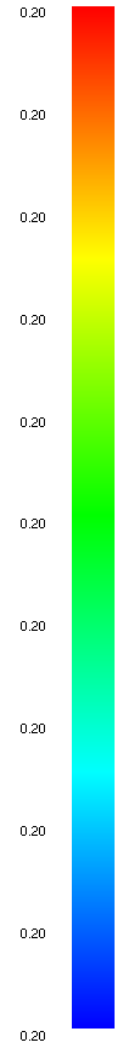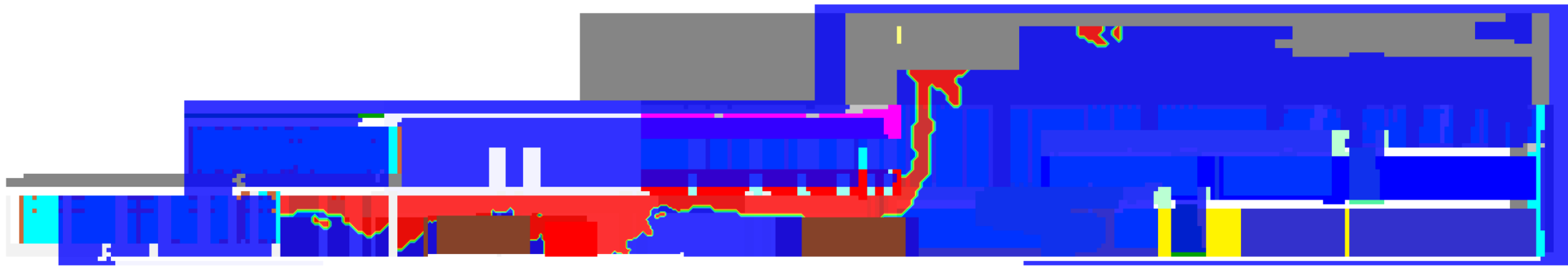
y: 15, 38.75 m
x: 52, 80.0 m

Post-processing

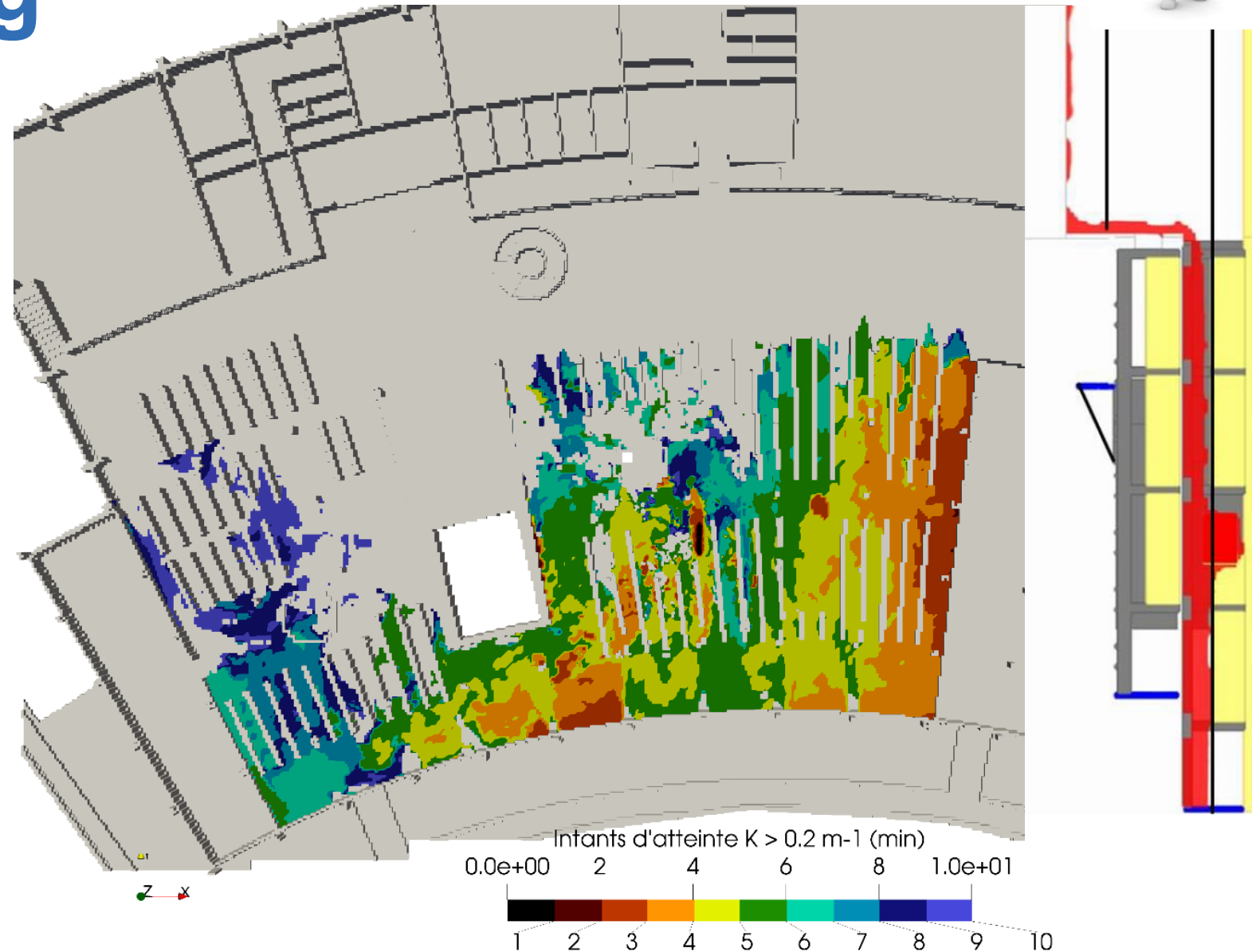➢ **Special development (not a Pathfinder output):**

➢ Time when criterion K is met:

  ➢ Defines the local ASET
  ➢ Overview of the results with only one figure per criterion

Intants d'atteinte K > 0.2 m-1 (min)

0.0e+00   2   4   6   8   1.0e+01

1   2   3   4   5   6   7   8   9   10
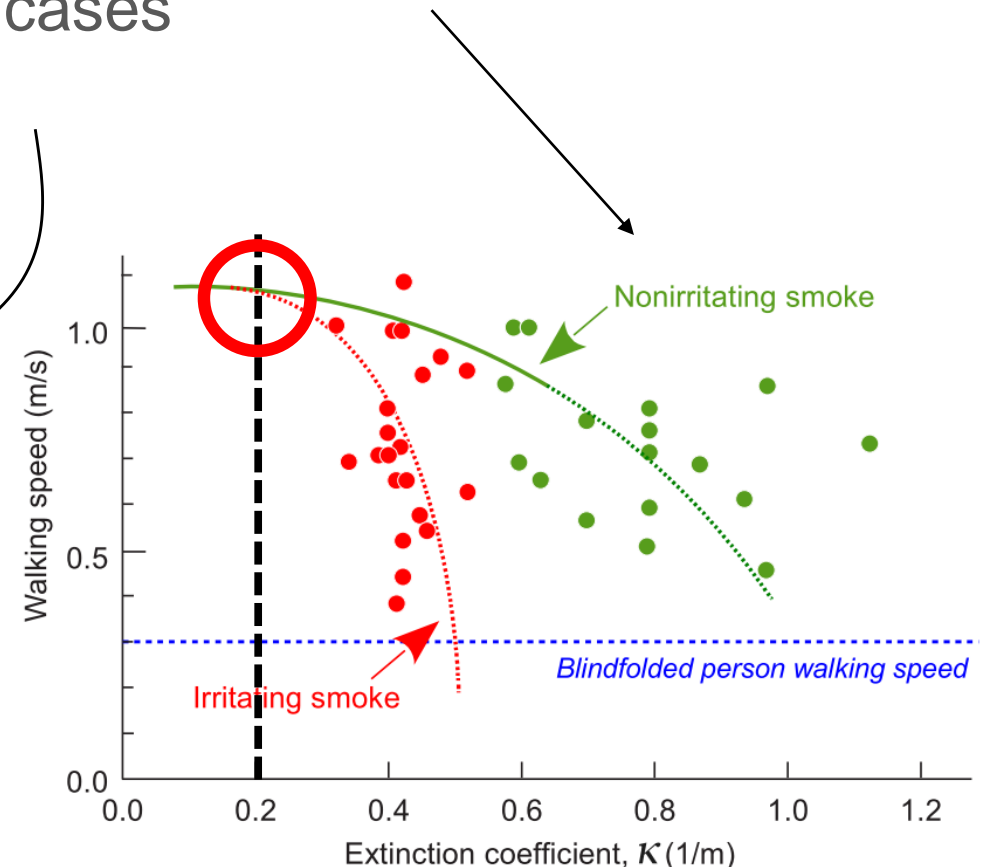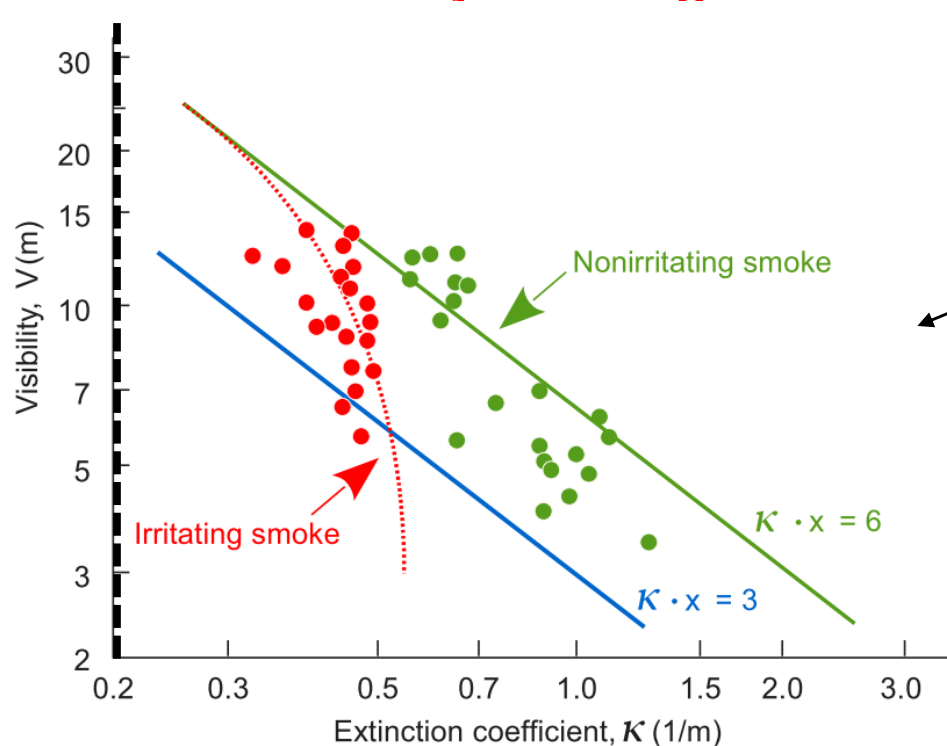
Discussion : decisive criterion

➢Extinction coefficient criterion

   ➢0.2 m^{-1} at 2.5 m is a very conservative approach !

      ➢Required to perform evacuation simulation without taking into account interaction with smoke in all cases

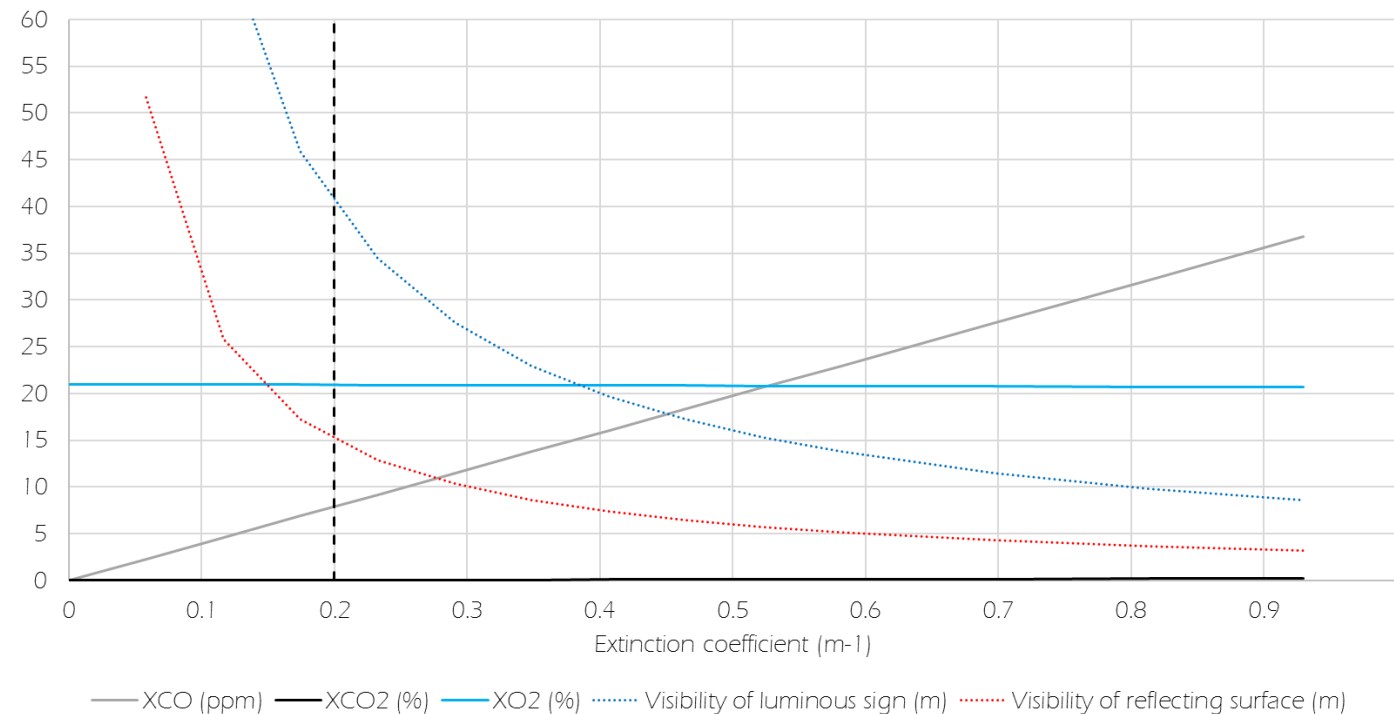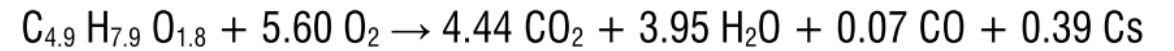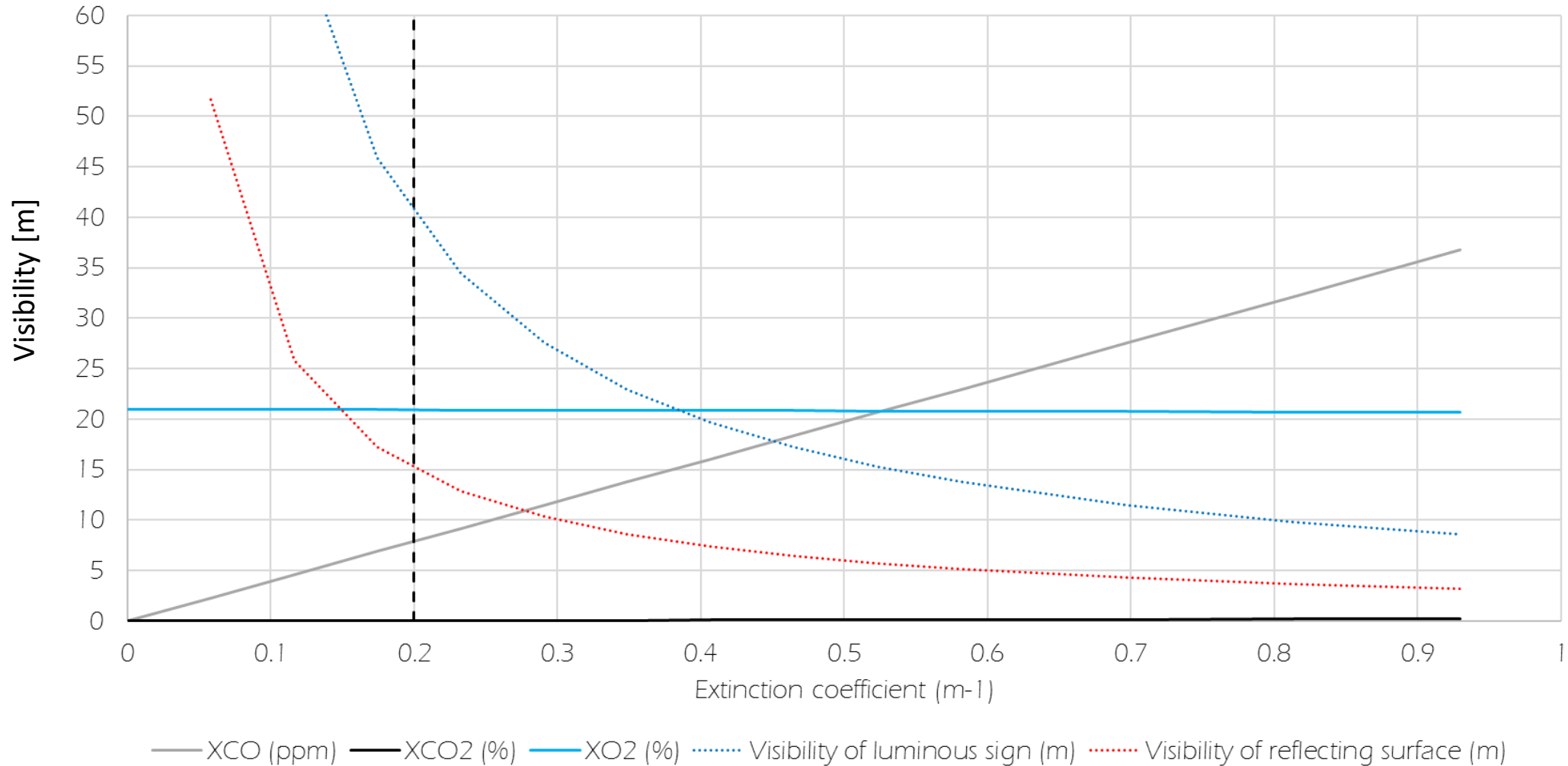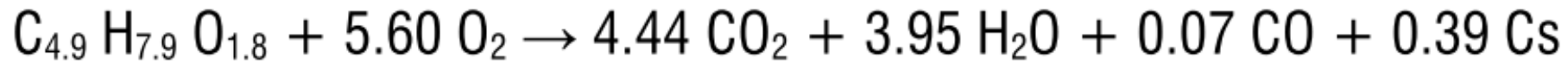   ➢But visibility is still good at 0.2 m^{-1}

Discussion

➤ Relationship between gas composition related output data with FDS

    ➤ First criterion met is always extinction coefficient

Critère	Seuil de danger
Hauteur de la couche libre	≥ 2.5 m ou ≥ 2.0 m sous conditions
Température de la fumée	≤ 200 °C
Température dans la couche libre	≤ 50 °C
Visibilité dans la couche libre	≥ longueur de fuite
Coefficient d'extinction dans la couche libre	≤ 0.2 m^{-1}
Concentration en CO_2 dans la couche libre	≤ 1 % vol
Concentration en CO dans la couche libre	≤ 300 ppm
Concentration en HCN dans la couche libre	≤ 30 ppm
Concentration en O_2 dans la couche libre	≥ 15 % vol
Rayonnement thermique dans la couche libre	≤ 2.0 kW/m^2

$$C_{4.9} H_{7.9} O_{1.8} + 5.60 \, O_2 \rightarrow 4.44 \, CO_2 + 3.95 \, H_2O + 0.07 \, CO + 0.39 \, Cs$$

Extinction coefficient (m-1)

XCO (ppm) — XCO2 (%) — XO2 (%) — Visibility of luminous sign (m) — Visibility of reflecting surface (m)

Discussion

$$C_{4.9} H_{7.9} O_{1.8} + 5.60\, O_2 \rightarrow 4.44\, CO_2 + 3.95\, H_2O + 0.07\, CO + 0.39\, Cs$$

Discussion : other issues

➢Positionning air inlets
   ➢High fresh air velocities can strongly disturb smoke stratification
   ➢High smoke extraction flowrates lead to high velocities in the room

   Reduce the volume of extraction / speed

➢Start with simplified geometry and assumptions
   ➢Several runs needed to desing a efficient solution
   ➢Use complex model only to validate solution

   ➢It's not because we can do complex models that we HAVE to do it !

Conclusions

- Smoke management in large volume
  - Extension of existing building
  - Large volume with several floors
  - Architectural constraints

- Fire safety engineering study
  - Fire scenarios + tenability criteria
  - Assumptions for evacuation modeling

- Numerical simulations
  - Evacuation modeling
  - Fire modeling

- Conclusion about the efficiency of the smoke management strategy
  - (too) many configurations have been studied
  - Ongoing dialogue with all partners during the project

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Thank you for your attention