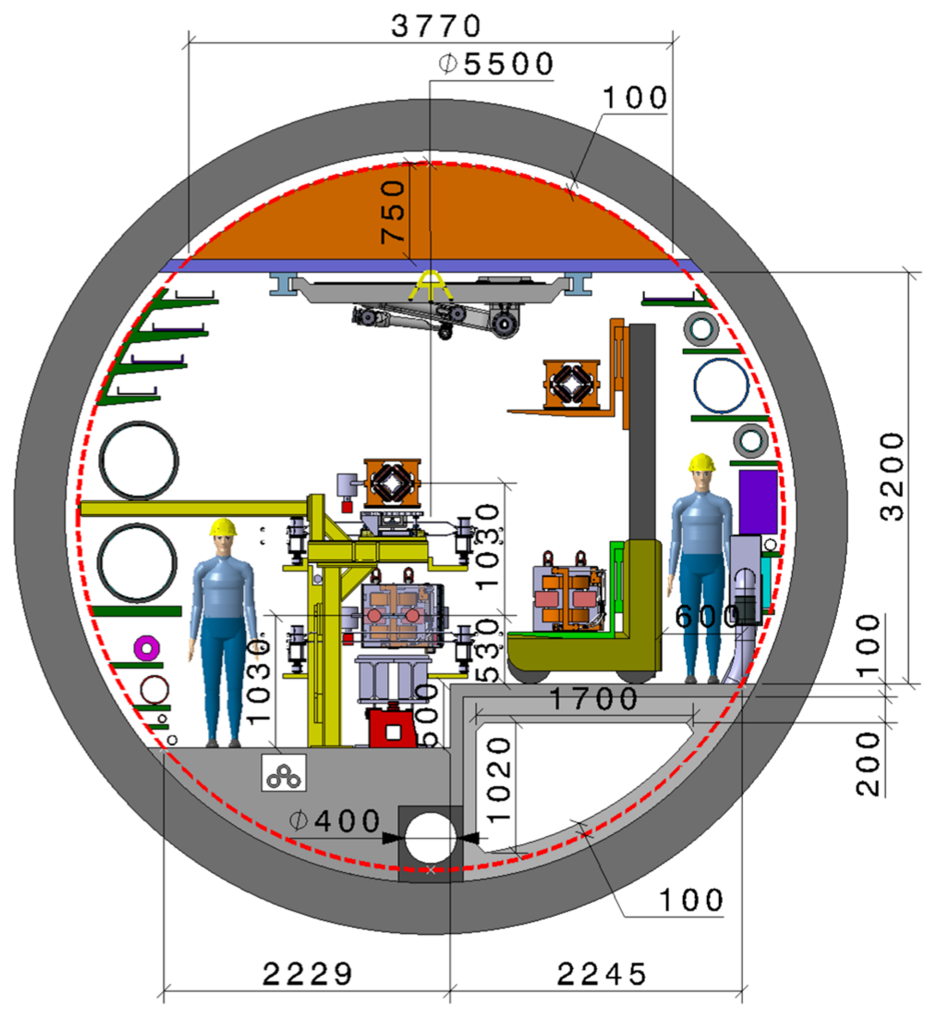
FUTURE CIRCULAR COLLIDER

OVERVIEW OF SAFETY SYSTEMS AND EVACUATION STUDY IN THE FCC TUNNEL

A. Henriques, T. Ladzinski, G. Nergiz, T. Otto, O. Rios
on behalf of the Safety WP team

Outline

- FCC Safety Work package
- Overview of the main safety features and advancements
- Quantitative assessments & analysis:
  - ❑ Evacuation modelling study
  - ❑ *Cryogen release simulations – preliminary*
  - ❑ *Fire Detection – preliminary*



See **G. Lavezzari et al** for "Radiation protection studies for the FCCee"

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FCC Safety Work package

Team

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WP leader
Study coordination, hazard register, editor

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Numerical modelling

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Environmental impact of ionising radiation

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Radiation protection

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Radiation protection

Tomasz Ladzinski
Safety systems

Acknowledgements: Contributions, exchanges from all

OVERVIEW OF THE MAIN SAFETY FEATURES AND ADVANCEMENTS

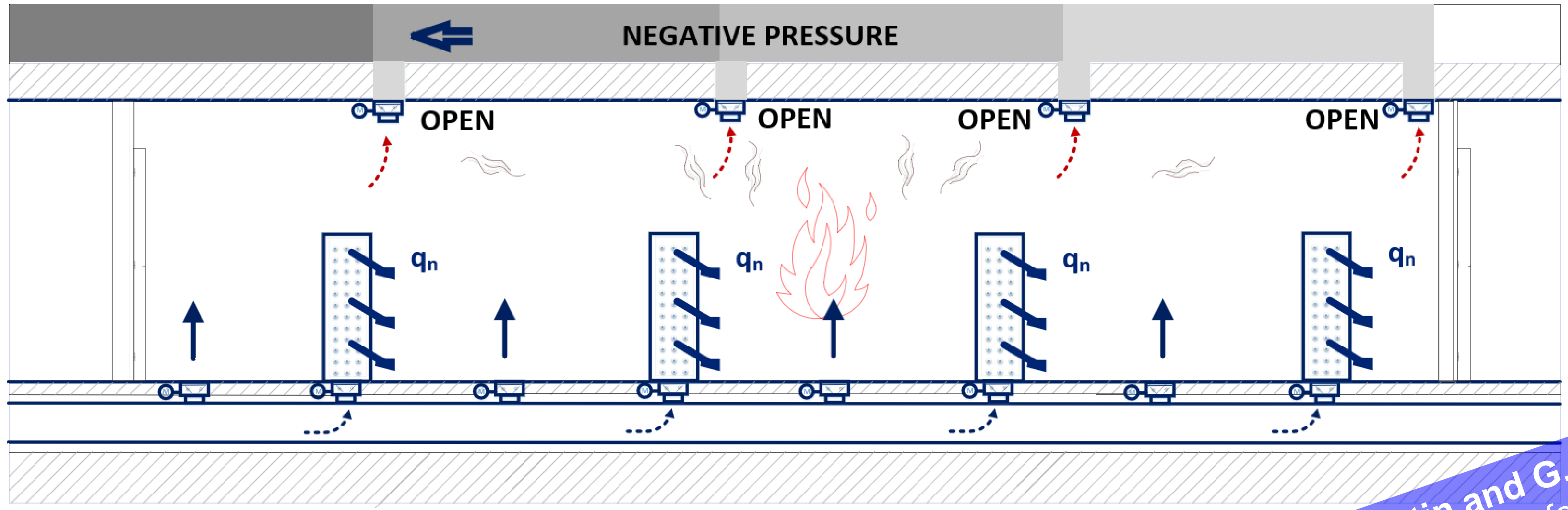
Ventilation & Emergency extraction

Studies for the effect on Helium extraction on-going

Objective:

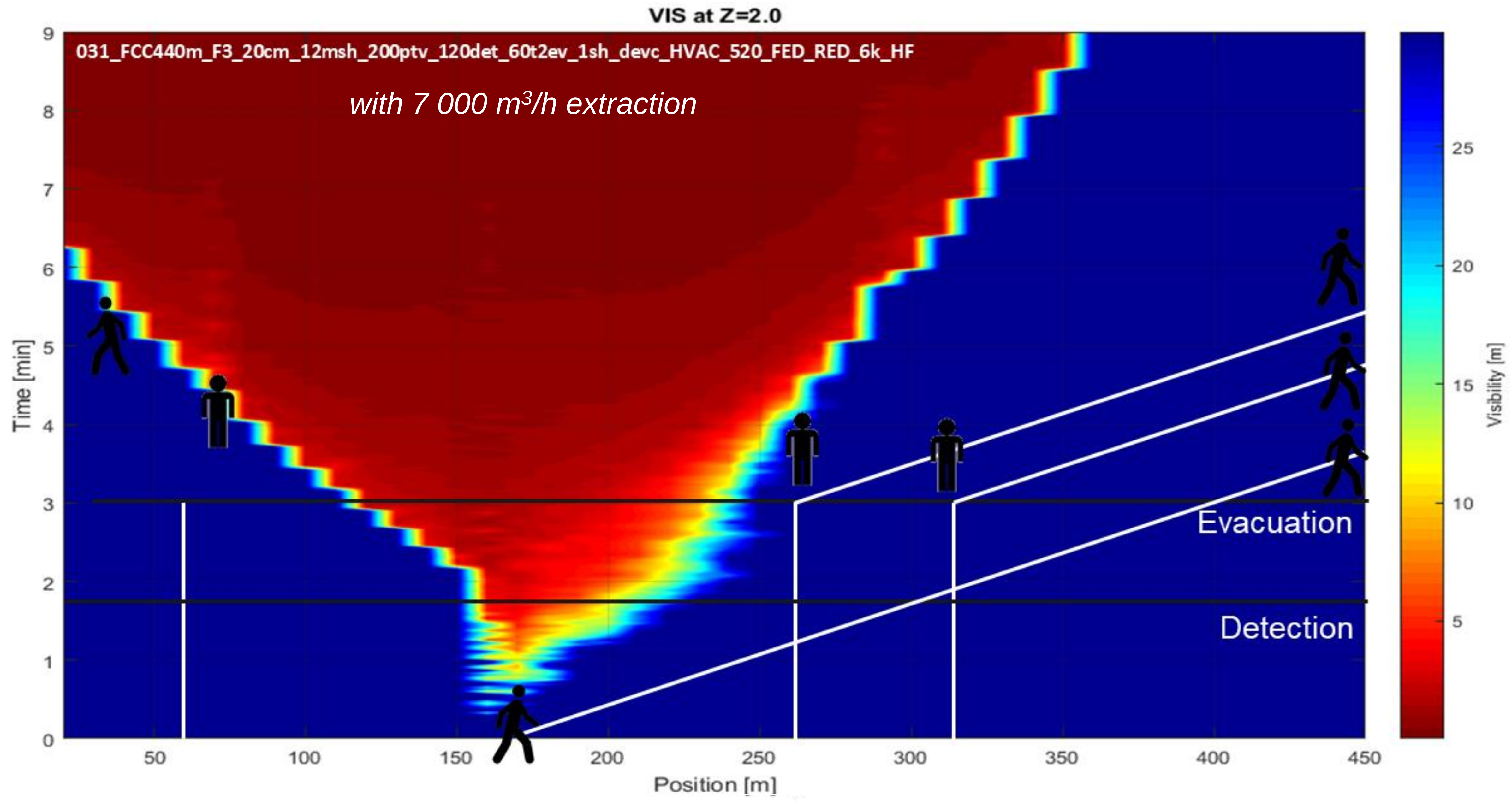
- Safe egress:
  - Maintain tenability conditions for occupants
  - Evacuation path free of toxic fumes (inhalation and visibility)
  - Dynamic confinement (prevent smoke propagation)

Up to 10 000 m³/h / compartment



Schematic of the ventilation system in a compartment

I. Martin and G. Peon
" Cooling & ventilation for RF, Klystrons and arc sector"
Tuesday (June 6th)



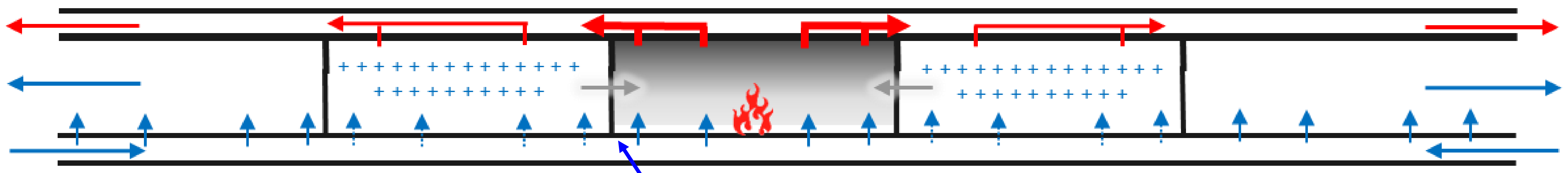
O. Rios et al
"Fire safety assessment for FCC - PBD study for FCC and HE-LHC", FCC Week 2018

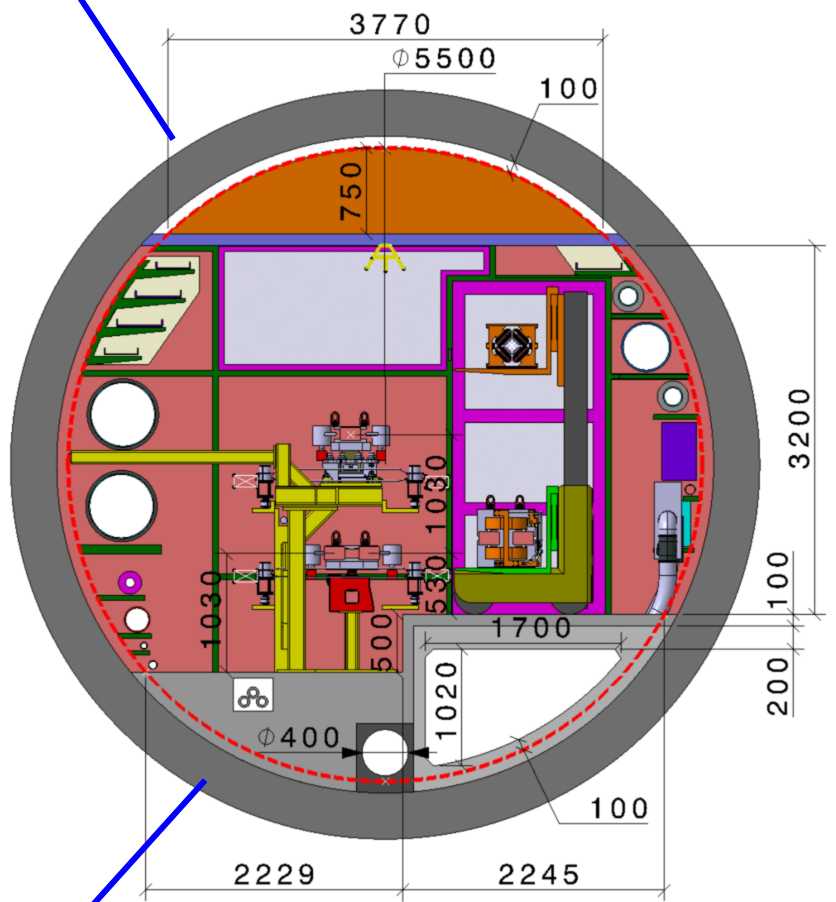
Baseline:
- Detection 120s
- > 7000m³/h per compartment (up to 10 000 per compartment)
- Extraction system less then 60s to ramp up

Fire compartments

Objectives:

- Safe egress:
  - Static confinement (prevent fire/smoke propagation)
  - Dynamic confinement (prevent fire/smoke propagation)
  - Increase possible waiting time for emergency vehicle
- Search & Rescue from Fire Brigade
  - Enables better operational tactics
  - Reduces the smoke diving (air supply)
- Reduces asset loss
  - Limits the propagation and damage to the accelerator and equipment

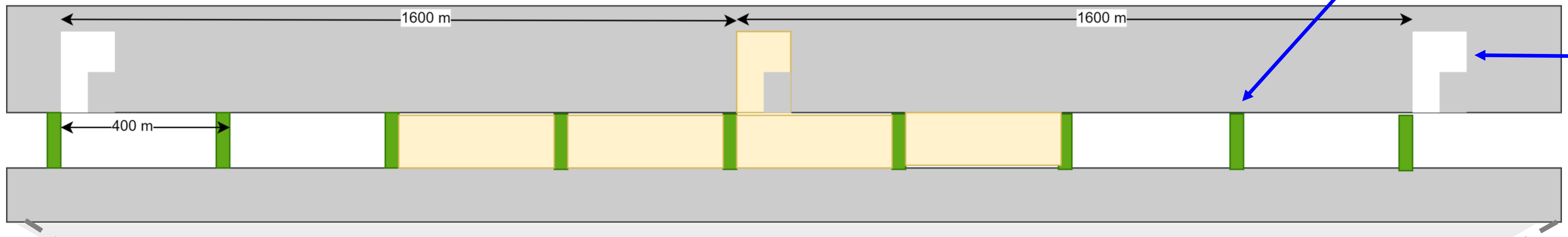




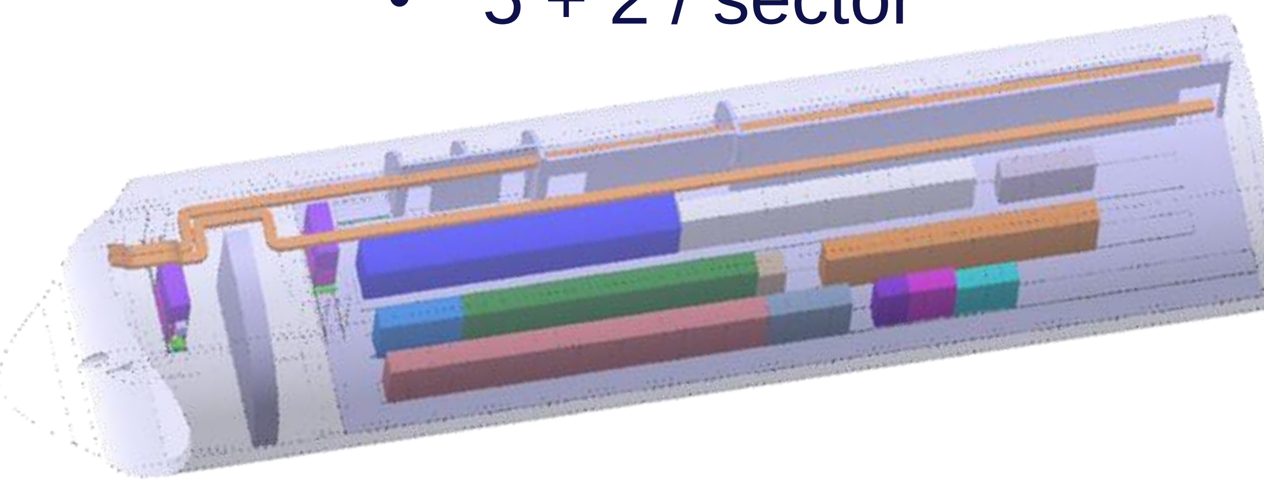
Fire compartments:
- 28 / sector

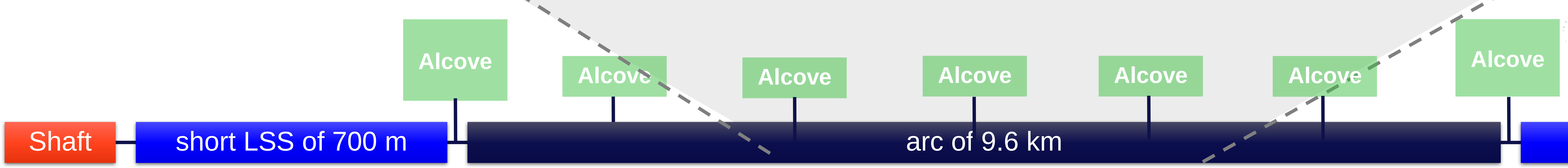
F. Valchkova-Georgieva
"Integration update tunnel"
Tuesday (June 6th)

Baseline modification:
Compartment length = **400 m**
(440 in CDR)



Alcoves
- 5 + 2 / sector





Safety systems

Objectives:

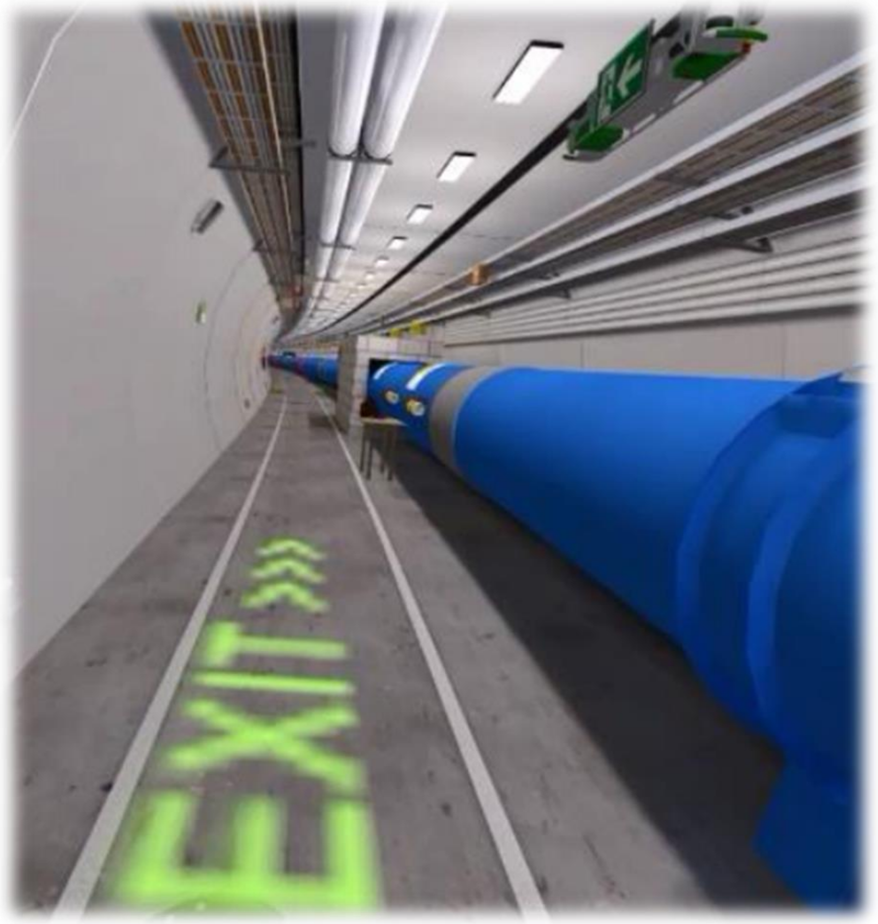
- Safe egress
  - Automatic trigger of safety-related actions
- Notification of emergency teams
  - Signal to the Safety Control Centre

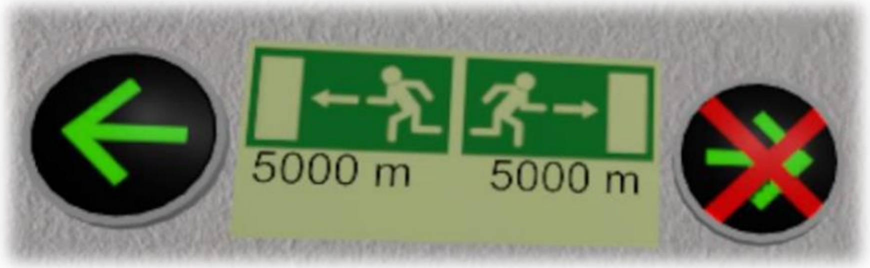
Main Safety Systems & Instrumentation :

- Compartment doors
- Fire (smoke) detection
- Smoke extraction dampers interface
- Call points
- Evacuation Signalization
- Access sectorization door(s), patrol boxes
- Occupancy tracking / logging per sector

Other FCC-tailored options are under investigation – R&D

Example in SPS





S. Arias et al, FCC Week 2018

Product Breakdown structure

FUTURE CIRCULAR COLLIDER | FCC-EE PROJECT BREAKDOWN STRUCTURE FOR SAFETY SYSTEMS | FCC-INF-PM-0080| EDMS 2874540 v.0.2 | Date: 5. 5. 2023 | Status: in work

Future Circular Collider

SAFETY NOTE

FCC-EE PROJECT BREAKDOWN STRUCTURE FOR SAFETY SYSTEMS

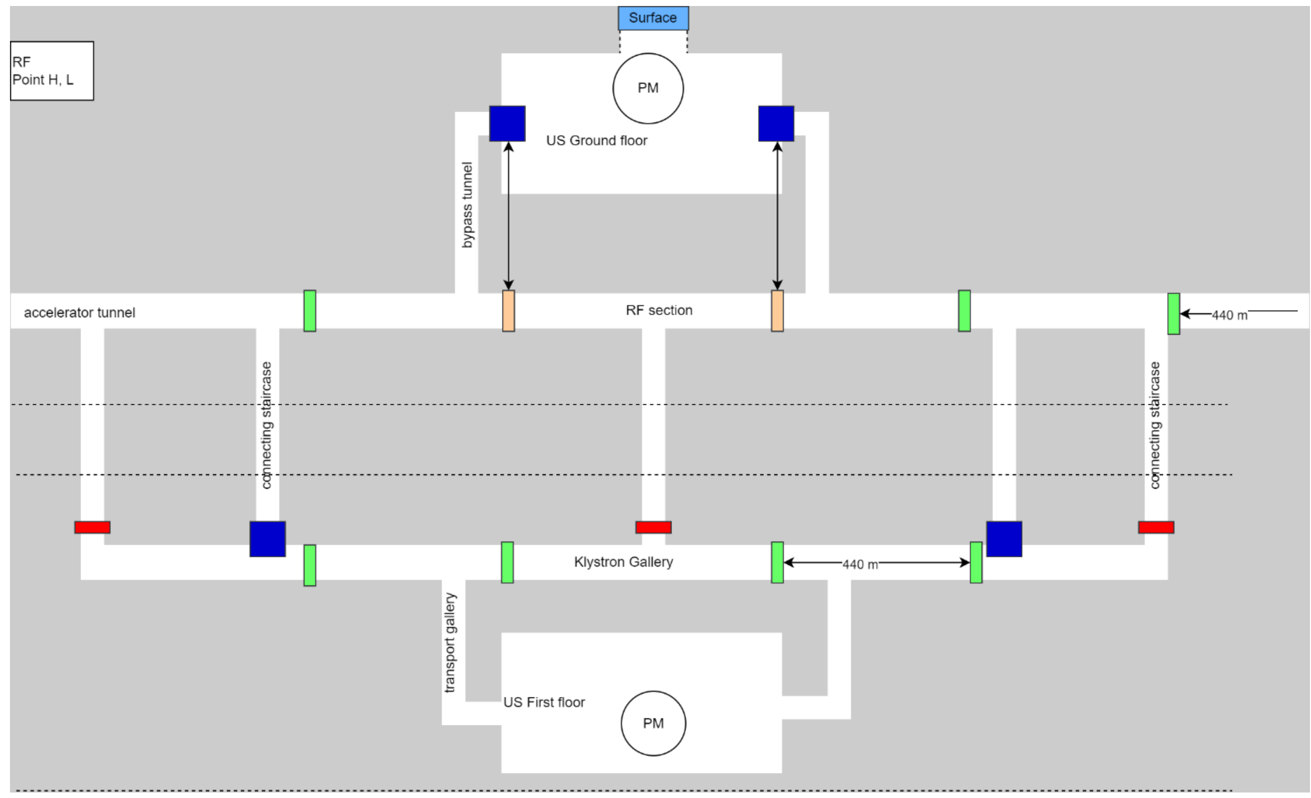
Document identifier:	FCC-INF-PM-0080| EDMS 2874540 v.0.2
Date:	5. 5. 2023
Work package/unit:	Technical Infrastructures / Safety
Version:	V0.2
Status:	In work

Objectives:

- Provide the most accurate cost-estimate

Process:

Layout of the access points (underground and surface) → Category of Safety-related equipment → Inventory per point & per safety system → Cost estimation

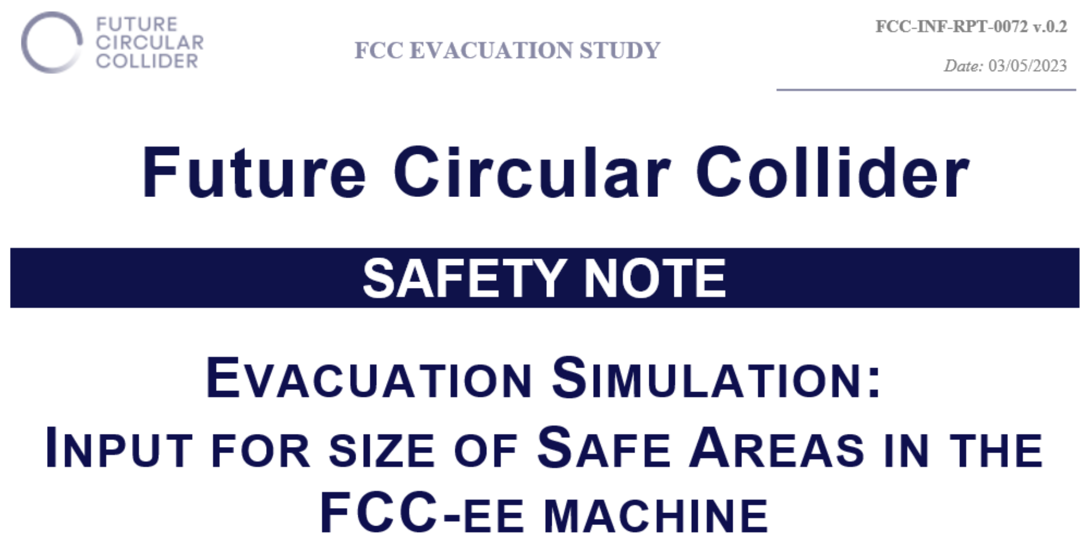


- Access doors;
- Fire detection;
- Sirens;
- Rad monitors;
- ODH detectors;
- …

	Access Control	Access Control/ interlock	Sector door w. Token	Sector door	End-of-zone door	Ventilation door	Patrol Boxes
Point A - Exp							
Arc + LSS					1(1)	28(2)	28
Exp. cavern		1		15	8		45
Service cavern	1	4		10	7	5	30
Point B -Tech							
Arc + LSS			2		1(1)	28(2)	28
Service cavern	1	2		10	5	5	25
Point D - Exp							
Arc + LSS						28(2)	28

SAFETY STUDIES

Evacuation study


FUTURE CIRCULAR COLLIDER — FCC EVACUATION STUDY — FCC-INF-RPT-0072 v.0.2 — Date: 03/05/2023

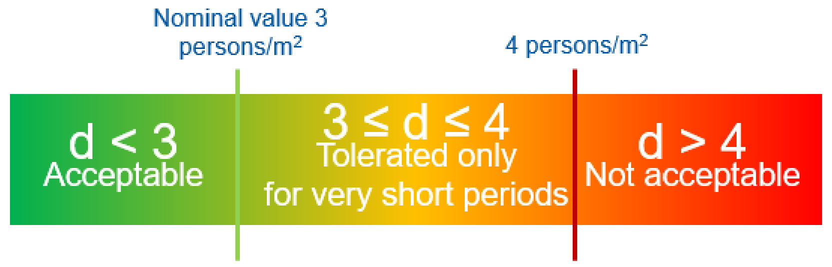
Future Circular Collider

SAFETY NOTE

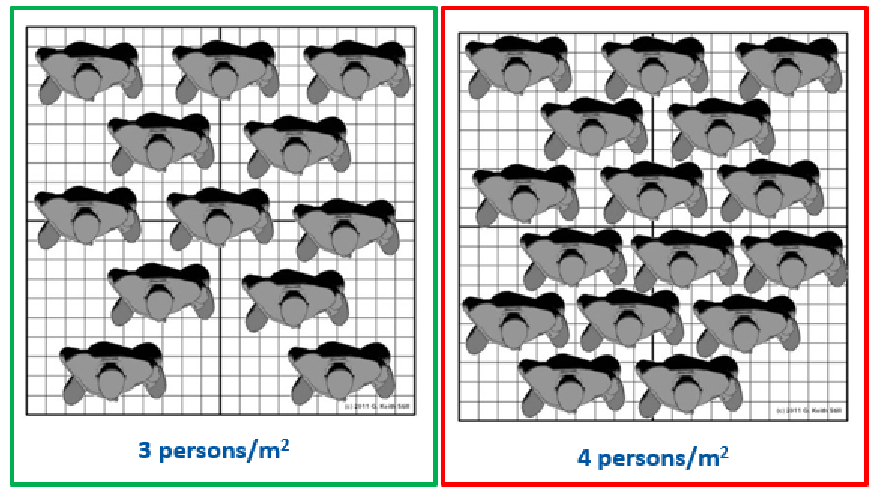
EVACUATION SIMULATION:
INPUT FOR SIZE OF SAFE AREAS IN THE FCC-EE MACHINE

Aim

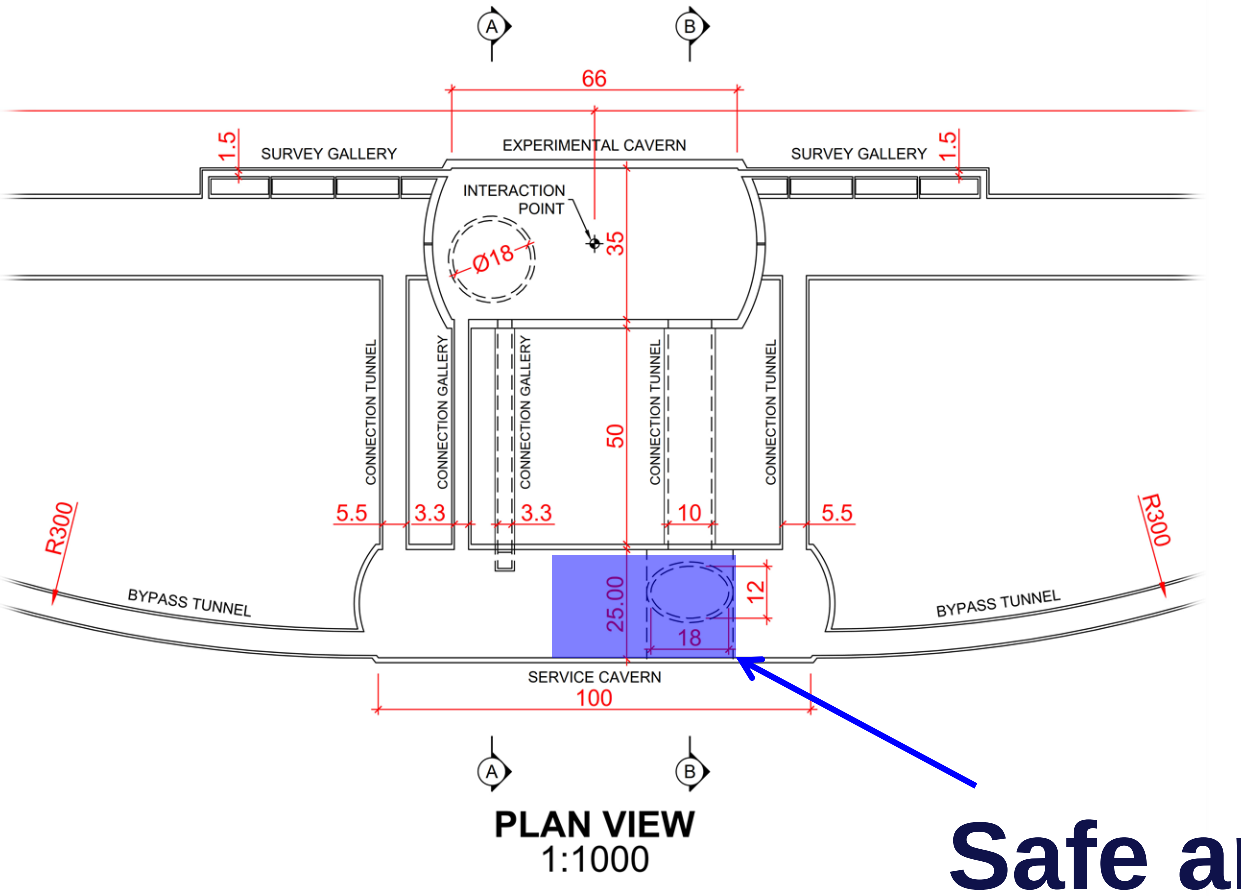
- **Define the surface of the safe areas at the bottom of the shaft** (protected area waiting for the lift to evacuate to the surface)
  - → Maximum number of simultaneous occupants allowed per sector
  - → *Longest evacuation time(s)*
  - → *Optimal personnel transportation during emergency*



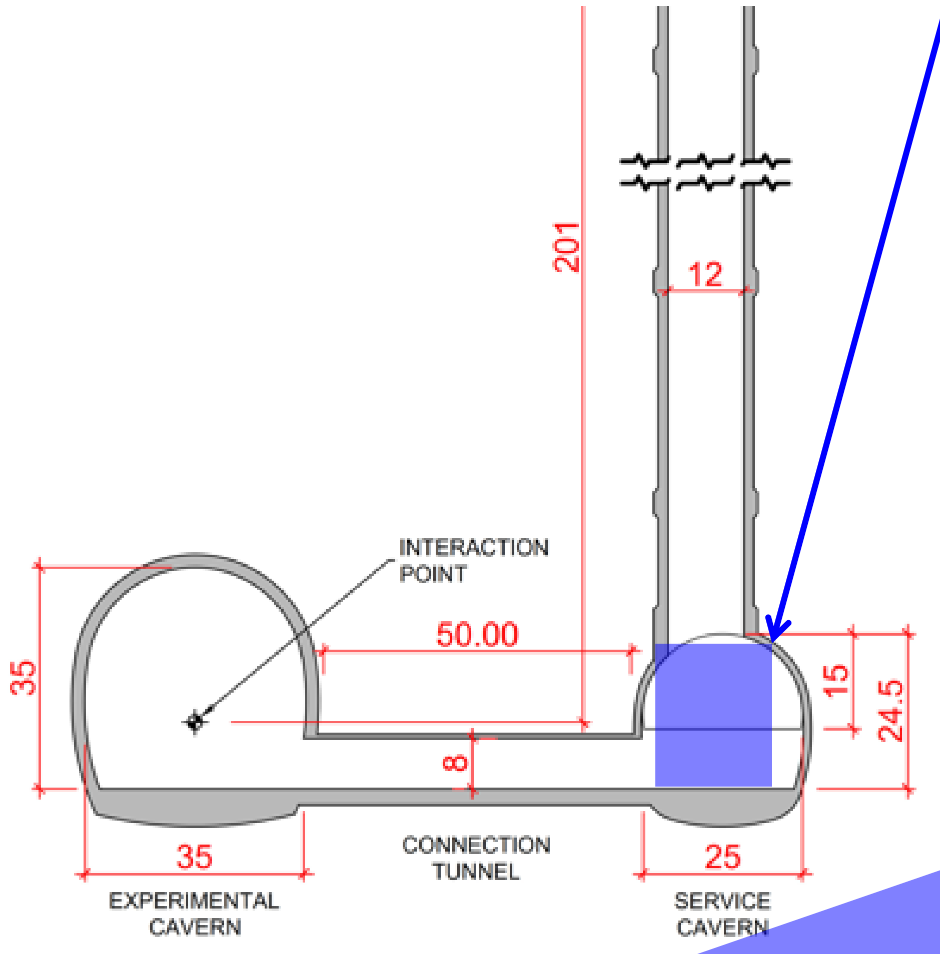
Art. L 3 of the ERP regulation fixes a maximum crowding of 3 persons/m² for people attending an event in a room without chairs or benches.



A. Henriques, S. La Mendola, FCC Week 2016



Safe area



T. Watson
"Civil Engineering" Monday (June 5th)

Scope

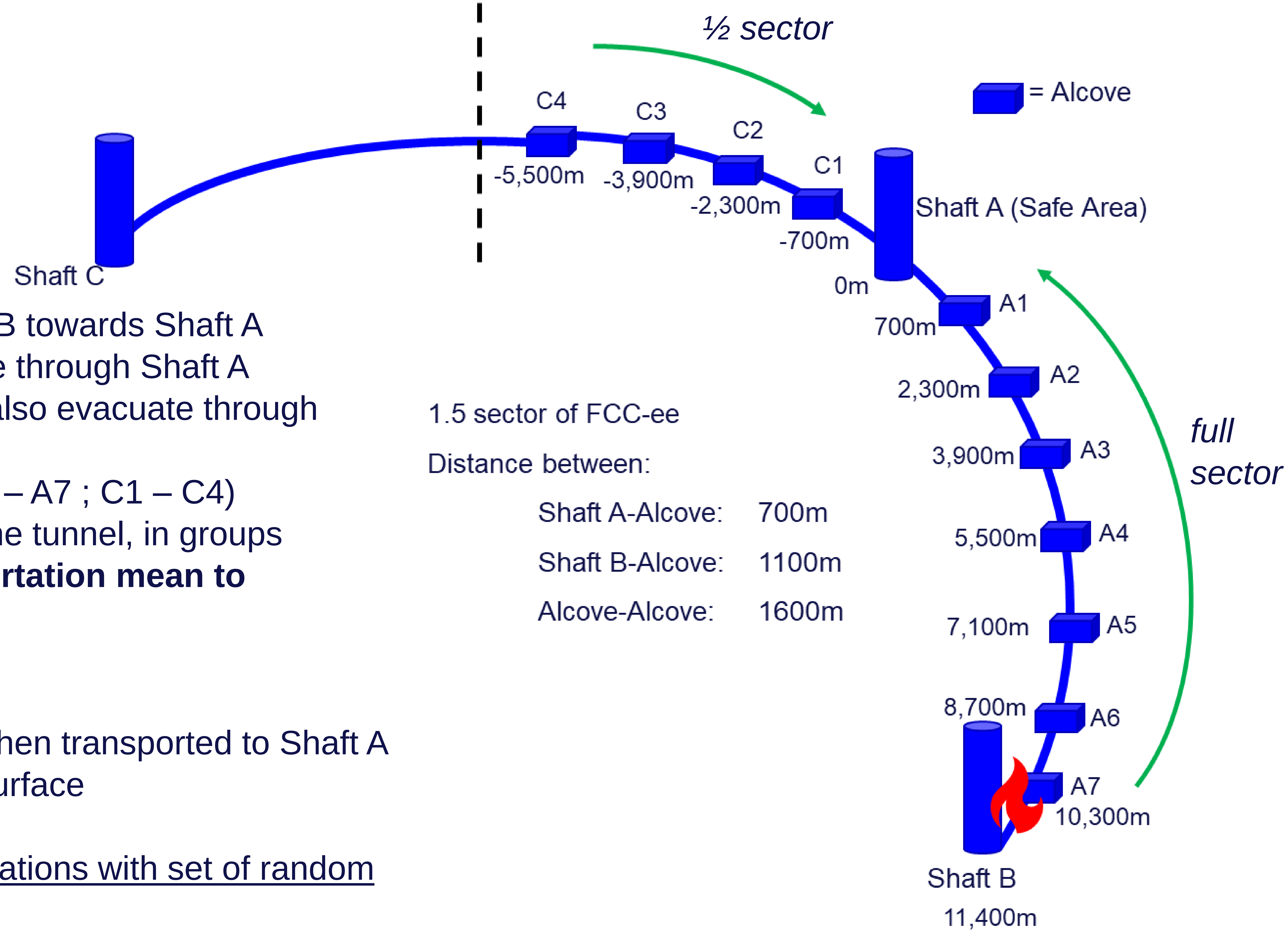
- **Study emergency situations:**
  - → During operation: Long shutdown
  - → Occupants are working in the tunnel

Note: Second step is to perform the same study for Installation phase of the FCC-ee machine

Evacuation study

Model

- Worst case scenario: fire in the vicinity of Shaft B towards Shaft A
  - → Occupants in sector A-B obliged to evacuate through Shaft A
  - → Occupants in the neighboring ½ sector will also evacuate through Shaft A
  - → Alcoves are distributed along the tunnel (A1 – A7 ; C1 – C4)
  - → Occupants are randomly distributed along the tunnel, in groups
  - → **Occupants each have a personal transportation mean to evacuate**, located in the nearest alcoves
  - → Evacuation alarm sounds:
    - Pre-movement
    - Occupants walk to the nearest alcove, then transported to Shaft A
    - Wait for the lift to be evacuated to the surface
  - → Traffic disturbance neglected
  - → <u>Probabilistic model: plain Monte-Carlo simulations with set of random variables:</u>
    - Occupant distribution; walking speed; transportation speed
    - Sample size: 1000



1.5 sector of FCC-ee

Distance between:

Shaft A-Alcove:	700m
Shaft B-Alcove:	1100m
Alcove-Alcove:	1600m

Evacuation study

Boundary conditions

- Occupancy:
  → Limited by the transportation means (each occ. has a vehicle to evacuate)

  Vehicle capacity:
  - ❑ Scenario 1: **2 occ. / vehicle**
  - ❑ Scenario 2: **3 occ. / vehicle**

  → Limited by the parking space (alcoves and shaft)

  Parking space:
  - ❑ Alcoves: **10**
  - ❑ Shaft: **20**

  → Total occupants:
  - ❑ Scenario 1: **260 occ. → 174 occ. / sector**
  - ❑ Scenario 2: **390 occ. → 260 occ. / sector**

***LHC data:** Max. 49 occ/sector (LS2) – 95% CI (T. Otto – EDMS N.2851367)*

Scaling factor of 3: ~150 occ/sector (Scenario 1: 15% ↑; Scenario 2: 70% ↑)

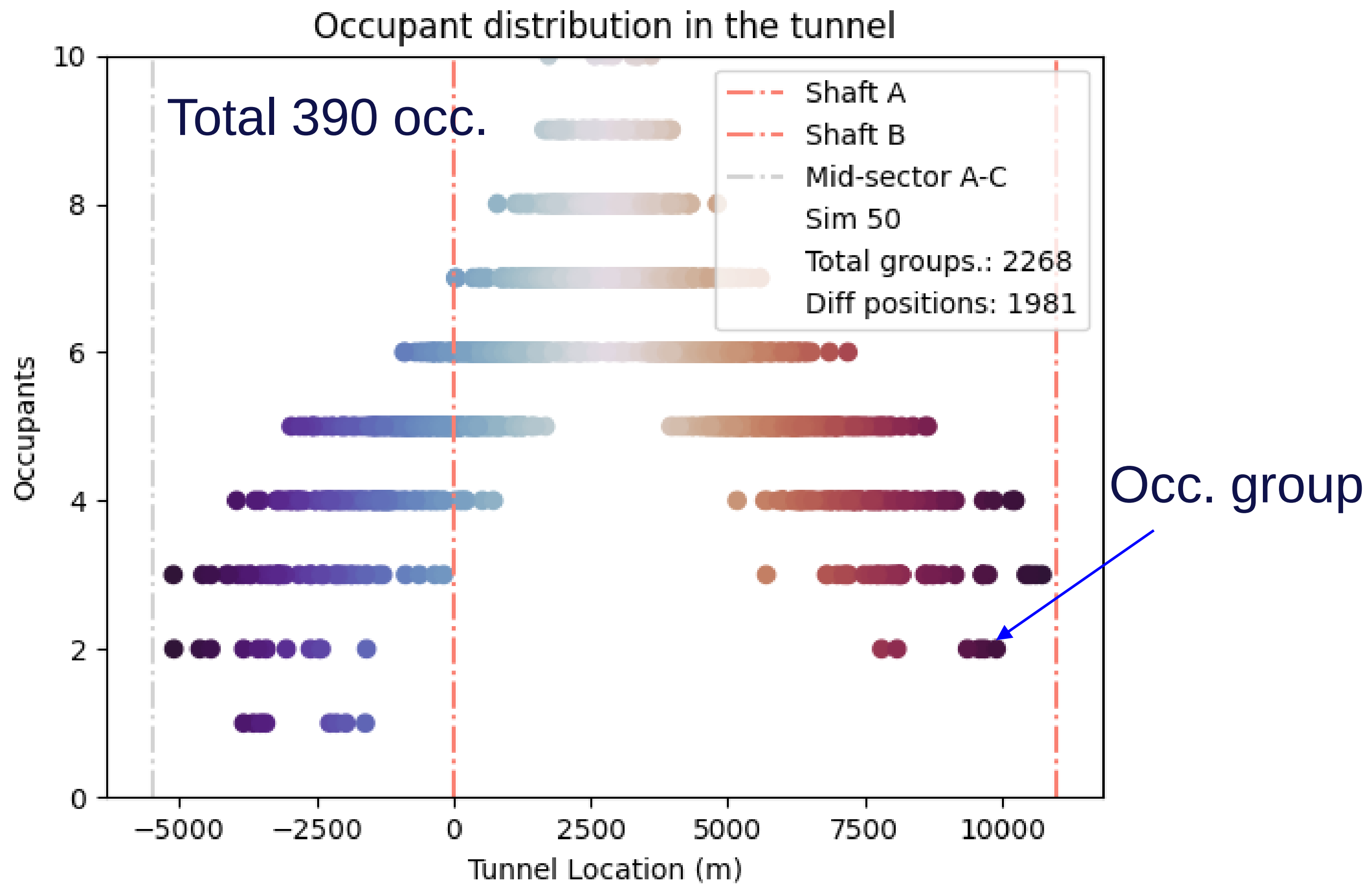
- Spatial distribution of the occupants:
  → Homogeneous (linear) occupancy will not result in possible overcrowding over time + doesn't reflect reality
  → Total occupancy is randomly distributed
  - ❑ In groups (2 – 10 occ.) along the 1.5 sector model
  - ❑ Normally distributed (binominal-type approach)
  - ❑ Relevant for the 'crowding' phenomena in the safe area

  → Each run will yield a different occupancy distribution (*x* groups of *y* occupants spread randomly along the tunnel)
  → Monte-Carlo sampling

Evacuation study

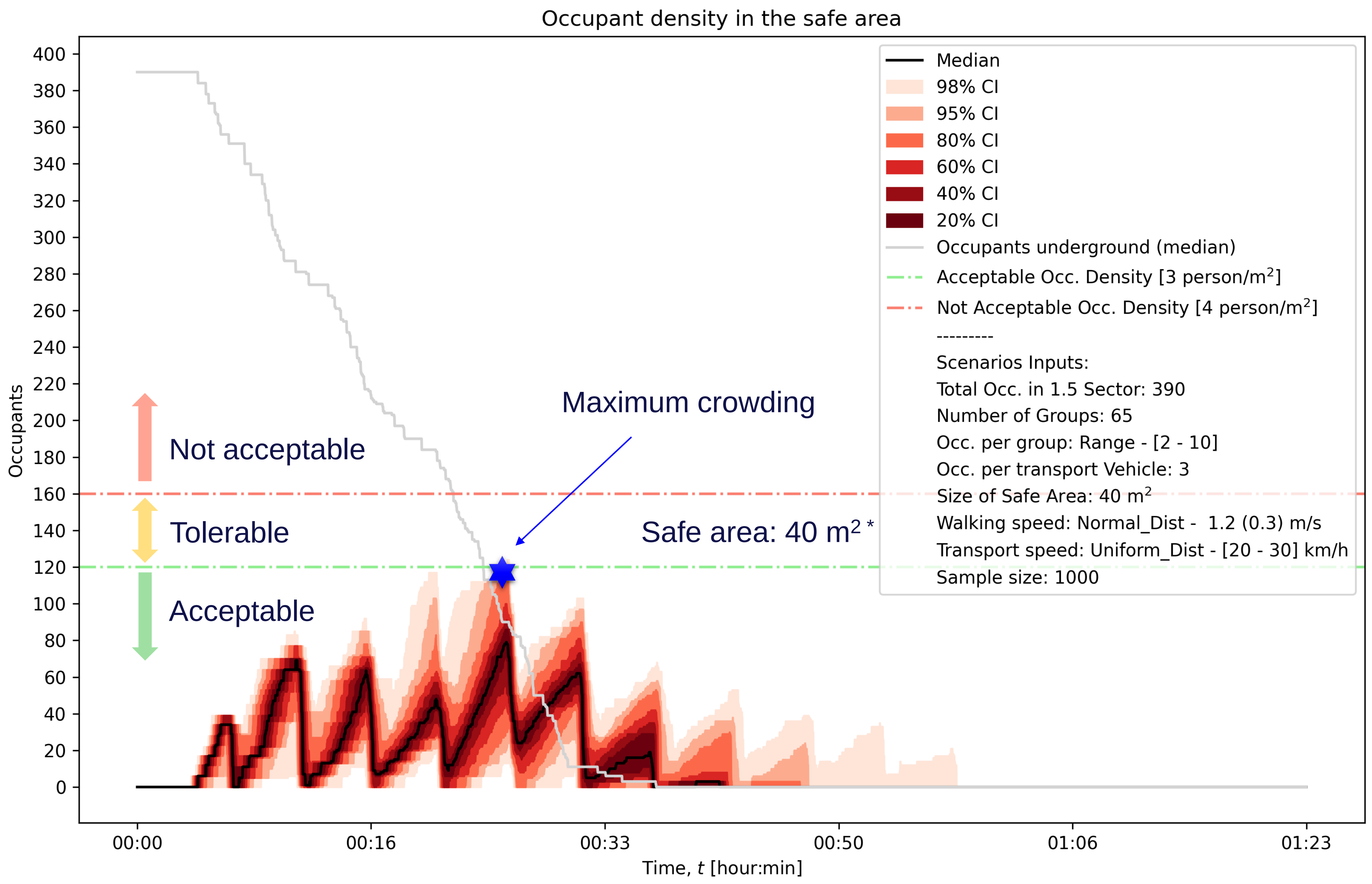
Results

Occupant distribution in the tunnel:



Probabilistic approach:

- 2000 – 4000 different group of occupants (2 – 10) spread in the 1 ½ sector



* LHC Safe area ~21 m^2

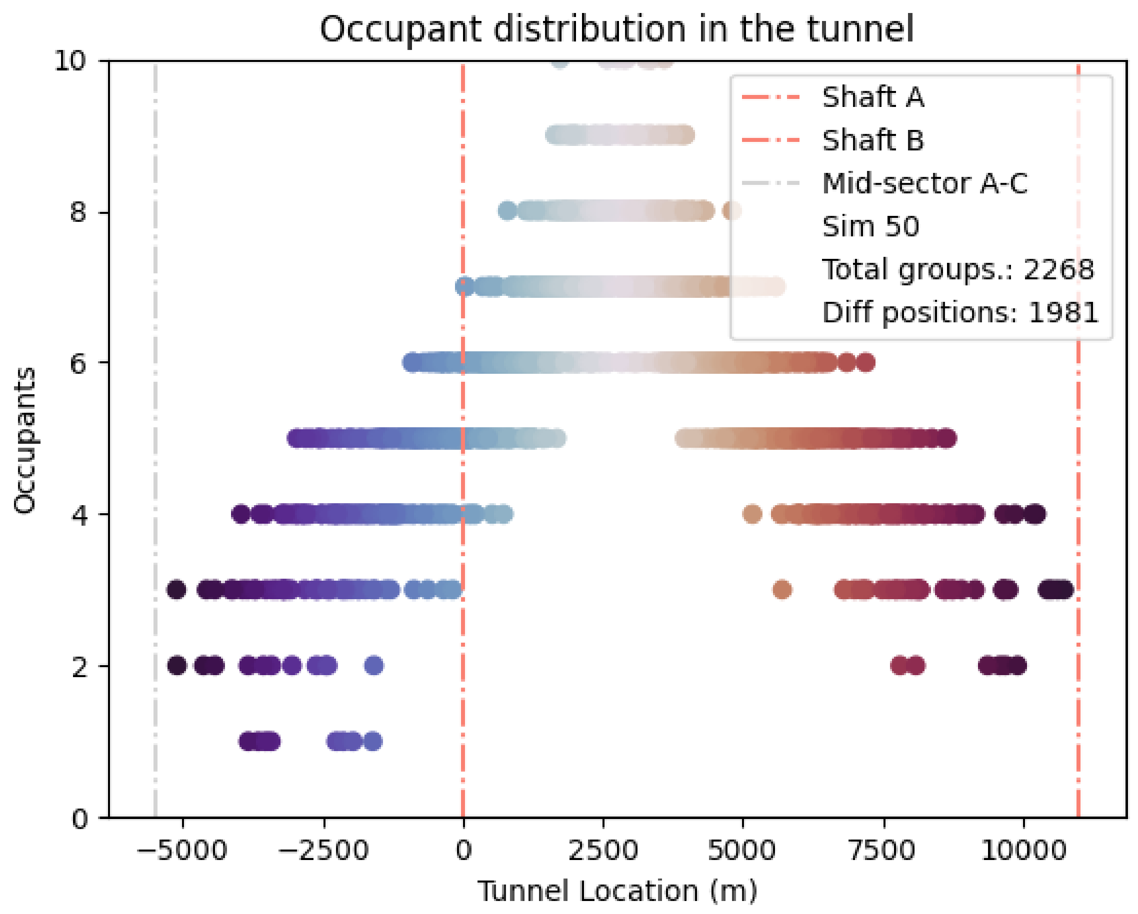
Other metrics:

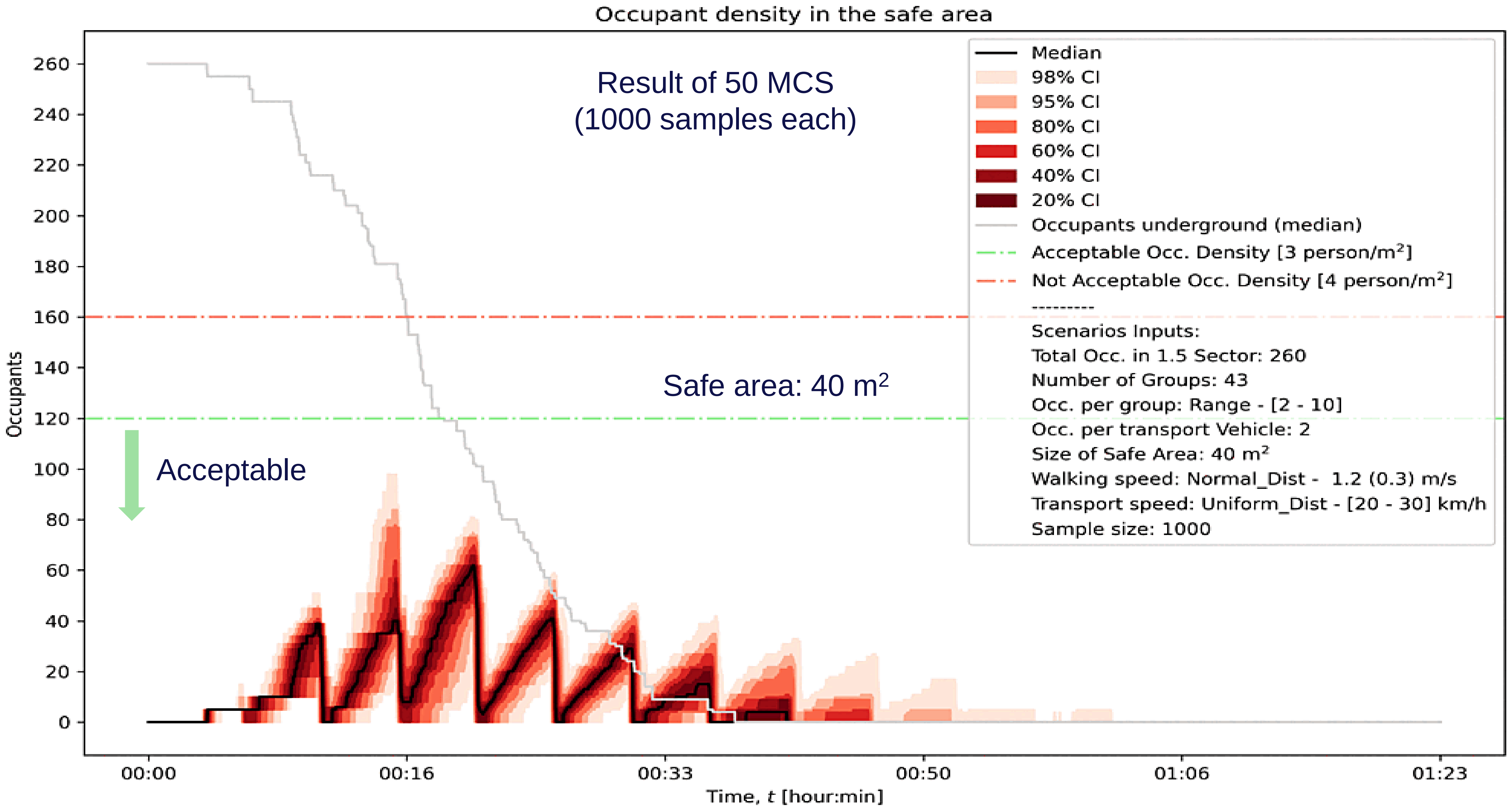
- Maximum avg. evacuation time
- Occupancy density in the first 20 min
- Effect of vehicle type
- ….

Evacuation study

Results – Scenario 1 (174 occ / sector – 260 total)

Occupant distribution in the tunnel:



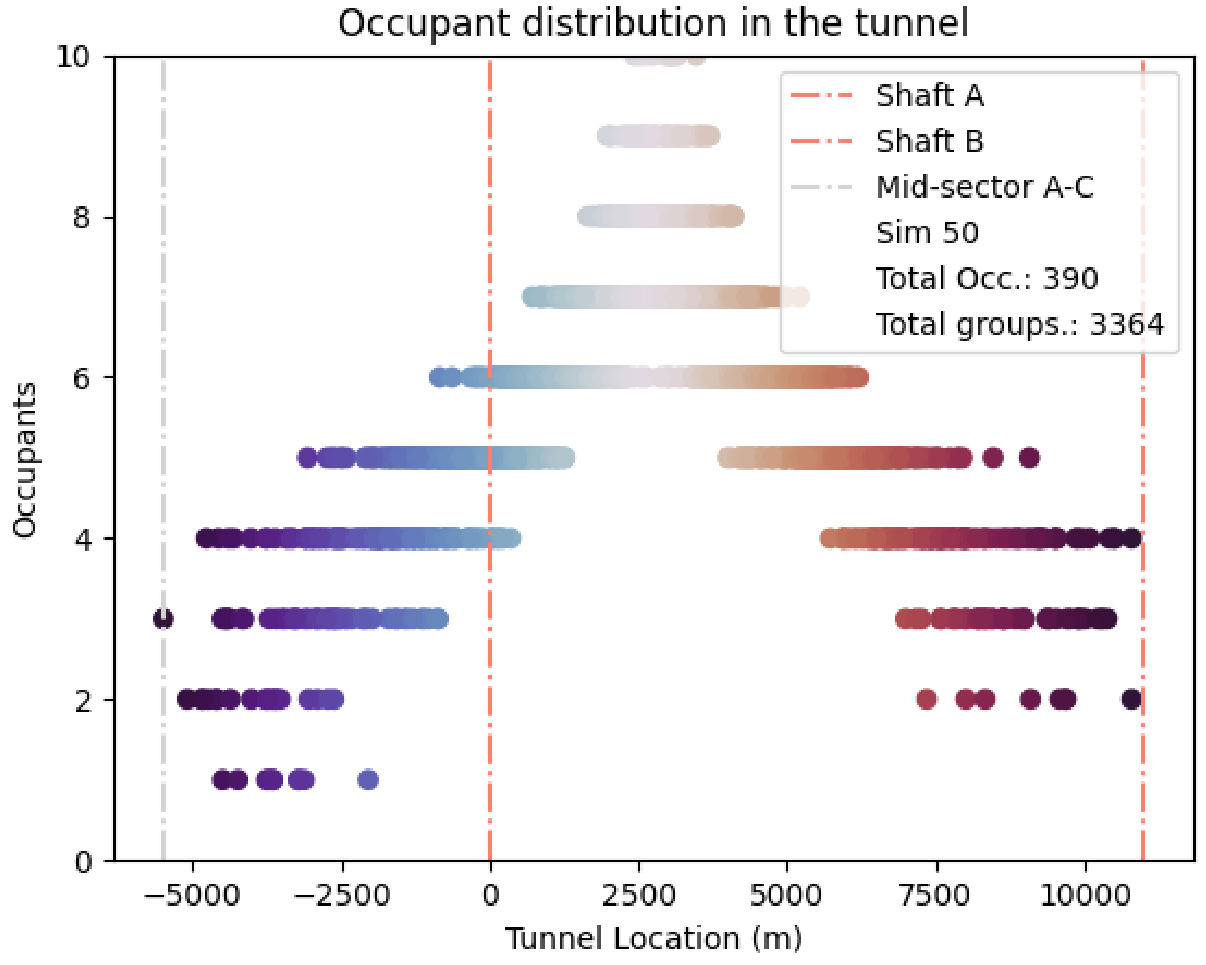


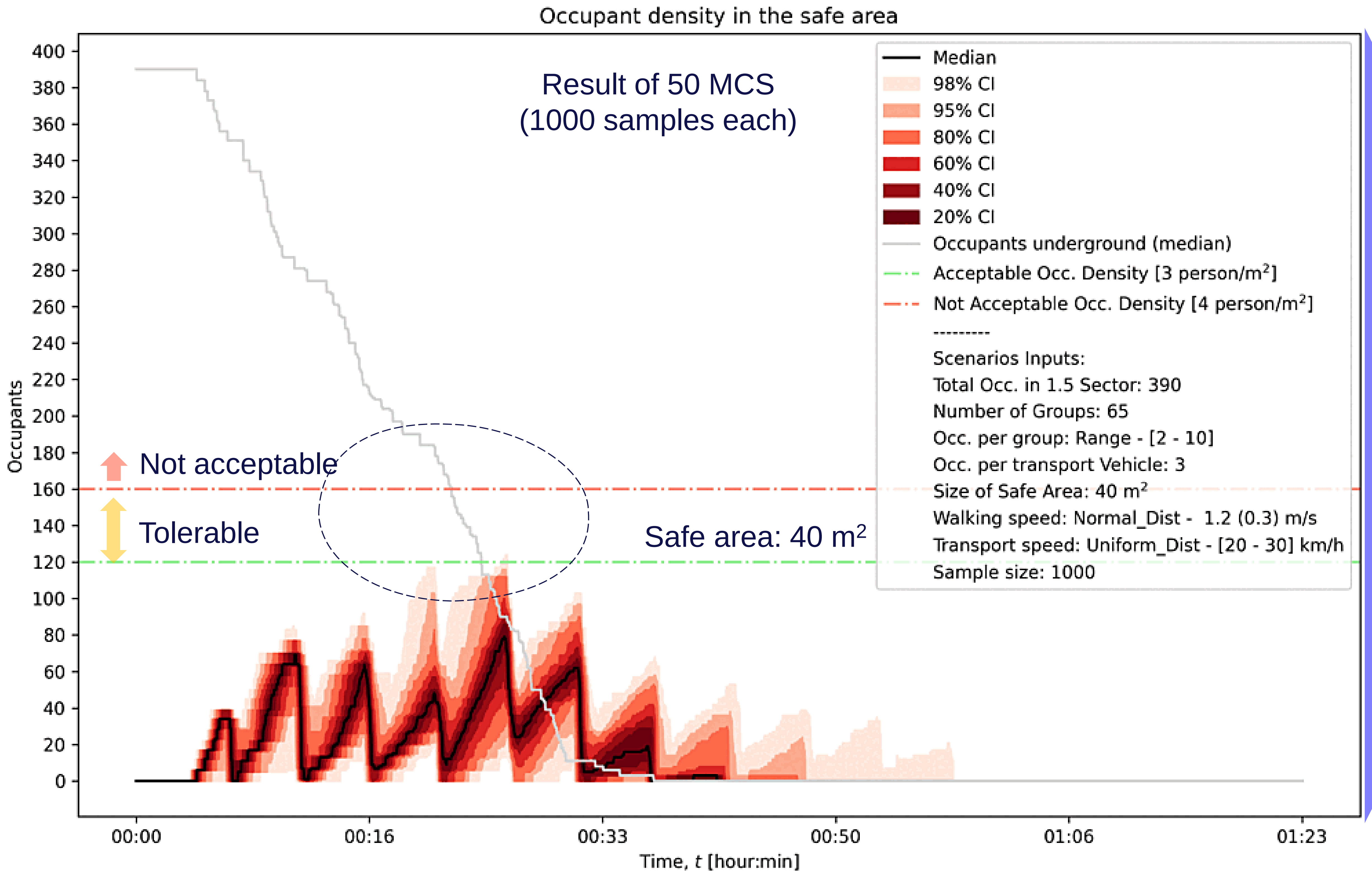
Safe area size of 40 m^2 **acceptable** !
No specific overcrowding

Evacuation study

Results – Scenario 2 (260 occ / sector – 390 total)

Occupant distribution in the tunnel:



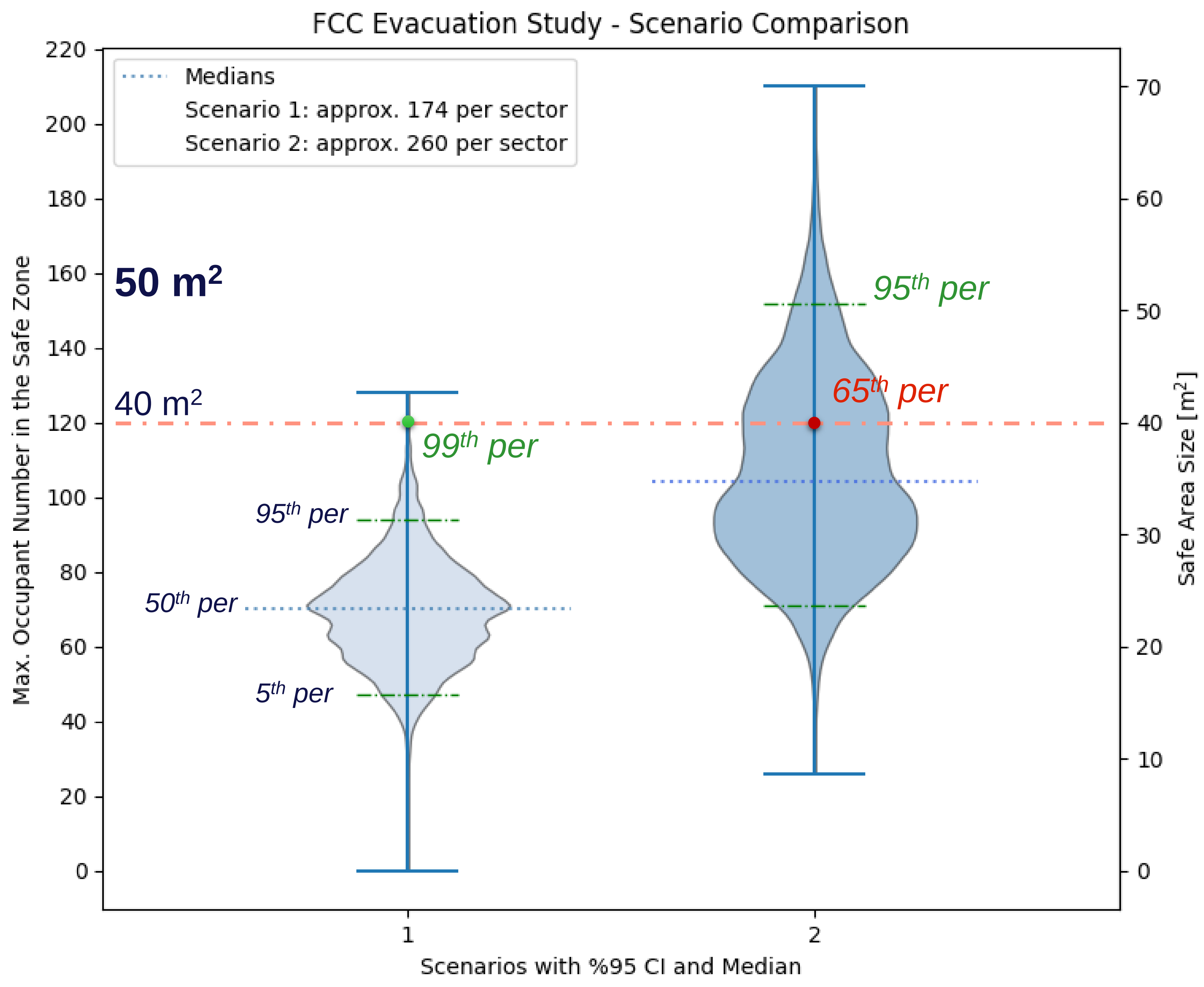


Maximum crowding

Safe area size of 40 m^2 **not** suitable !
Overcrowding observed at ~ 20 – 25 min
Optimal size ?

Evacuation study

Results – Maximum crowding



Outcome:
Safe area size of **50 m²**

The results show that having a safe area of 50 m² would be suitable in both scenarios, within a 95% confidence level.

Next steps

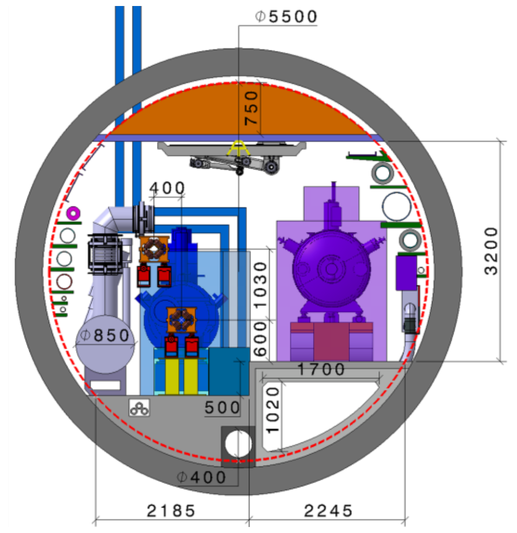
Use the model for other access modes:

- During machine installation
- During degraded modes

Improve the code to cope with other studies:

- Fire Brigade intervention in case of ‘ Search & Rescue’
- Results to feed into other studies (e.g. fire/smoke simulations)

Cryogen release – numerical simulations



Aim:

- **Simulate a Helium leak in the vicinity of the SRF cryomodules**
  - → None-stay zones
  - → Pressure build-up in a compartment
  - → Access conditions when cold

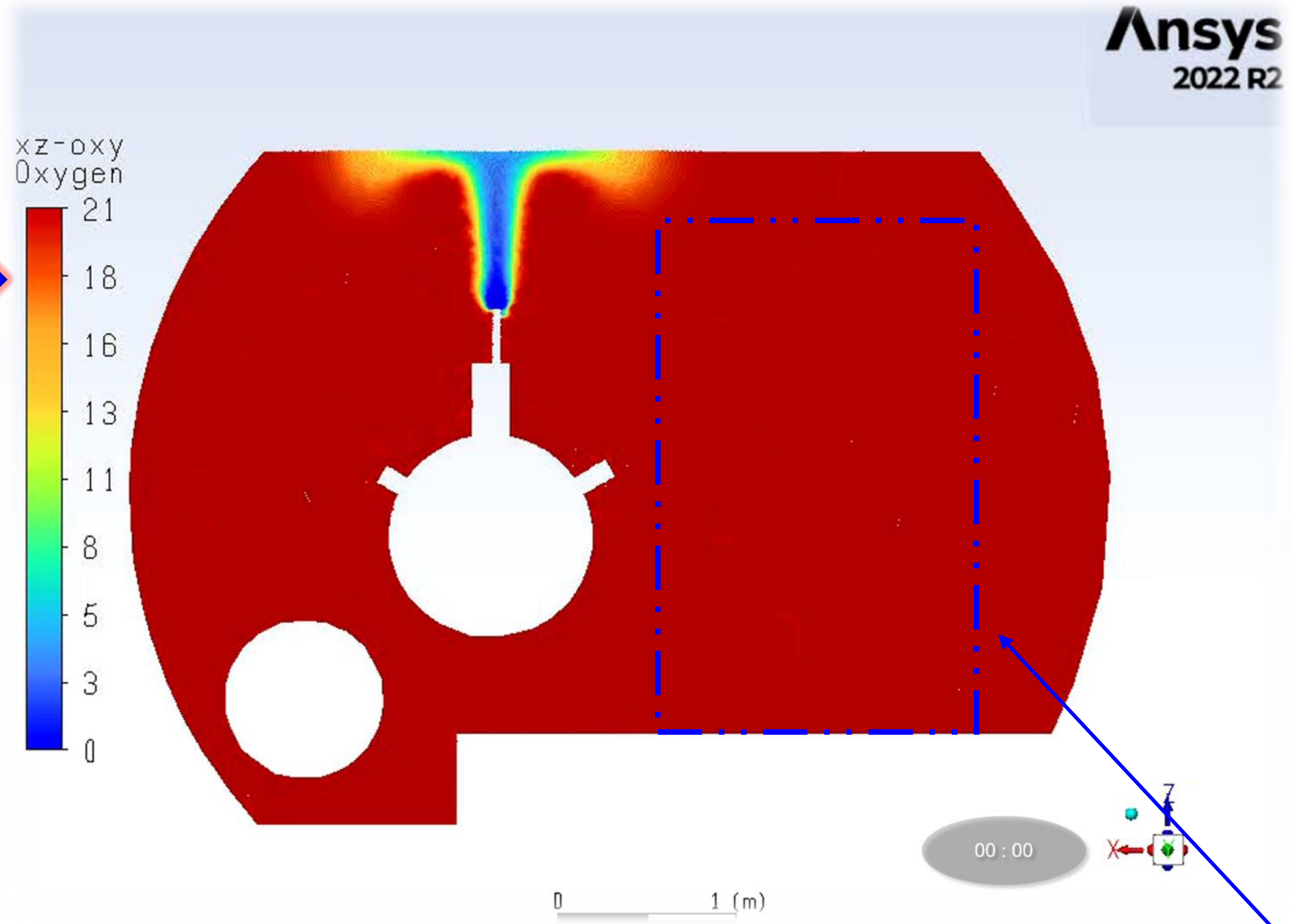
Preliminary results

Boundary conditions:

- Species transport CFD:
  - → Helium & air
  - → Mixture of chemical species
- Adiabatic (for now)
- SST (κ-ω) turbulence model
- Simulate a compartment in the RF sector – simplified geometry
- Air inlet = 4 * 510 m^3/h (diffusers)
- Longitudinal air velocity ~1 m/s
- Helium spill: 3.5 kg/s @ 5 K
- Rupture disk: 50 mm Ø
- Helium inventory: *still tbd*

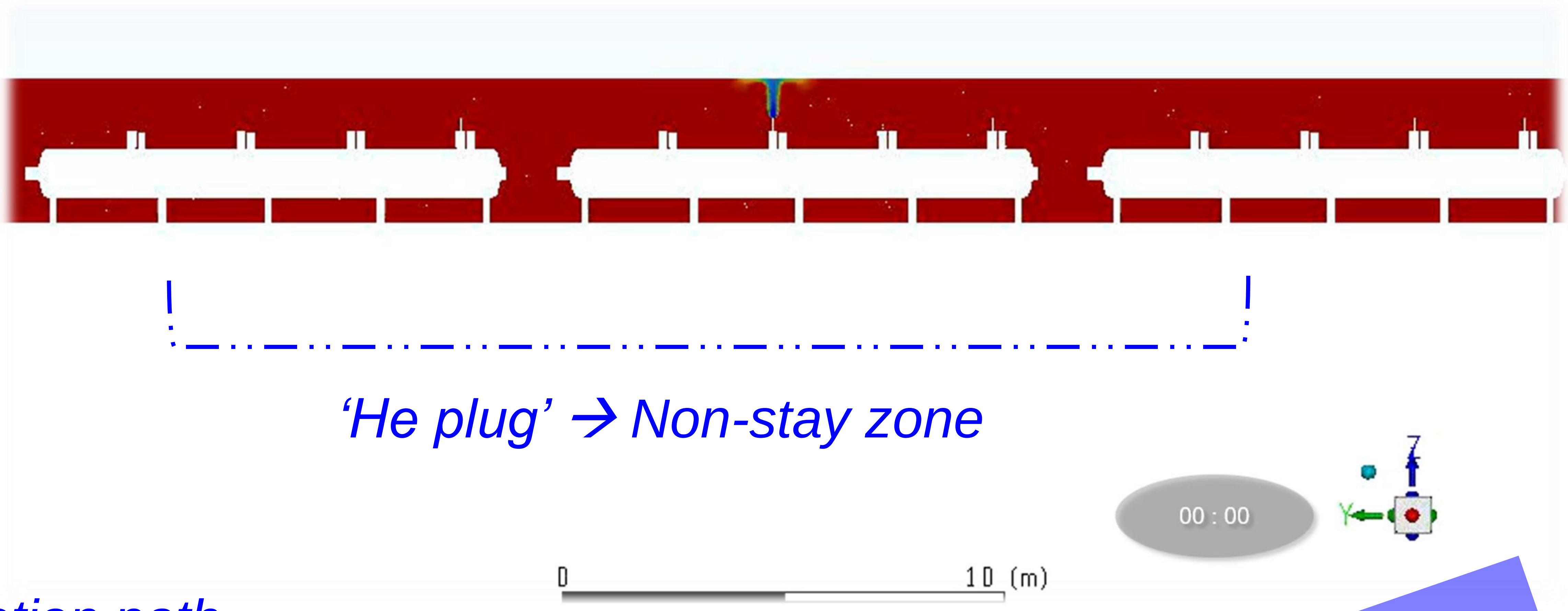
Preliminary - detailed input required from RF

Cross-section



Evacuation path

Longitudinal



'He plug' → Non-stay zone

In a few seconds (4 – 10s) the O_2 levels reach limit at the evac path and for several meters

V. Parma - "RF string or continous cryomodules"
B. Popov - "FCC cryogenics status" Tuesday (June 6th)

Fire Detection

Current state-of-the-art:

- Aspirating Smoke Detection (ASD) technology

Aspirating Smoke Detection (ASD) limitations:

- Technical: distance of aspiration tubes (M. Dole et al, “Long Distance Aspirating Smoke Detection for Large Radioactive Areas”)
- Integration: number of tubes

SPS example:

- 4 x 110m tube per compartment, giving ~15 tubes/alcove, 1-2 tubes/ASD
- 1 CIE (central) of Fire Detection / alcove

FCC-ee

	Per alcove	Per LSS/ARC	Total
Detection locations	8 in arc + 2 in alcove	70	560
Aspiration tubes	6.8 km	47.6 km	380.8 km
Fire detection central	1	14	56
Monitoring system			1

- The systems today in place in other accelerators meet the basic requirements. However, the technology is reaching its limits and not all solutions scale well for the FCC.
- Study generalized vs localized fire detection?

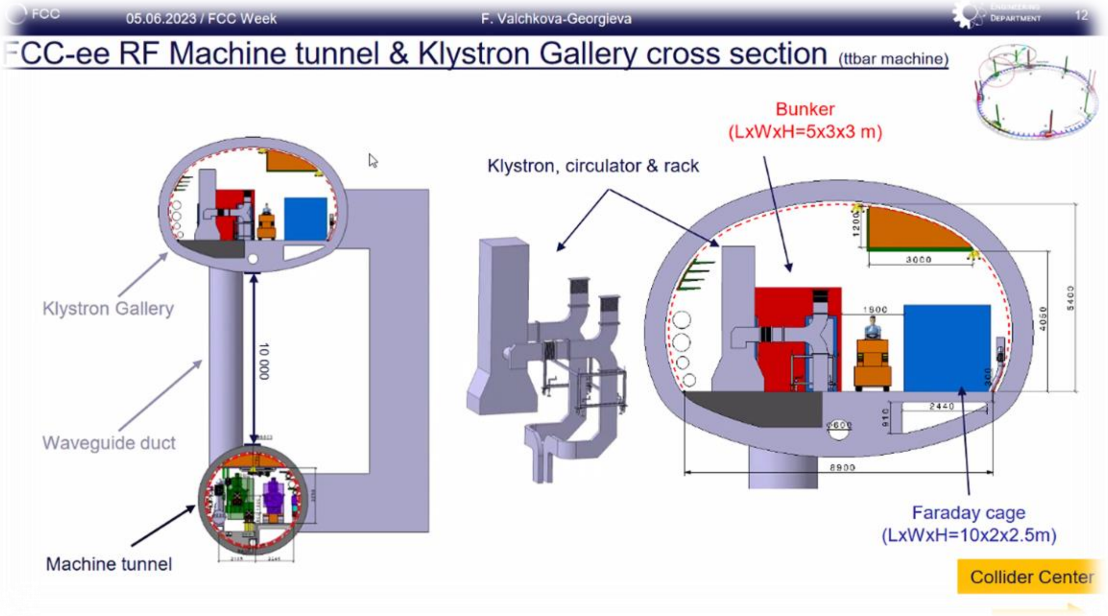
e.g.

https://youtu.be/etN0Qj2zSpQ

Further R&D is required

https://www.protectowire.com/products/fiber-optic/

Outlook



Ongoing studies / main focus for MTR:

- Complete the PBS (cost estimate)
- Complete the cryogenic release simulations
- Perform fire simulations in the Klystron gallery
- Perform the evacuation study during installation phase
- Use the FCC mock-up to integrate real scale safety systems

LEP mock-up
https://youtu.be/1YtNCi6CJWg

F. Carra
"Arc half-cell configuration and mock-up"
Thursday (June 8th)

Acknowledgements to the co-authors (Safety WP) and to the colleagues from the TIWG pillar for their contributions

FCC Safety WG is happy to receive ideas and have colleagues to join the effort

Thank you for your attention

SPARE SLIDES

Evacuation study - Fixed Conditions

Shaft parameters:

- Area 40 m^2
- Capacity of the Lift 76 (2 lift * 38 person)
- Lift speed 4 m/s
- Height of the shaft 400 m
- Un/Loading time of the lift 50 s

Occupant parameters:

- Occ. Walking speed Normal distribution 1.2(0.3) m/s, Sample Size 1000
- Occ. Transport velocity Uniform distribution [20,30] km/h, Sample Size 1000
- Occ. Numbers for each group Binomial Dist. (Max 10, Min 2, 3 Standard Deviations, Sample Size 1000)
- Occ. Premovement time 180 s

Group parameters:

- Group positions Binomial Dist. (Max 11400, Min -5503, 3 Std. Deviations, Sample Size 1000)

Evacuation study - Boundary Conditions

Number of studies:	2
For each study:	Occ. Capacity of the transport vehicle changes: 2 and 3 respectively
Number of runs for each study:	50
For each run;	Distribution of the group positions inside the tunnel, number of occupants in each group and the total group number randomly change
Group parameters:	
• Group positions:	Randomly picking from the sample
• Number of Groups:	Until sum of the occupant numbers in the groups is equal to Total Occupant Number
• Occ. Numbers for each group:	Randomly picking from the sample
Number of simulations for each run:	1000
For each simulation;	
• Occ. Walking speed:	Randomly picking from the sample
• Occ. Transport velocity:	Randomly picking from the sample

Evacuation study

FCC Evacuation Study

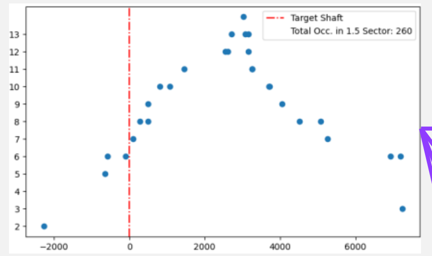
Transport Occ. Capacity [#2]

2 Cases
For each Occupant Capacity
of the Transport Vehicle

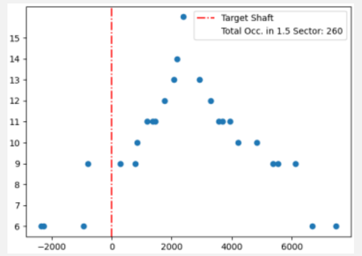
Transport Occ. Capacity [#3]

50 Runs
with
Different Occupant Distribution
in the Sector
For each case

Occupant Distribution in the Sector



Occupant Distribution in the Sector



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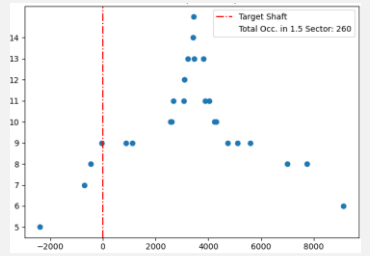

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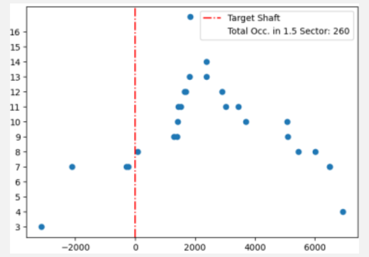

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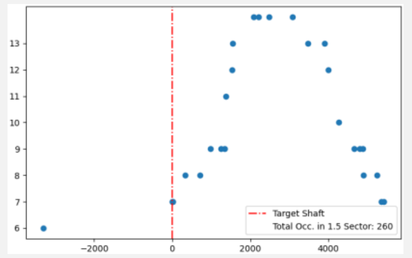

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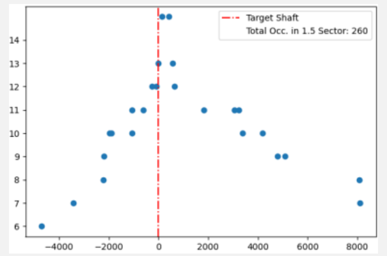

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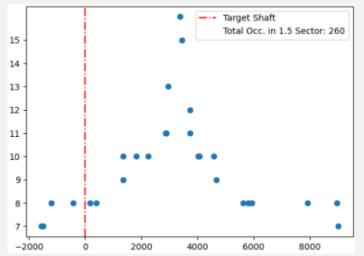

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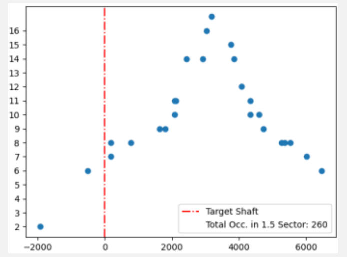

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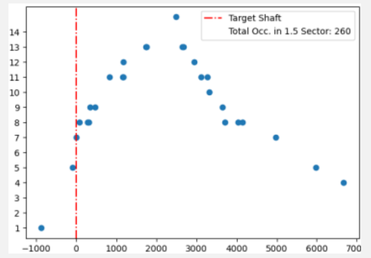
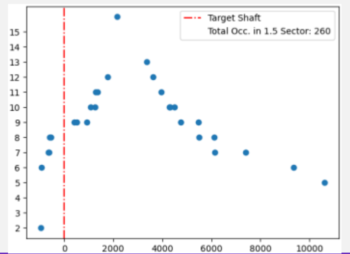


Occupant Distribution in the Sector



Random Occ. Walking Speed and
Random Transport Mean Velocity

Random Occ. Walking Speed
and
Random Transport Mean Velocity

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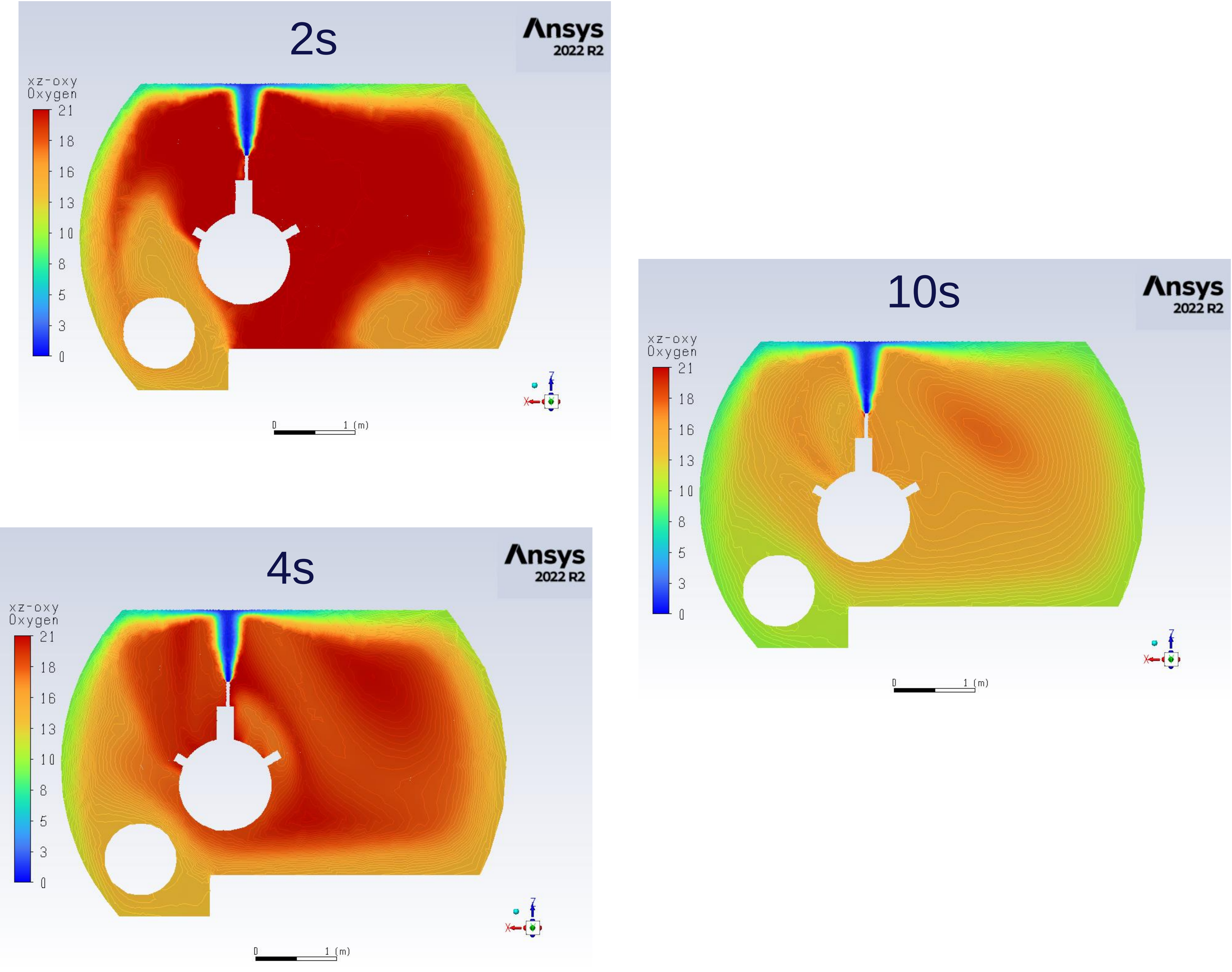
Random Occ. Walking Speed
and
Random Transport Mean Velocity

1000 Simulations
with
Different occupant walking speed
and
Occupant transport mean velocity
For each run

Cryogen release – numerical simulations

O_2 levels (%)



Temperature (K)