CERN

Lessons learnt and new concepts for conventional Safety in FCC

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For a general overview:

R. Trant, "Health, safety and environment, FCC Kick-off"

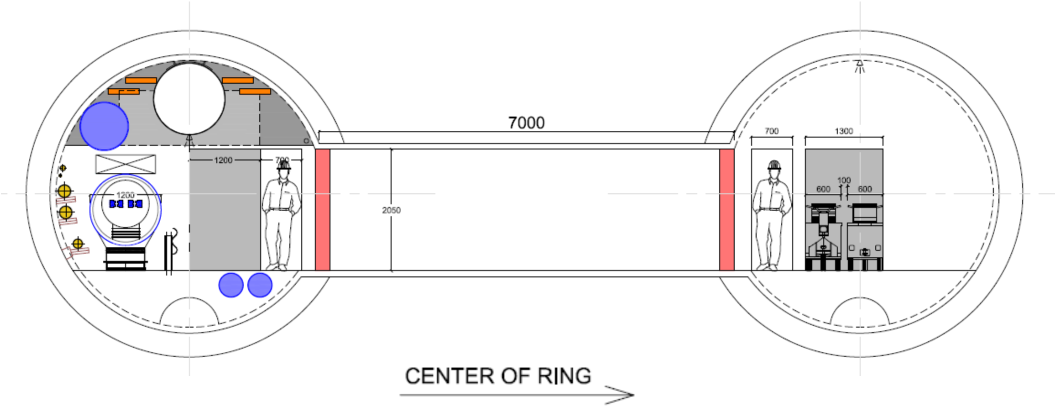
http://cds.cern.ch/record/1694672

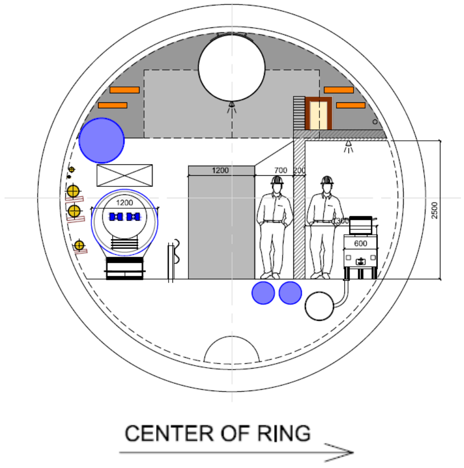
FCC Week 2015

26th March 2015

Overview

- Focus on studies for conventional Safety aspects:
  1. Air management[1]
  2. Cryogenic Safety
  3. Evacuation
- Studies focused on two main tunnel cross-sections FCC-hh:
  - ➢ 4.5 m Ø double tunnel
  - ➢ 6 m Ø single tunnel





- Outcome is in line with RP constraints

[1] Air Management for RP
See M. Widorski presentation

Air management functions

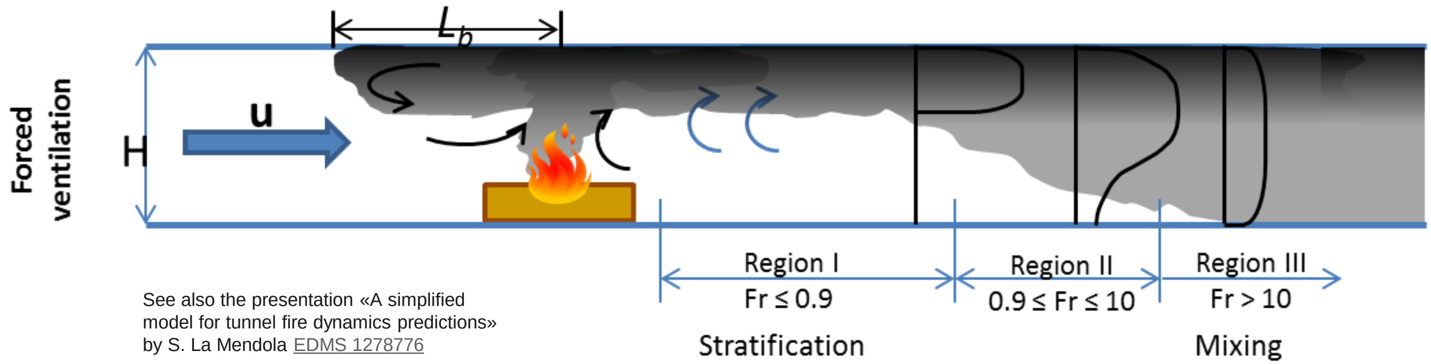
- Provide fresh air during access
- Cope with different accidental scenarios (e.g. fire, Oxygen Deficiency Hazard, gas leak)
- Provide dynamic confinement between “machine zone” and “safe zone” for protection of occupants in accidental scenarios
- Provide dynamic confinement between “controlled” areas and areas accessible during run for protection of occupants
- Provide sufficient air flow for heat removal during operation

Air management concepts

Longitudinal ventilation (LV):

Main Advantages, w.r.to conventional Safety	**Main Disadvantages**, w.r.to conventional Safety
- Provides fresh air for occupants during access - Regulate air speed in the tunnel	- Propagation and contamination of smoke to others volumes of the tunnel - Even if the ventilation is stopped , the smoke still propagates

Smoke propagation in LV:



See also the presentation «A simplified model for tunnel fire dynamics predictions» by S. La Mendola EDMS 1278776

The **back layering length** (L_b) is limited to a few tens of meters upstream the fire at worst

Fr = Froude number: ratio between flow inertia and buoyancy

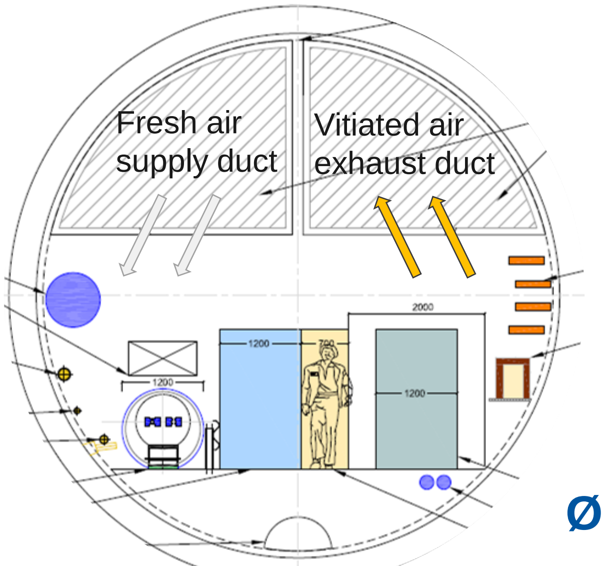
Courtesy of S. La Mendola

Air management concepts

Transverse ventilation (TV):

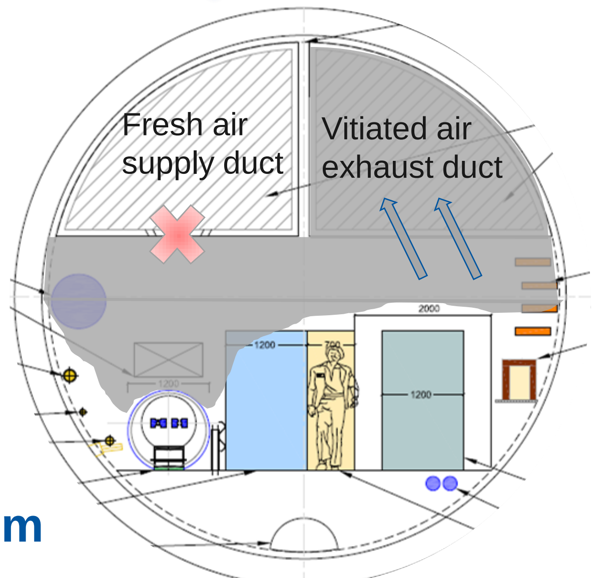
Main Advantages, w.r.to conventional Safety	**Main Disadvantages**, w.r.to feasibility of the system
- Limit the propagation and contamination of smoke to others volumes of the tunnel - Provide dynamic confinement localized near the fire	- Large ducts are needed → occupy ~50 % of the tunnel volume - Larger tunnel needed

Smoke propagation in TV:



Normal operation

Ø 7.5 m



Fire conditions

D = 7.5 m → A_{total} = 44 m^2

→ A_{useful} = 34 m^2

A_{ducts} = 14 m^2 →

41 % of the useful area

Air management concepts

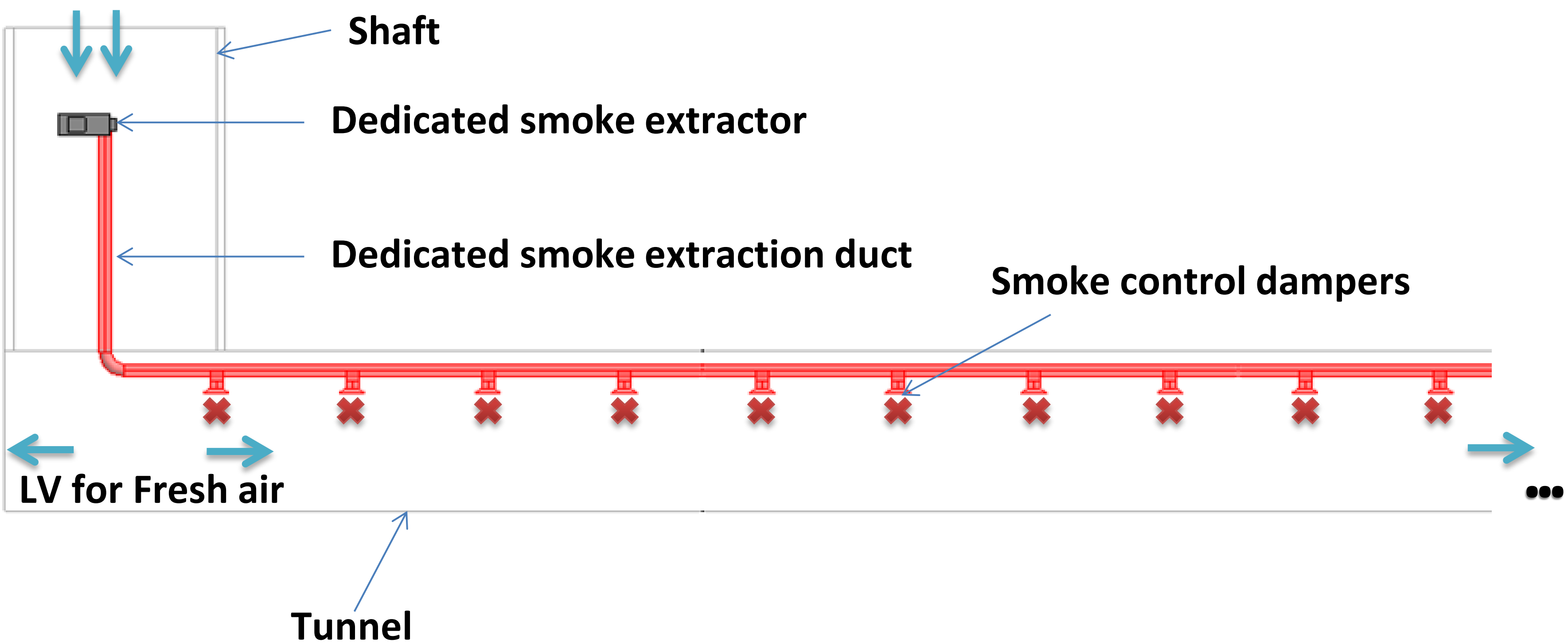
"Optimised" solution:

- Longitudinal Ventilation for normal operations
  - Provide the requirements for occupational health (Fresh air)

- Dedicated smoke extraction system
  - Limit propagation and contamination of smoke to others volumes of the tunnel
  - Provide the dynamic confinement
  - Reduced cross section of the smoke extraction duct

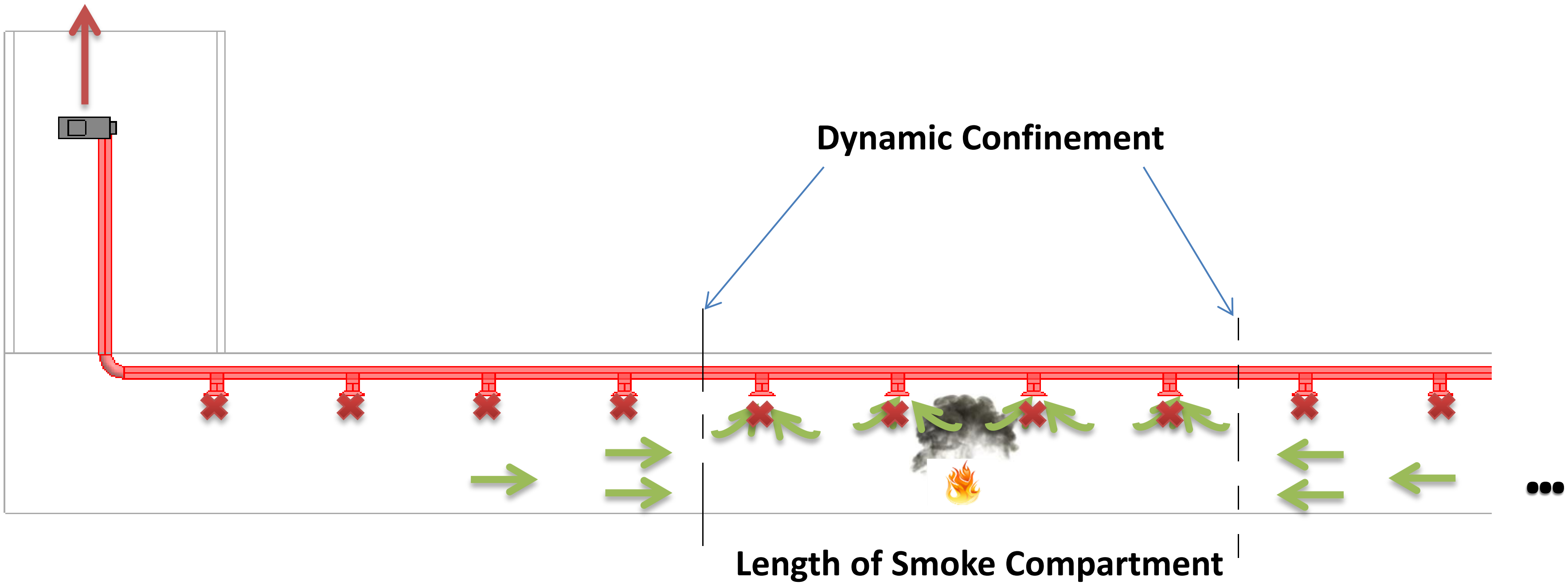
Smoke extraction system

- Example of a section of the FCC tunnel:
  - Nominal conditions



Smoke extraction system

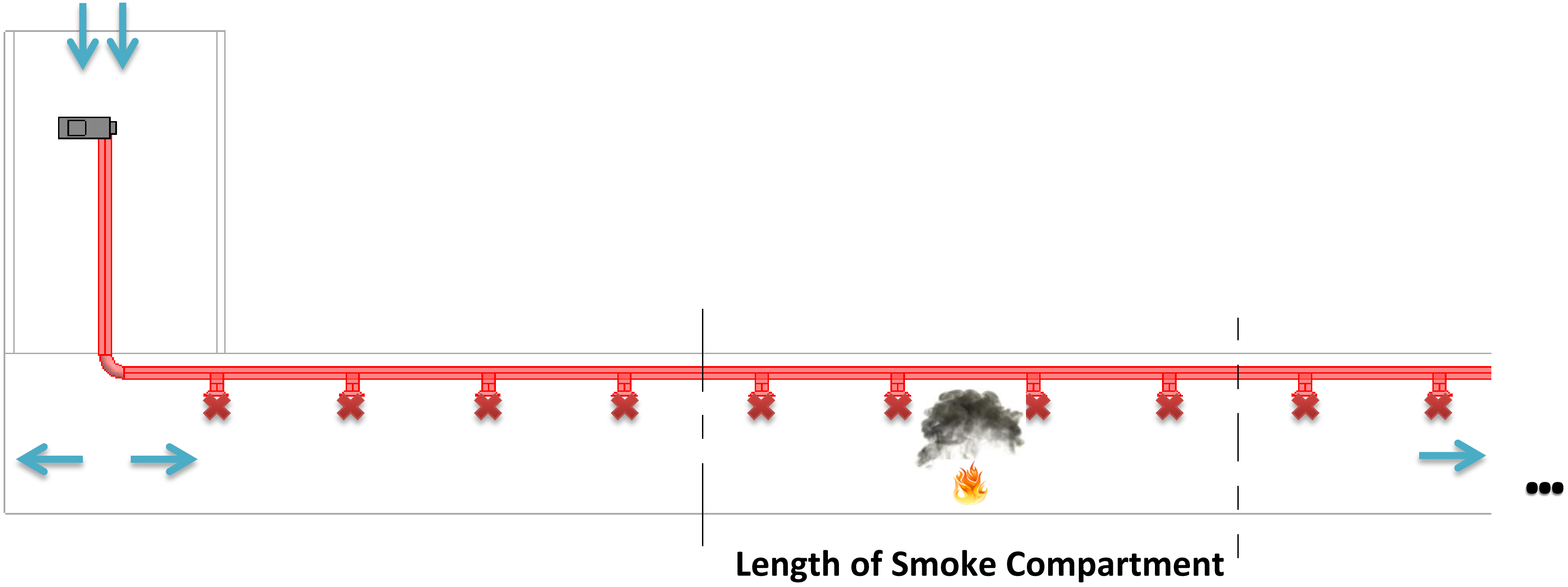
- Example of a section of the FCC tunnel:
  - Accidental scenario – e.g. Fire
  - Longitudinal ventilation is stopped



Smoke extraction system

- Fire Detection system:

- ➢ Shall be able to identify the fire location within a certain length, to ensure that the dampers open in the correct location



Smoke extraction system

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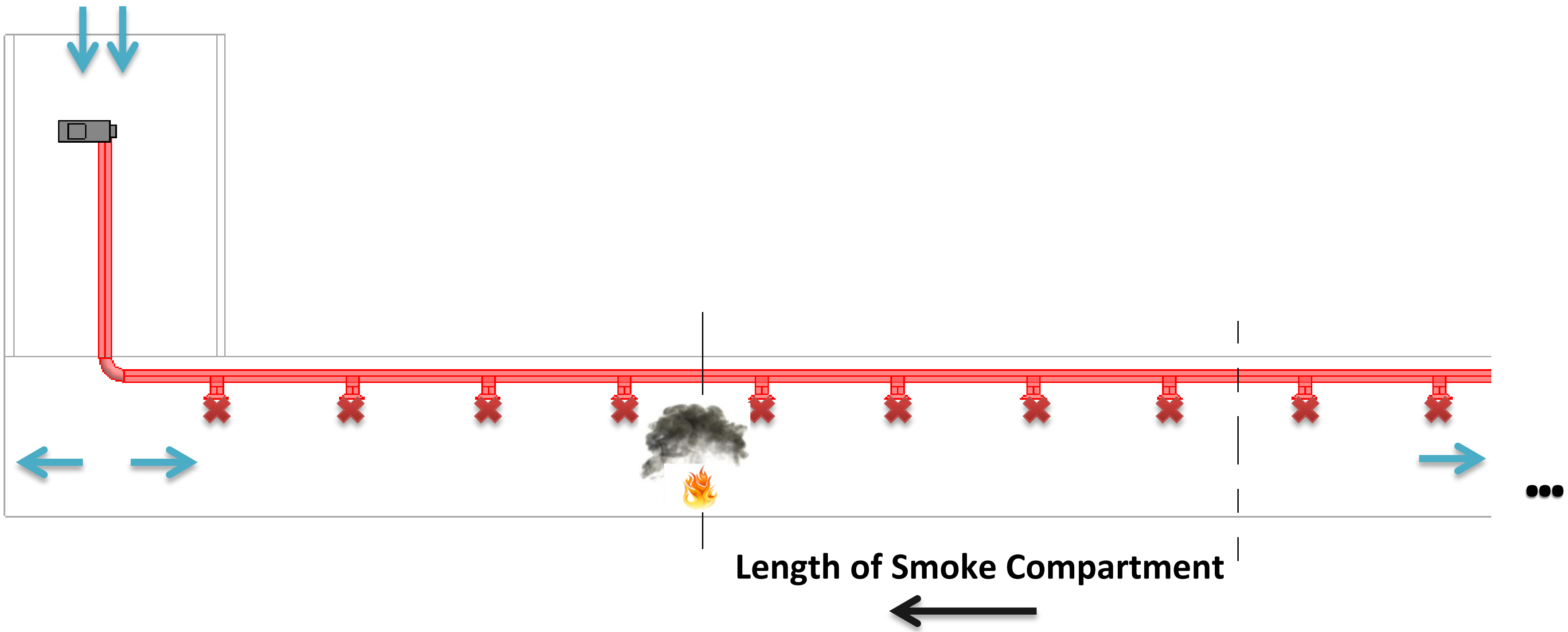

Smoke extraction system

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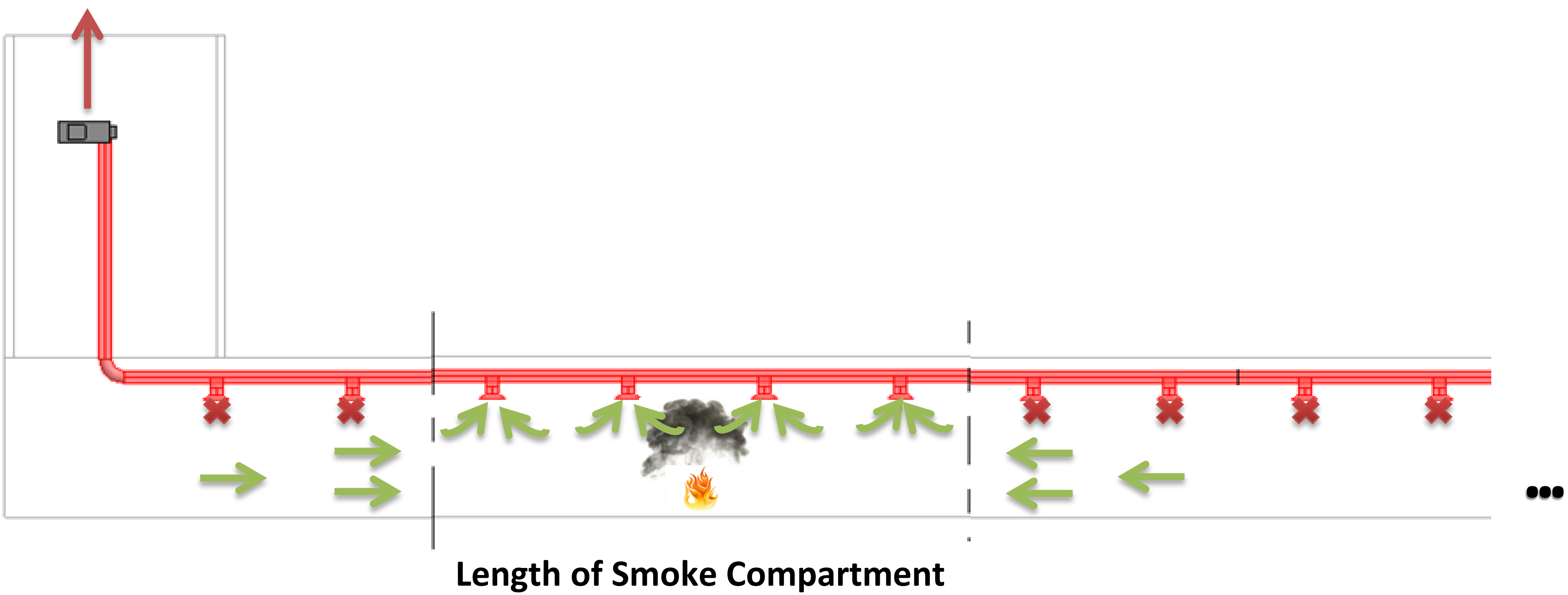
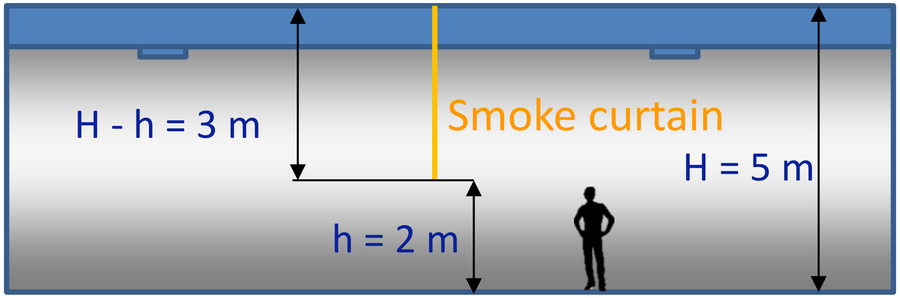


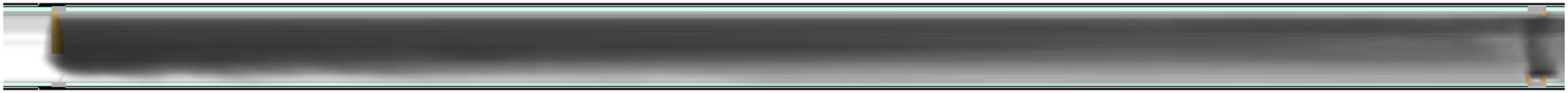
Smoke extraction system - Simulations

- Smoke compartment = 200m
- Extraction flowrate = 12 m^3/s
- Smoke curtain (in addition)

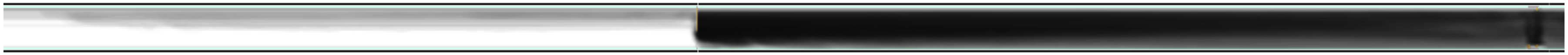


Full confinement within the 200 m compartment for a **1 MW** fire and 12 m^3/s

Full confinement within the 200 m compartment for a **2 MW** fire and 12 m^3/s



Partial confinement within the 200 m compartment for a **5 MW** fire and 12 m^3/s

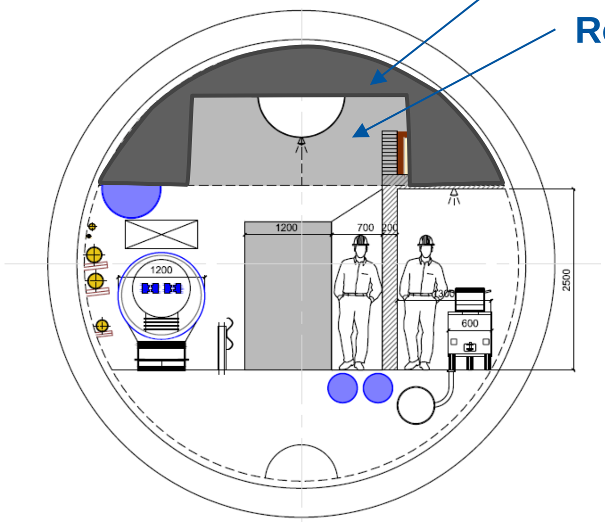


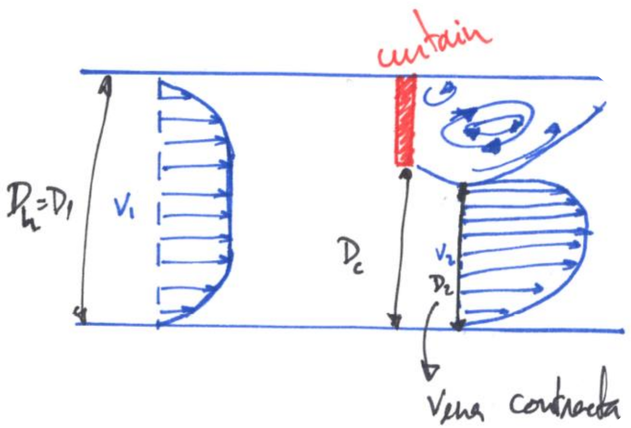
This system provides a good smoke confinement also in off-nominal conditions

Courtesy of S. La Mendola

Pressure drop – Curtains

- Ø 6 m tunnel
- Curtain: Fixed part
- Length = 10 km
- Air flow = 140 000 m^3/h (1 ACH)
- Dh = 4.2 m





	#	ΔP_{fixed} [Pa]	$\Delta P_{complete}$ [Pa]
Curtains	1	13.5	109
	50 (1 per 200m)	675	5450
	20 (1 per 500m)	270	2180

- **Feasible** from pressure drop point of view

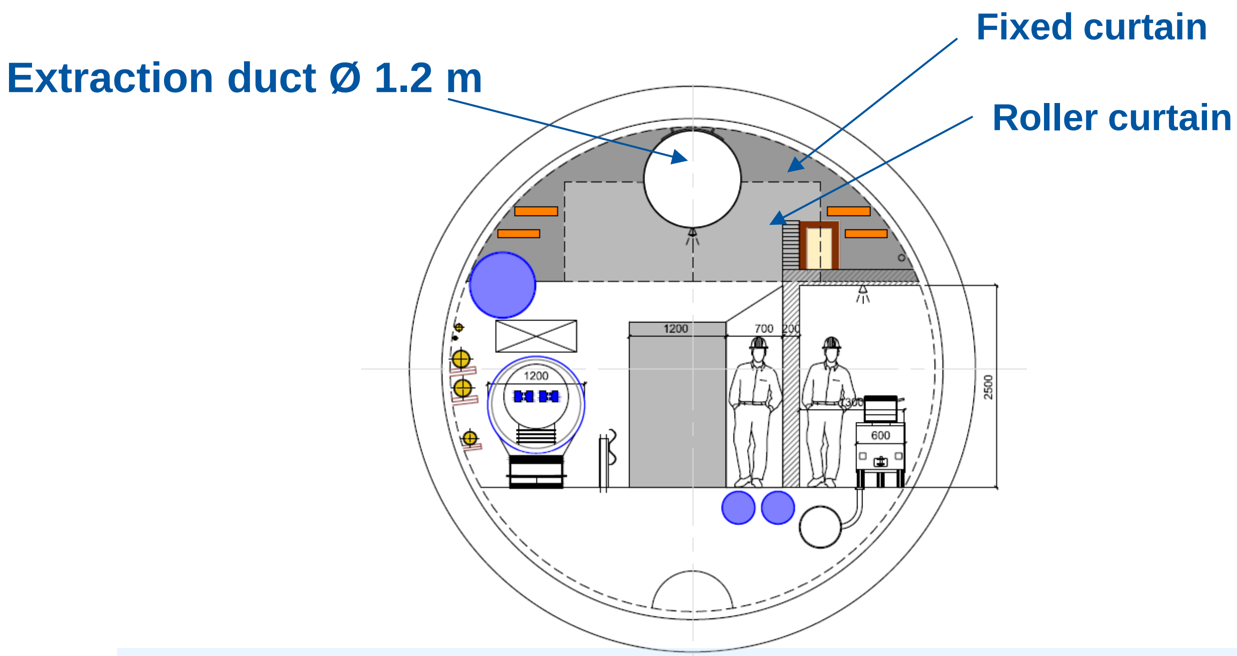
Tunnel → ΔP = 136 Pa

Smoke extraction system

Considering:

- Extraction flow rate of 12 m^3/s;
- Velocity in duct of 10 m/s;

Requires an extraction duct of 1.2 m



Can this system be used for other purposes?

Cryogenic Safety – ODH

Can the smoke extraction system also cope with a potential He release?

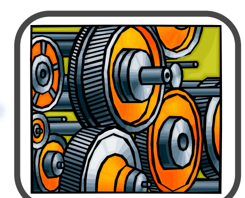
- Based on LHC, we have 2 scenarios:

1. **Access** (no powering): few hundred g/s

   → Compatible with smoke extraction proposal (12 m^3/s)

2. **No access** (beam mode / magnets powered): couple tenths kg/s

   → By far not compatible with smoke extraction proposal (12 m^3/s)



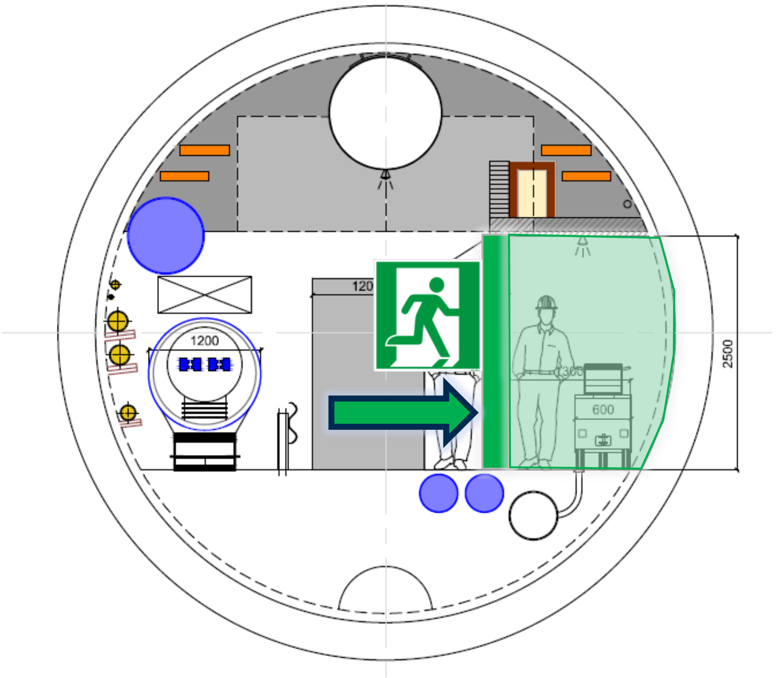
Smoke extraction system → **Emergency Extraction system (EES)**

Evacuation

<u>6 m Ø Single Tunnel</u>

Evacuate through a door leading to a “Safe Zone”:

- Fire resistant
- Air tight in case of cryogen release
- Overpressure, w.r.to machine zone
- Personnel transportation for evacuation



Safe zone with limited amount of combustible material

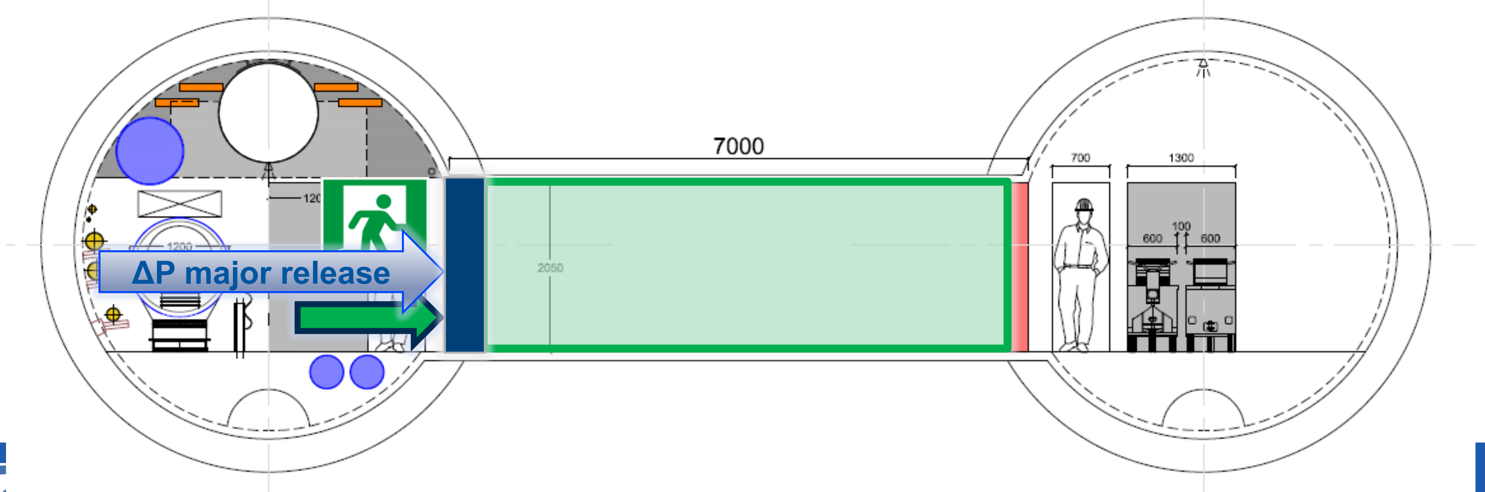
Evacuation

<u>4.5 m Ø Double Tunnel</u>

Evacuate through a passage way connecting to a "Safe Zone" in the parallel tunnel:

- Fire resistant
- Air tight in case of cryogen release
- Overpressure, w.r.to machine zone
- **More space** for transportation and for emergency intervention teams

- **If access to // tunnel during powering → "Pressure resistant" doors**



Evacuation

Dimensions for Safe Area in front of the lifts

Assumptions (rough scaling from LHC):

- **Maximum occupants x3**
- Accidental scenario
- Uniform distribution in arc
- …

Data:

- Lifts in machine shaft: 1 lift capacity of 30 people; velocity of **5 m/s**; stroke 300m
- Arc length 8 km
- Evacuation speed: 2.5 m/s (9 km/h)

Similar areas as for the LHC today

Courtesy of S. La Mendola

Conclusions

1. **Air Management:** Longitudinal ventilation → nominal operation
   Emergency Extraction system (EES) → accidental scenarios

2. **Smoke curtains:** Optimized → Fixed + Roller part
   Feasible solution w.r.to pressure drop

3. **Cryogenic Safety:** Release in access mode → can be handled by EES
   During powering → "pressure resistance" towards Safe Area

4. **Evacuation:** Separate hazards from Safe zone
   Dimensions of Safe area near lifts → further studies but comparable to LHC

5. **Cross-section:** Double tunnel has advantages for Safety and accessibility

Further Studies

- Additional simulations for the EES → optimisation
- Pressure build-up in case of major helium release (no access)
- Impact on the mechanical properties of the ventilation system (ducts, supports, etc.), due to the low temperatures
- Optimise sizing of cryogenic relief devices – Kryolize Project
- Optimisation of the transportation mean and layout for evacuation
- Evacuation scenarios for surface area in front of lifts
- Prepare environmental impact study

Support all FCC WGs on Safety issues

Thank you very much

for your attention

Acknowledgements:

C. Cook, S. La Mendola, P. Lebrun, M. Nonis, J. Osborne, I. Ruehl, L. Tavian, R. Trant, M. Widorski

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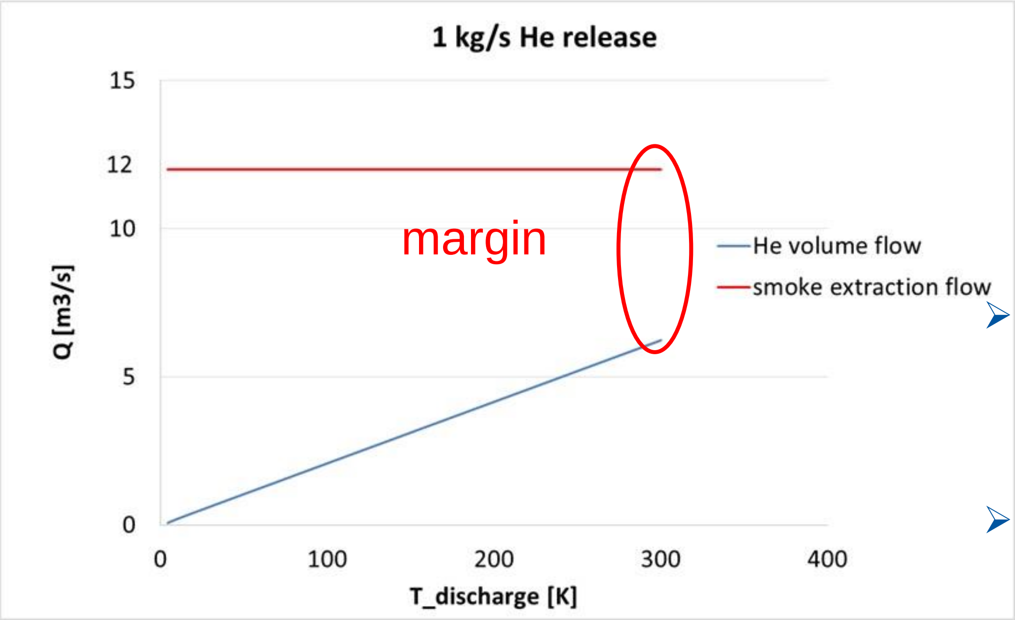
Spare Slides

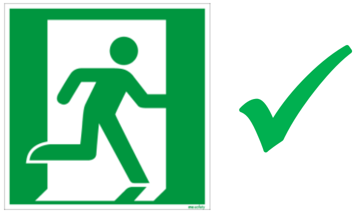
Cryogenic Safety – ODH

Access Mode:

- Release scenario of ~1 kg/s



- Aid evacuation

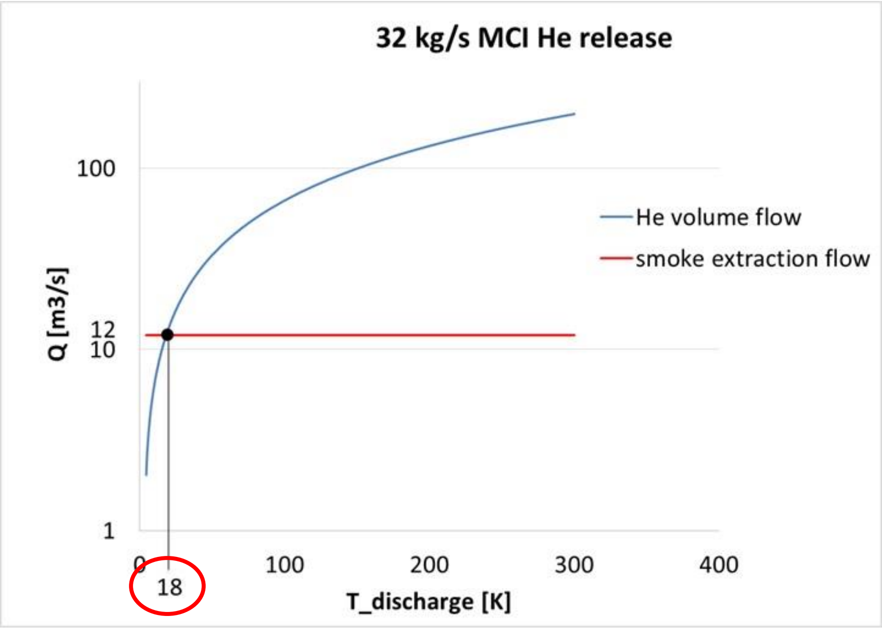


- Smoke extraction proposal **OK** to extract 1 kg/s He release, w.r.to flow rate capacity → **min margin by factor 2**
- Study the impact on the mechanical properties of the ventilation system (ducts, supports, etc.), due to the low temperatures

Cryogenic Safety – ODH

No Access "Beam Mode":

- Release scenario of ~ 30 kg/s (assumption from LHC)



- After 18 K, Q due to He leak > Q smoke extraction
- Smoke extraction proposal will, by far, not be possible to cope with MCI, but:

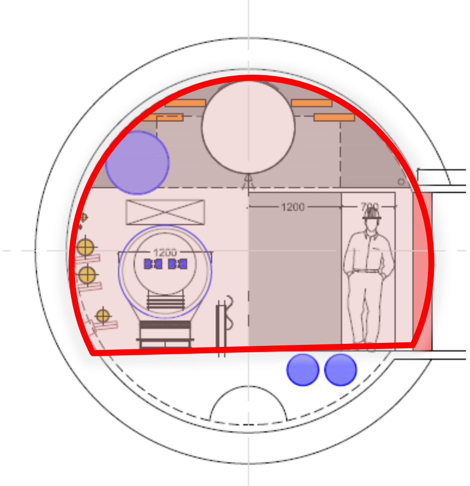
No access → Protect installation

Cryogenic Safety – ODH

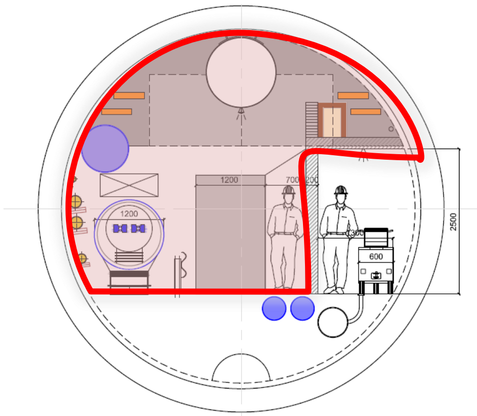
No Access "Beam Mode":

- Release scenario is 32 kg/s (assumption from LHC)

  - ~ Sectorise the QRL each 2 cells ~ 2*100m
  - 6 L LHe / m → 5200 L LHe @ 300 K → **3640 m³** GHe
  - FCC SACR: 3.2 km (most conservative)



4.5 m Ø : 11 m2

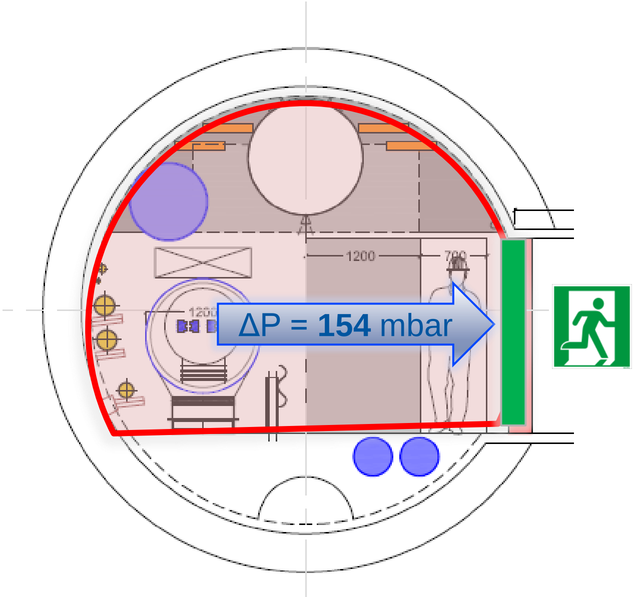


6 m Ø : 14 m2

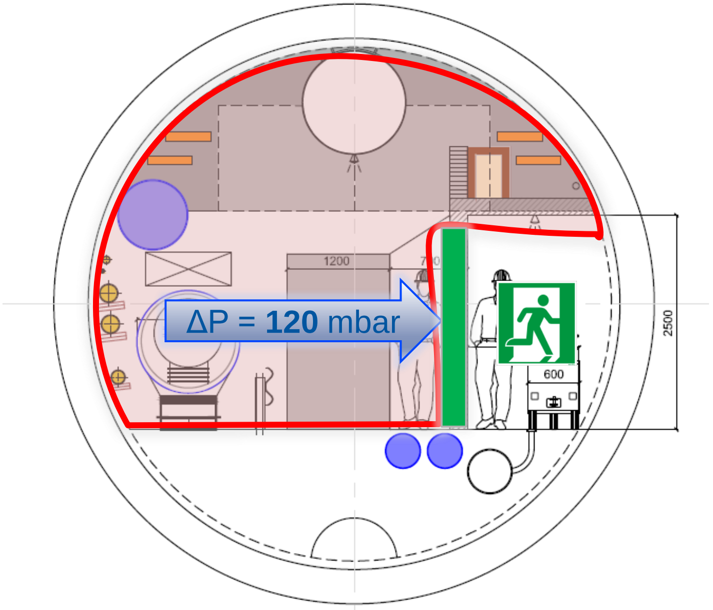
4.5 m Ø → 43100 m3 of air + 3640 m³ GHe → **154 mbar** pressure increase

6 m Ø → 33700 m3 of air + 3640 m³ GHe → **120 mbar** pressure increase

Cryogenic Safety – ODH



4.5 m Ø



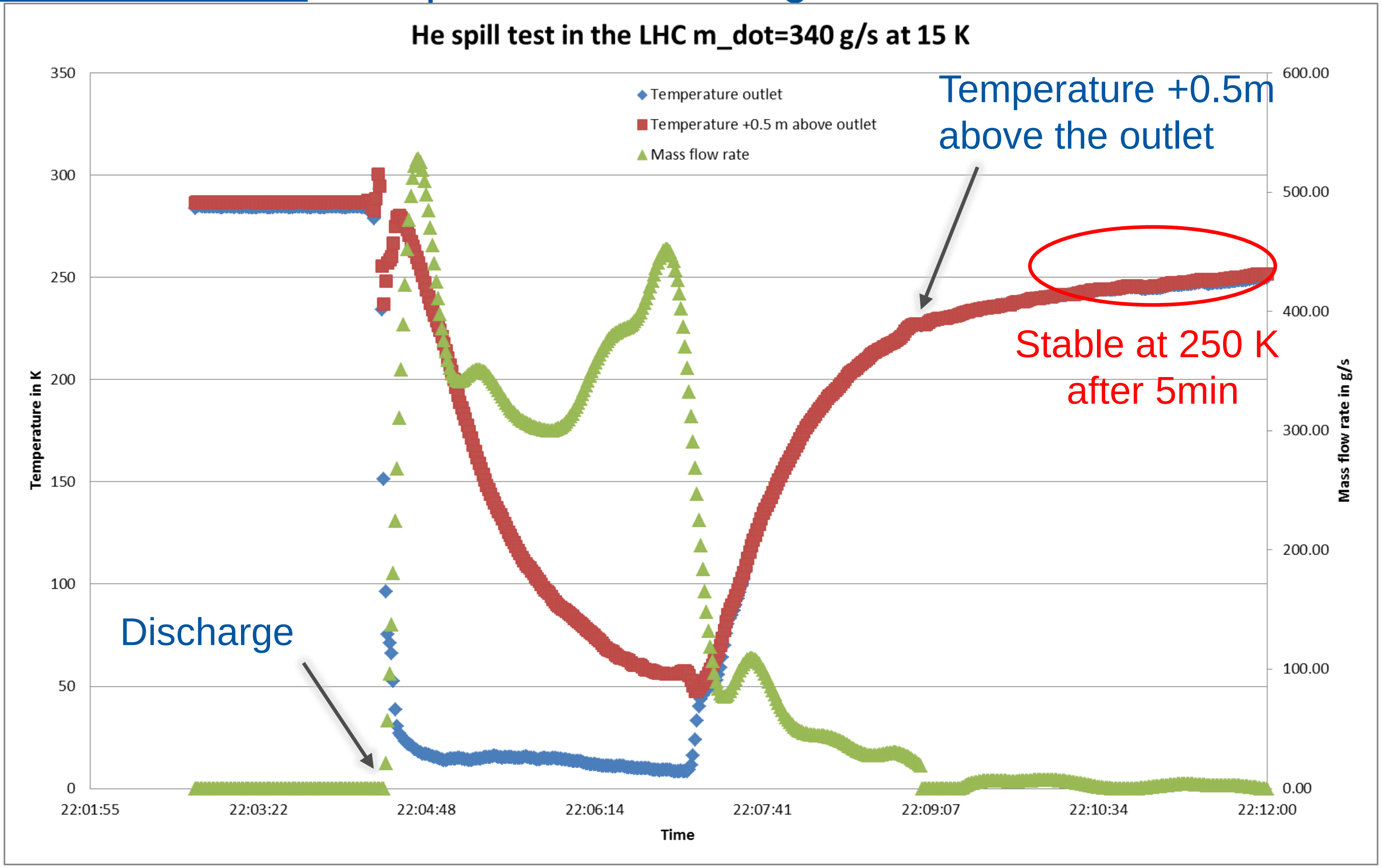
6 m Ø

In LHC (MCI): from 30 to 200 mbar

Ref: Report of the Safety task force, 2009

Cryogenic Safety – ODH

He Spill Test in LHC: Temperature for 340 g/s GHe release



Courtesy of T. Koettig TE/CRG, CERN

Evacuation

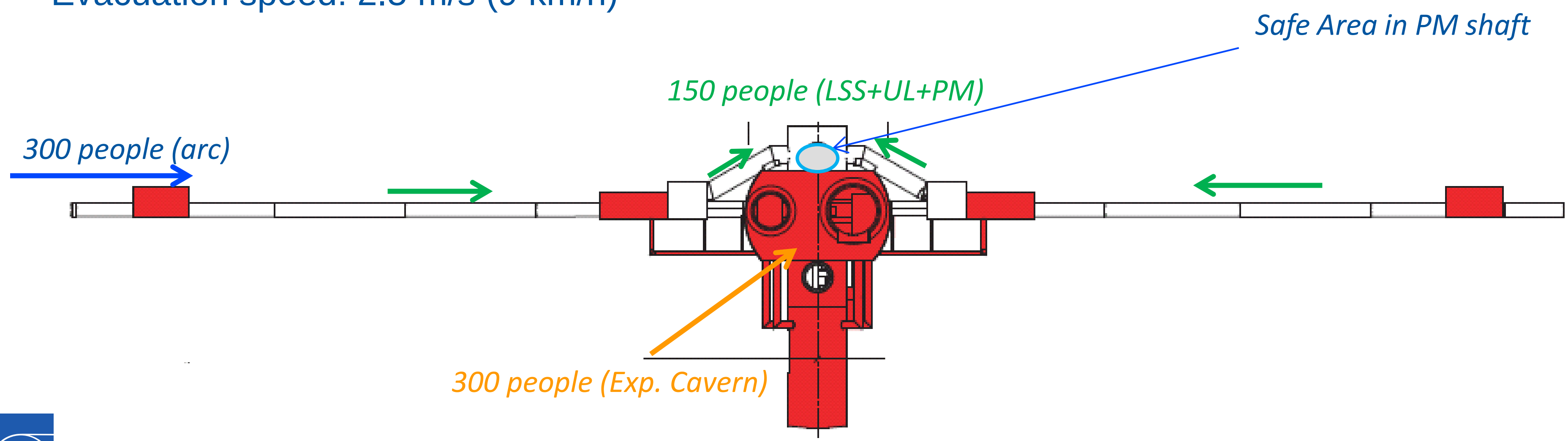
Dimensions for Safe Area (in front of the lifts)

Data:

- Lifts in machine shaft: 1 lift capacity of 30 people; velocity of 5 m/s; stroke 300m
- t = 0 s (evacuation alarm)
- Arc length 8 km
- Evacuation speed: 2.5 m/s (9 km/h)

Assumptions (rough scaling from LHC):

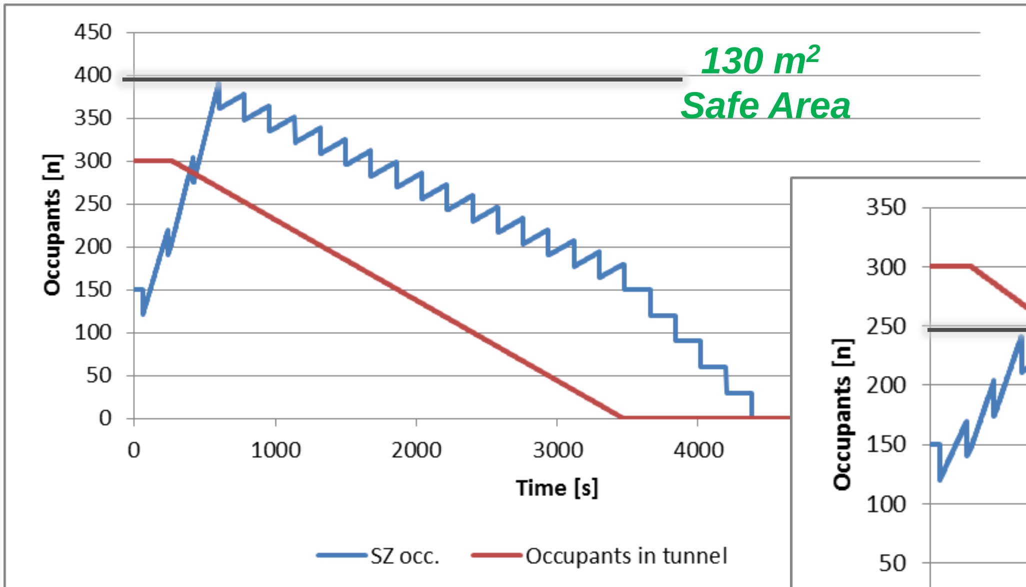
- Maximum occupants, accidental scenario
- Evacuation from experiments: 60s < t < 600s
- Uniform distribution in arc: ~4 occ. / 100m



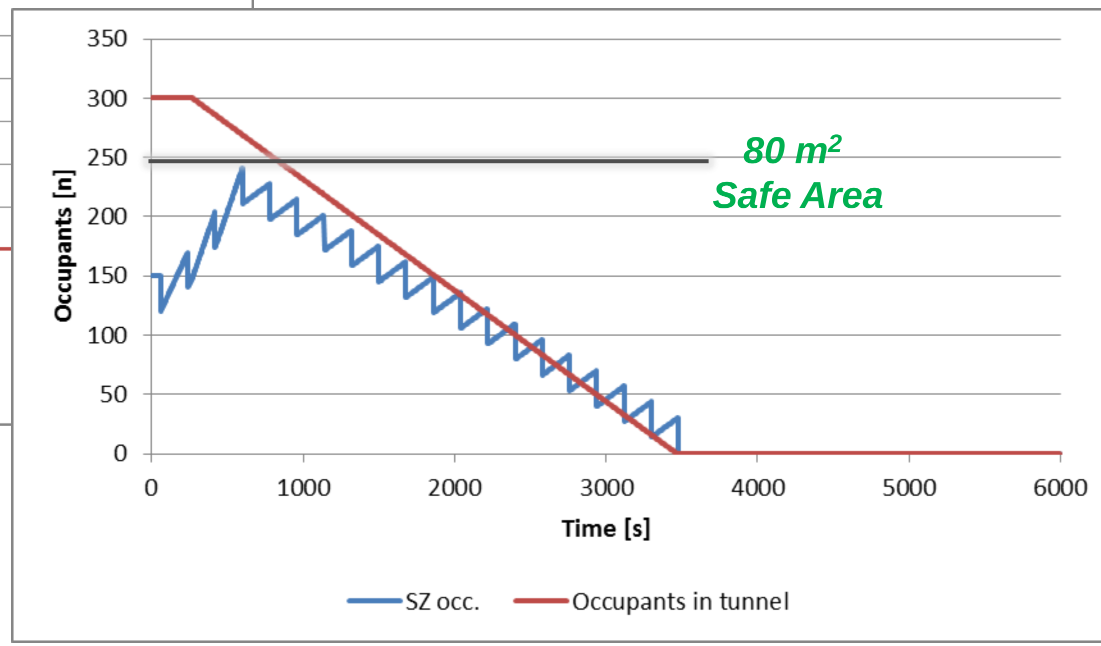
Evacuation

Dimensions for Safe Area

Scenario 1: alarm during maintenance of the experimental (PX) lift



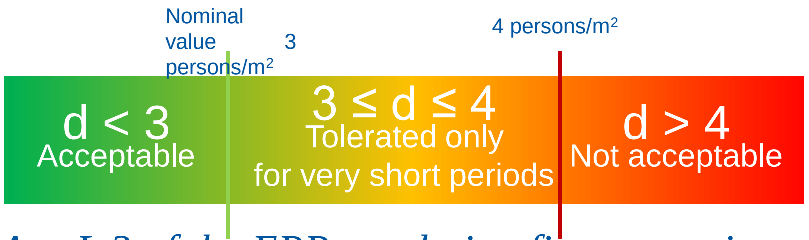
Scenario 2: alarm during maintenance in the PX lift
Limit the occ. In the exp. Cavern by ½



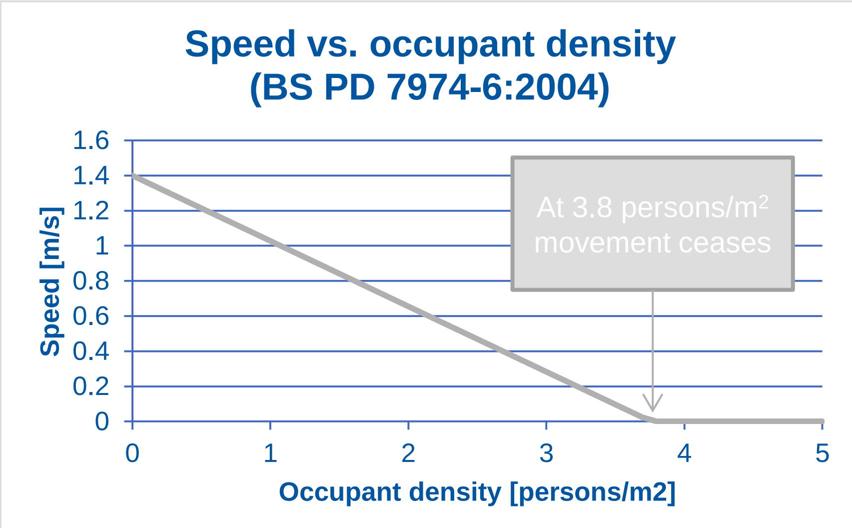
- Areas same order of magnitude as for the LHC today.

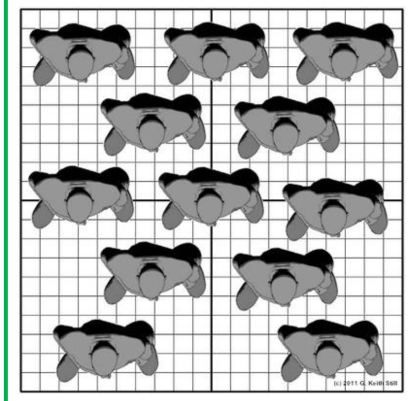
Courtesy of S. La Mendola

Maximum admissible crowding in safe zones

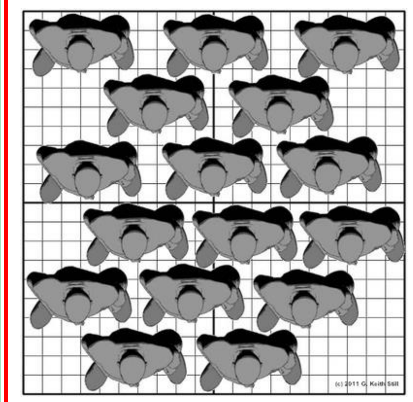


Art. L 3 of the ERP regulation fixes a maximum crowding of 3 persons/m² for people attending an event in a room without chairs or benches.





3 persons/m²



4 persons/m²

These figures have been tested for a number of fire scenarios.