General Safety studies and considerations for FCC

A. Henriques[1], S. La Mendola[1], M. Plagge[1], R. Trant[1], S. Arias[2]

FCC Week 2016
14th April 2016

[1]CERN
[2]Lund University

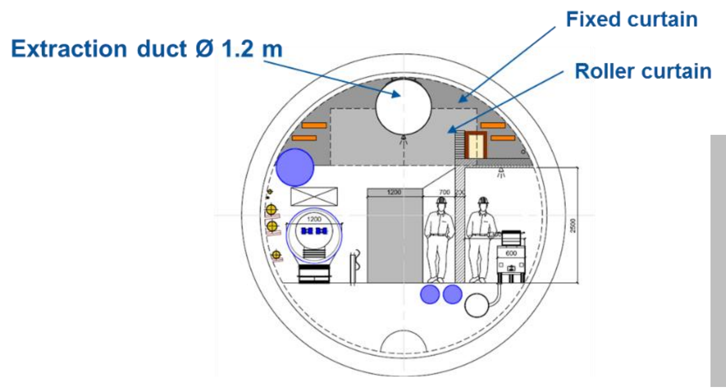
Topics

- Status & Overview
- FCC layout used for the studies
- Safety Studies (‘*conventional risks*’) for FCC
  - Fire Safety
  - Evacuation
  - Air management
  - Cryogenic Safety
- Future studies and contributions

Status & Overview

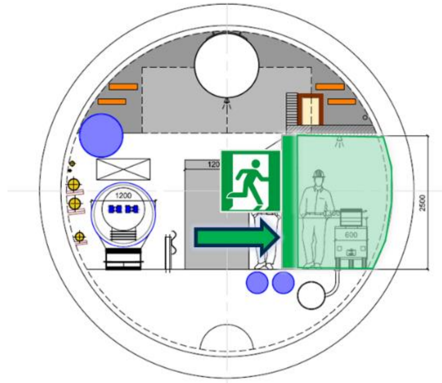
- FCC Week 2015 → FCC Week 2016

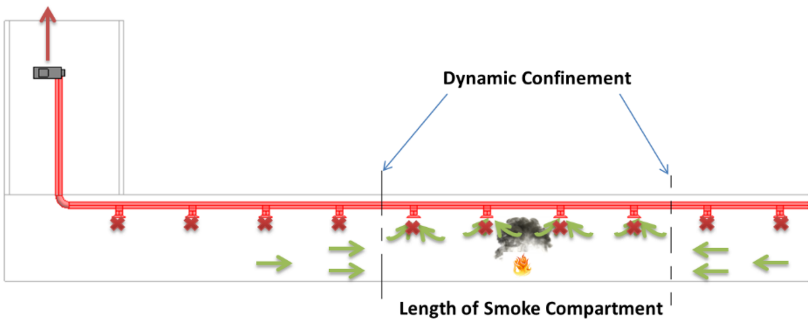
1. Smoke extraction concept:

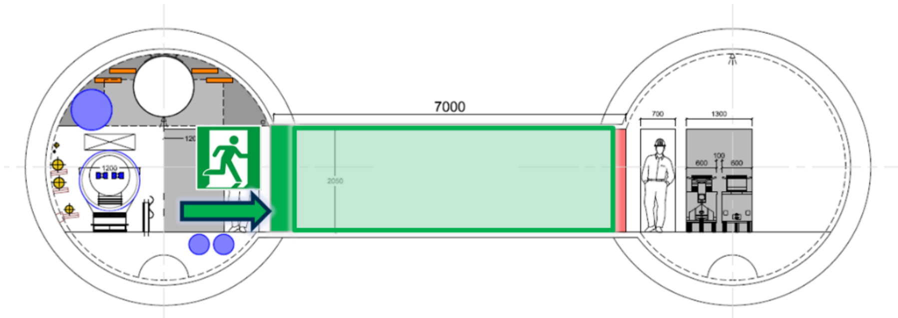


Optimisation
+
new studies

2. Safe Zone:

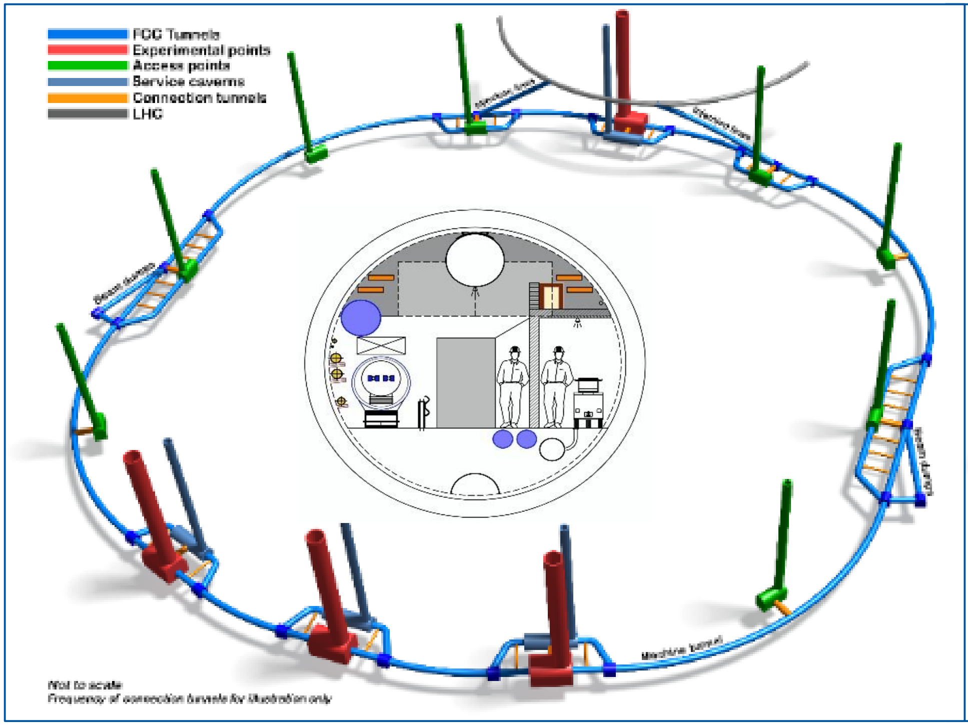


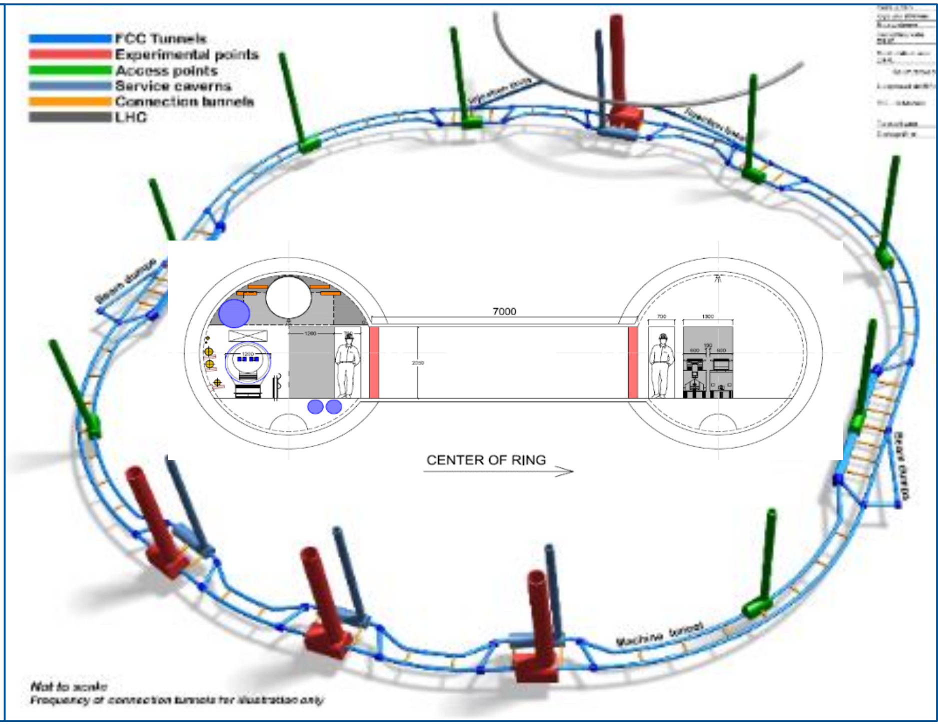




FCC Layout

- For the safety studies, both single and double tunnel solutions are considered:



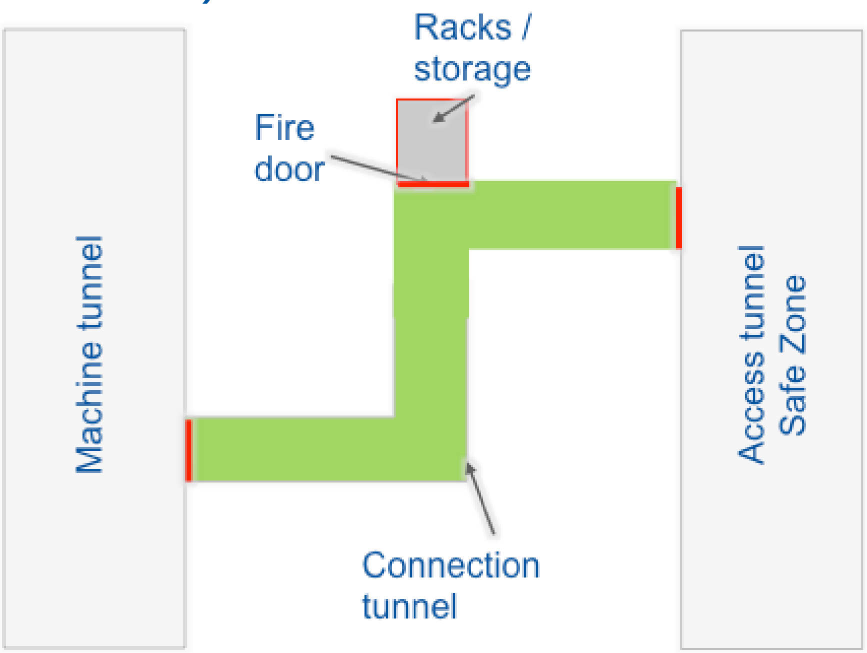


C. Cook, J. Osborne

Safety Studies

Fire risk in safe zones

- Limit the fire risk in the safe zones to absolute minimum (e.g. presence of lighting, signs, transportation)
- For single tunnel, equipment with high fire load installed in machine zone or surface (e.g. power transformers, racks)
- A possible solution for double tunnel:

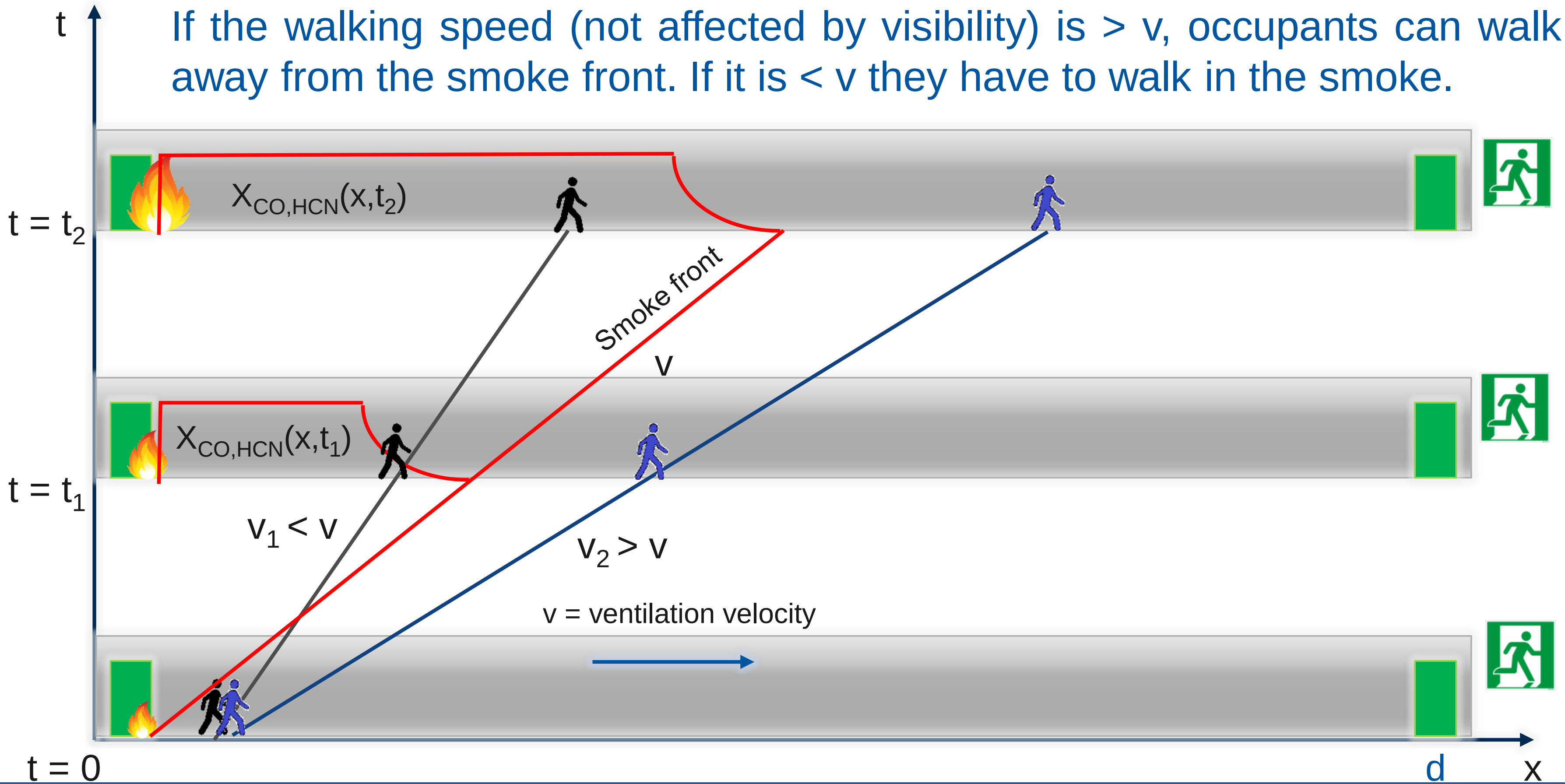


See Radiation Protection, M. Widorski

Maximum distance between accesses from machine to safe zone – in standard arc

Scenario description

If the walking speed (not affected by visibility) is > v, occupants can walk away from the smoke front. If it is < v they have to walk in the smoke.



Maximum distance between accesses from machine to safe zone – in standard arc

If Fractional Effective Dose (FED) = 0.3 is targeted (§5.2.1 of ISO 13571), the maximum walking time and distance can be calculated.

Results for both configurations (single and double) are reported in the table below.

Main assumptions:

- At t = 0 a fire starting next to an escape door;
- Smoke propagates with (conservative) ventilation speed v = 1.5 m/s;
- Polyethylene fire grows following an curve (medium) up to 5 MW;
- A minimum walking speed of 0.95 m/s has been assumed.

Quantity	Unit	Single tunnel	Double tunnel
Hydraulic diameter	m	4.5	Assumed 3.5
Distance *d*	**km**	**1.4**	**1.2**

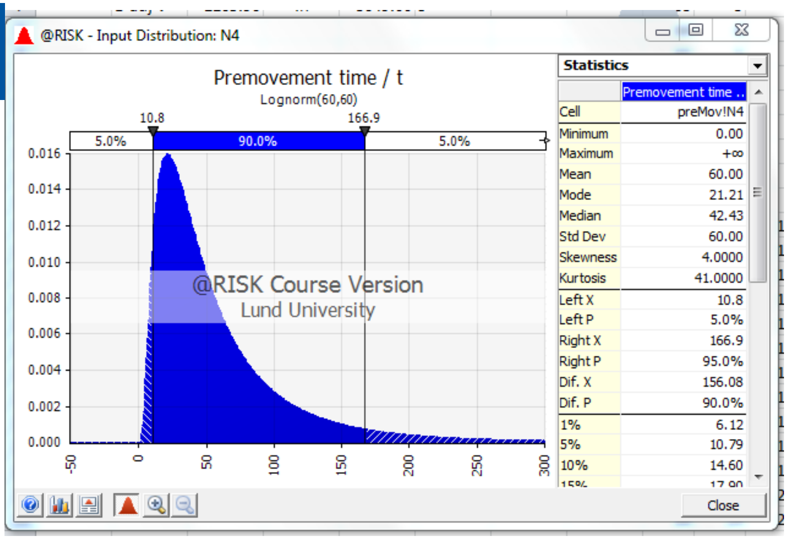
1 km distance should be considered as baseline for both solutions ✓

Maximum distance between accesses from machine to safe zone – in standard arc

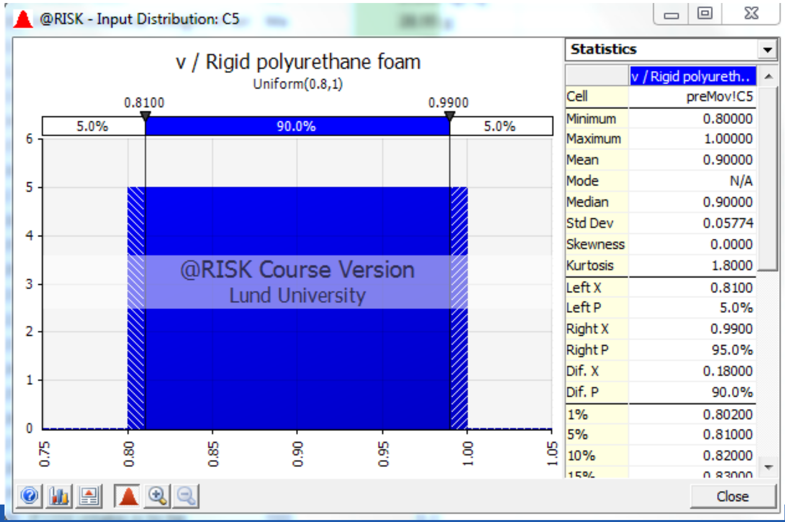
Refined modeling

New additional assumptions:

- ‘***Pre-movement***’ time (lognormal distribution):
  - ➢ detection time, either by people or devices
  - ➢ decision making by those in direct vicinity of the fire (e.g. attempts to extinguish it)



- A **walking speed** (uniform distribution) from 0.8 to 1 m/s

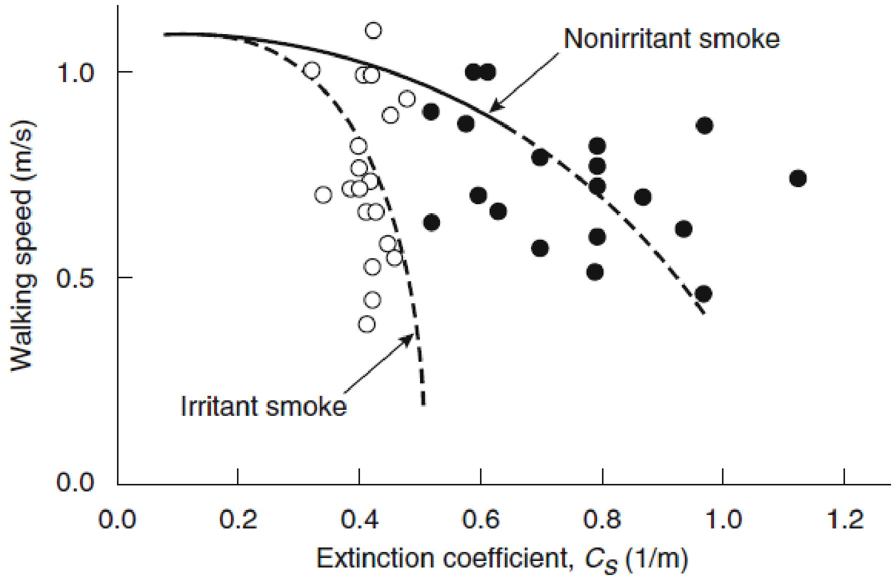


Maximum distance between accesses from machine to safe zone – in standard arc

New additional assumptions:

- Adjusted for walking speed reduction due to reduced visibility

Ventilation speed [m/s]	**Maximum distance** (mean value Monte Carlo sim.) **[km]***
1	2.0
1.5	0.73
2	0.61
	***preliminary results**



e.g. SFPE Handbook

« Underground air speed between 0.7 and 1.4 m/s »
Cooling and ventilation plants, M. Nonis

1 km baseline value validated
Optimisation once ventilation speed is fixed

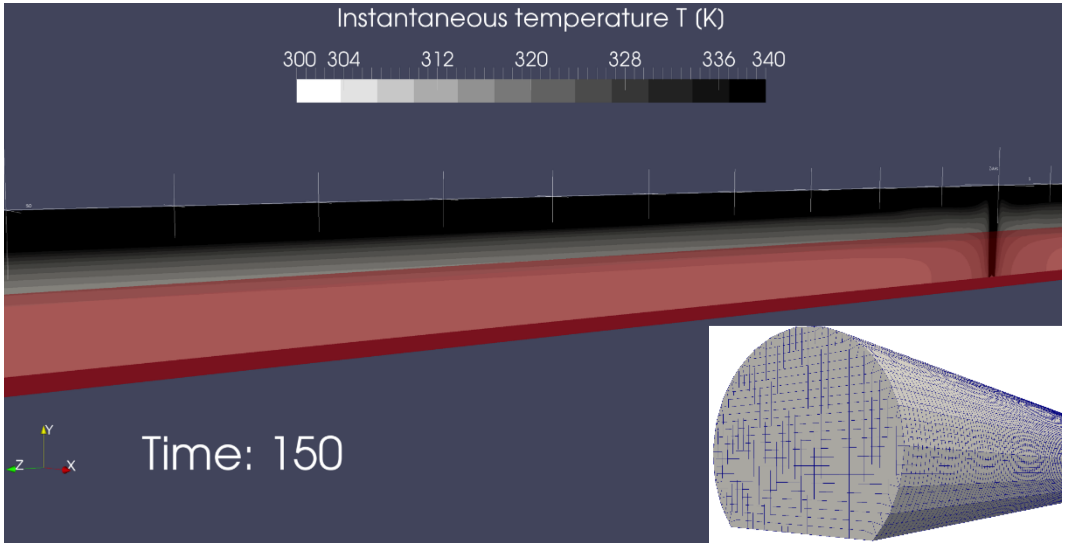
S. Arias

Tenability limits for FCC occupants

Extract from ISO 13571: tolerable limits of thermal radiation and convection

Mechanism	Intensity/Temperature	Tolerable time
Thermal radiation	10 kW•m^{-2}	Pain after 4 s
(on skin)	4 kW•m^{-2}	Pain after 10 – 20 s
Convective heat	< 40˚C (if H_2O saturated)	> 30 min

CFD modeling of 3D mass and heat transfer allows to compare different tunnel geometries with known tenability limits.
Further optimization, e.g. in terms of ventilation, smoke and helium emergency extraction follows.



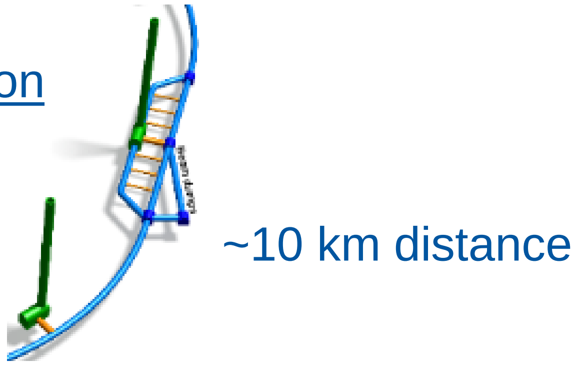
Evacuation modeling

Main Assumptions (based on LHC Long Shutdown 1 studies)
Max. occupant density in FCC tunnel – same as LHC (4 occ. /100 m)
Max. occupation in FCC experimental cavern – LHC x 1.5 (~150 occ.)
Max. occupation in FCC experimental service cavern – LHC x 1.5 (~75 occ.)
Lift travel time – same as LHC (3 x dist. – 3 x faster)
Distance between connection to safe zones – 1 km
Access to machine is denied during beam
Access to the service cavern is allowed during beam

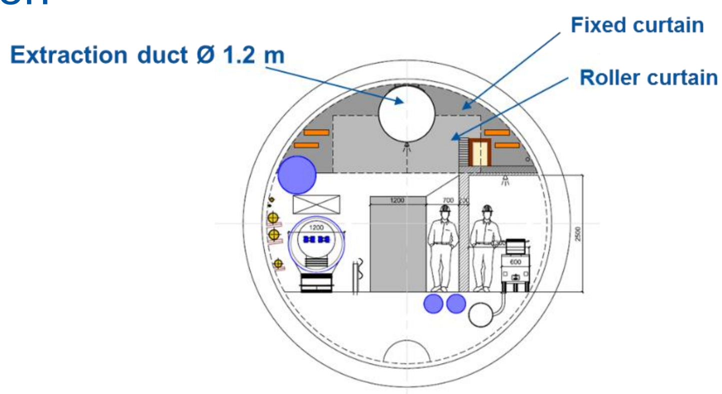
Evacuation modeling

General concepts on evacuation safety assessment

- Personnel transportation means necessary for evacuation



- Smoke compartmentalization



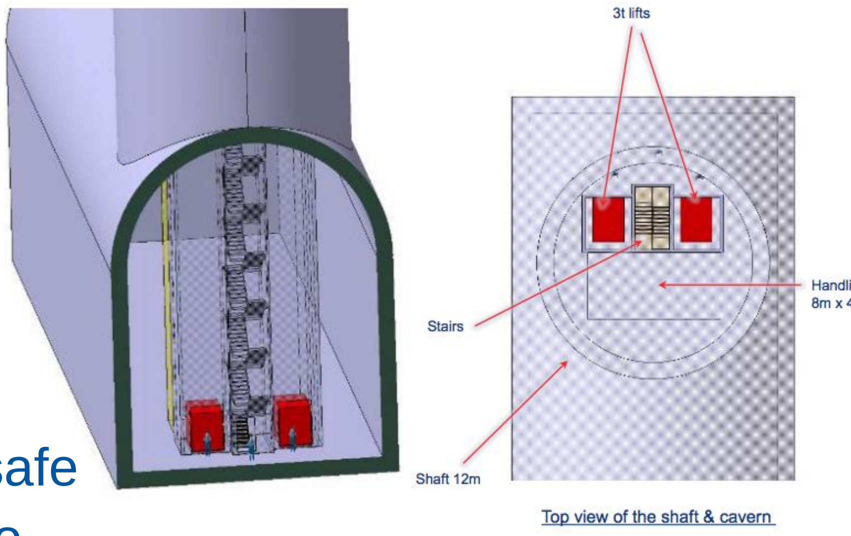
- Audible alarms
- Light emitting guidance systems to indicate right evacuation direction
- Training of staff

S. Arias

Evacuation modeling

General requirements for access shafts

- At least 2 distinct evacuation paths are required
- Only 1 access shaft per access point is acceptable
- At least 2 elevators per shaft for redundancy
- Protected staircase may be used as a safe area to reduce elevator ‘ *lobby area’* – to shelter all occupants



D. Lafarge, B. Feral

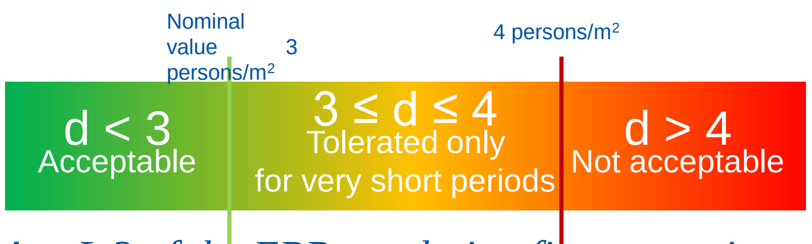
- Stairs may be used as ultimate evacuation mean and access of emergency intervention teams – present assumption, to be studied further

S. Arias

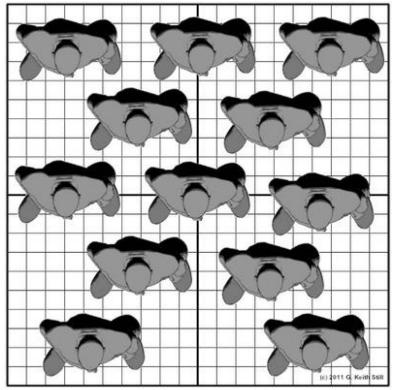
Evacuation modeling

General requirements for access shafts

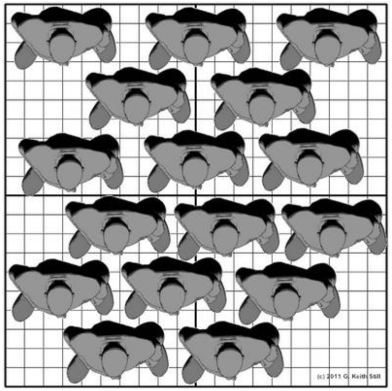
- Maximum density in safe area (‘ *lobby area* ’):
  - ➢ 2 people/m^2 (long waiting times)
  - ➢ 3-4 people/m^2 (nominal scenario)



Art. L 3 of the ERP regulation fixes a maximum crowding of 3 persons/m^2 for people attending an event in a room without chairs or benches.



3 persons/m^2

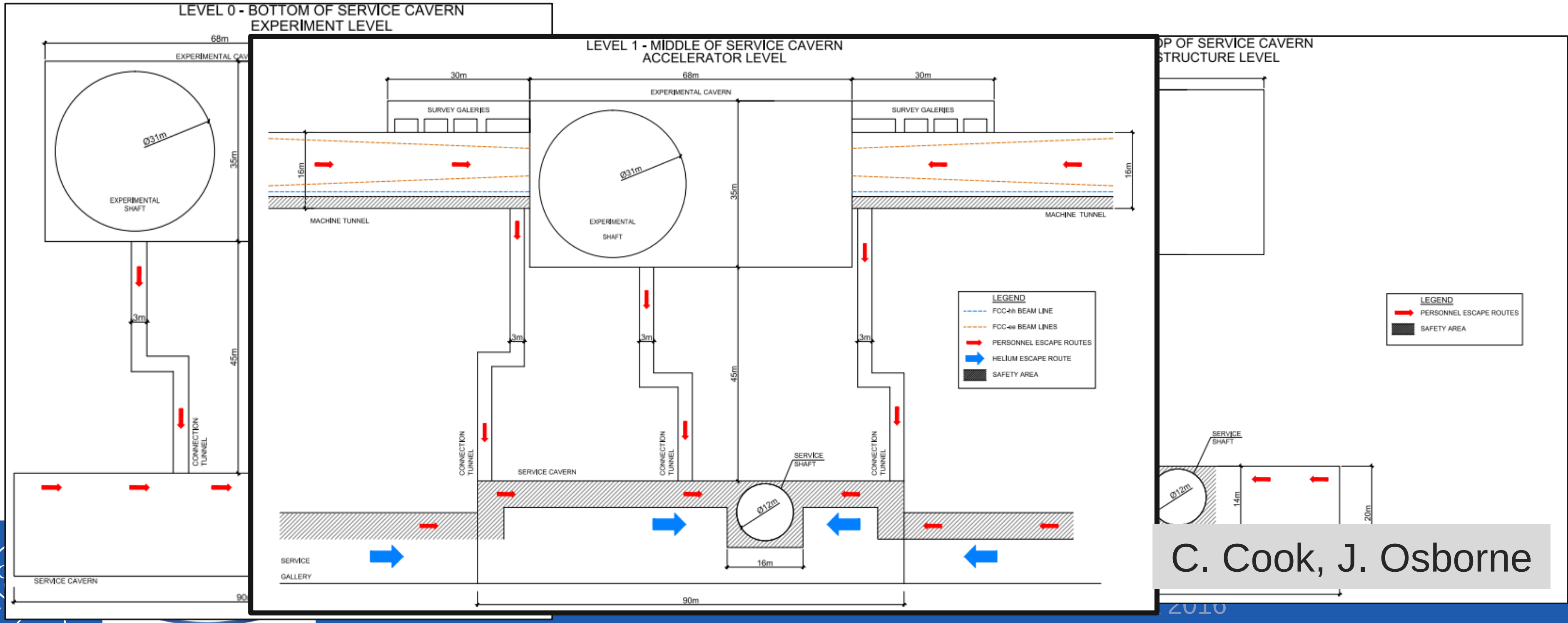


4 persons/m^2

S. Arias, S. La Mendola

Evacuation modeling

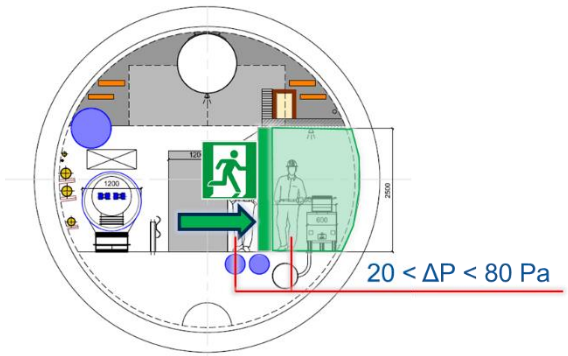
- In addition to the general requirements to experimental/service caverns:
  - Capacity of the lifts are adapted (more occ. than machine tunnel)
  - At least 2 distinct connections to the access shaft
  - Separate He release path (MCI case) – access to service cavern during beam
  - Access ‘flow’ of personnel is separate from machine (e.g. by floor levels)

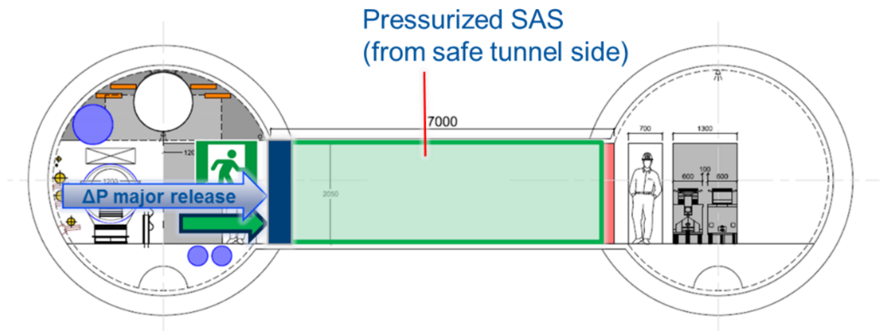


C. Cook, J. Osborne

Air management

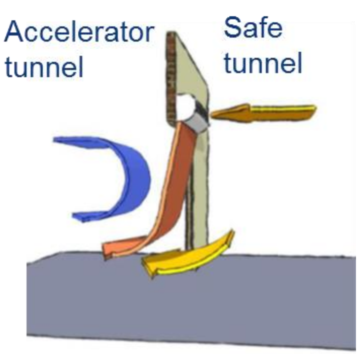
- Provide fresh air during access
- Provide dynamic confinement between "machine zone" and "safe zone" for protection of occupants in nominal and accidental scenarios

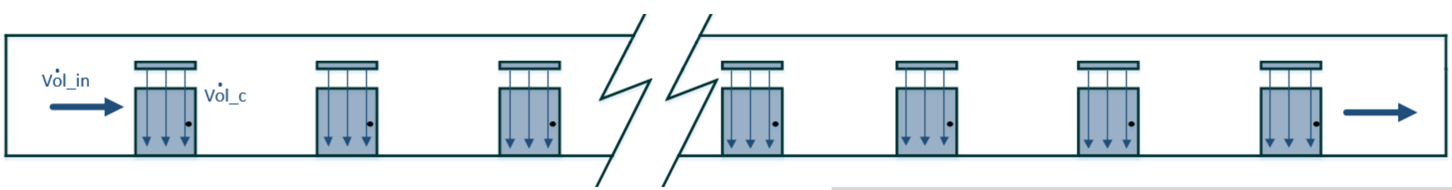




Technical solution:

➢ Air locks and air curtains to maintain ΔP

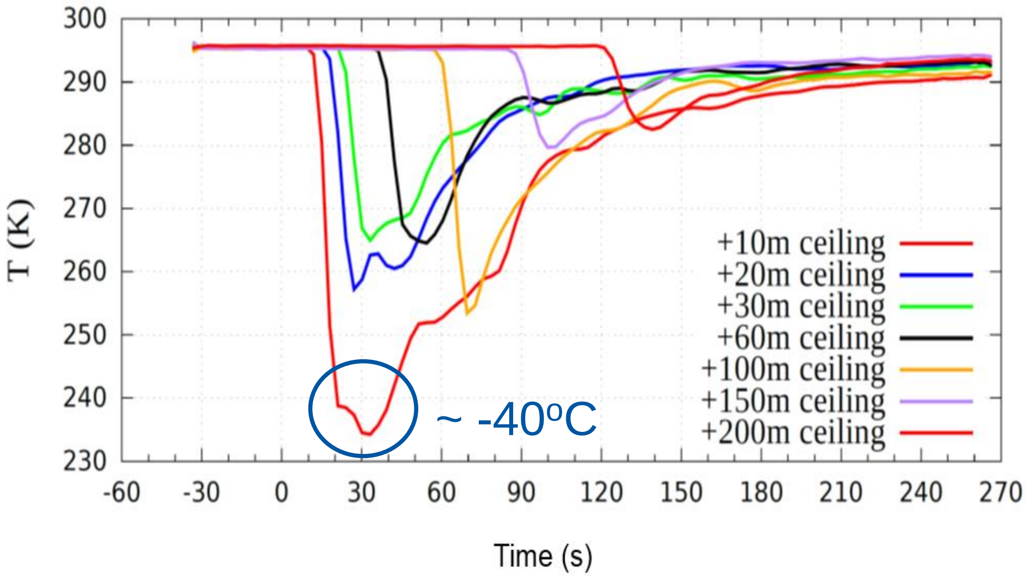




See Cooling and ventilation plants, M. Nonis

Accidental Helium extraction

- Use smoke extraction system to cope with an accidental He release, **during access mode**
- FCC Week 2015 – the system's capacity can cope up to ~1 kg/s release
- Mechanical properties of the ducts/supports can withstand low temperatures?



T. Koettig - ICEC ICMC 2014

As standard are Safe-fittings always supplied with an EPDM (ethylene-propylene rubber) seal moulding. The material has been chosen due to its long service life and the best possible resistance to ozone and UV radiation. It is also highly tolerant to temperature variations. Under normal conditions, the moulding can withstand:

-30 °C to +100 °C continuous
-50 °C to +120 °C intermittent

OK ✓

Magnetic field in Experimental caverns

- Technical Impact of Magnetic Stray Fields (HSE-DI/fs-FCC/2016-001)
- Stray flux density of 200mT assumed:
  - The hazards are of technical nature:

Impact Details of Static Magnetic Fields				
	field direction, flux density, effect			
what	**how**	**effect**	**remedy**	**remarks**
Transformers (50Hz)	field superposition	asymmetry	none	lower voltage possible
Transformers (kHz)	field superposition	saturation	none	do not use
DC motors	field superposition	speed change	adjust field	losses unavoidable
AC squirrel cage motors	rotor excitation	induction	none	do not use
electromagnetic valves	field superposition	parameter shift	unknown	use problematic
door latches	field superposition	opening impaired	none	do not use
ferromagnetic coils	field superposition	lower self-induction	none	do not use
vibration	induction	standing voltages	ground	ex currents
circuit breakers	field superposition	parameter shift	none	do not use
ventilators (fans)	field superposition	fan cannot start	none	do not use
Instruments	multiple	multiple	none	use only field proof stuff
ferromagnetic structures	carry flux	forces	design	no freely standing items

F. Szoncsó

Final Remarks

- Limit the fire risk in the safe zones to absolute minimum
- Maximum distance between connection to safe zone: roughly 1 km
- Smoke extraction system capable to extract He gas in case of accidental release during access mode
- At least 2 distinct evacuation paths are required
- 1 shaft with 2 separate elevators and staircase are required per access point
- The hazards due to stray flux density, arising from magnetic fields, in experiments are of technical nature

Further Studies

- Optimisation of smoke extraction following results of tenability limits
- Optimisation of evacuation modeling and new cutting-edge approaches including virtual reality and ascending evacuation experiments
- Studies of automated transportation for occupants – may have impact on the size of the safe zone
- Safety considerations of the proposed electrical network
- Continue safety considerations of the proposed cryogenic installation
- Other studies following the needs and advancement of the FCC study project

Support all FCC WGs on Safety issues

Thank you very much

for your attention

Acknowledgements:

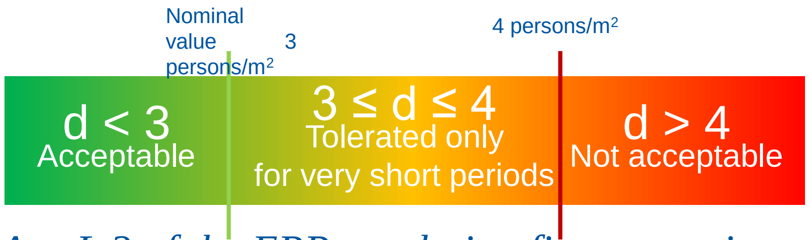
C. Cook, S. La Mendola, V. Mertens, M. Nonis, J. Osborne, M. Plagge, R. Trant, M. Widorski

CERN

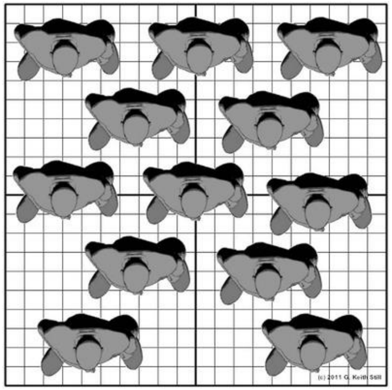
www.cern.ch

Spare Slides

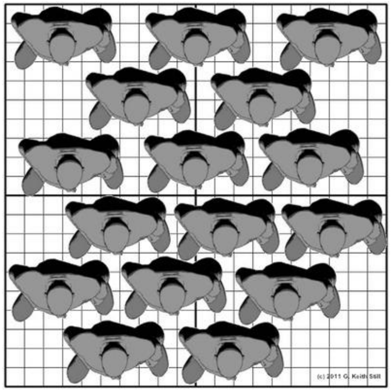
Maximum admissible crowding in safe zones



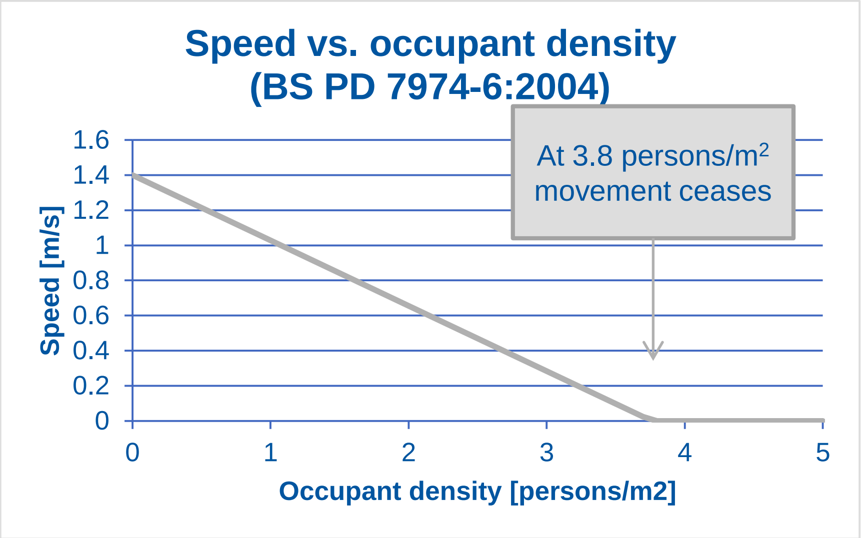
Art. L 3 of the ERP regulation fixes a maximum crowding of 3 persons/m² for people attending an event in a room without chairs or benches.



3 persons/m²



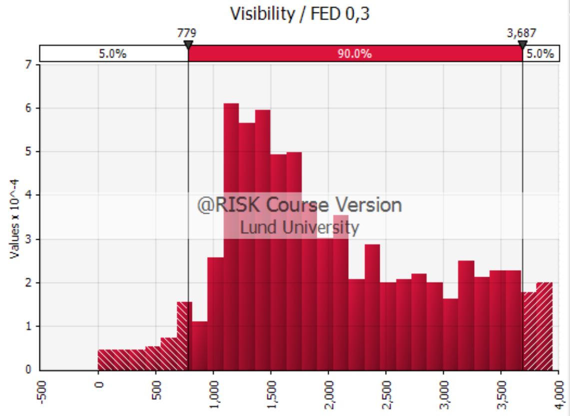
4 persons/m²



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

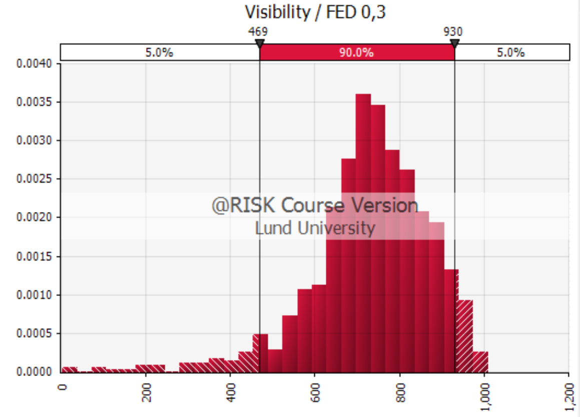
S. La Mendola

Maximum distance between accesses from machine to safe zone – in standard arc



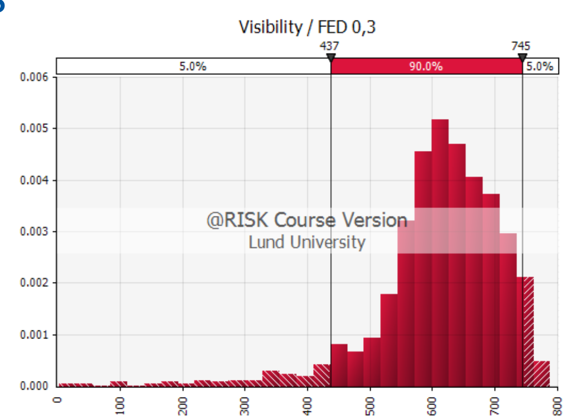
Statistics	Visibility / FED 0,3
Cell	preMov!C40
Minimum	3.18
Maximum	3,951.98
Mean	2,040.06
Mode	1,761.94
Median	1,824.66
Std Dev	911.12
Skewness	0.4078
Kurtosis	2.2413
Values	1000
Errors	0
Filtered	0
Left X	779
Left P	5.0%
Right X	3,687
Right P	95.0%
Dif. X	2,907.68
Dif. P	90.0%
1%	260.32
5%	779.41
10%	1,061.18

v = 1 m/s



Statistics	Visibility / FED 0,3
Cell	preMov!C40
Minimum	3.26
Maximum	1,010.40
Mean	732.91
Mode	766.06
Median	743.80
Std Dev	142.17
Skewness	-1.1944
Kurtosis	6.0607
Values	1000
Errors	0
Filtered	0
Left X	469
Left P	5.0%
Right X	930
Right P	95.0%
Dif. X	461.24
Dif. P	90.0%
1%	235.15
5%	468.56
10%	565.54

v = 1.5 m/s

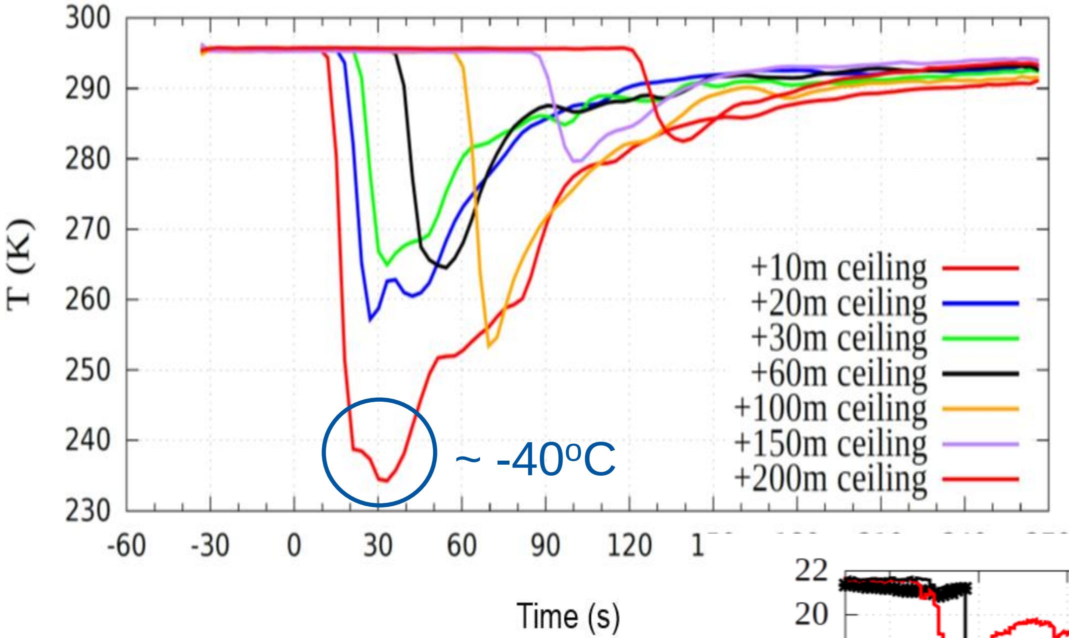


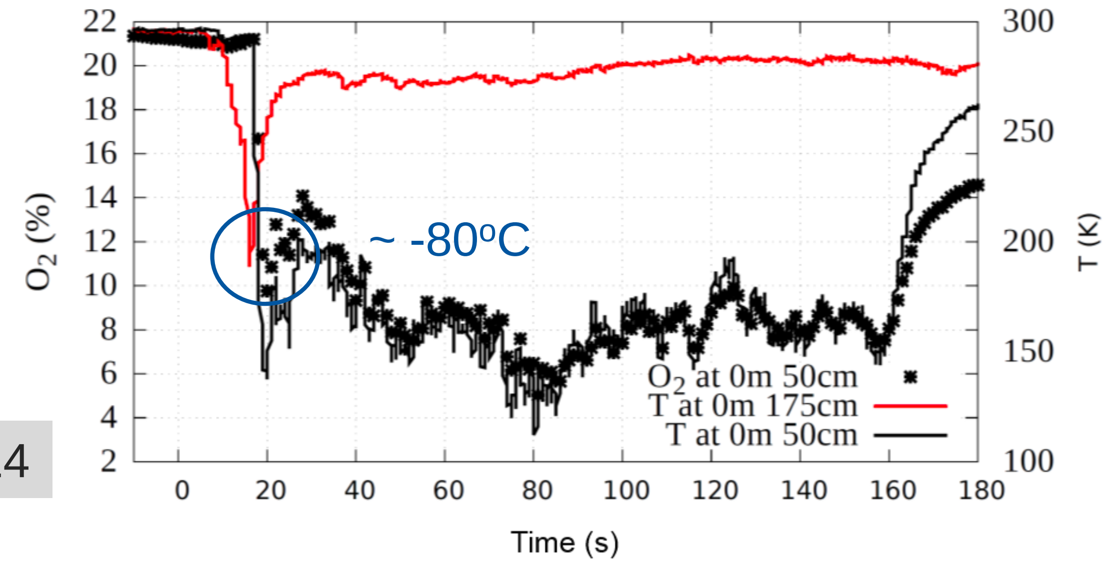
Statistics	Visibility / FED 0,3
Cell	preMov!C40
Minimum	3.69
Maximum	788.84
Mean	613.56
Mode	672.19
Median	624.32
Std Dev	100.48
Skewness	-1.6509
Kurtosis	8.2858
Values	1000
Errors	0
Filtered	0
Left X	437
Left P	5.0%
Right X	745
Right P	95.0%
Dif. X	307.46
Dif. P	90.0%
1%	234.16
5%	437.08
10%	502.65

v = 2 m/s

S. Arias

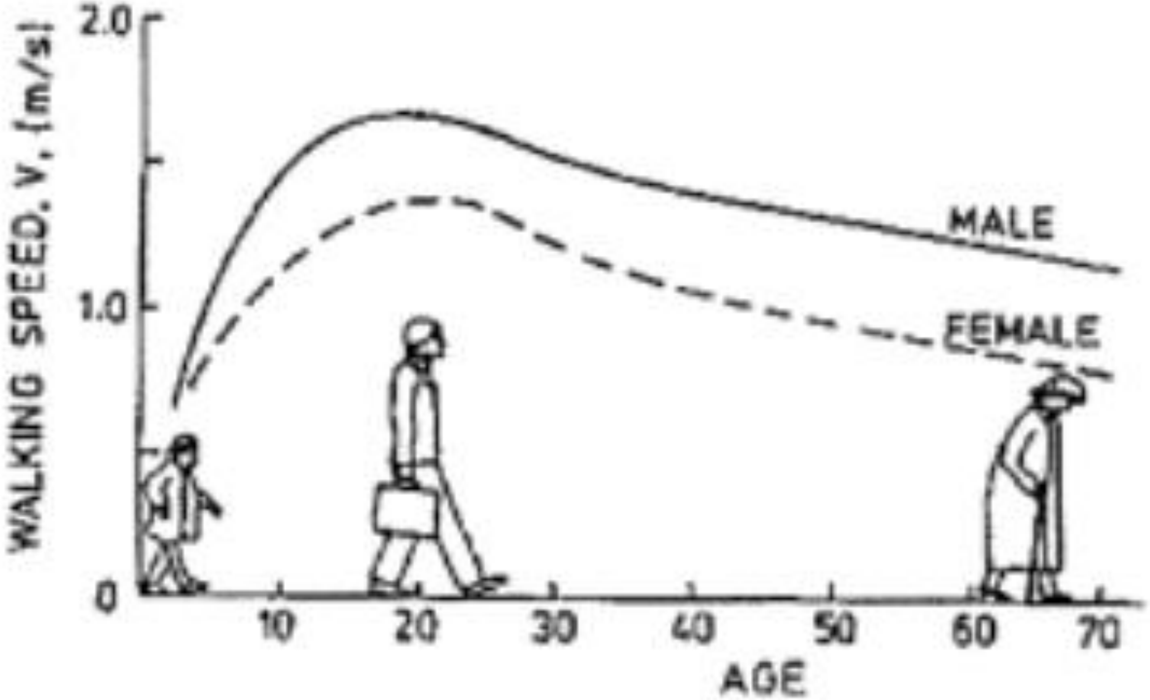
He Spill test – temperatures @ celling level





T. Koettig - ICEC ICMC 2014

Walking speed as a function of age



Source: www.wpi.edu