SPS CFD Fire simulation

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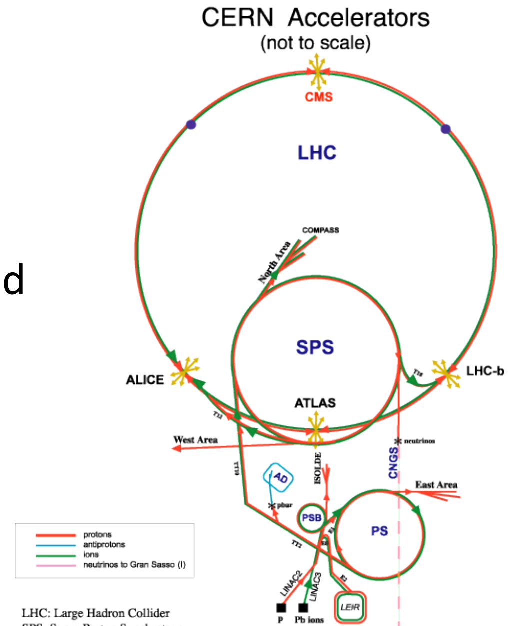
DGS-SEE Seminar on fire protection for physics research facilities CERN 7-8 Oct. 2015

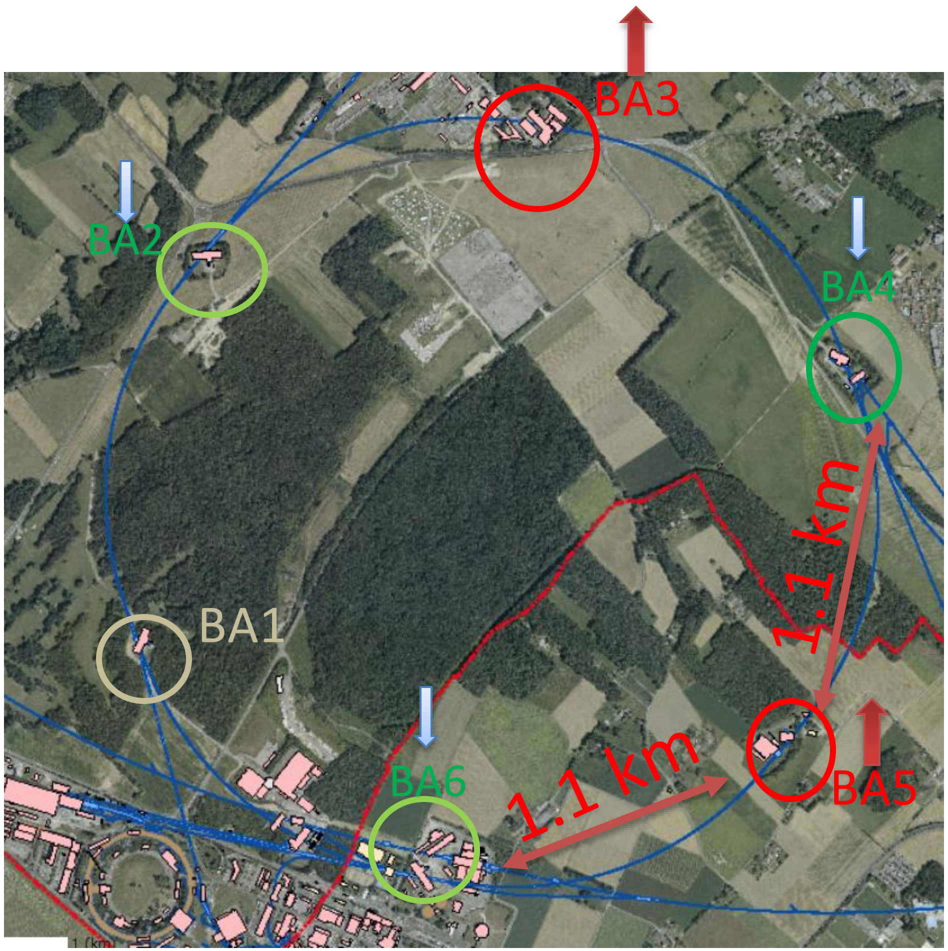
- SPS -> Super Proton Synchrotron
- Switched on in 1976
- 6.9 km circumference
- 1.1km distance between access points
- 1300 warm magnets (26->450GeV)
- Located at ~50m below ground level,
- Longitudinal push-pull ventilation roughly between 0.2m/s and 0.7m/s in the tunnels

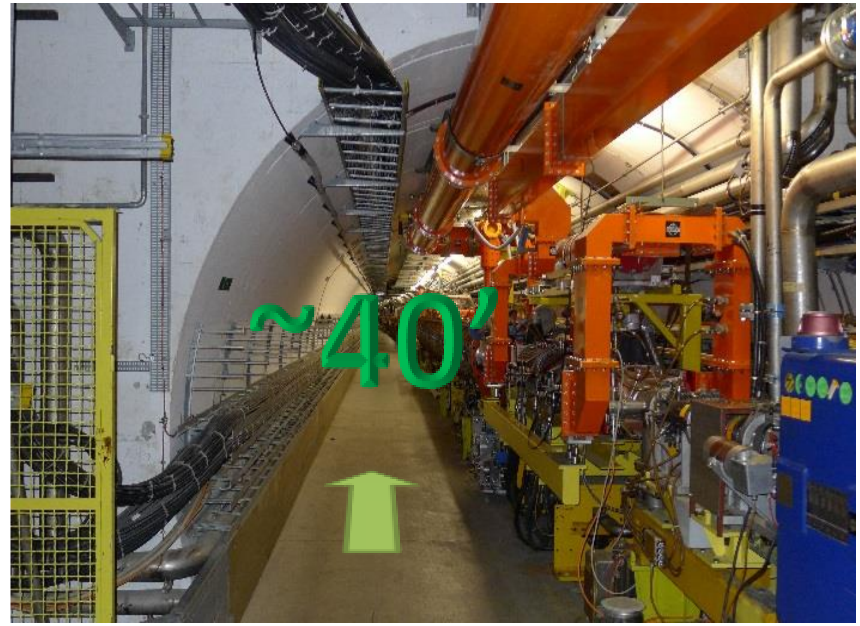


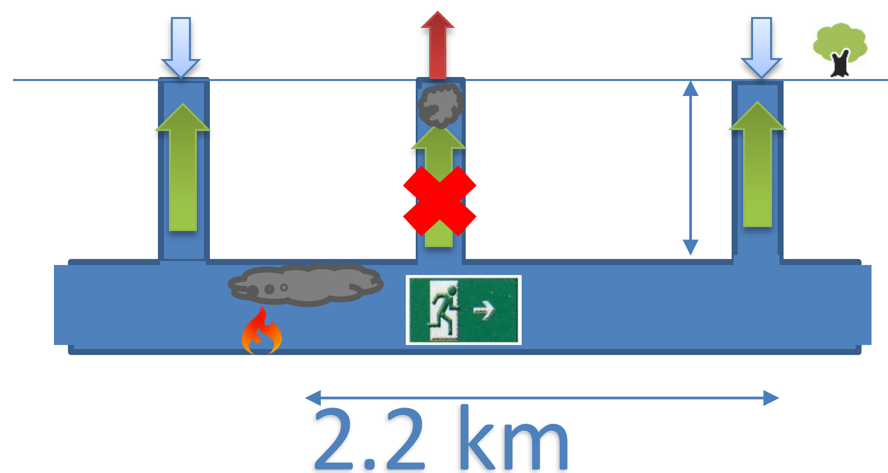
LHC Injector and Experimental Facilities Committee (IEFC) - **SPS fire safety WG** mandated to study the situation and propose measures that will make the fire safety in the SPS compatible with the modern standards.

Present status

Long unprotected evacuation paths (up to 2.2 km)



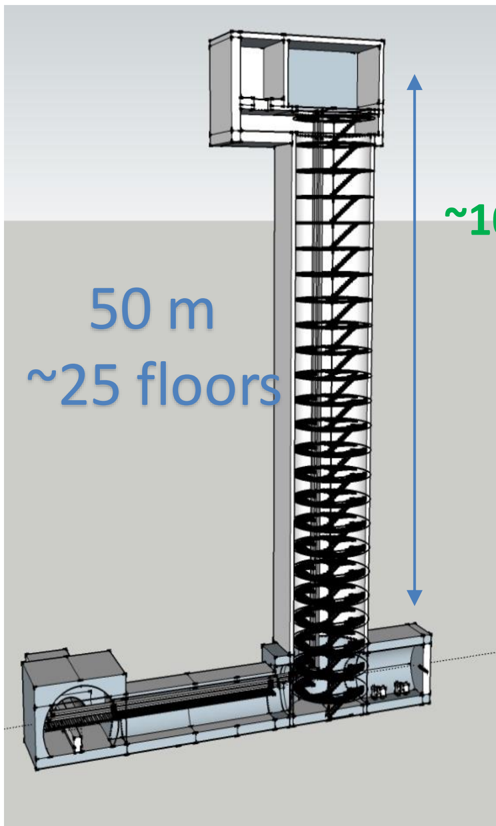


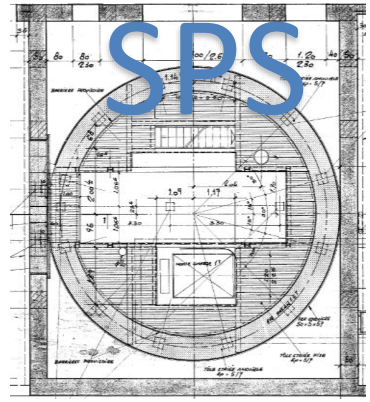


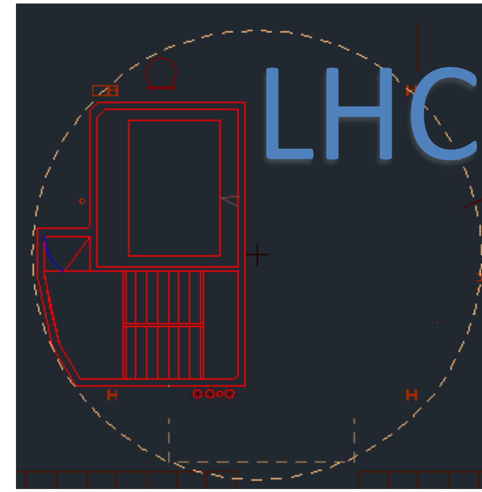
Present status

Present Status

- The access shafts have stair and lifts in the same pathway of the smoke



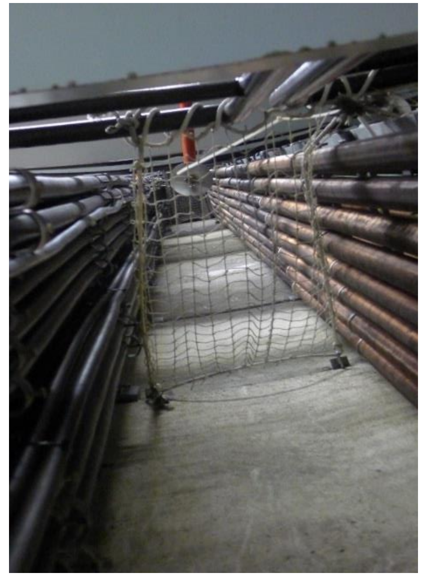


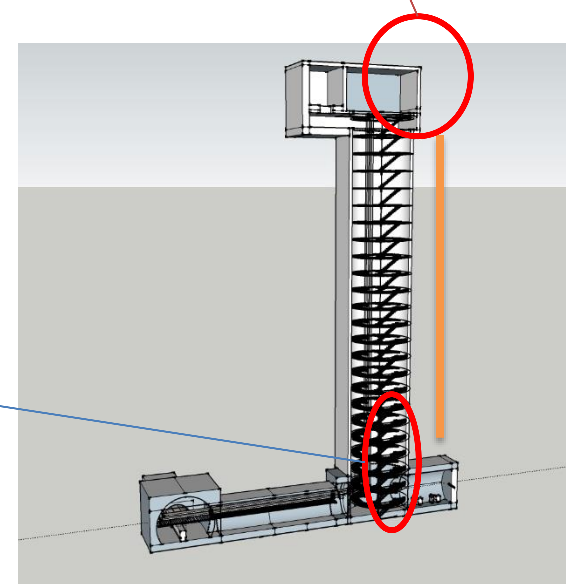


Several system are obsolete or need improvement

- Sprinkler system reached end of life and requires mayor revision
- Automatic fire detection require update and more granular localization
- Evacuation alarm system require more flexibility in order to accept new matrices linking detection to evacuation
- Manual fire-fighting means require adaptation to larger fire design scenarios
- Fire compartment scheme needs improvement
- Long distances require access clearing from smoke in order to be reachable within SCBA autonomy

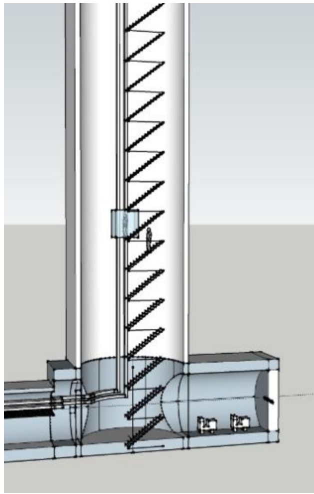
- Full consolidation list handled by the SPS fire safety WG





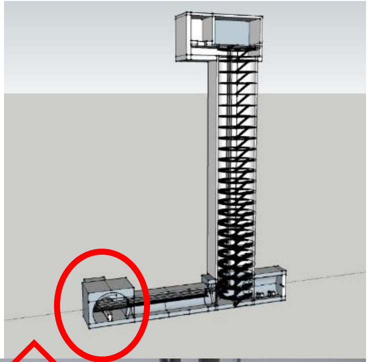
- How can we inject safety improvements in an existing facility?
- Do we need to replace automatic fire suppression systems?
- Do we need additional fire doors?
- What does the fire scenario look like when fire brigade arrives there?
- What is the order of magnitude of the mass combusted during a fire?

CFD to help in defining:
Worst case credible scenarios
Smoke propagation dynamic and temperature impacts



Fires of what?

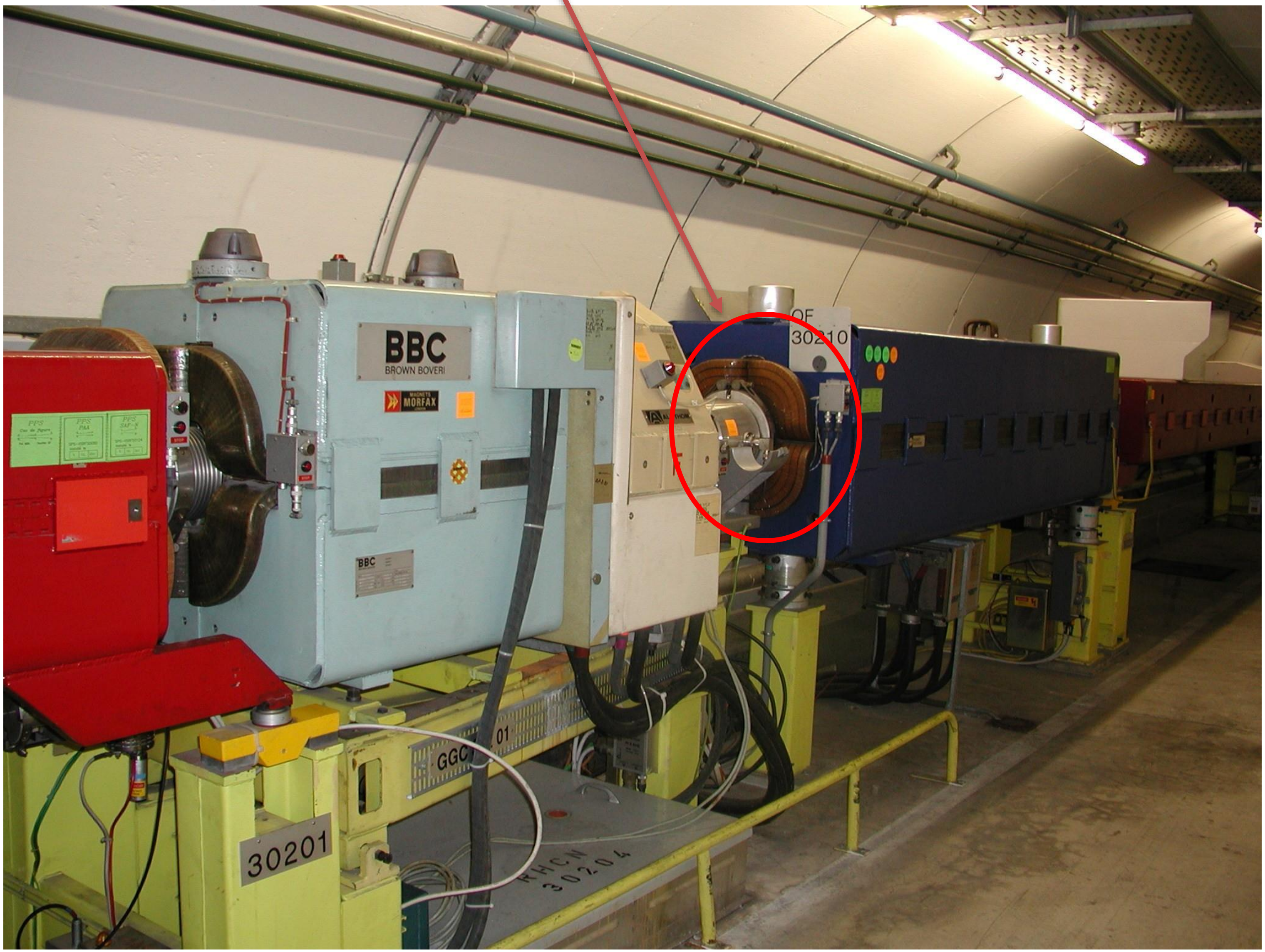
≈3000 cables by point
descending from surface into the tunnel



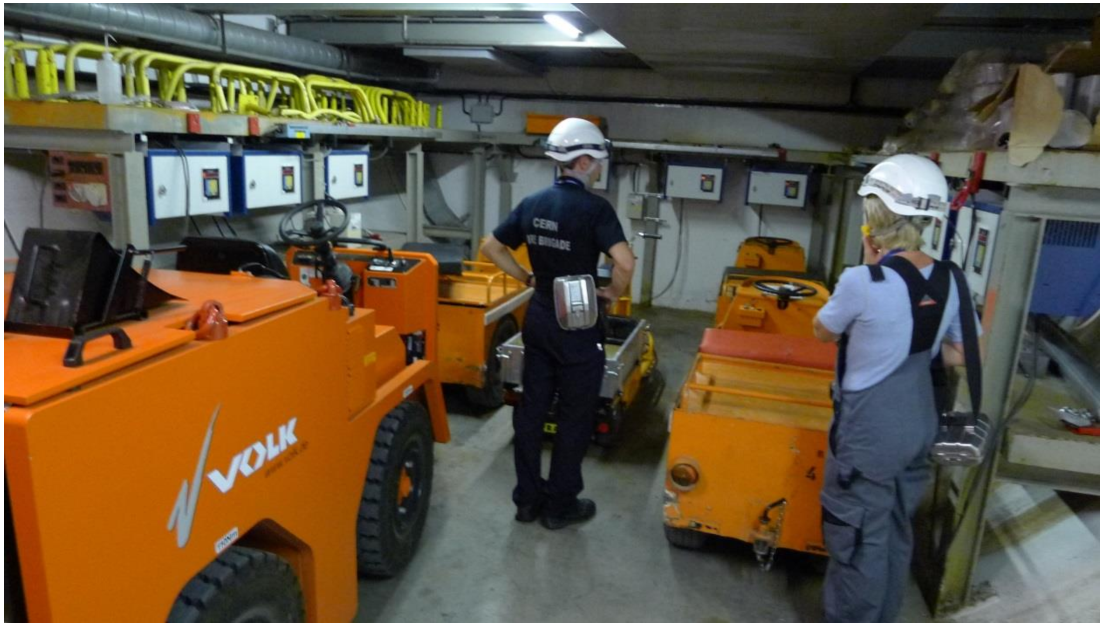
- Large amounts of cable, especially near the access points

Another view of the cable trays

Warm magnets are essentially made of steel, with relatively small amounts of polymers at the extremities free to burn



Tractors and reloading stations
are another other possible scenario,
but enveloped by the large cable fires (see 50MW fire scenario)



Heat Release Rate curves

- Velocities and Heat Release Rate per unit length

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Cable Heat Release, Ignition, and Spread in Tray Installations During Fire (CHRISTIFIRE) (NUREG/CR-7010)

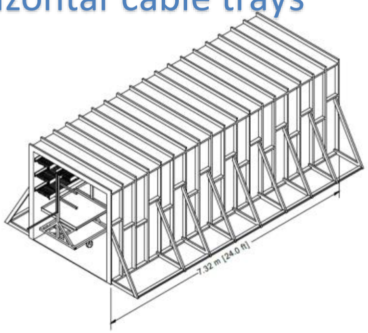
http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr7010/

Spread rate

horizontal cable trays, unconstrained

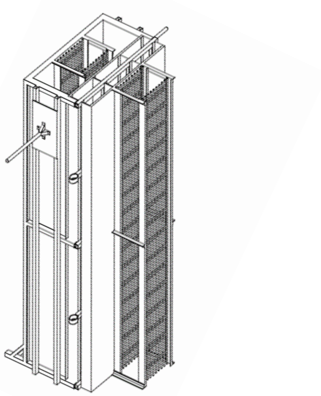
3.2 m/h
on each side
250kW/m^2

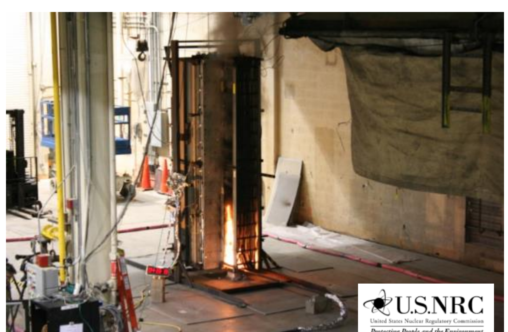
horizontal cable trays



near a ceiling

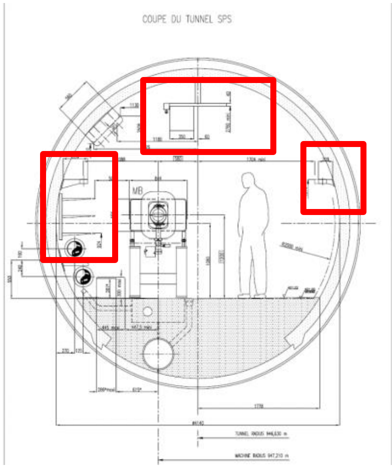
32 m/h
on each side
250kW/m^2

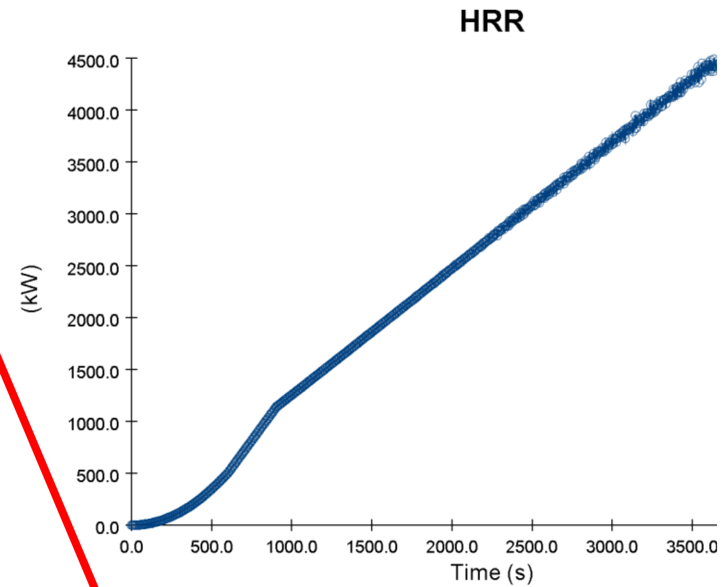


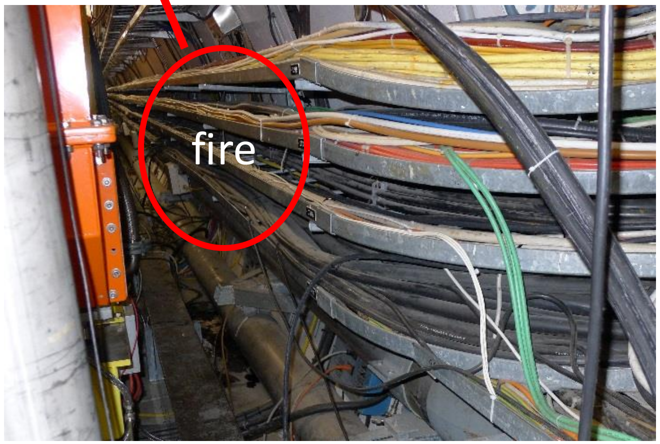


50 m/h
upward
250kW/m^2

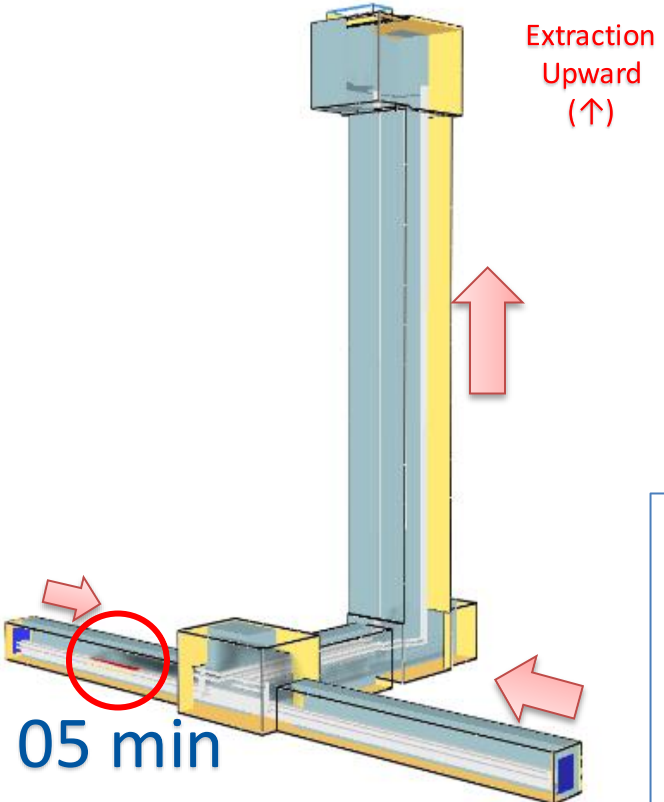
Scenario 1 : horizontal trays fire located in the tunnel LSS near one access point, reaching ~5 MW in one hour





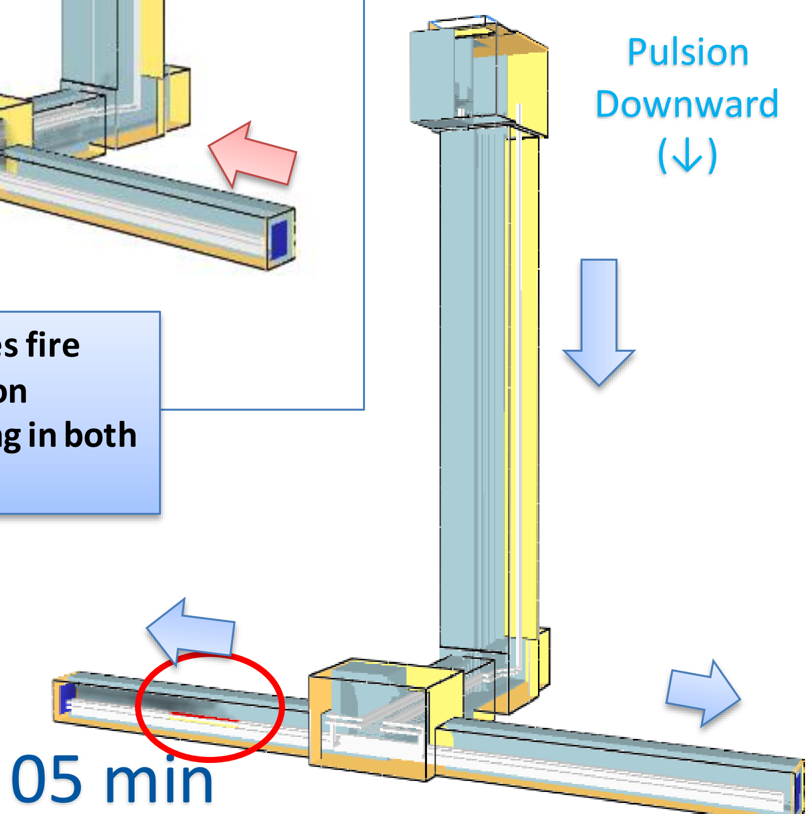


ventilation comparison: upward vs downward for a 5 MW fire



1_1_SPS_LSS_5MW_SMOKE_tunnel_and_Shaft_ven_45000m3_h_upward .wmv

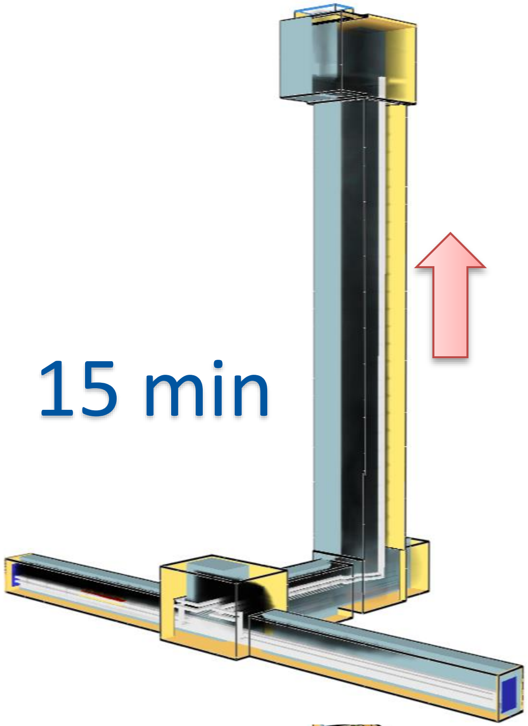
1_3_SPS_LSS_5MW_TEMP_tunnel_and_shaft_45000m3_s_upward.wmv



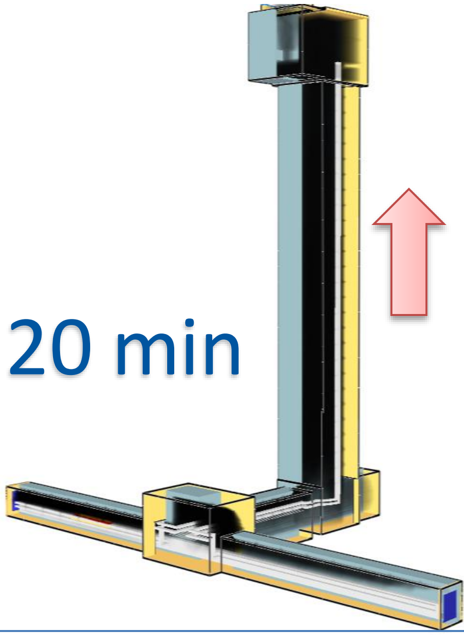
1_2_SPS_LSS_5MW_SMOKE_tunnel_and_shaft_vent_45000m3_h_downward.avi

At 5 minutes fire detection process starting in both cases

15 min

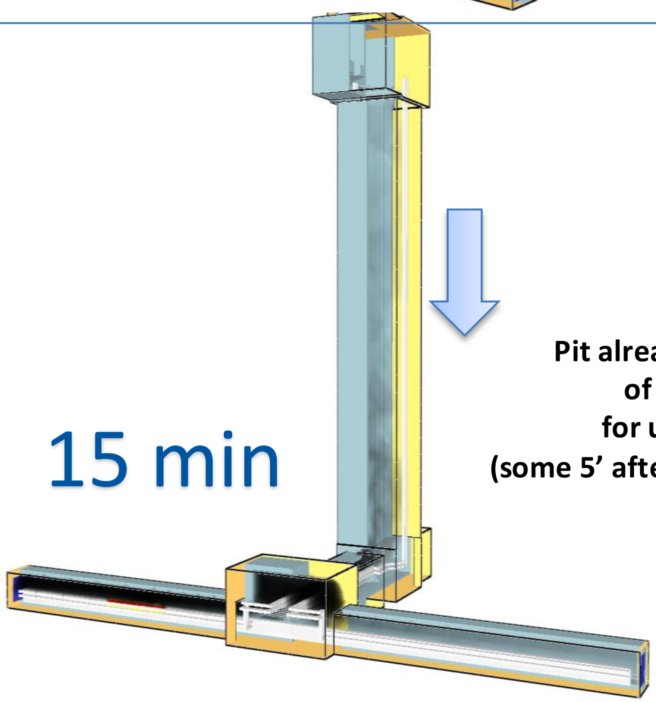


20 min



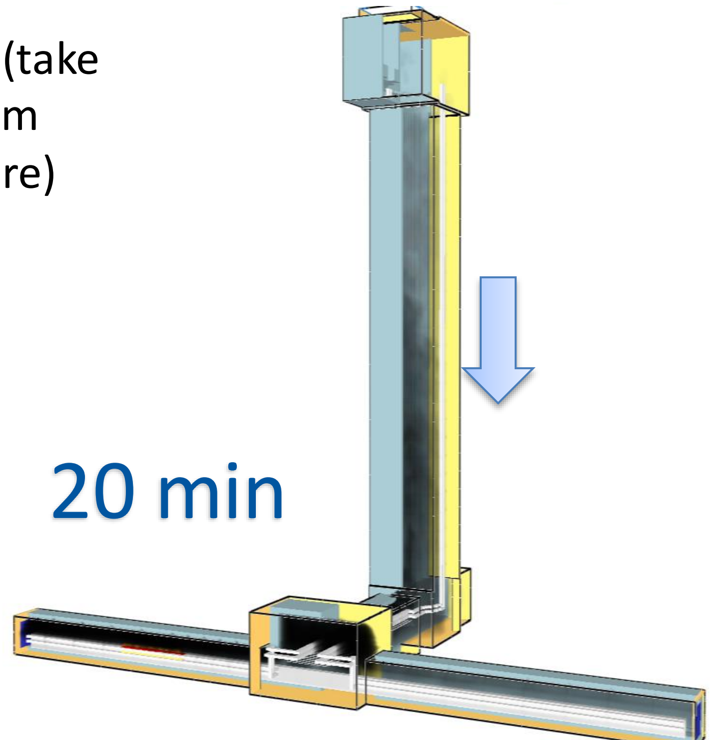
In both cases, the shaft can become untenable for unprotected people quite soon
~5-10’ from detection (take away 5-10 minutes from the timeline shown here)

15 min



Pit already at the limit of tenability for unequipped (some 5’ after the upward case)

20 min

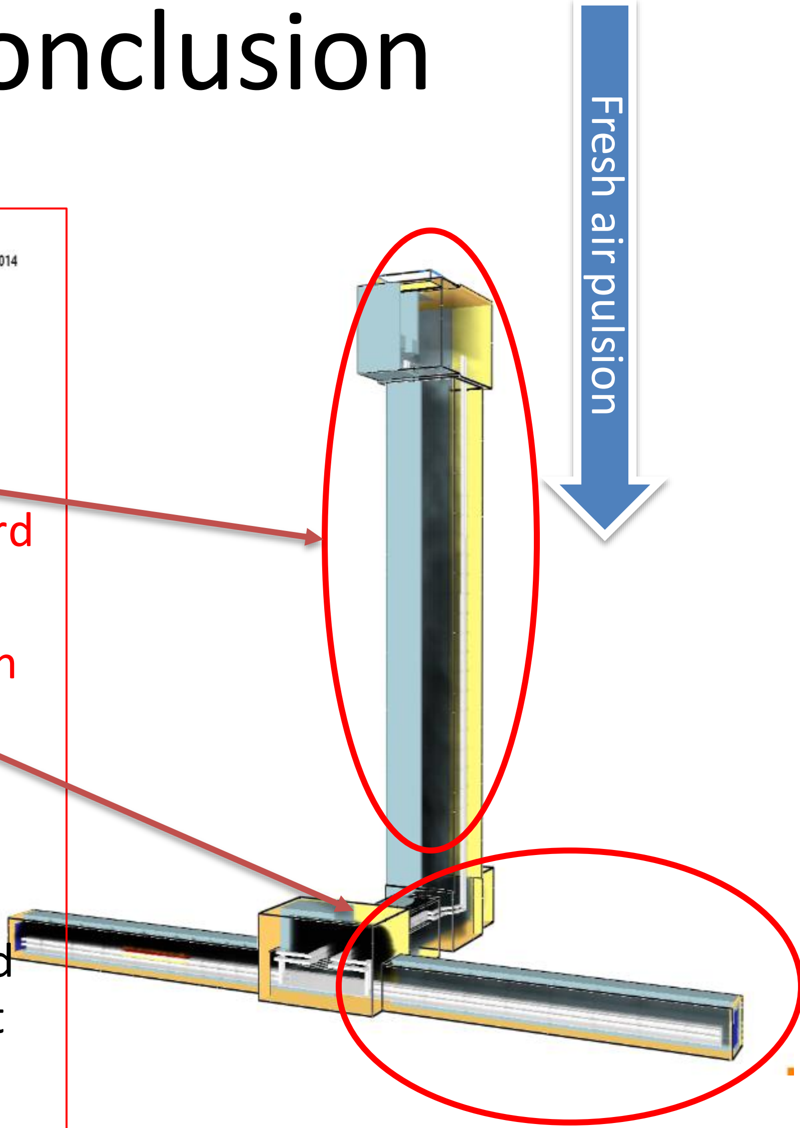


LSS 5MW fire Conclusion

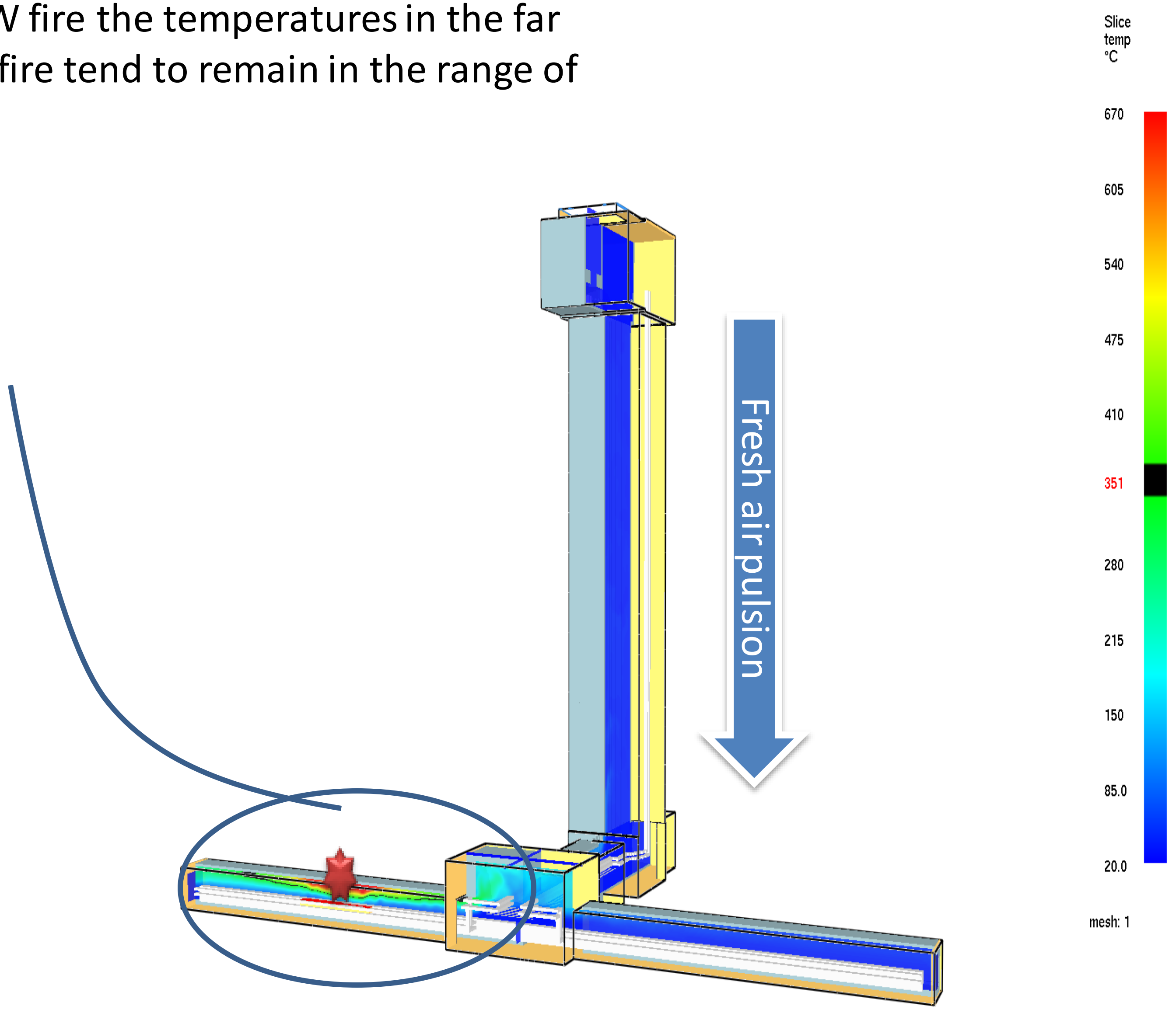
- In case of a fire as small as 5MW located in the vicinity of the access pit, the ventilation system alone look insufficient to prevent backflow and rising in the vertical access shaft:
- Smoke propagates upward in the evacuation shafts, also when the ventilation flow is downward

Smoke propagates also beyond the junction cavern in the other tunnel sextant; For this reason the smoke extraction alone does not guarantee any dynamic protection of areas past the junction point;

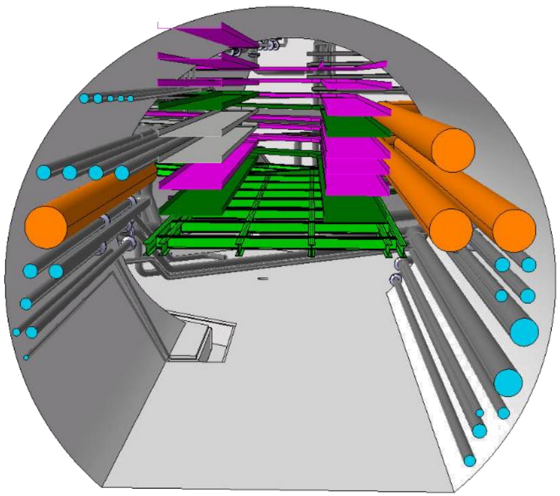
- Separation of vertical access point with doors and separation between octants look quite important to prevent smoke filling the stairs.

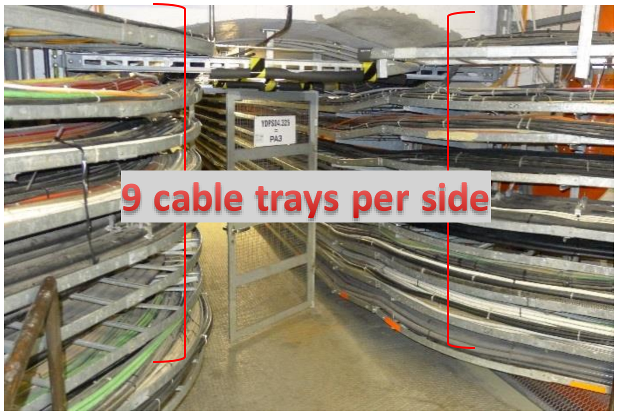


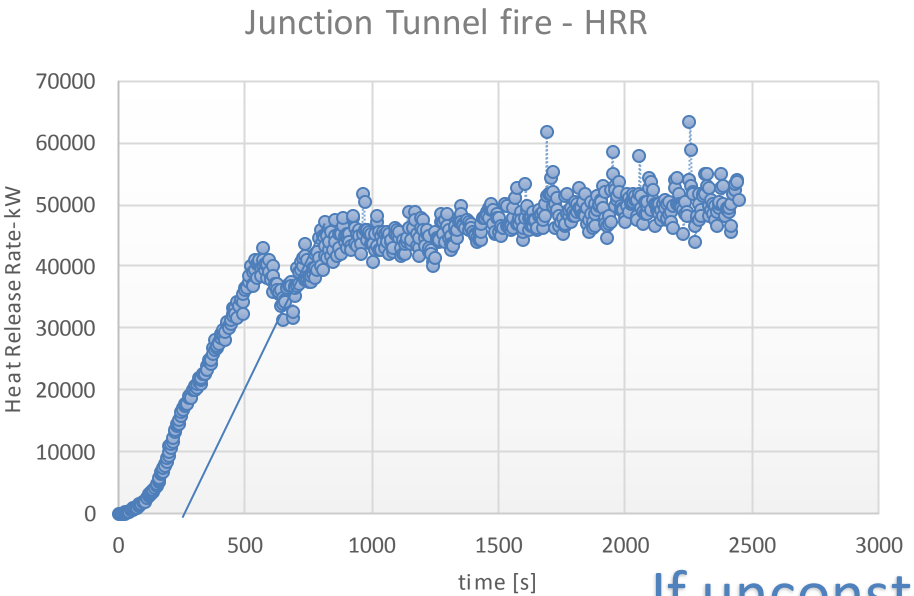
For a 5 MW fire the temperatures in the far field from fire tend to remain in the range of 200-300C

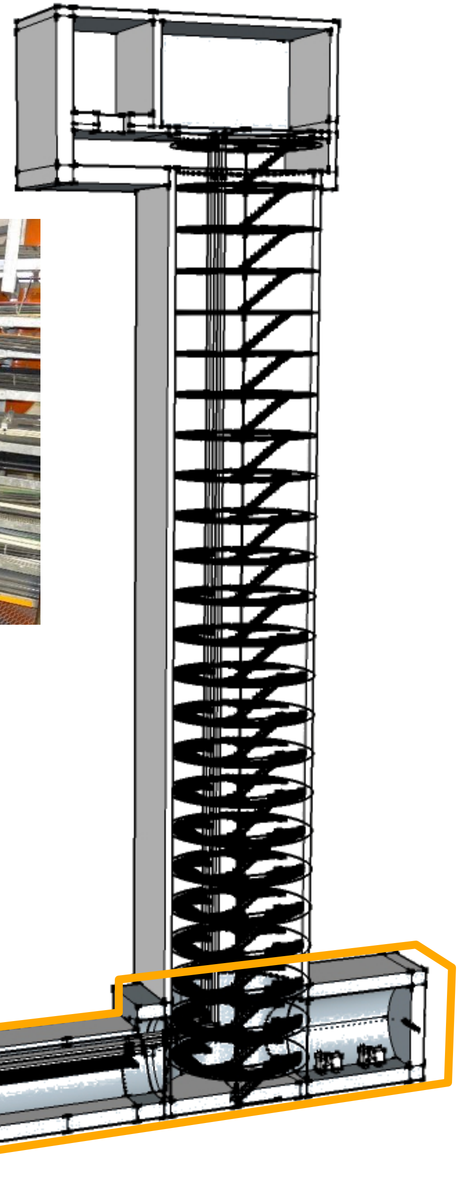


Scenario 2 : TA junction tunnel trays fire, ~50MW in 30 min then steady



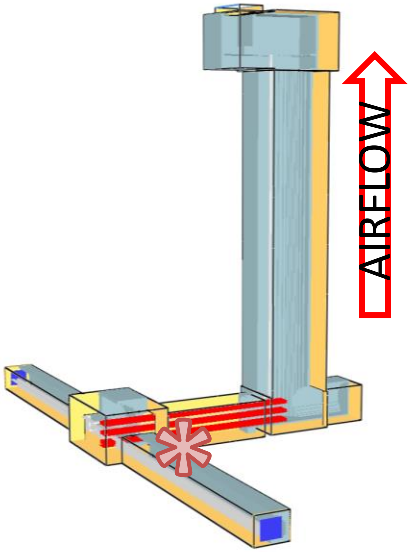




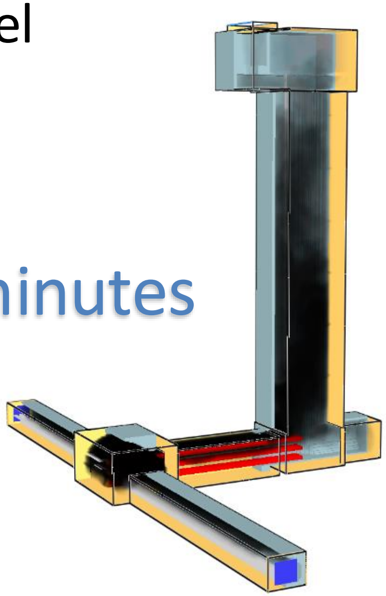


If unconstrained by ventilation
fire would grow up to ~100-150MW in one hour

50MW fire in TA junction tunnel

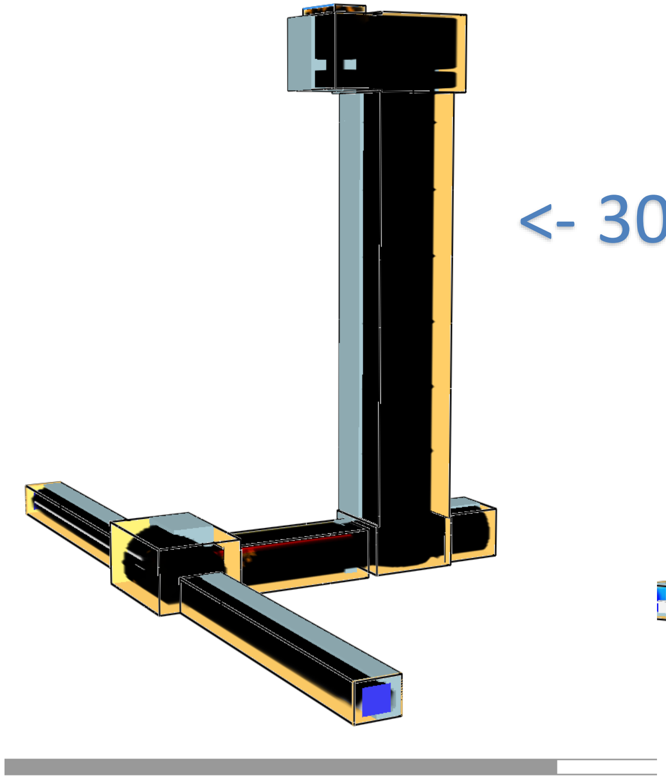


5-10 minutes

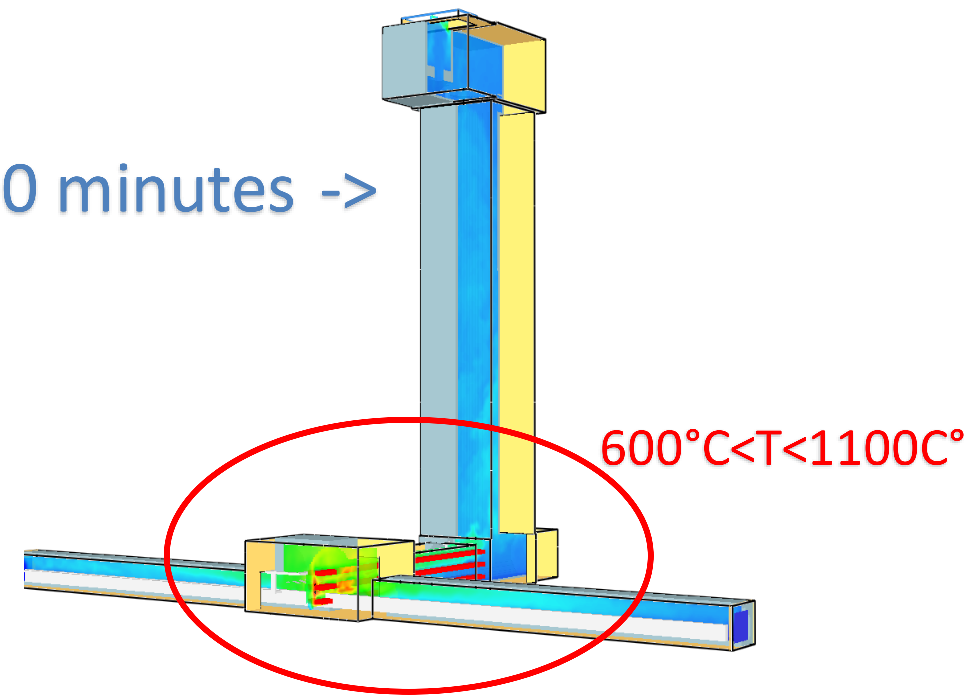


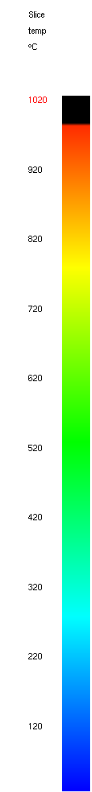
[2_1_SPS_50MW_JUNCTION_SMOKE_45000m3_s_upward_(1).wmv]

[2_2_SPS_50MW_JUNCTION_TEMP_45000m3_s_upward_(2).wmv]



<- 30 minutes ->





Conclusions for scenario 2 (50MW fire in TA junction tunnel)

- NOTE: CFD models for fire are best suited to give phenomenological trends, and are not advised for bold numeric predictions. PLEASE do not stick to the numbers of this presentation!!

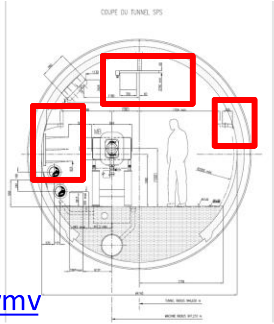
- Fire propagates quickly and flashover is possible within some 15-30 minutes

- Structural collapses are also possible given the hot temperatures registered

- Fire brigade access from top excluded, and from the nearby pits made practically impossible by long access path filled with smoke

- These results suggest strong need of fire doors at the base of the pit and renewal of fire suppression system to control fire and reduce thermal impact

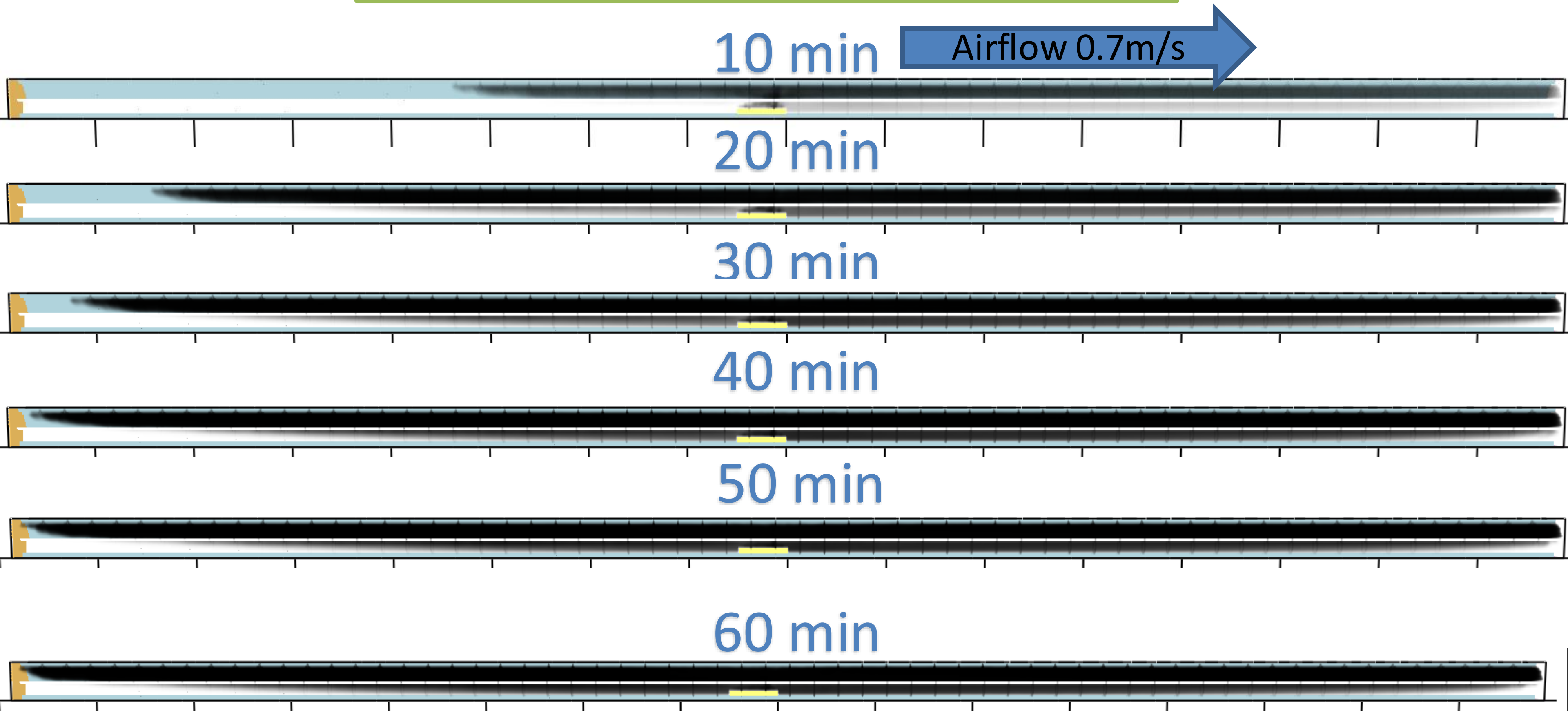
Scenario 3: 8 MW in 1 hr Fire midway in the machine tunnel, with 22500 m3/h ventilation (~0.7m/s)



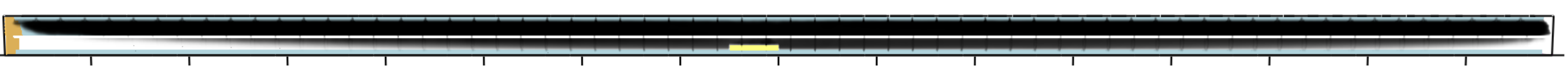
3_1_SPS_TUNNEL_8MW_SMOKE_MIDDLE_SMOKE_vent_from_left_22500m3_h.wmv

3_2_SPS_TUNNEL_8MW_TEMP_MIDDLE_TUNNEL_vent_from_left_22500m3_s.wmv

The modeled area has a length of 300m (out of 1100m)



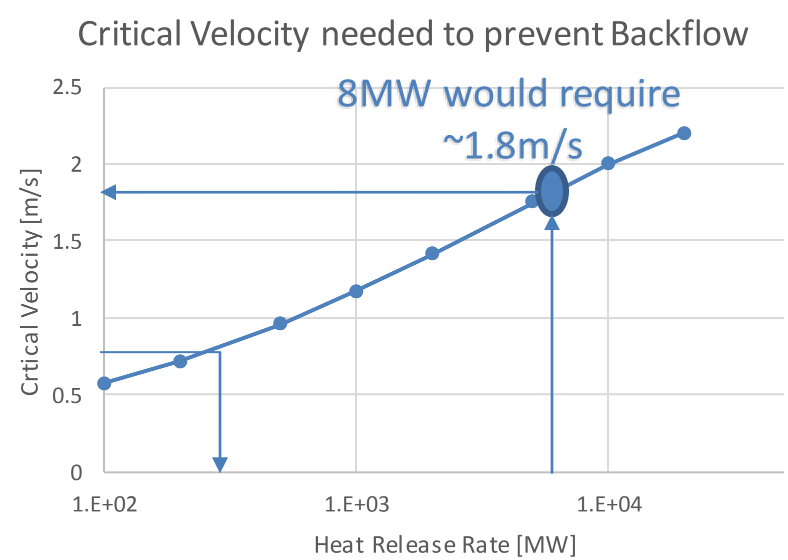
Conclusion for scenario 3 (8MW fire at mid-way in the machine tunnel)



- An airflow of 0.7 m/s looks insufficient to allow approaching in clean air from the fresh-air side
- In facts the airflow allows to control fires below 1 MW and is quite below the critical velocity for 8MW
- Fire brigade SCBA autonomy is not guaranteed to allow reaching the fire spot (and back!)

- Fire doors located at intermediate length, are under investigation of the fire safety WG as they look necessary to allow fire brigade safe access-retreat

Datum	Value
Height	~3m
Area of cross section	~9 m2
Grade (=slope)	~0%



$$Fr_m = gH\Delta\theta/(U^2T)$$

Calculated basing on http://mosenltd.com/wp-content/uploads/2011/01/Critical-Velocity.pdf

Conclusions

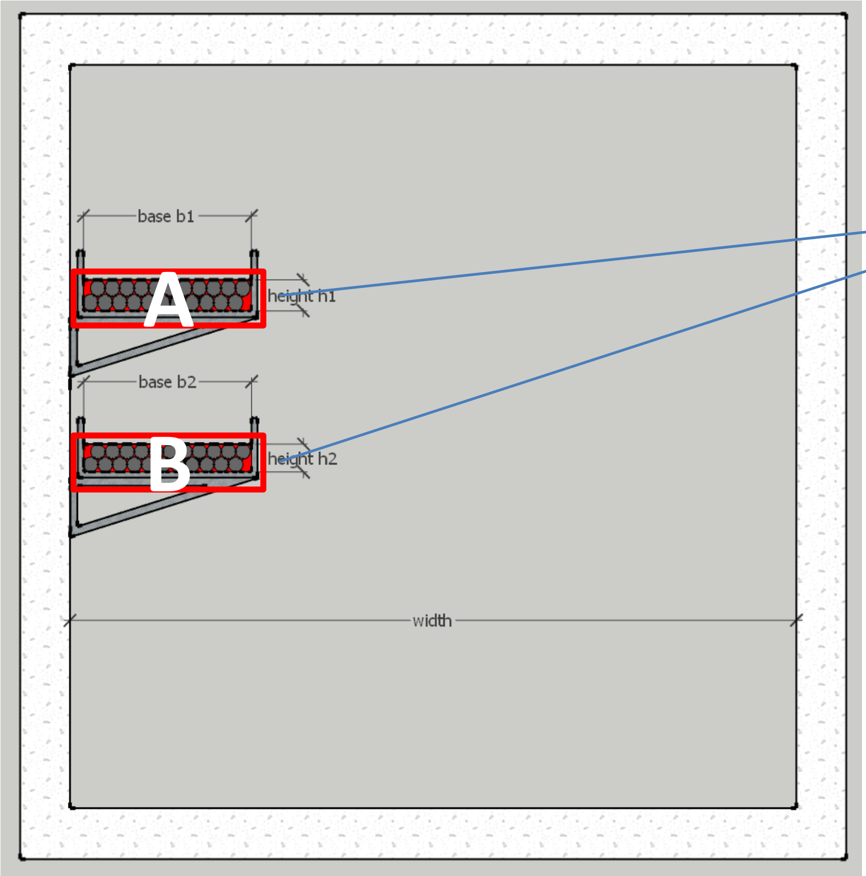
- CFD provided direct support to concepts carried on by the SPS fire safety WG:
  - upgrading the compartment scheme of the vertical access shafts
  - adding new doors splitting the 1.1 km section in several smaller units (doors closing upon fire detection)
  - reinstalling a fire suppression system to mitigate thermal impact in areas with high density of cables

This CFD activity is only one part of a collective effort of many departments and people carried on within the IEFP Fire Safety WG

Other aspects, like enhancing early detection & localization of fire, manual fire suppression means, are important but due to their nature are being developed with other methods than CFD, so were not discussed in this presentation

Method for quick and dirty calculation of FIRE LOAD

EDMS 1405658 Guideline calculation for method for fire tray load



Measure cumulate cable trays filled section [m^2] — (A+B)

Multiply by a "magic number" accounting for the average fractional mass of air, plastic, copper and heat of combustion — x 850 $kg/m^3 \cdot m^2$ x20MJ/kg

Obtain a quick and dirty "order of magnitude" result — (A+B)*850 *20 MJ/m

~16 GJ/m