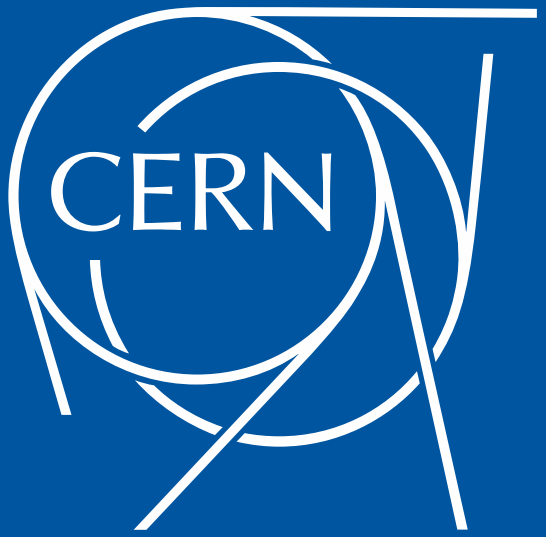
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Controlled Cold Helium Spill Test in the LHC Tunnel at CERN

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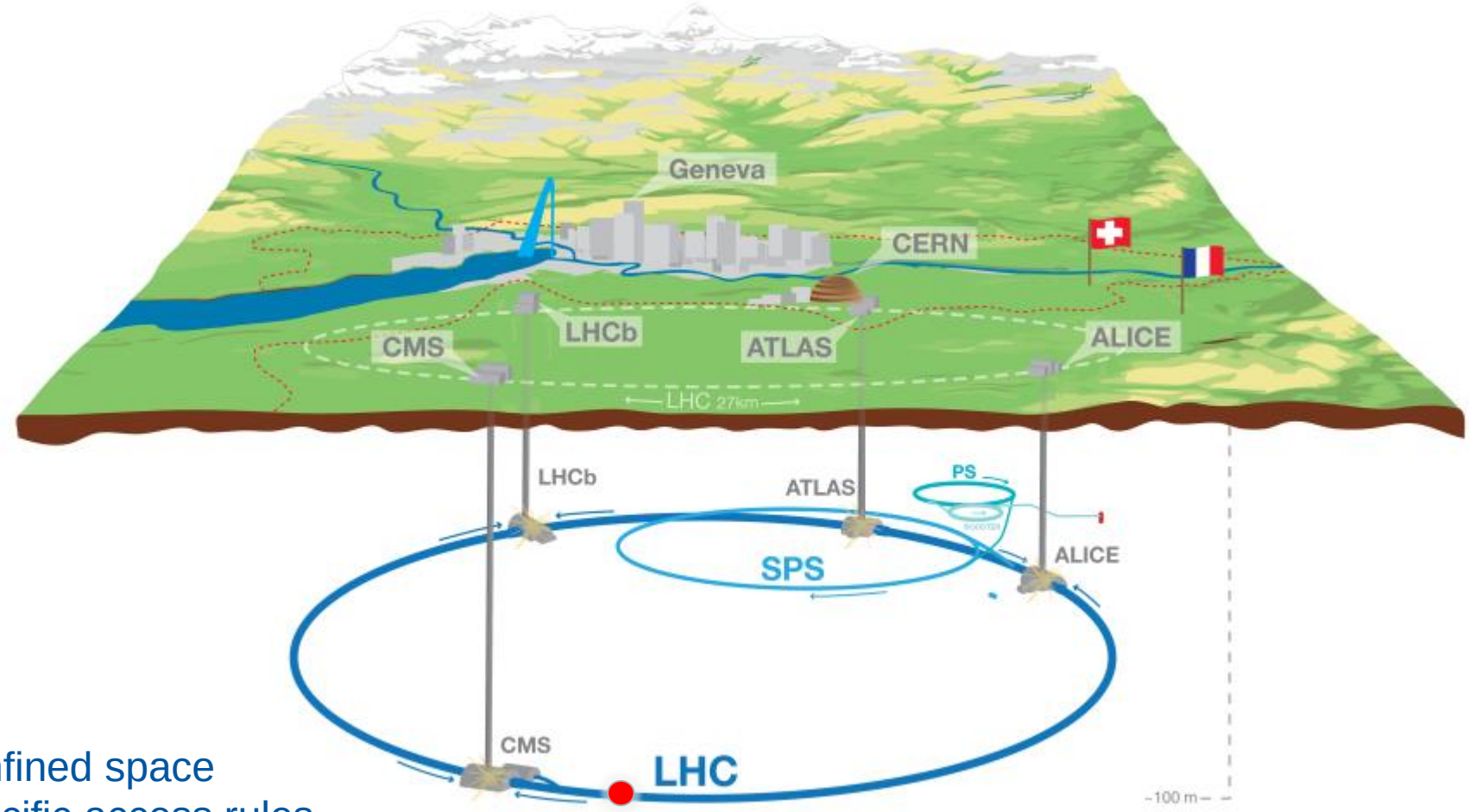
Content

- Situation of safety measures in the LHC tunnel related to ODH
- Requested parameters of the helium spill
- Experimental set-up in the LHC tunnel
- Measurement results along the tunnel
  - Movies in up- and downstream direction
  - Temperature
  - Oxygen content (ultrasonic and chemical sensors)
  - Tunnel air velocity and propagation speed of helium air mixture
- Conclusions

Helium Spill Test in LHC Tunnel – Current Situation

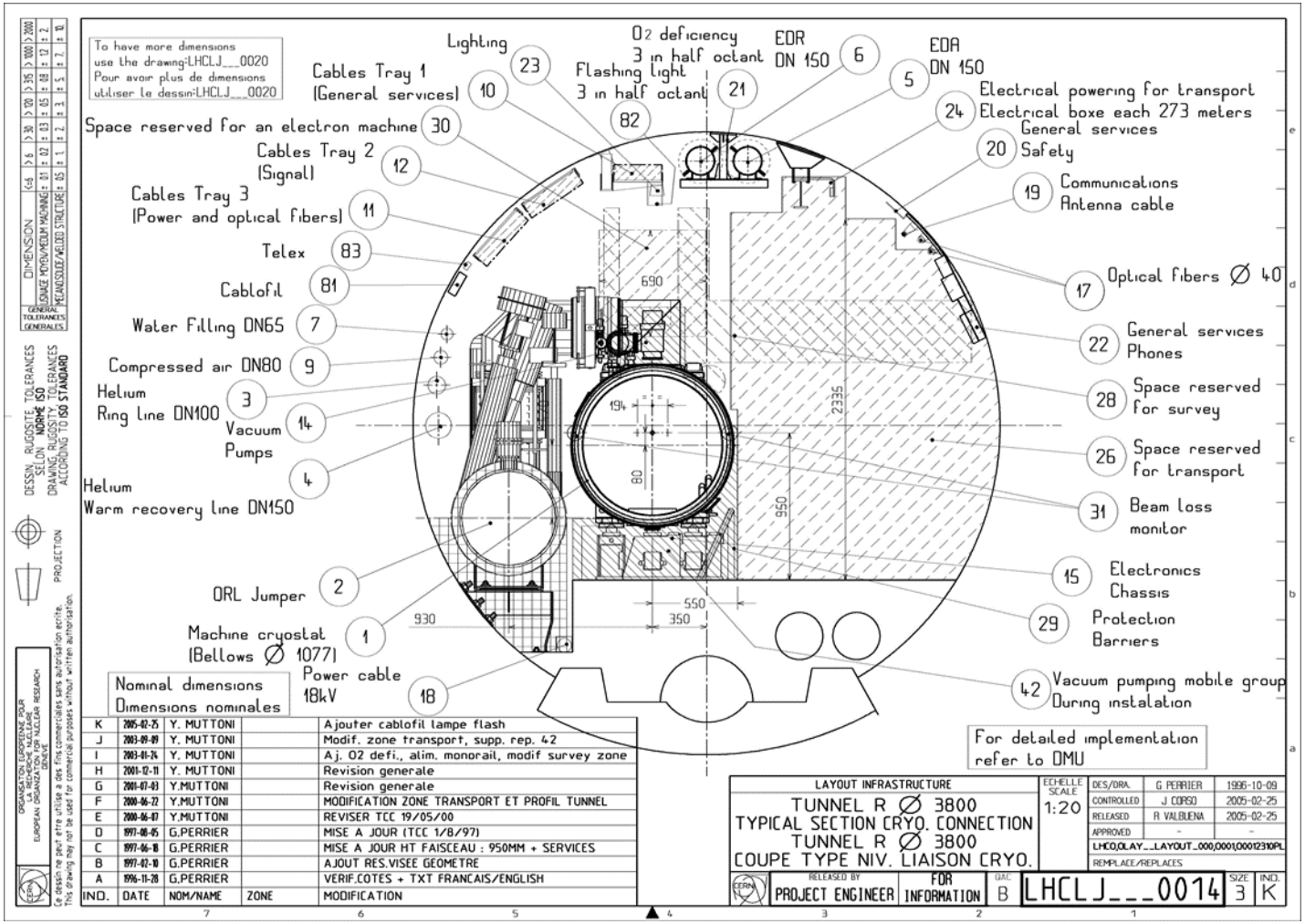


Confined space
Specific access rules
PPE

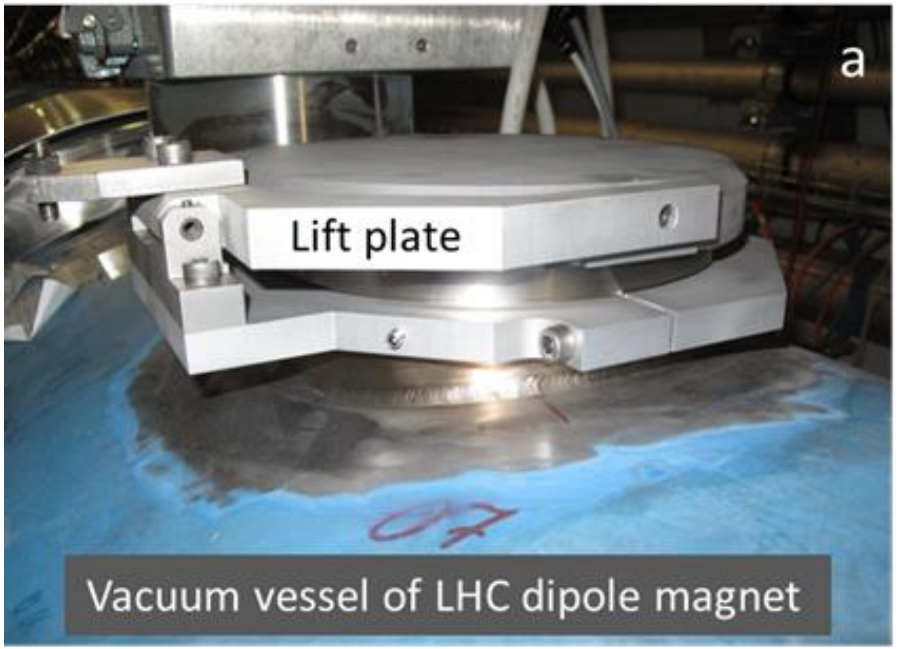
He spill test location

Helium Spill Test in LHC Tunnel – Cross section

LHC tunnel lay-out (including jumper)



Helium Spill Test in LHC Tunnel – Current Situation



After discussion (HSE)
and Departmental Safety Officer (DSO):

No stay zone of 3 m, centered around release point.

LHC Project Report 684*:	Header C	4.6 K & 0.36 MPa supply line
	Average flow	1 kg/s
	Length of helium jam	6 m

*SUMMARY OF THE EXPERIMENTAL STUDIES OF COLD HELIUM PROPAGATION ALONG A SCALE MODEL OF THE LHC TUNNEL

Helium Spill Test in LHC Tunnel – Proposed Updates

Scale model tests and several simulations have been performed.

Two different proposals are in place.

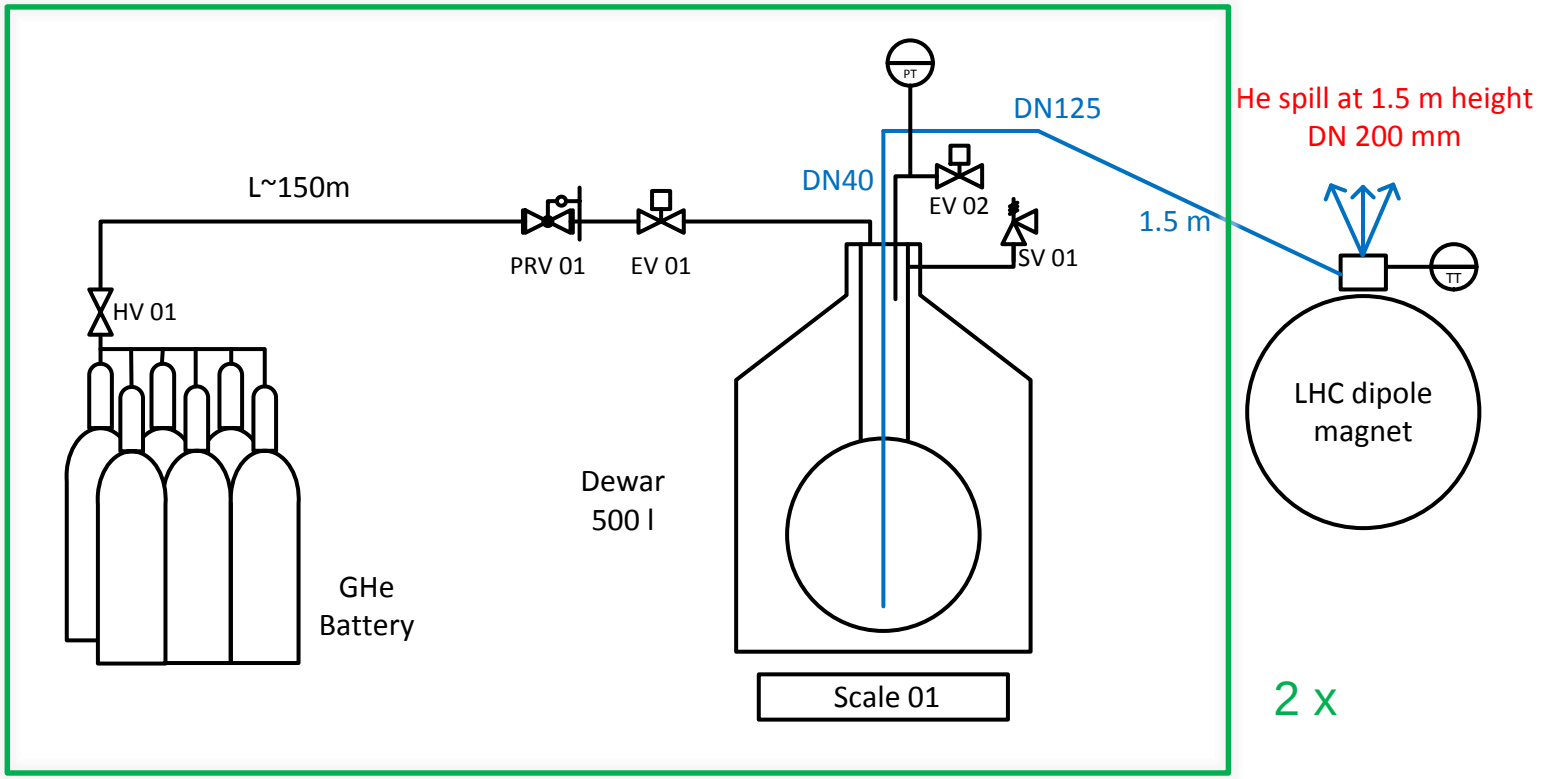
Helium Spill Test in LHC Tunnel – Requested Parameters

Enormous difference between proposal based on scale model and proposal based on simulation work

Perform a representative He spill test in the tunnel to check the validity of the different models and calculations and base new access rules on these validated calculations:

- Mass flow rate of the helium spill: 1 kg/s, 0.35 kg/s and 0.1 kg/s
- Total mass spilled per test: 125 kg (= 1000 liter LHe)
- Ventilation in “tunnel access speed”: 18000 m^3/h, equiv. to 0.7 m/s

Helium Spill Test in LHC Tunnel – Experimental Set-up

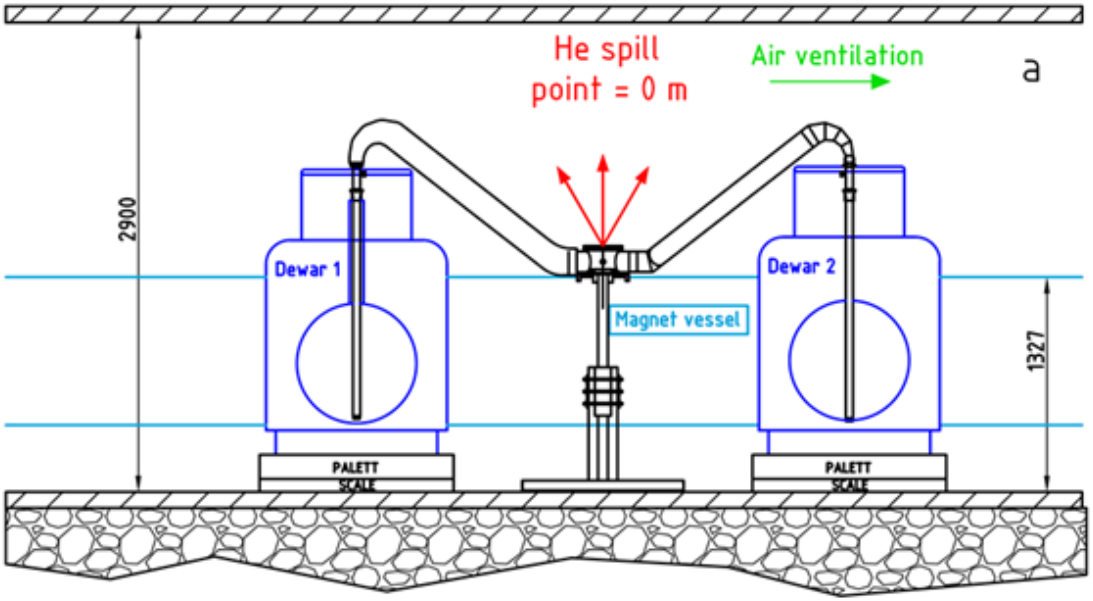


Pressurizing 2 Dewars with warm helium gas from gas cylinders at 150 m distance. The liquid mass flow will be measured by scales on which each Dewar is placed.

Dewar:	Design pressure	2 bar
	Primary safety valve	0.5 bar
	Pressure drop system	0.1 bar

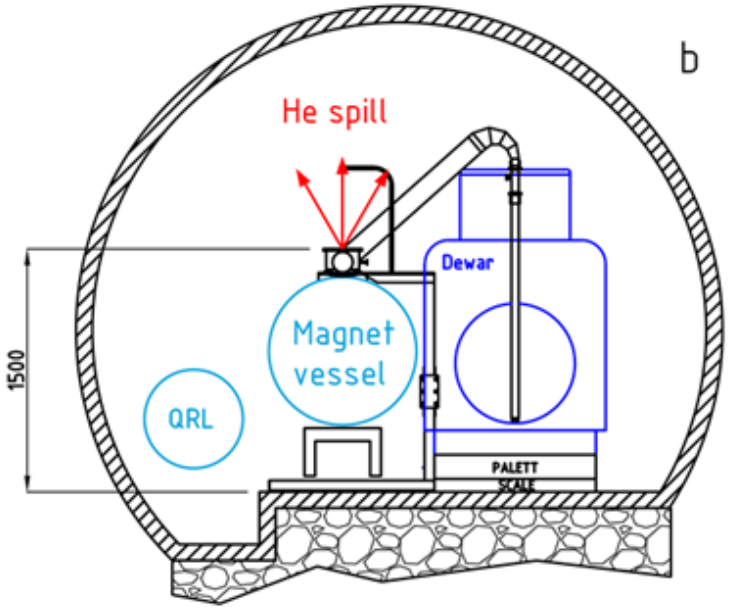
Helium Spill Test in LHC Tunnel – Experimental Set-up

Tunnel side view



Two 500 l Dewars with liquid helium combined extraction system

Tunnel cross section



Dewars placed in the walk way
Release mock-up on top of magnet

Helium Spill Test in LHC Tunnel – Instrumentation

- Equipment in the tunnel with measurement system
  - 25 Temperature sensors (Pt100)
  - 25 ODH (special development of fast reacting measurement head)
  - 3 ODH chemical type => GS Oxygen Sensor KE 25
  - 6 video cameras
  - 4 air velocity measurement stands
  - 2 scales (used for calculation of mass flow)

- Equipment was placed on 15 stands:
  - 8 downstream (over 200 meter) and
  - 7 upstream (over 100 meter) of air ventilation direction,
  - Spill point location as reference 0 m.

- ODH Sensors are placed at 0.5 m, 1.75 m height in passage area.

- Temperature sensors are also placed close to the ceiling.

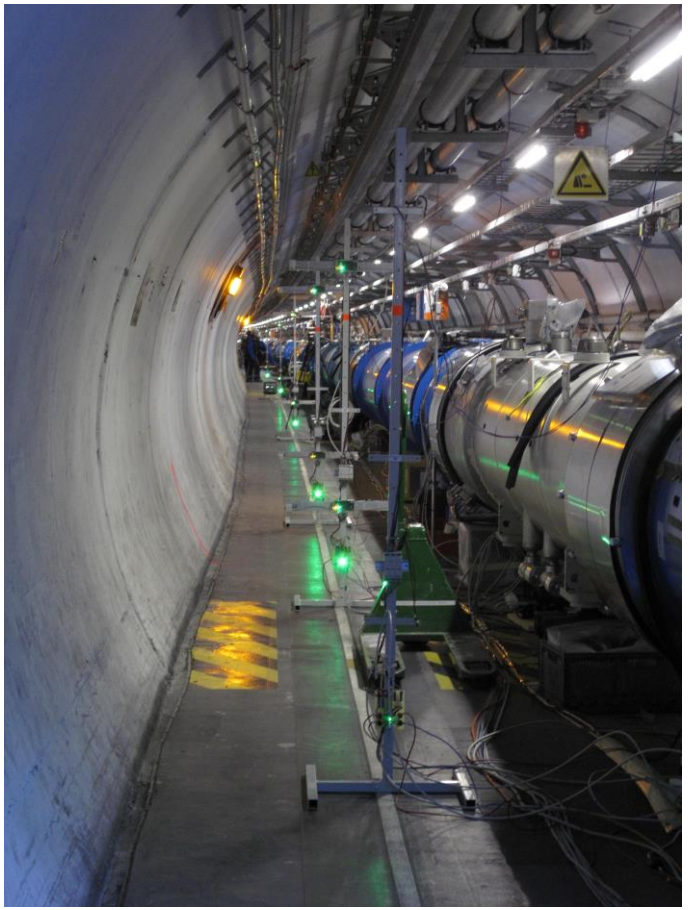
Helium Spill Test in LHC Tunnel – Set-up

Measured values:

- At spill location
- Upstream direction
- Downstream direction

Spill test set-up

Spill point with temperature sensors (at spill point and at 50 cm). Magnet vacuum vessel protected by Armaflex.



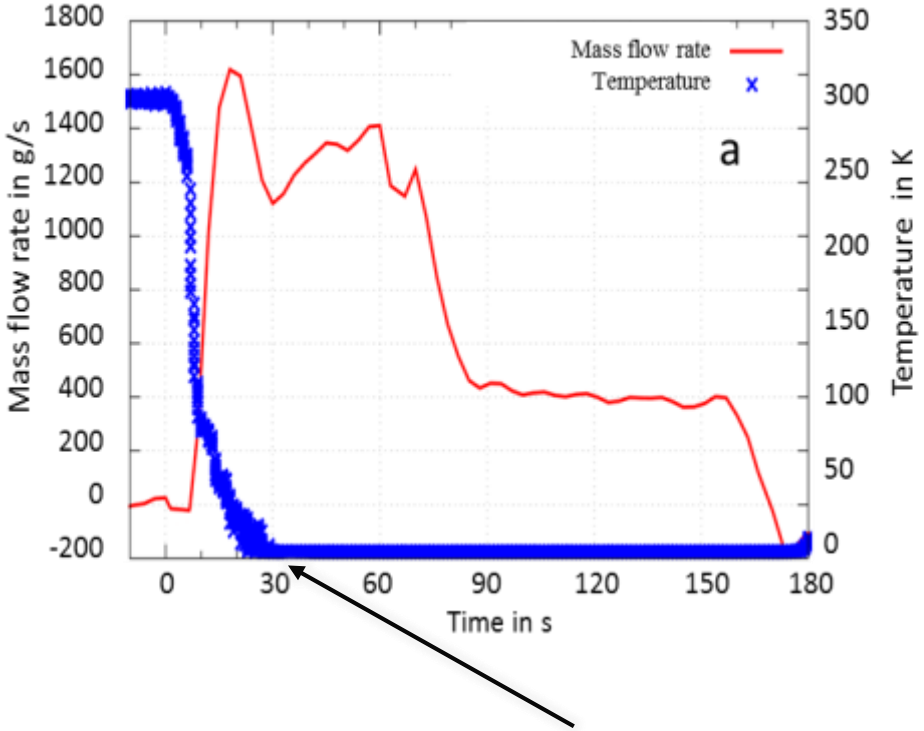
Test stand with ODH and temperature sensors at three levels. Also temperature sensors at top of tunnel

Helium dewars in place connected to the spill point. Dewars are pressurized by warm helium gas.

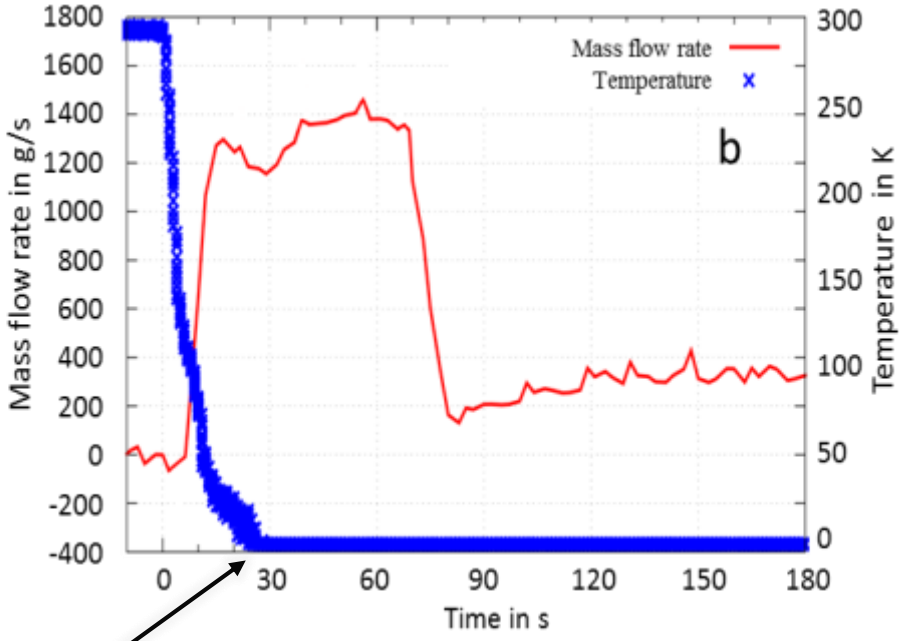
No persons were present in the tunnel during the test

“Parameters of the1 kg/s spill

06/Feb/2014



07/Feb/2014

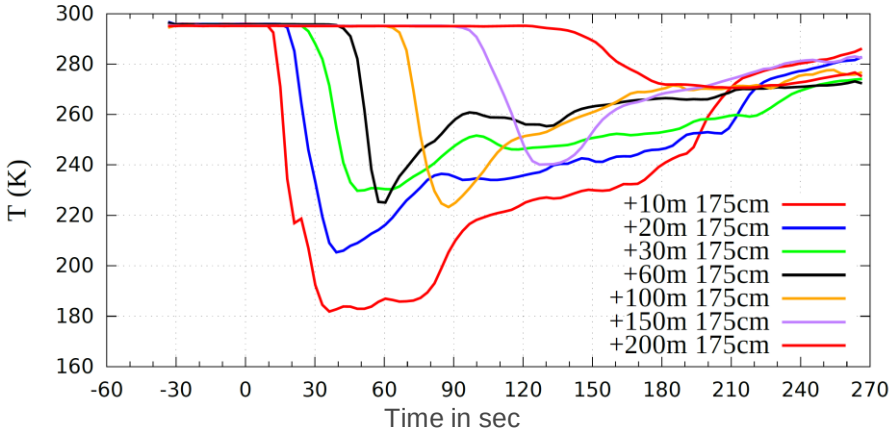


Temperature of the released helium approaches 4.2 K after ~ 25 sec.

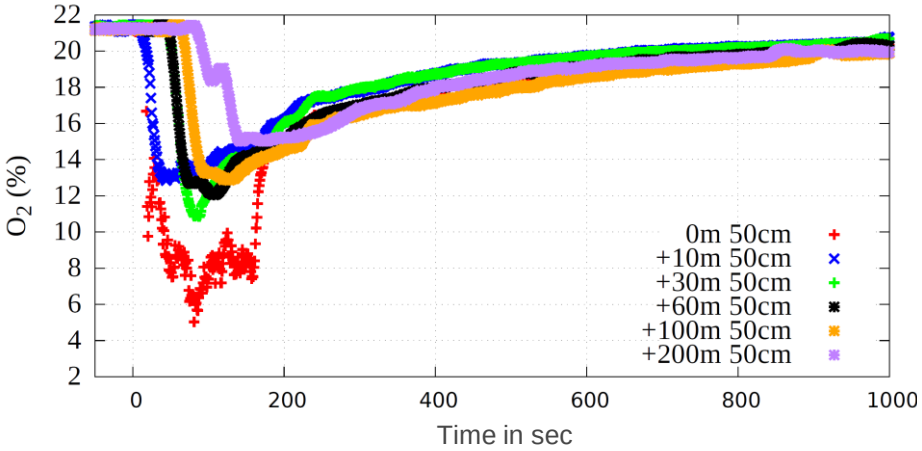
All personal O_2 deficiency detectors triggered including farthest one @ 200 m distance and 0.3 m height

Some results of the 1 kg/s spill

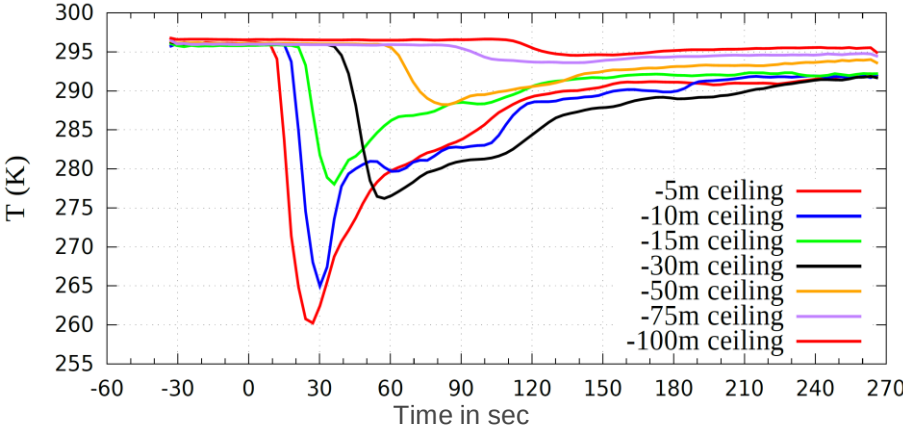
06/02/2014 : Men's height Temperatures from 0m to 200m
start of dewar's pressurization at t=0 s



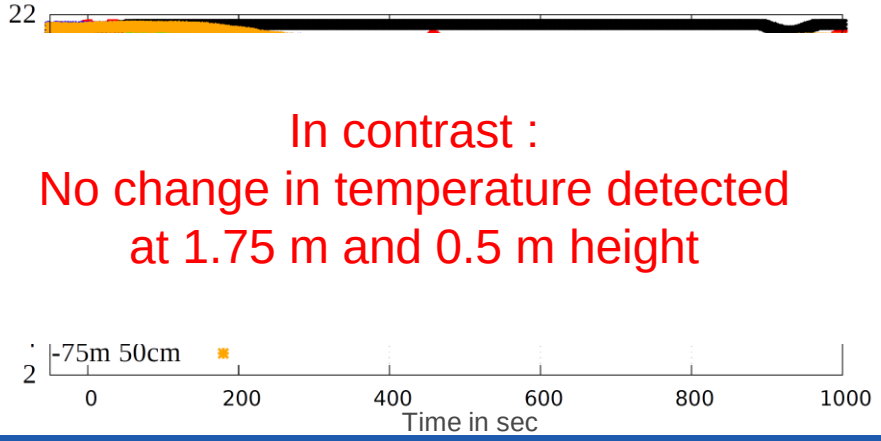
06/02/2014 : O_2 concentration from 0m to 200m at kneeling height
start of dewar's pressurization at t=0 s, Ultrasonic O_2 offset -0.5 %



06/02/2014 : Ceiling Temperatures from 0m to -100m
start of dewar's pressurization at t=0 s

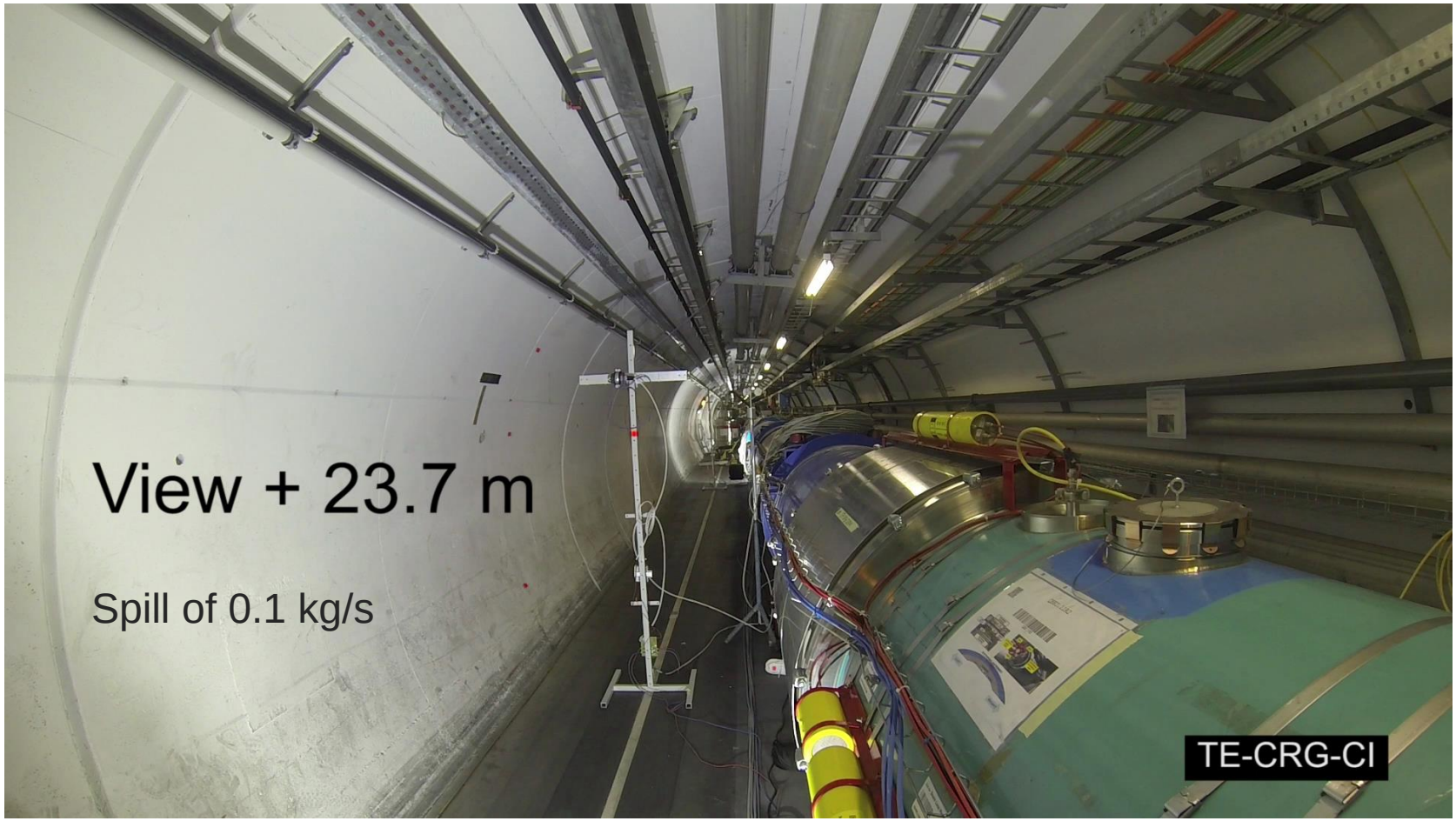


06/02/2014 : O_2 concentration from 0m to -100m at kneeling height
start of dewar's pressurization at t=0 s, Ultrasonic O_2 offset -0.5 %

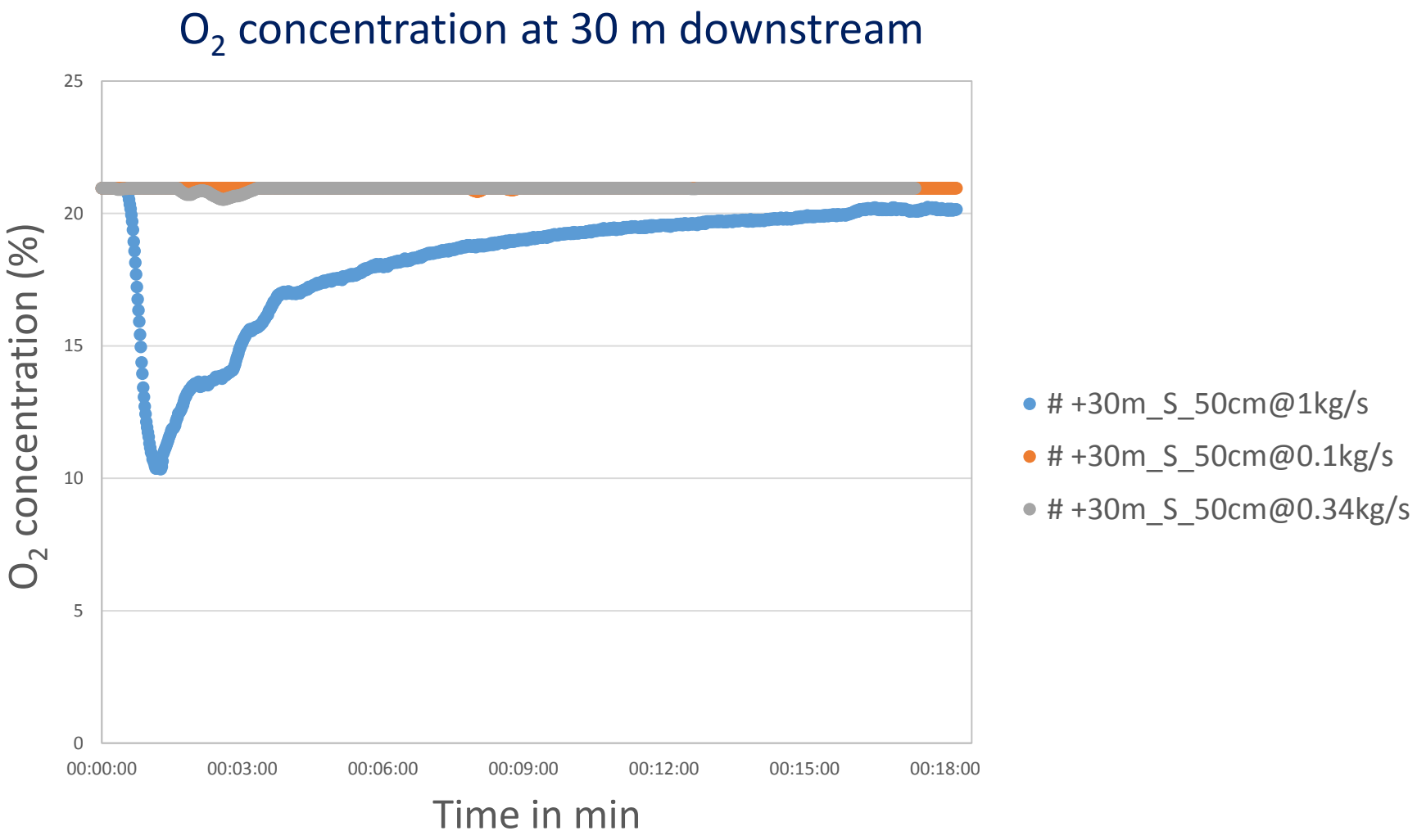


In contrast :
No change in temperature detected
at 1.75 m and 0.5 m height

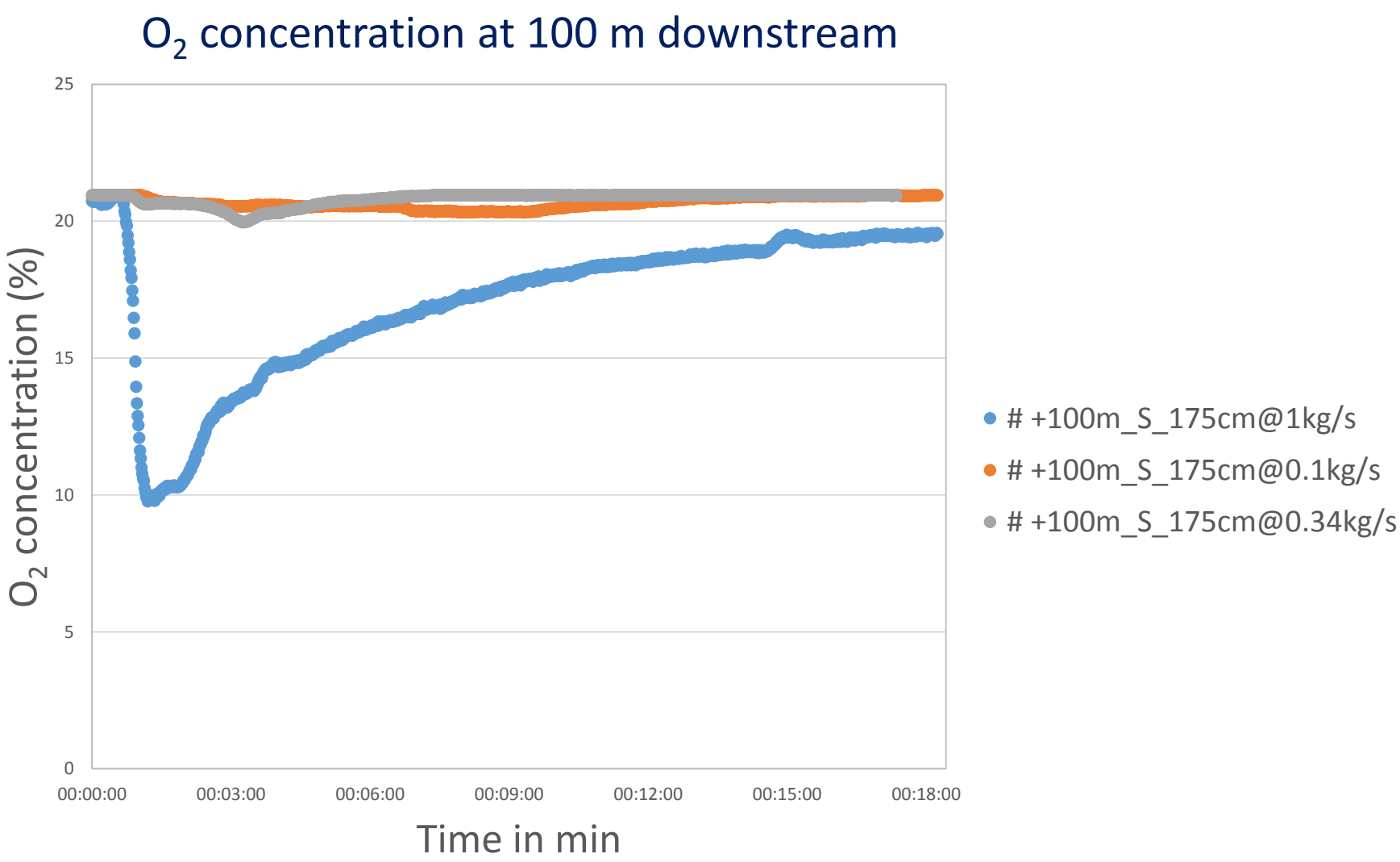
“Visual” results 0.1 kg/s spill @ T=20-25 K



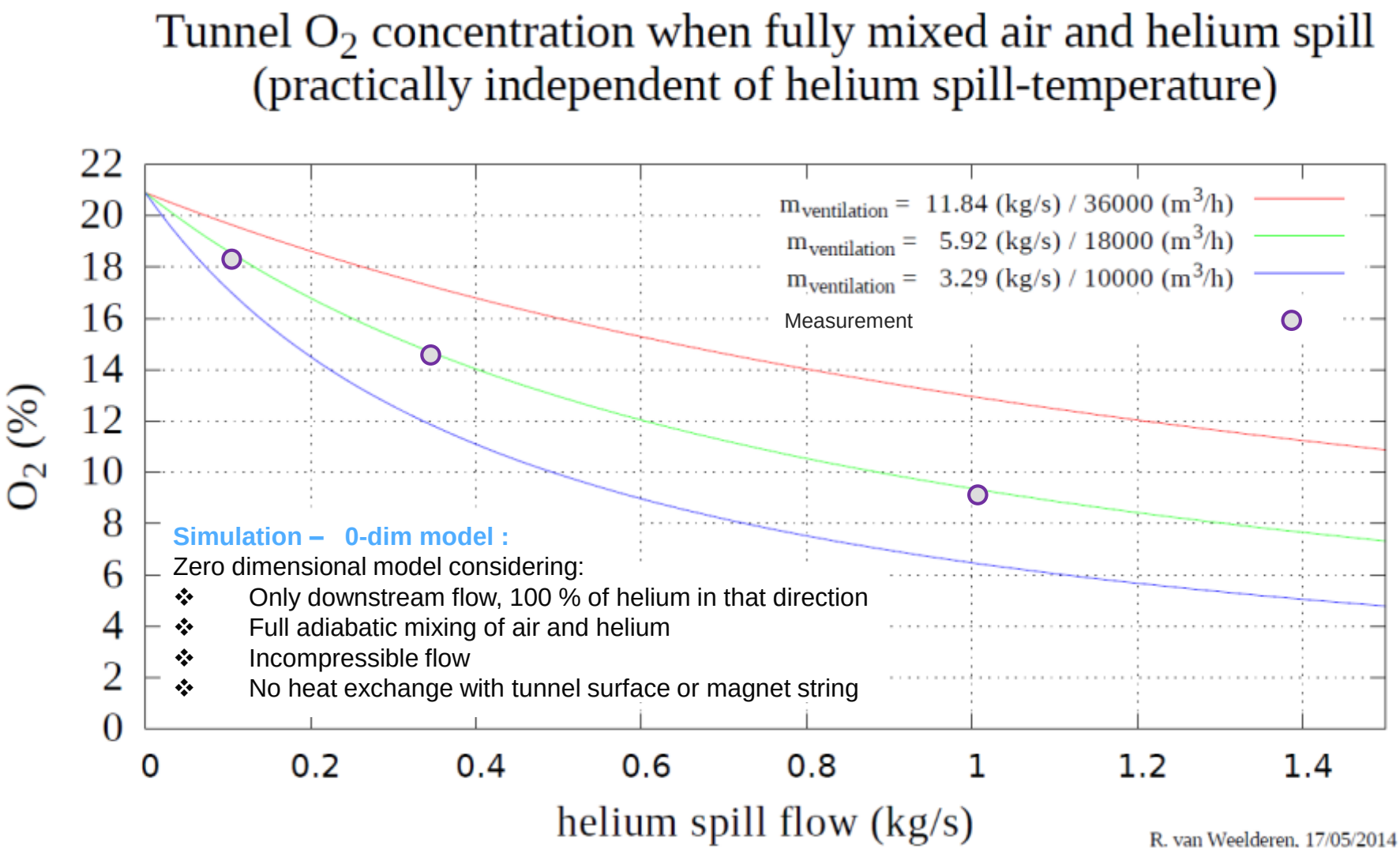
Comparison of result for different mass flows



Comparison of result for different mass flows



Simulated vs lowest measured O_2 concentration downstream



Results 0.1 kg/s spill test

- No noticeable lowering of temperature (T< 10 K) below 1.75 meter height anywhere in the downstream direction.
  At tunnel ceiling height => temperature lowers by about 40 K.
- No noticeable lowering of the ODH level (< 1%) at 20 meter or further downstream of the spill point and below 1.75 meter height
- Even at 10 meter downstream of the spill point and below 0.5 meter height no noticeable lowering of the oxygen (< 1%) content has been measured.
- No noticeable lowering of the temperature or the oxygen content in the upstream direction
- No visual obstruction at any distance from the spill point and below 1.75 meter.

Result of the He spill test

No access to the LHC tunnel:
- during transient conditions
- when magnets are energized

} Maximum estimated He spill < 0.1 kg/s

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Consequences of spill tests

After the results of the spill test became available, a working group has been studying the implementation of these results in the LHC tunnel access procedures.

Estimate MCIs which can create these spill flows:

1) Spill of 1 kg/s corresponds to the MCI:
   - during pressure test of “cryogenic infrastructure”
   - during cool-down from 300 K tot 80 K
   - when there is a current of 1 kA in one of the magnet systems (stored energy about 100 kJ);

2) Spill of 0.32 kg/s corresponds to the MCI:
   - during phase 1 of powering (max 30 kJ in circuit)
   - special test conditions

3) Spill of 0.1 kg/s corresponds to the MCI:
   - human mistake when the magnet system is not powered

Consequences of spill tests

Seen the analysis of the MCIs for the different conditions of the LHC, and seen the result of the different spill tests made, this working group recommended:

1. For pressure test: no access to arc of the LHC tunnel under test and to the upstream and downstream half-Long Straight Sections
2. No access to arc being in cool-down between 300 K and 80 K, and special access rules for adjacent areas;
3. Phase one of powering: use controlled instrumentation whenever possible, only access possible for powering experts;
4. Long Straight Sections: no recommendations
5. Special areas (stand alone magnets, cryo-feed boxes, cryolines) T<80 K: prior authorization needed for work in vicinity of these areas. Personal ODH needed;
6. Inner Triplets (no alternative escape route) are forbidden zones. Only access under very exceptional circumstances, work-plan must be submitted beforehand for approval (only access if “vacuum pressure is followed locally by second person”, or if the helium in the IT is emptied beforehand.
7. For interventions in the arc area (below 80K) personal ODH needed, number of persons in this area shall be limited; work declaration needed beforehand.