Helium Release from SC Link to UR

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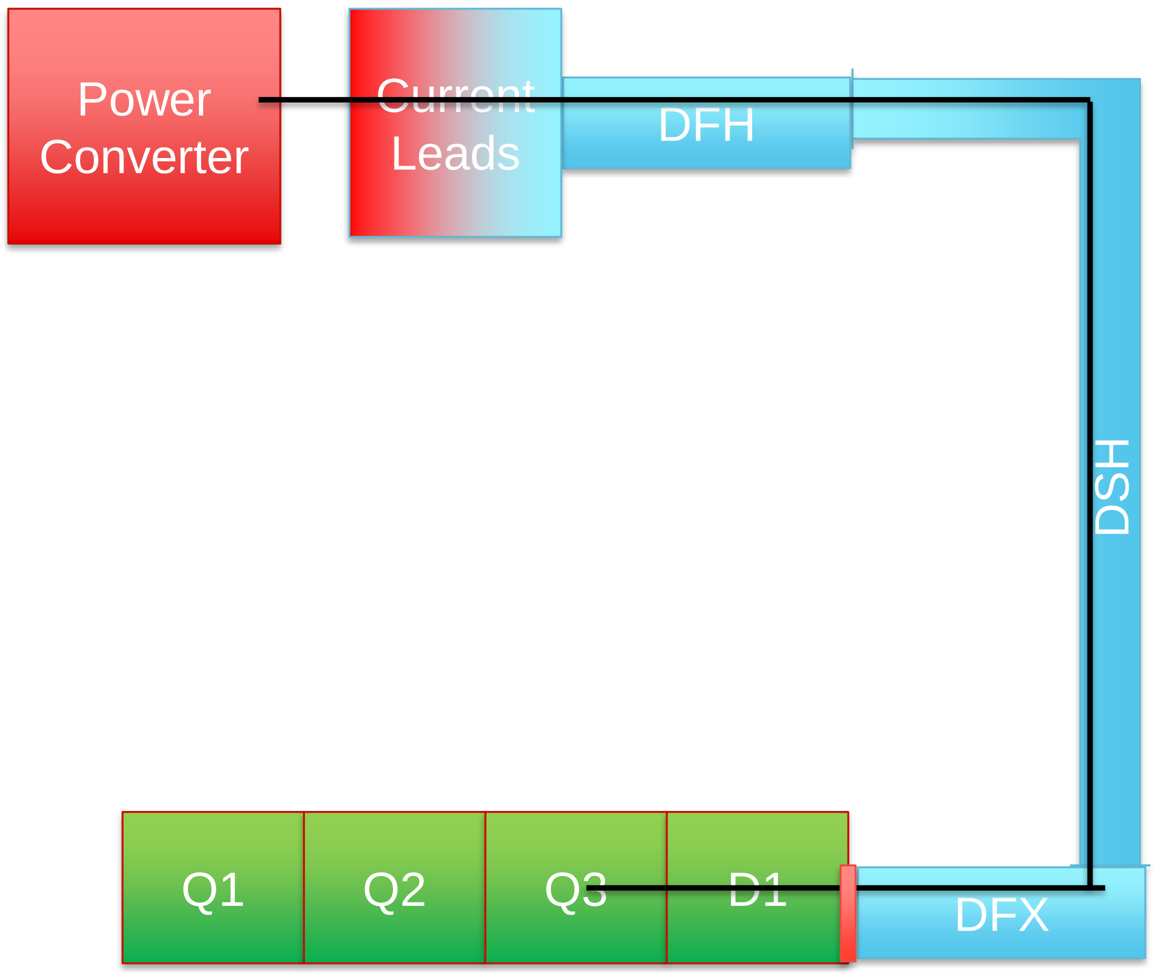
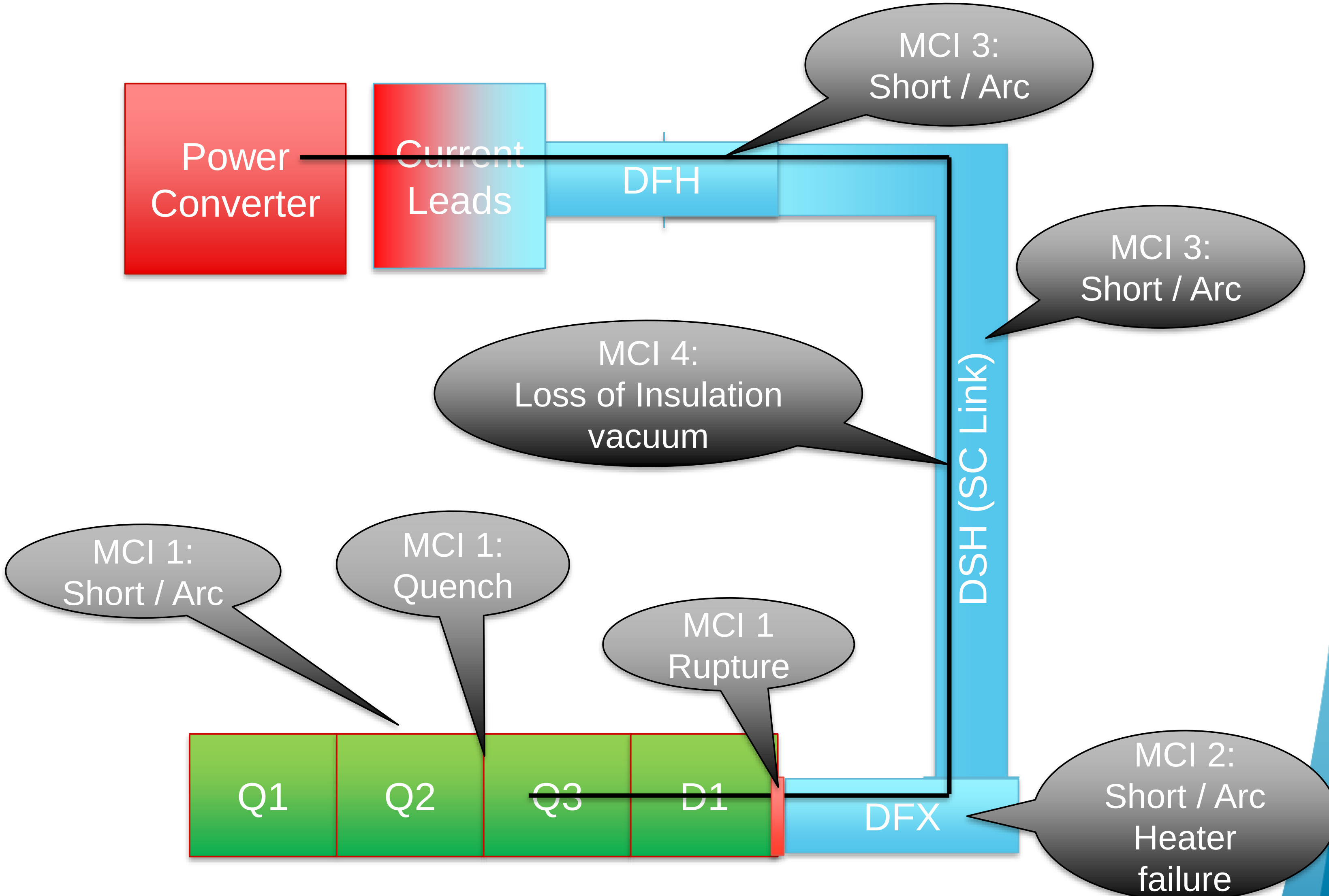
Cold Powering layout (schematic)



Failure Modes leading to Helium evaporation



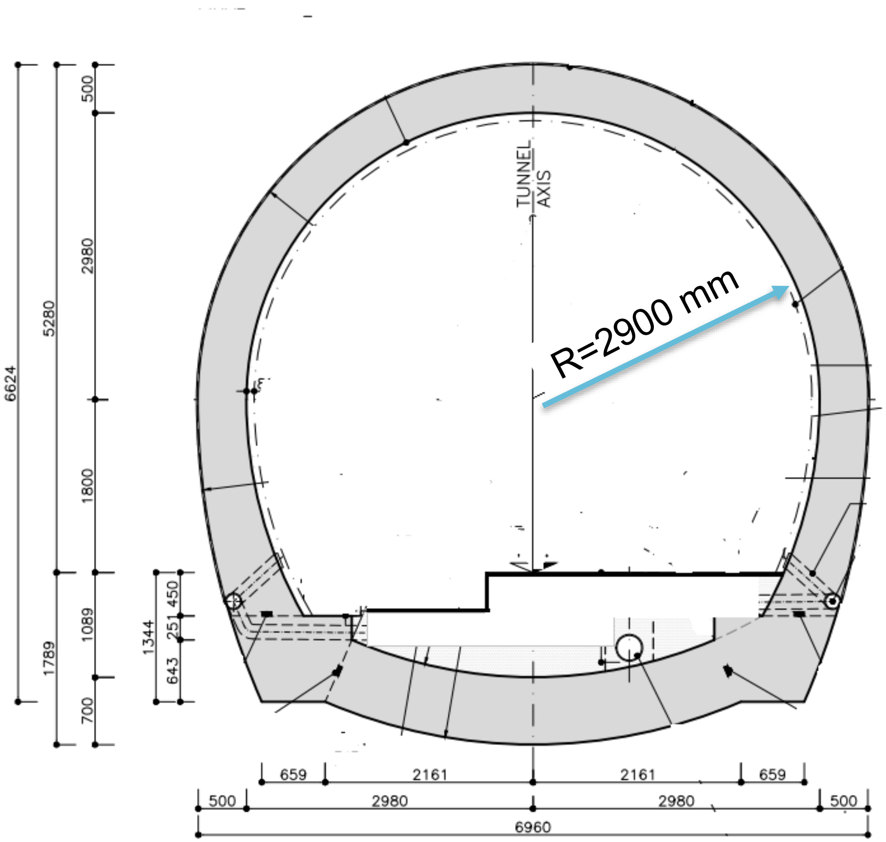
SC Link Options

- Different sources give different values for Helium content in SC Link – I use conservative values

- Free volume of SC link approx. 1 m^3
- SC link with MgB_2 cable
  - 25 kg Helium gas at p=1.3 bar and T =4.5 – 15 K
  - Active shield ($V \approx 1.5\ m^3$, $T \approx 40$ K): +2 kg Helium
  - Passive shield (MLI only) optional
  - DFX two-phase cryostat

- SC Link with Nb-Ti cable
  - 140 kg supercritical Helium at p = 3-4 bar and T = 4.5 K
  - Active shield as for MgB_2 link: +2 kg
  - DFX' one phase cryostat

UR Gallery – Accessible during Operation

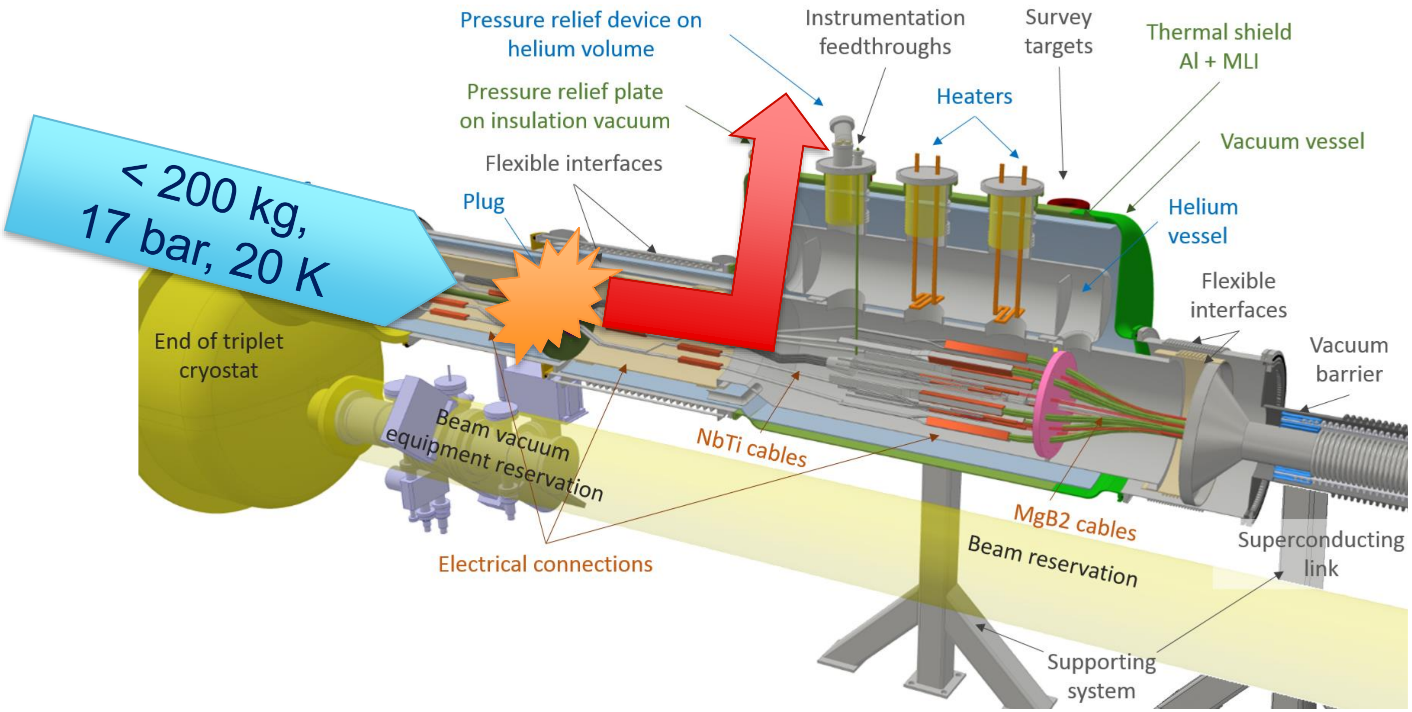


Volume of the gallery (300 m long)
$V_{free} \approx 6000\ m^3$ (25 % occupancy)

Ventilation:
mixing by Air handling units
Fresh air in UR : 10000 m^3/h
(1 exchange every 40 minutes)

Smoke extraction system:
18000 m^3/h, can be directed in one particular sector

MCI 1: Quench or Short in IT

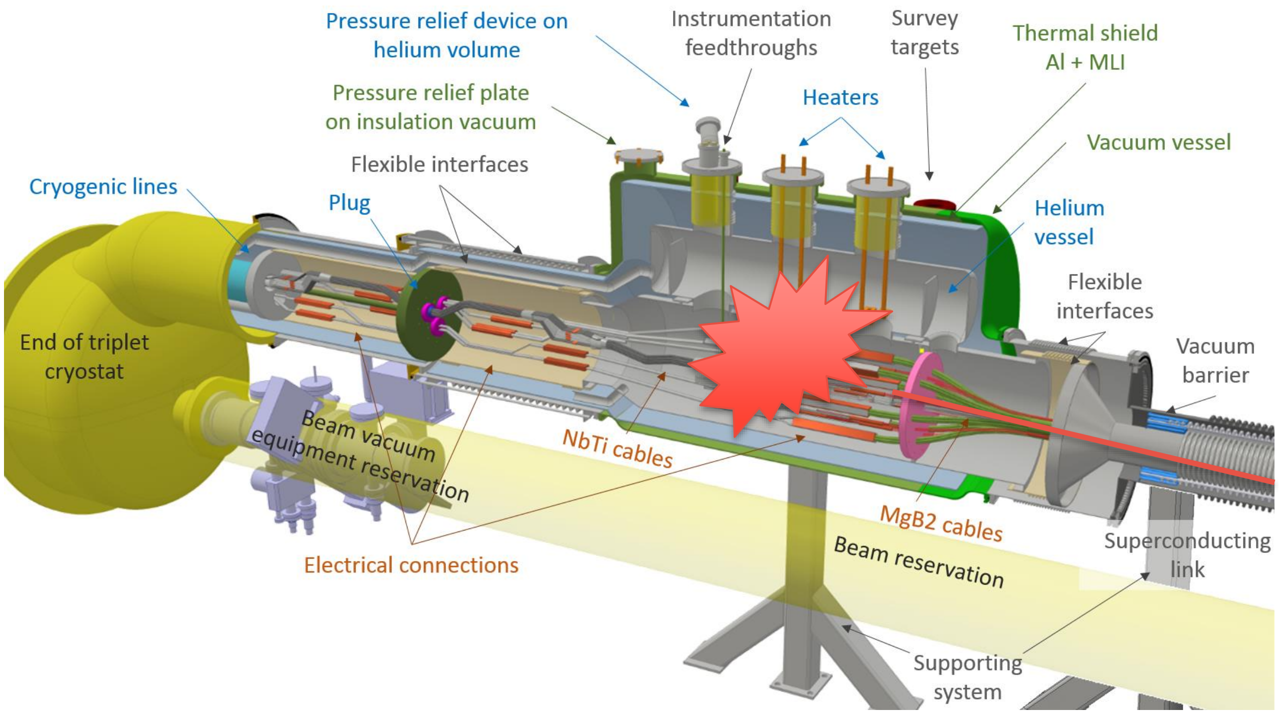


- Helium (p = 17 bar / T = 20 K) passes though ruptured plug
- Mass- and Heat Flow depends on rupture size:

A (cm2)	0,1	0,2	0,5	1	2	5
Q (kg/s)	0,04	0,08	0,22	0,45	0,90	2,25
ϕ (kJ/s)	4,42	8,84	24,31	49,7	99,5	248,6

- Full evacuation by DFX Safety Device to LHC Tunnel

MCI 2: Overheating or Short in DFX



- Helium evaporation in DFX
- MgB_2 may quench – resistive heating leads to full loss of Helium in SC Link => MCI 4a / 4b

MCI 3: Internal short or arc

- Consequence: rupture of cryostat to insulation vacuum
  - Size of the hole determines flow to insulation vacuum and release mass flow to tunnel
  - Bottom line: the full contents of the cryostat (and active shield) will be released, as in the LIV event.
  - From the point of view of Helium release, similar to MCI 4a/4b, only the dynamics may change

MCI 4: Loss of Insulation Vacuum in SC Link

- Cryostat surface 25 m^2, 10 layer MLI
- Heat load from LIV (0.6 W cm^{-2}): 150 kW

- Initial Mass Flow through SC Link Safety Device*:
  - MCI 4a: MgB_2 SC link: 2 kg s^{-1}
  - MCI 4b: Nb-Ti SC link: 4.5 Kg s^{-1}

* Estimated with CERN Kryolize Software

MCI 4a: Time evolution after LIV

- "Sizing of pressure relief devices for 60 m semi-flexible cryostats"*
- Illustrated option is MgB_2 link with active shield

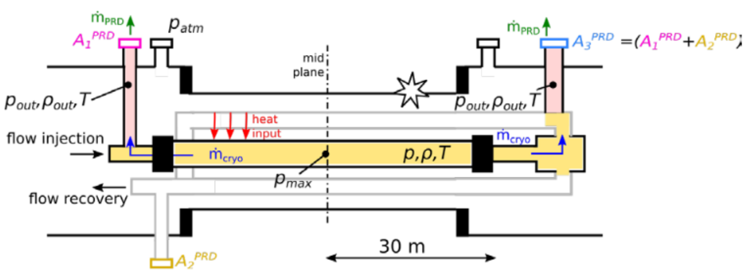
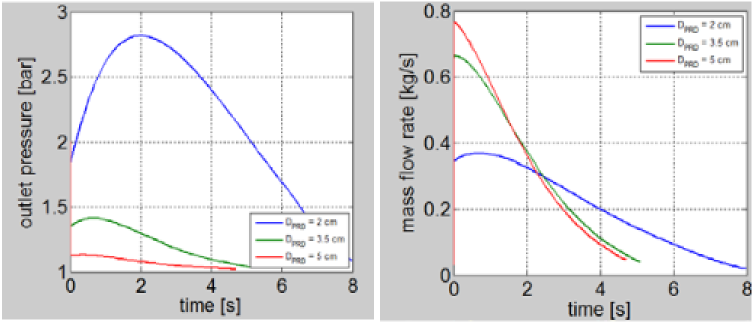


Figure 4 Break of vacuum envelope in Type A cryostat. Inner volume.



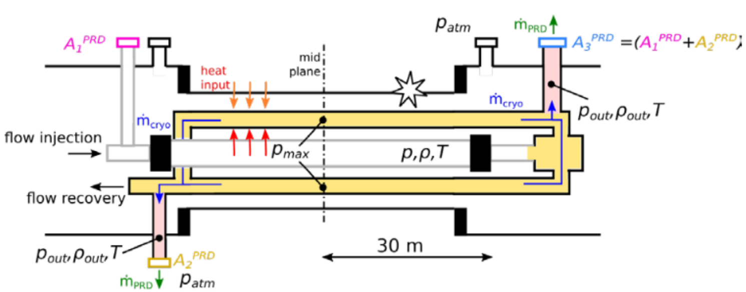
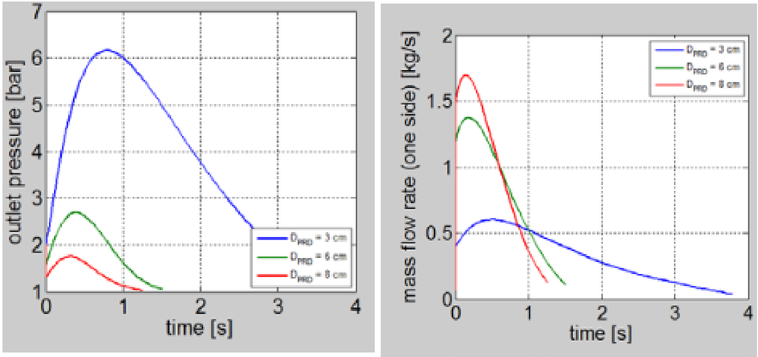
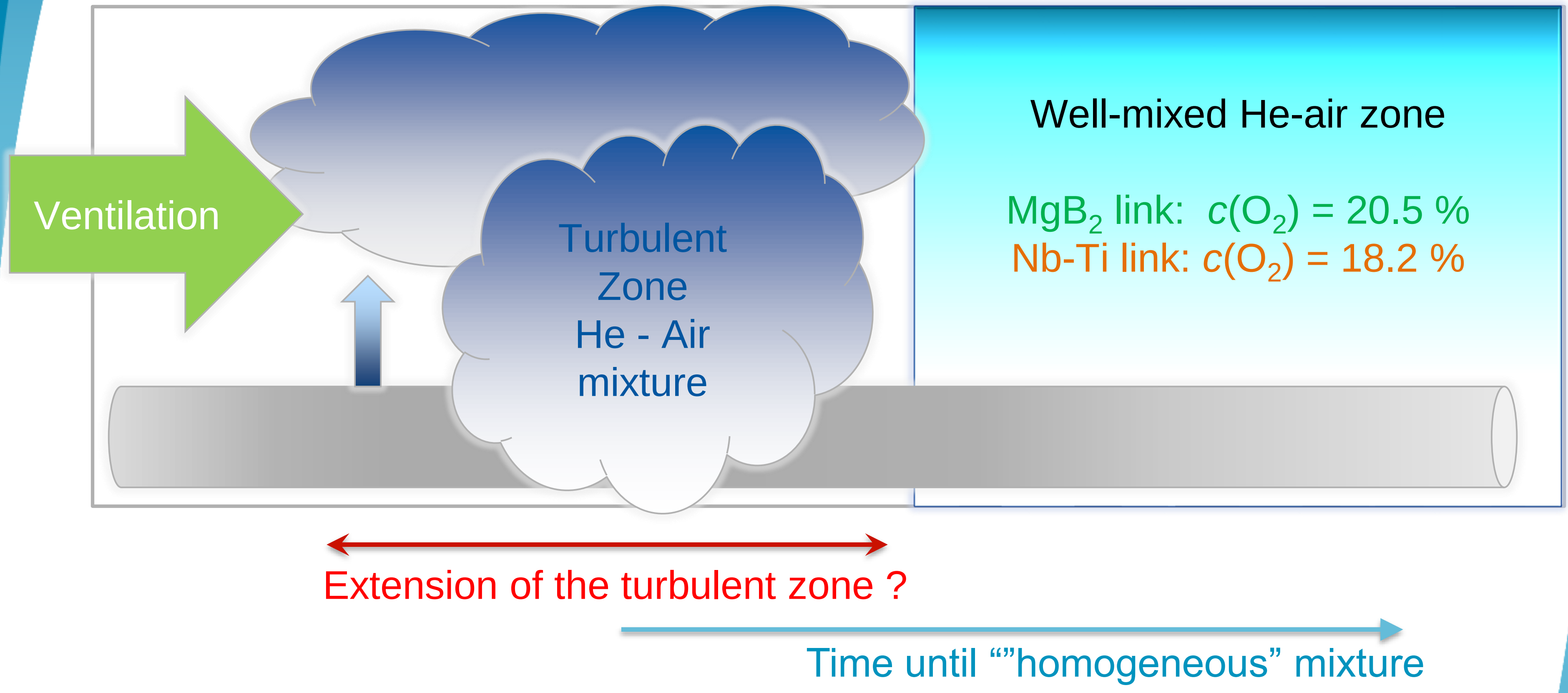


Figure 5 Break of vacuum envelope in Type A cryostat. Thermal shield volume.



* S. Giannelli, TE-MSC-SCD, EDMS 1722630

Helium Behaviour after release

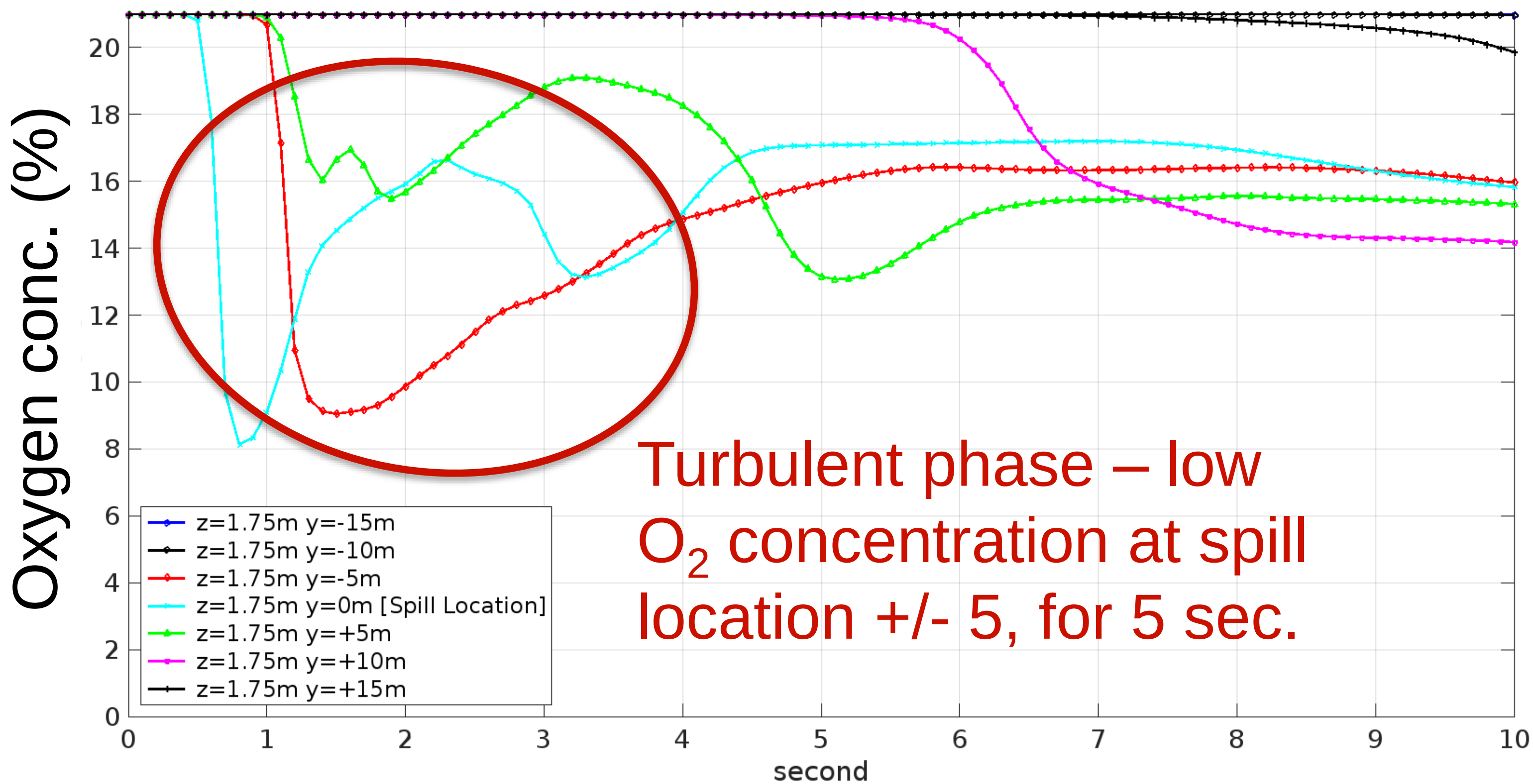


These variables depend on the mass flow, the total amount released and the dimension of the tunnel. Two known cases:

- Experimental and simulated He spill tests in LHC, 125 kg at at 0.1, 0.25 and 1.0 Kg s^{-1}
- Simulated release from SPS CC, 15 kg in very short time

MCI 4a – Comparison with SPS CC Test

- Small Helium Mass (15 kg vs. 27 kg)
- Rapid release, quickly ceasing



Numerical calculation: R. van Weelderen, F. Aabid, TE-CRG

MCI 4b: LIV in Nb-Ti cryostat

- Reminder:
  - 140 kg He in cryostat, +2 kg in active shield
  - 4.5 kg s^{-1} initial flow, total release within 1 minute (?)
  - 800 m^3 Helium gas at NTP

  - At the release location, a turbulent mixing zone with $c(O_2)$ << 18 % and low temperature will persist for the release location
  - Size of turbulent zone ?
  - Helium will warm up be mixed by AHU
  - Time until mixing
  - After turbulence has ceased, $c(O_2)$ close to alarm value of ODH detection

Conclusion

- MCI 1: IT Quench and ruptured cryogenic plug
  - DFX safety device shall be sized to release all helium in underground
- MCI 2: heater fault or short in DFX
  - Quench of MgB_2 cable, full evaporation => MCI 4a / 4b
- MCI 3: internal short or arc in SC link
  - Full evaporation => MCI 4a / 4b
- MCI 4: Loss of insulation vacuum in SC Link
  - 4a, MgB_2 link: release of up to 25 kg of He in UR:
    Similar to SPS CC test, short and limited turbulent zone
  - 4b, Nb-Ti link: release of 140 kg He in UR:
    Size and duration of the turbulent zone: need to evaluate helium behaviour after release

Homework

- WP 6a:
  - Terminate design of SC Link
  - Define Helium content and its thermodynamic state in cryostat (and shield)
  - Dimension safety devices to protect SC Link, DFX and DFH from overpressure
  - Determine proper dynamics of Helium outflow
- PSO
  - Model helium behaviour (mixing, purging) after release with consideration of the ventilation
  - Decide on ventilation options in case of He release: use smoke extraction, stop AHUs to allow stratification …
- PSO with WP 9:
  - Analyse cryoplant and QXL