Overview of the Air Management System in the ESS Accelerator tunnel

Duy Phan
Accelerator Safety Engineer

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www.europeanspallationsource.se
6th October 2015

Agenda

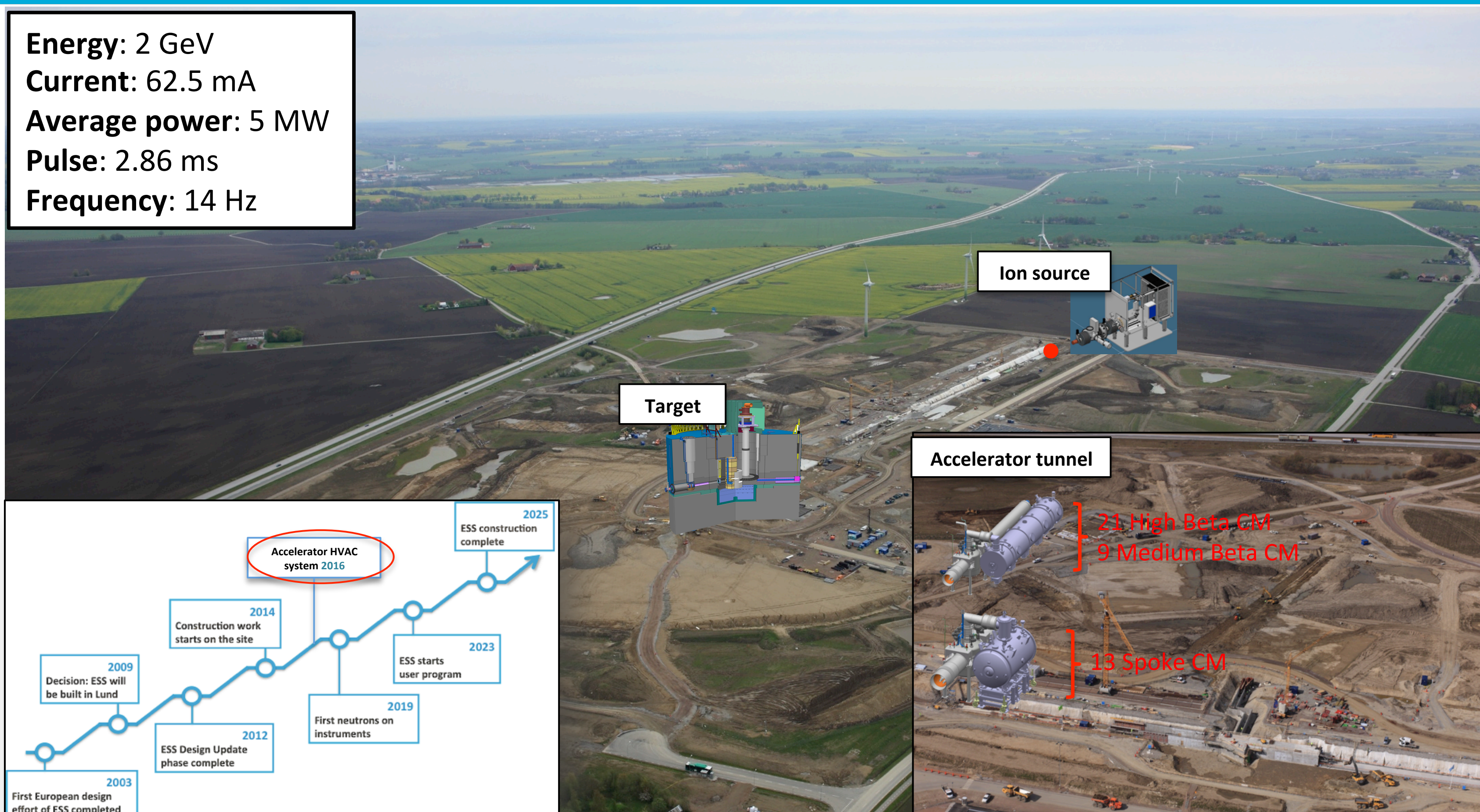
Main topics addressed

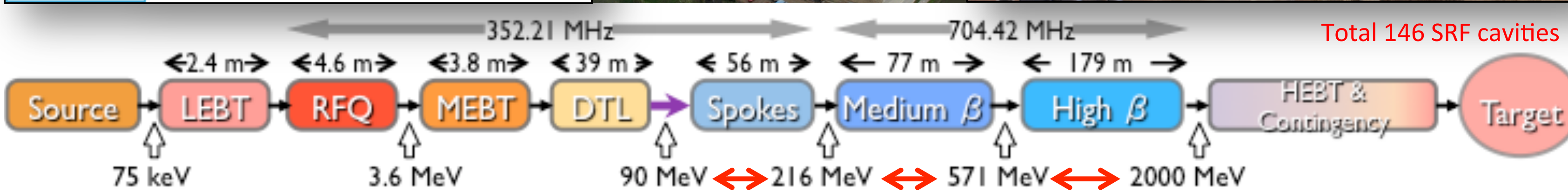
- **Current design** of the Accelerator HVAC system during normal operation…
- Overview of a **concept of fire control** in the tunnel…
- Safety approach against **Oxygen Deficiency Hazard** in the tunnel…
- On-going and foreseen **safety studies**…
- **Planning** for the Accelerator HVAC system…

Accelerator Air Management System

Introduction - ESS Project

Energy: 2 GeV
Current: 62.5 mA
Average power: 5 MW
Pulse: 2.86 ms
Frequency: 14 Hz



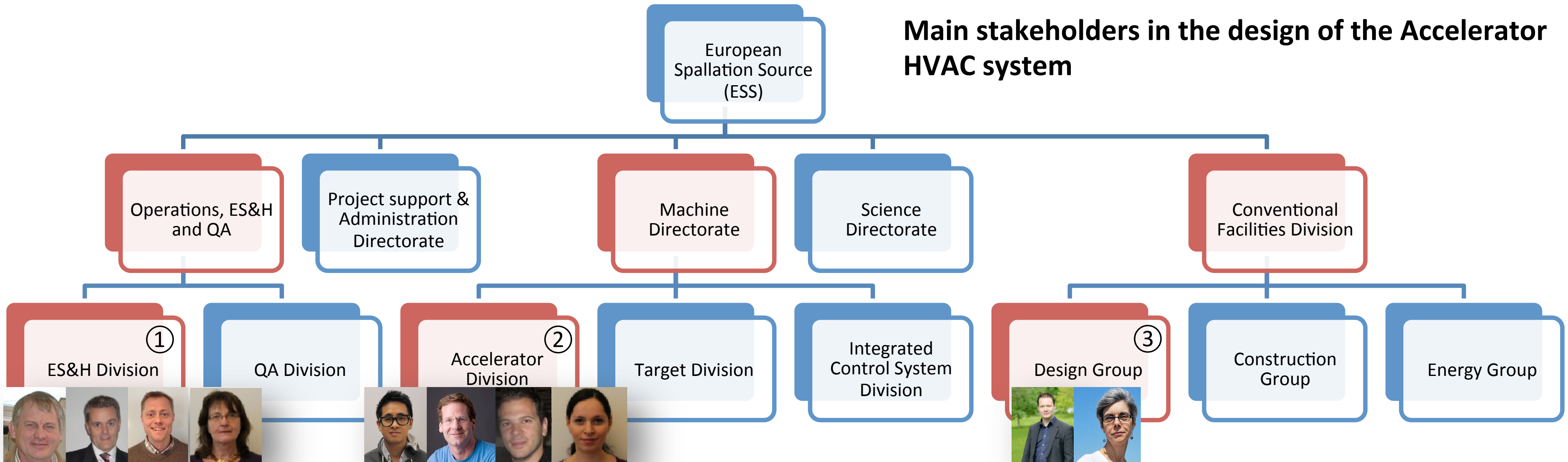


Accelerator Air Management System

Introduction

ESS Organization chart (simplified)

Main stakeholders in the design of the Accelerator HVAC system



① **Specifies the Safety requirements** for the design of the HVAC system (e.g. fire control philosophy, minimum air renewal for workers, minimum air flush before access, etc.)

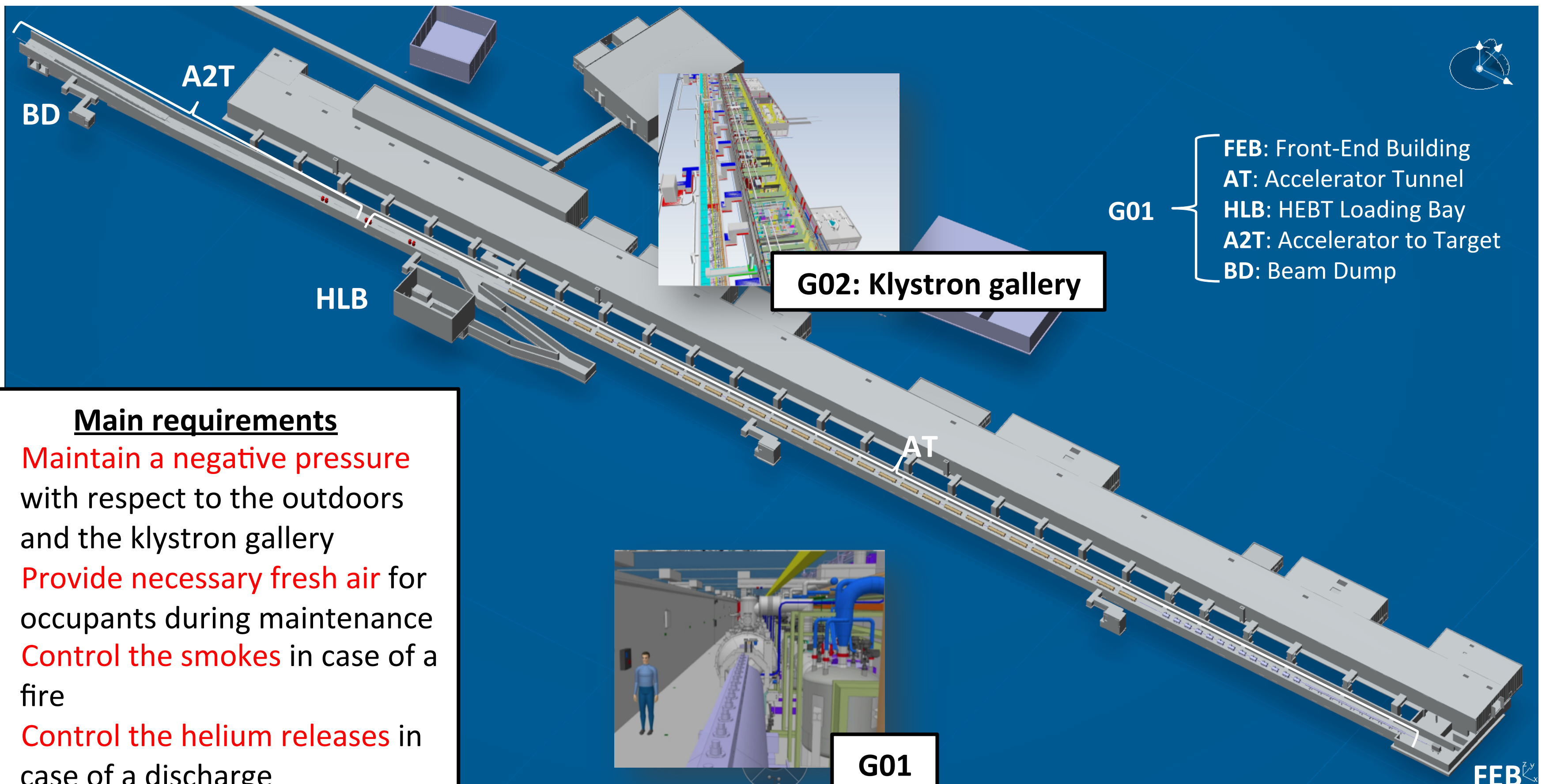
② **Specifies the performance requirements** for the design of the HVAC system (e.g. temperature and humidity control) and **provides support for the mitigation of the safety issues** (e.g. CFD simulations, hazard analysis, etc.)

③ **Designs the HVAC system according to the requirements** provided by the Accelerator and ES&H Divisions

Accelerator Air Management System

Introduction

Overview of the Accelerator areas



Main requirements

- Maintain a negative pressure with respect to the outdoors and the klystron gallery
- Provide necessary fresh air for occupants during maintenance
- Control the smokes in case of a fire
- Control the helium releases in case of a discharge

ACKNOWLEDGEMENT : N.GAZIS

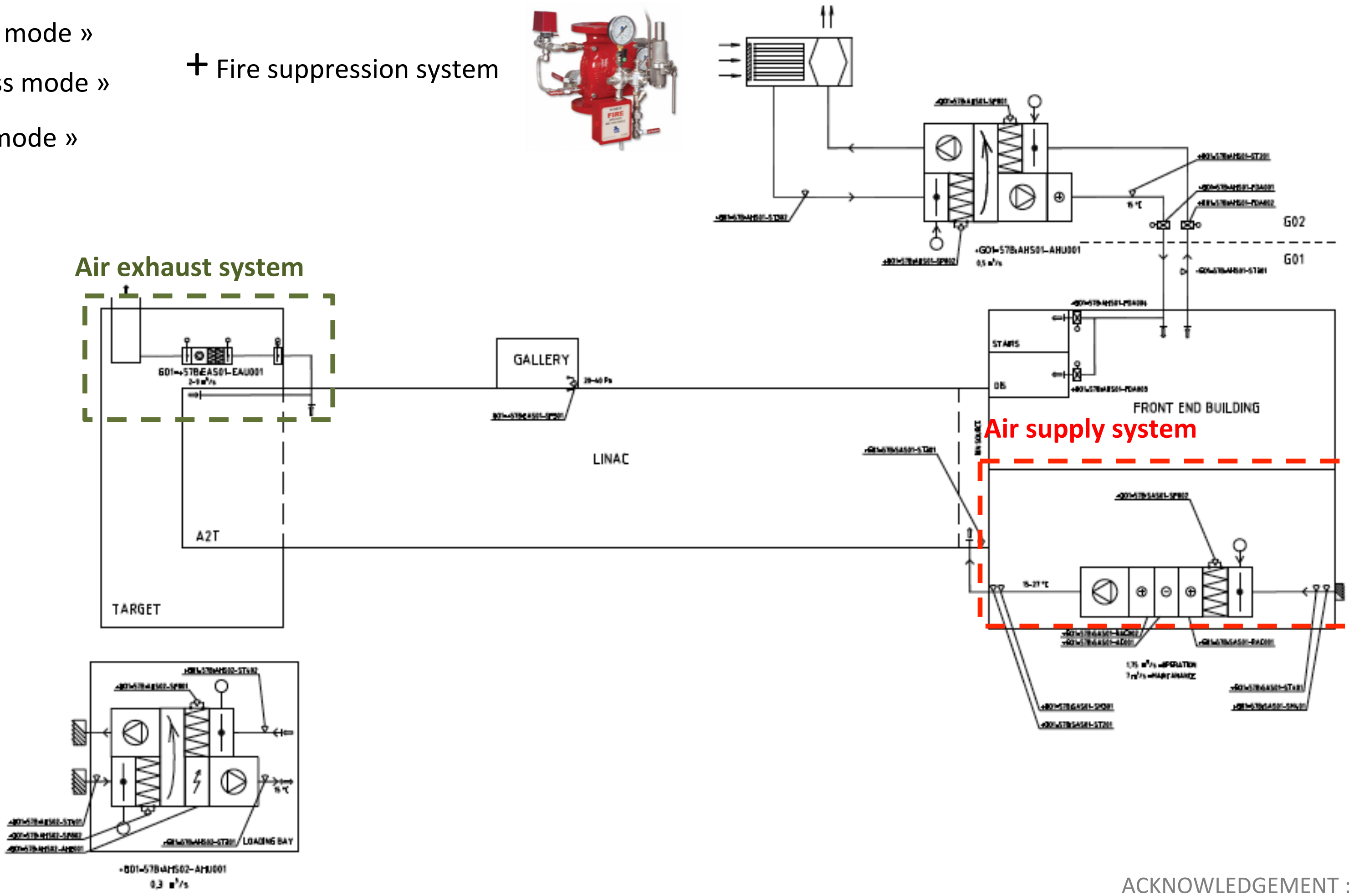
Accelerator Air Management System

Current design

4 Ventilation modes

1. « Beam mode »
2. « Flush mode »
3. « Access mode »
4. « Fire mode »

\+ Fire suppression system



ACKNOWLEDGEMENT : M.KELFVE

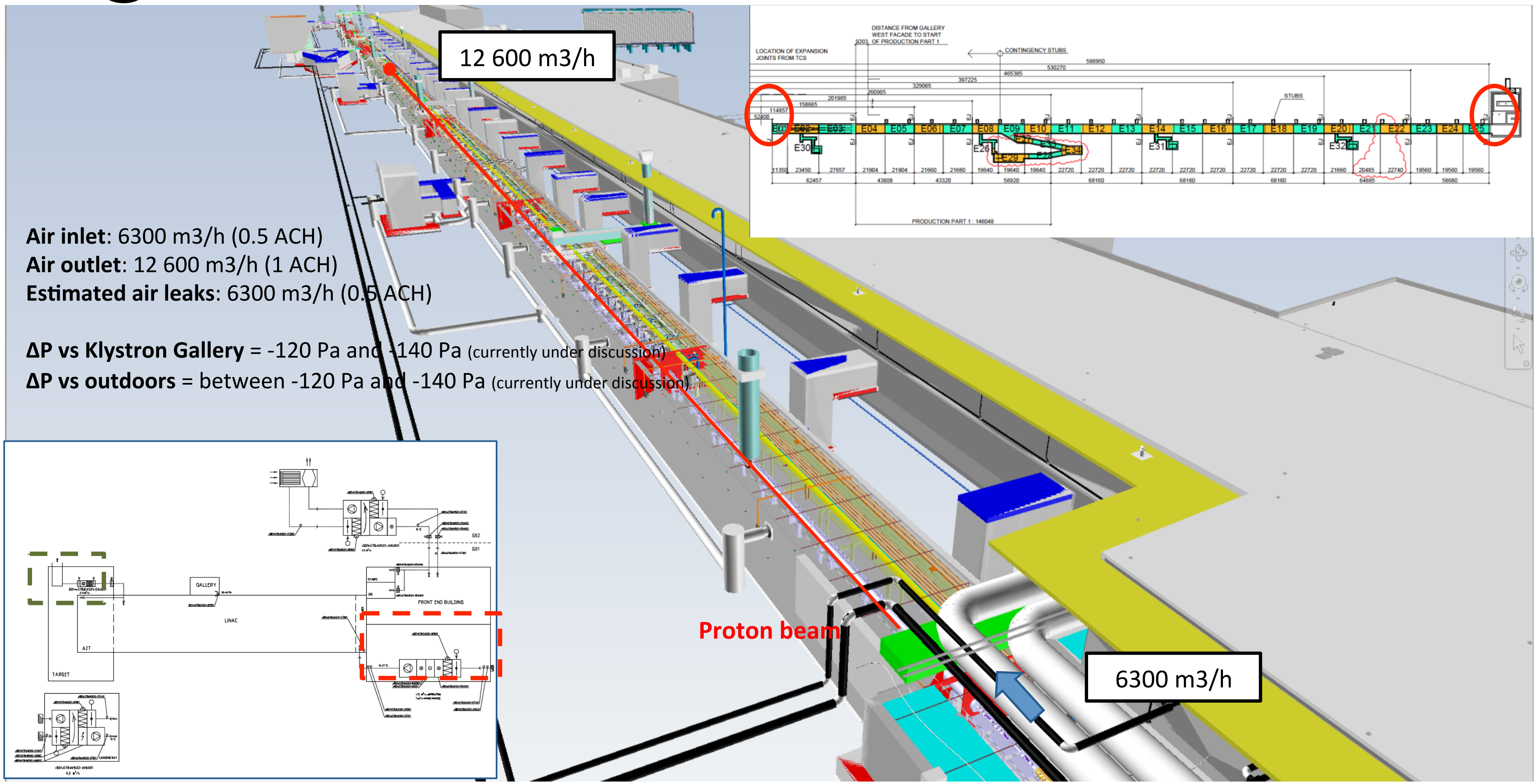
Accelerator Air Management System

Current Design

① BEAM MODE

Air inlet: 6300 m3/h (0.5 ACH)
Air outlet: 12 600 m3/h (1 ACH)
Estimated air leaks: 6300 m3/h (0.5 ACH)

ΔP vs Klystron Gallery = -120 Pa and -140 Pa (currently under discussion)
ΔP vs outdoors = between -120 Pa and -140 Pa (currently under discussion)



ACKNOWLEDGEMENT : M.KELFVE

Accelerator Air Management System

Current Design

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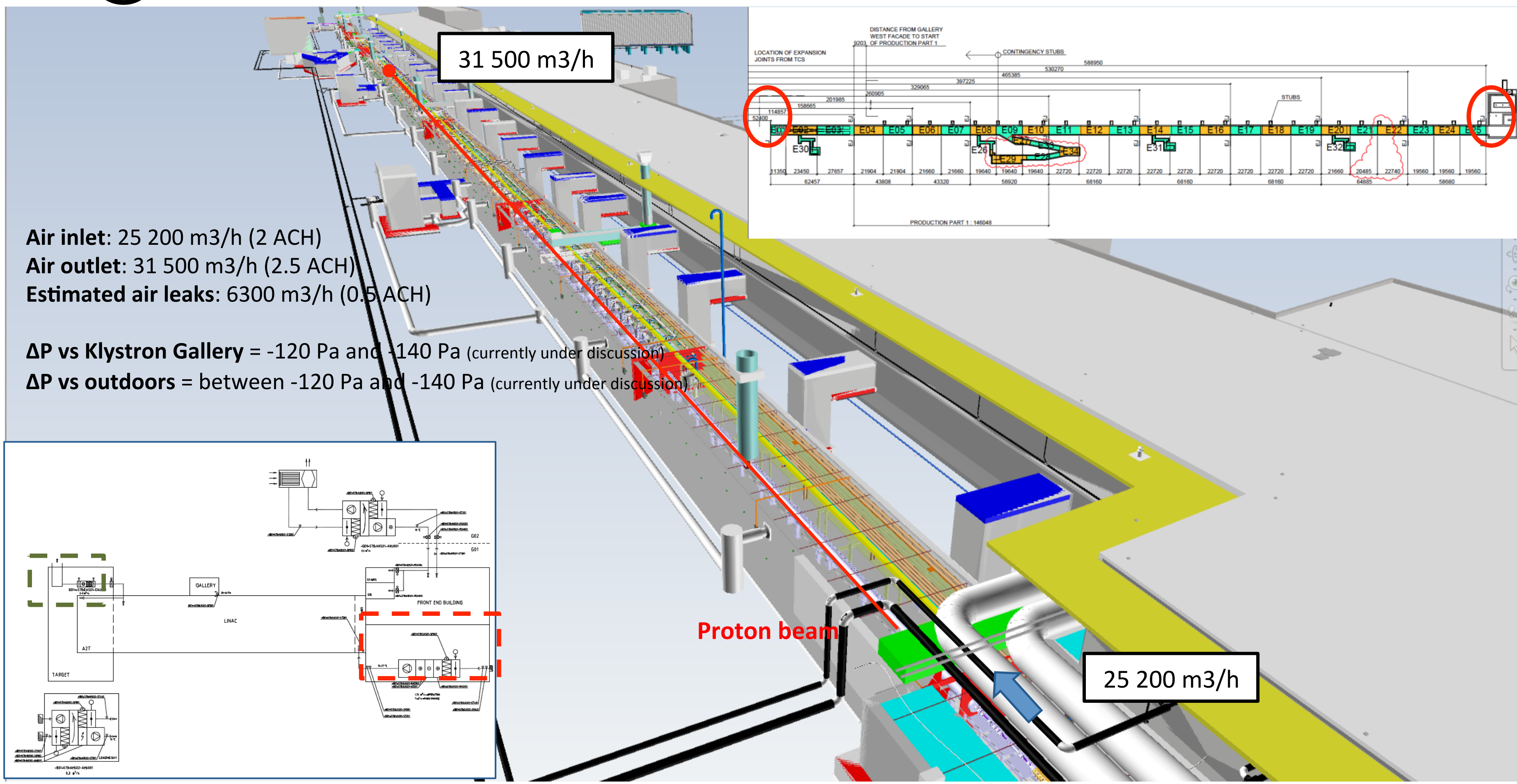
② FLUSH MODE



Air inlet: 25 200 m3/h (2 ACH)
Air outlet: 31 500 m3/h (2.5 ACH)
Estimated air leaks: 6300 m3/h (0.5 ACH)

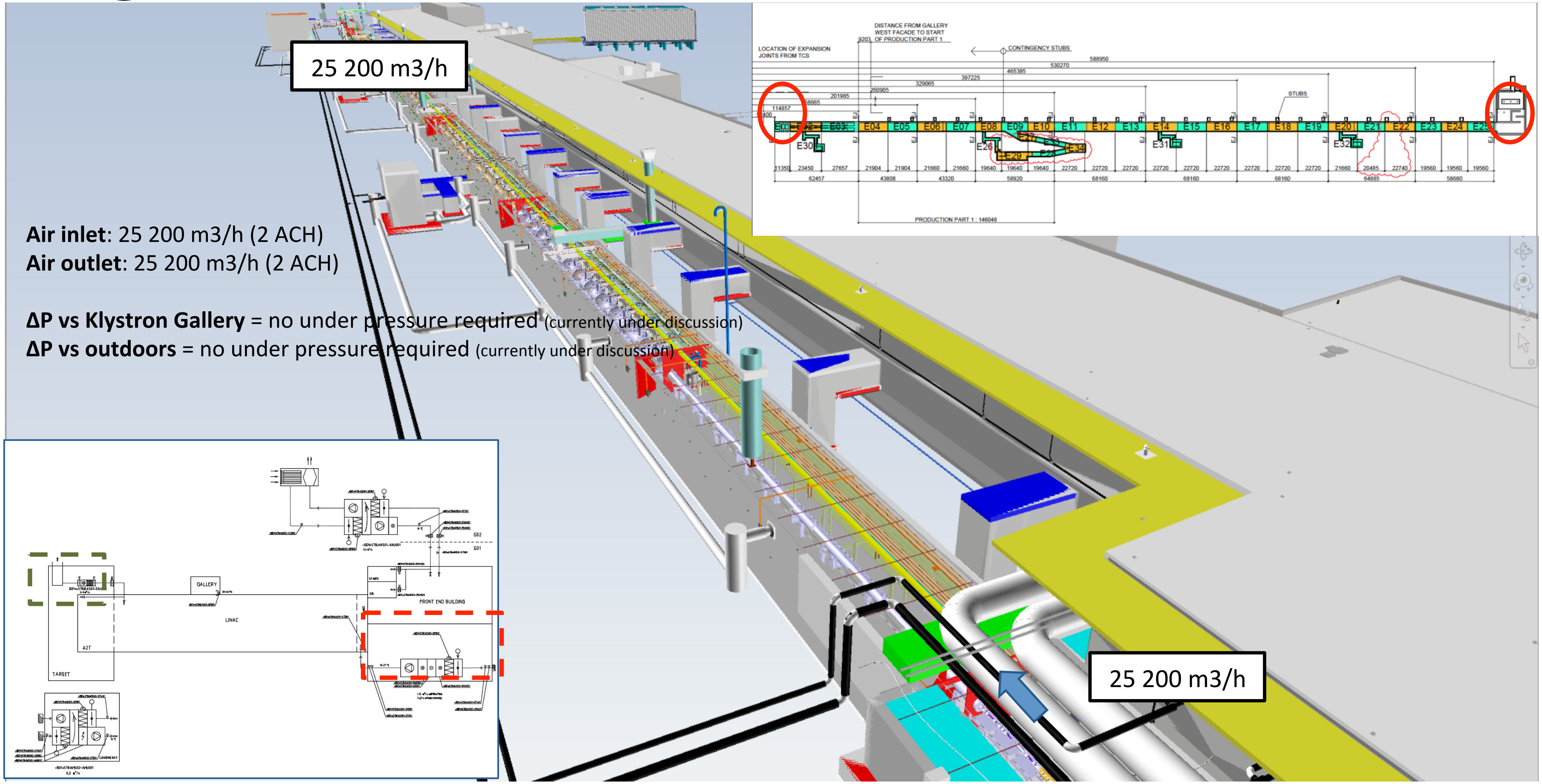
ΔP vs Klystron Gallery = -120 Pa and -140 Pa (currently under discussion)
ΔP vs outdoors = between -120 Pa and -140 Pa (currently under discussion)

ACKNOWLEDGEMENT : M.KELFVE

Accelerator Air Management System

Current Design

③ ACCESS MODE



Air inlet: 25 200 m3/h (2 ACH)
Air outlet: 25 200 m3/h (2 ACH)

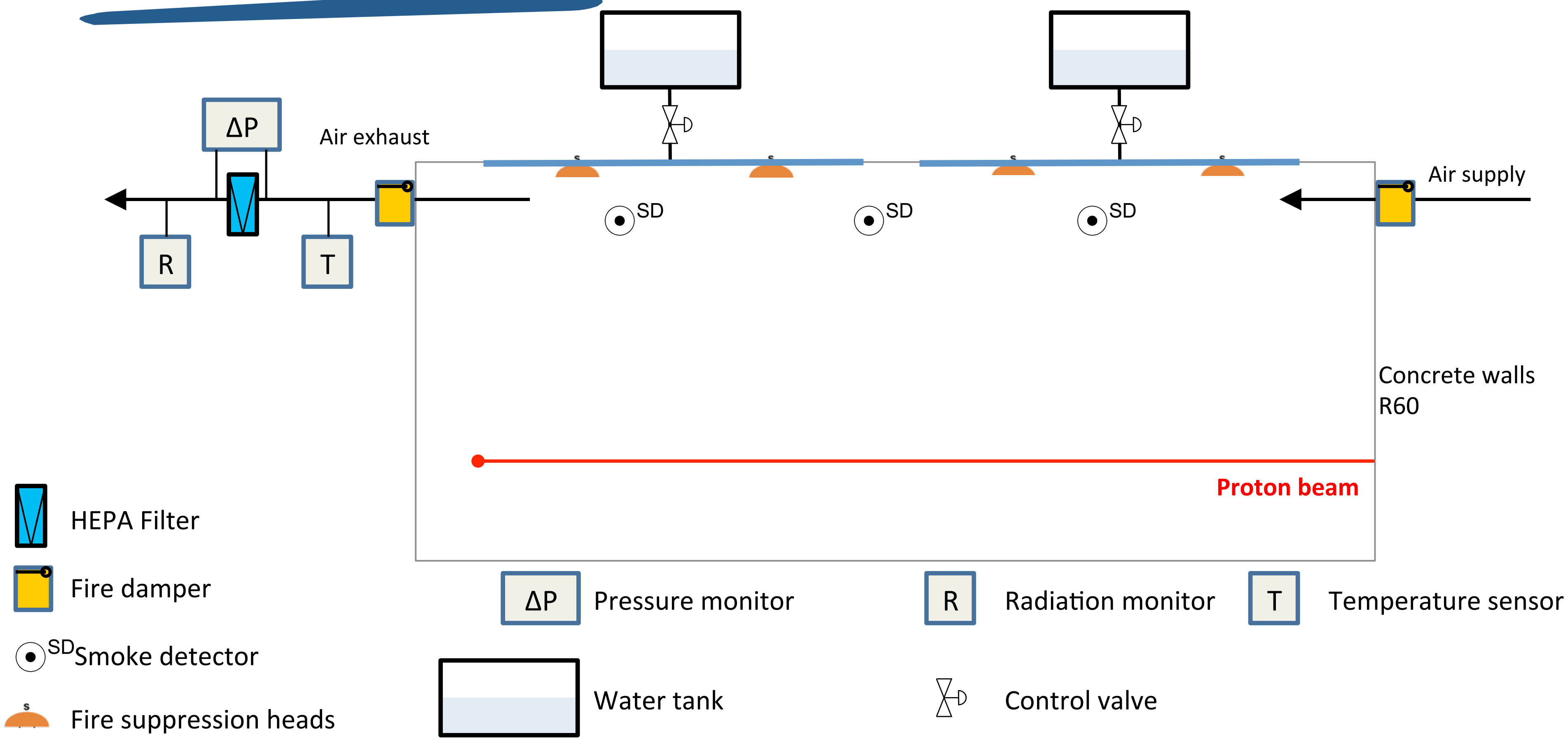
ΔP vs Klystron Gallery = no under pressure required (currently under discussion)
ΔP vs outdoors = no under pressure required (currently under discussion)

ACKNOWLEDGEMENT : M.KELFVE

Accelerator Air Management System

Fire control concept in the tunnel

Preliminary design

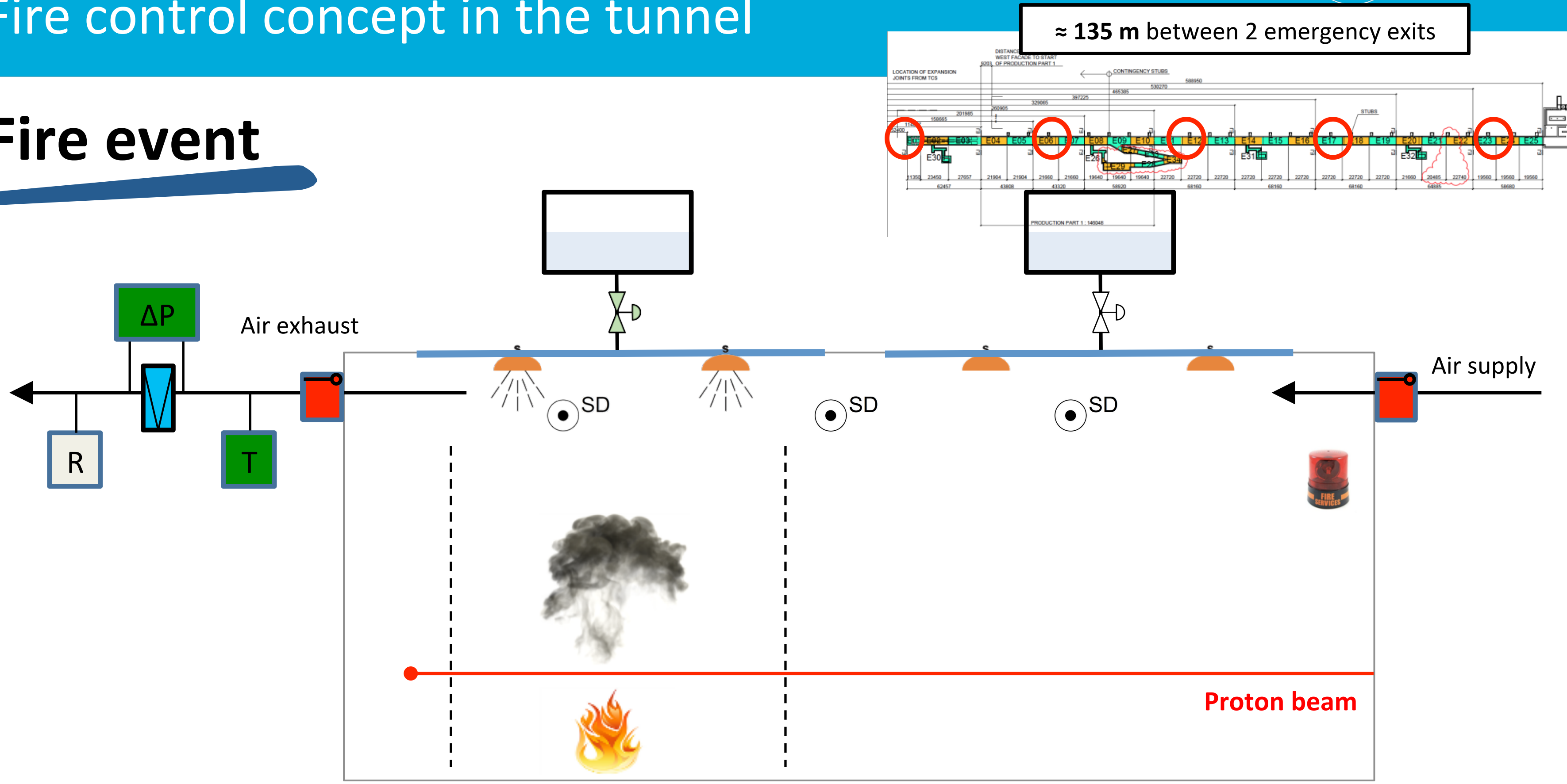


Status: currently under discussion with Conventional Facilities and ES&H…

Accelerator Air Management System

Fire control concept in the tunnel

Fire event



Step 1: a **fire occurs** in the tunnel

Step 2: the **fire is detected** by the smoke detection system

Step 3: the **fire alarm is sent**, the **fire damper of the air supply closes,** the **proton beam stops** and the **fire suppression system triggers** (opening of the control valve) upon detection of the fire and melting of the fusible alloy (O2 ➘ and dynamic confinement preserved)

Step 4: if the filter gets clogged or the maximum operative temperature is exceeded, the **fire damper of the air exhaust closes**

Accelerator Air Management System
Fire control concept in the tunnel

Pre-action system

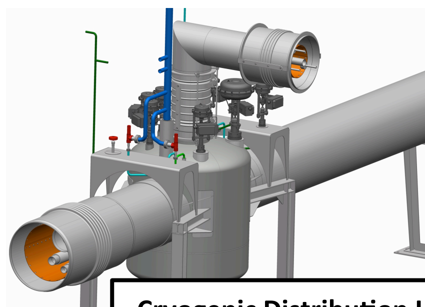
Main aspects:

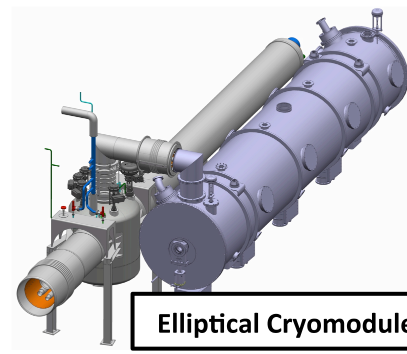
- **No standing activated water** in the tunnel
- **Double security** regarding unwanted activation
- Very well known and **reliable system** (e.g. pipe integrity monitored (air tightness)
- **Low amount of water** in case of a fire (600 l)
- Sectioned into **8 smaller subsystems**
- **Fairly low cost** → €270.000

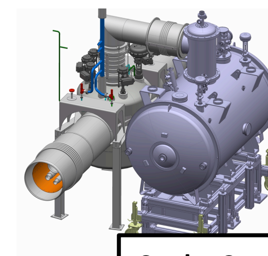
ACKNOWLEDGEMENT : M.KELFVE

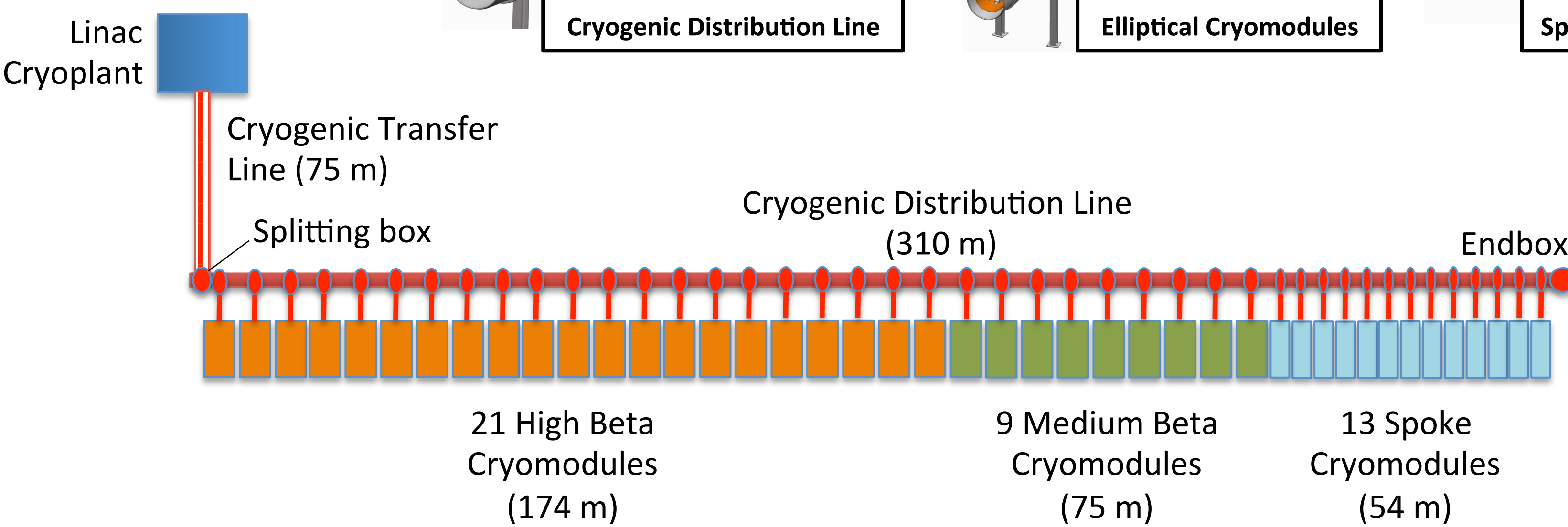
Accelerator Air Management System
Oxygen Deficiency Hazard in the tunnel

Overview of the helium inventory in the tunnel


Cryogenic Distribution Line


Elliptical Cryomodules


Spoke Cryomodules



ACKNOWLEDGEMENT : J.FYDRYCH

Accelerator Air Management System

Oxygen Deficiency Hazard in the tunnel

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Overview of the helium inventory in the tunnel

Component	Quantity	Maximum helium mass [kg]			
		Per item		In total	
		at nominal operation	at transient mode	at nominal operation	at transient mode
CDS	1	266 (315*)	605 (686*)	266 (315*)	605 (686*)
Elliptical CM	30 (44**)	34	29	1014 (1488**)	882 (1293**)
Spoke CM	13	21	18	277	240

* including additional distribution line

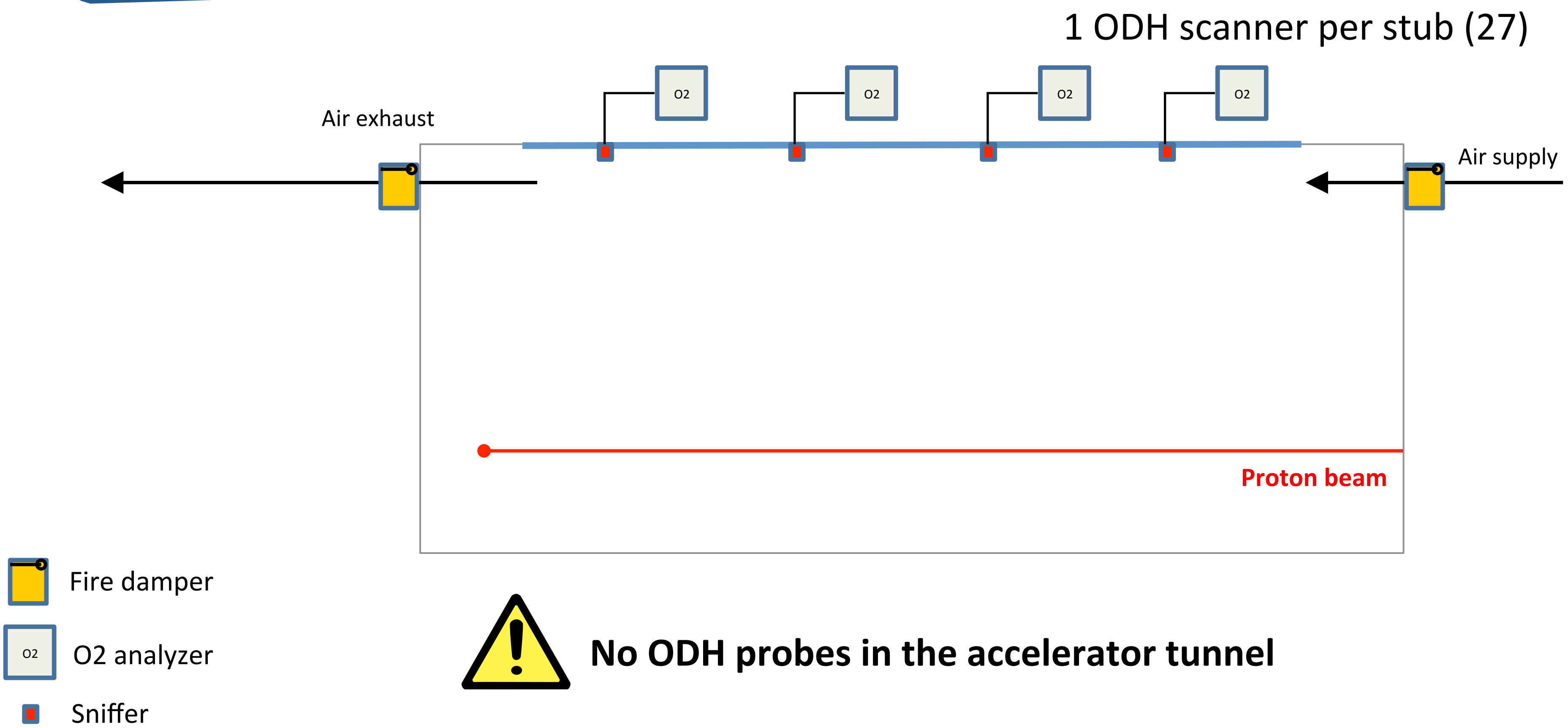
** including all contingent cryomodules

ACKNOWLEDGEMENT : J.FYDRYCH

Accelerator Air Management System

Oxygen Deficiency Hazard in the tunnel

Preliminary design

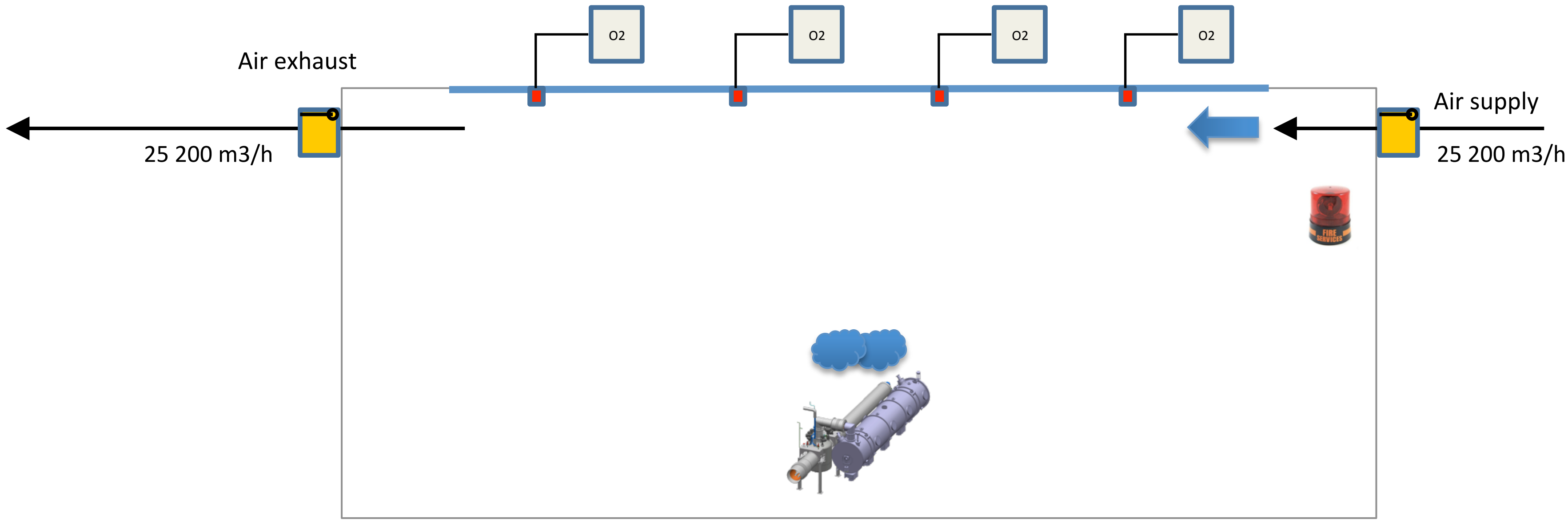


No ODH probes in the accelerator tunnel

Status: currently under discussion with Conventional Facilities and ES&H…

Accelerator Air Management System
Oxygen Deficiency Hazard in the tunnel

ODH event during Access Mode



If a Helium discharge occurs, **it will be partly handled by the ventilation system…**

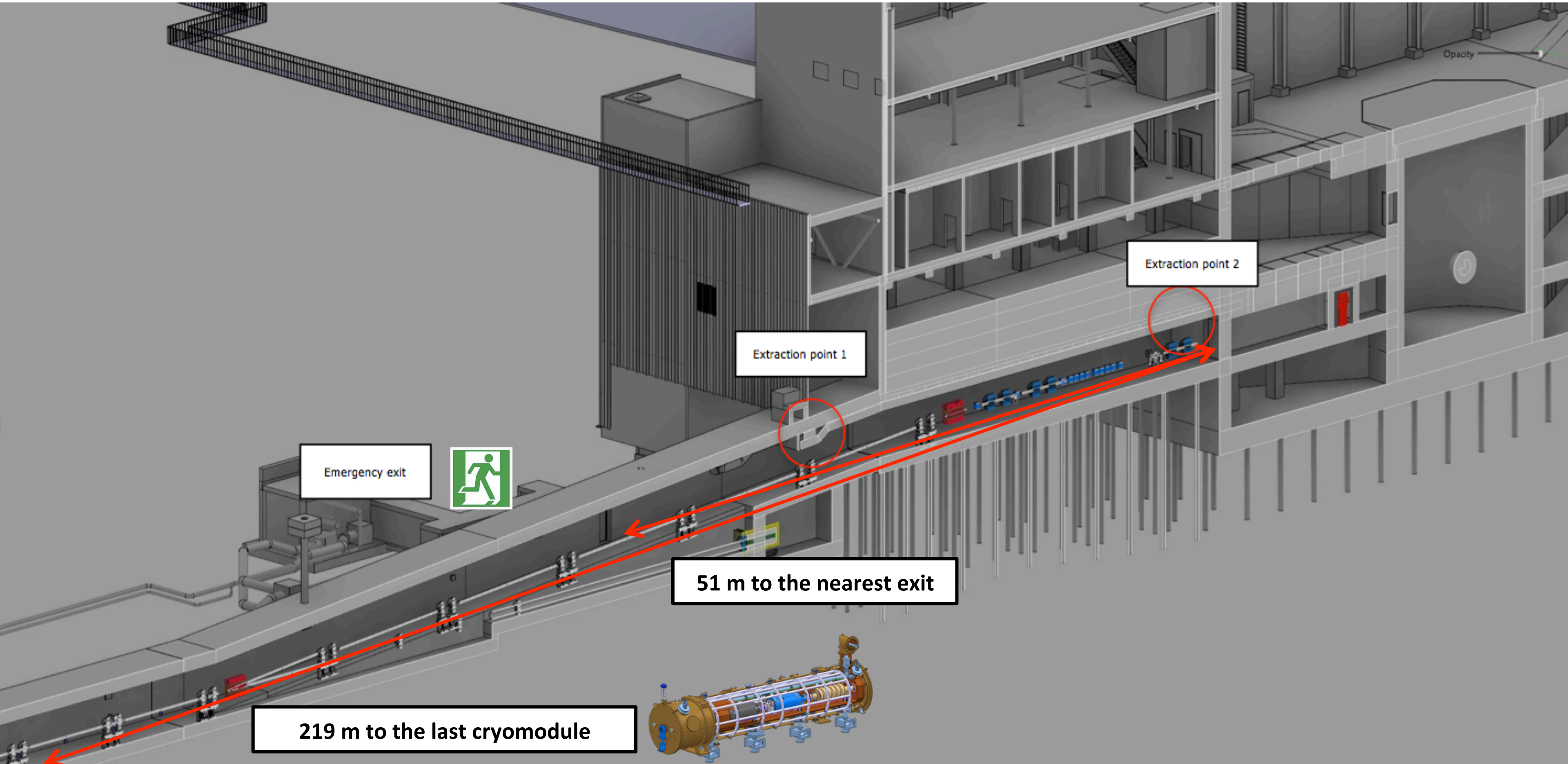
Lesson learnt from CERN visit (2 July 2015)
→ air speed from the ventilation should not exceed 1 m/s to facilitate evacuation

Accelerator Air Management System

Oxygen Deficiency Hazard in the tunnel

Open issue for evacuation

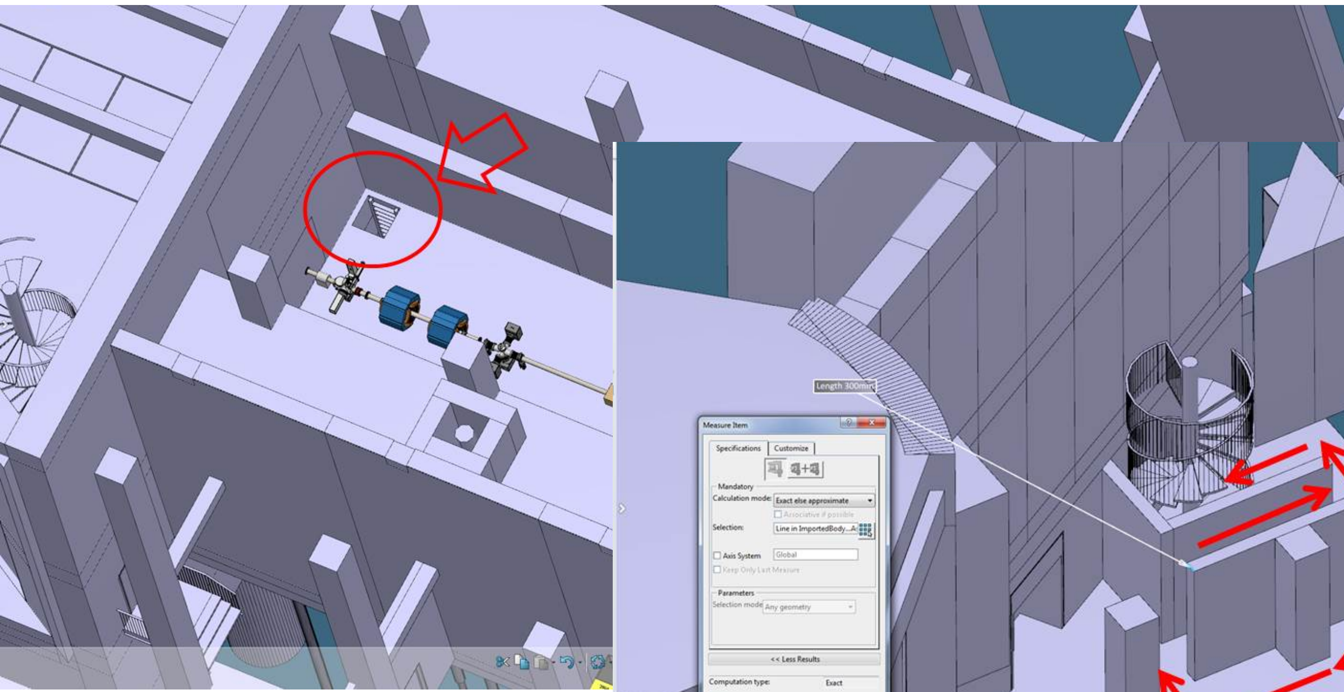
ACKNOWLEDGEMENT : N.GAZIS

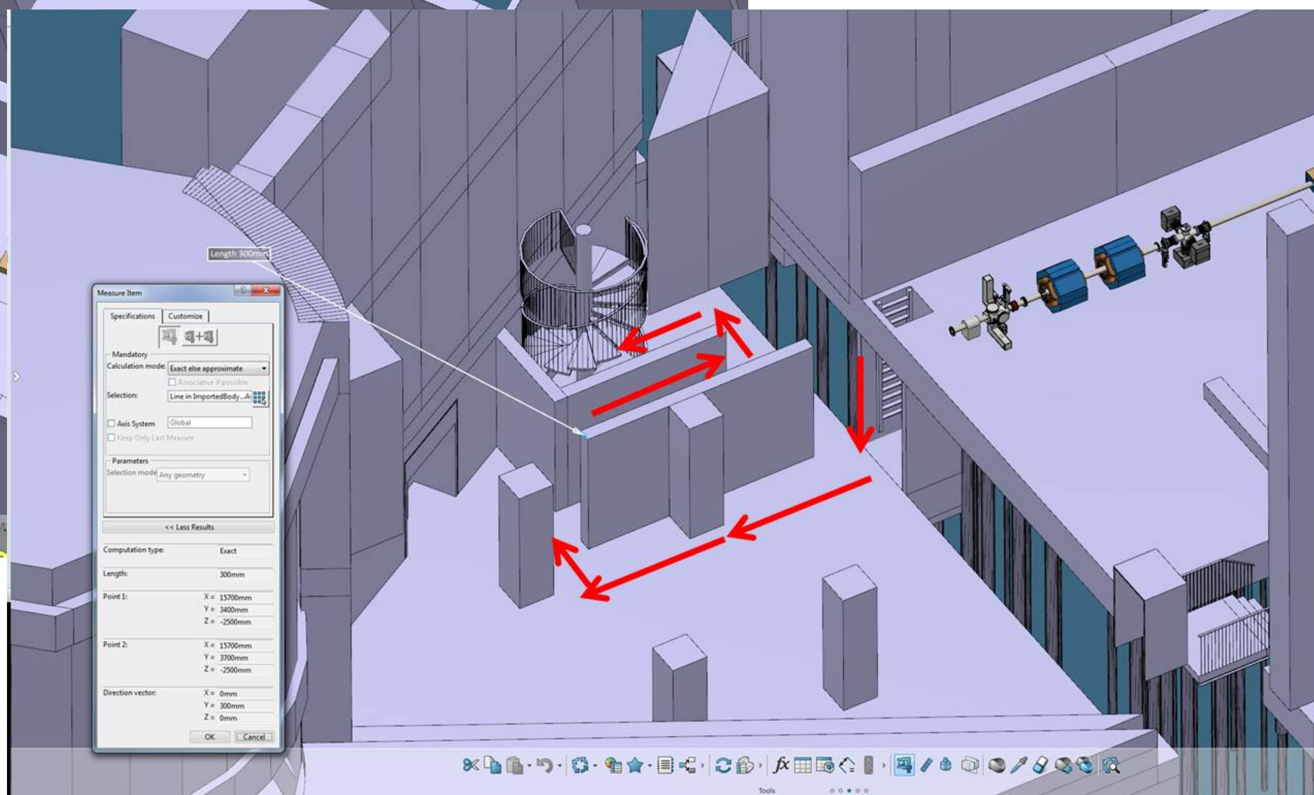


Accelerator Air Management System

Oxygen Deficiency Hazard in the tunnel

Open issue for evacuation



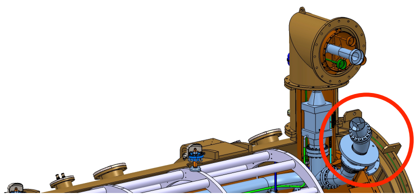


ACKNOWLEDGEMENT : N.GAZIS

Failure scenarios (during access)

Scenario

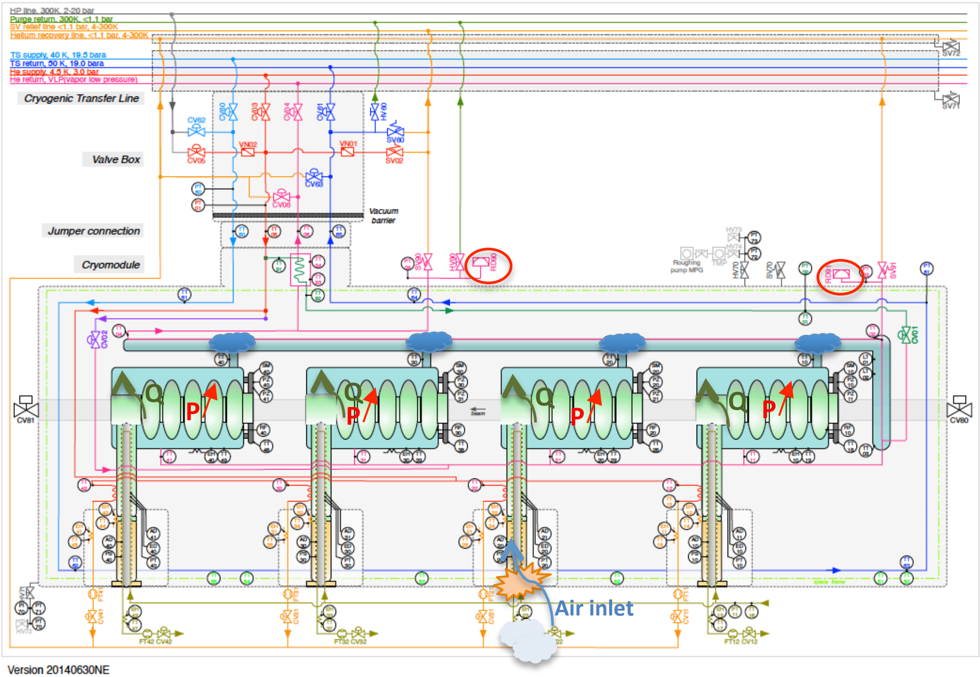
Rupture of the power coupler's window or beam line



Loss of the content of 1 High-Beta* cryomodule (28,4 kg)

Discharge of GHe through the 2 ruptu
disks located on the LHe line

Max. mass flow rate = 15,2 kg/s (current



the triggering of the fast valves in-between cryomodules

ACKNOWLEDGEMENT : J.P THERMEAU – WP5_SAFETYSIZING_SAFETY_DEVICES

Accelerator Air Management System

On-going Safety studies

https://ess-ics.atlassian.net/wiki/display/ASR/ODH+Assessment+Accelerator+Tunnel

ODH p

- Simple a
- Homoge atmosph
- Assessm respect t

→ Lowest

$\phi =$

ODH Control Measures

ODH Class	0	1	2	In place? Yes	In place? No
Technical Safety measures					
Warning signs	X	X	X	☐	☐
Ventilation		*	*	☐	☐
Area (fixed) Oxygen Monitoring	*	X	X	☐	☐
Organizational Safety measures					
Medical approval as ODH qualified		*	*	☐	☐
ODH traning (e-learning)	X	X	X	☐	☐
Personal oxygen monitor		X	X	☐	☐
Self-rescue mask		*	*	☐	☐
Presence of minimum 2 persons			X	☐	☐
Administrative Safety measures					
Access restricted to authorized personnel only		X	X	☐	☐
Emergency procedure		X	X	☐	☐
Working procedure	X	X	X	☐	☐

* to be evaluated case by case

According to the ODH process, depending of the complexity of the case the Cryogenic Safety Committee can require a further ODH analysis (e.g. Computation Fluid Dynamics) and/or additional control measures.

actor*

				Time needed to reach 18% O2
				Always above 18%
				31,2 s
				22,3 s
				11,5 s
5	135 m	1 smoke extractor	After 30 s	50,5 s
6	135 m	2 smoke extractors	After 30 s	40,9 s

Objective: Provide help to Conventional Facilities (CF) in the design of the HVAC system

Responsibility: Accelerator Division

Time frame: finalized

Accelerator Air Management System
On-going Safety studies

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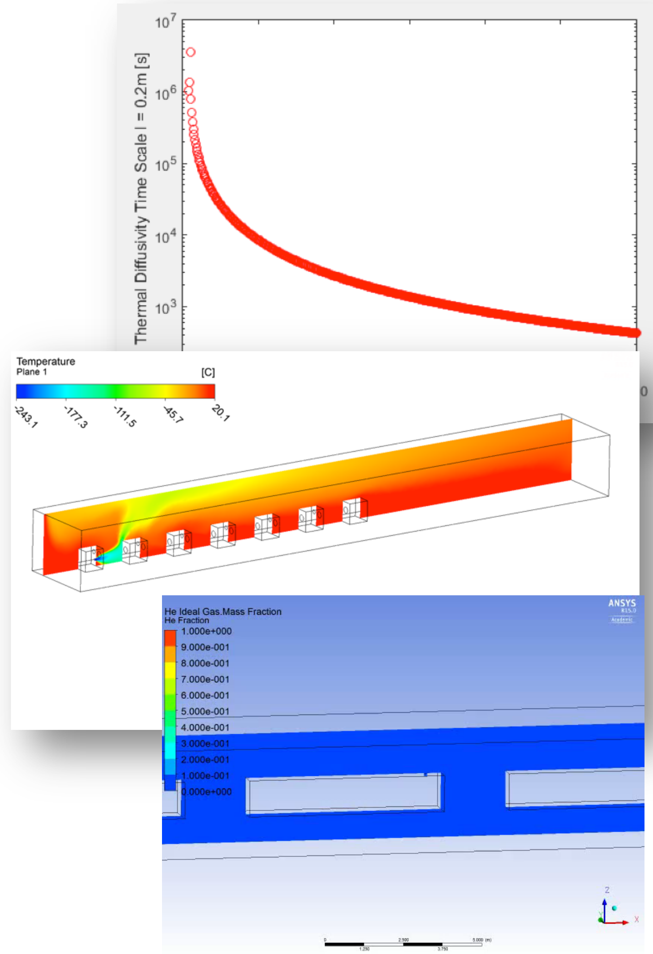
CFD simulation of Helium discharge

① Temperature and O2 concentration need to be evaluated locally (close to the He discharge points) as well as pressure rise

② Assessment of human evacuation (pathway, time) in case of a helium release

③ Help in the decision-making to CF for the design of the ventilation system

④ Help in the definition of the access procedure to the LINAC (warm-up, cool-down, steady-state)



Objective: Provide help to Conventional Facilities (CF) in the design of the HVAC system
Responsibility: Accelerator & EIS Divisions
Time frame: first results expected end October

ACKNOWLEDGEMENT : M.PUCILOWSKI, E.LUNDH

Accelerator Air Management System

On-going Safety studies

https://ess-ics.atlassian.net/wiki/pages/viewpage.action?pageId=46137511

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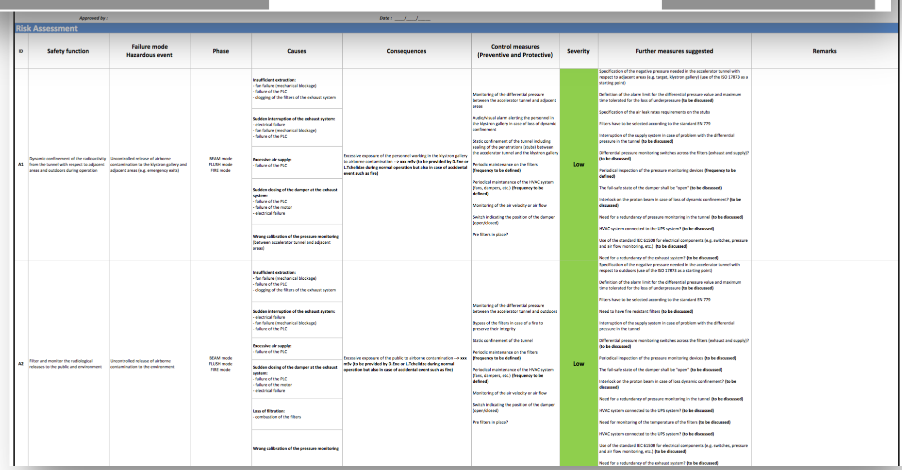
HVAC risk analysis

- ❑ **Identification of the failure modes** that could lead to exposure to ionizing radiation or conventional hazards (e.g. ODH, fire)
- ❑ **Identification & classification** of the safety functions → SSM requirement

Recommendation from CERN experts
during their visit on July 2nd

Objective: Provide help to Conventional Facilities (CF) in the design of the HVAC system
Responsibility: CF & Accelerator Divisions
Time frame: final version expected December

FROM ESS GSO			FROM SSM
ESS Safety Objectives			Current
Operating conditions Initiating event likelihood	Workers limit (effective dose)	Public limit (effective dose)	Public limit
Normal operation - H1	10 mSv/year	0,05 mSv/year	0,1 mSv
Incidents – H2 *$F > 10^{-2}$* *Ex : loss of external power or target cooling*	20 mSv/event	0,05 mSv/occurrence	0,1 mSv
Unexpected events - H3 *$10^{-4} < F < 10^{-2}$*	50 mSv/event	0,5 mSv/occurrence	1 mSv
Design Basis Accident – H4 *$10^{-6} < F < 10^{-4}$*	50 mSv/event	20 mSv/occurrence	20 mSv
Highly improbable events – H5 *$10^{-7} < F < 10^{-6}$* *Ex : plane crashes, major earthquake*			100 mSv



Accelerator Air Management System

On-going Safety studies

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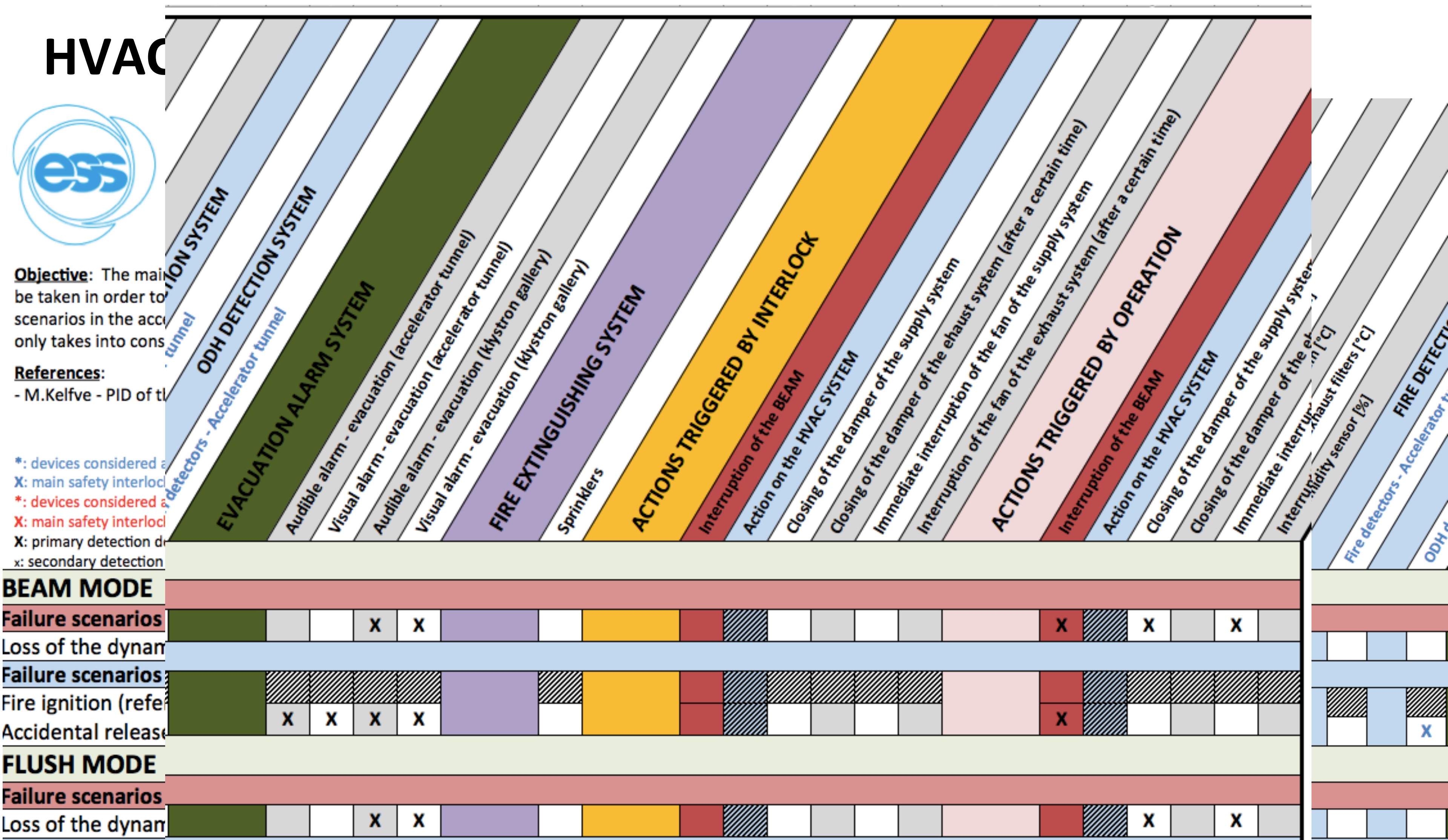

Acceler

On-going

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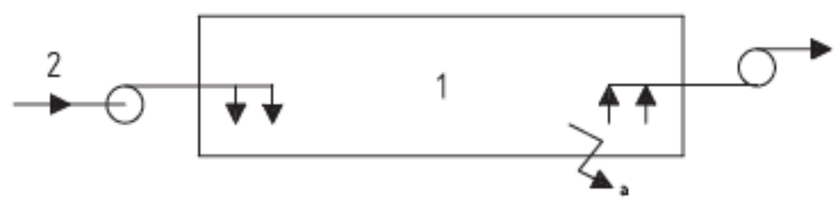
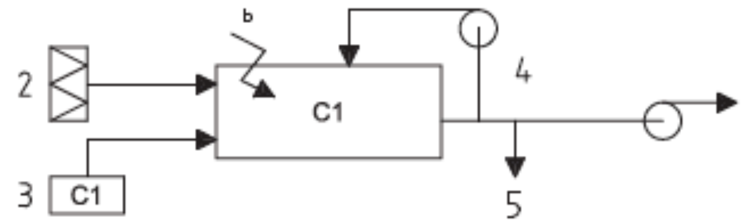
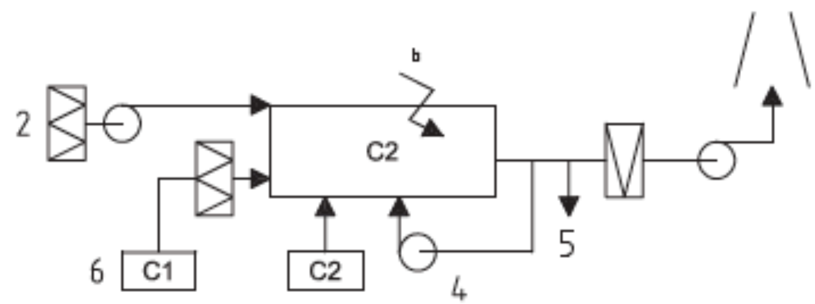
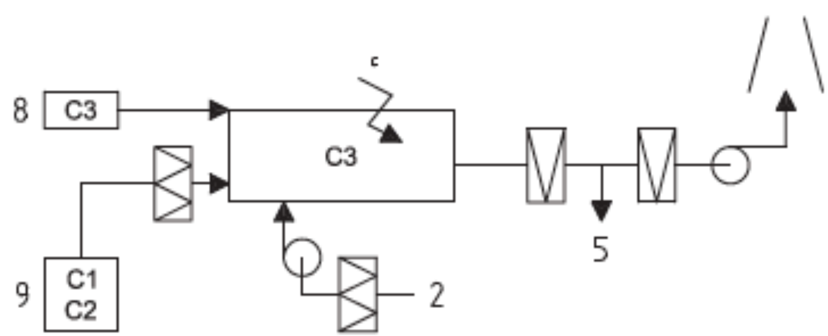
eport/ESS-0028010/1

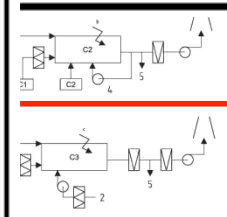
Calculatio

Type of ventilation	Foreseen radioactive contamination	Organization of the ventilation systems and filtration unit
Non-contaminated areas		
T I	Pc: Not significant Ac: Low	
T II A	Pc: Not significant Ac: Medium	
T II B	Pc: Not significant Ac: High	

Type of ventilation	ment-areas ification
I	C1
II A	C2
II B	C3
III A	C4*
III B	C4**
IV	4***

pressure

Responsibility:



* It is the amount of contami
result in the Annual Limit o
reference conversion factors

OWLEDGEMENT : D.ENE

Accelerator Air Management System

On-going Safety studies

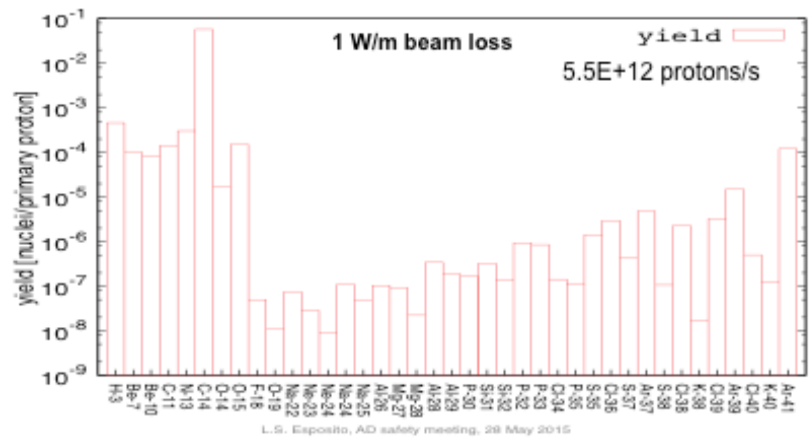
Releases of activated air: Linac

(5000 hr irradiation)

	Radionuclide	Released activity (Bq/y)	Maximum effective dose# (Sv/y) Västra Odarslöv	Hypotetical Critical Group	Östra Torn
vapour	H-3	8.18E+07	8.34E-13	1.77E-12	7.16E-13
aerosols	Be-7	4.50E+05*	4.55E-13	9.68E-13	3.92E-13
	Be-10	3.27E-02	1.10E-18	2.33E-18	9.42E-19
	C-11	2.64E+12	**1.91E-08**	**4.07E-08**	**3.78E-08**
	C-14	2.20E+07	1.06E-10	2.24E-10	9.13E-11
	N-13	6.77E+12	**4.20E-08**	**8.73E-08**	**9.27E-08**
gas	O-14	4.71E+11	1.82E-09	3.20E-09	8.62E-09
	O-15	3.98E+12	**9.67E-09**	**2.03E-08**	**3.49E-08**
	O-19	2.99E+08	2.97E-14	4.40E-14	2.53E-12
	Ne-23	7.70E+08	2.86E-14	5.80E-14	3.74E-13
	Ne-24	2.29E+08	4.67E-13	9.87E-13	1.25E-12
	Na-22	6.22E+04	1.57E-10	3.33E-10	1.35E-10
	Na-24	1.34E+08	3.03E-10	6.45E-10	2.65E-10
	Na-25	1.34E+09	4.66E-13	9.73E-13	3.08E-12
	Mg-27	2.08E+09	1.61E-10	3.41E-10	1.69E-10
	Mg-28	1.95E+07	1.87E-10	3.98E-10	1.61E-10
	Al-26	3.16E-01	1.31E-15	2.79E-15	1.13E-15
	Al-28	8.95E+09	7.03E-10	1.49E-09	1.14E-09
	Al-29	4.41E+09	4.30E-11	8.95E-11	8.38E-11
aerosols	Si-31	1.87E+09	4.82E-11	1.03E-10	4.19E-11
	Si-32	6.86E+02	1.52E-14	3.24E-14	1.31E-14
	P-30	1.30E+06	6.61E-15	1.42E-14	1.51E-14
	P-32	1.55E+04	4.97E-12	1.06E-11	4.29E-12
	P-33	8.04E+03	3.38E-13	7.20E-13	2.92E-13
	P-35	9.00E+05	2.99E-14	6.34E-14	1.30E-13
	S-35	3.93E+03	1.19E-13	2.54E-13	1.03E-13
	S-37	3.09E+06	4.85E-14	9.61E-14	1.03E-13
	S-38	1.70E+05	2.48E-14	5.27E-14	2.38E-14
	Cl-36	2.15E+01	8.86E-13	1.88E-12	7.63E-13
	Cl-38	3.32E+10	1.05E-09	2.20E-09	1.28E-09
	Cl-39	3.82E+10	1.40E-09	2.96E-09	1.67E-09
gas	Cl-40	1.34E+10	8.01E-11	1.51E-10	3.38E-10
	Ar-3	[illegible]	[illegible]	[illegible]	[illegible]
	Ar-3	[illegible]	[illegible]	[illegible]	[illegible]
	Ar-4	[illegible]	[illegible]	[illegible]	[illegible]
aerosols	K-3	[illegible]	[illegible]	[illegible]	[illegible]
	K-40	2.04E-04	3.92E-18	8.32E-18	3.37E-18
	Total	**1.49E+13**	8.57E-08	1.79E-07	**1.97E-07**

* Filter effect (0.03%) | # three age groups considered (SSM 13-3285, 2014)

"Skyshine" (direct radiation) and water activation not considered



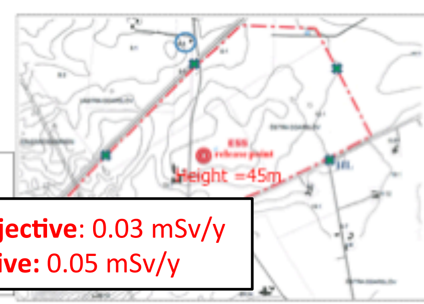
HVAC parameters: **Vol_{tunnel} = 12600 m³**

Function	Vent. Rate** (m³/hr)	Stack diameter (m)	Exhaust speed (m/s)	Hepa filter	Controlled exhaust
Tunnel on-line vent	12600	1.8 - 1.9	12	On main stack	yes
Flush mode >1/2 hr cool down	31500	1.8 - 1.9	12	On main stack	yes
Tunnel access	25200	1.8 - 1.9	12	On main stack	yes

** M. Kelfve, CF

Critical group	Distance+ (m)	Azimuth## (°)
Västra Odarslöv	660	0
Hypotehetical	650	90
Östra Torn	330	180

+ from the release point
degrees from North



ESS Accelerator Design objective: 0.03 mSv/y
ESS General Safety Objective: 0.05 mSv/y

ACKNOWLEDGEMENT : D.ENE

Accelerator Air Management System

Milestones

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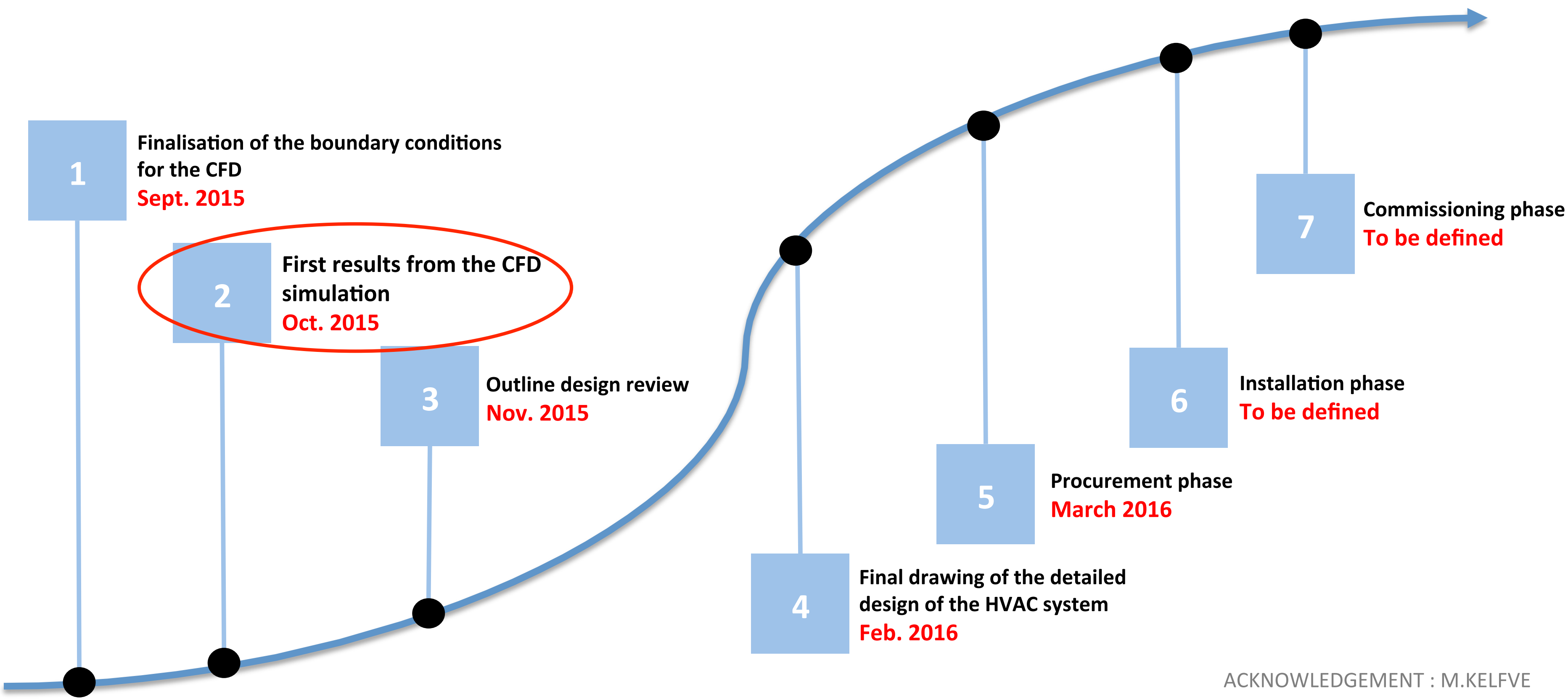
SOURCE

HVAC timeline



ACKNOWLEDGEMENT : M.KELFVE

Discussion

EUROPEAN
SPALLATION
SOURCE

Any **Q**uestions…?

Back-up slides

Accelerator Air Management System

Fire control concept in the tunnel

Fire load estimation

Fire load estimation

ELECTRICAL CABLES

Hypothesis:

- Cable weight = 60 kg/m -> total = 60 x 602 = **36 120 kg**
- Insulation weight (80% of the electrical cables) = 0,80 x 36120 = **28 896 kg**
- 126 types of electrical cables (ref. ESS Approved Cable List_2015_02_02_lia.xlsx)
  - PVC - 62 cables (49%)
  - PE - 42 cables (33%)
  - Teflon - 1 cable (0,8%)
  - Polyolefin - 1 cable (0,8%)
  - PVDF - 1 cable (0,8%)
  - No information about insulation - 6 cables (4,8%) --> as a conservative approach, these cables will be considered as isolated with PVC
  - No insulation - 13 cables (10%)
- Tray + support weight = 15 kg/m -> total = 15 x 602 = **9030 kg**

Type of material	Classification according to CERN IS 41 & ES&H requirements	Quantity	Lower heating value	Heat of combustion	Reference
PVC	Forbidden	0,49 x 28 896 = **14 159 kg**	20 MJ/kg	14 159 x 20 = **283 180 MJ**	SS-EN-1991-1-2
PE	Suitable only with fire retardant NOT containing halogen, sulphur and phosphorus	0,33 x 28 896 = **9536 kg**	40 MJ/kg	9536 x 40 = **381 440 MJ**	SS-EN-1991-1-2
Teflon	Forbidden	0,008 x 28 896 = **231 kg**	5 MJ/kg	231 x 5 = **1155 MJ**	Autocobtest
Polyolefin (PE)	Suitable only with fire retardant NOT containing halogen, sulphur and phosphorus	0,008 x 28 896 = **231 kg**	40 MJ/kg	231 x 40 = **9240 MJ**	SS-EN-1991-1-2
PVDF	Forbidden	0,008 x 28 896 = **231 kg**	20 MJ/kg	231 x 20 = **4620 MJ**	SS-EN-1991-1-2
Insulation not identified (considered as PVC)	Forbidden	0,048 x 28 896 = **1387 kg**	20 MJ/kg	1387 x 20 = **27 740 MJ**	SS-EN-1991-1-2
TOTAL		**26006 kg**		**707 375 MJ**	

BEAM DUMP

Type of material	Quantity	Lower heating value	Heat of combustion	Reference
Graphite	**350 kg**	33 MJ/kg	350 x 33 = **11 550 MJ**	Wikipedia

TOTAL HEAT OF COMBUSTION

Type of material	Heat of combustion	Ground surface	Fire load
Electrical cables + beam dump	707 375 + 11 550 = **718 925 MJ**	3600 m^2	**200 MJ/m^2**

Accelerator Air Management System
On-going Safety studies

EUROPEAN SPALLATION SOURCE

CFD Project Request

Objective: Define the boundary conditions necessary for the CFD simulation
Responsibility: Accelerator Division
Time frame: finalized

EUROPEAN SPALLATION SOURCE

Document Template	
Document Number	CHESS Controlled Core
Date	Mar 13, 2014
Revision	0 (4)
State	Released
Classification	
Page	1 (16)

CFD study for an accidental release of helium inside the ESS Accelerator tunnel

	Name
Owner	Duy Phan
Reviewer	Nuno Elias, Christine Darve, John Weisend, Stuart Birch, Nick Gazis, Jaroslaw Fydrych, Mikael Kelfve, Stuart Birch
Approver	John Weisend

- ✓ **Hazardous scenarios**
  - Leak, abrupt rupture, discharge from safety device, etc.
- ✓ **Tunnel dimensions and characteristics**
  - Length, width, height, internal volume, helium escape routes, etc.
- ✓ **Environmental conditions**
  - Pressure and temperature in the tunnel
- ✓ **Description of the cryogenic circuit**
  - Mass of helium, operating pressure and temperature, safety device, etc.
- ✓ **Description of the cryomodules**
  - Mass of helium, operating pressure and temperature, safety device, etc.
- ✓ **Description of the HVAC system**
  - Ventilation rate, location of the air inlet and outlet, etc.

Accelerator Air Management System

Failure scenarios

Failure scenarios (during access)

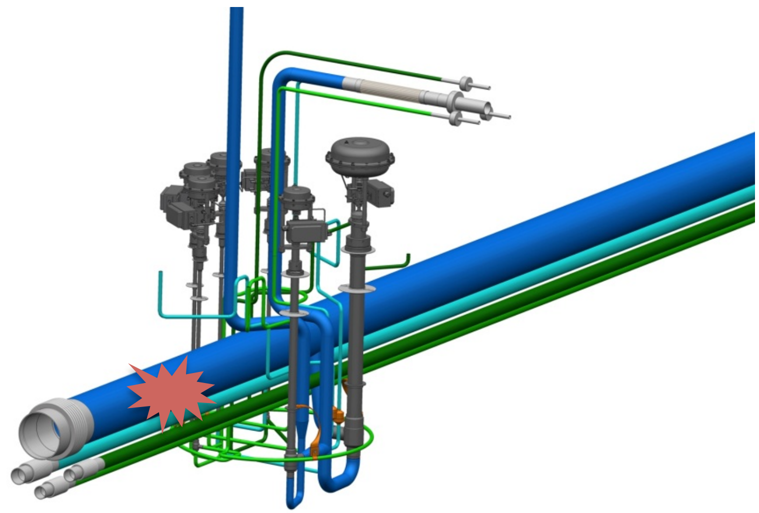
Scenario 2

Helium leakage in the insulation vacuum of the Cryogenic Distribution System

Loss of the content of the CDS (266 kg)

Discharge of GHe through the pressure relief device on the insulation vacuum jacket

Max. mass flow rate = 32 kg/s (currently under discussion)



ACKNOWLEDGEMENT : J.FYDRYCH

ODH case-study
Accelerator tunnel

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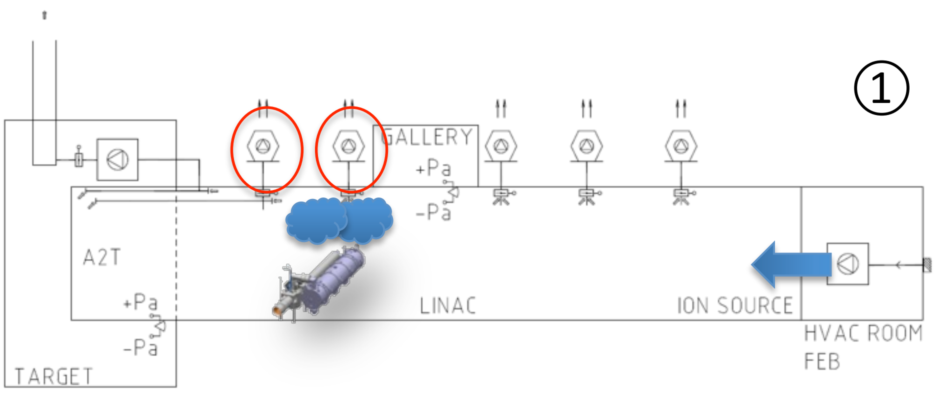
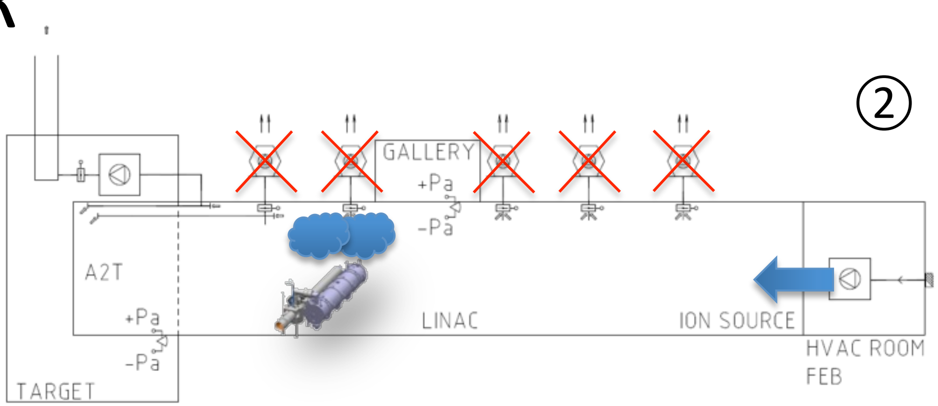
Smoke extraction VS normal ventilation system

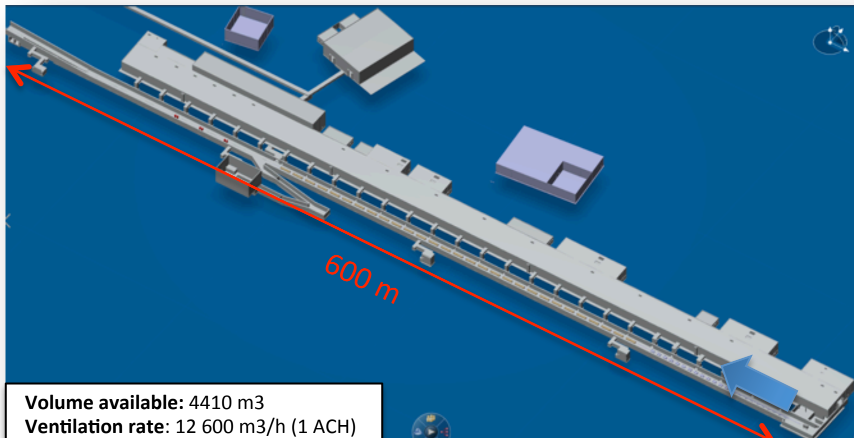


OR



ODH case-study
Accelerator tunnel

Case 1: full length – normal ventilation

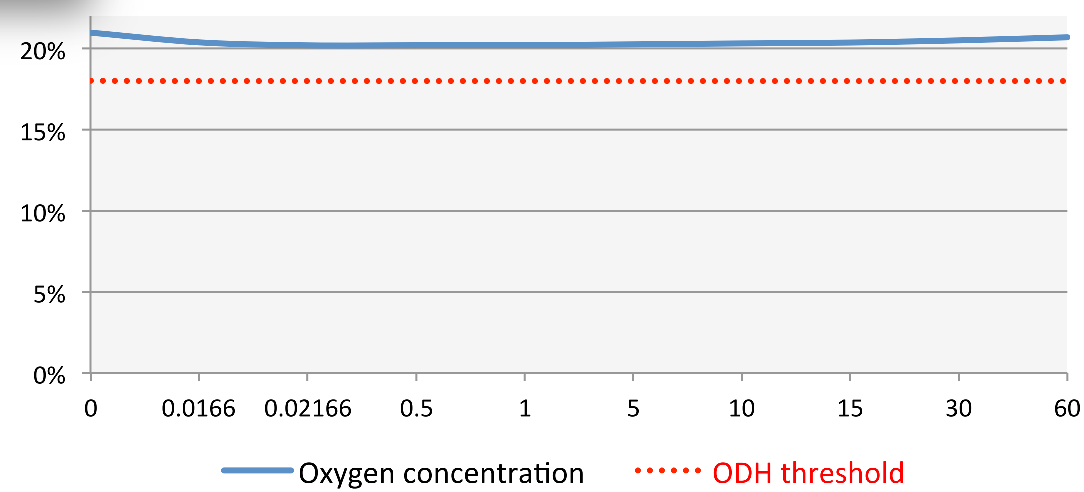


ACKNOWLEDGEMENT : N.GAZIS (ESS)

During release: $C(t) = 0.21\, e^{-\frac{R}{V}t}$

After release: $C(t) = 0.21 - \left[0.21 - C_r(t_e)\right] e^{-\frac{Q}{V}(t-t_e)}$

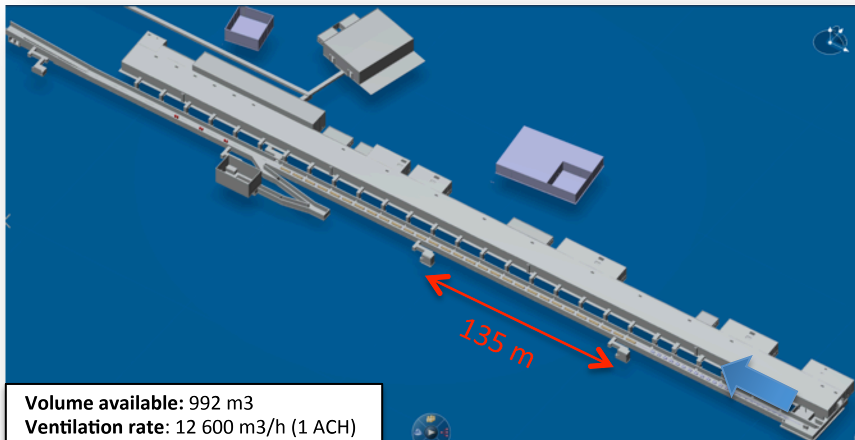
Oxygen concentration over time evolution (min)



ODH case-study

Accelerator tunnel

Case 2: section between 2 exits – normal ventilation



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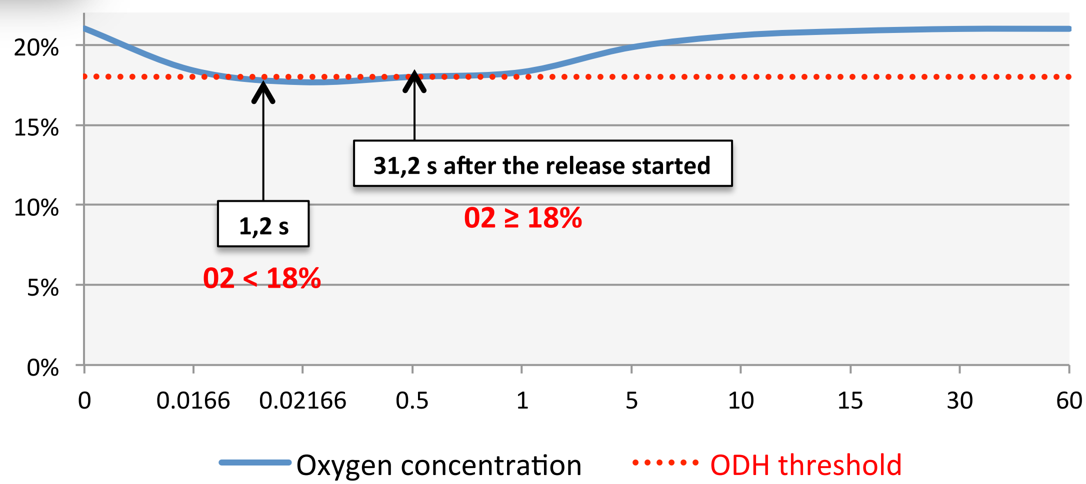
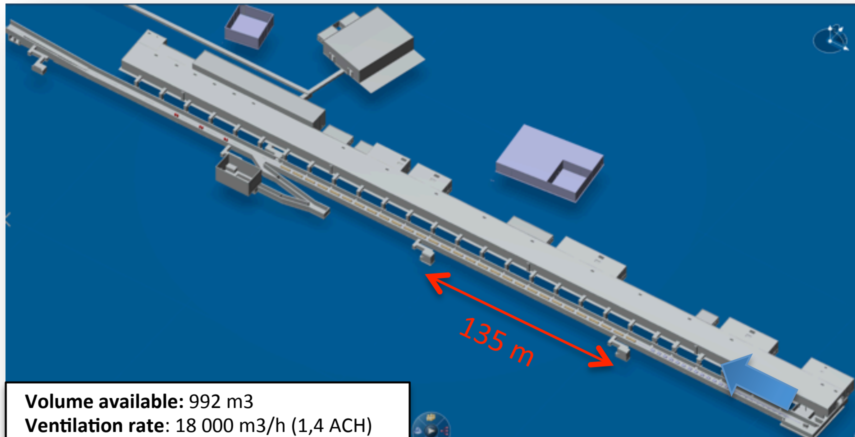
Oxygen concentration over time evolution (min)



ODH case-study
Accelerator tunnel

EUROPEAN SPALLATION SOURCE

Case 3: section between 2 exits – 1 smoke extractor*

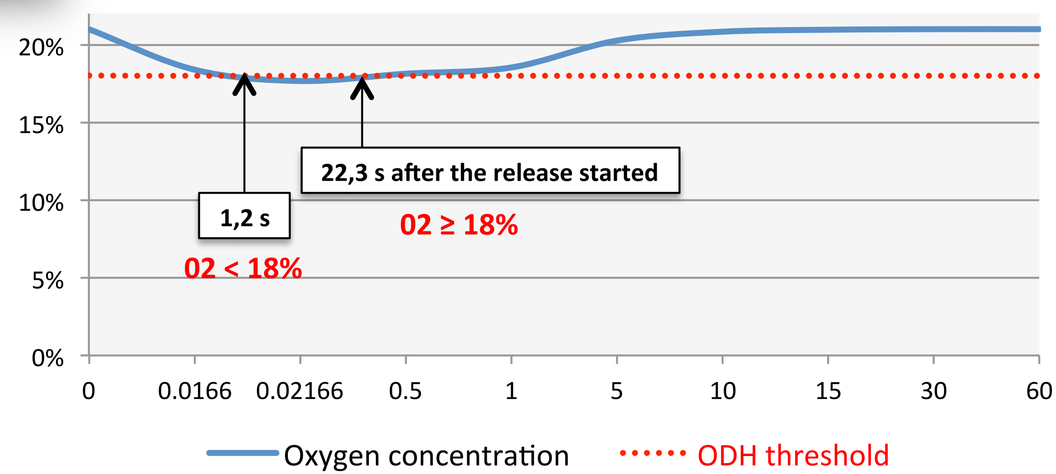


ACKNOWLEDGEMENT : N.GAZIS (ESS)

During release: $$C(t) = 0.21\, e^{-\frac{R}{V}t}$$

After release: $$C(t) = 0.21 - [0.21 - C_r(t_e)]\, e^{-\frac{Q}{V}(t-t_e)}$$

Oxygen concentration over time evolution (min)

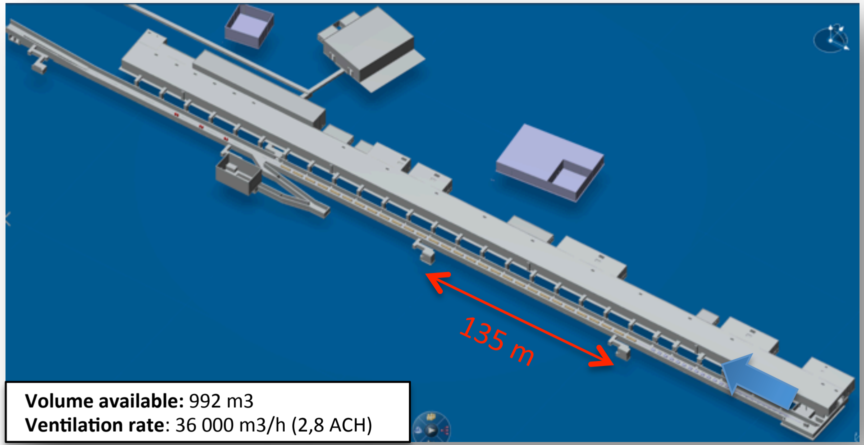


*considering a quasi-immediate trigger of the smoke extraction

ODH case-study

Accelerator tunnel

Case 4: section between 2 exits – 2 smoke extractors*

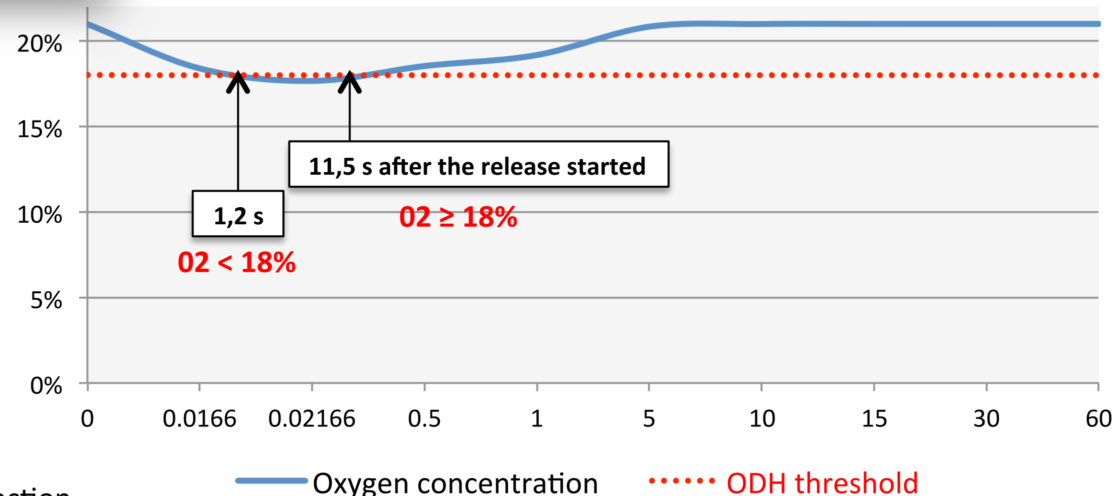


ACKNOWLEDGEMENT : N.GAZIS (ESS)

During release: $C(t) = 0.21\, e^{-\frac{R}{V}t}$

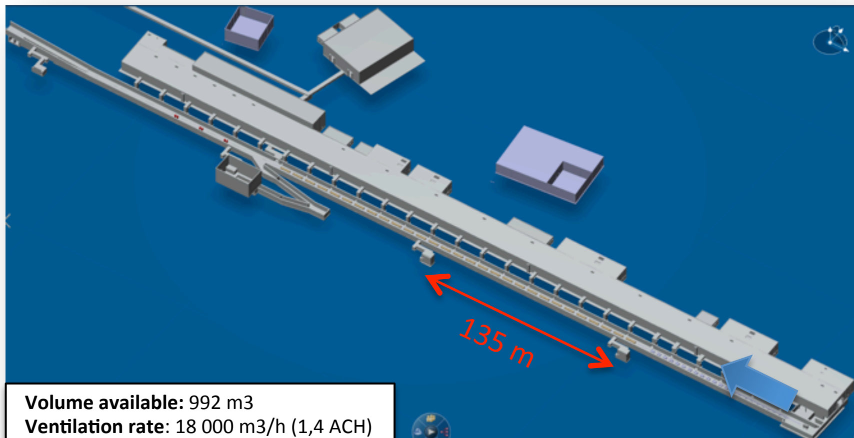
After release: $C(t) = 0.21 - [0.21 - C_r(t_e)]\, e^{-\frac{Q}{V}(t-t_e)}$

Oxygen concentration over time evolution (min)



*considering a quasi-immediate trigger of the smoke extraction

Case 5: section between 2 exits – 1 smoke extractor*

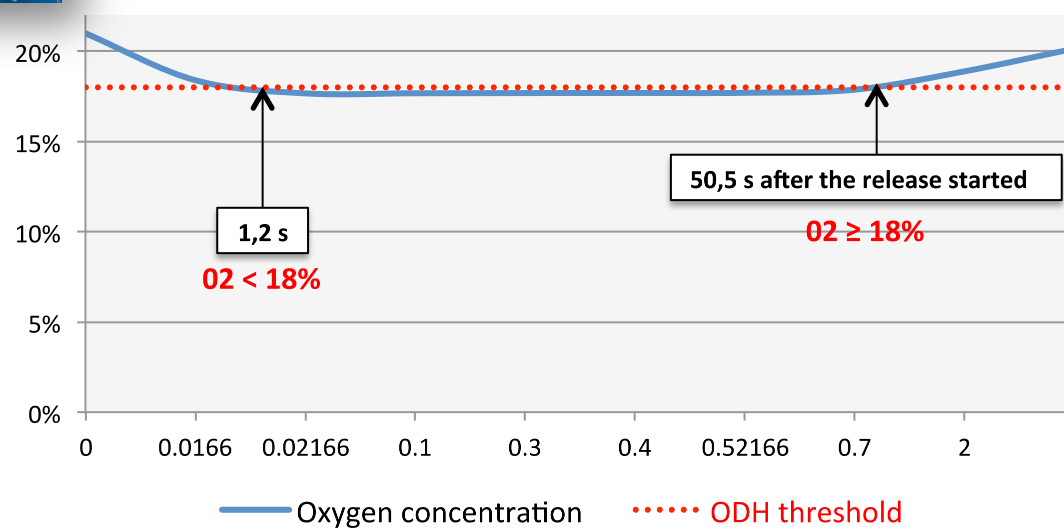


ACKNOWLEDGEMENT : N.GAZIS (ESS)

During release: $C(t) = 0.21\, e^{-\frac{R}{V}t}$

After release: $C(t) = 0.21 - \left[0.21 - C_r(t_e)\right] e^{-\frac{Q}{V}(t - t_e)}$

Oxygen concentration over time evolution (min)

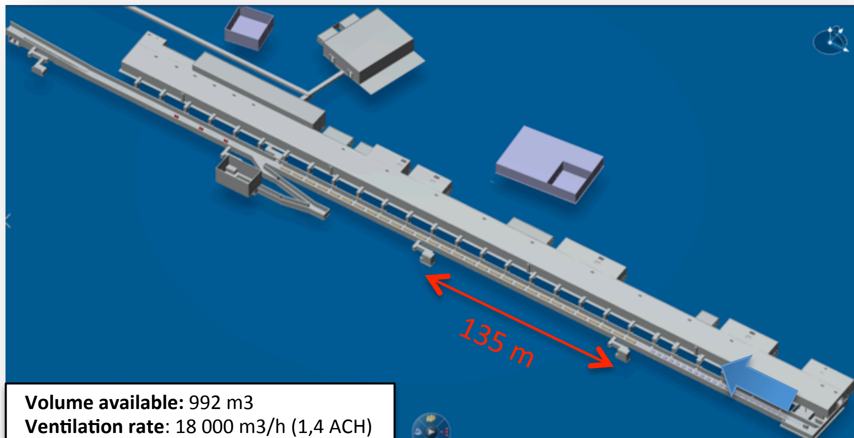


*considering a trigger of the smoke extraction after 30 s

ODH case-study

Accelerator tunnel

Case 6: section between 2 exits – 2 smoke extractors*



ACKNOWLEDGEMENT : N.GAZIS (ESS)

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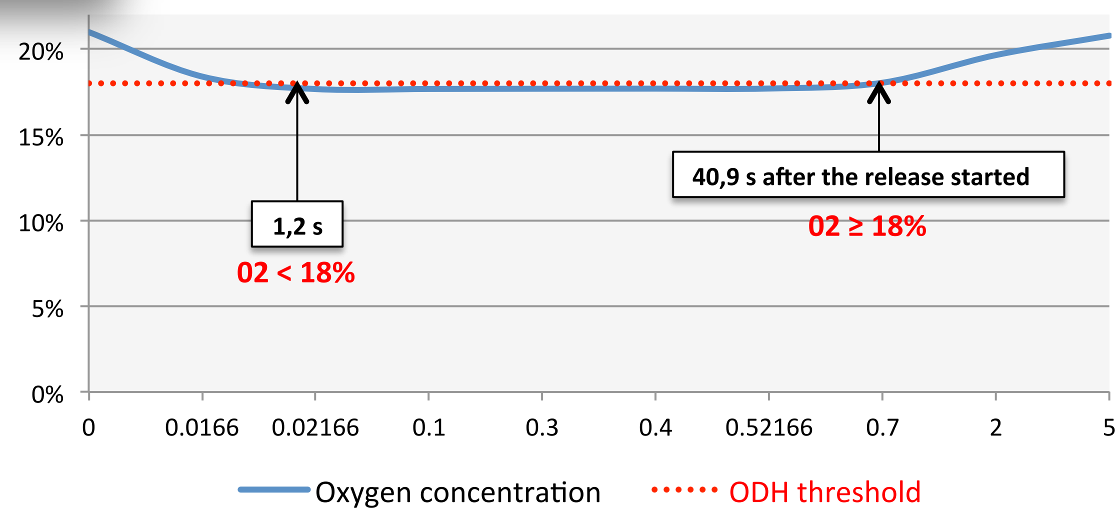
After release: $C(t) = 0.21 - [0.21 - C_r(t_e)]\, e^{-\frac{Q}{V}(t - t_e)}$

Oxygen concentration over time evolution (min)



*considering a trigger of the smoke extraction after 30 s

ODH case-study
Accelerator tunnel

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Summary table

Case	Length of the tunnel	Ventilation system	Trigger time	Time needed to reach 18% O2
1	600 m	Normal	N/A	Always above 18%
2	135 m	Normal	N/A	31,2 s
3	135 m	1 smoke extractor	immediate	22,3 s
4	135 m	2 smoke extractors	immediate	11,5 s
5	135 m	1 smoke extractor	After 30 s	50,5 s
6	135 m	2 smoke extractors	After 30 s	40,9 s

NOT REALISTIC

ODH Safety process

Preliminary ODH assessment

EUROPEAN SPALLATION SOURCE

Method n°1 (CERN approach)

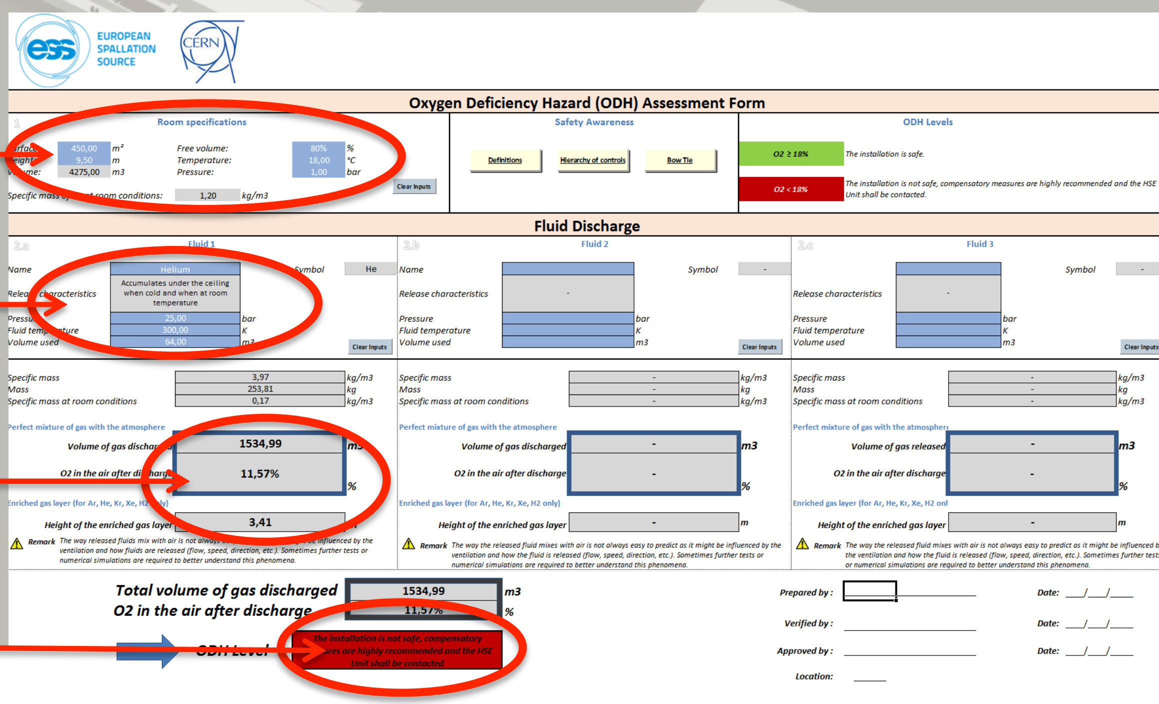
Objective: assess in a simple way consequences of the full loss of an asphyxiant fluid in a given volume <u>without considering</u> any ventilation and time parameter

Room parameters

Fluid parameters

O2 concentration
(perfect mixture)
+
Height of the gas layer
(stratification)

ODH Level
(O2≥18% **OR** O2<18%)



ODH Safety process

Preliminary ODH assessment

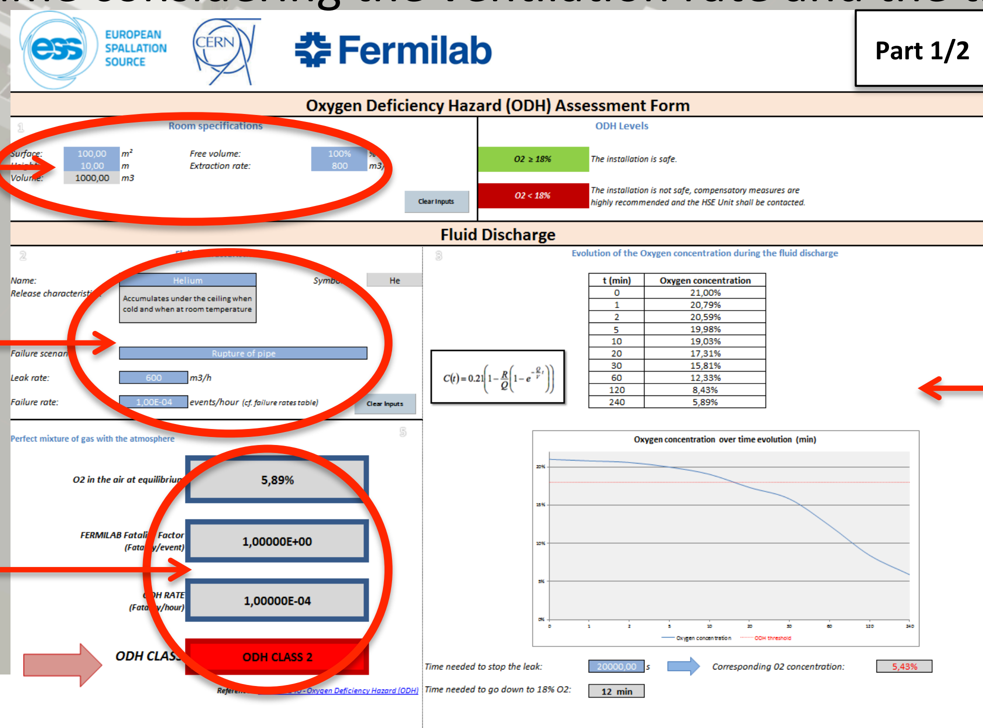
Method n°2 (Fermilab approach)

Objective: assess in a simple way the consequences of a leak of an asphyxiant fluid in a given volume considering the ventilation rate and the time evolution

Room parameters

Fluid + scenario characteristics

ODH parameters:
Fatality rate
Probability of fatality
ODH class



Part 1/2

Oxygen Deficiency Hazard (ODH) Assessment Form

1 Room specifications

Surface: 100,00 m²
Height: 10,00 m
Volume: 1000,00 m3
Free volume: 100% %
Extraction rate: 800 m3/h
Clear Inputs

ODH Levels

O2 ≥ 18% — The installation is safe.
O2 < 18% — The installation is not safe, compensatory measures are highly recommended and the HSE Unit shall be contacted.

Fluid Discharge

2

Name: Helium — Symbol: He
Release characteristics: Accumulates under the ceiling when cold and when at room temperature
Failure scenario: Rupture of pipe
Leak rate: 600 m3/h
Failure rate: 1,00E-04 events/hour (cf. failure rates table)
Clear Inputs

3 Evolution of the Oxygen concentration during the fluid discharge

$$C(t) = 0.21\left(1 - \frac{R}{Q}\left(1 - e^{-\frac{Q}{V}t}\right)\right)$$

t (min)	Oxygen concentration
0	21,00%
1	20,79%
2	20,59%
5	19,98%
10	19,03%
20	17,31%
30	15,81%
60	12,33%
120	8,43%
240	5,89%

Oxygen concentration over time evolution (min)

5 Perfect mixture of gas with the atmosphere

O2 in the air at equilibrium: 5,89%
FERMILAB Fatality Factor (Fatality/event): 1,00000E+00
ODH RATE (Fatality/hour): 1,00000E-04
ODH CLASS: ODH CLASS 2

Time needed to stop the leak: 20000,00 s — Corresponding O2 concentration: 5,43%
Time needed to go down to 18% O2: 12 min

O2 evolution during fluid discharge

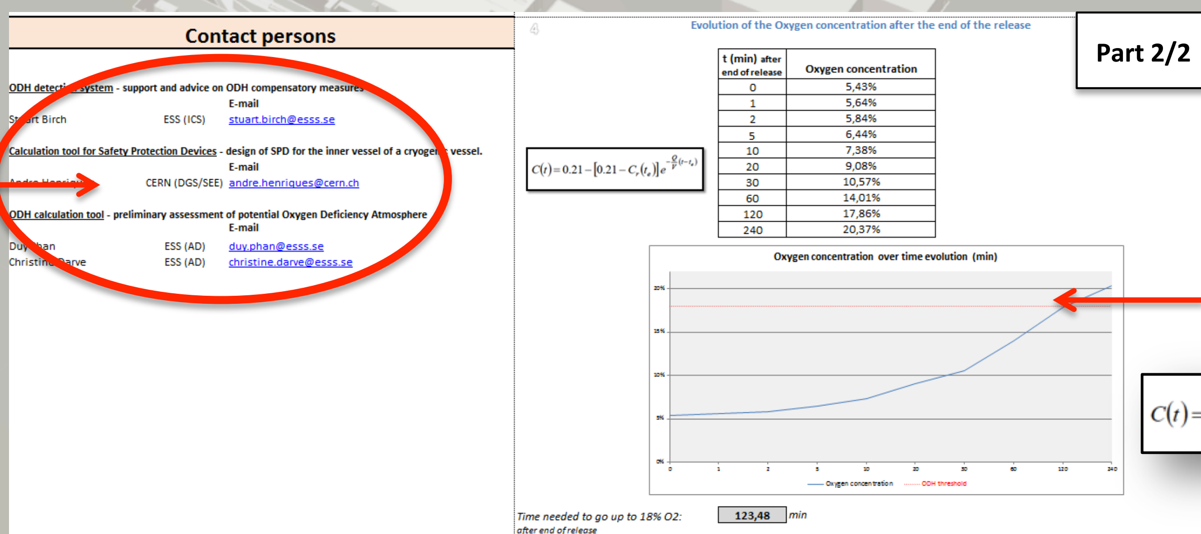
$$C(t) = 0.21\left(1 - \frac{R}{Q}\left(1 - e^{-\frac{Q}{V}t}\right)\right)$$

ODH Safety process
Preliminary ODH assessment

Method n°2 (Fermilab approach)

Objective: assess in a simple way the consequences of a leak of an asphyxiant fluid in a given volume considering the ventilation rate and the time evolution

Contact persons



t (min) after end of release	Oxygen concentration
0	5,43%
1	5,64%
2	5,84%
5	6,44%
10	7,38%
20	9,08%
30	10,57%
60	14,01%
120	17,86%
240	20,37%

Part 2/2

O2 evolution after fluid discharge

$$C(t) = 0.21 - [0.21 - C_r(t_e)]e^{-\frac{Q}{V}(t-t_e)}$$

ODH control measures

Which ones are relevant?

“*If this approach is taken, the ventilation system must now be treated as a safety system with appropriate controls and redundancies*” – John Weisend, January 2015

Simplication

of the approach to meet ESS needs…

OK

To be discussed

ODH Hazard Class	0	1	2
Environment controls			
Warning signs		X	X
Ventilation → **PSS? IEC 61508?**		X	X
Area (fixed) Oxygen Monitoring		X	X
ODH-Qualified Personnel Controls			
Medical approval as ODH qualified		X	X
ODH traning **ES&H?**		X	X
Personnel oxygen monitor		X	X
Self-rescue mask **Applicable?**		X	X
Multiple personnel in communication			X
ODH-Restricted Personnel Controls			
Must not be ODH-excluded		X	X
ODH briefing or training		X	X
Personnel oxygen monitor		X	X
Self-rescue mask		X	X
One-to-one escort by ODH qualified personnel		X	X
At least 2 ODH qualified personnel			X

ODH control measures

Other possible solutions…

EUROPEAN SPALLATION SOURCE

Solution 1

ODH Hazard Class	0	1	2
Environment controls			
Warning signs		X	X
Ventilation		X	X
Area (fixed) Oxygen Monitoring		X	X
ODH-Qualified Personnel Controls			
Medical approval as ODH qualified		X	X
ODH traning		X	X
Personnel oxygen monitor		X	X
Self-rescue mask		X	X
Multiple personnel in communication			X
ODH-Restricted Personnel Controls			
Must not be ODH-excluded		X	X
ODH briefing or training		X	X
Personnel oxygen monitor		X	X
Self-rescue mask		X	X
One-to-one escort by ODH qualified personnel		X	X
At least 2 ODH qualified personnel			X

Solution 2

ODH Hazard Class	0	1	2
Technical Safety measures			
Warning signs	X	X	X
Ventilation		*	*
Area (fixed) Oxygen Monitoring	*	X	X
Organizational Safety measures			
Medical approval as ODH qualified		X	X
ODH traning (e-learning)	X	X	X
Personnel oxygen monitor		X	X
Self-rescue mask		*	*
Presence of minimum 2 persons			X
Administrative Safety measures			
Access restricted to authorized personnel only		X	X
Emergency procedure		X	X
Working procedure	X	X	X

* to be evaluated case by case

Practical cases

Accelerator tunnel – Method n°**1**

Scenario: Helium discharge from the safety relief device of the insulating vacuum vessel from 1 High-β Cryomodule

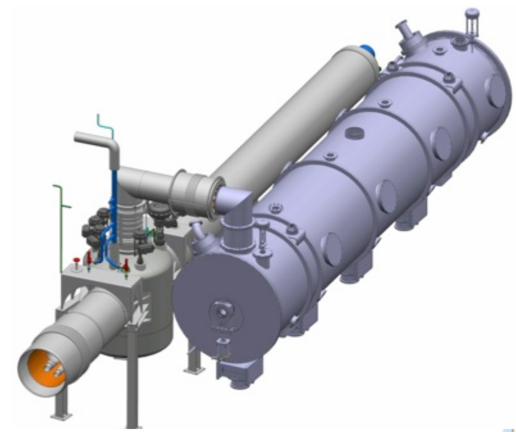
Cause: leak from junctions/welds from the cavities

Volume of LHe: 1 x 4 x 0.048 m3

Temperature of LHe: 2K

Pressure: 1,9 bara

Tunnel: 12 600 m3 x 35% (full volume)

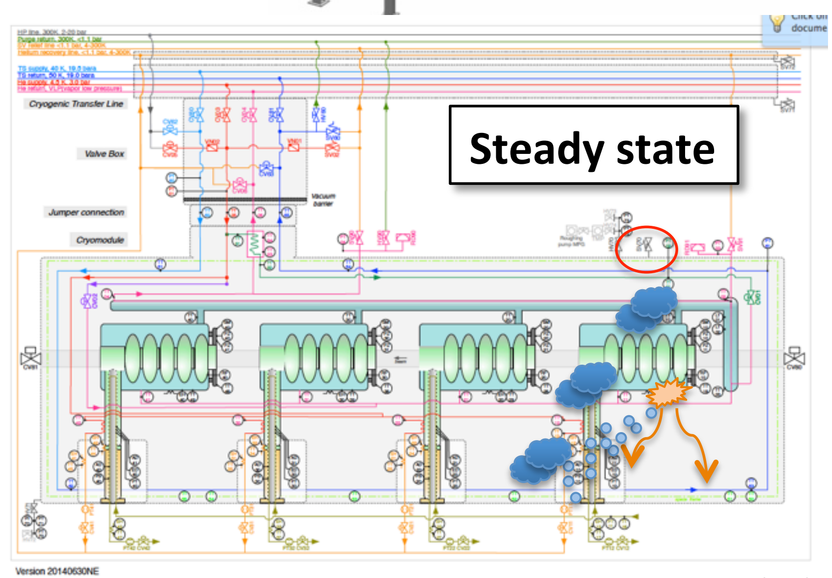


Volume of gas discharged: 174 m3

O2 concentration after discharge (homogeneous mixture): 20,17%

Height of gas layer (stratification): 0,05 m

ODH level: “SAFE”



ACKNOWLEDGEMENT : J.FYDRYCH (ESS)

Practical cases

Accelerator tunnel – Method n°**1**

Scenario: Helium discharge from the safety relief device of the insulating vacuum vessel from 1 High-β Cryomodule

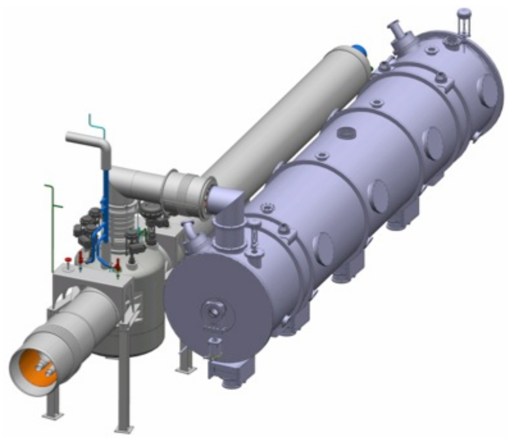
Cause: leak from junctions/welds from the cavities

Volume of LHe: 1 x 4 x 0.048 m3

Temperature of LHe: 2K

Pressure: 1,9 bara

Tunnel: 4200 m3 x 35% (1/3 of the total volume)

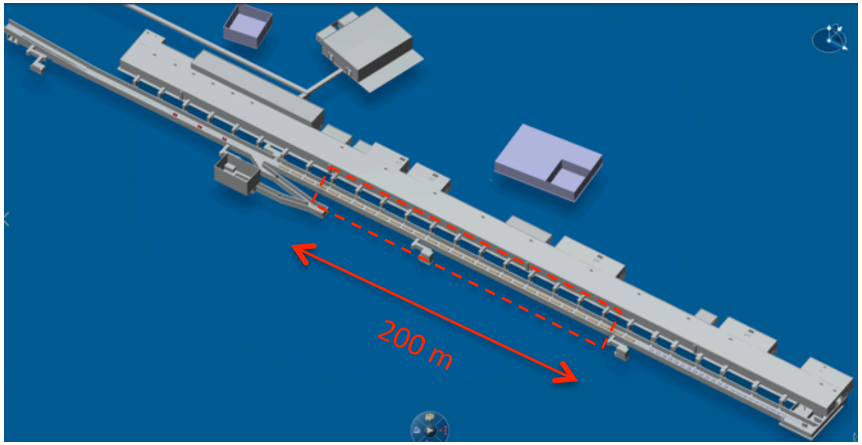


Volume of gas discharged: 174 m3

O2 concentration after discharge (homogeneous mixture): 18,52%

Height of gas layer (stratification): 0,14 m

ODH level: "SAFE"



ACKNOWLEDGEMENT : N.GAZIS, J.FYDRYCH (ESS)

Practical cases

Accelerator tunnel – Method n°2 Fermilab

EUROPEAN SPALLATION SOURCE

Scenario: Helium discharge from the safety relief device of the insulating vacuum vessel from 1 High-β Cryomodule

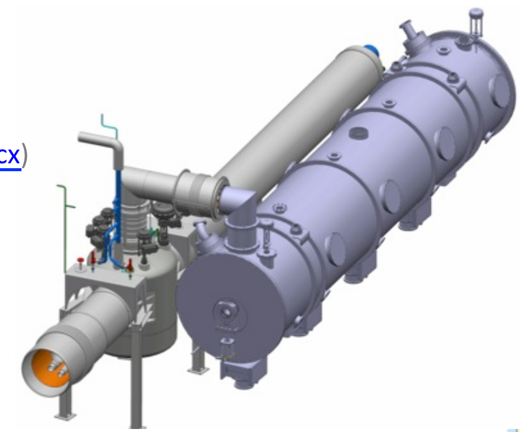
Cause: leak from junctions/welds

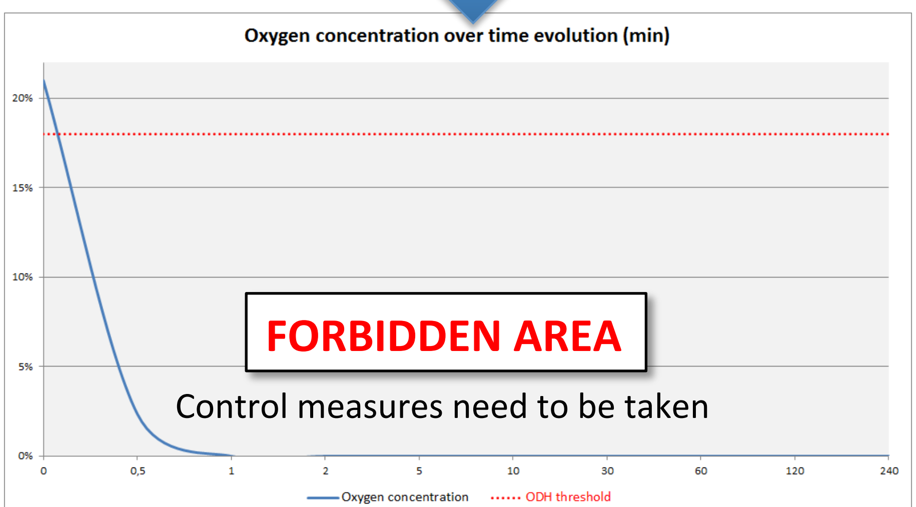
Leak rate: 475 200 m3/h (ref. WP5_SafetySizing__nt-safety-devices-2015-01-14.docx)

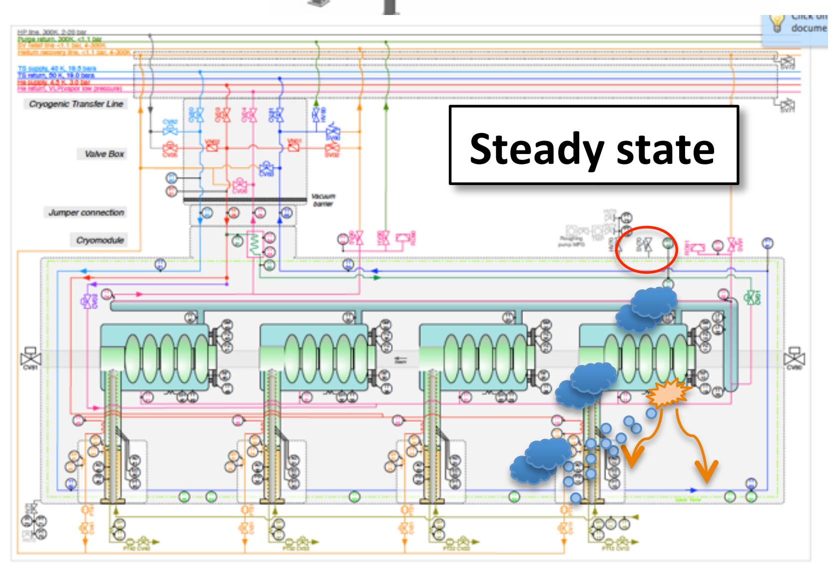
Duration of the leak: infinite (not realistic)

Ventilation rate: 1 vol/h (12600 m3/h)

Tunnel: 12 600 m3 x 35% (full volume)







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Practical cases

Accelerator tunnel – Method n°2 Fermilab

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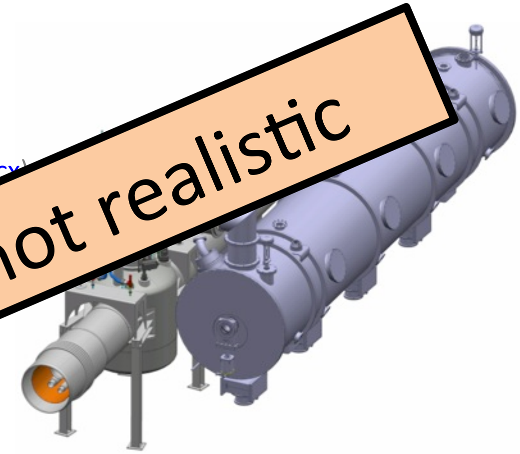
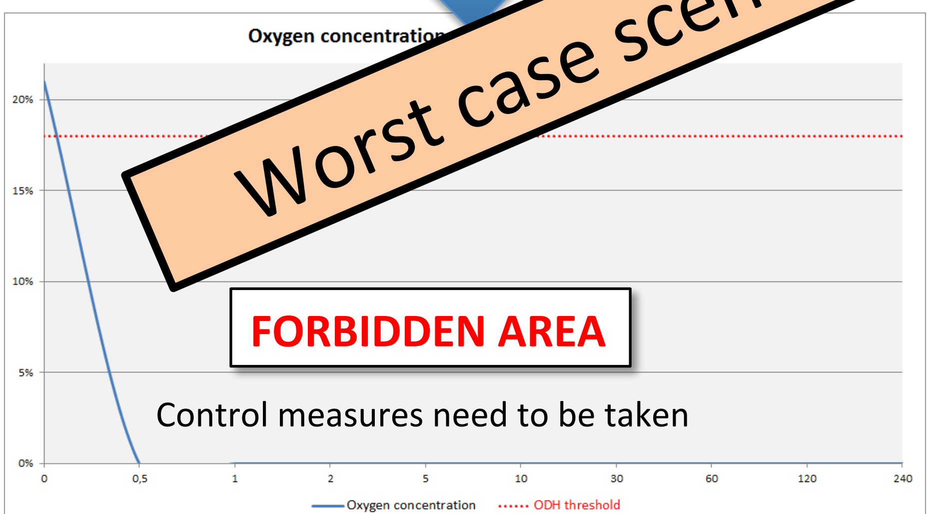
Duration of the leak: infinite (not realistic)

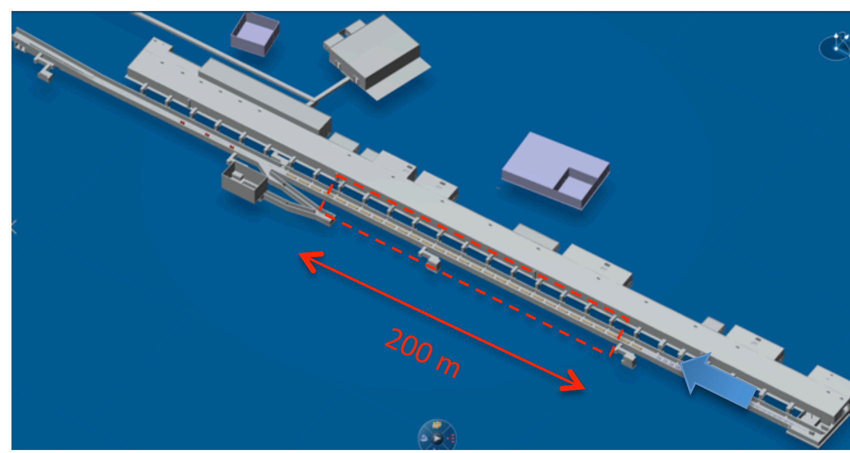
Ventilation rate: 1 vol/h (12600 m3/h)

Tunnel: 4200 m3 x 35% (1/3 of th…)

Worst case scenario but maybe not realistic







ACKNOWLEDGEMENT : N.GAZIS, J.FYDRYCH (ESS)

Practical cases

Compressor bldg. – Method n°2

Fermilab

EUROPEAN SPALLATION SOURCE

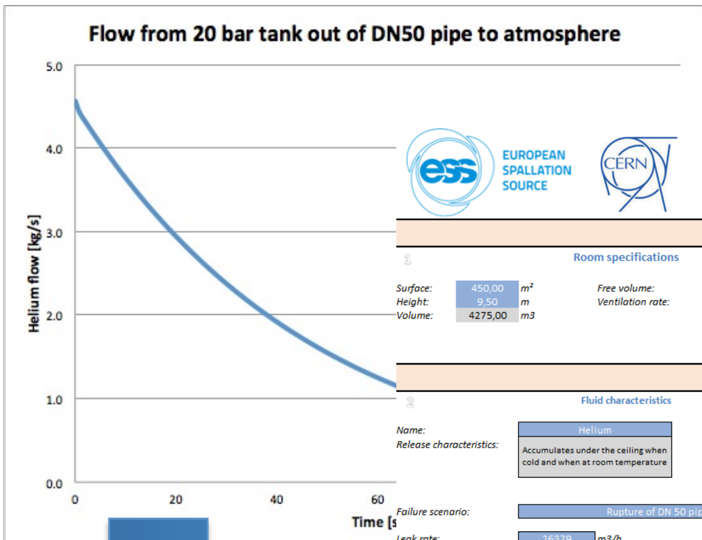
Alternative approach

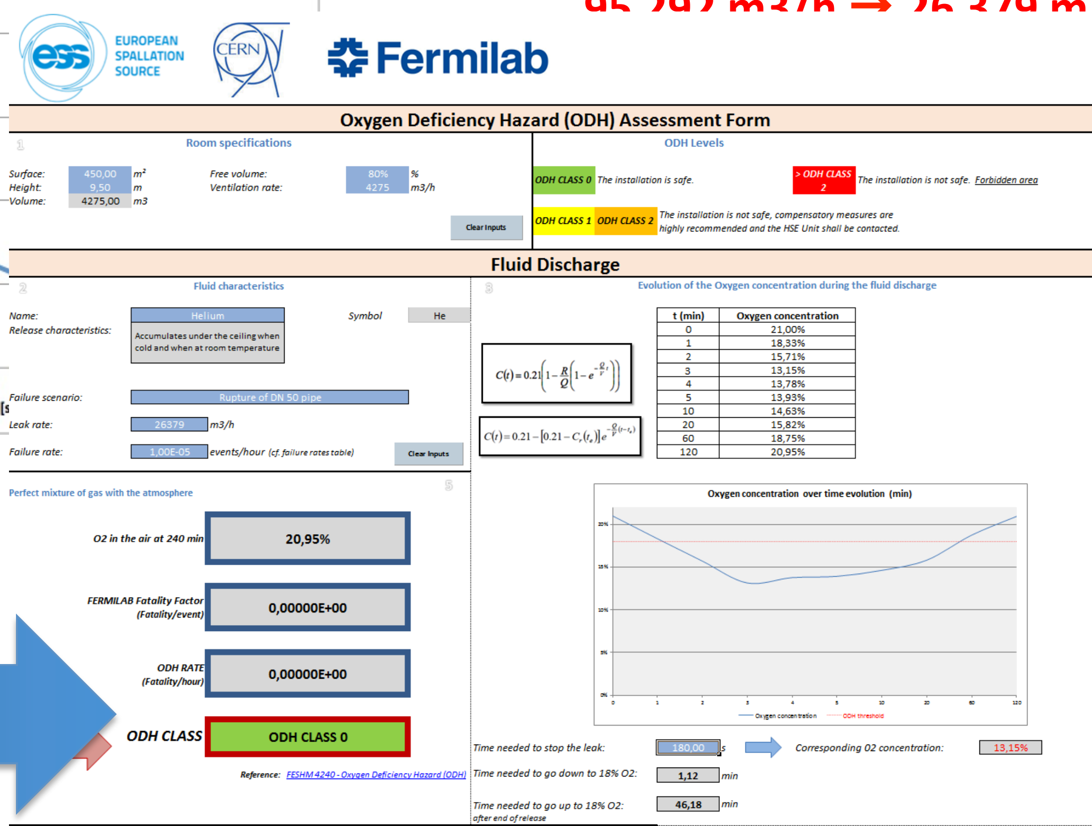
Thanks to Philipp Arnold !!!

No constant max flow rate → average flow rate

95 292 m3/h → 26 379 m3/h

mpty the





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CERN

Fermilab

Oxygen Deficiency Hazard (ODH) Assessment Form

Room specifications

Surface: 450,00 m²
Height: 9,50 m
Volume: 4275,00 m3

Free volume: 80 %
Ventilation rate: 4275 m3/h

Clear Inputs

ODH Levels

ODH CLASS 0 — The installation is safe.

> ODH CLASS 2 — The installation is not safe. Forbidden area

ODH CLASS 1 / ODH CLASS 2 — The installation is not safe, compensatory measures are highly recommended and the HSE Unit shall be contacted.

Fluid Discharge

Fluid characteristics

Name: Helium — Symbol: He
Release characteristics: Accumulates under the ceiling when cold and when at room temperature

Failure scenario: Rupture of DN 50 pipe
Leak rate: 26379 m3/h
Failure rate: 1,00E-05 events/hour (cf. failure rates table)

Clear Inputs

Evolution of the Oxygen concentration during the fluid discharge

$$C(t) = 0.21\left(1 - \frac{R}{Q}\left(1 - e^{-\frac{Q}{V}t}\right)\right)$$

$$C(t) = 0.21 - \left[0.21 - C_t(t_r)\right]e^{-\frac{Q}{V}(t - t_r)}$$

t (min)	Oxygen concentration
0	21,00%
1	18,33%
2	15,71%
3	13,15%
4	13,78%
5	13,93%
10	14,63%
20	15,82%
60	18,75%
120	20,95%

Perfect mixture of gas with the atmosphere

O2 in the air at 240 min	20,95%
FERMILAB Fatality Factor (Fatality/event)	0,00000E+00
ODH RATE (Fatality/hour)	0,00000E+00
ODH CLASS	ODH CLASS 0

Reference: FESHM 4240 - Oxygen Deficiency Hazard (ODH)

Oxygen concentration over time evolution (min)

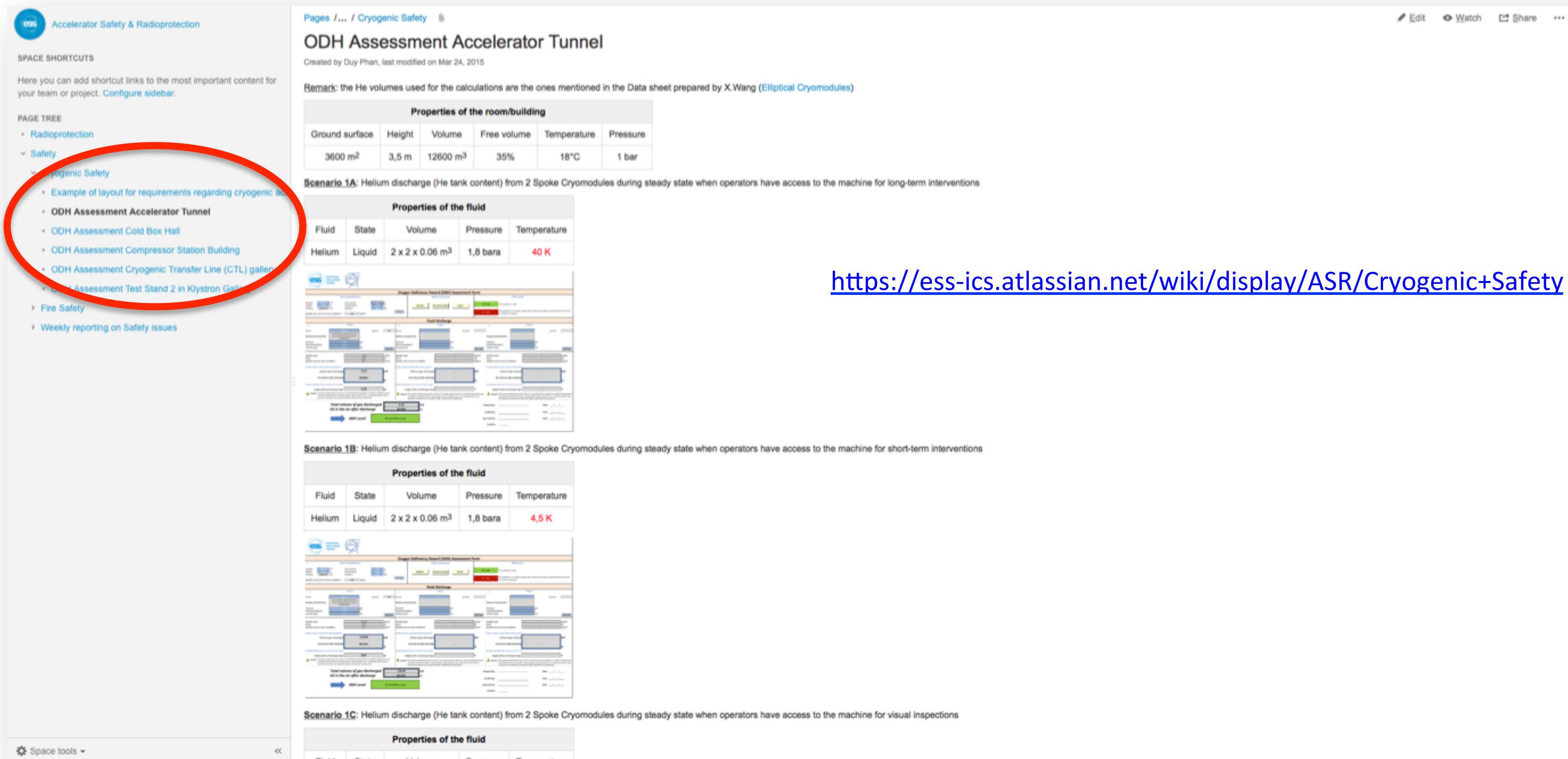
Time needed to stop the leak: 180,00 s → Corresponding O2 concentration: 13,15%
Time needed to go down to 18% O2: 1,12 min
Time needed to go up to 18% O2 after end of release: 46,18 min

ODH case-study

Where to find the ODH tools and results?

EUROPEAN SPALLATION SOURCE

Safety Wiki



Accelerator Safety & Radioprotection

SPACE SHORTCUTS

Here you can add shortcut links to the most important content for your team or project. Configure sidebar.

PAGE TREE

- Radioprotection
- Safety
  - Cryogenic Safety
    - Example of layout for requirements regarding cryogenic ...
    - ODH Assessment Accelerator Tunnel
    - ODH Assessment Cold Box Hall
    - ODH Assessment Compressor Station Building
    - ODH Assessment Cryogenic Transfer Line (CTL) gallery
    - ODH Assessment Test Stand 2 in Klystron Gallery
  - Fire Safety
  - Weekly reporting on Safety issues

Space tools

Pages /... / Cryogenic Safety

Edit Watch Share

ODH Assessment Accelerator Tunnel

Created by Duy Phan, last modified on Mar 24, 2015

Remark: the He volumes used for the calculations are the ones mentioned in the Data sheet prepared by X.Wang (Elliptical Cryomodules)

Properties of the room/building					
Ground surface	Height	Volume	Free volume	Temperature	Pressure
3600 m²	3,5 m	12600 m³	35%	18°C	1 bar

Scenario 1A: Helium discharge (He tank content) from 2 Spoke Cryomodules during steady state when operators have access to the machine for long-term interventions

Properties of the fluid				
Fluid	State	Volume	Pressure	Temperature
Helium	Liquid	2 x 2 x 0.06 m³	1,8 bara	40 K

Scenario 1B: Helium discharge (He tank content) from 2 Spoke Cryomodules during steady state when operators have access to the machine for short-term interventions

Properties of the fluid				
Fluid	State	Volume	Pressure	Temperature
Helium	Liquid	2 x 2 x 0.06 m³	1,8 bara	4,5 K

Scenario 1C: Helium discharge (He tank content) from 2 Spoke Cryomodules during steady state when operators have access to the machine for visual inspections

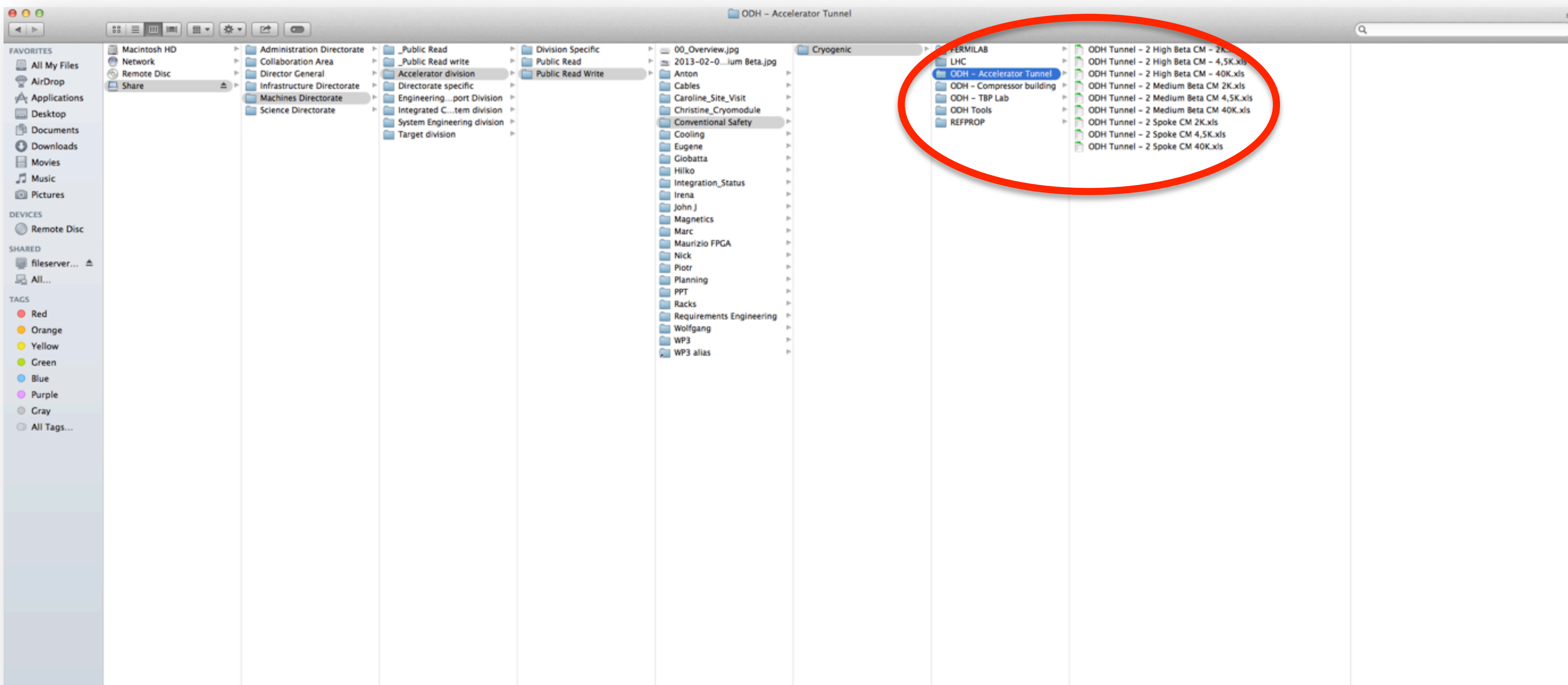
Properties of the fluid				
Fluid	State	Volume	Pressure	Temperature

https://ess-ics.atlassian.net/wiki/display/ASR/Cryogenic+Safety

Practical cases

Where to find the ODH tools and results?

ESSShare



ODH Tutorial ready…

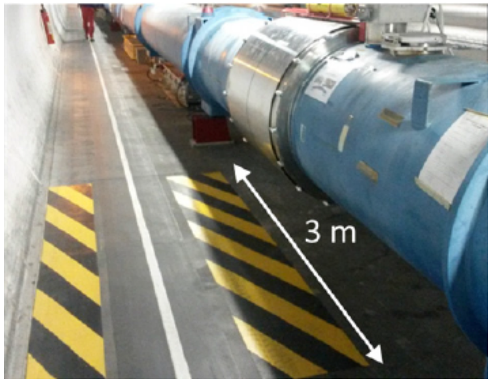
CERN LHC spill test

Lessons learnt (from a Safety point of view)

1. The drop of O2 content cannot be related to the visible formation of mist in the flow

2. **Exclusions zones** have been increased

	CERN LHC	ESS
Distance between rupture disks	200 m	?
Exclusion zones	Yes	Not applicable?



3. **No personnel access to the tunnel** while sectors are cooled down or warmed up or powering tests are performed of He cooled magnets

4. Access conditions for personnel redefined such that **no exposure to a MCI larger than 0,1 kg/s**

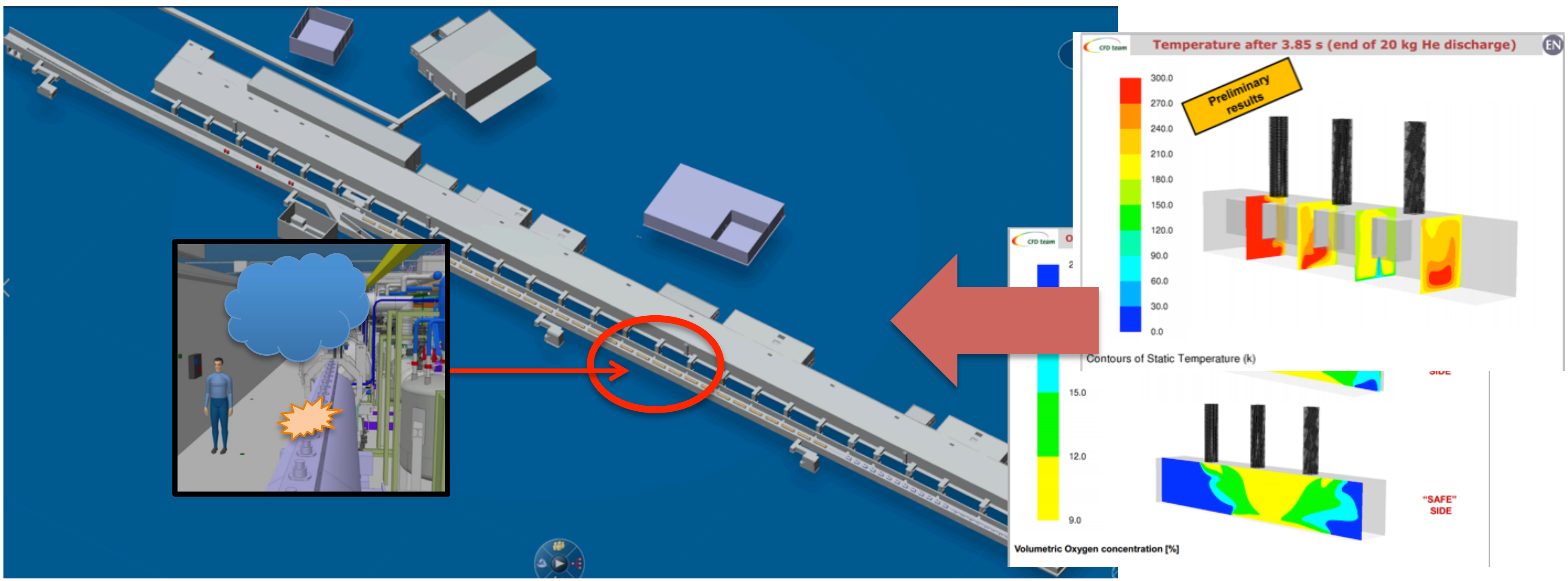
5. At kneeling height (0,5 m) **O2 can drop to 11%**

6. **No safe zone available** to put on the self-rescue mask

ACKNOWLEDGEMENT : T.KOETTIG (CERN) – REFERENCE: *CONTROLLED COLD HELIUM SPILL TEST IN THE LHC TUNNEL AT CERN*

Open question

- **I**s there any need for a CFD simulation at ESS…in particular in the tunnel?



ACKNOWLEDGEMENT : N.GAZIS (ESS), E.DA RIVA (CERN)

Open question

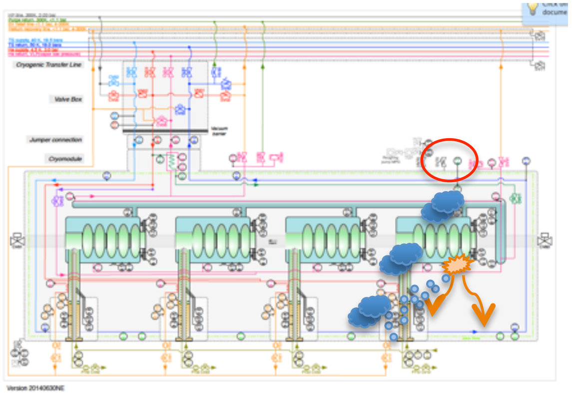
EUROPEAN SPALLATION SOURCE

Which Most Credible Incident (MCI) should be chosen?

During Access to the tunnel

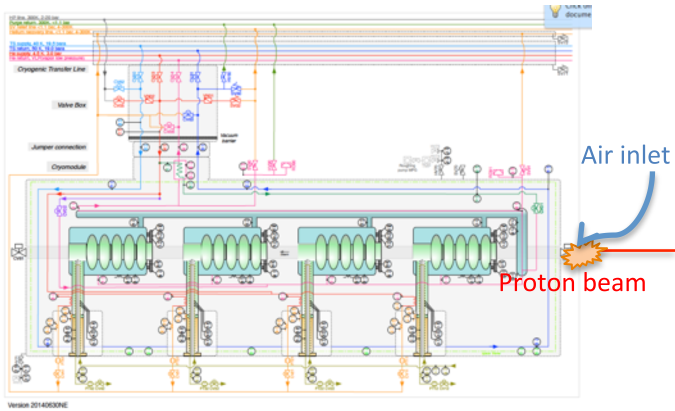
Scenario?

Mass Flow?



No Access to the tunnel

Beam loss?



ACKNOWLEDGEMENT : J.FYDRYCH (ESS)