Overview of the Air Management System in the ESS Accelerator tunnel

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www.europeanspallationsource.se
6th October 2015

Agenda

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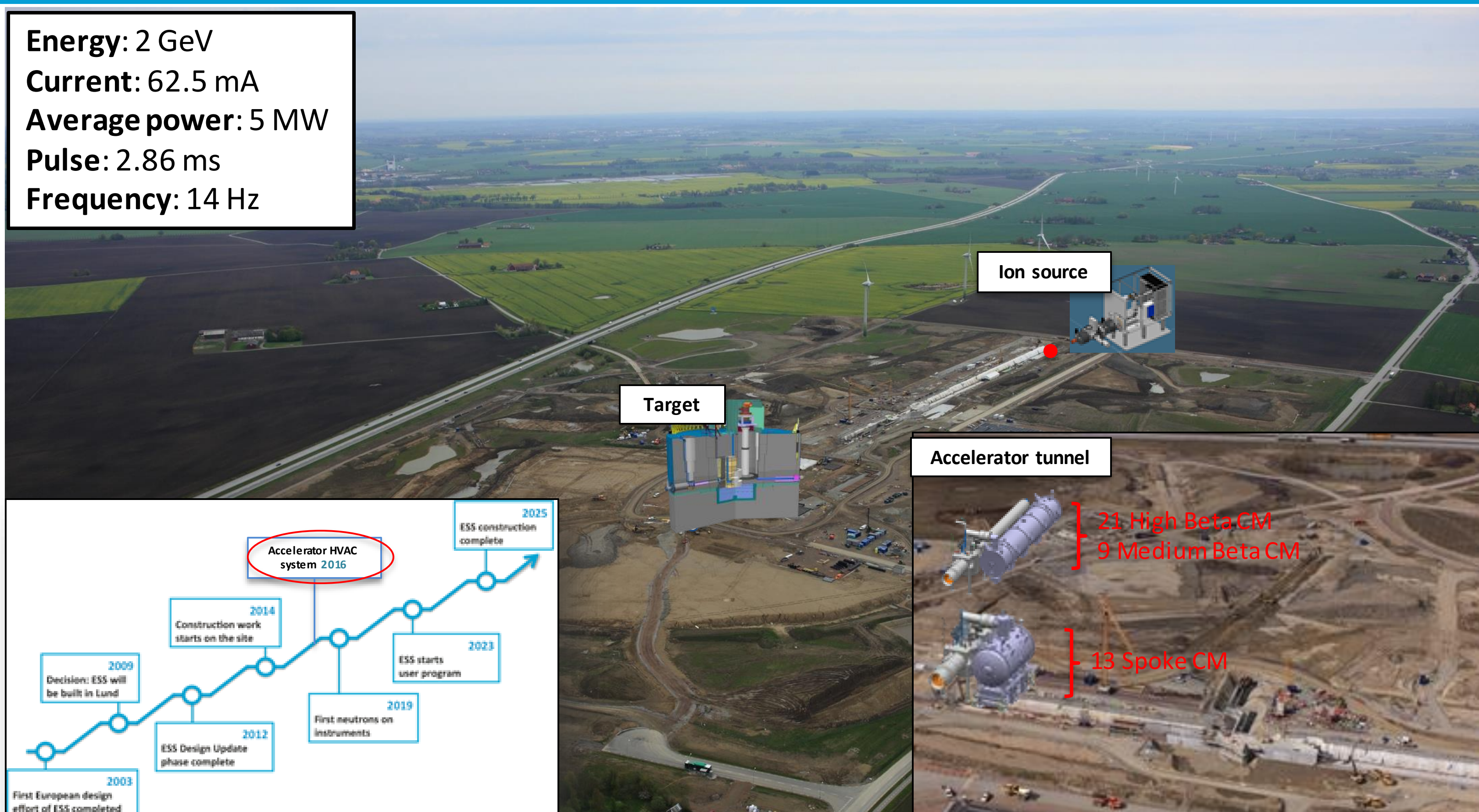
Main topics addressed

- **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

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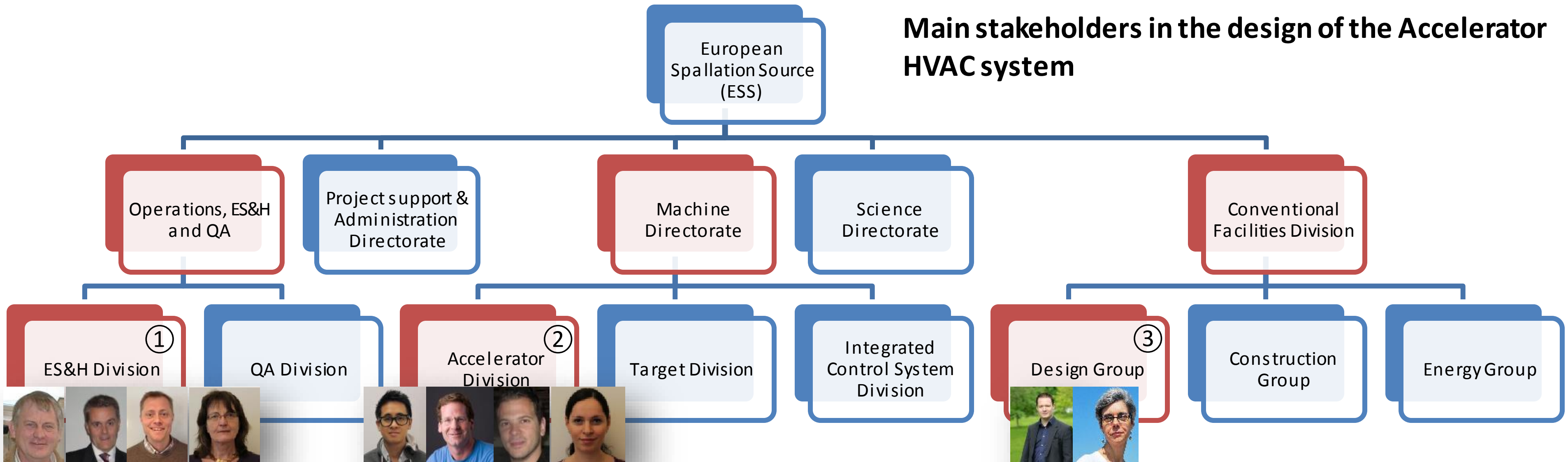
ESS Organization chart (simplified)

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.)

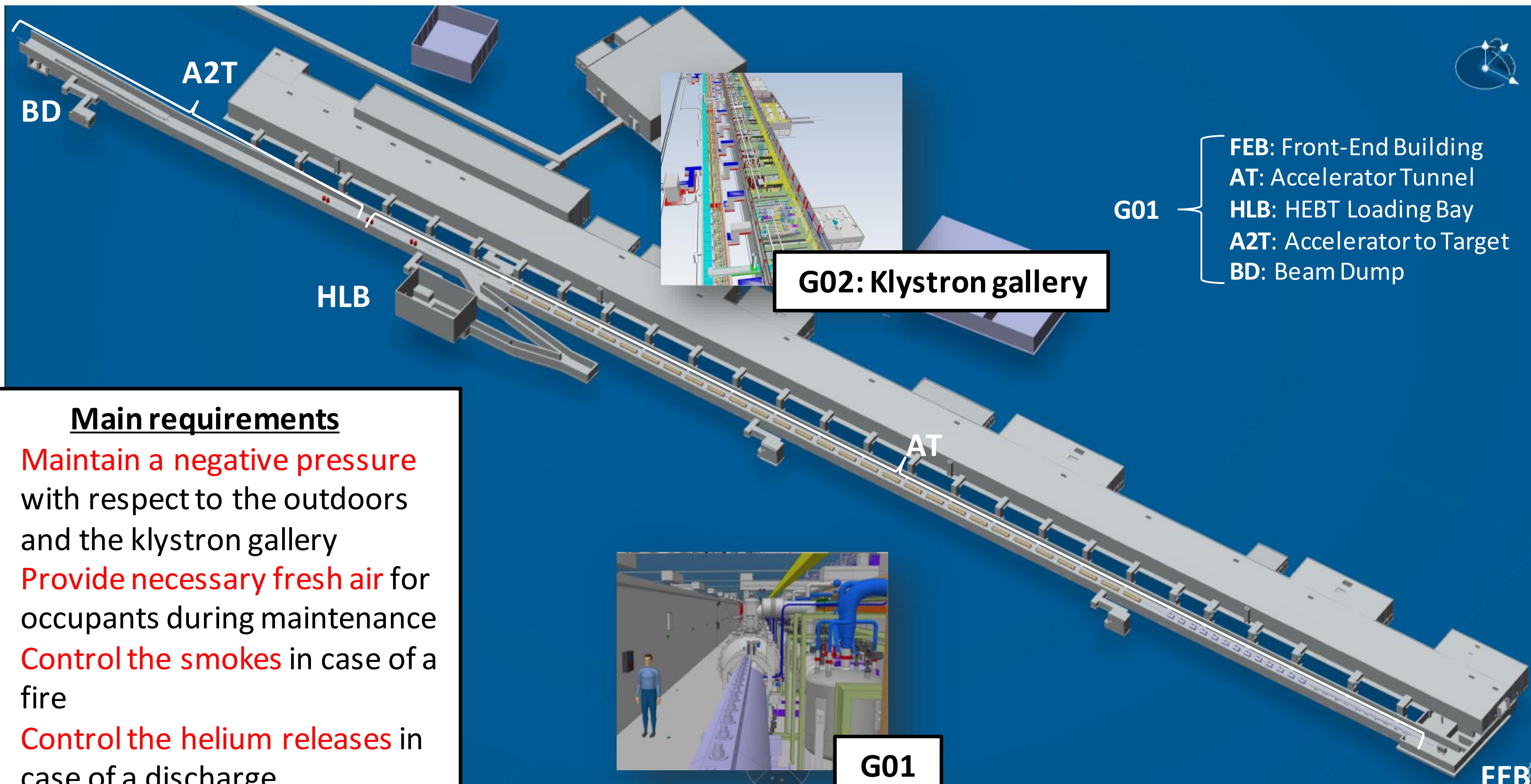
② **Specifies the performance requirements** for the design of the HVAC system (e.g. temperature and humidity control) and **provides support for the mitigation of the safety issues** (e.g. CFD simulations, hazard analysis, etc.)

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

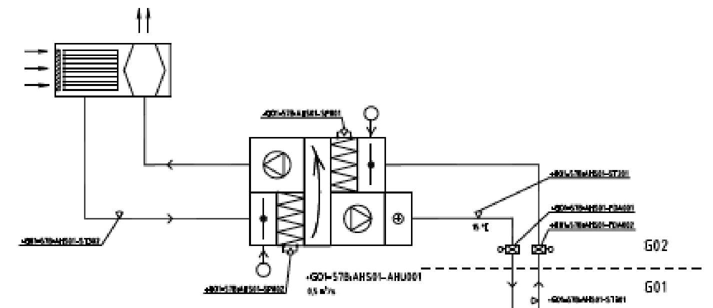
Accelerator Air Management System

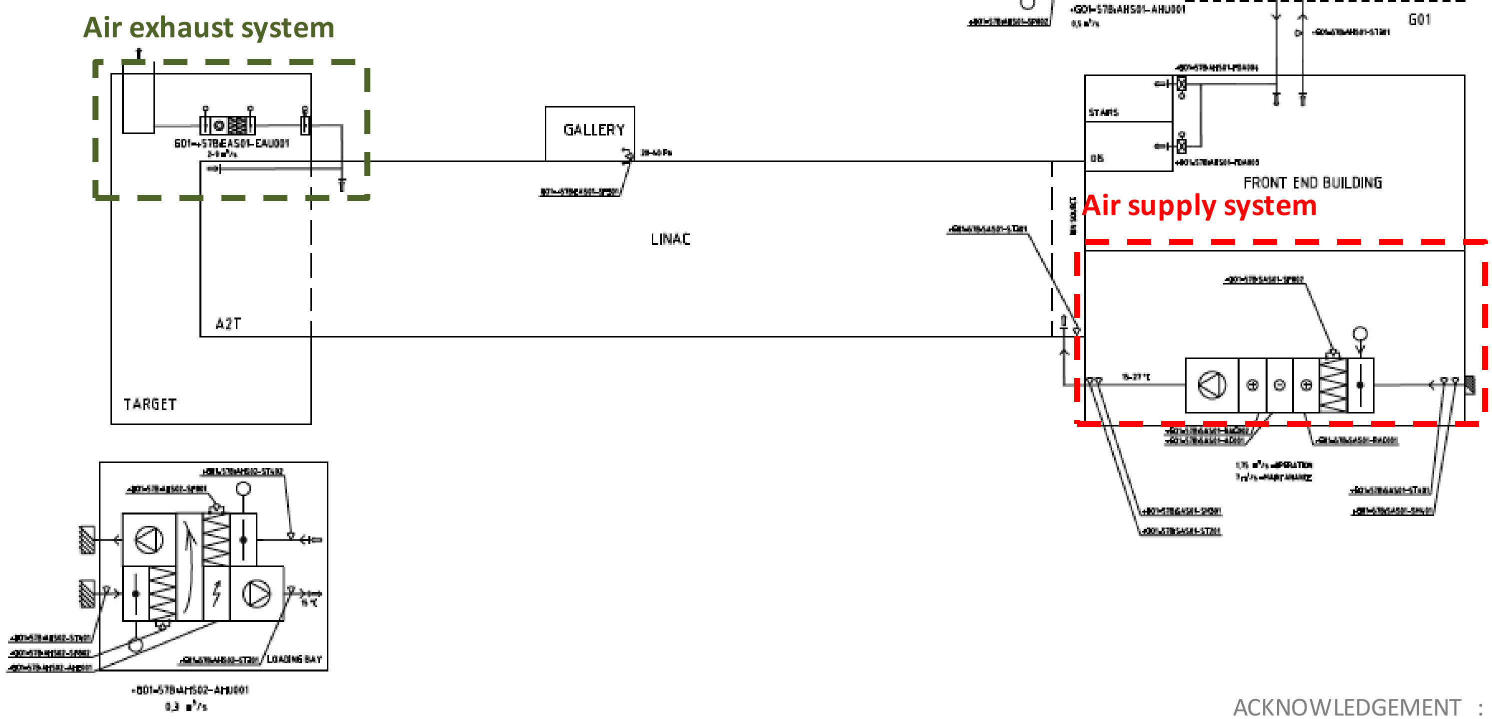
Current design

4 Ventilation modes

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

+ Fire suppression system



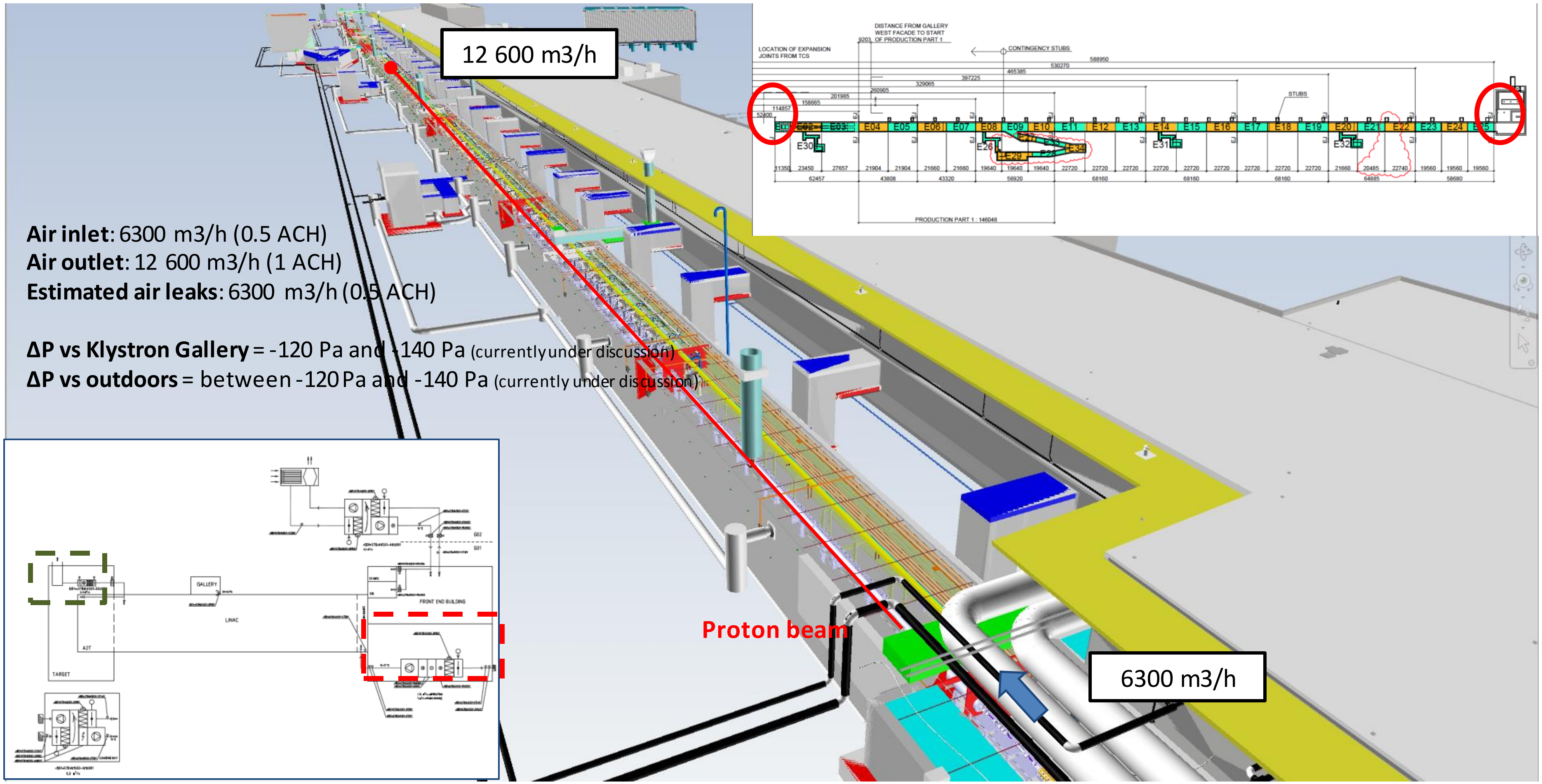


ACKNOWLEDGEMENT : M.KELFVE

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)

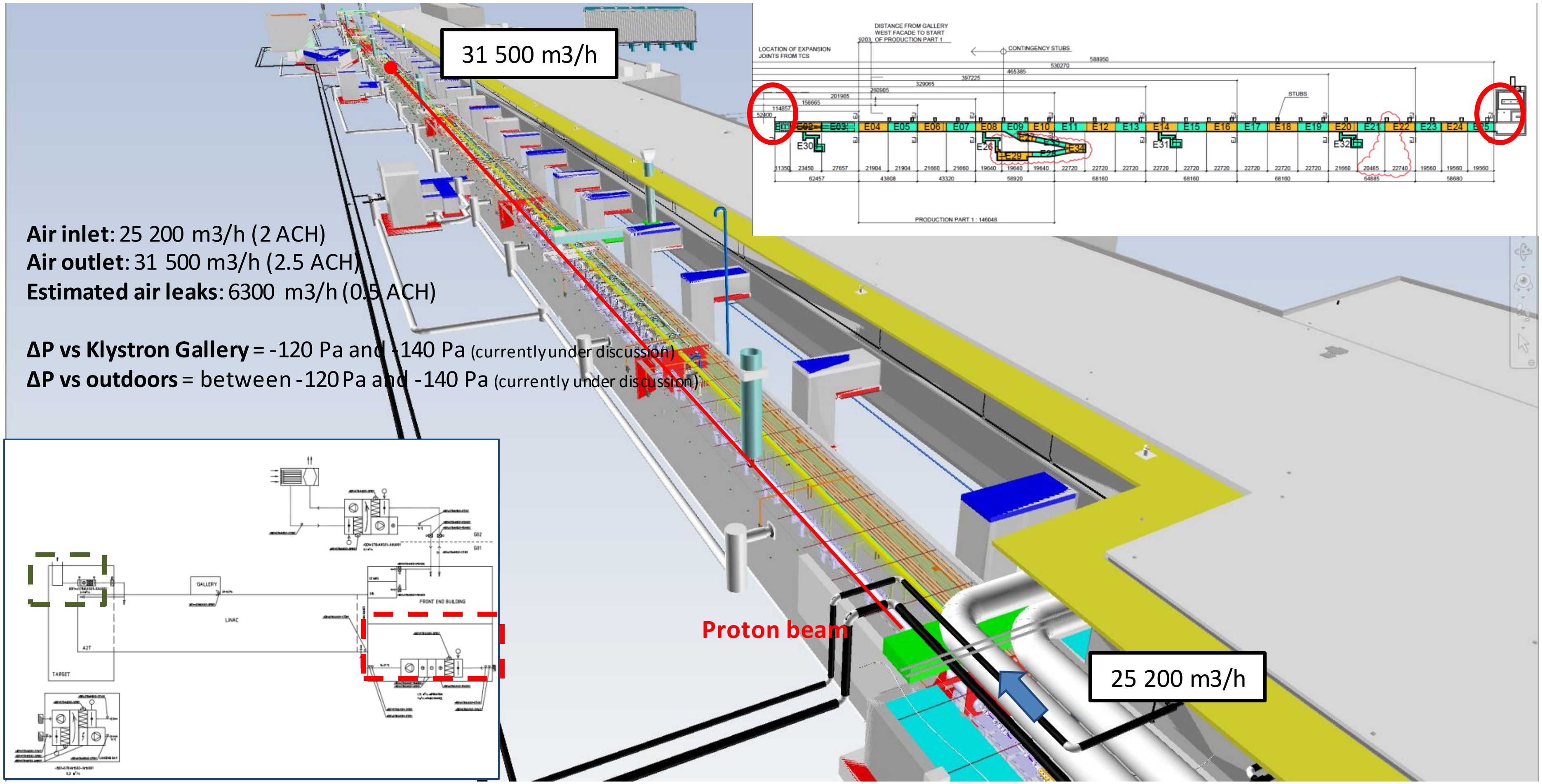
ΔP vs Klystron Gallery = -120 Pa and -140 Pa (currently under discussion)
ΔP vs outdoors = between -120 Pa and -140 Pa (currently under discussion)

ACKNOWLEDGEMENT : M.KELFVE

Accelerator Air Management System

Current Design

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

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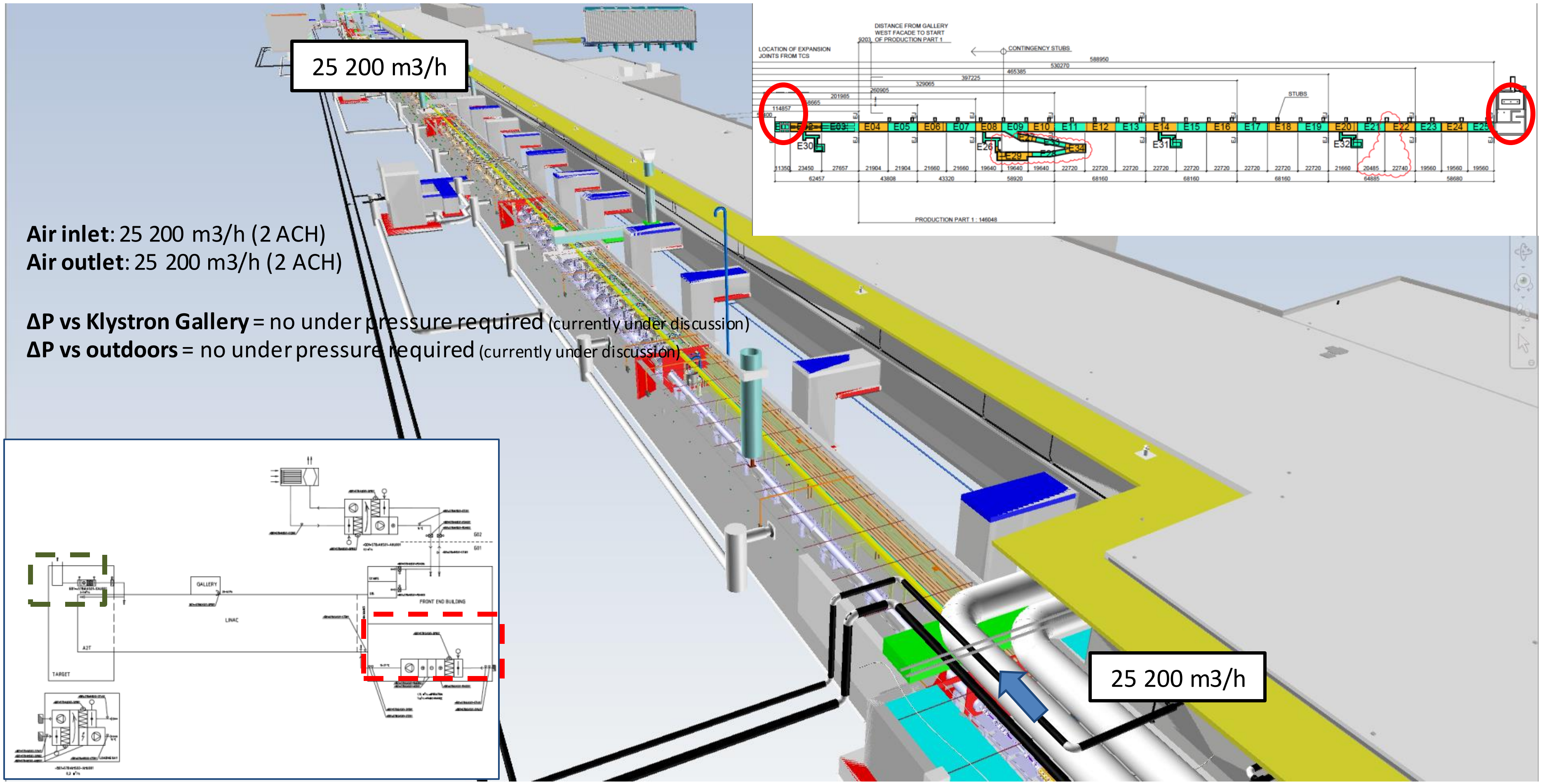
③ ACCESS MODE



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

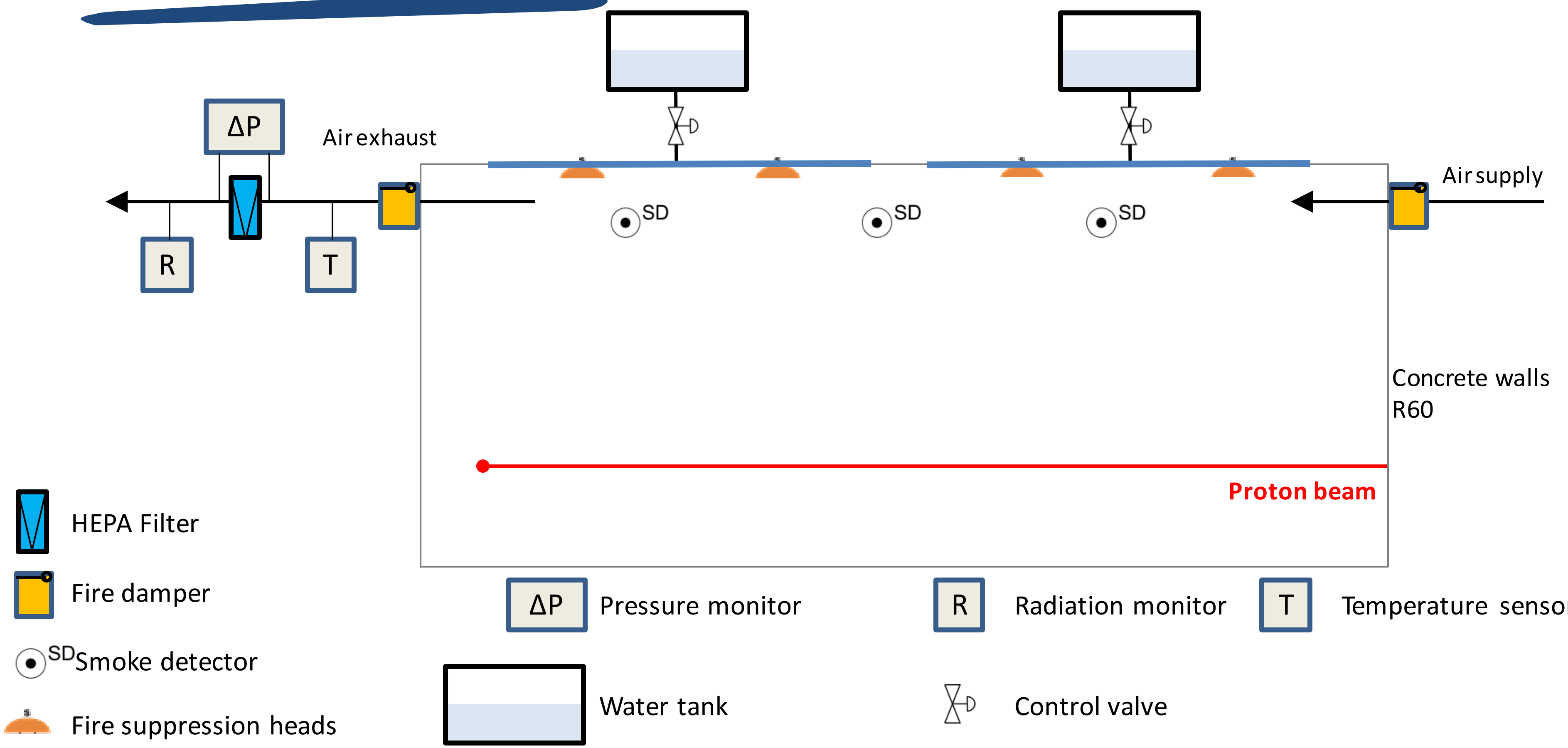
ΔP vs Klystron Gallery = no under pressure required (currently under discussion)
ΔP vs outdoors = no under pressure required (currently under discussion)

ACKNOWLEDGEMENT : M.KELFVE

Accelerator Air Management System

Fire control concept in the tunnel

Preliminary design

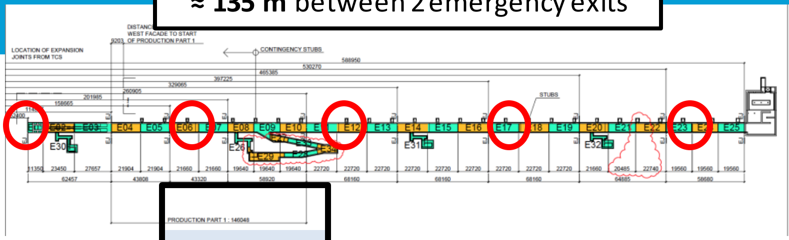


<u>Status</u>: currently under discussion with Conventional Facilities and ES&H…

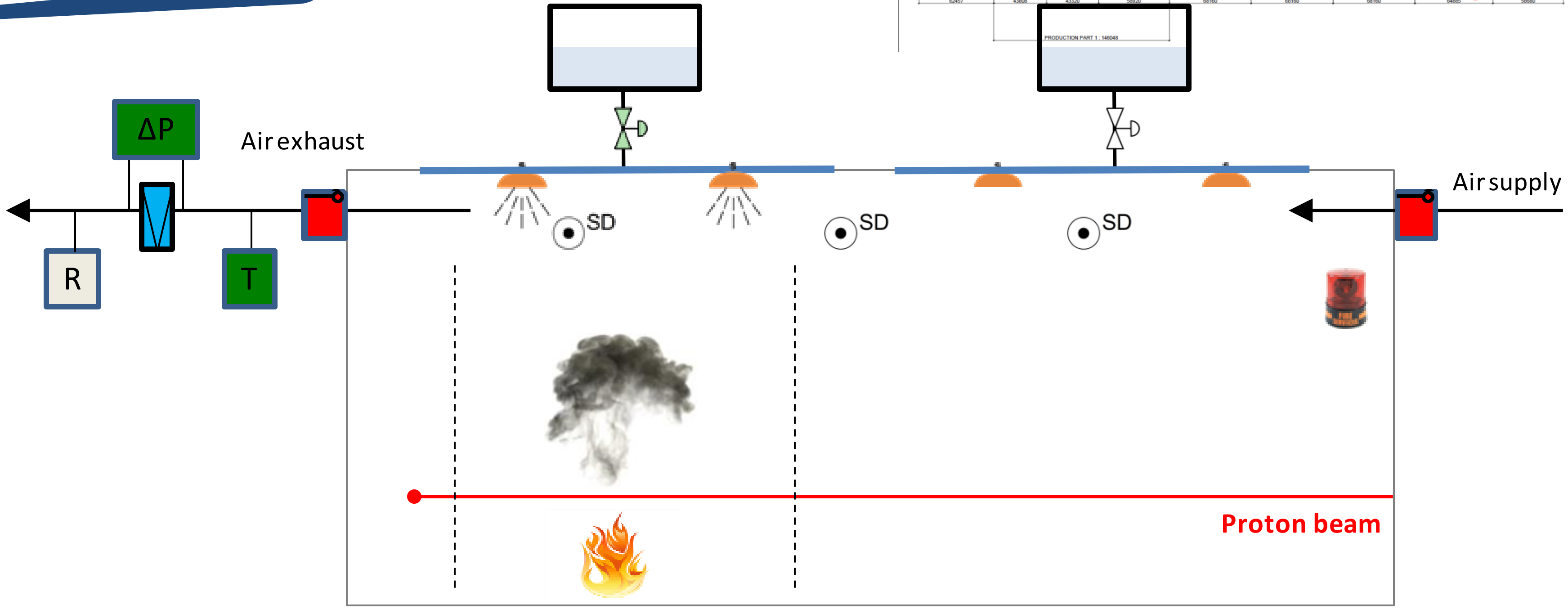
Accelerator Air Management System

Fire control concept in the tunnel

≈ **135 m** between 2 emergency exits



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:

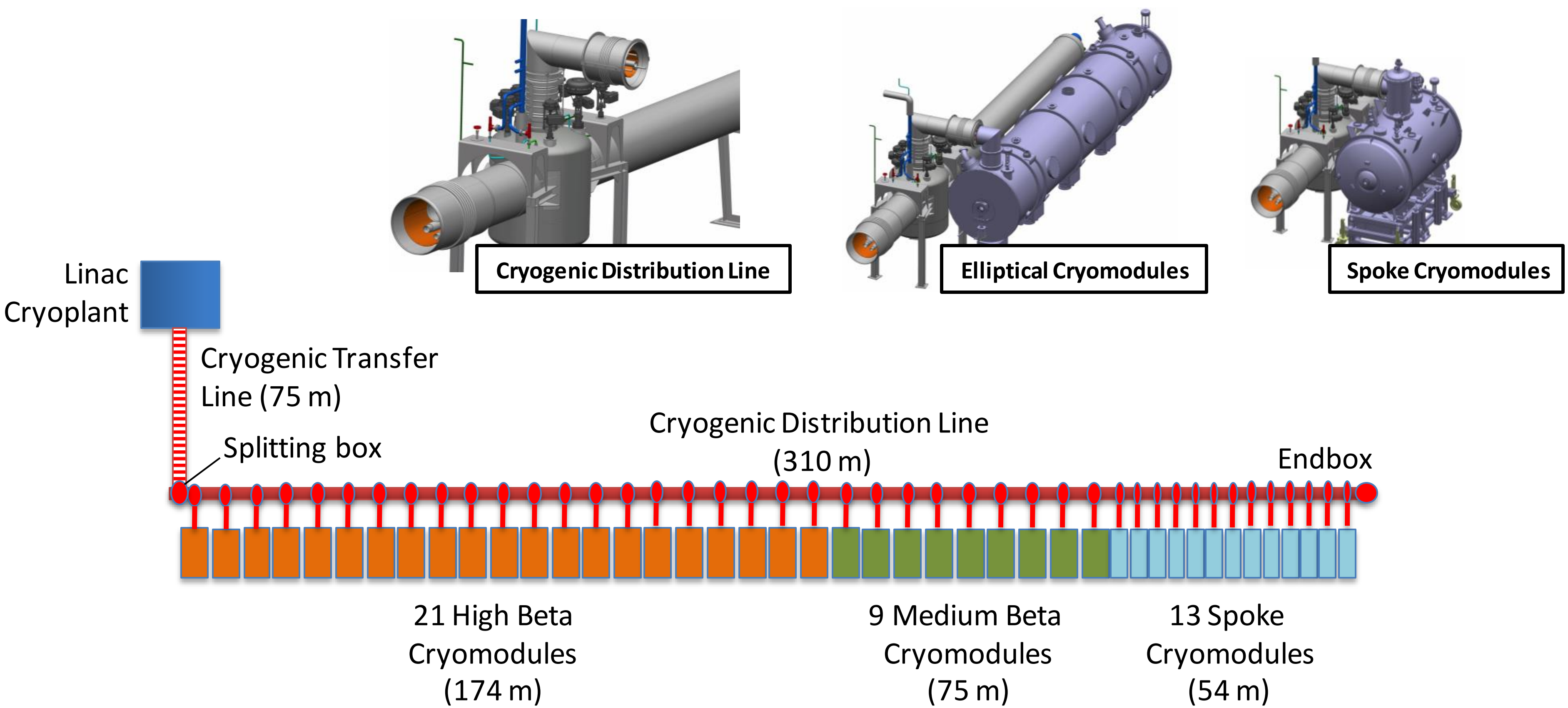
- **No standing activated water** in the tunnel
- **Double security** regarding unwanted activation
- Very well known and **reliable system** (e.g. pipe integrity monitored (air tightness))
- **Low amount of water** in case of a fire (600 l)
- Sectioned into **8 smaller subsystems**
- **Fairly low cost**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

ACKNOWLEDGEMENT : M.KELFVE

Accelerator Air Management System

Oxygen Deficiency Hazard in the tunnel

Overview of the helium inventory in the tunnel



ACKNOWLEDGEMENT : J.FYDRYCH

Accelerator Air Management System

Oxygen Deficiency Hazard in the tunnel

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

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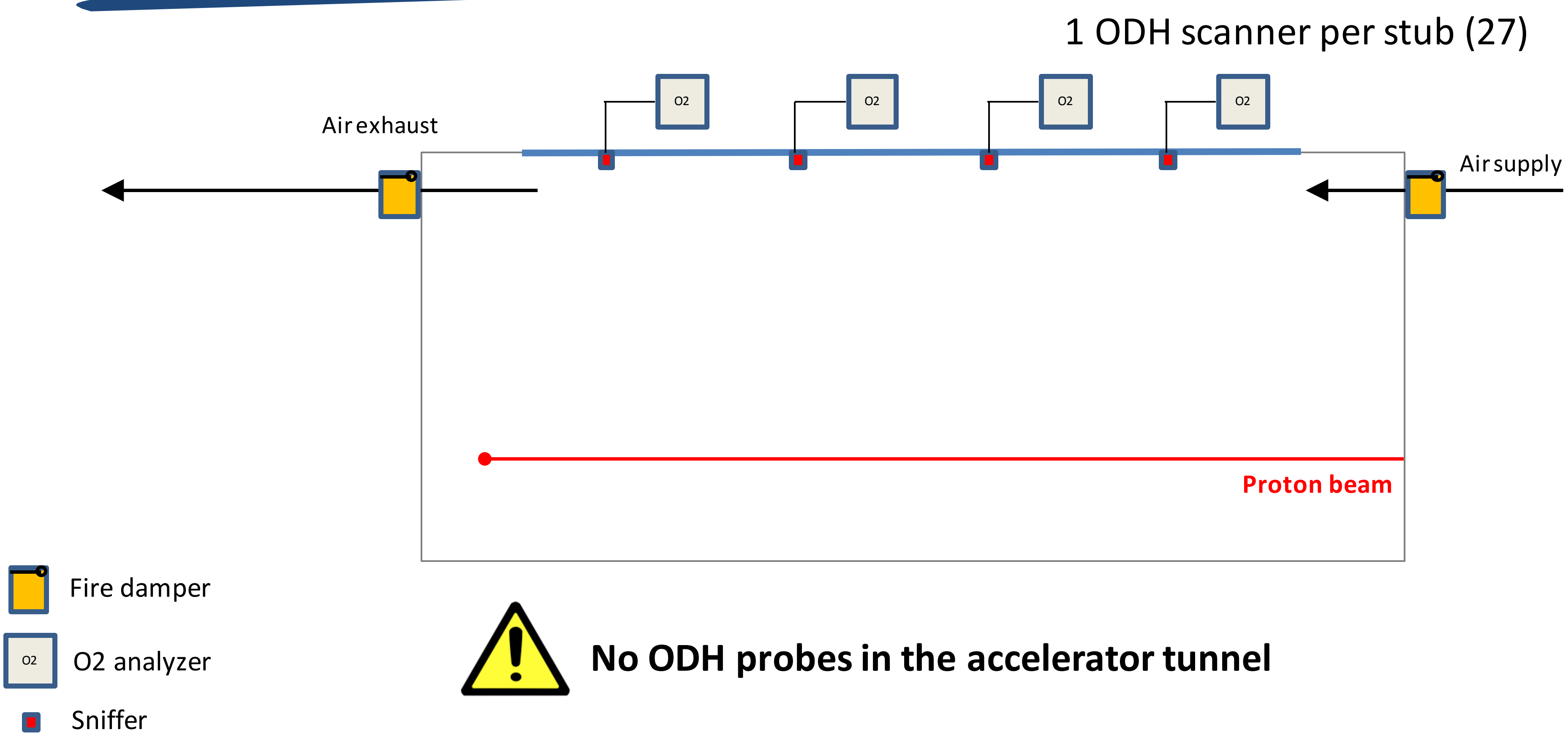
Preliminary design



No ODH probes in the accelerator tunnel

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

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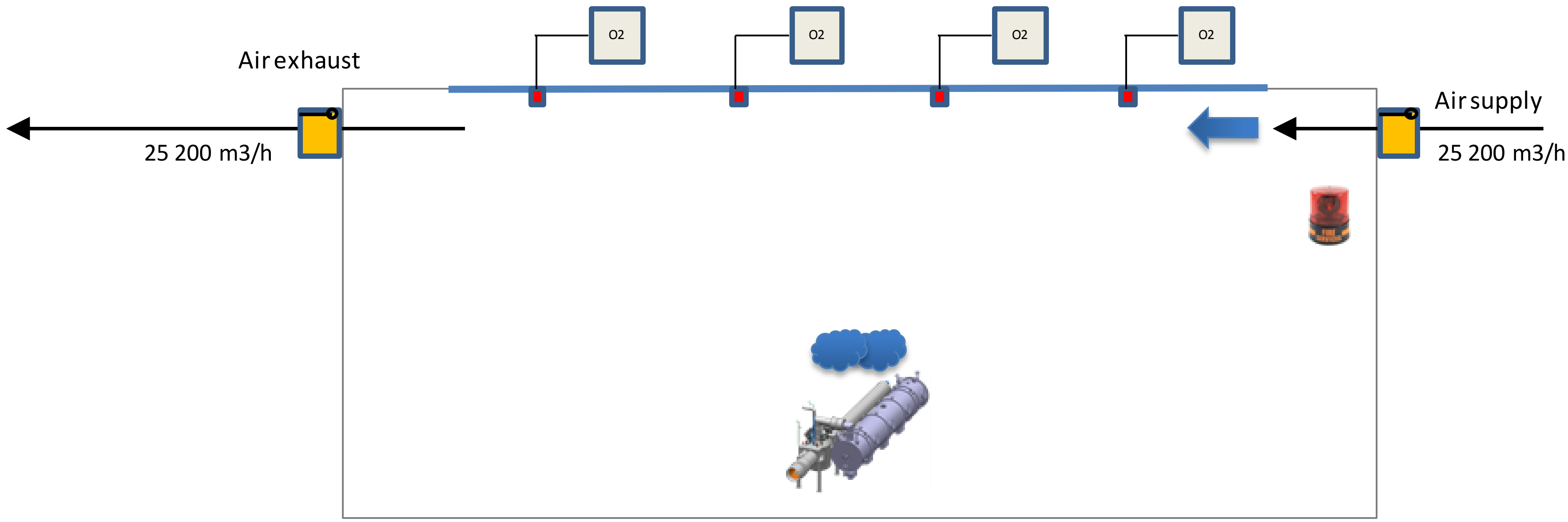
Oxygen Deficiency Hazard in the tunnel

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

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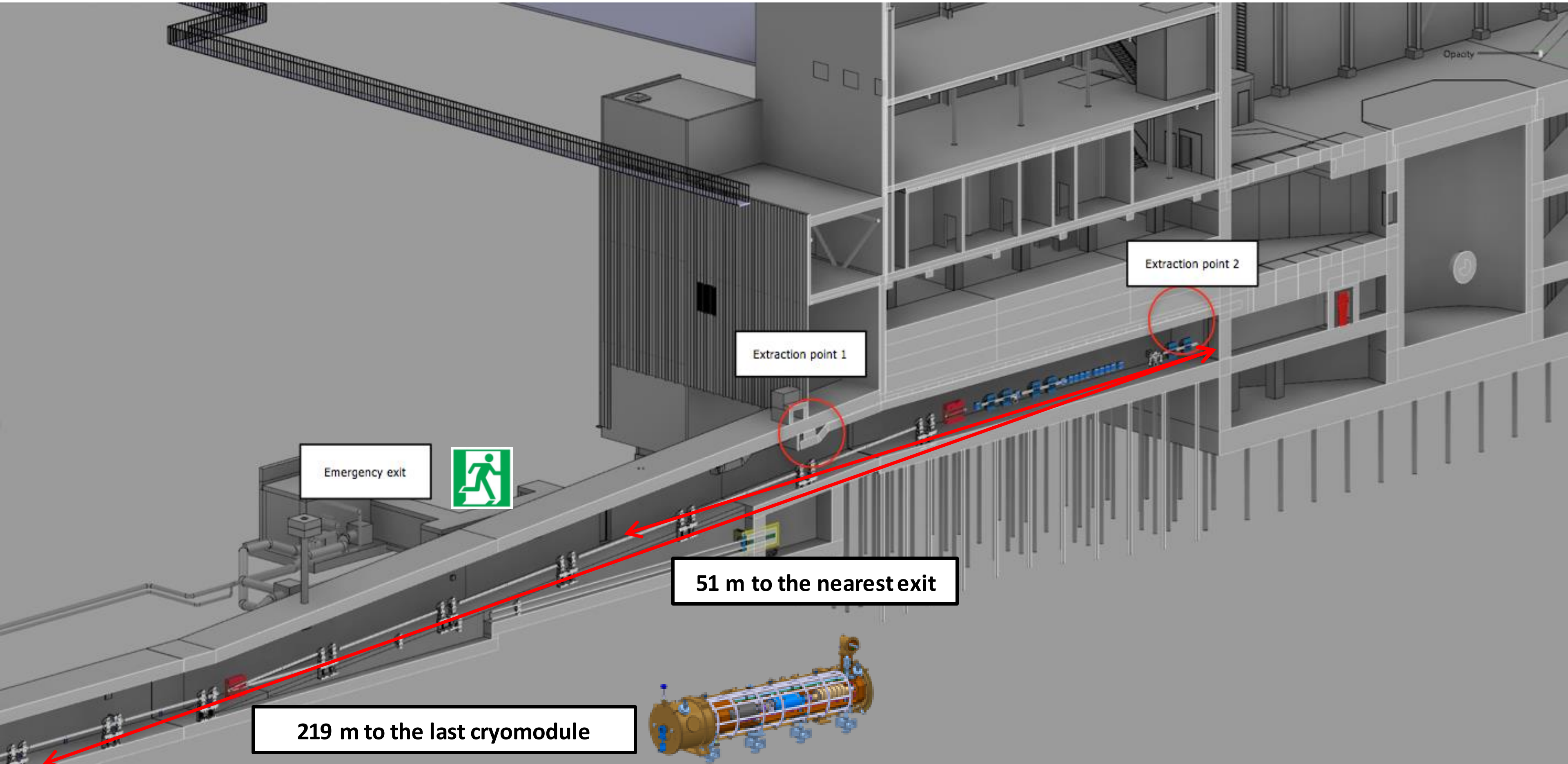
Oxygen Deficiency Hazard in the tunnel

Open issue for evacuation

ACKNOWLEDGEMENT : N.GAZIS



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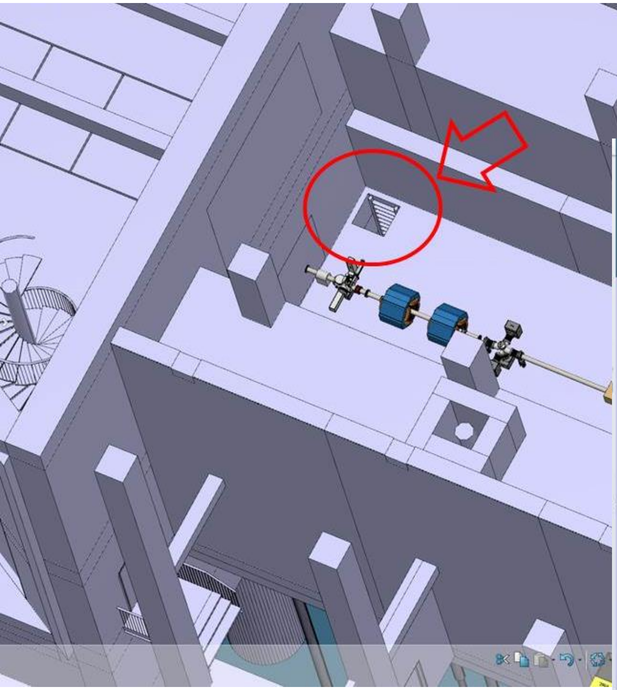
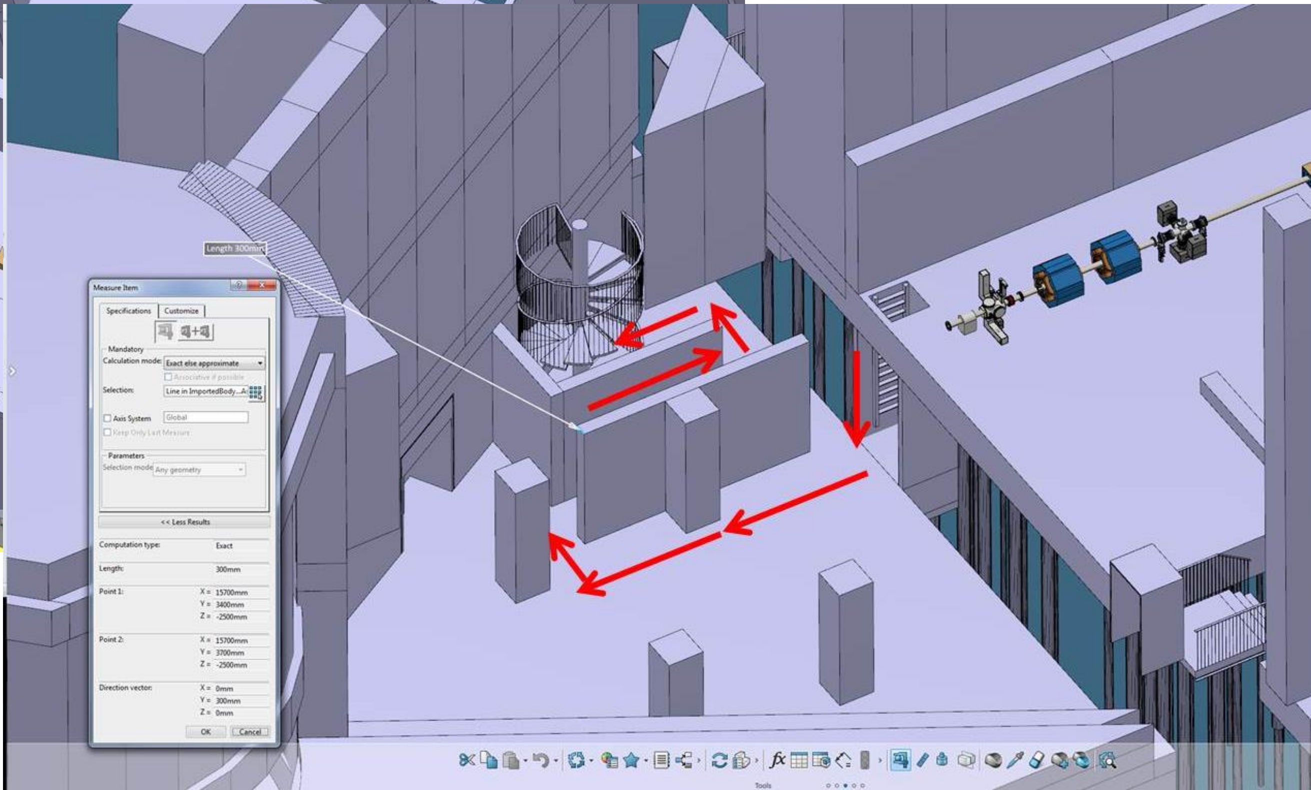
Oxygen Deficiency Hazard in the tunnel

Open issue for evacuation





ACKNOWLEDGEMENT : N.GAZIS

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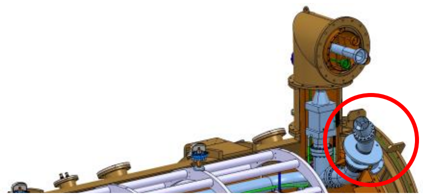
Oxygen Deficiency Hazard in the tunnel

Failure scenarios (during access)



Scenario

Rupture of the power coupler's window or beam line

↓

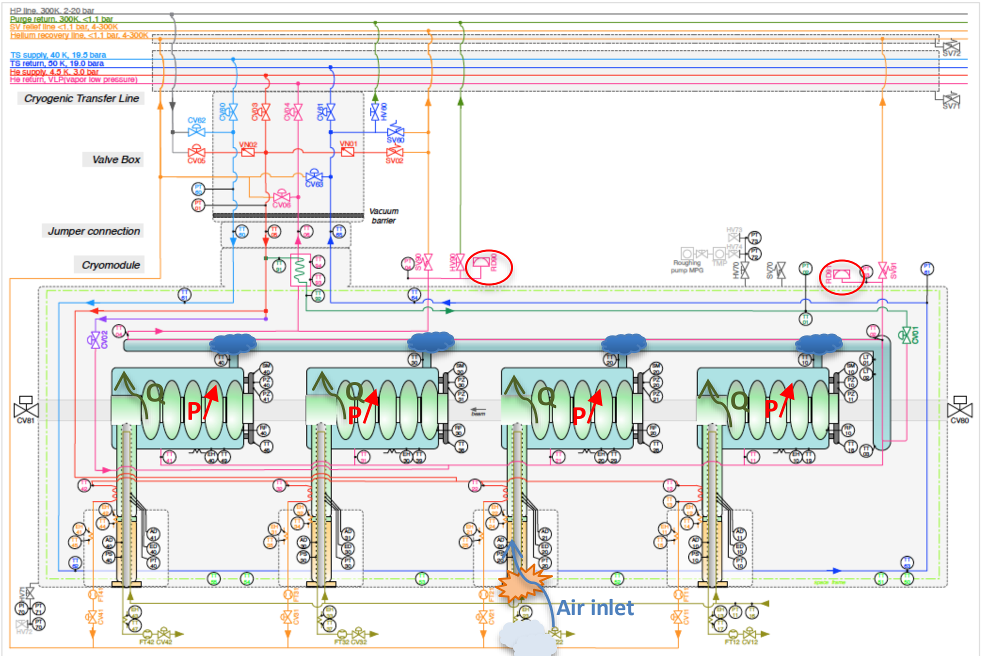
Loss of the content of 1 High-Beta* cryomodule (28,4 kg)

↓

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

↓

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



Version 20140630NE

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

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ODH p

- **Simple a**
- **Homoge** atmosph
- **Assessm** respect t

→ Lowest

$f =$

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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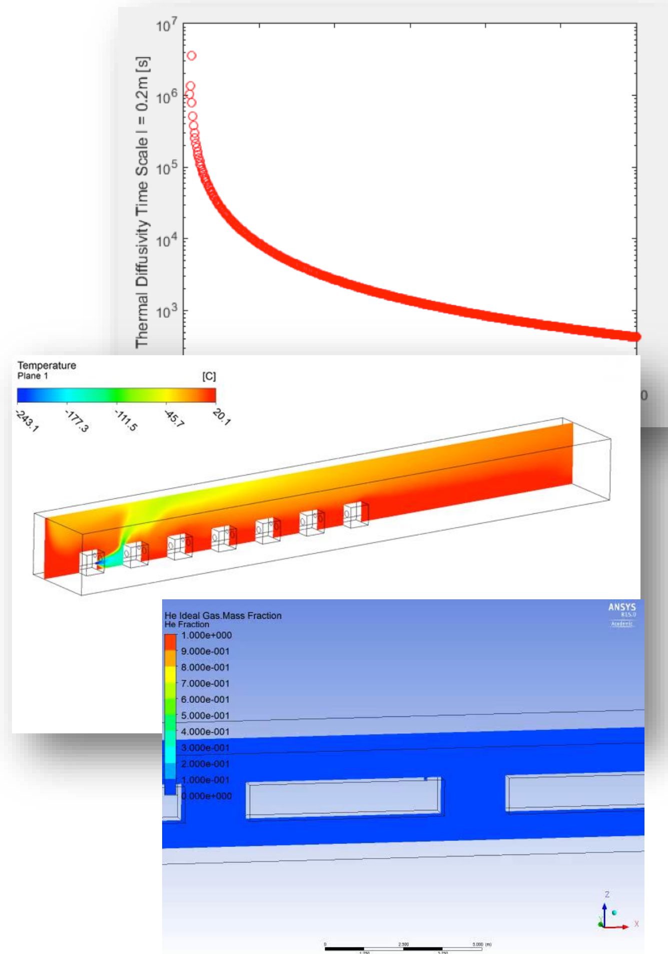
CFD simulation of Helium discharge

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

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

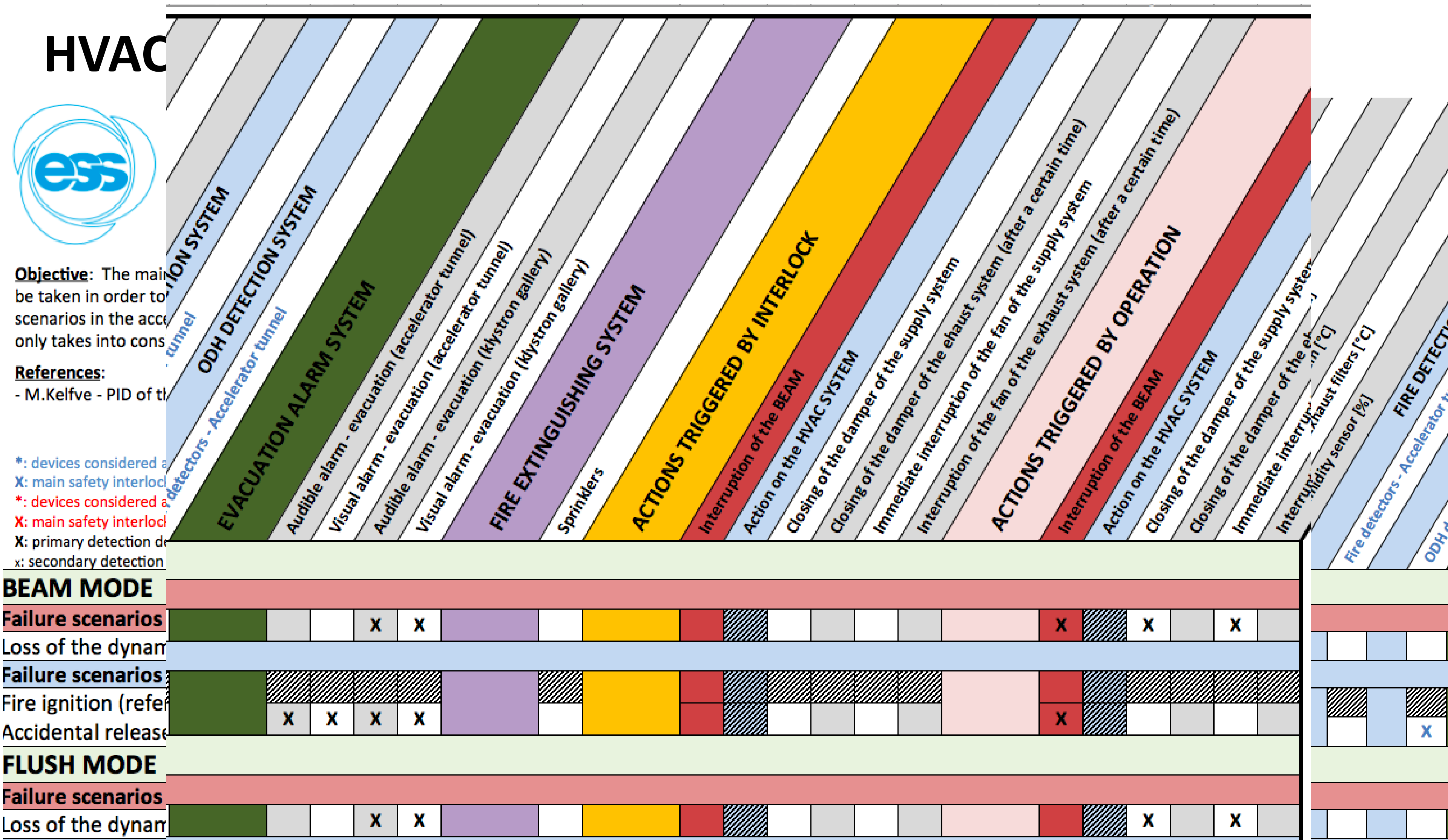
<u>Objective</u>: Provide help to Conventional Facilities (CF) in the design of the HVAC system
<u>Responsibility</u>: CF & Accelerator Divisions
<u>Time frame</u>: final version expected December

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

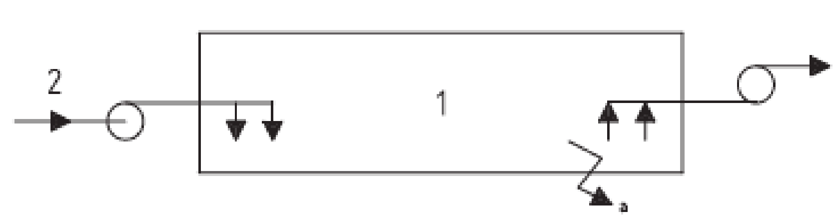
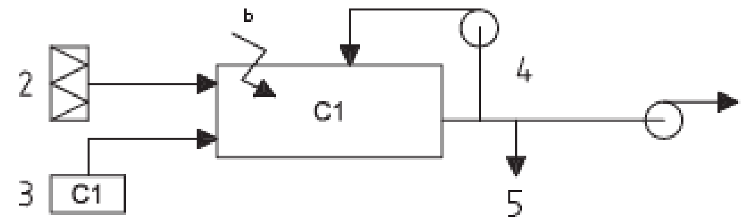
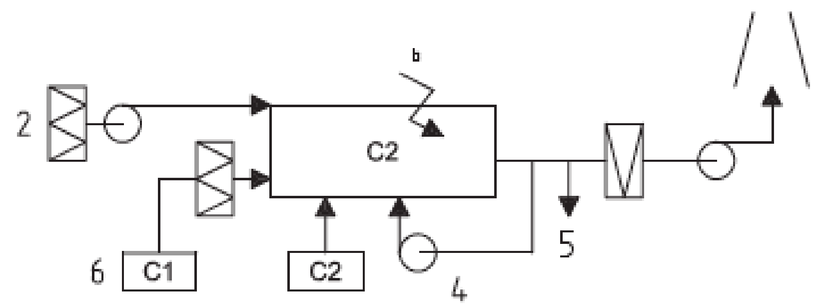
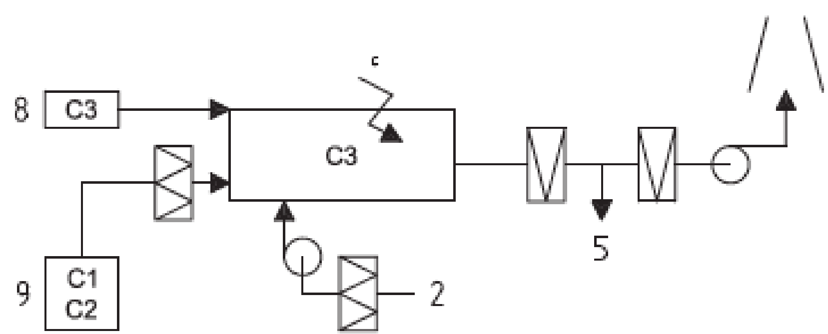
On-going Safety studies

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



Acceler

On-going

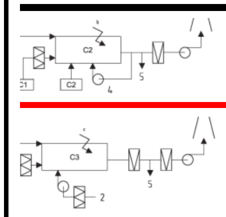
Type of ventilation	Foreseen radioactive contamination	Organization of the ventilation systems and filtration unit
Non-contaminated areas		
T I	Pc: Not significant Ac: Low	
T II A	Pc: Not significant Ac: Medium	
T II B	Pc: Not significant Ac: High	

Calculatio

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

Accelerator Air Management System

On-going Safety studies

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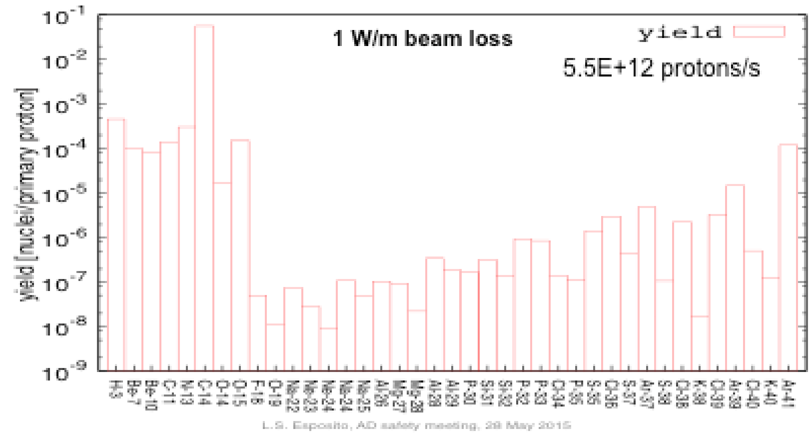
Releases of activated air: Linac

(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-37	1.09E+08	5.64E-19	1.20E-18	4.86E-19
	Ar-39	1.22E+05	2.39E-18	5.09E-18	2.06E-18
	Ar-41	9.15E+11	**8.64E-09**	**1.80E-08**	**1.69E-08**
aerosols	K-38	5.60E+09	2.13E-10	4.49E-10	3.17E-10
	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)



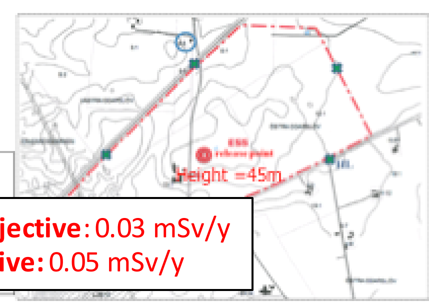
HVAC parameters: **Vol_{tunnel} = 12600 m³**

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



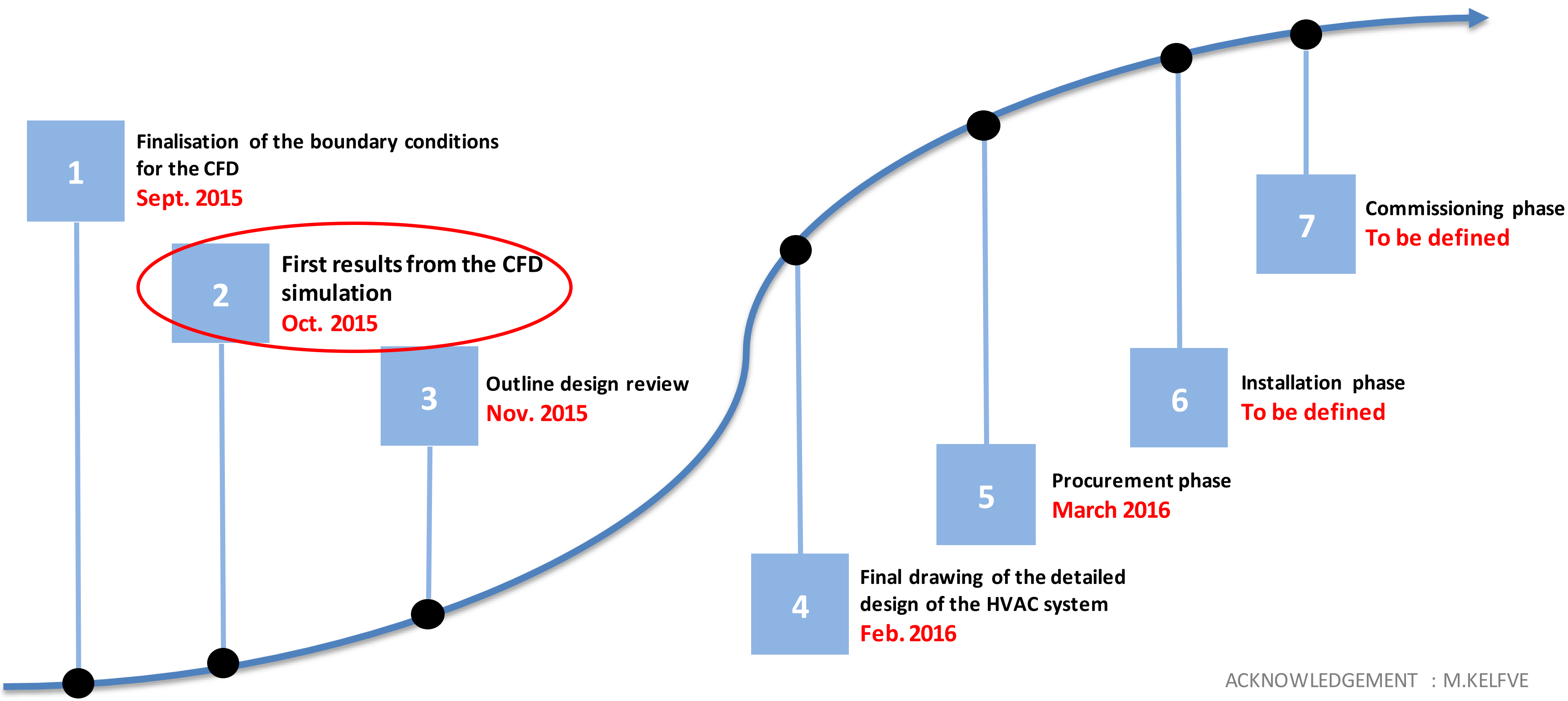
ESS Accelerator Design objective: 0.03 mSv/y
ESS General Safety Objective: 0.05 mSv/y

ACKNOWLEDGEMENT : D.ENE

Accelerator Air Management System

Milestones

HVAC timeline



ACKNOWLEDGEMENT : M.KELFVE

Discussion

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Any **Q**uestions…?

Back-up slides