Helium Vessel Cooling and Ventilation System Conceptual Design

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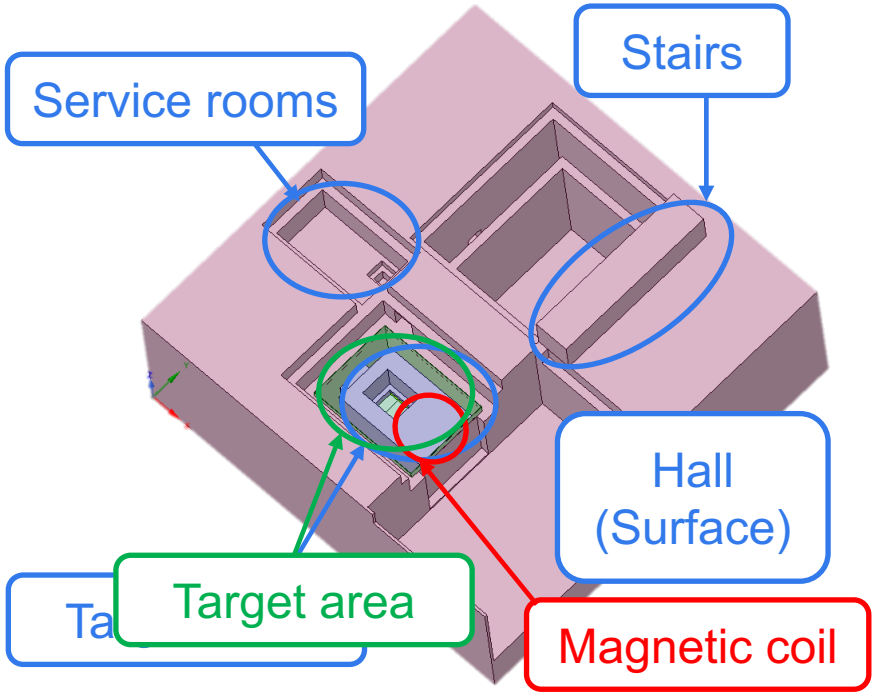
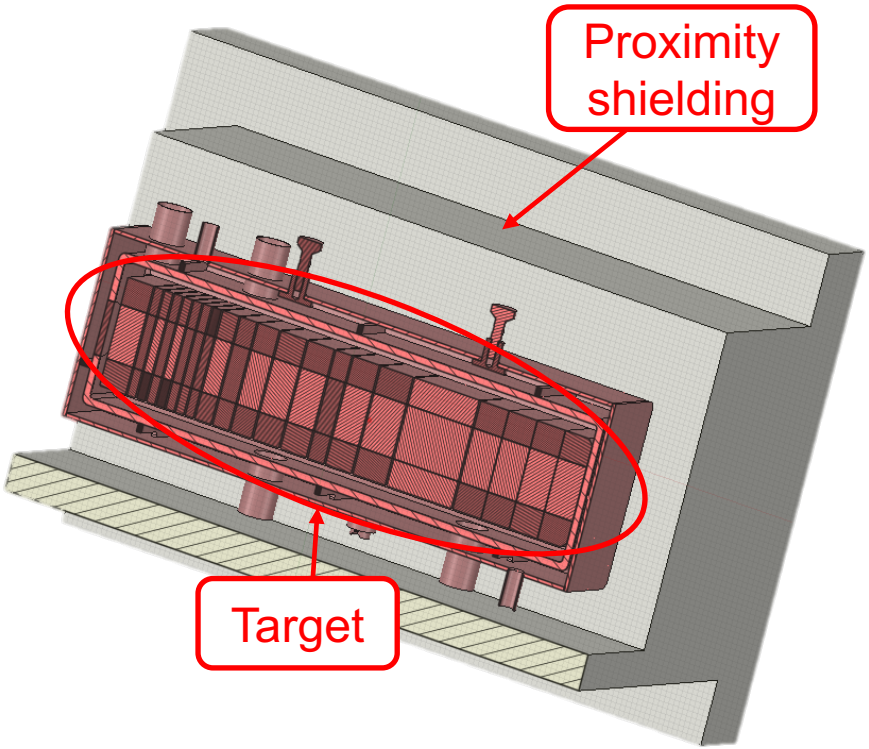
Outline

1. Beam Dump Facility CV systems overview
2. BDF Ventilation system
3. BDF Cooling system
4. Vessel Passivation
5. Conclusion

CV systems for BDF





- Ventilation: target area, service rooms, stairs, hall
- Cooling: target, proximity shielding, magnetic coil
- Passivation: target area cooling and gas purification

Let's start with the ventilation

Ventilation: Introduction

- Confinement of radioactive pollutants
  - Static: physical barriers
  - Dynamic: ventilation, pressure cascade
- ISO 17873:2004
  - "Criteria for the design and operation of ventilation systems for nuclear installations other than nuclear reactors"
  - The standard provides indications regarding the following aspects:
    1. A containment-area **classification**, from C1 to C4, defined on the base of permanent and potential levels of contamination;
    2. **Differential pressures** to be ensured in each of the zones (pressure cascade)
    3. Recommendations about **ventilation system** configurations for the different zones;
    4. A method to assess the **air change rate**;
    5. Indications relative to the ventilation behavior in a **fire scenario**.

Compartment Classification

- Classification tables:
  1. Permanent surface contamination (Bq/cm2)
  2. Permanent airborne contamination (%DAC)
  3. Accidental airborne contamination (%DAC)

RP analysis to determine the parameters that allow the classification.

No C4 compartment for BDF

Containment class	Surface contamination (Bq·cm^{-2}) 1	
	Alpha emitters of other toxicity [a]	Beta/gamma emitters and alpha emitters of low toxicity [b]
C1	Determined locally at each site, in agreement with the regulatory body ALARP but not exceeding C2 levels	
C2	Contamination level < 0,4	Contamination level < 4
C3	0,4 < Contamination level < 4,0	4 < Contamination level < 40
C4	Contamination level > 4	Contamination level > 40

[a] The definition of radiotoxicity corresponds to that given in the IAEA Safety Standards Series No. TS-R-1 (ST-1, Revised): *Regulations for the Safe Transport of Radioactive Material.*

[b] Low toxicity alpha emitters are: natural uranium; depleted uranium; natural thorium; uranium-235 or uranium-238; thorium-232; thorium-228 and thorium-230 when contained in ores or physical and chemical concentrates; or alpha emitters with half-lives of less than 10 days.

Containment class	Airborne contamination in normal conditions (% of DAC over a working year period) 2
C1	ALARP [a] principles and in any case < 10 %
C2	10 % < contamination level < 30 %
C3	30 % < contamination level < 100 %
C4	Contamination level > 100 %

[a] As Low as Reasonably Practicable.

Type of ventilation	Expected normal permanent contamination (Pc)	Potential accidental contamination (Ac) 3	Containment-areas classification
I	0	⩽ 1	C1
II A	⩽ 1	⩽ 80	C2
II B	⩽ 1	⩽ 4 000	C3
III A	⩽ 80	⩽ 4 000	C4*
III B	⩽ 4 000	⩾ 4 000	C4**
			C4***

This leads to the definition of the pressure levels

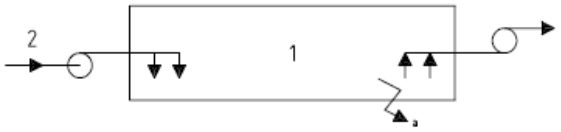
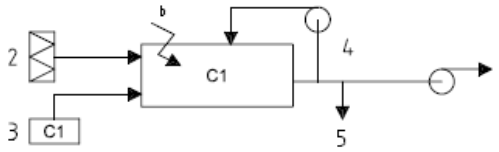
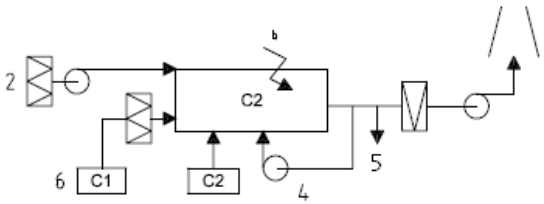
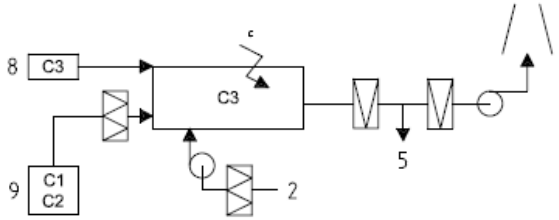
Pressure Cascade Definition

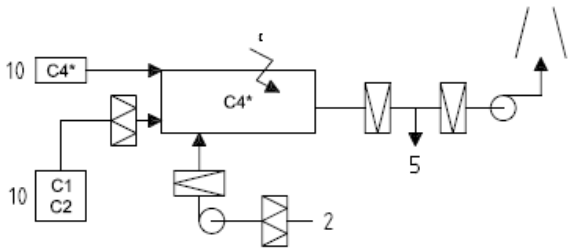
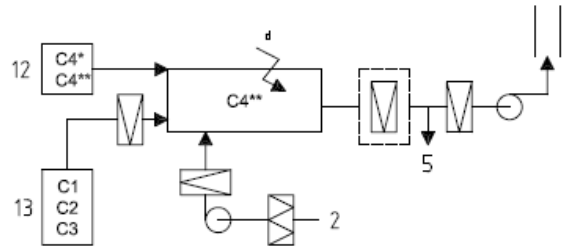
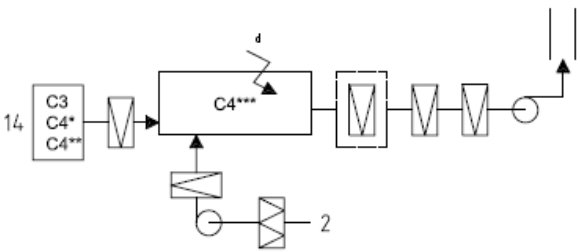
Nature of room or area	Depression value [a]	Containment class
Non-controlled rooms or areas free from contamination	Atmospheric pressure or small overpressure	Unclassified
Supervised areas with low levels of surface or airborne contamination	Less than 60 Pa	C1
C1 should be uncontaminated in normal operations		
Controlled areas with moderate levels of surface or airborne contamination	80 to 100 Pa	C2
Controlled areas with high levels of surface or airborne contamination	120 to 140 Pa	C3
Controlled areas with very high levels of surface or airborne contamination	220 to 300 Pa	C4
Areas which are not accessible except under specific circumstances		
[a] Compared to the reference pressure.		

- Pressure levels can be customized based on the specific layout of compartments
- Important to ensure high-to-low pressure for connected volumes
- Minimum suggested pressure difference: 40 Pa

…followed by the definition of the ventilation type

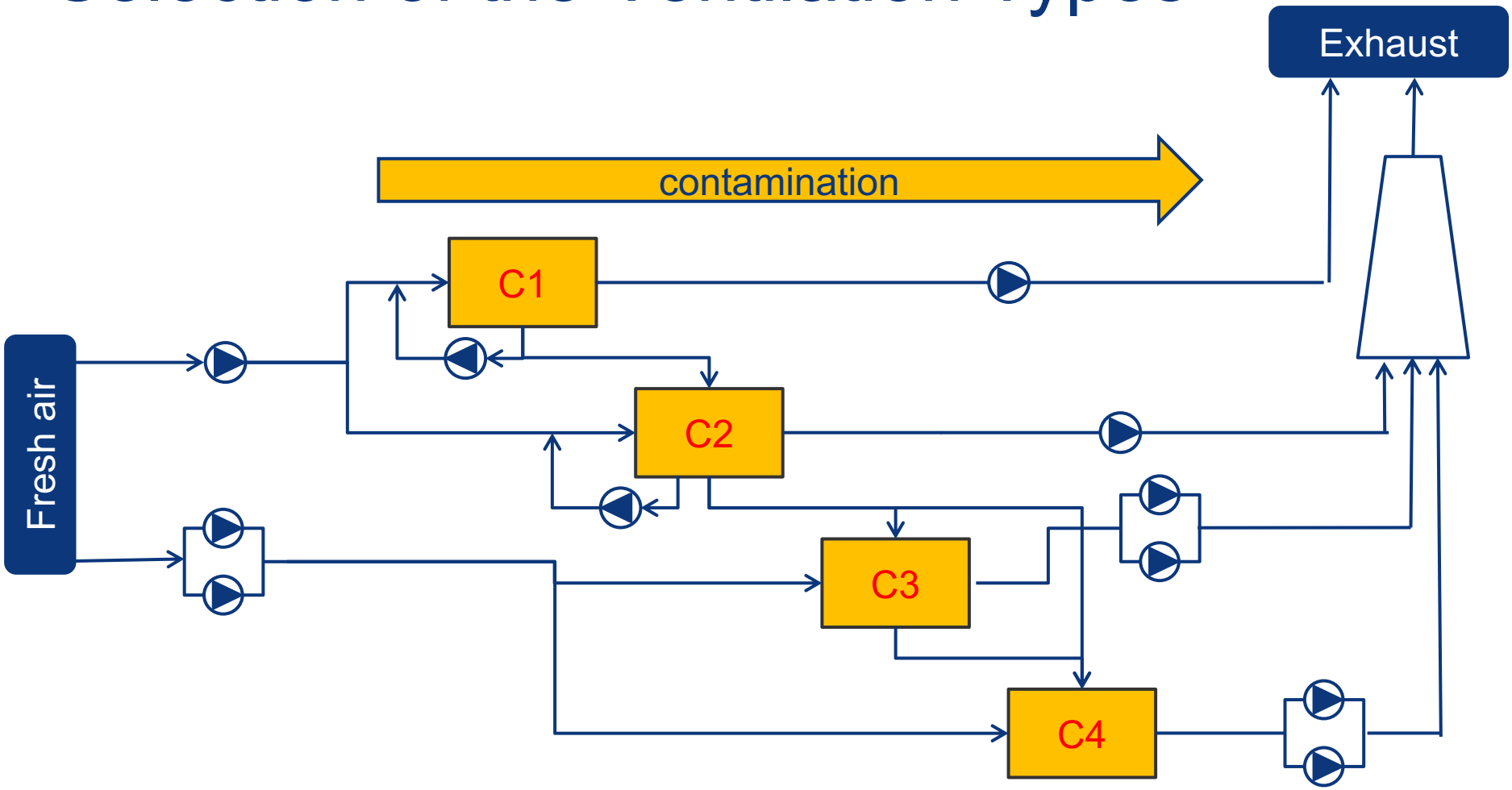
Selection of the Ventilation Types

Type of ventilation	Foreseen radioactive contamination	Organization of the ventilation systems and filtration unit
Non-contaminated areas		
C1 T I	Pc: Not significant Ac: Low	
C2 T II A	Pc: Not significant Ac: Medium	
C3 T II B	Pc: Not significant Ac: High	

Type of ventilation	Foreseen radioactive contamination	Organization of the ventilation systems and filtration unit
C4* T III A	Pc: Medium Ac: High	
C4** T III B	Pc: High Ac: Very high	
C4*** T IV	Pc: Very high Ac: Very high	

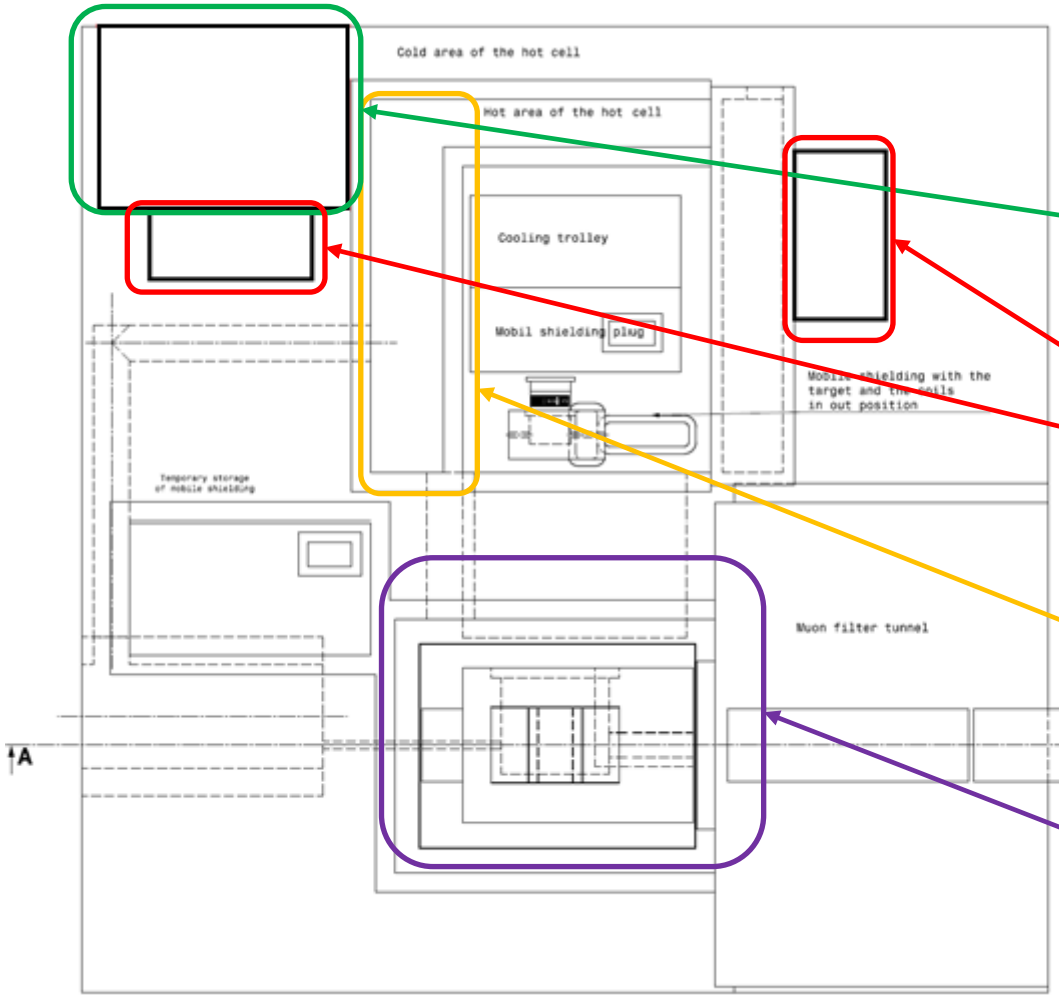
Ventilation systems are then integrated

Selection of the Ventilation Types



Let's see how all this applies to BDF configurations

Classification and Pressure Cascade for Trolley Configuration



Surface building: C1
-20 Pa

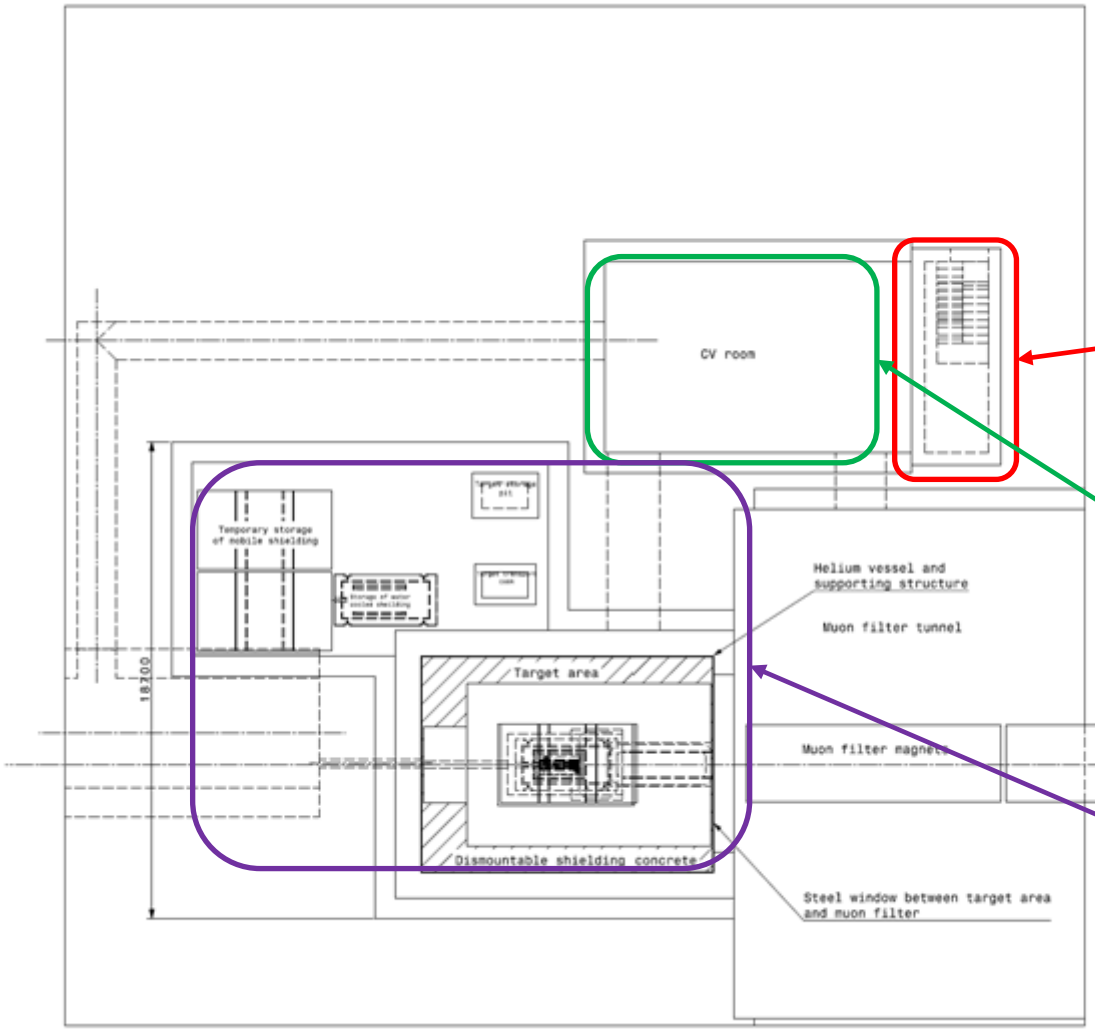
CV room: C2
-80 Pa

Stairs: C1
-40 Pa

Hot area: C1
-60 Pa

Target area: C2
-100 Pa

Classification and Pressure Cascade for Crane Configuration



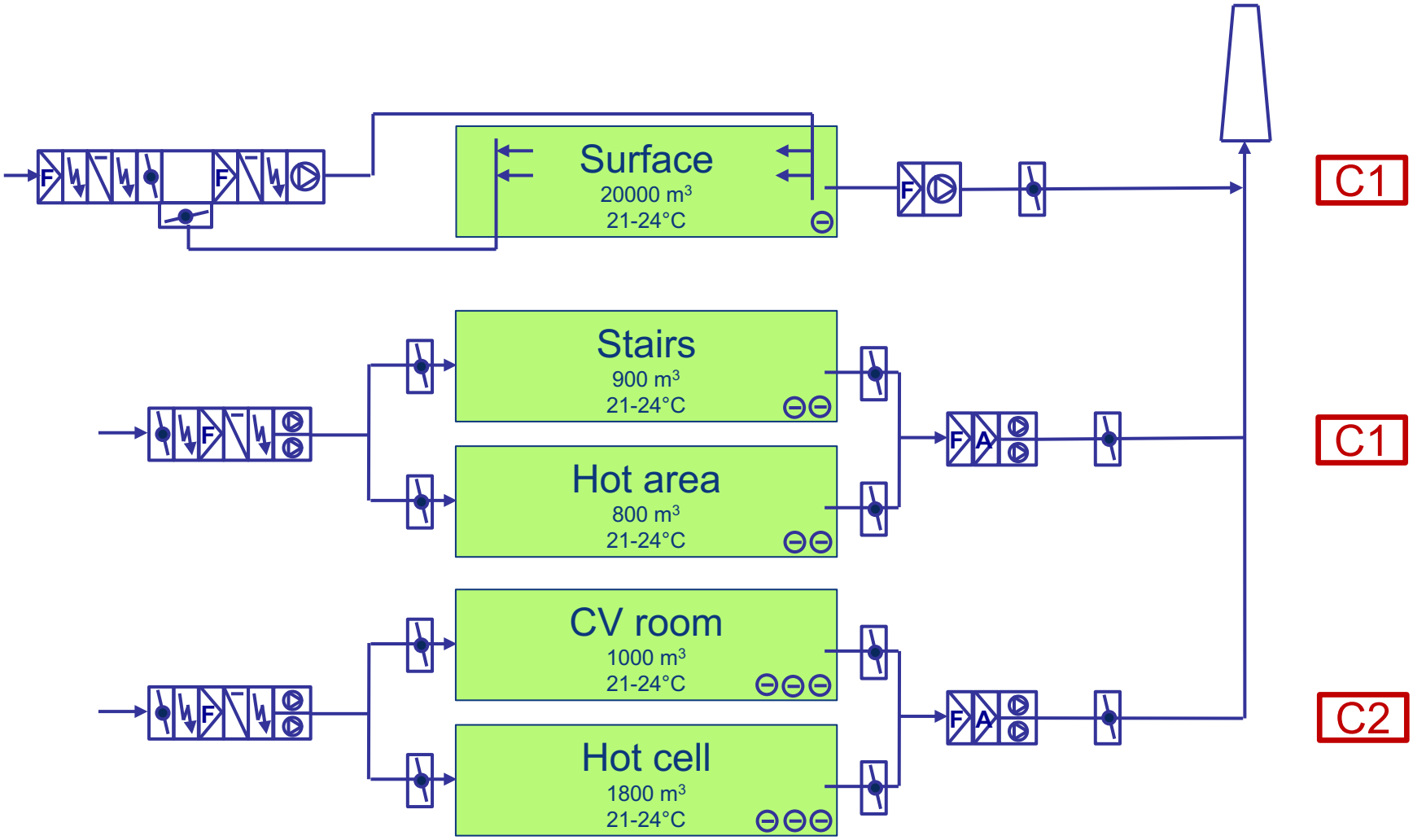
Surface building: C1
-20 Pa

Stairs: C1
-40 Pa

CV room: C1
-60 Pa

Target area: C2
-80 Pa

Preliminary P&ID for Trolley configuration



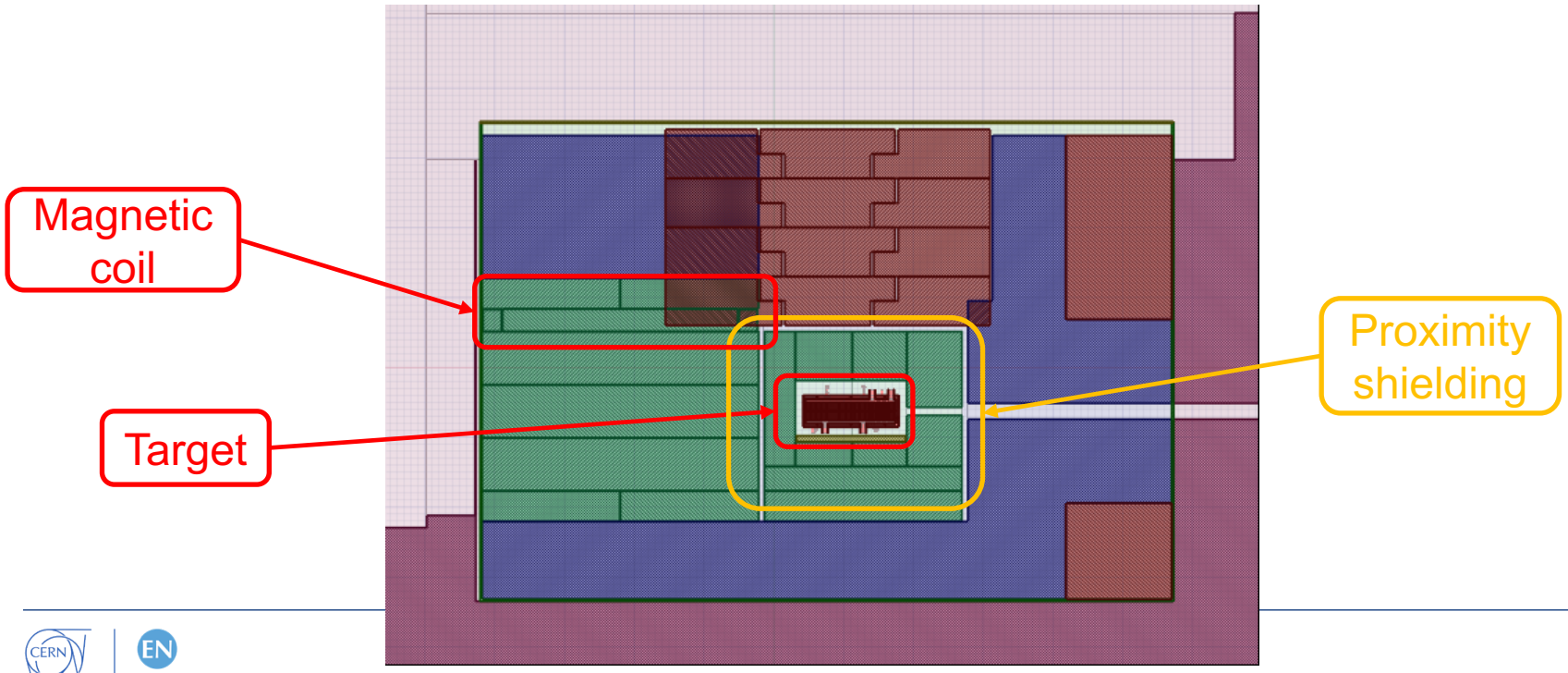
Ventilation: Next Steps

1. Collect the user requirements (heat load, humidity);
2. Define air change rates (flow rates);
3. Finalize P&ID and systems integration;
4. Size components;
5. Propose preliminary integration;
6. Perform cost estimate.

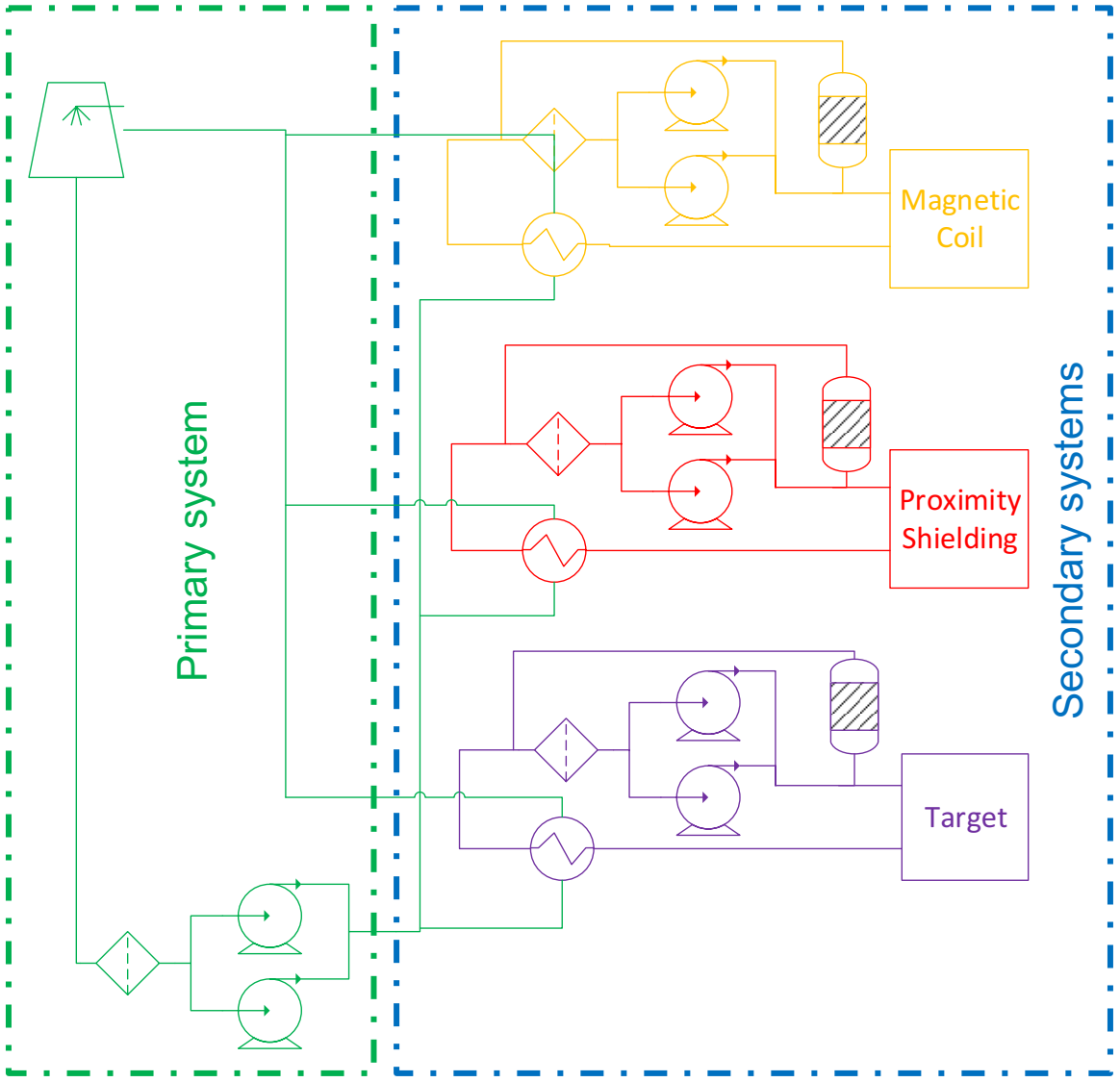
The equipment requires cooling…

Cooling User Requirements

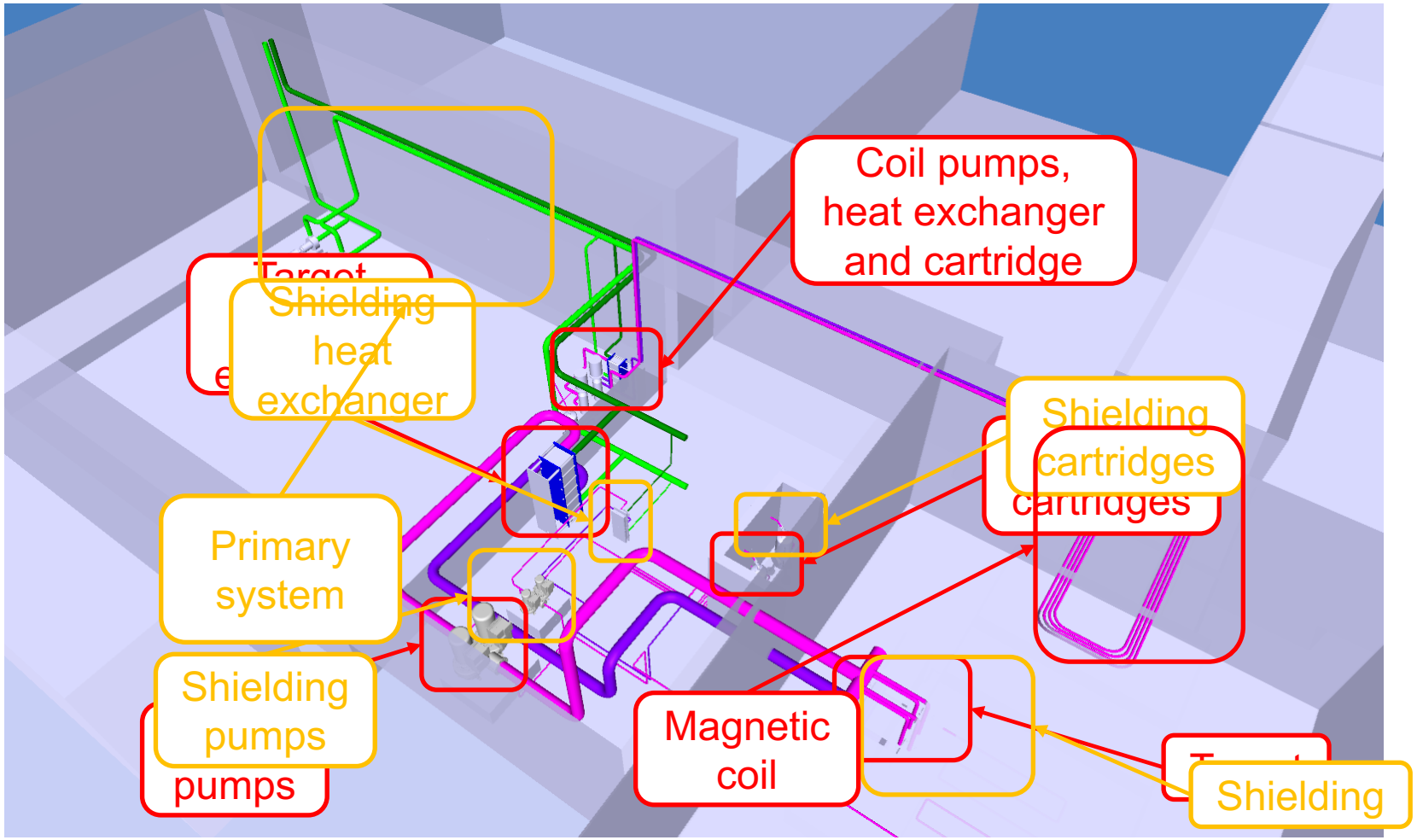
	Power [kW]	T_{in} [°C]	T_{out} [°C]	Flow rate [m^3/h]	Pressure [bar]
Target	350	28	29.5	200	20
Proximity Shielding	20	28	36.7	2	20
Magnetic Coil	150	28	36.7	15	20



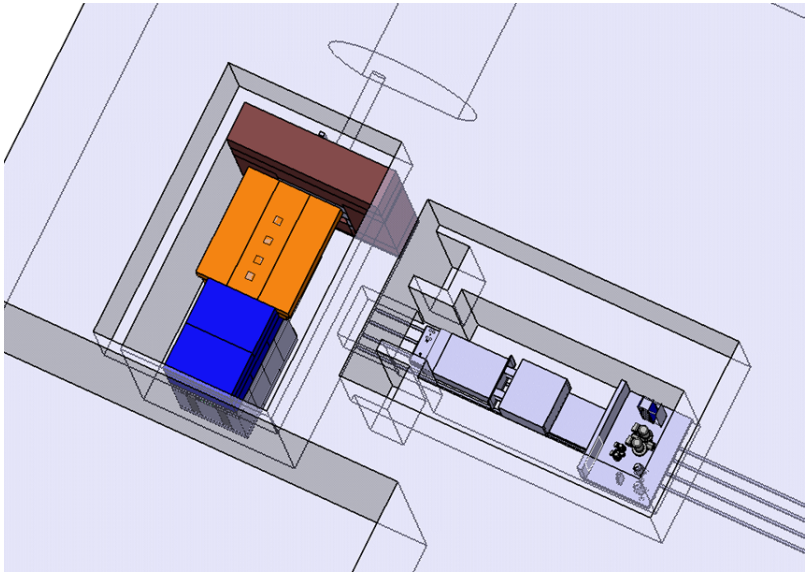
Cooling: Preliminary P&ID



Cooling: Preliminary Integration



Cooling: Trolley version

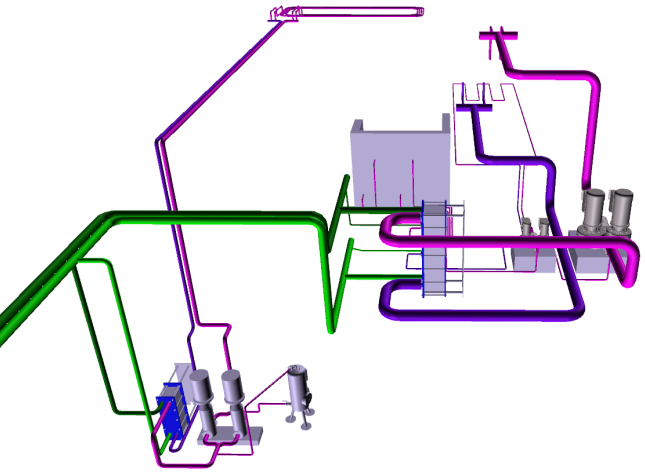


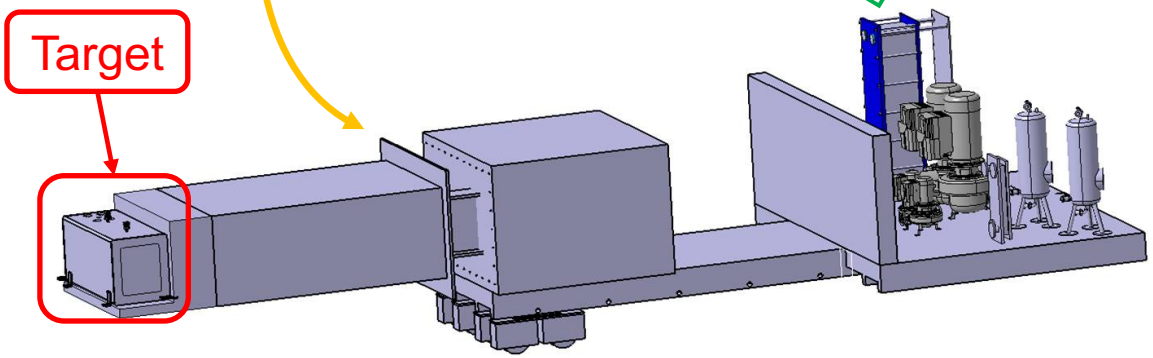
Components on trolley:

- Target cooling system
- Partial shielding cooling system
- Target He gas insulation
- Other services

Helium door:

- Shall be leak tight
- Shall allow for trolley translation





The target chamber needs helium passivation

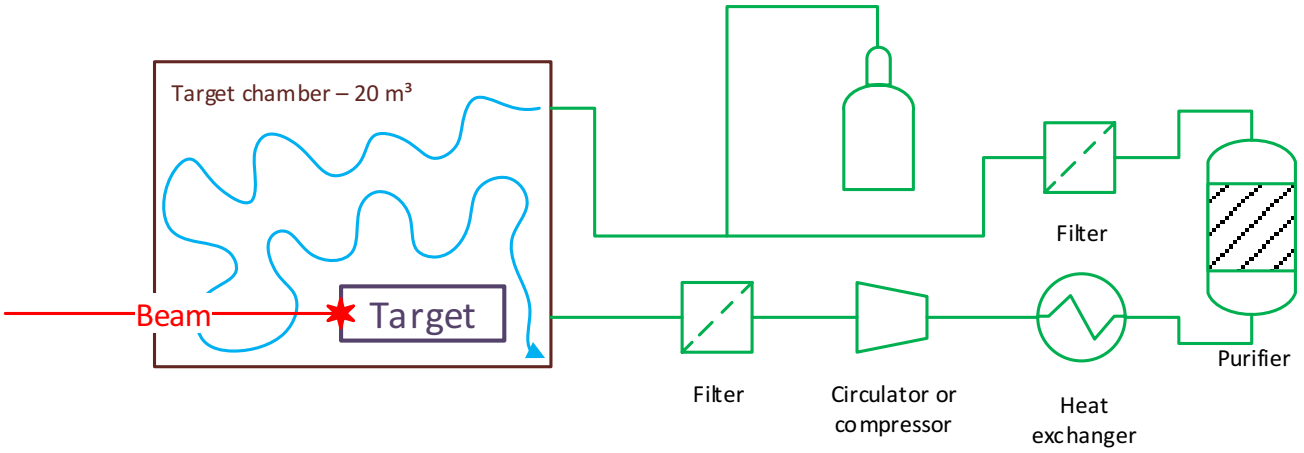
Passivation: Introduction

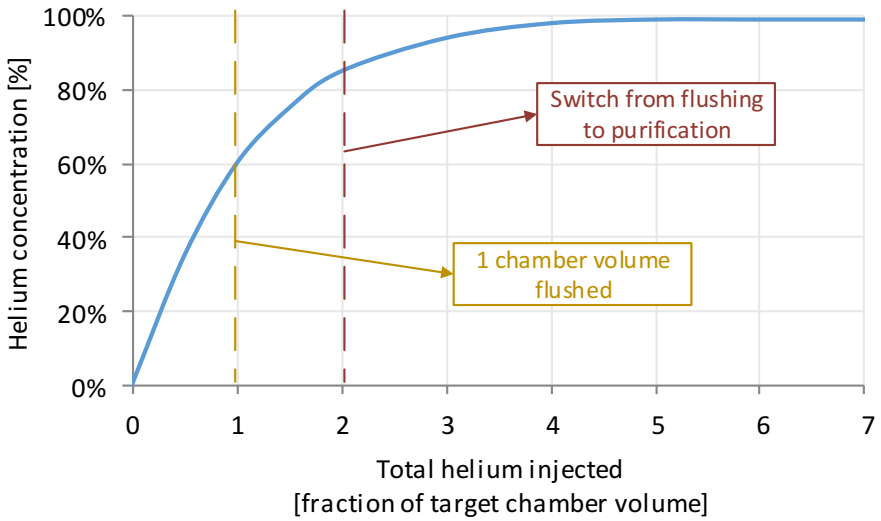
- Passivation/purification helps to:
  - Reduce activation;
  - Increase operational life of materials;

Vacuum + injection (JPARC);	He Flush + Regeneration (under investigation)	CO2 or N2 Flush + He Flush + Regeneration

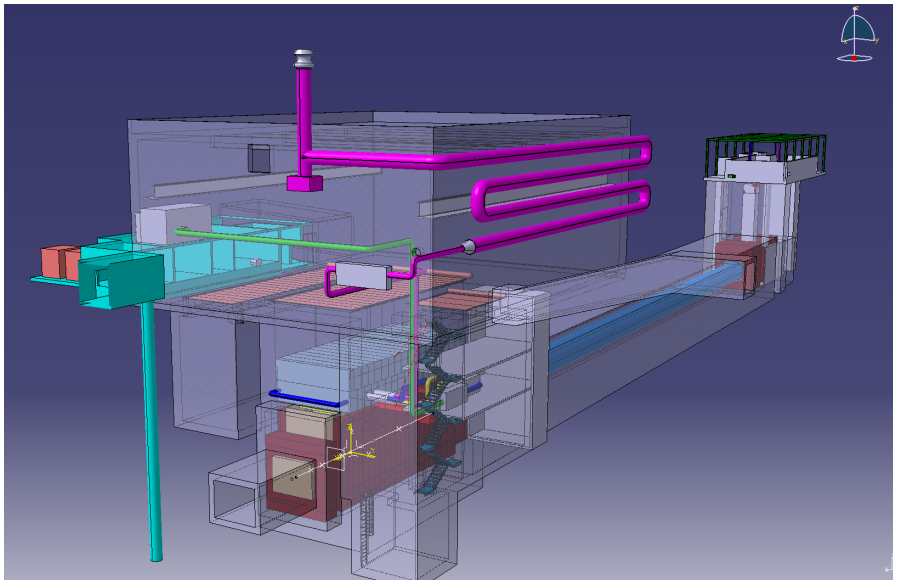
Thanks to Larry and this NBI workshop

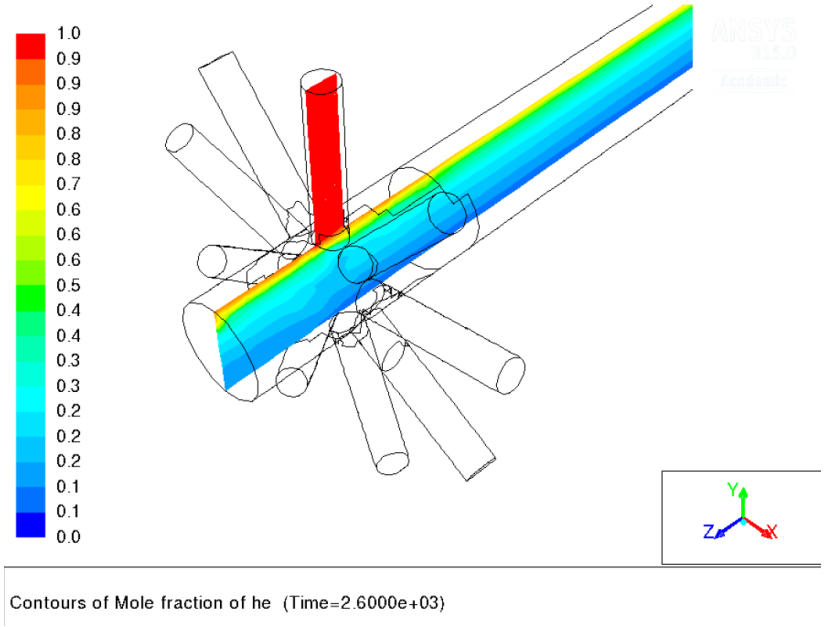
Passivation: Principle





Passivation: CENF Experience

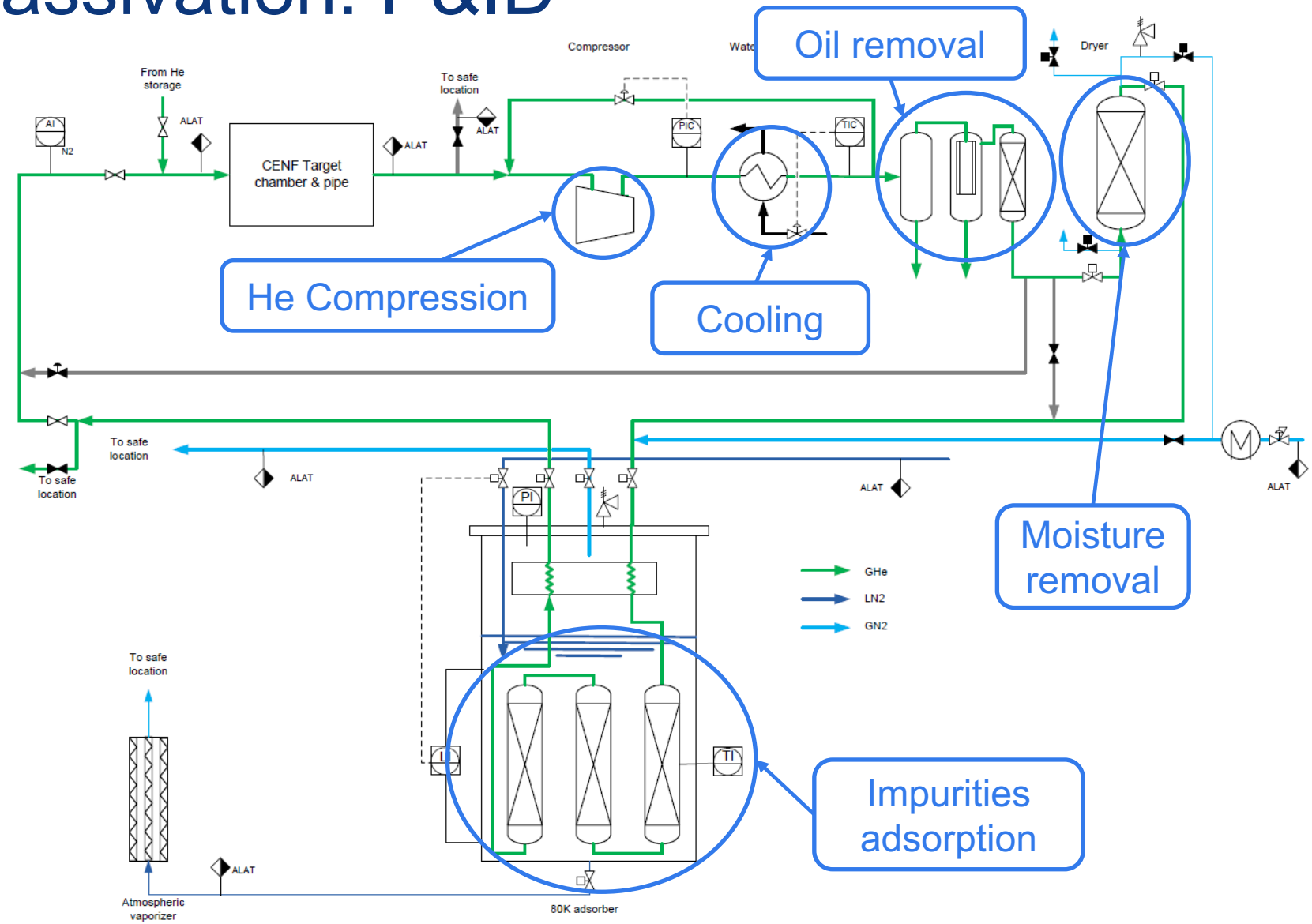




BDF profits from CENF experience

- Larger experiment and facility: more helium needs to be purified than for BDF;
- Other than size (1100 m^3 vs 20 m^3), conditions are similar.

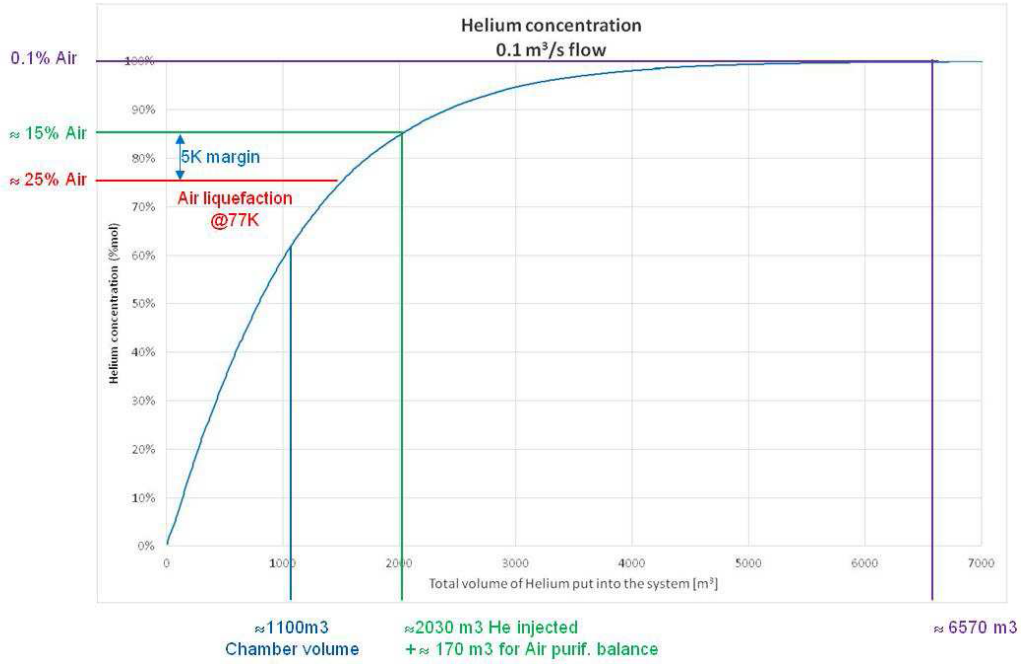
Passivation: P&ID



Passivation: Initial flush

Initial flush requires helium:

- Helium price: ~10 € /m^3;
- Saving 4000 m3 (CENF) means saving about 40 k€.



Requirements and open points:

- Time required for purification: few days;
- Need for refrigeration and purification phase;
- Need to regenerate cryogenic traps;
- Critical choice of compressor;
- Cost (for small volumes of helium);
- Hydrogen/tritium.

Passivation: He Purification

Cryogenic adsorption process:

- Trap air impurities
- Working temperature: 77K
- Reachable purity: much higher than 99.9%

Standard purifier:

- Purification vessel
- Regeneration system

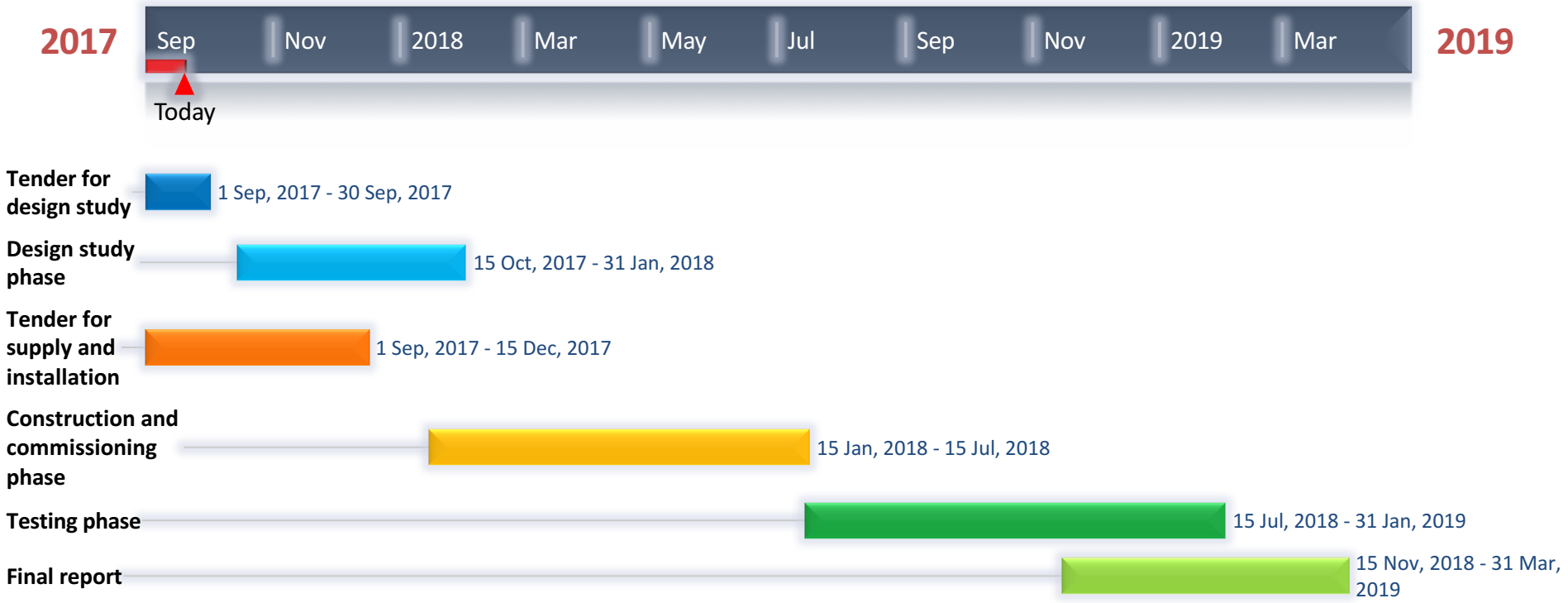
Adsorbent bed:

- Zeolite 13X (2 mm grain size)

Purification process characteristics:

- Adsorption duration: ~1 day
- Overall duration: ~5 days (including regeneration)

Passivation: Test Plan @ CERN



Passivation: Test objectives

1. Timescale of process
   - Show that the process is compatible with a “one week operation”;
2. Purification performance
   - The system can compensate impurities introduced by a (heated) piece of concrete or iron shielding;
   - The system can manage external air leaks
3. Any suggestion?

Conclusion

- Ventilation: compartments classification done, predesign ongoing
- Cooling: predesign ongoing
- Passivation: design & construction tendering phase ongoing

Any support/contribution is welcome !

Thank you for listening!
Any questions?