

# ESS Cryogenic System Process Design

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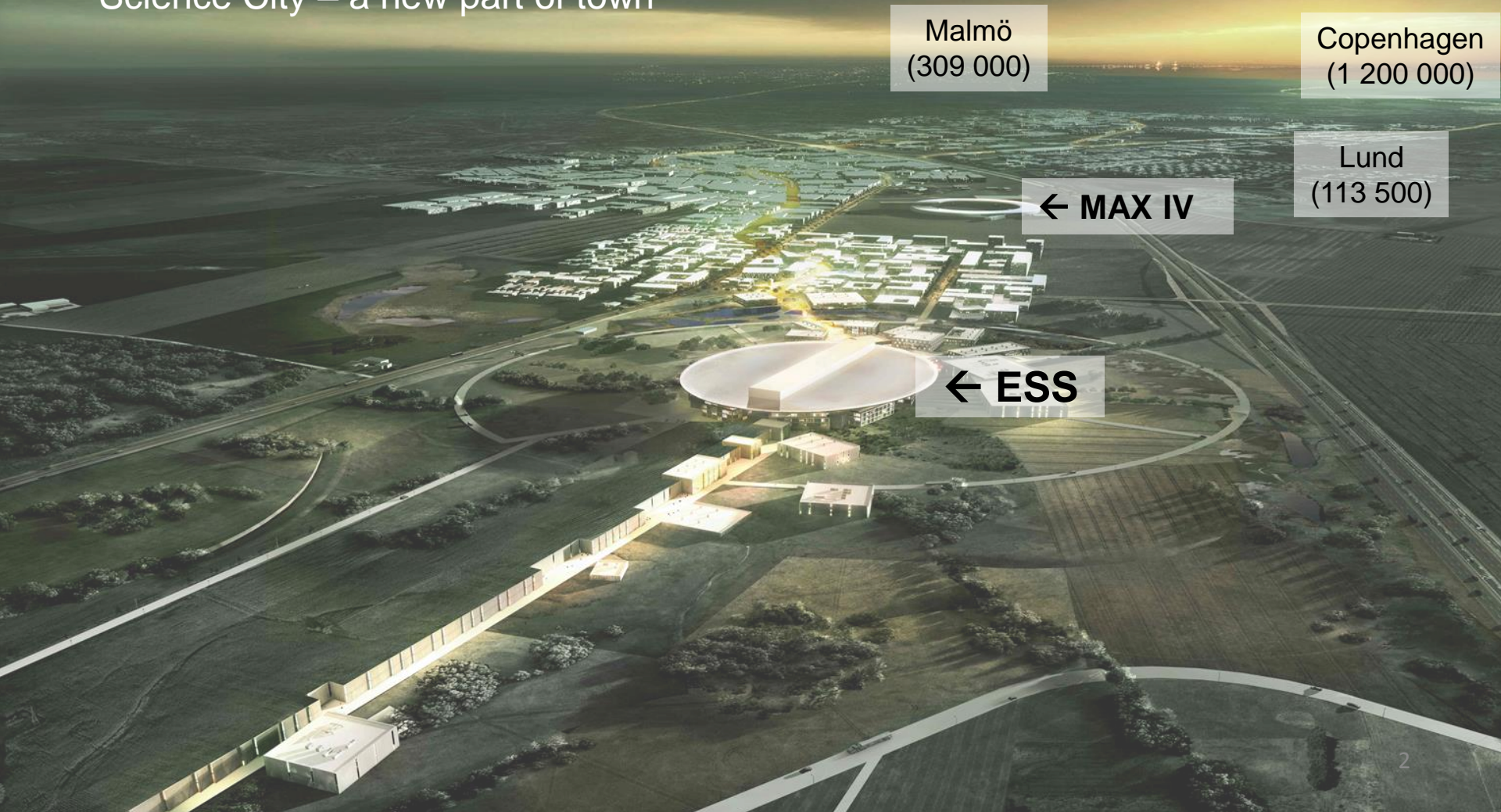
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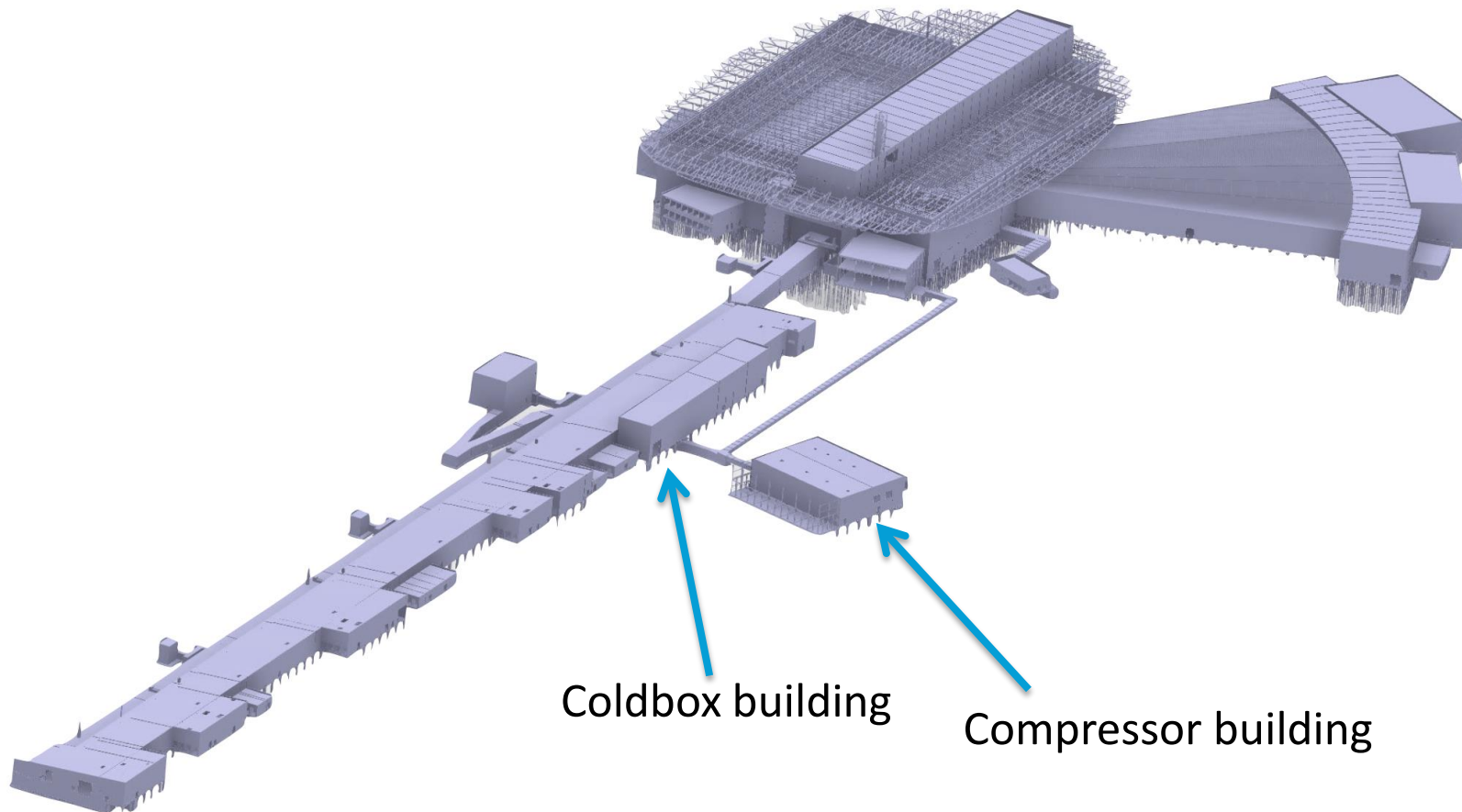
June 29, 2015

# View of the Southwest in 2025

- Max IV – a national research facility, under construction, opens up in 2016
- Science City – a new part of town

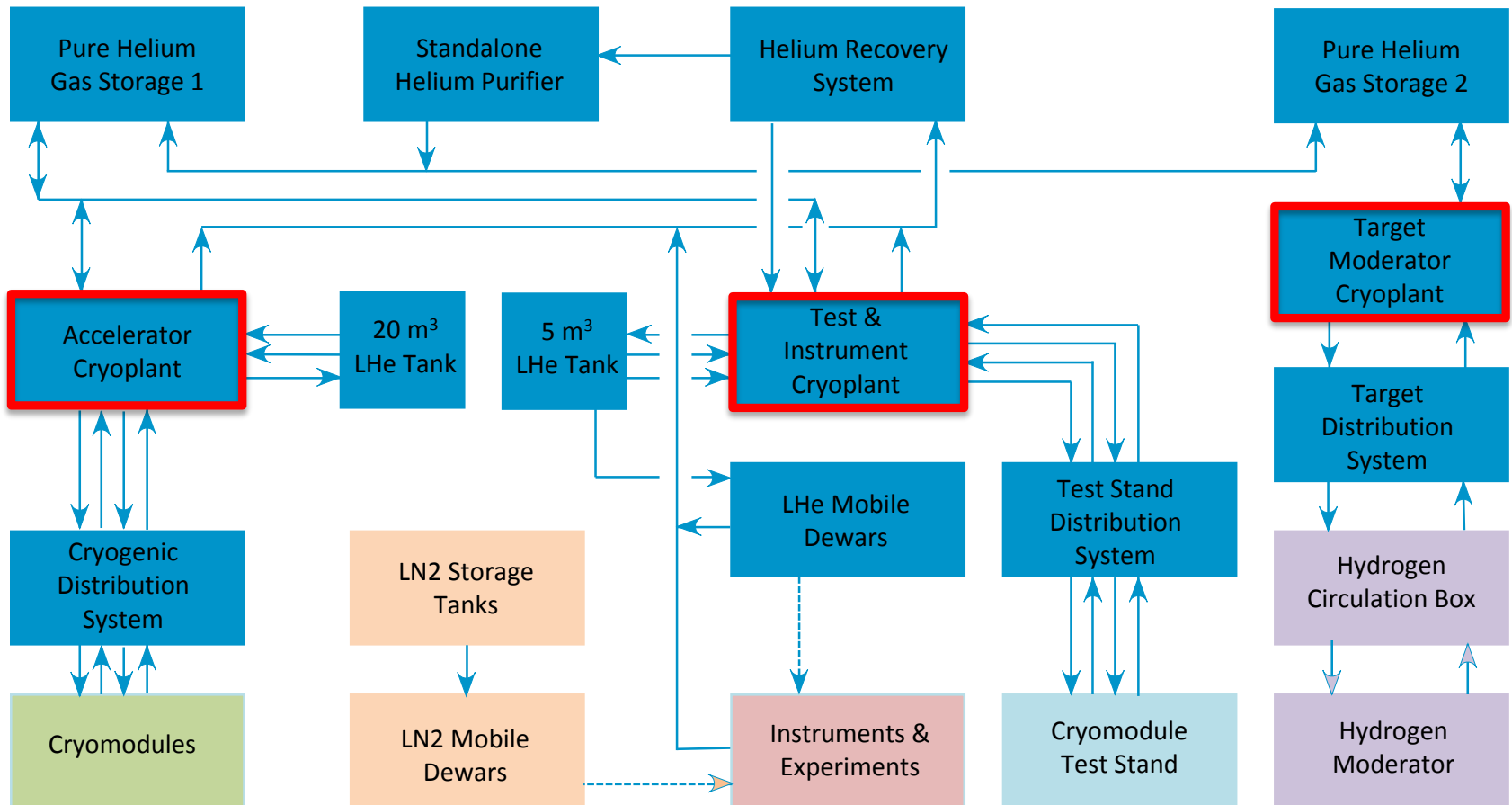


# Cryogenics at ESS



- 1) System Overview
- 2) Accelerator Load and its Cryoplant
- 3) Target Moderator Load and its Cryoplant
- 4) Helium Management and Storage
- 5) Reliability and Availability
- 6) Energy

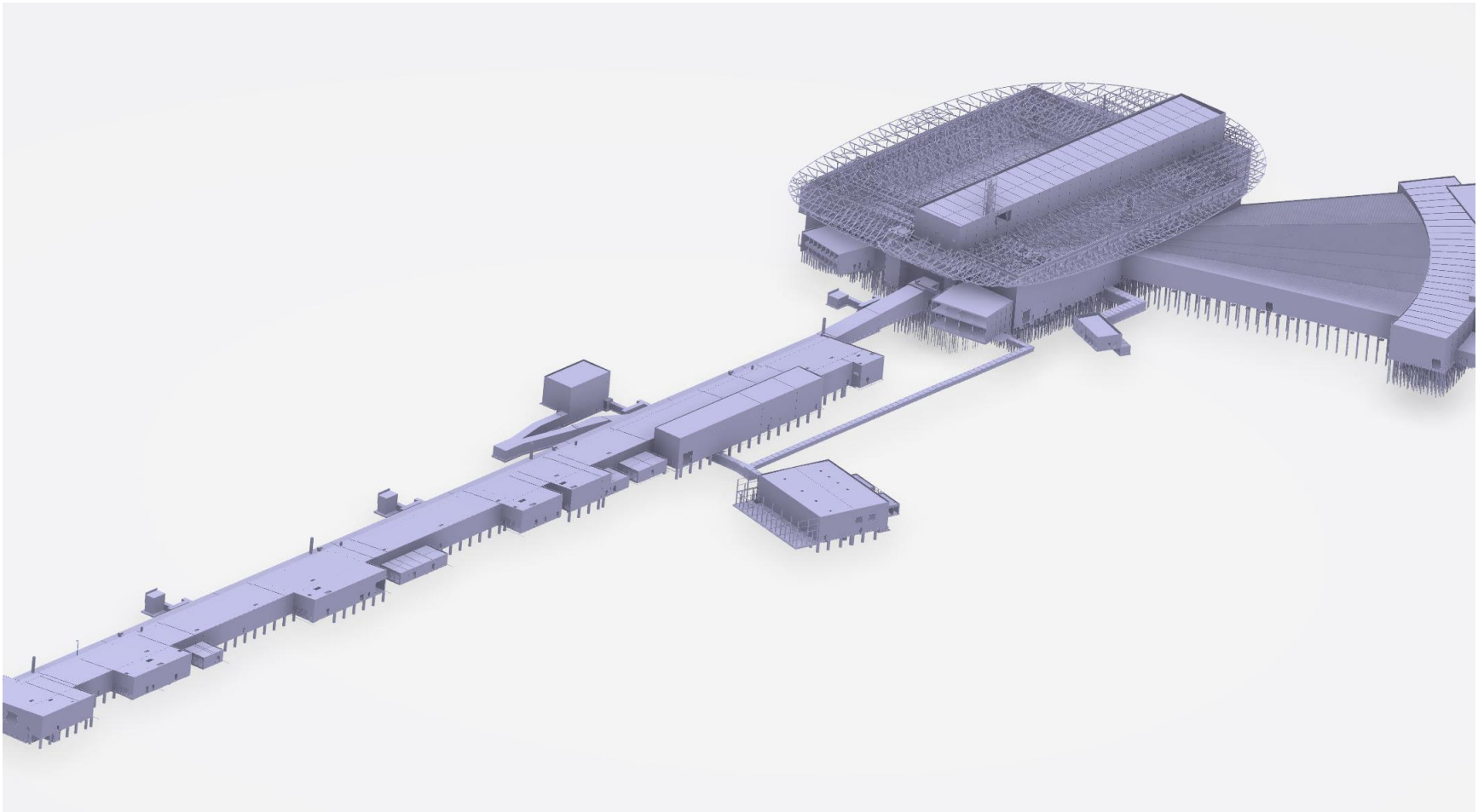
# (1) System overview



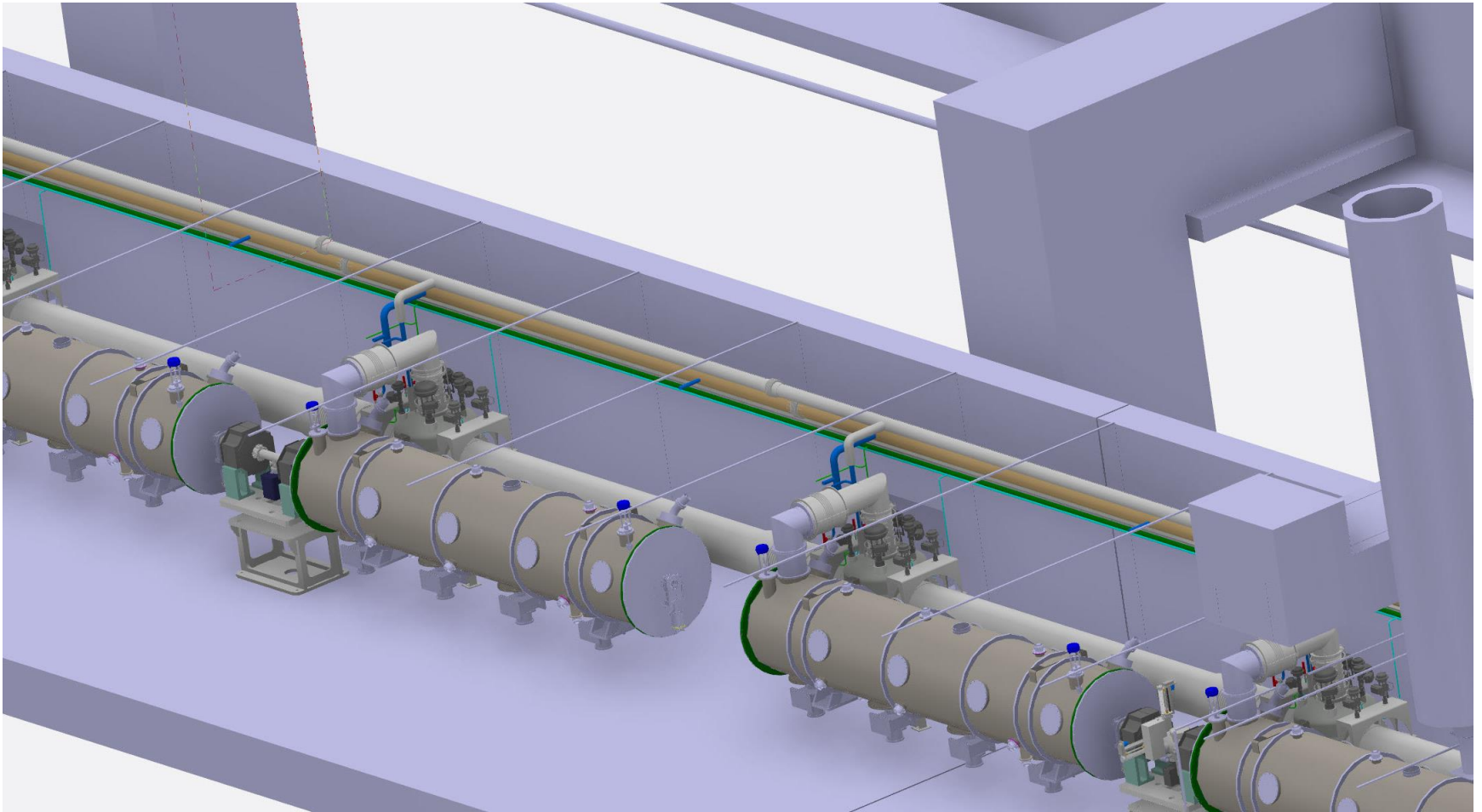
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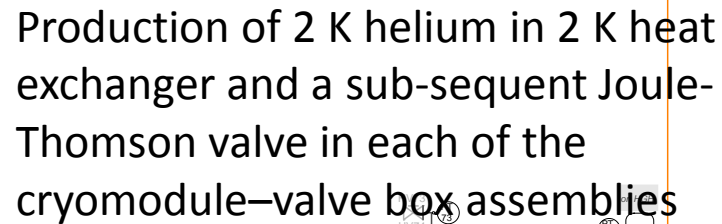
## (2.1) The Accelerator cryogenic setup



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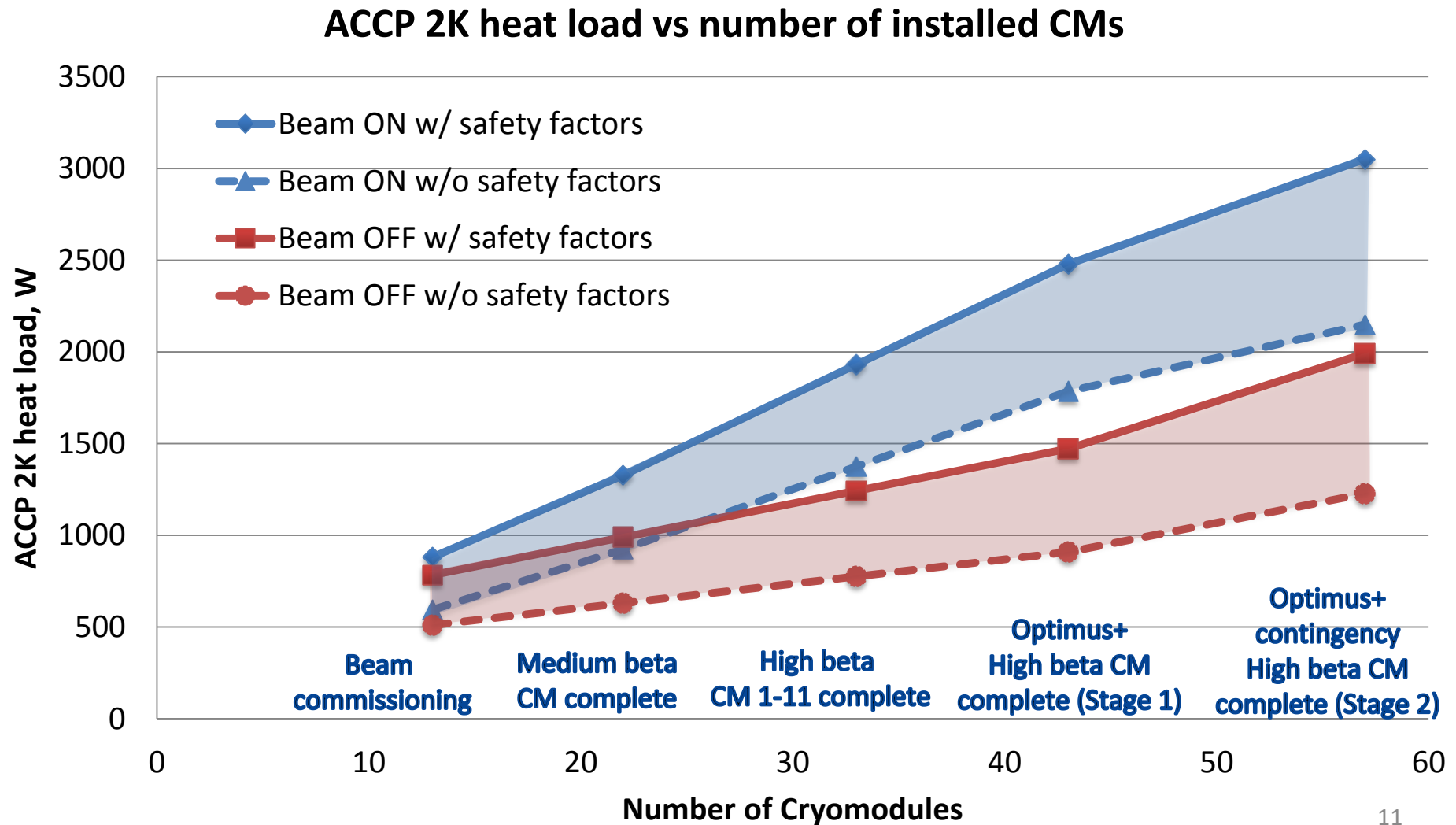




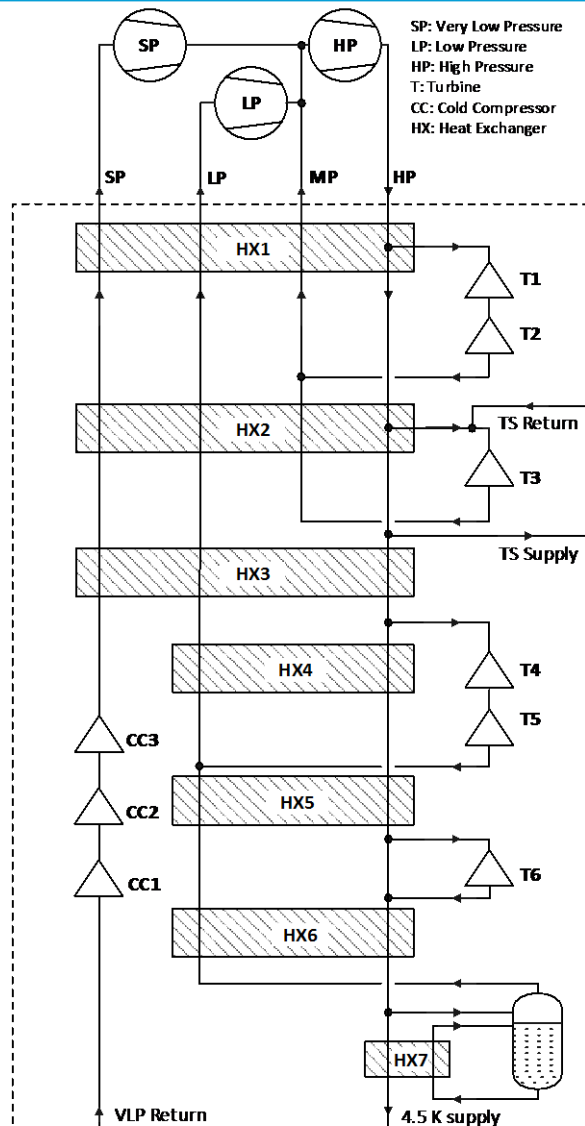
## (2.3) The Accelerator cryoplant dutyspec

Type	Temperature range	Max. load Stage 1	Max. load Stage 2
Static and dynamic load in CMs	2 K	1850 W	2230 W
Recuperators and CDS load	2 – 4 K	630 W	830 W
Thermal shields	33 – 53 K	8 550 W	11 380 W
Coupler cooling	4.5 – 300 K	6.8 g/s	9.0 g/s

# (2.4) The Accelerator cryogenic load



## (2.5) The Accelerator cryoplant process



300 K

Compressor skids with  
3 identical screws

115 K

VFD for SP→MP and LP→MP

70 K

53 K

Thermal shield ~43K

33 K

24 K

6 turbo expanders

9 K

3 cold turbo compressors

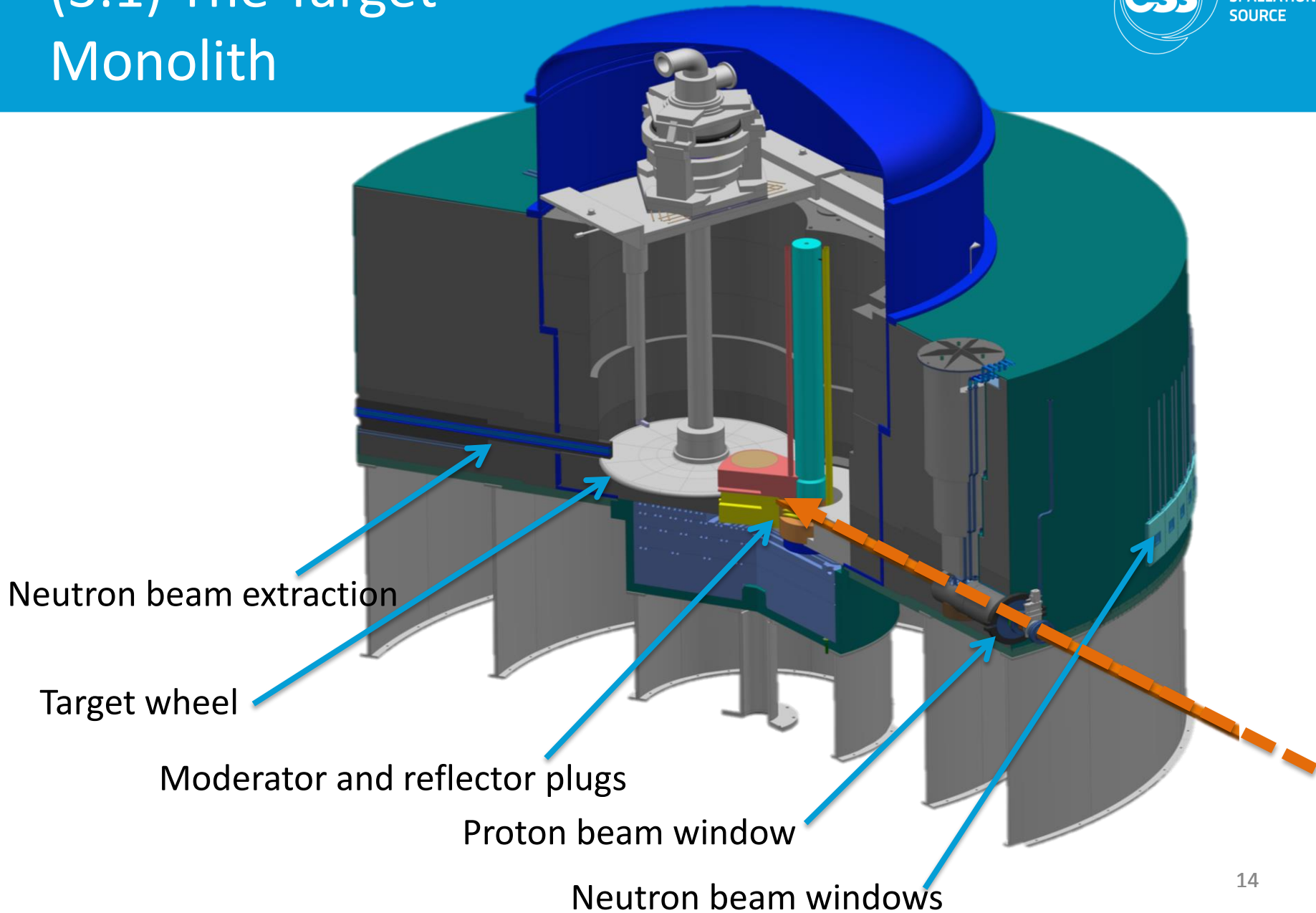
6 K

4.5 K

Connection to 20 m³ tank

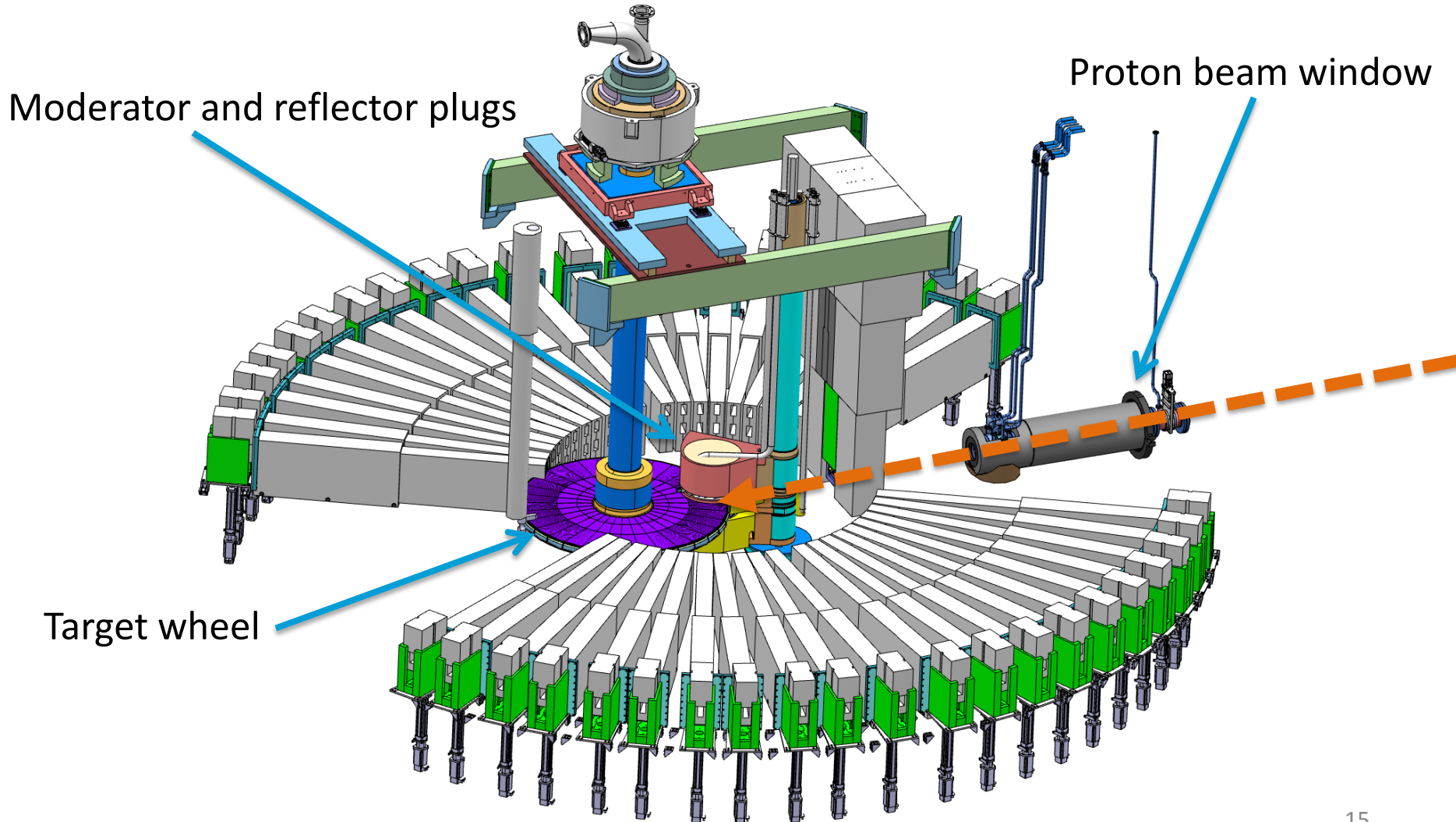
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# (3.1) The Target Monolith

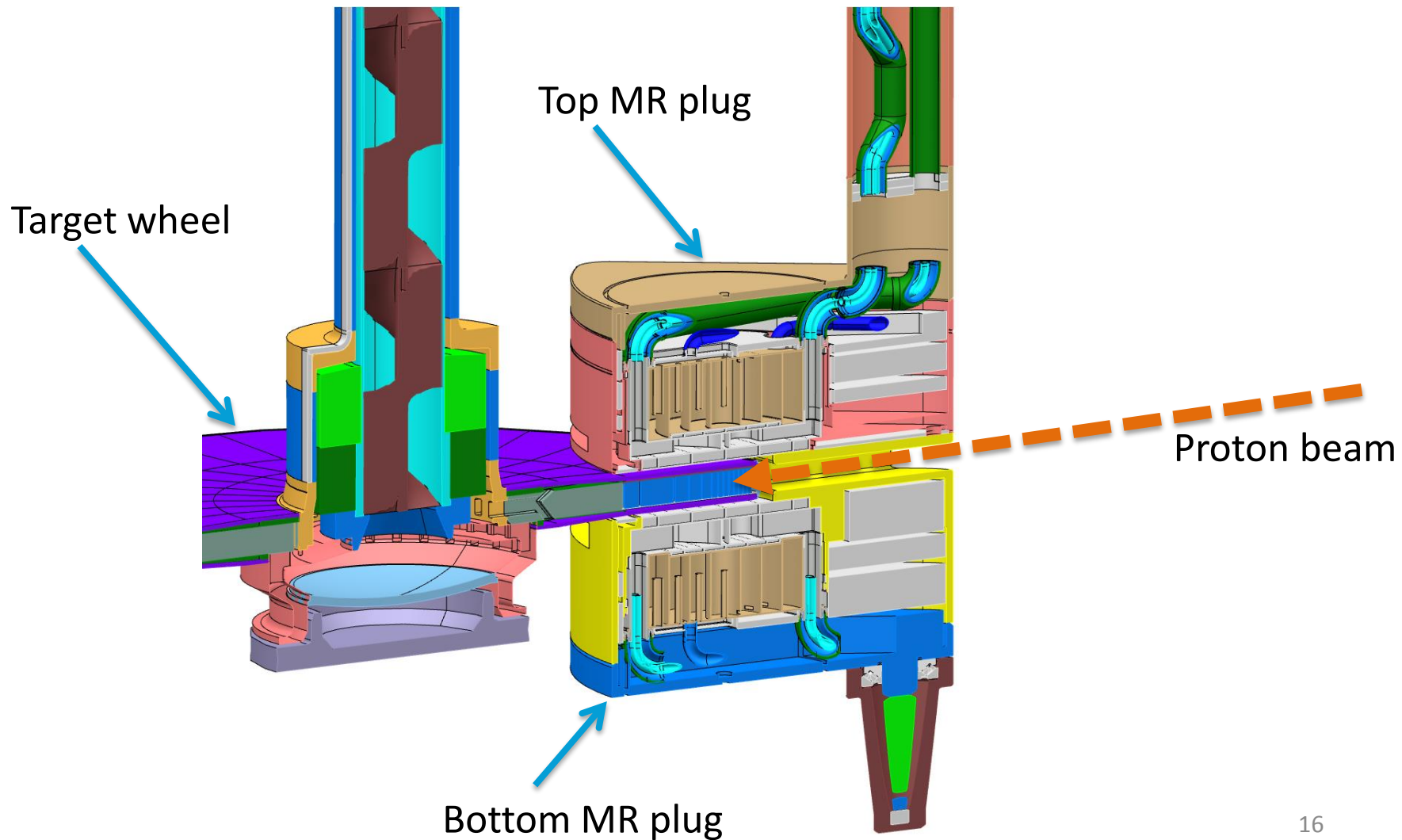




## (3.2) The Target Monolith inside

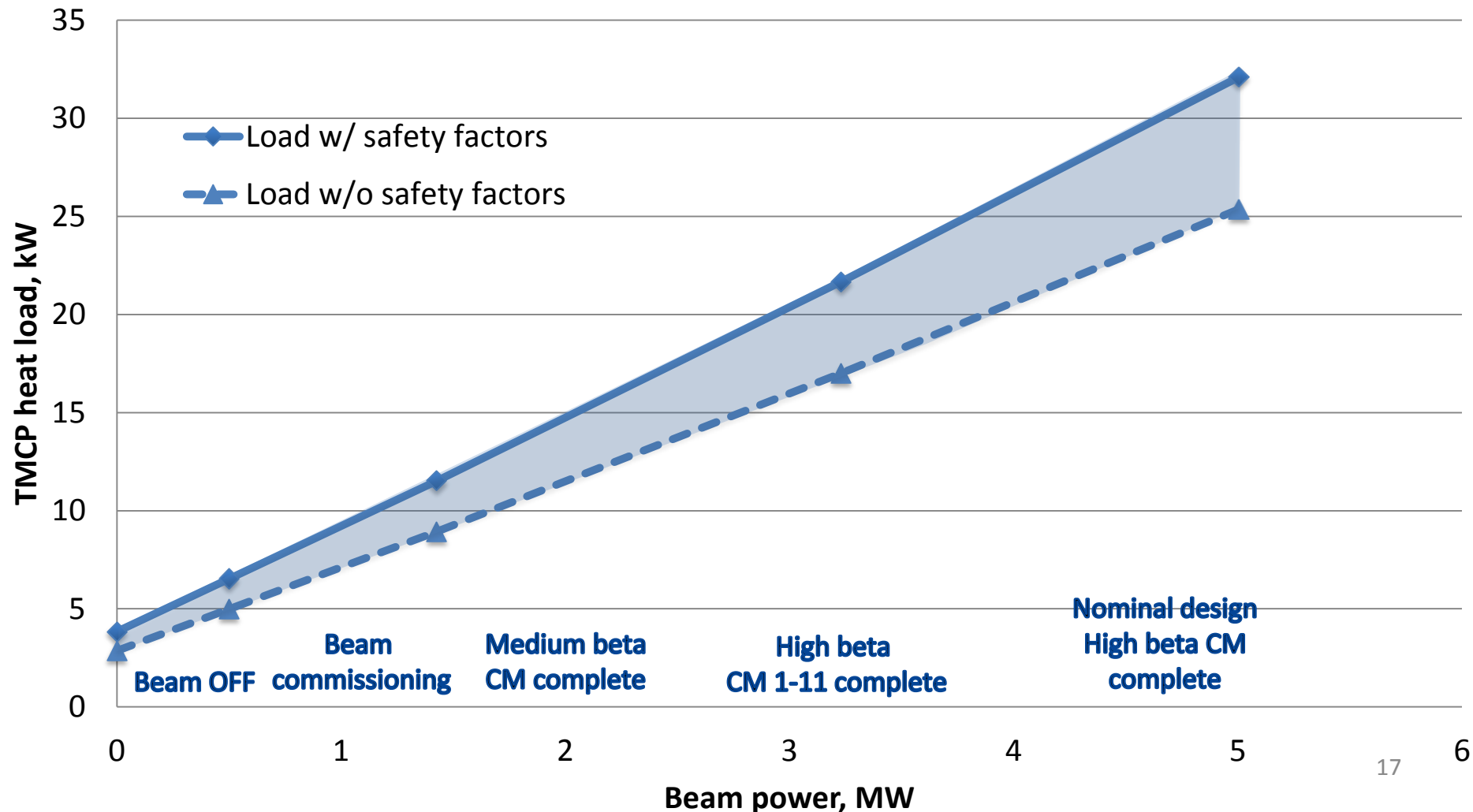


## (3.3) Moderator-Reflector system

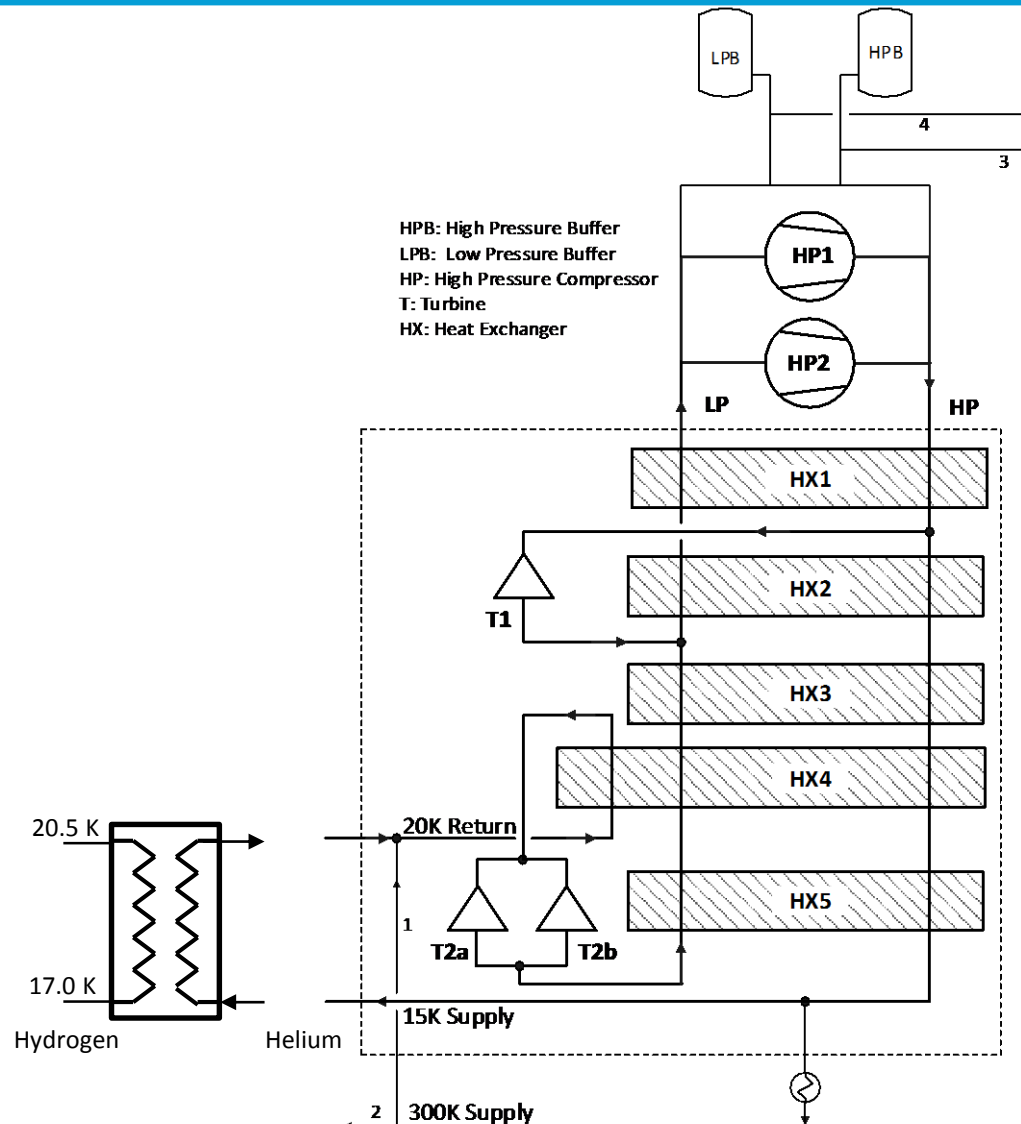


## (3.4) The Target cryogenic load

TMCP 15-20K heat load vs. beam power



# (3.5) The Target Moderator cryoplant process (proposed by ESS)



Helium buffers with “low” and “high” pressure region

2 screw compressor skids

300 K

90...120 K

60...80 K

23 K

20 K

15K

Turbine for HXs

Intermediate “heating” of feed flow upstream turbines

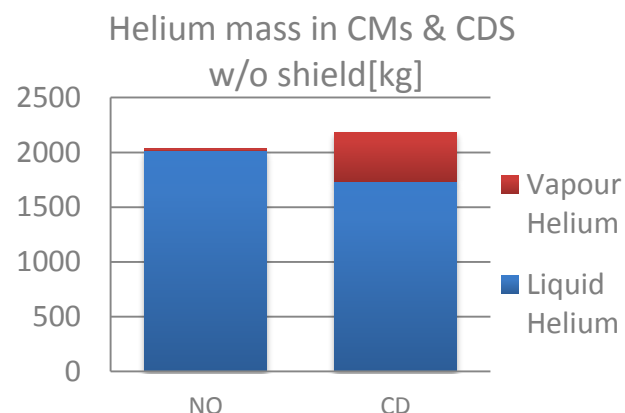
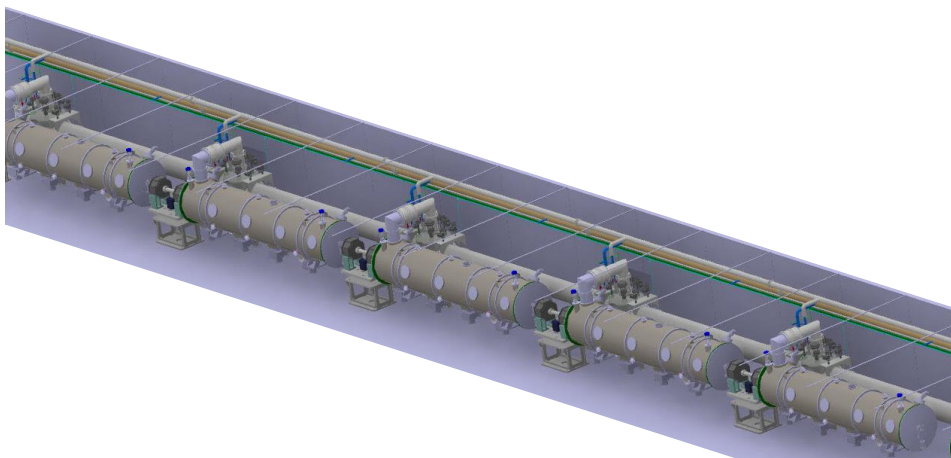
2 expansion turbines

Multi purpose ambient heater

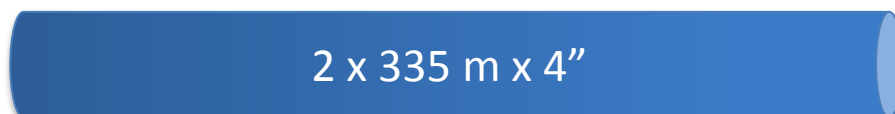
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# (4.1) Where sits the helium

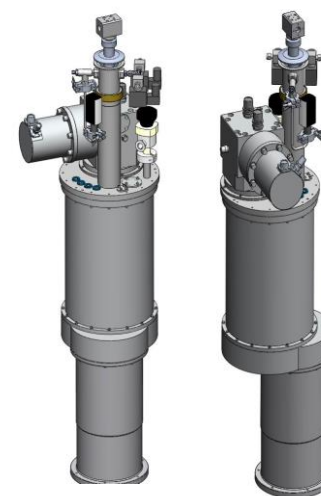
- 1) ACCP: Over 2000 kg in Cryomodules and distribution system



- 2) TMCP: Over 350 kg in Cryotransferline between helium and hydrogen box



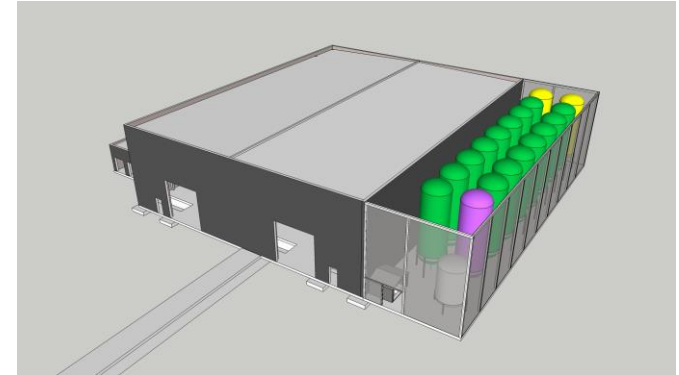
- 3) TICP: About 600 kg in open loop system for neutron instruments





## (4.2) Helium storage

- 1) Pure medium pressure tanks
  - 19 x 67 m<sup>3</sup>
  - Theoretically up to 3.5 tons
  - Pressure restrictions for TICP and TMCP
  - Effectively ~ 3 tons
- 2) Liquid helium storage tank
  - 20 m<sup>3</sup>
  - When filled to 80% another 2 tons
  - Used as "2nd fill" and help in transient modes (cool-down, pump-down)
- 3) Impure high pressure tanks or bundles
  - 12 m<sup>3</sup>
  - Nearly 300 kg
  - Used as buffer in recovery system



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## (5.1) Definitions

### Kinetic Experiments

A reliability of at least 90% should be provided for the duration of the measurement.

The measurement will be considered failed when the beam power is reduced to less than 50% of the scheduled power for more than 1/10th of the measurement length.

### Flux Integrated Experiments

For the duration of the experiment at least 90% of the experiments should have at least 85% of beam availability and on average more than 80% of the scheduled beam power.

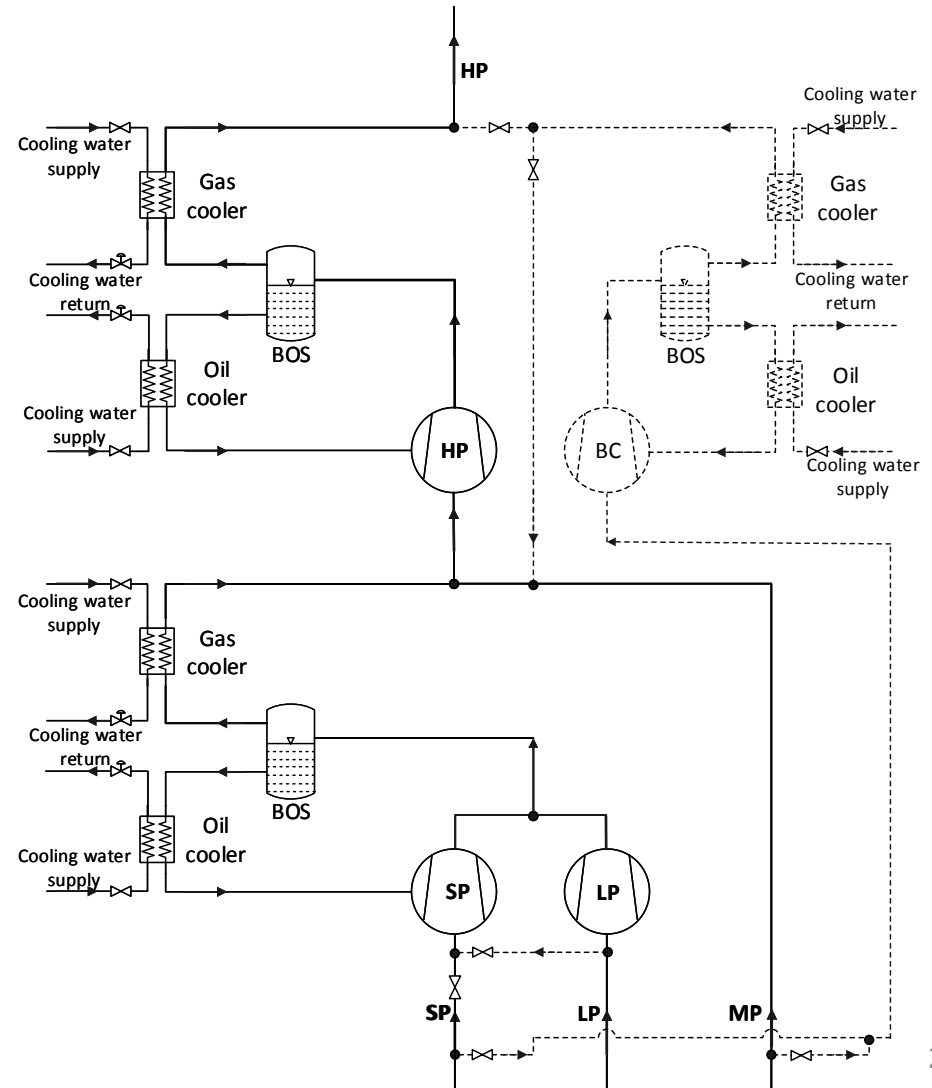
The beam will be considered unavailable when its power is less than 50% of its scheduled power for more than one minute.

*At least 90% of the users should receive a neutron beam that will allow them to execute the full scope of their experiments*

## (5.2) Anticipated failure rates

*Not relevant for the  
cryogenic system*

Downtime duration	Accelerator	Target	ICS	SI
3 hours - 8 hours	15 per year	1 every 2 years	1 every 2 years	1 every 2 years
8 hours - 1 day	5.5 per year	1 every 2 years	1 every 5 years	1 every 3 years
1 day - 3 days	2.3 per year	1 every 2 years	-	1 every 10 years
3 days - 10 days	1 every 5 years	1 every 20 years	-	-
more than 10 days	3 every 40 years	1 every 40 years	-	-



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## (6.1) Energy high level goals

### **Renewable:**

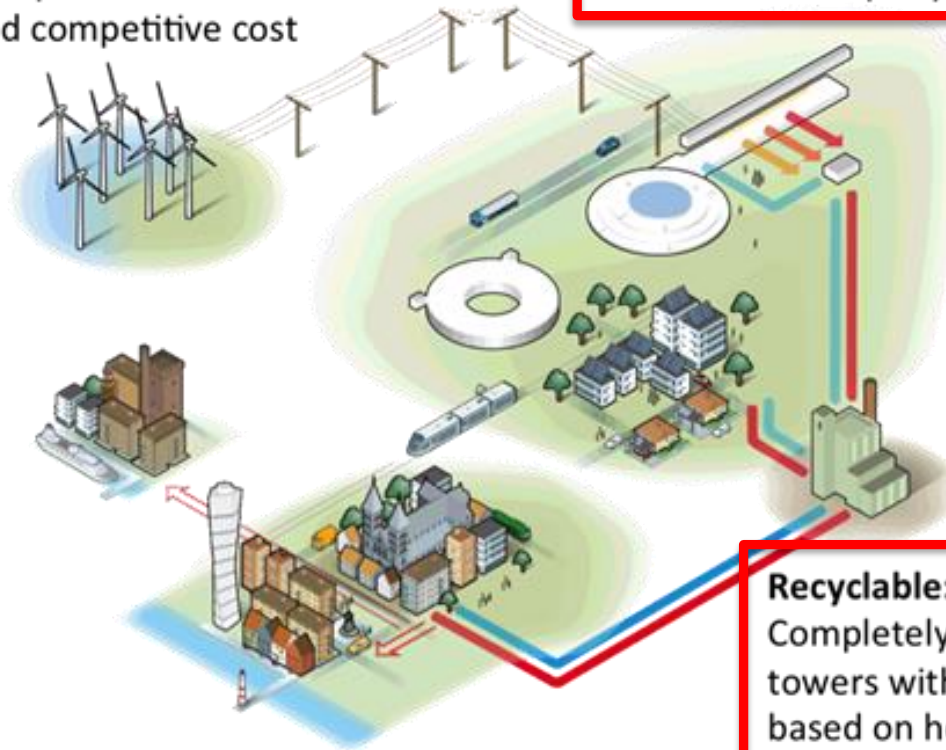
All energy from new, dedicated renewable production at a stable and competitive cost

### **Responsible:**

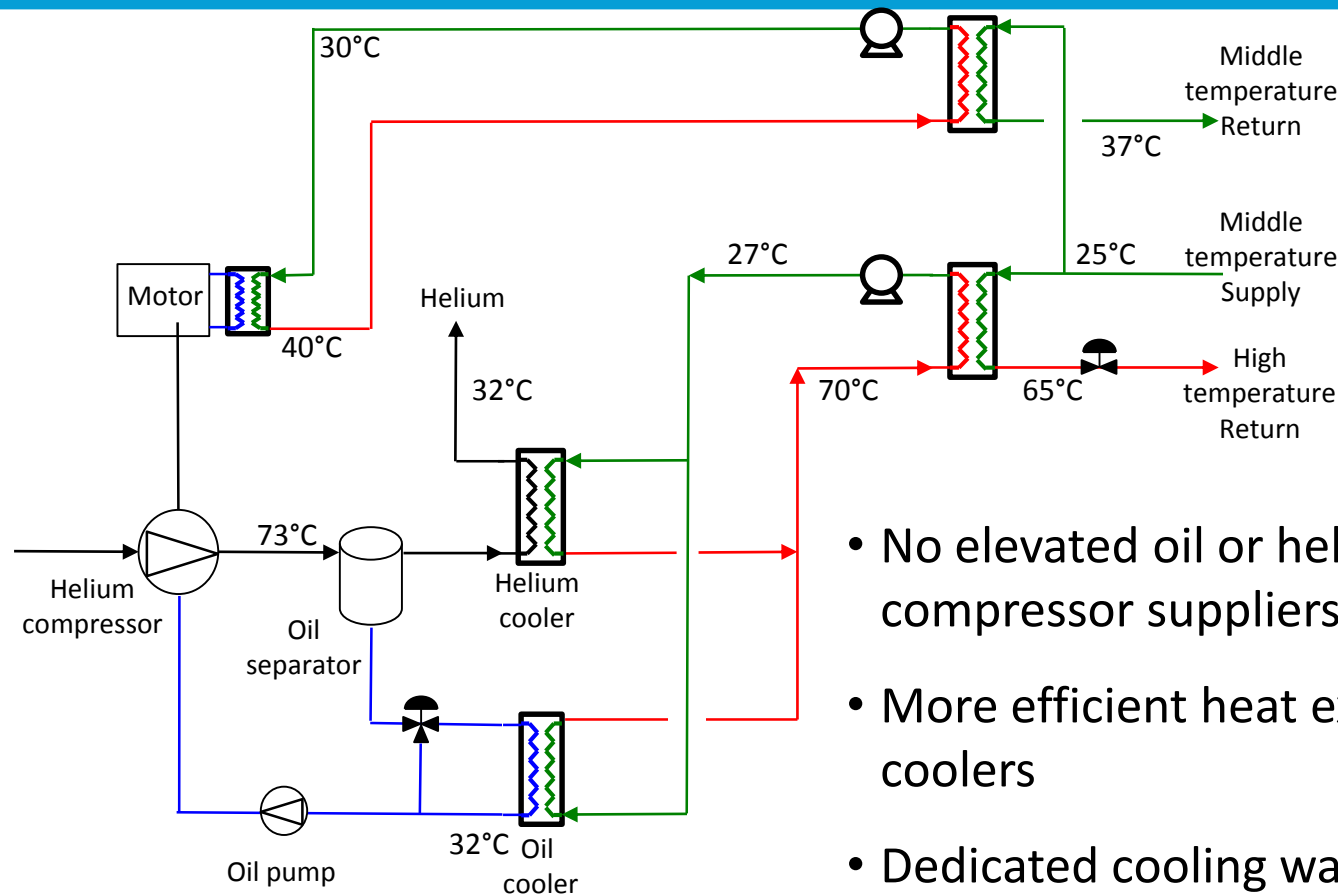
Reduce energy use to under 270 GWh per year

### **Recyclable:**

Completely replace cooling towers with a cooling system based on heat recycling.



## (6.2) Heat recovery



- No elevated oil or helium temperatures out of compressor suppliers specs
- More efficient heat exchangers, especially oil coolers
- Dedicated cooling water circuit for cryoplant
- Cooling function has priority over heat recovery

## (6.3) Energy efficiency and sustainability

- Focus on process design and optimization
- Good match between plant and load by staging, dual equipment, VFDs for low pressure machines
- Focus on turn-down scenarios
- Incentive OPEX approach in ACCP and TMCP tender evaluation and contracts as well
- As much as possible helium recovery

# Conclusions

- The conceptual design of the cryogenic system at ESS is finished
- One cryoplant is ordered, one out for quote, one to 90% specified → ESS is rolling
- High level goals in terms of energy efficiency and sustainability can be met
- Continued work on meeting reliability and availability requirements