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ESS Cryogenic System Process Design

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Section Leader Cryogenics

www.europeanspallationsource.se

CEC – ICMC 2015
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

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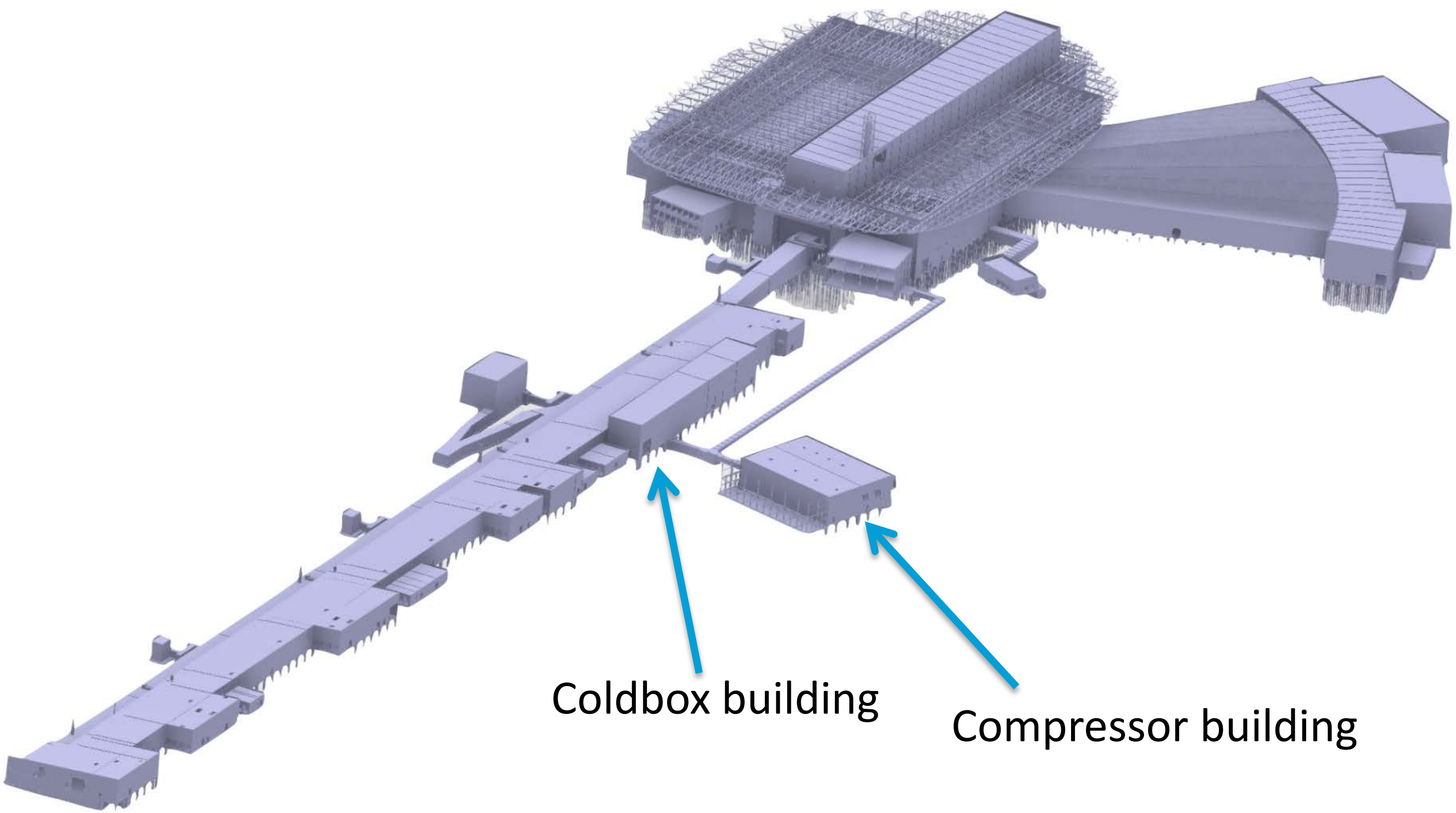

Outline

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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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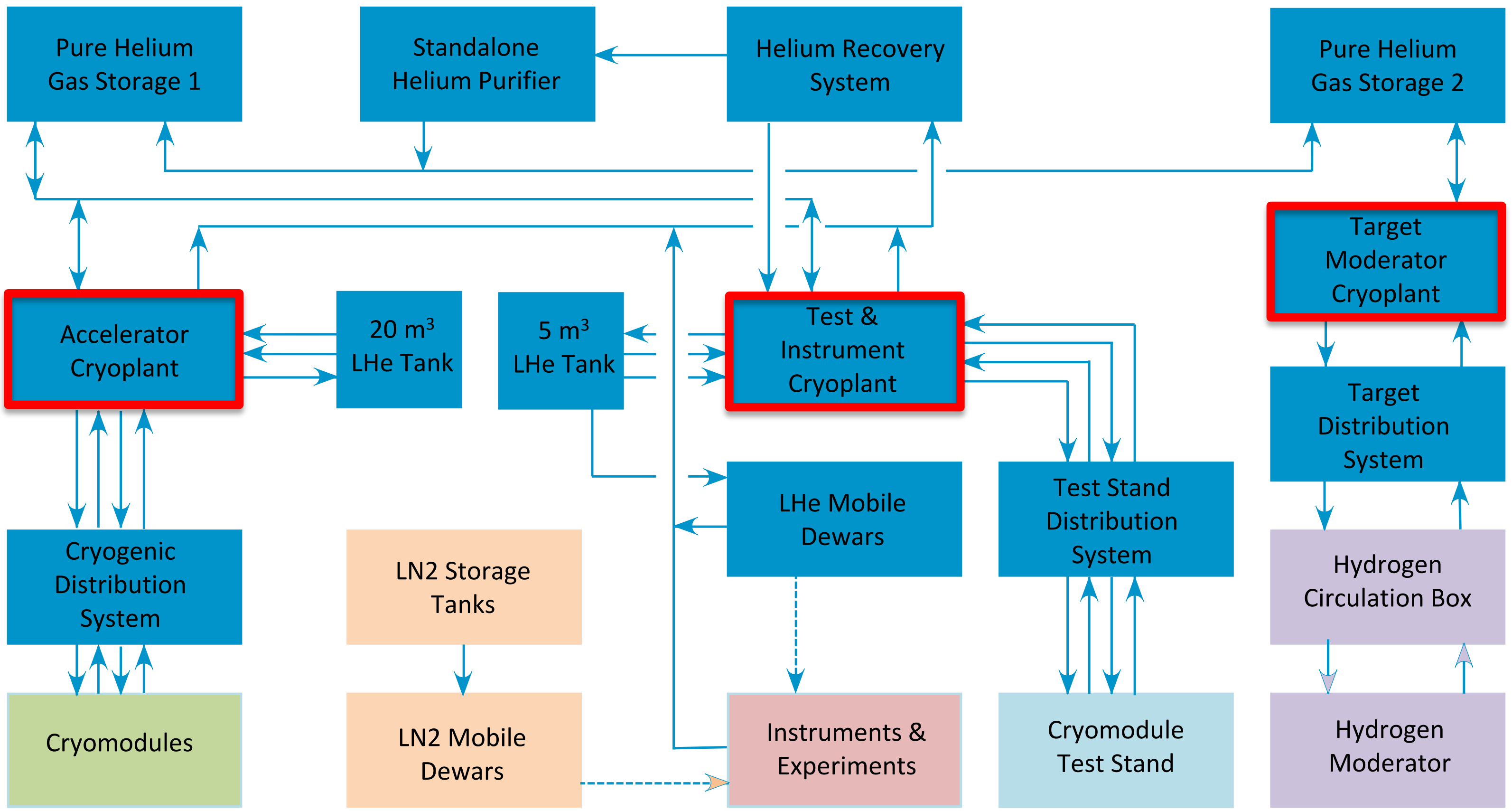

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(2.1) The Accelerator cryogenic setup

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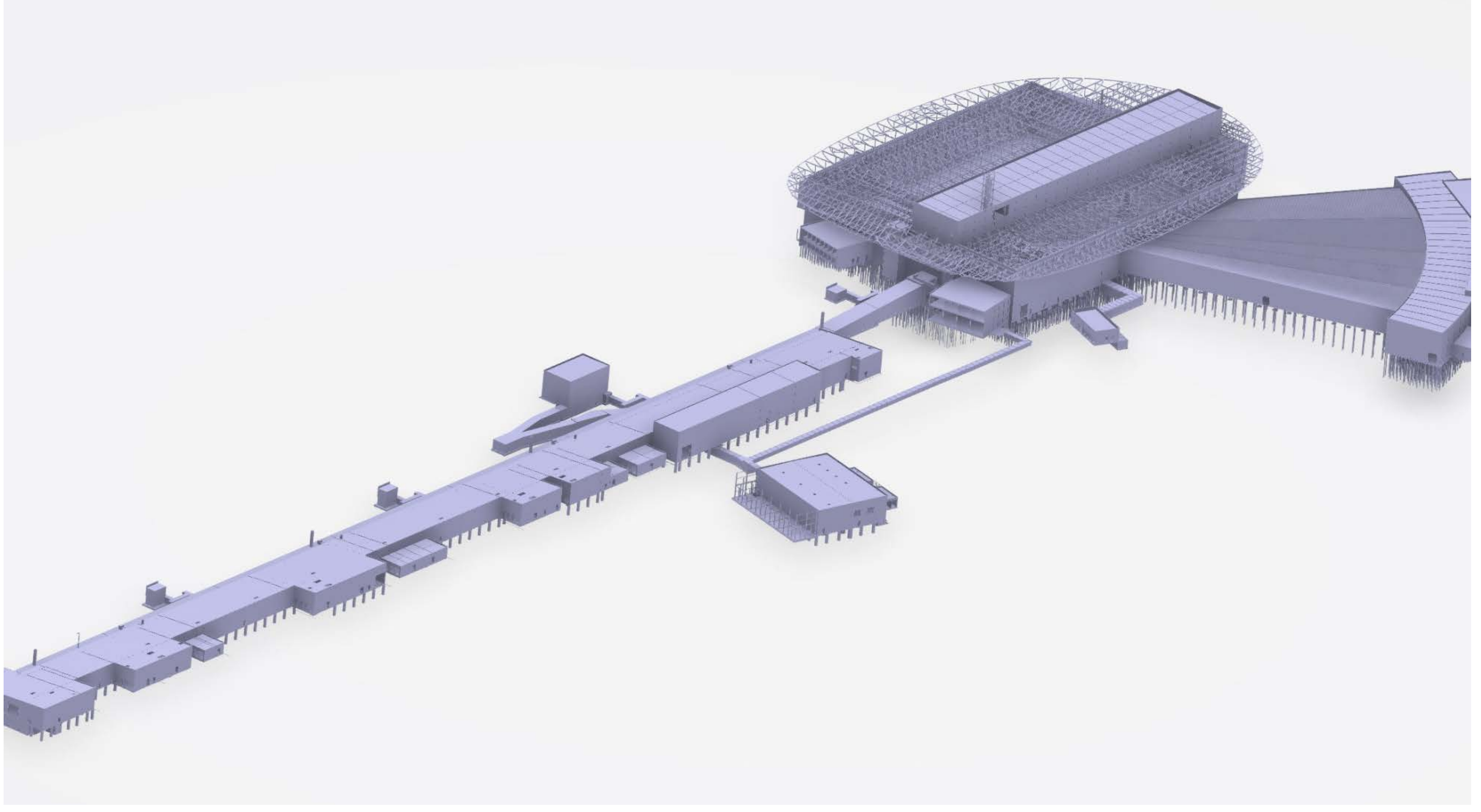

(2.1) The Accelerator cryogenic setup

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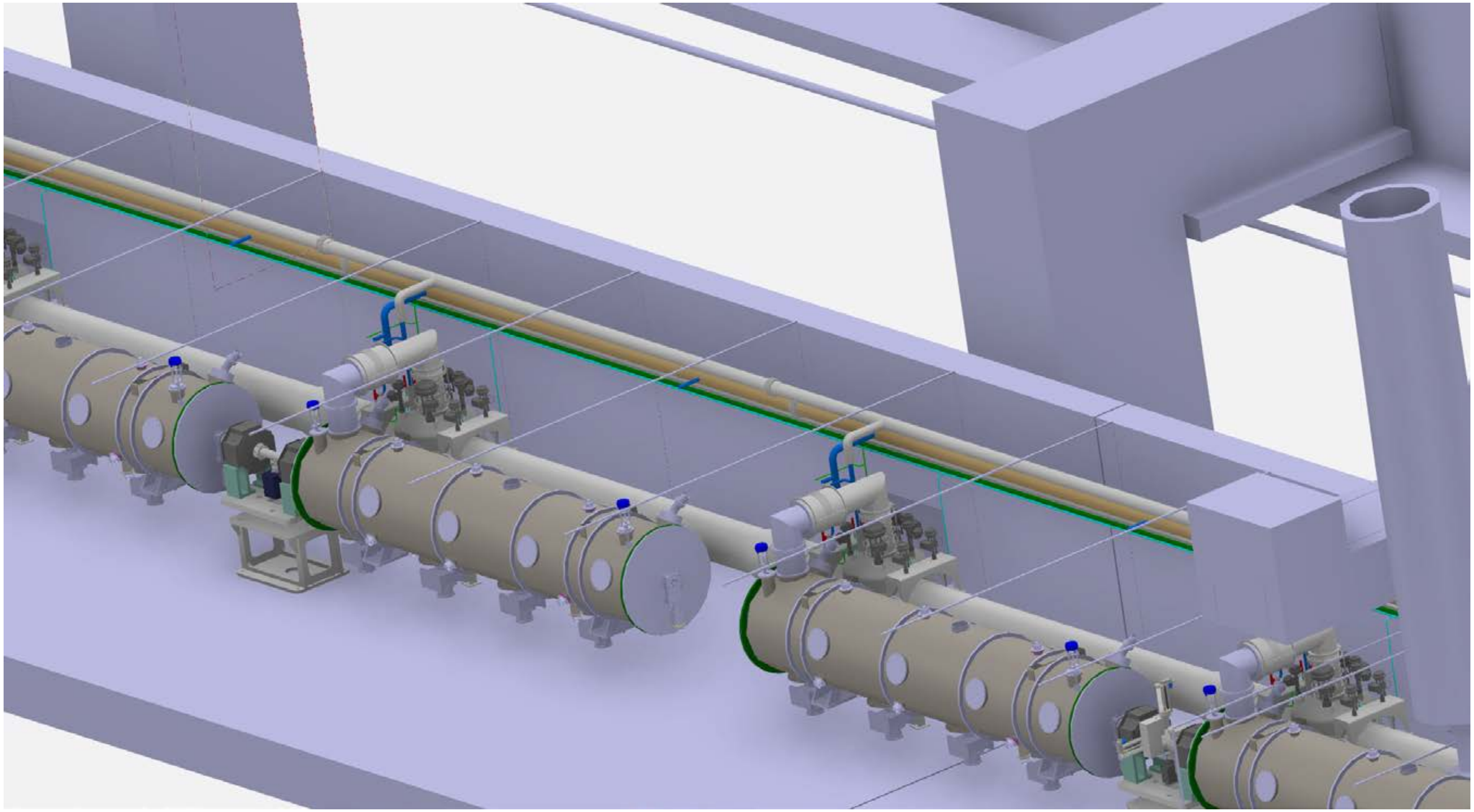

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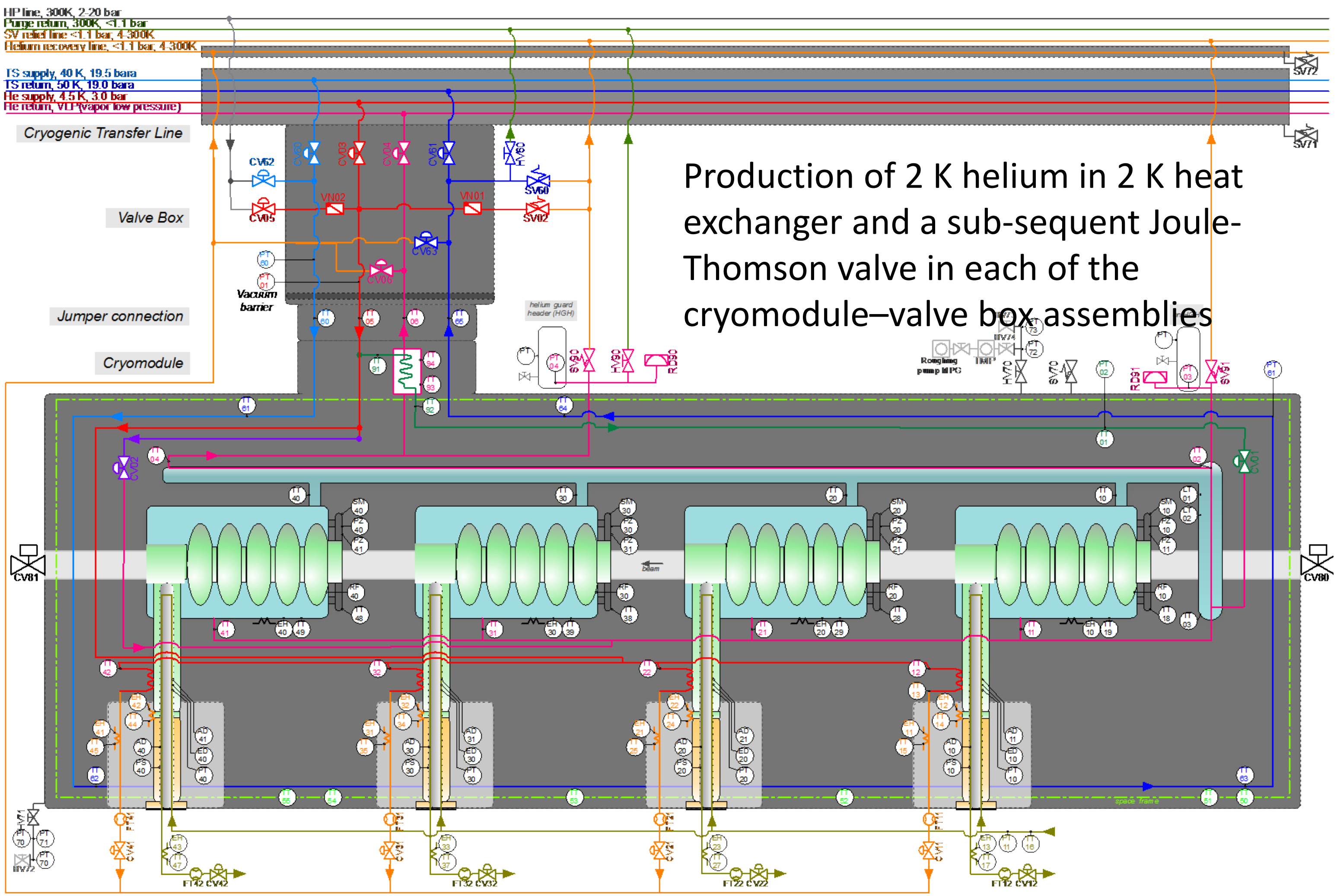
(2.2) Cryomodule cooling at 2K



Production of 2 K helium in 2 K heat exchanger and a sub-sequent Joule-Thomson valve in each of the cryomodule–valve box assemblies

(2.3) The Accelerator cryoplant dutyspec

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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

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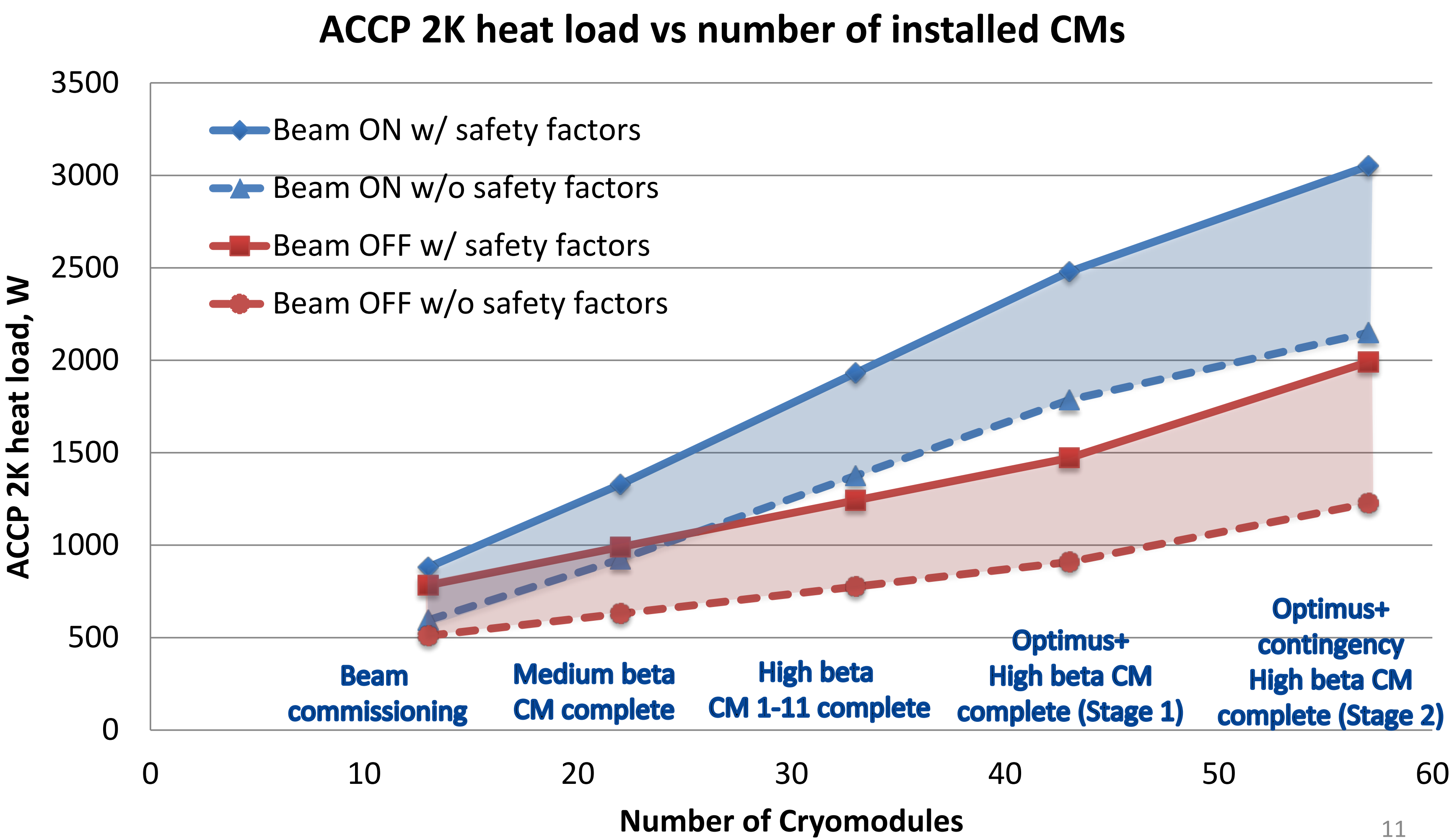

(2.5) The Accelerator cryoplant process

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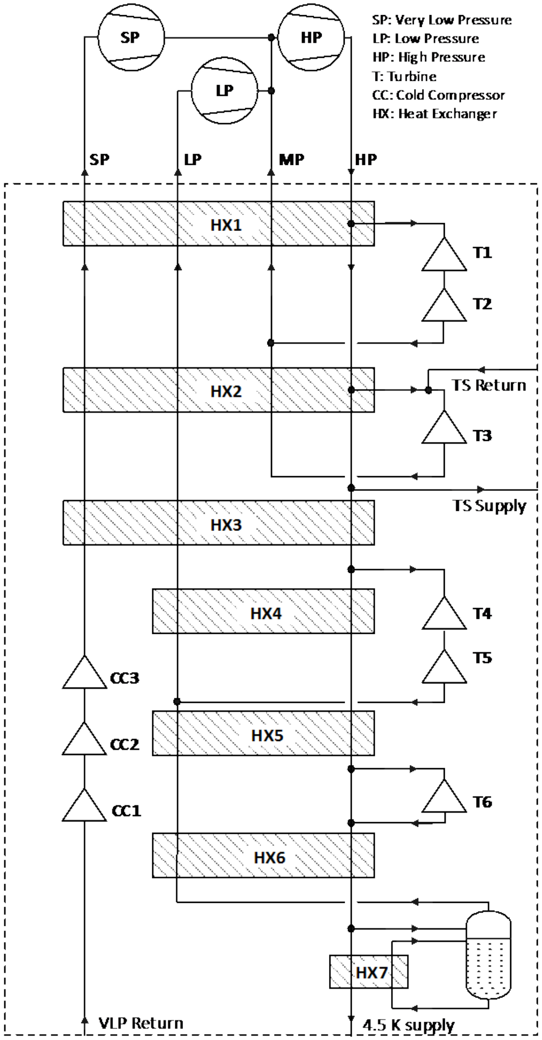

300 K

Compressor skids with
3 identical screws

VFD for SP→MP and LP→MP

115 K

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 m^3 tank

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(3.1) The Target Monolith

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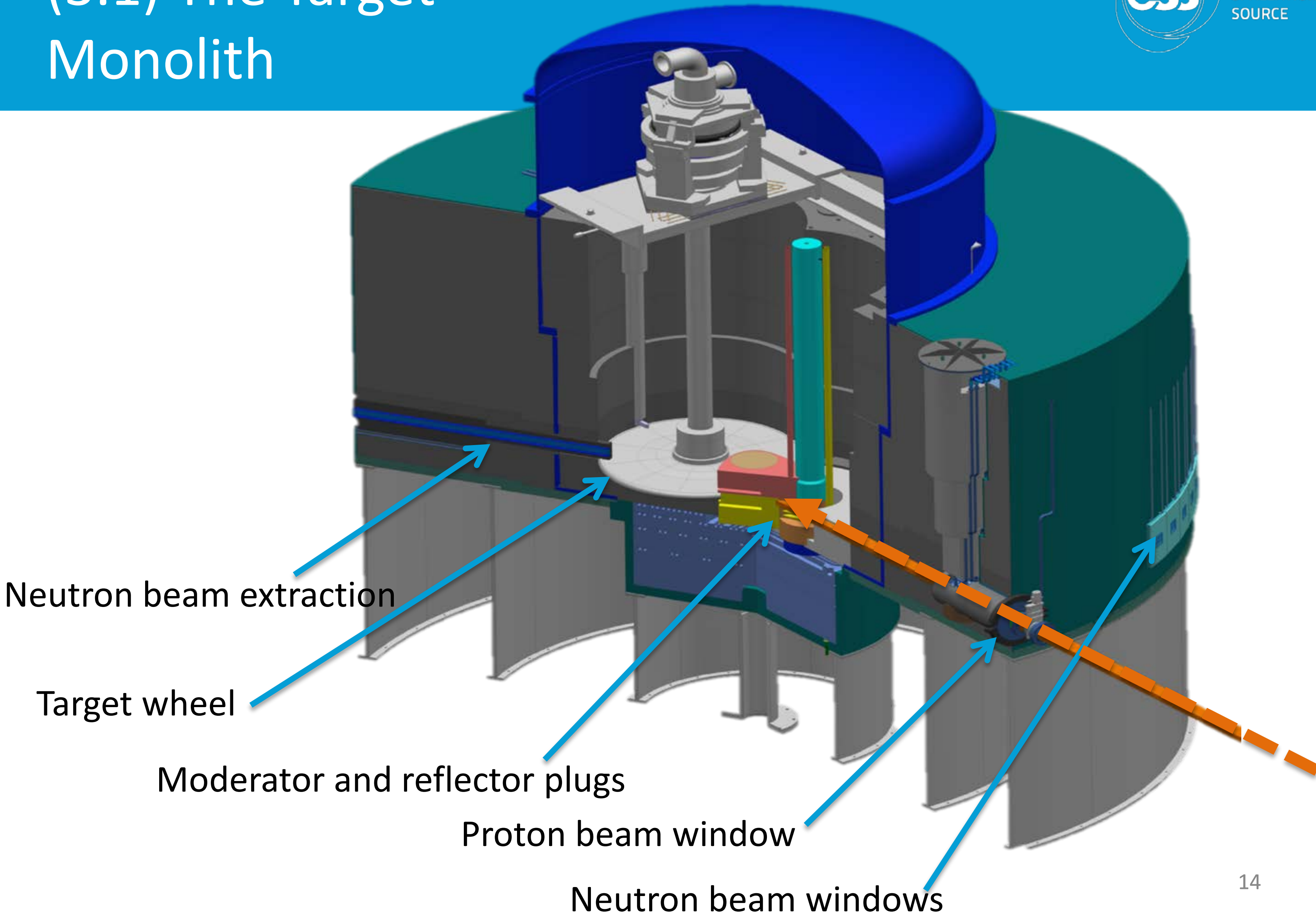
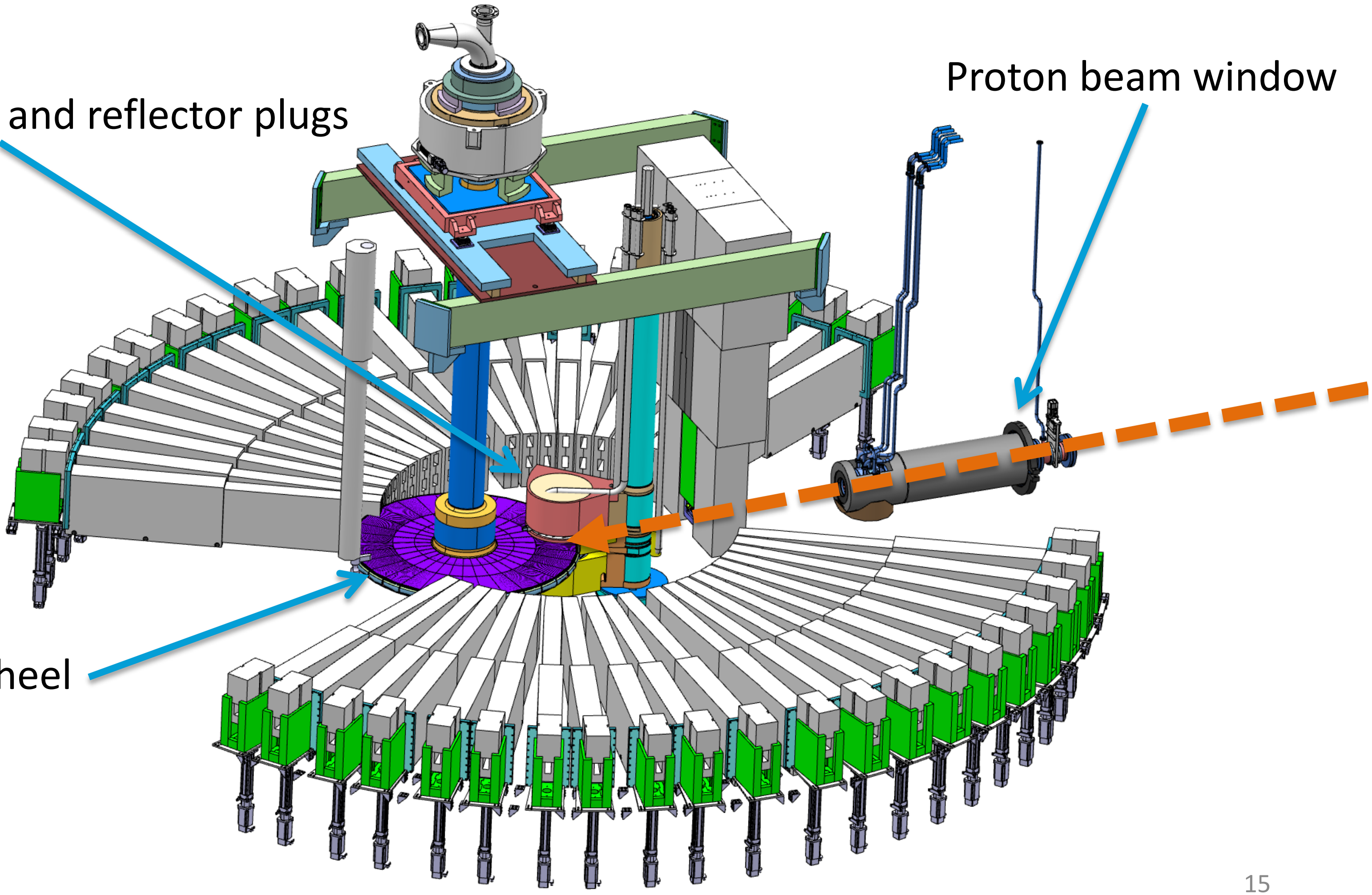


(3.2) The Target Monolith inside



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(3.3) Moderator-Reflector system

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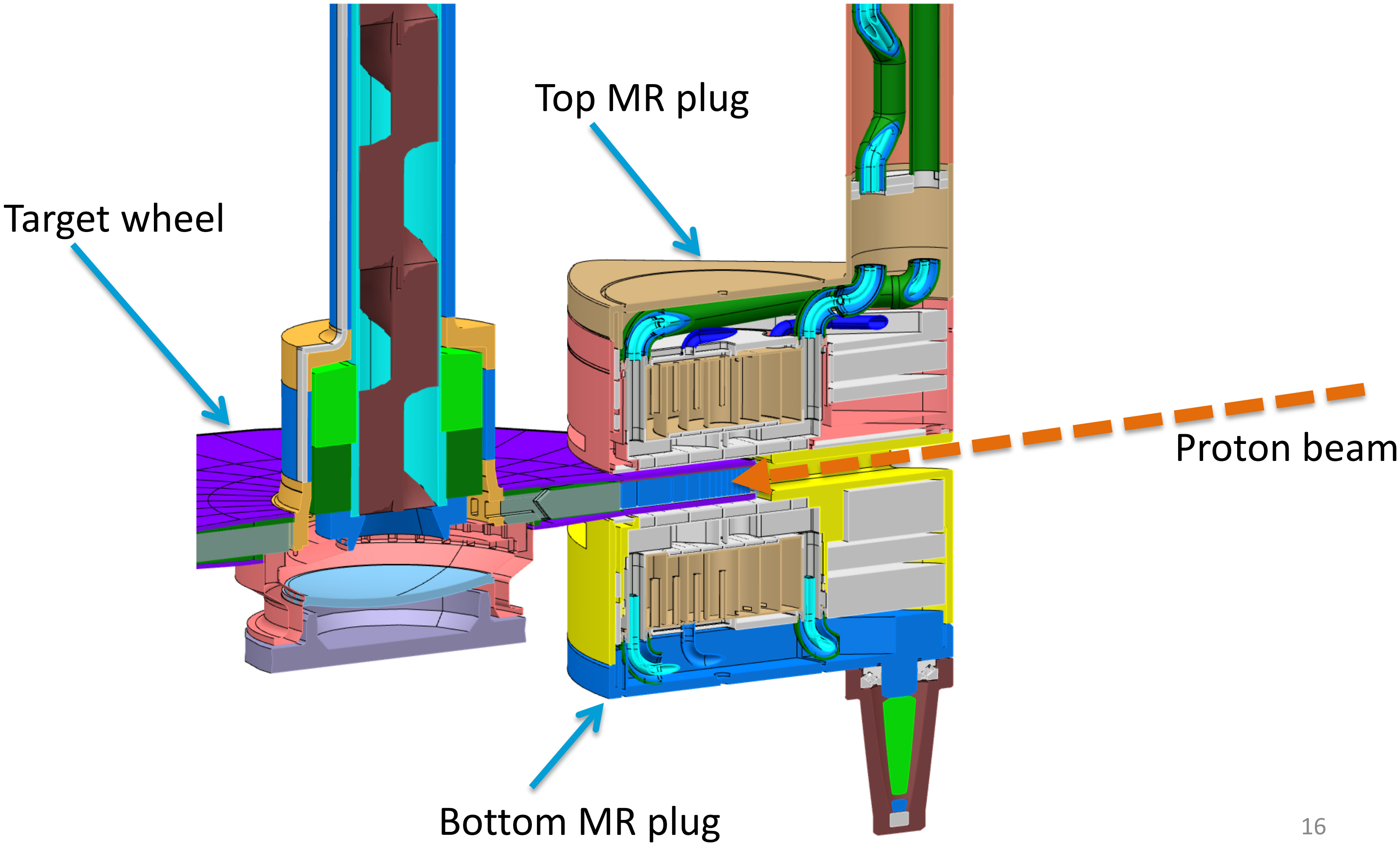
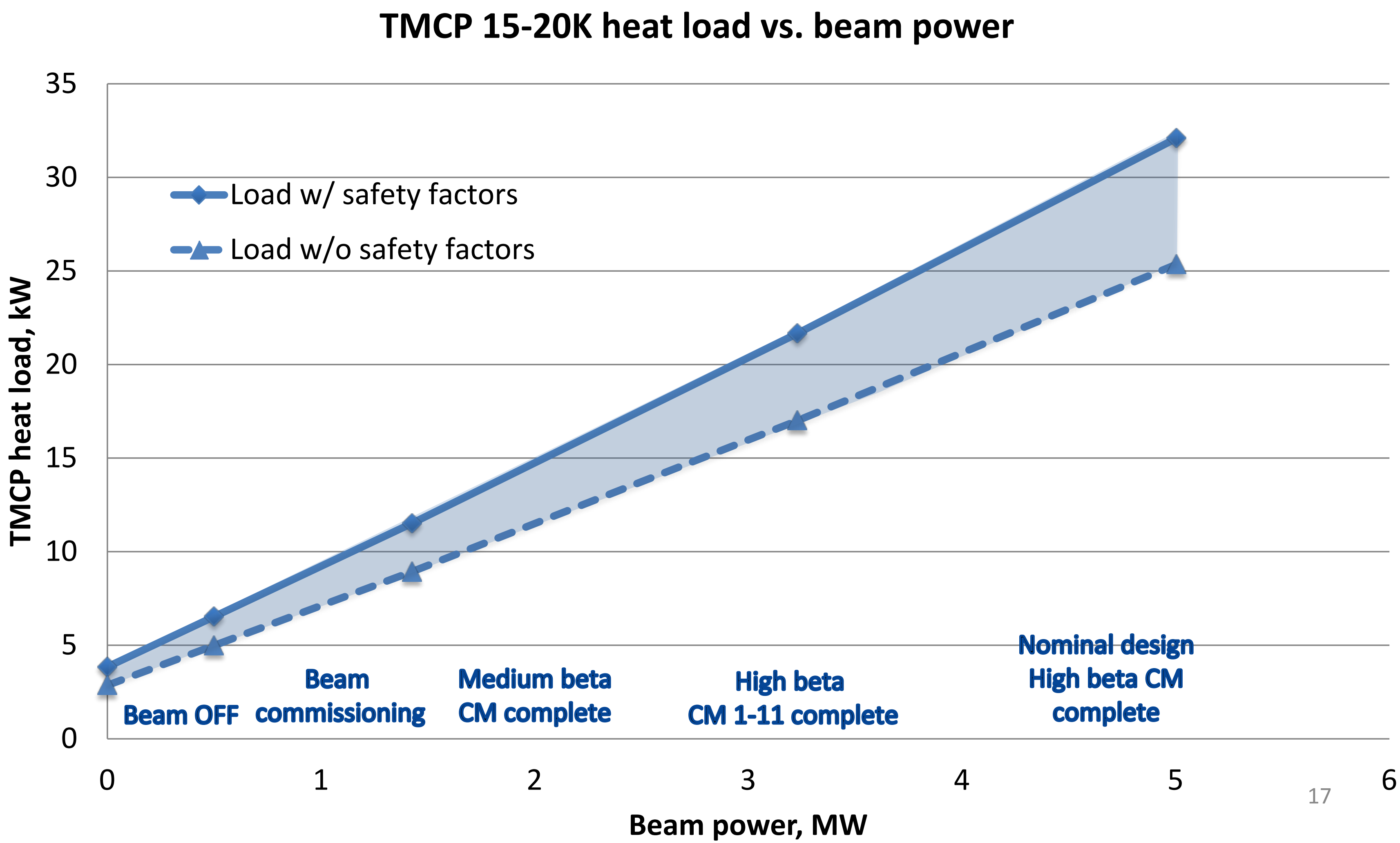


(3.4) The Target cryogenic load

EUROPEAN SPALLATION SOURCE



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

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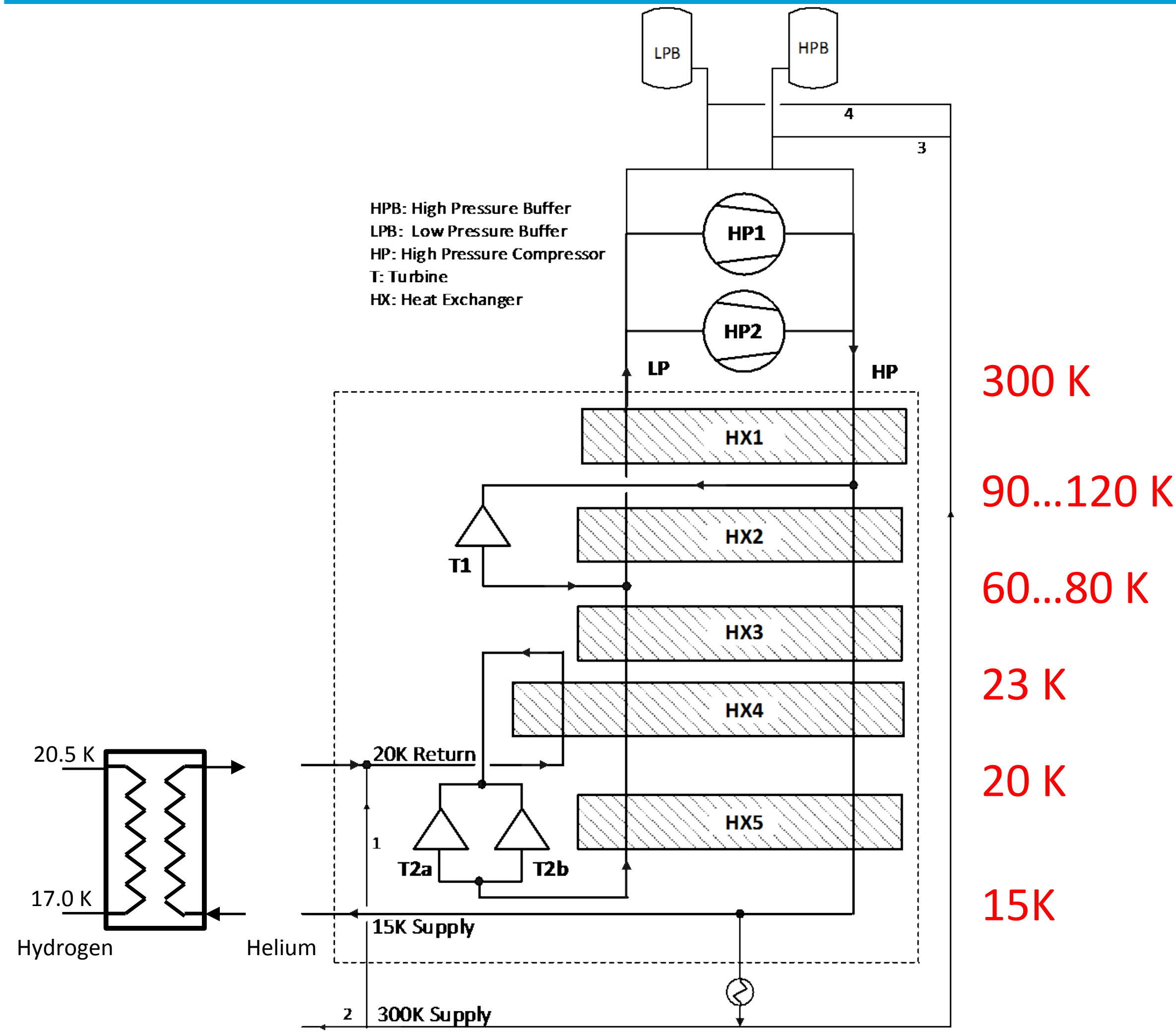

Helium buffers with "low" and "high" pressure region

2 screw compressor skids

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

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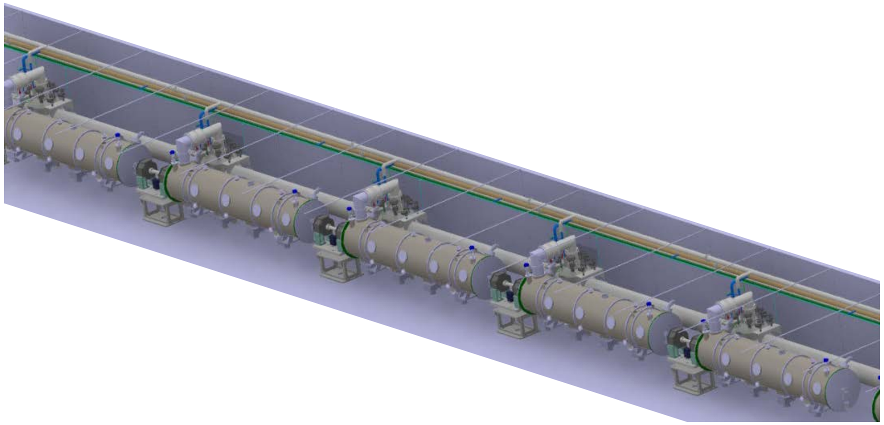
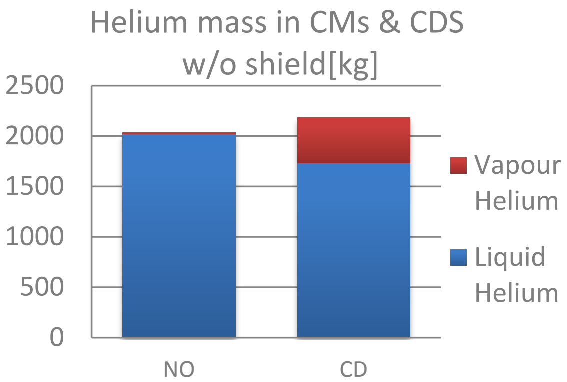
1) ACCP: Over 2000 kg in Cryomodules and distribution system

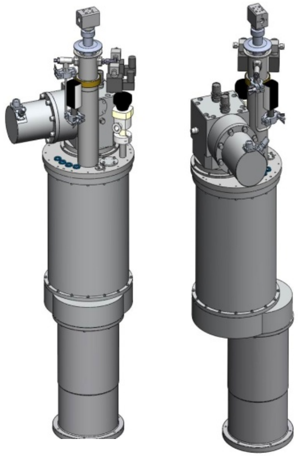




2) TMCP: Over 350 kg in Cryotransferline between helium and hydrogen box

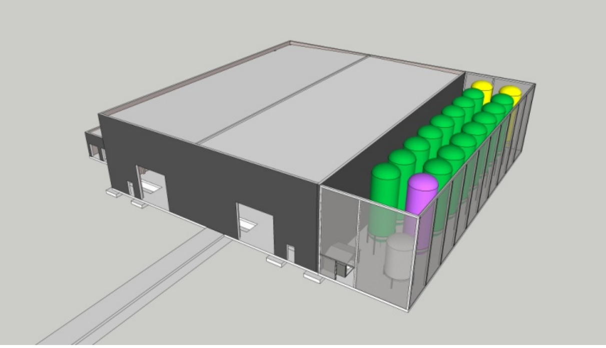
2 x 335 m x 4”

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^3
   - Theoretically up to 3.5 tons
   - Pressure restrictions for TICP and TMCP
   - Effectively ~ 3 tons



2) Liquid helium storage tank
   - 20 m^3
   - 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^3
   - Nearly 300 kg
   - Used as buffer in recovery system

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(5.1) Definitions

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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

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(5.2) Anticipated failure rates

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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	-	-

(5.3) Backup compressor system

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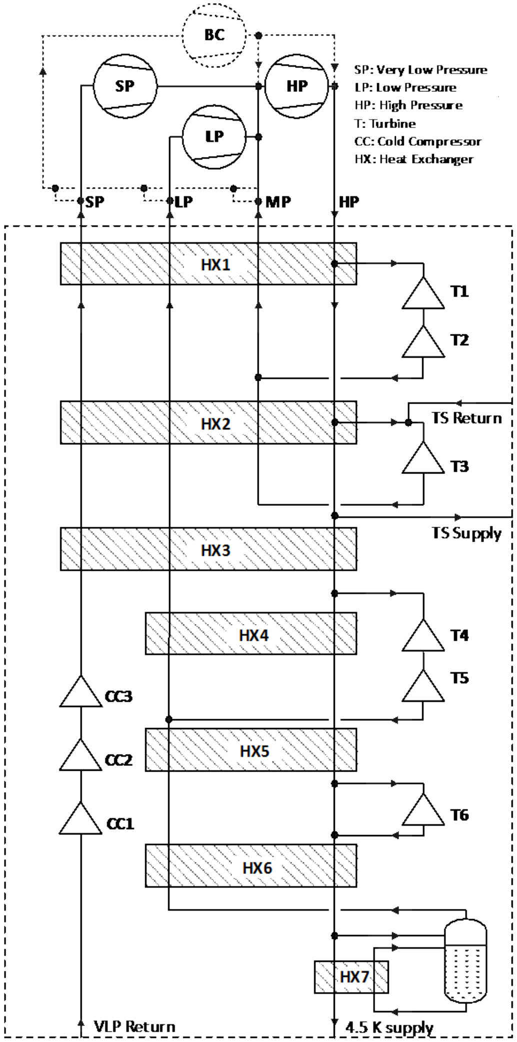

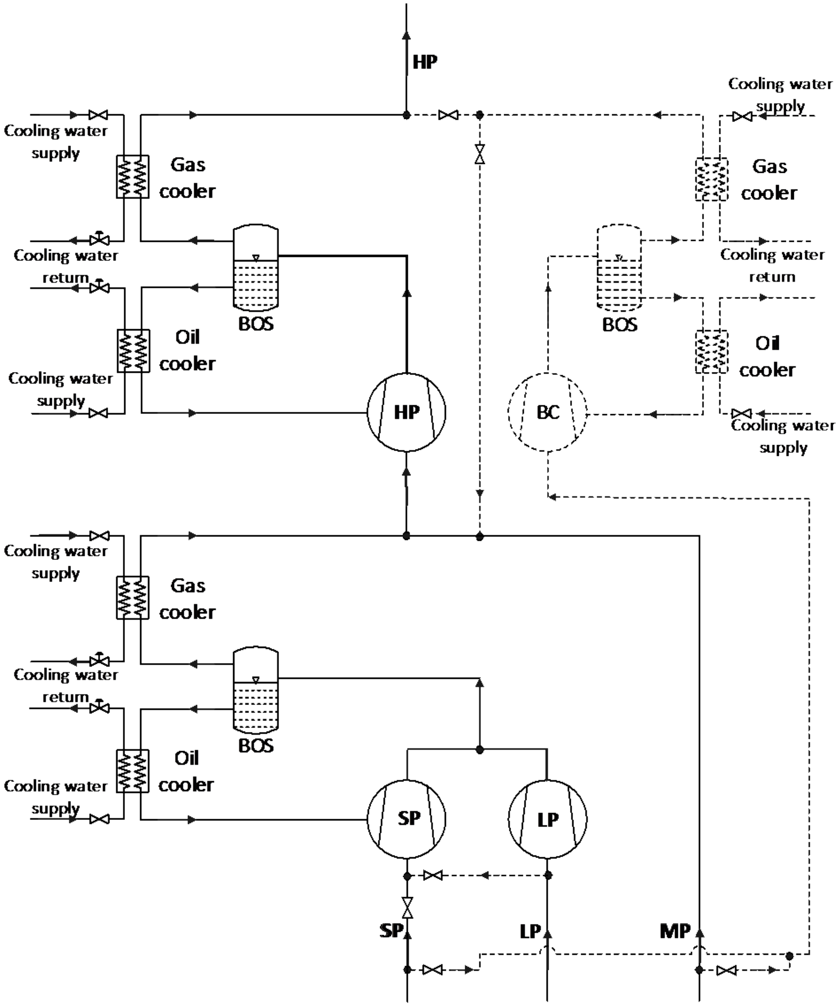

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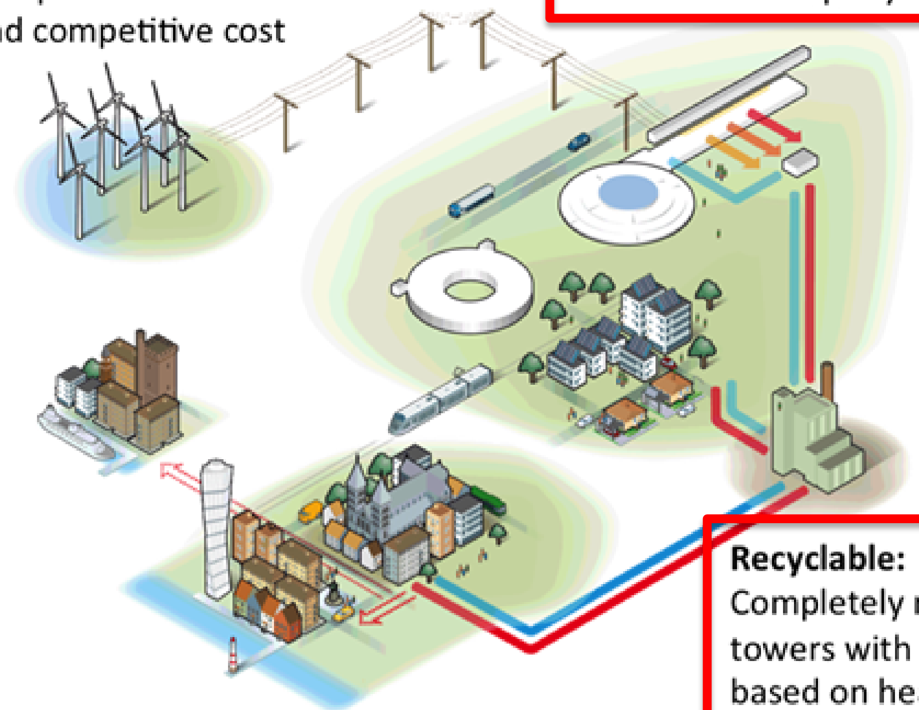
(6.1) Energy high level goals

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

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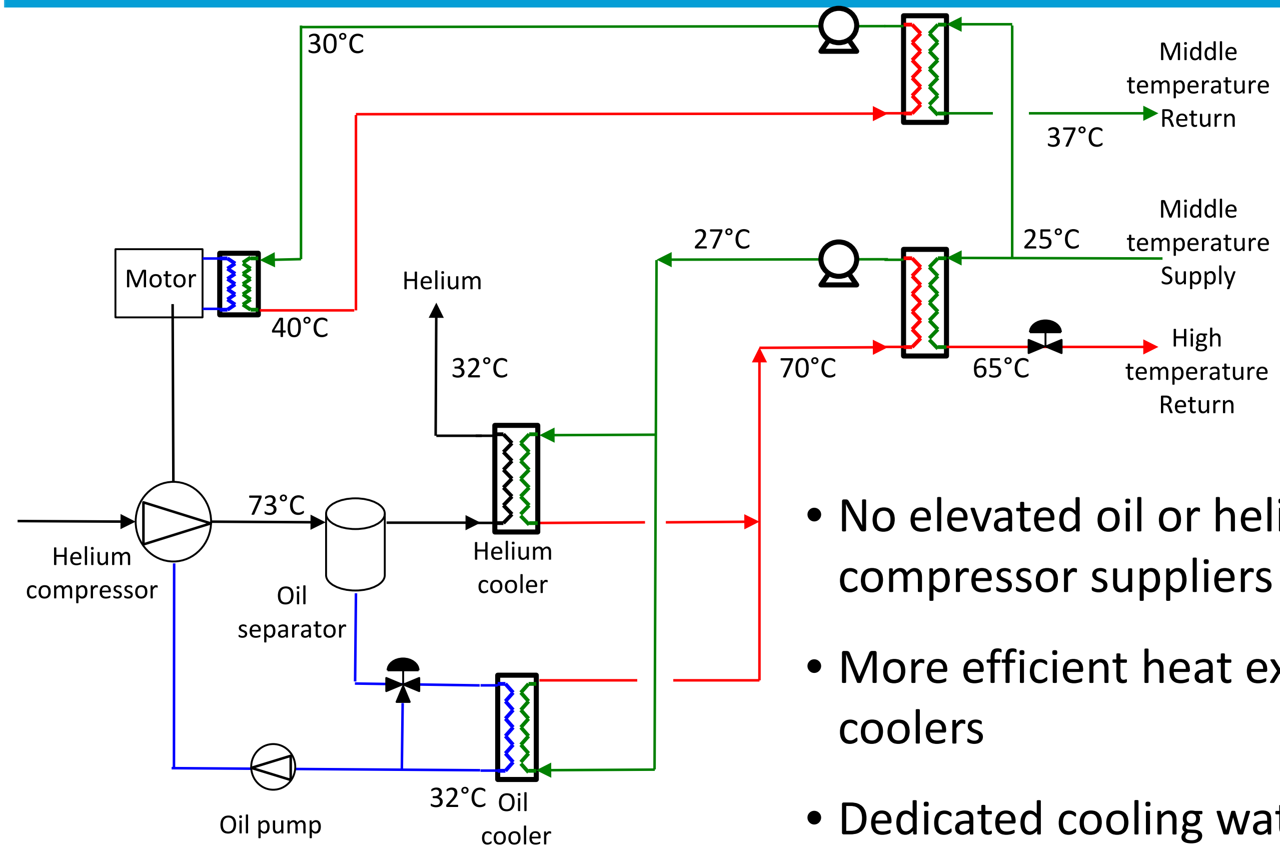

- No elevated oil or helium temperatures out of compressor suppliers specs
- More efficient heat exchangers, especially oil coolers
- Dedicated cooling water circuit for cryoplant
- Cooling function has priority over heat recovery

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(6.3) Energy efficiency and sustainability

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- 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

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Conclusions

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- 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