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Conceptual design of the Divertor Tokamak Test (DTT) Cryogenic System

M Angelucci, A Frattolillo, S Migliori, F Lisanti, R Bonifetto, A Froio, F
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M. Angelucci⁽¹⁾, A. Frattolillo^(1,2), S. Migliori⁽²⁾, F. Lisanti⁽³⁾, R. Bonifetto⁽³⁾, A. Froio⁽³⁾, F. Michel⁽⁴⁾, D. Duri⁽⁴⁾, P. Roussel⁽⁴⁾, A. Iaboni⁽⁵⁾

⁽¹⁾ENEA Frascati, Via Enrico Fermi 45 Frascati (Rome), Italy, ⁽²⁾DTT S.C.a.r.l., Via Enrico Fermi 45 Frascati (Rome), Italy

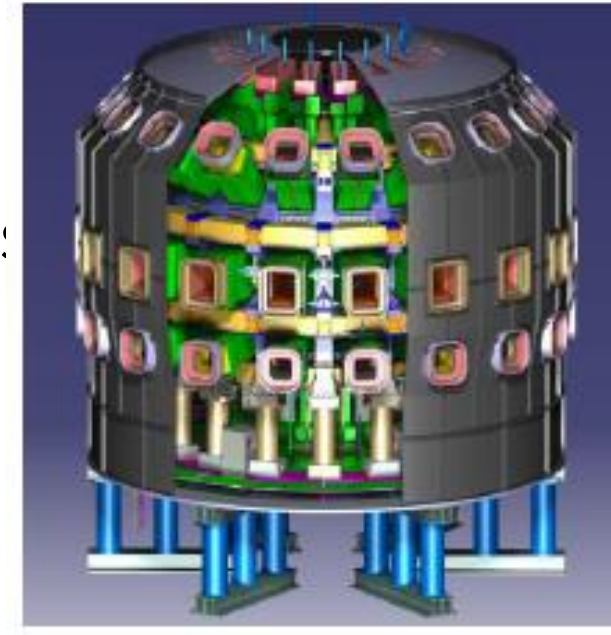
⁽³⁾Politecnico di Torino, Dipartimento Energia "Galileo Ferraris", Corso Duca degli Abruzzi, 24, Torino, Italy

⁽⁴⁾Univ. Grenoble Alpes, CEA, IRIG, Département des Systèmes Basses Températures, 17 Rue des Martyrs, F-38054 Grenoble, Cedex, France.

⁽⁵⁾Eni S.p.A., piazzale Enrico Mattei 1 00144, Roma, Italy

Introduction

- Divertor Tokamak Test (DTT) under construction at ENEA Frascati research centre (Italy) [1]
- High field superconducting (SC) tokamak (5,85 T) carrying 5.5 MA plasma current (~ 100 s plasma pulse): Cold magnet support structure.
- 18 Toroidal Field (TF) coils, 6 Central Solenoid (CS) modules and 6 poloidal Field (PF) coils.
- Active-cooled Thermal shield for magnet radiation protection.
- Cryogenic system overall capacity around 11 kW equivalent power at 4.5 K.

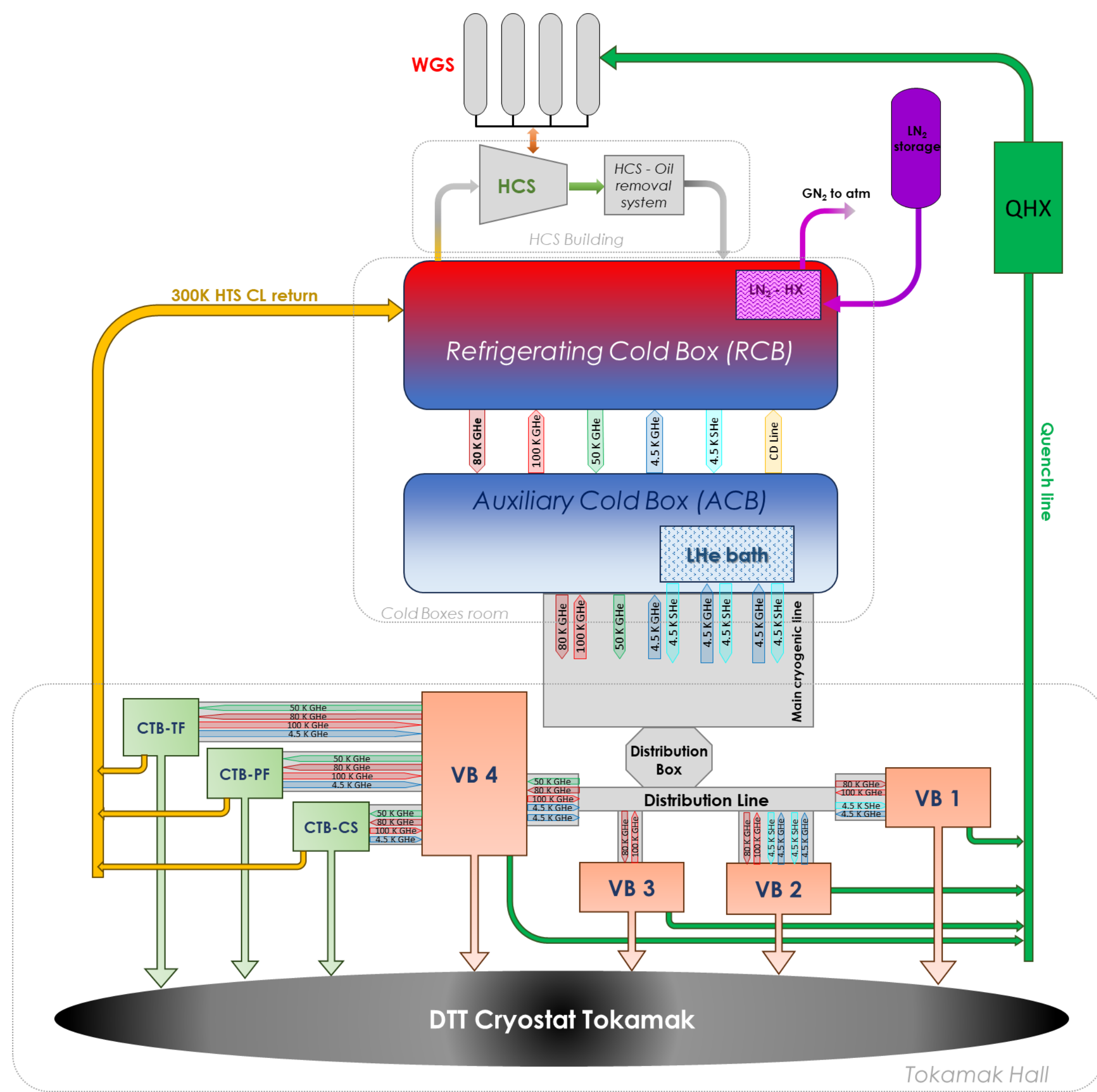


AIM OF THE DTT PROJECT: investigate alternative power exhaust solutions in EU DEMO relevant conditions

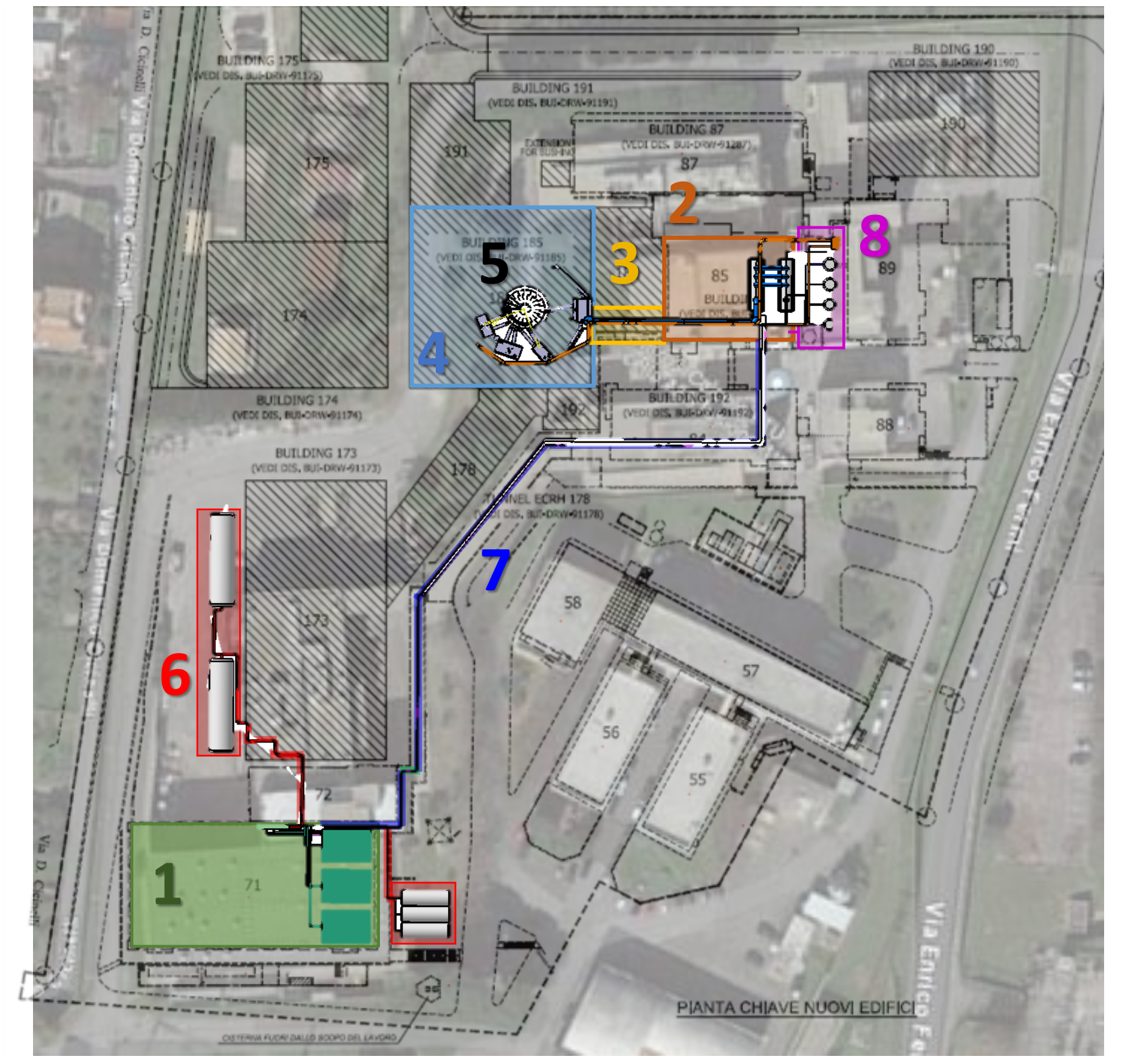
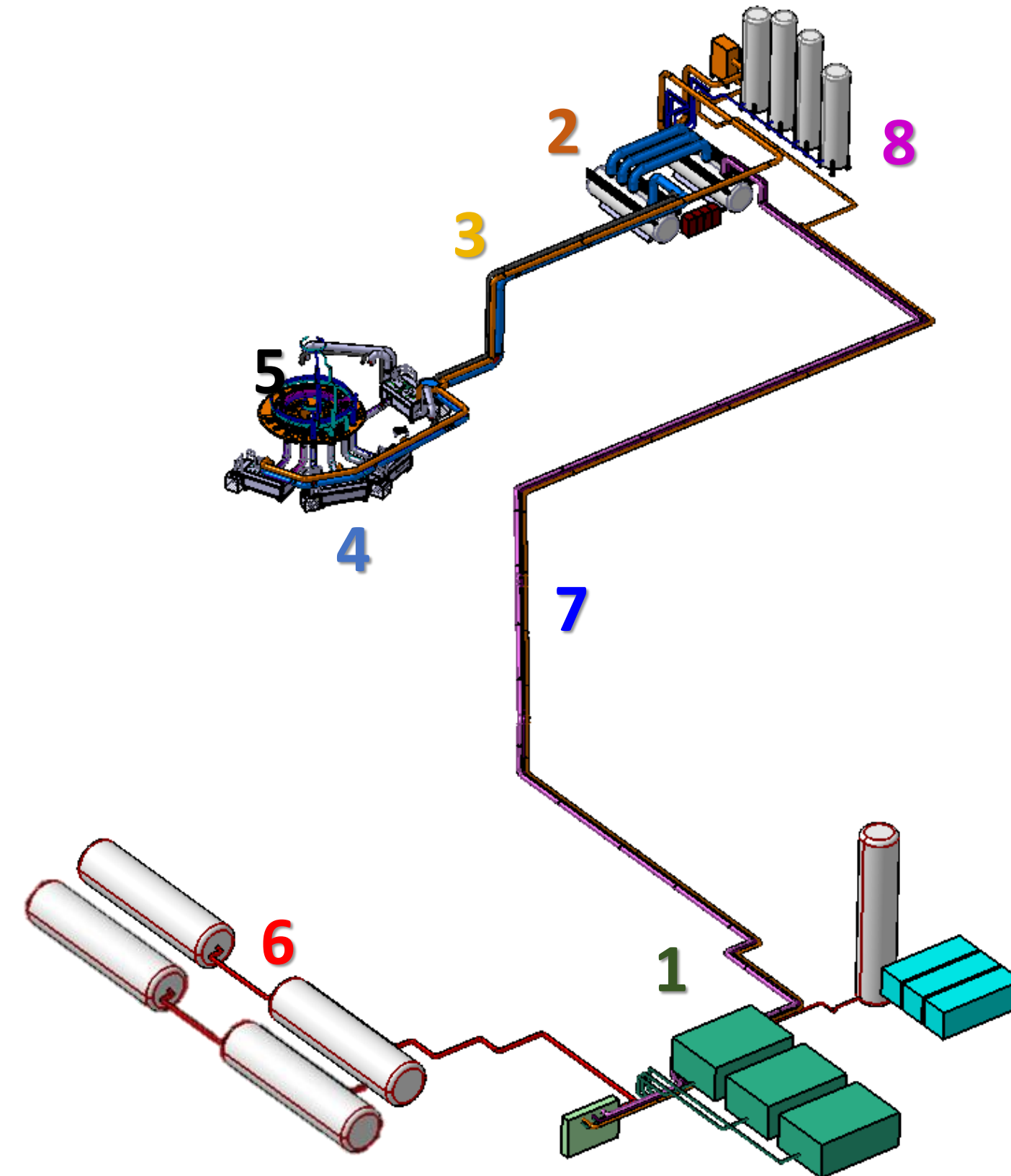
AIM OF THIS WORK:

Give an overview of the cryogenic system requirements, the conceptual design, the layout and main components

1.a From DTT Cryoplant architecture...



1.b ...To Cryoplant arrangement in DTT site



Cryogenic System is made up of 8 Sub-systems:

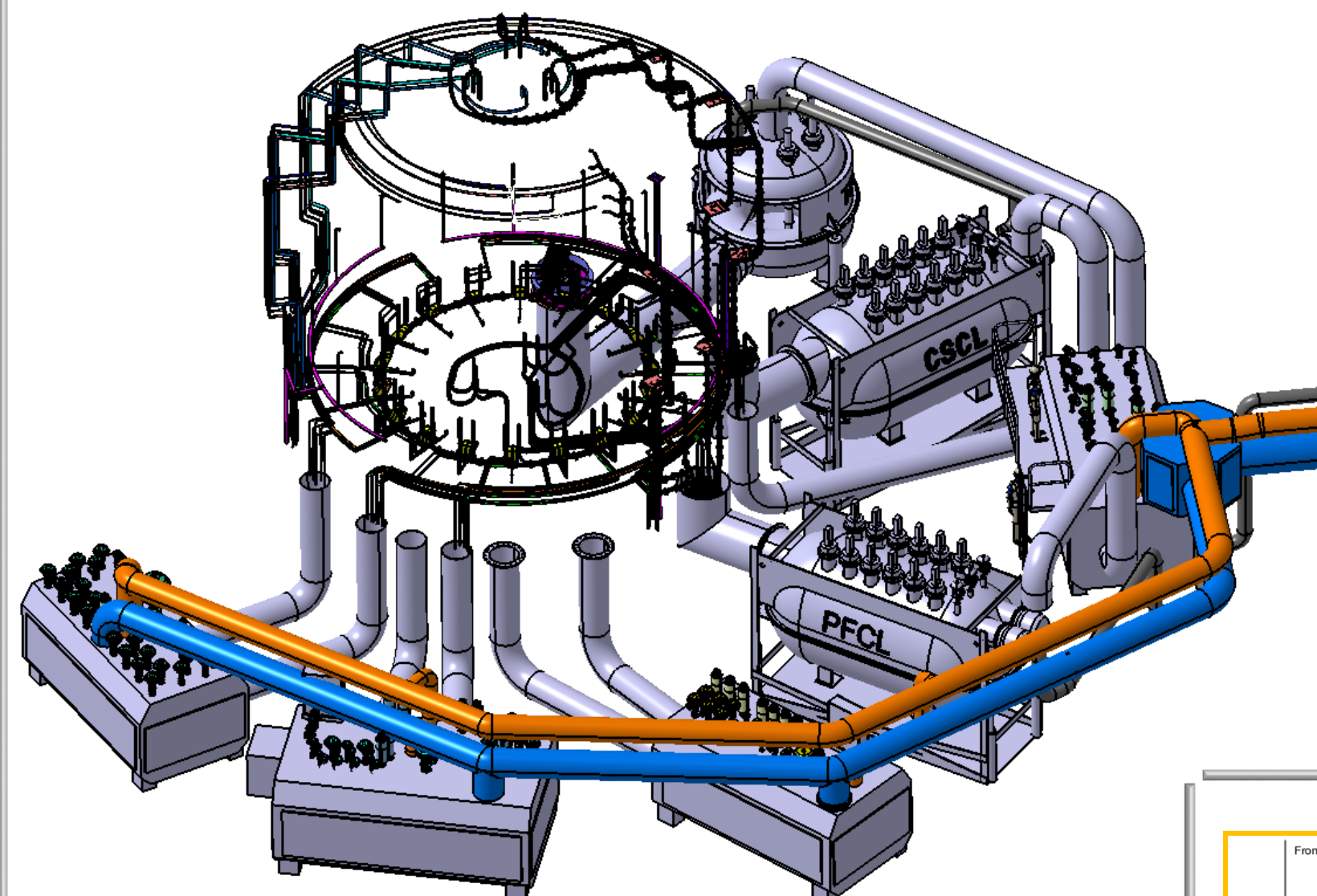
1. Helium Compression Station (HCS)
2. Cold Boxes (CB)
3. Distribution between Cold Boxes and Tokamak Hall
4. Distribution in Tokamak Hall
5. Cryo-distribution inside tokamak cryostat and Current Lead Boxes
6. Warm Gas Station (WGS)
7. Warm Lines (WL)
8. Liquid Nitrogen System (LNS)

2. DTT Cryogenic system users and requirements

Distribution loop	Component	Minimum Mass Flow Rate (g/s)	Maximum Supply Temp. (K)	Minimum Supply Pressure (bar)	Design Pressure Drop (bar)	Static Heat Load (W)	Pulsed Load per cycle (kJ)	Eq. Heat load @4.5K (W)	Eq. pressure drop load @4.5K (W)	Circulator dissipation load @4.5K (W)	Total equivalent load @4.5K
1	18 TFC	540	4.3	5.5	1.2	1800	800	3133	675	1088	4896
	18 TF Casings + 18 4KGSTA	180	4.3	5.5	0.1+0.1	700+450	500				
	6 TF Feeders + 15 Jumpers	105	4.3	5.5	1.0	250	Negligible				
2	6 CS Modules	330	4.3	5.0	1.0	Negligible	1100	1399	381	948	2728
	12 CS/12 PF Feeders	48	4.3	5.0	1.0	343	TBD				
3	10 CryoPanels	180 (TBC)	4.3	5.0	0.1	12	0.6	214	40	-	254
4	10 Chevron Baffles	80	80	15.0	2.0	7000	0	2152	788	-	2940
	Thermal Shields	400 (TBC)	80	15.0	2.0	40000 (TBC)	0				
	18 80KGSTA	36	80	15.0	2.0	1800	0				
	3 CLB-TSS	30	80	15.0	2.0	3120	0				
5	30 HTS-CLS	48*	50	4.0	1.0	62324*	0	1094	632	-	1726
								Total			12544

* Preliminary assessment - CL of DTT to be designed yet

3. DTT Cryo-distribution

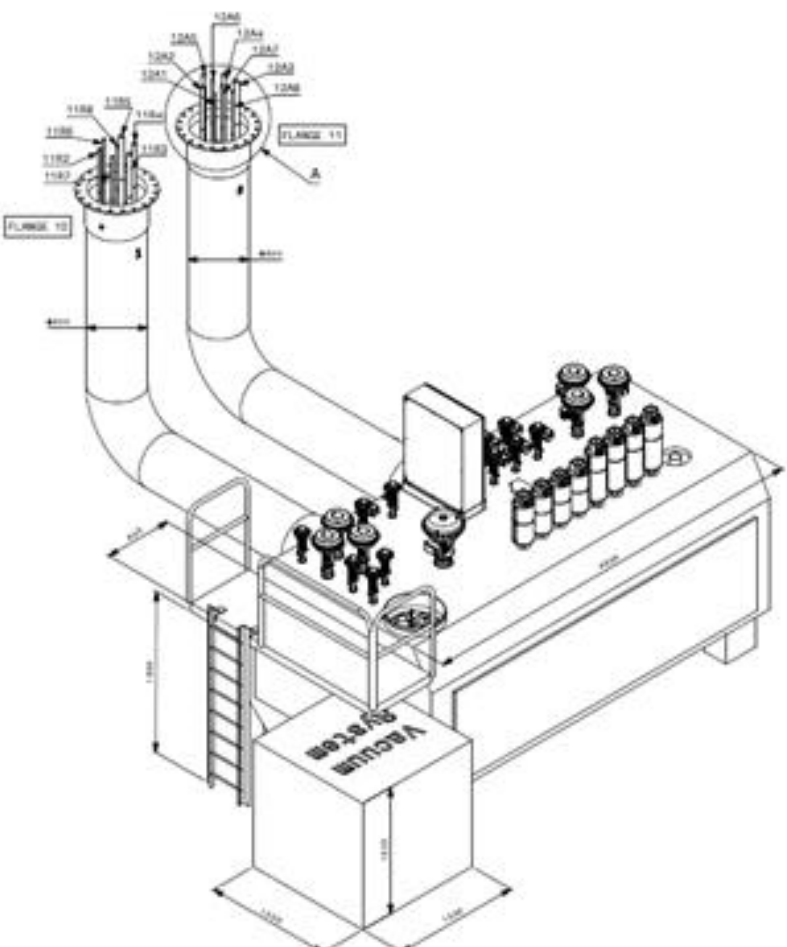


View of cryo-distribution system in Tokamak Hall

Cooling helium is transferred from Cold Boxes to Tokamak Hall through 9 distribution lines inside a Main Cryogenic Line (MCL) or multiple transfer lines.

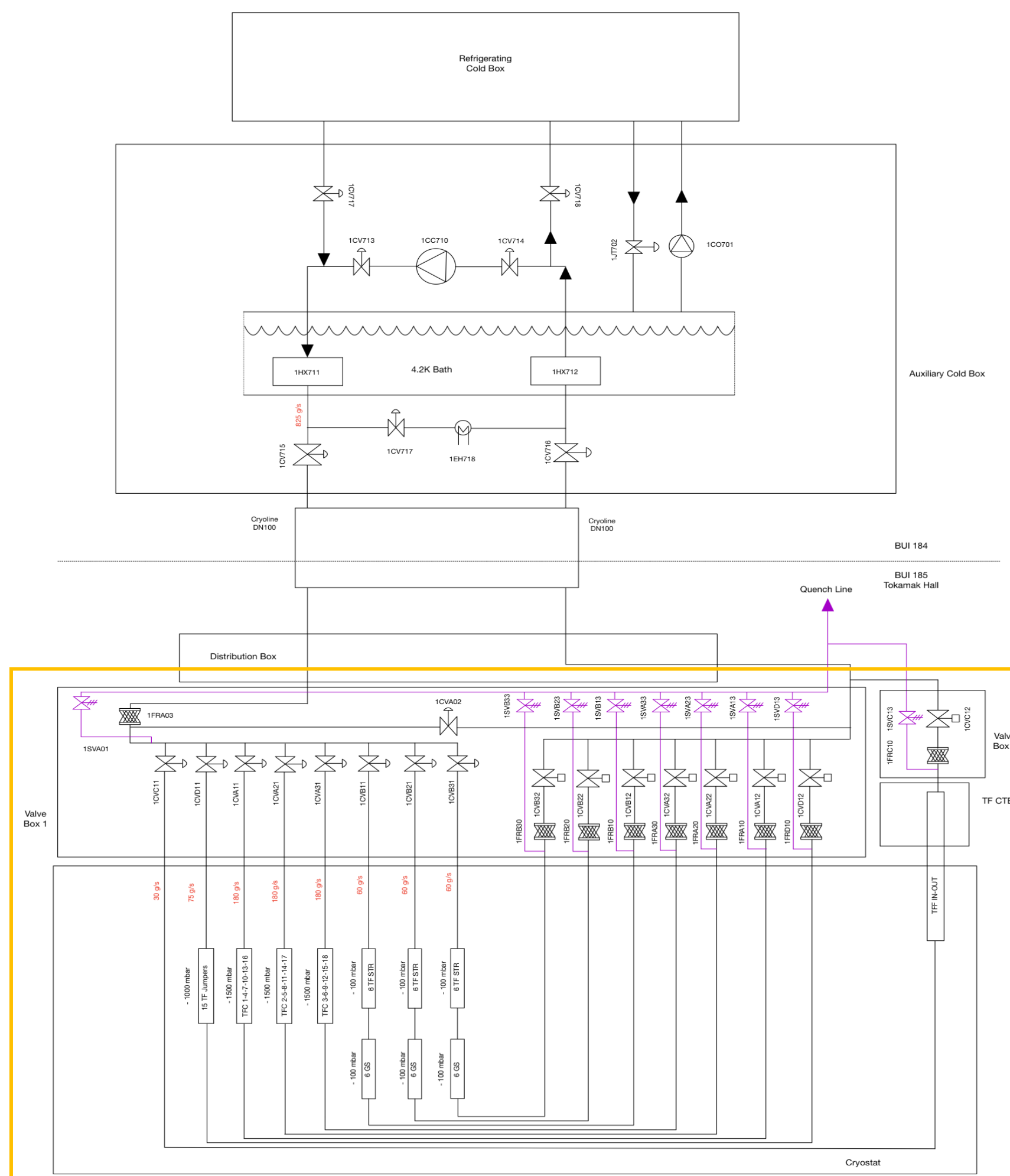
The distribution inside the Tokamak Hall is achieved by means of:

- 1 Distribution Box - connected to MCL
- Distribution CryoLine - about 30 m, DN 600
- 4 Cryogenic Valve Boxes, 20/30 m³ each, 4 independent vacuum systems, 700 measuring points, 127 Cryogenic valves
- 300 K line Section 1 - 50 m, DN 200 + 3 Warm Valves Units close to CLBs
- Quench Line Section 1 - 30 m, DN 200



Possible solution of Cryogenic Valve Box

4. DTT Cryo-distribution in Cryostat

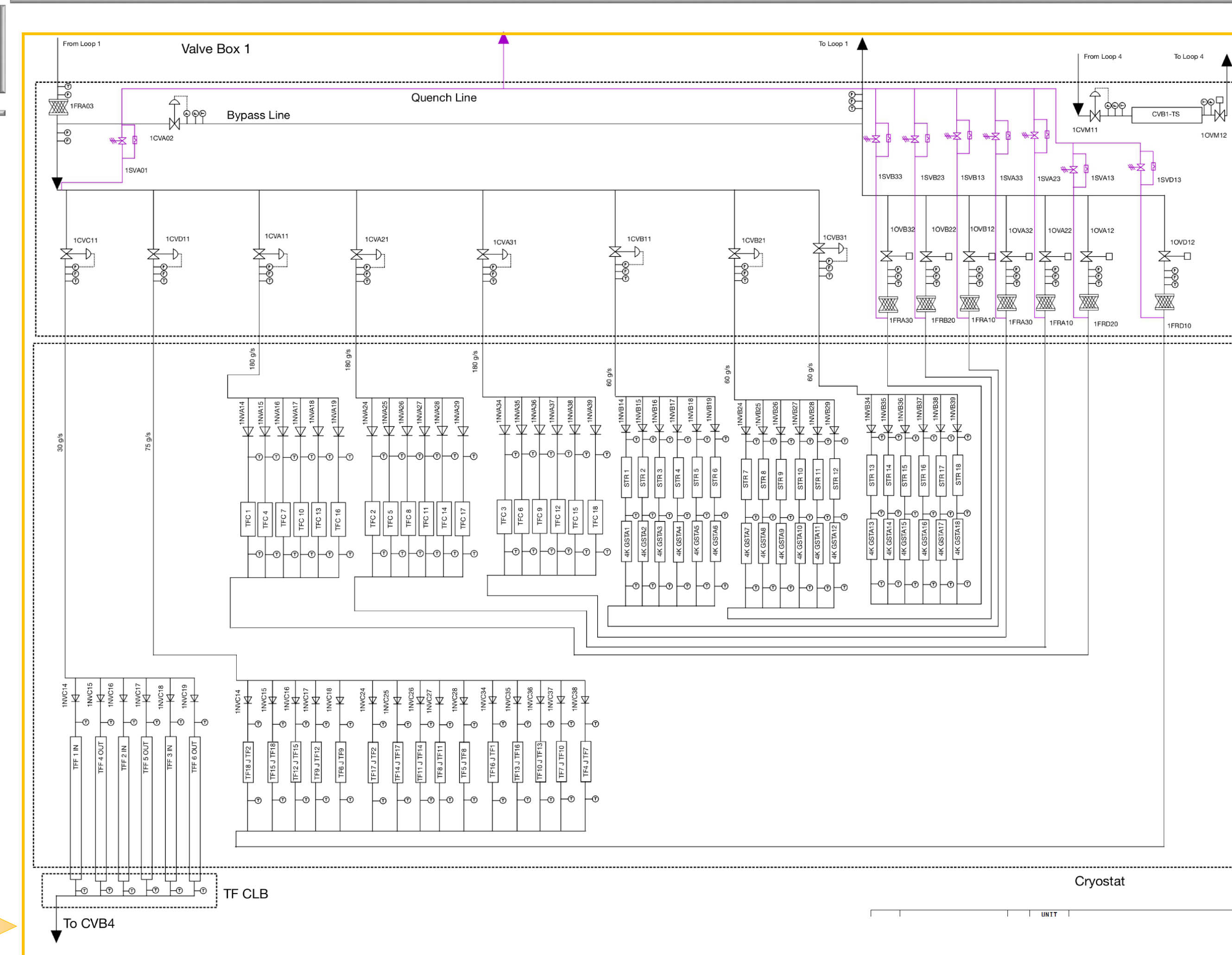


Example of cryo-distribution: PFD of loop 1

- 3 groups x 6 TF magnets
- 1 group x 6 TF feeders
- 1 group x 15 TF Jumpers
- 3 groups x 6 TF casings & 6 thermal anchor @4 K (in series)

Main Features:

- Cooling strategy with groups of same kind of users (e.g., magnets, thermal shield sectors, cryopump panels, etc.) cooled in parallel with 1 regulation valve at the inlet and 1 on/off valve at the outlet (e.g., TF cooled in 3 groups of 6 magnets, PF at CS cooled in 2 groups of 3 magnets, cryopumps cooled in 3 groups, etc.)
- Non-return Valves upstream each superconducting user (coils or cables) to avoid backward flow in case of quench with the aim to protect the other magnets of the same cooling group
- Filters inside the CVBs (to simplify maintenance and replacement): one upstream the distribution manifold and several at the outlet of each group of users (upstream the outlet cut-off valves)
- Temperature sensors upstream and downstream each cryogenic user
- Quench valves to release He in case of over pressure in the circuits are installed inside the CVBs and connected to the Quench Line



5. Outlook and schedule

- Preliminary design and layout of DTT cryogenic system is completed.
- Final design of the cryogenic process shall be developed and optimized by the supplier.
- The tender notice for DTT cryogenic plant (sub-system from 1 to 4 of Section 1) will be published in last quarter of 2024.

- The tender will last about 1 year to allow the development of the Cryoplant design.
- The supply of the Cryoplant includes executive design and procurement, Factory Acceptance Test, Transportation and Installation, On-site Acceptance Tests, Plant integration and assistance during commissioning and should last about 4 years.
- Commissioning is foreseen in second quarter of 2030.

