Symposium for the inauguration of the LHC cryogenics
31 May to 01 June 2007

Power refrigeration at 4.5K & 1.8K for the LHC

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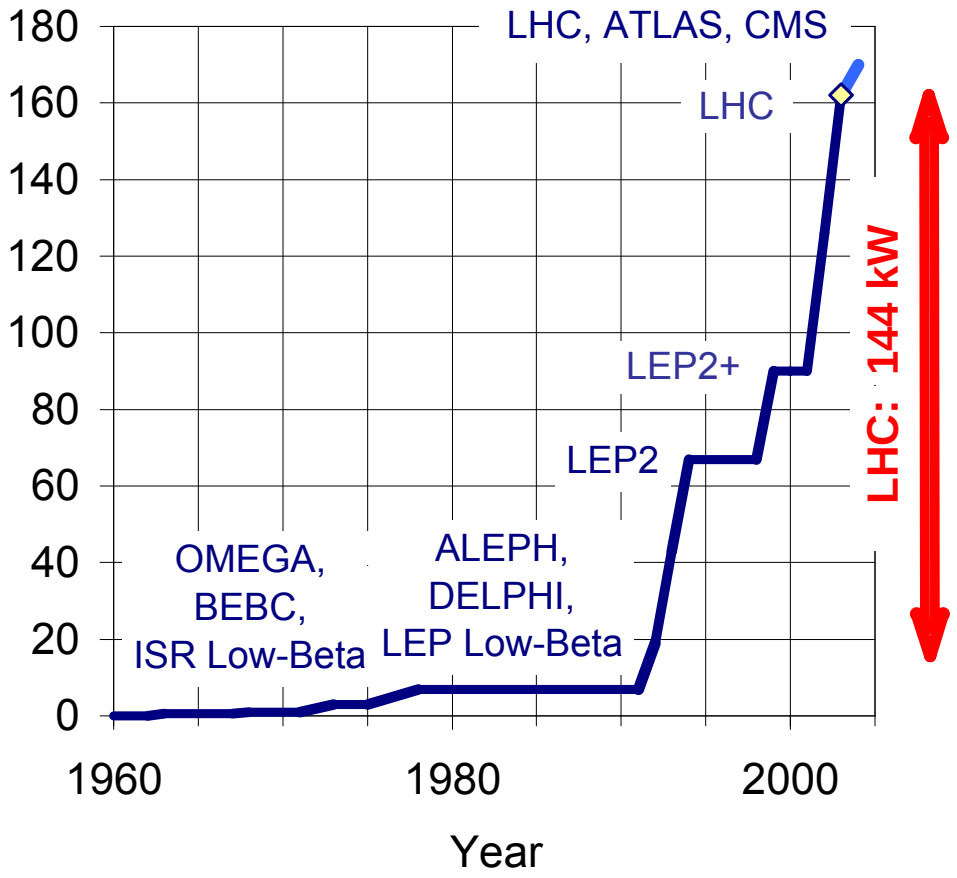
Content

- Introduction
- Required capacity and system architecture
- 4.5 K Refrigerators and 1.8 K Units
- Recent achievements
- Conclusion

Introduction

Long tradition and experience with cryogenics and refrigeration

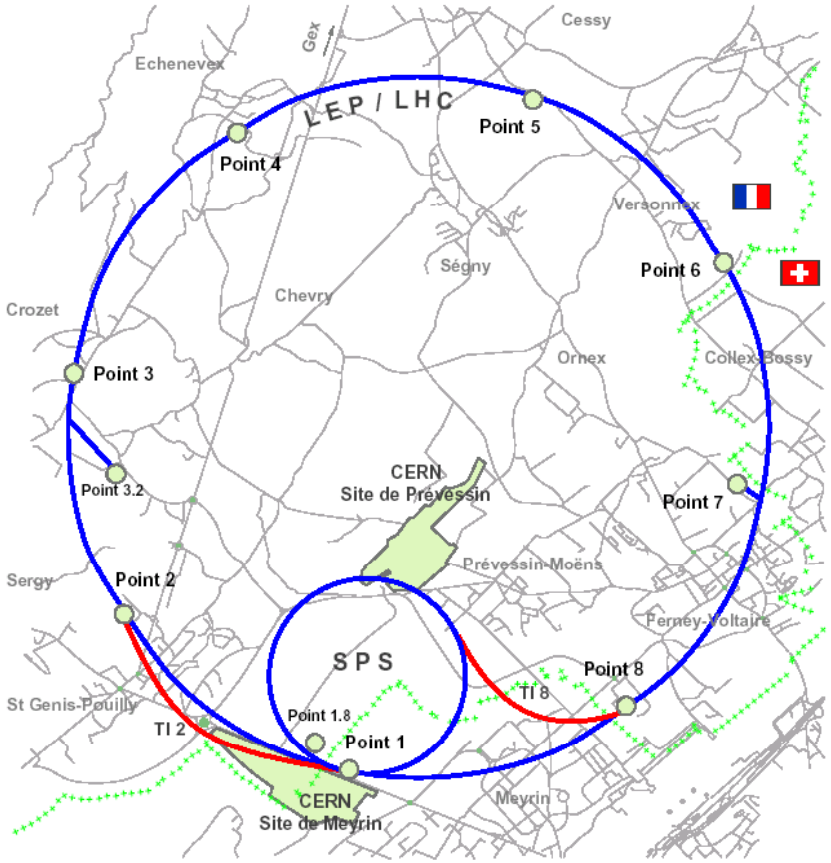


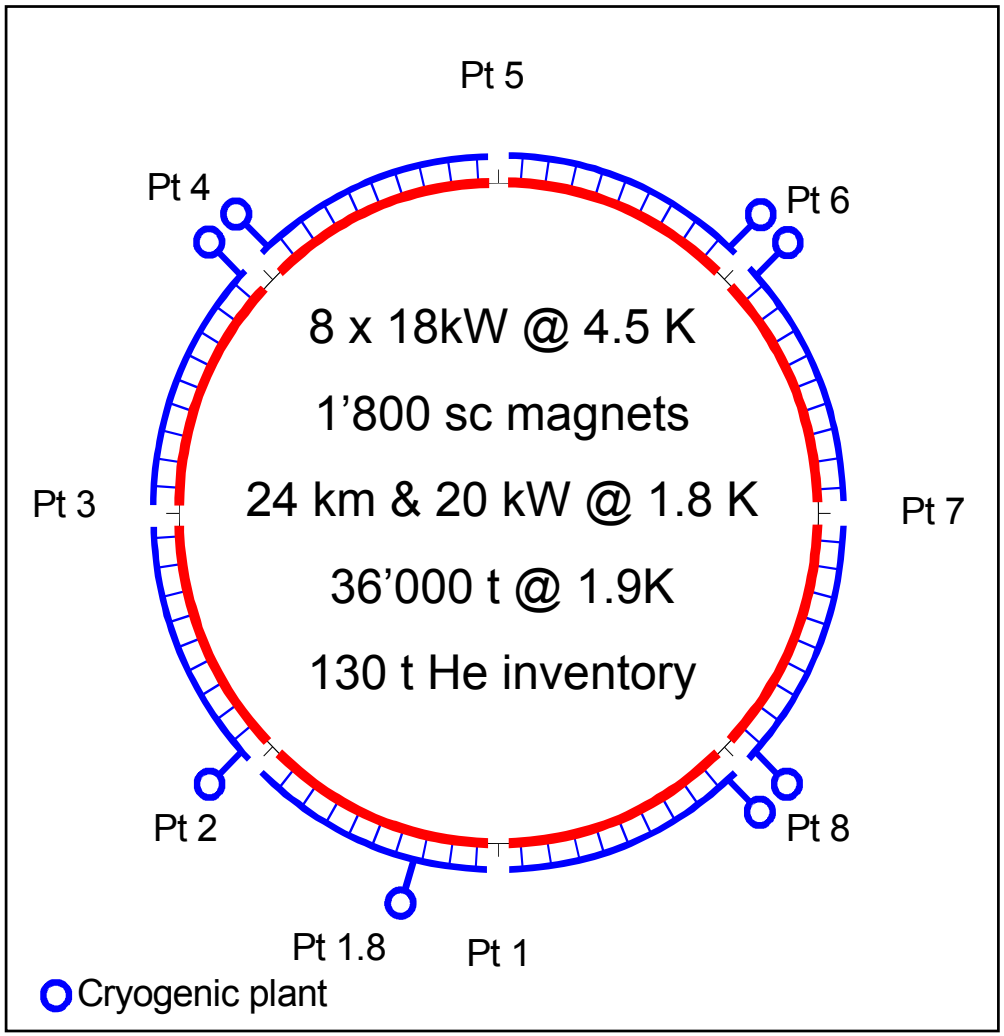
LHC, the largest helium refrigeration system ever built

Basic choices, design criteria

- Re-use of ex-LEP refrigerators to be upgraded for LHC requirements
- Site constraints for infrastructure => 5 islands
- 1.8K Refrigeration units to be connected to all types of 4.5K refrigerators
- General features:
  - Cool-down & Warm-up: 600kW
  - No global redundancy but doubling critical items
  - Impurities: continuous capacity for 50 ppm(v) air, water

Layout of LHC Cryogenics





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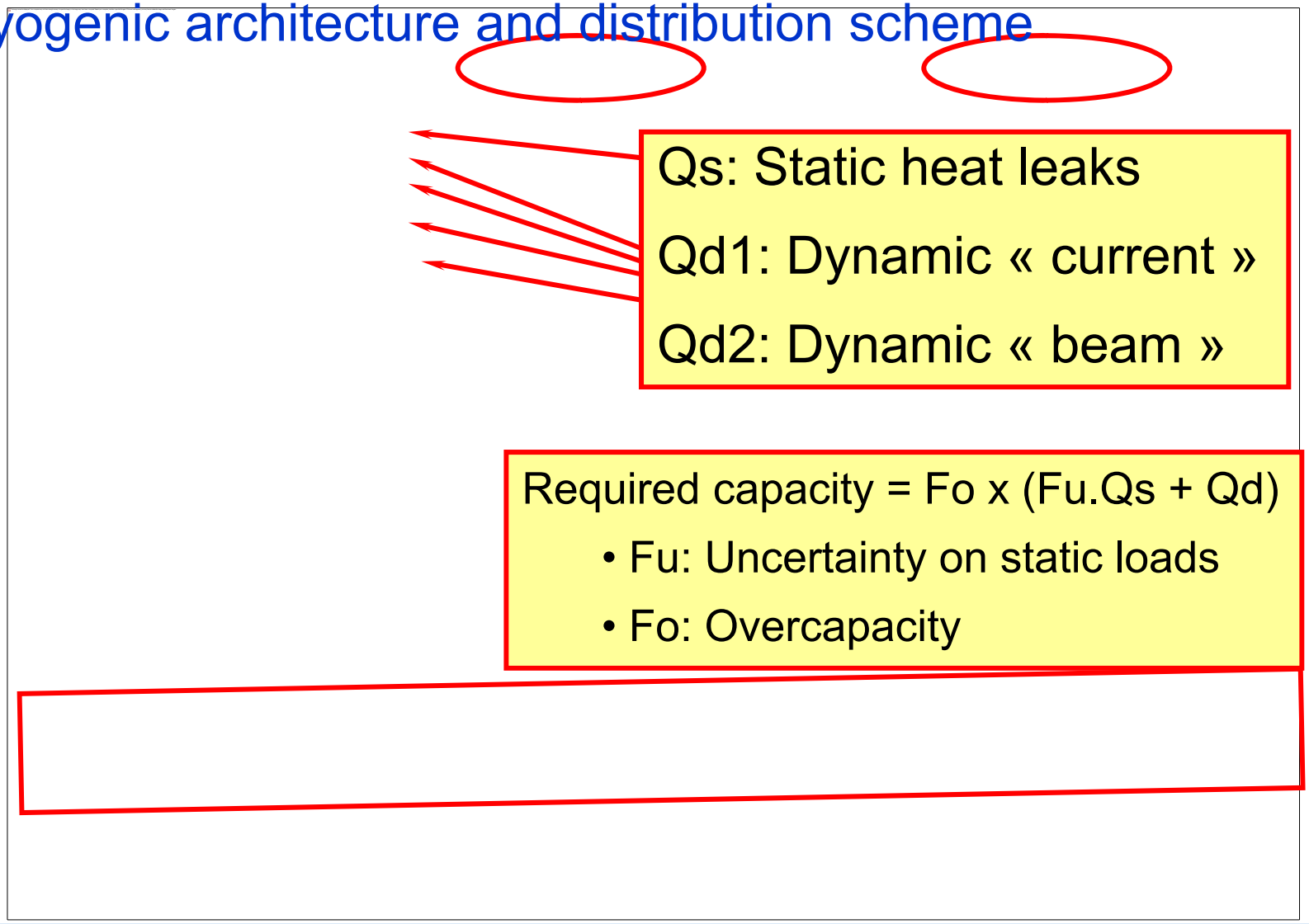
Heat loads for a sector

Early heat load inventory and follow-up, periodic update of cryogenic architecture and distribution scheme



Demands in refrigeration

1. Evaluation of heat loads (static, dynamic)
2. Required capacity with appropriate margins
3. Convertion in Demands for Refrigeration
4. Process studies to validate feasibility

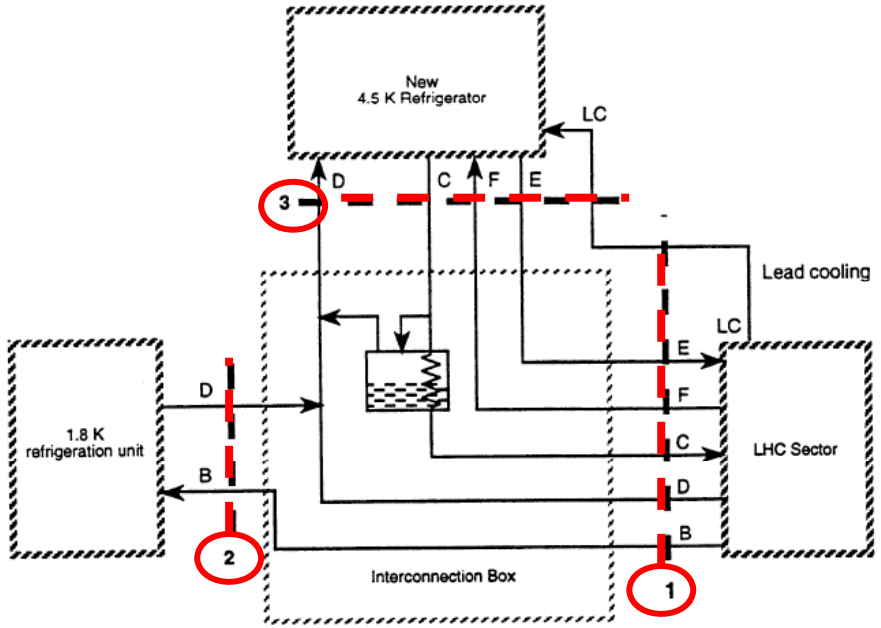
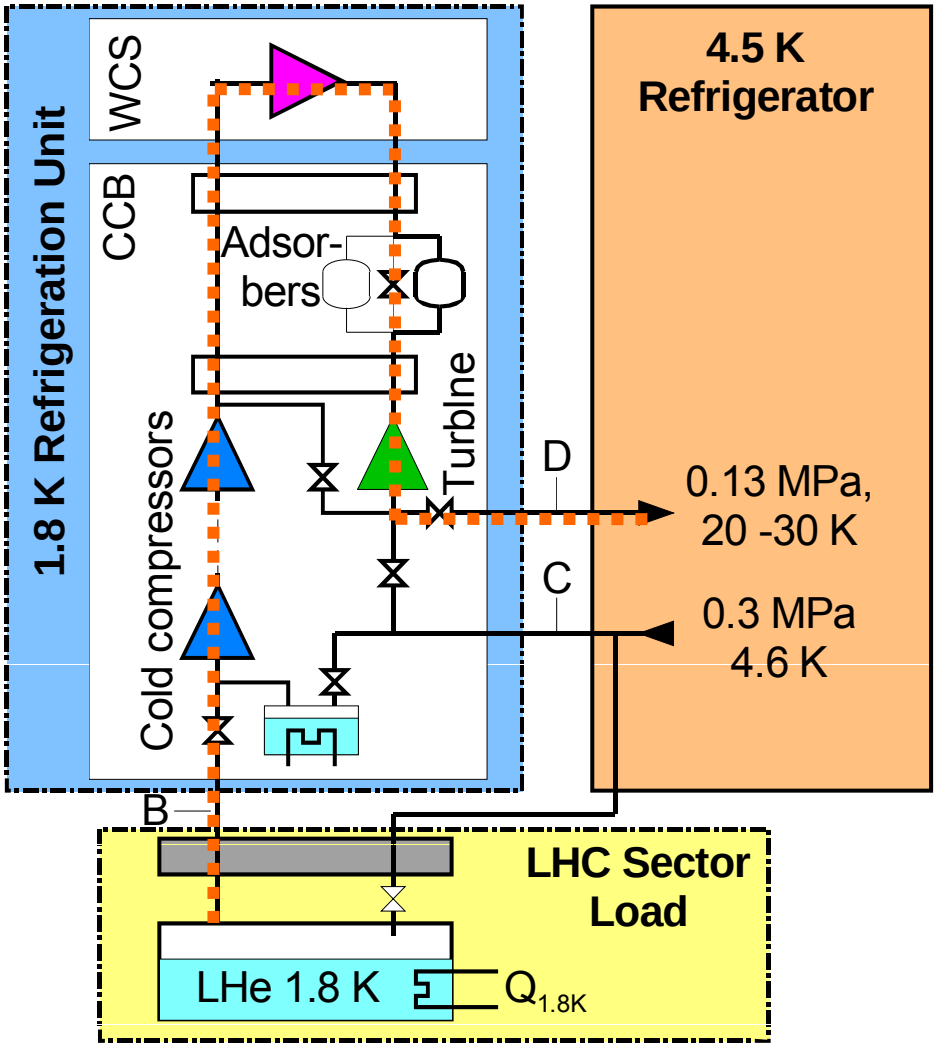


Figure 2: Simplified cryogenic block diagram for a high-load sector including cryogenic interconnection box, 1.8 K refrigeration unit and refrigerator.

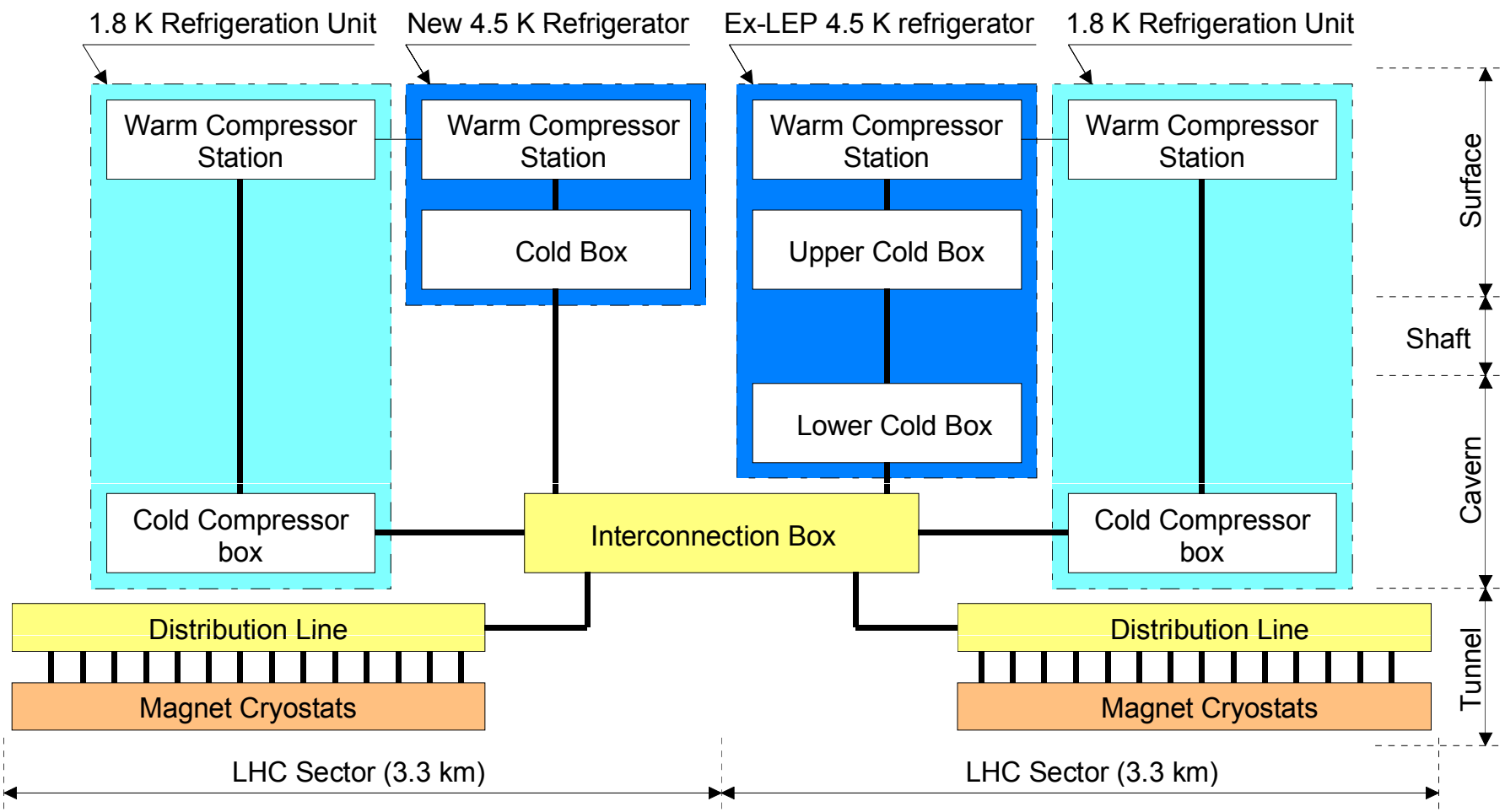
Possible cooling cycles



- Installed capacity:
  125 g/s @ 15 mbar
  (i.e. ~2,4 kW @ 1,8 K)
- Turn-down capability: **1 to 3**
- Return temperature at the 4.5 K Refrigerator:
  - Reduced mode: ≤ 30 K
  - Installed mode: ≤ 20 K
- 'Stand alone' capacity check (B interface closed)
- Process & components identified as a challenge
- Validation prior to series (1+n)

Cryogenic architecture

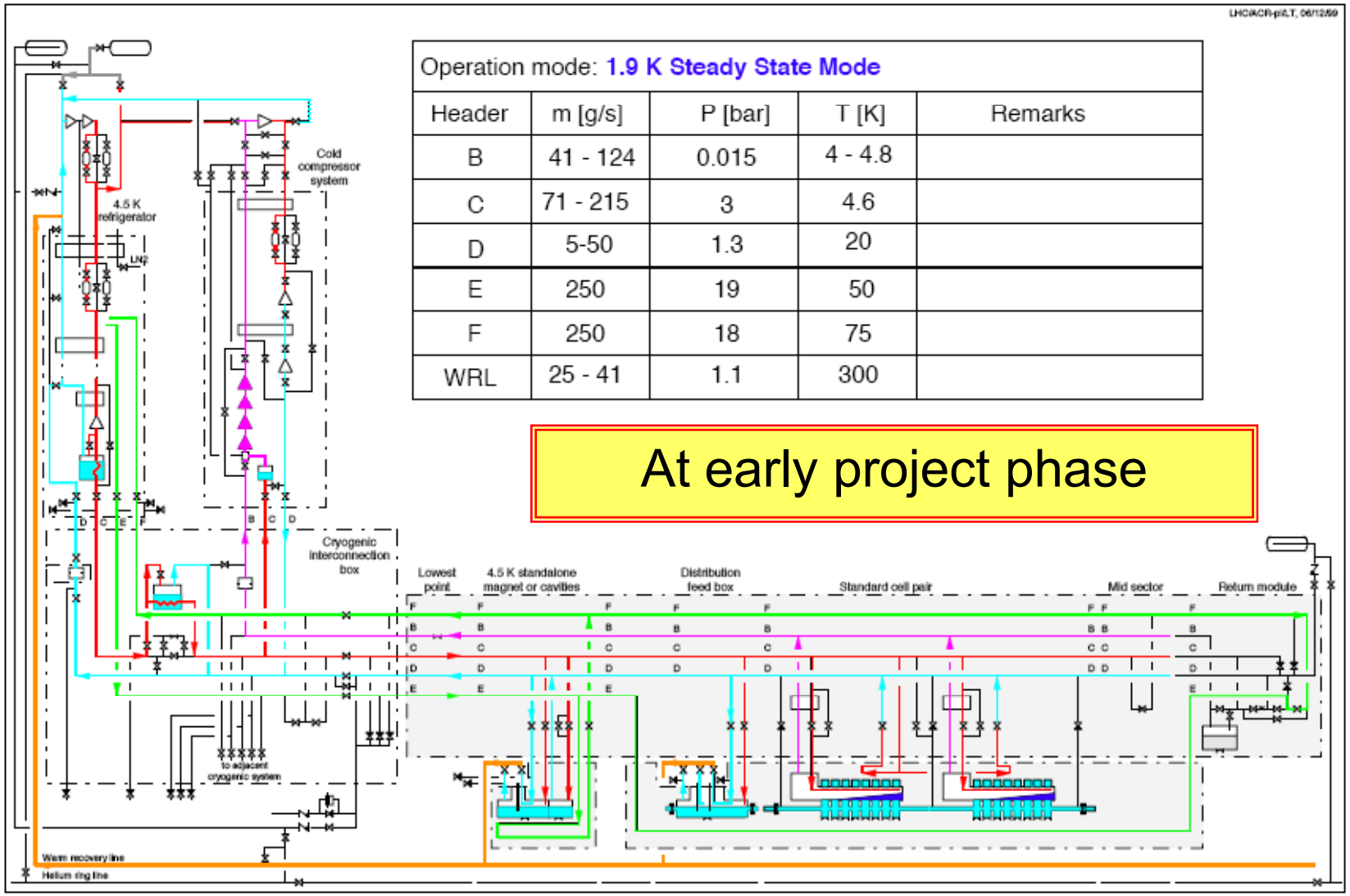
Typical LHC even point



Checking all modes

Operation mode: **1.9 K Steady State Mode**				
Header	m [g/s]	P [bar]	T [K]	Remarks
B	41 - 124	0.015	4 - 4.8	
C	71 - 215	3	4.6	
D	5-50	1.3	20	
E	250	19	50	
F	250	18	75	
WRL	25 - 41	1.1	300	

At early project phase



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Procurement strategy

- Sub-systems by type of functionality:
  - CERN defined interfaces and required performance
- Great majority procured from industry:
  - Competitive performance based tendering (capital and operation cost)
  - Detailed studies, manufacturing, site installation, commissioning, performance assessment
- Separate management of general services:
  - Interconnecting piping, controls, site utilities

Construction phase

- Industry available products:

  (storage tanks, piping, 4.5K refrigerators)

  - Functional technical specifications adapted => tests

- Extension of existing products

  (1.8K units, cryogenic lines, superconducting links)

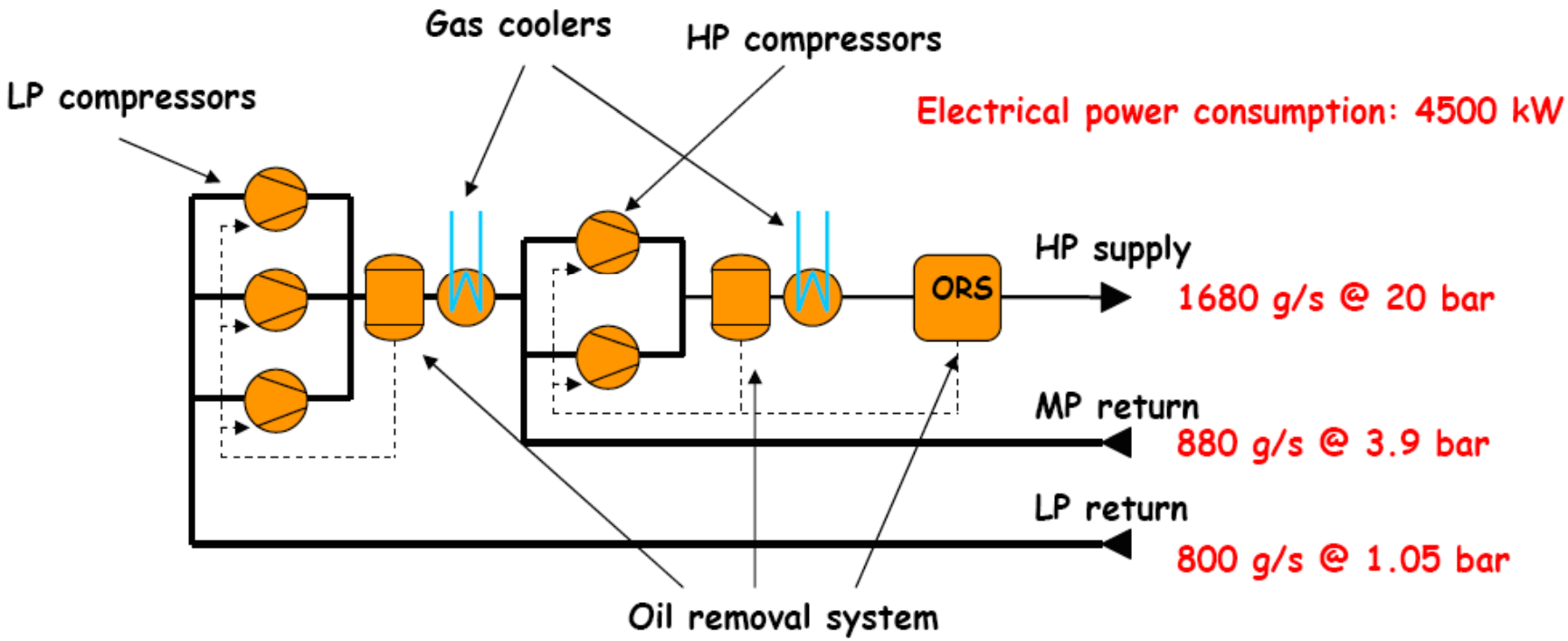
  - Complex performance & possible impacts
  - CERN add. design & support to fabrication

- Totally new products

  (Rad. tol. cryo thermometry - electrical feed boxes)

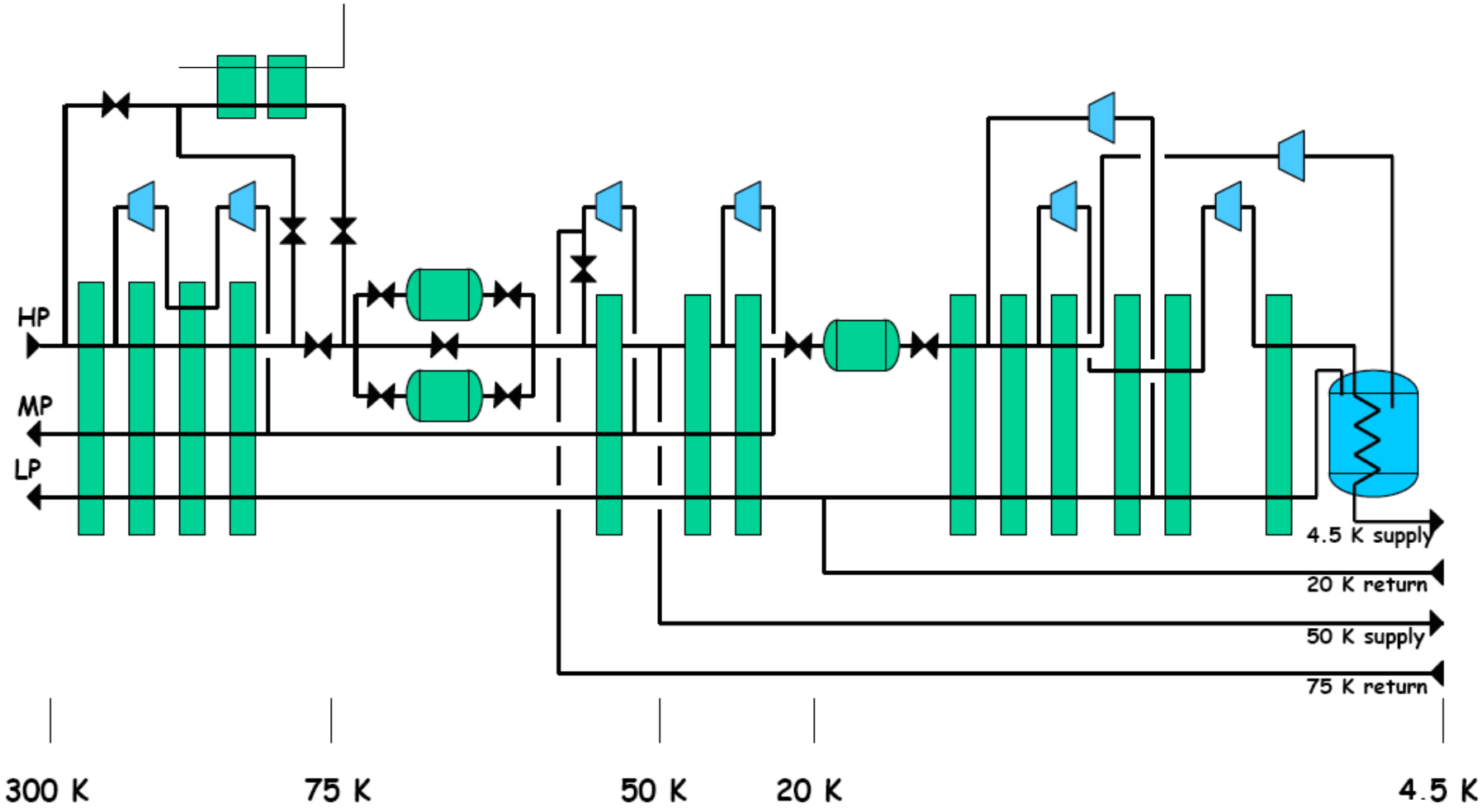
  - CERN with full responsibility for developments and "built to print" fabrication contracts

LHC 18 kW @ 4.5 K Refrigerator
Compressor stations



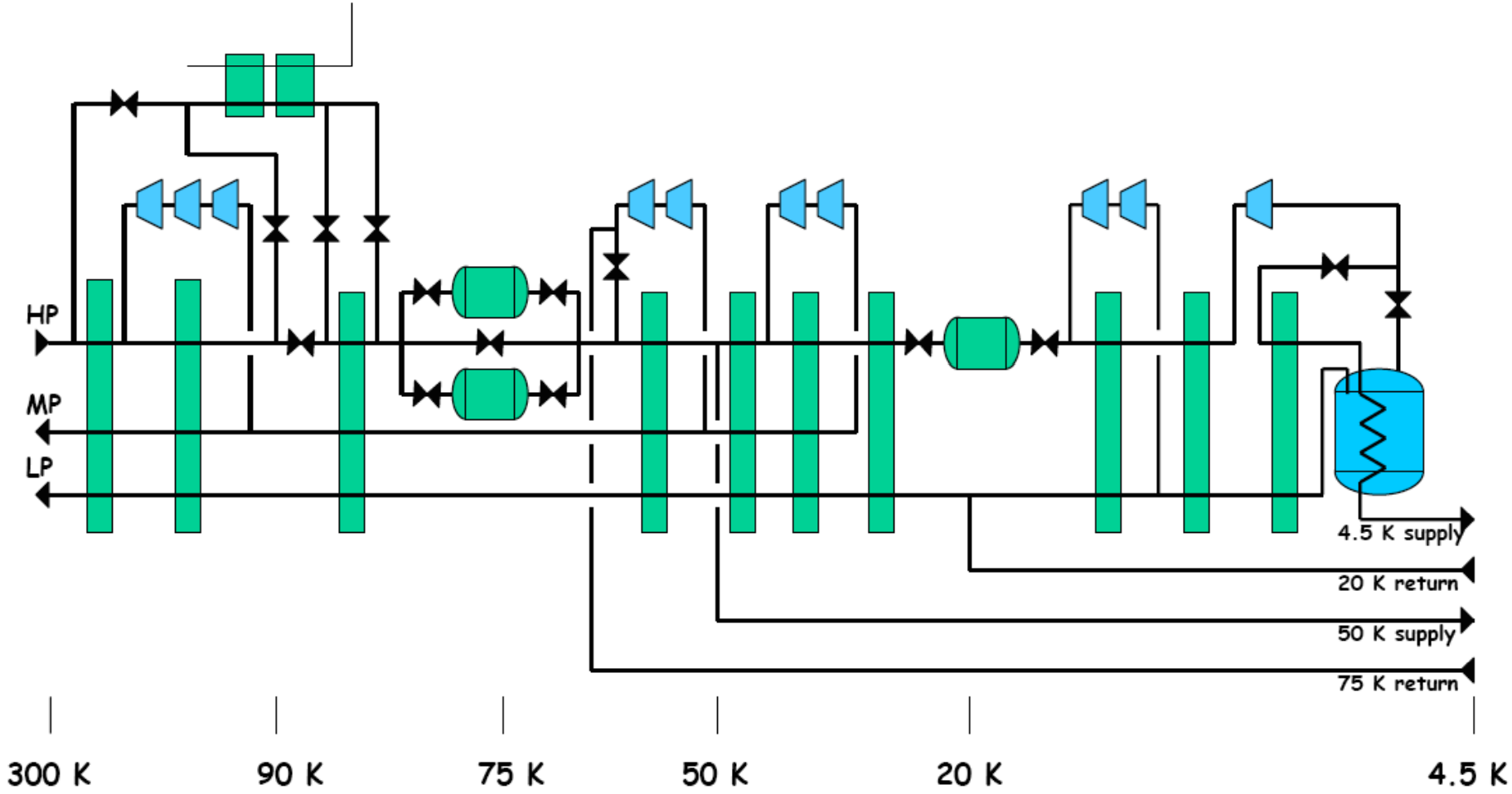
Identical installation for both suppliers, i.e. all new 4.5 K refrigerators

LHC 18 kW @ 4.5 K Refrigerator
Process cycle for Air Liquide



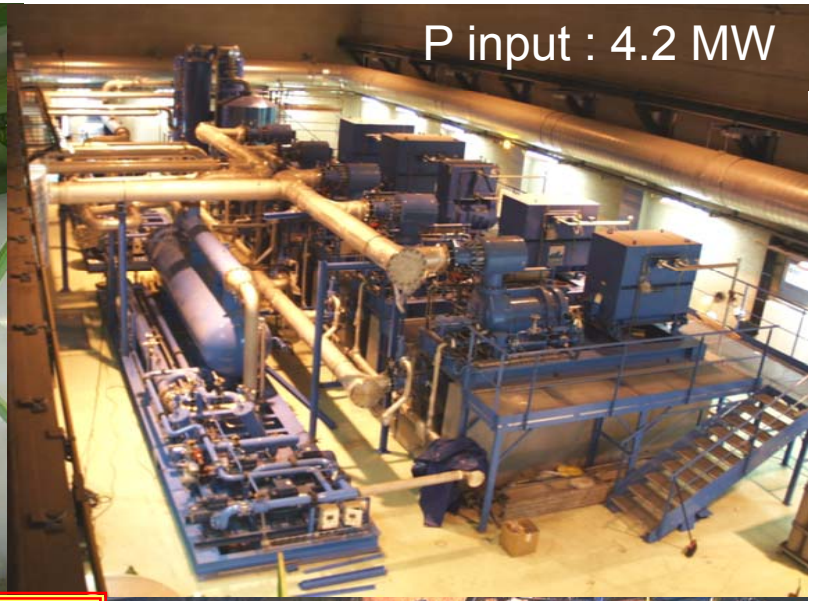
LHC 18 kW @ 4.5 K Refrigerator

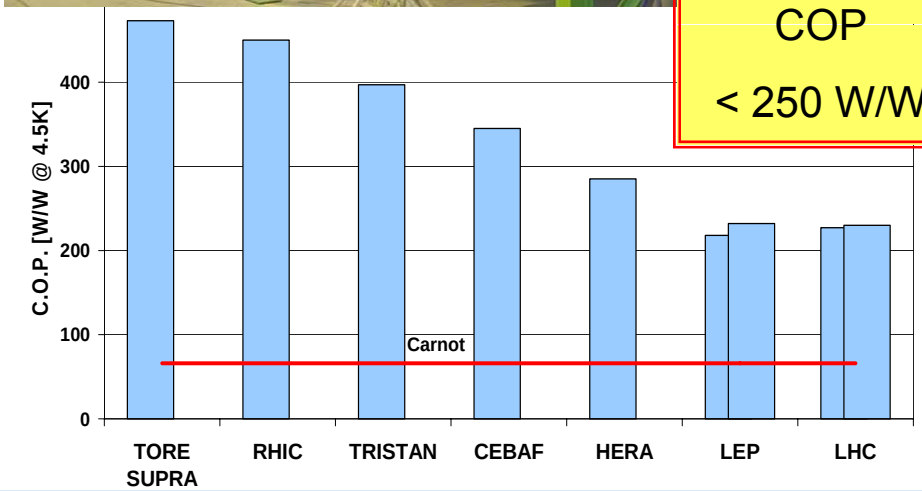
Process cycle for Linde



18 kW @ 4.5 K Refrigerators

33 kW @ 50 K to 75 K - 23 kW @ 4.6 K to 20 K - 41 g/s liquefaction



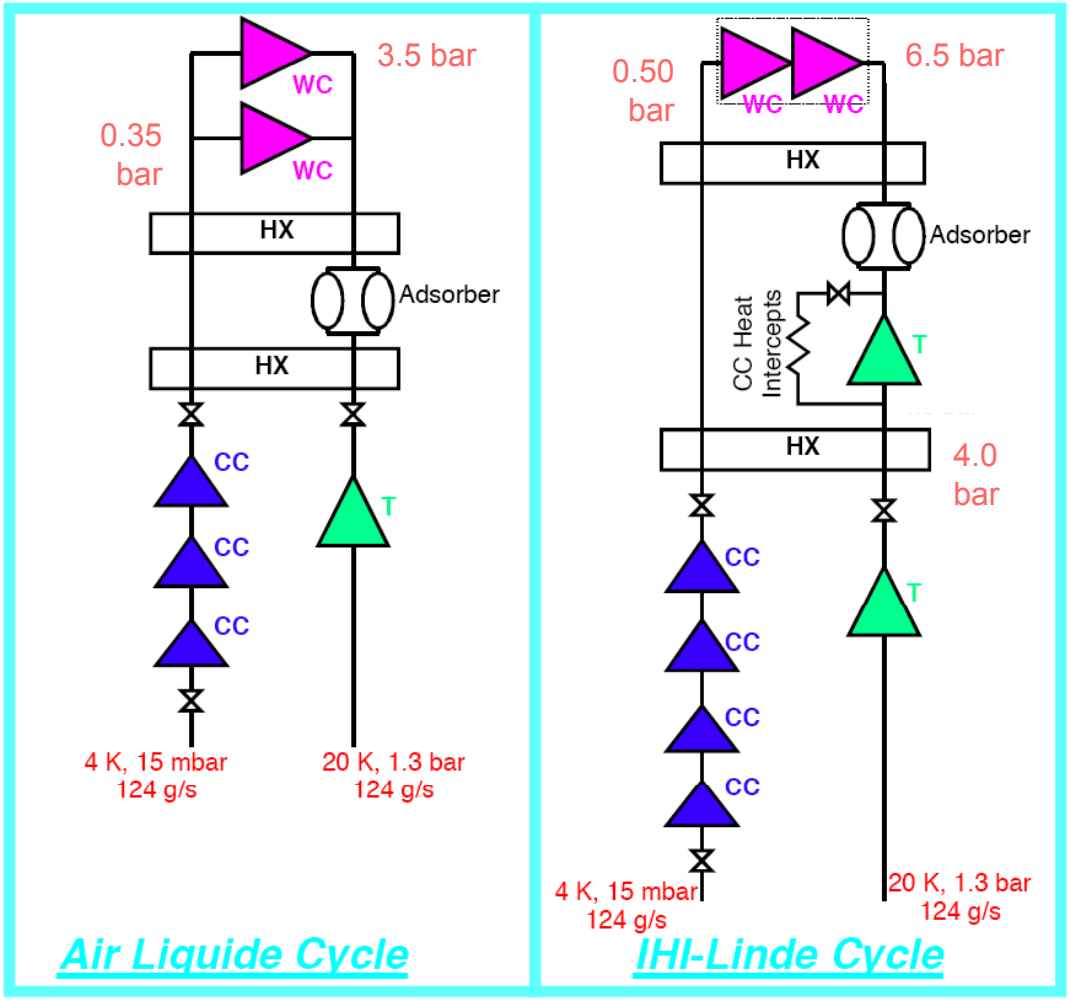


COP

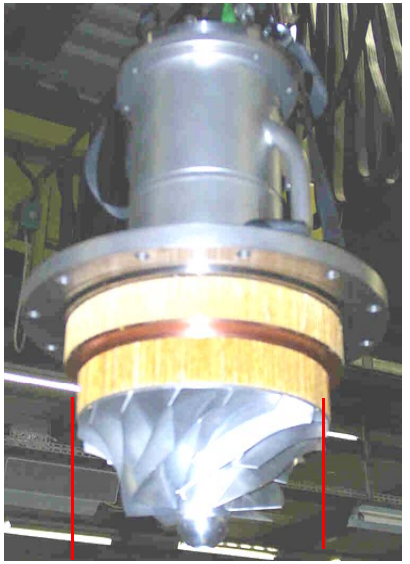
< 250 W/W

1.8K Refrigeration units

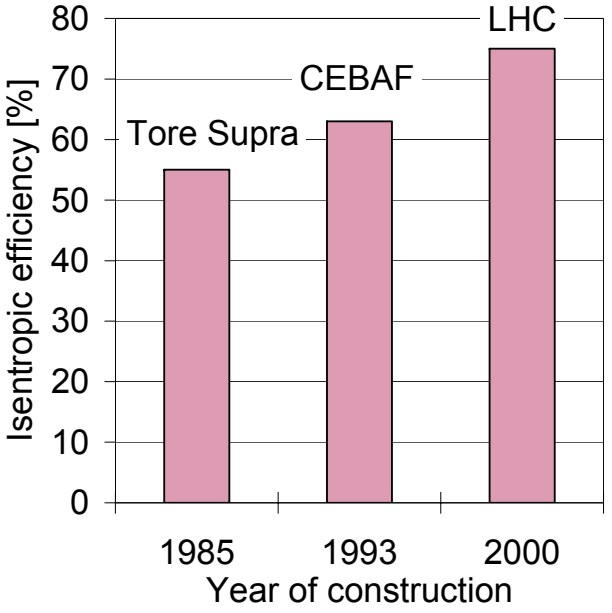
1.8 K Refrigeration Unit Cycles



2400 W @ 1.8K Refrigeration units



Diam:
250mm



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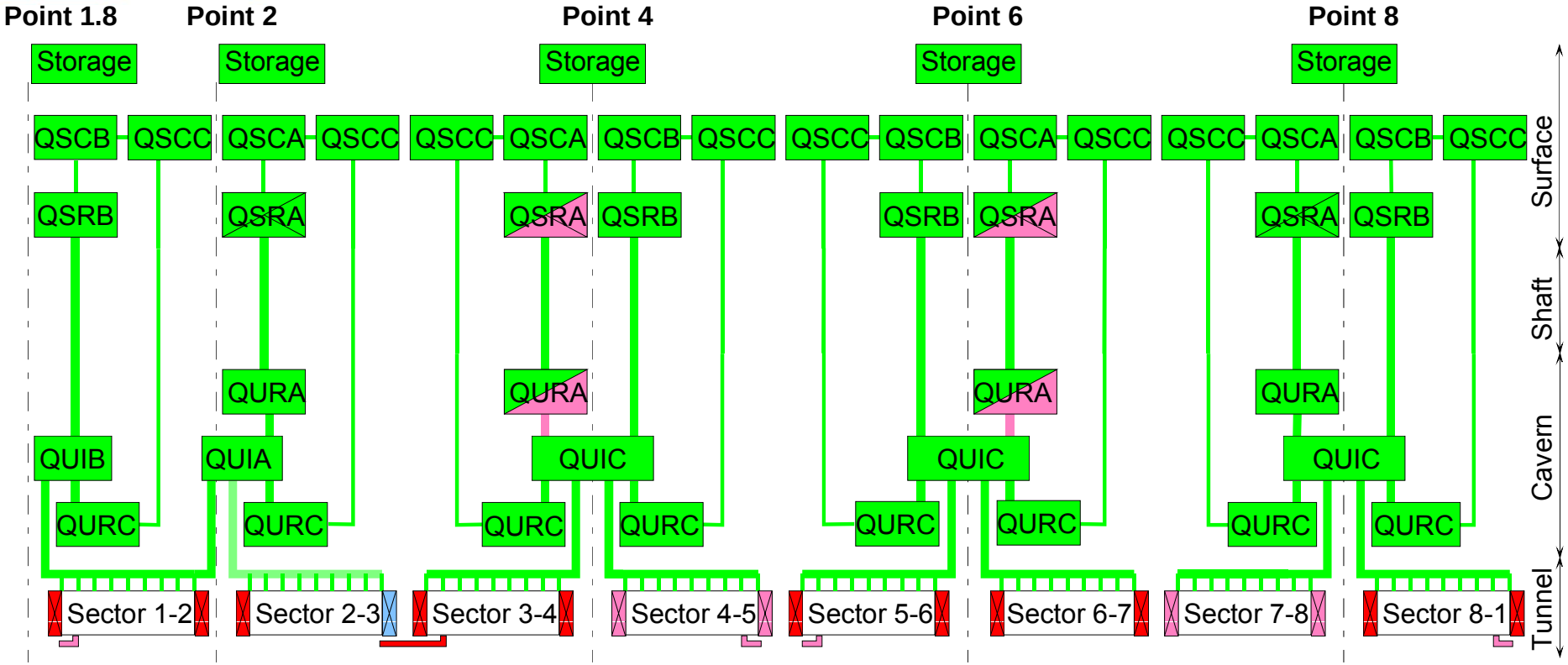
Progress overview



Legend

Cryogenic Distribution Line

QSC_(A,B,C): Warm Compressor Station
QSR_(A,B): Surface 4.5 K Refrigerator Cold Box
QURA: Underground 4.5 K Refrigerator Cold Box
QURC: 1.8 K Refrigeration Unit Cold Box
QUI_(A,B,C): Cryogenic Interconnection Box

Electrical Feed Box

Superconducting Link

Commisionned & accepted

Delivered / Under installation

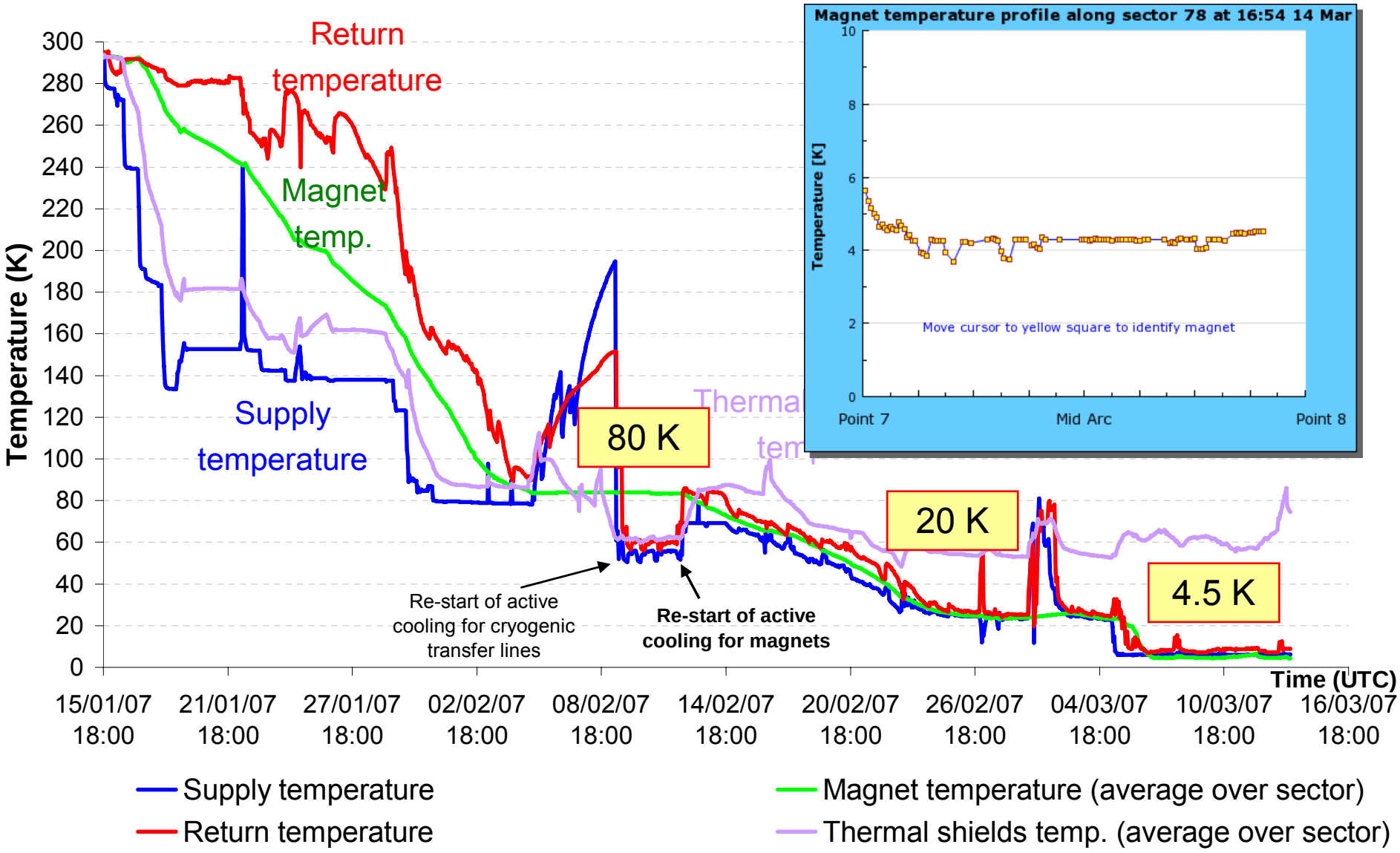
Ordered (Contract placed)

Under commissioning

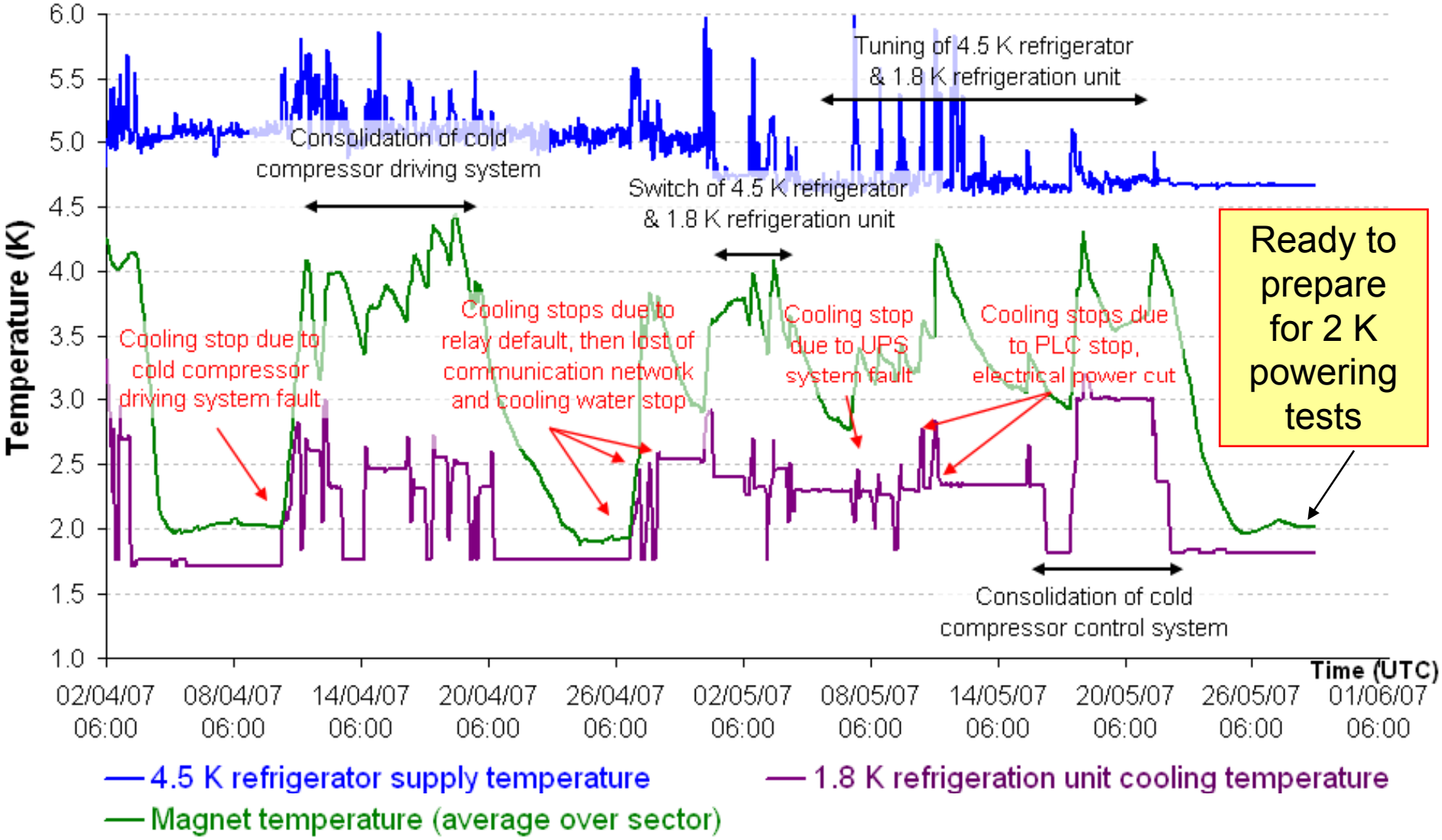
Under fabrication

Under definition

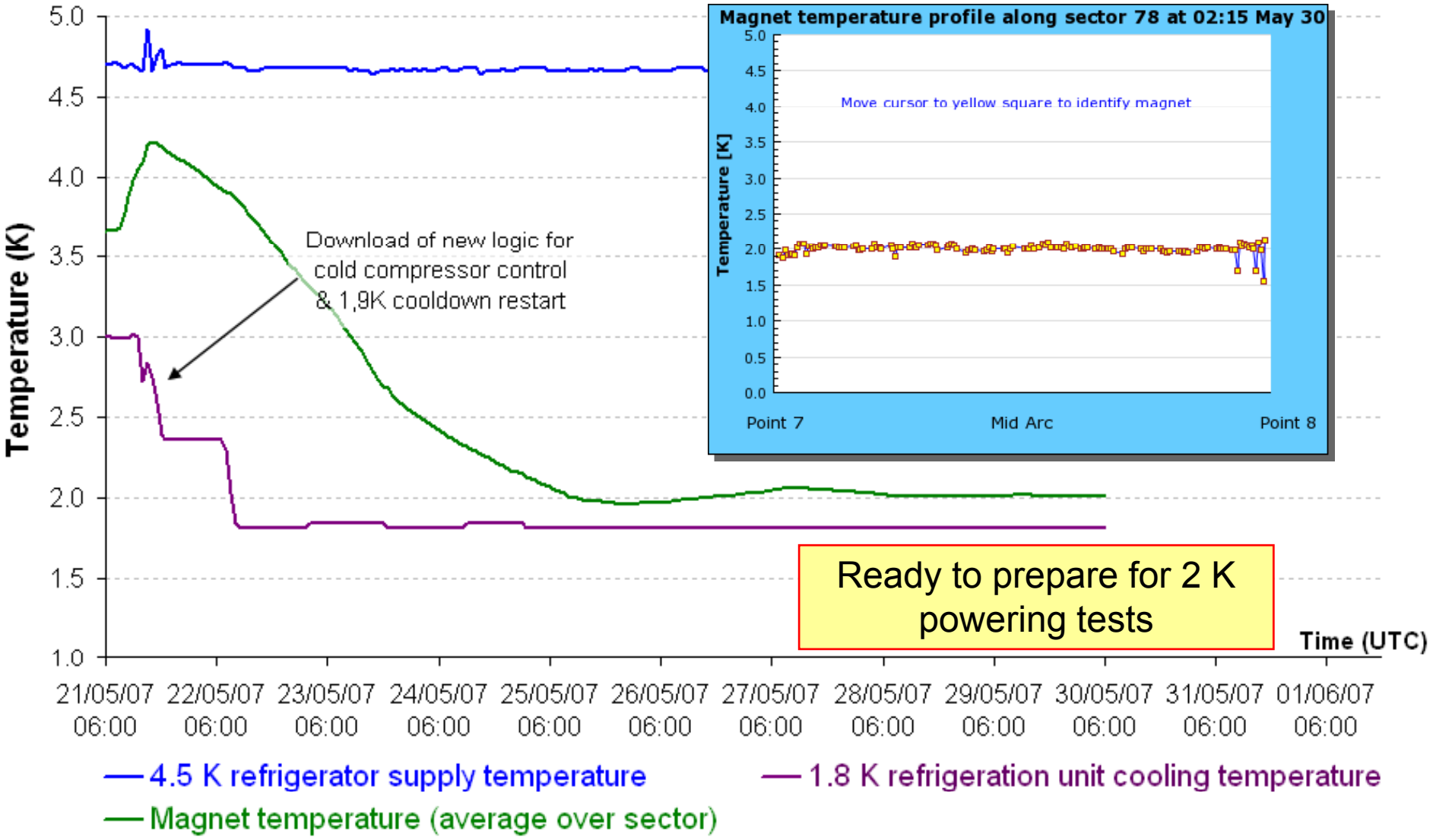
LHC sector 78 - First cooldown



LHC sector 78 - First cooldown - Tuning 1.9 K conditions



LHC sector 78 - First cooldown - 1.9 K normal operation



Conclusion

- It has been possible to design, built, install and validate all LHC refrigeration sub-systems
- Within a few weeks (2 to 6), the tuning with the 1st LHC sector has been made to allow magnet powering tests
- Early indications have to be evaluated (heat loads, response time, controls, availability)
- LHC commissioning: We are confident, and aware that it represents an enormous challenge with learning process, efforts and surprises!