Cryogenics in SPS & LHC (2 K / 4.5 K)

LHC-CC11, 14 November 2011
L. Tavian, CERN, TE-CRG

With the contribution of N. Delruelle, G. Ferlin & B. Vullierme

Content

- 4.5 K vs 2 K cryogenics for CC prototype testing
  - In SPS using an existing TCF20 cryogenic plant
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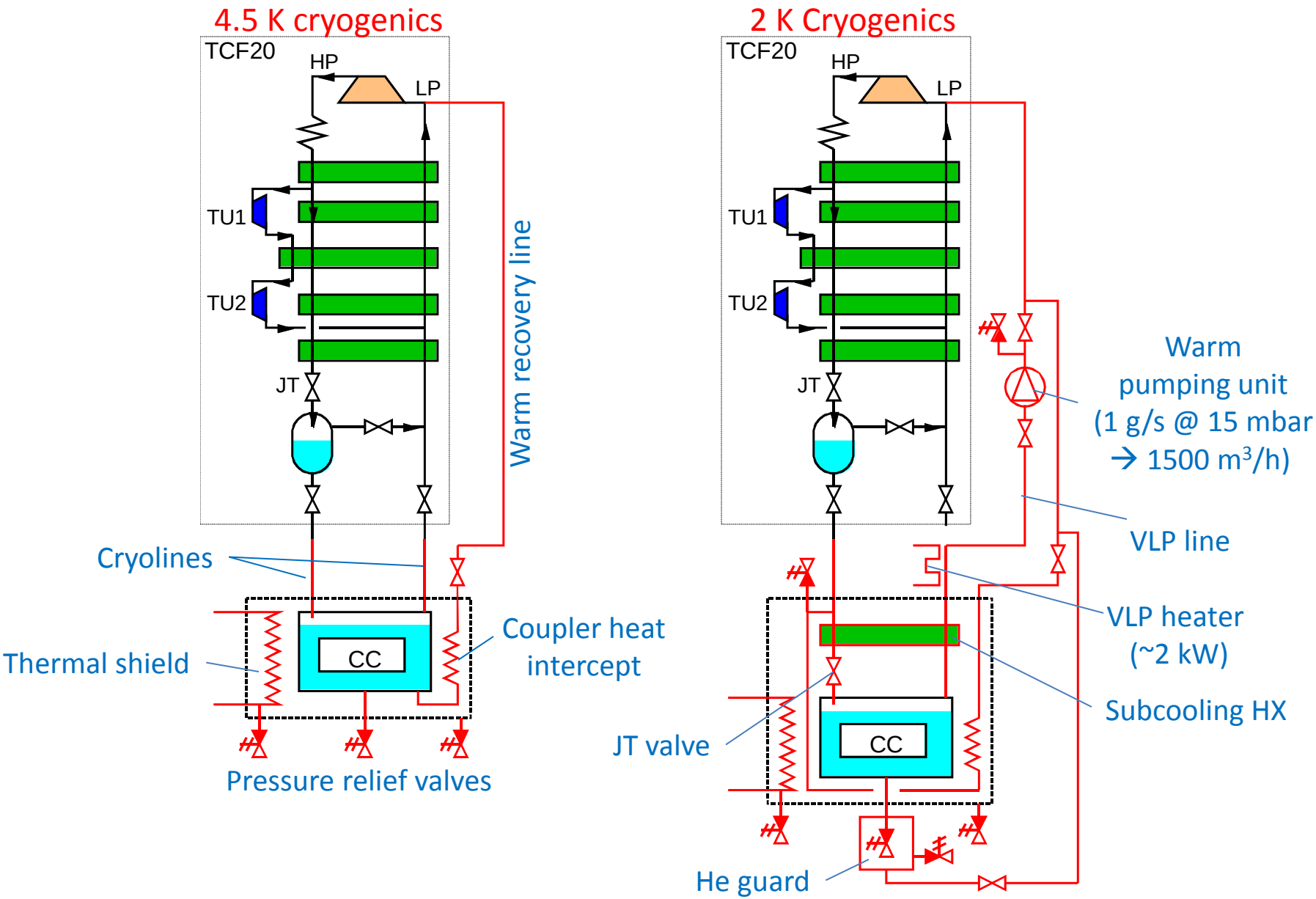
Sulzer-Linde TCF20 in BA4

Nicolas Delruelle

Crab-cavity test in SPS



Crab-cavity test in SPS
Additional specific 2 K equipments

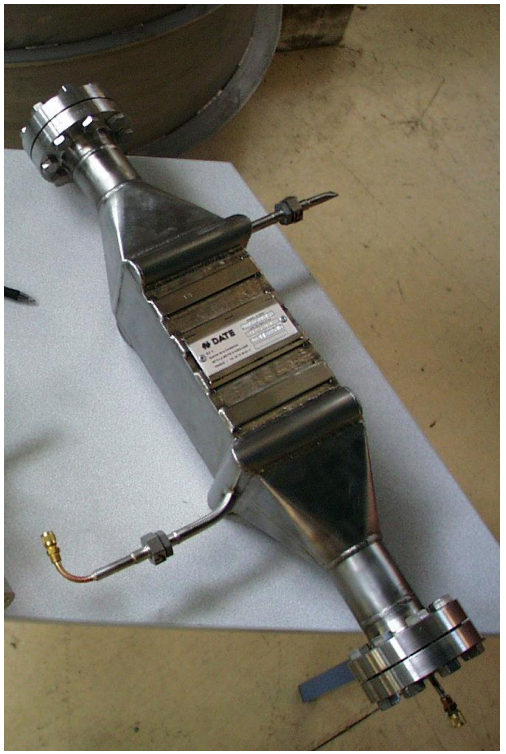
• Sub cooling heat exchanger	12 kCHF
• Warm pumping unit (WPU)	100 kCHF
• He guard for pressure relief valves	10 kCHF
• VLP electrical heater	20 kCHF
• JT expansion valve	4 kCHF
• Total additional equipments	~150 kCHF

To be added to the baseline CtC of ~300 kCHF for cryogenics.

Remarks:
1. additional cost for cryostat complexity not included !
2. if WPU cannot be installed underground, a new VLP line must be integrated in the BA4 shaft (DN100 – 20 kCHF)
3. No specific purifier foreseen for impurity management of the VLP circuit, i.e. lower availability for the 2 K option.

Crab-cavity test in SPS
Additional specific 2 K equipments

Warm pumping unit to be integrated in BA4 !



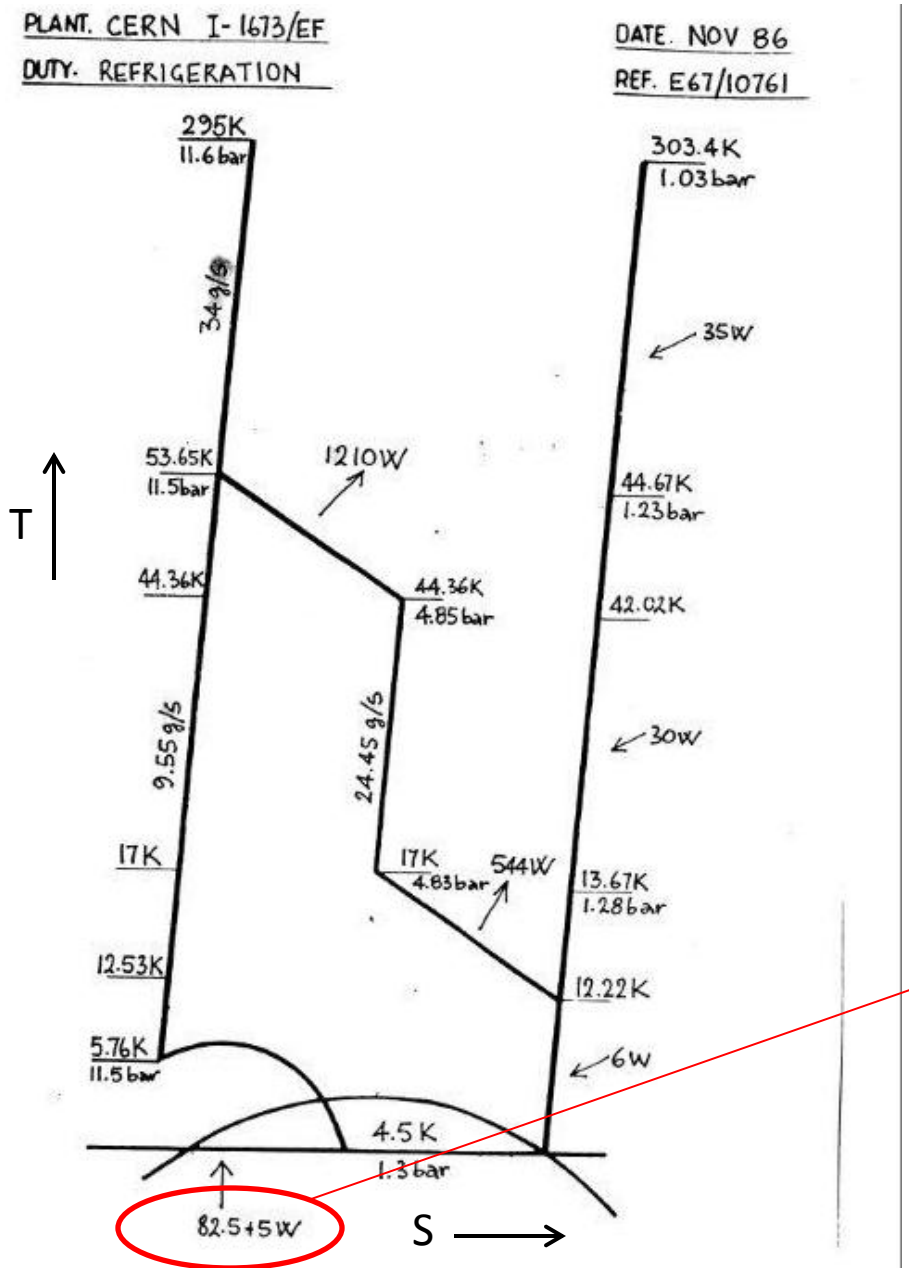
Subcooling heat exchanger and JT valve to be integrated in the CC cryostat !

Crab-cavity test in SPS
Capacity limitation

- Crab-cavity cooling @ 4.5 K (baseline)
  - Some liquefaction consumption for coupler heat intercepts: ~0.1 g/s of liquefaction
  - Dynamic RF load : ~ 80 W of refrigeration @ 4.5 K
  - Static heat inleaks (cryostat + transfer lines): ?

- Crab-cavity cooling @ 2 K (alternative)
  - TCF20 cryoplant used in pure liquefaction (TCF20 means 20 l/h = 0.7 g/s of LHe)
    - Coupler heat intercepts: ~0.1 g/s of liquefaction
    - Dynamic RF load: ~12 W i.e. ~0.57 g/s of liquefaction
    - Static heat inleaks (cryostat + transfer lines): ?

TCF20 TS-Diagram



Guaranteed capacity : 87.5 W

Measured TCF20 refrigeration capacity

120 W available in refrigeration mode ! (+ 35 %)

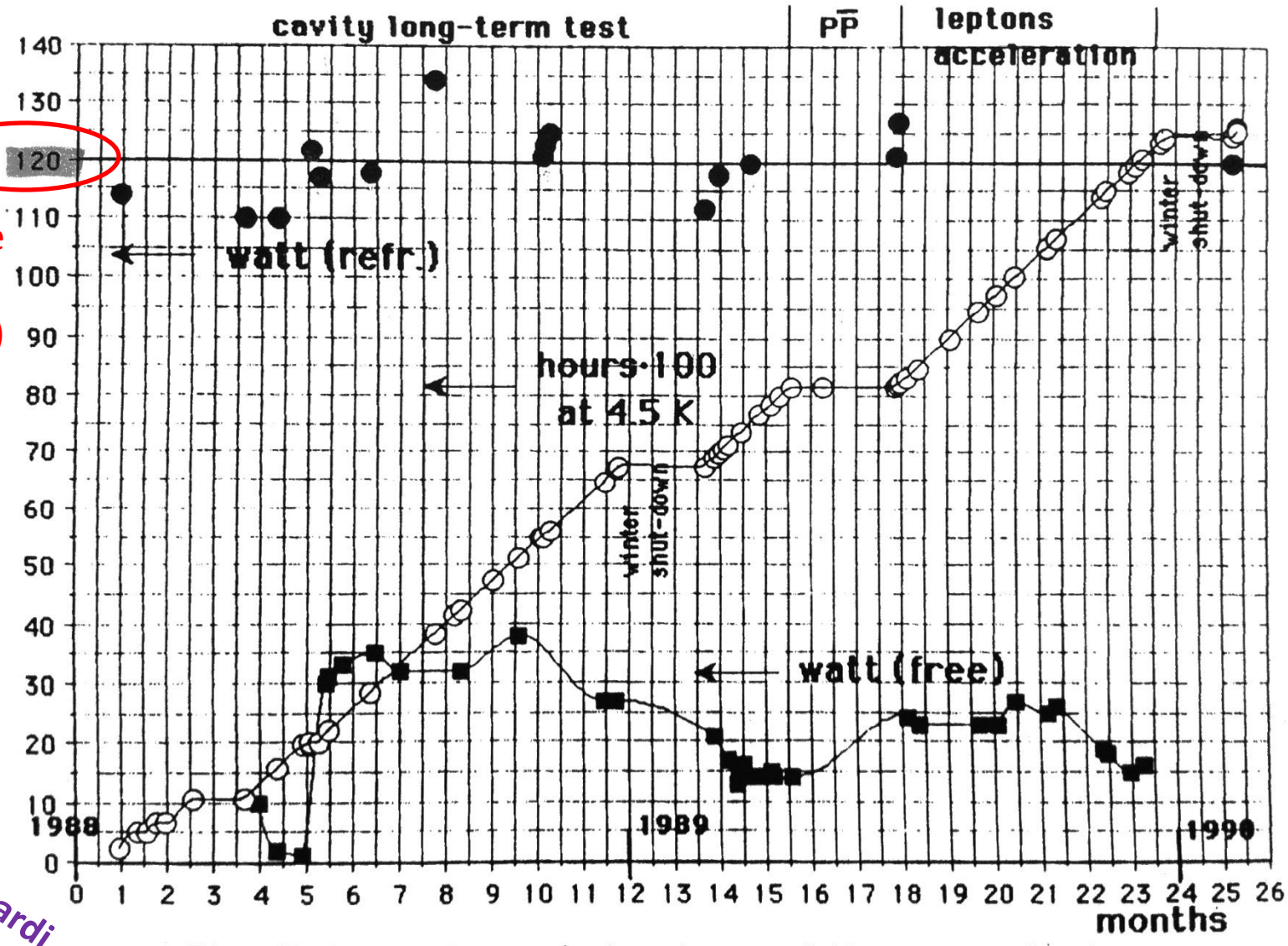
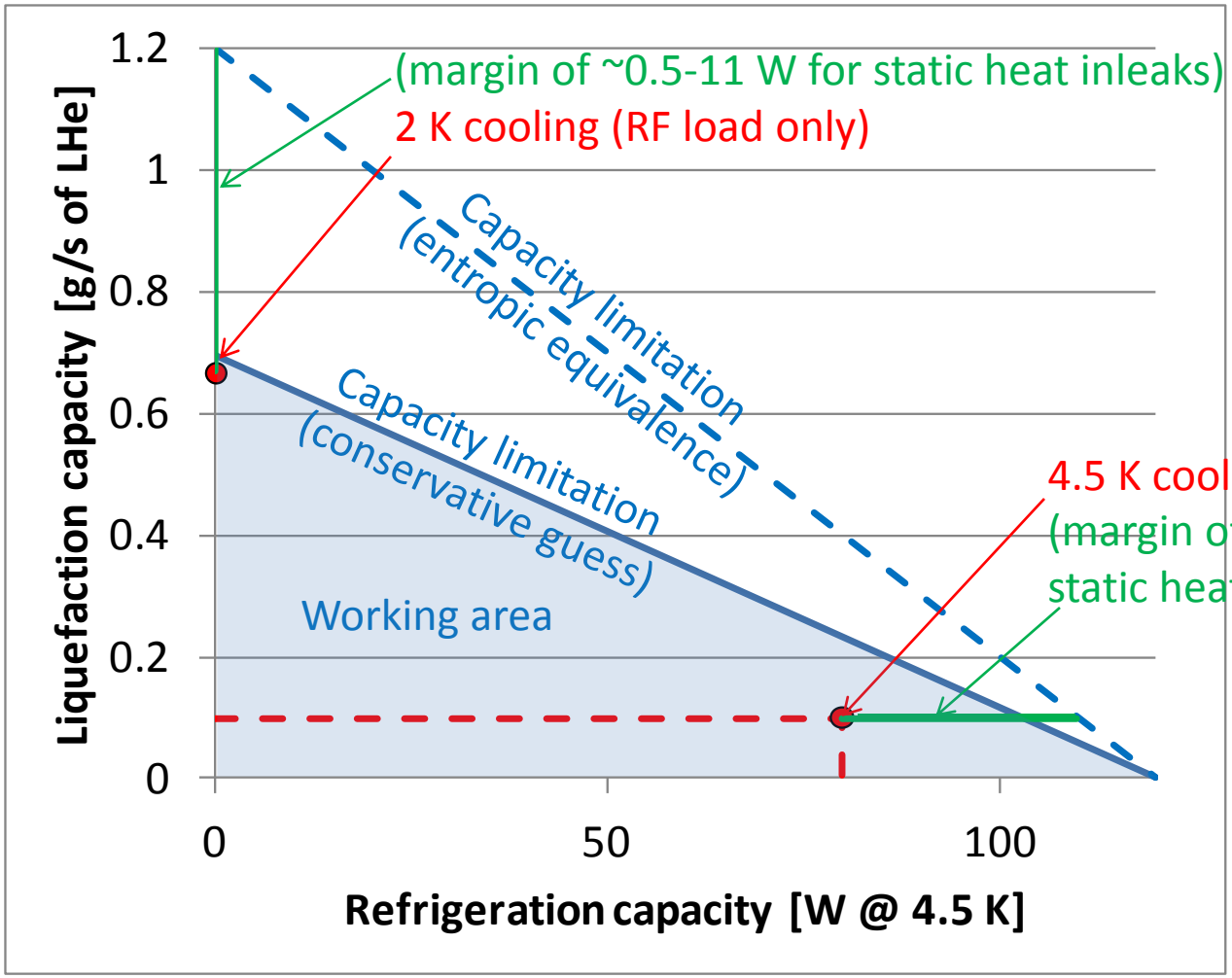


Fig. 5. Long-term behaviour of the cryoplant

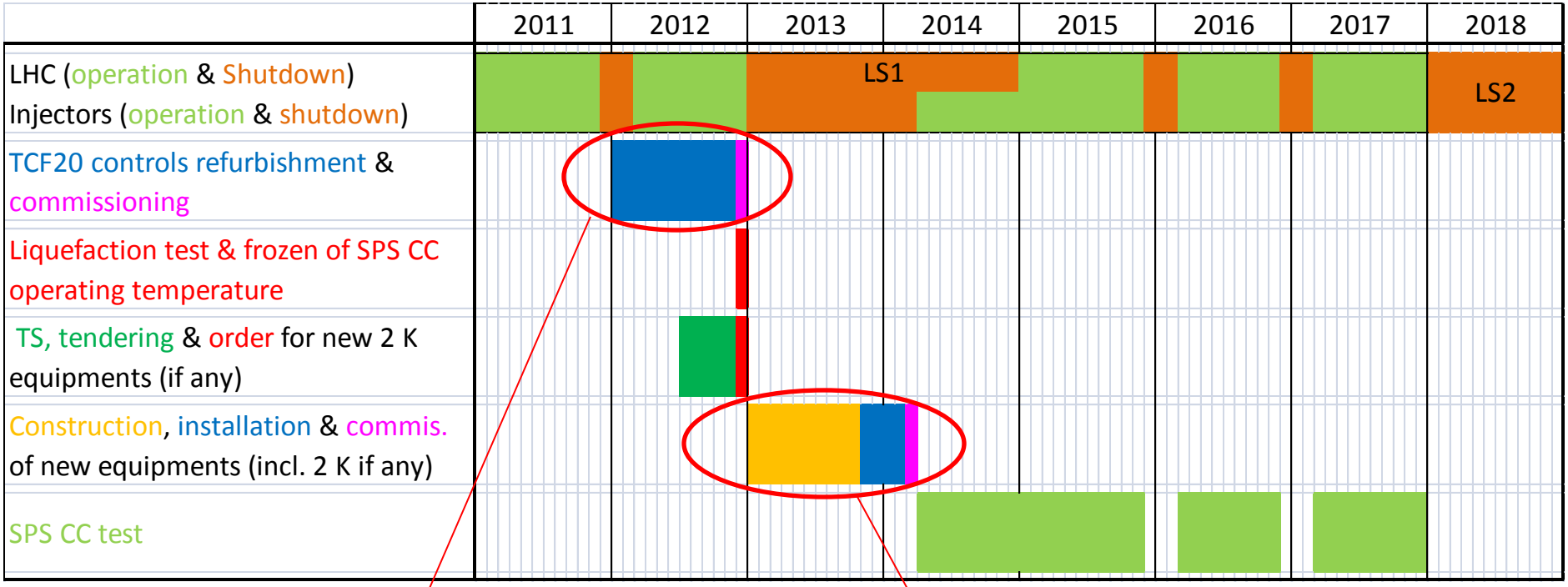
Giorgio Passardi

Crab-cavity test in SPS
TCF20 capacity limitation



Liquefaction capacity measurement mandatory to confirm the 2 K cooling option !

Tentative SPS CC cryogenic schedule



Compatibility with SPS run in 2012?
Transport-up of the cold box to ground level for "easier" refurbishment?

Could be in conflict with the LHC LS1,
especially if 2 K option is requested !

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Crab cavity test at Point 4

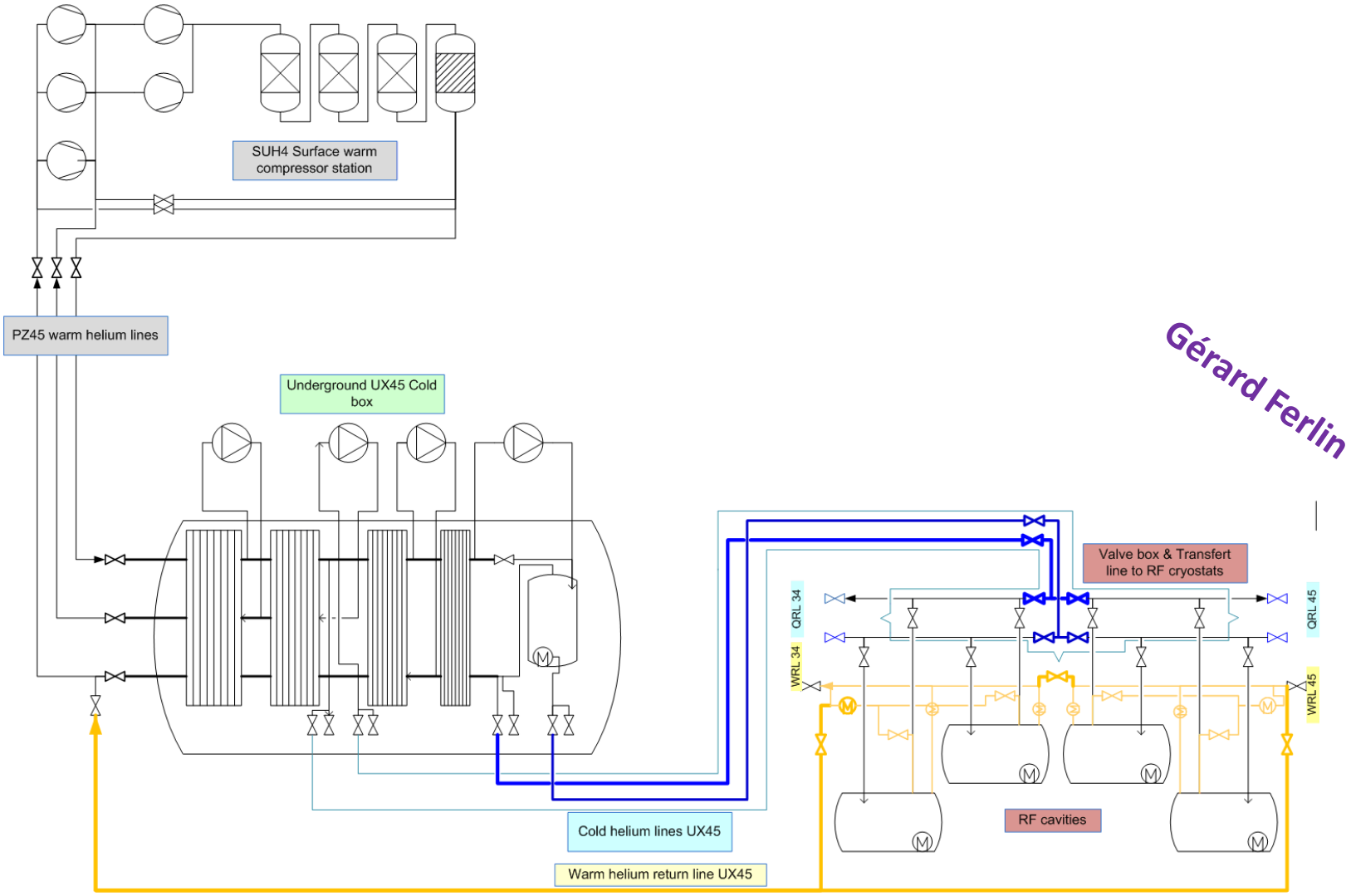
- The global scheme is no longer an option for the final HL-LHC, but a prototype cavity could perhaps be installed in Point 4 first for test purposes.
  - Basic question: Is LHC a test set-up?

- Installation of CC prototype could be:
  - Coupled to the RF cryogenic upgrade at P4
  - Scheduled during the LS2 (2018) for possible validation tests during 2019/20/21 (before the LS3 for P1/5 upgrade).

- 4.5 K operating temperature highly recommended as no 2 K refrigeration is foreseen in the present P4 upgrade.
  - Additional cooling capacity: ~170 W @ 4.5 K per CC module
  - Total number of CC modules to be installed : 2 i.e. 340 W @ 4.5 K in total

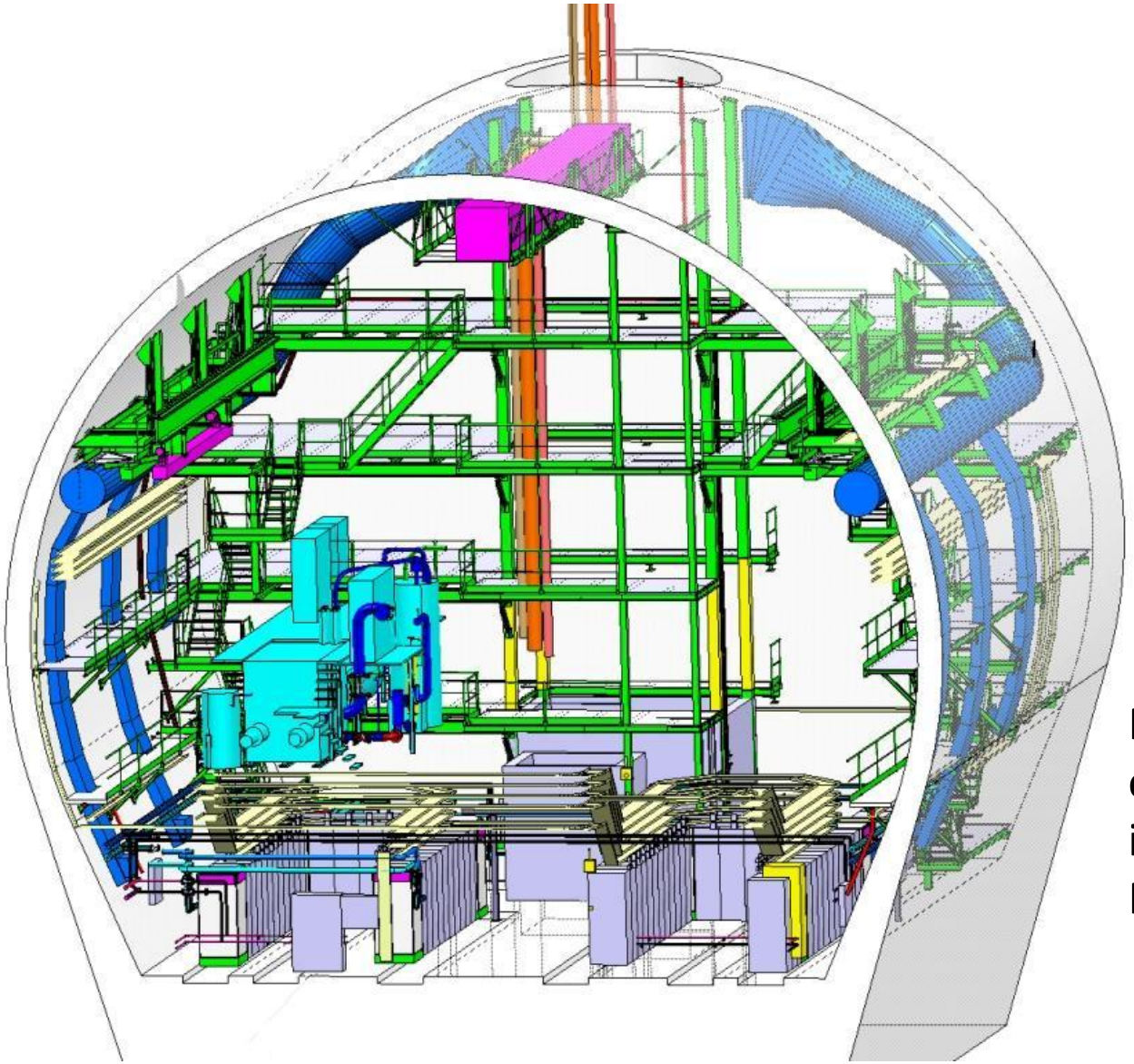
- If 2 K cooling mandatory, a new pumping system must be added:
  - Additional cooling capacity: ~26 W @ 2 K per CC module, i.e. 52 W in total
  - Warm vs cold pumping:
    - Pumping capacity: ~ 3 g/s → Warm pumping probably more dedicated
    - Warm pumping OK for no continuous test (i.e. during MD period) but lower system availability for continuous operation
  - Extra cost: ~0.5-1 MCHF depending impurity management
  - Amplified space conflict in the surface compressor building (Already problematic for the 4.5 K option)

Project Process & flow diagram without crab-cavities



Gérard Ferlin

P4 upgrade for RF cooling



Gérard Ferlin et al

First studies to install a cold box, 6.5 kW @ 4.5 K into UX45 cavern, above RF electrical cabinet

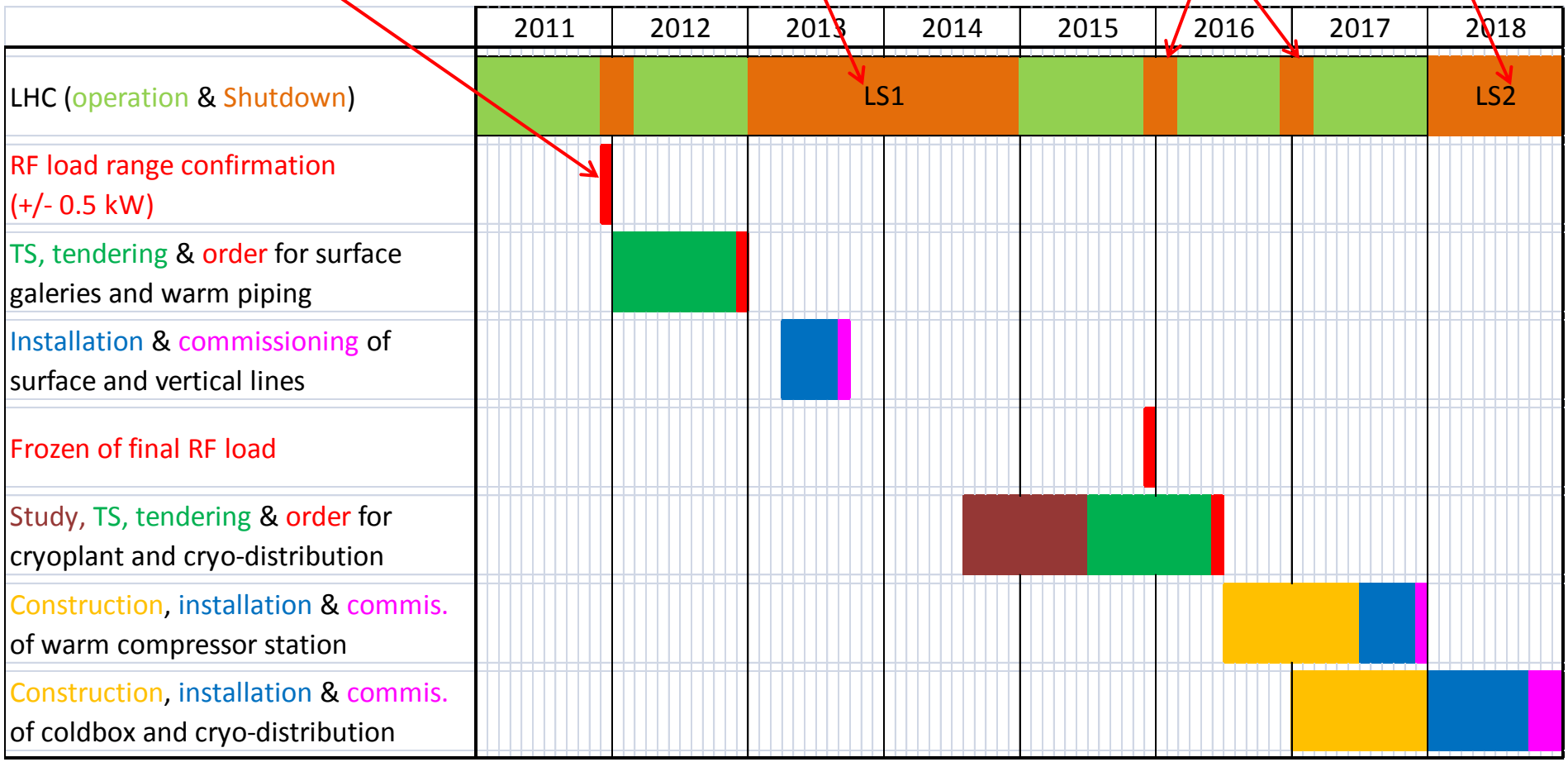
P4 upgrade schedule

Decision on CC operating temperature 2 K vs 4.5 K

LS2 (2018): best period for crab-cavity installation

LS1 (2013/14): too early & busy for CC installation

Too short



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Crab cavities for the final local scheme

- Configuration: 2 modules per beam, i.e. 4 per Interaction Points (IP1 & IP5)
- Installation: during the LS3 (2022) dedicated to the last phase of HL-LHC project
- Cooling capacity requirements:
  - 4.5 K cooling: ~170 W per CC module (i.e. 680 W per IP)
  - 2 K cooling: ~26 W per CC module (i.e. 104 W per IP)
- Energy consumption consideration:
  - COP @ 4.5 K refrigeration: ~250 W/W, i.e a consumption of 43 kW of electrical power per CC module
  - COP @ 2.0 K refrigeration: ~800-1000 W/W, i.e. a consumption of 21-26 kW of electrical power per CC module
  - Cooling at 2 K is globally more efficient.

Cooling of CC modules

- Two possibilities:
  - Via the 2 new cryoplants dedicated to the new inner triplets at IP1 and IP5 or
  - Via the 4 existing adjacent-sector cryoplants

- The choice will depend strongly on:
  - the operating temperature of the new Inner Triplets (IT): 4.5 K vs 2 K
  - the total added heat loads

Cooling comparison

Operating Temperature [K]		Cooling possibility (required added capacity per plant)	
CC	IT	New IT plants	Existing sector plants
2	2	Y (104 W @ 2 K)	Y (52 W @ 2 K)
	4.5	N	Y (52 W @ 2 K)
4.5	2	Y (700 W @ 4.5 K)	Y (350 W @ 4.5 K)
	4.5	Y (700 W @ 4.5 K)	Y (350 W @ 4.5 K)

OK but will recreate the same sector cooling unbalance presently existing in S34 and S45 which has justify the P4 upgrade

Preliminary conclusion for the final local scheme

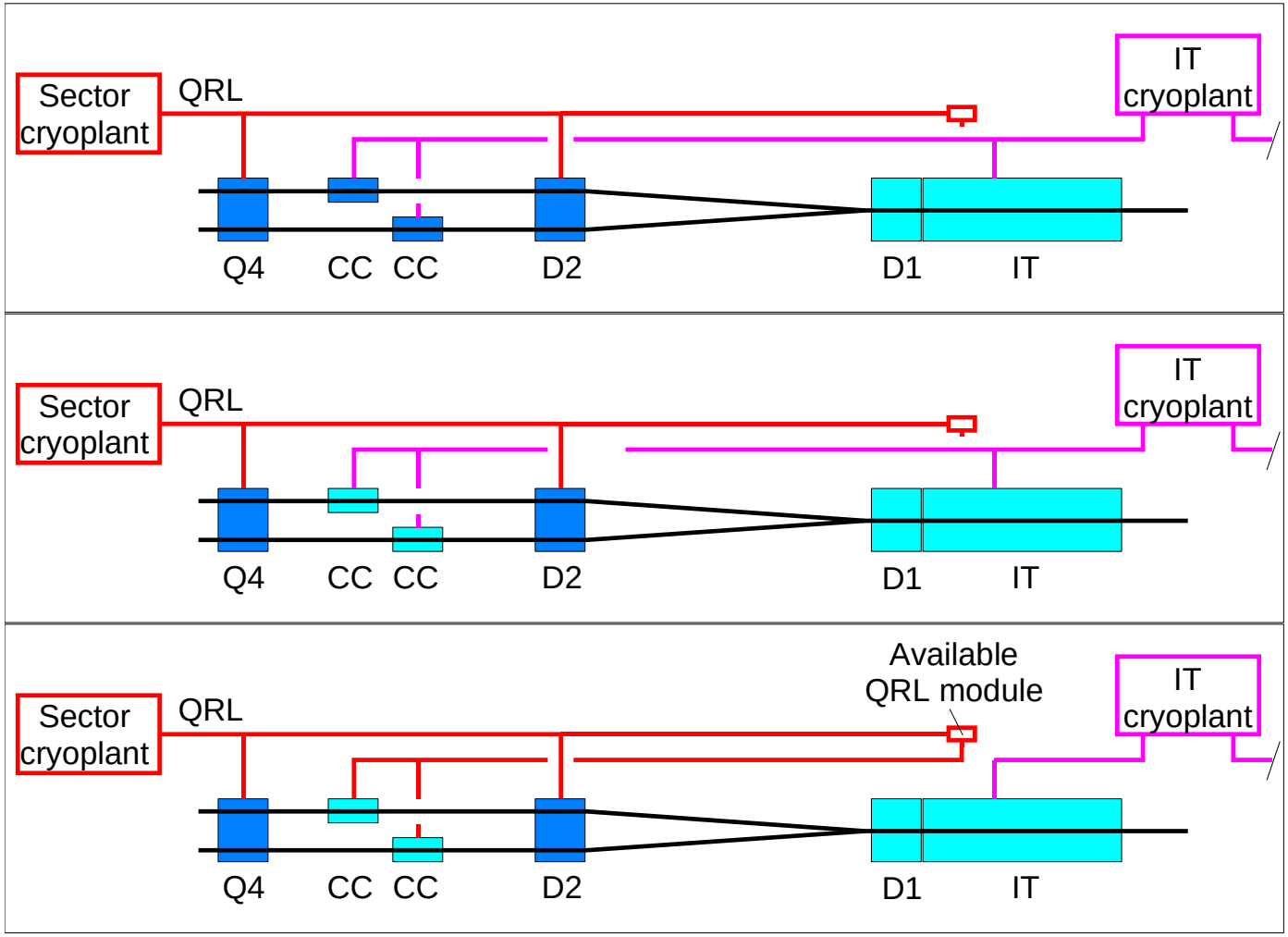
- If the CC operating temperature is 4.5 K, it is preferable to cool the CC modules using the new IT cryo-plants at P1 and 5:
  - Better balance in between LHC sector cooling
  - ~ 700 W @ 4.5 K (+ contingency) must be added per new cryo-plant
- If the CC operating temperature is 2 K, existing sector cryo-plants or new IT cryo-plants can be used.
  - As the CC module will be integrated in the Matching Section (MS), using the sector cryoplant which will cool the MS could simply the cryo-distribution.

Possible configurations

4.5 K CC modules cooled by new IT cryo-plants

2 K CC modules cooled by new IT cryo-plants

2 K CC modules cooled by existing sector cryo-plants



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Conclusion

- Prototype crab-cavity testing in SPS:
  - Test possible from 2014.
  - 2 K cooling not excluded but:
    - liquefaction capacity of the TCF20 must be measured and sufficient.
    - Additional resources (P + M) must be allocated.
  - Could be in conflict with the LHC LS1, especially for the 2 K cooling.

- Prototype crab-cavity testing at LHC P4:
  - Test possible from 2019.
  - 2 K cooling option expensive (~1 MCHF + 2 FTE + a possible noise-insulated building extension/construction).

- Series crab-cavities for the final HL-LHC local scheme:
  - Cryogenic implementation during the LHC LS3 (2022)
  - 2 K cooling globally more efficient
  - 2 K cooling via the existing sector cryoplants preferable:
    - Matching section area cooled by the same cryoplant
    - Let open the possibility of simpler new cryoplants at Point 1 and 5 if the new inner triplets are cooled at 4.5 K.