LHC Cryo-OP

Can we change a magnet without warming-up a full arc ?

Serge Claudet,

With help from P. Cruikshank & J-P. Tock

(Chamonix 2010 - 26Jan'10)

What would you expect ?

- The LHC sub-sectorisation baseline tells you: NO !
- Partial warm-up could damage PIM's, we remember we were told to periodically re-cool the magnets last year !!
- Air in the circuits could be trapped on cold surfaces, and perturbate operation of VAC and Cryo systems !!!
- The operation of the cryogenic system starts only to be under control, with great expectations for the coming years, and this could reduce their availability !
- Why me ?!?

Things may change and be reconsidered …

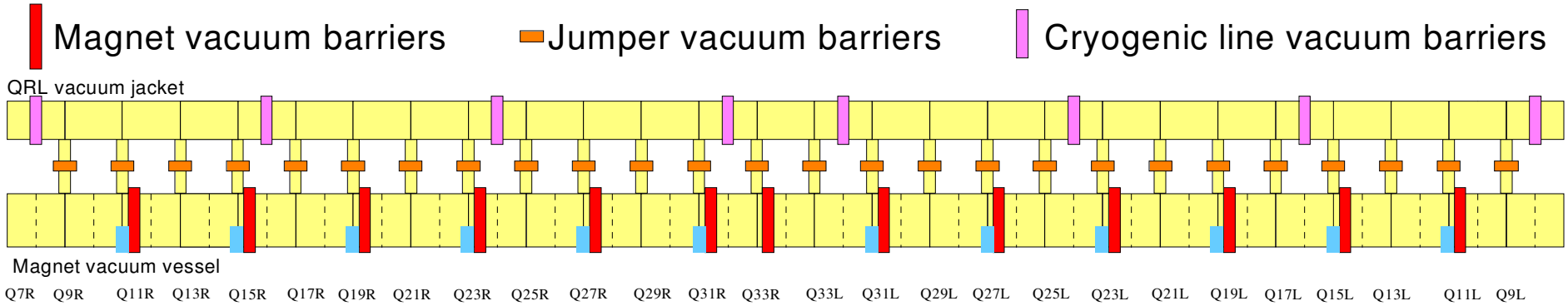
Content

- Present LHC baseline
- Developments made for PIM's issues (2008)
- Main actions & Warm-up cases
- Sequence:
  - Cutting
  - Re-installing
- Conclusion

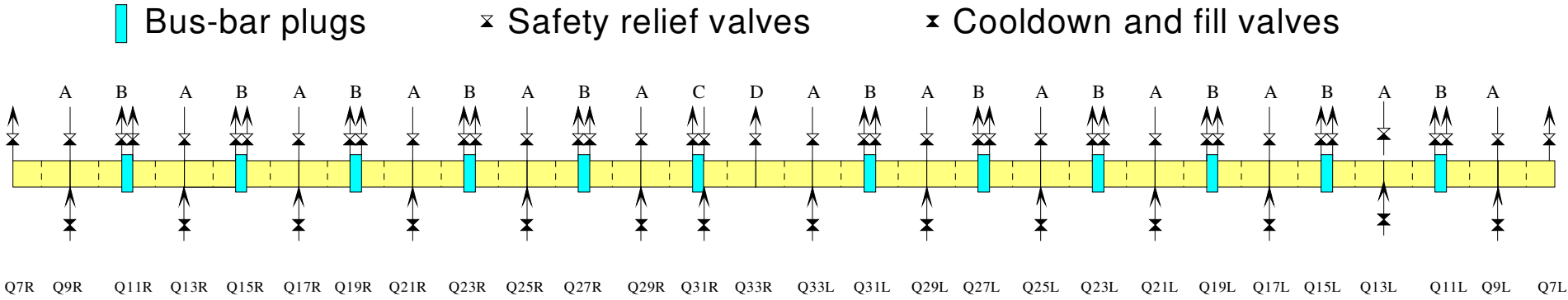
Present LHC baseline (1/3)

LHC ARC: CRYOGENIC AND INSULATION VACUUM BASELINE DESIGN

Insulation Vacuum sectorization:

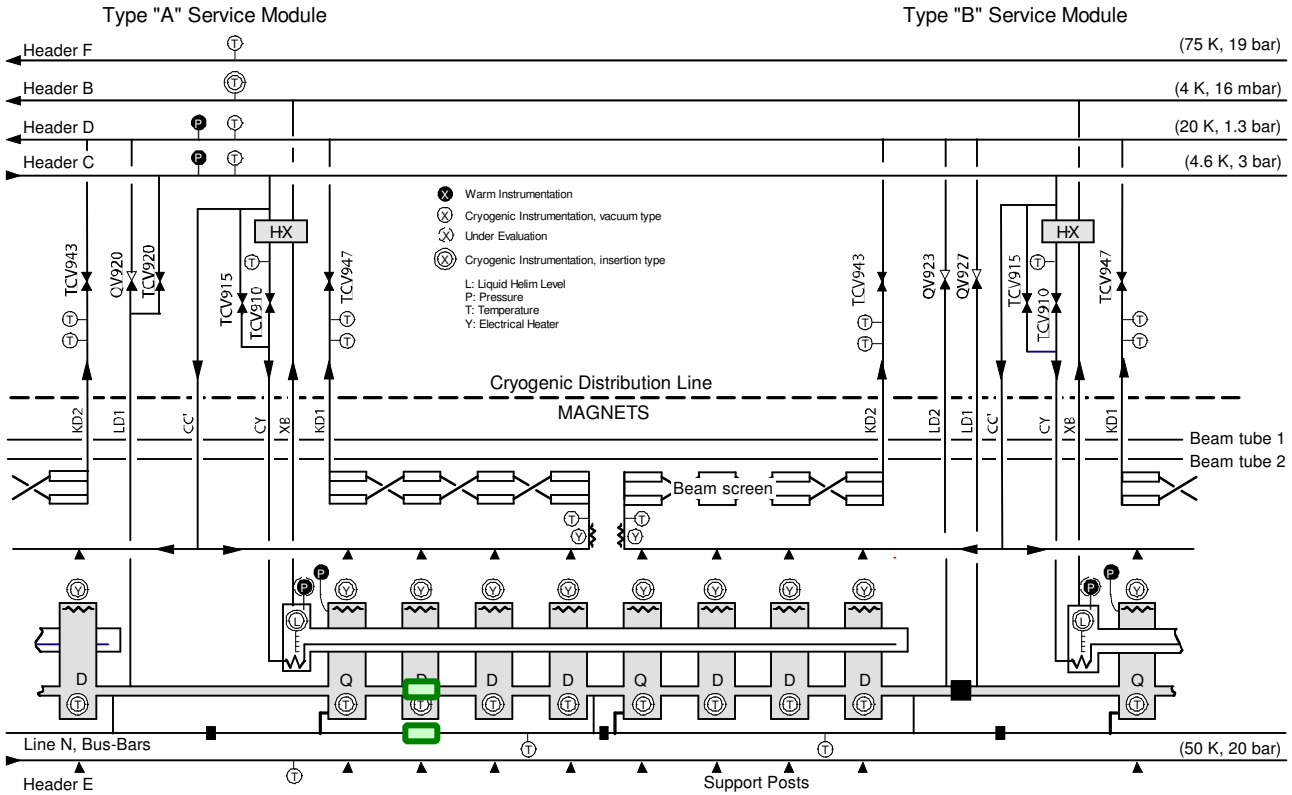


Cold-mass sectorization:



Present LHC baseline (2/3)

LHC Design Report, Figure 11.5 Cryogenic flow-scheme and instrumentation of a LHC lattice cell



Only interventions inside the cold mass volume (sectorised) could be envisaged with a partial warm-up: splices, diodes, He leak, …

Present LHC baseline (3/3)

[text extracted from LHC Design Report]

Together, these two sub-sectoring schemes for cold mass and insulation vacuum allow to warm-up a limited length of cryo-magnets (up to 600 m) to perform short interventions on the cold-mass components (splices, diodes, 60 A current leads…). In that case, the warm-up and re-cool-down time is reduced by a factor three with respect to the normal full sector warm-up and cool-down times. However, for removing cryo-magnets, which require the opening of cold bores or bayonet heat exchangers or main headers, the complete sector has to be warmed up and re-cooled down.

Developments for PIM's (1/3)

Baseline 'short interventions' in insulation vacuum subsectors

- Eg diode, busbar, [redacted] helium leak….but no intervention on beam vac

- Scenario from LHC Project Report 60
  - n-2…. floating, cold, under vacuum
  - n-1 thermal buffer, RT, under vacuum
  - n intervention, RT, vented, W opened
  - n+1 thermal buffer, RT, under vacuum
  - n+2…. floating, cold, under vacuum

- PIM WG: Impact of possible PIM failures:
  - PIMs may fail in any of the 3 RT vacuum subsectors
  - 2.8 km beam vacuum must be vented to exchange 1 PIM
  - PIMs in thermal buffers cannot be accessed

  ⇒ Whole arc must be re-warmed, and damaged PIMs repaired

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PIM WG Reported by P. Cruikshank to MaRiC

Developments for PIM's (2/3)

New proposal 'short interventions'

- **Goals:**
  - Allow short interventions – diode, busbar etc
  - Minimise number of PIMs which undergo thermal cycle to RT
  - Ensure access to PIMs which undergo thermal cycle to RT
  - Expected gain on total intervention time w.r.t. a sector warm-up
    - Local or systematic replacement of PIM = 4 – 6 weeks

- **Initial considerations:**
  - Contamination of insulation vacuum due to cold interfaces at the extremities of the vented subsector
  - Contamination of beam vacuum in the cold floating zones during exchange of PIMs in the RT zone

To be looked at

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Developments for PIM's (3/3)

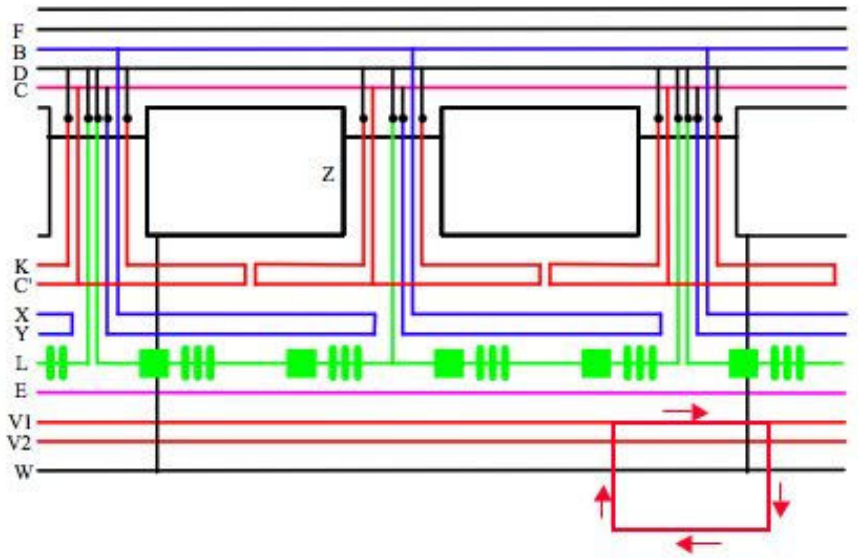
New proposal 'short interventions'

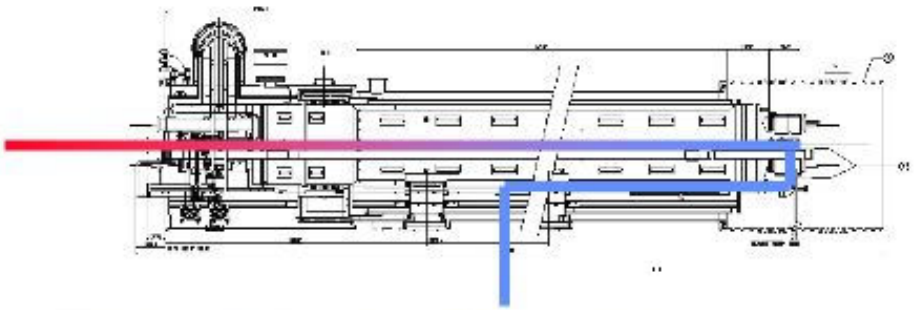
Scenario:

- Warmup whole arc to ~ 100 K
- Warmup the vacuum subsector to RT
- Warmup SSS at vacuum barrier using N2 flow through SSS pumping pipes of the adjacent half-cell
- Vent insulation vacuum and protect extremities from condensation with N2 pockets
- In parallel to short intervention, check PIM condition (eg x-ray etc)
- If PIM replacement required, overpressure beam vacuum and exchange

OK for 100K at cold/warm interface

Principle to be kept





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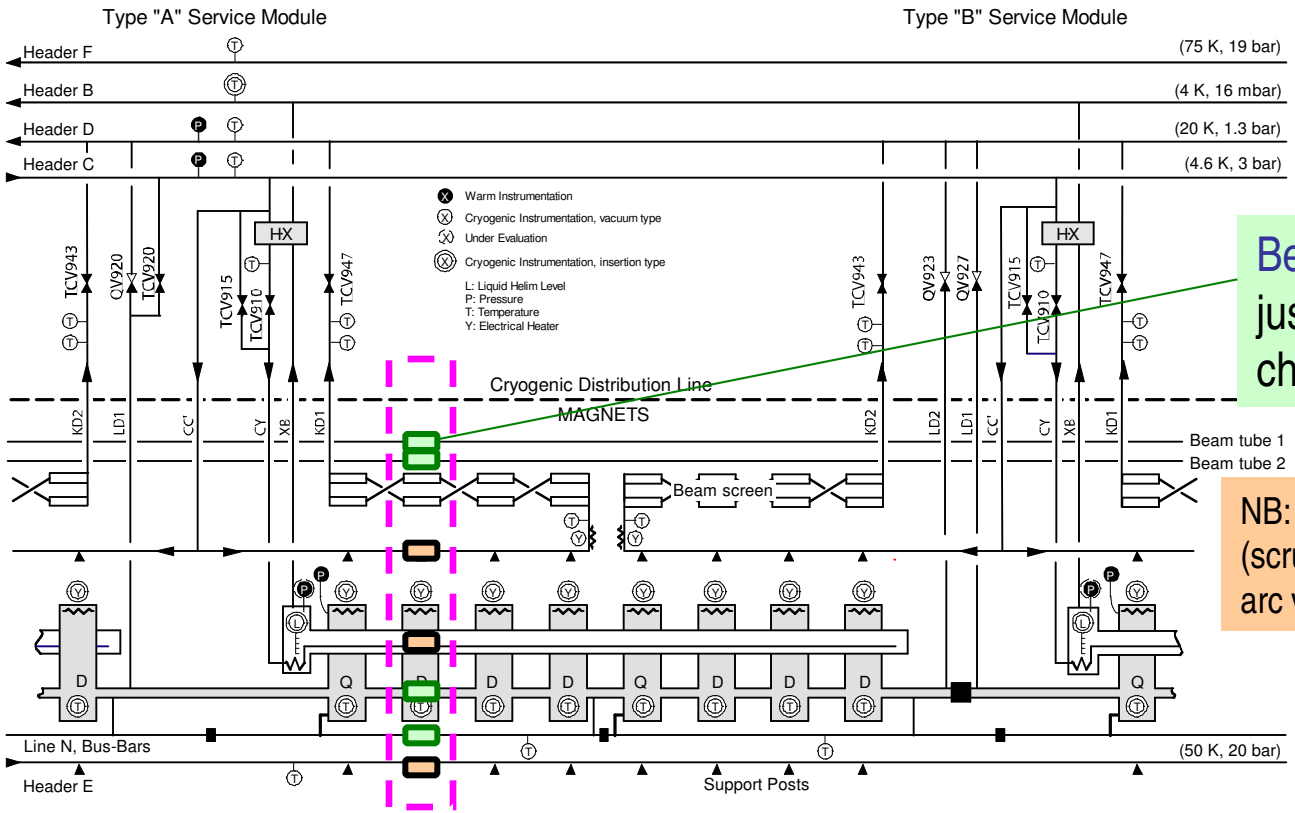
Main actions to be performed

Prevent air flow when cutting / welding



Beam tubes:
just like
changing a PIM!

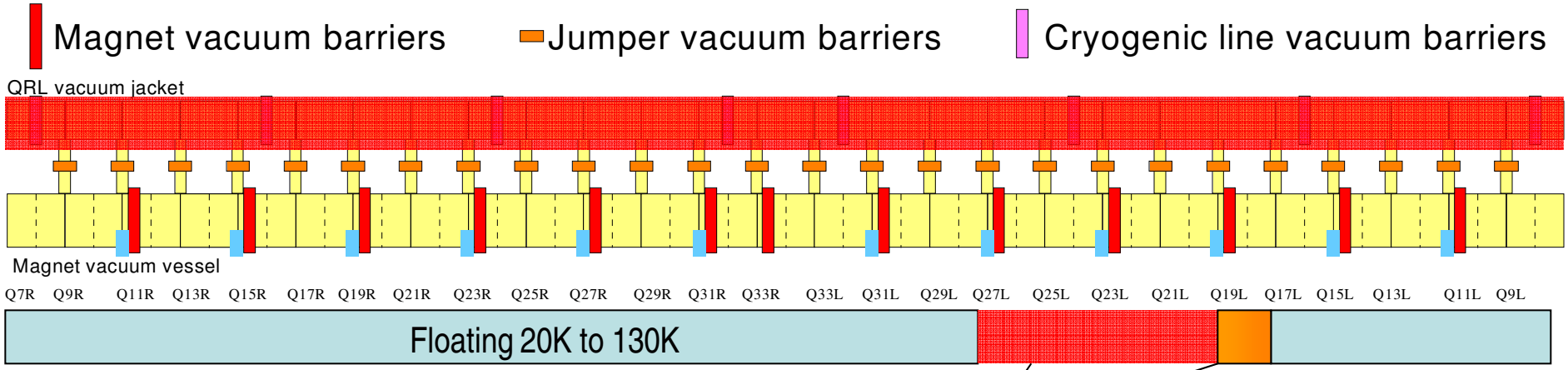
NB: future beam effect (scrubbing) as if entire arc vented

- Cold Mass, Line N: OK as according to baseline (sectorised)
- Line X/Y (bayonet HX), Line C' (cooling intercept): Even with a warm QRL, air would reach cold surfaces in the cold sub-sectors and get trapped !
- Line E (thermal shield): Air would reach cold surfaces in the cold sub-sectors and get trapped

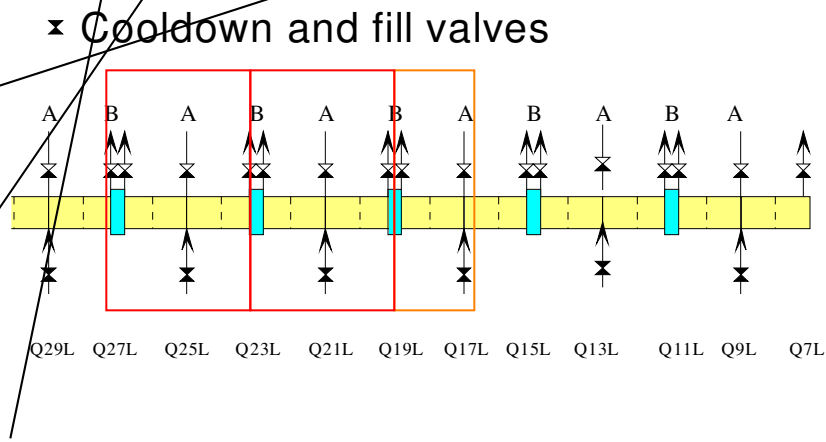
Prevent condensation in insulation vacuum

Required warm-up

Insulation Vacuum sectorization:



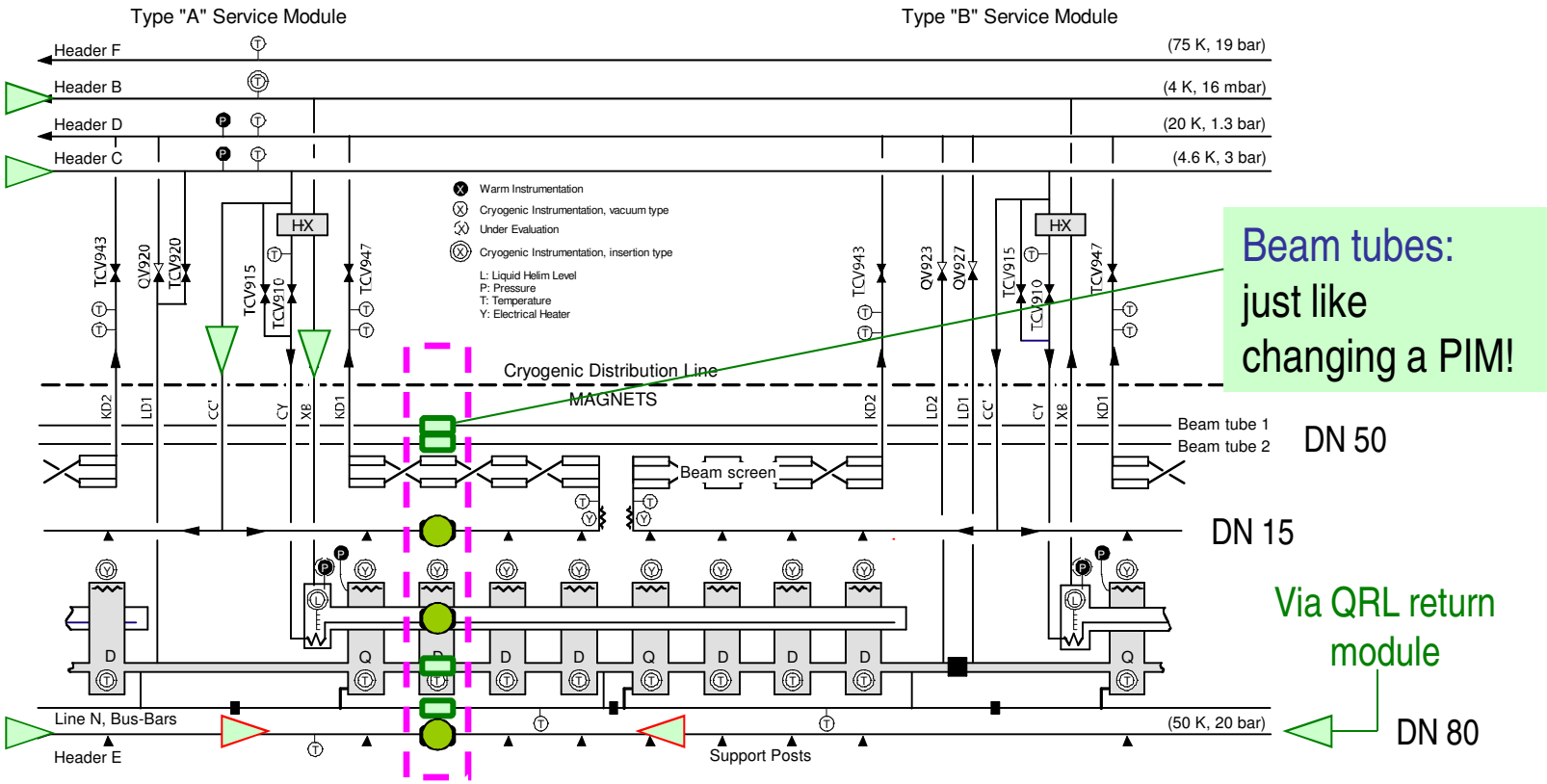
- Warm-up of concerned sub-sector to 300K, and adjacent right to 100K (then GN2 bag against condensation)
- Most likely a 2nd sub-sector to be warmed-up, as ELQA of Line N requires so far to access 4 boxes (3 x 54m)



Only PIM with potential (very) small risk by now

Cutting/Welding without air in pipes

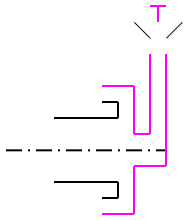
QUI



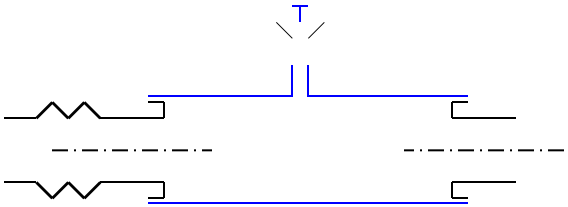
- Cutting to be made with little over-pressure (experience!)
- Temporary cap to be placed

Delicate definition of required over-pressure and pipe preparation, but seems possible without too much pollution of cryo pipes with air

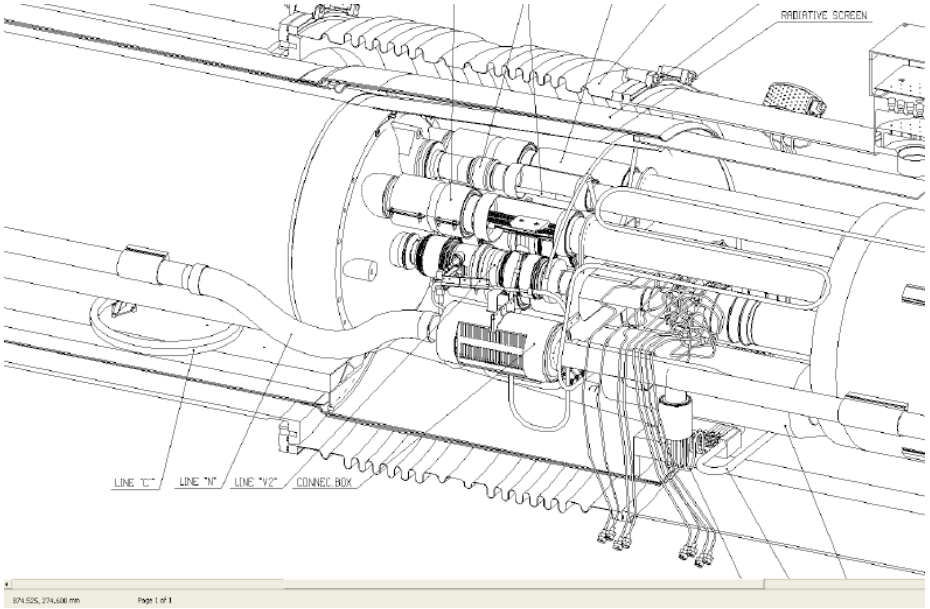
Caps or welding with He flow



Temporary caps on opened pipes, with GHe flow when fixing in place (kind of clamp + screw plug)

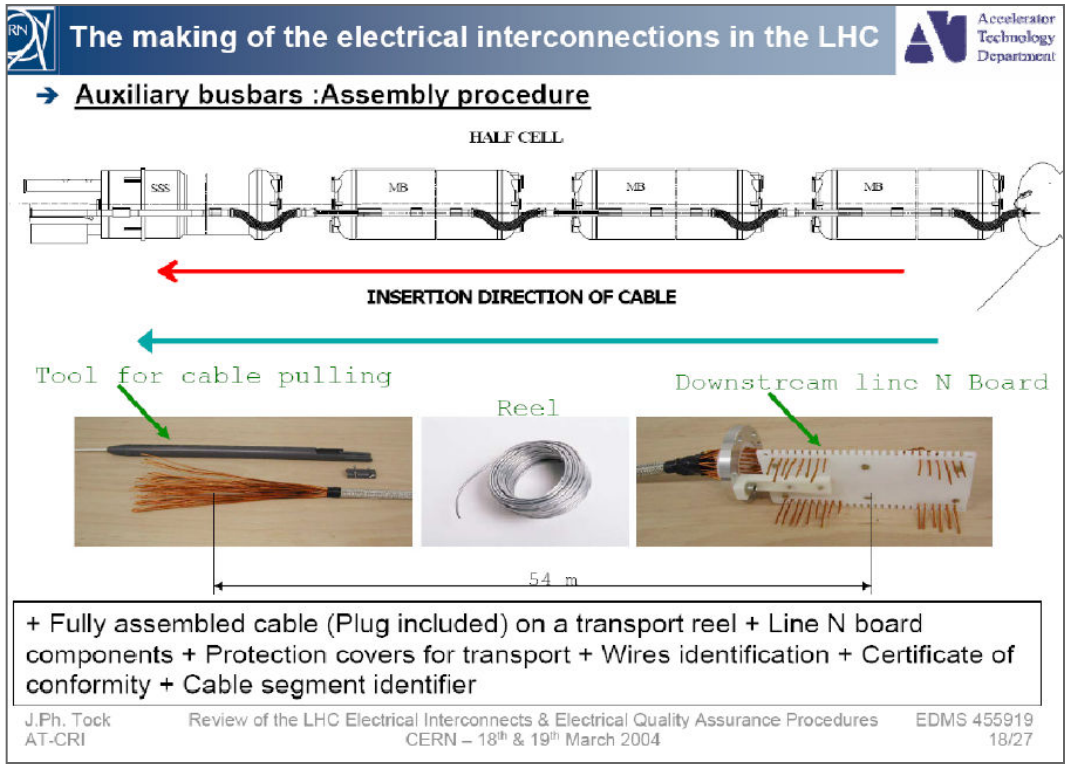


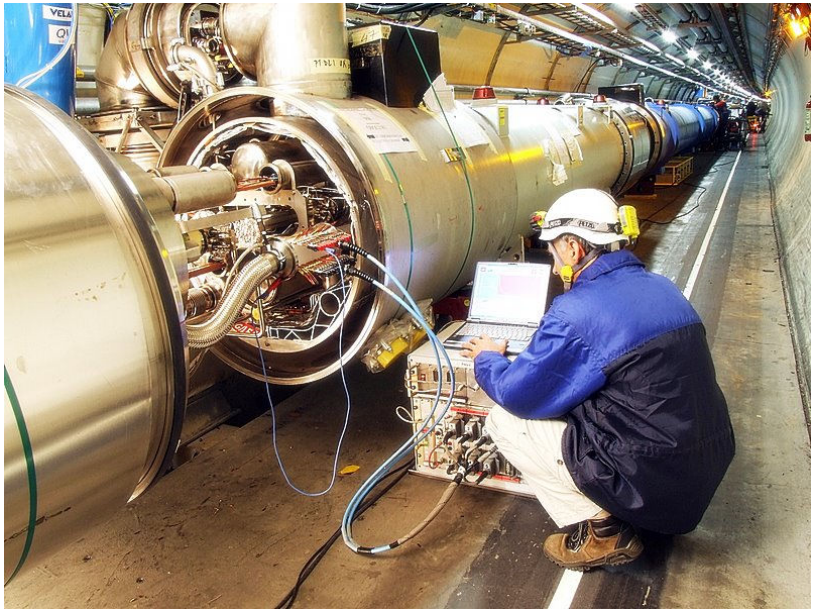
Pseudo leak-tight sleeve with exhaust for GHe before welding libs, and welding of plug at the end



Probably common development for Vacuum and Cryo pipes

Specific case of Line N





Very specific installation procedure, no splice designed yet except in junction box every 54m (an add. One would create a non standard magnet type), and specific ELQA tests requiring access to 4 such boxes

Conclusion

- Minimising the risks associated with a complete thermal cycle (plus cost and time advantages) is definitely worth being looked at
- This very preliminary evaluation tends to validate the principle of a partial warm-up (Maxi: 2 sub-sectors at 300K + 1/2 at 100K) for replacement of a magnet, provided:
  - We can develop tools and procedures for welding sleeves without entering massively air in the pipes
  - We do not have systematic problems at cold-warm interface (such as PIM's or other items)
- To be considered as a global optimisation process, as some systems could be penalised after restart of operation