Cryogenic update – Crab cavities and ColdEx

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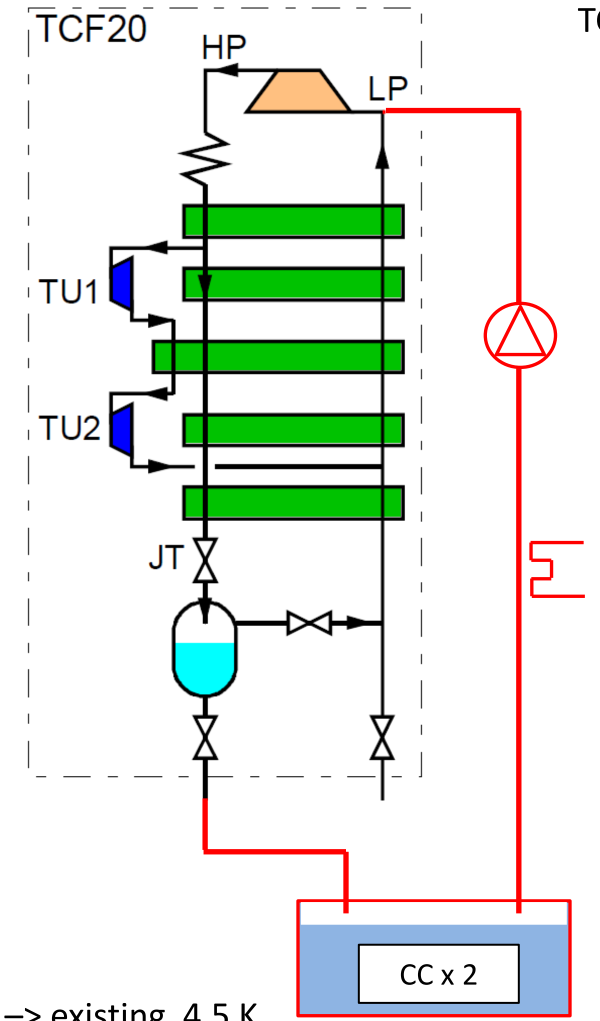
on behalf of cryogenic team at CERN

Contents

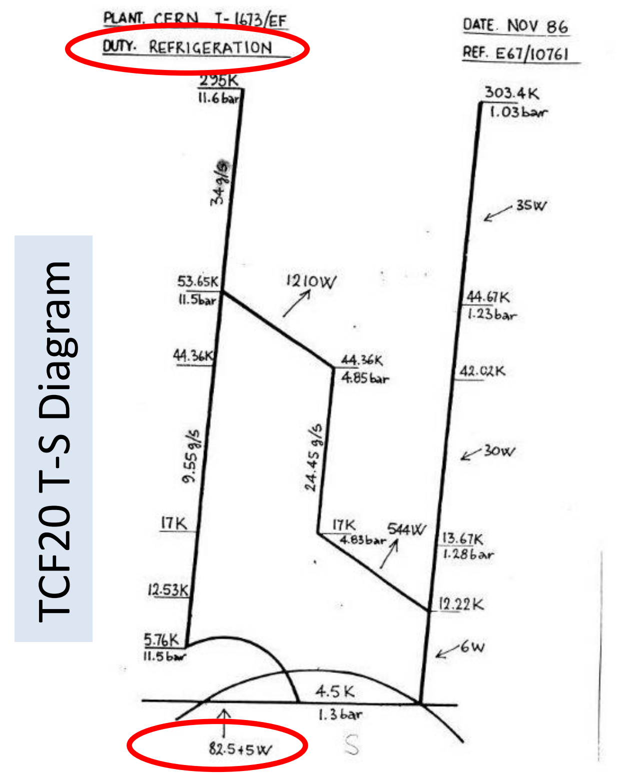
- Present cryogenic infrastructure in SPS
  - Cryogenics for COLDEX
  - COLDEX cryo operation for first SPS scrubbing run
- Planning – main guideline
- Cryogenic design for the crab cavities
  - Heat load and cold box solution
  - Architecture and circuits
  - SM-CM design progress
  - Work performed at BA4 during SPS LS1 – present status
- Cryogenics for LHC - concept for LHC P1 and P5
- Conclusions

Cryogenic infrastructure in SPS BA4

Crab cavity cooling at 2 K ➔ TCF20 cryoplant used in pure liquefaction
TCF20 means 20 l/h = 0.7 g/s of LHe, expected max.1.5 g/s with LN2 boost



black –> existing 4.5 K
red –> to be constructed 2 K

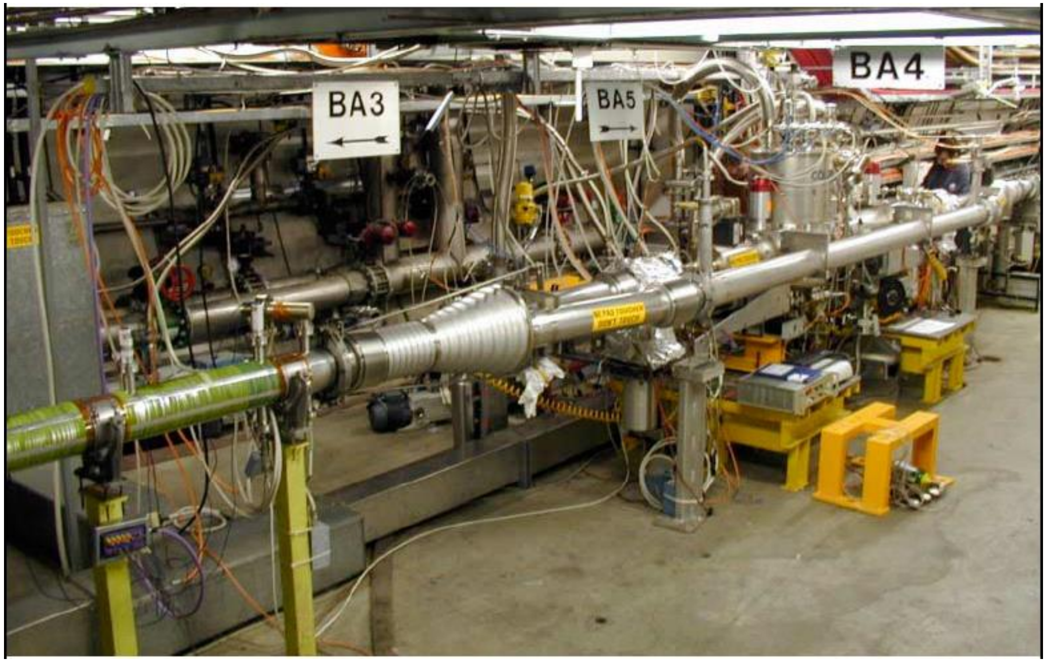


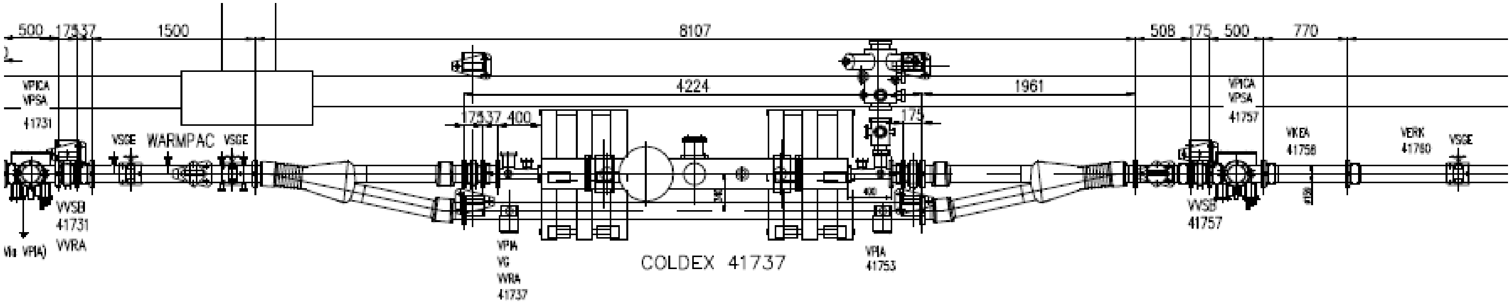
Guaranteed capacity in refrigeration mode: 87.5 W @ 4.5 K
(i.e. isentropic equivalent to ~0.85 g/s of liquefaction)

Cold box initially foreseen to run for Crab Cavities SPS testing, then for CC and Coldex, now only for Coldex (CC heat load too high to be covered by TCF20. Coldex is foreseen to operate over 2015 and 2016.

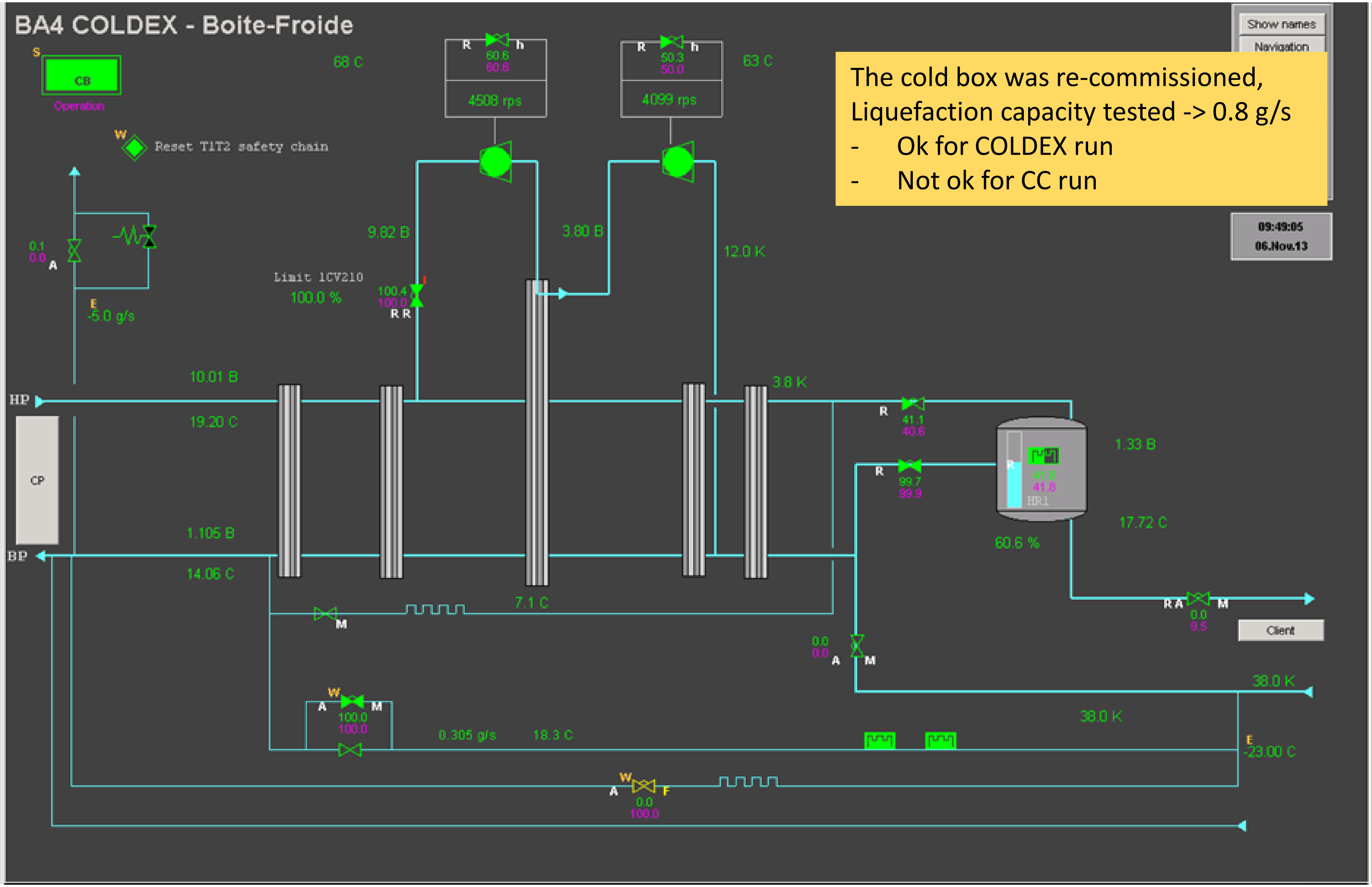
COLDEX in SPS BA4

COLDEX simulates LHC cold bore and beam screen for e-cloud study.
Currently new carbon coatings are tested to minimize the e-cloud effect in HL-LHC.
Request for COLDEX re-commissioning was raised up in January 2013.





TCF20 cold box and ColdEx cryostat

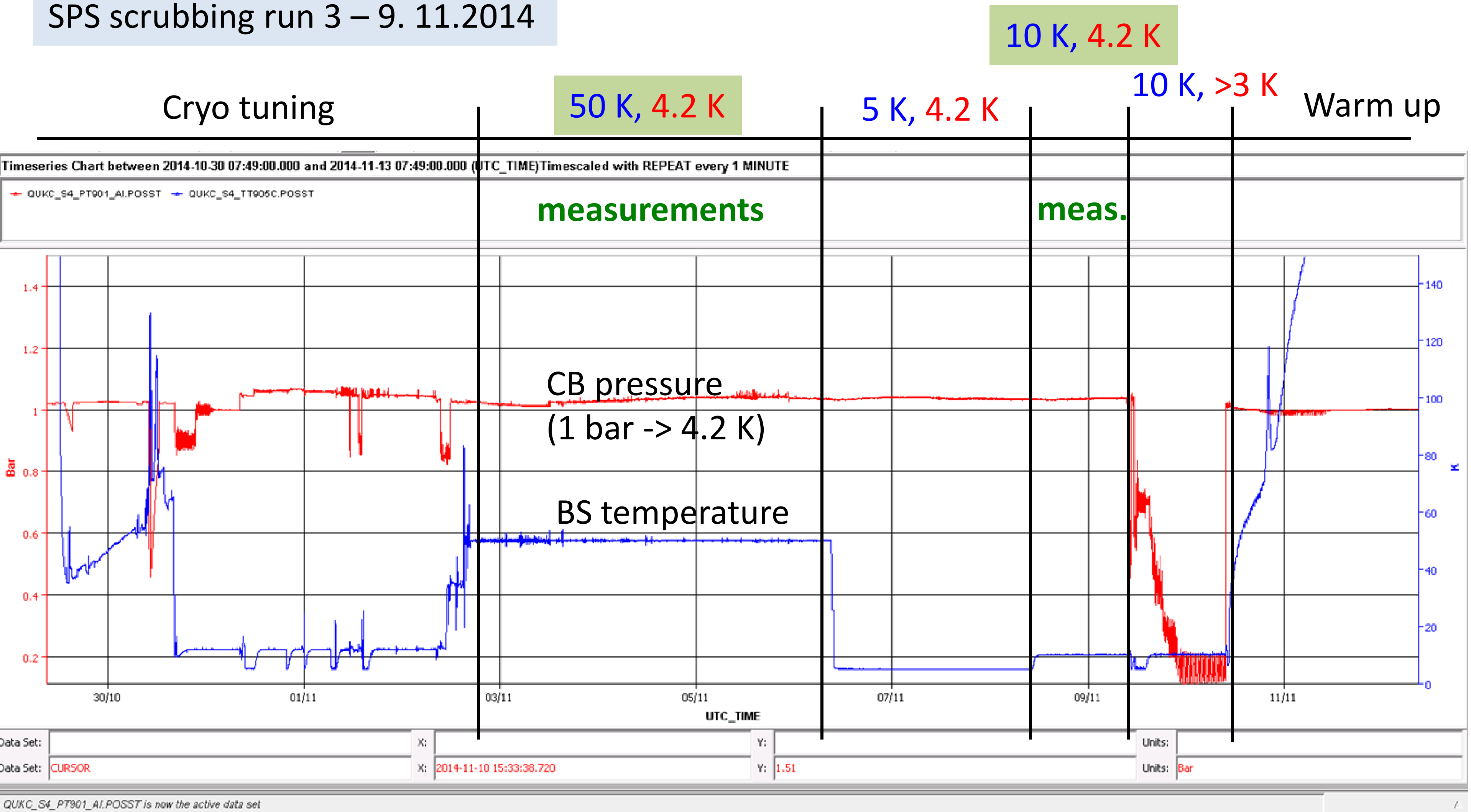


The cold box was re-commissioned,
Liquefaction capacity tested -> 0.8 g/s

- Ok for COLDEX run
- Not ok for CC run

Fist ColdEx run – cryo summary

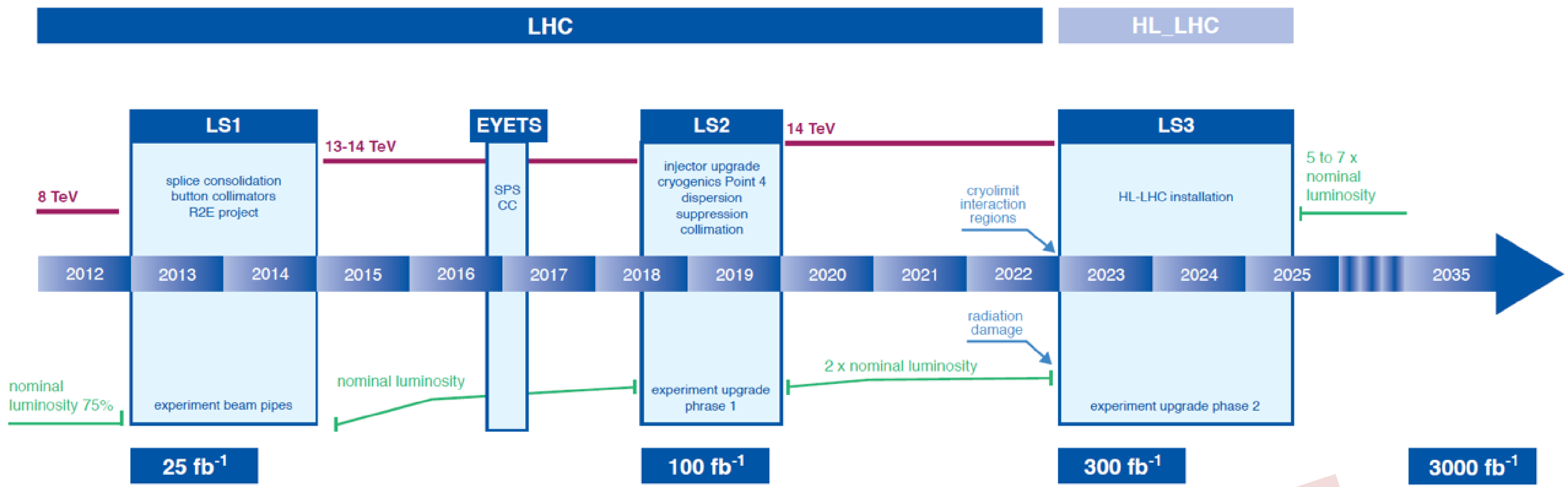
SPS scrubbing run 3 – 9. 11.2014



The installation is tested and operational for next run in December 2014 (week 50)

Planning projection

New LHC / HL-LHC Plan



COLDEX in BA4

Crab Cav. in SPS

Crab Cav. in SM18

by L.Rossi

The above planning is the baseline respected by CRG. Clear statement is to be made about the place allocation for SPS test! Large part of work was already done at BA4, some equipment is already installed.

Change of SPS location will not be for free in terms of time, money and manpower.

Heat load

Last estimation from BNL meeting in May 2014

Equipment	Heat load	Source of capacity
Service module	~2.5 W @ 4.5 K ~30 W @ 80 K	Cold box -> 0.13 g/s LN2
Buffer tank	~1.5 W @ 4.5 K	Cold box -> 0.08 g/s
Transfer lines	~4 W @ 4.5 K	Cold box -> 0.21 g/s
Cryo module static	~18.6 W @ 2 K 286 W @ 80 K	Cold box -> 0.9 g/s LN2
Cryo module dynamic	~13.4 W @ 2K ~30 W @ 80 K	Buffer -> 0.6 g/s LN2
Total static:	~26.6 W @ 4.5 K (2 K load converted to @4.5 K)	Cold box -> ~1.32 g/s

R. Bonomi, O. Capatina, F. Carra, V. Parma, K. Brodzinski

0.6*1.5=0.9 **g/s**

1.32*1.5=**1.98 g/s**

The applied factor is necessary to have capacity for heat extraction during cool down phase.

State of the Art is required for the CC cryo-module design.

Solutions for CC cryo capacity

Present baseline:

storage
TCF200 (w/o comp.)
max. 7 g/s

→

CryoLab
TCF50
max. ~3 g/s with LN2 boost, compatible with CC requirements

→

BA4

Summary (assuming cold box capacity of 3 g/s):

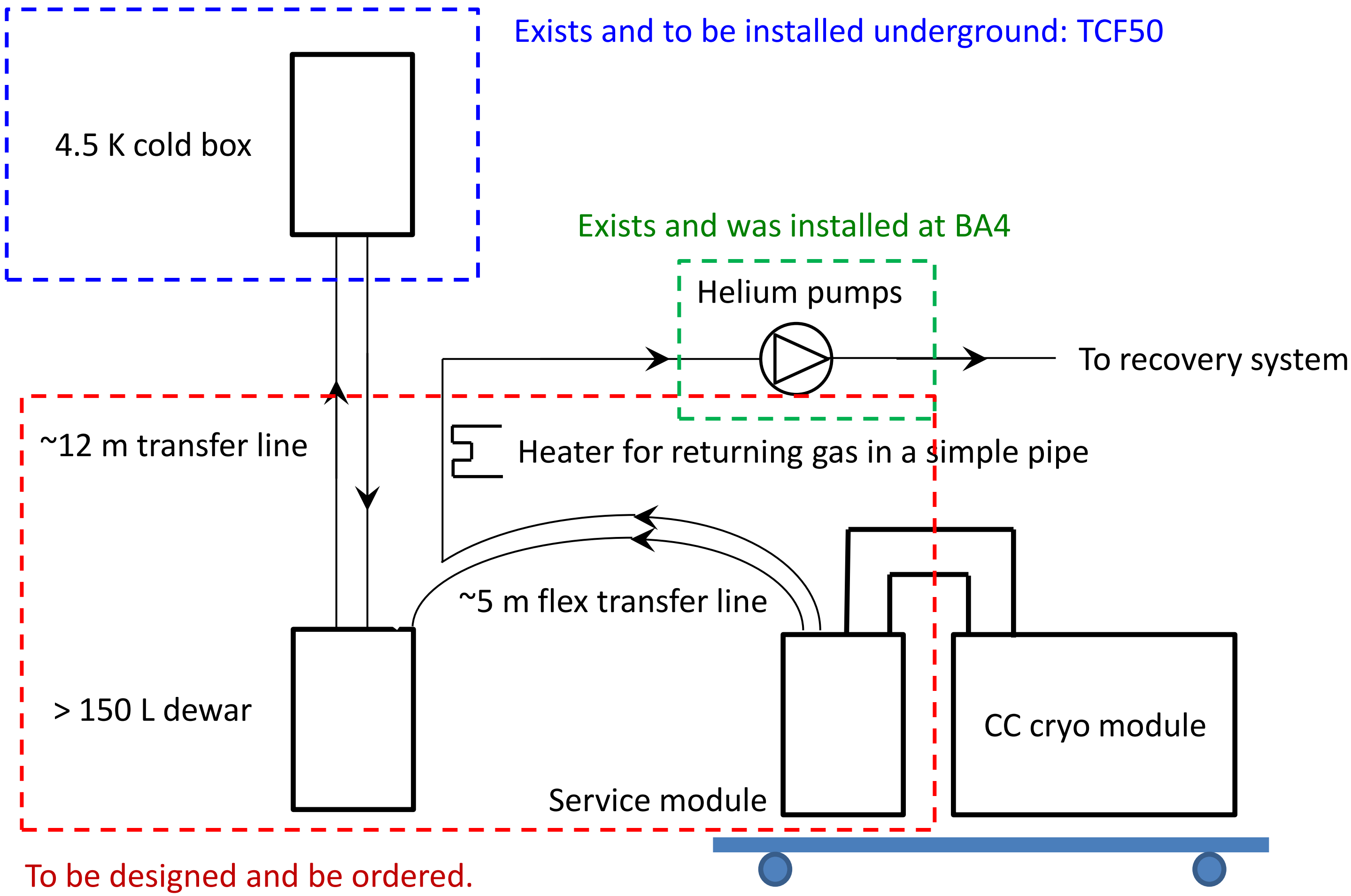
Total Static: 1.98 g/s
Dynamic: 0.9 g/s

Total Static + Dynamic = 1.98+0.9=~2.9 g/s < 3 g/s -> <u>run without buffer is theoretically possible</u>

For security reasons we plan to install >=150 L dewar for dynamic heat load compensation

The aim is to design the system in a such a way to provide cooling capacity for at least 8 hours of operation /day (refilling of the dewar will be done during the nights).

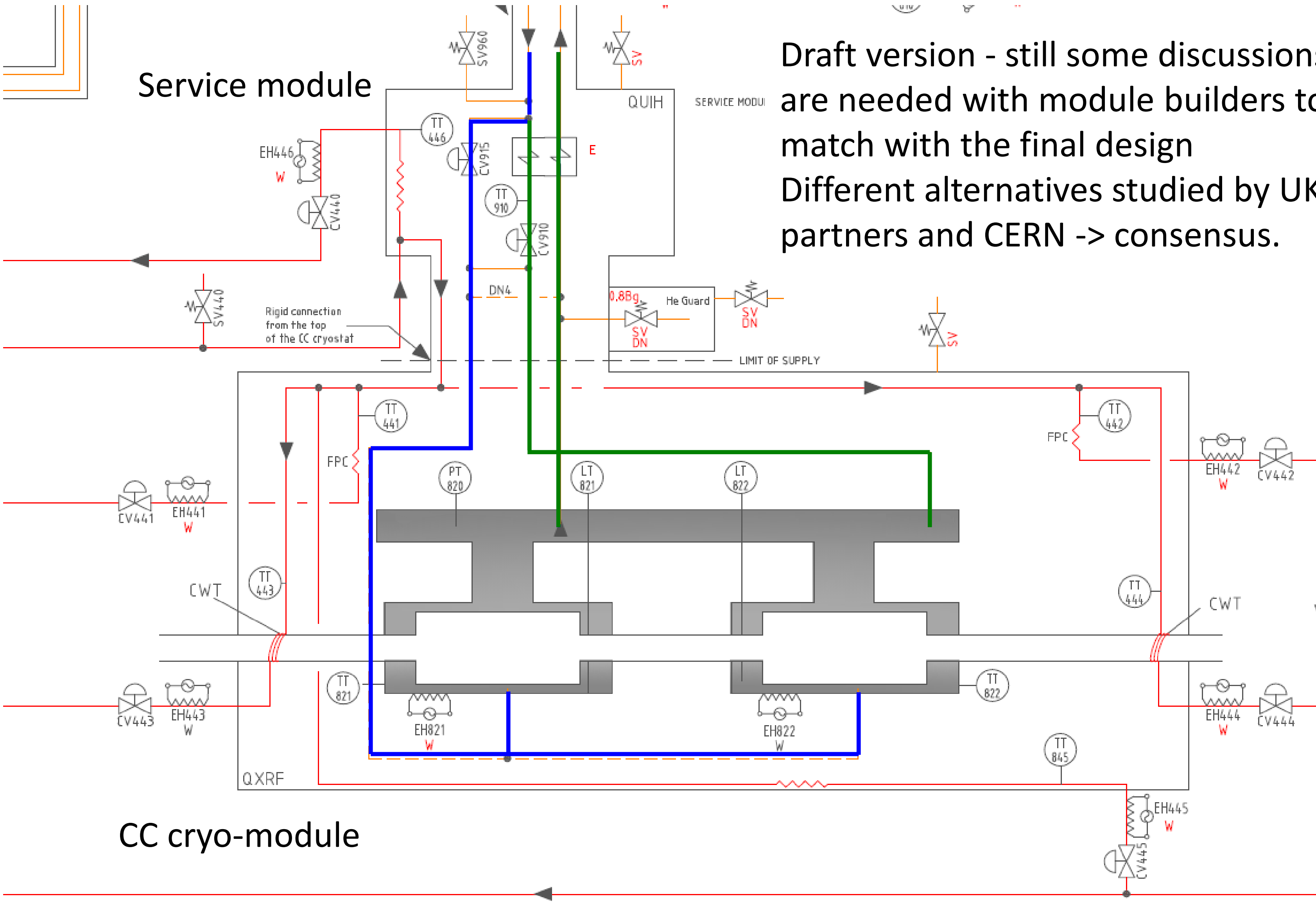
Architecture – TCF50 scenario



Change of location of the SPS test can and probably will have an impact on: length of the transfer lines -> thermal load -> needed cold box capacity (TCF50 in the cavern or e.g. TCF200 on the surface …?)

Process and instrumentation

Service module



Draft version - still some discussions are needed with module builders to match with the final design

Different alternatives studied by UK partners and CERN -> consensus.

CC cryo-module

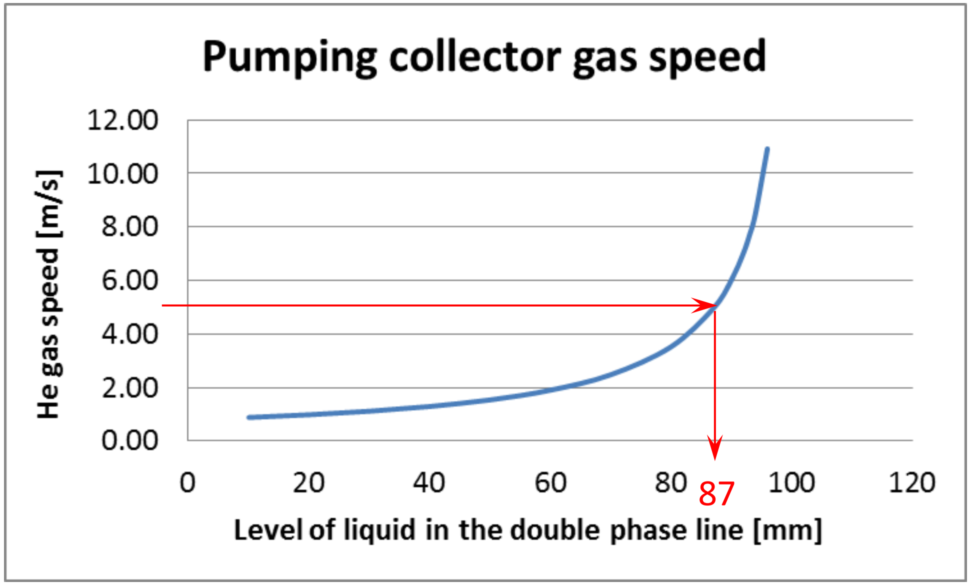
Pumping collector sizing

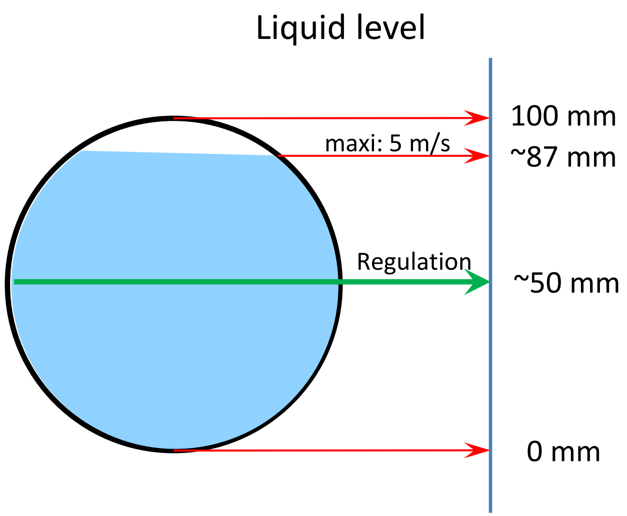
Requirements: gas speed lower than 5 m/s*, min 50 mm for level regulation, additional buffer for ~ 20 min of operation, compatibility with safety devices for pressure limit requirements.

Indications: Diameter of 100 mm (recommended) allows for:

- return gas speed below 5 m/s up to ~90 mm of liquid level in the collector (operation regulation level to be set at ~50 mm of LHe in the collector),
- buffer volume for transients/unexpected process perturbations (half filled collector allows for ~15-20 min of operation assuming collector length of ~1.6 m and 30 W of thermal load),
- *compatibility with safety valves sizing is still to be checked !*

* Standard design value confirmed by Rob van Weelderen and by T. Peterson on December 2012 Fermilab meeting





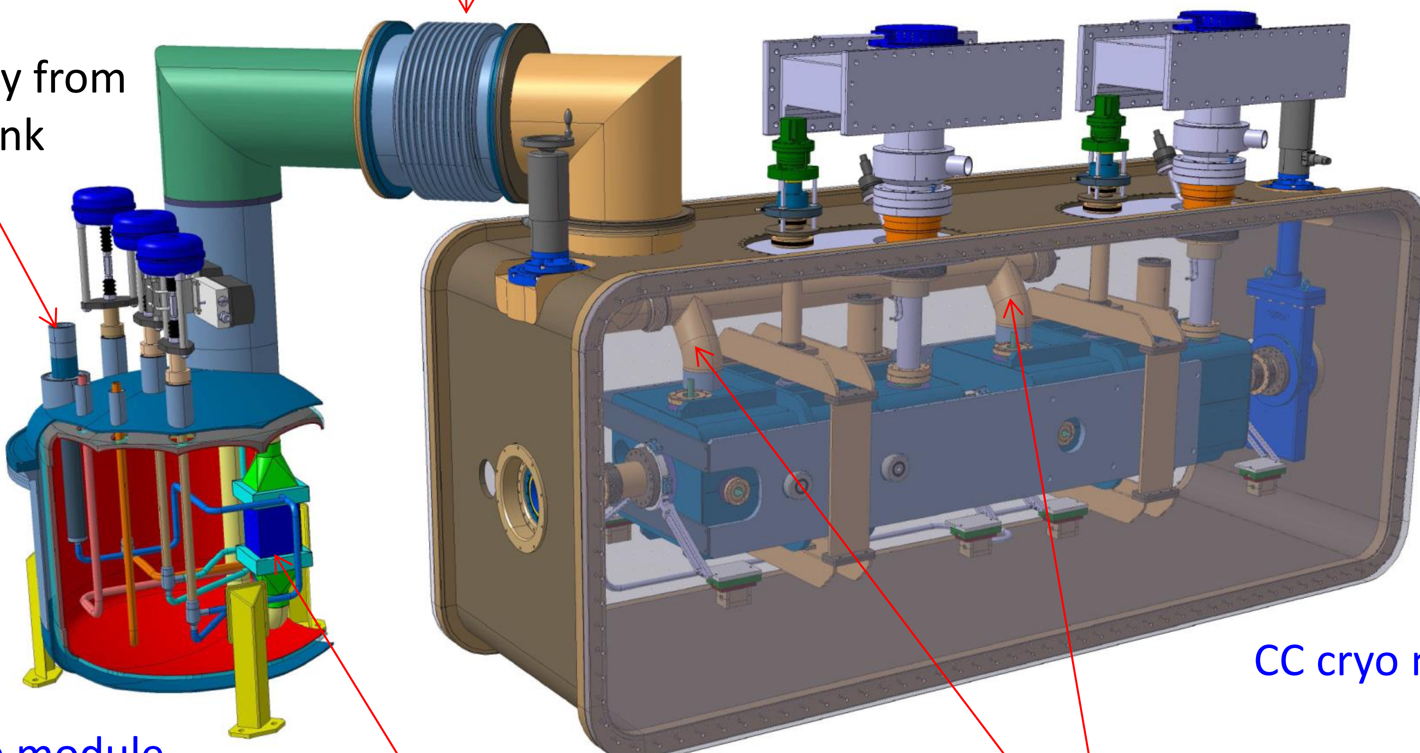
* Calculation done assuming: collector diameter of 100 mm, He mass flow = 3 g/s, GHe temp = 2 K, GHe press = 20 mbar.

Cryogenic design for SM and CM

Service module to CC cryo module interface:
- Welded internal lines, equipped with flexible hoses
- Bolted external bellow with vacuum sealing

Cryogenic part studied and designed in collaboration between CRG and MME

He supply from buffer tank



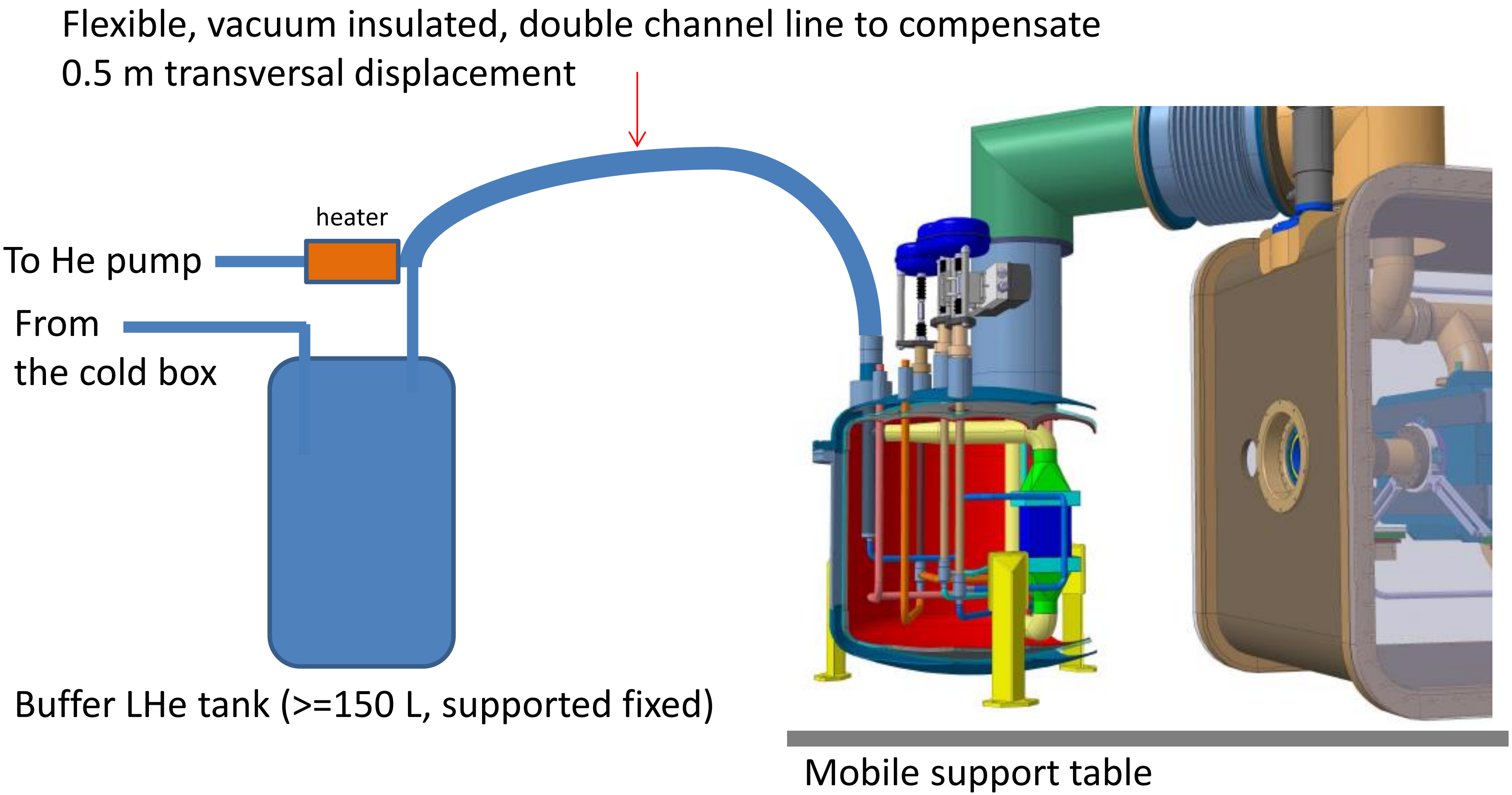
Service module

CC cryo module

Sub-cooling 2 K heat exchanger

Connections between double phase line and He tanks of the CC

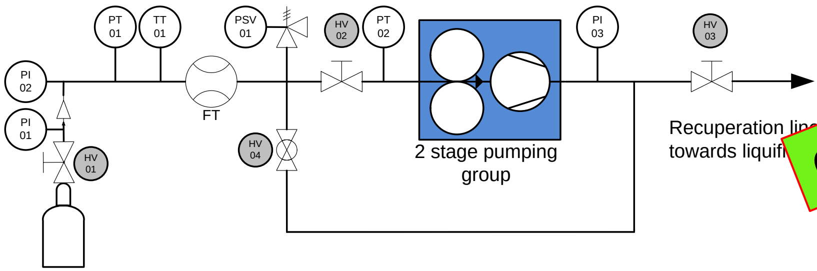
From CM to the buffer and pumps



Service module, flex line, buffer tank and heater need to be ordered in next 3-6 months.
The goal is to have the hardware at CERN on the beginning of 2016 for SM18 test.
Only tested on surface equipment will be installed in the tunnel.
Discussions and close collaboration with integration is needed.

2 K helium pumps

Capacity >2.9 g/s -> OK for CC SPS test

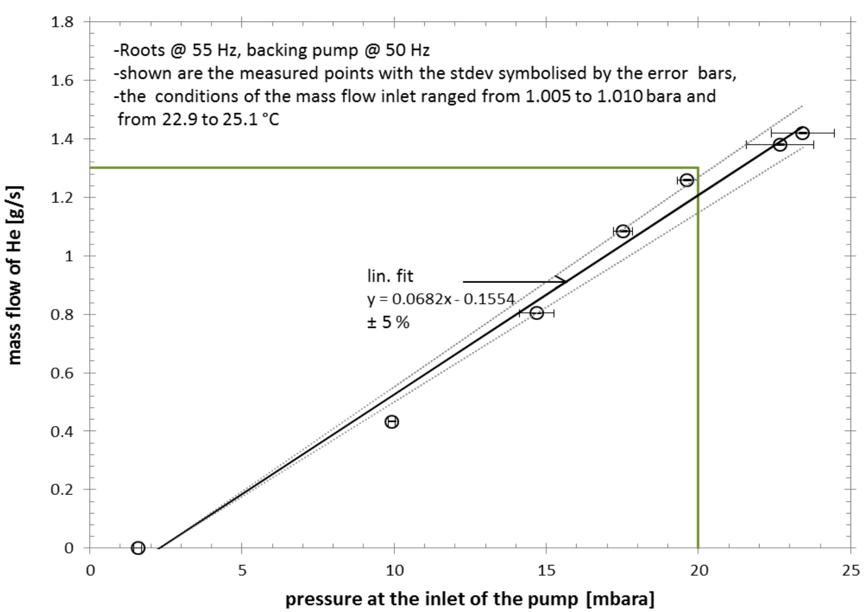


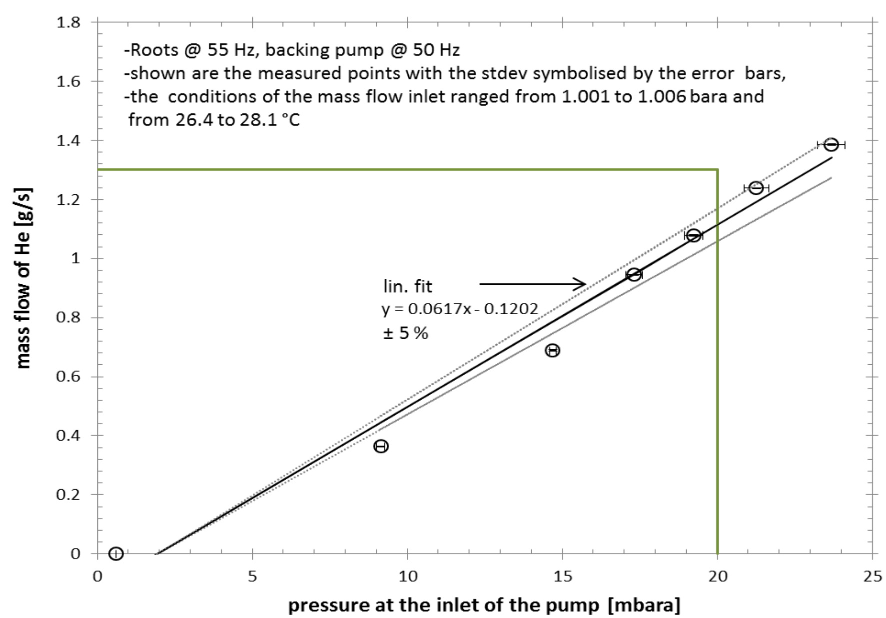
2 batteries of He gas bottles
<200 bar

2 stage pumping group (Leybold: RUVAG WS2001 and SV630)

PT01: pressure transmitter, Rosemount, 0… 2000 mbara
TT01: Pt100
FT: flow transmitter, Brooks, 0… 1.5 g/s
PT02: pressure transmitter, GE, 0… 100 mbara

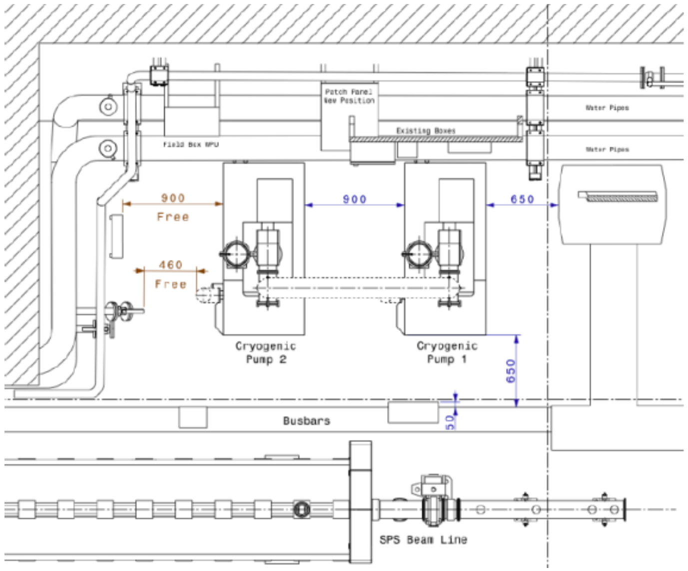
The check shows that assuming inlet pressure of 20 mbar two pumping units are capable to pump ~2.3 g/s of helium, what gives ~3.5 g/s at 30 mbar (2 K saturation)





Work progress at BA4

Top view



Significant part of equipment installation work at BA4 was done during LS1 regarding 2 K cooling capability.

- The 2 K helium pumps have been installed in the SPS cavern at BA4
- cooling water circuits installed for pumps cooling – EN/CV support
- electrical supply pulled from surface to TA4 and BA4 alcove EN/EL support
- Control racks installed in TA4 (shaft bottom area) – TE/CRG
- Ethernet network pulled and installed underground for control system – IT support

SPS LS1 was finished on 27^{th} June 2014.

Cryostat operation – first approach

Pressures – safety :

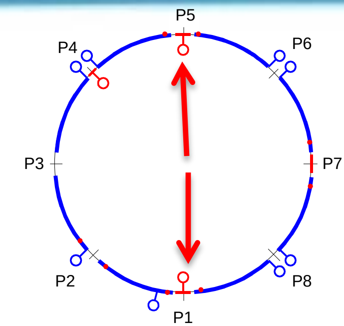
- The cavity should be designed to withstand external pressure of 2.6 bara (deltaP = 2.6 bar) at ambient temperature without plastic deformation,
- Design pressure for the cryostat should be based on installed safety devices according to design rules (cryostat equipped with a rupture disc set at 2.2 bara and safety valve set at 1.8 bara)
  - both safety devices should be placed on the cryostat in the way to avoid potential projection of helium towards the passages or transport area (deflectors installation to be analyzed),
  - Both safety devices should protect cavity and cryostat from pressure rise causing plastic deformations
- Operating pressure during the cool down can oscillate between 1.2 and 1.5 bara – estimation,
- Normal operation pressure will be set at ~ 30 mbara (for 2 K cooling)

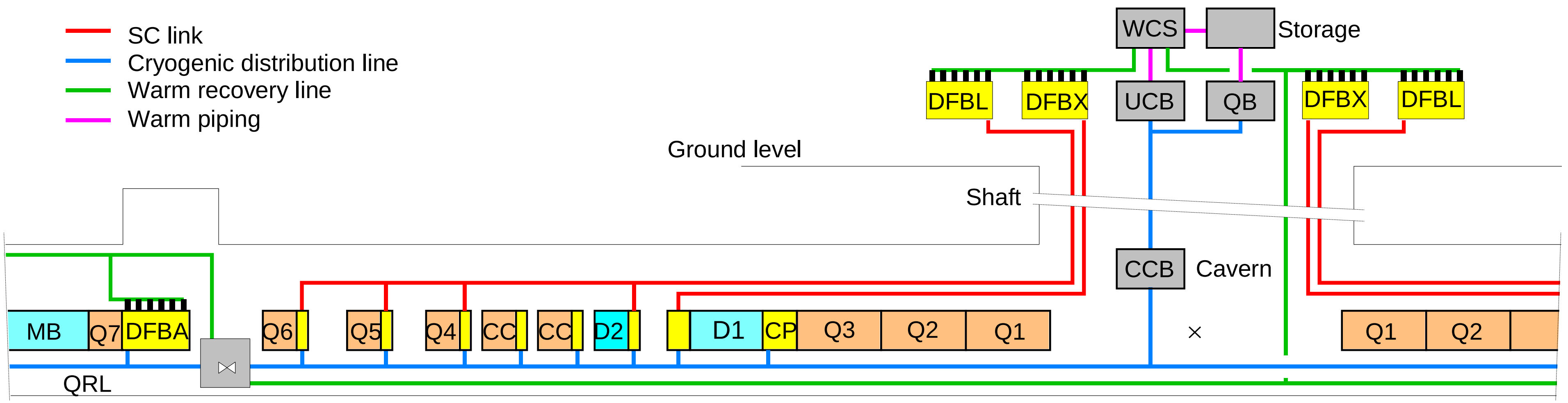
Cool down – stable operation – warm up:

- Cool down will be done with direct filling of LHe to the cavity cryostat, roughly estimated cool down time is ~ 1 day
- Stable operation availability can be affected by impurities in the system or unexpected utilities cut.
- Warm up of the cavities will be done by evaporation of helium and warm gas circulation

New cryogenic infrastructure at P1 and P5

L. Tavian_Daresbury 2013





- 1 warm compressor station (WCS) in noise insulated surface building
- 1 upper cold box (UCB) in surface building
- 1 cold quench buffer (QV) in surface
- 1 or 2 cold compressor boxes (CCB) in underground cavern
- 2 main cryogenic distribution lines
- 2 interconnection valve boxes with existing QRL

Suitable for cryogenics to have a common cryostat for 2 or 4 CC in one module. Supply and pumping lines architecture is being studied -> it will result in number of jumpers (consideration of tunnel slope is mandatory).

High Luminosity LHC

Conclusions

Coordination and planning:

- All work up to now was done considering BA4 location as a baseline.
- Decision about the location of the SPS test is highly important to progress with work! We need an input about: Where?, When? and What? (how much capacity is needed)

Engineering:

- Capacity of the cryogenic equipment estimated to cover heat load defined on BNL'14 meeting (TCF50 as a baseline to replace TCF20 used for COLDEX during EYETS.
- PID draft prepared, process analyzed, design of cryo module circuits well advanced (collaboration with MME – thanks),
- Design of the service module underway (collaboration with MME – thanks)

Progress of performed installation work:

- SPS LS1: BA4 alcove cleaned up, ECR approved, helium pumps and control electrical rack installed, utilities installed (cooling water, Ethernet and electrical power pulled).

Next steps:

Functional spec to be updated and equipment to be ordered -> towards SM18 test

Thank you! Questions?