Cryogenics and cryolines – Crab Cavities for HiLumi LHC

Crab Cavity review
10-11 November 2015
CERN – Geneva, Switzerland

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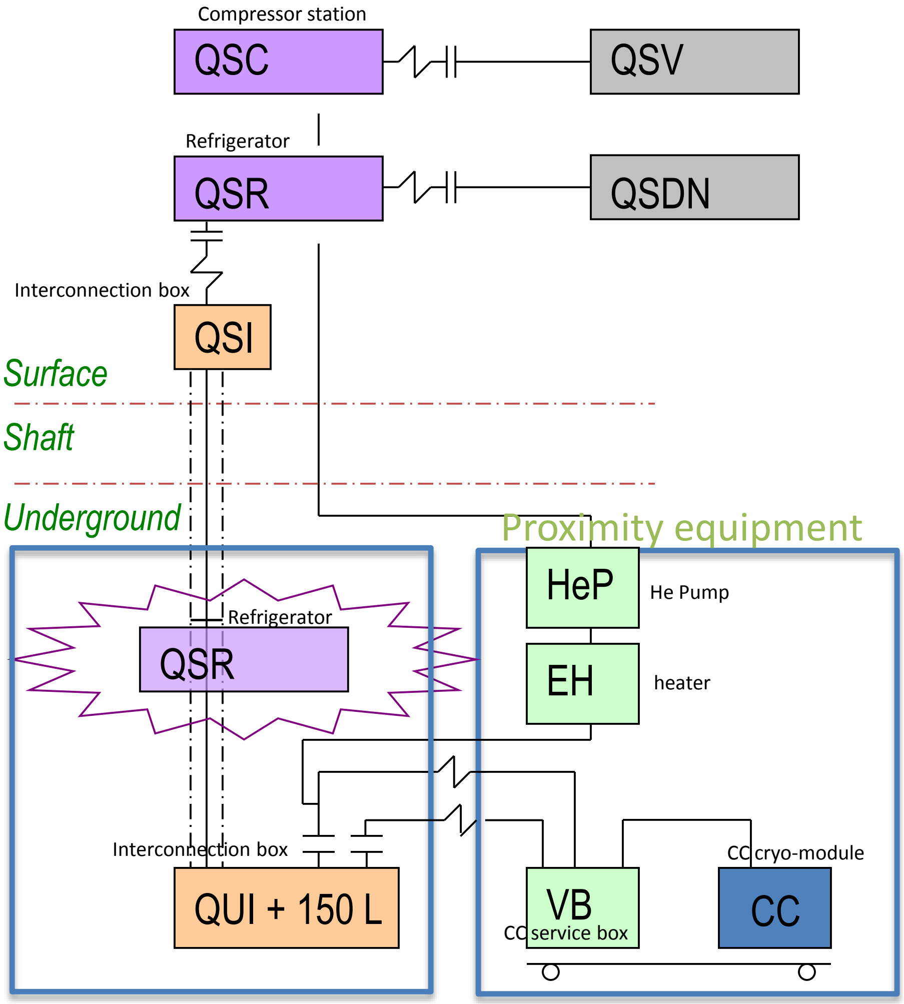
on behalf of involved team

Outlook

- General layout
- Crab Cavity cryogenics
    - Flow scheme
    - Circuits and instrumentation
- Proximity equipment
- Some operation aspects and limitations
- SM18 test requirements
- Cold box and input for integration
- BA4 to BA6 relocation and planning projection
- Conclusions

General layout

Cryogenic infrastructure layout for BA6 location.



Integration study re-started now for BA6 with G. Vandoni as a new interface for this aspect.

Cold box located on surface:
+ No problem of underground integration, easy access
- Complicated process,
- Higher heat load = more capacity required from the cold box,
- More complex design of the distribution,

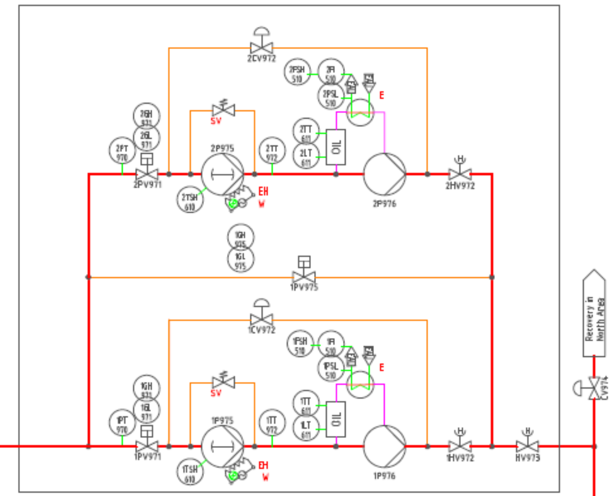
Cold box located underground:
- Limited access, complicated LN2 boost if necessary
+ standard cold helium handling (no problem of vertical head)
+ simple shaft piping distribution (only warm HP and LP pipes to be installed)
+ lower heat load,
+ lower investment and operation cost

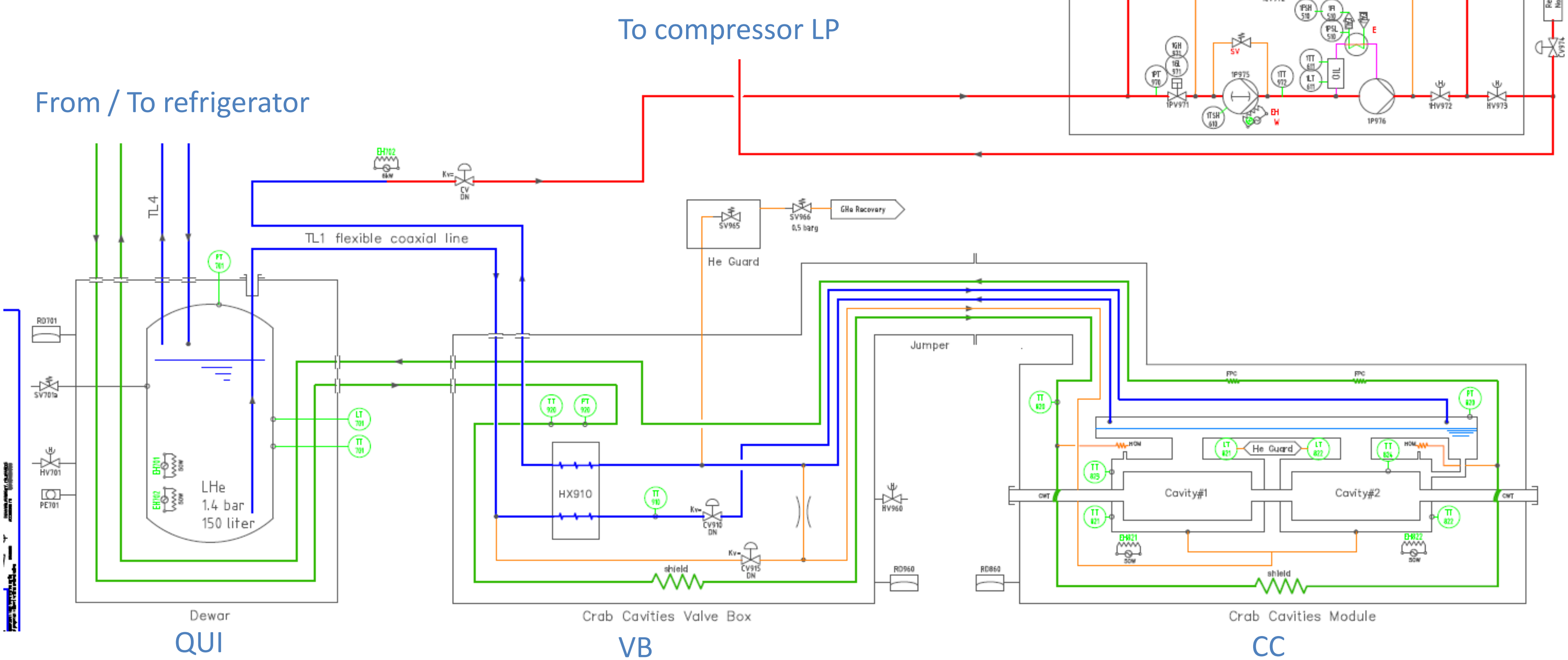
CRG preferred solution is to integrate the cold box underground. Study is underway with planned visit in situ before Xmas or during next YETS.

Main circuits and operation

CC cryostat will be operated in saturated superfluid helium bath at 2 K

- cool down and filling at 4.5 K, bypassing HX910 and bypassing 2 K pumps, sending the return gas to LP of compressor station
- Normal operation – HX910 in operation, 2 K pumps in operation for 30 mbar pumping





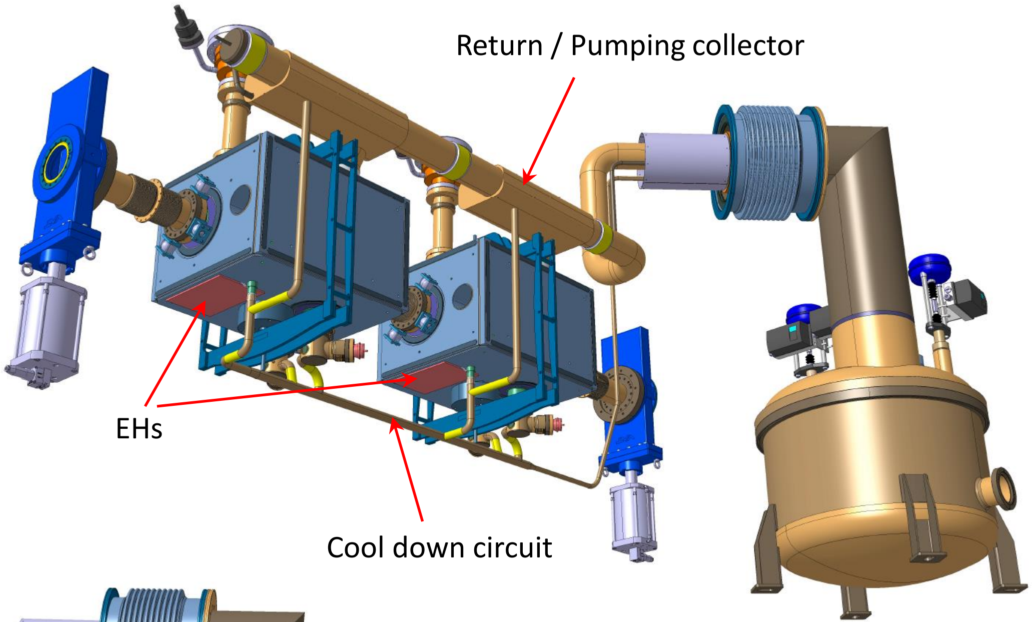
CC cryo-module circuits (2 K)

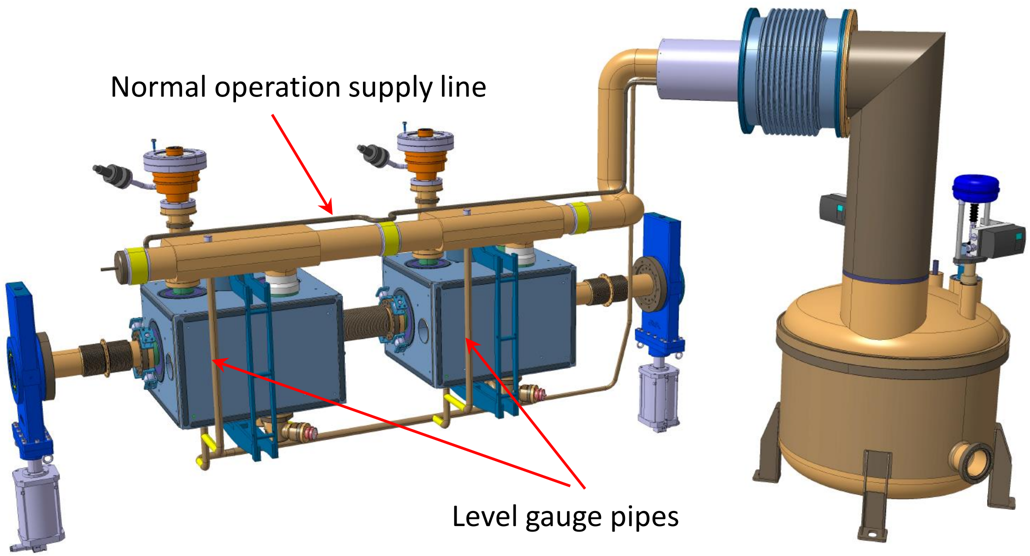
Cool down and 2 K normal operation circuits

DQW static HL: 12.5 W
RFD: static HL: 12 W

DQW synamic HL: 18.1 W
RFD dynamic HL: 15.9 W

Heat Loads from Federico Carra
– more details in Federico presentation





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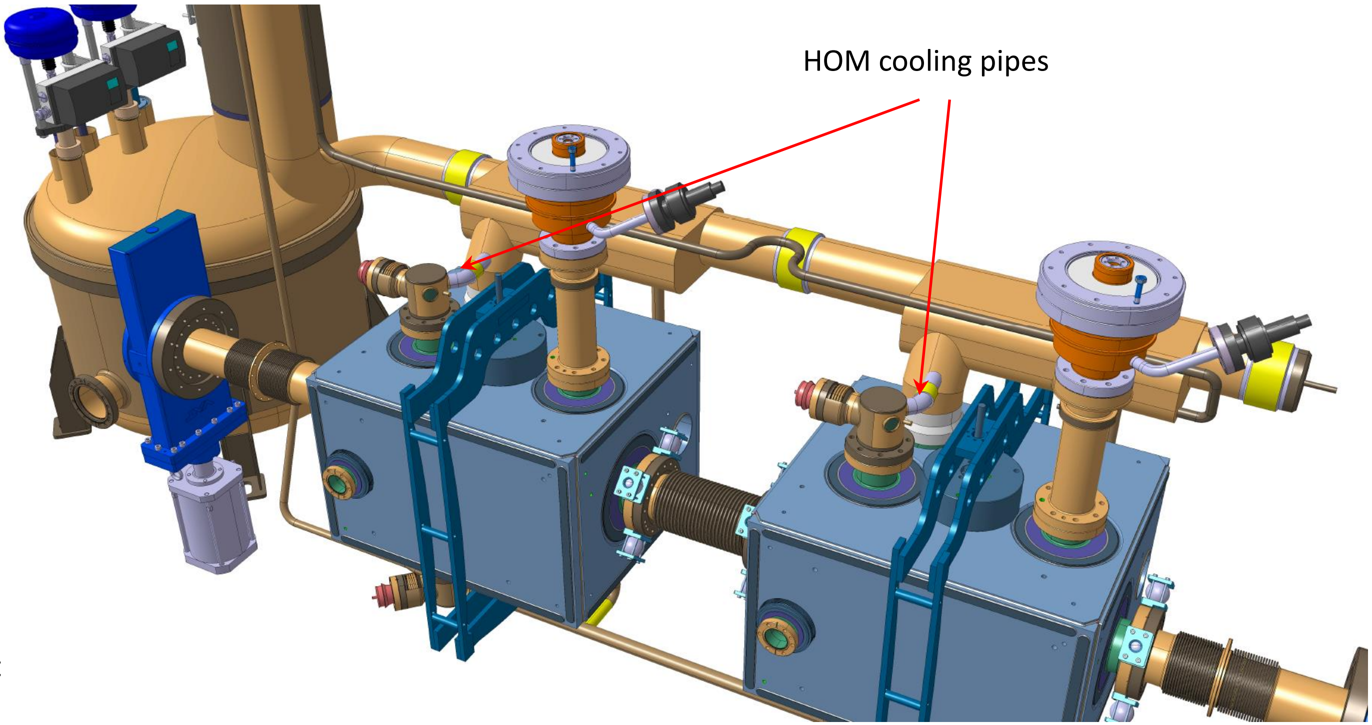
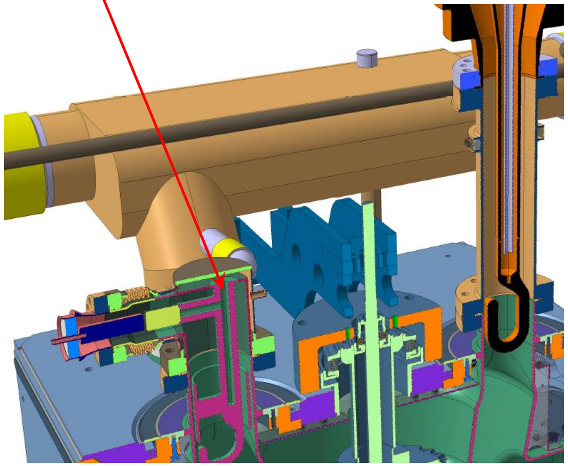
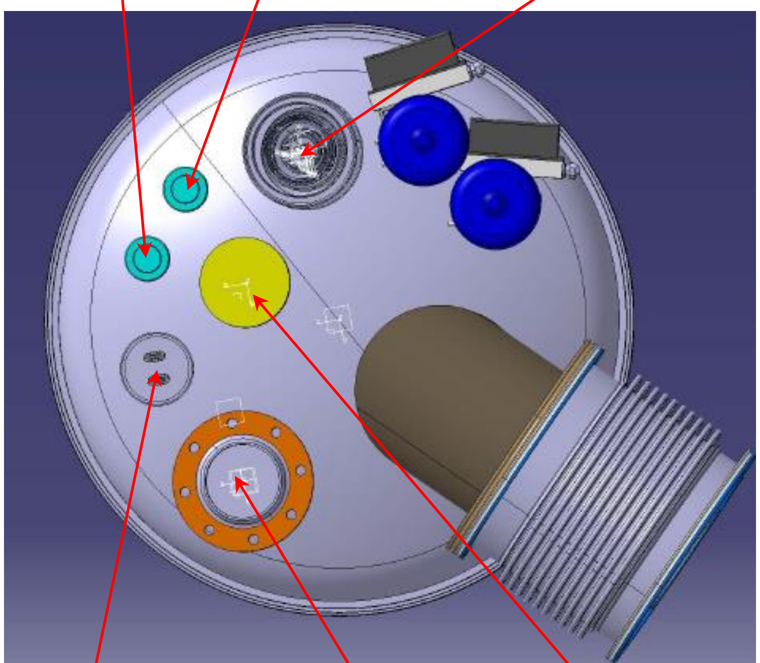


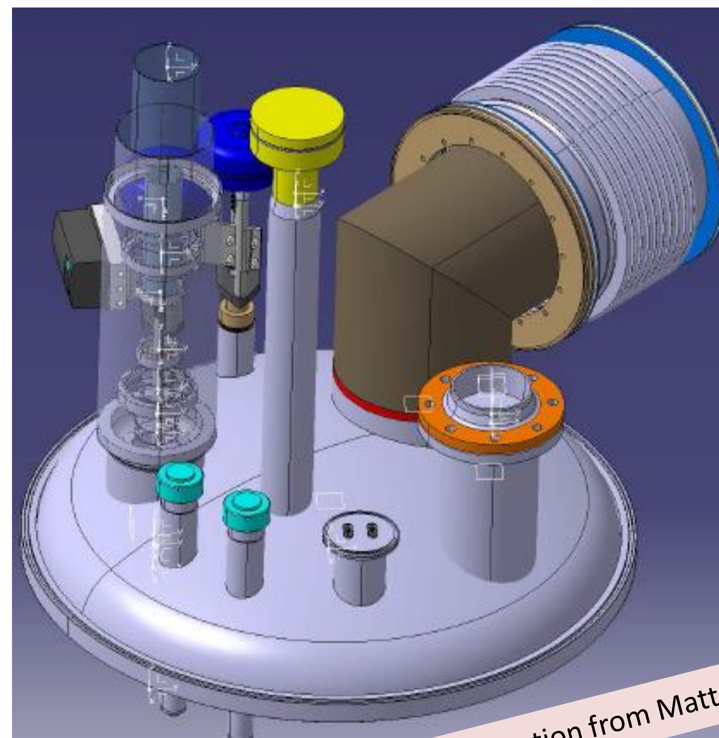


HOM pick up – HL at ~3 – 3.5 W in total

SM top service plate

Service module top plate will be defined by CERN with main parameters of the integrated components: valves, double channel line interface, screen interfaces, instrumentation flange for related connector and security devices.





Contribution from Matteo Chesi

CC cryo-module – instrumentation

- 2 electrical heaters of 50 W installed on Cu support of 5 mm thick then screwed on the bottom of the helium tanks
- 2 level transducers covering full depth of the helium tanks, wires to be routed in the pumping line with connector installed on the service box side
- 1 pressure transducer installed in pumping volume
- ~10-12 CERNOX temperature transducers – exact location to be defined for understanding of real thermal profile during cool down on the helium tanks
- One PT100 installed on the screen pipe, additional PT100 for screen mapping to be defined
- Safety valve with He guard at 1.8 bara + rupture disc at 2.1 bara to be installed on the service module to protect cavities (SV of DN40, RD of DN65 – exact sizing to be done)

Electrical heater – glued on heated surface
(CC dimensions 150 x 200 mm)

Instrumentation will be ordered in Q1 2016

Supra level transducer (d~5 mm),
CC required length is 720 mm

Rupture disc – fully welded
(no need of He guard)

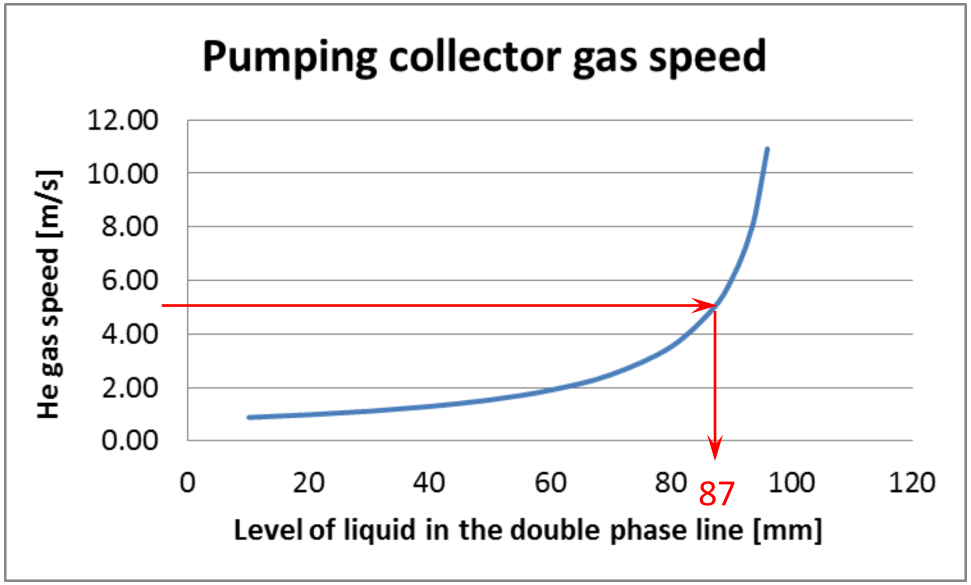
CC cryo-module operation

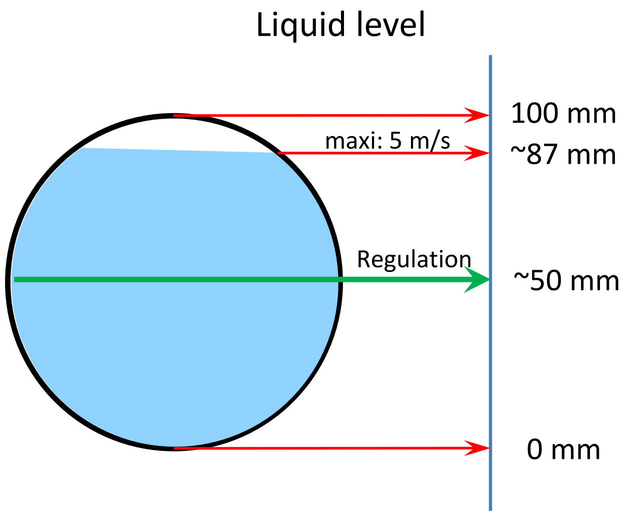
Requirements: gas speed lower than 5 m/s*, min 50 mm for level regulation, additional buffer for ~ 20 min of operation, compatibility with safety devices for pressure limit requirements.

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

- return gas speed below 5 m/s up to ~87 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 !*

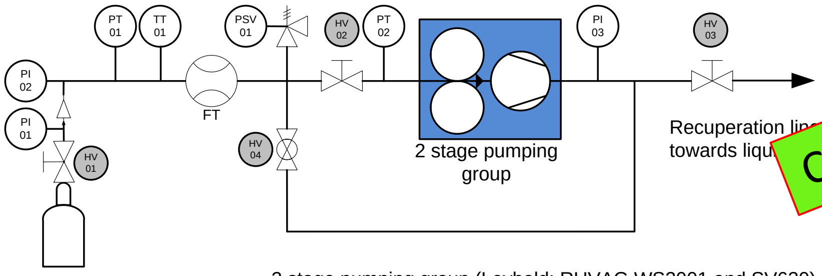
* Standard design value confirmed by Rob van Weelderen and by T. Peterson on December 2012 Fermilab meeting





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

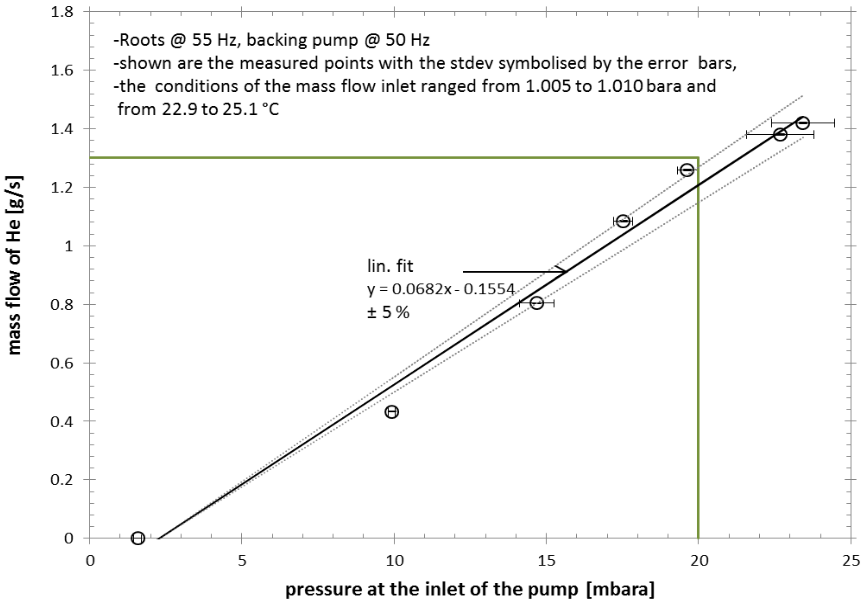
Pumping units

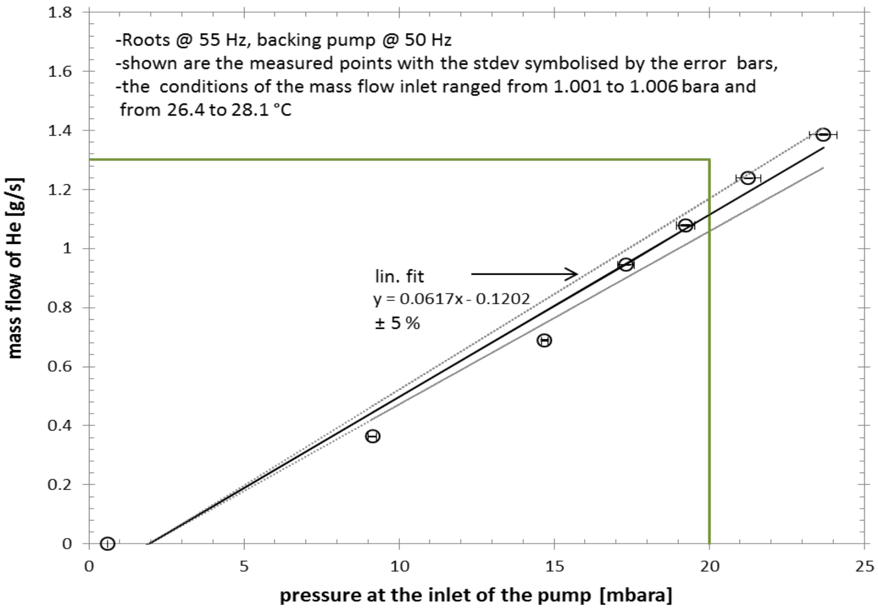


2 stage pumping group (Leybold: RUVAG WS2001 and SV630)

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)



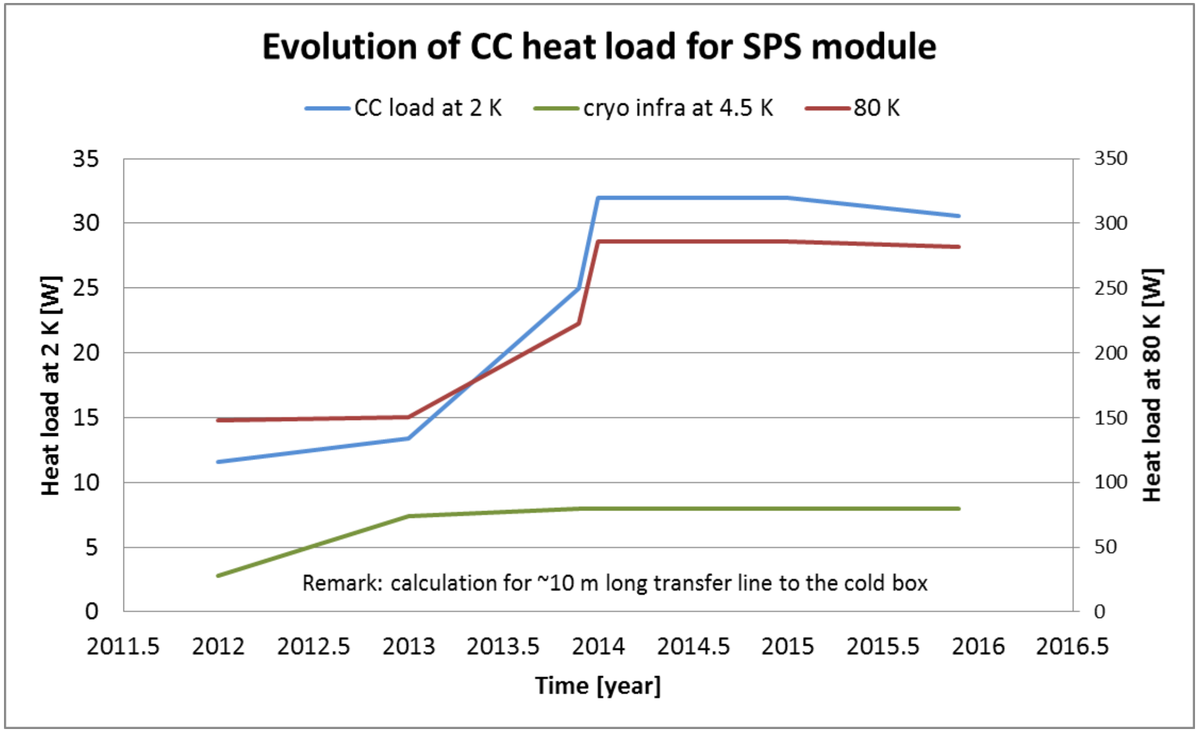


Heat load study

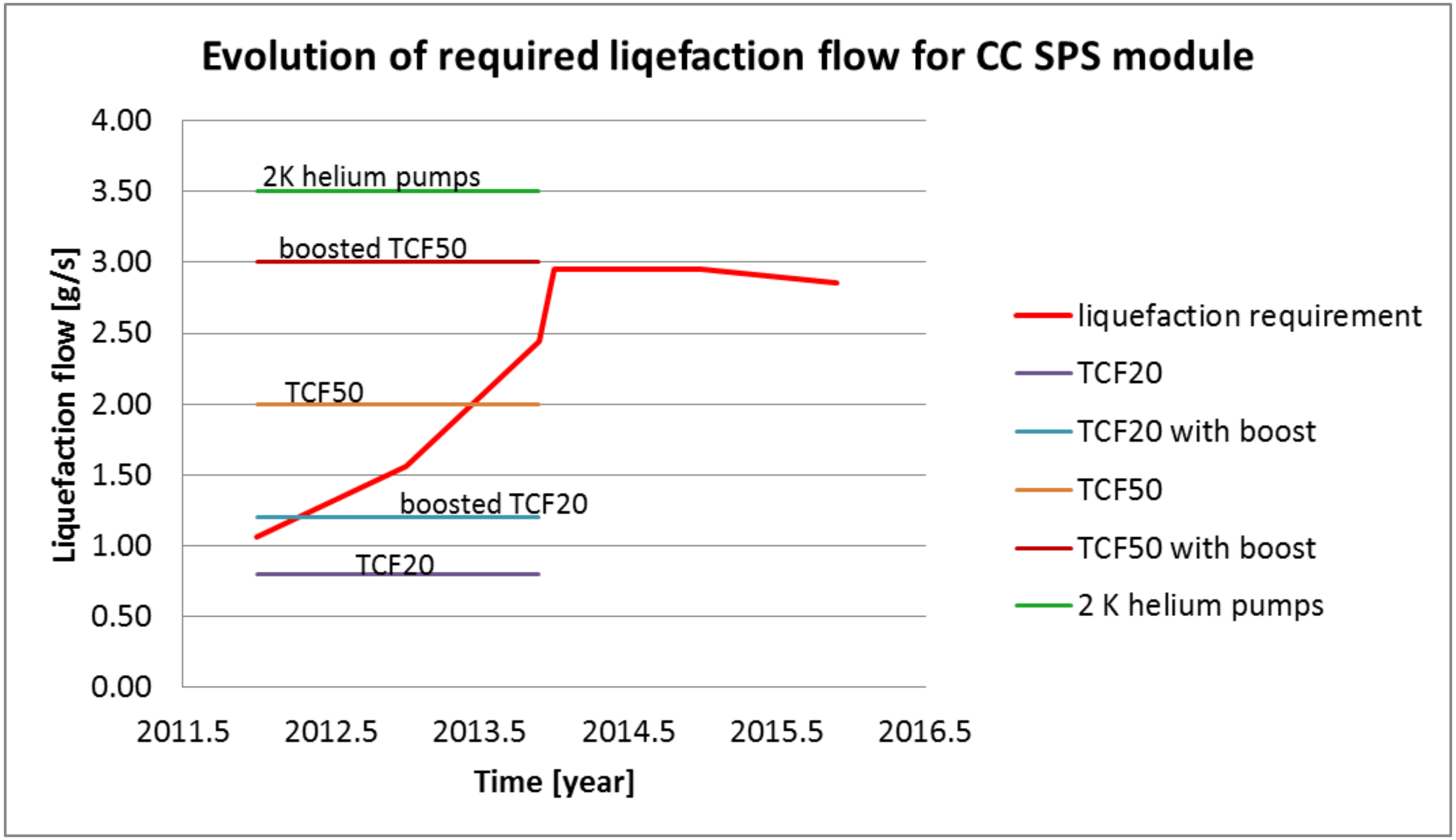
DQW static HL: 12.5 W @ 2 K
DQW dynamic HL: 18.1 W @ 2 K
Cryo prox. equipment: 8 W @ 4.5 K

Required liquefaction rate to cover cryomodule + prox. equipment heat loads is: 2.85 g/s @ 4.5 K with contingency factor of 1.5

(attention! Full cryo infrastructure HL not included since no location for cold box defined)



Heat load study



New 4.5 K cold box will allow for using of full capacity of 2 K pumping units (~3.5 g/s @30 mbar) as well as to cover requirements for 80 K screen cooling with helium gas.

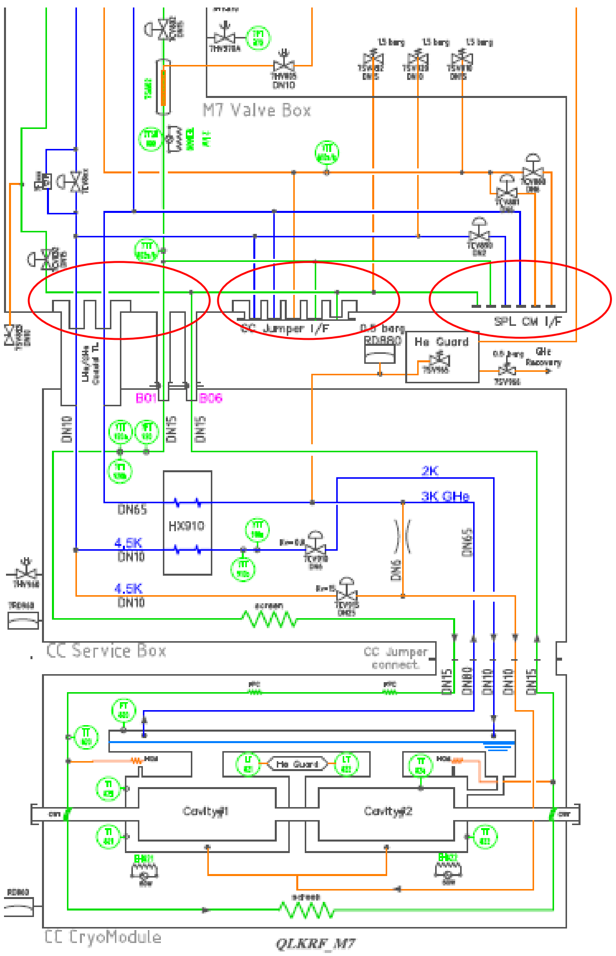
SM18 test preparation

From / to SM18 infrastructure

M7 adaptation valve box

CC service box

CC cryo-module



From / to SM18 infrastructure

M7 adaptation valve box

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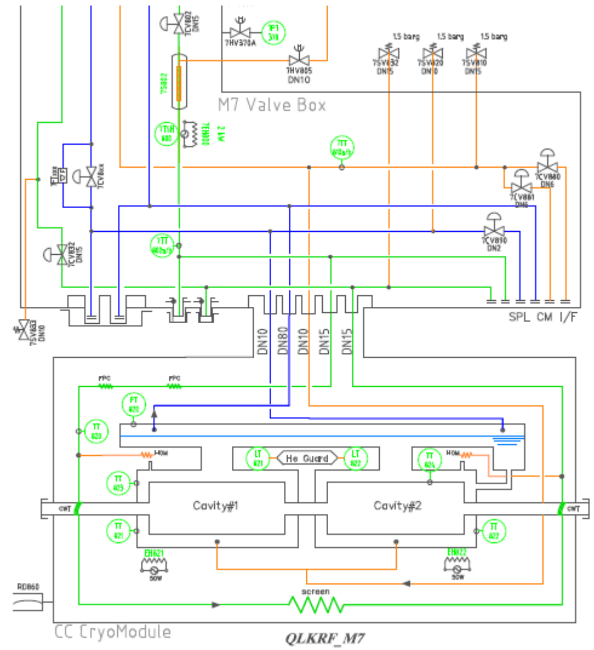


- First CC prototype will be tested at SM18 with its SPS service box (first slot on the adaptation valve box).
- Second CC prototype will be tested with direct connection to the adaptation valve box (second slot).
- Third slot is prepared for SPL

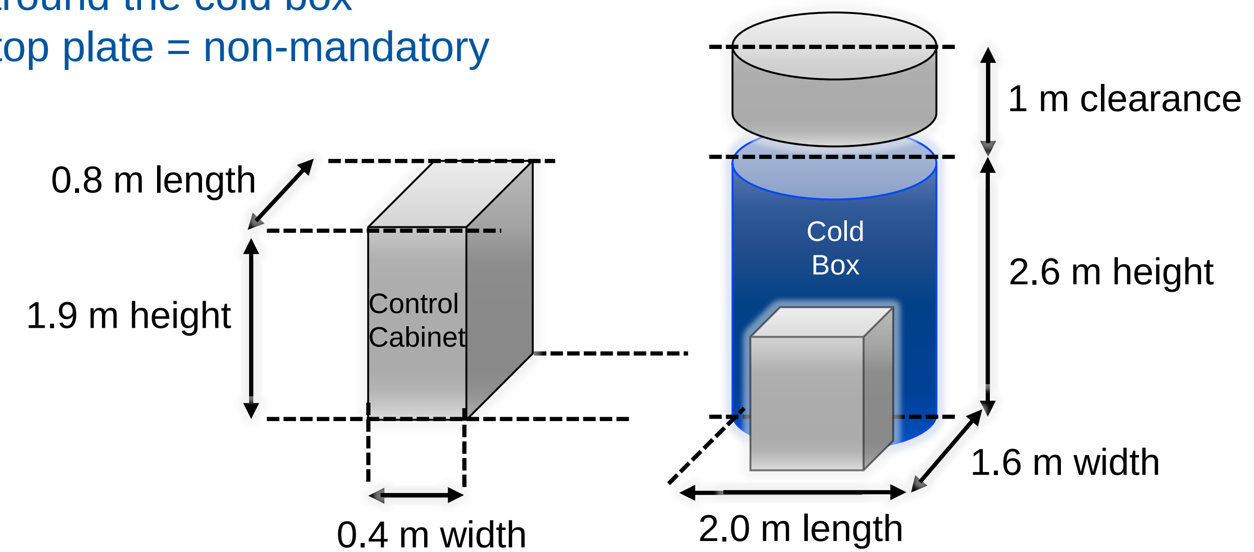
Remark: with direct connection related security devices must be integrated on M7 valve box

Cold box – input for integration 1/3

- **Space occupation**: L(2.0m) × W(1.6m) × H(2.6m) = 8.3 m^3 ; 2.5 tons **(LINDE option)**

- **Mobility aspects**:
  - Vertical / max 45° inclined: standard and preferable
  - Horizontal: could be a boundary condition but will have to be discussed

- **In situ accessibility**:
  - 1m above + 1m all around the cold box
  - Removability of the top plate = non-mandatory



- **Thermal budget**:
  - 100m if possible (cavern configuration) for max length of transfer line
  - 150m if surface configuration, but will impose *compulsory LN_2 consumption*

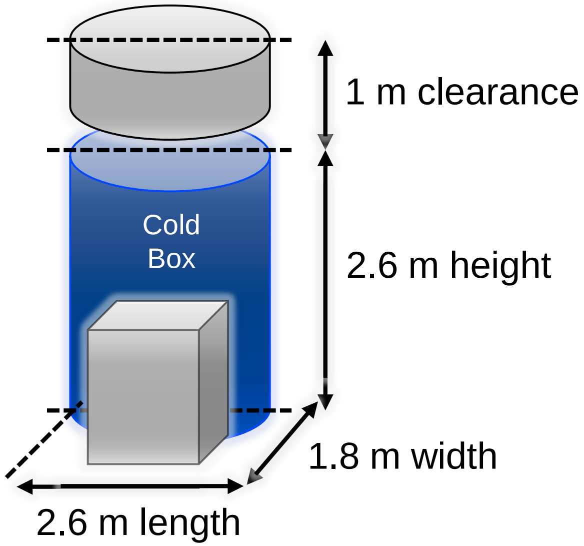
Cold box – input for integration 2/3

- **Space occupation**: L(2.6m) × W(1.8m) × H(2.6m) = 12.2 m^3 ; ≈ 2.5 tons **(AL option)**

- **Mobility aspects**:
  - Vertical / max 45° inclined: standard and preferable
  - Horizontal: could be a boundary condition but will have to be discussed

- **In situ accessibility**:
  - 1m above + 1m all around the cold box
  - Removability of the top plate = non-mandatory

- **Control Cabinet**: already integrated to the cold box here



- **Thermal budget**:
  - 100m if possible (cavern configuration) for max length of transfer line
  - 150m if surface configuration, but will impose *compulsory LN_2 consumption*

Cold box – input for integration 3/3

- **Disassembly**:
  - Transport preparation = 2-3 days
  - Back to surface = 2-3 days

  Wish = 1 week to have the cavern «cleared out» and the CB on a truck

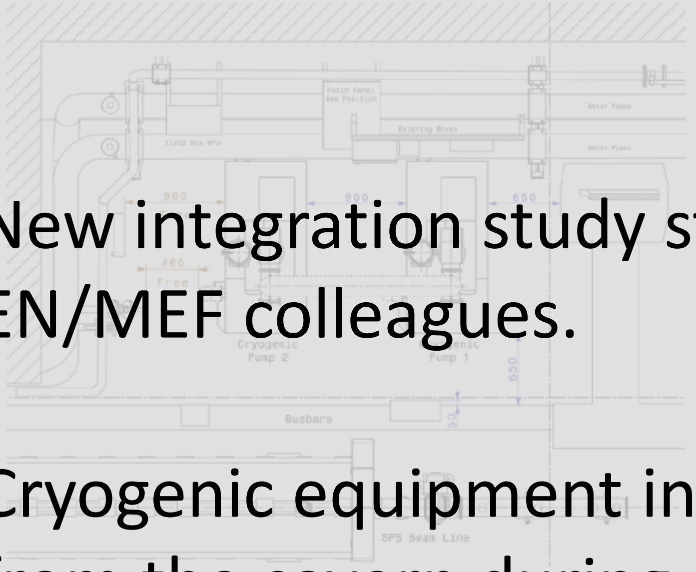
- **External interfaces**:
  - Electricity (400V, and 24V for control-command)
  - Water (raw water only, for cooling of 2K pumping units and turbines circuits)
  - Compressed air (dry air, 8 bar, mainly for regulation valves)
  - Control racks (CRG) and ethernet networks (IT)

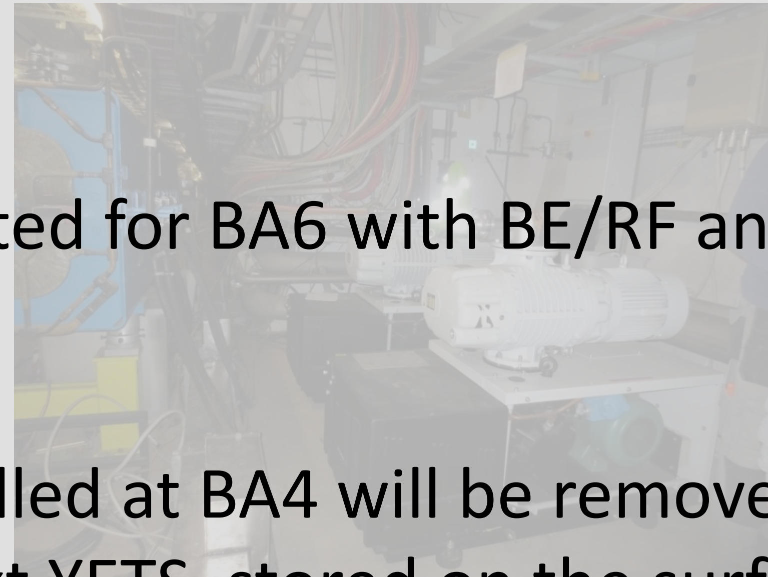
- **Deadline**:
  - Installation of these equipments during EYETS (2016-2017) to be operational in 2017

Relocation from BA4 to BA6

New integration study started for BA6 with BE/RF and EN/MEF colleagues.

Cryogenic equipment installed at BA4 will be removed from the cavern during next YETS, stored on the surface and installed at BA6 when all integration work is completed (most probably during EYETS).





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

Planning projection

- BA4 equipment removal – YETS 2015
- BA6 proximity equipment: technical specification well advanced, equipment to be ordered Q1 of 2016 with delivery beginning of 2017
- SM18 adaptation equipment: technical specification to be done, order to be made in Q1 of 2016 with delivery of equipment end of 2016 (tight planning)
- BA6 integration study started, cold box location to be chosen in Q1 2016
- ECR for BA6 integration to be prepared and approved in Q2/Q3 of 2016
- New 4.5 K cold box to be ordered in Q1 2016 with delivery for installation during EYETS
- Complete cryogenic infrastructure to be installed at BA6 during EYETS

Exact planning is under construction with impact of BA4 to BA6 relocation and open decision for surface or cavern cold box integration.

The priority is put on SM18 test preparation.

Conclusions and perspectives

- Globally, the work on cryogenics is progressing well, however affected with change of SPS location
- Cryomodule cryogenics well advanced, piping sized, instrumentation definition in final stage, thermal screen still under study, jumper design to be completed (mechanical aspects)
- Flow schemes: for SM18 – defined, for SPS – advanced but depends on cold box location
- Cryogenic proximity equipment design: service module top plate definition advanced, technical specification ~80% ready, order during next months
- Definition of requirements for integration at BA6 transmitted to RF and EN – close collaboration required

Thank you for your attention!