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ENGINEERING CHANGE REQUEST

WP11: Point 2 Connection Cryostat Full Assembly

BRIEF DESCRIPTION OF THE PROPOSED CHANGE(S):

The operation with ion beams foreseen in the High Luminosity LHC configuration requires upgrading the Large Hadron Collider (LHC) collimation system by installing additional collimators in the warm insertions and in the dispersion suppression (DS) regions. To this end, in the baseline scope of the HL-LHC, WorkPackage 11, it is foreseen to substitute in the DS region at point 2 two ~12 m long connection cryostats each with a cryo-assembly composed by a pair of 5.3 m-long cryostats with in the middle a 3.3 m long bypass cryostat in which is hosted the TCLD collimator.

DOCUMENT PREPARED BY:	DOCUMENT TO BE CHECKED BY:	DOCUMENT TO BE APPROVED BY:
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DOCUMENT SENT FOR INFORMATION TO:

ATS Group Leaders

SUMMARY OF THE ACTIONS TO BE UNDERTAKEN:

[List the main actions to be undertaken]

Note: When approved, an Engineering Change Request becomes an Engineering Change Order.

1. INTRODUCTION

The High Luminosity LHC baseline foresees to upgrade the LHC collimation system to protecting the dipoles from special losses coming from collision debris of the ions collision at Point 2 [1]. This upgrade must take place in LS2 in order to allow full exploitation of the beam properties already in Run 3 of the LHC.

To make space for the installation of this collimator, it is foreseen to substitute two ~12 m long connection cryostats each with an assembly consisting out of a pair of 5.3 m-long cryostats with in the middle a bypass cryostat (length 2.2 m) and the TCLD collimator (length 1 m). This choice avoids installing 11 T dipoles in Point 2.

The present state of the concerned areas is shown in Figures 1 and 2.

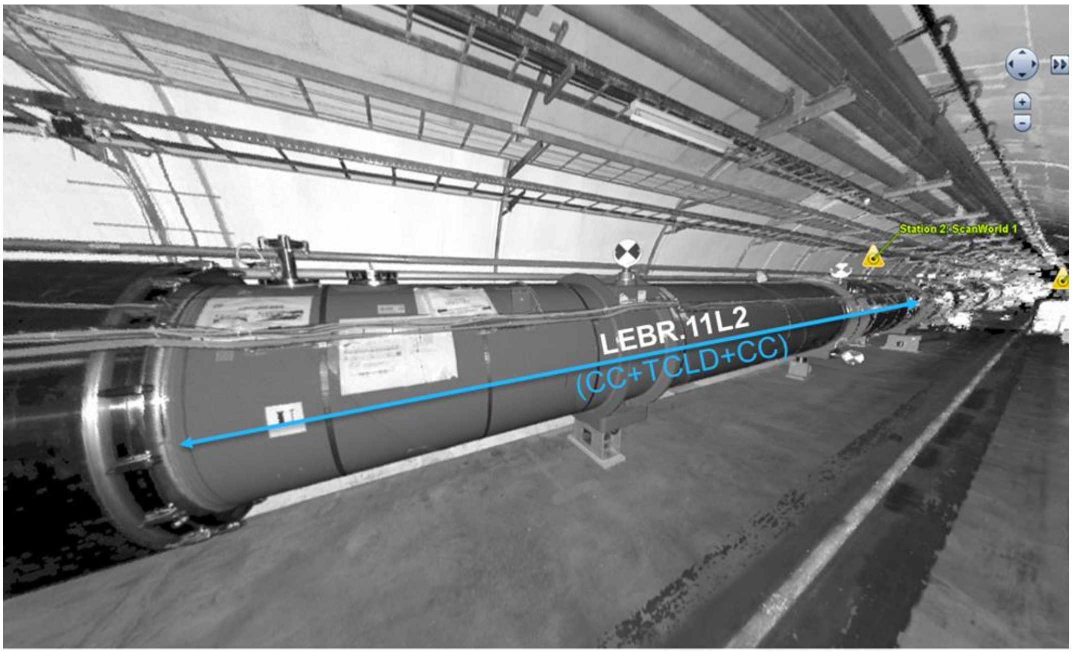

Figure 1 —Laser scan of area under change, R22 – present LEBR.11L2 (July 2017)

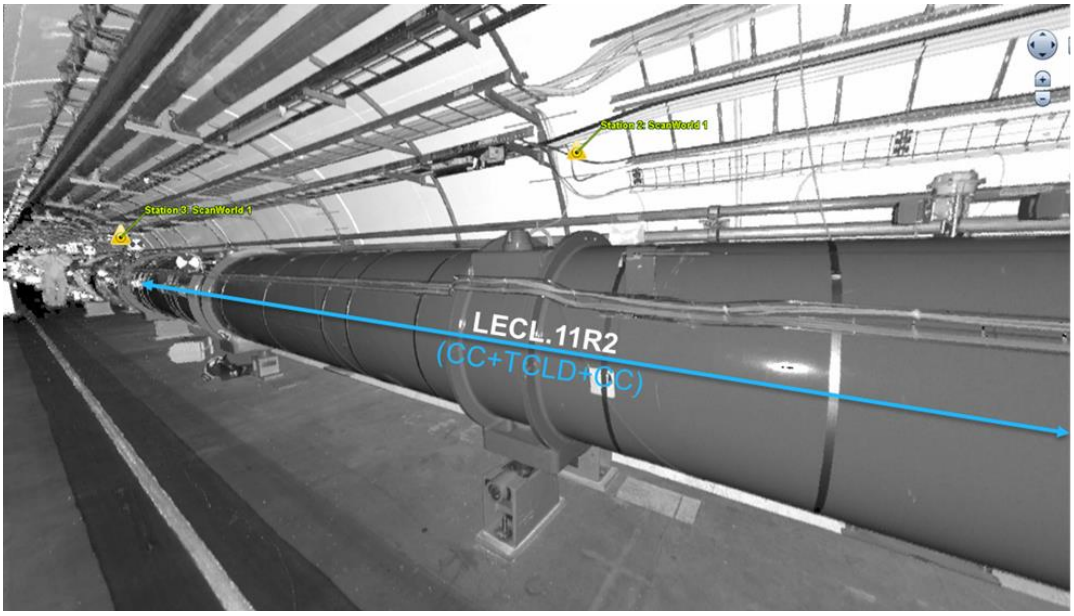

Figure 2 —Laser scan of area under change, R28 – present LECL.11R2 (July 2017)

2. REASON FOR THE CHANGE

As above mentioned, the increased intensity of the ion beams in the High Luminosity LHC configuration necessitates to protecting the dipoles at Point 2 from special losses coming from collision debris of the ions collision. In the present LHC configuration, there is no room left for this installation. An efficient solution, avoiding the installation of 11 T dipoles, is the replacement of two ~12 m long connection cryostats each with a cryo-assembly composed by a pair of 5.3 m-long cryostats with in the middle a 3.3 m long bypass cryostat in which is hosted the TCLD collimator.

3. DESCRIPTION

It is foreseen to exchange the following two cryostats:

- **LEBR.11L2**
- **LECL.11R2**

These cryostats are installed at the following positions:

- **LEBR.11L2:** distance from IP2: -432.1047 m, distance from IP1 (DCUM): 2900.2557 m
- **LECL.11R2:** distance from IP2: 419.33 m, distance from IP1 (DCUM): 3751.6904 m

In detail, the changes comprise the following:

P2 left side

- Removal of the present cryostat **LEBR.11L2.**
- Installation of the connection cryostat full assembly at the LEBR place. The assembly is composed of two new connection cryostats (shorter in length), with a bypass cryostat installed between them.
- After that, installation of a new TCLD collimator between the two connection cryostats, on the beam line 2, **B2I** (internal beam, passage side) will follow.

P2 right side

- Removal of the present cryostat **LECL.11R2.**
- Installation of the Connection Cryostat full assembly at the LECL place.
- After that, installation of a new TCLD collimator between the two connection cryostats, on the beam line 1, **B1I** (internal beam, passage side) will follow.

Layout drawings LHCLSS__0019/LHCLSS__0020 (LHC layout for the DS region at point 2) and LHCLSSH_0003/LHCLSSH_0004 (HL-LHC layout for the same zones) show the changes induced by the implementation of the TCLD collimator and the two connection cryostats where there was one ~12m long connection cryostat. Figures 3 and 4 show as an example the section of the LHC layout for P2 left before and after the change.

The components to be installed (Table 1), to be kept (Table 2), to be displaced (Table 3) or to be removed (Table 4) are listed below.

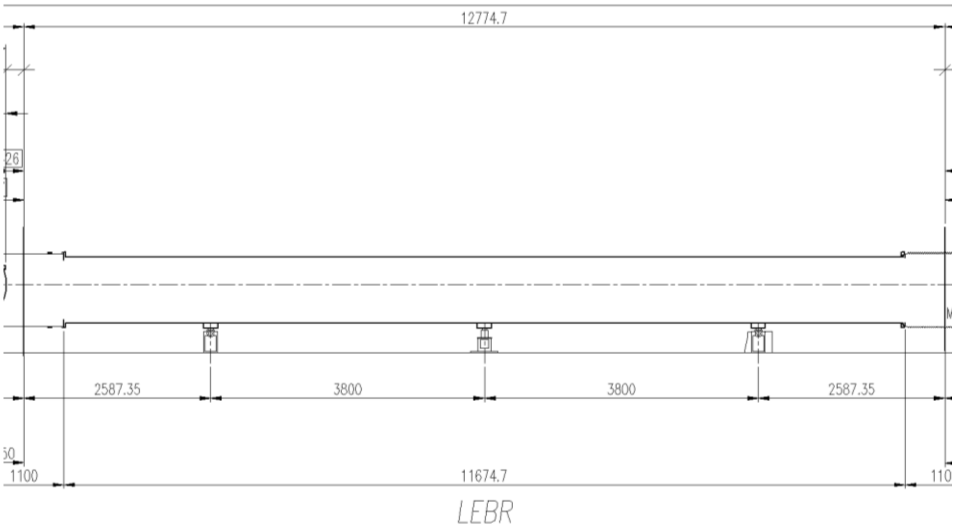

Figure 1: Section of LHC layout for P2 left (from LHCLSS__000019) – Replaced magnet.

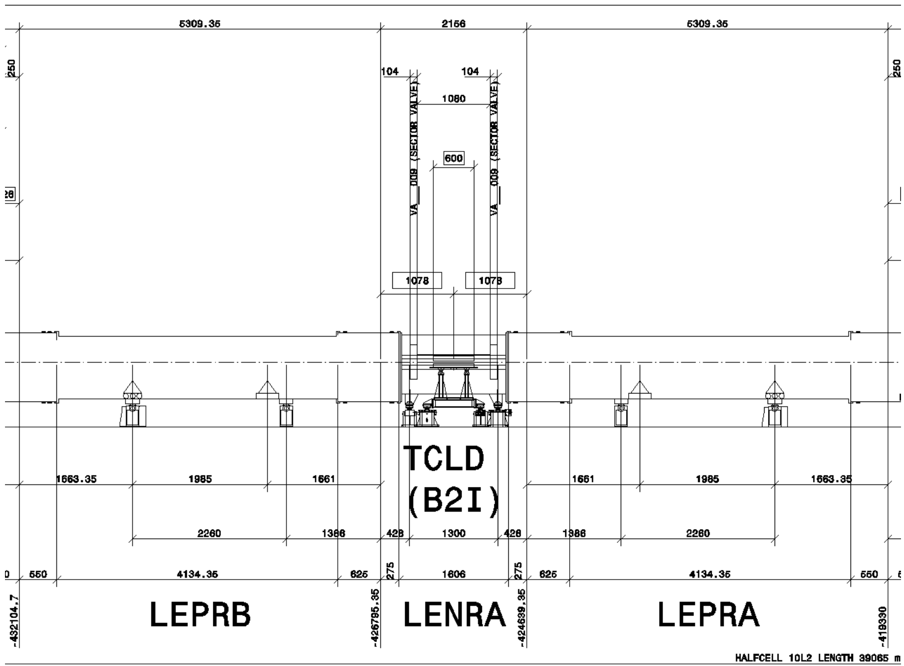

Figure 2: Section of HL-LHC layout for P2 left (from LHCLSSH_0003) – New components

Table 1: Components to be installed

Equipment name	**DCUM** [m]	**IP2** [m]	**Comments**
LEPRB+ **LENRA+** **LEPRA** – CC Full assembly L2	2900.2557 m 2905.56505 m 2907.72105 m	– 432.1047 m – 426.79535 m – 424.63935 m	Composed of 2 cryostats + 1 bypass cryostat.
New 6U crate	-	-	To be installed under MB.10L2. See 2.4.5 [2]
LEPLA+ **LENLA+** **LEPLB** – CC Full assembly R2	3751.6904 m 3756.99975 m 3759.15575 m	419.33 m 424.63935 m 426.79535 m	Composed of 2 cryostats + 1 bypass cryostat.
New 6U crate	-	-	To be installed under MB.10R2. See 2.4.5 [2]

Table 2: Components to be kept

Equipment name	**DCUM** [m]	**IP2** [m]	**Comments**
-	-	-	

Table 3: Components to be displaced

Equipment name	**DCUM** [m]	**IP2** [m]	**Comments**
1 BLM	-	-	See 2.4.8 [2]
Cable trays			Cable trays need to be displaced to tunnel wall at TCLD area
1 BLM	-	-	See 2.4.8 [2]
Cable trays			Cable trays need to be displaced to tunnel wall at TCLD area

Table 4: Components to be removed

Equipment name	**DCUM** [m]	**IP2** [m]	**Comments**
LEBR.11L2	2900.2557 m	– 432.1047 m	
LECL.11R2	3751.6904 m	419.33 m	

3.1 Integration

The integration is described in detail in the document [2].

3.2 Vacuum modifications

In order to provide beam vacuum continuity of the Connection Cryostat Full Assembly, the continuous beam line of the replaced cryostat must be segmented and adapted to accommodate the functioning of the TCLD collimator and the connection cryostats. The installation of the TCLD collimator, operating at room temperature, imposes a new sectorization of the vacuum lines and new transitions between cold and warm vacuum lines. The improved pumping strategy for these new vacuum sectors is proposed in [3].

Inside the 5.3 m long cryostats (LEP type) the standard LHC-type beam screens will be installed for both beam lines (cold bore inner diameter 50mm). Regarding the bypass cryostat (LEN type) there are two different configurations, one for each beam line, depending if it is the collimated or the non-collimated line.

For the collimated line, there will be one bellows to ease its mounting/dismounting and one sector valve installed on each side of the TCLD. The sector valves are then connected to the cold-warm transitions (short and long versions, located upstream and downstream respectively) and followed by the standard Plug-in-Module (PIM). The collimator itself will represent an added vacuum sector, described in detail within the TCLD ECR after ongoing tests. A vacuum port is integrated in the cold/warm transition, between the sector valves and the continuous cryostat, to allow the RF ball tests.

For the non-collimated line, a new concept of conduction cooled copper cold bore has been developed to reduce the equipment needed on this line of the bypass cryostat. It will be thermalized at both of extremities by two hoses routed from the M line, feeding superfluid helium at 1.3 bar to the collars brazed around the line. The copper cold line is linked to the PIMs at the extremities. A standard LHC-type beam screen is inserted in the cold line. To accommodate all the described equipment within the existing space, special short beam screen bellows had to be design and manufactured.

The insulation vacuum continuity is ensured by the LEN cryostat.

3.3 Cryogenics modifications

In between the connection cryostats a bypass cryostat is placed. This bypass cryostat causes a severe increase of the hydraulic impedance in the insulation vacuum-space compared to today's installation. In case of a cold helium leak from the cold mass into the insulation vacuum space, as identified as Maximum Credible Incident (MCI) in [4], sufficient safety valves have to be installed to limit the cryostat pressure to below 1.5 bar.

An investigation whether the MCI-discharge flow occurring on one side of the cryogenic bypass can be at least partly shared with the other side, without introducing an excessive pressure drop, showed that such sharing is insufficient. Therefore, each side of the cryogenic bypass is to be considered as an individual hydraulic sector with respect to MCIs and it must be made possible that the full flow can be taken by valves on either side of the bypass.

The first possibility is to equidistantly distribute along each of the individual hydraulic sectors, a minimum of 8xDN200 (CERN drawing LHCQBA_S0202 for cryodipole plug) insulation vacuum release valves.

The second possibility is to install on the longer hydraulic sector 8xDN200 valves and on the shorter hydraulic sector 5xDN200 valves, under the condition that the 5xDN200 valves are placed not further than 15 m distance from the cryogenic bypass and that the total hydraulic sector length is less than 30 m. In this scenario the cryostat pressure can be as well limited to below 1.5 bar. The calculation follows the MCI outlined in [4].

The dispersion suppressor (DS)-cryostats, installed on one side of the cryogenic bypass, have one non-spring-loaded DN200 release valve in the middle of their hydraulic sector (LBBRP.11L2-DCUM: 2928.6904 and LBALA.11R2-DCUM: 3720.3704, EDMS #1291202). This non-spring loaded DN200 valve is designed such to function first whenever an incident occurs under personal access conditions. It opens at an overpressure of 50 mbar, corresponding to a mass flow of slightly less than 1 kg/s at 90 K. The spring loaded valves open at 80 mbar overpressure thus leaving 30 mbar budget available for the cryogenic bypass, in case a non-spring loaded valve is only installed on one side of the bypass. The pressure drop across the cryogenic bypass alone has been assessed to be ~22 mbar. The remaining ~8 mbar are considered too little a margin for reliable distinction in opening between the spring and non-spring loaded valves, yielding to the hazard that actually the spring loaded valves open before the non-spring loaded valve.

Therefore, the following changes shall be performed:

- Non-spring loaded valves shall be foreseen on both sides of the cryogenic bypass;
- Springs have to be added to the valve in the middle of the hydraulic sector on the DS-cryostat (LBBRP.11L2-DCUM: 2928.6904 and LBALA.11R2-DCUM: 3720.3704, EDMS #1291202).

No specific cryogenic instrumentation is foreseen for the cryogenic bypass itself. However, since there will be now two cryostats they will each have to be equipped with temperature sensors in the pressurized superfluid helium enclosure, so the number of sensors will be doubled compared to today's situation.

3.4 Geometry and alignment modifications

The installation of the connection cryostat full assembly requires the alignment of two cryostats, the bypass cryostat and the TCLD collimator compared to previously only one connection cryostat. In detail, the following operations have to be performed:

First, the marking on the floor of the beam points, jacks heads position of the non-standard connection cryostats but also the beam points and component axis of the bypass cryostat and of the new TCLD collimator is required. A specific care will be brought to the jack configuration of the dipoles, as not standard.

Second, 12 jacks per Connection Cryostat Full Assembly will be installed.

Third, EN-SMM-ASG will align the jacks' heads at their nominal position, prior to the installation of any component.

Fourth, the connection cryostats will be installed and fifth, an initial alignment of the dipoles will be carried out with respect to the adjacent cryo-magnets. Following, as sixth step, the bypass cryostat will be installed and the TCLD collimator will be inserted as last component to be installed.

Seventh, an initial alignment of the dipoles will be carried with respect to the adjacent cryo-magnets and the alignment of the TCLD and cryo-bypass will be carried out from the both connection cryostats.

After this pre-alignment, the connection cryostat full assembly smoothing w.r.t. the adjacent components will be performed once all interconnections are closed, and the sector has been cooled down during the regular arc smoothing activity.

Roll measurements can only be performed by adding an inclinometer on a specific cylinder interface located on the plate that supports the survey socket on the tunnel transport side and on the double jack side.

To do all alignment operations described above, the MAD-X file providing the beam positions of the components must be available at least two months before any survey activity in the LHC tunnel. Drawings giving the positions of the jacks heads with respect to the component beam points must be available at least two weeks before the jack marking in the LHC tunnel.

3.5 Cabling

The nQPS instrumentation and interlock cabling need to be modified. All cables going through the connection cryostat must be re-routed to one of the cables trays on the tunnel ceiling to not interfere with maintenance operations of the collimators.

4. IMPACT

4.1 IMPACT ON ITEMS/SYSTEMS

LHC Layout	LHCLSS__0019 - IR2 LEFT, CELLS C8.L2 TO C11.L2 LHCLSS__0020 - IR2 RIGHT, CELLS C8.R2 TO C11.R2
Updated layout drawings	LHCLSSH__0003 - IR2 LEFT, CELLS C8.L2 TO C11.L2 LHCLSSH__0004 - IR2 RIGHT, CELLS C8.R2 TO C11.R2
Main dipole chain	No impact
MP3	No impact

4.2 IMPACT ON UTILITIES AND SERVICES

Raw water:	No impact
Demineralized water:	No impact
Compressed air:	TE-VSC: New sector valves feeding require compressed air cabling.
Electricity, cable pulling (power, signal, optical fibres…):	No impact
DEC/DIC:	TE-VSC: DICs (reference RQF0912879 already requested and approved)
Racks (name and location):	The racks to be installed, displaced and removed are listed in Table 1-4.
Vacuum (bake outs, sectorisation…):	Three new vacuum sectors can be distinguished on each side of P2 after this modification, obtained by installing two new sector valves. The strategy for the pumping of the sectors aside the collimator is described in EDMS 1966384. Details on the room temperature vacuum sector (TCLD) will be given in TCLD ECR.
Special transport/ handling:	The equipment listed in Tables 1, 2, and 3 needs to be transported and handled in the tunnel and on ground
Temporary storage of conventional/radioactive components:	The deinstalled equipment (Table 4, connection cryostats) may be radioactive and has to be stored.
Alignment and positioning:	Marking of the beam points and new jacks heads projections on the ground floor, aligning the jacks' heads at their nominal position, initial alignment of the components, then plus smoothing (cold temperature) w.r.t. adjacent components. Marking the new slot and alignment after installation.
Scaffolding:	No impact

Controls:	TE-VSC: New gauges and valves to be integrated in SCADA and VAC LDB update.
GSM/WIFI networks:	GSM should be available during the activity as communication means complementary to the red phones in case of emergency.
Cryogenics:	The impact on cryogenics is described in detail in Section 3.4.
Contractor(s):	No
Surface building(s):	No impact
Others:	The n-line may be around 8 cm too short due to the required deviation in the TCLD section. A solution to this issue is currently under study.

5. IMPACT ON COST, SCHEDULE AND PERFORMANCE

5.1 IMPACT ON COST

Detailed breakdown of the change cost:	The total cost of the deliverables of WP11 required for the change described in this ECR is borne by the HL-LHC project.
Budget code:	(see table below)

BC	Unit	Description
92518	TE-MSC-CMI	HL-LHC-WP11 Cryostat (Personnel)
92573	TE-MSC-CMI	HL-LHC-WP11 Cryostat

5.2 IMPACT ON SCHEDULE

Proposed installation schedule:	**P2 right side**: February 2020 (readiness for installation), +3.5 months (installation of the deliverables of WP11), +1 month complete installation with collimator **P2 left side**: February 2020 (readiness for installation) , +3.5 months (installation of the deliverables of WP11), +1 month complete installation with collimator
Proposed test schedule (if applicable):	The full test of the deliverables will be performed on surface before the installation starts. The quality control (QC) in the tunnel is included in the schedule. The ELQA tests are part of the machine commissioning.
Estimated duration:	Not applicable
Urgency:	Not applicable
Flexibility of scheduling:	In case the cryostats are ready for installation before the planned date, the planning may allow installing them earlier. In case the cryostats are ready for installation after the planned date, LS2 has to be extended according to the current baseline planning. A study how to compress the installation time is currently ongoing to gain some contingency in the planning. The installation could also be performed during an extended technical stop.

5.3 IMPACT ON PERFORMANCE

Mechanical aperture:	No impact on beam aperture is expected.

Impedance:	The vacuum installation at point 2 and 7 is equivalent, the impedance impact on point 2 and 7 is the same. Lorenzo Teofili in collaboration with Benoit Salvant will do a study of the impact on the impedance (11 T dipole/empty cryostat and the TCLD collimator/cryostat assembly) and present this study beginning of July in the WP11 interface working group meeting.
Optics/MAD-X	No negative impact on beam dynamics is expected. The LHC reference MAD-X file needs to be updated and the exact positioning of cryostats has to be agreed on.
Electron cloud (NEG coating, solenoid…)	No impact on the e-cloud effect is expected.
Vacuum performance:	No impact on vacuum, cryogenic beam vacuum.
Machine protection	No impact.
Cryogenics	No impact.
Others:	No impact.

6. IMPACT ON OPERATIONAL SAFETY

6.1 ÉLÉMENT(S) IMPORTANT(S) DE SECURITÉ

Requirement	Yes	No	Comments
EIS-Access		X	
EIS-Beam		X	
EIS-Machine		X	

6.2 OTHER OPERATIONAL SAFETY ASPECTS

Have new hazards been created or changed?	TE-VSC: The copper cold line in the bypass cryostat will be added (pressurized equipment).
Could the change affect existing risk control measures?	The hazard is of the same kind and of the same order of magnitude as for the currently installed device.
What risk controls have to be put in place?	To mitigate the risk of overpressure, safety relief devices are installed. For a DS hydraulic section of 214 m length, and according to the risk assessment cited (break of cold-mass helium), 8xDN200 cryostat insulation vacuum release valves per 107 m long half-cell suffice to keep the vacuum enclosure pressure below 1.5 bar, whereas in general an excess of 4 more (12 in total) are installed, providing a margin of 300 mbar. The conformity of the pressurized equipment is being addressed by HSE acting as notified body. HSE will deliver the safety clearance for operation and assess the conformity to the European PED The main dipole circuit are in the interlock for powering phase II, the trims will be also connected to the PIC.

	The cool down permits will be delivered to allow the safe cool-down of the sectors 67 and 78.
Safety documentation to update after the modification	All the safety documentation asked by the notified body will be archived in EDMS: https://edms.cern.ch/project/CERN-0000183369
Define the need for training or information after the change	No change required for the LHC online training course. The teams intervening on the new equipment need to be trained.

7. WORKSITE SAFETY

7.1 ORGANISATION

Requirement	Yes	No	Comments
IMPACT – VIC:	X		TE-MSC (Sandrine Le Naour) needs to trigger the VIC (Visite d'Inspection Commune) and create the IMPACT
Operational radiation protection (surveys, DIMR…):	X		The area will be surveyed by RP and it is expected that the intervention will be performed under ALARA level 1.
Radioactive storage of material:	X		It is expected that the activation level will allow storing the material in a fenced storage area (supervised radiation zone). Therefore, the radioactive material can be stored in building 180.
Radioactive waste:	X		Volume of radioactive waste will be generated by the worksite itself and will be very limited in volume The removed magnets will be kept as spare Vacuum cleaner for radiological area needed
Non-radioactive waste:	X		Very limited
Fire risk/permit (IS41) (welding, grinding…):	X		The fire permits and the fire mitigation procedures will be defined during the VIC
Alarms deactivation/activation (IS37):	X		The alarms deactivation or activation will be defined during the VIC
Others:	X		This task will be subjected to the WPA coordinated by the LHC coordination team in the framework of the LS2 activities

7.2 REGULATORY TESTS

Requirement	Yes	No	Responsible Group	Comments
Pressure/leak tests:	X		HSE TE-VSC	Work is organized by PSO and was delegated to Arnaud Foussat; PED to be followed Complete leak test will be performed on the entire arc during installation phase.
Electrical tests:	X		TE-MPE	Standard procedures will be applied as part of the main dipole circuit tests of LHC
Others:	X		BE-DSO	PIC will be validated during the DSO tests

7.3 PARTICULAR RISKS

Requirement	Yes	No	Comments
Hazardous substances (chemicals, gas, asbestos…):		X	
Work at height:	X		To be determined during the VIC
Confined space working:		X	
Noise:		X	
Cryogenic risks:		X	The sector will be warmed up and emptied before installation
Industrial X-ray (*tirs radio*):		X	No X-ray testing will be performed in the tunnel. Welds will be inspected only optical with a camera
Ionizing radiation risks (radioactive components):	X		All removed equipment and waste will be tracked by TREC
Electrical risks:		X	
Others:			

8. FOLLOW-UP OF ACTIONS BY THE TECHNICAL COORDINATION

Action	Done	Date	Comments
Carry out site activities:			
Carry out tests:			
Update layout drawings:			
Update equipment drawings:			
Update layout database:			
Update naming database:			
Update optics (MADX)			
Update procedures for maintenance and operations			
Update Safety File according to EDMS document 1177755:			
Others:			

9. REFERENCES

[1] G. Apollinari et al., High-Luminosity Large Hadron Collider (HL-LHC), Technical Design Report V. 0.1, CERN-2017-007-M.

[2] M. Gonzalez de la Aleja (WP15), WP11: 11 T Dipole full assembly integration study, EDMS 1904620.

[3] G. Bregliozzi and E. Page, "New Vacuum Pumping Ports in the ARCs linked to the 11T and TCLDs Installation", EDMS 1966384.

[4] M. Chorowski et al., "Upgrade on risk analysis following the 080919 incident in the LHC sector 3-4", CERN/ATS/Note/2010/033.