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LHC

REFERENCE
LHC-BGV-EC-0003

Date: 2015-01-09

ENGINEERING CHANGE REQUEST

Detector Cooling for the BGV Demonstrator in the LHC

BRIEF DESCRIPTION OF THE PROPOSED CHANGE(S):

The Beam Gas Vertex (BGV) detector is foreseen as a possible non-invasive beam profile measurement instrument [1]. The installation of the BGV demonstrator is ongoing and the commissioning is planned for 2015. With the current ECR the BE-BI group requests an approval for the installation of a cooling system for the detector of the BGV demonstrator.

The proposed validity of this ECR is until LS2.

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SUMMARY OF ACTIONS TO BE UNDERTAKEN:

List the main actions to be undertaken.

1. EXISTING SITUATION AND INTRODUCTION

A detailed description of the Beam-Gas Vertex (BGV) demonstrator can be found in the BGV Demonstrator ECR [1]. The vacuum system was installed in 2014, while the detector installation is planned for 2014 and 2015.

The BGV detector is composed of eight scintillating fiber modules read out by silicon photomultipliers (SiPMs). The SiPMs need to be operated at a temperature in the range between 20 and -40 °C, depending on the received radiation dose.

With this ECR the BI group requests an approval for the installation a cooling system for the BGV detector:

- A liquid cooling chiller located in the service tunnel UA43
- Cooling transfer lines to the BGV setup in RA43

2. REASON FOR THE CHANGE

The detector SiPMs exhibit a dark current (noise) which strongly depends on the radiation damage. In order to keep the noise at an acceptable level, the SiPMs must be cooled.

3. DETAILED DESCRIPTION

3.1 INTRODUCTION AND MOTIVATION

The BGV demonstrator detector is composed of eight scintillating fibre modules, arranged around a thin-walled vacuum chamber [1]. These detector modules are developed by EPFL (Lausanne) and RWTH (Aachen) and are based on the same technology that will be used in the LHCb upgrade [2]. The layout of one BGV detector module is shown in Figure 1.

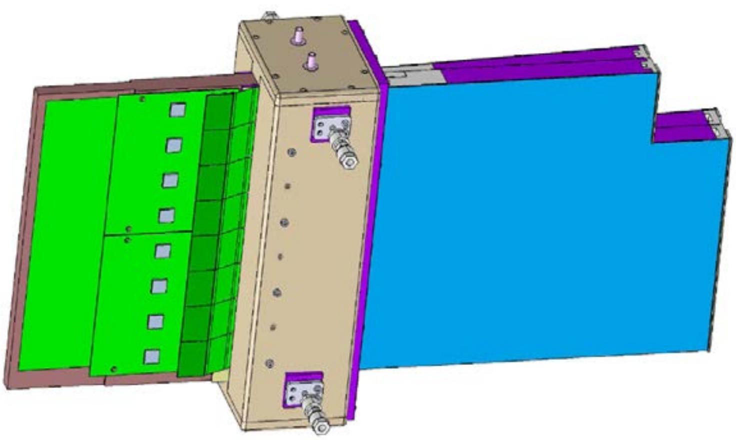


Figure 1: View of a single BGV detector module. The SiPMs sit in an enclosure box providing thermal insulation (brown). The two connections for the cooling pipe are visible. The connections visible on the top are for circulation of dry air to avoid frost/condensation inside the box on the cold elements.

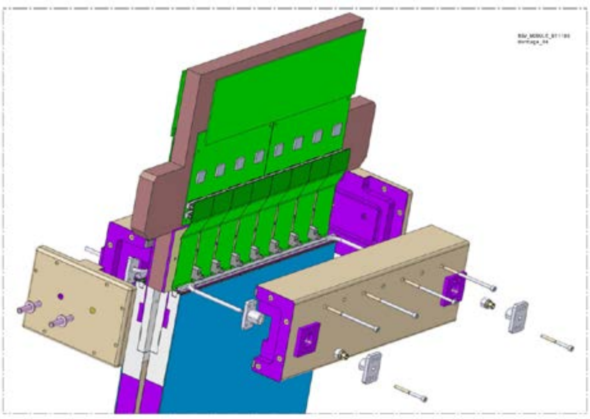
The scintillation light generated by the charged particles inside the fibres is collected at the end of the fibres by SiPMs. The SiPMs exhibit a dark current which strongly depends on the radiation damage. Therefore, in order to keep the noise at an acceptable level, the SiPMs must be cooled. The larger the exposure, the colder they must be operated.

The radiation dose received by the SiPMs is estimated from the charged particle flux which, at these distances, is expected to dominate over the neutron flux. Assuming 2600 bunches circulating in the LHC for most of the year (10^7 s), each with a beam-gas interaction rate of about 250 Hz over a 5 m length upstream of the detector, one arrives at a yearly charged-particle fluence of approximately 4 x 10^{10} cm^{-2} at the relevant radial distance to the beam (between 22 and 26 cm). Since most charged particles are high energy, this can be translated to about 2 x 10^{10} n_{eq} cm^{-2} (where n_{eq} stands for *1 MeV neutron equivalent*) and to a dose of about 20 Gy.

One of the principal aims of the BGV project is to acquire experience with the fabrication and operation of such fibre modules at the LHC in an environment that will be similar to the one in LHCb. Among the most difficult challenges is the cooling of the SiPMs. Although for the BGV the temperature requirement may not be as stringent as for the LHCb Upgrade SiPM, a similar requirement is imposed in order to test the design against the more challenging LHCb requirements. Therefore, the SiPM must be operated at a temperature in the range of 20 to -40 °C.

3.2 REQUIREMENTS FOR THE COOLING SYSTEM

Cooling of the SiPMs inside each detector module is achieved by pressing a cooling pipe onto a row of eight SiPMs (see Figure 2). There are two such SiPM rows, and therefore two such pipes, per module.



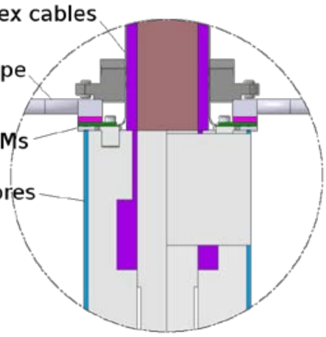


Figure 2: Exploded (left) and transverse (right) views of the BGV detector module. The cooling pipe is glued to an aluminium plate and pressed against a row of 8 SiPM by a system of springs.

Cooling capacity: one module is expected to dissipate at most 20 W, meaning that the whole detector would dissipate less than 160 W at -40 °C. The dominant effect comes from the heat leaks / insulation, while the SiPM power dissipation is almost negligible. The expected power dissipation in a transfer line is about 10 W/m: estimated for a silicone tube (16 mm ID and 22 mm OD) and Armaflex insulation with thickness 50 mm (two layers of 25 mm each). Overall, assuming a transfer line of 20 m (one way), the total needed cooling power is about 600 W at -60 °C. It is expected that the latter chiller set temperature will be sufficiently low to reach -40 °C for the SiPMs (expect 10 °C temperature increase until the liquid reaches the modules, and 10 °C difference between the temperatures of the cooling liquid and the SiPMs).

Type of cooling: single phase liquid cooling.

Type of coolant: NOVEC 649 by 3M [3] – not creepy or oily in order to preserve the cleanliness and the integrity of the SiPM and electronics in case of a leak. This coolant is being tested as an alternative to C6F14 with the aim of reducing GWP (Global-Warming Potential). Although NOVEC 649 is expected to have very similar cooling properties to C6F14, it is a new product at CERN, still under investigation. Yet unknown factors may force us to fall back to C6F14.

Operating temperature (at detector): settable between 20 and -40 °C. The cooling temperature of -40°C is certainly not required to be reached.

Dry air: the SiPM enclosure box and the cooling manifold must be flushed with dry air in order to avoid condensation.

Temperature stability: within ±1 °C.

Temperature gradient: less than 1 °C over one SiPM (33 mm length).

Temperature difference between the coldest and warmest SiPM: less than 10 °C.

Vibration: the detector spatial resolution is about 60 µm. Therefore, vibration amplitudes should be kept below 30 µm.

3.3 PROPOSED IMPLEMENTATION

The chosen chiller model is Julabo Presto A80 [4]. This model was preferred before another suitable model, Huber Unistat 705, because of the more powerful fluid pump. None of the considered chiller units were qualified for operation in ionizing radiation environment. This leads to the requirement to install the chiller in a radiation shielded area and use a transfer line to the BGV detector.

Chiller integration: given the significant power dissipation in the transfer line, it is essential to locate the chiller as close as possible to the detector. An integration study was performed by EN-MEF-INT to identify a possible location for the chiller unit and routing of the transfer line. Figures Figure 3, Figure 4, Figure 5 and Figure 6 show preliminary integration views of the proposed installation. The length of the cooling transfer line is about 20 m. This line will not constrain the space reserved for transport more than the currently existing systems in this region (cables, general and safety services). Concerning the patch panel, there is no interference nor trouble to access the adjacent VPIC pumping device

The dimensions of the Julabo chiller unit are: width = 430 mm, depth = 650 mm, height = 1260 mm. It is an air cooled device with maximal power dissipation of 3 kW.

Transfer lines: Silicone tubes with ID/OD 16/22 mm.
Insulation - double layer Armaflex:

- Inside: LTD (cryo) type, 25 mm thickness
- Outside: NH (halogen free) type, 25 mm thickness.

This insulation is sufficient to avoid condensation. Further increase of the insulation thickness has little effect on the power dissipation. The expected power dissipation, based on a simulation performed by EN-CV-DC, is 10 W/m for cooling liquid temperature of -60 °C.

A temperature sensor provided by Julabo will be used to monitor the temperature of the cooling liquid at the end of the transfer line.

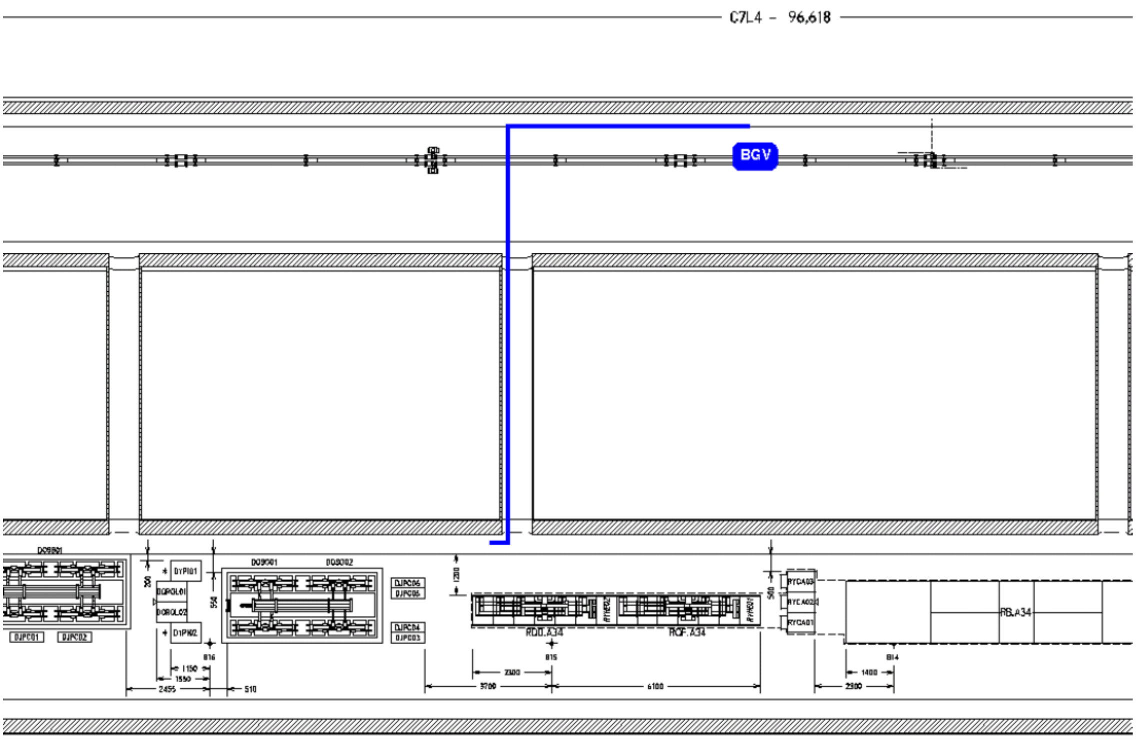


Figure 3: Proposed location of the chiller unit and path of the transfer line between UA43 and RA43.

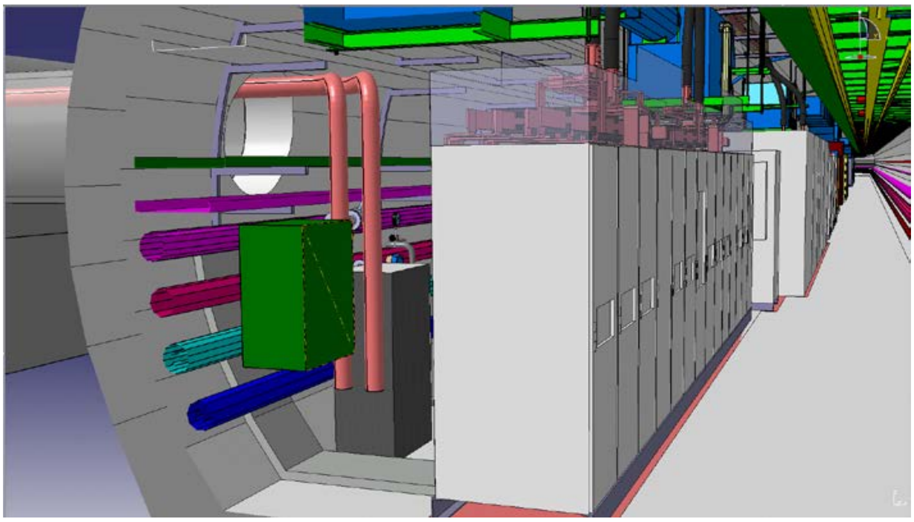


Figure 4: Proposed location of the cooling unit in UA43. The cooling unit is shown in grey and the transfer line in pink.

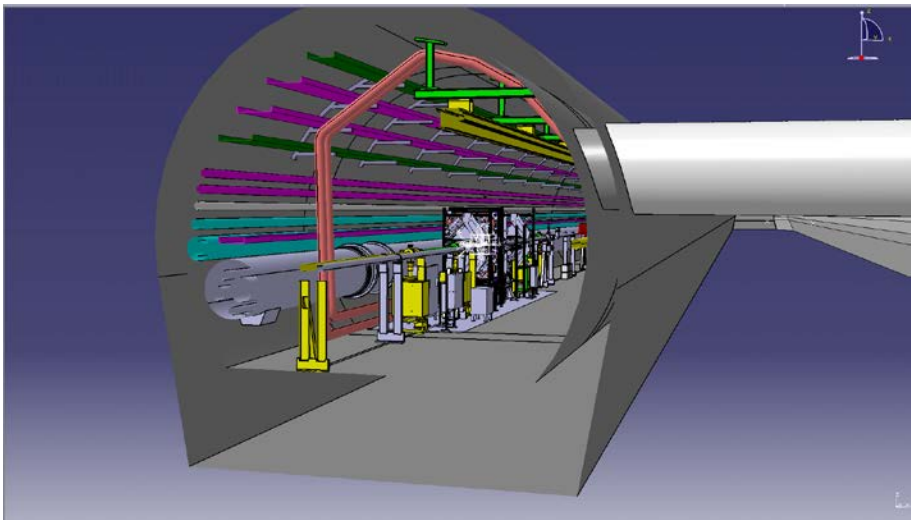


Figure 5: Routing of the cooling transfer line (Preliminary).

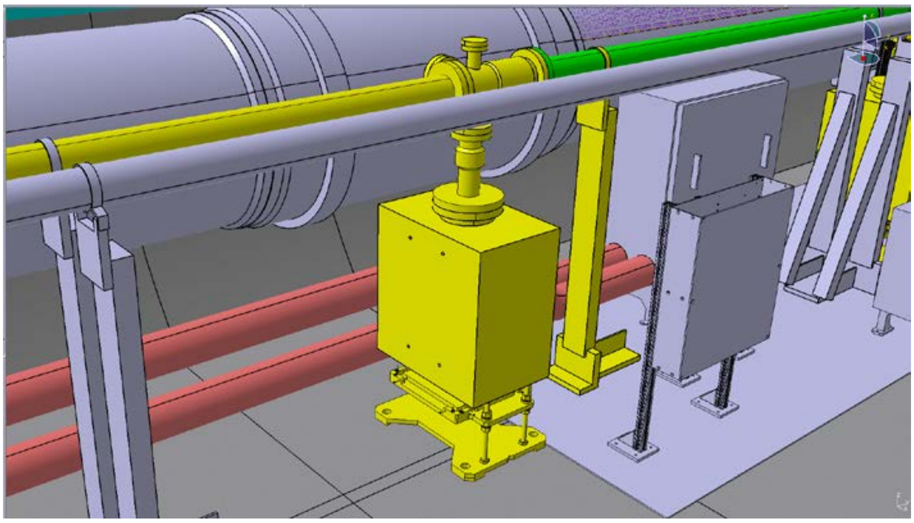


Figure 6: Connection of the cooling transfer line to the cooling distribution manifold near the BGV setup in RA43 (Preliminary).

Distribution to the detector modules: a manifold will be used to distribute the cooling liquid to the individual detector modules (see Figure 7). The intention is to use 4 parallel distribution lines, each supplying 4 module halves connected in series. The distribution lines will use the same material as the transfer lines. A development version of the connection tubes routing is shown in Figure 7.

Compressed/dry air: the compressed air distributed in the LHC tunnel is suitable for the application in the BGV detector. The content of dust and oil is low and the dew point is – 40 °C [5]. The total flux needed is about 0.1 l/s. A connection to the compressed air distribution line will be performed by EN-CV.

A feedback-control system will be used to ensure that the chiller operates only when there is a flow of dry air. The currently developed solution is based on a humidity sensor located inside the cooling manifold.

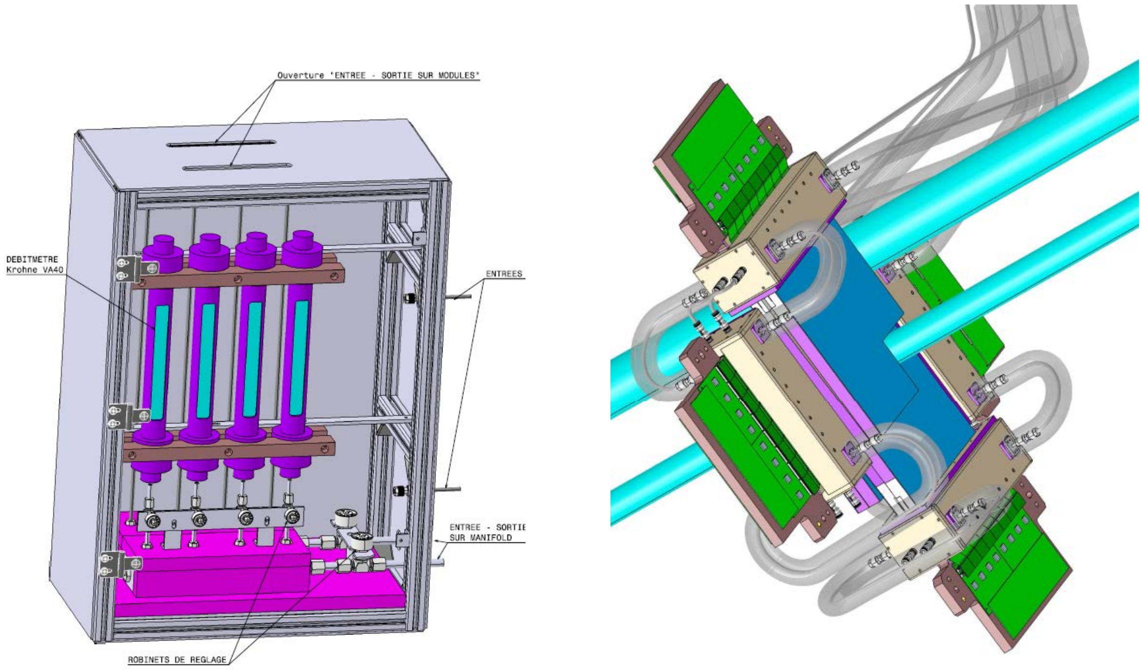


Figure 7: Left: manifold for the distribution of the cooling liquid to the BGV modules. Right: view of detector modules around the beam pipe (in cyan) with the cooling tube connections (in grey).

4. IMPACT ON OTHER ITEMS

4.1 IMPACT ON ITEMS/SYSTEMS

	Use this table to detail the impact on any equipment, items or systems that will be affected by the change.
Item/System	

4.2 IMPACT ON UTILITIES AND SERVICES

Raw water:	No
Demineralized water:	No
Compressed air:	Yes, about 0.1 l/s.
Electricity, cable pulling:	One 220 V / 16 A power plug is needed for the chiller. Will be requested to EN/EL.
Vacuum (bake outs, sectorisation…):	No
Special transport/ handling:	No
Temporary storage of conventional/radioactive components:	No
Survey:	No

Scaffolding:	Nacelle or scaffolding will be used for the installation of the cooling transfer line.
Controls:	No
Cryogenics:	No
Contractor(s):	EN/CV reserves the right to use the services of Contractors for the installation of the cooling transfer line.
Others:	Holes will be drilled in the tunnel wall for the fixation of the cooling transfer line. The installation of the cooling transfer line and connection to the compressed air distribution will be performed by EN/CV.

5. IMPACT ON COST, SCHEDULE AND PERFORMANCE

5.1 IMPACT ON COST

Detailed breakdown of the change cost:	Cooling chiller	21 000 CHF
	Transfer line	4 000 CHF
	Manifold	5 000 CHF
	Installation of transfer line	5 000 CHF (estimate)
Budget code:	64067	

5.2 IMPACT ON SCHEDULE

Proposed installation schedule:	Week 3, 2015
Proposed test schedule (if applicable):	
Estimated duration:	1 week
Urgency:	
Flexibility of scheduling:	

5.3 IMPACT ON PERFORMANCE

No impact on the LHC performance.

6. IMPACT ON OPERATIONAL SAFETY

This chapter aims at assessing the impact of the modification on people safety, on the environment, and on the safety of operations, including maintenance, access, egress, circulation and evacuation.

6.1 ELEMENT IMPORTANT DE SECURITE

Indicate if the change will have an impact on an Elément Important de Sécurité (EIS). The list of EIS components is available in EDMS document: 1182293 – 'Définition et Inventaire des EIS-Faisceau et EIS-Machine en Opération'

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?	Reduce the Global Warming Potential by using the coolant NOVEC 649 (see Section 3.2)
Could the change affect existing risk control measures?	No
What risk controls have to be put in place?	The protection index of the chiller power supply connection is IP2 (closed box)
Safety documentation to update after the modification	
Define the need for training or information after the change	A document will be prepared as a guide for manipulation of the chiller

7. WORKSITE SAFETY

Refer to EDMS document: 1155899 – “Contractors working on the CERN site”.

Following the implementation of the change, the Safety File of the facility shall be updated. In the temporary absence of the Safety File, the hazards inventory and risk analysis of the concerned installation shall be established.

7.1 ORGANISATION

Requirement	Yes	No	Comments
IMPACT – VIC:	X		A VIC will be carried out before the start of the works.
Operational radiation protection (surveys, DIMR…):		X	
Radioactive storage of material:		X	
Radioactive waste:		X	
Fire risk/permit (IS41) (welding, grinding…):		X	
Alarms deactivation/activation (IS37):		X	
Others:		X	

7.2 REGULATORY TESTS

Requirement	Yes	No	Responsible Group	Comments
Pressure/leak tests:		X		
Electrical tests:		X		
Others:		X		

7.3 PARTICULAR RISKS

Requirement	Yes	No	Comments
Hazardous substances (chemicals, gas, asbestos...):		X	
Work at height:	X		During the installation of the cooling transfer line.
Confined space working:		X	
Noise:		X	
Cryogenic risks:		X	
Industrial X-ray (*tirs radio*):		X	
Ionizing radiation risks (radioactive components):		X	Traceability by TREC.
Others:		X	

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] "Beam Gas Vertex (BGV) Demonstrator of a Beam Profile Monitor in LHC", LHC-BGV-EC-0002, EDMS 1324635

[2] "LHCb Tracker Upgrade Technical Design Report", CERN-LHCC-2014-001

[3] Novec 649 Engineered Fluid Technical Data Sheet: http://www.mgchemicals.com/downloads/3m/649-specs.pdf

[4] http://www.julabo.com/us/products/highly-dynamic-temperature-control-systems/temperature-control-presto/presto-a80

[5] "LHC Compressed Air Circuit", LHC-FA-ES-0001, EDMS 335007