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LHC

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ENGINEERING CHANGE REQUEST

Installation of Cryogenic Beam Loss Monitors on MBs in IR5 and IR7

BRIEF DESCRIPTION OF THE PROPOSED CHANGE(S):

The current Beam Loss Monitor (BLM) detectors are installed on the outside of the vacuum vessels of the superconducting magnets. In order to improve their sensitivity to beam losses and capability to detect quench-provoking loss levels it is proposed to install new BLMs inside magnets during LS2 and LS3. The installation proposed here for LS1 is a part of a study to select and test the optimal cryogenic detectors. The ECR describes the proposed location of the new detectors on the cold mass of dipole magnets in dispersion suppressors of IR5 and IR7

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SUMMARY OF ACTIONS TO BE UNDERTAKEN:

Approved at LMC 175 on 2014-03-05

Create an independent Engineering Specification for the DN200 safety relief valves

1. EXISTING SITUATION AND INTRODUCTION

The current Beam Loss Monitor detectors are installed on the outside of the vacuum vessels of the superconducting magnets. They are shielded from the beam losses occurring inside the magnet by about 50 cm of dense material (mainly stainless steel). For the particle shower, which develops in forward direction, it is a large distance. As a consequence the ratio of the BLM signal (S_{BLM}) and energy deposition in the coil (E_{dep}) depends relatively strongly on the loss scenario or in general on the source of the particles measured in BLM. Installation of the detectors inside the magnet, close to the coils, will decrease the spread of the S_{BLM}/E_{dep} ratio leading to more precise determination of quench-provoking beam loss. This will allow the BLM system to keep preventing from the quenches without provoking a significant number of false dumps. Another case, which actually triggered the Cryogenic BLMs project, is the triplet magnet case described in [1,2].

Various types of detectors have been already tested on the test beams [3]. The next stage of the detector R&D is a long-term observation of the behaviour of the detectors in conditions similar to the ones expected during the normal operation. Therefore we propose to install prototype detectors on the outside of helium vessels, close to the beam lines, in the MB interconnect zone, where the cold mass is easiest to access during LS1. After analysing the BLM data and operational experience of Run 1 two such locations have been chosen: one to observe luminosity losses and one for betatron cleaning losses. A constraint to mount the detectors on the left end cap of the magnet where the DN200 flange will not interfere with interconnection bellows was respected when choosing the locations.

1.1 LOCATION FOR LUMINOSITY LOSS OBSERVATION

The first location is chosen based on the integrated dose measured by the BLMs in November 2012 when LHC produced luminosity in stable conditions. The BLM mounted on MQM magnet in cell 9L5 received one of the highest dose (see Table 1, BLMQI.09L5.B2E10_MQM with 5.5 Gy). This magnet, together with the neighbouring dipole is shown in Figure 1. It is proposed to install detectors on the MB end cap marked with "X".

The luminosity losses are coming from the right side so this location is partially shielded by the magnet cold-mass, nevertheless it is found to be the most promising location among the ones which are accessible.

In the proposed location already two DN200 are installed. The standard DN200 has a collar shape which is not compatible with CryoBLM flange. Therefore it is proposed to fabricate an adaptor (see Figure 2) in order to fit CryoBLM flange on the existing DN200 and install another DN200 on the neighbouring magnet LBBLF.9L5. **This will require a revision of the Appendix files of the LHC-QJ-EC-0002 ver 1.0, presently describing the safety relief system of the LHC insulation vacuum system**. This will be done by writing an Engineering Specification independent from the different ECRs and keeping up-to-date the layout of the safety relief valves.

Backup solutions are installation of the detectors in the interconnections nearby the locations marked in green in Table 1. They are all significantly lower than the preferred location in cell 9L5. Other doses are given for reference.

BLM name	Dcum [m]	Integrated dose [mGy]
BLMQI.09L5.B2E10_MQM	12988.943	5545
BLMQI.09R1.B1E10_MQM	341.169	4196
(…)	(…)	(…)
BLMEI.11R1.B1E30_MBB	420.073	2549
BLMEI.11L5.B2E30_MBA	12909	2021
BLMEI.11R5.B1E23_MBB	13745.2	1759
BLMEI.11R5.B1E22_MBB	13743.1	1692
BLMEI.11R5.B1E24_MBB	13747.2	1449
BLMEI.11L5.B2E22_MBA	12915.3	1442
BLMEI.11R1.B1E24_MBB	417.7	1283
(…)	(…)	(…)
BLMEI.08L5.B2E30_MBB	13043.63	410
(…)	(…)	(…)
BLMEI.08R1.B1E30_MBA	285.819	309

Table 1: The maximum integrated BLM doses in chosen BLM detectors in dispersion suppressor cells of IR1(R) and IR5(L), ordered according to the dose. The dose was integrated during month of November 2012, when machine was focused on luminosity production from proton-proton collisions.

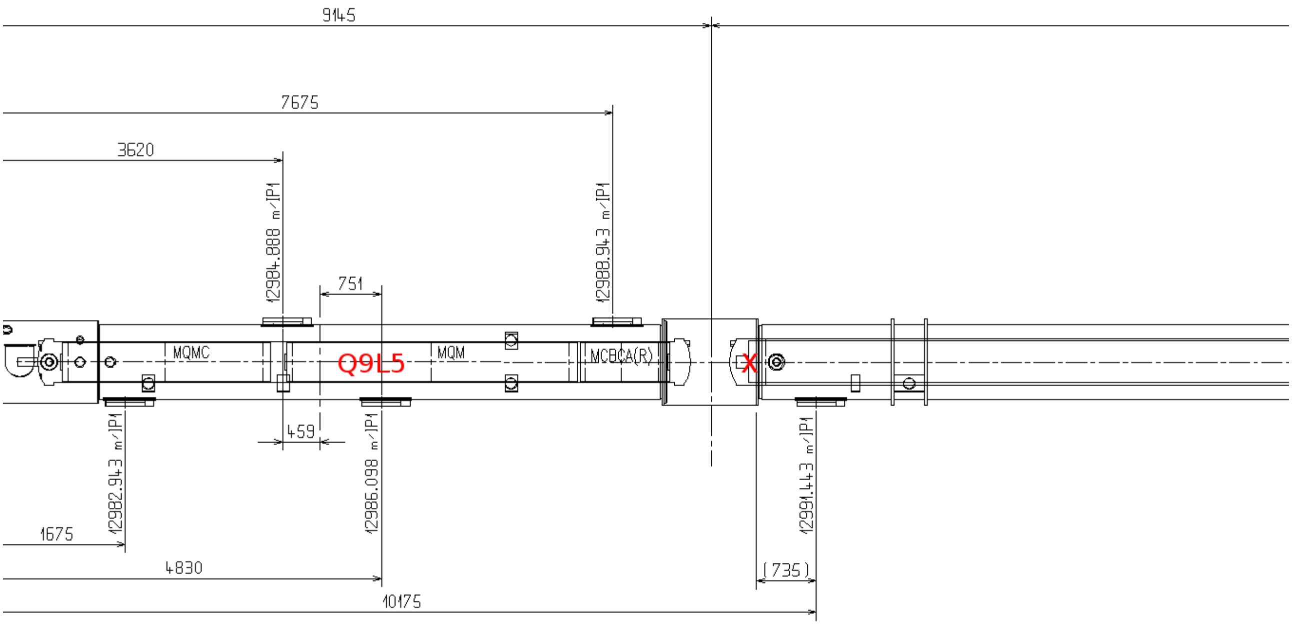


Figure 1: Top view of the BLM layout in cell 9L5. On the left there is Q9L5 magnet. Proposed location, optimized for measurement of luminosity losses, is marked with “X”. The interaction debris arrive from the right side.

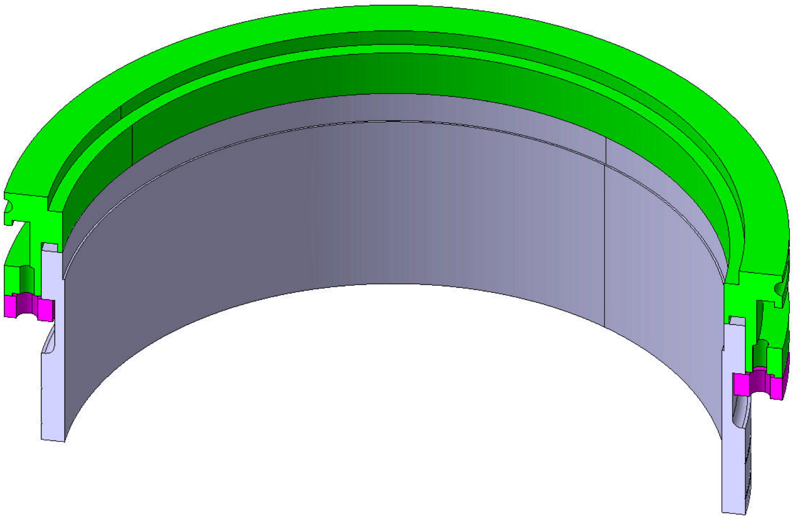


Figure 2: An adaptor which allows to install CryoBLM flange on DN200. Courtesy of Thierry Renaglia.

1.2 LOCATION FOR BETATRON CLEANING LOSS OBSERVATION

The second proposed location is on one of the MB magnets between Q8R7 and Q9R7. In this location high losses from betatron cleaning are observed as seen in Figure 3, which was registered during a collimation loss map exercise on September 25th, 2012. The values of the signals registered in dispersion suppressor during this particular loss map are shown in Table 2: BLM signals measured during collimation loss map.. Locations on end cap facing IR on MBB and MBA magnets do not differ significantly in terms of BLM signal, but because of existing two DN200 on MBA magnet it is proposed to install detectors on MBB as shown in Figure 4: The top view of the first proposed location in IR7 (cell 9) is the left end cap of the MBB magnet (left interconnect on the plot, marked with "X"). The losses from the collimation section arrive from the left side..

BLM name	Dcum [m]	Signal RS09 [μGy/s]
BLMQI.09R7.B1E10_MQ	20335.33	55.43
BLMQI.11R7.B1E10_MQ	20428.58	46.76
BLMQI.08R7.B1E30_MQ	20303.42	45.81
BLMEI.09R7.B1E30_MBA	20319.16	43.26
BLMEI.09R7.B1E21_MBA	20311.16	30.07
BLMEI.09R7.B1E22_MBA	20314.16	27.38

Table 2: BLM signals measured during collimation loss map.

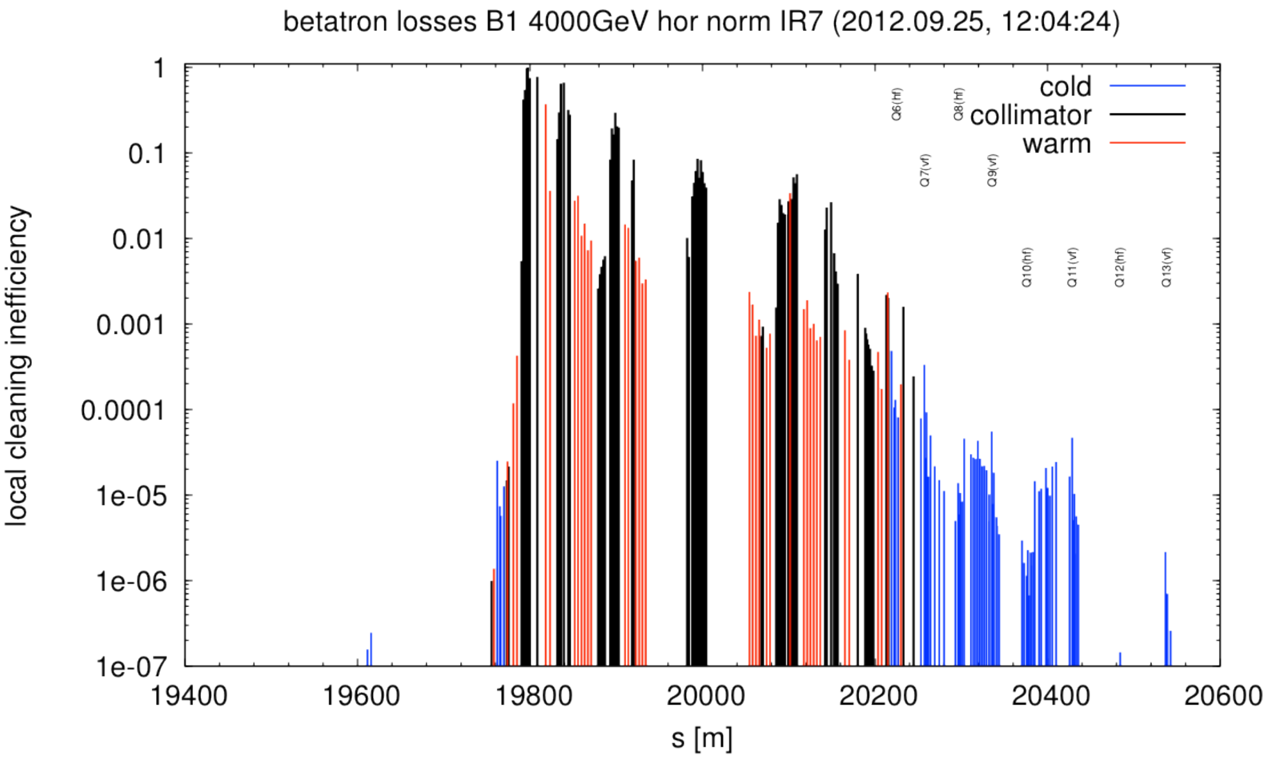


Figure 3: BLM signals during a horizontal loss map at 4 TeV. Courtesy of Belen Salvachua.

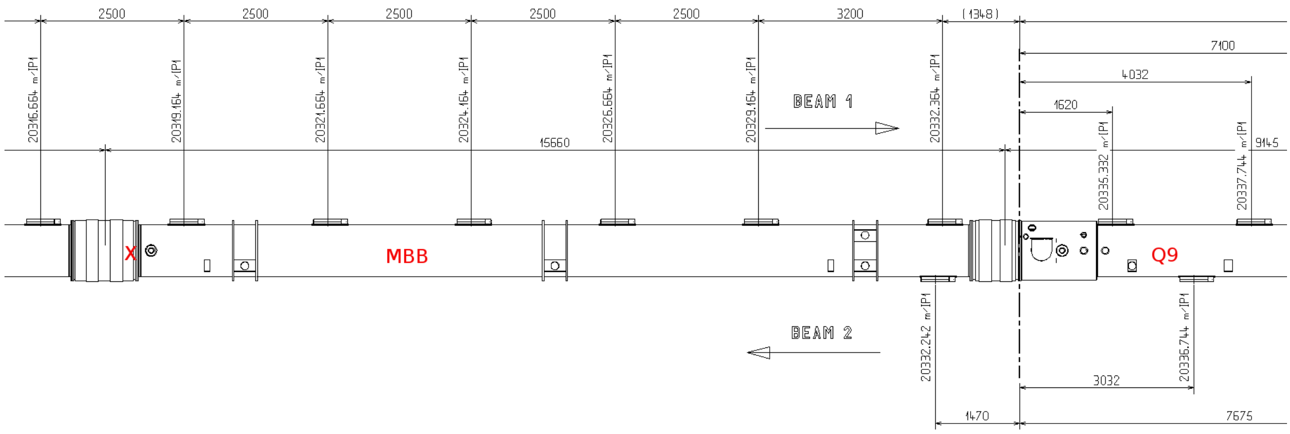


Figure 4: The top view of the first proposed location in IR7 (cell 9) is the left end cap of the MBB magnet (left interconnect on the plot, marked with "X"). The losses from the collimation section arrive from the left side.

In both locations the layout of the magnet and cryogenic equipment is expected to be similar. Figure 5 shows the proposed layout of the detectors on the cold mass of the MB magnet.

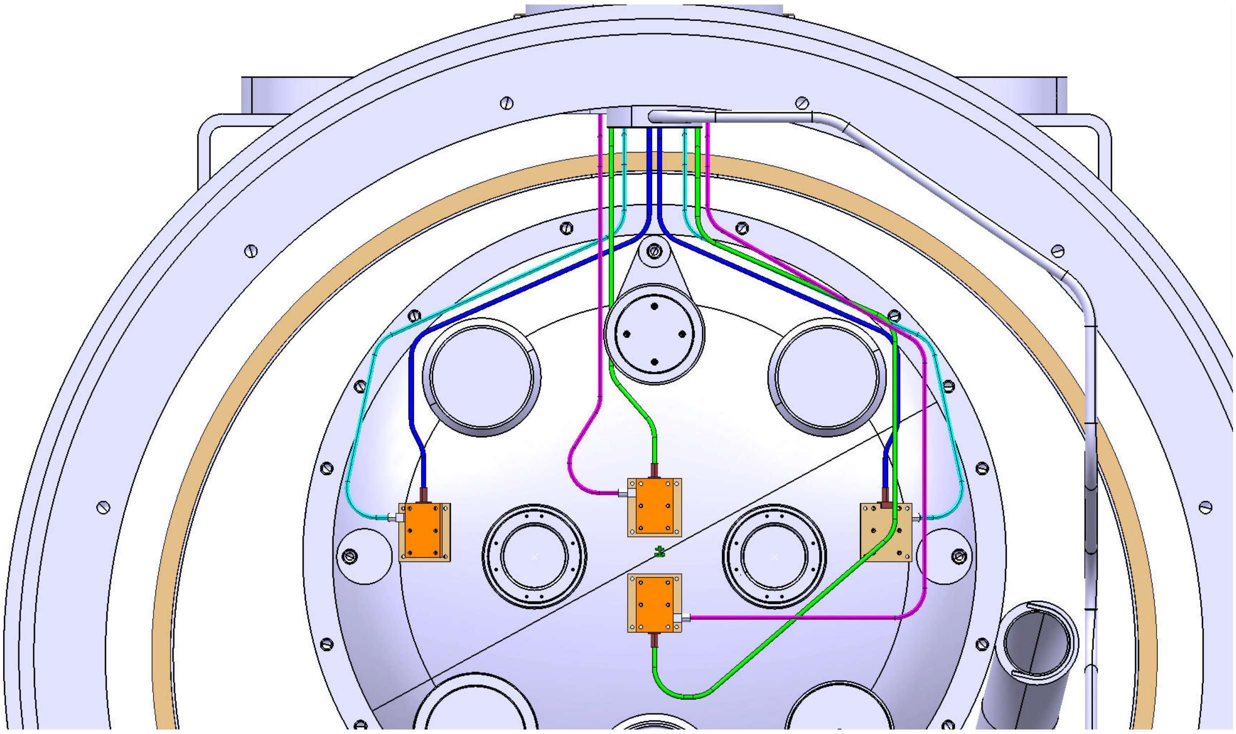


Figure 5: Layout of BLM detectors on the end cap of MB cold mass. Courtesy of Thierry Renaglia.

The detectors to be installed are semiconductor Silicon and diamond (scCVD) detectors. The thickness of the detectors varies between 100 µm and 500 µm, the other dimensions are about 5x5 mm. Their radiation hardness has been evaluated in [3] and the installation notes will be available [4]. The detectors will be constantly powered with positive voltage of 300-500 V, in case of strong losses the peak current will stay below 1 mA.

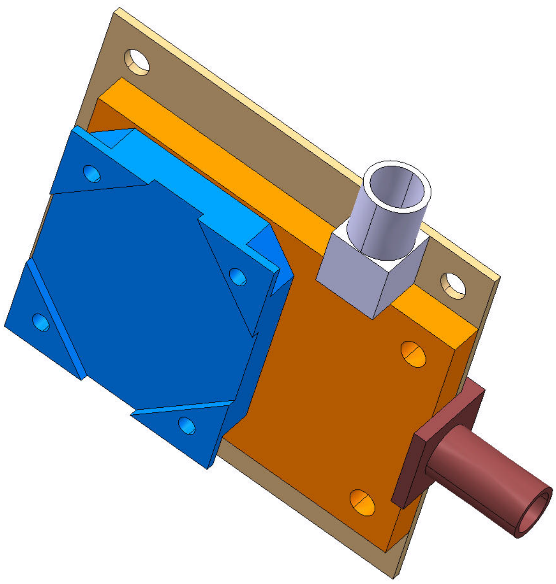


Figure 6: 3D view of the detector holder with 2 SMA connectors: one for HV and one for signal. Courtesy of Thierry Renaglia

Electrically the detectors are independent. Therefore each detector demands 2 cables: HV and signal one. All the cables used inside the insulation vacuum are high-performance semi-rigid SiO2 cables (AA9790 from Times Microwave Systems).
Figure 6 presents the detector holder with 2 SMA connectors: for HV (on the side) and for signal (brown one).

2. REASON FOR THE CHANGE

The reason for change is to test improvements in beam loss measurements foreseen to be deployed in a subset of LHC magnets during LS2 and LS3.

3. DETAILED DESCRIPTION

The overall assembly time for each dipole is detailed hereafter, with the groups in charge. Installation work (per unit): 6.5 full-time working days

- Installation of special DN200 flange: 1.5 days
  - ½ preparation (un-painting, etc.) (Alfa-Omega)
  - 1 day execution (Alfa-Omega)
  - Weld inspections (EN-MME)
- Installation of BLM supports on end caps: 1 day
  - Protecting work zone, positioning supports (SIT)
  - Tack welding (SIT)
  - Survey measurement of BLM's locations (ABP-SU)
- Installation of BLMs: 3 days
  - Mounting of BLM detectors (BE-BI)
  - Insertion of coax cables, fixing to BLMs, forming of cables (SIT+BE-BI)
  - Connectors connection, flange closing, electrical checks (SIT+BE-BI)
- Leak testing: 1 day
  - DN200 weld to vac.vessel (VSC)
  - Elbow/flange/connector feed-throughs checks (VSC)

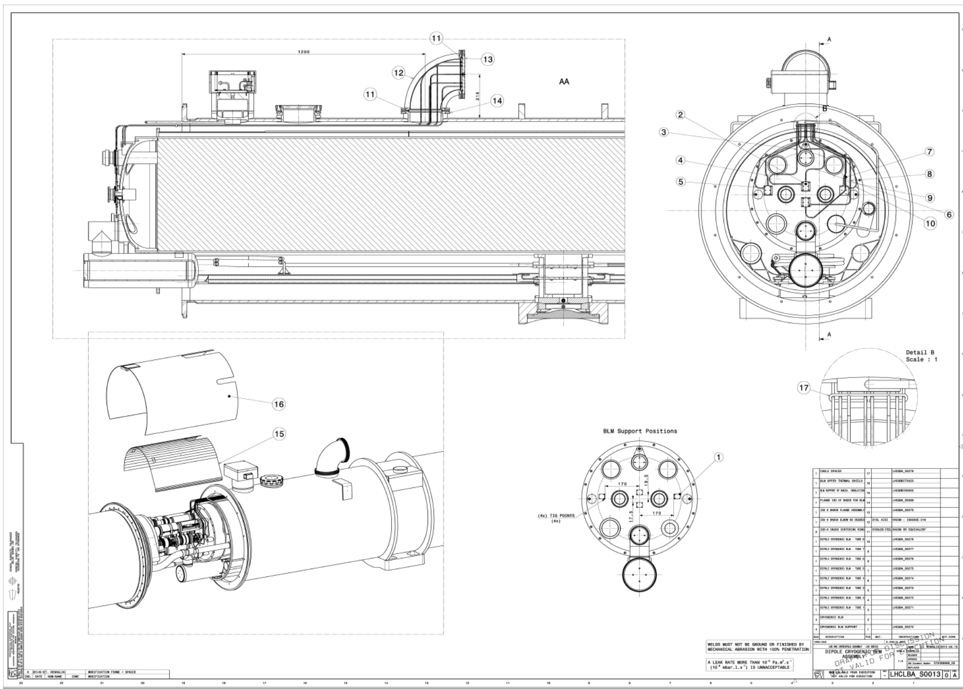
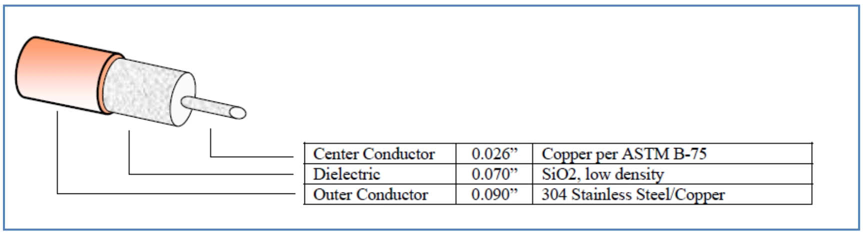
Resources have been identified but need to be integrated in the LS1 planning in order to avoid co-activity and conflict in resources usage.

SIT is the Special Intervention Team, and Alfa-Omega is the Open/Close team of the SMACC project.

4. IMPACT ON OTHER ITEMS

4.1 IMPACT ON ITEMS/SYSTEMS

Dipole Cryostat	A new DN200 must be installed in each location. A special flange with SMA feed-throughs must be mounted. Read-out electronics, in form of mobile BLM system, will be provided by BI. The installation of the BLM in the tunnel has been presented and discussed in several technical and management platforms: MSC Tech.Meeting, (19th September), TETM meeting (8 October) and LSC meeting (11 October). The installation is feasible with minimal consequence on the cryostat performance and the installation is possible with a moderate use of resources.

	Drawing LHCLBA_S0013 (see Figure 7), illustrates the installation of the 4 BLMs on the end cap of a dipole and the routing of the 8 coaxial cables (similar to those in use for the BPMs, Figure 8). The coaxial cables are pre-formed in order to be introduced from an interconnection and inserted between the vacuum vessel and the thermal shield. The warm ends of the coaxial cables are formed in situ in order to route them through the DN200 opening drilled specifically for this installation. A top elbow vessel and a flange with feed-throughs allow routing of the 8 cables through the cryostat.  Figure 7: Integration study on a dipole  Figure 8: Coaxial cable, 3 m long
Cryogenic System	The only consequence of installing the BLM is an increase heat load at 1.9 K due to conduction of the cables from 300 K. The additional heat loads of the 8 coaxial cables have been calculated to be about 144 mW (18 mW per cable). Note: these values are lower than those presented in the meetings which were conservative estimates.
Insulation vacuum Safety Relief system	The use of one of the 2 DN200 flanges for the BLM in cell 9L5, presently allocated to the safety relief system, will require a new installation of a DN200 port for the safety system on the neighbouring dipole LBBLF.9L5, and an updating of the ECO: LHC-QJ-EC-0002 ver 1.0 describing this change. An engineering Specification document will be issued and linked to the ECO: LHC-QJ-EC-0002; this will become the reference document to describe the positions and types of pressure relief devices.
Beam Loss System	The BLM need to operate at cryogenic temperature and their performance is optimal at a temperature below 30 K.

	The heat input from the coaxial cables increases the temperature of the detector which is mounted on a steel support welded to the end caps of the cold mass. The length of the weld seams is sufficient to keep the DT between the support and the cold mass to below 6.5 K. The detector is screw mounted to the steel support. Precautions are taken to use brass screws with Belleville washers to improve the thermalization of the detector to the support. As a result, the detector temperature is estimated to be at a temperature of about 10-15 K, while the cold mass is at 1.9 K, therefore remaining below 30 K. More details on the thermal analysis can be found in the calculation note EDMS 1320978

4.2 IMPACT ON UTILITIES AND SERVICES

Raw water:	None.
Demineralized water:	None.
Compressed air:	None.
Electricity, cable pulling:	16 cables will be pulled in the tunnel. 8 to power supplies and 8 signal cables to BLM electronics. Cables will be pulled by BI. Existing spare optical fibres will be used to send the data to the surface.
Vacuum (bake outs, sectorisation…):	None.
Special transport/ handling:	None.
Temporary storage of conventional/radioactive components:	None.
Survey:	None.
Scaffolding:	None.
Controls:	None.
Cryogenics:	As described in 4.1.
Contractor(s):	BI works with external company and academic contractor to construct the detectors. They will not be involved in tunnel works.
Others:	None.

5. IMPACT ON COST, SCHEDULE AND PERFORMANCE

5.1 IMPACT ON COST

Detailed breakdown of the change cost:	The impact on cost is small (design office, holders fabrication, preparation of flange with additional feed-thoughts), and has already been charged on a TE-MSC budget code. The readout electronics is in charge of BE-BI. Excluding the cost of the detectors/cables/feed-through plate (provided by BE-BI), the estimated material cost of the installation is for TE/MSC: – Components: ~ 20 kCHF – FSU/service contracts: ~ 6.5 kCHF
Budget code:	BE-BI and TE-MSC budget codes

5.2 IMPACT ON SCHEDULE

Proposed installation schedule:	Locations: – Right of Point 7. Dipole HCLBARA000-IN001052, with IC accessibility in QQBI.9R7 is provisionally compatible with an installation in a window end October 2013/beginning of November. – Left of Point 5. Dipole HCLBALE000-IN002136, with IC accessibility in QQBI.9L5, is provisionally compatible with an installation in April 2014 after the consolidation of the IC splices. It is proposed to execute the installation of the 2 DN200 as soon as possible in order to profit from the availability of the trained personnel who have just terminated the installation of DN safety relief devices. The Detailed schedule is to be discussed/agreed in the SMACC meetings.
Proposed test schedule (if applicable):	
Estimated duration:	
Urgency:	
Flexibility of scheduling:	

5.3 IMPACT ON PERFORMANCE

Impact on the performance can be only positive: additional data can be used for collimation studies.
Detectors and cables are shielded, so will not interfere with other measurements (BPMs, QPS). The proposed solution is fail-safe.

6. 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.

6.1 ORGANISATION

Requirement	Yes	No	Comments
IMPACT – VIC:			
Operational radiation protection (surveys, DIMR…):			Consider ALARA. If relevant, at what level? DIMR Level I?
Radioactive storage of material:		x	Radioactive storage space not needed.
Radioactive waste:		x	Activation of components is expected to be small due to used materials. They will stay inside the insulation vacuum at least until LS2.
Fire risk/permit (IS41) (welding, grinding…):			
Alarms deactivation/activation (IS37):			
Others:			

6.2 REGULATORY TESTS

Requirement	Yes	No	Comments
Pressure/leak tests:	x		Leak tests of flanges have been done. A leak test after installation is foreseen.
Electrical tests:	x		Detectors will be tested electrically by BI experts at various stages of installation.
Others:		x	

6.3 PARTICULAR RISKS

Requirement	Yes	No	Comments
Hazardous substances (chemicals, gas, asbestos…):		x	
Work at height:		x	
Confined space working:		x	
Noise:		x	
Cryogenic risks:		x	
Industrial X-ray (*tirs radio*):		x	
Ionizing radiation risks (radioactive		x	Traceability by TREC.

components):			
Others:			

7. 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 Safety File according to EDMS document 1177755:			
Others:			

8. REFERENCES

[1] http://indico.cern.ch/event/CryoBLM2011
[2] M. Sapinski et al., Estimation of thresholds for the signals of the BLMs around the LHC final focusing triplet magnets, proceedings of IPAC12, CERN-ATS-2012-093
[3] Ch. Kurfuerst et al., Investigation of the use of Silicon, Diamond and Liquid Helium Detectors for Beam Loss Measurements at 2 Kelvin, proc. of IPAC12, CERN-ATS-2012-094 and CERN-THESIS-2013-232
[4] EDMS-1342256