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Functional Specification

INSTRUMENTATION FOR THE LHC BEAM DUMPING SYSTEM

Abstract

This functional specification covers the beam instrumentation needs for the LHC beam dump system located in IR6. The beam observables include transverse beam position, transverse beam size, beam current and beam losses.

This functional specification implies a cost increase over the approved LHC baseline.

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History of Changes

Rev. No.	*Date*	*Pages*	*Description of Changes*
1.1	10-09-2003	-	Initial submission following BI technical board / July 2003 : • Intermediate screen in dump channel suppressed. • Screen design identical to TI2/TI8 lines. • Bunch-by-bunch requirements for BCT suppressed. • BPM and screen near dilution kickers moved downstream to the first vacuum chamber transition (25 m). • Difference between baseline 2000 and present specification clarified
2.0	11-11-2003	13	Main correction after approval procedure : • Synchronization requirements have been added.
	29-01-2004	all	Released version

Table of Contents

1. SCOPE

This functional specification covers the instruments dedicated to beam measurements for the two LHC beam dumping systems in Point 6. A schematic layout of the two systems is shown in Figure 1.

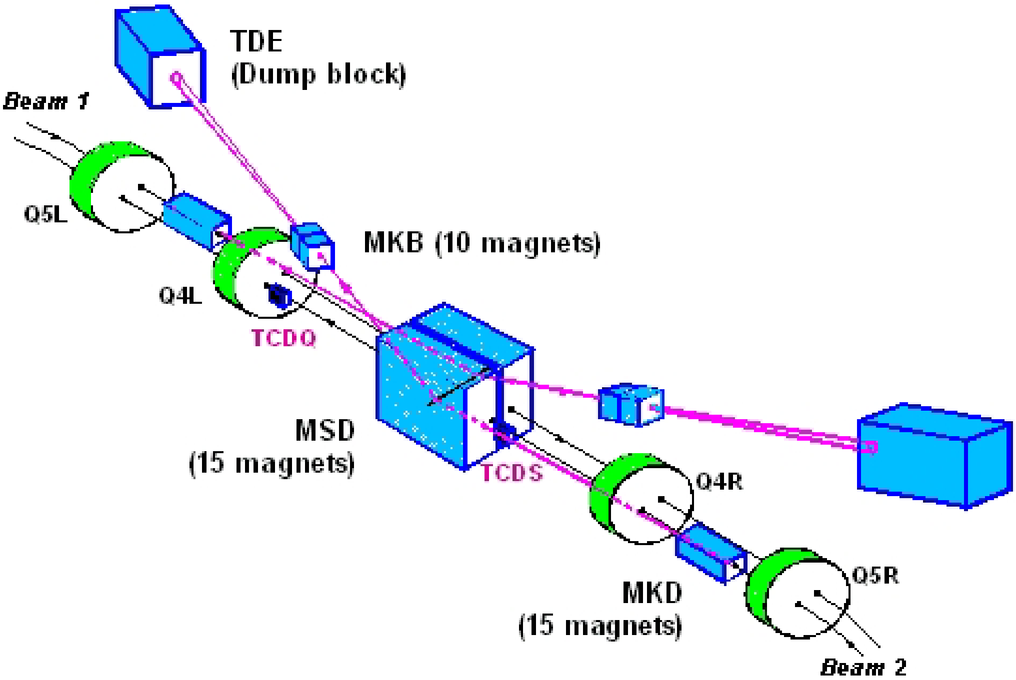

Figure 1 : Schematic layout of the LHC beam dumping systems.

2. THE LHC BEAM DUMPING SYSTEM

2.1 THE EXTRACTION CHANNEL

Each LHC beam is initially deflected by an assembly of 15 MKD kicker magnets that provide a total horizontal deflection of over 0.27 mrad. This deflection is increased (0.07mrad or ~ 30%) by Q4 to a total angle of 0.33 mrad. The beam then passes outside the TCDS diluter element and into the group of 15 MSD Lambertson-type septa magnets that provide a vertical kick of 2.4 mrad. Approximately 100 m downstream of the MSDs, 10 MKB dilution kicker magnets provide a sweeping deflection to distribute the extracted beam on the face of the TDE beam dump core over a 40 cm diameter area following a Lissajous figure. The distance from the dilution kickers to the dump is approximately 650 m as shown in Figure 2.

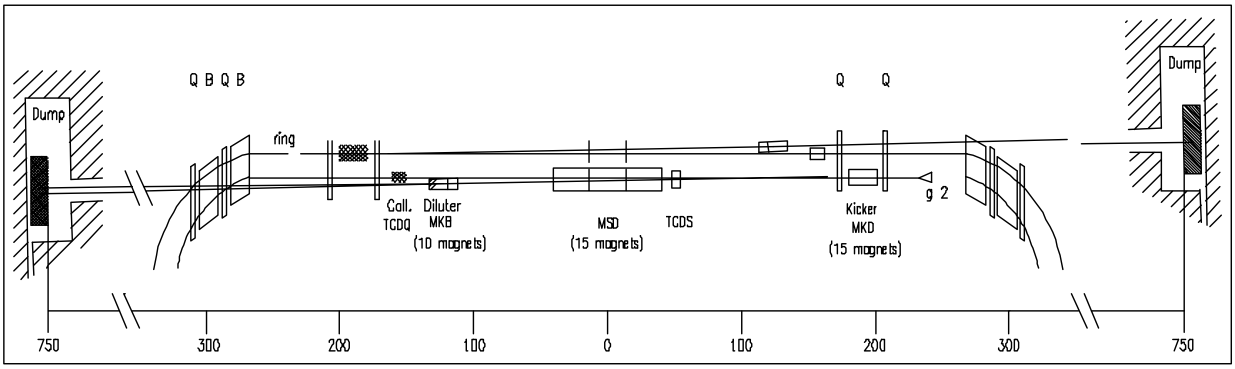

Figure 2 : Layout of the dump extraction channels.

2.2 THE BEAM DUMP

The detailed design study for the LHC beam dump block can be found in References [1-3]. The beam dump core is composed of a 7 m long Carbon cylinder with a diameter of 70 cm. Two types of carbon are used to decrease the peak temperature and reduce thermally-induced mechanical stresses. The core is followed by one Aluminum (1 m length) and one Iron absorber (2 m length). The core and absorbers are surrounded by an assembly of concrete/steel shielding blocks, as shown in Figure 3 and Figure 4.

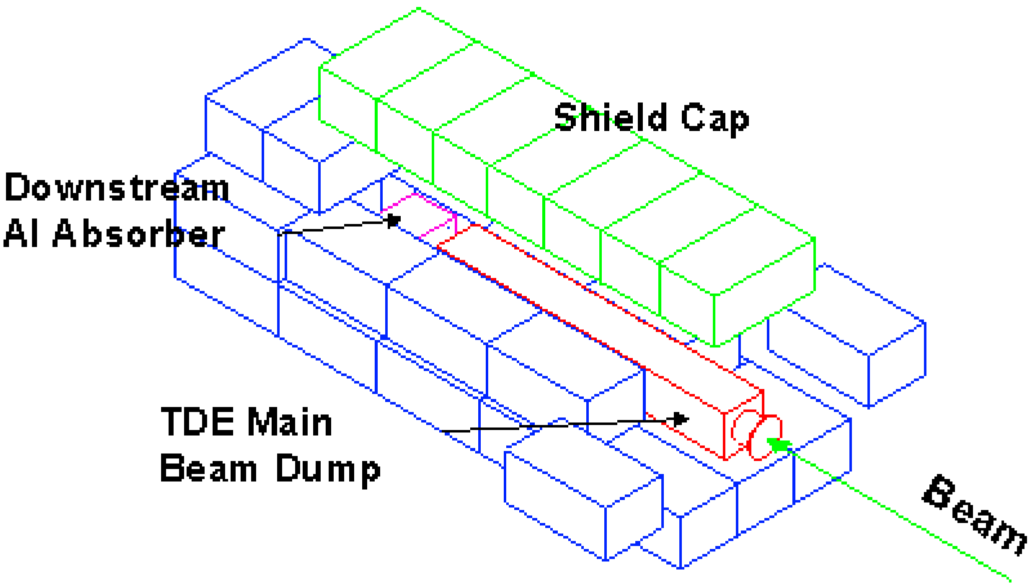

Figure 3 : Schematic view of the beam dump assembly with core, absorbers and shielding.

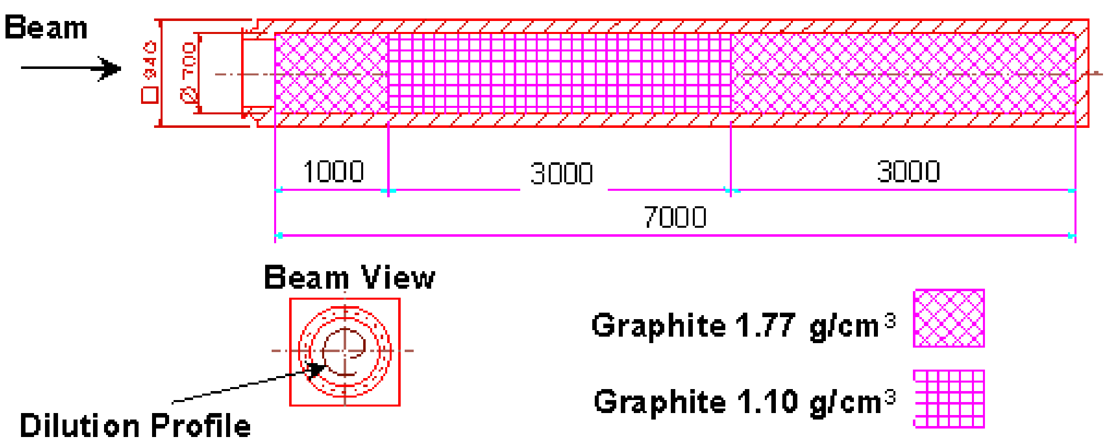

Figure 4 : Section of the beam dump core TDE. The density profile in the graphite core reduces the temperature increase for a dump of an ultimate intensity beam from 1800 to 1200 K.

2.3 BEAM DILUTION

The beam is distributed over the surface of the beam dump by 10 MKB dilution kickers. The optimised shape of the swept beam is shown in Figure 5. The average and extreme trajectories in the extraction channel due to the beam dilution are shown in Figure 6 and Figure 7.

The total length of the sweep on the surface is 120 cm. For ~3000 bunches this corresponds to an average distance between 2 bunches of ~0.4 mm for an r.m.s. transverse bunch size at 7 TeV of ~1 mm in both planes ($\beta \approx 5$ km, nominal normalized emittance of 3.75 μm). Without sweep, the maximum energy density in the core would be increased by 2 orders of magnitude, from ~2 MJ/kg to ~130 MJ/kg for ultimate beam intensities. Such energy densities, e.g resulting from a total failure of the dilution kickers, would cause a vaporization of the central part of the graphite core over a length of several meters (which happens for energy densities exceeding ≈ 30 MJ/kg).

The temperature increase of the central part of the graphite core reaches 1200 K for ultimate intensities, compared to a safe limit of 2500 K. Following a dump at 7 TeV, several hours are necessary for the dump block to cool down.

At 450 GeV dilution is not ‘mandatory’, i.e. failing to dilute will not damage the dump block.

The dilution kicker system will be installed in 2 phases. For the LHC commissioning foreseen in 2007, only half of the kickers will be installed, thus limiting the total stored beam intensity to approximately one half of the nominal intensity.

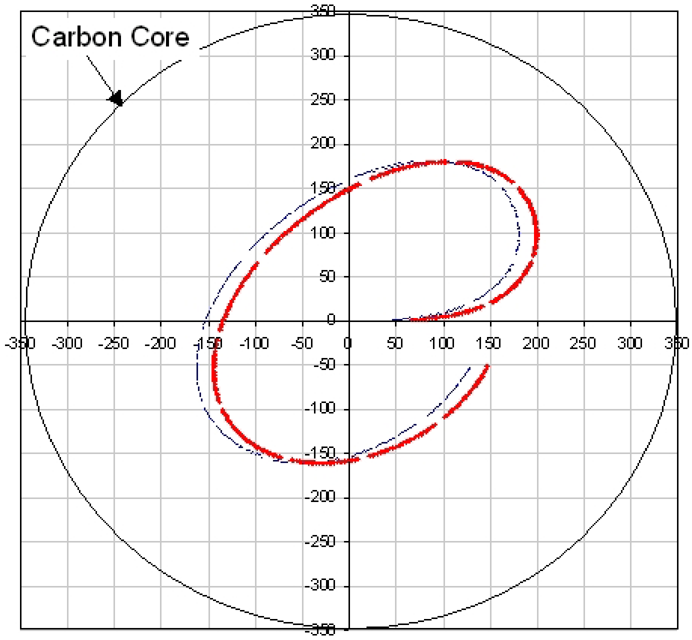

Figure 5 : Trace of the beam on the front face of the dump block. The total length of the trace is 120 cm (red = injection, black = 7 TeV).

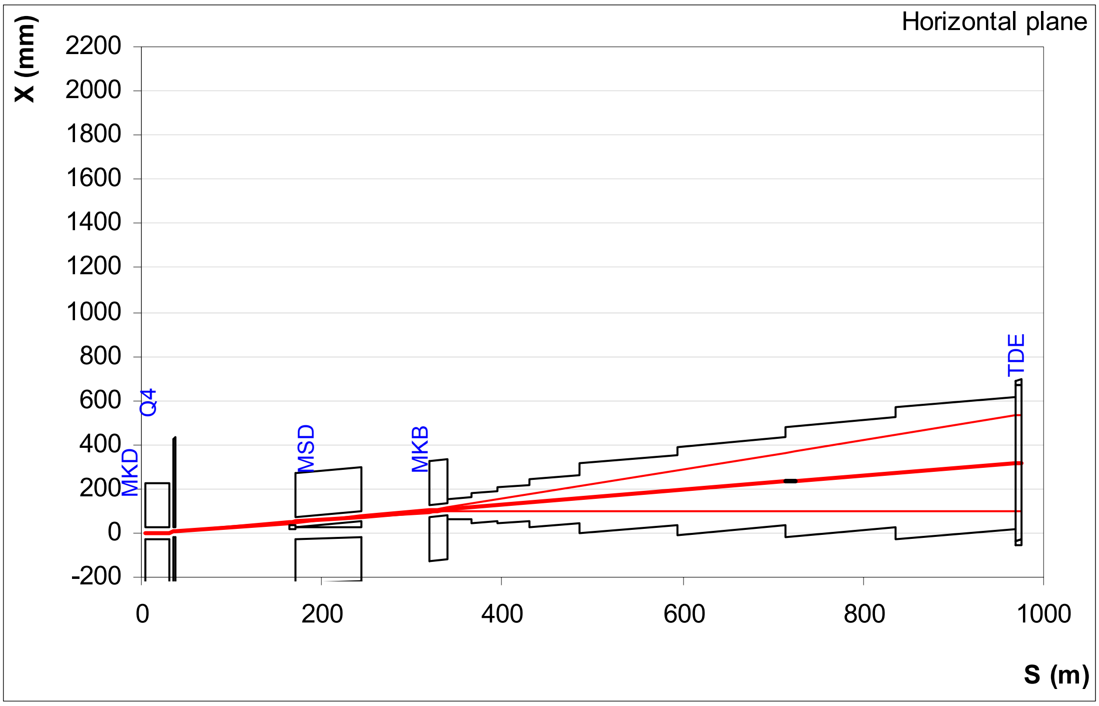

Figure 6 : Average and extreme trajectories in the LHC extraction line in the horizontal plane.

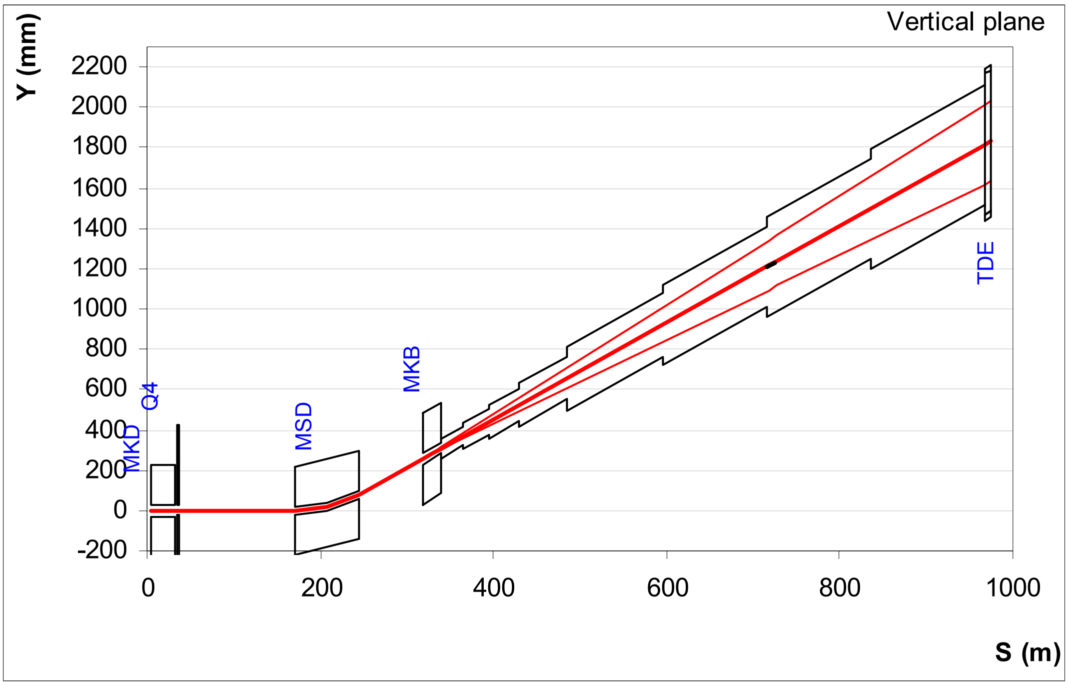

Figure 7 : Average and extreme trajectories in the LHC extraction line in the vertical plane.

3. DESCRIPTION OF THE OBSERVABLES AND MAIN USES

The fundamental observables are the beam position, the transverse beam size, the beam current and the beam losses.

3.1 ORBIT STABILIZATION

The beam position measurements of the LHC ring are used to steer and stabilize the circulating beam to an acceptable closed orbit around Point 6. The tolerances on beam position in Point 6 arise from the following requirements:

- The aperture limitations in the extraction septum magnets for the extracted beams require the horizontal orbit in the LHC ring to remain within a range of ±4 mm (peak) at the kicker and the septum for a loss free extraction [4, 5]. For slow orbit movements (1 Hz or less) the LHC orbit feedback can be used to stabilize the beam position within ±1 mm or better [7]. For certain equipment failures the orbit changes are too fast to be stabilized by a feedback. In such situations a fast beam dump request based on the beam position measured by 2 or 3 beam position monitors is required to ensure that the beam can be dumped correctly.
- The presence of the TCDQ absorber which protects downstream machine elements in case of un-synchronized beam dumps requires an orbit stabilization to better than $\sim\sigma_x/2$ to ensure a correct position of the TCDQ with respect to the collimators and apertures in the LHC ring. In collision the beam position must be stabilized to ±0.2 mm [7]. This requirement applies to steady state running with colliding beams at 7 TeV. An interlock system on the position at the TCDQ should react on the timescale of 0.1 to 1 second.

3.2 EXTRACTION LINE STEERING

The position of the extracted beam must be adjusted inside the extraction channel to ensure the best possible transmission efficiency to the dump block. At the septum entrance the distance between extracted and circulating beam is ~50 mm in the horizontal plane. At the exit of the septum, extracted and circulating beams are already in separate vacuum chambers. The position should be determined along the whole extraction line with profile monitors and BPMs, the latter being used to cover the highest intensity ranges where the profile monitors will probably have to be retracted from the line to avoid damage. The steering of the lines will be optimized to centre the beam in all available monitors and to minimize the beam losses.

3.3 TRANSMISSION OPTIMISATION

The beam position measurements made with BPMs and profile monitors are used to maintain the beam on a correct trajectory in the extraction channel. Beam loss monitors must be installed around the magnetic septa and along the line to monitor the extraction quality and detect aperture limitations. The position monitors are also used to measure the transverse offsets between bunches due to the MPD kicker ripple and to the dilution kicker sweeps.

The BCTs are used to measure the fraction of the circulating beam that is extracted and sent to the dump block. This measurement should be reasonably accurate (~ 1%) to prove that the beam has been correctly dumped. The intensity recordings must be available to provide information for INB. Since it is very difficult to obtain intensity measurements with higher accuracy (in particular for single shot measurements), beam losses in the extraction elements and during the last machine turn before extraction must be used to verify that the dump action was clean.

3.4 BEAM DILUTION CONTROL

An undiluted beam can destroy the dump block at full energy and intensity. It is therefore mandatory to determine the trace of the beam on the front face of the dump block. For correct operation the beam will be swept over the surface of the dump block as indicated in Figure 5. High resolution is not critical since no attempt is made to measure the beam sizes. Only the trace of the beam produced by the dilution kickers must be monitored using a large screen at the entrance to the dump block [12]. A redundant bunch-by-bunch position information must be provided by a beam position monitor installed some tens of meters downstream from the dilution kickers.

4. DESCRIPTION OF THE BEAM PROPERTIES

Instruments installed in the dump lines must be able to cope with the full variety of LHC beams.

For proton operation, the LHC bunch structure can vary from a single pilot bunch to ~3000 bunches. The intensity per bunch ranges from 2 10^9 to 1.7 10^{11} protons. The nominal bunch spacing in a batch is 25 ns. The nominal bunch intensity is 1.1 10^{11} protons.

For ion operation the nominal bunch charge may vary from the proton pilot charge of 5 10^9 to 1.1 10^{11} depending on the ion type.

5. OPERATION OF THE EXTRACTION LINES

5.1 COMMISSIONING AND SETTING UP AFTER A SHUTDOWN

The commissioning of the extraction line starts at injection energy with pilot bunches and proceeds by progressively increasing intensity and energy. It may be possible to take advantage of the 'Safe-Beam-Flag' [5] to ensure that beam dump commissioning cannot be performed with intensities above a preset threshold.

- First, pilot bunches are sent through the extraction channel until the steering is appropriate. At this stage the steering can rely entirely on the profile monitors and cross-calibration of the BPMs can be performed.
- The intensity is (progressively) increased to nominal bunches and batches to optimize losses and check the proper functioning of the dilution kickers.
- Once the setup at injection energy is finished, the energy tracking must be verified for the septa and kickers (including the interlocks).
- Setting up must then continue at higher energy, again starting with low intensities.

5.2 NORMAL OPERATION

During regular operation, the quality of each dump action must be verified to ensure that no degradation of the performance is occurring. Post-mortem data collection will be crucial to analyse the dumping system performance [8]. The Post-mortem data will include internal data from the beam dump (logical signals, kicker pulses…) as well as beam instrumentation data for the beam extraction line. Injection of beam will only be allowed if the Post-mortem analysis does not reveal any abnormal condition.

Whenever the Post-mortem analysis reveals abnormal internal signals or significant drifts of any observable with respect to its set-point, regular injection will be inhibited. It will be the responsibility of the equipment experts to define the correct repair actions and/or re-commissioning/checking of the dump with low intensities at injection energy.

6. FUNCTIONAL REQUIREMENTS

It is important to note that in this section on instrumentation requirements, the number of instruments corresponds to the needs of a **single** LHC ring.

6.1 BEAM POSITION MEASUREMENTS FOR STEERING

6.1.1 LAYOUT AND NUMBER

For the present LHC layout V6.4, both Q4 and Q5 quadrupoles are equipped with standard LHC BPMs providing positions in both transverse planes.

For the circulating beam an additional BPM block must be installed for each beam at the downstream face of the septum magnet (seen from the kicker). On that side of the septa circulating and extracted beams are already in separate vacuum chambers. This BPM provides redundant position information to the monitors installed next to the Q4 quadrupoles left and right of the MSD. The redundancy of the position reading can therefore be used to detect anomalous position readings in this critical area.

For the extracted beam, a first BPM must be installed adjacent to the TCDS to adjust and verify the MKD kick strength and the contribution of the Q4 quadrupole. The BPM will also be able to measure the circulating beam. A second BPM must be installed downstream of the dilution kickers MKB, if possible just in front of the first vacuum chamber transition at a distance of 25 m, visible on Figure 6. The presently foreseen diameter of this vacuum chamber is 96 mm. The bunch-by-bunch position information of the BPM can be used to observe the beam dilution since the width of the dilution trace 25 m downstream from the MKB kickers is approximately 15 mm.

Four position monitors must be installed for a beam position interlock system. One pair of redundant BPMs should be installed upstream of the TCDQ and a second pair downstream of the Q4 on the MKD side.

A schematic layout of the BPMs is shown in Figure 8.

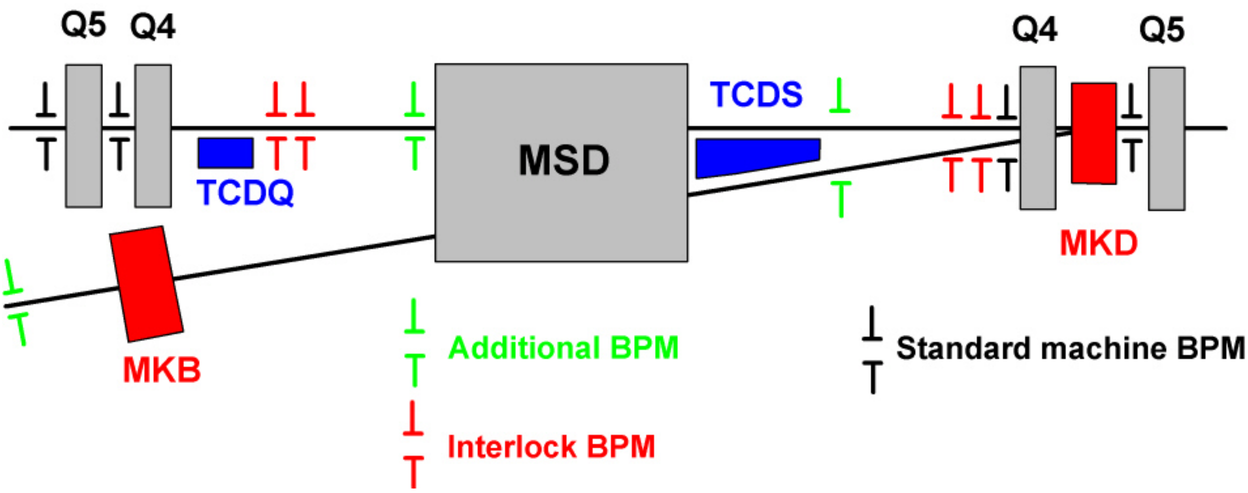

Figure 8 : Layout of beam position monitors in point 6 for LHC ring 2. For LHC ring 1, the position of MKD, MSD, TCDS, TCDQ, extraction line and interlock BPMs is mirrored around the center of the MSD septum.

The BPMs must measure positions for both horizontal and vertical planes.

Both BPMs in the extraction line must be complemented by transverse profile monitors (see below).

6.1.2 DYNAMIC RANGE & PRECISION

The monitors must cover the range of beam currents specified in chapter 4 with the precision target similar to the normal LHC machine BPMs [4].

The reproducibility must be ±0.2 mm from one dump action to the next and between pilot and ultimate intensity bunches.

6.1.3 TIME RESPONSE

For the two monitors in the dump extraction line, the acquisition system must return the individual position of each bunch that is extracted.

6.2 BEAM POSITION MEASUREMENT FOR INTERLOCKS

No final detailed strategy for the implementation of the beam position interlocks is available at the present time. For that reason the range and response times given below are indicative and may be subject to changes.

6.2.1 LAYOUT AND NUMBER

The small aperture of the extraction beam channel requires tight control over the closed orbit. While the foreseen real-time orbit feedback will be capable of stabilising the orbit for slow changes, fast failures leading to large position changes cannot be avoided by the feedback [7]. For that reason a fast interlock must be foreseen on the closed orbit between the Q4 quadrupoles on either side of IR6, based on the positions from 4 monitors grouped in two pairs downstream from the Q4 (seen from the kicker) and just upstream the TCDQ (radiation issues). The phase advance between the two BPM pairs is ~ 90 degrees.

The interlocks should be set for both horizontal and vertical planes.

The electronics of the interlock BPMs must be distributed over 2 independent front-end systems.

6.2.2 INTERLOCK RANGE AND PRECISION

6.2.2.1 FAST ORBIT MOVEMENTS

The fastest orbit changes are expected to reach 50 μm/turn (failure of the warm D1 separation dipoles). To avoid damage to the extraction elements the beam should be dumped before its position excursion with respect to the reference setting exceeds 4 mm. The nominal interlock threshold should therefore be set around 3.6 mm. Only experts must have the ability to modify the threshold. An accuracy of the position over the beam position interval of +3.6 mm and -3.6 mm of $\pm$0.2 mm (peak) is adequate.

It must be possible to deactivate the interlock for bunch intensities below 10^{10} p/bunch where no damage is expected even when the LHC is filled with the nominal number of bunches. This operation must be based on a reliable beam intensity signal, most likely based on the planned 'Safe-Beam-Flag' [5].

The interlock logic must not prevent tune measurements with amplitude up to 2σ at injection. Similarly injection oscillation amplitudes of 2-3σ (1σ ~ 2 mm at the position interlock monitors) must not lead to a dump by the position interlock system.

6.2.2.2 SLOW ORBIT MOVEMENTS

Since the position of the TCDQ must be maintained within $\sigma/2$, an interlock is required on slow orbit changes with a threshold around $\pm$0.2 mm for the squeezed optics at 7 TeV where the aperture is very tight in the triplets [10]. This interlock should be applied to the beam position averaged over approximately 1 second.

6.2.3 TIME RESPONSE

6.2.3.1 FAST ORBIT MOVEMENTS

The delay between the moment where the beam exceeds the threshold and the actual dump firing should be 5 turns or less for fast orbit movements

Transients due to injection oscillations must be filtered out.

6.2.3.2 SLOW ORBIT MOVEMENTS

The beam position can be integrated over a time span of 1-5 seconds.

6.2.4 RELIABILITY

A high reliability, corresponding to SIL3 [14], is required for the system. It is recommended to treat the signals in 2 separate electronics crates and to distribute the signals from each BPM pair over different front-end crates to avoid treating a given pair in within a single crate. This requirement applies only if it is compatible with the processing delays.

6.3 BEAM INTENSITY MEASUREMENT

6.3.1 LAYOUT AND NUMBER

The intensity of the extracted beam must be determined with high reliability for each dump action. The intensity extracted by each dump action must be logged to track the total load onto the dump block for radio-protection issues and to provide input for INB inquiries. For that reason two redundant Beam Current Transformers must be installed between the magnetic septum MSD and the dilution kickers. One of the two BCTs must always be operational, i.e. providing data to the control room and to the various data logging systems.

6.3.2 DYNAMIC RANGE & PRECISION

The monitors must cover the range of beam currents specified in chapter 4.

For beam intensities corresponding to one batch of 72 bunches with nominal intensity or higher, the cross-calibration of the total intensity measured by the BCTs must have an accuracy of 1-2% with respect to LHC ring measurements in order to determine the extraction efficiencies at the percent level. For single pilot bunches the best possible accuracy must be provided, aiming for an accuracy of ~5-10%, since the total intensity that is involved is small.

For relative measurements in case of transmission optimisation, the BCTs must have a relative accuracy of better than 0.5% (from one extraction to the next and one BCT with respect to the other, for intensity variations of ±50%). The relative accuracy is required to optimise the transmission of the lines with good operational efficiency. This criteria applies to intensities corresponding to at least one batch of 72 nominal bunches.

6.3.3 AVAILABILITY

The BCTs must be available for the diagnostics of every beam dump. Since the BCTs do not contribute actively to the dump action, they do not have to be failsafe but must have a high availability. After each beam dump, the BCT will be acquired and analysed. If all or part of the BCT data is missing, the LHC may not be able to operate with beam until at least one of the BCTs is operational again. A test dump with beam at 450 GeV will be performed after repair to ensure that the BCTs and their acquisition system are fully operational before regular operation can resume.

6.4 SYNCHRONIZATION REQUIREMENTS

A measurement of the longitudinal time structure of the circulating beam is required to adjust and subsequently monitor the synchronization of the extraction kicker pulse with the beam abort gap.

This measurement may be performed using a fast BCT or a BPM sum signal. The signal must be in analogue form. To obtain a sufficiently high reliability, two redundant signals must be provided for each LHC beam.

To avoid the installation of additional instrumentation, the synchronization signals can be obtained from the sum signal of the interlock BPMs.

6.5 BEAM LOSS MEASUREMENT

6.5.1 LAYOUT AND NUMBER

Due to the tight aperture of the extraction channel in the magnetic septa and the very long lines, a significant number of beam loss monitors are required to monitor beam losses in the channel.

Loss monitors (BLMs) must be installed around the magnetic septa, the absorber blocks (TCDQ and TCDS) and the dilution kickers as indicated in Figure 9. Those monitors come in addition to the normal BLMs that have to be installed around the Q4 and Q5 quadrupoles. For each ring, the proposed layout consists of :

- 4 monitors around the TCDS.
- 6 monitors around the MSD septum, with 2 monitors at the transitions between different septa types (MSDA->MSDB, MSDB->MSDC) and 2 monitors at the downstream end of the MSDC. The length of the cables must be sufficient to allow for a displacement of each monitor by 5 m, which corresponds to one septum magnet.
- 4 monitors around the TCDQ.
- 2 monitors around the dilution kickers MKB.

The number of monitors is 16 per ring. All 16 BLMs should be of the BLMS type as described in reference [11] since a turn-by-turn detection is required in this critical area.

BLMs must also be installed at each of the 7 vacuum chamber transitions in the long TD 62 and TD 68 transfer lines to the dump block to monitor losses arising from possible mis-steering, energy tracking errors… Two BLMs must be foreseen for each of the 7 transitions in each line that are visible in Figure 6 and Figure 7. The BLMs should be placed a few metres downstream of the section changes. The detailed layout will be defined at a later stage with the help of simulations. The cable layout must be compatible with a distribution of the BLMs over the entire length of the extraction channel.

Four additional BLMs must be foreseen around the Q4/Q5 cryostats that are close to the beam dump extraction lines.

6.5.2 DYNAMIC RANGE & PRECISION

The dynamic range to be considered for the LHC beam covers the range given in chapter 4.

Scaling of losses from pilot to full intensity is not mandatory. Progressive intensity increase at injection can be used to check the losses in the extraction channel.

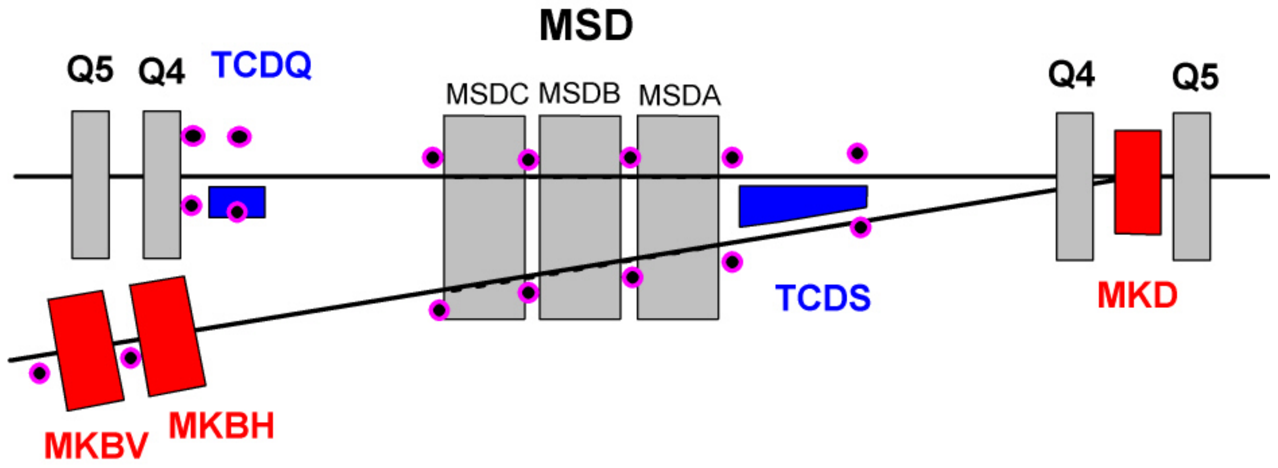

Figure 9 : Proposed layout of the BLMs for one ring. The total number of monitors is 16, not including the monitors to be placed near cross-section changes in the long TD62 and TD68 lines.

6.5.3 RELIABILITY

The reliability of the beam dumping system BLMs should be consistent with the reliability defined in Reference [11].

The BLMs around the septa, the TCDS, TCDQ and diluter kickers should satisfy the same criteria than the BLMS-type monitors.

The BLMs installed in the beam dump lines should satisfy the same criteria than the BLMA arc loss monitors.

6.6 TRANSVERSE PROFILE MEASUREMENT

The extraction line must be covered with a sufficient density of transverse profile monitors to determine the beam position and the aperture used by the beam. Due to the intrinsic sweep of the extraction kicker (7%), the requirements on transverse sizes are not very strict.

6.6.1 LAYOUT AND NUMBER

Three profile monitors must be distributed over each extraction channel. The location of the monitors is specified as follows:

- A first profile monitor must be installed upstream of the TCDS. This monitor is used to cross-calibrate the nearby BPM and will be used for the commissioning of the extraction channel.
- A second profile monitor must be installed downstream of the dilution kickers, again close to the foreseen BPM.
- A third profile monitor must be installed in front of the dump block (at the entrance of the dump cavern, ~5-10 m upstream of the dump block). The size of this monitor must be 60 x 60 cm^2 [12].

6.6.2 DYNAMIC RANGE & PRECISION

The monitors must be able to withstand the range of beam currents specified in chapter 4.

For the first two monitors the beam is not significantly diluted since only the intrinsic ~7% sweep of the kicker flat top provides some smearing of the bunch impact positions. The screens should be fixed and remain inside the beam path unless this proves technically impossible without causing damage, in which case those two monitors must be retracted for the highest intensities. The minimum intensity range that must be covered ranges from a single pilot bunch of 5 10^9 protons to 4 PS batches of 72 bunches at nominal intensity of 1.1 10^{11} protons/bunch. A system based on multiple screens adapted to a specific intensity range is acceptable. Operation of the beam dumping system (and therefore also of the LHC itself) is only possible if either the profile monitor or the BPM of each pair is operational.

In the situation where the screens cannot withstand the full beam intensity range, a hardware interlock signal must be used to block the screens out of the beam where the circulating intensity exceeds a predefined threshold.

Screen	r.m.s. bunch size σ_b[mm] 450 GeV	7 Tev	Trace length [mm]	Average bunch to bunch impact [mm]
Septa	1.2	~0.3	40	$<< \sigma_b$
Diluters	1.5	~0.4	80	$<< \sigma_b$
Bump block	4	~1	1200	0.4

Table 1 : Beam size, sweep length and average transverse impact distance between bunches at the location of the profile monitors.

Due to the sweep provided by the dilution kickers, the peak beam density is significantly reduced for the last monitor in the extraction tunnel and on the dump block. The peak particle density corresponds to an overlap of less than ~10 bunches. This monitor must always be operational.

For the two first screens the required accuracy on the r.m.s. beam size and position should be 0.5 mm r.m.s. The reproducibility should be better than 0.2 mm r.m.s.

Since the main aim of the screens downstream of the diluters is to monitor the dilution sweep and the position on the dump block, the requirements on accuracies are not very tight. A precision on the beam position and size around 2 mm r.m.s. is sufficient for the dump block monitor.

All profile monitors must provide two dimensional information averaged over all bunches.

6.6.3 AVAILABILITY

The profile monitor in front of the dump block must be permantly available during machine operation as dump action diagnostic. The screen and its associated electronics do not need to be failsafe since the screen does not contribute actively to the beam dumping process. After each beam dump, the data from this monitor will be acquired and analysed. If the data is missing or the screen is not functioning, the LHC will not be able to operate with beam until the screen is repaired. A test dump with beam at 450 GeV will be performed after repair to ensure that the screen and its acquisition system are fully operational before regular operation can resume.

7. POST-MORTEM SYSTEM

All instrumentation data must be available for Post-mortem analysis following a dump action. This requirement implies that all instrumentation that is part of the extraction beam line and its protection devices (TCDQ and TCDS) must be collected for every dump action. A special trigger must be provided to ensure that when only one of the two LHC beams is dumped, the instruments associated to the dumped beam are correctly triggered and read-out while the instruments associated to the second beam remain armed for an acquisition.

8. DIFFERENCES WITH RESPECT TO LHC "BASELINE"

Some of the instrumentation requirements presented in this document are not part of the LHC baseline [12], namely:

1. the interlock BPMs and their readout,
2. the beam loss monitors,
3. the position of the BPM upstream of the septum in a non-standard environment.

Recent detailed studies of the reliability of the beam dumping system and of the available aperture in the LHC extraction channel [4,5,7] have revealed that the LHC and the beam dumping system cannot be operated safely without this additional instrumentation. The interlock BPMs in particular play an important role in the protection of the beam dumping system septum magnets. The additional instrumentation was endorsed by the LTC in meeting 2003/12.

9. SAFETY AND REGULATORY REQUIREMENTS

9.1 RADIATION LEVELS

The area around the extraction septa magnets, the TCDQ and TCDS and the beam dump block are likely to be activated. Precautions must be taken concerning any equipment installed in the machine tunnel.

9.2 INTERNAL REGULATIONS

The Beam Transfer Instrumentation must meet the safety guidelines put forward by the CERN Technical Inspection and Safety Commission (TIS). TIS have issued safety documents in compliance with LHC-PM-QA-100 rev1.1, and the guidelines in these documents will be incorporated into the Beam Transfer Instrumentation design.

9.3 INB CONSTRAINTS

The LHC has been classified as an "Installation Nucleaire de Base" by the French Authorities. CERN is therefore obliged to conform to their relevant regulations, guidelines and procedures. Within this context CERN has to establish traceability & waste management procedures and maintain a radiological and zoning system. In order to meet these requirements, information such as: material content, location history, sub-assemblies, etc…, shall be supplied by the Contractor and will be maintained in a CERN database. CERN has created a set of procedures and conventions as part of the Quality Assurance System for LHC, which will also be used to facilitate these INB requirements. The relevant quality documents are listed below and shall be applied by the Contractor during the production, testing and assembly of components: "The Equipment Naming Convention", "The LHC Part Identification", "The Manufacturing and Test Folder".

10. REFERENCES

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