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Recommended Locations of Beam Loss Monitors for the ATLAS Roman Pots

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Summary

This note suggests suitable locations to position beam loss monitors to observe losses on the ATLAS Roman Pot station located close to 240m from IP1. This monitoring is envisaged to help to avoid quenches of the super-conducting magnets downstream of the roman pots and to avert damage to either the LHC machine elements or the roman pot detectors. The results presented in this note indicate the locations where the BLMs should be installed. The recommended locations are determined using previous simulation results on BLM response to losses; therefore these results should be considered in conjunction with the previous results. A more detailed note on the topic will follow later.

Introduction

Roman pots for the ATLAS experiment [1] are to be installed on both sides of IP1, in a "stations" close to 240m from the IP [2]. The roman pots contain detectors which, during stable operation, will approach very close to the beam axis. Depending upon the operational condition, this may be even as close as ten sigma from the beam. As extra elements in the beamline, there will be an aperture change within the vacuum chamber when they are inserted. This implies that there will be additional losses from protons in the beam halo striking the pots. In the positioning of the Beam Loss Monitors (BLM) [3] for the machine [4, 5], this loss mechanism has not been taken into account, therefore it is necessary to evaluate the topology of these additional losses and use it to evaluate suitable locations where the additional BLMs, which are already foreseen for the ATLAS roman pots [6], can be positioned to have sensitivity to this type of loss.

The purpose of installing the BLMs is not only for monitoring the impact of the losses — it is also active protection of both machine and detector, for example, in the catastrophic case of the pot approaching too closely the beam, arising from either movements of the pot or of the beam. In this event, there is potential for damage – as demonstrated by the

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incident at FERMILAB, where a CDF roman pot approached the beam, causing extensive damage to collimators and magnets downstream [7]. The BLMs should help guard against quenches which could be induced by these losses, instead dumping the beam before any magnet quenches or damage to the detector occurs, hence minimising machine inefficiency and downtime.

Results are already available on the topology of losses as detected by the BLMs, both for a simulation of losses on the TOTEM roman pots [8], based upon interactions with pots at 147m and 220m from IP5, and for proton losses from the halo around the LHC [4, 5]. The topologies of the results presented in the previous studies are used here to determine suitable positions to install BLMs to detect these losses from the ATLAS roman Pots, with due consideration given to the beamline geometry close to the ATLAS roman pot station.

1 ATLAS Roman Pots

The ATLAS roman pot stations, that are envisaged to be installed for the LHC startup phase, are close to 240m. Additional roman pot stations [9], which may be installed following a later shutdown are not considered further here, as they are still under study, and not yet endorsed. The locations of these stations in the long straight section 1 right (LSS1 R) are shown in Figure 1. The station comprises of a number of pots on the outgoing beam. Figure 2 shows the anticipated layout for the 240m station and the machine elements nearby.

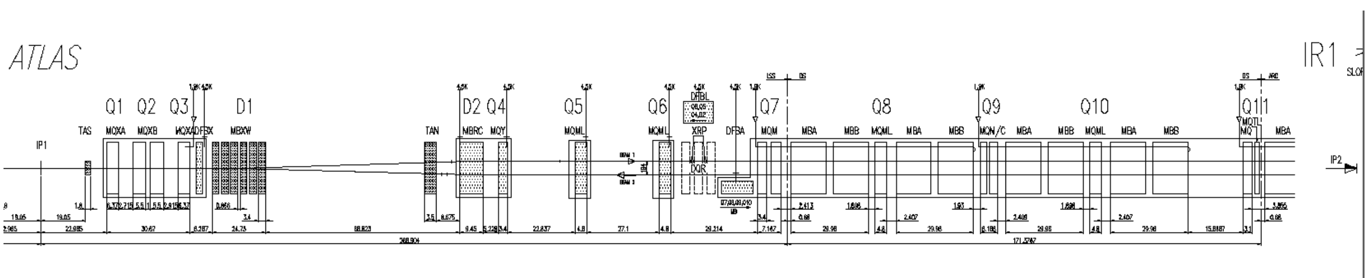

Figure 1: Machine Elements in LSS 1R. XRP indicates the location of the 240m station. Taken from [10].

Each pot unit contains 2 vertical detector pots; this implies 2 pots containing detectors above and below the beam respectively. Horizontal detectors are not forseen for the ATLAS roman pots at 240m in contrast to the design geometry for the TOTEM RPs [11]. The locations, as distance from IP1, and the orientations of the detectors for the 240m station are shown in Table 1.

Station	Orientation	
	Vertical	Vertical
	Distance from IP1 (m)	
240m Station	237.398	241.538

Table 1: Locations and orientations of midpoints of the ATLAS roman pot 240m station [2, 12].

The geometry of the pot, containing the detector, which is inserted into the beampipe will be similar to that of the TOTEM pots. The inner edge of the roman pot will be parallel to the beam, and for a proton in the halo will present a stainless steel target of 5cm in depth.

2 Machine Equipment surrounding ATLAS Roman Pots

As the roman pots are installed on the outgoing side of the IP for each beam, only the machine elements downstream (further from the IP) of the pots are potentially affected. Figure 1 shows a diagram of the magnetic elements in the Long Straight Section for IP1. It can be seen that the magnetic element closest to the 240m station is Q7, which is the beginning of the continious cryostat, which extends into the arc. All of the magnets, from Q7 onwards, are super-conducting magnets operating at 1.9K, so therefore, in danger of quenching if the energy deposition in the coils becomes too large.

Integration might be difficult in this region, due to the density of machine equipment close to the beamline. As can be seen in Figure 2, between Q6 and Q7 are also dump resistors (3 DQR units) and cryogenic electrical feedbox for the arc (DFBA unit). The two roman pots themselves are installed in the two gaps between the three DQR units between Q6 and Q7.

2.1 Beam Loss Monitors Close to the 240m Station

At the LHC, Beam Loss Monitors will be installed close to all known potential loss locations, to monitor and diagnose the levels of losses from the beam, and used to provide protection against magnet quenches which could be induced by these losses. As such, to provide active protection, the BLM system will be connected to the beam dump system, via the Beam Interlock System (BIS), so that the beam can be dumped in a timely manner (within three turns), if the levels of losses are approaching the quench levels of the magnets.

The 'standard' LHC beam loss monitors are cylindrical ionisation chambers, 60 cm in length with a diameter of 9 cm. Their response to different particle species and energies is highly non-linear [13, 14]. However, their response to charged hadrons is much larger than that of other particles in the energy range of interest here ($\sim$MeV—GeV), and so in the studies referred to here [4, 5, 8, 15], charged hadrons were assumed to be the dominant contribution to the signal.

The locations for these BLMs around the LHC ring have been chosen by simulating different loss-types, and the topology of the resulting showers evaluated [4, 5]. Typically the loss locations are aperture restrictions.

Several sets of BLMs are already envisaged to be installed near to the 240m ATLAS roman pot stations. Downstream of the 240m station, a set of six BLMs are foreseen to be installed on each quadrapole, Q7, Q8, etc., mounted approximately on the horizontal plane with the beamline, half on each side (ring-inwards, ring-outwards). This means that for each quadrapole, losses from one beam are predominantly measured by three BLMs.

3 Previous Results of Shower Simulations from Loss Mechanisms

Results exist from simulations of the showers resulting from both protons losses from the halo on the machine aperture [4, 5] and losses from protons in the beam halo on the TOTEM roman pots, which are downstream of IP5 [8].

For the losses of protons on the beampipe aperture limitation from the beam halo (typically on the beam screen in the cold sections), for both the arcs and the Long Straight Section, the peak of the energy response from a loss location on the beam screen has been found to be similar – the maximum of the loss, as observed on the outer wall of the cryostat, occurs approximately 1m after the loss location in the beam direction, s, and is approximately on a horizontal plane from the beam position, on the side of the cryostat nearest the beam from which the loss originated. So, detectors should be situated approximately 1m after loss locations, and on an approximately horizontal plane with the beams, to minimise cross-talk from differing loss locations in the response of the BLMs. This choice leads to the BLM closest to the loss location giving a response which is as independent as possible from losses elsewhere, aiding localisation of loss locations in post-mortem analysis of problems.

For the losses of protons in the beam halo on the TOTEM roman pots at IP5, the beamline downstream of the 150m and 220m stations was simulated. Particles yielded from the showers were then scored as they passed through a cylinder of radius 32cm from the centre of the outgoing beampipe – this corresponds approximately to the outer radius of the cryostat. Significant variations in flux over the length included in the simulation were observed. However the results from the simulations of the two different stations simulations bear a striking similarity to each other and to the results of the more general studies of losses around the LHC ring.

There are several general observations to make from the results — that the fluxes rise up to a plateau; this happens within 1-2m after the interaction. Aperture changes downstream give rise to peaks in particle fluxes, shortly after the change in aperture in ‘s’. The magnet cores significantly shield the charged particles fluxes. This means that the flux for the magnet which is to be protected can be best monitored just before the start of the core of the magnet — it is therefore sensible to install a BLM at this position.

In these studies, to determine the best location around the cryostat to locate the BLMs, the angle of exit on the cylindrical scoring plane for the particles from the shower was recorded. In all cases the ϕ distribution of the showers are peaked towards the ring outwards direction. At IP5, on both sides, the outgoing beam from the IP is on the outside of the ring, so the peak at ϕ of zero is due to the lower material thickness and distance on this side of the cryostat. Additionally, the ϕ distributions of positive and negative particles, in particular for charged pions, were checked, and no significant differences were found, indicating that the dominant influence on the shower topologies comes from the materials close to the beamline, and not the fields within the magnet, implying that the details of the optics should not affect significantly the results from the simulation. This location in ϕ, on the horizontal plane is also the same optimal position as was found for the BLMs to be positioned elsewhere in the LHC ring. In summary the optimal location to position the BLMs for the roman pots is approximately on the horizontal plane with the beams, on the outer side of the ring.

4 Suggested Locations for ATLAS BLMs

Considering the results of the simulations for the showers from losses presented above, and the similarities for the differing loss types and locations, recommended locations for the ATLAS BLMs can be given, with due consideration of the geometry in this region. It should be noted that integration of the BLMs in this location is expected to be difficult due to the density of machine equipment.

Firstly, as the losses will rise to a plateau in flux just after the roman pot (1-2m after the roman pot), then 2m after the second roman pot would be a suitable location to have good sensitivity to all of the losses on both roman pots. This location is also likely to have lower sensitivity to other non-roman pot related loss locations, therefore aiding in diagnosis of significant beam halo losses on the ATLAS roman pots. This position coincides with the dump resistors (DQR units).

Secondly, the magnet closest to the roman pots downstream is Q7. To provide active protection of this magnet from the roman pot losses, it is highly advisable to make sure that a BLM monitors this magnet, if not already done so for the 'standard' BLMs to be installed for the machine. As observed earlier, the core shields the flux from the surface of the cryostat, this leads to the preferred position, just before the start of the magnetic core of the magnet in the interconnection region, as the optimal location to install the BLM, in a similar fashion as for the 150m and 220m TOTEM roman pot stations. An additional optional location would be just after the first roman pot location, though this would be sensitive only to the losses from the first roman pot.

For all locations the BLMs for the roman pots should be installed on approximately the horizontal plane with the beams, on the outer side of the ring.

Conclusion

Suggested locations for the dedicated BLMs for the ATLAS roman pots have been evaluated considering the results from previous studies of the losses, with the aim of using the previous results on the topology to determine optimal locations for the positioning of LHC BLMs for detecting the magnitude of these losses. The optimal locations were determined by considering both the particle flux originating from these interactions passing through the radius of the exterior surface of the cryostat and the machine elements nearby that may quench as a result of these showers.

Two 'standard' LHC BLMs were foreseen by the BLM group to be available for each ATLAS roman pot station – this study suggests that they should be positioned and installed as follows:

- **240m station:**

  BLM A: As close as possible in 's' to the last detector plane **(s=±243m)**.

  BLM B: Just before, or at the start of the magnetic length of Q7 **(s=±259m)**.

The distances within parentheses indicate the approximate distance of the suggested location from IP1.

A 240m ATLAS roman pot station will exist on both beam 1 and beam 2 outgoing from IP1, i.e. for beam 1 the ATLAS roman pots will be on the right-hand side and for beam 2 the ATLAS roman pots will be on the left-hand side. Therefore BLMs need to be placed near to the stations in both directions, as indicated in the list above by the '±' notation on the distances from IP1.

In all cases, the BLMs should be positioned on a horizontal plane with respect to the beams, as close as possible to the beamline as is feasible – i.e. on the outside of the cryostat or bare beampipe as appropriate. The outgoing beam at IP1 is, for both beams, on the outside of the ring, and therefore the BLMs should be placed on the "ring-out" side.

This information is summarised in the table below. In the table, RHS and LHS indicate right-hand side and left-hand side of IP1 respectively, as seen by an observer at the centre of the LHC ring looking out, as defined in [16]:

IP1		**LHS**	**RHS**
Station	BLM	Beam 2	Beam 1
240 m	BLM A	-243 m	243 m
	BLM B	-259 m	259 m

Whilst the results suggested here are from based upon simulations of different locations, they are expected to be robust to the differences in the geometry and optics. Therefore, they can be taken with confidence as the appropriate locations of BLMs. Detailed simulations of this regions, however, should be performed to gain an insight into what the appropriate threshold levels should be for the BLMs during operation of the roman pots. The final locations for installation of the BLMs will be determined in consultation with the BLM group and the integration team [17].

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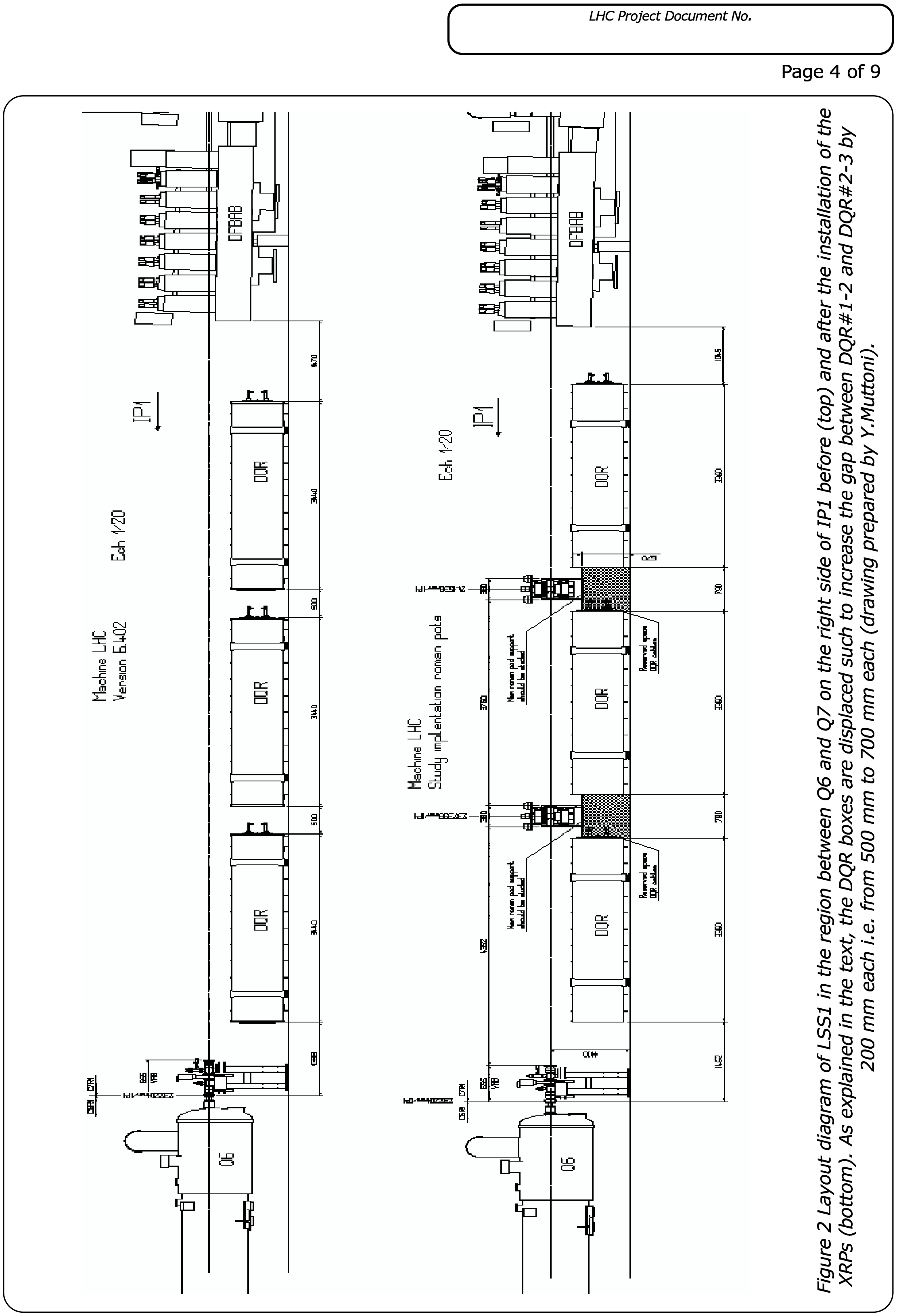

Figure 2: Drawing of the ATLAS 240m station showing the details of the integration between Q6 and Q7. From [2].