MD2725: 16L2 aperture measurement

D. Mirarchi, S. Redaelli, R. Rossi, CERN, Geneva, Switzerland

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Summary

Dumps induced by sudden increase of losses in the half-cell 16L2 have been a serious machine limitation during the 2017 run. The aim of this MD was to perform local aperture measurements in order to assess differences after the beam screen regeneration, compared to first measurements in 2017.

1 Introduction

Dumps induced by sudden increase of losses in the half-cell 16L2 have been a serious machine limitation during summer of 2017 [1]. The aim of this MD was to perform local aperture measurements at the location were the source of these losses was identified, i.e. at the interconnection between orbit corrector (MCB.16L2) and main dipole (MB.C16L2). These measurements are performed by shaping the beam with primary collimators and gently moving it through local orbit bumps until losses are observed. Only measurements in Beam 1 were carried out, due to time constraints (2 hours allocated for this MD). Measurements were performed at injection energy.

2 Measurements procedure

Local aperture measurements were performed, based on a well established procedure that is routinely used to probe the presence of geometrical local aperture restrictions. The main steps were:

1. Inject single probe bunch in Beam 1.

2. Remove the operational bump used to mitigate losses in 16L2 throughout the 2017.

3. Gently blow up using the ADT [2] the beam emittance in both horizontal and vertical planes until losses are observed at IR7 primary collimators (TCPs).
Figure 1: Local orbit bumps matched at the quadrupole 16L2. Left: 4 correctors bump in the horizontal plane. Right: 3 correctors bump in the vertical plane.

4. Trim 4-3 correctors bumps in the H-V plane, respectively, matched to specified value at the main quadrupole in 16L2 (MQ.16L2) increased in steps of 0.5 $\sigma$ until the aperture is touched.

5. Local bump reverted and gentle blow up each time the aperture is touched, to re-establish initial reference conditions.

The step 3 allow a precise knowledge of the beam dimension, i.e. 5.7 $\sigma$ as the TCPs aperture (using normalized emittance $\varepsilon^* = 3.5 \, \mu m$). This, combined with the amplitude of the local orbit bump, allows a direct measurement of the available geometrical aperture.

An example of the bump matched at MQ.16L2 in the horizontal and vertical planes is shown in Fig. 1 left and right, respectively. The choice of the bump shape is imposed by the polarity of the MQ.16L2. In Beam 1 this quadrupole is defocusing, thus the local orbit corrector acts in the vertical plane.

The step 5 allow to restore the initial tail population after its scraping when the aperture is touched. This ensures that the amplitude of the beam envelope is always equal to the TCPs aperture.

3 Beam Loss Monitor layout

Standard Beam Loss Monitor (BLM) [3] are used to detect hadronic showers produced when the beam touches locally the aperture. Additional movable BLMs were installed in 2017 for a more precise longitudinal evaluation of the source of hadronic showers causing the repeated dumps experienced during the year. The complete BLM layout is shown in Fig. 2. An example standard installation and new assembly of 15 BLMs is reported in Fig. 3. They refer to the BLMQI.16L2.B2I30_MQ and BLMMI.16L2.B2I50_MC in Fig. 2, respectively. Only two new assembly of 15 BLMs in series have been installed (BLMMI.16L2.B1E50_MC in Beam 1) to increase the sensitivity to local beam loss. All BLMs are installed on the internal/external side of the machine and are symmetric in the vertical plane. Thus, the same response is expected if the source of hadronic showers is located at the top/bottom of the beam screen.
4 Measurement results

An overview of the local orbit shifts performed is given in Fig. 4, where the beam screen is also shown. The initial closed orbit is indicated by the blue star, while black arrows illustrate the maximum shifts applied until losses are observed locally. The displacement in the horizontal plane is limited by the shift at MQ.17L2 and MQ.15L2, as can be clearly seen in Fig. 1 (left).

4.1 Measured orbit bump

The precise reconstruction of the available geometrical aperture is based on the knowledge of the orbit displacements applied. This is measured using standard LHC Beam Position Monitros (BPM) [4] data. An example of measured vertical orbit when touching the aperture is reported in Fig. 5, taking into account also the beam envelope. Black dots connected by dashed lines represent the close orbit measured by BPMs. The beam envelope of 5.7 $\sigma$ and the aperture model are shown by the red and black solid lines, respectively. The magnetic layout is also reported on the top. Main dipoles, quadrupoles, and orbit correctors are shown by white, blue and green boxes, respectively. The main considerations, based on Fig. 5, are:

- The bump is well matched and symmetric when scanning top/bottom directions
Figure 4: Overview of the local orbit shifts performed. The initial closed orbit is indicated by the blue star, while black arrows illustrate the maximum shifts applied until local losses are observed. The beam screen is also shown.

Figure 5: Example of measured vertical orbit plus beam envelope when touching the top/bottom aperture on the left/right, respectively. Black dots connected by dashed lines represent the measured close orbit by BPMs. The beam envelope of $5.7 \sigma$ and the aperture model are shown by the red and black solid lines, respectively. The magnetic layout is also reported on the top. Main dipoles, quadrupoles, and orbit correctors are shown by white, blue and green boxes, respectively.
The maximum orbit shift is at MQ.16L2, while 2% less amplitude at MCB.16L2 is present, as expected.

The aperture is reached in agreement with the aperture model (i.e. orbit + beam envelope $\sim 17$ mm).

It must be noted that the beam envelope amplitude is evaluated using perfect optics parameters. A systematic error is induced by the beta-beating, which has been measured to be below 10% [5].

4.2 Measured beam loss pattern

An example of local beam loss pattern when touching toward the top/bottom of the beam screen with 0 mm horizontal displacement is shown if Fig. 6 left/right, respectively. For each BLM the background is subtracted and losses are normalized to the highest peak for an easier visual comparison between different cases. Losses on cold elements are shown by the blue bars and magnetic layout is also reported on the top. The Beam 1 direction goes from the left to the right, as also clearly visible by the hadronic shower development leading to the characteristic beam loss pattern. A clear difference is present between two plots in Fig. 6:

- When touching on the top, the source of hadronic showers is at the beginning of the MQ.16L2, as expected due to the bump shape.

- When touching on the bottom, the source of hadronic showers is moved toward the MCB.16L2.

This difference could be due to either and internal misalignment of the beam screen, or something different is really touched on the top/bottom of the beam screen. This ambiguity can be solved looking at the pattern obtained when touching the top with an horizontal displacement of -10 mm, reported in Fig. 7. Also in this condition the local beam loss pattern
Figure 7: Local beam loss pattern when touching toward the top of the beam screen with -10 mm horizontal displacement. The Beam 1 direction goes from the left to the right.

Figure 8: Extrapolated available aperture from beam loss pattern observed. The red areas show the displacements for which the source of hadronic showers is at the MCB.16L2 (i.e. a local aperture restriction is present). The vertical dimension of these areas is given by the resolution of the measurements (i.e. 0.5 $\sigma$ steps). The greens areas show displacements for which the source of hadronic showers is at the MQ.16L2, as expected due to the bump shape.

Based on the different loss pattern observed one can extrapolate what reported in Fig. 8, where the red areas show the displacements for which the source of hadronic showers is at the MCB.16L2. The vertical dimension of these areas is given by the resolution of the measurements (i.e. steps of 0.5 $\sigma$). The green areas show displacements for which the source of hadronic showers is at the MQ.16L2, as expected due to the bump shape.
The extrapolated presence and shape of something sticking on the beam screen at the MCB.16L2 location is consistent with the pumping direction, as shown in Fig. 9. This goes in the direction of accidental air venting during at the end of EYETS 2017-2018, and the gas entered condensed in cold spots in the interconnection area during the cool down of the sector 12.

5 Conclusions

Local aperture measurements were performed to probe the presence of a geometrical aperture restriction at the MCB in cell 16L2. No evident aperture restriction were found, as the aperture is touched at values that are in good agreement with the design aperture model. However, the different beam loss pattern observed as a function of horizontal and vertical displacements may indicate the presence of something sticking on the beam screen at the location of the pumping port in the interconnection between the MCB.16L2 and MB.C16L2. As possible further investigations, energy deposition simulations are required to evaluate the change of beam loss pattern as a function of the hadronic showers source, to confirm what extrapolated from experimental data. Similar measurements were performed in May 2017 after the first dumps caused by sudden increase of losses in the half-cell 16L2. It was also found that no obvious aperture restriction were present. However, the poor BLM granularity without the mobile monitors added along the year do not allow meaningful comparisons with respect to the measurements reported in this note.

References


