EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN – ACCELERATOR AND TECHNOLOGY SECTOR

CERN-ATS-2011-112

FIRST BEAM RESULTS FOR A COLLIMATORWITH IN-JAW BEAM POSITION MONITORS

D. Wollmann, O. Aberle, R. W. Aßmann, A. Bertarelli, C. Boccard, R. Bruce,
F. Burkart, M. Cauchi, A. Dallocchio, D. Deboy, M. Gasior, R. Jones,
S. Redaelli, A. Rossi, G. Valentino, CERN, Geneva, Switzerland

Abstract

With more than 100 collimators the LHC has the most complex collimation system ever installed in an accelerator. The beam-based setup time of the system was a non-negligible factor during the commissioning of the LHC. In addition if the particle orbit at a collimator goes out of tolerance, this collimator needs to be setup again. To reduce the required setup time for the collimation system and to obtain the tight tolerances required for the LHC operation with small beta* and high beam energy, a new collimator design is being developed that integrates a beam position monitor (BPM) into the jaws of the collimator. A prototype of such a phase-II LHC collimator was installed in the SPS at CERN for the 2010 run. In this paper we present the first experimental results from the beam tests performed.

FIRST BEAM RESULTS FOR A COLLIMATOR WITH IN-JAW BEAM POSITION MONITORS

D. Wollmann*, O. Aberle, R. W. Aßmann, A. Bertarelli, C. Boccard, R. Bruce,
F. Burkart, M. Cauchi, A. Dallocchio, D. Deboy, M. Gasior, R. Jones,
S. Redaelli, A. Rossi, G. Valentino, CERN, Geneva, Switzerland

Abstract

With more than 100 collimators the LHC has the most complex collimation system ever installed in an accelerator. The beam-based setup time of the system was a non-negligible factor during the commissioning of the LHC. In addition if the particle orbit at a collimator goes out of tolerance, this collimator needs to be setup again. To reduce the required setup time for the collimation system and to obtain the tight tolerances required for the LHC operation with small beta* and high beam energy, a new collimator design is being developed that integrates a beam position monitor (BPM) into the jaws of the collimator. A prototype of such a phase-II LHC collimator was installed in the SPS at CERN for the 2010 run. In this paper we present the first experimental results from the beam tests performed.

INTRODUCTION

To intercept unavoidable losses of particles from the beam halo into the superconducting magnets the LHC has a powerful collimation system [1, 2, 3]. This system consists of 44 movable collimators per beam in the LHC ring. During the setup of the collimation system the collimators are centred around the particle orbit one by one with the help of beam loss monitors (BLM) installed close to each device [4]. This currently takes between 4 to 13 minutes per collimator [5]. The time consuming setup procedure has to be performed for several machine states: injection (450 GeV); flat top (3.5 TeV); squeezed optics with separated beams and finally with colliding beams. To guarantee the validity of the setup and therefore a sufficient cleaning strict requirements for long term orbit stability have to be fulfilled. The validity of a full setup is currently in the order of 6 months [6].

Collimators with in-jaw beam position monitors (BPM) will drastically reduce the setup time of the collimation system and therefore gain time for physics operation. Furthermore they allow to continuously monitor beam offsets at the collimators, which will increases the passive machine protection. In addition the requirements for long-term orbit stability could be relaxed as a re-setup of the system could be performed much more regular. They will further allow to follow local orbit changes with the concerned collimators and to reduce the margins between collimator families and therefore to improve the cleaning.

* daniel.wollmann@cern.ch

Figure 1: Jaw model of the mock-up collimator with in-jaw BPM buttons [7].

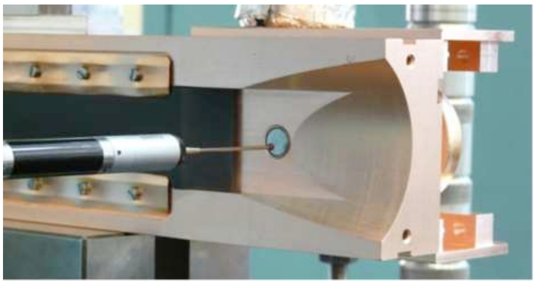

Figure 2: View of the BPM button in the taper at the beginning of the jaw during laboratory measurement of the button position [7].

A first mock-up collimator with in-jaw BPMs was produced at CERN, tested in the laboratory and installed into the SPS in January 2010 [7]. A sketch of the mock-up jaw is depicted in figure 1. Figure 2 shows on BPM button in the taper at the beginning of the jaw during laboratory measurements. An advanced mechanical design and a production prototype are currently under development at CERN [8].

RESULTS OF BEAM MEASUREMENTS

To test the behaviour of a collimator with in-jaw BPMs and the possible setup accuracy several measurements have been performed in the CERN-SPS. These measurements were carried out with circulating beam at 120 GeV.

Scans of gap across the beam

Figure 3 shows the beam offset measured with the in-jaw BPMs at the collimator against the set beam offset. Dur-

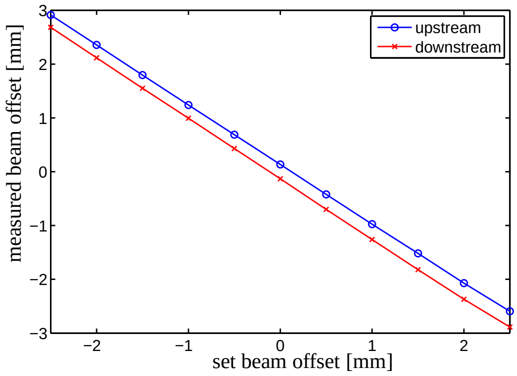

Figure 3: Beam offset measured with BPMs versus the set beam offset. The total gap in the mock-up collimator was 28 mm.

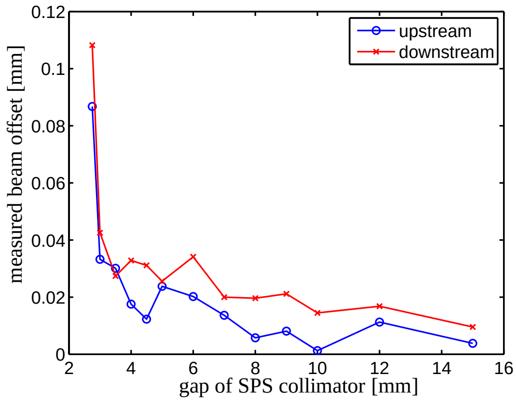

Figure 4: Beam offset measured with the upstream (blue) and downstream (red) BPMs in the mock-up collimator versus the gap of an upstream SPS collimator. The sharp increase of the BPM signal variation for smaller SPS collimator gaps is due to non-linearities in the BPM electronics at low beam intensities. The major part of the beam was already scraped away at that time.

ing this measurement the collimator gap - during this measurement 28 mm - was scanned in steps across the beam. It can be clearly seen that the upstream (blue) and downstream (red) BPM buttons pairs show a good linearity over the scanned range of $\pm 2.5\,\mathrm{mm}$.

Measurements with primary and secondary protons impacting on the jaw

One major expected obstacle for the use of collimators with jaw-integrated BPM buttons was a possible disturbance of the BPM signals due to particles impacting on the jaw.

Therefore several full beam scrapings have been performed with the mock-up collimator. No disturbances of the BPM signals by primary protons impacting on the jaws have been observed so far. The BPM buttons, positioned in the taper at the beginning and end of the jaws, are retracted by $10.5\,\mathrm{mm}$ with respect to the jaw surface. From the above results this retraction seems to be sufficient to avoid the direct impact of protons in the buttons.

To measure the possible impact of secondary protons on the BPM signals, an upstream SPS collimator was used to scrape the beam. The created secondary halo was then intercepted by the mock-up collimator, which was kept at a constant gap of 21 mm. Figure 4 shows the beam offset in the BPM mock-up measured with the upstream (blue) and downstream (red) BPM button pairs versus the gap of the upstream SPS collimator. Up to a SPS collimator gap of 3.5 mm the variation in the BPM signal was $\leq 35\,\mu\mathrm{m}$ which is below the expected accuracy of the used setup ($\sim 50\,\mu\mathrm{m}$). The sharp increase of the variation for smaller SPS collimator gaps is due to non-linearities in the BPM electronics at low beam intensities. The major part of the beam was already scraped away at that time.

Measurements with closed orbit bump

To compare the new BPM based alignment method with the currently used BLM based method a closed orbit bump was created at the mock-up collimator. The amplitude of this bump was changed in steps. After each step the beam offset in the collimator was determined with both methods. The BLM based alignment of the collimators jaws was performed with a step size of $50\,\mu\mathrm{m}$, which defines the accuracy of this method. Smaller step sizes could not be used as the losses then did not cause a clear signal in the BLMs installed close to the mock-up collimator. The accuracy of the BPM alignment was also about $50\,\mu\mathrm{m}$, as the BPM read-out electronics was not calibrated for the used setup.

Figure 5 depicts the beam offset measured with the in-jaw BPMs (red circles) and the BLM method (blue crosses) for the downstream (top) and upstream (bottom) ends of the collimator versus the expected amplitude of the three corrector orbit bump. From these plots it can be clearly seen that the three corrector orbit bump did not work as expected. As significant changes in the orbit were recorded the measurement gave still valid results. The big change of the beam offset in the centre of the plots is due to a re-fill of the beam. The centres determined with the two methods agree within the accuracy of the measurement. In most cases the agreement is significantly better than $50\,\mu\mathrm{m}$.

Figure 6 shows the correlation between the centres measured with the in-jaw BPMs and the BLM dependent method for the downstream (top, red squares) and upstream (bottom, blue diamonds) ends of the collimator. The data were fitted with linear functions (solid lines). The fitted functions are geven in the legends. The black dashed lines define a $70\,\mu\mathrm{m}$ band around the fitted function. The offset between the two methods was $\leq 60\,\mu\mathrm{m}$. All measurements lie within the $70\,\mu\mathrm{m}$ band. This means that the agreement of the two methods is within the accuracy of the measurement.

Measurements in the laboratory and the LHC with the

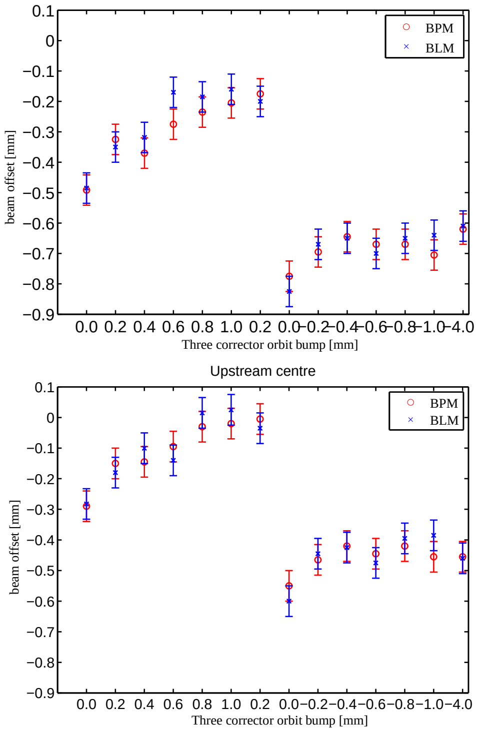

Figure 5: Beam offset measured with for the in-jaw BPMs (red circles) and the BLM method (blue crosses) for the downstream (top) and upstream (bottom) ends of the collimator versus the expected amplitude of a three corrector orbit bump.

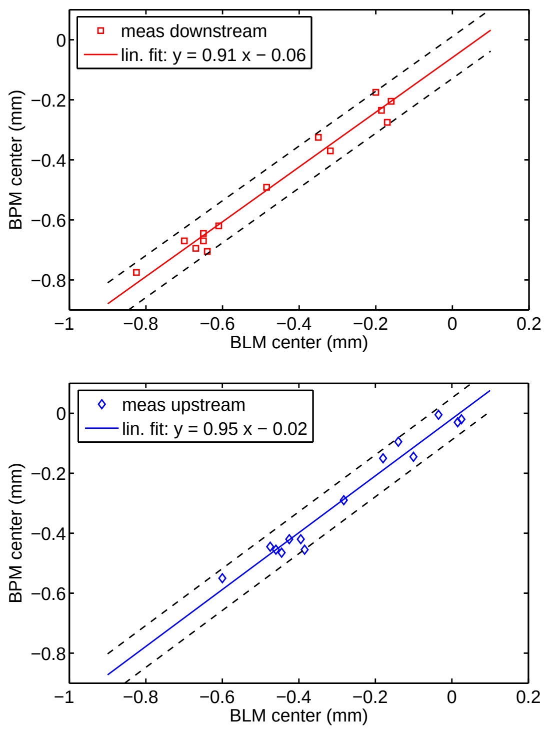

Figure 6: Correlation between the centres measured with the in-jaw BPMs and the BLM dependent method for the downstream (top, red squares) and upstream (bottom, blue diamonds) ends of the collimator. The data were fitted with linear functions (solid lines). The fitted functions are given in the legends. The black dashed lines define a 70 μm band around the fitted function.

BPM electronics, as used during these experiments, have shown that the beam offset can be determined with an accuracy $\leq 1\,\mu$m [7]. During collimator setups of the LHC collimation system at 3.5 TeV a minimum step size of 5 μm was used for the jaw movement [5].

CONCLUSION

Collimators with in-jaw BPMs promise a drastically reduced setup time of the LHC collimation system and less strict requirements for the long-term orbit stability. Furthermore they allow to continuously monitor beam offsets at the collimators and therefore increase the passive machine protection. They would allow tighter collimator settings and, thus, could help to improve the cleaning.

First experiments with a mock-up collimator have successfully been performed in the CERN-SPS. The in-jaw BPM buttons have shown a good linearity during the scans with fixed gaps. So far no disturbances in the BPM signals due to primary or secondary particles impacting on the collimator jaws have been measured. The agreement between the novel BPM and the state of the art BLM based collimator alignment method has been better then 70 μm, which was within the accuracy of the measurement. Taking into account the results of laboratory measurements, tests in the LHC and the LHC collimation setup experience it can be concluded that the accuracy of the BPM setup method will be better than the accurcay of the BLM based method.

REFERENCES

[1] R.W. Assmann. Collimators and Beam Absorbers for Cleaning and Machine Protection. In *LHC Project Workshop - 'Chamonix XIV'*, pages 261–267, 2005.

[2] The LHC design report, Vol. Chapter 2. Technical report, CERN, 2004-003.

[3] The LHC design report, Vol. Chapter 18. Technical report, CERN, 2004-003.

[4] D. Wollmann et al. First Cleaning with LHC Collimators. In *Proceedings of IPAC10 Kyoto, Japan*, 2010.

[5] G. Valentino et al. Comparison of the LHC collimation setups with manual and semi-autometic collimator alignment. In *These proceedings*.

[6] D. Wollmann et al. Multi-turn losses and cleaning. In *Proceedings of LHC Beam Operation Workshop, Evian, France*, 2010.

[7] C. Boccard et al. Embedded Collimator Beam Position Monitors. In *Proceedings of DIPAC 2011*.

[8] A. Dallocchio et al. LHC Collimators with Embedded Beam Position Monitors: A New Advanced Mechanical Design. In *These proceedings*.