BEAM-BEAM SIMULATIONS FOR SEPARATED BEAMS IN THE LHC[*]

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Abstract

We present beam-beam simulation results from a strong-strong gaussian code for separated beams for the LHC. We focus on the possible detrimental effects of the beam-beam interaction in cases when the beams are: (1) periodically swept about each other, and (2) brought into collision from separated orbits. For 10^5-turn runs we do not see significant emittance blowup for nominal bunch intensities, although there is significant blowup at intensities 10 times the nominal value.

1 INTRODUCTION AND SUMMARY

In this note we present an update for beam-beam simulations for the LHC with separated beams. There are two main motivations for these kind of simulations: (a) to assess undesirable effects from LBNL's luminosity monitoring scheme for the LHC [2], and (b) to assess undesirable effects form the process of bringing initially-separated beams into collision.

The results presented here were obtained with a three-dimensional strong-strong gaussian code whose main features are described in Ref. 1. This investigation is an extension of the work by Zorzano and Zimmermann [3], and of Krishnagopal [4].

In our simulations the ring lattice is represented by a linear one-turn map that depends on the machine tunes and beta functions at the interaction point. A synchrotron rotation is performed on the longitudinal coordinates of the macroparticles. For simplicity in this preliminary investigation we use a single bunch per beam (*i.e.*, parasitic collisions are ignored), we set the crossing angle to zero, we ignore radiation damping and quantum excitation, and we assume that there is only one interaction point in the ring. Our code can describe beam-beam collisions with separated beams by means of an input-specified closed-orbit displacement in the transverse plane. This displacement can be static or time dependent, and can be independently specified for either (or both) of the two beams. In all cases we use $M = 10^4$ macroparticles per bunch. Machine parameters are listed in Table 1 [5].

2 RESULTS

For nominal conditions, beams colliding center-on-center, the results are shown in Fig. 1. It is clear that the beam blowup is insignificant over 10^5 turns, and the rms

Table 1: Selected nominal LHC parameters

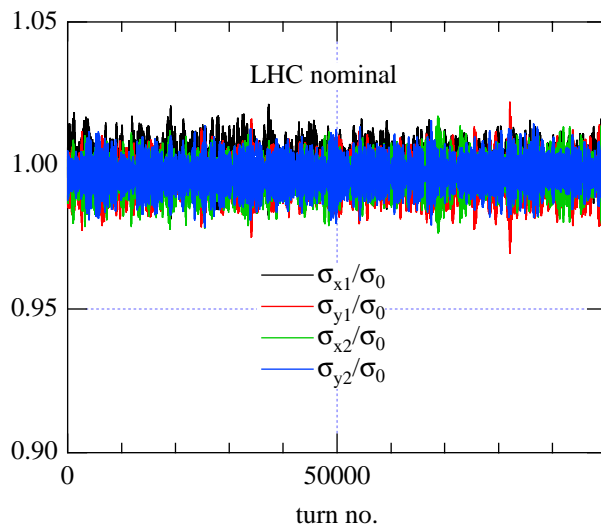|	
Beam energy parameter, γ	7460.52
Protons per bunch, N	1.05×10^{11}
Beta-function at the IP, β^* [m]	0.5
RMS spot size at the IP, σ^* [μm]	15.9
Nominal beam-beam parameter, ξ	-0.0034
Tunes, (ν_x, ν_y)	$(0.31, 0.32)$
RMS bunch length, σ_z [m]	0.077
Synchrotron tune, ν_s	0.0021

Figure 1: The rms beam sizes for nominal collisions.

sizes show the expected statistical fluctuations of order $M^{-1/2} = 1\%$.

If the bunch intensity is increased by a factor of 10 there is a $\sim 2\%$ beam blowup for center-on-center collisions, as seen in Fig. 2.

In the LBNL luminosity monitoring scheme [2] one beam is deliberately swept in a circle about the other beam, which remains fixed. As a first test, we have chosen here a sweeping radius of $0.6\sigma_0$ for beam #2 while beam #1 remains static and is offset by $0.2\sigma_0$ from the nominal IP at $45°$ relative to the horizontal axis. The luminosity per collision is shown in Fig. 3, exhibiting the characteristic fluctuations with a period of 10^3 turns, which is our trial sweeping period. The rms beam sizes (Fig. 4) do not show significant differences with the nominal conditions (Fig. 1), although there is clear beam blowup for $N = 1.05 \times 10^{12}$, as seen in Fig. 5.

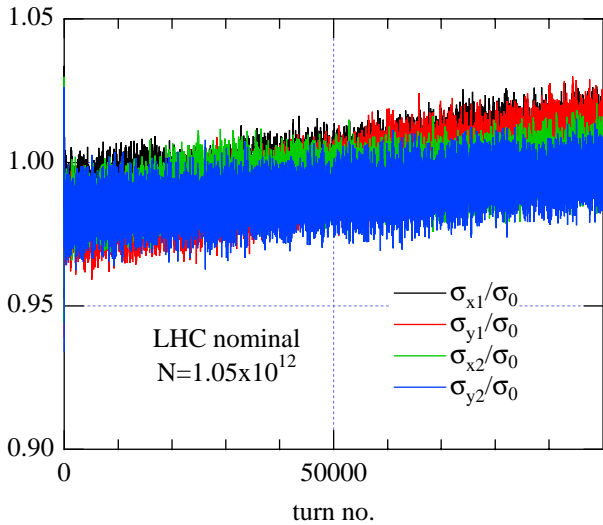When the beams are brought into collision from a sep-

Figure 2: The rms beam sizes for center-on-center collisions at high bunch intensity.
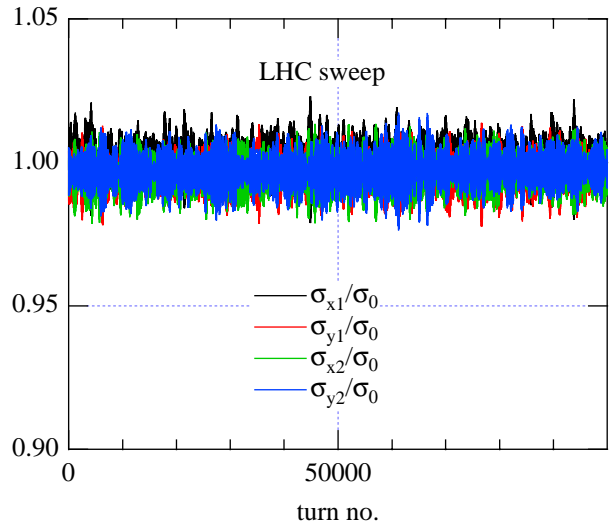

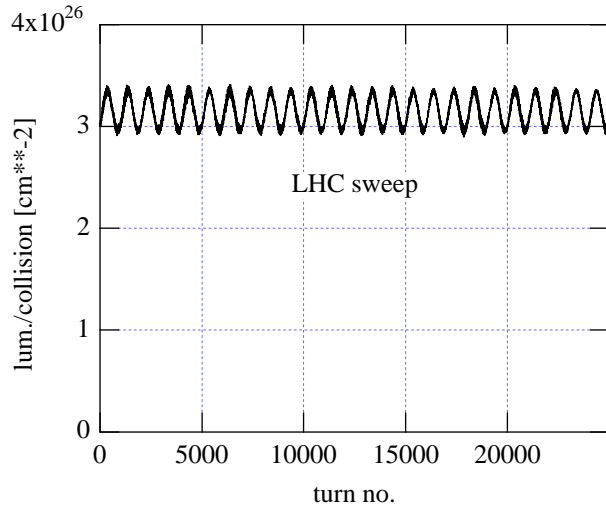Figure 4: The rms beam sizes during the sweeping process at nominal bunch intensity.

Figure 3: The luminosity per collision when bunch #2 sweeps about the nominal IP.

Figure 5: The rms beam sizes during the sweeping process at high bunch intensity.

arated state, we assume that the closed orbit of beam #2 starts out vertically displaced from the nominal IP by $3\sigma_0$ and is linearly brought down to the nominal IP over a time interval of 25000 turns, while beam #1 is held fixed at the nominal IP. Fig. 6 shows the normalized beam centers, and Fig. 7 shows the rms beam sizes. At high intensity the beam sizes clearly exhibit nontrivial dynamical effects, as seen in Fig. 8.

3   DISCUSSION

Since our results are obtained from relatively short runs, they may change upon further examination. For the high-intensity cases it is not clear how much the blowup is numerical, and how much it is a real physical effect (a scaling law for numerical beam blowup is suggested in Ref. 1). However, in the cases presented here, we have not found
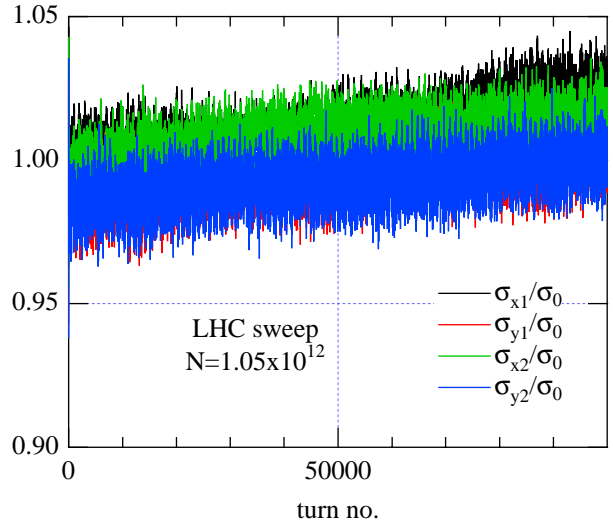
any indications of adverse effects for nominal bunch intensities. If the bunch intensity is increased by a factor of 10 there are clear indications of beam blowup in 10^5 turns. However, we find it interesting that the beam blowup for the beam sweeping case at high intensity is comparable to the center-on-center case. This suggests that the beam sweeping does not have a significant adverse effect on the machine operation relative to the normal operating mode. In contrast, when the beams are kept separated at a fixed distance, there is substantial beam blowup (at least for the chosen tunes) at high intensity, as seen in Fig. 9. This result suggests that this mode of operation should be minimized, or perhaps the machine working point should be dynamically adjusted when the beams are in this configuration.
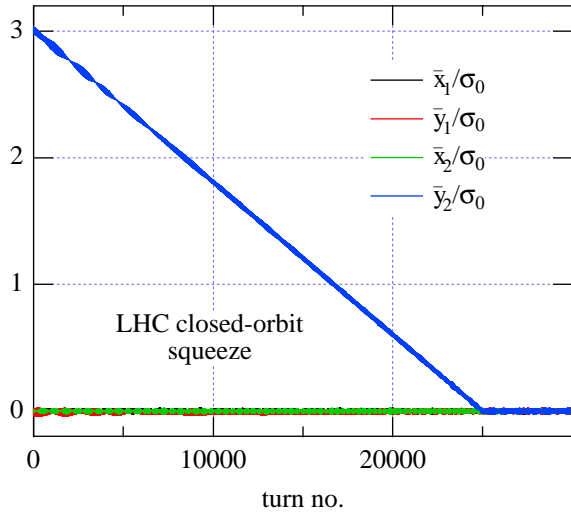
Figure 6: The normalized beam centers as a function of time during a vertical closed-orbit squeeze.
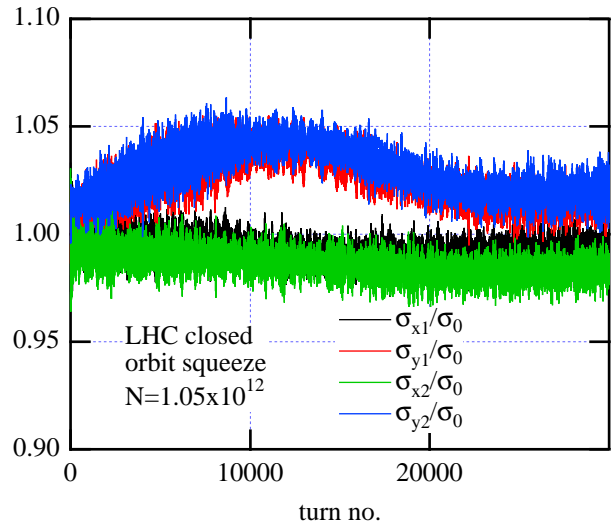

Figure 8: The rms beam sizes during a vertical closed-orbit squeeze at 10 times nominal beam intensity.
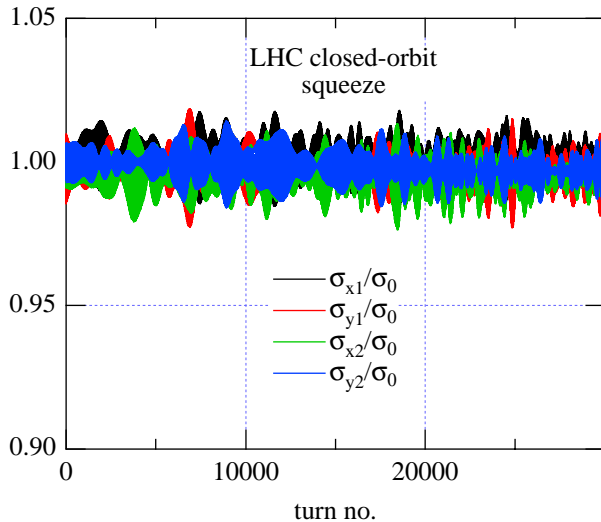

Figure 7: The rms beam sizes during a vertical closed-orbit squeeze at nominal bunch intensity.
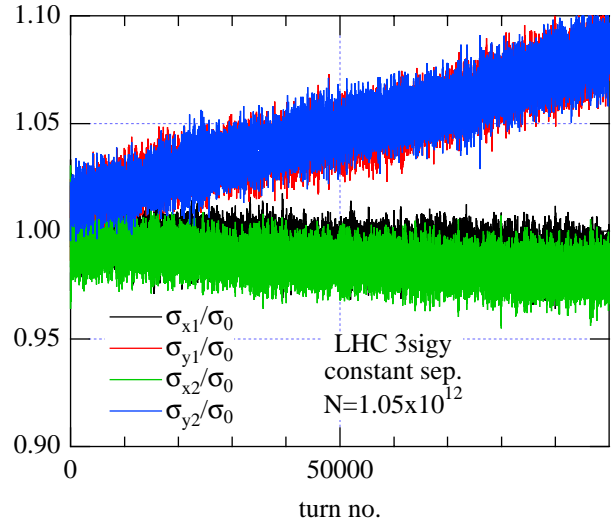

Figure 9: The rms beam sizes as a function of time in case the beams are kept vertically separated by $3\sigma_0$.

4   ACKNOWLEDGMENTS

5   REFERENCES

[1] M. A. Furman, Proc. US-LHC Collaboration Meeting, BNL, February 22–23, 2000.

[2] W. Turner, *ibid.*

[3] M. P. Zorzano and F. Zimmermann, PRST-AB **3**, 044401 (2000).

[4] S. Krishnagopal, M. A. Furman and W. C. Turner, Proc. PAC99, New York City, March 29–April 2, 1999, p. 1674; S. Krishnagopal, Proc. Workshop on Beam-Beam Effects in Large Hadron Colliders LHC99, April 12–17, 1999, CERN-SL-99-039 AP, p. 52.

[5] CERN/AC/95-05(LHC), 20 October 1995.