SIMULATIONS OF LONG RANGE BEAM-BEAM EFFECTS IN CESR IN A STRONG-STRONG SCENARIO*

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Abstract

The Long Range Beam-Beam Interaction (LRBBI) is one of major limiting factor to the performance of a pretzel collider machine like CESR in which each bunch has several tens parasitic crossing points along the ring. To investigate the effects due to LRBBI, simulation studies are done with new simulation code in weak-strong and strong-strong scenarios. The precise simulations reveal that LRBBI, in the case of CESR, has significant effects on machine parameters. Especially the bunch-by-bunch differences, which can hardly be compensated by routine adjustments of operation conditions, may affect the luminosity performance directly. In future, with possibly higher current, more bunches or higher current/ energy ratio, the dedicated compensation schemes are necessary.

1 INTRODUCTION

The Cornell Electron Storage Ring (CESR) has been operating at Wilson Laboratory on the Cornell University since 1979. The present operating energy range is 4.7 to 5.8 GeV per beam to study the B meson family. There is a plan to extend the operation range to as low as 1.5 GeV to study the charm physics in the coming years[1].

The luminosity of CESR has increased by a factor of nearly three orders of magnitudes since the first year of operation through a series of innovative upgrades in the storage ring configuration. A large part of increase has been due to using many bunches in each beam. The interaction between count-rotating bunches, primarily through long range electromagnetic fields, must be limited at all parasitic crossing points to avoid beam losses or other harmful effects. Since only a single vacuum chamber is available in CESR the interaction is reduced by establishing separate closed orbits for the two counter rotating beams by means of electrostatic separators. These separate orbits follow large pseudo-sine-like betatron trajectories (pretzel orbit) around the complete circumference. In such a colliding beam machine with a single ring and n bunch/beam, there are 2n-1 parasitic crossings of the counter-rotating bunches. The guide field of one beam depends on the charge per bunch in the opposing beam via the long range interaction at each of the parasitic crossing points. In recent CESR crossing angle configuration there are nine trains of four or five bunches in each beam.

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2 SIMULATION CODE

The simulation code is written based on BMAD, the major accelerator physics code used in CESR. The working procedure is:

- Calculate the TWISS parameters of one beam without LRBBI.
- Add LRBBI elements according to above beam parameters.
- Calculate the LRBBI effects on the EACH BUNCH in other beam(each bunch sees different LRBBI). This is called weak-strong calculation[2].
- Define LRBBI elements according to new TWISS parameters. Here, to define LRBBI elements seen by one bunch, one needs to know parameters of all bunches(each one has different orbit and beta-functions and so on due to LRBBI) in other beam.
- Do iterations until a good equilibrium is reached. This is what we call strong-strong calculation.
- Other simulations are done with this equilibrium machine condition.

Table 1: Main Parameters Used in Simulations

Beam Energy	5.3 GeV
Circumference	768.43m
Tunes	Qx=10.52, Qy=9.60
Nature emittance	2.1E-7 m.rad
Beta-functions at IP	1.0m/1.8cm(H/V)
Bunch current	6~9 mA
Bunches per Beam	45
Bunches per Train	5
Number of Trains	9
Bunch Spacing in train	14 ns
Train Spacing	280ns, 280ns, 294ns, 280ns, 280ns, 294ns, 280ns, 280ns, 294ns
Total Current	540mA ~ 810mA
Beam Optics	Normal HEP conditions

The head-on collision at south IP where CLEO detector is located is not included since two kinds of interactions are quite different in strength and properties. Please note term 'strong-strong scenario' used here is different from that in dealing with head-on collision where individual particle in a bunch see very different beam-beam force. In long range beam-beam interaction, since beams are well separated (usually 8-15 RMS beam sizes), individual particles in the same bunch experience the similar long range beam-beam force. Therefore the each bunch can be considered as a whole when LRBBI is evaluated.

The LRBBI element is defined as 2D Gaussian distribution bunch. The comparison between this model and line charge distribution is done. No obvious difference is found with current machine parameters.

The simulation results of some typical ring parameters, e.g., tunes, are compared to experiments. The good agreements are seen, including both absolute effects and bunch-by-bunch differences.

3 MAJOR RESULTS

Simulations are done with various machine conditions. Here results with typical CESR operation conditions (see Table 1) are shown.

Table 2: Effects of LRBBI on global ring parameters

	Overall effects	Bunch-by-bunch diff.
Qh	~ -0.02	~ 0.003
Qv	~ +0.02	~ 0.003
Chrom. h	mixed	~ 0.5
Chrom. v	mixed	~ 1.0
Emitt.	+	2~20%
βh/βv	mixed	0~10%
orbits	mixed	0~20%

Table 3: Effects of LRBBI on key parameters at IP

	Overall effects	Bunch-by-bunch diff.
V_offset*	Diff.	~ 1 μm
H_offset	Mixed	~ 100 μm
H_angle	Same	little
V_angle	Mixed	little
βh	+ 10~20%	~ 10%
βh	Mixed	~ 2%

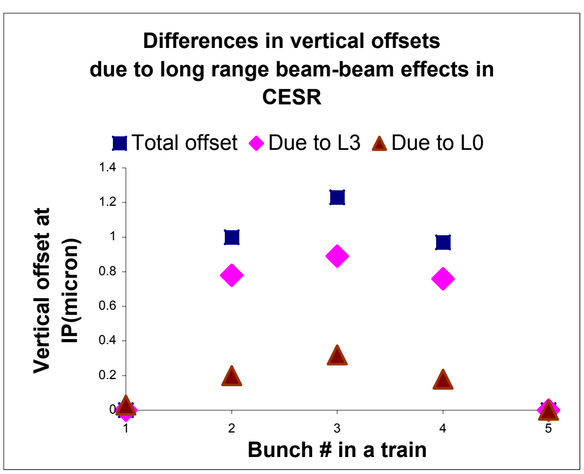


Figure 1

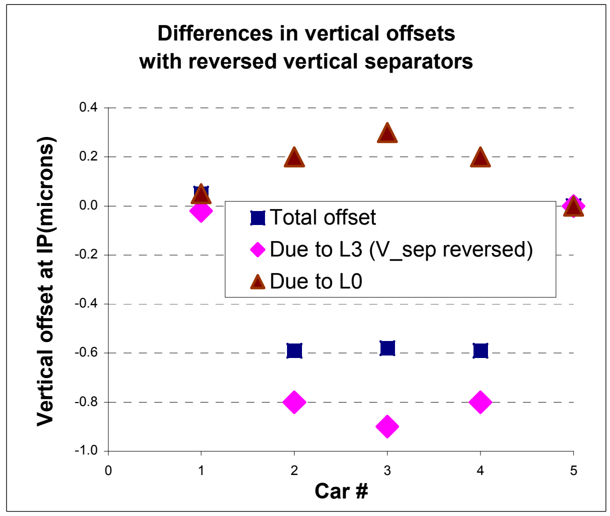


Figure 2

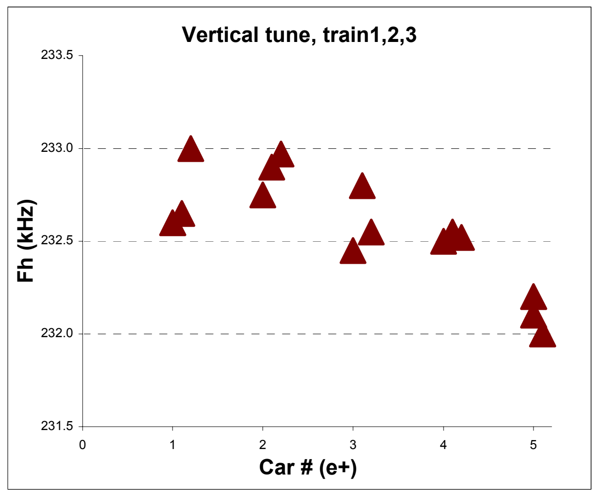
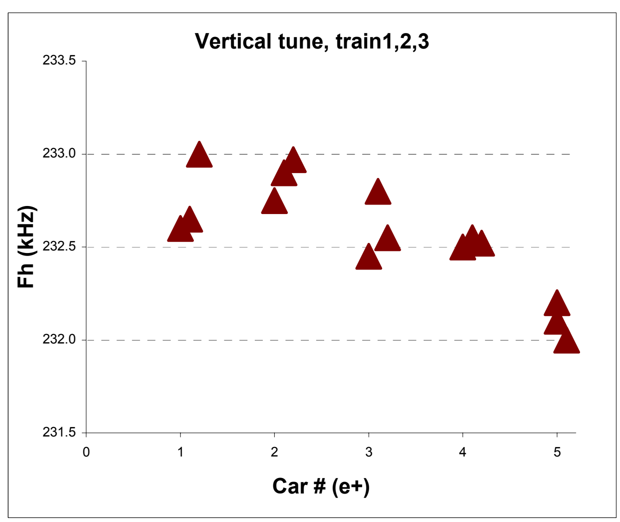


Figure 3



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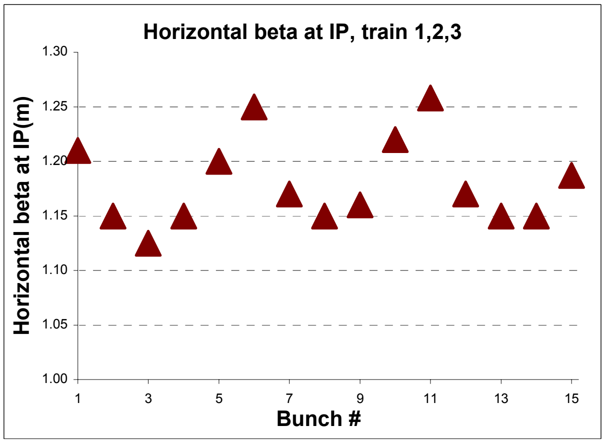

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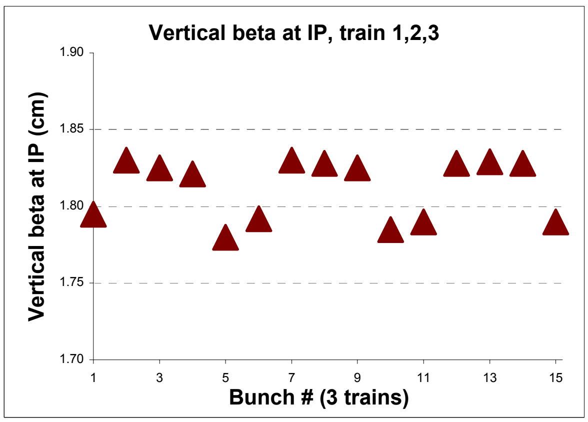

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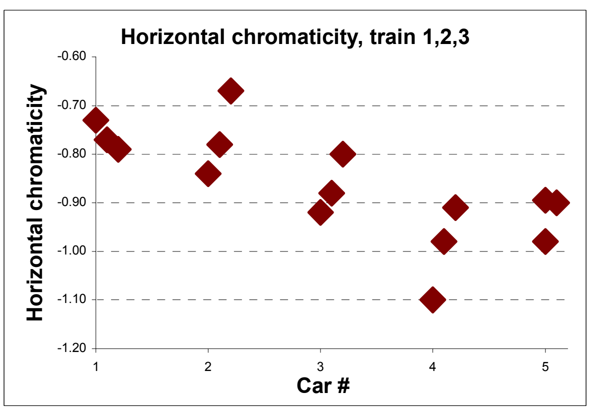

Figure 7

4 REMARKS

The precise simulations reveal that LRBBI, in the case of CESR, has significant effects on machine parameters. Especially the bunch-by-bunch differences, which can hardly be compensated by routine adjustments of operation conditions, may affect the luminosity performance directly.

- Vertical offsets at IP
  The bunch-by-bunch difference can be as large as 1 ~2 micron, a significant fraction of vertical beam size, depending on the vertical separator settings. Detailed experimental studies can be found in [3]. This effect results in significant difference in specific bunch luminosities. Those differences can only compensated by bunch-by-bunch techniques. The source of those vertical offsets are tracked down in simulation by
- Tunes
  The bunch-by-bunch difference may limit the range of tuning in tune space and may cause life time problem to some bunches.
- Chromaticities and emittance
  Chromaticites of bunches may vary about 1 unit amount. The change in emittance depends strongly on the horizontal tune.
- Beta-functions at IP
  The changes are not very significant.

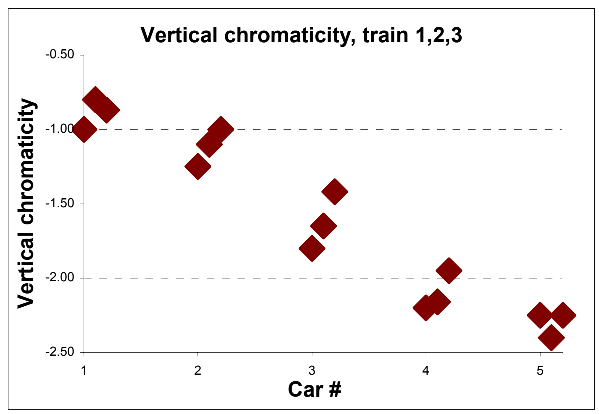

Figure 8

5 SAMMURY

Due to the fact that sources of LRBBI effect are multi parasitic beam-beam crossing points, the simulation is the best way to understand how they affect the beam parameters. Our study shows that the strong-strong simulation is a quite precise and powerful tool. With the increase of current/energy ratio and number of bunches, the LRBBI must be the essential part of optics design and optimization. Further compensation schemes are also necessary.

6 REFERENCES

[1] D. Rubin, CESR Status and Performance, these proceedings, 2001
[2] D. Rubin, Colliding Beam Note 96-02, 1996
[3] D. Sagan, These proceedings, 2001