CERN PS BOOSTER SPACE CHARGE SIMULATIONS WITH A REALISTIC MODEL FOR ALIGNMENT AND FIELD ERRORS

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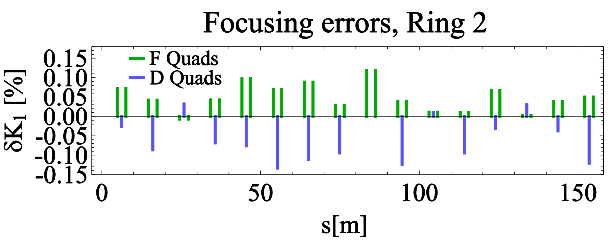
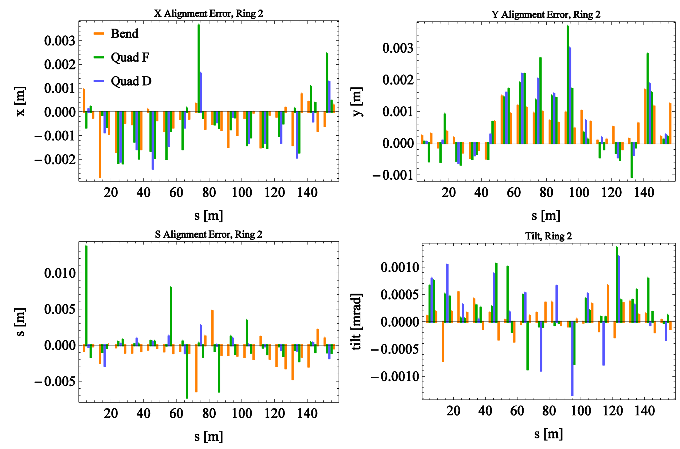
Abstract

The CERN PS Booster is one of the machines of the LHC injector chain which will be upgraded within the LIU (LHC Injectors upgrade) project. The injection energy of the PSB will be increased to 160MeV in order to mitigate direct space charge effects, considered to be the main performance limitation, thus allowing to double the brightness for the LHC beams. In order to better predict the gain to be expected, space charge simulations are being carried out. Efforts to establish a realistic modeling of field and alignment errors aim at extending the basic model of the machine towards a more realistic one. Simulations of beam dynamics with strong direct space charge and realistic errors are presented and analysed in this paper.

Estimation of lattice errors



- The distribution of linear errors in the machine lattice was estimated using the Linear Optics from Closed Orbits (LOCO) method [2] for the working point (4.20, 4.26).
- With alignment errors, the lattice model reproduced well the measured off-plane responses, so coupling parameters were not used in fit [3].
- The model parameters used as variables were the strengths of each of 16 defocusing quads and each of the 16 pairs of focusing quads and the calibration of the dipole correctors and of the BPMs [4].



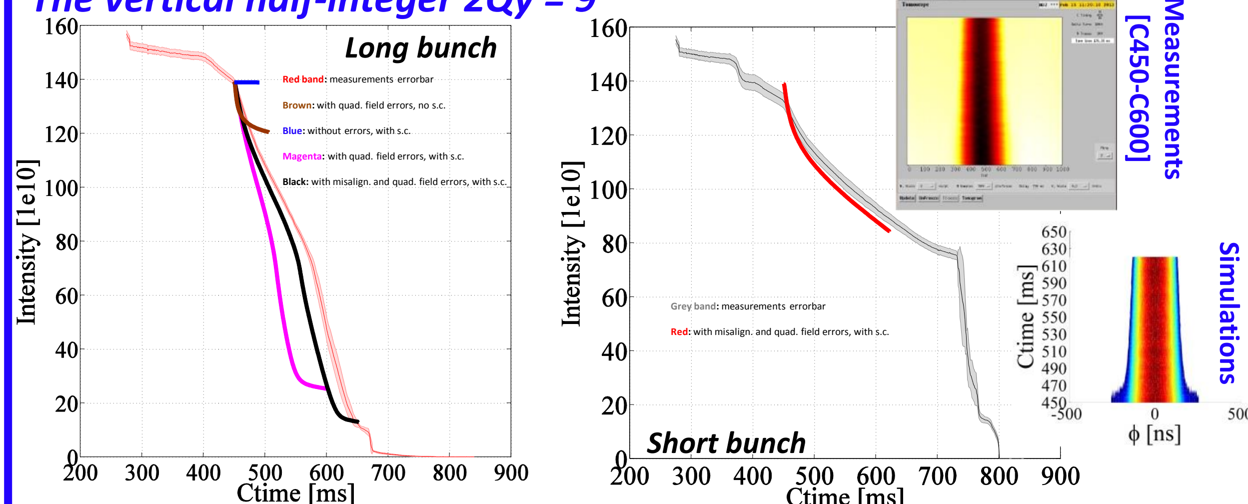
Introduction

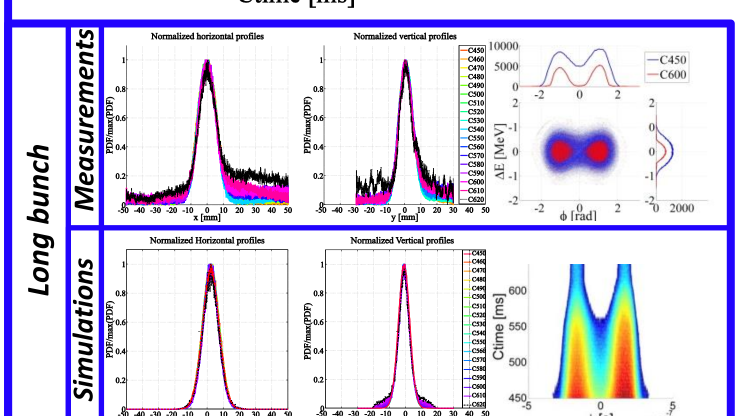
The evaluation of future space charge (s.c.) effects on the beam has to be performed through simulation codes. PTC-Orbit [1] has been selected as tracking code, as it includes the PTC tracking part and the contributions of collective effects (i.e. space charge) through Orbit. To benchmark the code with the measurements, an accurate model of the PSB lattice is necessary, including elements misalignments and magnetic fields errors. To underline the importance of a complete model in combination with direct space charge effects, measurements and simulations are shown in this paper on a 160MeV flat plateau. Two specific cases, concerning a half-integer (2Qy=9) and an integer (Qy=4) resonance, are analysed.

Simulations settings for space charge

Longitudinal s.c.	ON (128 bins)
Transverse s.c.	2.5D PIC-FFT w/o boundaries
N. of bins [x,y]	128, 128
N. of macrop.	500000
N. of s.c. nodes	201

The vertical half-integer 2Qy = 9

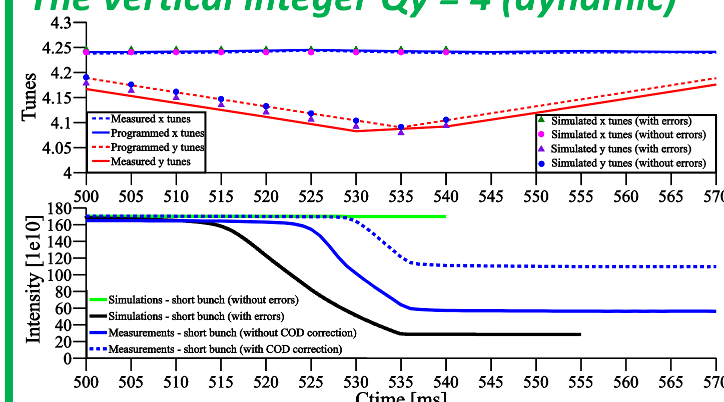


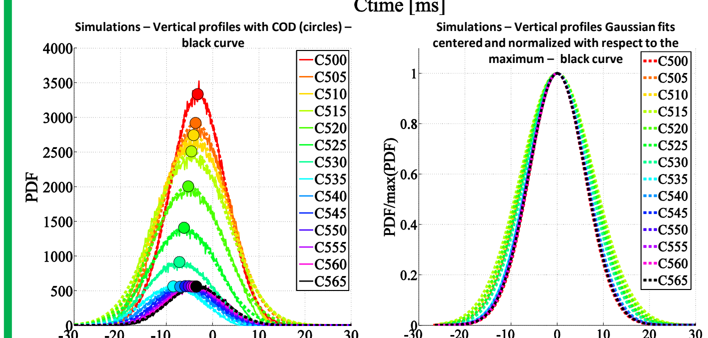


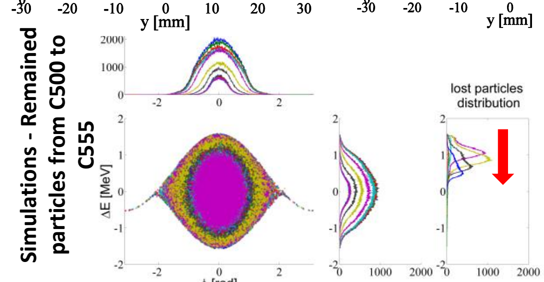
- Long-term measurements (170ms) on a 160 MeV plateau in Ring 2 (static tune).
- Very good agreement between measurements and simulations.
- Conservation of the transverse Gaussian beam core (1σ).
- Vertical tails after C600 (black curve) in the long bunch case due to resonance trapping.
- Longitudinal bunch shortening: large synchrotron oscillations particles are lost due to scattering mechanisms around the resonance [5].

Initial beam parameters	Long bunch	Short bunch
Bunch population [10^{12} p.]	1.39	1.32
σ_x, σ_y [mm]	5.21, 3.6	6.05, 3.67
ε^*_x, ε^*_y [mm mrad]	2.64, 2.05	3.24, 2.21
RF voltage (h=1, h=2)	8kV, 8kV	8kV, 8kV
RF cavities relative phase	π	0
Total bunch length [ns]	634	400
Bunching factor	0.44	0.24
Momentum spread (1σ)	1.35×10^{-3}	1.95×10^{-3}
Programmed tune [Qx, Qy]	4.28, 4.53	4.28, 4.53
Simulated [ΔQ_x, ΔQ_y]	-0.16, -0.24	-0.27, -0.37

The vertical integer Qy = 4 (dynamic)







- Dynamic vertical tune approach (toward Qy=4) on a 160MeV plateau in Ring 2.
- Closed Orbit Distortion (COD) and RMS emittance blow-up approaching the resonance [C500-C535].
- The bunch is scraped due to the COD.
- The chromatic tune spread affects the beam degradation: mainly particles with large longitudinal amplitude and positive Δp/p are lost.

Initial beam parameters	Short bunch
Bunch population [10^{12} p.]	1.7
σ_x, σ_y [mm]	5.68, 5.96
ε^*_x, ε^*_y [mm mrad]	2.68, 5.05
Starting programmed tune [Qx, Qy]	4.24, 4.19
Simulated [ΔQ_x, ΔQ_y]	-0.24, -0.23

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Conclusions

The combined effect of a realistic set of errors (alignment and quadrupolar fields) and direct space charge has been analysed in a benchmark between measurements and simulations with the PTC-Orbit code in the PSB. Two cases have been taken into account. In the first, concerning a static w.p. close to the 2Qy=9 half-integer resonance, simulations showed very good agreement with the measurements for long and short bunch. The second case, concerning the dynamic approach of the Qy=4 integer resonance, showed the coupled effect of space charge and closed orbit distortion on beam losses. This case has both RMS and COD blow-up while approaching the resonance, but requires further investigations adding the proper set of vertical steerers to the simulated lattice, in a way to obtain the closed orbit correction similar to the one observed in the control room during the measurements. Chromatic corrections are foreseen in future measurements and simulations to disentangle the chromaticity from the s.c. induced tune spreads.