Long-range beam-beam effects during injection oscillations

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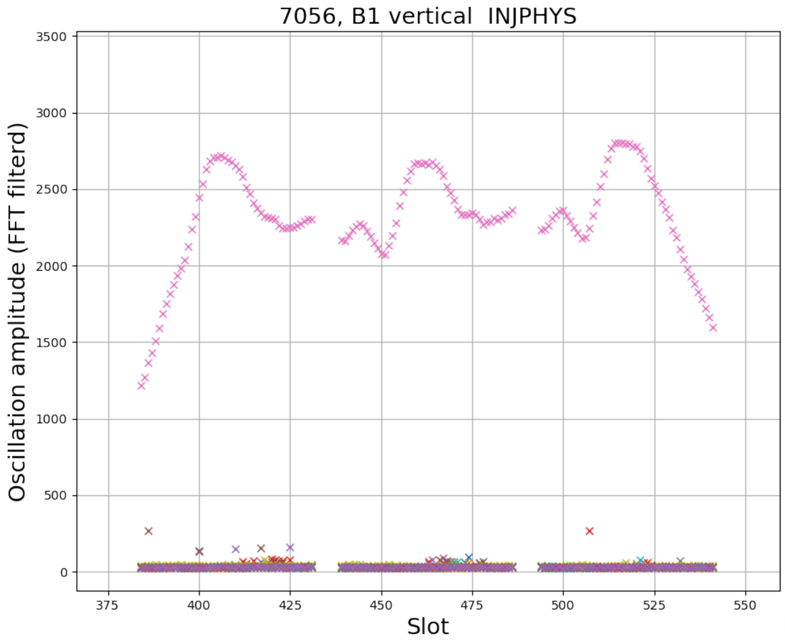
Content

- LHC observations
- Long-range beam-beam separation at injection
- Simulations
- Extrapolation to HL-LHC

Observation at LHC

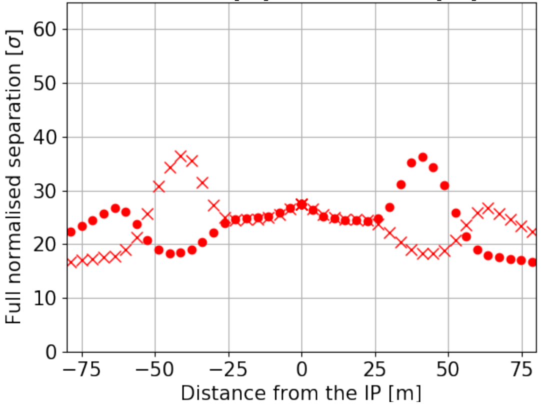
- The ADTObsBox often triggered on the oscillations of the circulating beam at injection (see also L. Carver, et al. @ LBOC 22.08.2017)
- The pattern associated with PACMAN effect (i.e. long-range beam-beam interaction) is clearly visible in the individual bunches' oscillation amplitude
- Such a pattern is however not observed in the emittances at flat top

  → The impact on the emittance is either not measurable or masked by other effects
- It is still the case for HL-LHC ? If not, shall we use the aperture margin to increase the crossing angle at injection ?

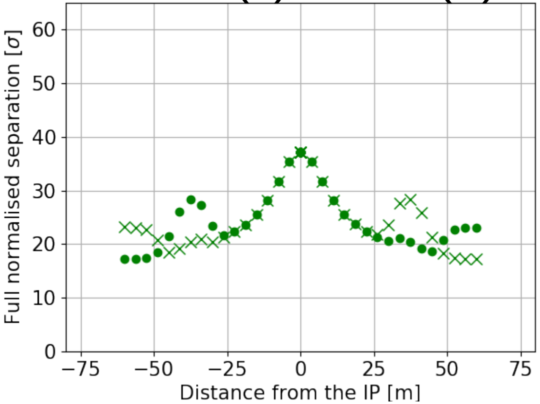


Normalised separation at injection

IPs 1 (x) and 5 (●)



IPs 2 (x) and 8 (●)

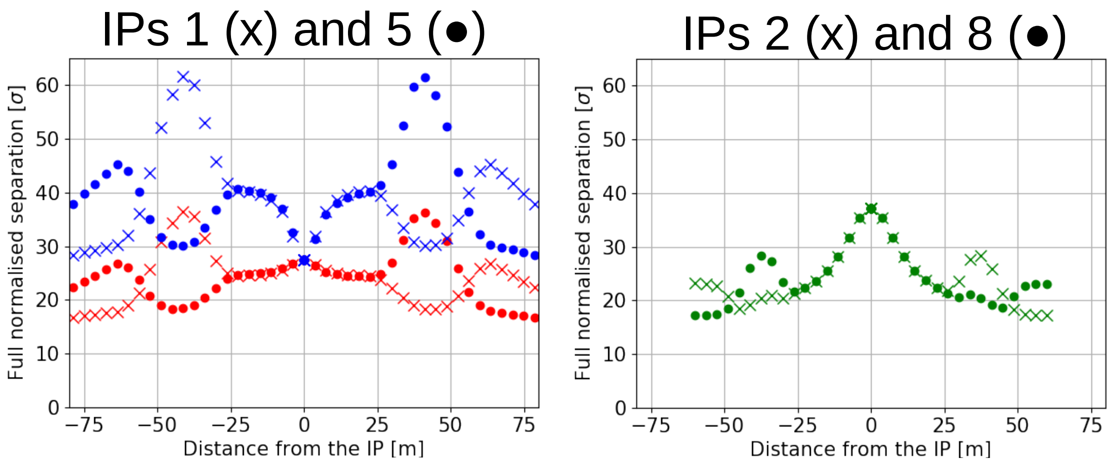


295 µrad
500 µrad
170 µrad

$$d = \sqrt{\left(\frac{x_{B1} - x_{B2}}{\sigma_x}\right)^2 + \left(\frac{y_{B1} - y_{B2}}{\sigma_y}\right)^2}$$

- In the baseline, the normalised separation at the long-range interactions is similar in all IRs at injection (crossing and separation bumps)

Normalised separation at injection



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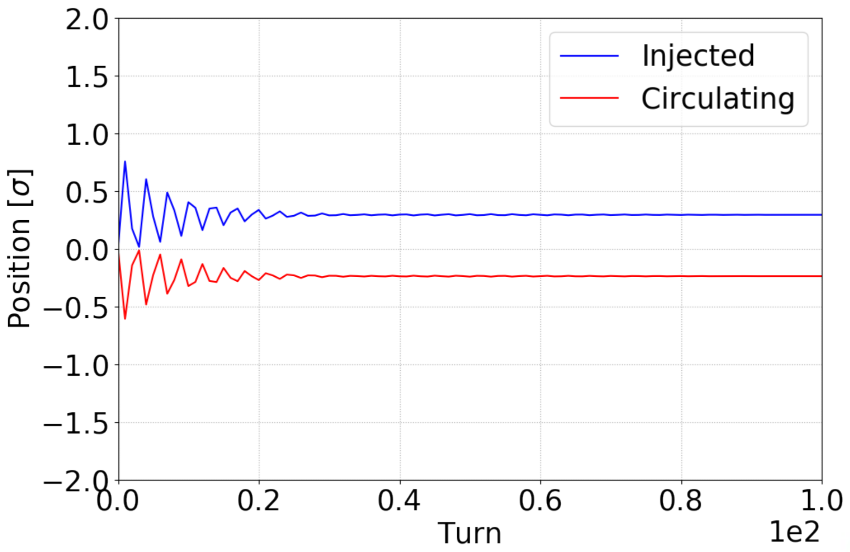
- In the baseline, the normalised separation at the long-range interactions is similar in all IRs at injection (crossing and separation bumps)
- Increasing the crossing angle in IPs 1 and 5 to 500 µrad brings their contribution in the shadow of IPs 2 and 8.

Orbit re-matching

- Numerical model (COMBI):
  - One bunch per beam, ε=1.7μrad, N=2.2E11, E = 450 GeV
  - 33 long-range interactions lumped into 1 (one IP), **d=16σ**
  - $Q_{x/y}$ = 0.31/0.32, Q' = 15, Q_s=0.0023
  - Octupole current 40A
  - Damper gain 0.02 (τ=10 turns)
  - Soft-Gaussian coherent beam-beam interaction, **including orbit effect**
  - Injection **on 'ideal' orbit**



- Even with a perfect injection, the closed orbit is modified by the long-range interactions leading to emittance growth by filamentation

  → This effect can only be mitigated by increasing the normalised separation

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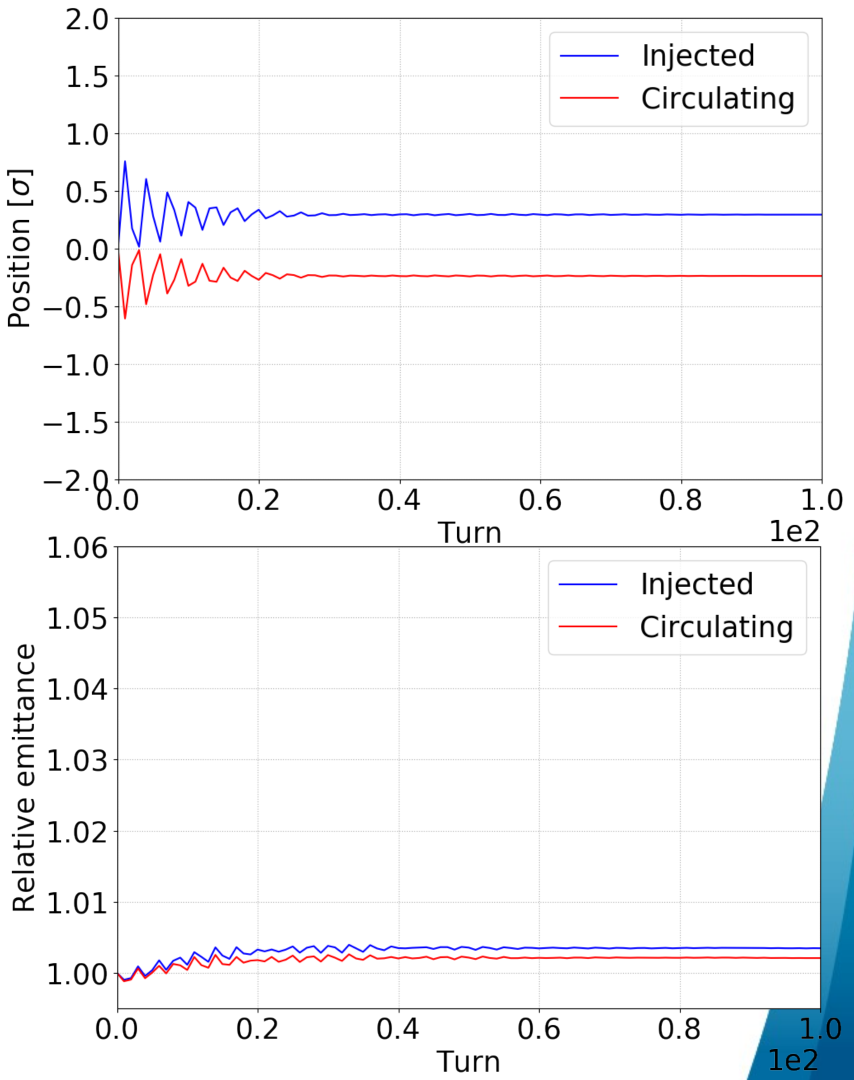
- Even with a perfect injection, the closed orbit is modified by the long-range interactions leading to emittance growth by filamentation

  → This effect can only be mitigated by increasing the normalised separation
- For an orbit effect of ±σ/4, the emittance growth remains at the permil level



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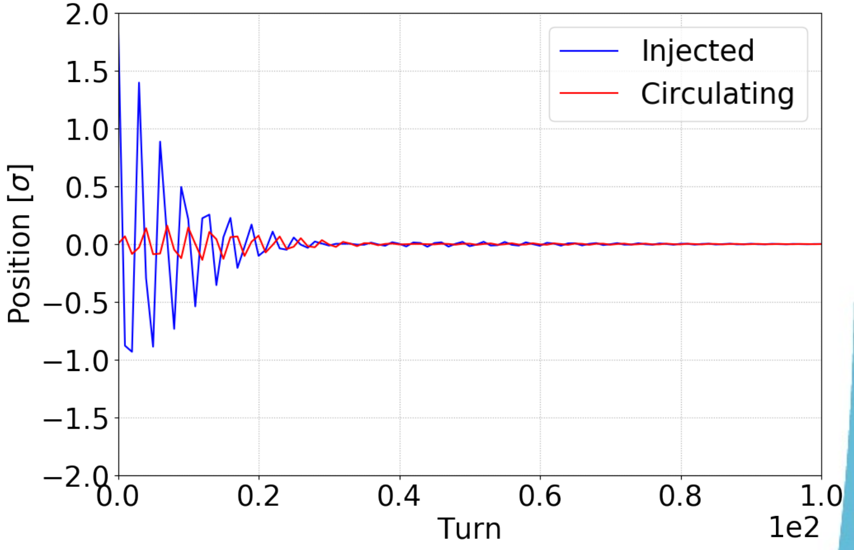

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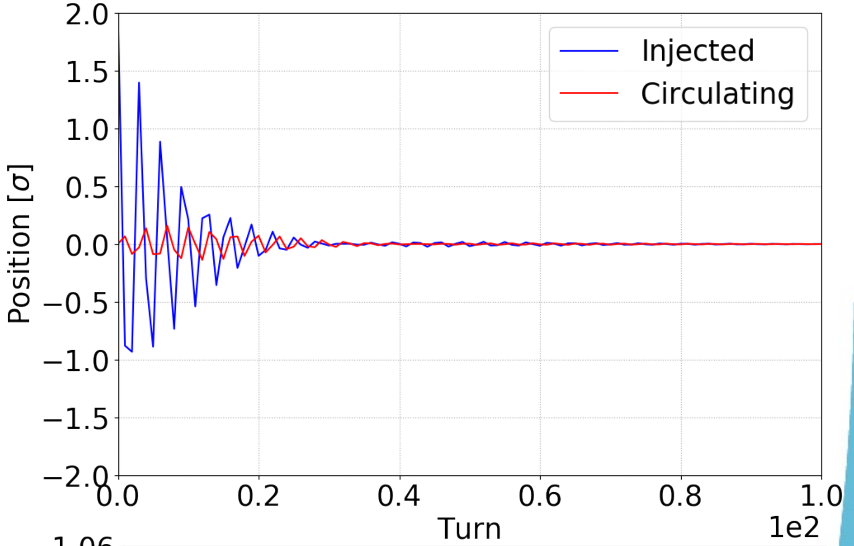
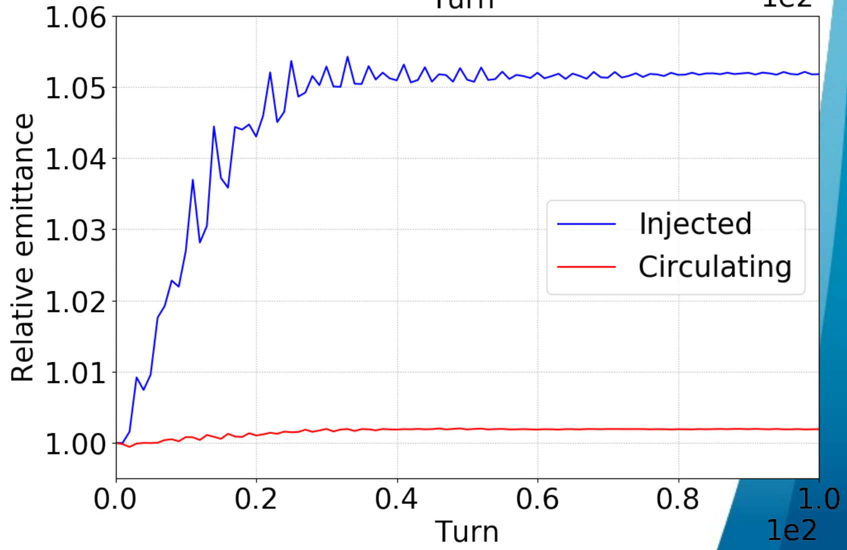
  - Octupole current 40A
  - G=0.02 (τ=10 turns)
  - Soft-Gaussian coherent beam-beam interaction **(w/o orbit effect)**
  - Injection **off by 2σ**
- Depends onquality of the injection steering
- The emittance growth resulting from the transmission of the oscillation remains significantly smaller than in the injected beam





Reduction with the separation

- As expected the orbit re-matching dominates at high separations (~1/d) and the transmission dominates at small separations (~1/d^2)
- The mitigation of the emittance growth resulting from the increase of the crossing angle from 295 to 500 μrad (~20σ to ~35σ) is marginal due to the weak dependence of the orbit part