Simulations of Noise and Emittance Growth in the LHC for Colliding Beams

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1. Abstract:

The use of luminosity levelling (LL) in the HL-LHC is likely and there are a number of different methods that have been suggested to implement this. In the case of β^* levelling, it has been suggested that flat beams might be advantageous [1]. Here we present preliminary results from simulations using the COherent Multi-Bunch Interaction code (*COMBI*), for two bunches colliding head on, under the influence of an arbitrary sourced white noise in the absence of any crossing angle, longitudinal motion and long range effects. Simulations were undertaken for flat and round beam profiles. These initial simulations suggest that there is no significant emittance growth due to the use of flat beams in comparison to round beams.

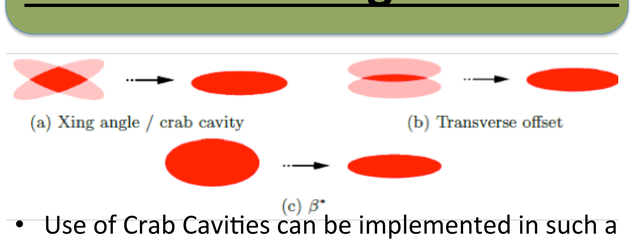
2. Objectives:

- Simulate an external white noise between colliding beams.
- Perform a beam-beam parameter scan to evaluate the dependency on the beam-beam strength and the dependency on the noise amplitude.
- Determine effect in context of HL-LHC upgrade.
- Compare results with simulations by Ohmi [2]

7. Results:

- Flat and Round beams simulated under the influence of an external undamped white noise.
- Preliminary results suggest no significant difference between emittance growth for flat and round beam profiles under the influence of an external noise.
- Results are preliminary so not yet conclusive, more work required.

3. Some other possible HL-LHC Levelling Scenarios



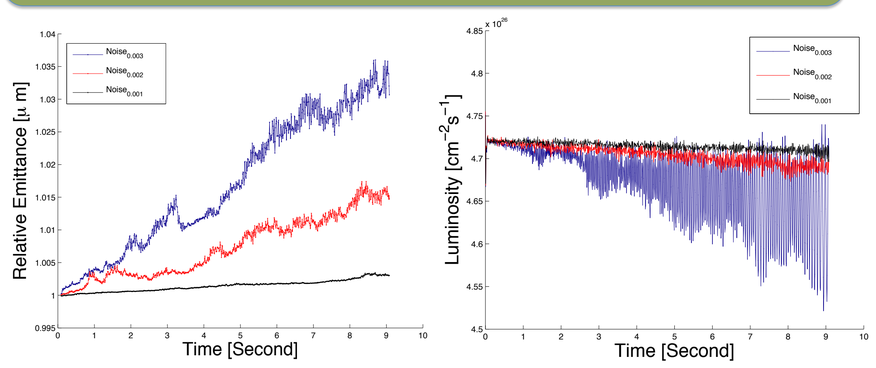
- Use of Crab Cavities can be implemented in such a way as to anti-crab the beam and sequentially increase the luminosity as the luminosity decays over time.
- Beam offset reduces the luminous overlap region between bunches. However, a large offset results in a small tune spread which can reduce beam stability.
- Beta star levelling can be utilised by slowly decreasing the beta function at the IP as the luminosity decays over time.

4. Beam Profiles and Aspect Ratios.

Altering the β-function in the *x* and *y* plane allows the beam aspect ratio to be altered. Hence enabling flat beams to be implemented in *COMBI*, only with head on collisions. To include long range collisions for the flat optics, further work on the code is required. The relationship between the β-function in the different planes and the aspect ratio is given by,

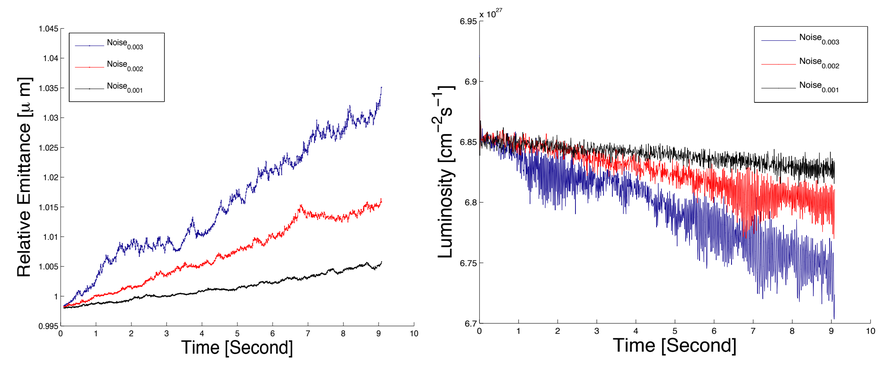
$$\beta_x^* = r\beta^*,$$
$$\beta_y^* = \frac{\beta^*}{r},$$
$$\beta^* = \sqrt{\beta_x^* \times \beta_y^*}.$$

5. Simulations of Round Beams:



Simulations for round beam profile. Figure on the left shows the relative emittance growth over 100,000 turns. As expected the largest noise that acts on the bunch causes the largest emittance growth. This leads to an increase in bunch size which will lead to a decay in luminosity. As shown in the figure on the right.

6. Simulations of Flat Beams:



Simulations for the flat beam profile. The beta functions are varied in the *x* and *y* plane, this will vary the beam aspect ratio in the two planes. The beam aspect ratio a value of 2, with a beta function along the *x* plane given by 0.3m and 0.075m along the *y* plane. The noise acts along the *x* plane, with a radial deflection applied to the particles in the bunch by a white noise. The figure on the left shows the emittance growth and the figure on the right shows the luminosity decay over 100,000 turns. There appears to be no significant difference in emittance growth between flat and round beam profiles.

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Conclusions and Further Work:

- Preliminary results suggest no significant emittance growth observed between the different beam profiles.
- Only head on collisions considered here, long range effects, longitudinal motion and crossing angle. These effects may have a more significant impact on the emittance growth.
- Only an uncoupled noise along the x axis was considered here, more complex noise models should also be simulated.
- Possibly further extend *COMBI* to include crossing angle and crab cavities.
- More work required, only preliminary simulations so not yet conclusive.

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