Beam-beam induced crabbing

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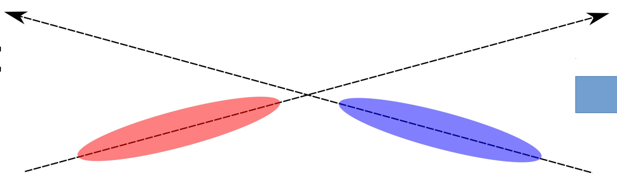
HL-LHC WP2 meeting 21.04.2020

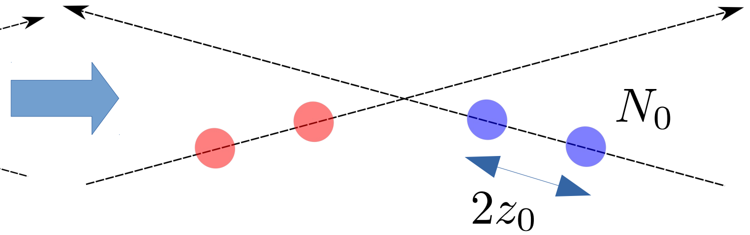
Content

- A pesssimistic model based on a simplified incoherent 6D beam-beam kick using the two particle model
- Coherent kick based on Hirata's 6D approach
- Results for the HL-LHC at start and end of collision

Two particle model :

(Incoherent)





- Reducing the distribution of N particles into two point-like particles:

$$N_0 = \frac{N}{2}, \quad z_0 = \int_0^{\infty} \frac{z}{\sqrt{2\pi}\sigma_z} e^{-\frac{z^2}{2\sigma_z^2}} \approx \frac{\sigma_z}{\sqrt{2\pi}}$$

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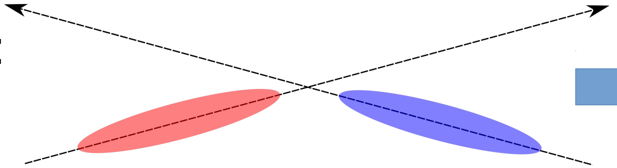

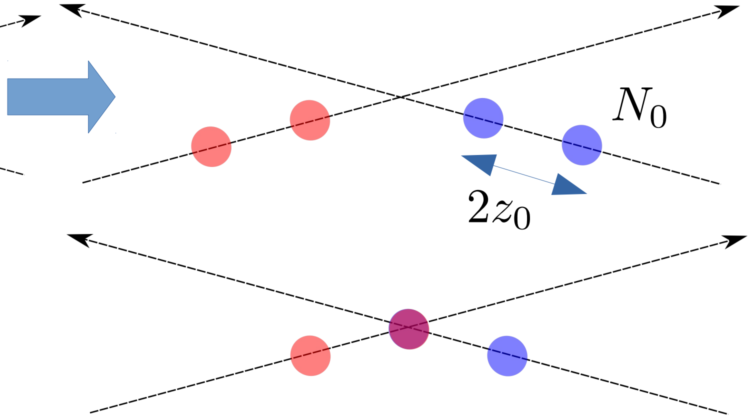

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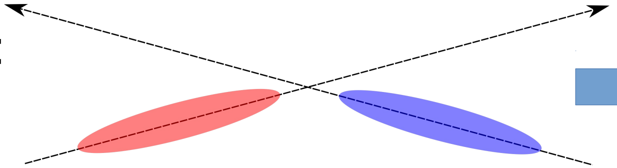

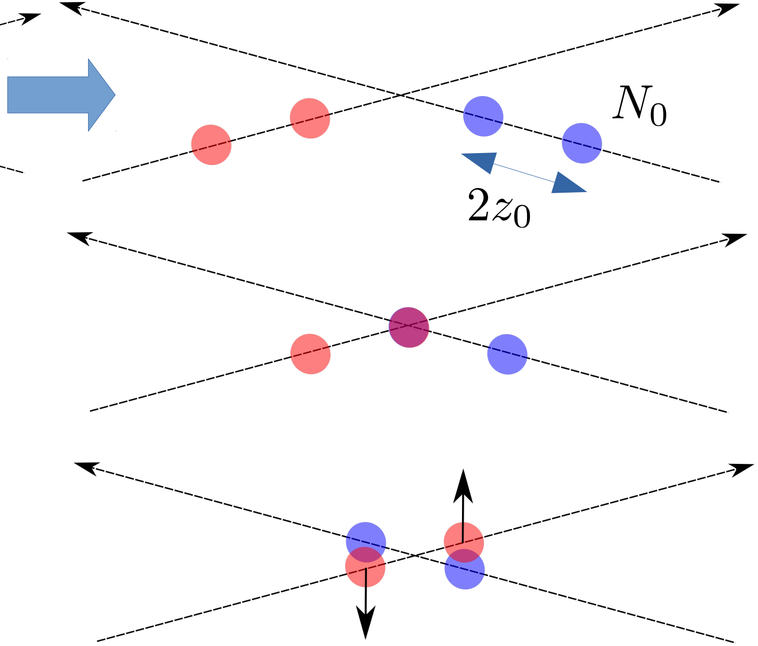

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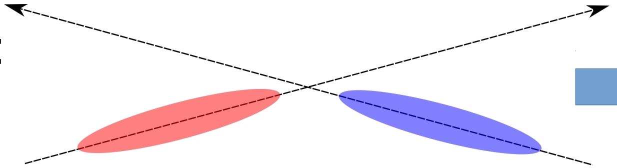

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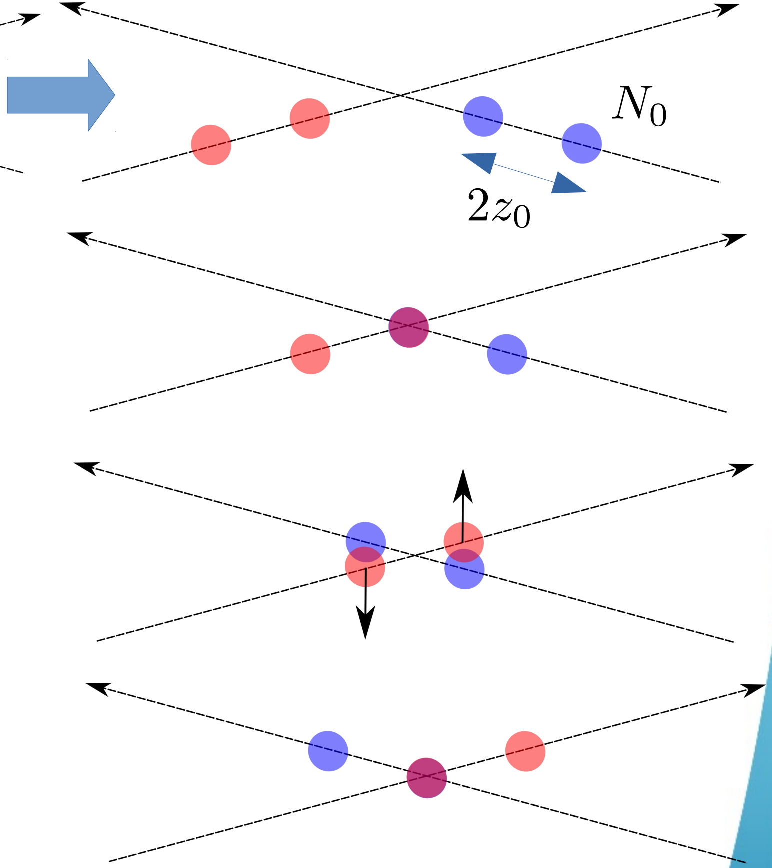

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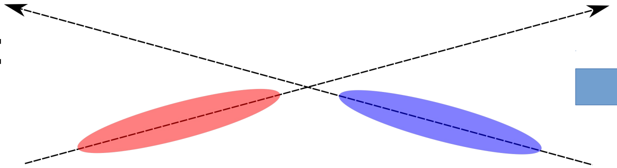

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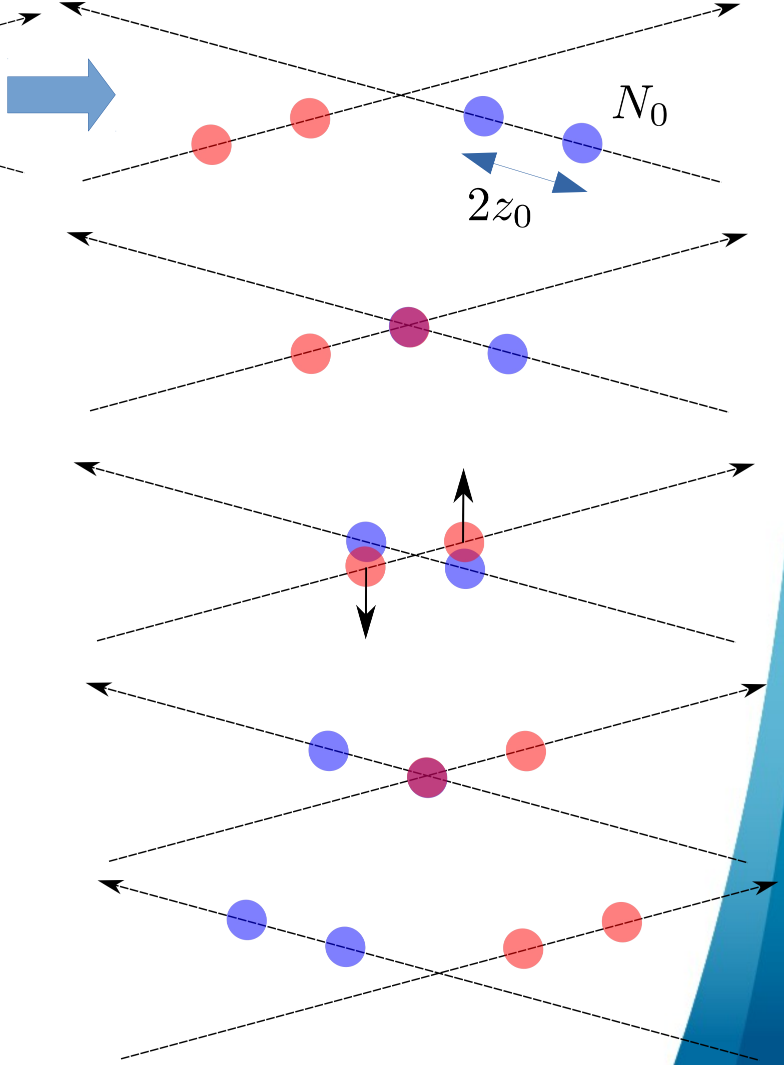

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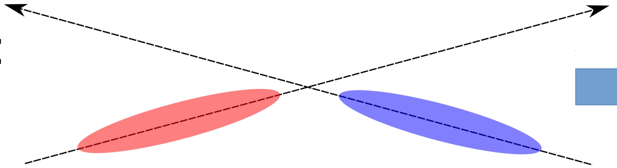

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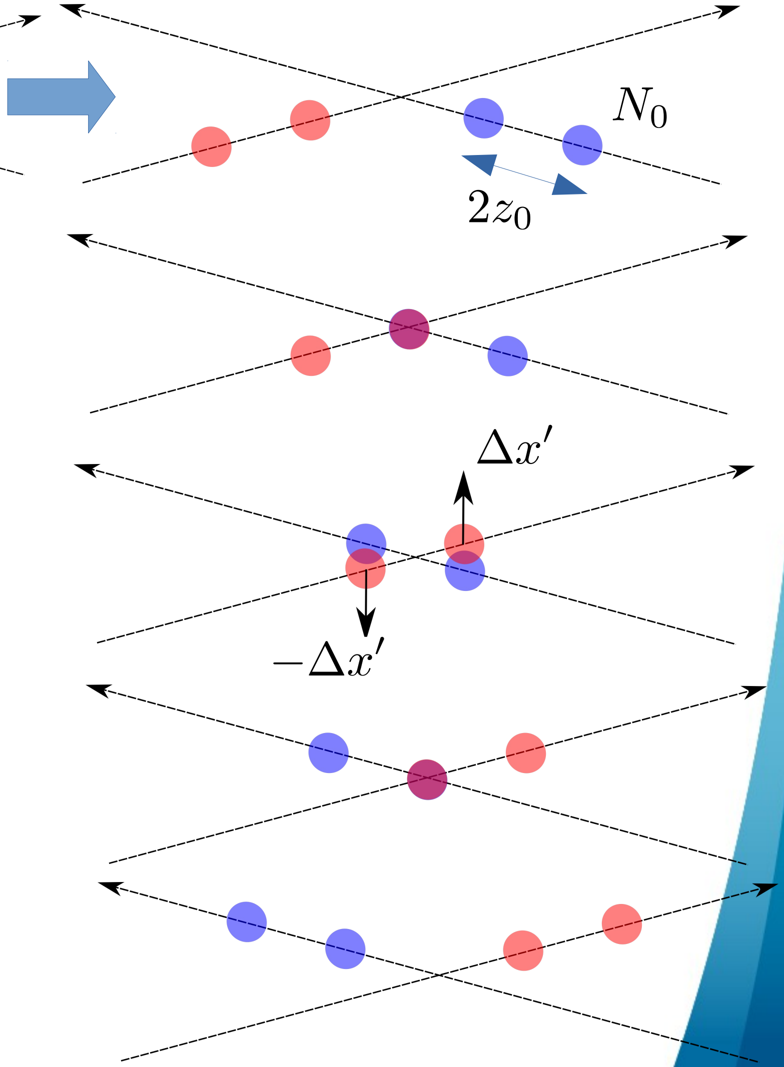
$$\max \Delta x' \approx 0.9 \frac{N_0 r_p}{\gamma \sigma}$$



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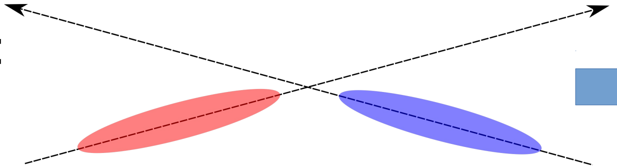

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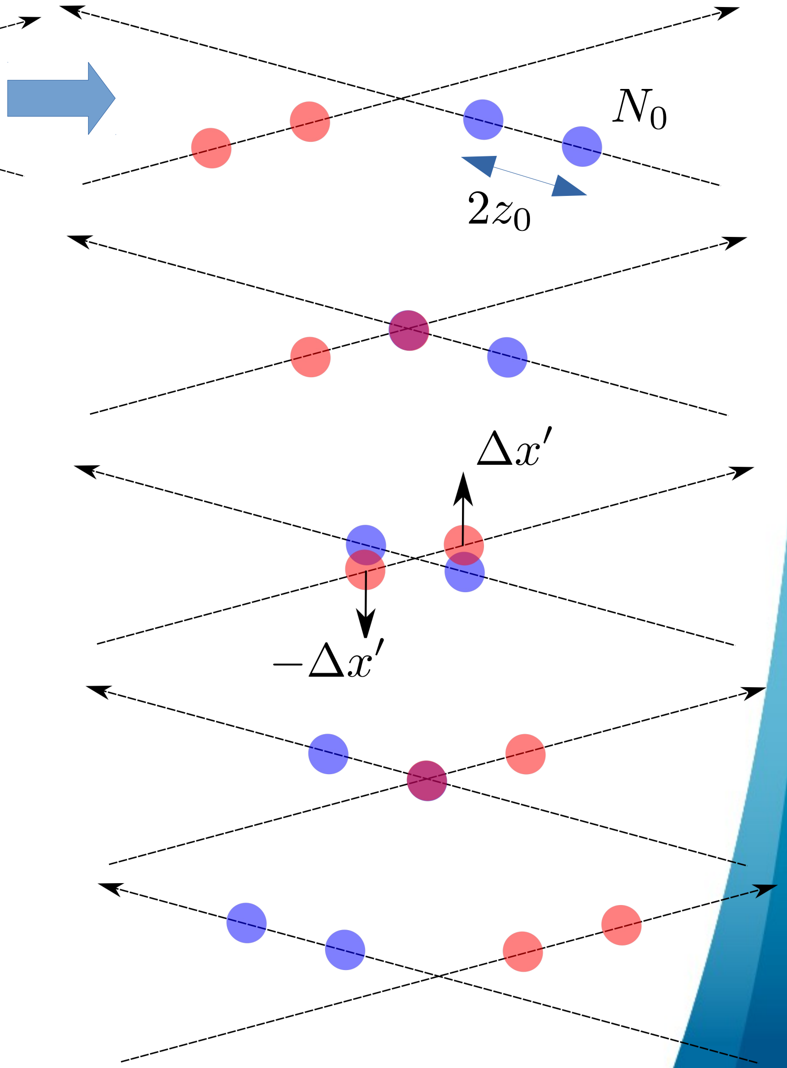
$$\max \Delta x' \approx 0.9 \frac{N_0 r_p}{\gamma \sigma}, \max \Delta x = \Delta x' \frac{\sqrt{\beta(s)\beta^*}}{2\sin(\pi Q)}$$

- The maximum beam-beam induced crab angle is:

$$\max \phi = \arctan\left(\frac{\max \Delta x}{z_0}\right)$$



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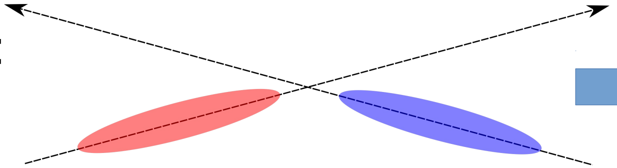

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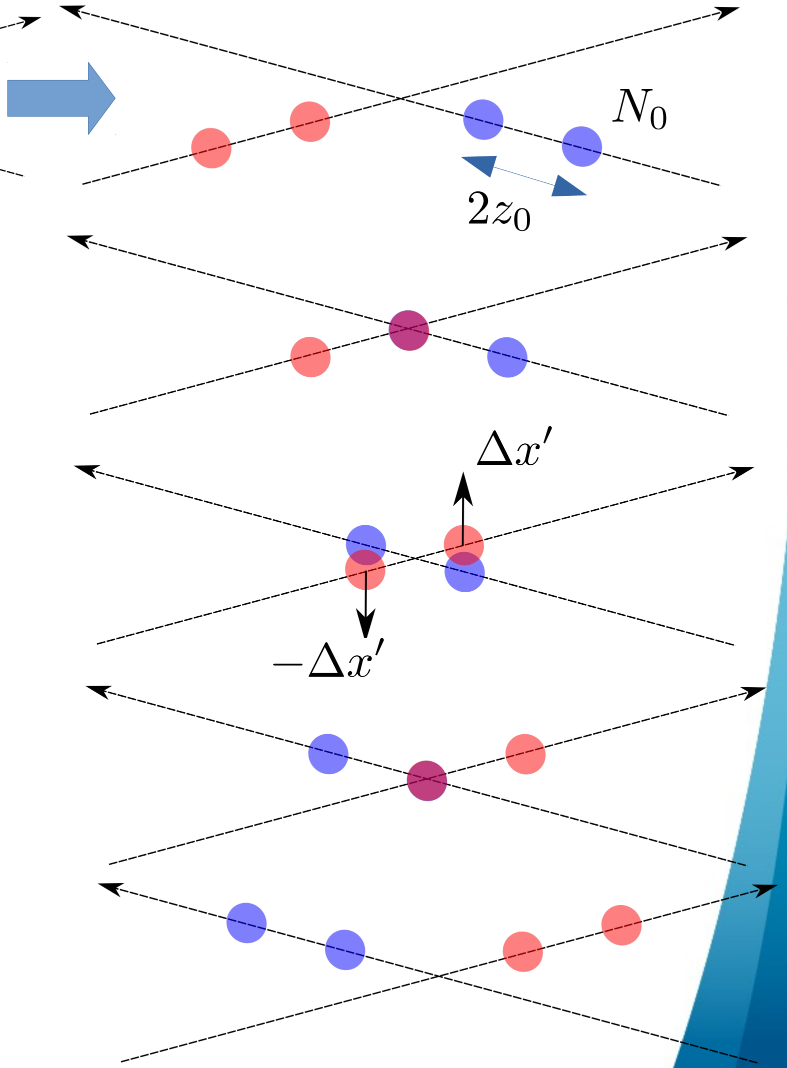
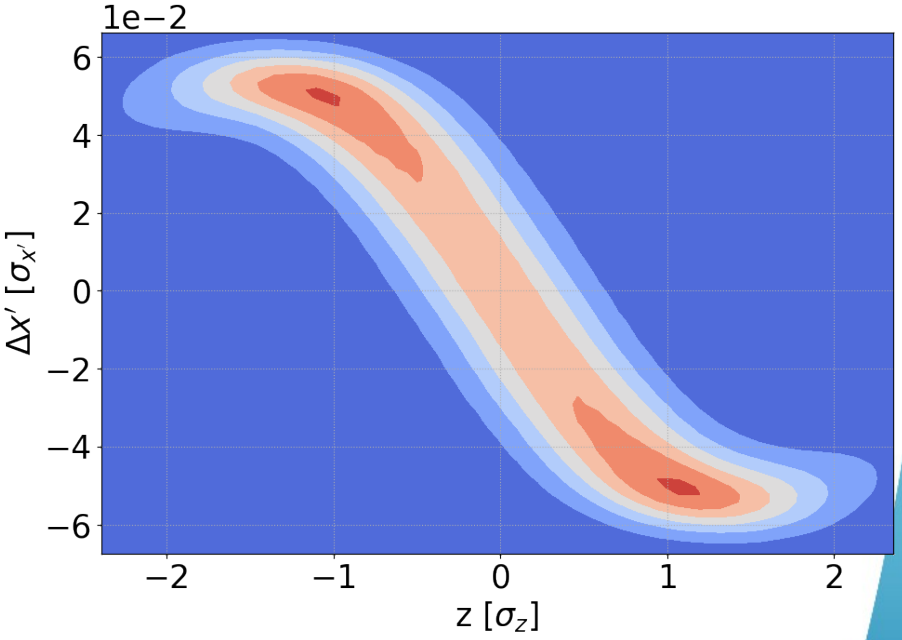


Using Hirata's model

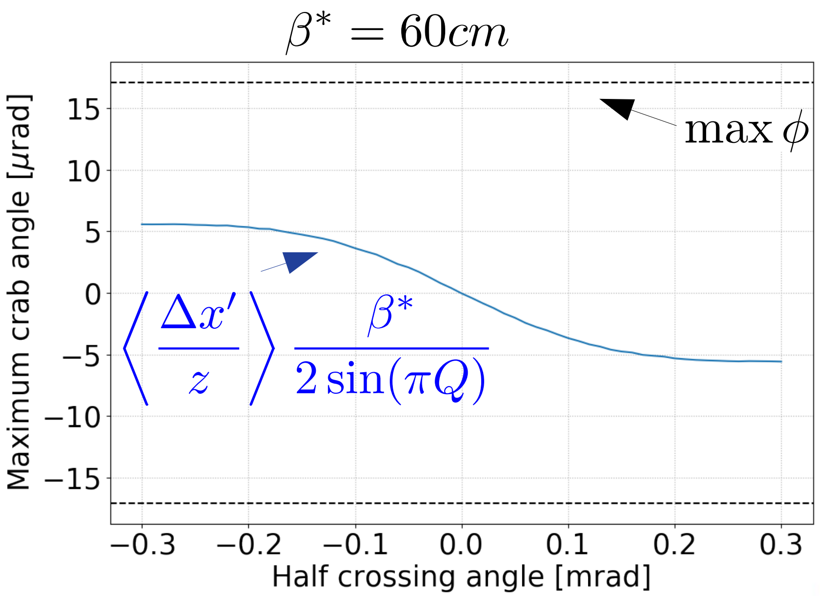
- Due to the non-linearity of the beam-beam force (in all d.o.f.) the transverse kick is not linear with the longitudinal position (~ CC RF curvature)
  - We use an average of the beam-beam kick over a 6D distribution of particle (i.e. coherent kick, but a not self-consistent treatment)*



*Obtained using *PySBC*, a python wrapper around the 6D beam-beam lens in Hirata's original code *BBC*

Dependence on the crossing angle

- The maximum of crab angle is expressed with the β* such that it can be compared to the CC induced angle
- The analytical estimation is quite pessimistic as expected



- A crab angle of maximum 5 μrad can be expected due to the crossing angle
  - The contribution from beam-beam is reduced by the CC induced crabbing
  - If needed, the contribution from beam-beam and the CC non-closure can be disentangled outside of the IR given that they are out of phase (given the proper hardware, i.e. well placed head-tail monitors)

Dependence on the β*

- Similar conclusions may be drawn for lower β*, in spite of the hourglass effect