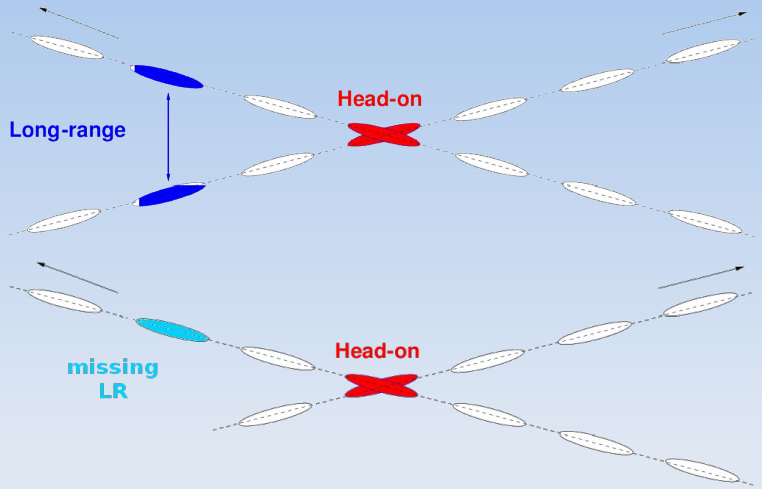
Status of beam-beam studies for the FCChh

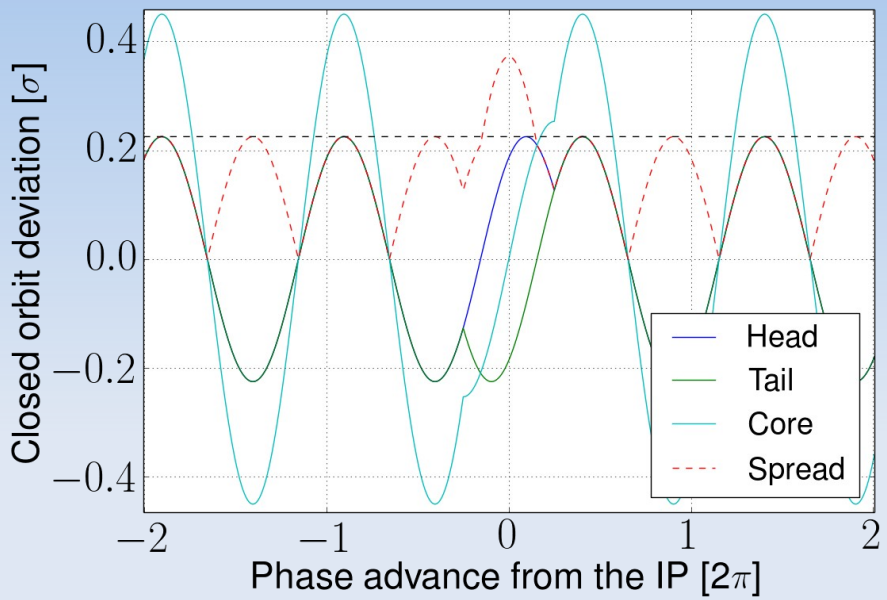
X. Buffat

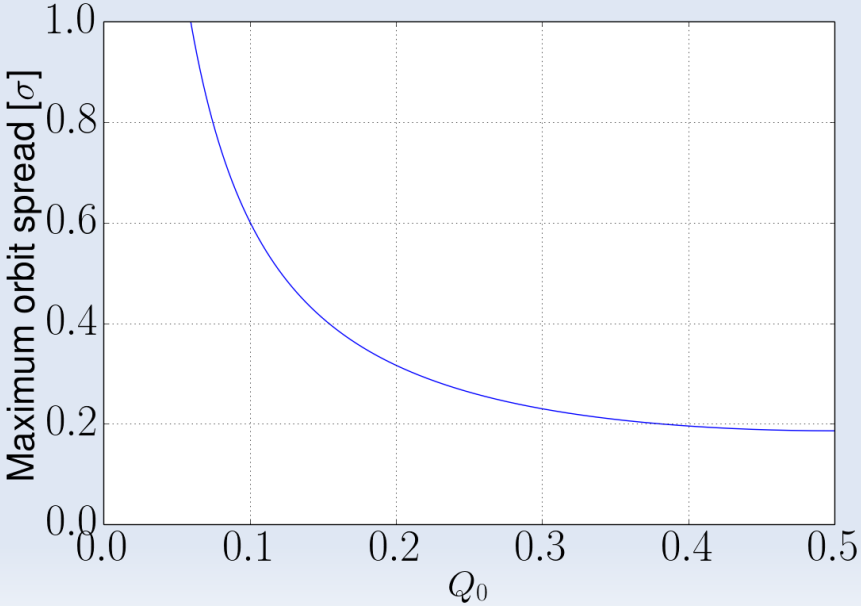
- Linear effects
- Non-linear effects
- Coherent effects
- Tentative plan

Orbit effect



$$\text{orbit spread} \propto \frac{N_{LR} N r_0}{\epsilon d} \frac{1}{sin(\pi Q_0)}$$





- Orbit effect from long-range beam-beam interaction might require mitigation in the 5 ns scenario
  - Needs to be taken into account in the aperture margin in any case

Dynamic β

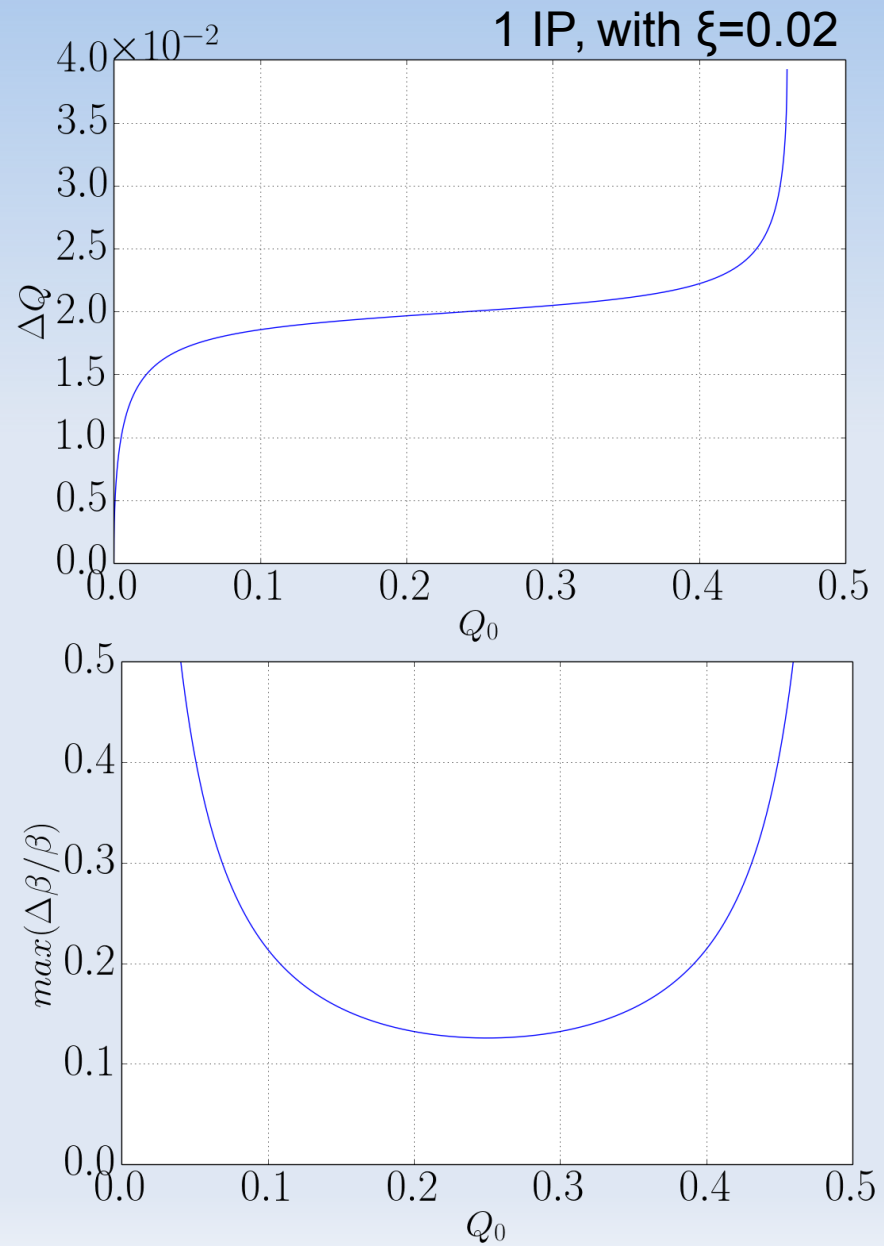
$$cos(2\pi Q) = cos(2\pi Q_0) - 2\pi\xi sin(2\pi Q_0)$$

$$\max\left(\frac{\Delta\beta}{\beta}\right) = \frac{2\pi\xi}{sin(2\pi Q_0)}$$

- The extra focusing due to head-on beam-beam interactions introduce a large β beating

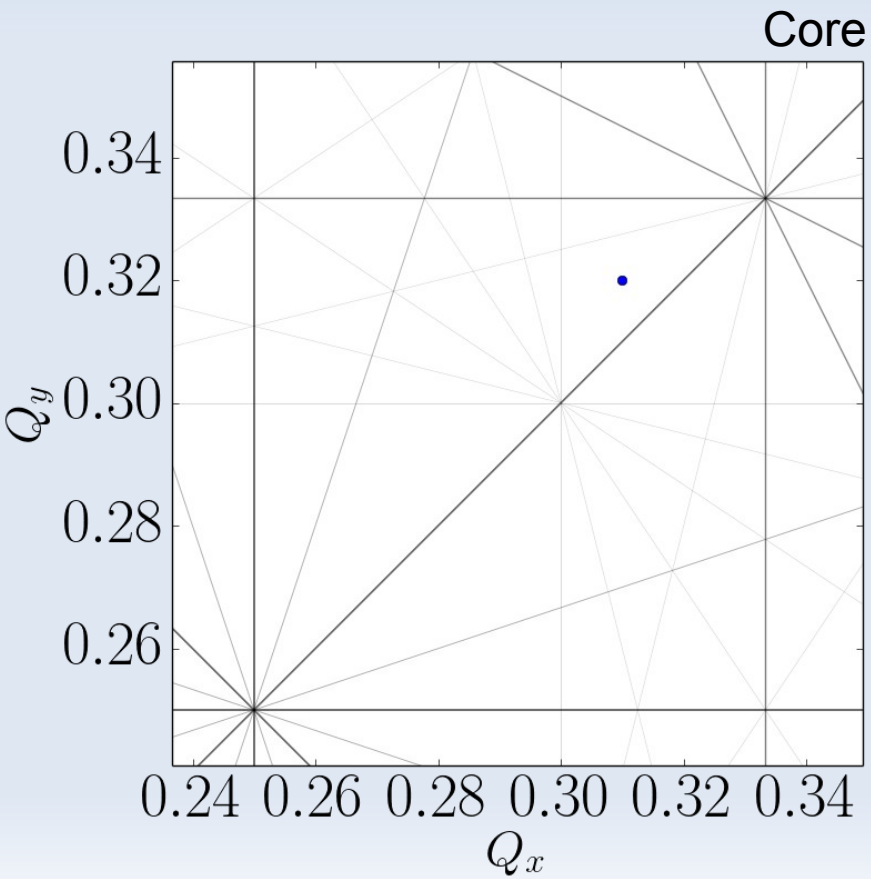
  → Effect of the phase advance between IPs

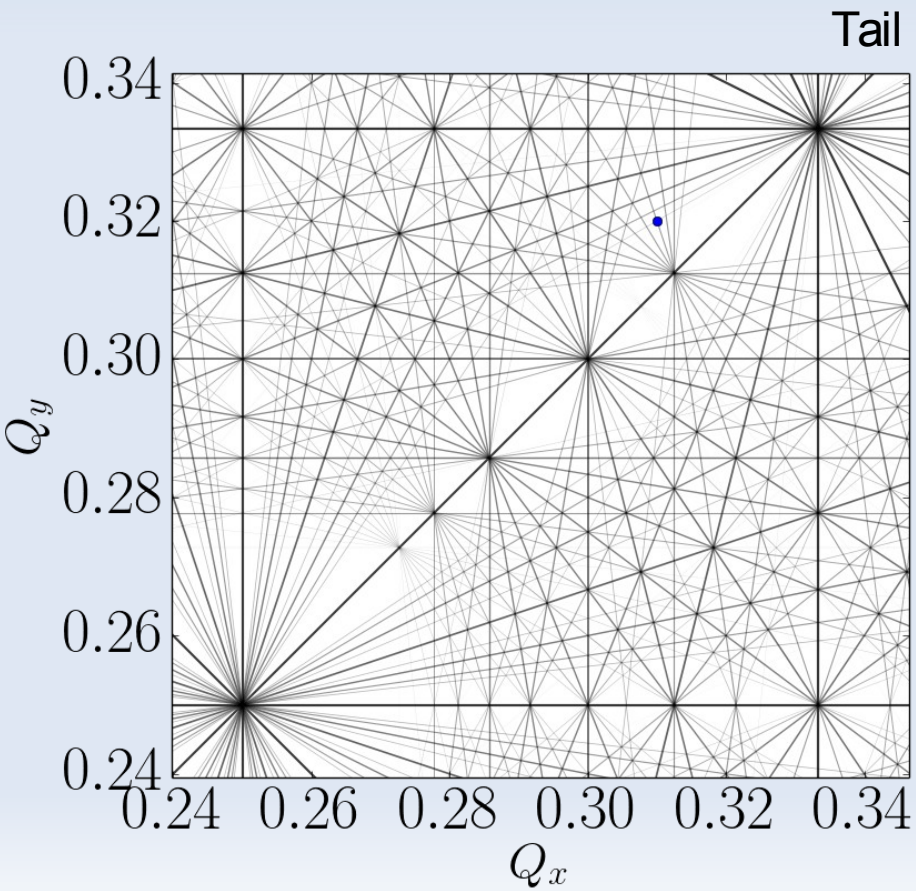
  → Local compensation ?



Non-linear effects
LHC working point

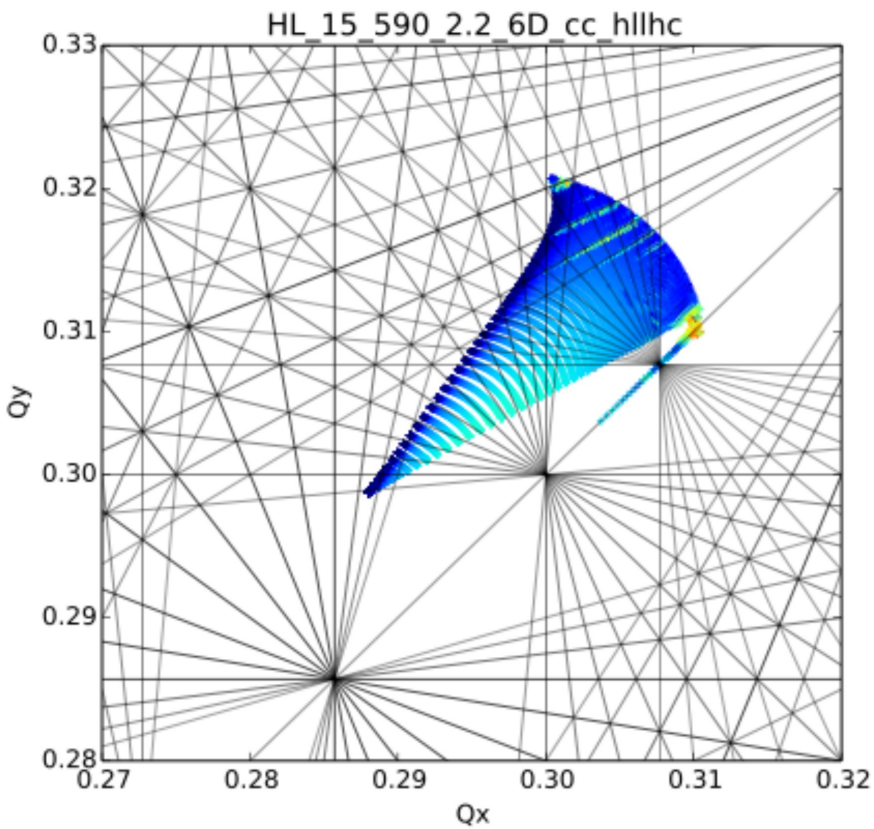
- Use the space between 1/3 and ¼
- Nominal beam-beam parameter is 0.0033 per IP
  - Operated with ~0.007 per IP in 2012

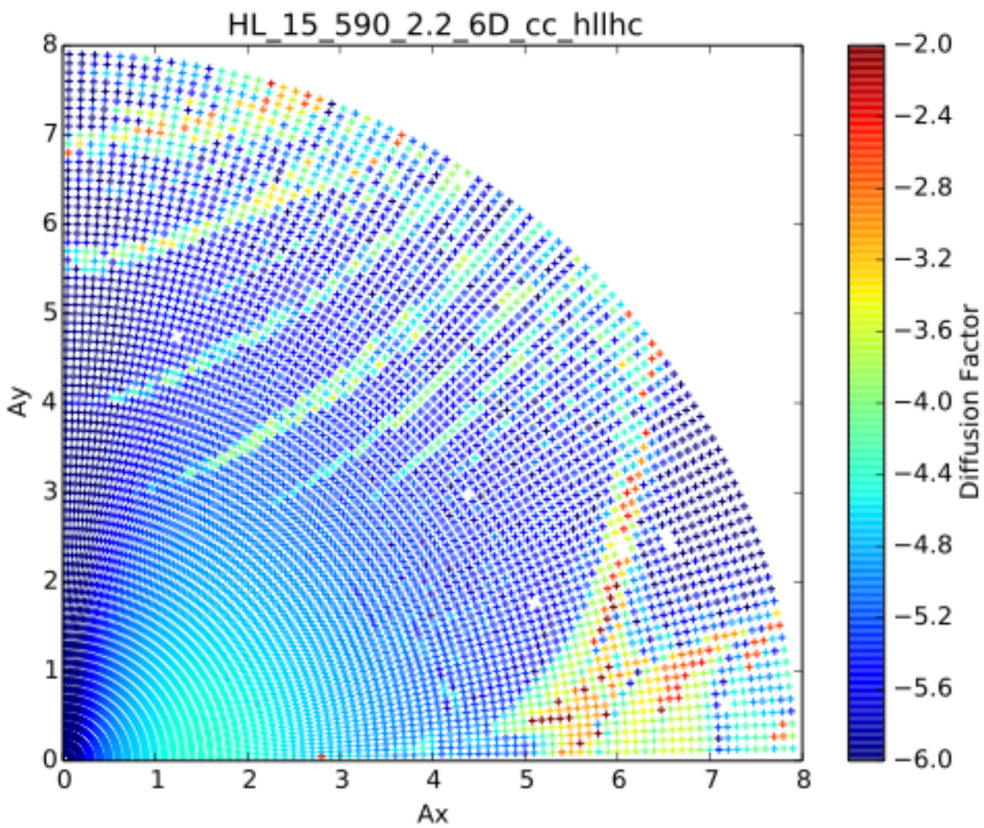




HL-LHC Frequency map analysis

- Dynamic aperture in the LHC seems mainly driven by the non-linear coupling terms and the 5th and 7th order resonance



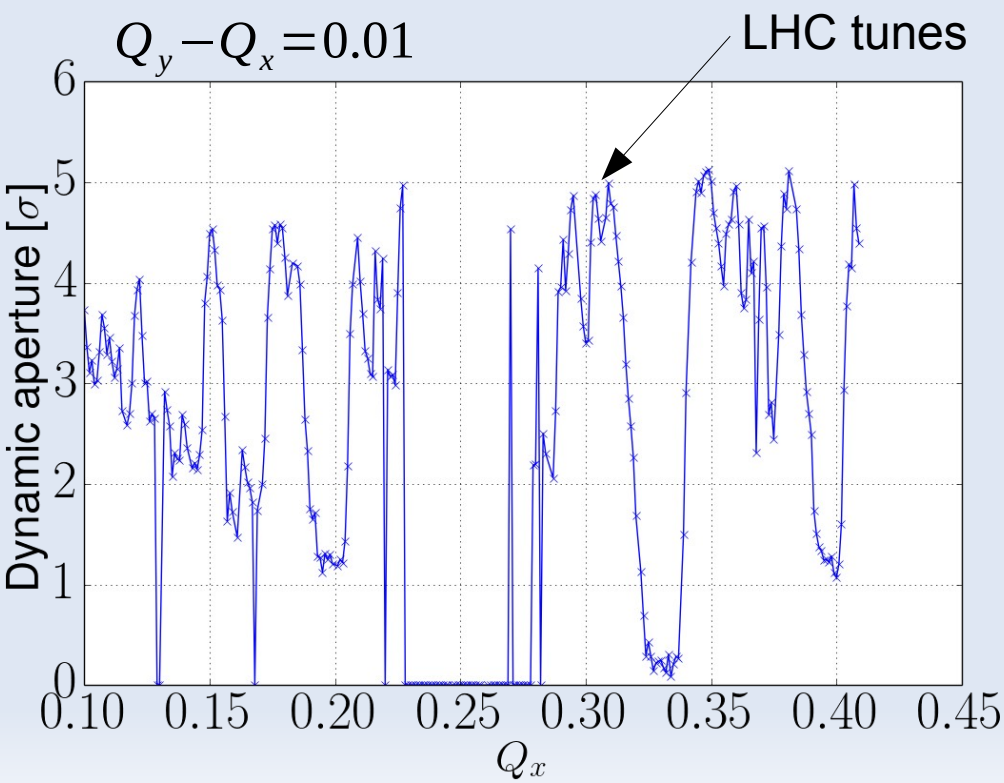


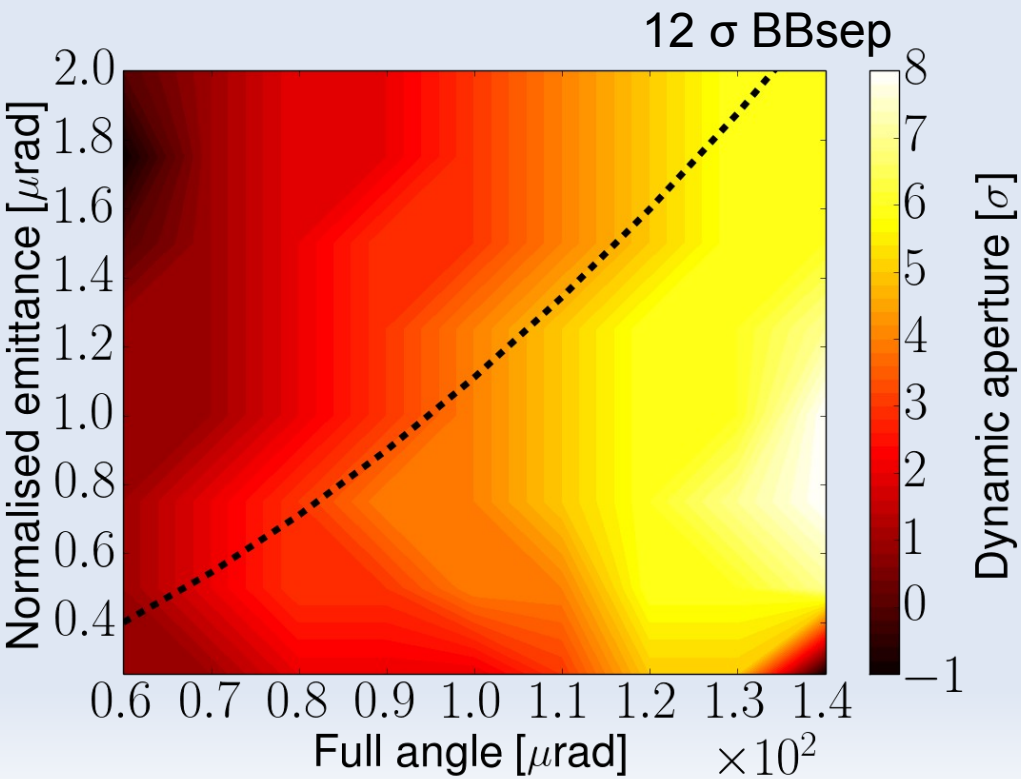
D. Banfi, J. Barranco (EPFL) and T. Pieloni (CERN)

Dynamic aperture

- Small effort to re-use software developed for the LHC and HL-LHC
- Dynamic aperture studies are on going using Sixtrack on LHC@home using the TOY_V1 lattice
  - Recovered LHC results

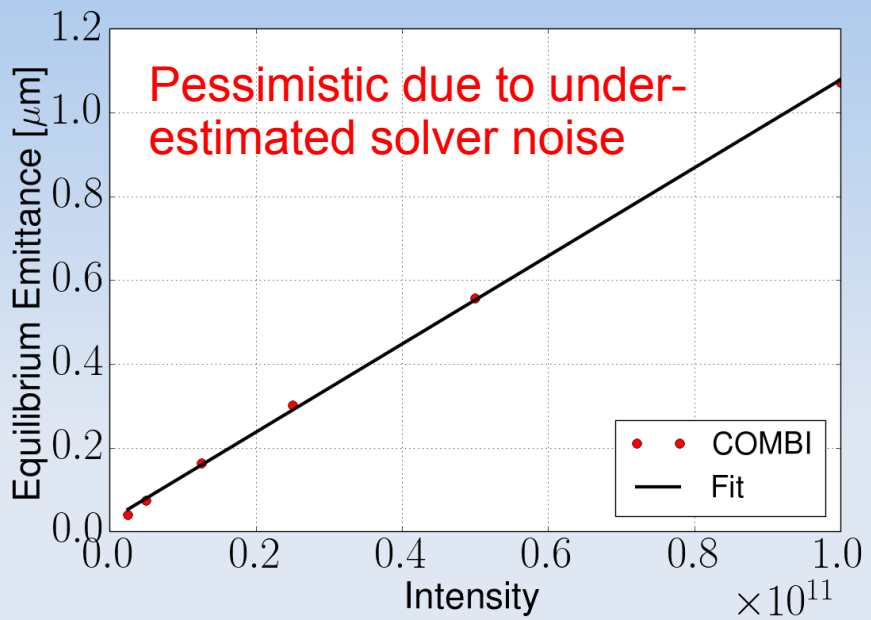
    → Need to characterize different IR design (L*, triplet length, Xing scheme, ...)

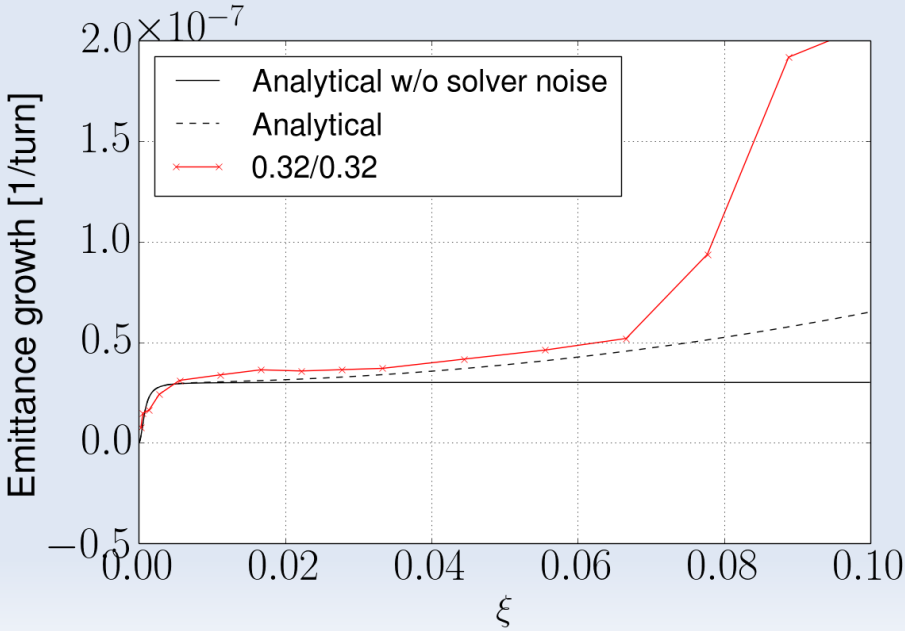




Emittance growth

- Synchrotron damping and quantum excitations were implemented in COMBI to estimate beam-beam limitations
  - Challenging in term of field solver noise
  - High computing resources are necessary (EPFL-HPC)
- Benchmark of the code against Analytical models for the emittance growth due to external sources of noise
  - Synergy with HL-LHC : J. Barranco (EPFL) and T. Pieloni (CERN)





Tentative plan

- Understand brightness limitations
  - External sources of noise / decoherence of beam-beam modes with large beam-beam parameter
  - Interplay between beam-beam interactions and quantum excitation and IBS (i.e. “beam-beam limit”)
  - Describe the dynamic aperture with small emittance beams and different IR design
  - All of the above with non-round beams
- Describe linear effects of beam-beam (orbit, dynamic β)
- For all of the above, study compensation scheme