EPFL Plans for Beam-Beam Studies

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Combined EuroCirCol annual meeting and review on FCC-hh optics & beam dynamics
19-20 November 2015 IPN Orsay, France

Baseline and Ultimate Scenarios

Parameters and Luminosity Target

Consider two main experiments
- Plus two side experiment for baseline

Baseline
- Goal is 250ab^{-1} per year
- Focus on 25ns spacing

Ultimate
- Goal is 1000ab^{-1} per year
- Focus on 25 and 5ns

Will consider reducing beam current for baseline, keeping luminosity target

	Baseline	Ultimate
Luminosity [10^{34}cm^{-2}s^{-1}]	5	20
Bunch distance [ns]	25 (5)	
Background events/bx	170 (34)	680 (136)
Bunch charge [10^{11}]	1 (0.2)	
Norm. emitt. [μm]	2.2(0.44)	
IP beta-function [m]	1.1	0.3
IP beam size [μm]	6.8 (3)	3.5 (1.6)
RMS bunch length [cm]	8	
Max ξ for 2 IPs	0.01	0.03
Turn-around time [h]	5	4
Crossing angle [σ□]	12	Crab. Cav.

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Relaxed versus Challenging scenario
Need to guarantee the Baseline and work to reach the Ultimate!

Tools

- **Sixtrack** single particle tracking for Dynamic aperture studies
  - **DA for beam-beam (crossing angles, intensity scaling, long-range wires)**
- **Frequency Map Analysis** (from Sixtrack developed for HL-LHC)
- **COMBI** (Coherent Multi Bunch multi Interaction code)
  - **Coherent Beam-beam**
  - **Impedance and beam-beam interplay**
  - **Landau Damping**
  - **Radiation Damping and beam-beam limit**
- **TRAIN** code → self consistent orbit, tune and chromaticity computations
- **MADX** code → optics considerations shifts, spread… footprints

Standard tools for Beam-Beam studies at CERN

Proposed contributions:
Experimental Insertion Region Design (WP3)

Beam-beam studies for FCC-hh:

- Linear effects dynamic beta, beating, optics considerations
- Dynamic aperture studies
- Beam-beam and radiation damping
- Coherent beam-beam
- Noise on colliding beams
- Orbit, chromatic, tune effects for train operation
- Leveling scenarios and beam-beam
- Mitigating techniques (e-lenses, wire compensators, crab cavities)
- Define operational scenarios (parameter space exploration)
- Landau Damping properties
- Interplay of beam-beam and machine impedance
- Stability of colliding beams with transverse feedback

Keep beam-beam effects under control, define IR operation, set parameters to avoid luminosity deterioration and instabilities

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Dynamic Beta and beating effect

Patrik Jorge (Travaux Pratique IV EPFL with X. Buffat)

Investigating the linear effects of beam-beam interactions

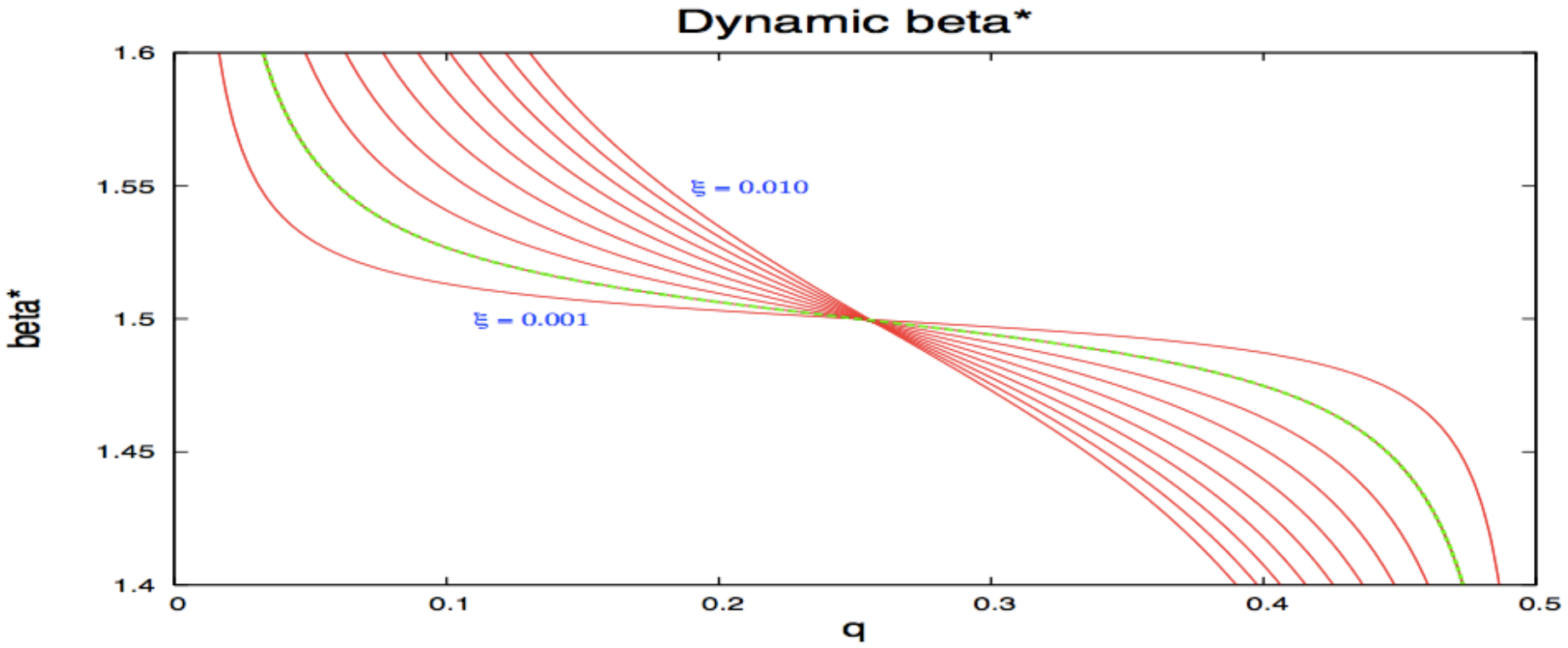
$$\frac{\beta^*}{\beta_0^*} = \frac{sin(2\pi Q)}{sin(2\pi(Q+\Delta Q))} = \frac{1}{\sqrt{1+4\pi\xi cot(2\pi Q) - 4\pi^2\xi^2}}$$

Beam-beam interaction leads to optical distortion at interaction point itself Dynamic beta

Beam-beam interaction leads to optical distortion at all other interaction points Dynamic beating

Expression above not valid during scan or several interaction points → needs optics code for calculation MADX

Dynamic Beta effect single Interaction point



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Depends on:

- **Beam-beam parameter: ξ**
- **Tune : Q**
- **Configuration (IPS) and optics (phase advance)**

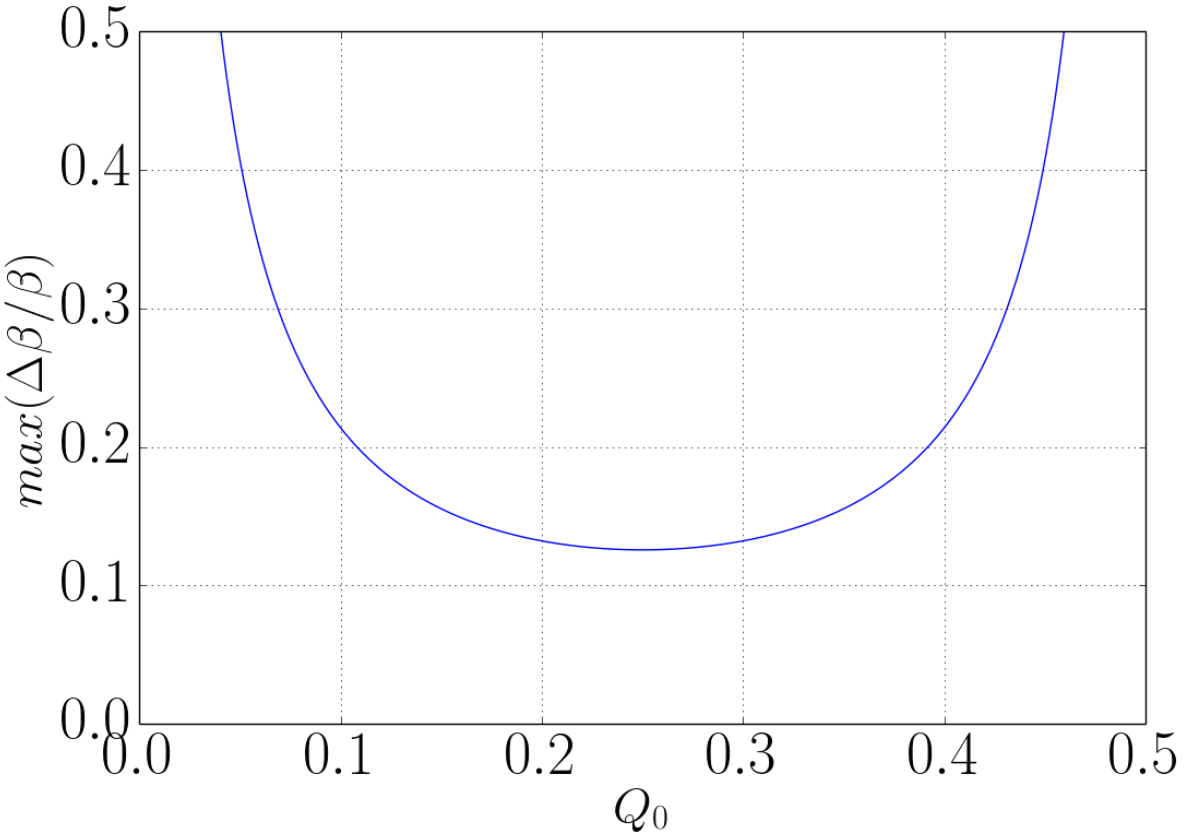
LHC case has 1-2 %
HL-LHC 8-10 %
FCC 1-10%

Dynamic beta-beating due to beam-beam effects

Maximum beta change as a function of unperturbed tune

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

$$\xi_{bb} = 0.02$$



Maximum beating as a function of tune

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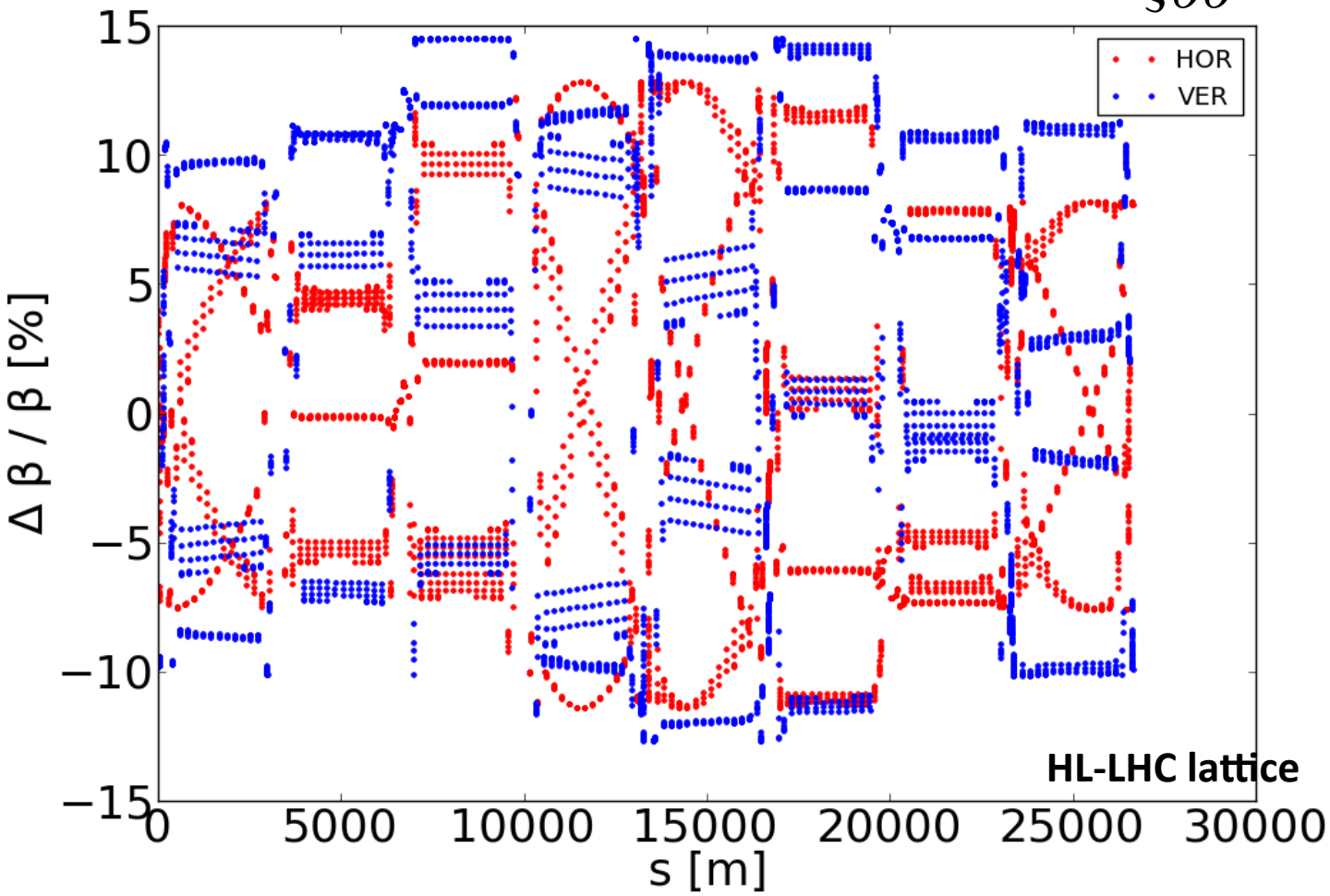

For beam-beam parameter of 0.03 this goes above 20%

Synergy with HL-LHC studies T. Pieloni and R. Tomas

Try to test experimentally local corrections in the LHC

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Sixtrack and COMBI
J. Barranco Post-doc 1st October 2015

Sixtrack

- Preliminary DA studies performed X. Buffat
- Tools in place
- Need to repeat for latest optics baseline and ultimate cases

→ Define crossing angles and scaling laws (intensity, #LRs)

Dynamic Aperture Studies

COMBI

- Includes already radiation damping, noise sources…
- Needs to identify beam-beam limit

→ is ultimate scenario achievable $\xi_{bb} = 0.03$?

Beam-Beam Limit in presence of radiation damping

Status and Plans EPFL from June

- 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, beta-beating)**
- For all of the above, study compensation scheme

Post-Doc
J. Barranco
since 1st Oct 2015 ~3 years

Under Graduated
Patrik Jorge
Sept2015-June2016

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Thank you!