At large beam-beam parameters $\xi_0 = 0.05$, beam-beam interaction is no longer a small perturbation, but modifies the dynamics significantly:

- Dynamic tune:

$$\begin{aligned} \cos\mu &= \cos\mu_0 - 2\pi\xi_0 \sin\mu_0, \\ Q &= \mu/2\pi \end{aligned}$$

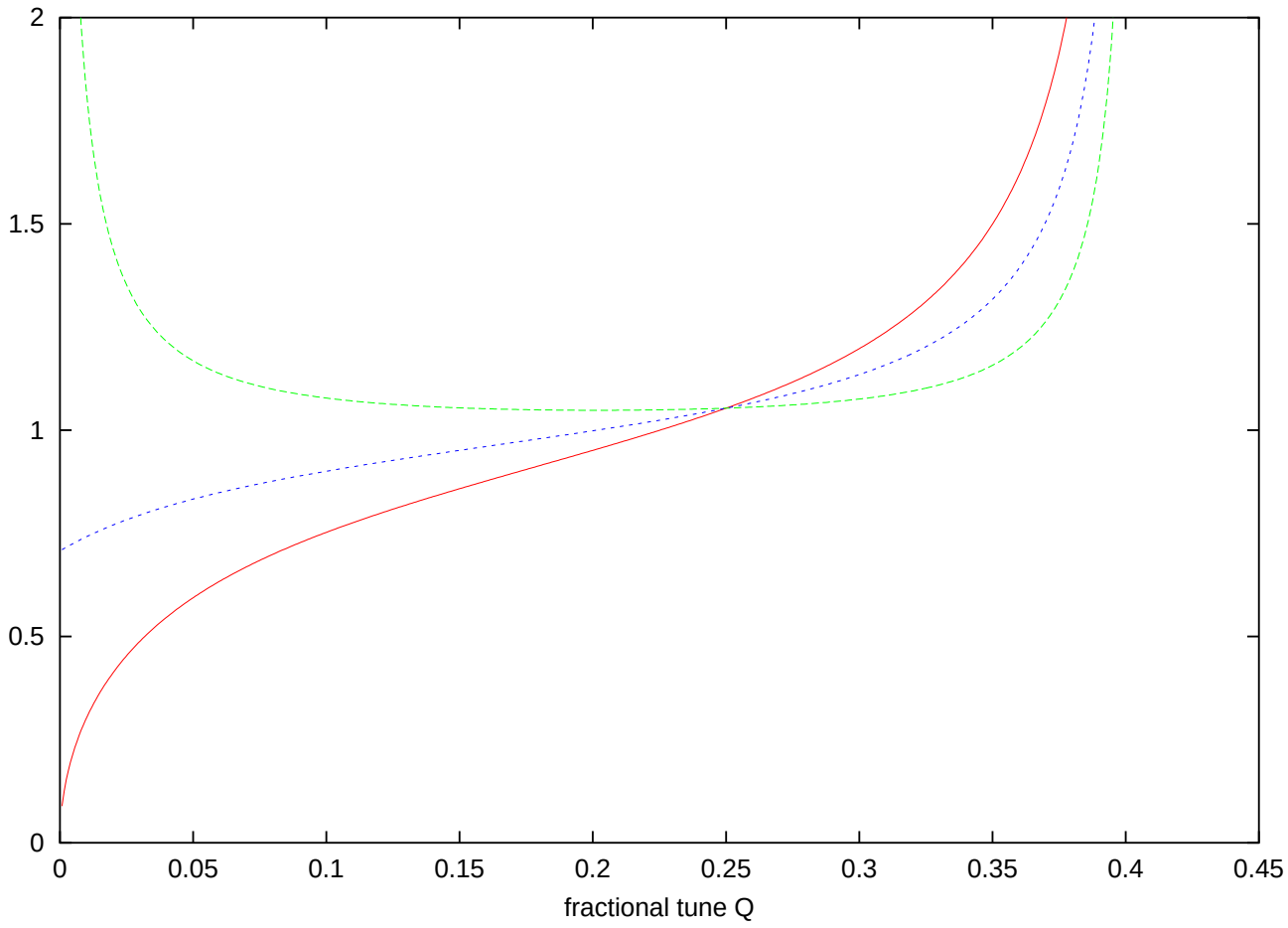
- Dynamic β:

$$\begin{aligned} \beta &= \beta_0 \frac{\sin\mu_0}{\sin\mu} \\ &= \frac{\beta_0}{\sqrt{1 + 4\pi\xi_0 \cot\mu_0 - 4\pi^2\xi_0^2}} \end{aligned}$$

- Dynamic emittance:

$$\epsilon = \frac{1 + 2\pi\xi_0 \cot\mu_0}{\sqrt{1 + 4\pi\xi_0 \cot\mu_0 - 4\pi^2\xi_0^2}} \epsilon_0$$

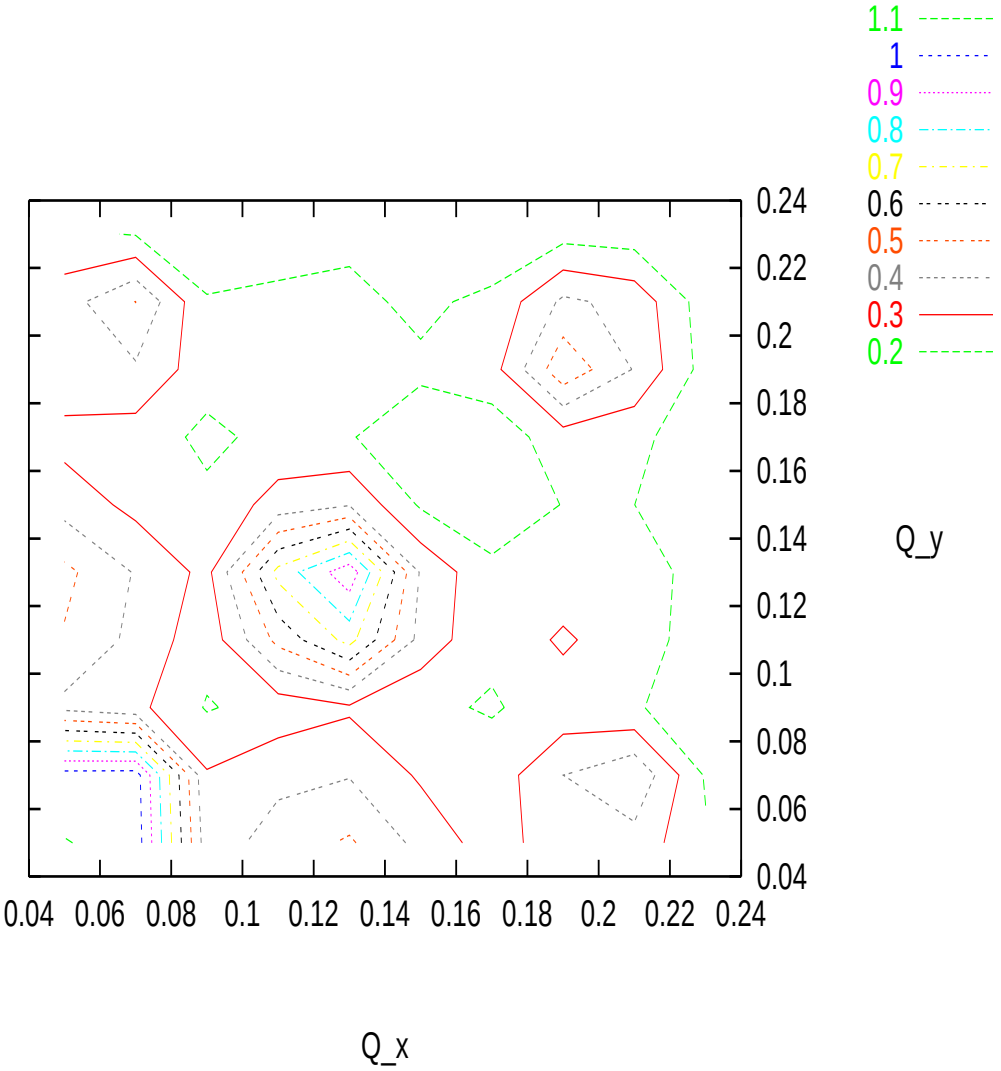
Dynamic β, emittance, and beam size σ (all normalized) vs. fractional tune:



Beam-beam simulation with eRHIC 10 GeV parameters (round beams):

- $\xi_0 = 0.05$
- transverse damping time: 1740 turns
- $\sigma_{x,y} = 48\,\mu$m (round beams)
- linear one-turn matrix
- $\Delta Q = 0.003$ (coupling in one-turn matrix)
- perfect head-on collisions
- no machine errors
- short bunches

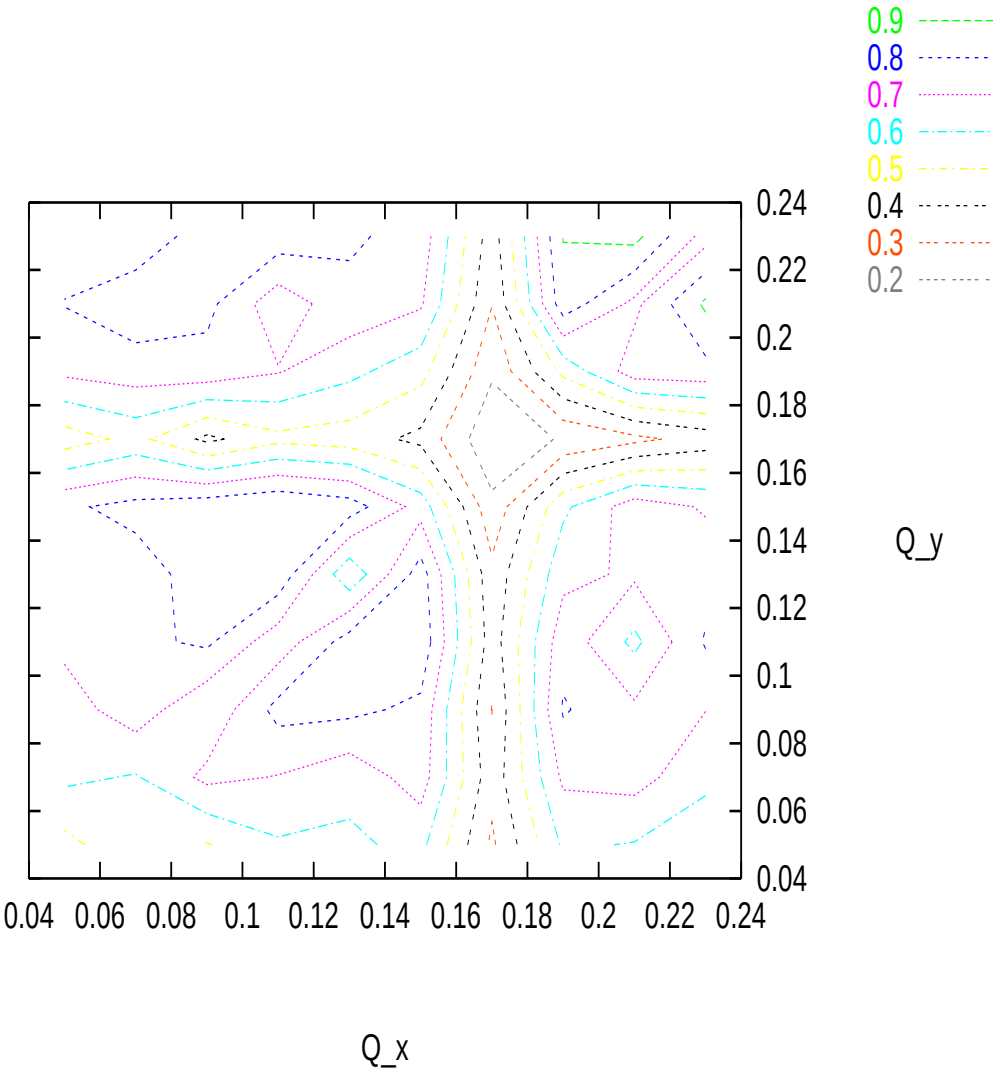
Resulting luminosity vs. fractional tunes:



Beam-beam simulation for flat beams:

- $\xi_{x,0} = 0.032$, $\xi_{y,0} = 0.051$
- transverse damping time: 1740 turns
- $\sigma_x = 100\,\mu\text{m}$, $\sigma_y = 20\,\mu\text{m}$ (flat beams)
- $\beta_x = 0.17\,\text{m}$, $\beta_y = 0.054\,\text{m}$
- linear one-turn matrix
- $\Delta Q = 0.003$ (coupling in one-turn matrix)
- perfect head-on collisions
- no machine errors
- short bunches

Resulting luminosity vs. fractional tunes:



Conclusions:

- More studies required: long bunches, machine errors, non-linear lattice, ...
- Select working point just above integer or half-integer.
- Dynamic aperture studies should be performed for such a working point.
- Are these tunes ok for polarization?
- At 5 GeV, radiation damping time is too long for a tune-shift parameter of 0.05. Need damping wigglers.