BTF of bunches influenced by an electron lens

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The transverse Beam Transfer Function (BTF) represents an important diagnostic tool for the tune spread and and damping rates in synchrotrons and storage rings. Here we investigate the BTF for bunches interacting with a localized electron lens. The investigation takes place in collaboration with BNL and focuses on BTF of relativistic bunches affected by the beam-beam interaction and an electron lens. The electron lens should compensate the beam-beam tune spread. We investigate the BTF using a threefold approach:

Firstly we use measurements taken at the Relativistic Heavy Ion Collider (RHIC) [1]. Similar bunch parameters are expected in the SIS100 during proton operation. We focus on RHIC measurements of beams under so-called split-tune conditions. In RHIC, the beam-beam interaction can couple the bunches in the two rings coherently. This coherent coupling is strong when the fractional tunes of the two beams lie close to each other. Under split tune conditions the difference in fractional tunes is chosen large to reduce the amplitude of the coherent modes and move them away from or into the incoherent spectrum. Apart from the coherent coupling, the amplitude dependent fields of the beams result in an amplitude dependent kick on the particles of the other beam in the machine. This leads to an incoherent amplitude dependent tune shift of the particles.

Secondly we use a particle tracking code wherein we built a simplified model of RHIC: We use the one-turn-map to translate particles around the lattice of the two rings of RHIC. For each collision point the interaction of the beams is taken into account by computing the two-dimensional transverse fields of the beams, exchanging them and kicking the particles of the other beam accordingly. The BTF is modeled as a sinusoidal signal modifying the trasverse momentum of the particles. The excitation is swept in frequency and the BTF are computed in post-processing as the fraction of the complex response amplitude and the excitation amplitude. The model of the BTF is directly applicable for modeling FAIR machines.

Thirdly we obtain the BTF analytically using the dispersion function in the integral representation provided in [2]. We include the electron lens and the beam-beam interaction as external tune shifts. The integral is solved numerically and the results are compared with the simulation in fig. 1. After the successful validation of the simulation code against analytic models [3] we focused on the scenario including an electron lens. Such a device is presently being installed at RHIC. The BTF should be used to analyze its performance. In an electron lens an electron beam with a Gaussian profile acts as a nonlinear lens compensating the beam-beam interaction. For a bunch interacting with an electron lens the aforementioned analytic BTF should

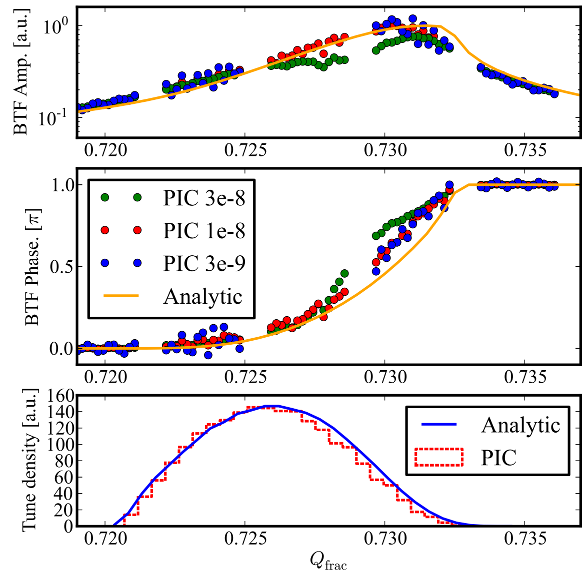

Figure 1: Horizontal BTF, particle tune density, comparison of simulation (PIC) for split tunes ($Q_h = 28.691$ and 28.735 in the two rings) and analytic results. Note the deviation for higher BTF excitation amplitudes in the simulations (at 3e-8). The observed agreement between simulation and analytic results holds for a range of beam currents. Higher currents give broader peaks shifted towards lower tunes.

hold. At split tune conditions the beam-beam should produce BTF comparable to an electron lens provided that the conditions are such that no coherent beam-beam modes lie near the incoherent spectrum. The double peak structure observed in some measured BTFs from beams under split tune conditions was reproduced in the simulations and found to be present only at high BTF excitation amplitude. At low excitation amplitude the analytic model reproduces the simulations of BTF both under e-lens and split tune conditions well. This allows to recover the strength of the observed interaction from the BTF of a beam interacting with an e-lens or a split-tune beam-beam interaction. We are confident we can now apply our method to SIS100 proton operation, where instead of beam-beam and e-lens we will encounter space charge and octupoles for Landau damping.

References

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