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Resonance crossing in imperfect scaling FFAG

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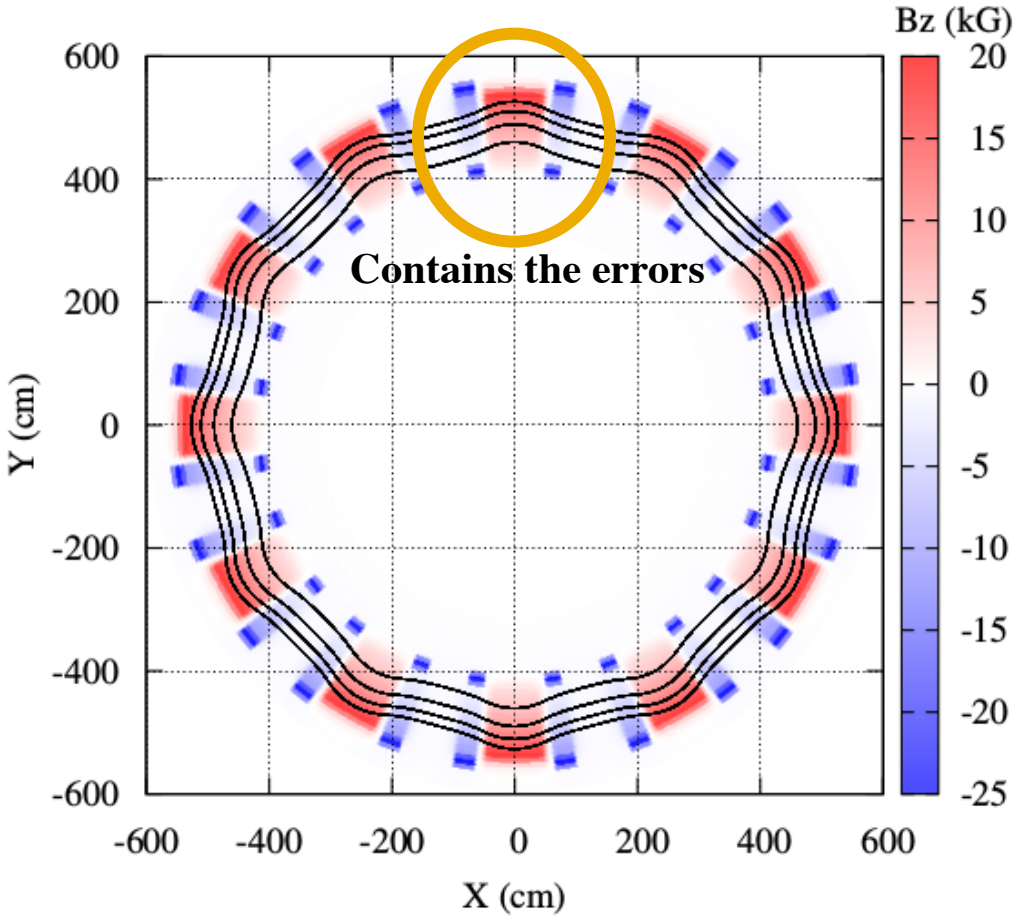
Lattice model

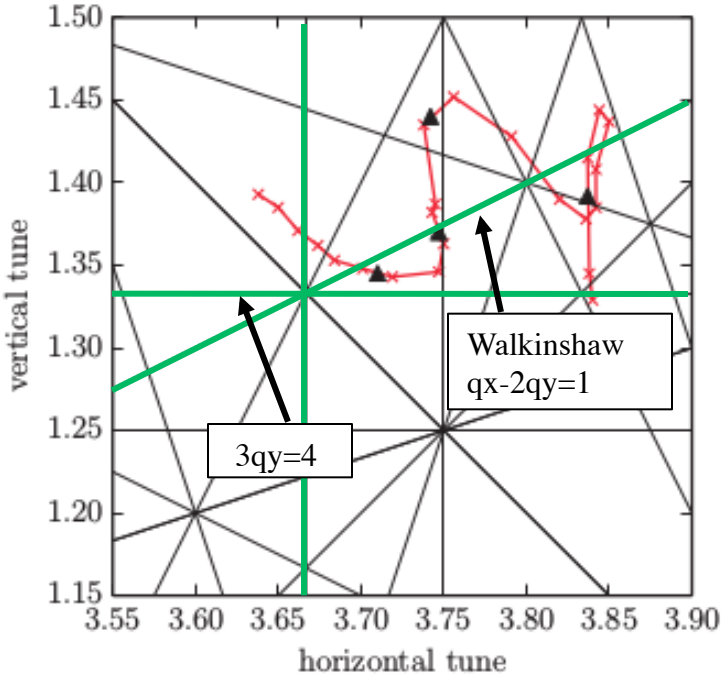
11 sectors error free FFAG such that kF ≠ kD in order to induce tune variations.

1 sector containing the field error: the idea is to perturb the average field index of the focusing and defocusing magnets in order to break the 12-fold symmetry and excite the random resonances.

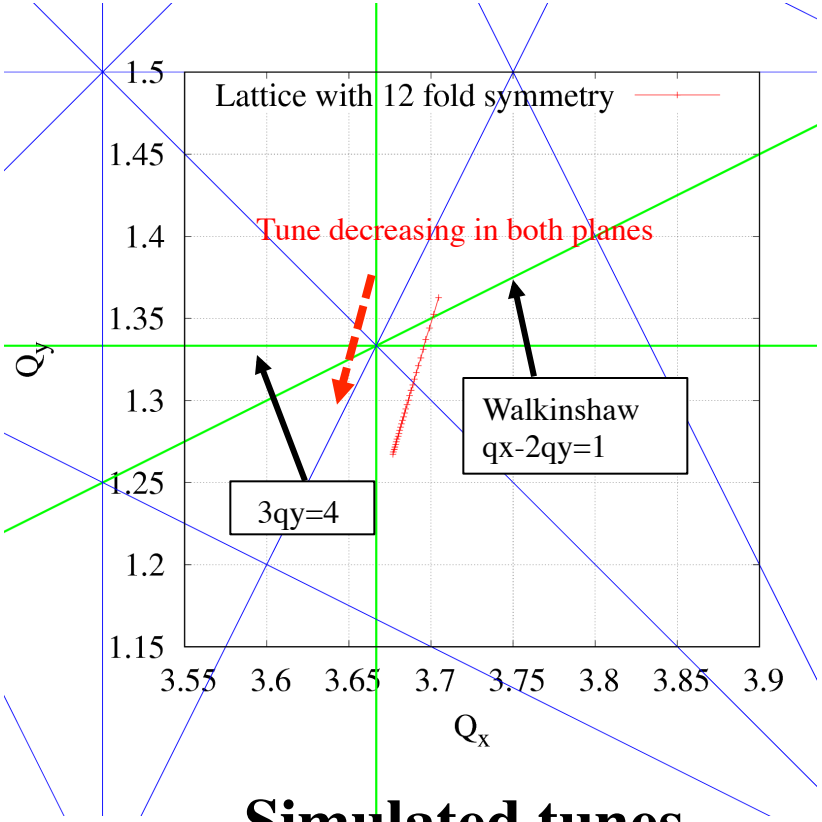


Lattice model

Lattice model



Measured tunes

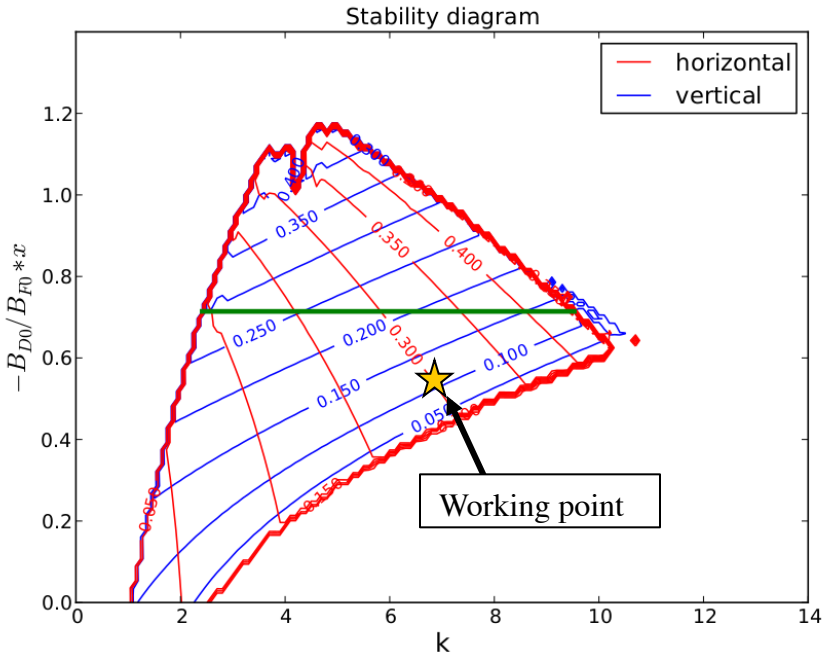


Simulated tunes

Main objective: simulate the crossing of the betatron resonances by creating a model that reproduces the experimental results of the measured tunes.

Lattice model

1st step: choose a working point in the tune diagram that matches the values of the measured tunes.

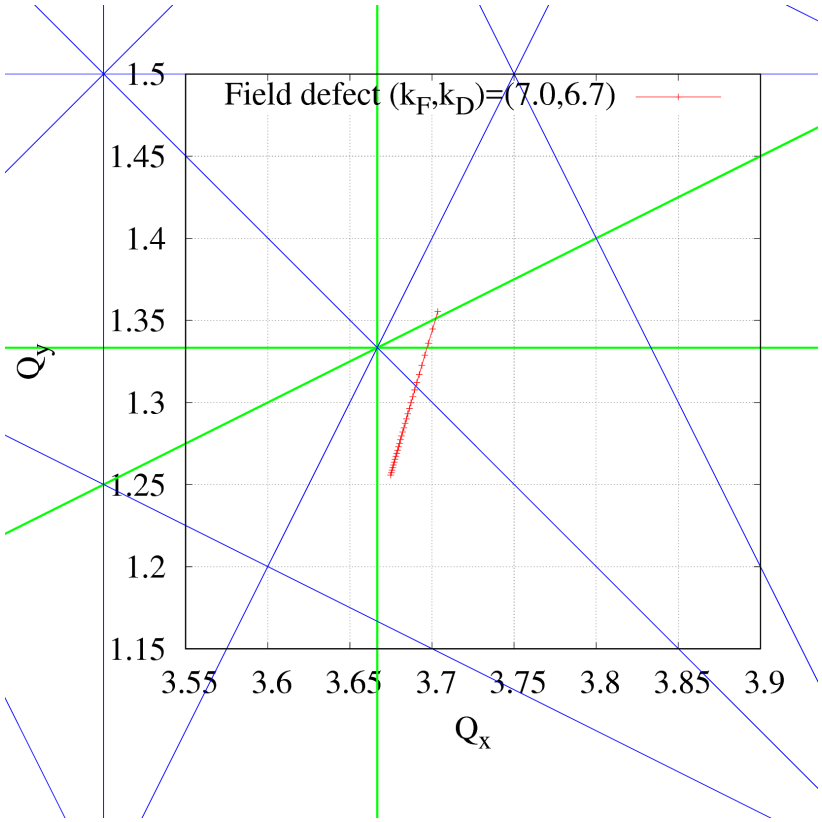


2nd step: introduce tune variations to simulate the crossing of the resonances: this is achieved by adding scaling imperfections, i.e. introducing a difference in the average field index of the F and D magnets. In what follows, I choose (kF , kD)=(7.0 , 6.8).

Walkinshaw resonance

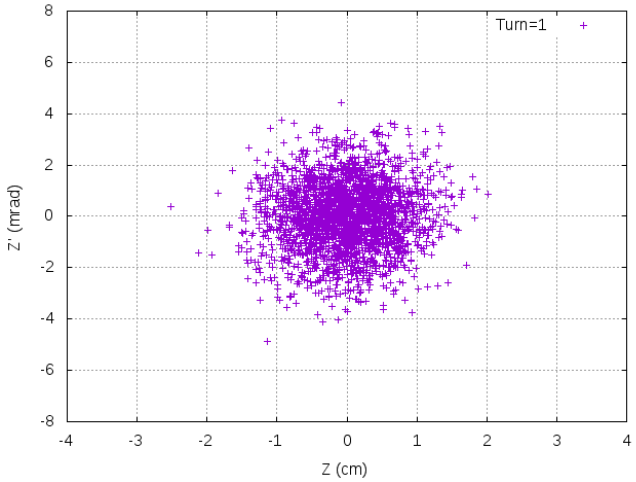
The perturbation is applied to the D magnet by modifying its average field index kD=6.7 instead of 6.8. This allows to bring the tunes at injection closer to the walkinshaw resonance and is predicted analytically.

It is important to highlight that perturbing the average field index of one of the magnets by more than 7-10% creates a highly unstable lattice.

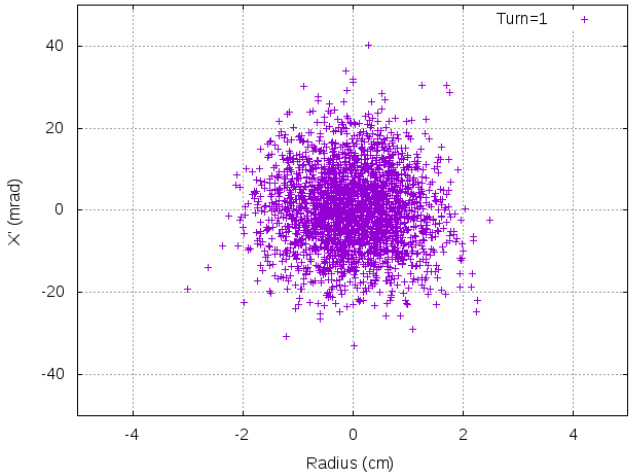


NB: the matching conditions of the perturbed FFAG are identical to those of the error-free FFAG, i.e. the closed orbits are kept the same as well as the matched envelope. This is a choice to simulate the conditions of real life..

Walkinshaw resonance

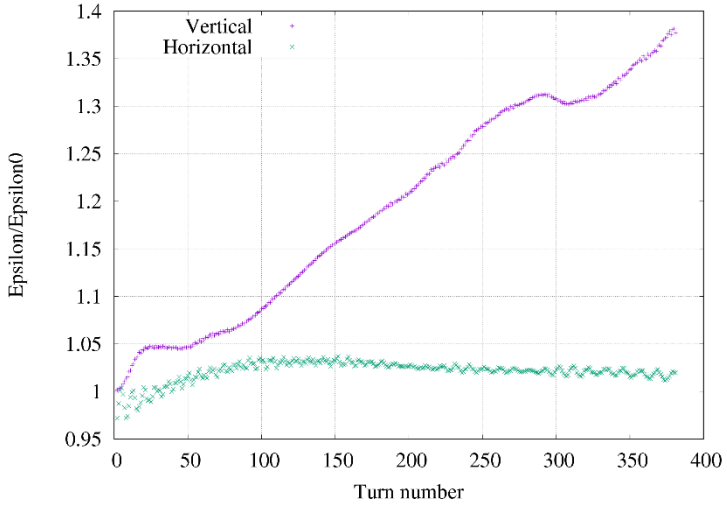


Vertical Phase space topology

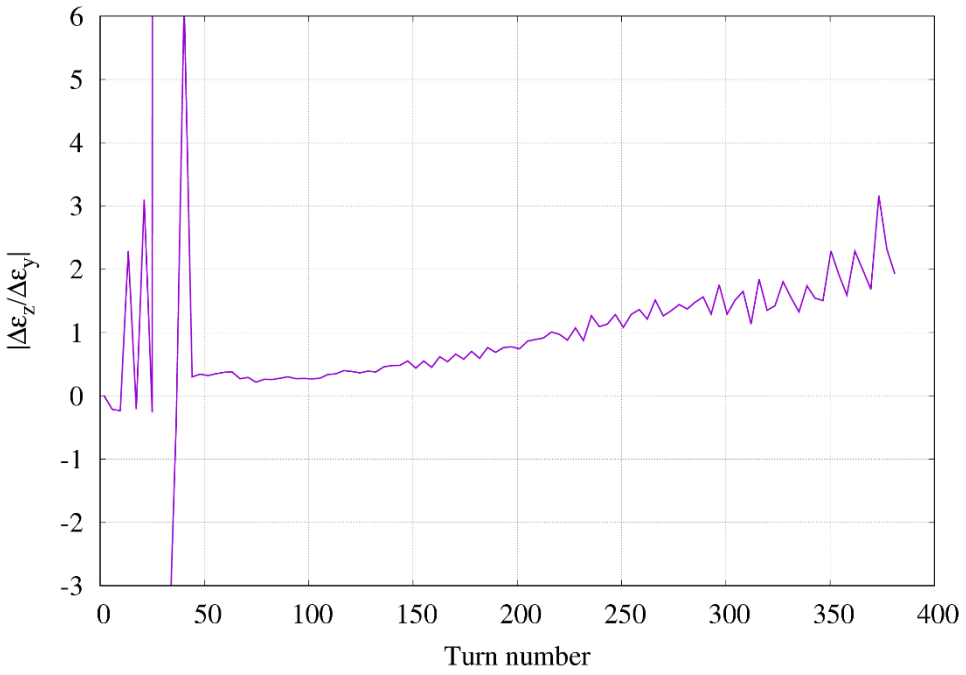


Horizontal Phase space topology

Crossing occurs (downward) around turn 80.
Energy gain per turn 20 keV~ 10 × the KURRI machine.



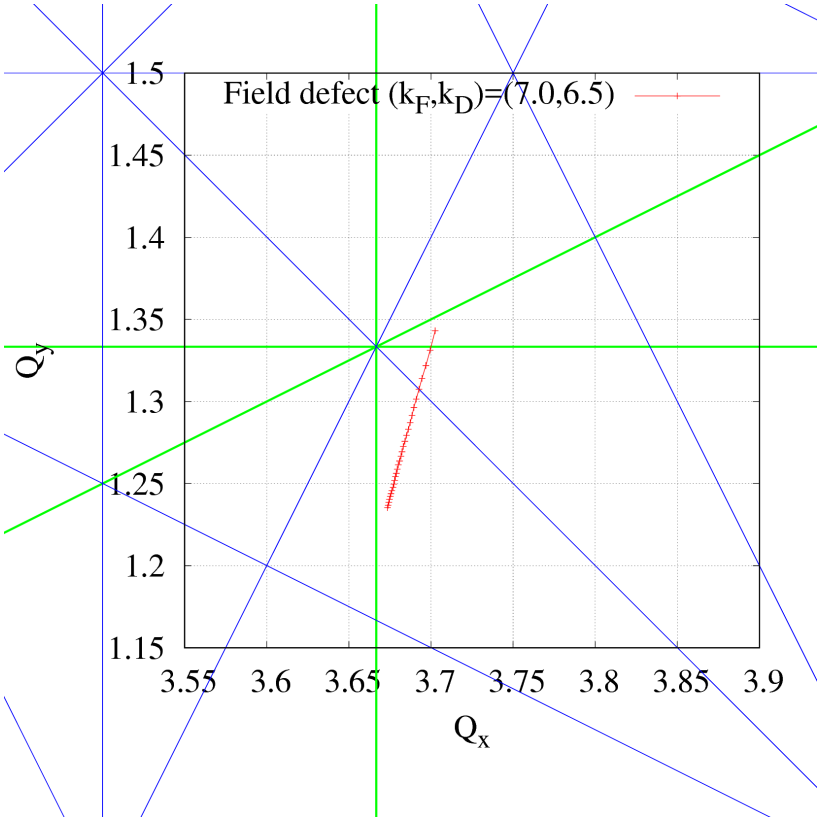
Walkinshaw resonance



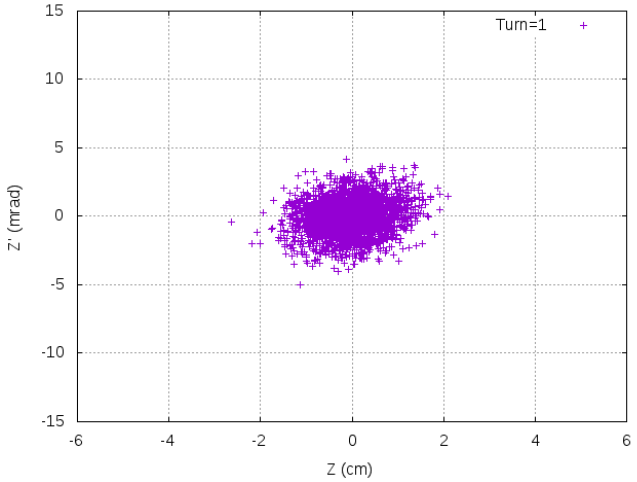
The Walkinshaw is a coupling resonance and one expects an exchange of the beam emittances between the horizontal and vertical planes. More precisely, it is known analytically that the emittance exchange follows $\left|\frac{\Delta\varepsilon_z}{\Delta\varepsilon_y}\right| = 2$.

3qy=4 resonance

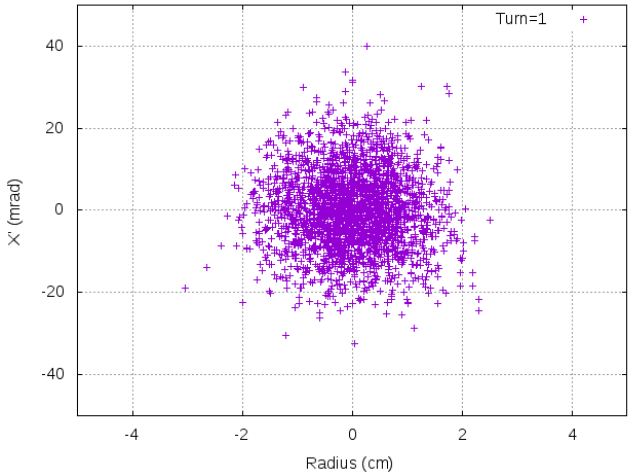
kD=6.5 instead of 6.8. This allows to bring the tunes at injection closer to the resonance 3qy=4.



3qy=4 resonance

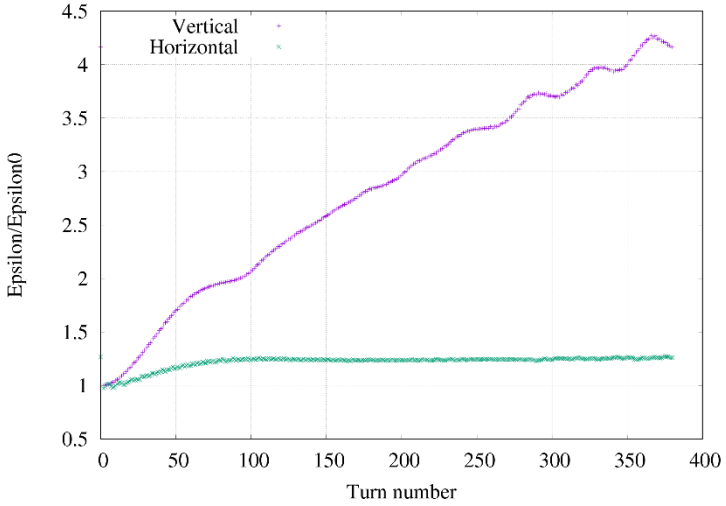


Vertical Phase space topology



Horizontal Phase space topology

Seems to be more detrimental to the beam in the vertical plane than the Walkinshaw.



Next

- Preliminary study of the resonance crossing in imperfect scaling FFAG.
- One confirms that the phase space is distorted when the crossing occurs. However, one expects different behavior when ramping upwards..
- Depending on the acceleration rate, the effect can be more or less pronounced.
- I believe Machida-san and others have done quite some work on this. So any advice is very welcome.
- Main question: is there any plan to measure the median plane field map of any of the magnets? Do we have any idea about the amplitude of the random errors of the field in the ring?