Local bump depolarizer review.

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Outline

- Requirements to a depolarizer at Z and W beam energies
- FCCee lattice update from K. Oide.
- Where we can install kickers of a local bump depolarizer?
- Depolarizer strength calculation for different bump locations
- Proposal for modifications of the arc lattice for beam energy 45 GeV
- Discussion

Requirements to a depolarizer at Z and W beam energies

- The depolarizer must not disturb the orbit at IP! Therefore, it must be designed as a local bump. It kicks the beam vertically in a section of an arc with πN phase advance. Beam oscillations then are trapped between two synchronized RF-kickers.

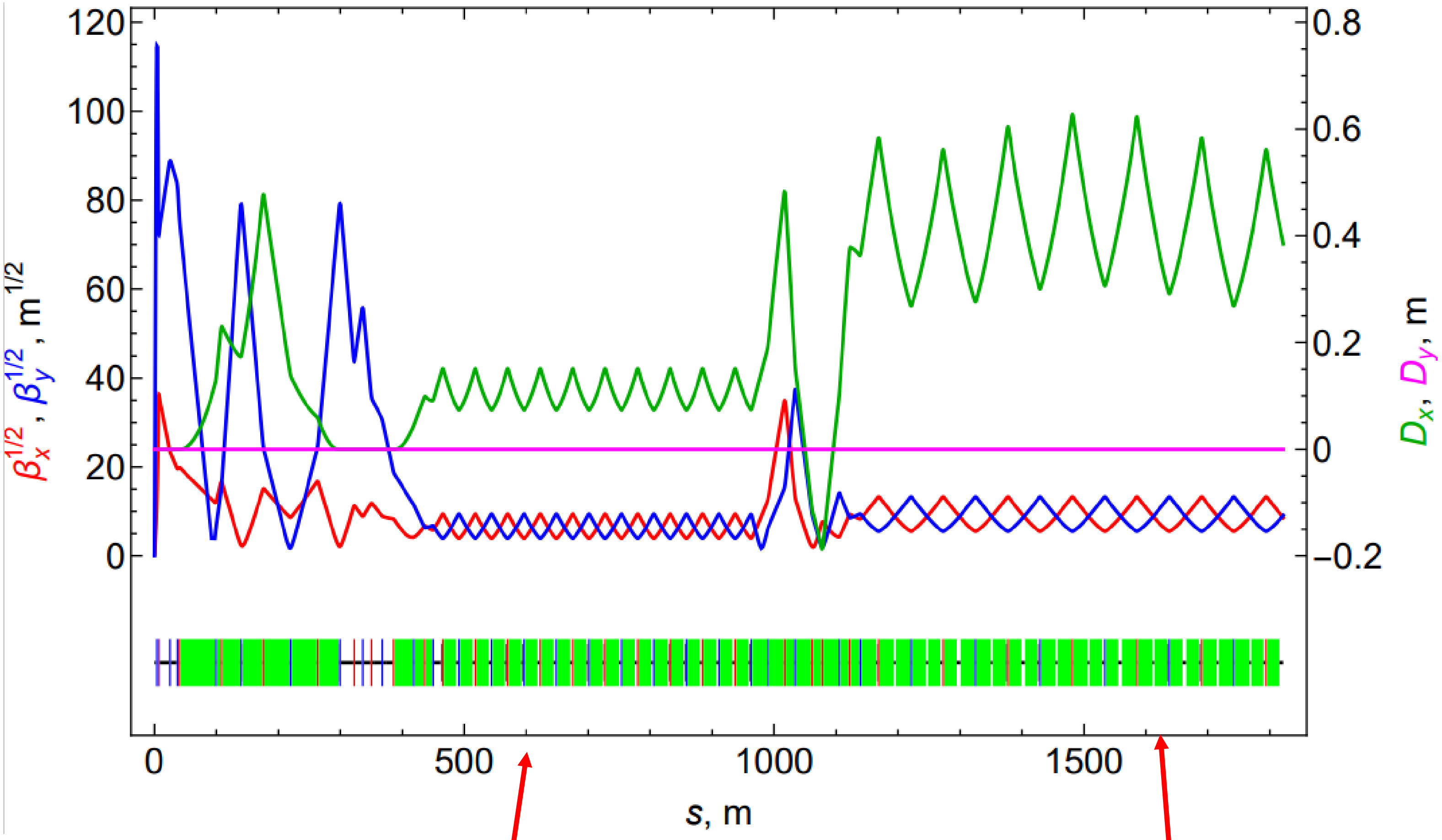
- Depolarizer's harmonic value should be in the order of $w \approx 1 \cdot 10^{-4}$ in the frequency scan mode (RDP) and be about $w \approx 1 \cdot 10^{-3}$ in case of use for Free Spin Precession method (FSP operation mode).

- With $w \approx 1 \cdot 10^{-4}$ RDP takes about 2 minutes to depolarize a single pilot bunch, if we start scan with $\Delta\nu \approx \pm 2 \cdot 10^{-3}$ from the resonance ($\Delta E/E = \pm 2 \cdot 10^{-5}$ at 45 GeV).
- To destroy the self-polarization of the colliding bunches we will need $w \approx 0.5 \cdot 10^{-4}$, almost continuesly switched on (producing a sinus wave at the resonance frequency with the tune error $\pm 2 \cdot 10^{-4}$).
- In the case of FSP, the spins of a single pilot bunch are rapidly deflected from their equilibrium vertical orientation by a much more powerful flipper, but in only 100-200 turns.

- The solenoid type depolarizer/flipper is too weak because its effect on spin rotation is not enhanced by the spin tune factor, which is of the order of $\nu_0 = 100 - 200$.

- So, as a basis for constructing a local depolarizer, we consider two strip lines separated by an integer or half-integer number of waves between them. The beam is kicked in a vertical direction, turn after turn, by means of a pulse generator controlled by a programmable oscillator. The pulses have a duration of about 20 ns, and the length of each strip line should not exceed 2.5 - 3 m.

Latest FCCee lattice update (with Q_s=0.034) from K. Oide



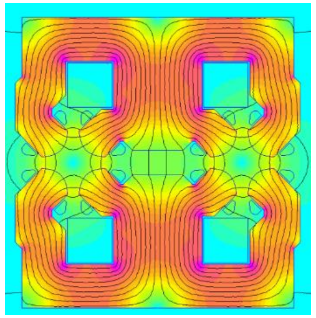
The updated version of FCCee lattice has longer dipoles, and their bending angle is approximately 10% larger.

As a result, the depolarizer's strength increases by 37% and its harmonic value is enriched to w=1.017e-04 with a single wave orbit bump. This is enough for RDP, but to implement the FSP method, 4 or 8 bumps per ring may be required.

My idea with the triplet cell modification of an arc lattice cannot be realized simply because of the pairing of F and D quads in the regular arcs. The triplet cell consists of one D and two F quads, while in the second ring it will become one F and two D lenses - the wrong combination!

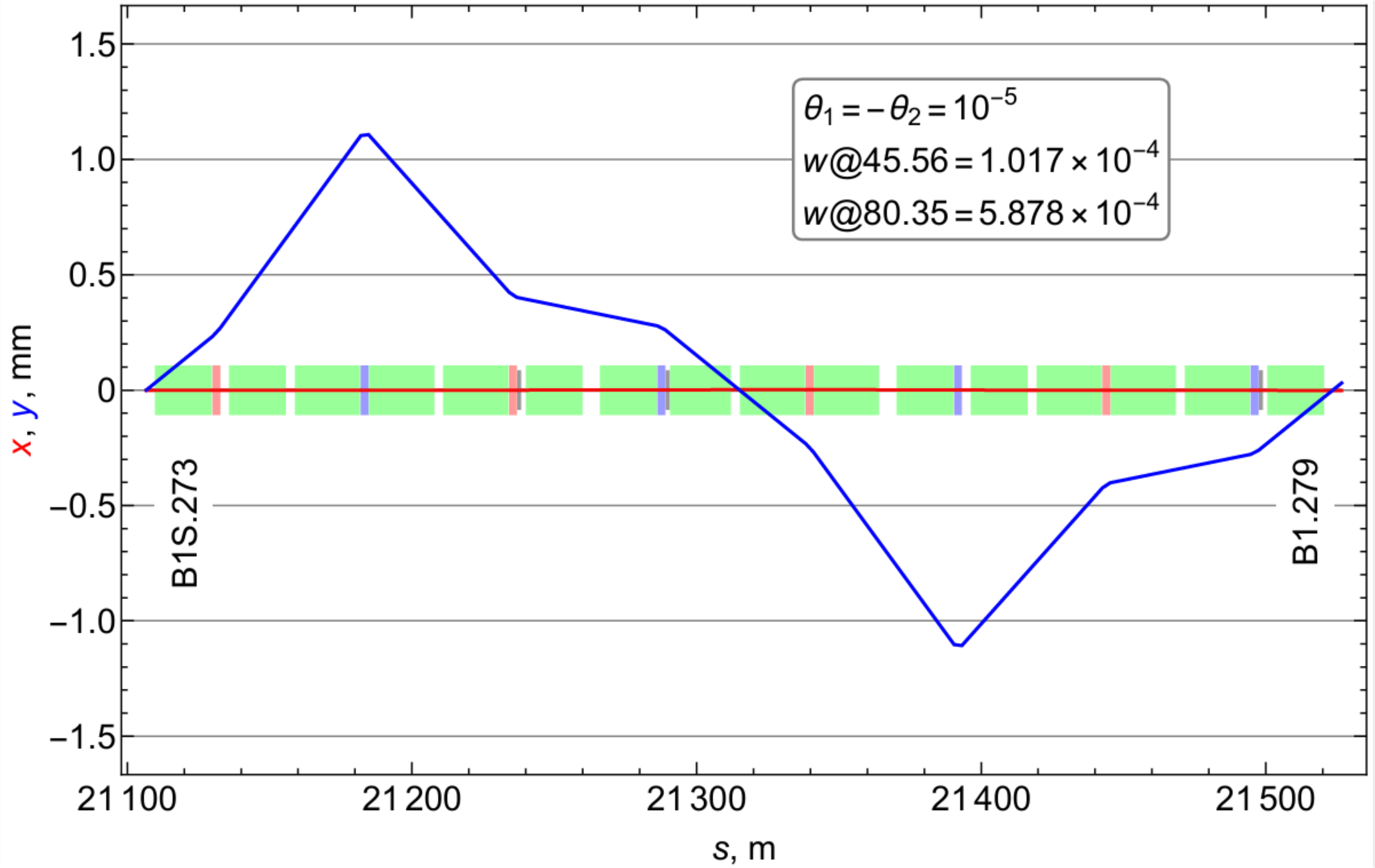
A local bump here, with only 2 dipoles per FODO cell, provides too small spin rotation. Not appropriate arc section to install here the depolarizer!

A local bump with 4 dipoles per cell rotates spin 6 times more efficiently at 45 GeV than an option with 2 dipoles per cell. Also here we have pretty long drifts to insert there the depolarizer's kickers…



Twin quad map from J. Bauche, C. Eriksson, FCC Week 2024

Single wave bump as a common solution for beam energies 45 and 80 GeV



Full wave orbit bump with a kick angle amplitude $\theta = 1 \cdot 10^{-5}$ produces the needed spin rotation at 45 GeV and almost 6 times larger at 80 GeV.

For symmetry and with some margin I propose to install 8 such depolarizers per ring (2 in each quadrant). Also this will permit to do fast spin rotation needed in FSP method.

A request to beam dynamics experts: let's evaluate the DA for such local bump!
Is it sufficient for the oscillation amplitude $\Delta y = \pm 1.1$ mm?

Algorithm to calculate w for the local vertical orbit bumps

The effective harmonic value *w* of a local bump spin rotator is just a sum of $\nu_0\alpha_m$ - spin rotations by the *M* kickers or quads around the *x*-axis. Each kick is included in the final sum with a weight factor $\eta_m = e^{i\nu_0\varphi_m}$:

$$w = \frac{1}{4\pi}\sum_{m=1}^{M}\nu_0\alpha_m \cdot \eta_m$$

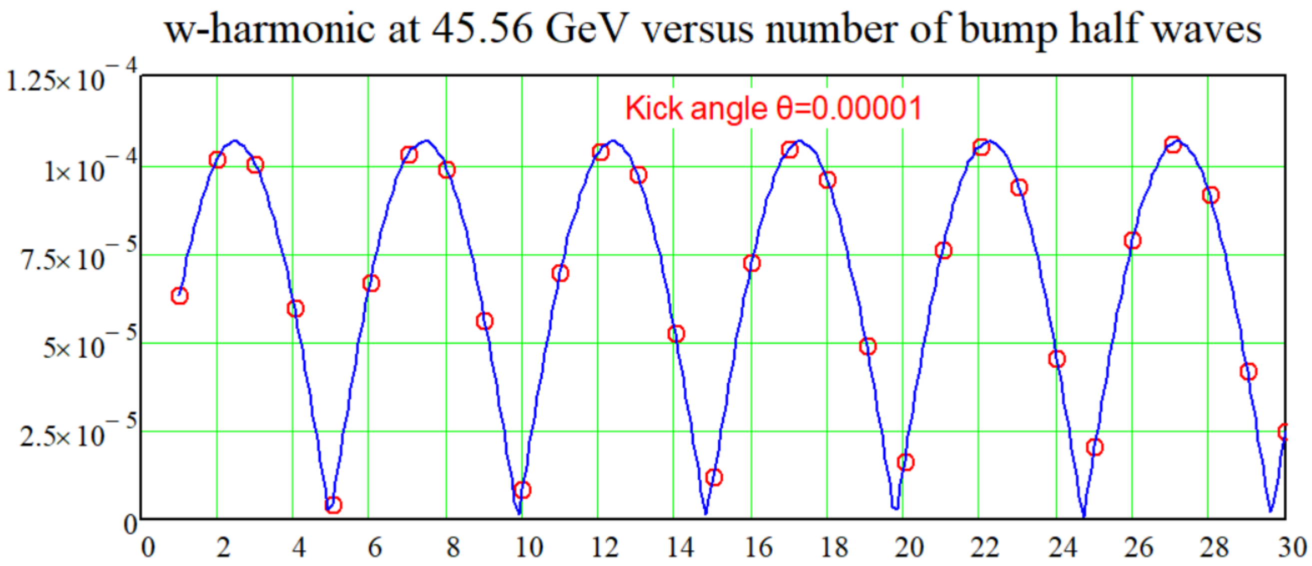
Where ν_0 is a spin tune, and φ_m is the accumulated horizontal bend angle starting from the first kick.

A half-wave bump is the shortest. Longer spin rotators consisting of N π-bumps could provide a greater value of the harmonic of the depolarizer. Their strength can be calculated as a sum of geometric progression:

$$w_N = w_1\left|\frac{1-\left(-e^{i\nu\cdot\Delta\varphi_M}\right)^N}{1+e^{i\nu\cdot\Delta\varphi_M}}\right|$$

At *Z* the spin phase advance $\nu\cdot\Delta\varphi_M = 1.869$ per one half-wave bump is small and increase of *N>2* is not efficient.
At *W* the spin phase advance $\nu\cdot\Delta\varphi_M = 3.297$ per one half-wave bump is close to π and increase of *N* is efficient.

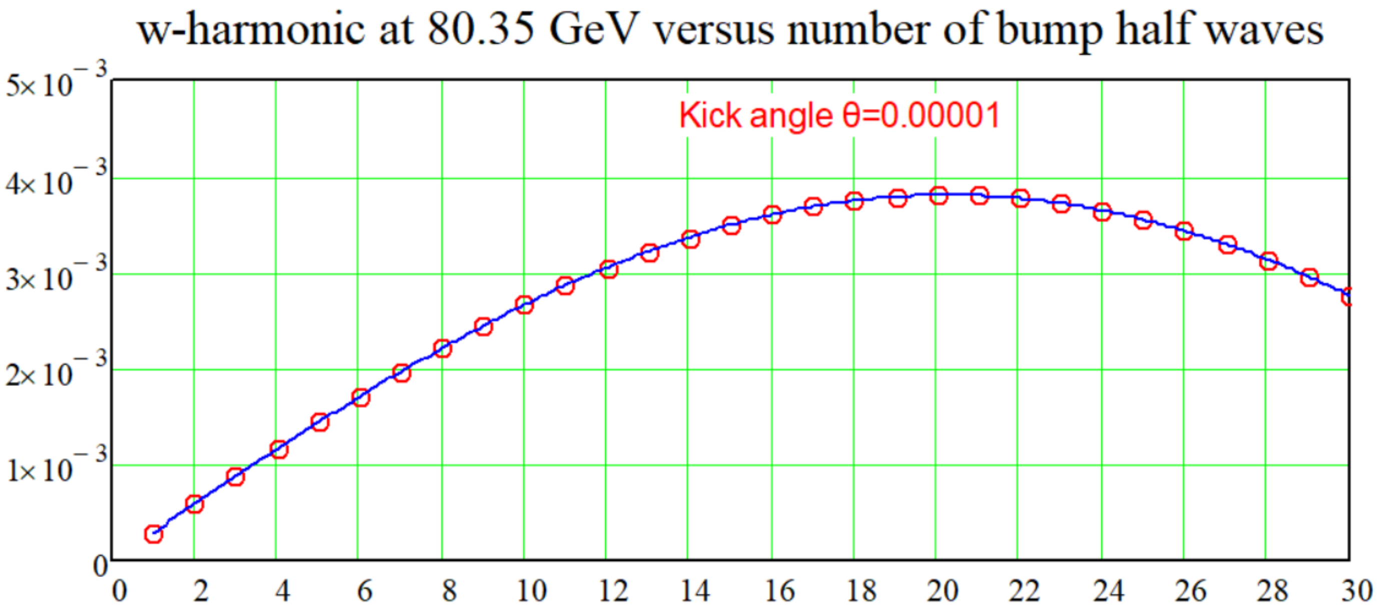
Dependence of w from a number of half-bumps



Interference of half-waves in the regular FODO lattice differs dramatically at 45 GeV and 80 GeV.

In the former case only 2 half-bumps interfere positively, while at 80 GeV almost 20 half-waves contribute positively to the total harmonic value.

This can be used to place two kickers 3, 7, 8, 12, 17 or 22 half-wavess apart.



Discussion

- The local bump depolarizer could be implemented in the regular arc without any change of its optics.
- A single full wave bump produces the wanted depolazer's harmonic value: $w \approx 1 \cdot 10^{-4}$ at 45 GeV and approximatelly 6 times larger value $w \approx 5.878 \cdot 10^{-4}$ at 80 GeV.
- Increasing a length of a bump up to 3-22 half-waves much higher harmonic value can be achieved $w \approx 1 \div 4 \cdot 10^{-3}$ at 80 GeV.
- At 45 GeV only 2 half-waves bump interfere more or less positively. Still, there are other combinations with somewhat longer bumps like 3, 7, 8, 12, 17, 22 half-waves with the same harmonic value at 45 GeV, but much larger its value at 80 GeV.
- Longer bumps could become less stable in terms of DA limit? Needs to be studed!