SIMULATION OF THE GUIDE FIELD FLIPPING PROCEDURE FOR THE FREQUENCY DOMAIN METHOD

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INTRODUCTION

The Frequency Domain Method aims at solving the geometric phase [1, p. 6] and machine imperfection [2, pp. 10, 11] systematic errors, encountered in any Frozen Spin Storage Ring EDM measurement method based on observation of a slow, gradual change in the beam polarization vector.

Geometric phase can be handled by dispensing with operation in the spin resonance (i.e., 3D Frozen Spin) state, in favor of the 2D FS state, generated by a Spin Wheel. [3, p. 1963] In order to eliminate the machine imperfection systematic error, we propose to utilize the imperfection fields themselves as a spin wheel.

Our method [4] is intended for a combined storage ring (bend fields are magnetic). Flipping of the spin wheel roll direction required by the SW methodology is executed via reversing the guide field polarity.Control of its roll rate is achieved via observation of the polarization precession frequency in the horizontal (closed orbit) plane.

FREQUENCY DOMAIN METHOD

- A combined ring method.
- The total (MDM+EDM) spin precession angular velocity is measured.
- The MDM roll rate is only due to machine imperfection fields.
- To make an EDM estimate, we need two cycles: one with a clockwise, and one with a counter-clockwise circulating beam.

$$\Omega_x^{CW/CCW} = \Omega_x^{MDM,CW/CCW} + \Omega_x^{EDM},$$
$$\Omega_x^{MDM,CW} = -\Omega_x^{MDM,CCW},$$

and the EDM estimator

$$\hat{\Omega}_x^{EDM} := \frac{1}{2}\left(\Omega_x^{CW} + \Omega_x^{CCW}\right) = \Omega_x^{EDM} + \underbrace{\frac{1}{2}\left(\Omega_x^{MDM,CW} + \Omega_x^{MDM,CCW}\right)}_{\text{systematic error term}}.$$

RESULTS

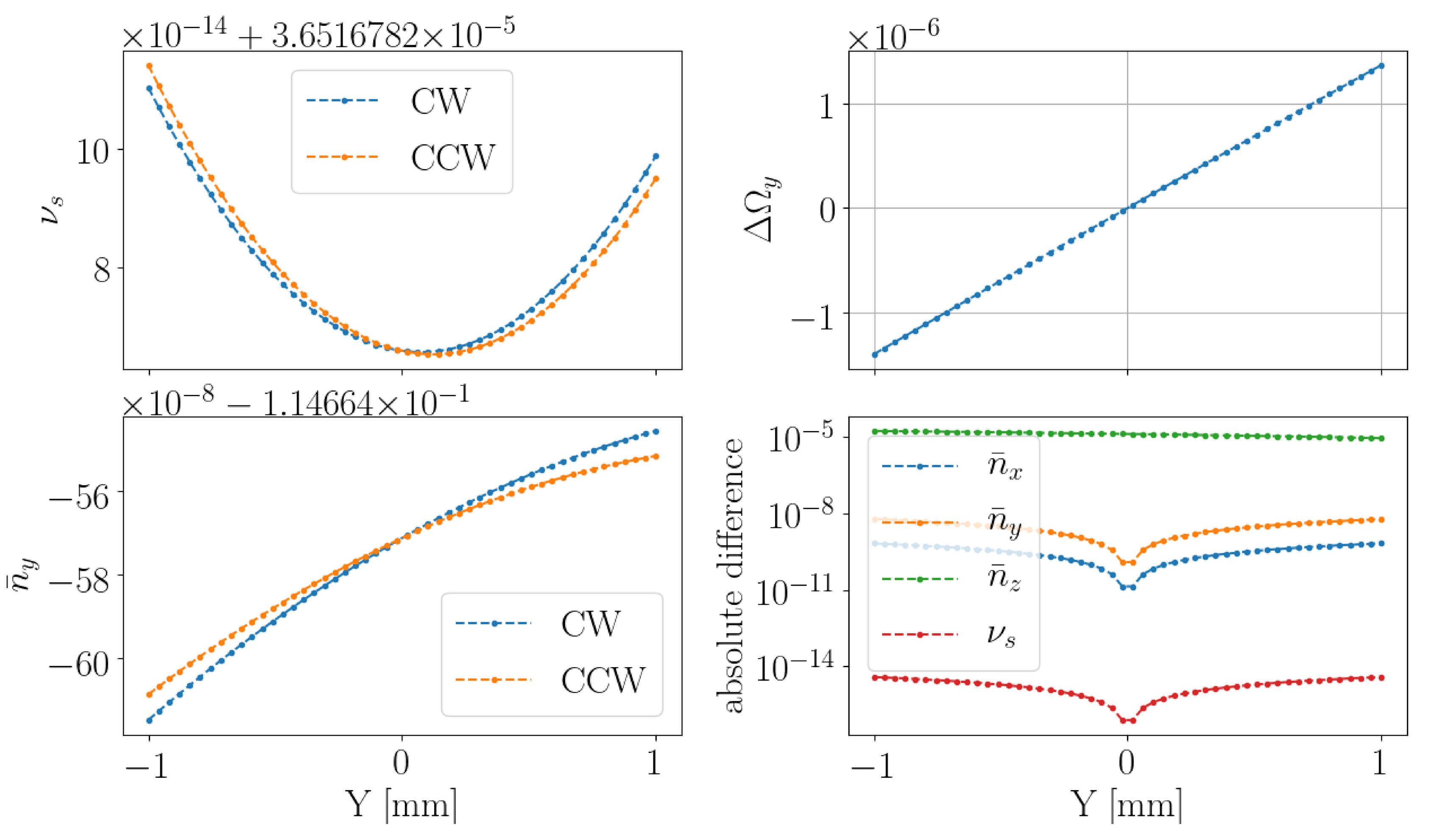

Figure 1: Spin tune and invariant spin axis dependencies on the particle vertical offset from the reference orbit for the CW and CCW moving beams

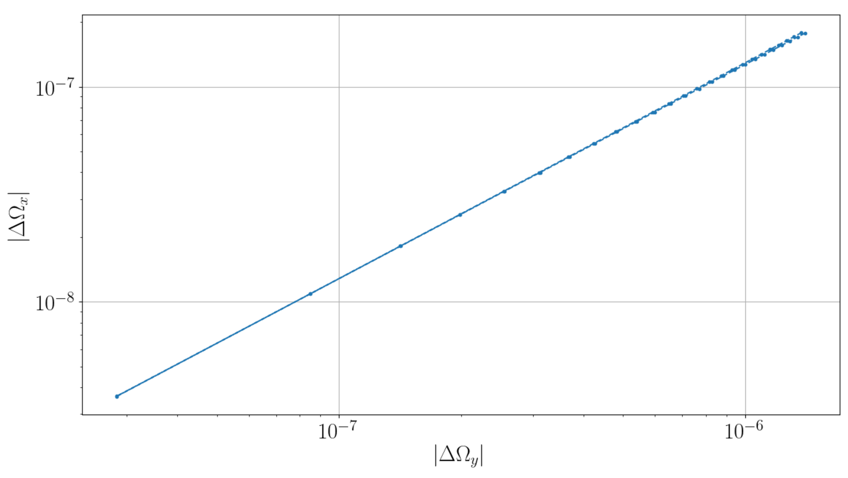

Figure 2: Calibration plot in the vertical betatron motion case

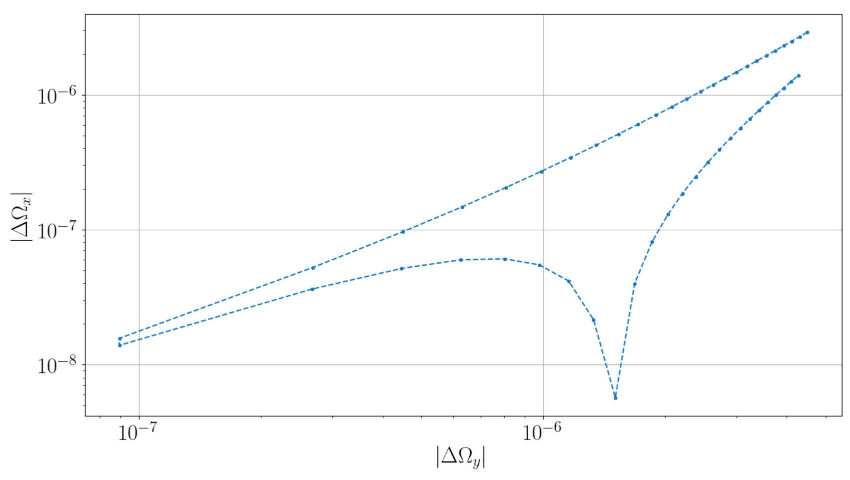

Figure 3: Calibration plot in the horizontal betatron motion case

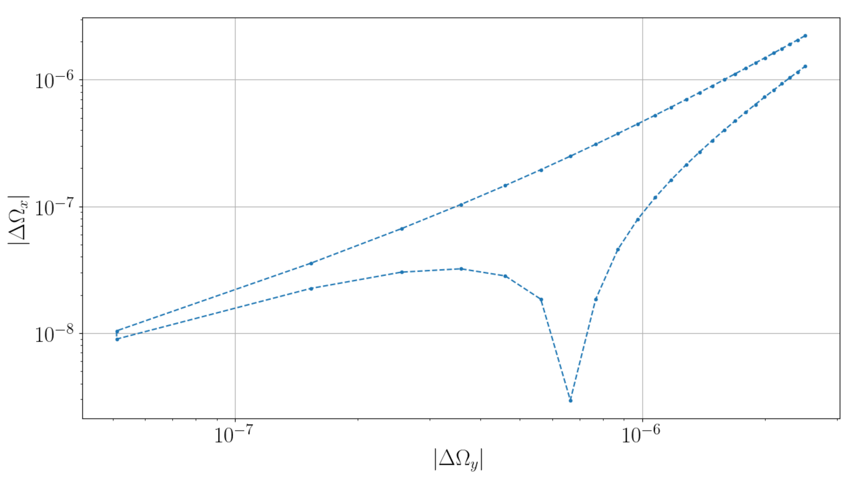

Figure 4: Calibration plot in the synchrotron motion case

Conslusion Equalization of the vertical plane MDM precession frequencies of counter-circulating beams by means of equalizing their horizontal plane precession frequencies is a viable technique.

PROBLEM STATEMENT

- The goal of flipping the direction of the guide field is to accurately reproduce the radial component of the MDM spin precession frequency induced by machine imperfection fields.
- A mere reproduction of the *magnetic field strength* would not suffice, since the injection point of the beam's centroid, and hence its spin tune is subject to variation.
- Also, the accelerating structure might be asymmetrical, in terms of spin dynamics, with regard to reversal of the beam circulation direction.
- What needs to be reproduced, therefore, is not the field strength, but the effective Lorentz factor of the centroid.

EFFECTIVE L-FACTOR CALIBRATION

- Spin tune is an injective function of the effective Lorentz-factor γ_{eff}, which means $\Omega_y(\gamma^1_{eff}) = \Omega_y(\gamma^2_{eff}) \to \gamma^1_{eff} = \gamma^2_{eff}$.
- Let $\mathcal{T}$ denote the set of all trajectories that a particle might follow in the accelerator.
- $\mathcal{T}$ is partitioned into equivalence classes according to the value of γ_{eff}.
- Since $\Omega_y(\gamma_{eff})$ is injective, $\exists!\gamma^0_{eff}$ at which $\Omega_y(\gamma^0_{eff}) = 0$: $[\Omega_y = 0] = [\gamma^0_{eff}]$.
- Once we ensure that the polarizations of both beams are frozen in the horizontal plane, their centroid's γ_{eff} are equal.

SIMULATION

Need to show

1. $[\gamma^0_{eff}]^{CW} = [\gamma^0_{eff}]^{CCW}$, that is $\Omega_y = 0$ for the same set of trajectories in CW & CCW.
2. $\forall t_1, t_2 \in [\gamma^0_{eff}]^{CCW}$: $\nu_s(t_1) = \nu_s(t_2)$, $\bar{n}(t_1) = \bar{n}(t_2)$, i.e., the same sextupole fields reduce decohrerence in CCW as in CW.

How

1. Compute $\nu_s(z)^{CW}$ and $\nu_s(z)^{CCW}$;
2. Evaluate discrepancy $\epsilon(z) = \nu_s^{CW}(z) - \nu_s^{CCW}(z)$.

Analysis

If $\epsilon(z) \ll 1$ for a large range of $z \in \{x, y, \frac{\Delta p}{p}\}$, then

- sextupole decoherence suppression works for both beams without gradient value change;
- $\nu_s^{CW} \approx \nu_s^{CCW}$, and hence $\Omega_x^{MDM,CW} \approx \Omega_x^{MDM,CCW}$.

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