NUMERICAL INVESTIGATION OF THE ROBUSTNESS OF SPIN-NAVIGATOR POLARIZATION CONTROL METHOD IN A SPIN-TRANSPARENT STORAGE RING

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Abstract

The robustness of spin-navigator based method for manipulating the beam polarization axis has been investigated with respect to bend magnet installation errors. Toward that end, variation of the invariant spin axis components along the beamline of an imperfect storage ring operating in the spin-transparent mode has been estimated. The beam polarization vector behavior in the given lattice has been investigated. Conclusions are made regarding the feasibility of using "spin navigator" solenoids for defining the beam polarization axis in the detector region.

Spin-Navigator Insertions

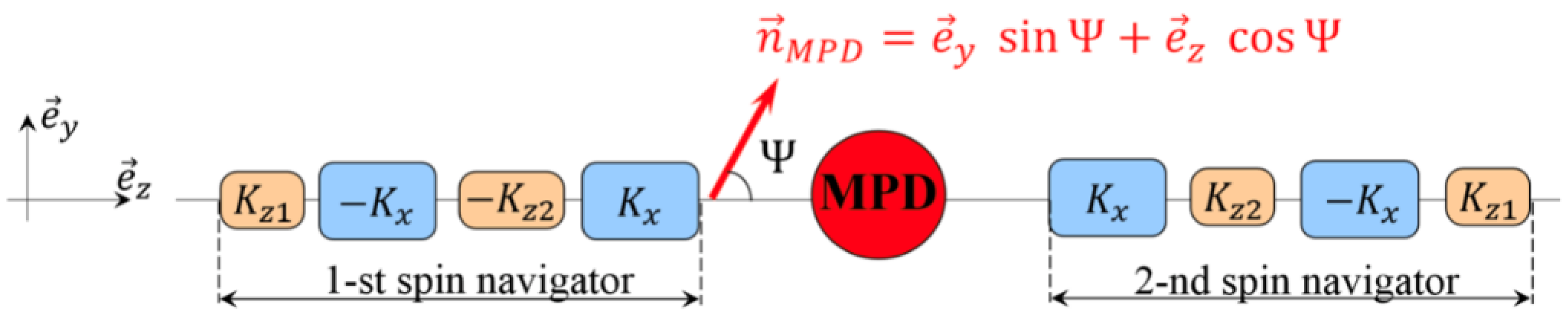

Fig. 1: The scheme of navigator solenoids location close to MPD detector [1].

Navigator insertions with weak fields are used for stabilization of polarization direction in the vicinity of an integer resonance (Fig. 1). They consist of solenoids with longitudinal field and magnets with radial field rotating spin-vectors of particles by small angles. In spin-transparent (ST) method one can obtain any polarization direction at any point of an orbit for arbitrary beam energy.
This method of polarization control is highly sensitive to errors. That is why it is necessary to investigate its robustness in the numerical simulation. For efficient polarization control the stabilizing influence of navigator solenoids in the vicinity of an integer resonance should be larger than the influence of effects arising from lattice imperfections.

Method "Spin-Kick"

$$\frac{d\vec{S}}{dt} = \vec{S} \times (\vec{\Omega}_{MDM} + \vec{\Omega}_{EDM}), \qquad \vec{\Omega}_{MDM} = \frac{q}{m\gamma}\gamma G\, \vec{B}_{\perp}, \;\; \Omega_{EDM} \ll \Omega_{MDM}, \qquad \psi = \frac{\alpha R}{v} \cdot \Delta\Omega_{MDM} = \frac{\alpha R}{v} \cdot \frac{qG}{m} B sin(\varphi).$$

In the simulation a simplifying assumption was used that orbital dynamics does not change with magnet tilts but spin transfer matrix of an element is rotated by an angle depending on a tilt. Spin dynamics of particles in a laboratory frame is described by T-BMT equation. In linear approximation the vertical precession frequency does not change. The radial component $\Delta\Omega_{MDM}$ emerges that is equivalent to spin-vector rotation around the radial axis by an angle ψ, where α and R – the angular size and trajectory radius of a particle in the magnet, B – guiding field, φ – random angle of a tilt around the longitudinal axis.

Simulation Results

COSY INFINITY, deuterons, $\gamma = 1.14$, X from -2 to 2 mm.

$\sigma(\varphi) = \sigma(h)/L$. With $\sigma(h) \sim 100$ um and $L \sim 1$ m, $\sigma(\varphi) \sim 10^{-4}$. Sample expectation of $\varphi \neq 0$. Then $\varphi \sim N(\pm 10^{-3}, 10^{-4})$.

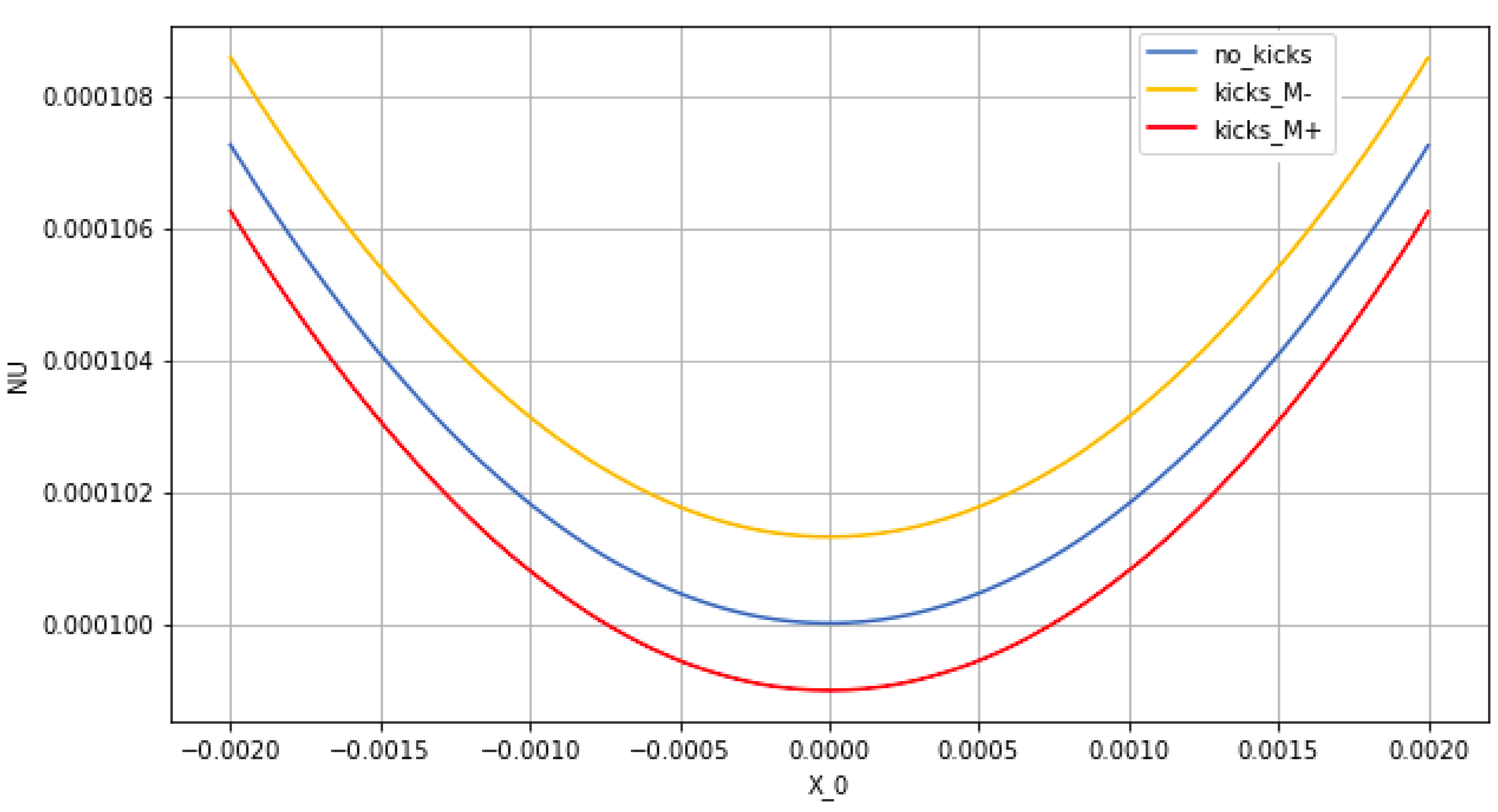

Fig. 2: Spin-tune for different transversely offset particles for ideal lattice and with magnet tilts around the longitudinal axis $\varphi \sim N(\pm 10^{-3}, 10^{-4})$.

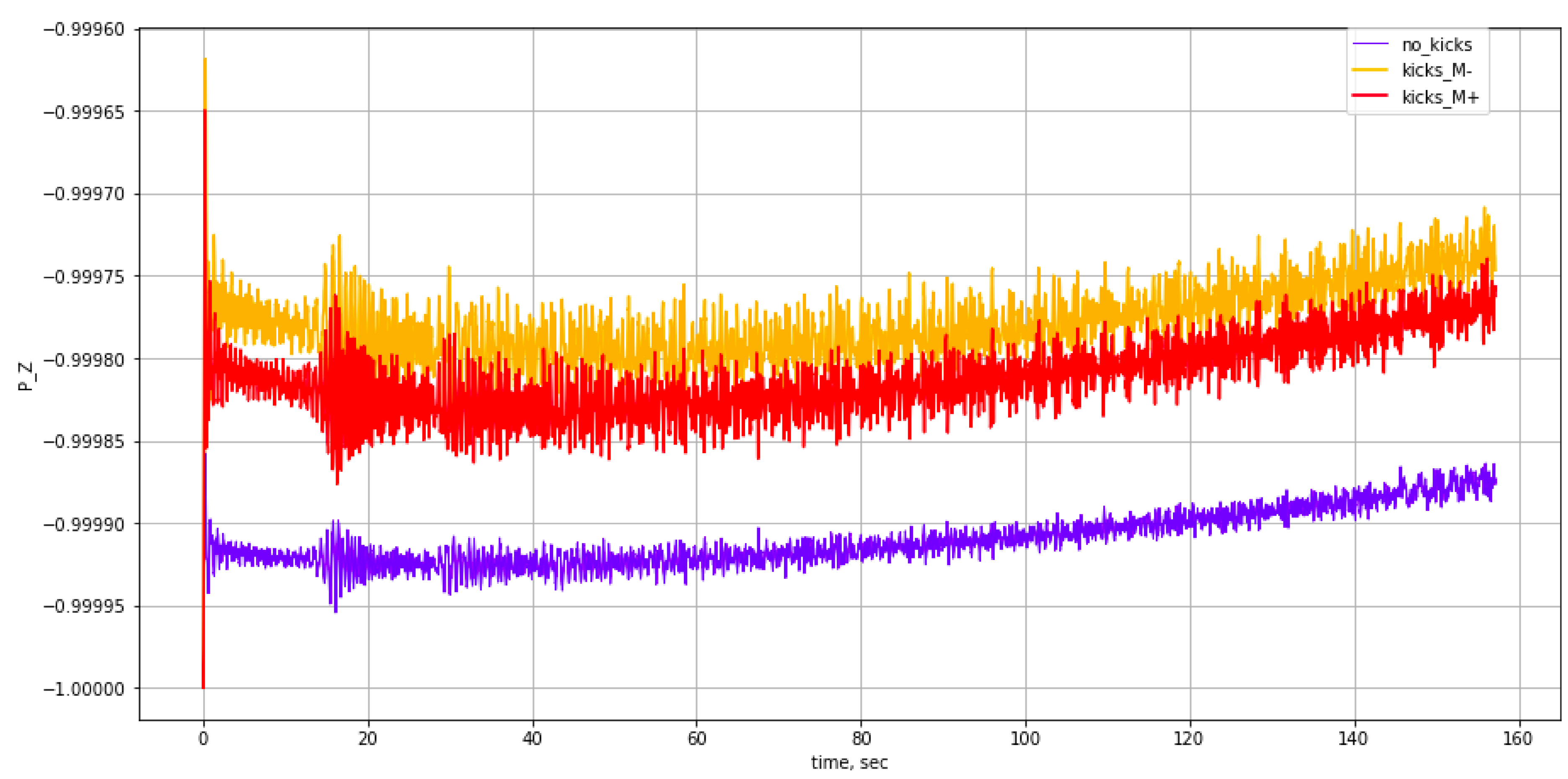

Fig. 3: The time dependence of a longitudinal beam polarization in the detector point for ideal lattice and with magnet tilts around the longitudinal axis $\varphi \sim N(\pm 10^{-3}, 10^{-4})$.

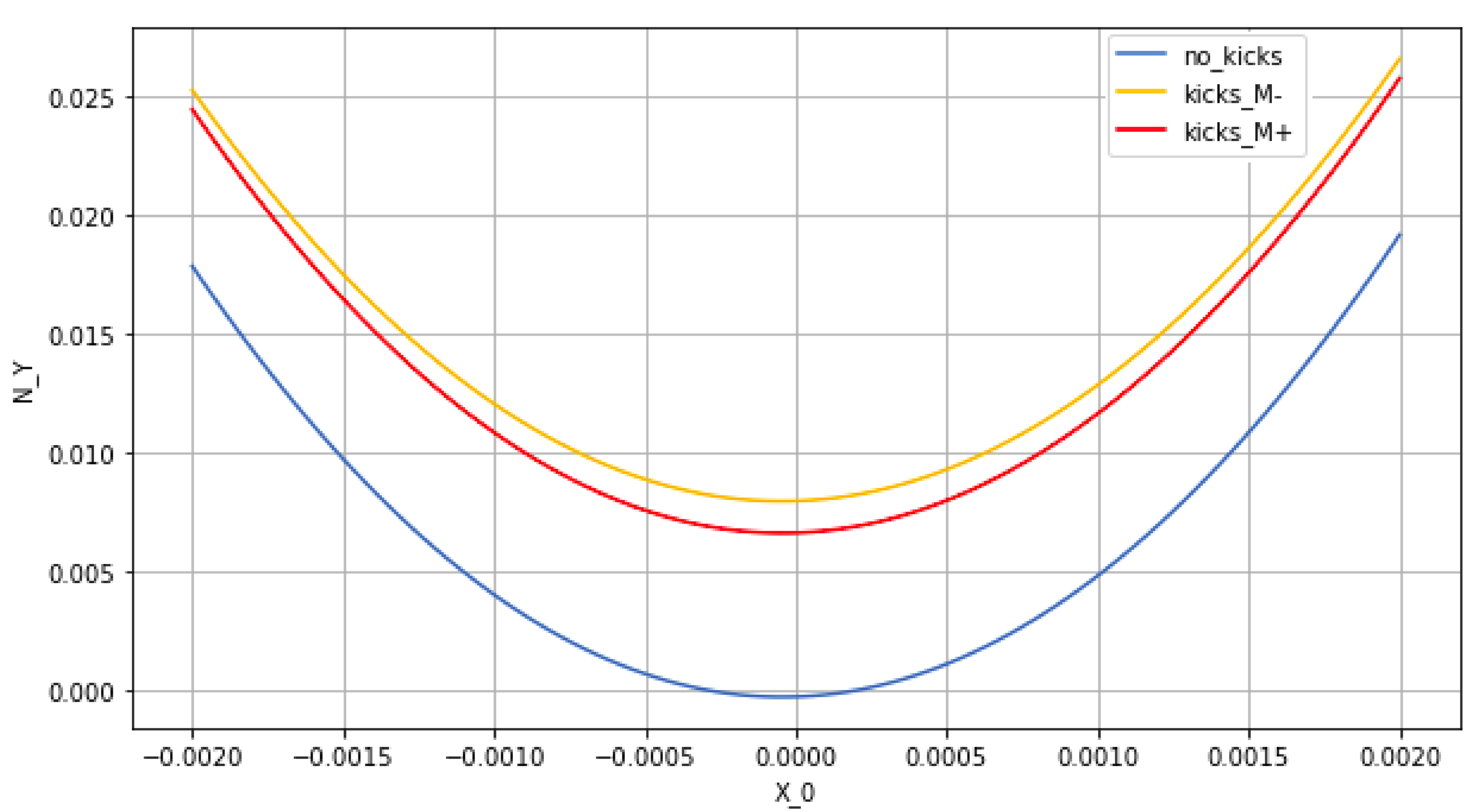

Fig. 4: The dependence of a vertical component of the invariant axis N_y in the detector point for different transversely offset particles for ideal lattice and with magnet tilts around the longitudinal axis $\varphi \sim N(\pm 10^{-3}, 10^{-4})$.

Outcomes:

- $\Delta\nu/\nu \sim 10^{-2}$, $\Delta P/P \sim 10^{-4}$, $\Delta N_y \sim 10^{-2}$ (Fig. 2, 3, 4).
- $\nu(X, tilts = 0) = 10^{-4}$, theoretical value (Fig. 2).
- Parabolic shape in Fig. 2 due to effective energy increase [2].
- The main source of depolarization is $\Delta N_y \neq 0$ in a detector (Fig. 4) due to rotation of emerged vertical polarization with a half-snake solenoid.
- **Spin motion remains stable in the vicinity of an integer spin resonance corresponding to ST regime.**

References:

[1] A. Kondratenko, M. Kondratenko, Y. Filatov, A. Kovalenko *et al.*, "Polarized ions at NICA complex. Project description", Dubna, august 2018.

[2] Y. Senichev, A. Aksentev, A. Ivanov, E. Valetov, "Frequency domain method of the search for the deuteron electric dipole moment in a storage ring with imperfections", arXiv:1711.06512v1.