Modeling of the spin-navigator method for manipulating the beam polarization in a spin-transparent storage ring

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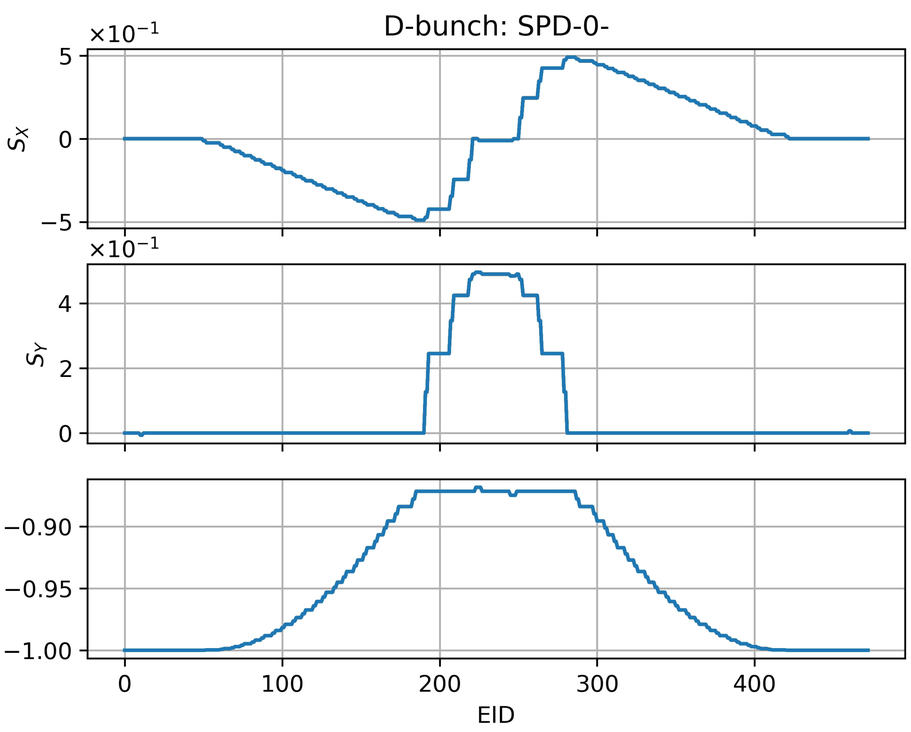
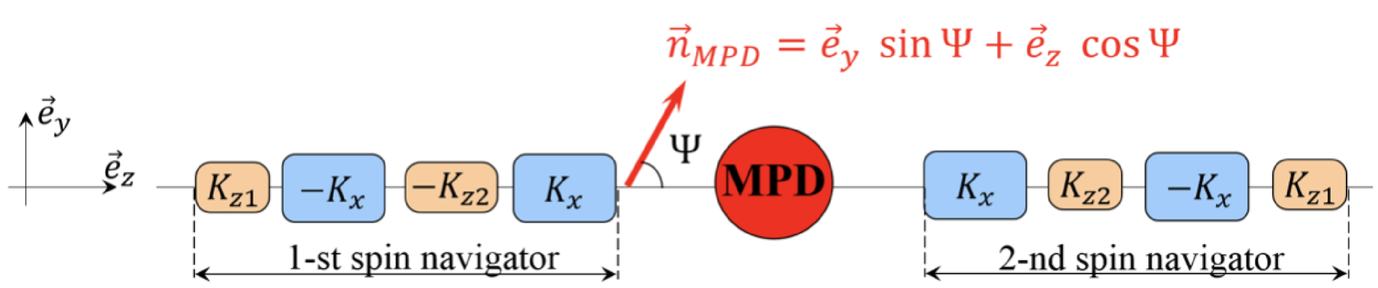
INTRODUCTION

In the projected method for the manipulation of the beam polarization, the spin-transparent (ST) regime is effected by means of "Siberian snakes" which set the beam particles' spin precession frequencies close to zero (in the beam rest frame). The additionally used "spin-navigating" solenoids have a two-fold purpose: not only to orientate the polarization axis, but also to stabilize this orientation by slowly turning the beam particles' spin-vectors about it, thus offsetting the "zero spin precession frequency" condition. [1] However, the finiteness of the beam phase space volume prevents the simultaneous satisfaction of the "zero precession frequency" condition by all beam particles. Due to the differences in their spin-orbit motion the particles' spin-vectors diverge (which phenomenon is termed "spin-decoherence"), which causes depolarization of the beam. One must meet certain conditions, homogenizing the distribution of the spin-precession axis over the beam phase space, in order to preserve the polarization. The purpose of the present work was to study the beam particles' spin-orbital dynamics in the neighborhood of the zero spin resonance and the determination of whether the spin-navigator method for manipulating the orientation of the beam polarization axis is a feasible option. To that end, the COSY INFINITY modeling environment was used. [2] Depolarization mechanisms, in particular those specific to the proposed polarization manipulation method, have been considered.

Spin-navigator scheme



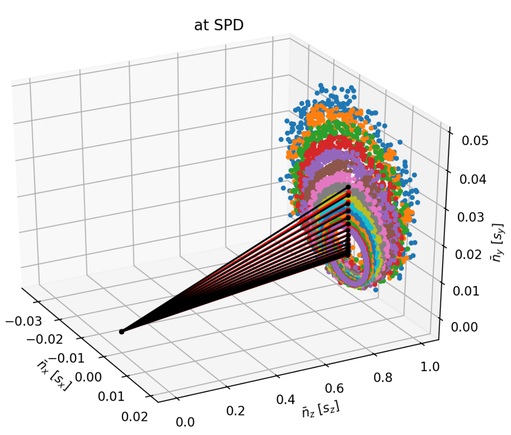


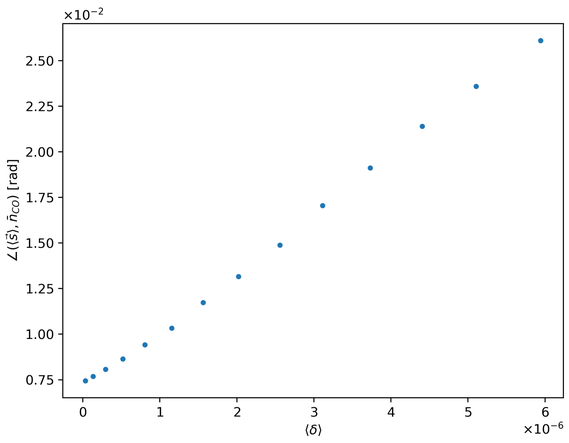
(Figure provided by Y.N. Filatov)

- X,Y,D bunches of **300** particles, uniform distribution in x, y $= \pm 2$ [mm] and $^{\Delta K}/_{K} = \pm 2 \cdot 10^{-4}$
- **four** cases of $\bar{n}_{MPD}$-orientations: **Up**, **Down**, **Forward**, **Backward**
- all spin-vectors **aligned** with $\bar{n}$ at injection: initial polarization $\boldsymbol{P = 1}$
- tracking for $3 \cdot 10^6$ turns (**10.5 sec** of real time)

Spin-dynamics study

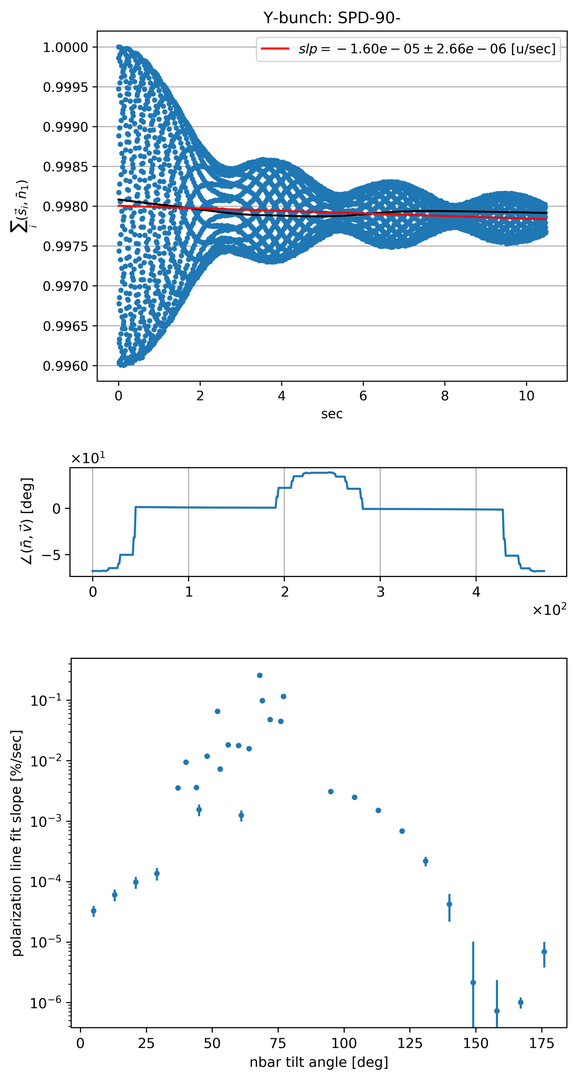
"Spin-precession" is the movement of a beam particle's spin-vector along the surface of a cone whose spray angle and axis orientation depend on the particle's *effective* kinetic energy

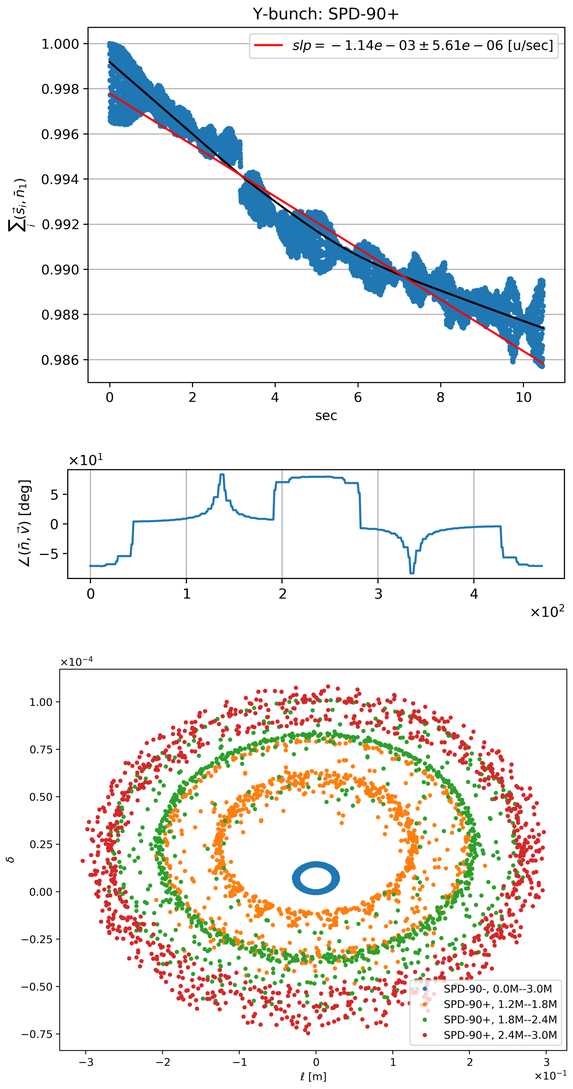




Spin-decoherence study

In the majority of considered cases depolarization has not been found; however, the manipulation of the $\bar{n}$-orientation is performed via creating an **asymmetry** in the magnetic field distribution along the beam-line; this can result in the instability in the beam's *orbital* dynamics





Conclusions

The feasibility of manipulating the direction of the beam polarization axis by means of spin-navigating solenoids in a spin-transparent storage ring has been confirmed. Depolarization mechanisms, in particular those specific to the proposed polarization manipulation method, have been considered.

References

[1] A. M. Kondratenko *et al.*, "Polarized ions in the NICA facility," Technical report, Dubna, Aug 2018.

[2] M. Berz, "Symplectic Tracking Through Circular Accelerators with High Order Maps" in *Proc., Workshop on Nonlinear Problems in Future Particle Accelerators*, Capri, Italy, April 19-25, 1990, pp. 288-296.