Multiparticle tracking results

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EDM search methods in storage rings

There are several methods to search EDM in storage rings.

Here we consider the “magic” method with initial spin orientation along the momentum.

“Magic” method in purely electrostatic ring

In purely electrostatic ring spin of “magic” particle rotates with the same angular frequency as the momentum and the vertical spin component S_y grows up due to the EDM.

T-BMT equation

Spin dynamics described by T-BMT equation:

$$\frac{d\vec{S}}{dt} = \vec{\Omega} \times \vec{S},$$

or

$$\begin{aligned}
\frac{dS_x}{dt} &= \Omega_y S_z - \Omega_z S_y \\
\frac{dS_y}{dt} &= \Omega_z S_x - \Omega_x S_z \\
\frac{dS_z}{dt} &= \Omega_x S_y - \Omega_y S_x
\end{aligned}$$

Vertical spin component

Let's have a look to S_y component:

$$\frac{dS_y}{dt} = \Omega_z S_x - \Omega_x S_z$$

In purely electrostatic ring we have $\overrightarrow{B} = 0$ and $\overrightarrow{E} = \{E_x, 0, 0\}$ (if we do not have fringe fields). Then

$$\begin{aligned} \Omega_x &= -\frac{e}{m}\frac{\eta}{2}E_x, \text{ where } \eta \text{ — EDM factor} \\ \Omega_z &= \frac{e}{m}\left\{ \left(\frac{1}{\gamma^2 - 1} - G\right) E_x\beta_y \right\}, \text{ where } \beta_y \text{ is vertical velocity} \end{aligned}$$

$$d = \frac{\eta e}{4mc}$$

Ω_z is zero in average (because of vertical betatron oscillations).

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Unfortunately vertical spin component grows very slow and if we assume $\eta = 10^{-15}$, machine precision is not enough to accumulate S_y component. In COSY Infinity we can simulate S_y growth with $\eta > 10^{-11}$.

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We define Spin Coherence Time (SCT) as time when RMS spin orientation in the bunch reaches one radian.
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Why horizontal polarization disappears?

Now let's have a look to the horizontal spin component equation:

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If we will make $\Omega_y = 0$, we will get infinite SCT.
The problem is that we can not make $\Omega_y = 0$ for each particle in the bunch.
Each particle has its own Ω_y, all spins rotate on different angles and polarization disappears after somewhile.

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There are many reasons why $\gamma \neq \gamma_{magic}$:

- $\frac{\Delta p}{p} \neq 0$.
- Initial offsets x, y (energy change depends on orbit lengthening due to initial distribution).
- Fringe fields influence (even reference particle changes its energy entering the deflector and leaving it).

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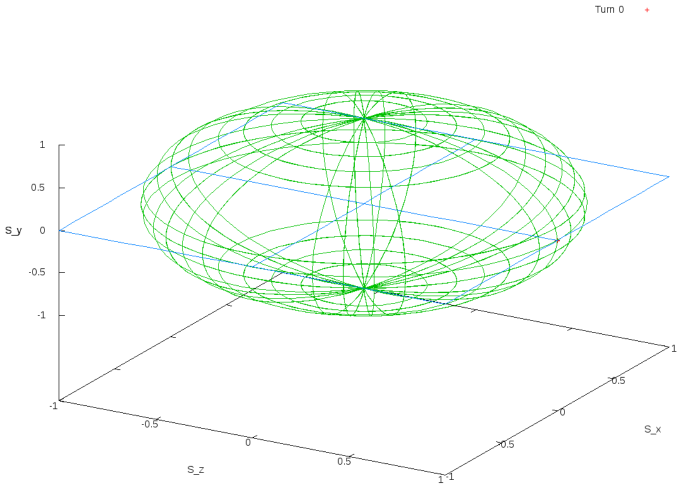
Initial distribution

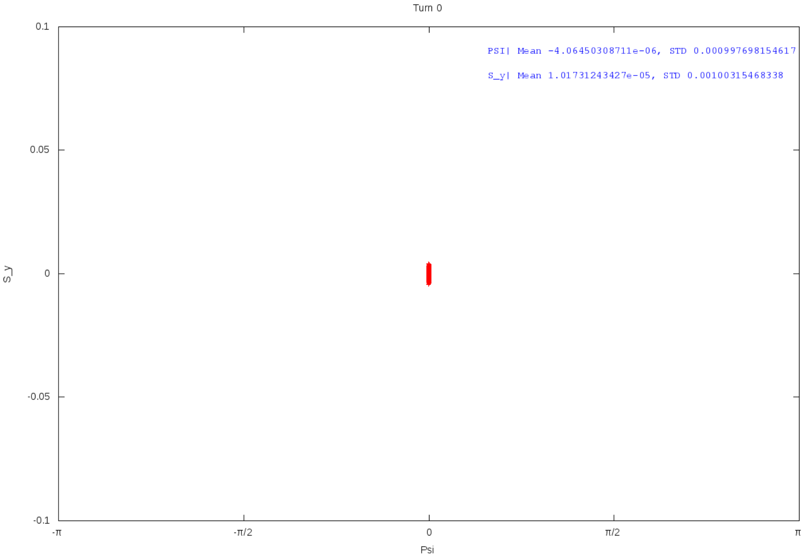
Calculations were made on JUROPA cluster.
Initial distribution:

- 39763 particles
- $\overline{x} = 0mm, \ \sigma(x) = 3mm$
- $\overline{y} = 0mm, \ \sigma(y) = 3mm$
- $\overline{\frac{\Delta K}{K}} = 0, \ \sigma(\frac{\Delta K}{K}) = 10^{-3}$
- $\overline{S_x} = 0, \ \sigma(S_x) = 10^{-3}$
- $\overline{S_y} = 0, \ \sigma(S_y) = 10^{-3}$
- $\overline{S_z} = 1, \ \sigma(S_z) = 10^{-6}$

Spins in 3D



Vertical spin component projection



Thanks

Thank you for your attention.