Study Of Possibilities For A Spin Flip In High Energy Electron Ring HERA

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In a high energy electron ring the spins of electrons become spontaneously polarized via the emission of spin-flip synchrotron radiation. By employing a radio frequency (RF) radial dipole field kicker, particle spin directions can be rotated slowly over many turns.

A model which couples three dimensional spin motion and longitudinal particle motion was constructed to describe non-equilibrium spin dynamics in high energy electron storage rings. We modeled the spin by a unit vector, parameterized using polar coordinates by angles (Θ, Ψ). The obtained model was used for a numerical study of possibilities to reverse the spin polarization.

The effects of a stochastic synchrotron radiation on the orbital motion in the accelerator synchrotron plane and its influence on the spin motion were studied. The main contributions to the spin motion - the synchrotron oscillations and the stochastic synchrotron radiation - have different influence on the spin polarization reversal in different regions of the parameter space.

It can be observed in Fig.1 that the impact of synchrotron radiation stochastic noise κ on spin motion is small in the scanned range of the frequency ramping rate α, although the synchrotron radiation noise strength in HERA storage ring is relatively high. As an example, the final vertical polarization component P_z is plotted against the frequency ramping rate for the integral field strength $1 \cdot 10^{-5}$ Tm (Fig. 2). The major effect on lowering the efficiency of the polarization reversal is due to synchrotron oscillations and not due to radiation effects.

When the integral perturbing field strength is increased, the impact of the synchrotron radiation stochastic noise κ on the polarization reversal efficiency becomes important for the low ramping rates α. Here the final vertical polarization component P_z is plotted against the frequency ramping rate for the integral field strength $5 \cdot 10^{-5}$ Tm (Fig. 2).

The results can be divided into two regimes. At high ramping rates results agree with the ones obtained for the case of integral perturbing field strength of $\int B^0_{RF} dl = 10^{-5}$ m. However, at very low ramping rates α, we found that there is a complete depolarization. One of the reasons would be, that the ramping time for low ramping rates increases. During the time before and after reaching the resonant frequency, the stochastic effects accumulate, leading to a partial or even the complete decoherence of spins.

Using the proposed model, it was found that even for a high energy electron storage ring with significant synchrotron radiation and synchrotron oscillations (as HERA electron storage ring) the spin polarization might be reversed with relatively small strengths of the radial perturbing magnetic field. This is in agreement with measurements [1] in LEP, where spin flips were reported.

The study shows that synchrotron oscillations mix up the spin angles during the passage through the horizontal plane and this results in the effectively lower polarization reversal efficiency. For small integral field strengths the effect of the synchrotron radiation noise on the polarization reversal efficiency is small compared to the effect of the longitudinal oscillations.

One measured datum [2] agrees well with the model prediction, however more experimental data would be needed to validate the model.

REFERENCES

[1] L. Arnaudon et al., Z.Phys. C66, 45. , 1995
[2] Vahagn Gharibyan, Status Report, HERMES Collaboration Group, August 2000.

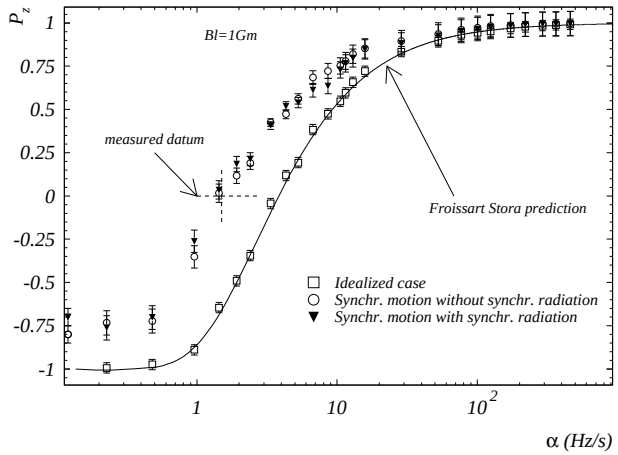

Fig. 1. The final vertical polarization component P_z for the HERA electron storage ring parameters as a function of ramping rate α of the radial perturbing magnetic field of integral strength 10^{-5} Tm, for three cases: idealized case without synchrotron radiation and synchrotron motion, a case without synchrotron radiation and with synchrotron motion and a case with synchrotron radiation and synchrotron motion. An experimental point from HERA electron beam energy measurements is also indicated. (ramping through a 30$\pm$5Hz range across the resonance, ramping time 20s$\pm 2s$ [2]).

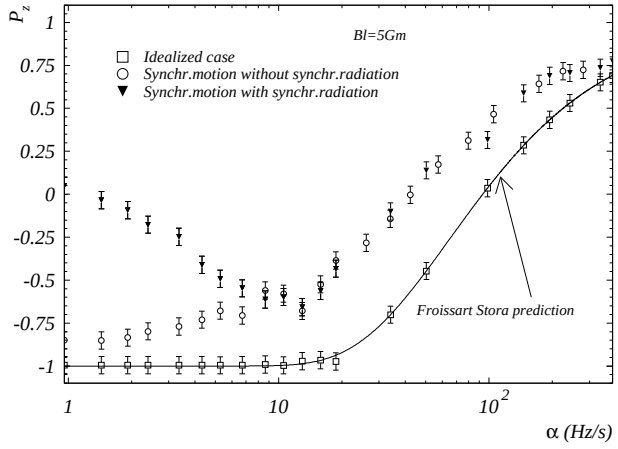

Fig. 2. The final vertical polarization component P_z as a function of the ramping rate α of the radial perturbing magnetic field of the integral strength of $5 \cdot 10^{-5}$ Tm (the HERA electron storage ring parameters used with a stronger perturbing field).