RESONANT DEPOLARIZATION AT THE ILC DR WITH RF DIPOLES

Valentyn Kovalenko[1], Gudrid Moortgat-Pick[1,2], Sabine Riemann[2], Andriy Ushakov[1], Andy Wolski[3]

1 University of Hamburg, Germany
2 DESY, Hamburg/Zeuthen, Germany
3 The Cockcroft Institute, University of Liverpool, UK

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MOTIVATION

- The undulator based positron source will provide *$|Pe^{+}| \geq 30\%$.*

- It is important to *identify and reduce any systematic errors* arising from the accelerator itself in the experiments with polarised beams.

- The direction of polarisation should be reversed or even some *bunches can be intentionally depolarised completely* in order to compare data for unpolarised and polarised beams under same machine conditions.The background processes can be identified thus reducing the systematic errors in the experiments.

- So it would be a good solution to have *possibility of destroying the positron polarization to reduce systematic errors and level of uncertainties* for experiment.

RESONANT DEPOLARIZATION

- Resonant depolarization is produced by exciting the beam with an oscillating magnetic field (kicker).

- The exciting field of the kicker is perpendicular to the beam axis and situated on the plane of the ring.

- A resonance occurs when the rf magnetic field's frequency is synchronized with the spin tune and the circulation frequency:

$$f_r = f_c(n \pm \nu_s)$$

- When the kicker frequency is close to the resonant frequency, the kicks add up coherently, and the cumulative effect of the kicks is to tilt the spins strongly away from the vertical.

- Positron spins are coherently swept away from the vertical direction and polarization disappears.

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The Single Resonance Model assumes that *one of frequencies of Fourier decomposition is nearly in resonance with the spin tune*.

Spin will see the same component of perturbing field turn after turn leading to build-up tilt of the spin. The *amplitude* of this single component is often called the *resonance strength*.

FROISSART-STORA FORMULA

Froissart and Stora (1960) found the *exact analytical solution* for the depolarization of a spinpolarized beam caused by the crossing of a *single resonance driving term*, i.e. only one Fourier harmonic in the perturbing Hamiltonian.

The Froissart–Stora formula assumes that the *depolarizing resonances are narrow and well-separated*. Hence the beam *crosses only one resonance* at a time.

$$\frac{P_f}{P_i} = 2\exp\left\{\frac{-\pi|\varepsilon|^2}{2\alpha}\right\} - 1$$

$$\varepsilon = \frac{(1+G\gamma)\int Bdl}{4\pi B\rho}$$ is resonance strength.

α is the rate of resonance crossing (crossing speed).

If the rf dipole tune is swept across an interval ΔQ in N turns, then $\alpha = \frac{\Delta Q}{2\pi N}$

Three distinct conditions for the variation rate crossing ΔQ are:

Rate	Polarization	Effect
Fast crossing	$P_f \approx P_i$	Little or no depolarization
Medium crossing	$P_i > P_f > -P_i$	Depolarization
Slow crossing	$P_f \approx -P_i$	Spin-flip

SIMPLIFIED MODEL

- The model consists of an RF dipole followed by continuous bending magnet.

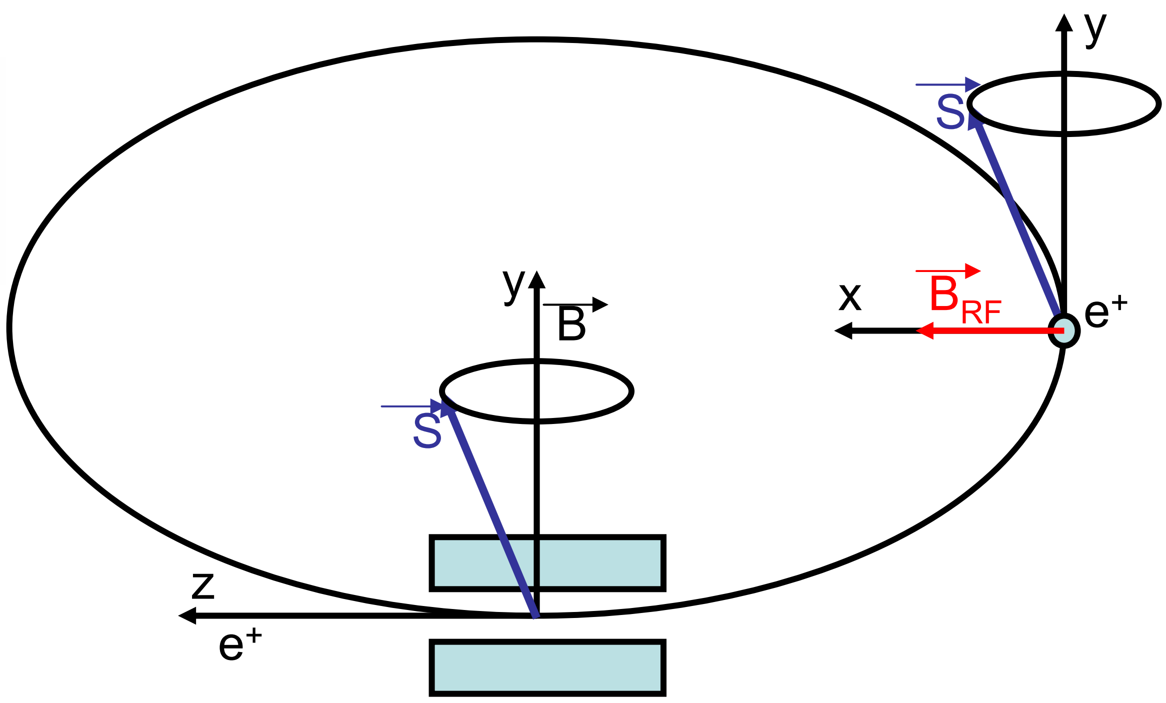
- Spin behaviour of bunch of particles is described by applying rotation matrices at each revolution turn.

RF Dipole

$$R_x(\theta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}$$

Dipole Magnet

$$R_y(\theta) = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix}$$



NUMERICAL SIMULATION

- Initial polarization (vertical): 30%
- Spin tune Gγ=11.35
- Revolution frequency=92.5 kHz
- Resonance frequency=60.17 kHz
- Number of turns (N)=9256

To depolarize beam, we scan the dipole frequency across the spin resonance.

Speed of crossing: $\alpha = \frac{\Delta Q}{2\pi N}$

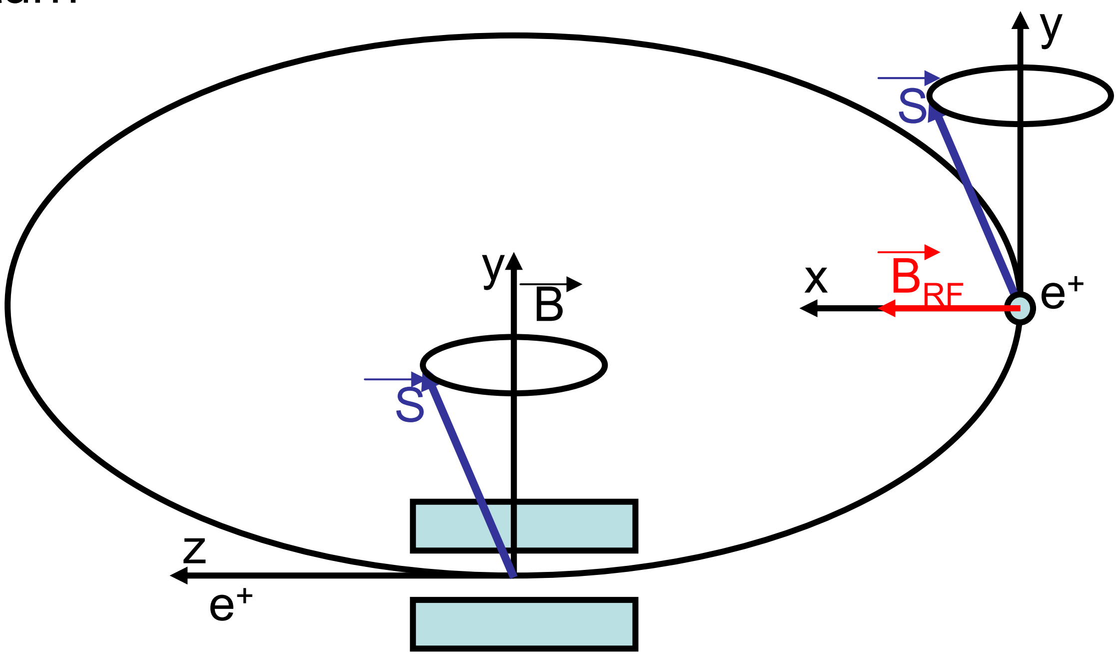
Spin vector gets precessed around the horizontal X-axis at every *m*th turn

$$\theta_{xm} = \frac{(1+G\gamma)\cdot B_{RF\,m} L_{RF}}{B\rho}$$

$$B_{RF\,m} L_{RF} = BL\cos(2\pi mQ)$$

A spin resonance is observed

$$G\gamma - Integer(G\gamma) = Q$$



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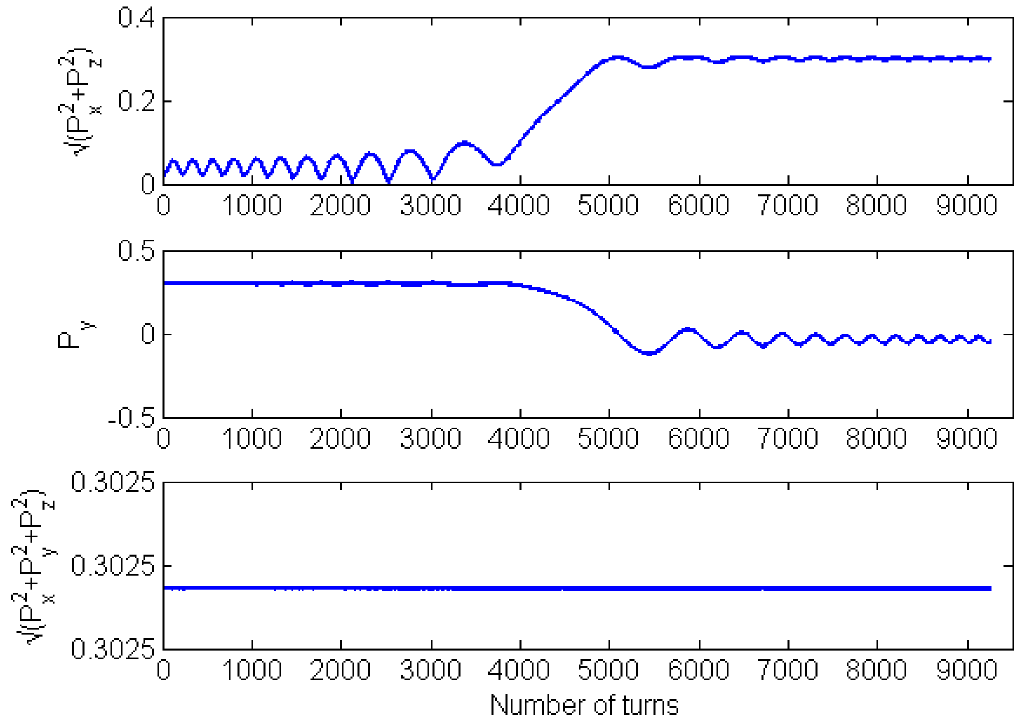

Energy spread = 0%

A spin resonance is observed

$$G\gamma - Integer(G\gamma) = Q$$

Mean polarization is

$$\sqrt{P_x^2 + P_y^2 + P_z^2}$$

DEPOLARIZATION CONDITIONS

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- Spin tune Gγ=11.35
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Integrated field of rf dipole was taken from the COSY experiment $\int Bdl$ 5.8×10^{-4} T m

Resonance strength is changed as follows:

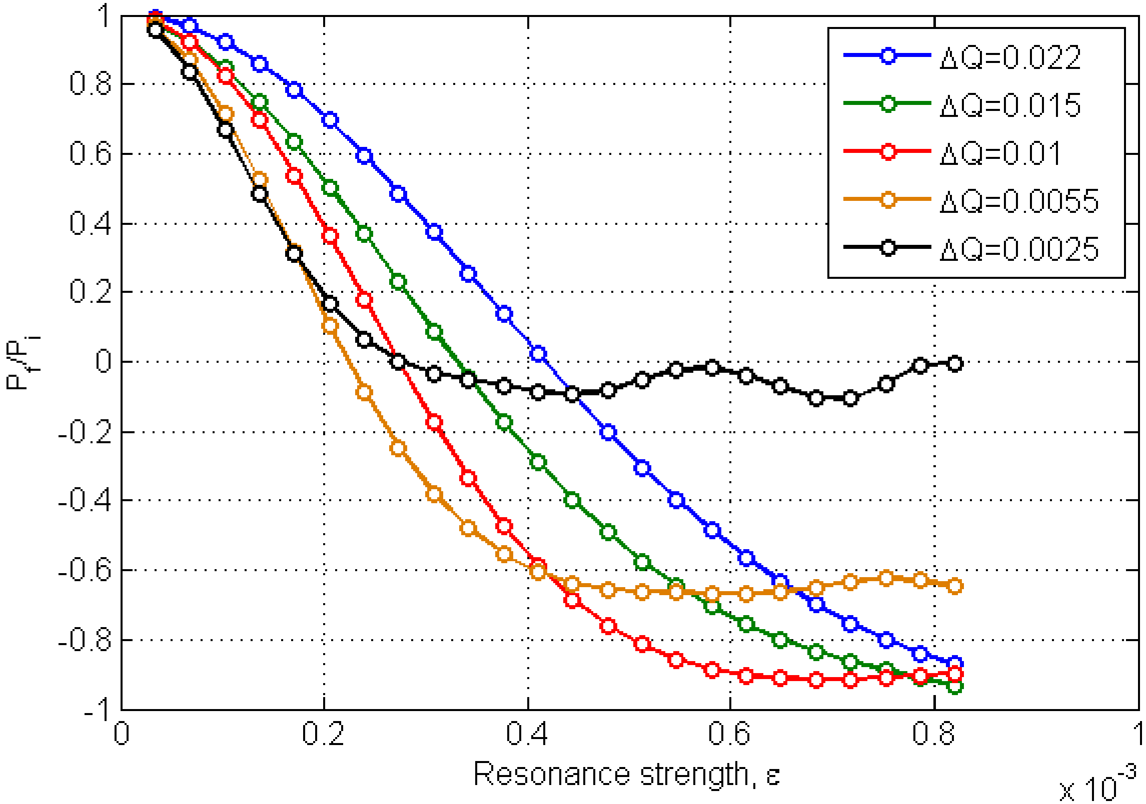
$$\varepsilon = \frac{(1+G\gamma)n\int Bdl}{4\pi B\rho}$$

$$n = 1,2,3...$$

Energy spread = 0.5%

Speed of crossing:

$$\alpha = \frac{\Delta Q}{2\pi N}$$



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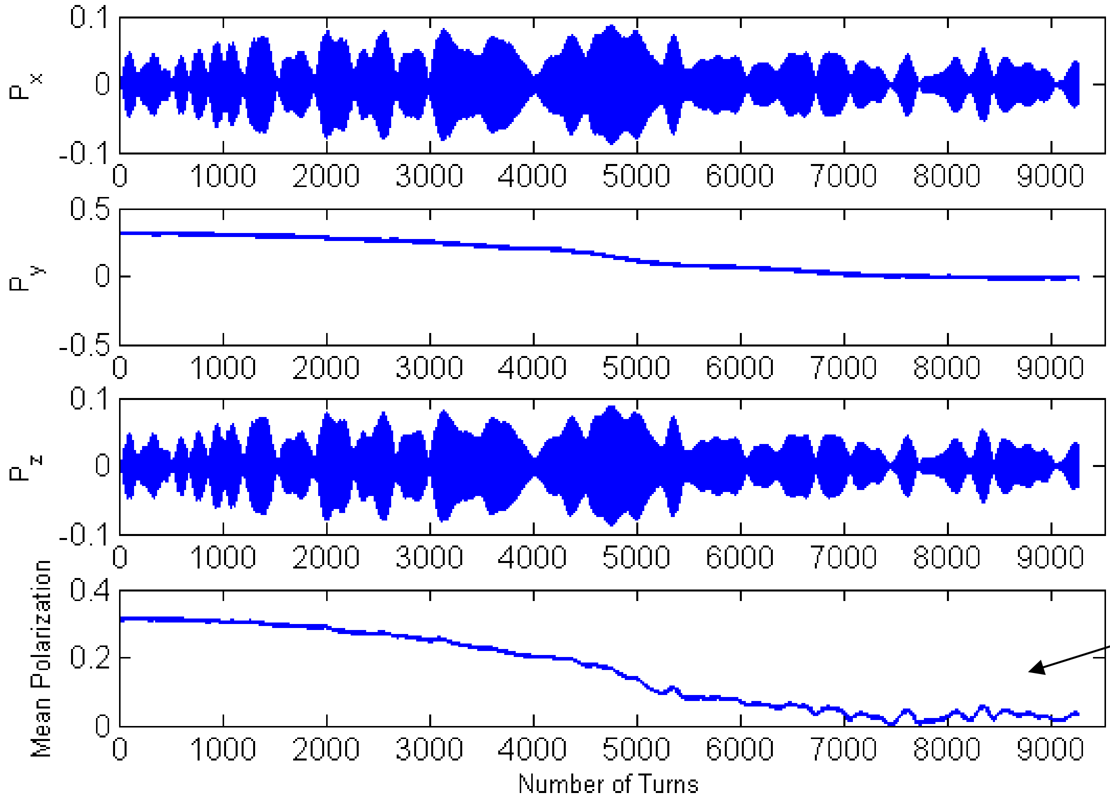
Integrated field of rf dipole:

$n \cdot \int Bdl$ = **8***5.8x10^{-4} = 0.0046 T m



Resonance strength:

$$\varepsilon = \frac{(1+G\gamma)n\int Bdl}{4\pi B\rho} =$$

$$= 2.73 \cdot 10^{-4}$$

Mean polarization goes to 0

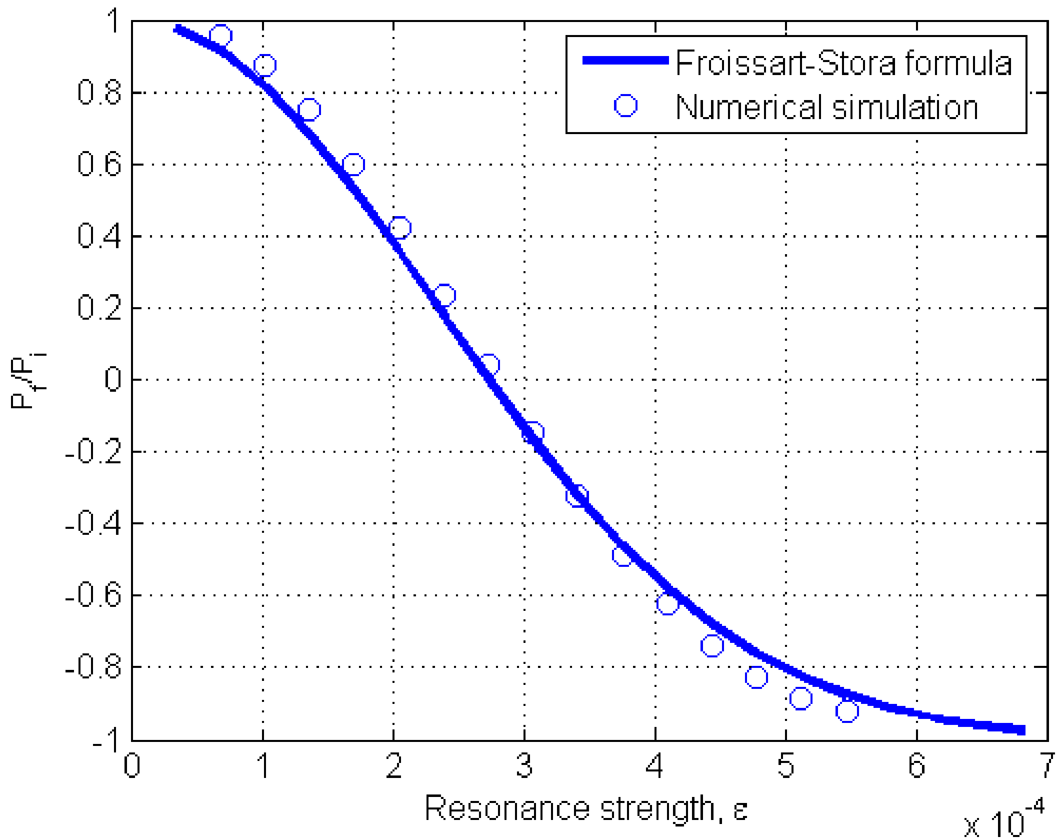
$$\sqrt{P_x^2 + P_y^2 + P_z^2}$$

NUMERICAL SIMULATION AND ANALYTICAL FORMULA

- Spin tune Gγ=11.35
- Revolution frequency=92.5 kHz
- Resonance frequency=60.17 kHz
- Number of turns =9256

Froissart-Stora formula:

$$\frac{P_f}{P_i} = 2\exp\left\{\frac{-\pi\,|\,\varepsilon\,|^2}{2\alpha}\right\} - 1$$



CONCLUSIONS

- An rf dipole with oscillating magnetic field can be used to induce a spin resonance.

- As a first approach the simplest model was investigated and the appropriate value for resonance strength was found in order to depolarize the beam. The results are in a good agreement with analytical Froissart-Stora formula.

FUTURE PLANS

•The rf dipole also excites a vertical coherent betatron oscillation. This coherent oscillation introduces additional perturbations on the spin motion due to the quadrupole fields the particle experiences along its trajectory.

•This effect can either cancel or enhance the rf dipole driven resonances depending on the lattice parameters.

•Therefore spin tracking through the real lattice including the rf dipole has to be simulated.