Precise Electron Energy Measurement at the SLS Storage Ring

- Motivation for precise energy measurement
- Spin dynamics
- Polarization model for SLS
- Resonant spin depolarization
- Advantages of method
- Possible problems
- Goals of this thesis

Energy Measurement

- First approach: Measure dipole magnet strength

  $B\rho = E/ec$ ($\beta \sim 1$)

- Until now $\Delta E/E \sim 10^{-3}$

- Fundamental user interest:
  - more precise energy measurement
  - stability of beam energy over large time scale?

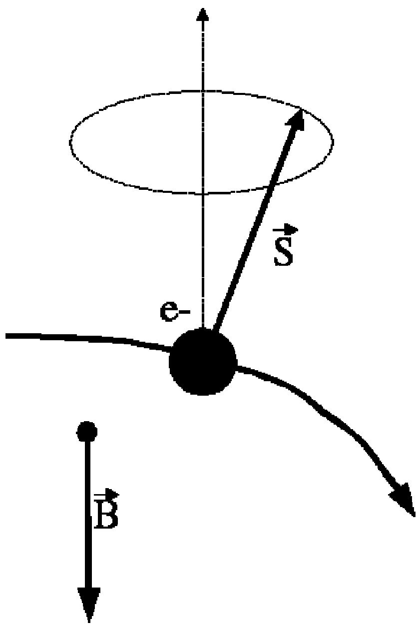
=> Resonant Spin Depolarization

Spin Dynamics (1)

- Thomas−BMT equation: $\frac{d\vec{S}}{ds} = \vec{\Omega}_{rest} \times \vec{S}$

  Spins precess around direction of main bending field

$$f_{spin}\, f_{rev}^{-1} = \nu_{ST} = a\gamma = aE\,(mc^2)^{-1} \qquad a = (g-2)/2$$

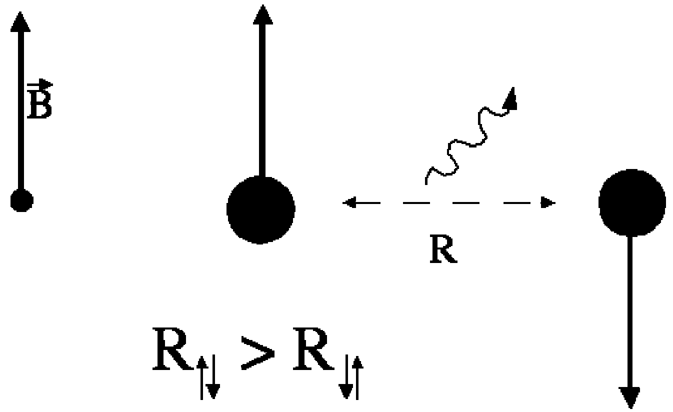


f_{rev}	$\simeq$	1 MHz
a	$\simeq$	0.0016
E	$\simeq$	2.4 GeV
γ	$\simeq$	4697
ν_{ST}	$\simeq$	5.45

Spin Dynamics (2)

- Spin Flip Radiation causes up/down spin flip

  (< 1e−11 of all Synchrotron Radiation processes)

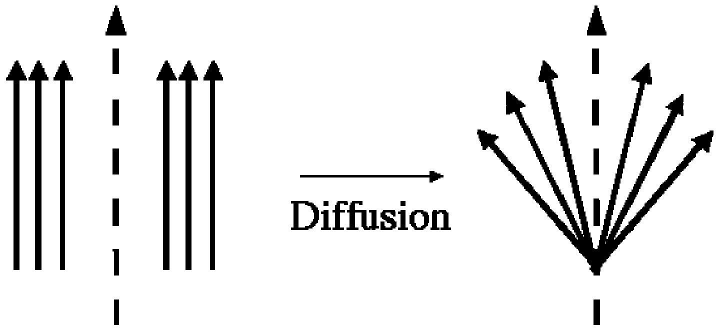


- Polarization not 0%
- Sokolov−Ternov: maximum Polarization 92.4%

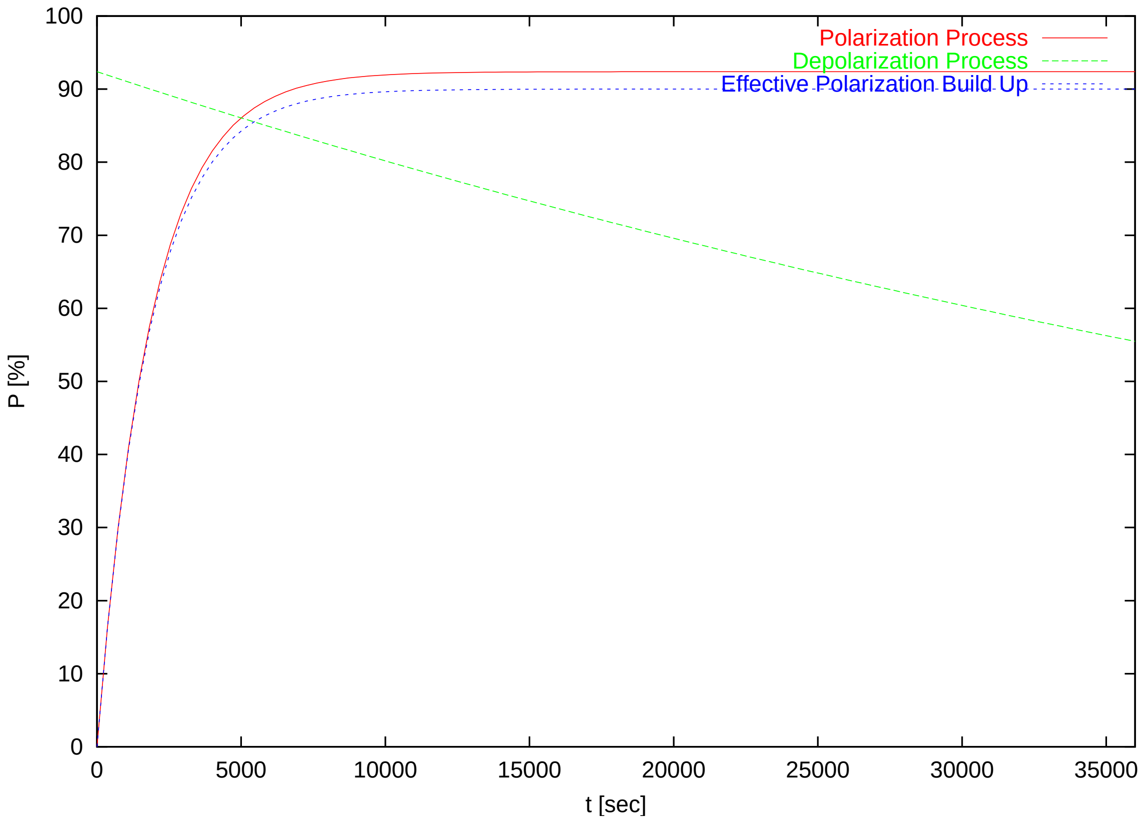
Spin Dynamics (3)

- Photon emission is stochastic
- Under presence of horizontal magnetic fields

  => Spin diffusion



Polarization Model for SLS



$$P(t) = P_{ST} \cdot \tau_D / (\tau_P + \tau_D) \cdot (1 - \exp(-t/\tau))$$

$$\tau^{-1} = \tau_D^{-1} + \tau_P^{-1}$$

$\tau_P \simeq 1865$ s
$\tau_D \simeq 19.6$ h
$\Rightarrow \tau \simeq \tau_P$

Resonant Spin Depolarization (1)

- Touschek scattering of beam particles depends on polarization
  => strongly polarized beams loose less particles through scattering processes than weakly polarized beams

- Use kicker magnet (transverse magnetic field) to perturb spins at various frequencies
  => Mean polarization reduces if perturbation in resonance with f_{spin}

Resonant Spin Depolarization (2)

- Observe increased loss of particles (3 different approaches)
  - Beam lifetime reduces (PCT derivative)
  - BPM intensity signal reduced
  - Scintillation monitor signal intensity rises (coincidence)

=> Find resonance frequency!

$$f_{spin} = f_{rev} \nu_{ST} = f_{rev} a \gamma = f_{rev} a E \left(mc^2\right)^{-1}$$

Advantages

- Very precise measurement because induced resonance has extremely narrow FWHM

- No absolute polarization level measurements needed (requires Compton Polarimeter)

- Numerical simulations can be done using spin tracking code
  - linear (SITF)
  - nonlinear (SITROS)

Possible Problems

- Sidebands i.e. expect resonant behaviour also at $\nu_{ST} + k\nu_s$ ($\forall\ k \in \mathbb{Z}$)

  => Adjust ν_s and see if shift can be observed

- Actual resonant frequency only measured within a half−integer interval (Nyquist Theorem); it is not obvious if the measured value is between n and n+½ or between n+½ and n+1, i.e. is the resonant frequency above or below the half−integer?

  => Adjust energy of machine and observe incease or decrease of resonance position

Goals of this Thesis

- High energy precission ($\Delta E/E \sim 1e{-}5$)
- Measurement of long term energy stability
- Measure the momentum compaction factor α
  - $\alpha = -(E/\Delta E)\cdot(\Delta\nu/\nu)$
  - non−linearity of α