Longitudinal Polarization in SuperB

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Content

Injection of polarized electrons from a source.

Siberian Snake in a LER – simplest solution to get longitudinally polarized electrons with E<4 GeV.

Estimations of polarization and depolarization times.

Requirements to a snake lattice. Snake's optics decoupling. Spin transparency.

Conclusion.

Polarization Scenario

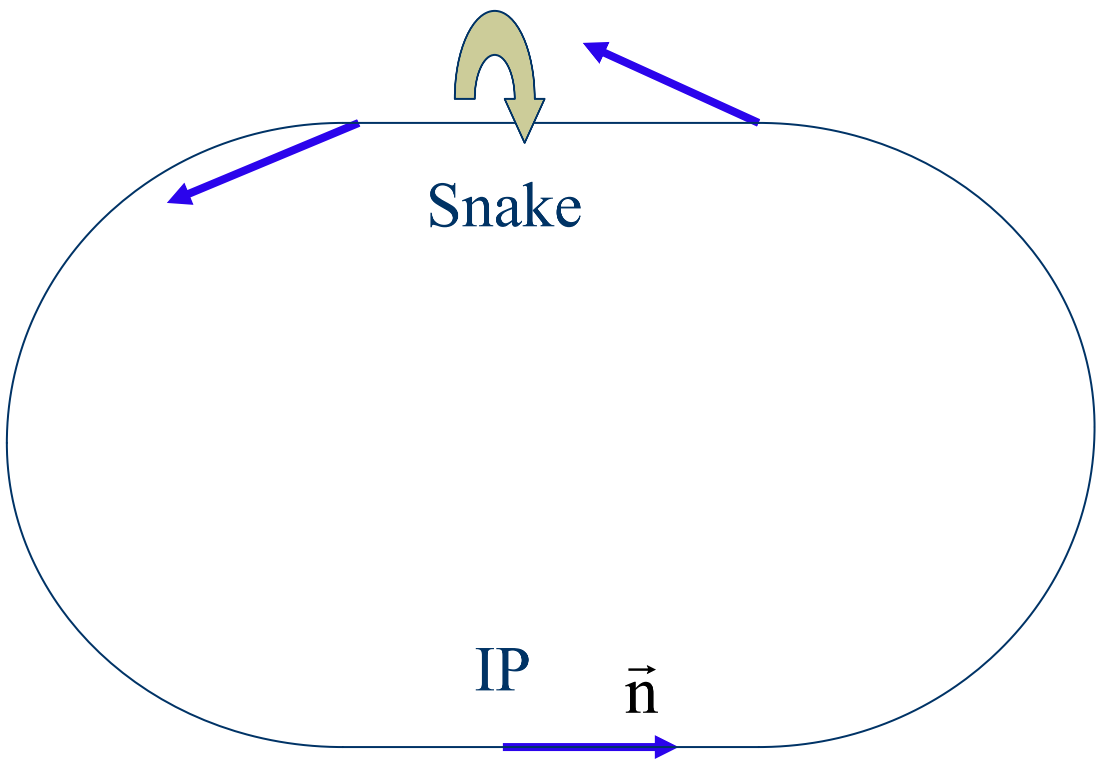
Accelerate polarized electrons from a gun. About $5*10^{10}$ polarized electrons/pulse at about 40 Hz are needed to compensate particle losses caused by beam-bremsstrahlung and by Touschek effect. Estimation of lifetime gave about 100 s. Depolarization time is expected much higher!

Establish closed spin orbit in LER by placing Siberian Snake in the straight opposite to IP. Rotation of spin by 180^0 around z-axis is provided by the solenoidal field integral Bl=πBR =21 Tm for E=2 GeV. Partial Snake also can be considered as option. It require much lower field integral but can operate only near the integer spin resonances, say at “magic” enenrgies: E=1.76 GeV or E=2.2 GeV. Probably OK?

Spin at IP is directed longitudinally at any energy! Spin tune is half integer in case of full Snake and fractional with the Partial Snake.

Closed spin orbit with the snake

Derbenev, Kondratenko, Skrinsky, 1977



Snake rotates the spin by 180^0 around z-axis

In arcs spin lie everywhere in the horizontal plane

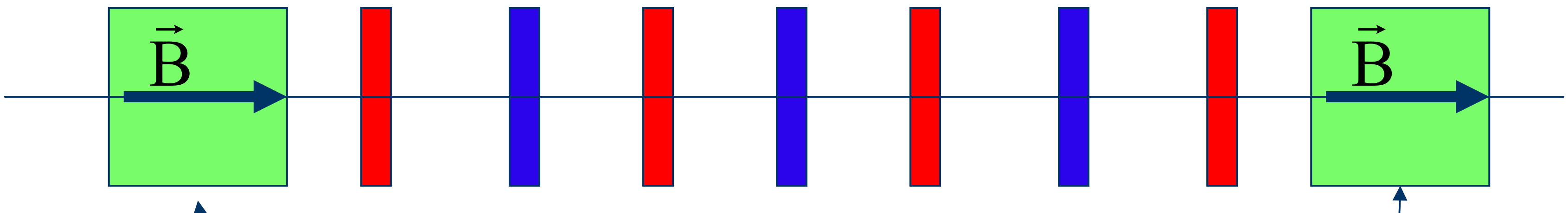
At IP spin is directed longitudinally

With a partial snake at a magic energy spin is directed longitudinally at IP and also at the snake's location

180^0 Spin Rotator for Siberian Snake

Decoupling FODO Optics: $T_x=-T_y$

Litvinenko, Zholentz, 1980



Two solenoids provide 90^0 spin rotation each

Depolarization time in presence of Siberian Snake

$$\tau_p^{-1} = \frac{5\sqrt{3}}{8}\lambda_e r_e c\gamma^5 \left\langle \frac{1-\frac{2}{9}(\vec{n}\vec{v})^2 + \frac{11}{18}\vec{d}^2}{|r|^3} \right\rangle$$

$\vec{d} = \gamma \frac{\partial \vec{n}}{\partial \gamma}$ is the spin – orbit coupling vector

$$\left\langle \vec{d}^2 \right\rangle_{min} = \frac{\pi^2}{3}\nu^2$$

Betatron oscillations could increase |d|!
Spin transparency for the snake is desirable.

For $E = 2\,\text{GeV}$ $(\nu = \gamma a = 4.54)$, $r = 20\,\text{m}$, $\tau_p = 4000\,\text{s} >> \tau_{life}$

Equilibrium selfpolarization degree ζ □ $\vec{b}\vec{n} = 0$!!! (Here $\vec{b} = \vec{B}/B$)

Comparison with a Beam Lifetime

Beam bremsstrahlung cross – sec tion :

$$\sigma_{\mathrm{Loss}} \approx 5 \cdot 10^{-25}\ \mathrm{cm}^2$$

$$\text{For } L = 10^{36}\ \mathrm{cm}^{-2}\mathrm{s}^{-1} \qquad \dot{N} \approx 5 \cdot 10^{11}\ \mathrm{s}^{-1}$$

$$\tau_{\mathrm{Lum}} = \frac{2.4 \cdot 10^{14}}{5 \cdot 10^{11}(\mathrm{s}^{-1})} = 480\ \mathrm{s}$$

$$\tau_{\mathrm{Touschek}} = 100\ \mathrm{s}\,?$$

$$\tau_p = 4000\ \mathrm{s}$$

$$\tau_p / \tau_{\mathrm{Life}} \approx 40$$

Decoupling Insertion between two Solenoids

$$M_{Sol} = \begin{pmatrix} A & 0 \\ 0 & A \end{pmatrix} \cdot \begin{pmatrix} I \cdot \cos(\varphi) & I \cdot \sin(\varphi) \\ -I \cdot \sin(\varphi) & I \cdot \cos(\varphi) \end{pmatrix}$$

$$M_{Sol} \cdot \begin{pmatrix} T_x & 0 \\ 0 & T_y \end{pmatrix} \cdot M_{Sol} = ???$$

$$\text{For } T_x = -T_y \rightarrow$$

$$\begin{pmatrix} I \cdot \cos(\varphi) & I \cdot \sin(\varphi) \\ -I \cdot \sin(\varphi) & I \cdot \cos(\varphi) \end{pmatrix} \cdot \begin{pmatrix} T & 0 \\ 0 & -T \end{pmatrix} \cdot \begin{pmatrix} I \cdot \cos(\varphi) & I \cdot \sin(\varphi) \\ -I \cdot \sin(\varphi) & I \cdot \cos(\varphi) \end{pmatrix} =$$

$$= \begin{pmatrix} T & 0 \\ 0 & -T \end{pmatrix} \rightarrow \quad M_{Sol} \cdot \begin{pmatrix} T & 0 \\ 0 & -T \end{pmatrix} \cdot M_{Sol} = \begin{pmatrix} ATA & 0 \\ 0 & -ATA \end{pmatrix}$$

Spin Transparency Condition

Transparency condition:

$$\int_{\theta 1}^{\theta 2} \vec{\eta}\vec{w}\,d\theta = 0$$

$\theta 1$, $\theta 2$ –entrance & exit azimuths of the insertion, $\theta = z/R$

$$\vec{\eta} = \vec{\eta}_1 + i\vec{\eta}_2 \qquad \vec{\eta}_1 \times \vec{\eta}_2 = \vec{n} \qquad |\vec{\eta}_{1,2}| = |\vec{n}| = 1$$

$$w_x = \nu \cdot (K_y \frac{\Delta\gamma}{\gamma} + y''), \quad w_y = \nu \cdot (K_x \frac{\Delta\gamma}{\gamma} - x''), \quad w_z = -K_z \frac{\Delta\gamma}{\gamma}$$

–spin pertubations. $K_{x,y,z} = B_{x,y,z} / < B_y >, \quad \nu = E(GeV)/0.44$

The spin transparency could be fulfilled more or less easily by the right choice of transformation matrices of a snake.

Polarization Measurements

Compton scattering of circular polarized light on longitudinally polarized electrons – 100% asymmetry!

Conclusions

- Polarization of electrons with a high degree $\zeta > 80\%$ is achievable (from a gun). Particles per bunch?

- Siberian Snake provides the stable longitudinal direction of a spin at IP. A Partial Snake concept works at magic energies: 1.76, 2.2, 2.64, … GeV.

- Depolarization by quantum fluctuations of SR is relatively weak at least at E=2 GeV.

- Should be paid some attention to spin transparency to maximize the depolarization time.