Longitudinal polarization and acceleration of polarized beams

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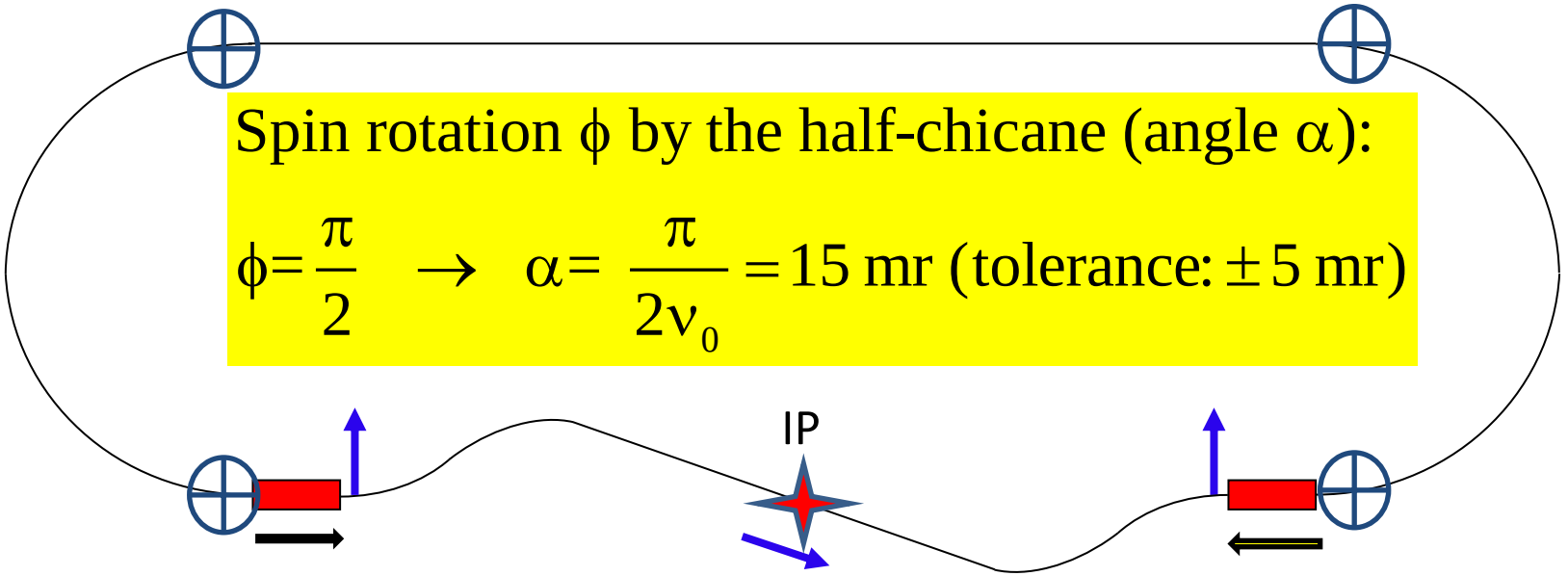
Outline

- Longitudinal polarization at IP
- Solenoid type spin rotators
- Acceleration of polarized beams in a booster synchrotron
- Depolarization rates
- Compton light scattering based polarimetry
- Conclusion

Longitudinal polarization at Z peak

Anti-symmetric layout of the Interaction Region Chicane provides the longest depolarization time!



Advantage: Spin direction in arcs is vertical and achromatic: $|d|_{arcs}=0$.
Chicane magnets only contributed to the radiative depolarization, therefore the spin relaxation time exceeds 24 hours!

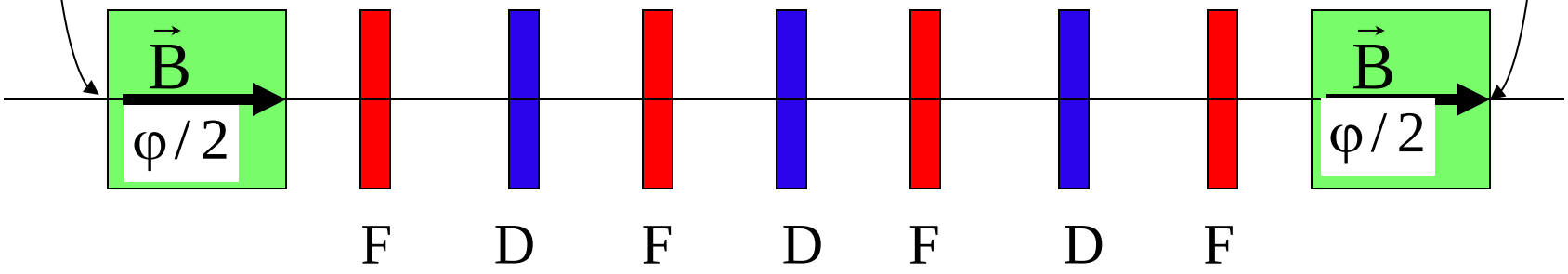
Spin transparent rotator for the solenoid type Snake

For decoupling should be $T_x = -T_y$ ← Litvinenko, Zholentz, 1980

$$T_x = \begin{pmatrix} -\cos\varphi & -2r\sin\varphi \\ (2r)^{-1}\sin\varphi & -\cos\varphi \end{pmatrix}$$ for the spin transparency!

(Koop et al., SPIN2006)

$r = pc/eB$



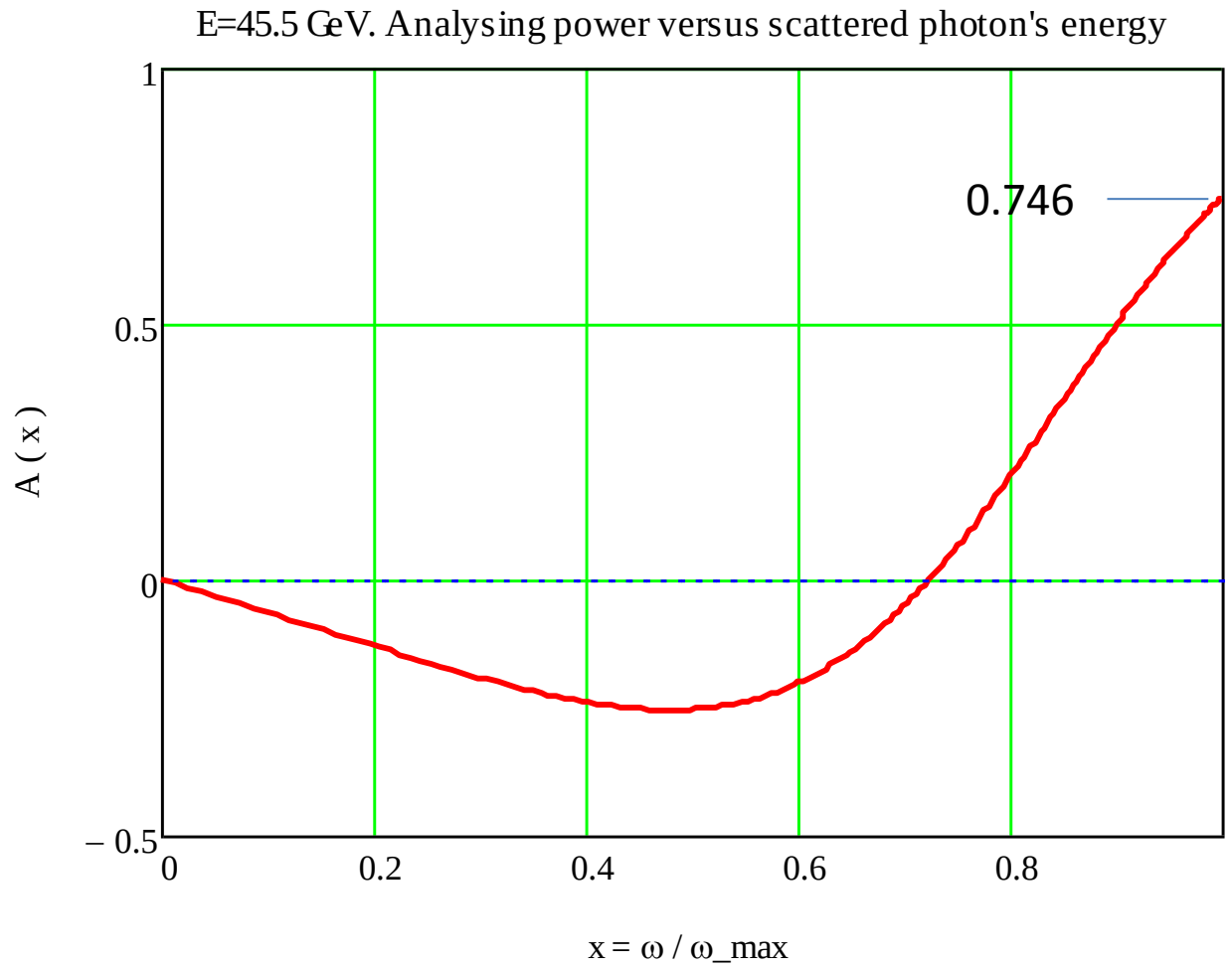
Two solenoids, each L=40 m B=5 T, provide spin rotation by $\varphi = 180^0$

at E=45.5 GeV. Extension to 120 GeV with B=10 T looks feasible.

All quads don't need to be skewed! Spin transparency require:

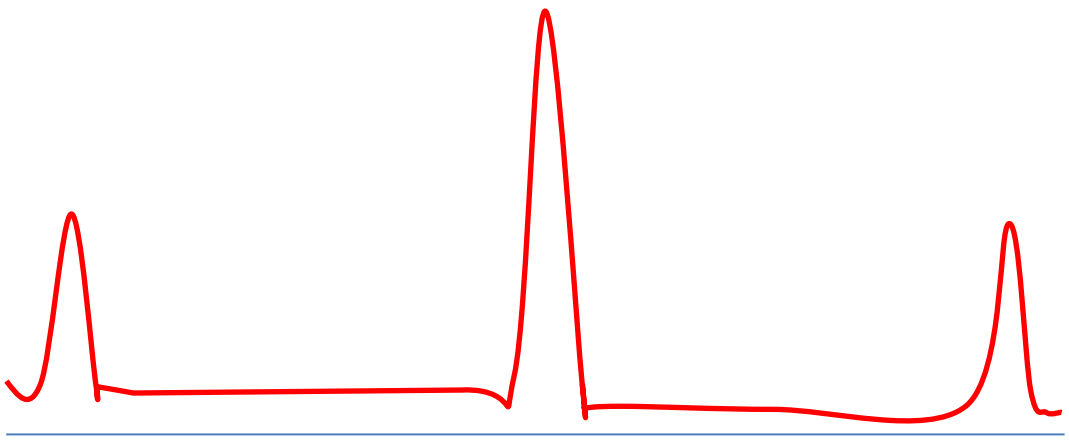
Full Snake: $\cos\varphi = -1, \quad \sin\varphi = 0;$ 90^0 - spin rotator: $\cos\varphi = 0, \quad \sin\varphi = 1$

Compton scattering of a laser light



The longitudinal Compton polarimeter shall be used due to its huge sensitivity to the longitudinal component of the polarization. Detection of the scattered electrons provides excellent spectral selectivity to their energy loss. Thus, can use events at the spectrum edge!

Free spin precession data analysis



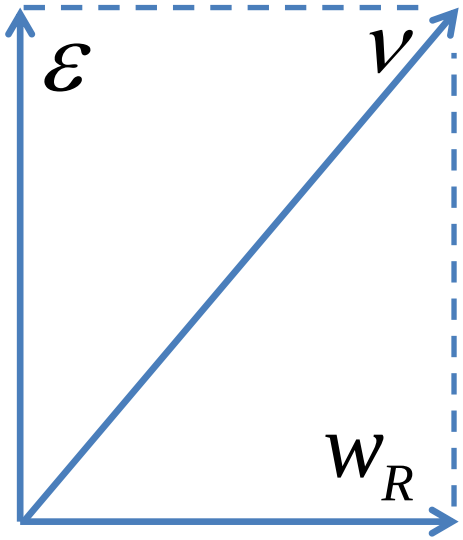
$\{\nu\}-\nu_s$ $\{\nu\}$ $\{\nu\}+\nu_s$

Could be observed also other picks, say from coherent betatron oscillations. But the central pick always will dominate.

Free spin precession data analysis, cont.

Resonance frequency: $\nu_R = k \pm \nu_s \pm m\nu_x \pm n\nu_y$

Detuning: $\varepsilon = \nu_0 - \nu_R$ with $\nu_0 = \gamma a$



Resonance perturbation w_R

Corrected energy formula:

$$\nu_0 = \nu_R \pm \sqrt{\nu^2 - w_R{}^2}$$

Energy can not be determined without measuring w_R !!!

Spin precession frequency must be measured in few energy points near a point of interest!
Spin Harmonic Matching should be applied to minimize the nearby resonances strength!

Free spin precession data analysis, cont.2

- Spin decoherence may limit energy determination accuracy achievable in one injection short.
  Some very rough estimation for Z-peak :

$\sigma_{\langle\delta\rangle} \simeq \sigma_{\delta}{}^{2} \simeq 1.6\cdot 10^{-7}$ - energy spread $\left(\sigma_{\delta} \equiv \sigma_{\Delta E/E} \simeq \pm 4\cdot 10^{-4}\right)$

$\sigma_{\langle\nu\rangle} = \sigma_{\langle\delta\rangle}\cdot\nu_0 \simeq 1.6\cdot 10^{-5}$ - spread of average spin tunes

$N_{Cohr} = \dfrac{1}{2\pi\sigma_{\langle\nu\rangle}} \approx 1\cdot 10^{4}$ - spin coherence time (in turns)

Is sufficient to determine E_b with 44 keV or 10^{-6} accuracy!

Energy limits for polarization

- First limit comes from the high order synchrotron satellites. Can be cured by the use of Siberian Snakes in the booster ring! Still the collider shall operate without any snake!
- The second limit is more fundamental: due to high rate of the spin tune diffusion, caused by fluctuations of SR. For FCC-ee it is 80-100 GeV ?

  (see talk by Yu.Shatunov at the SPIN14 conference)
- Above that limit only Compton based methods could work, be proofed at lower energies.

Conclusion

- Polarization is useful for direct energy calibration of up to W threshold. Free precession method, based on use of the Compton polarimeter, shall provide the energy determination with 10^{-6} accuracy in one short!

- Polarization will help calibrate@validate Compton based methods of the energy control/monitoring.

- Acceleration of a polarized e-beam in a synchrotron, equipped with Siberian Snakes, opens possibility to perform experiments with longitudinal polarization at IP (Z-peak).

Conclusion, cont.

- Solenoid type spin rotators minimally interfere with the Interaction Region optics: basically no any orbit and the betatron coupling distortions.

- Longitudinal type Compton polarimeter, based on detection of the scattered by the laser light electrons, can provide ultra-fast determination of the degree of longitudinal polarization, due to its almost 100% analysing power.