Longitudinal Polarization in Novosibirsk c-tau factory

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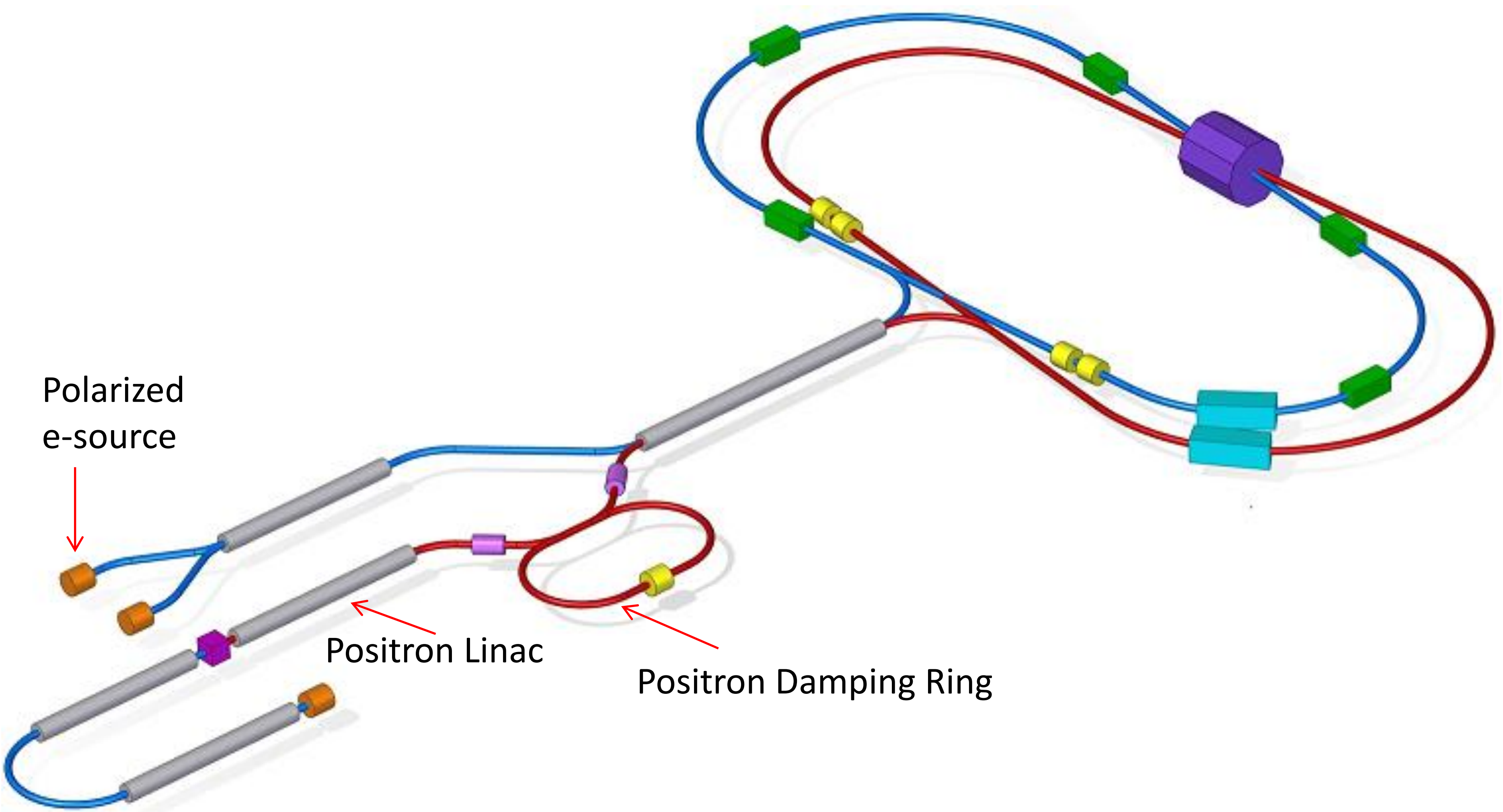
Outline

- C-tau complex with the longitudinally polarized electrons.
- Siberian Snakes Concept.
- Radiative self-polarization processes. Formulae Derbenev - Kondratenko.
- Few options with different number of snakes.
- Results and conclusion.

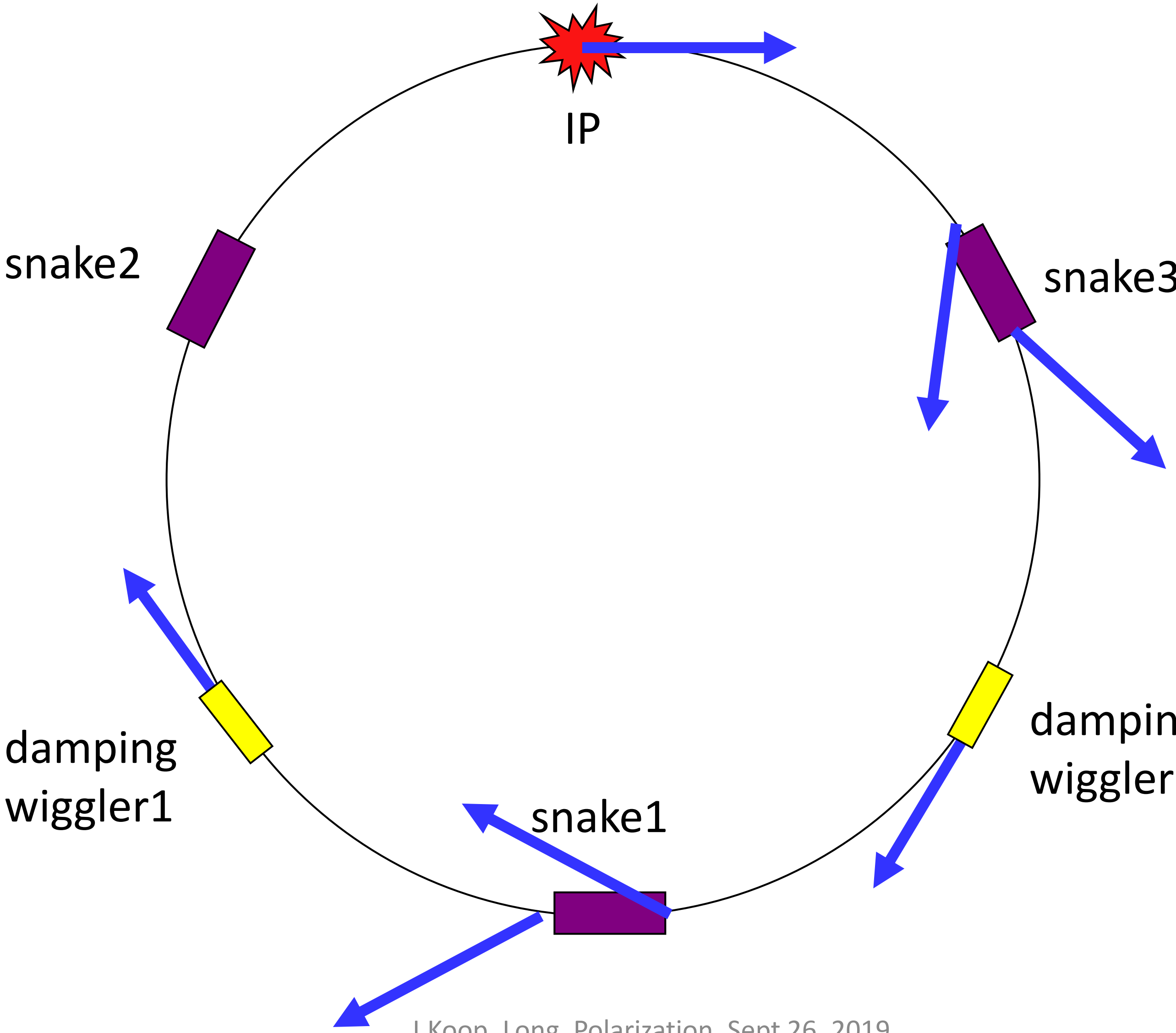
Novosibirsk c-tau complex layout



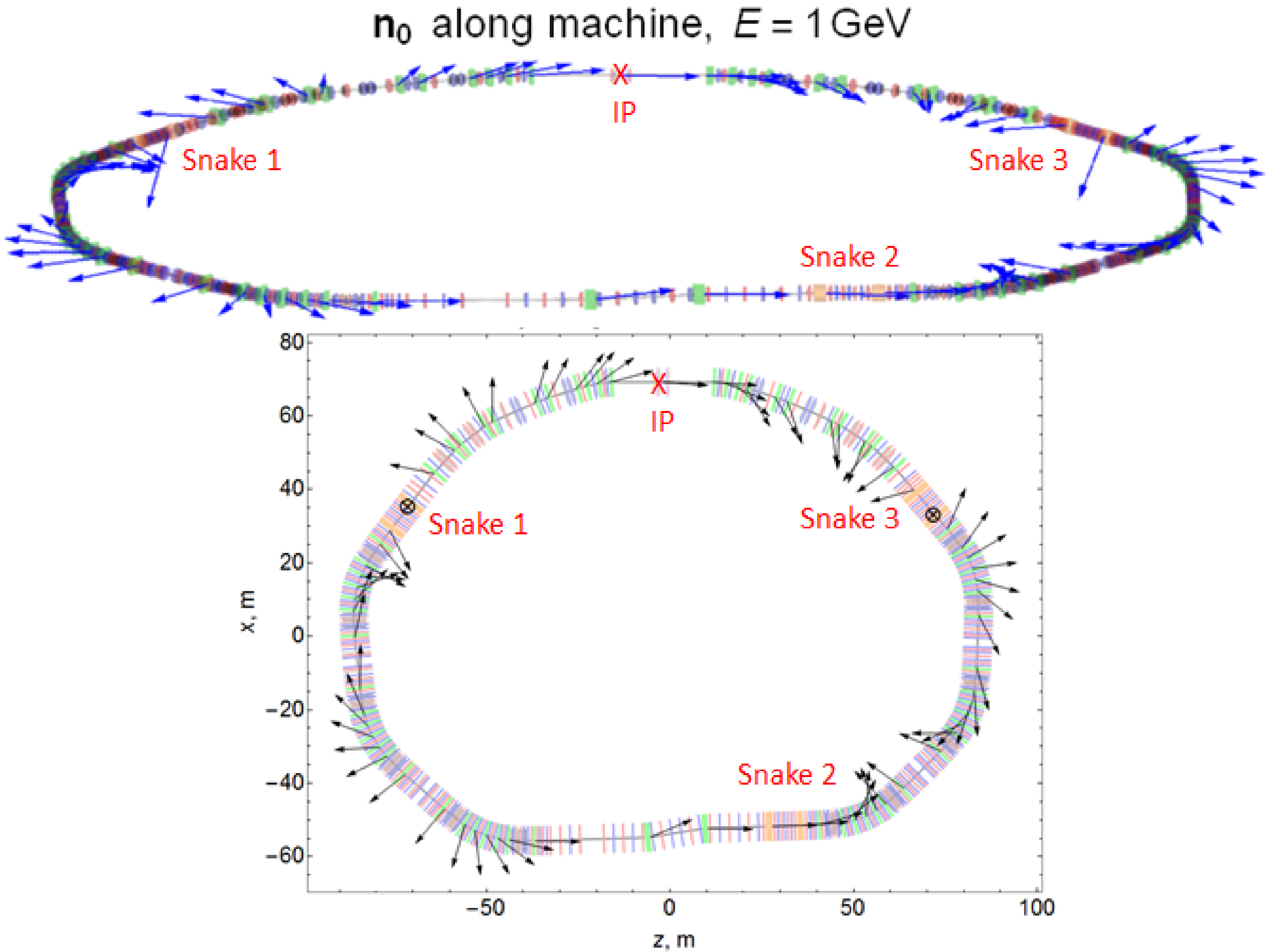
The Novosibirsk c-tau factory parameters

Beam Energy	1.0 – 3.0	GeV
Circumference	522	m
Crossing angle	60	mr
Emittances, $\varepsilon_x / \varepsilon_y$	4.8 / 0.025	nm
Number of bunches	270	
Number of particles/bunch	$9 \cdot 10^{10}$	
Total current	2.2	A
Beta function, β_x / β_y	50 / 0.5	mm
Sigma, σ_x / σ_y	15/0.1 (3 GeV)	mkm
Luminosity	$0.9 - 2.8 \cdot 10^{35}$	$cm^{-2}s^{-1}$

Polarization scheme with 3 snakes (arc=120^0 +2 damping wigglers in the arc's middle)



Spin directions in the Novosibirsk Super c-tau factory

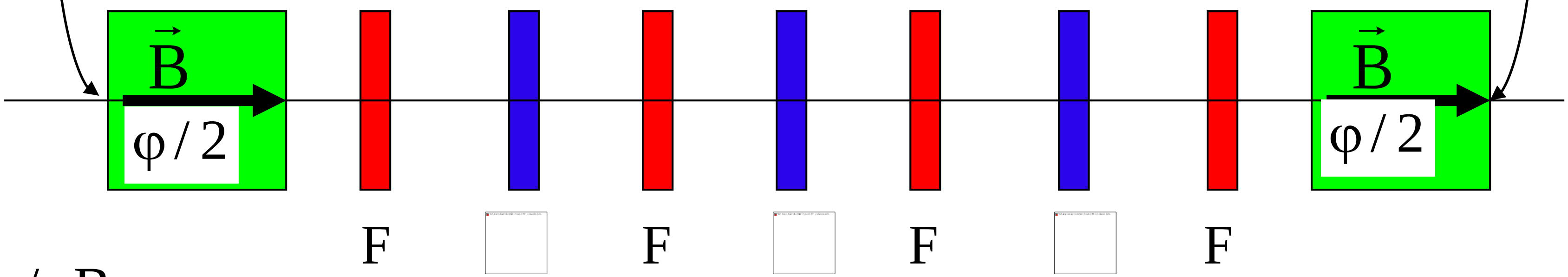


Transparent spin rotator (partial snake)

To decouple x,y-motions 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)

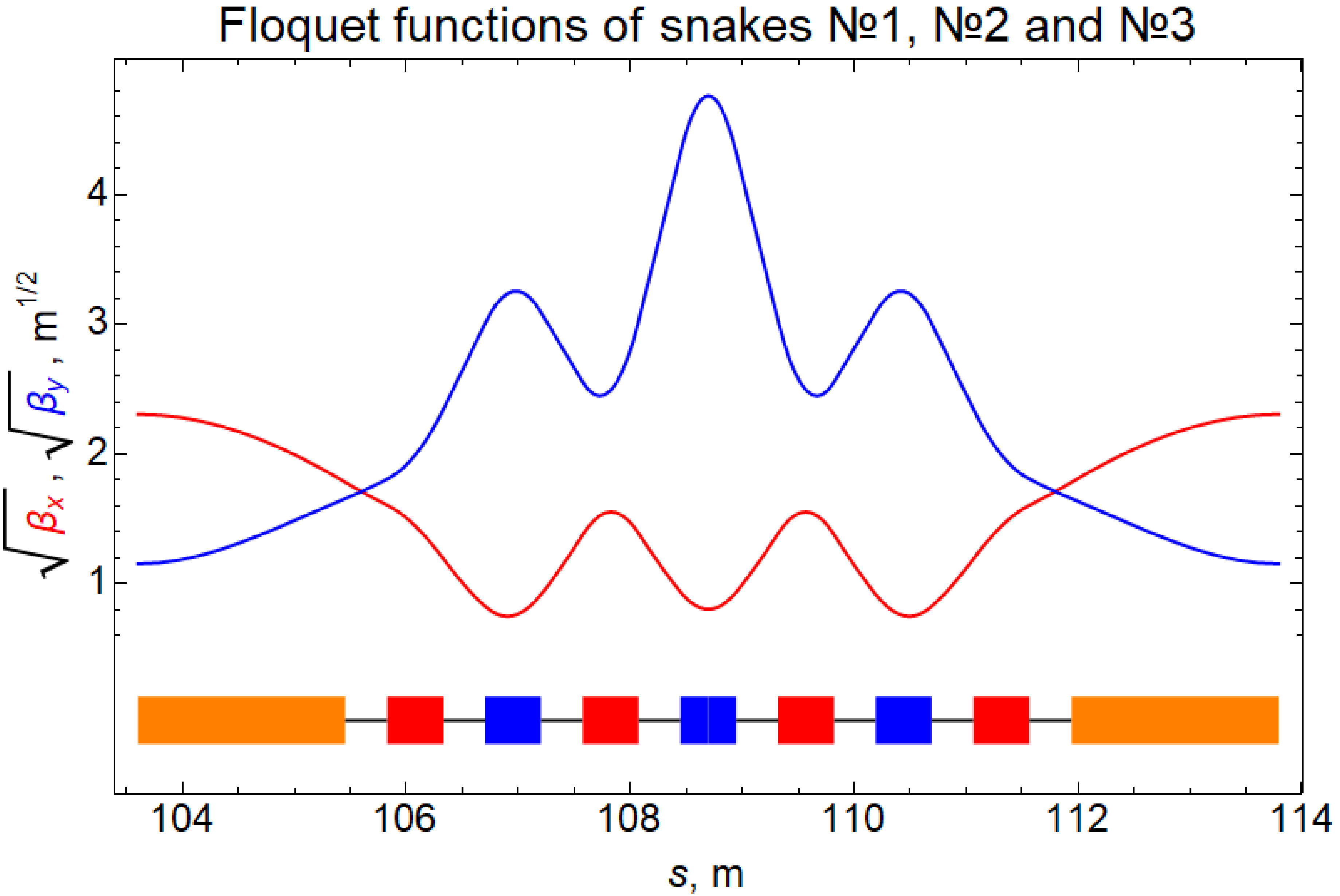


$r = pc/eB$

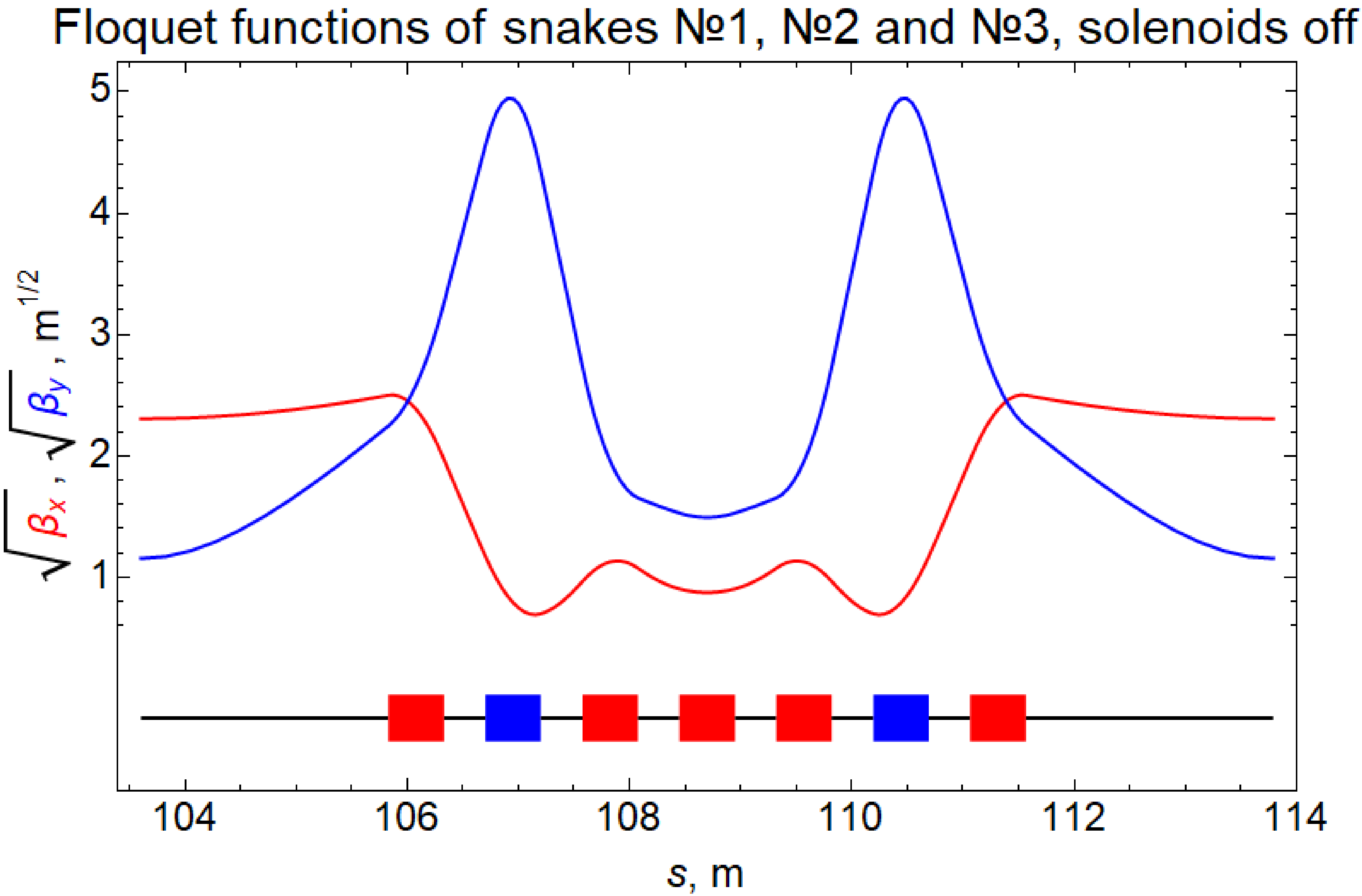
Two solenoids rotate spin by the angle φ

All quads don’t need to be skewed!

180^0 spin rotators, in places 1, 2, 3



Equivalents of 180^0 spin rotator, drifts 1, 2, 3



Depolarization time in presence of snakes

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

Here $K = \rho^{-1}$, $\quad |\vec{v}| = 1$

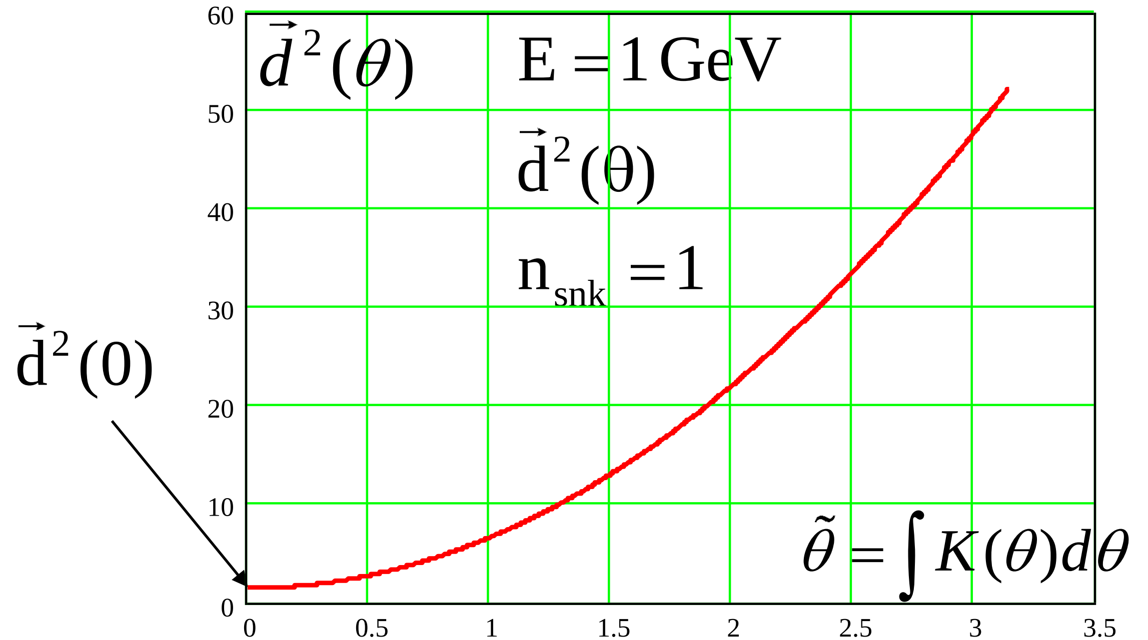
$\vec{d} = \gamma \dfrac{\partial \vec{n}}{\partial \gamma}$ is the spin – orbit coupling vector

Spin transparency cancels the betatron contribution to d: $\vec{d} = \vec{d}_\gamma + \cancel{\vec{d}_\beta}$, then:

$$\vec{d}^2(0) = \frac{\pi^2}{4}\sin^2\frac{\pi\nu}{n_{snk}}$$

$$\left\langle \vec{d}^2 \right\rangle = \vec{d}^2(0) + \frac{\pi^2}{3}\frac{\nu^2}{n_{snk}^2}$$

Placing damping wigglers in minimum of |d| weakens depolarizing effects of SR



Self-polarization in presence of snakes

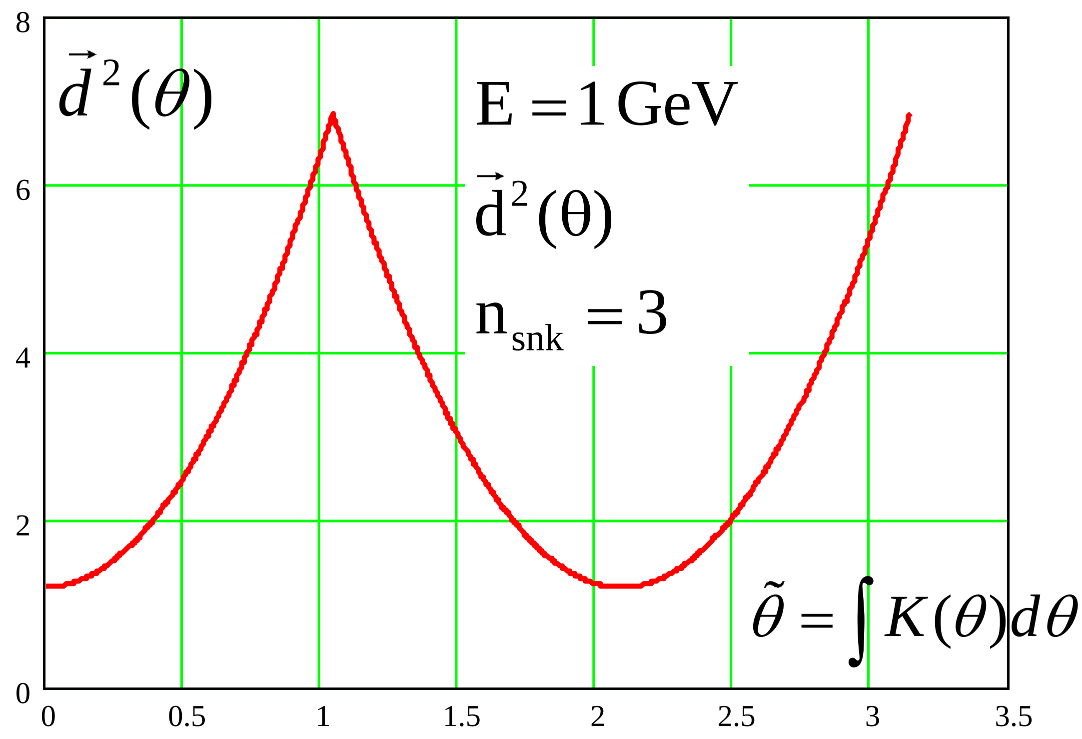
$$\varsigma_p = \frac{8}{5\sqrt{3}} \cdot \frac{(\pi/2)\sin(\pi\nu/n_{snk})\left\langle K_B^3 + K_W{}^3 \right\rangle}{\left\langle K_B^3 + |K_W|^3 \right\rangle 7/9 + \left[\left\langle K_B^3 d^2(\theta) \right\rangle + |K_W|^3 d^2(0)\right] 11/18}$$

$$K_W \equiv \rho_W^{-1}$$

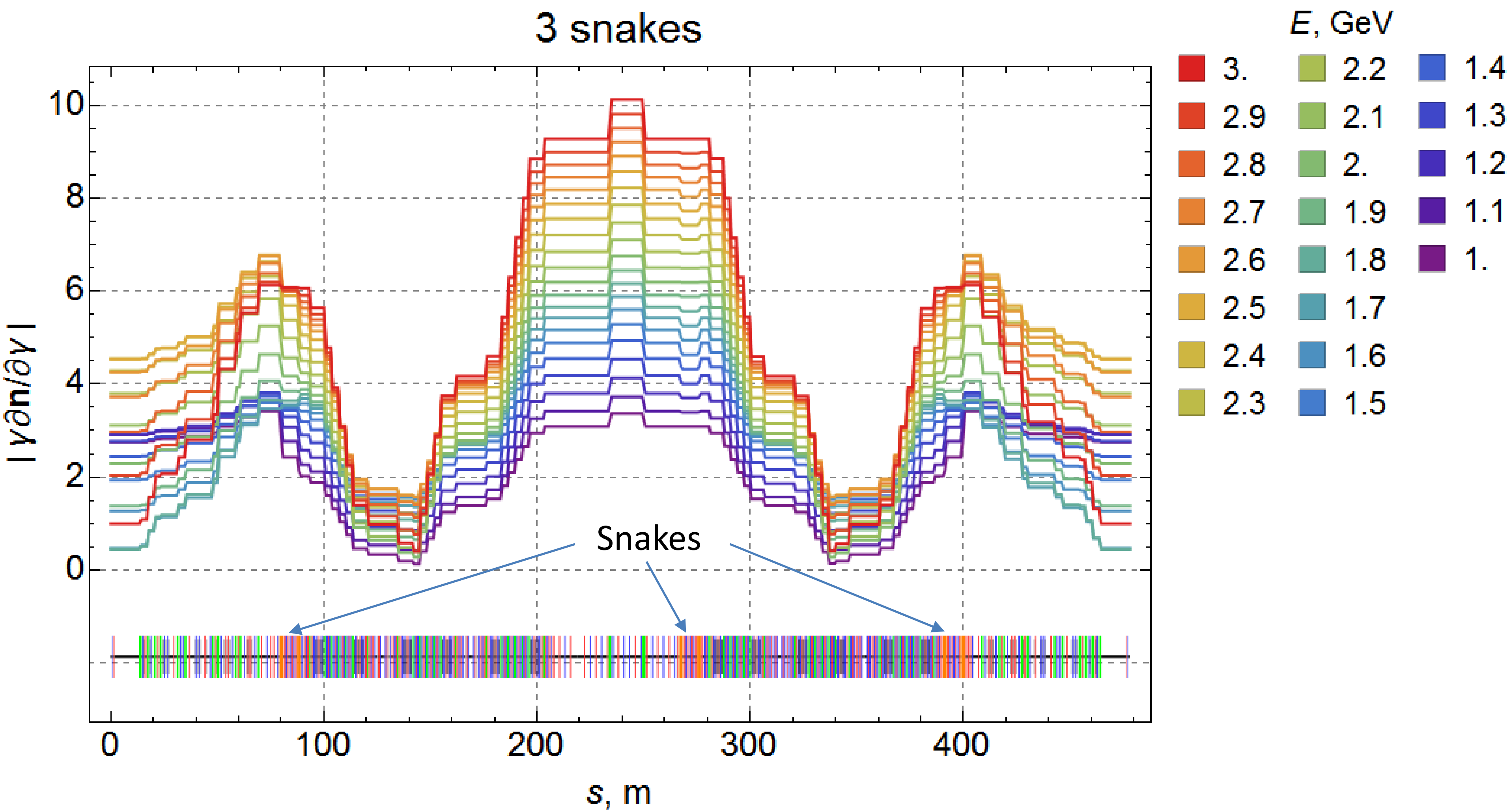
Symmetric wigglers do not contribute to the nominator, but asymmetric will do. That can be used to polarize the positron beam.

$$\vec{d}^2(0) = \frac{\pi^2}{4}\sin^2\frac{\pi\nu}{n_{snk}}$$

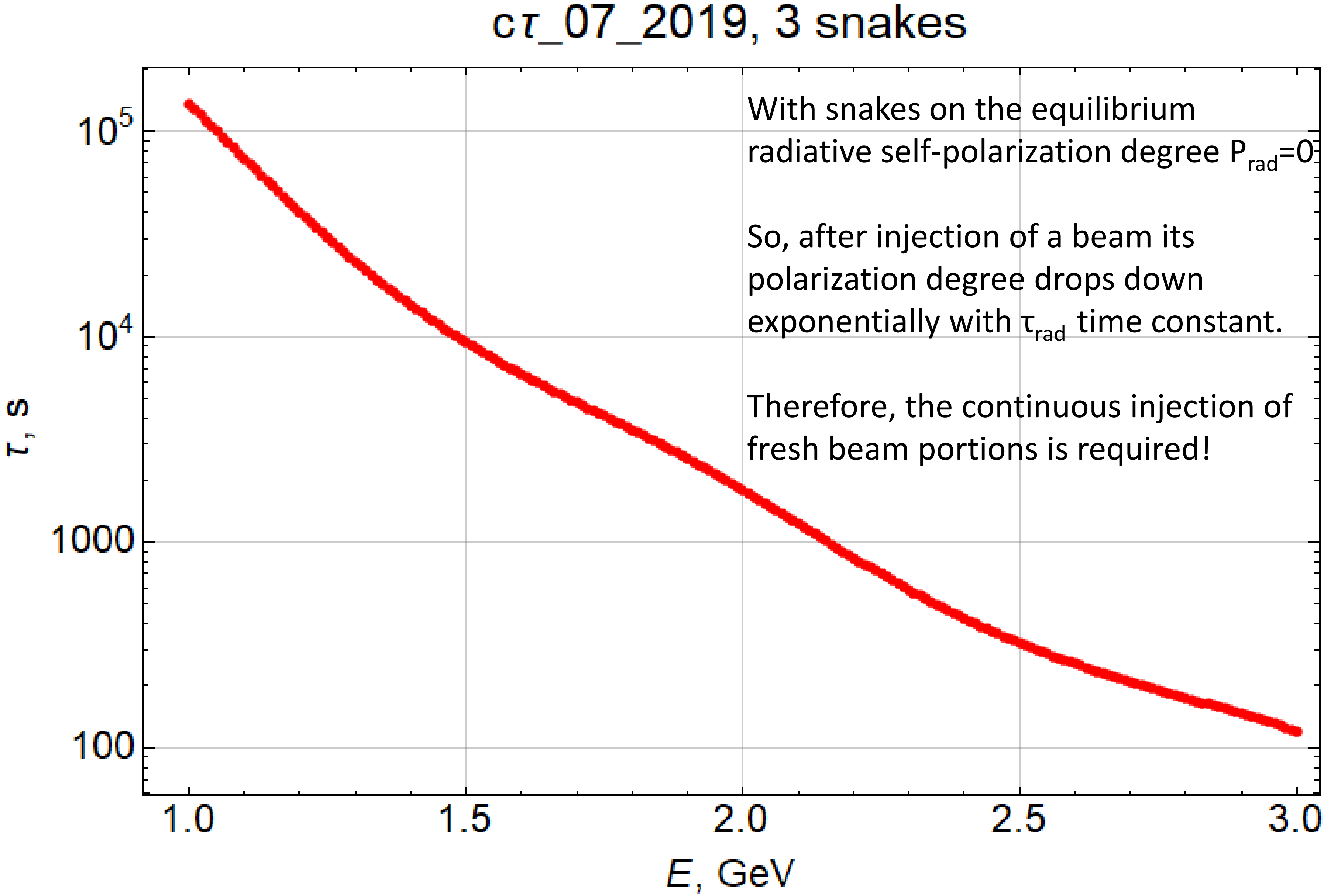
$$\left\langle \vec{d}^2 \right\rangle = \vec{d}^2(0) + \frac{\pi^2}{3}\frac{\nu^2}{n_{snk}^2}$$



Module of Spin-Orbital Function, 3 Snakes



Radiative polarization relaxation time, τ_{rad}

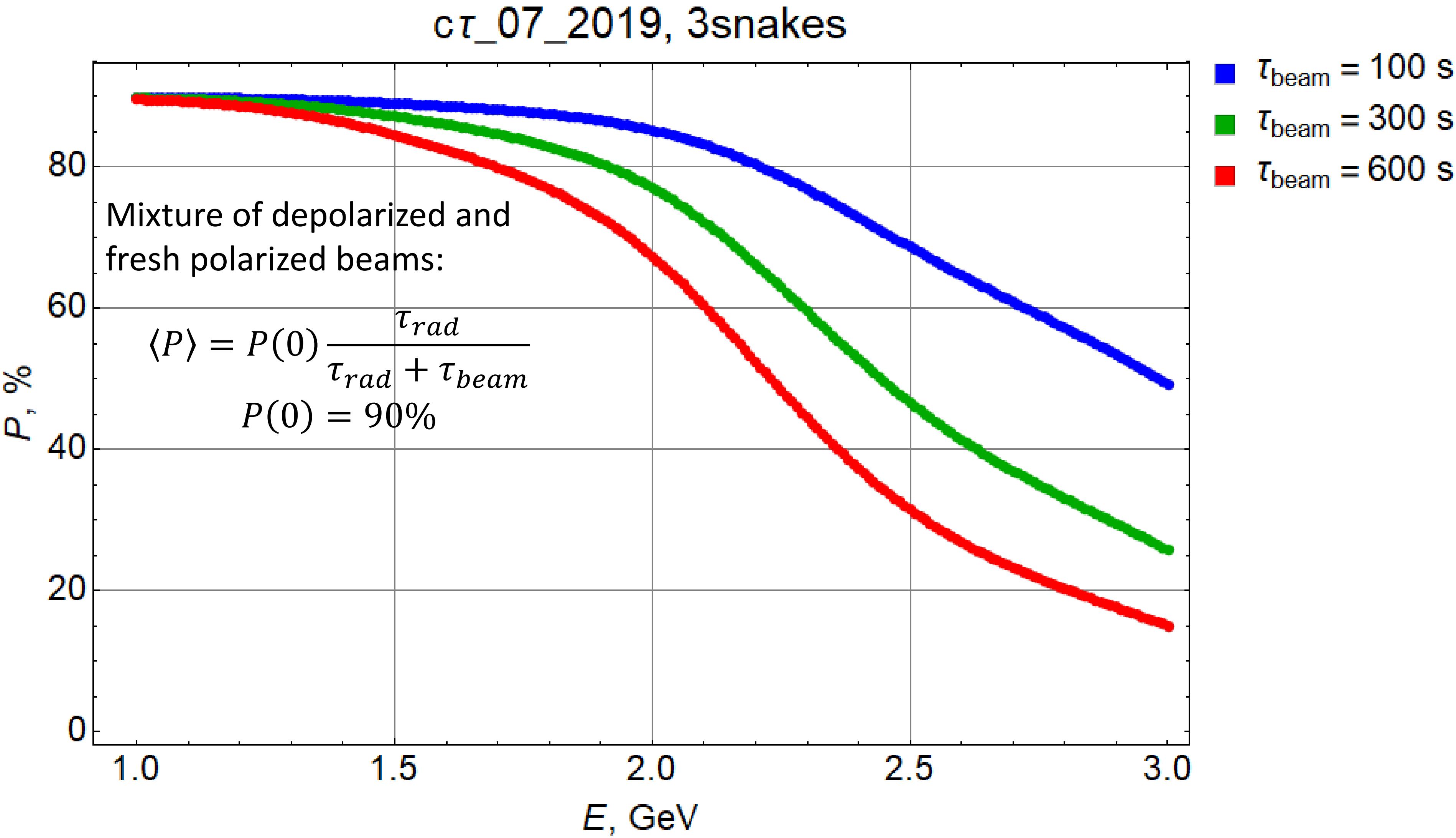


With snakes on the equilibrium radiative self-polarization degree $P_{rad}=0$

So, after injection of a beam its polarization degree drops down exponentially with τ_{rad} time constant.

Therefore, the continuous injection of fresh beam portions is required!

Polarization degree overview



The effective beam refreshment time τ_{beam} =100 s looks feasible with our polarized e^- source.

What about polarized positrons?

- The production rate of polarized electrons from a source is unlimited.
- But use of the Sokolov-Ternov mechanism to produce the polarized positrons in ~1 GeV Damping Ring is not so effective.
- Only 40-60% of the polarization degree (in average) can be achieved by this manner. Polarization time about 1 min looks feasible.
- Besides, the double set of the Siberian Snakes should be installed in two storage rings to handle the longitudinal polarization of both beams.
- The question arises: is there any sense to go this way? How much we gain from having 40-60 % for positrons and 70-80% of electrons polarization?
- Until now we do not consider this option seriously.

Conclusion

- 1 snake provides up to 80% - 90% of the longitudinal polarization at low energies: E < 1.5 GeV. This option can be considered as a first stage for polarization program.

- 3 snakes provide also high enough polarization degree, about 70-80%, in the energy range E < 2.5 GeV and only about 50% at 3 GeV. Currently this is the main scenario, because it fulfils to the main physics program requirements.

- No preferable sign of the polarization! This helps to fight with not all but many systematic errors, caused by the detector registration efficiency asymmetries.

- The preliminary design of the superconducting solenoids and of the polarized electron source was already done. Practical experience was achieved in 90-th at AmPS stretcher ring in NIKHEF, Amsterdam.

- And the last remark: the tolerances on the quads gradient integrals and the solenoid field integrals in Snakes are not too much stringent: in a range of few percent.