BINP's Polarization Proposal for Tau-Charm Factory

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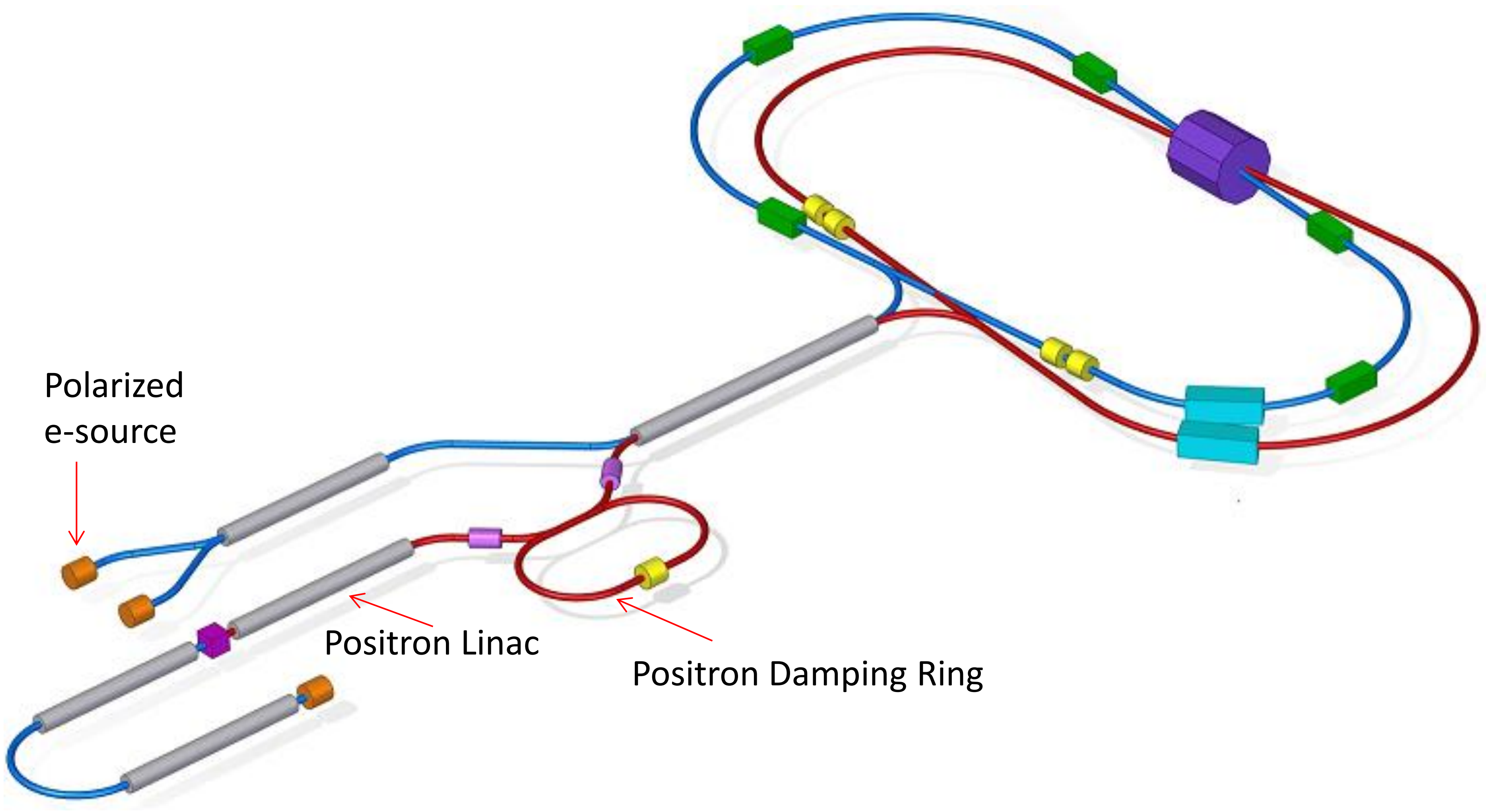
Outline

- BINP’s c-tau complex with the longitudinally polarized electrons.
- Multiple Siberian Snakes concept.
- Radiative self-polarization processes. Formulae Derbenev - Kondratenko.
- Option with two 90^0 spin rotators.
- Results and conclusion.

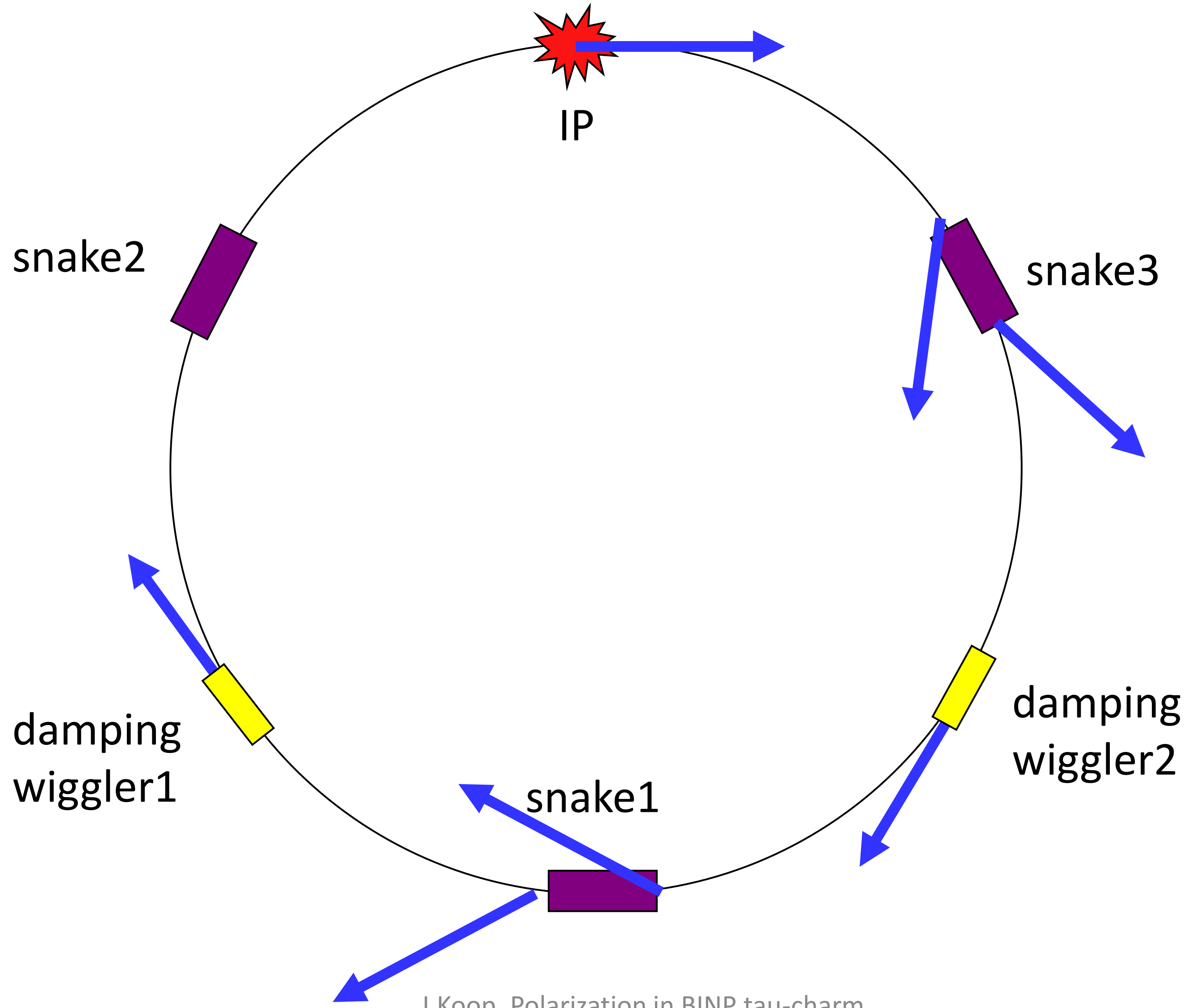
Novosibirsk c-tau complex layout



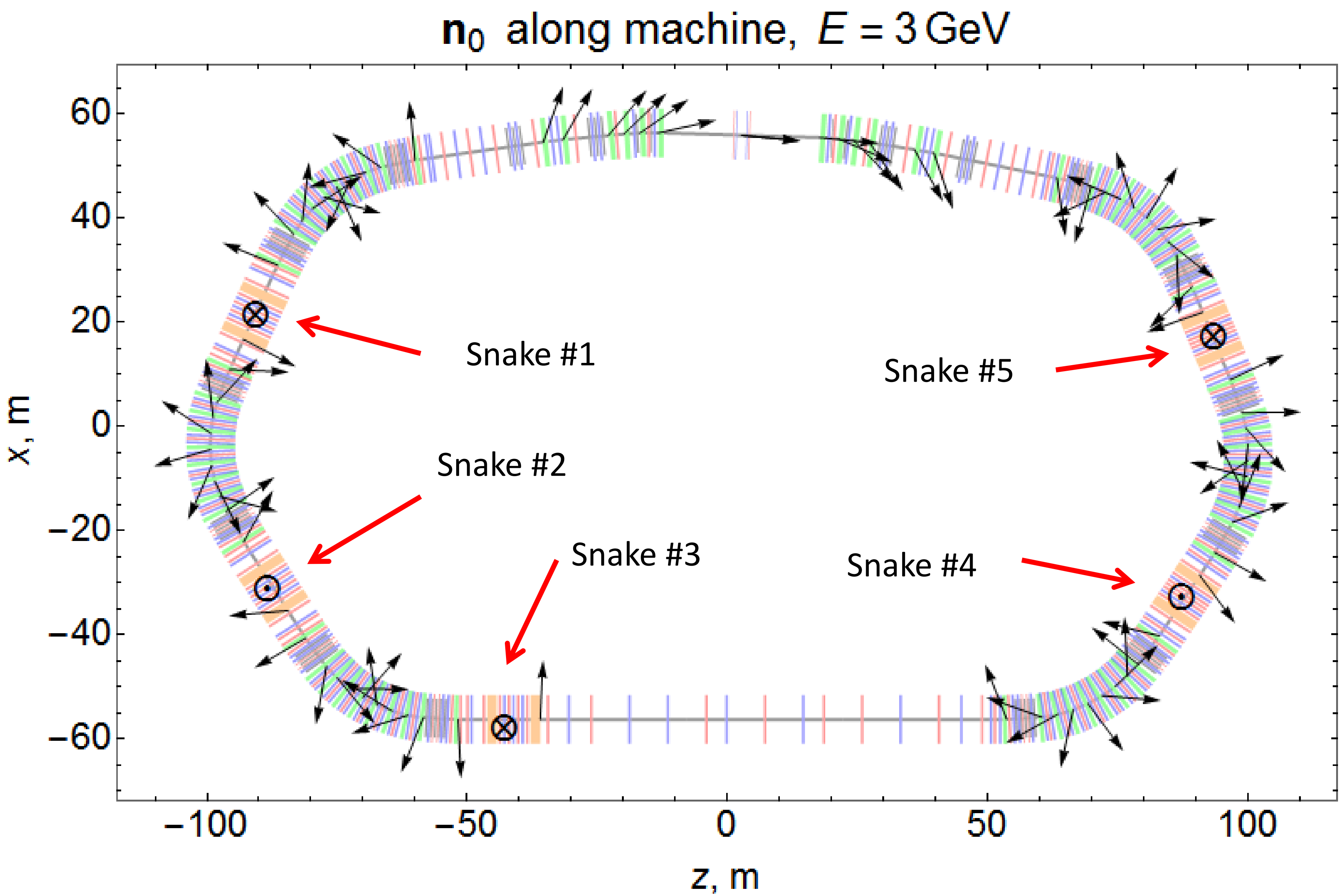
The Novosibirsk c-tau factory parameters

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)



Polarization vector in BINP's c-tau e-ring. 5 snakes option.

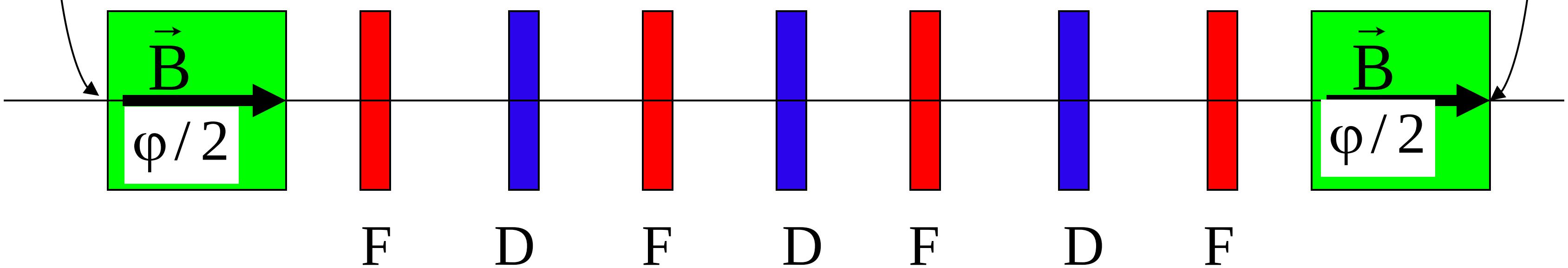


Transparent spin rotator (or partial snake)

To decouple x,y-motions should be $T_x = -T_y$ (Litvinenko, Zholentz,1980)

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

Additional requirement
- for spin transparency!
(Koop et al., SPIN2006)

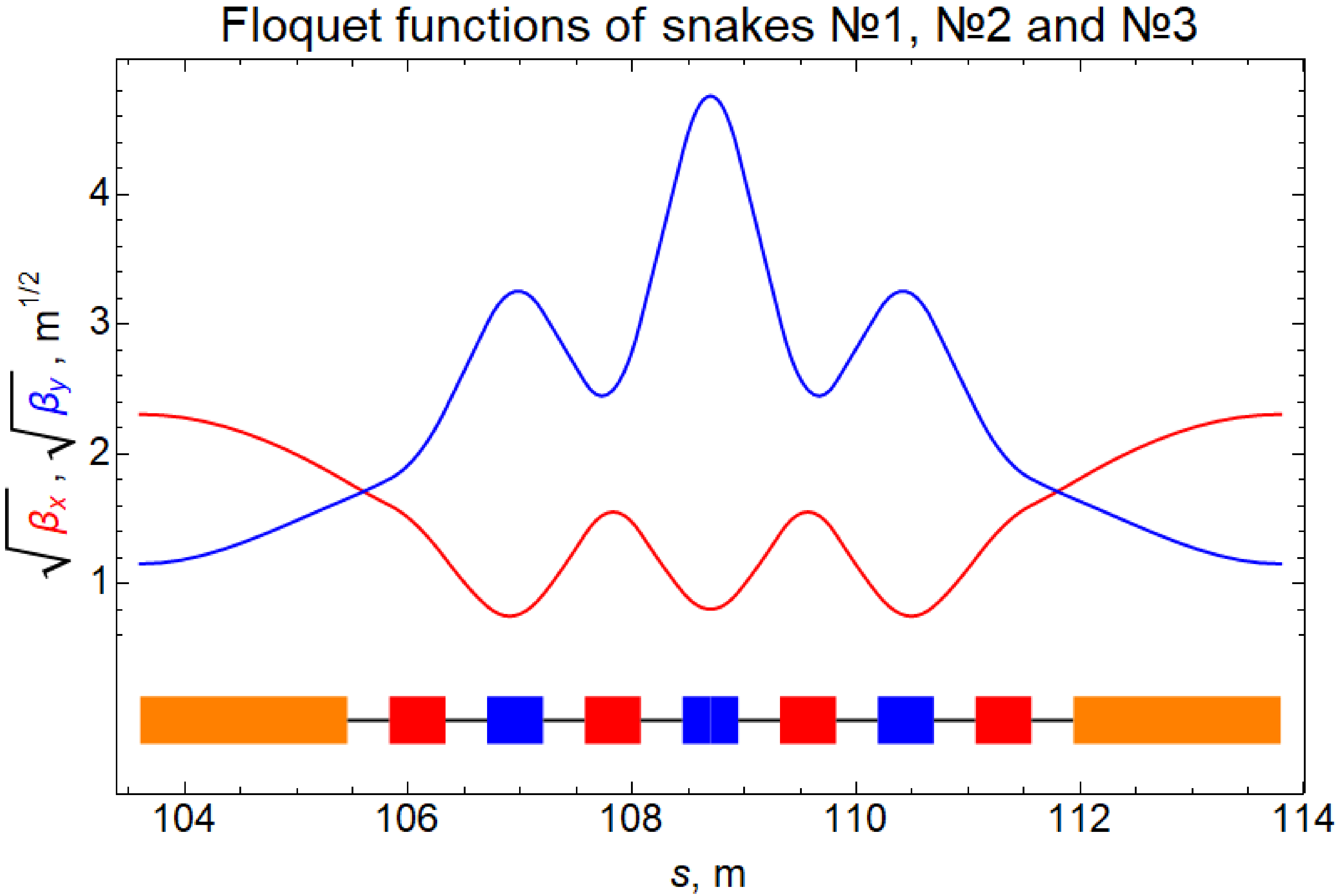


$r = pc/eB$

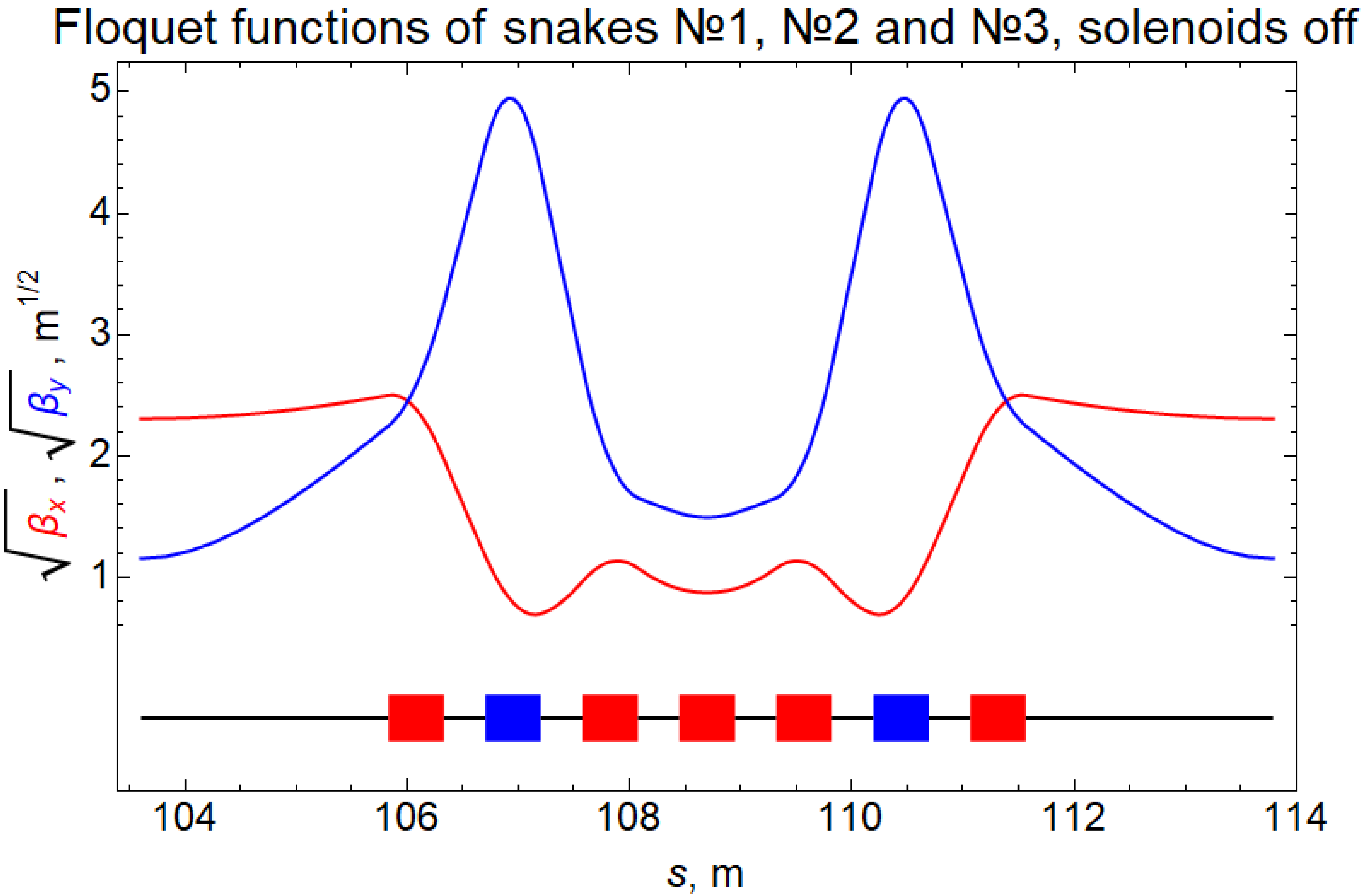
Two solenoids rotate spin by the total angle φ

All quads don't need to be skewed! This is the main advantage to place quads between two solenoid-halves.
Another feature: one can switch off solenoids keeping same transformation matrices by re-tuning these 7 quads – make equivalents in optics!

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

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

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

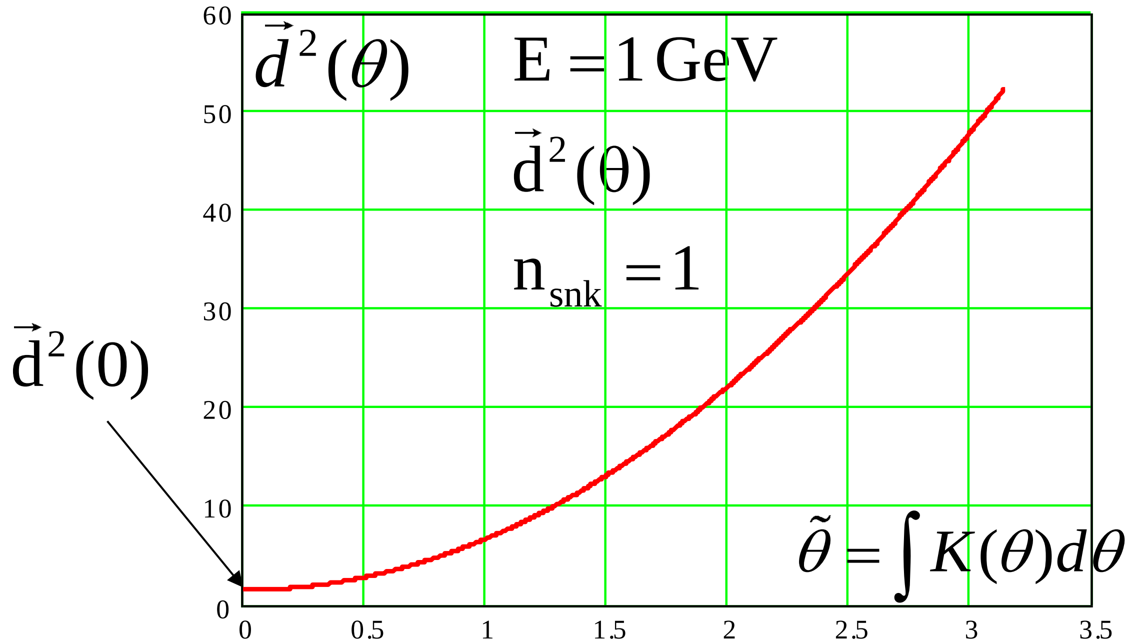
Derbenev, Kondratenko, in 70-th

$\vec{d} = \gamma \frac{d\vec{n}}{d\gamma}$ 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 degree in presence of snakes and wigglers

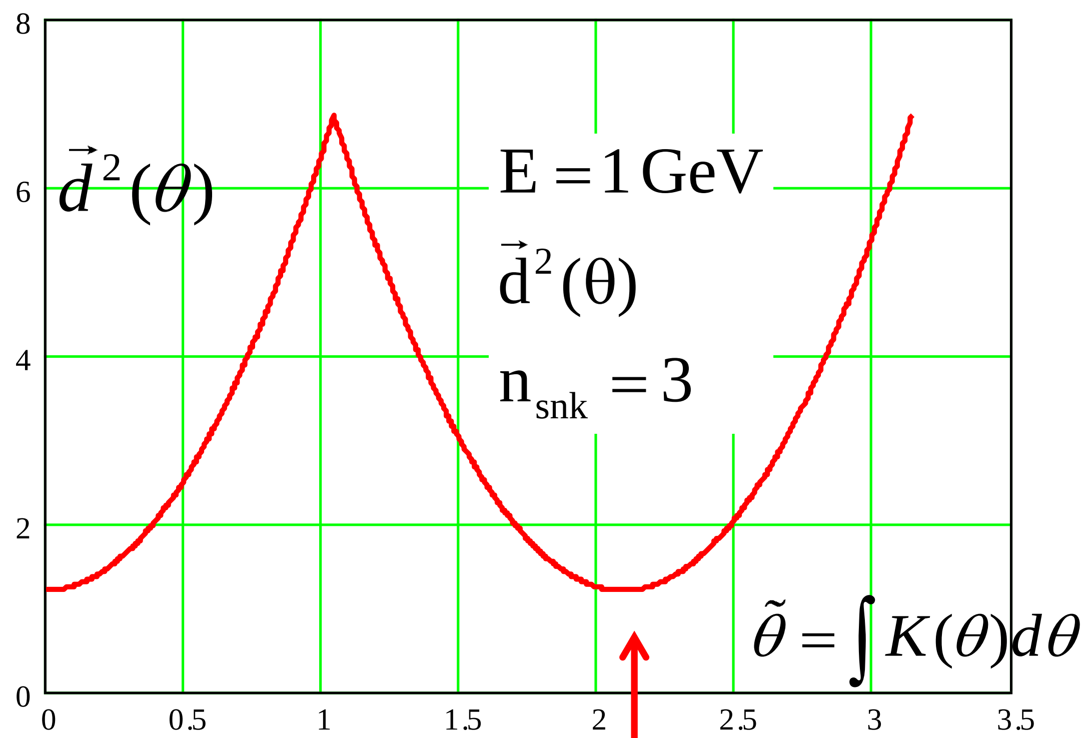
$$\varsigma_p = \frac{8}{5\sqrt{3}} \cdot \frac{(\pi/2)\sin(\pi\nu/n_{snk})\left\langle K_B^3 + K_W{}^3 \right\rangle}{\left\langle K_B^3 + |K_W|^3 \right\rangle 7/9 + \left[\left\langle K_B^3 d^2(\theta)\right\rangle + |K_W|^3 d^2(0)\right] 11/18}$$

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

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

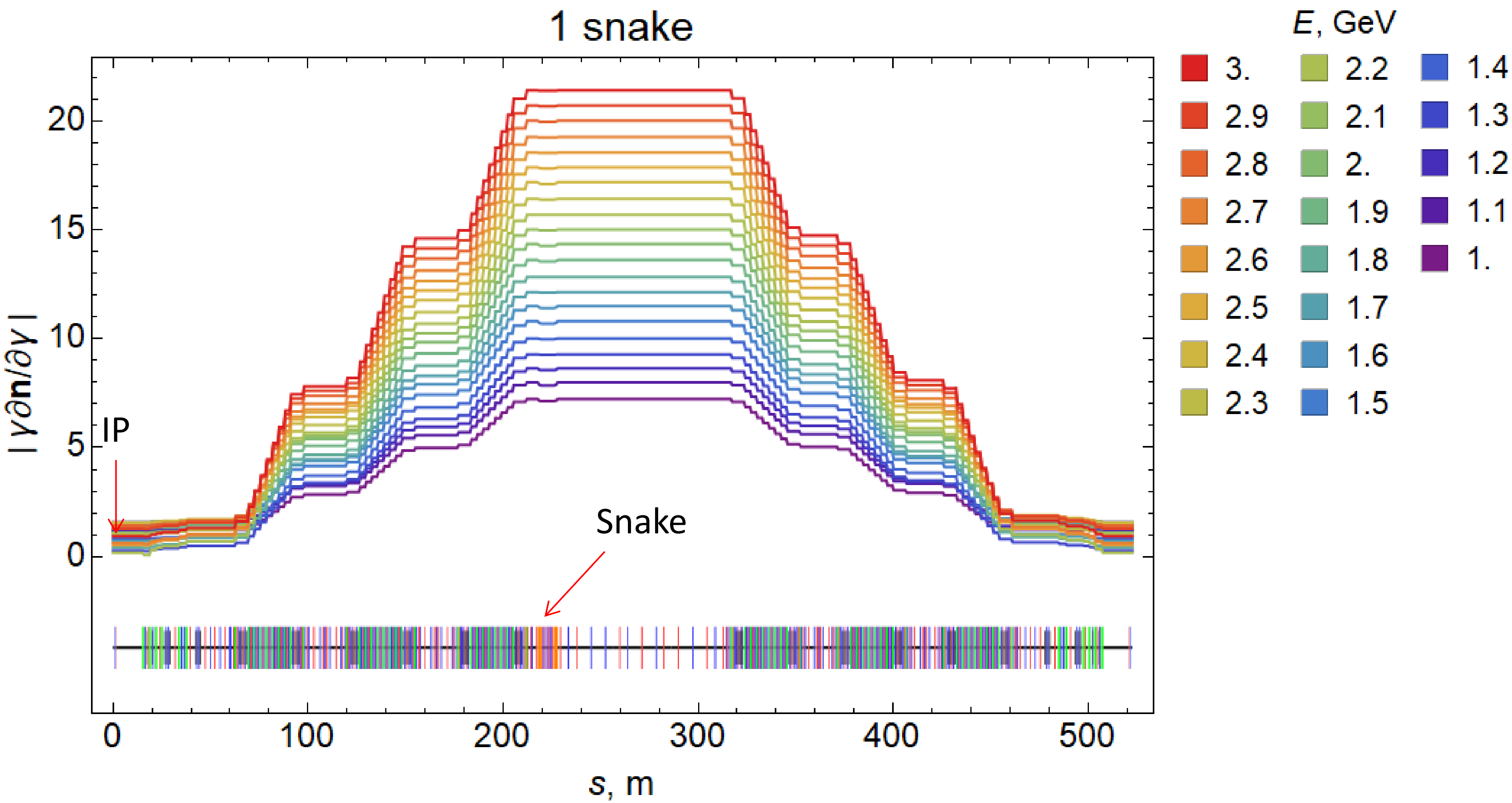
$$\vec{d}^2(0) = \frac{\pi^2}{4} \sin^2 \frac{\pi\nu}{n_{snk}}$$

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



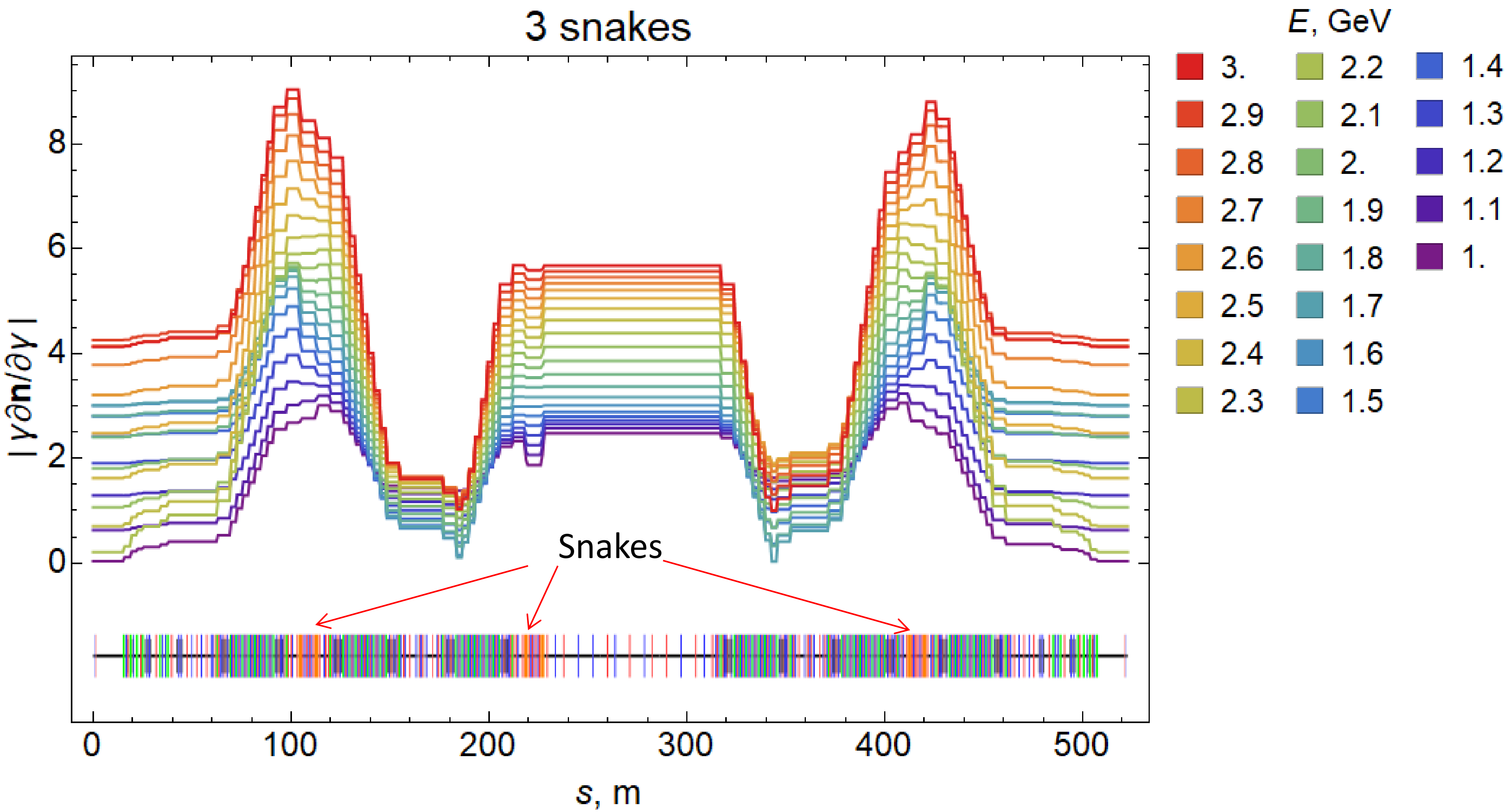
Optimal location for a wiggler

Module of Spin-Orbital Function, 1 Snake

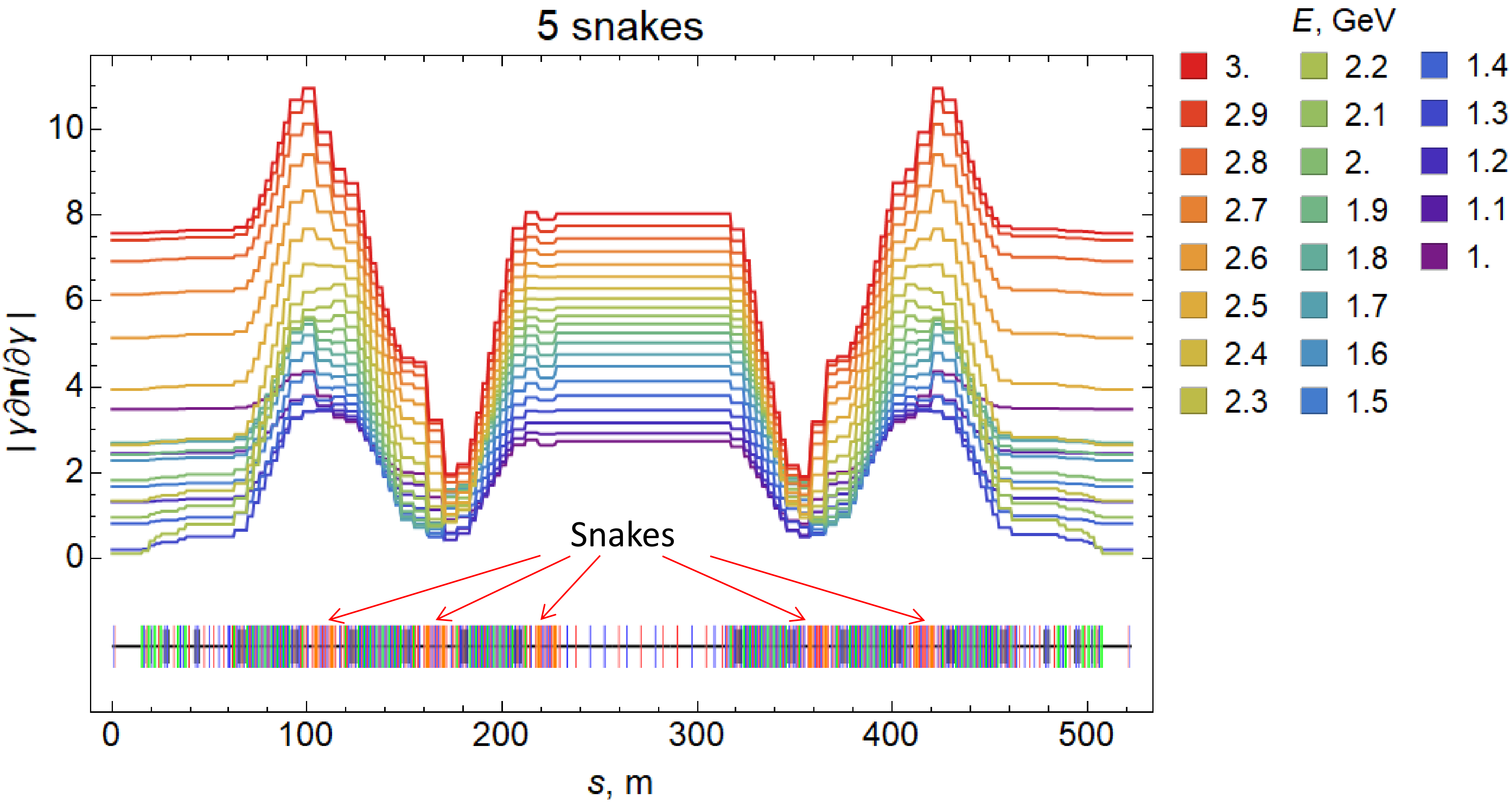


Here the Spin-Orbit coupling function d=|γd$\vec{n}$/dγ| was calculated by the code ASPIRRIN, written in 90-th by V. Ptitsyn and updated later on by S.R. Mane.

Module of Spin-Orbital Function, 3 Snakes

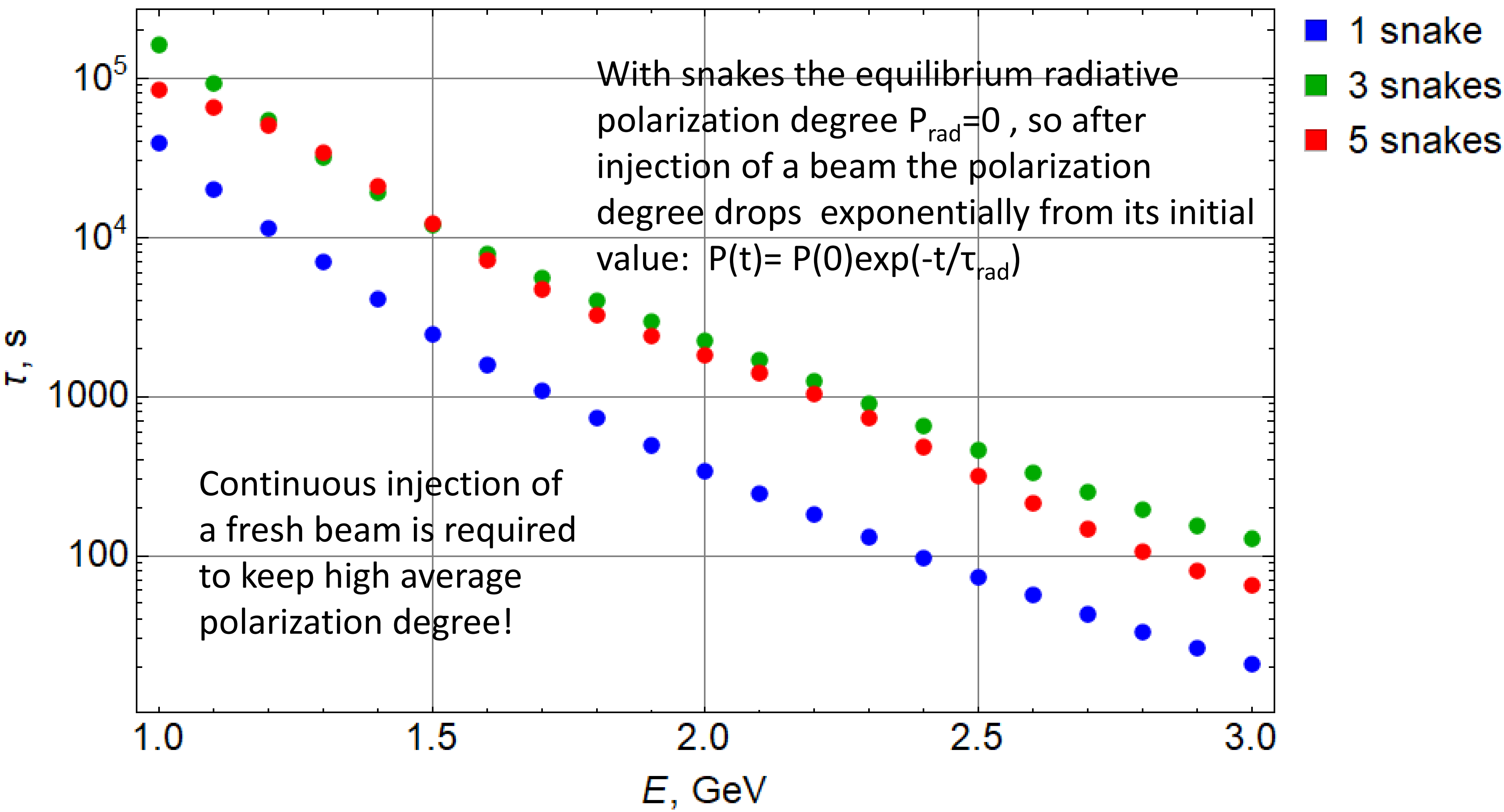


Module of Spin-Orbital Function, 5 Snakes



Arc's angles between snakes are chosen not optimal for 5 snakes. Therefore maximums of d-function are much higher than what was expected for their uniform distribution.

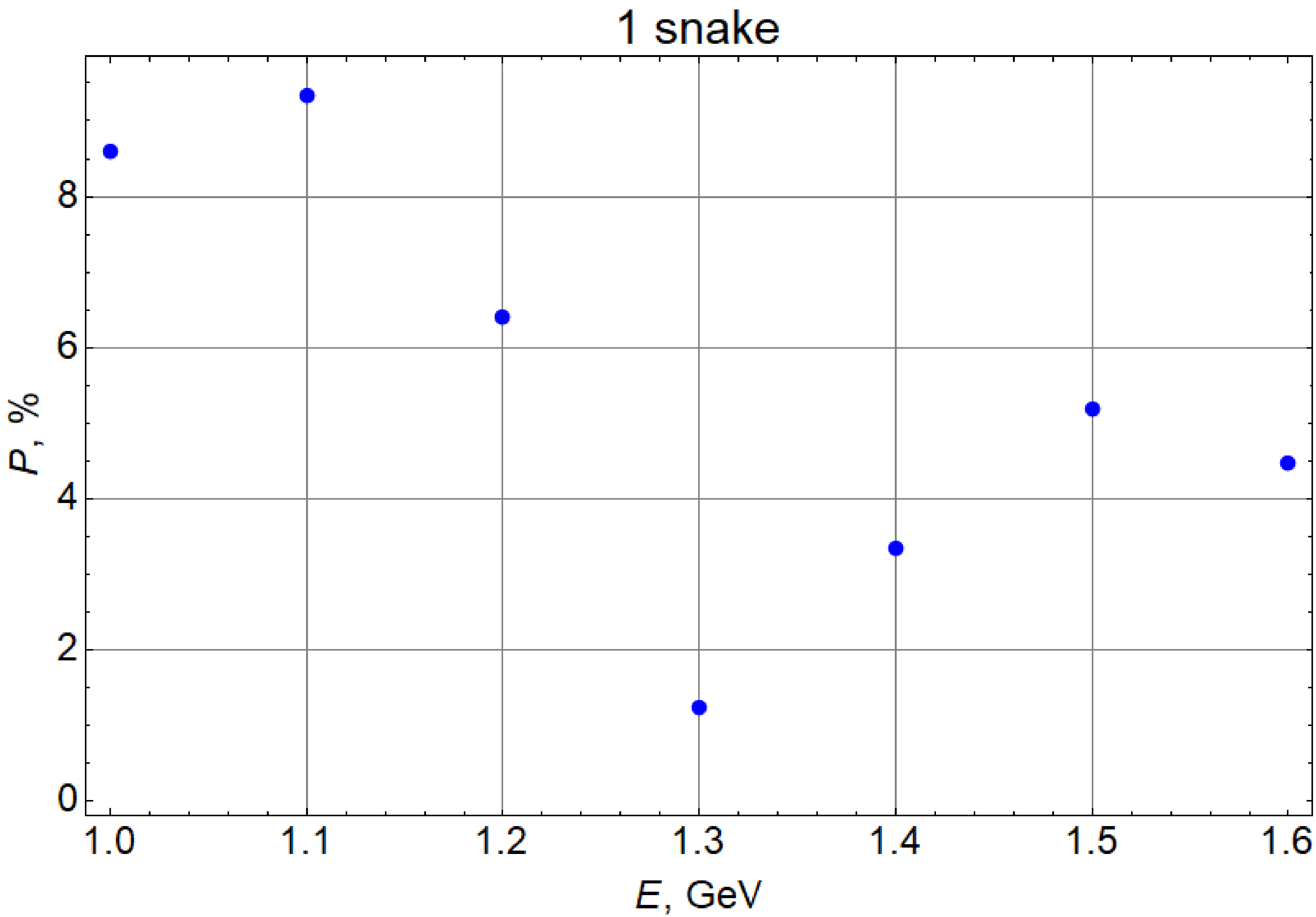
Radiative polarization relaxation time, τ_{rad}



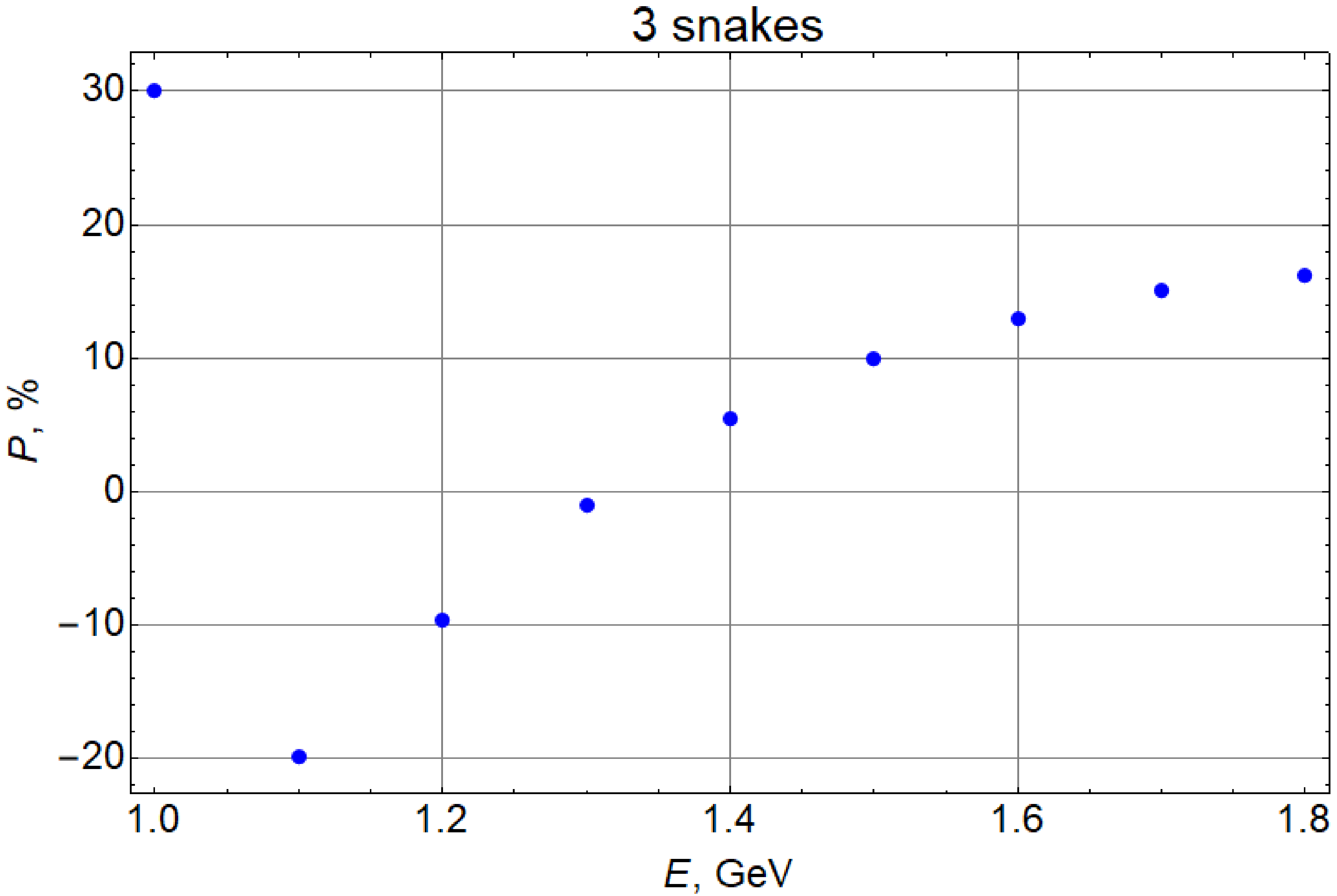
With snakes the equilibrium radiative polarization degree $P_{rad}=0$, so after injection of a beam the polarization degree drops exponentially from its initial value: $P(t)= P(0)\exp(-t/\tau_{rad})$

Continuous injection of a fresh beam is required to keep high average polarization degree!

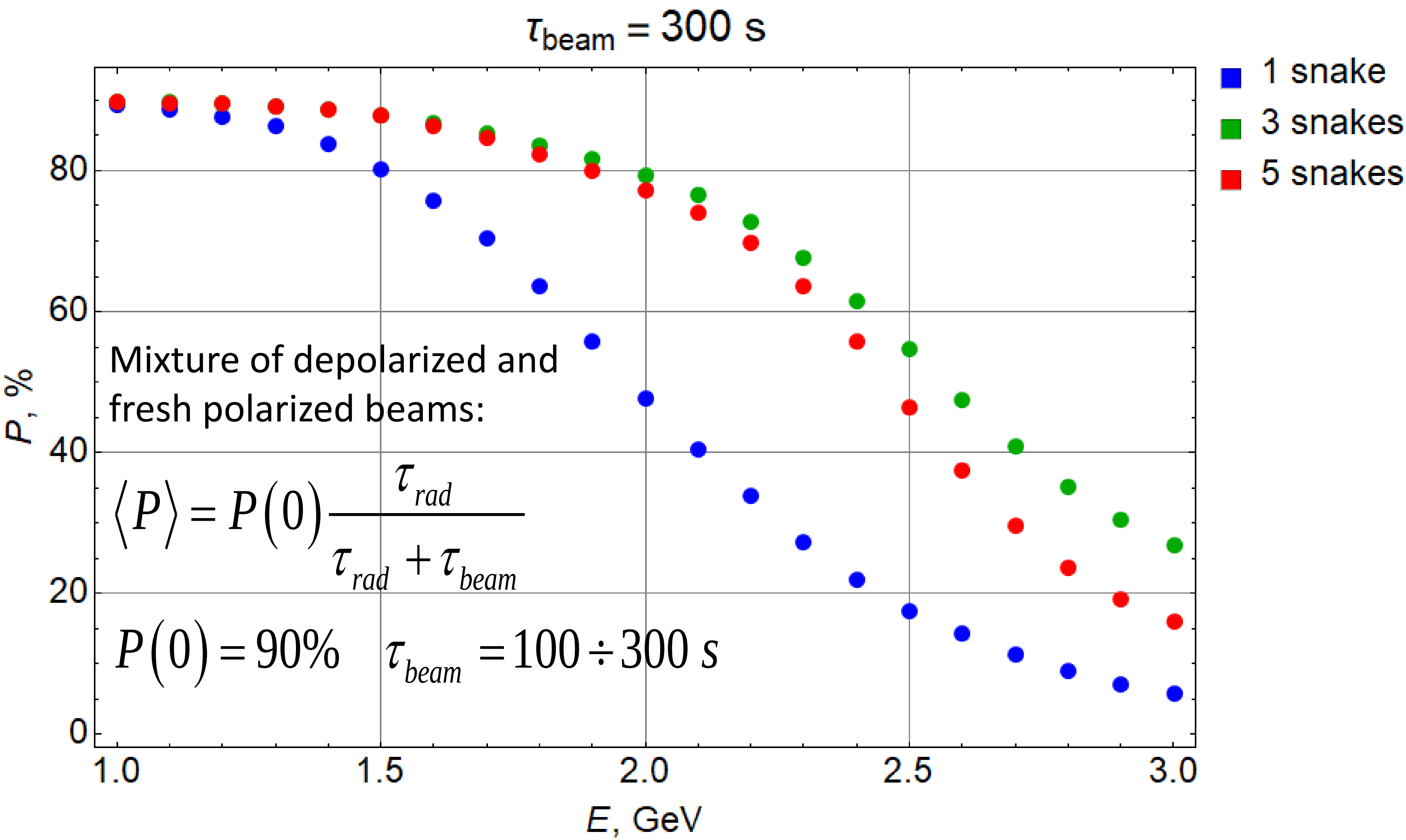
Radiative equilibrium polarization, P_{rad}, 1 snake



Radiative equilibrium polarization, P_{rad}, 3 snakes



Polarization degree overview, if τ_{beam}=300 s

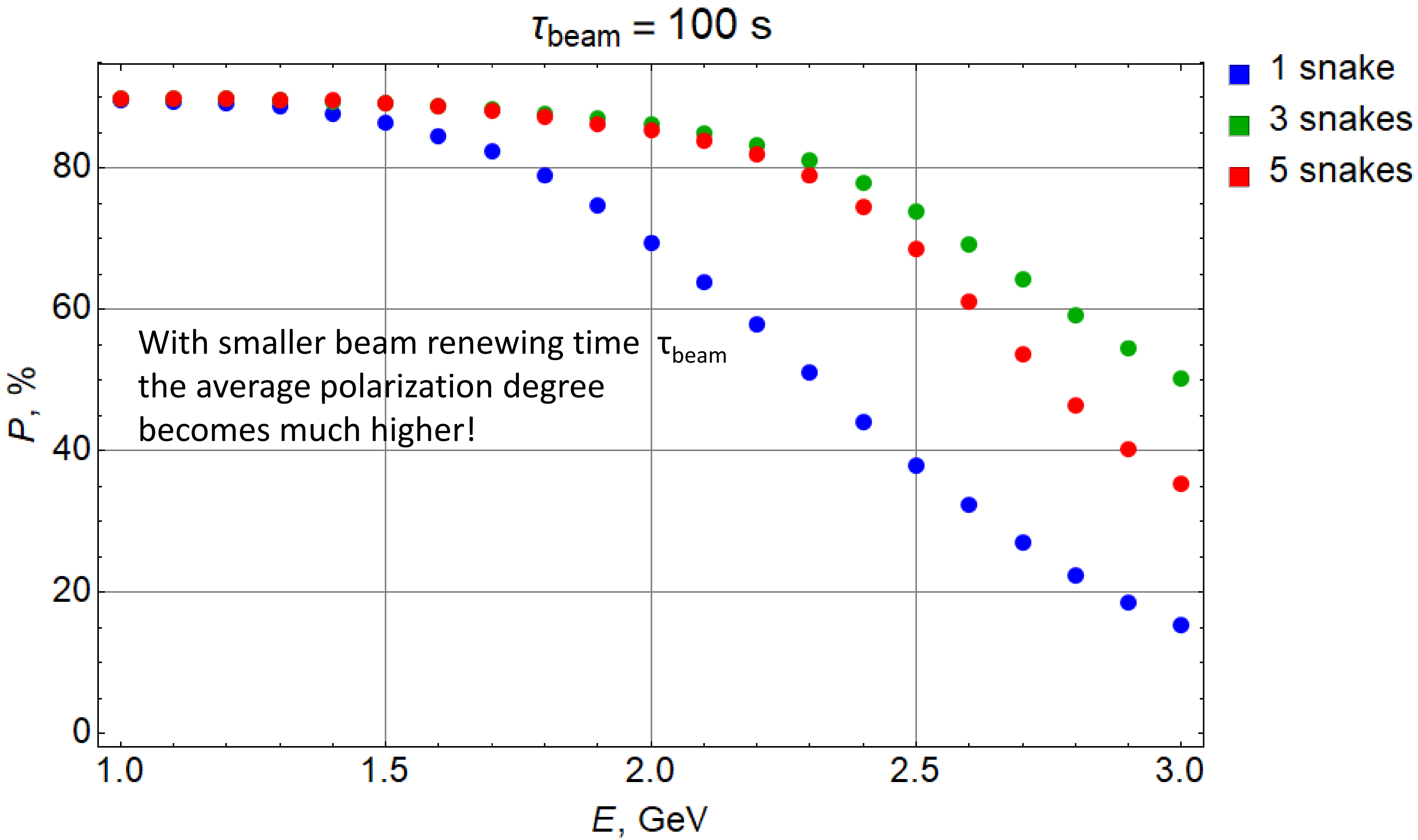


Mixture of depolarized and fresh polarized beams:

$$\langle P \rangle = P(0)\frac{\tau_{rad}}{\tau_{rad} + \tau_{beam}}$$

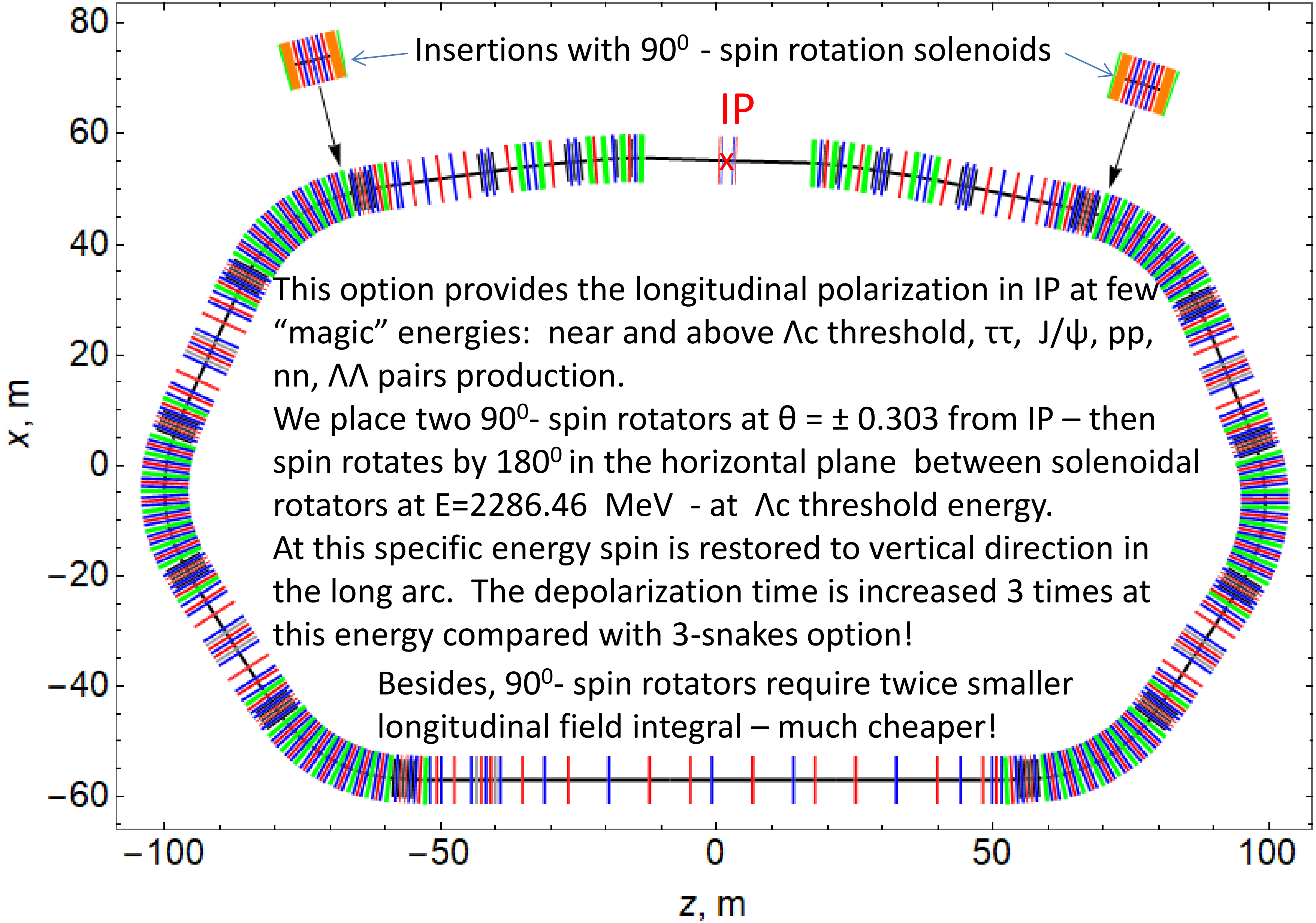
$$P(0) = 90\% \quad \tau_{beam} = 100 \div 300\ s$$

Polarization degree overview, if τ_{beam}=100 s

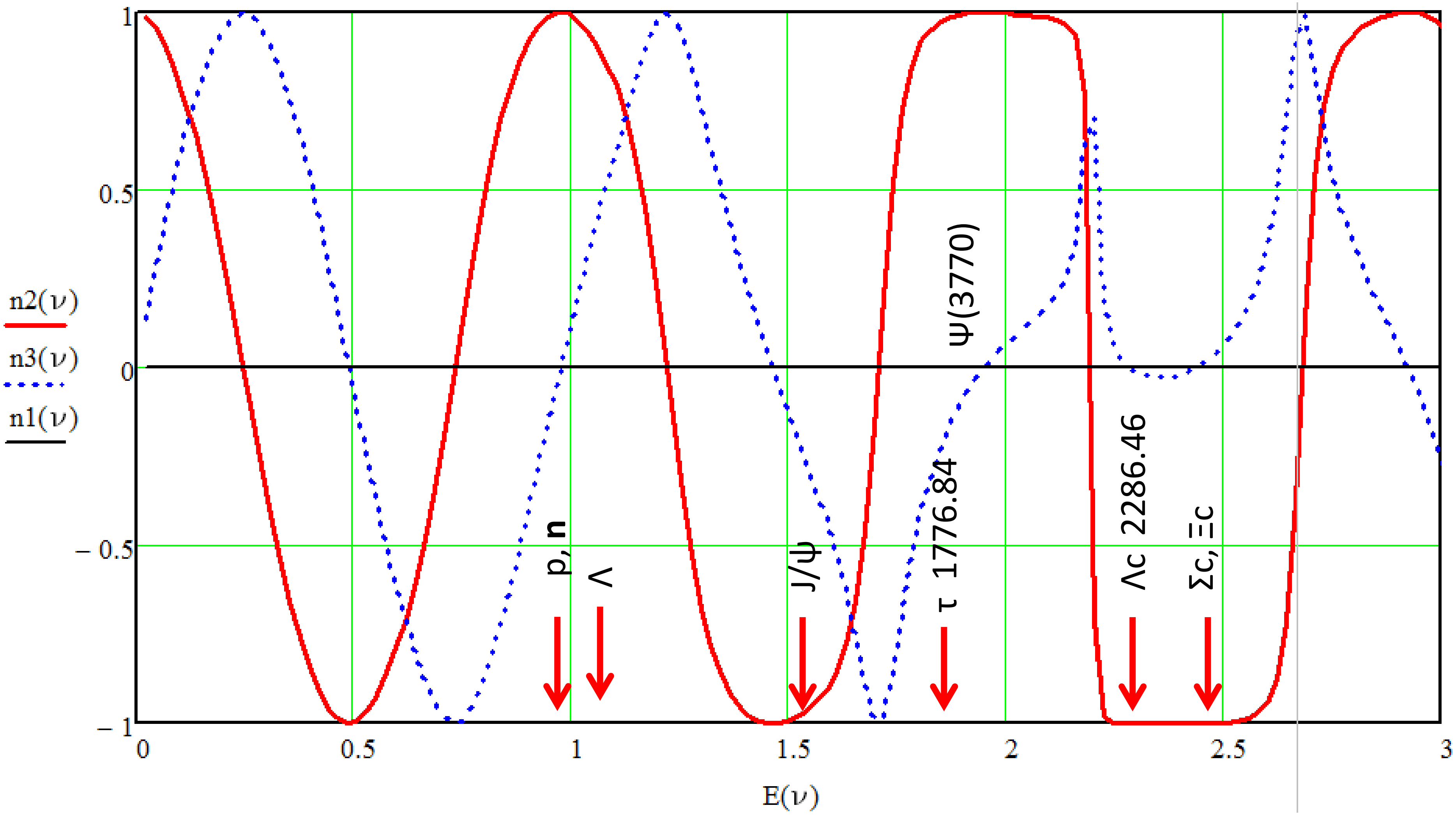


With smaller beam renewing time τ_{beam} the average polarization degree becomes much higher!

Alternative option with two 90^0- spin rotators.

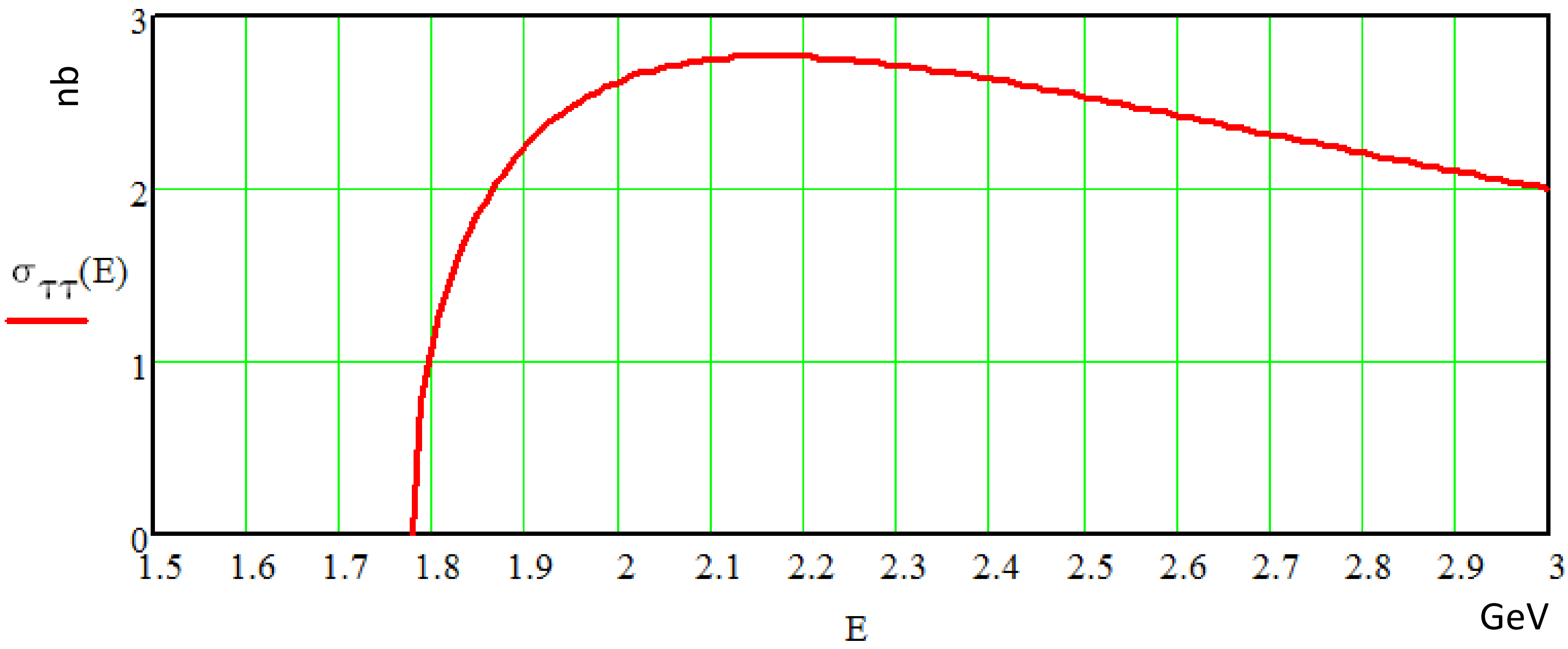


Version with two 90^0-rotators. Spin components at IP.



Two 90^0-rotators are placed at $\theta = \pm\, 0.303$ from IP - optimal for polarization at Λc =2.285 GeV.
Polarization at IP is longitudinal also at "magic" energies $E=0.44\ (\mathrm{GeV})\cdot n\cdot\pi/(\pi-\theta)$, n=1, …,6.
Then the spin tune is integer at long arc between rotators. So, they do act as a Siberian Snake!

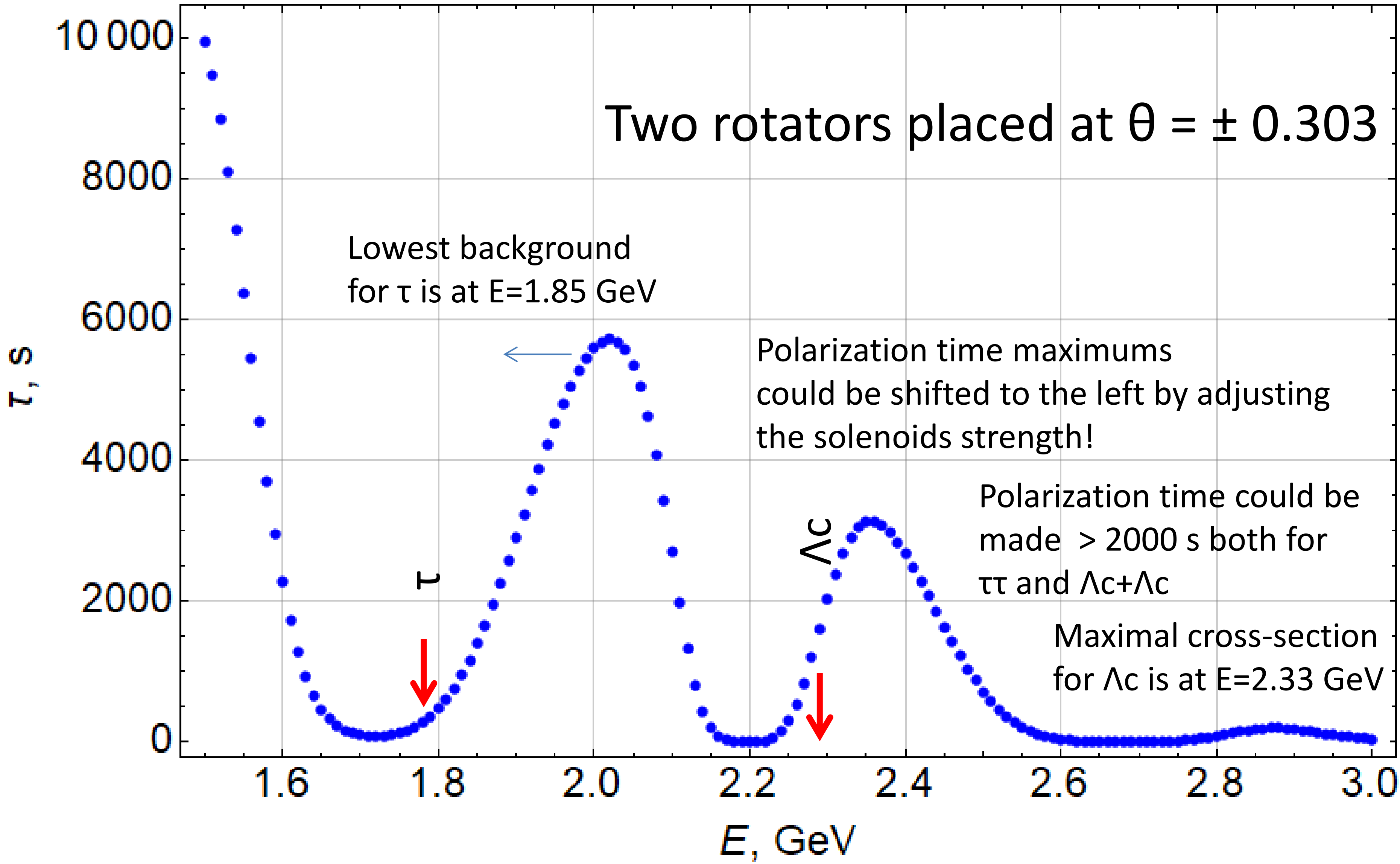
Tau-tau production cross-section.



M_τ = 1776.82±0.12 MeV

At threshold $\sigma_{\tau\tau} \approx 0.4$ nb

Depolarization time in option with two 90^0-rotators.



Rotators are placed at θ= ± 0.303 - optimal azimuth value for E=2.2865 GeV (Λc mass!).

Conclusion

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

- 3 snakes provide sufficiently high polarization degree, about 75-90% 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.

- 5 snakes option requires different optimization of a ring layout to place snakes uniformly in terms of the velocity circulation angle. Now not under consideration.

- Option with two 90^0 spin rotators is not as universal as multiple snakes version, but its price is much lower. We shall make final choice after discussions with the detector community.