Polarization at SuperB

I.A.Koop, BINP, 630090 Novosibirsk, Russia

2nd SuperB Collaboration meeting @ INFN-LNF
Frascati (Italy), December 13 - 16, 2011

Contributors :

U.Wienands, SLAC

D.P.Barber, DESY

A.V.Otboev, BINP

S.A.Nikitin, BINP

K.Moffeit, SLAC

C. Rimbault, LAL, IN2P3/CNRS

Acknowledgements to: Marica, Pantaleo, John, Pavel, Sergei and many others!

Outline

- **Longitudinal polarization of an electron beam at LER – physics request**
- **Two 90^0 spin rotators scheme with restoration of the vertical direction of a spin in arcs - main option for E=4.18 GeV and for some specific energies below**
- **Scheme with 1 or 3 Siberian Snakes - possible options for E < 3 GeV**
- **Analytical estimations, ASPIRRIN code results**
- **Open questions list**
- **Conclusion**

Polarization review at Annecy, 2010

- **U.Wienands, D.P.Barber - “Polarization update”, scheme with two 90^0 spin rotators**

- **Ken Moffeit - “Polarization at SuperB” (Physics request and a measurement)**

- **Cecile Rimbault – “Beam-beam depolarization. Spin tracking. GUINEA-PIG++ code.”**

- **N.Monseu – “Spin tracking. Zgoubi code.”**

- **Other workshops; SPIN-2010, Juelich; Elba meeting.**

- **SuperB Progress Reports, the Collider, Dec.27, 2010.**
  http://arxiv.org/abs/1009.6178v3

Requirements to longitudinal polarization

High polarization degree demands: $\tau_{DK} >> \tau_b = 3$ min

Expected polarization from a gun: $P_i = 90\%$

Mixing of fresh beam with an old one slightly dilutes *P*:

$\tau_b = 3\,\text{min}, \quad P_i = \pm 90\%; \quad \tau_{DK} = 12.7\,\text{min}, \quad P_{DK} = +5.9\%.$

$$P = P_i \frac{\tau_{DK}}{\tau_b + \tau_{DK}} + P_{DK} \frac{\tau_b}{\tau_b + \tau_{DK}} \quad \rightarrow \quad P = +73.9\% \ \text{ or } -71.6\%$$

Continuous polarization monitoring (bunch to bunch) using the Compton back-scattering technique.

To fight with systematics the polarization measurement accuracy needs to be better than: $|\Delta P / P| \leq 1 \div 5 \cdot 10^{-3}$

Alter a sign of *P* from bunch to bunch, randomly!

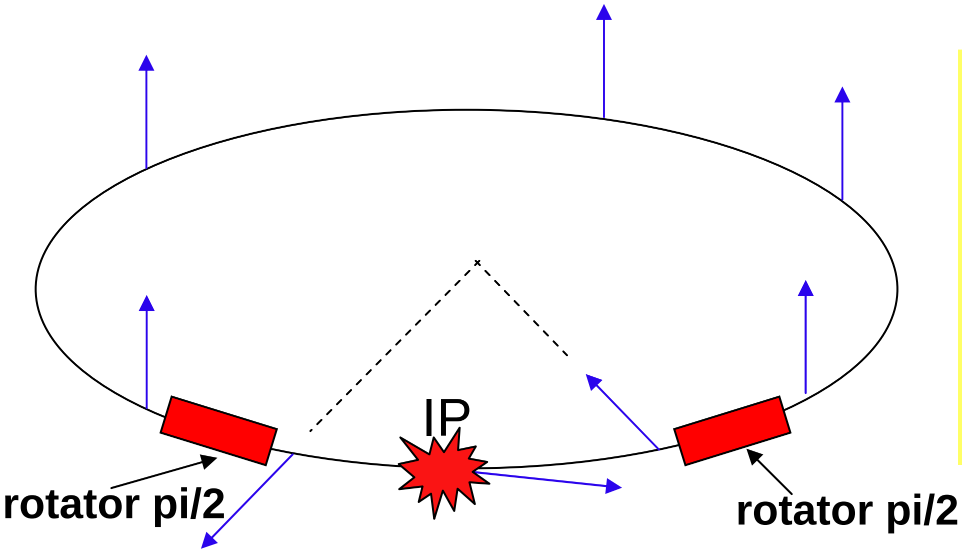
Alter sometimes the spin filling pattern in a train!

Two 90^0 spin rotators scheme at LER

Spin is directed longitudinally at IP at two specific energies.

It makes a half-turn in the FF-arc when $E = 1.4$ GeV

and it makes 1.5 turns at E=4.18 GeV (that is a nominal energy)



$\vec{d} = \gamma \frac{\partial \vec{n}}{\partial \gamma}$ - the spin – orbit coupling vector, $|\vec{d}| \sim \gamma$

r - bending radius

$$\tau_{DK}^{-1} = \frac{5\sqrt{3}}{8} \lambda_e r_e c \gamma^5 \left\langle \frac{1 - \frac{2}{9}(\vec{n}\vec{v})^2 + \frac{11}{18}\vec{d}^2}{|r|^3} \right\rangle \sim \begin{cases} \gamma^5 \text{ if } |\vec{d}| \le 1 \\ \gamma^7 \text{ if } |\vec{d}| \gg 1 \end{cases}$$

LER lattice design specific features

- Two pi/2 spin rotators are located at slightly different azimuth angles from the IP - phi1=0.462773 and phi2=0.528773

- This asymmetry results in about 5% loss of the longitudinal spin projection at 4.18 GeV.

- Spin at 4.18 GeV is almost longitudinal at IP (ny=0.95138) and after few bending magnets near IP:

  ny=0.94083 in B2AR - B3R, ny=0.99046 in B3R - B3R

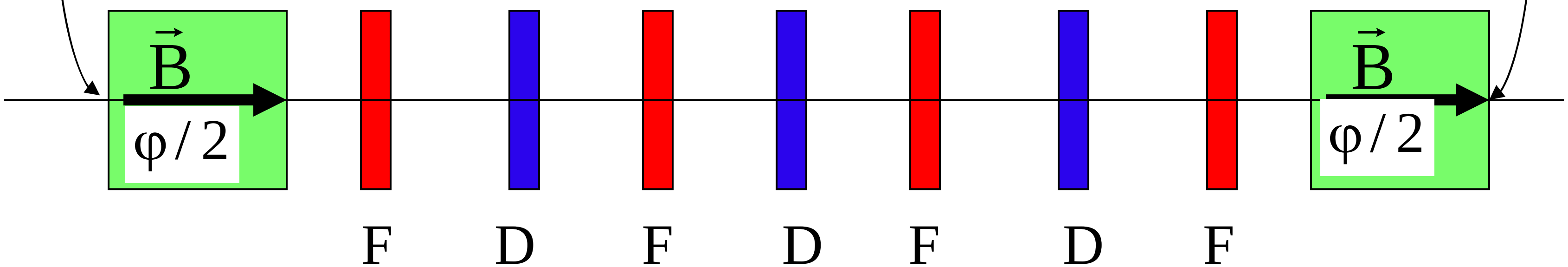
  ny=0.99431 in B3L - B3L, ny=0.92571 in B3L - B2AL - also suitable for 1.4 GeV: with ny=0.604

  Plan use for Compton backscattering polarimetry (see K.Moffeit report at Annecy, 2010)

Spin Rotator for an arbitrary partial

For decoupling should be $T_x = -T_y$

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



$r = pc/eB$

Two solenoids provide spin rotation by $\varphi \le 180^0$

All quads don't need to be skewed!

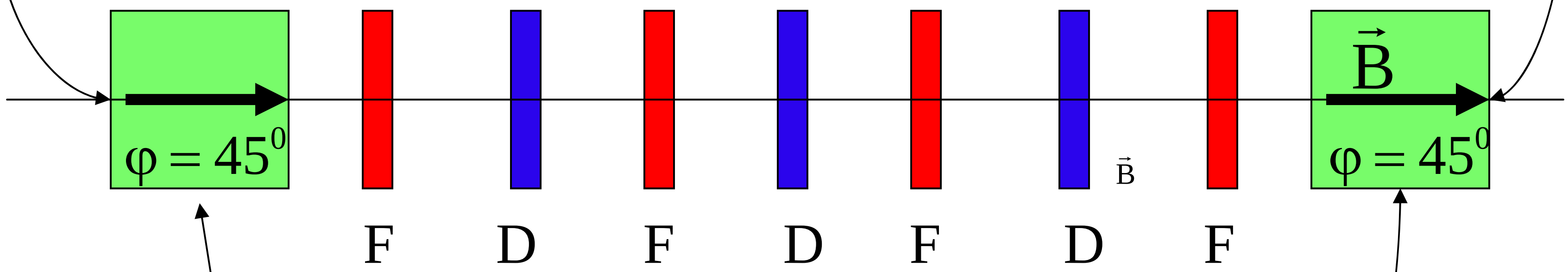
Spin transparency cancels the contribution of betatron oscillations to |d|-factor

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

90^0 Spin Rotator optics

Decoupling condition: T_x=-T_y

$$T_x = -T_y = \begin{pmatrix} 0 & -2r \\ (2r)^{-1} & 0 \end{pmatrix}$$ for the spin transparency!

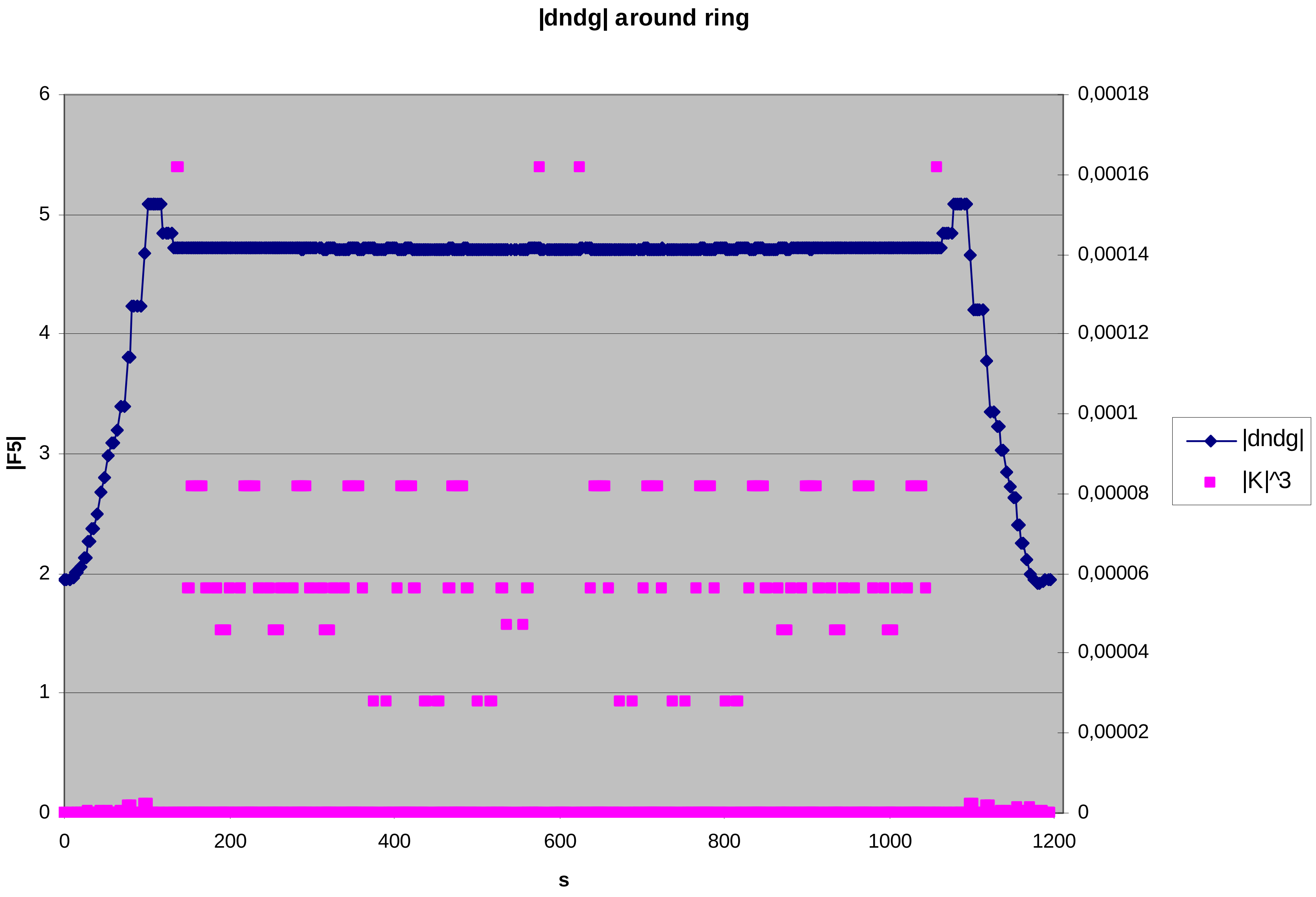


$r = pc / eB$

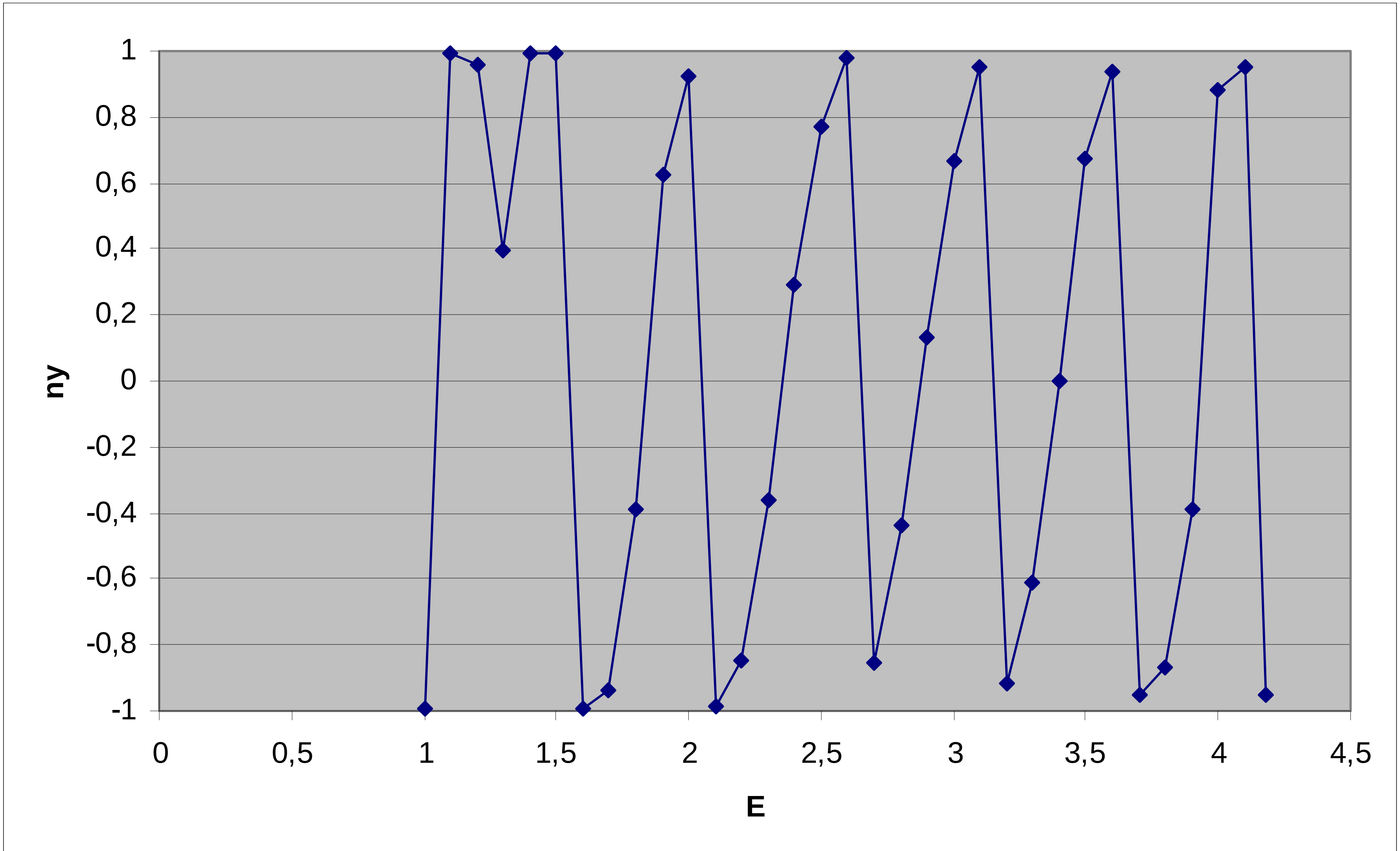
Each of two solenoids provides 45^0 spin rotation

At 4.18 GeV each solenoid is: L=2.1878 m, H=4.999591 T, HL=10.938106 T*m

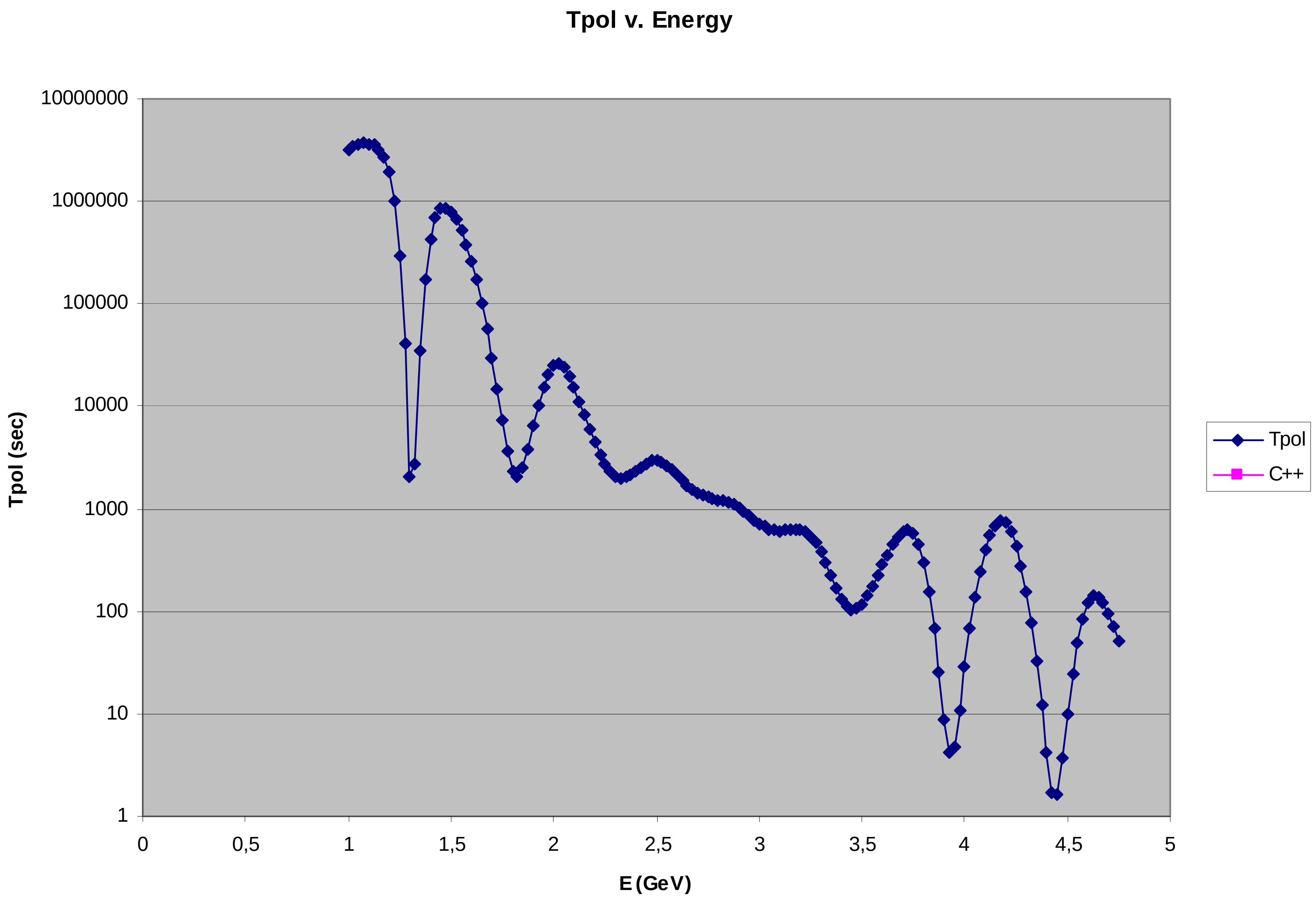
ASPIRRIN: two 90^0 rotators, E=4.18 GeV



ASPIRRIN: 2 x 90^0 option, ny(E) scan

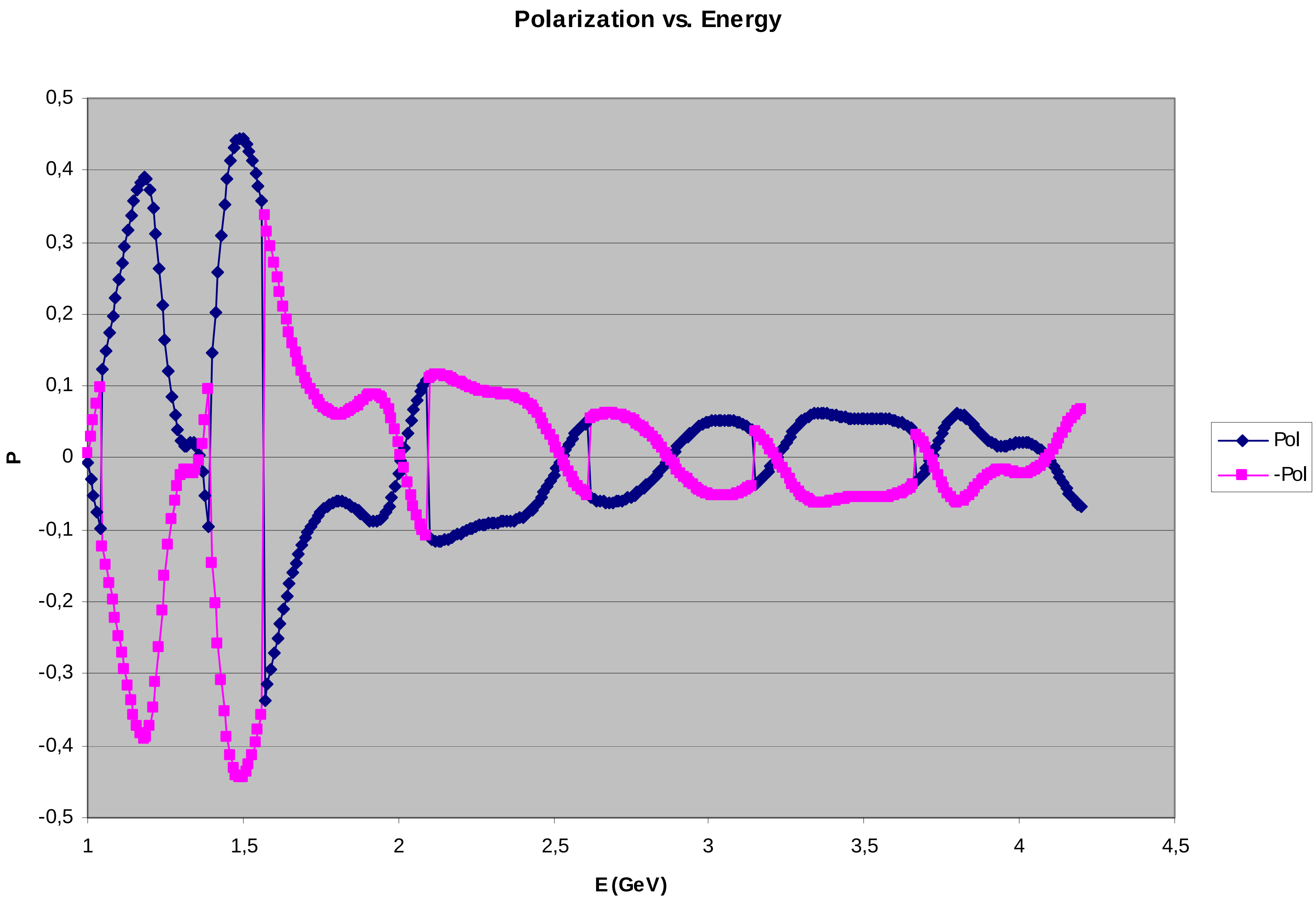


ASPIRRIN: 2 x 90^0 spin rotators, tau_DK scan

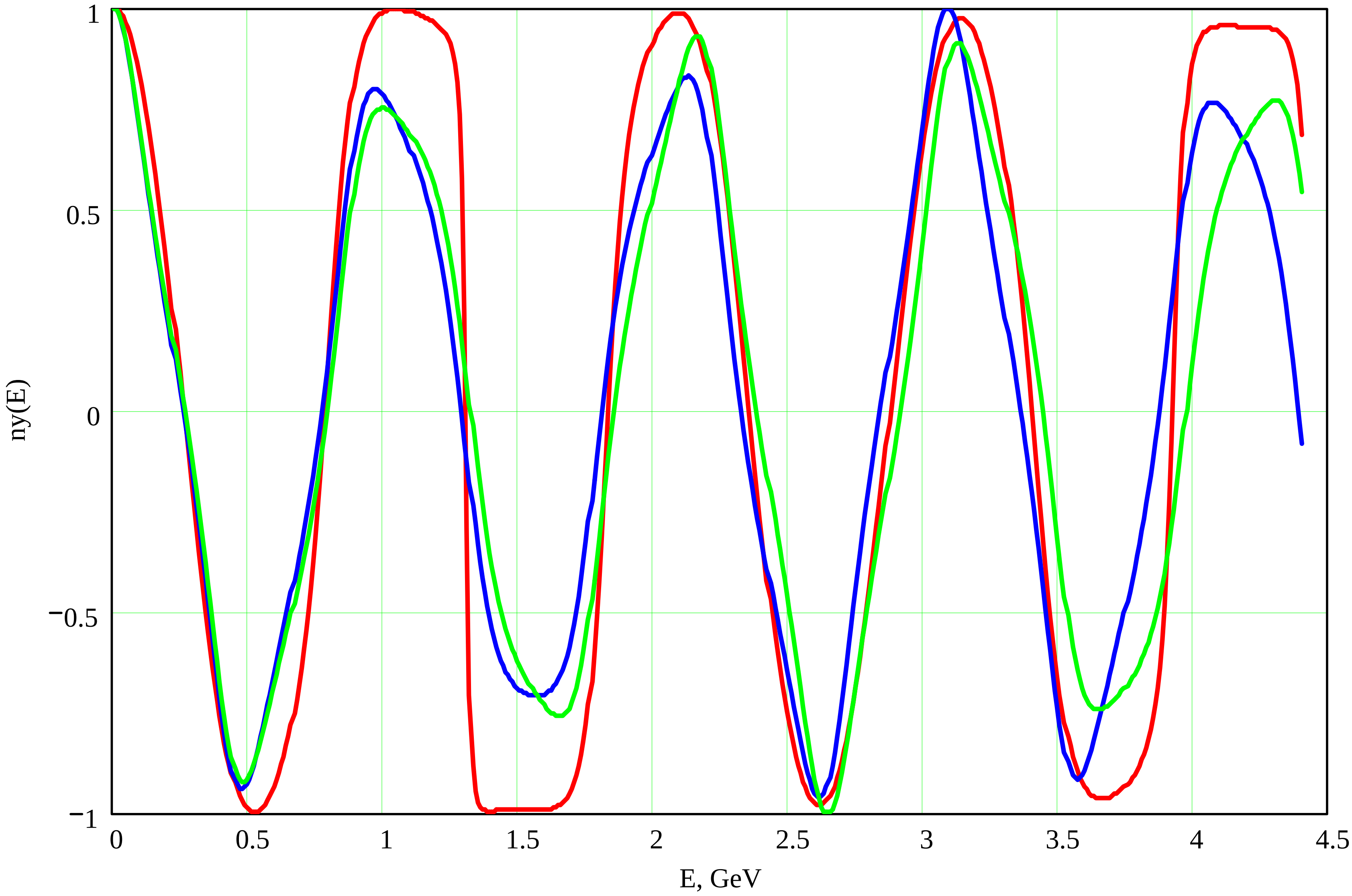


$$\tau_{DK} = 760\ s, \quad P_{DK} = +5.9\% \ \text{ at } \ E = 4.18 \text{ GeV}$$

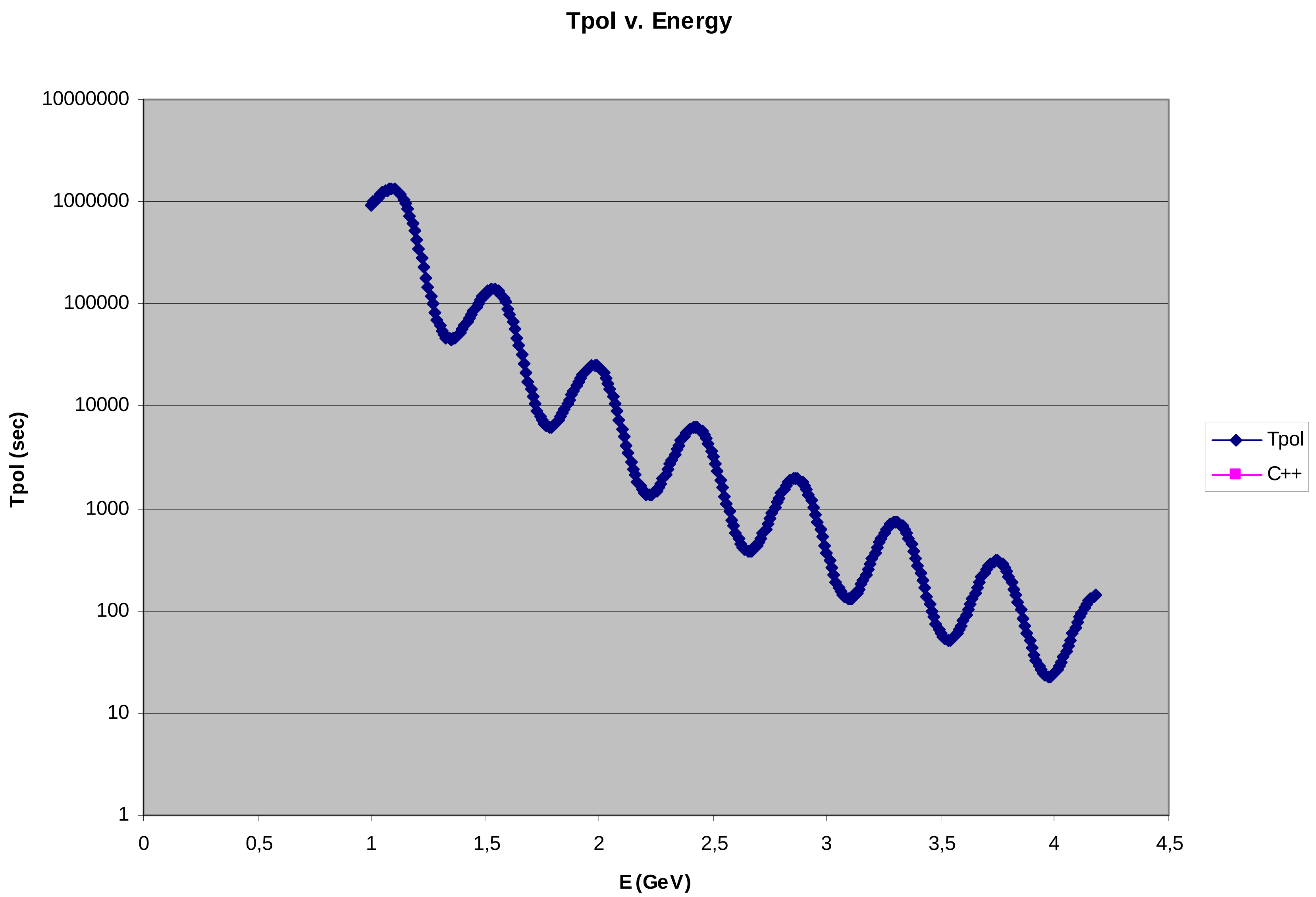
Self-polarization degree for 2 x 90^0 option



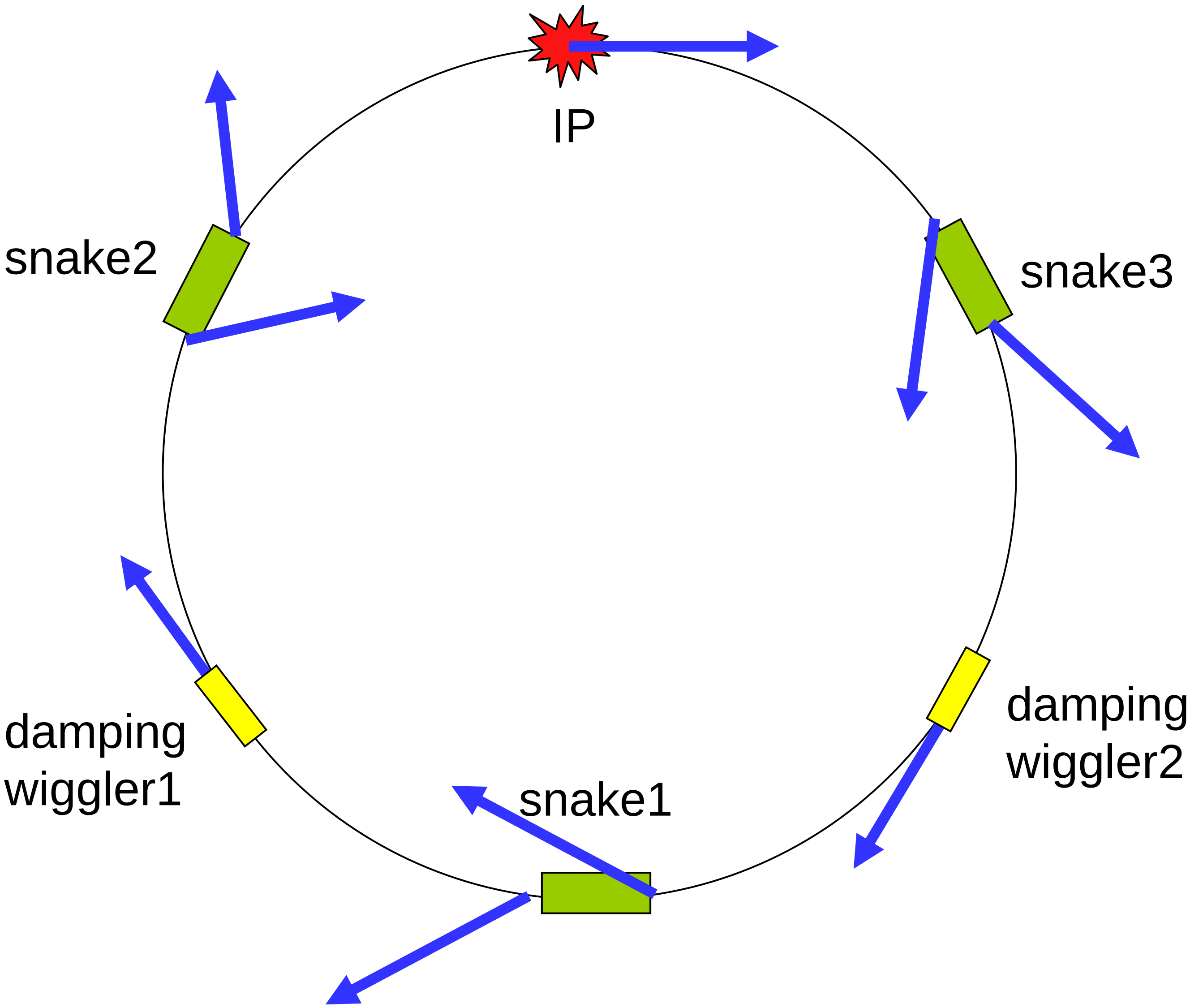
ny(E): left, right or both rotators are powered



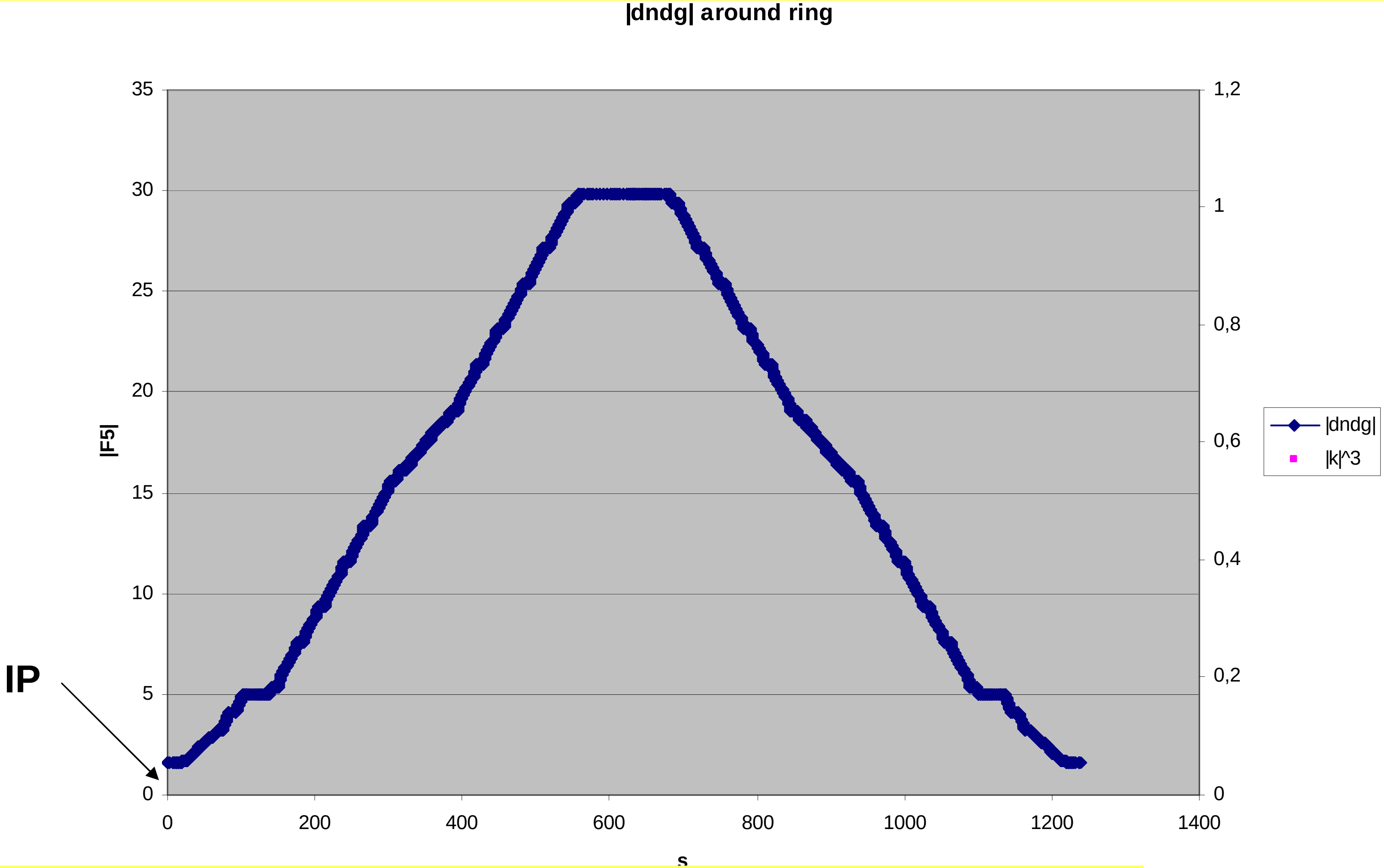
Tau(E), a single (left) rotator is switched on



Single or 3 snakes options (arc=120^0 + two damping wigglers in the arc's middle point)



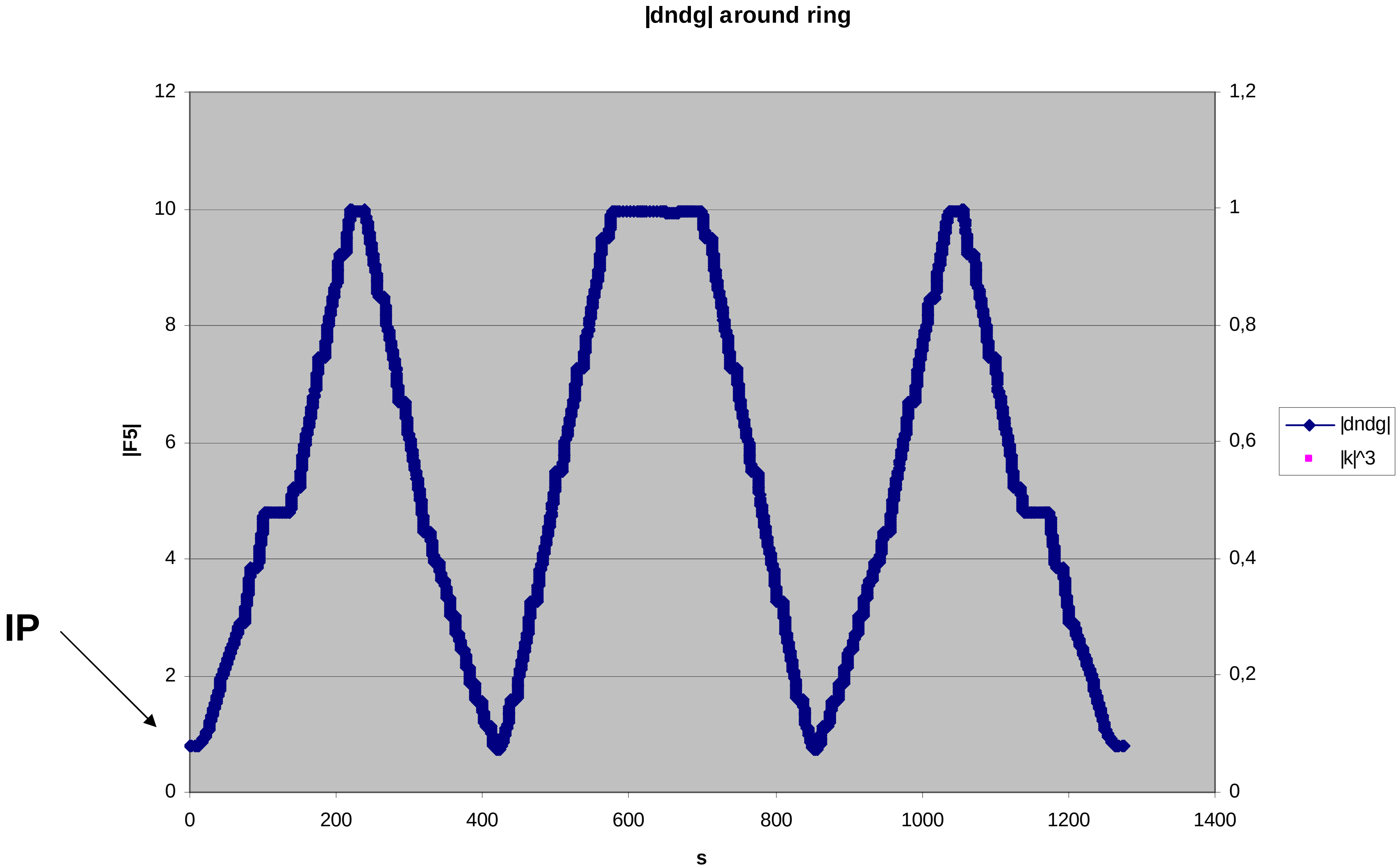
|d|, single snake option, 4.18 GeV



$$\tau_{DK} = 90\ s \ \text{ at }\ E = 4.18\ \text{GeV},\ \tau_{DK} = 900\ s \text{ at 3 GeV}$$

$$\tau_{DK} = 181000\ s \ \text{ at }\ 1.4\ \text{GeV (but no wigglers!)}$$

ASPIRRIN: 3 snakes option, 4.18 GeV



$$\tau_{DK} = 780\ s, \quad P_{DK} = +2.7\% \text{ at } E = 4.18 \text{ GeV}$$

Some open questions

- Optics regime below 4.18 GeV. Influence of wigglers on the depolarization time – we need a response from the lattice design team.
- Spin dynamics simulation (linear and nonlinear optics imperfections, tolerances) with the advanced tracking codes: D.P. Barber, SLICKTRACK; P.A.Piminov, Acceleraticum;
- Beam-beam simulation with the emphasis on depolarization - N.Monseu, Zgoubi code; Cecile Rimbault – GUINEA-PIG++ code; D.N.Shatilov, LIFETRAC.

Conclusion on polarization

- A scheme with two 90^0 spin rotators provides up to ~70% of the longitudinal polarization in LER at 4.18 GeV and at some magic energies.
- Below 3 GeV each single 90^0 spin rotator works as a partial snake, providing a high enough longitudinal polarization at some magic energies, but almost everywhere two rotators scheme looks better.
- Single snake, being placed in technical straight section, works well at any energy below 3 GeV.
- 3 snakes option works well in the full energy range, but is more expensive and needs somewhat longer circumference – not feasible?
- Tolerances on the quads gradient integrals and the solenoid field integrals are in a range of few percents.
- TDR could start with the solenoid design and, probably, with the Compton polarimeter.