Polarisation in the eRHIC electron(positron) ring.

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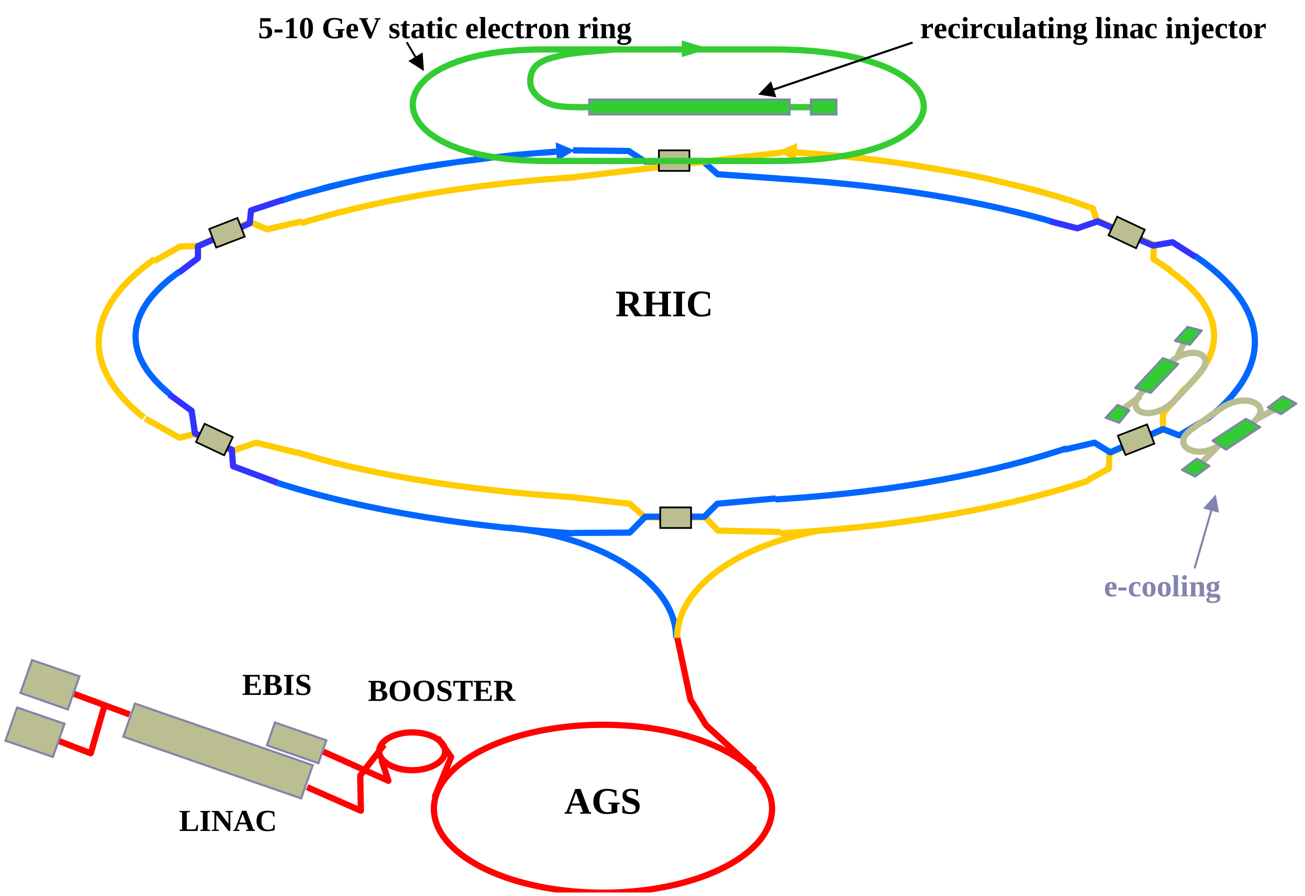
For the eRHIC team

Plan

- The project
- Phenomenology: Self polarisation/depolarisation/spin matching
- Calculations at first order.
- Beam–beam/thick beams.
- Summary.

The Layout


5-10 GeV static electron ring
recirculating linac injector
RHIC
e-cooling
EBIS
BOOSTER
LINAC
AGS

eRHIC

Zeroth-Order Design Report

BNL: L. Ahrens, D. Anderson, M. Bai, J. Beebe-Wang, I. Ben-Zvi, M. Blaskiewicz, J.M. Brennan, R. Calaga, X. Chang, E.D. Courant, A. Deshpande, A. Fedotov, W. Fischer, H. Hahn, J. Kewisch, V. Litvinenko, W.W. MacKay, C. Montag, S. Ozaki, B. Parker, S. Peggs, T. Roser, A. Ruggiero, B. Surrow, S. Tepikian, D. Trbojevic, V. Yakimenko, S.Y. Zhang

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Parameters

Table 1.1. Luminosities and main beam parameters for electron(positron)-proton collisions.

	High energy setup		Low energy setup	
	p	e	p	e
Energy, GeV	250	10	50	5
Bunch intensity, 10^{11}	1	1	1	1
Ion normalized emittance, π mm·mrad , x/y	15/15		5/5	
rms emittance, nm, x/y	9.5/9.5	53/9.5	16.1/16.1	85/38
β*, cm, x/y	108/27	19/27	186/46	35/20
Beam-beam parameters, x/y	0.0065/0.003	0.03/0.08	0.019/0.0095	0.036/0.04
$\kappa=\varepsilon_y/\varepsilon_x$	1	0.18	1	0.45
Luminosity, 1.e32 $cm^{-2}s^{-1}$	4.4		1.5	

Table 1.2. Luminosities and main beam parameters for electron(positron)-Au collisions.

	High energy setup		Low energy setup	
	Au	e	Au	e
Energy, GeV/u	100	10	100	5
Bunch intensity, 10^{11}	0.01	1	0.0045	1
Ion normalized emittance, π mm·mrad , x/y	6/6		6/6	
rms emittance, nm, x/y	9.5/9.5	54/7.5	9.5/9.5	54/13.5
β*, cm, x/y	108/27	19/34	108/27	19/19
Beam-beam parameters, x/y	0.0065/0.003	0.0224/0.08	0.0065/0.003	0.02/0.04
$\kappa=\varepsilon_y/\varepsilon_x$	1	0.14	1	0.25
Luminosity, 1.e30 $cm^{-2}s^{-1}$	4.4		2.0	

Table 1.3. . Luminosities and main beam parameters for electron(positron)-$^{3}He^{+2}$ collisions.

	High energy setup		Low energy setup	
	He	e	He	e
Energy, GeV/u	167	10	167	5
Bunch intensity, 10^{11}	0.7	1	0.18	1
Ion normalized emittance, π mm·mrad , x/y	10/10		10/10	
rms emittance, nm, x/y	9.4/9.4	48/13	9.4/9.4	48/13
β*, cm, x/y	108/27	21/19	108/27	21/19
Beam-beam parameters, x/y	0.0065/0.003	0.045/0.08	0.0065/0.003	0.02/0.04
$\kappa=\varepsilon_y/\varepsilon_x$	1	0.28	1	0.28
Luminosity, 1.e32 $cm^{-2}s^{-1}$	3.1		0.8	

Spin motions

- Protons: largely deterministic — unless IBS.
- Electrons/positrons:
  If a photon causes a spin flip, what are the other $\approx 10^{10}$ photons doing? ===>

  Stochastic/damped orbital motion due to synchrotron radiation
  \+ inhomogeneous fields
  \+ spin–orbit coupling via T–BMT
  ===> spin diffusion i.e. depolarisation!!!

  Self polarisation: Balance of poln. and depoln. ===>

  $$P_\infty \approx P_{BK} \, \frac{1}{1 \; + \; (\frac{\tau_{dep}}{\tau_{BK}})^{-1}} \qquad (P_{ST} \to P_{BK})$$

  In any case:

  $\tau_{dep}^{-1} \; \propto \; \gamma^{2N} \, \tau_{st}^{-1}$ (actually a polynomial in γ^{2N})

  ===> Trouble at high energy!

Spin–orbit resonances

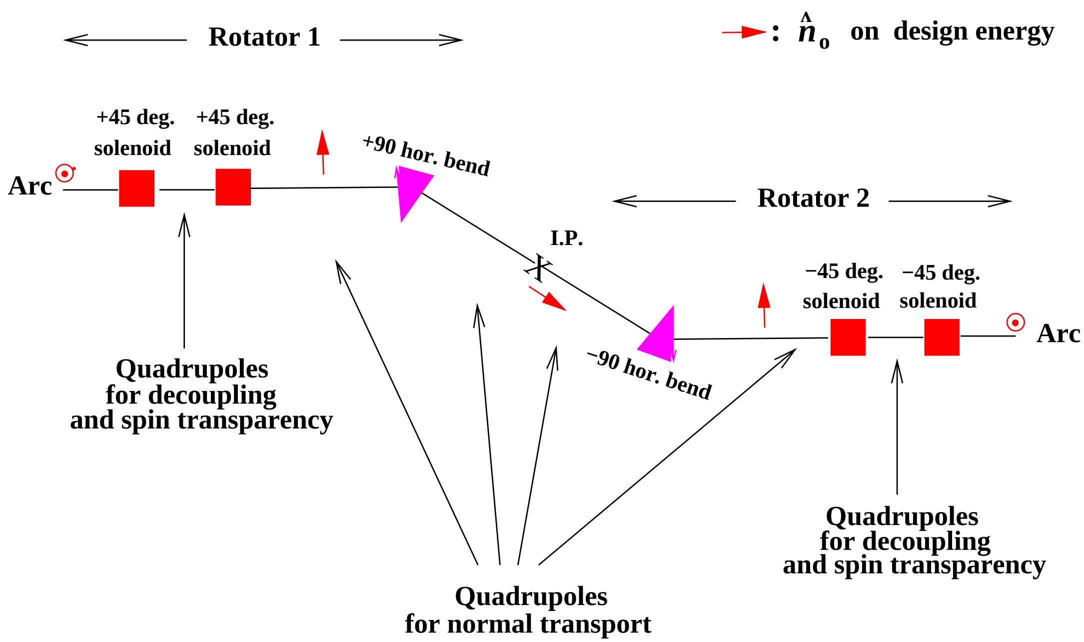
$$\nu_{\text{spin}} = k + k_I \nu_I + k_{II} \nu_{II} + k_{III} \nu_{III}$$

ν_{spin} : amplitude dependent spin tune $\approx$ closed orbit spin tune = precessions /turn on CO

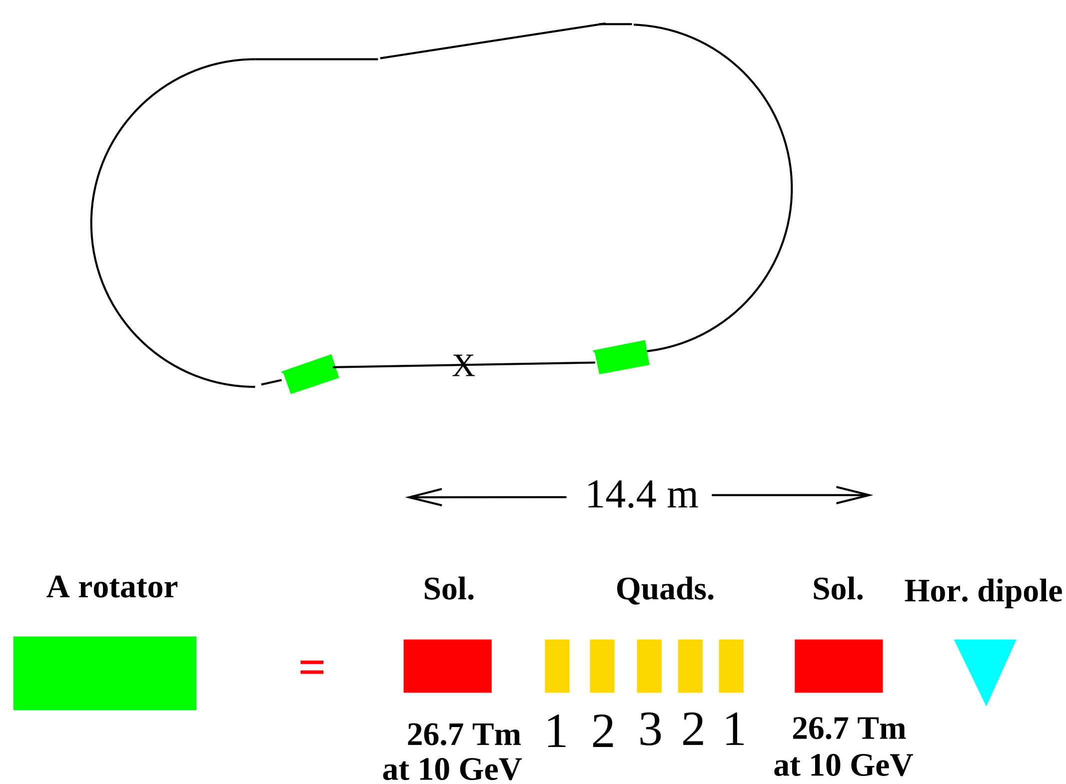
- Orbit "drives spins" ===> Resonant enhancement of spin diffusion.
- Resonance order: $|k_I| + |k_{II}| + |k_{III}|$
- First order: $|k_I| + |k_{II}| + |k_{III}| = 1$ e.g. SLIM like formalisms.
- Strongest beyond first order:
  synchrotron sidebands of first order parent betatron or synchrotron resonances

$$\nu_{\text{spin}} = k + k_i \nu_i + k_{III} \nu_{III}, \quad i = I, II \text{ or } III$$

The solenoid spin rotators



The basic eRHIC geometry for spin−−exaggerated

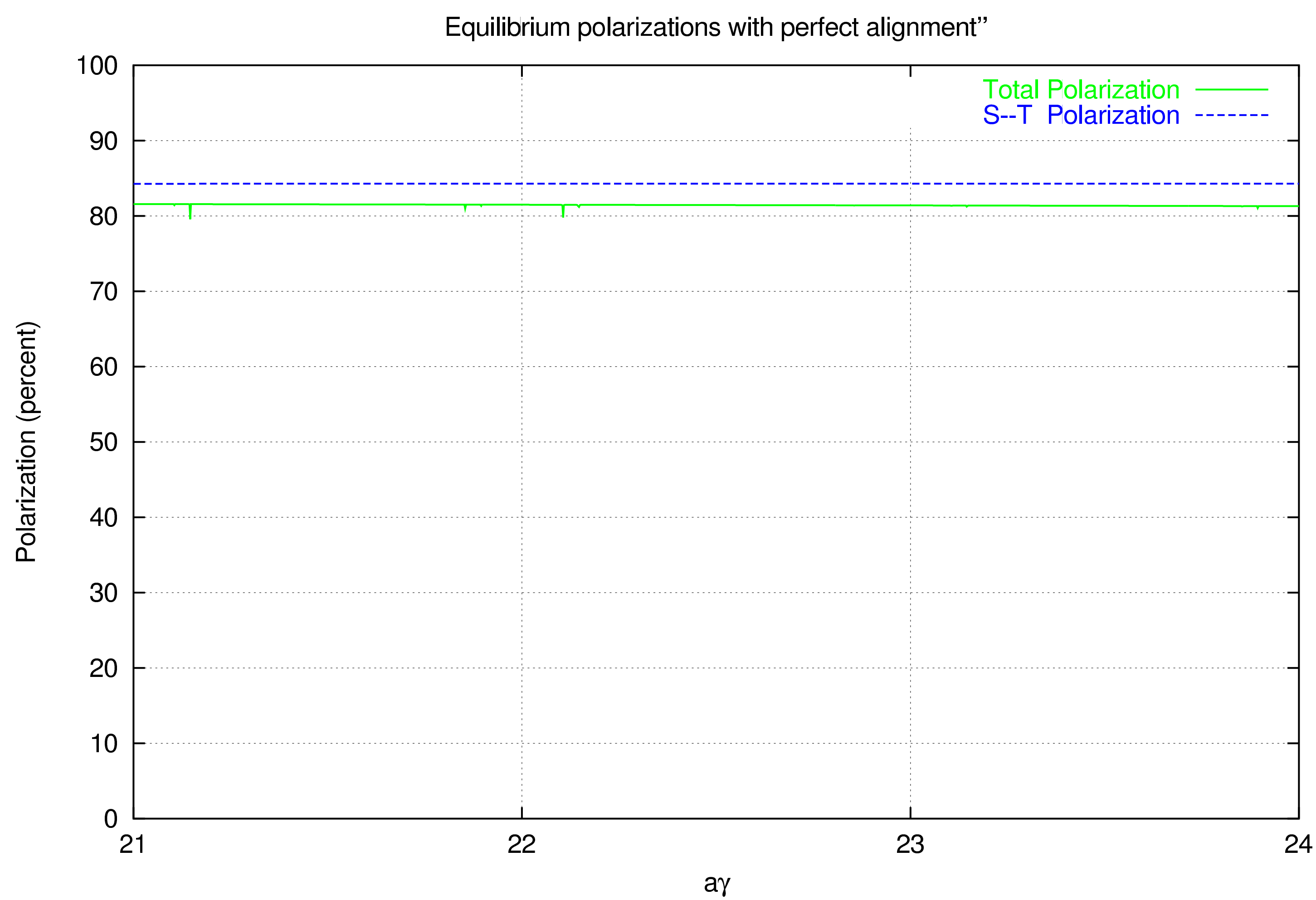


The 4×4 transfer matrix for the transverse motion through a pair of solenoids:

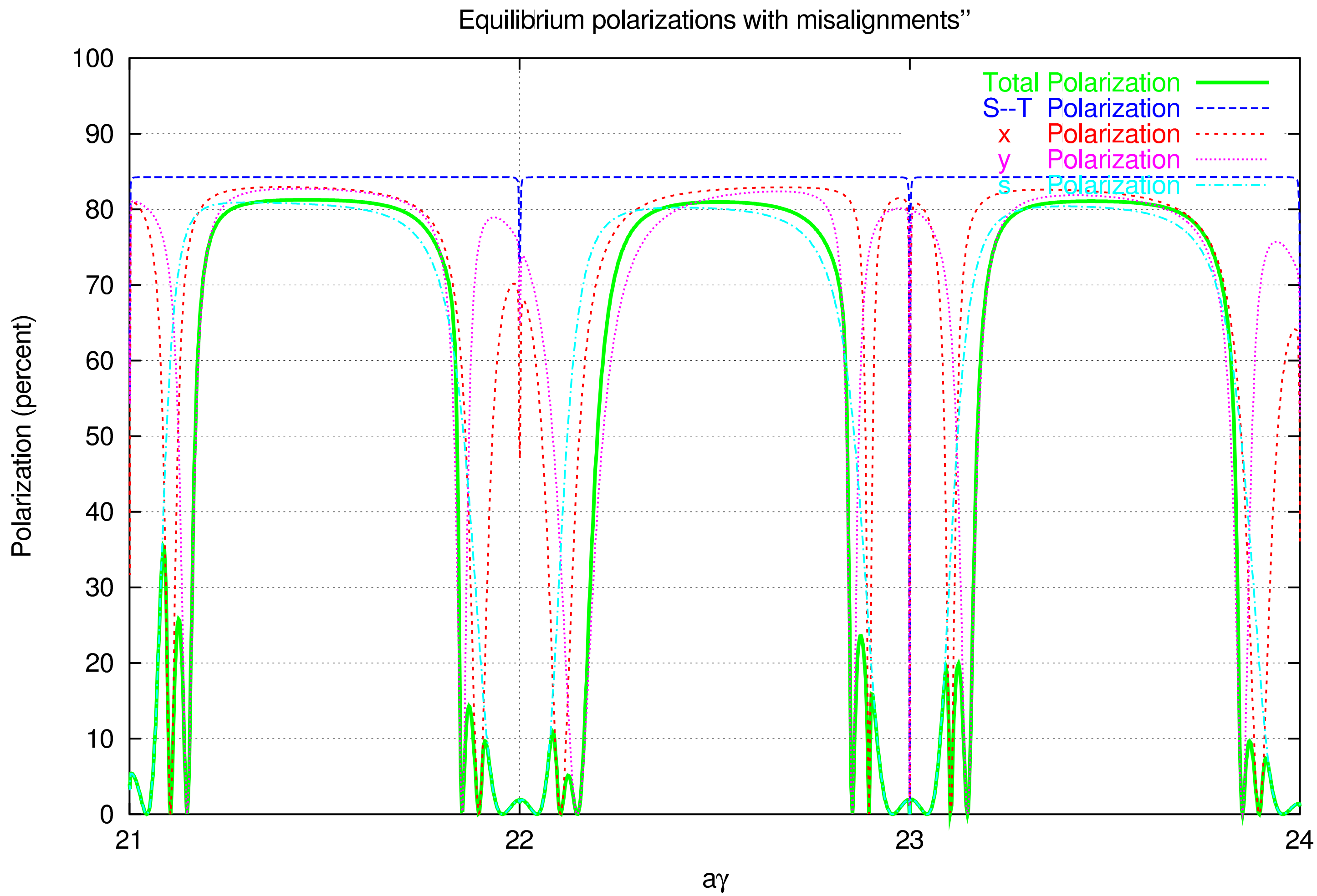
$$\begin{pmatrix} 0 & -2r & 0 & 0 \\ 1/2r & 0 & 0 & 0 \\ 0 & 0 & 0 & 2r \\ 0 & 0 & -1/2r & 0 \end{pmatrix}$$

where r is the radius of orbit curvature in the longitudinal field.

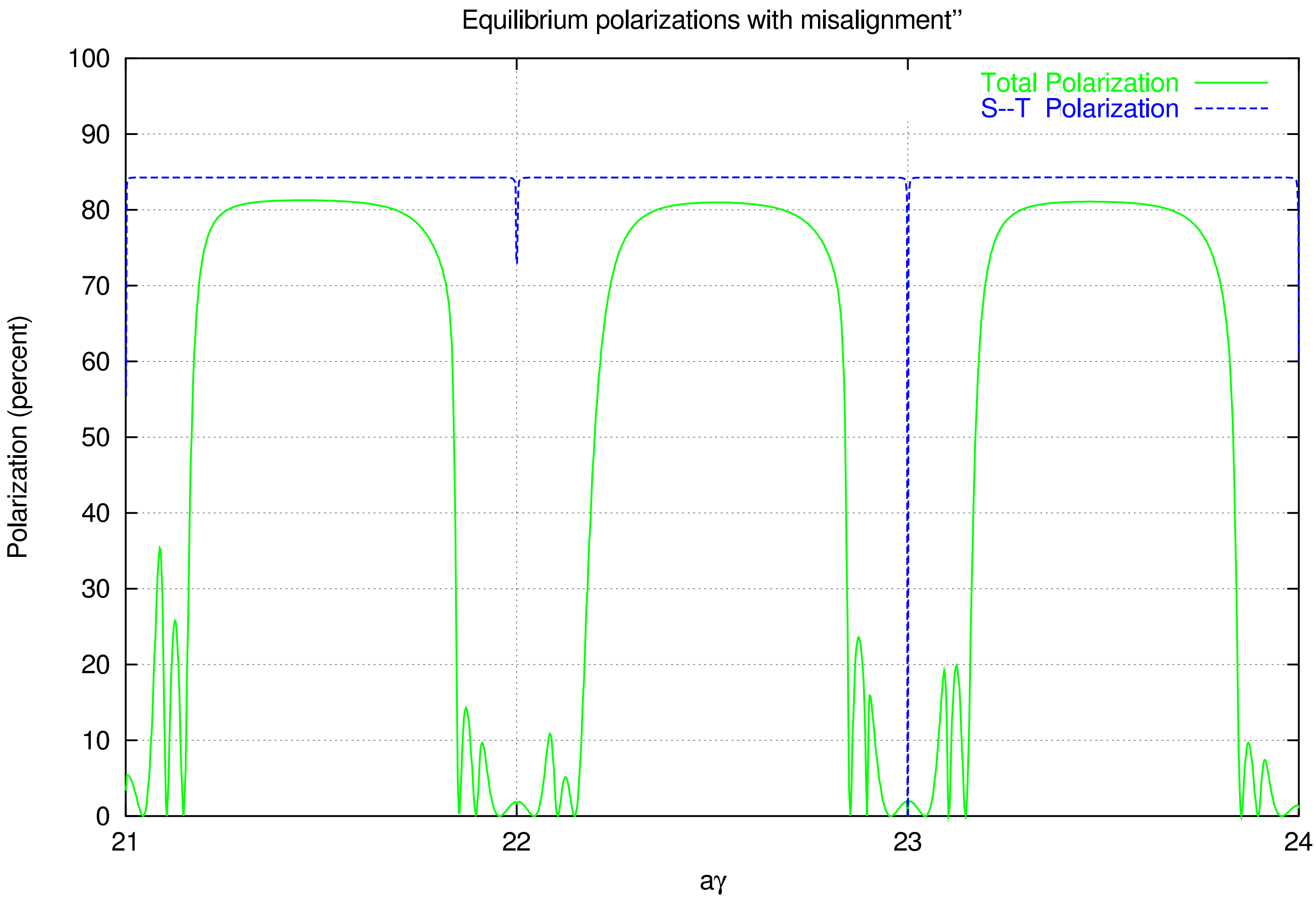
Use 5 back–to–back symmetric quadrupoles.


Equilibrium polarizations with perfect alignment”
Total Polarization
S--T Polarization
Polarization (percent)
aγ
0
10
20
30
40
50
60
70
80
90
100
21
22
23
24

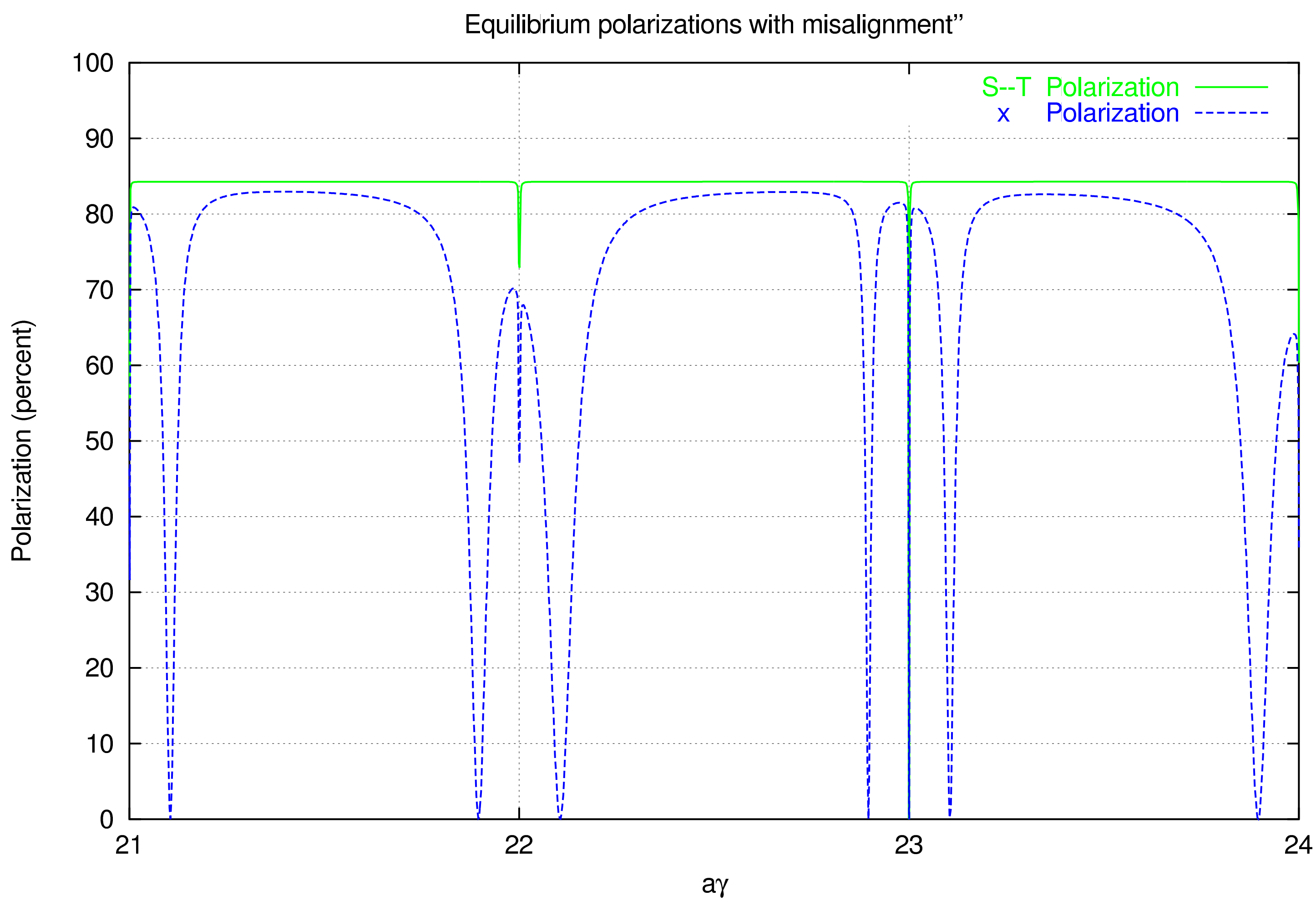
All monitors on



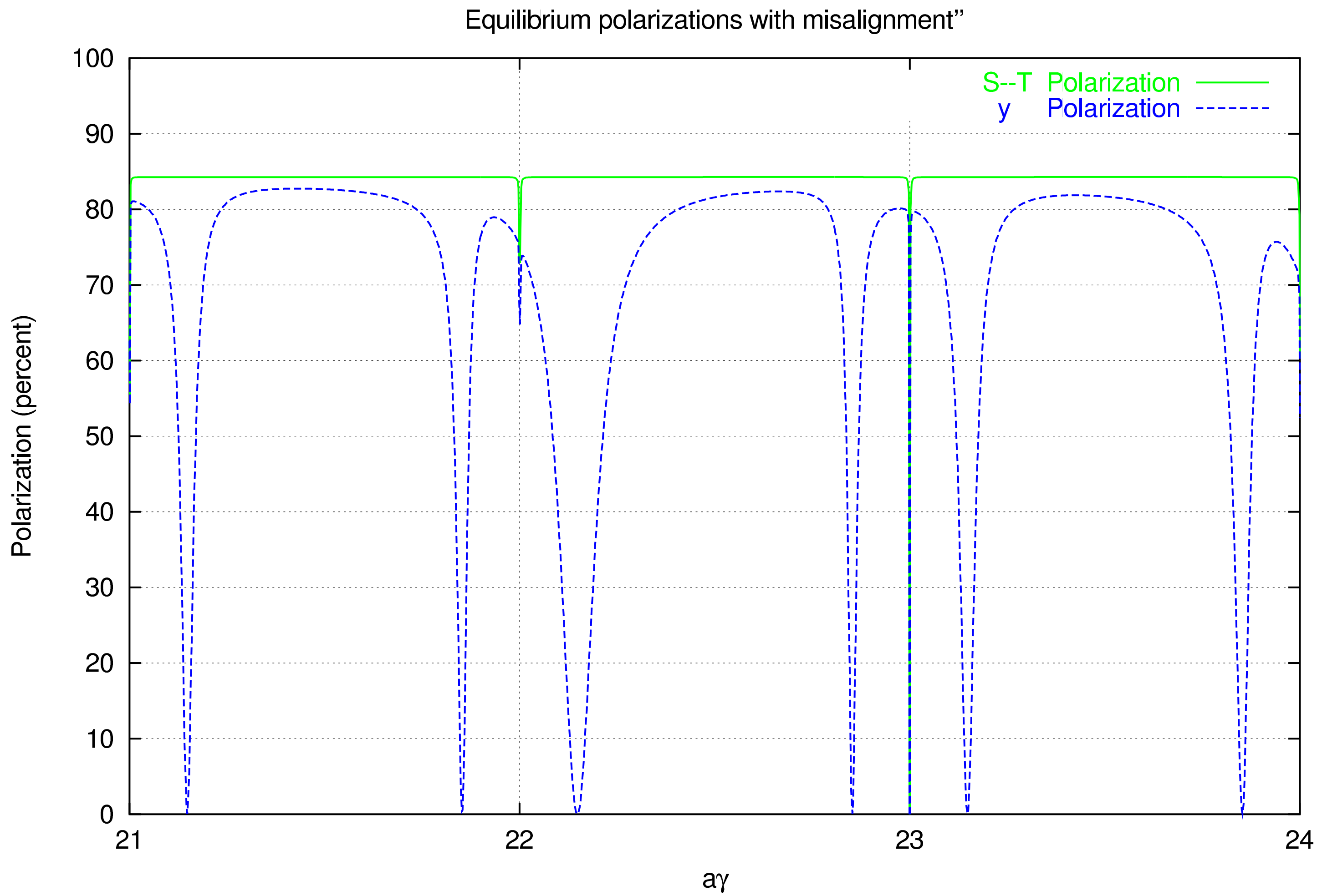
All monitors on



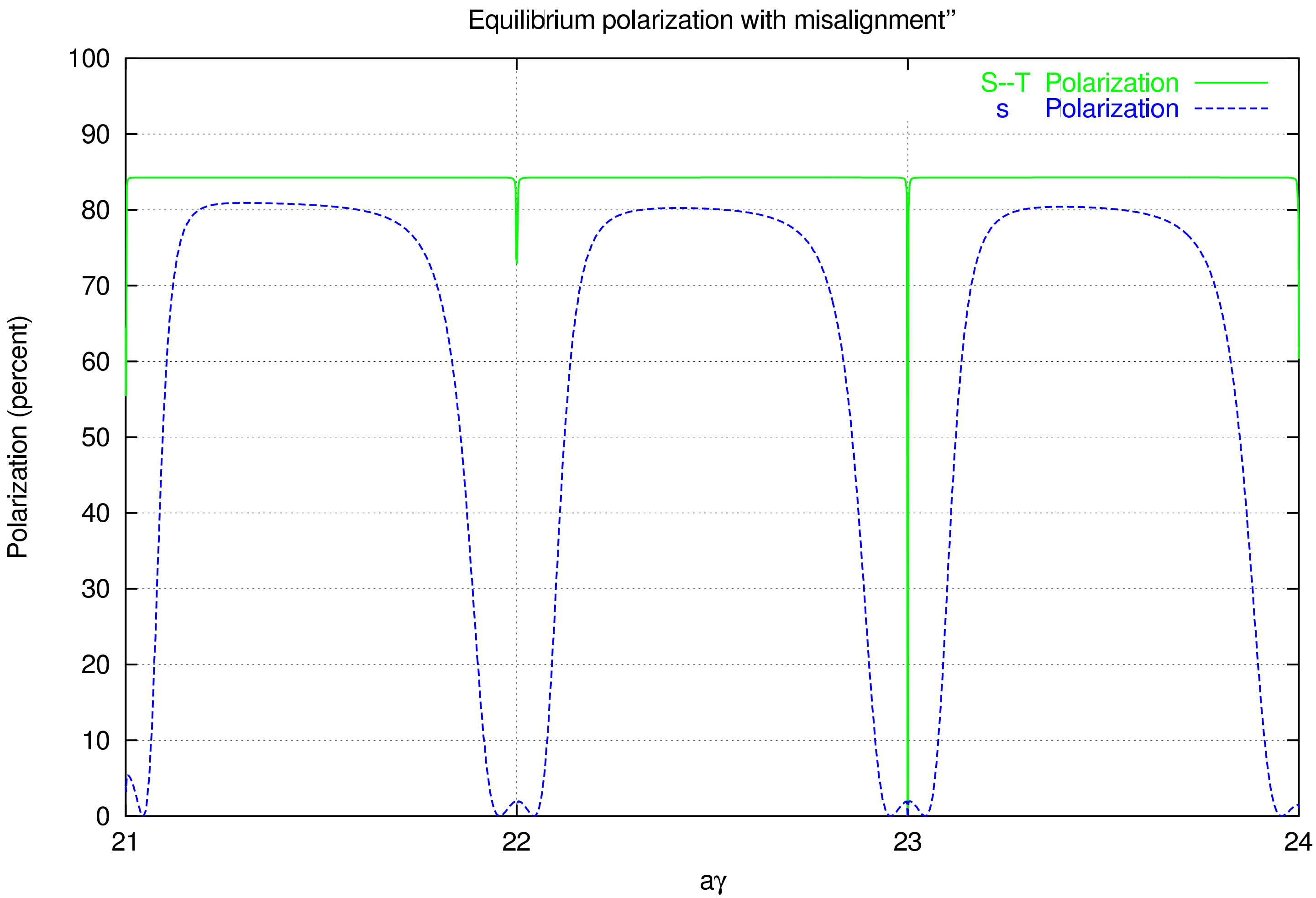
All monitors on



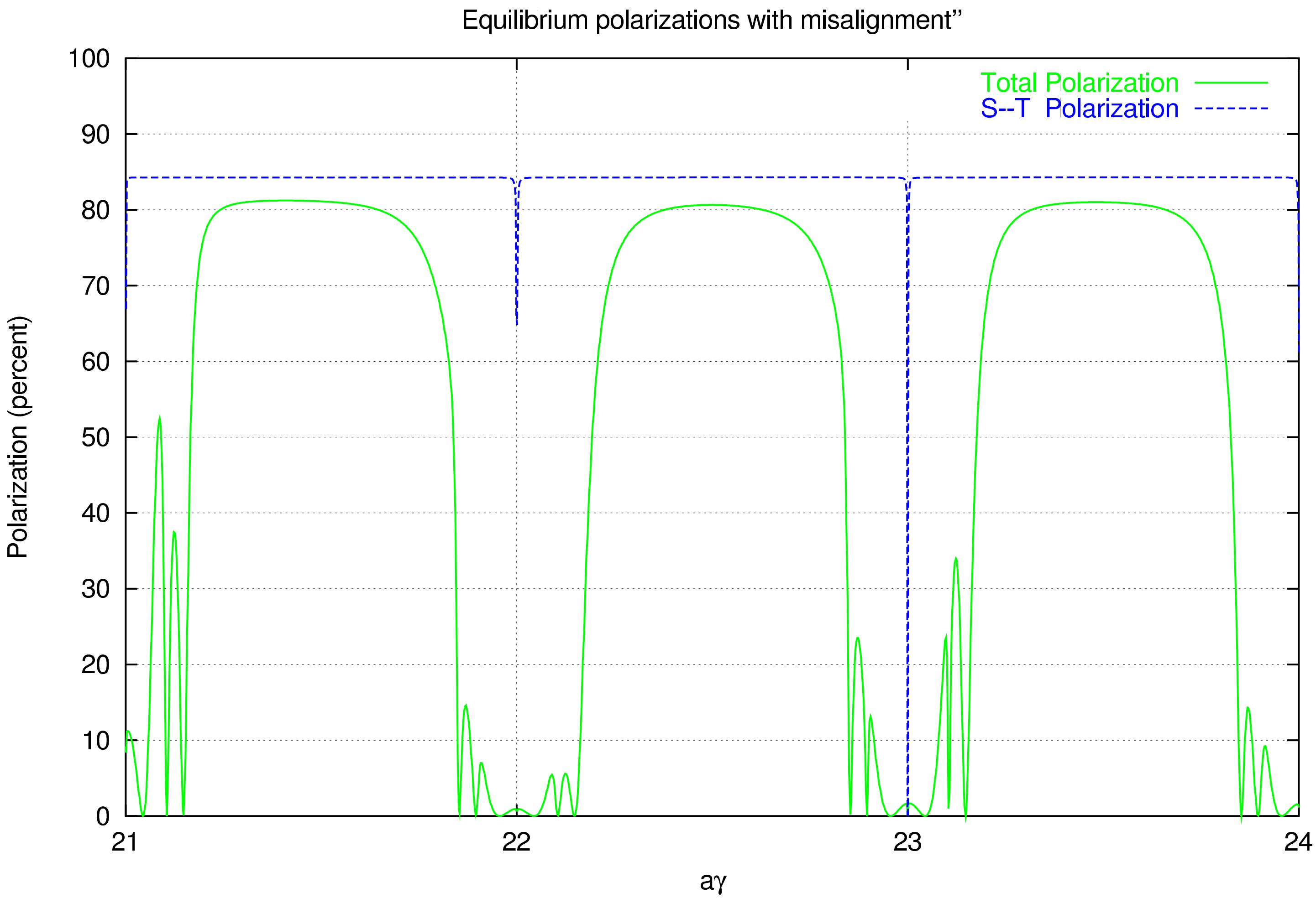
All monitors on



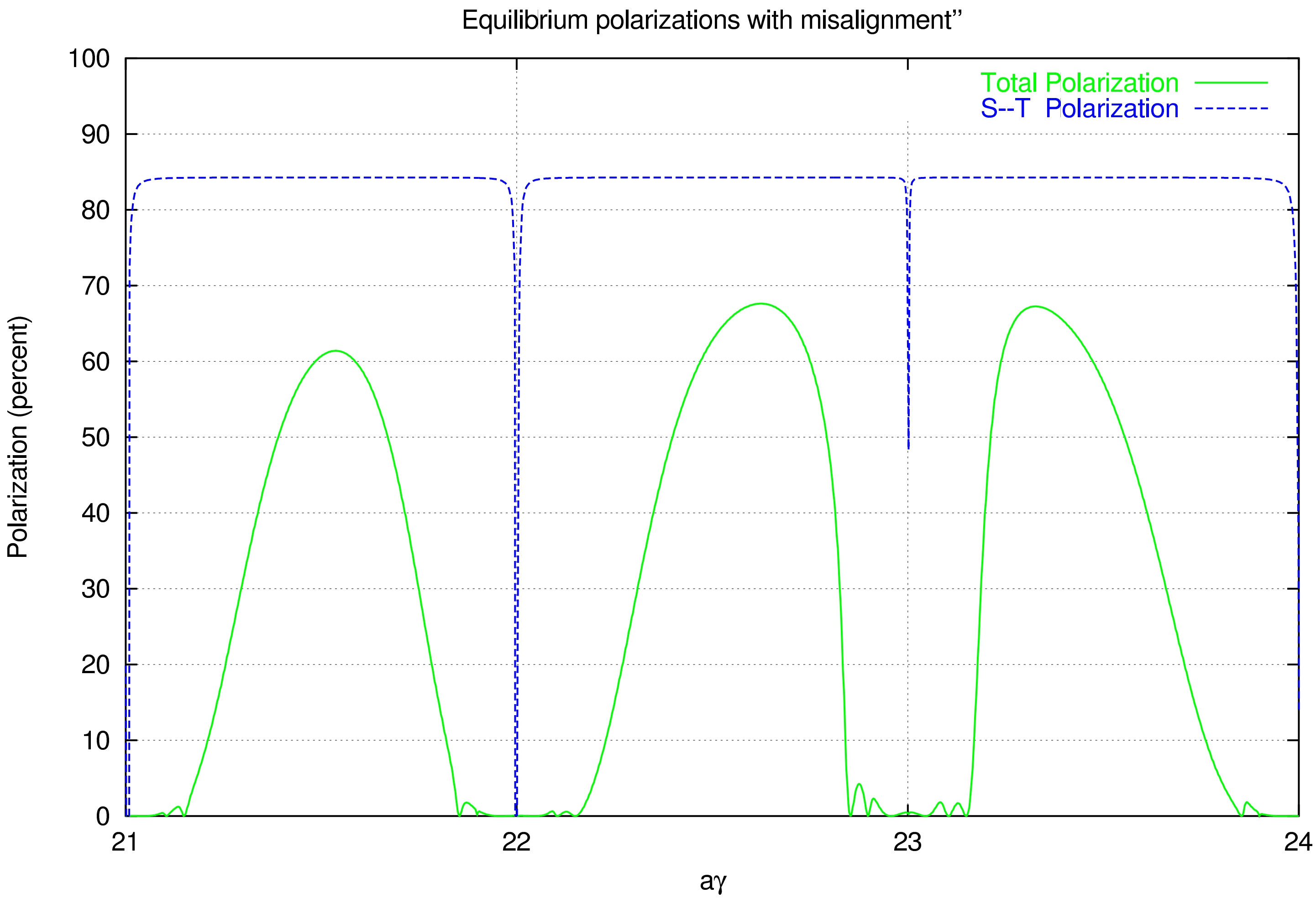
All monitors on

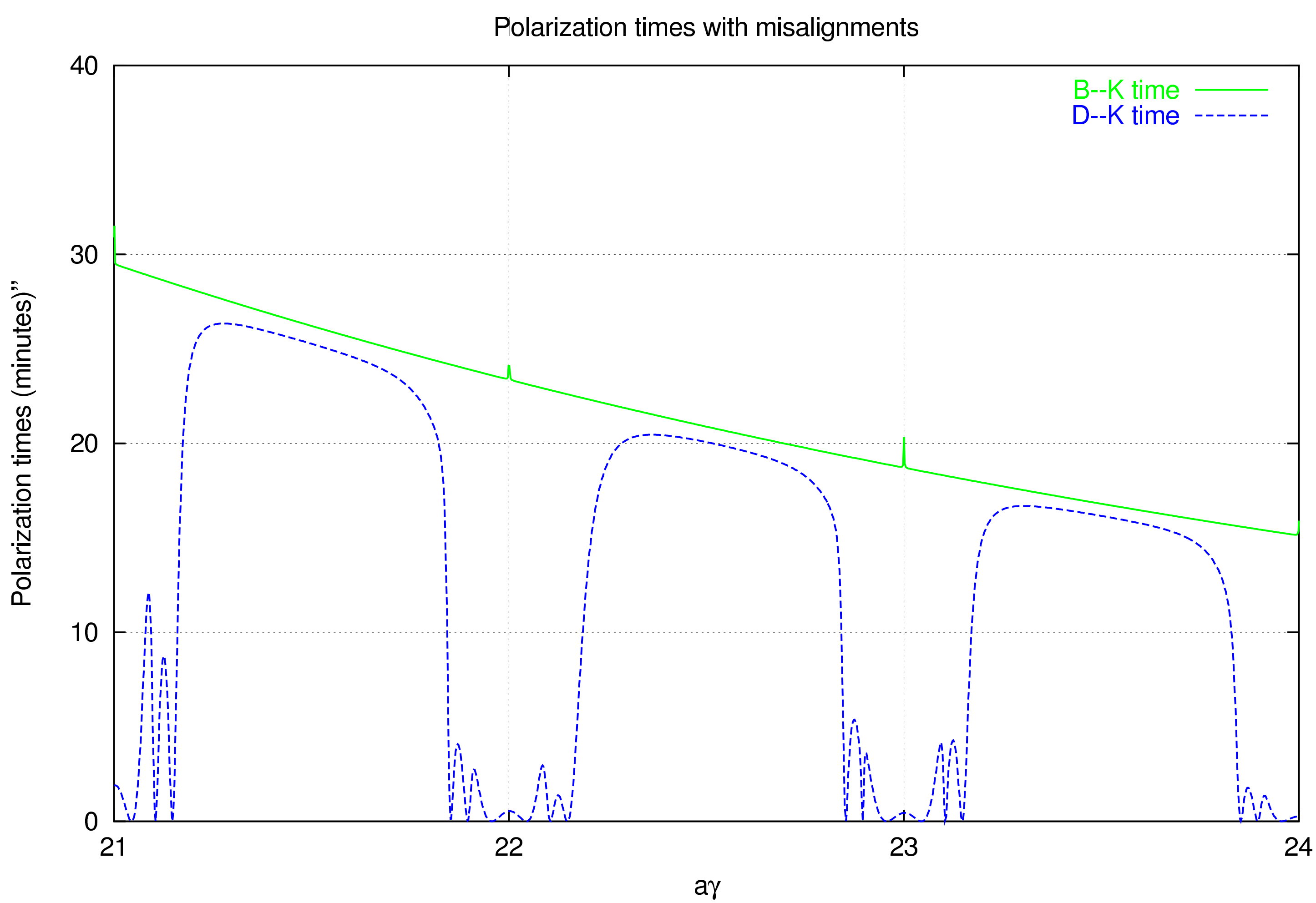


80 percent monitors on

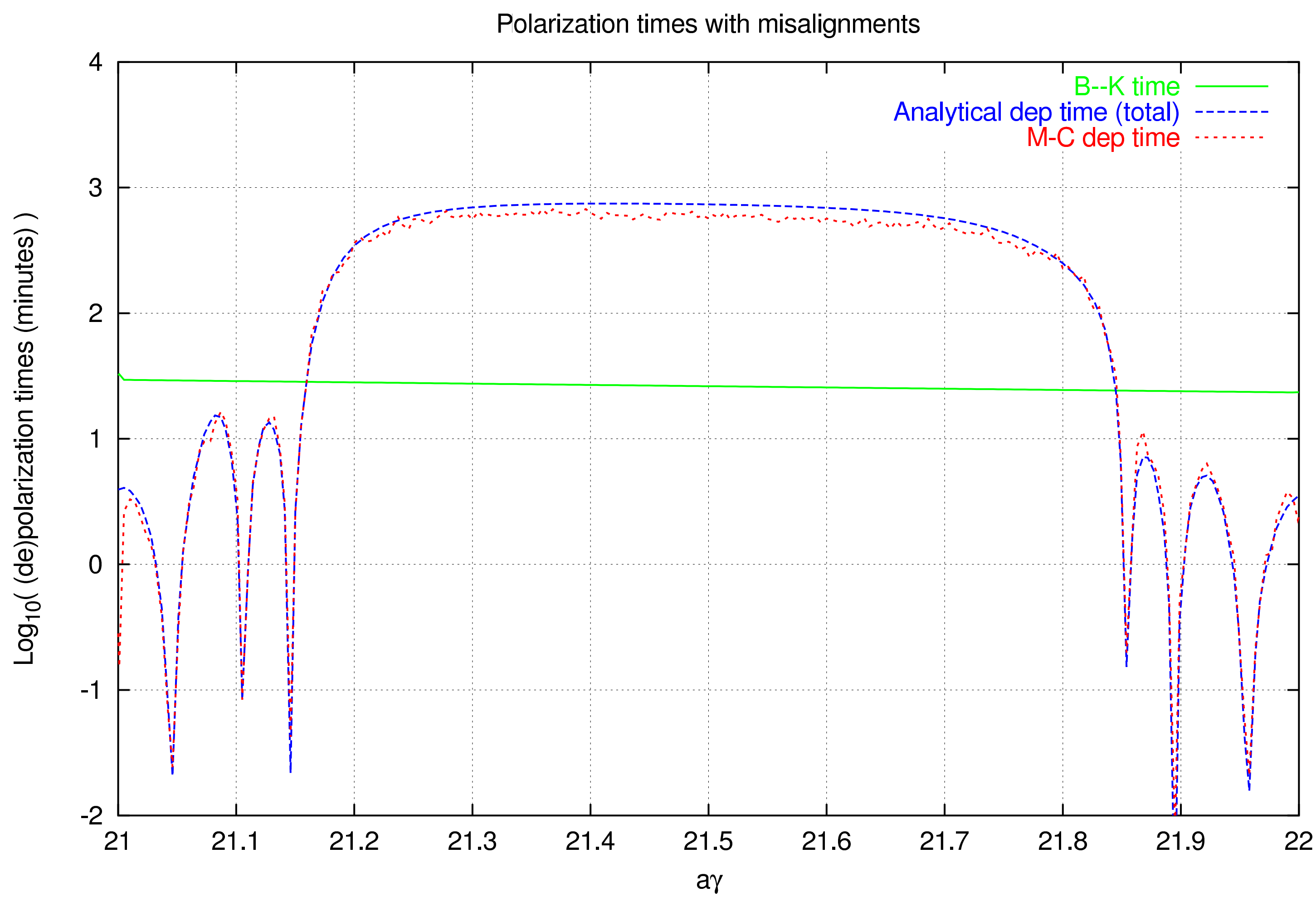


20 percent monitors on



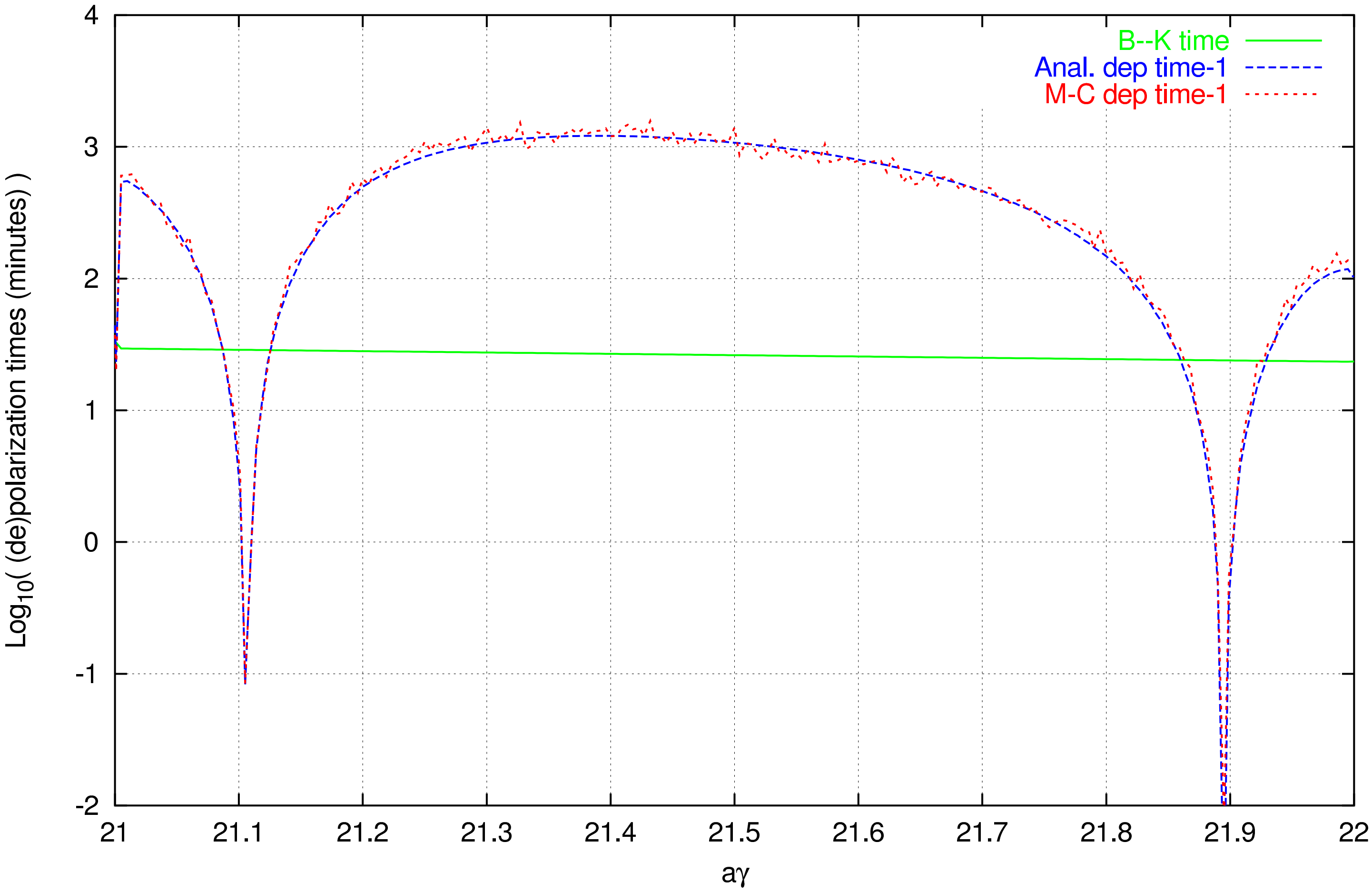

Polarization times with misalignments
B--K time
D--K time
Polarization times (minutes)"
aγ
0
10
20
30
40
21
22
23
24

Calibrating the M-C software structure against SLICK

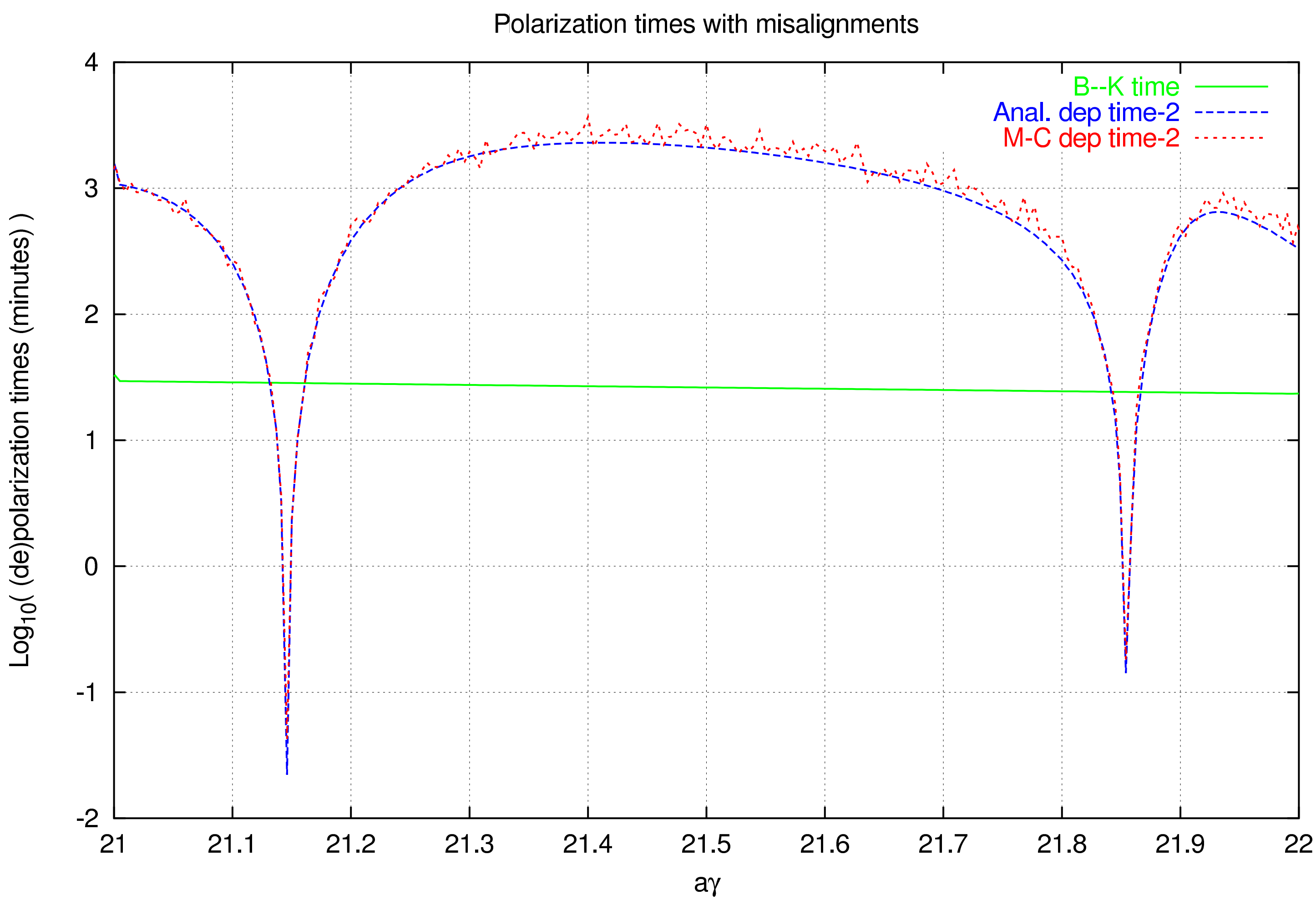


Calibrating the M-C software structure against SLICK

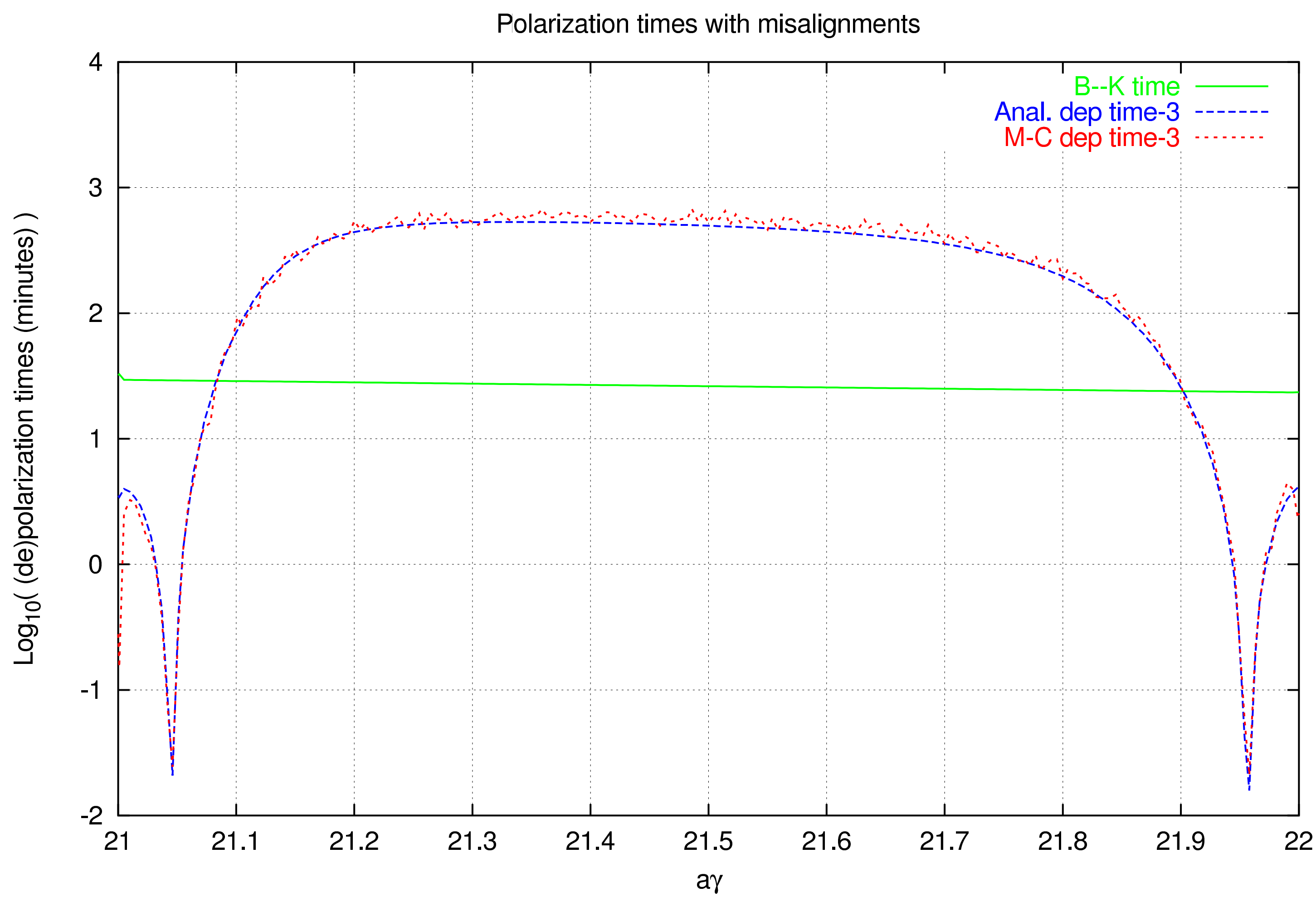
Polarization times with misalignments



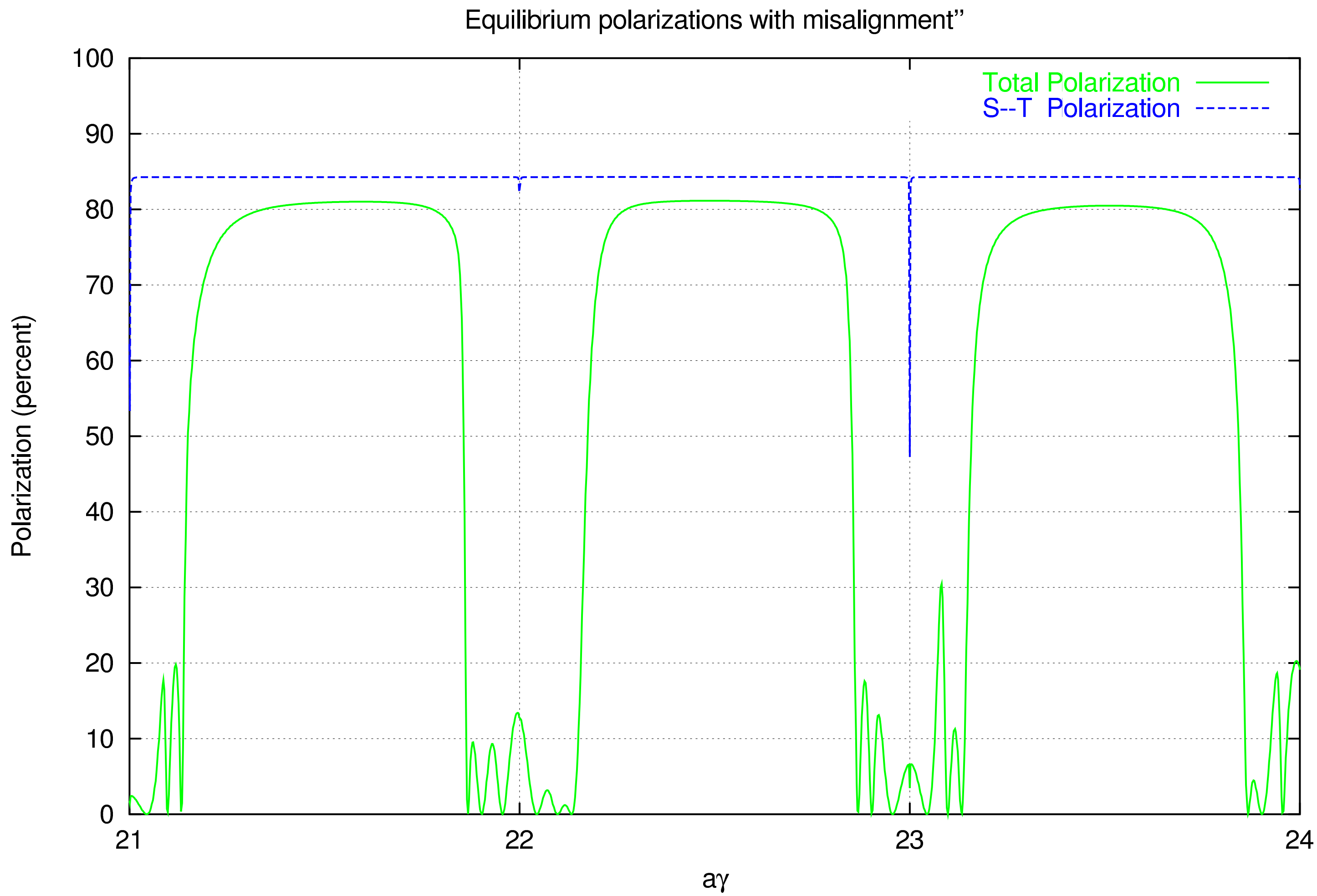
Calibrating the M-C software structure against SLICK



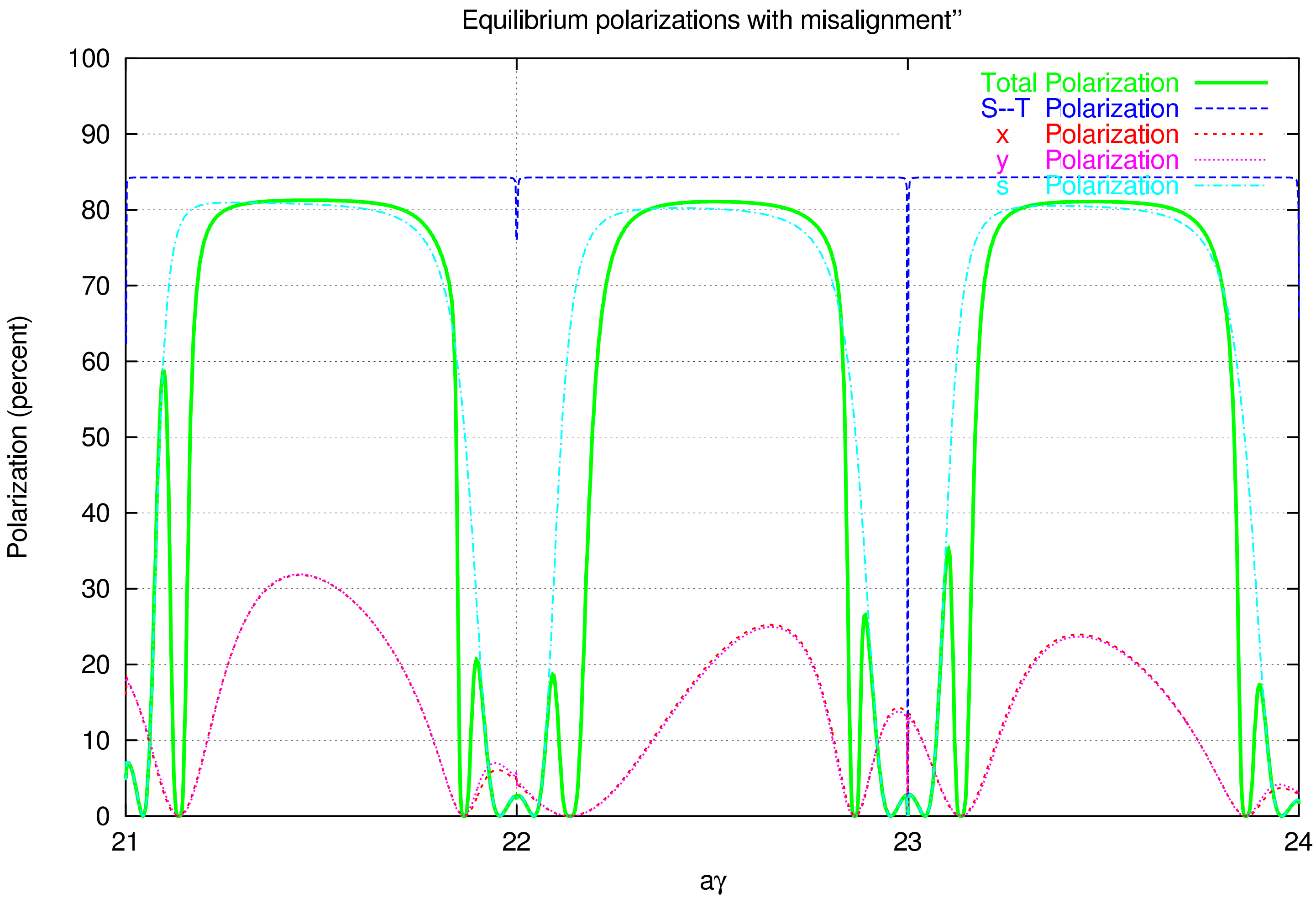
Calibrating the M-C software structure against SLICK



All monitors on and about half of the “b–b”



All monitors on, no “b–b”, near coupling resonance



Summary

- First order calculations OK. Attention to alignment, monitoring and correction.
- Initial indications that beam-beam is not too troublesome.

Next steps

- M-C spin diffusion simulations (in progress) – best way to get at higher order resonances.
- Generation of thick beams with polarisation.
- Include effects of detector fields.

We have longitudinal polarisation e^+ at 3 IPs in HERA at $3\times$ higher energy!