Electron Ring Polarization

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Plan

- Phenomenology: Self polarisation/depolarisation – a reminder
- Spin rotators and spin matching
- Calculations at first order in spin: $\longrightarrow$ SLICK.
- Thick beams.
- Calculations with 3–D spin motion $\longrightarrow$ SLICKTRACK.
- Summary and plans.

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:

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

  ===> Trouble at high energy!

Spin–orbit resonances

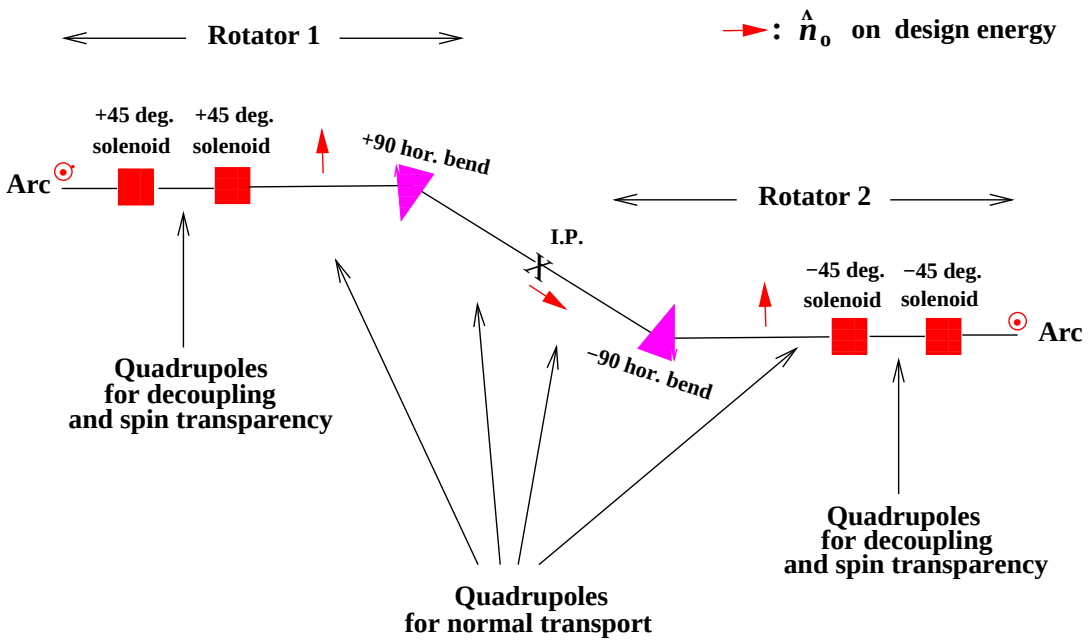
$$\nu_{\rm spin} \;=\; k + k_I\nu_I + k_{II}\nu_{II} + k_{III}\nu_{III}$$

$\nu_{\rm spin}$: 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

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

The solenoid spin rotators



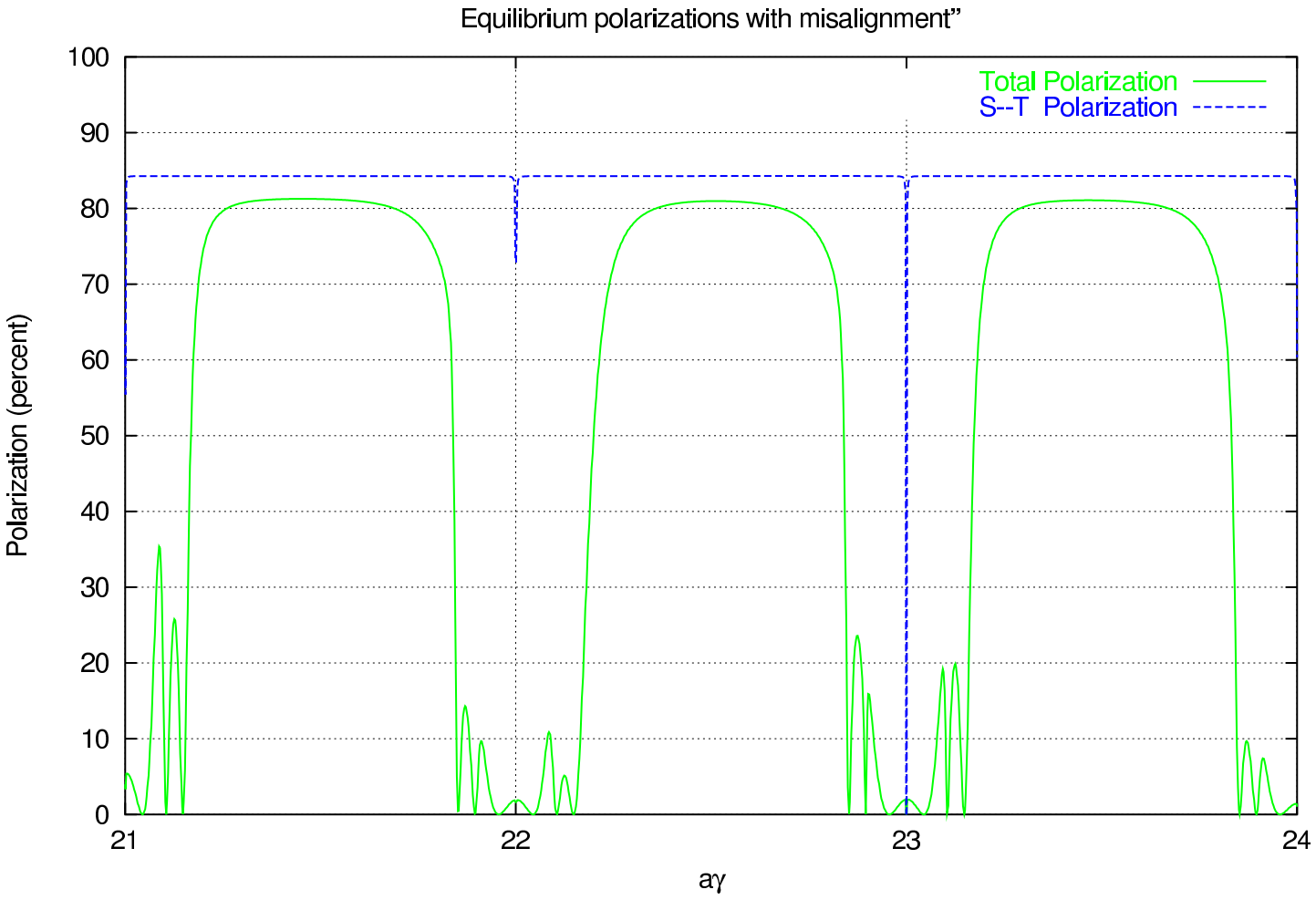
The 4×4 transfer matrix for the transverse motion through a pair of solenoids:

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

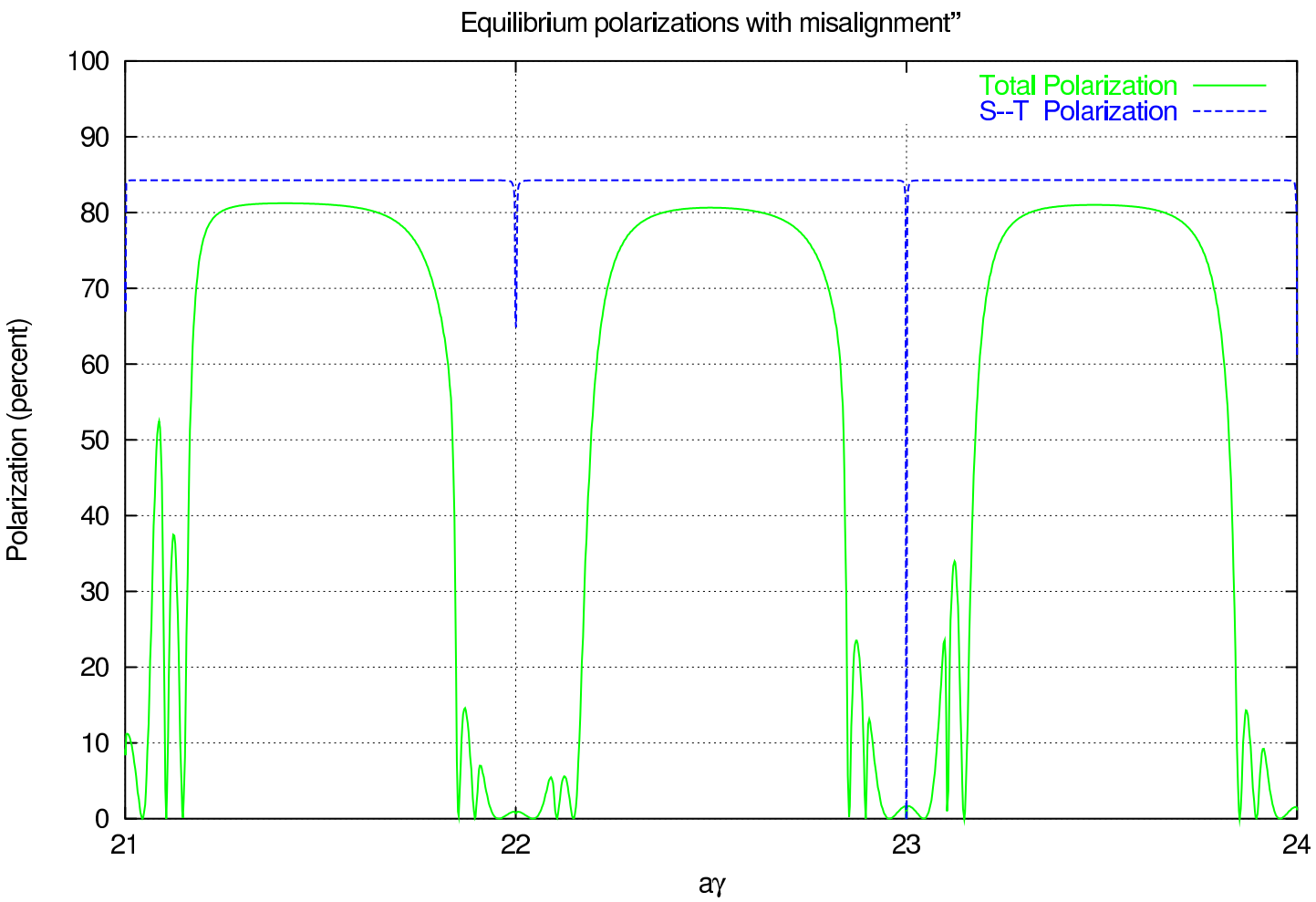
where r is the radius of orbit curvature in the longitudinal field.

Use 5 back–to–back symmetric quadrupoles.

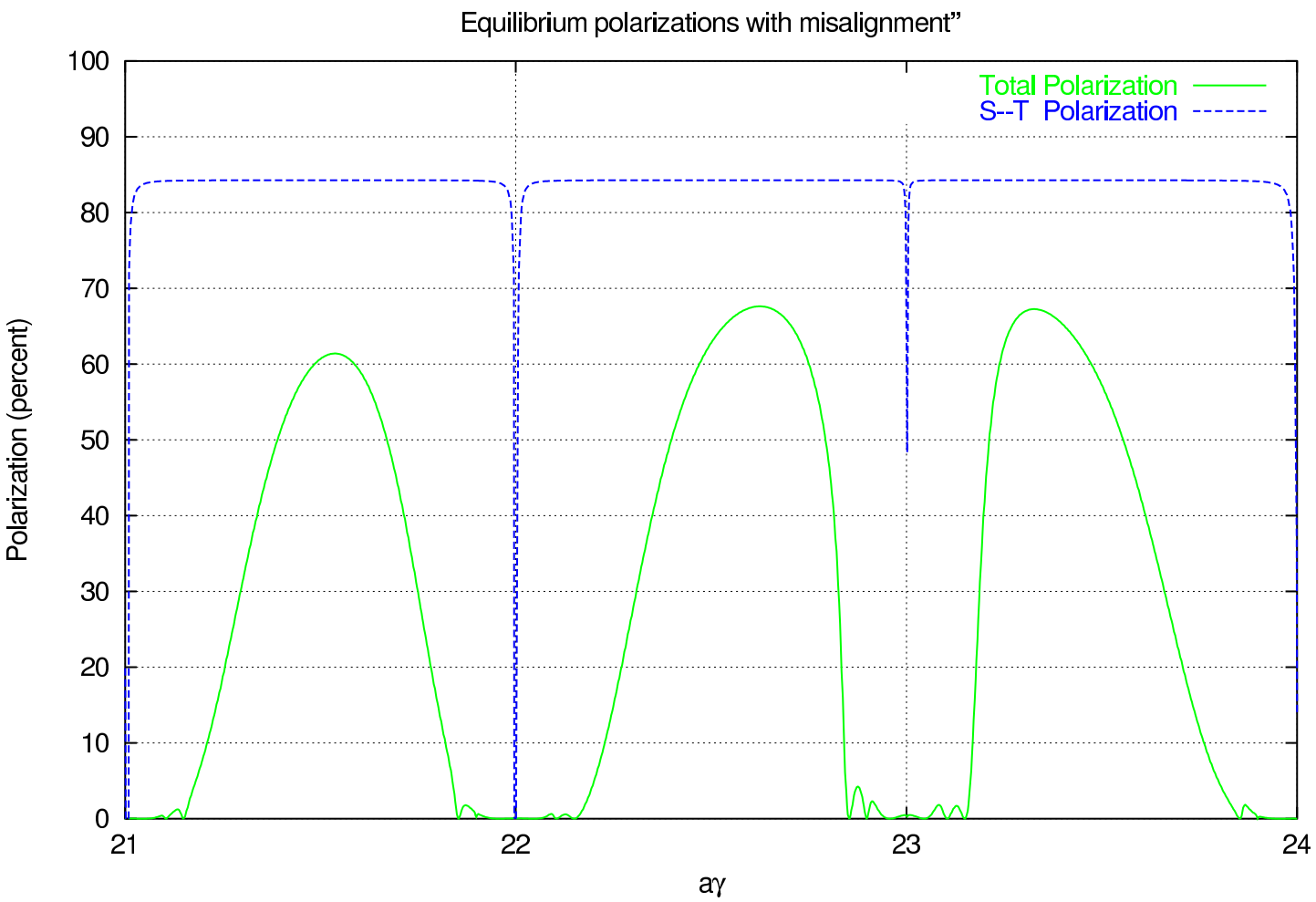
All monitors on

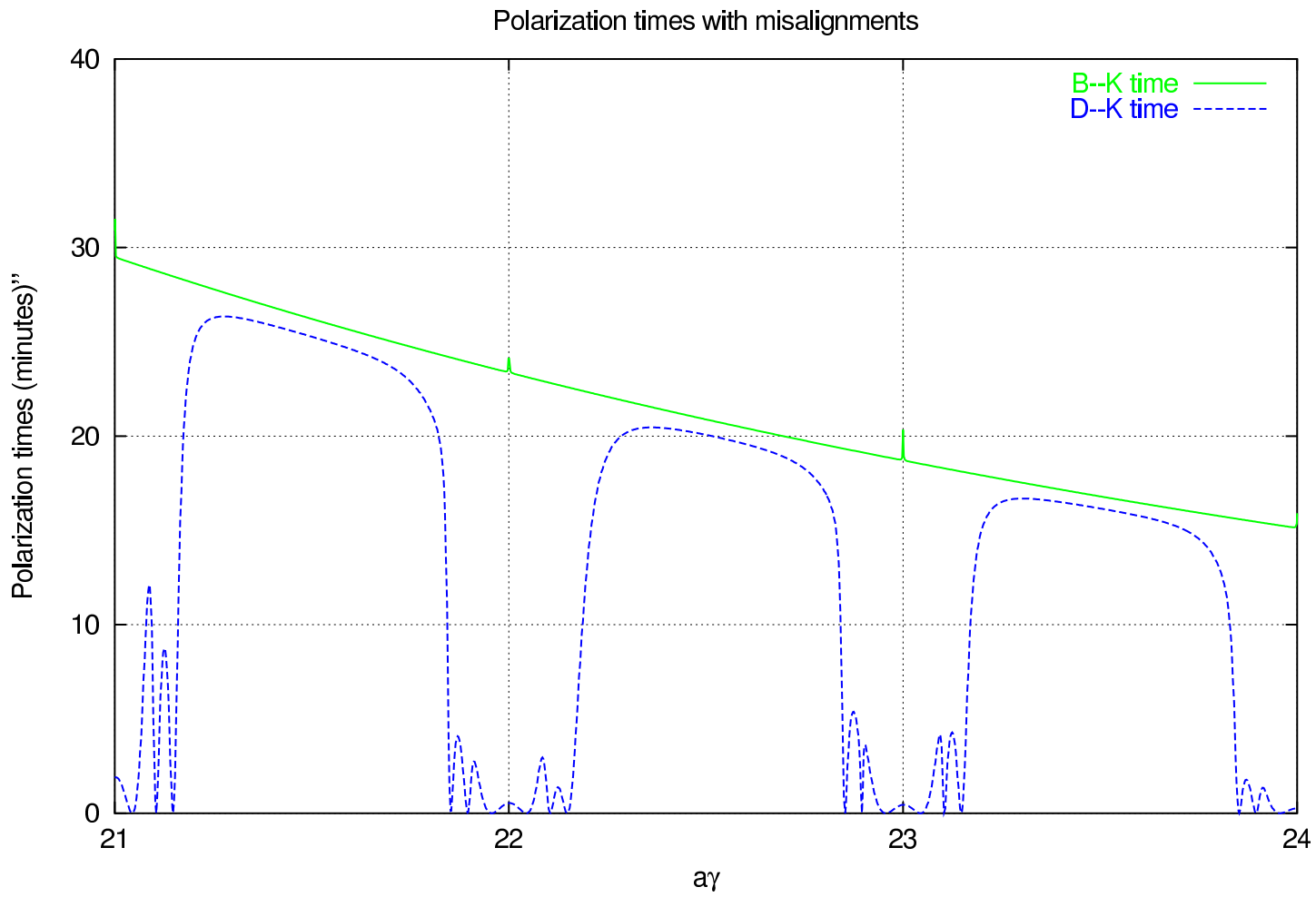


80 percent monitors on

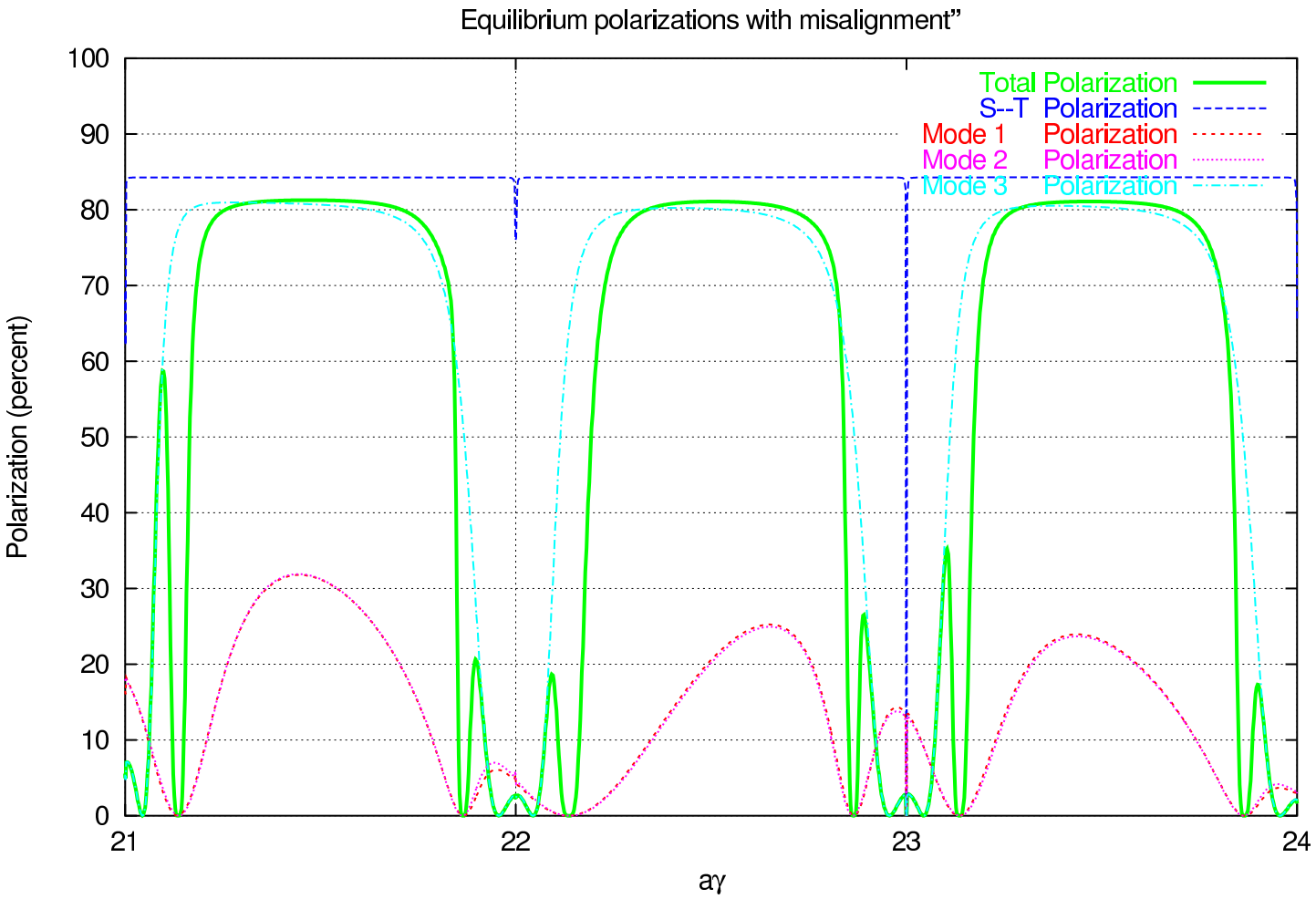


20 percent monitors on

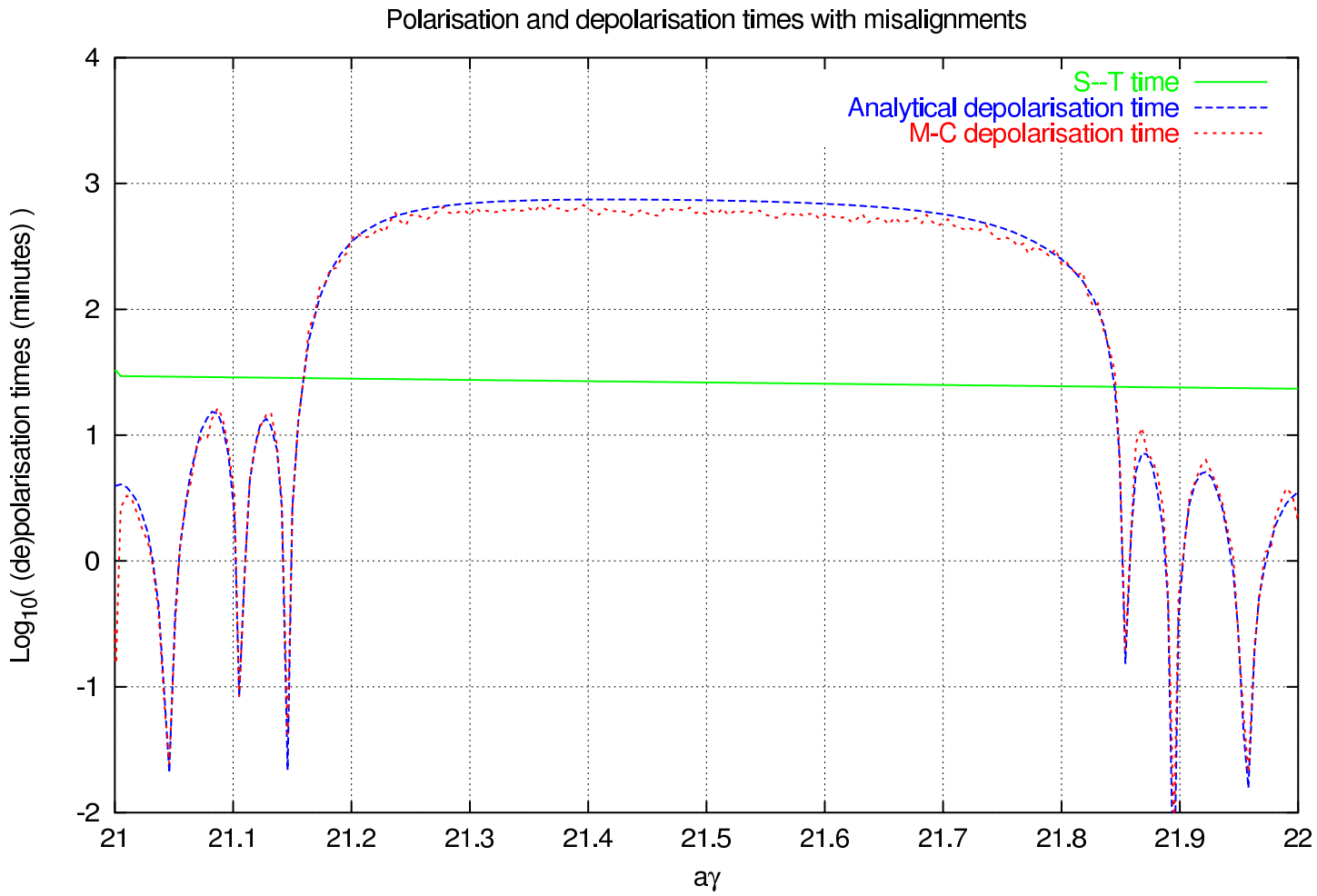



Polarization times with misalignments
B--K time
D--K time
Polarization times (minutes)"
40
30
20
10
0
21
22
23
24
aγ

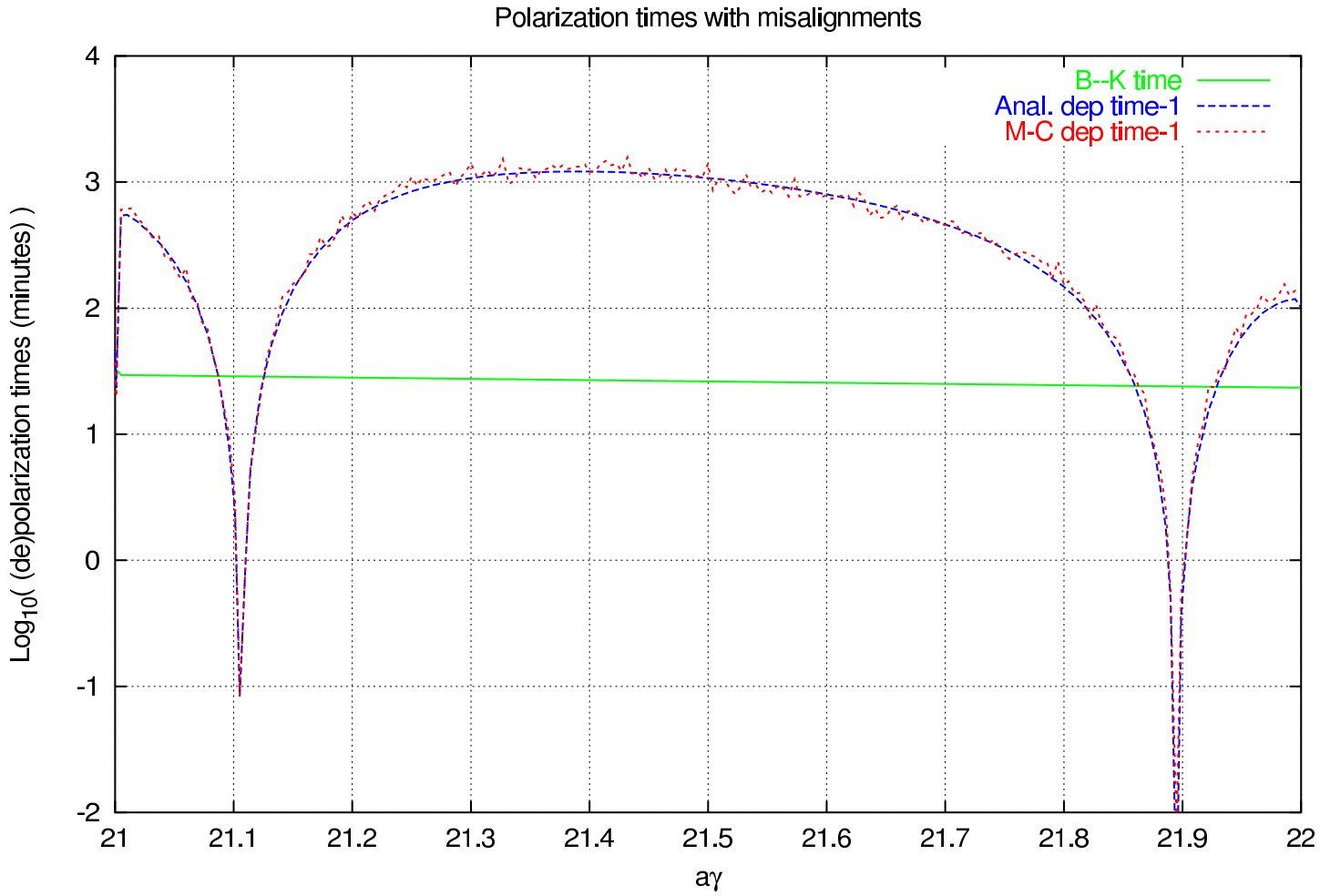
All monitors on, near coupling resonance



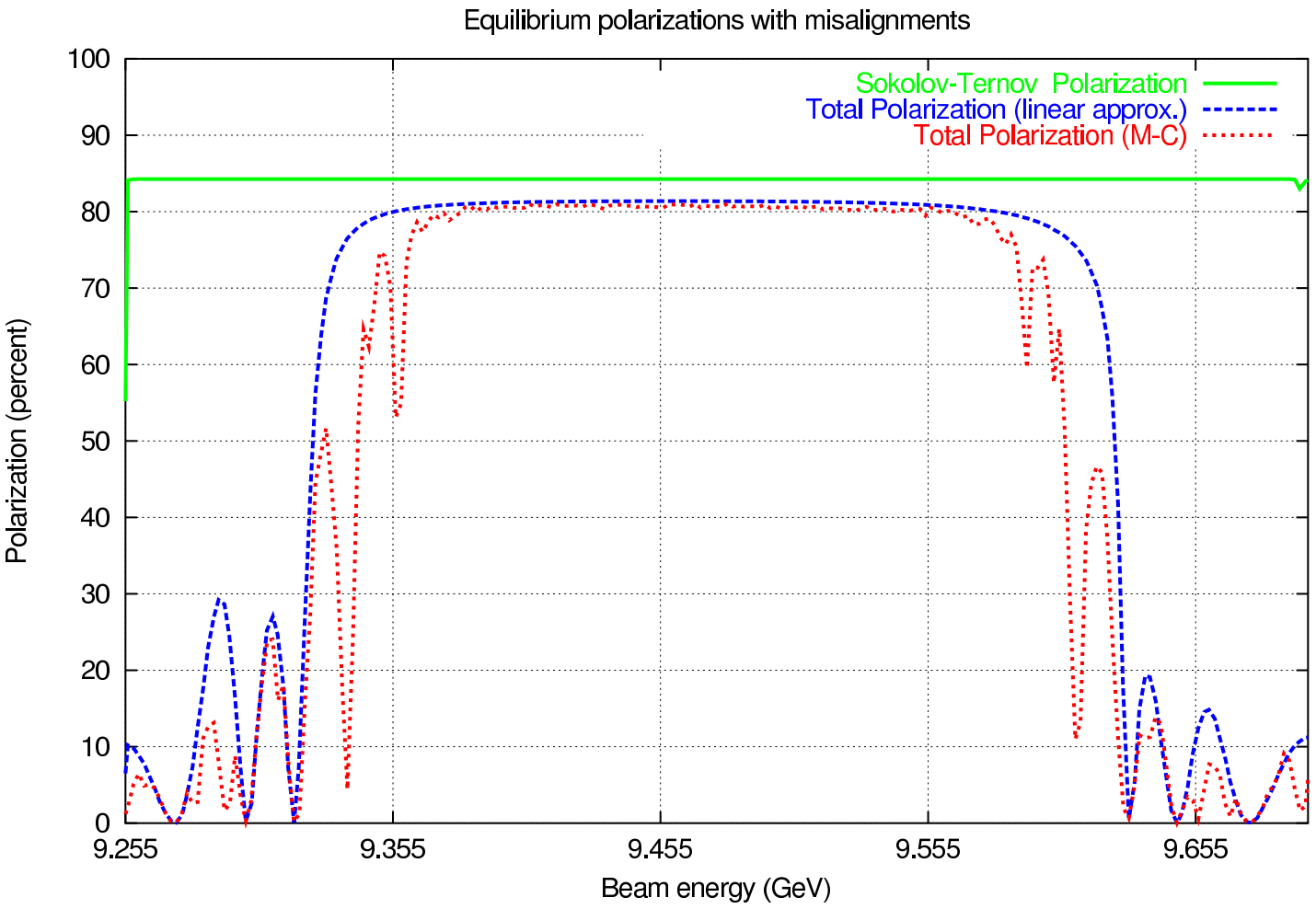
Calibrating the (first order) M-C software structure against SLICK



Calibrating (first order) the M-C software structure against SLICK



Full 3–D spin motion



Summary so far

- First order calculations OK. Attention to alignment, monitoring and correction.
- New M-C code, SLICKTRACK, for HERA and eRHIC and damping rings etc., up and running and making sense.
- Then, initial indications that thick beams are OK at higher order.

Plans

- SLICKTRACK $\Longleftrightarrow$ HERA!!
- $\Longrightarrow$ Careful study of the effects of beam–beam forces $\Longrightarrow$ eRHIC.
- Include effects of detector fields.
- Apply SLICKTRACK to pre-accelerators.

We have longitudinal $e^{\pm}$ polarisation at 3 IPs in HERA at 3$\times$ higher energy and with non-optimal C.O. control for spin!