

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? \implies

Stochastic/damped orbital motion due to synchrotron radiation

+ inhomogeneous fields

+ spin-orbit coupling via T-BMT

\implies spin diffusion i.e. depolarisation!!!

Self polarisation: Balance of poln. and depoln. \implies

$$P_{\infty} \approx P_{BK} \frac{1}{1 + \left(\frac{\tau_{dep}}{\tau_{BK}}\right)^{-1}} \quad (P_{ST} \rightarrow P_{BK})$$

In any case:

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

\implies Trouble at high energy!

Spin-orbit resonances

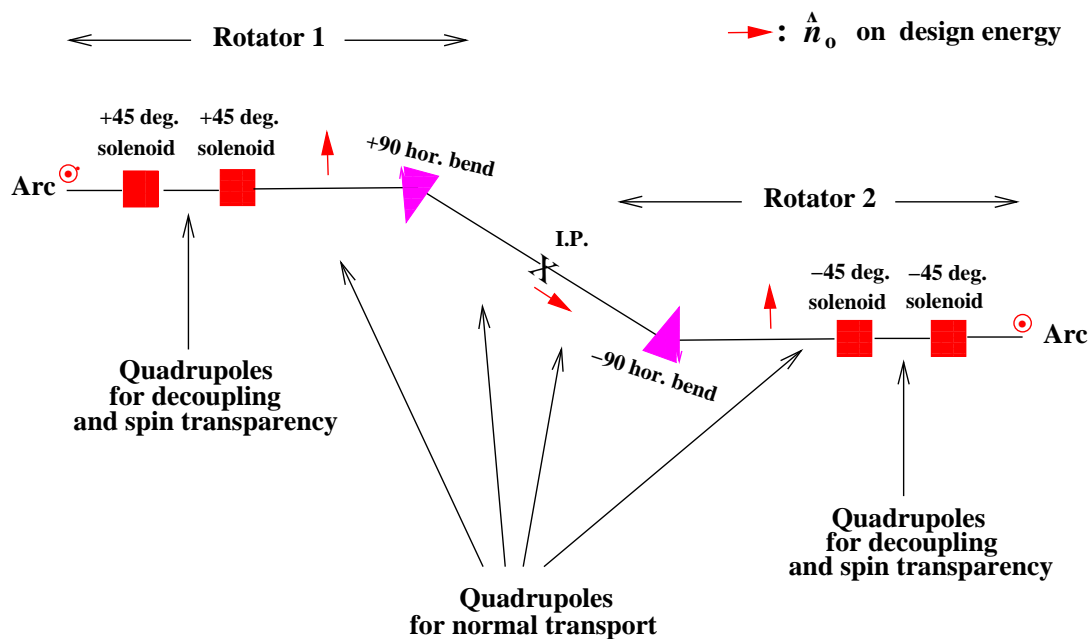
$$\nu_{\text{spin}} = k + k_I \nu_I + k_{II} \nu_{II} + k_{III} \nu_{III}$$

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

- Orbit “drives spins” \implies 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



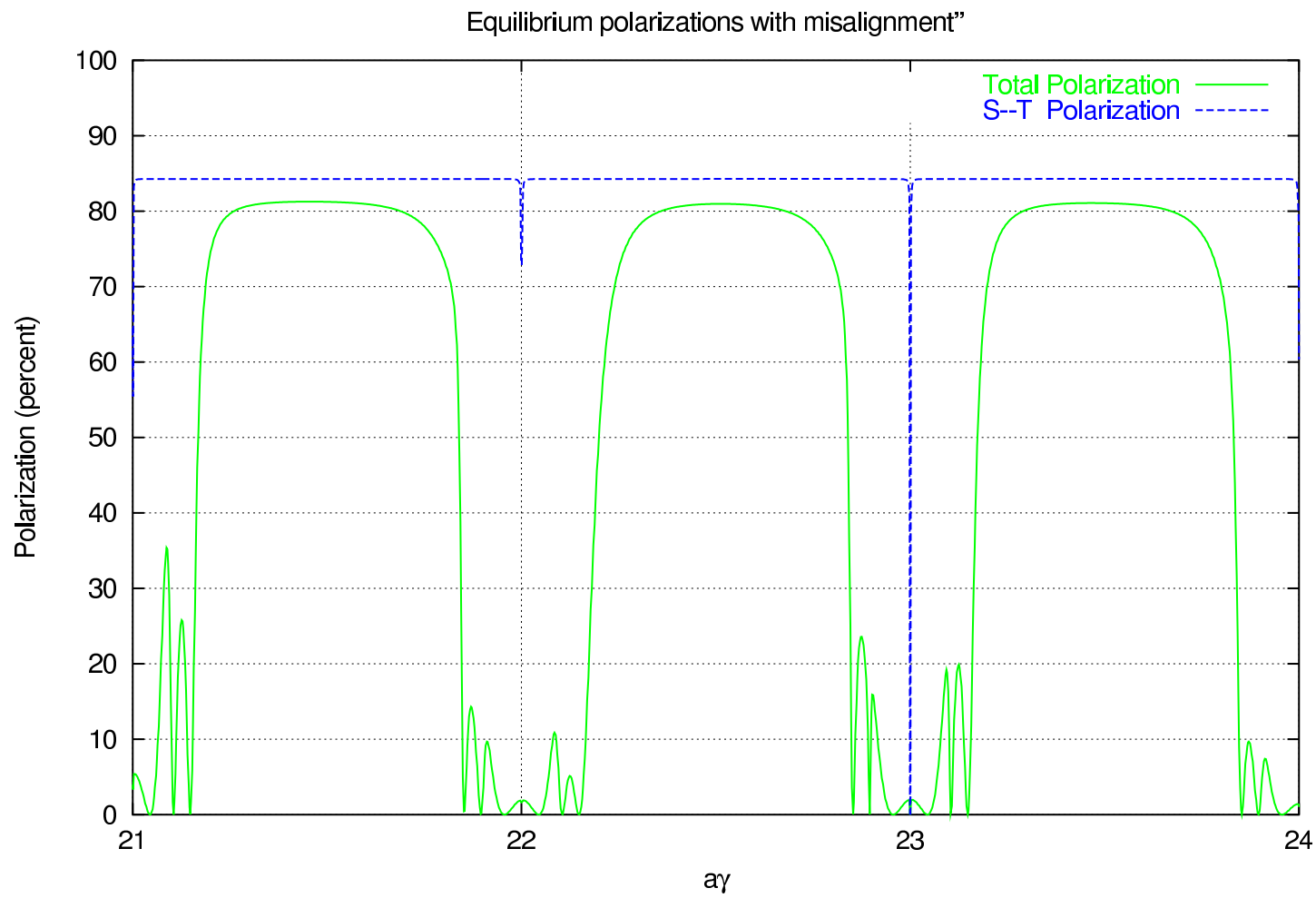
The 4×4 transfer matrix for the transverse motion through a pair of solenoids:

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

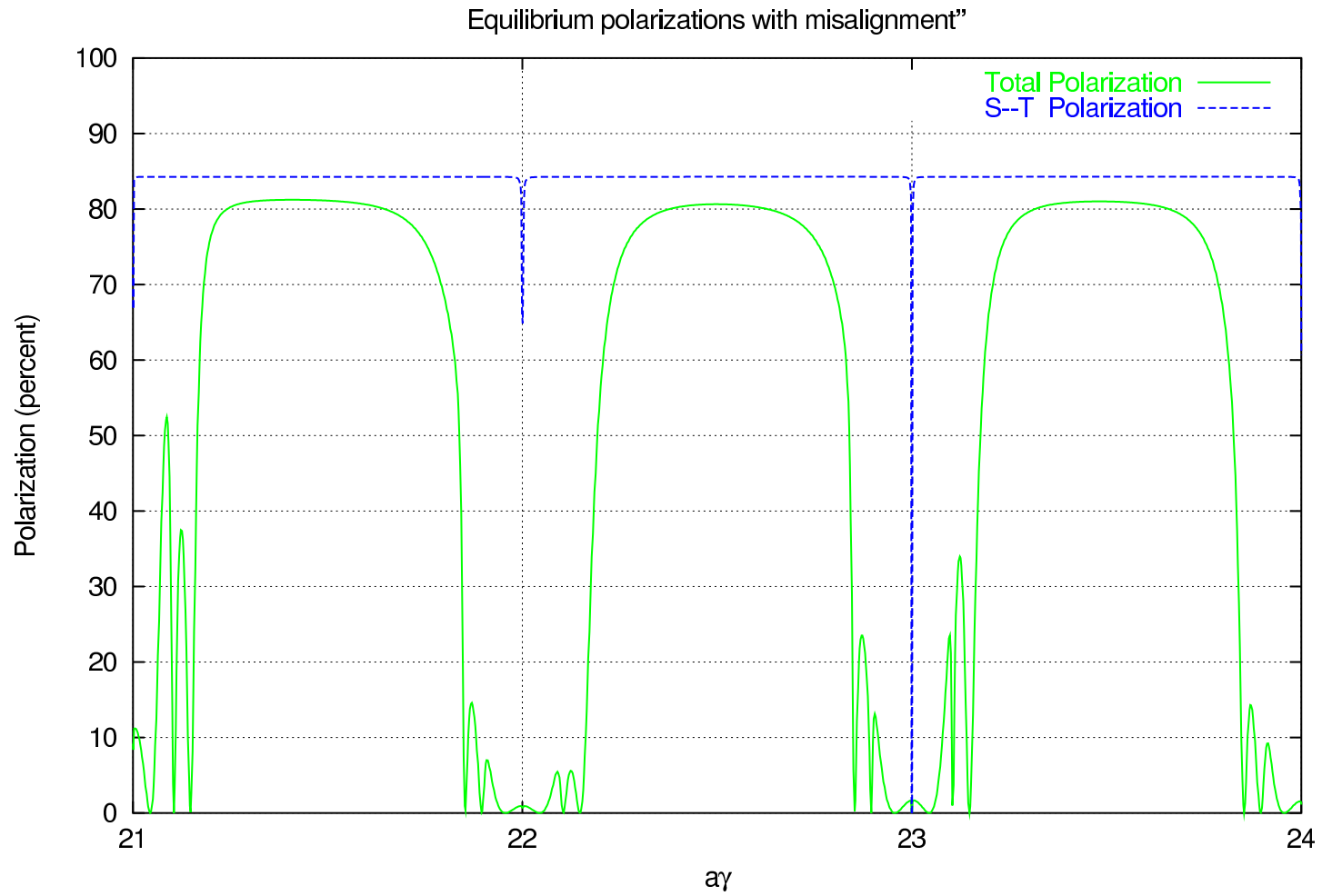
where r is the radius of orbit curvature in the longitudinal field.

Use 5 back-to-back symmetric quadrupoles.

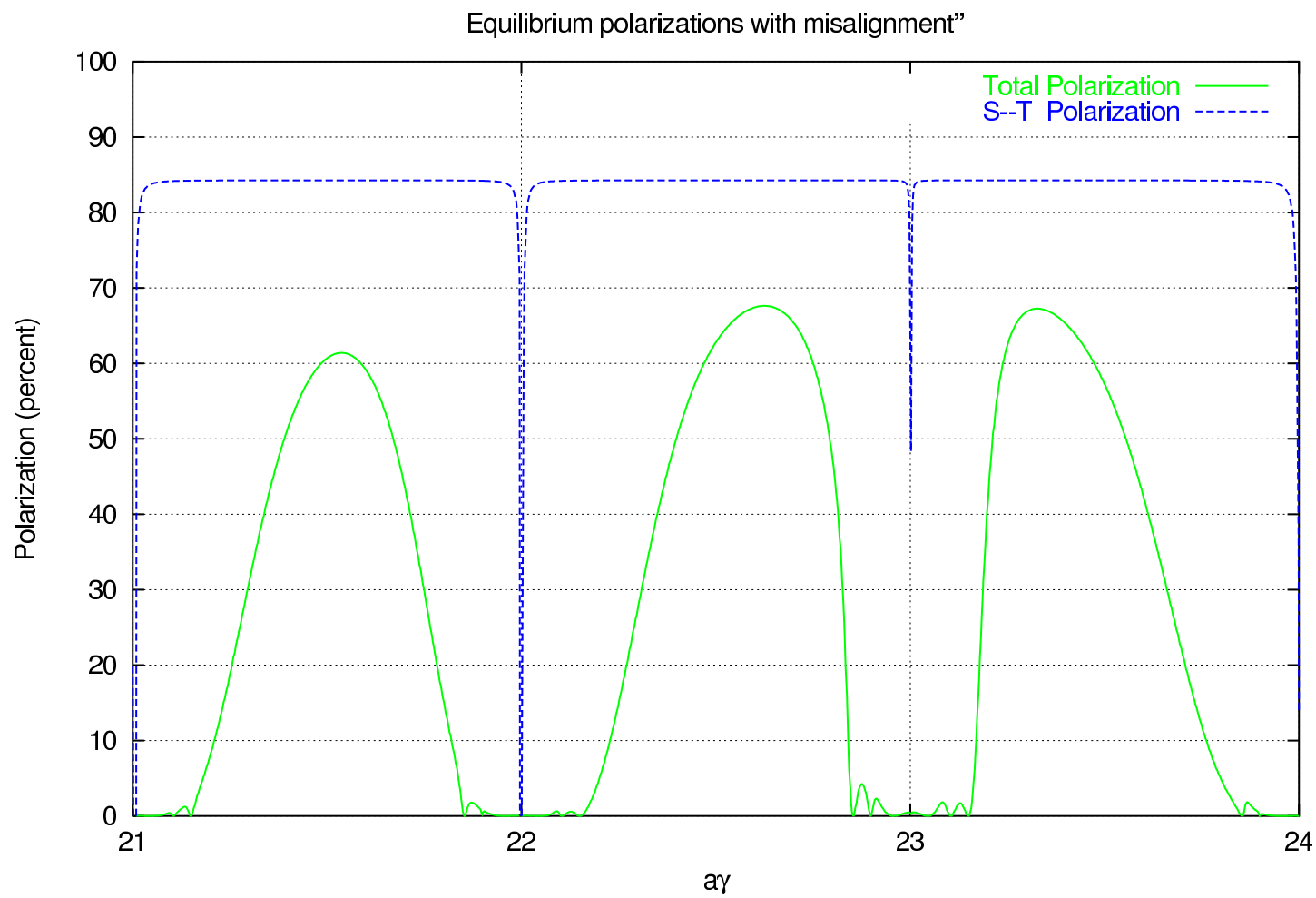
All monitors on

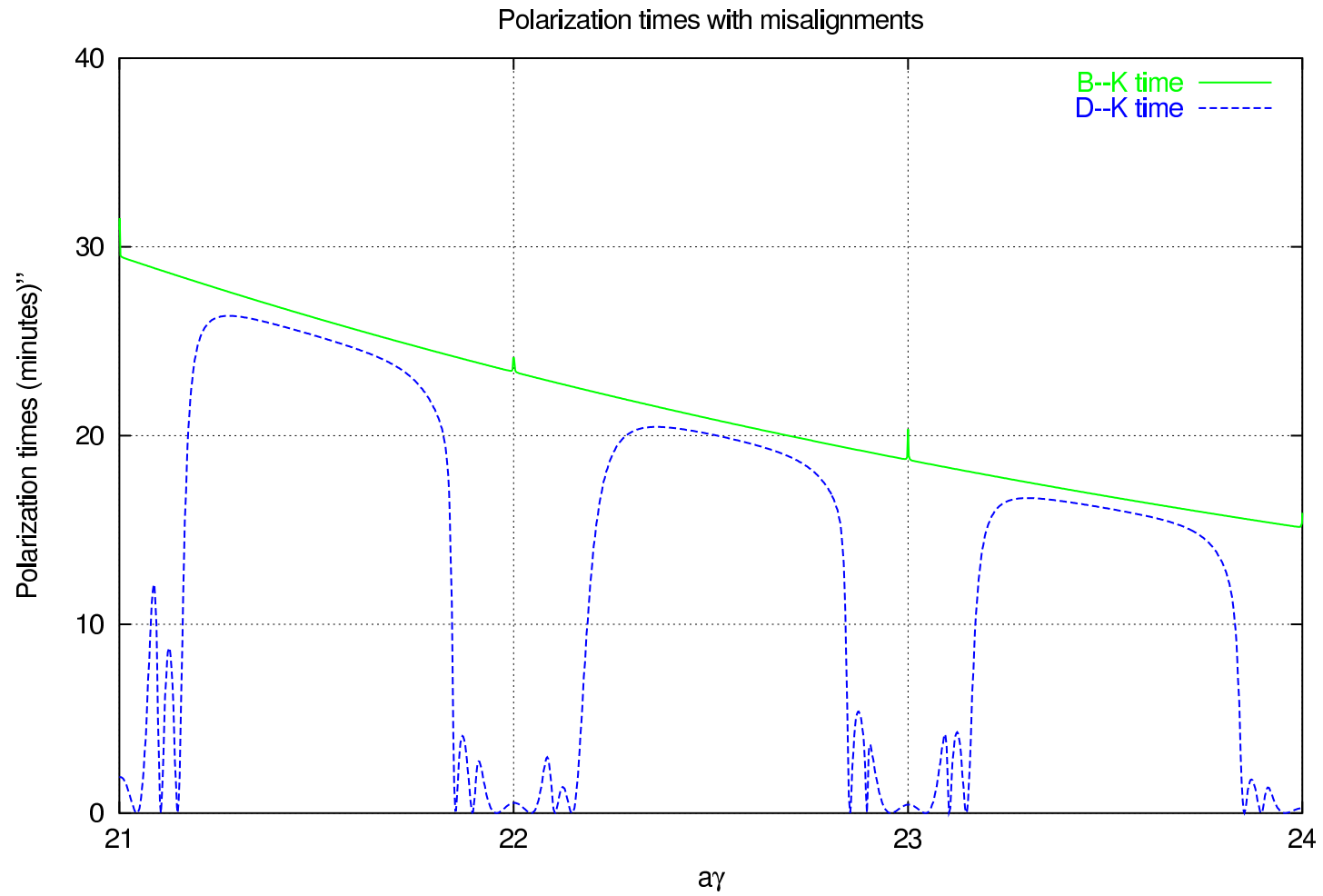


80 percent monitors on

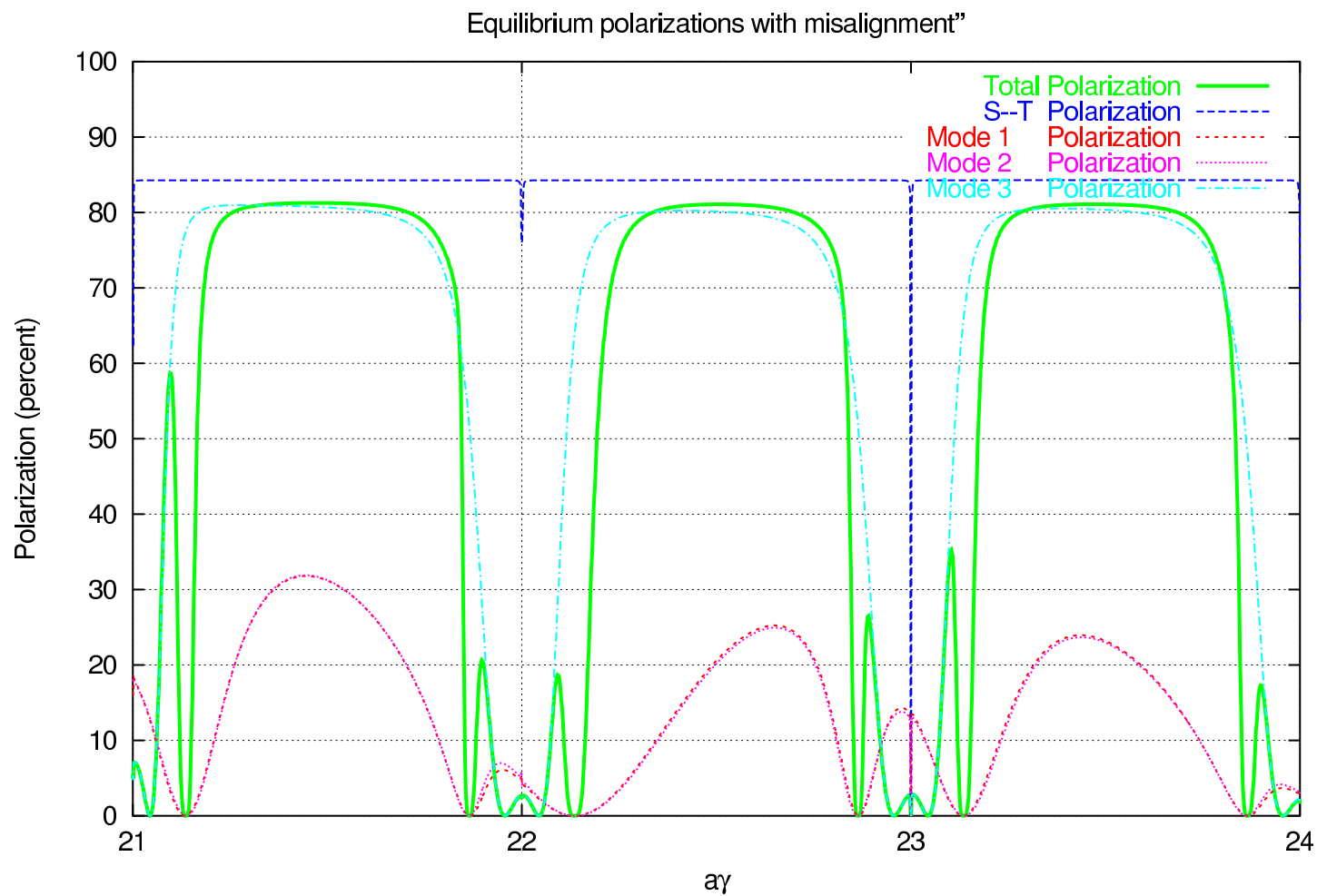


20 percent monitors on

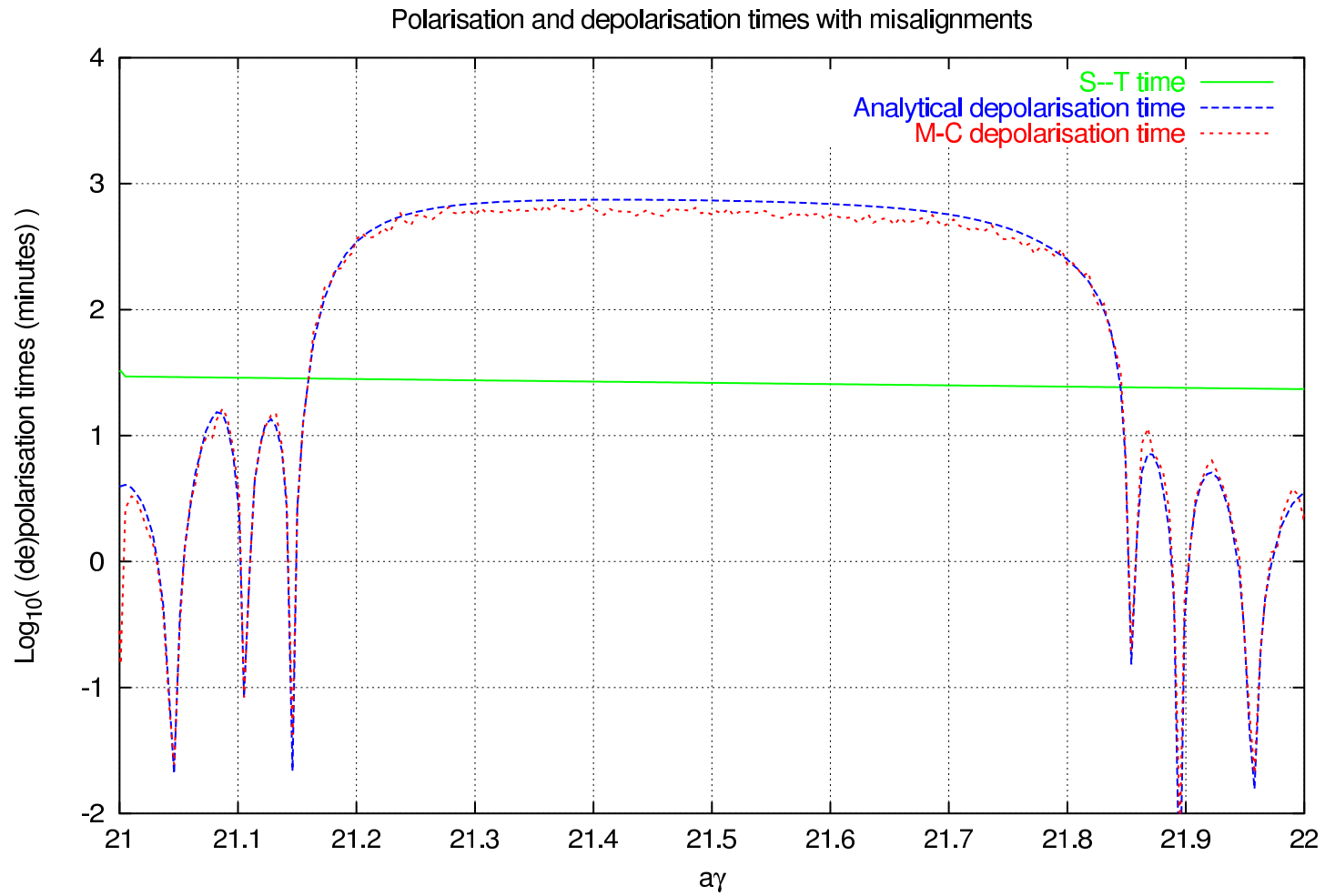




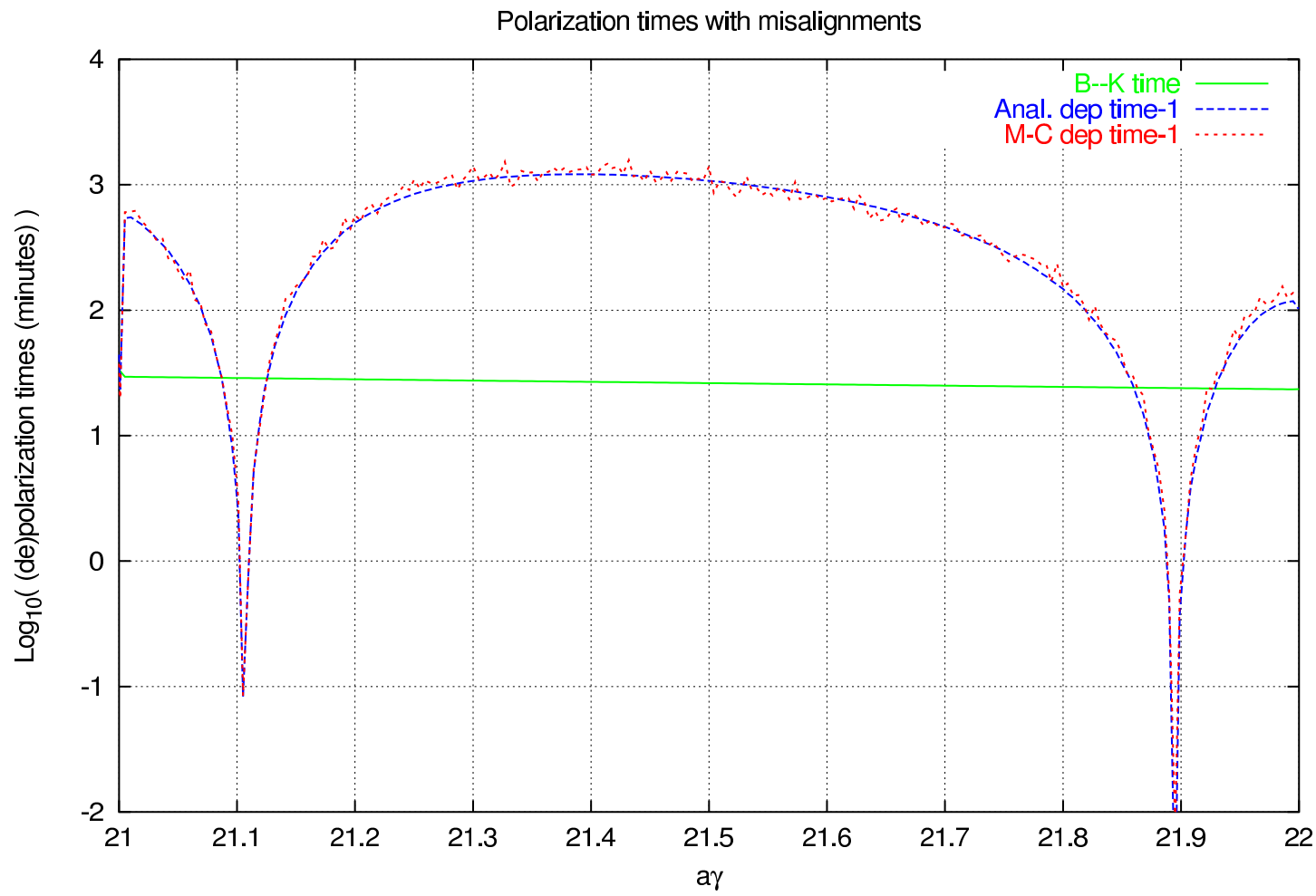
All monitors on, near coupling resonance



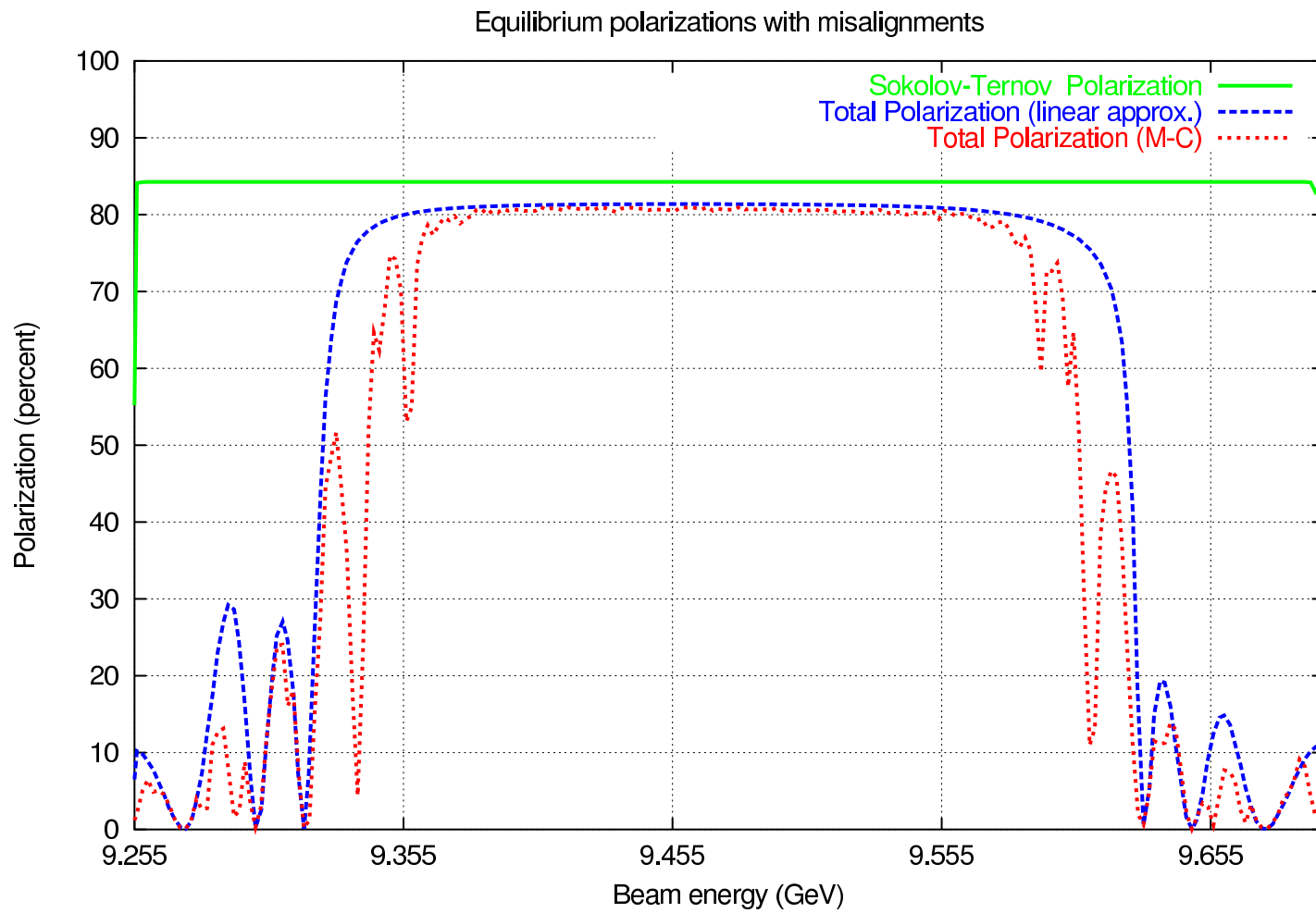
Calibrating the (first order) M-C software structure against SLICK



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 \iff HERA!!
- \implies Careful study of the effects of beam-beam forces \implies 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!