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Depolarisation Effects at the ILC

Cockcroft Institute

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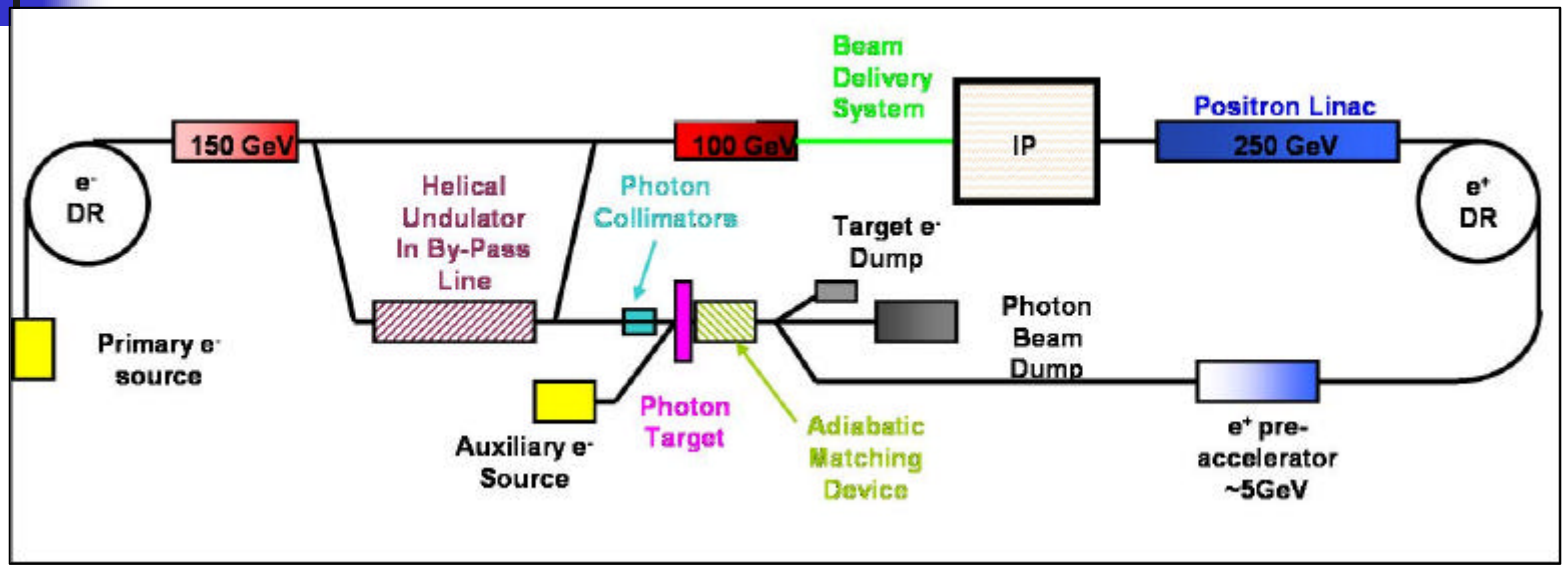
Introduction

- International Linear Collider (ILC)----new life of an old idea.
- A high intensity polarised e^+ beam is essential for realising the total physics potential of the ILC (*http://www.ippp.dur.ac.uk/~gudrid/source/ to be published in Phys. Rep.)*
- Delivery of the beam polarisation to the interaction region must be robust and without loss of intensity
- Reliable software tools are required to optimise the machine for polarisation as well as luminosity

ILC layout (undulator positron source)



polarised

e-/(e+) beam →Depolarisation? →Depolarisation?? → ????

Misalignments, Synchrotron radiation, Spin precession, Resonances, bunch- bunch effects ...

Spin behaviour in guide fields

SPIN PRECESSION (THOMAS-BARGMANN-MICHEL-TELEGDI)

$$\frac{d\vec{S}}{ds} = \vec{\Omega} \times \vec{S}, \text{ where } \vec{\Omega}(\vec{E}, \vec{B}, g, \vec{v}) \Rightarrow dq_{spin} \propto \frac{(g-2)}{2} g dq_{orbit}$$

Synchrotron Radiation $\Rightarrow$ SPIN DIFFUSION

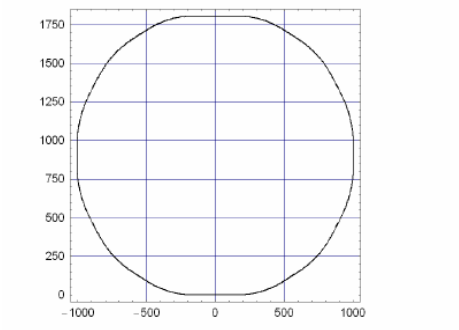
$$\vec{S} = \sqrt{1-a^2-b^2}\,\hat{n}_0(s) + a\,\hat{m}(s) + b\,\hat{l}(s)$$

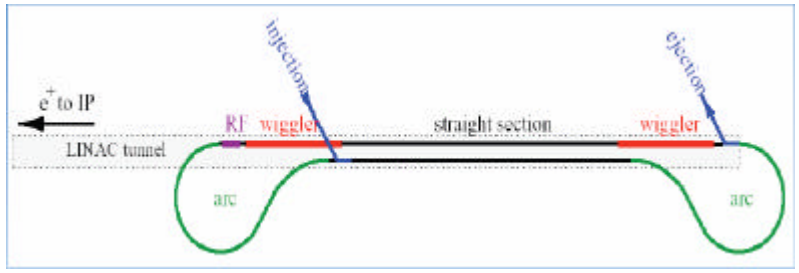
$$\vec{P} = \left\langle \vec{S} \right\rangle_{bunch}$$

$$\frac{dP}{dt} \approx -\frac{1}{2}\frac{d}{dt}\left\langle a^2 + b^2 \right\rangle = -\frac{1}{2}\frac{d}{dt}(s^2{}_a + s^2{}_b)$$

Damping rings for the ILC

- In ideal Damping Ring depolarising effects are expected to be negligible
- Enhancement of synchrotron radiation (wigglers) might lead to the depolarisation effects
- Two out of seven reference lattices were selected: OCS 6km (circle) and TESLA 17 km (dogbone)





DAMPING RING

- damping time (msec)
- S –T effect negligible
- No equilibrium polarisation

  (evolution of spin distribution over a few damping times)
- MERLIN and SLICKTRACK

STORAGE RING

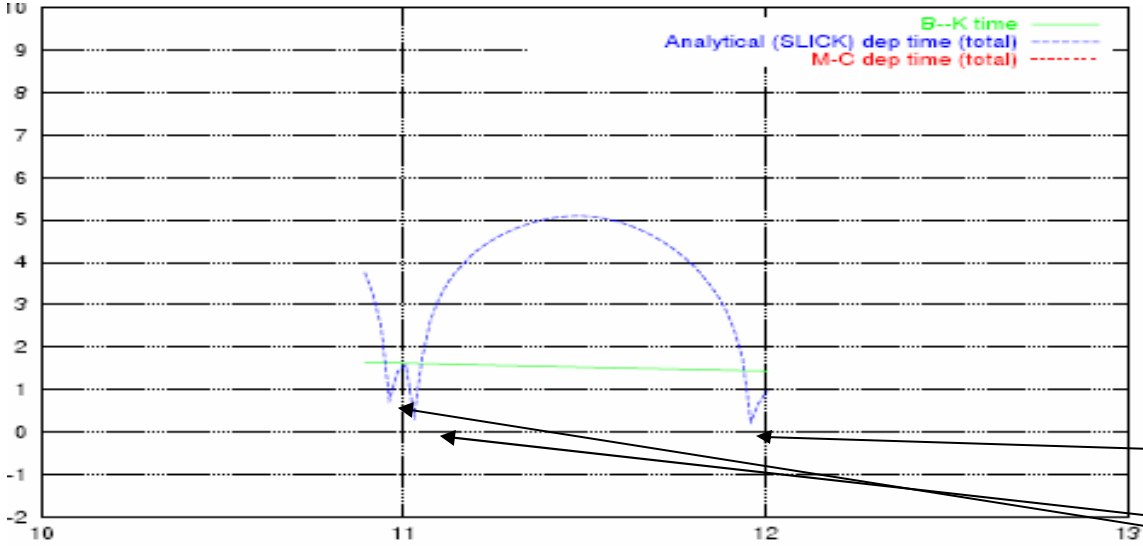
- storage time (hours)
- S –T effect significant
- Equilibrium polarisation (depolarisation rate can be "measured")
- More then 10 different codes available (Handbook of Accelerator Physics and Engineering)

Computer Simulation

- Misalignments were introduced
- STEP 1 (SLICK): linearised orbital and spin motion. Reference point as well as an energy scan
- STEP 2 (SLICKTRACK): Monte-Carlo simulation of the effects of synchrotron radiation, i.e. evolution of the spin distribution over a few damping times including full 3-D spin motion
- NO significant depolarising effects have been detected confirming the earlier works

Spin-orbit resonances

- Spin tune on the closed orbit : $n_{spin} = ag_0$
- First order resonances:



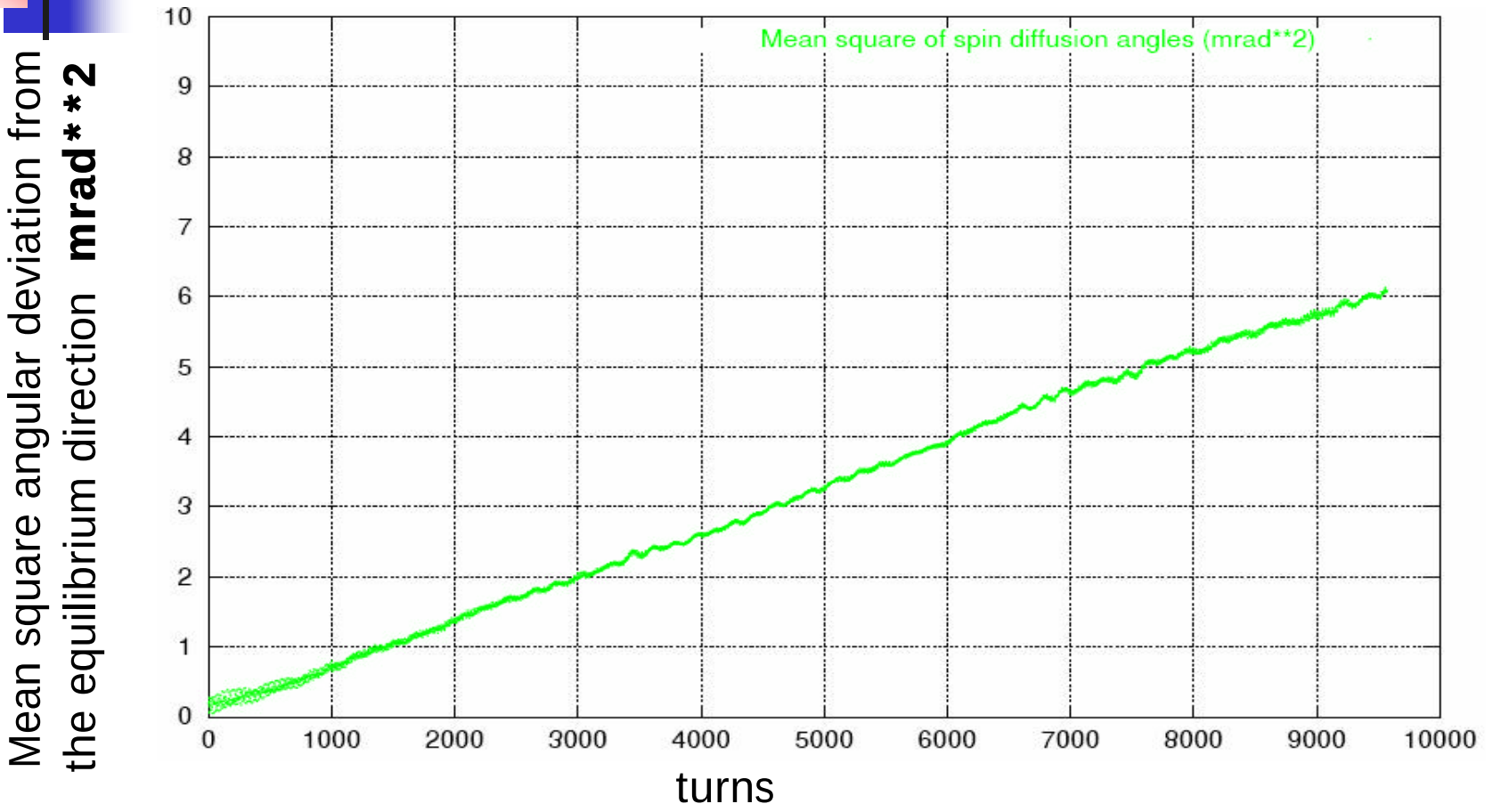
$$n_{spin} = k \pm Q_x$$

$$n_{spin} = k \pm Q_y$$

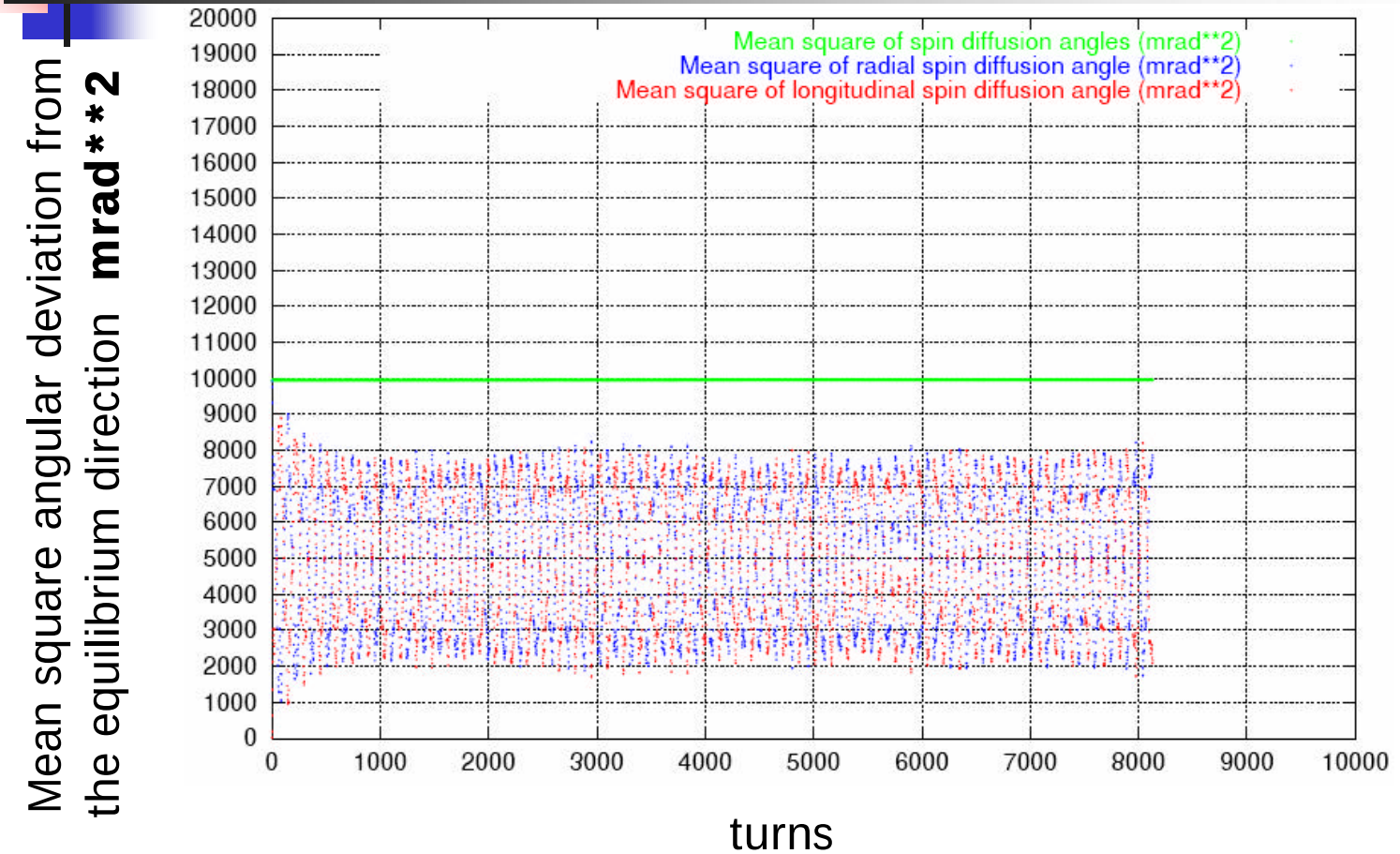
$$n_{spin} = k \pm Q_s$$

OCS ring depolarisation time with misalignments

OCS Spin Diffusion at 4.8 GeV

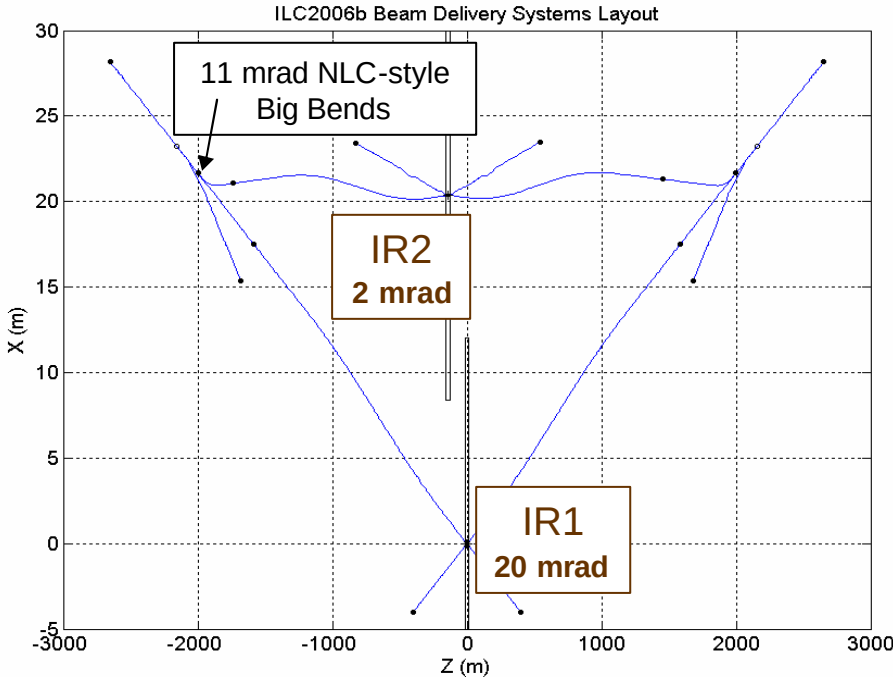


OCS Spin Diffusion at 5.066GeV for spins initially at 100 mrad from $\hat{n}_0$



Beam Delivery System (BDS)

- Beam transport to the Interaction Region via bending and focusing magnets.
- The 2-mrad beam line selected (spin precession $\approx 332^0$)
- SLICKTRACK
- NO noticeable depolarisation (even with misalignments)



Copy from BDS ILC@SLAC presentation

Beam-Beam Interactions

- **CAIN bunch-bunch depolarisation: survey of theoretical uncertainties complete.**
- **Studies of possible ILC beam parameters:**

Parameter set	Depolarization ΔP_{lw}		
	T-BMT	S-T	total
Nominal	0.08%	0.02%	0.10%
low Q	0.04%	0.02%	0.06%
large Y	0.17%	0.02%	0.19%
low P	0.15%	0.09%	0.24%
TESLA	0.11%	0.03%	0.14%

Theoretical work ongoing into

- **Validity of T-BMT equation in strong fields**
- **validity of equivalent photon approximation (EPA) for incoherent pair production processes**
- **higher-order processes**
- **macro-particle dynamics**

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Conclusions

- DR: New lattice design + NEW LAYOUT!! (under discussion) ... we will maintain a rolling study to include extra effects as necessary
- BDS: Include non-linear optics
- Beam-beam effects: CAIN code will be updated and a comparison with code GUINEA-PIG