Robust Spin Polarisation Status

Helical Collaboration

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Introduction

- Aims
- Depolarisation
- Software
- Damping Ring
- Linac simulation
- Beam delivery system simulation
- Beam-beam interaction
- What we have done
- What we will do next

Aims

- **Develop reliable software tools that allow the ILC to be optimised for spin polarisation as well as luminosity via full cradle-to-grave simulations.**

- **Carry out simulations of depolarisation effects in damping rings, beam delivery system, main linac and during bunch-bunch interactions.**

- **Develop simulations of spin transport through the positron source.**

- **Why? Sensitivity to new physics and enables background reduction**

Collaborating with

T. Hartin (Oxford)
P. Bambade, C. Rimbault (LAL)
J. Smith (Cornell)
S. Riemann, A. Ushakov (DESY)

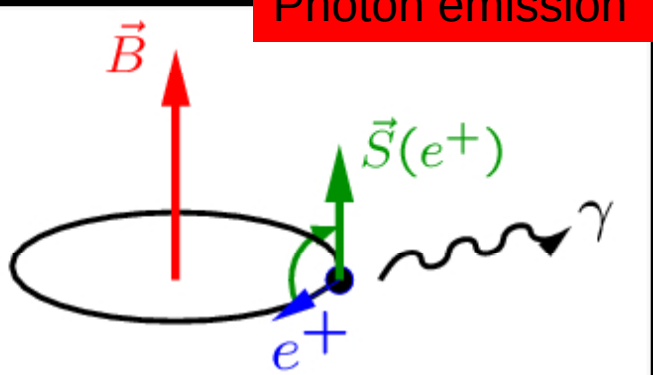
Depolarisation

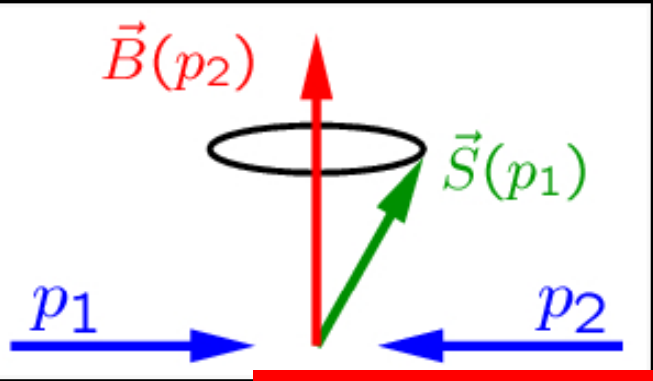
- **The spin state of particles within a bunch can change wrt each other by photon emission or classical spin precession through inhomogeneous magnetic fields**

$$\delta\theta_{spin} \propto \frac{(g-2)}{2}\gamma\delta\theta_{orbit}$$

- **Described by Thomas-Bargmann-Michel-Telegdi equation (TBMT)**
- **Largest depolarisation effects are expected at the Interaction Points**

Photon emission



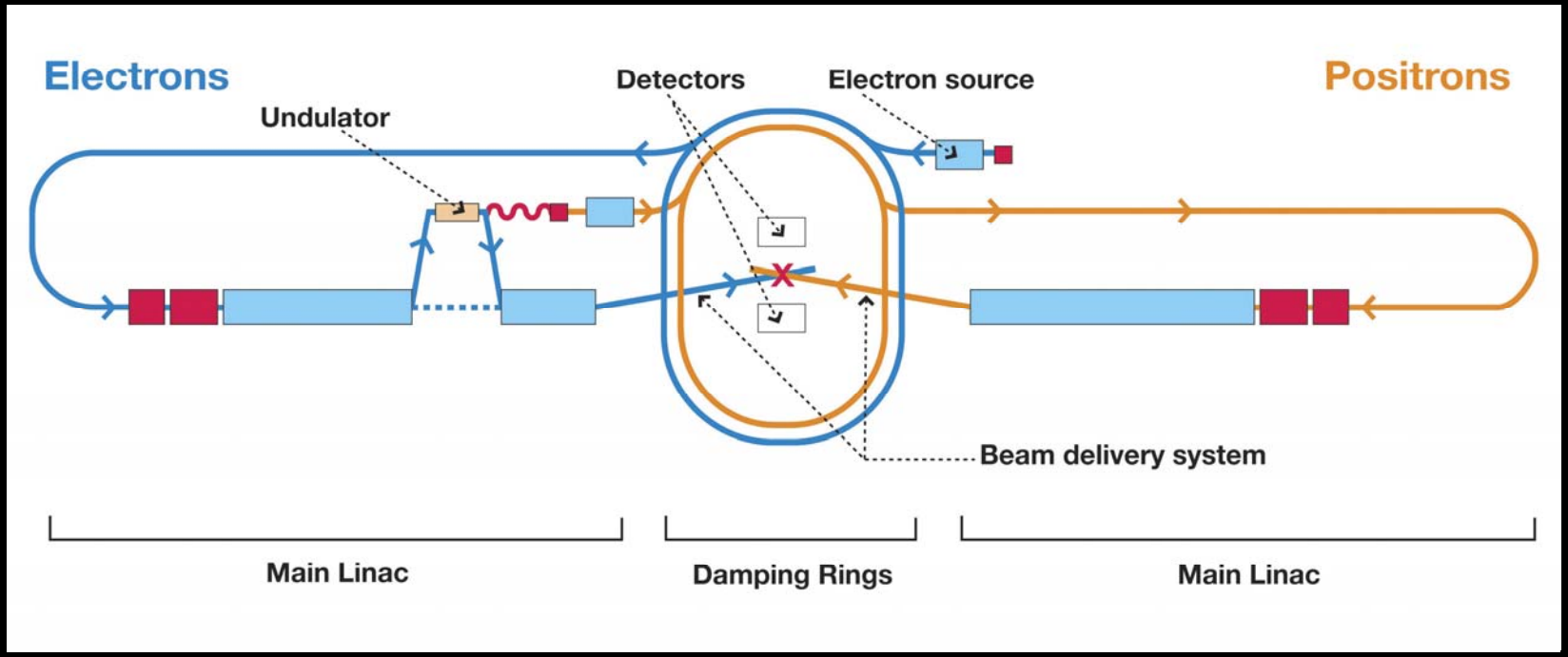


Spin precession

	Undulator	Collimator / Target	Capture Optics
Physics Process	Electrodynamics	Standard Model	T-BMT (spin spread)
Packages	SPECTRA, URGENT	GEANT4, FLUKA	ASTRA

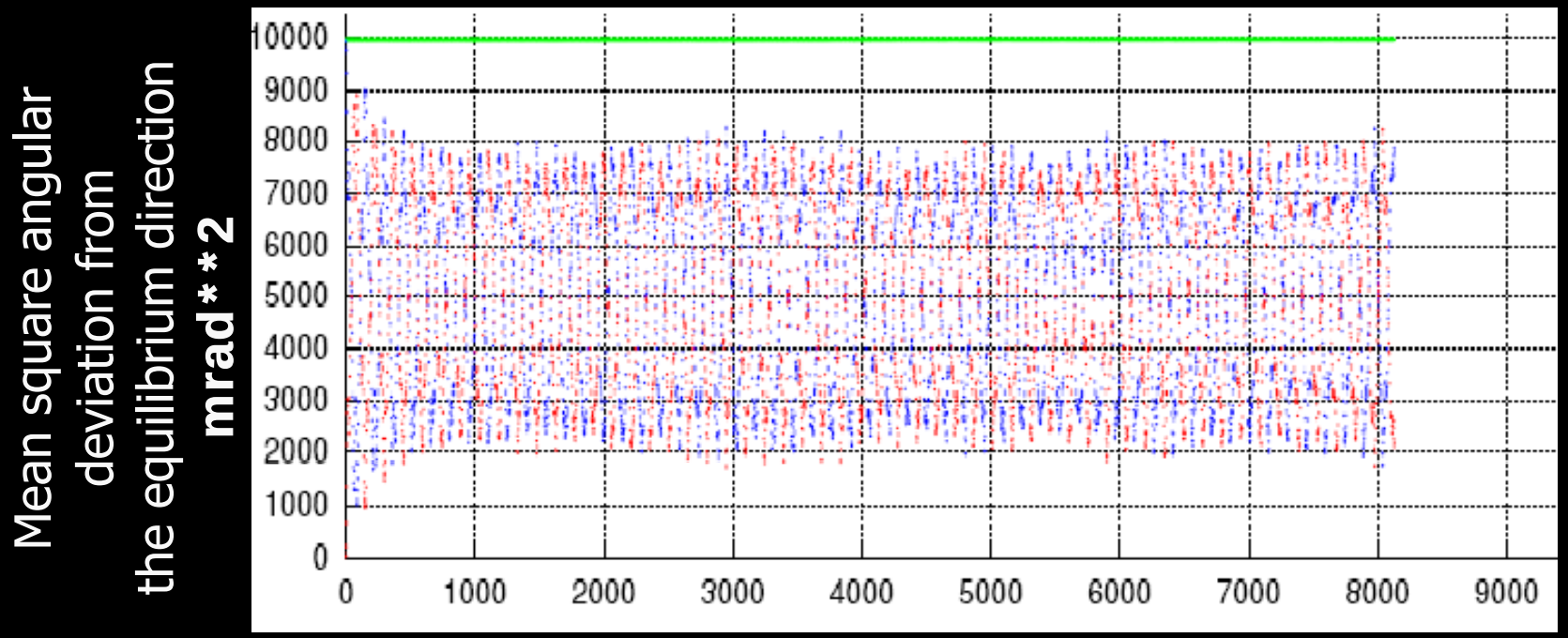
	Damping ring	Main Linac / BDS	Interaction Region
Physics Process	T-BMT (spin diffusion)	T-BMT	Bunch-Bunch
Packages	SLICKTRACK, (Merlin)	SLICKTRACK (Merlin)	CAIN2.35 (Guinea-Pig)

Positron Linac



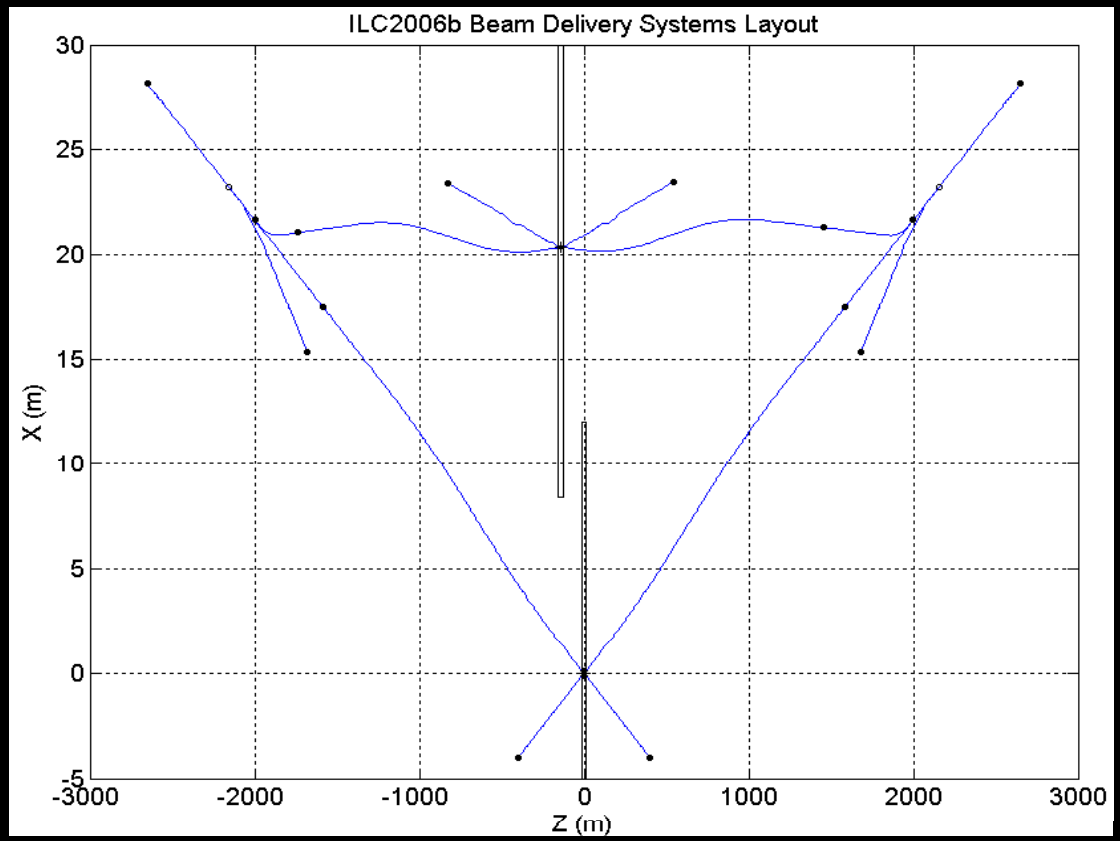
- SLICKTRACK code has been updated to include acceleration
- First results confirms that the loss of polarisation is negligible.
- The spin precesses by approx 26° between injection and BDS due to the earth's curvature
- Further investigation and benchmarking (BMAD, Jeff Smith, ILC-NOTE-2007-012).

Positron Damping Ring



- Polarisation loss at 5.066 GeV in the damping ring
- After many turns, the spin is not diverging
- See talk by Larissa Malasheva !

Beam Delivery System



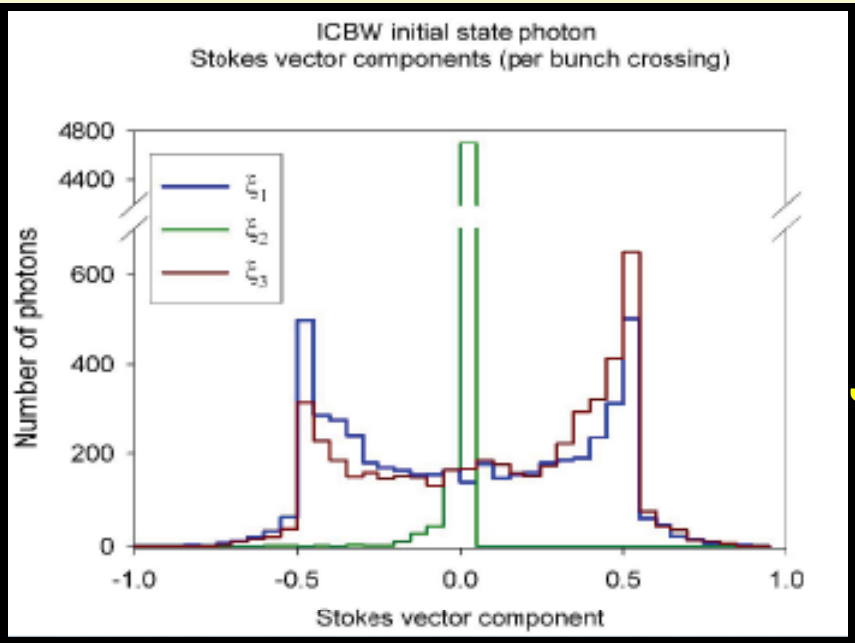
- Slicktrack
- Old 2-mrad beam line selected
- Spin precession ≈ 332°
- No noticeable loss of polarisation (0.06%)
- Results in good agreement with BMAD

Beam-Beam Interactions

- Beam-beam interactions are modelled by exchanges of photons between colliding bunches
- Coherent (bulk) effects do not affect polarisation much
- Incoherent (individual) effects do since initial photons have little polarisation

Polarised cross-sections for incoherent Breit-Wheeler pair production added to CAIN:

$$\frac{d\sigma}{d\cos(\theta)d\phi} = \frac{\alpha^2}{4s^2x^2y^2} \sum_{ii'jj'} F^{ii'}_{jj'} \xi_j \xi_{j'} \zeta_i \zeta_{i'}$$



Tony Hartin

Ongoing Beam-Beam theory

- **Completed theoretical study of approximation used for anomalous magnetic moment in T-BMT equation implemented in CAIN. This approximation has been shown to be valid!**

- **Begun first steps towards long term goal of including non-linear transfer maps into SLICKTRACK software package.**

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 non-conservation

To date…

- **Updated SLICKTRACK software to include full non-commuting spin rotations and acceleration**
- **Simulated spin dynamics in ILC**
  - **damping rings**
  - **beam delivery system**
  - **main linac**
- **Evaluated theoretical uncertainties in beam-beam interactions at the ILC**
- **Instigated first polarised pair-production processes into CAIN.**

Future Plans…

- The motivation for a complete cradle to grave spin tracking simulation has grown as the high energy physics community has increasingly identified the importance of polarised beams as a means to offset any reduction in ILC luminosity.
- This work has been identified as high priority by the Global R&D board.
- We need (LC-ABD2, etc):
  - Further development of SLICKTRACK for full non-linear orbital motion study of BDS and study of main linac.
  - Further development of positron source simulation including effects such as beam jitter and the investigation of spin flip techniques.
  - Assess affect of higher energy spread in damping rings.
  - Theoretical work on beam-beam interactions.
  - Fully integrated software framework.
  - Benchmark vs Merlin.
  - A continued rolling study of the whole machine to allow optimum use of polarisation as a tool for the ILC.