LC IP Depolarisation Studies

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Depolarisation at IP

$$\vec{P} = \frac{\sum_{i=1}^{N} \langle \vec{S}_i \rangle}{|\vec{S}| N}$$

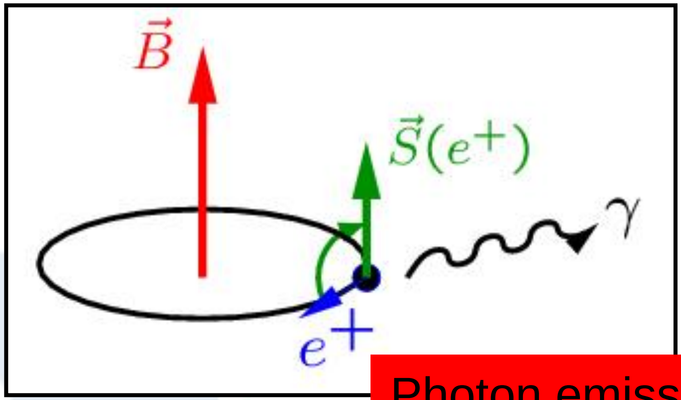
Generally most interesting spin dynamics effects occur in rings…

However, even in a linear collider, both stochastic spin diffusion through photon emission and classical spin precession in *inhomogeneous* magnetic fields can lead to depolarisation.

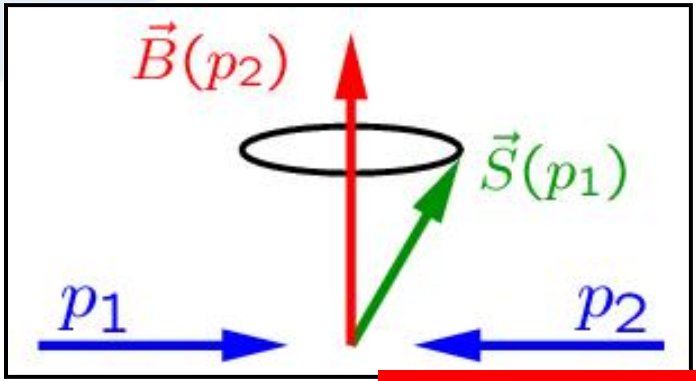
$$\delta\theta_{spin} \propto \frac{(g-2)}{2} \gamma \delta\theta_{orbit}$$

1 mrad orbital deflection $\Rightarrow$ 30 spin precession at 250GeV.

Largest depolarisation effects at ILC / CLIC are expected at the Interaction Points.



Photon emission



Spin precession

Depolarisation at IP

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* Values obtained from SLICKTRACK simulations by D.Barber and L. Malysheva (2008)

Depolarisation at the ILC (RDR)*

- **Damping Rings**
  - **Depolarization (e^-) ~5 10^{-5} %**
  - **Depolarization (e^+) ~1 10^{-3} %**
- **Main linac**
  - **Spin precession ~26**
  - **Depolarization~5 10^{-7} %**
- **BDS**
  - **Spin precession ~332**
  - **Depolarization~6 10^{-2} %**
- **IP**
  - **Depolarization ~0.2 %**

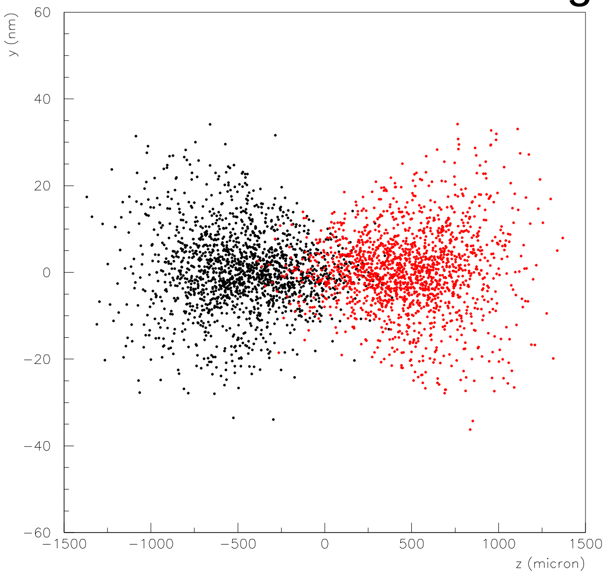
Depolarisation at IP

- Simulations to calculate luminosity-weighted polarisation
  - CAIN
  - GP++
- Comparison of effects of T-BMT and S-T in CAIN simulations in presented in EPAC08 proceedings

Parameter set	Depolarization ΔP_{lw}		
	ILC 100/100	ILC 80/30	CLIC-G
T-BMT	0.17%	0.14%	0.10%
S-T	0.05%	0.03%	3.4%
incoherent	0.00%	0.00%	0.06%
coherent	0.00%	0.00%	1.3%
total	0.22%	0.17 %	4.8%

$$\Delta P_{\rm lw} \equiv \left|\vec{P}\right|^{e-}_{\rm initial} - \left|\vec{P}\right|^{e-}_{\rm lw}$$

e^- & e^+ bunches colliding



GP++ Simulation. C. Rimbault, LAL

Representation of Spin States

•The mixed spin states of the electron and positron bunches are conveniently represented by spin density matrices (SDM)

$$\rho_{e-} = \frac{1}{2}\left(1 + \vec{P}_{e-}.\sigma\right) \qquad \rho_{e+} = \frac{1}{2}\left(1 + \vec{P}_{e+}.\sigma\right)$$

•The joint SDM $\rho_{e-} \otimes \rho_{e+}$ has 15 free parameters.

•Equivalently, the spin states can be represented by

$$\vec{P}^{e-}, \vec{P}^{e+}, \frac{1}{N}\sum_j \sum_i \left\langle \vec{S}_i^{e-} \right\rangle \otimes \left\langle \vec{S}_j^{e+} \right\rangle$$

•All values calculated in CAIN (LUMP array) but not in GP++ which only calculates the average product of the z-components of the spin vectors.

•Or perhaps helicity basis makes more sense (LUMH array in CAIN)

•Should macroparticles always be represented by pure spin states?

Recent Work (C. Pidcott)

- Optimise CAIN parameters
  - number macro-particles,
  - mesh sizes for beam-beam field calculations,
  - etc
- Determine statistical uncertainty on ΔP_{lw}
- Reproduce/improve 2008 results.
- Compare CAIN and GP++ depolarisations for spins aligned along z direction.
  - Implement calculation of luminosity-weighted polarisation vectors and 'covariance' in GP++
- Compared CAIN depolarisations for spins aligned in x, y and z directions.
- First look at effects of energy spread and crossing angle with / without crab cavity.

Updated CAIN results for CLIC

- ΔP_{lw}

Model	CLIC-G 2008	CLIC 2010
T-BMT	0.10%	0.09%
S-T	3.40%	3.81%
Incoherent	0.06%	0.00%
Coherent	1.30%	1.51%
Total	4.80%	5.53%

Statistical uncertainty ~ 0.10%

Values shown correspond to effect of turning off the corresponding part of the model.

Comparing CAIN and GP++ results for CLIC

- ΔP_{lw}

Model	CLIC 201 0 CAIN	CLIC 2010 GP++
T-BMT	0.09%	0.16%
S-T	3.81%	3.48%
Incoherent	0.00%	0.00%
Coherent	1.51%	0.00%
Total	5.53%	3.64%

Statistical uncertainty ~ 0.10%

Values shown correspond to effect of turning off the corresponding part of the model.

NB T-BMT cannot be turned off in GP++ at present.

Pairs produced in CAIN will be unpolarised. Are these being included in luminosity-weighted polarisation calculation?

Luminosity consistent between CAIN and GP++.

Some variation in maximum values of upsilon (10%)

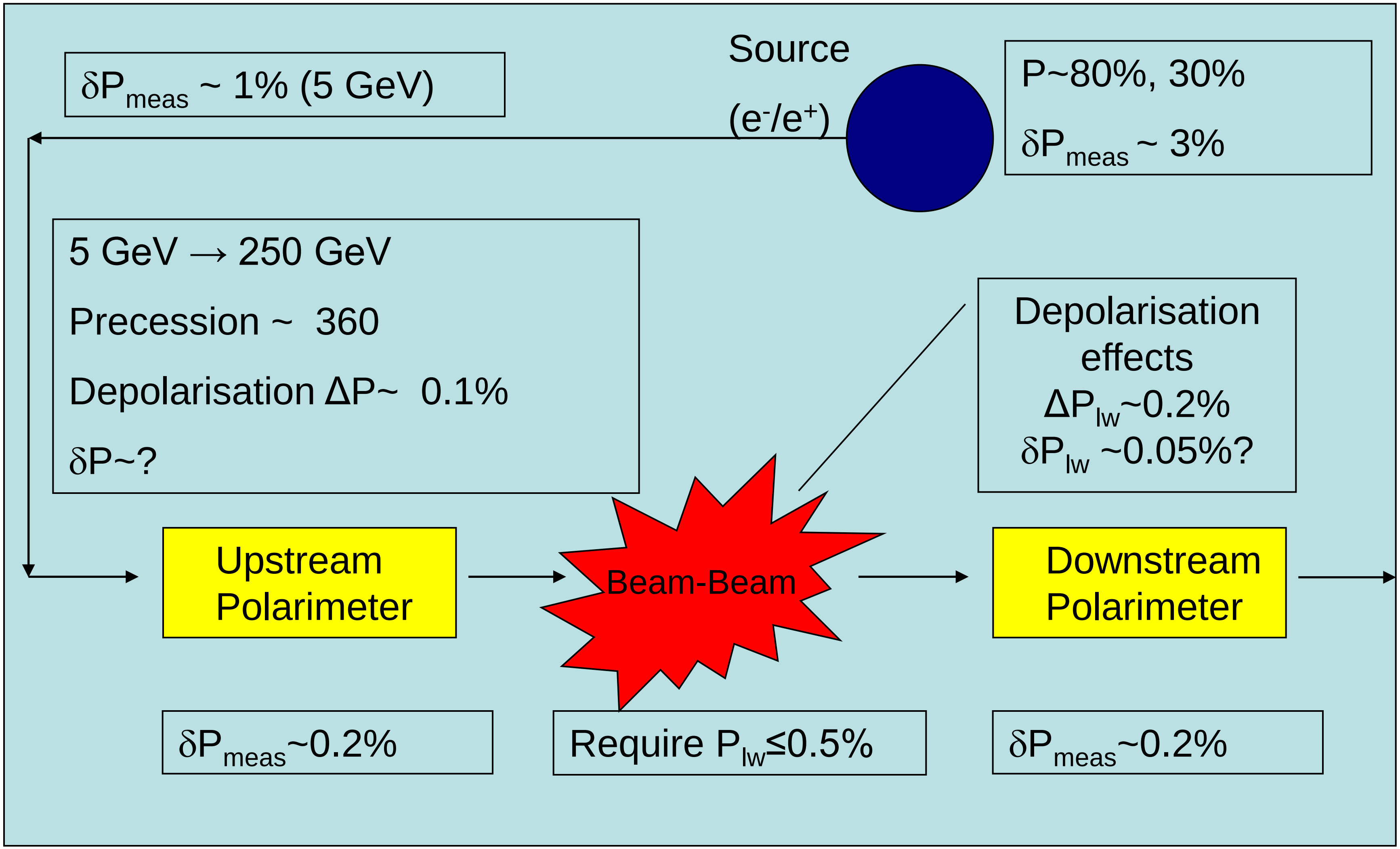
CAIN – Effect of varying initial polarisation vector

- ΔP_{lw}

Initial Polarisation	ILC	CLIC
100% z	0.26%	5.53%
80% z	0.21%	4.65%
30% z	0.08%	1.77%
100% x	0.26%	9.23%
100% y	0.11%	9.42%

Statistical uncertainty ~ 0.10%

Depolarisation simulations and polarimetry at the ILC



Summary

- GP++ modified locally at Lancaster to calculate equivalent of joint SDM as in CAIN
  - Upload to LAL repository?
- Still appear to be some discrepancies between CAIN and GP++ models
  - Further work needed.
  - Difference in field strengths?
- Theoretical uncertainties on depolarisation models at IP not fully understood yet, (see Tony Hartin's presentation).