Some 'news' from depolarization effects in beam-beam interaction

- **Physics requirements on polarization**
  - accuracy and open questions
- **Spin Precession: T-BMT equation**
  - anomalous magnetic moment of the electron
  - quasiclassical approximations
- **Incoherent processes**
  - equivalent photon approximation
  - validity for bremsstrahlung
- **Conclusions and outlook**

Physics requirement

- Goals: Polarized beams needed to
  - analyze the structure of all kinds of interactions
  - improve statistics: enhance rates, suppress backgrounds
  - detect new physics via deviations from SM predictions in high precision measurements
- Needed accuracy
  - expected: for most physics studies $\Delta P/P = 0.5\%$ sufficient; for precision measurements $\Delta P/P < 0.1\%$ required
  - polarization@IP = lumi-weighted polarization $\neq$ polarization@polarimeter
- Plans for the ILC
  - downstream polarimeter at z~147 m
  - expected: Compton polarimetry can provide $\Delta P/P <$ 0.5% ,...,0.25%, up to ... ?

(Some) open questions

- **What are the possible systematical uncertainties?**
  - SLC experience: analyzing power calibration, detector linearity, chromatic effects, etc.
- **Helicity flipping of both beams:**
  - needed to get systematics under control?
  - needed for physics purposes?
  - at which frequency?
- **Analysis of possible depolarization effects:**
  - needed to derive the lumi-weighted polarization precisely
  - since $\Delta P/P<0.5\%$ required .... even small depolarization effects have to be known
  - major component in beam-beam interaction: spin precession (T-BMT) and spin-flip (Sokolov-Ternov) processes
  - take into account coherent and incoherent (background) processes

a) Spin precession

- PPARC review committee: check if used equations in CAIN are applicable!
  - validation of T-BMT equation
- What has been used?

$$\frac{dS}{dt} = -\frac{e}{m\gamma}\left[(\gamma a+1)B_T + (a+1)B_L - \gamma(a+\frac{1}{\gamma+1})\beta e_v \times \frac{E}{c}\right] \times S$$

  - 'a' is anomalous magnetic moment of electron a=(g-2) / 2=$\alpha/2\pi$ + ...
  - higher-order effect, radiative corrections to eeγ vertex
  - measured up to accuracy of 10^{-11}
- Due to strong fields (beamstrahlung), a is function of field
  - unpublished expression from V. Baier used.....
  - has been checked now

Spin precession -- some news

- **Baier derived**

a) expression for anomalous moment of e in a medium

➾ use ansatz in perturbation theory

➾ relates spin-dependent part of corrections with magn. moment

b) get expression valid in beam-beam interactions

➾ use this expression for the case that 'no' scattering happens

➾ that has been used in CAIN

c) used approximation: quasi-classical approximation

➾ (one) condition: change of momentum due to external field has to be slowly

➾ applicable if: Larmor radius in magn. field much larger than particle wavelength

➾ ok for our case, even although fields are strong

Expression for anom. magn. moment

Quasi-classical approximation in our case

- particle wavelength in our cases:
  - ~h / p
- Larmor radius:
  - typical magnetic field in the bunches O(kT)
  - radius ~ pc / eB
  - much larger than characteristic wavelength

→ used approximation seems to be ok in our case

- used equation in CAIN now obvious

b) incoherent processes

- **Become important/dominant for high energies!**
- **For beam-beam interaction: four incoherent processes as 'background'**
  - **Breit-Wheeler:** $\gamma + \gamma \longrightarrow e^+ + e^-$ (real photons)
  - **Bethe-Heitler:** $e^\pm + \gamma \longrightarrow e^\pm + e^+ + e^-$

    becomes in EPA: $\gamma^* + \gamma \longrightarrow e^+ + e^-$
  - **Landau-Lifshitz:** $e^+ + e^- \longrightarrow e^+ + e^- + e^+ + e^-$

    becomes in EPA: $\gamma^* + \gamma^* \longrightarrow e^+ + e^-$
  - **Bremsstrahlung:** $e^+ + e^- \longrightarrow e^+ + e^- + \gamma$

    becomes in EPA: $e^+ + \gamma^* \longrightarrow e^+ + \gamma$

Equivalent photon approximation -- intro

- Idea: approximate virtual photon via a real photon with:
  - *mass on-shell*
  - *only transversely polarized*
- Approximation ok, if dynamical cut-off exists
  - limes for $q^2 \to 0$: $\sigma_S \sim q^2 \to 0$

    $\sigma_T \sim \sigma_\gamma$
- Approximation ok, if spin-density matrix is taken into account:
  - expand amplitude in 'transverse' and 'scalar' photon contribution
- Cross section can then be expressed:
  - $d\sigma_{EPA} \sim \sigma_\gamma \; dn(w, q^2)$
- Check for every process whether EPA is applicable!
  - Bethe-Heitler and Landau-Lifshitz in principle ok

CAIN: status with incoherent processes

- Bremsstrahlung process cannot be approximated via EPA!
  - terms proportional $\ln(k^2/m_e^2)$ neglected !
  - has to checked in our energy region
  - in CAIN: bremsstrahlung only included via EPA
- EPA only in proper use, if polarization of virtual γ has been taken into account
  - in CAIN no polarization of photons for BH, LL and Bremsstrahlung process
- No correlation between polarization of final particles included
  - can only be done if for all processes spin-density matrix has been calculated...
  - concerning ILC sets: incoherent processes are dominant!
- No secondary processes included
  - see ...

Some news concerning this part

- **Breit-Wheeler process well under control**
  - Tony did second order QED calculation in his thesis
  - *see next talk*
- **Other processes**
  - BH and LL later on in a second step in EPA
  - including full spin-density matrix ...
- **but: bremsstrahlung contribution has to be derived without EPA**
  - i.e. include the missing log terms and the spin

Summary and Outlook

- T-BMT and anomalous magnetic moment of the electron
  - managed to recalculate Baiers expression
  - seems to be ok for our cases
- Incoherent processes
  - Spins for BW, BH and LL
  - Needed corrections for bremsstrahlung (logs and spins)
  - see also Tony's talk
- Still to be done: CAIN update
- Still to be done: detailed polarization simulations
  - for some physics examples: simulations including 'full' expected systematics
  - taking into account variable flipping frequency
  - not very urgent but should be done in time ...