Polarization modelling

- **Physics requirements**
  - on the machine
  - on polarization
- **Depolarization processes**
  - spin Precession: T-BMT equation
  - anomalous magnetic moment of the electron
- **Alternative method**
  - required steps and checks
- **Conclusions and outlook**

ICFA Parameter Group

- 'Scope Document no.1' (2003) and 'no.2' (2006): baseline
  - 'full luminosity of 2 x $10^{34}cm^{-2}s^{-1}$'
  - 'beam energy stability and precision below tenth of percent level.'
  - 'Machine interface must allow measurements of beam energy and diff. lumi spectrum with similar accuracy.'
  - 'electron beams with polarisation of at least 80% within whole energy range.'
- Options:
  - 'e^+ polarisation ~50% in whole energy range wo sign. loss of lumi...., Reversal of helicity ... between bunch crossings.'
  - GigaZ: e^+ polarisation+frequent flips essential; energy stability+calibration accuracy below tenth of percent level.'

Physics case for polarized e^- and e^+

- **comprehensive overview given in 'POWER' report**
  - **hep-ph/0507011, now in press as Physics reports**
  - **see also 'executive summary' at**

    www.ippp.dur.ac.uk/~gudrid/source/
- **added soon:**
  - **Alexanders (many thanks to Alexander!) program 'KONN' for tracking undulator e+ from source up to acceleration**
  - **ennables systematic studies of undulator parameters**
  - **Tony's (many thanks also to Tony!) updated version of CAIN**
  - **included polarization (full BW and initial+final states)**
- **would be very thankful for further input and provided tools!**

Physics requirements

- Goals: Polarized beams required to
  - analyze the structure of all kinds of physics
  - improve statistics: enhance rates, suppress backgrounds
  - get systematic uncertainties under control

→ Discoveries via deviations from SM predictions in precision measurements

- Needed accuracy
  - expected: for most physics studies $\Delta P/P=0.5\%$ (0.25%) sufficient; for precision measurements $\Delta P/P<0.1\%$ required
  - polarization@IP = lumi-weighted polarization $\neq$ polarization@polarimeter

Depolarization processes

- **Analysis of possible depolarization effects:**
  - **needed to derive the lumi-weighted polarization precisely**
- **major component in beam-beam interaction:**
  - **spin precession (T-BMT)**
  - **spin-flip (Sokolov-Ternov) processes**

- **In the following: status report for deriving a method to calculate T-BMT in strong fields**

Spin precession

- **T-BMT equation:**

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

  - **'a' is anomalous magnetic moment of electron a=(g-2) / 2=$\alpha/2\pi$ + ...**
  - **higher-order effect, radiative corrections to eeγ–vertex**
  - **experimentally measured up to accuracy of 10^{-11}**

- **So far: used medthod in CAIN and Guinea-Pig**

Due to strong fields (beamstrahlung):

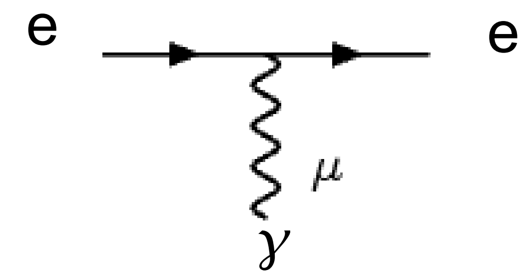
  - **' a' expressed as function of field in a medium**
  - **excellent work of V. Baier, V. Katkov**
  - **several approximations and assumptions have been made**

Used approximations

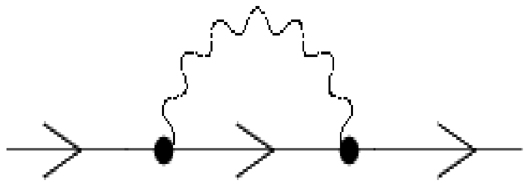
- expression for anomalous moment of e in a medium
  - used kind of perturbation theory
  - relates spin-dependent part of mass corrections with magn. moment
- applies expression for beam-beam interactions
  - assuming the case that 'no' scattering happens
- used quasi-classical approximation
  - change of momentum due to external field has to be slowly
  - Larmor radius (~pc/eB) in magn. field much larger than particle wavelength (~h/p)
  - neglect quantization of motion and recoil of radiation on particle
  - assuming basic features of motion independent of spin property

Anomalous magn. moment of e

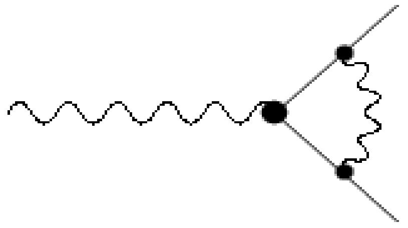
- **Contributions to the QED vertex**



at 1-loop order:



'self-energies
~mass corrections'



'vertex correction'
~decisive for an. magn. moment

QED vertex

- lowest order: e u(p2) γ^{μ} u(p1)
- any order: u(p2) Γ^{μ} u(p1)
  - divide vertex in vector and tensor (~spin) part
  - $\Gamma^{\mu} = \gamma^{\mu} F_1 + \sigma^{\mu\nu} F_2$
- in lowest order: F_1= e (electric charge), F_2=0
- at 1-loop: F_2 = anom. magn. moment of e a=0.5(g-2)
  - contributions come from vertex corrections
  - precise recipe how to calculate
- higher order: precise agreement between theory and experiment

  $a_{exp}=1159652188 \times 10^{-12}$ vs. $a_{theo}=1159652157 \times 10^{-12}$

Alternative to derive a in beam-beam

- **derive H in external field**
  - remember H-atom: spin-orbit term (l*s), interaction terms (B*s,B*l)
  - often A^2-terms neglected
  - important for strong fields (laser)
- **use Furry representation**
  - use explicit fermion operator in external field
  - 'usual' Feynman rules in perturbation theory
  - explicit fields in beam-beam zone required
  - straight forward.....but mathematically rather complex
- **status: not yet final results, but hopefully at EPAC08**
  - in collaboration with T. Hartin

Conclusions

- **Physics precision requirements challenging for LC**
  - **all depolarization effects have to be accurately calculated**
  - **precise spin tracking required for baseline design**
  - **needed for polarized e^- as well as baseline e^+ source**
- **Further theoretical studies needed to describe spin precession in strong fields**
  - **under work**
- **Also further theoretical examinations of 2nd depolarization process**
  - **description of Sokolov-Ternov spin-flip effect in strong fields (see also Yokoya, Chen)**
  - **collaboration with Ph. Bambade, T. Hartin, C. Rimbault**