Spin Control and Transportation

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Information & outline

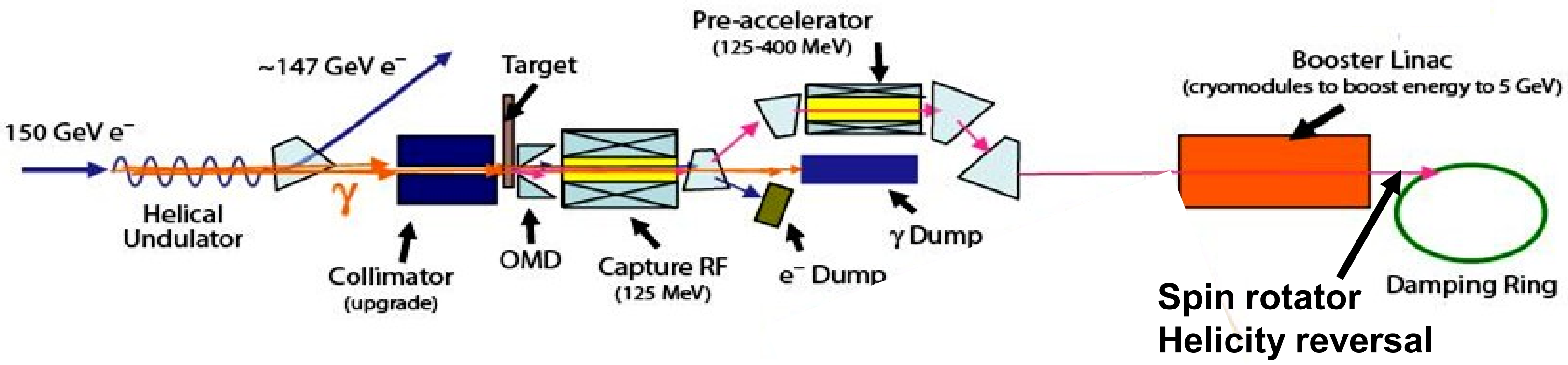
Project "Spin Management"

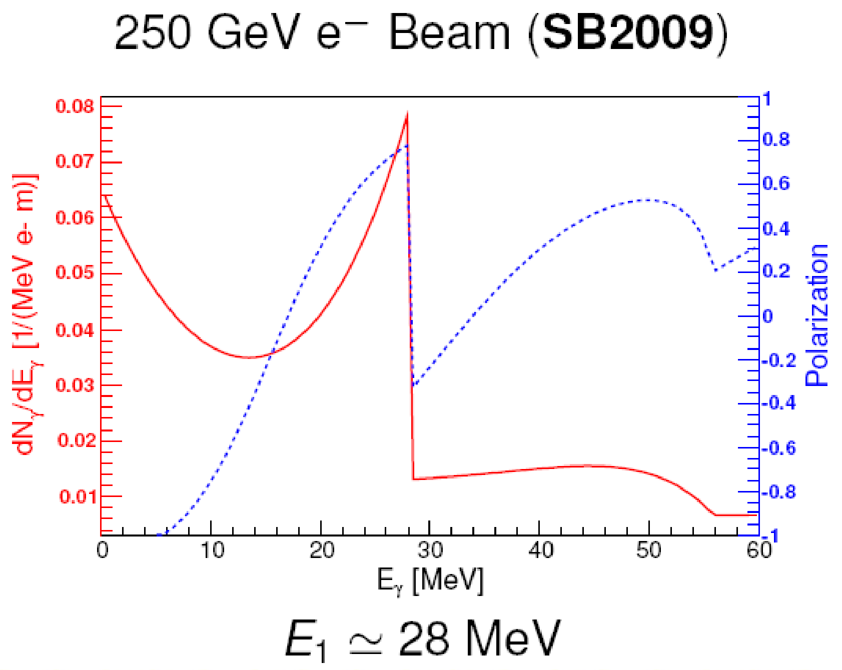
- **Network of Uni Hamburg, Uni Bonn and Uni Mainz, associated partner: DESY**
- **Focus for Uni Hamburg and DESY groups:**
  - Spin tracking from start (source) to end (IP) for future linear colliders
  - Shock wave in target and collimator materials
  - Precision polarimetry at the IP

Outline:

- Status
  - **Spin tracking for positrons**
  - **Spin rotation**
  - **Spin tracking at IP**
- Summary & future plans
  - **What has to be done for the TDR?**

ILC Positron Source





- Spin transfer $\gamma \rightarrow e$
  - Circularly polarized photons → longitudinally polarized positrons
- Capture of polarized e+
- Spin transport & rotation

→ 'optimal' e+ polarization

Spin transport simulation

Tools to simulate spin transport:

- γ conversion to $e^{\pm}$
  - **Geant, EGS**
- tracking codes
  - **Parmela, Elegant, BEAMPATH, MAD-X, BMAD, Slicktrack, Zgoubi, MERLIN, Geant4,…**
- Beam-beam effects
  - **GuineaPig++, CAIN**

→ Source: G4 (or EGS) + tracking code

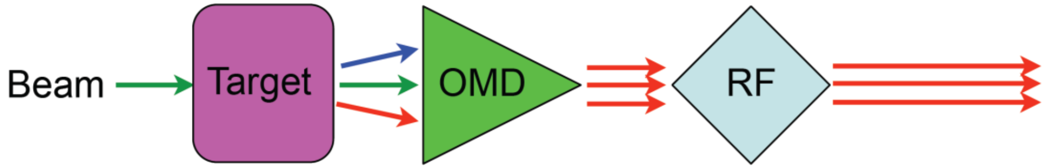
Workshop on Spin Simulation Tools at DESY Hamburg, November 2010 http://indico.desy.de/event/3515

PPS-Sim

Polarised Positron Source Simulation http://pps-sim.desy.de

See also talk:

Schälicke, Ushakov: http://indico.desy.de/event/3515



Input:

- Primary beam
  - Photons from Undulator
    - simplified collimator
  - Electrons (conventional source)
  - Input file (Compton photons, Crystal target)
- Target
  - Ti wheel, Liquid Lead
- Positron Capture Optics (OMD)
  - AMD, QWT, Li-Lens, (no FC)
  - Solenoid B-field, RF E-field

Output:

- Positron yield
- Positron polarization
- Energy deposition (average & PEDD)
- Full information about each photon (before target) and e+ (after target, OMD, acc.)

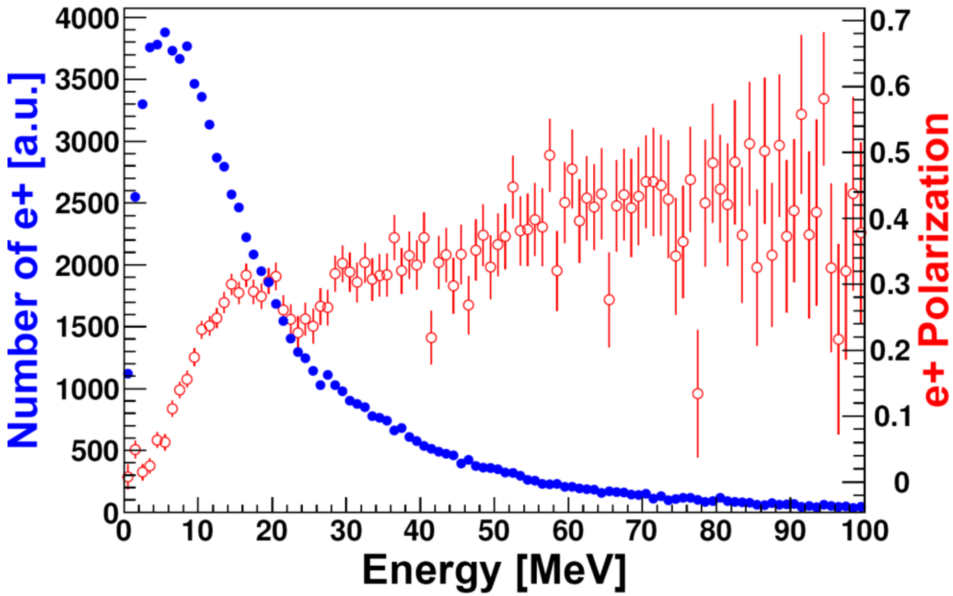
Procedure:

- PS-Sim is G4 based, includes el-magn polarized processes
- Spin tracking using T-BMT equation

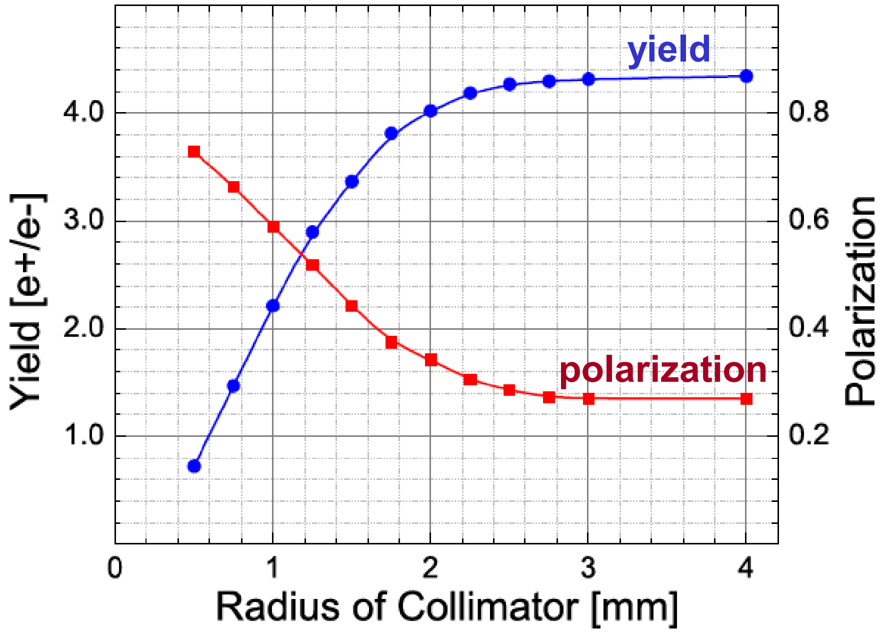
Positron spectrum and polarization

PPS-Sim result for RDR Undulator,
distance undulator – target ~500m, e- energy 250 GeV

Positrons after target



Yield and Polarization vs Radius of **Virtual** Collimator (QWT)



PPS-Sim positron tracking to DR

- tracking of polarized positrons in target and capture section:
  - **e+ yield, polarization, energy spread**
    - <δE> ~100% after target, ~ 50% after OMD + 1.3m acceleration
  - **Lose about 20-30% of the positrons in OMD and 11 accelerating cells**

- Further 'tracking' through missing lattice
  - **DR acceptance**
    - Apply cut on $\gamma(A_x+A_y) < 0.09$ rad·m
    - Energy spread ⇔ longitudinal cut ~10mm
      - Resulting energy spread at 5 GeV ~ 50 MeV (1%)

  → **Polarization and yield at the source**

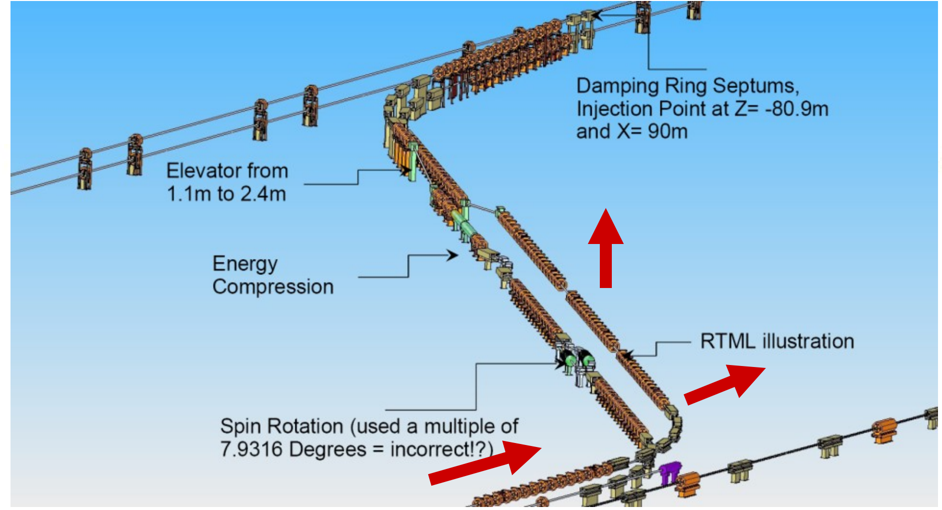
- Not yet included:
  - **Detailed spin tracking from capture section to DR**
  - **Detailed spin rotation and helicity reversal**
  - **Tolerances and misalignment studies**

→ positron polarization could be better (or worse)

Spin rotation

e+ spin rotation upstream DR

See also Moffeit et al., (2005), SLAC-TN-05-045



– **Rotate spins to horizontal transverse direction (dipole)**

$$\theta_{spin-bend} = \frac{E[GeV]}{0.44065} \cdot \theta_{bend}$$

$n \cdot 7.9316^\circ$ for E = 5 GeV

99.146° for E = 400 MeV

– **Rotate spins from horizontal to vertical with solenoid**

$$\Delta\theta_{spin-sol} = \left(1 + \frac{g-2}{2}\right) \frac{B_{sol} \cdot L_{sol}}{B_0\rho} \approx \frac{B_{sol} \cdot L_{sol}}{B_0\rho}$$

$B_0\rho$ – magnetic rigidity

– **For 90° spin rotation at 5GeV $B_{sol} \cdot L_{sol}$ = 26.23 Tm**

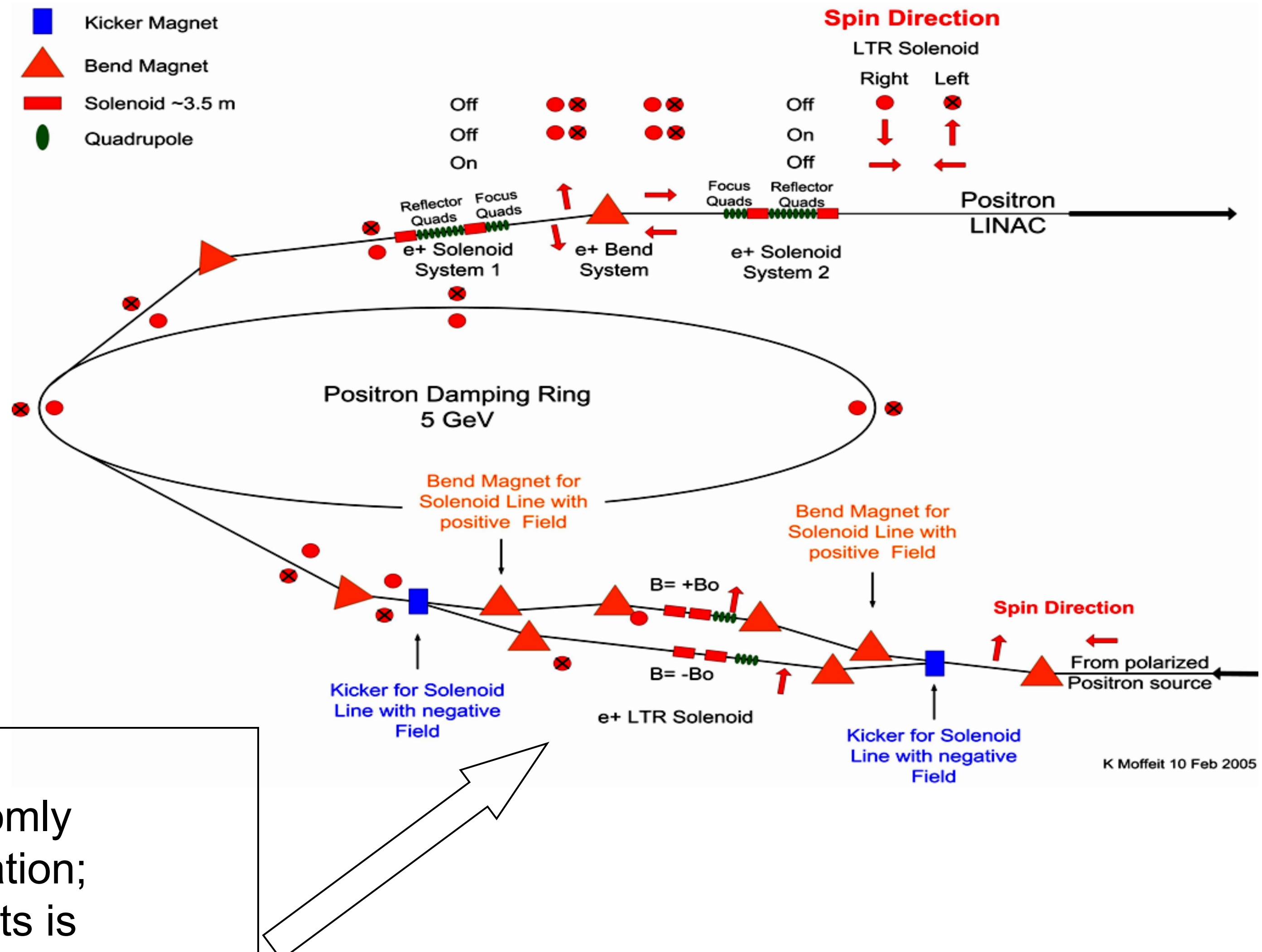
RDR: two 2.5m sc solenoids of 5.2T

– **Spin rotation angle is inversely proportional to momentum**

→ Large energy spread yields large spread of transverse polarization

e+ spin rotation and **helicity reversal** @ 5GeV

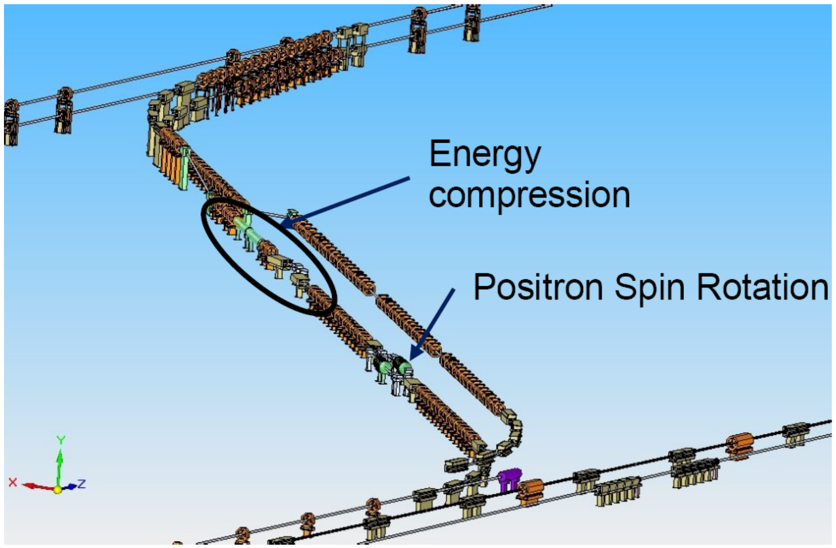
K. Moffeit et al.,
SLAC-TN-05-045



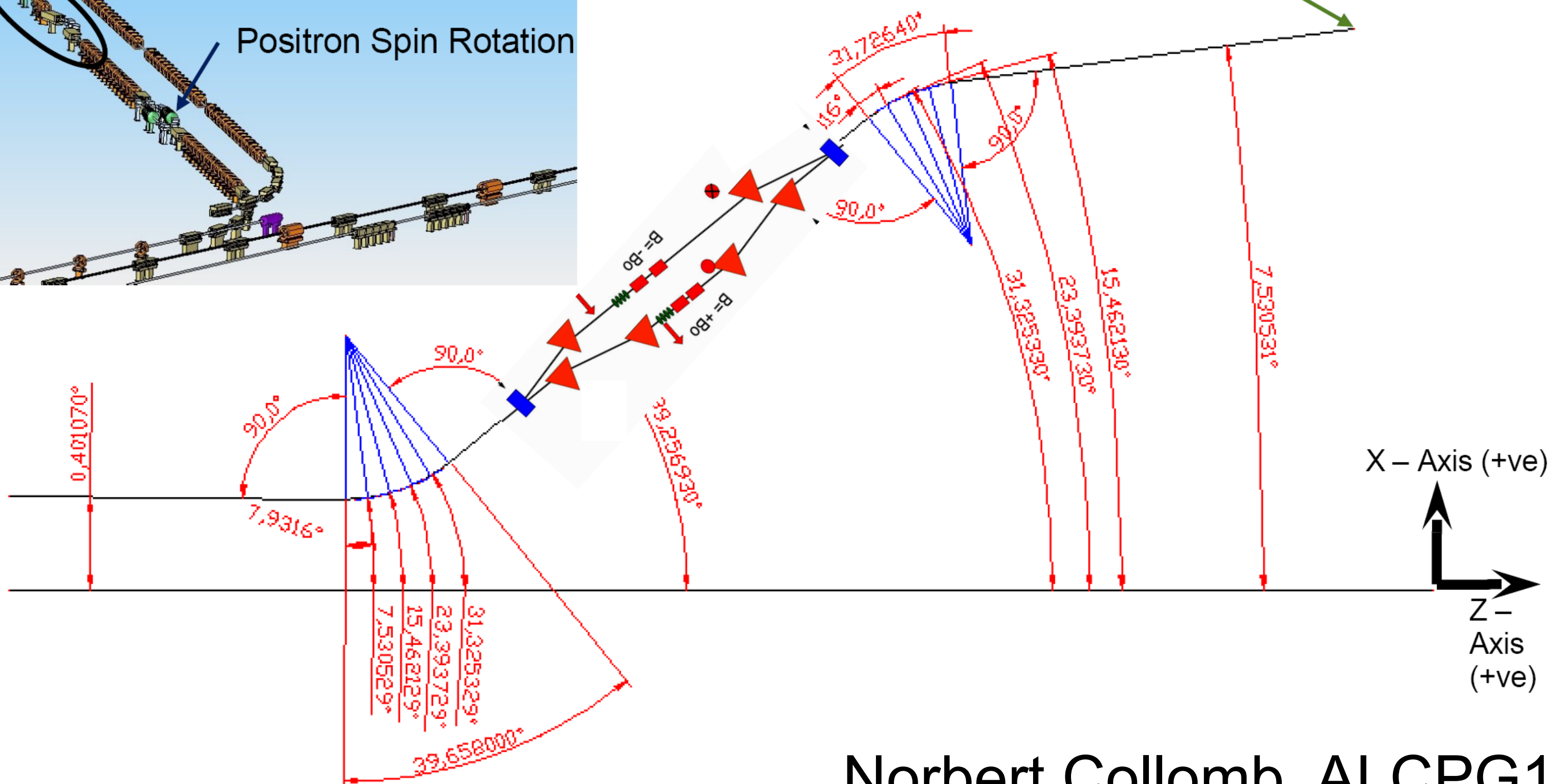
parallel spin rotation
beam lines for randomly
selecting e+ polarization;
pair of kicker magnets is
turned on between pulse-trains

Science & Technology Facilities Council

Theoretical PLTR



DR Injection point at:
X= 90 m, Y= 1.3m and
Z: -80.9m



Norbert Collomb, ALCPG11

Depolarization due to spin precession

See A. Latina et al., IPAC'10

- Mean polarization

$$\langle P_z \rangle = P_0 \exp\left(-\frac{(a\,\gamma_0\,\theta\,\delta E)^2}{2} \right)$$

a = (g-2)/2 ≈ 0.00116
δE – relative energy spread
θ – deflecting angle

- Relative depolarization due to spin transport through bending magnet

$$\langle \Delta P \rangle = 1 - \frac{\langle P \rangle}{P_0}$$

→ Depolarization due to energy spread at bending arcs

- **At positron spin rotator (energy spread δE = 1%)**
  - depolarization at 5 GeV and 7 · 7.9316° = 55.52°
    $\langle \Delta P \rangle \sim 0.6\%$
  - depolarization at 5 GeV and 5 · 7.9316° = 39.66°
    $\langle \Delta P \rangle \sim 0.3\%$

Spin tracking studies (RDR)

…incomplete selection….

- for the electron source:
  - **F. Zhou et al., Start-to-end Transport Design and Multi-particle Tracking for the ILC Electron Source (2007)**
    - http://www-public.slac.stanford.edu/sciDoc/docMeta.aspx?slacPubNumber=slac-pub-12240
- for the positron source:
  - **F. Zhou et al., Start-to-end beam optics development and multi-particle tracking for the ILC undulator-based positron source (2007)**
    - http://www-public.slac.stanford.edu/sciDoc/docMeta.aspx?slacPubNumber=slac-pub-12239
- Spin rotation
  - **P. Schmid, A Spin Rotator for the ILC.**
    - http://www.eurotev.org/reports__presentations/eurotev_reports/2005/e382/EUROTeV-Report-2005-024.pdf
    - http://www.eurotev.org/reports__presentations/eurotev_reports/2006/e654/EUROTeV-Report-2006-010.pdf
  - **J. Smith, The preservation of emittance and polarization in the International Linear Collider**
    - http://gradworks.umi.com/32/60/3260825.html
  - **Batygin, Spin Rotation and Energy Compression in the ILC LTR Positron Beamline (2006)**
    - http://slac.stanford.edu/pubs/slacpubs/12000/slac-pub-12044.pdf
- Spin tracking at ILC
  - **J. Smith Spin transport in the International Linear Collider (2007)**
    - http://accelconf.web.cern.ch/AccelConf/p07/PAPERS/WEOAAB01.PDF
- Depolarization in DR
  - **L. Malysheva, D. Barber, Depolarisation in the damping rings of the ILC.**
    - http://www.slac.stanford.edu/econf/C0705302/papers/DR003.pdf

Spin tracking at IP

- Precision polarimetry
  - **Spin tracking from upstream to downstream polarimeter**
- Knowledge of depolarizing effects at IP
  - **Higher order effects in beam-beam interactions**
  - **Implementation of traveling focus in GP++**

Polarized beams at IP

High precision e± polarization measurement, $\delta P/P \sim 0.25\%$

- Sources of systematic errors
  - **Depolarization due to strong fields in crossing beams**
    - ILC RDR ~0.22%, SB2009 slightly higher (under study)
  - **Misalignment of spins in polarimeter and IP (should be parallel)**

Upstream polarimeter

- Clean environment
- Stat. error 1% after 6μs
- Machine tuning possible

Downstream polarimeter

- High background
- Stat. error 1% after ~1min
- Access to depolarization at IP

Combination of both polarimeters

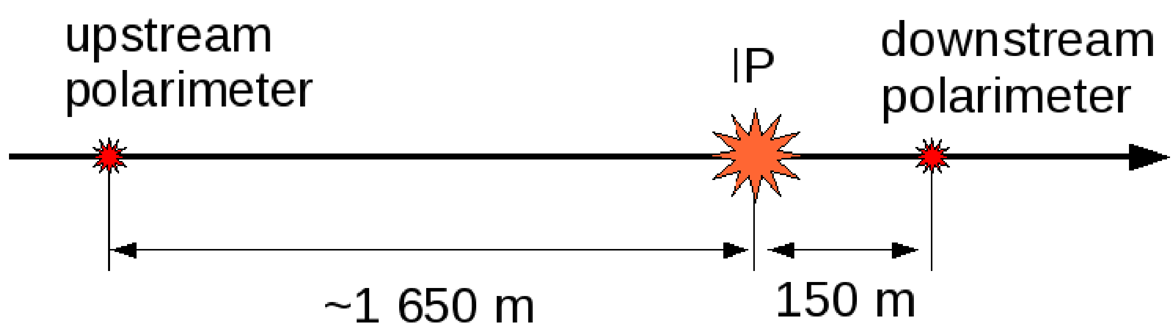
- Cross checks ⇔ redundancy for high precision
- With collisions: depolarization at IP
- Without collisions: control spin transport in BDS

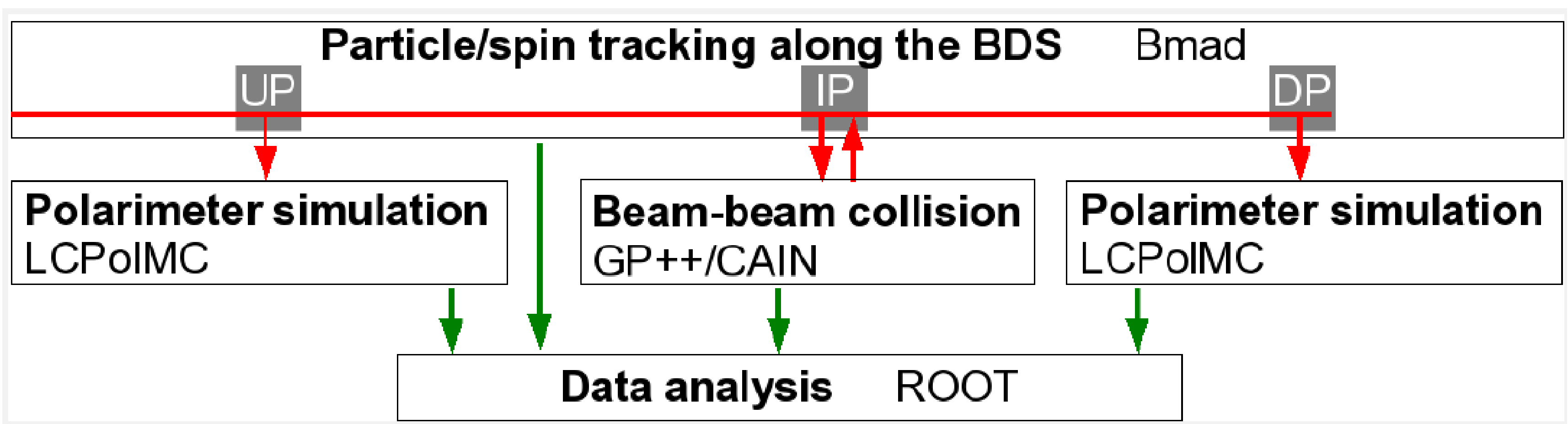
➔ have to understand spin diffusion and depolarization at the 0.1% level

Spin tracking at the IP

M. Beckmann

Goal:
Understand spin diffusion and depolarization at the 0.1% level

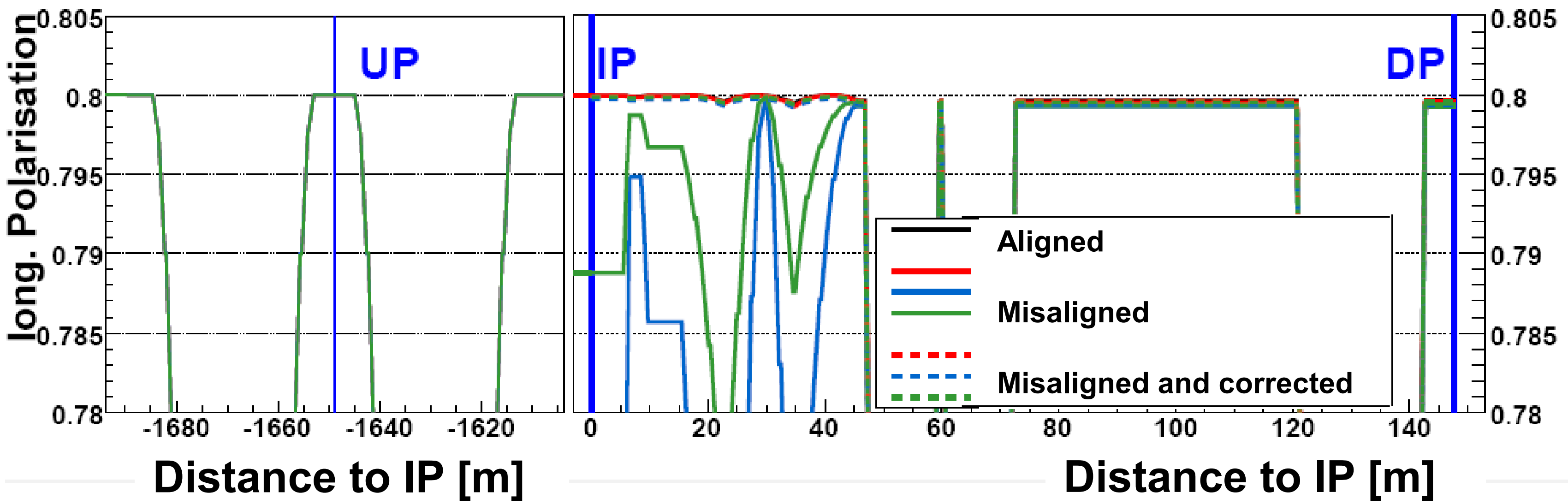




Spin tracking for polarimetry

M. Beckmann

- Polarization studies from upstream (UP) to downstream polarimeter (DP)
  - **Particle/spin tracking using BMAD**
  - **study includes misalignments, and allows corrections**



To be included: crab cavities, detector magnets, feed-back corrections, collision effects

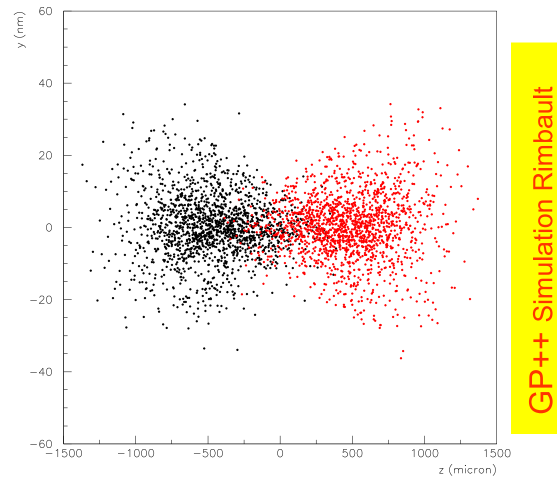
Depolarization at IP

- Beam-beam interaction

  T. Hartin

  - **Beamstrahlung and spin precession result in uncertainties in the polarization state at the IP**
  - **δP ~ 0.2% (ILC RDR) … 4.8% (CLIC)**

  → Precise modeling required



- Traveling Focus (TF) and depolarization

  L. Malysheva

  - **TF has never been tested in experiments**
  - **Increased beamstrahlung due to TF could depolarize electron and positron beams**

  → Studies needed how TF effects spin

  - Polarization and TF are implemented in GP++
  - Have to study (de)polarization and its uncertainty

Summary

- A lot of work has to be done
- Focus of our group (Hamburg and Zeuthen):
  - **spin tracking**
  - **Increase of polarization**
    - γ collimation: Heat load on materials to be studied
    - use energy spectrometer at positron capture section to remove low-energy positrons with ‘wrong’ polarization (K. Moffeit)
  - **Spin transport at IP (incl. TF)**
- Polarimetry at the source – status frozen as it is:
  - **concept for a Bhabha polarimeter at 400MeV**
- Do we need an equipment to depolarize ?
- 1 TeV upgrade has to be included