Towards Precision Polarimetry at the ILC: Concepts, Simulations, Testbeam Results

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The International Linear Collider

the goals:

- Unveil the nature of physics beyond the Standard Model
- **precision measurements** of known and new particles

the tools:

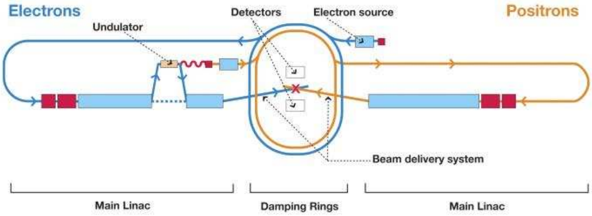
- Electron - positron collisions at $\sqrt{s} = 90$ GeV up to 1 TeV
- Polarisation: $\mathcal{P}_{e^-} = 80\text{-}90\%$, $\mathcal{P}_{e^+} = 30\text{-}60\%$

the challenge:

- determine luminosity weighted average polarisation at the collision point to $\delta\mathcal{P}/\mathcal{P} = \mathbf{0.1\%}$
- ... and in some cases even to $\delta\mathcal{P}/\mathcal{P} = \mathbf{0.01\%}$

Compton Polarimetry at the ILC

- Compton scattering off laser beam:
  - hit $\mathcal{O}(10^3)$ $e^{\pm}$ per bunch of 10^{10}
  - $\mathcal{P}$ propotional to energy asymmetry
  - scattered $e^{\pm}$ colimated within 10 μrad
  - $\Rightarrow$ spectrometer magnets: energy $\rightarrow$ position
- achieved (SLD): $\delta\mathcal{P}/\mathcal{P} = 0.5\%$, ILC: $\delta\mathcal{P}/\mathcal{P} = 0.25\%$ (syst.)
- not possible at e^+e^- IP, but upstream and downstream
- typical timescales: few bunches / trains



Polarimetry with Annihilation Data

$e^+e^- \rightarrow W^+W^-$

- from total cross-section or $\frac{d\sigma}{d\cos\theta}$
- contribution of new physics?
  $\Rightarrow$ common determination with triple gauge couplings
- **longterm ($\mathcal{O}$ (years))** absolute scale to $\delta\mathcal{P}/\mathcal{P} = 0.1\%$

c.f. LC-PHSM-2001-022, update underway

Blondel Scheme

- needs $\mathcal{P}_{e^+} \neq 0$ and all four $e^\pm$ helicity combinations
- determines $\mathcal{P}_{\text{eff}} = \frac{|\mathcal{P}_{e^-}|+|\mathcal{P}_{e^+}|}{1+|\mathcal{P}_{e^-}||\mathcal{P}_{e^+}|}$ to $\delta\mathcal{P}_{\text{eff}}/\mathcal{P}_{\text{eff}} = 0.01\%$

c.f. K. Mönig, LCWS S2004

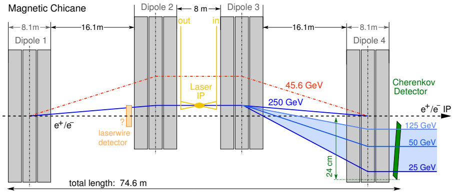
Complementarity of Polarimeters and Annihilation Data

Tasks	Tools
▶ tune spin rotators, monitor time dependence and correlations	▶ fast → polarimeters
▶ determine spin transport effects	▶ 2 locations → polarimeters
▶ depolarisation due to collisions	▶ non-colliding → polarimeters
▶ analysis of first years' data	▶ „fast“ → polarimeters
▶ direct access to luminosity weighted average polarisation	▶ annihilation data
▶ ultimate calibration of absolute polarisation scale	▶ annihilation data
▶ cross check, cross check, cross check!	▶ polarimeters and annihilation data

Complementarity of Up- and Downstream Polarimetry

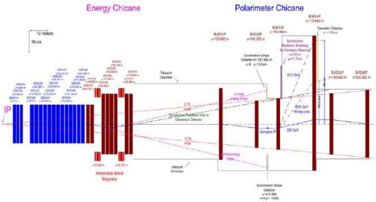
Upstream Polarimeter

- 1.8 km upstream of IP



Downstream Polarimeter

- 140 m downstream of IP



Combination

- without collisions: spin transport in Beam Delivery System
- with collisions: depolarisation at IP
- cross check each other![1]

[1] cf. „Spin Dance“ Exp., Phys. Rev. ST Accel. Beams 7 042802 (2004)

Complementarity of Up- and Downstream Polarimetry

Upstream Polarimeter

- 1.8 km upstream of IP
- clean environment
- stat. error 1% after 6 μs
- machine tuning (upstream of tune-up dump)

Downstream Polarimeter

- 140 m downstream of IP
- high backgrounds
- stat. error 1% after $\simeq$ 1 min
- access to depolarisation at IP

Combination

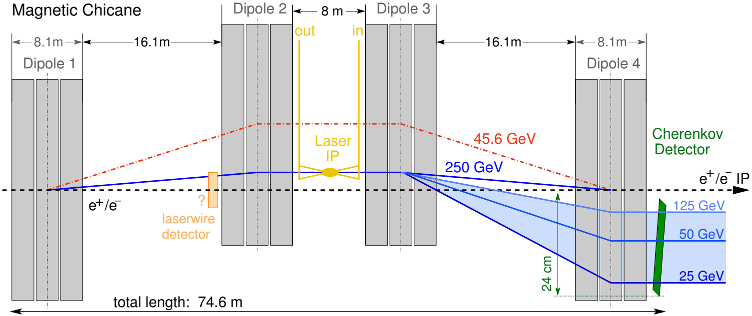
- without collisions: spin transport in Beam Delivery System
- with collisions: depolarisation at IP
- cross check each other![1]

[1] c.f. „Spin Dance“ Exp., Phys. Rev. ST Accel. Beams **7** 042802 (2004)

Design of the Upstream Polarimeter Chicane

Why a 4-Dipole-Chicane?

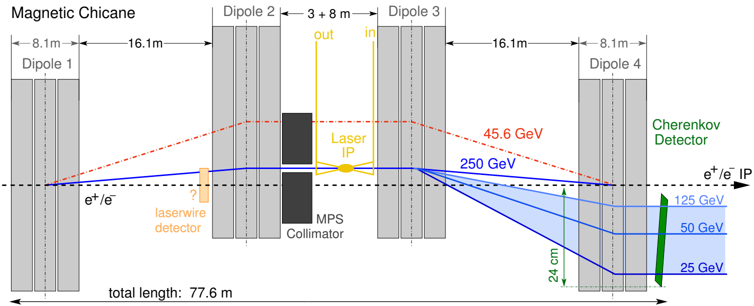
- Compton edge position (least energetic $e^{\pm}$) at detector independent of E_{beam} if B-field constant
- price to pay: Compton IP moves laterally with E_{beam}



Design of the Upstream Polarimeter Chicane

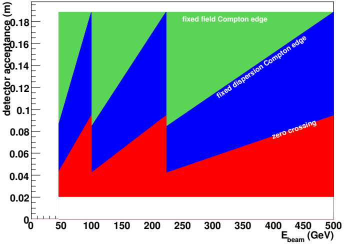
Scaled field operation?

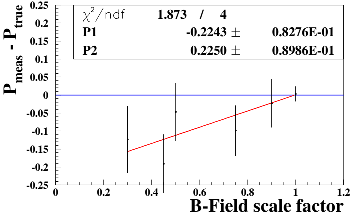
- fixed Compton IP position
- facilitates energy collimation, emittance diagnostics



Scaled vs Fixed Field Operation

- detector acceptance varies with E_{beam} $\Rightarrow$ inhomogeneous quality of polarisation measurement
- calibration of polarimeter: Compton edge position w.r.t. main beam
- simulation study for 1cm channels:
  - fixed field: $\delta\mathcal{P}/\mathcal{P} = 0.1\% \Leftrightarrow \delta x$ 0.4 mm
  - scaled field: $\delta\mathcal{P}/\mathcal{P} = 0.1\% \Leftrightarrow \delta x$ 0.2 mm
  - $\Rightarrow$ systematic deviations for large scale factors
- not compatible with extreme precision requirements c.f. ILC-NOTE-2008-047

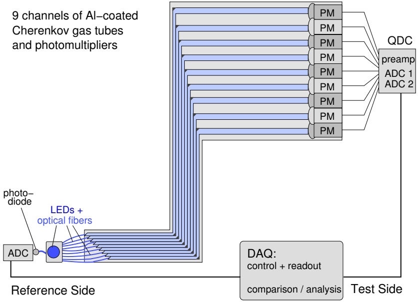




The Cherenkov Detector of the SLD Polarimeter

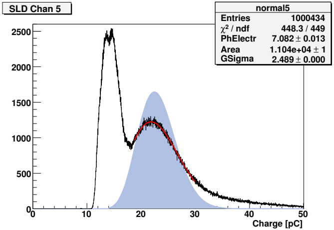
LED & DESY Testbeam

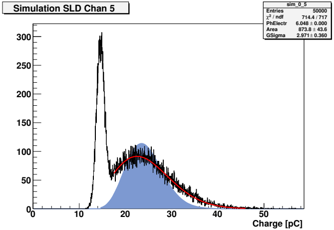
- Cherenkov gas C_4F_{10}, n = 1.0014, 10 MeV threshold
- 3 GeV single e^- at DESY II



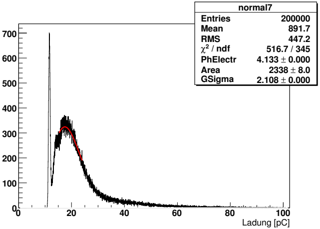
Single Electron Response

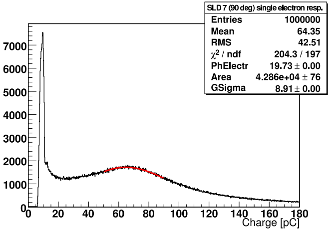
Channel 5, Data & Simulation





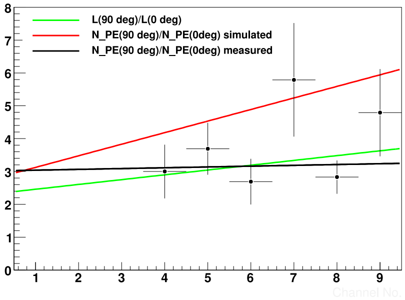
Channel 7, 0° & 90°





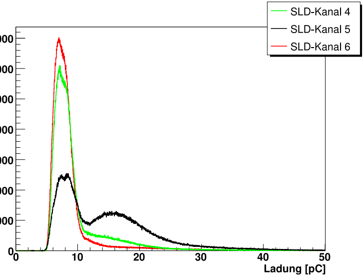
0° / 90° ratio vs channel number

- channels' „middle“ sections longer ⇒ more light yield
- length of middle sections scales with channel number
- less reflections to PMT for 90° orientation
- goal: determine reflectivity, tune simulation (red line: $R = 0.94\%$)



Results: Crosstalk & Channel Geometry

- observation: neighboring channels on the **outside** of the first bend observe part of signal



Results: Crosstalk & Channel Geometry

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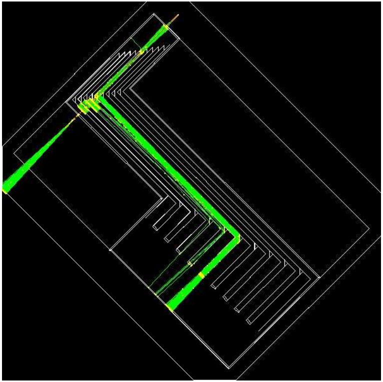
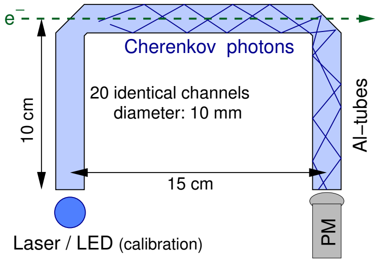
- explanation: cross-talk if e^- traverses neighboring channel close to mirror!



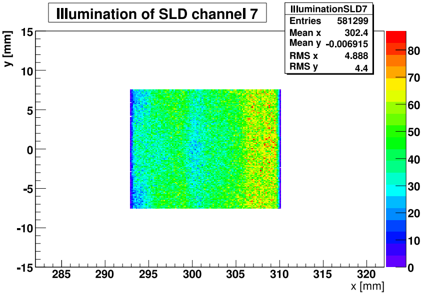
Results: Crosstalk & Channel Geometry

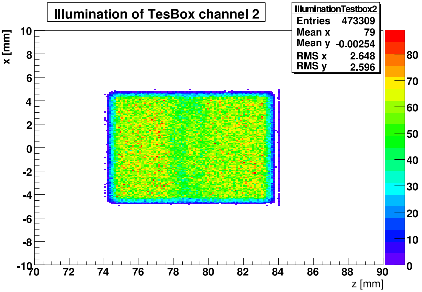
- observation: neighboring channels on the **outside** of the first bend observe part of signal
- explanation: cross-talk if e^- traverses neighboring channel close to mirror!
- ILC solution: use U-shaped channels, bend in 3rd dimension!



Spatial Distribution of Light in Channel

- SLD: inhomogenous light yield due to widening of channels
- avoid in ILC design!



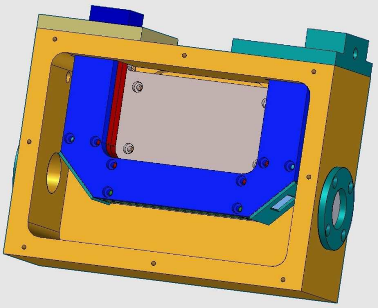


Summary

- precision goals of ILC require combination of upstream and downstream polarimeters as well as annihilation data
- best design for upstream polarimeter is a four-magnet chicane with fixed field operation at all beam energies
- polarimters should improve by factor of 2 w.r.t. SLD
- Cherenkov detector of SLD has been operated in testbeam
- good agreement with simulation
- several improvements for ILC design identified

Outlook

- ILC-like prototype under construction
- various photodetectors under test (c.f. poster session)
- testbeam measurements with multiple electron events at ELSA in spring 2009



BACKUP

Synchrotron Radiation