Upstream Polarimeter Status

C. Bartels, C. Helebrant, Dr. D. Käfer, Dr. J. List

DESY Hamburg

LCWS 2008 Chicago

Reminder: Precision goals

- ew physics: down to 0.01%
- Higgs, SUSY: 0.1%
- needs polarimeters & physics data
- 0.25% is NOT the physics requirement, but what we hope to achieve with optimal polarimeters!

Overall Polarimetry Scheme

Complementarity of Polarimeters and Annihilation Data

Tasks

- tune spin rotators, monitor time dependence and correlations
- determine spin transport effects
- depolarisation due to collisions
- analysis of first years' data
- direct access to luminosity weighted average polarisation
- ultimate calibration of absolute polarisation scale
- cross check, cross check, and again cross check!

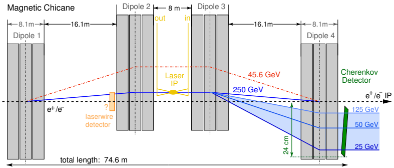
Tools

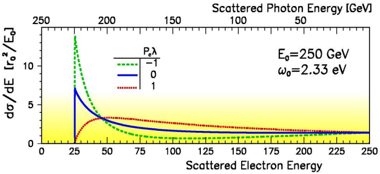
- fast → polarimeters
- 2 locations → polarimeters
- non-colliding → polarimeters
- „fast“ → polarimeters
- annihilation data
- annihilation data
- polarimeters and annihilation data

Polarimeters: Compton-Scattering $e^- \gamma \rightarrow e^- \gamma$

Concept:

- circularly polarised laser
- energy spectrum of scattered e^- depends on P
- want high statistics $\rightarrow$ many scatterings per bunch
- magnetic chicane $E \rightarrow x$
- Cherenkov hodoscope detector
- asymmetry w.r.t. laser helicity: $P(e) = \frac{1}{P_\lambda \cdot AP} \frac{N_L(x) - N_R(x)}{N_L(x) + N_R(x)}$





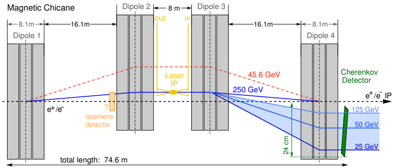
dominant systematics:

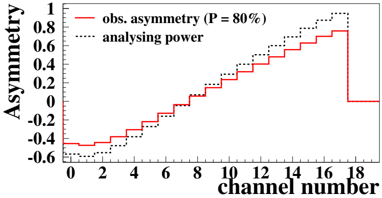
Analysing Power AP (0.2%), detector linearity (0.1%)

Polarimeters: Compton-Scattering $e^{-}\gamma \rightarrow e^{-}\gamma$

Concept:

- circularly polarised laser
- energy spectrum of scattered e^{-} depends on P
- want high statistics $\rightarrow$ many scatterings per bunch
- magnetic chicane $E \rightarrow x$
- Cherenkov hodoscope detector
- asymmetry w.r.t. laser helicity:
  $P(e) = \frac{1}{P_{\lambda} \cdot AP} \frac{N_L(x) - N_R(x)}{N_L(x) + N_R(x)}$





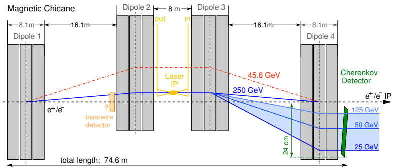
dominant systematics:

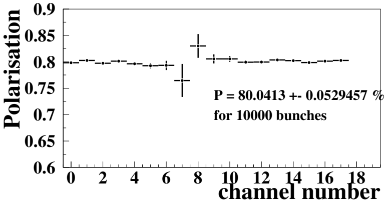
Analysing Power AP (0.2%), detector linearity (0.1%)

Polarimeters: Compton-Scattering $e^-\gamma \rightarrow e^-\gamma$

Concept:

- circularly polarised laser
- energy spectrum of scattered e^- depends on P
- want high statistics → many scatterings per bunch
- magnetic chicane $E \rightarrow x$
- Cherenkov hodoscope detector
- asymmetry w.r.t. laser helicity: $P(e) = \frac{1}{P_\lambda \cdot AP} \frac{N_L(x) - N_R(x)}{N_L(x) + N_R(x)}$





dominant systematics:

Analysing Power AP (0.2%), detector linearity (0.1%)

Error Budget (factor 2 down from SLD)

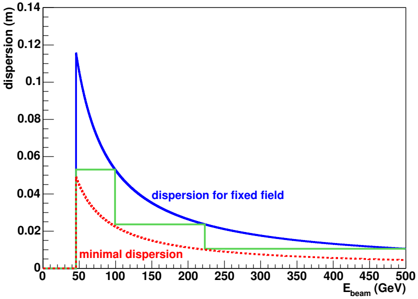
- analyzing power: 0.2%
  - no preradiator needed
  - chicane magnets: negligible
  - relative edge position w.r.t. beam $\mathcal{O}(0.5\text{ mm}) \rightarrow 0.1\%$
- detector linearity 0.1%
- laser 0.1%
- false aymmetries $< 0.1\%$ (unexpected effects!)

$\Rightarrow$ **in total: 0.25%, but tight!**
high redundancy crucial for precise AP and detector calibration!

Scaled vs Fixed Field Operation

Dispersion Ranges

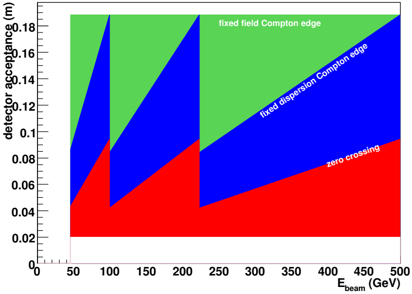
- fixed field dispersion, defined by emittance constraints
- detector constraint: at least two channels below asymmetry zero crossing
- minimum three dispersion ranges, minimal scale factor of magnetic field w.r.t. to fixed field: 0.45



Scaled vs Fixed Field Operation

Detector Coverage

- fixed field: detector coverage independent of E_{beam}
- scaled field: detector coverage shrinks with field scale factor
- zero crossing position

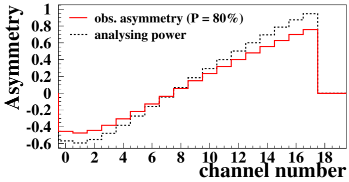


⇒ detector performance — and thus $\delta P/P$ — will depend on E_{beam}!

Calibration consequences

Calibration of Edge Position

- calculation shown before assumed perfect knowledge of detector position relative to beam
- real life: need to determine from data!
- one important point: Compton edge
  - look for last non empty detector channel
  - fit neighboring channels, extrapolate to last channel
  - difference of extrapolated and observed difference → edge position within last channel

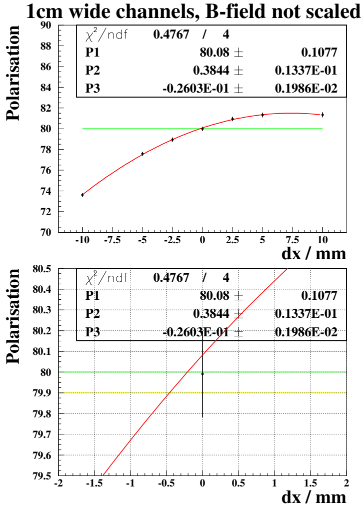


Calibration consequences

Calibration of Edge Position

- calculation shown before assumed perfect knowledge of detector position relative to beam
- real life: need to determine from data!
- one important point: Compton edge
- scan over various misalignments

fixed field: $\delta P/P = 0.1\%$
$\Rightarrow$ calibrate egde position to
$\delta x = 0.4$ mm

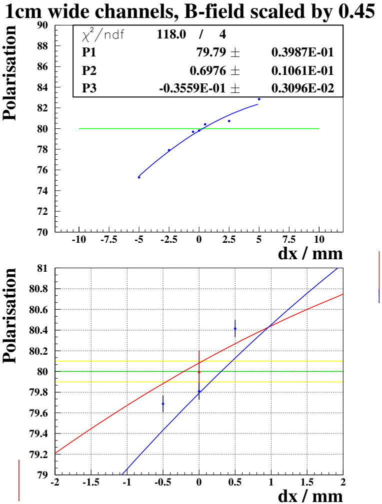


Calibration consequences

Calibration of Edge Position

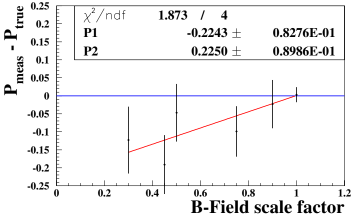
- same for scaled field
- larger part of spectrum in one channel
- edge position determination from data less reliable
- polarisation more sensitive to edge position:

fixed field: $\delta P/P = 0.1\%$
$\Rightarrow$ calibrate egde position to
$\delta x = 0.2$ mm



Polarisation consequences

- scaled field needs better calibration
- **but:** effective position resolution of detector worse (larger part of spectrum / channel)



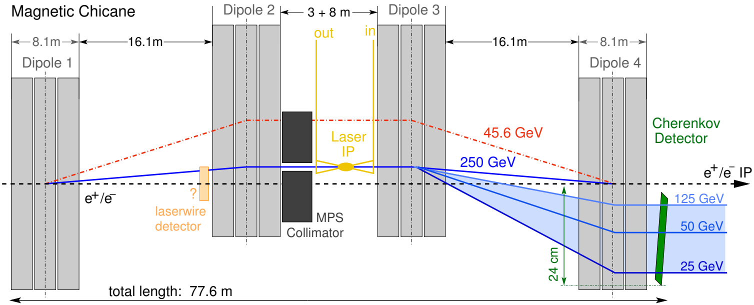
- MC studies (syst. error = difference to true edge):
  - fixed field: $x_{edge} = (19.760 \pm 0.024(stat) \pm 0.003(syst))$ cm
  - scaled field: $x_{edge} = (8.622 \pm 0.010(stat) \pm 0.271(syst))$ cm
- effect of getting edge wrong is a **bias in measured polarisation!**

To be investigated:

- with other detector technologies higher granularity possible?
- but: cost/channel $\simeq$ constant, i.e. 10 $\times$ more channels $\Rightarrow$ detector costs go up by factor of 10...
- TESLA TDR numbers for detector (kEuros, 2000):
  - detector: 50
  - cables: 10
  - readout / electronics: 165
- one detector 225 kEuro $\rightarrow \times 10 = 2.25$ Mio

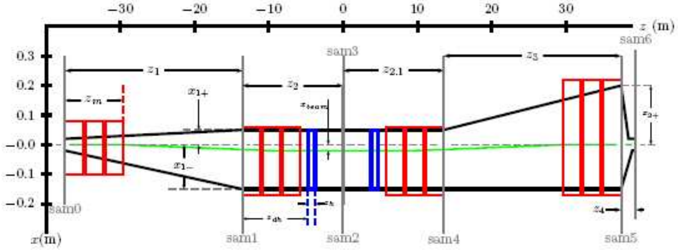
Conflicts with Collimator / Laser Wire

- first remark: scenario completly changed if positron source undulator moved into BDS?!
- but: what happens on the positron side?
- let's still look at the issues...



Collimator conflicts with precision polarimetry

- tapered vaccum chamber:
  - need wide vacuum chamber even with scaled field (3 steps!)
  - classic design carefully avoids wakefields
  - completely obstructed by collimator???



- backgrounds!!! → would need more precise description of collimator for quantitative study
- scaled field scenario → see above!

Laser wire conflicts with precision polarimetry

Backgrounds

- per BX: 370 ± 60 $e^-_{Compton}$ and 320 ± 30 $e^{\pm}$ from $\gamma_{Compton}$
  $\simeq$ 60% of polarimeter signal !!! $\rightarrow$ alternating operation?

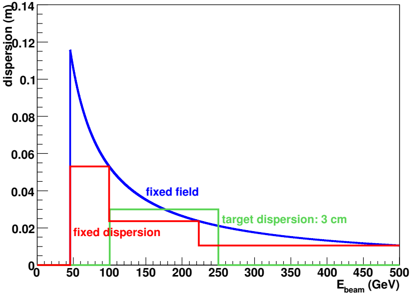
Space constraints

- Photon detection:
  - in direct line of sight of all synchrotron radiation from Linac
  - $\rightarrow$ convert to $e^{\pm}$ $\rightarrow$ creates a lot of background for polarimeter
  - not enough beam clearance at *high* energies
- Electron detection:
  - promissing, without additional backgrounds for polarimeter
  - needs retractable detectors in vacuum chamber
  - scaled field: not enough beam clearance at *low* energies

best compatibility: fixed field, electron detection, share bunches

Minimal Machine: 100 GeV $< E_{beam} <$ 250 GeV

- single fixed field dispersion range
  - minimal scale factor 0.56
  - polarimetry significantly degraded for Higgs precision measurements (or much more expensive detector?)
  - at 250 GeV even larger dispersion → need larger detector by 1.5
    - no upstream polarimetry @ Z
      - ⇒ no calibration of polarimeter at Z
      - Z calibration data definitely useless for physics[1]



[1] c.f. talk by Gudrid Moortgat-Pick in Higgs/EW session

Laser wire / Collimator

- vacuum chamber could be narrow before Compton IP
- but needs to be larger afterwards: last dipole triplet needs $> 30\ cm$ aperture!
- for lower or higher energies complete accelerator region has to be redesigned and rebuilt
- background problems are still the same!
- no fast positron helicity flipping $\Rightarrow$ Z pole would be only chance to calibrate polarimeters against annihilation data (using A_{LR} from SLD[2])
- but polarimeter not operational at Z
- $\Rightarrow$ no calibration with physics data....

[2] but $\sin\theta_{eff}$ in disagreement with A_{FB}^{had}!

Recommendations

1. Separate the functions of the upstream polarimeter chicane. Do not include an MPS energy collimator or laser-wire emittance diagnostics; use instead a separate setup for these two.
2. Modify the extraction line polarimeter chicane from a 4-magnet chicane to a 6-magnet chicane to allow the Compton electrons to be deflected further from the disrupted beam line.
3. Include precise polarisation and beam energy measurements for **Z**-pole calibration runs into the baseline configuration.
4. Keep the initial positron polarisation of 30-45% for physics (baseline).
5. Implement parallel spin rotator beamlines with a kicker system before the damping ring to provide rapid helicity flipping of the positron spin.
6. Move the pre-DR positron spin rotator system from 5 GeV to 400 MeV. This eliminates expensive superconducting magnets and reduces costs.
7. Move the pre-DR electron spin rotator system to the source area. This eliminates expensive superconducting magnets and reduces costs.

BACKUP

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![3]

[3] c.f. „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![3]

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

Synchrotron Radiation