Global scheme for polarimetry

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Disclaimer: This talk summarises ideas, questions and qualitative statement. A quantitative analysis is still needed

Global setup

- Interaction region with $\sim 12\,\text{mrad}$ crossing angle
- DID, antiDID, no DID possible
- Polarimetry from GigaZ to high energy
- With or without positron polarisation
- Aim: $\Delta\mathcal{P}/\mathcal{P} = 0.25\%$ (better would still be useful)

Differences without/with positron polarisation

No positron polarisation:

Cross section $\sigma = \sigma_0(1 + \mathcal{P}_{e^-} A_{\mathrm{LR}})$

- Polarisation error: $\Delta ALR/A_{\mathrm{LR}} = \Delta\mathcal{P}_{e^-}/\mathcal{P}_{e^-}$
- Only average polarisation relevant

With positron polarisation:

Cross section typically $\sigma = \sigma_0(1 - \mathcal{P}_{e^+}\mathcal{P}_{e^-} + (\mathcal{P}_{e^+} - \mathcal{P}_{e^-})A_{\mathrm{LR}})$

- Observables depend on $\mathcal{P}$ and polarisation products
  $\Rightarrow$ (time-) correlations between electron and positron polarisation matter
- Effective polarisation enters in observables
  $\Rightarrow$ polarisation error usually reduced by a factor up to three
  (e.g. $\mathcal{P}_{\mathrm{eff}} = \frac{\mathcal{P}_{e^+}+\mathcal{P}_{e^-}}{1+\mathcal{P}_{e^+}\mathcal{P}_{e^-}}$ for left-right asymmetry)

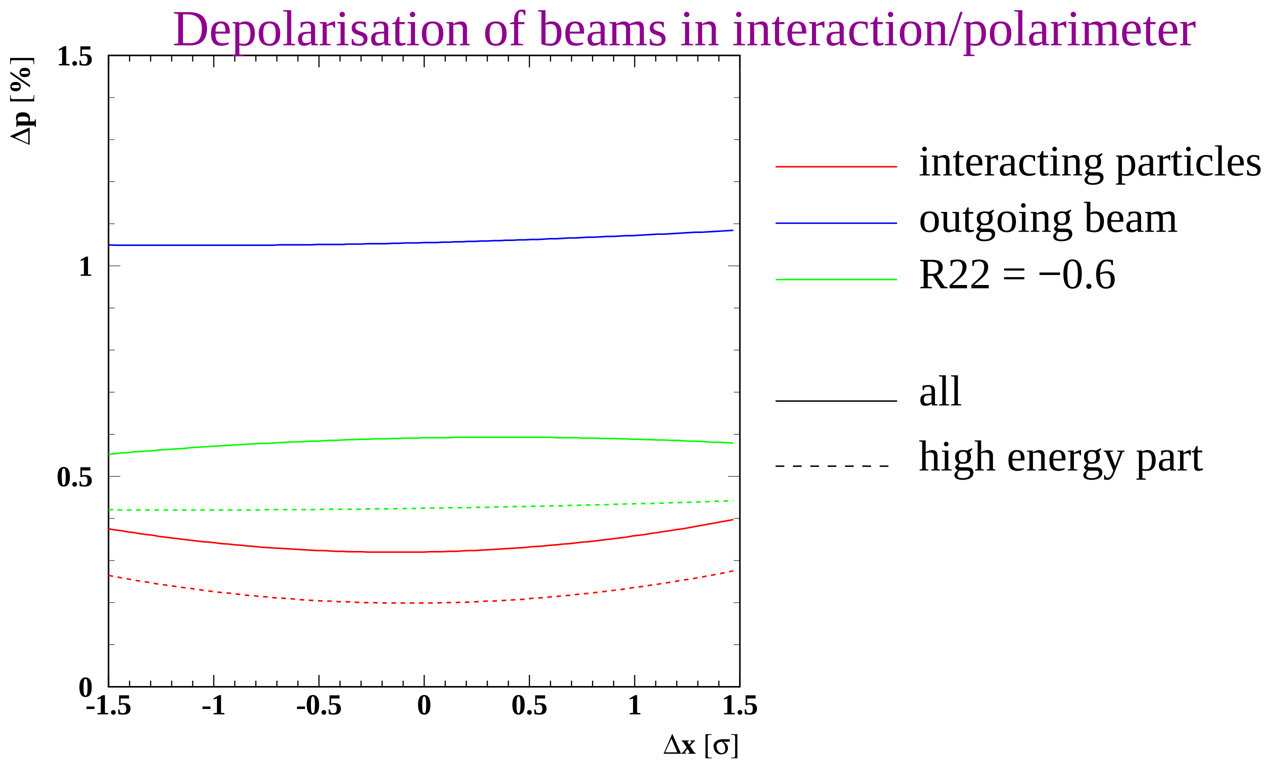
Upstream polarimetry

- Measures polarisation before interaction
- Depolarisation in interaction needs to be calculated
- This introduces unavoidably uncertainties from unknown beam parameters
- (Depolarisation for interacting particles $\sim 0.3\%$ at $500\,\mathrm{GeV}$)
- Clean environment allows measurement of every bunch individually
- Statistical error $\ll 1\%/\mathrm{s}$
- Large variation in analysing power allows internal cross checks like control of a possible polarisation dependent $e\gamma$ luminosity

Downstream polarimetry

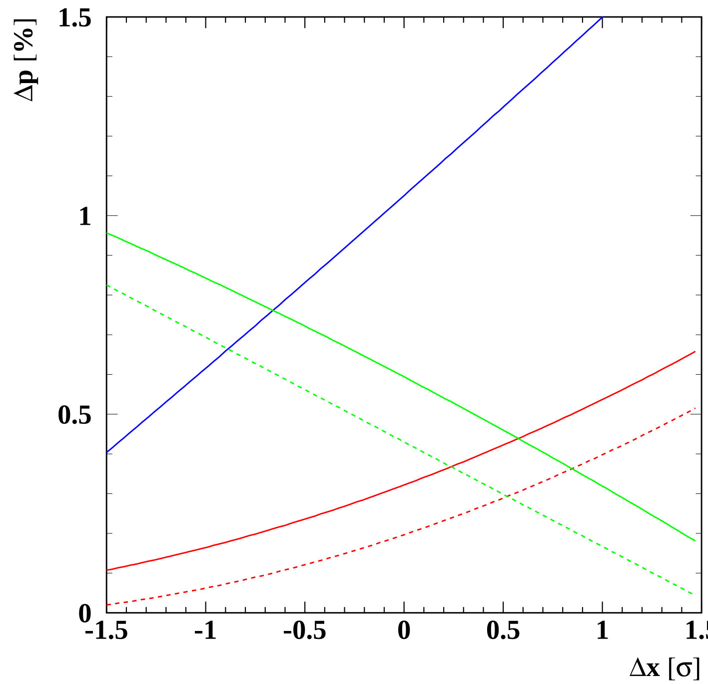
- Because of larger background only measurement of one (three) bunches per train is possible
- Polarisation of beam after interaction is measured
- Polarisation of non-interacting beam can be measured outside collisions
- Depolarisation of outgoing beam is about twice the depolarisation of interacting particles
- However with the right transfer matrix in the extraction line the depolarisation can be adjusted to the one of the interacting particles
- (The matrix trick works only for the (larger) BMT-depolarisation, not for the (small) ST-one)
- Absolute value of matrix can be adjusted relatively easily
- Sign is more difficult, but important if collision is not exactly head-on and spin not perfectly aligned
- Variation in analysing power smaller but should be sufficient

Spin aligned:

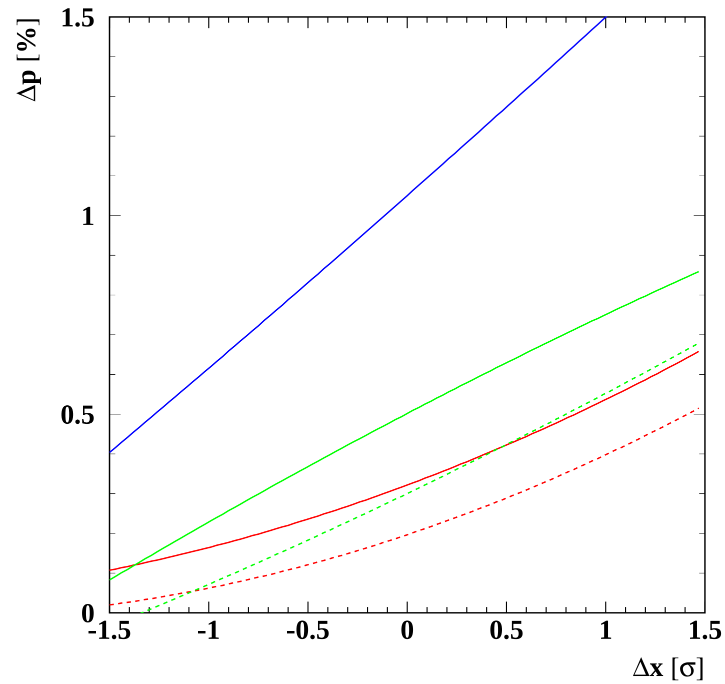


$\theta_{\text{spin}} = 50\,\text{mrad}$

$R_{22} = -0.6$



$R_{22} = +0.6$



Issues of crossing angle and DID

See Mike's talk yesterday

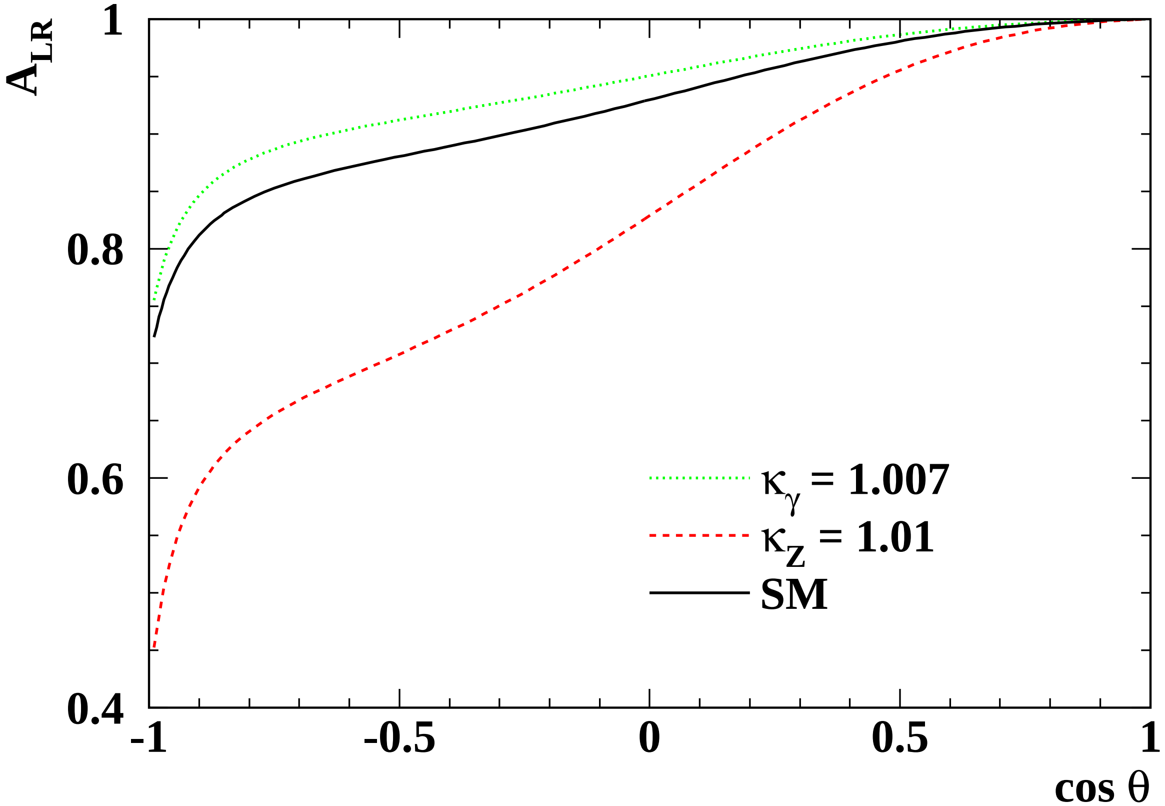
- Spin rotation $\propto (g-2) \cdot \gamma \cdot \int B_{\perp} dl$
- Spin rotation can be up to $\sim 100\,\mathrm{mrad}$ if solenoid and (anti)DID add
- This corresponds to a depolarisation of 0.6%
- Potential problem: spin direction is not perfectly aligned
  $\Rightarrow$ $100\,\mathrm{mrad}$ misalignment corresponds to 1.5% polarisation error
- However only relevant that beam in IP and polarimeter are parallel
- Some compensation scheme is needed
- Can the compensation be changed fast enough for push/pull?

Polarimetry from annihilation data

No positron polarisation

- Cross section $\sigma = \sigma_0(1 + \mathcal{P}_{e^-} A_{\mathrm{LR}})$
- 3 unknowns for two measurements
- In principle no model independent measurement possible
- However W-pair production in forward direction dominated by ν t-channel exchange low t
  $\Rightarrow$ can be reasonably sure on the physics assumption

Left-right asymmetry for W-pair production



With positron polarisation:

- 2-fermion production: $\sigma = \sigma_0(1 - \mathcal{P}_{e^+}\mathcal{P}_{e^-} + (\mathcal{P}_{e^+} - \mathcal{P}_{e^-})A_{\mathrm{LR}})$
- 4 measurements with four unknowns
  $\Rightarrow$ polarisations can be measured in a model independent way

Both cases

- Measurement needs high statistics ➟ takes months
- Polarimeters are needed for left/right differences and, in case of positron polarisation, time dependencies
- In case of scan the statistics might not be sufficient for each scan point
- Polarisation extraction from data requires always some data with all polarisation states

Possible precision

- Both methods offer a precision around 0.1% for $\mathcal{L} = 500\ \mathrm{fb}^{-1}$
- In case of positron polarisation the two measurements are anticorrelated so that the effective polarisation can be even on the 0.02% level
- However in case of positron polarisation there is a significant dependence on a non-equal left and right polarisation and on correlated time dependence
- These effects are larger than for polarimeter-only measurements
- In case of positron polarisation the precision depends on the time spent on the "uninteresting" settings $(++, --)$

Where can $\mathcal{P}_{e^+} - \mathcal{P}_{e^-}$ correlations come from?

- Variations inside a train
- Daily variations from outside temperature etc.
- Long term improvements
- Variations from beam-beam interactions
- Trains, airplanes, football results...

For a quantitative assessment we need a detailed model on possible (correlated) polarisation variations

Global scheme high energy

- Some processes can have up to 10^6 events
- For electron polarisation only and 0.25% precision error might be limited by polarisation uncertainty
- Need all possible cross checks and redundancy
- Complementary between methods:
  - Upstream gives cleanest measurement with highest time granularity
  - Downstream gives access to depolarisation in collision
  - Annihilation data measurement has potential for smaller error when corrections are known from polarimeters (and maybe free!!!)
- Possible scheme:
  - Both polarimeters for cross check and redundancy
  - Annihilation data for absolute calibration
  - Up-stream gives main input for correlations and left-right difference
  - Downstream device gives main input for depolarisation
  - Outside collisions the polarimeters calibrate each other

Global scheme GigaZ

- With 10^9 events the polarisation can only be obtained from the data themselves
- Precise correction factors are needed from polarimeters
- One might consider if one polarimeter is sufficient, depolarisation effects are small on the Z and in the cleaner GigaZ environment a higher frequency laser maybe possible for the downstream polarimeter
- However the polarimeters are there already from high energy running
- At least the downstream polarimeter needs upgrading if the upstream one is dropped

Conclusions

- Polarimetry is an essential part of the ILC detector

- Polarimetry may be the limiting precision for some measurements

- We should make every effort to get the error down

- Only a combination of the schemes can give us the cross checks and redundancy to achieve this goal