Polarimetry at ILC

Daniela Käfer

daniela.kaefer@desy.de

Beam Delivery Meeting, SLAC

January 30, 2007

1. Basics of Polarimetry
   - Why do we want polarised beams?
   - Principle and aim of the measurement
   - Polarimeter requirements
   - Possible location(s)?
2. Assembly of a test bench
   - Concept, setup and photos
   - Planned measurements
3. Detector MC simulations. . .
   - Perfect detector
   - Linearity $\leftrightarrow$ Non-linearity
4. Summary

Basics
of Polarimetery

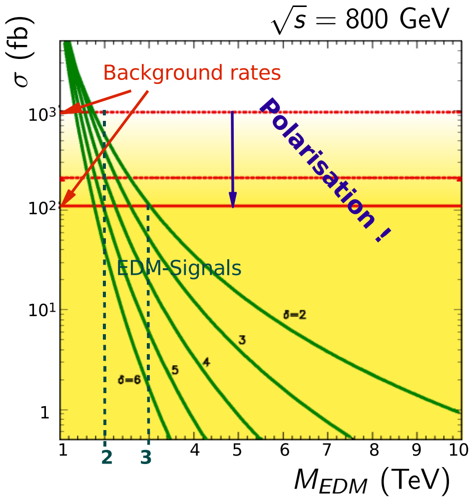
Why do we want polarised beams?

The spin orientation of the colliding e^-/e^+ determines the frequency of the different physical processes. $\longleftrightarrow$ Tuning of the beam polarisation!

- Background events are suppressed while
- the rate of signal events is augmented.

This is important for searches for new phenomena (DM, SUSY, EDM . . .)

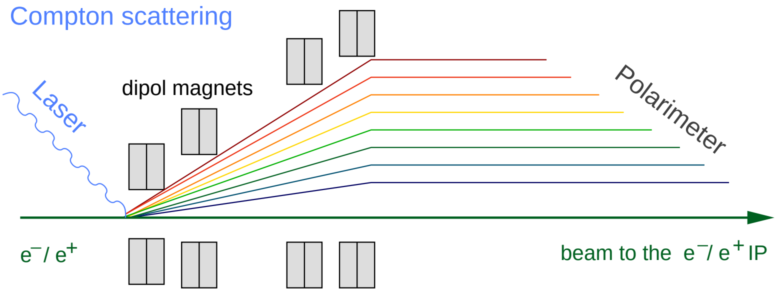
BUT:
The polarisation level must be known precisely $\leftrightarrow$ Measurement!
(a few per mill only)



Principle of measurement I

Compton scattering of laser photons:

- scatter circularly polarised laser light off e^-/e^+ bunches
- about 10^3 e^-/e^+ are scattered per beam crossing
- deflect the scattered e^-/e^+ via dipole magnets ("magnetic chikane")
- measure the energy distribution of the e^-/e^+ (prob. also γ's)

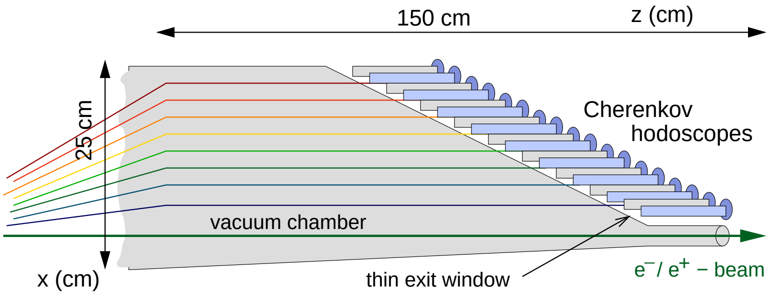


Scheme of the Compton-IP and of the deflecting dipole magnets.

Principle of measurement II

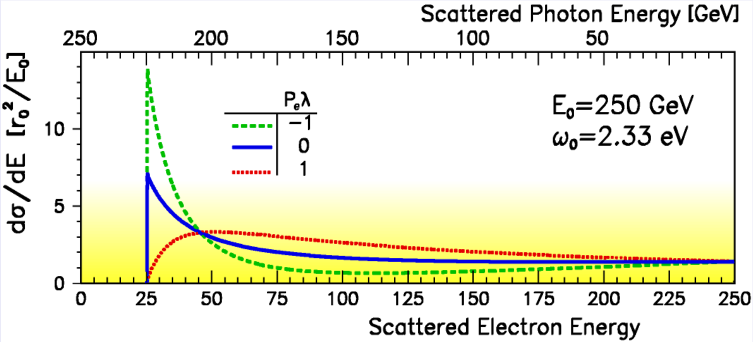
Measurement of the energy distribution via Cherenkov detectors

- incident e^-/e^+ generate Cherenkov radiation
- detection of the Cherenkov photons with photo detectors
- count the photo electrons per channel → linearity important!
  (Size and shape of possible non-linearities need to be measured very precisely and correctd for.)



The aim of the measurement

What should be achieved?



A measurement as precise as possible of the asymmetry generated by laser light of different helicity states. → Level of Polarisation!

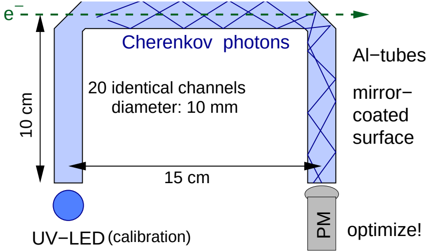
Cherenkov detectors: but how?

Cherenkov-Effekt: $N_\gamma^{\mathrm{Ch}} = \varepsilon^{\mathrm{Ch}} N_e^{\mathrm{Co}}$ $\leftrightarrow$ hodoscope length / refraction index

Photo electrons: $N_e^{\mathrm{Ph}} = \varepsilon^{\mathrm{PM}} \varepsilon^{\mathrm{Att}} N_\gamma^{\mathrm{Ch}}$ $\leftrightarrow$ type of the photo detector!

Variety of techniques available & rapid development (esp. PMs)!

- Concept 1:
  gas tubes + PMs (conventionel)
  similar to SLD polarimeter
  $\rightarrow$ gas? mirror coating?
- Concept 2:
  quartz fibers + SiPMs (new!)
  sensitive area? dynamic range?



Detection method $\longleftrightarrow$ required precision!

Quantum efficiency, sensitive area, light extraction, sensitive range of wavelengths (dynamic range) . . . have to be optimized.

Requirements & Locations

Type of measurement / Precision:

- Measurement of the longitudinal beam pol. $\rightarrow$ energy measurement!
- required precision: $\frac{\delta p}{p} \leq 2.5‰$
  2 times better than the existing SLD polarimeter
- but: time of measurement only $\approx$ 1s due to high interaction rate, ca. $\mathcal{O}(10^3)$ scattered e^-/e^+ per beam crossing (time of meas. of the SLD pol. $\approx$ 3 min.)
- (Additional measurement of the scattered photons?)

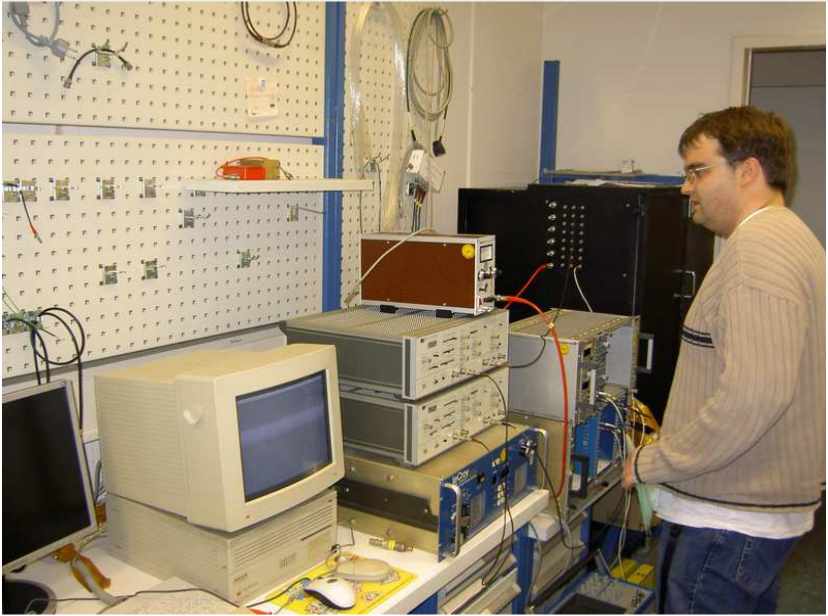
Possible locations - open questions:

- upstream / downstream of the e^-/e^+ IP ?
- only for the e^- beam, for the e^+ beam, or for both beams ?
- Spin transport is difficult to calculate! $\leftrightarrow$ Measurement better...
  but: measurement not directly at the e^-/e^+ IP possible, thus: still calculations & simulations necessary!

Assembly of a Test Bench

Development of a test bench

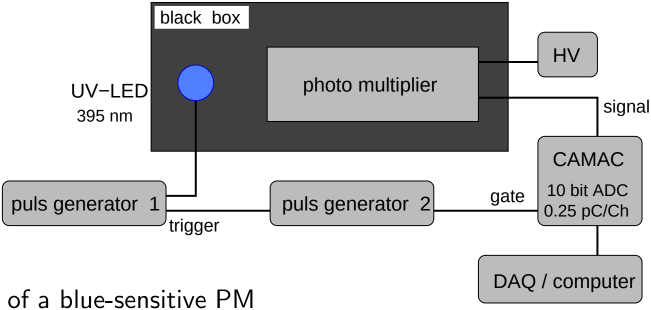
Table-top setup, in September 2006



Test bench setup: Scheme

Analysis of many different components are planned

- linearity of: ADC pulse generator, etc.
- tests with LEDs. . .



- next steps:
  - ▷ Charakterisation of a blue-sensitive PM
  - ▷ Comparison with SiPM + Quartz fibers
  - ▷ Investigation of temperature effects
- later: Assembly of Cherenkov counters, etc.
- . . . and. . . . . . some time in the future: a first proto type.

Software concept

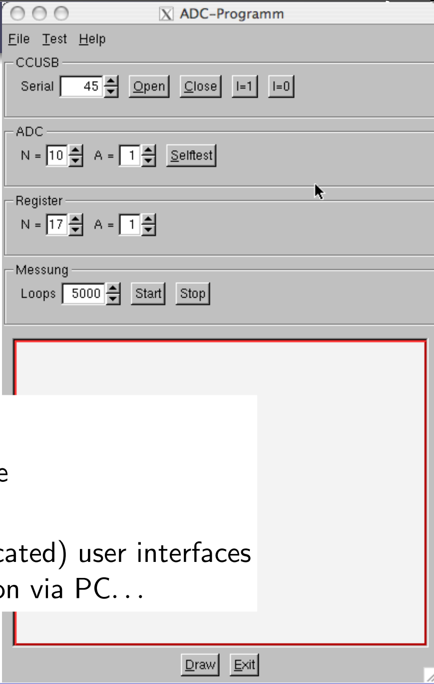
concept: modular setup

- Steering: high voltage, number of channels, etc.
- Slow Control: temperature, low voltage, etc.
- Data acquisition. . .

Initially: pursue two tracks:

- LABVIEW:
  - ▷ Easy to create user interfaces
  - ▷ Linking with ROOT (analysis) more complicated
- C/C++ and Java(?):
  - ▷ also easy to program (use of libraries)
  - ▷ Linking with ROOT much easier
  - ▷ Java for the creation of user interfaces?

Software status

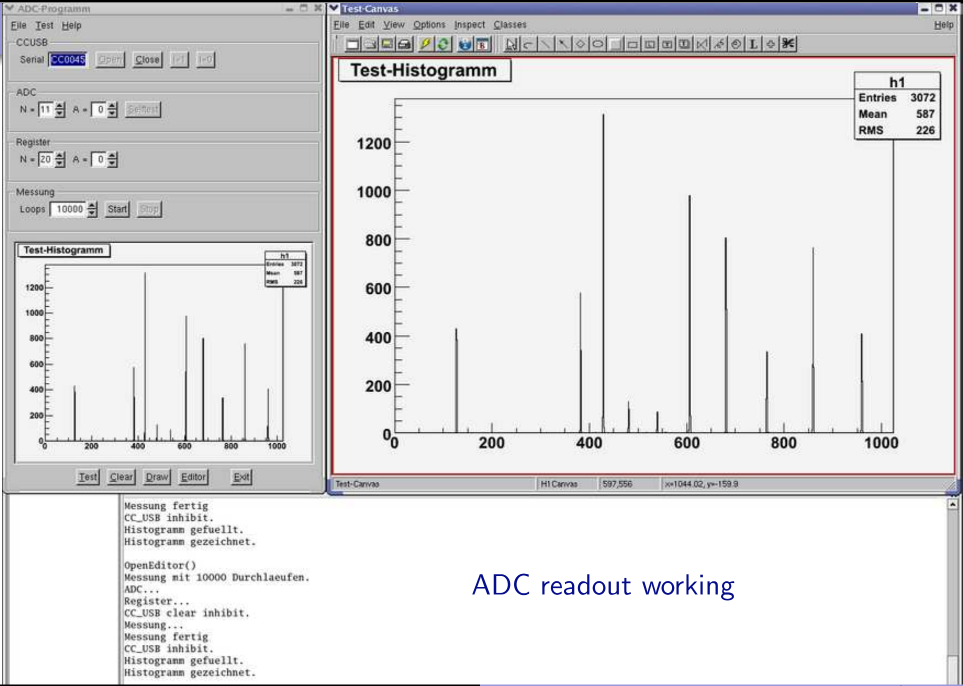


up to now:

- Communication Soft- ↔ Hardware is working: LABVIEW & C/C++
- Crate Controller & ADCs tested
- Data Acquisition

Next steps:

- Development of simple user interfaces
- Decision for one programming language
  LABVIEW or C/C++ and Java
- Development of further (more sophisticated) user interfaces for steering, control and data acquisition via PC. . .



ADC readout working

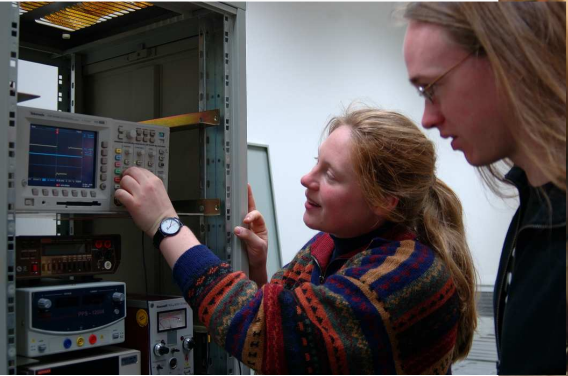
Test bench - photos I

Separation into "two sites":

- Software/DAQ (new devel.)
- Hardware (old DAQ-system)

Status: Dezember 2006

Test bench - photos II

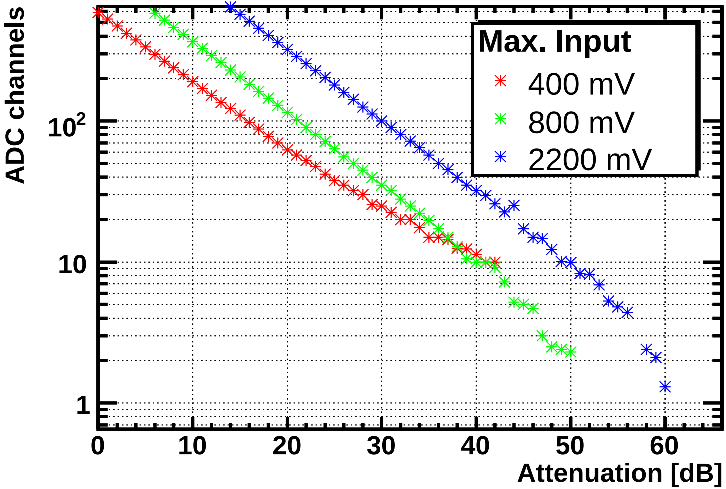


another photo session. . .

Dezember 2006

First Measurements

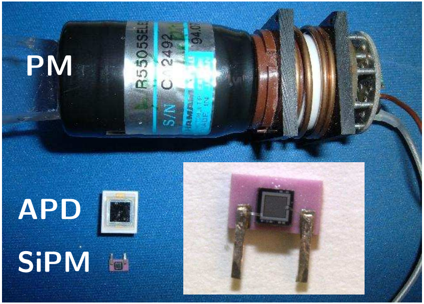
Linearity of the ADC for different input voltages [mV]



Aside:

PMs – SiPMs

Photo detectors in general



- conventional PMs
- APDs (Avalanche Photo Diods)
- HPDs (Hybrid Photo Diods)
- SiPMs (Silicon PMs)

... some properties:

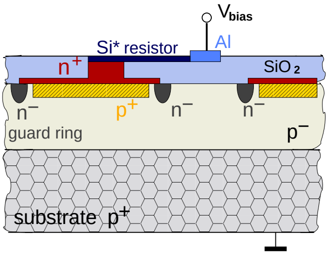
		PM	APD	SiPM
Quantum	blue	20 %	50 %	12 %
efficiency	green	a few %	60-70 %	15 %
	red	<1 %	80 %	15 %
Amplification (Gain)		10^6-10^7	100-200	10^6
Threshold ($S/N \gg 1$)		1 photo-e^-	$\approx$ 10 photo-e^-	1 photo-e^-
dynamic range		$\approx 10^6$	large	$\approx 10^3/mm^2$

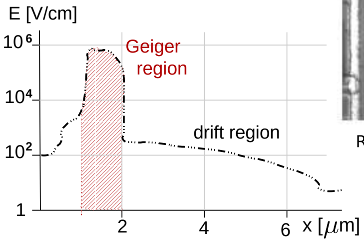
APD/SiPM: low operating voltage (100 V/10 V), insensitive to magnetic fields

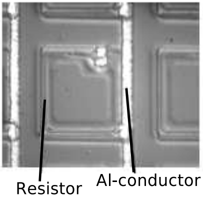
Silicon photo detectors I

Short overview of SiPMs:

- new photo detectors based on semi-conductor technology
- Avalanche Photodiode with many pixels, operated in Geiger mode
- about 10^3 pixel$/mm^2$, $R_{pixel} \approx 400$ kΩ, $C_{Pixel} \approx 50$ fF $\longrightarrow$ Gain $\approx 10^6$
- industrial mass production (Hamamatsu): $\sim \mathcal{O}(1$ Euro) low priced!
- usage within the ILC calorimeter: intensive analyses before choosing the scintillating fibers







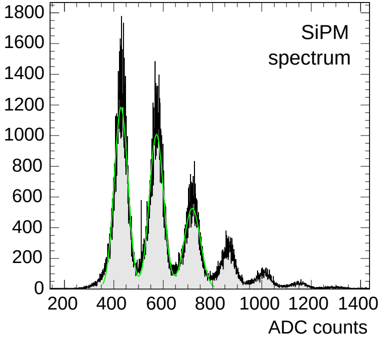
Silicon photo detectors II

Soon available:

- New developments of SiPMs (by Hamamatsu)
- larger sensitive area (up to 5 cm^2)
- much better sensitivity for blue and near UV light!

But: new SiPMs need detailed testing:

- dynamic range, spectra
- stability, linearity, etc.
- temperature effects
- (behaviour in magnetic fields)



Detector
MC Simulations

Start: on the detector surface!

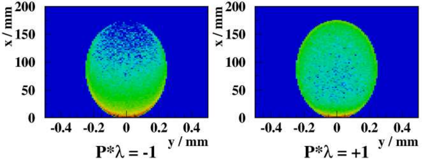
⇓

simulation of:

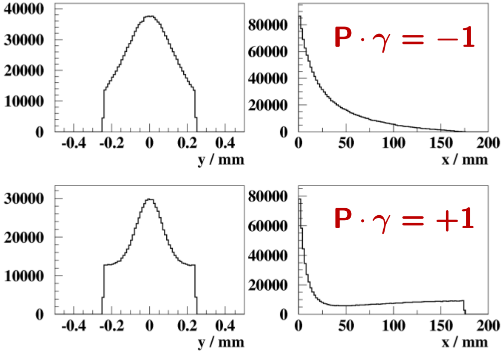
- Compton scattering
- beam & laser parameters
- deflecting dipole fields

⇓

Position distribution of e^-/e^+ on the detector surface

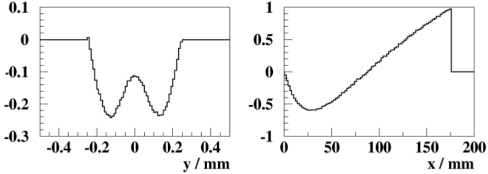


y [mm] projections x [mm]



⇓

y [mm] asymmetries x [mm]



Detector simulation - setup

Start with a general photo detector:

- Size & geometry of the channels
- Output: $\approx$ number of Compton electrons (+ syst. effects)

Add other modules: e.g. gas filled tubes + PMs (as in TESLA TDR)

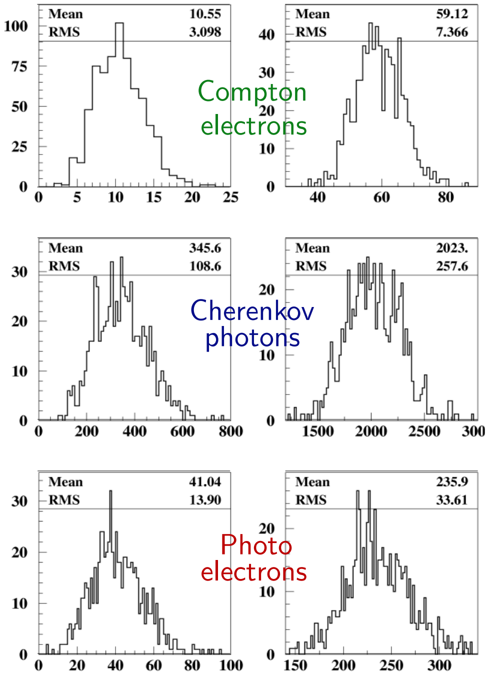
- Number of channels (20) $\rightarrow$ Cherenkov spectrum
- Losses due to reflection/refraction
- Quantum efficiency of the photo detectors
- Non-linearities of ADCs, photo detectors, (others devices?)

Detector simulation I

Ansatz: ideal detector

- no systematic effects
- Example: channel 15
  $\approx$ 30 Cher.-γ (300-600 nm)
  $\approx$ 3/4 Photo electrons (12%)
- Number of $e^-_{Compton}$ varies between 1. . . 250 per channel and beam crossing

- optimize the design parameters one by one. . .
- later: utilize realistic resolution



Detector simulation II

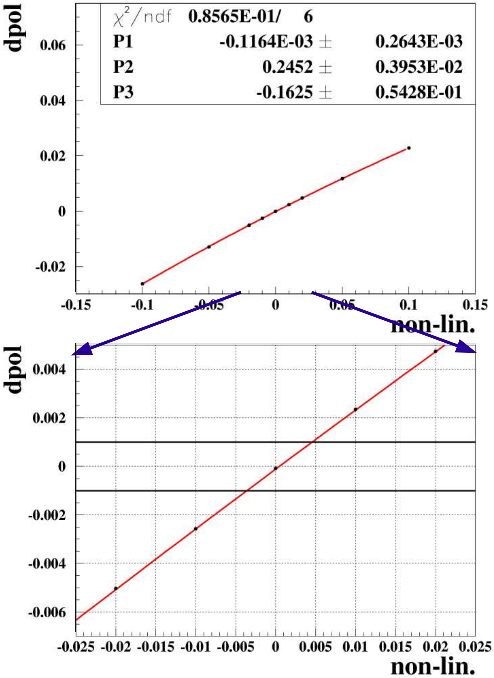
Example of a simulation:
quadratic non-linearities

- vary the size by: -10%. . . +10%
- otherwise: ideal detector

⇓

Control non-linear effects down to 0.5% in order to reach a precision of $\delta P/P = 0.1\%$!

Further:
Consider & investigate other systematic effects



Summary

- Polarisation measurements at the ILC need to be more than 2 times more precise than all previous measurements (incl. SLD polarimeter)
- Design of Laser cavities and dipole magnets ("chikane") done
- Cherenkov detector: design, photo detectors, simulations, . . .
- The required precision has to be achieved!
- Number of polarimeters not yet clear: 3 . . . 8 ?
  (depends on the number of IPs and up-/downstream measurements)
  Spin transport: calculations & simulations are difficult
  $\Longrightarrow$ Measurement is clearly preferred !
- Assembly of a first proto type. . .

BACKUP