Compton Polarimetry after the ILC Dumping Ring

Gideon Alexander[(a)], Pavel Starovoitov[(b)]

(a)Tel Aviv University (b)NC PHEP, Minsk

08 April 2008

Outline

Introduction

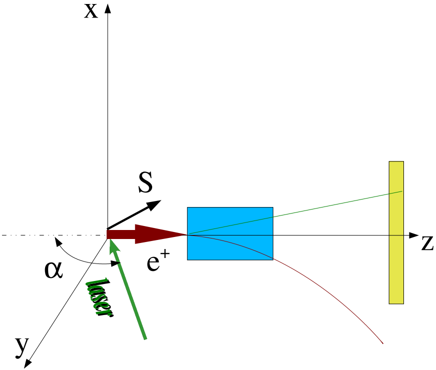
Among the options for the polarimetry of the positron beam near its production region in the International Linear Collider (ILC) we consider here the Compton polarimeter which has been used previously in several electron-positron colliders at their interaction point. Here we study in some details this option at the low energy around 5 GeV where the Damping Ring of the ILC is expected to be located.

A priori there are several methods that can be adopted for Compton polarimetry, among them, one can choose between the detection of the final state photon or the final state positron or one can choose to detect them in coincidence. Furthermore when adopting to detect e.g. the photon final state, one does distinguish between the method known as the Multi-Photon mode and the Single-Photon mode.

As for the laser system one may consider the continuous laser mode or a pulsed laser configuration.

Setup

$$\gamma\left(k_1,\zeta\right)+e^+\left(k2,s\right)\to\gamma\left(p_1\right)+e^+\left(p_2\right)$$



Default	Parameters
Positron energy:	$E_0 = 5$ GeV
Positron spin:	$\vec{S} = (0\ ,0\ ,s_3)$
Laser energy:	$\omega_0 = 2.33$ eV
Crossing angle:	$\alpha = 180^0$

This setup aims at measurement of final state photons.
We want to measure the asymmetry in the energy depositions in a calorimeter, which is proportional to the positron beam polarisation.

Polarimeter options

There are number of options for a polarimeter

- Crossing angle (head-on or perpendecular γe^+ collision)
- Longitudinal or transverse positron beam polarisation (before or after spin rotator)
- Laser system parameters (laser energy, pulsed or continuous mode, etc)
- Detection of the scattered photons or the scattered positrons or the measurement the two together in coincident

Laser system parameters

- Continuous wave laser operating at $P_L = 1$ W. Crossing angle $\alpha = \pi$.

$$\mathcal{L} = 0.4 \times 10^{27} \frac{1}{cm^{-2}s^{-1}} \rightarrow \text{ Rate } = \frac{227\gamma}{s} = \frac{2events}{100 \text{ bunches}}$$

- Pulsed laser@3MHz. Pulse duration 10ps. Pulse energy 10μJ. Crossing angle $\alpha = \pi$.

$$\mathcal{L} = 7.2 \times 10^{30} \frac{1}{cm^{-2}s^{-1}} \rightarrow \text{ Rate } = \frac{4 \times 10^{6}\gamma}{s} = \frac{300events}{\text{bunch}}$$

The choice between CW and Pulsed lasers is equivalent to the one of Single-Photon and Multi-Photon modes.

Detector mode

Single-photon mode

The advantages are:

1. Can choose large asymmetry;
2. Easy comparison with $d\sigma/d\omega$;

The disadvantages are:

1. Needs long time to achieve, say a precision of $\Delta P/P = .01$;
2. Detector is more complex;

Multi-photon mode

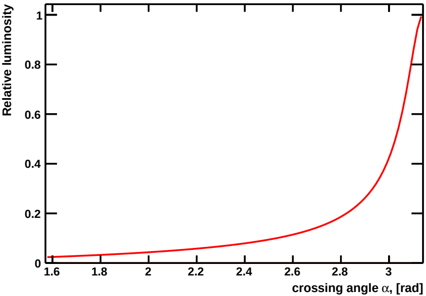
The advantages are:

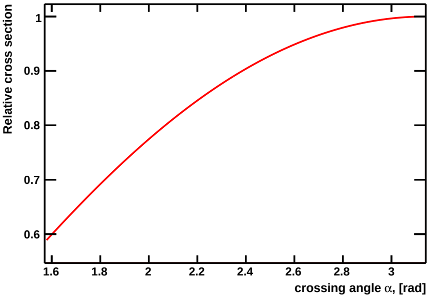
1. Essentially independent of Bremsstrahlung background and detector cutoff energy;
2. Needs much shorter time to arrive to say $\Delta P/P = .01$;

The disadvantage is:

1. No easy monitoring of calorimeter performance.

Luminosity and cross section vs crossing angle

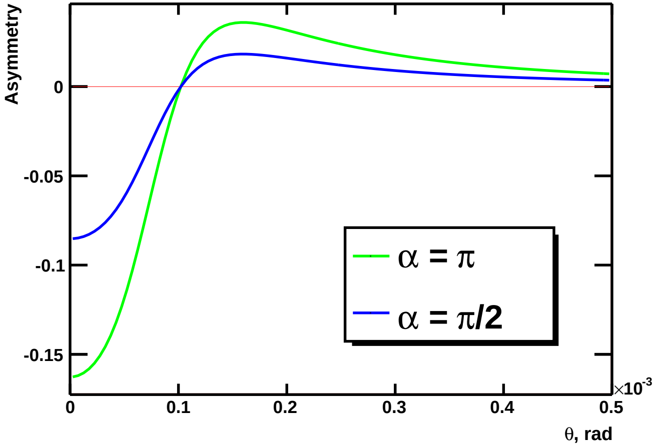




The relative luminosity(left) and relative total cross section(right) as a function of the crossing angle between incident positron and laser beams.

Asymmetry vs crossing angle

Longitudinal positron beam polarisation



Differential cross section asymmetry as a function of the polar angle of a final photon. Two different value of crossing angle between incident positron and laser beams are presented.

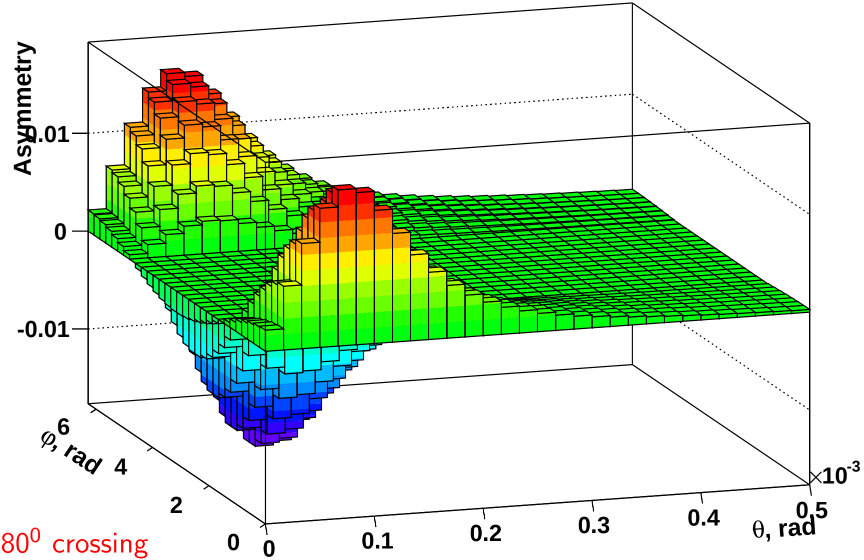
Crossing angle summary

With $\alpha = \frac{\pi}{2}$ crossing angle

- Luminosity is reduced by two orders of magnitude
- Cross section is reduced by a factor of ~ 1.5
- Asymmetry is reduced by a factor of ~ 2

Head on collisions provide more precise and fast measurement of the beam polarisation

Asymmetry due to transverse positron beam polarisation

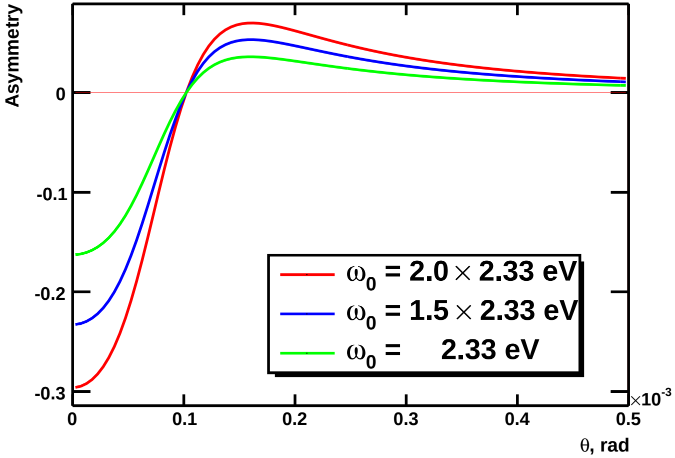


180^0 crossing

Transverse polarisation summary

- Luminosity and cross section are the same as for the longitudinal beam polarisation
- Asymmetry is very small $\sim 1 \div 2\%$
- One have to use quite complicated detector to resolve the φ dependence

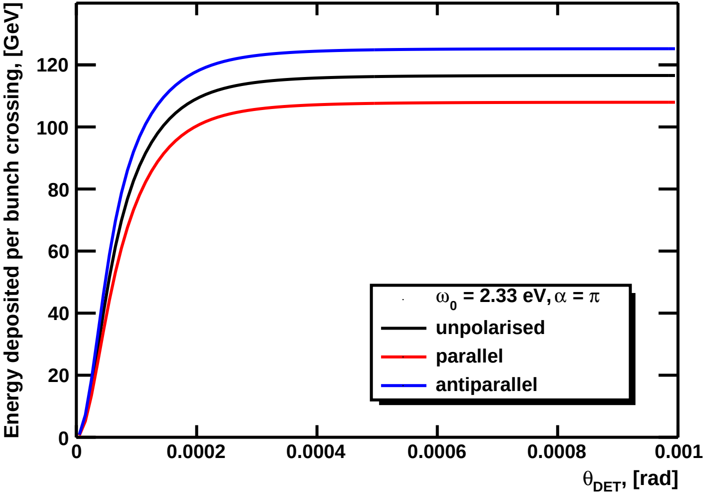
Longitudinal Positron Beam Polarization I



Differential Compton scattering asymmetry as a function of final positron scattering angle. Asymmetry for several laser energies is shown.

Longitudinal Positron Beam Polarization II

Pulsed laser



Energy deposited in a detector as a function of its angular acceptance

Detector parameters

For pulsed laser we will get

parallel spins: 301 photons depositing 108 GeV

antiparallel spins: 323 photons depositing 125 GeV

for each bunch crossing

For the measurement of the longitudinal positron beam polarisation we would need single crystal calorimeter.

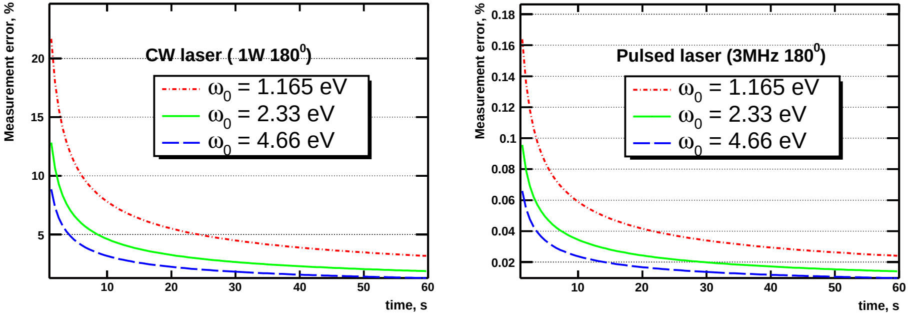
- Radius of the crystal $\sim$ 0.5 mrad $+2 \div 3 R_M$. Length $15 \div 20\ X_0$
- Characteristic time $<$300ns (bunch spacing) to avoid pile-up
- good radiation hardness

Probably BGO or PbWO?

Measurement error

Here we select a polarimeter calorimeter with an energy resolution of the form:

$$\frac{\sigma}{E} = \frac{10\%}{\sqrt{E(GeV)}} .$$



The relative error of asymmetry measurement as a function of the measurement time for a 5 GeV positron beam and laser energies ω_0 of 1.165, 2.33 and 4.66 eV

Summary & Outlook

- The asymmetry in total energy deposition due to the longitudinal positron beam polarisation is $\sim 15 \div 30\%$ depending on laser energy
- Longitudinal positron beam polarisation could be measured with very high accuracy within several seconds with a quite simple detector

Next steps

- Simulations for realistic beam conditions
- Background studies