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POLARISATION MEASUREMENT AT HERA II*

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After its recent upgrade, the HERA storage ring will provide longitudinally polarised leptons not only to the fixed target experiment HERMES, but also to the two collider experiments H1 and ZEUS, requiring a more precise polarisation measurement compared to run I. The upgrade of the transverse polarimeter is nearly finished and shows first promising results indicating a much improved performance. An upgrade of the longitudinal polarimeter is underway.

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1. Introduction

While the main objective of the HERA upgrade has been an increase in luminosity, an additional aspect concerns the installation of two additional pairs of spin rotators around the interaction regions of the collider experiments H1 and ZEUS. As routinely shown during the HERA I run at the HERMES experiment, the spin rotators allow to convert the transverse polarisation, which builds up in a storage ring via the Sokolov–Ternov effect [1], to longitudinal polarisation and *vice versa* [2]. In the kinematic region of high momentum transfer Q^2, the neutral and charged current cross sections observable by the collider experiments depend on the longitudinal beam polarisation, thus providing important opportunities to test the electroweak sector of the Standard Model as well as to search for new phenomena in a manner complementary to e^+e^- or $p\bar{p}$ colliders. For a more detailed review of the HERA II physics programme see [3].

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To illustrate the precision requirements on the polarisation measurement, consider the measurement of the vector and axial vector couplings of the up and down quark to the Z boson, which will be possible at HERA II due to the polarisation dependence of the neutral current cross section via the Z exchange and γZ interference terms. The expected 1σ precision of such a measurement for the up quark is shown in Fig. 1 by the dashed ellipse, compared to the corresponding result for the charm quark by the LEP electroweak working group. Fig. 1 furthermore demonstrates the importance of a precise knowledge of the beam polarisation, since a 1% bias in the polarisation leads to the dotted ellipse instead of the dashed one. Hence, understanding the polarisation measurement down to the subpercent level is important for electroweak physics programme at HERA II.

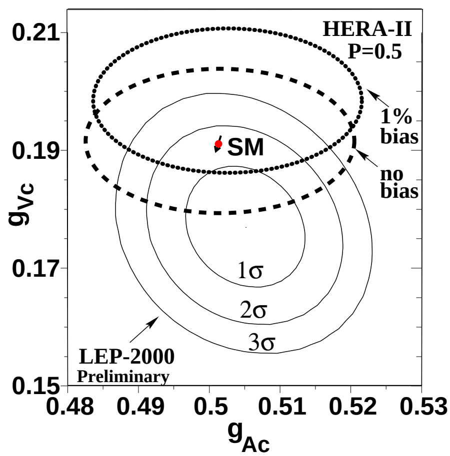

Fig. 1. Expected precision of the HERA II measurement of the vector and axialvector couplings of the up quark to the Z boson, compared to the corresponding measurement for the charm quark at LEP. The effect of an 1% bias in the polarisation is also shown [4].

2. The polarisation measurement at HERA

The longitudinal (LPOL) as well as the transverse polarimeter (TPOL) make use of the polarisation dependence of Compton scattering. In both cases, a circularly polarised laser is focused on the lepton beam, and the backscattered Compton photons are detected in a calorimeter. The helicity of the laser can be flipped between right and left handed using a Pockels cell, leading to a cross section asymmetry depending on the degree of lepton polarisation. In case of the LPOL, it is sufficient to measure the energy of the Compton photons, since longitudinal polarisation leads to an asymmetry in the energy spectrum. On the other hand, the transverse polarisation leads to an angular asymmetry only (which is also energy dependent), so that a measurement of both the photon's energy and scattering angle is required.

2.1. The longitudinal polarimeter

The present LPOL can be operated in two different ways. In the single photon mode the power of the pulsed laser is kept so low that the single photon energy spectrum, which provides prominent features like the Compton edge for calibration purposes, can be measured directly. Due to the laser's low repetition rate of max. 100 Hz this mode does not provide the required statistical precision per minute. Therefore the LPOL is usually operated in the multi photon mode, where the average number of backscattered photons is about 1000 per bunch crossing, of which the total energy is measured. This method reaches a statistical error of 1% per minute when averaged over all HERA bunches. To deduce the polarisation from the observed energy difference, a thorough understanding of the calorimeter's energy response is essential. In the last years of the HERA I run, the systematic understanding of the LPOL has reached the level of $\delta P/P = 1.6\%$ [5]. The measurement of the LPOL could be substantially improved with a continuous wave laser. In order to reach the required power it is planned to upgrade the LPOL with a 1 W cw laser plus a Fabry–Pérot cavity with a Q-factor of the order of 10000 as shown in Fig. 2. This setup will allow to operate the LPOL in a few photon mode, which overcomes the statistical problems of the single photon mode in the current setup, while preserving the features of the single photon energy spectrum allowing for precise calibration of the system. A prototype of the LPOL cavity has been built and is operating successfully. The assembly of the final cavity is underway and its installation is expected for end of 2002 or beginning of 2003.

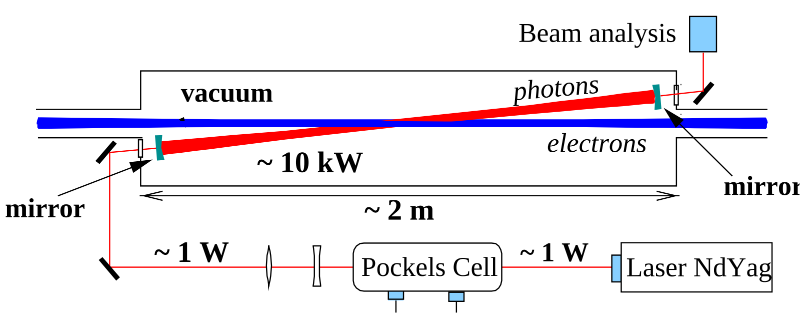

Fig. 2. Schematic view of the laser cavity upgrade for the LPOL

2.2. The transverse polarimeter

In case of the transverse polarisation it is necessary to measure not only the energy, but also the position of the backscattered photon. Therefore the TPOL calorimeter is segmented into an upper and lower half, allowing a position measurement via the up-down-asymmetry of the energy deposition $\eta = (E_{\rm up} - E_{\rm down})/(E_{\rm up} + E_{\rm down})$. The conversion of η into a y-coordinate depends on the exact shower development inside the calorimeter, and has been the dominant source of systematic uncertainty for the TPOL measurement. Therefore a silicon strip detector has now been installed front of the calorimeter, allowing to calibrate the position measurement continuously during polarisation measurement. The present setup comprises also a preradiator and a movable scintillating fibre for monitoring the response of the silicon detector. The first in-situ measurements of the η–y-transformation have been performed and the analysis is ongoing.

Since not all lepton bunches collide with a proton bunch in HERA and the polarisation differs for colliding and non-colliding bunches, it is important to measure the polarisation for every single bunch. This required a completely new and much faster data acquisition system for the TPOL, which now allows bunch by bunch measurements of the polarisation, and which additionally improves the data quality substantially. The first data taken at HERA II with positron currents of about 3 mA give a statistical error of 0.015 per minute, corresponding to less than 0.005 per minute when scaled to nominal HERA II currents.

In order to reach the goal of subpercent precision, also the analysis of the TPOL data is being revised. The online analysis translates the observed cross–section asymmetry into a polarisation value by multiplying it with an analysing power which has been determined for the TPOL setup at HERA I via risetime measurements and which is assumed to be constant w.r.t. to all the parameters of the system, like resolutions, η–y-transformation, beam position and size or the residual linear laser polarisation. This has been shown to be valid within an systematic error of 3.4%. The improved offline analysis takes parameter changes into account by fitting the measured double differential cross section directly, leaving all parameters mentioned above free, thus not assuming any a priori knowledge of for example of the η–y–transformation. First, a fit to the sum of the spectra recorded with right and left handed laser polarisation, which is not sensitive to the lepton beam polarisation, determines all calibration parameters. These are then held constant in a second fit to the difference of the same spectra, which yields the actual beam polarisation. Although the new analysis is not final yet and thus no final number for the remaining systematic uncertainty can be quoted here, the preliminary results shown in Fig. 3 look promising: in the left part two slices of the double differential cross section at different

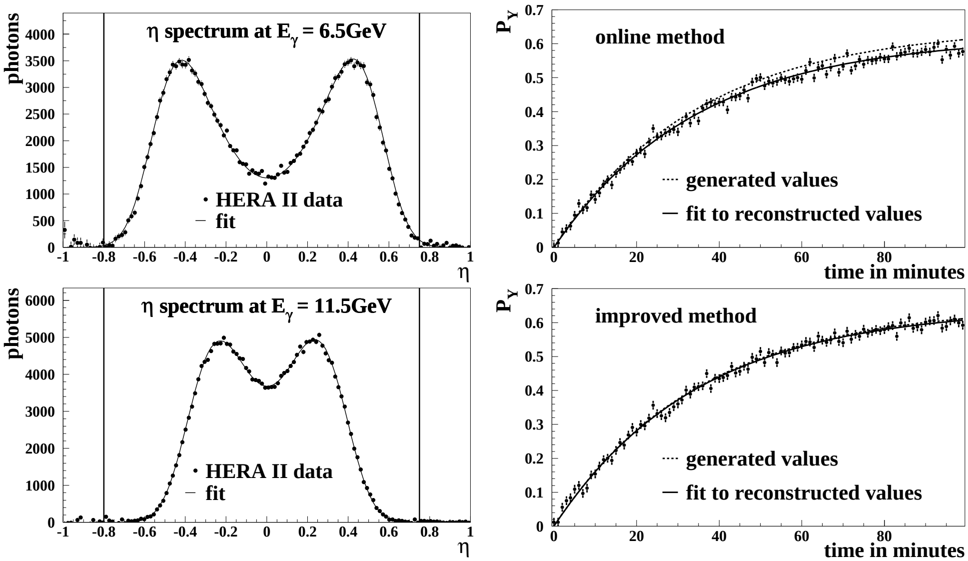

Fig. 3. TPOL analysis upgrade: fit to η distributions in HERA II data (left) and MC studies comparing online and improved analysis method (right).

values of the scattered photon's energy are shown. The dots represent some recently taken HERA II data, while the line shows the result of the fit, which describes the data perfectly ($\chi^2/dof = 1977/1890$). On the right side, a Monte Carlo simulation of 100 minutes of data taking is shown. The light grey line indicates the polarisation values the Monte Carlo was generated at, while the dark grey line is a fit to the reconstructed values shown as dots. In the upper plot, the online method is used for the reconstruction and a small but clear deviation from the generated values can be seen. In the lower plot the new fit method is used, and here the reconstructed values agree very well with the generated ones, indicating the increase in precision.

3. Summary

After the luminosity upgrade, HERA will provide longitudinally polarised leptons not only to HERMES, but also to H1 and ZEUS. The physics programme of the collider experiments requires a precise measurement of the degree of beam polarisation to better than $\delta P/P = 1\%$ per minute, making major changes to both HERA polarimeters necessary. The longitudinal polarimeter will be upgraded by a new laser–cavity, which is currently under construction. The transverse polarimeter has already been successfully upgraded with a new silicon strip detector and a new data acquisition. An understanding of the device down to the subpercent level seems feasible.

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