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Overview of the Systematic Studies on the Hermes Longitudinal Polarimeter during the 2005 HERA Running Period

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Contents

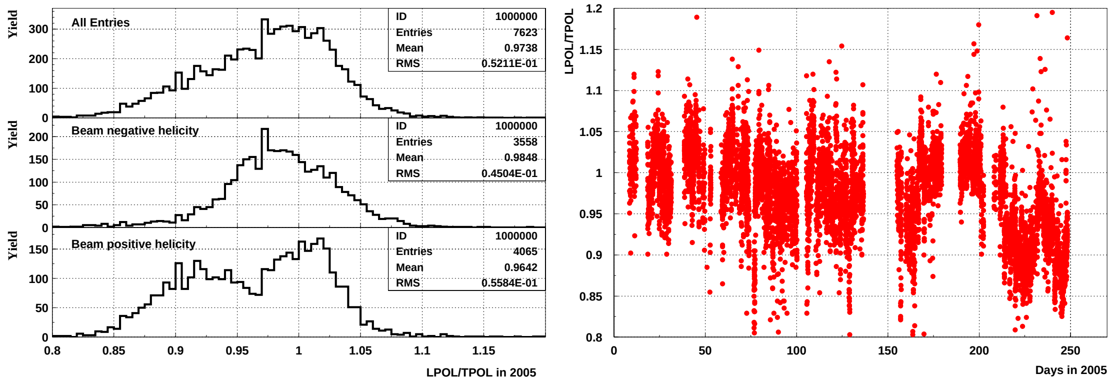


Figure 1: The distribution of the ratio P_{LPOL}/P_{TPOL} from the beginning of 2005 until September 6^{th} 2005. In the top left panel, both helicity states are combined. The measurements for negative and positive beam helicity seperately are shown in the middle and bottom left panel. The measurements of the two HERA polarimeters were in disagreement in August 2005, a period with positive beam helicity, leading to a second peak at a P_{LPOL}/P_{TPOL} ratio of 0.92. The corresponding measurements are consistently below 1 in the right panel.

1 Introduction

The HERMES longitudinal polarimeter (LPOL) is already in operation since 1996, and provides important information for the physics analyses performed at DESY. Its performance is continuously monitored and its results are verified to be reliable and within the cited systematic uncertainty [1].

This requirement has become even more important after the replacement in July 2004 of the original calorimeter crystals, which were cracked due to radiation damage, with a set of spare crystals. The crystals that are currently in use have the same characteristics as the original ones; both sets belong to the same production batch. Consequently, the response of the polarimeter, in particular the *analyzing power*, is not expected to be affected by the crystal replacement. Indeed, the comparison of the measurements by the LPOL and the transverse polarimeter (TPOL) before and after the crystal replacement did not show a measurable difference. Nevertheless, for the LPOL data since July 2004 a conservative systematic uncertainty of 5% was assigned, until subsequent systematic studies could confirm the consistency of the rebuilt calorimeter and the original calorimeter [2].

The need for an extensive systematic study has also been motivated by the observation of a sizeable disagreement between the polarization measurements provided by the LPOL and the TPOL in August 2005. Except for the period in August, the two polarimeters provided measurements in agreement within the statistical and systematic uncertainty, Fig. 1.

This report gives a detailed overview of the most significant systematic studies performed on the LPOL during the spring and autumn of 2005. These studies refer to data collected using the crystal calorimeter, the reference polarimeter for measuring the electron beam polarization in HERMES. Whenever the measurements by the TPOL were considered, the TPOL online data have been used. The results of studies similar to what is shown in a previous report [3] and of additional crucial measurements are reported.

The obtained results show no dependence of the polarization measurement on the possible systematic sources studied. Furthermore, they allow to reduce the systematic uncertainty on the measurements by the LPOL to 2%.

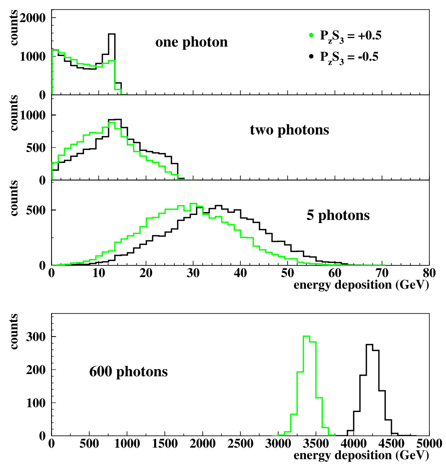


Figure 2: Model calculations for ADC spectra when the laser is firing only few photons (upper panels) and 600 photons (bottom panel). The spectra are shown for realistic conditions with a 50% polarized lepton beam and 100% left and right handed circular polarization of the laser, corresponding to $S_3P_3 = -0.5$ (black) and $S_3P_3 = +0.5$ (green), respectively.

2 Physics Overview and Apparatus Setup

At HERMES, the polarization measurement of the lepton beam (either positrons or electrons) is performed by scattering a laser beam off the leptons. The backscattered Compton photons are detected by a crystal calorimeter 54 m downstream of the interaction point (*IP*). In this section, a brief overview of the physics involved and of the calorimeter are given. For a detailed description the reader is referred to [4, 5].

The differential angular cross section for scattering polarized photons off polarized leptons is given by:

$$\frac{d\sigma}{d\Omega}(\vec{S},\vec{P}) = \frac{r_0 k_f^2}{2m_e k_i^2}\left(\Sigma_0 + \Sigma_1(S_1) + \Sigma_2(S_3,\vec{P})\right), \tag{1}$$

with the photon (lepton) polarization $\vec{S}$ ($\vec{P}$), the classical electron radius r_0, the initial (final) photon momentum k_i (k_f), the electron mass m_e, the unpolarized term Σ_0, and the polarized parts $\Sigma_1(S_1)$ and $\Sigma_2(S_3,\vec{P})$. In particular, S_3 corresponds to the circular polarization of the photon, and for perfectly circularly polarized light $S_1 = S_2 = 0$.

The longitudinal polarimeter LPOL exploits the dependence of the cross section on the energy of the scattered photon E_γ, by measuring the asymmetry of the energy deposition integral in the calorimeter for left (I^-) and right (I^+) circularly polarized photons and longitudinally polarized lepton beam.

In this case is $P_x = P_y = 0$, $\Sigma_1 = 0$, and:

$$P_z = \frac{1}{A\bar{S_3}}\frac{I^+ - I^-}{I^+ + I^-}, \tag{2}$$

with the averaged circular polarization of the laser light $\bar{S_3} = \frac{1}{2}(\mid S_3^+ \mid + \mid S_3^- \mid)$ measured with both the analyzer $AB1$ in the laser room, and with the analyzer $AB2$ in the HERA tunnel after the interaction point with the lepton beam. The *analyzing power* A is calculated using QED and calorimeter test beam calibrations.

The energy deposition integral is measured by operating the HERMES polarimeter in the so-called *multi-photon mode*, by detecting many backscattered Compton photons in one collision between the laser and the positron bunch. This mode allows a better separation of the ADC spectra with left and right circular laser polarization, as shown in Fig. 2. Also, while operating the polarimeter in this mode the contribution from bremsstrahlung to the energy deposition integral becomes negligible [6].

3 Dependence on the Energy Deposition

The accuracy of polarization measurement depends on the linearity of the crystal calorimeter. During a fill the lepton current decreases and therefore also the energy delivered to the calorimeter decreases.

To check how much a non-linearity of the calorimeter affects the polarization measurement, data was collected while delivering different amounts of energy to the detector by changing the intensity of the laser. This procedure was performed by varying the laser attenuation factor provided by an optical laser attenuator located in the laser beam path. The intensity of the laser light deposited in the calorimeter during the systematic study was monitored by measuring the ADC signal generated by the Compton photons. During normal operation the laser is operated at an energy of 200 mJ per pulse and a repetition rate of 98 Hz with a power $P_{laser} = 19.6\,\mathrm{W}$. The nominal laser attenuator factor is 0.19, resulting in effectively $\approx 3.8\,\mathrm{W}$ delivered through the laser transport system.

The results of the measurements taken in August and September 2005 are shown in Fig. 3, where for each plot the upper panel shows the change of the ADC signal in the calorimeter ("Luminosity") versus time, due to the change of the attenuation factor. The calorimeter response is plotted in arbitrary units. The ratio of the polarization values taken with the longitudinal and transverse polarimeters ("LPOL/TPOL") is shown in the bottom panel of the plots. The result of a linear fit to the data is also shown. Considering all the measurements, the luminosity has been varied over one order of magnitude.

The result of this systematic study suggests that there is no energy dependence of the polarization measurement by the LPOL.

4 Dependence on the PMTs High Voltage

The sensitivity of the polarization measurement to the luminosity delivered in the calorimeter has been tested by varying the high voltage (HV) applied to the PMTs. Furthermore, when the HV is increased seperately for all four photomultipliers, additional information about an effect from a mismatch of the PMTs HV can be retrieved.

On August 12^{th} 2005, during stable conditions with polarization $\approx 40\%$ and positron current $\approx 20 - 25\,\mathrm{mA}$, the HV was increased by 50 V for both PMT1 and PMT3, and by 140 and 150 V for PMT2 and PMT4, respectively, to mismatch the four photomultipliers artificially. When considering the TPOL measurement as the reference polarization value, the quantity P_{LPOL}/P_{TPOL} has been monitored as a function of time. Fig. 4 shows that by changing the HV and providing an HV photomultiplier mismatch the LPOL polarization measurement remains constant within 1%.

5 Spatial x Scan of the Calorimeter

During a HERA fill the lepton beam and slope drift, resulting in a Compton cone that is not properly centered on the calorimeter. Even though during normal LPOL operation the Compton photons are centered on the crystals by the software to within 1 mm, it is crucial to verify how much a spatial offset of the Compton photons may affect the polarization measurement.

On August 11^{th} 2005, during stable conditions with polarization $\approx 44\%$ and positron current decreasing from 23 to 18 mA, the calorimeter table was moved in the horizontal direction. Because only 3 mm separate the beam pipe from the calorimeter table, a limited horizontal scan ranging from -3 to $+2$ mm was performed.

When considering the TPOL measurement as the reference polarization value, the LPOL polarization measurement was found to be stable within 2% during the x-table scan, as shown in Fig. 5. In the figure, the result from a linear fit to the data is shown.

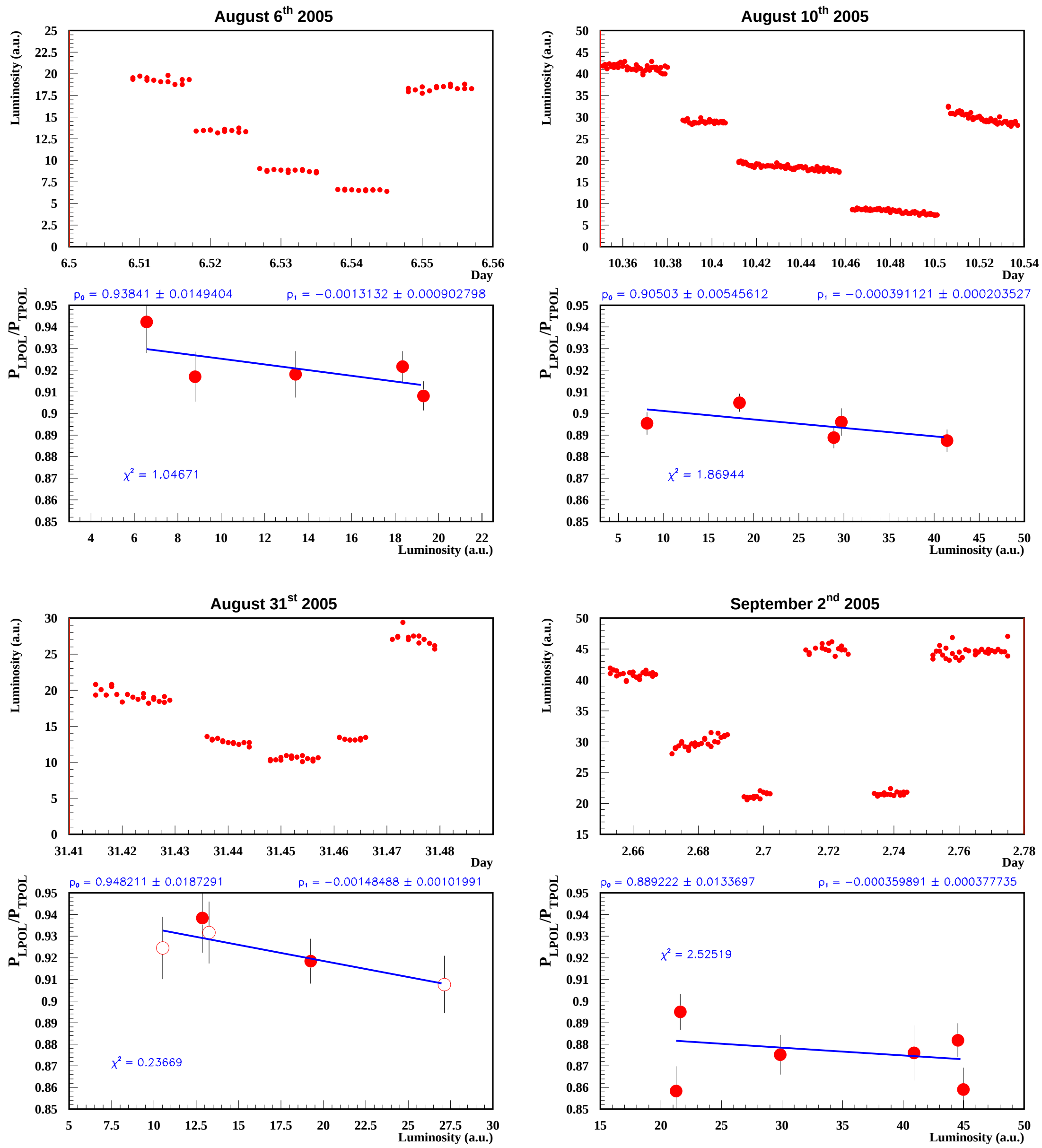
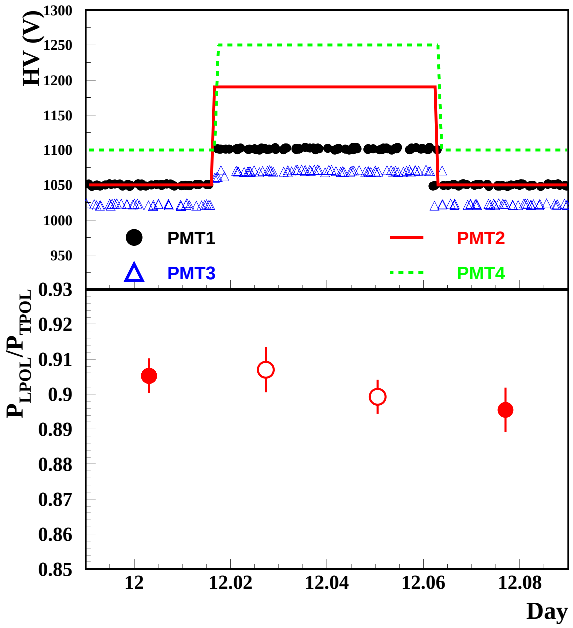


Figure 3: Polarization measurements taken in August and September. The luminosity versus time is shown in the upper panels of each plot. The dependence of the ratio P_{LPOL}/P_{TPOL} on the luminosity is presented in the bottom panels. The open circles refer to the measurements taken during high density runs, when the transverse target magnet was off, different from the normal running conditions.



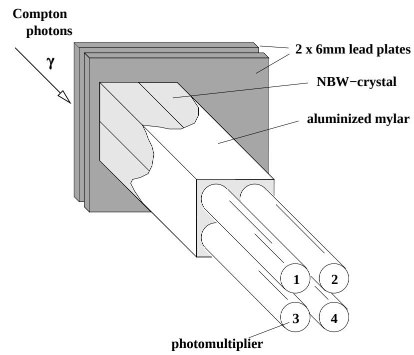


Figure 4: The ratio P_{LPOL}/P_{TPOL} is monitored while varying the HV for the photomultupliers, and is found to remain constant within 1%, as can be seen on the left panel. The location of the different PMTs is shown in the right panel.

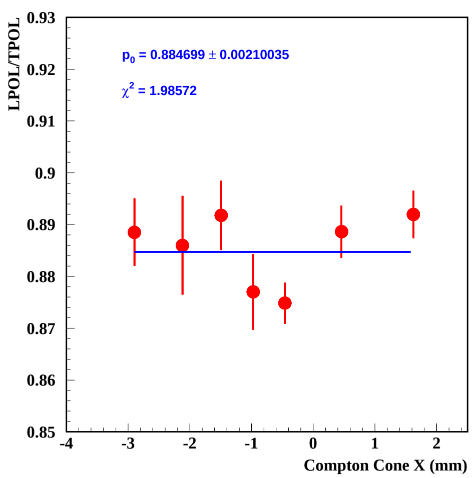


Figure 5: When considering the TPOL measurement as the reference polarization value, the LPOL polarization measurement was found to be stable within 2% during the x-table scan. In the plot, the result from a fit to the data with the constant line $y = p_0$ is shown.

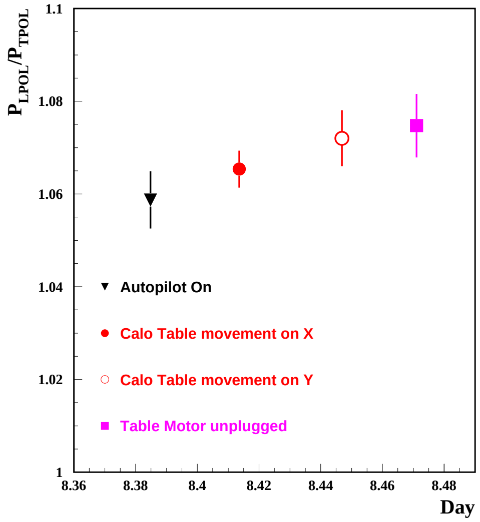


Figure 6: The ratio P_{LPOL}/P_{TPOL} is shown for four different running conditions of the LPOL: normal running mode (triangle), calorimeter deliberately moved continuously in the x (filled circle) and y (empty circle) direction, and with the motor driving the table disconnected from its power supply (square).

6 Noise Introduced by Calorimeter Table movement

During normal LPOL operation the calorimeter is moved by the software to keep the Compton cone centered within 1 mm on the crystals. As a consequence, electrical noise can be induced and propagated into the electronic trailer (ET), thus affecting eventually all ADC values.

To quantify the influence of this noise on the polarization measurement, on November 8^{th} 2005 a dedicated study was performed. This measurement was initially done during normal running conditions, and then while deliberately moving the calorimeter table continuously during the measurement. As a last step, the motor driving the table was disconnected from its power supply to avoid any noise from the power supply itself.

The result of this study is reported in Fig. 6. Possible noise induced by the calorimeter table movement and by the cable connections to the table motor affects the polarization measurement by at most 1%.

7 False Asymmetry

To verify that no false asymmetry between the energy deposition integral of the left and right circularly polarized photons is generated, polarization measurements with the crystal calorimeter were taken with the Pockels Cell (PC) switched off. The scattering of linear polarized laser light off positrons should result in a zero asymmetry measurement, as can be understood from eq. (1).

The results of this study on August 3^{rd} 2005 are shown on Fig. 7. The measurements have a mean value of -0.43 and an estimated uncertainty on the mean of 0.29, indicating that the false asymmetry generated by the hardware is negligible compared to the systematic uncertainty cited for the LPOL.

8 Sensitivity to the Linear Polarization of the Laser

In this section the contribution of the linear component of the laser polarization is shown not to be responsible for the disagreement between the measurements by the LPOL and the TPOL observed in August 2005. In this period the average ratio P_{LPOL}/P_{TPOL} was 0.92, as already shown in Fig.1.

From eq. (1), the differential Compton cross section can be written as a function of the initial lepton and photon polarization $\vec{P}$ and $\vec{S}$. The term $\Sigma_1(S_1)$ depends on the linear component of

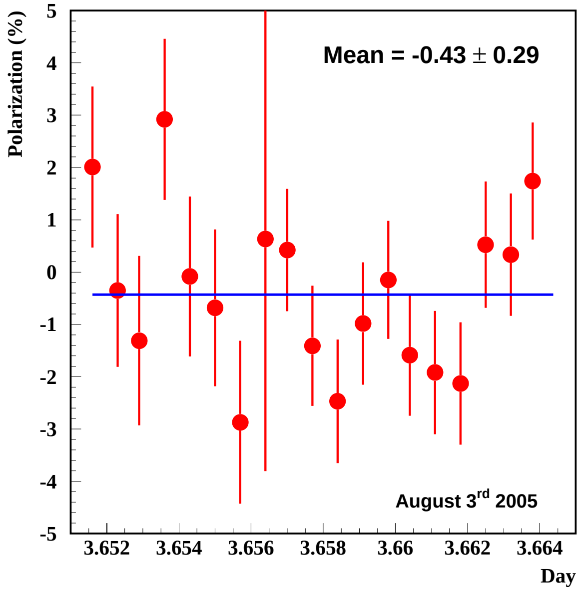


Figure 7: The polarization measurements using the crystal calorimeter when the Pockels Cell is switched off, taken on August 3^{rd} 2005, show no false asymmetry generated by the LPOL hardware.

the photon polarization, and in the laboratory frame its dependency on kinematic variables can be written as [7]:

$$\Sigma_1 \propto cos(2\phi)\sin^2(\theta), \tag{3}$$

where θ and ϕ are the polar angles of the backscattered Compton photons.

The energy-weighted cross section integrated over the angles θ and ϕ in the geometrical acceptance of the detector is measured via the energy deposited in the calorimeter by the scattered photons. The Compton cone cross section has dimensions $\sigma_x = 3.8\,\mathrm{mm}$ and $\sigma_y = 1.1\,\mathrm{mm}$, and during regular LPOL operation the Compton cone is kept centered on the calorimeter. Therefore no geometrical acceptance effects on the variables θ and ϕ are present, and the above mentioned cross section integral term from the linear polarization component is null. As a consequence, no direct contribution from linear polarization component should affect the measured energy asymmetry in eq. (2).

A linear component can still affect the polarization measurement through the decrease of the circular laser polarization S_3. The lepton beam polarization is measured using eq. (2) where the laser is always considered completely circular polarized, $\bar{S_3} = 1$. As can be deduced from eq. (2), even with a very high linear component of more than 30%, corresonding with an averaged circular polarization of 95%, the measured values of the polarization would be only 5% lower than the actual beam polarization,

$$P_{measured} = P_{beam} \cdot \bar{S}_{3real}. \tag{4}$$

To explain a disagreement of 10% between the actual beam polarization and the beam polarization measured by the LPOL a linear component of 42–50% ($S_3 = 90\%$) is required. This seems to be ruled out by several measurements of the laser light polarization performed during the period when the disagreement between the LPOL and TPOL polarimeters was observed.

Fig. 8 shows the circular and linear laser polarization as measured by three devices: the analyzer AB1 located in the laser room immediately after the PC, and the two analyzers AB2/1 and AB2/2 located in the HERA tunnel after the interaction point (IP) with the positron beam. The measurements indicate that during the whole year 2005 the laser was operated with a circular polarization component larger than 98%, which can be responsible for a systematic shift of the positron beam polarization measurement of at most 2%.

The measured laser polarization in the analyzer AB2 is lower than the polarization in AB1 mostly due to the fused silica entrance and exit windows. Mechanical stress in these windows,

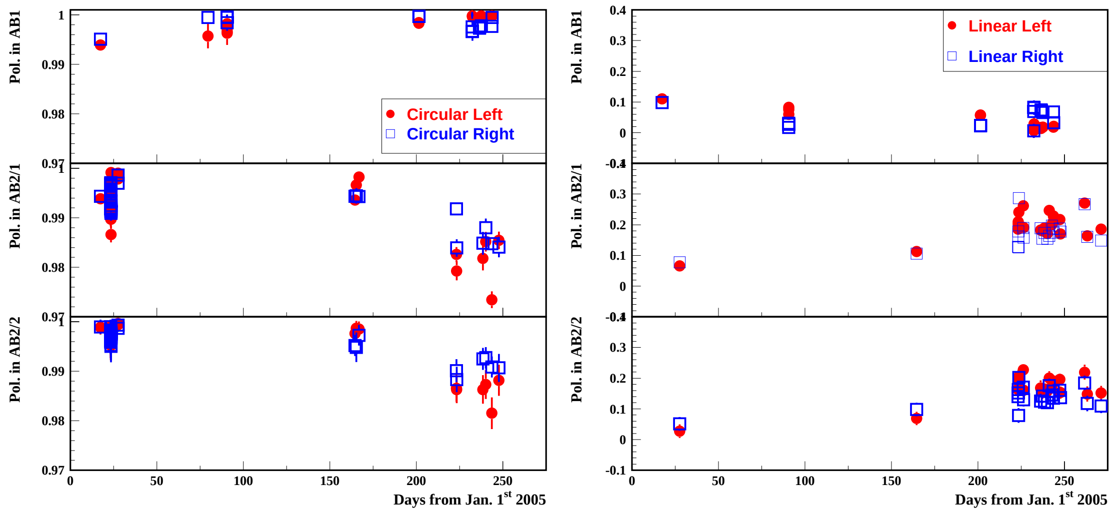


Figure 8: Measurements of the circular (left panels) and linear (right panels) laser polarization as measured by the analyzer AB1 in the laser room, and by the analyzers AB2/1 and AB2/2 located after the IP with positron beam. The measurements referring to linear left (right) represent the linear polarization component when the Pockels Cell is used to turn the vertically polarized laser light into the left (right) handed circular polarized state. For convenience and visualization, only the measurements with statistical error lower than 3% (25%) for the circular (linear) component are shown.

which separate the vacuum of the laser transport system and the lepton beam pipe, respectively, the lepton beam pipe and the analyzer box at atmospheric pressure, causes birefringence.

Taking this into account, the actual circular laser polarization at the interaction point might be even larger than the 98% measured in AB2.

In order to verify whether the intensity of the laser light is the same for the left and right polarization state, a dedicated measurement was performed on August 25^{th} 2005. Fig. 9 shows that the asymmetry in the intensity of the two laser circular polarization states using a gaussian fit is 0.00443 ± 0.00053, close to zero.

9 Sensitivity to Synchrotron Radiation

The synchrotron radiation emitted by the lepton bunches traveling throught the HERMES target magnetic field represents a possible source which can affect the measurement of the beam polarization. In principle, also bremsstrahlung can be a background source. However, this contribution is reduced by operating the LPOL polarimeter in multi-photon mode [6].

In order to monitor the level of the synchrotron radiation continuously, several complementary tools are used. By monitoring the scaler counting rates of the signals from the calorimeter on-line, and by monitoring the temperature on the front face of the calorimeter the presence of intense synchrotron radiation can be detected. In that case, the beam slope in the HERMES target region can be corrected to reduce the synchrotron rates measured by the LPOL.

Furthermore, to verify whether background radiation contaminates the signal from the Compton photons, the ADC spectra from two independent events can be analyzed and compared. With the laser switched off ("laser off") only the contribution of the synchrotron radiation from the lepton beam bunches to the polarization measurement shows up in the ADC spectrum, when

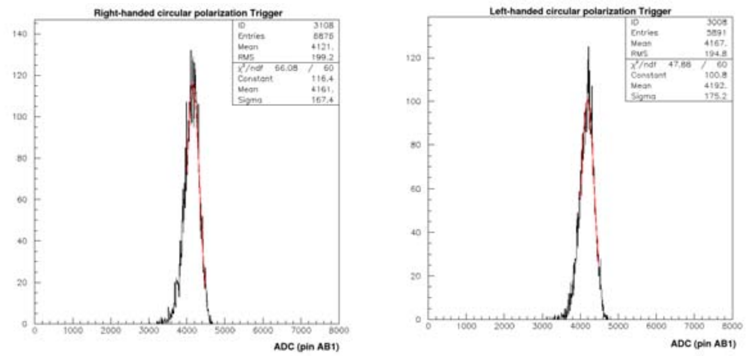


Figure 9: ADC laser intensity as measured in the analyzer box AB1 located after the Pockels Cell, for the right and left circular laser polarization state. In order to measure the total intensity of the laser beam, the measurement was performed without introducing a half-wave plate and a Glan-Thompson prism between the Pockels Cell and the analyzer. The result of a gaussian fit to the ADC distributions is also shown.

selecting filled bunches ("beam on"). This contamination is absent in the spectra when selecting empty bunches ("beam off"). Fig. 10 shows a comparison between the ADC spectra for these two types of events. The measurement was taken on August 5^{th} 2005 when sizeably different values for the beam polarization were measured by the LPOL and TPOL polarimeters. Within the statistical error, no difference is visible while comparing these spectra, suggesting that the synchrotron radiation does not affect the LPOL measurement.

10 Sensitivity to the Electronic Gate Delay

A shift of the electronic gate for Compton photon signal at the input to the ADC module in the Electronic Trailer (ET) can affect the measurement of the beam polarization.

In the ET the signal from the calorimeter is split into two lines by a fan-in/fan-out module. A trigger generates a gate with a width of 100 ns, starting integration in the ADC module. The signal in the first line falls within the gate, while the second line is delayed by 100 ns, bringing it outside the gate (left panel of Fig. 11).

In case of a shift of the gate with respect to the incoming signal, part of the Compton photon signal can be lost during digitization. If the calorimeter response is linear, as shown already in this report, the signal loss for the left and right handed circular laser polarization triggers is expected to be equal, and will therefore not affect the polarization measurement. At the same time, part of the Compton photon signal in the second (delayed) line will fall within the ADC gate (right panel of Fig. 11), thus affecting the proper subtraction of electronic noise when evaluating the beam polarization.

On October 19^{th} the ADC gate was deliberately delayed to verify the previous expectations. When considering the measurement by the TPOL as the reference polarization measurement, the ratio P_{LPOL}/P_{TPOL} versus the additional delay of the gate is shown in Fig. 12. The result of this study confirmed the expectation that the polarization measurement is affected when the ADC gate is delayed, but also shows that we are working in a safe regime and a shift of more than 10 ns is necessary to affect the polarization measurements.

Under the assumption that the electrical noise is constant on a long time scale, an average value for the background noise can be extracted from the data during the time before an anomaly is observed in the LPOL/TPOL ratio. Then, this value can be used to correct the data taken during the period when the anomalous LPOL/TPOL ratio shows up, and check the hypothesis that the gate delay might be the reason for the observed anomaly.

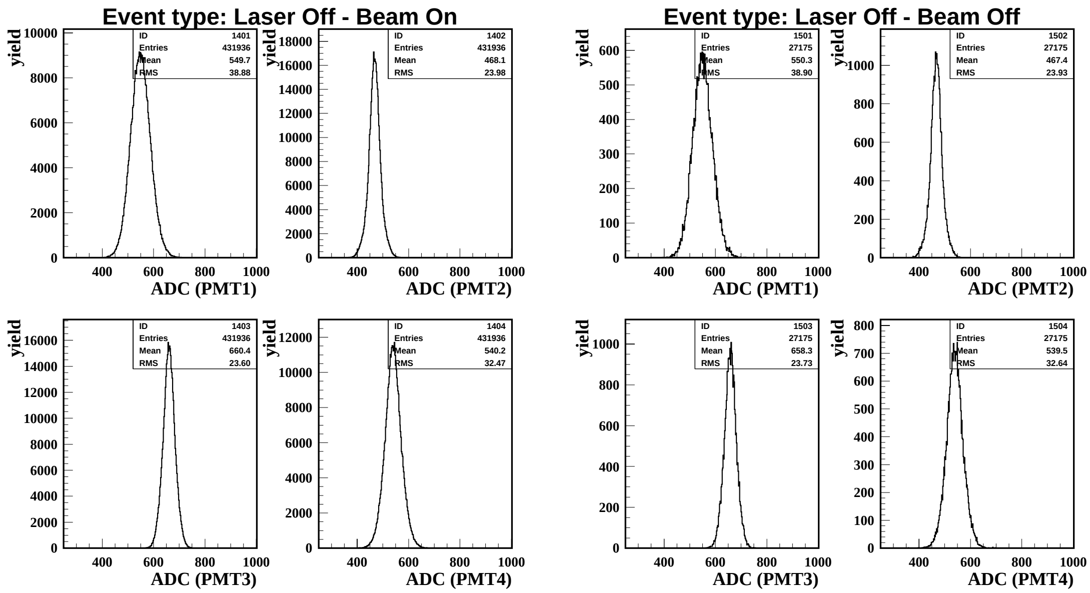


Figure 10: ADC spectra for two different types of events: laser off/beam on (left panels) and laser off/beam off (right panels) events, as described in the text. Within the statistical uncertainty, no difference is visible between the two sets of spectra.

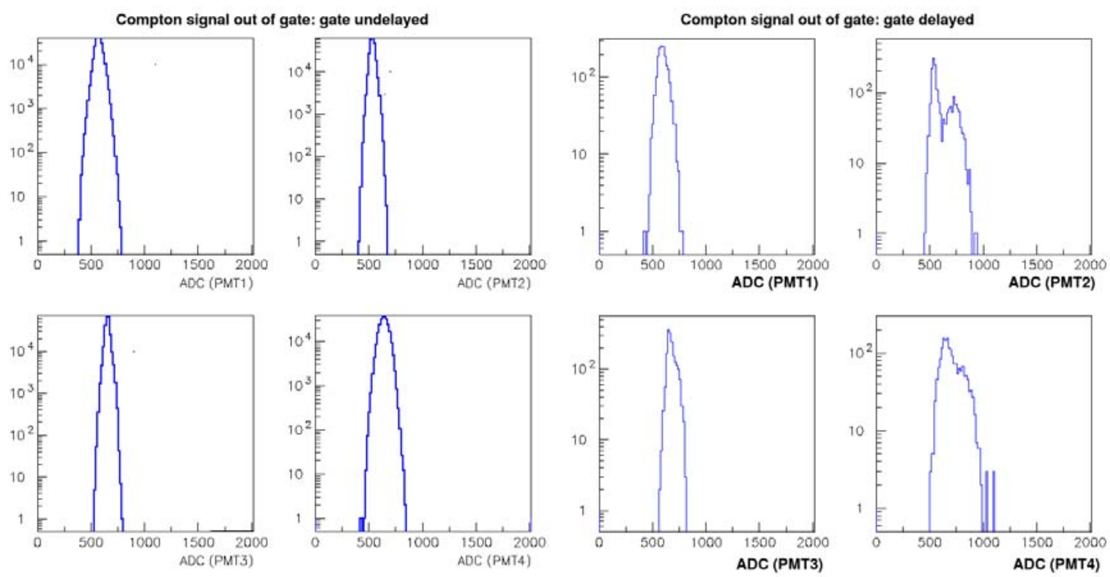


Figure 11: ADC spectra from the delayed signal line used for the electrical noise subtraction in the two different scenario: undelayed (left panels) and 24 ns delayed (right panels) gate for all four PMT responses. Note that the scale on the y-axis (yield) is logarithmic.

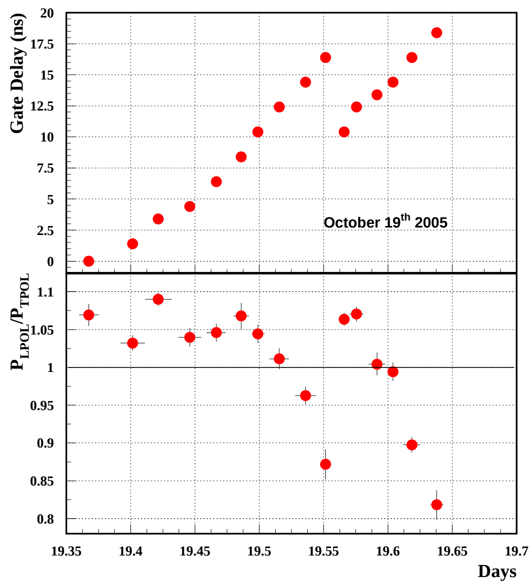


Figure 12: Shift of the gate (upper panel) and corresponding value for the ratio P_{LPOL}/P_{TPOL} versus time during the systematic study performed on October 19^{th} 2005.

As an example, the LPOL data of August 2005, when a sizeable disagreement with the TPOL data was observed, have been re-analyzed offline by using this method. Using the average value for the noise correction extracted from July 11^{th} 2005 data, the comparison of the LPOL online and offline values to the TPOL online data is shown in Fig. 13 for the data of August 5^{th} 2005. The result of this analysis clearly shows the LPOL online and offline values in agreement at the per-mill level, and that no anomalous gate shift in the LPOL electronics can explain the observed disagreement between the two polarimeters.

11 Sensitivity to the Laser Trigger Delay

The internal electronics of the laser responds with a jitter of ± 1.5 ns to an externally applied trigger pulse. Thus, different parts of the 1 m laser pulse are sampled by the 11 mm long lepton beam bunch. In order to correct for this effect, during data taking a model for the response is fitted to the temporal profile of the calorimeter signal, and used to correct for the timing jitter measured by a timing diode.

With this procedure the size of the timing correction needed to fire the laser for optimal photon-lepton collisions, and consequently increased calorimeter signals, is determined. This timing correction, called *laser trigger delay*, is normally of the order of 0.1–0.2 ns, and its effect on the polarization measurement is negligible. Nevertheless, it is desirable to quantify the reliability of the measurement when larger values of the delay offset are observed.

The upper panel of Fig. 14 shows the impact of the laser trigger delay on the polarization measurement for the August 2005 data. The data are mostly concentrated between -1.0 and $+0.5$ ns. The laser pulse is 3 ns long, and when large trigger delay values are determined the laser can miss the lepton bunch altogether. Therefore, values for the delay offset larger (smaller) than 1 ns (-2 ns) are always limited by the software to 1 ns (-2 ns). In the statistically most significant region, a linear fit can be performed to the ratio P_{LPOL}/P_{TPOL} versus the absolute value of the trigger delay. The result of this fit is displayed in the bottom panel of Fig. 14, showing that the LPOL polarization measurement remains constant within 2%.

The reason for the anomalous variation of the laser trigger delay is at the moment still unclear. Possible scenarios are under investigation, *e.g.* the jitter of the laser firing response, or jitter in the measured HERA clock. The HERA clock signal is provided by a dedicated *Bunch Trigger*

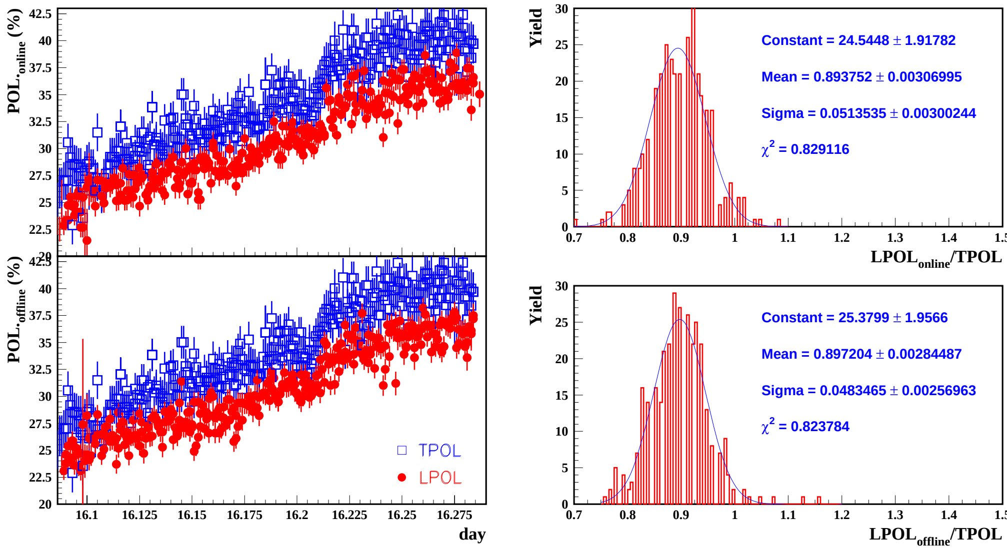


Figure 13: The polarization measurement values of the TPOL is compared with the ones obtained by the LPOL polarimeter, online and offline extracted, (left panels). The procedure used in re-analyzing the LPOL data is described in the text. The ratio distributions of the online and offline LPOL values with the TPOL ones are shown in the right panels. The result of a gaussian fit to the ratio distributions is also reported. Within the statistical error the two distributions are in agreement at a per-mill level.

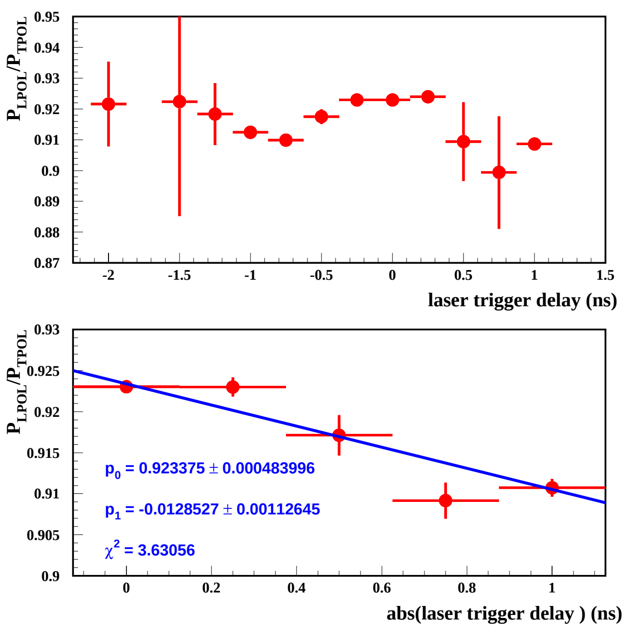


Figure 14: For the August 2005 data, the ratio P_{LPOL}/P_{TPOL} is evaluated versus the laser trigger delay (upper panel) and for the statistically most significant region, versus the absolute value of the trigger delay (bottom panel). The result of a linear fit is also shown.

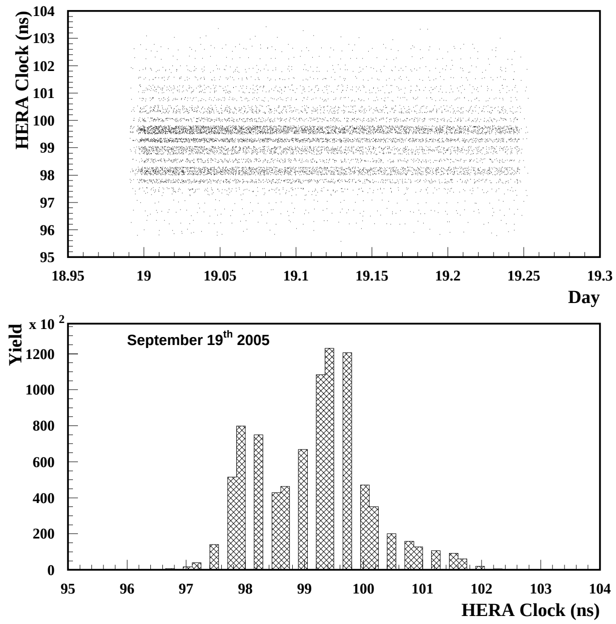


Figure 15: Time profile of the HERA clock signal as measured in the LPOL electronics on September 19^{th} 2005.

Module (BTM). Fig. 15 shows that the jitter of the measured HERA clock can be as large as 5 ns.

The observed jitter could affect the correct operation of the LPOL by triggering the laser to fire not in coincidence with the bunch transits. More detailed studies are needed to clarify this scenario.

12 Systematic Effect from the DSP

A fundamental element in the LPOL electronics is the *Digital Signal Processor (DSP)*. This module usually selects a random lepton beam bunch from a preloaded bunch pattern, and generates the input for the *bunch trigger module (BTM)* in order to trigger the laser on the selected bunch.

It has been observed that the DSP does not always load the correct lepton bunch pattern. In particular, the last bunch in each bunch train is sometimes missing in the trigger sequence for the laser. The reason for this behavior of the DSP is not yet understood.

As an example, the running period of August can be analyzed, when the ratio P_{LPOL}/P_{TPOL} was ≈ 0.9. Fig. 16 shows the beam bunch pattern and the ADC signal collected in the LPOL calorimeter for each bunch which the laser fired on, for August 5^{th} 2005. The comparison of the two patterns clearly shows that for this particular fill the DSP failed to load the last bunch for each train in the trigger sequence.

In general the real beam polarization can be expressed as

$$P^R = \frac{N_{NC} \star \langle P_{NC} \rangle + N_C \star \langle P_C \rangle}{N_{NC} + N_C} \tag{5}$$

where N_C (N_{NC}) refers to the number of colliding (non-colliding) beam bunches with an average polarization $\langle P_C \rangle$ ($\langle P_{NC} \rangle$). The colliding bunches are the lepton bunches which collide head-on with proton bunches in the HERA ring. For the particular example shown in Fig. 16 $N_C = 7$ and $N_{NC} = 146$, resulting in

$$P^R = \frac{7}{153} \star \langle P_{NC} \rangle + \frac{146}{153} \star \langle P_C \rangle. \tag{6}$$

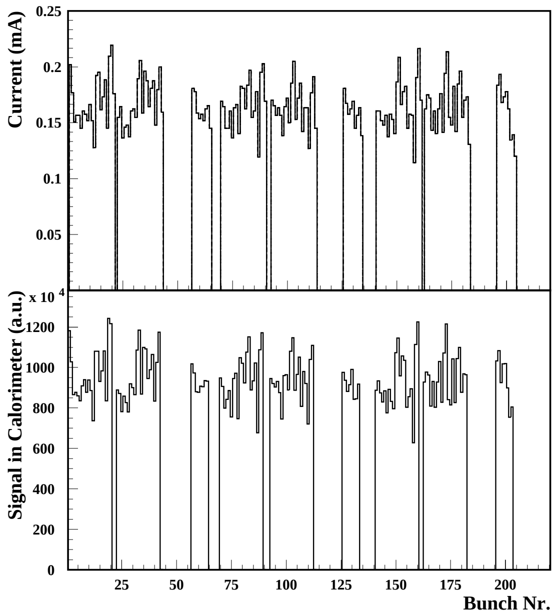


Figure 16: The lepton bunch pattern in the HERA ring is shown in the upper panel for August 5^{th} 2005. The bottom panel shows the corresponding bunch pattern used for triggering the laser firing. The DSP does not properly load the bunch pattern, and the last bunch of each train is missing in the trigger bunch sequence of the laser.

The actual number of bunches on which the laser fired instead leads to a measured polarization

$$P^M = \frac{7}{146} \star \langle P_{NC} \rangle + \frac{139}{146} \star \langle P_C \rangle \ . \tag{7}$$

The discrepancy between the actual and the measured beam polarization can be then evaluated, using simple algebra, as

$$\frac{P^M}{P^R} = 0.9977 \star \frac{1 + 7/139 \star \langle P_{NC} \rangle / \langle P_C \rangle}{1 + 7/146 \star \langle P_{NC} \rangle / \langle P_C \rangle} \ . \tag{8}$$

Assuming an unusually high ratio $\langle P_{NC} \rangle / \langle P_C \rangle = 2$, it turns out that the incorrect loading of the bunch pattern into the DSP results in a discrepancy $\frac{P^M}{P^R}$ of at most 2‰.

13 Polarimeter Performance monitored by an Independent Sampling Calorimeter

To address concerns about long-term stability, linearity, and radiation damage of the $NaBi(WO_4)_2$ calorimeter, a tungsten scintillator sampling calorimeter [9, 10] was built and is moved in the Compton photon beam periodically. It acts as an independent device to check the beam polarization measurement. The result of such a measurement is even more important after the replacement of the four crystals of the LPOL calorimeter in the summer of 2004. The polarization measured by the re-built calorimeter should be checked to be consistent within the systematic uncertainty of the previous device.

Between January and June 2005 several measurements were taken while switching the polarimeter operation between the crystal and the sampling calorimeters. Considering the TPOL as a reference, for each of these measurements, the average ratio $r = \frac{P_{crystal}}{P_{TPOL}} / \frac{P_{sampling}}{P_{TPOL}}$ was extracted, where the term P_X refers to the the polarization as measured by the polarimeter X. In case of stable beam conditions, with constant polarization measured by the TPOL during the systematic study, the quantity r can be considered as a measurement for the ratio $P_{crystal}/P_{sampling}$, assuming there is no time dependence in P_{TPOL}.

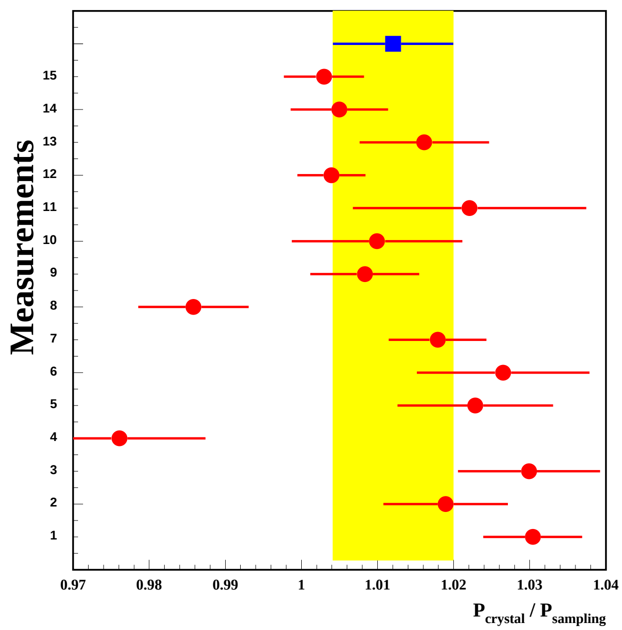


Figure 17: The 15 measurements of the ratio $P_{crystal}/P_{sampling}$ (red circles) are combined into a weighted mean value (blue square). Measurement #15 was done after repairing the sampling calorimeter in September 2005. The shadowed area shows the statistical uncertainty of the weighted ratio obtained from the measurements, as extracted via the error propagation formula for independent measurements. On the y-axis the measurements are labeled according to their time sequence.

During August 2005 the sampling calorimeter showed a anormal luminosity dependence of the measured polarization, therefore it could not be used for checking the realibility of the crystal calorimeter measurements in that period. The wave-length shifters and the scintillator plates of the calorimeter were found radiation damaged and replaced in September 2005. To verify whether the measurements taken with the repaired sampling calorimeter are in agreement with the ones taken before the radiation damage was observed, a new measurement was taken.

A measurement was discarded if the width of the distribution $\frac{P_{crystal(sampling)}}{P_{TPOL}}$ was larger than what is expected from propagating the statistical uncertainty of the polarization measurement. The 15 results satisfying this condition (including the measurement taken after rebuilding the sampling calorimeter) were combined in the weighted average

$$\langle R \rangle = \sum_i w_i \cdot r_i \tag{9}$$

where the weight of the measurement i is defined as $w_i = N_i/N_{tot}$, with N_i the number of entries accumulated during the study i, and N_{tot} the total number of polarization points accumulated over all 15 measurements.

The result of this analysis, shown in Fig. 17, gives a weighted average value for the ratio $P_{crystal}/P_{sampling}$ of 1.012 ± 0.008. Other measurements are planned to understand the systematics of the sampling calorimeter better. Nevertheless, this result allows us to reduce the systematic uncertainty of 5%, conservatively assigned to the re-built crystal calorimeter [2] in the summer of 2004, to 2%.

14 Conclusions

During the year 2005, several systematic studies have been performed in order to evaluate the realibility of the polarization measurements taken by the longitudinal polarimeter at HERMES. As described in this report, the measurements show no particular effect from the possible systematic sources studied.

The results obtained by previous studies and calibrations are confirmed, and no anomalous behavior of the longitudinal polarimeter is found, similar to the performance observed during the

2000 data taking. In particular, the dependence on the energy deposition in the calorimeter, on the linear component of the laser polarization, on the HV setting of the calorimeter photomultipliers and on their mismatch was found to be negligible. The polarization measurement was found not to be affected by the Compton cone offset along the x direction on the calorimeter surface during normal working conditions. The sensitivity to specific possible hardware malfunctioning, in particular the electronic gate delay, the laser trigger delay, the loading of the bunch pattern into the DSP, and the noise induced by the calorimeter table movement, was studied and found to affect the measurements by less than 2%. Negligible false asymmetry induced by the hardware was observed. Also, the synchrotron radiation was found not to affect the polarization values provided by the LPOL.

Considering also the result obtained by operating a third independent sampling calorimeter, the polarization measurement is stable within 2%. This allows the LPOL group to decrease the systematic uncertainty of the measurements with the crystal calorimeter re-built in July 2004 from the assigned conservative value of 5% to 2%.

The LPOL was found to work properly and, as far as the systematic sources investigated in this report are concerned, is not the source of the disagreement between the LPOL and TPOL measurements observed on August 2005. Nevertheless, the study of the longitudinal polarimeter performance is still in progress, in order to investigate possible systematic source different from the ones shown in this report.

During the HERA machine shutdown from November 2005 to January 2005, a detailed inspection of the laser transport system, which can not be performed during normal HERA running, is planned. The mirrors along the laser path and the windows through which the laser passes in and out of the lepton beam pipe will be checked to investigate any possible anomaly present, and eventually correct it.

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