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

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1 Introduction

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

This requirement has become even more important after the replacement on July 2004 of the original calorimeter crystals, cracked due to radiation damage, with spare crystals. The crystals currently in use have the same characteristics as the original ones, both sets belonging to the same production batch. Consequently, the response of the polarimeter, namely the *Analyzing Power* is not expected to be affected by the crystal replacement, and the comparison of the measurements by the LPOL and the transverse polarimeter (TPOL) before and after the crystal replacement indeed doesn't show a measurable change. 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 current re-build calorimeter with the original one [2].

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

This report gives an overview on the most significant systematic studies performed on the LPOL during the period spring-autumn 2005. These studies refer to data collected by using the crystal calorimeter, the reference polarimeter for measuring the beam polarization in HERMES. Whenever the measurements by TPOL were considered, the TPOL online data have been used. The results of studies similar to what 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 analyzed possible systematic sources. Furthermore, they allow to reduce the systematic uncertainty to 2% on the measurements done by the LPOL.

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 back scattered Compton photons are detected by a crystal calorimeter 54 m downstream of the interaction point (*IP*). In the following, a brief overview of the physics involved and of the apparatus is 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:

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

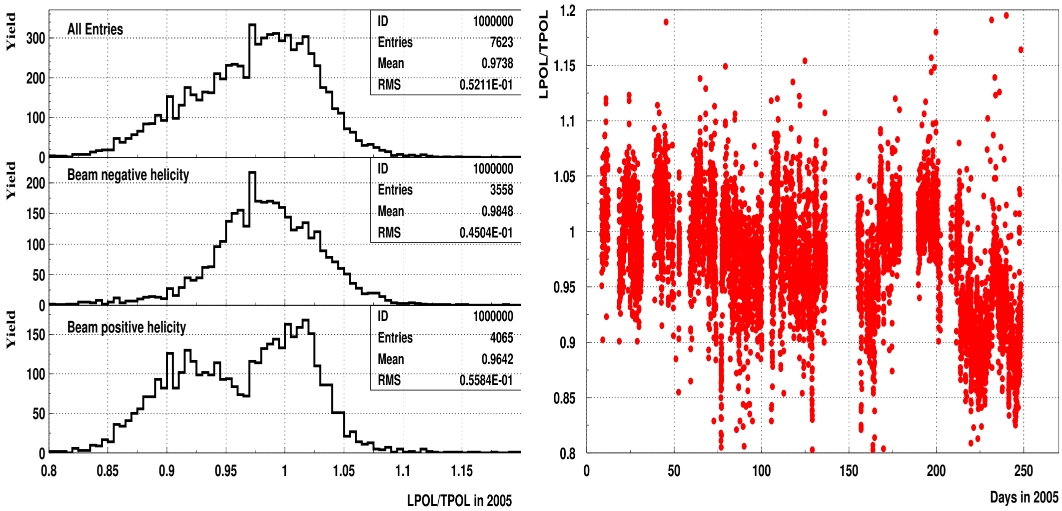

Figure 1: Left plot: distribution of the ratio P_{LPOL}/P_{TPOL} in 2005 until September 6^{th}, upper panel. The measurements relative to the negative and positive beam helicity state are shown in the middle and bottom panel, separately. The measurements of the two HERA polarimeters showed a sizeable disagreement in August, with positive electron beam helicity, with an average ratio P_{LPOL}/P_{TPOL} of 0.92, right plot.

with the photon (lepton) $\vec{S}$ ($\vec{P}$) polarization, 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 E_γ of the scattered photon, by measuring the asymmetry of the energy deposition integral in the calorimeter for left (I^-) and right (I^+) circular photon polarization while having the lepton beam longitudinal polarized.

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

$$P_z = \frac{1}{A\bar{S}_3} \cdot \frac{I^+ - I^-}{I^+ + I^-} \, , \tag{2}$$

with the averaged circular 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, and the *Analyzing Power A* calculated by 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*, that is by detecting many back

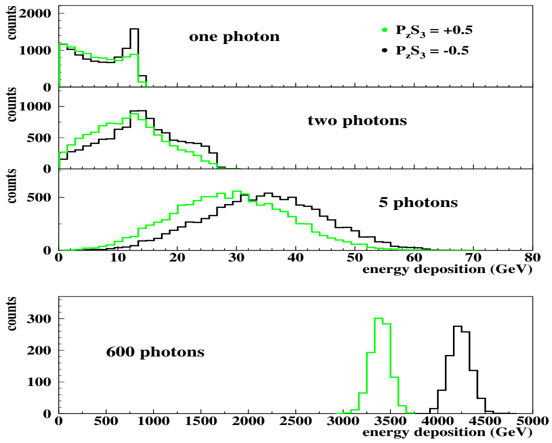

Figure 2: Model calculations for ADC spectra by laser firing few photons (upper panels) and 600 photons (bottom panel). The spectra are shown for realistic conditions with 50% polarized lepton beam and 100% circular left and right handed polarization of the laser, $S_3P_3 = -0.5$ (black line) and $S_3P_3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

scattered 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, respectively, as shown in the example of Fig. 2. Also, while operating the polarimeter in this mode the contribution from the Bremsstrahlung radiation to the energy deposition integral becomes negligible [6].

3 Dependence on the Energy Deposition

The accuracy of polarization measurement strongly 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 monitor whether any non-linearity of the calorimeter affects the polarization, measurements have been done delivering different amount 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 energy deposited in the calorimeter during the systematic study is monitored by measuring the ADC signal generated from 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 $P_{laser} = 19.6$ W. The nominal laser attenuator factor is 0.19, resulting in effective ≈ 3.8 W delivered through the laser transport system.

The results of the measurements taken on August and September 2005 are shown in Fig. 3, where on each plot the upper panel shows the change of the ADC signal in the calorimeter (Luminosity) versus time, due to the attenuation factor change. The calorimeter response is plotted in arbitrary units. The behavior of 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 increased up to a factor of ten.

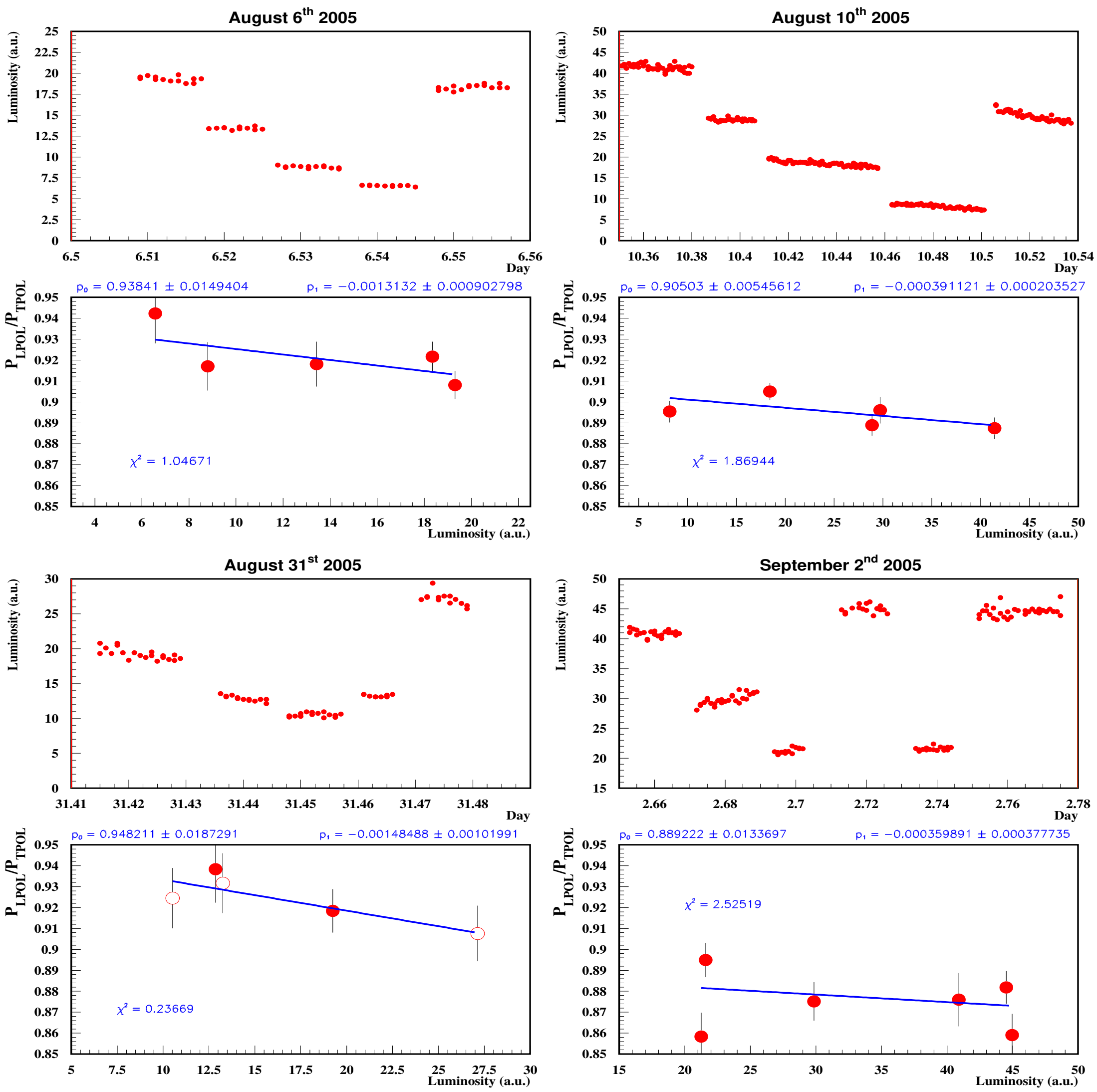

Figure 3: Polarization measurements taken on August and September. The luminosity versus time is shown in the upper panel of each plot. The dependence of the ratio P_{LPOL}/P_{TPOL} on the luminosity is presented in the bottom panels. The open circle points refer to the measurements taken during high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

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

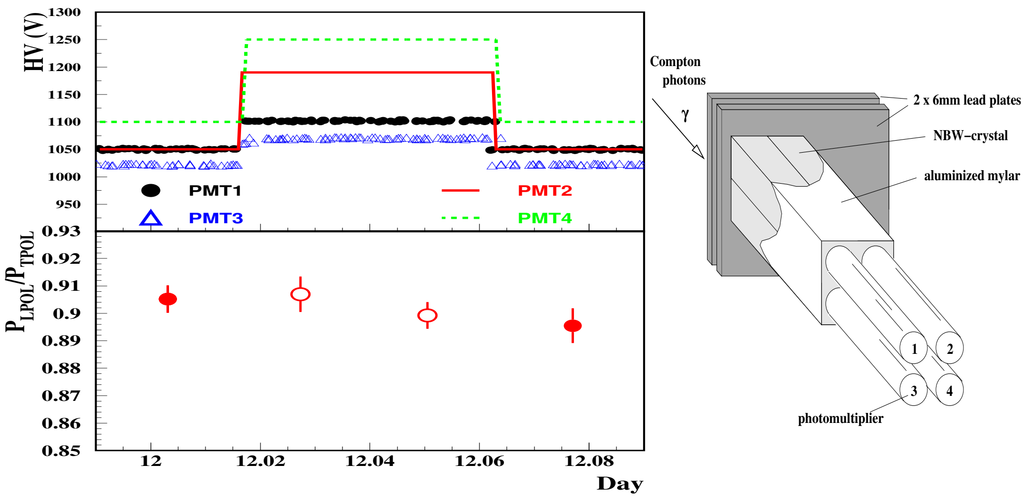

Figure 4: The ratio P_{LPOL}/P_{TPOL} is monitored while varying the HV for the photomultupliers, and is found to remain constant within 1%, left panel. The location of the different PMTs is shown in the right panel.

4 Dependence on the PMTs High Voltage

The sensitivity of the polarization measurement to the luminosity delivered into the calorimeter has been complementary tested by varying the high voltage (HV) applied to the PMTs. Furthermore, when the HV is increased not equally for all the four photomultipliers, then additional information about any effect from a mismatch of the PMTs HV can be retrieved.

On August 12^{th}, during stable conditions with polarization $\approx$ 40% and positron current $\approx 20-25$ mA, the HV has been increased of 50V for both PMT1 and PMT3, and of 140 and 150 V for the PMT2 and PMT4, respectively, to artificially mismatch the four photomultipliers. While 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 the HERA fill the lepton beam and slope can drift, resulting in a Compton cone not properly centered on the calorimeter. Even though during normal LPOL operation Compton photons are centered, by the software, on the calorimeter within 1 mm, it is crucial to verify how much an offset of the Compton photons may affect the polarization measurement.

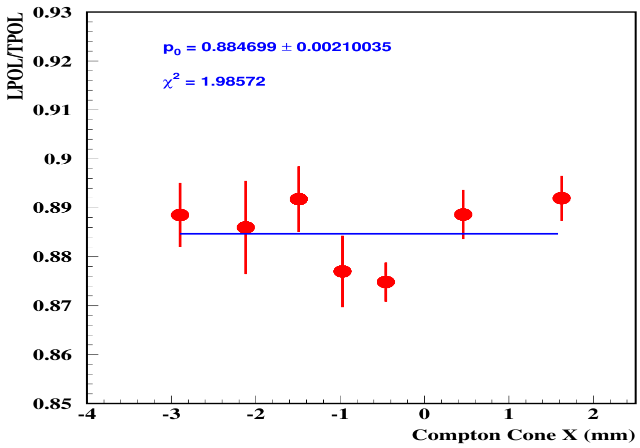

Figure 5: While considering the TPOL measurement as the reference polarization value, during the x-table scanning the LPOL polarization measurement was found to be stable within 2%. In the plot, the result from a fit to the data with the constant line $y = p_0$ is reported.

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

While considering the TPOL measurement as the reference polarization value, during the x-table scanning the LPOL polarization measurement was found to be stable within 2%, Fig. 5. In the plot, the result from a linear fit to the data is reported.

6 Noise Introduced by Calorimeter Table movement

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

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

The result of this study is reported in Fig. 6. It shows that the noise possibly induced by the calorimeter table movement, and by the cable connections to the table motor can affect the polarization measurement at most within 1%.

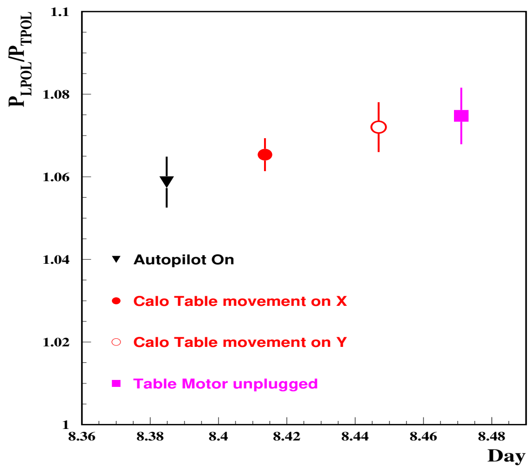

Figure 6: The ratio P_{LPOL}/P_{TPOL} is shown for four different running conditions of the LPOL: normal running mode (triangle), calorimeter deliberately continuously moved on x (filled circle) and y (empty circle) direction, and with the motor driving the table unplugged from its power supply (square).

7 False Asymmetry

To verify that no false asymmetry of the integral energy deposition for left and right circular polarized photons is generated, polarization measurements have been taken with the crystal calorimeter while switching the Pockels Cell off. The scattering of linear polarized laser light off positrons should result in a zero asymmetry measurement, eq. 1.

The results of such a study taken on August 3^{rd} 2005 is shown in Fig. 7. The

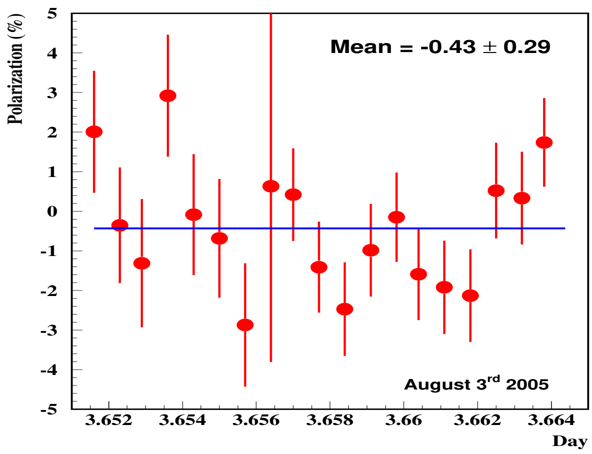

Figure 7: The polarization measurement taken on August 3^{rd} shows no false asymmetry generated by the *LPOL* hardware while using the crystal calorimeter with the Pockels Cell switched off.

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 Laser Linear Polarization

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

As shown in 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 the photon polarization, and in the laboratory frame it can be decomposed in its kinematic dependences as [7]:

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

where θ and ϕ are the polar angles of the back-scattered Compton photons.

During the operation of the longitudinal polarimeter the energy-weighted cross-section, integrated over the θ and ϕ angle region covered by the geometrical acceptance of the detector, is measured via the deposited energy in the calorimeter by the scattered photons. The Compton cone cross section has dimensions $\sigma_x = 3.8\ mm$ and $\sigma_y = 1.1\ mm$, and the LPOL is operated regularly by keeping the Compton cone centered in 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 decreasing of the circular laser polarization S_3. The beam polarization is measured by using eq. 2 where the laser is always considered as being completely circular polarized ($\bar{S}_3 = 1$). As can be deduced from eq. 2, even on extreme linear component with 95% average circular polarization (more than 30% of linear component), the measured values of the polarization can only be 5% lower than the actual beam polarization,

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

To explain a 0.9 relative disagreement between what is measured by the LPOL and the actual beam polarization a linear component of 42-50% (90% of S_3) is required. This possibility seems to be ruled out by several measurements of the laser light polarization performed all along the period when the above mentioned disagreement between the LPOL and TPOL polarimeters was observed.

The Fig. 8 shows the circular and linear laser polarization as measured by three devices, the analyzer AB1 located in the laser source room after the Pockels Cell, and the two analyzers AB2/1 and AB2/2 located in the HERA tunnel after the interaction point with the positron beam. The measurements indicate that during the whole 2005 the laser was operated with circular component larger than 98%, which should be responsible of not more than 2% systematic relative shift of the positron beam polarization measurement. It should be noted that,

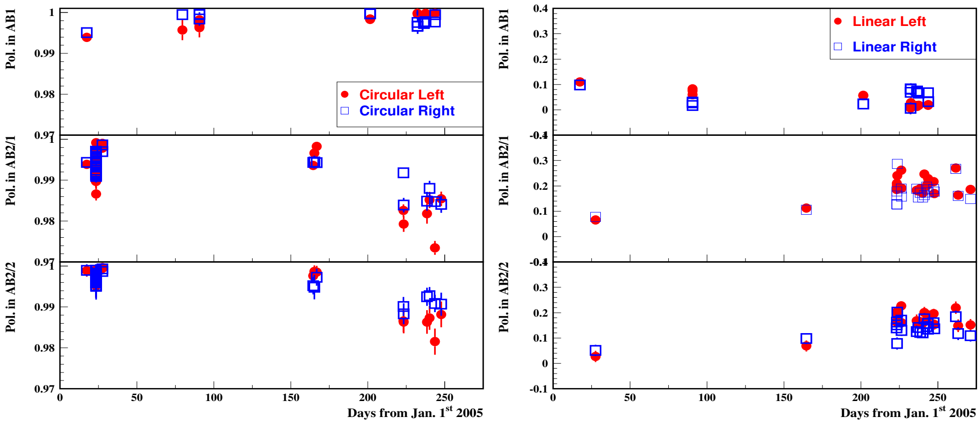

Figure 8: Measurements of the circular (left panels) and linear (right panels) laser polarization as measured by the analyzer AB1, in the laser source room, and by the analyzers AB2/1 and AB2/2 located after the IP with positron beam. The measurements referring to linear left (right) represent the linear 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% and 25% for the circular and linear component are shown, respectively.

as already previously demonstrated [8], the measurement of the polarization in the analyzers AB2/1-2 can be less accurate than the measurement with AB1. This feature was shown by measuring the polarization after the IP directly with the analyzer AB1. A reason for the above behavior can be radiation damage induced by synchrotron radiation in the optic system which guides the laser light from the IP to the analyzer box AB2 [9]. Therefore, taking into account the above mentioned considerations, the actual circular polarization might be, in principle, even larger that 98% at the IP.

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}. The 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, very close to zero.

9 Sensitivity to Synchrotron Radiation

The synchrotron radiation emitted by the beam bunches represents a possible source which might affect the correct measurement of the beam polarization.

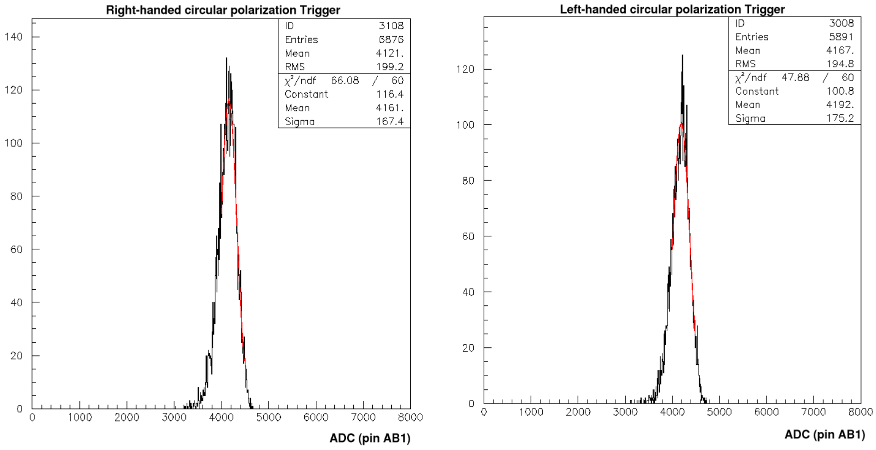

Figure 9: ADC laser intensity as measured in the analyzer box AB1 located after the Pockels Cell, for the right and left circular polarization state. In order to measure the whole intensity of the laser beam, the measurement was performed without introducing a half-wave plate and a Glam-Thompson prism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

In principle, also the Bremsstrahlung radiation can be a background source. Its contribution is reduced by operating the LPOL polarimeter in multi-photon mode [6].

In order to continuously monitor the level of the synchrotron radiation, different complementary tools are used. By on-line monitoring the scaler rates of the signals from the calorimeter, and by monitoring the temperature in the front-face of the calorimeter the presence of huge synchrotron radiation can be detected. In this 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 Compton photons, the ADC spectra from two independent events can be analyzed and compared. With the laser switched off any contribution of synchrotron radiation from the lepton beam bunches to the polarization measurement should show up in the ADC spectrum while triggering the laser firing on filled bunches (beam-on events). This contamination should be absent in the spectra while triggering on empty bunches (beam-off events).

Fig. 10 shows a comparison between ADC spectra for these two types of events. The measurement has been taken on August 5^{th} when sizably 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 doesn't affect the LPOL measurement.

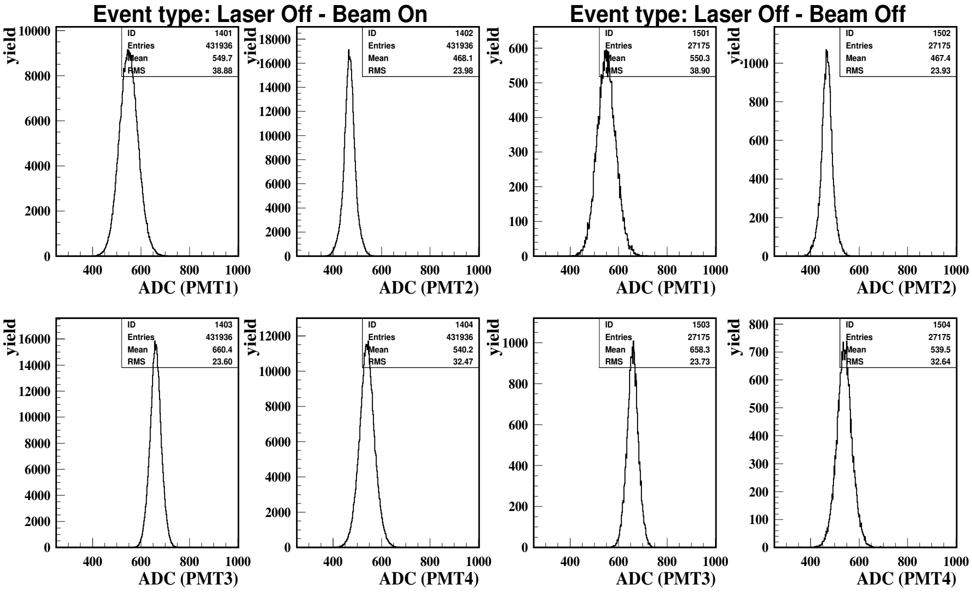

Figure 10: ADC spectra for two different types of events: laser off - beam on (left panels) and laser off - beam off (right panels) events, as described in the text. Within the statistical error, no difference is visible between the two sets of spectra.

10 Sensitivity to the Electronic Gate Delay

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

In the ET the signal from the calorimeter is splitted into two lines by a Fan-In-Fan-Out module. A trigger generates a gate with 100 ns width opening the ADC module, the first signal-line falls within the gate while the second signal is delayed by 100 ns, falling out of 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 to digitization. If the calorimeter response is linear, as previously shown in this report, the signal loss for the left and right handed circular laser polarization triggers is expected to be equal, therefore not affecting the polarization measurement. At the same time, part of the Compton photon signal in the piped second line can fall within the ADC gate (right panel of Fig. 11), thus affecting the proper subtraction of electronic noise for evaluating the beam polarization.

On October 19^{th} the ADC gate has been deliberately delayed to verify the above expected scenario. While considering the measurement by the TPOL as

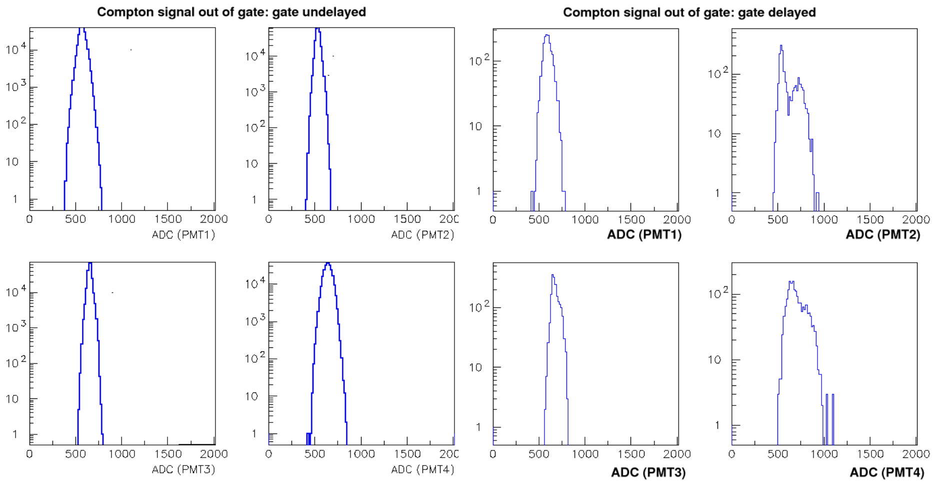

Figure 11: ADC spectra from the delayed signal line used for the electrical noise subtraction in the two different scenario: un-delayed (left panels) and 24 ns delayed (right panels) gate for all four PMT responses. Note that the scale on the y-axis (yield) is logarithmic.

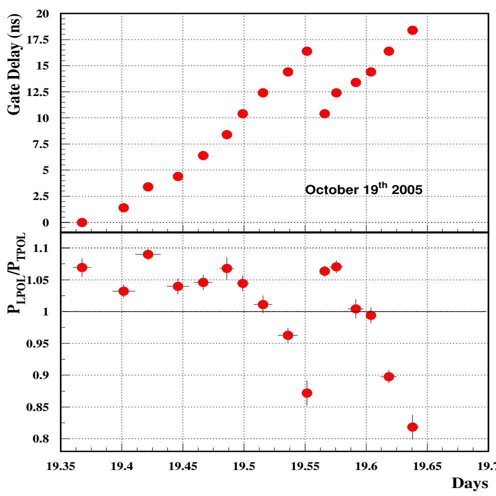

Figure 12: Amount of gate shift (upper panel) and corresponding value for the ratio P_{LPOL}/P_{TPOL} versus time during the systematic study performed on October 19^{th}2005.

the reference polarization measurement, the ratio P_{LPOL}/P_{TPOL} was measured versus its dependence on the gate delay, Fig. 12. The result of this study confirmed the expectation that the polarization measurement is affected when

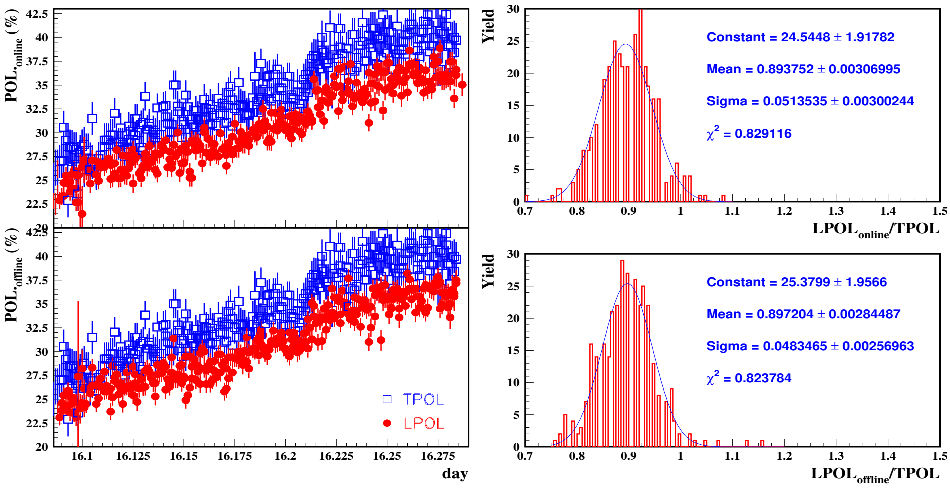

Figure 13: The polarization measurement values of the TPOL is compared with the ones obtained by the LPOL polarimeter, online and offline extracted, (left panels). The procedure used in re-analyzing the LPOL data is described in the text. The ratio distributions of the online and offline LPOL values 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.

the ADC gate is delayed.

Under the assumption that the electrical noise is constant on a long time scale, an average noise background value can be extracted from the data during the running 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.

As an example, the LPOL data of August 2005, when a sizable disagreement with the TPOL data was observed, have been re-analyzed offline by using the above method. Using the average noise correction value extracted from July 11^{th} 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}. 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. 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 response is fitted to the temporal profile of the calorimeter signal, and used to correct for time jitter measured by a timing diode.

From this procedure, the amount of time correction needed to fire the laser optimizing the photon-lepton collision, and consequently increasing the calorimeter signal, is determined. This time correction, called *laser trigger delay*, is normally of the order of $0.1-0.2$ ns, and its effect on the polarization measurement is completely negligible. Nevertheless, it is desirable to quantify the reliability of the measurement when larger values of the delay offset are observed.

Fig. 14, upper panel, shows the impact of the laser trigger delay on the polarization measurement for the August data. The data are mostly concentrated within -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 (-2) ns are always limited by the software to 1 (-2) ns. While considering the most statistical significant region, a linear fit can be performed to the data for the ratio P_{LPOL}/P_{TPOL} dependence on 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 such 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 the HERA clock jitter. This signal is provided by a dedicated *Bunch Trigger Module*. Fig. 15 shows that the jitter of the HERA clock can also be spread over a 5 ns region. The observed jitter could in turn affect the correct operation of the LPOL by triggering the laser to fire not in coincidence with the bunch transit. More detailed studies are needed in order

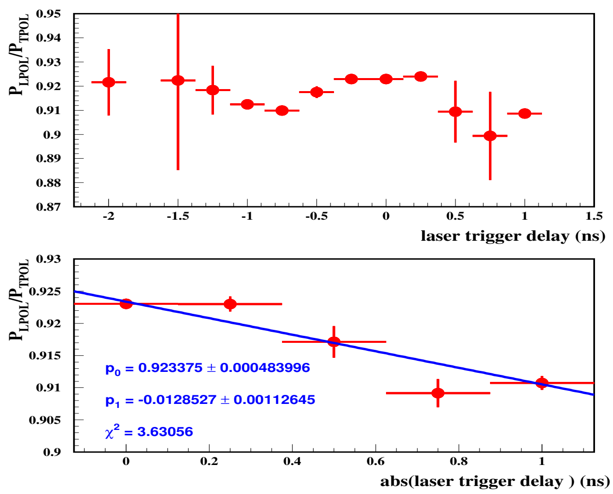

Figure 14: For the August 2005 data, the ratio P_{LPOL}/P_{TPOL} is evaluated versus the laser trigger delay, upper panel, and, for the most statistical significant region, versus the absolute value of the trigger delay, bottom panel. The result of a linear fit is also shown.

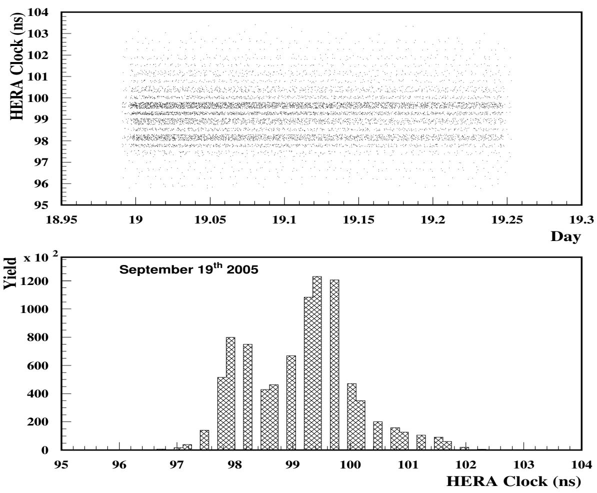

Figure 15: Time profile of the HERA clock signal as measured in the LPOL electronics on September 19^{th} 2005.

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 selects a particular lepton beam bunch number randomly within a pre-loaded bunch pattern, and sets the input on the *bunch trigger module* (BTM) in order to trigger the laser on the selected bunch.

It has been observed that the DSP does not properly load the correct bunch pattern on rare occasions. In particular, the last bunch in each bunch train can be missed in the trigger sequence of the laser, which might result in a wrong measurement of the beam polarization. The reason for this behavior of the DSP is not yet understood. From the analysis of the data it can be shown that this hardware malfunction can affect the measurement only at the per-mill level during normal running conditions of the HERA machine.

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}. The comparison of the two patterns clearly shows that for this particular fill the DSP failed in loading 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

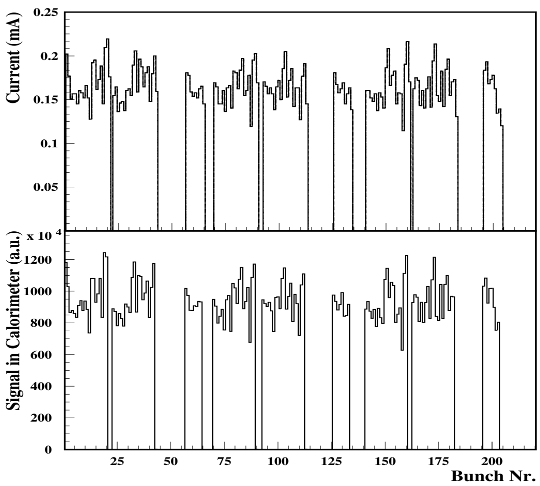

Figure 16: The lepton bunch pattern in the HERA ring is shown in the upper panel for August 5^{th} 2005. The bottom panel shows the corresponding reduced bunch pattern which triggered the laser firing. The DSP does not properly load the bunch pattern, and the last bunch of each train is missed in the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

bunches which, in the HERA ring, collide head-on with proton bunches. For the particular example shown in Fig. 16 $N_C = 7$ and $N_{NC} = 146$, resulting in

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

The actual smaller number of bunches, which the laser fired on, resulted instead in the 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, via a 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 $\frac{P^M}{P^R}$ at most at the level of 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 [10, 11] is moved in the Compton photon beam periodically. It acts as an independent device to check the beam polarization measurement. The result of such kind of measurement is even more important after the replacement of the four crystals of the LPOL calorimeter in summer 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 have been taken while switching the polarimeter operation between the crystal and the sampling calorimeter. Considering as a reference the TPOL, 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 that it does not have a time dependence.

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

The result of any measurement was discarded if the width of the distribution $\frac{P_{crystal(sampling)}}{P_{TPOL}}$ was found to be larger than what expected from propagating the statistical error of the polarization measurement. The 15 results satisfying the above mentioned condition (including also the measurement taken after rebuilding the sampling calorimeter) have been combined in the weighted average value

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

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

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

14 Conclusions

During 2005, systematic studies have been performed in order to evaluate the realibility of the polarization measurements taken by the Longitudinal Polarimeter at HERMES. The more significant results are described in this report showing no particular effect from the analyzed possible systematic sources to such measurements.

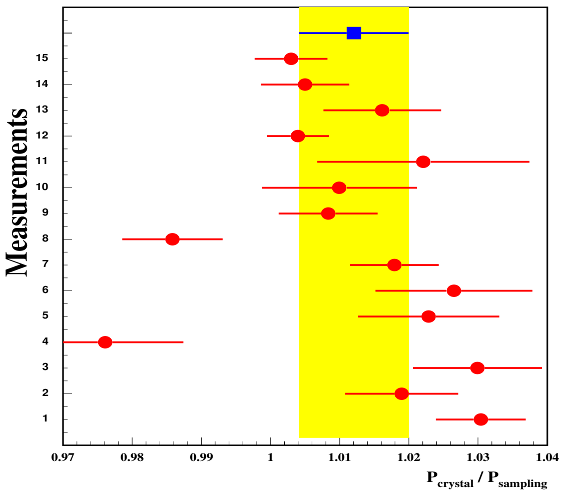

Figure 17: The 15 measurements of the ratio $P_{crystal}/P_{sampling}$ (circle points) are combined into a weighted mean value (squared point). The measurement #15 was done after repairing the sampling calorimeter on September 2005. The shadowed area shows the statistical error of the weighted ratio obtained from the measurements, as extracted via the error propagation formula from independent measurements. On the y-axis of the panel the values are labeled according to their time sequence.

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 negligible. The polarization measurement was found to be not 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, as the electronic gate delay, the laser trigger delay, the bunch pattern loading into the DSP, and the noise induced by the calorimeter table movement, was studied, and found to provide an effect 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 appear to be stable within 2%. This allows the LPOL group to decrease the systematic uncertainty of the measurements with the crystal calorimeter re-built on July 2004. From the assigned conservative value of 5% the systematic uncertainty is now reduced to 2%.

The LPOL was found to work properly and, as far as it concerns the systematic sources investigated in this report, 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 feasibly performed during normal HERA running, is planned. The mirrors all along the laser path and the windows which drive the laser into and out of the lepton beam pipe will be checked to investigate any possible anomaly present, and eventually correct it.

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