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Documentation 2000: Longitudinal Polarimeter

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Abstract

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Part I: GENERAL DOCUMENTATION

(for experts and interested non-experts)

1 Introduction

The primary physics program of the the HERMES experiment is based on a longitudinal polarisation of the electron [1] beam in HERA with the aim to investigate the origin of the nucleon spin using longitudinally and transversely polarised targets.
In the HERA-e storage ring, the 27.5 GeV/c electron beam is naturally polarised transversely to the beam (Fig.1) through emission of synchrotron radiation in the curved sections. A longitudinal beam polarisation is achieved in the HERMES interaction region via two sets of spin rotators upstream and downstream of the experiment. The polarisation of the beam is measured by two independent polarimeters through Compton backscattering of circularly polarised laser light off the polarised electrons. The Compton scattering cross section depends on both the polarisation of the laser photons (Stokes vector $\mathbf{S} = (S_0, S_1, S_2, S_3)$) as well as on the polarisation $\mathbf{P} = (P_X, P_Y, P_Z)$) of the electron beam:

$$d\sigma_c/d\Omega = f(\theta, \phi, \mathbf{S}, \mathbf{P})$$

By scattering with almost perfect circularly polarised light ($|S_3| \approx 1$; linear component $S_1 = \sqrt{1 - S_3^2} \sim 0.01$) and alternating between right ($S_3 = +1$) and left ($S_3 = -1$) circular light polarisation, cross section asymmetries can be measured. The *Transverse Polarimeter* (TPOL) makes use of *vertical spatial* asymmetries in the Compton photon count rates to extract the transverse polarisation P_Y in the ring. The *Longitudinal Polarimeter* (LPOL) computes *energy weigthed* cross section asymmetries and extracts directly the longitudinal polarisation P_Z in the HERMES interaction region. Obviously the two polarimeters must give the same results for the beam polarisation (up to the sign), since the degree of polarisation is invariant over the whole ring and the spin rotators in the HERMES interaction region turn the polarisation vector by 90^o forth and back.

1.1 Overview of LPOL setup

A schematic overview of the longitudinal plarimeter setup and the HERA-e beamline components of interest are sketched in Fig.2. Circularly polarized photons from a pulsed laser are focused on the HERA electron beam. The longitudinal polarisation of the beam is measured downstream of a first dipol magnet (BH39) which bends the electron beam by 0.54 mrad. The corresponding reduction of the longitudinal beam polarisation is however negligible (0.06% corresponding to cos 0.54). The high energy Compton photon beam separates from the electron beam in a second dipole magnet (BH90) about 38m downstream of the LPOL interaction point (IP). The Compton beam exits the beam pipe through a 2mm thin copper exit window and hits the following LPOL calorimeter at about 54m downstream of the LPOL IP. At the position of the calorimeter, the transverse separation between the Compton photon beam and the electron beam has reached about 42 mm.
Fig.3 shows the LPOL laser optics setup and the laser beam transport system in the East Right section of the HERA tunnel. The laser provides linearly polarised light which is turned into circularly polarised light of alternating helicity via a Pockels cell switching at a rate of about 100 Hz. The laser beam is steered via mirrors onto the electron beam at a very tiny angle of 7

[1] For the whole document we refer to electrons as the beam particles in the HERA-e ring irrespective of the specific operation with either electrons or positrons during the various running periods since 1995.

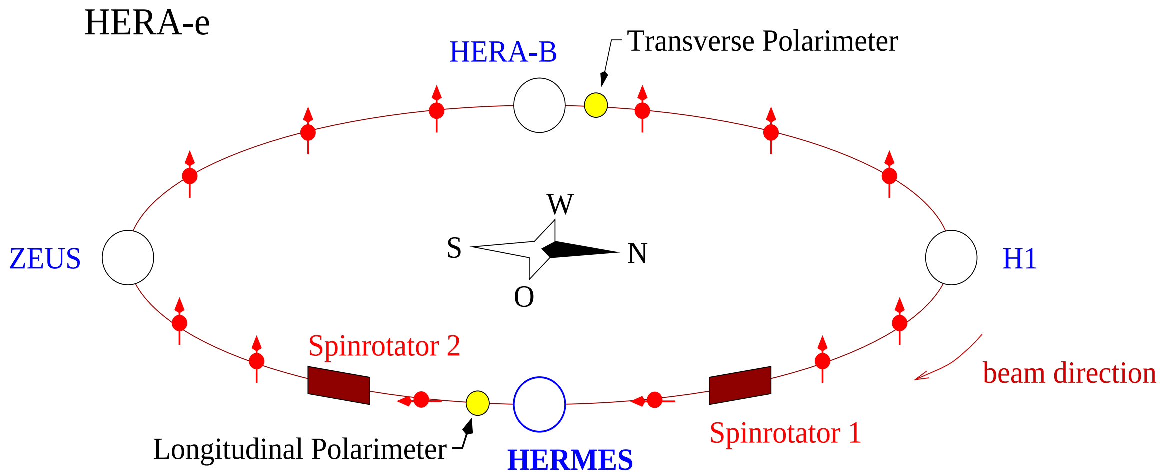


Figure 1: Beam polarisation in the HERA-e ring. The Transverse Polarimeter is located in the West Left, the Longitudinal Polarimeter in the East Right section of the electron ring.

mrad. The corresponding laser-electron IP is located about 52m downstream of the HERMES experiment. The backscattered Comptons are detected in an electromagnetic calorimeter 54m downstream of the LPOL IP.

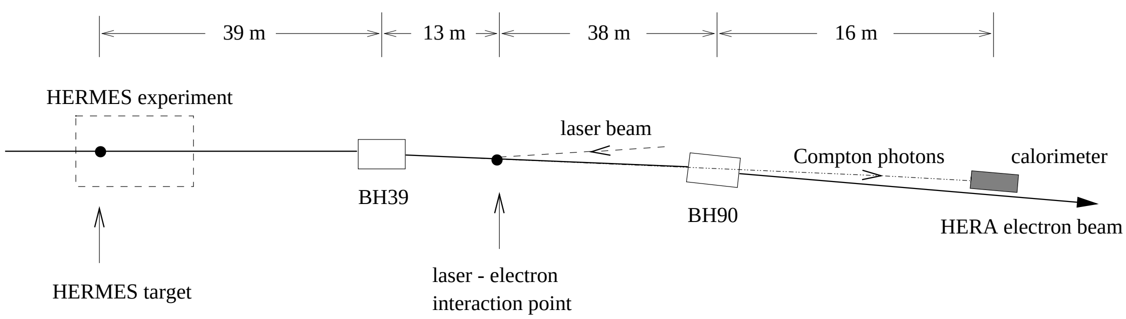


Figure 2: Layout of the of HERA-e beamline downstream of the HERMES experiment. The backscattered Compton photons separate from the deflected electron beam in the dipole magnet about 38m downstream of the LPOL laser-electron IP. They are detected by the LPOL calorimeter further 16m downstream.

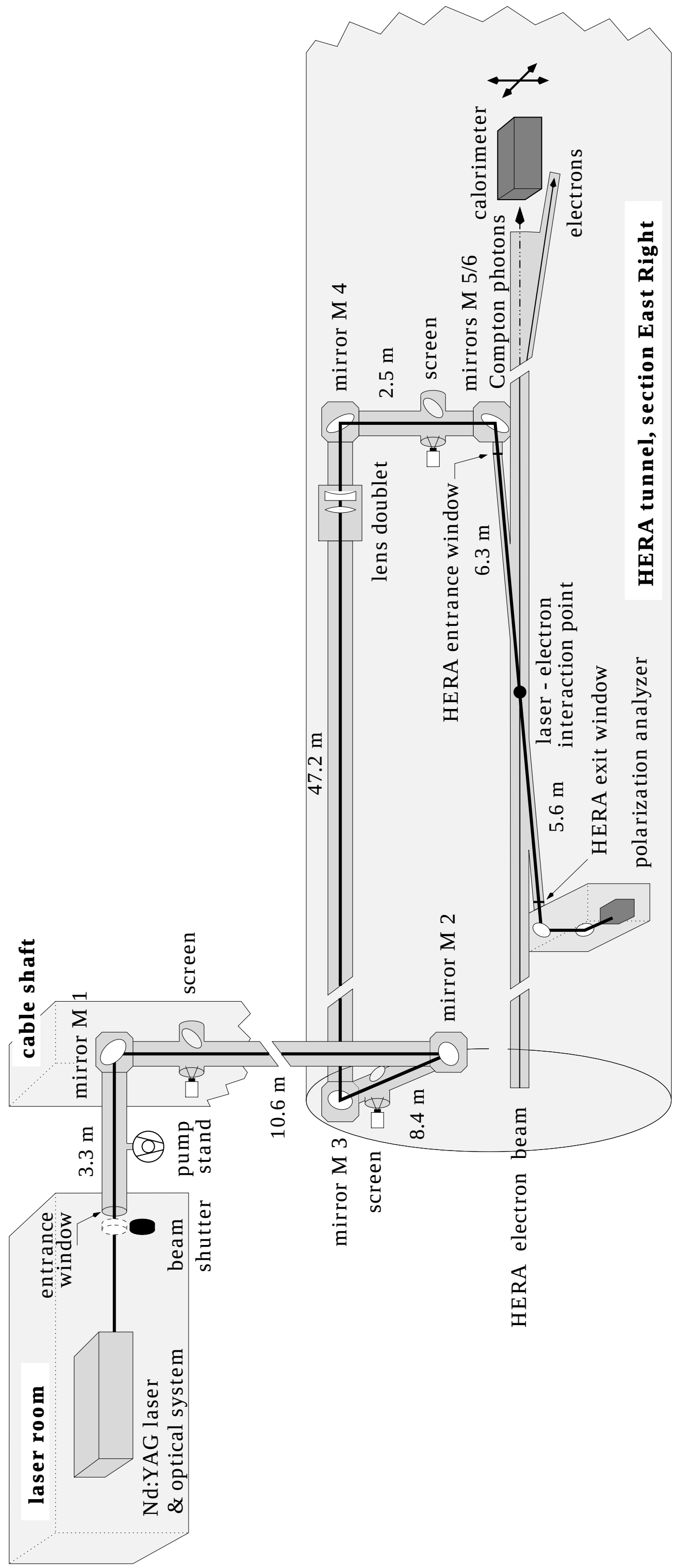


Figure 3: Layout of the LPOL laser beam optics and transport system.

1.2 Determination of longitudinal beam polarisation in multi-photon mode

The determination of the longitudinal beam polarisation P_Z with the LPOL is based on the measurement of the energy difference (asymmetry) of backscattered Compton photons for left and right circularly polarised laser light. The basic observable is the energy-weighted differential Compton cross section $\frac{d\sigma}{dE} \cdot E$ which is shown in Fig.4 for the two laser helicity states $S_3 = \pm 1$, assuming 100% beam polarisation. This spectrum would be ideally observed in the LPOL calorimeter in the case where any background would be negligible and the laser pulse-electron bunch interaction would result in exactly 1 Compton photon per event ('Single-photon mode').

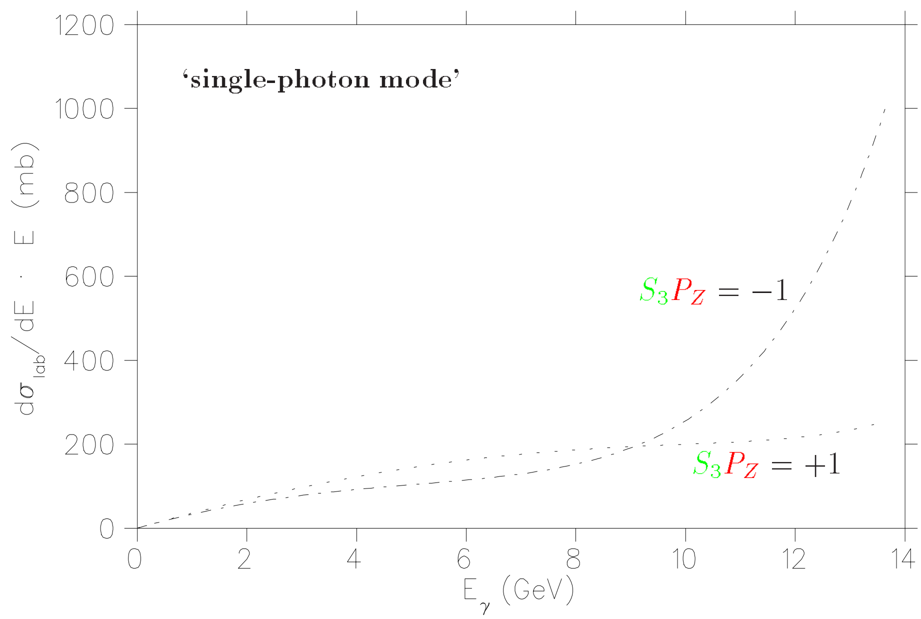


Figure 4: The energy weigthed Compton spectra in the case of a 'Single-photon mode' operation of the LPOL. The two curves show the different functional forms of the spectra for left (dashed-dotted) and right (dashed) circular polarised light, respectively.

Unfortunately, the background conditions in the OR section are such that the number of Bremsstrahlungs events from upstream rest gas interaction (mainly due to the poor vacuum conditions in the cavities) or originating from the HERMES target is of the order of 1 per bunch. As a consequence, the above 'single-photon mode' spectrum would be highly distorted and an extraction of the beam polarisation based on the different functional forms of the two spectra not possible. or this reason the LPOL is operated in the 'multi-photon mode' in which the high-intensity laser is tuned such that typically 10^3 Compton photons are backscattered from a single laser pulse-electron bunch interaction and registered simultaneously in the calorimeter. In this mode the background contribution (at the GeV scale) is negligible compared to the energy scale of the Compton signal (TeV scale).
Mathematically this means that the integrated spectrum

$$\mathrm{E}_i = \int_{\min}^{\max} \left(\frac{d\sigma}{dE}\right)_i \cdot E \cdot dE \quad (i = L, R)$$

is used to extract the beam polarisation by computing the energy asymetry

$$\mathcal{A} \;=\; \frac{< E_L > - < E_R >}{< E_L > + < E_R >}$$

between the two calorimeter signals measured for left and right circular laser light polarisation, repectively. The resulting distributions for the case of 10^3 Compton photons is shown in Fig.5. Finally, the electron beam polarisation is extracted from the measured asymmetry with the help of the known circular laser light polarisation and the analysing power of the LPOL (about 18%):

$$\mathcal{A} \;=\; P_Z \, \Delta S_3 \, \Sigma_{Z,LR}$$

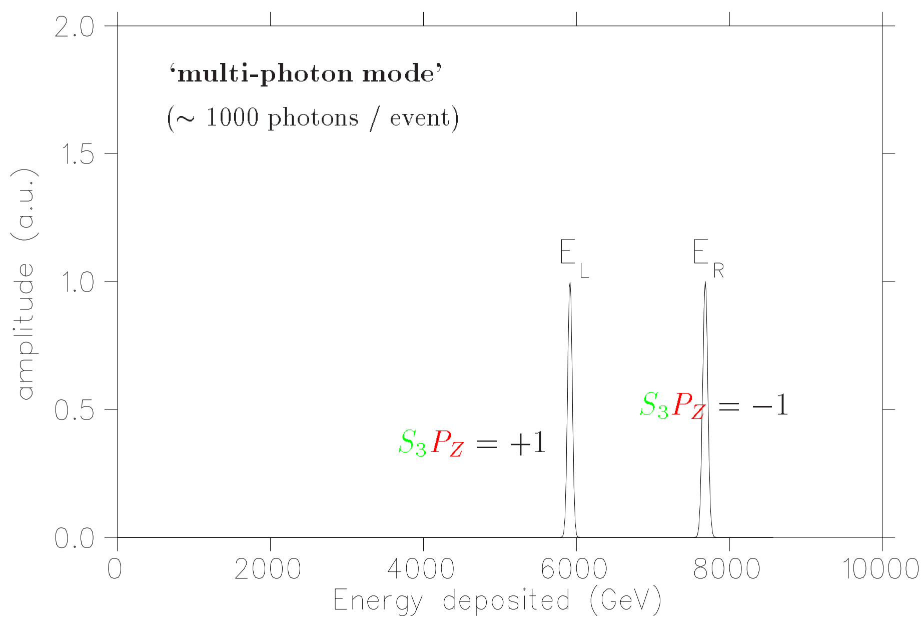


Figure 5: The energy spectra of the backscatterd Compton photons in the multi photon mode (here ~ 1000 photons / event). The two curves correspond to the left (dashed-dotted) and right (dashed) circular polarised light.

2 Detector description

2.1 Laser system

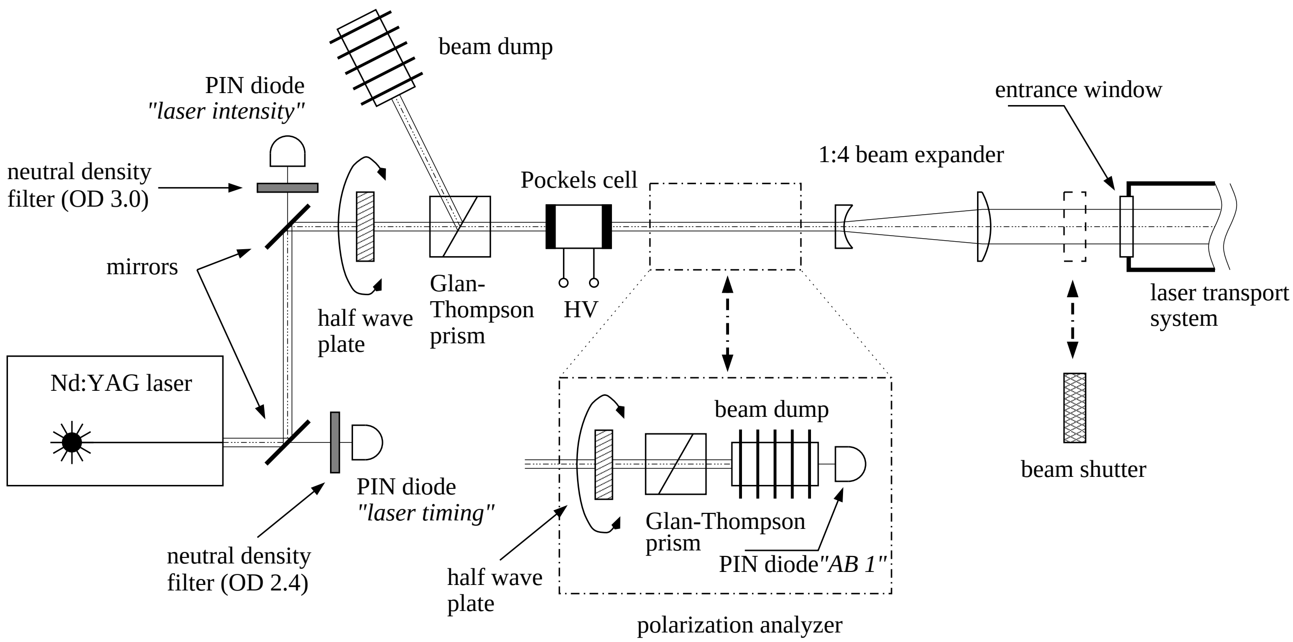


Figure 6: The optical setup in the laser hut in room 616 in the East Hall.

2.1.1 The Laser

The Nd:YAG laser *(Infinity 40–100, Coherent)* and the optical breadboard for the optics components described below are mounted on a concrete socket in the laser hut. The laser is not damped against motions/vibrations of the hall to ensure a fixed relative position to the electron ring which is also connected to the hall through the tunnel.

The laser consists of a diode pumped master oscillator and a two pass flash–lamp pumped optical power amplifier. The flash lamp has a rated lifetime of 70. . . 100 million shots. With an old flash lamp the pulse–to–pulse energy fluctuations increase and the laser might not be capable to attain the maximum specified IR energy within the allowed limits of the lamp voltage. After amplification the primary wavelength of 1064 nm is frequency doubled by a Second Harmonic Generation (SHG) crystal. Only the visible, frequency doubled laser beam with a wavelength of 532 nm (green) is emitted from an aperture in the laser housing, the infrared beam is completely absorbed within.

The infrared laser energy is measured internally in the laser and is displayed on the laser control PC in the laser lab and in the COP laser control window. To determine the exact timing when the laser actually fired, the small part of the laser intensity which is transmitted by the first "dog leg" mirror (cf. Fig.6) is sampled by a fast PIN diode *"Laser Timing"* after additional attenuation with a neutral density filter by a factor of 250. Another PIN diode *"Laser Intensity"* is installed behind the second "dog leg" mirror in order to measure the relative intensity of each laser pulse. The signal from this PIN diode is used to correct the individual Compton events for the laser pulse intensity and to monitor the pulse–to–pulse intensity fluctuations of the laser.

Variable	Specification	Operation	Comment
Wavelength [nm]	532	532	
Pulse energy IR per pulse [mJ]	$0 \ldots 400$	$100 \ldots 200$	
Pulse width [ns]	3.0	3.0	
Intensity fluct. at 50-100 Hz [%]	2.5	4.0	8% @100mJ, 4% @200mJ
Rep. rate [Hz]	0.1 - 100	97.8	
Trigger delay [ns]	0.0 - 25	~ 11	
Timing jitter (rms) rel. Q-switch synch. [ps]	< 500	??	
Divergence [mrad]	< 0.7	??	
Beam diameter at exit aperture (90% of total intensity) [mm]	5.5	5.5	

Table 1: Specifications and operating values of the Nd:YAG laser parameters.

$E_{1064\text{nm}}$ [mJ]	$E_{532\text{nm}}$ [mJ]	$E_{1064\text{nm}}$ [mJ]	$E_{532\text{nm}}$ [mJ]	$E_{1064\text{nm}}$ [mJ]	$E_{532\text{nm}}$ [mJ]
5	0.2	70	20.7	225	116.9
10	0.7	75	22.4	250	136.3
15	1.5	80	25.9	275	156.1
35	6.5	85	28.1	300	176.6
40	8.1	95	31.6	325	200.0
45	10.1	100	33.1	350	220.0
50	11.6	125	48.1	375	239.3
55	14.0	150	64.5	400	259.2
60	16.2	175	81.0		
65	18.4	200	98.2		

Table 2: Measured relation between the visible light energy $E_{532\text{nm}}$ (green) and the energy $E_{1064\text{nm}}$ (IR) of the laser light.

...More about laser control, PC etc.

Component/optical system	*"Laser Timing"*, *"AB 1"*, *"AB 2"*	*"Laser Intensity"*
Manufacturer	Newport	Semicoa
Model Number	818–BB–20	
Spectral Range	0.3...1.1 μm	
Rise / Fall ime	$<$ 200 ps / $<$ 350 ps	
Sensitivity @ 830 nm	0.4 mA/W	
Relative Response @ 532 nm	53 % typ.	
Bias Voltage	3 V	9 V
Load Impedance	50 Ω	50 Ω
Active Area	6×10^{-3} mm^2	
Junction Capacitance	$<$ 4 pF	
Saturation Current	50 mA	
Pulse polarity	positive	negative
Coupling		RC - 2.2 nF
Filter property		High pass - $\tau = 100$ ns

Table 3: Specifications of the PIN diodes.

2.1.2 The Optical Components in the Laser Lab

The optical setup consists of a variable attenuator, polarizing optics in order to produce and measure circular polarization of the laser light and a beam expander (see Fig.6, p. 10).
The laser beam is first steered by the two, so–called "dog leg" mirrors onto the optical axis of all optical elements mounted on the breadboard. These two mirrors facilitate the exact alignment of the laser beam with the other optical elements if the laser head has been moved or readjusted. After the second "dog leg" mirror, the laser beam passes through a rotatable half–wave plate $\lambda/2$ and a fixed Glan–Thompson prism which deflects the fraction of the incident laser light with horizontal linear polarization. By turning the half–wave plate, the orientation of the plane of polarization of the linearly polarized laser light can be rotated away from vertical and the intensity of the transmitted laser light can be adjusted. The component with horizontal polarisation is deflected by 67° and absorbed by a beam dump.

Manufacturer	CVI
Model Number	QWPM-532-10-2-R15
Diameter	ø 38.1 mm

Table 4: Specifications of the half–wave plates $\lambda/2$.

Optical system	"Attenuator"	"AB 1", "AB 2"
Manufacturer	Melles Griot	CVI
Model Number	03PGL303/A	CPAD-20.0-532.0
Clear Aperture	ø 15.0 mm	ø 20.0 mm
Deflection angle	90° (??)	67°

Table 5: The various models of Glan–Thompson prisms used in the Longitudinal Polarimeter.

The Pockels cell behind the Glan–Thompson prism converts the linearly polarized laser light into circularly polarized light. The applied high voltage is synchronized with the laser trigger and switched between every laser pulse to generate left and right handed polarization for every other light pulse. The current values for the positive and negative voltages (for right and left helicity, respectively) are tabulated in Table 6. The technical specifications of the Pockels cell are summarized in Table 7. The high voltages are set by two CAN DAC channels which drive two adjustable high voltage supplies, one of which is selected by a fast high voltage switch in synchronization with the laser trigger.

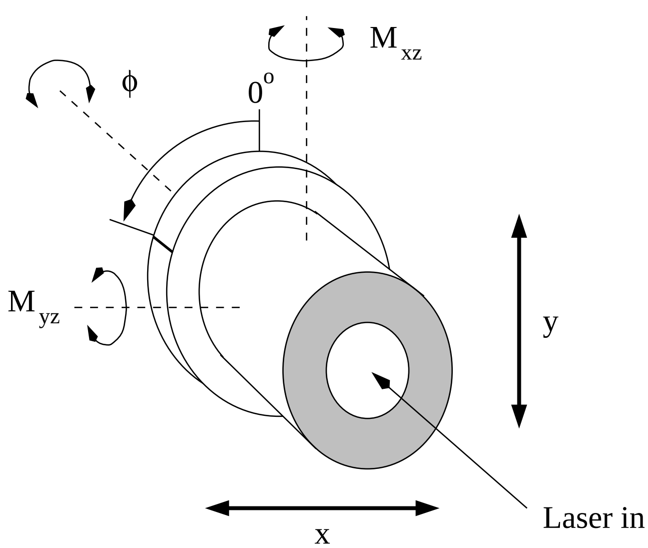
Polarity	Voltage
Pos. helicity	+ 1933 V
Neg. helicity	– 1814 V

Table 6: Current Pockels cell operation voltages.

Extinction (U=0)	1:8700	
Extinction (U=$U_{\lambda/2}$)	1:1000	
Beam deflection	< 10	$''$
$U_{\lambda/4}$	≈ 1900	V
Diameter of clear aperture	21	mm
Resilience	> 500	MW/cm^2
Transmission	98	%
Capacity	4	pF

Table 7: Specifications of the Pockels cell at a wavelength of $\lambda = 1064$ nm.

The Pockels cell is installed on a mount which allows adjustment in five axes (linear translation in both directions perpendicular to the laser beam axis and rotation about all three directions, see Fig.7). Note that the azimuthal orientation in ϕ is only reproducable as long as the Pockels cell is not dismounted from the ring adaptor. The current nominal value of $\phi = +66°$ corresponds to the voltage terminals in an approximately vertical orientation. The values for the rotation about the x and y axes, M_{yz} and M_{xz}, resp., are given in 0.1 inch which is the division of the corresponding set screws.



Parameter	Nominal value	
x	12.81	mm
y	7.87	mm
M_{xz}	$0.86 \cdot \frac{1}{10}$	inch
M_{yz}	$2.64 \cdot \frac{1}{10}$	inch
ϕ	$+66°$	

Figure 7: The degrees of freedom of the Pockels cell mount.

Behind the Pockels cell the analyzer box #1 can be moved into the beam path by a remotely controlled motorized stage. The analyzer box again consists of a rotatable half–wave plate, a fixed Glan–Thompson prism and a beam dump which absorbs the transmitted intensity. At the back of the beam dump a PIN diode *"AB 1"* is mounted which samples a small fraction of the absorbed light emerging from an aperture in the housing of the beam dump. The deflected beam leaving the Glan–Thompson prism to the side (not sketched in Fig.6) is absorbed by an additional absorber block consisting of a stack of razor blades, which is also not shown in Fig.6. By rotating the half–wave plate by a full turn the degree of circular and linear polarization can be determined from the intensity variation depending on the angle of the half–wave plate. The analyzer box #1 provides the possibility to measure the degree of polarization directly after the Pockels cell.

Before entering the laser transport system the beam diameter is expanded by a factor of four. The beam expander consists of a plano–concave and a plano–convex lens, where the plane lens surfaces are oriented towards the laser. Note that this arrangement does **not** provide the best optical imaging quality possible, yet it has been chosen to avoid a focal point for reflected rays from the lens surfaces. This latter requirement is more important in our application (the best setup in terms of image quality would be with the concave side of the plano–concave lens towards the laser). The two lenses are separated by approx. 450 mm, the exact distance can be set by a micrometer screw driving stage.

Please note: This screw must not be touched! Adjusting the separation of the beam expander lenses requires access to the tunnel in exclusive mode and operation of the laser transport system in an open mode!

The specifications of the lenses used in the beam expander are given in Tab. 8.

Lens Type	Model Number	f_{nominal} [mm]	$f_{532\mathrm{nm}}$ [mm]	ø [mm]
Plano–Concave	CVI PLCC-25.4-77.3-UV	− 150	− 168	25.4
Plano–Convex	CVI PLCX-50.8-309.1-UV	+ 600	+ 671	50.8

Table 8: Technical data for the lenses of the beam expander. The focal widths at a wavelength of 532 nm ($f_{532\mathrm{nm}}$) have been calculated from the nominal values using a dispersion model for the refractive index of fused silica.

2.1.3 The Laser Transport System

The beam shutter is located in front of the entrance window into the laser transport system and is controlled by the laser safety interlock system. The beam shutter is pneumatically driven and will fall into the closed position if the compressed air supply is cut. The laser beam gets blocked by a wedged tungsten plate in the beam path if the shutter falls into the closed position. **Be aware** that this plate does not absorb the laser beam and that there are intense, yet rather diffuse reflections of laser light from this shutter in the closed position! If all interlock conditions for a safe operation are met, the shutter will open with a delay of ~ 30 seconds after resetting the interlock system.

The entrance window into the vacuum of the laser transport system is made from fused silica and has a diameter of $\o = 80$ mm and a thickness of $d = 10$ mm. The current pressure in the laser transport system as displayed on the Thermovac gauge *(Leybold–Heraeus, TM 201S 2H)* is $\sim 6 \cdot 10^{-2}$ Torr. Note that the pressure in the transport system should not be lower than

$\sim 10^{-4}$ mbar as the lubricants used for the stepping motors and mirror mounts in the vacuum are only compatible with these intermediate pressures. At lower pressures the lubricants will evaporate and eventually condense on the optical surfaces and reduce the functionality of the bearings of these devices.
All mirrors for the Longitudinal Polarimeter are custom made *(CVI, Albuquerque, New Mexico)* with a special coating of 37 dielectric layers specifically designed to exhibit the same reflectivity for S– and P–waves of a wavelength of $\lambda = 532$ nm incident at an angle of 45°. The quoted damage threshold is above 1 J/cm^2, tests with energy densities up to 1.6 J/cm^2 could not produce laser damage on a test sample. The mirrors M1 to M4 are 101.6 mm in diameter, the two "dog leg" mirrors and mirrors M5 to M8 are 50.8 mm in diameter. Mirror M7 has a special substrate which is cut under 45 degrees at one edge to allow mounting the mirror as close as possible underneath the HERA electron beam pipe. The substrates of all mirrors consist of fused silica. Table 9 summarizes the specifications of all mirrors.

Mirror Numbers	Ordering Code	Reflectivity [%]	ø [mm]	d [mm]
M1 ... M4	CVI Y2-4050-45UNP-37-SPECIAL	> 99 (S & P)	101.6	12.7
M5, M6, M8	CVI Y2-2037-45UNP-37	> 99 (S & P)	50.8	9.525
M7	CVI Y2-2037-45UNP-37-CUT	> 99 (S & P)	50.8	9.525

Table 9: The mirror specifications.

Between every pair of mirrors on the path from mirror M1 to M5/6 there is one screen (screens 1...4) which can be driven into the beam path under an angle of 45° to find the laser beam if it is not already hitting the next downstream mirror. For this purpose vacuum viewports allow a CCD camera to view the screen if it is moved into the beam path under an angle of 90° and determine the location where the metal screen intersects the laser beam path and hence deduce the position of the laser beam within the beam transport tube. The screens are moved also pneumatically into and out of the beam path and can be controlled via the COP user interface. Note that the laser intensity should be set to low values (≤ 5 mJ) before moving a screen into the beam path to prevent damage of the CCD cameras from excessive light intensity. COP automatically reduces the laser intensity before driving a screen into the beam path.
The lens doublett which is located about 1 meter upstream of mirror M4 focusses the laser beam onto the interaction point (IP) with the electron beam. It consists of a plano–convex and a plano–concave lens which are arranged as shown in Fig.8. The specifications of the lenses comprising the doublett are summarized in Tab. 10.

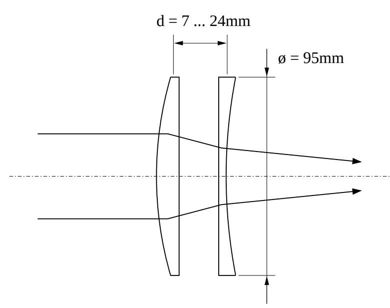


Figure 8: Sketch of the adjustable lens doublett upstream of mirror M4. The laser beam is entering from the left.

The orientation of the lens surfaces could be chosen both in a way to avoid foci from backreflections and to achieve minimum image distortions. By varying the distance d between the two lenses the focal width of the lens system can be varied between $f_{\mathrm{Doublett}} = 6.7 \ldots 22.9$ m. The separation of the two lenses can only be varied manually in the tunnel and again **requires profound knowledge** (see section 2.1.2) of the procedure, how to adjust the laser beam focus!

Lens Type	Model Number	f_{nominal} [mm]	ø [mm]	d [mm]
Plano–Concave	CVI PLCC-95.0-206.0-C-532	-400	95.0	
Plano–Convex	CVI PLCX-95.0-206.0-C-532	$+400$	95.0	
Doublett		$(6.7 \ldots 22.9) \cdot 10^3$		$7 \ldots 24$

Table 10: Specifications of the lens doublett upstream of M4.

The HERA entrance and exit windows connect the laser transport system with the HERA high vacuum. They consist of Fused Silica and are mounted with Helicoflex gaskets. The entrance window is located ?? cm behind the mirror pair M5/6 while the exit window is mounted ?? cm upstream of the mirror M7. Table 11 summarizes some of their properties. Systematic

Manufacturer	CVI
Type code	PP 1537 UV
Diameter	38.1 mm
Thickness	9.525 mm
Material	Fused Silica
Coating	AR for 532 mm
Gaskets	Helicoflex, HNV 200

Table 11: The HERA window specifications

studies on the effect of the windows on the light polarization revealed that the entrance and exit windows induce a phase shift (?) of $\approx +2^\circ$ and $\approx +10^\circ$, respectively. The circular polarization is affected by less than 1%.

2.1.4 The Light Analyzer Box in the Tunnel

A second analyzer box (AB#2) is located inside the tunnel behind the interaction point and is used to monitor the circular polarization of the laser light. The light is steered into the box by a pair of mirrors (M7 and M8) while M8 can be moved remotely by two OWIS stepping motors. Like the AB#1 the box consists of a rotatable half-wave plate and a Glan-Thompson prism but uses both ordinary and extraordinary axes to measure the intensity variation with two PIN diodes (see Fig.9). The diodes measure only a small fraction of the scattered light in the beam dumps.

Figure 9: The analyzer box # 2, located behind the HERA exit window. The polarization can be measured with the two PIN diodes independently.

2.1.5 The Electron Beam

The electron-photon interaction point of the longitudinal polarimeter assembly (LPOL-IP) is located 52 m downstream of the HERMES target (see also Fig.2). It is situated between the bending magnet 39BH and a set of cavities. After the electron-photon interaction the backscattered Compton photons travel along the electron beam pipe until they reach the next bending magnet, 90BH, the field of which separates Compton photons from the electron beam. This separation reaches 4.2 cm at the position of the Compton photon calorimeter, 54 m downstream from the LPOL-IP. Along the beam line from the HERMES experiment to the position of the LPOL calorimeter many active elements for beam stearing and manipulation are installed. A list of the beam line elements is given in Table 12.

check 4.2cm

The HERA electron beam is discontinuous and consists of a train of 220 bunches with a bunch repetition time of 96 ns. Not all 220 bunches are filled at injection time, their distribution is:

filled bunches:	1 - 63		71 - 133		141 - 203	
empty bunches:		64 - 70		134 - 140		204 - 220

The length of a single electron bunch is energy dependent. With "Luminosity" conditions, i.e. at 27.56 GeV and HERA optimized for polarisation the e^- bunch length is 1.07 cm (σ_{rms}) whereas at injection energy (12.9 GeV) the e^- bunch length is only 3.02 mm (σ_{rms}). The shape of the electron beam in transverse direction is given by the beam envelope and is dependent on the emittance and the beta function of the machine lattice. The emittance at 27.56 GeV is $\varepsilon_x = 4.1 \cdot 10^{-8}$ m·rad and $\varepsilon_y \approx 0.1 \cdot \varepsilon_x$. At the LPOL-IP, which is at 51.7 m downstream of the HERMES target the calculated beta function values are $\beta_x = 8.41$ m and $\beta_y = 25.19$ m. From this we get for the transverse distribution $\sigma_x = \sqrt{\varepsilon_x \beta_x} = 0.59$ mm and $\sigma_y \approx 0.3$ mm in horizontal and vertical direction, respectively. An schematic overview of the electron beam line in the LPOL IP neighbourhood is shown in Fig.10

In the bending magnet 39BH the longitudinal electron spin is precessed – we have to calculate how much !!

2.1.6 The Laser-Electron Beam Interaction

The laser beam comes from above and intersects the electron beam in the vertical plane under an angle of 179.5°. The designed interaction point is located at OR 51700, i.e. 51.7 m downstream of the HERMES target. Fig.11 shows the layout of the HERA-e beam at the HERMES IP.
At this point laser pulses and electron bunches have to overlap optimally in time and space. The laser beam is focussed at the LPOL-IP and from the hits on "Knallpapier" the lateral extension of a laser pulse is estimated to be ≈ 0.5 mm. The laser pulse has a typical intensity disribution over it's length of ≈ 3 ns. For the laser beam the timing of the foreseen interaction can be controlled by an external delay which is adjustable over a 25 ns range in 0.1 ns steps. The spatial overlap is controlled via the mirror system of the laser beam assembly and the optimization is mainly done by movements of mirror M4 which give a horizontal sweep of the laser beam.
The electron beam can be manipulated by elements of the electron beamline. In activating different bumps the position and slope of the e^- beam can be changed horizontally as well as vertically. Symmetric bumps are used to move the position of the beam, with asymmetric bumps the slope can be changed. In figures 12-15 examples are given for each change. The detailed procedure how to tune the electron beam at the LPOL IP is described in sect. 6.4.

give example of lumi. iopti- mization

Label	Function	Position /mm	Remarks
OR 10 QC	Quadrupole C?		
OR 12 QC			
OR 14 QC			
KV 16		Correction Coil Vert.	
KH 17		Correction Coil Hor.	
OR 34 QL	Quadrupole L?		
	Beam Position Monitor		BM35
KV 35			
OR 39 BH	Bending Magnet		
OR 44 QL			
KH 45			
	Beam Position Monitor	45870	BM46
	Analyzer Box 2	46270	
KCI 51			like KH
	Beam Position Monitor	51700	BM52
KCI 52			
OR 53 QL			
KV 54			
OR 60 QL			
OR 67 QL			
	Beam Position Monitor		BM68
KV 68			
O 69 CE			3764
O 72 CE			3089
OR 74 QL			
KH 75			
O 76 CE			3081
O 78 CE			3275
OR 80 QL			
KV 81			
O 82 CE			2245
O 85 CE			3084
OR 87 QL			
OR 90 BH			
OR 94 QL			
KV 94			
			2687
	Collimator		
			3274
OR 100 QL			
KH 101			
			3087
			3082
	LPOL Calorimeter	105650	exit window
OR 107 QK			
KV 108			
			3083
TP 110 OR	Pump Stand		
OR 113 QL			

Table 12: Electron beam line elements in the OR tunnel section up to 113m downstream of the HERMES IP

optimal lumi conditions: *optimal timing*, *vertical steering* of laser beam, *optimal overlap in transverse direction*
Consequences from *non-optimal lumi* conditions
IP: position, scans, ..
Compton cone and phase space, dependence on beam (range?)
Compton rates = f (threshold)

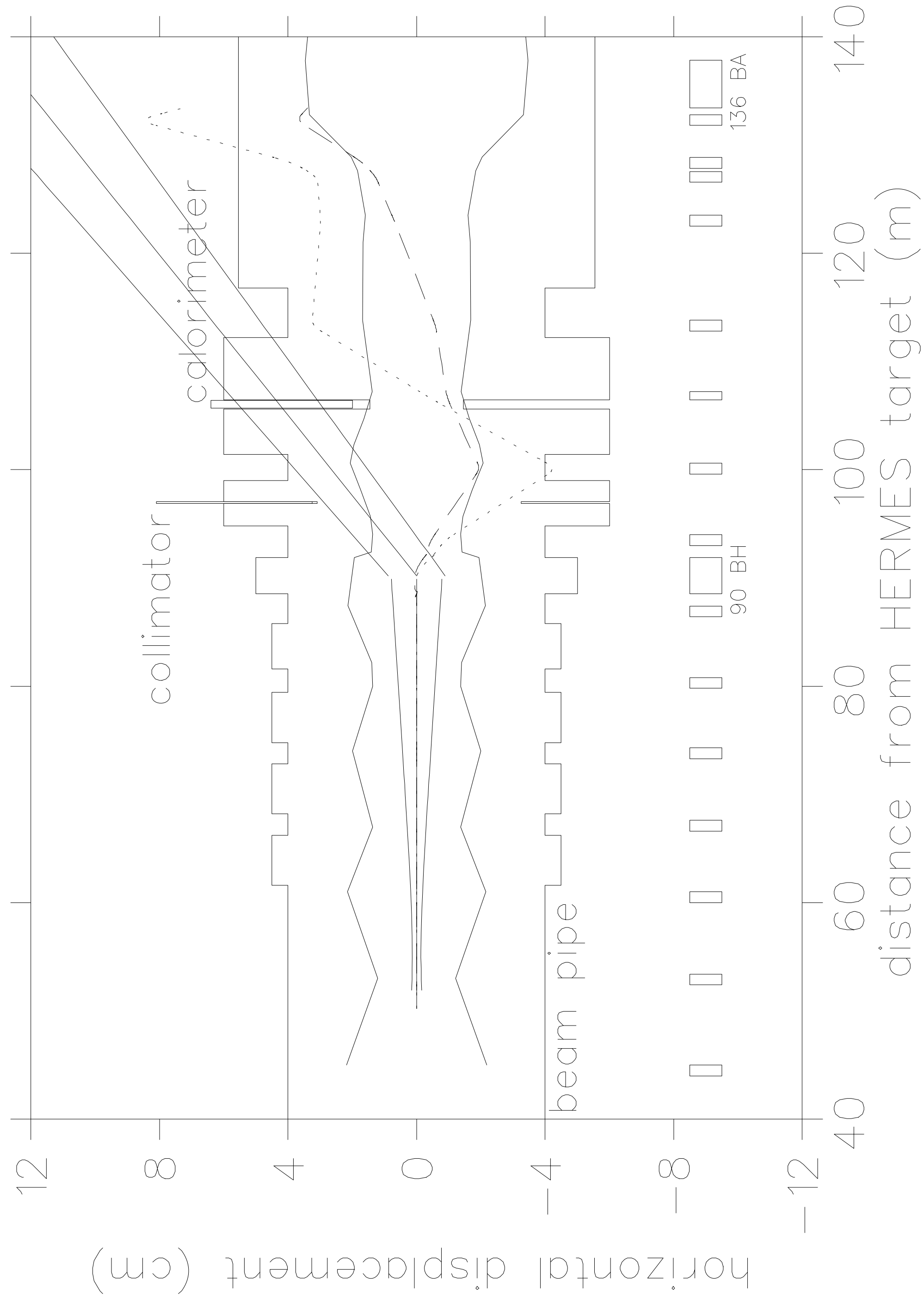


Figure 10: Schematic view of the HERA-e beam line and phase space in the neighbourhood of the LPOL IP. The dotted line corresponds to the Compton edge electrons (13.9 GeV photons), the dashed line to the electrons belonging to the 9 GeV photons (which is the zero crossing in the energy asymmetry function). The wiggly line is the beta function of the electron beam and the three lines going through the calorimeter are the (center $\pm$ 3 σ) distributions of the Compton photons.

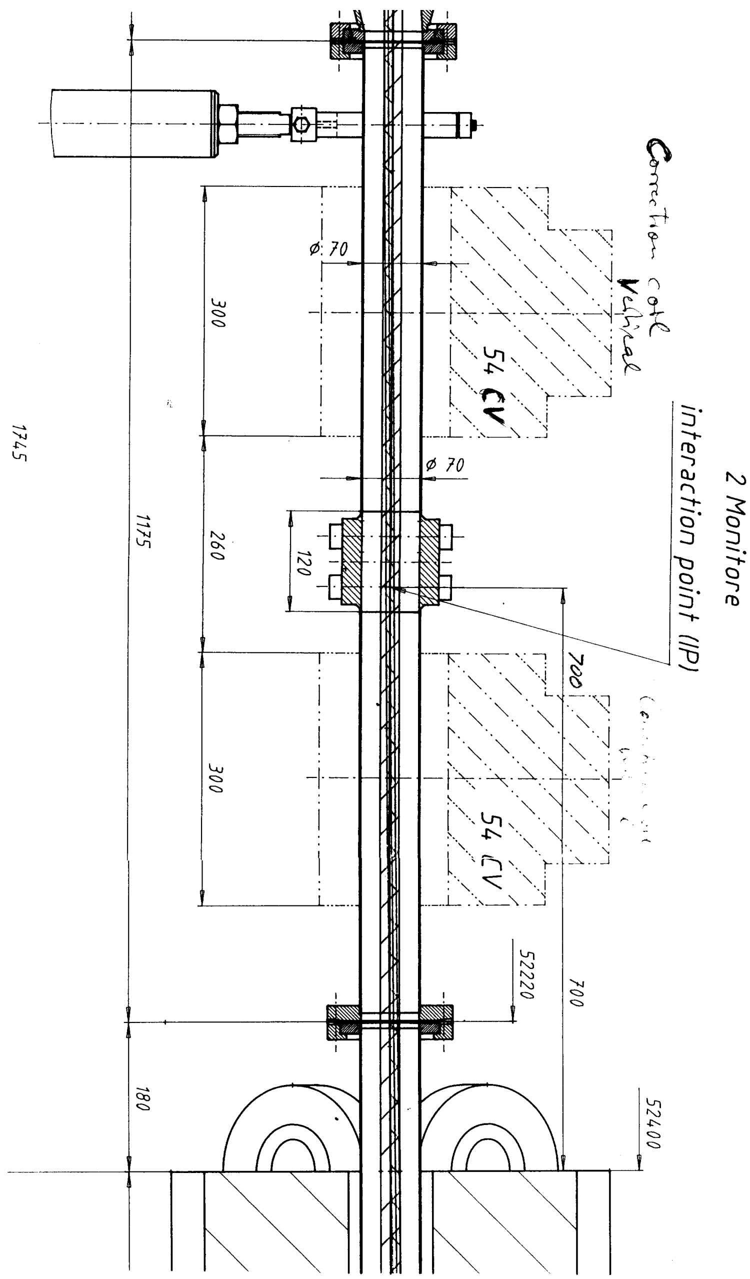


Figure 11: HERA-e beam line layout at the HERMES IP

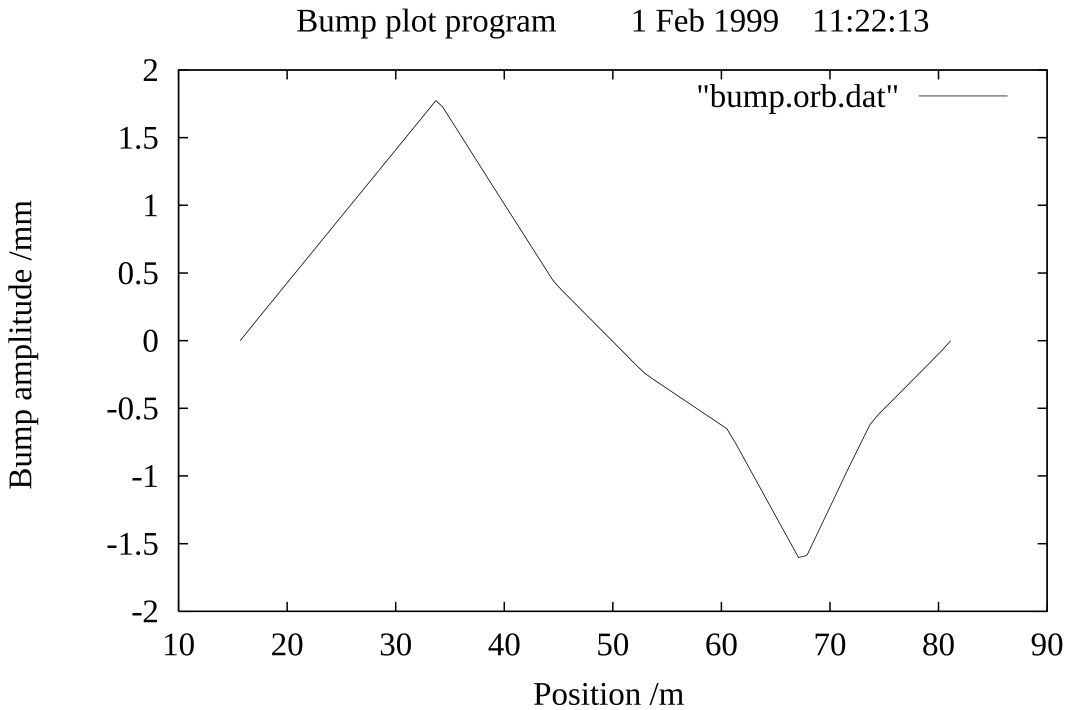


Figure 12: Asymmetric vertical slope bump from OR-16CU, -35CV, -68CV and -81CV

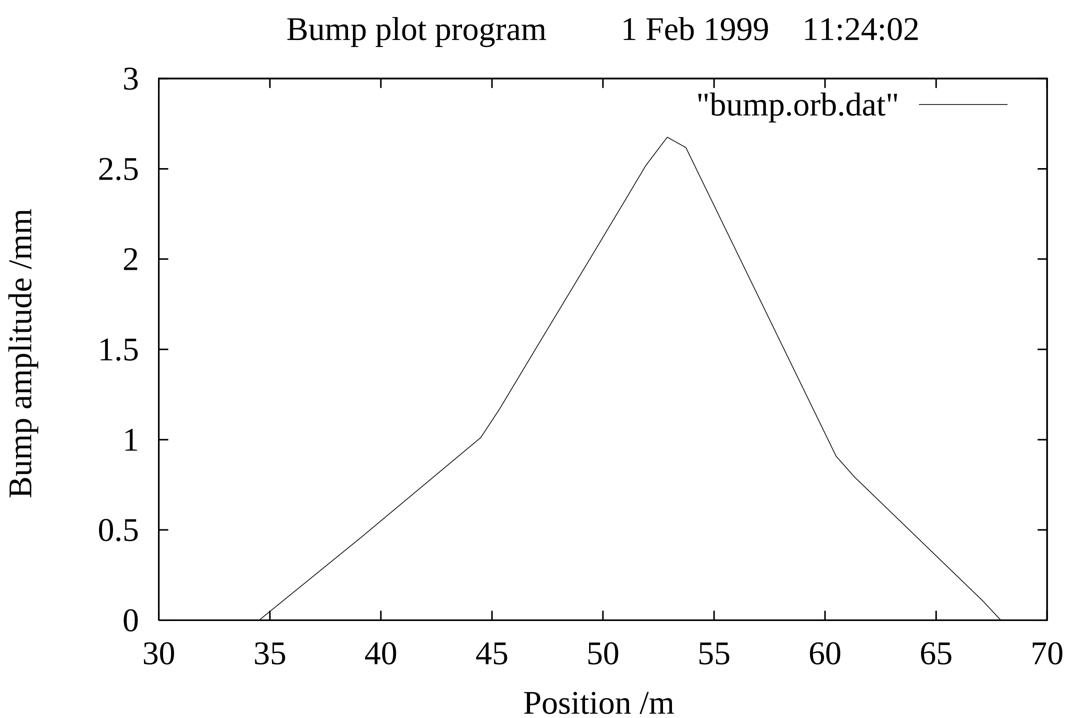


Figure 13: Symmetric vertical position bump from OR-35CV, -54CV and -68CV

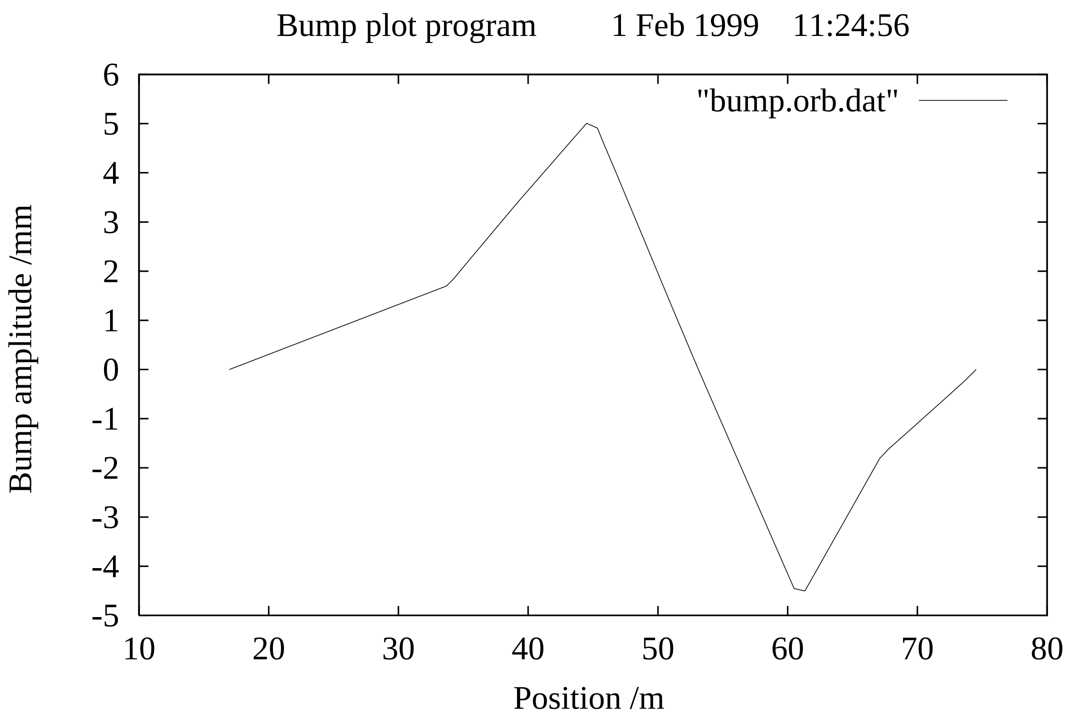


Figure 14: Asymmetric horizontal slope bump from OR-17CV, -45CH, -61CH and -75CH

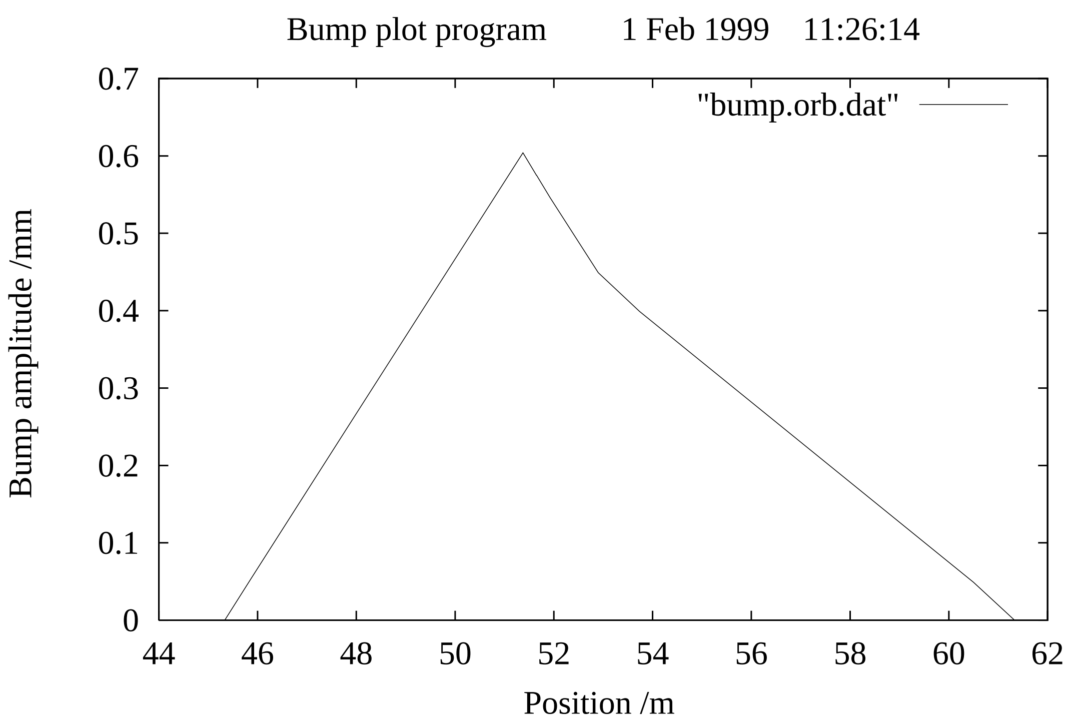


Figure 15: Symmetric horizontal position bump from OR-45CH, -51CI and -61CH

2.2 Detection of the Compton photons

2.2.1 The Compton cone phase space at the HERA exit window

The scattered Compton photons ([11]).

2.2.2 The Scintillating Fibre Hodoscope/preshower

Since January 1999 a fibre hodoscope, preceeded by a ??mm Pb preshower, is installed in tunnel in front of the LPOL crystal calorimeter (at present in front of the sampling calorimeter, for testing). This additional detector provides

- an independent and fast position measurement of the Compton photons
- the spatial distribution of the Compton photons
- a determination of the number of Compton photons per laser pulse-electron beam interaction
- a further reduction of the LPOL systematic uncertainty (e.g. check of gain matching, etc.)

Description of the detector ...

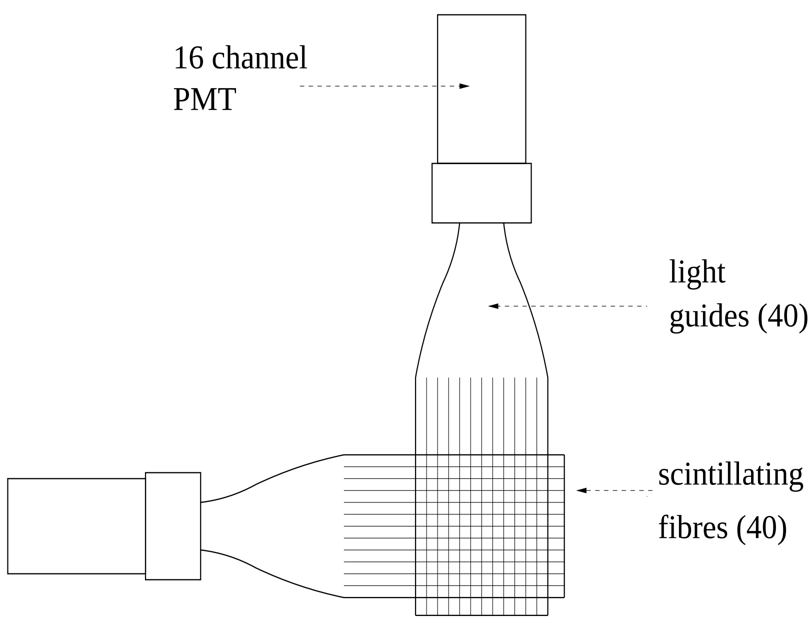


Figure 16: Layout of the Scintillating Fibre Hodoscope/preshower installed in front of the crystal calorimeter.

2.2.3 The NaBi(WO_4) calorimeter

Fig.17 shows the layout of NBW crystal calorimeter set up.
present *setup*: as in testbeam DESY and CERN July/August 98
PM parameters: HV, gain

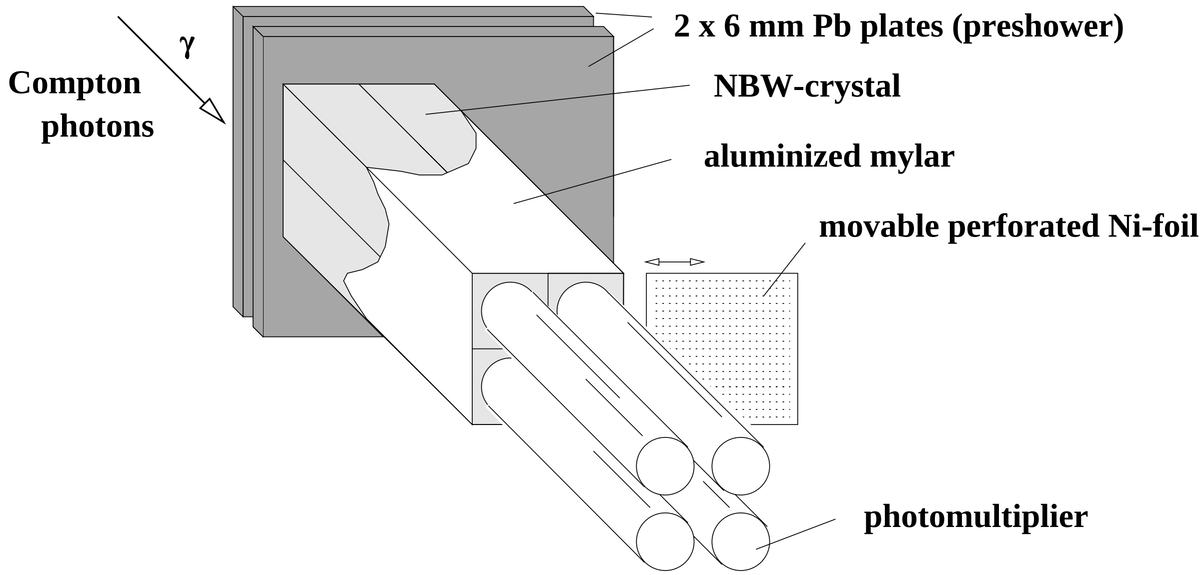


Figure 17: Layout of the NBW crystal calorimeter.

position: vert. and horiz.
effect from *bi-refringence*?

Figure 18: Technical drawing of the crystal calorimeter (side view).

Figure 19: Technical drawing of the crystal calorimeter (top view).

2.2.4 The mechanical mount of the detectors at OR106m

Text....

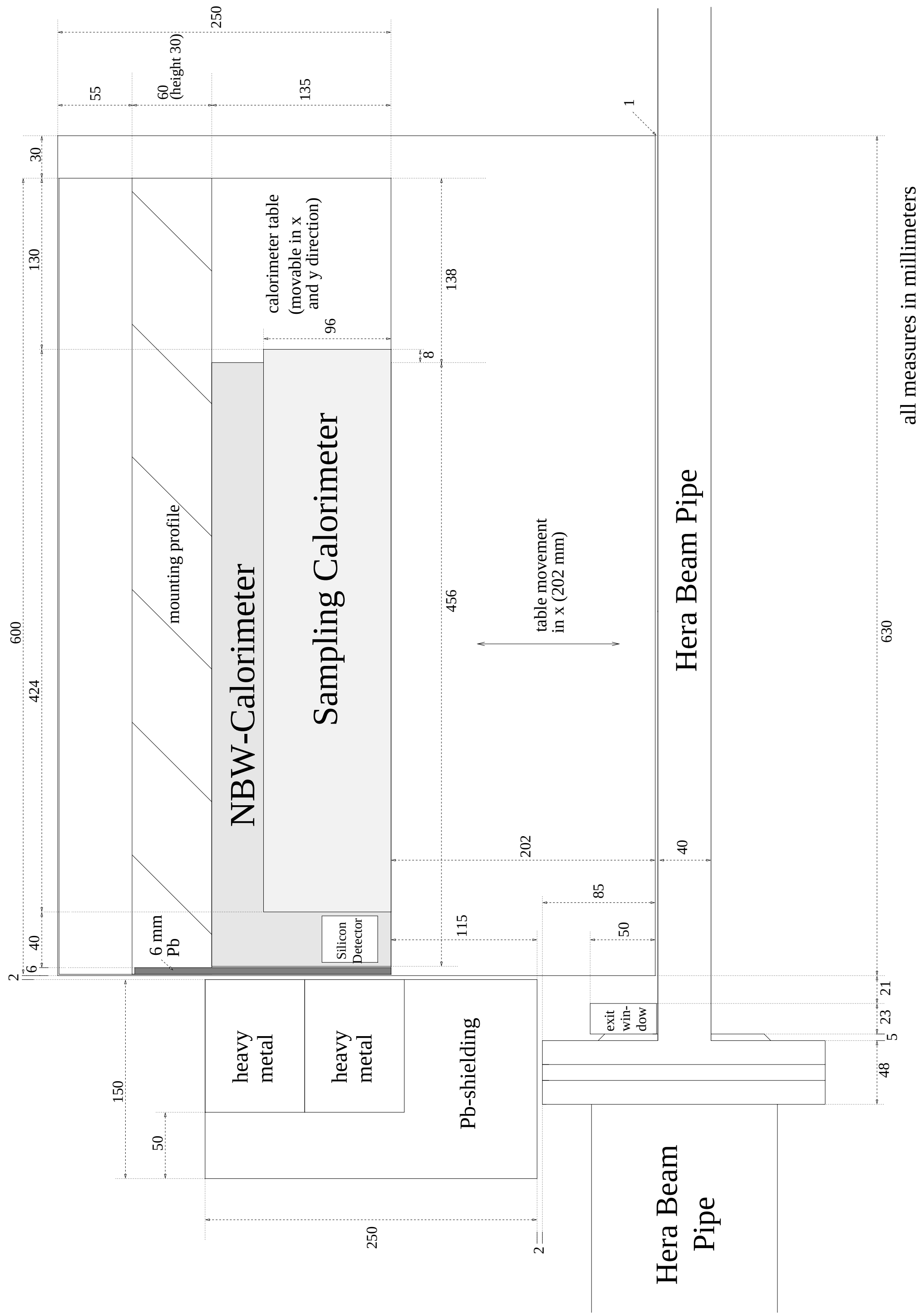


Figure 20: Mechanical mount of the LPOL detectors on the xy-table (top view).

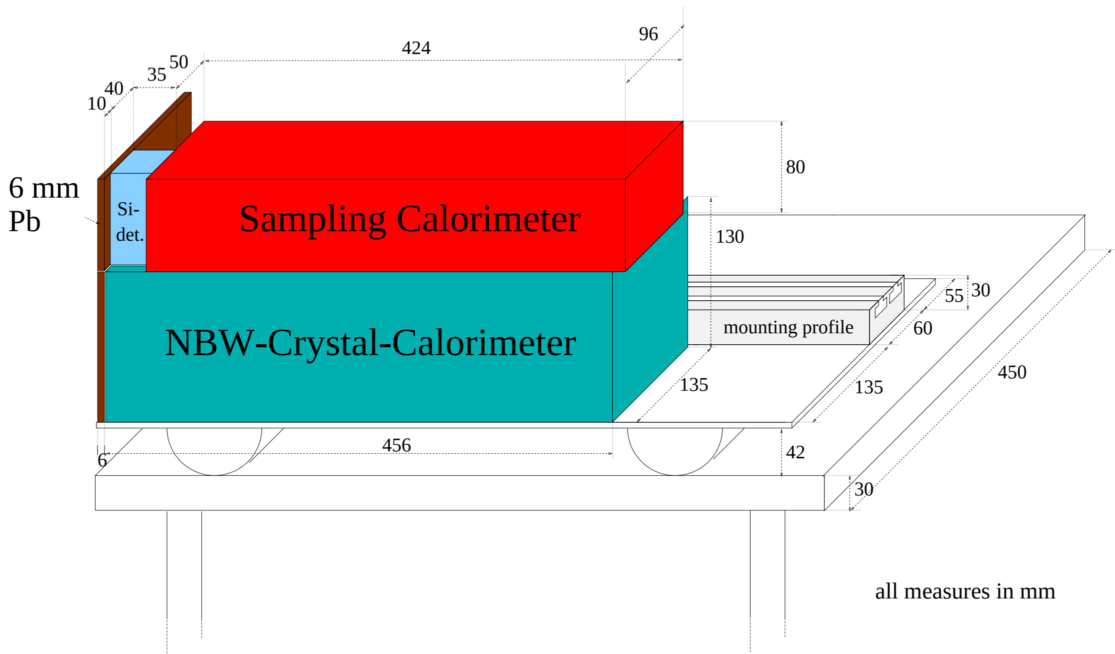


Figure 21: Mechanical mount of the LPOL detectors on the xy-table (side view).

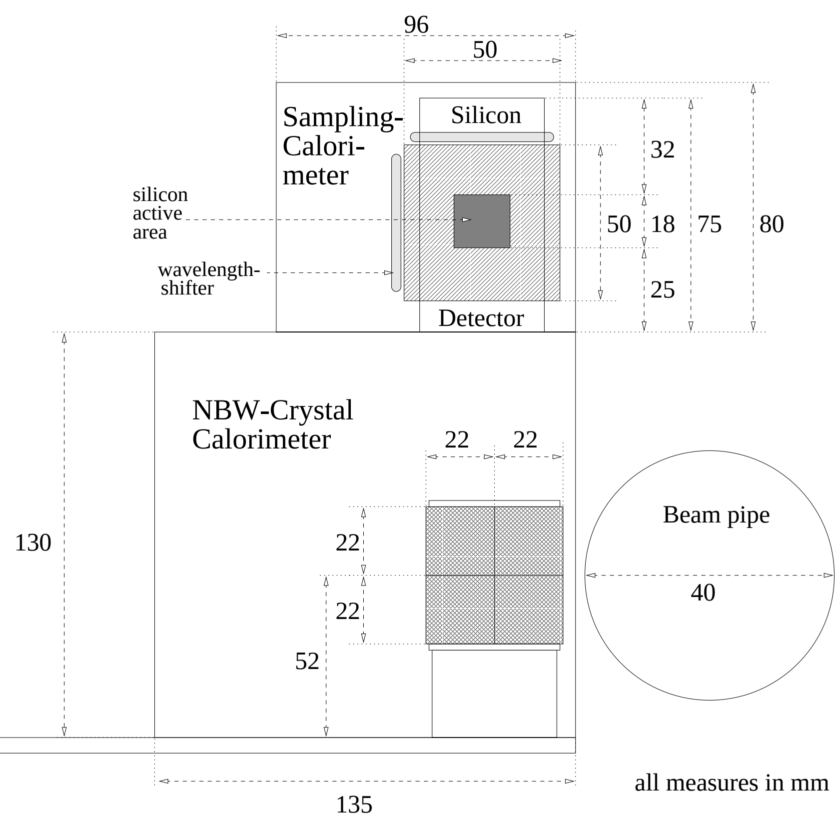


Figure 22: Mechanical mount of the LPOL detectors on the xy-table (front view).

2.2.5 The LPOL Gain Monitoring System (GMS)

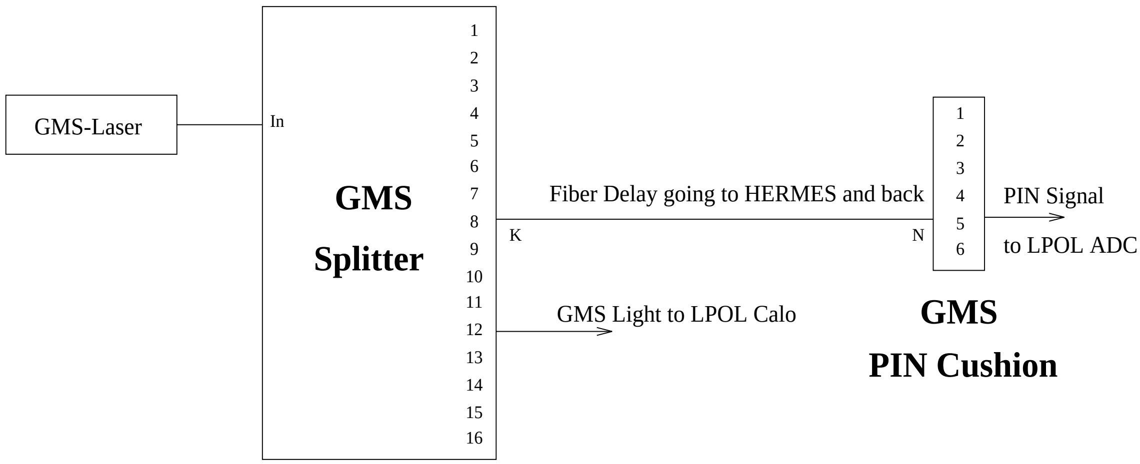


Figure 23: Scheme of the LPOL GMS on the 2nd floor of the ET, rack G3-5.

3 Electronics

3.1 Trigger system

3.1.1 Laser timing

The scheme for the laser timing is sketched in Fig.24. For the following description, we assume that the LPOL is working in the multi-photon mode and that we trigger randomly on the various bunches.

Starting point is the pulser (**PDGG**) which generates - for a given bunch number- events of the following type and in the following sequence:

- background event (i.e. gate generated but laser not fired) to determine the pedestal, including possible energy deposits from Bremsstrahlung processes
- multi-Compton event (typ. 10^3 Compton photons) with laser light helicity state "left" (S_3=-1)
- background event (as above)
- multi-Compton event (typ. 10^3 Compton photons) with laser light helicity state "right" (S_3=+1)

After such a 4-event sequence, the bunch trigger module (**BTM**) is set to a different bunch number by the DSP (which includes a random generator) and the whole process repeats itself. The BTM generates a signal ('B Trigger') whenever the specific bunch passes by i.e. with a repetition rate of 220 * 96 ns = 21.12 μs within a given 4-event sequence. This signal is used as start and synchronisation pulse for the pulser (**PDGG**), although the effective start rate is reduced to 200 Hz by a feedback coincidence of the PDGGs 5 ms long $\overline{NIM}$ output with the BTM signal. All the relevant signals in the laser timing system are synchronised by the HERA clock (**HC**) which is generated by the 'Bunch Clock' output of the BTM.

The basic signal is the pulser signal with a frequency of about 200 Hz. It generates any of the 4 events listed above and is latched as **T2 := laser fired .OR. background** -signal in an input register.

The laser is fired at about 100 Hz i.e. half of the initial pulser frequency. This is realised using a prescaler (**2^n**) with n set to 1. The following gate generator (**GG**) uses its L-output to get the laser ready (**LAMP TRIG IN**) and to effectively fire the laser via its Q-switch (**Q-SWITCH TRIG IN**). Most of the necessary delay between getting the laser ready and firing it is realised with two clock counters (the first one counting 10 bunch passes (989 $\rightarrow$ 999), the second one 434 Hera clocks (565 $\rightarrow$ 999)) making up for a total delay of about 253 μs. In addition, a delay cable is inserted in the Q-SWITCH TRIG IN branch for synchronisation of the laser beam packages with the electron beam bunches. A **T1 := laser fired** -signal marks this type of event as multi-Compton event in an input register.

The Pockels Cell (**PC**) is also operated at about 100 Hz, but the switching of the helicity state accours with 180^o phase shifted w.r.t. the laser signal (see timing diagram in Fig.24). This is realised electronically by feeding the 200 Hz pulse into a system consisting essentially of a branch that sets an RS-flip flop and a branch with a prescaler ($\mathbf{2^n}$ n=1) to reset the flip flop. In addition, the system is gated with the $\overline{\mathrm{L}}$-output of the gate generator in the laser firing branch in order to prevent the prescaler unit from resetting the flip flop at the occurence of a laser signal.

The **Trigger T1/2** -signal is the main trigger, used for the determination of the beam polarisation. It is one of the 4 type of events listed above and goes into the LPOL Trigger-OR module which eventually generates the gate for the ADCs. The T1/2-signal is first delayed via a third clock counter (counting 20 bunch passes (979 $\rightarrow$ 999)) and then passing through a delay cable that allows to adjust the timing between the calorimeter signals (Compton+ background) and the ADC gate. In the later analysis, the distinction between multi-Compton and background event is done using the information from the T1 and T2 input register signals.

3.1.2 Trigger scheme

The scheme for the trigger system is sketched in Fig.25.

Central piece of this system is the fan in (**Trigger-Or**) of all trigger signals from individual subsystems:

- **Trigger 1/2** : laser fired .OR. background event
- **PED Trigger** : pure 'pedestal' event (no Bremsstrahlung background included, sice the pecestal trigger fires only on 'empty' bunches)
- **GMS Trigger** : event in which the GMS laser has fired to monitor the PMT gains
- **SUM Trigger** : event, which is triggered by 4 coincident signals of all PMTs in the crystal calorimeter. This trigger has to be deactivated in standard operation by the output register **'enable sum'** set to LOW. The status of this output register is set in the COP **Trigger** window.

The pattern of these triggers as well as some additional signals are latched in an input register:

- **Trigger bit 1** : = T1 : laser fired
- **Trigger bit 2** : = T2 : laser fired .OR. background
- **Trigger bit 3** : SUM
- **Trigger bit 4** : GMS
- **Trigger bit 5** : PED
- **Trigger bit 6** : Helicity bit: Left (=-) or Right (=+) circular polarisation state

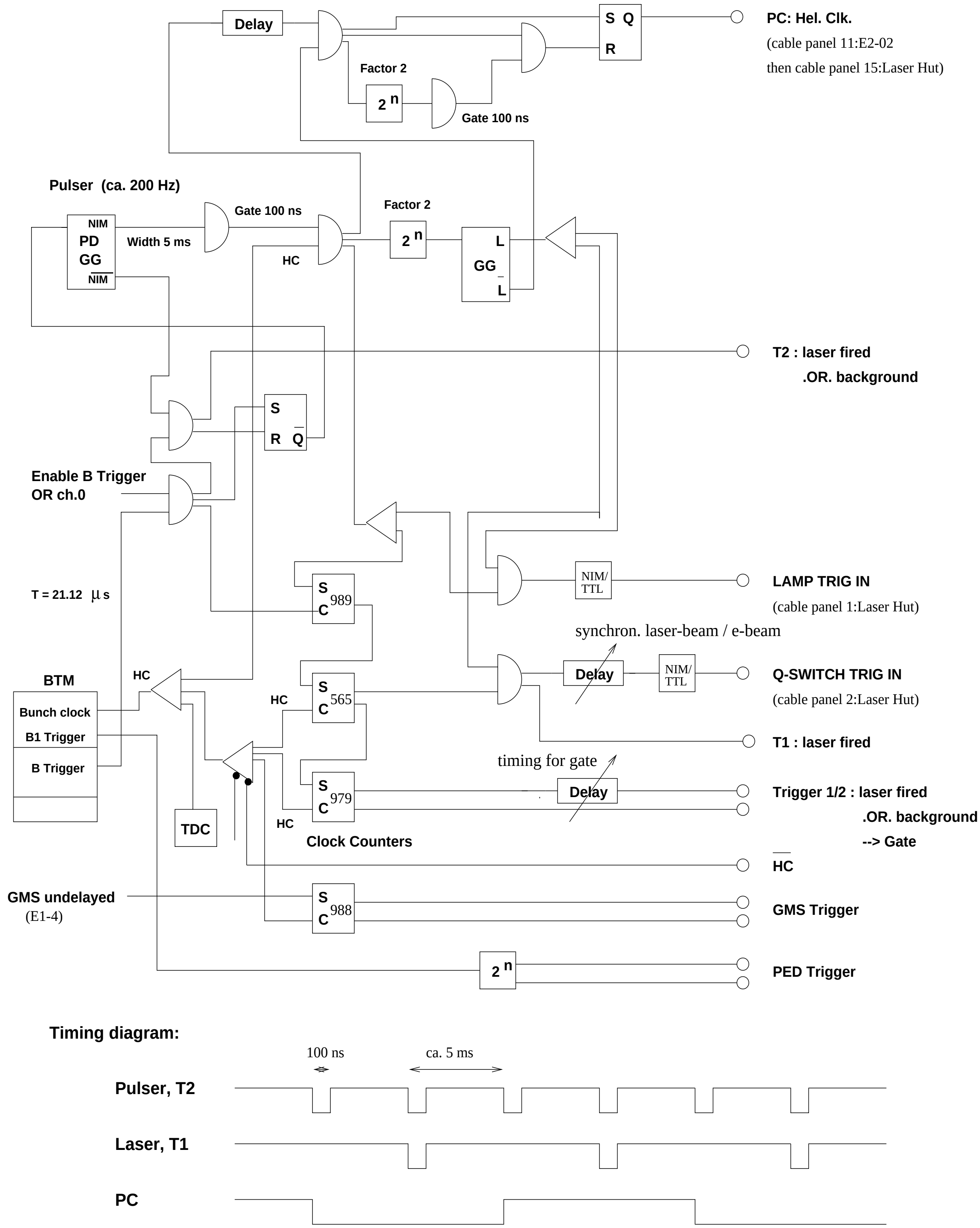


Figure 24: Scheme of the LPOL laser timing. The electronics is located in the ET rack E1-11 (top crate and 2nd crate from the top) and rack E1-10 (2nd crate from the top).

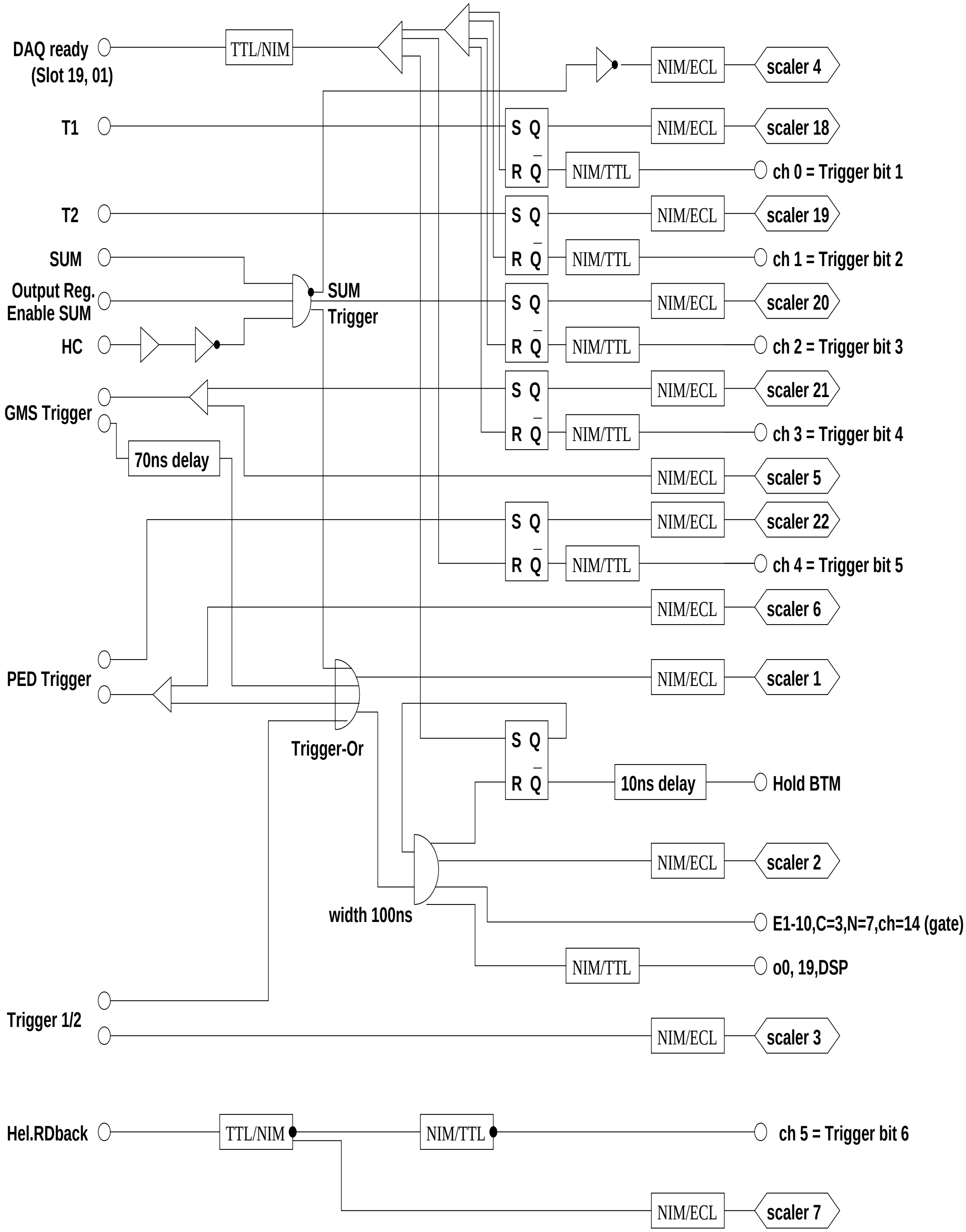


Figure 25: Scheme of the LPOL trigger system. The electronics is located in the ET rack E1-11 (1st, 2nd and 3rd crate from the top) and rack E1-10 (2nd and 3rd crate from the top).

```
 Scaler Page          18

 Counts per second

Triggers gen.             198.8                              0.0
Triggers acc.             198.6   Tr.bit 1 (L)              96.5
Trg. 1/2 gen.             192.9   Tr.bit 2 (L/P)           192.9
SUM Trg. gen.               0.0   Tr.bit 3 (SUM)             0.0
GMS Trg. gen.               3.0   Tr.bit 4 (GMS)             3.0
PED Trg. gen.               2.9   Tr.bit 5 (PED)             2.9
Helic. flips               48.2                              0.0
                            0.0                              0.0
NBW Coinc.                 83.0                              0.0
NBW PMT 1                 226.8                              0.0
NBW PMT 2                 287.6   PIN Las. tim.             96.5
NBW PMT 3                 890.6   PIN Las. int.             96.5
NBW PMT 4                 100.5   PIN AB1                    0.0
                            0.0   PIN 1/AB2                 96.5
Sampl. PMT                  0.0   PIN 2/AB2                 92.3
Sampl. PMT+Filt             0.0   PIN GMS                    3.0
```

Figure 26: The LPOL scaler page 18. The description of the various scaler inputs is contained in the file /us0/mki/conf/scaler.conf → /ult0/haas/Pub/scaler.conf.

3.1.3 Signal timing and pulse shapes

Pulse shape parameters are determined according to the nomenclature specified in Fig.27. The reference times for the ADC gate (t_o^{gate}) and the start of the PMT signal pulses (t_o^{signal}) are defined as follows: t_o^{gate} is measured at the OUT of the trigger dead time logic coincidence unit in rack E1-11, 2nd crate from the top, NIM station 11; t_o^{signal} is measured at the connection to the LEMO-to-ECL ADC cable i.e. 5ns before the ADC input.

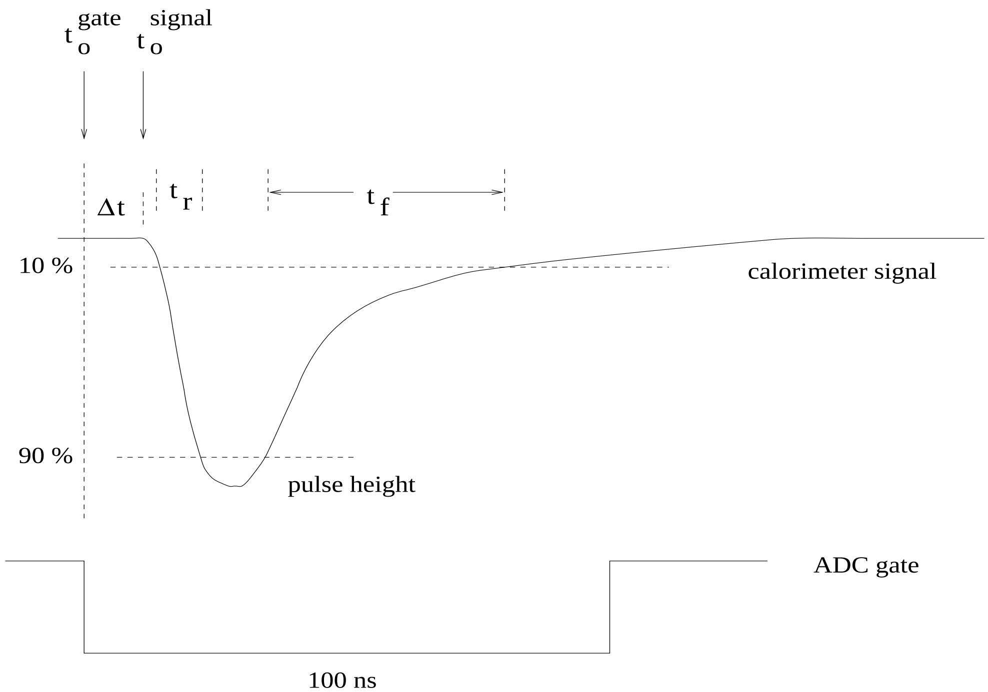


Figure 27: Definition of the timing and the pulse shape parameters of the analogue signals.

The correct timing of the analogue signals is determined by running a delay curve on the PMT signals w.r.t. the ADC gate generated by Trigger 1/2 events (3.1) with laser ON in the presence of e-beam. The resulting curve is shown in Fig.28. Zero corresponds to the optimal timing (chosen to be $\sim$ 10 ns away from the point of cutting into the leading edge of the analogue signals) and translates into a time difference $\Delta t_{gate}^{signal} = t_o^{signal} - t_o^{gate}$ of (52.0 ± 0.5) ns adjusted on the oscilloscope by an appropriate delay of the gate signal. The same time difference is subsequently adjusted for the 3 PIN diodes "Laser Timing", "Laser Intensity" and "AB1" by adapting the delay of the signal cables, leaving the ADC gate untouched. The correct timing of these diodes is confirmed by the delay curve of Fig.29. The timing for Trigger 1/2 events is then transferred to the GMS Trigger by adapting the GMS Trigger signal entering the TRIGGER OR module in such a way that the PMT signals originating from the GMS laser pulses have the same timing Δt_{gate}^{signal} of (52 ± 2) ns w.r.t. the ADC gate as generated by the GMS Trigger. At the end, the PIN diode "GMS" is timed in using the GMS Trigger. The correct timing of the PMT and the GMS PIN diode signals w.r.t. the GMS Trigger time is also cross checked via a delay curve (Fig.30).

Signal	PMT Comptons	PMT GMS	PIN GMS	PIN "Laser Timing"
Δt_{gate}^{signal}	52.0 ns ± 0.5 ns	52 ns ± 2 ns	57 ns ± 2 ns	52 ns ± 2 ns
t_r		5 ns ± 1 ns	7 ns ± 1 ns	2.5 ns ± 0.5 ns
t_f		30 ns ± 5 ns	130 ns ± 10 ns	20 ns ± 2 ns
pulse height normal. to	400 mV ± 100 200 mJ IR , 45mA e-	7 mV ± 1 mV max. setting	50 mV ± 5 mV max. setting	400 mV ± 50 mV 200 mJ IR

Signal	PIN "Laser Intensity"	PIN "AB 1"	PIN "1/AB 2"	PIN "2/AB 2"
Δt_{gate}^{signal}	52 ns ± 2 ns	52 ns ± 2 ns		
t_r	5 ns ± 0.5 ns	2.5 ns ± 0.5 ns		
t_f	50 ns ± 10 ns	25 ns ± 5 ns		
pulse height norm. to	600 mV ± 50 mV 200 mJ IR	450 mV ± 50 mV 200 mJ IR; $\lambda/2$=120^o	 200 mJ IR	 200 mJ IR

Signal	Sampling calo PMT+Filter Comptons
Δt_{gate}^{signal}	52 ± 0.5 ns
t_r	
t_f	
pulse height normal. to	400 mV ± 100 mV 200 mJ IR, 45 mA e-

Table 13: Pulse shape parameters and timing of the NBW and sampling calorimeter PMT and the PIN analogue signals used in the LPOL system. All PMT signals are timed in relative to each other within ± 1 ns.

Figure 28: Delay curve of the NBW crystal PMT1-4 signals w.r.t. the ADC gate timing for Trigger 1/2 laser ON conditions. Zero corresponds to the optimal timing as determined and stored in Tab.13, negative values correspond to signals coming earlier in time w.r.t. the gate.

Figure 29: Delay curve of the 3 PIN diode signals w.r.t. the ADC gate timing for Trigger 1/2 laser ON conditions. Zero corresponds to the optimal timing as determined and stored in Tab.13, negative values correspond to signals coming earlier in time w.r.t. the gate.

Figure 30: Delay curve of the NBW crystal PMT1-4 and the GMS PIN diode signals w.r.t. the ADC gate timing for GMS Trigger conditions. Zero corresponds to the optimal timing as determined and stored in Tab.13, negative values correspond to signals coming earlier in time w.r.t. the gate.

Figure 31: Delay curve of the sampling calorimeter PMT+Filter and PMT signals w.r.t. the ADC gate timing for Trigger 1/2 laser ON conditions. Zero corresponds to the optimal timing as determined and stored in Tab.13, negative values correspond to signals coming earlier in time w.r.t. the gate.

3.2 Readout

3.2.1 Readout scheme and event structure

The LPOL is read out (on r5) via the DSP and transfered to the CHI61/Equipment 8 in Walter's DAQ system. Here the data are integrated into the general HERMES EPIO event structure as user event **1352**. Such an user event contains the data of 500 68-word event records. The event record (Tab.14) contains data from the machine data module (MDM), from an input register and a 64-channel ADC (Fig.32,33). [N.B. the correct connection of the black 16-fold ECL connector with the 4 16-fold ADC channel groups is the following. If looking onto the connector as it is put on the ADC, the mass connections must be on the left side and the signals on the right, the channels are numbered 1...16 from top to bottom and the 17th input channel on the ADC stays free of any connection]. The four calorimeter signals are also used to generate a logic signal (**SUM**) indicating coincident signals in all four calorimeter modules above a threshold of 30 mV (Noise is about 5 mV).

cable panel	word	variable	channel	explanation
-	0	misc.		length in words = 30622
-	1-22	misc.		empty
-	23	bunch		low byte contains bunch nr. from MDM
-	24	trigger	input reg.	low byte contains bitpattern:
				1 = T1 laser fired
				2 = T2 laser fired or background evnt.
				4 = T3 SUM trigger
				8 = T4 GMS event
				16 = T5 pedestal event
				32 = T6 Pockels cell helicity
1:OR107	25	ADC1	ADC ch 0	PMT Calo 1
"	26	ADC2	ADC ch 1	PMT Calo 1 out of gate
2:OR107	27	ADC3	ADC ch 2	PMT Calo 2
"	28	ADC4	ADC ch 3	PMT Calo 2 out of gate
3:OR107	29	ADC5	ADC ch 4	PMT Calo 3
"	30	ADC6	ADC ch 5	PMT Calo 3 out of gate
4:OR107	31	ADC7	ADC ch 6	PMT Calo 4
"	32	ADC8	ADC ch 7	PMT Calo 4 out of gate
7:LaserHut	33	ADC9	ADC ch 8	PIN diode 'Laser timing'
"	34	ADC10	ADC ch 9	PIN diode 'Laser timing' out of gate
9:LaserHut	35	ADC11	ADC ch 10	PIN diode 'Laser intensity'
"	36	ADC12	ADC ch 11	PIN diode 'Laser intensity' out of gate
4:LaserHut	37	ADC13	ADC ch 12	PIN diode 'AB1'
"	38	ADC14	ADC ch 13	PIN diode 'AB1' out of gate
-	39	ADC15	ADC ch 14	-
-	40	ADC16	ADC ch 15	-
SF1:OR107	41	ADC17	ADC ch 16	Scint. Fibre Hodoscope ch.1
SF2:OR107	42	ADC18	ADC ch 17	Scint. Fibre Hodoscope ch.2
SF3:OR107	43	ADC19	ADC ch 18	Scint. Fibre Hodoscope ch.3
SF4:OR107	44	ADC20	ADC ch 19	Scint. Fibre Hodoscope ch.4
SF5:OR107	45	ADC21	ADC ch 20	Scint. Fibre Hodoscope ch.5
SF6:OR107	46	ADC22	ADC ch 21	Scint. Fibre Hodoscope ch.6
SF7:OR107	47	ADC23	ADC ch 22	Scint. Fibre Hodoscope ch.7
SF8:OR107	48	ADC24	ADC ch 23	Scint. Fibre Hodoscope ch.8
14:OR46	49	ADC25	ADC ch 24	PIN diode '1/AB2'
"	50	ADC26	ADC ch 25	PIN diode '1/AB2' out of gate
11:OR46	51	ADC27	ADC ch 26	PIN diode '2/AB2'
"	52	ADC28	ADC ch 27	PIN diode '2/AB2' out of gate
rack G3-5	53	ADC29	ADC ch 28	PIN diode 'GMS'
"	54	ADC30	ADC ch 29	-
SF9:OR107	55	ADC31	ADC ch 30	Scint. Fibre Hodoscope ch.9
SF10:OR107	56	ADC32	ADC ch 31	Scint. Fibre Hodoscope ch.10

	57	ADC33	ADC ch 32	PMT Sampling Calo
	58	ADC34	ADC ch 33	PMT Sampling Calo out of gate
	59	ADC35	ADC ch 34	PMT+Filter Sampling Calo
	60	ADC36	ADC ch 35	PMT+Filter Sampling Calo out of gate
SF11:OR107	61	ADC37	ADC ch 36	Scint. Fibre Hodoscope ch.11
SF12:OR107	62	ADC38	ADC ch 37	Scint. Fibre Hodoscope ch.12
SF13:OR107	63	ADC39	ADC ch 38	Scint. Fibre Hodoscope ch.13
SF14:OR107	64	ADC40	ADC ch 39	Scint. Fibre Hodoscope ch.14
SF15:OR107	65	ADC41	ADC ch 40	Scint. Fibre Hodoscope ch.15
SF16:OR107	66	ADC42	ADC ch 41	Scint. Fibre Hodoscope ch.16
SF17:OR107	67	ADC43	ADC ch 42	Scint. Fibre Hodoscope ch.17
SF18:OR107	68	ADC44	ADC ch 43	Scint. Fibre Hodoscope ch.18
-	69	ADC45	ADC ch 44	-
-	70	ADC46	ADC ch 45	-
-	71	ADC47	ADC ch 46	-
	72	ADC48	ADC ch 47	HERA clock time - laser trigger time
	73	ADC49	ADC ch 48	HERA pickup time - laser trigger time
-	74	ADC50	ADC ch 49	-
SF19:OR107	75	ADC51	ADC ch 50	Scint. Fibre Hodoscope ch.19
SF20:OR107	76	ADC52	ADC ch 51	Scint. Fibre Hodoscope ch.20
SF21:OR107	77	ADC53	ADC ch 52	Scint. Fibre Hodoscope ch.21
SF22:OR107	78	ADC54	ADC ch 53	Scint. Fibre Hodoscope ch.22
SF23:OR107	79	ADC55	ADC ch 54	Scint. Fibre Hodoscope ch.23
SF24:OR107	80	ADC56	ADC ch 55	Scint. Fibre Hodoscope ch.24
SF25:OR107	81	ADC57	ADC ch 56	Scint. Fibre Hodoscope ch.25
SF26:OR107	82	ADC58	ADC ch 57	Scint. Fibre Hodoscope ch.26
SF27:OR107	83	ADC59	ADC ch 58	Scint. Fibre Hodoscope ch.27
SF28:OR107	84	ADC60	ADC ch 59	Scint. Fibre Hodoscope ch.28
SF39:OR107	85	ADC61	ADC ch 60	Scint. Fibre Hodoscope ch.29
SF30:OR107	86	ADC62	ADC ch 61	Scint. Fibre Hodoscope ch.30
SF31:OR107	87	ADC63	ADC ch 62	Scint. Fibre Hodoscope ch.31
SF32:OR107	88	ADC64	ADC ch 63	Scint. Fibre Hodoscope ch.32

Table 14: Structure of the LPOL event record.(1 word=INT *2).

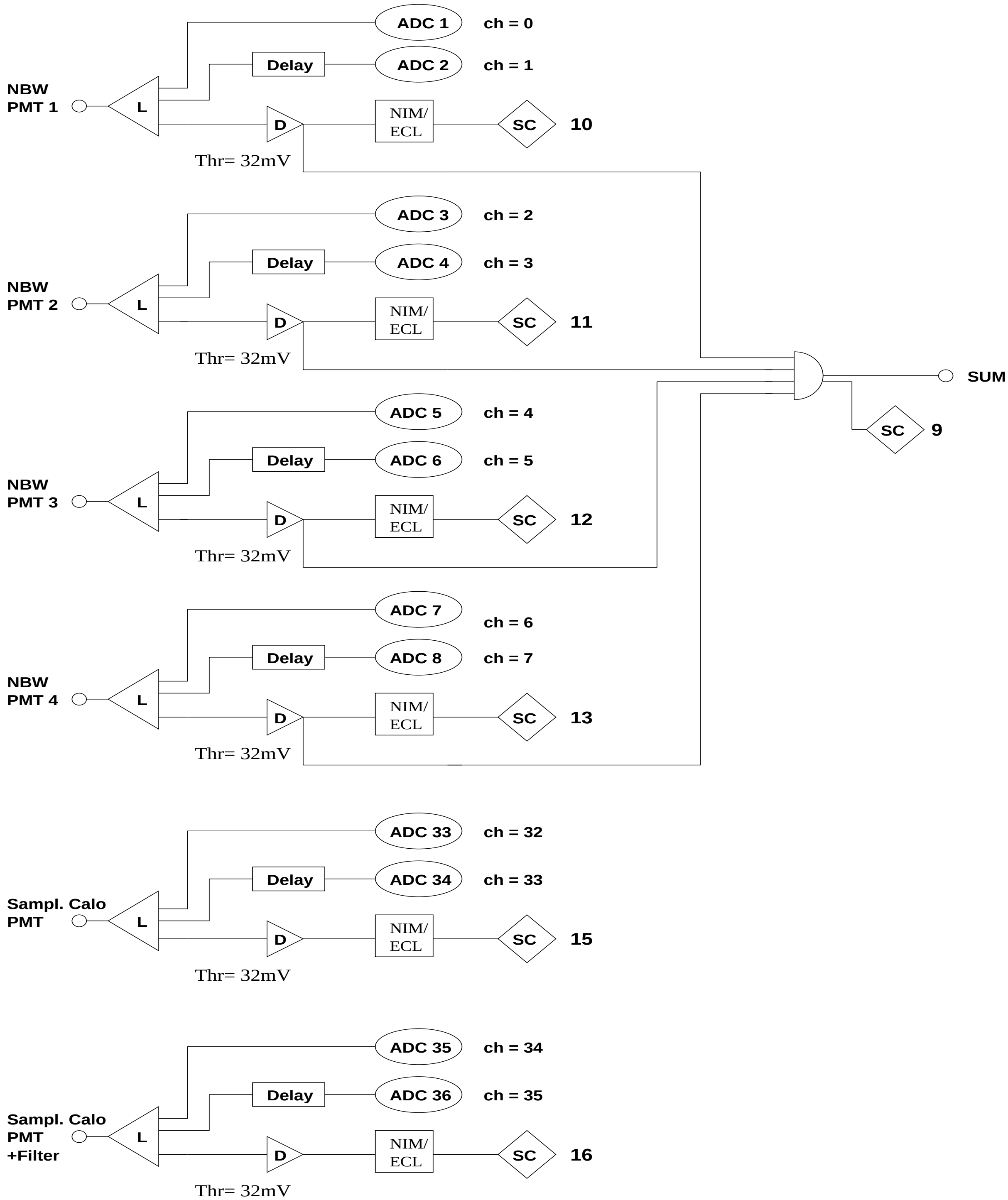


Figure 32: Scheme of the readout of the NBW and sampling calorimeter modules. The linear fan-outs are located in the ET rack E1-10 (2nd crate from the top), the discriminators and the sum coincidence module in rack E1-11 (2nd crate from the top), the ADC module in rack E1-11 (bottom crate) and the scaler module in rack E1-12 (3rd crate from the top).

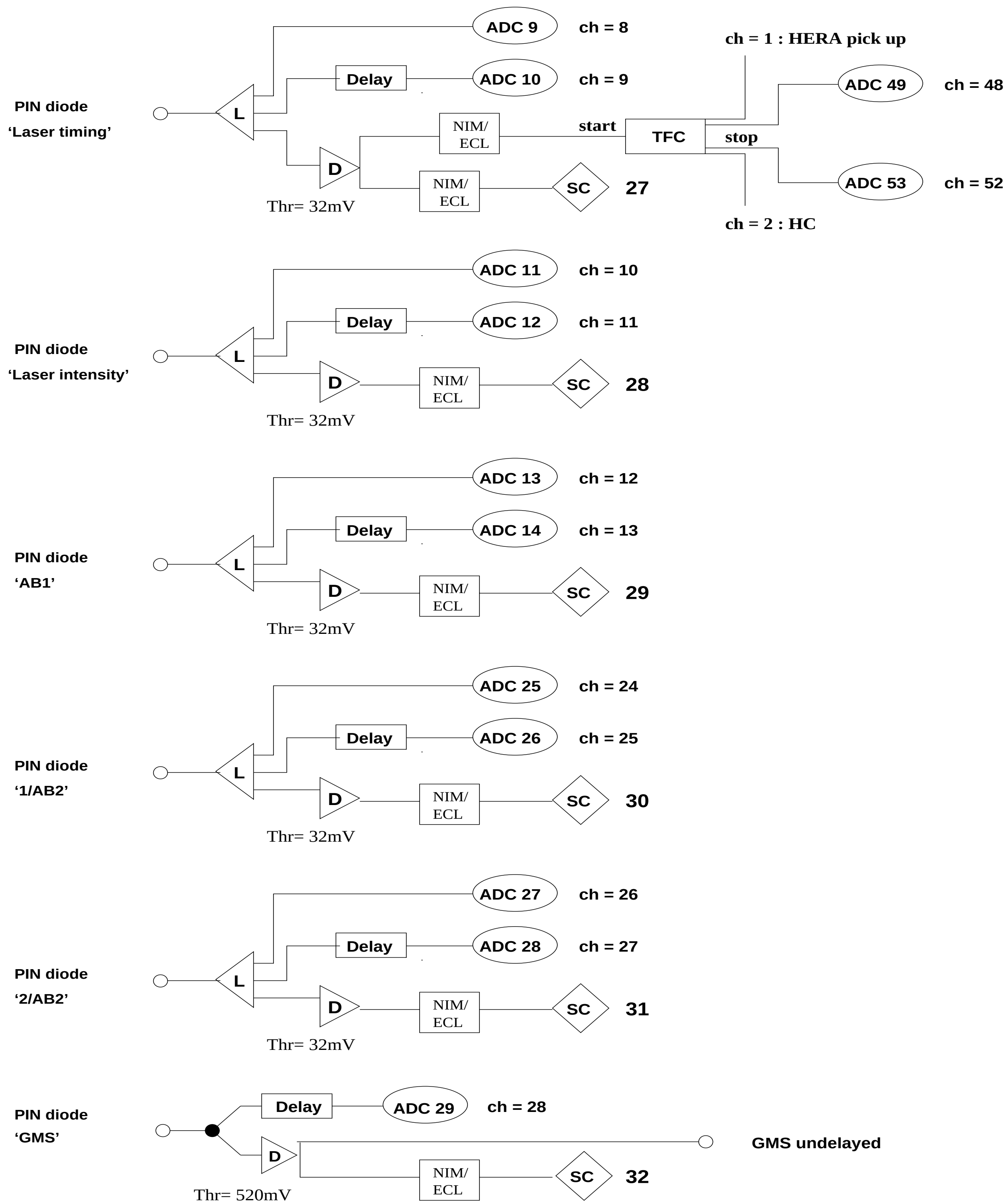


Figure 33: Scheme of the readout of the PIN diodes. The linear fan-outs are located in the ET rack E1-10 (2nd crate from the top), the discriminators in racks E1-11 and E1-10 (2nd crate from the top) and rack E1-4 (2nd crate from the bottom) for the GMS discriminator, the ADC module in rack E1-11 (bottom crate), the TFC in rack E1-11 (top crate) and the scaler module in rack E1-12 (3rd crate from the top).

The online analysis (program: lponl on the r* in /ush1/ofl/lpol.studies/, which pipes data into the .prim files) selects 50000 events which corresponds to a measurement period of approx. 5 min. The ASCII data can be read in into PAW using the macro adcraw.kumac in the directory /ush1/ofl/lpol.studies/lponl.log.

3.2.2 The Digital Signal Processor (DSP)

4 Determination of beam polarisation

4.1 Primary Signal Distributions

All the following plots are taken in the LPOL multi-photon mode, with the trigger working in the random bunch mode.

4.1.1 Determination of pedestal and noise correction

Multi-Compton photon signals for the two laser helicity states originate from **Trigger 1/2** events with **laser ON**, helicity $\pm$ (Tab.14: trigger bits 1 and 2 set, trigger 6 helicity bit = 0 or 1). The corresponding spectra are obtained from the raw ADC signals by subtraction of a "pedestal" which takes into account the electronic noise behaviour of the calorimeter readout system (PMT + cables + ADC input) as well as possible Bremsstrahlungs background events accompanying the laser-electron beam interaction within a time window of 100 ns (= width of the ADC gate). This pedestal is determined by the complementary **Trigger 1/2** events with **laser OFF**, helicity $\pm$ (Tab.14: trigger bit 2 set but 1 not set, trigger 6 helicity bit = 0 or 1). Fig.34, 35 show such pedestal spectra for the calorimeter modules 1-4 and for the PIN diodes, respectively.

An obvious check of this method to determine the pedestal comes up in absence of the electron beam. In this case, both the Trigger 1/2 events with laser ON and laser OFF should lead to the same pedestal as the ADCs are recording the pure noise behaviour of the system. This is indeed the case, after finally decoupling galvanically all the PIN diode and logic signals coming from the laser hut before they enter electronic modules in the crates of the ET. [Prior to these measures, the difference in pedestal mean values between laser ON and laser OFF was typ. +10 ADC channels, corresponding to a +2% effect in the energy asymmetry and a +10% effect in the measurement of the polarisation! The firing of the laser causes electromagnetic noise of very high frequency that couples into the PIN diodes and the signal cables in the laser hut and that propagates into the crates in the ET thus affecting finally all ADC signals. In addition, an electromagnetic noise burst is seen about 10 μs after the firing, dying out exponentially with a time constant of silimar value; this component however comes too late to have any impact on the readout.]

The results from two other studies are of interest here. Trigger 1/2 events with laser OFF show no difference in pedestal for helicity + and - states, as expected. Hence both states are used together in the determination of the pedestal. Also do Trigger 1/2 events with laser OFF make no difference in the value of the pedestal for full and empty bunches. This is less obvious but nevertheless expected as the influence of Bremsstrahlungs background processes on the spectra is effectively marginal. This is the result of the high light reduction before the PM cathode such that single Bremsstrahlungs photons (with energies of order 10 GeV) only lead to negligible ADC signals in the selected energy range of a few 10 TeV. Hence also all bunches without further selection can be used to determine the pedestal. Not surprising the do even pedestal data taken with the **PED Trigger** (Tab.14: trigger 5 bit set, trigger 6 helicity bit arbitrary) lead to the same results. PED trigger events are recorded with the laser being OFF and are synchronised to bunch nr. 211 ('B1 Trigger' signal from the BTM) which is part of the empty bunch train at the end of the bunch cycle.

As can be seen from the Fig.34 and 35, the pedestal spectra are generally very broad (typ. 40 ADC channels). This is due to noise contributions that are either induced in the PMT system and in the long cables from the LPOL at OR107 on the way to the ET, or directly fed in at the level of the NIM/FB crate & modules as a result of the poor grounding situation in the ET. This last component has a frequency of about 150 Hz and is by far the most dominant one. In order to get rid of the low frequency noise components, the ADC signals are splitted and the second signal is fed with a delay of 96 ns into a neighbouring ADC channel. The 2 signals are highly correlated as can be seen from Fig.36, 37 and the linear correlation (with slope α and offset β) can be used to subtract the noise component for each PMT calorimeter signal on an event by event basis: $ped' = ped - (ped_{-96ns} - \beta)/\alpha$. The width of the pedestal distributions reduces drastically to typ. ?? ADC channels, as can be seen in Fig.38, 39 in comparison to Fig.34, 34. The mean value stays unaffected by the width correction, as expected. All the pedestal signals are well reproduced by Gaussian fits and no difference is observed between the histogram mean & RMS and the fitted mean & σ, respectively. Due to the Bremsstrahlungs background contribution, it is in principle more appropriate to use the histogram mean of the spectra, not the fitted means, to determine the pedestal.

Figure 34: Pedestal spectra of PMT 1-4, taken with Trigger 1/2 laser OFF (triggermask=2 or 34); both helicity states, all bunches.

Figure 35: Pedestal spectra of the PIN diodes, taken with Trigger 1/2 laser OFF (triggermask=2 or 34); both helicity states, all bunches.

Figure 36: Noise correlations of PMT1-4, taken with Trigger1/2 laser OFF (triggermask=2 or 34); both helicity states, all bunches.

Figure 37: Noise correlations of the PIN diodes, taken with Trigger1/2 laser OFF (triggermask=2 or 34); both helicity states, all bunches.

Figure 38: Noise corrected pedestal spectra of PMT 1-4, taken with Trigger 1/2 laser OFF (triggermask=2 or 34); both helicity states, all bunches.

Figure 39: Noise corrected pedestal spectra of the PIN diodes, taken with Trigger 1/2 laser OFF (triggermask=2 or 34); both helicity states, all bunches.

4.1.2 Pedestal subtracted and noise corrected ADC signals

4.2 Determination of Compton photon asymmetry

4.3 Measurement of laser light polarisation

The measurement of the light polarization with the analyzer boxes in the laser hut (AB#1) and in the tunnel (AB#2) is based on the following principle:
A half-wave plate rotates the electric field vector of the linear component of the incoming elliptically polarized light by an angle which is twice the orientation angle of the optical axis of the plate with respect to the field vector (see Fig.40):

$$\Delta\alpha = 2 \cdot \alpha_{\lambda/2} \tag{1}$$

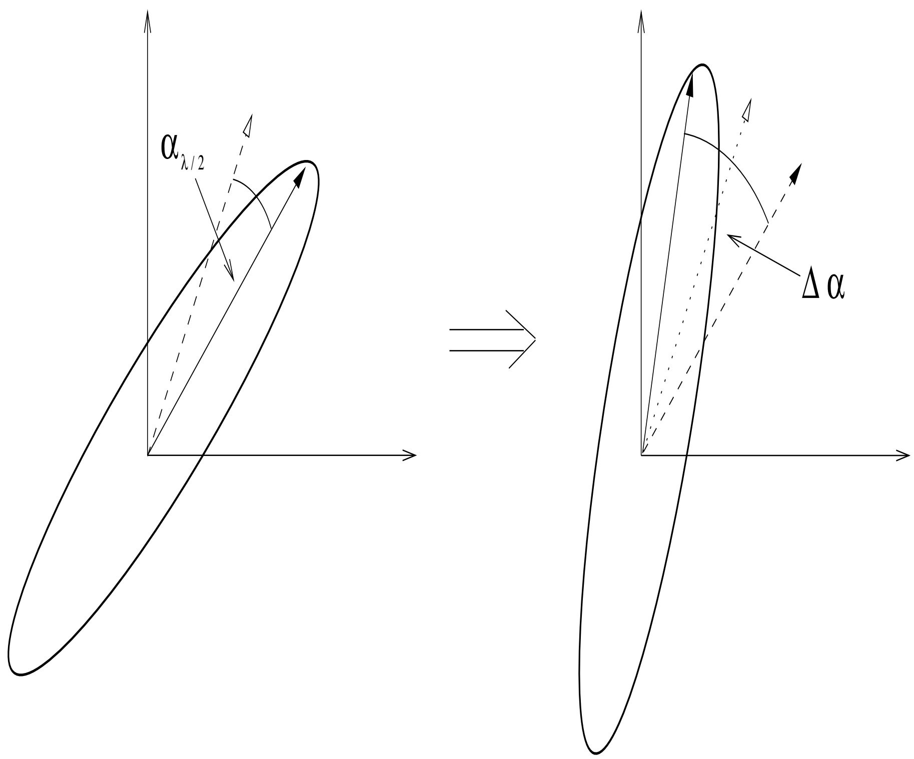


Figure 40: Effect of a half-wave plate on elliptically polarized light.

A Glan-Thompson prism works as an analyzer of the incoming light:
It splits the light into an ordinary and an extraordinary part
corresponding to the optical axes of the birefringent crystal. The amplitude of the ordinary (extraordinary) component is proportional to the cosinus (sinus) of the orientation to the optical axis (see Fig.41). With α_{GT} being the orientation of the Glan-Thompson prism with respect to the main axis of the ellipse, the intensity varies as

$$I = A^2 \propto \sin^2(\alpha_{GT}). \tag{2}$$

Figure 41: Intensity of the ordinary ($I_{o.}$) and extraordinary($I_{e.o.}$) component.

Thus, by rotating the half wave plate by $\alpha_{\lambda/2}$ and allowing a phase δ, the intensity behind the GT prism is given by

$$\begin{aligned} I(\alpha_{\lambda/2}) &= C_0 + C_1 \sin^2(2 \cdot (\alpha_{\lambda/2} + \delta)) \\ &= C_0 + C_1 \frac{1}{2}(1 - \cos(4 \cdot (\alpha_{\lambda/2} + \delta))) \\ &= I_0 + I_1 \cos(4 \cdot (\alpha_{\lambda/2} + \delta)). \end{aligned} \quad (3)$$

I_1 denotes the amplitude of the oscillation, while I_0 is an offset which is given by the laser intensity. This intensity variation of the ordinary and (or) the extraordinary beam is being detected by a PIN diode. It measures the amount of scattered laser light in a beam dump behind the Glan-Thompson prism.
In Fig.42 and 43 the results of two polarization measurements are shown. One can clearly see the $\cos(4(\alpha_{\lambda/2} + \delta))$ behaviour over the full 360° range. The maximum and minimum values of the function are given by

$$I_{max} = I_0 + I_1 \quad (4)$$
$$I_{min} = I_0 - I_1 \quad (5)$$

The linear light polarization is calculated by the asymmetry of these extrema:

$$P_{lin} = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} = \frac{I_1}{I_0} \quad (6)$$

From eq. (6) one can see that the linear component is > 1 for $I_{min} < 0$. To avoid this problem, one should proof that the pedestals are measured and subtracted correctly.
The circurlar component can be calculated via

$$P_{circ} = \sqrt{1 - P_{lin}^2}. \quad (7)$$

The deviations from the expected curve can originate either from a nonhomogenious transmission or from an additional phase shift of the half wave plate or the Glan-Thompson prism. In case of a phase shift, one can determine the $\cos(4\alpha)$ component by a fourier transformation of the data points, as it is described in the next section.

Fourier transformation

One can approximate a set of N equidistant data points by a trigonometrical polynomal of the following form:

$$T(\alpha) = \frac{a_0}{2} + \sum_l (a_l \cos(l \cdot \alpha) + b_l \sin(l \cdot \alpha)), \tag{8}$$

with the coefficients

$$a_l = \frac{2}{N} \sum_{k=0}^{N-1} I(\alpha_k) \cos(l \cdot \alpha_k), \tag{9}$$

$$b_l = \frac{2}{N} \sum_{k=0}^{N-1} I(\alpha_k) \sin(l \cdot \alpha_k). \tag{10}$$

Again, the linerar polarization depends on the mean value and amplitude of the term for $l = 4$:

$$P_{lin} = \frac{\sqrt{a_4^2 + b_4^2}}{a_0/2}. \tag{11}$$

The advantage of the fourier method is the independence of the measurement on the angle range and on small phase shifts induced by the optical components.

The fourier transformation is being performed automatically by the COP program, whenever a light polarization measurement has been done. The results are written to the slowlogs and are valid as long as there is no new measurement.

High Voltage Optimization of the Pockels Cell

In order to achieve the maximum amount of circularly polarized light at the interaction point, one has to perform a scan of the pockels cell high voltage. This is being done automatically by changing the HV in steps of 200 Volts and measuring the light polarization with either the AB#1 or AB#2. The optained maximum circular polarization depends strongly on the adjustment of the pockels cell. An example is shown in Fig.44.

4.4 Systematic uncertainties

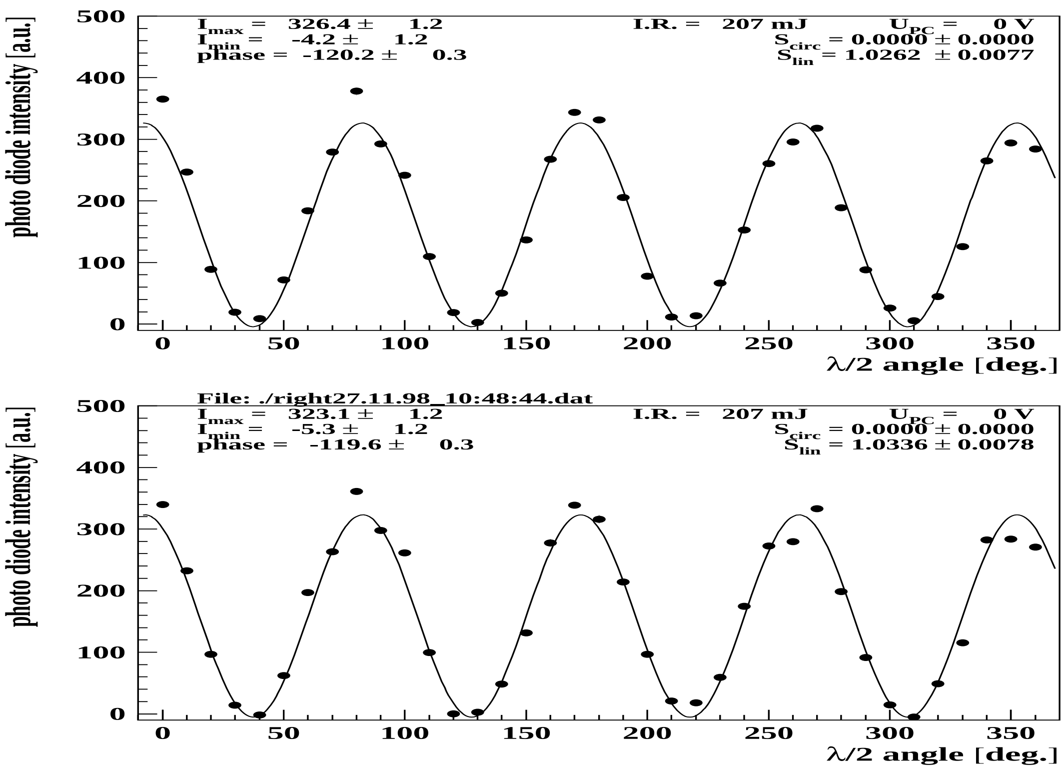


Figure 42: Light polarization measurement which resulted in $> 100\%$ linear polarization. This is being caused by a negative pedestal value (see text).

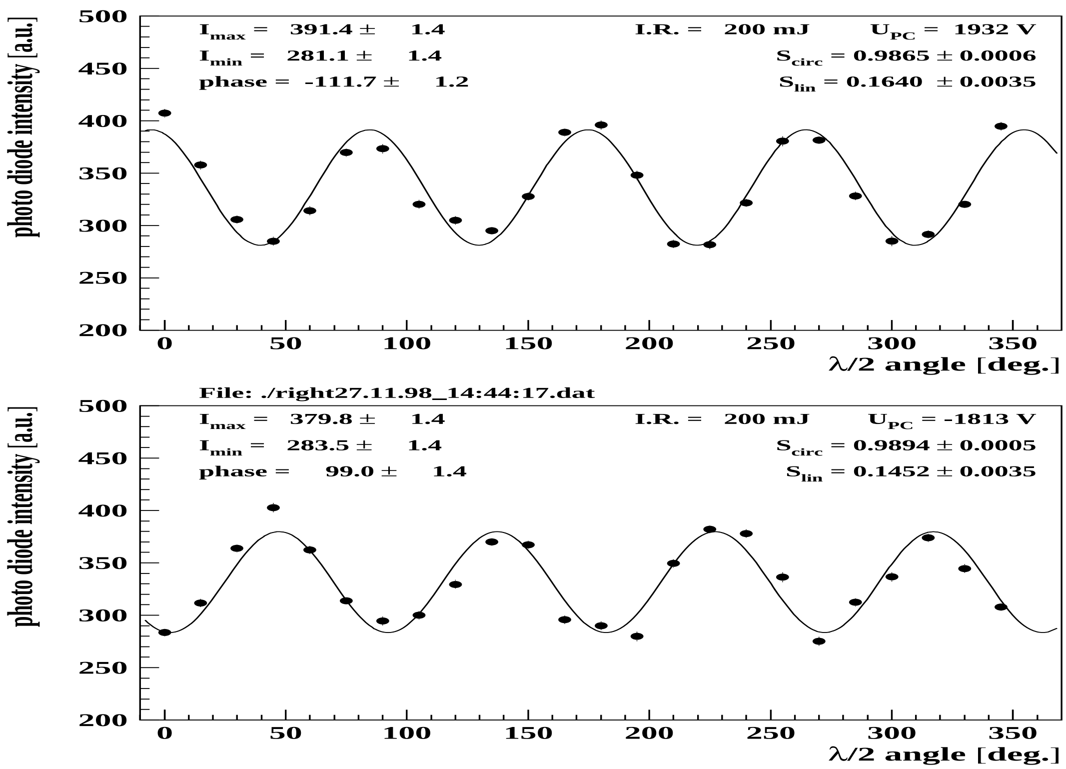


Figure 43: Light polarization measurement with $P_{lin} \approx 15\%$ The curve should be flat for $P_{circ} = 100\%$.

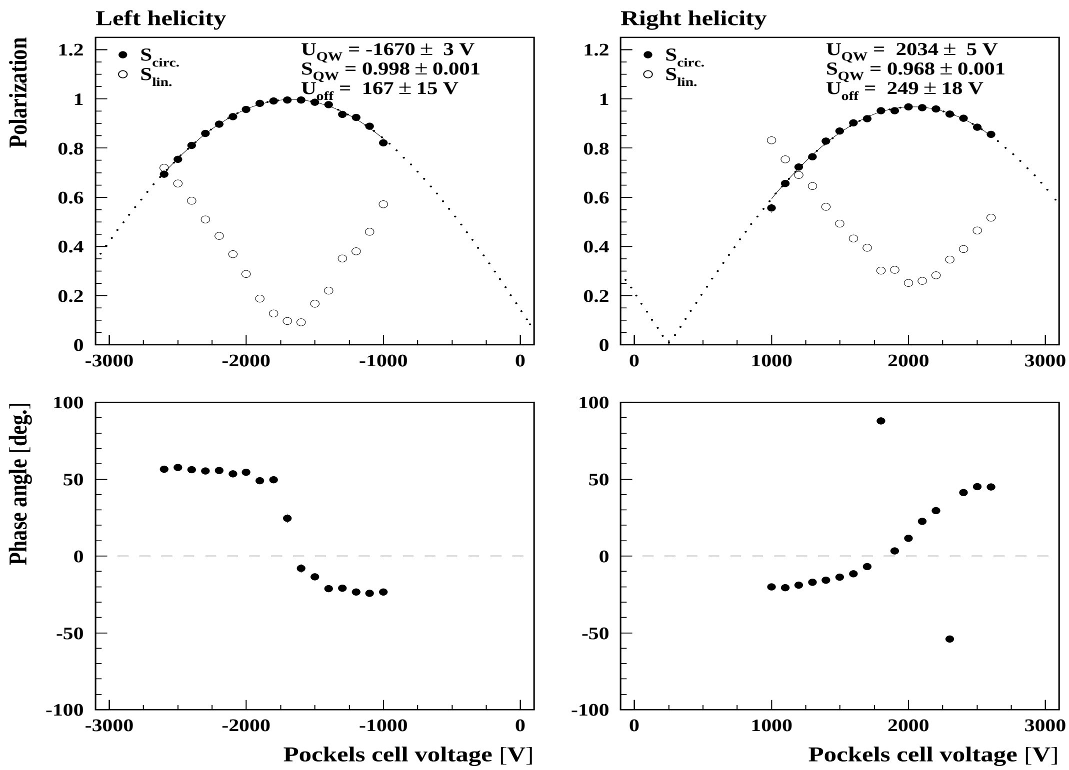


Figure 44: High voltage scan with the AB#1 (in the laser hut). The filled circles are the circular and the open circles the linear component. A polarization of $P_{lin} < 10\%$ is desirable.

Subsystem	Parameter	Range	Uncertainty
Formula	Theoretical error	-	
	Analysing power	-	
	radiative corrections	-	
	Background	-	
	Timing & amplitude corrections	-	
Laser	Circular polarisation	-	
	Dependence on PC HV	-	
	Effect of mirros and entrance windows	-	
	Diff. AB2 wrt AB1 in tunnel	-	
Laser beam parameters	Path steering (mirrors)	-	
	Spot size	-	
	Focus position (hel.dep.)	-	
	Intensity	-	
	Delay	-	
e^- **beam parameters**	Slopes and position at IP	-	
Laser-e^- **interaction**	Position of IP (long.)	-	
Compton beam	Centering on exit window	-	
	Centering on calorimeter	$\pm$ 2 cm	
Calorimeter	Crystal Non-Linearity	-	
	Shower leakage	-	
	Non-uniformity	-	
	Pb absorber thickness	-	
	Crystal damage	-	
Electronics	Pedestal, Noise	-	
	PMT Non-Linearity	-	
	PMT Gain miscalibration	-	

Table 15: Specific contributions to the total systematic error on the beam polarisation determination.

5 Software

The user interface to the Longitudinal Polarimeter is completely based on four PinK applications:

- The main program to control the polarimeter is called *COP* (*CO*mpton *P*olarimeter) and can be run under the `onl` account from the Online Alpha cluster. (see section 5.2).
- The second application is the analysis program called *LPOL Online Monitor* (see section 5.3).
- The *Bunch Polarisation* display which displays the polarisation of the individual bunches as well as an average for all pilot and all colliding bunches separately (see section 5.5).
- The beam position display which calculates the position and the slope of the HERA electron beam at the LPOL IP (see section 5.4).

The Longitudinal Polarimeter has its own dedicated machine: axher7 and COP is to be run exclusively on this machine! The console of the axher7 machine is clearly marked with the label "Long. Pol. only" and is located in room 101 underneath the monitor board between the target control terminals and the UG printer. You should always be logged in at this terminal as `onl`.

5.1 Overview: LPOL clients, servers and pink displays

Except for the control software of the laser which is running on a PC in the laser hut, all control programs of the LPOL are running under job control on one of the online machines or PC. This means that if a program stops for any reason it will be restarted automatically after 40 or 45 seconds. The jobs are running on the following computers:

Program	Host name	Job name	Description
`copserver`	axher6	**copserver**	server for LPOL hardware control
`lpolyserver`	axher6	**lpolyserver**	server for LPOL online analysis
`copclient`	axher7	**copclient**	client to control the LPOL hardware
`lpolyclient`	axher4	**lpolyclient**	client for the LPOL online data
`cop.tcl`	hercules	**coptcl**	COP Compton Polarimeter Main Window
`lp.pink`	hercules	**lp_r7**	LPOL Online Monitor (axher7 console)
`lp.pink`	hercules	**lp_101**	LPOL Online Monitor (inner sanctum)
`longpolIP.pink`	hercules	**longpol_r7**	Beam Position @ LPOL IP (axher7 console)
`bunchpol.pink`	hercules	**bunchpol_r7**	LPOL Bunch Polarizations (axher7 console)

To change or check the program status, log on as onl and type `scdj <hostname>`

- ▷ to stop a job, type: `stop <jobname>`
- ▷ to start a job, type: `start <jobname>`
- ▷ to check the status, type: `status <jobname>`

▷ to exit jobctrl, type: `exit`

Example: To start the PinK script cop.tcl and check its status:

```
axher7:~/run> rlogin -l onl hercules
onl@hercules:/home/onl > scdj
JobCtrl hercules 15:33 1> start coptcl
Starting coptcl: preparing, launching, running !

JobCtrl hercules 15:33 2> status coptcl

Status of coptcl:
 Command   : cop.tcl  -display axher7:0
 Process   : pid=26713 running since Thu Feb 11 15:33:48 CET 1999.
 Controller: pid=26694 running since Thu Feb 11 15:33:48 CET 1999.
 Host      : hercules
 Restart   : after 40 seconds.
 Diskspace : 37 kB
 Logfiles  : 11
 Core files: 0

JobCtrl hercules 15:33 3> exit
Goodbye...
axher7:~/run>
```

Note: specific procedure for **copclient**!:

If copclient does not come up after a restart, take the following additional measures:

▷ logon as onl on axher7

▷ get the copclient process id:
`ps -A | grep copclient`

▷ read all process id's for copclient and kill them:
`kill -9 pid1 pid2 ...`

▷ remove lockfile:
`rm /us0/onl/cop/client/coplock`

▷ now go to job control an axher7; stop and start copclient (see above)

5.2 The COP control program

In Fig.45 you see how the main COP screen looks like.
The COP main window is divided into several sections which are a menu bar with a status bar below in the top part. All items in the menu bar contain one or more subitems which are

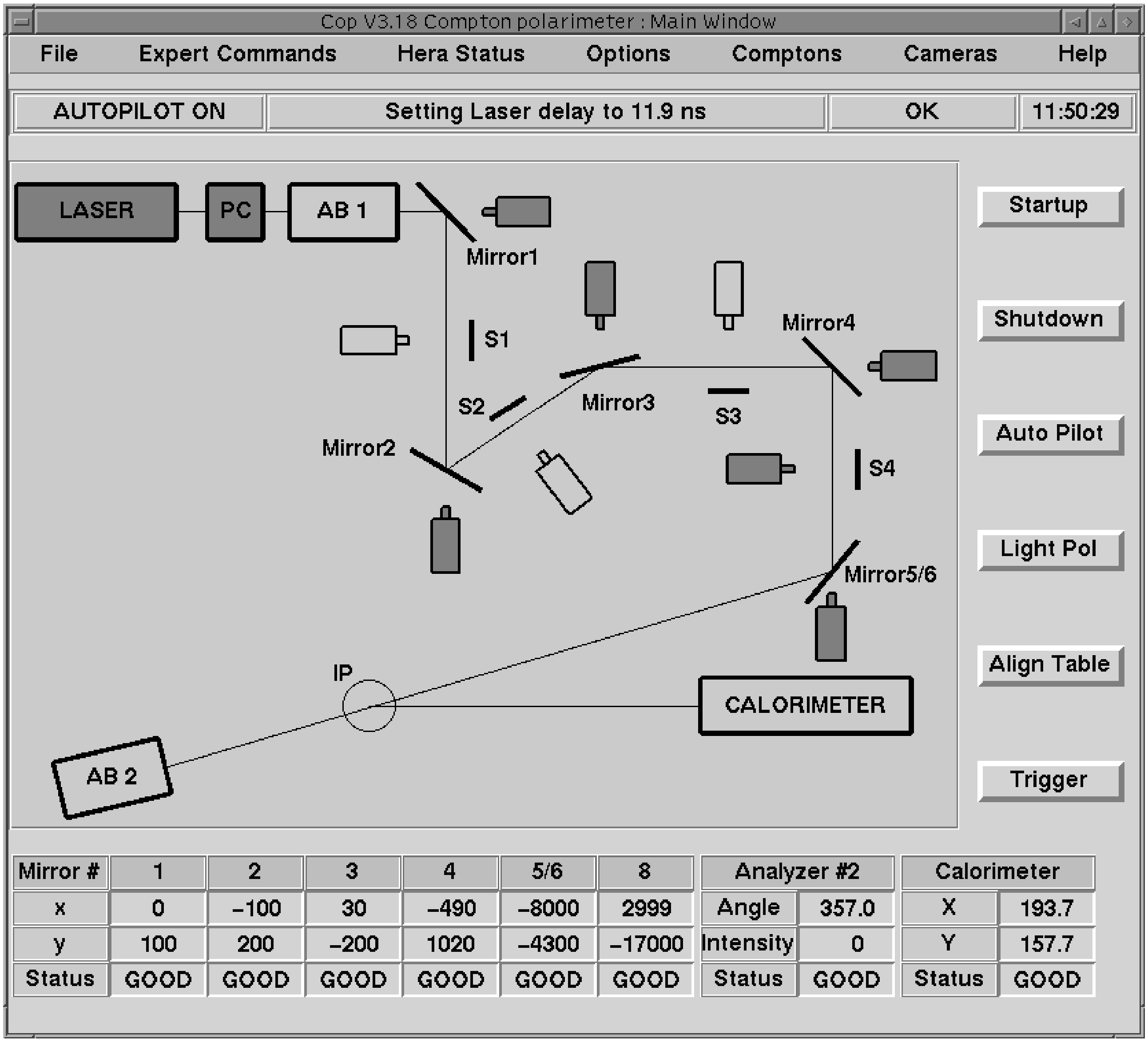


Figure 45: Main window of the COP user interface.

fully described in section 5.2 below. The status bar is divided into four parts: in the left–most column the current status of the auto pilot is shown (see section 6.2), it can be either "ON" or "OFF". In the largest, central part the last command issued is echoed and the return value of the command is displayed in the next to right part of this line. In the right–most field the update time of the latest message shown in the central field is displayed.

The largest fraction in the center of the window is filled with a schematic drawing of the beam path together with the major components of the LPOL . To change or check the parameters of any component displayed there, simply click on it and a window with the current settings and/or the selectable options will appear. The meaning of these parameters and of all other controls will be explained in detail later for each component of the LPOL in sections 5.2 to 5.2. In the column on the right hand side there are a couple of buttons to start a selection of automated standard procedures. All buttons are explained in detail in sections 5.2 to 5.2 below.

Finally, in the bottom part of the main window the current positions of all mirrors M1...M8 and the status read back from the mirror controllers are shown. Note that mirror M7 inside the analyzer box #2 is the only mirror in the system which can not be moved remotely. Also the angular setting of the half–wave plate, the intensity measured by one photo diode and the controller status of analyzer box #2 as well as the calorimeter table height, the status of the shutter and the status of the corresponding controller are displayed in the lower right hand corner.

Menu items

In the top part of the COP main window there is a line with menu items which are explained in detail in this section.
The first item is File with only one subitem Exit. If you select Exit you will shut down the whole COP software with only the servers left running. You will be asked to confirm if you select the Exit procedure. Jobctrl will restart COP after a while.

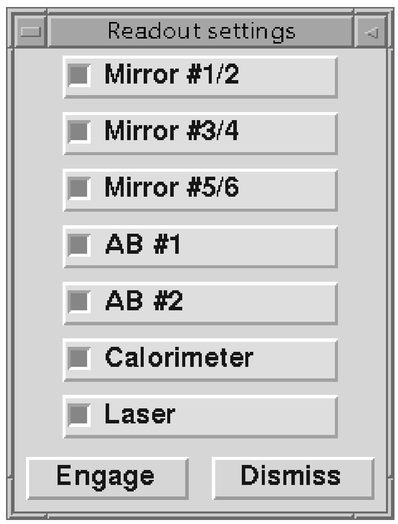


Figure 46: Control window for the selection of equipment to be polled by COP.

The next menu item is called Expert Commands and is of no interest for the shift crew. The LPOL experts can issue low level commands to various devices via the CAN bus system and via serial interface channels. In particular, the setting in the Expert Commands|Security window should always remain in the ON position — **do not change this setting!**
If you select the menu item Hera Status a window with the latest status messages and information on the beams in HERA will appear.
The menu item Options offers a lot of possible subselections: The first subselection Options|Logbook opens a history list of the commands issued and the status messages generated together with a time stamp up to a size of 200 entries. Under Options|Update|UpdateTime a window like shown in Fig.47 will appear where you can modify the time interval when COP will poll all controllers and update their readings and status messages in the main window. In general, if a command is sent to a device by COP it will read back the return value and/or status of this device immediately and display the actual values in the main window. The value of Update Time determines at what rate all equipment will be read out if **no** specific command by the

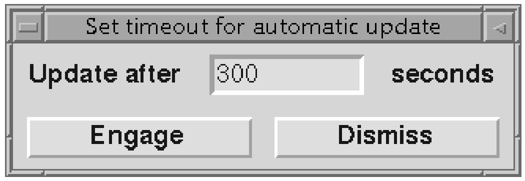
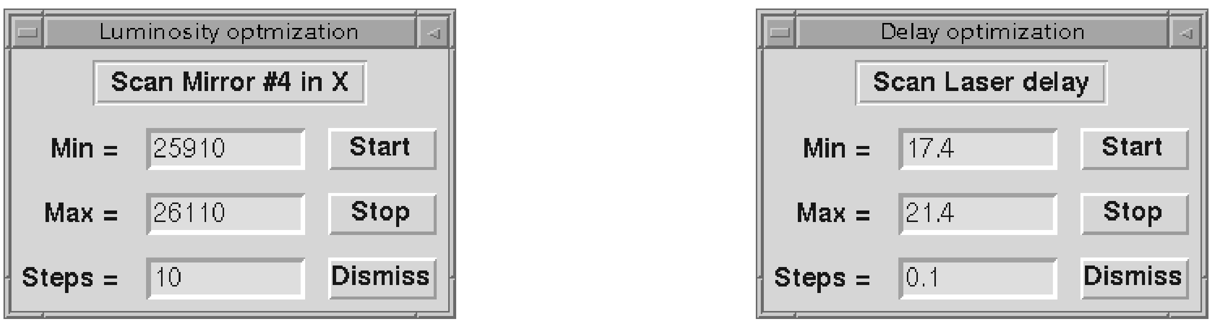


Figure 47: Control window for the update time of COP.

user has been given. Engage will change the update time to the number entered in seconds, Dismiss leaves the current value unchanged.
The next subitem Options|Update |Readout options is related very closely to the previous item. As shown in Fig.46 the user can select which controllers shall be polled at the rate defined by Options|Update|UpdateTime. Normally, all pieces of equipment should be included in the update process as shown in Fig.46. If for test reasons only a specific subset of these devices is to be read out, the user can disable the unwanted controllers in this window. Note that one should not operate the LPOL for an extended period of time with some equipment disconnected from polling as error messages also will not be displayed any more. Again, Engage will update the selection while Dismiss leaves the current settings unchanged. With the third option Options|Update |Update Now! you can finally force a readout cycle of all equipment selected with Options|Update |Readout options.



(a) Mirror scan

(b) Delay scan

Figure 48: Windows for optimization of the spatial and the temporal overlap of the laser pulse and HERA electron bunch for maximum Compton rate.

In the menu last item Options|Optimize there are two subitems Options|Optimize|Luminosity and Options|Optimize|Laser delay where the user can optimize the spatial and temporal overlap of the laser pulses with the electron bunches, respectively. The two control windows are shown in Fig.48. When the auto pilot is activated (see section 6.2) it will usually perform both optimization procedures (see section 5.2). For both windows the range from Min to Max is scanned with a step size of Steps where the units are "mirror steps" and "nanoseconds", respectively. The practical ranges for the movement of mirror M4 are $\pm$ 100 steps and for the laser delay ± 2 ns. The displayed value for the laser delay is some relative delay between the HERA bunch clock signal and the trigger for the laser with an additional fixed offset. The duration of the laser pulse is $\sim$ 3 ns, therefore shifting the value of the laser delay by more than 3 ns will definitely yield zero Compton rate. Start will start the scan, the Stop button will interrupt

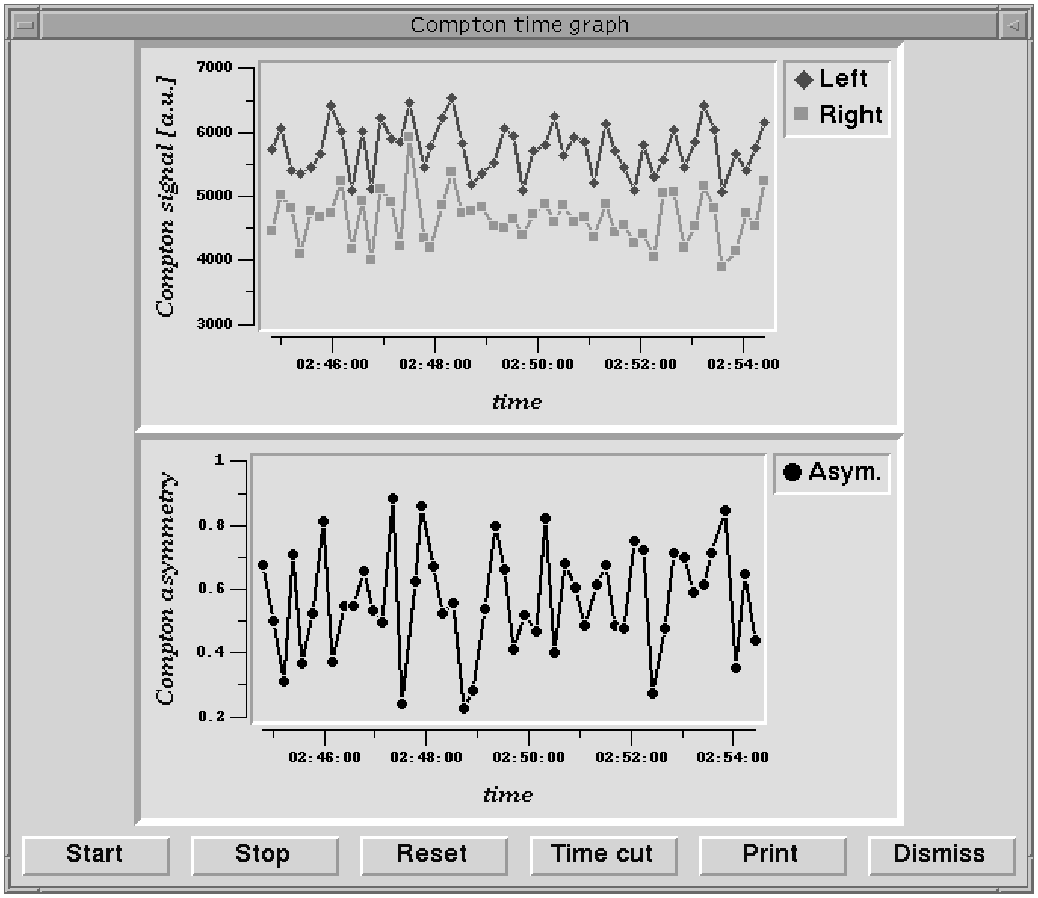


Figure 49: Window with the raw Compton ADC sum signal for left and right circularly polarized light and the raw asymmetry divided by a factor of 0.184. This quantity is equal to the polarization of the electron beam if one assumes perfectly polarized light at the IP and neglects any further corrections which have to be applied to these raw data.

an optimization scan and Dismiss will close the window without any action taken.

The menu Comptons offers three items, Comptons|Time graph, Comptons|Luminosity and Comptons|Buffer size. The first option will open a window as shown in Fig.49 with two time graphs displaying the Compton ADC signals which are summed up over all 4 PM channels separately for left and right laser light helicity and the calculated asymmetry from the two helicity states divided by 0.184, which is the calculated analyzing power of our instrument. Therefore the displayed value for the asymmetry is identical to the electron beam polarization under the assumption of perfectly circular light polarization at the IP and neglecting any other corrections which might be required for a solid measurement. Hence, this value should only be regarded as a crude estimate of the electron polarization...
To start or stop the display of actual values press the appropriate buttons. Reset will clear the display but continue the update. The button Time cut will open a small window as shown in Fig.50 where you can select the upper and lower time cuts for accepting events for this display. The laser pulse has a certain time jitter with respect to the exact arrival time of the HERA

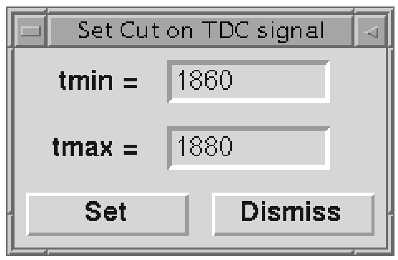


Figure 50: Window for selecting the lower and upper time cuts for accepting events in the Comptons time graph display.

electron bunches. In order to increase the resolution of the Compton signal, only these events are being analysed which have an appropriate timing between the laser and the electron bunch. While being on shift, changing these time cut values is a topic for the experts only (so far). We are working on a more fancy scheme anyway to eliminate the influence of this time jitter... To close either of these windows again, select Dismiss.
The second option will open a window as shown in Fig.51. The quantity plotted in this time graph is simply the sum of the Compton signals of all 4 photo multipliers for one helicity state of the laser light divided by the total current in the HERA electron machine. We call this quantity *luminosity* although when defined properly, one should take the average of the Compton signals for the two helicity states of the laser light.
This display should anyhow only serve as a rather crude tool to monitor the overlap of the laser beam with the electron beam. It updates somewhat faster than the corresponding time graph in the Online Monitor program (see section 5.3, p. 87) but the latter should certainly be chosen if you are interested in a more complete display of the luminosity at the IP of the LPOL . To clear the time graph and restart the display, select the Reset button; to close this window again, choose the Dismiss button.
The third option Comptons|Buffer size opens a small window as shown in Fig.52 where one can select the buffer size for one data point in the Comptons time display. As with the time cuts option, it is good idea to leave changes in this window for the experts...
The last menu item Cameras offers a selection of subitems to control the numerous cameras we have installed in the LPOL . Starting with Cameras|Pictures| Show one can invoke a window like the one shown in Fig.53 where the pictures taken by the CCD cameras behind mirrors M1

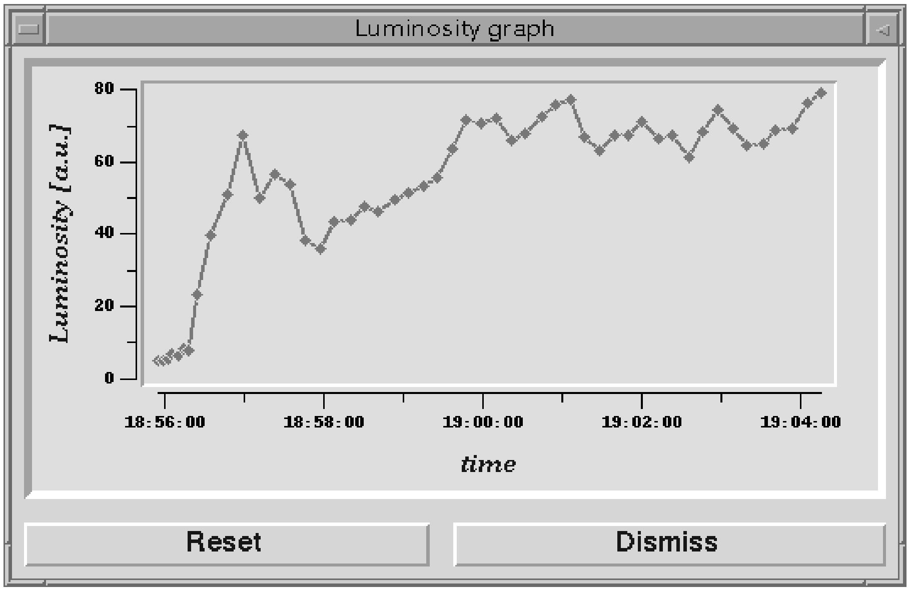


Figure 51: Time graph of the luminosity at the IP of the LPOL.

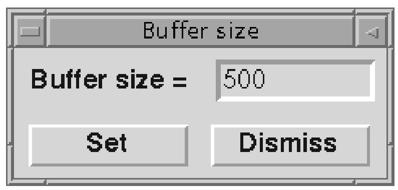


Figure 52: Window for selecting the buffer size for one data point in the Comptons time graph display.

to M5/6 and behind mirror M8 are displayed. You can see all of these images in real–time on the monitors above the LPOL terminal in room 101 (the two left–most screens) whereas the images in this window are generated by a separate Personal Computer with a frame grabber card which digitizes the CCD signals. This Personal Computer (`obscura.desy.de`) calculates the spot position and diameter on every mirror from these images and sends them to the auto pilot. The calculated centroid position of the laser spot on each camera image is displayed with a green cross hair. If the intensity of the laser spot is too low (as for the images from mirrors M1 and M3 in the example of Fig.53), the algorithm fails to identify the beam spot and computes wrong values. In this case the auto–tracking mechanisms has to be disabled to prevent it from driving the mirrors all over the place (see next paragraphs).
The transfer of the image data is bandwidth consuming, so do not have this window activated all the time. You might want to have a look at it once in a while or if you suspect any problem with the tracking system (see chapters 6.2 and 8) but for online monitoring of the laser beam position watch the real–time displays in room 101. You see an ellipse in light grey on each of these images with a reticule and two circles in it — the light ellipse is the outline of the mirror as seen from behind (you are looking on a circular disk under 45°. . .), the distance of the grid lines is 10 mm in reality and the circles mark the center on the mirror front faces (the offset from the point where you think the center should be comes from the displacement of the light in a material with refractive index larger than 1), except for M1. The large button Cancel will

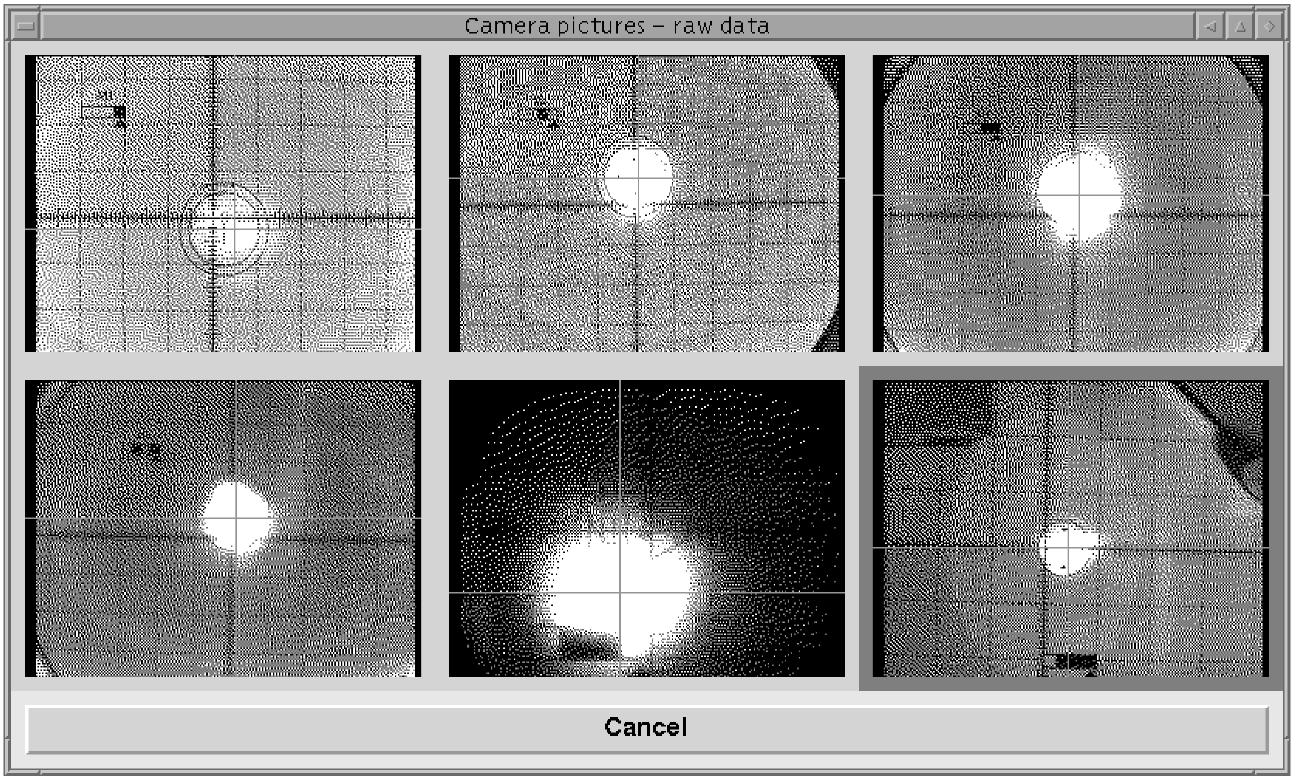
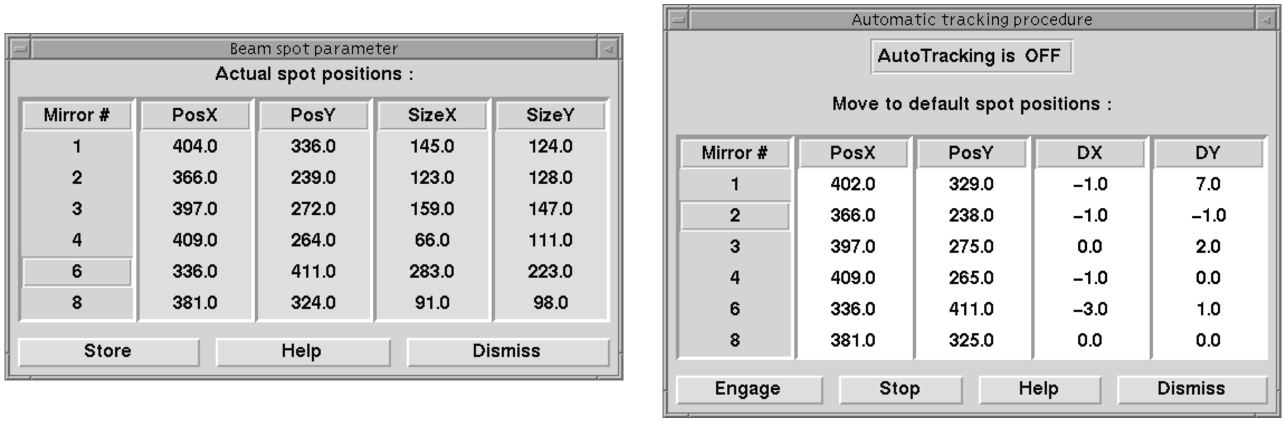


Figure 53: Images from the CCD cameras behind M1, M2, M3, M4, M5/6 and M8 as starting from the upper left corner. The (green) cross hair indicates the calculated centroid of the laser beam spot as computed by the frame grabber hardware. In case the laser spot intensity is too low (as on mirrors M1 and M3) the algorithm fails to identify the laser spot and calculates wrong values.

shut the camera window — don't forget it!
From time to time, especially if the network conditions are unstable, and always if a camera has been switched off, the frame grabber hardware stalls and the images will not be updated any longer. If this happens, you can reset the frame grabber card with the menu item Cameras|Pictures|Reset. You will get an acknowledgement message if you select this item and the card has been reset successfully.
There are two more subitems for the CCD cameras available, Cameras|Spot parameter which will display the actual calculated values from the images and Cameras|Auto Track which shows the actual parameters of the auto tracking algorithm. In Fig.54 (a) and (b) a sample window for each display in shown. In the left window in Fig.54 the actual laser beam spot values calculated by the frame grabber card are listed. This display should being updated constantly and the rectangle in the leftmost column around one of the mirror numbers indicates, which image is currently being processed.
In the right window in Fig.54 parameters from the auto–tracking system are displayed. The auto–tracking system continuously monitors the position and the diameter of the laser beam spot on each mirror and resteers the mirrors if necessary to keep the spot well centered or shuts off the laser if the diameter of the laser beam becomes too small on any of the mirrors monitored. The current state of the auto–tracking system is displayed in the status bar of the auto–tracking window in the top part. In order to start the auto–tracking system, press the



(a) Actual spot parameters

(b) Auto–tracking parameters

Figure 54: Windows with the actual laser beam spot parameters calculated by the frame grabber card. The image which is currently being updated and processed is indicated by the rectangle around the mirror number in the leftmost column.

[Engage] button; for interrupting it, you have to select the [Stop] button. The [Dismiss] button will close any of these windows.

Laser control

The laser control window as shown in Fig.55 will open if you click on the frame LASER in the COP main window (see Fig.45). Without opening this detailed window, however, you can already deduce the current status of the laser from the fill color of the rectangle. If the box is transparent, the laser is switched "Off ", if it is yellow the laser is in "Standby"[2] mode. A green fill color corresponds to the laser being "On", i.e. the laser emits light pulses and the color red finally should alert the user of an error condition of the laser.
If you want to change the current status of the laser or need more information about it, select the laser control window. The window itself is divided into several parts. To change the status of the laser, i.e. to switch it "On", to "Standby" or to "Off ", select the appropriate radio button. After a short update period the black diamond will acknowledge the selected status. If you do not get an acknowledgement within a maximum of 2 minutes nor an error message, a problem with the Slow Control software is likely and an expert should be contacted.
The next field controls the energy per laser pulse, measured in mJ. Below the latest reading of the energy **as measured by the laser** there is a field ("demand") where you can enter a new value for the pulse energy. This value will be sent to the laser after you push the button [Engage] and you should see the measured energy approach the desired value (with some intermediate values, depending on the pulse repetition rate) **if (and only if) the laser is switched "On"!** If the laser is in "Standby" or "Off " mode no light is generated, hence no actual energy reading

[2] In "Standby" mode the laser does not generate or emit light pulses but its cooling circuit and power modules remain switched on. It is not possible to overheat the laser by switching it "Off" immediately but if you want to stop the laser only temporarily (for less than about two hours) it is better to keep the supply systems of the laser running in "Standby" mode rather than switching it "Off" completely.

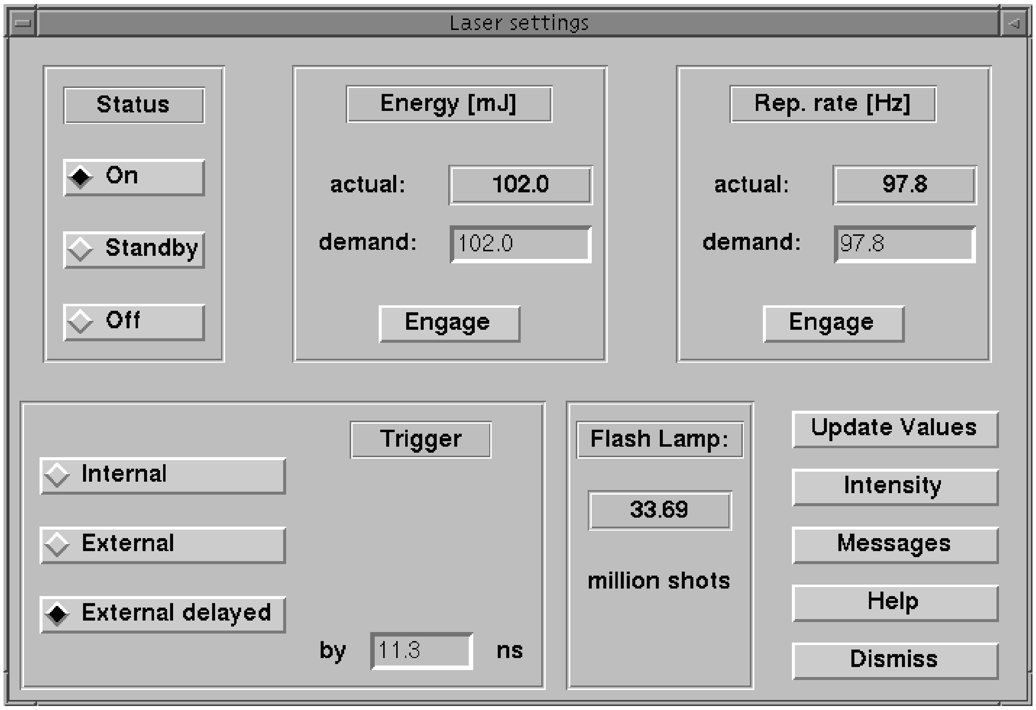


Figure 55: Control window for the laser.

can be produced. The valid range for the pulse energy extends from 1.0 to 250.0 mJ[3].
In the right–most section in the top part of the laser control window you can set the repetition rate in Hz. Valid numbers range from 0.1 to 100.0 Hz. As with the energy section, the demand value only is sent to the laser if the Engage button is pressed.
The left–most section in the lower row deals with the trigger of the laser. During data taking the External delayed trigger mode always has to be selected. Make sure that this option is selected and the black diamond appears in the right place. The delay value in nanoseconds is a variable delay between the HERA bunch clock signal and the trigger pulse for the laser with an additional fixed offset. In order to maximize the temporal overlap between the laser pulse and the electron bunch one can change the value displayed here. **In contrast to most other COP control windows, any number entered in this field will be sent to the laser as soon as you hit the Return key or click on the button External delayed.** The valid range for the delay extends from 0.1 to 25.6 ns. If you play with this number be aware that the laser pulse only has a duration of 3 ns and a Compton signal will disappear if you change the delay by more than this value. In order to optimize the Compton rate in the calorimeter you should choose Options|Optimize|Laser delay from the menu bar (see section 5.2, p. 66).
The last display in the laser control window is the flash lamp counter. Here the number of shots of the flash lamp is shown. The rated lifetime for a flash lamp is 70. . . 100 million shots. Despite the flash lamp may live even a lot longer than this rated lifetime, the pulse–to–pulse energy fluctuations start to increase with an old flash lamp. If this counter exceeds a value of 80 million shots the background will turn yellow and you should leave a note in the logbook for the

[3]The laser is capable of generating pulse energies up to 400 – 550 mJ, depending on the repetition rate. With the beam optics realised in 1997 a pulse energy exceeding 150 mJ should never be necessary in order to achieve very high luminosity (limited by saturation of the photo multipliers). To protect the optical elements in the beam path we set an upper limit for the laser energy of 250.0 mJ.

experts. They will then examine the performance of the laser and decide when to replace this lamp. **If you are on shift and the counter turns yellow: this is NOT an emergency situation! As long as the laser still operates there is no need to alert the experts during the night or on the weekend. It should only focus the attention to a lamp exchange in the near future!**
The button Update Values will load the actual readings from the laser if you desire an update in between the regular update intervals. As we need only a small fraction of the maximum energy the laser can deliver but the laser runs less stable if operated at very low intensities we have a variable attenuator introduced right after the laser. The setting of this attenuator can be controlled with the Intensity button which will be described in detail in the following paragraph. With Messages you can access a window with messages sent from the laser to specify an error which might have occured (if the laser symbol has turned red). The Help button will display a short online help menu and Dismiss closes the laser control window without any further changes.
The button Intensity will open a window as shown in Fig.56. The upper section of this

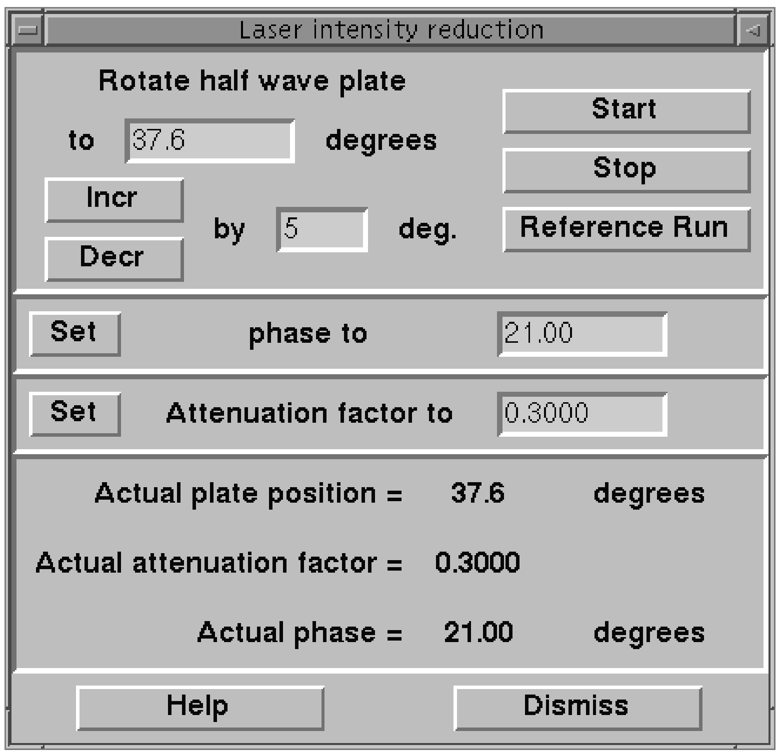


Figure 56: Control window for the variable laser attenuator.

window is expert business only (You can rotate the half–wave plate which is responsible for the attenuation to a certain angular setting here). You should rather use the Set button in the central part of the window. Here, one can enter an attenuation factor in the field to the right which will be set as soon as you hit the Set button. You can verify the actual setting of the attenuator in the lower part of the window. Again, Help will display a short online help menu and the Dismiss button will close this window.

Pockels cell control

As with the laser, the status of the Pockels cell (PC) can be deduced from the fill color of the symbol in the COP main window. If the PC symbol is transparent the high voltage is switched off, i.e. the light is linearly polarized. A green fill color indicates that high voltage is sent to the PC and the color red corresponds to an error condition which can not be specified in more detail. Call an expert, if the Pockels cell display turns red. If you select the PC symbol a control window as shown in Fig.57 will appear.

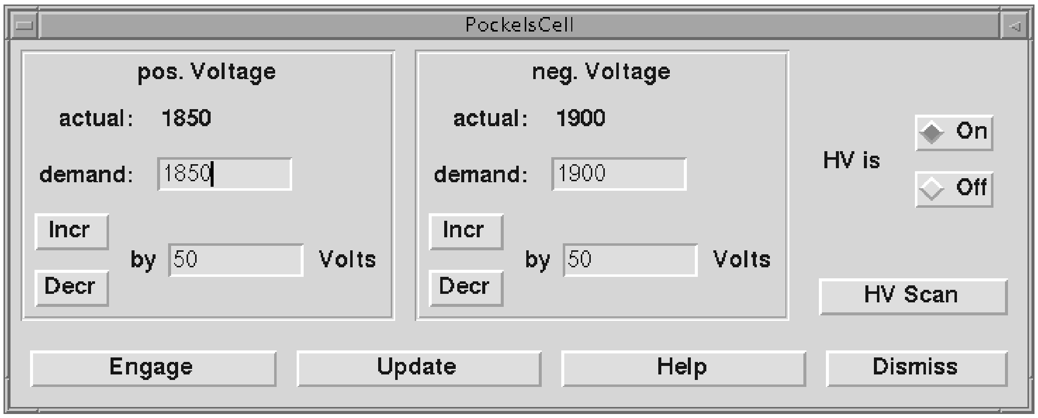


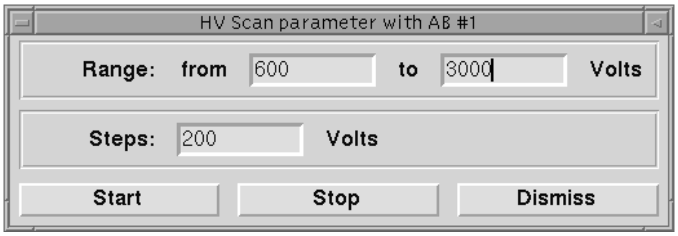
Figure 57: Window for control of the Pockels cell (PC).

There are two identical fields for each polarity of the high voltage, positive and negative (corresponding to right– and left–handed circular light polarization, respectively). For each polarity the actual high voltage is displayed in the top row. You can set new voltages separately in the line "demand". The default values in these two fields are the actual values. You can increase or decrease these predefined voltages with the buttons Incr and Decr by a value selectable in the adjacent entry field. Valid values for the high voltage range from 0 to 3000 volts. Note that only the absolute values are relevant, you don't have to bother about the sign convention. The new voltages entered in the "demand" fields will be sent to the PC controller after pressing the Engage button. If you want to switch the high voltage for the Pockels cell completely off, you can select the radio button in the upper right corner of the window. Entering demand values of 0 volts will have the same result.

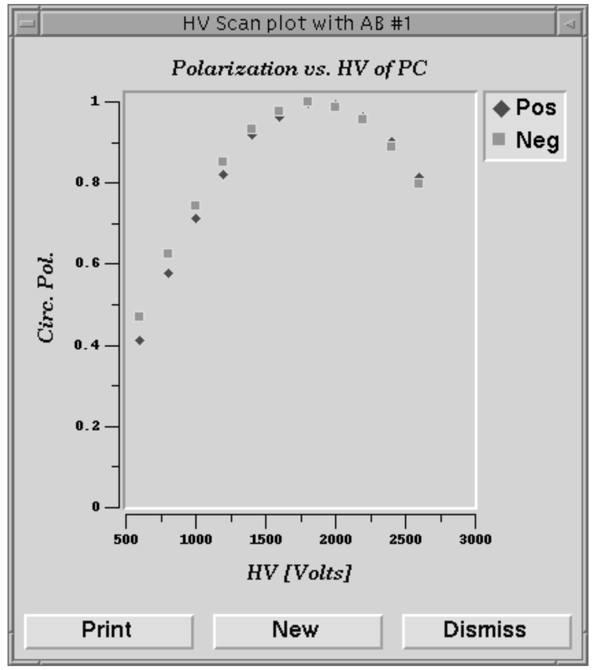
As with other control windows the Update button will display the current high voltage readings in between the regular update intervals. Also a short online Help is available.

The button HV Scan in the right column of the window will pop up two new windows shown in Fig.58 below. Depending on whether analyzer box #1 has been moved into the beam path or not (see the following section 5.2), you can start a highly automated optimization of the degree of circular polarization either in analyzer box #1 (in the laser lab) or in analyzer box #2 (in the tunnel) by scanning the high voltage on the PC separately for each polarity. There is an optimum voltage, called the quarter–wave voltage, where the PC produces almost 100% circular polarization. This optimum voltage may drift with time and one should check this value in regular intervals. A large drift might indicate problems with the Pockels cell or the high voltage supply system[4] and **you should notify an expert immediately!**

[4]The high voltage supply for the Pockels cell is not incorporated into the standard spectrometer high voltage



(a) HV–Scan control window



(b) HV–Scan results window

Figure 58: Windows for control of and results from a scan of the Pockels cell high voltage.

To perform a high voltage scan, enter the range and the step size in the appropriate fields in the control window (cf. Fig.58 (a)) and hit the Start button. The Stop button will interrupt a scan and the button Dismiss will close the window without any action taken. You can see which analyzer box is selected in the title bar of the two windows. If you want to switch to the other analyzer box, interrupt the current scan with Stop, close the two HV scan windows and (de)select analyzer box #1 before you reopen the HV scan windows. You will see the degree of circular polarization for each helicity state and every high voltage value plotted in the results window (cf. Fig.58 (b)). After the scan has been completed you can print it out by selecting the Print button and eventually obtain new values for the quarter–wave voltages (where the parabola has its maximum). The button New clears the display for a new set of data.

Analyzer box #1 control

The symbol for the analyzer box #1 in the COP main window is usually transparent, telling you that it is not moved into the beam path. If the analyzer box has been moved in, the laser beam gets completely absorbed within and no light is visible any more on any camera display! This is symbolized by a green fill color of the AB 1 symbol and the rest of the beam path drawn in light gray. If you click on the symbol for the analyzer box #1 the control window will appear as shown in Fig.59.

system. We rather generate two adjustable high voltages, one for each polarity, which are alternately selected by a fast high voltage switch. All these components are located in the laser lab in room 616 and cannot be accessed by the shift crew. If you suspect a problem with this high voltage system, call an expert.

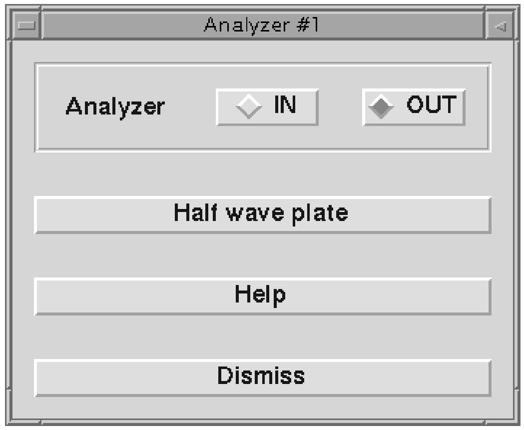


Figure 59: Window for control of the analyzer box #1 (AB 1).

With the two radio buttons in the top part of the window you can move AB 1 into the laser beam path and out again. The actual position of AB 1 is displayed by the black diamond. In order to prevent damage of the optical mounts and excessive scattered light in the laser lab when the setup transverses the beam path, the laser is switched to "Standby" mode before the table starts moving. For safety reasons the laser does not switch back on automatically; you rather have to do this manually (see section 5.2).
If you select the button lambda/2 plate a new window as shown in Fig.60 below will appear. In this window you can manually control the rotatable half–wave plate which is mounted in

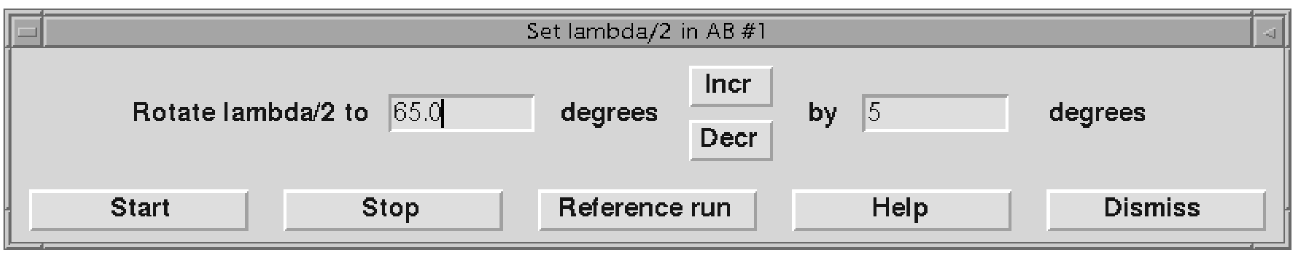


Figure 60: Window for control of the half–wave plate in analyzer box #1 (AB 1).

a motorized rotation stage. During a measurement of the light polarization this half–wave plate is scanned over an angular range of 90°, at least. Generally, you should perform a light polarization measurement by selecting the automated procedure described in section 5.2 on page 85. If you want to move the half–wave plate by hand you can select an angle (with respect to an arbitrary, yet fixed axis) in the top left field in this window. The half–wave plate will start moving after you press the Start button and you can interrupt the motion with the Stop button. The Reference run button will move the plate back to the 0° setting and Help will display a short online help. You can leave this window without any action taken by selecting the Dismiss button.
The latter two buttons are also available in the main control window (cf.Fig.59) for AB 1.

Analyzer box #2 control

The control window for the analyzer box #2, which is located in the tunnel and cannot be moved out of the beam path, is very similar to the one for analyzer box #1 (see section 5.2). If you select the AB 2 symbol in the main window, the control window as shown in Fig.61 will be opened.

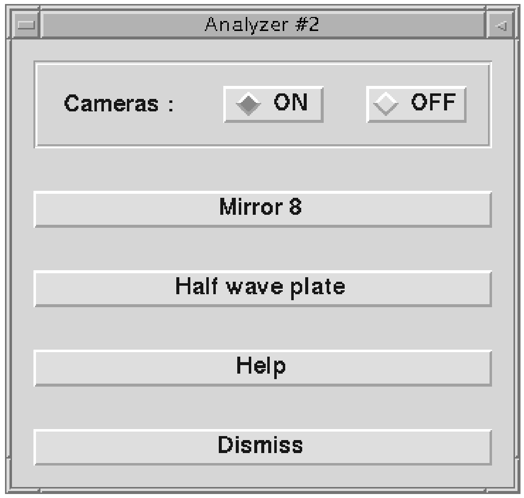


Figure 61: Window for control of the analyzer box #2 (AB 2).

It also provides in the top section two radio buttons to switch the CCD camera monitoring the beam dump on or off. If the LPOL is not taking data for more than a couple of hours it is a good idea to switch off all CCD cameras together with the illuminating light bulbs to extend their lifetime. The image from this camera is displayed on the monitors overhead of the LPOL console in room 101 (labeled "BEAM DUMP"). The camera is looking at the entrance aperture of the beam dump in AB 2 at the end of the laser beam path where the unscattered laser light finally should get absorbed. During operation you should see this aperture more or less homogeneously illuminated without a very intense spot from the outside of this aperture (compared to the intensity within the visible aperture).
Not all cameras in the LPOL setup are decoupled, some of them are combined in groups of two cameras. The camera for the beam dump in AB 2 is coupled to the camera for mirror M8 which also will be switched on/off if you select this option for AB 2!
In order to steer the beam fully into the aperture of the beam dump, the last mirror in the analyzer box, mirror M8, is moveable. If you select the Mirror 8 button a control window similar to the one shown in Fig.62 in the next section 5.2 (*"Mirror controls"*) will appear. For a description how to move this mirror (like any one in the system) refer to the following section 5.2.
Like at analyzer box #1 the user can also control the moveable half–wave plate manually by selecting the button lambda/2 plate and a window similar to the one shown in Fig.60 on page 76 will be opened. Again, it is recommended to use the automated procedure described in section 5.2 on page 85 for a light polarization measurement. The manual motion of the half–wave plate should not be necessary during data taking.

As with almost every COP window, you can invoke a short online Help or close the window with the Dismiss button.

Mirror controls

To move any mirror manually, just click on its symbol in the COP main window (see Fig.45). To steer mirror M8 in the analyzer box #2 (see previous section) you have to select the button Mirror 8 in the control window for AB 2. In both cases a window similar to the one shown in Fig.62 will be opened.

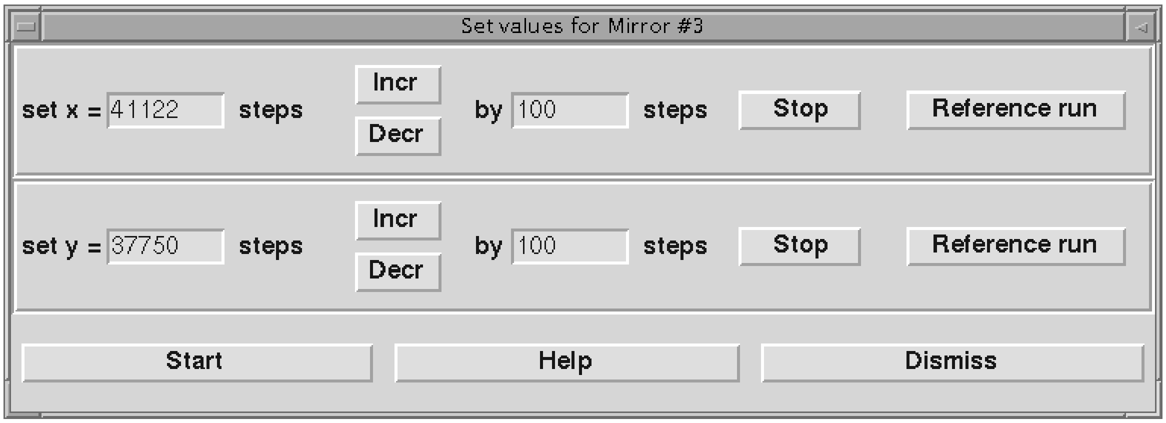


Figure 62: Window for control of one of the mirrors (here: mirror M3).

For each mirror you can set values for the x and the y coordinate in units of steps of the stepping motors. All motors have end switches and are protected against driving them out of range. Note that the valid range is NOT checked by the software as it differs slightly from mirror to mirror and as it is possible to add an arbitrary offset to the positions[5]. The positions of all mirrors are displayed in the bottom part of the main COP window together with the status of the controller channel.
To manually set a new value for a mirror position enter the desired step value in the appropriate field in the left column of the control window. If you want to scan the mirror relative to its current position, you may increase or decrease the actual value with the Incr or Decr buttons, respectively, separately for each axis. The step size for this operation can be adjusted independently for each axis in the fields in the center row of the window. To start the motion of the mirror to the new coordinates entered in the fields in the left, press the Start button in the bottom line. The motion can be interrupted (if you are fast enough :-) separately for each axis with the two Stop buttons in the lines for the x and the y axis, respectively. If you require very accurate positioning of the mirrors (in the order of 10 up to 30 steps) note that there is some backlash in the gears of the stepping motors. To obtain reproducable results, always approach your desired position from lower step values, i.e. if you want to drive in negative direction, move **beyond** the desired position by $\sim$ 100 steps and then approach it with a final motion in positive direction.

[5]This case may happen when there is a power trip causing the mirror controllers to loose the actual step counts. After recovery all controllers read zero and the mirror positions now are relative to the last setting. It is possible to recover absolute values by performing a reference run (see section 8).

The right–most buttons Reference run for the two axes provide the possibility for a motion of the corresponding stepping motor to its limit switch at the lower end of the range of travel. When you start a reference run, the motor will move to its lower limit where it will stop **and the step counter will be reset to zero**. Although no information is finally lost at this point, it is a non–standard procedure to go back to the previous positions (including hardware resets and recovering the old mirror positions from log files unless you noted them before starting the reference run) which should be left to the experts. Under normal conditions it is certainly not necessary to make use of this option and the shift personnel **should not use the** Reference run **buttons**.
The last two buttons in the window are Help which will display some short online help and Dismiss to close the window without any further action taken.

Screens & camera controls

The screens and numerous cameras in the laser transport system of the LPOL can be controlled in the COP main window by clicking on the appropriate symbol. In Fig.63 an example is shown where screen S3 has been selected and moved into the beam path.
The symbol for screen S3 changed to a diagonal line and the laser beam path downstream from this screen is drawn in light gray, indicating that the laser beam is not transmitted beyond this screen. When you select a screen to move into the beam, the laser energy is reduced first to a save level of 5 mJ to protect the CCD cameras from excessive light intensities. The motion of the screen will not start until the **measured** energy from the laser drops below this limit. For safety reasons the original laser power will not be restored automatically after the screens have been withdrawn again but has to be set manually by the operator.
Depending on the system load and the repetition rate of the laser this process may take a little while and the symbol for the screen may even switch back to the "Out" position (a straight line). **Be patient! If your command has been acknowledged in the status bar of the COP main window do not click again on the screen symbol. Otherwise the screen will be withdrawn again immediately after it has been moved in and you watch another cycle of "Out – In – Out" display in the main window...**
Under normal running conditions it is not necessary to move in any of the screens — they only help the experts to feed the laser beam through the pipe if the beam gets lost completely somewhere in the transport system. Therefore, the images from the cameras monitoring the screens are not displayed on a monitor in room 101.
If you think you lost the laser beam in the transport system refer to chapter 8 ("*Troubleshooting*") before you call an expert!
The symbols for the CCD cameras indicate whether the supply voltage and the light bulb for illumination (with exception of the camera behind mirror M 5/6) are switched on or off. A green fill color of the camera symbol corresponds to "On", an open symbol tells you that this camera and light bulb are "Off". The location of each camera should be self–explaining and the images from these cameras can be seen on the left–most monitors above the LPOL console in room 101 except for the cameras at screens S1 to S4. The camera looking at the calorimeter is a different model which can not be switched remotely and remains on all the time.
In order to extend their lifetime, all cameras should be switched off if the LPOL does not take data for more than a couple of hours. There is an option in the shutdown window (see section 5.2) to switch off all cameras automatically after the end of a lumi run and to bring them back

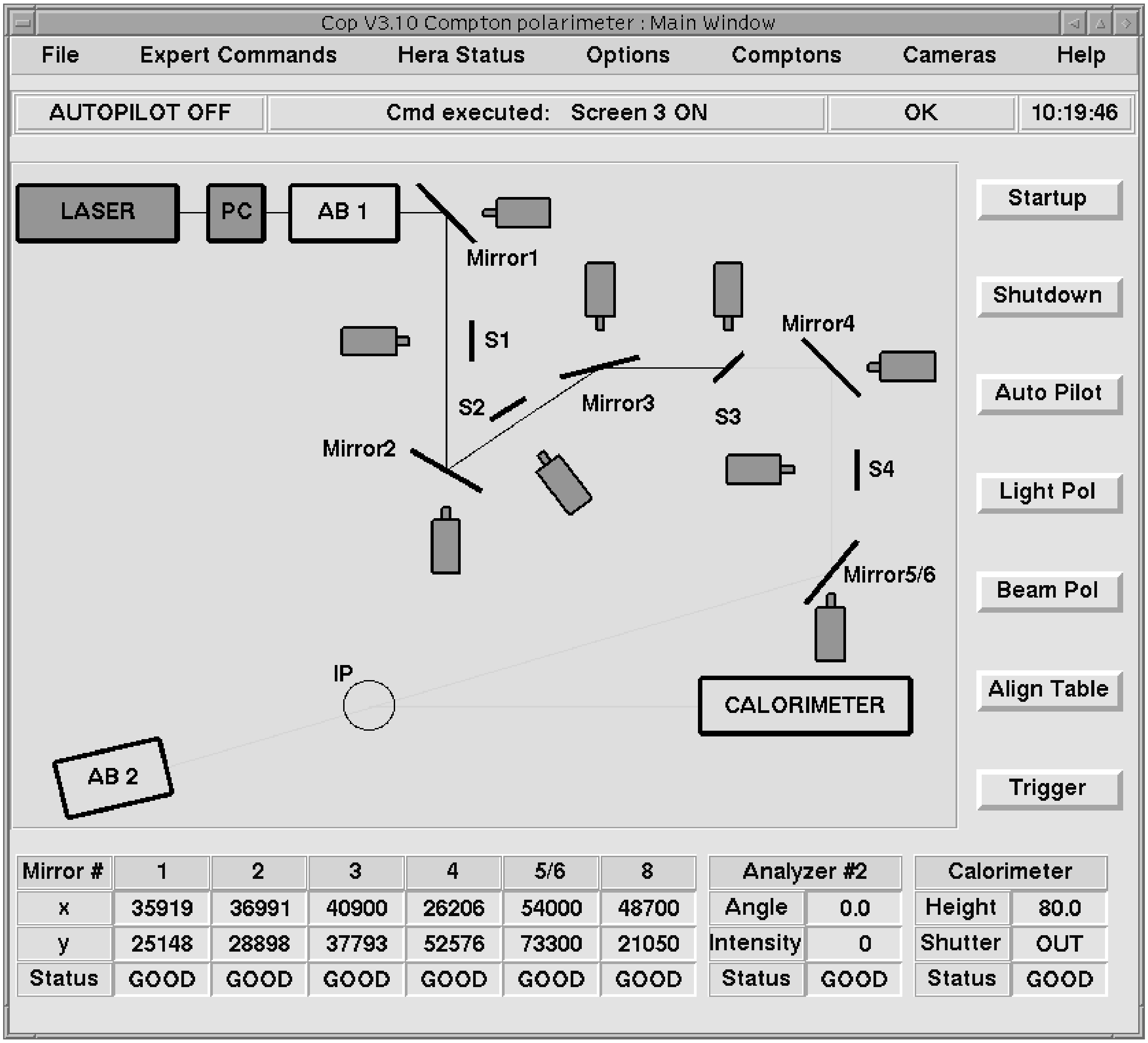


Figure 63: Main window of COP with screen S3 enabled.

up during start up (see section 5.2).

Calorimeter controls

The calorimeter is the only device in the LPOL system which cannot be completely controlled from the COP software. The high voltages for the photo multipliers are generated by a CAEN high voltage module which is incorporated into the standard HERMES high voltage system. To monitor or switch the high voltages for the calorimeter on or off, go over to the HV control window (usually running on the r8 console right behind the entrance door to the ”sanctum”) and follow the instructions there. The name for our detector is LP.

Current HV values are

PM	Voltage
LP1	1200 V
LP2	1200 V
LP3	1200 V
LP4	1200 V

All other settings of the calorimeter can be accessed from the control window shown in Fig.64 which will open if you click on the calorimeter symbol in the COP main window. If the calorimeter symbol is filled in red color an error occured with the controller for the moveable table. This error message should also be visible in the bottom right part of the COP main window. If an error message persists for longer than 2 minutes, call an expert.

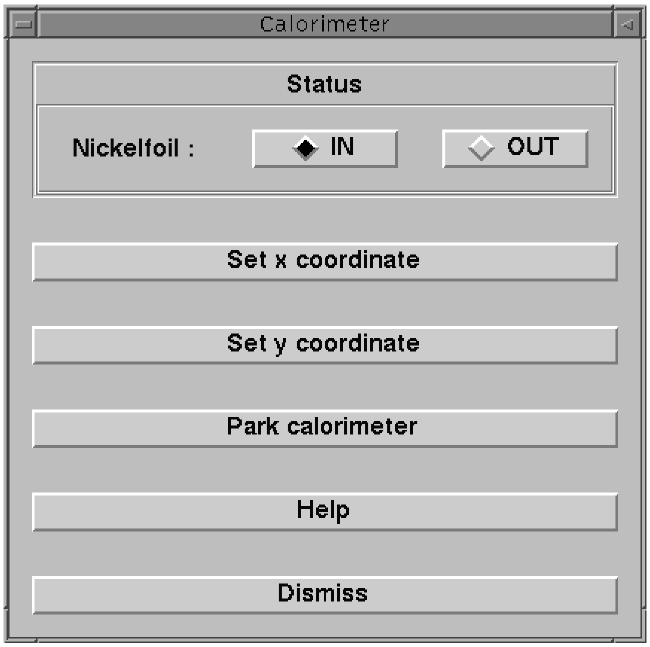


Figure 64: Main control window for the calorimeter.

In the top part of the main control window for the calorimeter there are radio buttons for the nickel foil to attenuate the light signal from the crystals. The current status is displayed by the black diamonds and you can move the device in or out by clicking on the appropriate button.

Do NOT move the nickel foil out if the laser is running — the photomultipliers might be destroyed by excessive Čerenkov light from the crystals!

We have the option to run the LPOL in the "single–photon" method where the light intensity from the crystals is much lower and it is necessary to withdraw the nickel foil to achieve a good signal to noise ratio However, these measurements are expert business and the normal shift crew should never move the nickel foil out.

The calorimeter is mounted on a table which can be moved in the horizontal (x coordinate) and vertical direction (y coordinate). To move this table horizontally, select the button Set x coordinate and a window as shown in Fig.65 will be displayed.

For movement in y direction use the button Set y coordinate which displays the window shown in Fig.66.

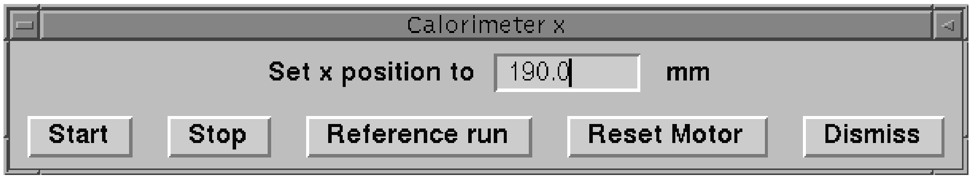


Figure 65: Window for control of the calorimeter table in x.

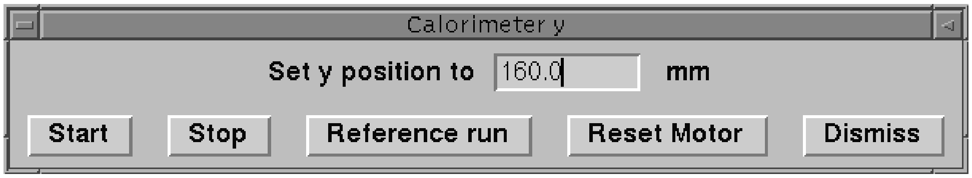


Figure 66: Window for control of the calorimeter table in y.

In these windows you can enter a new table position in millimeters in the entry field. The maximum range for the table extends in x from 0 to 1??? mm and in y from 0 to 1??? mm. To start the table moving, select the Start button. You can interrupt the motion with the Stop button. Be patient, the calorimeter table moves **very** slowly! During the motion of the table no valid numbers for the current position are shown in the display field in the COP main window and even worse, the status might turn to red and an error be displayed during the motion! **This is a bug of the stepping motor controller!** If you get any error message when moving the calorimeter table, wait at least for 3 minutes — if the error still persists, call an expert.

With the button Reference run you can move the stepping motor to its lower limit switch and reset the stepping counter. This option is not as tricky as the same option for the mirror motors and can be used by the shift crew although it should not be necessary in normal operation. The same is true for the button Reset Motor which will reset the stepping motor controller in the rare occasions that an unrecoverable error occurs when a command is issued to the controller. You will be asked to confirm your selection and the current height will be lost during this reset. After resetting the motor you should always perform a Reference run!

The last button Dismiss will close the window without any further action taken and in the main calorimeter control window a short online help menu is available with Help.

To move the calorimeter into the park position in front of the tungsten shield to protect the calorimeter against high radiation doses use the button Park calorimeter, which displays the window shown in Fig.67.

Figure 67: Window to park the calorimeter.

The Startup button

The Startup button in the right column of the COP main window allows the user to select a list of actions to be taken during the startup of the LPOL. If you select this button a window as shown in Fig.68 will be opened.

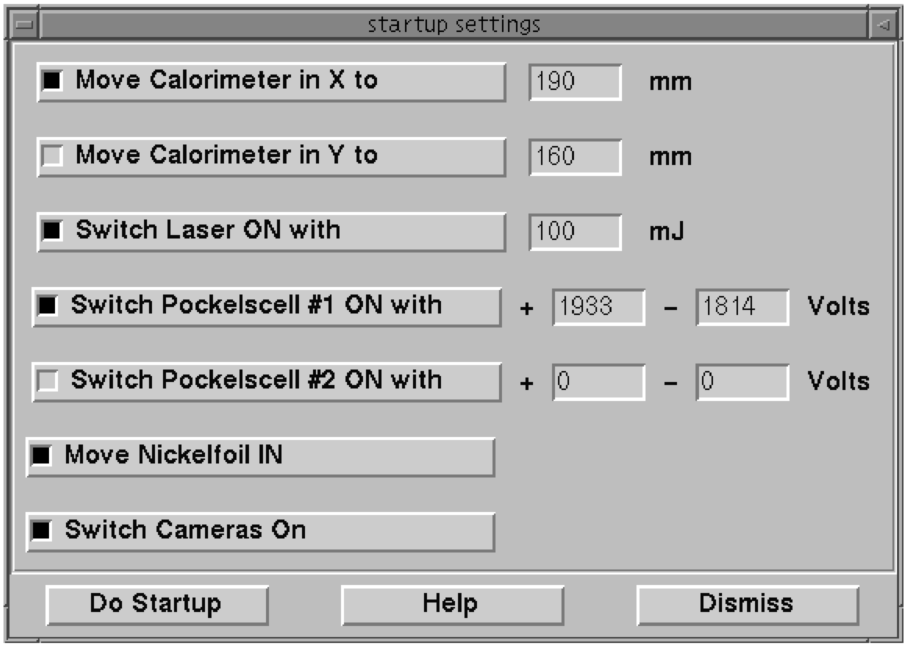


Figure 68: Window with options for the automatic startup procedure.

In this window you can select or deselect specific items for the automatic startup process which should be performed once lumi run conditions are declared by the HERA shift crew. As default setting, all available items are selected, except Move Calorimeter in Y to and Switch Pockelscell #2 ON with. To select or deselect a specific item of this list, simply click on the appropriate button. Normally the default settings should be correct.

There are seven entry fields in the right column where the displayed default values can be changed towards different settings, if desired. Refer to the chapters 5.2, 5.2 and 5.2 for a description of the parameters and the valid ranges. Once you have (de)selected all items as desired, press the Do Startup button to execute all selected options.

If the auto pilot is running (see section 6.2) then it will perform all selected options during the automatic startup after injection and ramping of the HERA electrons. To change the settings for the startup procedure performed by the auto pilot, select or deselect the appropriate options in this window and close it with the Dismiss button — do not press the Do Startup button! The same applies if you just want to check which commands will be performed during the startup operation. The Help button will display a short online help menu.

The Shutdown button

The Shutdown button in the right column of the COP main window is the counterpart for the Startup button described in the previous section 5.2. On selecting the Shutdown button a window as shown in Fig.69 will appear.

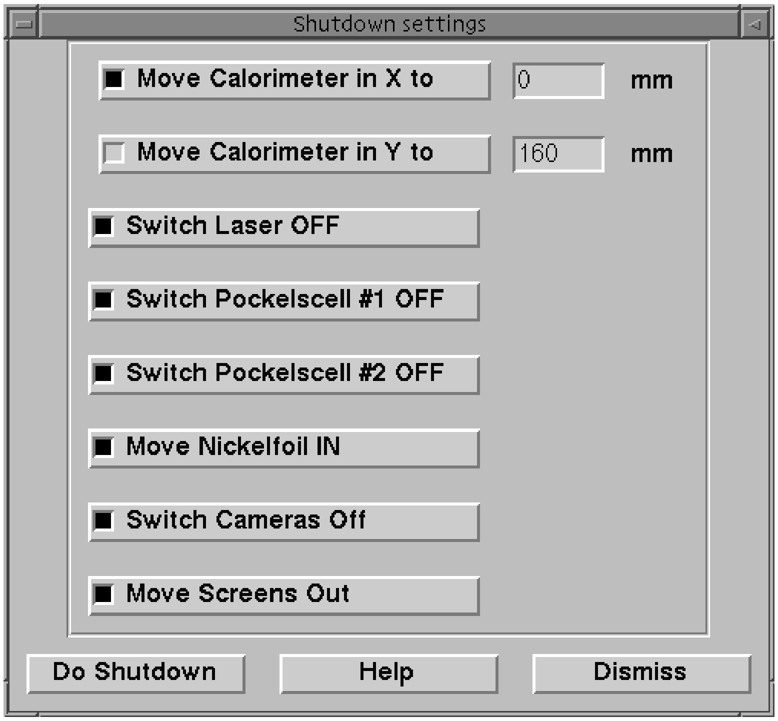


Figure 69: Window with options for the automatic shutdown procedure.

Again, you can select or deselect items from the list of commands to be performed during the shutdown process of the LPOL at the end of a luminosity run. Normally all options should be selected except Move Calorimeter in Y to. The entry field next to Move Calorimeter in X to should be set to 0. This will move the calorimeter in front of a tungsten shield to protect it from radiation.
To manually start the shutdown sequence, press the Do Shutdown button, to change the selection of items without performing the shutdown procedure select Dismiss. If the auto pilot is running and you want to check or change the shutdown options, also select the Dismiss button. And as a prize question: who can guess what the button Help will do? (If you are lucky and your answer is right, you might win a free guided tour to the LPOL laser hut...)

The Auto Pilot button

The Auto Pilot button in the right column will open a window as shown in Fig.70 to control parameters for the auto pilot. For a description of the auto pilot itself, refer to section 6.2.
In the control window you can optionally select two tasks for the auto pilot while it will always automatically perform the startup and the shutdown procedure described in the two previous sections 5.2 and 5.2. The two options are

- Optimize Compton rate by scanning the laser beam across the electron beam with mirror M4 and scanning the delay time between the HERA clock signal and the laser pulse.
- Align Calorimeter by moving the calorimeter table up, down, left or right until the calculated position of the center of the Compton beam spot on the front face of the calorimeter is in the center in the horizontal and vertical direction.

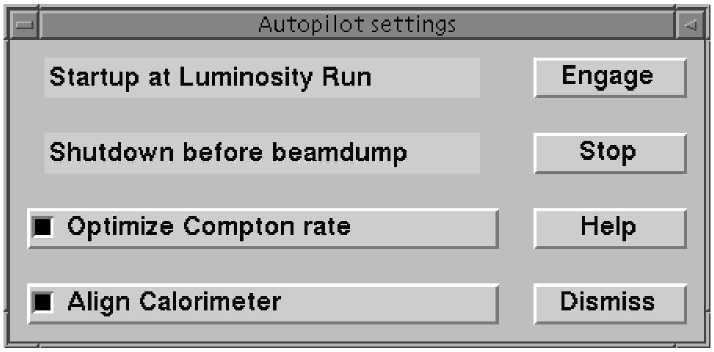


Figure 70: Window with options for the auto pilot.

During data taking these two options should be selected.
To start the auto pilot if it is not running (see the display in the status bar of the main COP window), press the Engage button, to stop a running auto pilot, select the Stop button. And again, you can access a short online Help menu or leave the window with the Dismiss button.

The Light Pol button

On pressing the button Light Pol two new windows as shown in Fig.71 will be opened. They are the interface to highly automated light polarization measurements in either analyzer box #1 or analyzer box #2, depending on the status of analyzer box #1 (see section 5.2 for a description how to switch between these two options).
The left window in Fig.71 (a) is the control window of a light polarization measurements and the results are displayed in the right window in Fig.71 (b). You can see which analyzer box is selected in the title bar of either of these two windows. Also the results window will look different for a measurement in analyzer box #1 as there is only one photo diode in this box. If you want to switch to the alternate analyzer box, close both windows with the Dismiss buttons, (de)select AB 1 and reopen the light polarization windows.
A measurement of the light polarization is performed by scanning the half–wave plate in the analyzer box over an angular range of at least 90°. You can select the starting and final angle plus the step size in the control window in the appropriate fields. A smaller step size will yield more precise results but also the time needed will increase. The default values displayed in these fields are a good compromise and you should not change them unless you want to perform very specific tests. To yield reliable results the step size should be an integer fraction of 90, the range should be from 0 to (90,180 or 360)-(step size). **The recommended settings are: alpha(min)=0, alpha(max)=345, steps=15.** The Start button will start a measurement which can be interrupted at any time with the Stop button. A short online help menu is accessible with the Help button.
Once a measurement has been started, you will see the data points displayed in the results window as they are taken. After the last data point has been taken, a fit to the measured data is performed and the results in terms of the linear and circular component of the light, S_{lin} and S_{circ}, respectively, are printed in the bottom part of the window, separately for each helicity state and also for each photo diode (this is only true if the measurement is performed in AB 2; there is only one photo diode in AB 1 therefore just half of the information is available). You

can clear the data points and results from previous measurements with the New button before you start a new measurement in the control window. The Print button will send a hardcopy of the results window to the UG printer in room 101 and Dismiss will close the window.

The Align Table button

The button Align Table will open a window as shown in Fig.72 where the calculated offset of the center of gravity of the Compton beam from the center of the four crystals in the calorimeter is displayed.
The displayed values are calculated by the analysis program from the height of the Compton signal in the four individual crystals and sent to COP via a server connection. If the measurement by the analysis program has not been started no numbers are calculated and sent. You will notice this if the displayed values are not updated at least once a minute (the exact time interval depends on the system load and a parameter set in the analysis program).
If you select the Align X button, the calorimeter will be moved left or right and if you select the Align Y button the calorimeter table will be moved up or down by <dy> millimeters to center the calorimeter in the vertical direction on the center of the backscattered Compton beam.
The Help button will display a short online help menu and Dismiss will close the window.

The Trigger button

The final button in this row is the Trigger button. If you select this button a window as shown in Fig.73 will be opened.
The LPOL can be operated in different trigger modes which can be selected in the left half of this window. For measurements of the electron polarization always the Comptons trigger has to be selected. If you select this option the Background trigger will automatically be selected, too. This combination as shown in Fig.73 is the standard trigger configuration which has to be used for electron (po polarization measurements in the multi photon method. The third option Bremsstrahlung is not required for the multi photon method and should therefore not be selected in normal shift operation of the LPOL. To adopt a trigger mode you have to select the Engage button.
In the right part of this window you can select the electron bunch number to be measured. The LPOL has the capability to measure the polarization of single bunches and the user can select the bunch number in this field. Note that not all of the possible 240 HERA buckets are filled with electron bunches. The potentially filled bunches range from bunch number 1...64, from number 75...138 and from number 149...212. **If you select an empty bunch you will see no Compton signal in the calorimeter! Always check whether the bunch selected has some electrons (there is a display on one of the HERMES status PinK displays in the "sanctum") before you suspect a failure of the polarimeter!** To select a single bunch, enter the number in this field and press the Engage button.
The standard measurement mode, however, is the "random" mode which can be selected by pressing the Random button. In this case the polarization will be averaged over single measurements on randomly chosen bunch numbers. The "random" mode will be activated without pressing the Engage button !

The Help button will display a short online help menu and Dismiss will close the trigger window.

5.3 The LPOL Online/Offline monitor and analysis program

We have an online display which calculates preliminary polarization values and provides the shift crew with all relevant quantities for operating the LPOL.
In Fig.74 an example of the online polarization display is shown. Under the jobctrl (section 5.1 page 62) on the hercules computer you find two different programs to start the display:

1. `lp_r7`
2. `lp_101`

The first script will start the display on the axher7 console, the second will start a display on the polarimeter screen in the "sanctum".
These displays get their values from an analysis program called `lpolyse` which has to be started on axher7 (see section 5.3 page 87):

```
axher7:> cd ~/cop/analysis
axher7:~/cop/analysis> lpolyse
```

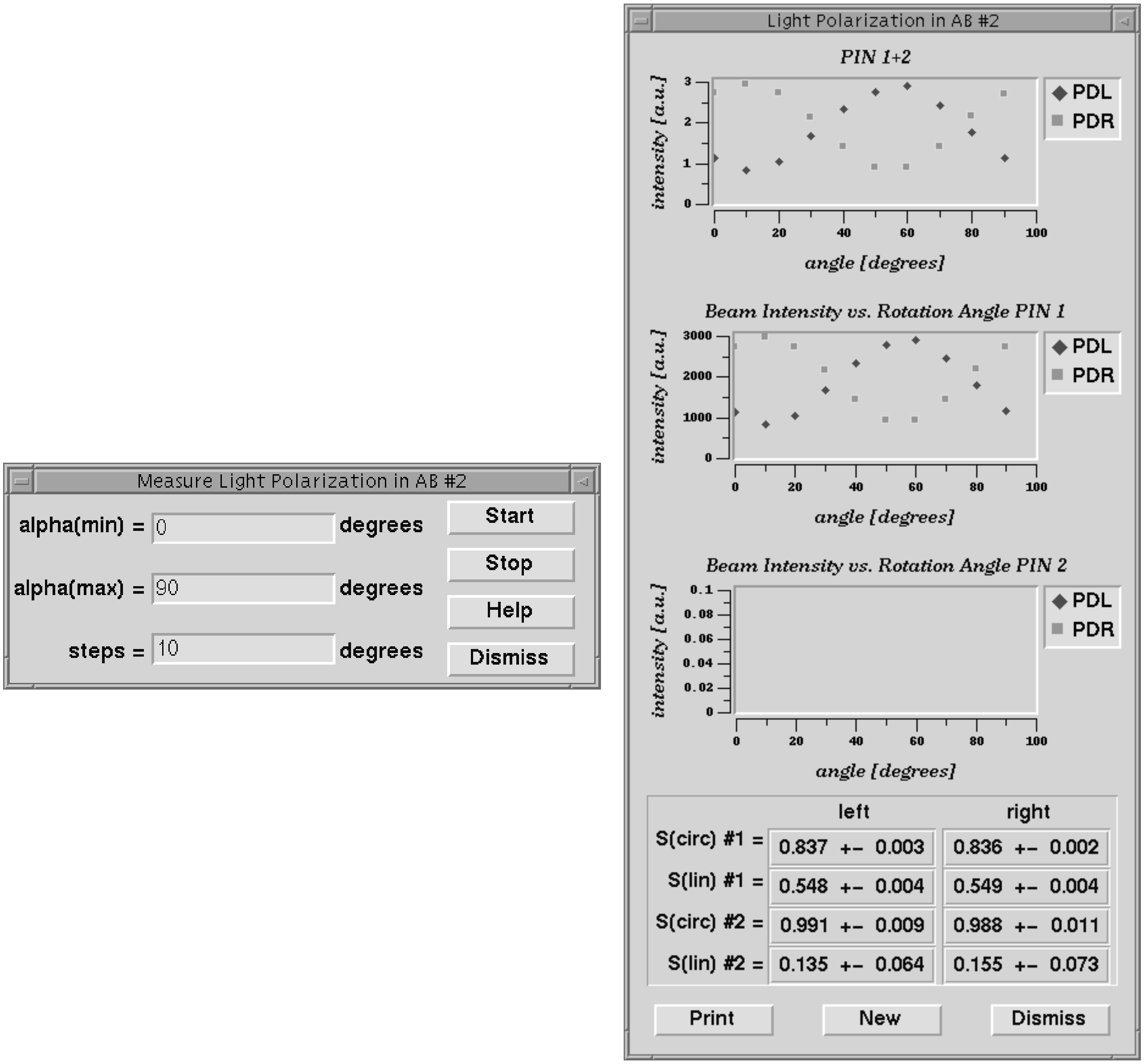
In the online display window you find five time graphs and a selection of important parameters in numeric format in the lower part of the window. Starting from the top these time graphs are

- The *Polarization* time graph, where the beam polarization as measured both by the Longitudinal and the Transverse Polarimeter is displayed. The data points for the LPOL correspond to a measurement of about 20 seconds, whereas the points for the Transverse Polarimeter are measured over 1 minute. The statistical uncertainty in these two measurements is about the same for the Longitudinal and the Transverse Polarimeter.
- The *LPOL/TPOL Ratio* time graph, which shows the history of the ratio of the measured values from the two instruments and facilitates to identify unstable operation of one of the polarimeters if it starts to deviate from 1.0 systematically. It should of course always be close to unity. The ratio is calculated from the average of the last ten values measured by the LPOL and the TPOL. **Thus always 10 displayed points are not statistically independent!**
- The *Luminosity* time graph, which displays the luminosity at the Compton IP, normalized to the beam current in the electron machine. A drop in this quantity indicates a drift of either the electron or the laser beam leading to less Compton scattering events. If this time graph shows a drop, you should optimize the luminosity and/or the timing of the laser (see sect. 6.3, p. 97).
- The *Coordinates* time graph, where the offset of the Compton photon beam from the center the calorimeter in both coordinates is shown. This offset is normalized to one, therefore a value of 1.0 corresponds to the edge of the calorimeter. During data taking the offsets should never be larger than 0.2 in either coordinate; otherwise you have to center the beam on the calorimeter (see sect. 6.3 p. 97).

- The *IP Position* time graph, which displays the longitudinal offset of the Compton IP (on the electron beam axis) relative to an arbitrary, yet fixed reference point. The IP position does **not** necessarily have to be at 0 m, however, it should not jump or drift away from the previous values as this influences the timing for the laser. A jump in the IP position will coincide with a drop in the *Luminosity* graph unless you optimize the timing of the laser.

Below these five time graphs you find the following quantities displayed:

- **Polarization**: The value of the last data point of the measured polarization in per cent. Note that the choice of the sign is somewhat arbitrary. It was defined to be positive at the beginning of data taking in 1997 and changed to negative after the access day in July 97, when the spin rotators were moved and the spin direction was reversed.



(a) Light polarization control window

(b) Light polarization results window

Figure 71: Main control and results window for the measurement of the light polarization.

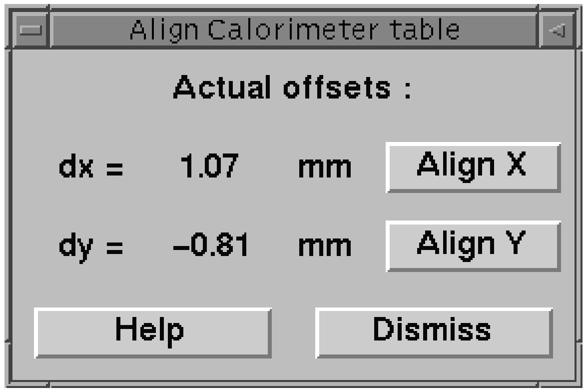


Figure 72: Control window for the alignment of the calorimeter table.

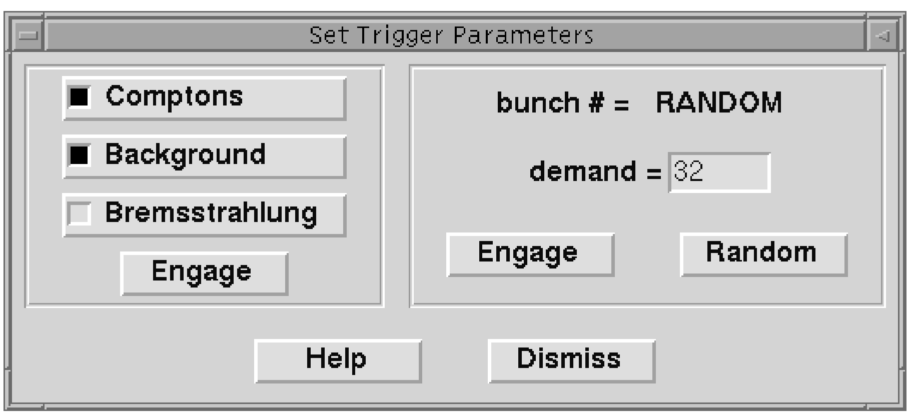


Figure 73: Control window for the trigger.

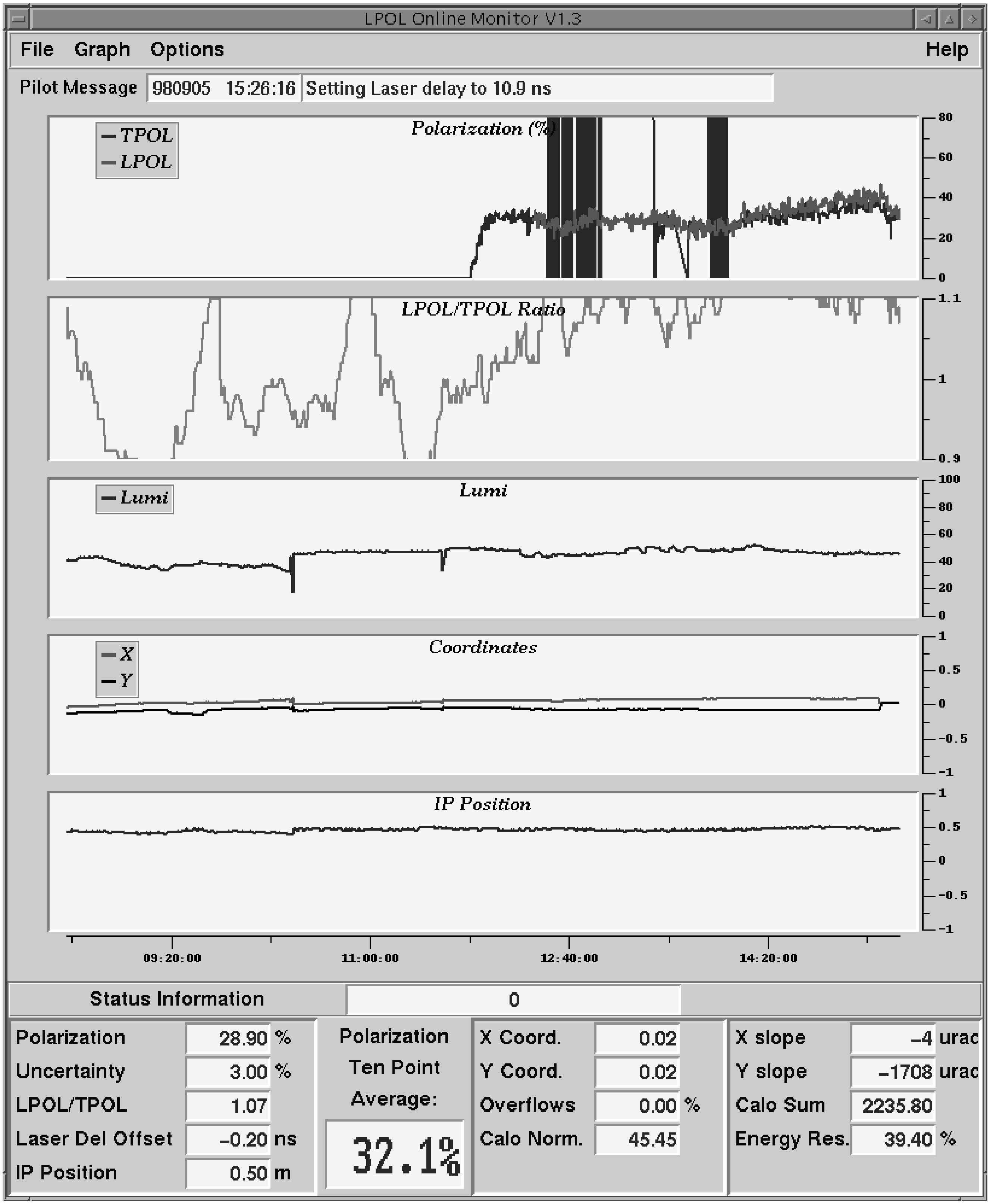


Figure 74: The LPOL online monitor polarization display `lp_r7`

- **Uncertainty**: The statistical uncertainty on the above value in per cent.
- **LPOL/TPOL Ratio**: The ratio of the last 10 data points measured by the Longitudinal and the Transverse Polarimeter.
- **Laser Delay Offset**: This number in nanoseconds indicates the amount the laser delay has to be changed in order to achieve the best temporal overlap possible between the laser pulse and the electron bunch. If the absolute value is larger than 0.1 ns you should open the laser control window from the main COP window (see sect. 5.2, p. 72) and change the timing delay there by the amount displayed in this field. For example, if the value displayed in **Laser Delay Offset** is −0.6 ns, **reduce** the number set in the laser timing window by 0.6 ns.
- **IP Position**: This is the actual value of the longitudinal offset of the Compton IP in meters, relative to some arbitrary, yet fixed reference point.
- **Polarization Ten Point Average**: This number in the center of the lower part of the window is probably the most important number and this is why it is in a large font and boldface. . .

  The sign is defined in a way that the configuration of the spin rotators in the beginning of data taking in 1997 corresponded to **positive** polarization values. The spin rotators were moved during the access day in July 1997 so that the sign changed to **negative** after that date.

  The average is taken over 10 data points which corresponds to 8 minutes of data taking, roughly. The exact duration depends on the laser repetition rate which can vary between 90 and 100 Hz and is therefore not given in this display.
- **X Coordinate/Y Coordinate**: These are the actual offsets of the center of the Compton beam from the center of the calorimeter, normalized to 1. If any of these quantities becomes larger than 0.2 you have adjust the horizontal or vertical position of the calorimeter table. For small offsets you can multiply this value by 10 to get the actual offset in mm. For offsets larger than 0.5 you have to move the calorimeter by bigger values or have to adjust it in several steps.
- **Overflows**: This is the fraction of events which caused an overflow in the ADC and had to be cut out. In order not to take data inefficiently and not to bias the polarization measurement[6] this quantity should be 0.0. The measured polarization values will not be spoiled as long as this number is below 0.1 %. If this quantity becomes larger than 0.1 % you have to reduce the intensity of the laser light with the [Intensity] button from the laser control window (see sect. 5.2, p. 73).
- **Calo Normalized**: This number is the sum signal of all four PMT channels divided by the electron current in HERA. A drop in this quantity indicates a drift of either the laser or the electron beam.

[6] If more events of one light helicity state are cut out then one had to weight the samples for left and right circular polarization of the laser light differently — this is not implemented in our current online analysis of the data.

- **Calo Sum**: This is the sum signal of all four PMT channels in channel numbers (a.u.). At the beginning of a fill ($\sim$ 30 mA) this number should at least be 4500. If it is significantly lower, this indicates a bad overlap of the electron with the laser beam and you have to optimize the luminosity and/or the laser timing.

- **Energy Resolution**: This is the width of distribution of the calorimeter sum signal which is currently still very broad. However, this quantity should always stay below 50%. Also, a bad resolution is a hint for non optimal overlap of the laser and the electron beam.

5.4 The Beam Position display

Fig.75 shows how the beam position display looks like.

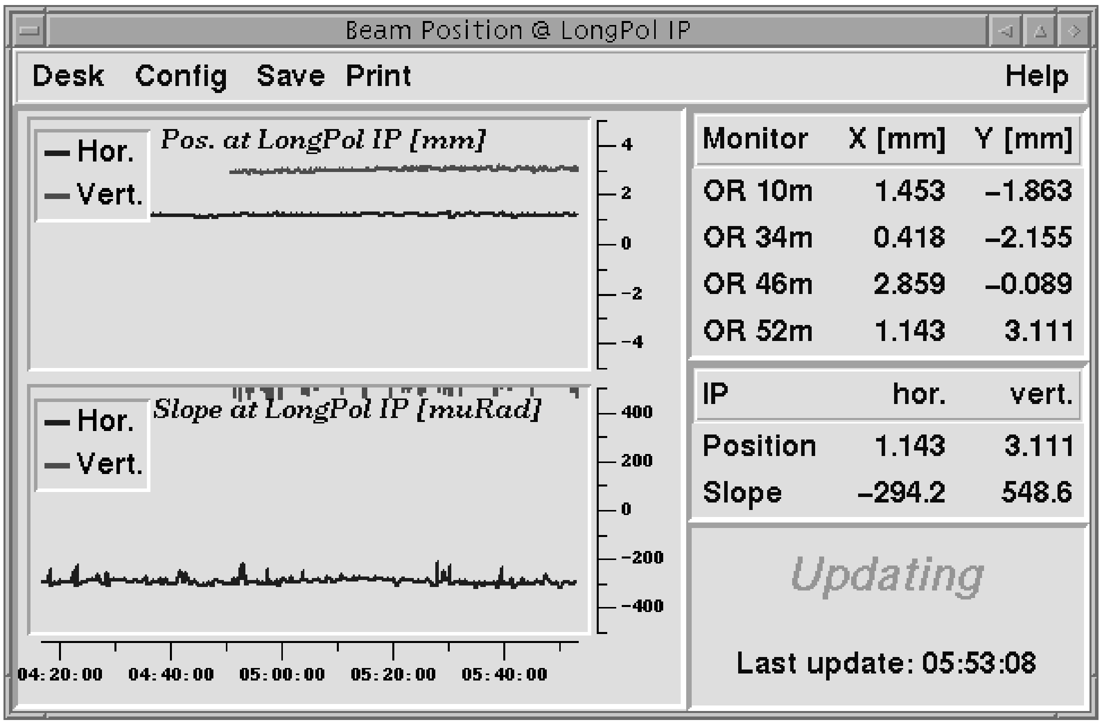


Figure 75: The beam position display at the LPOL interaction point.

There are two time graphs in this window. The upper one is the position time graph and shows the history of the readings from the BPM at OR 52m (the IP), the slope in the lower time graph is calculated from a straight line fit through the readings from the BPMs at OR 46m and OR 52m. The actual values are also displayed in the middle section of the right column.
In the lower right section of this window you see the current status of this display. If the server connection is established and there is no beam in HERA the phrase *"No Beam"* will be displayed, if there is beam the word *"Updating"* should be displayed. If the message *"Not Updating"* appears for more than a couple of minutes there is a problem with the connection to the server or with the update of the BPM values from the BKR. HERMES can not read out these BPMs but we get the values from the HERA machine group.
If one or more BPMs read out erroneous values (99.999 mm) for longer than a couple of minutes there is a problem with the controller for this specific BPM. Unfortunately this occurs rather

often and you have to call the BKR (ext. 3700) and ask them to adjust the attenuation for the specific BPM.

5.5 The Bunch Polarisation program

6 Detector operation

6.1 Switching on the LPOL system (from scratch)

Switching on the laser, steering the laser up to M8; switching on the electronics in the ET; switching on HV; starting up all the software; ....

6.2 Autopilot operation of LPOL

The auto pilot is supposed to do the same as its relative in aviation, namely to perform all tasks in the standard running situation *under the supervision of a human operator!* If any exceptional situation occurs which is not foreseen in the algorithm the operator has to take over manual control and clear the situation!
First check the current status of the auto pilot in the status bar of the main COP window to see whether it is already running. To start up the auto pilot, open the control window with the [Auto Pilot] button The two options "Startup at Luminosity Run" and "Shutdown before beam-dump" are always active. The two latter options [Optimize Compton rate] and [Align Calorimeter] should always be selected.
If you select the [Align Calorimeter] option, the auto pilot will center the Compton beam horizontally and vertically on the calorimeter by performing the align table procedure, as described in section 5.2 (p. 86).
Watch all actions taken by the auto pilot carefully and leave notes in the LPOL logbook about all reactions which appear unusual to you! ***Never let the auto pilot run the LPOL unattended for a long time (more than 30 minutes)!***

Auto pilot conditions
The auto pilot performs the following operations automatically under the given conditions:

Startup: Electron energy $>$ 27.5 GeV **and** electron current $>$ 1 mA
and no message "Switch HV OFF"

Shutdown: (Electron energy $<$ 27.0 GeV **and** electron current $<$ 5 mA)
or (Message: "Switch HV OFF")
for at least 3 times (updates of HERA server).

Optimize Compton rate: If the Compton rate in the calorimeter drops below 80(initial) rate, a luminosity optimization is performed with the mirror 4 in X. The new optimal luminosity is the measured luminosity after 100 seconds.

Align calorimeter: If the center of the Compton photons on the calorimeter is more than 1 mm off the middle of the four crystals, the calorimeter is steered horizontally (X) and vertically (Y) until the Compton beam is centered.

6.3 Manual operation of LPOL

The LPOL is automated to a high degree, but it is a very complex system and does require the supervision of the person on shift. In addition, there might be periods or circumstances which require to operate the LPOL by manual control.

You find here a complete list of what has to be done under the various conditions during a HERMES shift to operate the LPOL in case the auto-pilot operation is not possible or not correctly working or for some reason simply not wishful.
Note: the operation of the LPOL with COP is done by clicking on buttons in the main COP window or in related windows and/or selecting commands or options in the menu task line below the COP window title. By doing so, you will get always another window, which you can eventually click away by using the [Dismiss] button.

Step 0: Preparation

① Go through the items (A) - (G) of the regular shift work (→ sect. 7.1) and check that all is OK at this level. If not, you find first instructions in (→ sect. 7.2) on how to react.

Step 1: Start–up after injection

If the auto pilot is running it should perform the steps ①, ③, ④ and ⑤ described below automatically. However, it still does not check the positions of the laser beam spot (see step ②), which remains to be judged by the person on shift. **In case you perform these operations manually, please make sure that the autopilot is off. Do not forget to start the auto pilot after you finished manual operation.**
In principle all steps can be performed right after ramping up of the HERA electrons to the lumi run energy (currently 27.570 GeV), although steps ④ and ⑤ have to be repeated when the orbit has become stable and "Luminosity run" has been declared.

① Switch all on:

Press the [Startup] button (→ sect. 5.2, p. 83), select all available options and press the [Do Startup] button in this window. You should see the images from the cameras appear on the monitors overhead. Also the laser beam spot should become visible on the images as a bright white spot[7] and the symbol for the Pockels cell in the main COP window should turn green.

② Check the laser beam position on mirrors M2…M4 and M8. The nominal position for the beam spot is marked by the double ring on each mirror grid. The position on M1 is always off center but should also be within the circles. The position on M6 is usually outside the marked ring on the left lower corner. The position on M6 is not as critical as long as the spot on M8 is well–shaped (no intense fringes) and close to the center. If the position is off by more than 10 mm (one box is 10×10 mm^2) on M1 through M4 or looks very asymmetric on any mirror, call an expert to have a look at it. Our mirror system has proven to be very stable over the time so we consider a sudden change of the laser spot positions as an exceptional situation and we want the experts to be aware of it!

③ Select the correct trigger (Compton & Background events → sect. 5.2, p. 90) and the right trigger mode. In general we would like to measure in "random" mode, which means that we are measuring the average polarization of all electron bunches in HERA, just as the Transverse Polarimeter does.

[7] Do not get confused by the vertically running spot on some images — this is an artefact of the CCD cameras.

If for specific reasons you want to measure on single bunches, select the bunch number you want to measure from the Trigger window.[8]

④ Optimize the luminosity:

Open the Comptons|Time graph display (→ sect. 5.2, p. 68) and check whether you see a Compton signal at all. If the display is not updating press the Start button. A Compton signal can be identified by values larger than 300 channels in the upper time graph. If you do not see any Compton signal, check first whether the high voltage for the photo multipliers is on (→ sect. 5.2, p. 80), the calorimeter is in beam position and the shutter has been opened (→ sect. 5.2, p. 81).

After that you should perform a mirror scan with M4 by selecting Options|Optimize|Luminosity (→ sect. 5.2, p. 66) in the COP menu task line. The range to scan is ±100 steps from the actual x–position of M4 with a step size of 10 steps which are the default values in the control window. The algorithm will automatically set mirror M4 to the position with the maximum luminosity after completion of the scan.

Finally you should perform a laser delay timing scan (in the COP menu task line choose Options|Optimize|Laser delay, → sect. 5.2, p. 66). Scan by ±2 ns around the actual laser delay (open the laser control window to get the actual value → sect. 5.2, p. 71) with a step size of 0.1 ns. These numbers are set as default values. After completion of the scan the algorithm will set the laser delay to the value with the highest luminosity.

Watch the Compton time graph during these scans. The update time is reduced during the scans and you should be able to see what these scans actually do. If you have the impression that the optimum occured at one limit of the scanned range, repeat the scan with a larger or a shifted range.

If you still do not see any Compton signal, double–check whether the laser is running at an energy of 200 mJ, whether you can see a nice beam spot on mirror M8, whether the calorimeter has the HV switched on, the table is at the correct height (∼ 169 mm) and horizontal position (∼ 201 mm). You should also check whether HERA still has electrons filled in, whether you have selected the correct trigger and whether the optimization steps have been performed correctly. If all this is true and there is still no Compton signal in the calorimeter, this is the right time to call the Polarimeter Coordinator...

⑤ Center the Compton beam on the calorimeter:

Press the Align Table button (→ sect. 5.2, p. 86) to get numerical values for the offset in horizontal and vertical direction[9]. A horizontal and vertical offset can be eliminated by pressing the Align X and Align Y button in this window, respectively.

[8] All bunch numbers which carry electrons are fine. If you are not sure, check the display of bunch currents on the rightmost screen at the far end of the "sanctum". Note that currently there is an offset of 11 bunches between the numbering by our software and the HERA scheme. To convert from our to the HERA numbering, add 11 to our bunch number! (This offset may be currently different, ask an expert.)

Also make sure that the selected bunch does have electrons in. Otherwise you will see no Compton signal in the calorimeter!

[9] These values will not be updated if the Online Monitor program does not send them to the server. If they are not updating, check whether the lpolyse program is running and calculating these values (section 5.3 page 87.

Step 2: Monitoring the LPOL during a measurement

In this section we imply that there are luminosity run conditions and that the LPOL was started successfully as described in the previous section. If the polarimeter is not yet running, follow the list there to start up the measurement.

① Check and optimize the Compton rate:

Every fifteen minutes or so you should have a look at the normalized luminosity as displayed in the middle time graph of the Online Monitor program (→ sect. 5.3, p. 87). If the normalized luminosity falls off try to optimize luminosity with a scan of the laser delay and the laser beam across the electron beam by selecting in the COP menu bar Options|Optimize|Laser delay and Options|Optimize |Luminosity, respectively (→ sect. 5.2, p. 66).[10]

If the normalized luminosity is still very low due to bad beam conditions, or if it so high, that you get overflows, you can adjust the laser intensity (→ sect. 5.2, p. 73).

② Check the Compton beam position on the calorimeter:

If the auto pilot is running it will permanently check the offset of the Compton beam from the center of the calorimeter and align the calorimeter horizontally and vertically, if necessary.

To force the alignment press the [Align Table] button (→ sect. 5.2, p. 86).

③ Check the stability of all displayed time graphs:

Have a look at the time graphs for the longitudinal polarization, for the coordinates of the Compton beam on the calorimeter and for the IP position. If one value starts to take off, check and try to optimize the Compton rate as described in item ① in this section.

Step 3: Preparing for a beam dump

If the auto pilot is running it should perform the steps described in this section. On preparing for a beam dump, carefully watch the actions taken by the auto pilot (if it is running at all). If the auto pilot is off or does not recognize the beam dump condition you have to perform the shutdown procedure manually.

① Shut down the LPOL :

Open the [Shutdown] window and select all options in this window (→ sect. 5.2, p. 83). The calorimeter has to be moved in X to a position of 0 mm which should be the default setting anyway.

Make explicitely sure that the options [Move Calorimeter in X to] 0, [Switch Laser Off] and [Move Nickelfoil OUT] are selected — these are the real vital ones!

In order to initiate the shutdown process you have to press the [Do Shutdown] button. **Just opening and closing this window will NOT start the shutdown procedure!**

[10] If you are measuring in single–bunch mode, have a look at the single bunch current display in the inner "sanctum". If the current in the bunch you are measuring on has become too low, select another bunch from this display.

After you start the shutdown procedure check the displays in the main COP window. The laser symbol should turn transparent while the calorimeter will turn green when it starts moving.

It is not necessary to switch off the high voltage for our calorimeter as it is protected effectively by a tungsten shield, when moved into the zero position in x! Therefore the HV for the LPOL will not be switched off by the `@alloff` script for the CAEN HV system.

All cameras should be switched off in between fills to extend their lifetime and the lifetime of the illuminating light bulbs. You will see all images from the CCD cameras disappear from the monitors and all camera symbols should turn transparent. If some cameras "survive", switch them off by simply clicking on the appropriate symbol in the main COP window. Do not switch off the monitors in room 101 as this might only confuse the next person on shift when she/he wants to switch on the cameras and does not see any images...

② Relax! — The LPOL is now ready for a beam dump and does not require substantial supervision until the next fill.

6.4 Beam tuning at the LPOL IP

Beam tuning is possible at the LPOL IP upon request at the BKR. The values of the position and slopes of the beam in the LPOL interaction area are available via the "Beam Position @ Longpol IP" pink display on the LPOL terminal in R101 and also in the "Applications" menu on the HERMES display in the BKR. Besides the current position and slope values calculated from the LPOL BPM coordinates, the pink window also contains suggested best values for the beam parameters.

Changes in the beam parameters affect the LPOL system in several ways:

- **the interaction between the laser beam and the electron beam changes in space and time**.
  In general, no action is needed here since the COP auto-pilot adjusts regularly the mirrors and the Laser Delay such that the overlap between the laser and electron beam phase space is maximized. Such an optimization can also be initiated manually at any time:

  ☞ 1.) in COP menu bar: click Options|Optimize|Luminosity|Start
  2.) in COP menu bar: click Options|Optimize|Laser Delay|Start
  During the optimization procedures, watch the Compton time graph and Luminosity windows to see what the effects of your action are.

- the path of the Compton photons changes and **the Compton cone might not be centered anymore on the exit window of the beam pipe**.
  You will notice this if the values for the Table Position offset: "X Table offset" and "Y Table offset" on the "LPOL Online Monitor" pink display will turn yellow or red thus exceeding the tolerances we allow.

  ☞ phone BKR and ask them to retune the LPOL IP beam parameters (see procedure below).

- the path of Compton photons changes and **the Compton cone might not be centered on the calorimeter anymore**.
  You will notice this if the values for the Position of the Compton cone on the calorimeter: "X Compton" and "Y Compton" on the "LPOL Online Monitor" pink display will turn yellow or red thus exceeding the tolerances we allow.
  In general, no action is needed since the COP auto-pilot adjusts regularly the calorimeter such that the barycentre of the Compton photon showers is centered on the calorimeter in X and Y. Such a realigment can also be initiated manually at any time:

  ☞ in the COP right window: click [Align Table] button, then [Align X(Y)] button.
  Note: the alignment procedure may take up to 5 minutes; during this time no 2nd Align Table command must be given!

  However!: the calorimeter can move horizontally only up to the limit where it touches the electron beam pipe (in COP: absolute x-table position = 201.5 mm)! In other words, if the electron beam and by that the Compton cone has drifted in the course of a fill too much towards the centre of the beam pipe, the calorimeter is unable to follow and the only way out is to retune the electron beam back away from the centre of the beam pipe i.e. to make the horizontal beam slope more negative.

  ☞ phone BKR and ask them to retune the LPOL IP beam parameters (see procedure below).

How to proceed to get the LPOL beam parameters tuned:

The BKR has specially designed bumps to tune the beam parameters at the LPOL IP. They are accessible via their "Variable Bump Program", in which one has to click on "HERA-e" and select "helumiv7" optics. Depending if the beam should be tuned in the vertical or the horizontal direction, one then clicks on "Vertical"("Horizontal"), selects "Get Bump List" and chooses the corresponding bump "LPOL V3A"("LPOL H4A strong"). The rest of the operation should be standard to the BKR crew. Here are more details about the 2 bumps which we propose to use for LPOL (slope) tuning:

✉ **LPOL V3A** (3 v-bump): uses the magnets OR 16 CU, OR 68 CV, OR 81 CV.
Your aim is to get both the "Y Compton" and "Y Table offset" centered on 0 within 1-2 mm.

  ☞ ask BKR to go to the best value for the vertical slope suggested in the "Beam Position @ Longpol IP" pink display.

  ☞ If the best value does not allow you to reach the goal as defined above, here is a rule of thumb on how to evaluate the amount of remaining vertical tuning needed: to move the Compton photon spot down (i.e. decrease the values for "Y Compton" and "Y Table offset") by $\sim$ 8 mm at the exit window/LPOL calorimeter, the BKR needs to change the slope by -2500 'pulses' (this corresponds to a change of 2.1 A in the 1.coil OR 16 CU and a calculated change in slope by -170 μrad).

✉ **LPOL H4A strong** (4-a h-bump): uses the magnets OR 17 CI, OR 45 CH, OR 61 CH, OR 75 CH.
Your aim is to get both the "X Compton" and "X Table offset" centered on 0 within 1-2 mm.

- ☞ ask BKR to go to the best value for the horizontal slope suggested in the "Beam Position @ Longpol IP" pink display.
- ☞ If the best value does not allow you to reach the goal as defined above, here is a rule of thumb on how to evaluate the amount of remaining horizontal tuning needed: to move the Compton photon spot further away from the centre of the beam pipe (i.e. decrease the values for "X Compton" and "X Table offset") by $\sim$ 4 mm at the exit window/LPOL calorimeter, the BKR needs to change the slope by +460 'pulses' (this corresponds to a change of -0.12 A in the 1.coil OR 17 CI and a calculated change in slope by +140 μrad).

[N.B. During beam tuning, the calorimeter will keep readjusting itself to be centered on 0 if the AUTOPILOT is ON. In this case, only the "X Table offset" ("Y Table offset") is an appropriate measure of the Compton beam shift at the exit window/LPOL calorimeter position. Note that the "LPOL Online Monitor" display updates only once per minute].

Part II: INFORMATION FOR THE SHIFT

N.B. This part of the document should be taylored to the level of information we want our shift crews to be knowledgable about when operating this detector and potentially dealing with its problems in an initial phase!

The information should be organsized and presented such that the shift does *not need to read through* Part I to know how to behave and what to do. You should rather use *references* to particular subsections or paragraphs in Part I if more specific explanation is required.

N.B. Part II will eventually replace any shift-relevant information in the present documents in the Experimenter's Guide.

7 Specific instructions to the shift

7.1 Shift work

⇒ **The following items should be checked regularly during the shift:**

A) Are these processes running under jobctrl: copclient, copserver, lpolyclient, lpolyserver? (to see on which computers the programs run and how to check their status: → sect. 5.1).

B) Are the following windows present on the LPOL terminal ? :

(a) COP Compton Polarimeter Main Window
(b) Compton time graph
(c) LPOL Online Monitor
(d) Beam Position @LongPol IP
(e) LPOL Bunch Polarizations

C) Are all these windows updating ?

D) Is anything marked yellow or red on these windows ?

E) Is the LPOL auto-pilot running ?

F) Check if the camera laser spots on the sreen monitors located above the LPOL terminal are centered on the references marked by pen on the screen.

G) Check that the Relative Luminosity on the LPOL Online Monitor window stays about constant throughout a fill. The autopilot should take care of a significant drop of this quantity - watch out that the result of such automatic adjustments is successful.

⇒ **The following checks should be done twice per fill: (once 1/2-1 h after Lumi Run declaration and once a few hours later)**

H) Fill out the LPOL checklist (see next page)

I) Check scaler page 18: type *scaler* on any r- or b-machine and enter 18 (for reference rates: see next page at the bottom)

⇒ **The following windows should be printed out and glued into the LPOL logbook twice per fill: (once after reaching the asymptotic polarisation value and once right after the end of the fill)**

J) LPOL Online Monitor window

K) LPOL Beam Position @LongPol IP window

L) LPOL Bunch Polarizations window

Observations?/Comments?:

LPOL CHECK LIST / Date: Shift: TP-Person:

	Item to check	**Ref. value**	1^{st} **check** **time:**		2^{nd} **check** **time:**	
	Check and record values from LPOL Online Monitor window:					
1	LPOL polarisation value	-	=		=	
2	LPOL/TPOL	$\sim 1.00 \pm 0.05$	=		=	
3	Laser Delay Offset	< 0.25 ns	=		=	
4	Relative Luminosity	≥ 20	=		=	
5	Pos. Compton Cone on Calo	< 2 mm	x=	y=	x=	y=
6	Table position offset	< 5 mm	x=	y=	x=	y=
7	Overflows	= 0.00%	=		=	
8	Calo PMT signals 1-4	$\approx$ equal	$\approx \pm$ 20%?		$\approx \pm$ 20%?	
9	Calo Sum	> 1000	=		=	
	Check and record values from COP Main window:					
10	Circular Light Polarisation (AB2)	$> 90\%$	L=	R=	L=	R=
11	Pressure in laser beam pipe	< 0.5 mbar	=		=	
12	Position mirror M1	-	x=	y=	x=	y=
13	Position mirror M2	-	x=	y=	x=	y=
14	Position mirror M3	-	x=	y=	x=	y=
15	Position mirror M4	-	x=	y=	x=	y=
16	Position mirror M5/6	-	x=	y=	x=	y=
17	Position mirror M8	-	x=	y=	x=	y=
	Check and record values from COP Compton time graph window:					
18	Mean Compton signals Left,Right	> 1000	L=	R=	L=	R=
	Check values from scaler page 18:					
19	LPOL Scalers	see ref. below	OK?		OK?	
	Check and record values from HERA display:					
20	Electron Current	-	=		=	

Ad (19): Agreement with the reference rates below should be better than 1% , except for the NBW calo rates which agree typically at the ± 20% level only (dep. on background).

```
LPOL Trg.gen.          199.4                          0.0
LPOL Trg.acc.          199.2   Tr.bit 1 (L)          96.8
Trg. 1/2 gen.          193.6   Tr.bit 2 (L/P)       193.6
SUM Trg. gen.            0.0   Tr.bit 3 (SUM)         0.0
GMS Trg. gen.            3.0   Tr.bit 4 (GMS)         2.9
PED Trg. gen.            3.0   Tr.bit 5 (PED)         2.9
Helic. flips            48.4                          0.0
                         0.0                          0.0
NBW Coinc.              81.2                          0.0
NBW PMT 1               82.4                          0.0
NBW PMT 2               81.8   PIN Las. tim.         96.8
NBW PMT 3               82.1   PIN Las. int.         96.8
NBW PMT 4               81.7   PIN AB1                0.0
                         0.0   PIN 1/AB2             96.6
Sampl. PMT               0.0   PIN 2/AB2             96.6
Sampl. PMT+Filt          0.0   PIN GMS                3.0
```

7.2 Shift work - Getting help

How to proceed in case of problems related to the shift work (p. 104):

ad (A): If any one of the 4 processes is not running under jobctrl:
☞ restart it under jobctrl (→ sect. 5.1).

ad (B): If any one of the 5 windows on the LPOL terminal is misssing:
☞ For windows (a),(c),(d),(e): restart them under jobctrl (→ sect. 5.1).
☞ Window (b) is started in the COP menu bar by clicking on Comptons|Time graph.

ad (C): If a window is not updating anymore:
☞ exit the window (click File|Exit or Desk|Exit) and wait for automatic restart. If the window is not coming up after a few minutes, restart it under jobctrl (→ sect. 5.1).

ad (D): If anything is marked yellow or red on the COP or LPOL Online Monitor window:
☞ you need to take immediate action.

- on the LPOL schematic drawing in the center of the COP main window:
  ☞ click the yellow/red [button] in question to get the status of this component. Try to understand what is failing and use your common sense to react to the problem. If you do not succeed or judge the operation too risky without expert help ✆ call the Polarimeter Coordinator.
- in the bottom table of the COP main window or the LPOL Online Monitor:
  ☞ see next page on how to proceed for the most important parameters in case they turn yellow/red. In all other cases, just make a note in the LPOL logbook and inform the Polarimeter Coordinator by email.

ad (E): If the LPOL auto-pilot is not running:
☞ in the COP right window: click the button [Auto Pilot] and check that the options Optimize Compton rate and Align Calorimeter are selected; then ⇒ click [Engage]; check that the COP status bar shows *AUTOPILOT ON* now.

ad (F): If the camera laser spots on the screen monitors are not centered on the references marked by pen on the screen:
☞ ✆ call the Polarimeter Coordinator if in addition the Relative Luminosity (see item (4) in the checklist) is significantly below its reference value. Otherwise, just make a note in the LPOL logbook and inform the Polarimeter Coordinator by email.

ad (G): If the Relative Luminosity decreases significantly during a fill:
there are 2 actions that can help here:
☞ 1.) in COP menu bar: click Options|Optimize|Luminosity|Start
2.) in COP menu bar: click Options|Optimize|Laser Delay|Start

During the optimization procedures, watch the Compton time graph and Luminosity windows to see what the effects of your action are.

Note: Printing out complete windows might take a few minutes and the corresponding window might remain inaccessible for some time until the executing shell script has grabbed the pink window and finished all its file format conversions.

$\Rightarrow$ Do NOT change to another screen page while these actions are going on!.

How to proceed in case the current values in the CHECK LIST (table p. 105) deviate from the reference values:

ad (1): if the asymptotic polarisation stays significantly below 50 %
☞ inform the shift leader. Under normal running conditions he should ask the BKR to re-optimise the polarisation.

ad (2): ☞ Make a note in the LPOL logbook and inform the Polarimeter Coordinator by email.

ad (3): ☞ in COP: check in the status bar that *AUTOPILOT* is *ON*, otherwise switch it on (see previous page). Then click the [Auto Pilot] button in the COP right window and check if Optimize Compton rate is activated; if not: activate it and press [Engage] button.

ad (4): there are 2 actions that can help here:
☞ 1.) in COP menu bar: click Options|Optimize|Luminosity|Start
2.) in COP menu bar: click Options|Optimize|Laser Delay|Start
During the optimization procedures, watch the Compton time graph and Luminosity windows to see what the effects of your action are.

ad (5): First try do align the calorimeter manually:
☞ in the COP right window: click [Align Table] button, then [Align X(Y)] button.
Note: the alignment procedure may take up to 5 minutes; during this time no 2nd Align Table command must be given!
If realignment does not help and the LPOL beam parameters have significantly diverged from the "best values" displayed on the "Beam Position @ LongPol IP" pink window
☞ ask BKR to retune the beam parameters at the LPOL IP (→ sect. 6.4).

ad (6): as in ad (5).

ad (7): ✆ call the Polarimeter Coordinator.

ad (8): ✆ call the Polarimeter Coordinator.

ad (9): ☞ if the HERA-e current is still > 10mA: ✆ call Polarimeter Coordinator. Otherwise make a note in the LPOL logbook and inform the Polarimeter Coordinator by email.

ad (10): ☞ call Polarimeter Coordinator.

ad (11): Make a note in the LPOL logbook. In addition, if value is still close to 1 mbar, ☞ inform the Polarimeter Coordinator by email; else if the value is larger then a few mbar, ✆ call the Polarimeter Coordinator.

ad (18): as in ad (9)

ad (19): ✆ call the Polarimeter Coordinator.

Note: Sometimes actions started in COP are executed rather slowly; be patient!
Also, some actions (e.g. lumi optimisation) need a while to be processed; wait and watch the corresponding monitor window and the message line in the status bar for a couple of minutes before taking any further action!

8 Troubleshooting

8.1 Most prominent problems

Due to its large scale installation and the fact that the laser lab is not accessible to the shift crew, the troubleshooting facilities for the person on shift are rather limited. Nevertheless, in case of a problem go through this list and try to specify the problem as closely as possible. This will help the experts when you call them and you might even be able to fix minor problems yourself.
The order in the following list follows the way of the visible photons from the generation by the laser through the transport system to the IP and the detection of the unscattered (visible) photons in the analyzer box #2 and the Compton scattered photons (1-14 GeV) in the calorimeter.

Problem: No response from COP

① The auto pilot is not reacting on a 'Please switch your HV off' message.

☞ Click on the `Shutdown` button. Make sure that all available options are selected and press the `Do Shutdown` button. Within one minute the shutdown procedure should start (→ sect. 5.2, p. 83). If the shutdown procedure does not start, proceed with the following item.

☞ Open a terminal window on the `axher7` machine, change to the directory `~onl/cop/` and run the

`lpshut`

command there. If the shutdown procedure still does not start,

✆ **call an expert immediately!**

② COP is not reacting to any user command any more.

☞ You will have to shut down and restart the whole LPOL software. To do this, proceed as follows:

- Select File|Exit from the main COP menu and confirm the exit procedure.
- COP is under jobctrl and should restart automatically (→ sect. 5.1).
- You may have to check the status of the `copserver` and `copclient` programs. They are both controled by the jobctrl and can be stopped and started from there (→ sect. 5.1).

If you are unable to restore the COP software,

✆ **call an expert!**

Problem: No Compton signal at all

① Is there still beam in HERA?

② What is the status of the laser?

☞ Open the laser control window by clicking on the `Laser` button (→ sect. 5.2, p. 71) and check the status of the laser. You should press the `Update Values` button to get an actual update. If the laser is switched off, try to switch it on again. If an error message is persistent in the `Messages` window,

✆ **call an expert immediately!**

☞ If the laser is "On", check the measured energy. Press the `Update Values` button to get an actual value. If the measured energy is too low (< 5 mJ), increase it to a value between 100 and 200 mJ (default is 200 mJ) and wait for an acknowledge in the energy field. If you do not get an actual energy reading which is at least close to the demand value after waiting for two minutes,

✆ **call an expert!**

☞ Check the trigger setting and the repetition rate: The trigger has to be in the `External delayed` mode and the repetition rate should be around 95 Hertz.

✓ **You can change these settings to the correct values yourself.**

③ Is the laser beam spot visible on the mirrors?

☞ Check that you get images from the CCD cameras on the monitors on the overhead board in room 101. If the monitors are switched on but the labeling ("`MIRROR 1`", etc.) is not visible (it is a little faint!), then there is a problem with the video multiplex units which combine four images into one.

See instructions for the Problem: 'No images from one or all cameras' **below.**

☞ If you get images from the CCD cameras (i.e. you see the grids and marks for each mirror) but no laser beam spot **on any mirror**, the laser beam shutter might have fallen into its shut position. Check whether the HERA beam release signal ("HERA Freigabe") is given (if there is beam in the machine then the beam release signal is given, if the HERA status display tells you about "Technical problems" or anything like that, it is rather likely that they perform a short access to the HERA tunnel and therefore the beam release signal has been disabled).

If the beam release signal is not given, wait until it comes back — the laser beam shutter will reopen automatically with a delay of 30 seconds.

If no laser beam spot is visible although the HERA beam release signal is given,

✆ **call an expert!**

☞ If the laser spot is visible on some mirrors but disappears on the way through the laser transport system, check whether a screen has been moved into the beam path accidentally (→ sect. 5.2, p. 79). If this is the case, withdraw the screen. The laser beam spot should become visible again on all mirrors. If you had to remove a screen from the beam path, you will have to increase the laser energy back to its nominal value by hand (→ sect. 5.2, p. 71).

If no laser beam spot is visible although no screen is moved into the beam path,

✆ **call an expert!**

☞ If the laser beam spot is visible on mirror M6 but not on mirror M8, it has to be resteered through the HERA electron machine:

✆ **call an expert!**

④ What is the status of the calorimeter?

☞ Check the status of the calorimeter. If the Calorimeter in the main COP window is red, wait for one minute. The table controller spuriously generates fake error messages which disappear again without any action taken. If the error condition persists, try the Reset Motor button from the calorimeter control window (→ sect. 5.2, p. 82) and Reference run thereafter. If this operation is successful (it may take up to five minutes), you have to move the calorimeter back to into the beam position (→ sect. 5.2, p. 80).

If none of the above helps,

✆ **call an expert!**

☞ Open the calorimeter control window and check that the horizontal (X) position is around 201 mm, that the vertical (Y) position is around 169 mm and the nickel foil is OUT! (→ sect. 5.2, p. 80).

✓ **You can change these settings to the correct values yourself.**

☞ Check that the HV for the calorimeter is switched on. Go to the HERMES Status Display next to the HV control terminal in the inner "sanctum". If the symbol for the Longpol ("LPO") is not filled with green color, switch the high voltage on using the CAEN control program.

✓ **You can change these settings to the correct values yourself (possibly with the help from the spectrometer person on shift).**

⑤ Is the timing and the positioning of the laser beam relative to the HERA electron beam correct?

☞ Perform a timing delay scan (in the COP menu bar: click Options|Optimize|Laser delay) over the entire range from 0.1 to 25.6 ns with a step size of 0.5 ns. If you do get a Compton signal at some delay setting, repeat the scan with a smaller step size around this value to optimize. If not, try the next step also, before you call an expert!

☞ Perform a scan of the laser beam across the HERA electron beam (in the COP menu bar: click Options |Optimize|Luminosity) over a range of ±100 steps around the actual value of the y–coordinate of mirror M4 with a step size of 10 steps.

If you still do not see a Compton signal,

✆ **call an expert!**

Problem: Low or unstable polarization measurements

① Is the laser beam well adjusted?

☞ Follow the procedure in item ⑤ on page 111.

② What is the light polarization?

☞ Perform a measurement of the laser light polarization up on the optical bench with analyzer box #1 (→ sect. 5.2, p. 85). If the values for $S_{\mathrm{circ.}}$ in the two helicity states differ by more than 5%, check the high voltages for the Pockels cell (→ sect. 5.2, p. 74) against the nominal values which should be noted in the logbook. The default values in September 1998 were +1933 V and −1814 V. If they are O.K.,

✆ **call an expert!**

☞ Repeat the measurement in the analyzer box #2 (→ sect. 5.2, p. 85) and proceed as described in the previous item.

③ Has the correct trigger been selected?

☞ Open the trigger control window (→ sect. 5.2, p. 86) by clicking on the `Trigger` button and make sure that the options `Comptons` and `Background` are selected. Also check that 'Random' bunch triggering is selected.

✓ **You can change these settings to the correct values yourself.**

④ Is the Compton beam well centered on the calorimeter?

☞ Look at the coordinates time graph (→ sect. 5.3, p. 87) and check that the horizontal and vertical offsets are less than 0.3 cm. To center the Compton beam on the calorimeter, follow the procedure described in section 6.3, item ⑤ on page 97.

✓ **You can perform the centering yourself.**

Problem: No images from one or all cameras

① Are all four cameras on a monitor screen affected?

☞ If a group of all four cameras on one screen fail at the same time, a problem in the video multiplexer units is likely. First make sure that the monitor and all cameras are switched on. You should also check whether the images sampled by the frame grabber card are still available (→ sect. 5.2, p. 68). If these sampled images are O.K., only the display in room 101 is affected:

✍ **This is usually not an emergency condition which requires an expert call during the night. You should, however, leave a note in the logbook and inform the Polarimeter coordinator during daytime or per email.**

② Only one or two camera images are affected.

☞ Check that the corresponding `camera` buttons are green and the supply voltage is switched on (→ sect. 5.2, p. 79). Some of the cameras are coupled in pairs (e.g. the cameras for mirrors M1 and M2). If you click on both of the camera symbols coupled in a pair this is equivalent to clicking on one of them twice... Therefore they will be switched on and off again and the update in the main COP window will take some time.

✓ **You can change these settings to the correct values yourself.**

☞ If the camera appears to be switched on (see above item) but you do not get an image, neither on the live display (on the monitors in room 101) nor in the sampled images from the frame grabber card (→ sect. 5.2, p. 68), a problem with this particular camera, the light bulb or the power supply is likely.

8.2 What to do after a power failure

A) check in the ET if row E1 (LPOL Trigger electronics) and E2 (Table/Mirror Control) have power

B) check the scalerpage 18 and compare to checklist.
If the scaler rates look weird try to set output register 0:

- you do this by clicking on the Trigger button in the COP Main window
- make sure you selected Comptons and Background and press Engage
(Make sure that Bremsstrahlung is NOT selected!)
- press also Random to select random bunch triggering

C) do a 'copinit' which you find under Expert Commands in the menu task line of the COP main window

D) check the calorimeter table movement; if you have problems here:

- click on the Calorimeter button in the COP Main window; select x or y
- reset motors before and after reference runs
- do reference runs in x (takes $\sim 2\,\text{min}$) and y (takes $\sim 20\,\text{min}$)
- go back to nominal positions

E) in the ET have a look on the Bunch Trigger Modules (BTM) which are located in the rack E1-9 (top)

- if you read '- - -' on both displays call BKR to reset these modules
- once they are reset, one display should show '001' and the other one should show alternating numbers from '001' to '220'

F) in rare cases you will have to reload the LPOL DSP program. This is done by rebooting the DAQ frontends; contact the shift leader or call a DAQ expert

G) press the Startup button in the COP main window.
Check gain all scalers, the calo positions (x should be around 201 and y around 169), make sure the laser is firing and check for a Compton signal on the Compton time graph. You might also perform delay and lumi optimisations.

9 Emergency procedures / Safe state

Follow the following instructions to get the LPOL into a safe state in case of emergencies:

- ☞ Click on the [Shutdown] button. Make sure that all available options are selected and press the [Do Shutdown] button. Within one minute the shutdown procedure should start (→ sect. 5.2, p. 83). If the shutdown procedure does not start, proceed with the following item.

- ☞ Open a terminal window on the `axher7` machine, change to the directory `~onl/cop/` and run the

  `lpshut`

  command there. If the shutdown procedure still does not start,

  ✆ **call an expert immediately!**

10 Further documentation & References

References

[1] Proposal to DESY for a Longitudinal Electron Polarimeter at HERA-East Section, *W. Lorenzon for the HERMES Collaboration*, IPR-95-03, May 1995 (2nd version).

[2] Report on the Test Beam Results for Longitudinal Polarimeter, *S. Rudnitsky*, IPR-96-03, February 1996.

[3] Study of the Longitudinal Polarization in the Single Photon Method, *S. Rudnitsky*, IPR-96-06, May 1996.

[4] Transverse Polarization Measurements at the Longitudinal Polarimeter, *B. Tipton*, IPR-96-07, June 1996.

[5] Test of the new 37-layer CVI mirrors for the Longitudinal Polarimeter, *M. Beckmann*, IPR-97-01, January 1997.

[6] GEANT simulation for the Longitudinal Polarimeter, *S. Rudnitsky, W. Lorenzon, A. Most*, IPR-97-03, February 1997.

[7] Study of Circular Polarisation in the HERMES Longitudinal Polarimeter, *F.H. Heinsius*, IPR-97-04, March 1997.

[8] Overview on Systematic Studies of the Compton Asymmetry Measurement with the HERMES Longitudinal Polarimeter, *F.H. Heinsius*, IPR-97-06, May 1997.

[9] Summary of Systematic Studies performed between June 3 and July 8, 1997 on the Longitudinal Polarimeter, *M. Beckmann*, IPR-97-08, August 1997.

[10] Summary of Systematic Studies at the Longitudinal Polarimeter in June and July 1997, *S. Brauksiepe, M. Ruh*, IPR-97-09, August 1997.

[11] Mapping of the Cross-Section of the Beampipe at the HERMES Longitudinal Polarimeter, *F.M. Menden*, IPR-98-01, March 1998.

[12] Studies on the Light Polarization at the Longitudinal Polarimeter, *S. Brauksiepe*, IPR-98-03, April 1998.

[13] Status and Studies of the Circular Light Polarization During the 1997/1998 Shutdown, *M. Beckmann, F.M. Menden*, IPR-98-04, October 1998.

[14] Tests of Photomultipliers Concerning Linearity, *F.M. Menden*, IPR-98-05, October 1998.

[15] Testbeam Results on Different LPOL Calorimeter Assemblies, *F.M. Menden*, IPR-98-06, October 1998.

[16] Testbeam Results on the Final 1998 LPOL Calorimeter Setup (DESY/CERN Jul.25 - Aug.1 1998), *F.M. Menden*,
IPR-98-07, October 1998.

11 Spares & Maintenance

All the spare parts of the LPOL can be found either in the cupboards in the entrance room of the Laser Hut (LH) on the 6th floor (all the optical components) or in the cupboards in the Polarimeter room 261 on the 2nd floor (all mechanical parts and electronics).

Component	Specification	Producer/Vendor	Location od spare	nr. of spares
$\lambda/2$ plate	....	....	LH cupb. nr. 1	?

Table 16: List of LPOL spare optical parts and components

Component	Specification	Producer/Vendor	Location od spare	nr. of spares
....	....	....	....	?

Table 17: List of LPOL spare mechanics parts

Component	Specification	Producer/Vendor	Location od spare	nr. of spares
....	....	....	LH cupb. nr. 1	?

Table 18: List of LPOL spare electronic parts and NIM/CAMAC/FB modules

Description of exchange procedures or references to documents ?

Maintenance: what kind of maintenance has to be done in which time intervalls?

Contactpersons/phone numbers for our main suppliers: COHERENT, OWIS, Melles-Griot, etc.