Proposal for an Upgrade of the HERA Polarimeters for HERA 2000

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Abstract

Hera will be significantly upgraded in the year 2000, aiming for a five-fold increase of the luminosity. At the same time spin rotators will be installed at the H1 and ZEUS experiments, in addition to those already installed at the HERMES experiment, making longitudinally polarized electrons available at all experiments. The aim of the Polarization 2000 group is to set up a system of polarimeters which is able to measure the electron / positron polarization to an accuracy of better than 2 %. The proposed system consists of the existing transverse polarimeter located in the HERA West area and the longitudinal polarimeter which is located in the HERA East area near the HERMES experiment. In this proposal the changes necessary to the hardware of the existing transverse polarimeter are discussed. Possible improvements to the existing longitudinal polarimeter are presented.

1 Introduction and Physics Motivation

In the HERA Shutdown 1999/2000 spin rotators will be installed around the interaction regions of the H1 and ZEUS experiments to enable these experiments to run with longitudinally polarized electrons and positrons[1]. Together with the realization of the HERA luminosity upgrade program electroweak precision measurements will be feasible. The HERA physics program with polarized electrons has mainly been defined in the Workshop *Future Physics at HERA* [1]. The central goal of this program is to set limits on right-handed charged current reactions, to measure standard model parameters and to test the neutral current couplings of the quarks. These studies are based on a delivered total luminosity of 500–1000 pb^{-1} and a degree of polarization P of 70 %. Under these conditions the electron polarization has to be known to at least 2 % relative accuracy in order to fully exploit the potential of HERA for the proposed measurements.

Currently the measurement of the electron polarization at HERA is done with two different devices. The transverse polarimeter (TPOL) [2] which is located in the West area of HERA measures the polarization of the – at that location – transversely polarized beam. The longitudinal polarimeter (LPOL) [3] in contrast measures the longitudinal polarization of the beam near the HERMES interaction point.

Both devices and their current performance will be discussed below, followed by a section which describes the requirements for future polarization measurements. The next chapter then deals with the proposed upgrades. First the proposed changes to the transverse polarimeter are presented. The major part of the upgrade concerns the data acquisition system. Then the feasibility of using the longitudinal polarimeter in the single photon mode is discussed. The proposal closes with a brief presentation of a working plan and some discussion of the finances.

2 The Measurement of Polarization

The details of the measurement and the derivation of the polarization for both the transverse and the longitudinal polarimeter have been described in previous publications [2, 4, 5]. Here only the basic concepts are repeated.

The differential Compton cross section $\mathrm{d}\sigma_\mathrm{C}/\mathrm{d}\Omega(S,P)$ as a function of the polarization S of the laser light and the degree of polarization P of the electron beam can be written as

$$\frac{\mathrm{d}\sigma_\mathrm{C}}{\mathrm{d}\Omega}(\vec{S},\vec{P}) = \Sigma_0 + S_1(0)\Sigma_1' + S_3\left[P_Y\Sigma_{2Y} + P_Z\Sigma_{2Z}\right] . \quad (1)$$

Here $S_1(0)$ is related to the linearly polarized component of the laser light, S_3 to the circular polarized one. The Σ-functions describe the distributions of the scattered photon as a function of the scattering angles (θ,Φ) and are completely described by the Compton scattering process. The variables P_Y and P_Z are the transverse and longitudinal polarization, respectively.

The transverse polarization component P_Y is measured from the vertical asymmetry function $\mathcal{A}(y)$. Neglecting longitudinal components this asymmetry can be written as

$$\mathcal{A}(y) = \Delta S_1\ \Sigma_{1/0}' + \Delta S_3\ P_Y\ \Sigma_{2Y/0} \quad (2)$$

[1] In the following the term "electrons" will be used to denote both, electrons and positrons.

where $\Sigma'_{1/0}$ is defined as $\int \Sigma'_1 \mathrm{d}E_\gamma / \int \Sigma_0 \mathrm{d}E_\gamma$ with the integration running over the considered energy range ΔE, and $\Sigma_{2Y/0}$ is defined analogously. $\Delta S_{1,3}$ are one half of the differences of the linear and circular polarisation components of the two laser states. The transverse polarization is obtained by fitting eq. 2 taken the finite resolution of the measurement device into account. Alternatively one can integrate eq. 2 over all scattering angles for one polarization state of the laser light, and determine the difference of the mean vertical position of the backscattered photon when the laser light polarization is switched between left and right circular polarization:

$$\Delta y(E_\gamma) = \Delta S_3 \; P_Y \; \Pi(E_\gamma) \; . \tag{3}$$

Here $\Pi(E_\gamma)$ is often referred to as the analysing power. Typical values of this vertical shift are of the order of $140 \mu m$ for the existing setup for photon energies between 5.2 and 11.9 GeV.

The longitudinal polarization component is determined from the energy asymmetry

$$\mathcal{A}(E_\gamma) = \Delta S_3 \; P_Z \; \Sigma_{2Z/0} \; , \tag{4}$$

where $\Sigma_{2Z/0} = \int_y \Sigma_{2Z} \mathrm{d}y / \int_y \Sigma_0 \mathrm{d}y$. The current longitudinal polarimeter is operated in the multi-photon mode, where the laser intensity is chosen such that many Compton photons are produced for one bunch of the electron beam. The longitudinal polarization is then obtained from measurements of the energy weighted asymmetry:

$$\mathcal{A}(E_\gamma) = \Delta S_3 \; P_Z \; \mathcal{S}_Z \; , \tag{5}$$

where

$$\mathcal{S}_Z = \frac{\mathcal{S}_L - \mathcal{S}_R}{\mathcal{S}_L + \mathcal{S}_R} \; , \quad \text{and} \quad \mathcal{S}_i = \int_{E_{min}}^{E_{max}} (\frac{\mathrm{d}\sigma}{\mathrm{d}E})_i \cdot E \cdot r(E) \, \mathrm{d}E \; , i = L, R \; . \tag{6}$$

The analyzing power $\mathcal{S}_Z$ is 0.184 for the ideal energy response function $r(E) = 1$. The polarization is finally obtained from the measured shifts in the energy spectra for the two polarization states.

If the Polarimeter can be operated in the single photon mode, P_Z can be obtained from fitting directly eq. 4. For energies of the scattered photon above 11 GeV this asymmetry reaches values of larger than 40%.

3 Performance of the current Polarimeters

Both the TPOL and the LPOL have been operating for some time, and a lot of experience concerning its performance and possible systematic errors has been gathered [2, 6, 7]. A summary of the relevant errors from recent analyses is given in table 1 for the TPOL and table 2 for the LPOL.

The dominant error for the TPOL at the moment is the determination of the polarisation scale, which depends on the rise time method (see [8] for a detailed discussion).

For the LPOL it should be noted that at the moment there is an overall scale mismatch of 25% in the determination of the beam polarisation. Apart from this calibration correction factor, however, the polarisation measurements by the LPOL and TPOL track each other very well over entire running periods. A conservative estimate for the systematic uncertainty associated with the LPOL miscalibration is

Source	Rel. uncertainty $\delta P/P$ [%]
Calorimeter centering	0.55
Calorimeter calibration	0.08
Rate dependence	0.10
Light polarization	0.52
Point-to point quadratic sum	0.87
Rise time calibration	3.26
Total average syst. error	3.42

Table 1: *Current systematic errors of the transverse polarization measurement (from [7])*

Source	$\delta P/P$ [%] 1997
Helicity dependence of IP position	<1%
Slope & horiz. beam pos. at IP	<1%
Laser polarization	0.5%
Detector linearity	0.5%
Electronic noise	<1.0%
Calorimeter Calibration	1.5%
Scale uncertainty rel to TPOL	2.7%
Calibration TPOL	3.3%

Table 2: *List of various measured (1997) systematic errors of the longitudinal polarization measurement using the multi photon method.*

the level of fluctuations in the ratio of the LPOL to TPOL polarisation measurements; these fluctuations were found to be 2.7% over the '97 run.

During the past '98 run further efforts were made to understand the origin of the LPOL miscalibration.

The whole LPOL system (optics, electronics, calorimetry) has been reviewed in detail and subjected to extensive tests. The determination of the polarisation in the multi photon mode was checked carefully, and the various corrections entering the analysis programs were reconsidered and redetermined. Even though these investigations are still in progress and some minor effects were found that need to be taken into account in future online and offline polarisation analyses, no major source for the miscalibration has emerged so far.

Single photon measurements were done to check more particularly the performance of the crystal calorimeter. The main interest in this running mode is to see if the single photon method leads to the same wrong determination of the polarisation (which would point to a principle problem with the crystal calorimeter) or if the problem only arises when making the transition from the single to the multi photon method. In a first online analysis the known Compton spectra could be qualitatively reproduced. The offline analysis of the data is still in progress and certainly more data in single photon mode need to be taken at the beginning of the '99 run.

In addition the crystal calorimeter was temporarily replaced by a prototype sampling calorimeter consisting of alternating plates of tungsten and scintillator read out by a wave length shifter on one side. First results in multi photon mode operation show indeed a very different behavior between both calorimeters. The sampling calorimeter seems to reproduce the beam polarisation as measured with the TPOL much better. These results have to be confirmed by the offline analysis; in addition, the sampling calorimeter should also be operated for some time in the single photon mode and demonstrate that it is able to correctly reproduce the expected energy spectra.

If it would turn out that there exists an intrinsic problem to measure the polarisation using the crystal calorimeter, one would plan to upgrade the prototype calorimeter for future permanent use. The optical readout should be made more uniform and a measurement of the position of the Compton photons must be provided. This could happen e.g. with a thin position sensitive device in front of the calorimeter (a test set up of a silicon system is already in preparation) or by redesigning the active calorimeter components such as to allow position determination by energy sharing methods (e.g. separate readouts for top/bottom and left/right as for the TPOL calorimeter).

4 Requirements for Future Polarization Measurement

After the HERA luminosity upgrade the default mode of running for HERMES, H1 and ZEUS will be with longitudinally polarized electrons at their interaction points. The compensation coils in H1 and ZEUS which at the moment make running with transversely polarized electrons possible will be removed in the upgrade.

After the upgrade the polarization measurement will become as important as the luminosity measurement for H1 and ZEUS, since neutral and charged current ep cross sections and hence the corresponding event rates depend sensitively on the beam polarization. Therefore care has to be taken that a continuous, reliable beam polarization measurement is available throughout the HERA collision program with a relative accuracy of $\leq 2\,\%$ to satisfy the physics requirements quoted above. Ideally, the accuracies of both, luminosity and polarization measurement, should be the same. The luminosity measurement for H1 and ZEUS currently has an uncertainty of about 1–2 % in accordance with the projected polarization uncertainty.

The physics done with H1 and ZEUS is based on the colliding bunches in the machine only. This is in contrast to the HERMES experiment, where the scattering between all electron bunches in the machine and the gas target is studied, and therefore the average polarization of all electron bunches in the machine is relevant. Hence the polarization has to be measured separately for colliding and for non-colliding bunches. The existing TPOL data acquisition system does not allow this differentiation to be made. The LPOL is capable of measuring the polarization of single bunches, small bunch groups, or the mean polarization of all electron bunches.

This flexibility in the measurement of the polarization is particularly important because measurements done with the LPOL indicate that non-colliding electron bunches can have different polarizations than colliding ones (Fig. 1). The pattern observed depends sensitively on the tuning of the polarization, and may also vary in time.

Since the absolute value of the degree of polarization of the electron beam is the same everywhere in the ring, in particular $|P_{\rm long}| = |P_{\rm trans}|$, the location of the polarization measurement is not confined to the experiments' interaction regions. The two existing locations for polarimeters in the west and in the east area are well suited for

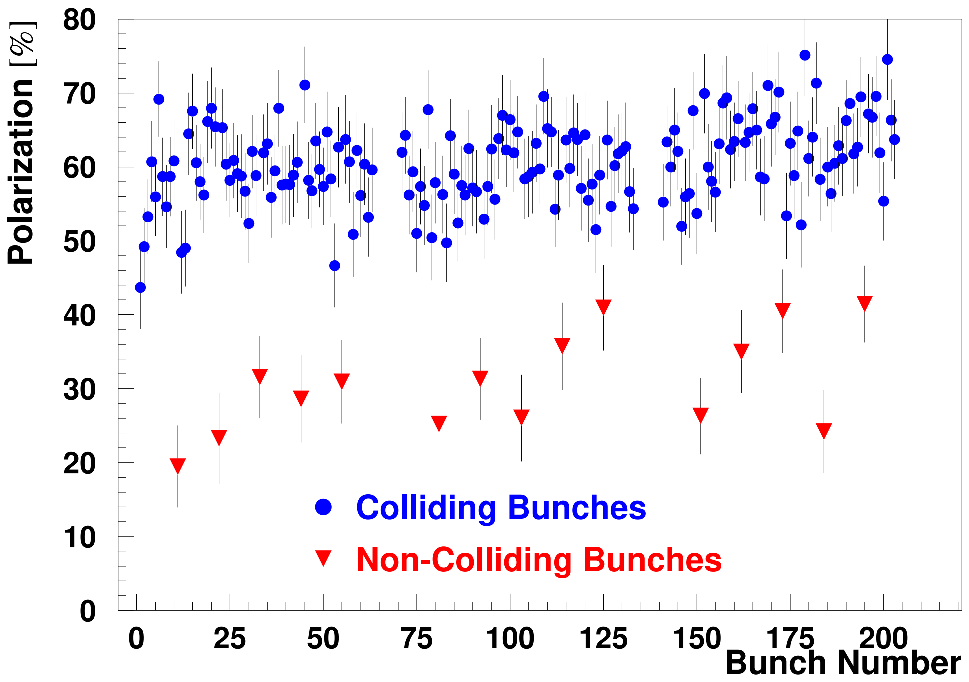

Figure 1: *Polarization measurement of single electron bunches with the longitudinal polarimeter. In this specific measurement the non-colliding electron bunches show a systematically lower polarization than the electron bunches which collide with proton bunches at ZEUS and H1, but this might depend on the exact tune of the machine and might vary.*

the measurement, and there is no clear need for yet another installation. In addition the methods to measure the polarization at these points are well established, and a clear understanding exists how the specific hardware and the methods need to be improved in order to reach the required accuracy of $< 2\%$. We think that the best way to proceed therefore is an upgrade of the existing facilities.

The design of the new system should fulfill the following goals:

- allow a determination of the polarization with a total uncertainty of $\leq 2\%$;
- allow the flexibility to measure the polarization individually for every bunch in the machine, for groups of bunches, or averaged over all bunches;
- provide a stable and reliable measurement of the polarization with a high uptime. This favours the scenario of having two independent polarimeters, TPOL and LPOL, so that redundancy exists in the system.

These goals will have to be approached from three sides:

- upgrade of TPOL,
- understand the LPOL fully,
- improve the Monte Carlo simulation.

5 The Upgrade of the Transverse Polarimeter

The transverse polarimeter was the first polarimeter to be installed in HERA, and is located in the West Area of the HERA ring. In Fig. 2 an overview over the current experimental setup is shown including the laser, the light transport and analysis system, the HERA tunnel and the calorimeter for the Compton photons. More details on the setup and its performance may be found in [2].

The proposed upgrades for the transverse polarimeter are discussed in detail in this section. They mostly involve a replacement of the data acquisition system, but a number of other points are raised as well.

The main goals of the upgrade can be summarised as follows:

- upgrade the data acquisition system so that
  - a bunch by bunch measurement of the polarization is possible,
  - make provisions to control the systematics at the required level by allowing flexible and frequent calibration runs,
  - the system is easier to maintain and will operate reliably for the next > 5 years of HERA operation.
- make the overall system more stable and reliable, re-design part of the laser beam optics to allow easier beam control and steering.

In the following all the components of the TPOL will be discussed in terms of necessary upgrades. Table 5 gives an overview of the proposed actions in order to fulfill the requirements outlined in the previous chapters.

5.1 DAQ and Trigger System

The current TPOL DAQ system was designed to measure the average polarization of all bunches in HERA, and does not provide the possibility to do a bunch-by-bunch measurement. It is implemented as a very heterogeneous system, based on a number of different standards and a dedicated DSP architecture. The proposed DAQ system has been designed with a high degree of flexibility in mind. The required accuracy and stability of operation places stringent requirements on the analogue and the digital part of the system. In table 4 the specifications of the system are given. They were calculated based upon the assumption that the total contribution to the final error from electronic effects should be below 1%.

The proposed new DAQ system is based upon a commercial VME based fast processor, with a custom designed fast ADC board to digitize the incoming events.

The general layout of the electronics is shown in Fig. 3. The system is closely modeled after the DAQ system for the luminometer for the H1 experiment, which is currently undergoing a major upgrade [9]. The calorimetric chain consists of a fast analog shaping, a 12 bit ADC providing up to 4 energy samples per bunch and a dedicated fast readout by a commercial processor (Power PC) which performs on-line histogramming at a high rate ($\sim 1\,\mathrm{MHz}$). The analysis of the produced histograms provides the polarization measurements bunch by bunch. In the following the main elements of the proposed system are described in some detail.

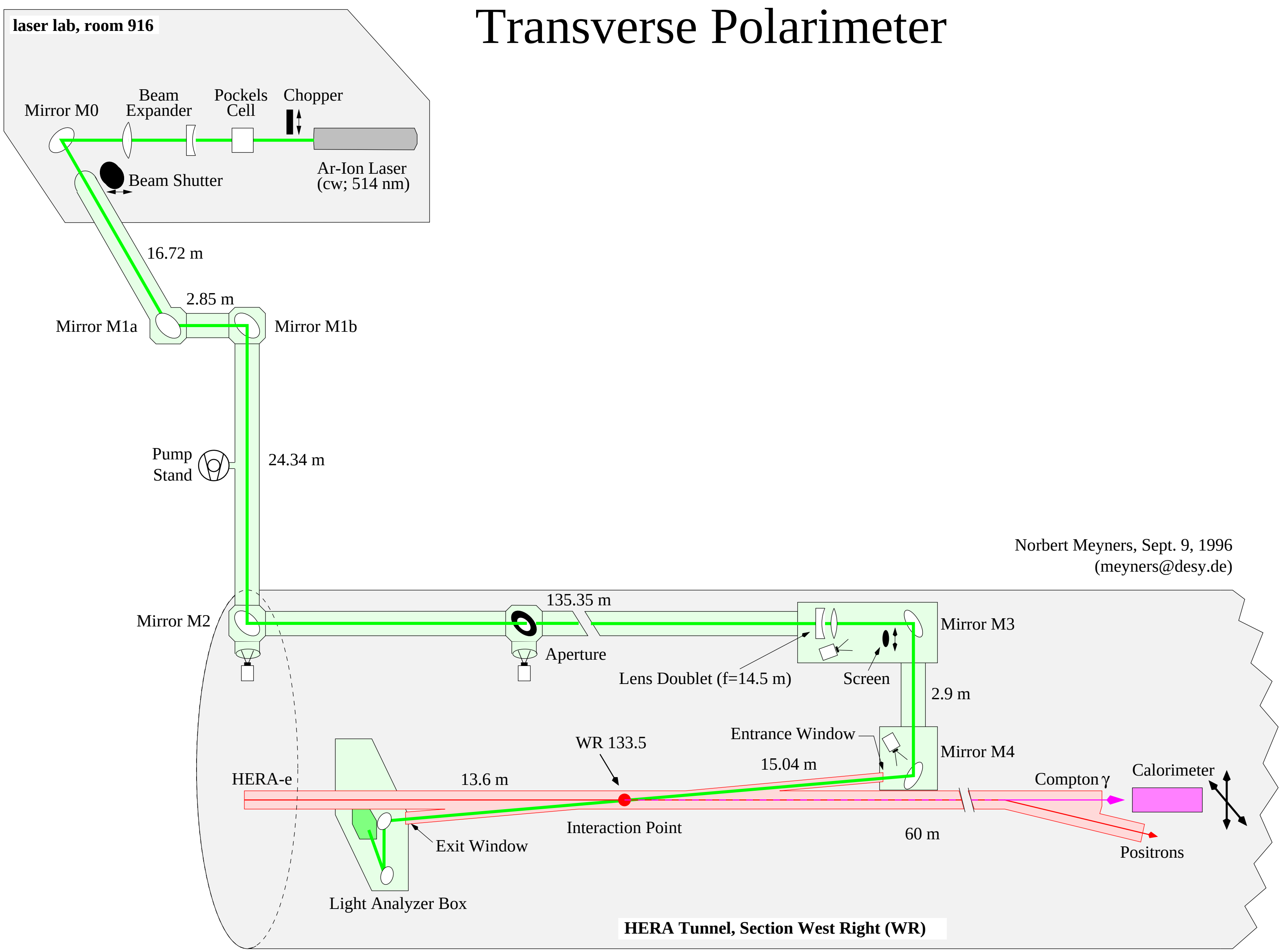

Figure 2: *Schematic overview of the transverse polarimeter at HERA. Shown are the laser beam line, the electron beam line and the calorimeter which measures the backscattered Compton photons.*

Component	Task	Comment
Laser	Reevaluate	Ensure reliability and service
Optical System	Reevaluate	Examine measurement of laser light polarization
	New	Laser-electron beam pipe extension, laser spot size measurement
Calorimeter	Reevaluate	Upgrade (replace) LED systems
DAQ, Trigger	New	New analog and digital signal chain (ADC, trigger logic, readout, computer)
Miscellaneous Electronics	New	Pulse generator to simulate calorimeter signals, signal generator and dedicated kicker magnet for beam depolarization
Online Software	New	New run control, new readout software, adapted slow control
Offline Software	Upgrade	Extend and refine analysis procedures
Monte Carlo	Upgrade (New)	Produce improved MC simulation of data distributions, understand detector, beam and laser parameters in more detail

Table 3: *Overview of components of the transverse polarimeter at HERA and proposed upgrades.*

- **Analogue Receiver Card:**
  The calorimeter is read out with four photo multipliers, with charge sensitive preamplifiers mounted on the calorimeter. The signal is then sent via four high speed cables over a distance of ≈ 300 m to the counting room.

  At the receiving end signals will be connected to the analogue receiver card. There shapers will be installed to remove part of the skewing effects of the cables. The current design foresees a three-fold pole-zero compensation with a return to the baseline within 96 ns at the level of 1%. This essentially removes pile up effects from following bunches.

  The board includes also constant fraction discriminators (CFD) for each analogue input, their outputs being on one hand used for event counting and, on the other hand, digitized in TDCs (see below).

  The board will have a total of 16 channels so that a certain amount of flexibility is given for future upgrades or additional channels.

- **Digitization:**
  The pulses are digitised in a fast 12 bit ADC (e.g. AD9042 from Analog Devices), running at 40MHz. Between two HERA bunches the pulses will thus be sampled four times. Provisions are made for a programmable phase shift between the HERA clock signal and the actual clock signal for the ADC, such that the timing can be adjusted so that the peak of the signal is always sampled.

  The ADC is located on a separate custom designed VME module. The digitised signals are stored in a pipeline on the board. Signals are clocked into the pipeline

Item	Limit
Noise	$<$ 100 MeV (but should be much better)
Baseline stability	
rate 0–1 MHz	$<$ 30 MeV (0.1 % Q_{max})
short term	$<$ 30 MeV (0.1 % Q_{max})
long term	depends on frequency of calibration
Rejection signal at -96 ns	$<$ 2 %
Rejection signal at -192 ns	$<$ 0.1 %
Gain stability	
rate 0–1 MHz	$<$ 1.3 %
short term	$<$ 1.3 %
long term	depends on frequency of calibration
Nonlinearity (max. deviation from line 0-Q_{max})	$<$ 1.3 %

Table 4: *Specifications for analog electronics requirements for the new TPOL readout*

with the ADC clock frequency of 40 MHz. The pipeline is 4×220 samples deep, thus allowing the storage of one full bunch train from HERA.

In addition to the actual ADC the board will contain a programmable digital threshold, applied to all four input signals. The output from these digital threshold discriminators will be used in the trigger system.

- **Digital unit:**
  This unit consists of a few VME boards which will enable various digital information to be recorded.

  Timing: A number of TDC channels with a resolution of 0.5 ns will be available. The TDC is based on a custom designed chip developed by Paris University for the BaBar experiment at SLAC. The timing information will be useful in the tuning and monitoring of the calorimeter readout. Under normal operating conditions the TDC will look at the signals after the constant fraction discriminators located on the analogue receiver card. It will store the times of hits during one HERA revolution in a pipeline.
  Scalers: A few scaler channels will be made available in a service module. These scalers can be used for various monitoring purposes.
  Others: A few other modules will be needed for various control and test purposes. these will include a DAC system to be able to supply programmable levels and pulses for calibration, and a digital voltmeter for a number of monitoring purposes.

- **Readout:**
  The core of the functionality of the system is concentrated in a VME based powerPC computer, equipped with a MFCC (Multi-Function Computer Core, developed by the CES company). the system is shown in Fig. 4.

  - *Altera bus:* The MFCC card communicates with the ADC card via a dedicated high speed bus, called "Altera-bus" in the following. This bus operates

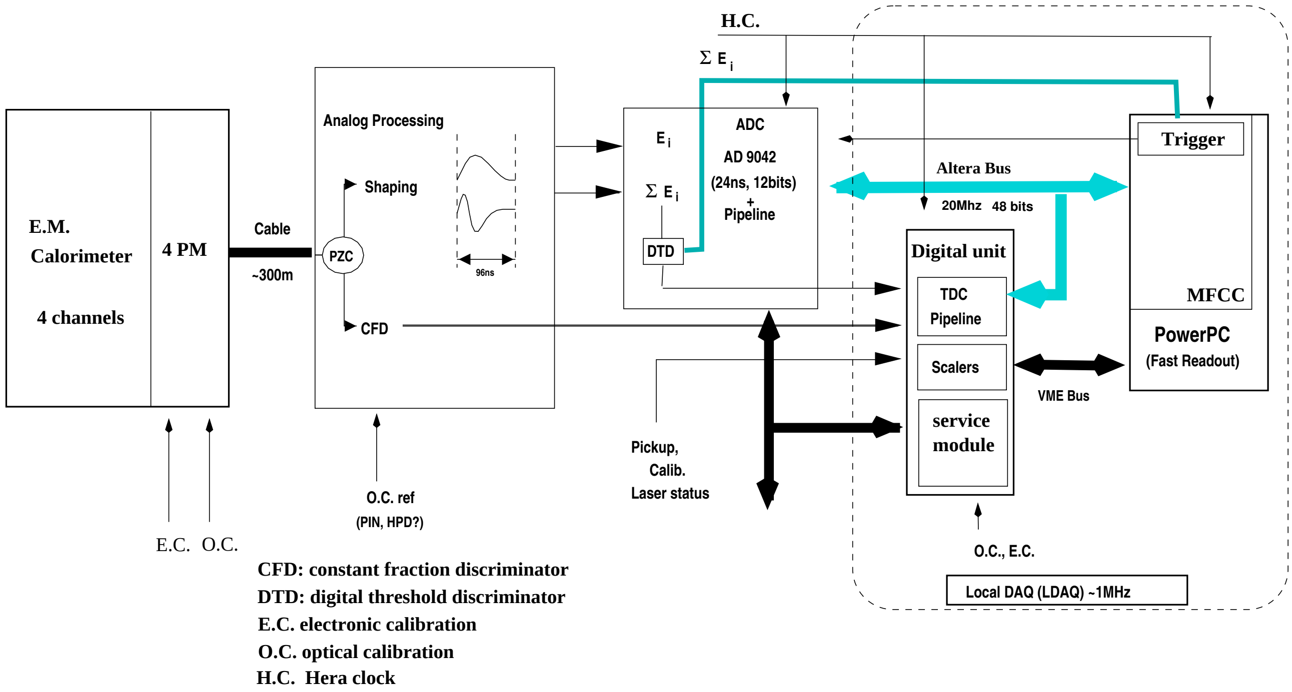

Figure 3: *Electronics scheme for the TPOL*

at 20 MHz and is 48 bits wide. On the MFCC card an Altera chip controls the communication between the CPU and the Altera bus. This chip is programmable via the high level language VHDL [10] to do simple logical operations and control functions. It is foreseen to implement the trigger and readout control into the Altera chip.

The Altera chip receives as input the Hera clock, information about the state of the data taken (that is, whether the data are considered real data, or calibration data, and the trigger signal. If they are calibration data, the type of calibration is indicated). The system knows two different modes of operation: a fast readout mode, and a full readout mode.

– *Trigger and readout:* The trigger will be implemented as a simple programmable energy threshold, using as input the signals sent to it from the digital discriminators located on the ADC board. If a trigger is recognized its associated bunch number is stored in a buffer, together with the information about the trigger type, and about the requested readout mode. This bunch number is then sent via the address bus to the corresponding Altera chip on the ADC card. There the address of the triggered bunch in the fast ADC pipeline is calculated, and the content of the buffer is put onto the Altera bus. Depending on the type of readout requested, all four samples of the pulse are read (full readout), or only the peak and one other sample (fast readout) are read.

  In the very unlikely event that the address at which the event is read passes the current address at which new events are written into the pipeline, a dead time flag is raised to flag these events as bad.

  Since the bus is 48 bits wide the information from one sample of all four channels (4 channels a 12 bit each) of the calorimeter can be read at once.

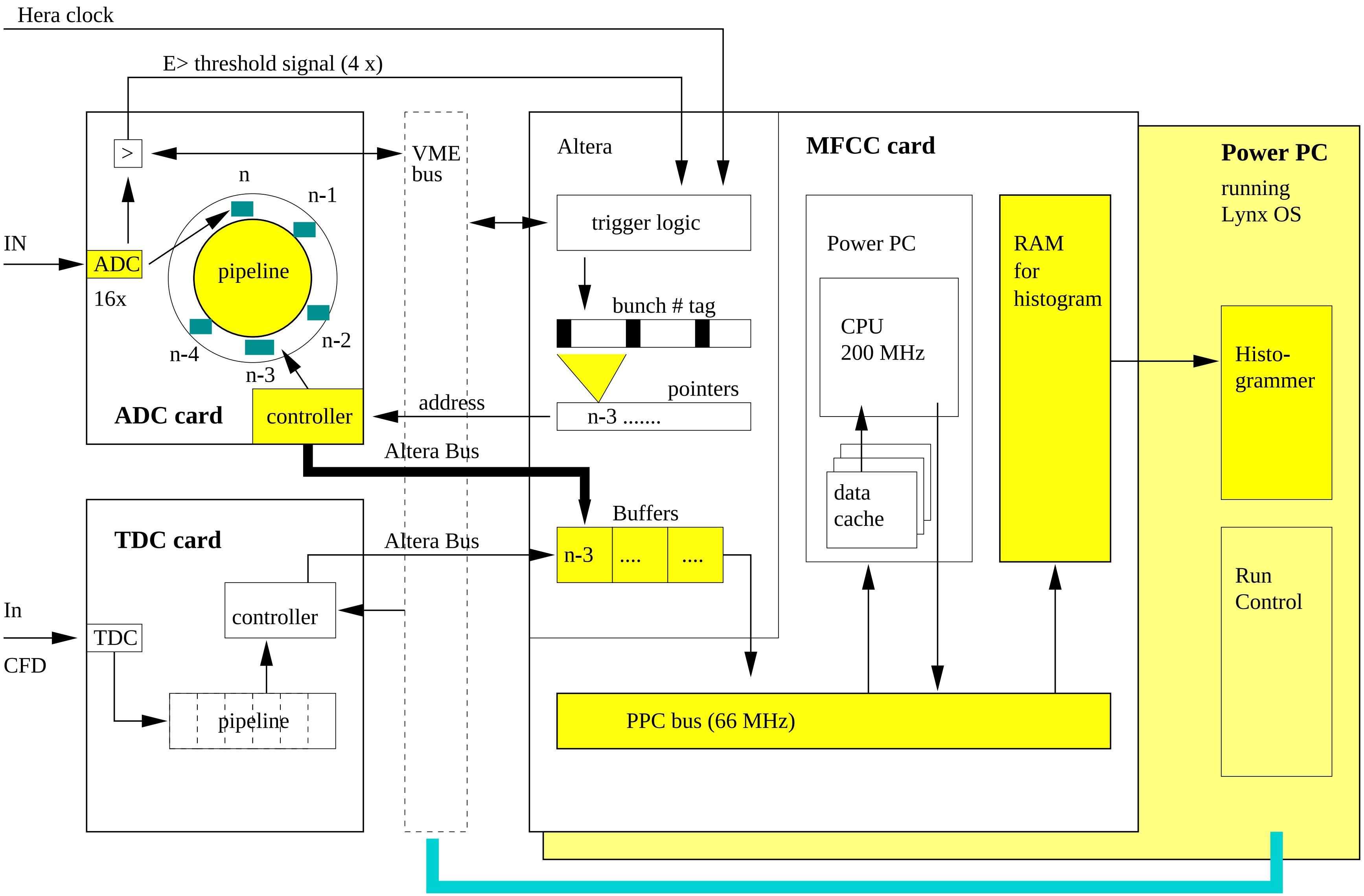

Figure 4: *Block diagram of the fast part of the DAQ*

The two samples therefore are transfered in two cycles, or 120 ns. With a depth of the pipeline of 220 samples, and an average occupancy of 1 %, dead time will be negligible.

– *MFCC function:* Data are written into an input buffer on the MFCC. This buffer only contains triggered data, which arrive with a frequency of around 100 kHz. The buffers are emptied through the PPC bus (transfer rate 60×32 bit Mwords/ s) into the data cache of the power PC. The powerPC then performs the pedestal subtraction, and writes the appropriate histograms into the RAM of the MFCC board. One event as recorded by the MFCC contains the following information:

full readout	
4 data words of 12 bit each, 4 samples	192 bit
4 TDC samples of 16 bit, 1 sample	64 bit
1 bunch counter	8 bit
1 trigger word:	
trigger type	3 bit
laser light status	3 bit
fast readout	
4 data words of 12 bit each, 2 samples	96 bit
1 bunch counter	8 bit
trigger type	3 bit
laser light status	3 bit

– *Histogramming:* The main polarization analysis is done based on a set of two dimensional histograms of the energies measured in the calorimeter. Plotted is the total energy $E_u + E_d$ versus the energy asymmetry $(E_u - E_d)/(E_u + E_d)$ in 64×128 channels. Here the index u and d denote the upper (lower) part of the calorimeter, respectively. For each bunch crossing and each state of the laser a separate histogram will be filled, amounting to a total of just above 10 MByte of data. In addition various monitoring and calibration histograms are filled depending on the state of the data acquisition. A list of all required histograms is given in table 5.

– *PowerPC function:* At fixed intervals of every few seconds or minutes the memory of the MFCC is read by the main computer, and transfered into the memory on the main board. The PowerPC on the main board then does the actual polarization analysis as well as the monitoring and displaying of the information. At the moment the design calls for one set of memory banks into which the results are written on the MFCC. In this case the readout sequence of the ADC would have to be stopped during the transfer time, so that the system is at every time in a well defined state. If a readout frequency of around 1/min is chosen, the dead time introduced is completely negligible.

- **Slow Controls:**
The state of the system is constantly monitored through a set of slow controls variables. If necessary corrective actions - e.g., moving the calorimeter to maintain a centered position are undertaken. All this is done via a set of RS232 control

Purpose	histogram	type	laser	per bunch	size [byte]
polarization	$E_u + E_d$ vs $(E_u - E_d)/(E_u + E_d)$	2D	3	yes	10.8 M
Pedestal	p_u, p_d, p_l, p_r	1D	2	yes	2M
Calibration electronic	E_u, E_d, E_r, E_l	1D	1	no	100k
Calibration light	E_u, E_d, E_r, E_l	1D	1	no	100k
Calibration data	$E_u, E_d, E_r, E_l, E_u + E_d, E_l + E_r$				
	$E_l/(E_l + E_r), E_u/(E_u + E_d)$	1D	3	no	100 k
Calibration random	E_u, E_d, E_r, E_l				
	$E_u + E_d, E_l + E_r$	1D	1	no	100k

Table 5: *List of the different histograms accumulated in the RAM of the MFCC and filled during different states of the data acquisition. In the fast mode only the first histogram is filled. The column "per bunch" indicates whether one histogram should be filled for every bunch, or whether one histogram averaged over all bunch crossings is expected. The column "laser" refers to the at most three possible states of the laser: off, right-, left-polarized. Sizes indicated are in Bytes and are approximate.*

lines. In table 6 a list of the slow control channels is given. Most of the slow control devices were moved to VME some time ago. They will fit naturally into the new system.

A significant amount of work will need to be done to adopt / rewrite the slow control software to the new system. The slow control software contains not only code to record and store the status of the experiment, but is also responsible for the active positioning of the calorimeter, for the control of the collimator in front of the calorimeter as a function of the HERA status, and for the steering of the laser system. It is foreseen to port this code to the new powerPC based DAQ system.

- **Online Software:**
  With the new DAQ hardware a completely new set of data acquisition programs have to be developed. The tasks this program need to do are the following:

  Run control: A program to control the data taking, analysis and storage of data. This program will run on the PowerPC main board. The user will interact with the program via an easy to use graphical user interface. Run control manages a number of tasks, of which the main ones are listed below:

  - *Autopilot:* Under the control of run control, an autopilot should be provided, which routinely steers the experiment without human intervention. The autopilot should recognize, if a fill is in HERA, should start a run, prepare the detector, if beam conditions allow, and start the measurement cycle. The autopilot should be able to recover automatically from most error conditions.
  - *DAQ, high level:* Data stored in the RAM of the MFCC has to be read at regular intervals and transfered into storage on the powerPC main board.
  - *DAQ, low level:* A dedicated program runs on the MFCC processor, independent of the rest of the system, reads the data from the buffer at the end of the Altera bus into MFCC RAM and fills the relevant histograms in the MFCC RAM. Run Control has to download this program into the MFCC at boot time.

unit	name	current connection
1	Laser	RS232/ VME
2	Mirror2	RS232/ VME
3	Mirror3	RS232/ VME
4	Diode3	RS232/ VME
5	Diode5	RS232/ VME
6	Depolarizer	RS232/ VME
7	Calorimeter_H	RS232/ VME
8	Calorimeter_V	RS232/ VME
9	Collimator_H	RS232/ VME
10	Collimator_V	RS232/ VME
11	GT_prism	RS232/ VME
12	Chopper wheel	Out. Reg./ CAMAC
13	Pocket cells	Out. Reg./ CAMAC
14	High Voltage	CAEN bus/ VME

Table 6: *List of slow controls signals currently used in the TPOL data acquisition system.*

- *Trigger:* The trigger and readout control is implemented in the ALTERA via a high level programming language VHDL. This program flags the bunches as triggered, and transfers triggered ones from the pipeline on the ADC board onto the Altera bus. Run control has to download the program at boot time.
- *Analysis program, histogram presenter:* The polarization analysis is done on the powerPC main board with a dedicated program, started and controlled by run-control. This program in turn calls a histogram presenter (e.g. PAW or root) to present the results to the user in a graphical form.
- *Slow Control:* A suite of programs to record and control the different slow control devices. It is itself controlled from run-control. The slow control program has to adjust and optimize the laser beam and the state of the laser system, position the detector and control the high voltage. At the same time it has to read information from a number of slow controls devices, and make this information available to the central DAQ.
- *Interface package:* The results from the analysis have to be made available to the outside world, in particular to HERA and to the three experiments. The interface package is responsible for this task. At the same time the interface package sends the data in a suitably compressed format to be stored on mass storage media.

5.2 Miscellaneous Improvements

This section deals with mainly small but nevertheless important improvements which are proposed for various components of the TPOL.

Laser: The CW Argon ion laser usually runs at constant power at the maximum of 10 W. Its operation needs some tuning from time to time and yearly service and maintenance must be assured. A possible new feature of laser operation is the increase of the laser power from a certain value up to the maximum power during a beam fill such that the Compton rate would be constant in time. In this way the decreasing electron beam current would be compensated and possible rate dependencies of the measurement as well as statistical fluctuations would be minimized. However the stability of the laser beam spot and polarization for such an operation has to be investigated. Most likely this scheme would only be applicable when the full design electron current of 60 mA can be injected in order to run close to the maximum possible count rate.

Optical System: The performance of the optical system has to be reevaluated in order to produce laser light with circularity as high as possible and to pin down tight systematic errors on the measurement of circularly and linearly polarized light. The operation and control of the optical system can be facilitated with an improved and automated (digitized) position measurement of the laser beam and with a laser spot size measurement at a virtual interaction point. Currently it is not possible to measure the light polarization and the beam polarization simultaneously which would be important for better control of systematic errors. This can only be done if the entrance and exit pipes for the laser light to and from the electron beam pipe are enlarged in diameter.

Calorimeter: Two sets of calibration signals are foreseen. First a charge calibration system, where charge is injected at the preamplifiers, allows the calibration and monitoring of the electronic chain. Secondly, an improved LEP system will be developed, the details of which still need to be decided.

Cables: At the moment six cables are installed which are suited to route fast analogue signals from the detector to the counting room, of which four are being used. Their quality is currently being investigated with the aim to decide whether or not new cables need to be laid.

Miscellaneous Electronics: A pulse generator (charge injection system) is needed to simulate detector signals for testing (in the set up phase) and for checking (in the running phase) of the signal processing chain. The output signal of this should be tuned to reproduce the dynamic range of a normal calorimeter signal at a rate comparable to actual data.

For the control of the kicker magnet which is used as a depolarization device a signal generator is needed. This signal generator has to generate the full and partial depolarization modes in a flexible way. This functionality is needed to control the stability of beam and polarimeter during rise time measurements.

6 Measurement of Longitudinal Electron Polarization

The measurement of longitudinal electron polarization P_Z is based on the energy dependence of the Compton cross section σ_c. The energy spectrum $\mathrm{d}\sigma_c/\mathrm{d}E_\gamma$ of backscattered Compton photons is shown in Fig. 5 for unpolarized electrons and for the two cases of longitudinally polarized electrons ($P_Z = 1$) and left(L)/right(R) circular polarized laser light ($S_3 P_Z = \pm 1$). There is a large difference in the spectra most prominent at energies close to the Compton edge.

This energy dependence for different laser helicities can be exploited for the electron polarization measurement with different methods. In the multi-photon method a pulsed laser with high intensity but moderate repetition rate (few 100 Hz) is used. For each

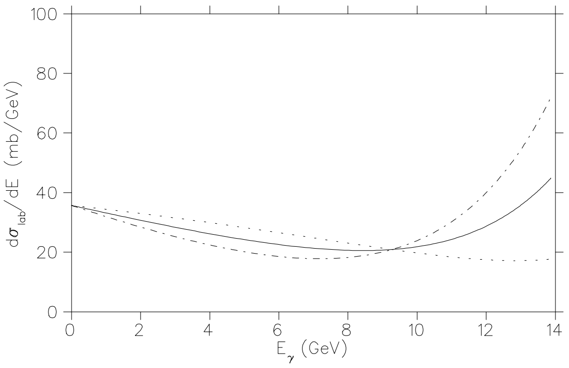

Figure 5: *Energy spectra of the scattered photon as calculated from the Compton cross section for unpolarised electrons (solid line) and for longitudinally polarised electrons for the cases* $S_3P_Z = +1$ *(dotted curve) and* $S_3P_Z = -1$ *(dash-dotted curve)*

laser shot at an electron bunch up to a few thousand Compton photons are produced which are simultaneously registered in a calorimeter. This method is currently used for the existing longitudinal polarimeter set-up and is further described in [3, 8]. Its performance has been briefly summarized in Chap. 3.

In the following the single photon mode using the LPOL system is discussed. In this mode a pulsed laser with high repetition rate or a cw laser has to be used. As for the transverse polarimeter the laser intensity is tuned such that only single Compton photons are produced. The energy of these photons is then individually measured in a calorimeter.

6.1 Single-Photon Method

Consider the asymmetry $\mathcal{A}(E_\gamma)$ of single Compton photon counting rates (N_L, N_R) for left(L) and right(R) circularly polarized laser light:

$$\begin{aligned} \mathcal{A}(E_\gamma) &= \frac{N_L(E_\gamma) - N_R(E_\gamma)}{N_L(E_\gamma) + N_R(E_\gamma)} \\ &= \Delta S_3 P_Z \Sigma_{2Z/0} \; . \end{aligned} \tag{7}$$

Here $\Sigma_{2Z/0}$ is the asymmetry function which is solely determined (and known) from the Compton cross section (see eq. 4). It is shown in fig. 6 and exhibits large asymmetries up to values of 0.6 for fully longitudinally polarized electrons. The longitudinal electron polarization P_Z can be derived by fitting eq. 7 to an experimentally measured asymmetry with $\Delta S_3 P_Z$ as free parameter. To isolate P_Z an independent measurement of the laser polarization S_3 is necessary which is done regularly. An alternative way to exploit the energy asymmetry would be to integrate the asymmetry yield above the zero crossing at 9.3 GeV (corresponding to 90° scattering in the electron-photon c.m.s. for a 27.5 GeV electron beam energy). This integral is also given by the Compton cross section and can be calculated exactly. In this case the experimentally obtained integral is related to the integral of $\Sigma_{2Z/0}$ above 9.3 GeV by the factor $\Delta S_3 P_Z$.

For a real measurement one has to consider the energy resolution of the calorimeter which leads to a smearing of the theoretical spectra. Furthermore background events will enter the data set and have to be subtracted statistically. These effects have to be taken into account for the extraction of $S_3 P_Z$.

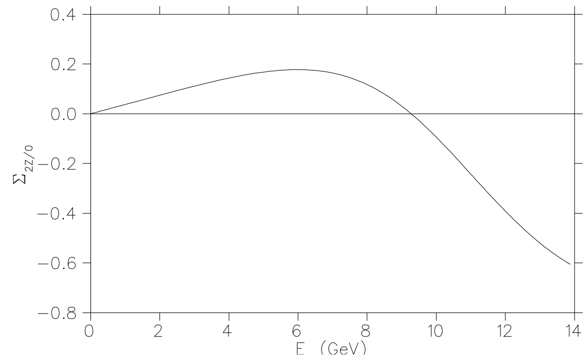

Figure 6: *Energy asymmetry function $\Sigma_{2Z/0}$ as calculated from the Compton cross section*

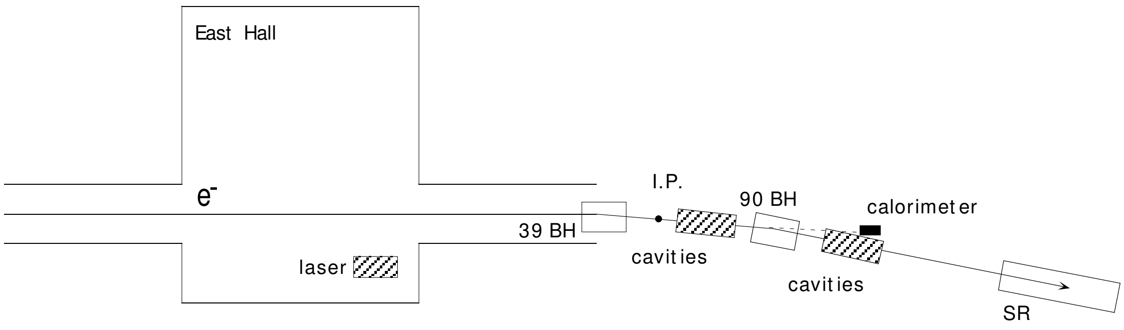

Figure 7: *An overview of the longitudinal polarimeter in the HERA East Hall.*

6.2 Study of Experimental Conditions for Single-Photon Mode

In this section the feasibility of a single-photon Compton measurement using a cw laser system is considered. This has been discussed already in a first proposal to install a Longitudinal Polarimeter at HERA in September 1994 ([11]). The idea was dropped in late 1994 due to large background rates associated with the relatively high vacuum pressure in the electron beam pipe in section Ost-Rechts between dipole 39 BH and dipole 90 BH where a large number of cavities are installed (Fig. 7). At that time it seemed very costly to reduce the vacuum pressure by an order of magnitude, since it was very hard to install additional pumps.

The main advantages of running in single Compton mode are the large asymmetries at the Compton edge and the exact knowledge of the expected energy spectra which can be used to calibrate the calorimeter and to understand detector effects. The main (experimental) disadvantage is the sensitivity to background events, mainly from bremsstrahlung of the electrons on the residual gas in the beam pipe. The opposite is true for the multi-photon mode: In this case the background from bremsstrahlung is negligible but the detected energy spectra are not straightforward to interpret.

It should be clearly pointed out that a change from multi-photon to single-photon mode not only is a matter of background conditions but a lot of modifications to the polarimeter have to be done. A new cw laser would be needed, the DAQ system would need a significant upgrade to handle the higher rates, and a calorimeter optimised for the single-photon mode had to be chosen. The full system then would look very similar to the (upgraded) transverse polarimeter set-up. Thus no principal new developments would have to be done and no principal technical problems are expected.

6.2.1 Background Sources

There are two important background sources which have to be considered. One is the rather intense synchrotron radiation from the near-by bending magnet 90 BH (see Fig. 7). The more important background is originating from beam-gas bremsstrahlung in the straight section of the electron ring between bending magnets 39 BH and 90 BH

Synchrotron Radiation: The polarimeter is illuminated by the synchrotron radiation produced in the 90 BH bending magnet (2.7 mr). In order to avoid high frequency energy deposits of more than 100 MeV in the calorimeter the detector has to be shielded by about one radiation length of absorber material (e.g. 6 mm of lead). For a calorimeter with reasonable energy resolution ($\approx 10\,\%/\sqrt{E}$) this would lead only to a small deterioration in the energy resolution by a factor < 1.05.

Electron-Gas Bremsstrahlung: The background resulting from beam-gas bremsstrahlung is much more severe. The energy spectrum scales approximately like $1/E_\gamma$ with bremsstrahlung photons emitted up to the kinematical limit of the beam energy $E_e = 27.5\,\mathrm{GeV}$.

Recently measurements of the bremsstrahlung rate were performed in situ with the current longitudinal polarimeter set-up. The laser intensity was lowered to the regime of the single-photon mode and the calorimeter scale was adjusted to detect single photons in the GeV region instead energies in the TeV range (for the multi-photon mode). These adjustments clearly cause some uncertainty in the results given below. The measured rate amounted to about 100 kHz for Compton photon energies above 9 GeV and an electron beam current of 26 mA. The average vacuum pressure calculated from these numbers for the 50 m long straight section then is about $2\cdot 10^{-8}$ Torr (assuming a mean charge of $Z = 5$ for the gas atoms in the beam pipe). This number is still in agreement with the typical average pressure in the cavity section of about 10^{-8} Torr under similar beam conditions.

Background rates from bremsstrahlung of the measured order would pose two problems, the statistical dilution of the Compton energy asymmetry and an increase in the overall event rate to be handled by the polarimeter. In comparison, the transverse polarimeter experiences typically a few kHz of background rate.

It should be noted that the bremsstrahlung background originating from the HERMES target is successfully filtered with a collimator just behind dipole magnet 90 BH and therefore contributes only little to the measured bremsstrahlung rate.

6.2.2 Statistical dilution of asymmetries due to background

In this section the influence of high bremsstrahlung background rates on the statistical error for the asymmetry measurement are investigated. For simplicity a method is studied where the integrated asymmetry above the crossing point at 9.3 GeV is exploited. This asymmetry then is written as

$$\mathcal{A}(E_\gamma > 9.3\,\mathrm{GeV}) = \frac{N_L(E_\gamma > 9.3\,\mathrm{GeV}) - N_R(E_\gamma > 9.3\,\mathrm{GeV})}{N_L(E_\gamma > 9.3\,\mathrm{GeV}) + N_R(E_\gamma > 9.3\,\mathrm{GeV})}\,, \tag{8}$$

where background has already been subtracted from the counting rates $N_{L,R}$ (e.g. $N_L = N_{L,total} - N_{background}$ and the total rate is the sum of Compton and background contribution). It should be pointed out that the background rates can be measured independently from events where the laser is switched off.

For a Compton scattering rate of 100 kHz for a trigger threshold of $E_{min} \approx 2\,\mathrm{GeV}$ over a period of one second this translates into mean event yields of $N_L(E_\gamma > 9.3\,\mathrm{GeV}) = 32\,\mathrm{k}$ and $N_R(E_\gamma > 9.3\,\mathrm{GeV}) = 55\,\mathrm{k}$. For the background event yields in the energy range $E > 9.3\,\mathrm{GeV}$ we assume 0, 5, 10, 20, 50, 100, 200 k (for a 1 s measurement).

Using conventional error propagation taking into account the correlations due to the (correlated) background subtraction procedure and using Poissonian statistics for the rate errors, we arrive at the results which are summarized in table 7.

Background rate [kHz]	Signal:Background	$\delta\mathcal{A}/\mathcal{A}$ [%]	Dilution factor
0	-	1.31	1.00
5	8.7	1.40	1.07
10	4.4	1.48	1.13
20	2.2	1.64	1.26
50	0.9	2.04	1.56
100	0.4	2.57	1.97
200	0.2	3.39	2.60

Table 7: *Expected statistical errors of the polarisation measurement with the LPOL in the single-photon mode for a 1 second measurement and different signal-to-background ratios*

The dilution factor reflects the relative increase in the statistical error due to the background contribution compared to a background-less measurement. For background rates up to the signal rates of $\approx 50\,\mathrm{kHz}$ the statistical error increases only moderately.

6.2.3 Background rates

The total background rate above threshold of $E_{min} \approx 2\,\mathrm{GeV}$ is a factor ≈ 5 larger than the one in the energy range used for the polarisation calculation. That could lead to a very high total trigger rate and to an increasing probability to "overlay" events, i.e. events which have a Compton and a bremsstrahlungs photon simultaneously, which would distort the energy spectra.

For the background measurement mentioned above a total background rate above threshold of more than 500 kHz would be the consequence. This rate could not be handled by the data current acquisition system. Raising the threshold to $E_{min} = 5\,\mathrm{GeV}$ would decrease this rate to about 350 kHz but would be still too high.

In view of this discussion the total rate for bremsstrahlung above threshold should be limited to about 100 kHz. This number then would give rise to a background rate of about 20 kHz in the region of interest for the polarisation calculation. Compared to the current situation that would ask for a reduction of the residual gas pressure in the beam pipe by at least a factor 5.

6.3 Discussion

With its large rate asymmetry the single-photon Compton scattering on longitudinally polarized electrons is conceptionally the simplest method to determine the polarization of the electron beam at HERA. This simplicity is also reflected in the small expected systematic errors of the measurement [11], which are believed to be controllable to better than 2%. Experimentally the only obstacle to overcome is the current high rate from beam-gas bremsstrahlung.

The reduction of the bremsstrahlung rate to a tolerable level of about 100 kHz (above $E_{min} = 2\,\mathrm{GeV}$) at the longitudinal polarimeter requires a reduction of the residual gas pressure in the HERA ring by a factor of 5. Since the pressure in the ring is time dependent a factor of 10 reduction in the gas pressure would be preferable. Without major modifications a reduction by a factor of 2 seems possible. Larger reductions require extensive modifications of the beam line, including the installation of additional pumps, possibly the change of the beam pipe and/or the removal of (some) cavities.

To operate the longitudinal polarimeter setup in the single photon mode requires a major upgrade of both the detector hardware and the data acquisition system. Even though this upgrade could profit from the development and the experiences gained with the TPOL upgrade it remains a significant project and investment.

Certainly for a well understood photon detector there is (from a theoretical point of view) no principal advantage for using the single-Compton method instead of the multi-Compton method at the level of accuracy attempted at HERA (≤ 2 % systematic uncertainty). This has been demonstrated by the SLAC polarimeter team who have achieved a 1% measurement with the multi-Compton method ([12]). However for practical reasons (in situ energy calibration, easy-to-understand energy spectra, gain monitoring, etc. and reduced radiation levels) the single-photon method is a legitimate alternative for future running of the longitudinal polarimeter at HERA.

7 Possible Improvements to the Analysis Techniques

The main improvement for the analysis of the polarization data has to be made to the determination of the polarization scale. Different methods of polarization calculation require the knowledge of different functions which represent the polarization scale. For the TPOL the current method using the vertical shift of the mean, $\Delta\eta$, requires the knowledge of the analysing power Π_η. The main uncertainty on this quantity comes from the knowledge of the $\eta - y$ transformation (see table 8). An alternative method would be to fit the full vertical asymmetry function $\mathcal{A}(\eta)$. This requires the calculation of the asymmetry functions $\Sigma_{2Y/0}$ and $\Sigma'_{1/0}$ (cf. [2], see eq. 2). In table 8 the current understanding of these functions is summarised.

For the LPOL running in the multi photon mode an exact knowledge of the energy asymmetry function $\mathcal{S}_\mathrm{Z}$ (see eq. 6) is mandatory.

All these functions depend on the Compton cross section, and indirectly through smearing and resolution effects on the calorimeter properties and on the electron beam parameters, and can be determined with the help of Monte Carlo techniques, test beam measurements and real data distributions. Compared to the current understanding of these functions it is believed that significant improvements can be made if all available test beam and calibration data are used and if the simulation is improved.

In the current analysis the limiting input is the determination of the polarisation scale uncertainty, which at the moment is based upon the rise time method. It is important to realize that the most recent rise time measurements were done in 1994, at a slightly lower electron beam energy than the machine is currently operated at. These measurement should be repeated with a flat machine as soon as possible. In addition it is not clear, in terms of the technical feasibility and loss of beam time, how often such a rise time calibration can be done. In the longer term, with improved analyses techniques and better understood detectors the rise time method will be used as an important cross check of the other calibration procedures.

Source	Uncertainties in (%) for $\Sigma'_{1/0}$	$\Sigma_{2Y/0}$	Π_η
η–y Transformation	3.0	2.5	4.4
Position resolution	8.9	1.1	0.0
Electron spot size	14.0	5.9	2.6
Calibration	0.6	1.6	0.1
Calorimeter centering	0.7	2.6	0.3
Pedestal	2.8	1.5	1.1
Total	17.1	7.4	5.3

Table 8: *Relative uncertainties in % for the analysing power Π_η and asymmetry functions $\Sigma'_{1/0}$ and $\Sigma_{2Y/0}$ for different sources (from [6]) for the transverse polarisation measurement.*

It is evident from table 8 that significant progress has to be made to reduce the errors on the different quantities so that the intended accuracy for the TPOL below 2% can be reached. Already in the last proposal to the PRC [8] a strategy has been defined how this can be achieved. The various error sources which are considered and which need to be reduced are:

- *η–y Transformation:* Use precise test beam data to better constrain the relation between the space coordinate y and the energy asymmetry η. Test beam measurements with a spare calorimeter indicate that the error for Π_η due to this source can be reduced to at least 1.5 % [13].

- *Position resolution:* Data from test beam measurements can be used to better map the position resolution of the calorimeter. The current uncertainty of this parameter is about 15 % and this should be reduced by a factor 2–3.

- *Electron spot size:* The projected electron spot size on the calorimeter front needs to be measured from real Compton photons. A first estimate can be obtained from beam optics calculations. The electron beam spot size needs to be well known in order to disentangle the effects on the measurement from the beam spot size from other effects like calorimeter resolution. Investigations of circular and linear laser light distributions with different energy ranges of the Compton photons will provide a redundant set of results on the spot size parameter. It is the aim to improve the knowledge on this parameter significantly to the level of $5 - 10$ %.

- *Calibration:* The energy calibration can be controlled very well in the data and can be corrected offline if necessary. This will reduce the error listed in Table 8, especially for $\Sigma_{2Y/0}$.

- *Calorimeter centering:* The centering of the calorimeter can be controlled very well and corrected for if necessary. This is important for decreasing the uncertainty in $\Sigma_{2Y/0}$.

- *Pedestal:* Care will be taken by the analog signal handling (new DAQ) to reduce variations in the pedestal and baseline as much as possible which will result in reduced errors due to this source.

Overall it is believed that a reduction of the current errors to below 2% total error is feasible. It should be noted that this goal implies not only a careful and complete analysis of all available test beam and real data, but also significant work to improve the current modelling of the calorimeter in the different Monte Carlo programs available.

Groups from YALE, LPI and DESY have started working on procedures to demonstrate this using the current TPOL data, and on improvements to the Monte Carlo.

8 Schedule, Responsibilities, Finances

Members of the 3 HERA experiments HERMES, H1 and ZEUS and from the HERA machine groups have formed the Polarization 2000 Group with the common aim to produce and measure precisely high electron beam polarizations. This inter-collaborational effort stresses the importance of polarized physics at HERA and will cover all aspects of electron beam polarization in a coherent way. The group has agreed on a management structure. It will be lead by one coordinator, who is appointed by the group for a period of two years. Each of the three experiments and the machine has named a contact person for the Pol2000 group, who are responsible for maintaining a close contact between the respective experiment and the group.

The proposed upgrades to the polarimeters have to be done in parallel with the current running of the polarimeters in order to guarantee the undisturbed polarization measurement during beam time for HERMES. It follows that all hardware of the upgrade project must be set up independently from the existing devices and the primary testing of the new systems has to be done with signal generators and the spare calorimeters.

However, especially for the TPOL data acquisition upgrade, a test under real conditions is necessary and we propose to connect the real calorimeter signals to the new DAQ system for about 2 months during beam time in 1999/ 2000. This operation will help in optimizing the system to have it fully functional when HERA turns back on after the luminosity upgrade.

In this section we discuss a draft of the schedule and the distribution of responsibilities and costs. It is mostly concerned with the upgrade of the TPOL system.

8.1 Milestones and Schedule

The time critical item for the upgrade program is the data acquisition system for the TPOL. The aim is to have a prototype system running in the summer of 1999, and then complete and improve it over the next year. In parallel, Monte Carlo and possibly test beam studies have to be done for the TPOL and the LPOL from which already the current polarization analysis will benefit. HERA related upgrade items (e.g. upgrades of the optical system in the HERA tunnel) can only be done during the HERA shutdowns in 1999 or in 2000. After the first year of real operation of the upgraded polarimeter systems the projected precision of the polarization measurement should be reached. Table 9 shows an overview of the time schedule.

In table 8 a first draft of the detailed schedule of the TPOL DAQ upgrade and installation plan is presented.

As far as the DAQ upgrade for the TPOL is concerned, a number of milestones have been identified, which are indicated in the graph by cross-hatched upright boxes. These milestones are:

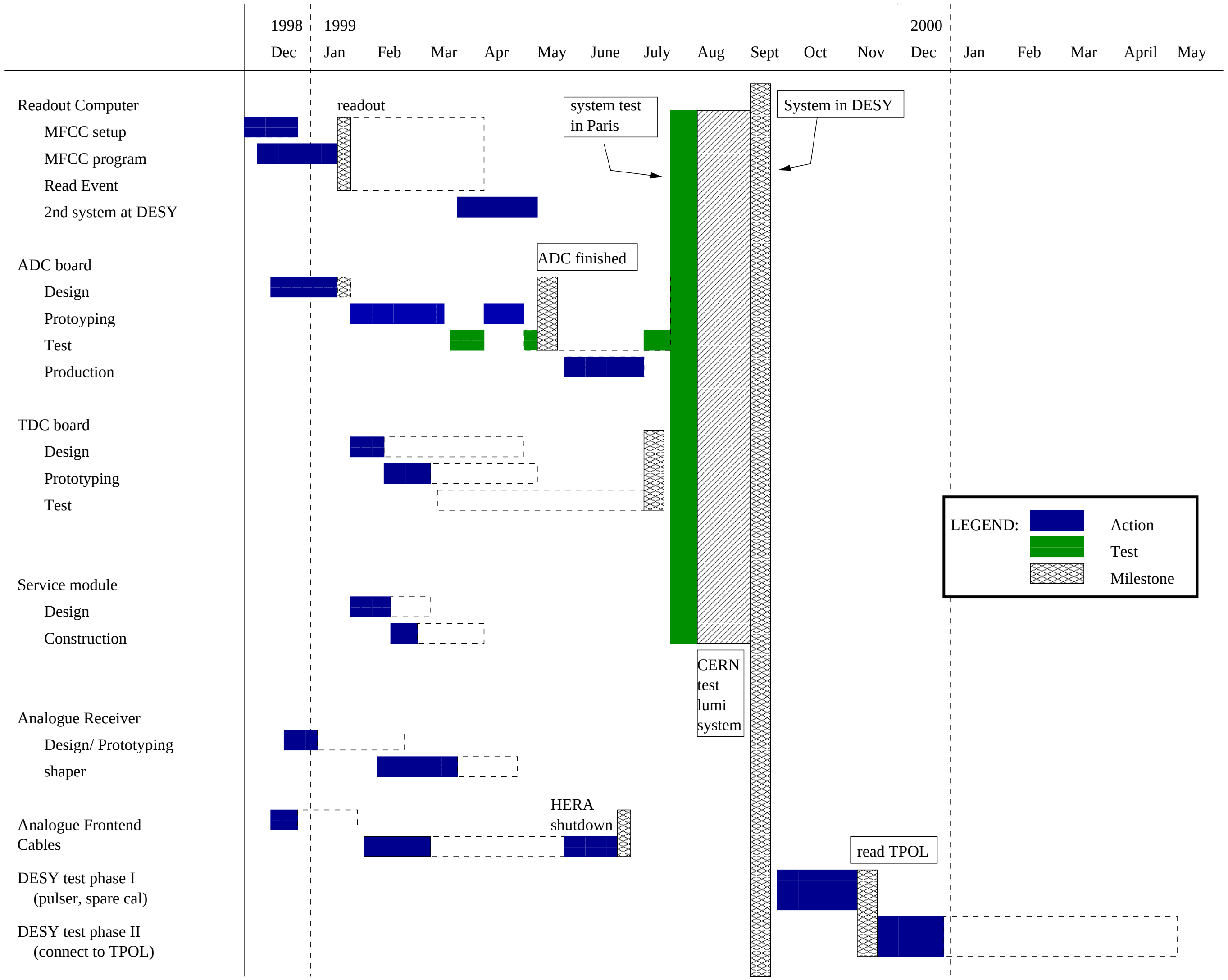

Figure 8: *Draft of schedule for the TPOL DAQ upgrade.*

Date	Task
End 1998	Start offline analysis of existing data and MC studies
End 1998	Do detailed design of the TPOL DAQ.
Mid 1999	Prototype DAQ setup with spare calorimeter/pulse generator
1999, 2000	Improve optical system (laser pipe, laser spot size measurement)
Mid 1999	Optimize depolarizer operation
End 1999	Concluding results on the test setup, connect real signals to new DAQ system for 1–2 months
Beg 2000	Results from test run with real data
Beg 2000	Install corresponding improvements
Mid 2000	Analyze data taken with new system, develop analyses, reach desired precision
2001	Routine operation, understand system in detail, further improve analysis

Table 9: *Time schedule for the development and set up of the upgraded transverse polarimeter system. The exact dates depend also on the final HERA schedule for the luminosity upgrade.*

- **end of January 99:** finish a first version of the low level programs of the MFCC, transfer a full event from the ADC board into MFCC memory.
- **Apr 99:** Finish, prototype and test the analogue receiver and shaper.
- **mid Apr 99:** Have a VME crate with powerPC main board and MFCC running at DESY as a test and development system.
- **May 99:** finish the design, prototyping and test of the of the ADC board.
- **May 99:** finalize the cable setup in the April/May HERA shutdown, if necessary. This point can be moved into the long 2000 shutdown if needed.
- **Sept 99:** Start full system tests at DESY, first with a test setup using pulser and possibly the spare calorimeter, then using real data from the TPOL.
- >**2000/2001:** Routine operation of the new system

8.2 Responsibilities and Costs

Groups from DESY (F and M), Michigan (Hermes), Freiburg (Hermes), LPI Moscow (H1), Paris/ Ecole Polytechnique/ Orsay (H1), Hamburg (ZEUS) and Yale (ZEUS) have joined to form the Polarization 2000 Group. The responsibilities for the TPOL upgrade work have been distributed for the time being as shown in Table 10.

The total cost of the DAQ upgrade is of the order of 100000 DM, probably slightly below this figure. Approximately 50000 DM will be needed to provide additional hardware for the system like programmable signal generators etc. Should it be decided that the optical system needs to be upgraded as well, a significant amount of money will have to be invested into this. The most expensive item is the modification of the laser - electron beampipe. No final estimate existed for this item at the time of writing this proposal. A preliminary table of the costs associated with the TPOL upgrade are given in table 11. The distribution indicated in the table is not yet finalised.

Item	responsible group
Optical system (reev./ upgrade)	MEA, LPI
Front-end electronics + Trigger	IN2P3 (LAL, Orsay, Paris VI)
Data acquisition (Hardware)	IN2P3
Data acquisition (Software)	IN2P3, LPI + ZEUS
Slow control, information distribution	LPI +ZEUS
Calorimeter, HV, LED, Test measurements	DESY, Hamburg
Monte Carlo	Yale, LPI
Offline Analysis	HERMES, H1, ZEUS
Depolarization	MPY
Machine aspects	MPY

Table 10: *Distribution of responsibilities for the TPOL upgrades*

item	estimated cost	institute
TPOL DAQ upgrade		
Unix Station	25 kDM	IN2P3
VME crate	10 kDM	
ADC and related electronics	20 kDM	IN2P3
TDC, service module	10 kDM	IN2P3
misc.	6 kDM	IN2P3
TPOL hardware		
laser and optics upgrade		DESY
laser control		DESY
signal generator	50kDM	DESY
Calorimeter LED system		
contingency	50kDM	

Table 11: *Preliminary list of costs associated to the proposed upgrades, and preliminary distribution.*

9 Conclusions

Starting in the year 2000 the experiments H1 and ZEUS will be equipped with spin rotators and will take data — as HERMES has been doing since 1995 — with longitudinally polarized electrons. For H1 and ZEUS the measurement of the electron polarization then becomes as important as the luminosity determination.

The HERA Polarization 2000 Group has formed as an inter-collaborational working group in order to concentrate the efforts for an effective and precise measurement of the electron beam polarization.

The Polarization 2000 group proposes the upgrade of the existing polarimeters at HERA in order to assure a reliable polarization measurement of the electron beam with a relative precision of $\leq 2\,\%$. This accuracy should be achieved with several independent analysis methods and methods to calibrate the polarization scale. The upgrade program is necessary to exploit fully the potential of HERA physics after the luminosity upgrade in the year 2000/2001.

The group proposes to significantly upgrade the current TPOL system to face the more stringent requirements after the HERA upgrade. Major upgrade needs have been identified for the data acquisition system (hardware and software) and the trigger system of the transverse polarimeter. Smaller changes are needed to other parts of the current system and the Monte Carlo simulation. A new DAQ system has been detailed in this proposal which should ensure that the electron polarisation can be measured at HERA with the required accuracy.

Detailed studies are under way to investigate the potential of the longitudinal polarimeter to reach the same level of precision as expected from the upgraded TPOL. The systematic investigations of the LPOL miscalibration will continue during the 1999 run (studies in single photon mode, different calorimeter, etc.). At this moment, however, no clear decision can be taken whether or not an upgrade to single photon operation should be done. This should be re-discussed taking into account the technical feasibility of the required vacuum pressure reduction and more experimental input after the conclusion of the current LPOL investigations, probably during the summer of 1999.

Members of the Polarization 2000 Group

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