HERA Polarimeter Operation in 1995

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Abstract

In 1995 HERA routinely delivered polarized positron beam for the HERMES experiment. The beam polarization was measured with a transverse Compton polarimeter. A pair of spin rotators provided longitudinal spin polarization at the experiment. The value of the polarization during HERMES data taking varied between 45% and 60%, with maximum values close to 70% observed. During the running period the polarimeter was operational 90% of the time. The beam polarization was measured every minute with a statistical error of 2% to 4%. The precision of the beam polarization measurement is of great importance for the HERMES experiment since the error propagates directly into the physics results of interest. Measurements of the polarization build-up time, in combination with Monte Carlo studies and the offline analysis of the data acquired, indicate that the relative overall error of the polarization was approximately 5%. For the 1996 run both statistical and systematic uncertainties are expected to improve.

1 INTRODUCTION

A precise meaurement of the electron/positron beam polarization is essential for the HERMES experiment [3], which investigates the spin structure of the proton and neutron. It had its first data taking run in 1995. A pair of spin rotators is employed to obtain the required longitudinal spin orientation at the experiment. Additional spin rotators are forseen for the H1 and ZEUS experiments which plan to utilize polarized electrons and positrons in spin-dependent electro-weak investigations. A laser backscattering Compton polarimeter is used at the HERA e-p collider to measure and monitor the transverse beam polarization which developes naturally through the Sokolov-Ternov effect [1, 2]. An argon-ion laser provides a 10 Watt continuous beam of $2.41 eV$ photons. Lenses and mirrors transport the beam over more than $200 m$ to the $e\gamma$ interaction point. A Pockels cell switches the photon polarization with a frequency of 83.8 Hz. Energy and vertical position of the backscattered Compton photons are measured in a tungsten-scintillator calorimeter about $65 m$ from the interaction point. When the stored electrons or positrons are vertically polarized, the Compton photons will show an up-down asymmetry proportional to the spin polarization, which changes sign when switching between left and right circular polarized laser photons. This asymmetry shifts the center of gravity of the vertical position of the Compton photons on the calorimeter by $0.3 mm$ for 100% electron polarization.

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2 RESULTS

2.1 HERA Polarization Performance

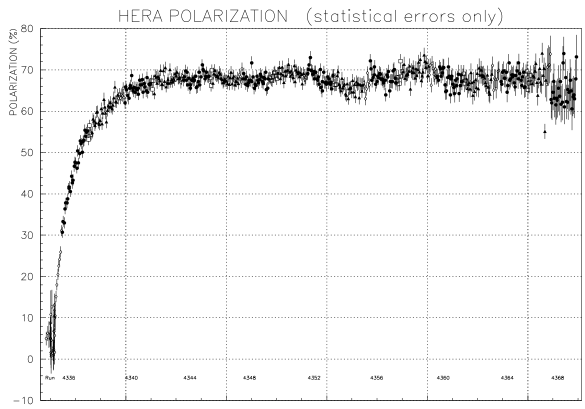

Figure 1: Example for a normal fill with high polarization

Figure (1) shows the polarization for a particular fill at HERA where exceptionally high asymptotic polarization near 70% was a achieved. More typical asymptotic polarization values were 45% to 60%. The machine energy was $27.51 GeV$, corresponding to a spine tune of 62.5, with typical initial beam currents of $30 mA$.

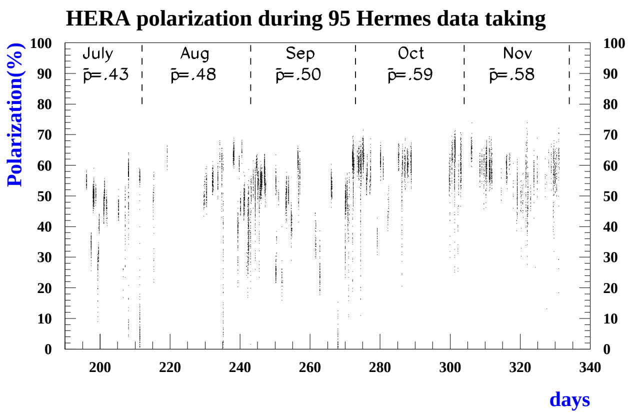

Figure 2: HERA polarization during 95 HERMES data taking

The overall polarization performance of HERA throughout the data taking of the HERMES experiment is displayed in

figure (2).
In order to maximize the beam polarization it is essential to minimize the depolarizing effects in the machine. After minimizing the vertical orbit displacements harmonic bumps are introduced intentionally [2]. A kick minimizing orbit correction, which looks very promising, was also tested at the end of the running period [5]. It may speed up the polarization optimization procedure and increase attainable polarization.

2.2 Errors

Typical statistical errors were $\Delta P/P = 2\%$ to 4% for a measurement time of 1 minute. This error should be significantly reduced in further running since the laser beam transport to the interaction point has been improved. The dominant corrrections and associated systematic errors are as follows:

1. A correction which accounts for the residual vertical offset of the Compton photons with respect to the center of the calorimeter.
2. A correction which accounts for shifts in the photomultiplier signals of the calorimeter.
3. A correction of the absolut polarization scale as determined from an indepent measurement of the asymptotic polarization by the rise time calibration method. (The error of this correction has to be added linearly.)

The typical overall error for a 10 min measurement is about 5%, as shown in table (1).

Table 1: $\Delta P/P$ of Polarization Measurements

statistical error ($10min$)	0.8%
calorimeter signal shifts	2.0%
risetime corrections ($k = 0.946$)	3.2%
overall typical error	5.4%

2.3 Rise Time Calibration Method

The rise time calibration method is based on the fact that the slope of the exponential polarization build-up gives an independent determination of the asymptotic polarization. The polarization increases in time according to

$$P(t) = P_{\max}(1 - e^{-(t-t_0)/\tau}), \qquad (1)$$

where $P_{\max}$ is the asymptotic polarization and τ is the polarization build-up time, given by

$$\frac{1}{\tau} = \frac{1}{\tau_{\rm ST}} + \frac{1}{\tau_{\rm D}}. \qquad (2)$$

$\tau_{\rm ST}$ is the Sokolov-Ternov time constant of an ideal machine and $\tau_{\rm D}$ characterizes the depolarization effects of a real machine which attains less than the maximal polarization of 92.4%.
The rise-time curves are fitted to a rescaled version of Eq. (1),

$$kP(t) = P_{\max}(1 - e^{-(t-t_0)/\tau}), \qquad (3)$$

where the rescaling constant k is obtained from the fit.
In the fall of 1994, prior to the HERMES data taking, 14 build-up curves were acquired from which an overall calibration factor $k = 0.946$ was determined. This factor was used to correct the polarization values. An important requirement for the validity of this calibration method is a nearly flat machine. Therefore, the spin rotators, which produce sizeable vertical orbit excursions, were turned off during these risetime calibrations. In order to collect build-up curves of sufficient quality it is important that the machine is very stable throughout the measurement. During 1995 we developed the following criteria to indicate this:

1. The machine energy should not drift by more then $0.5 MeV$, as measured by the resonant depolarization technique.
2. The fitted calibration factor k should not depend on the duration of the measurement.
3. A reliable baseline polarization near zero must be established for more than 10 minutes, while the depolarizer is kept on, before the rise of the polarization is initiated.

3 OUTLOOK

3.1 Transverse Polarimeter

The laser laboratory, the electronics and much of the laser beam line had to be relocated in the 95/96 winter shutdown, as necessitated by the advent of the new HERA-B experiment. The laser has been replaced by a more modern model. The laser beam transport system has been considerably improved, with three mirrors under vacuum. A new laser interlock system allows to make critical adjustments to the optics with minimal interference with other activities in the HERA tunnel. The online software is also being modified, to be more user-friendly and more automatic.

3.2 Longitudinal Polarimeter

A further effort to reduce the systematic error of the beam polarization is the installation of a second Compton polarimeter close to the HERMES detector which will measure the longitudinal electron or positron spin polarization between the spin rotators [4]. Figure (3) shows the layout of the longitudinal polarimeter. It will be commissioned in 1996.

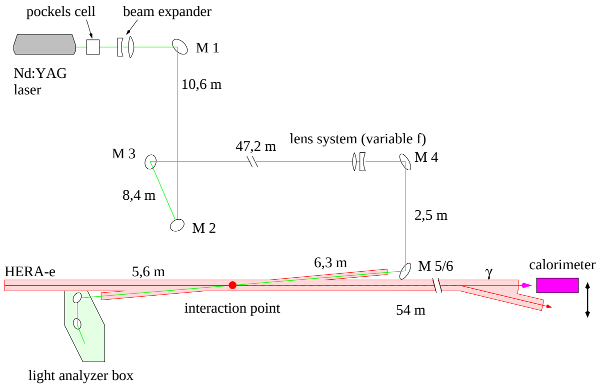

Figure 3: Layout of the longitudinal polarimeter

3.3 Partial Depolarizer

To improve the accuracy of the rise time calibration method, it is planned to selectively depolarize a fraction of the bunches, while the other bunches remain polarized. This will allow to measure the asymptotic polarization (from the still polarized bunches), which indicates the machine stability, and the rise time (from the depolarized bunches) simultaneously. The hardware and software of this new partial depolarizer has been implemented [6, 7] and will be tried out soon.

4 REFERENCES

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