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A Polarimeter for HERA

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Abstract

The electron–proton machine HERA is under construction at DESY in Hamburg. The machine consists of two independent storage rings designed for 30 GeV electrons and 820 GeV protons. The counter rotating beams can collide head on in four interaction regions spaced uniformely around its 6.3 km circumference. At two of them HEP detectors are under construction: The experiment H1 is situated in the North area and the experiment ZEUS in the South. In an ideal circular electron machine the spin of the particles becomes polarized transversely by the *Sokolov–Ternov* effect. The second generation HERA experiments will be done with longitudinally polarized electrons. This requires the installation of spin rotators. But as a first step the build up of the transverse spin polarization without rotators will be investigated and for this experiment a polarization monitor is necessary. This paper describes plans for the first polarimeter for HERA, designed for measuring the transverse polarization. This monitor utilizes the *Compton* scattering of circularly polarized light: The number of back scattered photons is asymmetric with respect to the machine plane when the target electrons are vertically polarized. During the next stage of the commissioning of HERA, in August and September this year, it will be possible to make background measurements in preparation for the installation of the complete polarimeter next year.

Introduction

In an electron storage ring the circulating particle beam may become polarized transversely by the *Sokolov–Ternov* effect[1]: In a flat storage ring the spin quantisation axes are aligned almost parallel to the bending field. However, synchrotron radiation can cause the spin to flip from up to down and vice versa. The two transition rates are unequal and as a result the beam becomes spin polarized antiparallel

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to the guide field; the spin orientation of positrons is parallel to the field. The degree of polarization increases in time according to

$$P(t) = P_\infty \left(1 - e^{-t/\tau}\right) \tag{1}$$

where P_∞ is the asymptotic equilibrium degree of polarization and τ the polarization build up time. In the absence of depolarizing effects these parameters are given by

$$P_\infty = \frac{8}{5\sqrt{3}} = 92.4\,\% \quad \text{and} \quad \frac{1}{\tau} = 3.534\,10^{-19}\,\frac{\text{m}^3}{\text{s}}\,\frac{\gamma^5}{R\rho^2}$$

where R is the mean radius, ρ the bending radius and $\gamma m_0 c^2$ the beam energy.

For future high energy experiments the polarization of the electrons could be used as an additional degree of freedom. For deeper investigation of the electroweak interaction and to search for new phenomena, it would be very useful if the electrons in the electron-proton machine HERA could be longitudinally polarized at the interaction points. For this reason it is intended to convert the vertical polarization in the arcs to longitudinal polarization at the interaction points with special arrangements of vertical and horizontal bending magnets called spin rotators[2]. In the presence of rotators the degree of polarization is reduced. But already in a flat machine various effects, like closed orbit distortions, could destroy the polarization. Thus it is essential to investigate the built up of the polarization at an early stage of the machine. As a development first step a monitor for measuring the degree of polarization will be installed and its behaviour investigated.

Various methods have been used to measure the beam polarization in electron storage rings. The polarimeter for HERA is based on the *Compton* scattering of circularly polarized photons from a laser. If the electrons are polarized transversely, the angular distribution of the scattered photons has the form[3]

$$\frac{d^2\sigma}{d\phi d\theta} \sim f(\theta) \pm P \cos\phi \, g(\theta) \tag{2}$$

where P is the degree of polarization and ϕ is the azimuthal angle relative to the polarization direction. The choice of the sign depends on the laser light helicity. From this formula we can see that the number of backscattered photons is asymmetric with respect to the machine plane when the electron beam is vertically polarized and the incident laser light is circularly polarized.

The Electron Storage Ring of HERA

The electron-proton machine HERA has been under construction since April 6, 1984 and is scheduled to be completed at the end of next year. HERA consists of a 6.3 km long circular tunnel housing a 820 GeV proton storage ring on top of a 30 GeV electron storage ring. Beams of both rings can collide head on at four interaction points. In the first stage two experiments will be installed: The experiment H1 is situated in the North area and the experiment ZEUS in the

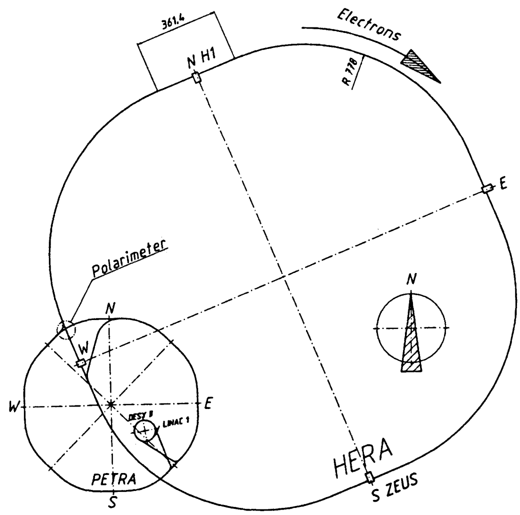

Figure 1: Overview of HERA and the injection complex.

experiment H1 is situated in the North area and the experiment ZEUS in the South (see Figure 1). The straight section in hall East is identical to the sections containing these experiments. There, a first spin rotator will be installed for studies on longitudinal polarization.

The electron storage ring of HERA is complete. First storage trials were made last year. During the second commissioning period, in August and September this year, the installed rf-power should make storage of 26 GeV electrons and positrons possible. Next year, after superconducting cavities have been installed, higher energy will be possible.

Parts of a polarimeter will be installed in octant West right at the end of August. The outlet vacuum chamber for the backscatterd photons and a shower counter are now available. With this equipment, measurement of backgrounds will be possible.

HERA has been described in other papers[4]. The status of HERA is presented as an invited contribution to this conference. Some parameters are shown again in Table 1.

Circumference L	6335.83 m	Polarization time τ	
Mean radius $R = \frac{L}{2\pi}$	1008.38 m	for $E = 30$ GeV	25 min
Bending radius ρ	608.13 m	Rf power (in 1989)	7.6 MW

Table 1: Parameters of the HERA e^- storage ring.

Layout of the HERA Polarimeter

The layout of the HERA polarimeter is shown in Figure 2. The principle is similar to that of the polarimeter used at SPEAR[5], PETRA[6] and DORIS[7]: In Hall West a high power laser will be installed outside the shielding wall. The laser light enters the interlocked area of HERA through a pipe (see Figure 3) and will be guided by mirrors to the interaction region in octant West right. The light enters the machine vacuum system vertically through a viewing port. and will be reflected by a remote controlled vacuum mirror towards the electron beam. The interaction region is between two weak bending magnets. At the point opposite to the entrance, the laser light leaves the vacuum and can be analysed. The crossing angle between the laser light and the electron beam is about 3.5 mrad. The electron beam and the backscattered photons are separated by a bending magnet. In order to make the synchrotron radiation spectrum soft, the electron photon separator is a weak bending magnet with a radius of about 3220 m. The rate of synchrotron radiation photons is negligible above energies of 500 keV (nearly no pair production). After a drift space an additional strong bending magnet with a radius of about 524 m increases the separation and at the end of this magnet the photons leave the vacuum through a 0.5 mm thin aluminium window. Then the angular distribution with respect to the machine plane can be analyzed by a shower counter. The detector measures the centre of gravity of the shower generated by a backscattered photon and the asymmetry is deduced from the photon distribution.

Laser System. Two laser systems are being considered. For the single photon method a laser with a relatively low peak power, but with a high repetition rate or duty cycle will be used. In this scheme, photons arrive singly at the detector. For the multi photon method a laser with high peak power, but low repetition rate will be used. Here, thousands of photons arrive at the detector simultaneously in

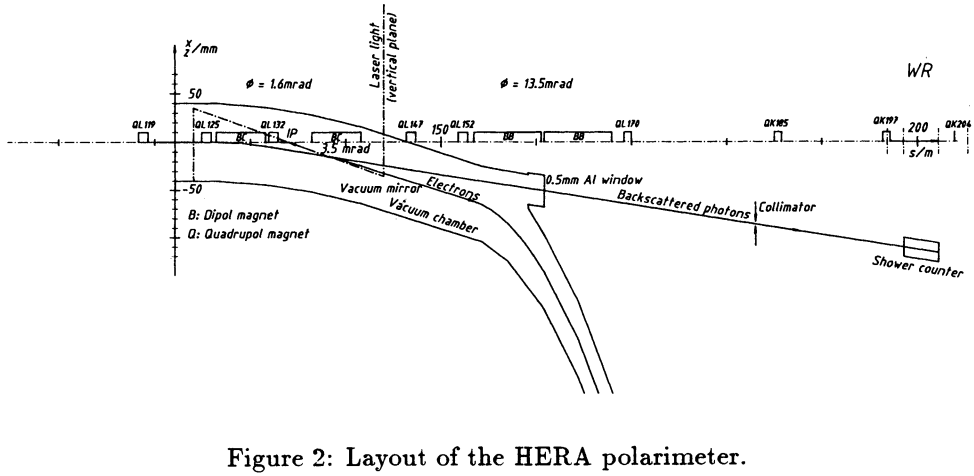

Figure 2: Layout of the HERA polarimeter.

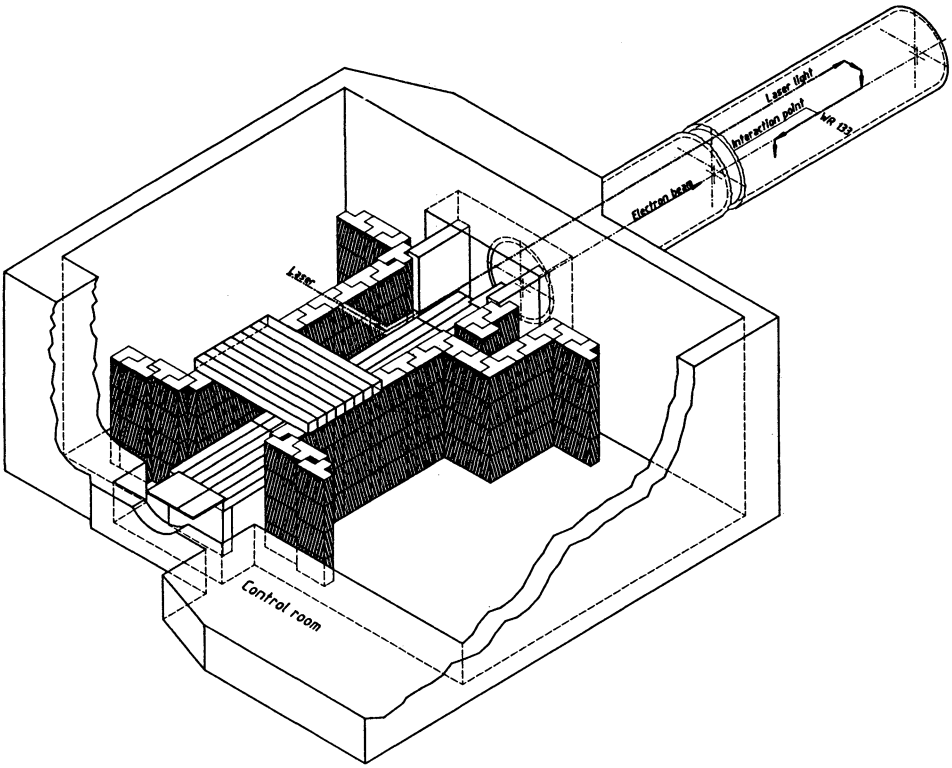

Figure 3: Perspective view HERA Hall West.

bursts. The advantage of the second system is that the instantaneous backscattering rate is much higher so that backgrounds are insignificant. However,the laser system is more complicated than in the single photon scheme. The choice of a system will be made after the backgound measurements.

Vacuum Components. The two vacuum chambers of the polarimeter, the interaction region and the separation region with the outlet, are made of 4 mm thick extruded copper. The complete chambers consisting of cooling channels, beam chamber, pumping channel, flanges and beam monitors are brazed in a 15 m long stove inside a protecting gas atmosphere. This technique was developed for the standard vacuum chambers of the electron storage ring. With this chamber 90 % of the synchrotron radiation is absorbed in the watercooled chamber walls. In addition the chambers are covered by lead shielding.

Shower counter. A cross section of the shower counter is shown in Figure 4. The detector consists mainly of a stack of lead framed tungsten plates, each 6.3 mm thick and scintillator plates, each 3 mm thick. The entrance window of the detector is a 15 mm thick lead plate for shielding against the soft synchrotron radiation. A high energy photon entering the shower counter will be converted into a shower of charged particles which excite visible light in the scintillator plates. The scintillation photons are detected by four photomultipliers which are connected via

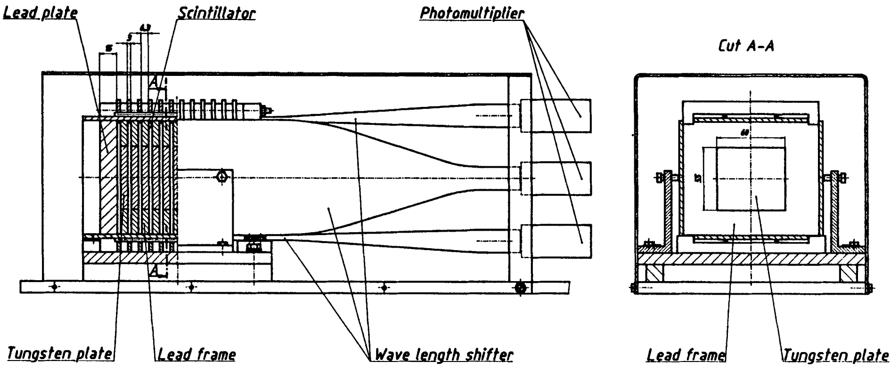

Figure 4: Cross section of the shower counter.

wave length shifters to the scintillator plates. The scintillator plates are optically insulated at the horizontal centre line and the centre of gravity of the shower generated by a backscattered photon will be measured by comparing the photomultiplier signals. The detector is mounted on a remotely controlled table that can be moved both horizontally and vertically. With this table the shower counter can be precisly aligned with respect to the backscattered photon beam. To shield it against the "4π" background, the detector is housed in a lead cover.

Summary

The electron storage ring of HERA has begun to operate and a polarization monitor is currently being installed. Background measurements will be made this year. The polarimeter will be completed next year. Then the electron energy will also be high enough, and τ small enough, for measurements of polarization to begin.

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