TRANVERSE AND LONGITUDINAL ELECTRON POLARIZATION
AT HERA

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Abstract

HERA made spectacular progress in 1993 in achieving high transverse electron polarization by applying harmonic spin correction techniques. In May 1994 spin rotators have been brought into operation and for the first time longitudinal electron polarization has been produced in a high energy storage ring. A degree of about 65% polarization has been achieved and will be further optimized. Longitudinal polarization at HERA will be used by the HERMES experiment starting in 1995 and later also by the collider experiments H1 and ZEUS.

1. Introduction

Longitudinal polarized electron beams are perfect probes in two basic fields of high energy physics: The investigation of the spin structure of the nucleon as it will be done by the HERMES experiment and the investigation of the weak interaction with a polarized beam as planned by the collider experiments H1 and ZEUS.

Electrons in a storage ring become naturally transverse polarized due to the Sokolov-Temov effect4: A small but significant asymmetric spin flip amplitude connected to synchrotron radiation enhances the polarization state anti-parallel to the magnetic field of the bending magnets. Depolarizing resonances counteract the polarization build up. Polarization approaches exponentially an asymptotic value which is determined by details of the electron orbit. Empirical correction schemes have been invented which allow to optimize the degree of polarization, making use of the fast and reliable HERA polarimeter.

As the experiments require longitudinal polarization, a spin-rotator is needed in front and behind each interaction region in order to rotate the spin direction from the vertical to the longitudinal direction and vice versa.

2. The Compton Polarimeter

The polarimeter at HERA is based on the spin dependence of the Compton scattering of circularly polarized laser light off the electron beam. The up-down asymmetries of the back scattered photons are measured in a position sensitive calorimeter. The spatial asymmetry is of the order of $\Delta y / P_x \approx 3 \mu m / \%$. Correlations between position and energy of the Compton photons are used to study the systematic precision of the polarization results.

The polarimeter provides fast real-time information of the actual degree of polarization with a statistical and systematical precision of a few percent. A detailed description of the polarimeter can be found in references5-8.
3. Optimization of Transverse Polarization

Spin diffusion in quadrupoles and depolarizing resonances easily destroy polarization in a high energy storage ring. Important countermeasures are: a precise alignment of the quadrupoles (< 1 mm), closed orbit corrections and a careful selection of the betatron tunes, of the beam energy and especially of the synchrotron tune.

It turned out that the most effective improvement of polarization could be obtained by empirical optimization of harmonic correction bumps. These are combinations of 8 vertical closed bumps of the orbit at 'strategic' positions in HERA. They reduce (for a given harmonic) the coupling between the stochastic excitation of the horizontal motion (by synchrotron radiation) and the spin motion (which is governed by vertical motion). The theoretical ideas were proven with the SITROS spin tracking Monte-Carlo, which shows good agreement of the simulations with the observed polarization effects at HERA.

4. The Spin Rotators

From the Thomas-BMT equation follows that the precession of the spin in a dipole at the HERA energy of 27.52 GeV is 62.5 times larger than the bending of the orbit. A combination of horizontal and vertical dipole magnets allows to rotate the polarization axis from the vertical to the longitudinal direction. The 'mini'-rotator scheme from Buon and Steffen achieves this with a closed vertical bump of only 22 cm height.

As spin rotators are strong sources for depolarization, several measures were taken to minimize the effect of the rotators: there are no quadrupoles between the dipoles of each rotator, the beam optics between the rotators is horizontally spin-matched (i.e. the effect of the quadrupole fields on the spin for electrons with horizontal betatron motions is compensated) and the beam optics in the ring is vertically spin-matched from rotator to rotator.

After putting the spin rotators into operation in May 94, polarization went up to $P = 55\%$ (fig.1). With additional fine tuning it was possible to obtain longitudinal polarization of about $P \approx 65\%$. Polarization was reproducible and stable.

5. Resonance Depolarization and Spin Flip

Beam polarization can be artificially destroyed by applying a horizontal magnetic field with a frequency which is resonant to the spin precession. This effect was used at HERA to determine precisely the beam energy. One should mention that the width of the depolarizing resonance is smaller (< 2 MeV) than the energy spread of the beam ($\approx 24$ MeV). At HERA a field strength of $\sim 2 \cdot 10^{-4}$ Tm was sufficient to depolarize the beam efficiently within a few seconds.

Up to now it is not possible to flip the spin at HERA by spin resonance as the depolarization time is large compared to the spin diffusion time. However it will be investigated if an efficient spin flip can be achieved by stronger depolarization magnets. In order not to disturb the orbit, a combination of magnets with different phase advances for the orbit and for the spin motion will be required.

In case that an efficient spin flip is possible, it can be used to periodically invert the helicity of the beam and such reduce the systematic errors of the asymmetry measurements of the experiments. However, an additional trick is needed: Due to the Sokolov-Ternov effect, the flipped polarity decays rather quickly and high (negative) polarization is lost after
Fig. 1: Polarization rise with activated spin rotators. Transverse polarisation above 50% is measured with the HERA polarimeter. Spin rotators turn the polarization vector into longitudinal direction at the HERMES experimental area.

5-10 minutes. A quick flip back (e.g. after 1.5 min) saves high polarization. The next flip to negative polarization may only be done after the original degree of polarization is recovered. This way a periodic operation (e.g. 1.5 min negative, 10 min positive helicity) seems to be possible.

It should be mentioned that the helicity of the electrons can also be inverted by inverting the direction of the vertical bump in the spin rotators. This requires however a mechanical movement of the rotator magnets which can only be done between two electron fills.

6. Conclusions

The spin rotators at HERA were sucessfully tested. The achieved longitudinal polarization of $P \approx 65\%$ is well above the design value for the HERMES® experiment. The polarisation in HERA behaves as predicted by the spin tracking program SITROS. Additional spin rotators for H1 and ZEUS are ordered.

References