II. LONGITUDINAL ELECTRON SPIN POLARISATION AT 27.5 GEV IN HERA [a]

D.P. BARBER
for the HERA Polarisation Group.
Deutsches Elektronen–Synchrotron, DESY,
22603 Hamburg, Germany.
E-mail: mpybar@mail.desy.de

The first attainment of longitudinal spin polarisation in a high energy electron (positron) storage ring is described.

Summary

An integral part of the design of the HERA *ep* collider has been the provision of longitudinally spin polarised electrons for the high energy physics experiments at the interaction points [1]. At HERA, electrons or positrons of energy up to 30 GeV are brought into collision with 820 GeV protons.

As outlined in Article I, stored electron beams can become vertically polarised by the Sokolov–Ternov effect [2]. The maximum ST polarisation achievable is 92.4% corresponding to a planar ring. To provide longitudinal polarisation at an interaction point the naturally occuring vertical polarisation in the arcs must be rotated into the longitudinal direction just before the interaction point (IP) and back to the vertical just after the IP using special magnet configurations called spin rotators.

At HERA the spin rotators consist of strings of interleaved horizontal and vertical bending magnets each of which deflects the orbit by no more than about 20 milliradians. Dipole rotators exploit the prediction of Eq. (4) in Article I that for motion transverse to the magnetic field, the spin precesses around the field at a rate which is $a\gamma$ times faster than the rate of rotation of the orbit direction. At HERA energies $a\gamma$ is between 60 and 68. So it can be arranged that small commuting deflections of the orbit can result in large noncommuting precessions of the polarisation vector which can be utilised to rotate the polarisation from the vertical to the longitudinal direction and vice versa. For HERA, the Mini-Rotator design of Buon and Steffen was adopted [3]. The first pair of these spin rotators was intalled at the East straight section for the HERMES experiment.

Synchrotron radiation not only generates polarisation but can also cause depolarisation (Article I). This is especially the case in the presence of spin rotators. Furthermore the ratio: (depolarisation rate/polarisation rate) increases strongly with energy. However, the depolarising effects can in principle be minimised by special choice of the optic called 'spin matching' [4]. But owing to the difficulty of obtaining reliable numerical predictions of the polarisation in the presence of rotators throughout the preparatory stage of the project and because of the initially very pessimistic

[a] A talk presented at the 15th ICFA Advanced Beam Dynamics Workshop: "Quantum Aspects of Beam Physics", Monterey, California, U.S.A., January 1998. Also in DESY Report 98–096, September 1998.

predictions, it was by no means clear that longitudinal polarisation could be obtained even after spin matching.

Nevertheless, on the first attempt with the rotators switched on at the chosen energy of 27.5 GeV, a longitudinal electron polarisation of about 56% was attained. This is to be compared with the 65% polarisation attained immediately beforehand with the rotators turned off.

This was the first time in the history of high energy storage ring physics that longitudinal polarisation had been attained. Space limitations prevent my giving more details here but complete information and diagrams can be found in [1].

Subsequently longitudinal polarisation levels of about 70% for periods of up to ten hours for positrons in collision with tens of milliamps of high energy protons have been achieved. Furthermore by measuring the polarisation of individual positron bunches the influence of the beam–beam interaction on the polarisation has been observed and found to be exotic. For example positron bunches in collision with protons can have a higher polarisation than non–colliding bunches and the polarisation of both groups of bunches is very sensitive to the tunes of the machine. Obviously, complicated resonance phenomena are at work [5].

Outlook

In the year 2000 two more pairs of spin rotators will be installed so that three HERA experiments can work with longitudinally polarised electrons or positrons.

References

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