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Abstract: For some years HERA has been supplying longitudinally spin polarised electron and positron ($e^{\pm}$) beams to the HERMES experiment and in the future longitudinal polarisation will be supplied to the H1 and ZEUS experiments. As a result there has been a development of interest in complementing the polarised $e^{\pm}$ beams with polarised protons. In contrast to the case of $e^{\pm}$ where spin flip due to synchrotron radiation in the main bending dipoles leads to self polarisation owing to an up–down asymmetry in the spin flip rates (Sokolov–Ternov effect), there is no convincing self polarisation mechanism for protons at high energy. Therefore protons must be polarised almost at rest in a source and then accelerated to the working energy.

At HERA, if no special measures are adopted, this means that the spins must cross several thousand "spin–orbit resonances". Resonance crossing can lead to loss of polarisation and at high energy such effects are potentially strong since spin precession is very pronounced in the very large magnetic fields needed to contain the proton beam in HERA–p. Moreover simple models which have been successfully used to describe spin motion at low and medium energies are no longer adequate. Instead, careful numerical spin–orbit tracking simulations are needed and a new, mathematically rigorous look at the theoretical concepts is required.

This thesis describes the underlying theoretical concepts, the computational tools (`SPRINT`) and the results of such a study. In particular strong

emphasis is put on the concept of the invariant spin field and its non–perturbative construction. The invariant spin field is then used to define the amplitude dependent spin tune and to obtain numerical non–perturbative estimates of the latter. By means of these two key concepts the nature of higher order resonances in the presence of snakes is clarified and their impact on the beam polarisation is analysed. We then go on to discuss the special aspects of the HERA–p ring and measures for minimising the perturbations to the spin motion ($\rightarrow$ depolarisation) and thereby obtain first upper bounds on the permissible beam emittances needed to maintain polarisation up to high energy in HERA–p.

In the near future, first experimental results on acceleration and storage of polarized protons in RHIC will be available. RHIC will be operated at less than a third of the top energy of HERA–p, is flat and has a higher superperiodicity (P=6). It will be interesting to see in how far the effects on polarisation, e.g. partial depolarisation due to crossing of higher order resonances in the presence of snakes, as predicted by the theory described in this thesis and found numerically for the HERA–p ring can already be clearly resolved experimentally in RHIC.