ABSTRACT

ASPECTS OF THE INVARIANT SPIN FIELD FOR HIGH ENERGY POLARIZED PROTON BEAMS

By

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So far polarized proton beams have never been accelerated to energies higher than about 25GeV. Up to these energies the beam polarization is quite undisturbed when the accelerator is well adjusted, except at special energies where resonances occur. In particular, it has not been necessary to study the variation of the protons' spin direction across the phase space of the beam. Taking the pre–accelerators of HERA–p at DESY as an example, methods will be described which have already been established in the AGS at the Brookhaven National Laboratory and which could therefore be used to avoid a reduction of the polarization at resonance energies. But when accelerating to energies of several hundred GeV as in RHIC, TEVATRON, or HERA–p, new phenomena can occur which can lead to a significantly diminished beam polarization. For these high energies, it is necessary to look in more detail at the spin motion at each point in phase space and the *invariant spin field* will prove to be a useful tool. This is a vector field over the phase space of the proton beam which describes a polarization state that is periodic from turn to turn, and it is already widely used for the description of high energy electron beams which become polarized by the emission of spin–flip synchrotron radiation.

It will be proven that this field gives rise to an adiabatic invariant of spin–orbit motion and that it defines the maximum time average polarization that is usable in a particle physics experiment. Furthermore, the invariant spin field allows the amplitude dependent spin tune to be defined and computed and thereby opens the way to a clear evaluation of the effects of higher–order spin–orbit resonances. In particular the strengths and the depolarizing effects of these resonances can only be determined once the amplitude dependent spin tune has been computed.

These concepts make it possible to optimize HERA–p for acceleration and storage of a polarized proton beam. For example, it will be shown that schemes with 4 and 8 Siberian Snakes can be so chosen that the influence of higher–order spin–orbit resonances, the spread of the spin tune over the particle amplitudes in the beam, and the variation of the invariant spin field over orbital phase space are reduced and then polarization can be maintained for a significantly increased region of the beam while accelerating to high energy and therefore more polarization can be delivered for particle physics experiments.

The utility of the invariant spin field will be illustrated by simulations of spin motion up to 920GeV in HERA–p and various methods for computing the invariant spin field, the adiabatic spin invariant, and the amplitude dependent spin tune will be presented. Moreover, several high energy spin–orbit dynamical effects will be discussed which go beyond conventional models of spin dynamics and were observed with these novel methods.